CPSC Staff Statement on SEA, Ltd. Report "Effects on ATV Vehicle Characteristics of Rider Active Weight Shift"[1]
January 2018

The report titled, "Effects on ATV Vehicle Characteristics of Rider Active Weight Shift," presents results of autonomous dynamic vehicle testing conducted by SEA, Ltd. (SEA), on 12 model year 2014-2015 adult, single-rider all-terrain vehicles (ATVs) to study the effects of rider lean on a single-rider ATV. The same 12 vehicles were previously tested under a separate task order to establish baseline performance of the vehicles with a single rider, and the results were published in a report titled, "Vehicle Characteristics Measurements of All-Terrain Vehicles."[2] All task orders were conducted under contract HHSP233201400030I. This contract is funded by CPSC and is administered under an interagency agreement with the U.S. Department of Health and Human Services. The work represented by this report is part of a larger effort by CPSC staff to develop test methods, collect static and dynamic data, and identify opportunities for improvements in ATV performance characteristics related to vehicle stability and safety. Follow-on work is underway to measure characteristics for the same 12 vehicles when operated on a groomed dirt surface and to test three selected vehicles with characteristics that have been modified to study effects on steering and stability. Additionally, staff has previously identified a need for future testing, when resources are available, to include autonomous rollover testing and rollover simulation testing, with a goal to discover opportunities to reduce the likelihood and severity of injury.

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[1] This statement was prepared by the CPSC staff, and the attached report was produced by SEA for CPSC staff. The statement and report have not been reviewed or approved by, and do not necessarily represent the views of, the Commission.

[2] Report titled, "Vehicle Characteristics Measurements of All-Terrain Vehicles," retrieved from: **https://www.cpsc.gov/s3fs-public/SEA_Report_to_CPSC_Vehicle_Characteristics_Measurements_of_All_Terrain_Vehicles.pdf**.

Effects on ATV Vehicle Characteristics of Rider Active Weight Shift

Results from Tests on Twelve 2014-2015 Model Year Vehicles

for:
U.S. Consumer Product Safety Commission

December 2017

Vehicle Dynamics Division
7001 Buffalo Parkway
Columbus, Ohio 43229

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Report prepared by Gary J. Heydinger, Ph.D., P.E.,
with primary support from Anmol Sidhu, Ph.D., Scott Zagorski, Ph.D., P.E.,
Joe Yapp, Jim Nowjack, Hank Jebode, Jon Coyle and Dale Andreatta, Ph.D., P.E.

Vehicle Dynamics Division
7001 Buffalo Parkway
Columbus, Ohio 43229

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1. OVERVIEW

This report contains results from measurements made by SEA, Ltd. (SEA) for the U.S. Consumer Product Safety Commission (CPSC) under U.S. Department of Health and Human Services (HHS) contract HHSP233201400030I.

This report covers work completed on Task Order 3 of the multi-task contract:

- Test twelve (12) ATV vehicles in dedicated testing to evaluate the effects on rollover resistance and vehicle handling characteristics when Rider Active weight shift is employed.

This report contains test results for measurements made on twelve 2014-2015 model year vehicles. The vehicles are designated Vehicle A through Vehicle L. Vehicles A-J are model year 2014 vehicles, and Vehicles K and L are model year 2015 vehicles.

Task Order 1 on this contract was to make characteristics measurements on these same 12 vehicles in the Driver Plus Instrumentation (DPI) loading condition (representing a nominal 215 lb driver) and in the Gross Vehicle Weight (GVW) loading condition. The SEA report to CPSC on these measurements is titled *Vehicle Characteristics Measurements of All-Terrain Vehicles – Results from Tests on Twelve 2014-2015 Model Year Vehicles,*[3] and it contains results from laboratory and dynamic test track measurements made on all 12 vehicles. For the previous Task 1 testing, all 12 of the vehicles were tested in DPI loading condition and nine of them were tested in the GVW loading condition. Vehicles B, H and I, were tested only in the DPI loading condition; because for these vehicles the added weight of the test driver and instrumentation brought the total test weight up to near their manufacturer-specified maximum weight ratings. Vehicles B, H and I are the only three manual transmission vehicles and they are the three lightest vehicles. All the dynamic testing for the Task Order 1 measurements was conducted with a human test driver.

Task Order 2 on this contract was to make characteristics measurements on these same 12 vehicles in a two-person (driver and passenger) loading condition. For the two-person loading condition, the vehicles were each tested at a total test weight nominally 430 lb (representing two 215 riders) above the curb weight for each vehicle. The SEA report to CPSC on these measurements is titled *Effects on Vehicle Characteristics of Two Persons Riding ATVs – Results from Tests on Twelve 2014-2015 Model Year Vehicles*.[4]

[3] *Vehicle Characteristics Measurements of All-Terrain Vehicles – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, November 2016. **https://www.cpsc.gov/s3fs-public/SEA_Report_to_CPSC_Vehicle_Characteristics_Measurements_of_All_Terrain_Vehicles.pdf**

[4] *Effects on Vehicle Characteristics of Two Persons Riding ATVs – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, September 2017. **https://www.cpsc.gov/s3fs-public/SEA-Final-Report-to-CPSC-2-Rider-ATV-Study.pdf?V0ixJO3o_kbtsmIBeKUInRAFx6hVocs5**

Task Order 3 (as did Task Order 2) involved doing only dynamic tests. For the Task Order 3 driver weight shift study, the vehicles were each tested at a total test weight nominally 215 lb (representing a 215 lb driver) above the curb weight for each vehicle. All the testing was conducted using SEA's ATV Robotic Test Driver (ATV RTD). The ATV RTD is a system of automated steering, throttle, brake, and clutch controllers along with differential GPS that was used to conduct the tests in a fully autonomous mode, without a human test driver.

Conducting the tests autonomously provided a means to use ballast weight fixed rigidly to the vehicle to represent the driver mass. The same ballast weight frame that was used to load the vehicles to the 2-Rider loading condition in the Task Order 2 study was used in this study. Three different driver lateral lean angles were evaluated, one representing an upright driver (0° lateral lean angle), one representing a driver with a 20° lateral lean angle, and one representing a driver with a 40° lateral lean angle.

Conducting the tests without a human driver mitigated the potential for having the test results influenced by using different human drivers for the tests and it eliminated the need to have the drivers attempt to lean to specific lateral lean angles. Conducting the tests autonomously and using a ballast weight frame to adjust to specific representative driver lean angles provided a means to consistently replicate the same degree of driver lateral lean for each vehicle. Details of the loading conditions, including the rationale used for selecting the representative driver lean angles used in this study, are provided in Section 2.1.

All of the vehicles were selected by CPSC. All of the vehicles have straddle seating and their intended use is for a single occupant, the driver. All of the vehicles have clear warning labels stating "Never Carry a Passenger" or "Never Carry Passengers." All of the vehicles have handlebar (tiller) steering, thumb activated throttles, and hand and foot activated brakes.

The measured curb weights (weights with full fluids and no drivers or cargo) of the vehicles ranged from 395.5 lb to 832.0 lb. The measured average maximum speeds of the vehicles ranged from 45.7 mph to 74.0 mph in a loading condition representing driver-only loading.

Table 1 contains a list of assorted vehicle information and tire specifications for the 12 vehicles. The measured curb weights and maximum speeds are listed.

Also listed in Table 1 is information on the transmission types (automatic or manual) and whether the vehicle has a solid rear axle or independent rear suspension. All of the vehicles with solid rear axles are two-wheel drive (2WD) only vehicles. All of the vehicles with independent rear suspensions are equipped with selectable four-wheel drive (4WD) or all-wheel drive (AWD). Table 1 contains the manufacturers' specified driveline setting options for each of the vehicles. All vehicles were tested in two-wheel drive mode, and in their most open driveline configurations.

Table 1 also lists the front and rear tire make, tire size, and tire pressure for each vehicle.

The dynamic tests were performed by SEA on numerous dates between July 25, 2016 and December 21, 2016. All of the vehicles were tested at SEA in Columbus, Ohio. The following suite of dynamic tests were performed in each of the three driver-active (Rider Active) loading conditions for each vehicle:

- **Constant Radius (50 ft) (Circle) Tests**
- **Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)**
- **Constant Steer Tests (Yaw Rate Ratio Tests)**

This report contains four main sections: Overview, Dynamic Testing, Discussion of Test Results, and Comparison of Autonomous Rider Active Results to Human Driver DPI Results. There are also three appendices containing test results, and one appendix containing photographs of test equipment.

Table 1: Test Vehicle Information and Tire Specifications		
Vehicle A **Curb Weight: 523.9 lb** **Maximum Speed: 47.0 mph**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU13	Maxxis MU13
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	3.6	3.6
Vehicle B **Curb Weight: 432.8 lb** **Maximum Speed: 70.0 mph**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Maxxis M976Y	Maxxis M976Y
Tire Size	AT21X7-10	AT20X10-9
Tire Pressure (psi)	4	4
Vehicle C **Curb Weight: 650.8 lb** **Maximum Speed: 66.0 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Maxxis MU19A	Maxxis MU19A
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	4.4
Vehicle D **Curb Weight: 714.0 lb** **Maximum Speed: 45.8 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle E **Curb Weight: 734.1 lb** **Maximum Speed: 45.7 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD, 4WD, or 4WD Lock**	
	Front Tires	Rear Tires
Tire Make	Kaden Duro 45J	Kaden Duro 52J
Tire Size	AT25X8-12 6 Ply	AT25X10-12 6 Ply
Tire Pressure (psi)	5	5
Vehicle F **Curb Weight: 526.2 lb** **Maximum Speed: 53.5 mph**	**Automatic Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Kenda Pathfinder	Kenda Pathfinder
Tire Size	AT22X7-10 4 Ply	AT22X10-10 4 Ply
Tire Pressure (psi)	4	3.5

Table 1 (Continued): Test Vehicle Information and Tire Specifications		
Vehicle G **Curb Weight: 694.0 lb** **Maximum Speed: 69.0 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD or 4WD**	
	Front Tires	Rear Tires
Tire Make	Duro DI-K911	Duro DI-K911
Tire Size	AT25X8-12 4 Ply	AT25X10-12 4 Ply
Tire Pressure (psi)	5	5
Vehicle H **Curb Weight: 395.5 lb** **Maximum Speed: 71.5 mph**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT391	Dunlop KT396
Tire Size	AT21X7R10 ☆☆	AT20X10R9 ☆☆
Tire Pressure (psi)	4.4	3.9
Vehicle I **Curb Weight: 408.4 lb** **Maximum Speed: 63.0 mph**	**Manual Transmission** **Solid Rear Axle** **2WD**	
	Front Tires	Rear Tires
Tire Make	Ohtsu Radial HTRAK M/R101	Ohtsu Radial HTRAK M/R101
Tire Size	AT22X7-10 4 Ply	AT22X10-9 4 Ply
Tire Pressure (psi)	4	4
Vehicle J **Curb Weight: 649.8 lb** **Maximum Speed: 60.5 mph**	**Automatic Transmission** **Independent Rear Suspension** **2WD or AWD**	
	Front Tires	Rear Tires
Tire Make	Dunlop KT511	Dunlop KT515
Tire Size	AT25X8 R12	AT25X10 R12
Tire Pressure (psi)	4.4	3.6
Vehicle K **Curb Weight: 832.0 lb** **Maximum Speed: 74.0 mph**	**Automatic Transmission** **Independent Rear Suspension** **2x4, 4x4, or 4x4 Lock**	
	Front Tires	Rear Tires
Tire Make	Carlisle AT489 II	Carlisle AT489 II
Tire Size	AT 26X8-14 6 Ply	AT 26X10-14 6 Ply
Tire Pressure (psi)	7	7
Vehicle L **Curb Weight: 716.4 lb** **Maximum Speed: 52.7 mph**	**Automatic Transmission** **Independent Rear Suspension** **2x4 or AWD**	
	Front Tires	Rear Tires
Tire Make	Wanda NS388	Wanda NS388
Tire Size	AT24X8-12 6 Ply	AT24X10-12 6 Ply
Tire Pressure (psi)	5	5

2. DYNAMIC TESTING

This section describes the dynamic tests conducted on numerous dates between July 25, 2016 and December 21, 2016. All of the vehicles were tested at SEA in Columbus, Ohio, on their flat dry asphalt vehicle dynamics test pad. All of the vehicles with automatic transmissions were tested in two-wheel drive mode, and in their most-open driveline configurations. The vehicles with manual transmissions were tested in second gear (as they were when they were tested previously using human test drivers and in the autonomous 2-Rider study).

2.1 Vehicle Loading Conditions

To quantify the magnitudes of the driver lateral lean angles used in this study, a series of 50 ft radius circle test drives were conducted and videotaped. Two different test drivers (the two drivers who drove the ATVs during the Task Order 1 testing) drove two different ATVs around the 50 ft radius circle to a speed where the lateral acceleration was in the range of 0.4 g. One of the vehicles was one of the smaller ATVs (Vehicle I with a curb weight of 408.4 lb and a solid rear axle) and the other vehicle was one of the larger ATVs (Vehicle E with a curb weight of 734.1 lb and an independent rear suspension).

During one set of tests, the drivers were instructed to drive using an upright posture, like they were instructed when they drove the vehicles during the Task Order 1 testing. During the other set of tests, the drivers were instructed to lean into the circle in a manner to represent modest driver lean. For both the upright and leaning posture tests drives, the vehicles were driven in both the clockwise (CW) and counterclockwise (CCW) directions, and all of the tests were conducted two times.

A video camera was positioned along a line tangent to the radius of the circle so the lean angle of the driver's torso and the lean (roll) angle of the vehicle chassis could be determined for each test. To facilitate measuring torso angle, white tape was placed on the front and rear of each driver to indicate the position of their spine. Figure 1 shows video frames from four of the 32 runs used to quantify the magnitudes of the driver lateral lean angles used in this study. The top two images show Driver 1 upright and modest lean positions on the small vehicle during CW tests, and the bottom two images show Driver 2 upright and modest lean positions on the large vehicle during CCW tests. Below each image is a list of the driver and chassis lean angles relative to the horizon, as well as the relative angle between the driver and the vehicle chassis.

For the small vehicle, for all CW and CCW tests with both drivers in the upright position, the average vehicle chassis lean angle was 1.9° outward, the average driver lean angle was 9.0° inward, and the relative angle between the driver and chassis was 10.9°. With both drivers in the modest lean position, the average vehicle lean angle was 2.1° outward, the average drive lean angle was 25.1° inward, and the relative angle between the driver and chassis was 27.2°.

For the large vehicle, for all CW and CCW tests with both drivers in the upright position, the average vehicle chassis lean angle was 6.0° outward, the average driver lean angle was 1.9° inward, and the relative angle between the driver and chassis was 7.9°. With both drivers in the modest lean position, the average vehicle lean angle was 6.4° outward, the average drive lean angle was 15.6° inward, and the relative angle between the driver and chassis was 22.0°.

Driver 1: Upright Position
Small Vehicle – Clockwise Circle Test
Driver Lean Angle: 8.0° Inward
Chassis Lean (Roll) Angle: 2.0° Outward
Relative Angle of Driver to Chassis: 10.0°

Driver 1: Modest Lean Position
Small Vehicle – Clockwise Circle Test
Driver Lean Angle: 24.0° Inward
Chassis Lean (Roll) Angle: 3.5° Outward
Relative Angle of Driver to Chassis: 27.5°

Driver 2: Upright Position
Large Vehicle – Counterclockwise Circle Test
Driver Lean Angle: 1.5° Outward
Chassis Lean (Roll) Angle: 7.0° Outward
Relative Angle of Driver to Chassis: 5.5°

Driver 2: Modest Lean Position
Large Vehicle – Counterclockwise Circle Test
Driver Lean Angle: 20.0° Inward
Chassis Lean (Roll) Angle: 7.0° Outward
Relative Angle of Driver to Chassis: 27.0°

Figure 1: Sample Video Frames Used to Quantify Driver Lateral Lean Angles

Based on this study to quantify driver lean, on average the drivers leaned 16.3° more on the small vehicle and 14.1° more on the large vehicle during the tests when they drove with modest lean than during the tests when they tried to be remain upright. Based on this, three loading conditions were chosen for this study: one representing 0° driver lean angle, one representing 20° driver lean angle, and one representing 40° driver lean angle.

Although the test drivers leaned during the tests when they were attempting to remain upright, the decision was made to use a loading condition representing 0° driver lean angle (as a baseline to represent a truly upright driver position). The 20° driver lean angle was selected to represent a driver with modest lean position, and the 40° driver lean angle was selected to represent a driver with more than modest lean position.

The same weight frame that was used to represent the driver and passenger weight during the 2-rider study was used during the tests conducted for this study. (For the 2-rider study, the ballast weight frame was loaded to represent a 0° lean angle.) The weight frame, constructed of 80/20 T-slot aluminum bars, was used to rigidly hold enough steel weights to bring the total test weight up to nominally 215 lb (representing a 215 lb driver) above the curb weight for each vehicle. The frame was designed so the steel weights could be adjusted vertically, so that the center-of-gravity (CG) height of the added ballast would represent the CG height of a 215 lb driver (with a nominal CG height 10 inches above the lowest point of their position on the seat). Also, the frame was designed so that some of the steel weights could be moved laterally, to represent a leaning driver.

To represent 0° driver lean angle, all of the weight inside the weight frame was positioned directly above the seat. To determine how much weight needed to be moved laterally to represent the 20° and 40° driver lean positions, an analysis of human body segment weights and segment center-of-gravity (CG) locations was conducted based on data determined by Paolo de Leva in 1996.[5] Using the head, trunk, and upper arm segment masses and CG locations for a representative 215 lb male, and rotating these segments 20° laterally about the center of the hips, a 215 lb male leaning 20 degrees would generate a roll moment of 625 in-lb about the longitudinal centerline of the vehicle. The laterally adjustable weight on the weight frame was moved to a fixed lateral position to develop the roll moment. For example, moving the 55 lb movable mass laterally 11.4 inches develops nominally 625 in-lb of roll moment; and this was used to represent the 20° driver lean position. The movable mass was moved twice as much to represent the 40° driver lean position.[6]

Figure 2 shows the three loading conditions used for one of the vehicles tested. As shown on Figure 2, the movable mass was only moved outward to the left side of the vehicle. Therefore, tests were conducted only in the left turning direction, to evaluate the effects on the vehicle characteristics when a driver leans into a turn. Leaning into a turn generally has a stabilizing effect on rider-active vehicles like the ATVs tested in this study.

The method used to represent a leaning driver in this study used fixed lateral lean angles. No lateral "shifting" of the movable mass was made during the maneuver to replicate how an actual driver might shift their body weight during the maneuver. Rather, the lean angles were set prior to each test and they were held steady throughout each test. Also, the method used to represent a

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[5] *Adjustments to Zatsiorsky-Seluyanov's Segment Inertia Parameters*, Paolo de Leva, J. Biomechanics, Vol. 29, No. 9, pp. 1223-1230, 1996. (Summary at **https://www.exrx.net/Kinesiology/Segments.html#comparison**)

[6] 1250 in-lb of roll moment equates to a 43 degree lean.

leaning driver in this study does not account for any vertical change in driver CG height that would occur when an actual driver leans their body during the maneuver.

When leaning into a turn ATV drivers can also shift the bulk of their body weight into the turn by sliding their body laterally on the seat. For example, if a 215 lb driver moved their entire body weight laterally by 3 inches (by sliding laterally on the seat) it would generate 645 in-lb of roll moment. If a driver leaned 20° and shifted their weight laterally by 3 inches, they would generate about the same roll moment as the representative 40° lean angle loading condition. Accordingly, the 40° lean angle loading condition represents a more than modest leaning driver or a driver with a modest lean and some lateral weight shift.

As mentioned, all three of the loading conditions used represent a 215 lb driver loading condition. Page 1 of Appendix D contains a side view of one of the test vehicles in the 0° driver lean loading condition.

The driver-only loading condition was specified to be the vehicle curb condition plus the weight (nominally 215 lb) of the test instrumentation and equipment that included: measurement transducers, SEA's ATV RTD,[7] SEA's ATV safety outriggers,[8] an auxiliary 24V battery, and the ballast weight frame described above. Table 2 lists the nominal weights of the components that comprise the driver-only loading condition.

The columns labeled "Autonomous Ballast to Driver Loading" (second columns from the right) in the tables contained in Appendix A contain the test weight, corner weights, track widths, wheelbase, and CG longitudinal and lateral positions for all 12 vehicles in the driver only, 0° driver lean loading condition (test weights for other loading conditions used for CPSC tests are also included in these tables). The total test weights for the 20° and 40° driver lean loading conditions are same as those for the 0° driver lean loading condition. However, the lateral CG locations move to the left, the left side wheel weights increase, and the right side wheel weights decrease because of moving the movable mass to the left. As mentioned, a nominal static leftward-acting roll moment of 625 in-lb was used to represent the 20° driver lean loading condition and 1,250 in-lb was used to represent the 40° driver lean loading condition.

[7] SEA designed and fabricated the ATV RTD. The ATV RTD consists of a computer-controlled 24V electric motor that mounts to the front rack of an ATV for steering control. A four-bar linkage arrangement is used to connect the motor drive gear to an aluminum rod that is connected to the ATV steering column beneath the ATV handlebars. The ATV RTD also includes up to three other computer-controlled 24V electric motors that mount to the aluminum rod inserted beneath the ATV handlebars. One motor is used to control the throttle, one is used to apply the right hand brake, and in the case of the manual transmission vehicles, one is used to control the clutch on the left side of the handlebar. The ATV RTD also includes a GPS/IMU (OxTS RT3002), an electronics box (with a National Instruments (NI) cRIO, the on-vehicle computer with the motor controllers and data acquisition software), and antennas for wireless communication. Pages 2-4 of Appendix D contain photographs of the ATV RTD.

[8] SEA designed ATV-specific safety outriggers consisting of a single aluminum tubular beam structure that mounts to the underside of the ATVs. Adjustable height nylon pads are mounted to the ends of the outrigger beam, and these interact with the test surface to prevent the vehicles from tipping over. Page 5 of Appendix D contains photographs of these standard ATV safety outriggers. These standard ATV outriggers could not be used on the three lightest ATVs tested, the manual transmission vehicles, because their frames were too close to the ground when they were loaded to test weight. For these three vehicles, SEA designed, built and used the light-vehicle ATV outriggers shown on Page 6 of Appendix D. These outriggers attached to the foot pegs of the vehicles and were further supported by an aluminum brace to the frame.

Loading Condition Representing:

0° Driver Lean

Loading Condition Representing:

20° Driver Lean

Loading Condition Representing:

40° Driver Lean

Figure 2: Loading Conditions Representing 0°, 20° and 40° Driver Lean Angles

Table 2: Driver-Only Loading		
Component	**Automatic Transmission Vehicles** **Nominal Weight (lb)**	**Manual Transmission Vehicles** **Nominal Weight (lb)**
Components Mounted at Front of Each Vehicle Base Plate, Steer Motor, Throttle Motor, Brake Motor, Clutch Motor (for Manual Transmission Vehicles), Steering Column Transducer, and Associated Linkages	37.2	47.7
Components Mounted at Rear of Each Vehicle Base Frame, Electronics Box, GPS/IMU (RT3002), 24V Battery, and Antennas	57.6	57.6
Standard ATV Outriggers	29.0	NA
Light-Vehicle ATV Outriggers	NA	23.5
Ballast Frame without 215 lb Steel Weights (Includes 45 lb Laterally-Adjustable Steel Weights Used for Rider-Active Study)	91.2	91.2
Total Nominal Driver Only Weight	**215.0**	**215.0**

Appendix A contains all of test weights used for the current autonomous Rider Active study, as well as the previous studies using an autonomous driver with 2-Rider loading and human drivers with DPI and GVW loading. For the previous human driver DPI tests, the total vehicle test weights were greater than the actual curb weights plus 215 lb (representing a 95th percentile male driver). This was because the weight of test drivers used plus the weight of all of the test instrumentation and equipment used during the tests exceeded 215 lb. For the autonomous Rider Active study, the test vehicle weights were much closer to the actual curb weights plus 215 lb (representing a 95th percentile male driver). As listed in Table 2, the nominal instrumentation and equipment weight used for these autonomous tests was 215 lb. However, some vehicles required extra batteries to run the test equipment, so their autonomous test weights are somewhat greater than vehicle loading with a 215 lb driver. In all cases, for the autonomous tests the CG height of all of the test instrumentation and equipment (including the safety outriggers) was positioned to represent the CG height of an upright 215 driver.

For all of the human driver DPI tests (except for Vehicle K), the longitudinal CG locations of the loaded vehicles were ahead of the longitudinal CG locations measured with only a 215 lb driver. The configuration of the test equipment and instrumentation used for these tests resulted in the longitudinal CG locations being forward of the position measured with only a 215 lb driver (by a 12-vehicle average value of 1.57 in).

A concerted effort was made to position the autonomous test equipment and instrumentation so that the longitudinal CG locations would better match the longitudinal CG locations measured with only a 215 lb driver. However, for all of the autonomous Rider Active tests (except for Vehicle B), the longitudinal CG locations of the loaded vehicles were behind the longitudinal CG locations measured with only a 215 lb driver (by a 12-vehicle average of 0.80 in).

2.2 Test Instrumentation

The instrumentation used during the testing is listed in Table 3. The GPS/IMU (RT3002) was mounted on the rear base frame of each vehicle. The base frames were constructed using 80/20 T-slot aluminum bars and aluminum plates. For each vehicle, the longitudinal, lateral, and vertical offsets from the center of the RT3002 to the actual vehicle CG location were measured and entered into the RT3002 system software. This information was used to translate the measured quantities to those at the CG of the vehicle. The lateral accelerations measured and reported herein are accelerations parallel to the road plane, as opposed to vehicle body-fixed accelerations.

Steering column angle (handlebar steering angle) was measured using either a digital rotary encoder or an analog string potentiometer. For several of the test vehicles, electronic noise was present in the digital encoder signal. This noise is presumably related to the vehicle's electronic output and the ATV RTD electronic sensing configuration or grounding. After this problem was identified, all subsequent vehicles were tested using the analog string potentiometer to measure steering column angle. Page 7 of Appendix D contains photographs of the arrangement used to measure steering column angle using both instruments. A split sheave, with an inner (bore) diameter sized to fit securely around the steering column shaft was fixed around each steering column. In all cases, the steering ratios between the steering column sensor and roadwheel angles were measured, and these were used to determine the Roadwheel Steer Angles (shown on the graphical results in Appendix C).

Table 3: Instrumentation Used During Dynamic Testing

Transducer	Measurement	Range	Accuracy
Oxford Technical Solutions (OxTS) RT3002 Inertial and GPS Navigation System	Longitudinal, Lateral, and Vertical Accelerations	$\pm$ 100 m/s^2 ($\pm$ 10 g)	0.01 m/s^2 (0.001 g)
	Roll, Pitch, and Yaw Rates	$\pm$ 100 deg/s	0.01 deg/s
	Speed	No Limit Specified	0.05 km/h (0.03 mph)
	Roll and Pitch Angles	-180 to +180 deg	0.03 deg
	Vehicle Heading	0 to 360 deg	0.1 deg
Steering Column Encoder or Potentiometer	Steering Column Angle (Handlebar Angle)	No Limit Specified	$\pm$ 0.25 deg

2.3 Constant Radius (50 ft) (Circle) Tests

Constant Radius or Circle tests were used to evaluate the vehicles' understeer characteristics.[9] A Constant Radius test involves driving a vehicle on a circular path of constant radius (50 ft in this case). The test vehicles were autonomously driven in the counterclockwise direction. The ATV RTD was used to steer the vehicles and control the vehicle throttle (speed) during these tests.

A circular path was generated in GPS coordinates to match the physical location of the 50 ft radius circle on the SEA test pad. The "path-following" feature of the RTD was used to control the steering input during these tests. The path-following algorithm has a collection of parameters used to model driver look-ahead distance, vehicle steering properties, and other steering-related control gains that were adjusted to provide good path following behavior for each vehicle tested.

For the vehicles with automatic transmissions, the throttle input was increased in piecewise linear steps to generate speed profiles from a very low speed up to a speed where the lateral acceleration reached 0.4 g.

For vehicles with manual transmissions, the vehicles were tested in second gear. For these vehicles, the RTD was programmed to increase the throttle and slowly engage the clutch. The throttle and clutch positions were synchronized and tuned for each vehicle to provide smooth take offs. Once the vehicles started moving, the throttles were backed off so the vehicle could achieve a low speed at the start of the circle tests. The throttle inputs were then increased in piecewise linear steps to generate speed profiles up to a speed where the lateral acceleration reached 0.4 g.

Constant Radius tests were used to determine if the vehicles transitioned from understeer to oversteer during the tests. Roll gradients, vehicle roll angle response as a function of lateral acceleration, were also computed from these tests. Detailed results from the Constant Radius tests are contained in Appendix C.

2.4 Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)

J-Turn tests, often referred to as step steer tests, involve imparting a rapid steering input up to a fixed magnitude while the vehicle is traveling along a straight path. Only left turn J-Turns were conducted in this study. For the dropped throttle J-Turn tests, the RTD drove each vehicle along a straight-line path (defined by GPS coordinates) from low speed up to a speed of 21 mph. The RTD throttle inputs were programmed to generate the appropriate speed profiles so that the J-Turn maneuvers would take place near the center of the test pad. Once 21 mph was achieved, the RTD then dropped the throttle and triggered the steering input precisely when the vehicle speed reached 20 mph. For the manual transmission vehicles, the clutch was left engaged when the throttle was dropped. The handlebar (motor) steering input rates used were 40 deg/sec, and the steering dwell or hold time used was 10.0 seconds, at which time the steering angle was programmed to return to 0 deg. The test engineer typically stopped the RTD program once the vehicle came to a stop at the end of each test, before 10 seconds of steering hold time. This eliminated the need to return the steering angle to zero while the vehicle was stopped, which helped preserve RTD 24V battery life by eliminating the need to use relatively high steering

[9] SAE Surface Vehicle Recommended Practice - Steady-State Directional Control Test Procedures for Passenger Cars and Light Trucks, SAE J266, 1996.

torques to steer the vehicle while it was not moving.

The J-Turn test procedure involved initially running tests with steering magnitudes less than the steering required to produce tip-up events, events that have visual two-wheel lift outcomes. The handlebar steering input magnitude was gradually increased in 1.0 degree increments to the point where a test run resulted in a two-wheel lift event. Then another test run using 0.5 degrees less steering input was used to refine the steering required for two-wheel lift. Once the steering input magnitude required for visual two-wheel lift was determined, repeat test runs using this steering input were conducted. Enough tests using this steering magnitude were conducted until three visual two-wheels lifts were achieved in each heading direction.

These tests provided a measure of the minimum peak lateral acceleration (Threshold Ay) required to cause visual two-wheel lifts during the tests. Detailed results from the Dropped Throttle J-Turn tests are contained in Appendix C.

2.5 Constant Steer Tests (Yaw Rate Ratio Tests)

Constant Steer tests are yet another well-established method used to evaluate a vehicle's understeer characteristics.[10] The ROV industry groups Recreational Off Highway Vehicle Association (ROHVA) and Outdoor Power Equipment Institute (OPEI), as well as CPSC, have used Constant Steer tests to evaluate vehicle yaw rate divergence. The industry groups have developed protocols for computing the ratio of yaw rate gain at a high lateral acceleration range (0.4 g to 0.5 g) divided by the yaw rate gain at a low lateral acceleration range (0.1 g to 0.2 g), and this ratio is referred to here as Yaw Rate Ratio. Both ROHVA[11] and OPEI[12] have industry voluntary standards that describe similar test and data reduction protocols for computing Yaw Rate Ratio for ROVs. The same test and data reduction protocols were used for the current ATV testing. The only significant difference is that for the ATV testing, the high range of lateral accelerations was reduced to a range of 0.3 g to 0.4 g because the ATVs tested exhibit rollover at a lower lateral acceleration range (from 0.38 g to 0.56 g) than ROVs.

The test procedure used for the Yaw Rate Ratio tests was:

1. Follow a 100 ft diameter (50 ft radius) circle at a speed less than 10 mph until the mean steer angle required to maintain the circular path is established (this is referred to as "initial steer" in this report). *Test Note: For the autonomous tests conducted using steering based on a 50 ft radius path, the initial steer was determined from the 50 ft radius circle tests. If a vehicle understeers during portions of a Yaw Rate Ratio test, its path radius could increase significantly, based on the amount of its understeer. If the path of a vehicle became large enough to run off of the available test surface, the test starting on a 50 ft radius was terminated and the testing was conducted using a starting diameter of 25 ft. For tests conducted using steering based on a 25 ft radius path, a test*

[10] Ibid

[11] American National Standard for Recreational Off-Highway Vehicles, ANSI/ROHVA 1-2016, May 2016.

[12] American National Standard for Multipurpose Off-Highway Utility Vehicles, ANSI/OPEI B71.9-2016, August 2016.

driver drove the loaded test vehicles counterclockwise slowly around a 25 ft radius circular path to determine the initial steer.

2. The ATV RTD was then used to steer the steering column (handlebars) to the initial steer angle and hold it there for the duration of the test.
3. The vehicle was then steadily accelerated at a rate not to exceed 1 mph/second. Efforts were made to program the RTD throttle to complete each test run in about 60 seconds, and the tests for many of the vehicles are close to 60 seconds in duration. However, some of these autonomous tests were in the range of 40 seconds in duration and some were close to 80 seconds in duration.
4. The test engineer ended the tests when a lateral acceleration of at least 0.4 g was achieved.
5. Items 2-4 were repeated until at least five runs in the left steer direction were completed.

Detailed results from the Constant Steer tests are contained in Appendix C.

3. DISCUSSION OF TEST RESULTS

Appendix B contains a collection of tables and bar charts summarizing selected results from the dynamic testing. Detailed graphical results from all of the dynamic testing conducted are contained in Appendix C. This section of the report contains discussions of the results in Appendices B and C.

3.1 Discussion of Appendix B: Summary Tables and Bar Charts

Page 1 of Appendix B contains a summary table and Page 2 a bar chart of the lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the autonomous Rider Active CCW Circle tests. "NA" in the table indicates that no transition to oversteer occurred. For all eight of the vehicles that exhibited transition from understeer to oversteer, the lateral acceleration levels at which the transitions occurred increased for both the 20° driver lean and 40° driver lean loading conditions.

Page 3 of Appendix B contains a bar chart showing the Average Roll Gradients from the CCW Circle tests, the amount of roll angle in degrees per "g" of lateral acceleration measured during the CCW Circle tests. The average values are the average of the roll gradients determined from tests using the three different driver lean loading conditions.

Page 4 contains a table and Page 5 a bar chart of the Threshold Lateral Acceleration (Threshold Ay[13]) determined from the 20 mph Dropped Throttle Left J-Turn tests. Threshold Ay is the minimum peak lateral acceleration required to cause visual two-wheel lift during the J-Turn tests, and it is a metric that is used to categorize a vehicle's tip-up or rollover resistance. The Threshold Ay values increased for both the 20° driver lean and 40° driver lean loading conditions. The fact that the Threshold Ay values increased as the driver lean angles increased was an expected outcome of this study; since the roll stability of an ATV is greater when a driver leans into a turn. The increase in Threshold Ay is more pronounced on the lighter vehicles (Vehicles B, H and I are the three lightest vehicles with manual transmissions). For a light vehicle, the driver weight is a larger portion of the overall test weight than it is for a heavy vehicle, so driver lean has a more pronounced effect on the roll response of a light vehicle.

Page 6 of Appendix B contains a table listing the values for the Yaw Rate Ratios determined from the CCW (left turn) Constant Steer (Yaw Rate Ratio) tests for all three loading conditions. This table also contains a column listing the maximum lateral acceleration (Ay) used during the post-processing of the test results (0.4 g for all vehicles in this study), and a column listing the initial path radius used for each vehicle. Page 7 is a bar chart of the Yaw Rate Ratio results. In general, the Yaw Rate Ratios decreased for the 20° driver lean and 40° driver lean loading conditions. For some of the vehicles with the greatest amount of oversteer, vehicles F, I, G, H and J, the Yaw Rate Ratios decreased moderately to significantly for the 20° driver lean and 40° driver lean loading conditions. These results are consistent with results from the Circle tests, in that increasing driver lean angle generally increases vehicle understeer behavior. The four vehicles that did not transition to oversteer in the Circle tests (Vehicles C, D, E and L) have the lowest yaw rate ratios.

[13] In test programs that include both left and right turns, the Threshold Ay values are typically the average of the left and right turn threshold values. In this study, the Threshold Ay values are computed from left turn J-turn tests only.

3.2 Discussion of Appendix C: Results from Dynamic Tests

Appendix C contains the graphical test results for all 12 vehicles tested, in the following order:

- Constant Radius (50 ft) (Circle) Tests
- Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)
- Constant Steer Tests (Yaw Rate Ratio Tests)

Table 4 contains a table of contents for Appendix C, listing the pages containing results for each of the 12 vehicles.

Table 4: Appendix C Table of Contents

Vehicle	Page Numbers	Vehicle	Page Numbers
A	1-26	G	157-182
B	27-52	H	183-208
C	53-78	I	209-234
D	79-104	J	235-260
E	105-130	K	261-286
F	131-156	L	287-312

The discussion in this section will cover each test in the order listed above. A couple of general comments regarding the graphs presented for all test types are:

- The lateral accelerations shown on the graphs are the lateral accelerations parallel to the road plane, not the vehicle body-fixed lateral accelerations.
- For the 20° and 40° driver lean loading condition tests the roll angle has some static, negative-valued offset angle caused by the fact that movable mass was moved to the left to represent a driver leaning to the left during a left turn maneuver.
- The steering angles shown on the graphs are generally roadwheel steer angles, which are the measured steering column angles divided by the measured steering ratios (The measured steering ratios between the steering columns and roadwheels ranged from 1.21:1 to 1.62:1). However, in the case of all of tests conducted on Vehicle B and the Yaw Rate Ratio tests conducted on Vehicle J, the steering column angle sensor was not functioning. In these cases, the steering angles shown on the graphs are Steer Motor/Ratio (where Ratio is the measured steering ratio between the handlebar angle, the ATV RTD input angle, and the roadwheels).
- The ATV RTD was used for all of the Circle, J-Turn, and Yaw Rate Ratio tests. For tests using the ATV RTD, the commanded steering input is the input to the ATV RTD steering

motor. The ATV RTD steering angle and the steering column angle are not exactly one-to-one, due to compliance in the ATV RTD four-bar linkage arrangement, its motor base mounting to the vehicles, and the handlebars.

3.2.1 Constant Radius (50 ft) (Circle) Tests

For each vehicle, there are four pages showing results from the counterclockwise (CCW) Circle tests in all three loading conditions. The first page shows time domain plots of Roadwheel Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate. All of the dynamic test data is sampled at 100 Hz. For the Circle test results, the data shown was digitally low-pass filtered to 1.0 Hz using a phaseless, eighth-order, Butterworth filter. The circle tests are quasi-steady state tests, and it is common to use a low pass filter on data from these tests. The time domain data shown for each vehicle contains all of the data from the time the test engineer started the ATV RTD data acquisition (prior to when the vehicle started to move forward on the circle) to the time when the ATV RTD stopped collecting data (after at least 0.4 g lateral acceleration was achieved and the test was ended).

On the first page of Circle test graphs for each vehicle, the thin black lines show the full range of data collected. The thicker lines (red for No (0°) driver lean, blue for 20° driver lean, and green for 40° driver lean) indicate the range of data used to fit the subsequent understeer and roll gradient characteristic curves. These ranges typically start from the time the vehicle attained a speed of 5.5 mph, which is a lateral acceleration of 0.04 g on a 50 ft radius circle. By the time most of the vehicles reached 5.5 mph, the RTD steering had settled to a steady state. However, in a few cases, a speed somewhat greater than 5.5 mph was needed before the RTD steering settled to steady state. The range of data used for the curve fits was ended when the vehicle attained a lateral acceleration of 0.40 g. The speed plots show that the Circle tests were conducted using a very slow rate of increase in speed during the circle tests. Regarding conducting circle tests for passenger vehicles, SAE J266[14] states: “If speed is steadily increased, the rate of increase shall not exceed 1.5 km/h per second (0.93 mph per second), and data shall be recorded continuously, so long as the vehicle remains on radius.” The overall rates of speed increase during the Circle tests conducted are less than the J266 recommended maximum allowable rate.

The second page for each vehicle shows graphs of Roadwheel Steer Angle versus Ay (lateral acceleration). The thin lines show data in the selected ranges, as described above. The thicker lines show second-order polynomial curve fits to the range of data selected. The red circles on these graphs are the geometric Ackermann steer angles, a function of the steering ratio (K) times the wheelbase (L) divided by the circle radius (R), given by:

$$\delta_{sw\,(Geometric\,Ackermann)} = \frac{(180/\pi)\times K\times L}{R}$$

The geometric Ackermann steer angles are not the same as the actual roadwheel steer angles required to negotiate the circles at very low speed, with Ay close to zero. The actual roadwheel

[14] SAE Surface Vehicle Recommended Practice - Steady-State Directional Control Test Procedures for Passenger Cars and Light Trucks, SAE J266, 1996.

steer angles, which can be referred to as the measured Ackermann steer angles, are generally greater than the geometric Ackermann steer angles due primarily to compliance and lash in the steering system, and compliance in the suspension systems and tires.

The third page for each vehicle contains a graph of Roadwheel Steer Angle minus Ackermann Angle versus Ay (lateral acceleration). Again, the thin lines show data in the range of data selected for each vehicle as described above, and the thick lines are the second-order polynomial curve fits to the data. Notice that the measured Ackermann steer angles are the abscissae of the curve fits taken at Ay equal to zero, so the curve fits tend to zero as Ay goes to zero. For a circle test: understeer can be defined as the condition when the steering input required to maintain the circular path increases as the vehicle speed increases, neutral steer can be defined as the condition when the steering input required to maintain the circular path does not change as the vehicle speed increases, and oversteer can be defined as the condition when the steering input required to maintain the circular path decreases as the vehicle speed increases. The second-order polynomial curve is a fair representation of the underlying data whether the particular test vehicle exhibits understeer, neutral steer, or oversteer characteristics during the Circle tests.

All of the vehicles tested exhibit understeer at low levels of lateral acceleration and then all of the vehicles except Vehicles C, D, E and L transition to oversteer at higher levels of lateral acceleration. The points of transition from understeer to oversteer are indicated on the graphs by black circles, and they are mathematically the points where the slopes of the curve fits change from being positive to negative. For circle tests where the vehicles exhibited a transition from understeer to oversteer, the values of the lateral acceleration at the points of transition are indicated on the graphs for all three loading conditions.

As mentioned, for all eight of the vehicles that exhibited transition from understeer to oversteer, the lateral acceleration levels at which the transitions occurred increased for both the 20° driver lean and 40° driver lean loading conditions. For these vehicles, the graphs show an overall trend in increased understeer (and reduced oversteer) for the 20° driver lean loading conditions and again for the 40° driver lean loading conditions. For the vehicles that did not exhibit a transition to oversteer, the graphs show that there is little difference in the understeer trends between the three driver lean loading conditions.

The fourth page for each vehicle contains a graph of Roll Angle versus Ay (lateral acceleration) for all three loading conditions. Again, the thin lines show data in the range of vehicle speeds selected for each test. The thick lines are linear curve fits to the data over the selected ranges. Notice that the magnitude of the roll is less for the 20° driver lean loading condition tests and further less for and 40° driver lean loading condition tests. As mentioned, this is a result of the static, negative-valued offset angle caused by the fact that movable mass was moved to the left to represent a driver leaning to the left during a left turn maneuver. However, as the graphs indicate, the static roll angle offset does not influence the roll stiffness (the slopes on the graphs). Thus, the Roll Gradient values listed on the graphs is the average of the roll gradients for the tests using the three different driver lean loading conditions.

3.2.2 Dropped Throttle J-Turn (Step Steer) Tests (Initial Speed of 20 mph)

For each vehicle, there are seven pages of results for the Dropped Throttle J-Turn tests. The first six pages show time domain plots for the tests. For each vehicle, plots of Roadwheel Steer Angle, Lateral Acceleration, Speed, Roll Angle, and Yaw Rate are shown on the first, third, and fifth pages for the 0°, 20° and 40° driver lean loading conditions, respectively. The second, forth, and sixth pages for each vehicle show larger plots of Lateral Acceleration, also for the 0°, 20° and 40° driver lean loading conditions, respectively. Each of the graphs contains plots from six runs, three Northwest bound left steer J-Turns and three Southeast bound left steer J-Turns. All of the tests shown in the plots resulted in visually determined two-wheel lift outcomes. An SAE standard sign convention is used, with Roadwheel Steer Angle, Lateral Acceleration, and Yaw Rate being negative for left turns and Roll Angle being positive for left turns.

For the J-Turn test results, the data shown was digitally low-pass filtered to 2.0 Hz using a phaseless, eighth-order, Butterworth filter. For tests conducted by SEA for CPSC on Recreational Off-Highway Vehicles (ROVs), the same 2.0 Hz. filter was used to filter all J-Turn test data used to select peak lateral acceleration values (Threshold Ay values) during J-Turn tests that resulted in two-wheel lift outcomes. Justification for using a 2.0 Hz low pass filter for selecting peak lateral accelerations is presented in the SEA report to CPSC titled *Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles*.[15] The time domain data shown for each vehicle contains data from 0.5 seconds before the ATV RTD steering input was applied until 5.0 seconds after it was applied.

The seventh page shown for each vehicle contains a summary of the peak lateral accelerations measured in each test. These values are the maximum values of lateral acceleration shown on the plots, which contain data that has been filtered to 2.0 Hz.

The summary pages show the peak lateral accelerations for the three runs conducted in the Northwest left steer direction and in the Southeast left steer direction, for all three loading conditions. The mean values and standard deviations from each set of three Northwest runs and for each set of three Southeast runs are shown on the summary pages. For all three loading conditions, the average of all 6 runs is also shown, and this is the Threshold Ay value. Pages 4 and 5 of Appendix B contain a table and a bar chart, respectively, listing the Threshold Ay values for each vehicle. A discussion of these results is provided in Section 3.1 above.

3.2.3 Constant Steer Tests (Yaw Rate Ratio Tests)

There are 15 pages of Constant Steer test results for each vehicle, five for each loading condition. For each loading condition, the first page shows time domain plots of Roadwheel Steer Angle, Estimated Ay (Estimated Lateral Acceleration), Speed, Roll Angle, and Yaw Rate. Each plot contains results from five left direction steer tests (CCW tests). For all of the graphs from the Constant Steer tests, the Roadwheel Steer Angle, Speed, Roll Angle and Yaw Rate data shown is unfiltered. Per the OPEI and ROHVA ANSI protocols, the Estimated Ay data shown is

[15] *Repeatability of J-Turn Testing of Four Recreational Off-Highway Vehicles*, CPSC Contract CPSC-D-11-0003, SEA, Ltd. Report to CPSC, September 2013. **https://www.cpsc.gov/s3fs-public/SEAReporttoCPSCRepeatabilityTestingSeptember%202013.pdf**

computed by multiplying the Yaw Rate (filtered using a low-pass Butterworth filter with a cut-off frequency of 1.0 Hz) and Speed (filtered using a low-pass Butterworth filter with a cut-off frequency of 1.0 Hz). The thin lines show all of the data collected for each run, and the thick lines show the data from the start of each test to the end of the data range that was selected for post processing, when the lateral acceleration reached 0.4 g.

The second page of results for each loading condition contains the plots of Estimated Ay versus Speed for all five CCW tests. The third page of results contains the plot of Yaw Rate versus Speed for all five tests, and this is the graph that also shows the slope values for the individual test run initial and final ranges (and their standard deviations), the individual test run CCW slope ratios (and their standard deviations), and the average CCW slope ratios (the Yaw Rate Ratios). All of the linear curve fits in the initial and final ranges are shown, and the thick black lines indicate where combinations of yaw rate and speed equal 0.4 g of lateral acceleration.

The following steps were taken to compute the slopes and Yaw Rate Ratios contained on the third page graphs:

1. For each test run, to determine the data regions for analysis, the yaw rate and speed channels were filtered using a low-pass Butterworth filter with a cut-off frequency of 1 Hz. Then the estimated lateral acceleration in units of "g" was computed using the following equation:

$$\text{Estimated } A_y = \frac{\pi}{180} \times \frac{\text{Yaw Rate} \times \text{Speed}}{32.2}$$

   where Yaw Rate is in deg/sec and Speed is in ft/sec.

   The protocol used to compute Estimated Ay is the same as the protocols contained in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016.[16]

2. The estimated lateral acceleration, Estimated A_y, was used to determine the start and stop points for the following regions:

   a. The Initial Region is from 0.1 to 0.2 g.
   b. The Final Region is from 0.3 to 0.4 g.

[16] The equations given in ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 to compute Estimated Ay differ from the equation listed above because metric dimensions are used in the voluntary standards. However, all of the equations compute Estimated Ay in units of "g's", by dividing by the gravitational constant defined as 9.8 m/s^2 or 32.2 ft/s^2.

3. For each test run, in the initial and final regions, linear slopes of unfiltered yaw rate versus data index and linear slopes of unfiltered speed versus data index were computed.[17] The slopes can be classified as:

   a. Y1 = linear slope of the yaw rate versus index plot for Initial Region
   b. Y2 = linear slope of the yaw rate versus index plot for Final Region
   c. V1 = linear slope of the vehicle speed versus index plot for Initial Region
   d. V2 = linear slope of the vehicle speed versus index plot for Final Region

4. The Yaw Rate Ratio (R) for each run was then computed using the following equation:

$$\text{Yaw Rate Ratio (R)} = \frac{\left(\frac{\text{Y2}}{\text{V2}}\right)}{\left(\frac{\text{Y1}}{\text{V1}}\right)}$$

Note: This value may be negative or positive.

5. Steps 1 through 4 were then repeated for all five test runs.

6. The following final slope ratio was then computed:

   Left Turn Yaw Rate Ratio (CCW Average) = Average of the absolute values of the 5 left turn test runs

The fourth page for each test condition contains magnified sections of the individual final slope regions for the left turn (CCW) runs. These graphs also contain black lines indicating where combinations of yaw rate and speed equal 0.4 g of lateral acceleration. A vehicle with severe oversteer in the final slope region will have a steep slope (high Final Slope value), and this will produce a high Yaw Rate Ratio. Steep final slopes are indicative of divergent vehicle behavior, a condition when the yaw rate and lateral acceleration gains are high and the vehicle is prone to yaw and/or tip-up instability.

The fifth page shows individual path plots for the left turn (CCW) runs. As speed is increased during a Constant Steer test, an understeering vehicle will travel on a path of increasing radius, and an oversteering vehicle will travel on a path of decreasing radius. The path plot graphs have green, red, and black line portions, indicating ranges of lateral acceleration during the runs. The initial regions are shown with the green lines and the final regions are shown with the red lines.

Page 7 in Appendix B is a bar chart summarizing the Yaw Rate Ratio results. In the loading conditions tested, Vehicles C, D, E and L are the most understeering vehicles; and they did not transition to oversteer during any of the Circle tests conducted. As mentioned previously, in general, the Yaw Rate Ratios decreased for the 20° driver lean and 40° driver lean loading conditions. For some of the vehicles with the greatest amount of oversteer, Vehicles F, I, G, H and J, the Yaw Rate Ratios decreased moderately to significantly for the 20° driver lean and 40°

[17] The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 protocols specify computing slopes as versus *time*. Given the form of the final computation for Yaw Rate Ratio, computing the slopes versus *time* or versus *data index* result in the same answer for Yaw Rate Ratio.

driver lean loading conditions. These results are consistent with results from the Circle tests, in that increasing driver lean angle generally increases vehicle understeer behavior.

The ANSI/ROHVA 1-2016 and ANSI/OPEI B71.9-2016 criteria for passing their constant steer handling test using an ROV is that neither the right turn Yaw Rate Ratio nor the left turn Yaw Rate Ratio exceeds 4.5.

4. COMPARISON OF AUTONOMOUS RIDER ACTIVE RESULTS TO HUMAN DRIVER DPI RESULTS

As mentioned, for the previous Task Order 1 testing,[18] all 12 of the vehicles were tested using a human driver in the representative driver-only (DPI) loading condition. This section contains a comparison of the results from the autonomous Rider Active tests, conducted using 0°, 20° and 40° driver lean angles, with those from some of the human driver DPI tests conducted previously.

To meet the objective of the Rider Active study, which was to evaluate the effect of rider lean on rollover resistance and vehicle handling characteristics, autonomous tests were conducted with each vehicle in the counterclockwise and left-turn directions at 0º rider lean, and then at angles representing 20º and 40º rider lean. Tests were only conducted in the CCW and left-turn directions.

In the sections below, Circle Test Transition values and J-Turn Test Threshold Ay values from Rider Active tests in the CCW and left turn directions are compared with averaged CW/CCW and right/left values from the human driver DPI tests. Circle Test Transition values and J-Turn Test Threshold Ay values are normally averaged and not significantly different in different turn directions. However, for Yaw Rate Ratio values, which sometimes differ significantly in different turn directions, comparisons are made between results from CCW tests only.

4.1 Comparison of Circle Test Results

Table 5 is a summary table of the lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the autonomous Rider Active and human driver DPI Circle tests. For the autonomous Rider Active tests, the values listed are from one CCW Circle test, and for the human driver DPI tests the values listed are the average of CW and CCW Circle tests. "NA" in the table indicates that no transition to oversteer occurred.

Two of the vehicles, Vehicles D and E, understeered through the entire range of lateral accelerations tested in all three autonomous Rider Active and in the human driver DPI loading conditions (i.e. they did not transition to oversteer). For these two vehicles, the general shapes of their characteristics curves (graphs of Roadwheel Steer Angle versus Ay) are similar between all four loading conditions (graphs from the human driver DPI loading condition tests are included in the reference cited below).

Two other vehicles, Vehicles C and L, did not transition to oversteer during any of the autonomous tests using all three driver lean angles, but they did during the human driver DPI loading condition tests. Vehicles C and L also had lower Yaw Rate Ratios (below and close to 1.0, respectively) in all of the autonomous Rider Active tests than they did during the human driver DPI tests (Table 7). The lower Yaw Rate Ratio values measured during the autonomous tests indicate that the vehicles remained understeering up to 0.4 g of lateral acceleration, as was shown by the autonomous Circle tests.

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[18] *Vehicle Characteristics Measurements of All-Terrain Vehicles – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, November 2016. https://www.cpsc.gov/s3fs-public/SEA_Report_to_CPSC_Vehicle_Characteristics_Measurements_of_All_Terrain_Vehicles.pdf

Eight of the vehicles (Vehicles A, B, F, G, H, I, J and K) transitioned from understeer to oversteer in all three autonomous Rider Active and in the human driver DPI loading condition tests. For all of these vehicles except Vehicle I, the transition values measured during autonomous tests with 0° driver lean are very close (within 0.02 g) to the values measured during human driver DPI tests. For Vehicle I, the transition value is 0.05 g higher during the autonomous test with 0° driver lean than during human driver DPI tests. As mentioned previously, for all eight of these vehicles, the transition values and graphs from the Rider Active tests show an overall trend in increased understeer (and reduced oversteer) for the 20° driver lean loading conditions and again for the 40° driver lean loading conditions.

Figure 3 is a bar chart showing the Roll Gradients, the amount of roll angle in degrees per “g” of lateral acceleration, measured during the autonomous Rider Active and human driver DPI Circle tests. The autonomous Circle tests were conducted in the CCW direction only, but nevertheless the measured roll gradients are relatively close between the autonomous Rider Active and human driver DPI test conditions.

4.2 Comparison of J-Turn Test Results

A summary of the Threshold Lateral Acceleration (Threshold Ay) values determined from the 20 mph Dropped Throttle J-Turn tests for all four loading conditions is given in Table 6. A bar chart with the same information is provided in Figure 4. The bar chart also shows each of the vehicle curb weights.

As mentioned, for the autonomous test, the Threshold Ay values increased for both the 20° driver lean and 40° driver lean loading conditions. The fact that the Threshold Ay values increased as the driver lean angles increased was an expected outcome of this Rider Active study; since the roll stability of an ATV is greater when a driver leans into a turn.

For all of the vehicles except Vehicle L, the Threshold Ay values were greater during the autonomous Rider Active tests than they were for the human driver DPI tests. Figure 5 is a bar chart showing the Threshold Ay values for the autonomous tests with 0° driver lean and for the human driver DPI tests. The bar chart is ranked using the autonomous 0° driver lean test Threshold Ay values, with the vehicle with the lowest value starting on the left. There are several differences in the loading and test conditions that could explain the differences shown on Figure 5. The autonomous tests were conducted in only the left-turn direction (but this does not explain why Threshold Ay values are greater in autonomous tests than in human driver tests for 11 of 12 vehicles). Although the drivers attempted to remain upright during the tests, the study done to quantify driver lateral lean angles suggests that they did lean somewhat during the human driver DPI tests. While they were likely leaning into the turn, they might have shifted their weight laterally or adjusted their feet/leg positions and loads in a manner that actually reduced the Threshold Ay values (compared to the rigidly affixed weight frame that did not lean or move relative to the chassis during the autonomous tests). Also, the drivers likely reacted differently on the different ATVs tested (for example, during the upright-driver tests conducted to quantify driver lean angles, both test drivers leaned more relative to the chassis on the light vehicle than they did on the heavy vehicle).

All of the vehicles exhibit rear wheel lift prior to front wheel lift in the J-turn tests with two-wheel lift outcomes. Another difference between the autonomous tests and the human driver tests is the fact that the overall vehicle longitudinal CG locations were more rearward during the autonomous tests than they were for the human driver tests. Moving the CG rearward causes more roll moment to be carried by the rear suspension during the J-turn tests, and all of the ATVs tested likely have rear suspensions with greater roll stiffness on their rear suspensions than on their front suspensions. Therefore, more rearward loading would somewhat increase the rollover resistance of the vehicles. The more rearward loading also reduces the roll moment transferred on the front suspension, and this might retard front wheel lift; thus requiring slightly great lateral acceleration to cause a visual two-wheel lift outcome.

Despite the differences in the loading and test conditions, the vehicles' Threshold Ay rankings are similar for the autonomous Rider Active and human driver DPI tests. The five vehicles with the lowest Threshold Ay values and the five vehicles with the highest Threshold Ay values are the same for both the autonomous and human driver tests.

4.3 Comparison of Yaw Rate Ratio Test Results

Table 7 contains results comparing the CCW Yaw Rate Ratios determined from the autonomous Rider Active tests and human driver DPI tests.

As mentioned, Vehicles D and E are the most understeering vehicles tested, and these two vehicles have Yaw Rate Ratios less than one in all of the loading conditions tested.

In the autonomous Rider Active loading conditions, Vehicles C and L did not transition to oversteer in the Circle tests, but they did in the human driver DPI Circle tests. For these two vehicles, their Yaw Rate Ratios were less than or close to 1.0 (0.18 to 0.53 for Vehicle C and 1.20 to 1.32 for Vehicle L) in the autonomous tests. These Yaw Rate Ratios are less than the Yaw Rate Ratios measured during the human driver DPI loading condition tests. The autonomous values indicate that Vehicle C and L remained understeering throughout the autonomous constant steer tests (up to 0.4 g), and this is consistent with the autonomous Circle tests done using the same loading conditions.

As mentioned previously, in general, the Yaw Rate Ratios decreased for the 20° driver lean and 40° driver lean loading conditions. For some of the vehicles with the greatest amount of oversteer, Vehicles F, G, H, I and J, the Yaw Rate Ratios decreased moderately to significantly for the 20° driver lean and 40° driver lean loading conditions. These results are consistent with results from the Circle tests, in that increasing driver lean angle generally increases vehicle understeer behavior.

Figure 6 is a bar chart showing the Yaw Rate Ratio values for the autonomous tests with 0° driver lean and for the human driver DPI tests. The bar chart is ranked using the autonomous 0° driver lean test Yaw Rate Ratio values, with the vehicle with the lowest value starting on the left. The vehicles with the lowest Yaw Rate Ratios in the autonomous 0° driver lean tests (Vehicles E, D, C and L) have been discussed above. Vehicle H had similar Yaw Rate Ratios in both test conditions.

The remaining seven vehicles, Vehicles A, B, F, G, I, J and K had higher Yaw Rate Ratios in the autonomous 0° driver lean tests than in the human driver DPI tests. In the human driver DPI loading condition tests, Vehicles A and F exhibited the phenomenon of going from understeer to oversteer and then back to understeer, all at lateral acceleration levels less than 0.4 g. For Vehicles A and F, the human driver DPI Yaw Rate Ratio values shown on Figure 6 are based on using estimated lateral acceleration ranges extending up to the point of inflection from oversteer back to understeer (0.27 g to 0.32 g for Vehicle A and 0.26 g to 0.31 g Vehicle F) to compute the final slope ratios. The fact that lower lateral acceleration final slope ranges were used for Vehicle A and Vehicle F explains some of the reasons why Yaw Rate Ratios were lower for these two vehicles in the human driver DPI tests.

For the constant steer tests, the differences in the loading and test conditions described above could explain the differences shown on Figure 6. How the drivers' moved and how they supported themselves on particular ATVs during the tests, and the fact that the longitudinal CG locations were more rearward during the autonomous tests than during the human driver tests, could have some influence on the Yaw Rate Ratio values. These influences resulted in some vehicles having lower, and some vehicles having higher, Yaw Rate Ratios in the autonomous tests compared to the human driver DPI tests.

4.4 Summary

The differences in the loading and test conditions between the autonomous Rider Active tests and the human driver DPI tests caused differences in the test results for the two series of tests. Vehicles C and L exhibited understeer through 0.4 g of lateral acceleration in both the Circle and Yaw Rate Ratio tests in the autonomous Rider Active loading condition tests but not in the human driver DPI tests. The Circle test results for the other vehicles were fairly consistent for the two series of tests.

For 11 of the 12 vehicles tested, the Threshold Ay values were greater during the autonomous Rider Active tests than they were for the human driver DPI tests. Differences in longitudinal CG location between the two series of tests, and the fact that one series used human drivers (that moved in response to the tests) while the other series used a fixed weight frame for driver ballast, were likely the main causes of the differences in the Threshold Ay values. However, the ranking of the vehicles' Threshold Ay values were fairly consistent between the two series of tests.

The same two vehicles (Vehicles D and E) had the two lowest and the same two vehicles (Vehicles H and J) had the two highest Yaw Rate Ratios in both series of tests. Vehicles C and L had lower Yaw Rate Ratios in the autonomous tests than in the human driver tests. Vehicle H had similar Yaw Rate Ratios in both test conditions. Vehicles A, B, F, G, I, J and K had higher Yaw Rate Ratios in the autonomous tests than in the human driver tests.

The autonomous tests using the fixed weight frame for driver ballast removed the influence of driver motion from the tests. Also, although the longitudinal CG locations were rearward of the longitudinal CG locations measured with only a 215 lb driver, they were closer to the measured locations than they were in the human driver DPI tests. For the most part, both series of tests – despite the differences in loading and test conditions – produced test results that ranked the 12 vehicles similarly and they are both useful for comparing the performance of the vehicles to one another.

Table 5: Comparison of US to OS Transitions Points

Constant Radius (50 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer Autonomous Values: CCW Tests Human Driver Values: Average of CW and CCW Tests				
	Autonomous 0° Driver Lean (g)	Autonomous 20° Driver Lean (g)	Autonomous 40° Driver Lean (g)	Human Driver DPI (g)
Vehicle A	0.17	0.21	0.24	0.16
Vehicle B	0.18	0.21	0.25	0.18
Vehicle C	NA	NA	NA	0.21
Vehicle D	NA	NA	NA	NA
Vehicle E	NA	NA	NA	NA
Vehicle F	0.13	0.16	0.25	0.13
Vehicle G	0.17	0.19	0.22	0.18
Vehicle H	0.15	0.18	0.24	0.13
Vehicle I	0.18	0.21	0.24	0.13
Vehicle J	0.17	0.21	0.24	0.15
Vehicle K	0.25	0.27	0.29	0.24
Vehicle L	NA	NA	NA	0.24

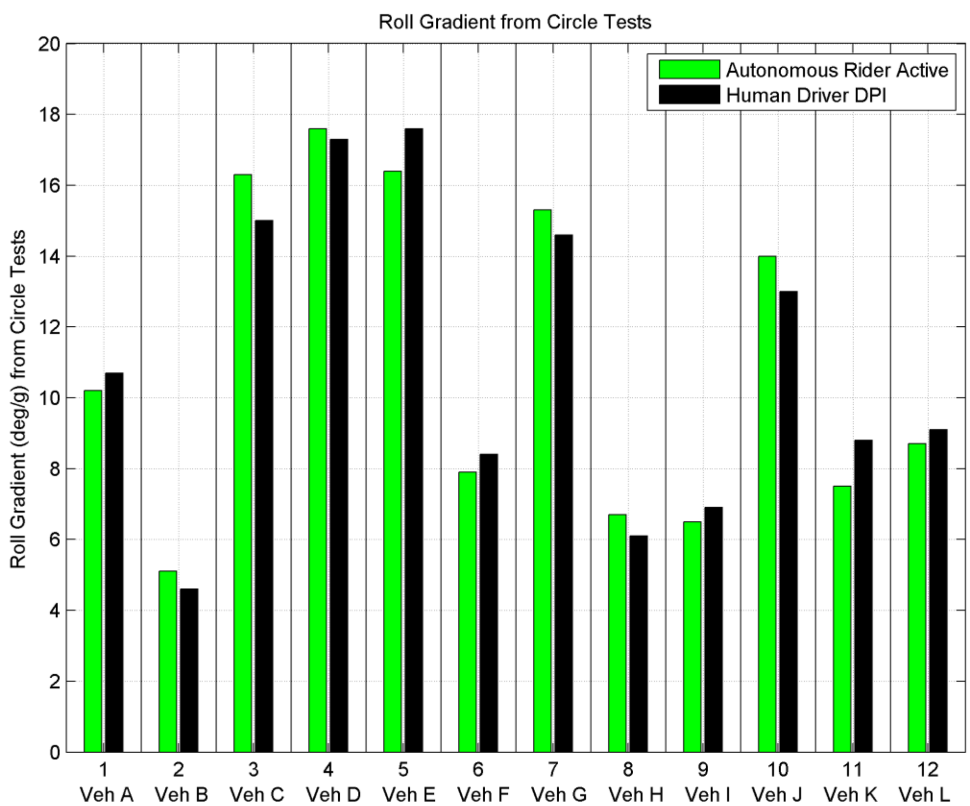


Figure 3: Comparison of Roll Gradients

Table 6: Comparison of Threshold Ay Values

20 mph Dropped Throttle J-Turn Tests **Threshold Lateral Acceleration** Autonomous Values: Left Turns Human Driver Values: Average of Right and Left Turns				
	Autonomous 0° Driver Lean (g)	**Autonomous 20° Driver Lean (g)**	**Autonomous 40° Driver Lean (g)**	**Human Driver DPI (g)**
Vehicle A	0.448	0.465	0.485	0.385
Vehicle B	0.585	0.616	0.650	0.548
Vehicle C	0.520	0.540	0.561	0.495
Vehicle D	0.579	0.596	0.621	0.553
Vehicle E	0.570	0.589	0.597	0.548
Vehicle F	0.465	0.470	0.528	0.411
Vehicle G	0.459	0.481	0.497	0.425
Vehicle H	0.602	0.645	0.685	0.548
Vehicle I	0.551	0.594	0.626	0.502
Vehicle J	0.505	0.528	0.554	0.493
Vehicle K	0.540	0.549	0.577	0.538
Vehicle L	0.558	0.569	0.592	0.565

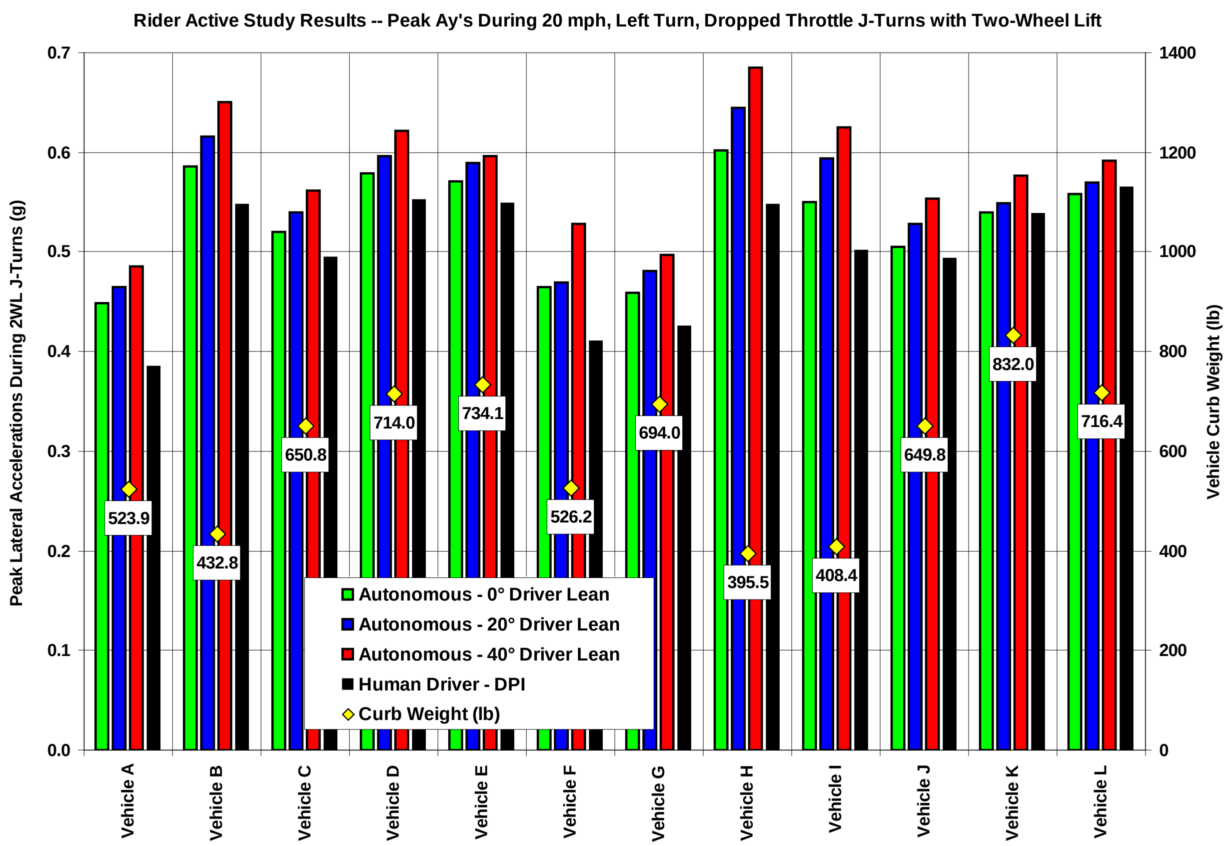


Figure 4: Comparison of Threshold Ay Values

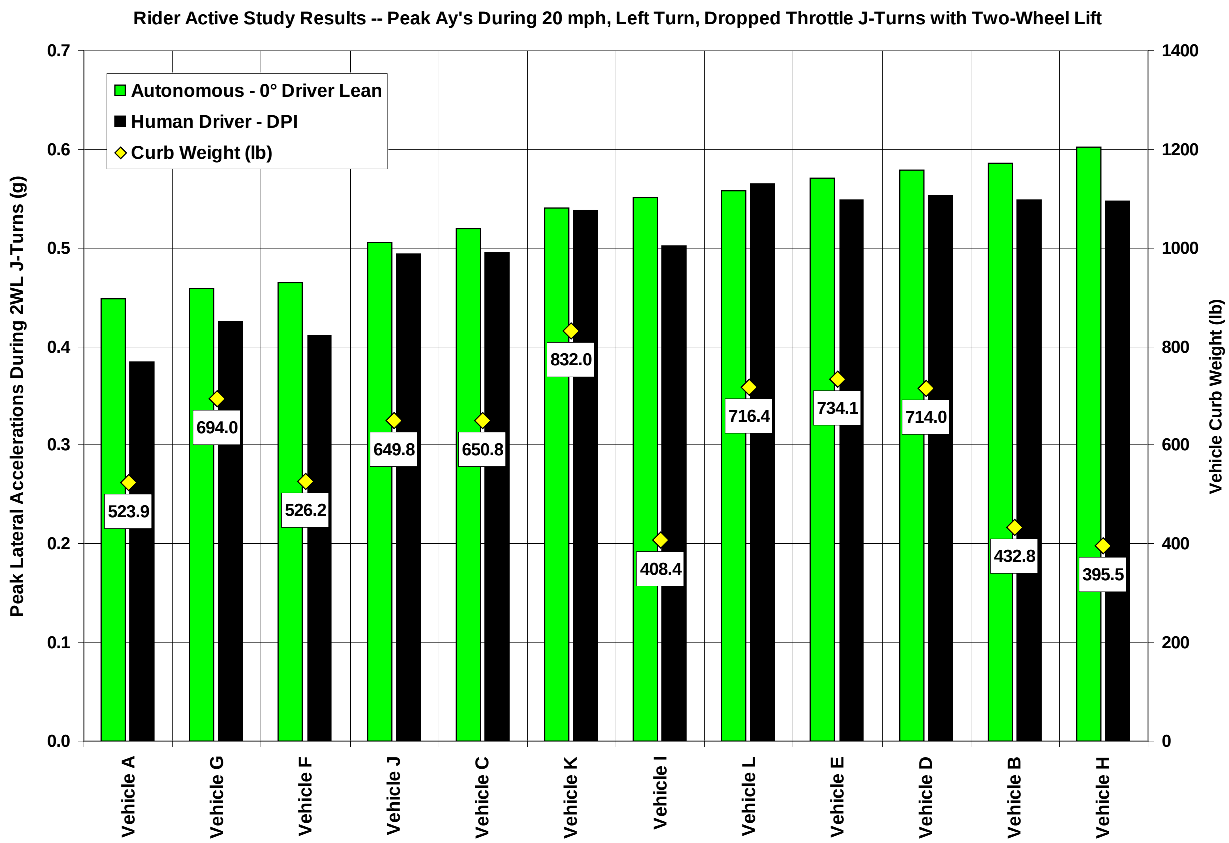


Figure 5: Ranked (by Autonomous 0° Driver Lean Tests) Threshold Ay Values

Table 7: Comparison of Yaw Rate Ratio Values

Constant Steer Tests Yaw Rate Ratios Autonomous Values: CCW Tests Human Driver Values: CCW Tests				
	Autonomous 0° Driver Lean Ratio	Autonomous 20° Driver Lean Ratio	Autonomous 40° Driver Lean Ratio	Human Driver DPI Ratio
Vehicle A	9.70	10.5	8.09	2.50
Vehicle B	3.36	4.16	1.82	3.05
Vehicle C	0.53	0.33	0.18	3.35
Vehicle D	0.25	0.19	0.17	0.19
Vehicle E	0.14	0.20	0.15	0.15
Vehicle F	4.65	3.08	3.38	2.64
Vehicle G	8.40	4.00	4.06	6.93
Vehicle H	9.89	4.38	4.54	10.2
Vehicle I	7.22	4.92	4.08	2.86
Vehicle J	18.1	3.40	2.11	8.96
Vehicle K	2.24	2.44	2.14	1.73
Vehicle L	1.27	1.32	1.20	3.50

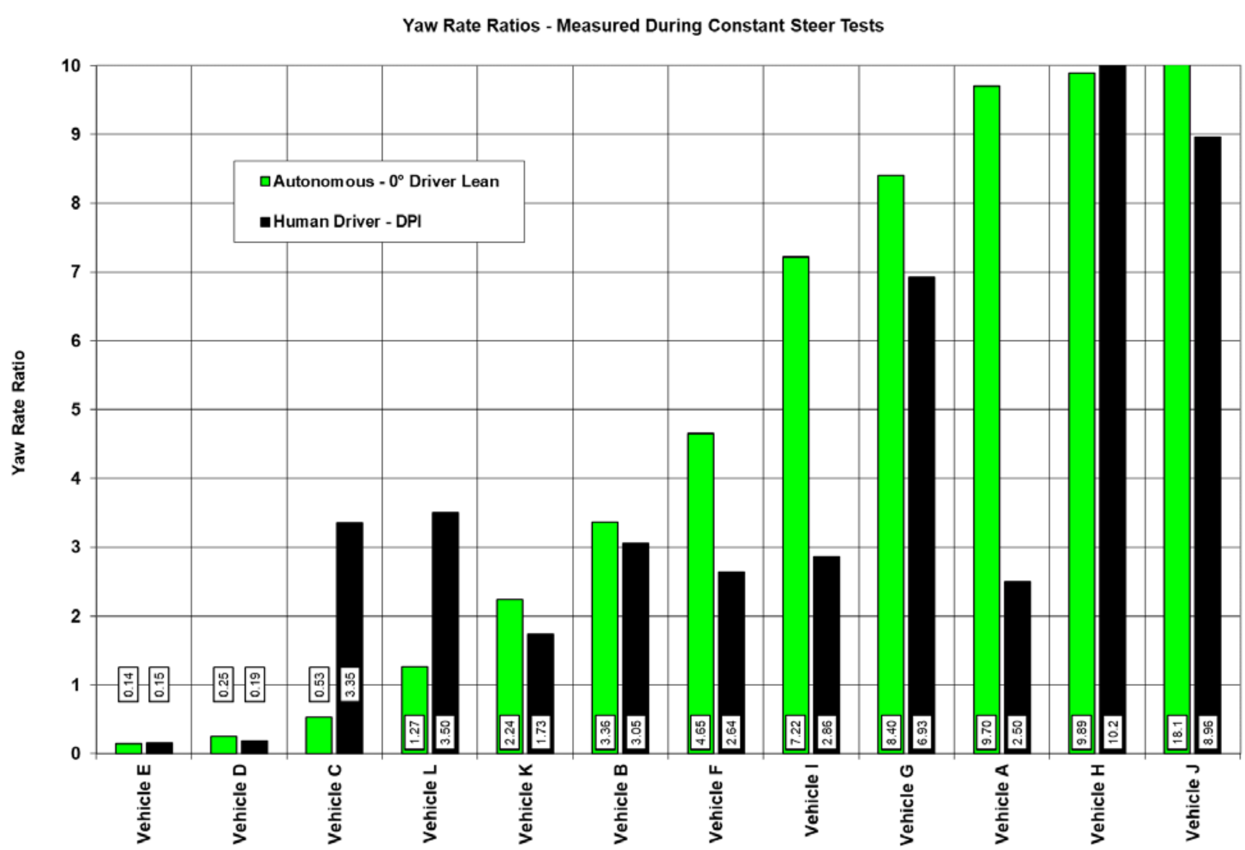


Figure 6: Ranked (by Autonomous 0° Driver Lean Tests) Yaw Rate Ratio Values

5. COMPARISON OF AUTONOMOUS RIDER ACTIVE RESULTS TO AUTONOMOUS 2-RIDER RESULTS

As mentioned, for the previous Task Order 2 testing[19] all 12 of the vehicles were tested autonomously in a 2-Rider (representative 215 lb driver and 215 lb passenger) loading condition. For the 2-Rider loading condition, the vehicles were each tested at a total test weight nominally 430 lb above the curb weight for each vehicle (representing two 215 riders). This section contains a comparison of the results from the autonomous Rider Active tests, conducted using 0° driver lean angle, with those from autonomous 2-Rider tests. The same weight frame was used for both test programs, but the 2-Rider loading condition included adding 215 lb of weight to the frame with no representative driver or passenger lean (i.e. 0° lean angle).

In the sections below, Circle Test Transition values and J-Turn Test Threshold Ay values from Rider Active tests in the CCW and left turn directions are compared to with averaged CW/CCW and right/left values from the 2-Rider tests. Circle Test Transition values and J-Turn Test Threshold Ay values are normally averaged and not significantly different in different turn directions. However, for Yaw Rate Ratio values, which sometimes differ significantly in different turn directions, comparisons are made between results from CCW tests only.

5.1 Comparison of Circle Test Results

Table 8 is a summary table of the lateral acceleration levels at which the vehicles that transitioned from understeer to oversteer did so during the autonomous 0° driver lean (representative 215 lb driver-only loading condition) and autonomous 2-Rider Circle tests. For the autonomous 0° driver lean tests the values listed are from one CCW Circle test, and for the autonomous 2-Rider tests the values listed are the average of CW and CCW Circle tests. “NA” in the table indicates that no transition to oversteer occurred.

Three of the vehicles, Vehicles C, D and E, remained understeering through the entire range of lateral accelerations tested (up to 0.4 g) in both loading conditions (i.e. they did not transition to oversteer). For these three vehicles, the general shapes of their characteristics curves (graphs of Roadwheel Steer Angle versus Ay) are similar for both loading conditions (graphs from the autonomous 2-Rider loading condition tests are included in the reference cited below).

Vehicle L did not transition to oversteer in the autonomous 0° driver lean loading condition, but it did in the autonomous 2-Rider loading condition. In both loading conditions, the Circle test characteristic curves indicate that this Vehicle L is close to neutral steer up to 0.4 g, and this was confirmed by the Constant Steer Tests which yielded Yaw Rate Ratios slightly above 1.0 in both loading conditions (Table 9).

All of the other eight vehicles (Vehicles A, B, F, G, H, I, J and K) transitioned from understeer to oversteer in both loading conditions, and for all of them the transition values measured during autonomous 0° driver lean tests are greater (albeit only slightly greater) than during the autonomous 2-Rider tests.

[19] *Effects on Vehicle Characteristics of Two Persons Riding ATVs – Results from Tests on Twelve 2014-2015 Model Year Vehicles*, HHS Contract HHSP233201400030I, SEA, Ltd. Report to CPSC, In Review.

Figure 7 is a bar chart showing the Roll Gradients measured during the autonomous tests in both loading conditions. The Roll Gradients are greater for of all tests conducted in the 2-Rider loading condition than they were for the tests conducted in 0° driver lean loading condition.

5.2 Comparison of J-Turn Test Results

A summary of the Threshold Lateral Acceleration (Threshold Ay) values determined from the 20 mph Dropped Throttle J-Turn tests for both loading conditions is given in Table 9. A bar chart with the same information is provided in Figure 8. The bar chart also shows each of the vehicle curb weights.

For all of the vehicles, the Threshold Ay values are greater during the autonomous 0° driver lean tests than they are for the autonomous 2-Rider tests. This general result, that a two-rider loading condition provides less rollover stability than a driver-only loading condition is as expected. The comparisons provided in this section are consistent in that there are no influences from a human driver and the changes made between the 0° driver lean loading condition and the 2-Rider loading condition tests were the same for all 12 vehicles.

5.3 Comparison of Yaw Rate Ratio Test Results

Table 10 contains results comparing the CCW Yaw Rate Ratios determined from the autonomous 0° driver lean tests and the autonomous 2-Rider tests. Figure 9 is a bar chart showing the Yaw Rate Ratios for these tests, ranked using the autonomous 0° driver lean test Yaw Rate Ratio values, with the vehicle with the lowest value starting on the left.

The three vehicles that remained understeering during Circle tests in both loading conditions, Vehicles C, D and E, have Yaw Rate Ratios less than 1.0 in both loading conditions. As mentioned, Vehicle L exhibited neutral steer characteristic response in the Circle tests for both loading conditions, and its Yaw Rate Ratios are slightly above 1.0 in both loading conditions.

Vehicle B has a lower Yaw Rate Ratio in the 2-Rider loading condition than in the 0° driver lean loading condition. However, the 2-Rider Constant Steer tests for Vehicle B were terminated due to imminent two-wheel lift at a maximum lateral acceleration level of 0.35 g, and this likely resulted in a lower Yaw Rate Ratio value for the 2-Rider tests than if the they had been conducted up to an acceleration level of 0.4 g.

All of the other seven vehicles (Vehicles A, F, G, H, I, J and K) have higher Yaw Rate Ratios in the 2-Rider loading condition than in the 0° driver lean loading condition. In general, the vehicles with high Yaw Rate Ratios in the 0° driver lean loading condition had significantly higher Yaw Rate Ratios in the 2-Rider loading condition. These results indicate that, for an ATV that exhibits oversteer response with a driver only, adding a second passenger will intensify its oversteer behavior.

5.4 Summary

The Circle test results indicated that the autonomous 2-Rider loading condition generally produces more oversteer than the autonomous 0° driver-only lean loading condition.

For all 12 of the vehicles tested, the Threshold Ay values are greater during the autonomous 2-Rider tests than they are for the autonomous 0° driver lean tests. Also, for all 12 vehicles tested, the Roll Gradients measured during the Circle tests are greater during 2-Rider tests than they are for the 0° driver lean tests. These results indicate that adding a second passenger on an ATV will reduce its tip-up and rollover resistance.

The vehicles with high Yaw Rate Ratios in the 0° driver lean loading condition have significantly higher Yaw Rate Ratios in the 2-Rider loading condition. This indicates that, for an ATV that exhibits oversteer response with a driver only, adding a second passenger will intensify its oversteer behavior. This finding, that lateral stability is reduced by the addition of a passenger, was also indicated by the Circle test results.

As mentioned, the comparisons between the autonomous tests conducted in two different loading conditions provided in this section are consistent in that there are no influences from a human driver and the changes made between the 0° driver lean loading condition and the 2-Rider loading condition tests were the same for all 12 vehicles.

Table 8: Comparison of US to OS Transitions Points

Constant Radius (50 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer Autonomous 0° Driver Lean Values: CCW Tests Autonomous 2-Rider Values: Average of CW and CCW Tests		
	Autonomous 0° Driver Lean (g)	Autonomous 2-Riders (g)
Vehicle A	0.17	0.15
Vehicle B	0.18	0.16
Vehicle C	NA	NA
Vehicle D	NA	NA
Vehicle E	NA	NA
Vehicle F	0.13	0.12
Vehicle G	0.17	0.16
Vehicle H	0.15	0.11
Vehicle I	0.18	0.11
Vehicle J	0.17	0.10
Vehicle K	0.25	0.23
Vehicle L	NA	0.36

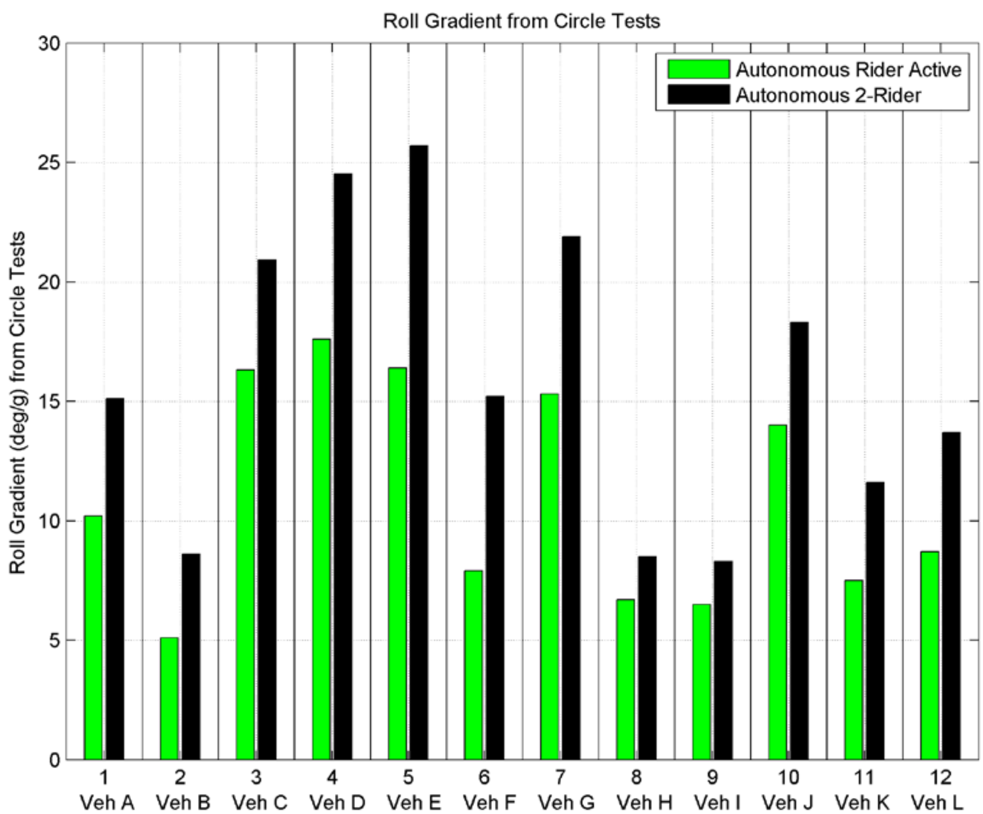


Figure 7: Comparison of Roll Gradients

Table 9: Comparison of Threshold Ay Values

20 mph Dropped Throttle J-Turn Tests Threshold Lateral Acceleration Autonomous 0° Driver Lean Values: Left Turns Autonomous 2-Rider Values: Average of Right and Left Turns		
	Autonomous 0° Driver Lean (g)	Autonomous 2-Riders (g)
Vehicle A	0.448	0.364
Vehicle B	0.585	0.548
Vehicle C	0.520	0.448
Vehicle D	0.579	0.489
Vehicle E	0.570	0.493
Vehicle F	0.465	0.371
Vehicle G	0.459	0.399
Vehicle H	0.602	0.546
Vehicle I	0.551	0.513
Vehicle J	0.505	0.431
Vehicle K	0.540	0.494
Vehicle L	0.558	0.519

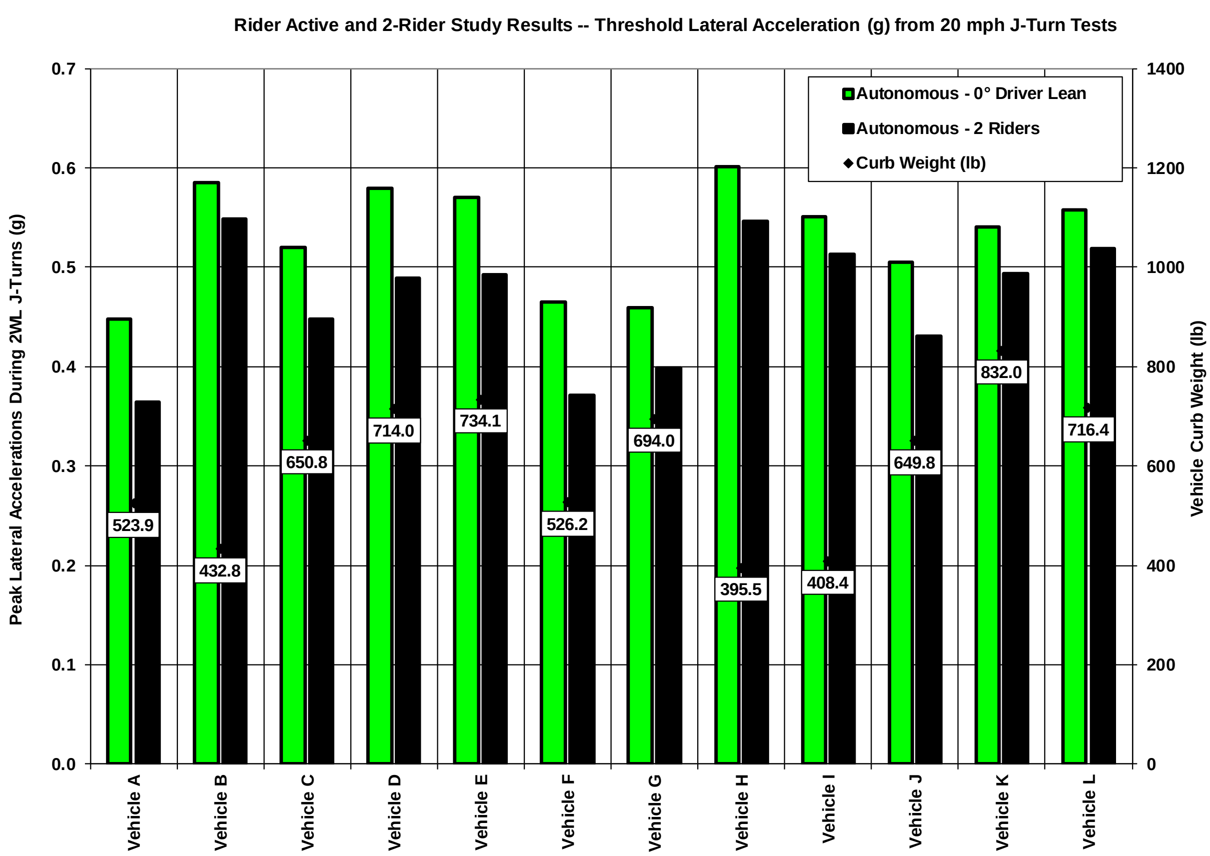


Figure 8: Comparison of Threshold Ay Values

Table 10: Comparison of Yaw Rate Ratios Values

Constant Steer Tests Yaw Rate Ratios Autonomous 0° Driver Lean Values: CCW Tests Autonomous 2-Rider Values: CCW Tests		
	Autonomous 0° Driver Lean Ratio	Autonomous 2-Riders Ratio
Vehicle A	9.70	34.7
Vehicle B	3.36	2.40
Vehicle C	0.53	0.15
Vehicle D	0.25	0.16
Vehicle E	0.14	0.22
Vehicle F	4.65	15.5
Vehicle G	8.40	35.6
Vehicle H	9.89	23.2
Vehicle I	7.22	27.5
Vehicle J	18.1	36.3
Vehicle K	2.24	5.91
Vehicle L	1.27	1.37

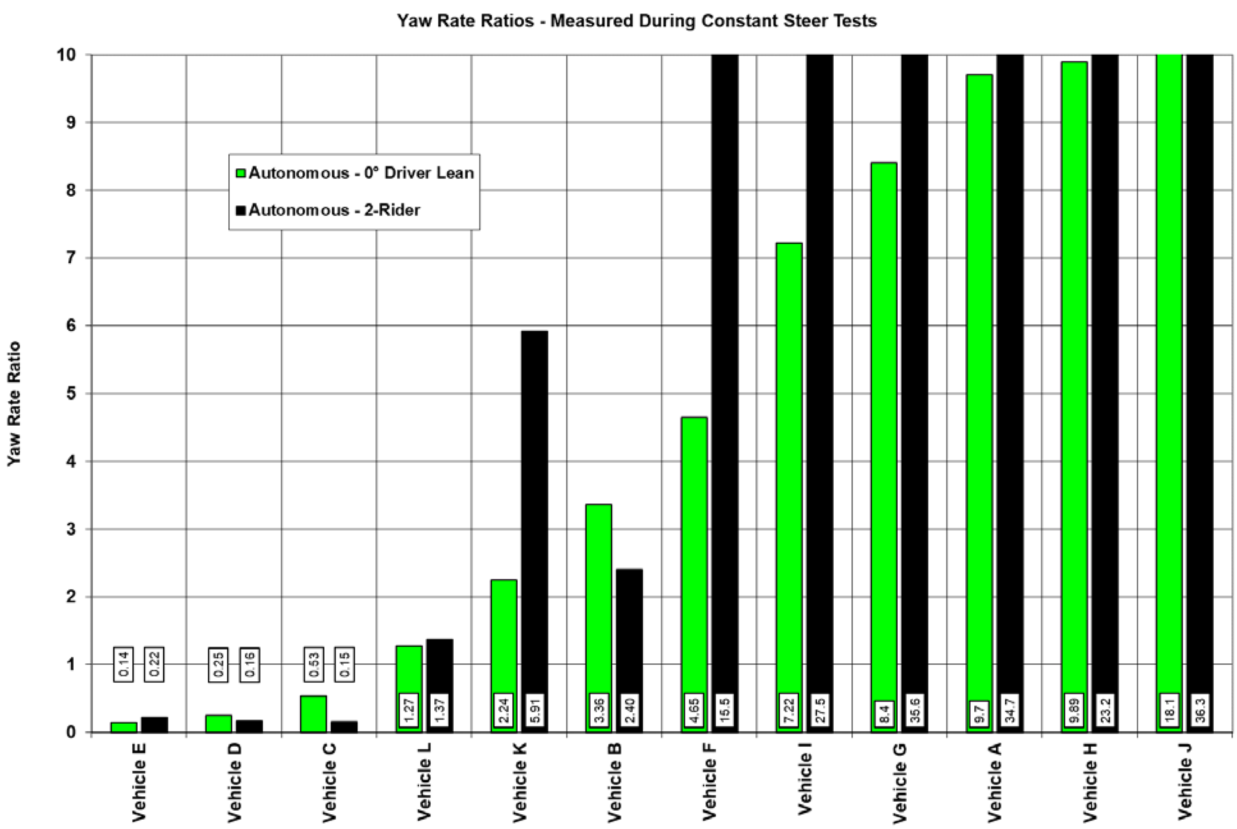


Figure 9: Ranked (by Autonomous 0° Driver Lean Tests) Yaw Rate Ratio Values

Vehicle A

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5765	5766	5842		
Total Vehicle Weight (lb)	523.9	737.1	759.6	989.7	741.1	954.4
Left Front Weight (lb)	151.5	177.3	198.3	232.2	168.4	187.6
Right Front Weight (lb)	118.4	161.0	176.8	212.1	160.4	176.3
Left Rear Weight (lb)	132.0	206.1	204.4	293.5	211.6	300.2
Right Rear Weight (lb)	122.0	192.7	180.1	251.9	200.7	290.3
Front Track Width (in)	33.20	33.50	33.66	33.93	33.50	33.93
Rear Track Width (in)	32.25	32.30	32.28	32.35	32.30	32.35
Average Track Width (in)	32.73	32.90	32.97	33.14	32.90	33.14
Wheelbase (in)	48.40	48.35	48.30	48.25	48.35	48.25
CG Longitudinal (in)	23.47	26.16	24.45	26.59	26.90	29.85
CG Lateral (in)	-1.36	-0.66	-0.99	-1.02	-0.42	-0.37
CG Height (in)		23.61	22.65	25.00		
Roll Inertia - I_{XX} (ft-lb-s^2)		55	66	86		
Pitch Inertia - I_{YY} (ft-lb-s^2)		73	80	141		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		54	63	115		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	3	8		
SSF		0.697	0.728	0.663		
KST		0.698	0.728	0.664		
Steering Ratio (deg/deg)			1.42			

Vehicle B

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5768	5769			
Total Vehicle Weight (lb)	432.8	644.9	689.6		660.8	859.6
Left Front Weight (lb)	117.8	144.0	174.5		143.8	164.2
Right Front Weight (lb)	101.4	130.9	156.6		140.9	158.4
Left Rear Weight (lb)	107.7	181.7	172.0		185.1	258.1
Right Rear Weight (lb)	105.9	188.3	186.5		191.0	278.9
Front Track Width (in)	37.78	38.13	38.45		38.13	38.58
Rear Track Width (in)	35.58	35.50	35.40		35.50	35.50
Average Track Width (in)	36.68	36.81	36.93		36.81	37.04
Wheelbase (in)	50.30	50.85	50.85		50.85	51.50
CG Longitudinal (in)	24.82	29.17	26.44		28.94	32.17
CG Lateral (in)	-0.79	-0.21	-0.13		0.07	0.30
CG Height (in)		22.77	22.34			
Roll Inertia - I_{XX} (ft-lb-s^2)		48	48			
Pitch Inertia - I_{YY} (ft-lb-s^2)		61	71			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		42	56			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	4			
SSF		0.808	0.826			
KST		0.813	0.828			
Steering Ratio (deg/deg)			1.34			

Vehicle C

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5771	5772	5844		
Total Vehicle Weight (lb)	650.8	863.6	885.0	1135.1	864.0	1080.2
Left Front Weight (lb)	175.1	208.3	224.7	251.5	195.0	212.7
Right Front Weight (lb)	163.9	199.5	221.9	245.1	194.0	210.3
Left Rear Weight (lb)	155.9	231.6	225.7	317.5	236.7	324.6
Right Rear Weight (lb)	155.9	224.2	212.7	321.0	238.3	332.6
Front Track Width (in)	39.71	39.95	39.95	40.10	39.95	40.10
Rear Track Width (in)	37.66	38.40	38.45	38.85	38.40	38.85
Average Track Width (in)	38.69	39.18	39.20	39.48	39.18	39.48
Wheelbase (in)	49.33	49.30	49.30	49.30	49.30	49.30
CG Longitudinal (in)	23.63	26.02	24.42	27.73	27.10	29.99
CG Lateral (in)	-0.34	-0.37	-0.35	-0.05	0.01	0.10
CG Height (in)		23.74	22.97	25.50		
Roll Inertia - I_{XX} (ft-lb-s^2)		75	78	109		
Pitch Inertia - I_{YY} (ft-lb-s^2)		92	101	174		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		72	83	147		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		7	5	18		
SSF		0.825	0.853	0.774		
KST		0.826	0.853	0.776		
Steering Ratio (deg/deg)			1.62			

Vehicle D

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5774	5775	5845		
Total Vehicle Weight (lb)	714.0	927.4	948.8	1227.9	929.7	1143.8
Left Front Weight (lb)	179.9	216.3	234.7	268.9	206.6	229.5
Right Front Weight (lb)	169.7	205.7	223.9	269.9	203.7	225.5
Left Rear Weight (lb)	181.7	254.2	246.6	352.7	254.2	338.6
Right Rear Weight (lb)	182.7	251.2	243.6	336.4	265.2	350.2
Front Track Width (in)	39.46	39.90	39.99	40.40	39.90	40.40
Rear Track Width (in)	38.08	38.88	38.85	39.64	38.88	39.64
Average Track Width (in)	38.77	39.39	39.42	40.02	39.39	40.02
Wheelbase (in)	50.05	49.88	49.90	50.00	49.88	50.00
CG Longitudinal (in)	25.54	27.18	25.78	28.06	27.87	30.11
CG Lateral (in)	-0.26	-0.29	-0.29	-0.25	0.17	0.13
CG Height (in)		24.14	23.54	26.27		
Roll Inertia - I_{XX} (ft-lb-s^2)		75	74	119		
Pitch Inertia - I_{YY} (ft-lb-s^2)		108	114	200		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		88	99	170		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		9	6	16		
SSF		0.816	0.837	0.762		
KST		0.817	0.838	0.763		
Steering Ratio (deg/deg)			1.22			

Vehicle E

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5777	5778	5846		
Total Vehicle Weight (lb)	734.1	947.6	968.9	1248.5	948.5	1160.7
Left Front Weight (lb)	190.3	221.1	245.4	277.0	208.9	231.9
Right Front Weight (lb)	168.5	210.1	220.9	260.1	209.1	230.7
Left Rear Weight (lb)	186.9	260.3	251.7	357.8	257.0	346.4
Right Rear Weight (lb)	188.4	256.1	250.9	353.6	273.5	351.7
Front Track Width (in)	39.48	39.80	40.05	40.50	39.80	40.50
Rear Track Width (in)	38.13	39.05	39.20	39.80	39.05	39.80
Average Track Width (in)	38.80	39.43	39.63	40.15	39.43	40.15
Wheelbase (in)	49.95	49.95	49.95	49.95	49.95	49.95
CG Longitudinal (in)	25.54	27.22	25.91	28.46	27.94	30.04
CG Lateral (in)	-0.55	-0.32	-0.52	-0.34	0.34	0.07
CG Height (in)		23.70	23.12	26.24		
Roll Inertia - I_{XX} (ft-lb-s^2)		72	76	125		
Pitch Inertia - I_{YY} (ft-lb-s^2)		108	116	201		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		95	100	169		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	6	20		
SSF		0.832	0.857	0.765		
KST		0.832	0.857	0.766		
Steering Ratio (deg/deg)			1.21			

Vehicle F

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5780	5781	5847		
Total Vehicle Weight (lb)	526.2	739.8	761.4	924.0	741.5	954.5
Left Front Weight (lb)	149.1	166.1	190.7	211.9	162.4	188.7
Right Front Weight (lb)	122.7	172.1	179.2	198.3	159.4	184.3
Left Rear Weight (lb)	151.6	213.1	208.6	270.9	220.8	300.9
Right Rear Weight (lb)	102.8	188.5	182.9	242.9	198.9	280.6
Front Track Width (in)	32.14	32.55	32.45	32.76	32.55	32.76
Rear Track Width (in)	30.71	30.95	30.89	30.98	30.95	30.98
Average Track Width (in)	31.43	31.75	31.67	31.87	31.75	31.87
Wheelbase (in)	46.20	46.20	46.20	46.20	46.20	46.20
CG Longitudinal (in)	22.34	25.08	23.76	25.69	26.15	28.15
CG Lateral (in)	-2.23	-0.38	-0.77	-0.71	-0.52	-0.40
CG Height (in)		23.45	22.38	24.04		
Roll Inertia - I_{XX} (ft-lb-s^2)		53	60	74		
Pitch Inertia - I_{YY} (ft-lb-s^2)		74	78	114		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		52	60	93		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		6	4	11		
SSF		0.677	0.708	0.663		
KST		0.678	0.708	0.665		
Steering Ratio (deg/deg)			1.29			

Vehicle G

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5783	5784	5848		
Total Vehicle Weight (lb)	694.0	909.4	928.6	1168.7	913.5	1127.7
Left Front Weight (lb)	174.2	215.4	223.9	253.3	198.2	220.2
Right Front Weight (lb)	168.1	199.1	219.4	251.0	198.7	222.5
Left Rear Weight (lb)	175.9	246.6	242.5	332.9	253.8	337.6
Right Rear Weight (lb)	175.8	248.3	242.8	331.5	262.8	347.4
Front Track Width (in)	36.35	36.45	36.50	36.45	36.45	36.45
Rear Track Width (in)	35.60	36.10	36.06	36.60	36.10	36.60
Average Track Width (in)	35.98	36.28	36.28	36.53	36.28	36.53
Wheelbase (in)	50.55	50.65	50.60	50.60	50.65	50.60
CG Longitudinal (in)	25.62	27.56	26.44	28.77	28.64	30.74
CG Lateral (in)	-0.16	-0.29	-0.08	-0.06	0.19	0.20
CG Height (in)		24.07	23.34	26.13		
Roll Inertia - I_{XX} (ft-lb-s^2)		79	75	109		
Pitch Inertia - I_{YY} (ft-lb-s^2)		110	117	198		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		88	96	163		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	5	17		
SSF		0.753	0.777	0.699		
KST		0.754	0.777	0.699		
Steering Ratio (deg/deg)			1.41			

Vehicle H

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5789	5790			
Total Vehicle Weight (lb)	395.5	608.7	654.6		621.6	821.2
Left Front Weight (lb)	103.2	130.8	160.0		123.8	138.0
Right Front Weight (lb)	93.4	121.8	161.2		126.9	148.0
Left Rear Weight (lb)	99.6	178.8	163.7		186.9	269.7
Right Rear Weight (lb)	99.3	177.3	169.7		184.0	265.5
Front Track Width (in)	38.75	39.00	39.35		39.00	38.85
Rear Track Width (in)	35.30	35.35	35.33		35.35	35.60
Average Track Width (in)	37.03	37.18	37.34		37.18	37.23
Wheelbase (in)	49.25	49.60	49.30		49.60	50.13
CG Longitudinal (in)	24.77	29.02	25.11		29.60	32.67
CG Lateral (in)	-0.49	-0.33	0.20		0.01	0.15
CG Height (in)		22.08	21.45			
Roll Inertia - I_{XX} (ft-lb-s^2)		48	46			
Pitch Inertia - I_{YY} (ft-lb-s^2)		59	69			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		43	52			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		3	4			
SSF		0.842	0.870			
KST		0.849	0.871			
Steering Ratio (deg/deg)			1.41			

Vehicle I

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5786	5787			
Total Vehicle Weight (lb)	408.4	621.6	656.8		633.2	837.5
Left Front Weight (lb)	100.9	131.8	157.7		123.2	142.4
Right Front Weight (lb)	95.9	132.1	147.1		125.3	140.4
Left Rear Weight (lb)	113.6	187.3	186.3		198.1	284.9
Right Rear Weight (lb)	98.0	170.4	165.7		186.6	269.8
Front Track Width (in)	35.85	36.40	36.50		36.40	36.30
Rear Track Width (in)	35.55	35.63	35.63		35.63	35.63
Average Track Width (in)	35.70	36.01	36.06		36.01	35.97
Wheelbase (in)	47.95	48.35	48.40		48.35	49.35
CG Longitudinal (in)	24.84	27.82	25.94		29.37	32.69
CG Lateral (in)	-0.90	-0.48	-0.85		-0.26	-0.36
CG Height (in)		23.29	22.71			
Roll Inertia - I_{XX} (ft-lb-s^2)		51	49			
Pitch Inertia - I_{YY} (ft-lb-s^2)		56	68			
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		51	53			
Roll/Yaw - I_{XZ} (ft-lb-s^2)		2	3			
SSF		0.773	0.794			
KST		0.774	0.795			
Steering Ratio (deg/deg)			1.33			

Vehicle J

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5792	5793	5851		
Total Vehicle Weight (lb)	649.8	862.4	885.2	1135.3	869.1	1086.3
Left Front Weight (lb)	172.3	202.7	216.1	255.7	195.7	218.1
Right Front Weight (lb)	160.9	195.8	208.8	248.6	195.9	220.9
Left Rear Weight (lb)	151.2	230.4	228.1	313.0	232.7	321.3
Right Rear Weight (lb)	165.4	233.5	232.2	318.0	244.8	326
Front Track Width (in)	36.05	36.73	36.79	36.96	36.73	36.96
Rear Track Width (in)	37.13	38.01	38.00	38.38	38.01	38.38
Average Track Width (in)	36.59	37.37	37.39	37.67	37.37	37.67
Wheelbase (in)	50.50	50.45	50.35	50.25	50.45	50.25
CG Longitudinal (in)	24.60	27.14	26.18	27.93	27.72	29.94
CG Lateral (in)	0.09	-0.08	-0.06	-0.03	0.27	0.13
CG Height (in)		23.76	23.08	25.40		
Roll Inertia - I_{XX} (ft-lb-s^2)		69	68	87		
Pitch Inertia - I_{YY} (ft-lb-s^2)		98	103	176		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		69	89	154		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		8	8	14		
SSF		0.786	0.810	0.742		
KST		0.785	0.810	0.740		
Steering Ratio (deg/deg)			1.42			

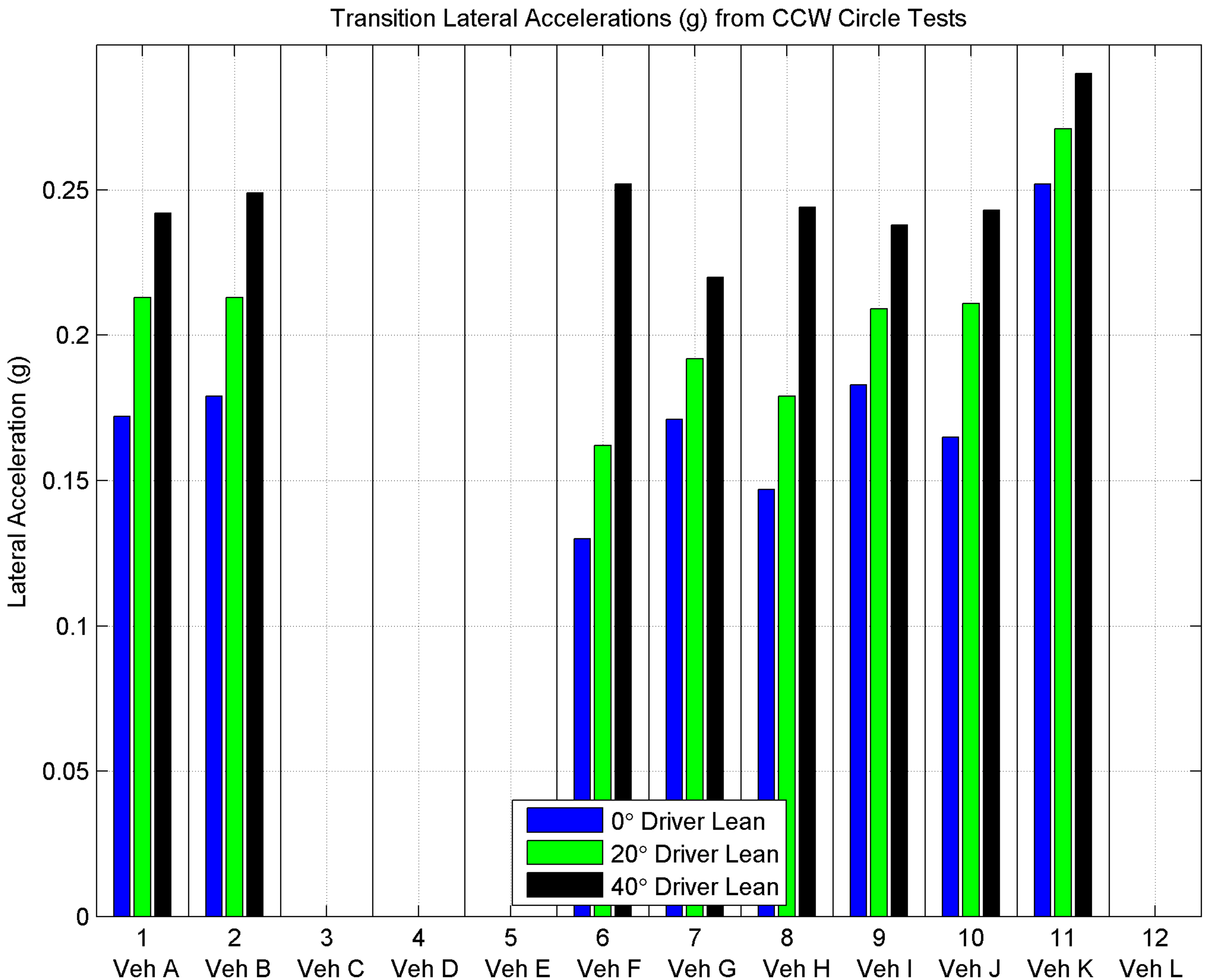
Vehicle K

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5795	5796	5852		
Total Vehicle Weight (lb)	832.0	1044.8	1070.7	1412.1	1045.6	1258.7
Left Front Weight (lb)	206.7	239.9	241.8	283.8	227.0	253.4
Right Front Weight (lb)	192.0	220.6	224.7	268.3	217.7	246.7
Left Rear Weight (lb)	227.2	295.8	303.9	435.4	294.9	372.6
Right Rear Weight (lb)	206.1	288.5	300.3	424.6	306.0	386.0
Front Track Width (in)	39.96	40.83	40.83	41.30	40.83	41.30
Rear Track Width (in)	38.20	39.24	39.16	40.13	39.24	40.13
Average Track Width (in)	39.08	40.03	39.99	40.71	40.03	40.71
Wheelbase (in)	53.15	53.15	53.20	53.20	53.15	53.20
CG Longitudinal (in)	27.68	29.72	30.02	32.40	30.54	32.06
CG Lateral (in)	-0.84	-0.51	-0.39	-0.38	0.03	0.10
CG Height (in)		23.44	22.92	25.51		
Roll Inertia - I_{XX} (ft-lb-s^2)		73	79	110		
Pitch Inertia - I_{YY} (ft-lb-s^2)		130	138	234		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		116	126	208		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		4	5	17		
SSF		0.854	0.873	0.798		
KST		0.856	0.875	0.800		
Steering Ratio (deg/deg)			1.43			

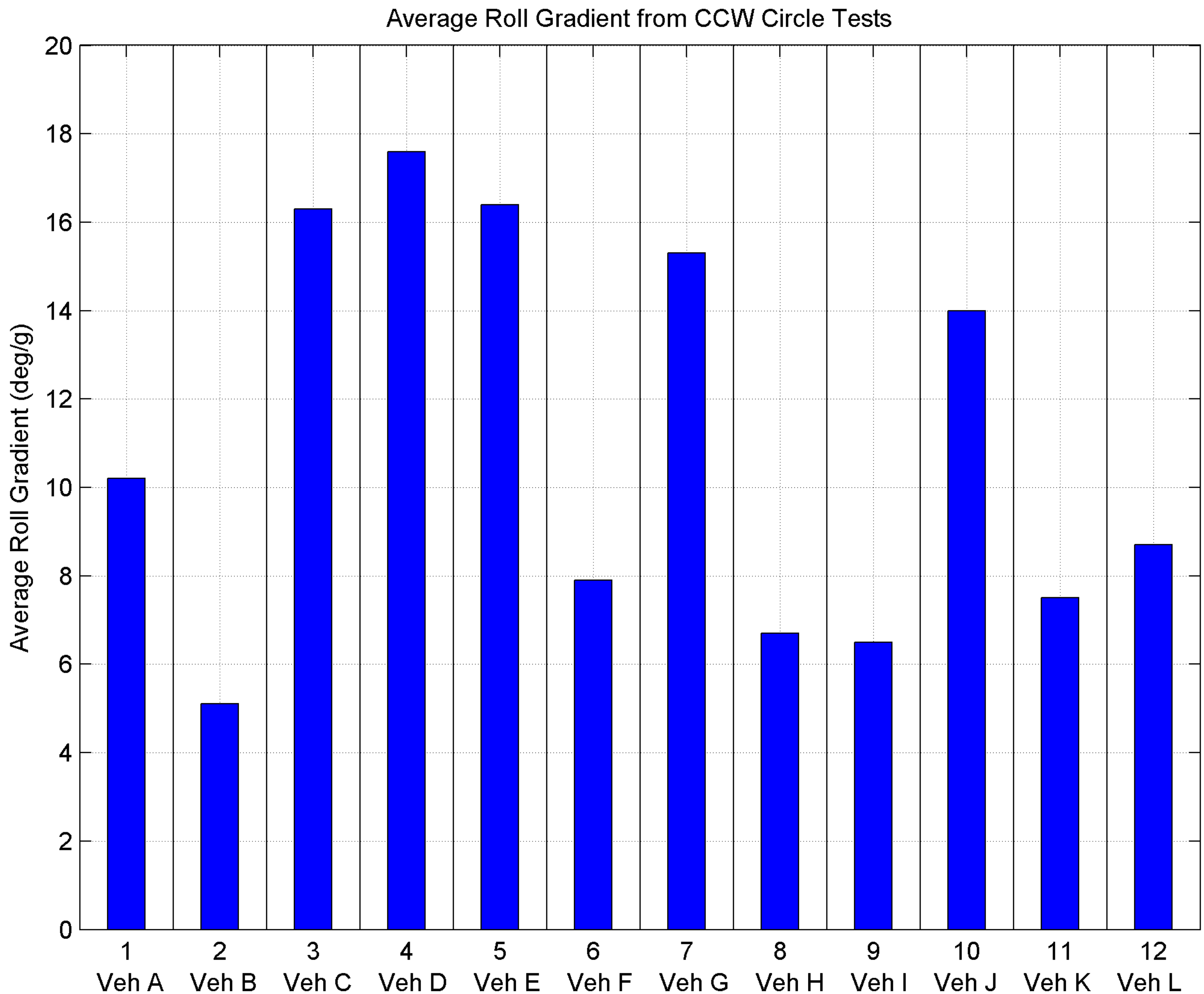
Vehicle L

	Curb	Driver	Driver Plus Instrumentation (DPI)	Gross Vehicle Weight (GVW)	Autonomous Ballast to Driver Loading	Autonomous Ballast to 2 Riders
VIMF Test Number		5798	5799	5853		
Total Vehicle Weight (lb)	716.4	929.1	951.1	1201.3	932.4	1142.1
Left Front Weight (lb)	185.8	216.9	235.3	261.4	205.6	231.1
Right Front Weight (lb)	159.6	202.4	217.1	250.3	197.4	221.0
Left Rear Weight (lb)	189.5	253.1	246.8	342.1	253.1	334.7
Right Rear Weight (lb)	181.5	256.7	251.9	347.5	276.3	355.3
Front Track Width (in)	39.59	39.76	39.80	39.40	39.76	39.40
Rear Track Width (in)	37.00	37.50	37.50	36.90	37.50	36.90
Average Track Width (in)	38.29	38.63	38.65	38.15	38.63	38.15
Wheelbase (in)	50.50	50.60	50.60	50.45	50.60	50.45
CG Longitudinal (in)	26.15	27.76	26.53	28.96	28.73	30.48
CG Lateral (in)	-0.93	-0.24	-0.28	-0.10	0.29	0.16
CG Height (in)		22.96	22.53	25.02		
Roll Inertia - I_{XX} (ft-lb-s^2)		78	84	132		
Pitch Inertia - I_{YY} (ft-lb-s^2)		115	120	185		
Yaw Inertia - I_{ZZ} (ft-lb-s^2)		98	101	157		
Roll/Yaw - I_{XZ} (ft-lb-s^2)		5	7	18		
SSF		0.841	0.858	0.762		
KST		0.844	0.859	0.766		
Steering Ratio (deg/deg)			1.60			

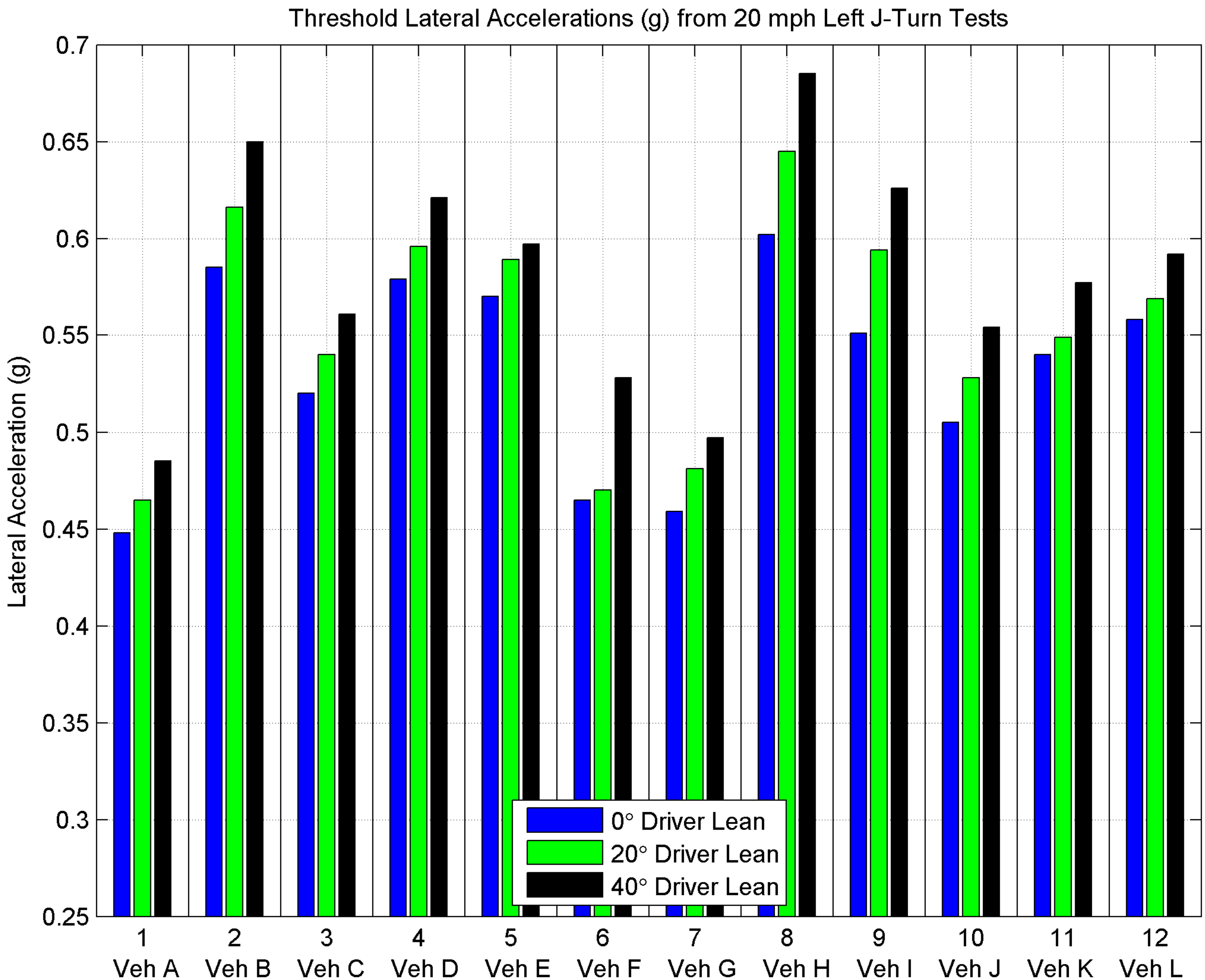
CCW Constant Radius (50 ft) Circle Tests Lateral Acceleration Level at Point of Transition from Understeer to Oversteer (Autonomous Rider Active Loading)			
	0° Driver Lean (g)	20° Driver Lean (g)	40° Driver Lean (g)
Vehicle A	0.17	0.21	0.24
Vehicle B	0.18	0.21	0.25
Vehicle C	NA	NA	NA
Vehicle D	NA	NA	NA
Vehicle E	NA	NA	NA
Vehicle F	0.13	0.16	0.25
Vehicle G	0.17	0.19	0.22
Vehicle H	0.15	0.18	0.24
Vehicle I	0.18	0.21	0.24
Vehicle J	0.17	0.21	0.24
Vehicle K	0.25	0.27	0.29
Vehicle L	NA	NA	NA



Transition Lateral Accelerations (g) from CCW Circle Tests
Lateral Acceleration (g)
0.25
0.2
0.15
0.1
0.05
0
0° Driver Lean
20° Driver Lean
40° Driver Lean
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L


Average Roll Gradient from CCW Circle Tests
Average Roll Gradient (deg/g)
0
2
4
6
8
10
12
14
16
18
20
1
Veh A
2
Veh B
3
Veh C
4
Veh D
5
Veh E
6
Veh F
7
Veh G
8
Veh H
9
Veh I
10
Veh J
11
Veh K
12
Veh L

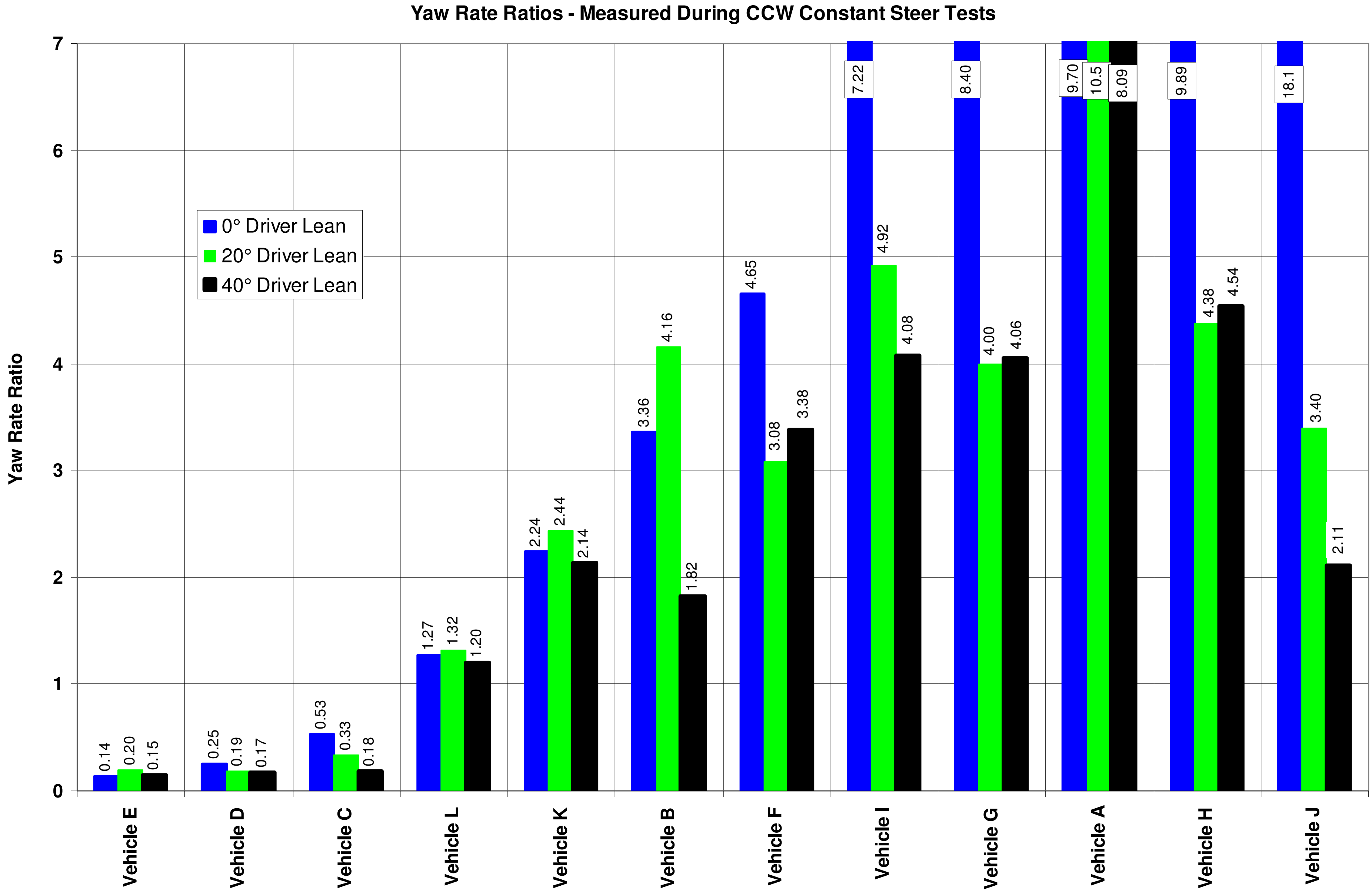
20 mph Left Turn Dropped Throttle J-Turn Tests Threshold Lateral Acceleration (Autonomous Rider Active Loading)			
	0° Driver Lean (g)	20° Driver Lean (g)	40° Driver Lean (g)
Vehicle A	0.448	0.465	0.485
Vehicle B	0.585	0.616	0.650
Vehicle C	0.520	0.540	0.561
Vehicle D	0.579	0.596	0.621
Vehicle E	0.570	0.589	0.597
Vehicle F	0.465	0.470	0.528
Vehicle G	0.459	0.481	0.497
Vehicle H	0.602	0.645	0.685
Vehicle I	0.551	0.594	0.626
Vehicle J	0.505	0.528	0.554
Vehicle K	0.540	0.549	0.577
Vehicle L	0.558	0.569	0.592


Threshold Lateral Accelerations (g) from 20 mph Left J-Turn Tests
Lateral Acceleration (g)
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
1 Veh A
2 Veh B
3 Veh C
4 Veh D
5 Veh E
6 Veh F
7 Veh G
8 Veh H
9 Veh I
10 Veh J
11 Veh K
12 Veh L
0° Driver Lean
20° Driver Lean
40° Driver Lean

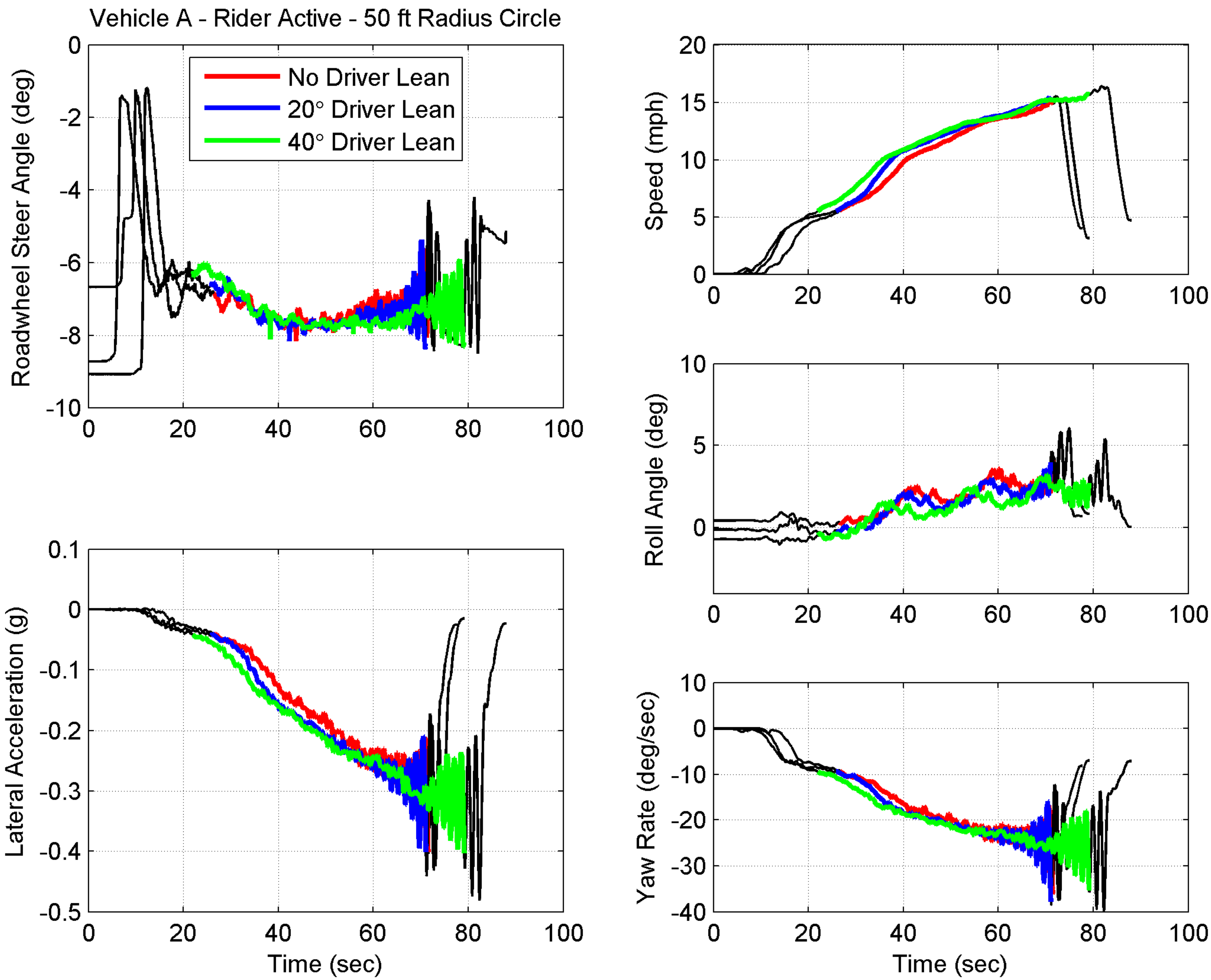
CCW Constant Steer Tests

Yaw Rate Ratios
(Autonomous Rider Active Loading)

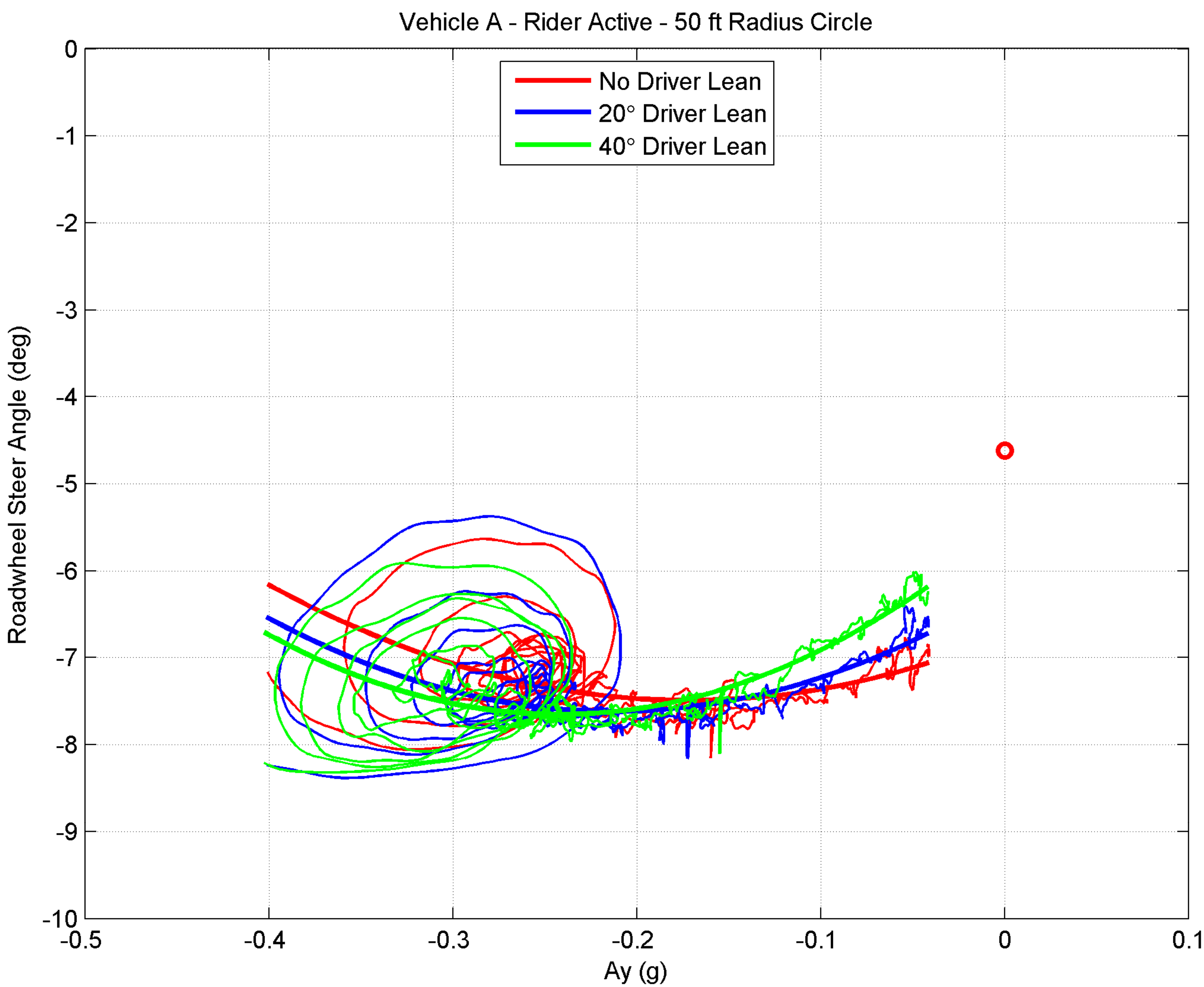
	Maximum Ay Used (g)	Initial Path Radius (ft)	0° Driver Lean Ratio	20° Driver Lean Ratio	40° Driver Lean Ratio
Vehicle A	0.40	50	9.70	10.5	8.09
Vehicle B	0.40	50	3.36	4.16	1.82
Vehicle C	0.40	50	0.53	0.33	0.18
Vehicle D	0.40	25	0.25	0.19	0.17
Vehicle E	0.40	25	0.14	0.20	0.15
Vehicle F	0.40	25	4.65	3.08	3.38
Vehicle G	0.40	50	8.40	4.00	4.06
Vehicle H	0.40	50	9.89	4.38	4.54
Vehicle I	0.40	50	7.22	4.92	4.08
Vehicle J	0.40	50	18.1	3.40	2.11
Vehicle K	0.40	25	2.24	2.44	2.14
Vehicle L	0.40	25	1.27	1.32	1.20



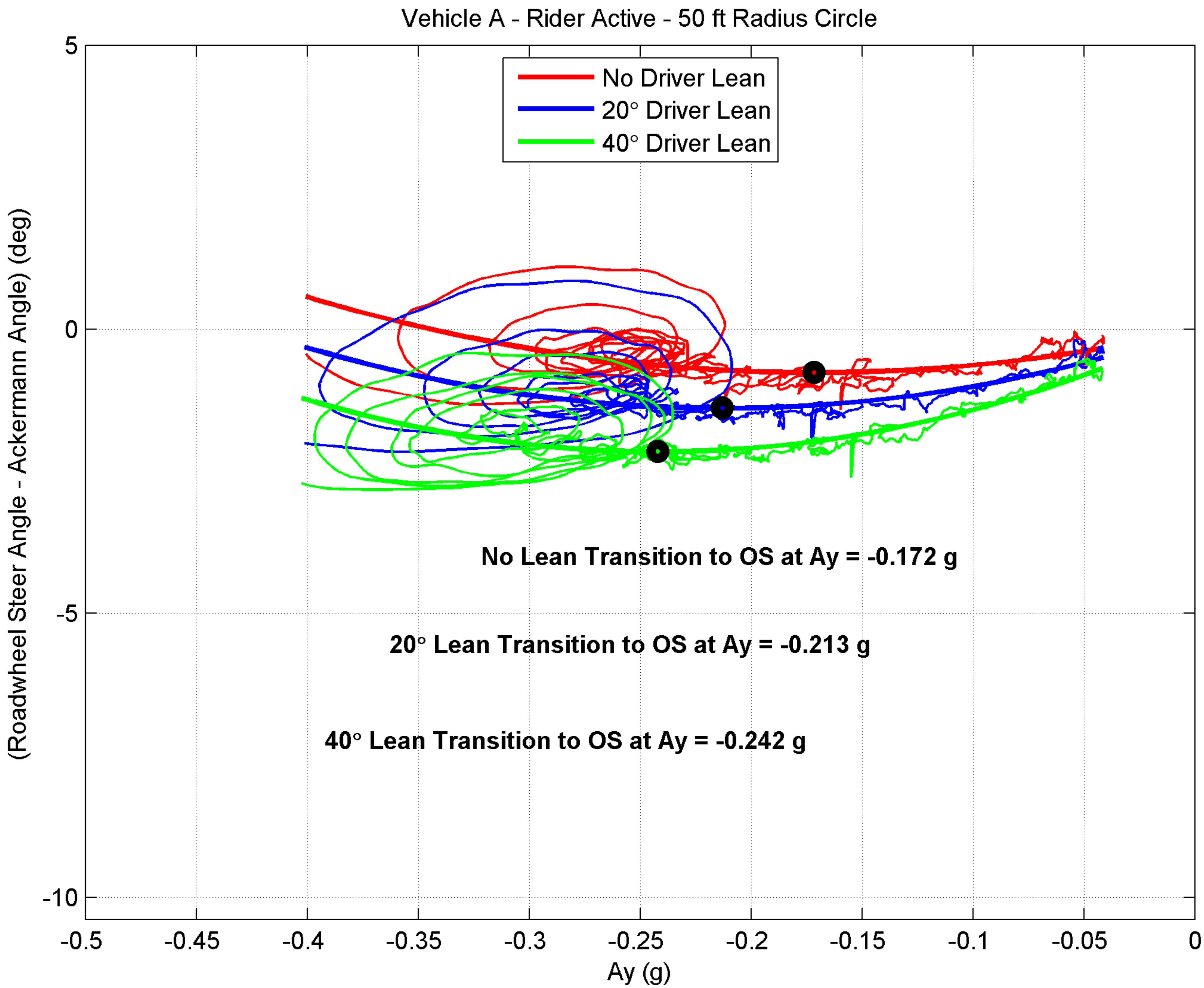
Yaw Rate Ratios - Measured During CCW Constant Steer Tests
Yaw Rate Ratio
0° Driver Lean
20° Driver Lean
40° Driver Lean
0
1
2
3
4
5
6
7
0.14
0.20
0.15
0.25
0.19
0.17
0.53
0.33
0.18
1.27
1.32
1.20
2.24
2.44
2.14
3.36
4.16
1.82
4.65
3.08
3.38
7.22
4.92
4.08
8.40
4.00
4.06
9.70
10.5
8.09
9.89
4.38
4.54
18.1
3.40
2.11
Vehicle E
Vehicle D
Vehicle C
Vehicle L
Vehicle K
Vehicle B
Vehicle F
Vehicle I
Vehicle G
Vehicle A
Vehicle H
Vehicle J

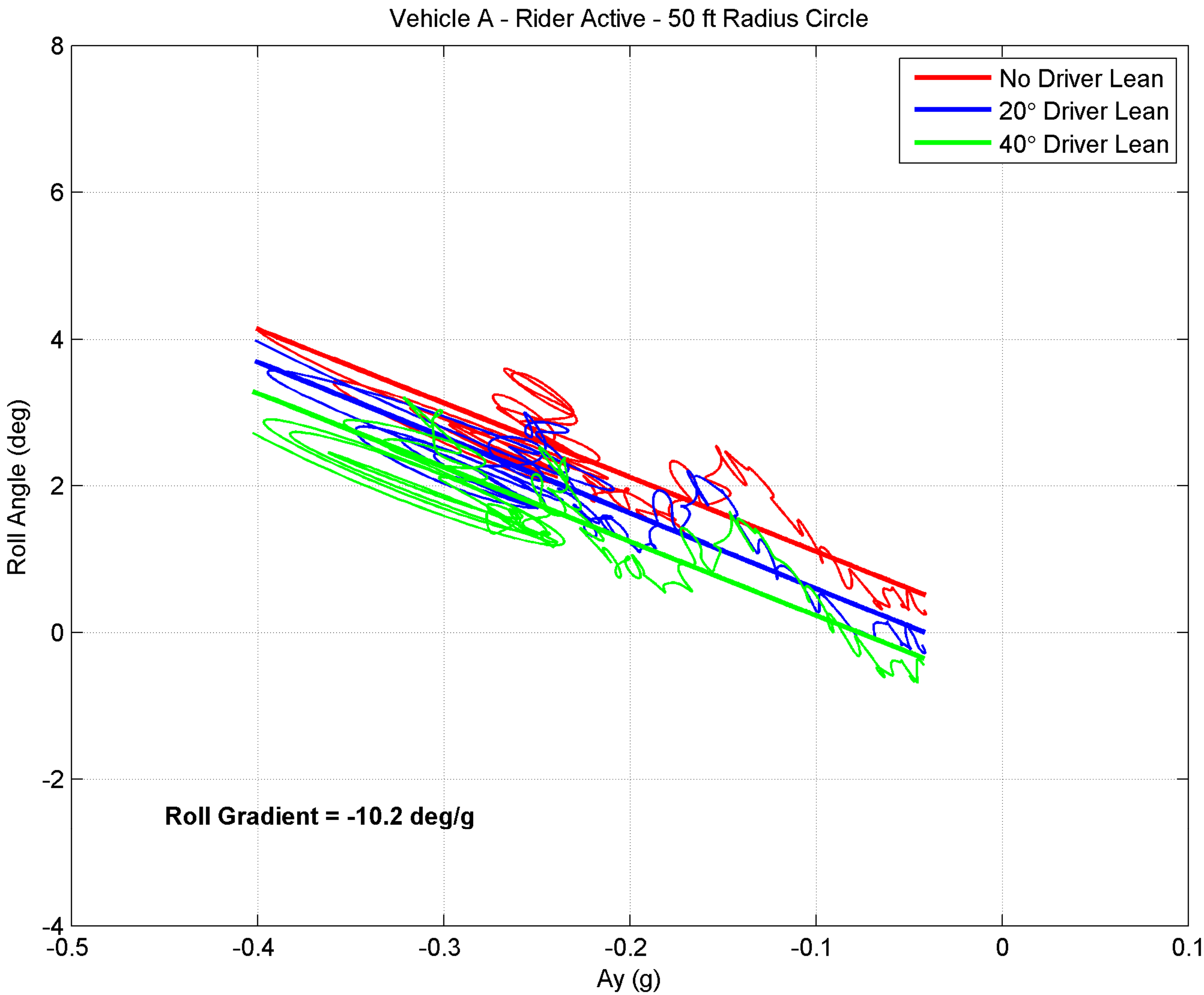


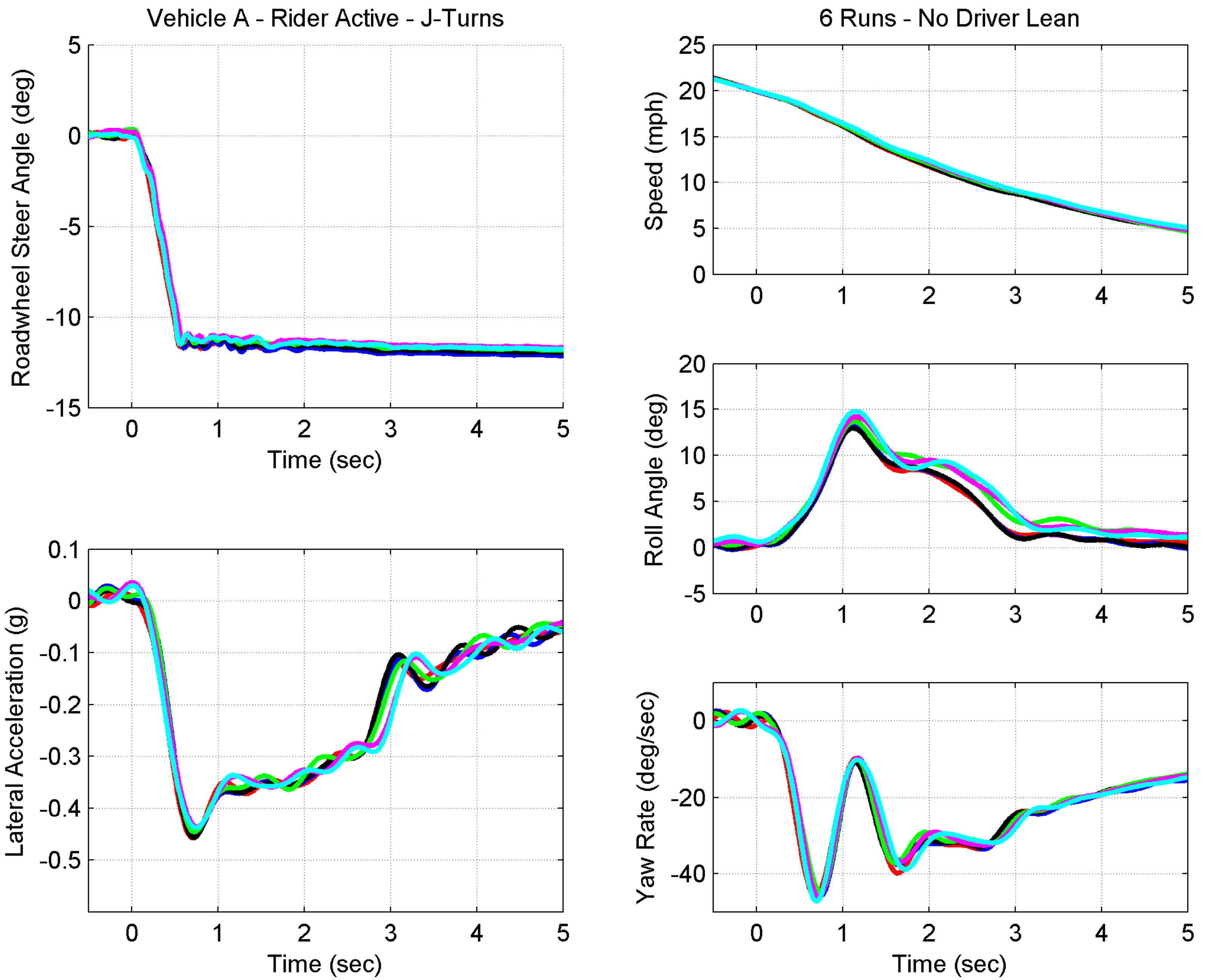
Vehicle A - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

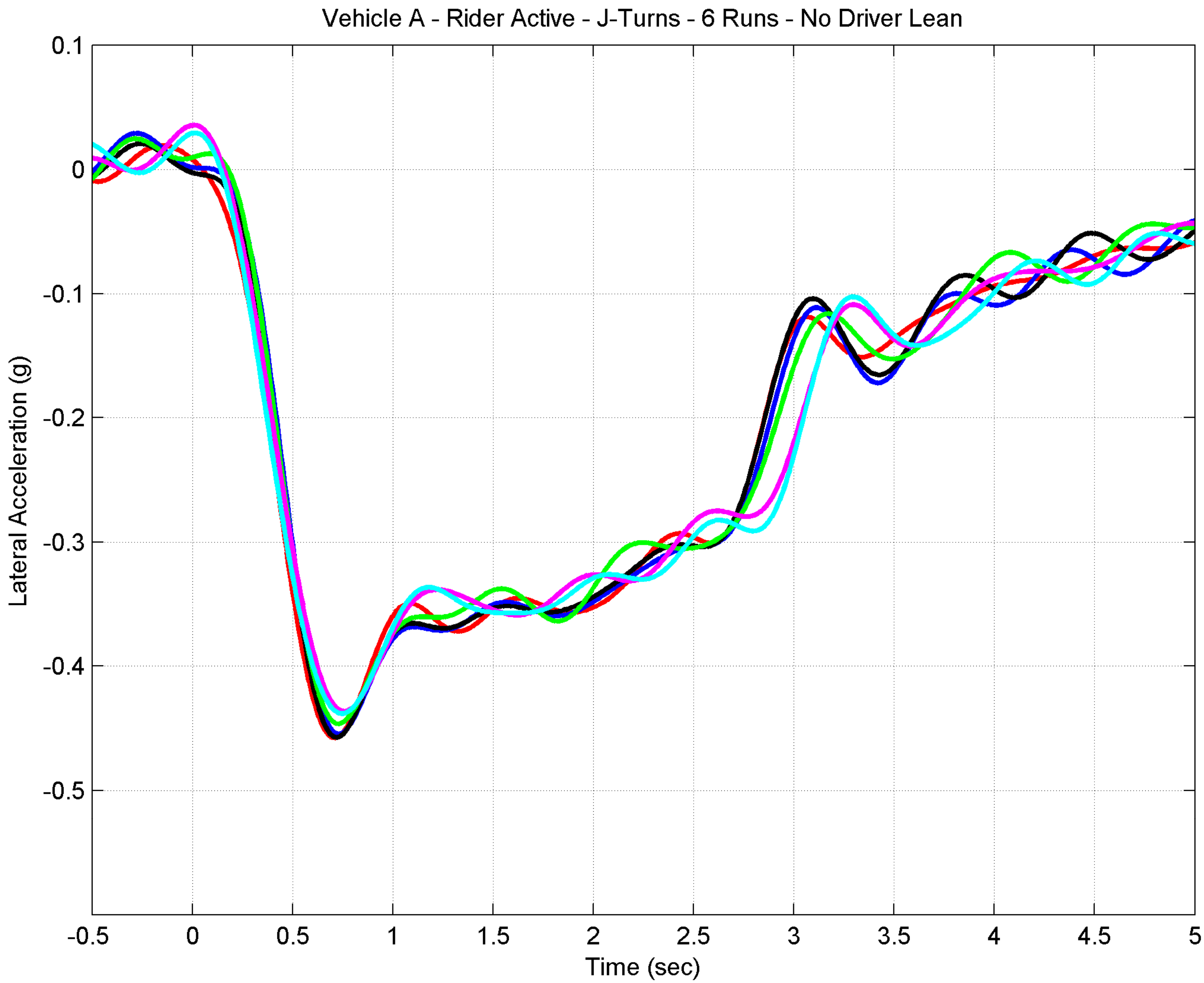


Vehicle A - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Ay (g)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

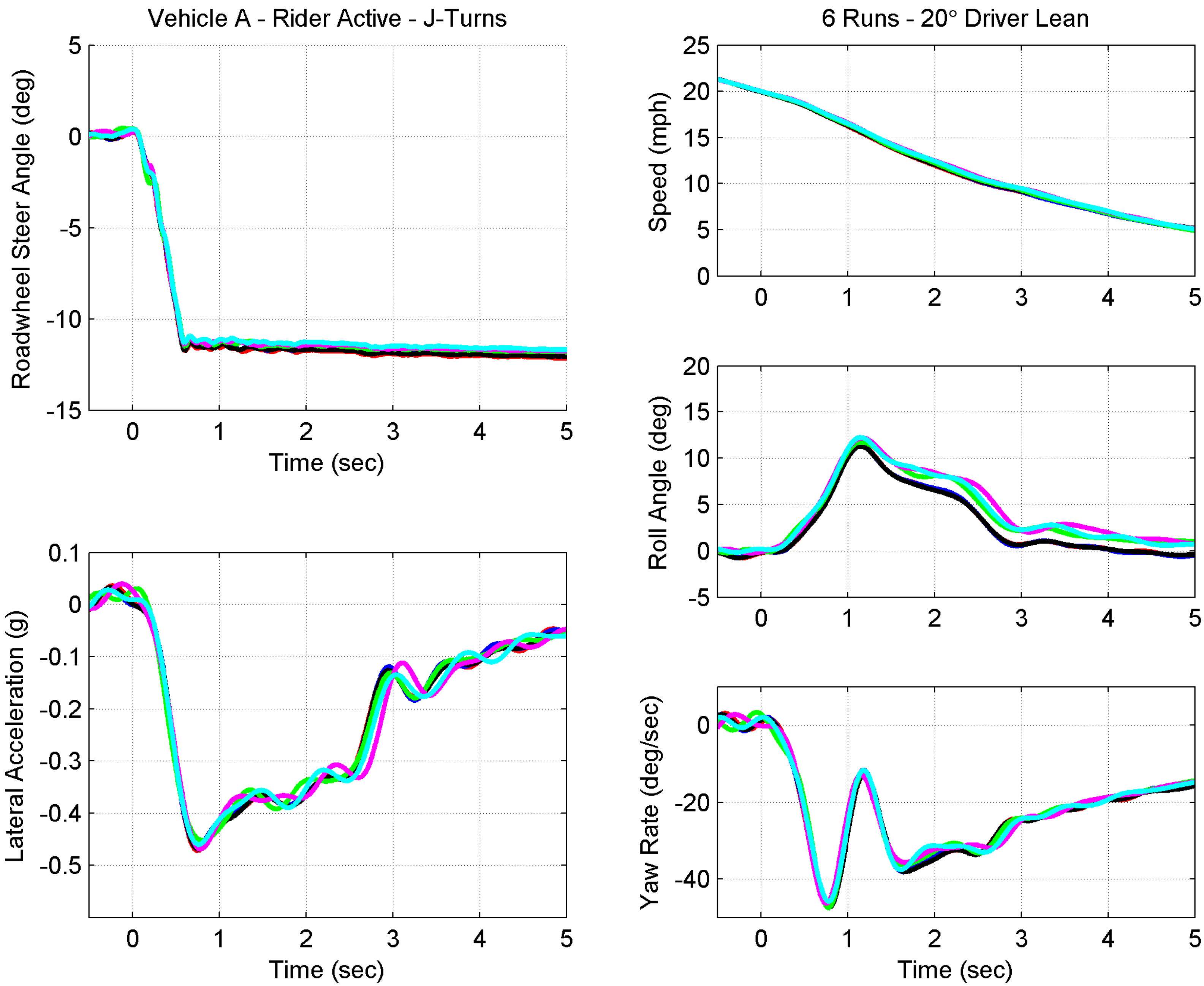

Vehicle A - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.172 g
20° Lean Transition to OS at Ay = -0.213 g
40° Lean Transition to OS at Ay = -0.242 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0


Vehicle A - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -10.2 deg/g
8
6
4
2
0
-2
-4
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

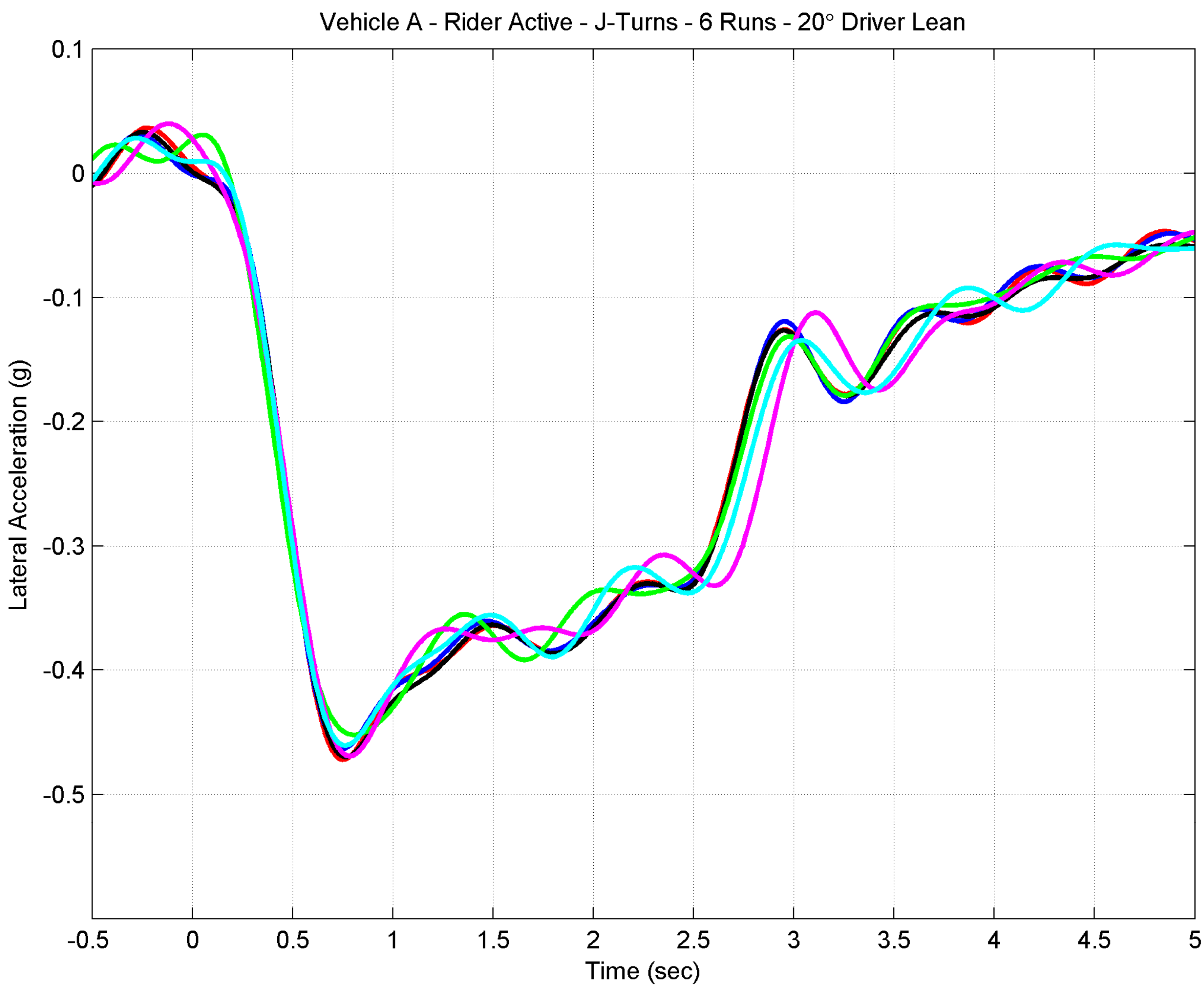

Vehicle A - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

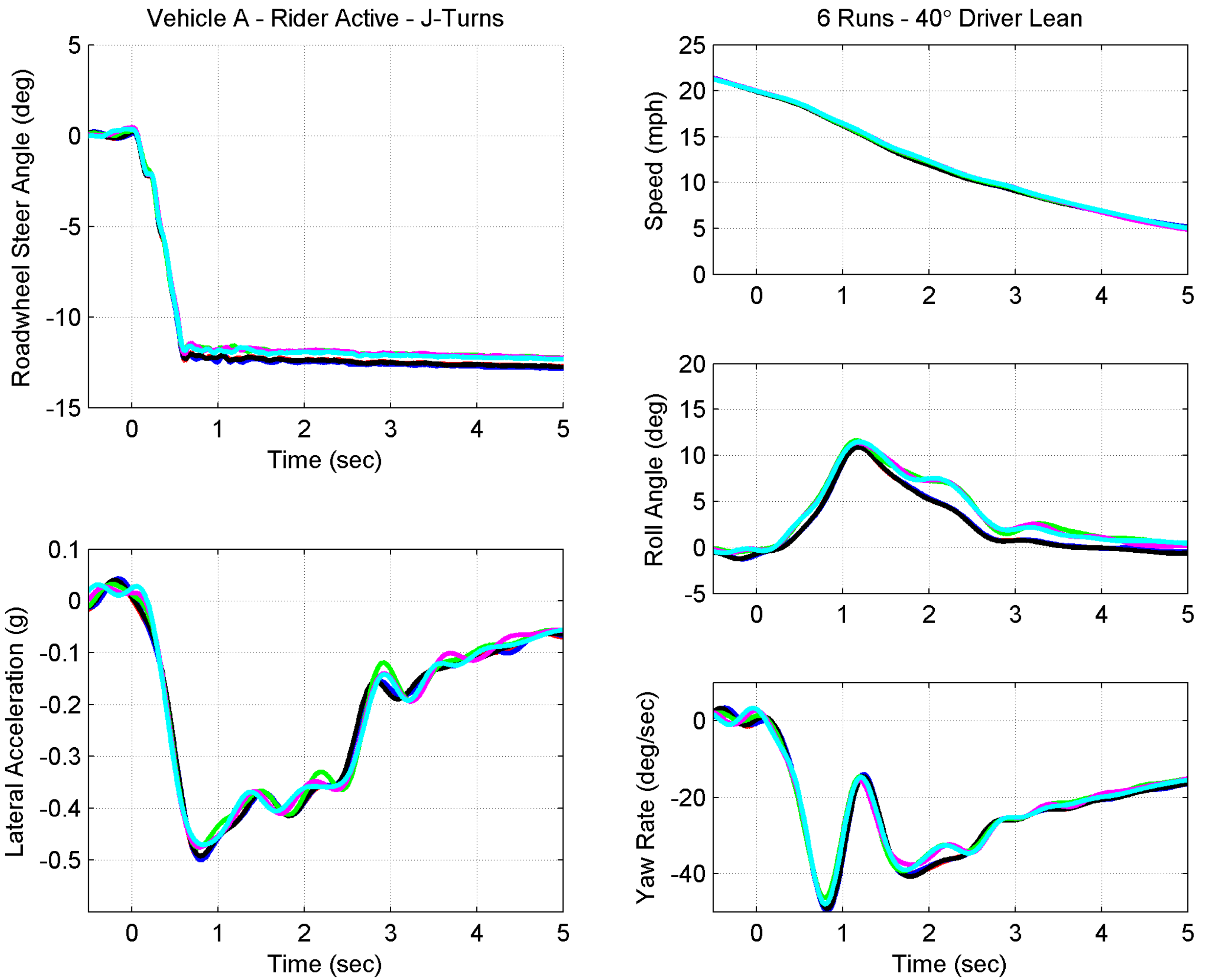


Vehicle A - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

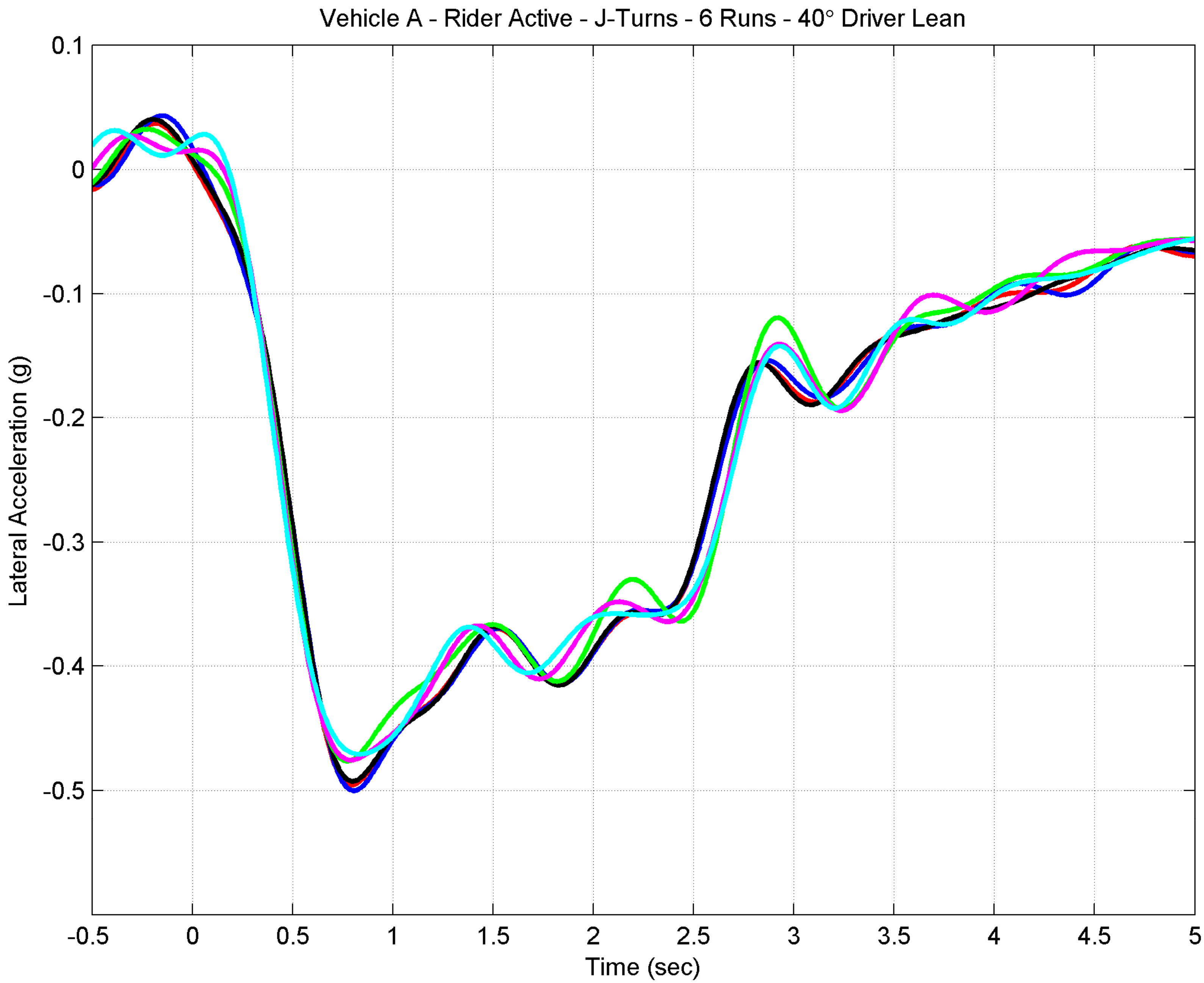


Vehicle A - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)


Vehicle A - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle A - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle A - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

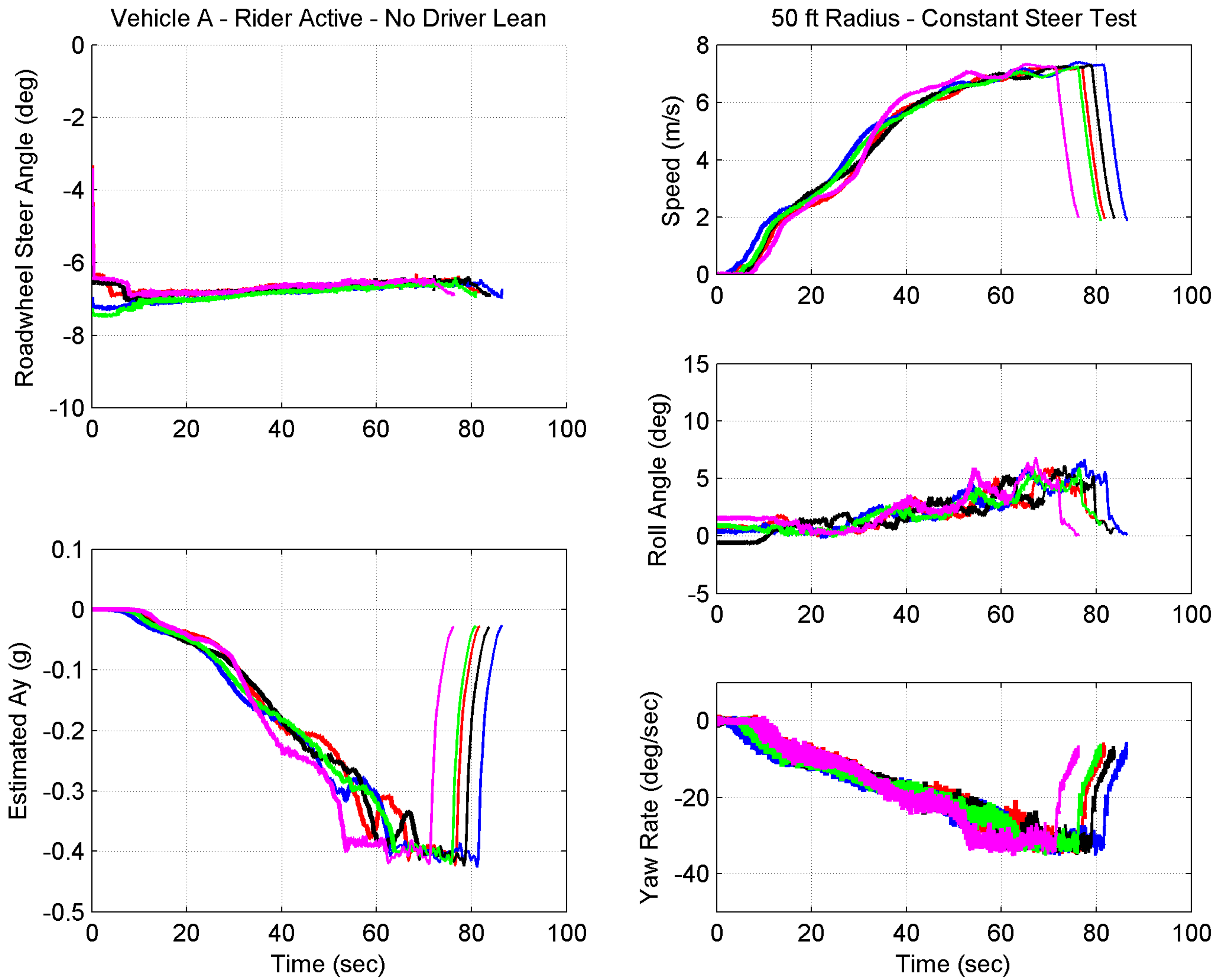
Vehicle A - Rider Active Results

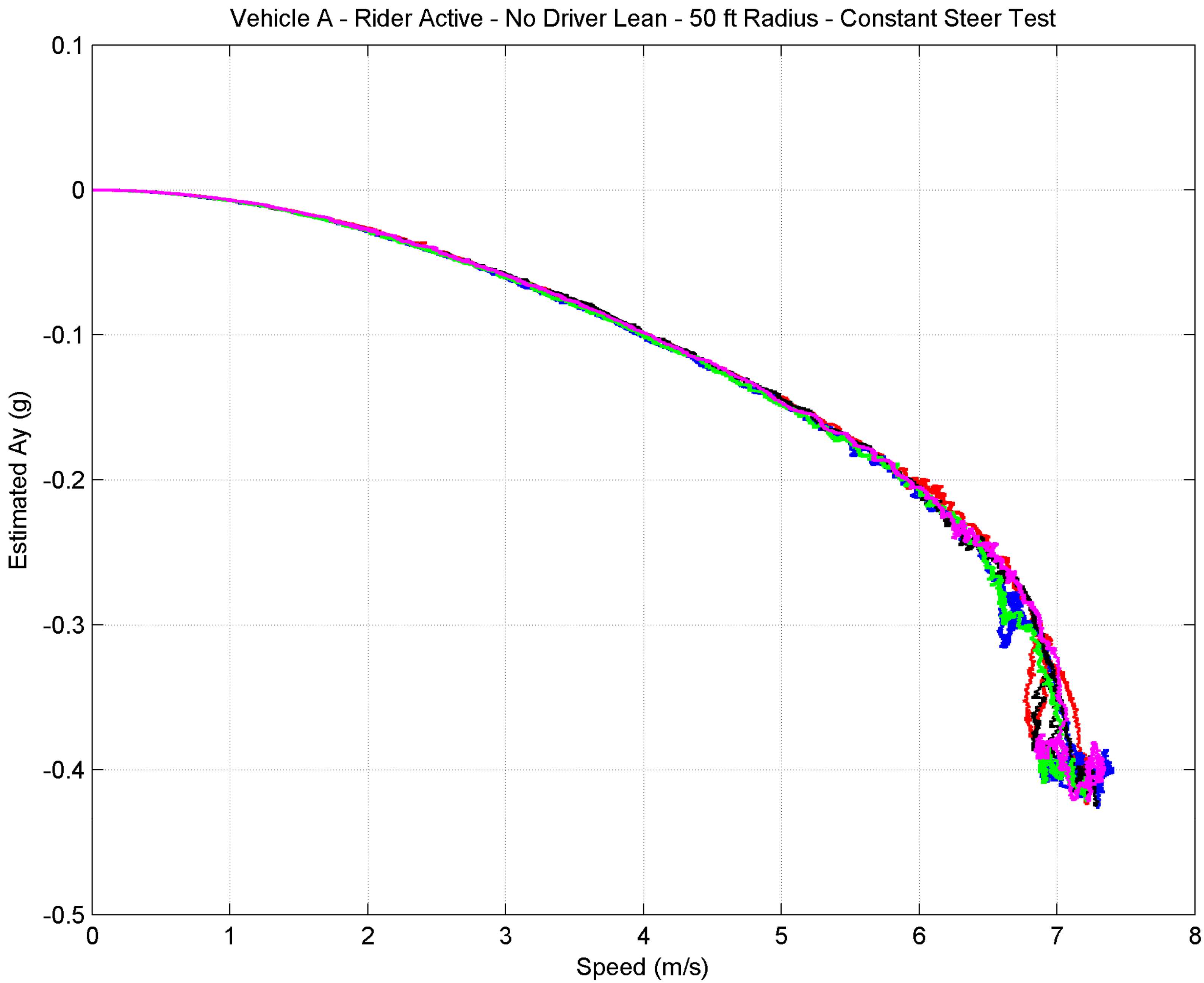
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

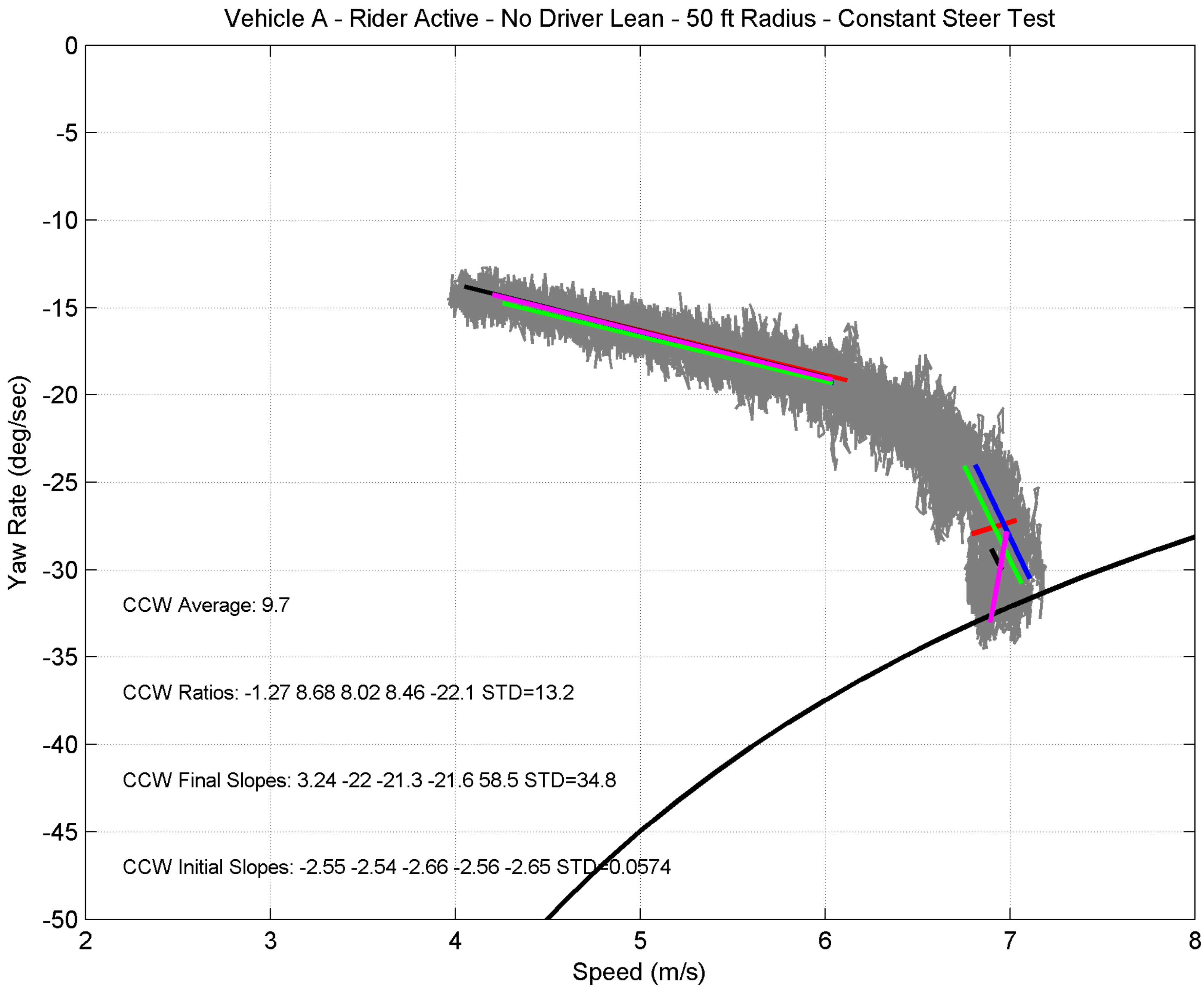
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.458	-0.472	-0.496
	-0.455	-0.463	-0.500
	-0.457	-0.470	-0.493
Mean Value of 3 Runs	-0.457	-0.468	-0.496
Standard Deviation of 3 Runs	0.002	0.005	0.004

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.446	-0.452	-0.476
	-0.436	-0.469	-0.476
	-0.438	-0.461	-0.471
Mean Value of 3 Runs	-0.440	-0.461	-0.474
Standard Deviation of 3 Runs	0.005	0.009	0.003

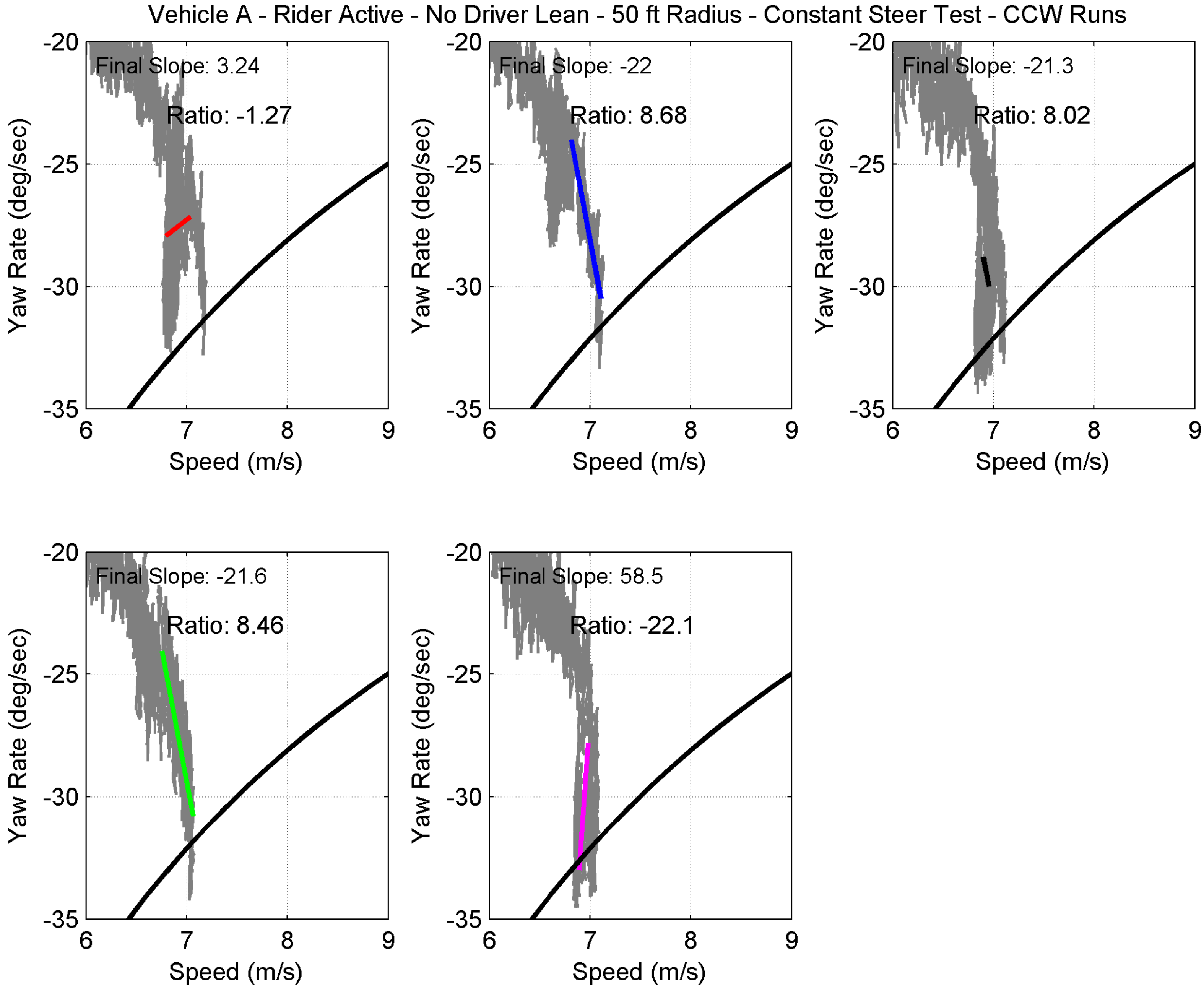
Average of All 6 Runs	**0.448**	**0.465**	**0.485**


Vehicle A - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

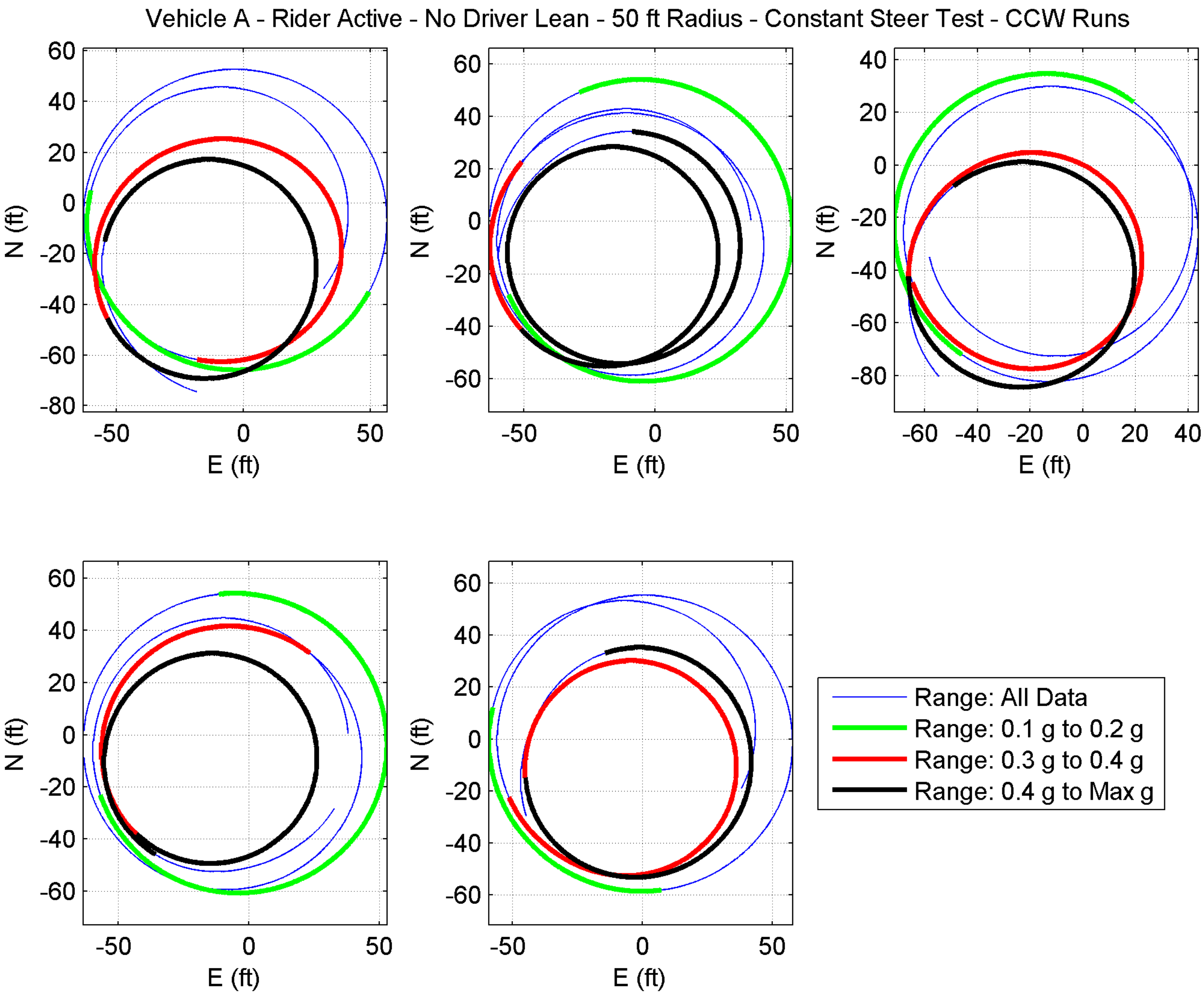

Vehicle A - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8



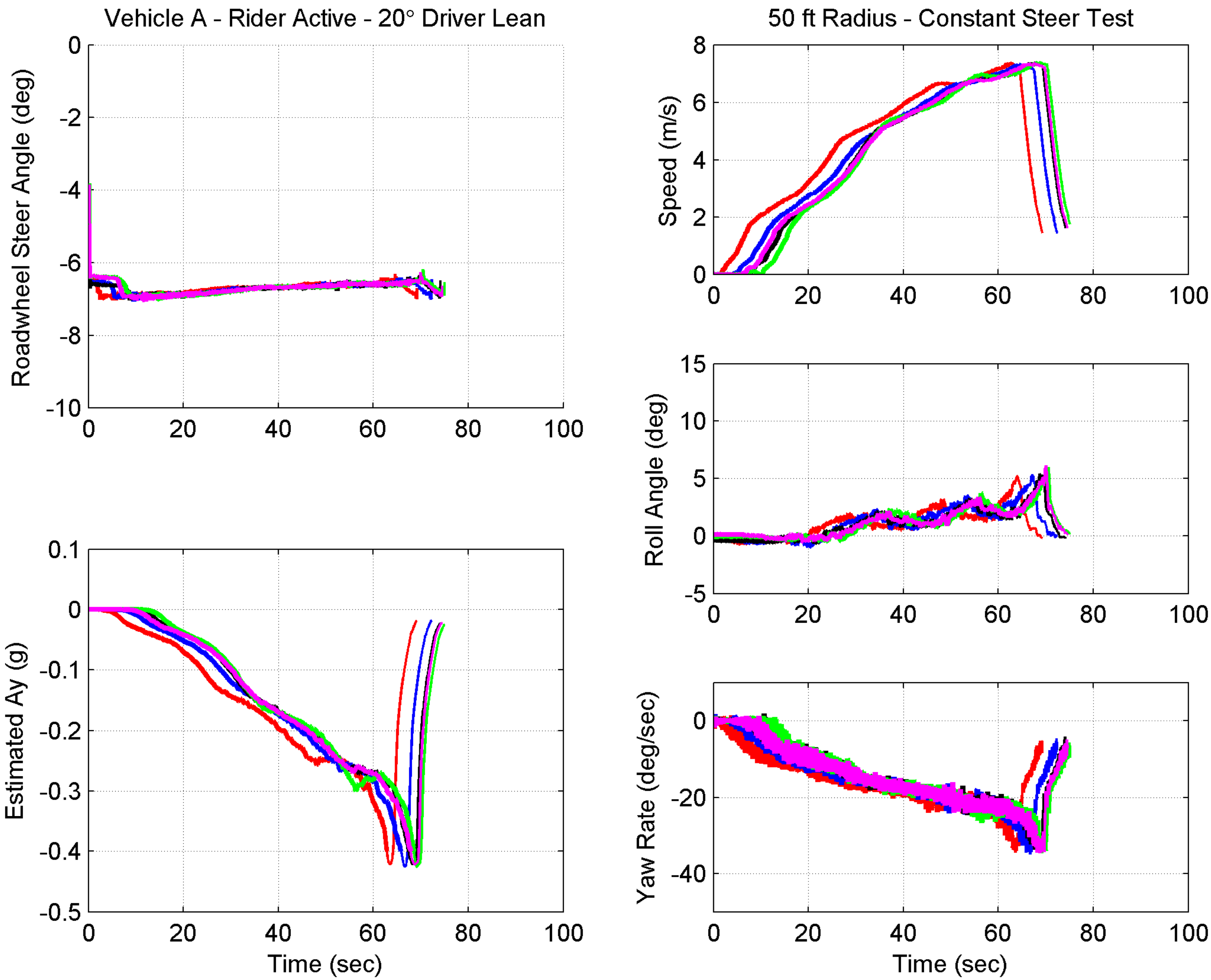
Vehicle A - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
CCW Average: 9.7
CCW Ratios: -1.27 8.68 8.02 8.46 -22.1 STD=13.2
CCW Final Slopes: 3.24 -22 -21.3 -21.6 58.5 STD=34.8
CCW Initial Slopes: -2.55 -2.54 -2.66 -2.56 -2.65 STD=0.0574

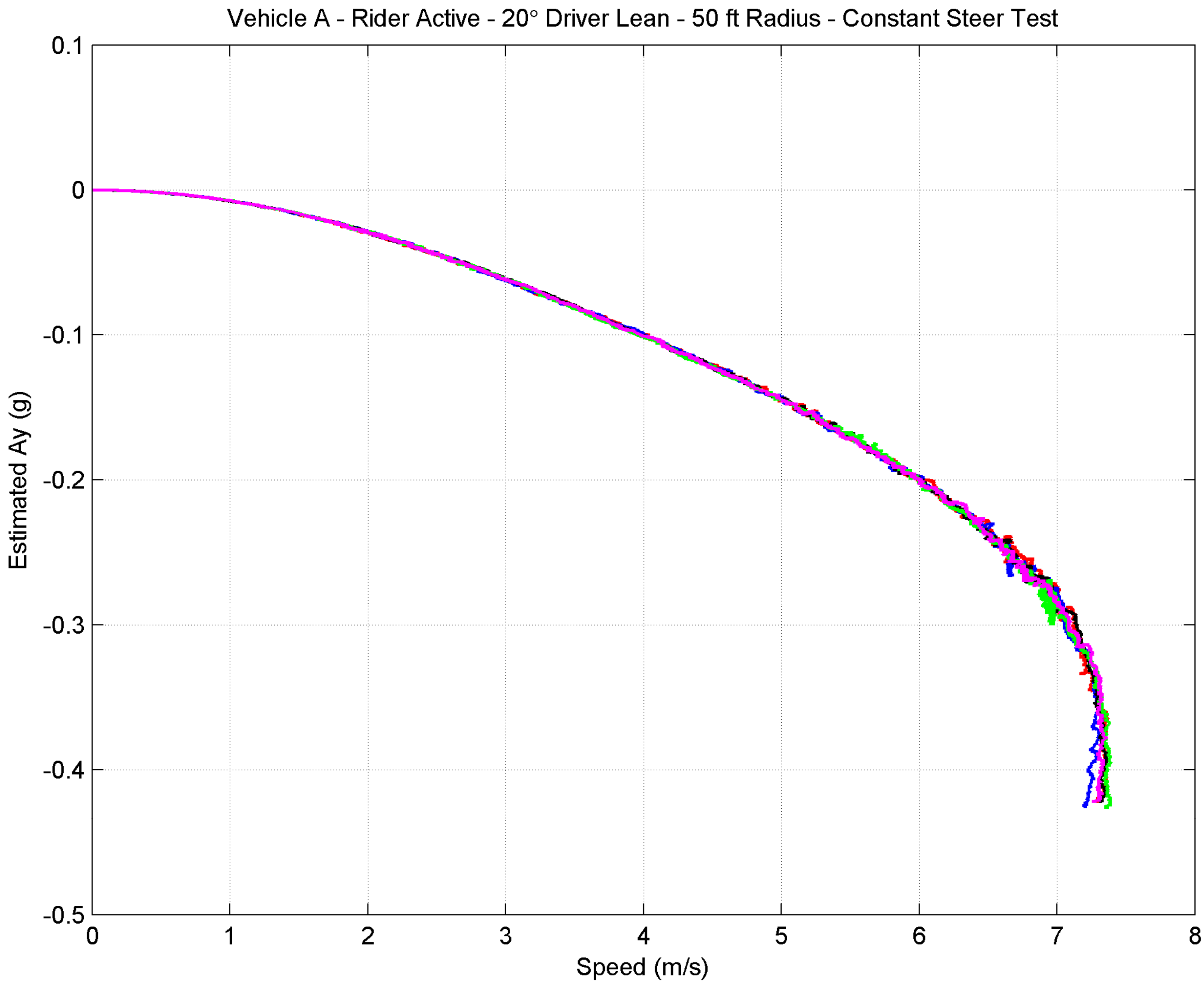


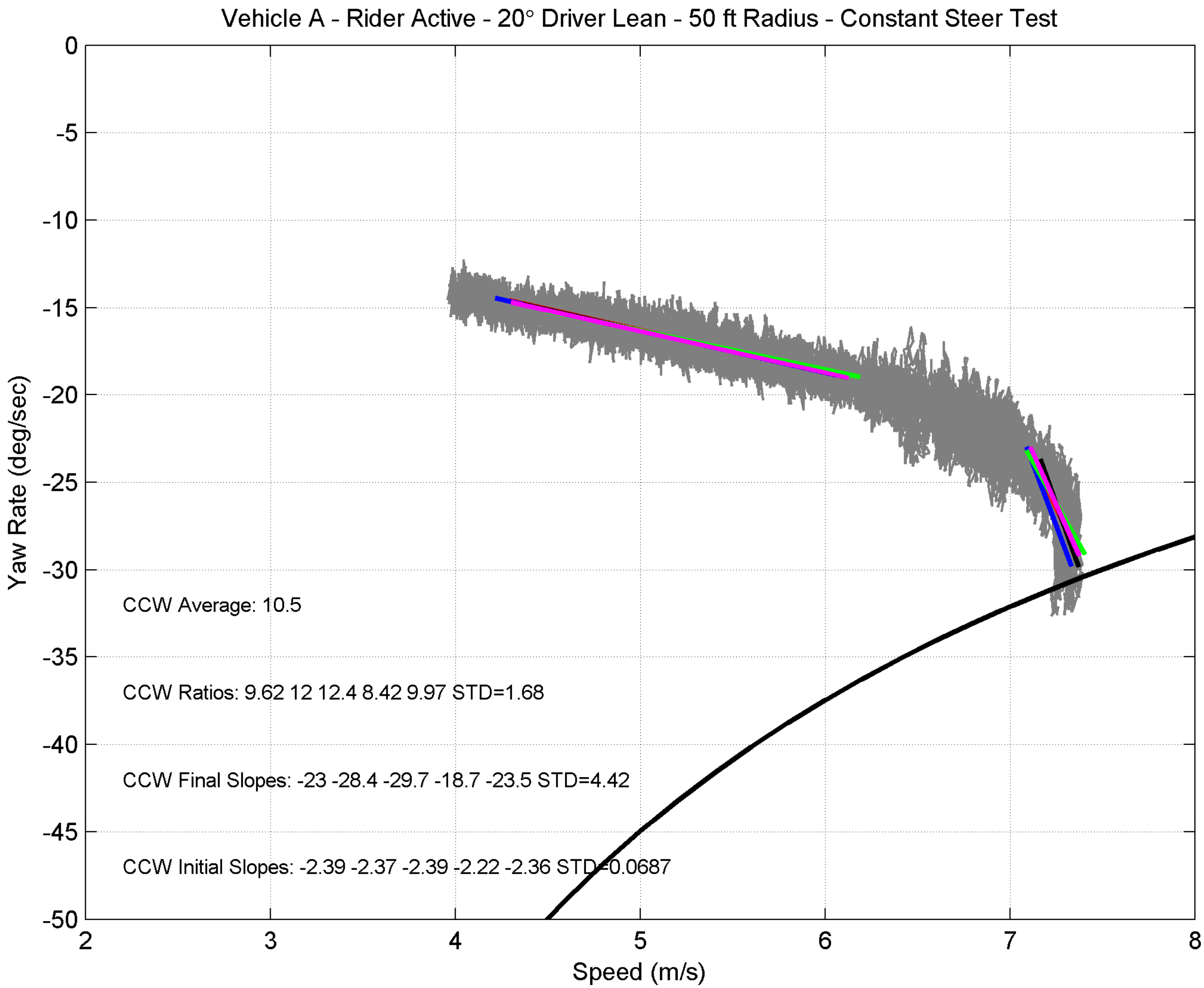
Vehicle A - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 3.24
Ratio: -1.27
Final Slope: -22
Ratio: 8.68
Final Slope: -21.3
Ratio: 8.02
Final Slope: -21.6
Ratio: 8.46
Final Slope: 58.5
Ratio: -22.1
Yaw Rate (deg/sec)
Speed (m/s)

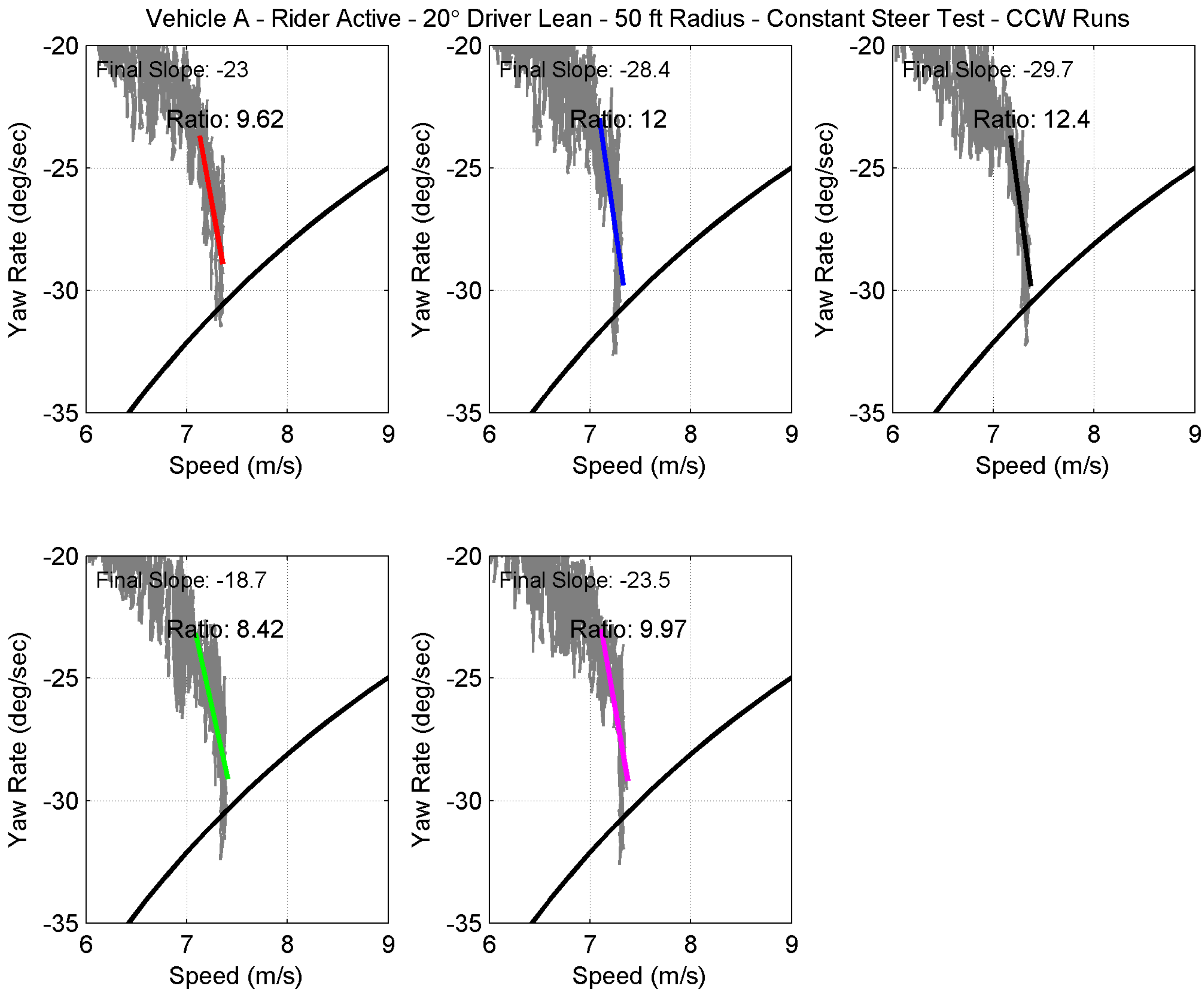


Vehicle A - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g


Vehicle A - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
0
-2
-4
-6
-8
-10
0 20 40 60 80 100
Speed (m/s)
8
6
4
2
0
0 20 40 60 80 100
Roll Angle (deg)
15
10
5
0
-5
0 20 40 60 80 100
Estimated Ay (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0 20 40 60 80 100
Time (sec)
Yaw Rate (deg/sec)
0
-20
-40
0 20 40 60 80 100
Time (sec)

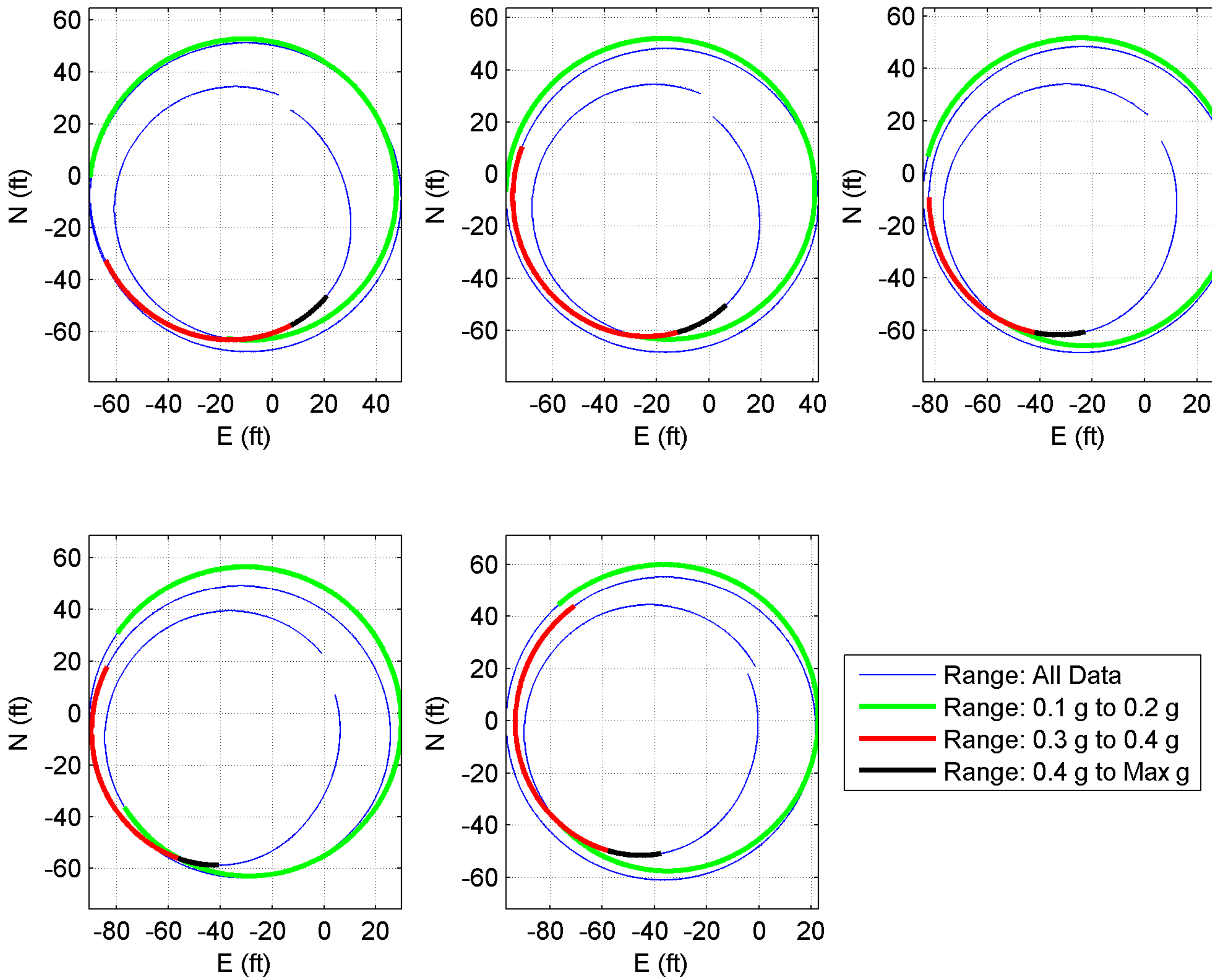

Vehicle A - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

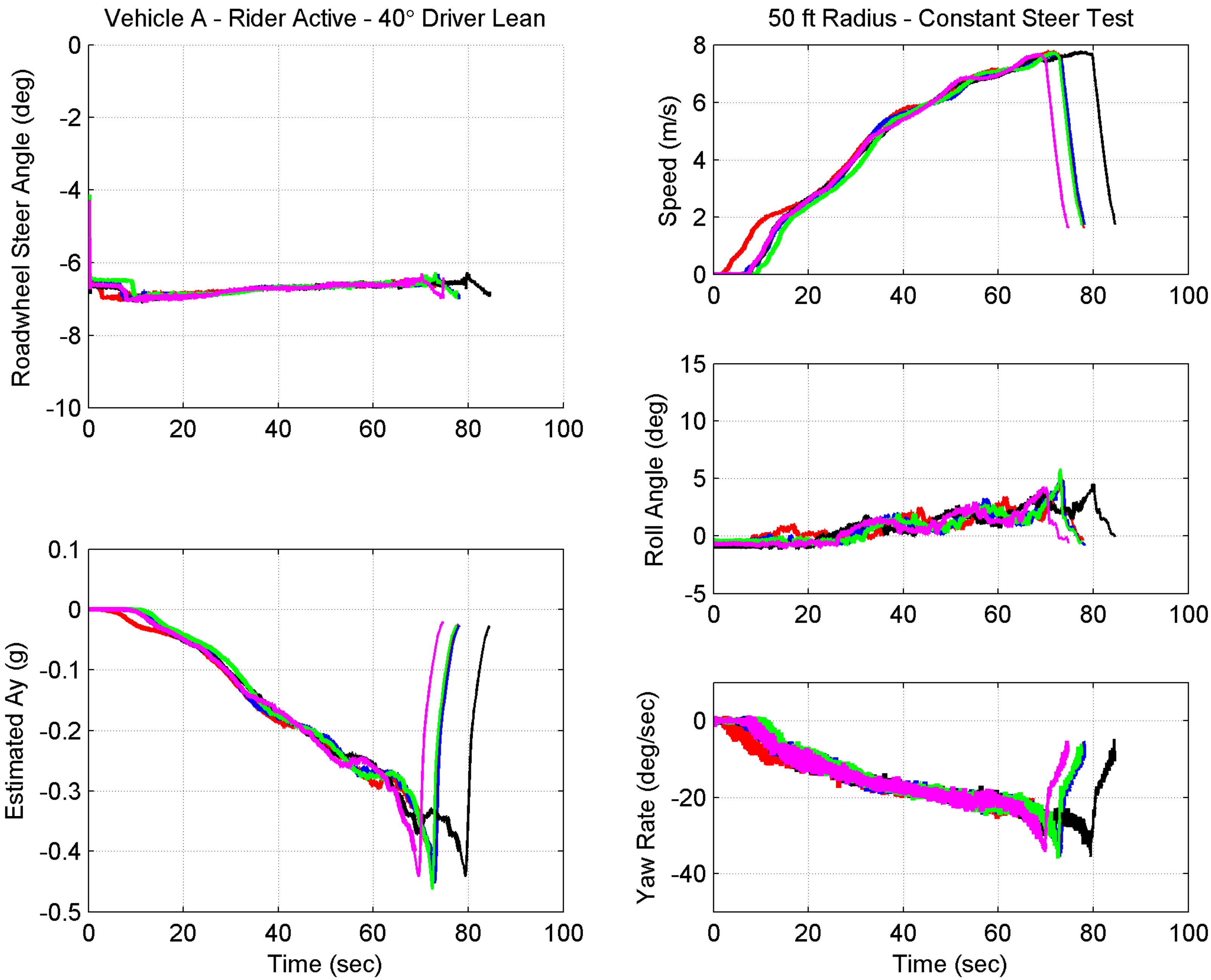

Vehicle A - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
CCW Average: 10.5
CCW Ratios: 9.62 12 12.4 8.42 9.97 STD=1.68
CCW Final Slopes: -23 -28.4 -29.7 -18.7 -23.5 STD=4.42
CCW Initial Slopes: -2.39 -2.37 -2.39 -2.22 -2.36 STD=0.0687



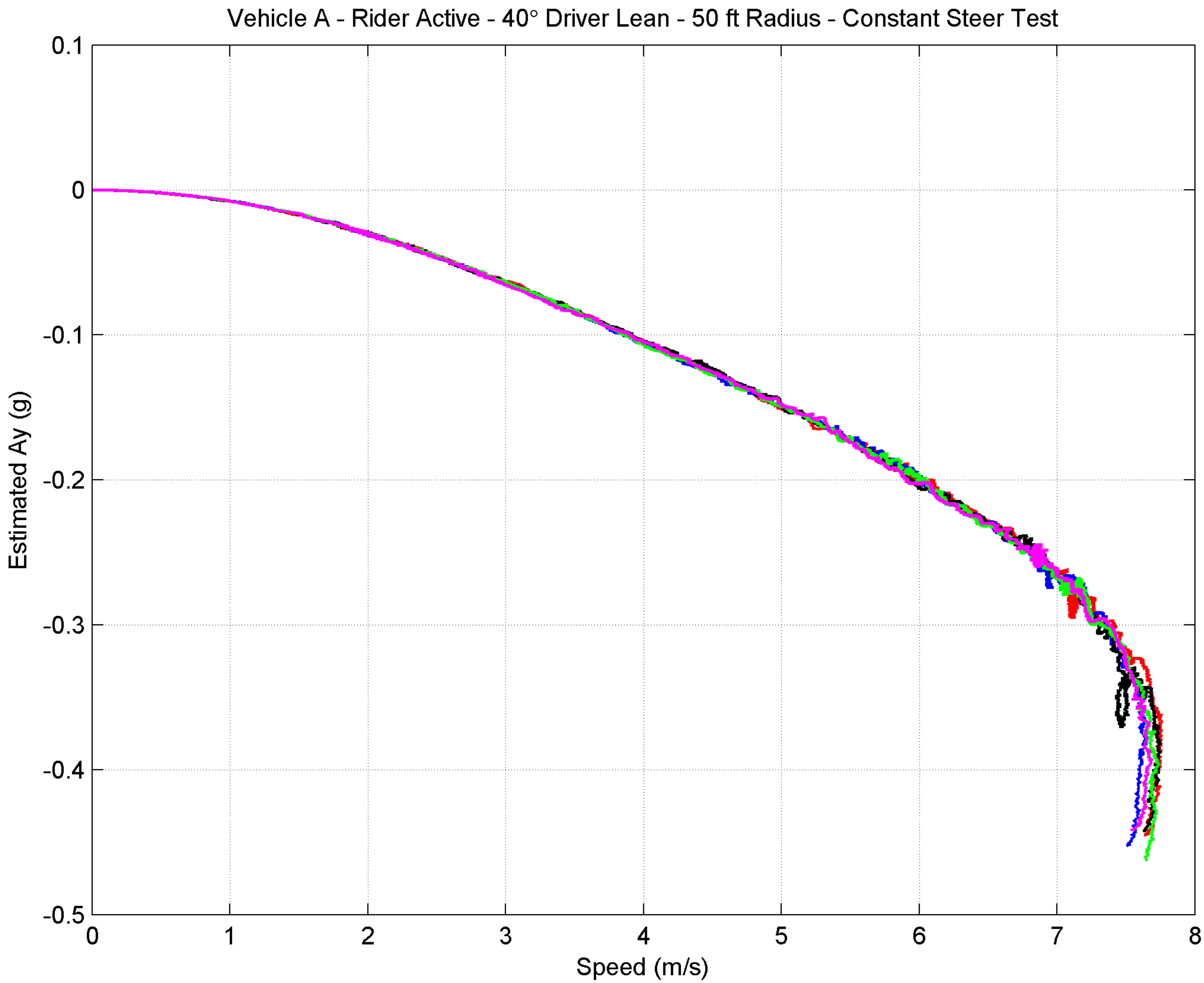
Vehicle A - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -23
Ratio: 9.62
Final Slope: -28.4
Ratio: 12
Final Slope: -29.7
Ratio: 12.4
Final Slope: -18.7
Ratio: 8.42
Final Slope: -23.5
Ratio: 9.97
Yaw Rate (deg/sec)
Speed (m/s)

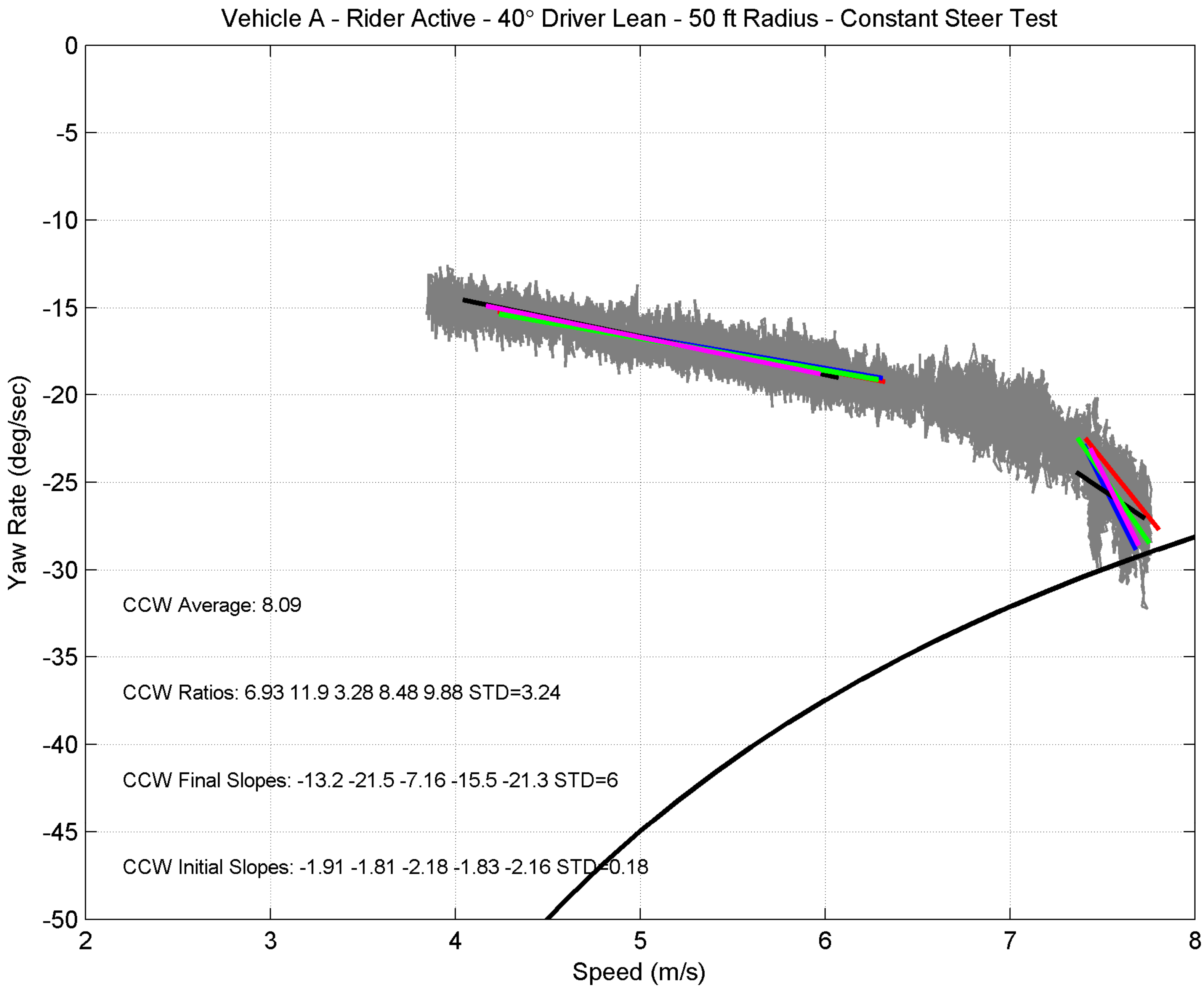
Vehicle A - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



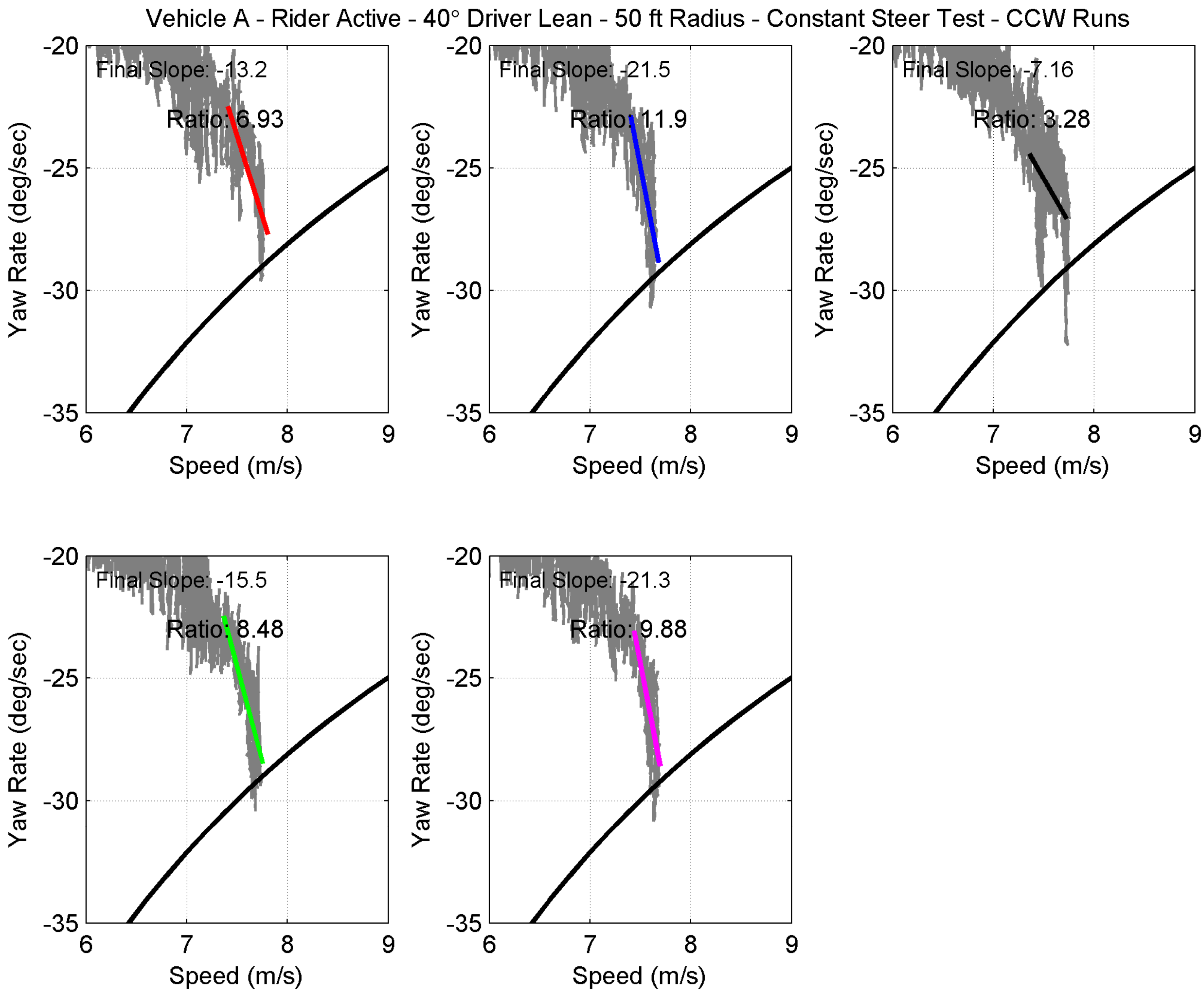


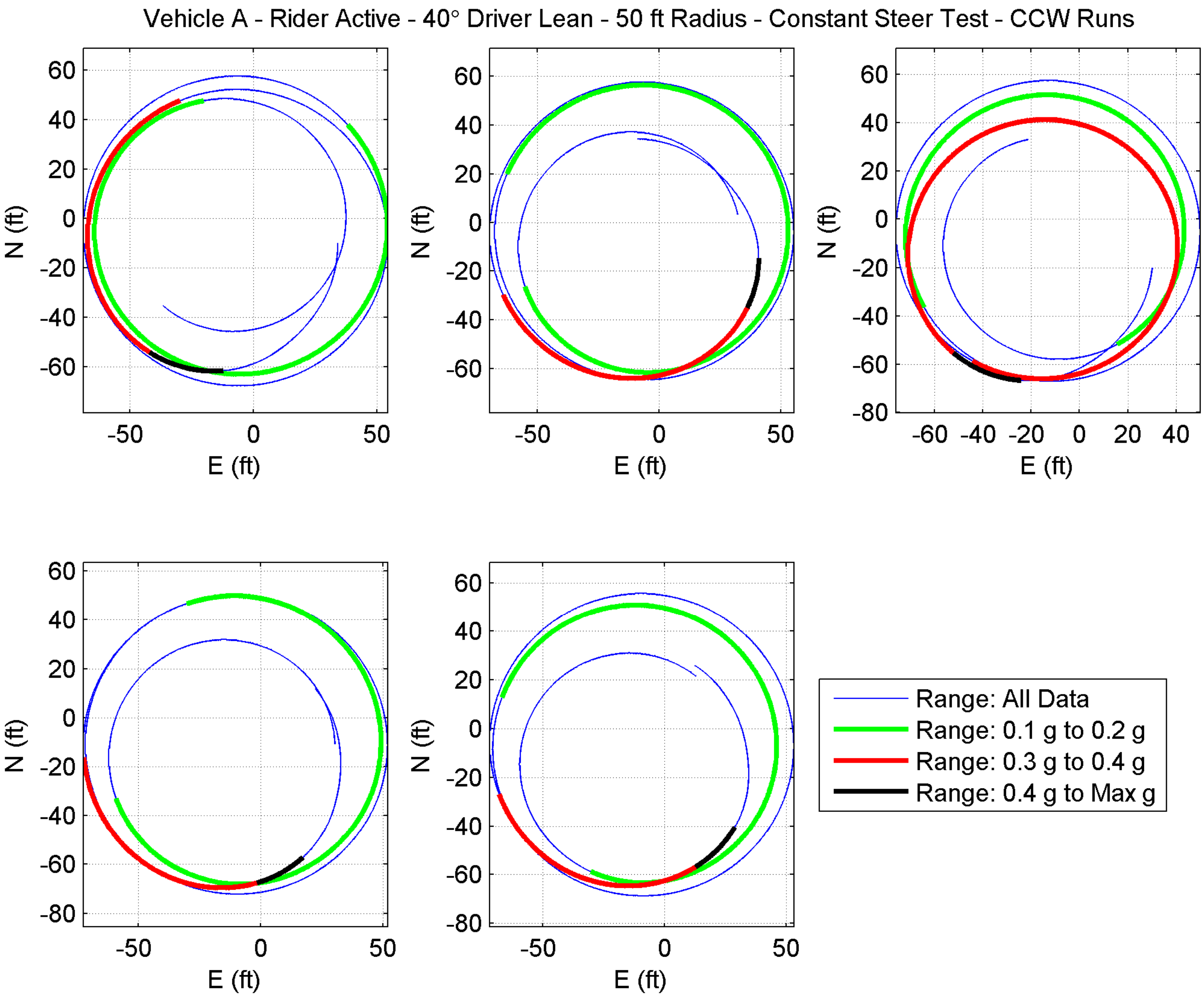
Vehicle A - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

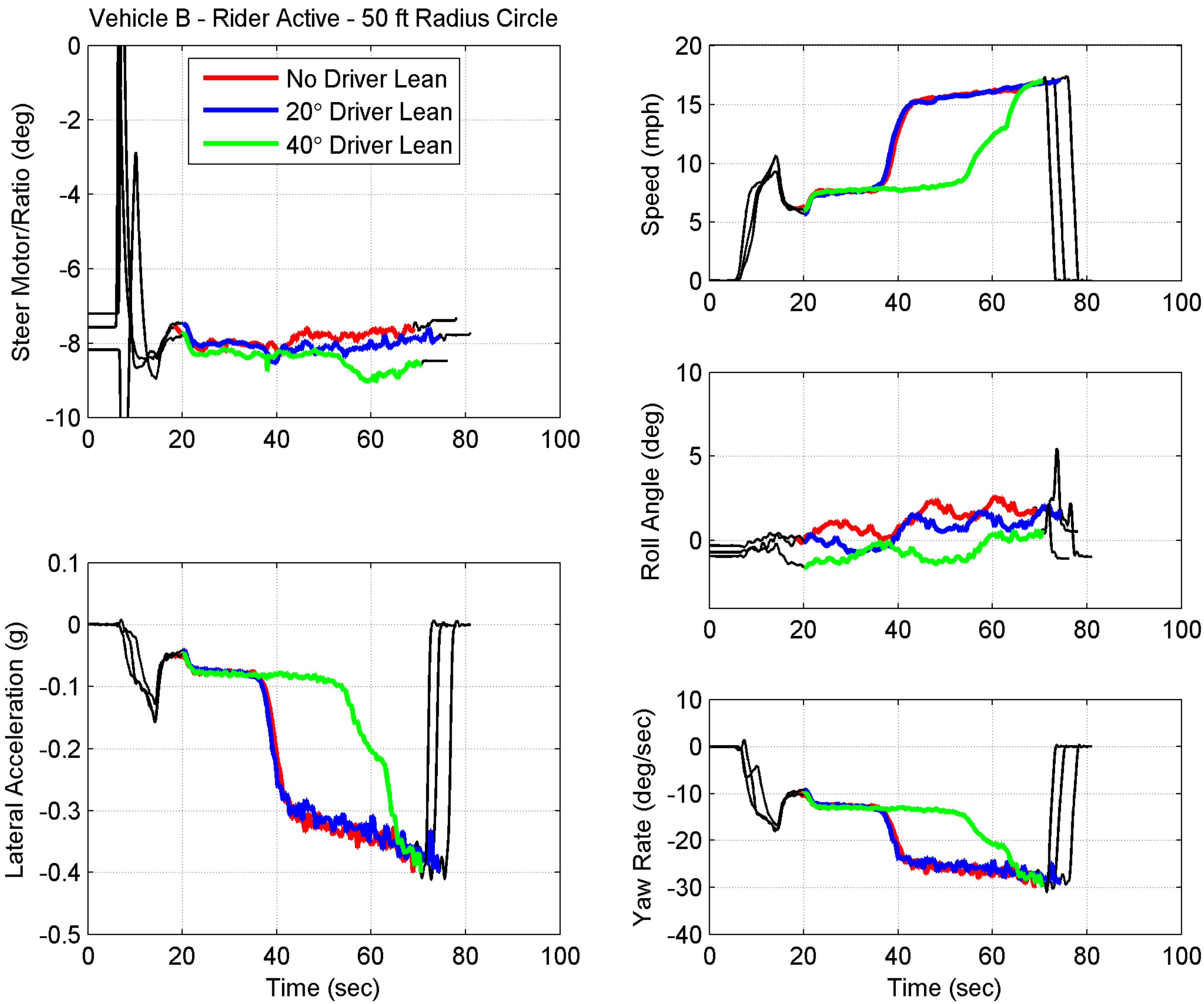

Vehicle A - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

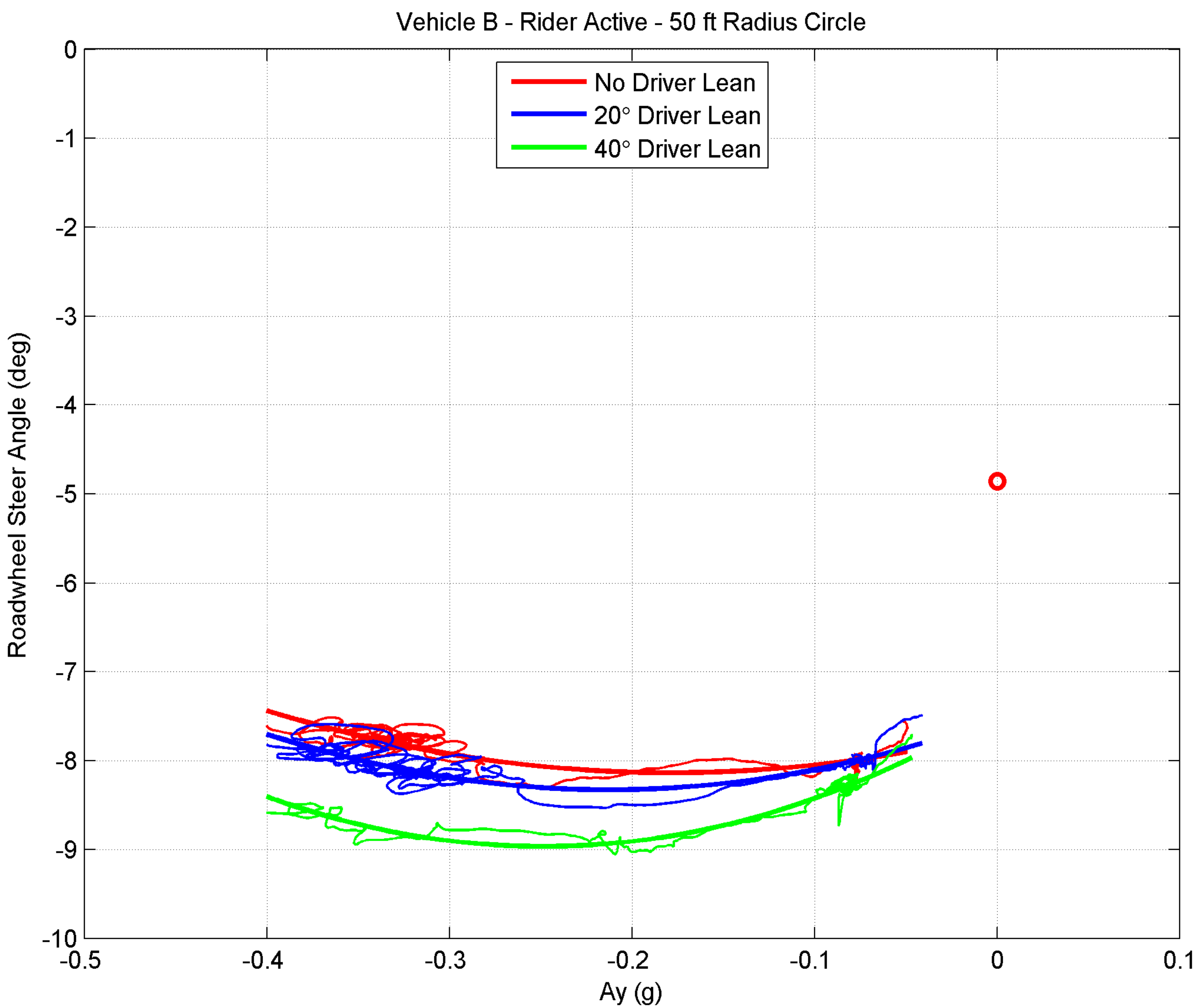


Vehicle A - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
CCW Average: 8.09
CCW Ratios: 6.93 11.9 3.28 8.48 9.88 STD=3.24
CCW Final Slopes: -13.2 -21.5 -7.16 -15.5 -21.3 STD=6
CCW Initial Slopes: -1.91 -1.81 -2.18 -1.83 -2.16 STD=0.18

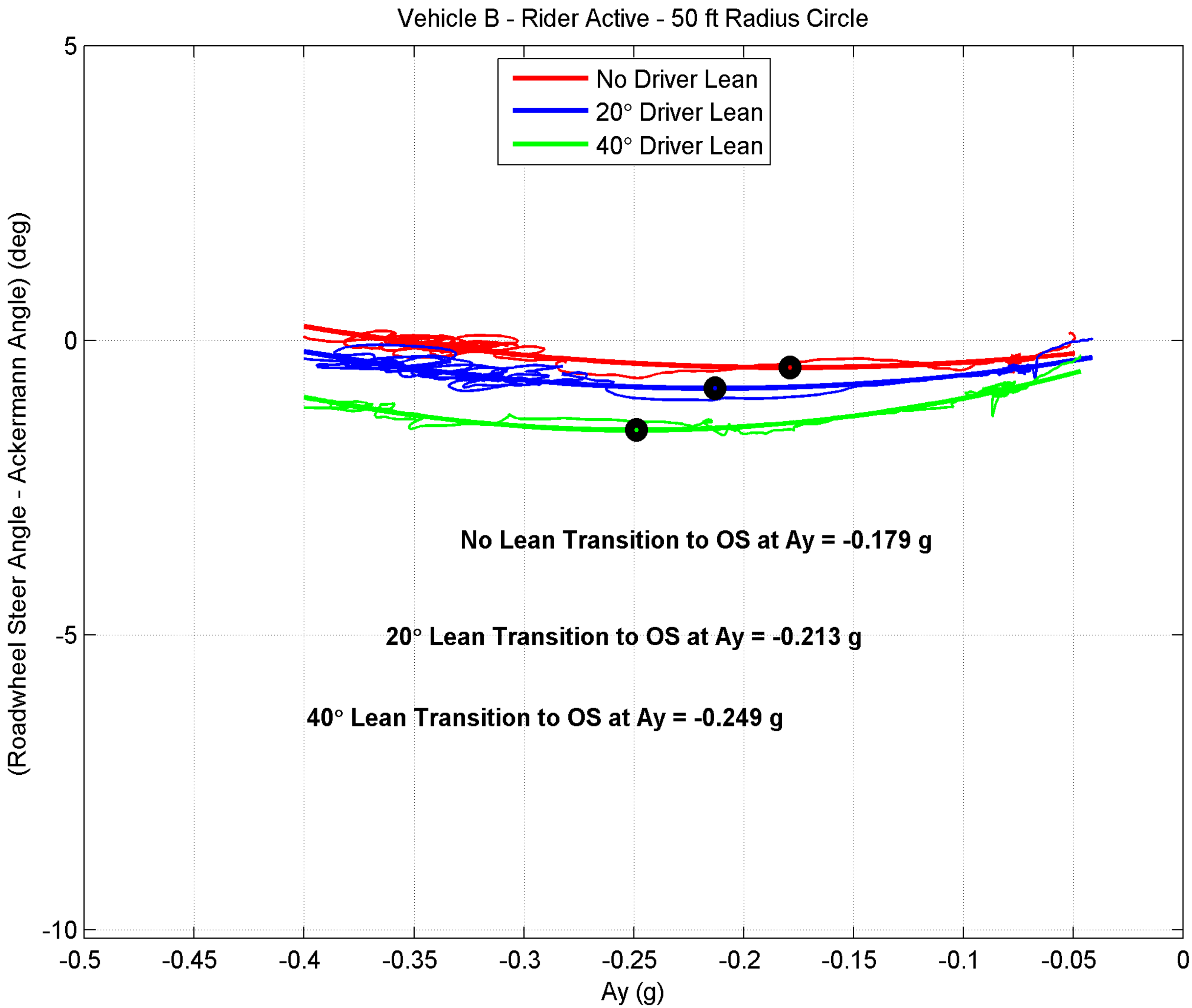

Vehicle A - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -13.2
Ratio: 6.93
Final Slope: -21.5
Ratio: 11.9
Final Slope: -7.16
Ratio: 3.28
Final Slope: -15.5
Ratio: 8.48
Final Slope: -21.3
Ratio: 9.88
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9


Vehicle A - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

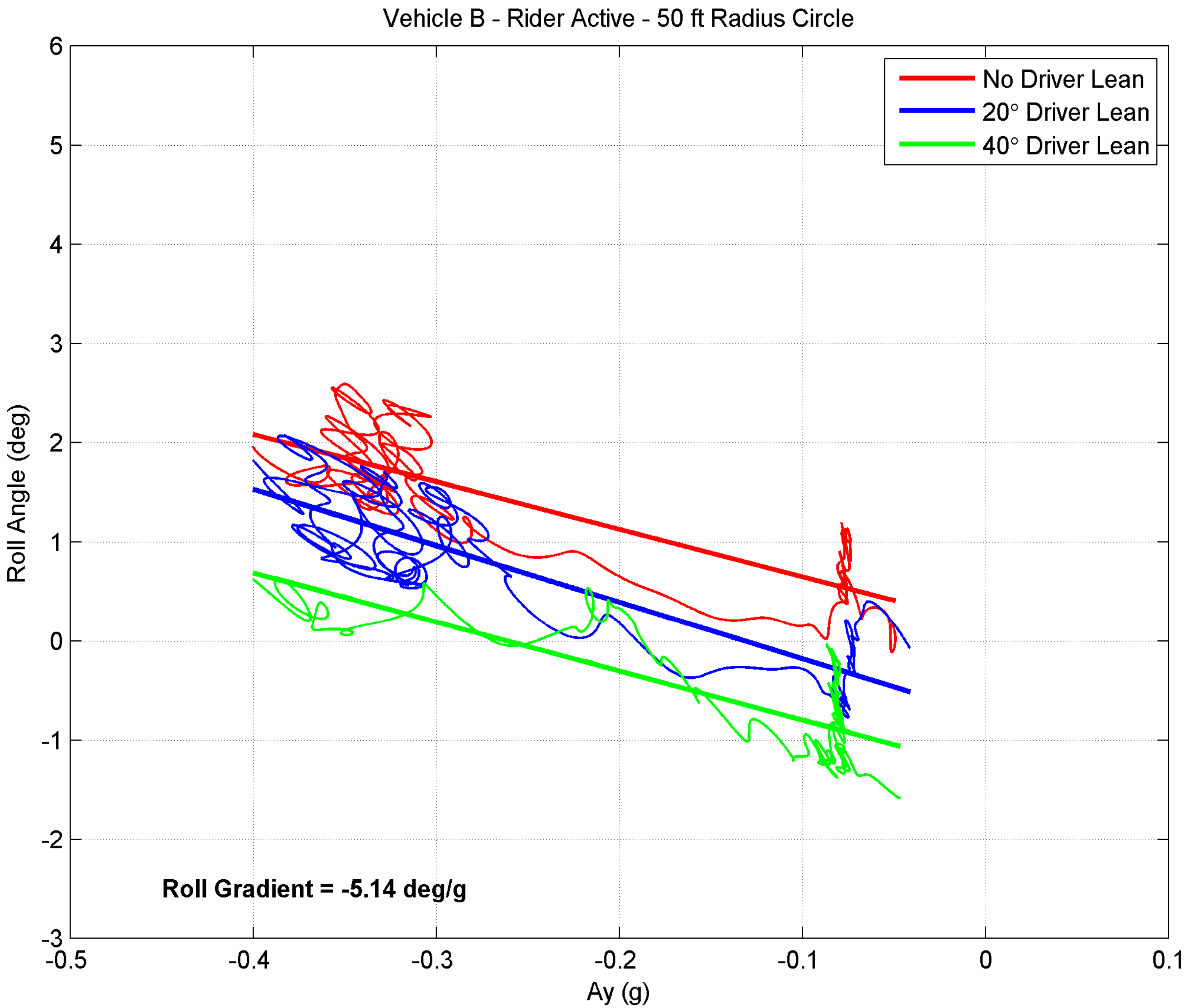

Vehicle B - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Steer Motor/Ratio (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



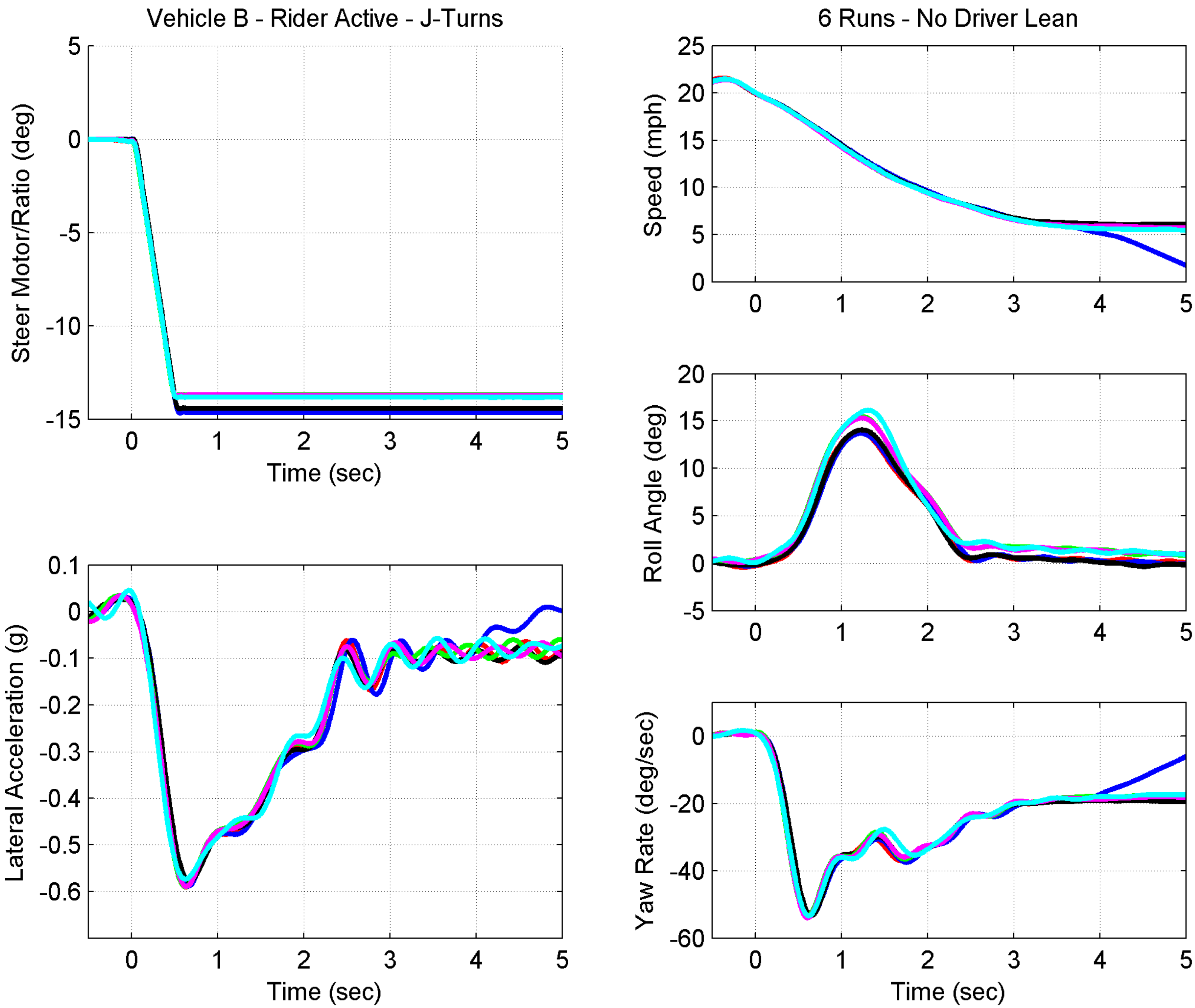
Vehicle B - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Ay (g)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1



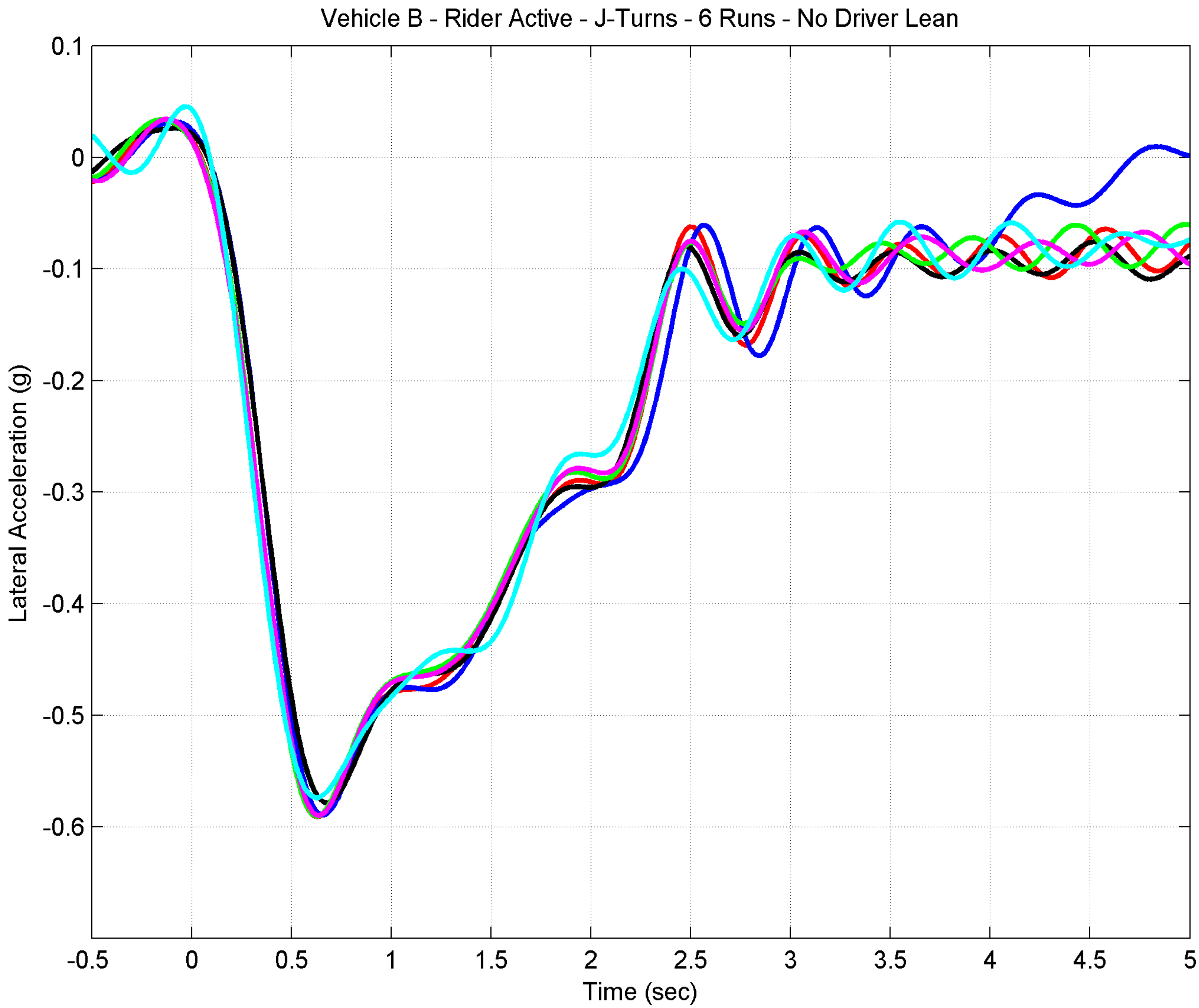
Vehicle B - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.179 g
20° Lean Transition to OS at Ay = -0.213 g
40° Lean Transition to OS at Ay = -0.249 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

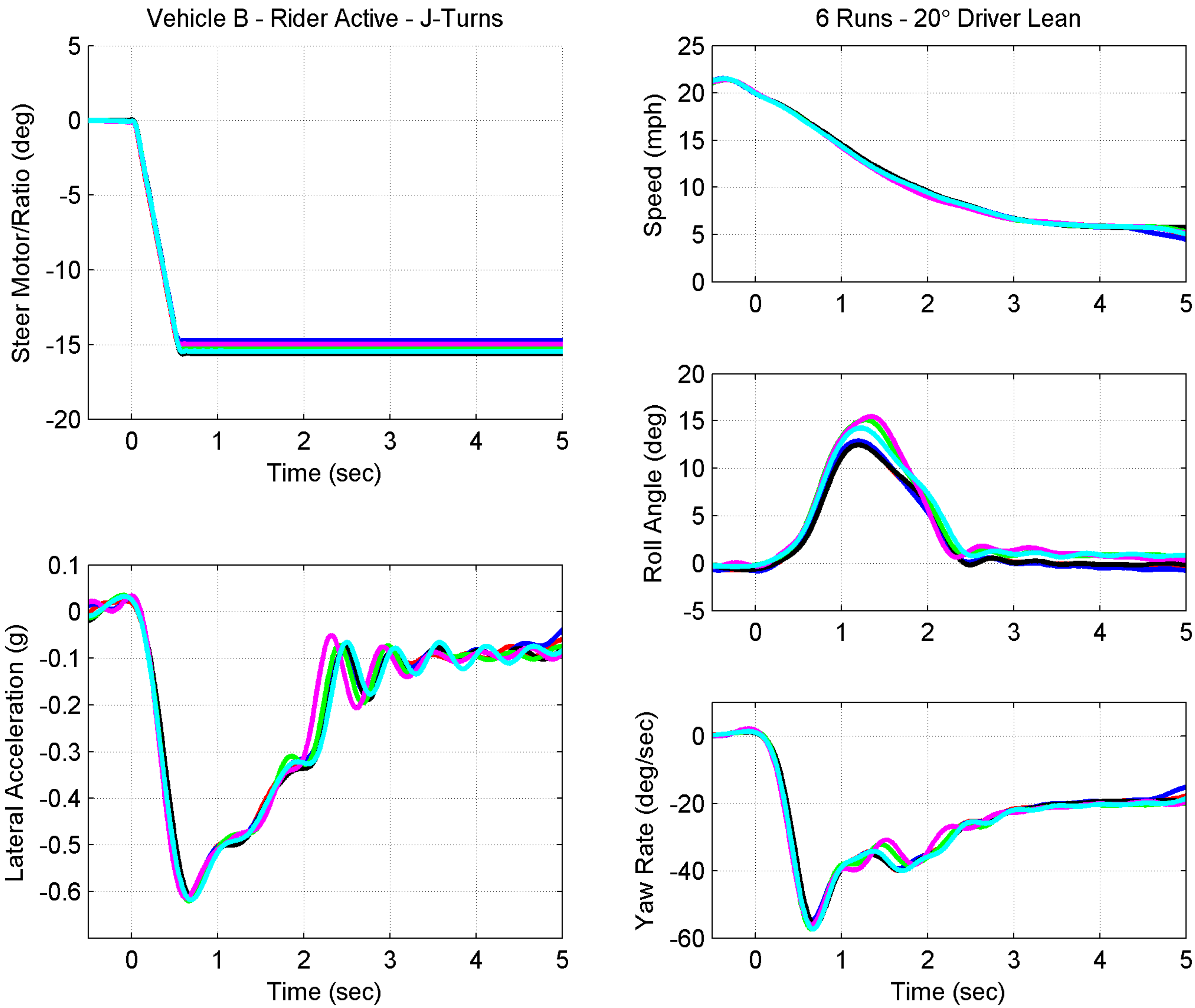


Vehicle B - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -5.14 deg/g
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

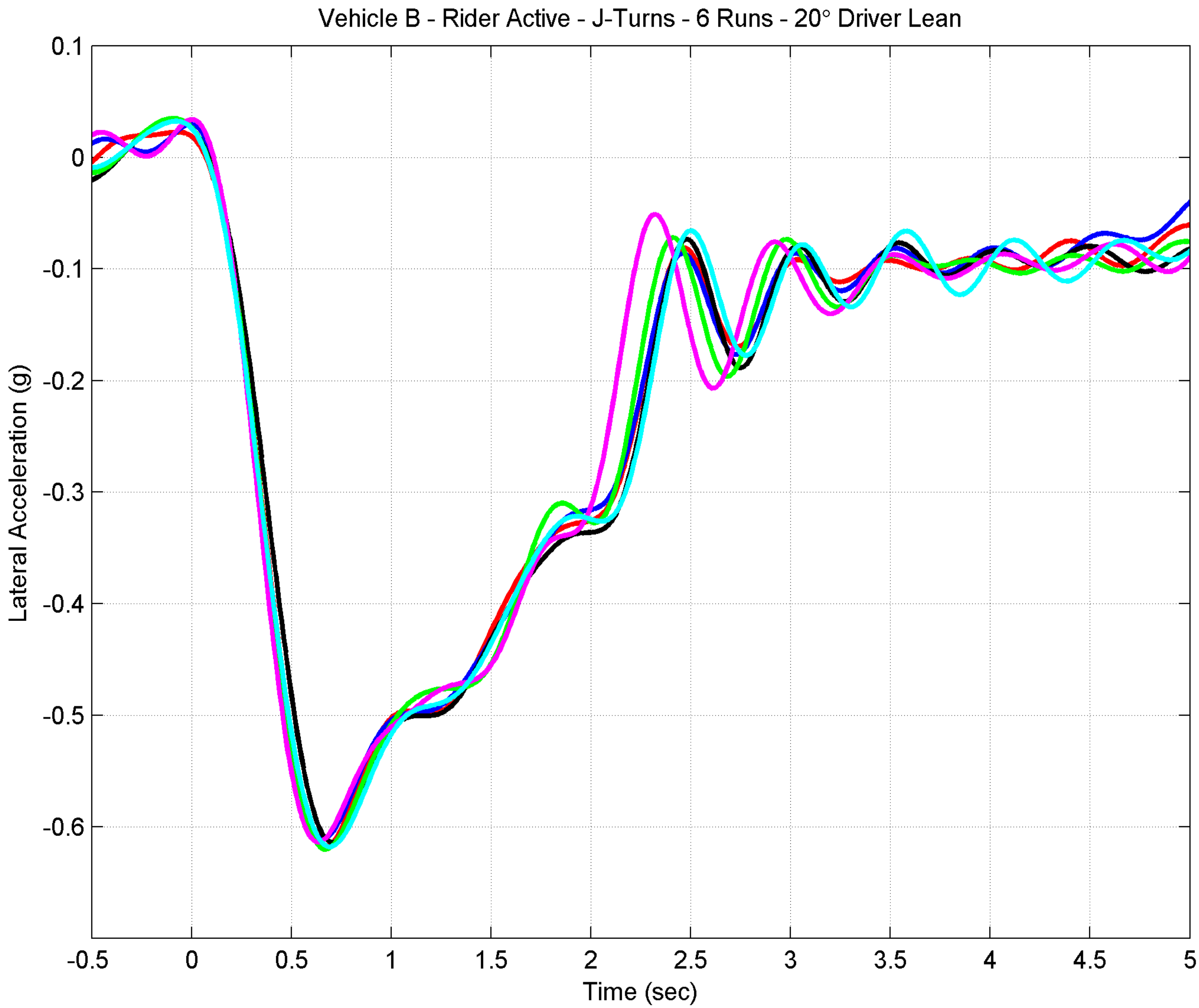


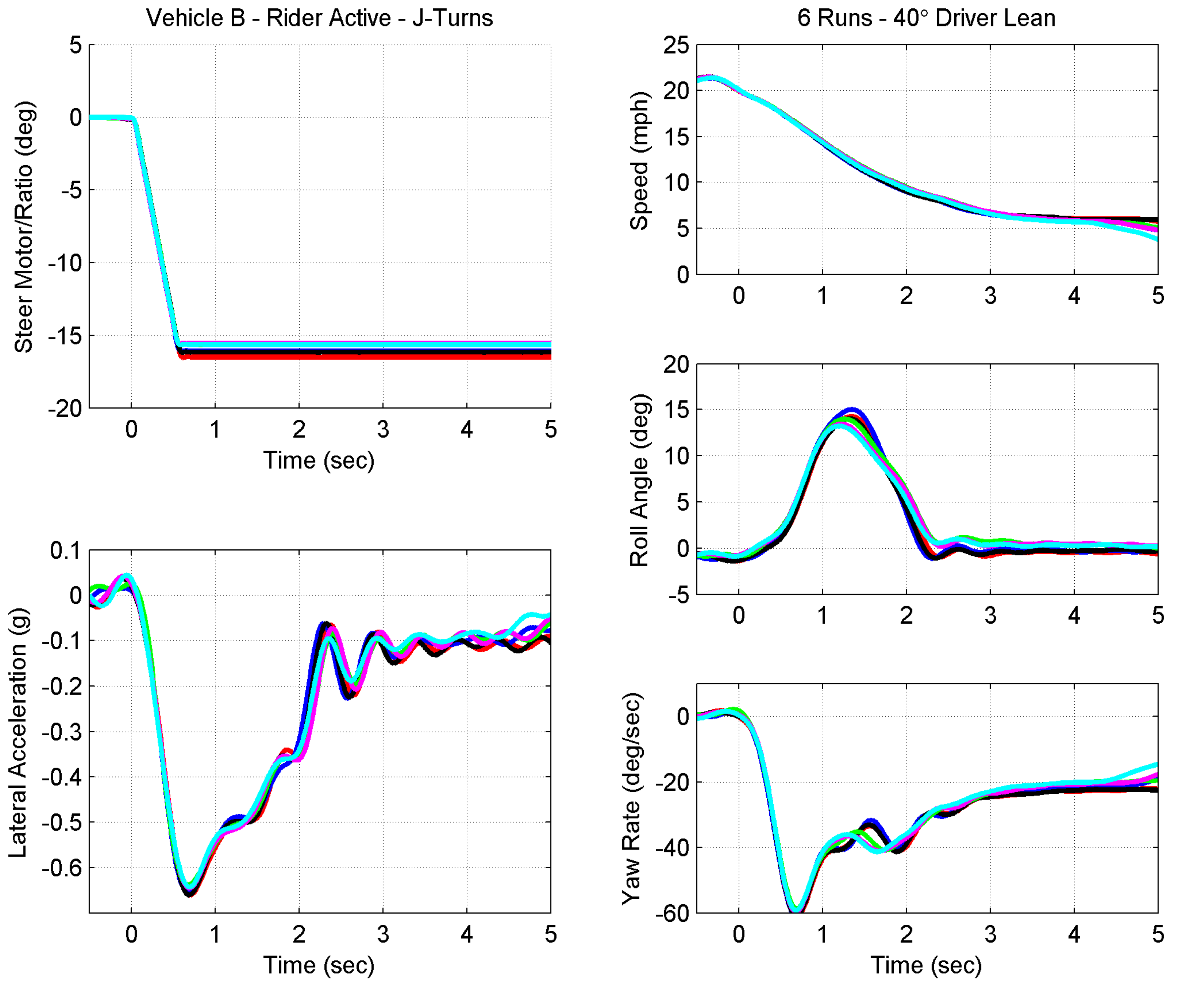
Vehicle B - Rider Active - J-Turns
6 Runs - No Driver Lean
Steer Motor/Ratio (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

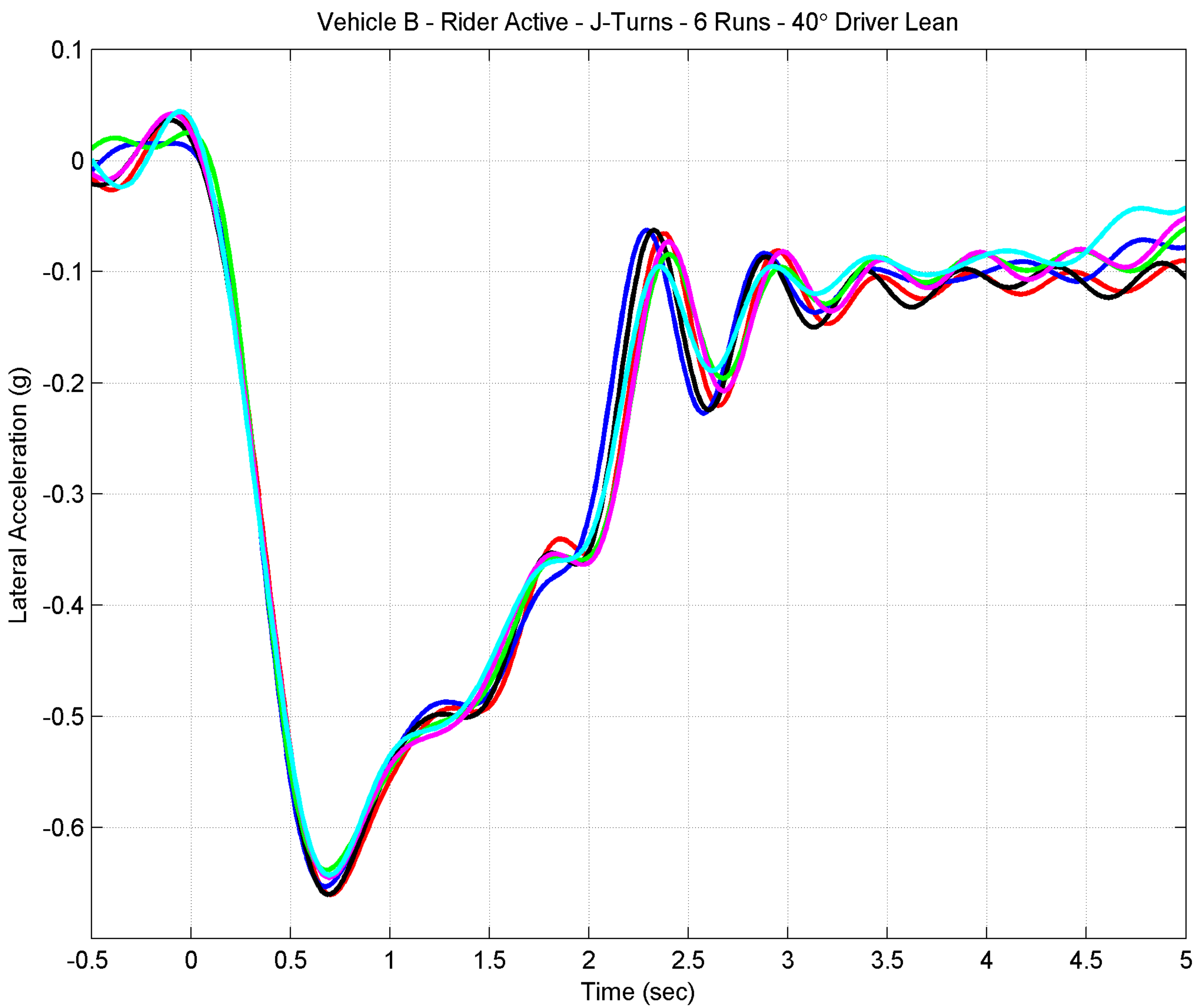

Vehicle B - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Time (sec)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle B - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Steer Motor/Ratio (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle B - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle B - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Steer Motor/Ratio (deg)
5
0
-5
-10
-15
-20
0
1
2
3
4
5
Time (sec)
Speed (mph)
25
20
15
10
5
0
Roll Angle (deg)
20
15
10
5
0
-5
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Yaw Rate (deg/sec)
0
-20
-40
-60



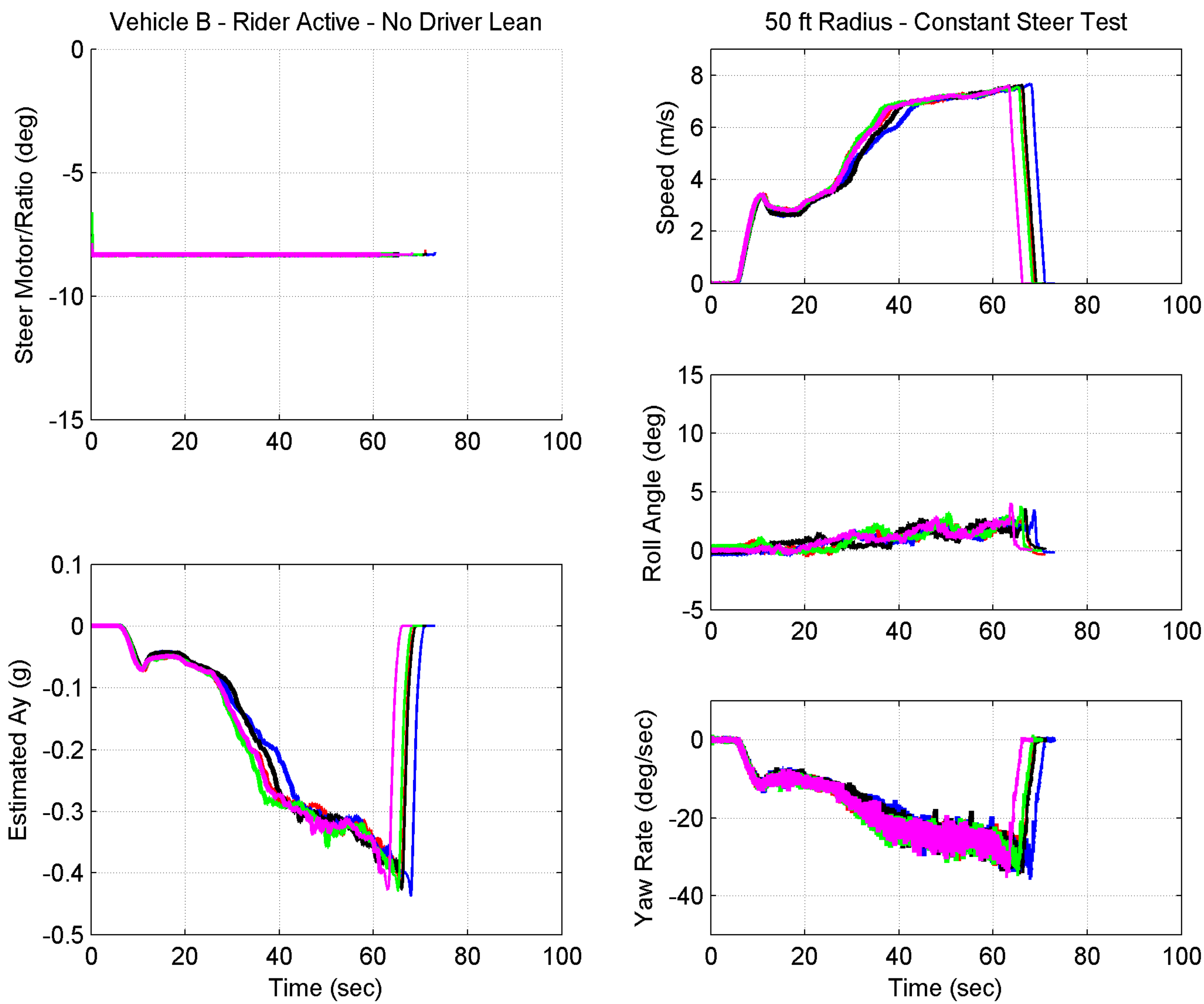
Vehicle B - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle B - Rider Active Results

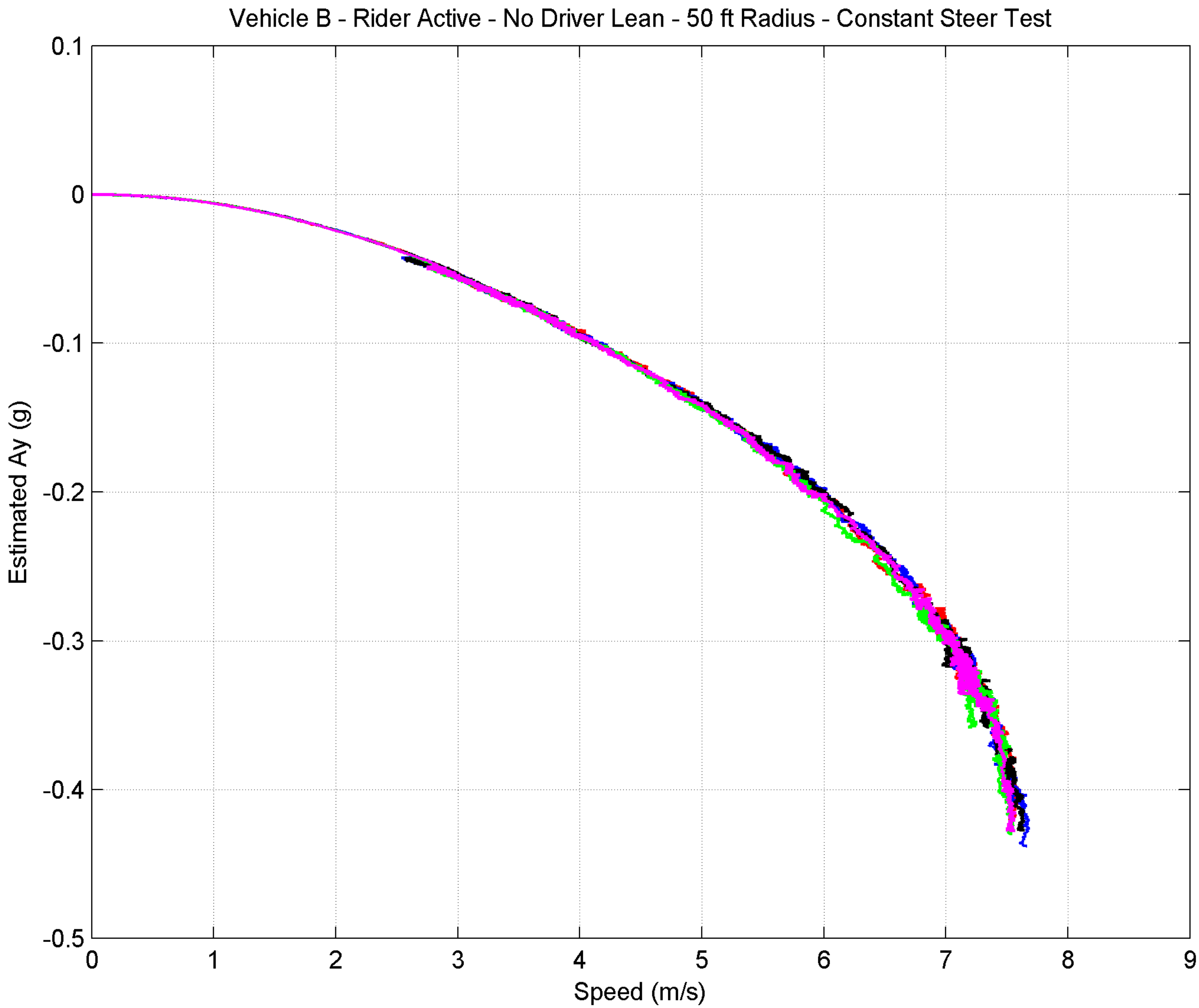
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.591	-0.618	-0.661
	-0.589	-0.610	-0.653
	-0.578	-0.614	-0.661
Mean Value of 3 Runs	-0.586	-0.614	-0.658
Standard Deviation of 3 Runs	0.007	0.004	0.004

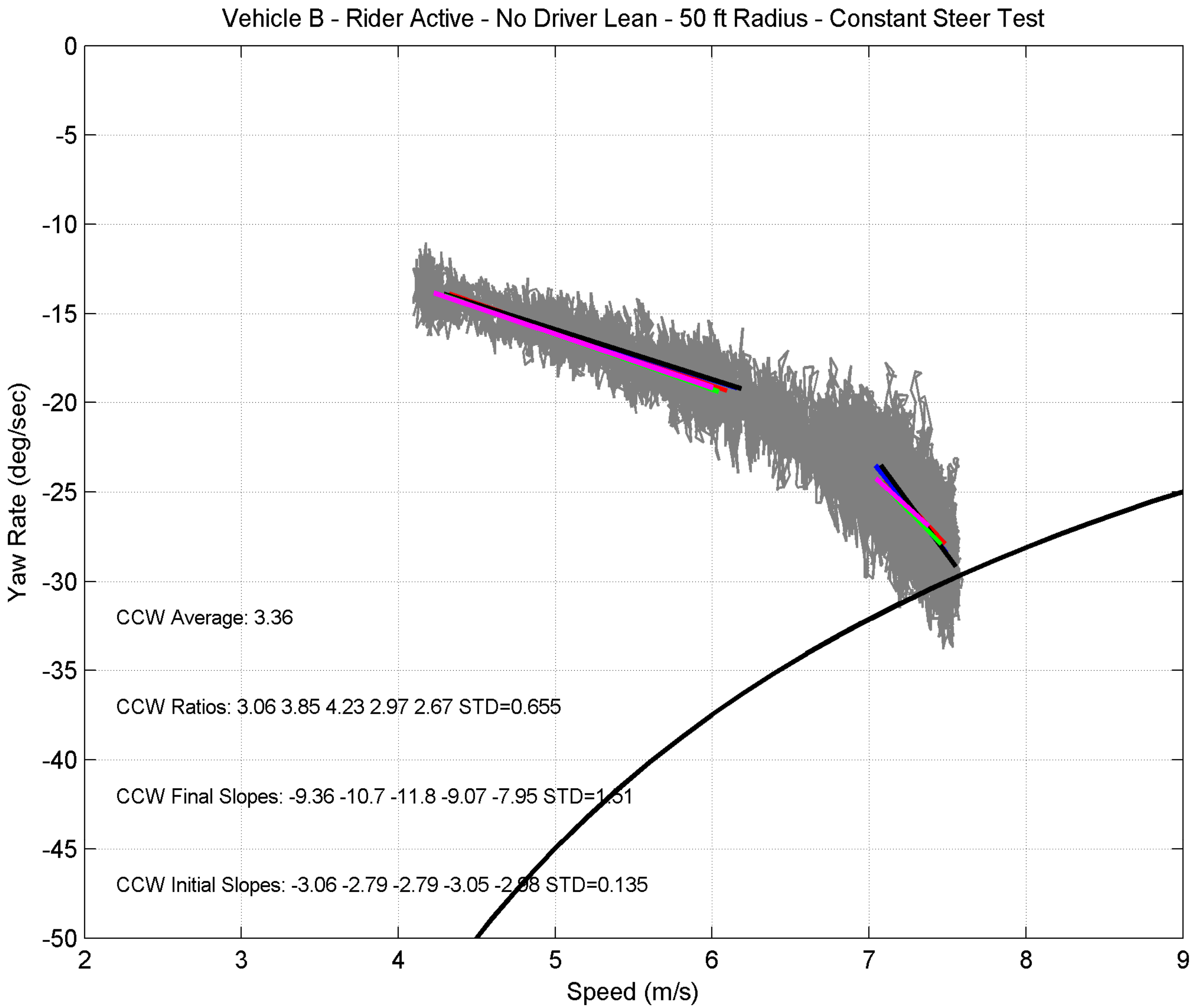
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.590	-0.621	-0.639
	-0.590	-0.614	-0.645
	-0.574	-0.618	-0.643
Mean Value of 3 Runs	-0.585	-0.617	-0.642
Standard Deviation of 3 Runs	0.009	0.003	0.003
Average of All 6 Runs	**0.585**	**0.616**	**0.650**

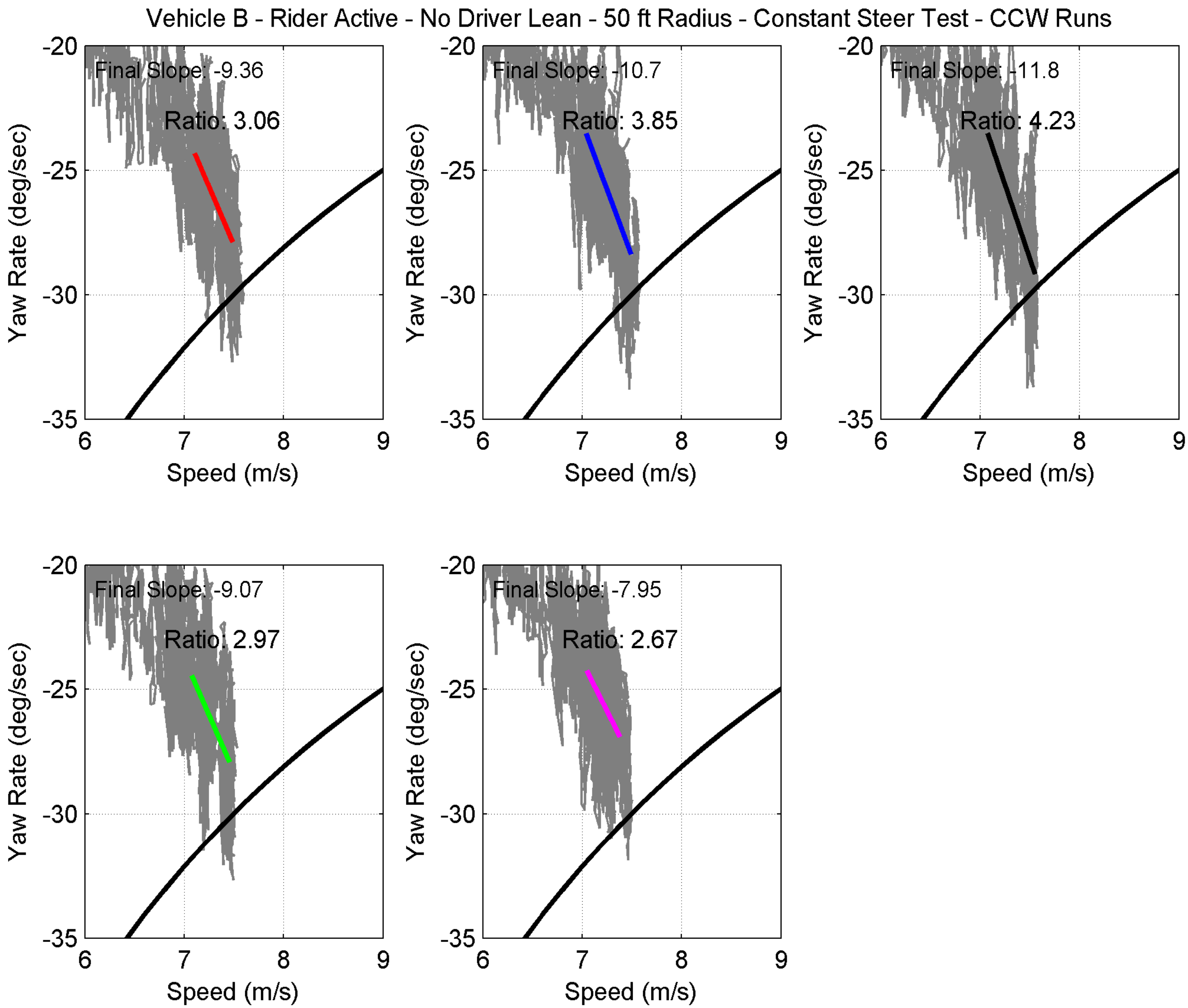


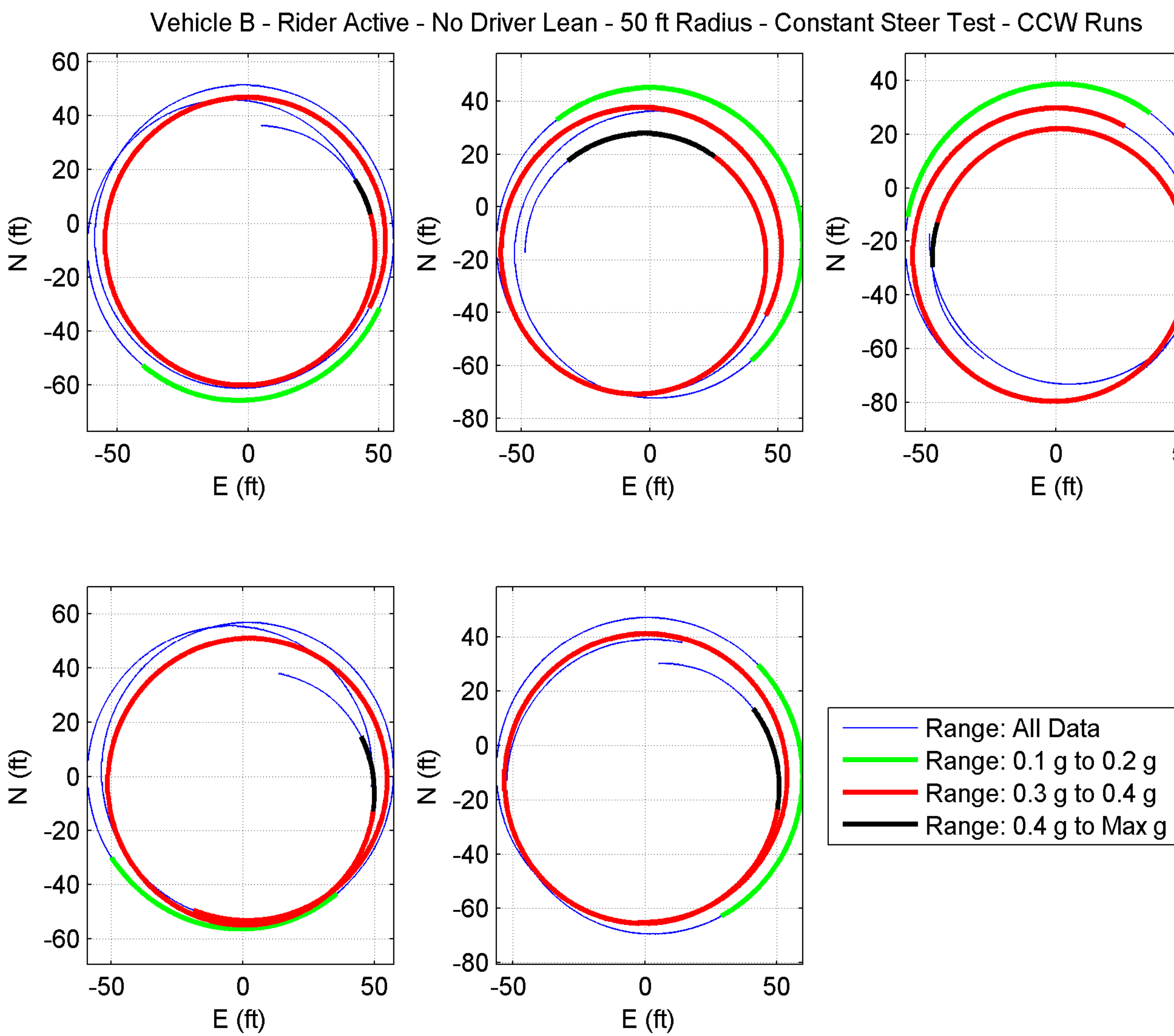
Vehicle B - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Steer Motor/Ratio (deg)
0
-5
-10
-15
0 20 40 60 80 100
Speed (m/s)
8
6
4
2
0
0 20 40 60 80 100
Roll Angle (deg)
15
10
5
0
-5
0 20 40 60 80 100
Estimated Ay (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0 20 40 60 80 100
Time (sec)
Yaw Rate (deg/sec)
0
-20
-40
0 20 40 60 80 100
Time (sec)



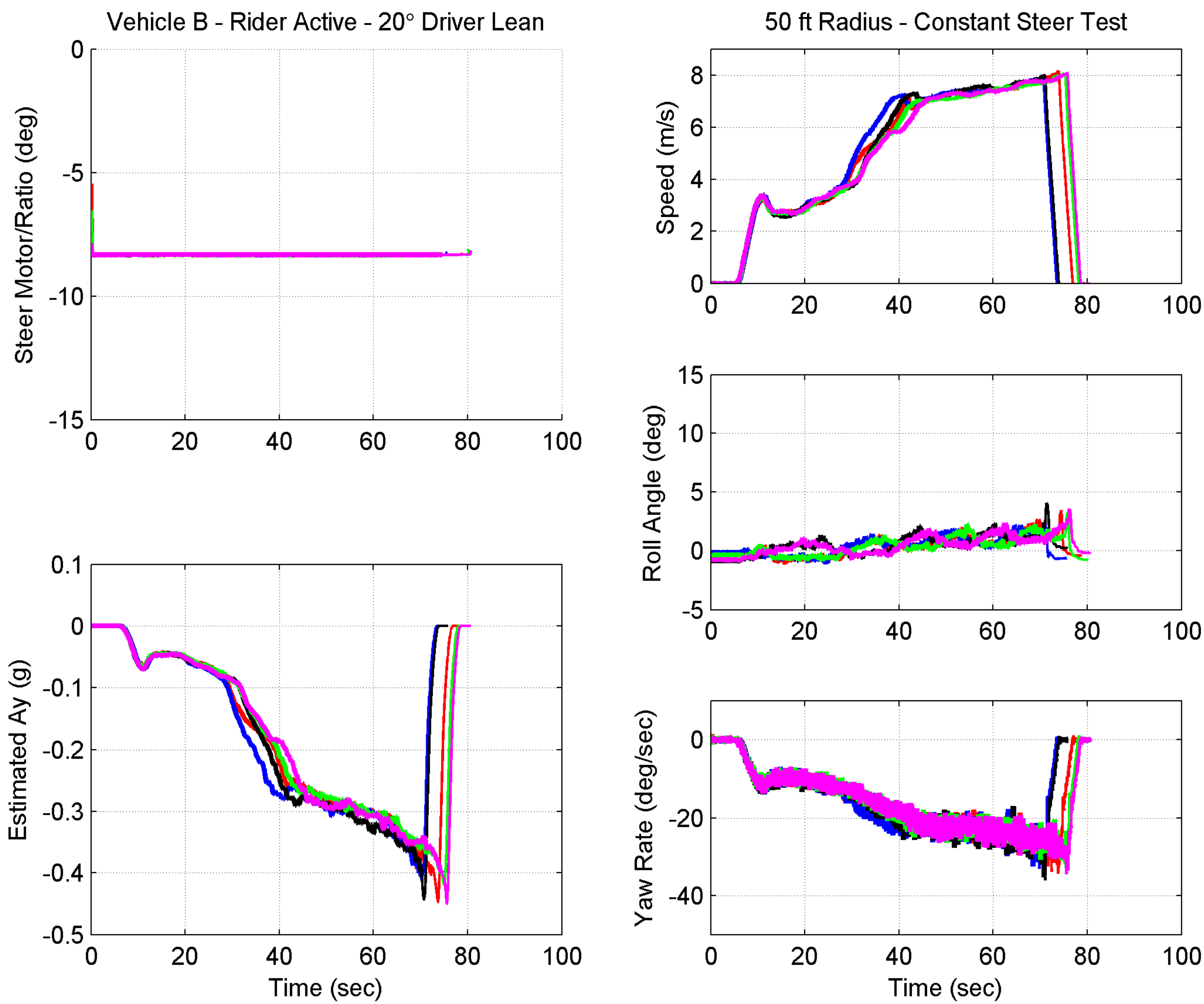
Vehicle B - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9


Vehicle B - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 3.36
CCW Ratios: 3.06 3.85 4.23 2.97 2.67 STD=0.655
CCW Final Slopes: -9.36 -10.7 -11.8 -9.07 -7.95 STD=1.51
CCW Initial Slopes: -3.06 -2.79 -2.79 -3.05 -2.98 STD=0.135

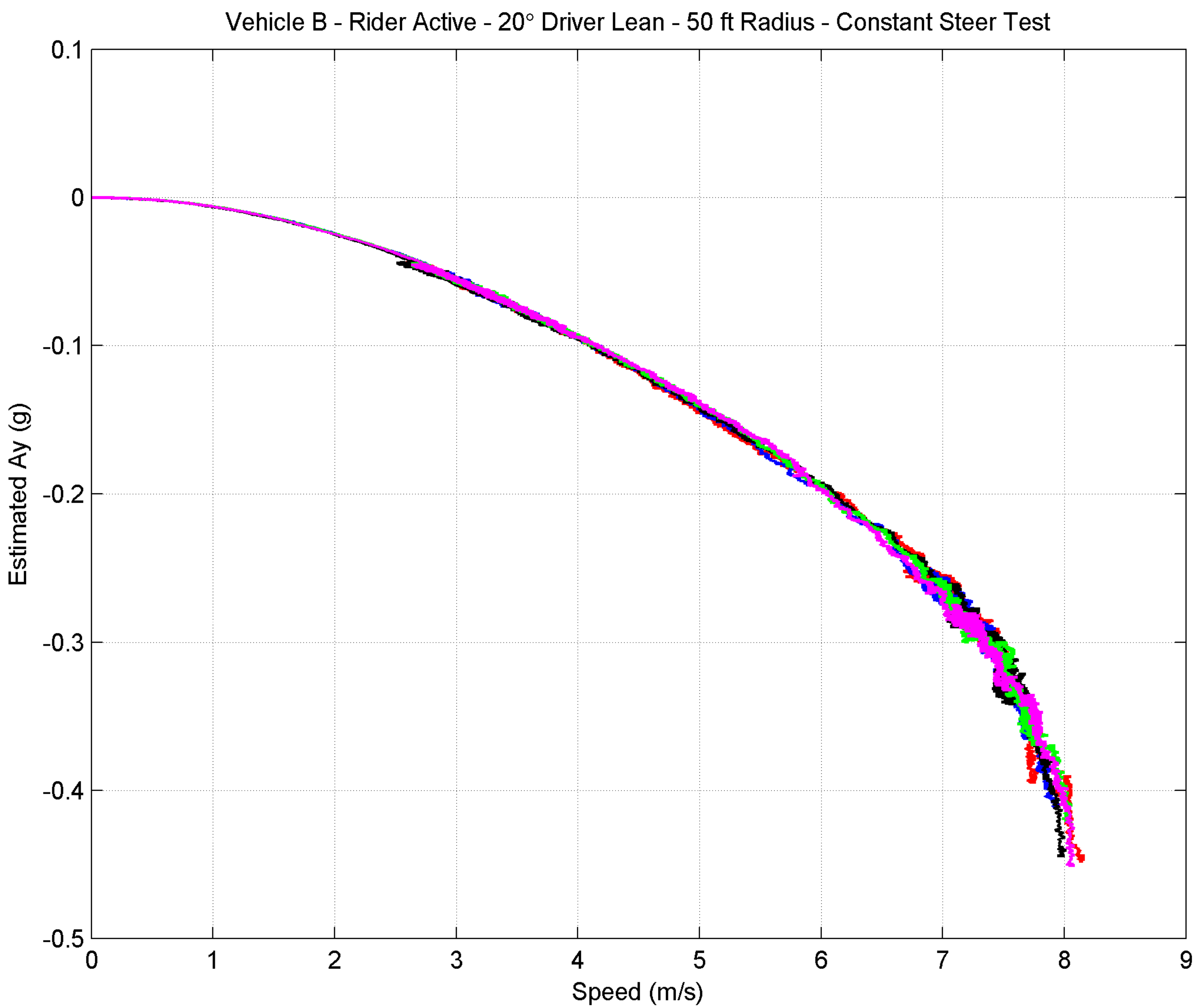

Vehicle B - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -9.36
Ratio: 3.06
Final Slope: -10.7
Ratio: 3.85
Final Slope: -11.8
Ratio: 4.23
Final Slope: -9.07
Ratio: 2.97
Final Slope: -7.95
Ratio: 2.67
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

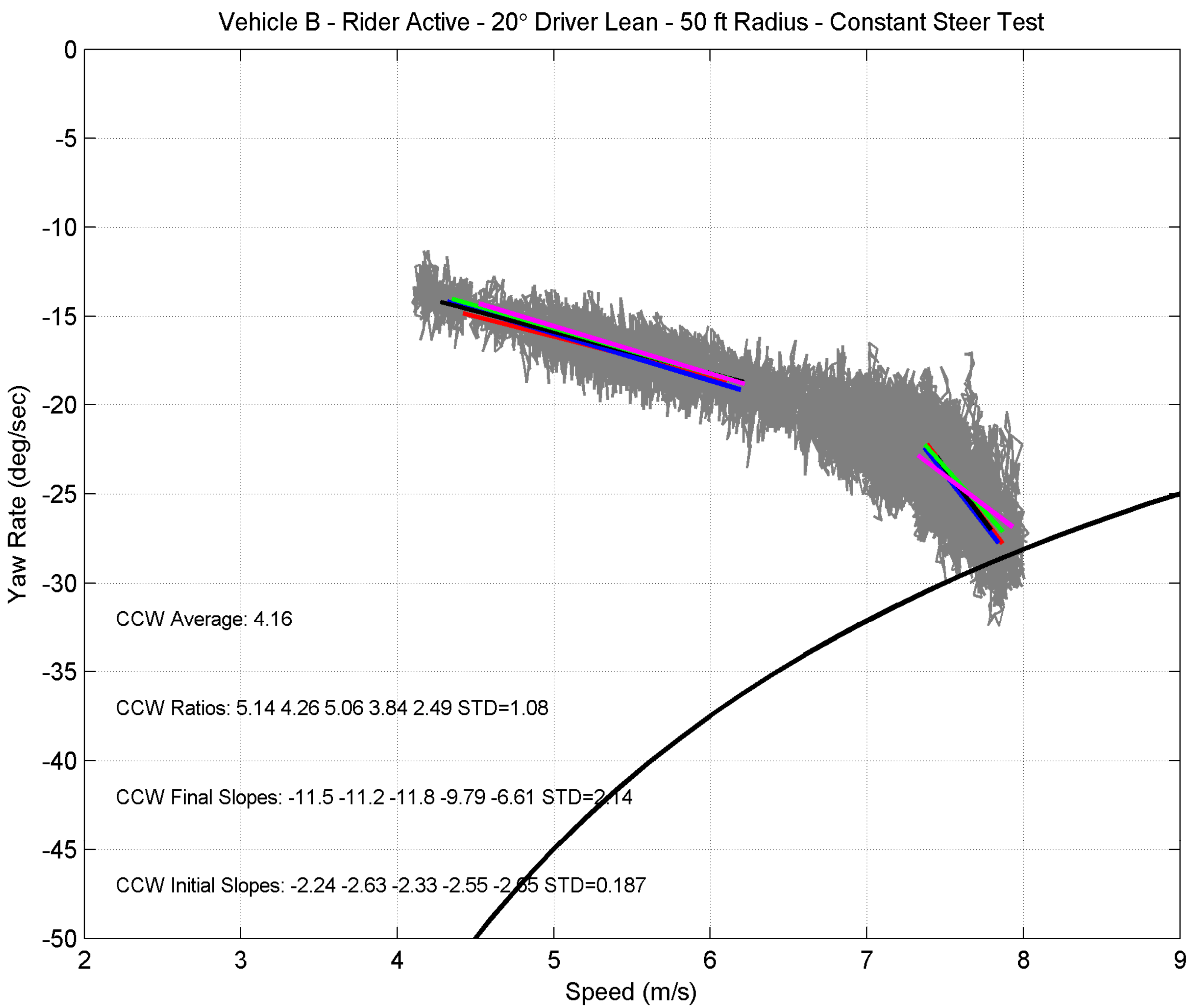


Vehicle B - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

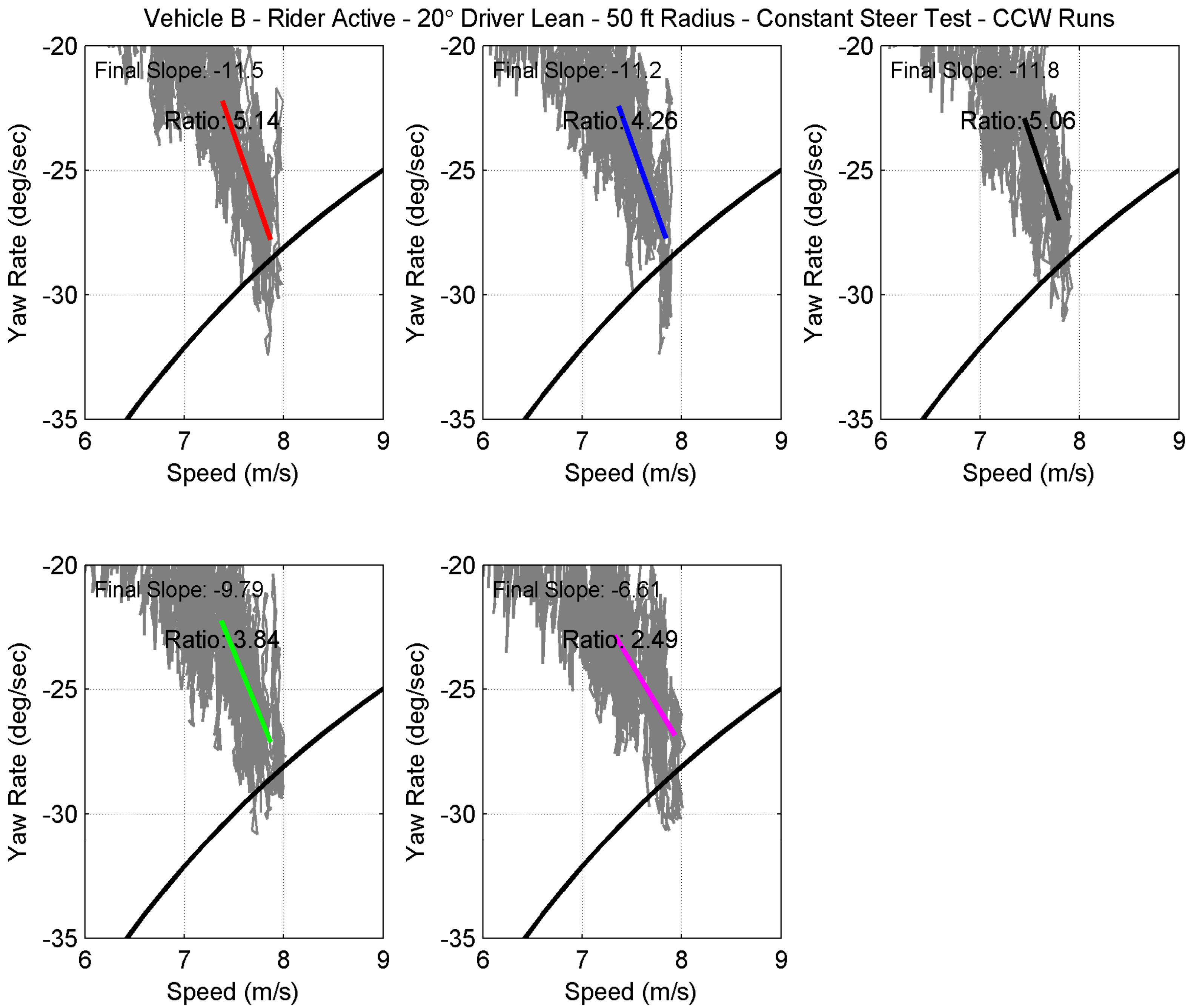


Vehicle B - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Steer Motor/Ratio (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

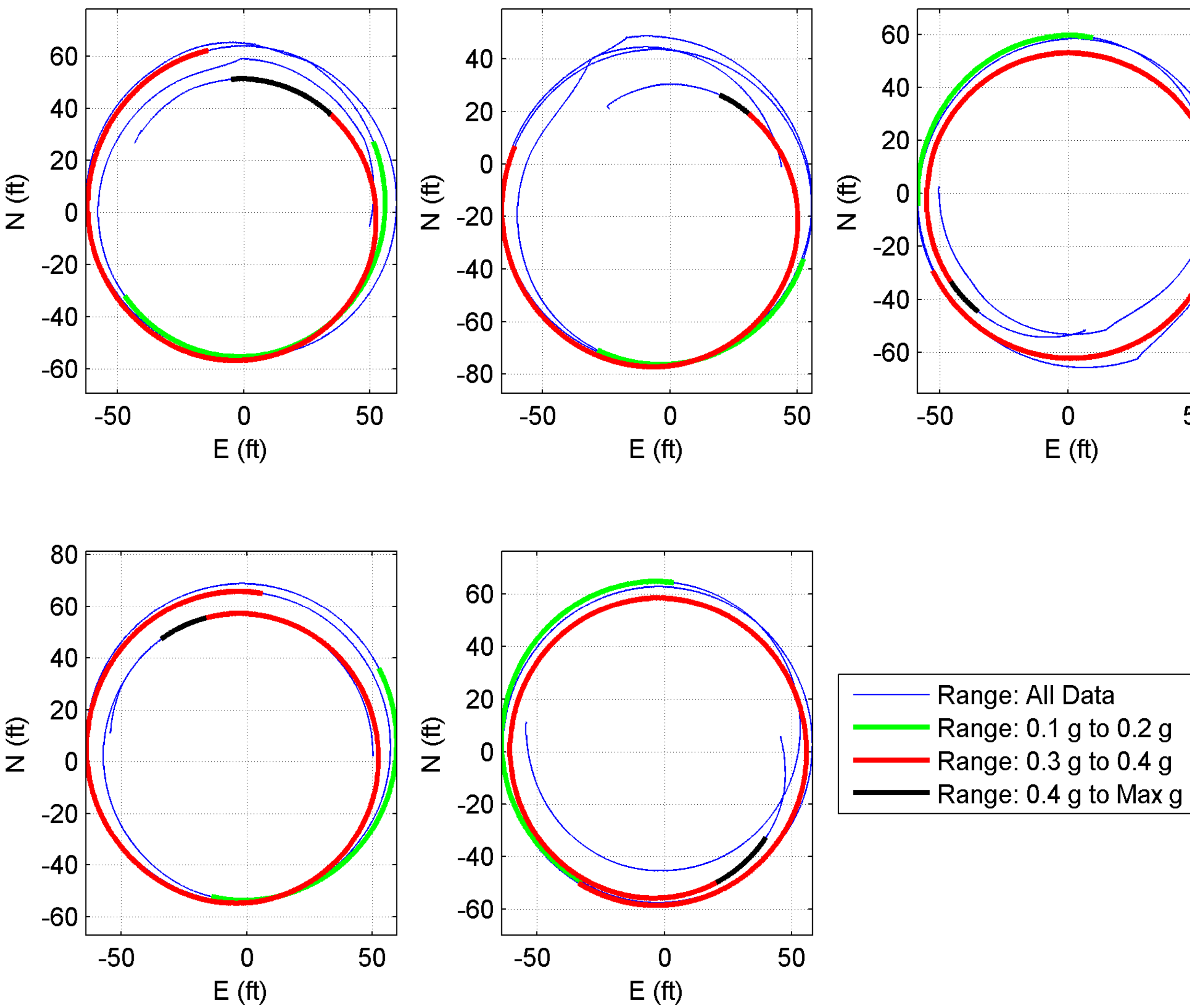

Vehicle B - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

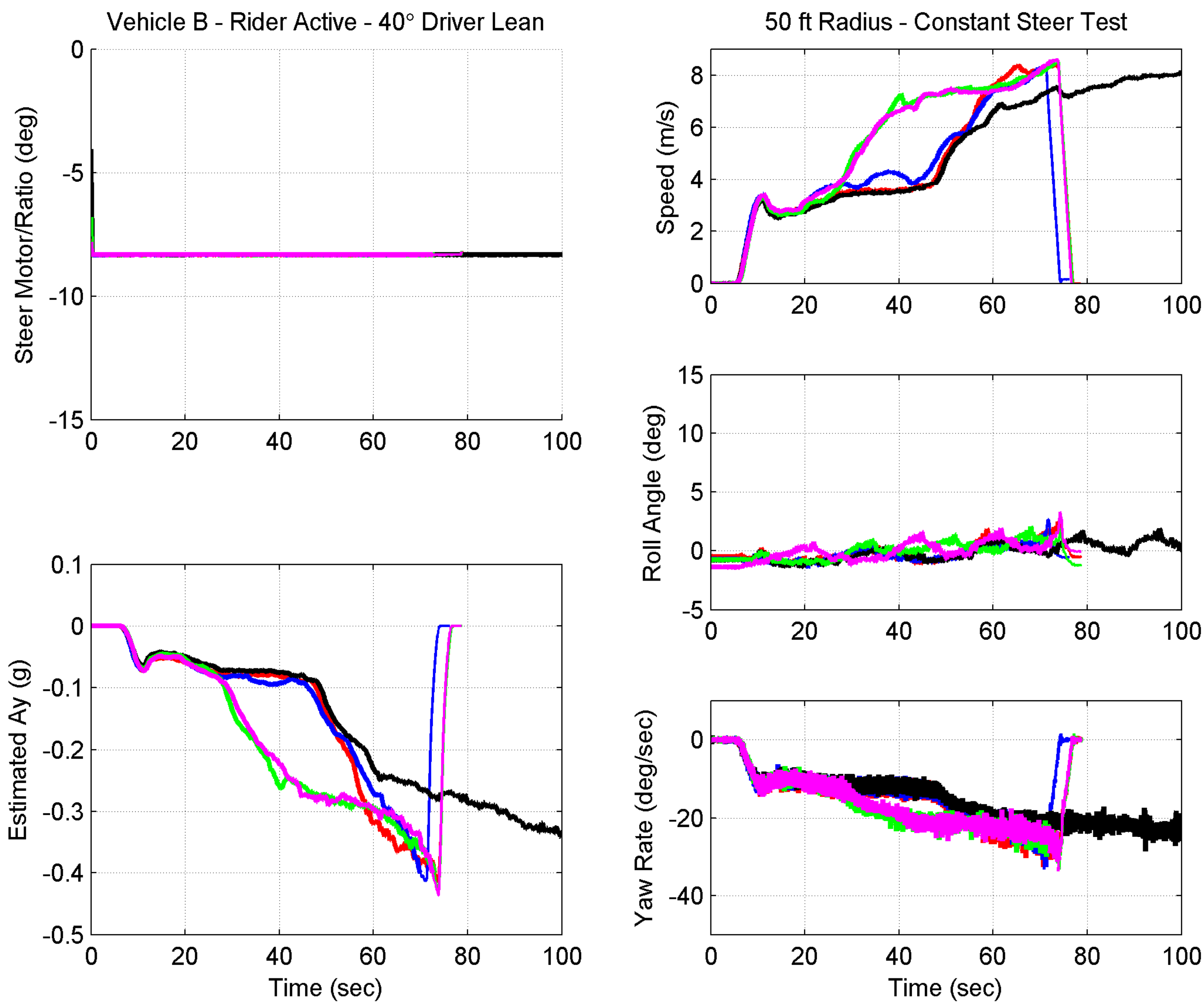


Vehicle B - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 4.16
CCW Ratios: 5.14 4.26 5.06 3.84 2.49 STD=1.08
CCW Final Slopes: -11.5 -11.2 -11.8 -9.79 -6.61 STD=2.14
CCW Initial Slopes: -2.24 -2.63 -2.33 -2.55 -2.65 STD=0.187

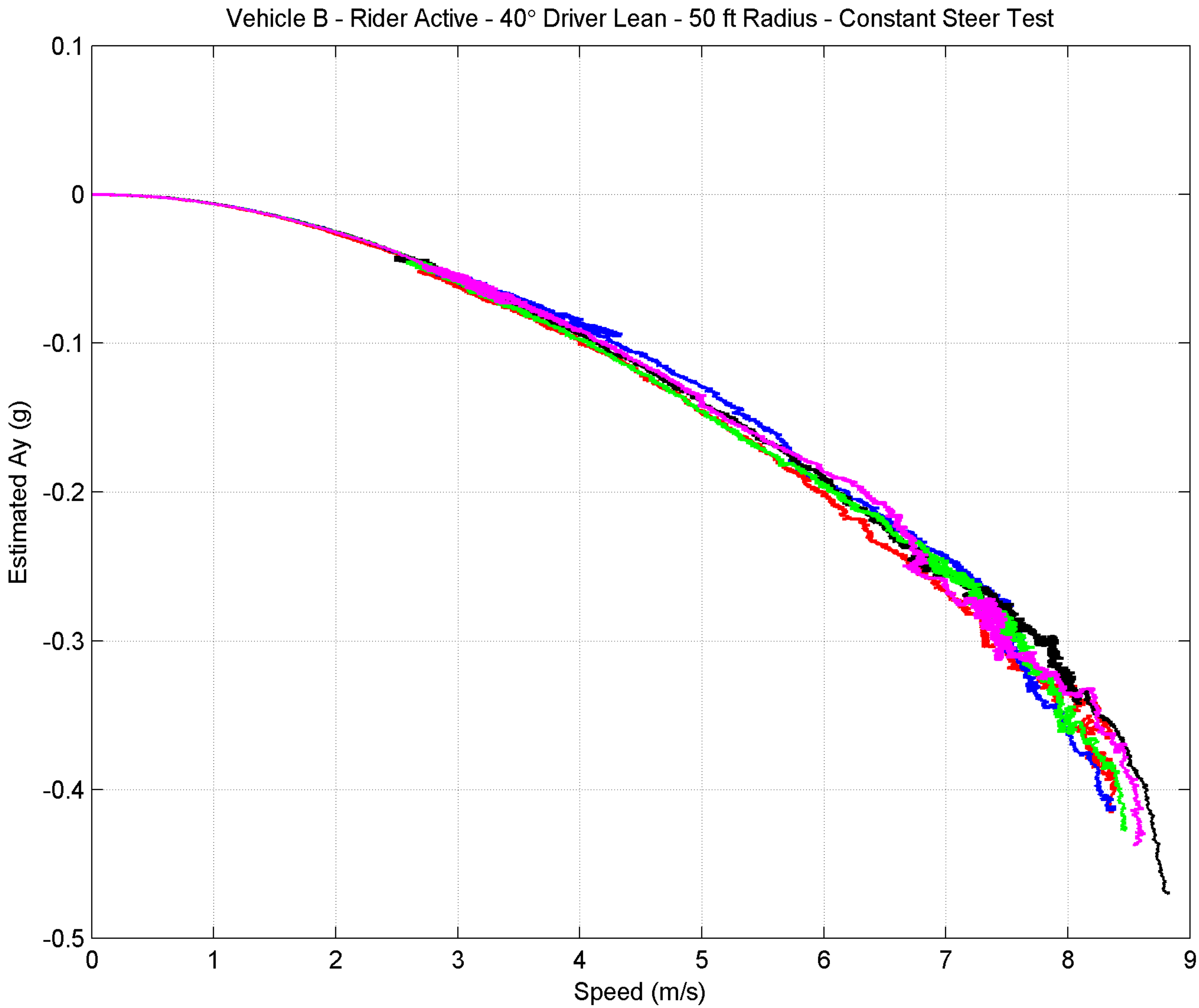

Vehicle B - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -11.5
Ratio: 5.14
Final Slope: -11.2
Ratio: 4.26
Final Slope: -11.8
Ratio: 5.06
Final Slope: -9.79
Ratio: 3.84
Final Slope: -6.61
Ratio: 2.49
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

Vehicle B - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

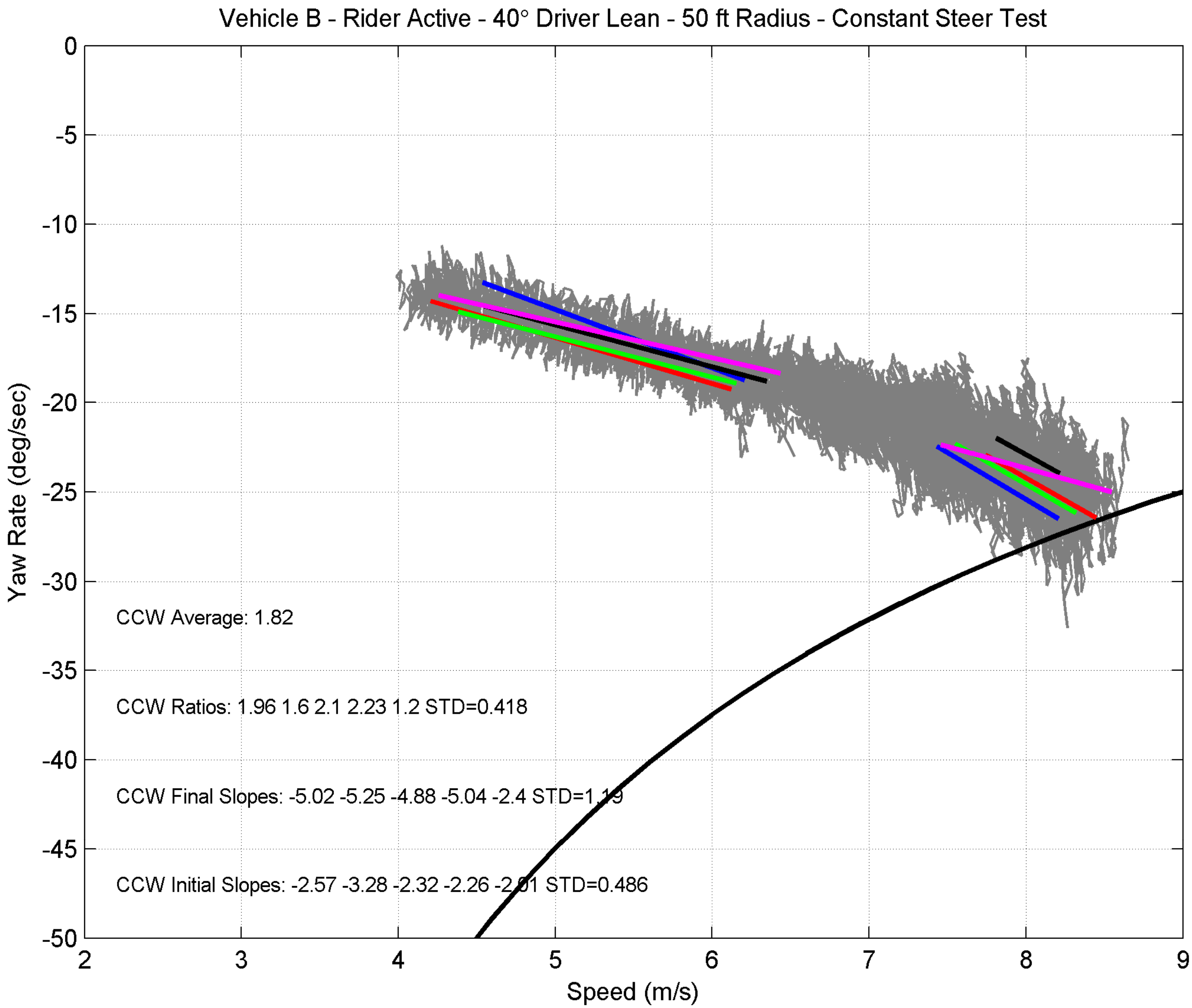




Vehicle B - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Steer Motor/Ratio (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

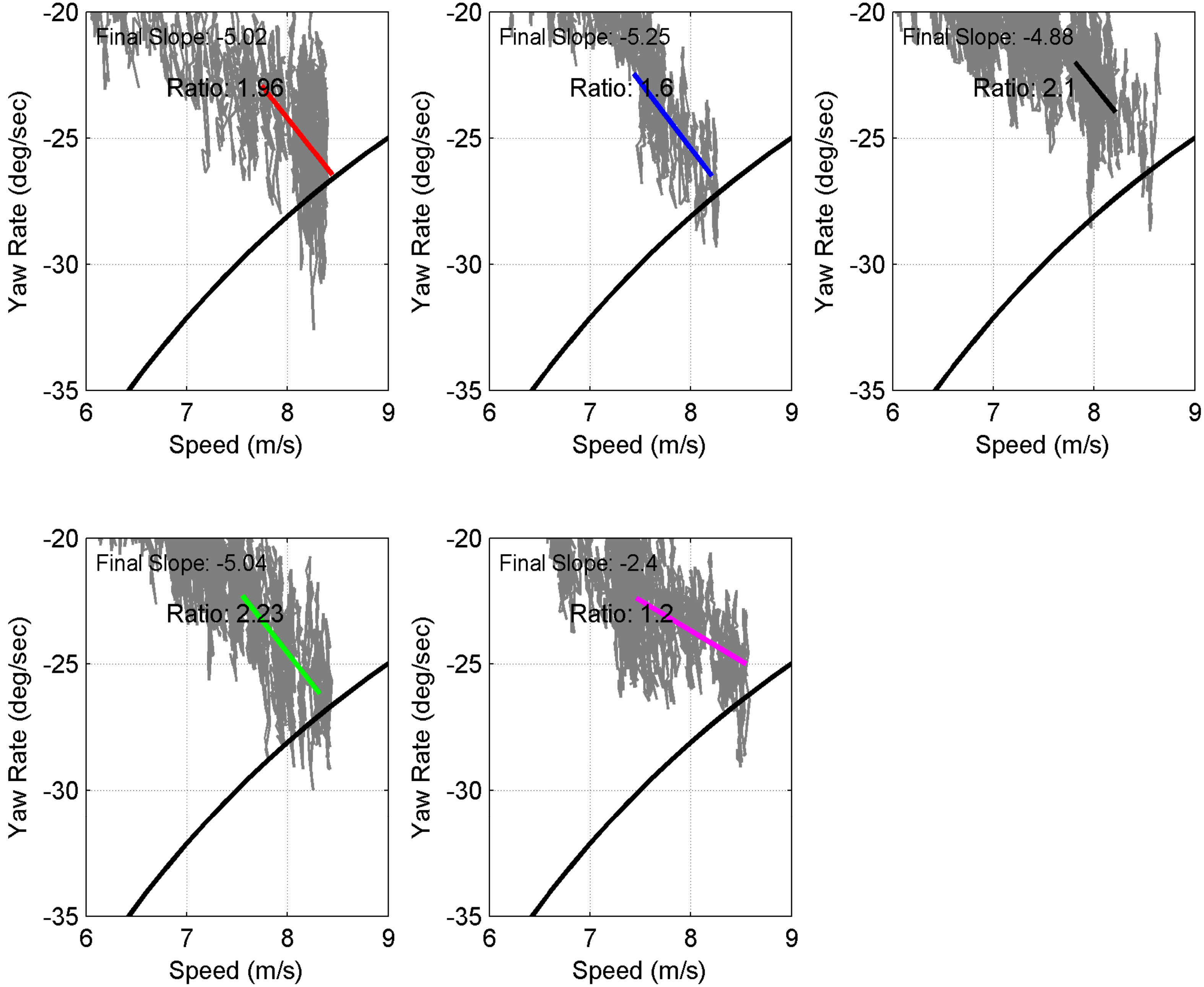


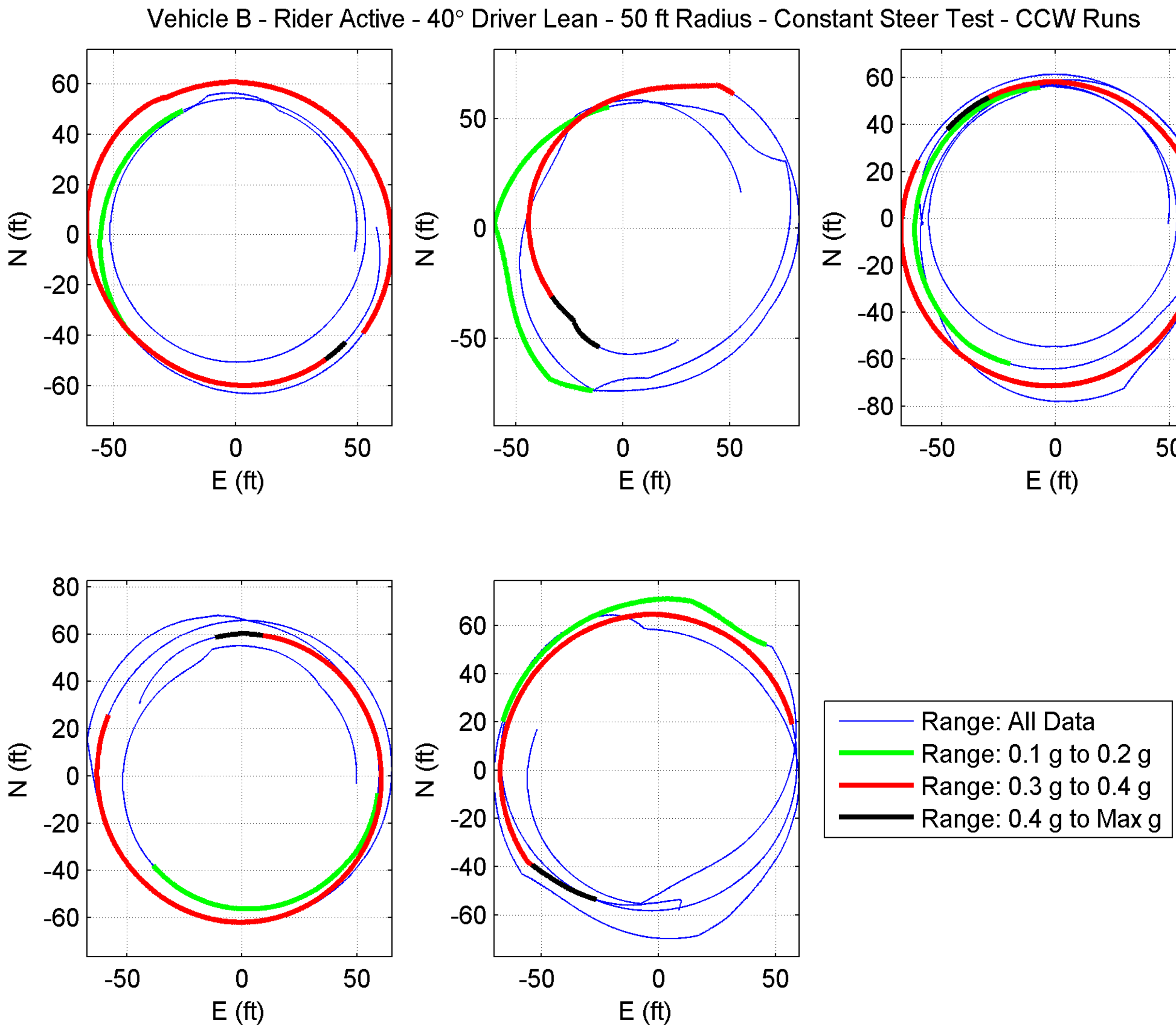
Vehicle B - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9



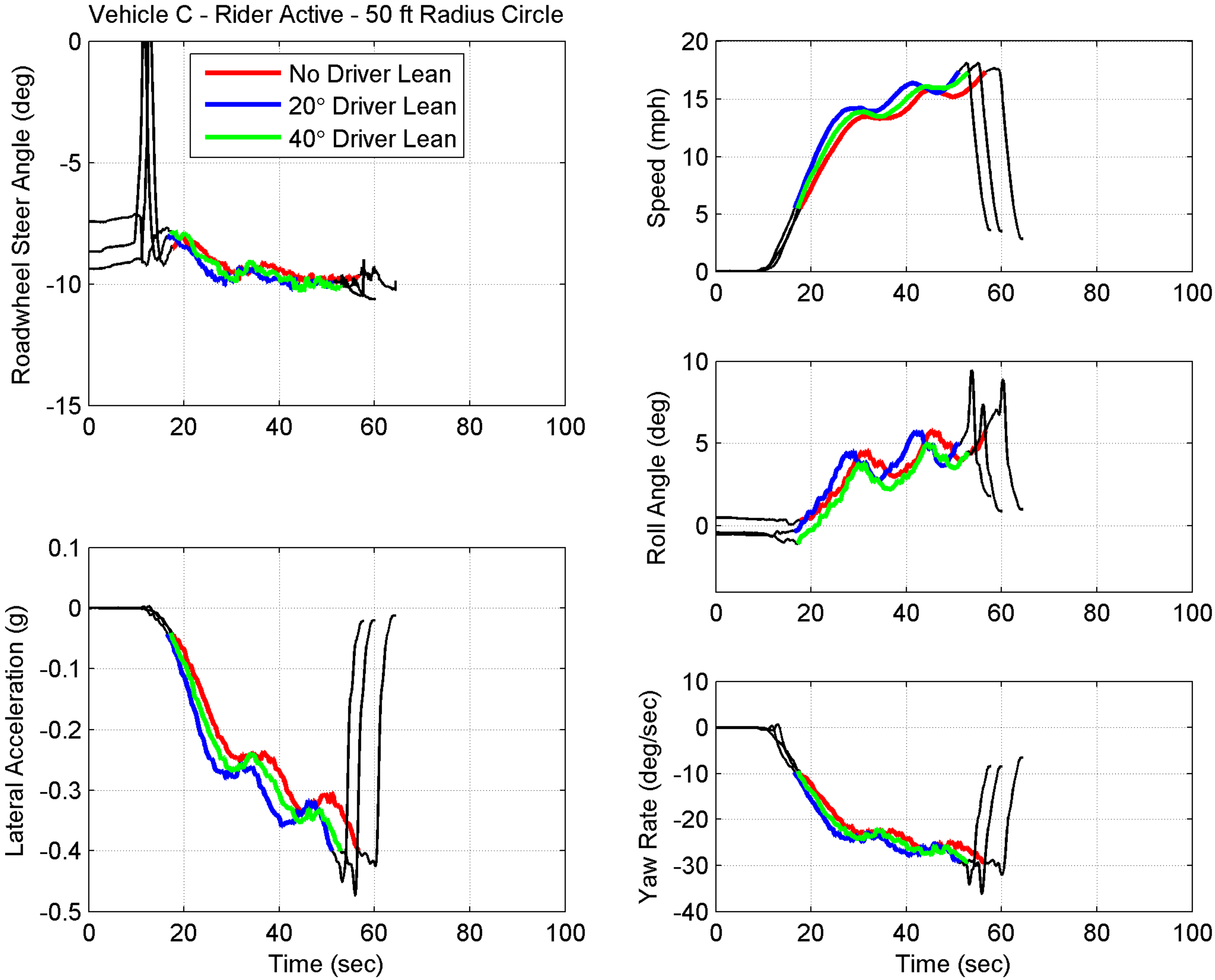
Vehicle B - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 1.82
CCW Ratios: 1.96 1.6 2.1 2.23 1.2 STD=0.418
CCW Final Slopes: -5.02 -5.25 -4.88 -5.04 -2.4 STD=1.19
CCW Initial Slopes: -2.57 -3.28 -2.32 -2.26 -2.01 STD=0.486

Vehicle B - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

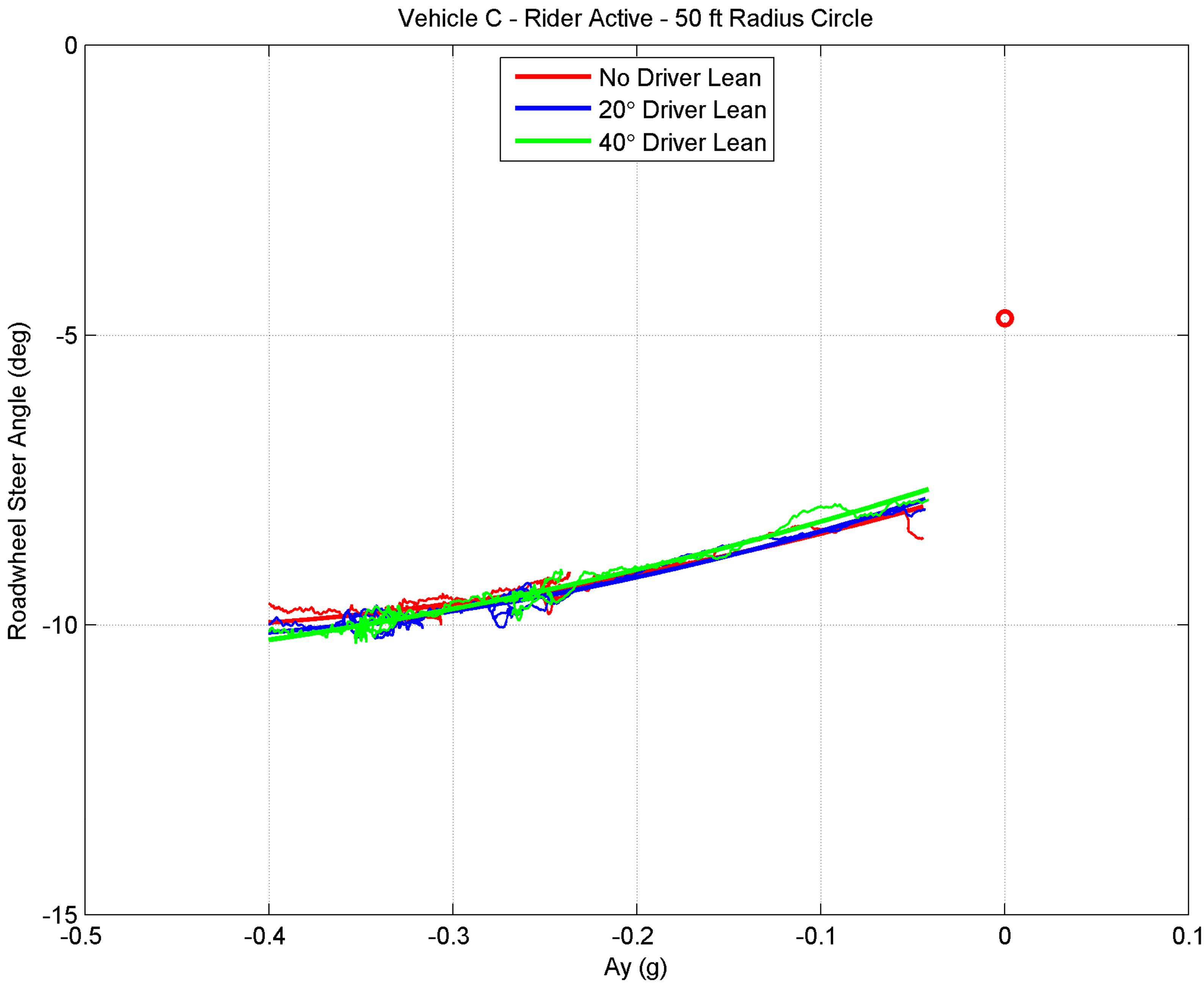




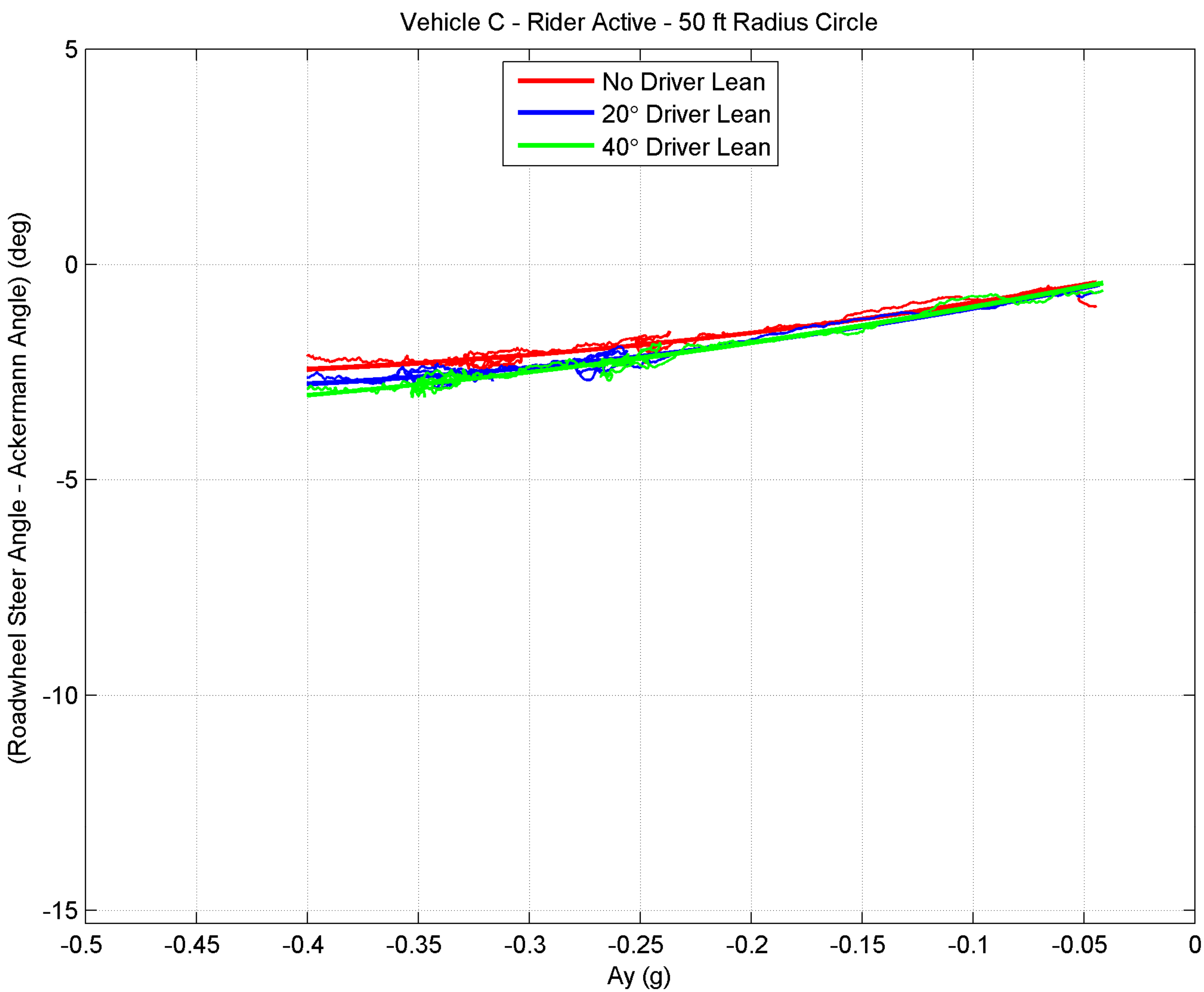
Vehicle B - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

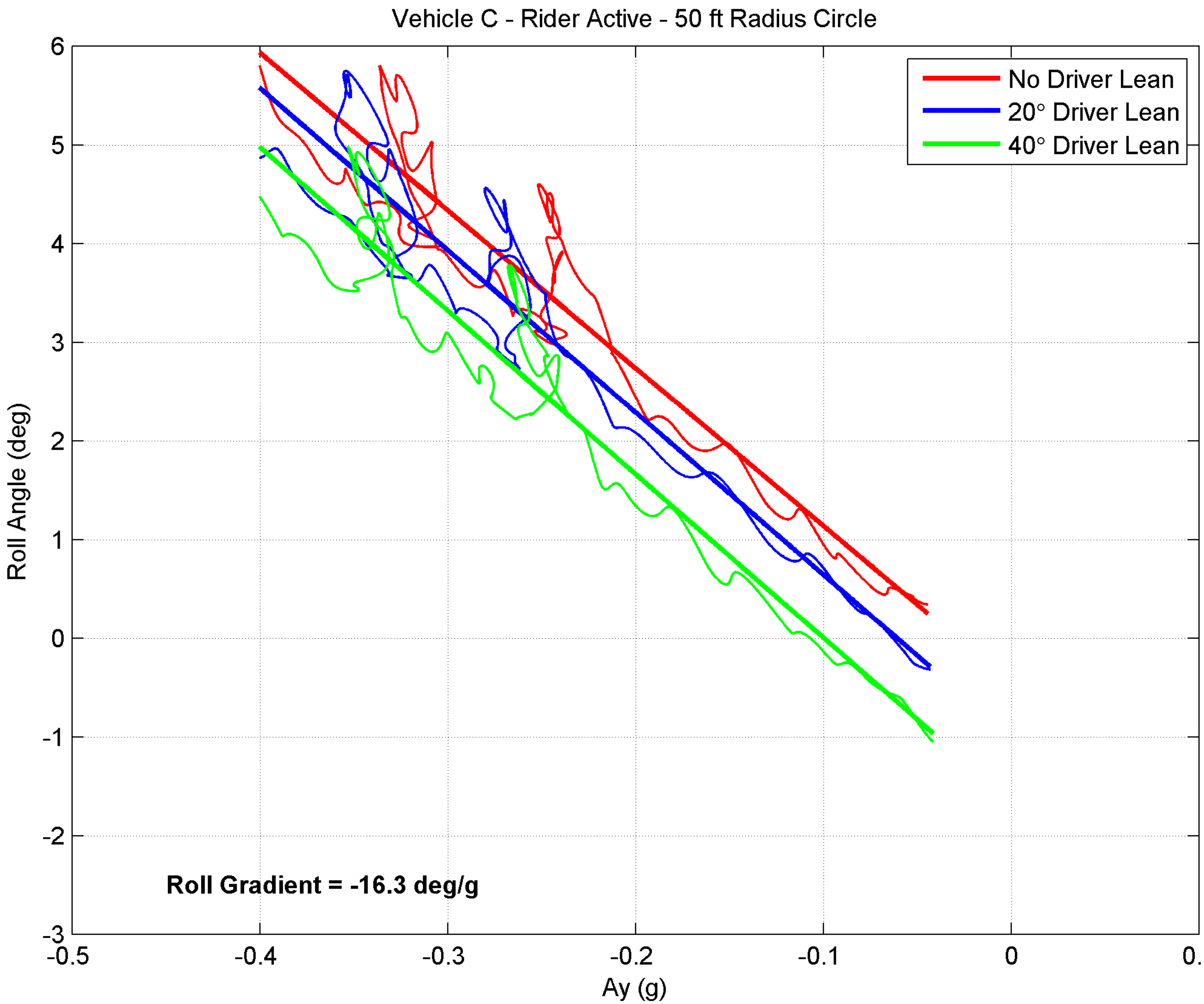


Vehicle C - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

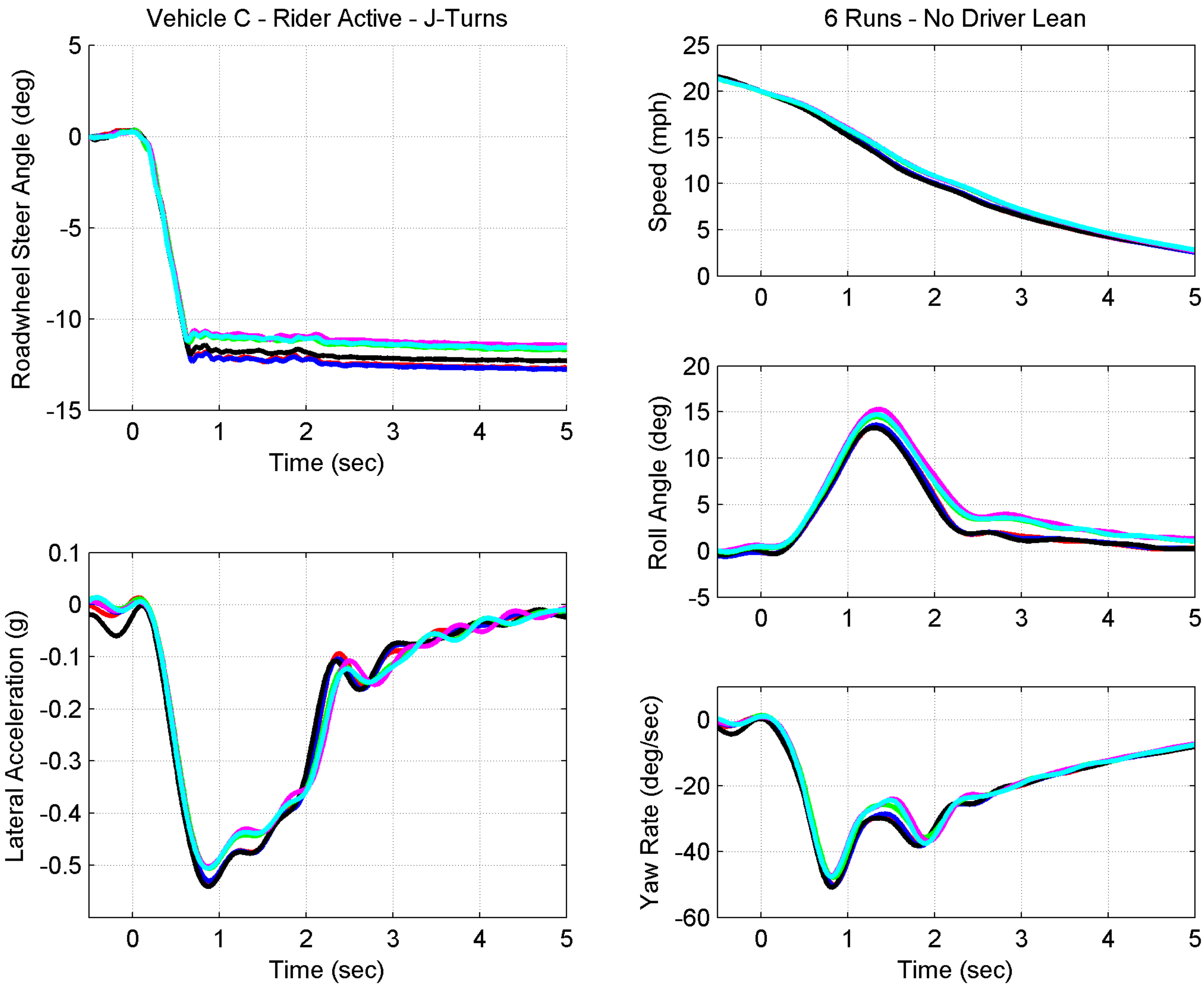


Vehicle C - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Ay (g)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

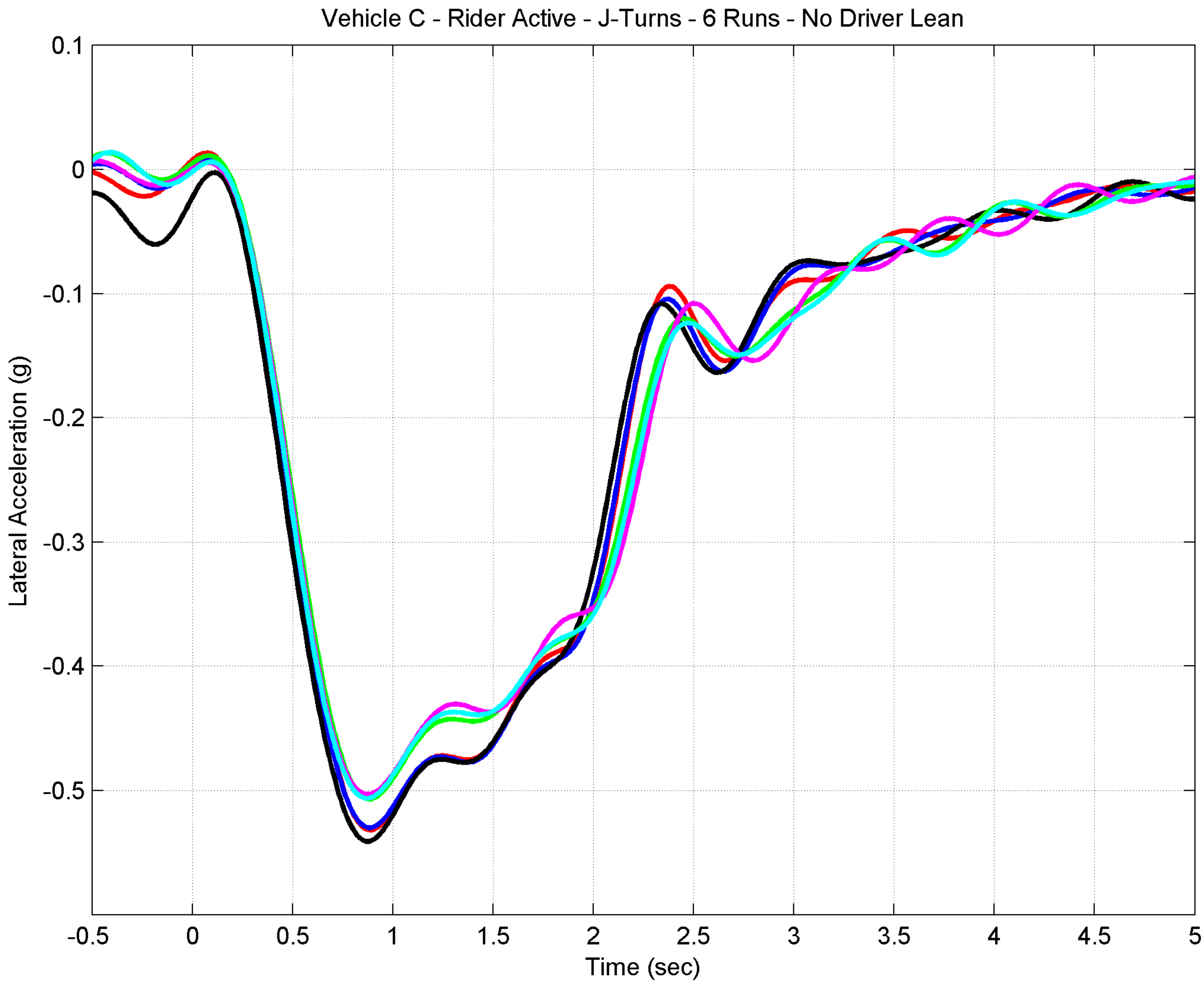

Vehicle C - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
(Roadwheel Steer Angle - Ackermann Angle) (deg)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
Ay (g)



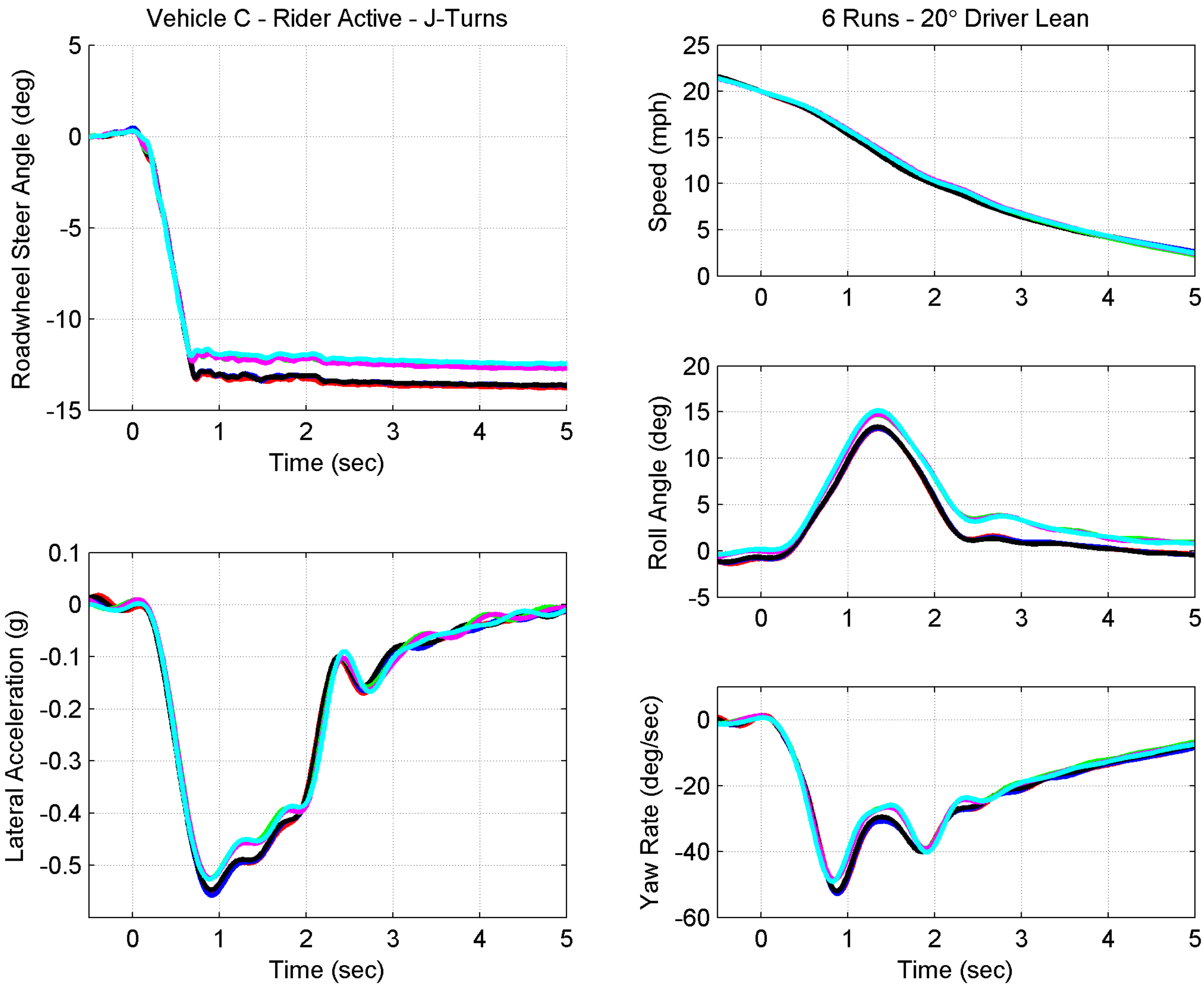
Vehicle C - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -16.3 deg/g
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1



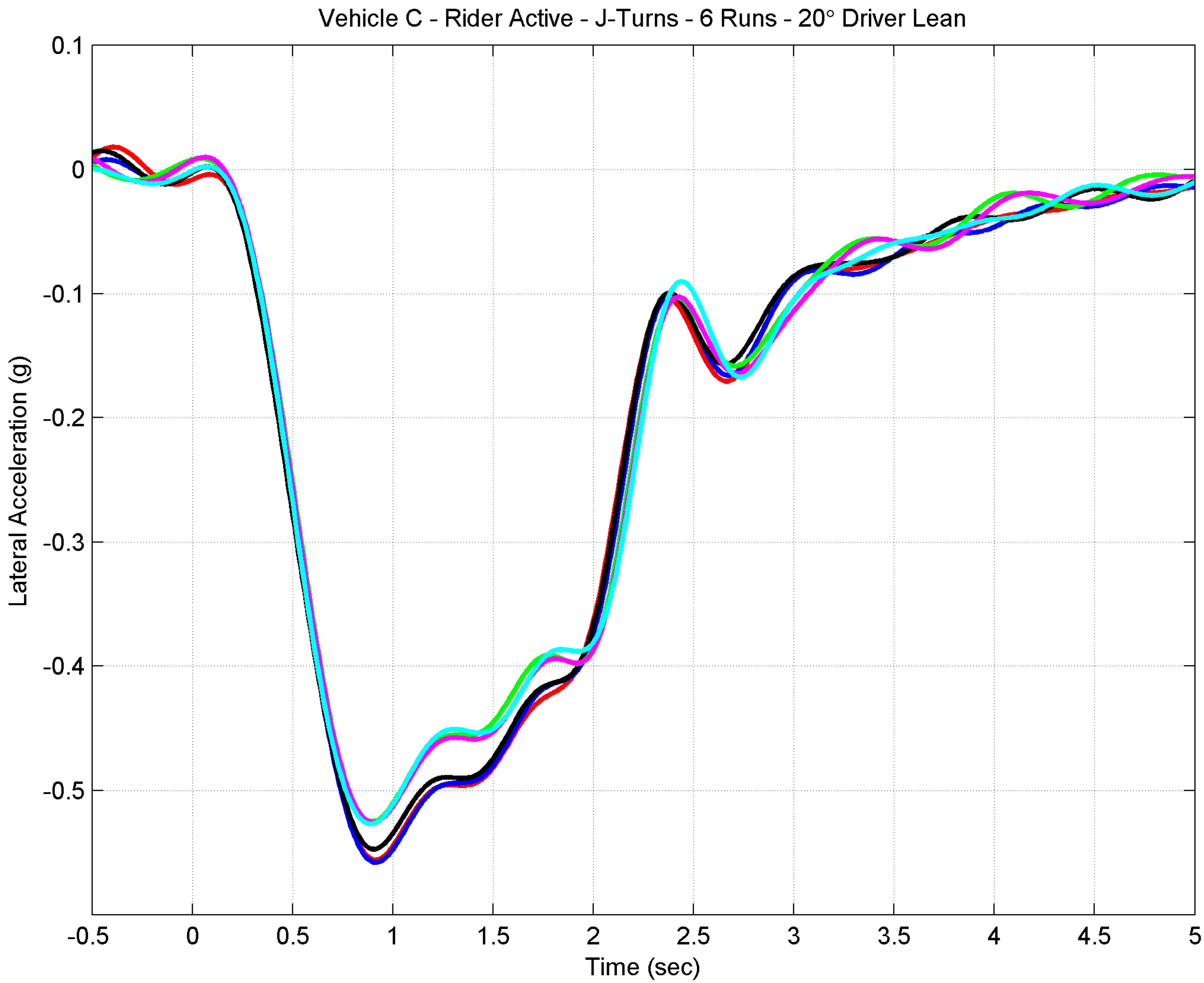
Vehicle C - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

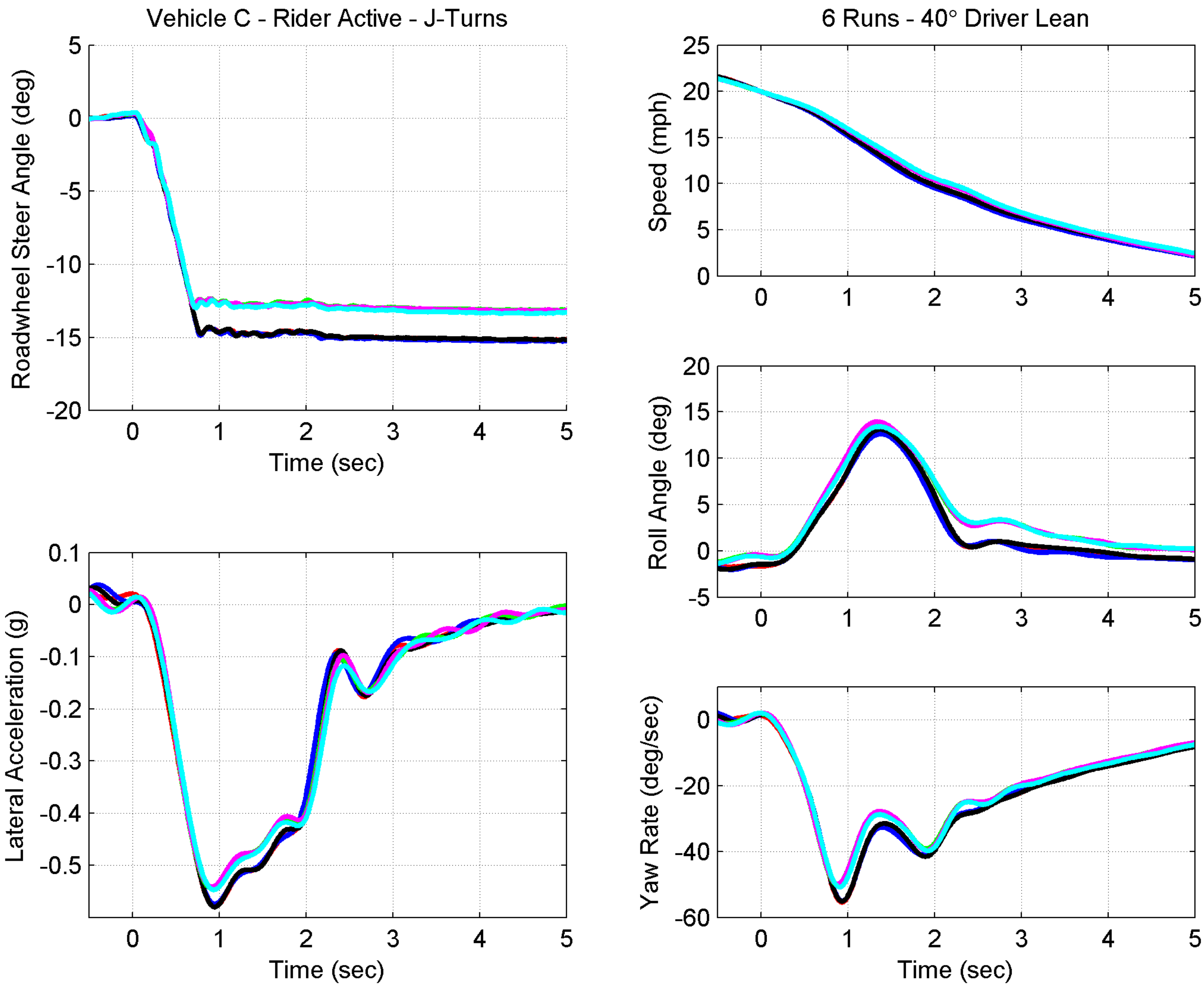


Vehicle C - Rider Active - J-Turns - 6 Runs - No Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

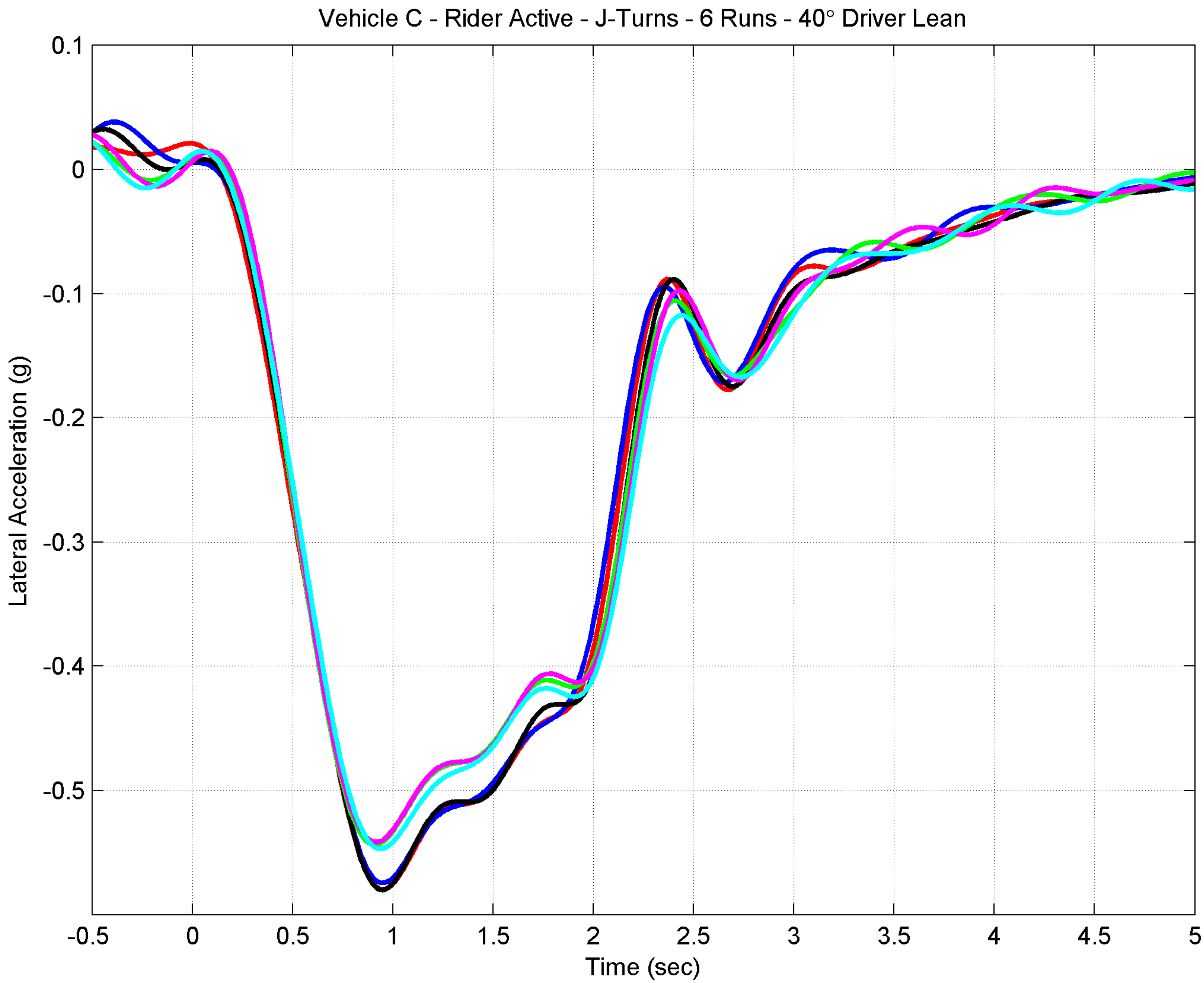


Vehicle C - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle C - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle C - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)


Vehicle C - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

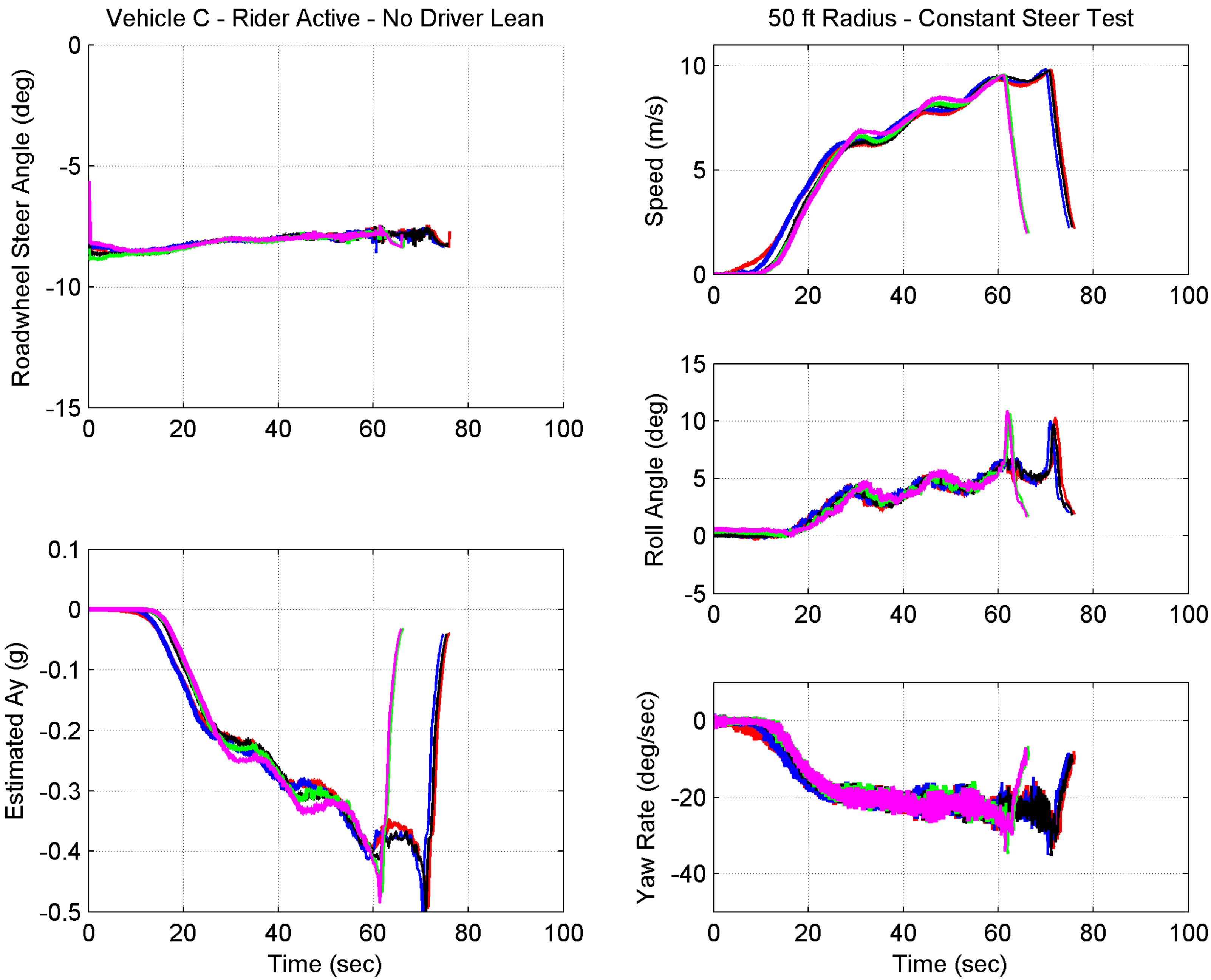
Vehicle C - Rider Active Results

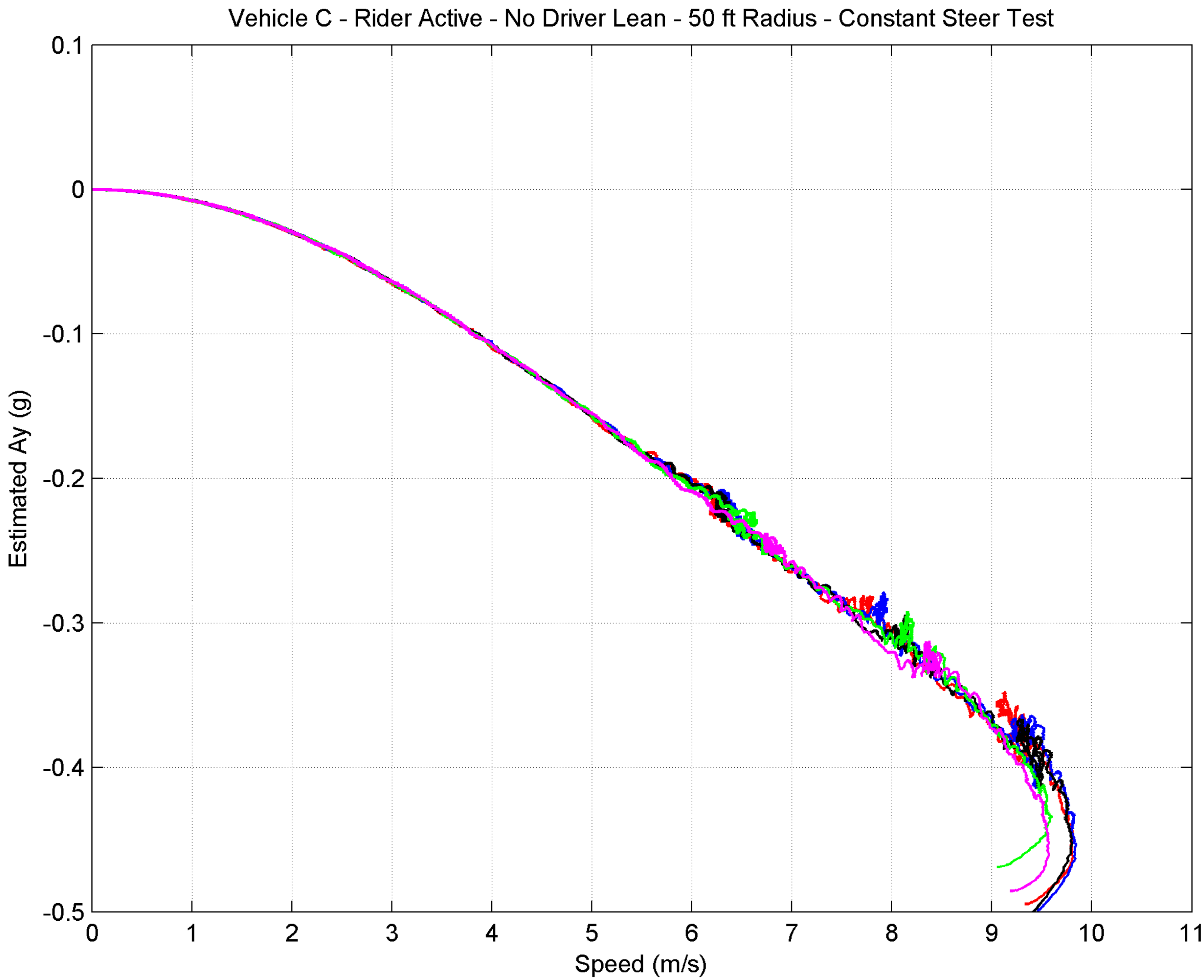
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

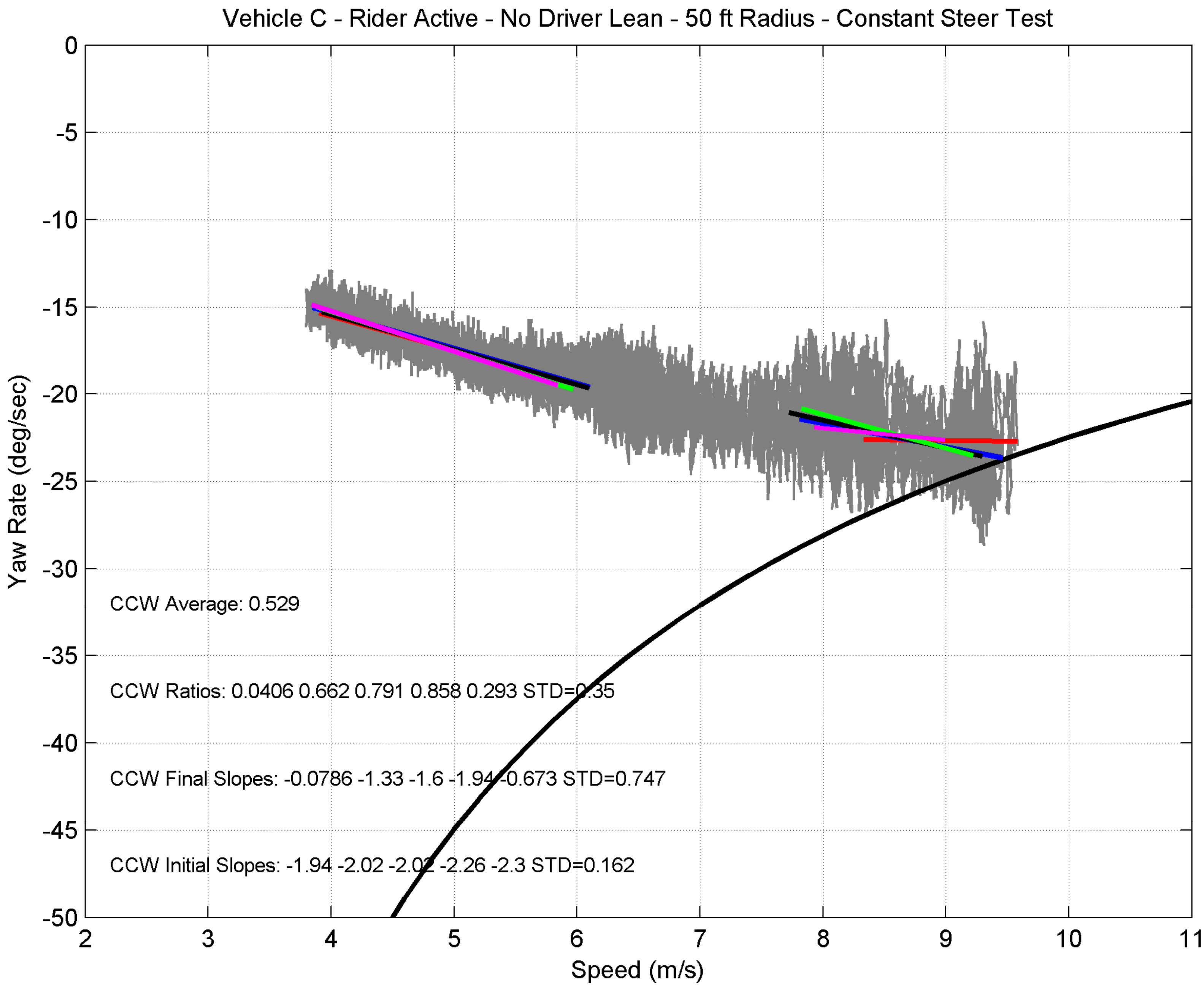
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.532	-0.556	-0.580
	-0.530	-0.558	-0.575
	-0.541	-0.547	-0.580
Mean Value of 3 Runs	-0.534	-0.554	-0.578
Standard Deviation of 3 Runs	0.006	0.006	0.003

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.507	-0.525	-0.544
	-0.503	-0.526	-0.542
	-0.506	-0.527	-0.547
Mean Value of 3 Runs	-0.505	-0.526	-0.544
Standard Deviation of 3 Runs	0.002	0.001	0.003

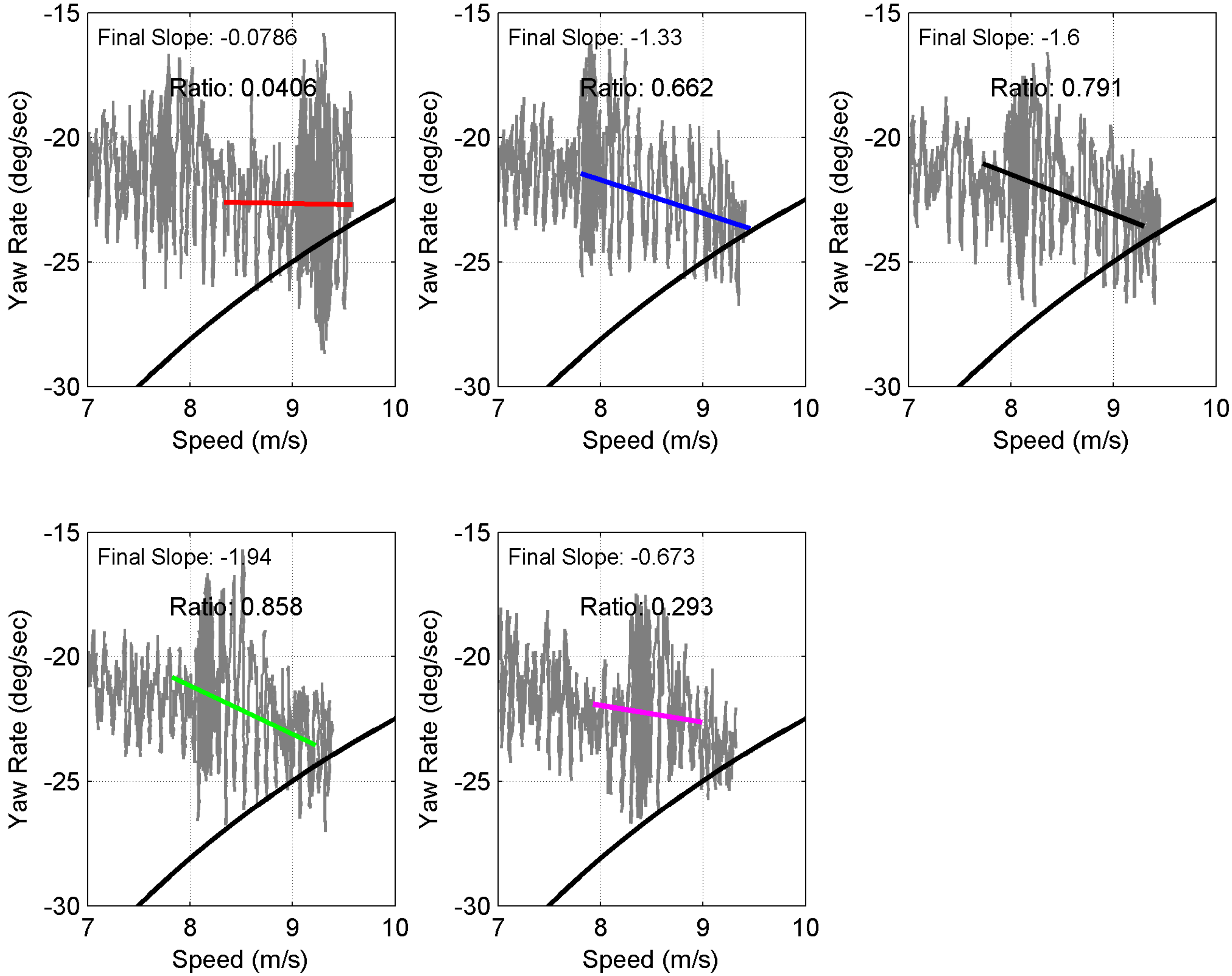
Average of All 6 Runs	**0.520**	**0.540**	**0.561**

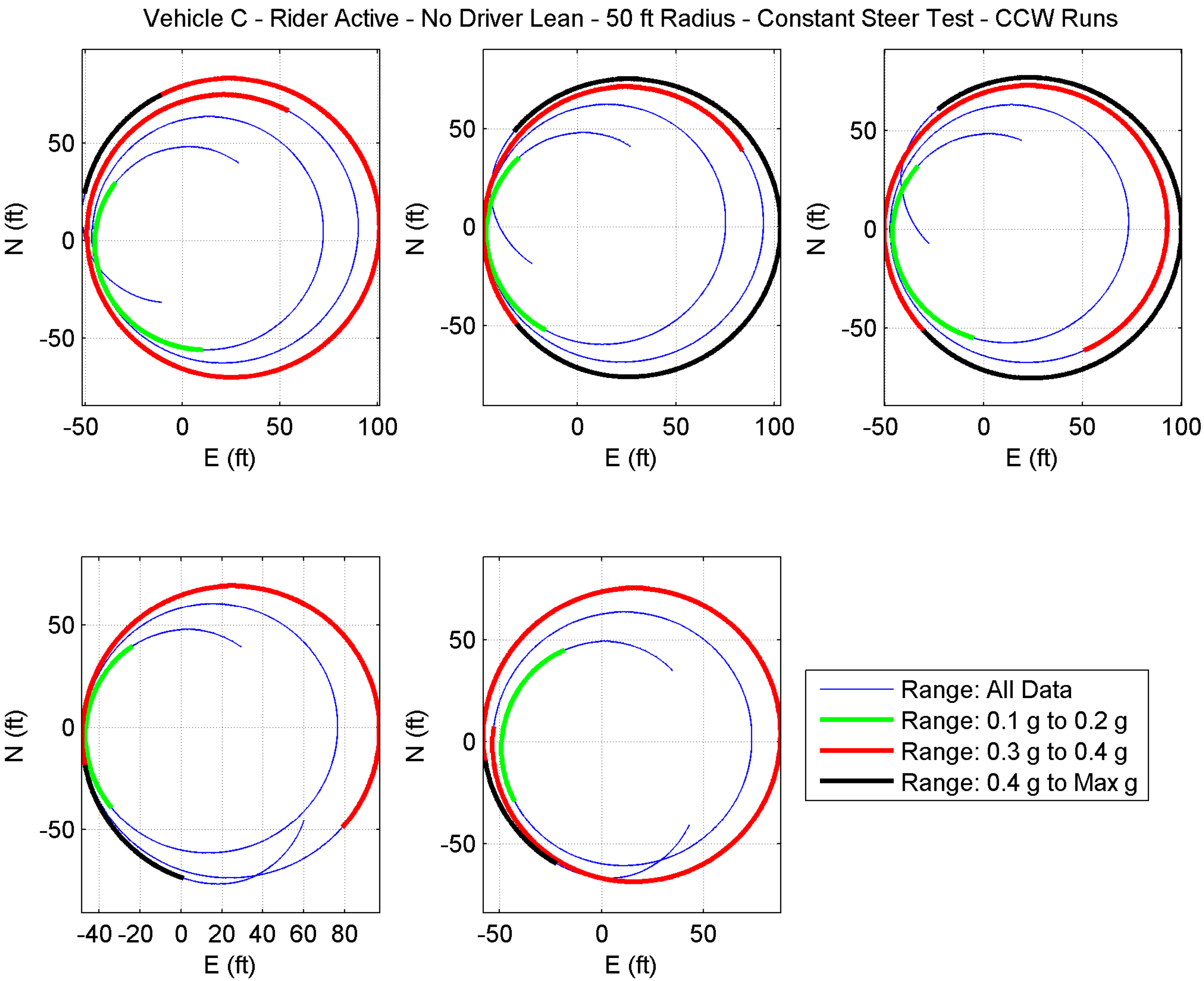

Vehicle C - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle C - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
7
8
9
10
11
Speed (m/s)

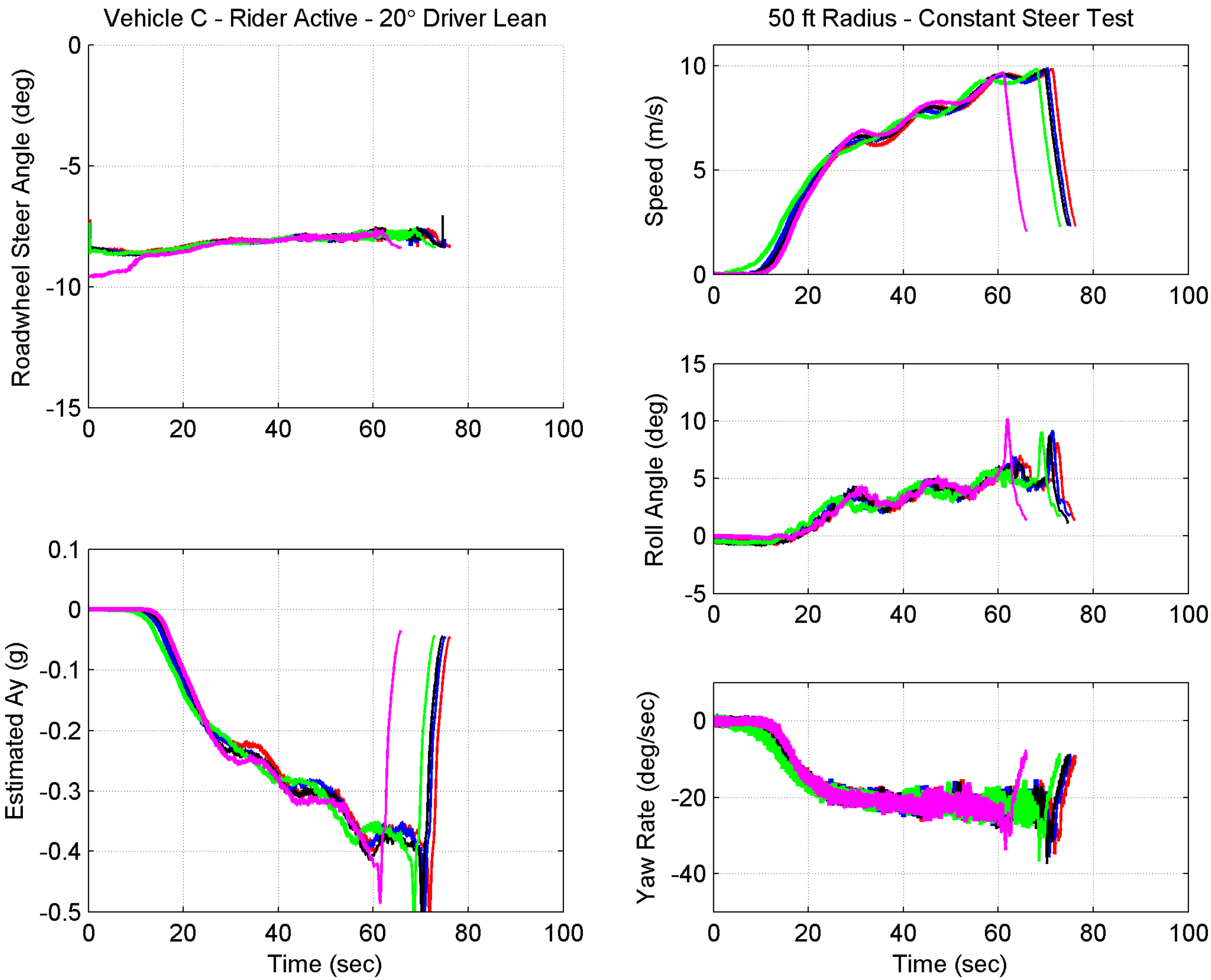

Vehicle C - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
10
11
CCW Average: 0.529
CCW Ratios: 0.0406 0.662 0.791 0.858 0.293 STD=0.35
CCW Final Slopes: -0.0786 -1.33 -1.6 -1.94 -0.673 STD=0.747
CCW Initial Slopes: -1.94 -2.02 -2.02 -2.26 -2.3 STD=0.162

Vehicle C - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

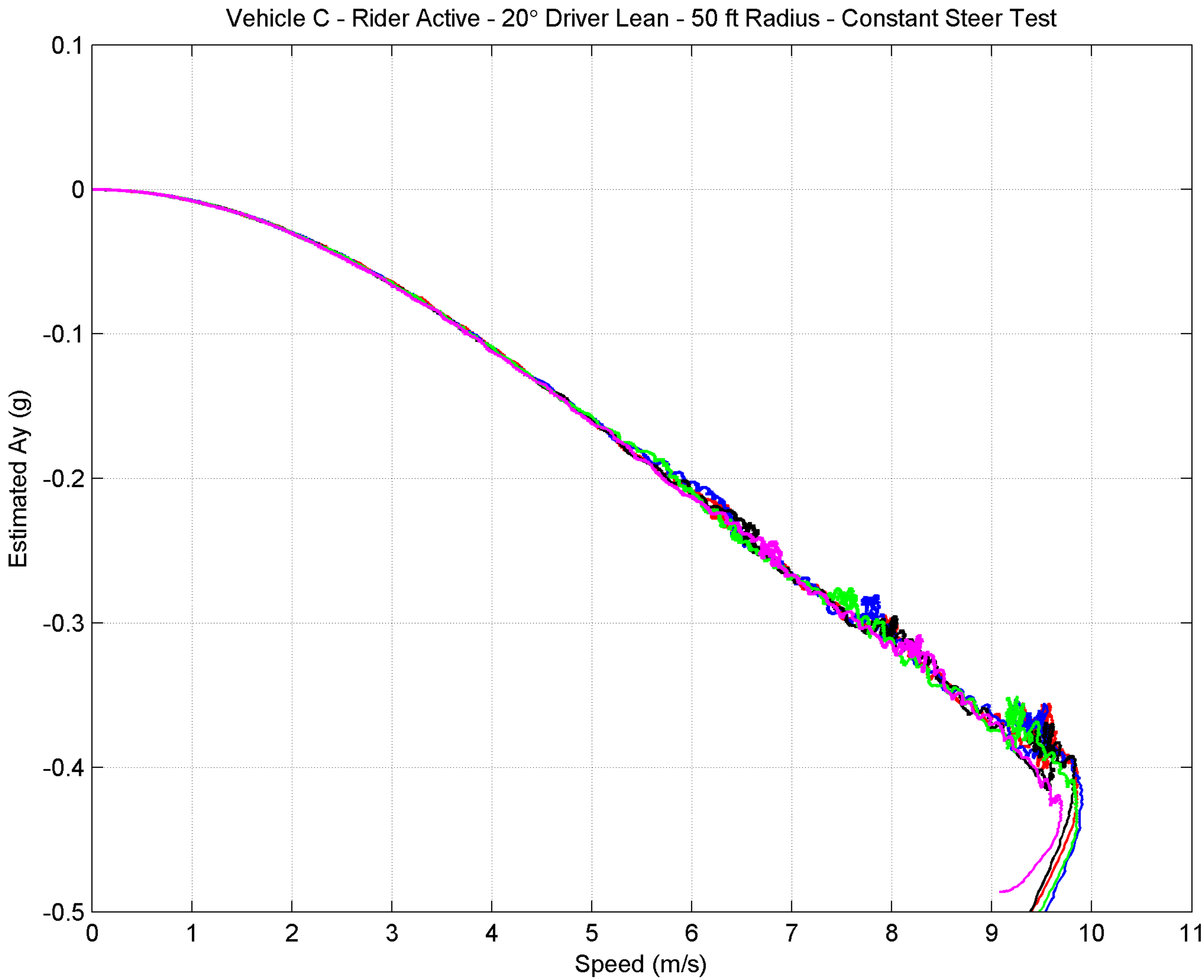


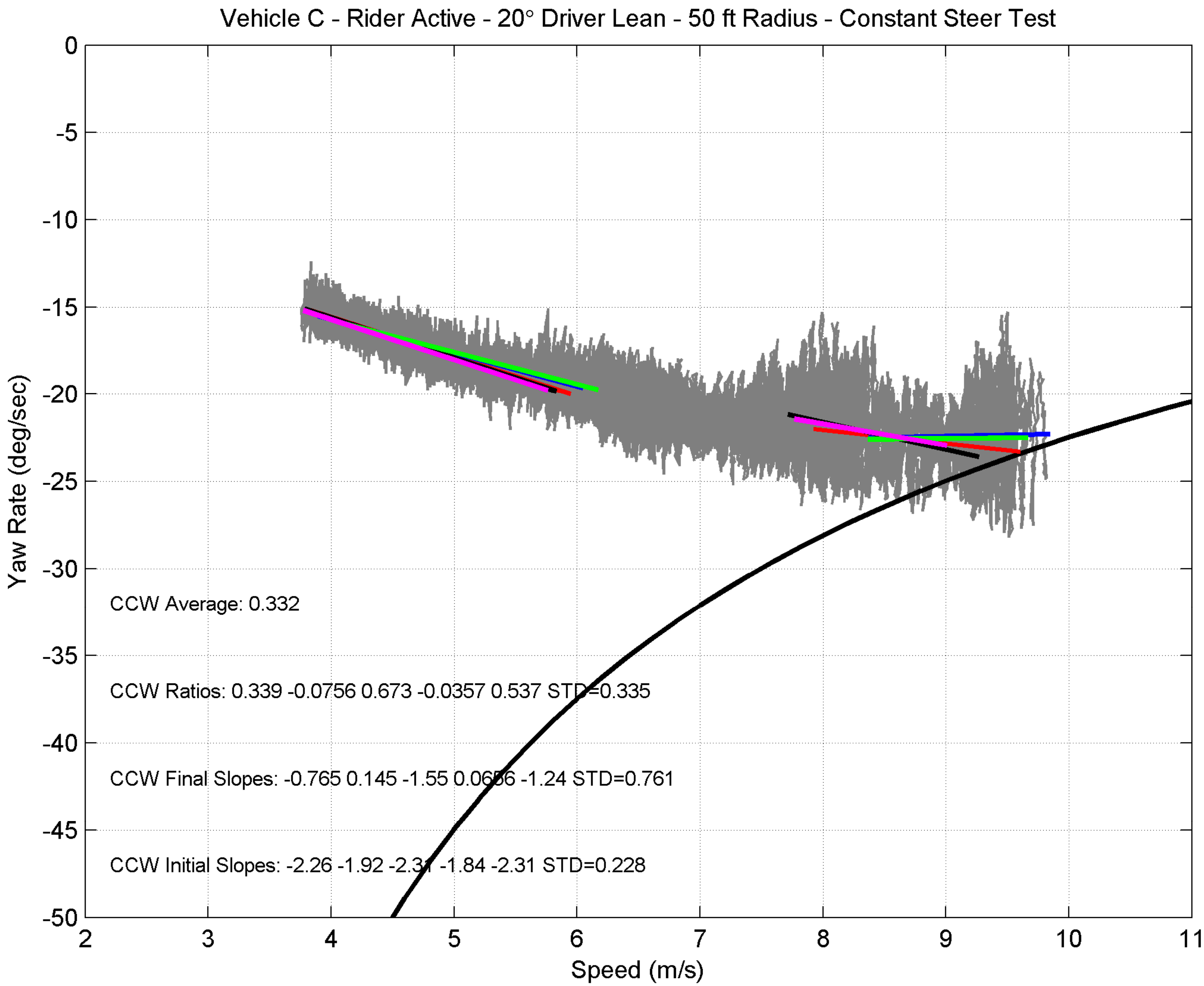


Vehicle C - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



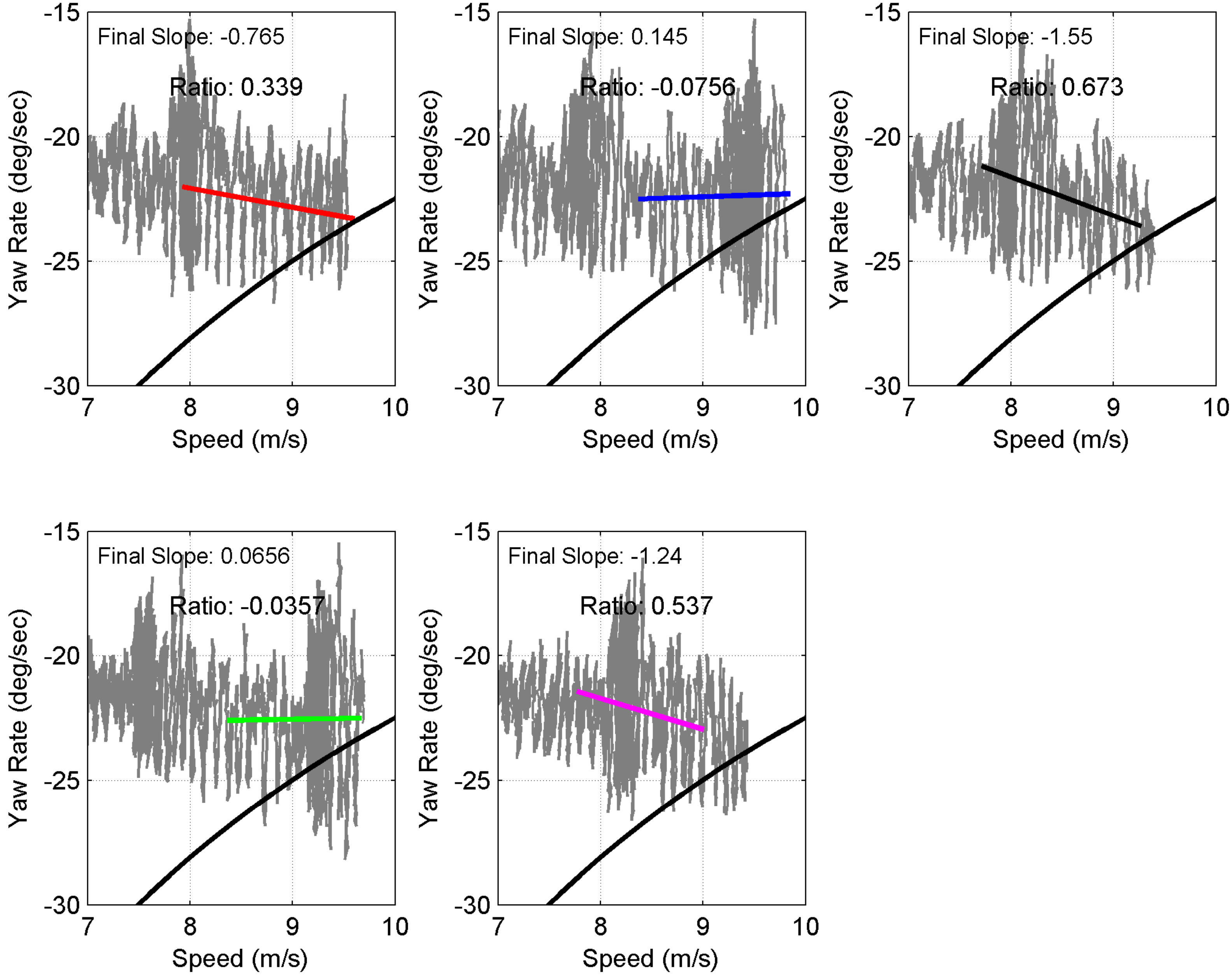
Vehicle C - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

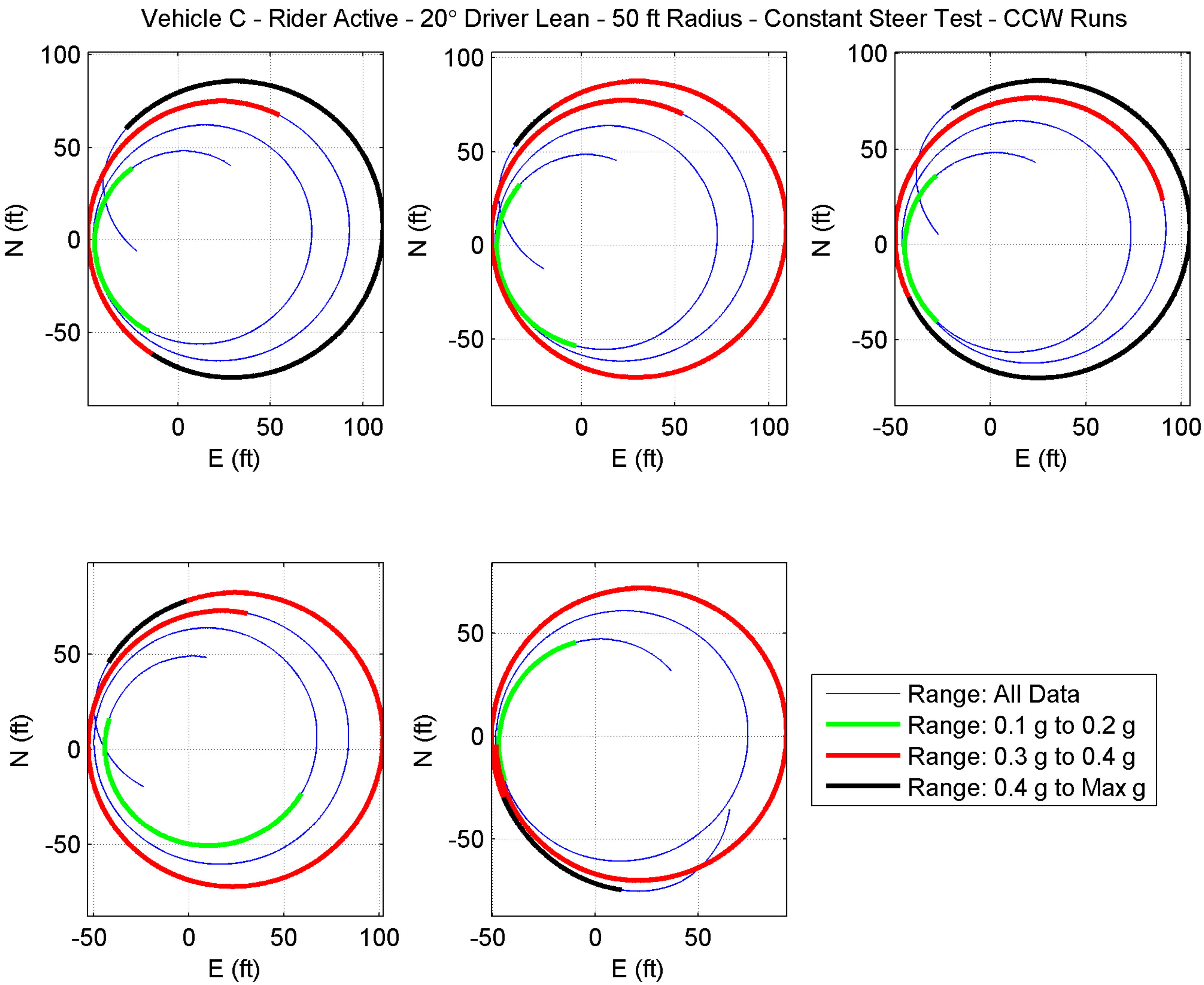

Vehicle C - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10
11

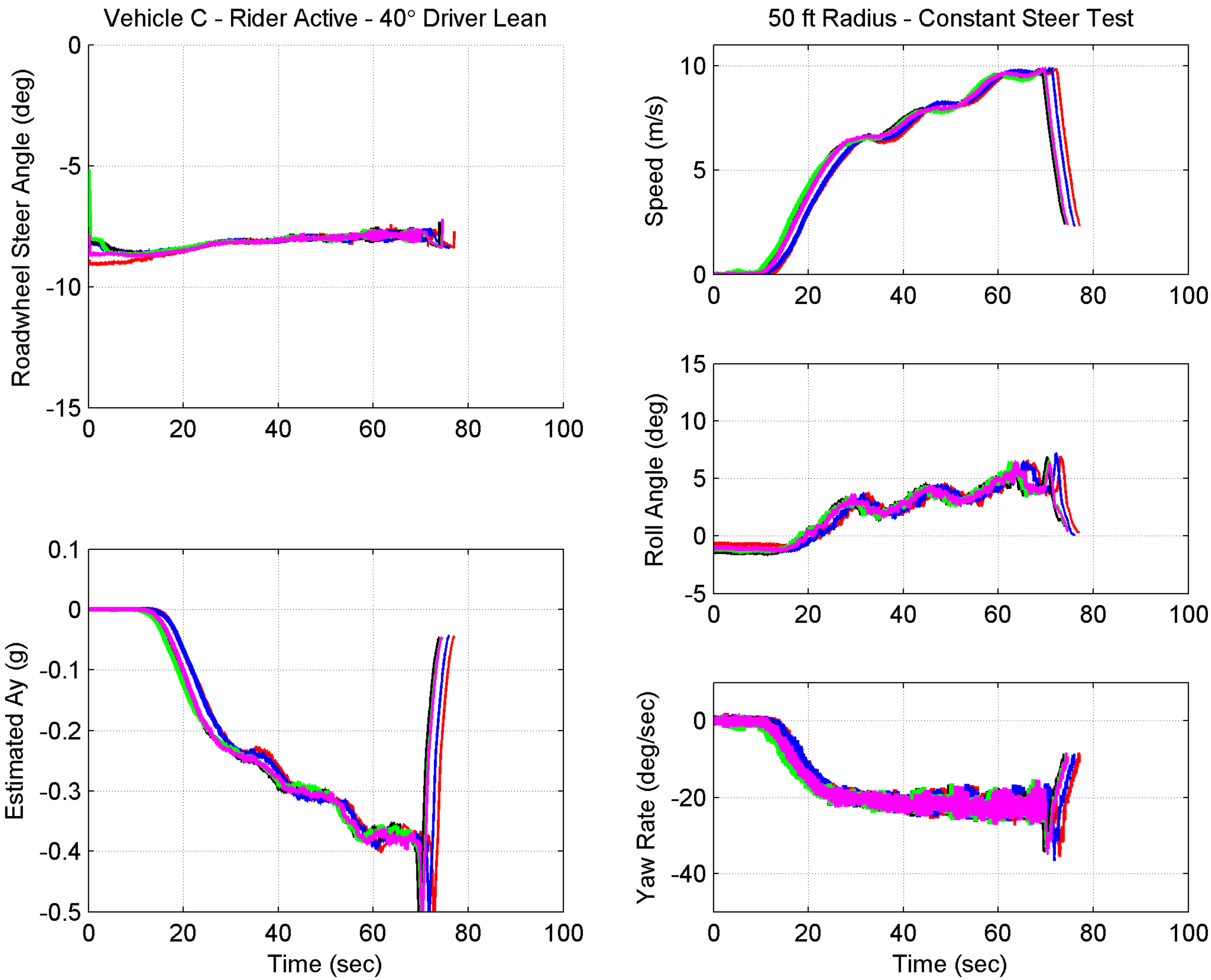


Vehicle C - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
10
11
CCW Average: 0.332
CCW Ratios: 0.339 -0.0756 0.673 -0.0357 0.537 STD=0.335
CCW Final Slopes: -0.765 0.145 -1.55 0.0656 -1.24 STD=0.761
CCW Initial Slopes: -2.26 -1.92 -2.31 -1.84 -2.31 STD=0.228

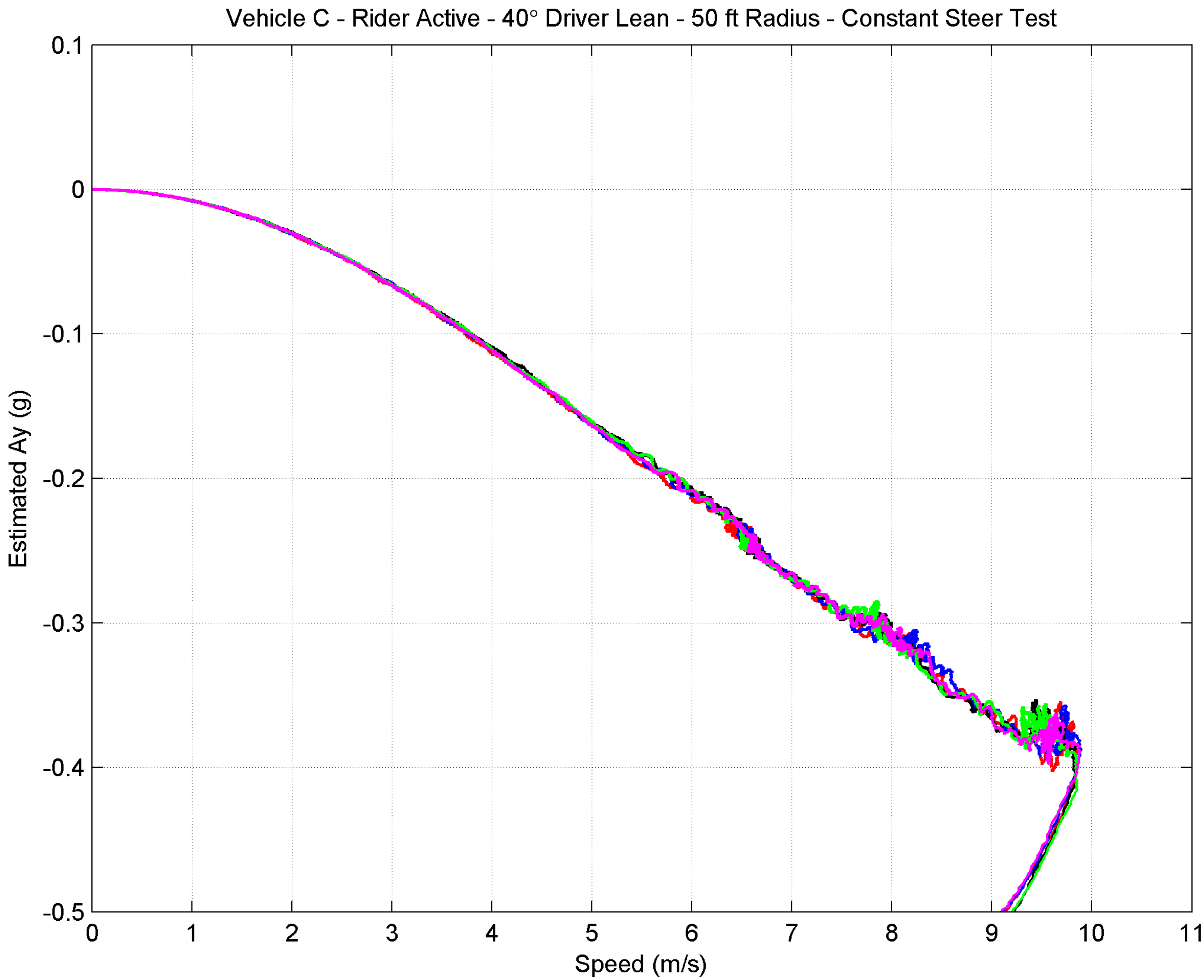
Vehicle C - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

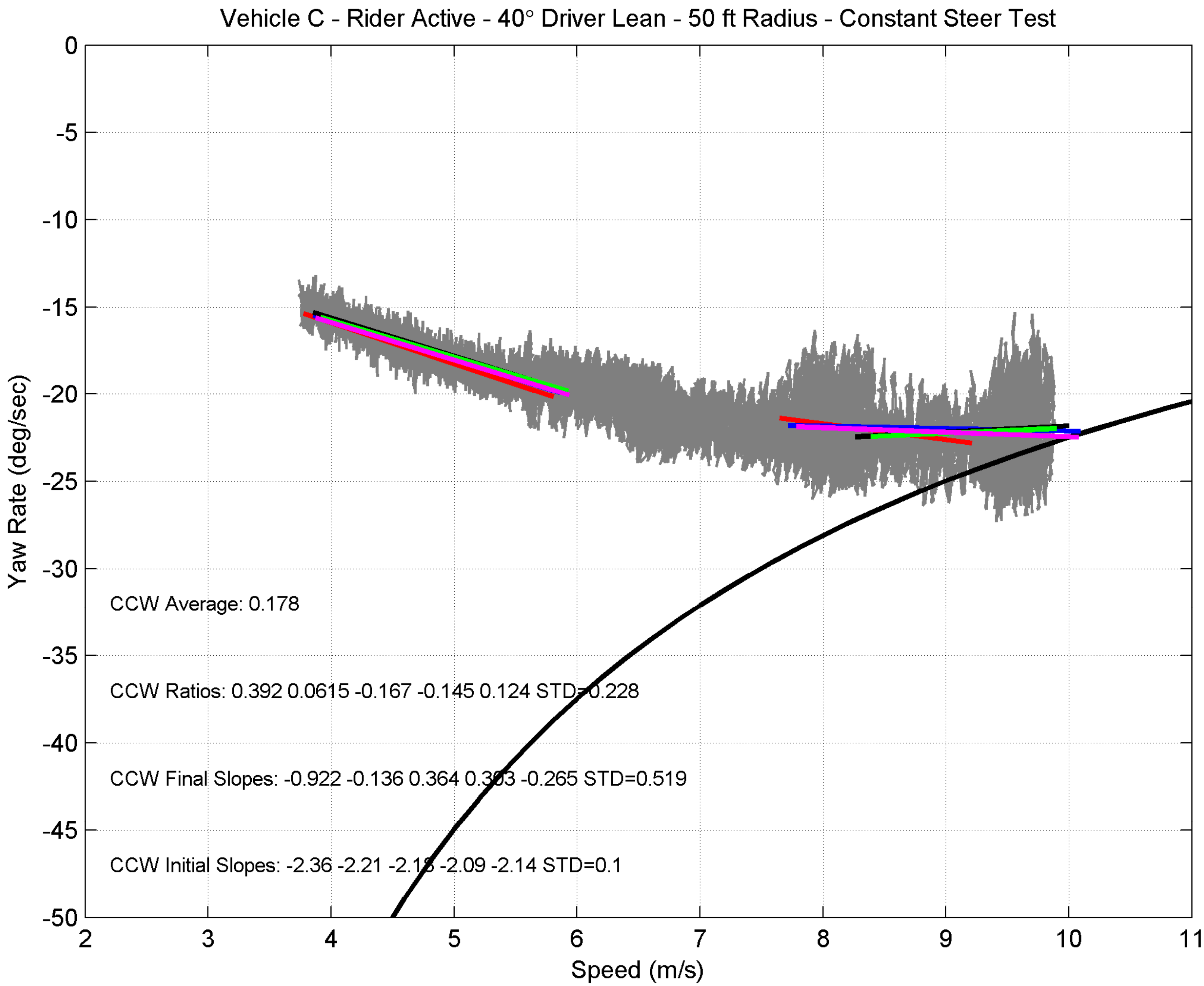


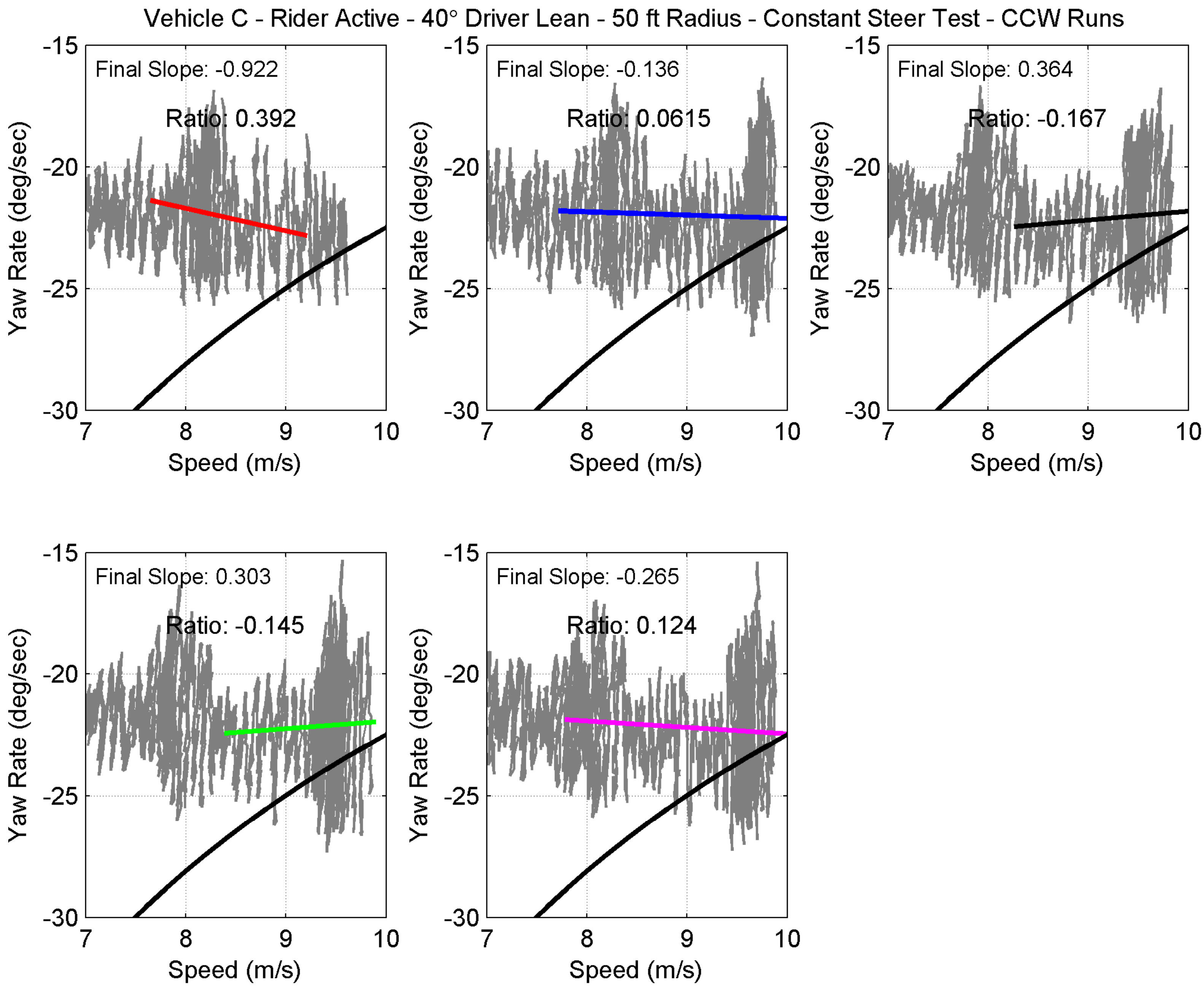

Vehicle C - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



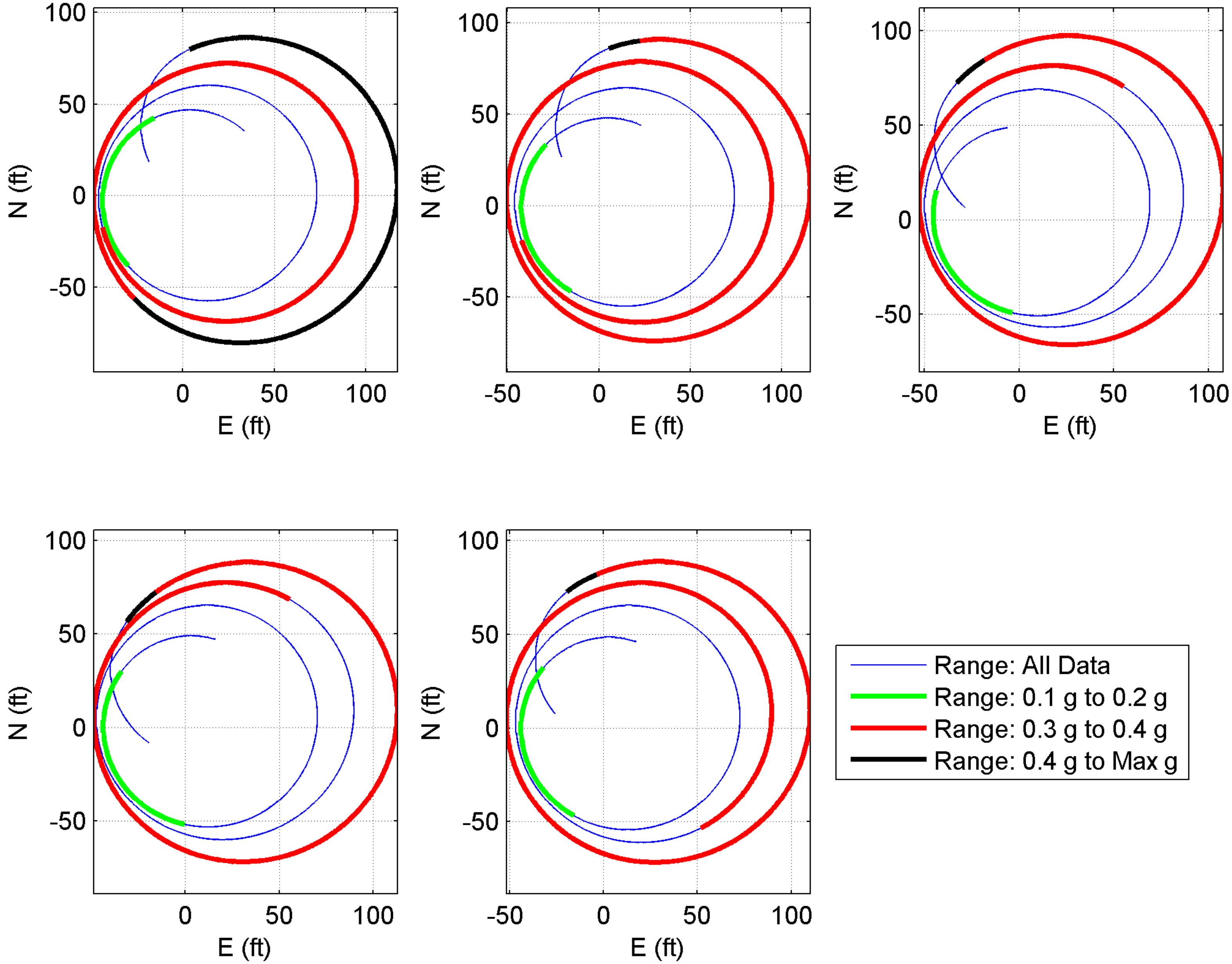
Vehicle C - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

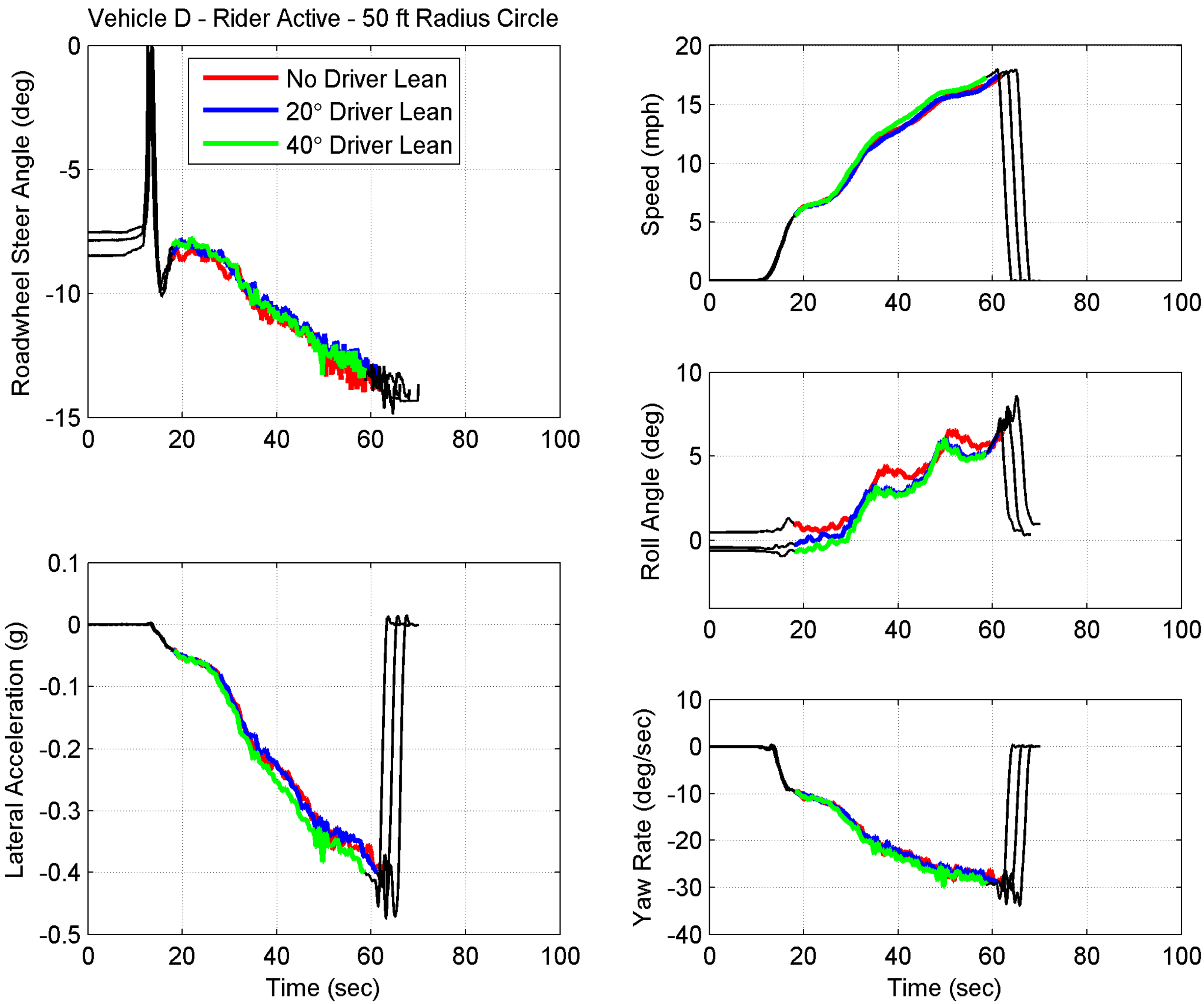

Vehicle C - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10
11

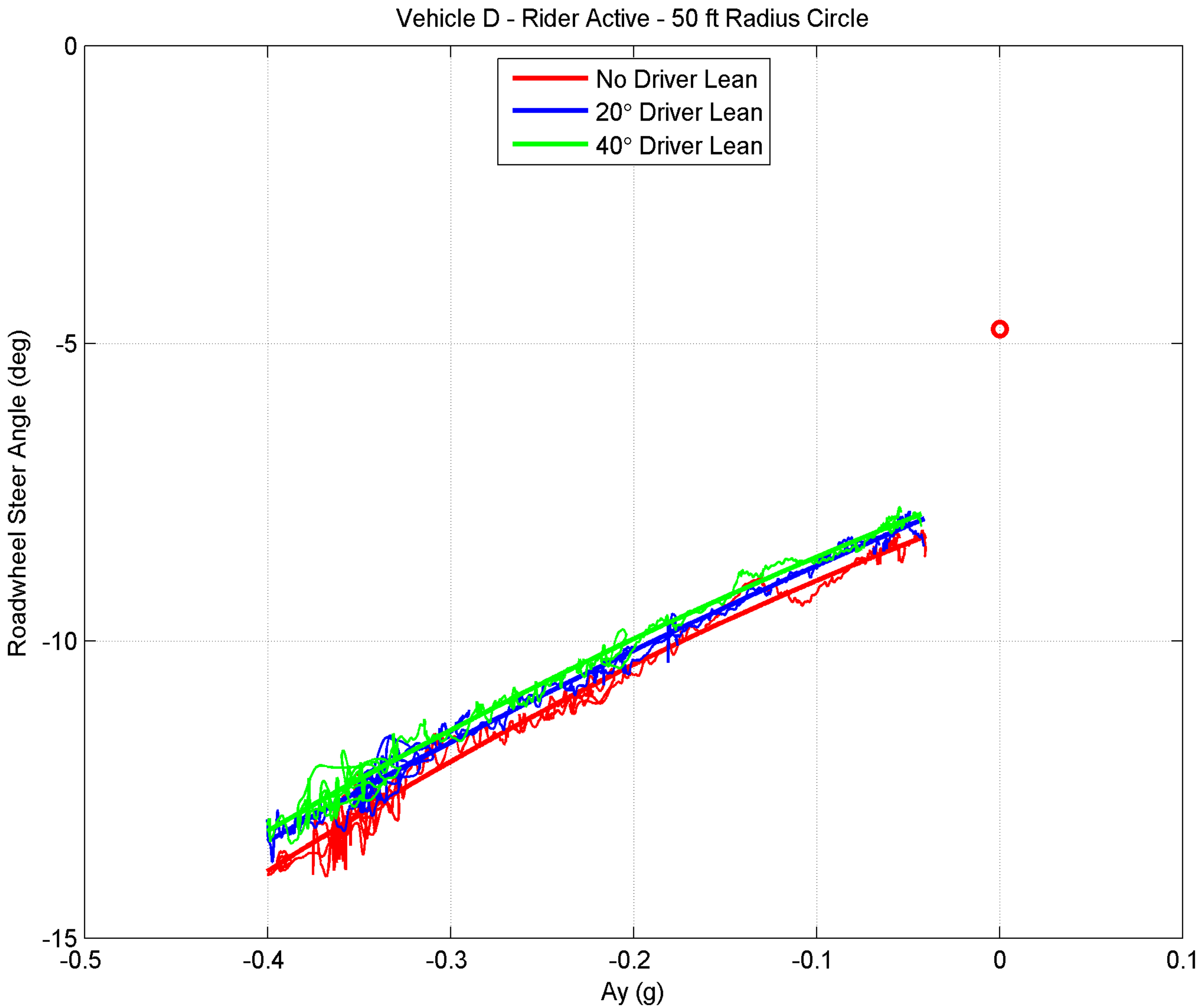

Vehicle C - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
CCW Average: 0.178
CCW Ratios: 0.392 0.0615 -0.167 -0.145 0.124 STD=0.228
CCW Final Slopes: -0.922 -0.136 0.364 0.303 -0.265 STD=0.519
CCW Initial Slopes: -2.36 -2.21 -2.18 -2.09 -2.14 STD=0.1
2
3
4
5
6
7
8
9
10
11
Speed (m/s)


Vehicle C - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -0.922
Ratio: 0.392
Final Slope: -0.136
Ratio: 0.0615
Final Slope: 0.364
Ratio: -0.167
Final Slope: 0.303
Ratio: -0.145
Final Slope: -0.265
Ratio: 0.124
Yaw Rate (deg/sec)
Speed (m/s)

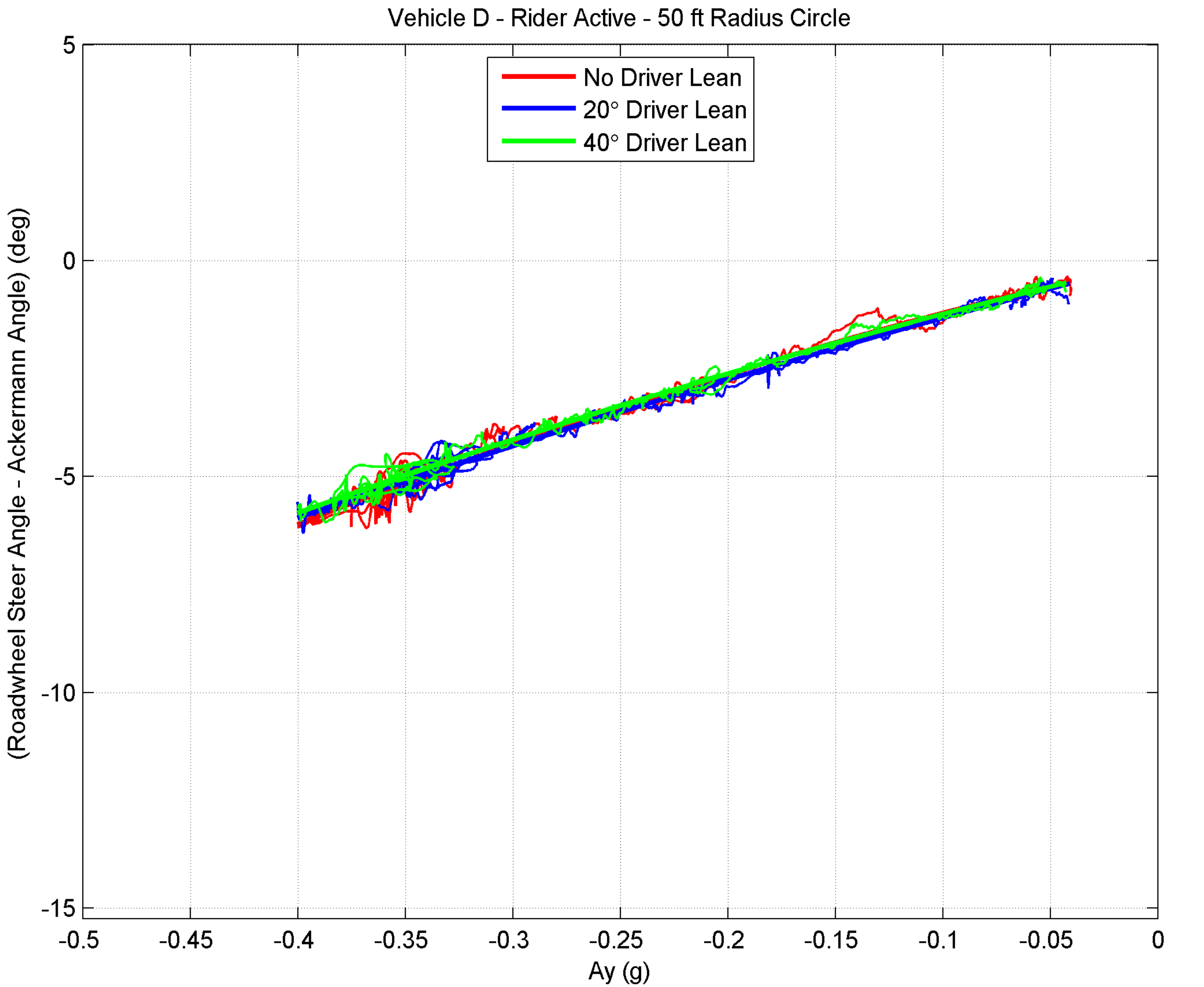
Vehicle C - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

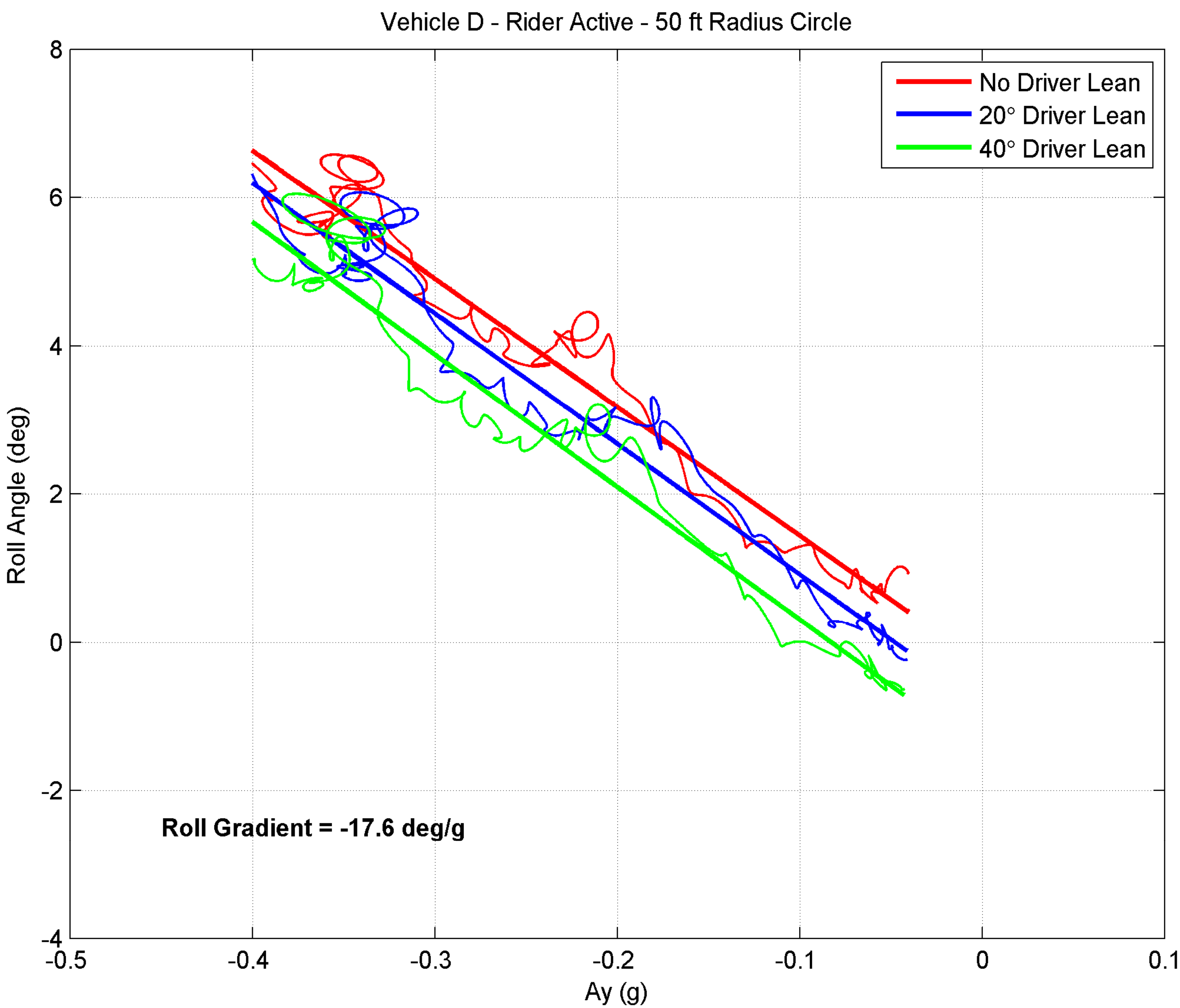


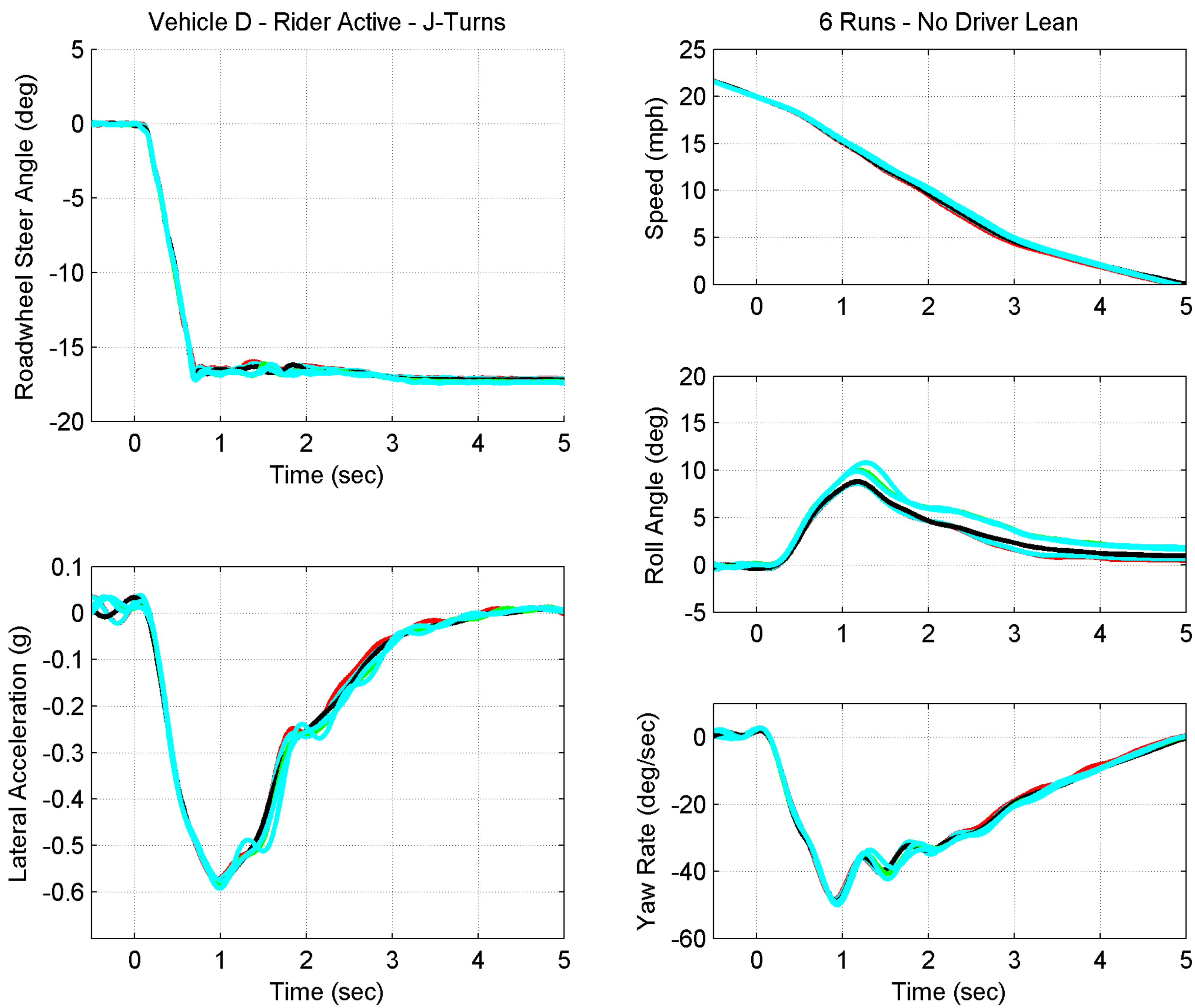

Vehicle D - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



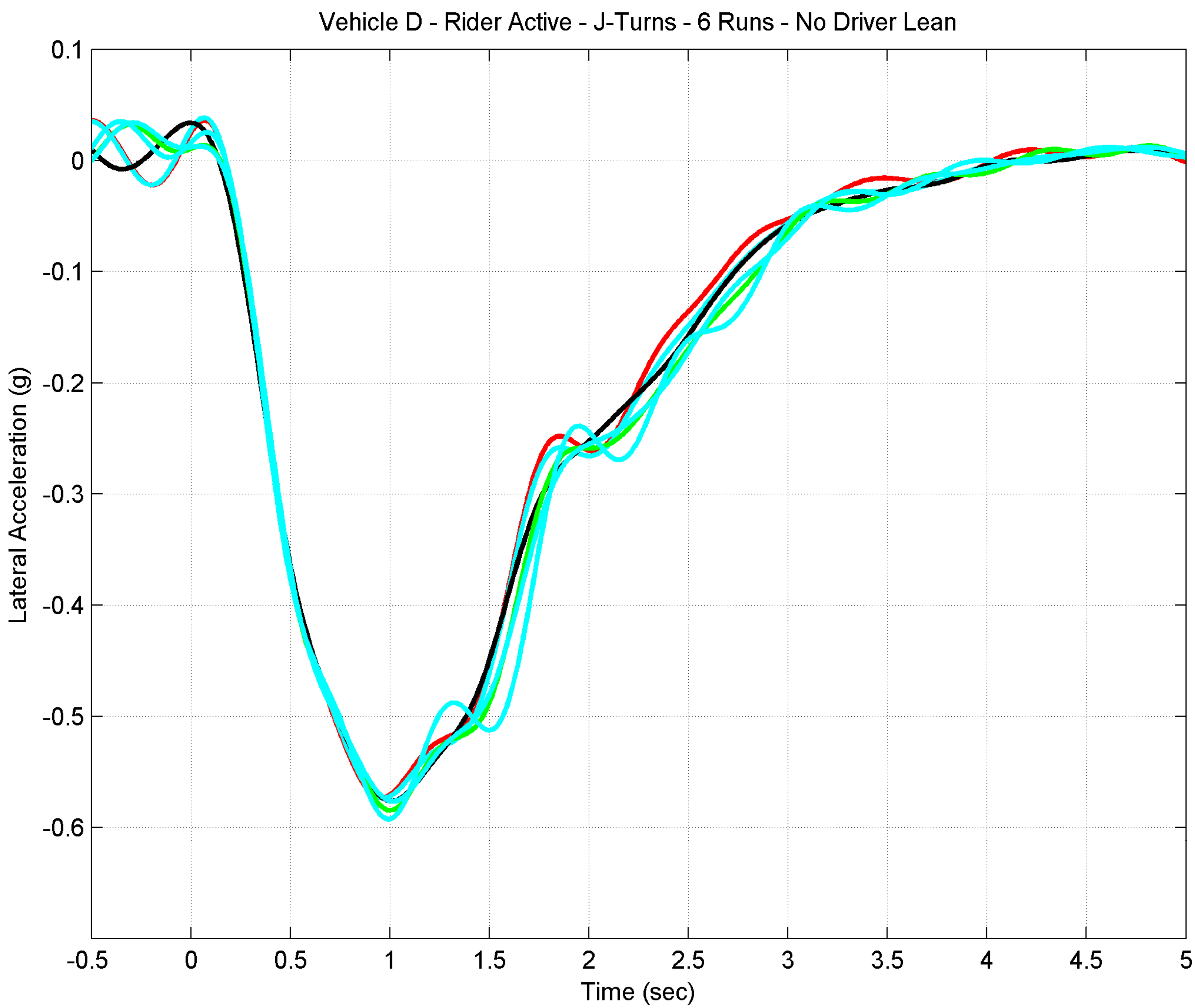
Vehicle D - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)

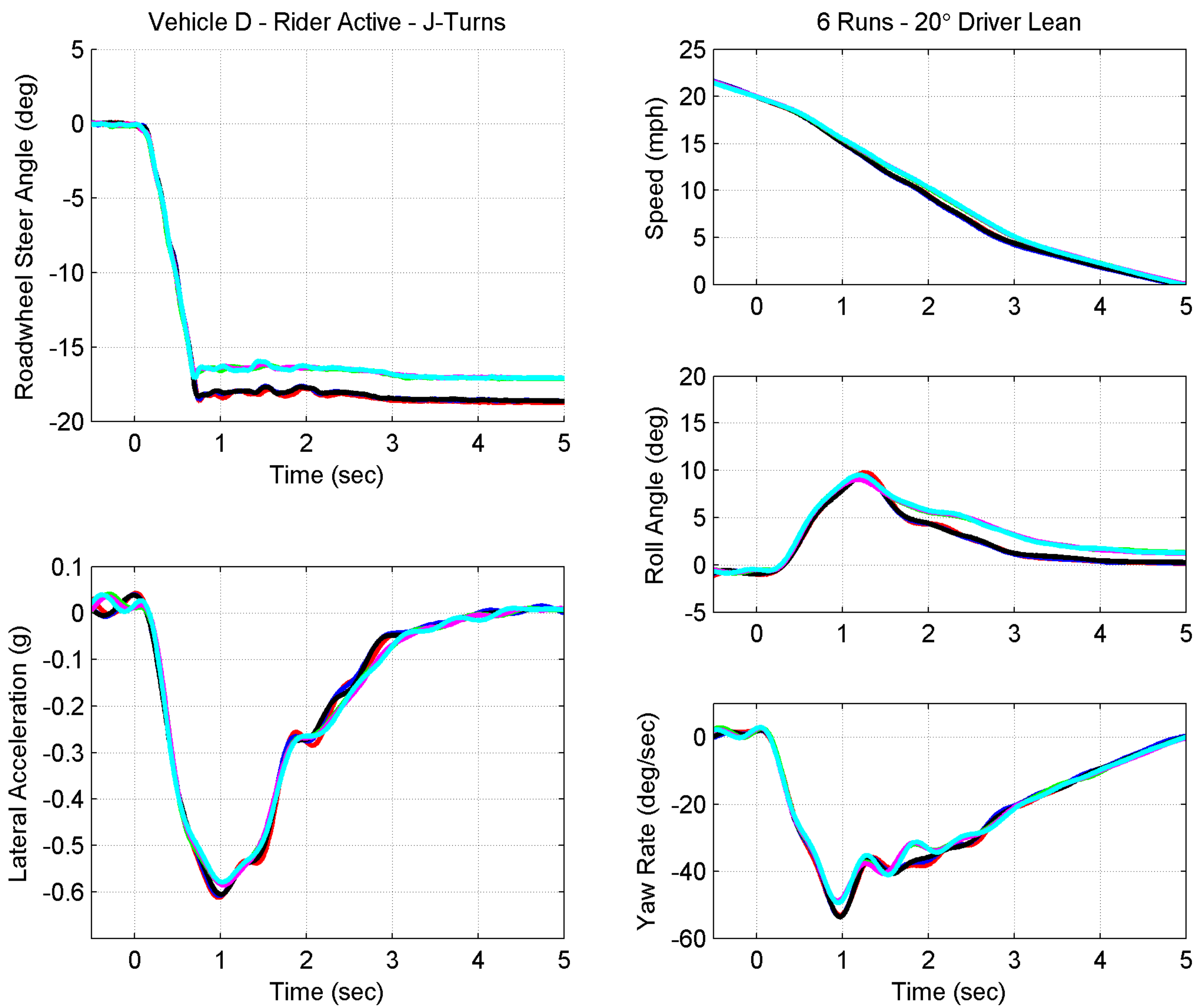

Vehicle D - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0


Vehicle D - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Gradient = -17.6 deg/g
Roll Angle (deg)
Ay (g)
8
6
4
2
0
-2
-4
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

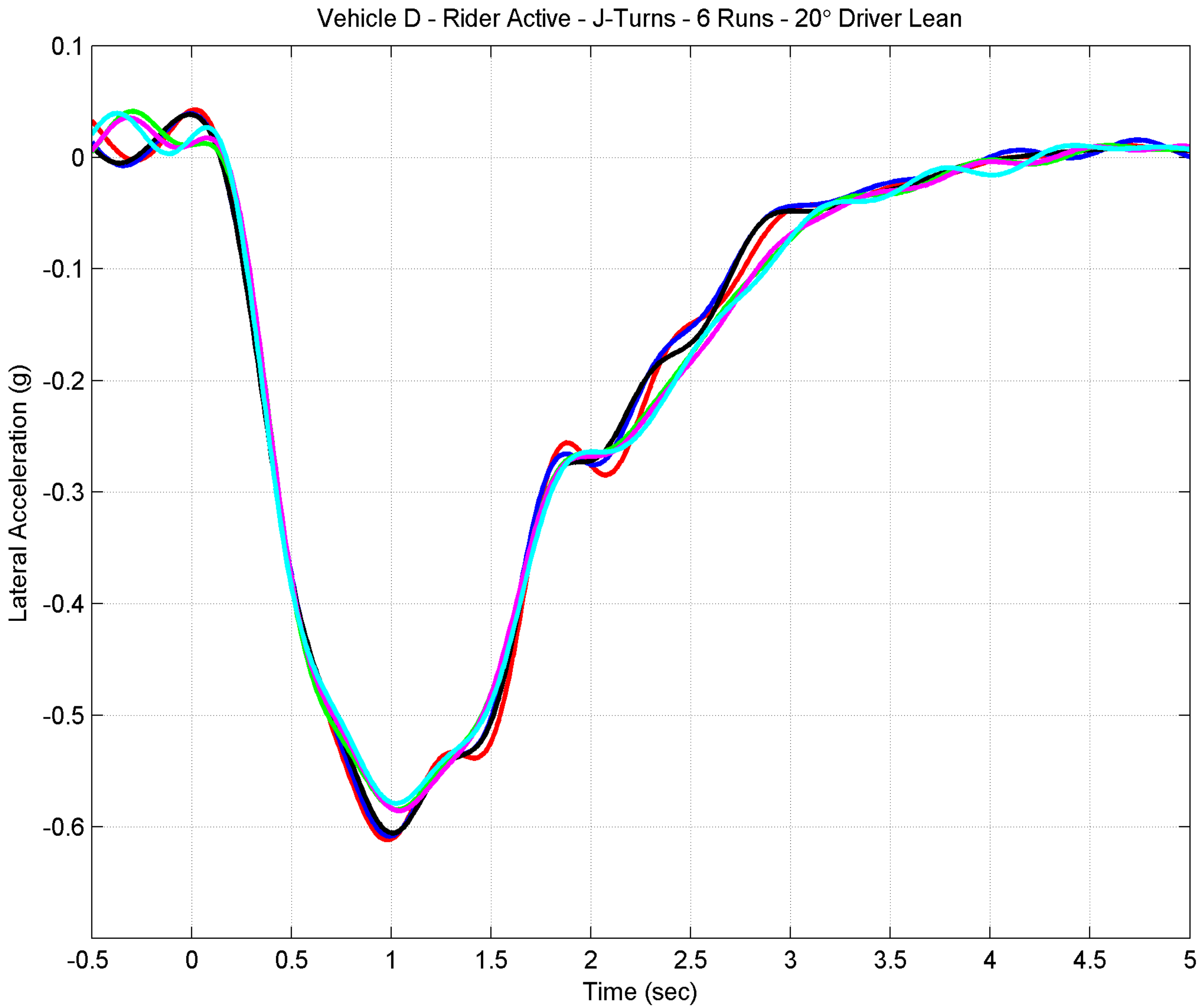


Vehicle D - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

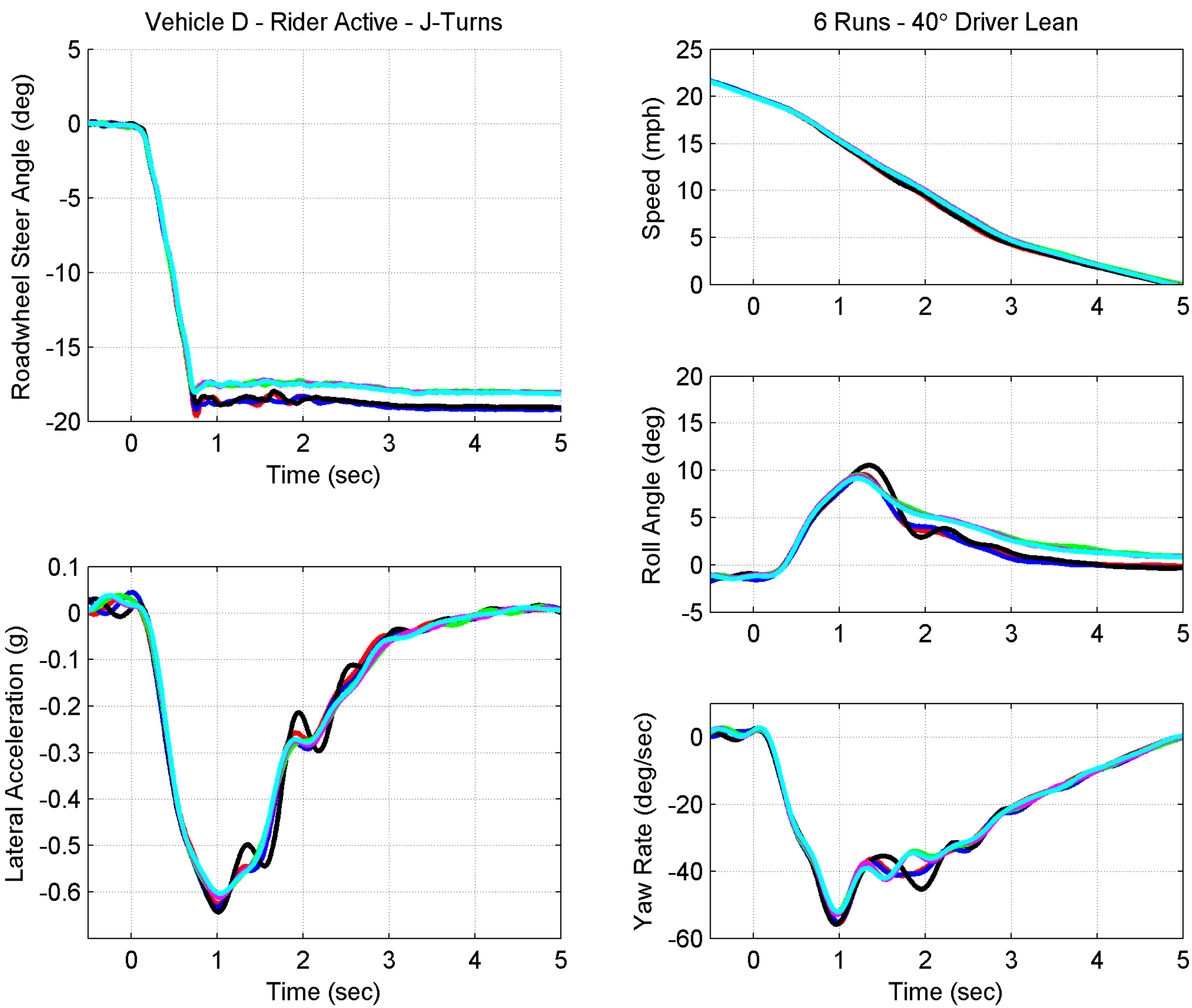

Vehicle D - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



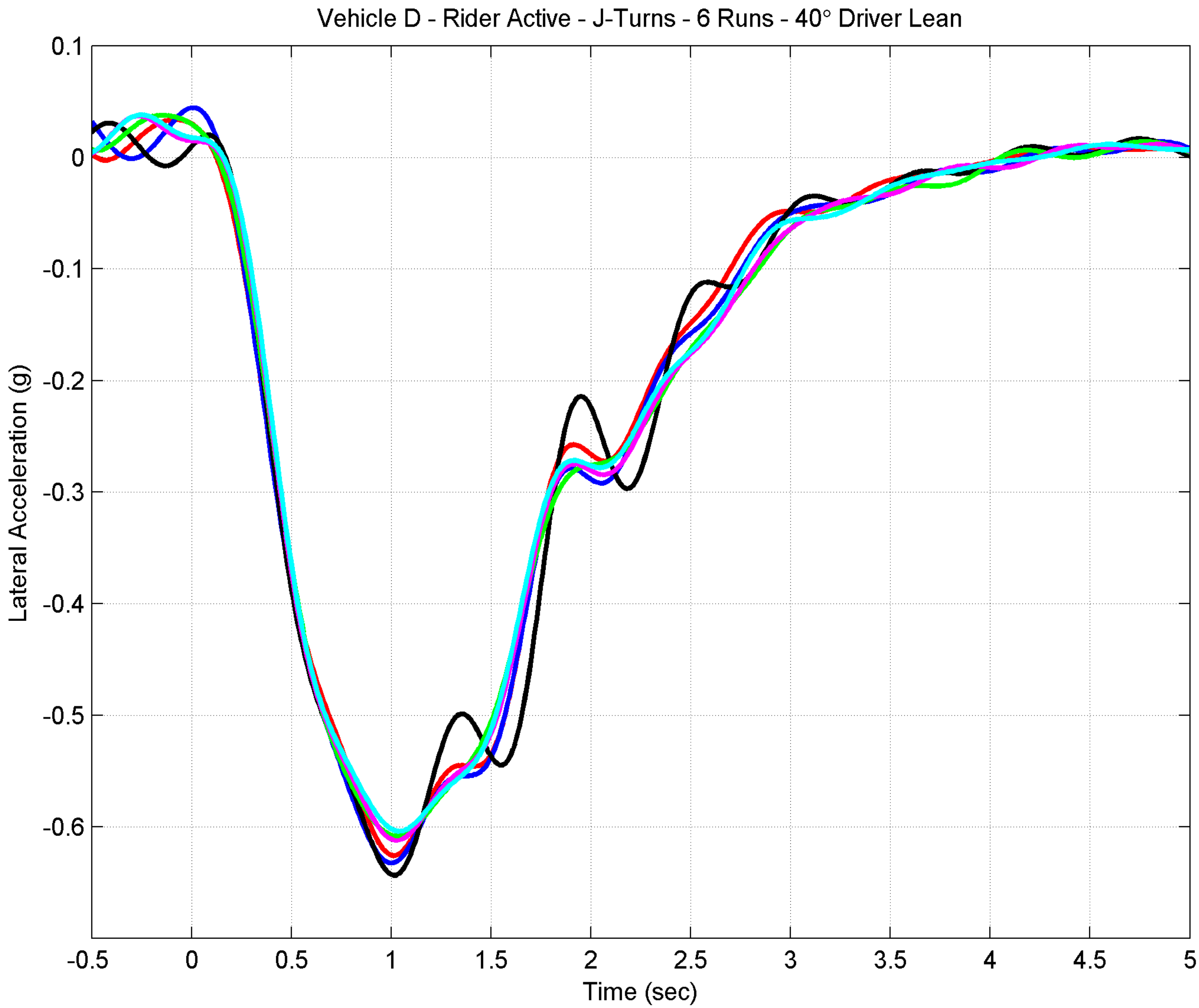
Vehicle D - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle D - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle D - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle D - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

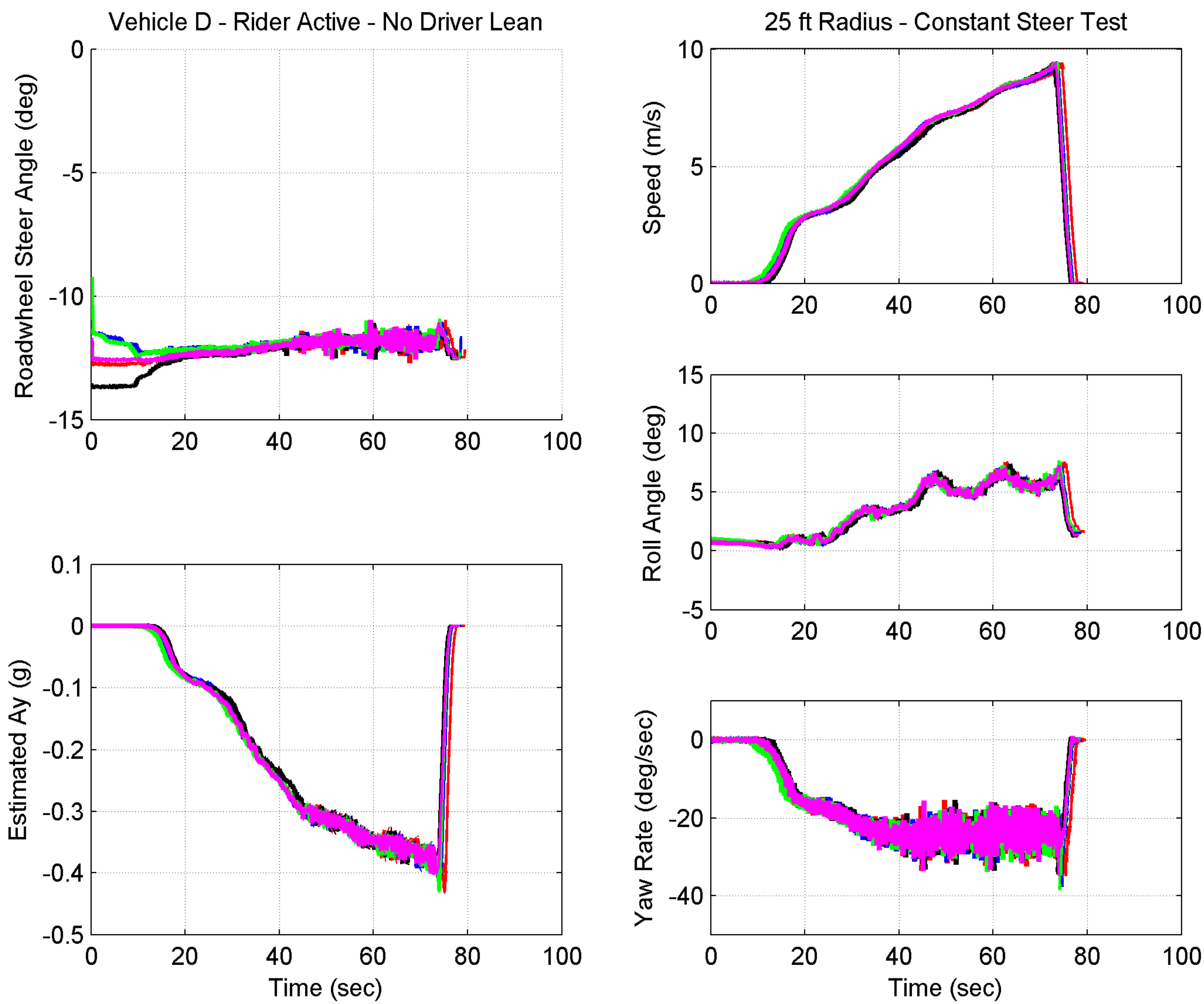
Vehicle D - Rider Active Results

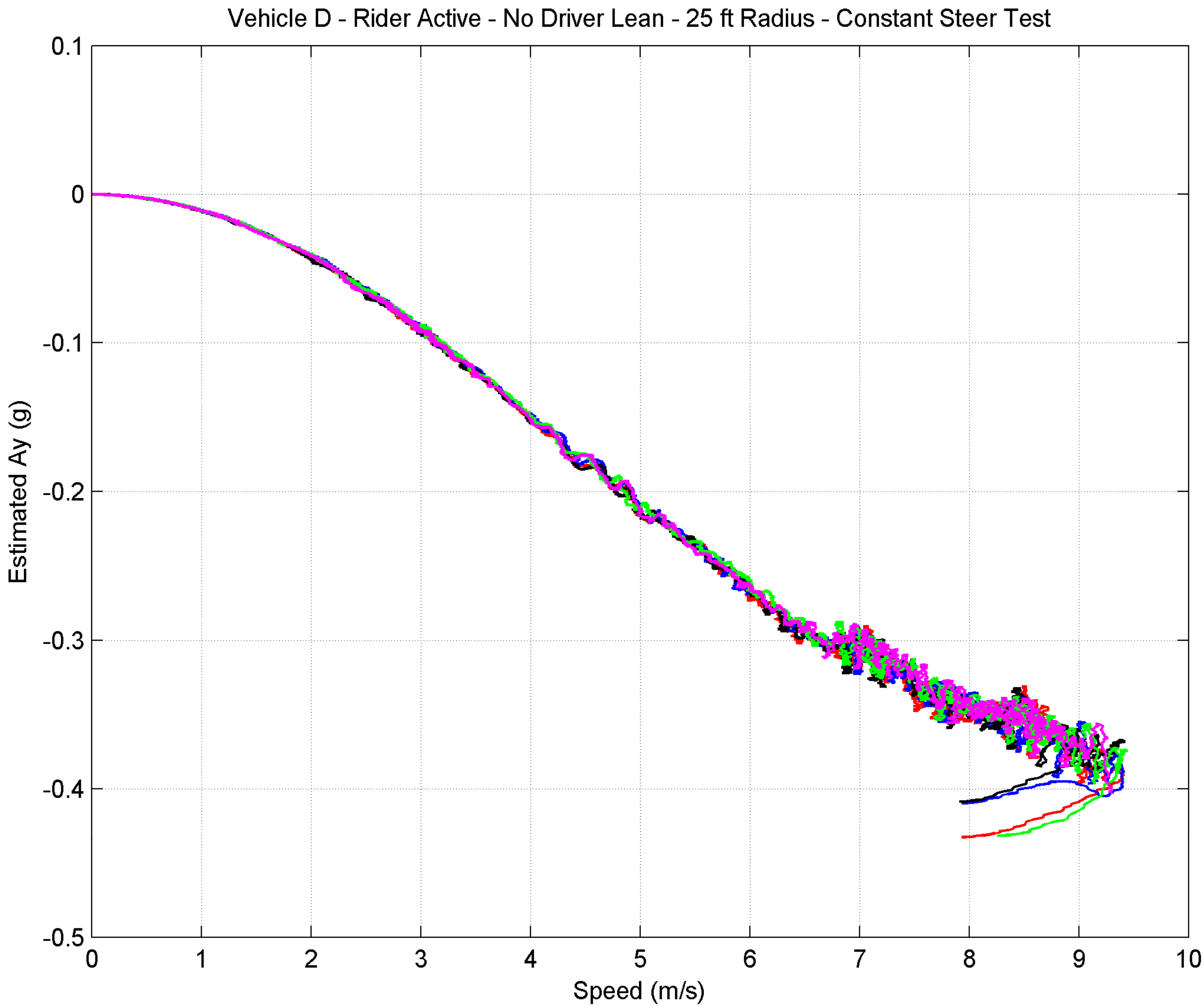
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

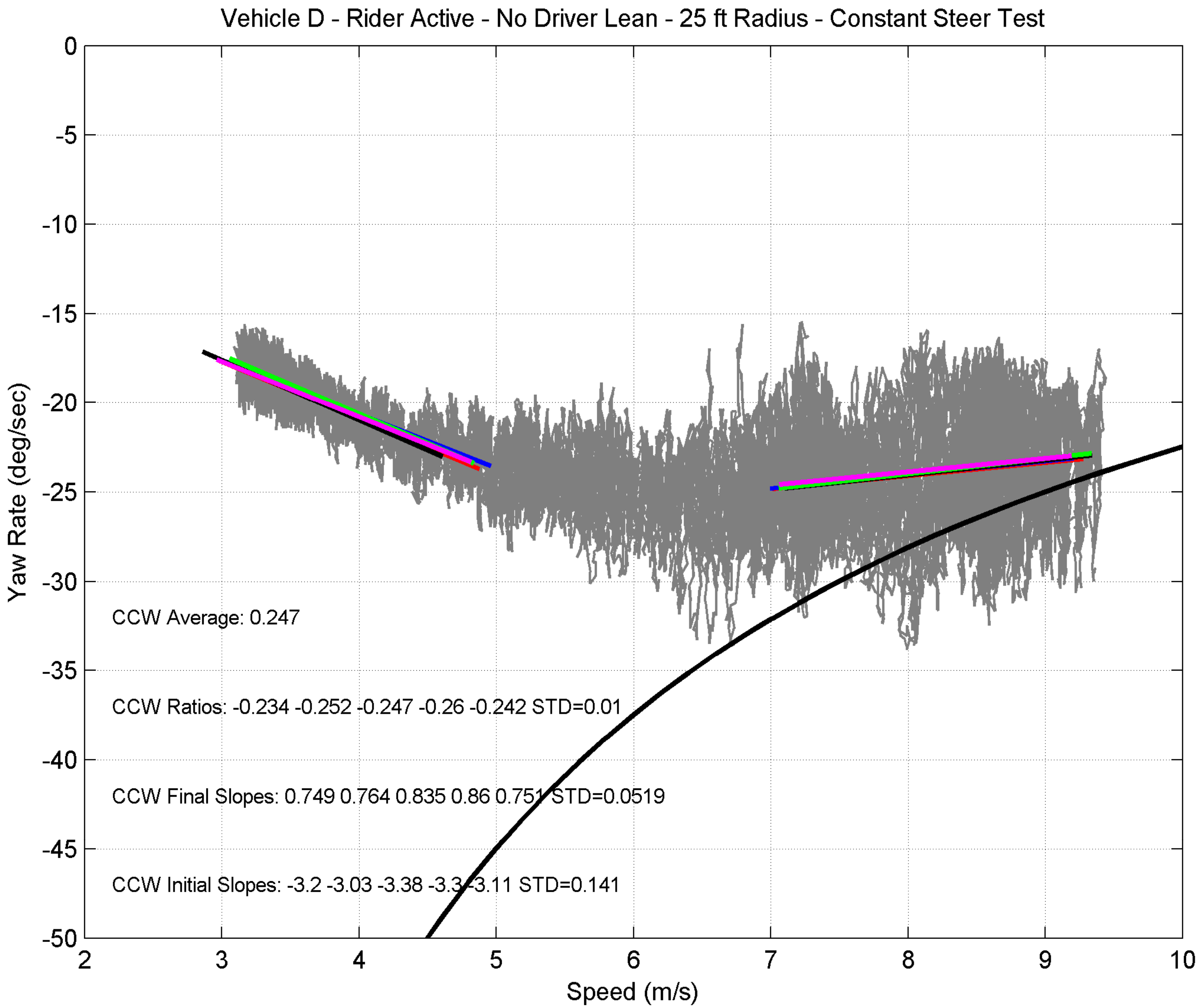
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.573	-0.612	-0.626
	-0.573	-0.608	-0.633
	-0.576	-0.606	-0.644
Mean Value of 3 Runs	-0.574	-0.609	-0.634
Standard Deviation of 3 Runs	0.002	0.003	0.009

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.585	-0.584	-0.608
	-0.592	-0.585	-0.612
	-0.576	-0.579	-0.604
Mean Value of 3 Runs	-0.584	-0.583	-0.608
Standard Deviation of 3 Runs	0.008	0.003	0.004

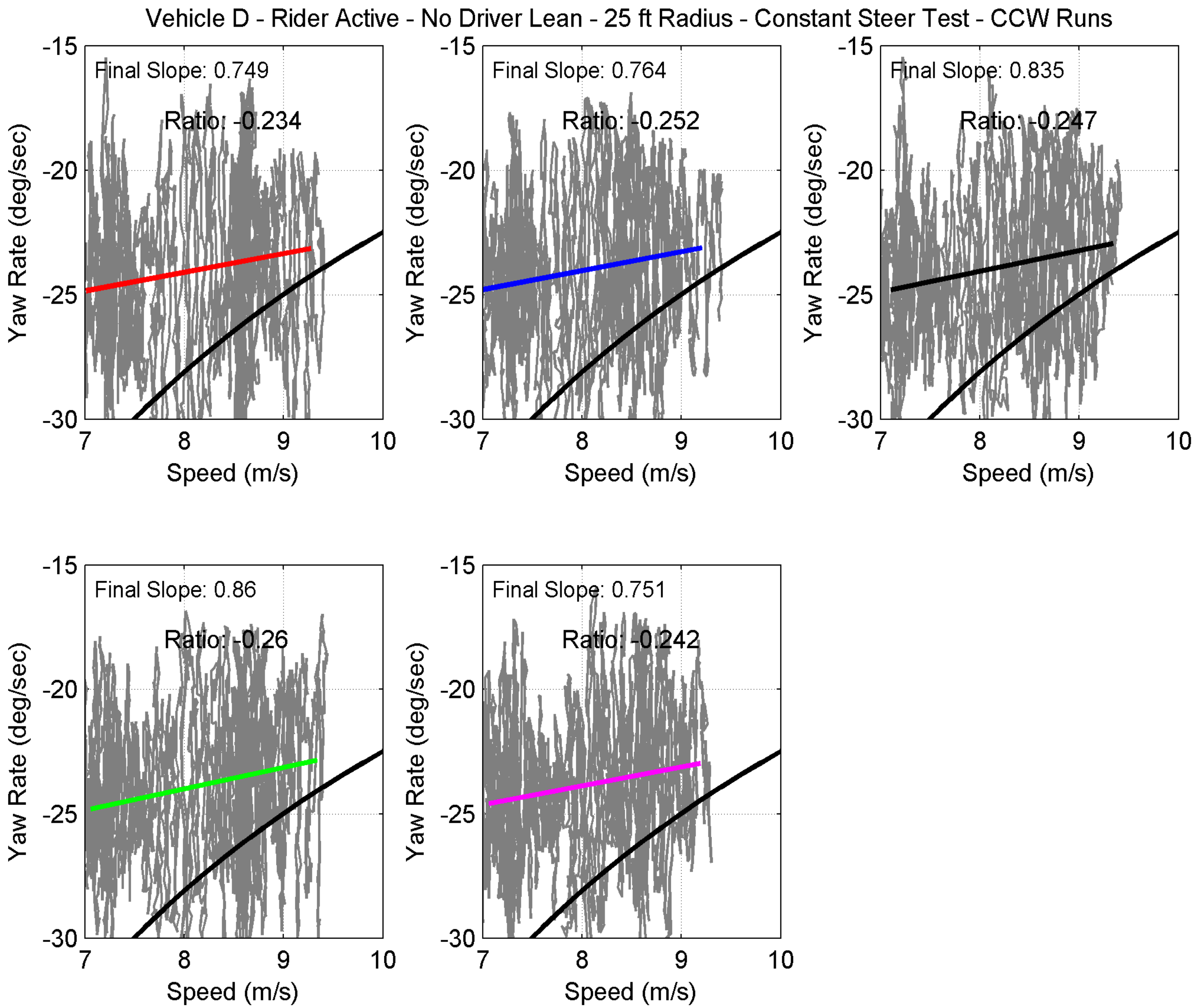
Average of All 6 Runs	**0.579**	**0.596**	**0.621**


Vehicle D - Rider Active - No Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

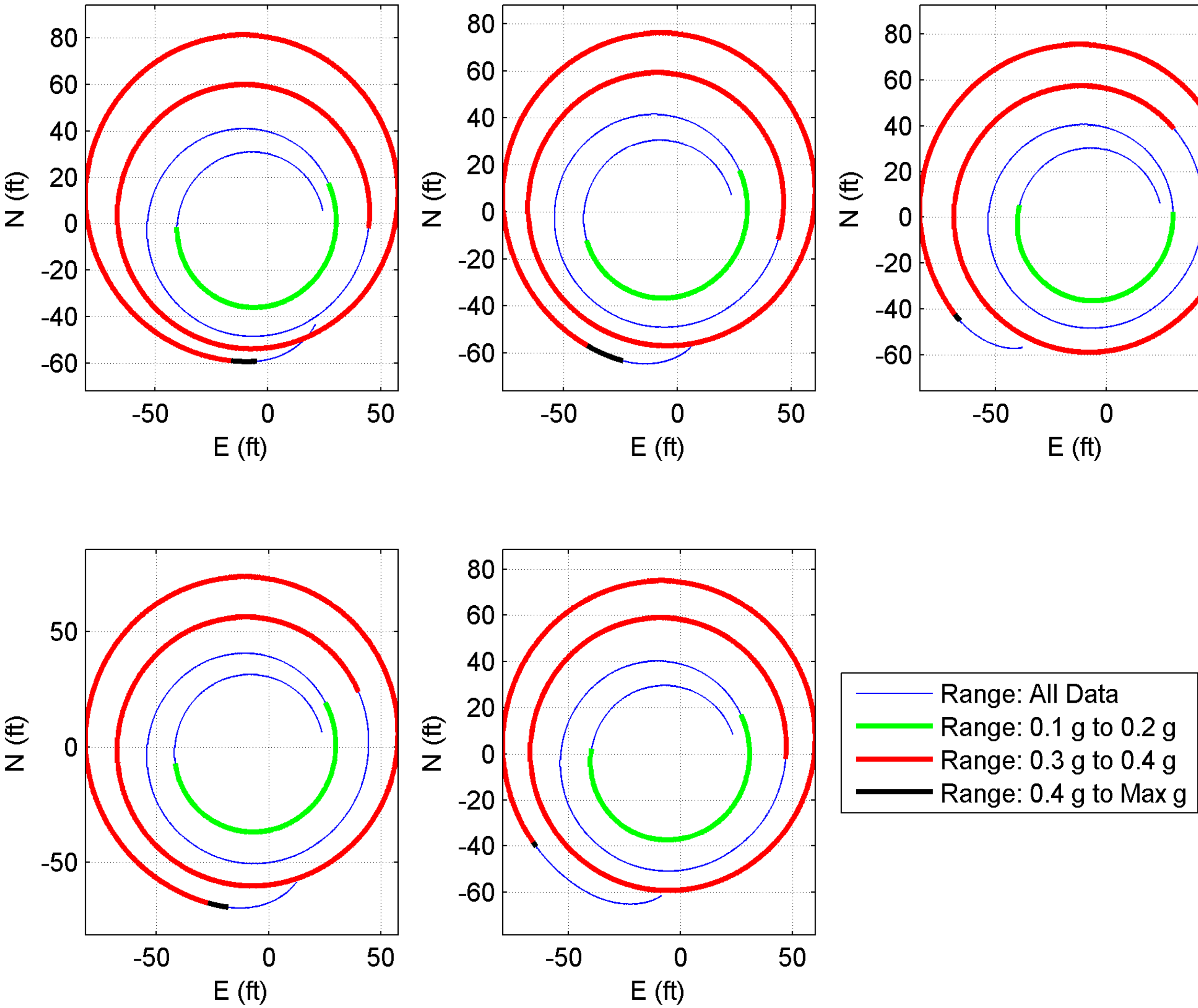

Vehicle D - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
7
8
9
10
Speed (m/s)

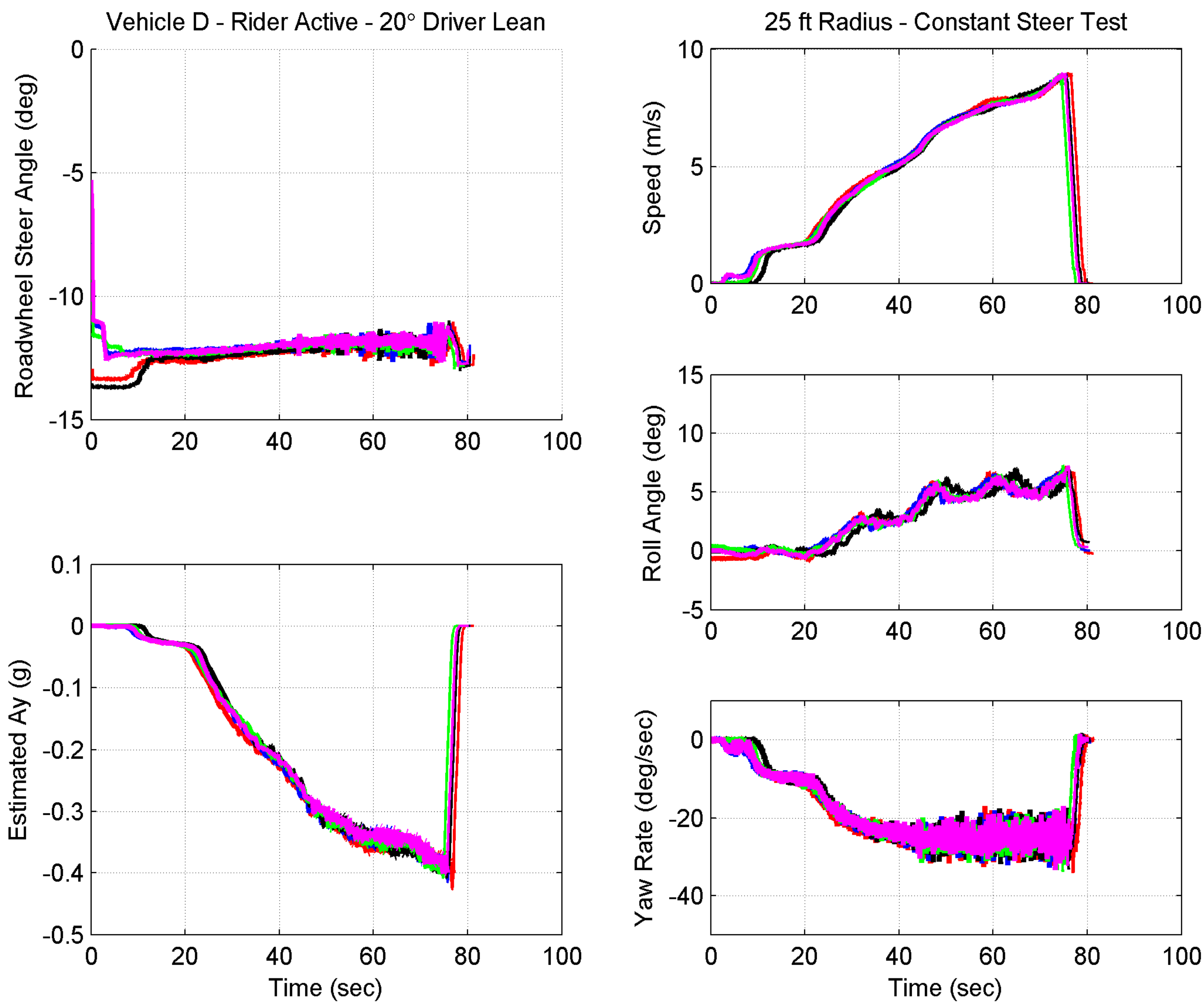


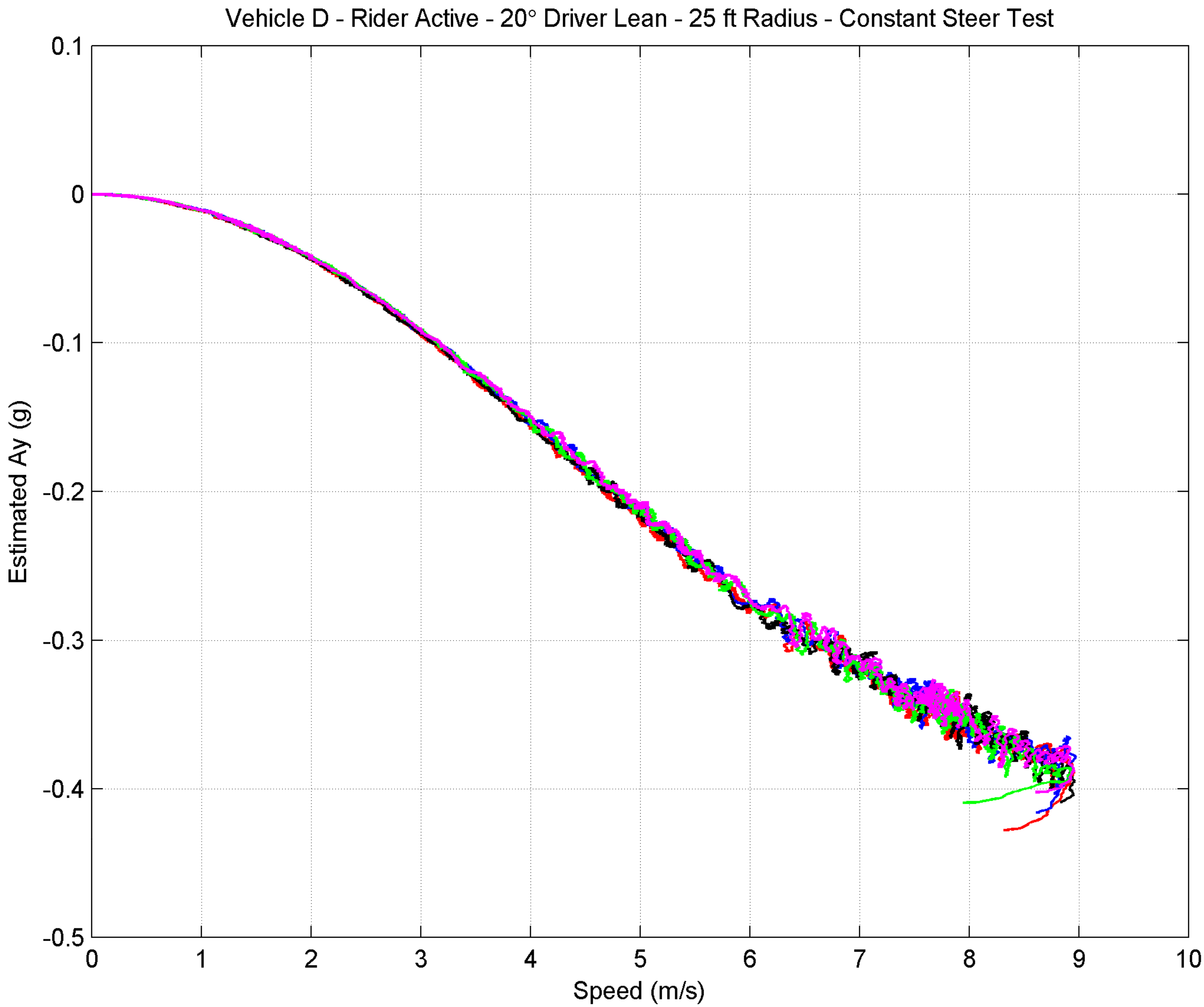
Vehicle D - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
10
CCW Average: 0.247
CCW Ratios: -0.234 -0.252 -0.247 -0.26 -0.242 STD=0.01
CCW Final Slopes: 0.749 0.764 0.835 0.86 0.751 STD=0.0519
CCW Initial Slopes: -3.2 -3.03 -3.38 -3.3 -3.11 STD=0.141


Vehicle D - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 0.749
Ratio: -0.234
Final Slope: 0.764
Ratio: -0.252
Final Slope: 0.835
Ratio: -0.247
Final Slope: 0.86
Ratio: -0.26
Final Slope: 0.751
Ratio: -0.242
Yaw Rate (deg/sec)
Speed (m/s)
-15
-20
-25
-30
7
8
9
10

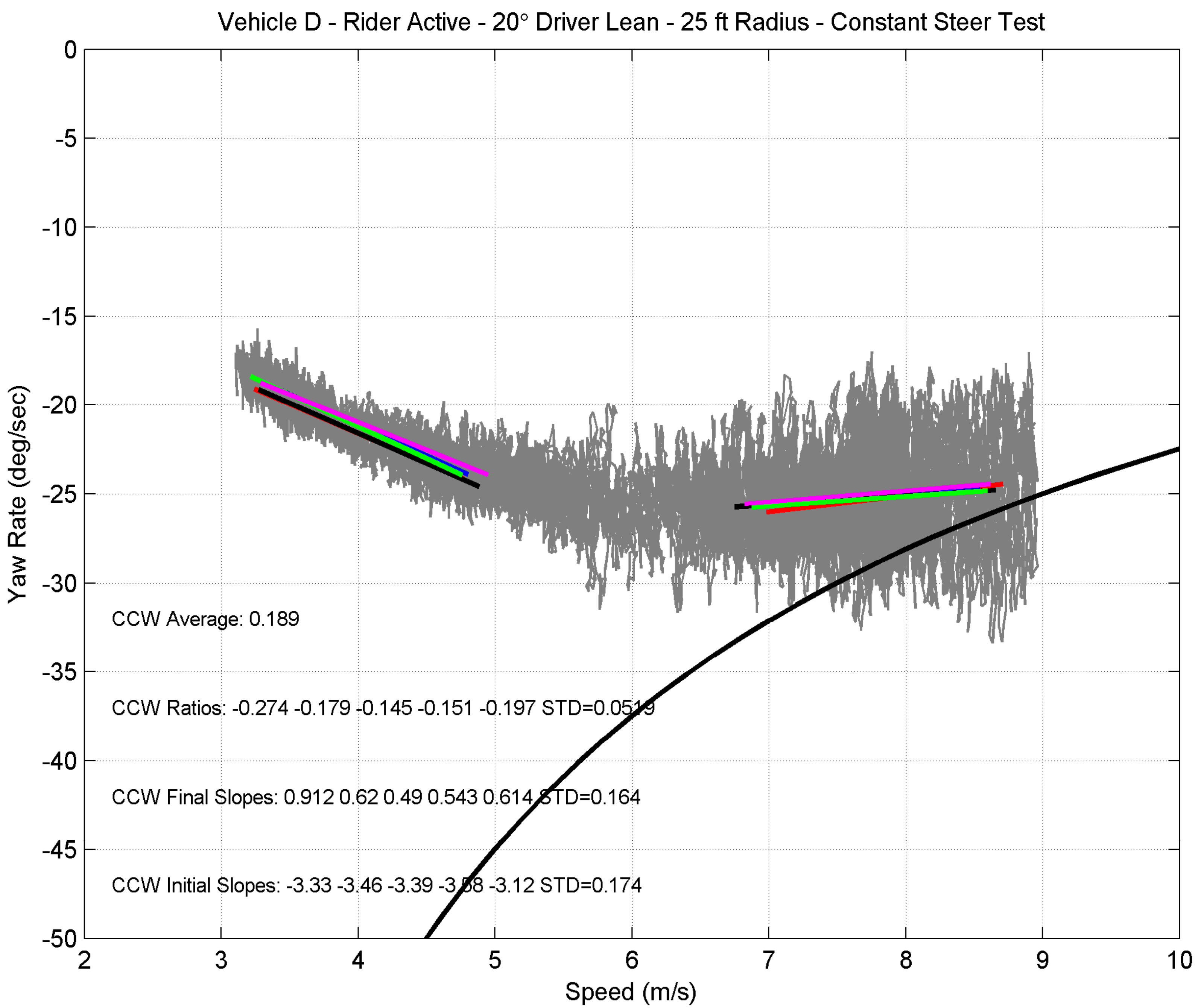
Vehicle D - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs



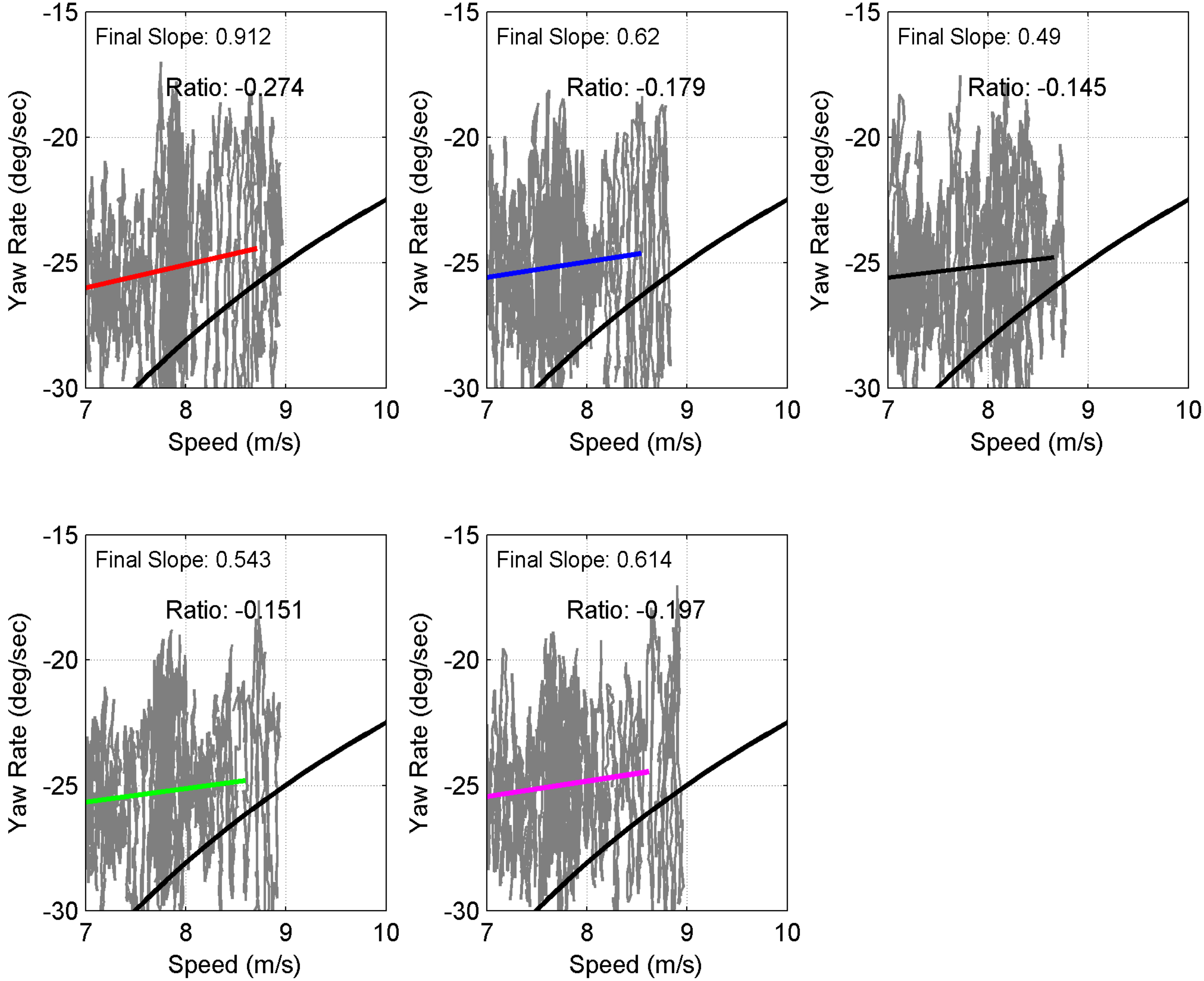

Vehicle D - Rider Active - 20° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

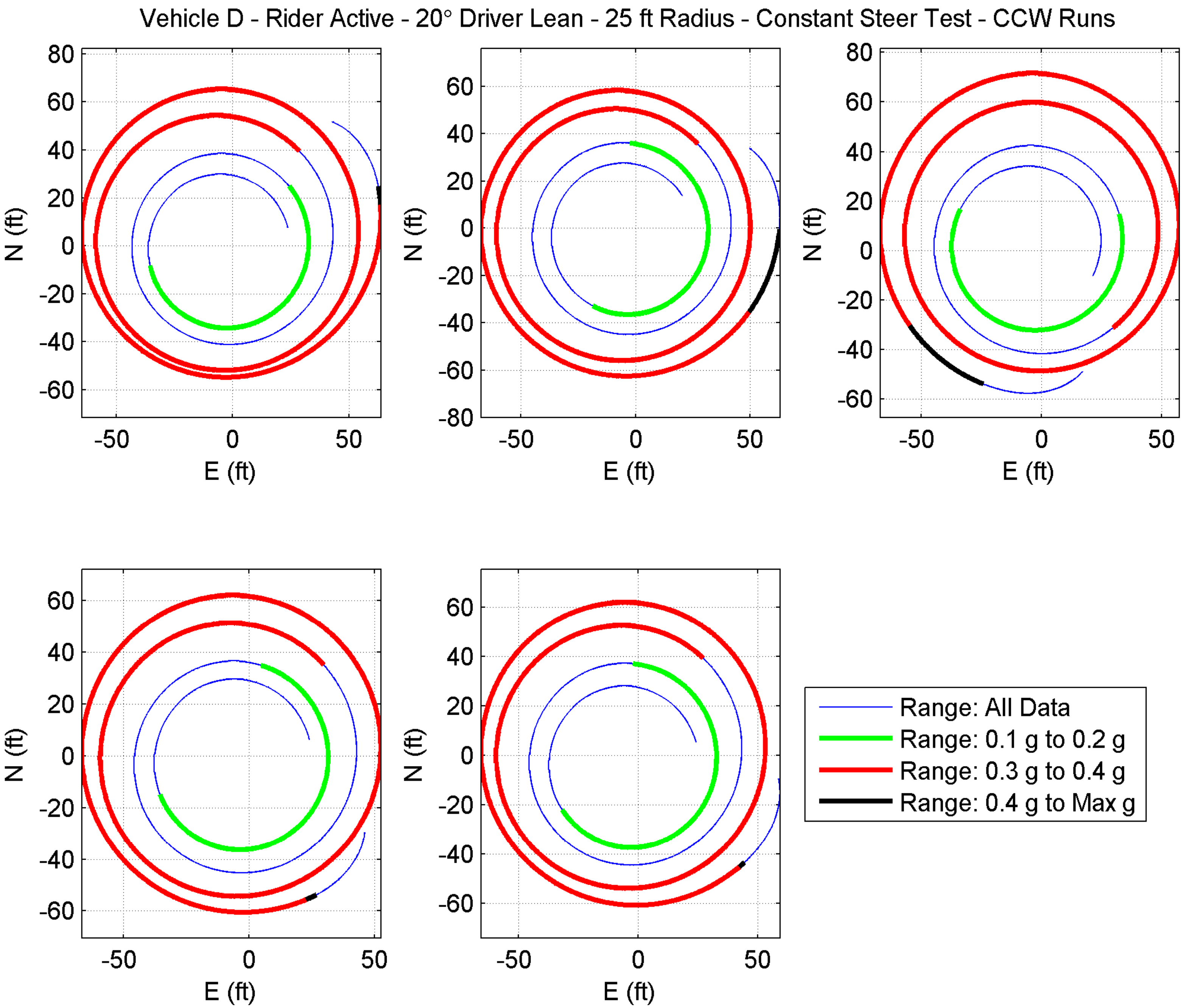


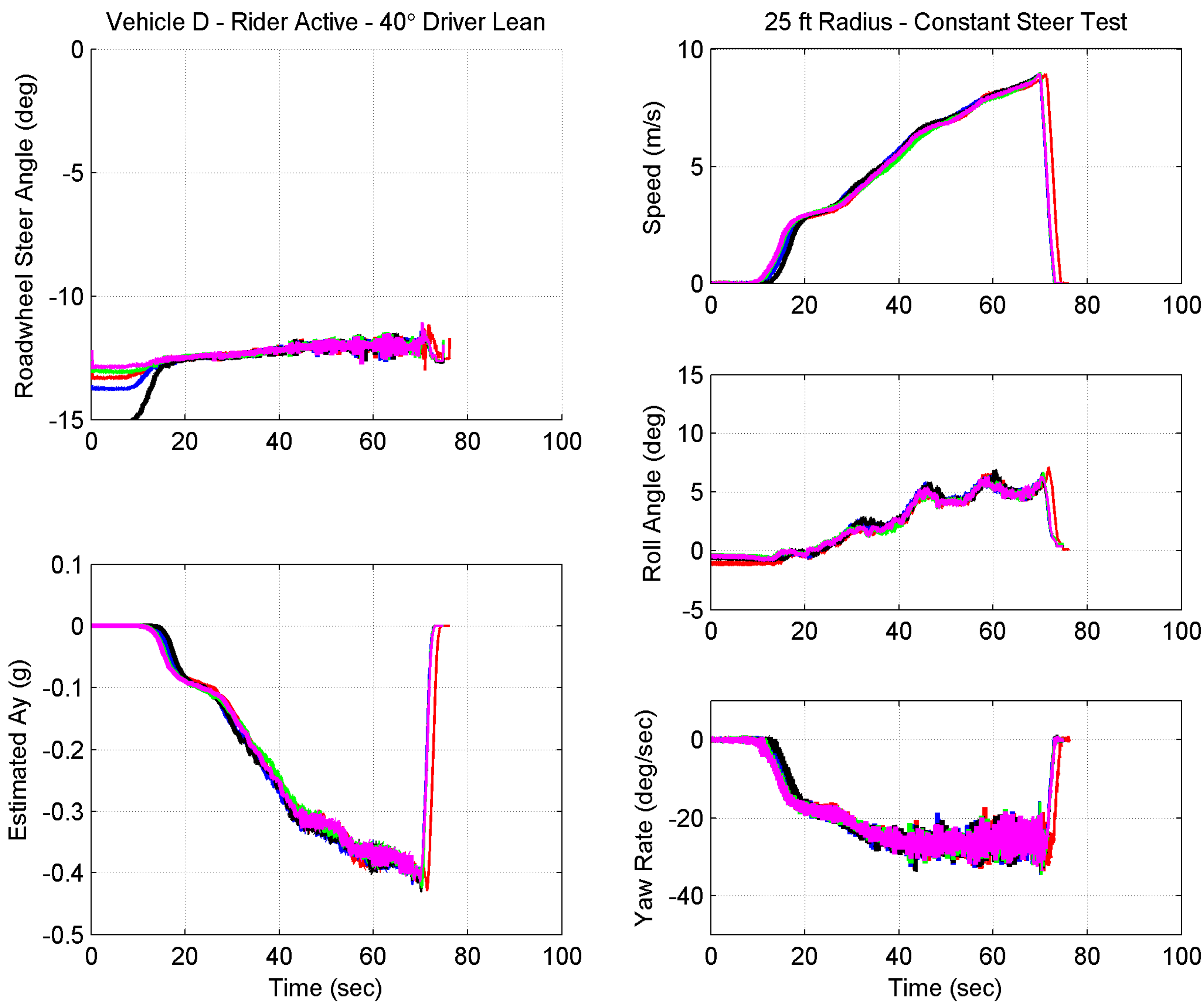
Vehicle D - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10

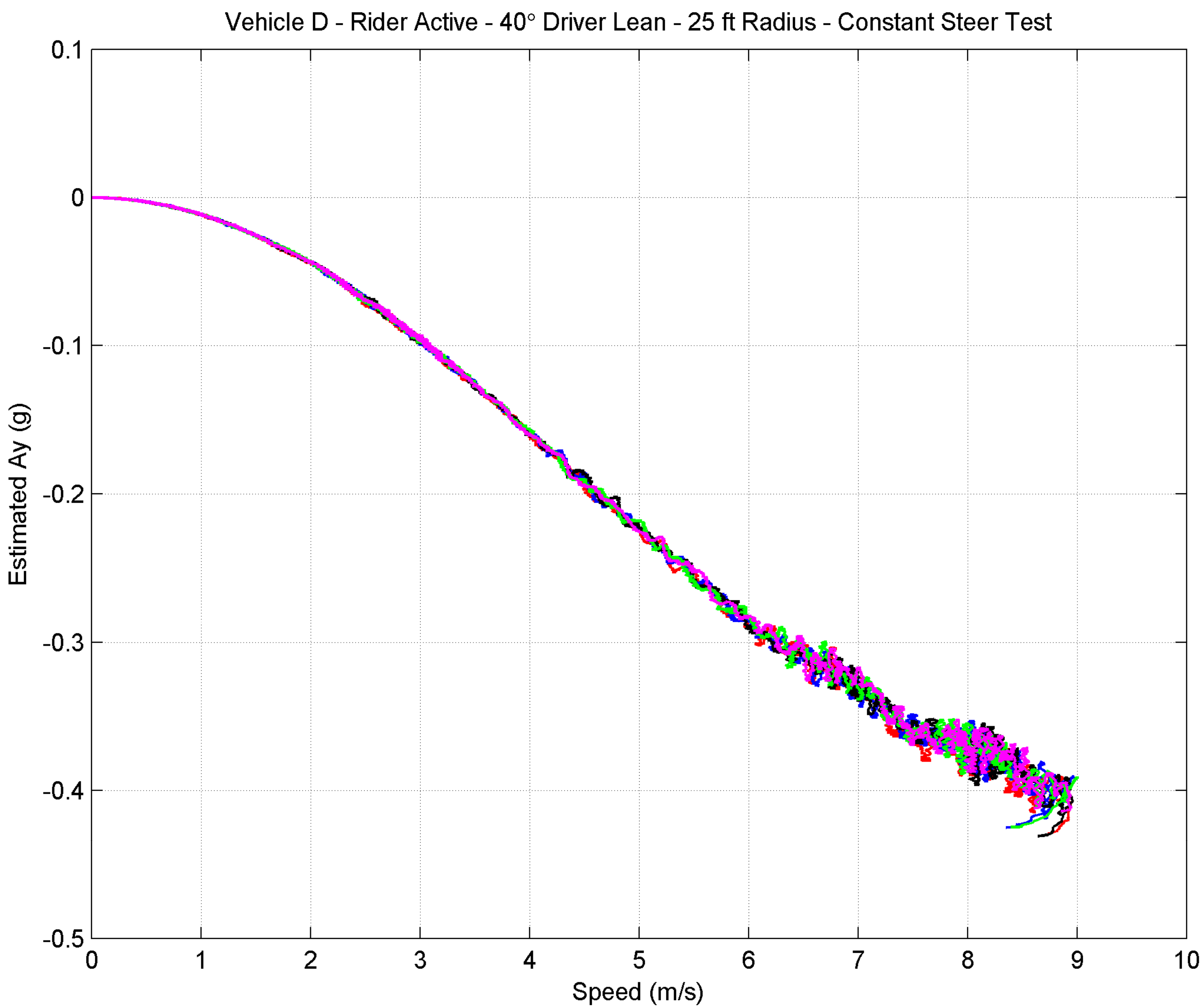

Vehicle D - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
10
CCW Average: 0.189
CCW Ratios: -0.274 -0.179 -0.145 -0.151 -0.197 STD=0.0519
CCW Final Slopes: 0.912 0.62 0.49 0.543 0.614 STD=0.164
CCW Initial Slopes: -3.33 -3.46 -3.39 -3.58 -3.12 STD=0.174

Vehicle D - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

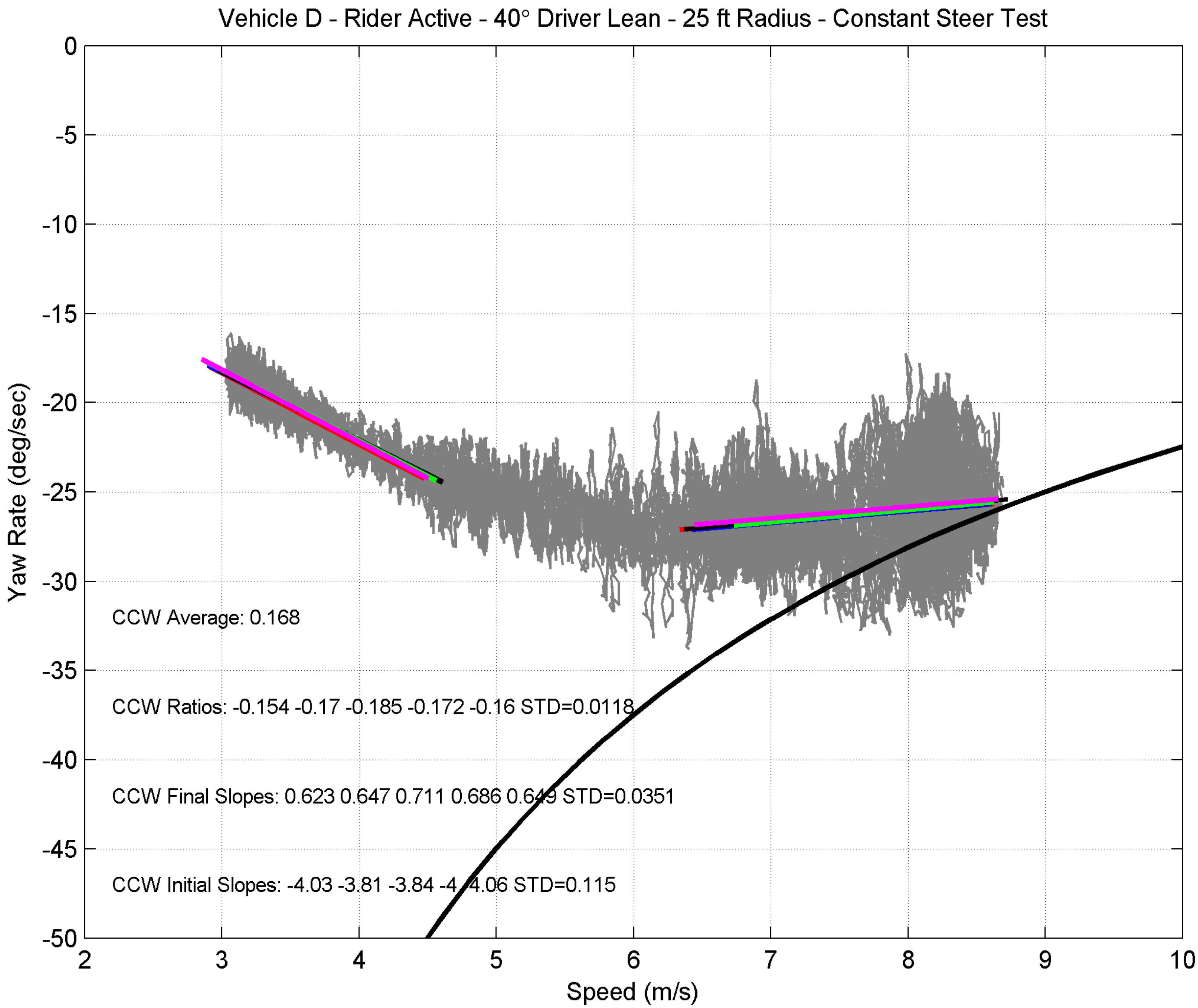



Vehicle D - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

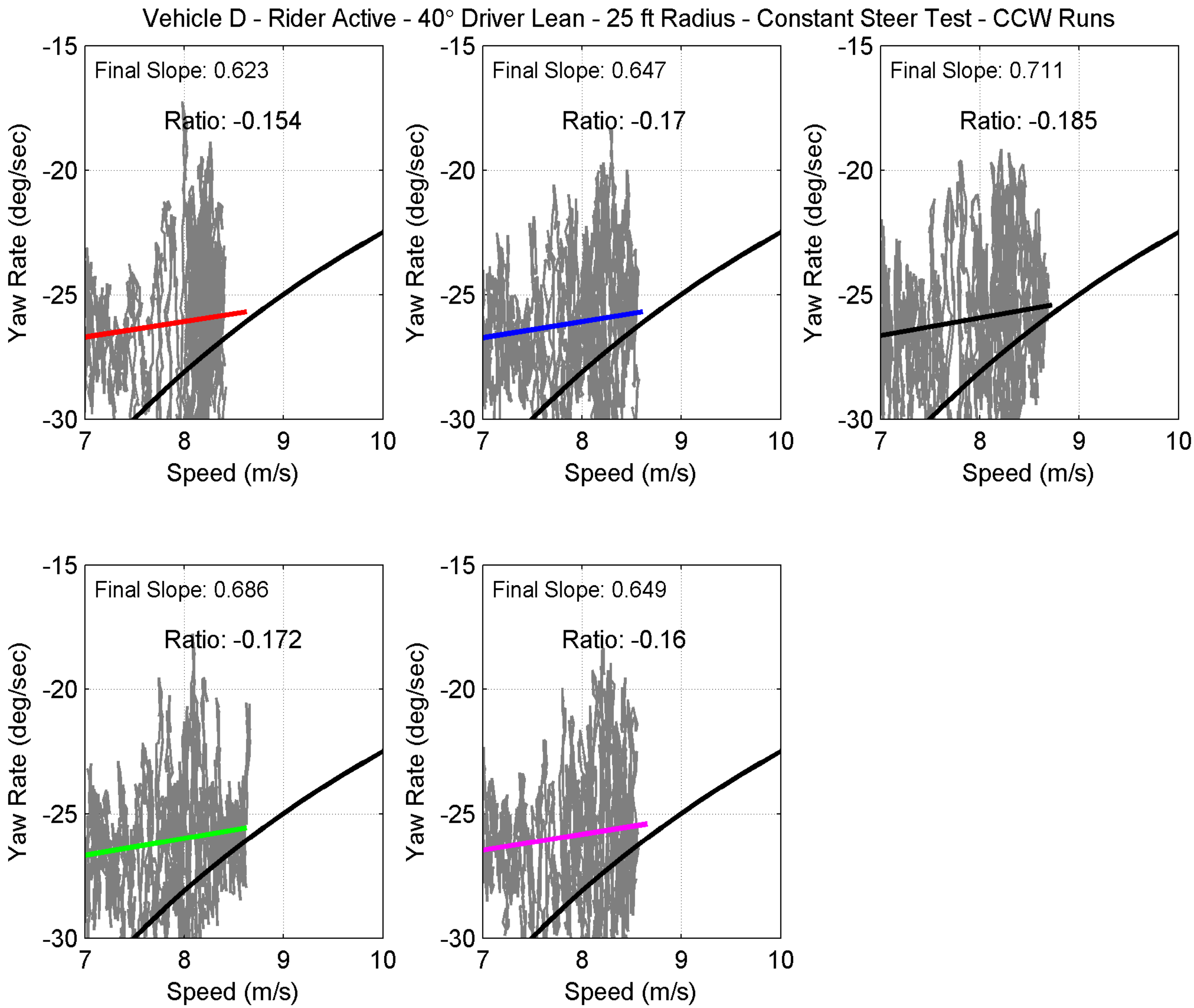

Vehicle D - Rider Active - 40° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



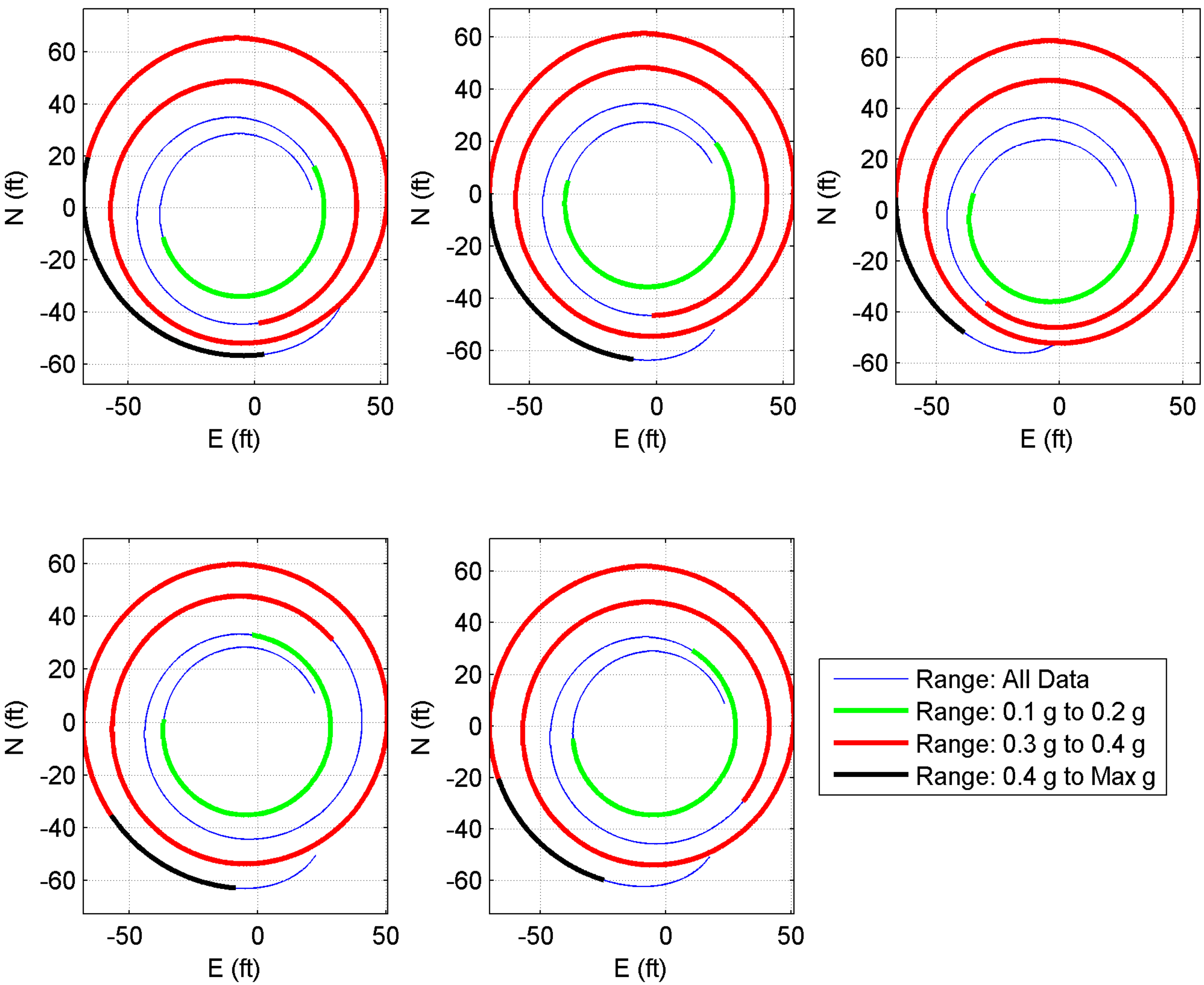
Vehicle D - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10

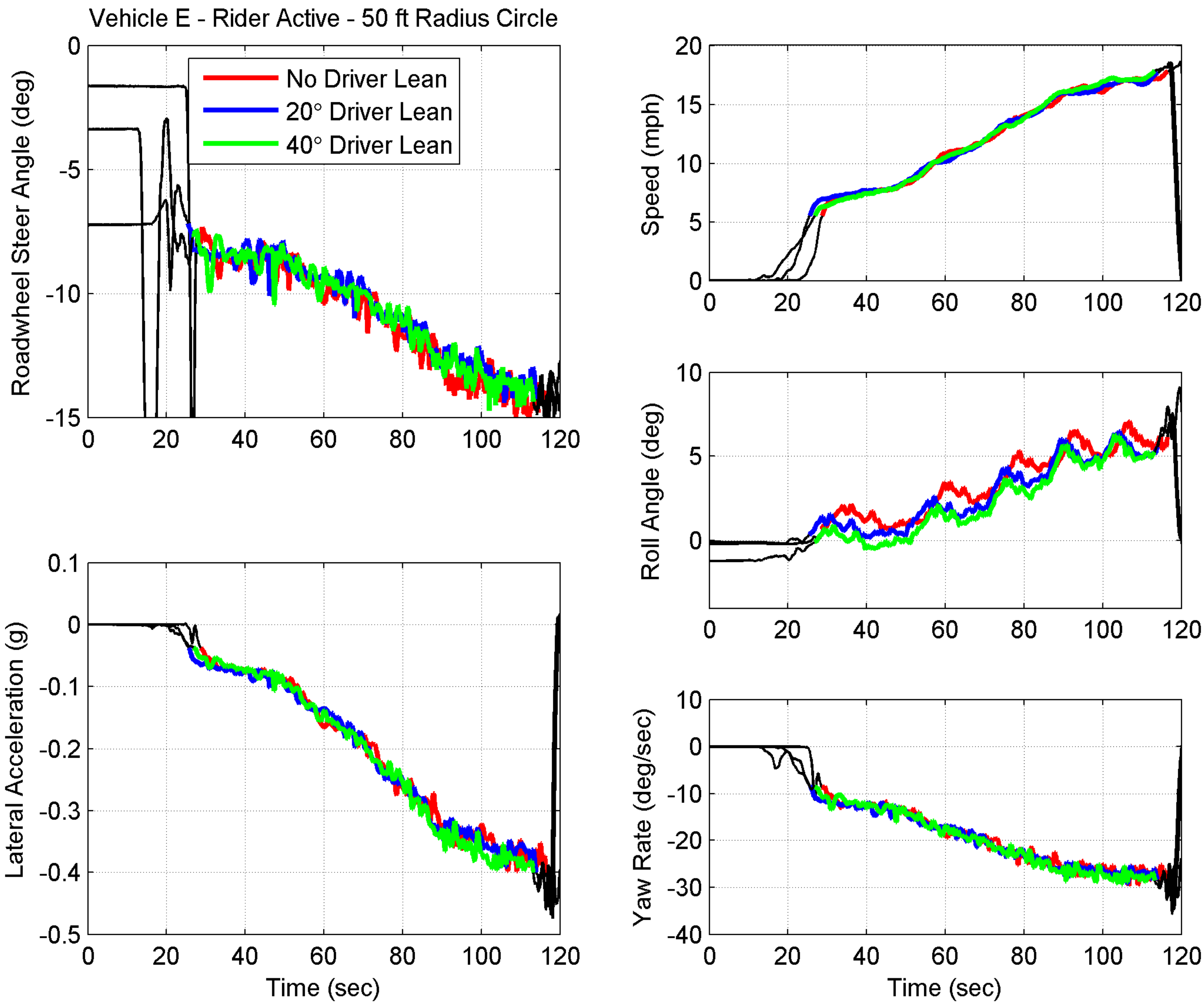


Vehicle D - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
10
CCW Average: 0.168
CCW Ratios: -0.154 -0.17 -0.185 -0.172 -0.16 STD=0.0118
CCW Final Slopes: 0.623 0.647 0.711 0.686 0.649 STD=0.0351
CCW Initial Slopes: -4.03 -3.81 -3.84 -4 -4.06 STD=0.115

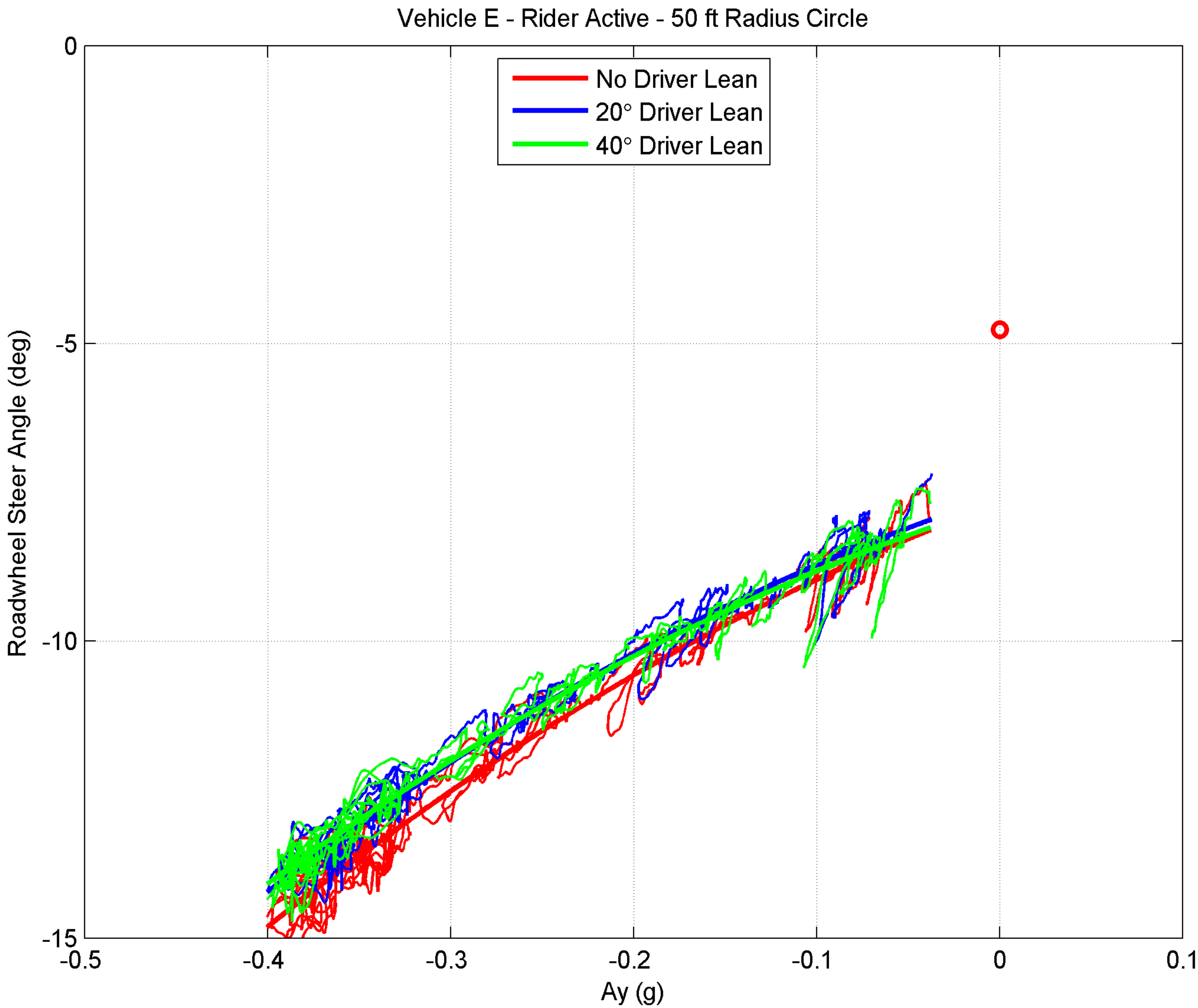

Vehicle D - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 0.623
Ratio: -0.154
Final Slope: 0.647
Ratio: -0.17
Final Slope: 0.711
Ratio: -0.185
Final Slope: 0.686
Ratio: -0.172
Final Slope: 0.649
Ratio: -0.16
Yaw Rate (deg/sec)
Speed (m/s)
-15
-20
-25
-30
7
8
9
10

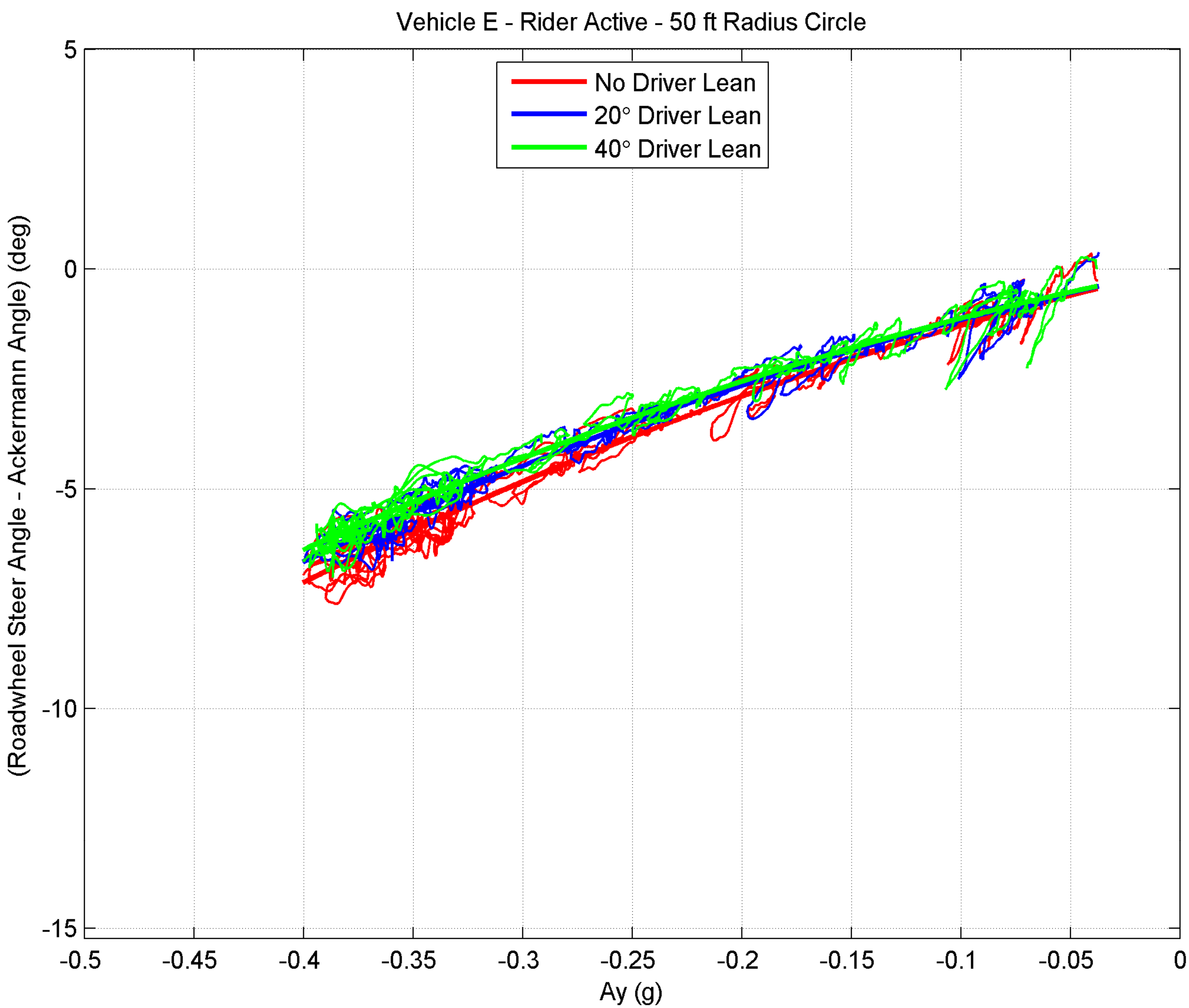
Vehicle D - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

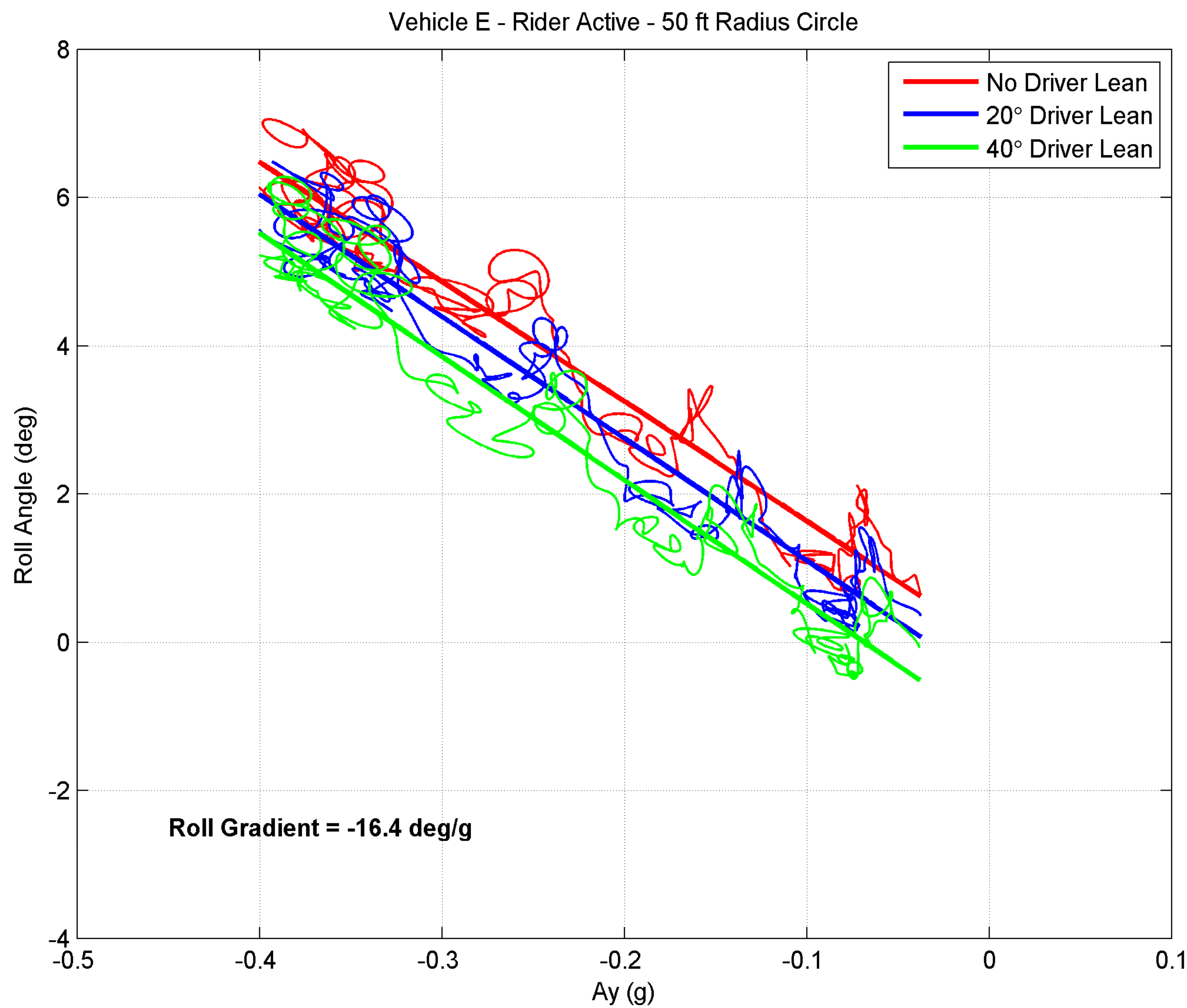


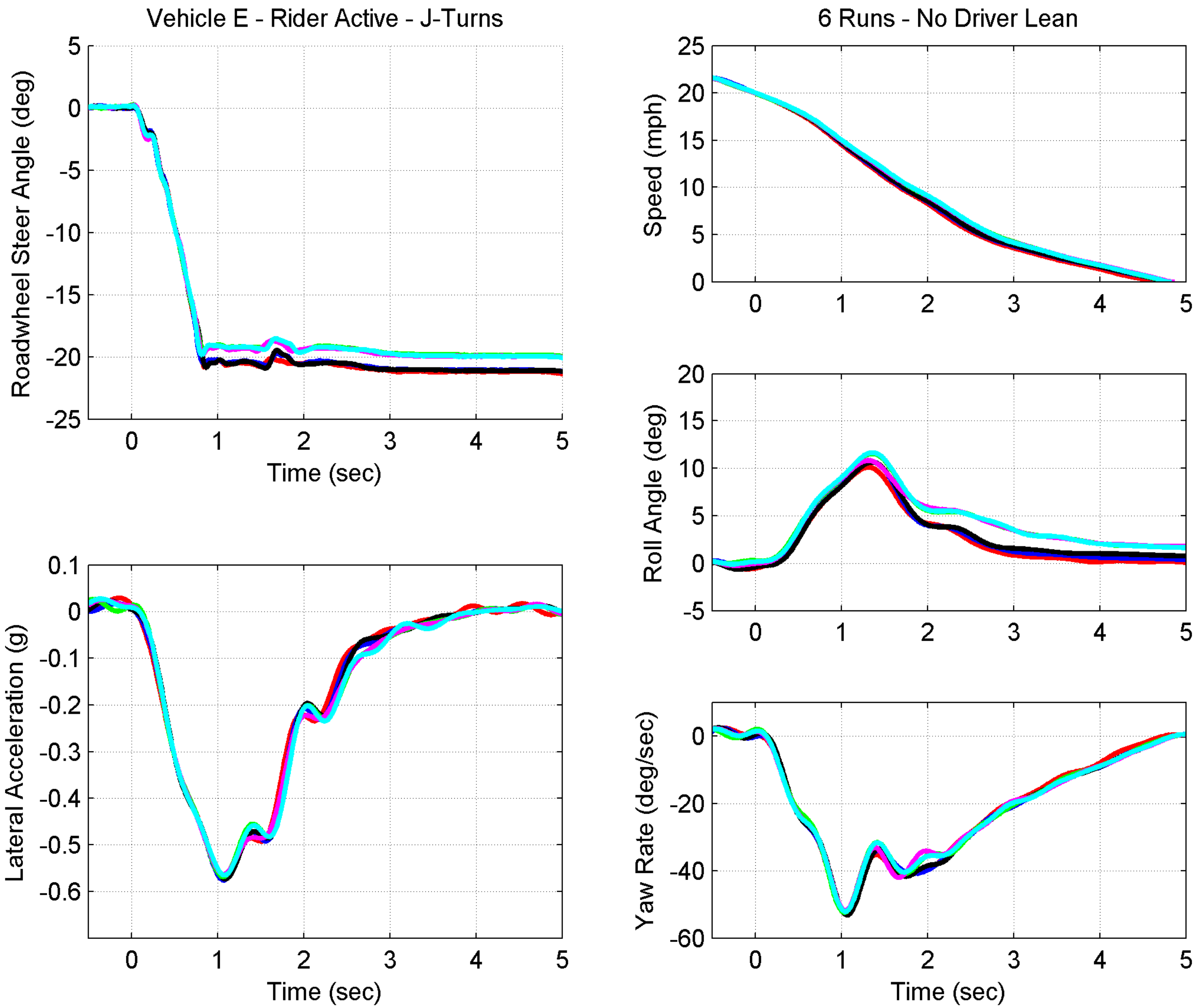


Vehicle E - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle E - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)

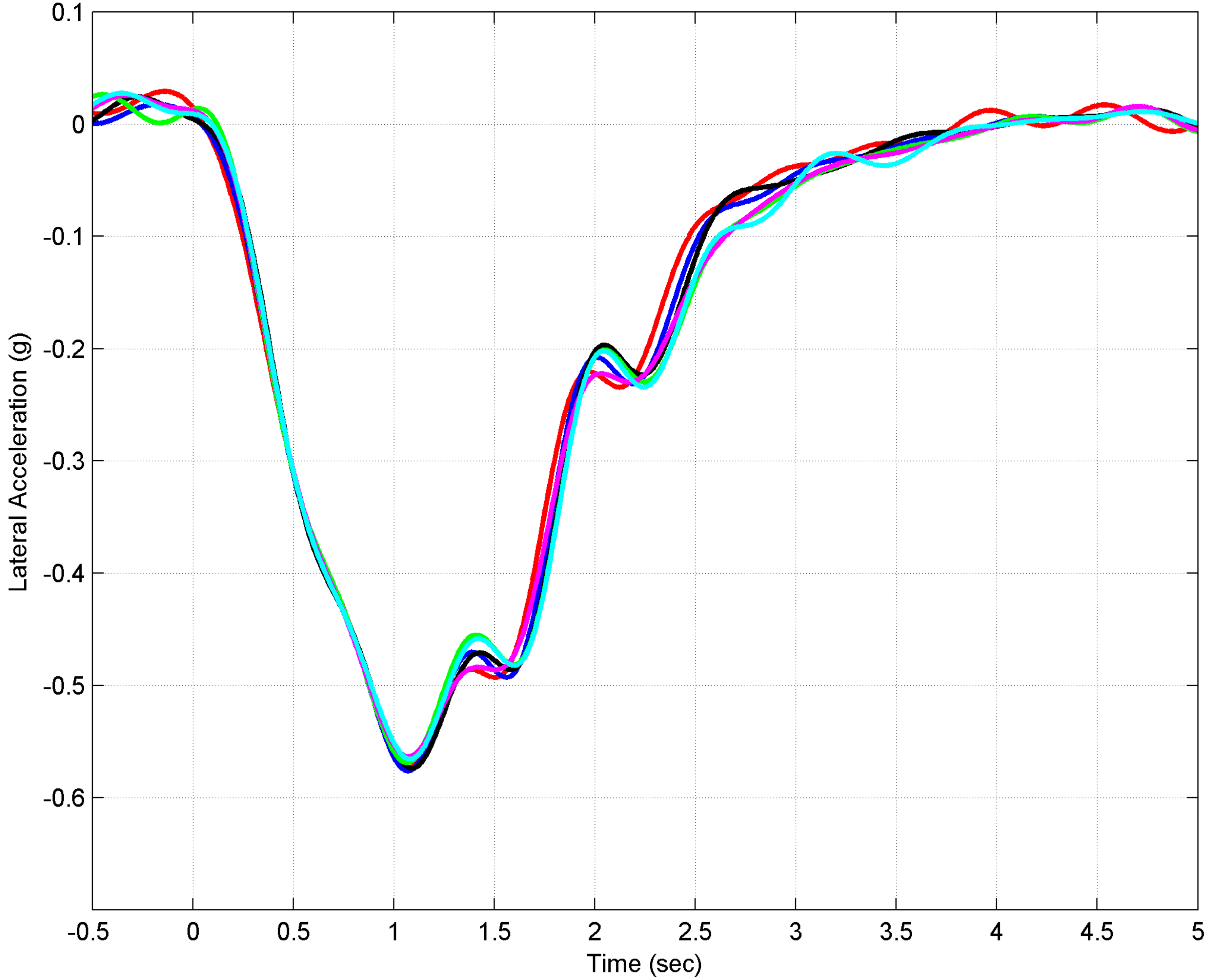

Vehicle E - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
(Roadwheel Steer Angle - Ackermann Angle) (deg)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
Ay (g)

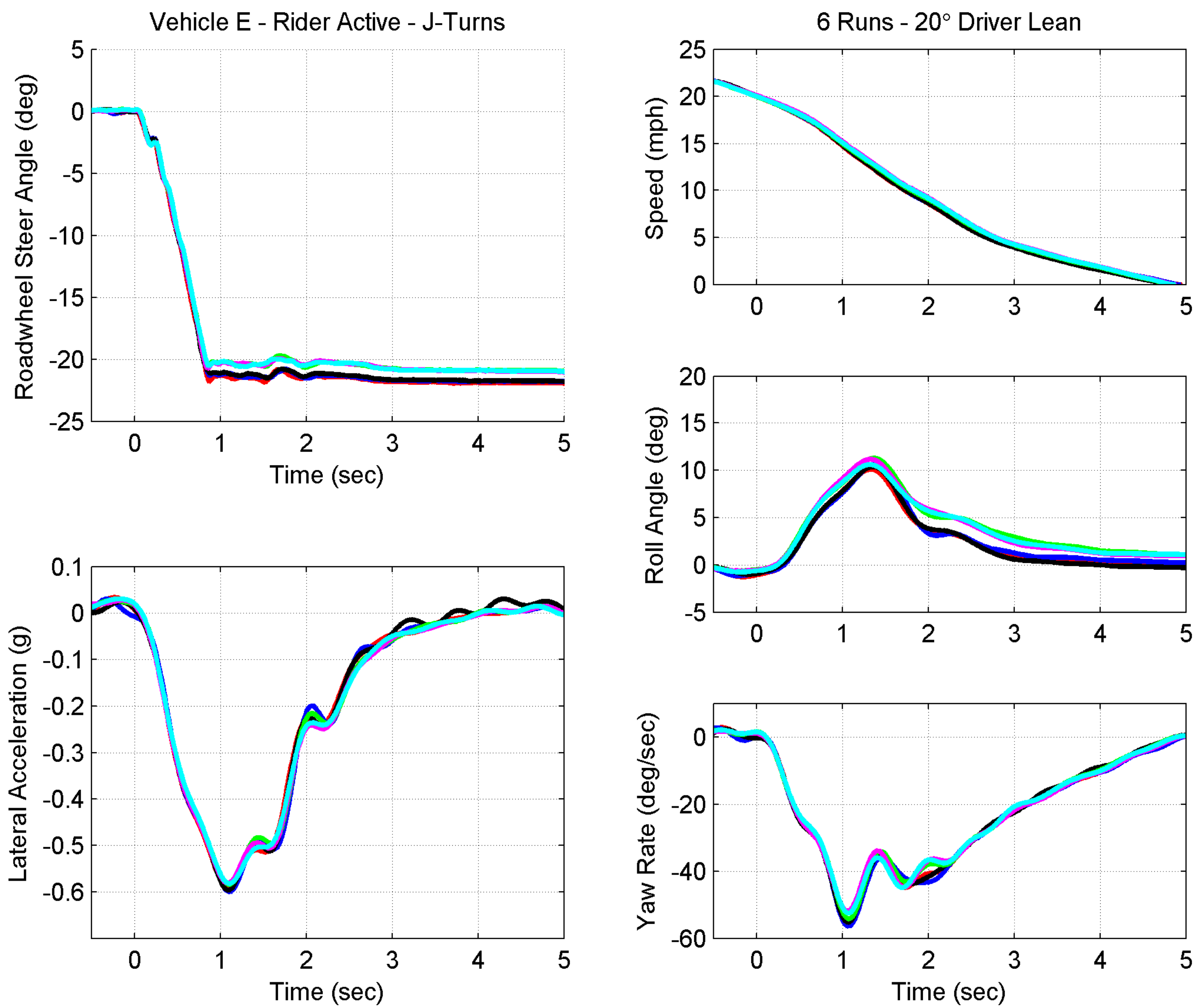

Vehicle E - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -16.4 deg/g
8
6
4
2
0
-2
-4
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

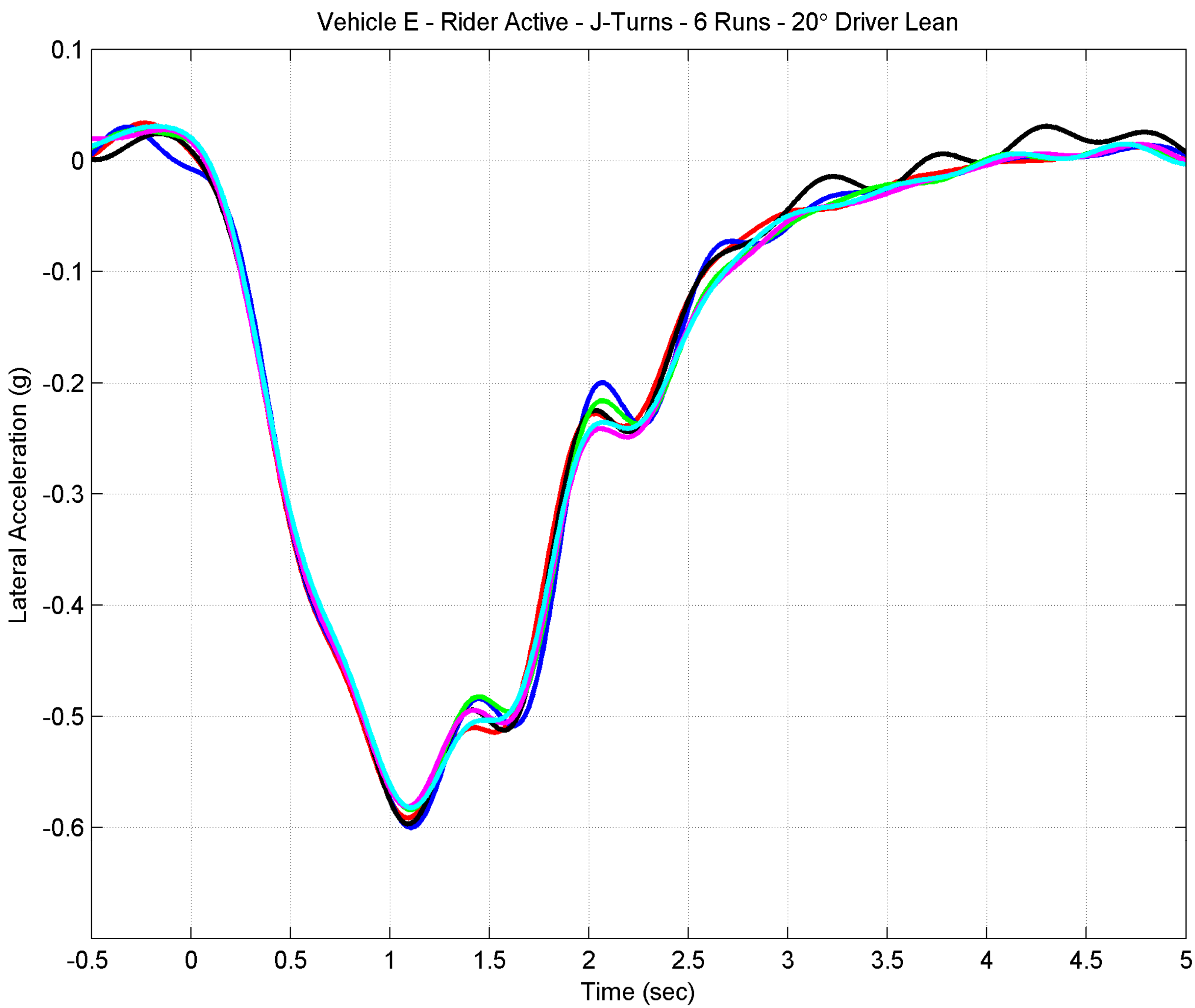


Vehicle E - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
5
0
-5
-10
-15
-20
-25
0 1 2 3 4 5
Time (sec)
Speed (mph)
25
20
15
10
5
0
0 1 2 3 4 5
Roll Angle (deg)
20
15
10
5
0
-5
0 1 2 3 4 5
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
0 1 2 3 4 5
Time (sec)
Yaw Rate (deg/sec)
0
-20
-40
-60
0 1 2 3 4 5
Time (sec)

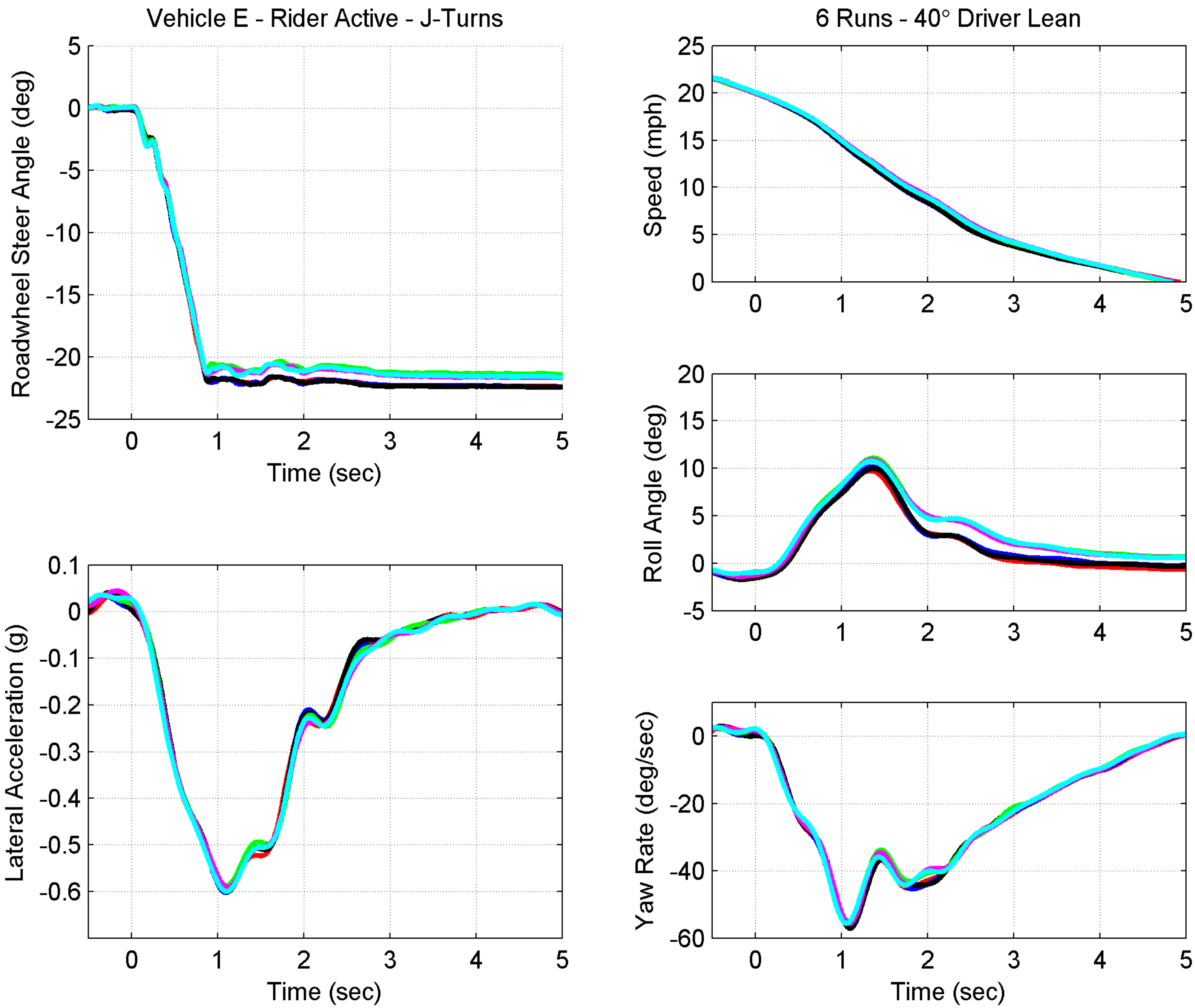
Vehicle E - Rider Active - J-Turns - 6 Runs - No Driver Lean

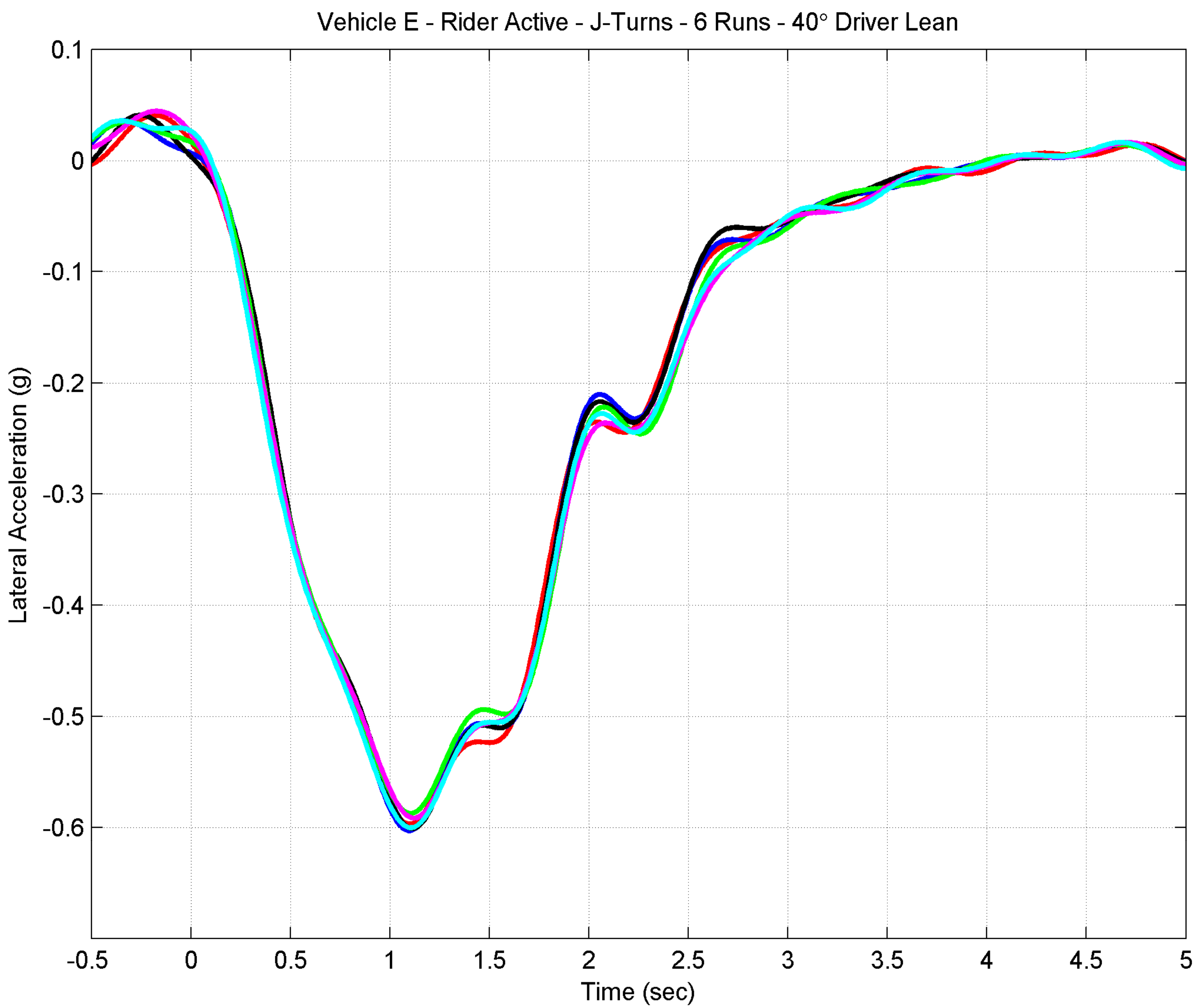



Vehicle E - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
5
0
-5
-10
-15
-20
-25
Time (sec)
Speed (mph)
25
20
15
10
Roll Angle (deg)
Lateral Acceleration (g)
0.1
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Yaw Rate (deg/sec)
-40
-60
0
1
2
3
4
5



Vehicle E - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle E - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



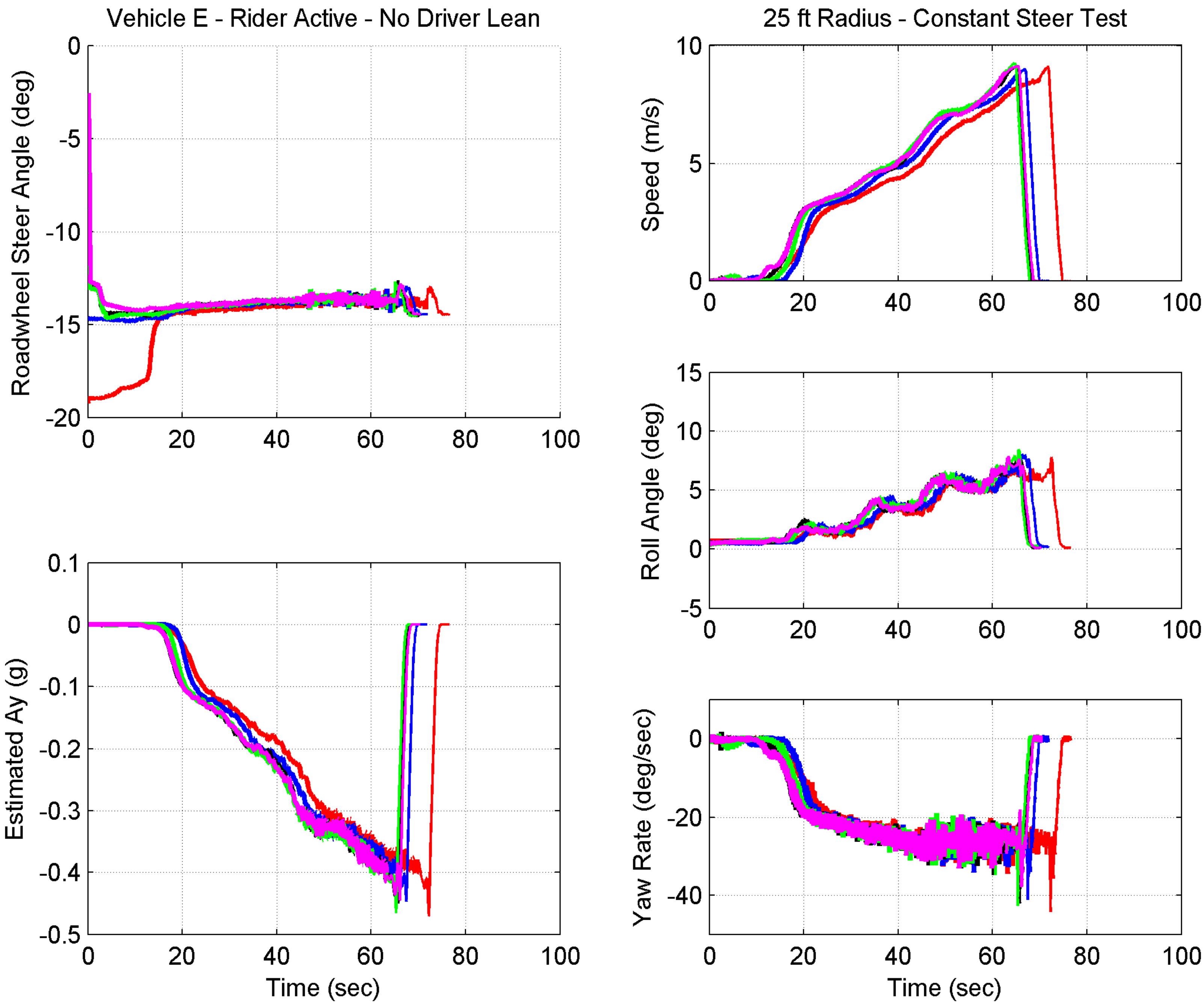
Vehicle E - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

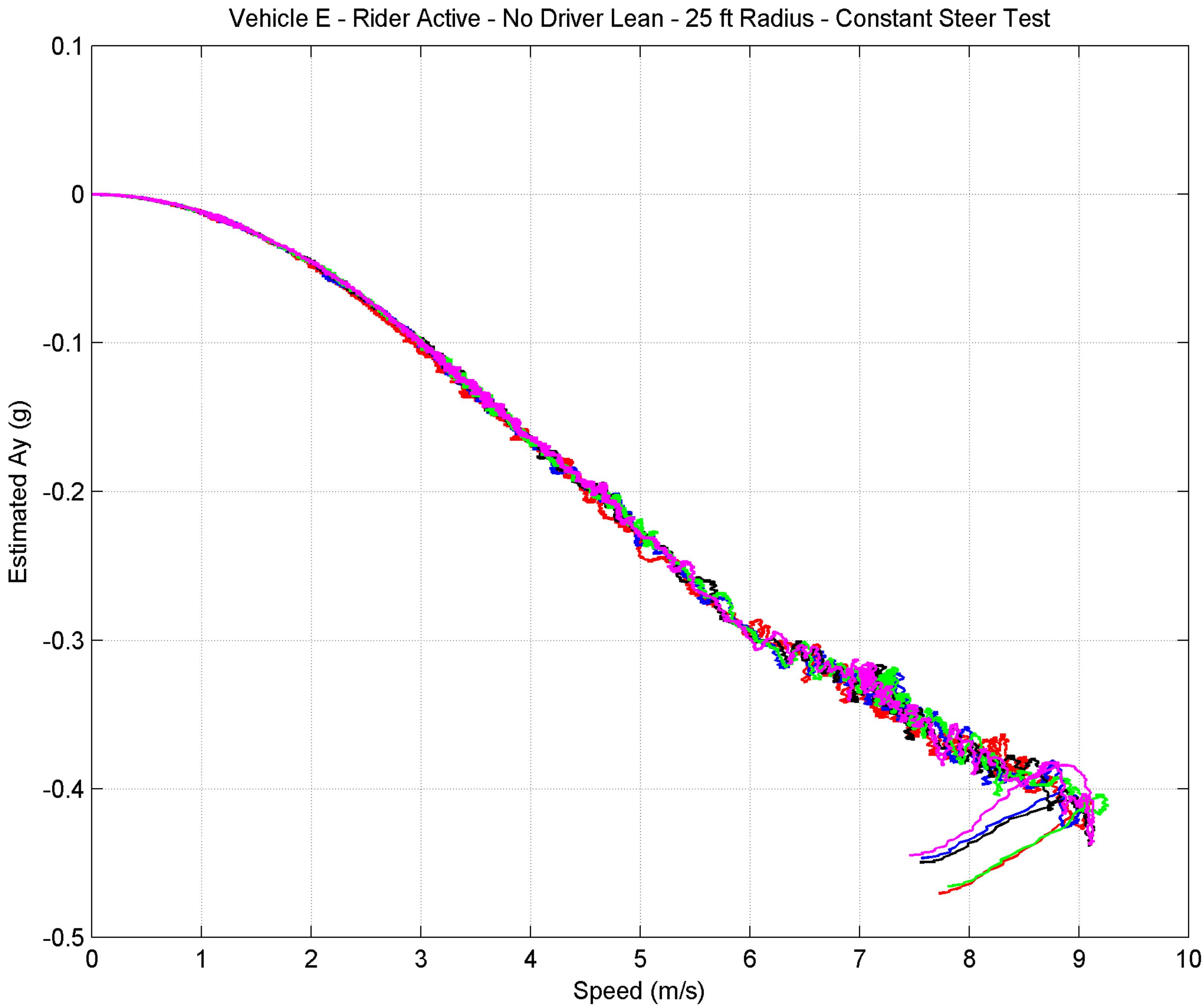
Vehicle E - Rider Active Results

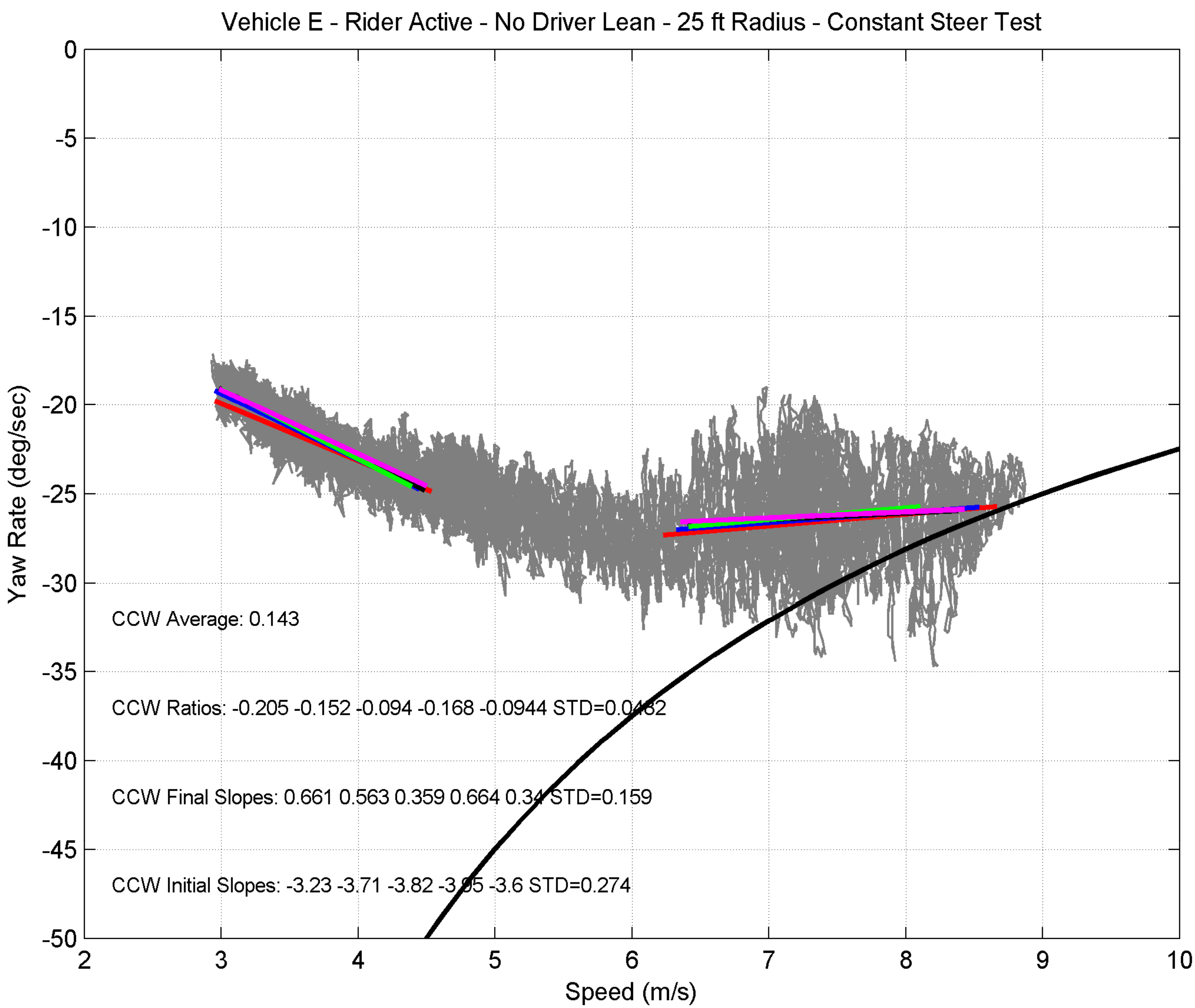
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.574	-0.591	-0.597
	-0.576	-0.600	-0.603
	-0.574	-0.597	-0.601
Mean Value of 3 Runs	-0.575	-0.596	-0.600
Standard Deviation of 3 Runs	0.001	0.004	0.003

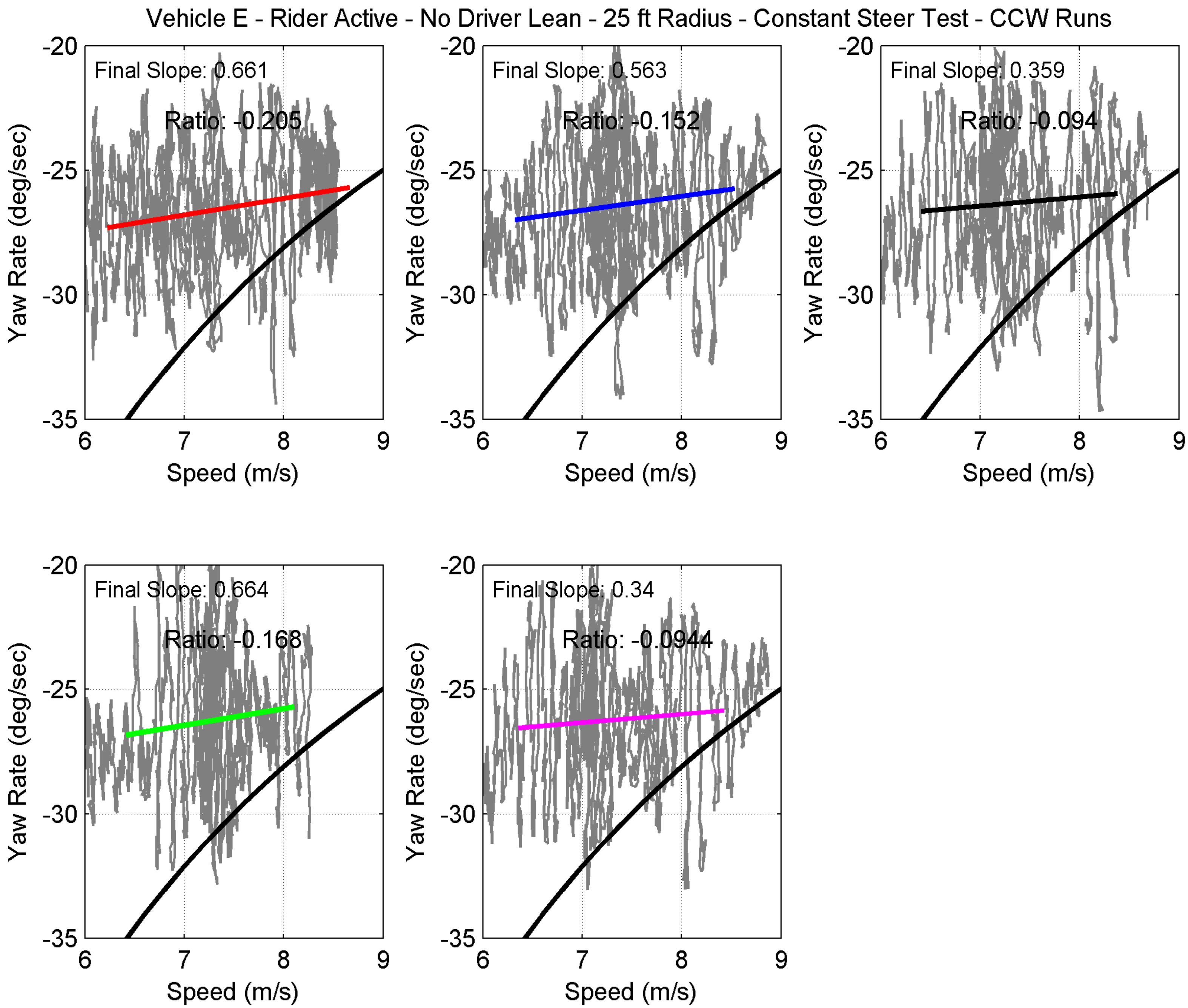
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.569	-0.584	-0.587
	-0.564	-0.581	-0.592
	-0.566	-0.582	-0.600
Mean Value of 3 Runs	-0.566	-0.582	-0.593
Standard Deviation of 3 Runs	0.003	0.001	0.007
Average of All 6 Runs	**0.570**	**0.589**	**0.597**

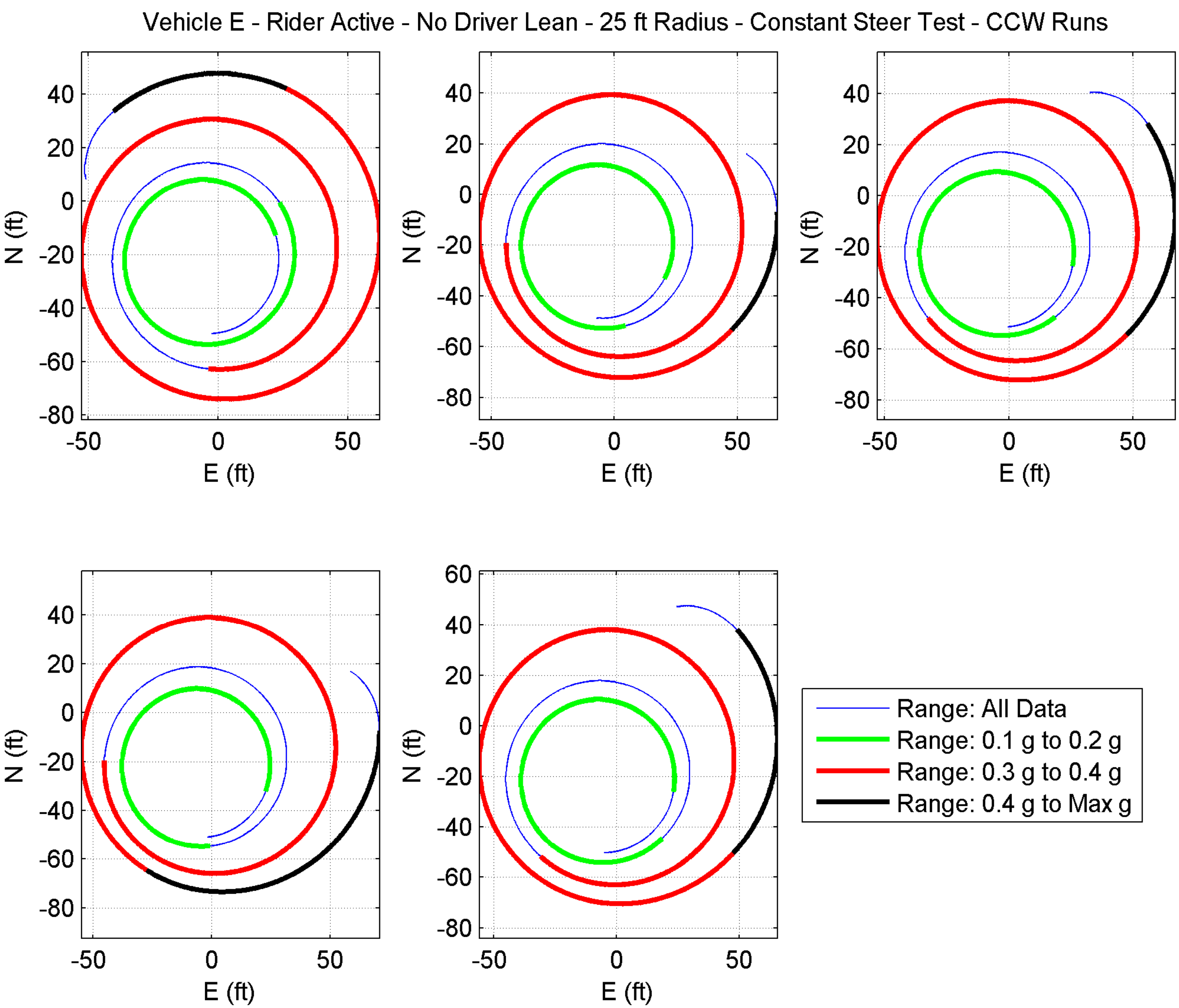

Vehicle E - Rider Active - No Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

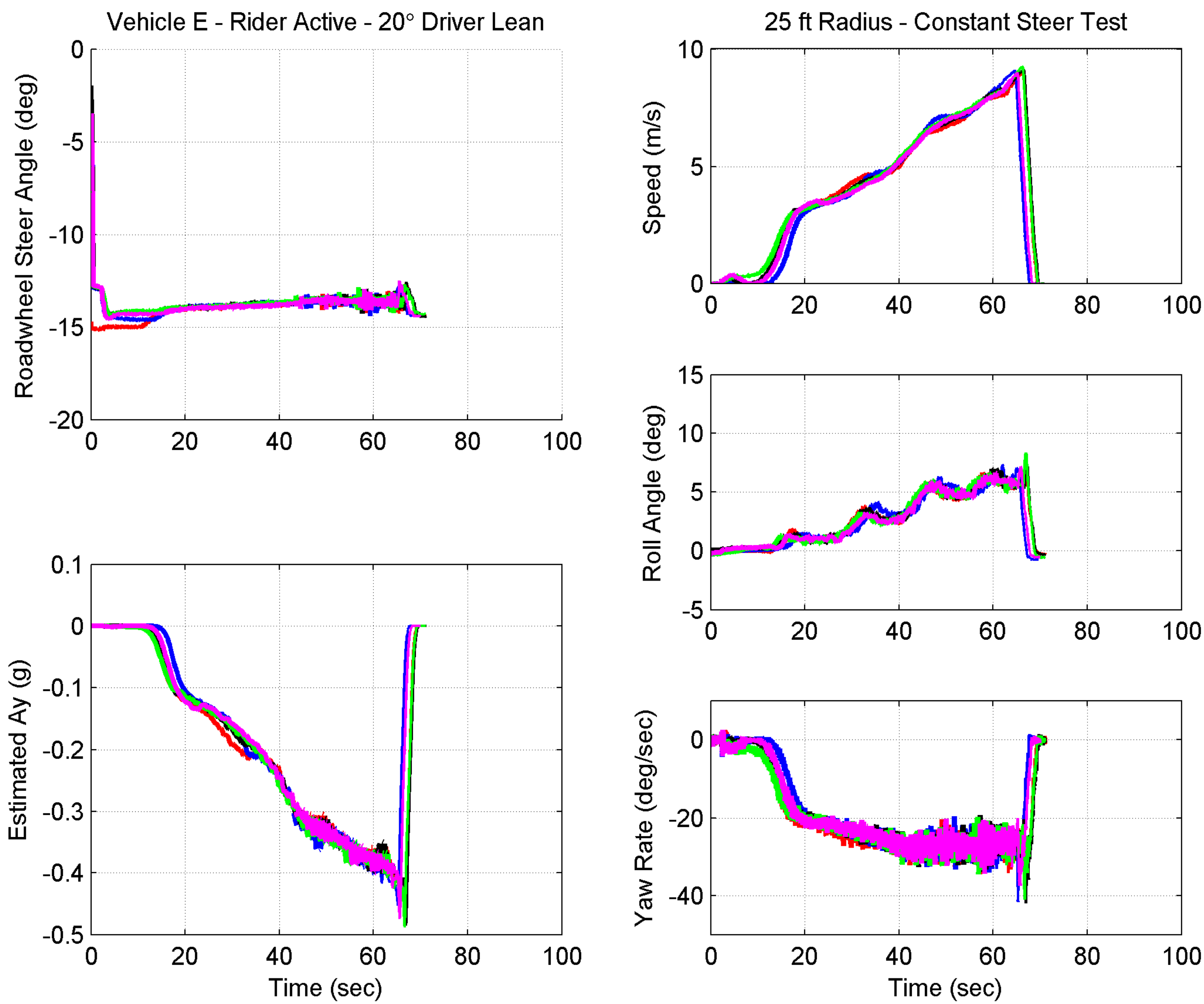

Vehicle E - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10



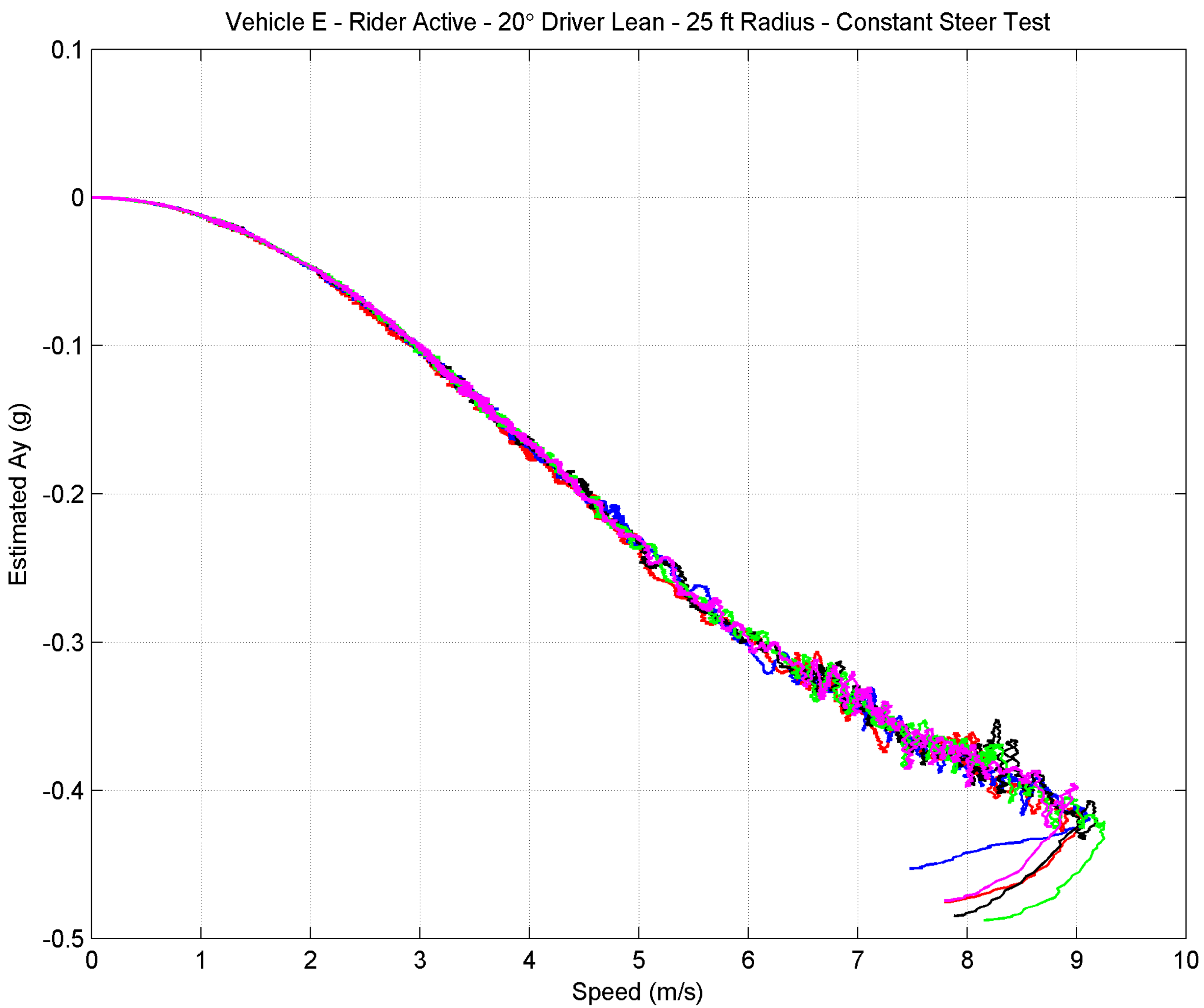
Vehicle E - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
10
CCW Average: 0.143
CCW Ratios: -0.205 -0.152 -0.094 -0.168 -0.0944 STD=0.0462
CCW Final Slopes: 0.661 0.563 0.359 0.664 0.34 STD=0.159
CCW Initial Slopes: -3.23 -3.71 -3.82 -3.95 -3.6 STD=0.274


Vehicle E - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 0.661
Ratio: -0.205
Final Slope: 0.563
Ratio: -0.152
Final Slope: 0.359
Ratio: -0.094
Final Slope: 0.664
Ratio: -0.168
Final Slope: 0.34
Ratio: -0.0944
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

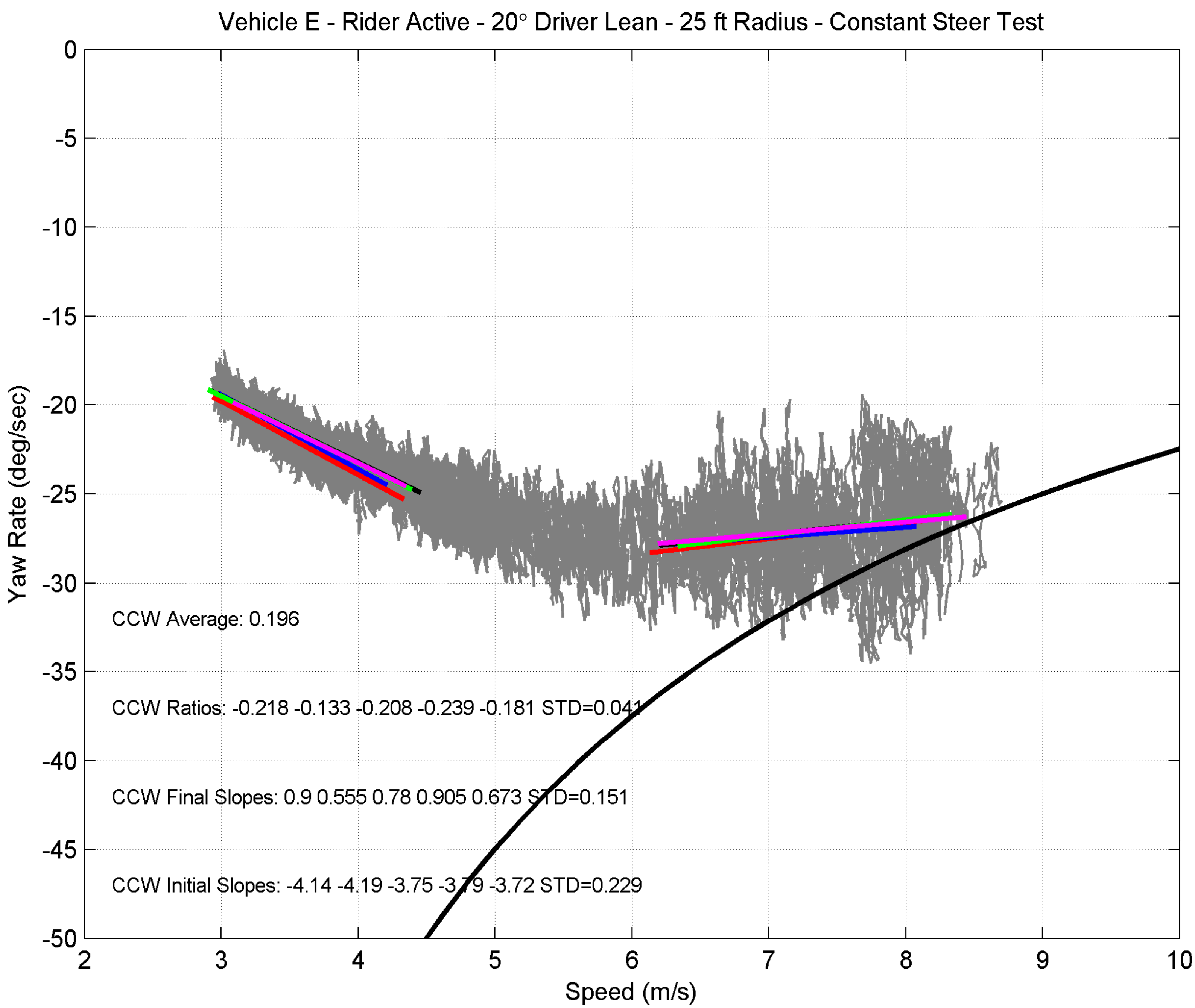

Vehicle E - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

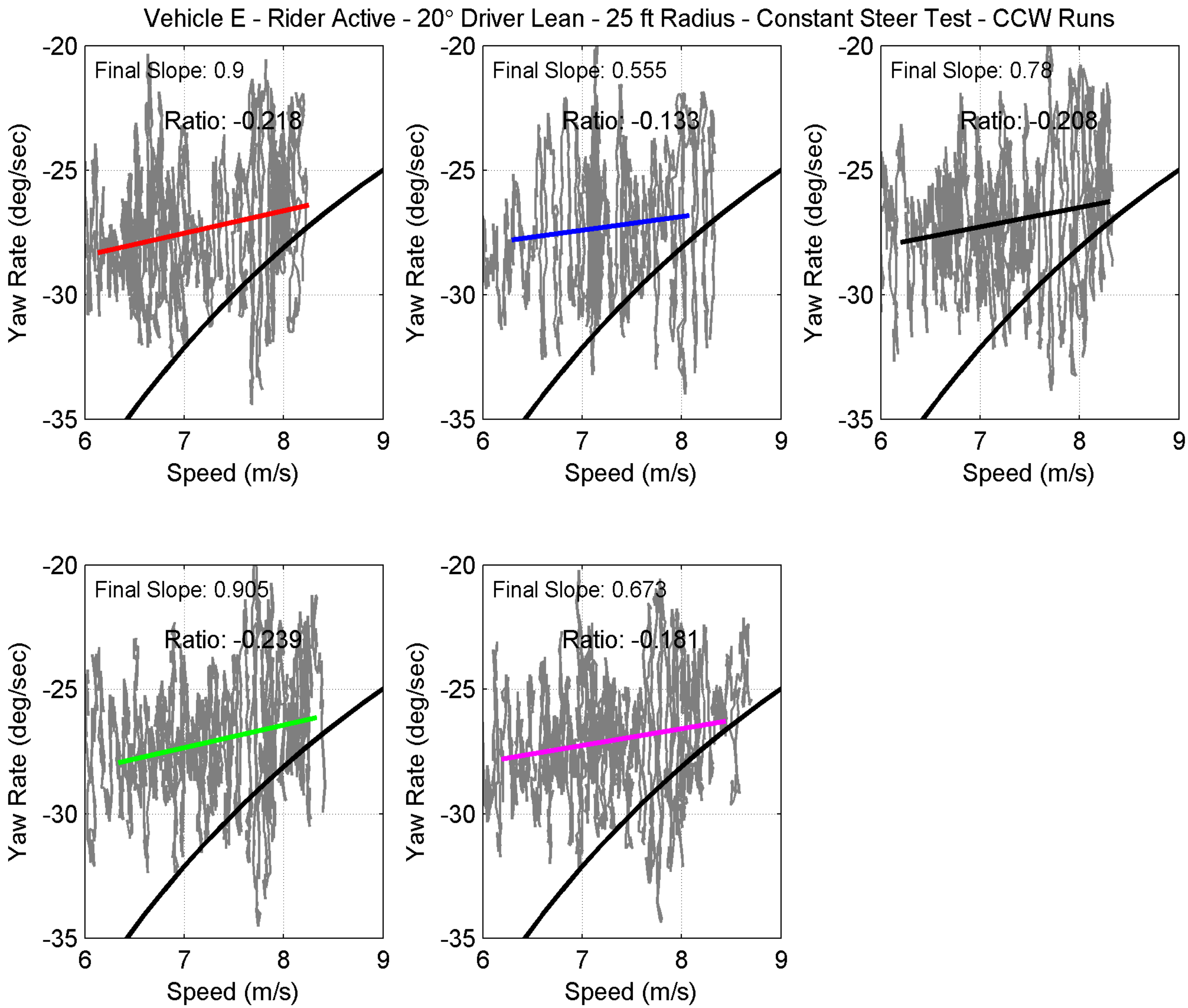


Vehicle E - Rider Active - 20° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

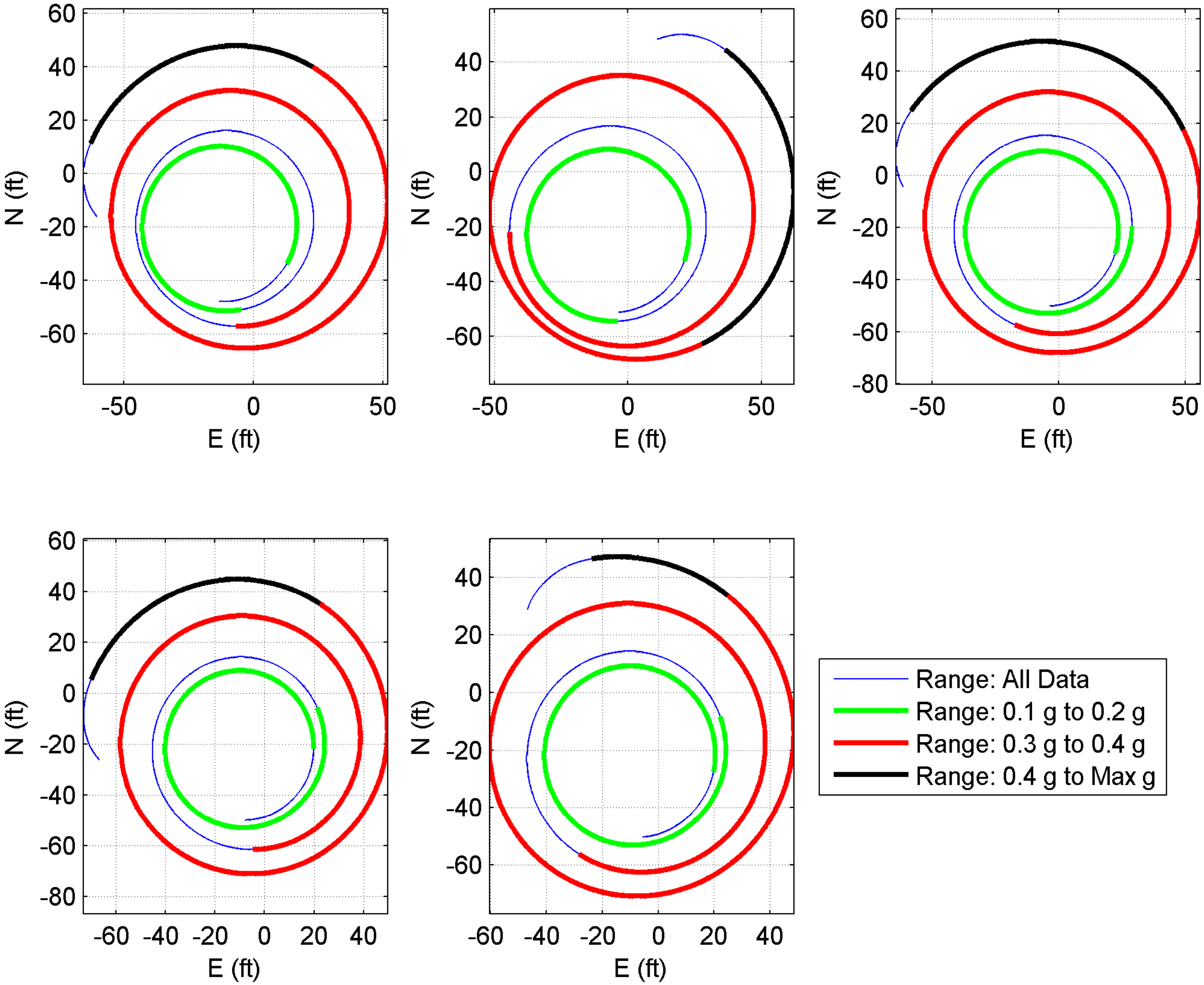


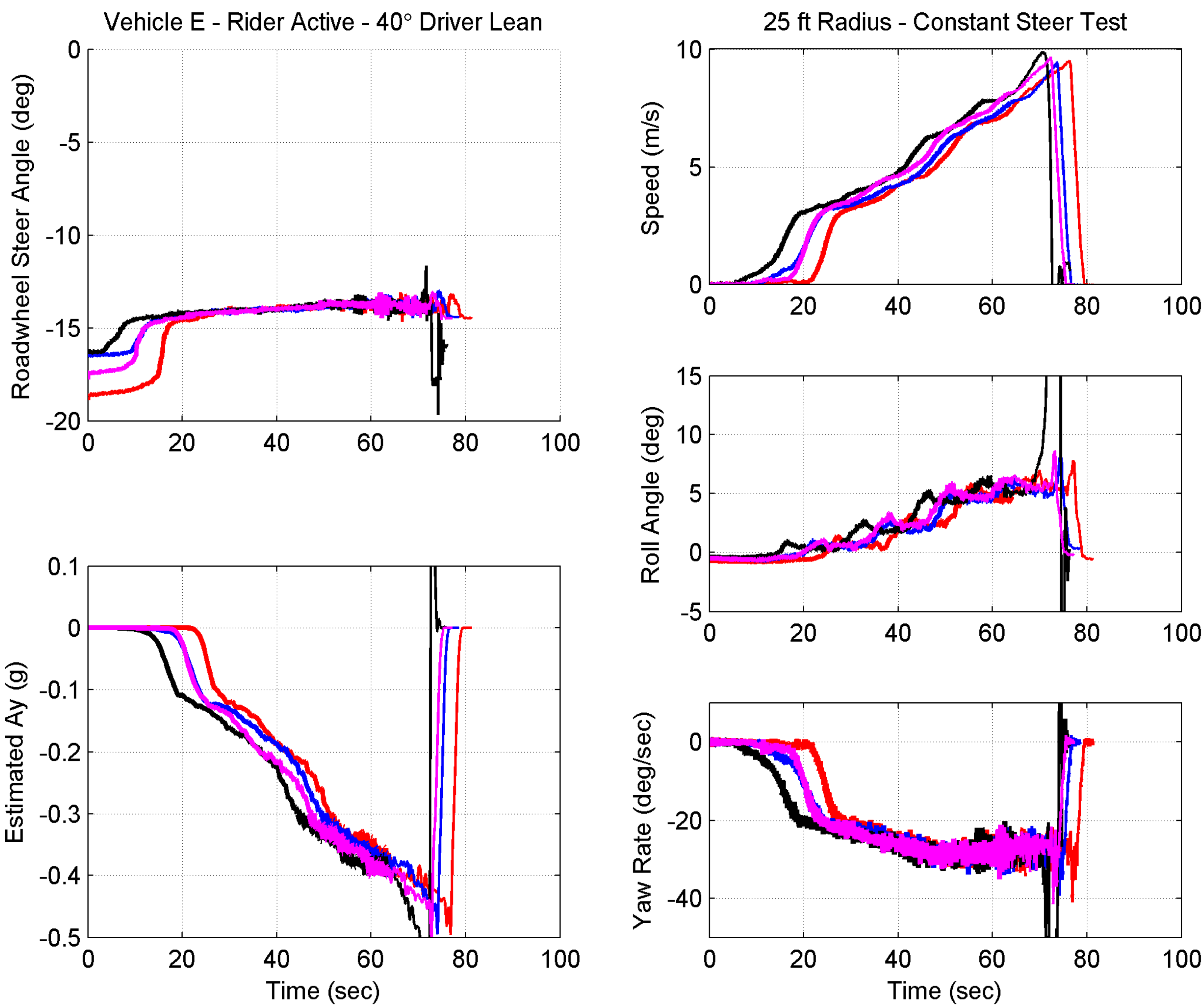
Vehicle E - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10

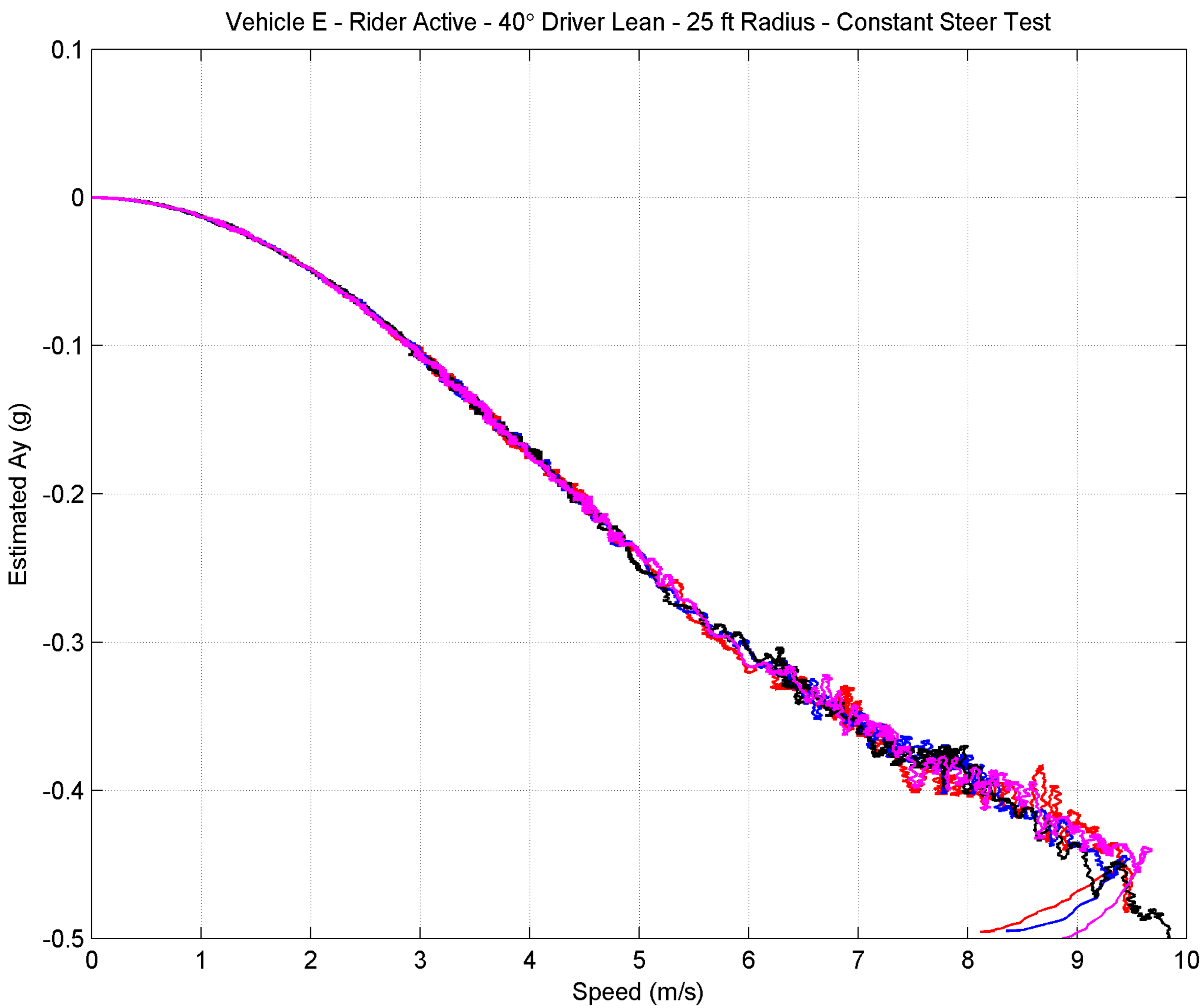

Vehicle E - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
CCW Average: 0.196
CCW Ratios: -0.218 -0.133 -0.208 -0.239 -0.181 STD=0.041
CCW Final Slopes: 0.9 0.555 0.78 0.905 0.673 STD=0.151
CCW Initial Slopes: -4.14 -4.19 -3.75 -3.79 -3.72 STD=0.229


Vehicle E - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 0.9
Ratio: -0.218
Final Slope: 0.555
Ratio: -0.133
Final Slope: 0.78
Ratio: -0.208
Final Slope: 0.905
Ratio: -0.239
Final Slope: 0.673
Ratio: -0.181
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

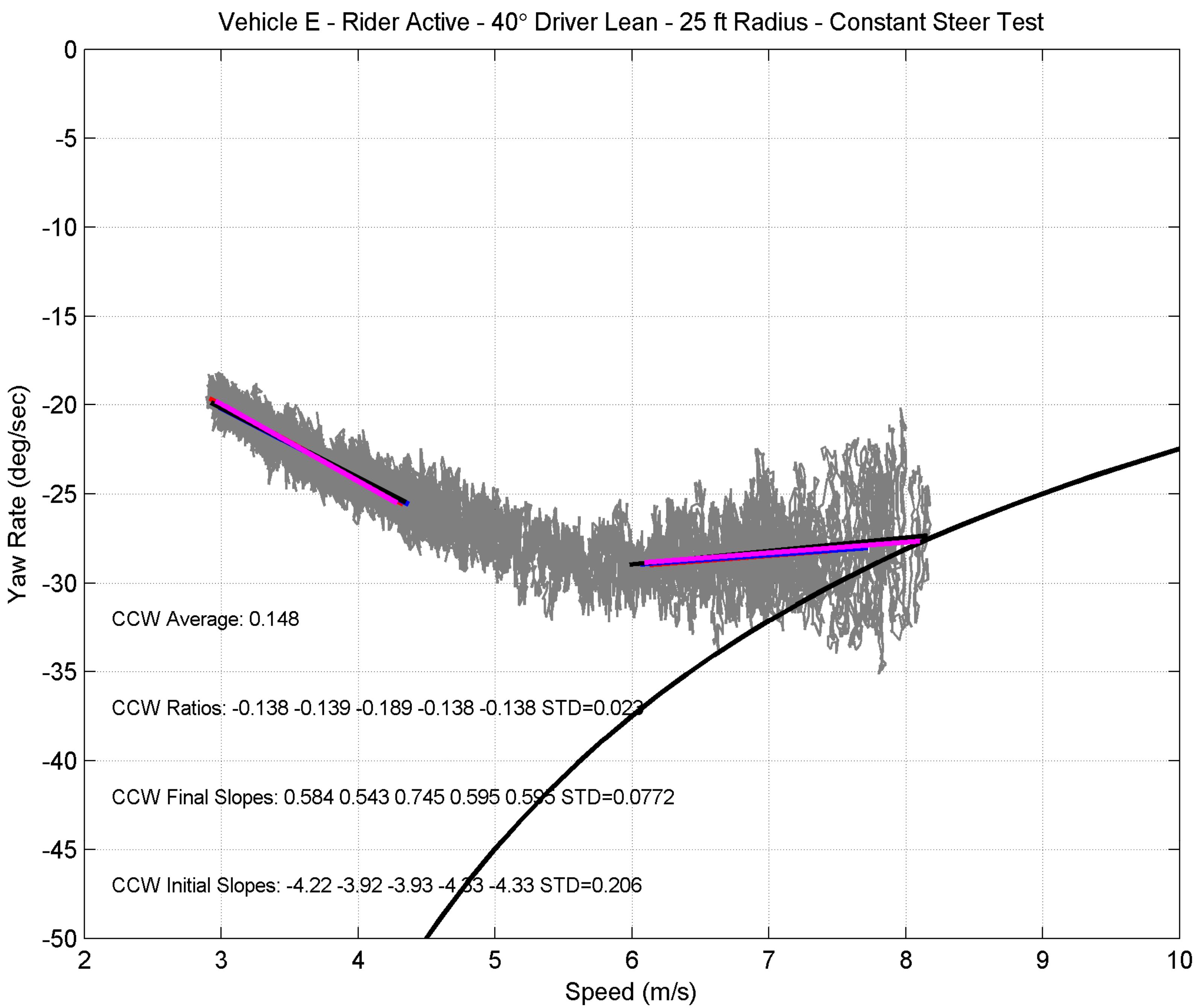
Vehicle E - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs



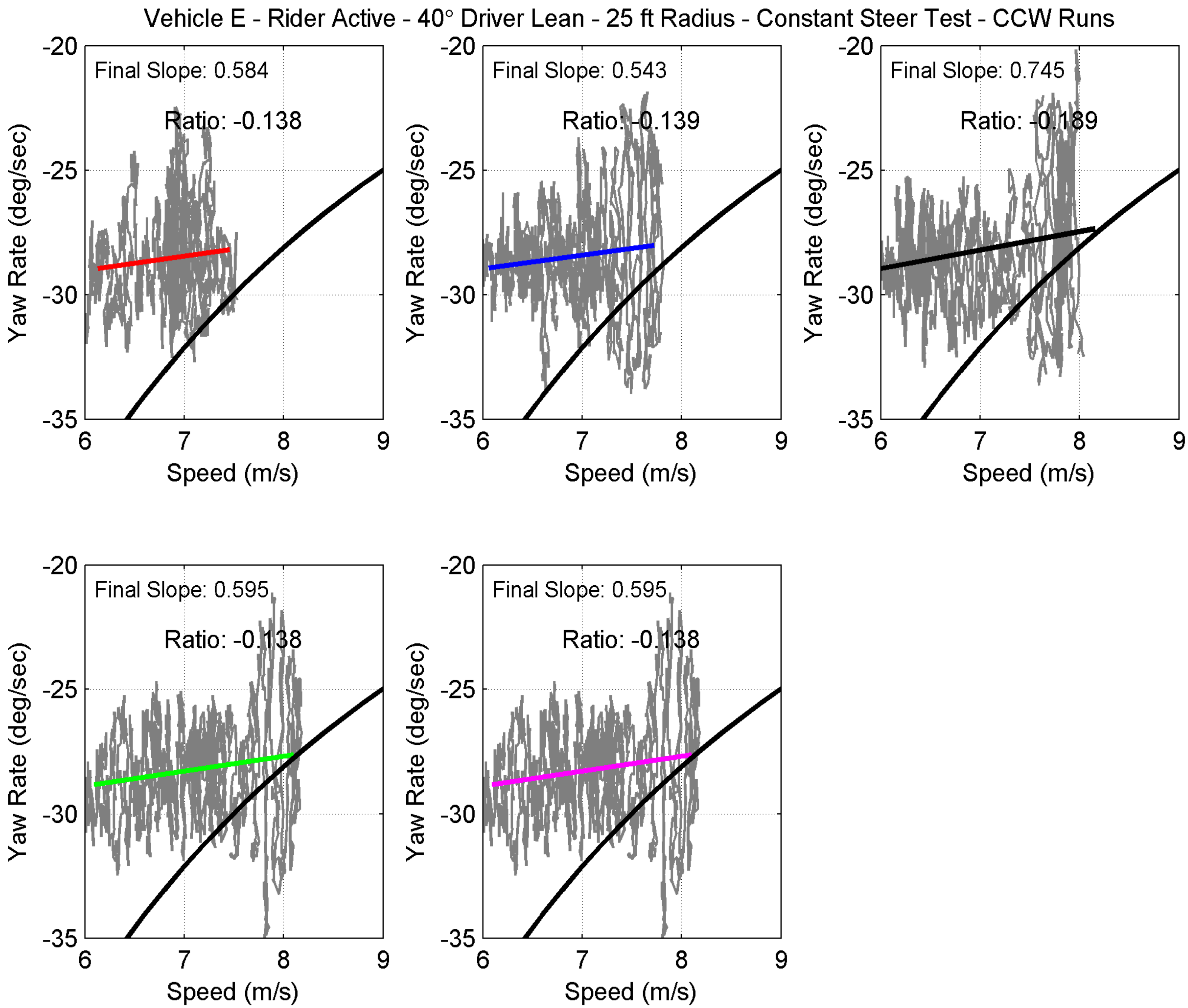

Vehicle E - Rider Active - 40° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-20
0
20
40
60
80
100
Speed (m/s)
10
5
0
Roll Angle (deg)
15
10
5
0
-5
Estimated Ay (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Time (sec)
Yaw Rate (deg/sec)
0
-20
-40
Time (sec)



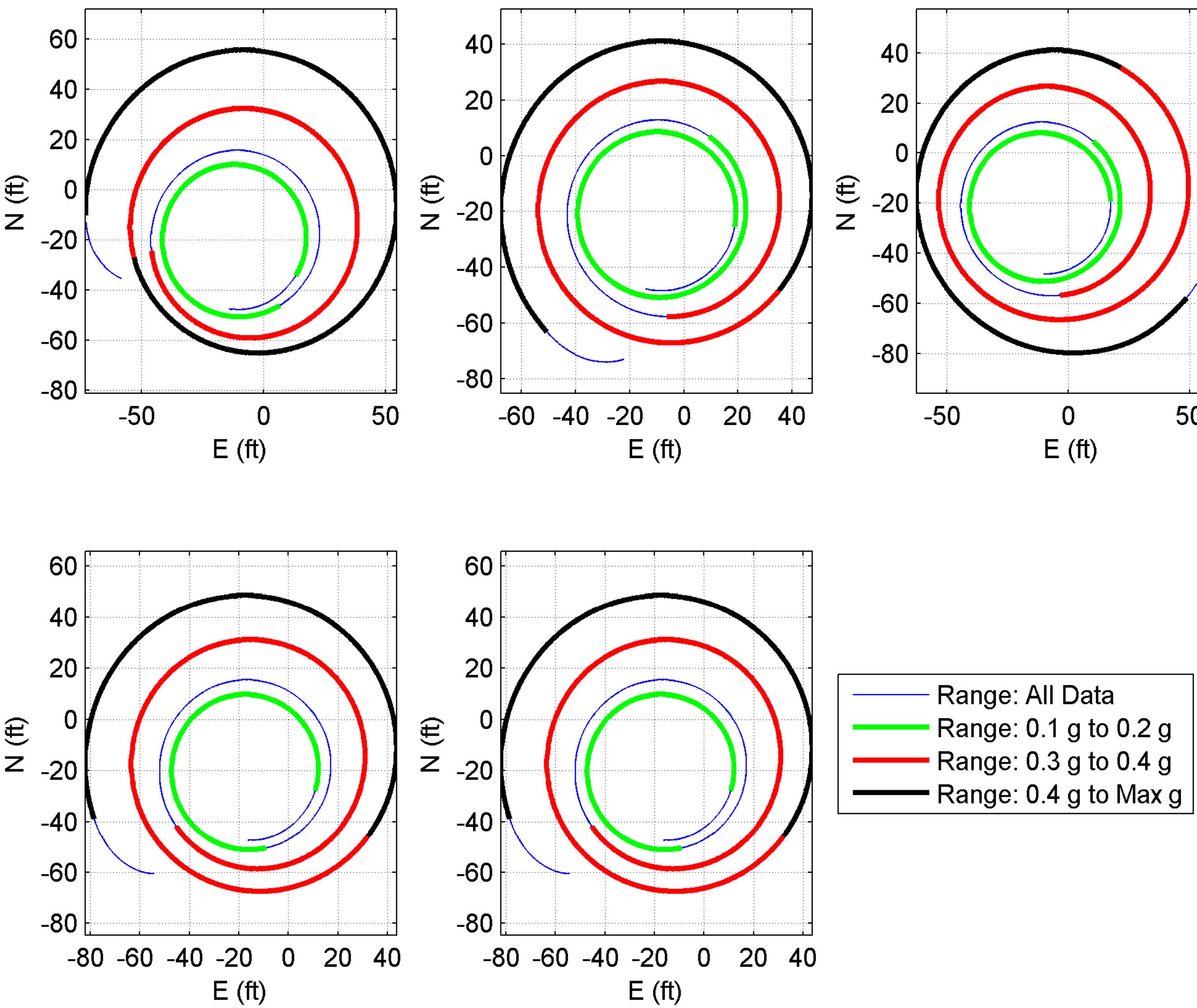
Vehicle E - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9
10

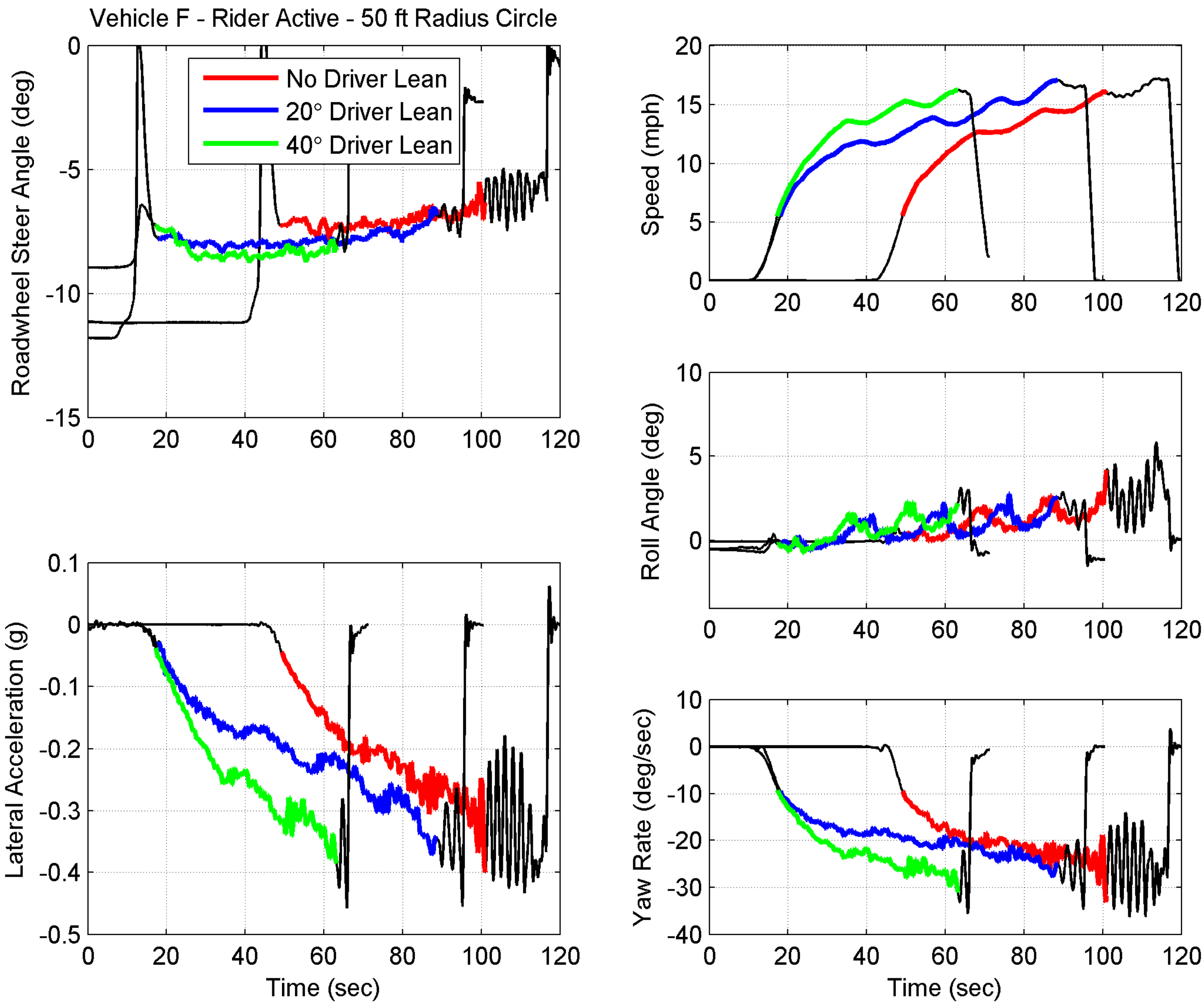


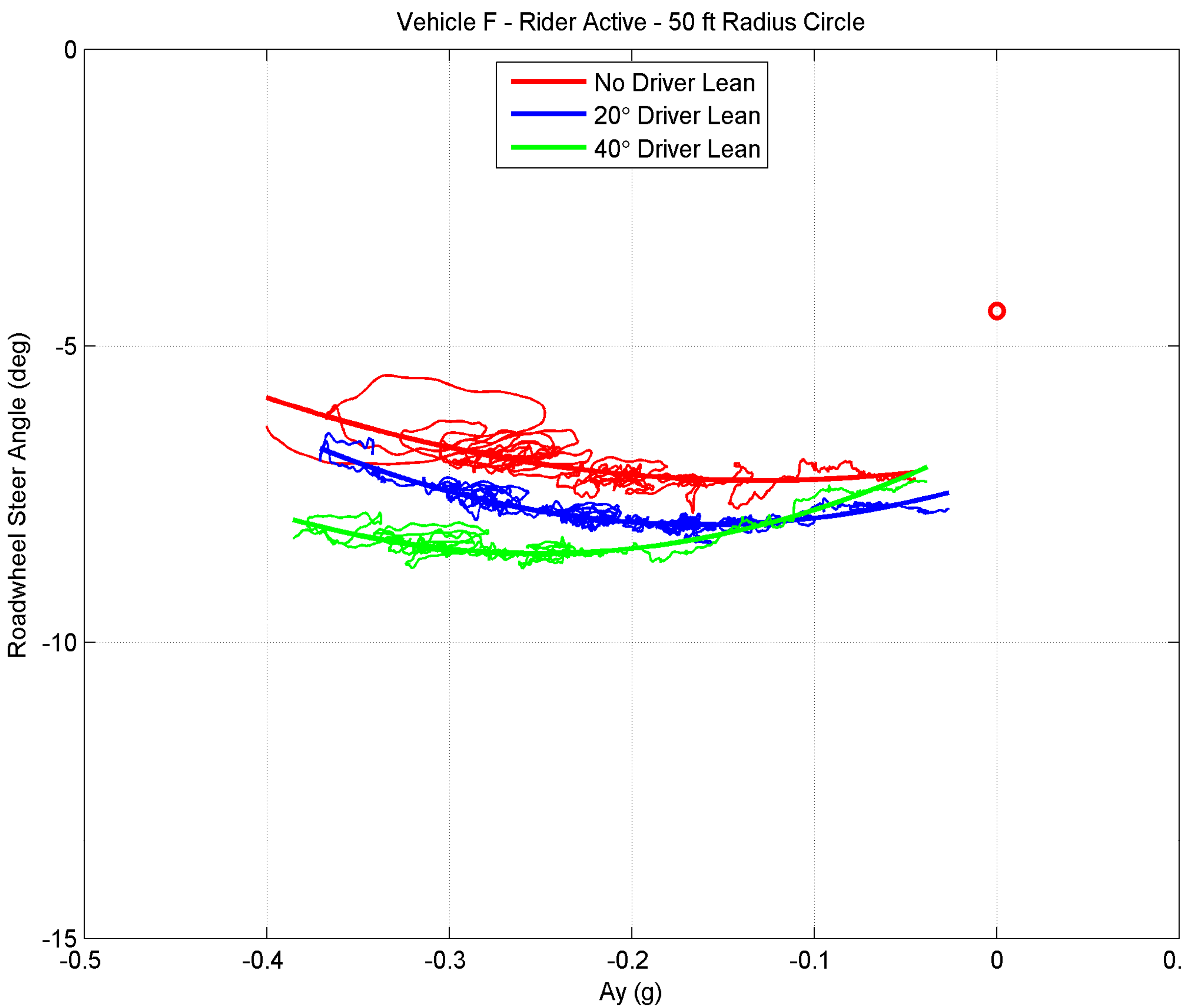
Vehicle E - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
CCW Average: 0.148
CCW Ratios: -0.138 -0.139 -0.189 -0.138 -0.138 STD=0.023
CCW Final Slopes: 0.584 0.543 0.745 0.595 0.595 STD=0.0772
CCW Initial Slopes: -4.22 -3.92 -3.93 -4.33 -4.33 STD=0.206


Vehicle E - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: 0.584
Ratio: -0.138
Final Slope: 0.543
Ratio: -0.139
Final Slope: 0.745
Ratio: -0.189
Final Slope: 0.595
Ratio: -0.138
Final Slope: 0.595
Ratio: -0.138
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

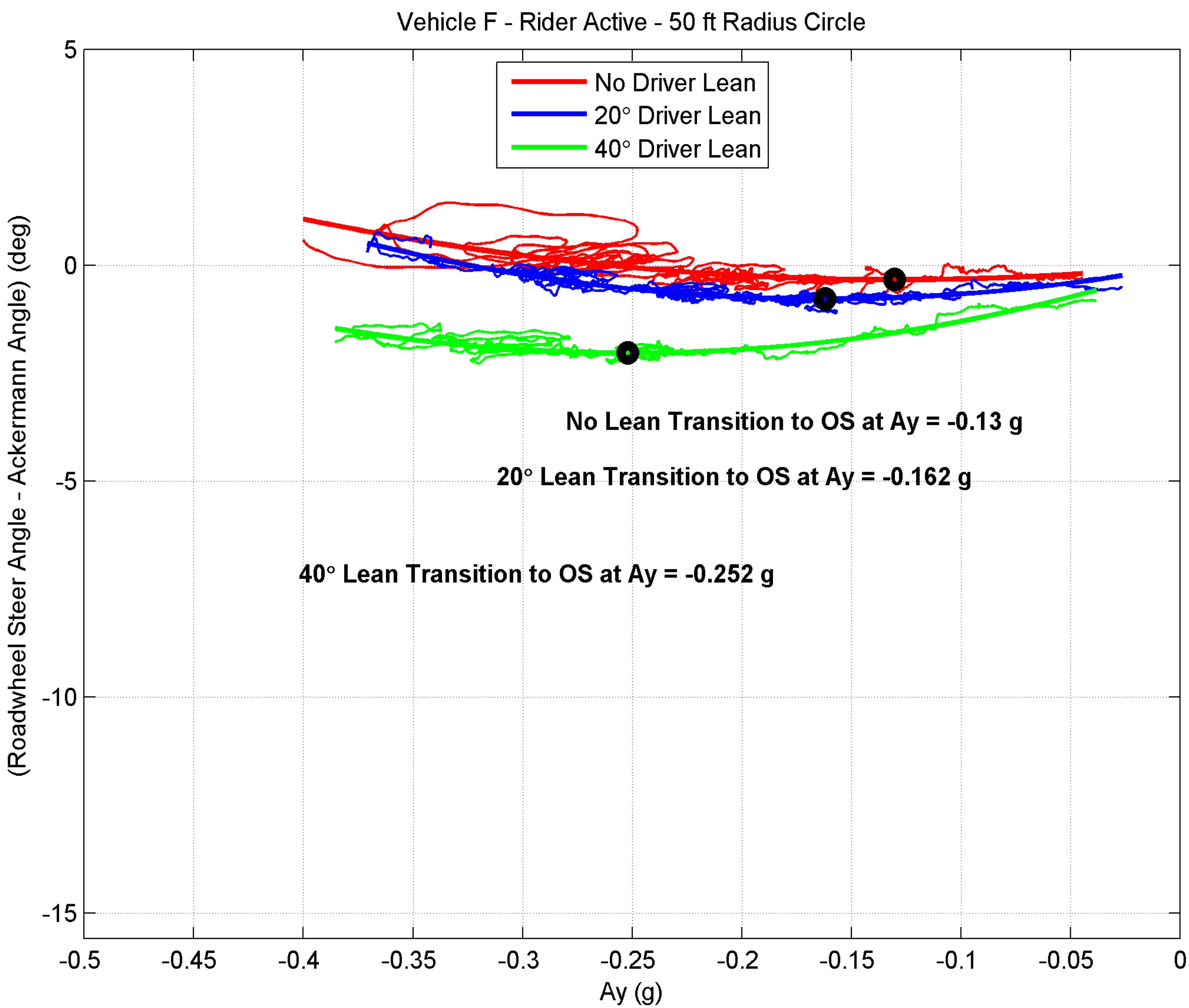
Vehicle E - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

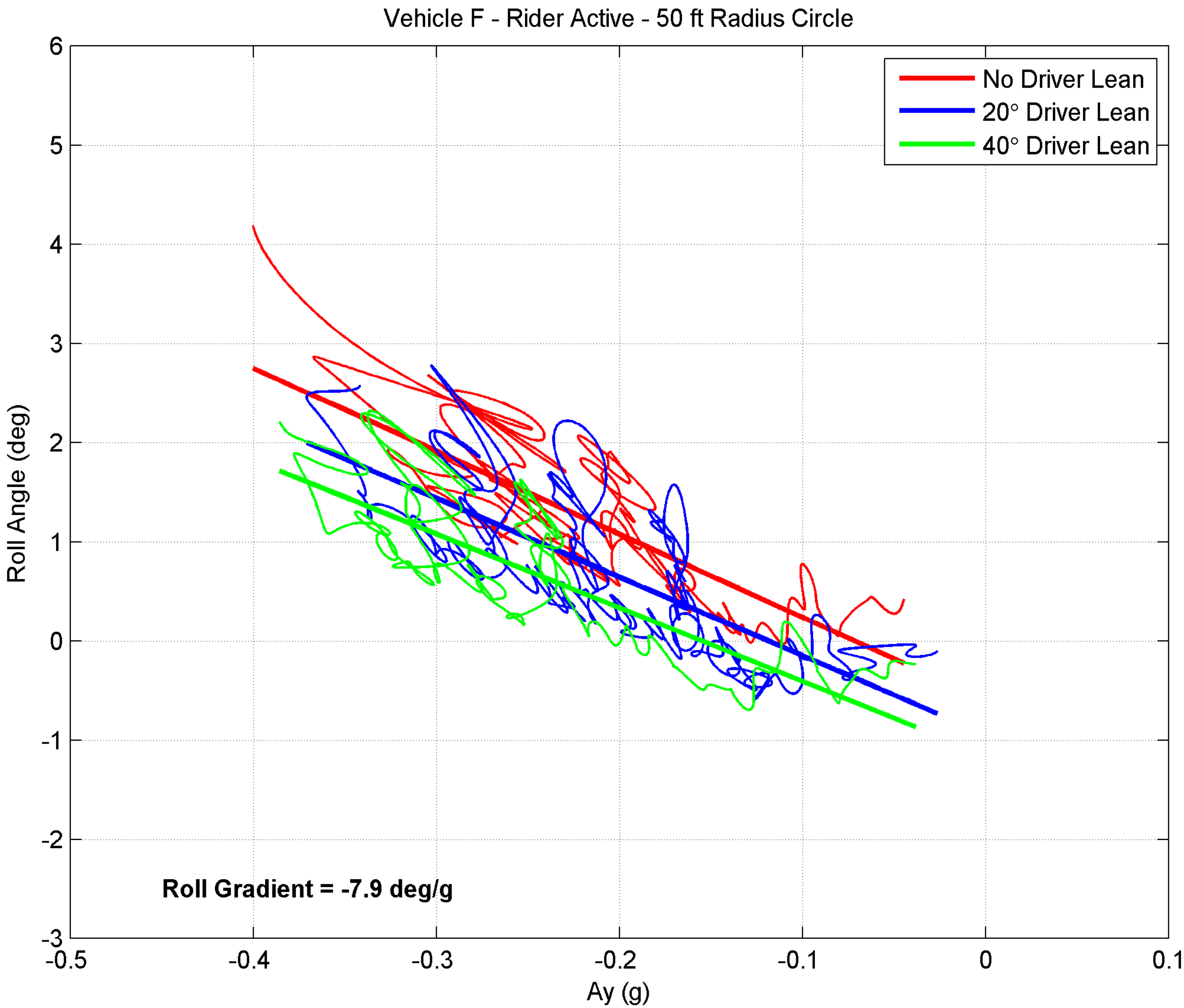



Vehicle F - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

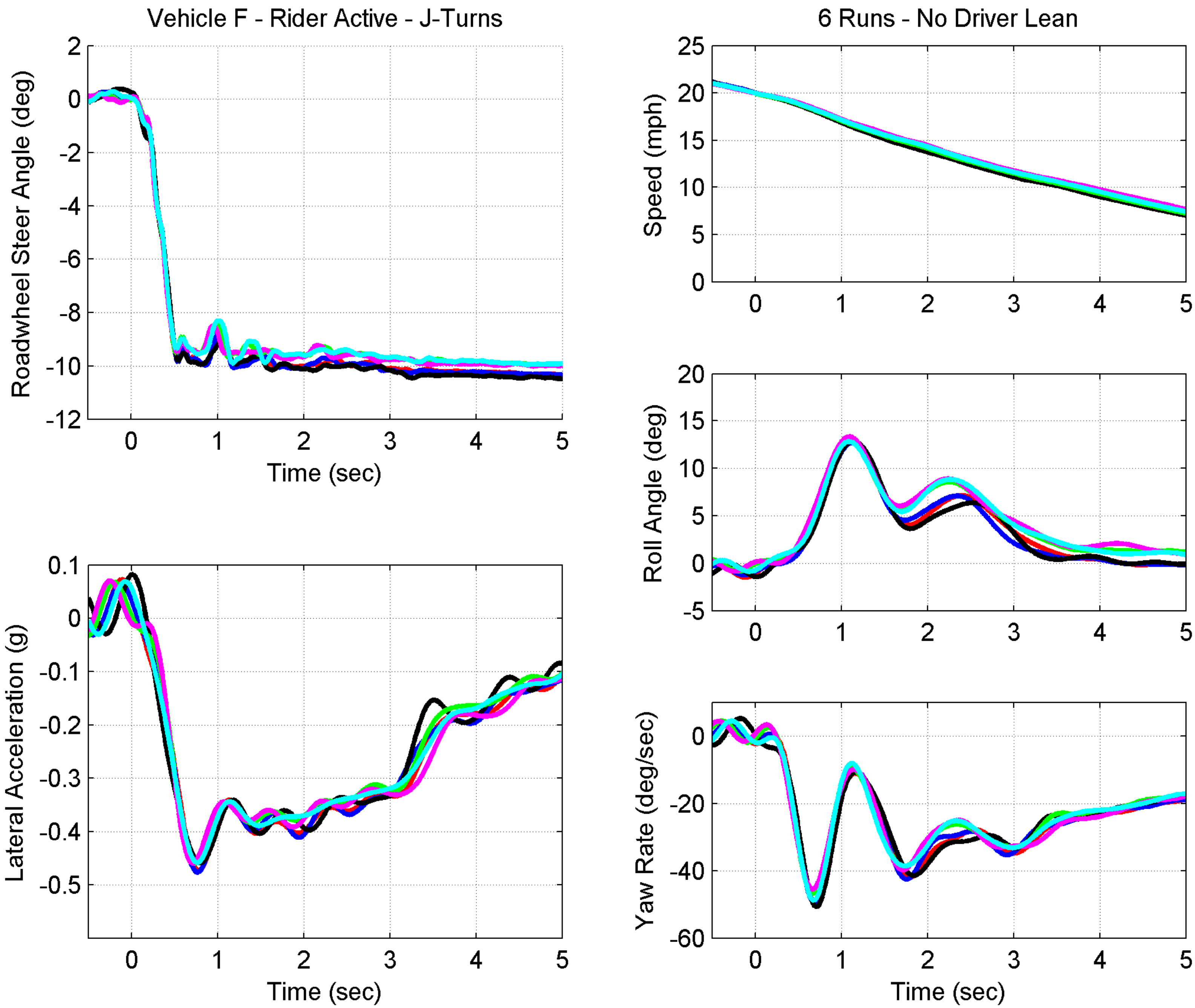


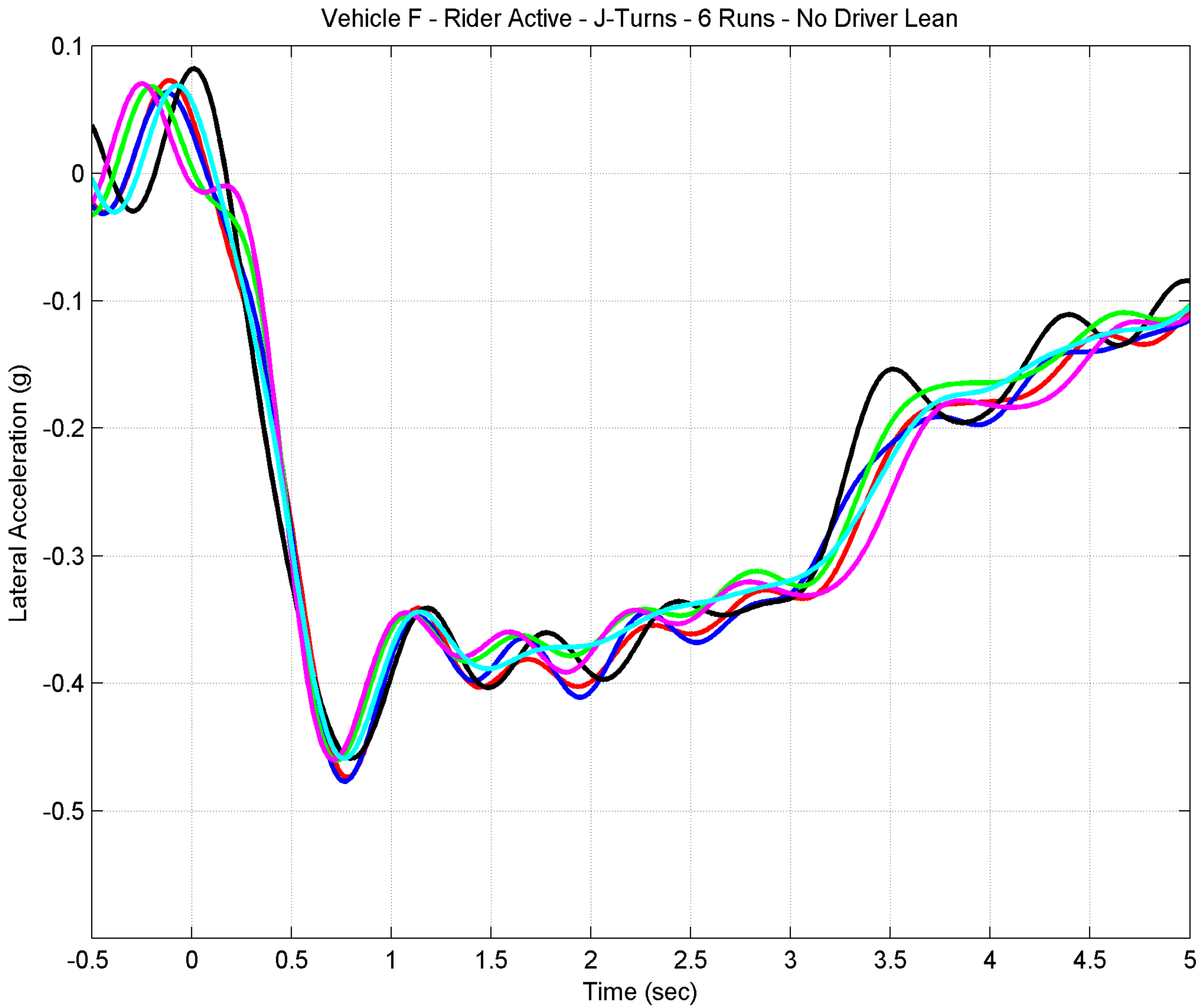
Vehicle F - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Ay (g)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

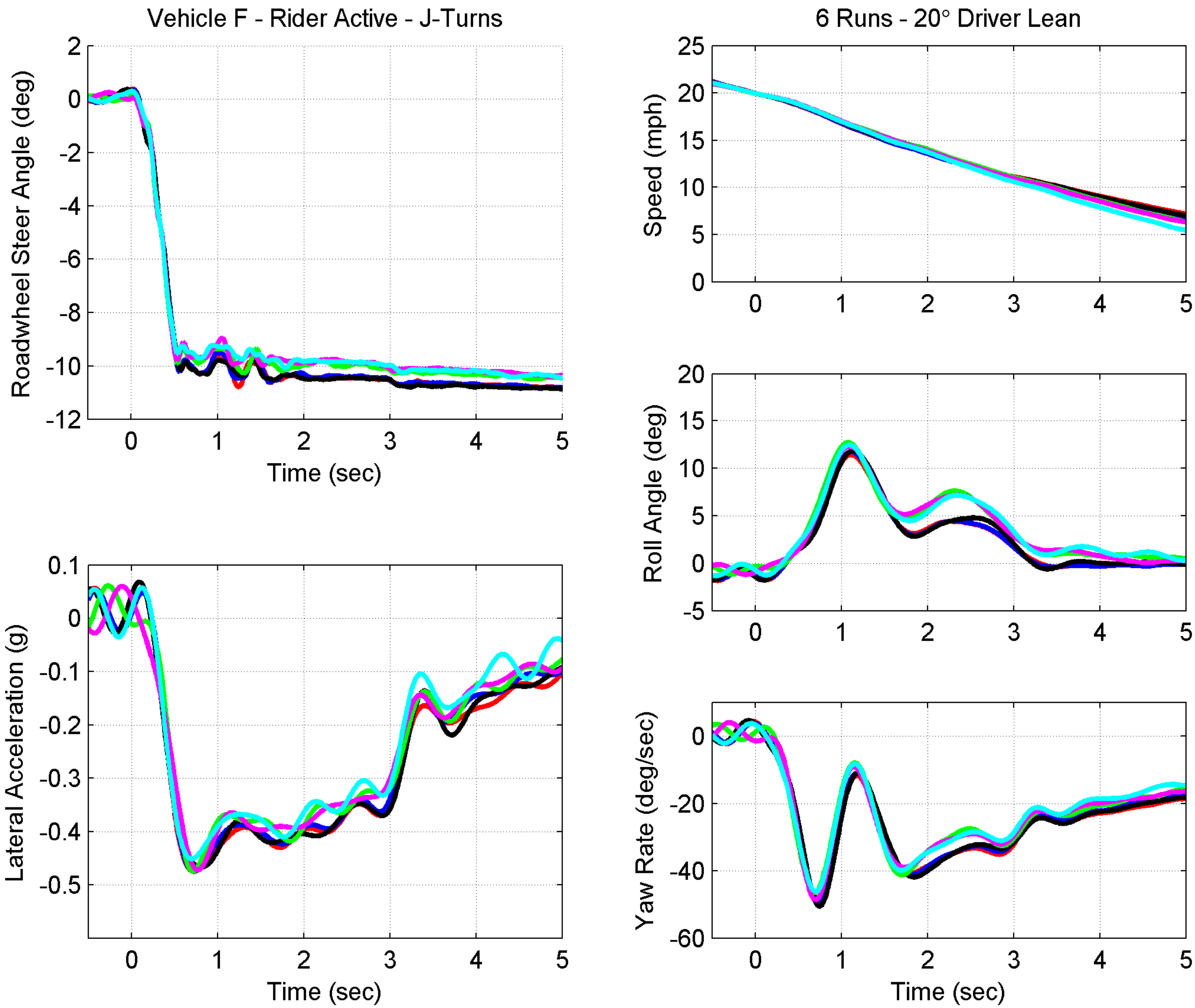

Vehicle F - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.13 g
20° Lean Transition to OS at Ay = -0.162 g
40° Lean Transition to OS at Ay = -0.252 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

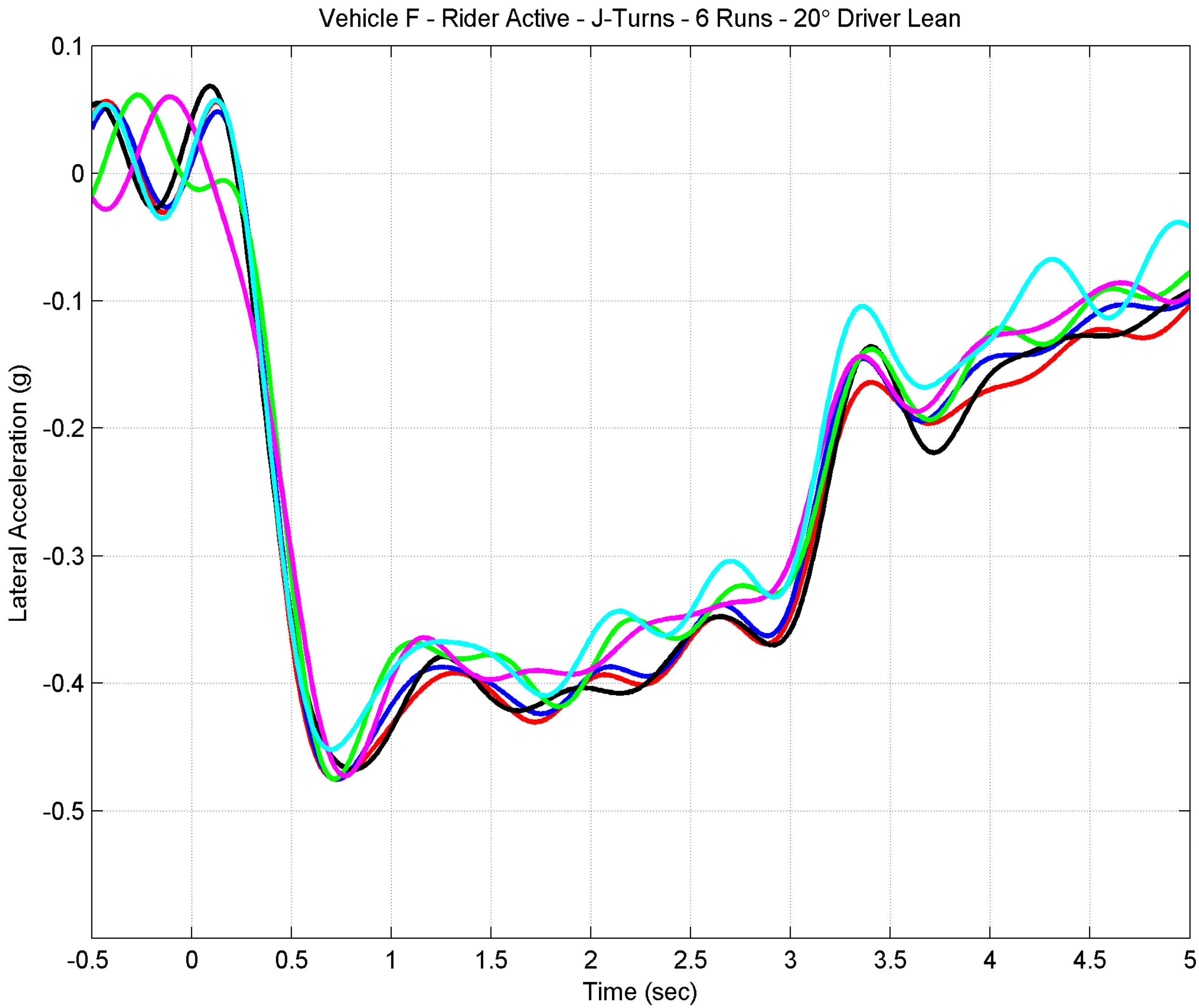


Vehicle F - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -7.9 deg/g
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

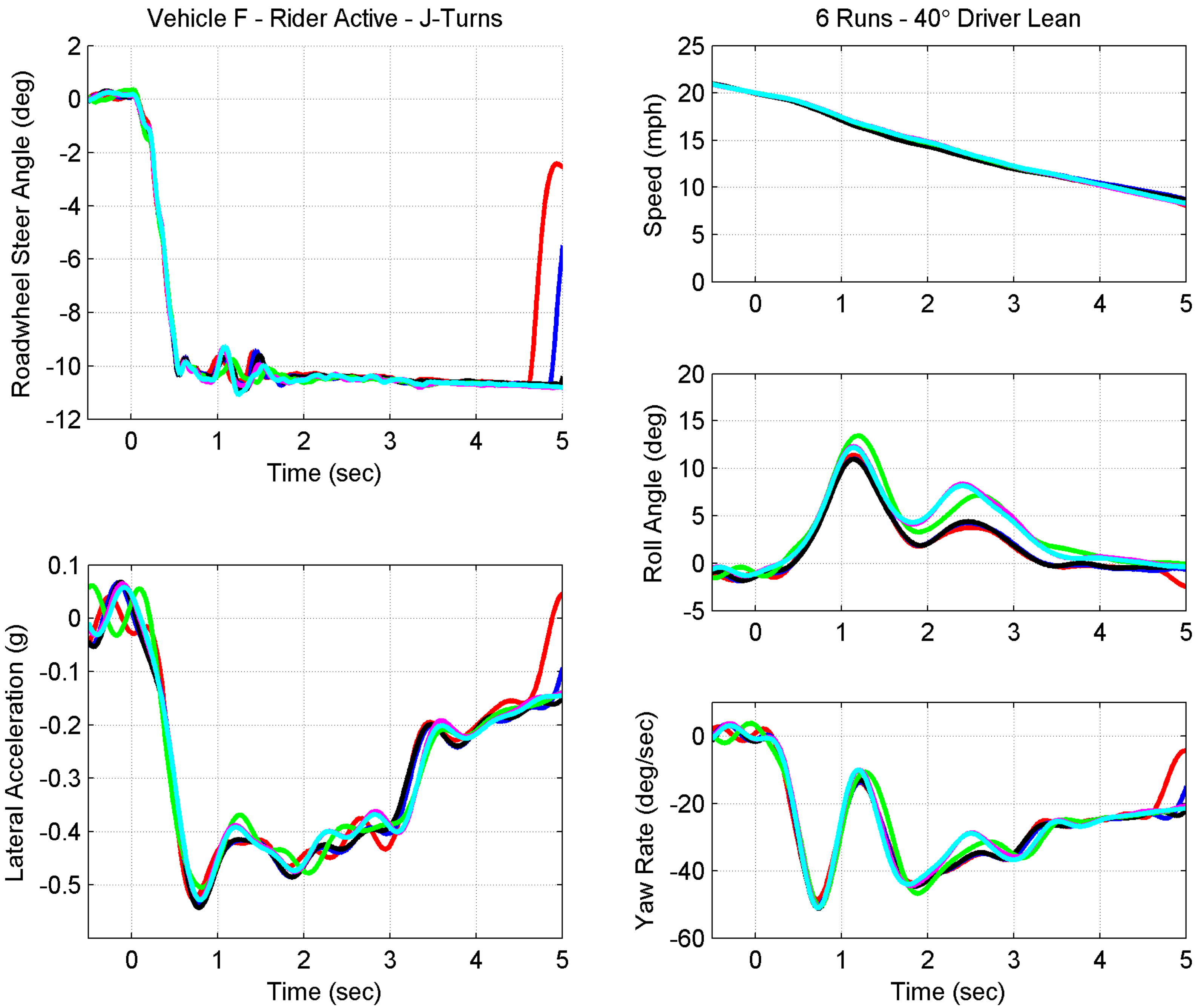

Vehicle F - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

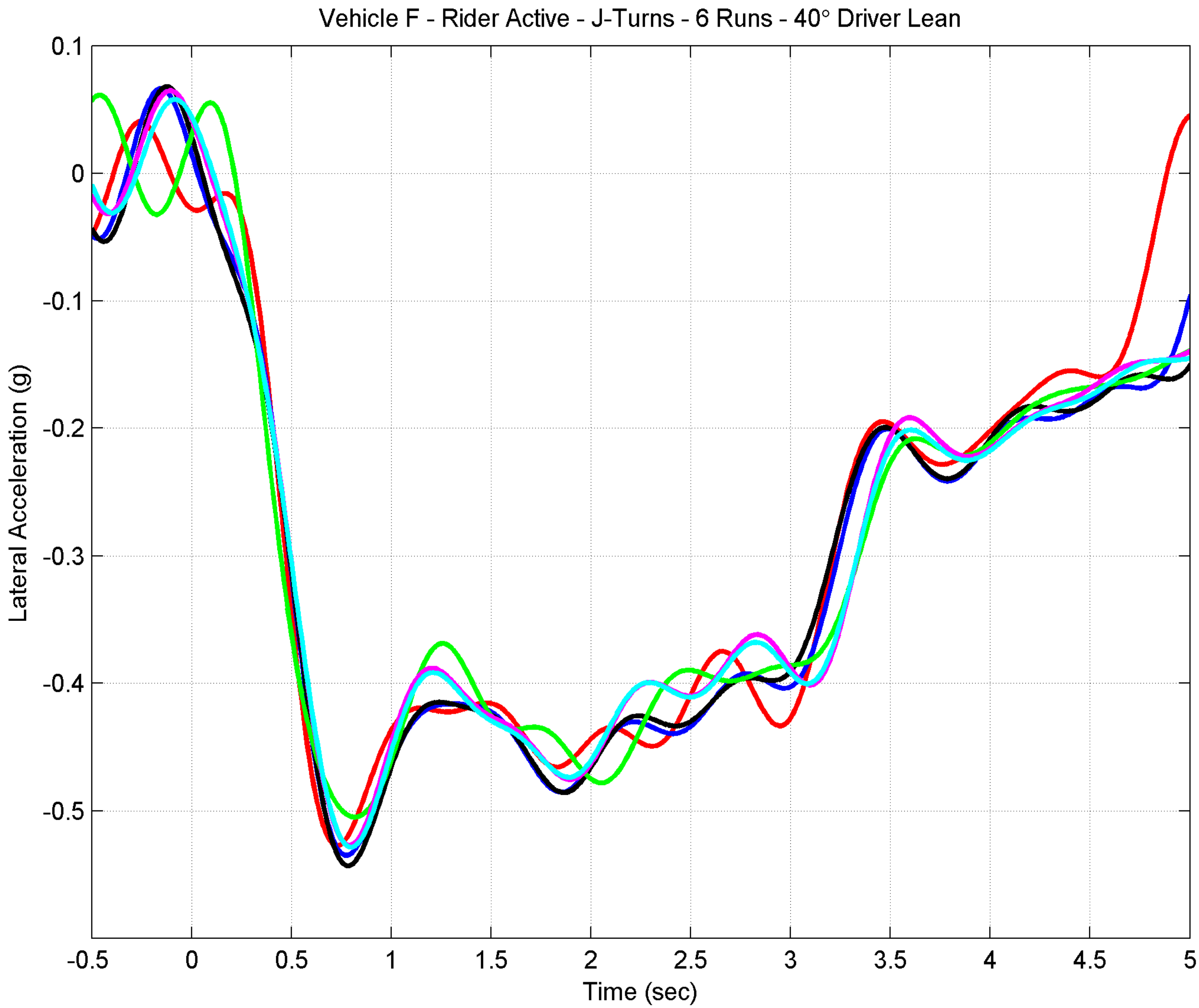

Vehicle F - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle F - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle F - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle F - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)



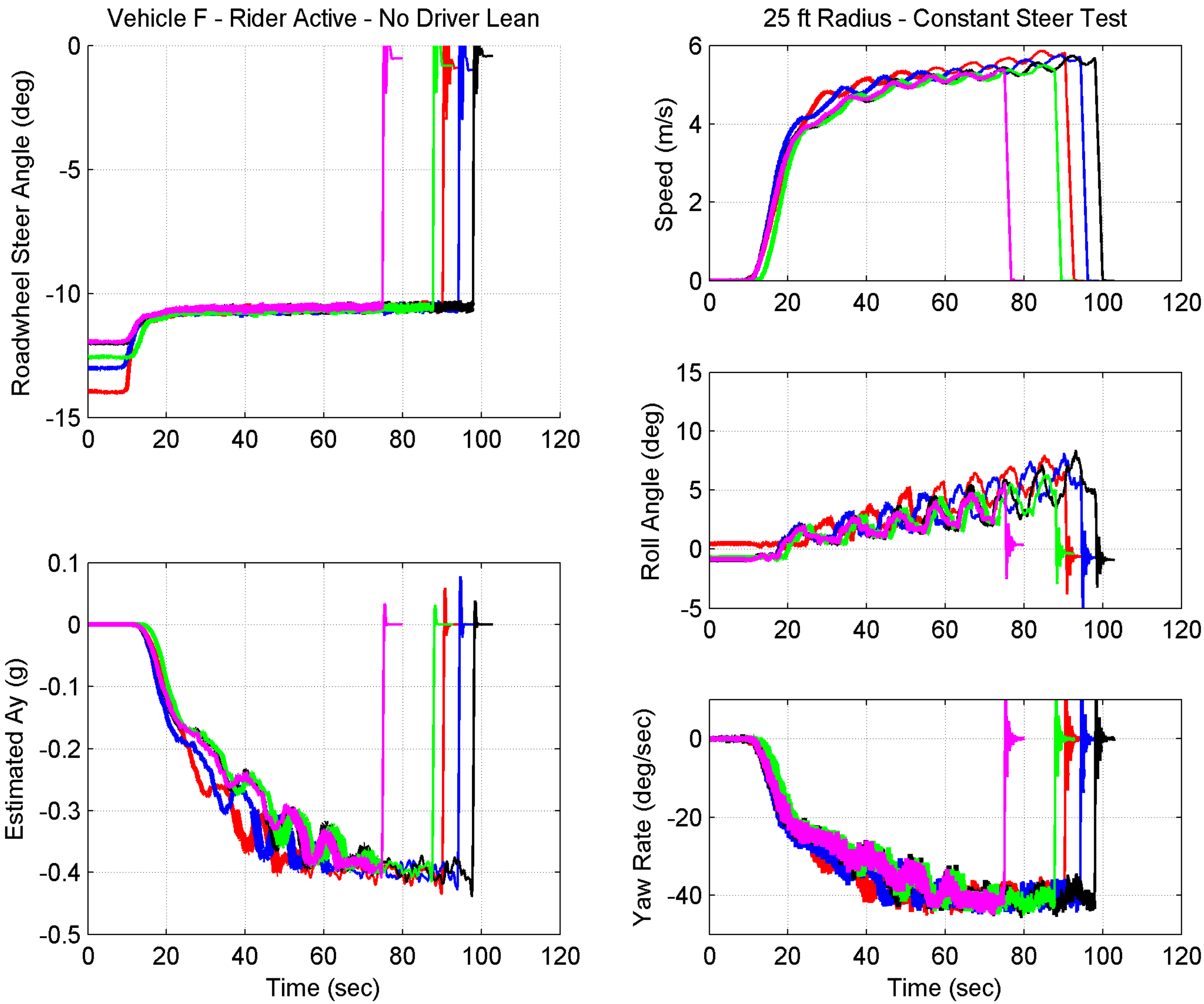
Vehicle F - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle F - Rider Active Results

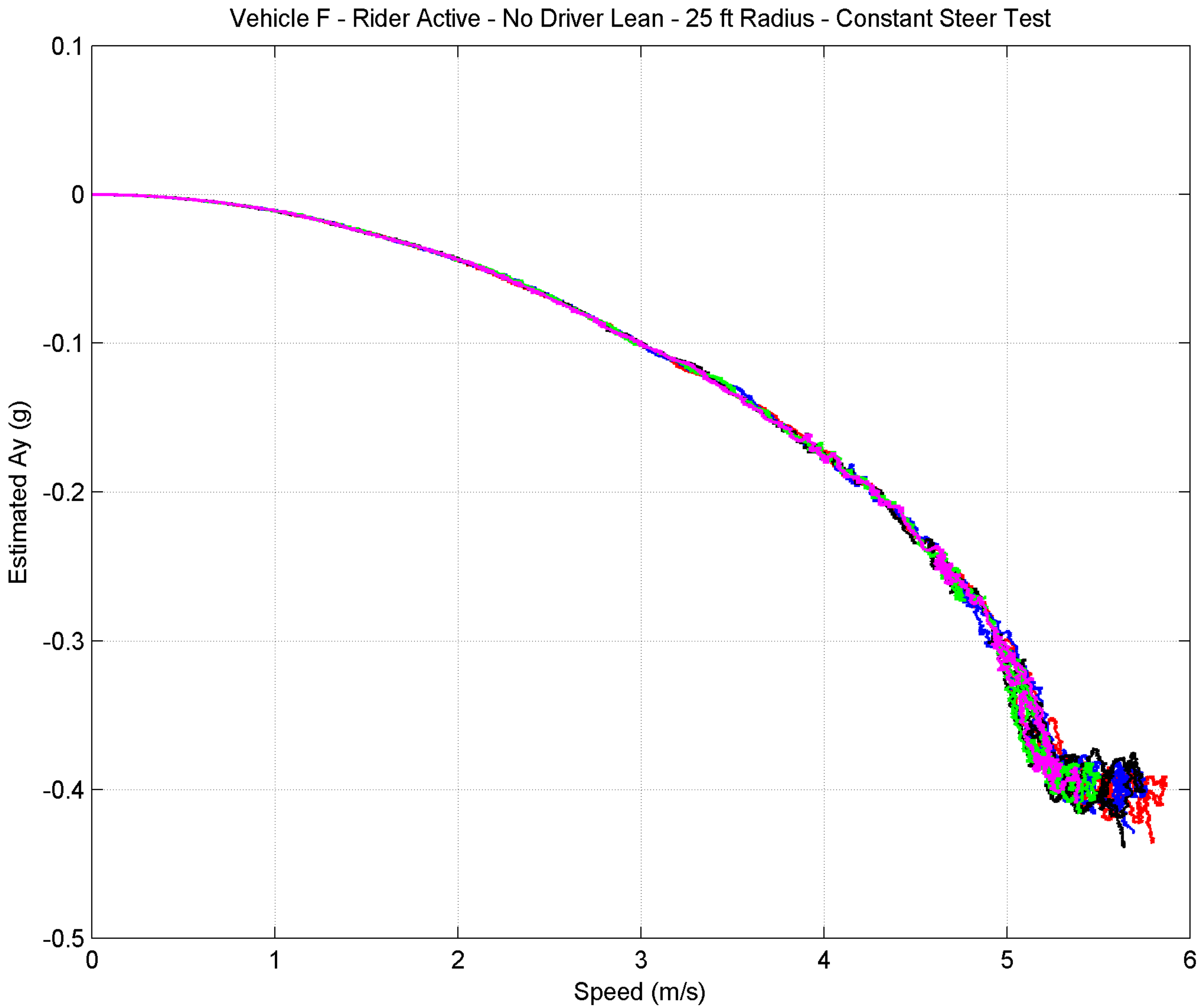
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

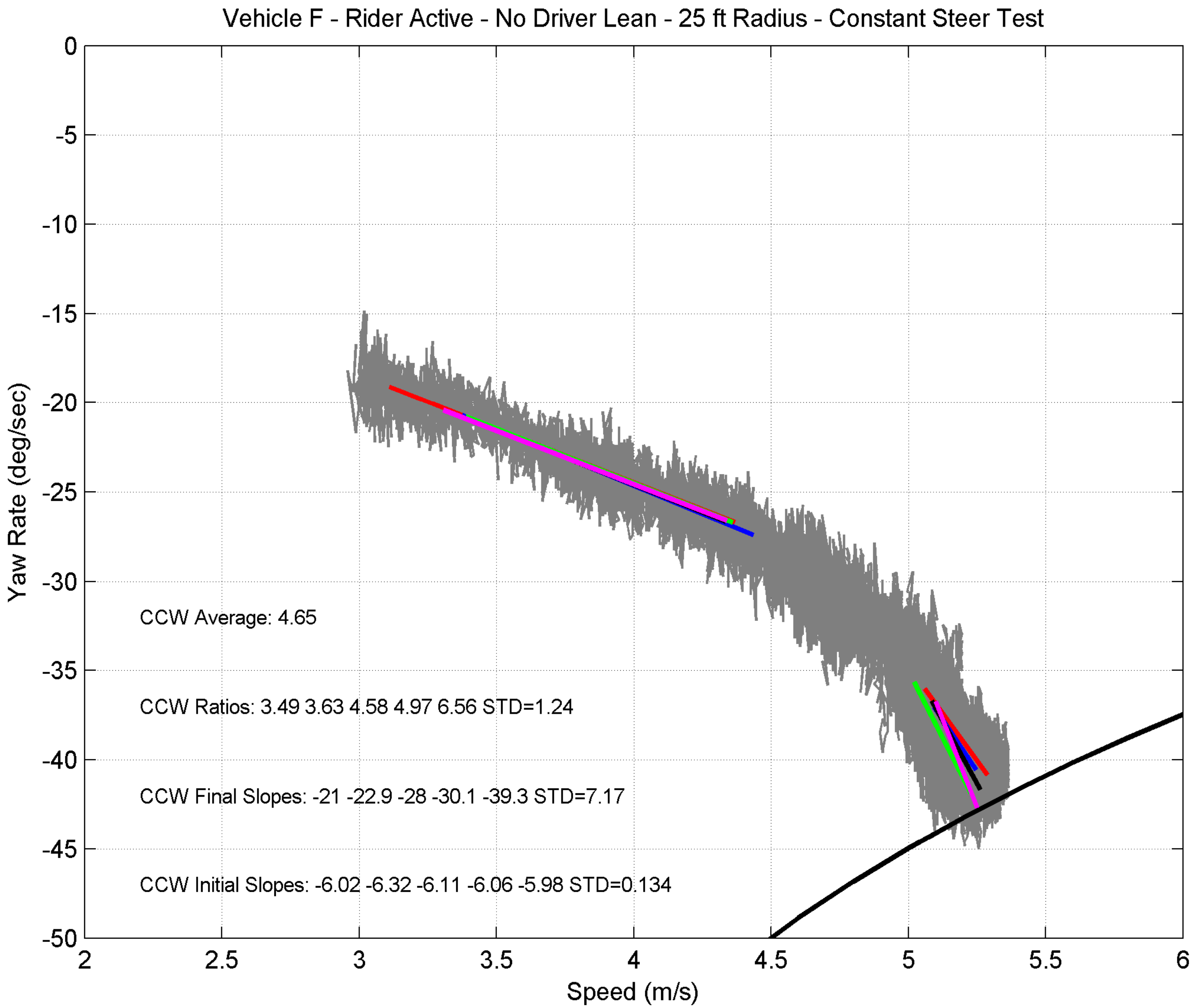
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.473	-0.475	-0.527
	-0.477	-0.475	-0.535
	-0.459	-0.468	-0.543
Mean Value of 3 Runs	-0.470	-0.473	-0.535
Standard Deviation of 3 Runs	0.010	0.004	0.008

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.460	-0.475	-0.505
	-0.460	-0.472	-0.527
	-0.459	-0.452	-0.529
Mean Value of 3 Runs	-0.460	-0.466	-0.520
Standard Deviation of 3 Runs	0.001	0.013	0.013
Average of All 6 Runs	**0.465**	**0.470**	**0.528**

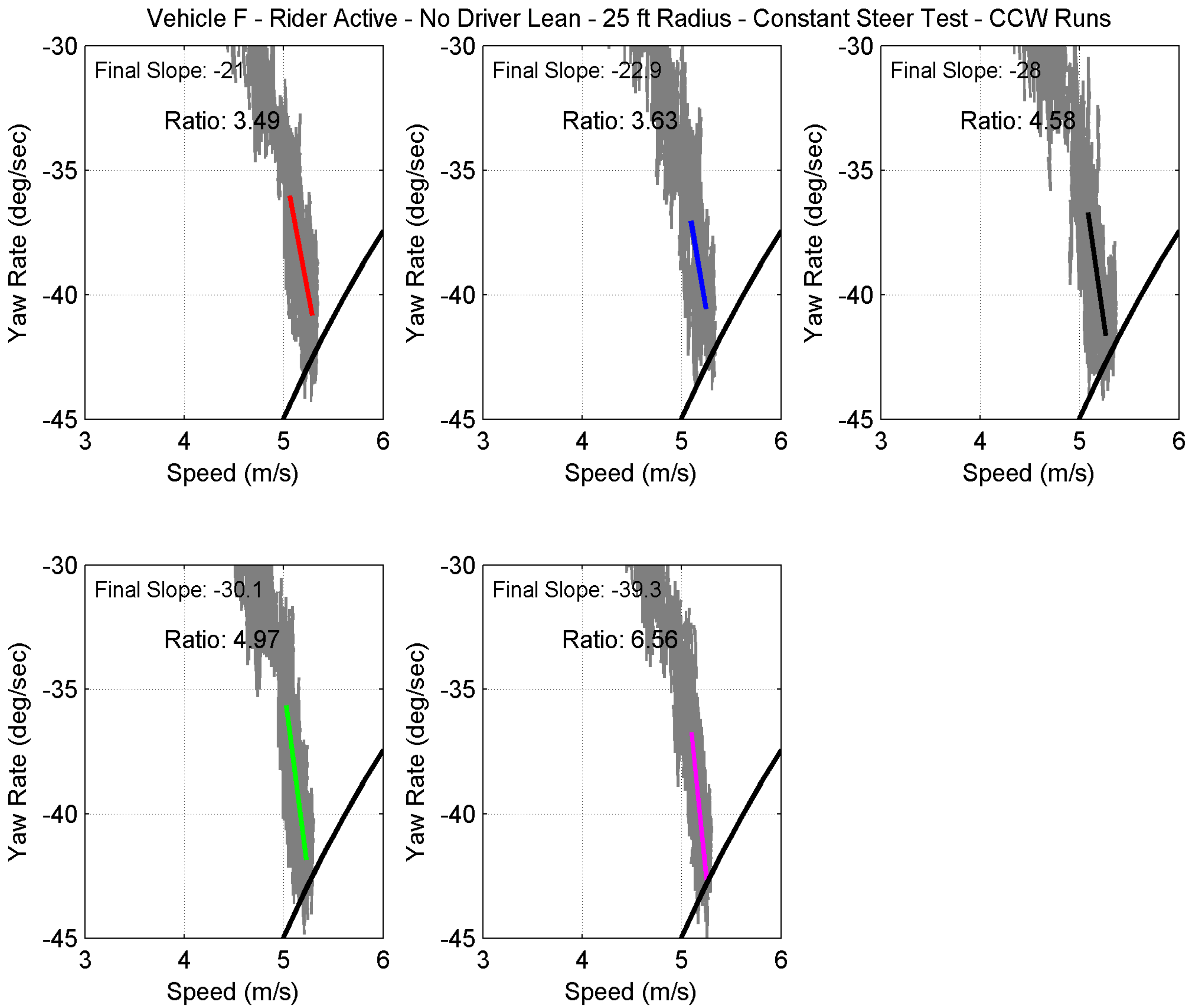


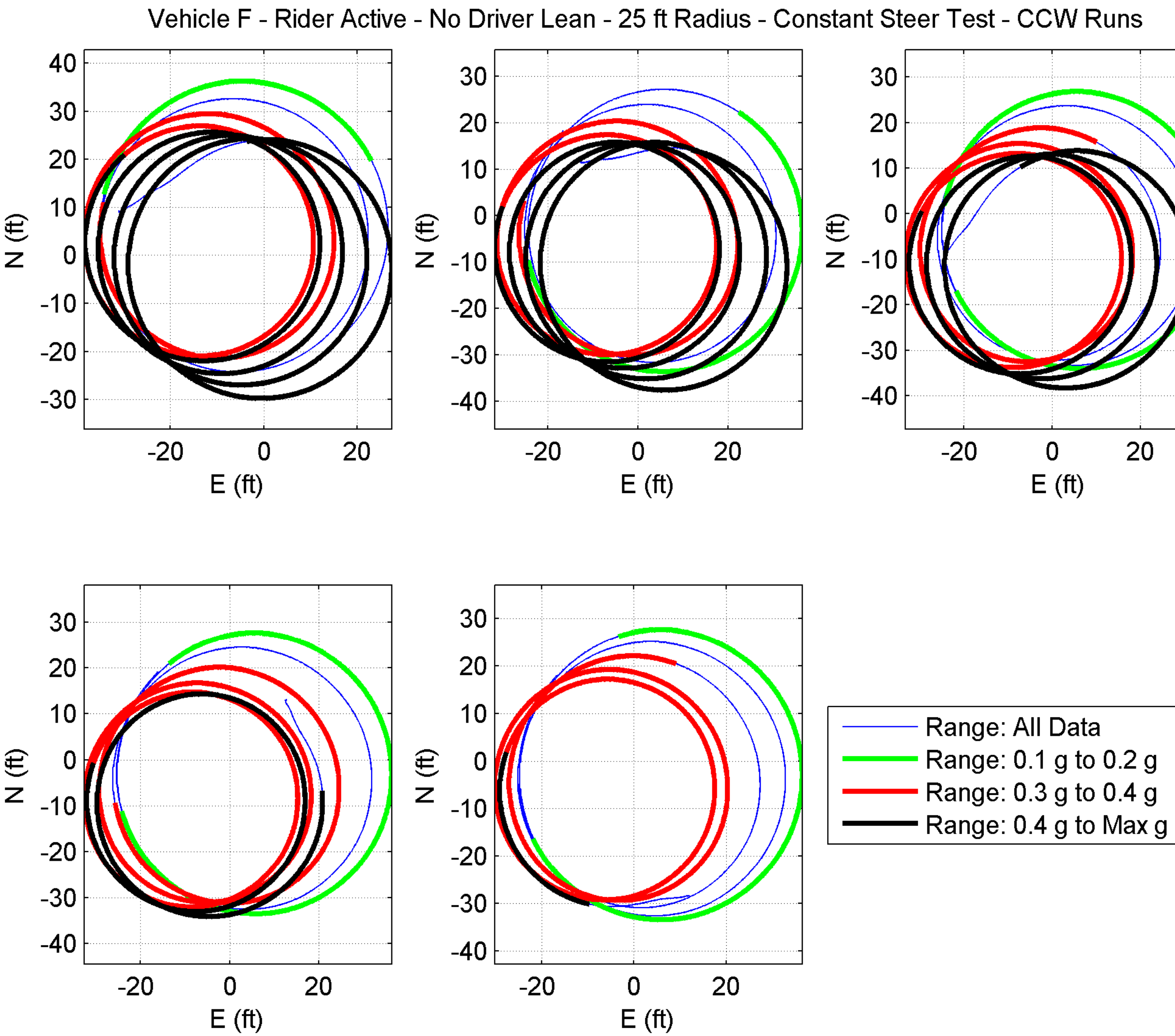
Vehicle F - Rider Active - No Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle F - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6

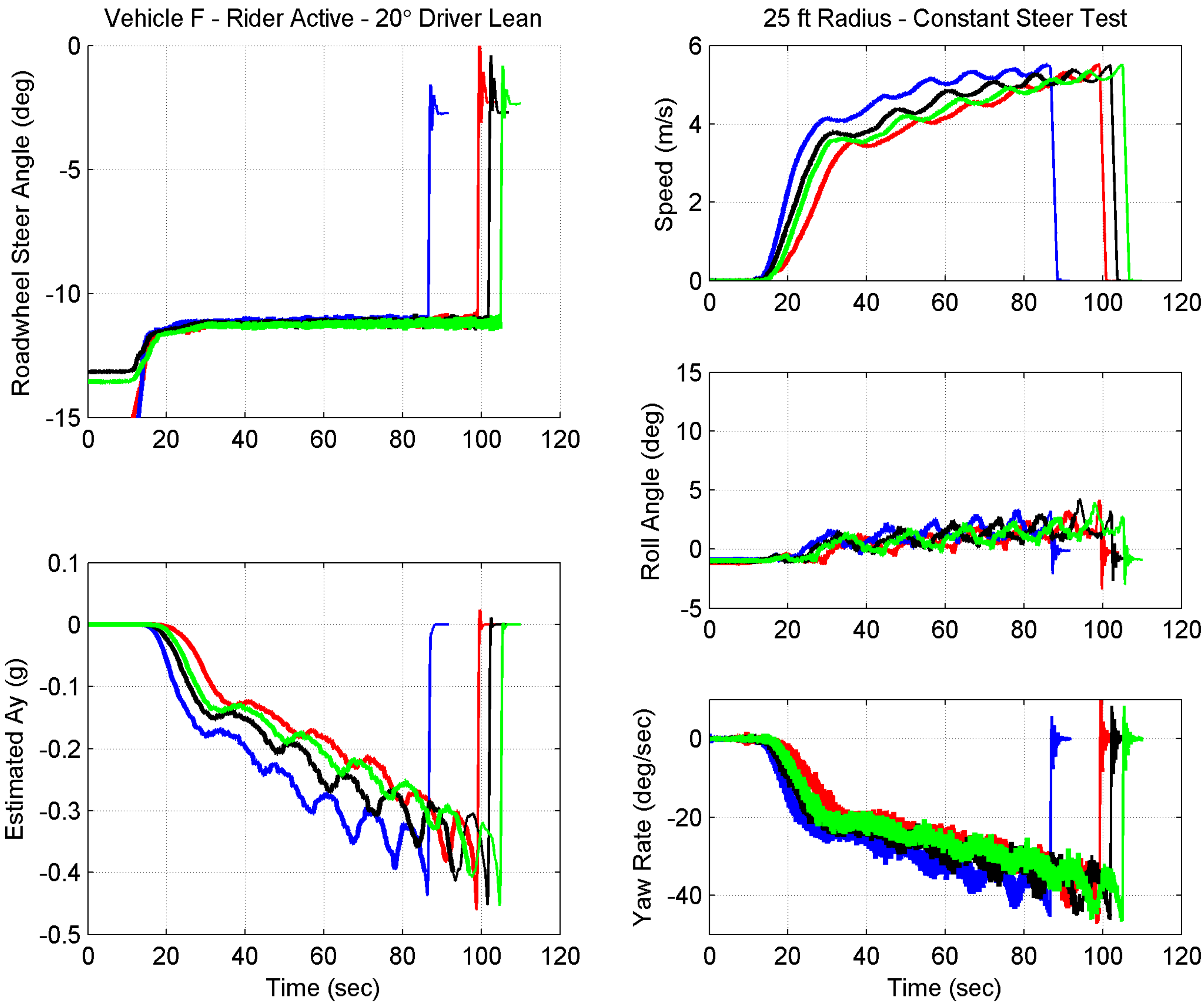


Vehicle F - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
CCW Average: 4.65
CCW Ratios: 3.49 3.63 4.58 4.97 6.56 STD=1.24
CCW Final Slopes: -21 -22.9 -28 -30.1 -39.3 STD=7.17
CCW Initial Slopes: -6.02 -6.32 -6.11 -6.06 -5.98 STD=0.134

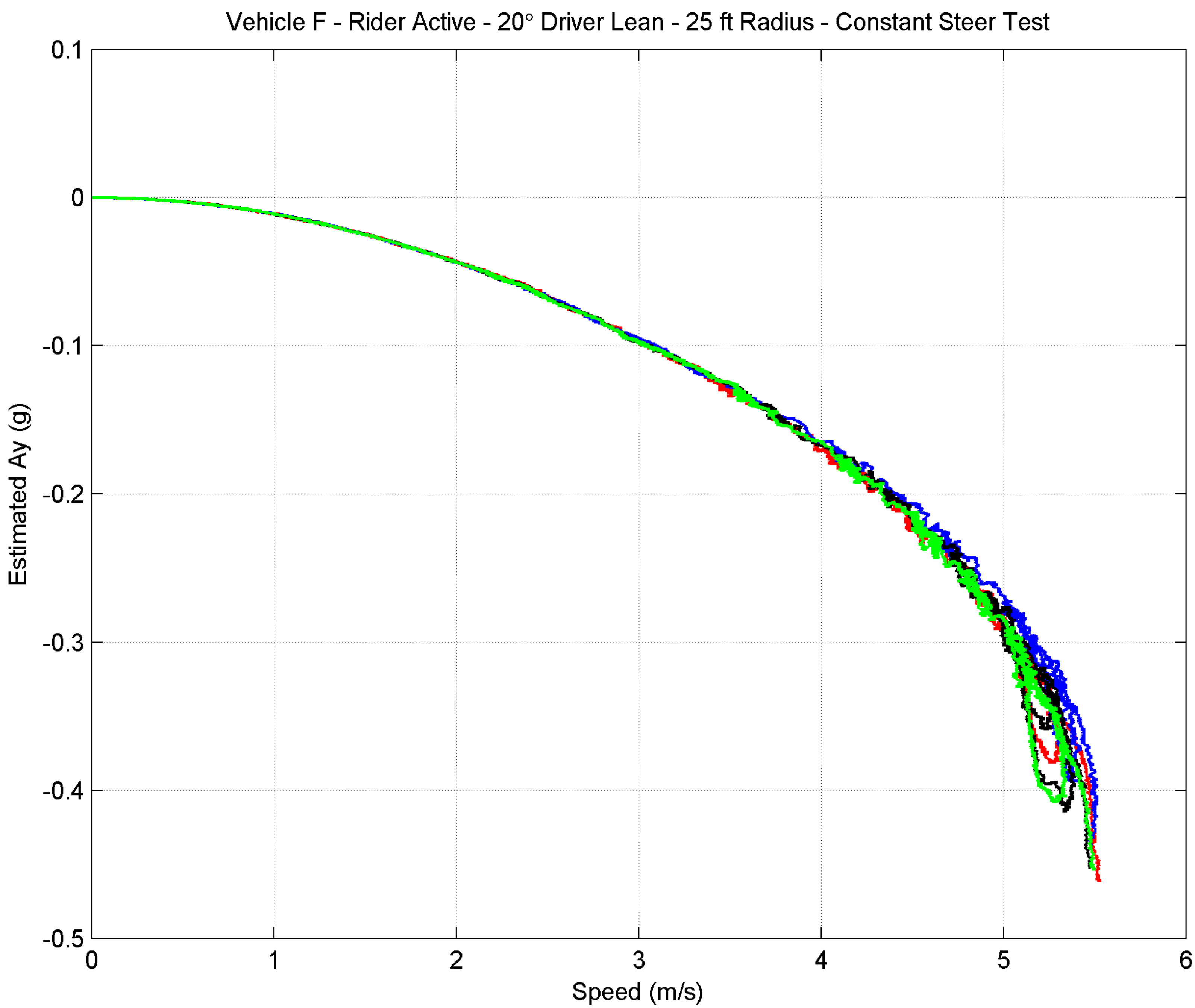

Vehicle F - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -21
Ratio: 3.49
Final Slope: -22.9
Ratio: 3.63
Final Slope: -28
Ratio: 4.58
Final Slope: -30.1
Ratio: 4.97
Final Slope: -39.3
Ratio: 6.56
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6



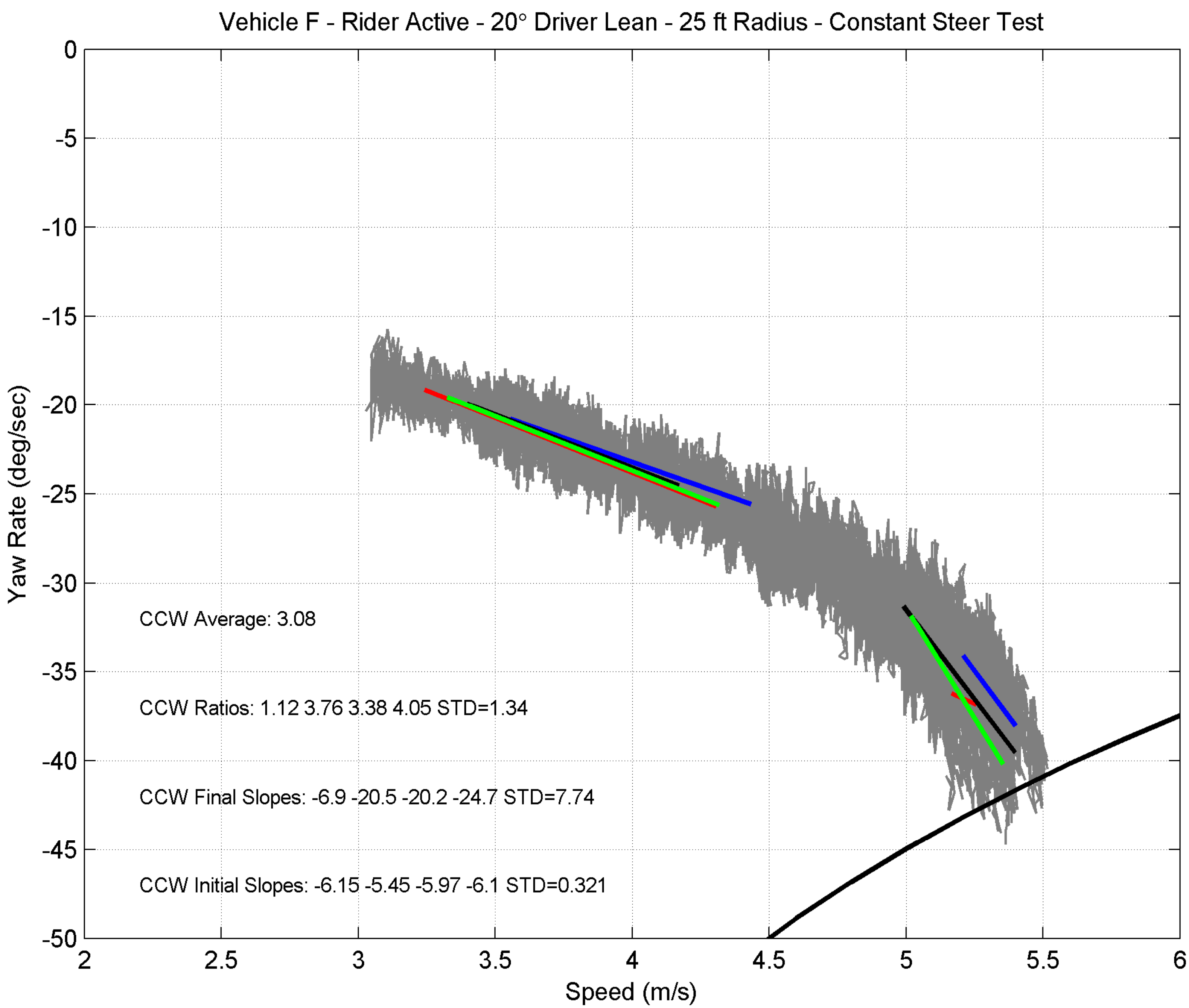
Vehicle F - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



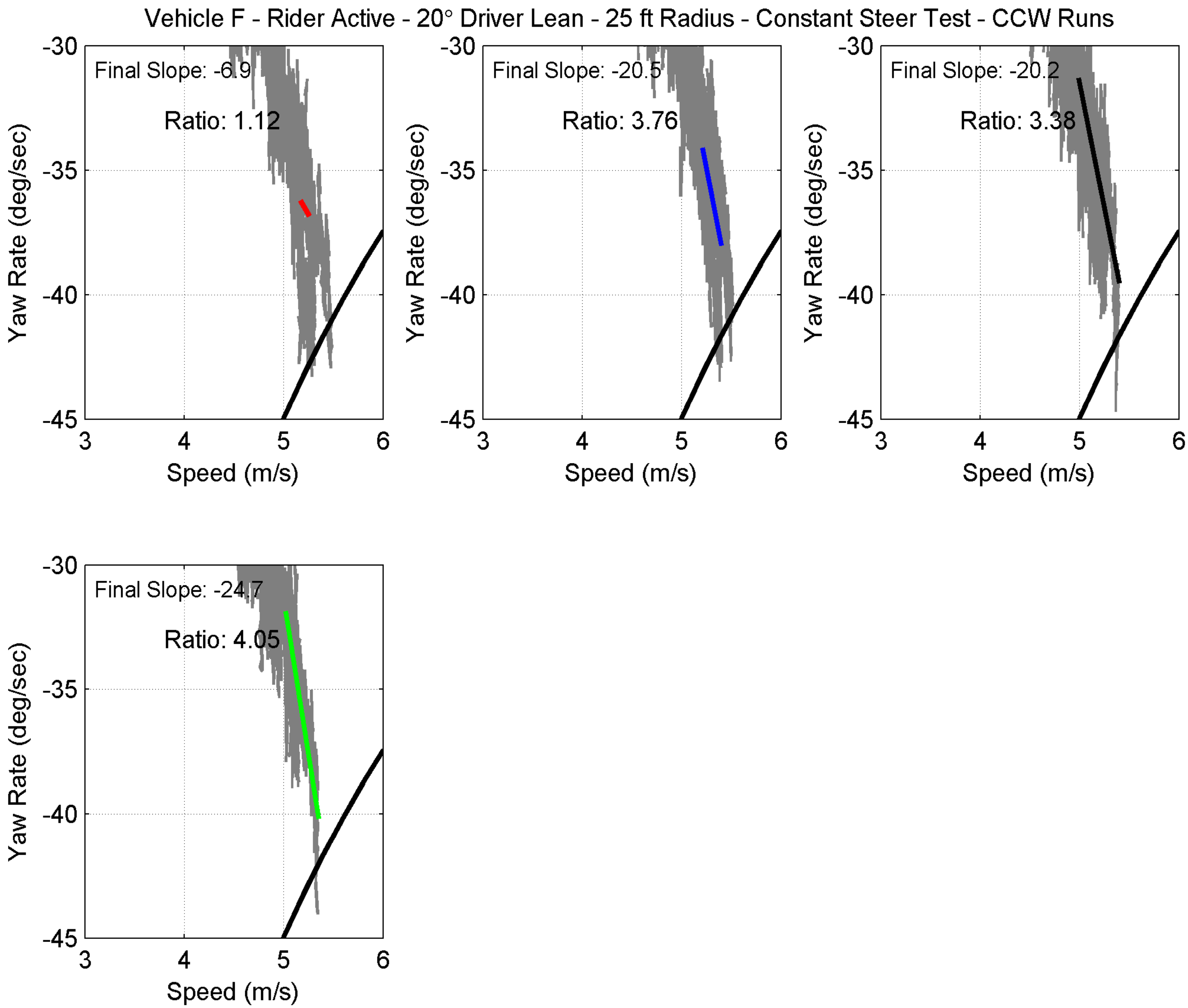
Vehicle F - Rider Active - 20° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



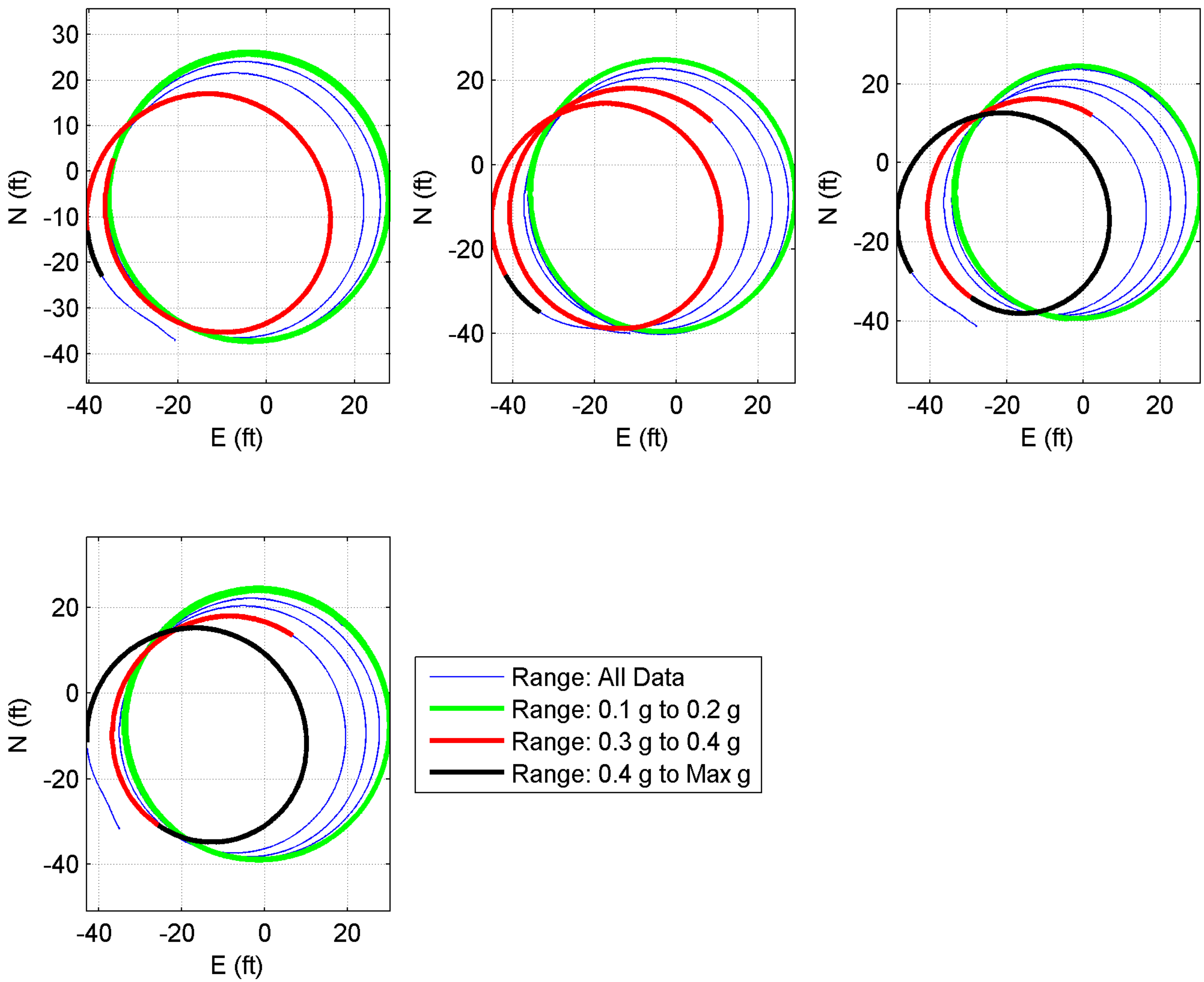
Vehicle F - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6

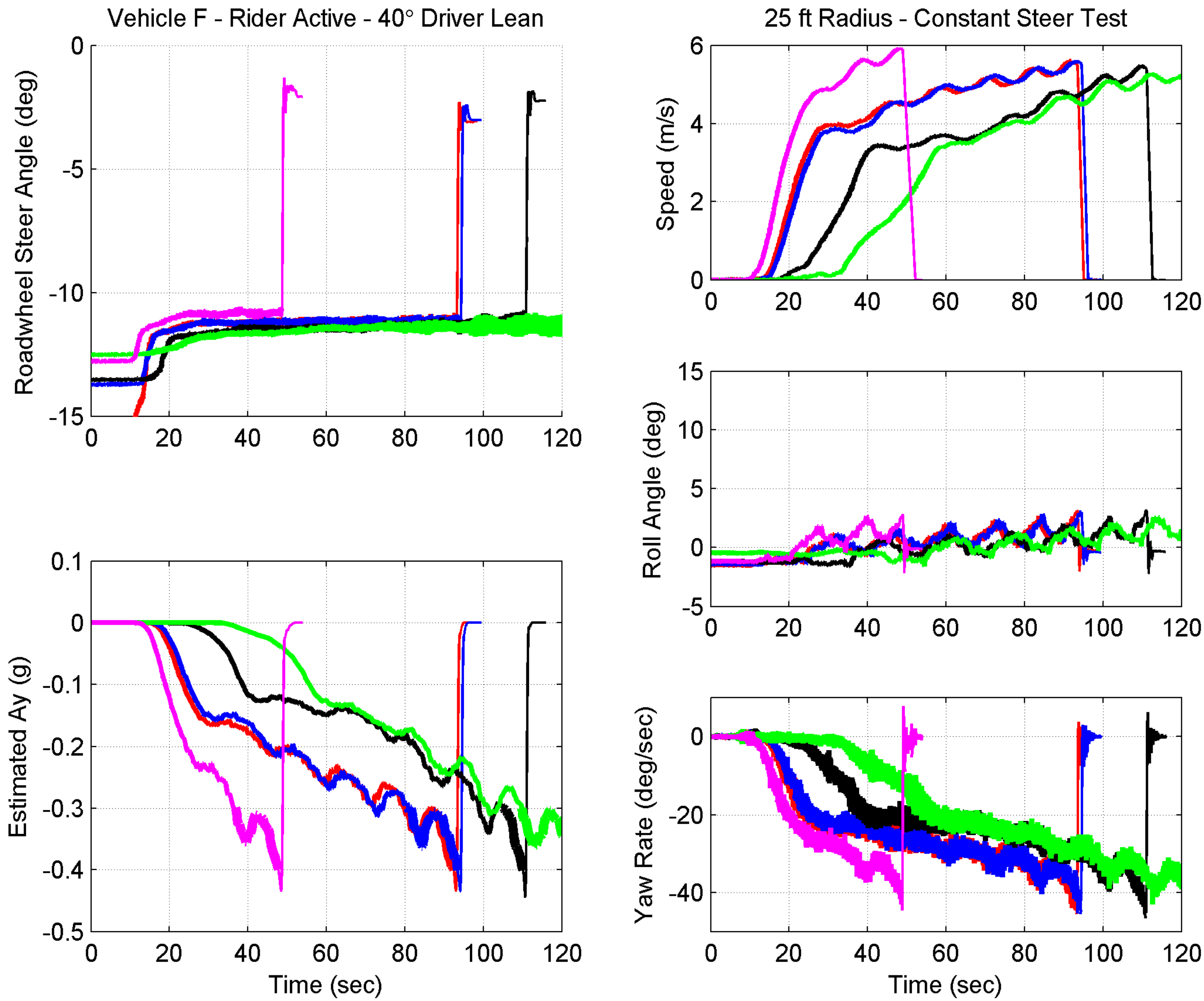


Vehicle F - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
CCW Average: 3.08
CCW Ratios: 1.12 3.76 3.38 4.05 STD=1.34
CCW Final Slopes: -6.9 -20.5 -20.2 -24.7 STD=7.74
CCW Initial Slopes: -6.15 -5.45 -5.97 -6.1 STD=0.321

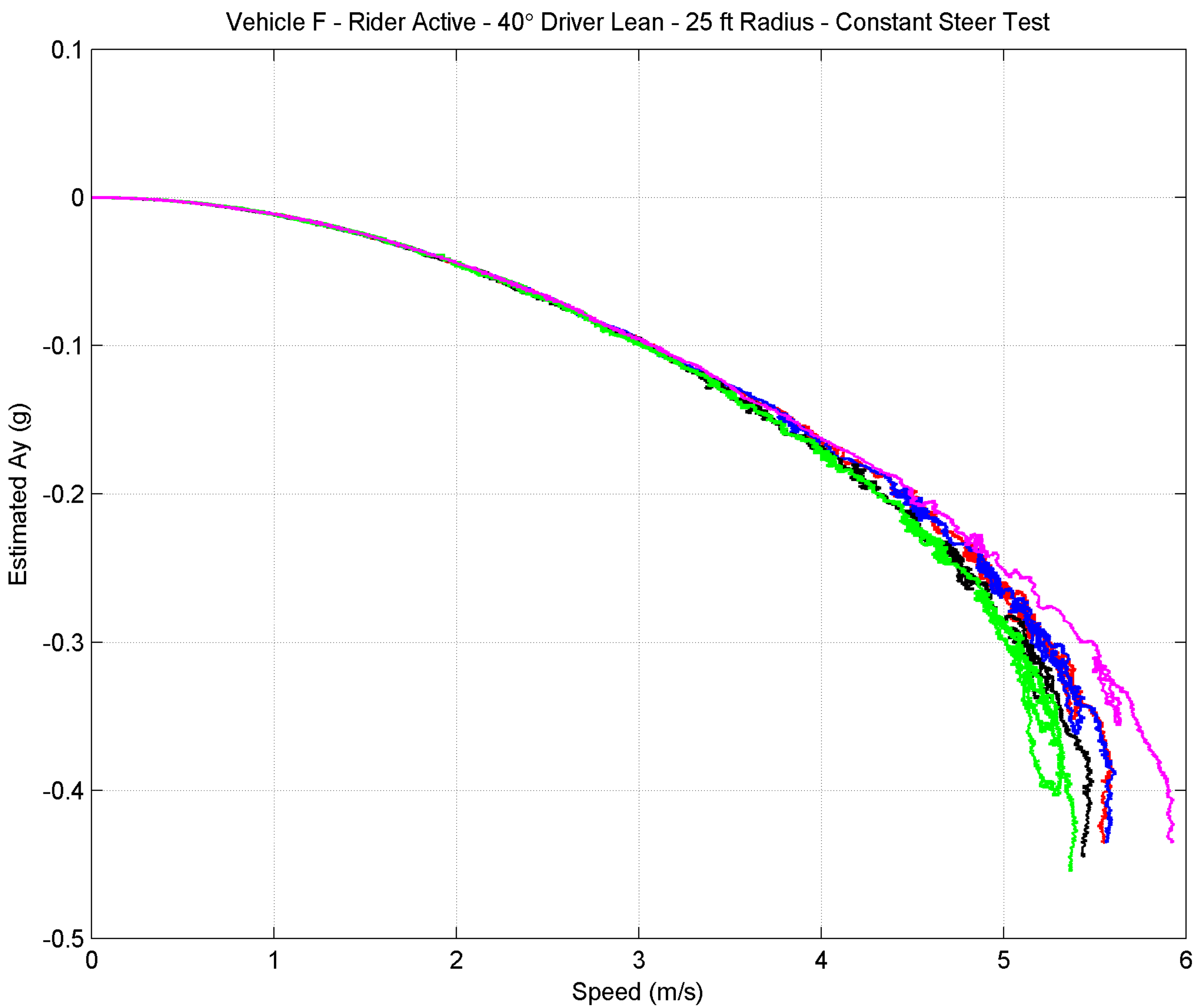

Vehicle F - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -6.9
Ratio: 1.12
Final Slope: -20.5
Ratio: 3.76
Final Slope: -20.2
Ratio: 3.38
Final Slope: -24.7
Ratio: 4.05
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6

Vehicle F - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

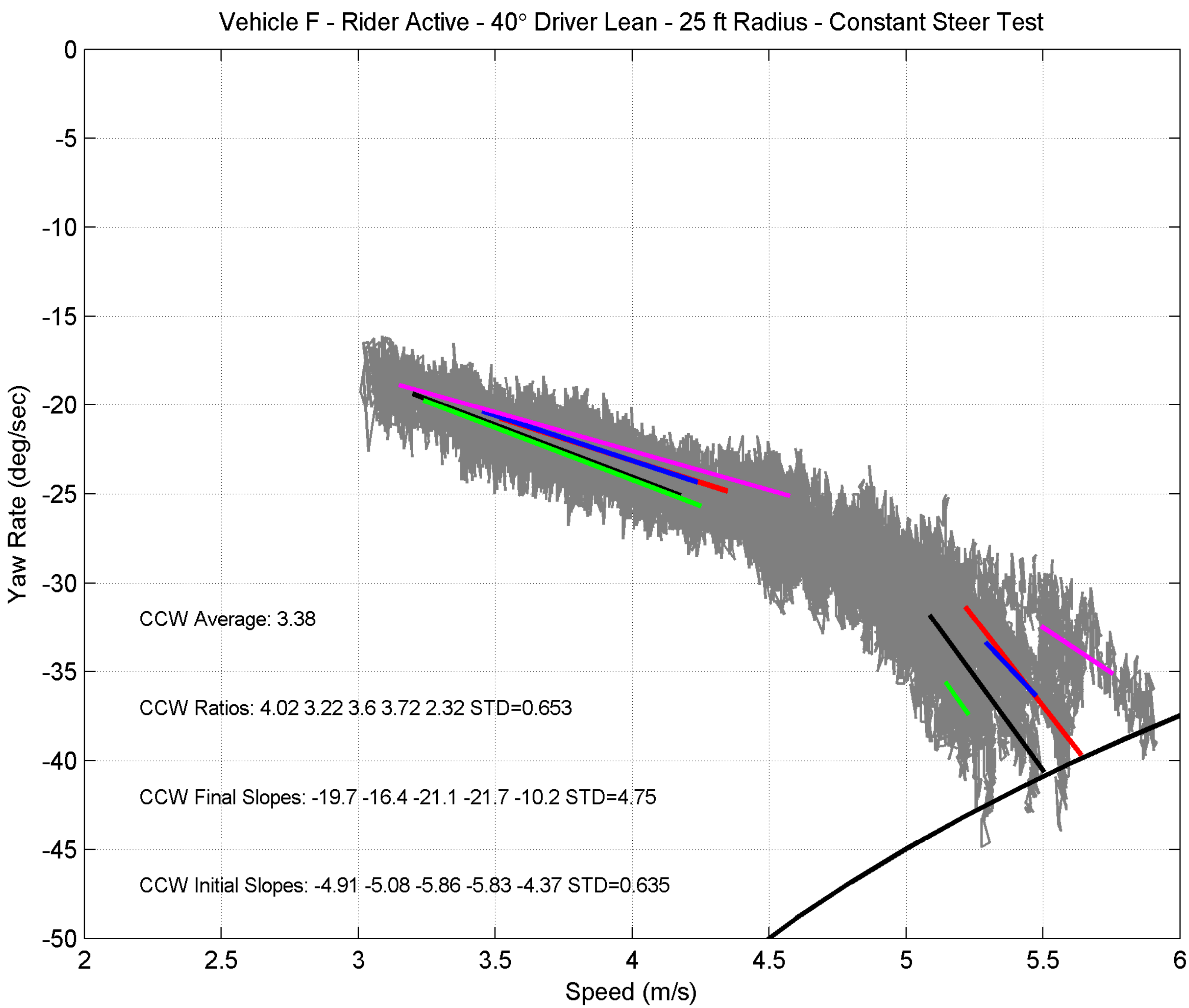


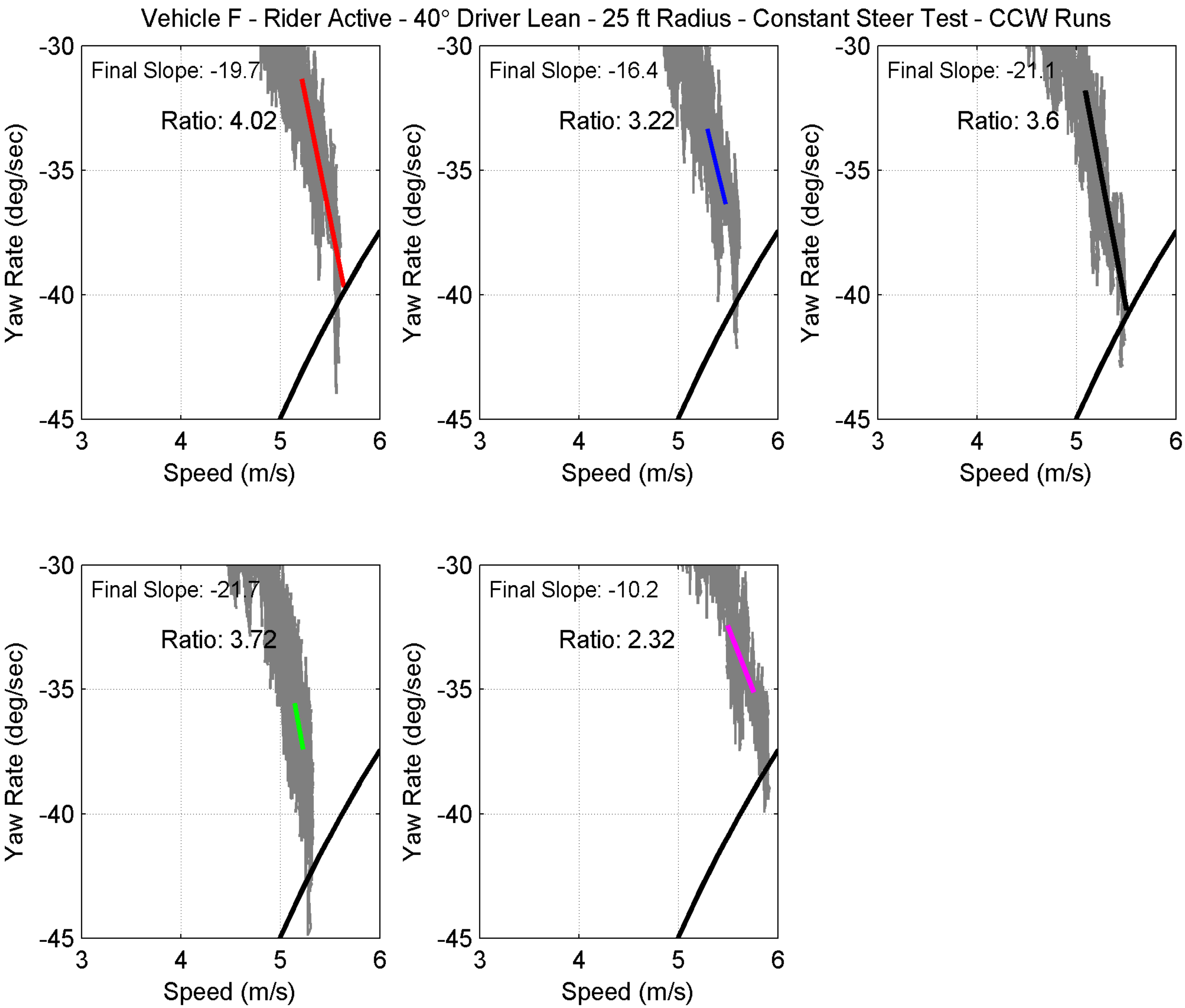


Vehicle F - Rider Active - 40° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Estimated Ay (g)
Speed (m/s)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



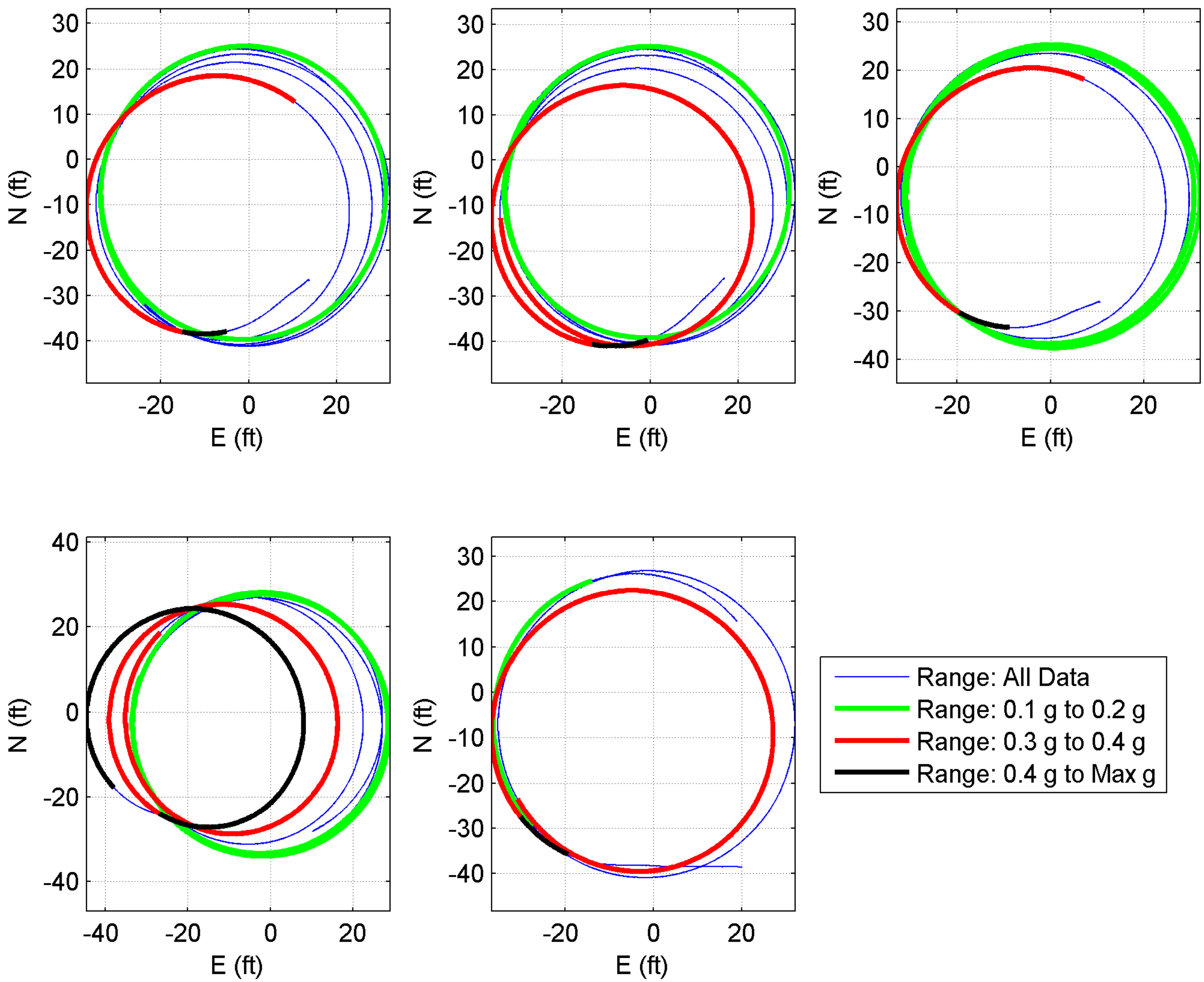
Vehicle F - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6

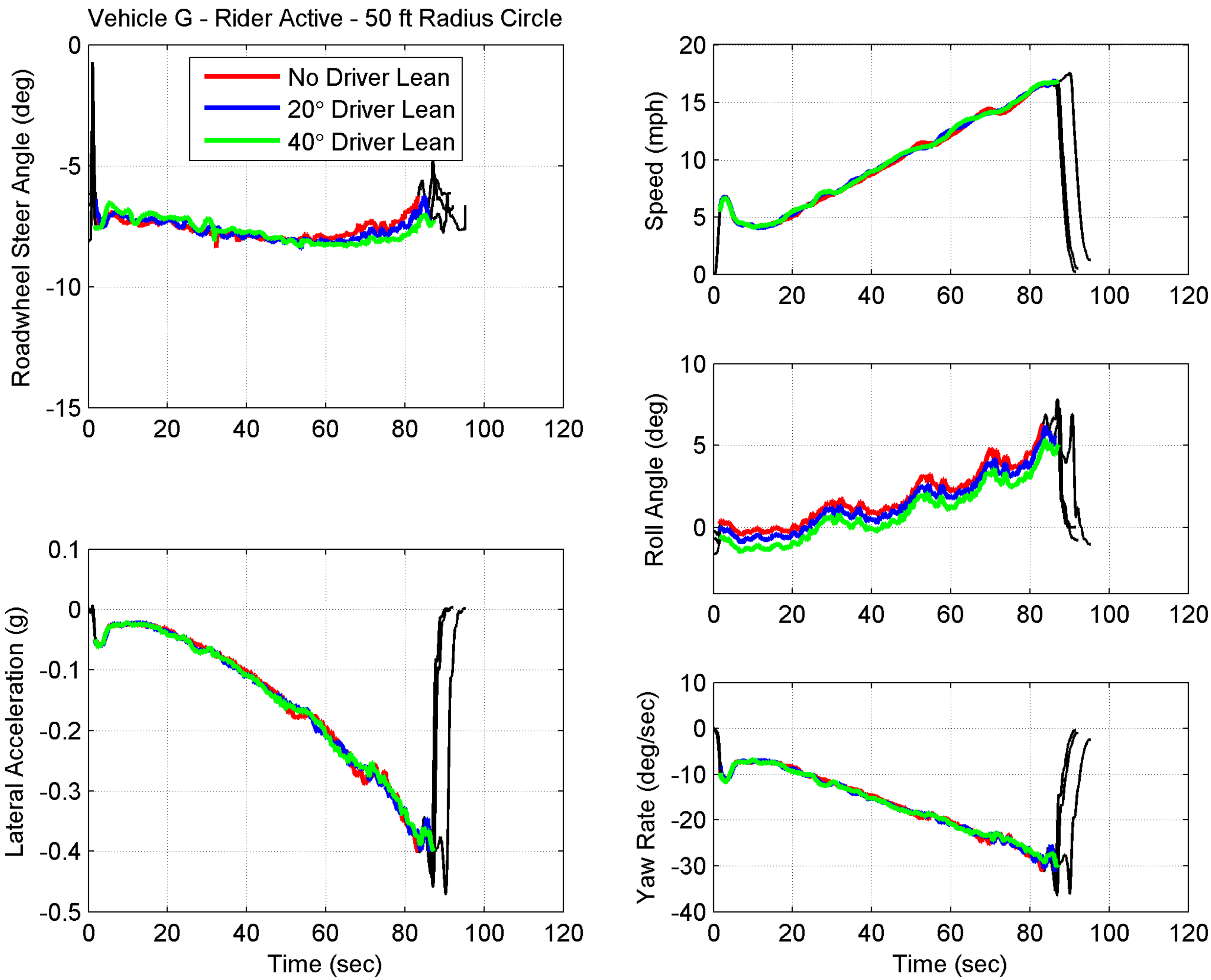

Vehicle F - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
CCW Average: 3.38
CCW Ratios: 4.02 3.22 3.6 3.72 2.32 STD=0.653
CCW Final Slopes: -19.7 -16.4 -21.1 -21.7 -10.2 STD=4.75
CCW Initial Slopes: -4.91 -5.08 -5.86 -5.83 -4.37 STD=0.635
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6



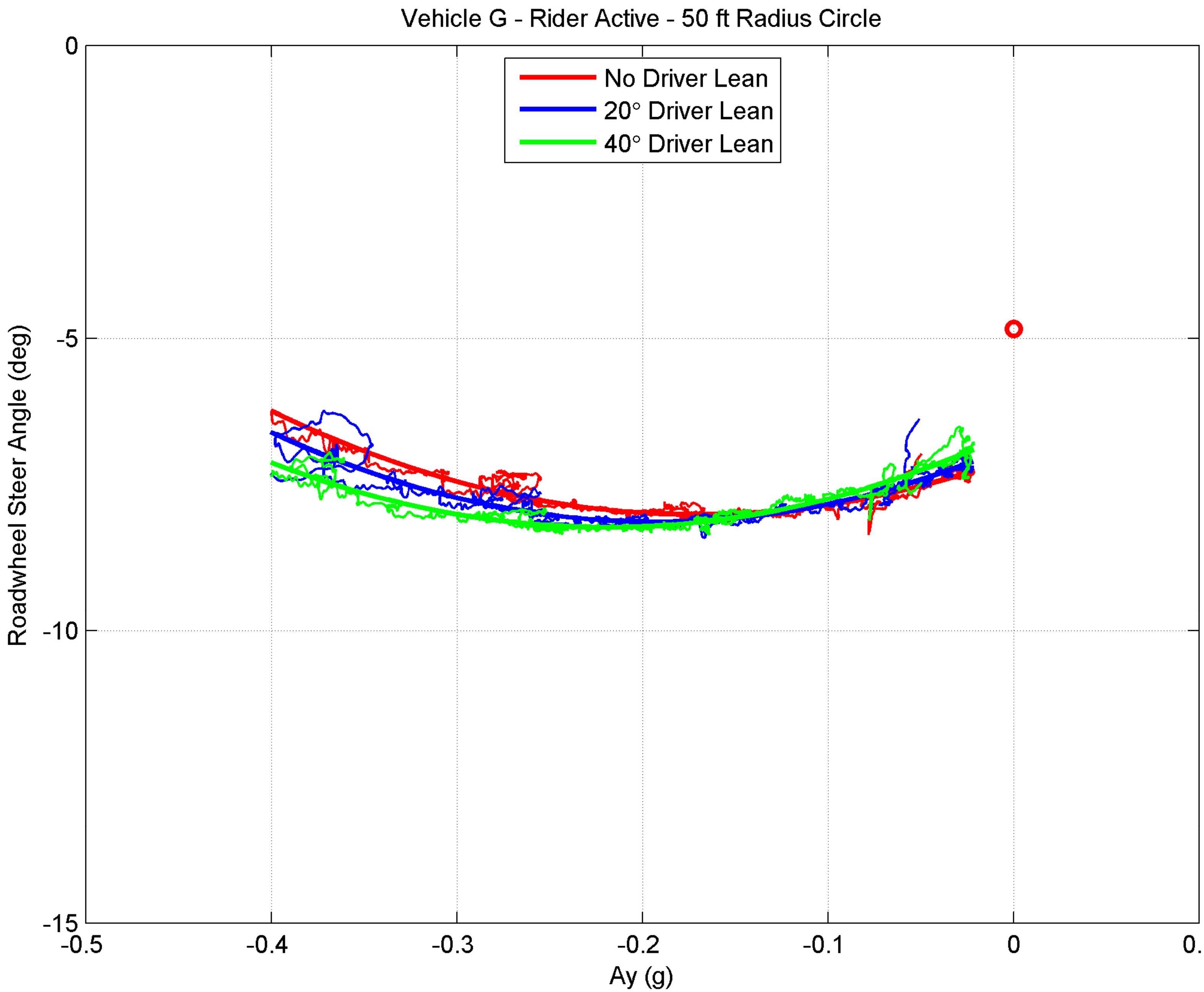
Vehicle F - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -19.7
Ratio: 4.02
Final Slope: -16.4
Ratio: 3.22
Final Slope: -21.1
Ratio: 3.6
Final Slope: -21.7
Ratio: 3.72
Final Slope: -10.2
Ratio: 2.32
Yaw Rate (deg/sec)
Speed (m/s)

Vehicle F - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

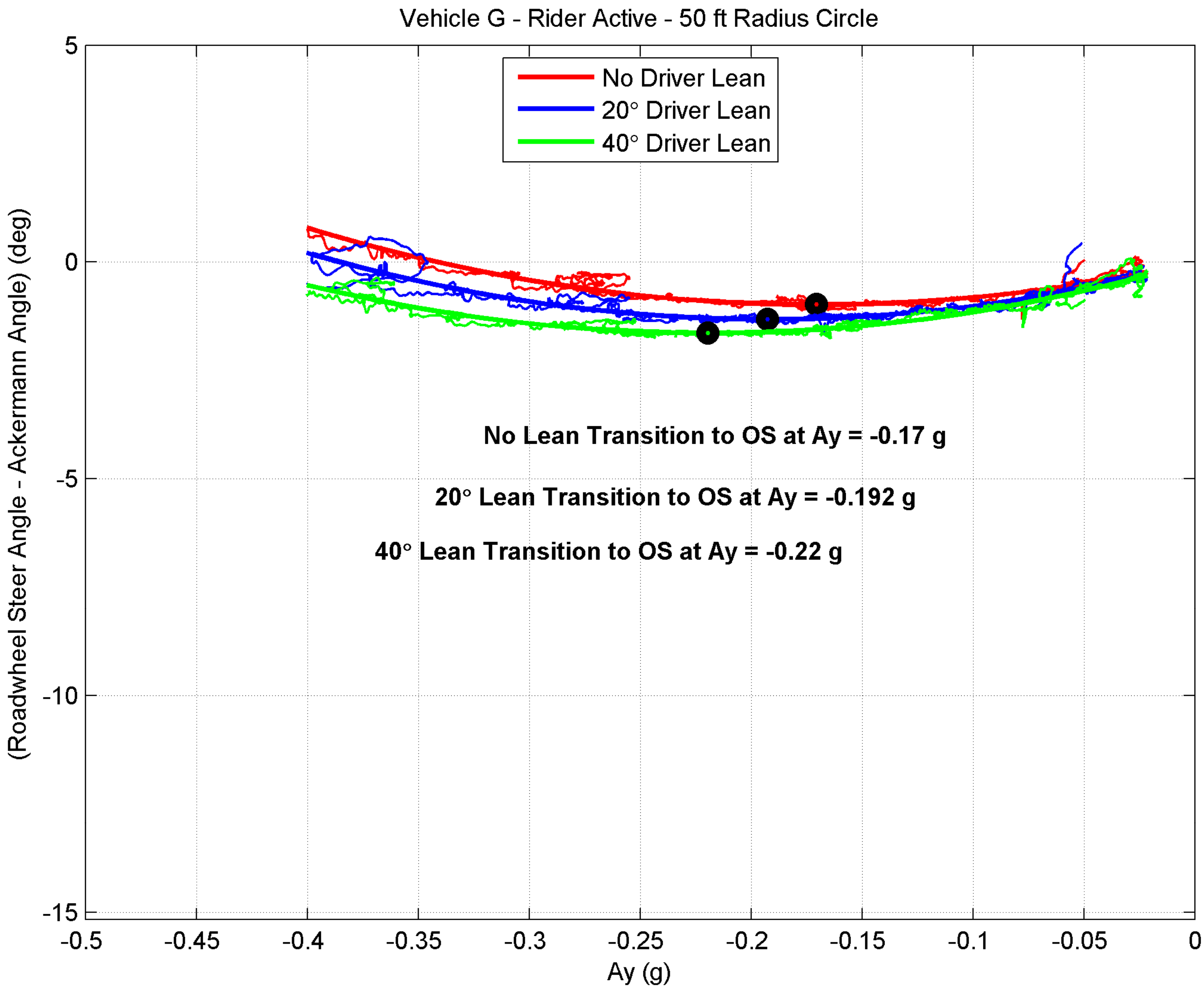


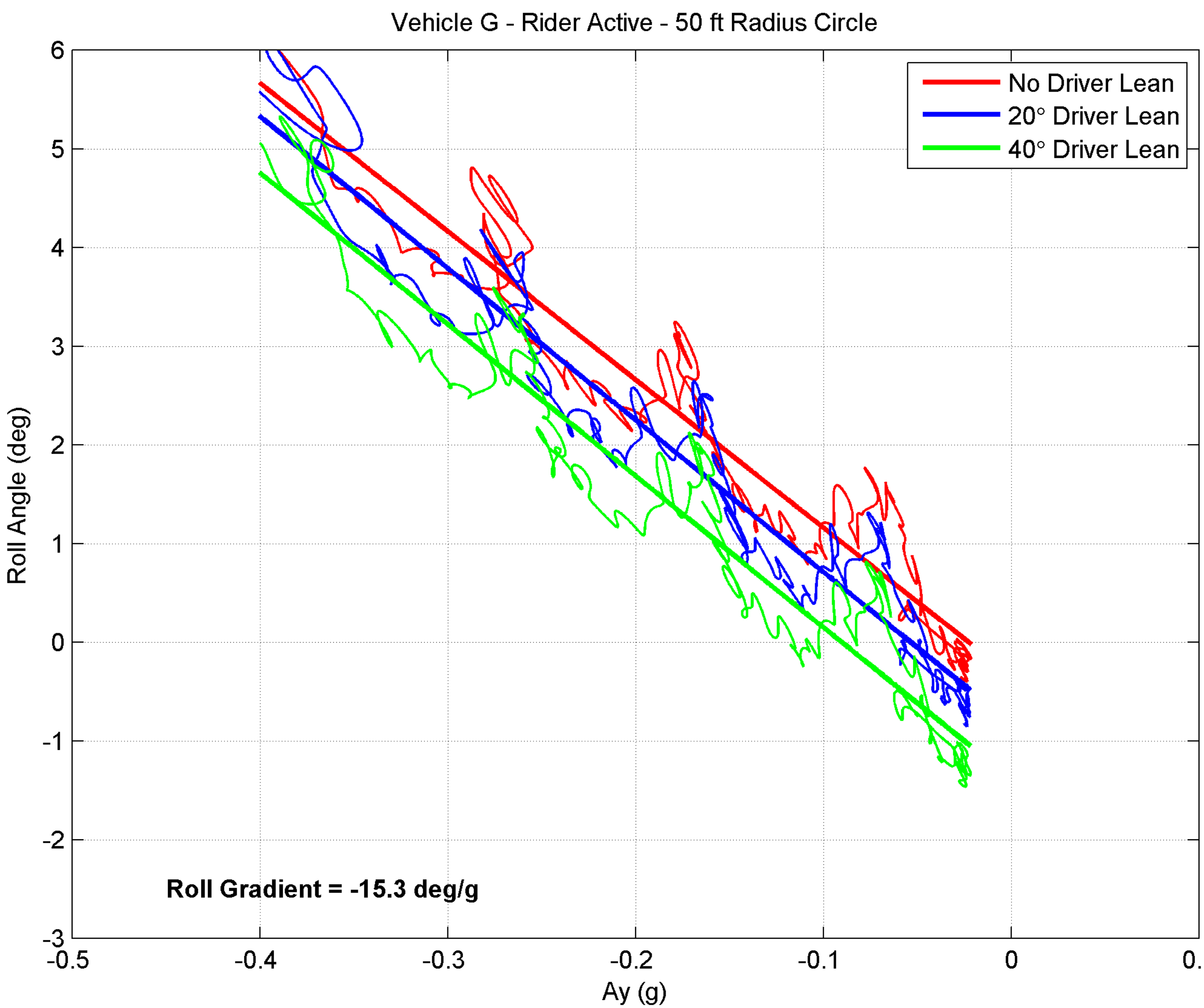


Vehicle G - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

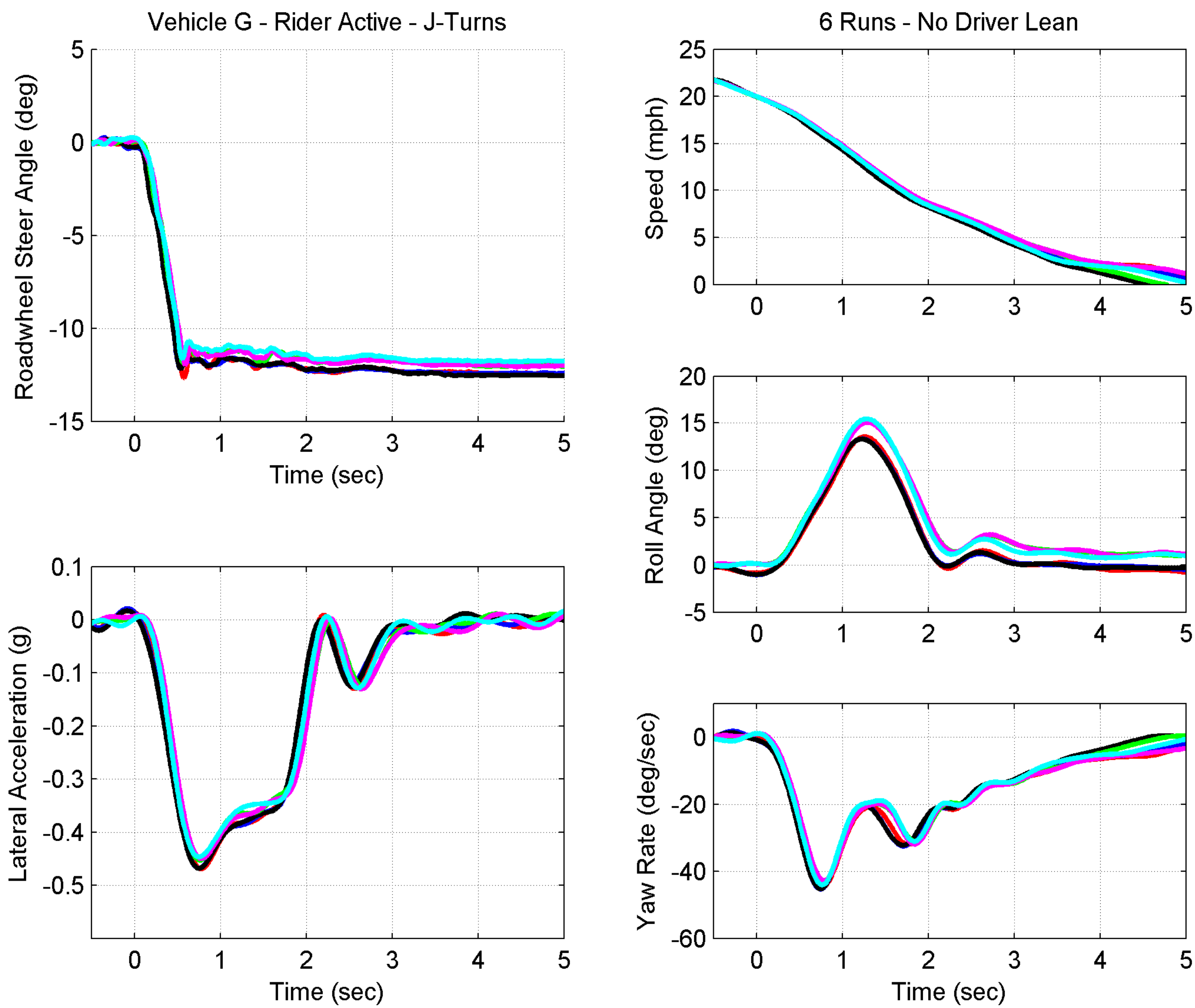


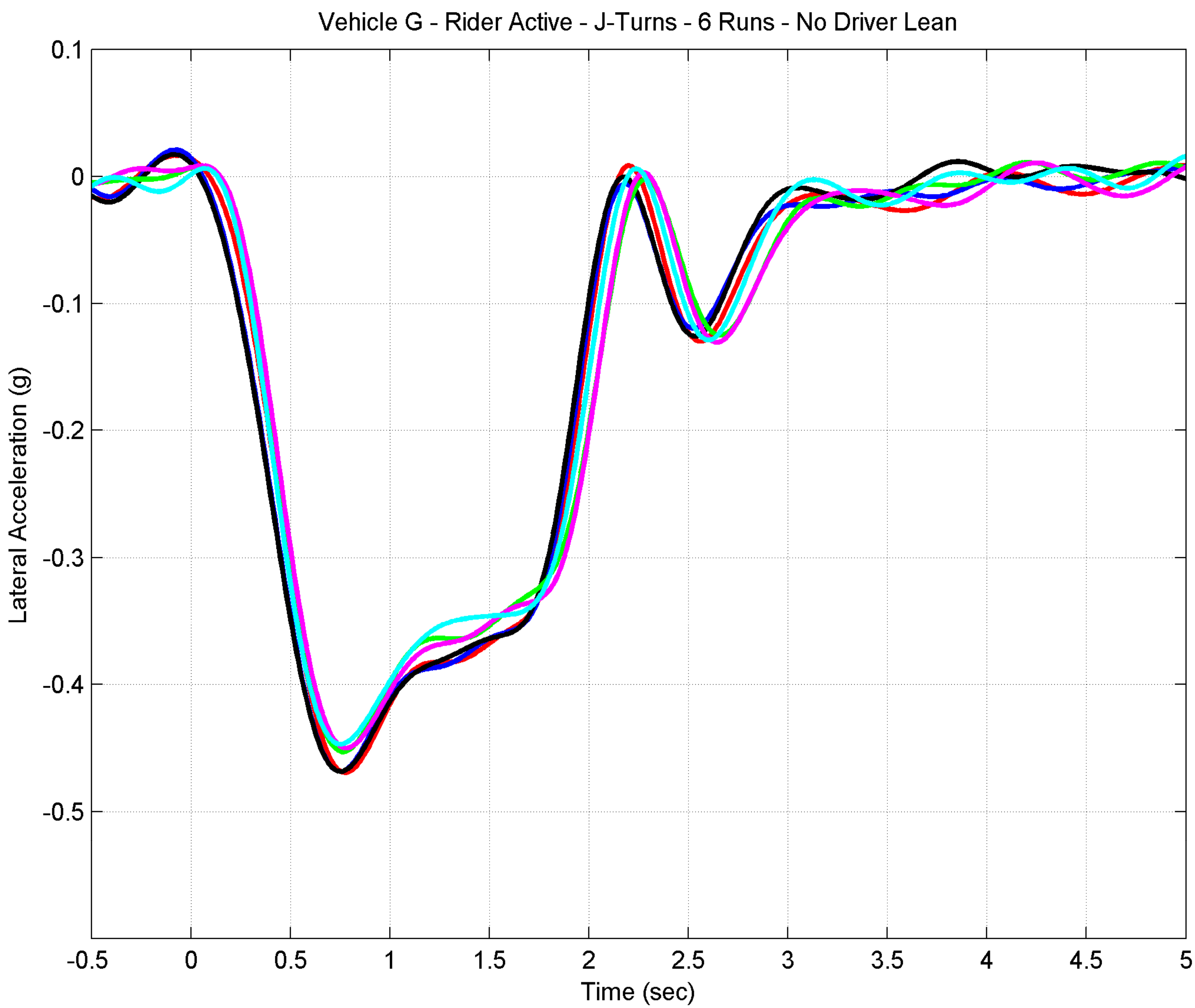
Vehicle G - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Ay (g)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1


Vehicle G - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.17 g
20° Lean Transition to OS at Ay = -0.192 g
40° Lean Transition to OS at Ay = -0.22 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

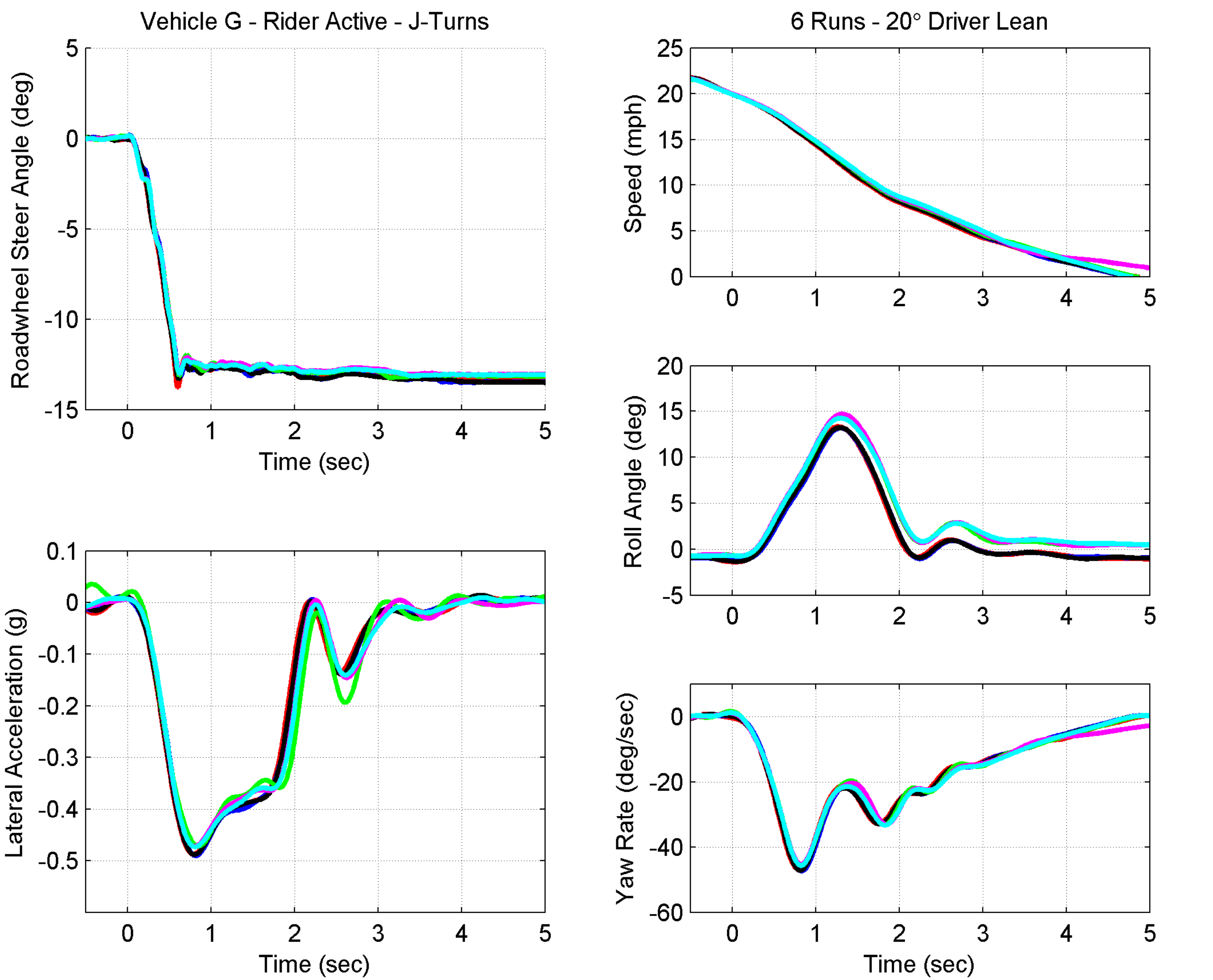


Vehicle G - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -15.3 deg/g
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

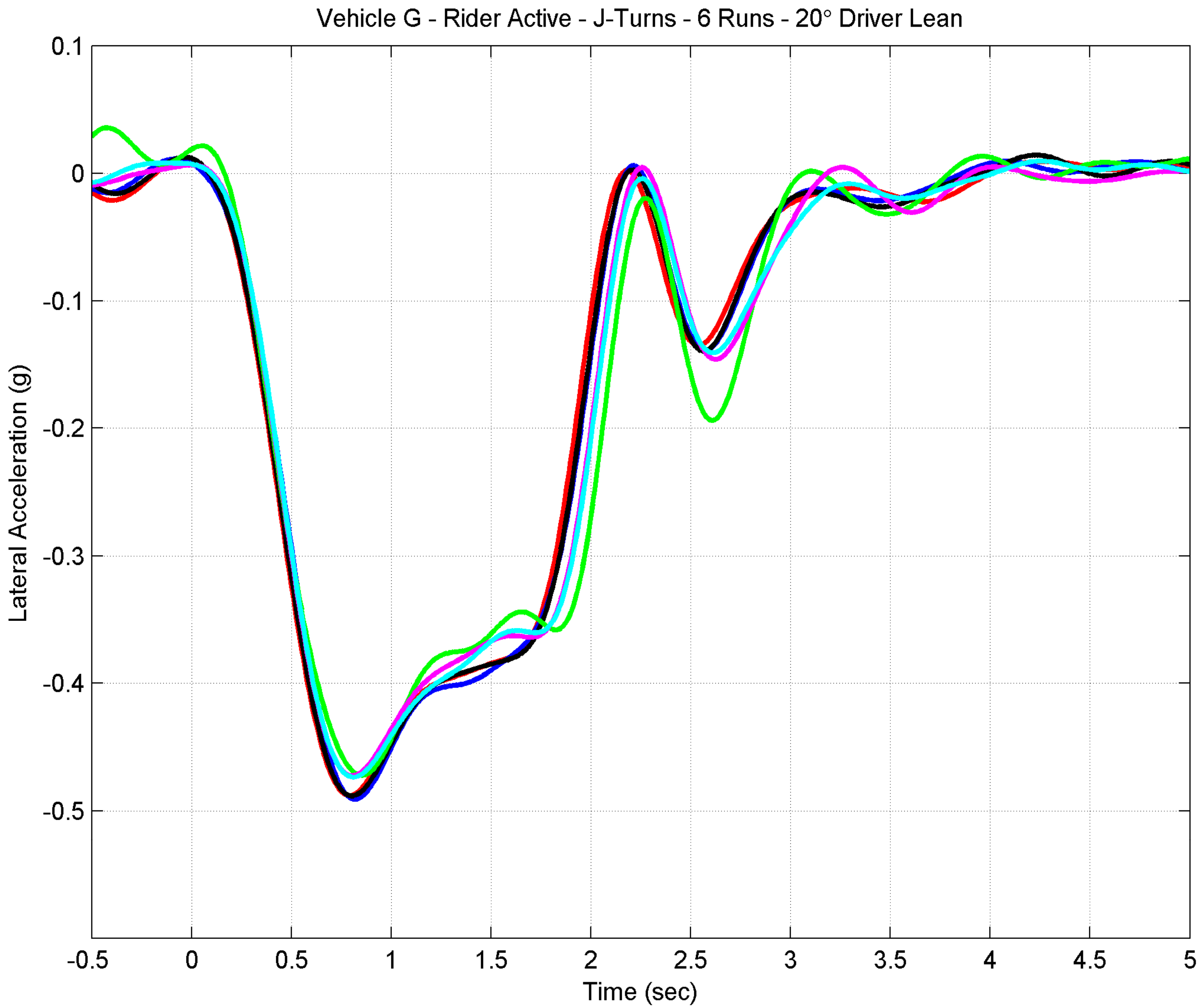

Vehicle G - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

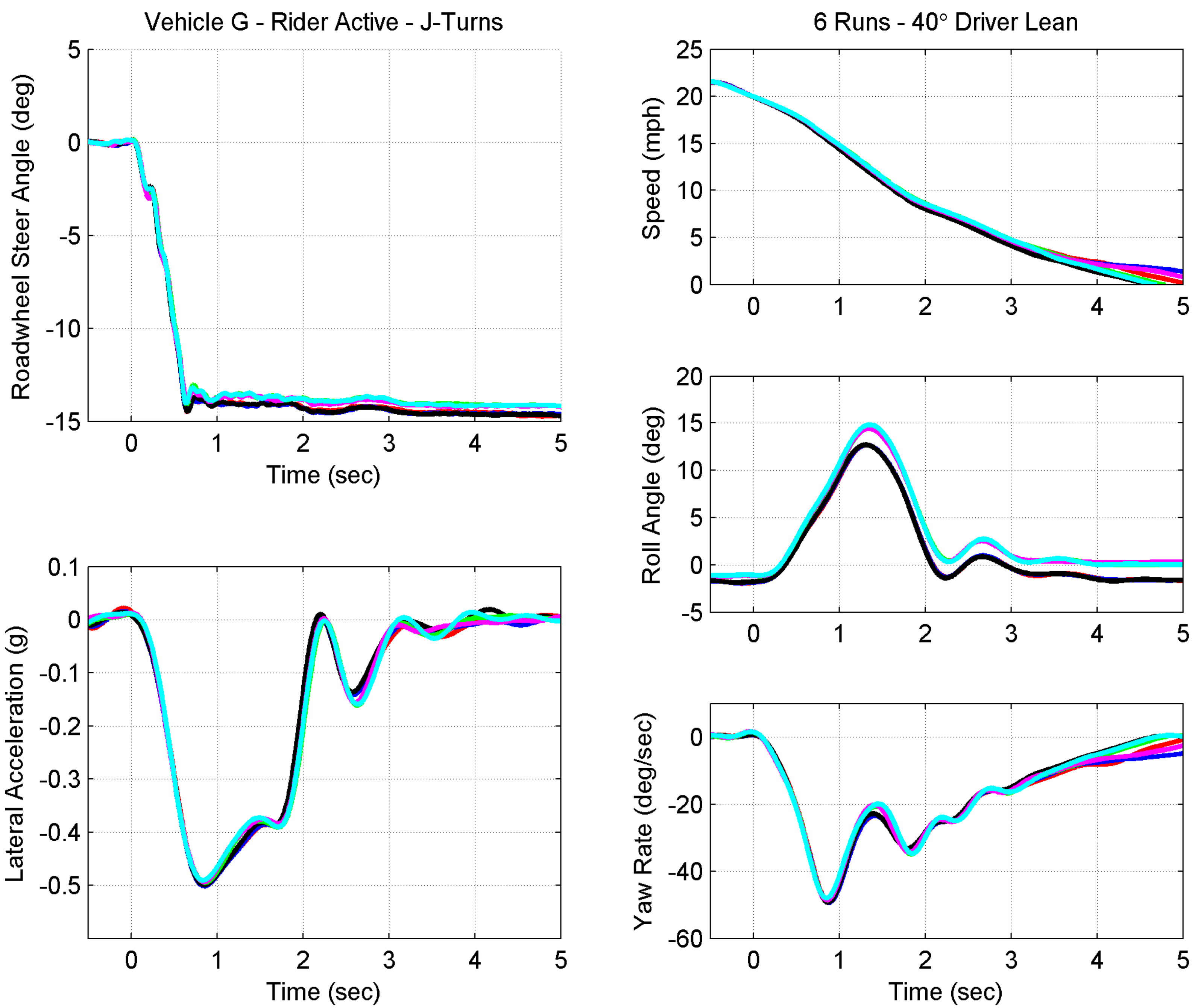


Vehicle G - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

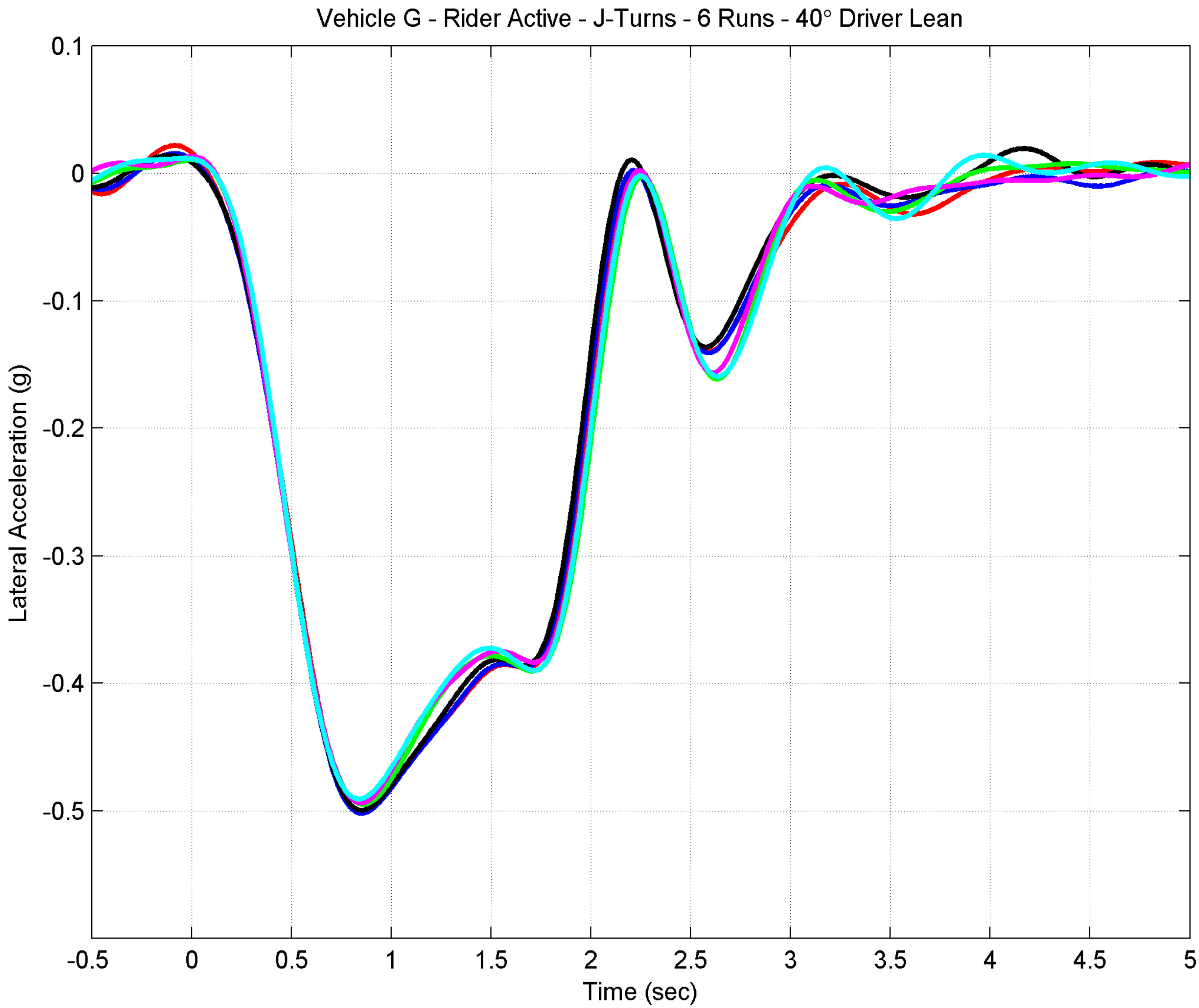


Vehicle G - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle G - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle G - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



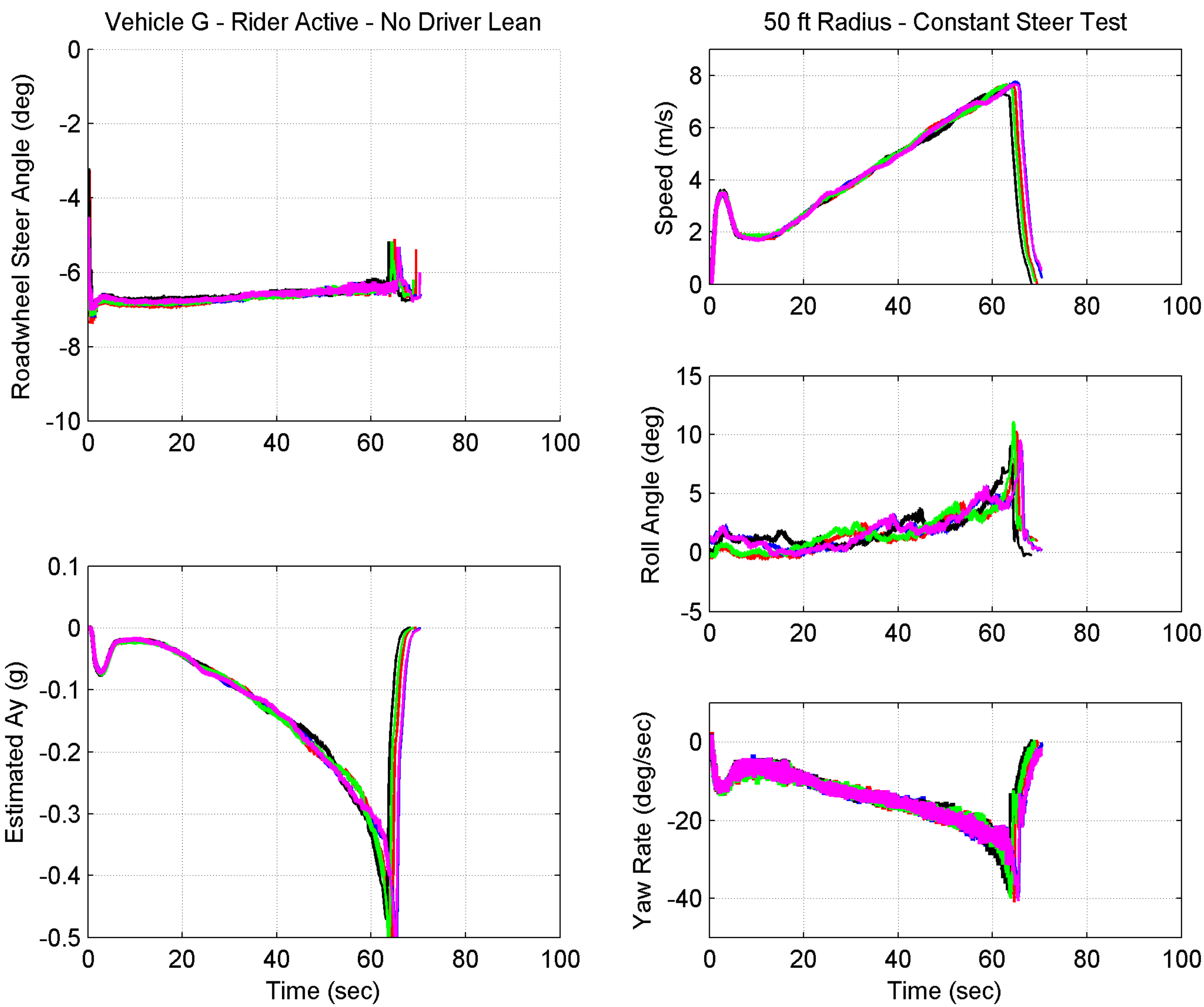
Vehicle G - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

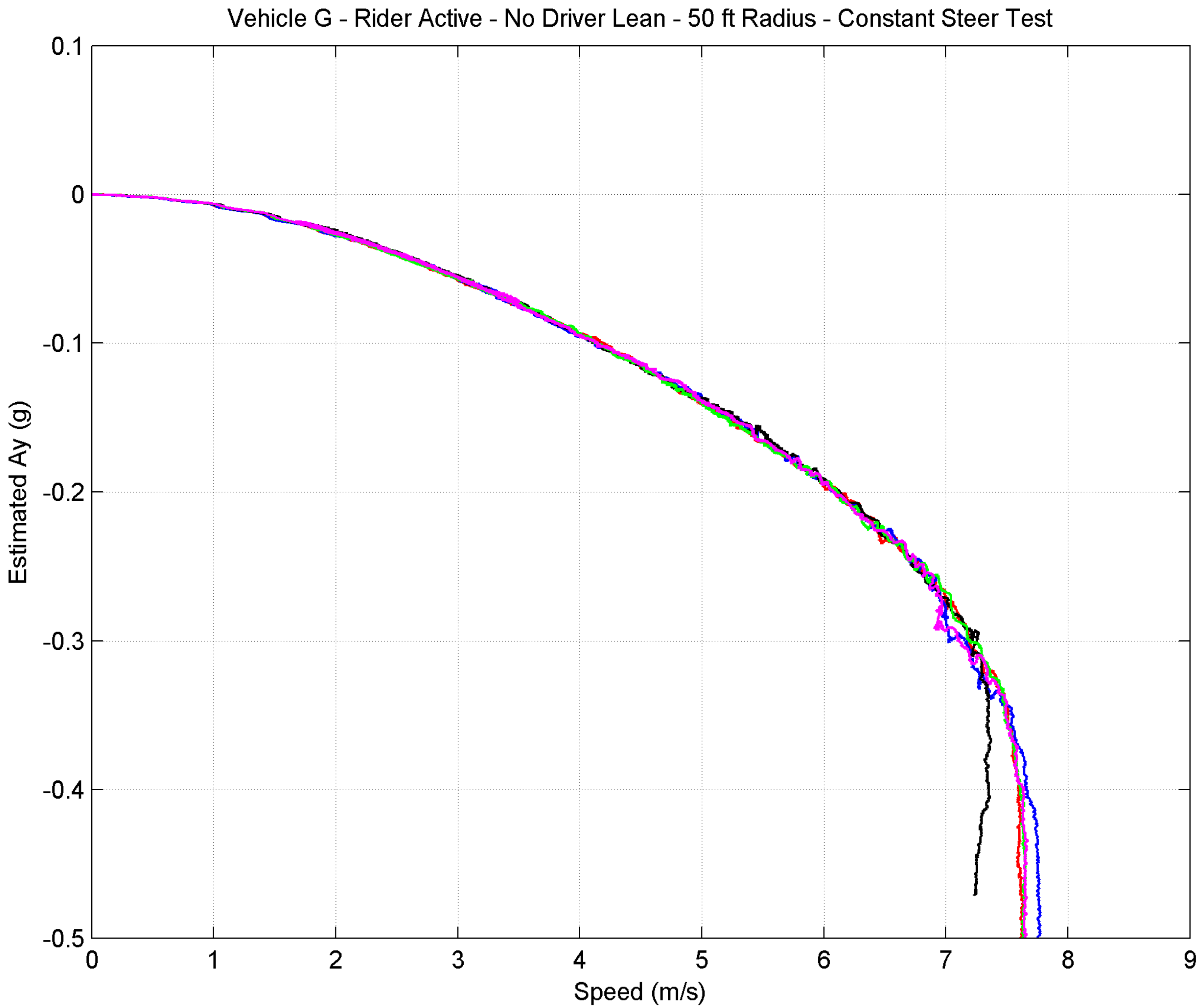
Vehicle G - Rider Active Results

Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

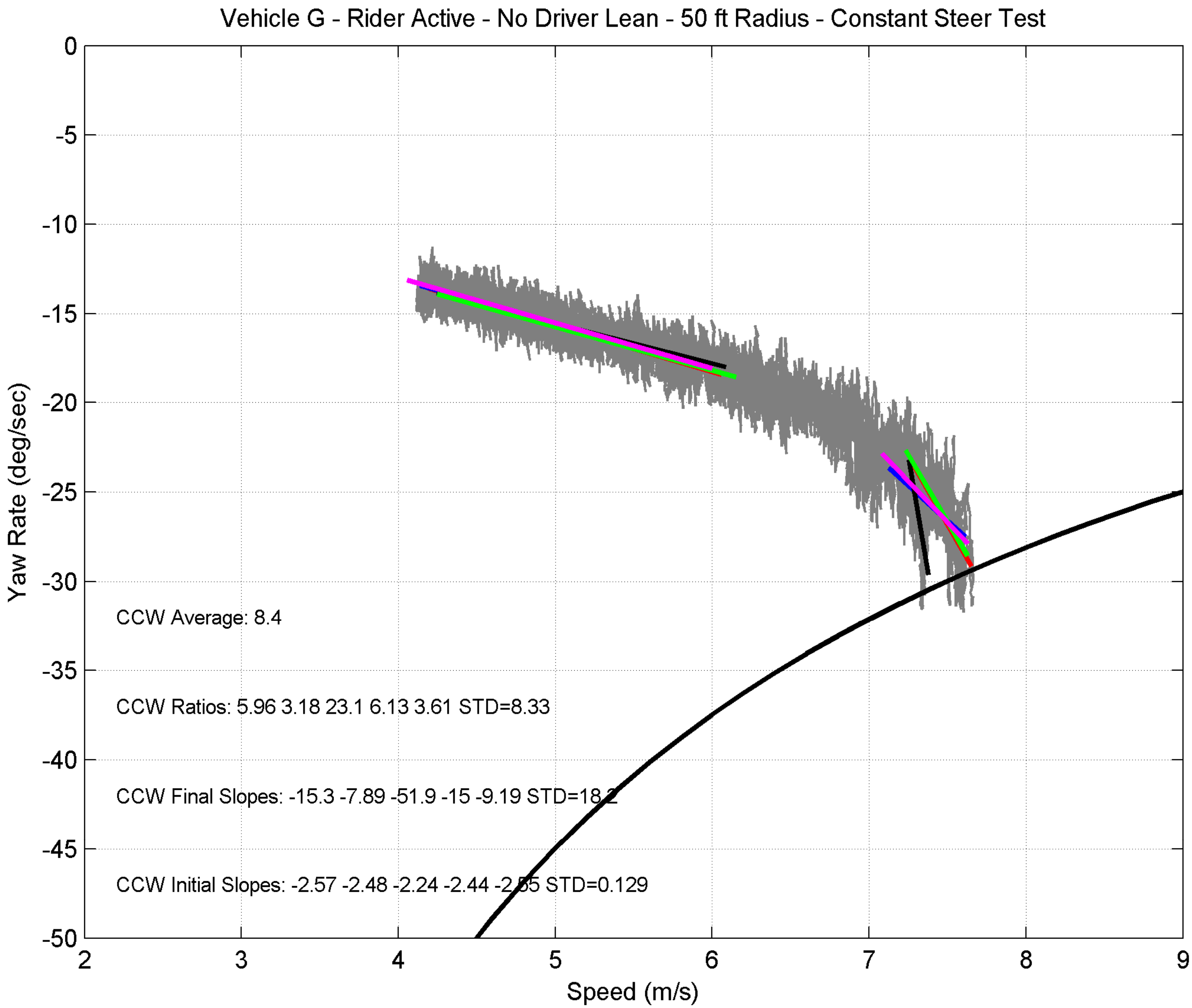
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.469	-0.488	-0.500
	-0.468	-0.491	-0.502
	-0.468	-0.488	-0.499
Mean Value of 3 Runs	-0.469	-0.489	-0.501
Standard Deviation of 3 Runs	0.000	0.002	0.001

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.453	-0.472	-0.495
	-0.450	-0.472	-0.494
	-0.447	-0.474	-0.491
Mean Value of 3 Runs	-0.450	-0.473	-0.493
Standard Deviation of 3 Runs	0.003	0.001	0.002
Average of All 6 Runs	**0.459**	**0.481**	**0.497**

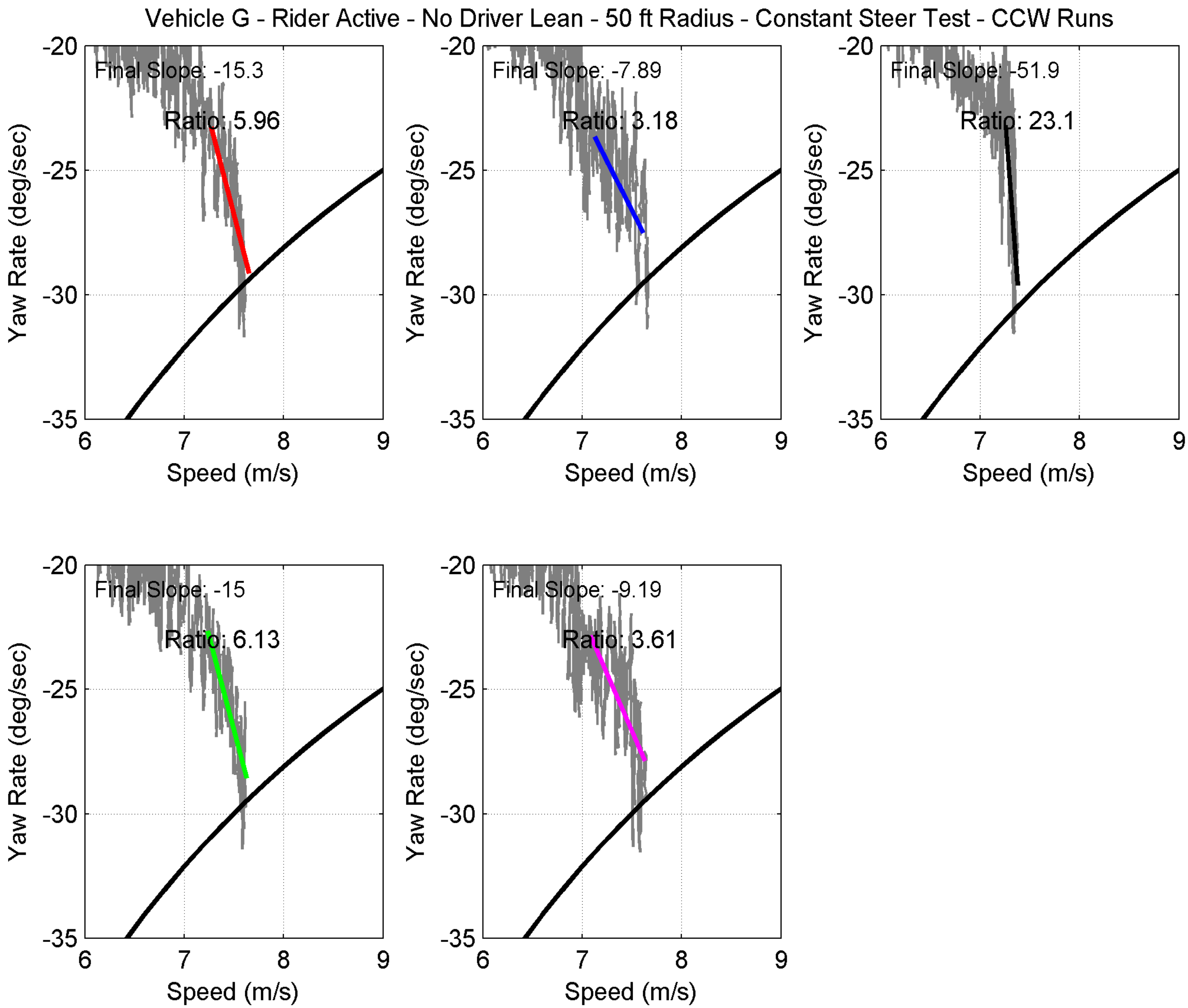

Vehicle G - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



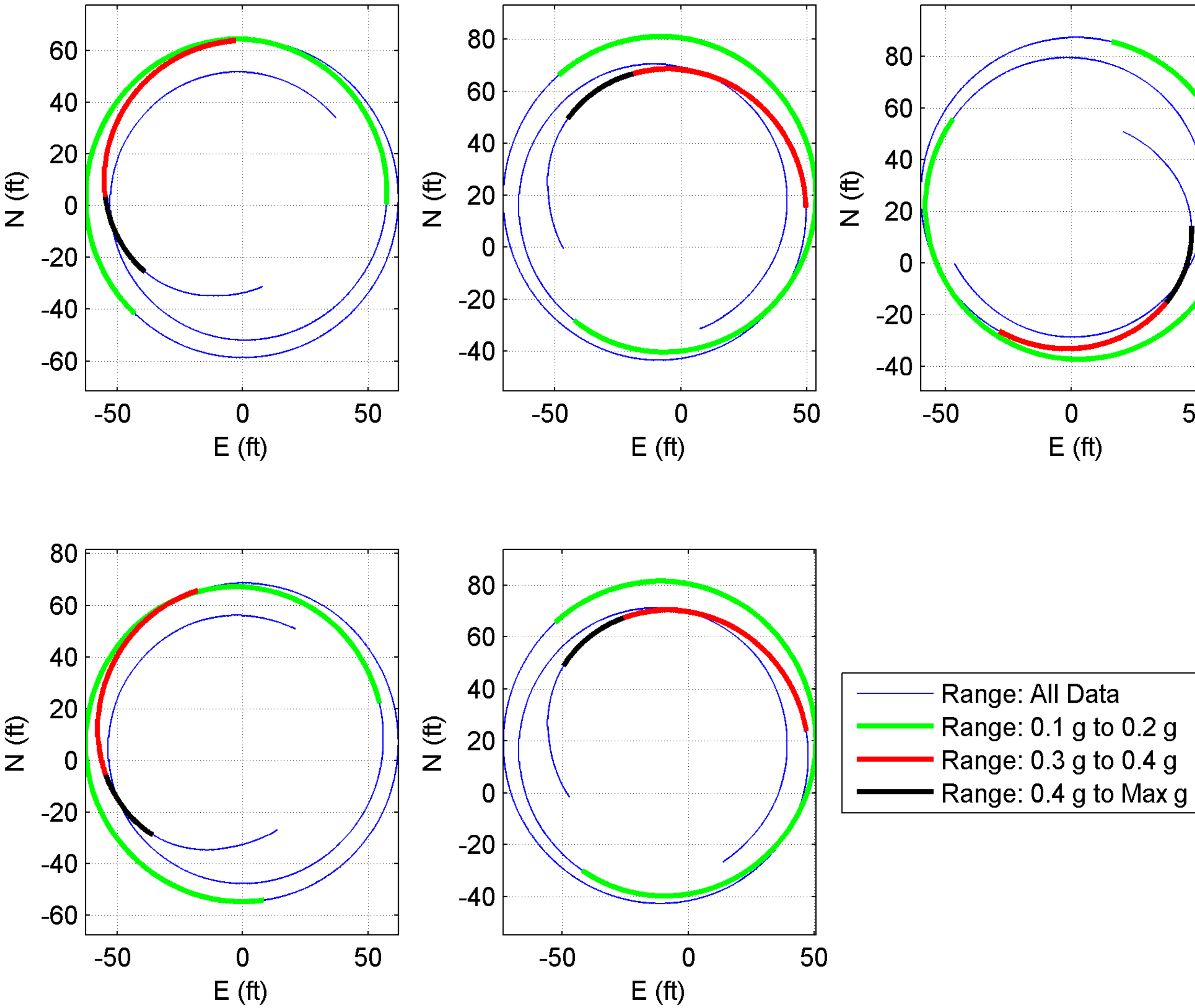
Vehicle G - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

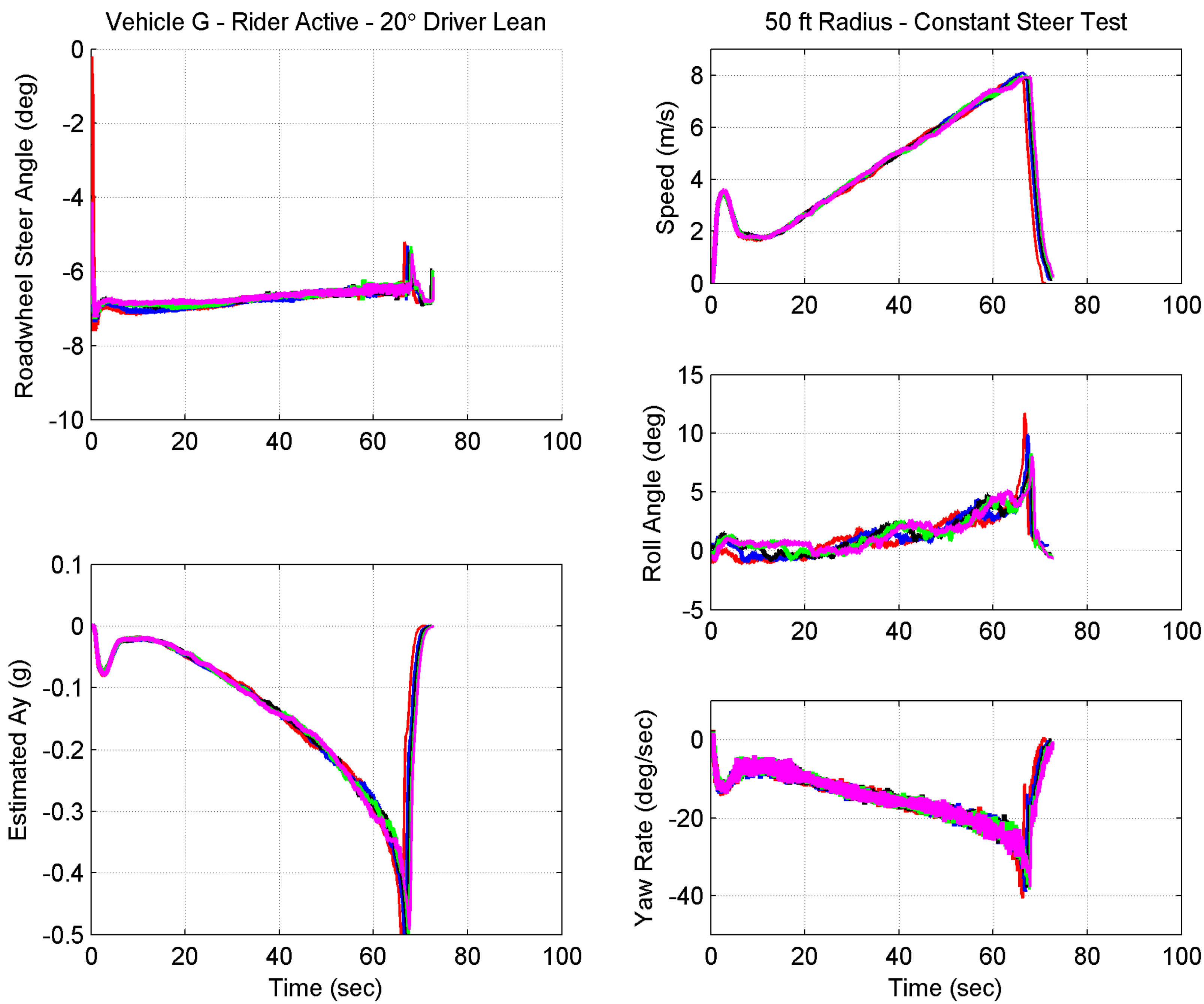


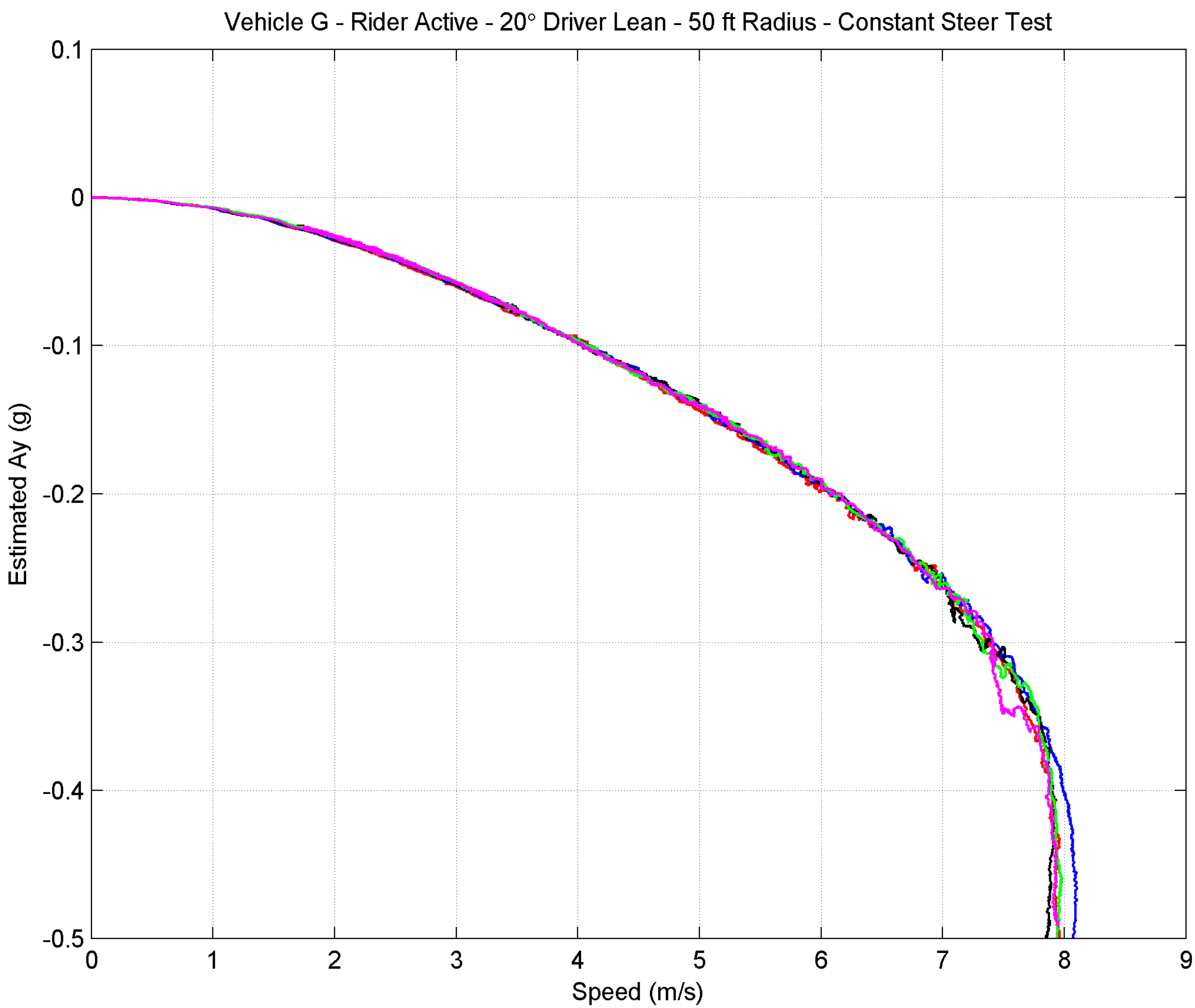
Vehicle G - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 8.4
CCW Ratios: 5.96 3.18 23.1 6.13 3.61 STD=8.33
CCW Final Slopes: -15.3 -7.89 -51.9 -15 -9.19 STD=18.2
CCW Initial Slopes: -2.57 -2.48 -2.24 -2.44 -2.55 STD=0.129

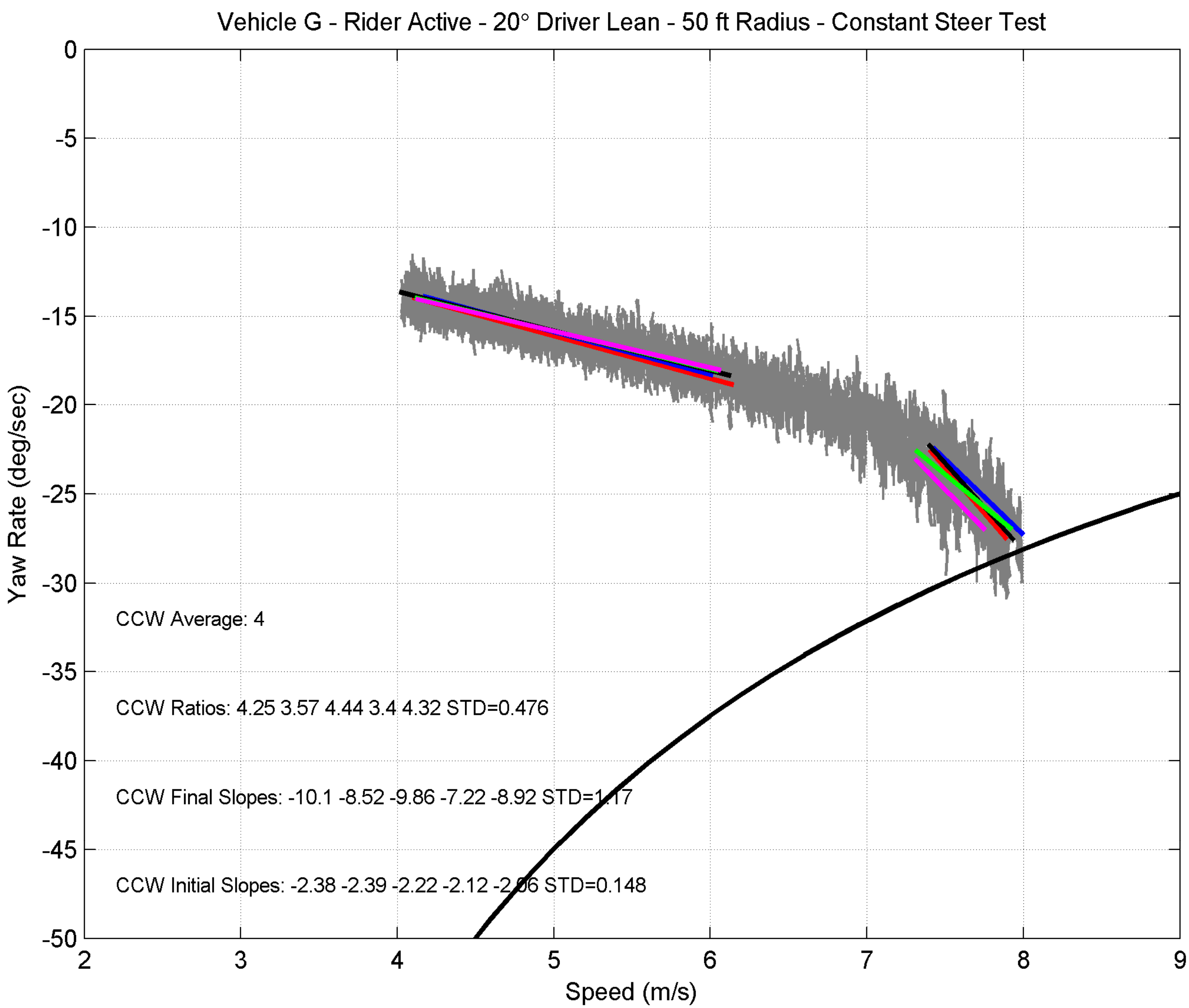

Vehicle G - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -15.3
Ratio: 5.96
Final Slope: -7.89
Ratio: 3.18
Final Slope: -51.9
Ratio: 23.1
Final Slope: -15
Ratio: 6.13
Final Slope: -9.19
Ratio: 3.61
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

Vehicle G - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



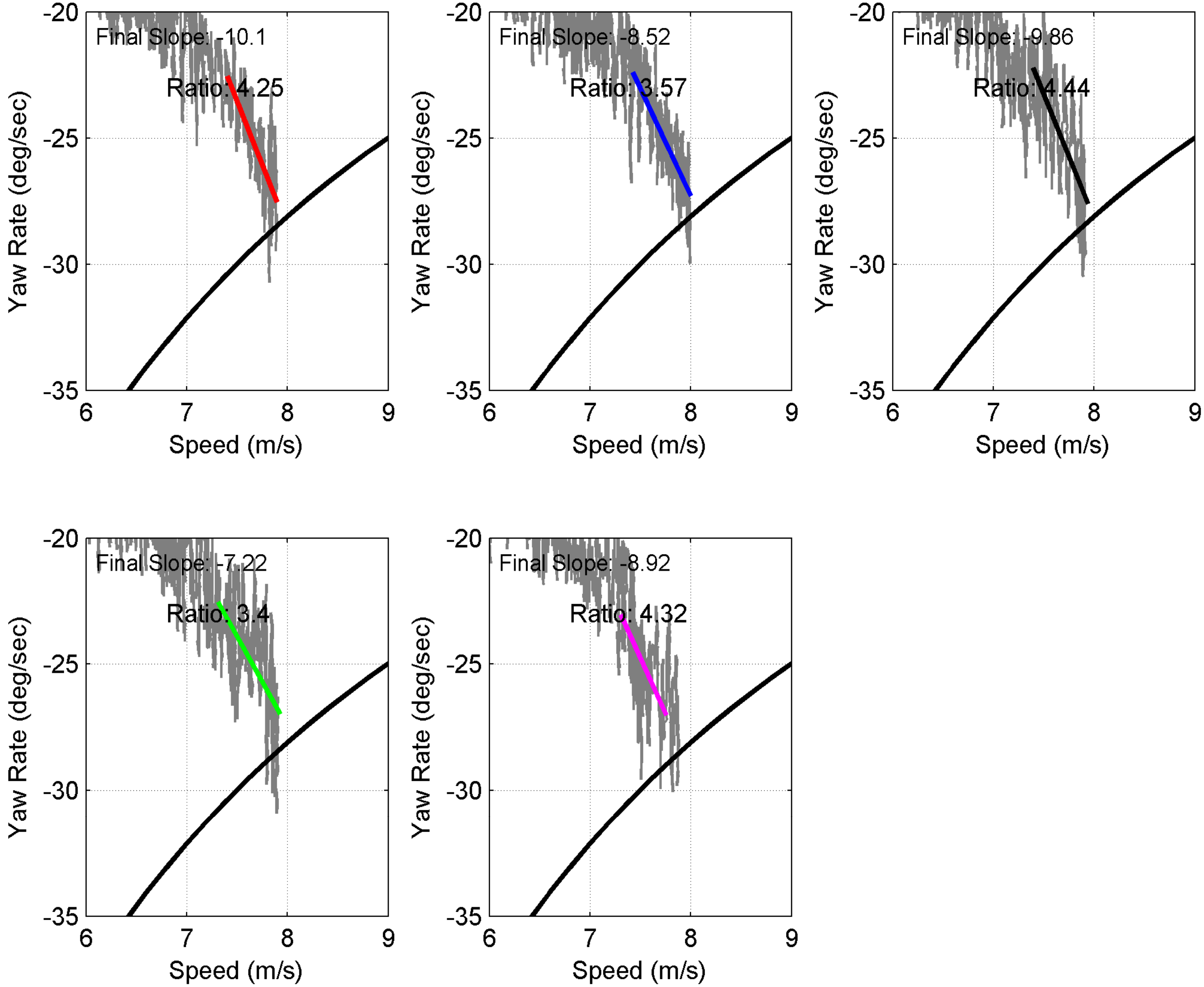

Vehicle G - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle G - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

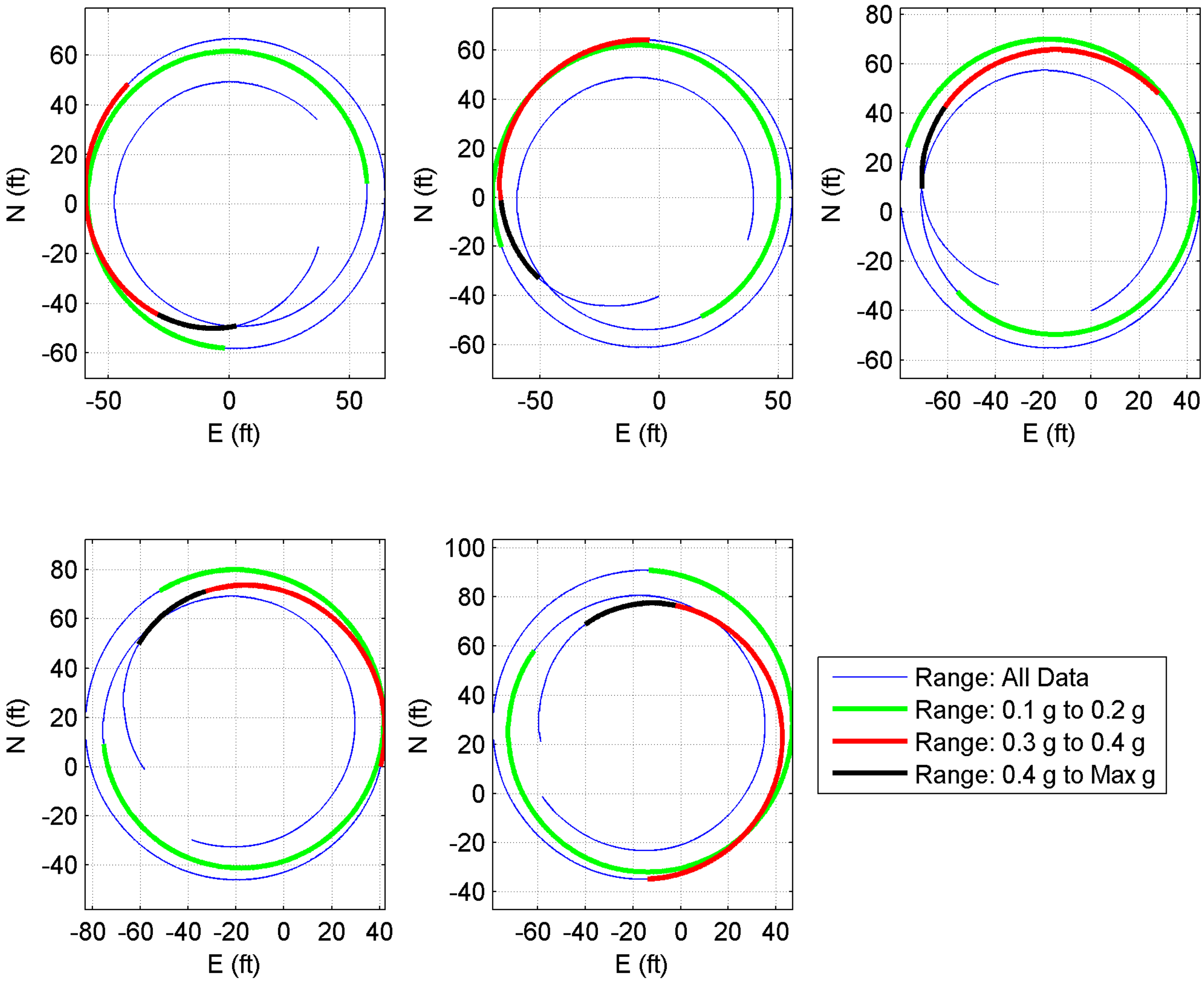


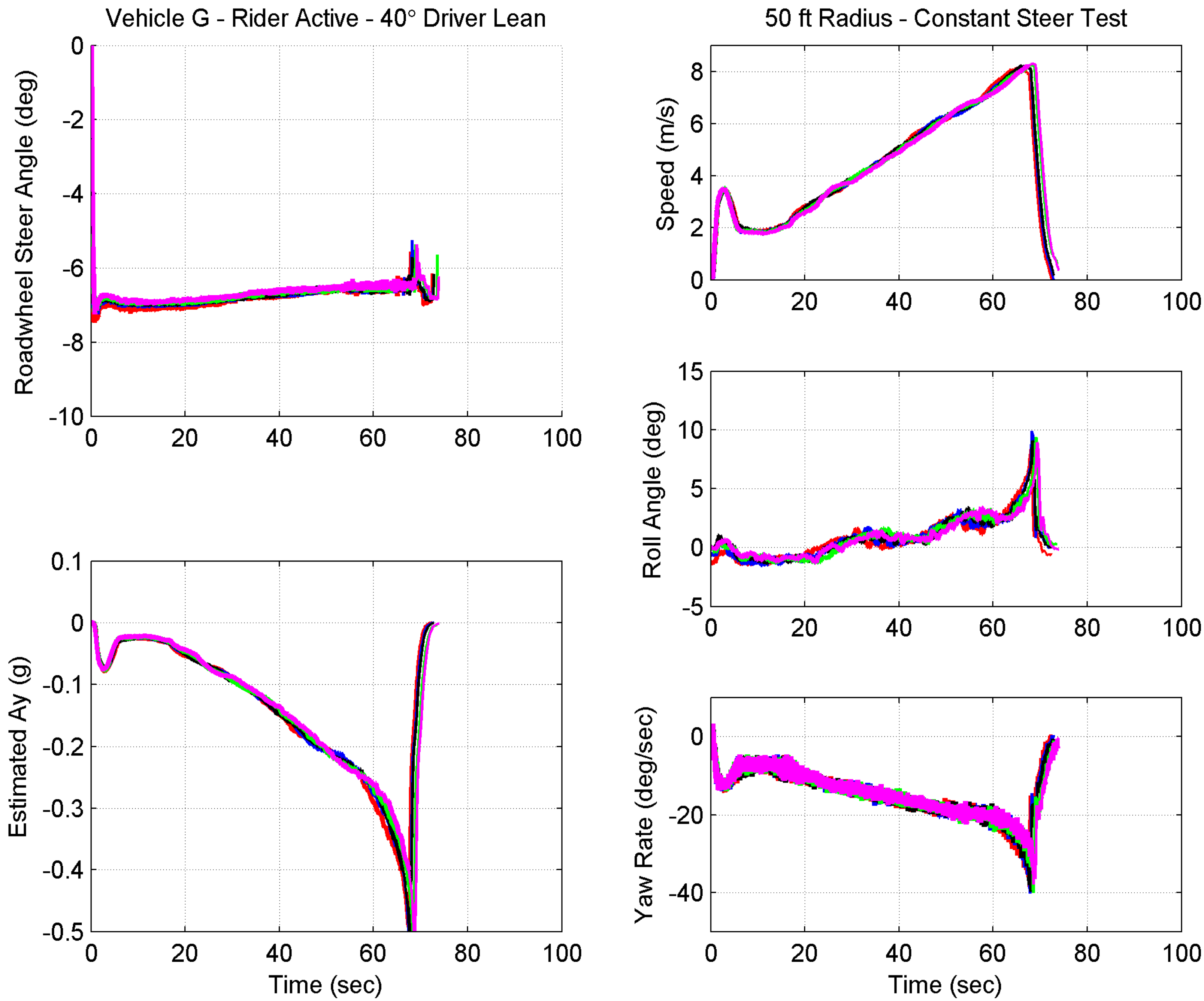
Vehicle G - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 4
CCW Ratios: 4.25 3.57 4.44 3.4 4.32 STD=0.476
CCW Final Slopes: -10.1 -8.52 -9.86 -7.22 -8.92 STD=1.17
CCW Initial Slopes: -2.38 -2.39 -2.22 -2.12 -2.06 STD=0.148

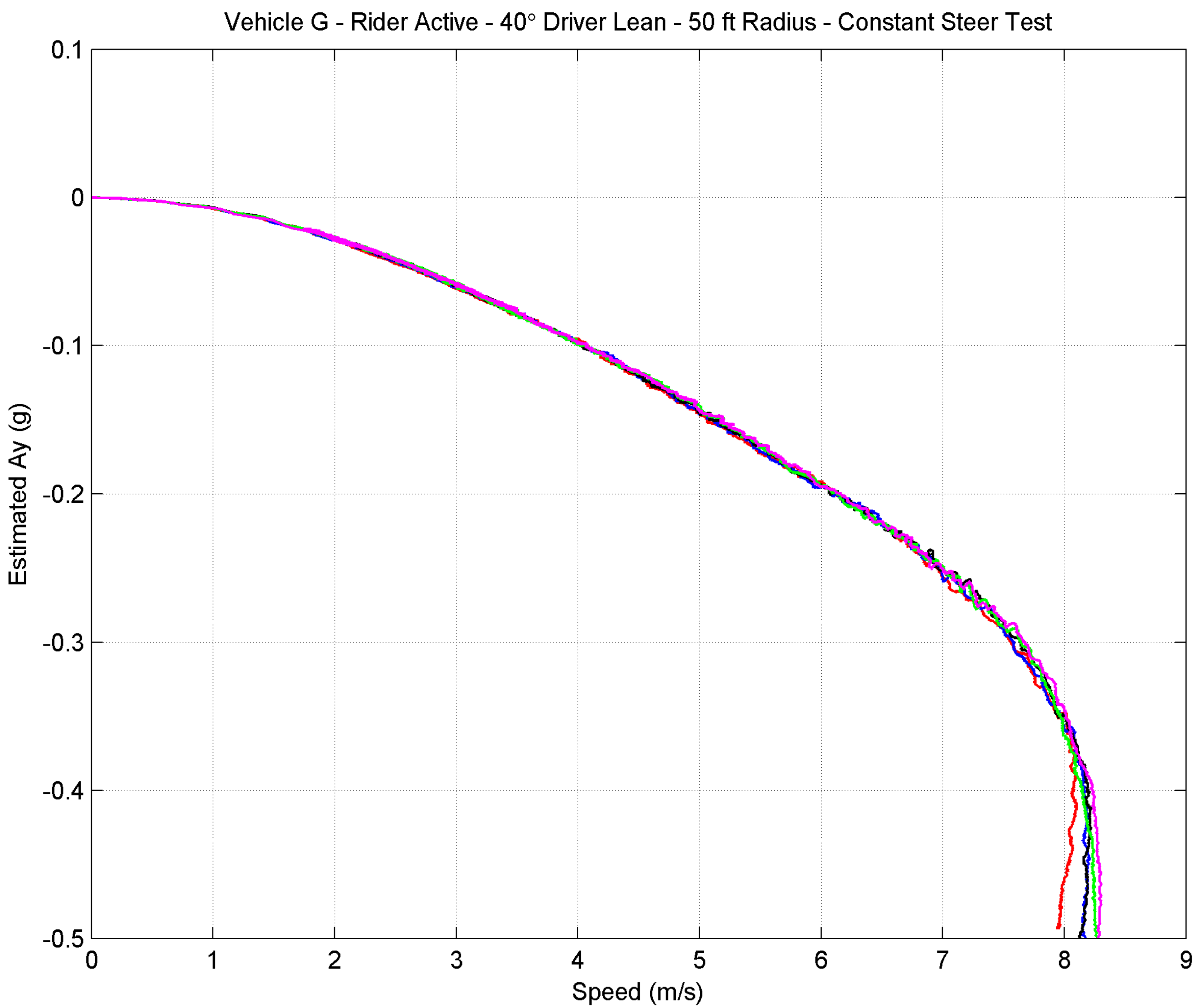
Vehicle G - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



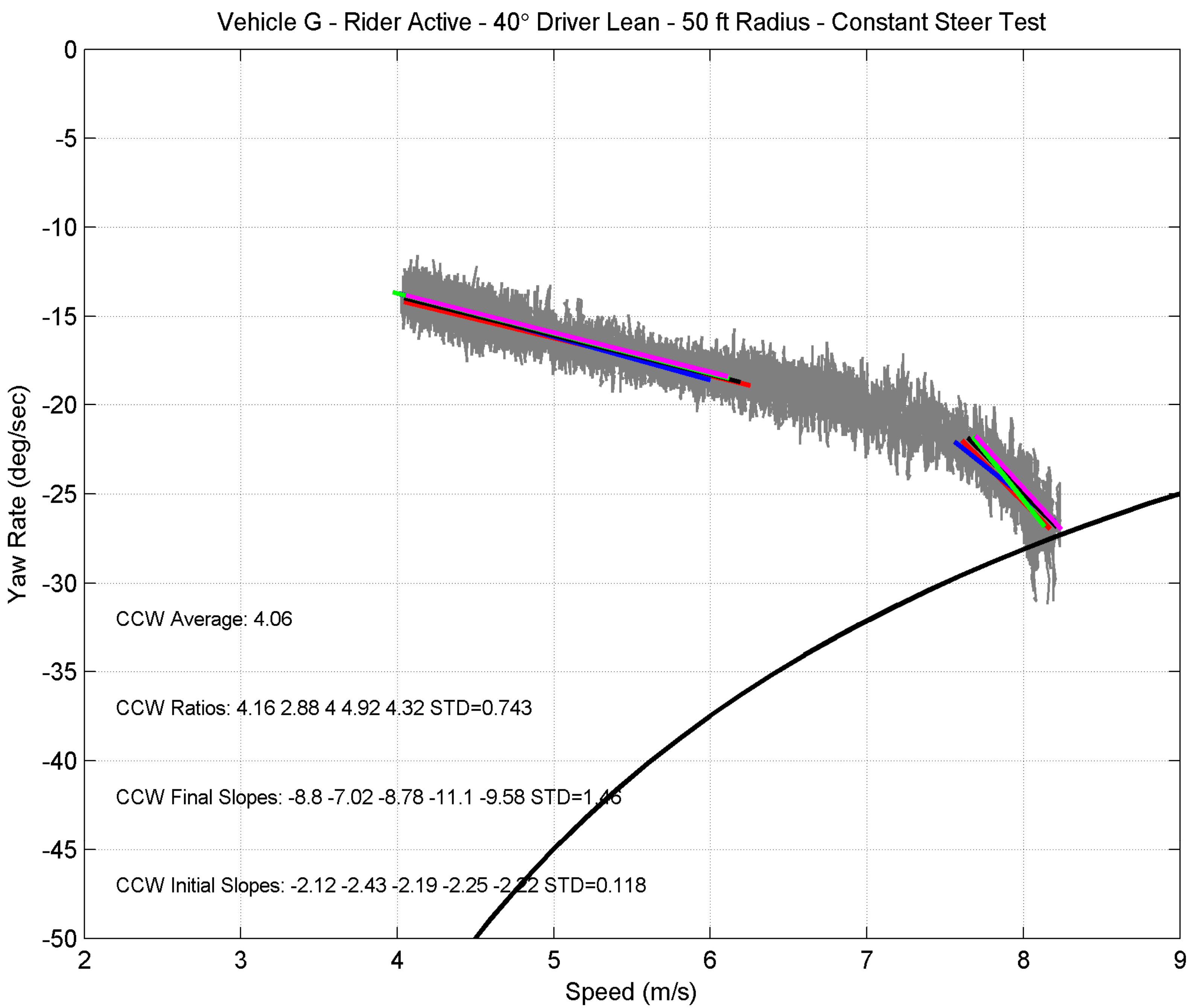
Vehicle G - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

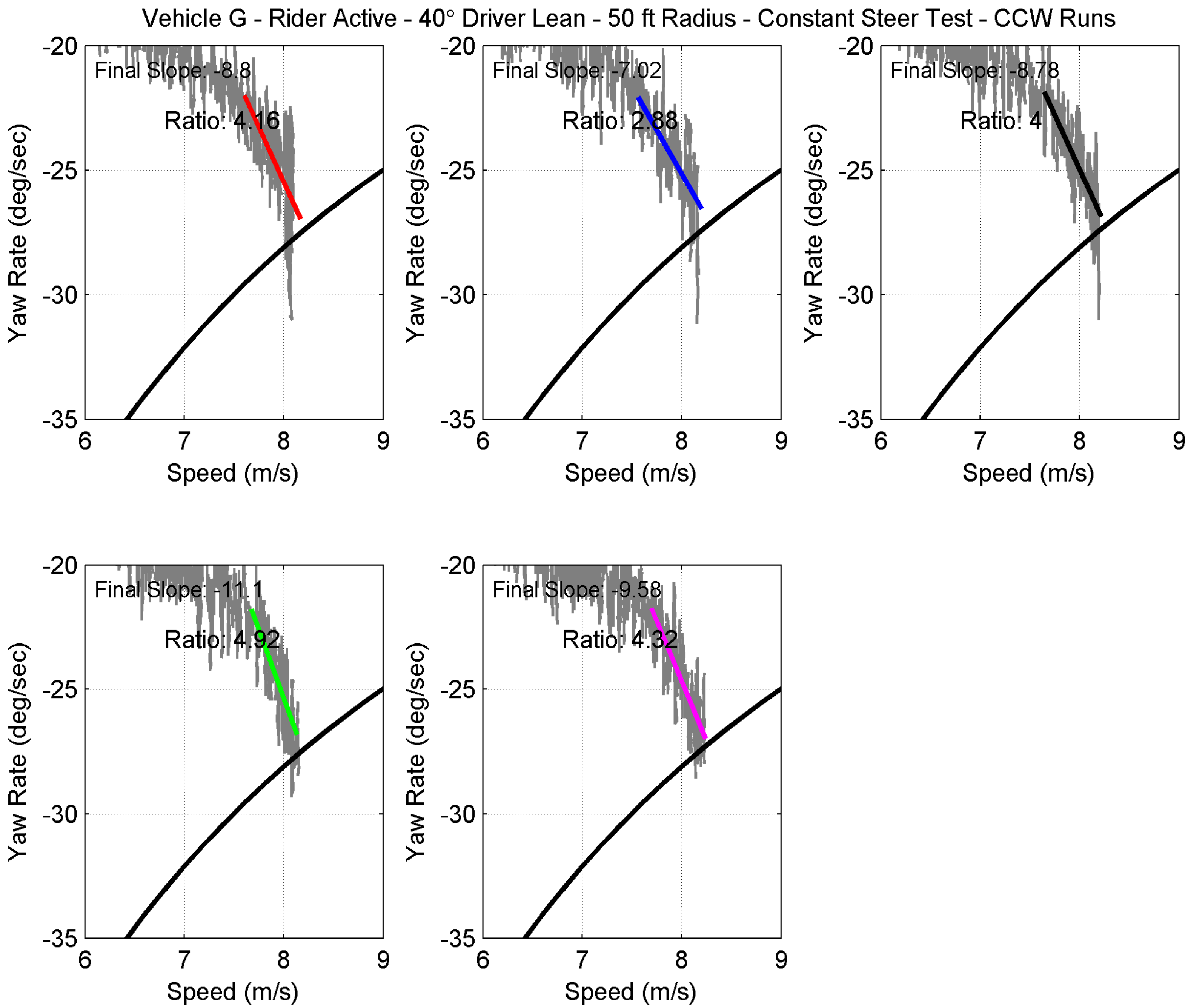


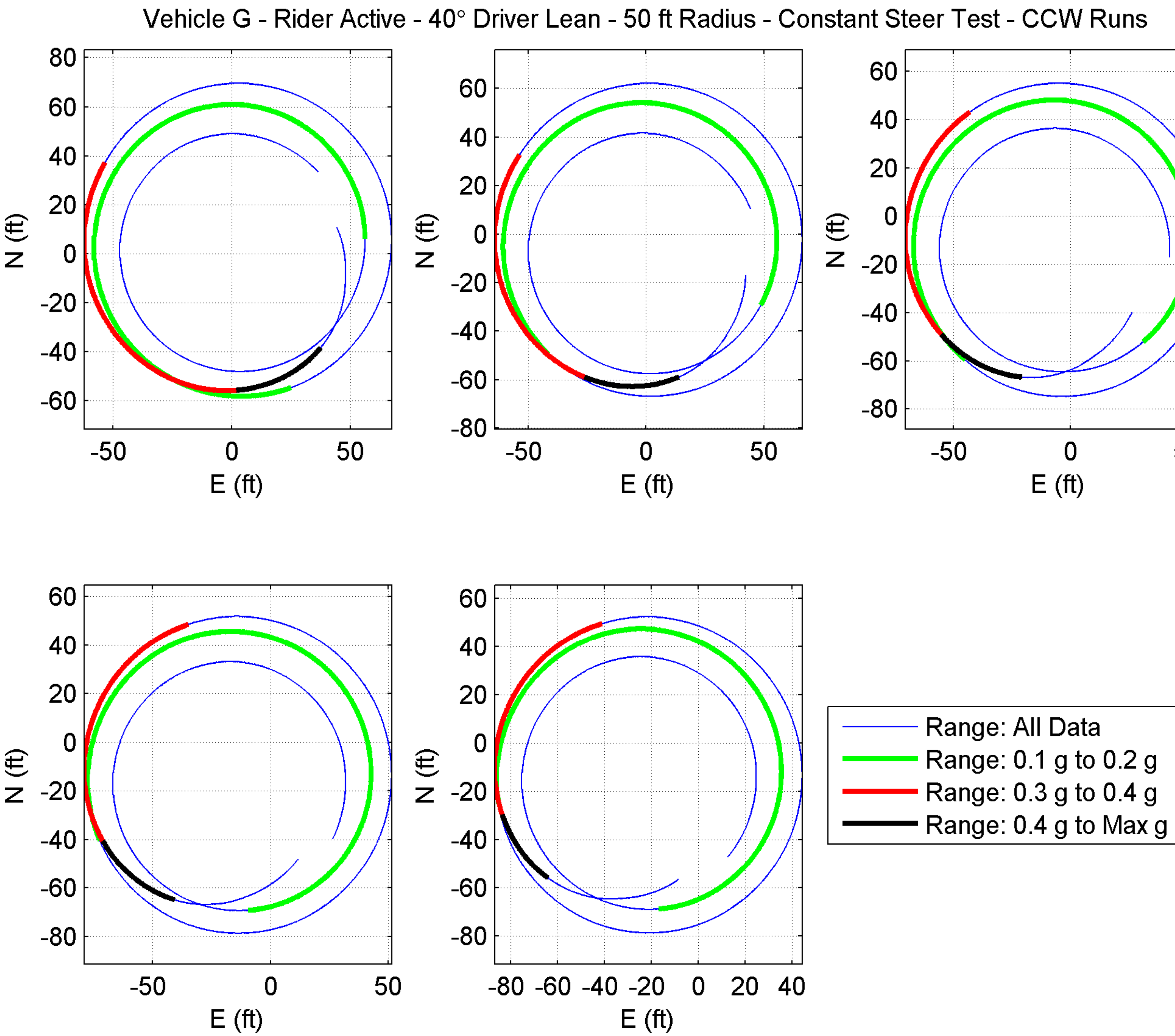

Vehicle G - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
0
-2
-4
-6
-8
-10
Speed (m/s)
8
6
4
2
0
Roll Angle (deg)
15
10
5
0
-5
Estimated Ay (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Yaw Rate (deg/sec)
0
-20
-40
0
20
40
60
80
100
Time (sec)
Time (sec)

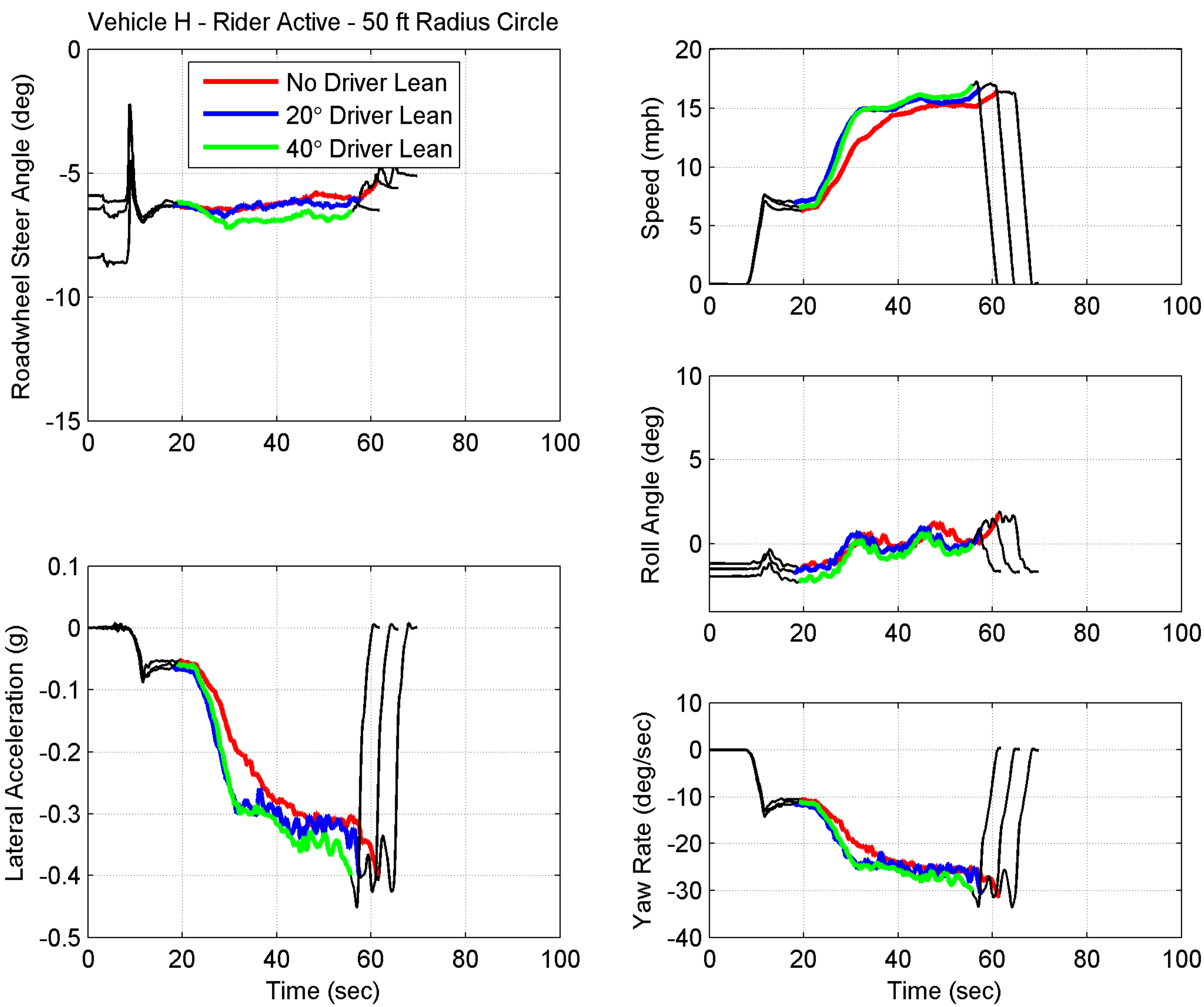


Vehicle G - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

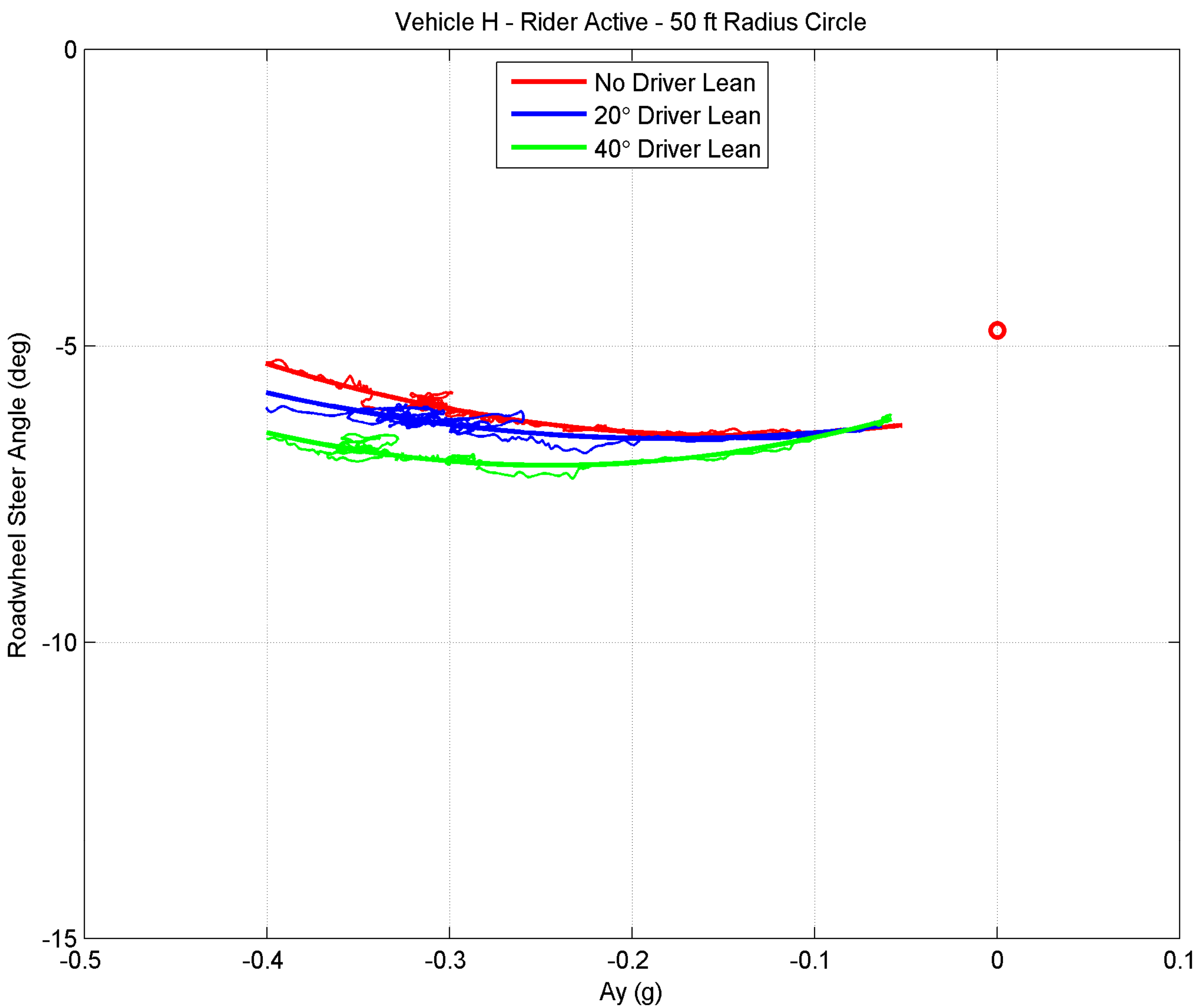

Vehicle G - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 4.06
CCW Ratios: 4.16 2.88 4 4.92 4.32 STD=0.743
CCW Final Slopes: -8.8 -7.02 -8.78 -11.1 -9.58 STD=1.46
CCW Initial Slopes: -2.12 -2.43 -2.19 -2.25 -2.22 STD=0.118

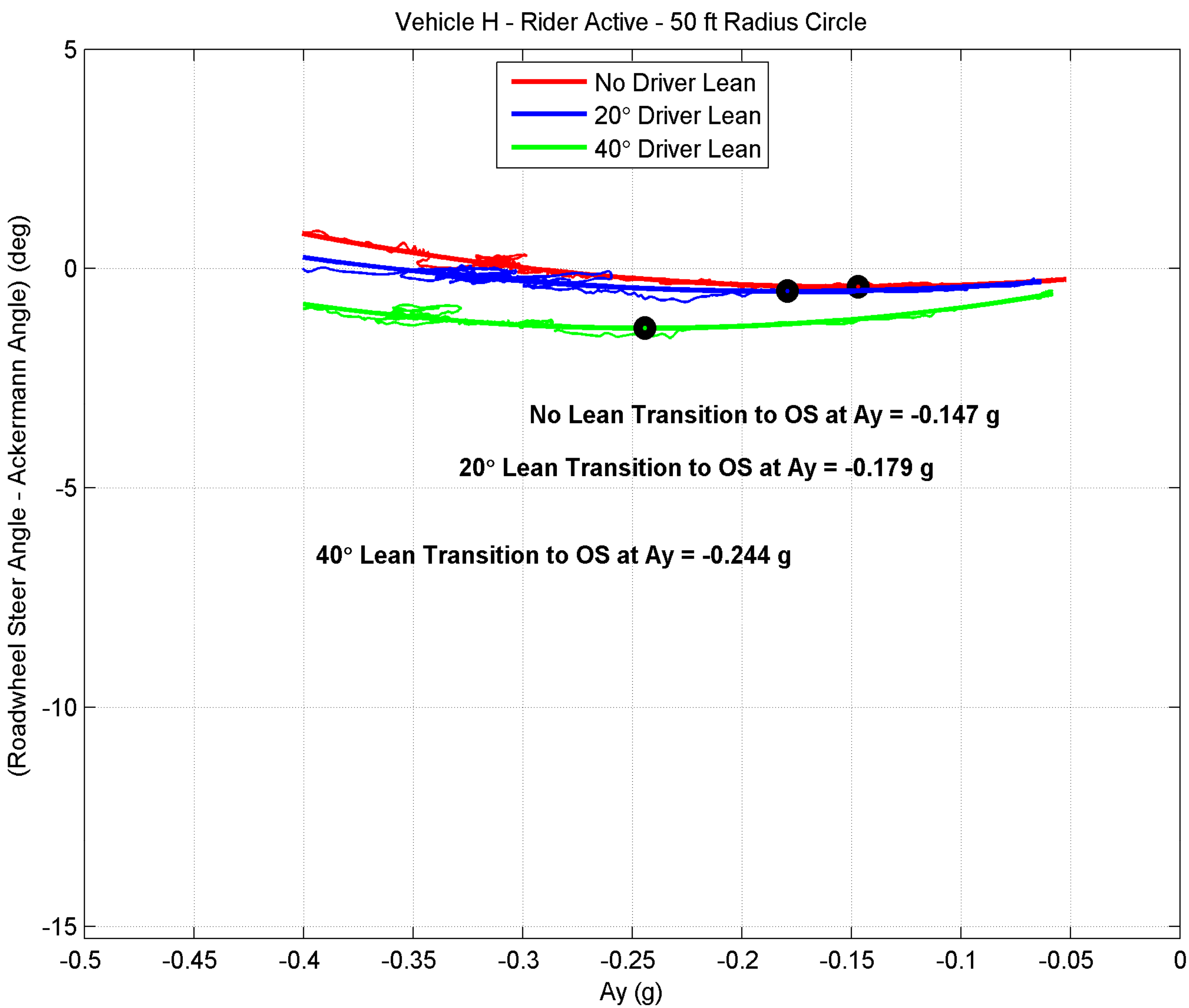

Vehicle G - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -8.8
Ratio: 4.16
Final Slope: -7.02
Ratio: 2.88
Final Slope: -8.78
Ratio: 4
Final Slope: -11.1
Ratio: 4.92
Final Slope: -9.58
Ratio: 4.32
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

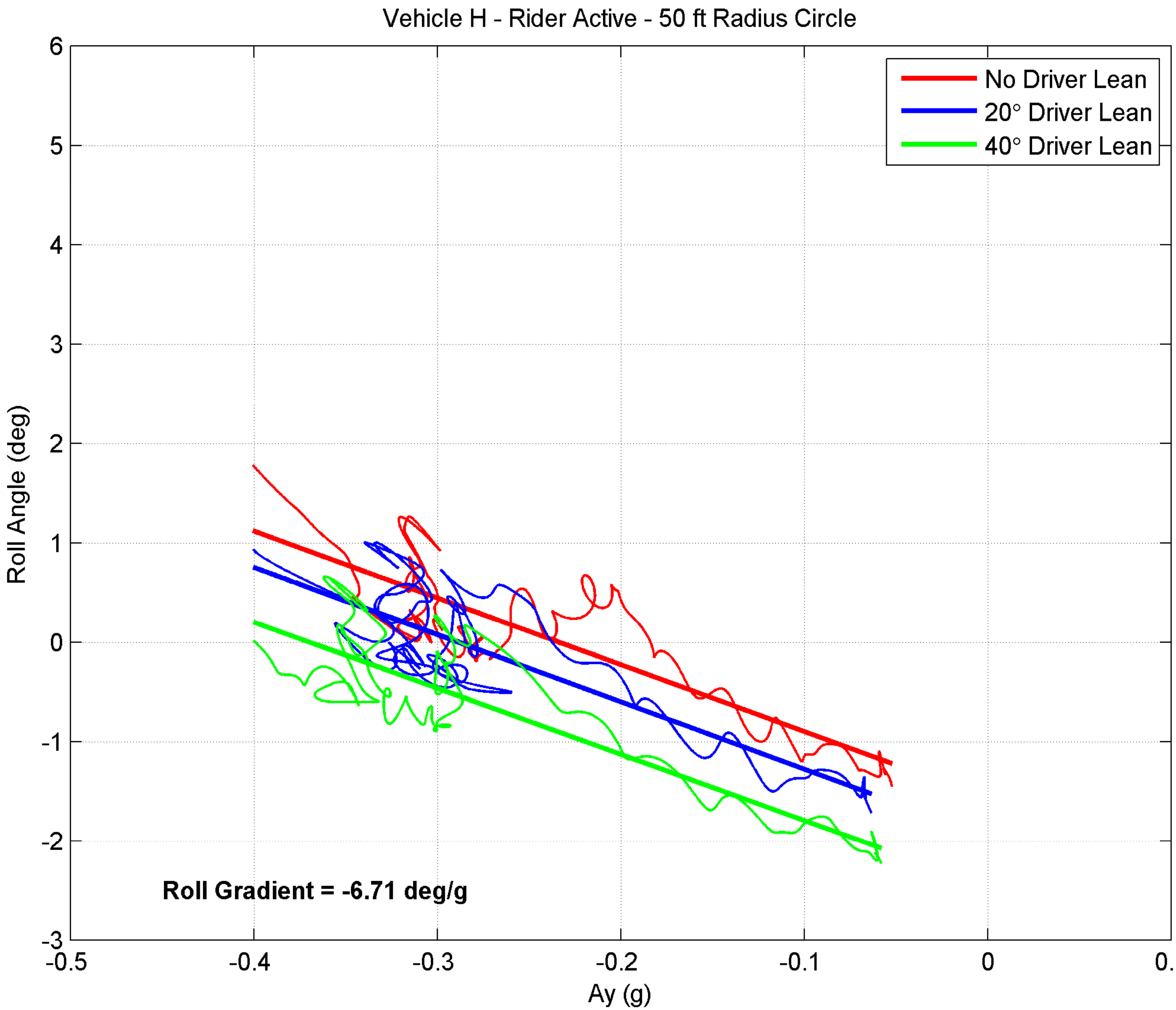

Vehicle G - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



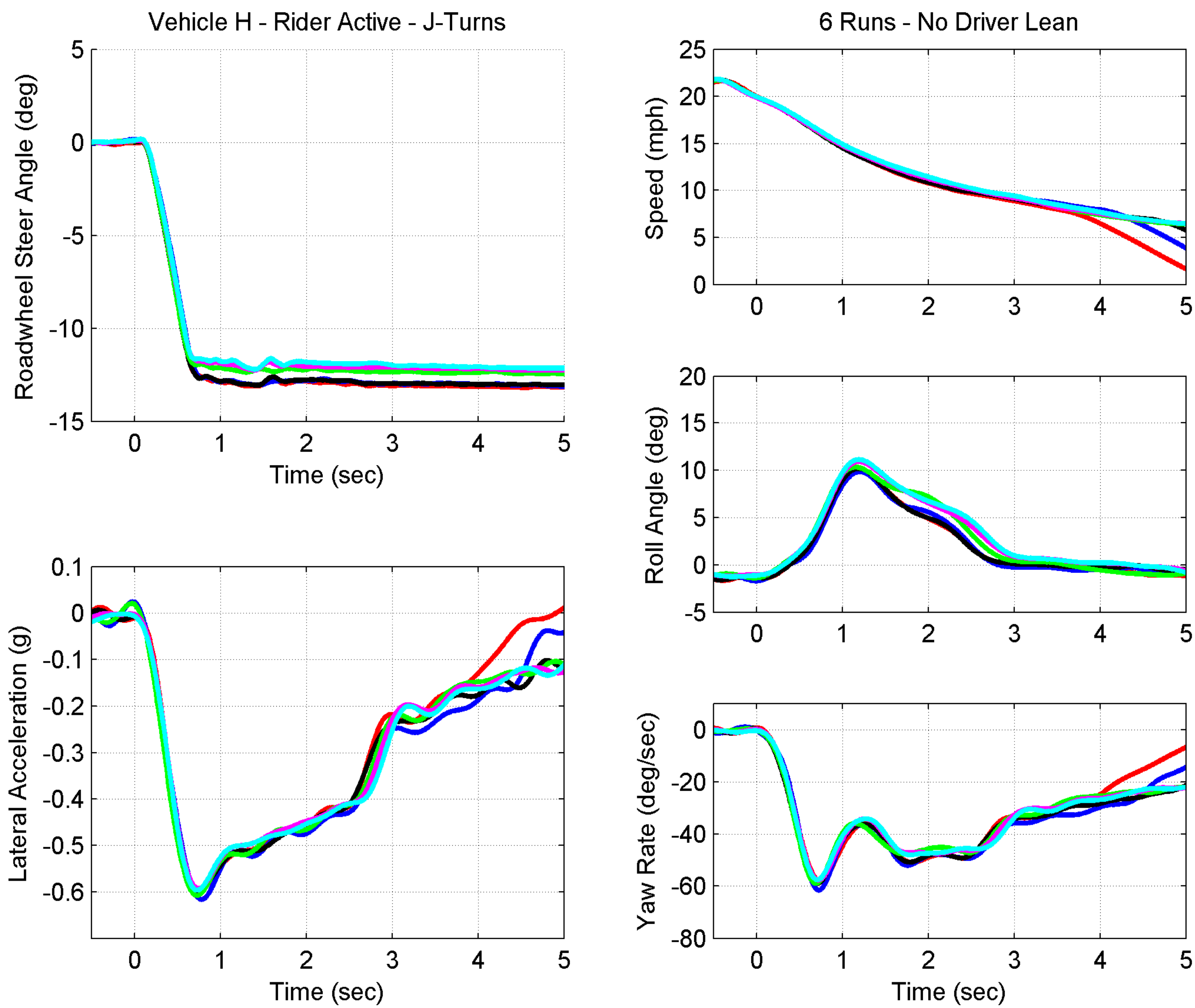
Vehicle H - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
0
20
40
60
80
100
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Time (sec)
Speed (mph)
20
15
10
5
0
Roll Angle (deg)
10
5
0
Yaw Rate (deg/sec)
10
0
-10
-20
-30
-40
Time (sec)


Vehicle H - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)

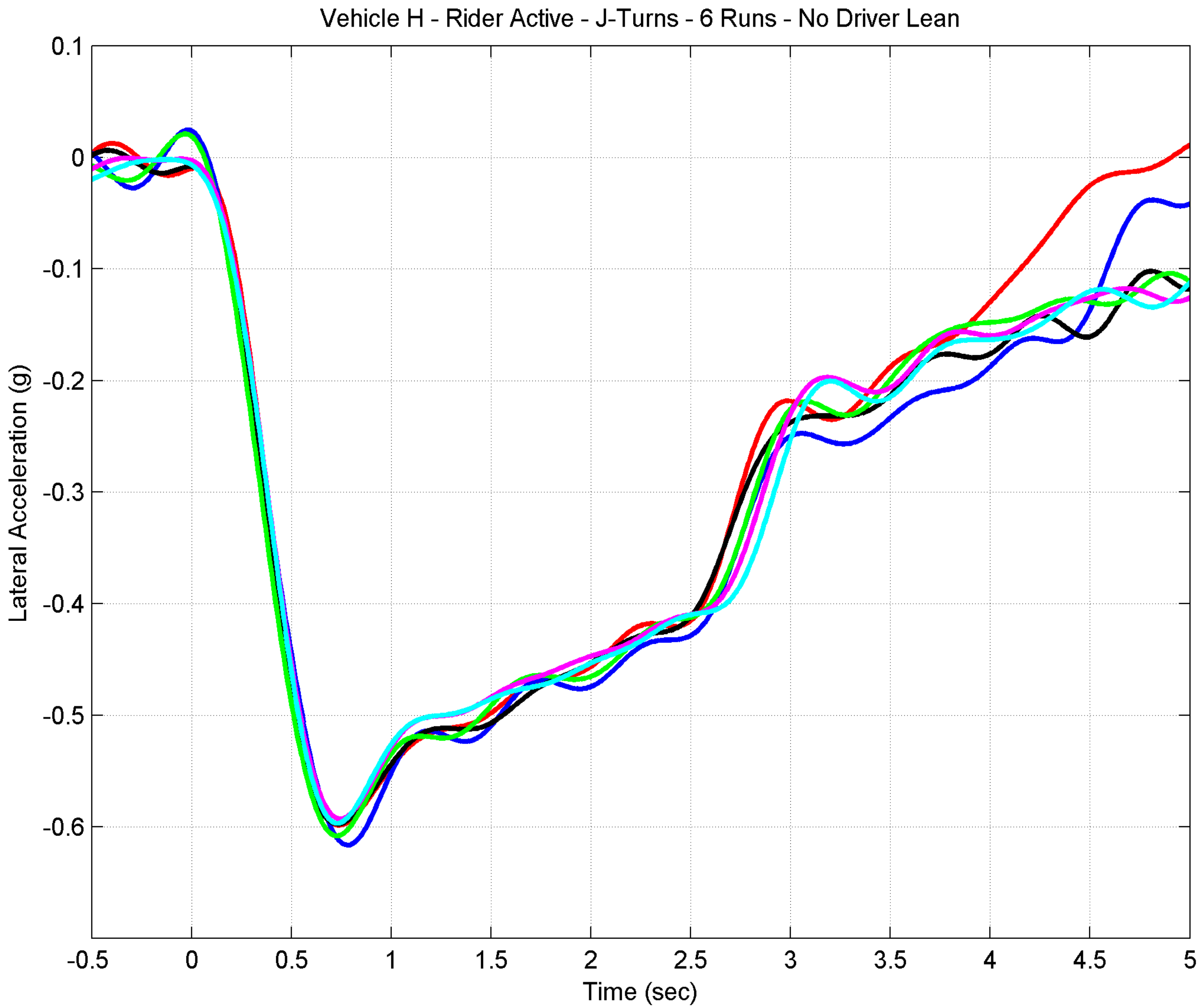

Vehicle H - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.147 g
20° Lean Transition to OS at Ay = -0.179 g
40° Lean Transition to OS at Ay = -0.244 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

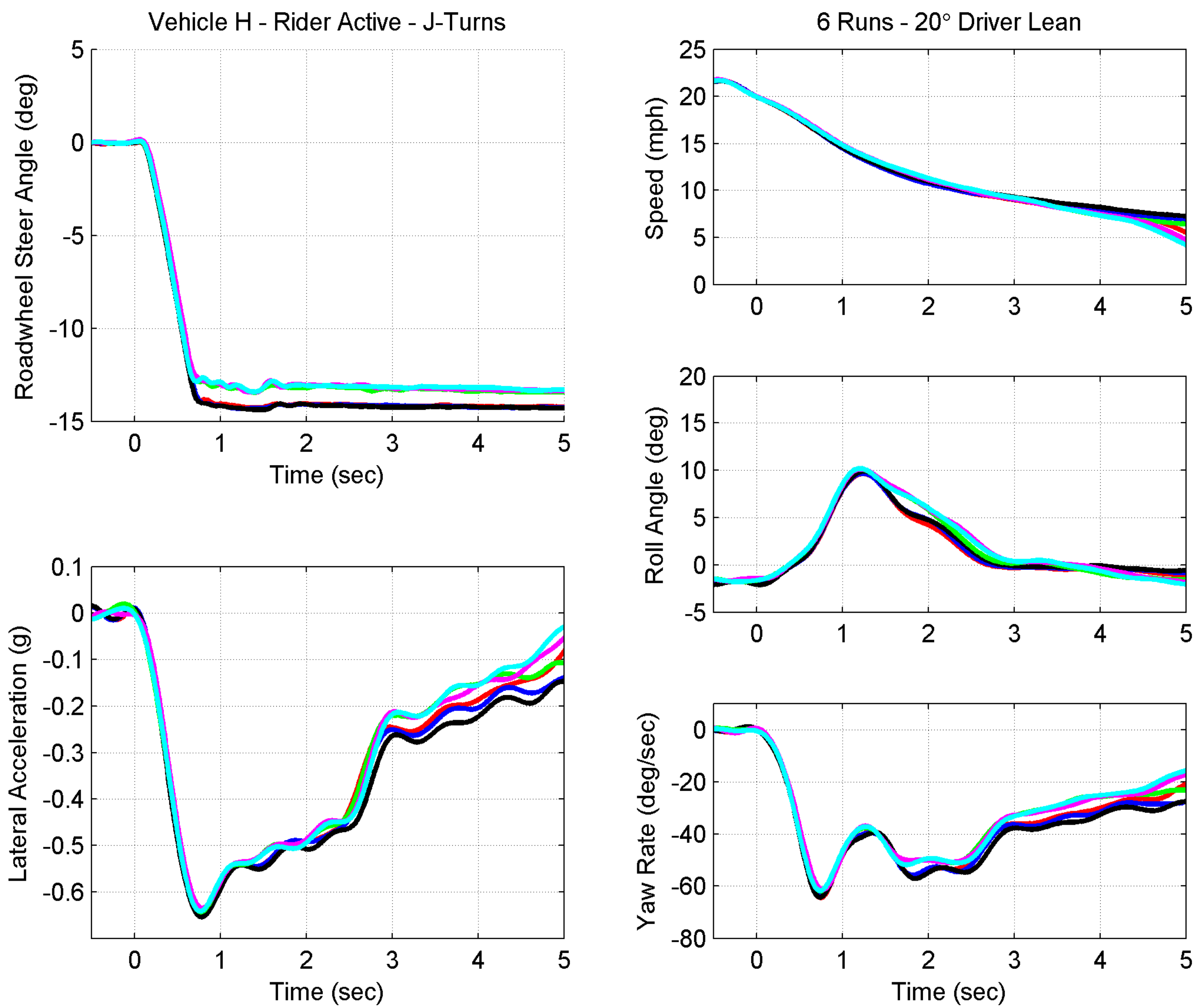


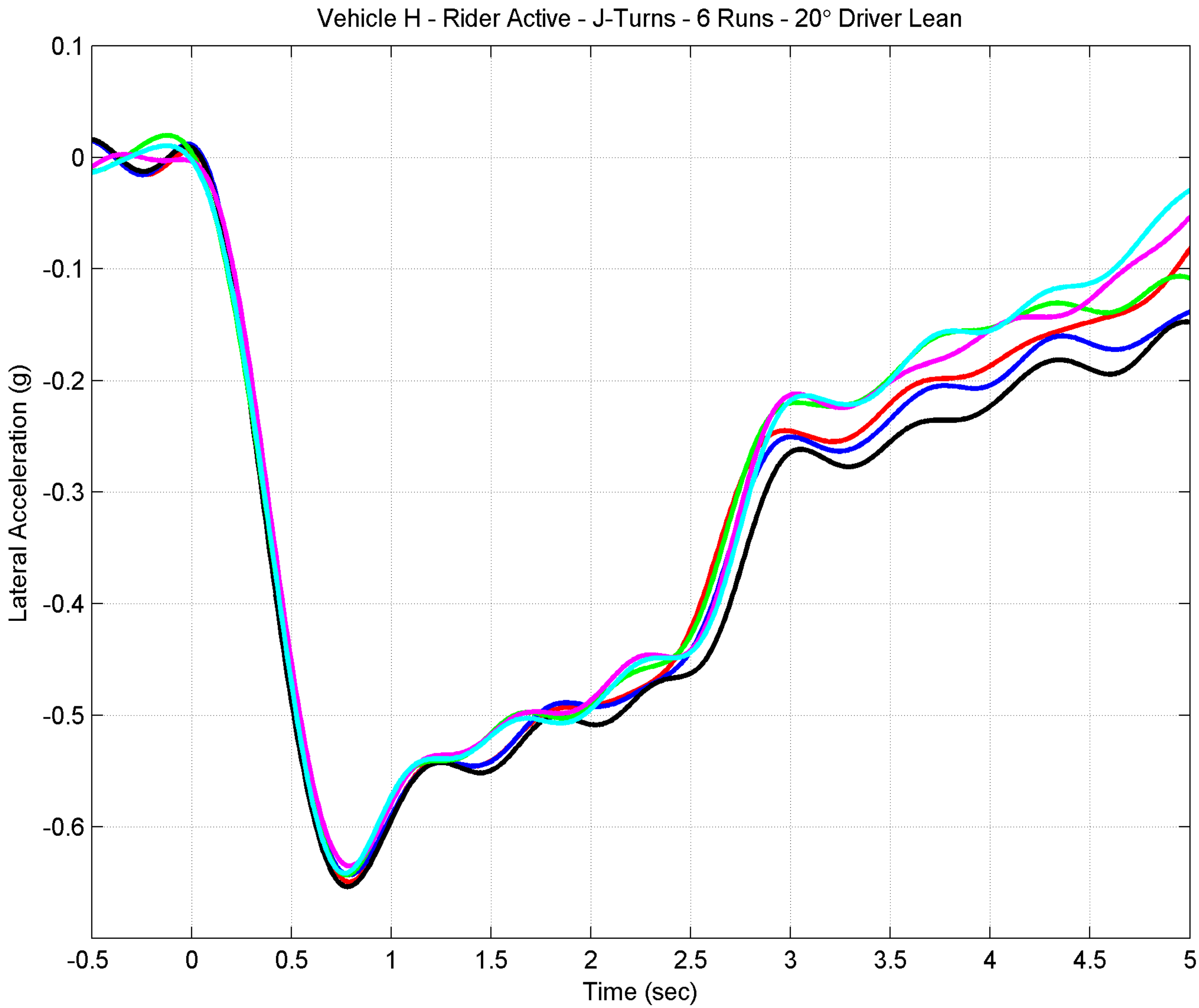
Vehicle H - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Gradient = -6.71 deg/g
Roll Angle (deg)
Ay (g)
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

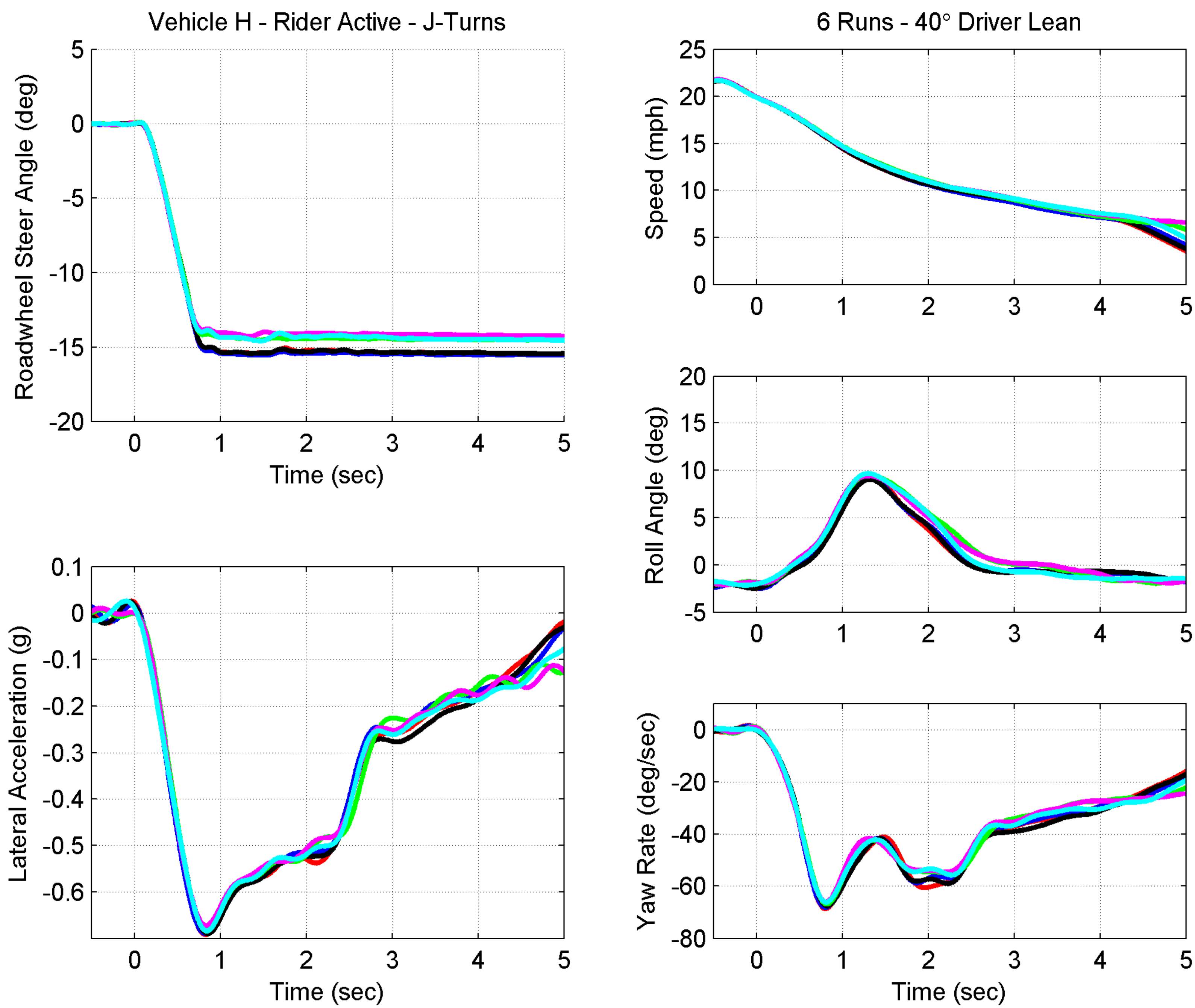


Vehicle H - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)

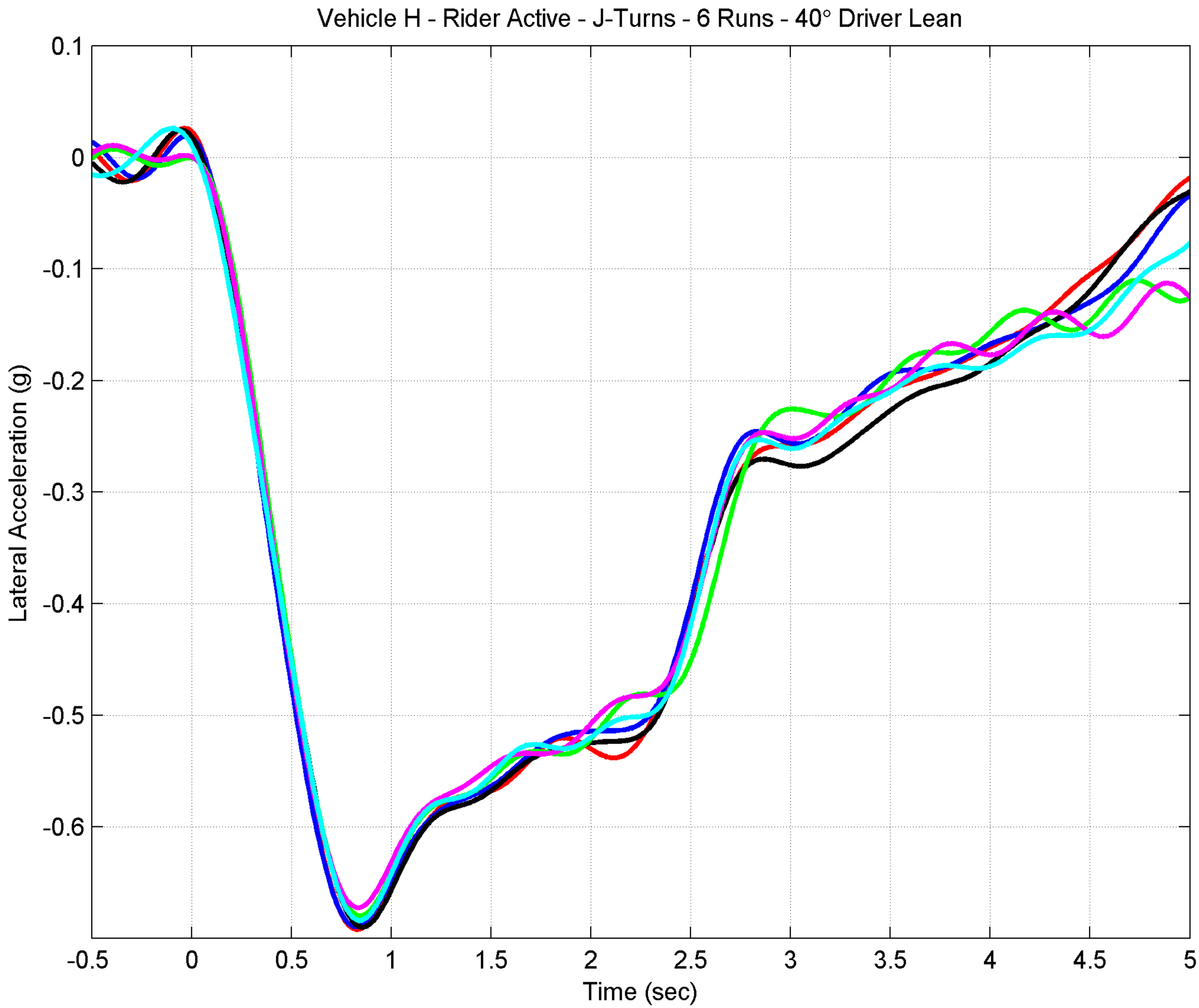

Vehicle H - Rider Active - J-Turns - 6 Runs - No Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle H - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Lateral Acceleration (g)
Time (sec)
Speed (mph)
Roll Angle (deg)
Yaw Rate (deg/sec)
Time (sec)


Vehicle H - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle H - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)



Vehicle H - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

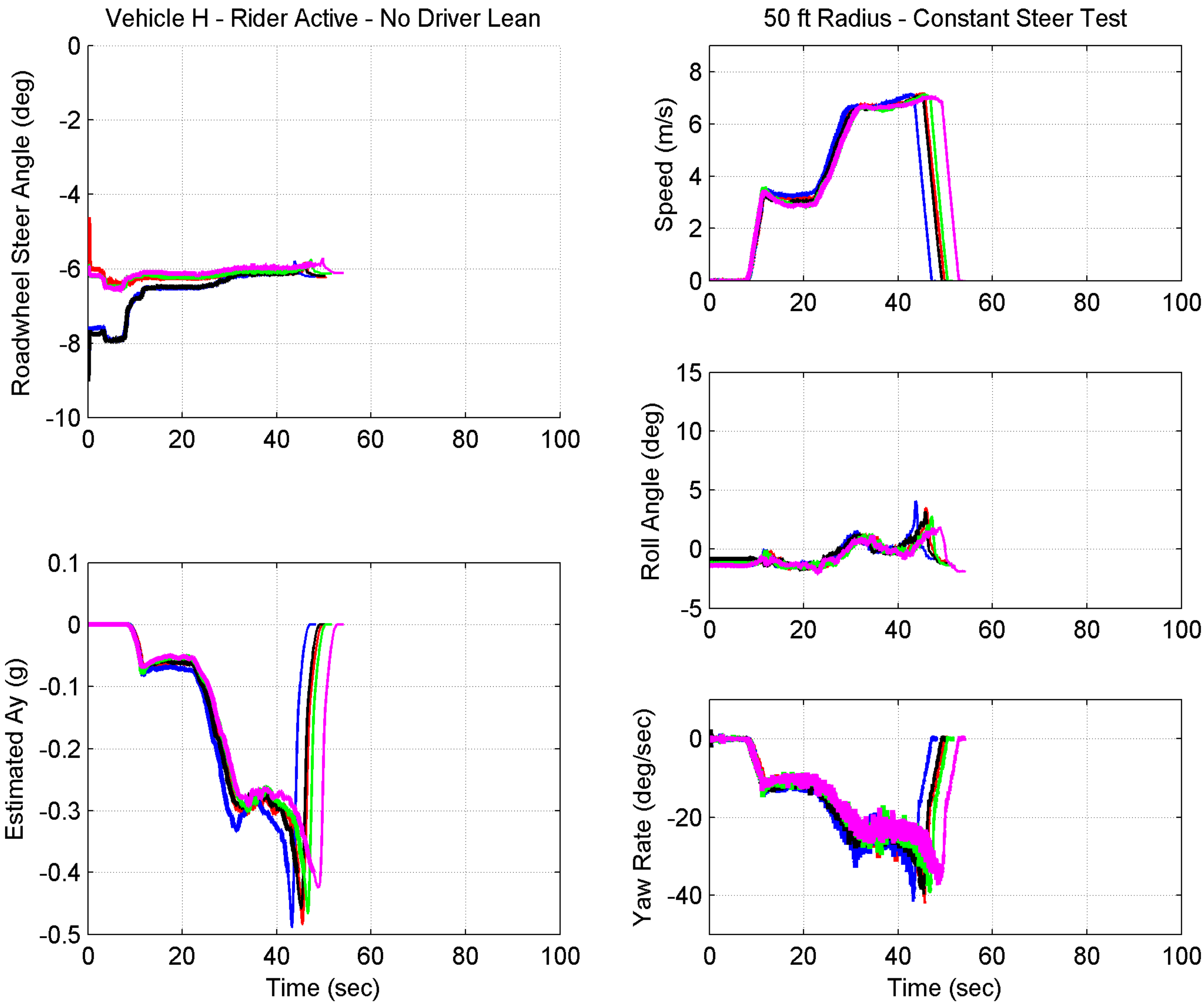
Vehicle H - Rider Active Results

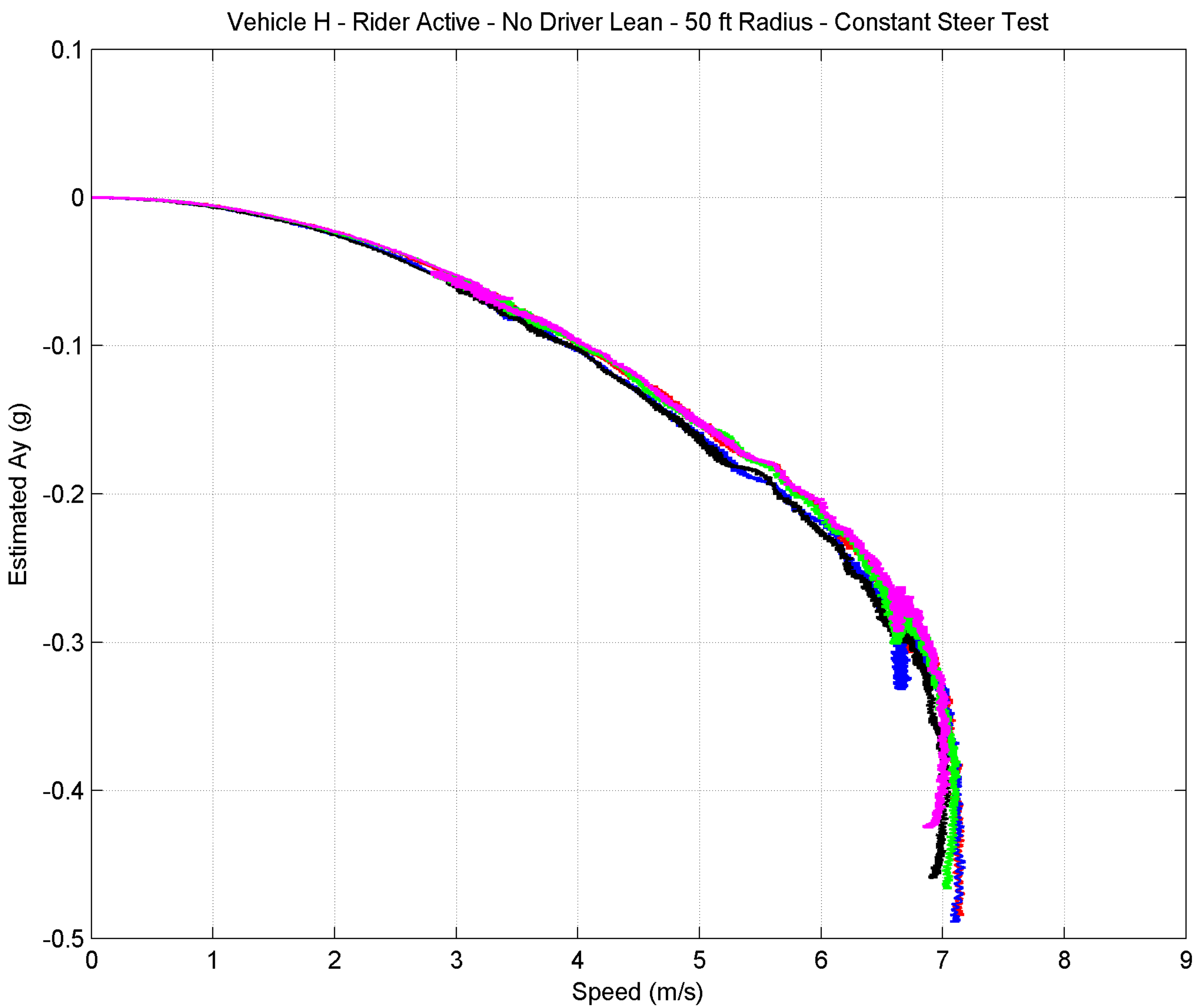
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

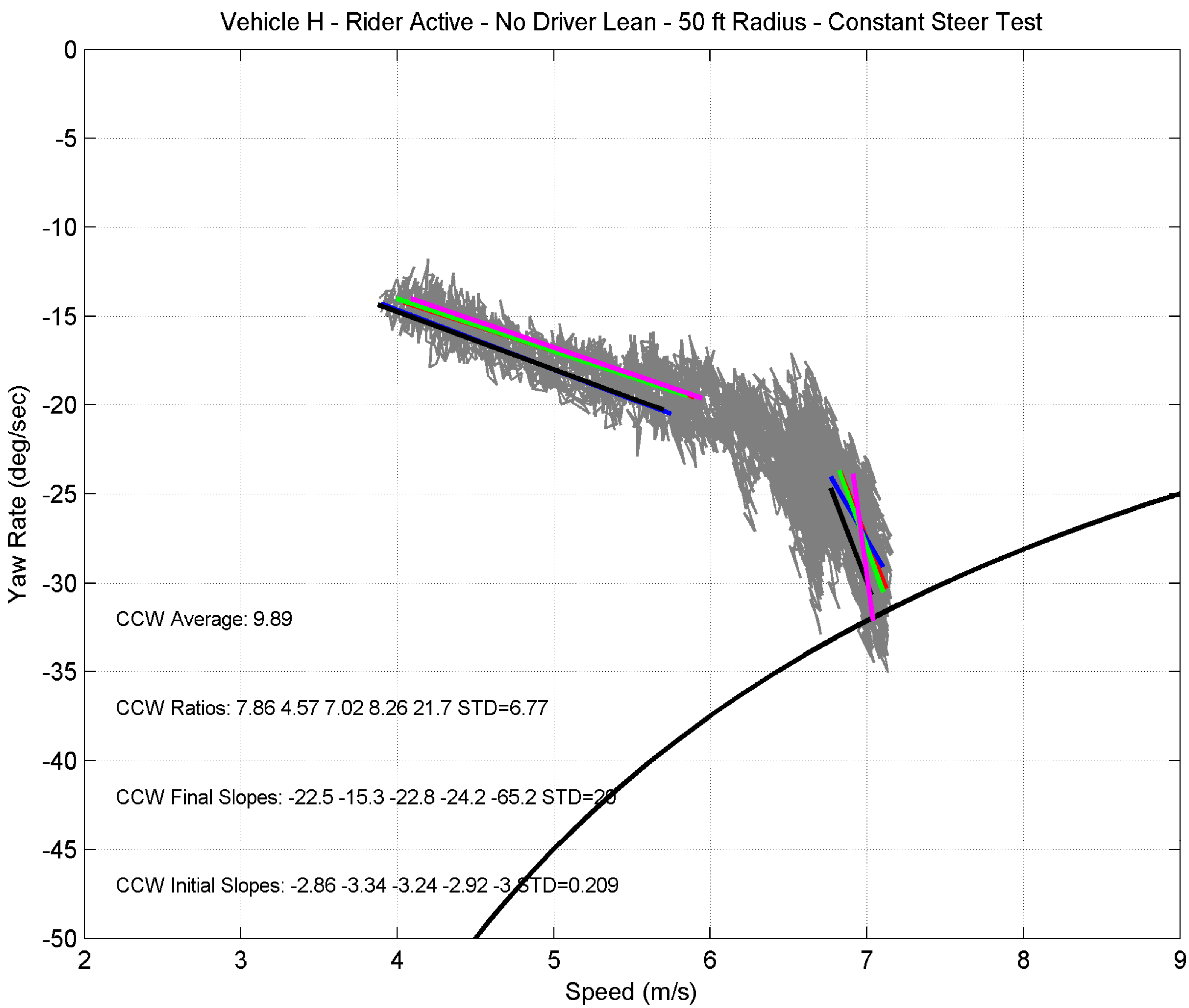
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.599	-0.650	-0.692
	-0.617	-0.643	-0.690
	-0.597	-0.654	-0.690
Mean Value of 3 Runs	-0.604	-0.649	-0.691
Standard Deviation of 3 Runs	0.011	0.005	0.001

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.608	-0.643	-0.680
	-0.593	-0.635	-0.673
	-0.597	-0.642	-0.684
Mean Value of 3 Runs	-0.599	-0.640	-0.679
Standard Deviation of 3 Runs	0.008	0.004	0.006

Average of All 6 Runs	**0.602**	**0.645**	**0.685**

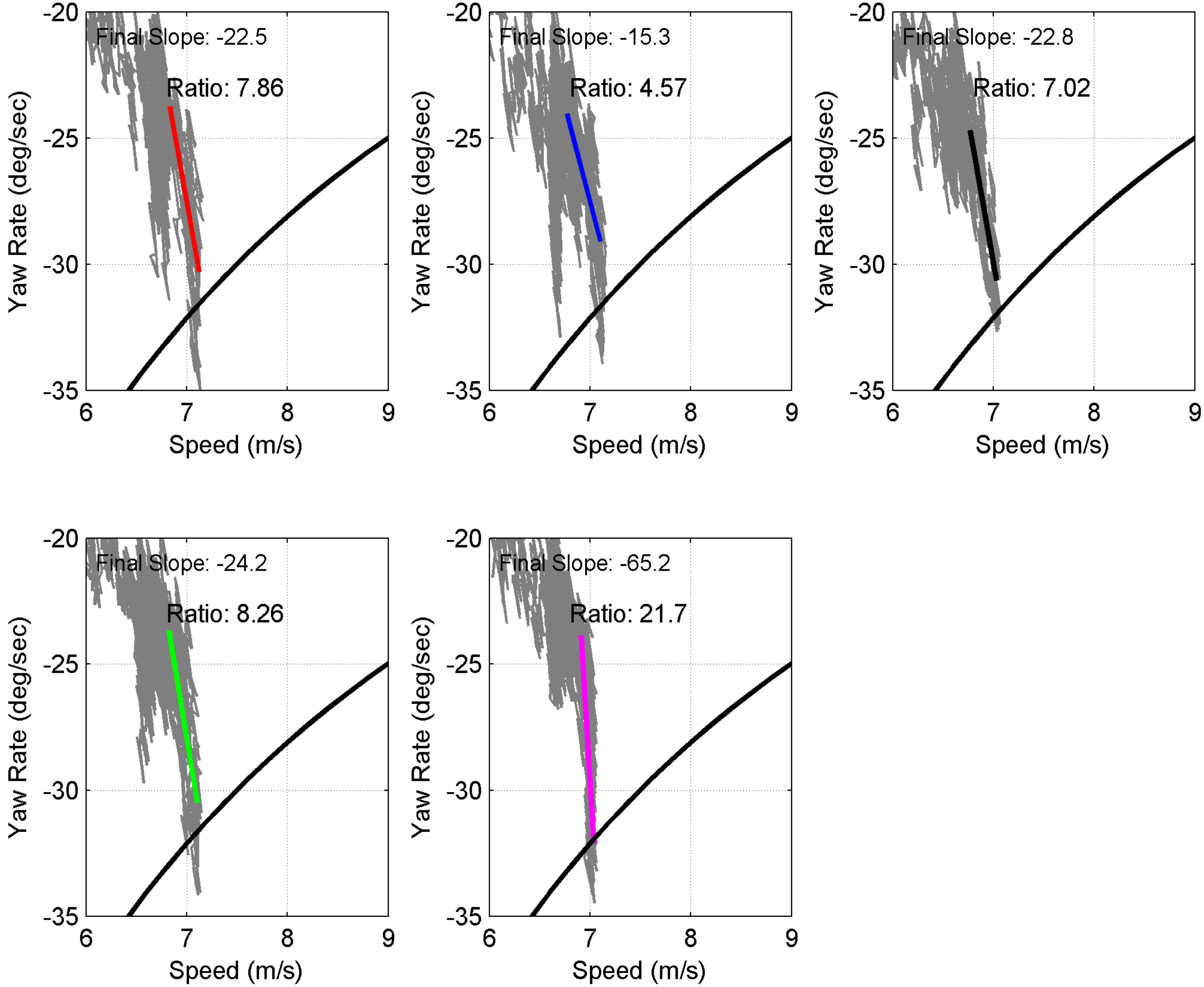

Vehicle H - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

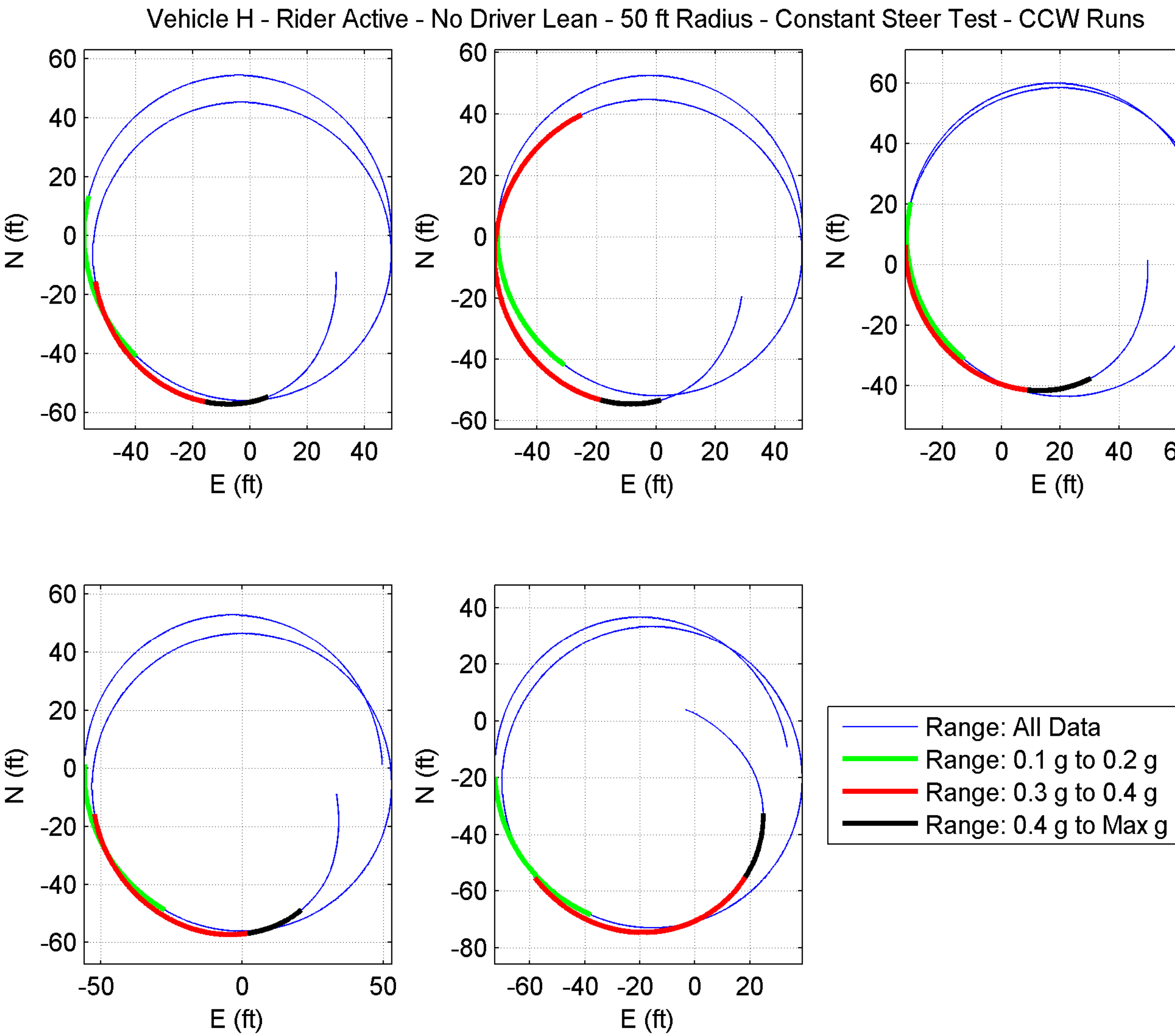

Vehicle H - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9



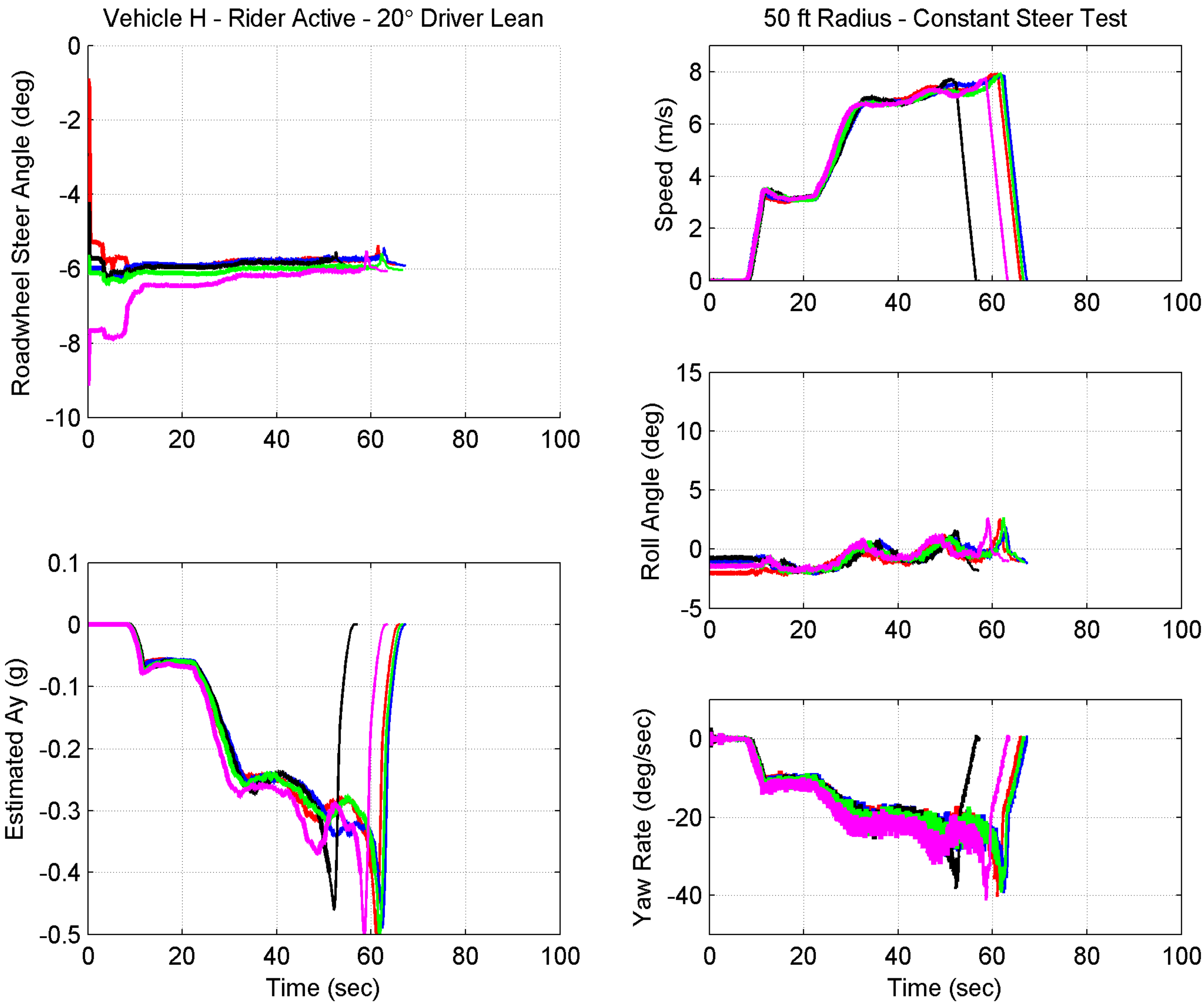
Vehicle H - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 9.89
CCW Ratios: 7.86 4.57 7.02 8.26 21.7 STD=6.77
CCW Final Slopes: -22.5 -15.3 -22.8 -24.2 -65.2 STD=20
CCW Initial Slopes: -2.86 -3.34 -3.24 -2.92 -3 STD=0.209

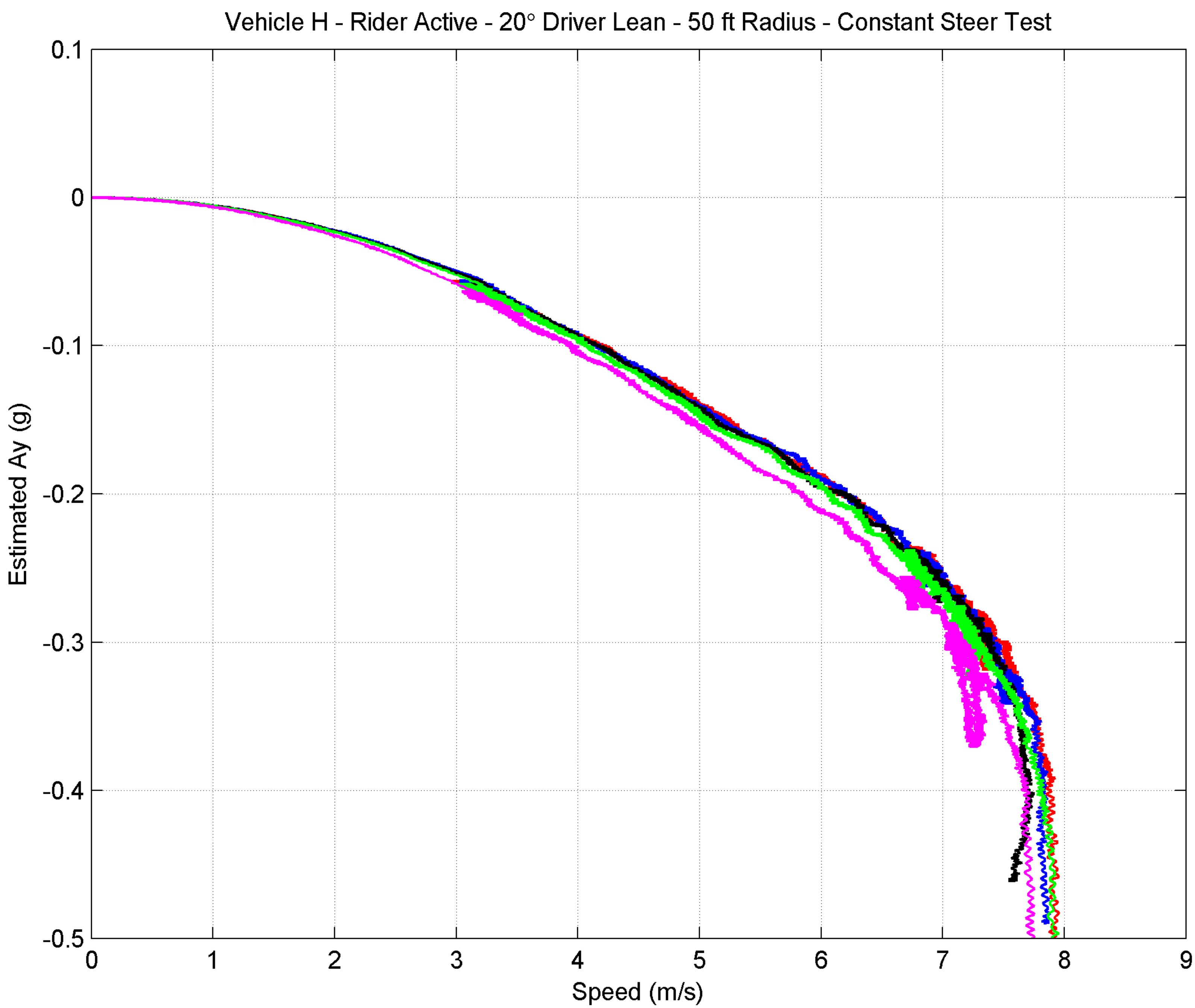
Vehicle H - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



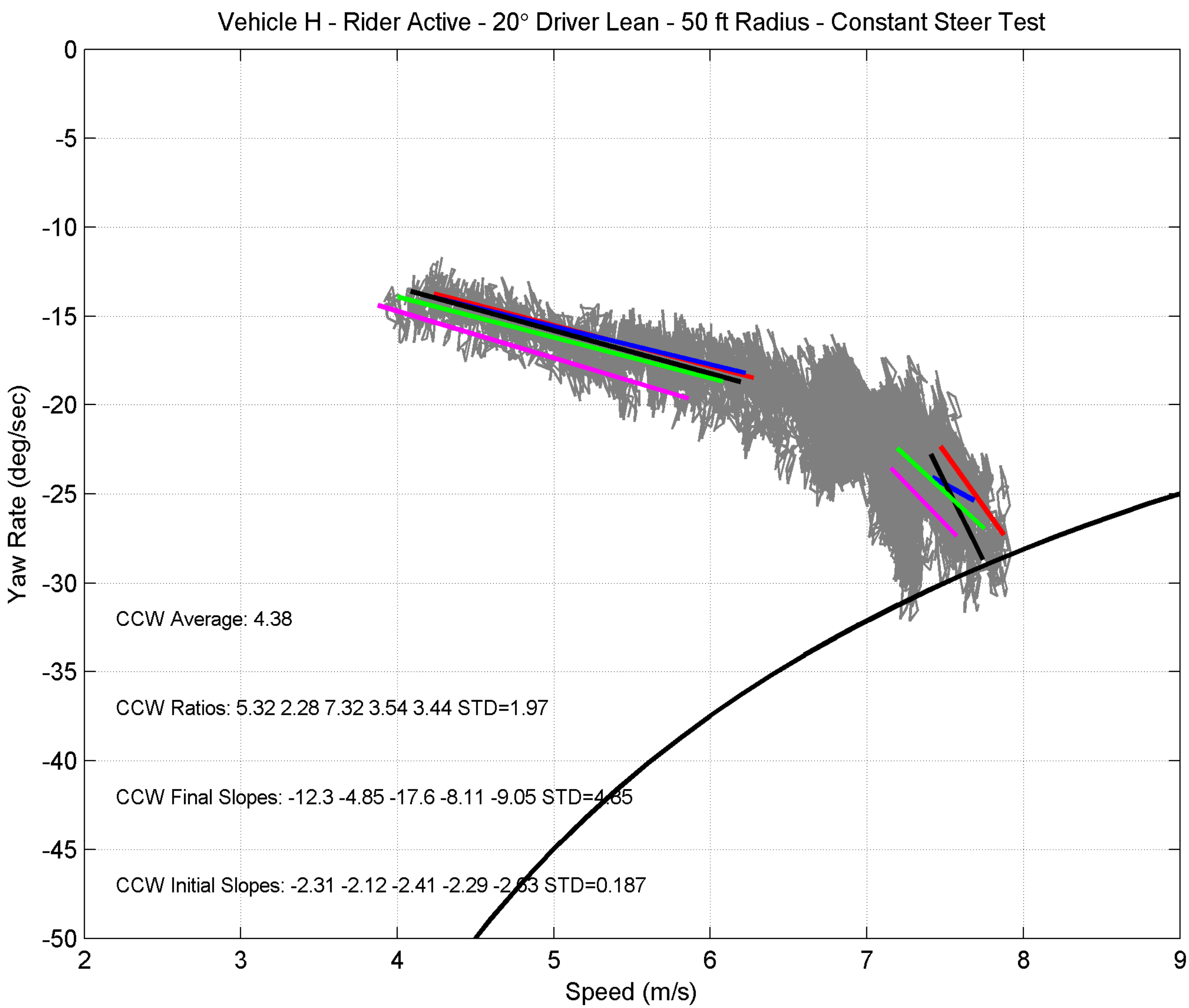


Vehicle H - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

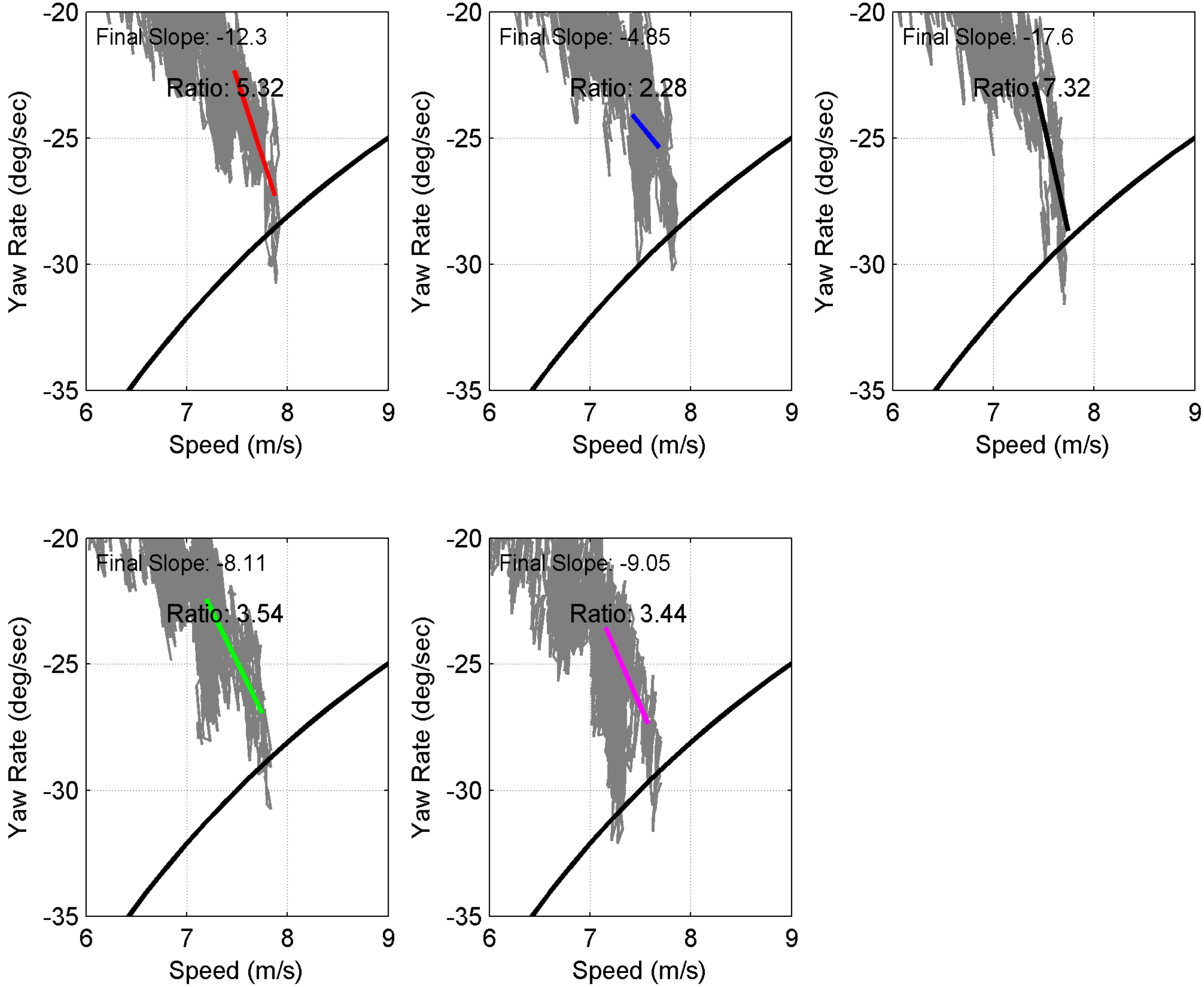

Vehicle H - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

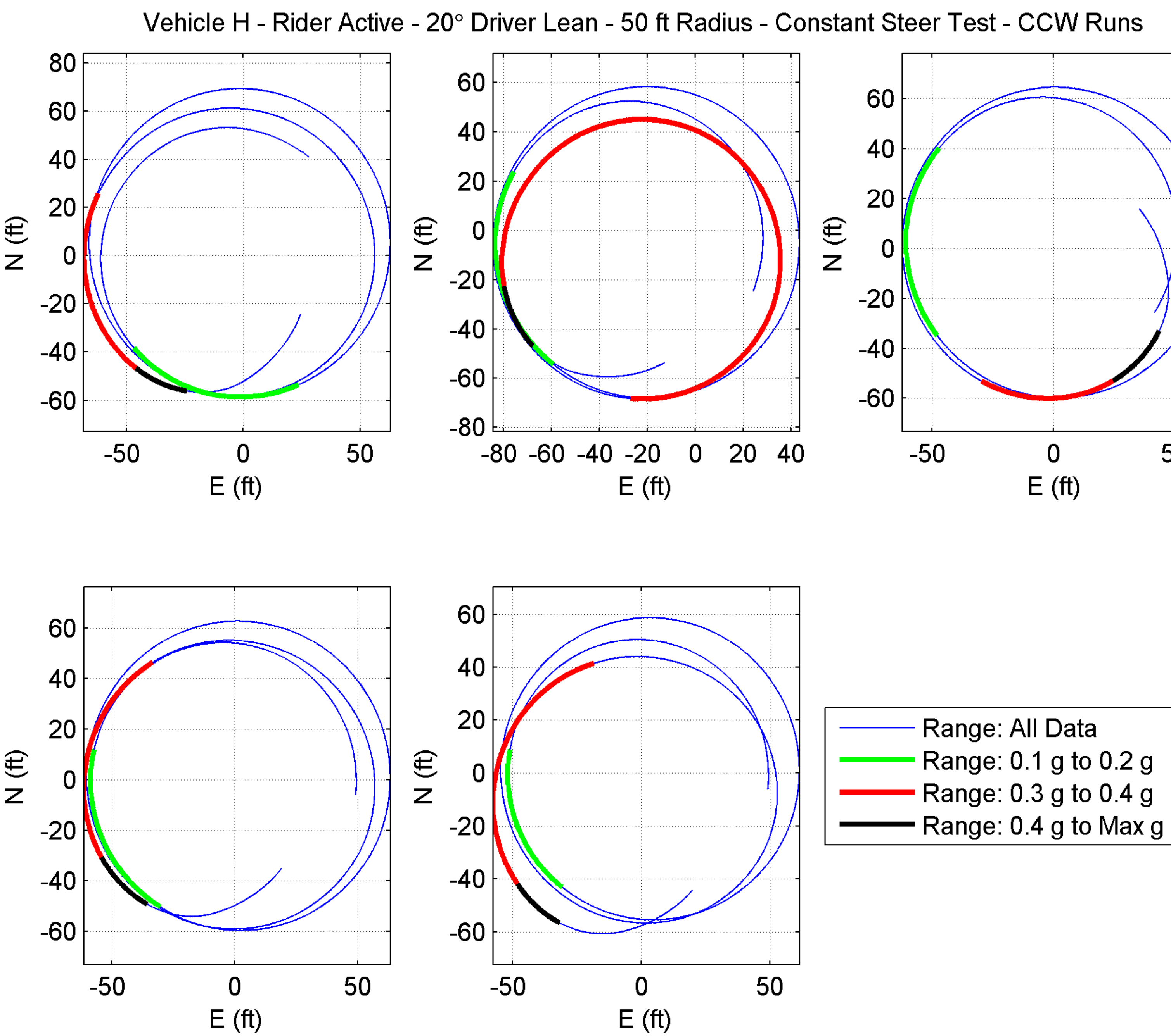


Vehicle H - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

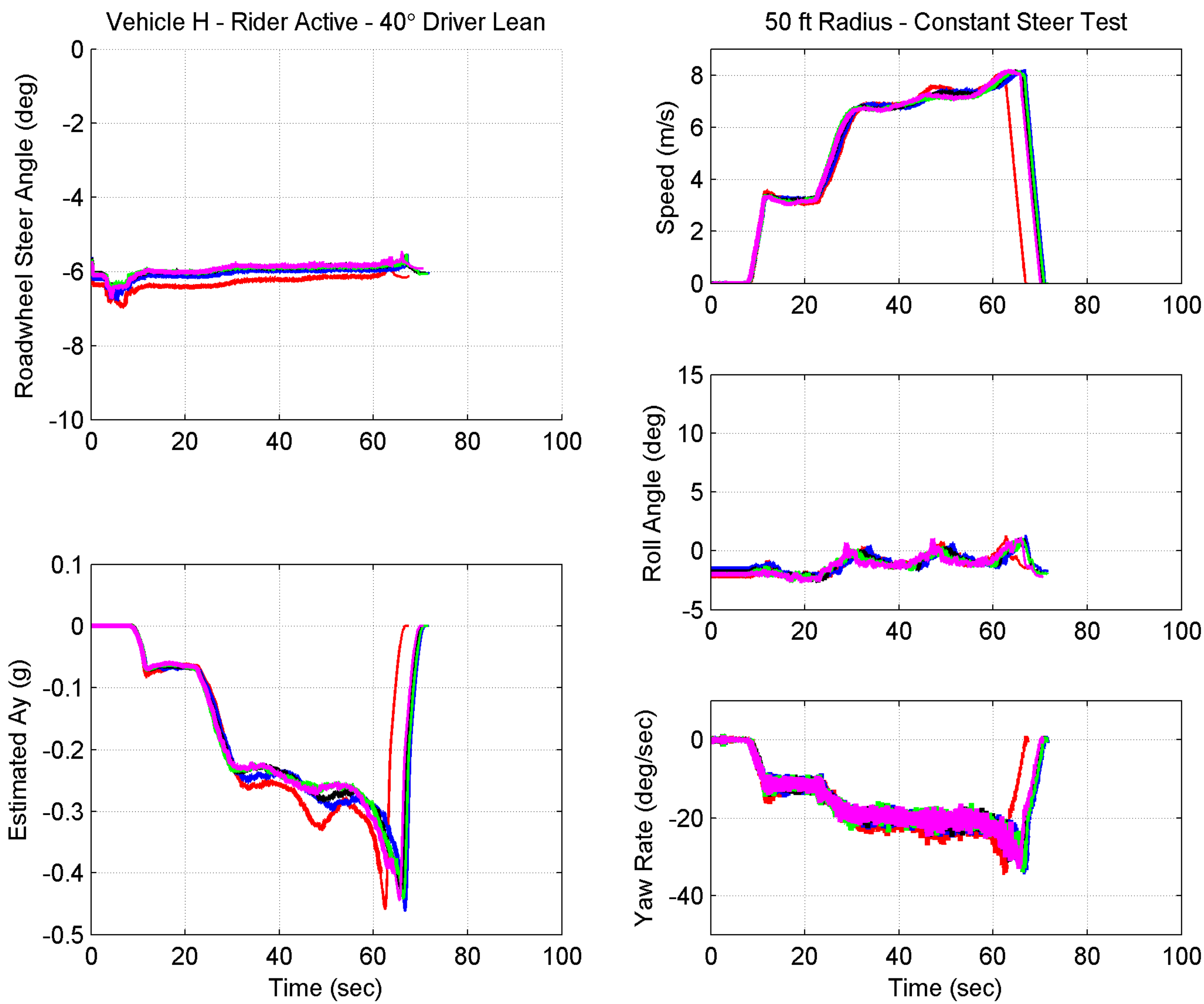

Vehicle H - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 4.38
CCW Ratios: 5.32 2.28 7.32 3.54 3.44 STD=1.97
CCW Final Slopes: -12.3 -4.85 -17.6 -8.11 -9.05 STD=4.85
CCW Initial Slopes: -2.31 -2.12 -2.41 -2.29 -2.63 STD=0.187

Vehicle H - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

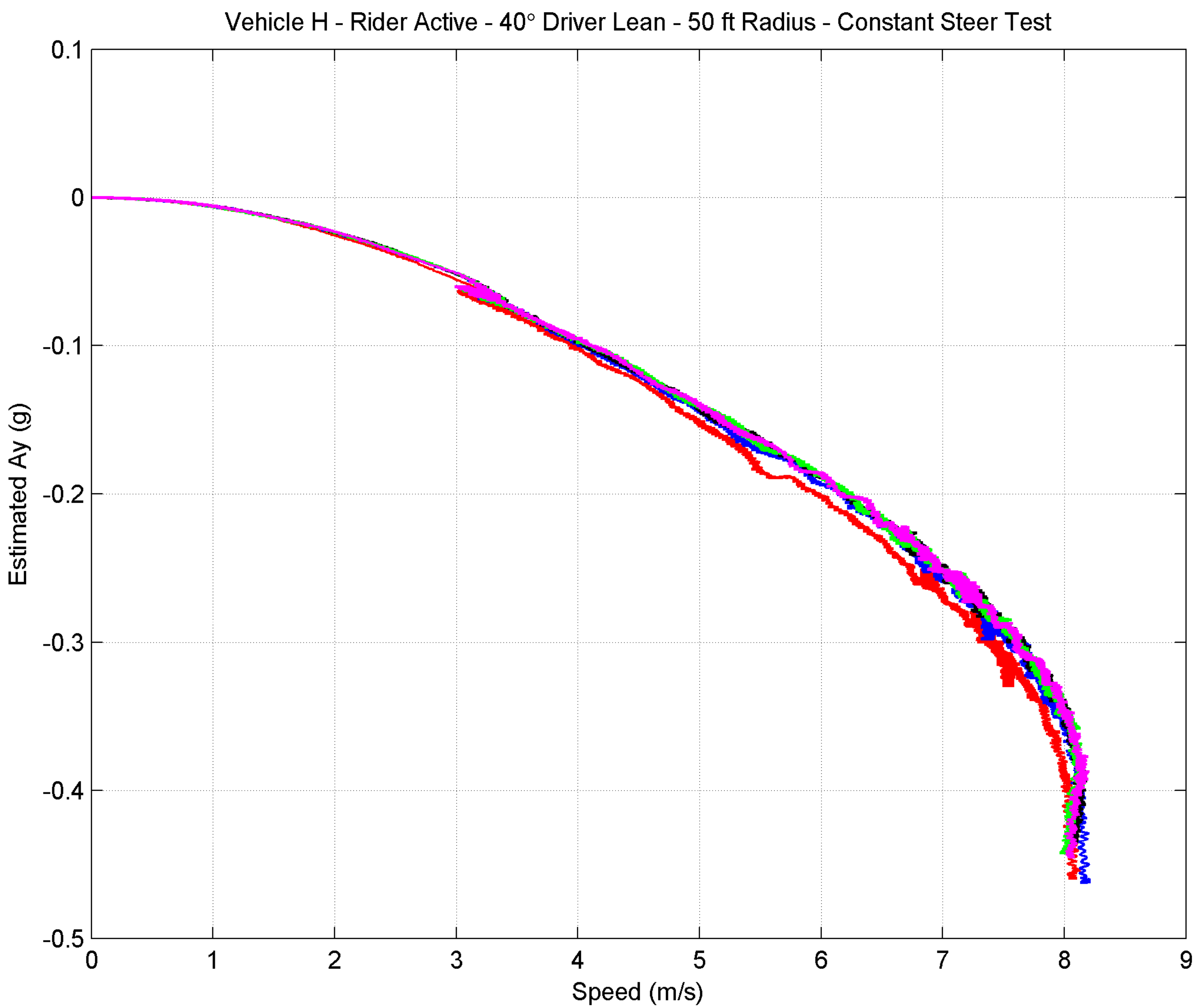


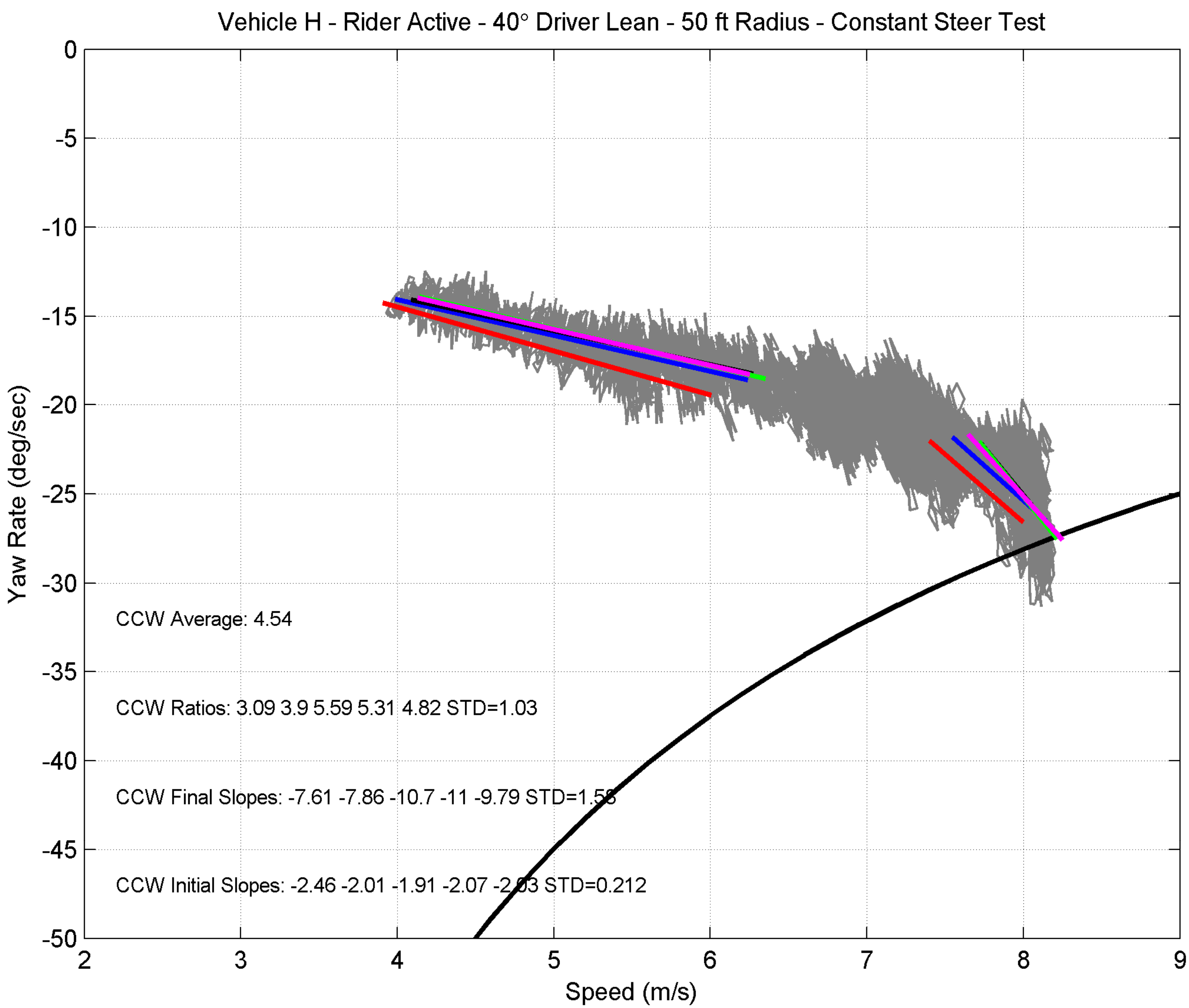


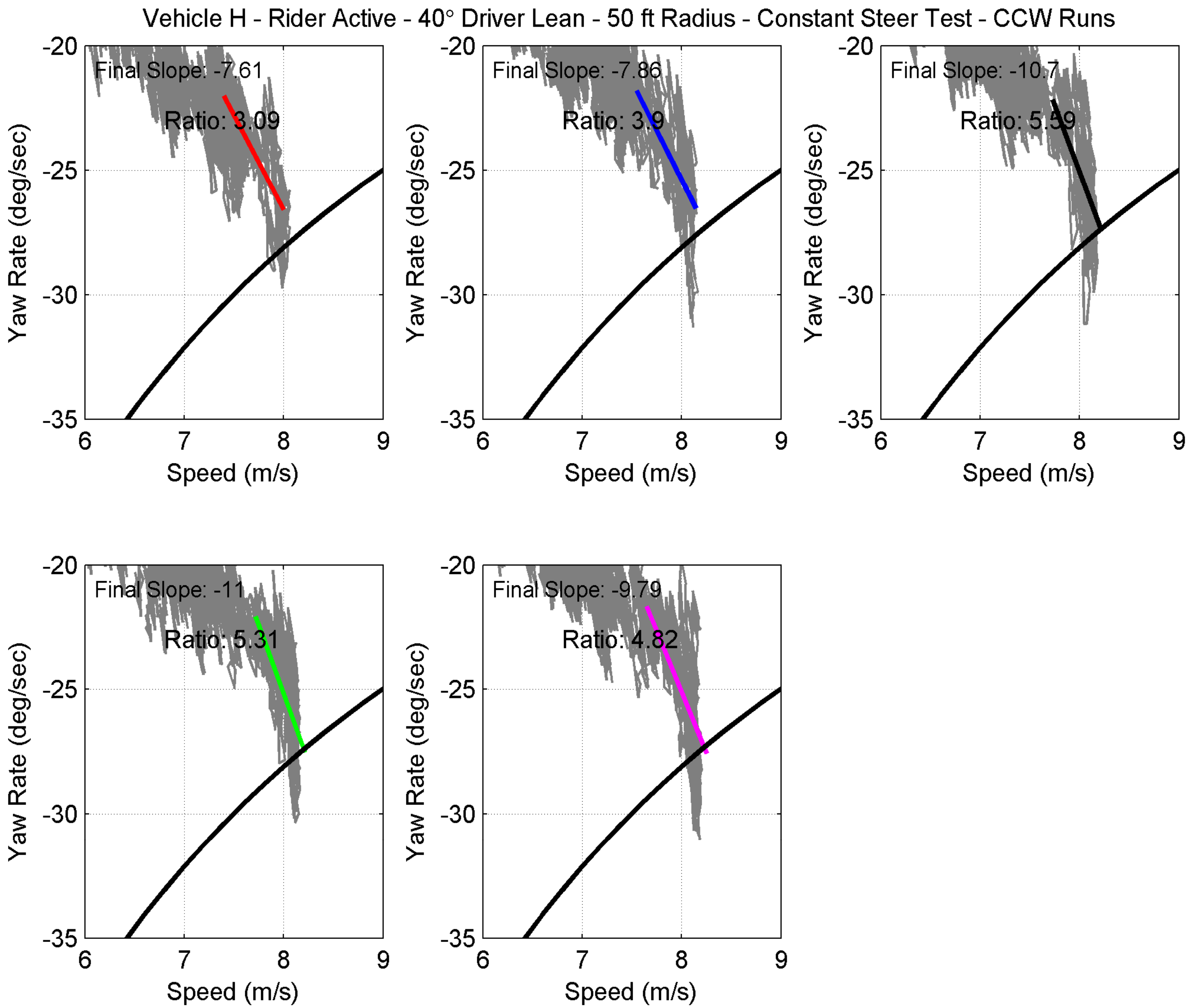
Vehicle H - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

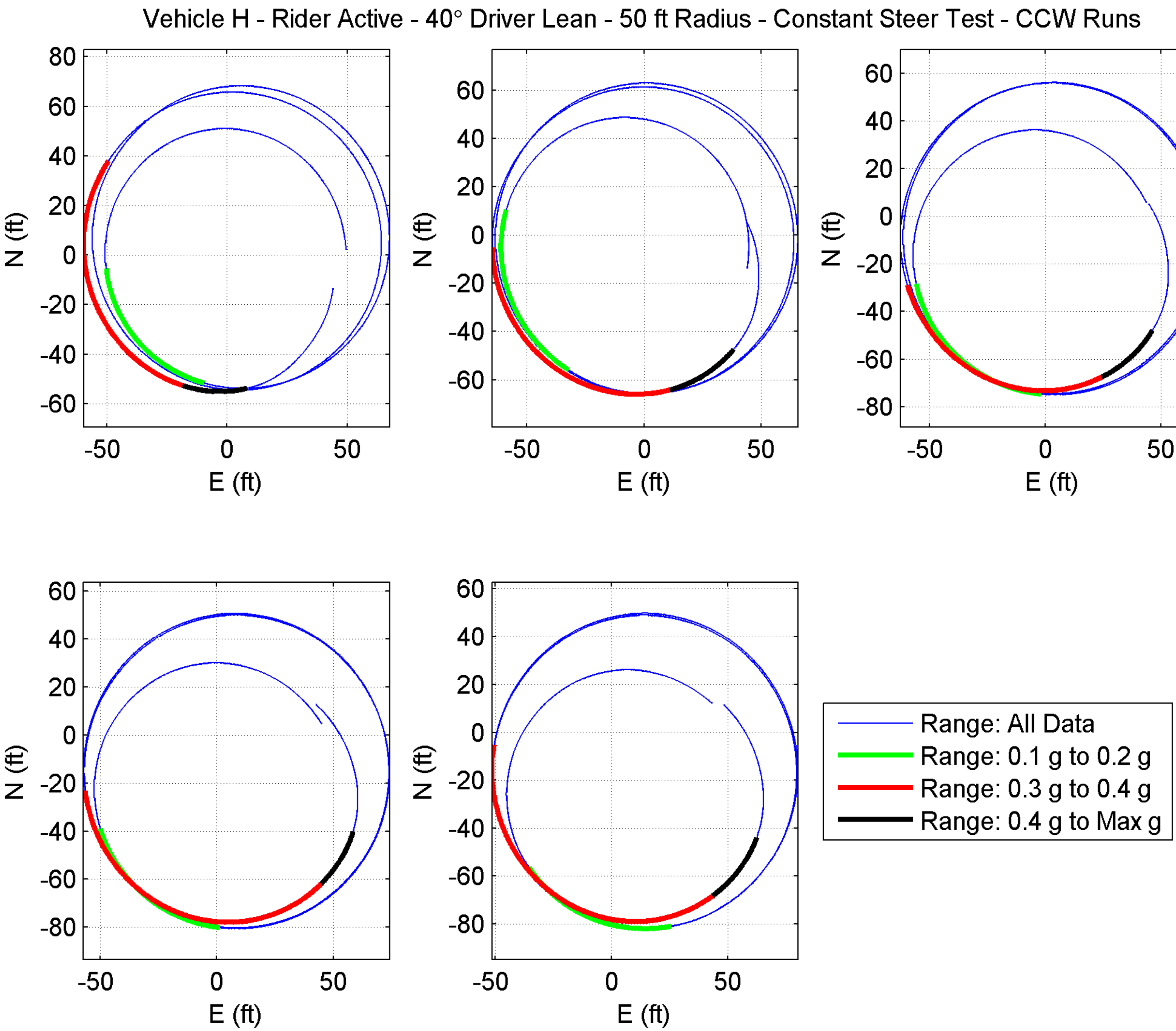


Vehicle H - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

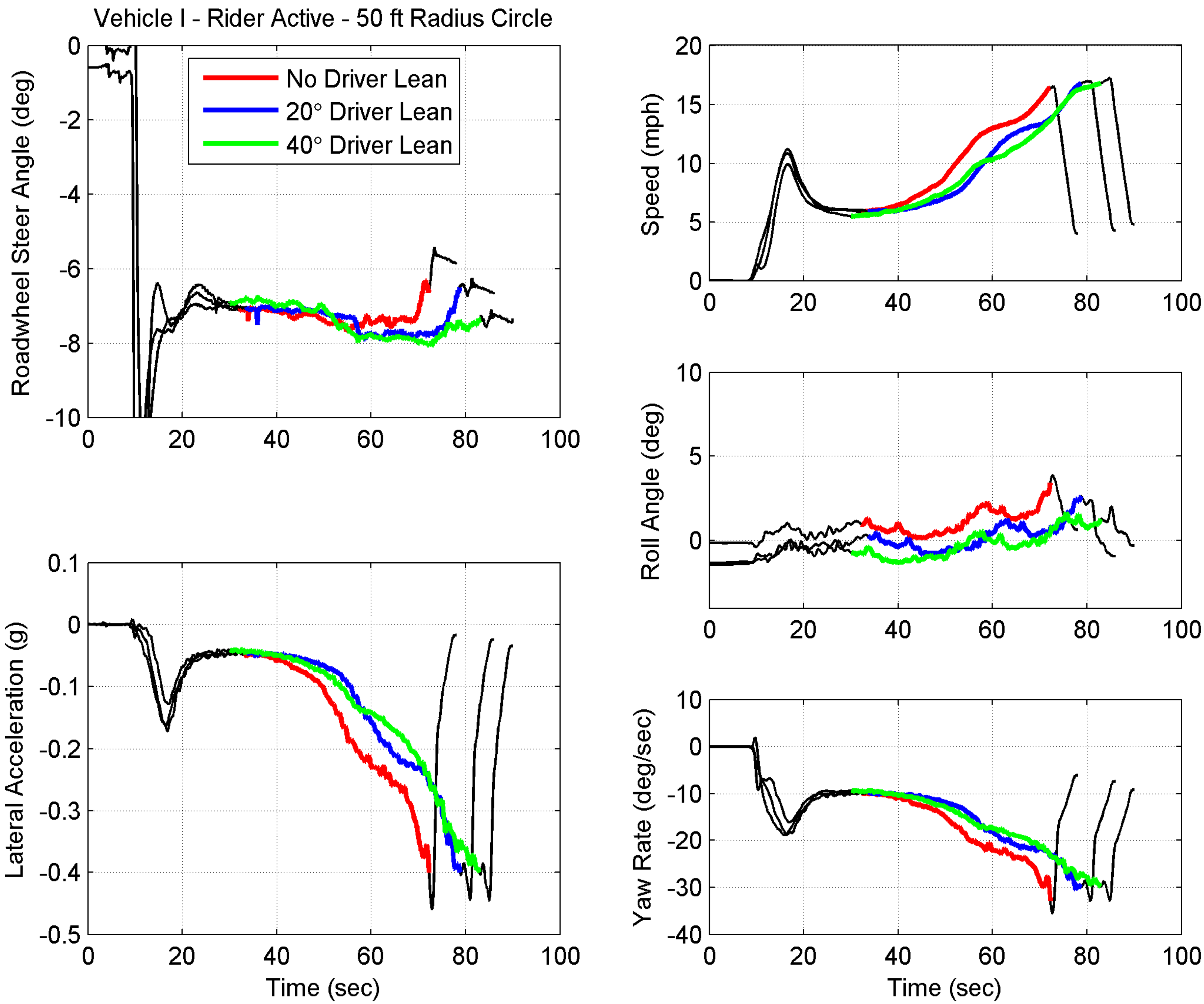

Vehicle H - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9


Vehicle H - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 4.54
CCW Ratios: 3.09 3.9 5.59 5.31 4.82 STD=1.03
CCW Final Slopes: -7.61 -7.86 -10.7 -11 -9.79 STD=1.56
CCW Initial Slopes: -2.46 -2.01 -1.91 -2.07 -2.03 STD=0.212

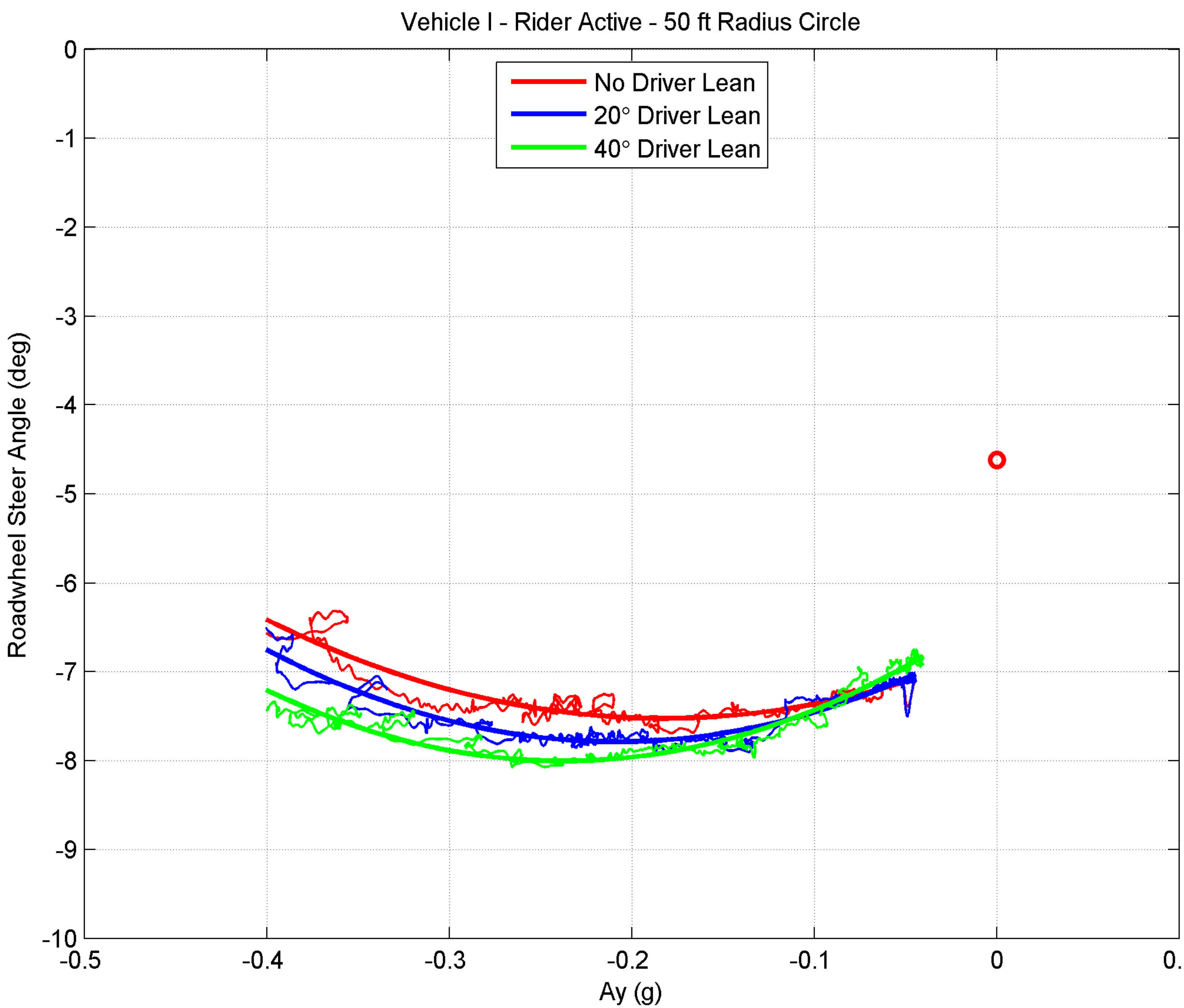

Vehicle H - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -7.61
Ratio: 3.09
Final Slope: -7.86
Ratio: 3.9
Final Slope: -10.7
Ratio: 5.59
Final Slope: -11
Ratio: 5.31
Final Slope: -9.79
Ratio: 4.82
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9



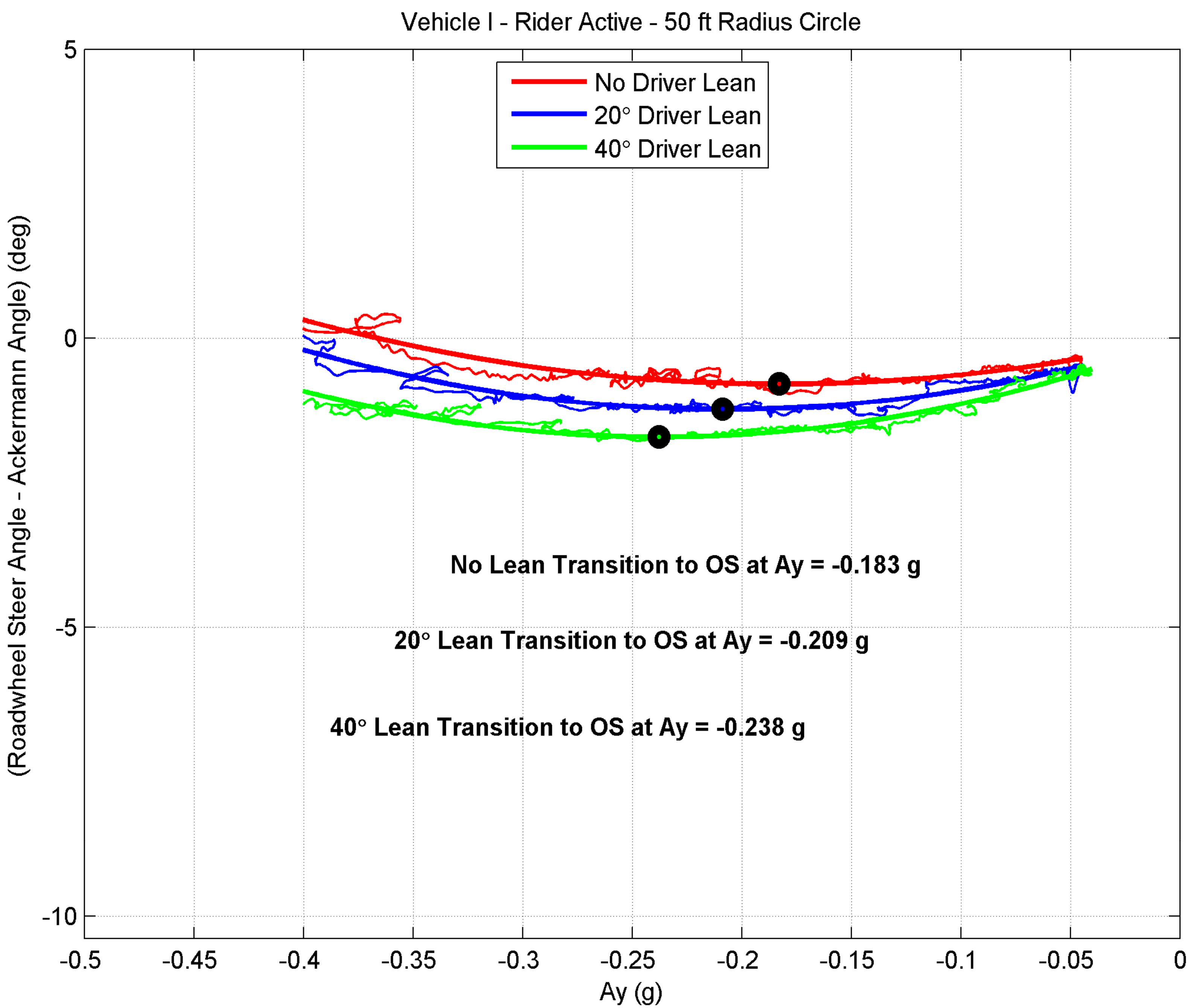
Vehicle H - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



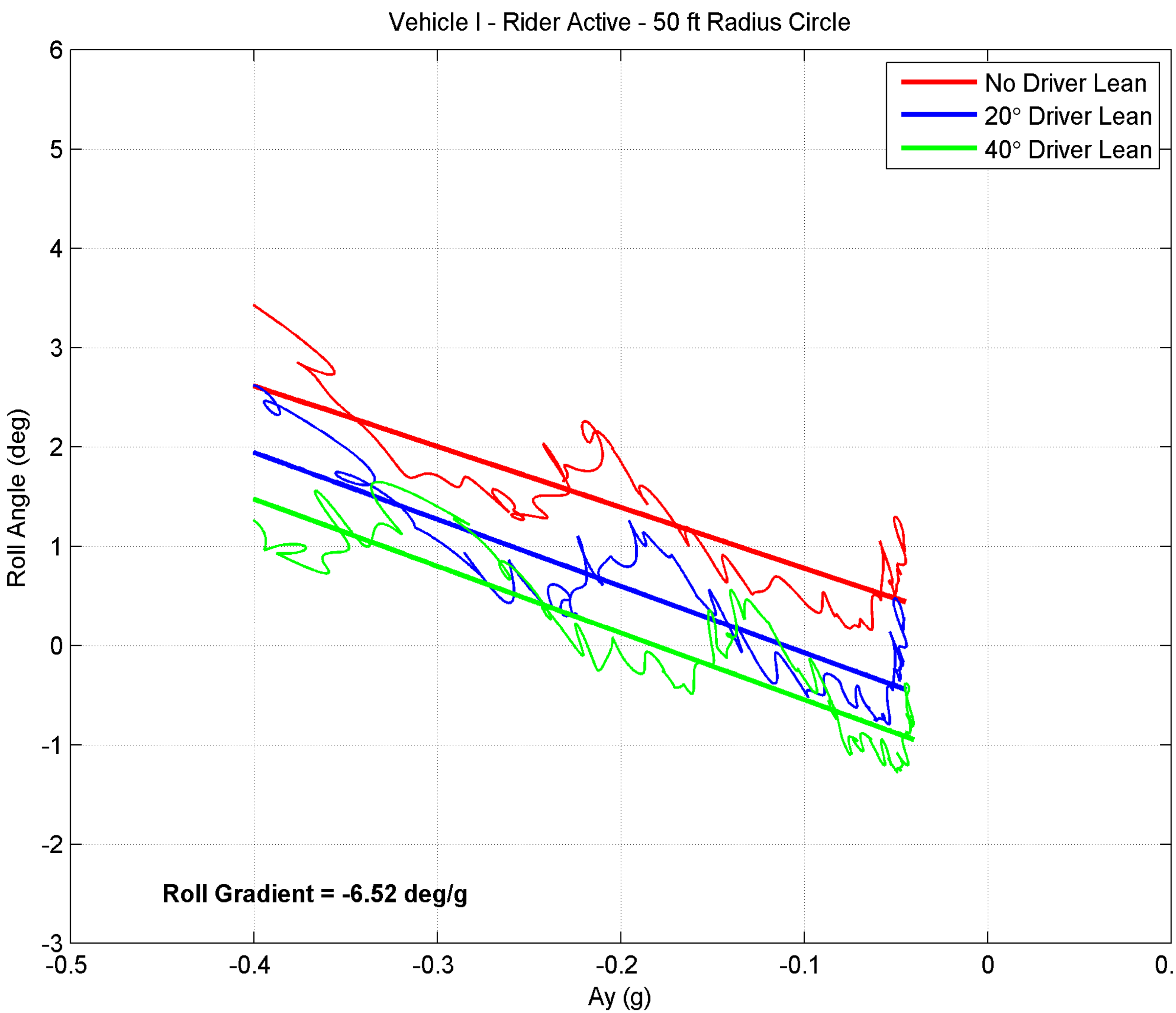
Vehicle I - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



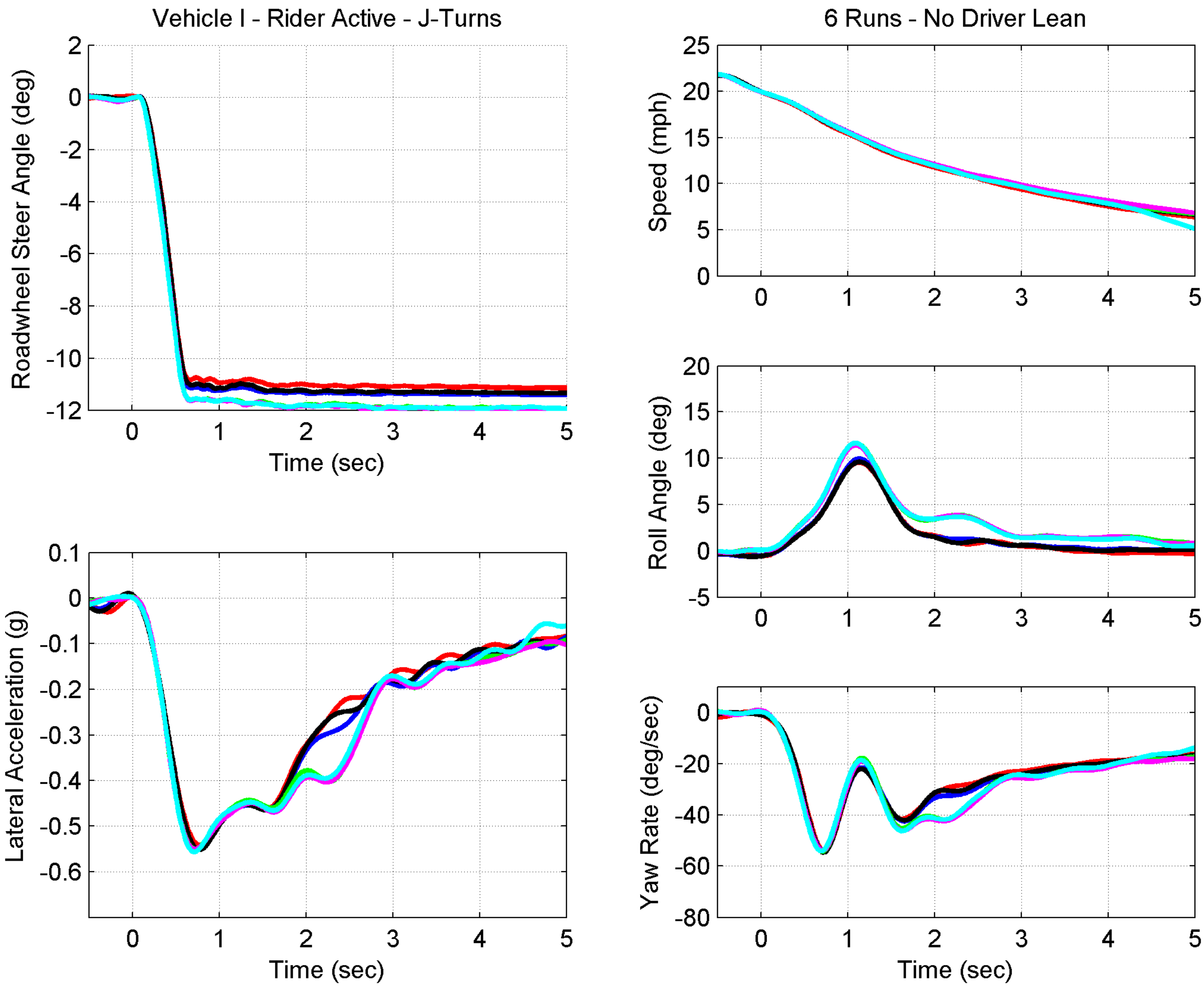
Vehicle I - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Ay (g)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

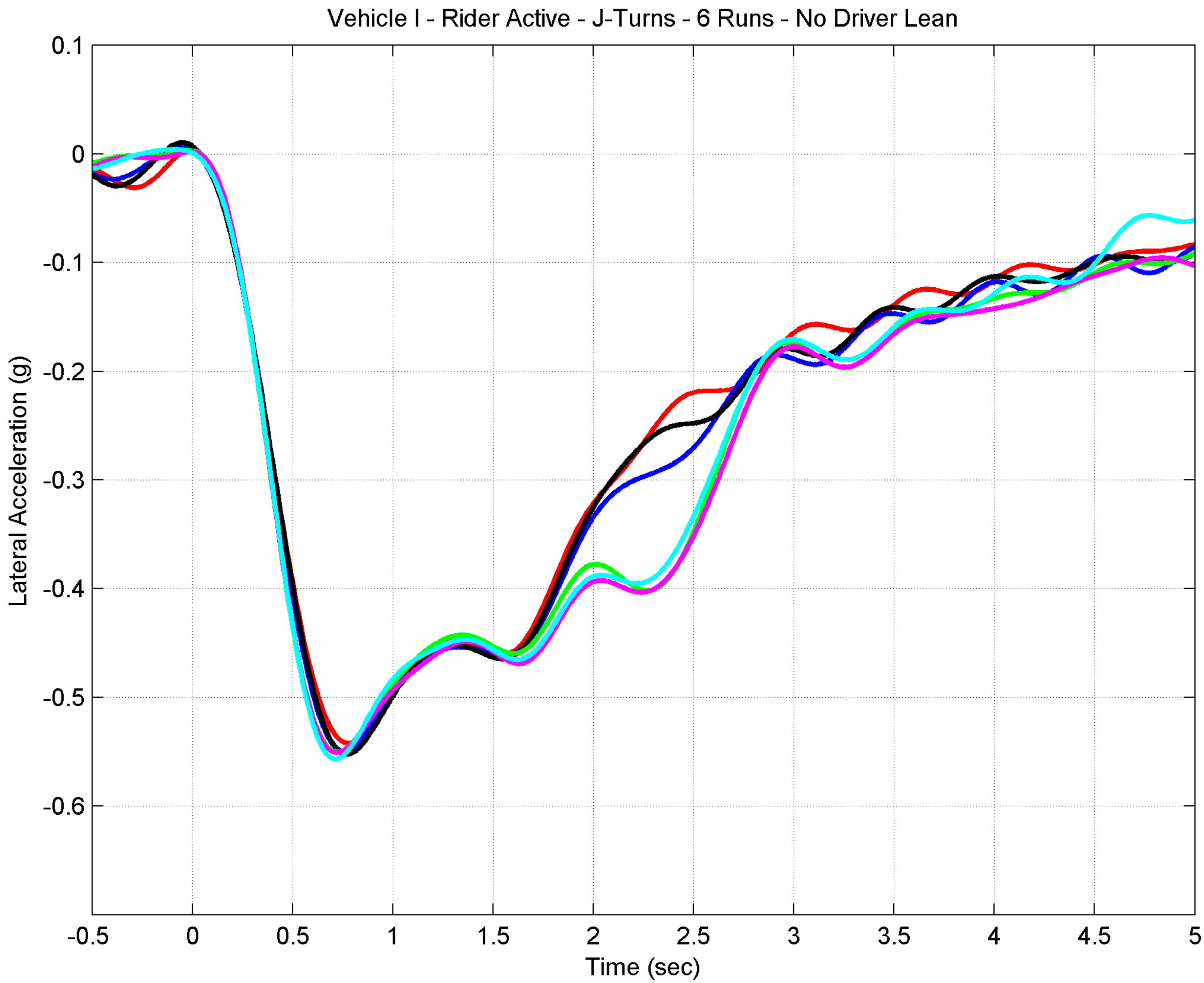


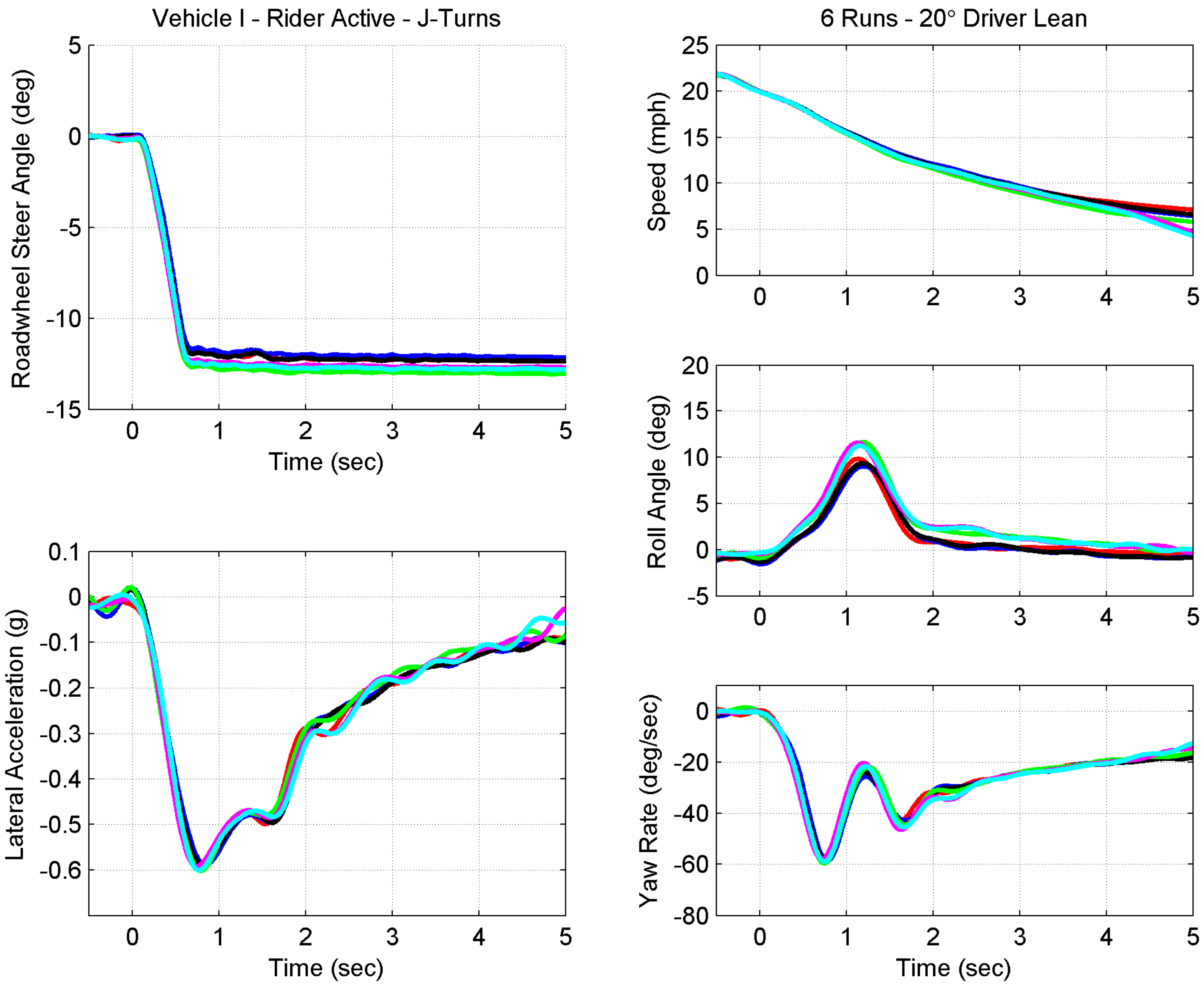
Vehicle I - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.183 g
20° Lean Transition to OS at Ay = -0.209 g
40° Lean Transition to OS at Ay = -0.238 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

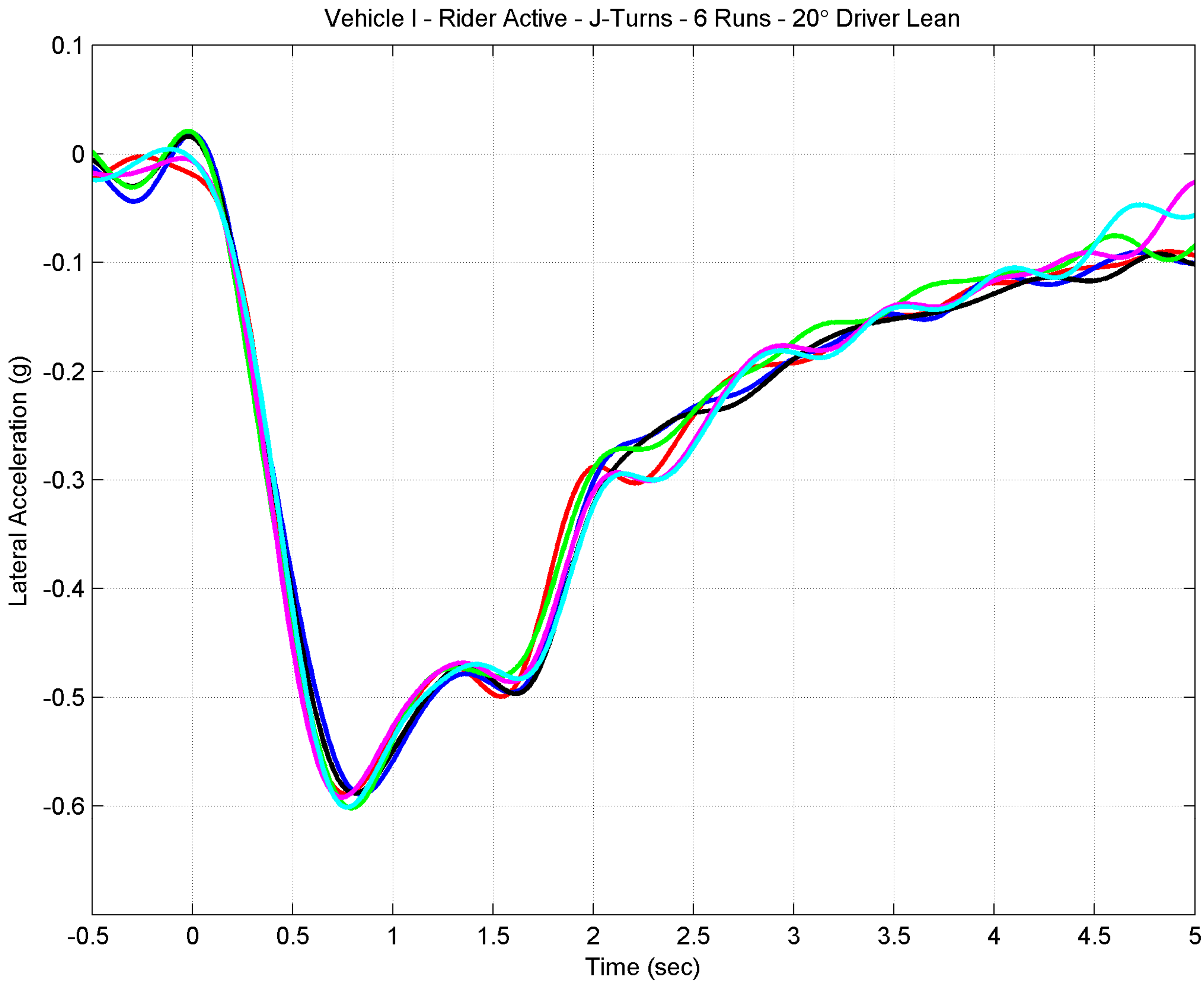


Vehicle I - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -6.52 deg/g
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

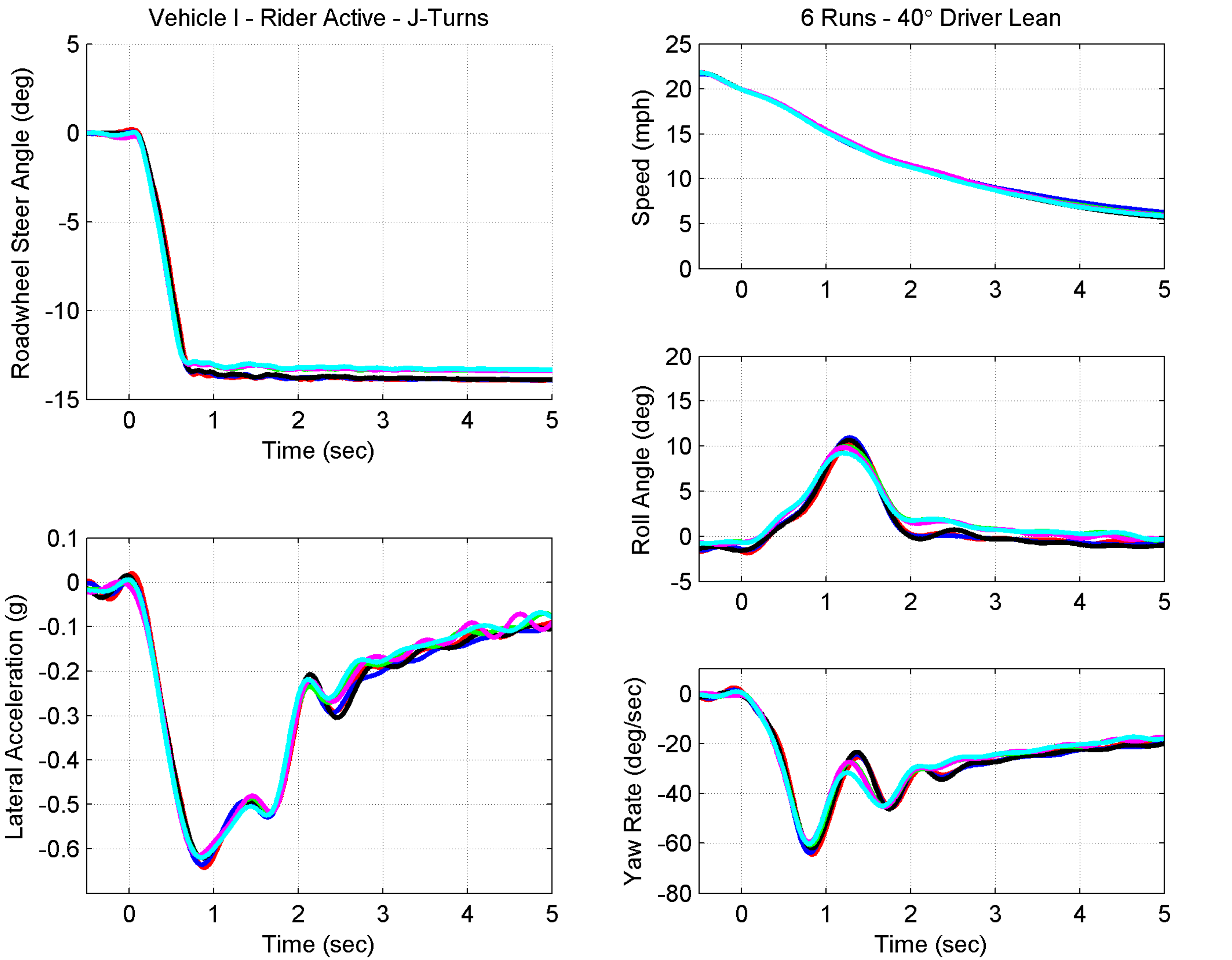

Vehicle I - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

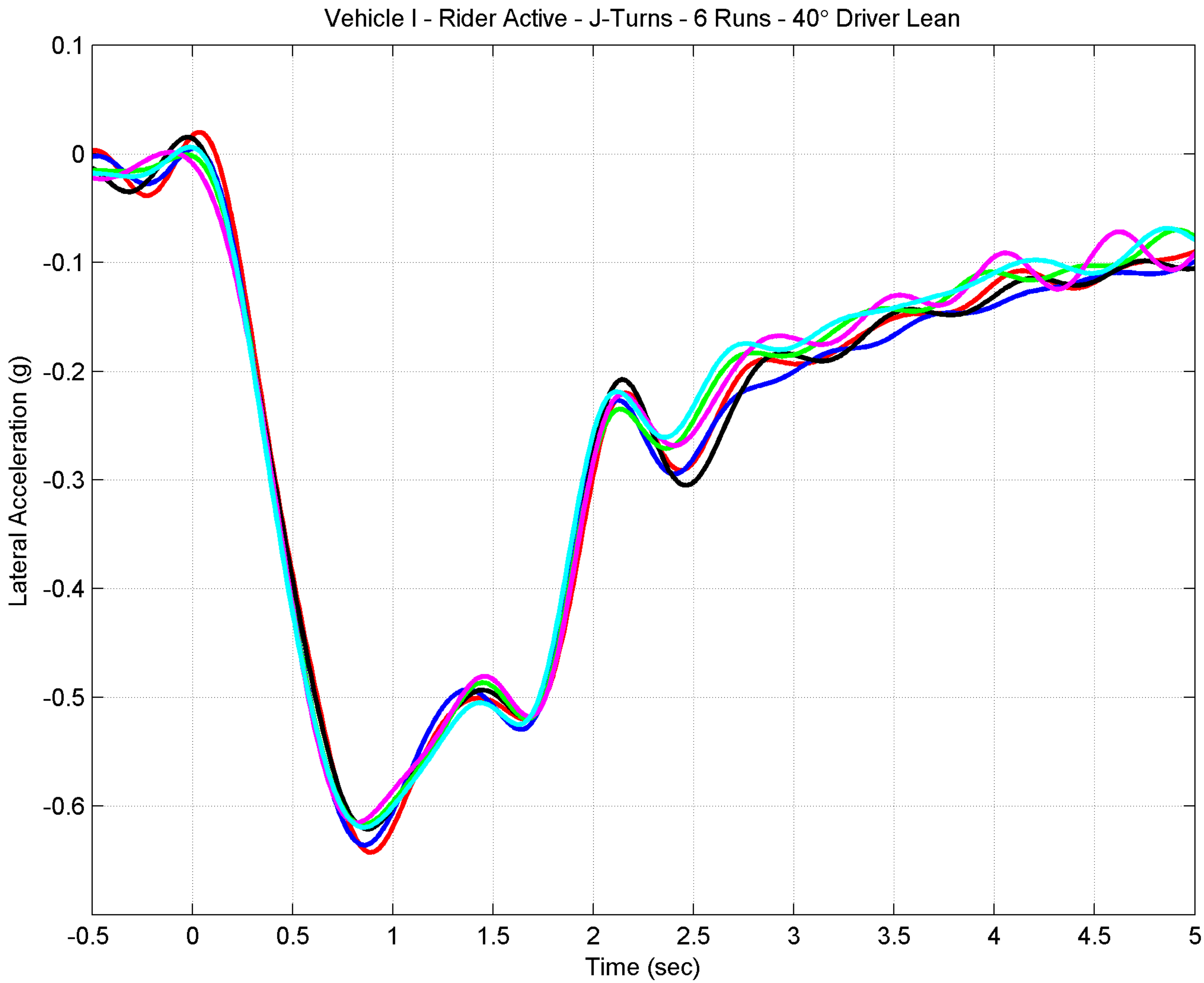

Vehicle I - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle I - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)



Vehicle I - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle I - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)
Time (sec)

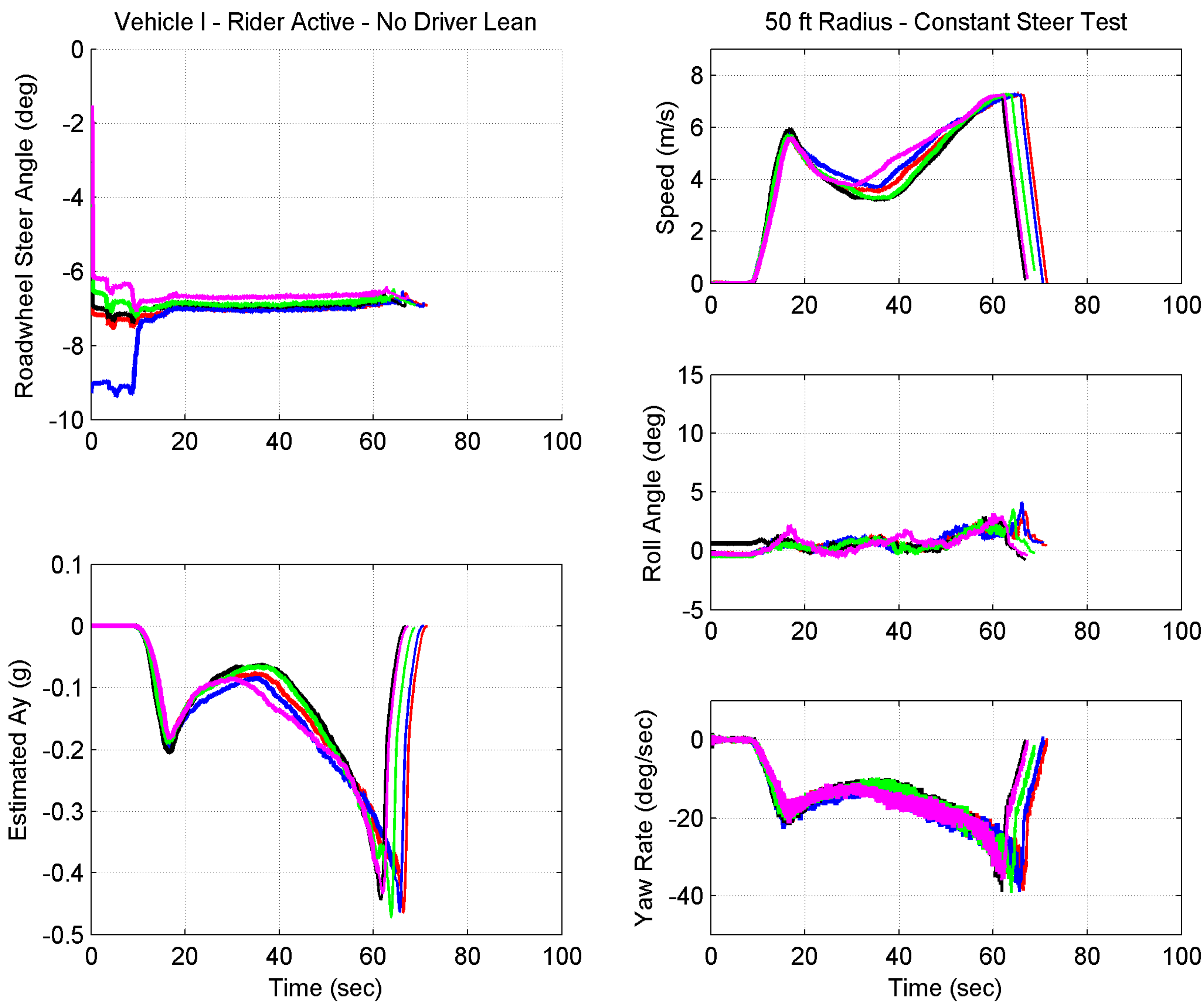

Vehicle I - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

Vehicle I - Rider Active Results

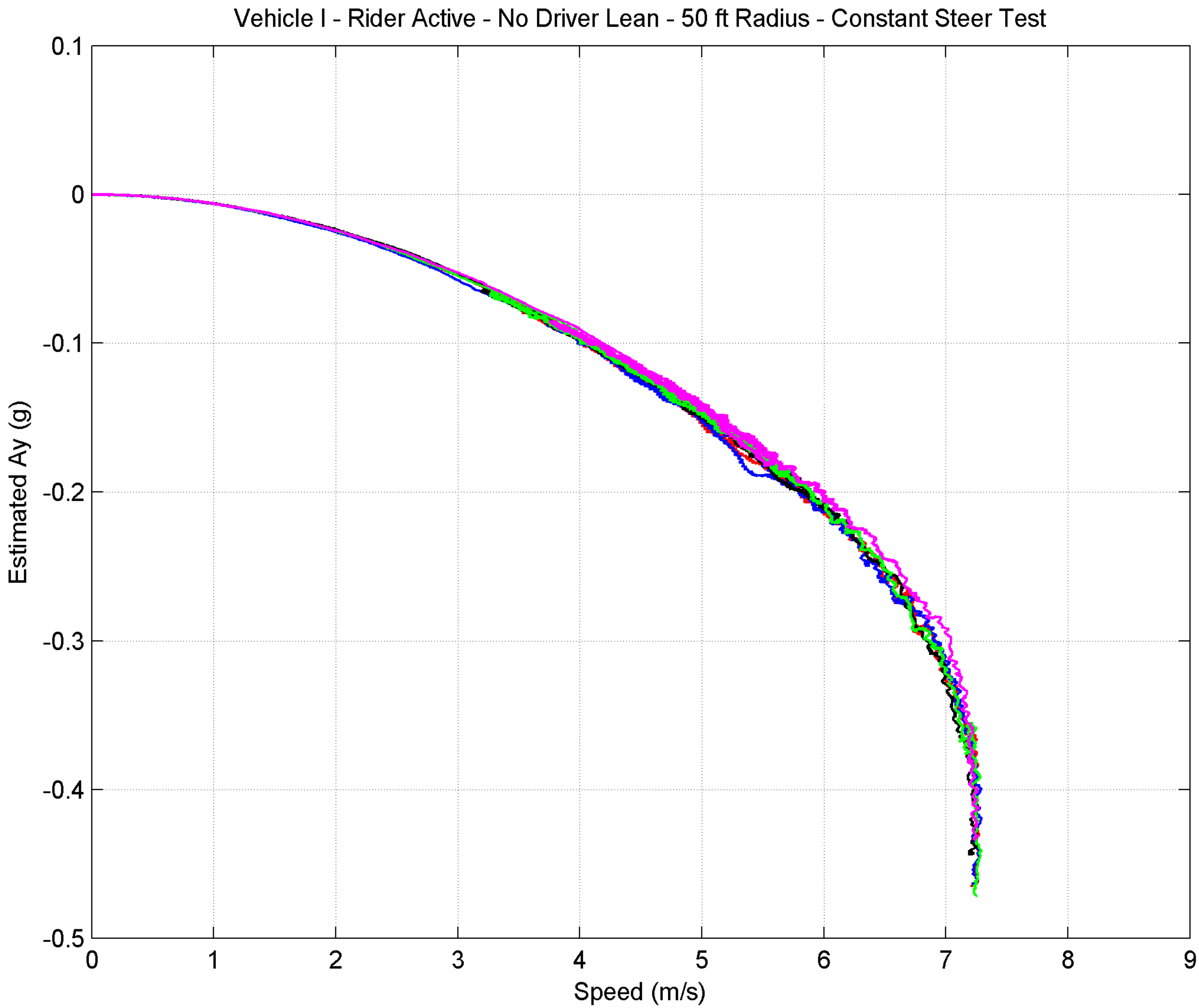
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

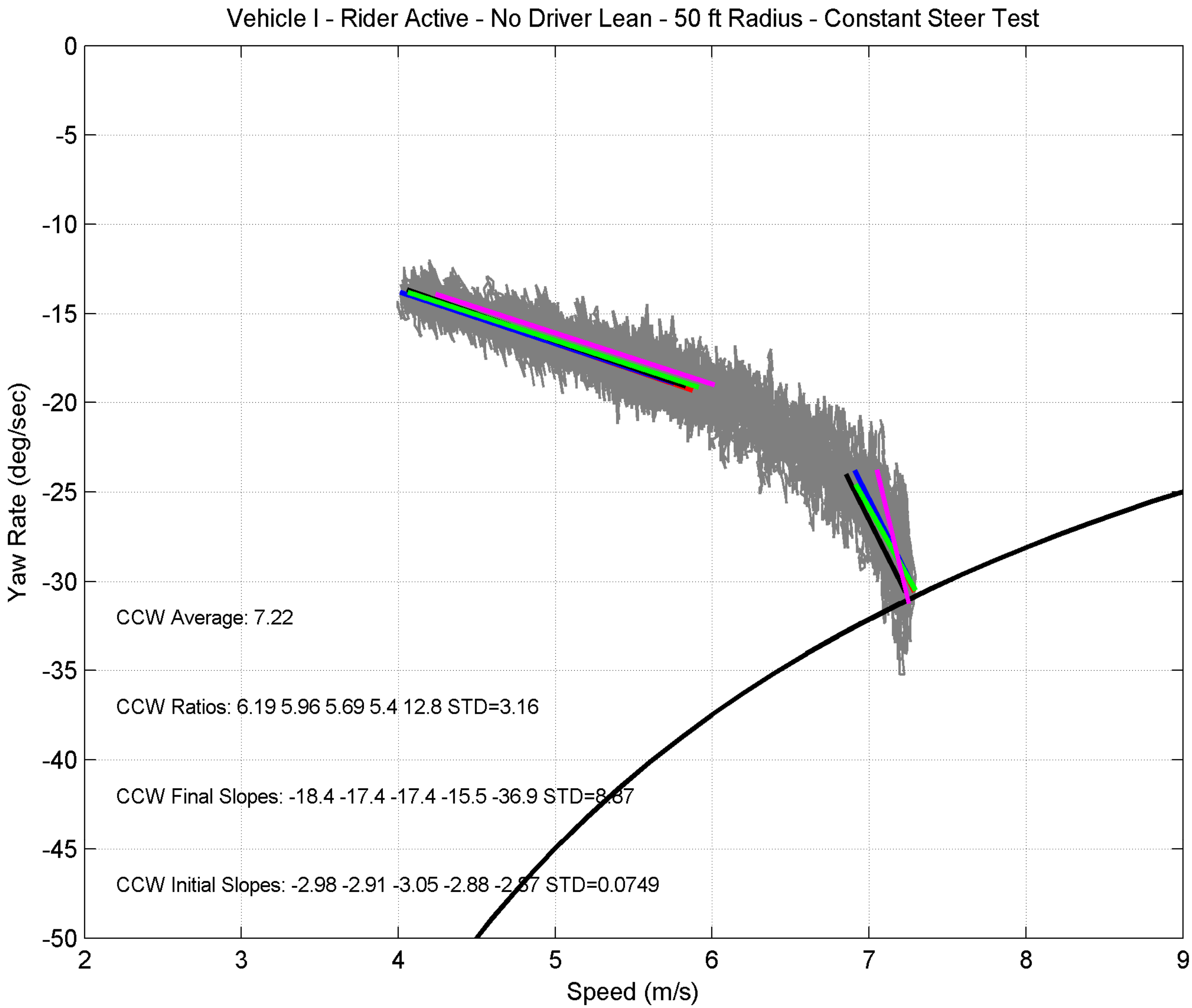
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.542	-0.589	-0.643
	-0.550	-0.589	-0.636
	-0.553	-0.588	-0.621
Mean Value of 3 Runs	-0.548	-0.589	-0.634
Standard Deviation of 3 Runs	0.005	0.001	0.011

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.550	-0.602	-0.617
	-0.551	-0.592	-0.615
	-0.557	-0.601	-0.620
Mean Value of 3 Runs	-0.553	-0.598	-0.618
Standard Deviation of 3 Runs	0.004	0.006	0.002
Average of All 6 Runs	**0.551**	**0.594**	**0.626**



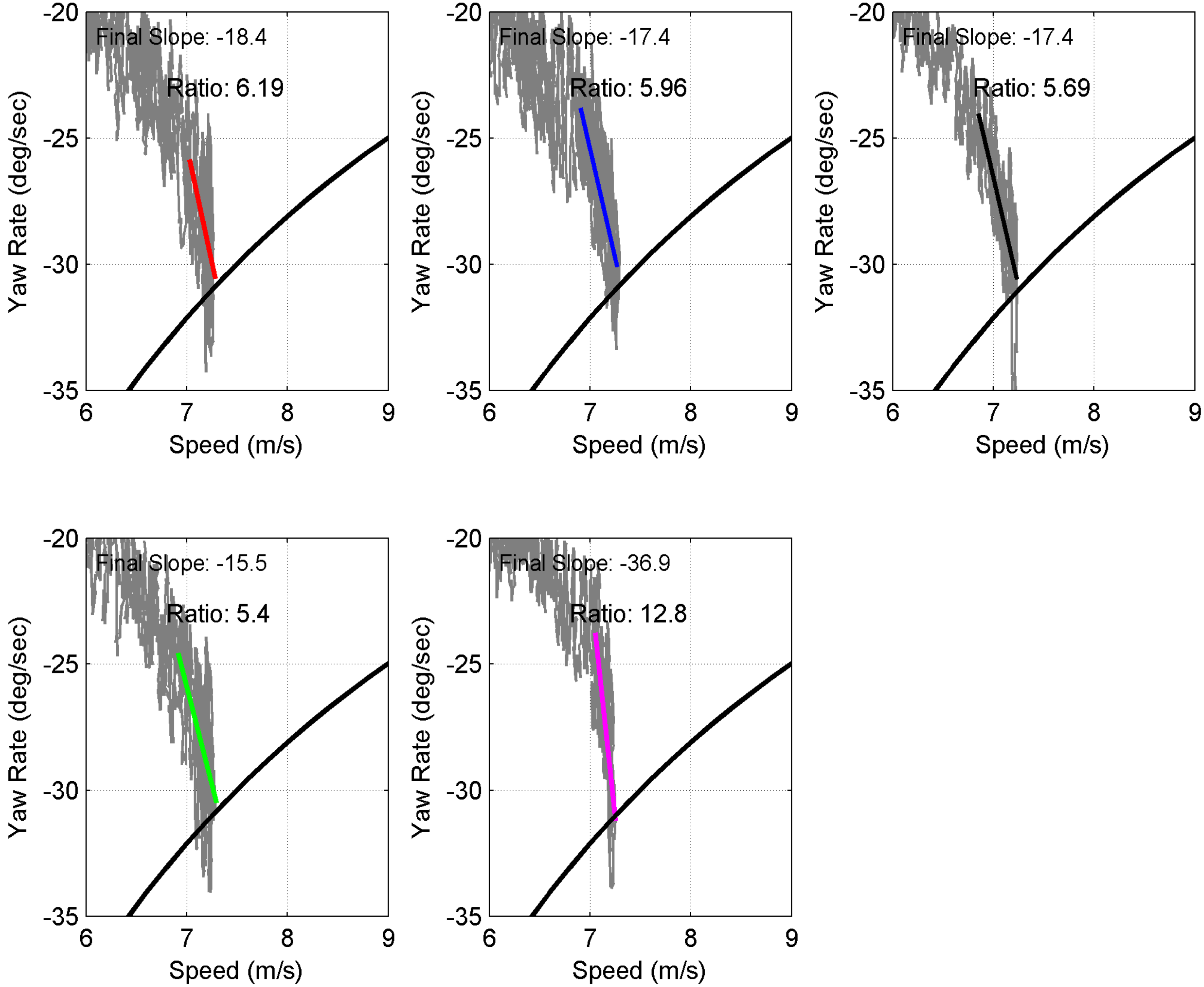
Vehicle I - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

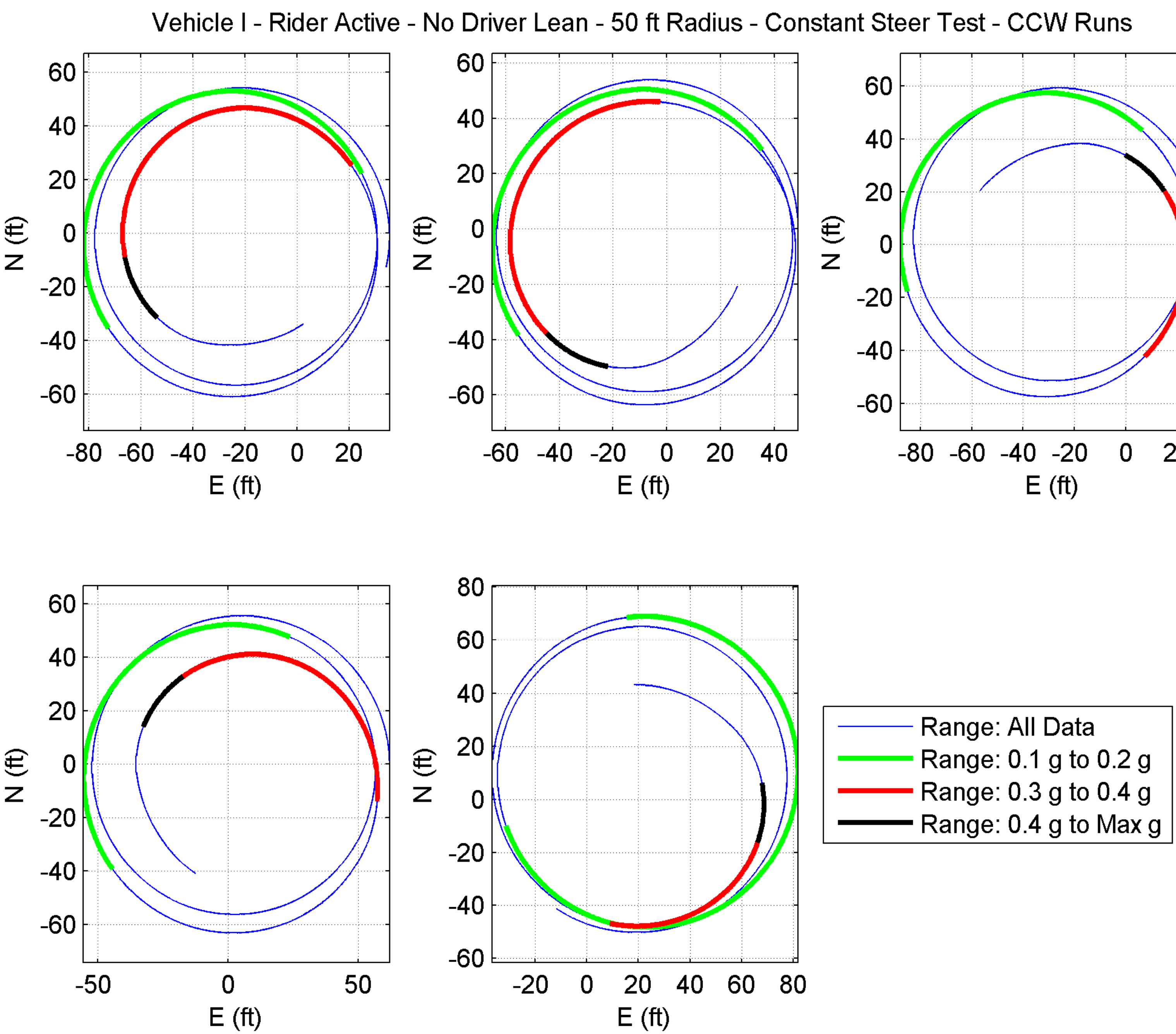

Vehicle I - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9



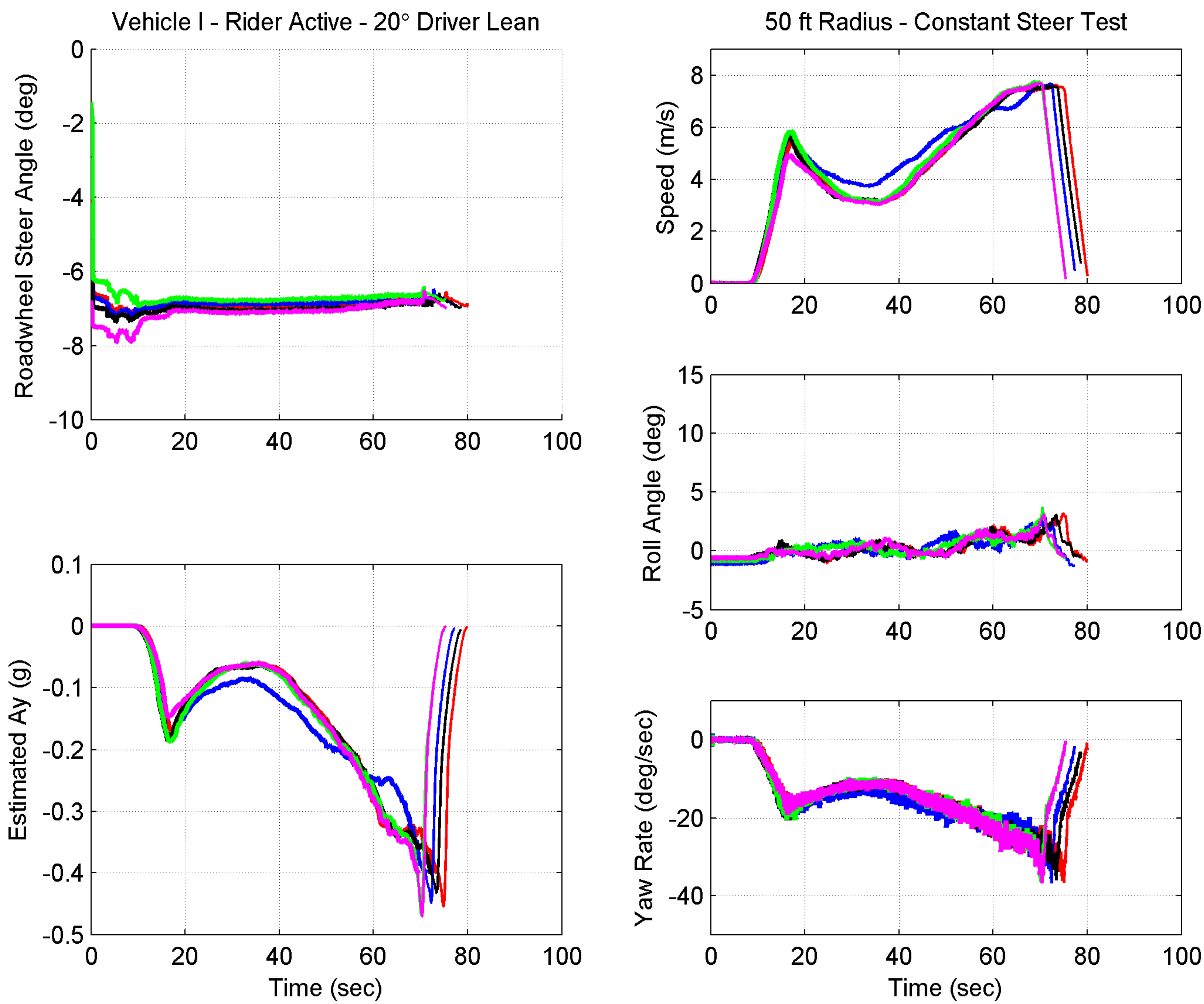
Vehicle I - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 7.22
CCW Ratios: 6.19 5.96 5.69 5.4 12.8 STD=3.16
CCW Final Slopes: -18.4 -17.4 -17.4 -15.5 -36.9 STD=8.87
CCW Initial Slopes: -2.98 -2.91 -3.05 -2.88 -2.87 STD=0.0749

Vehicle I - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

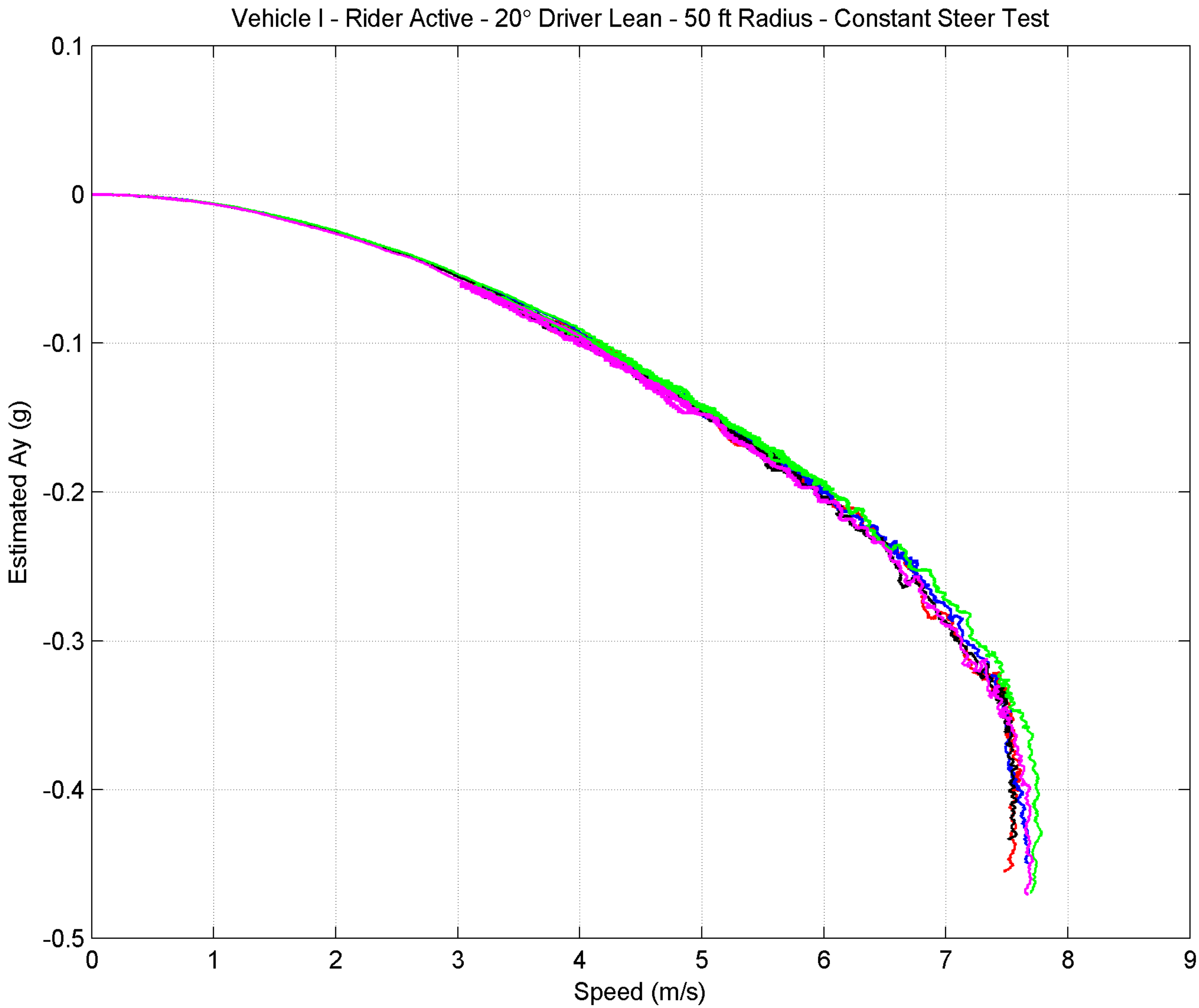


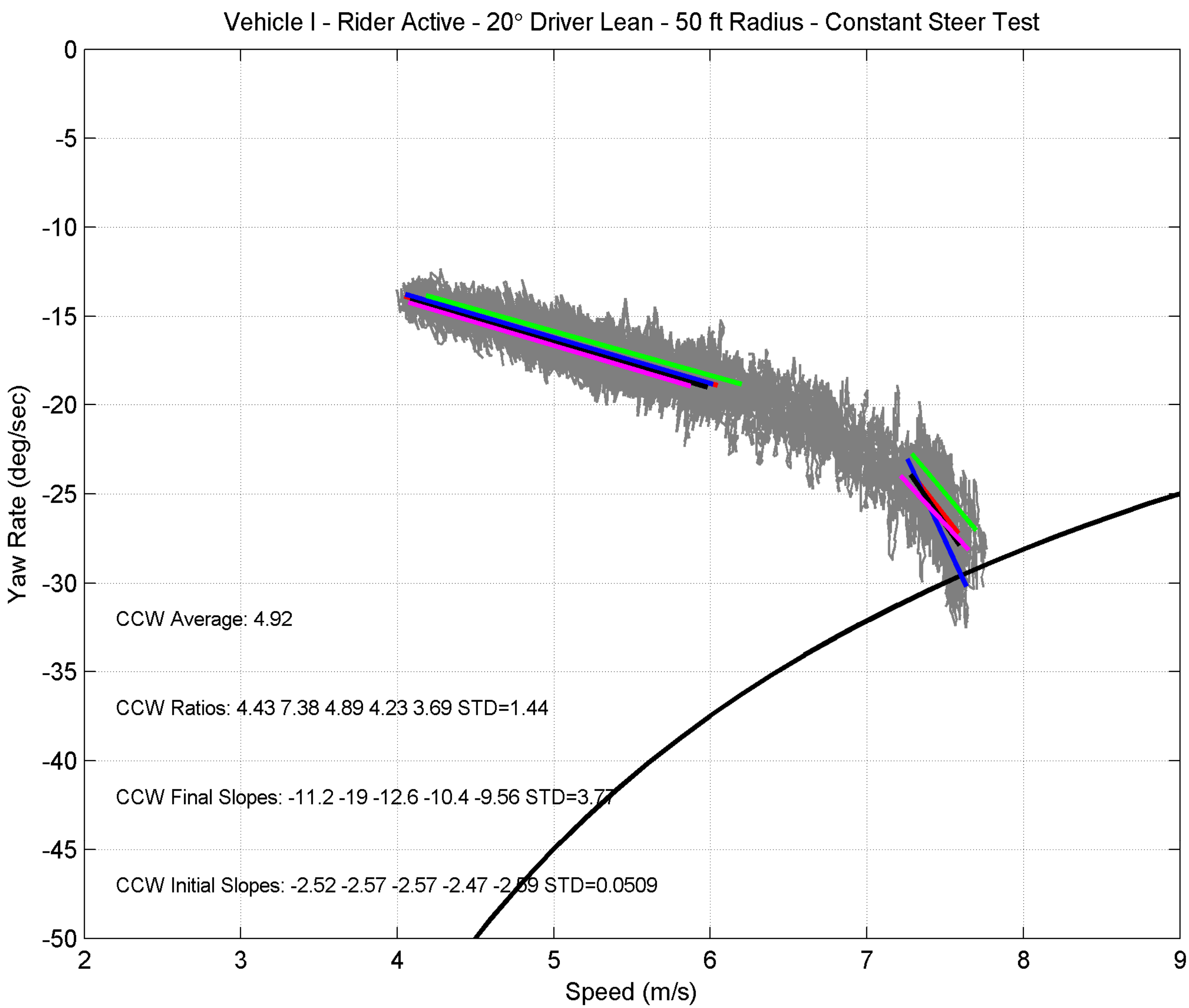


Vehicle I - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



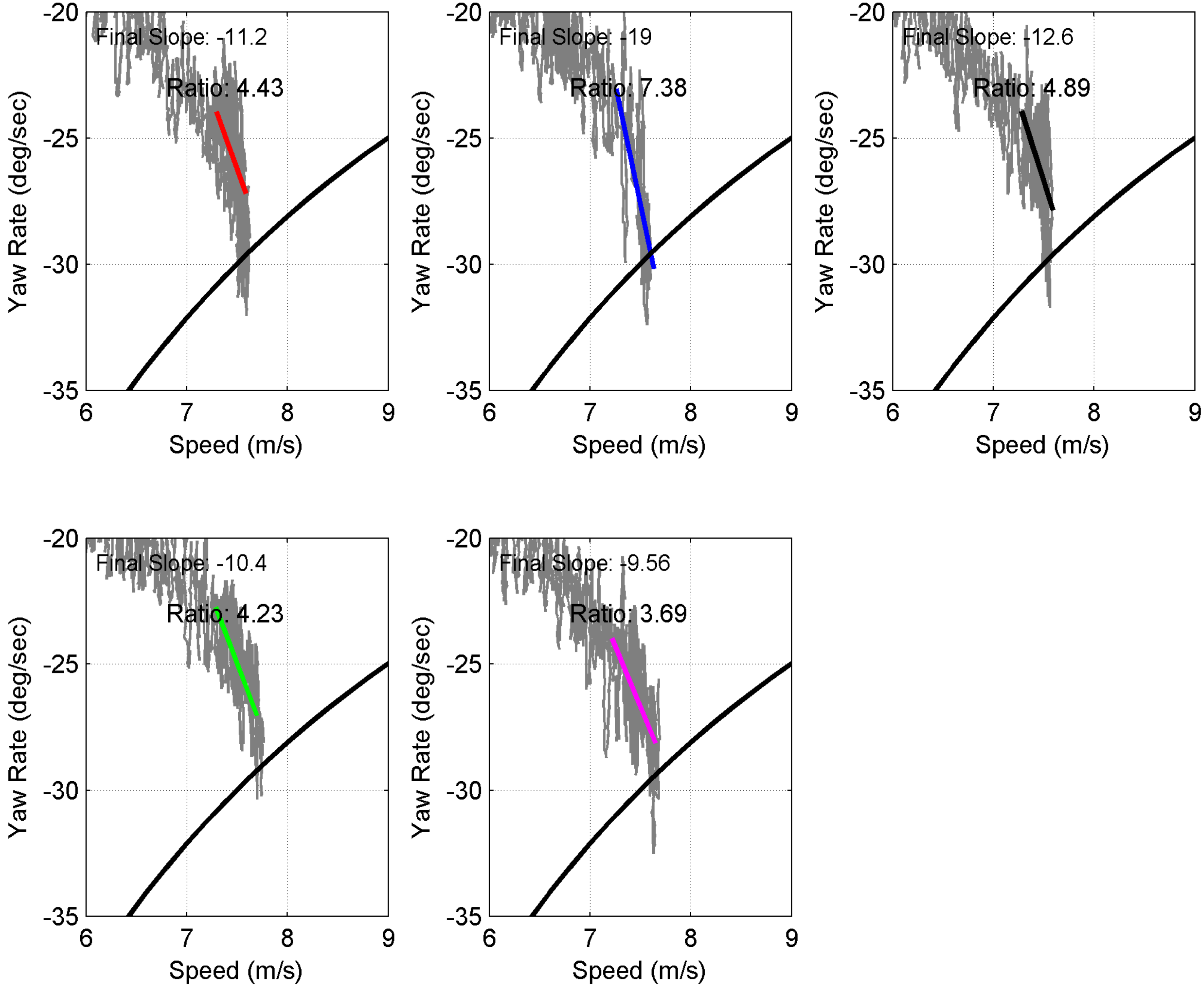
Vehicle I - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle I - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
7
8
9
Speed (m/s)

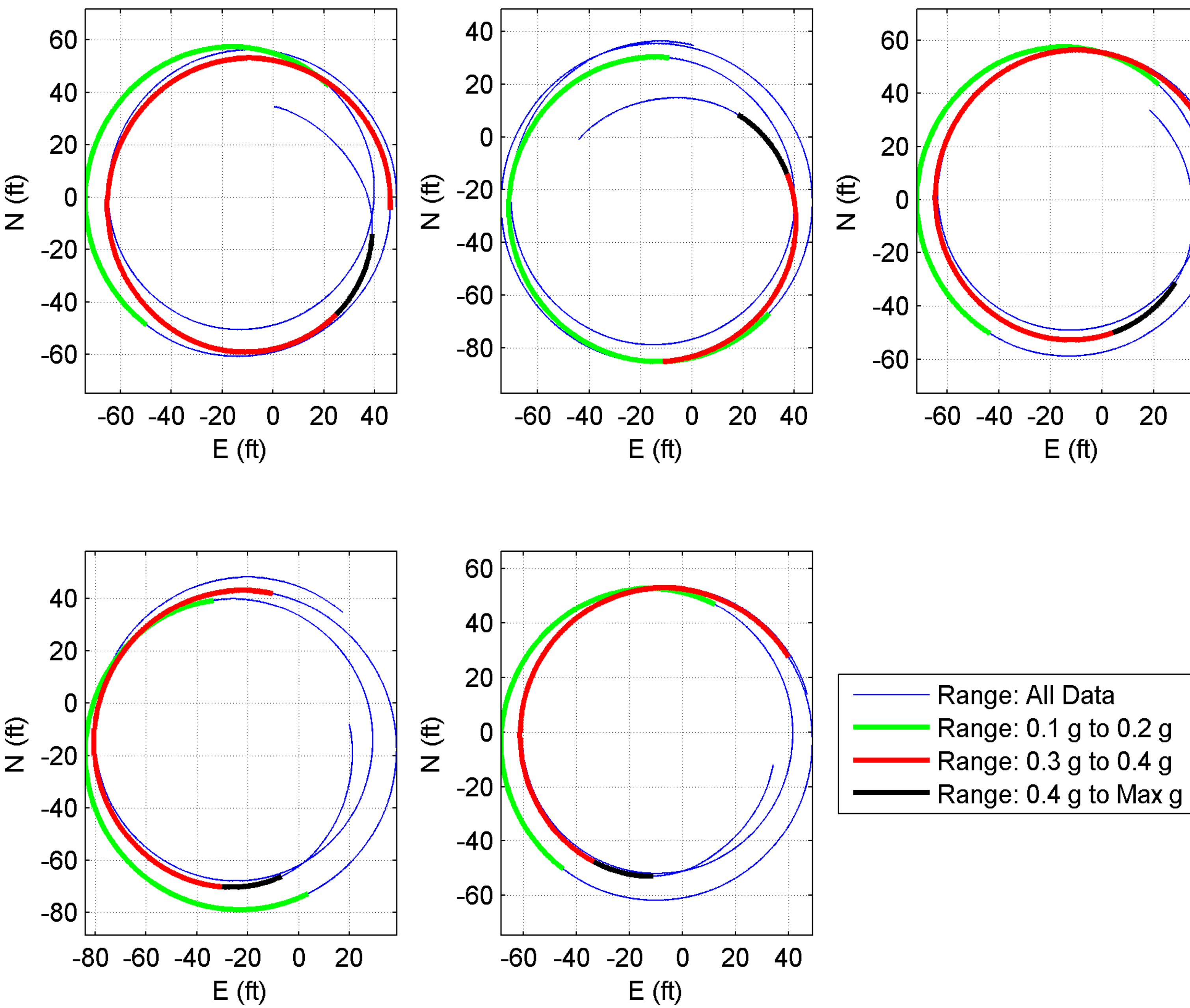


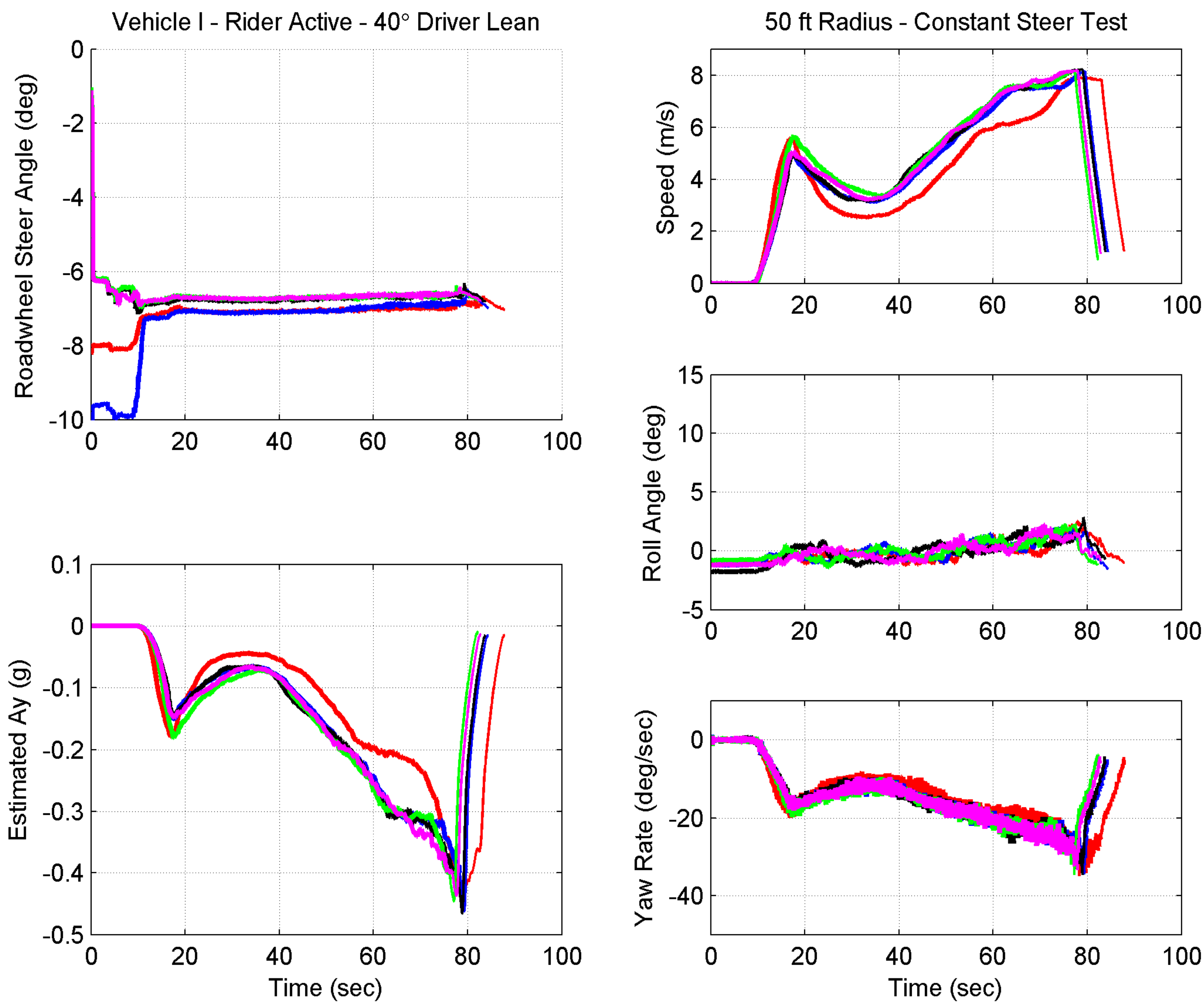
Vehicle I - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
9
CCW Average: 4.92
CCW Ratios: 4.43 7.38 4.89 4.23 3.69 STD=1.44
CCW Final Slopes: -11.2 -19 -12.6 -10.4 -9.56 STD=3.77
CCW Initial Slopes: -2.52 -2.57 -2.57 -2.47 -2.59 STD=0.0509

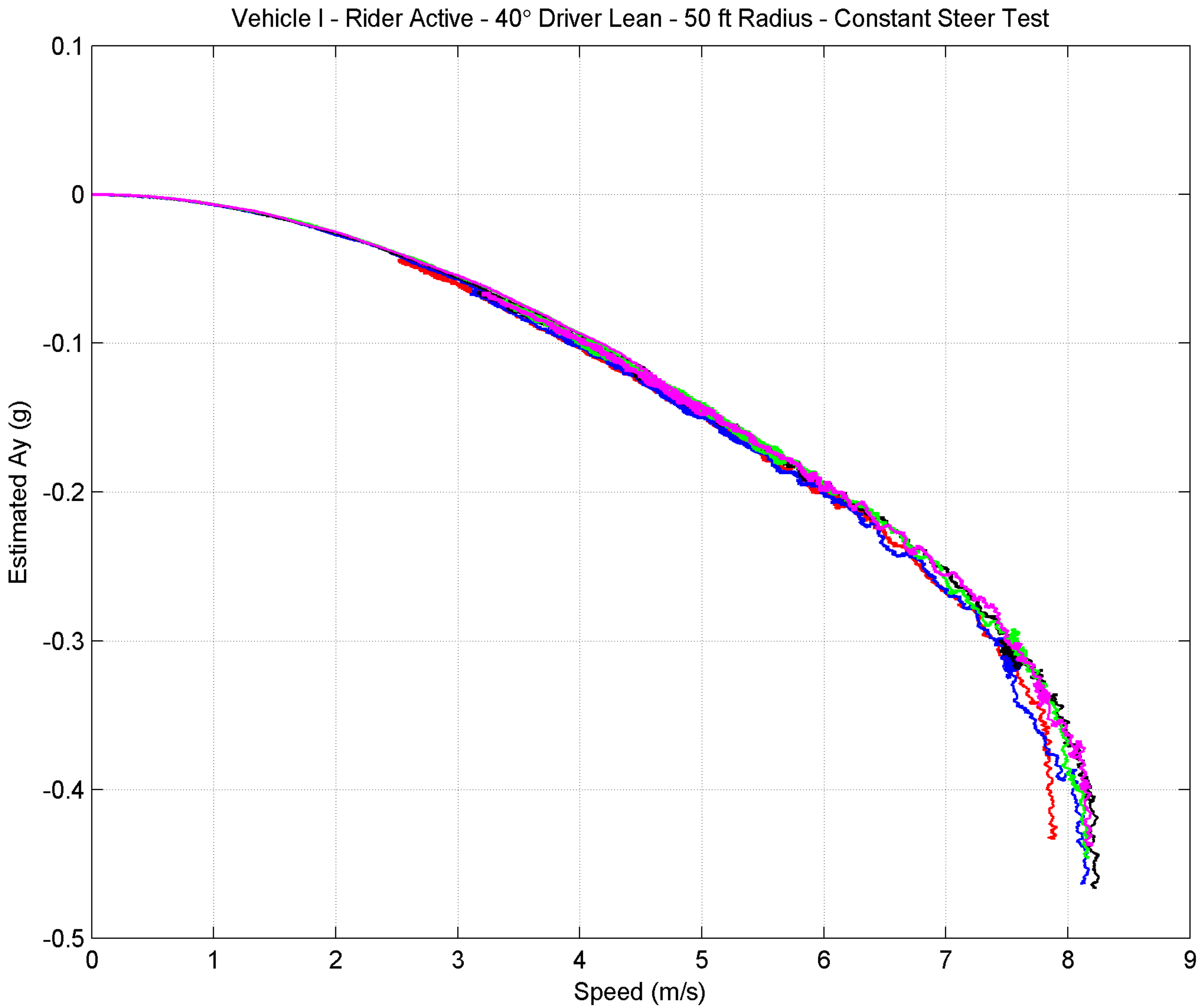
Vehicle I - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

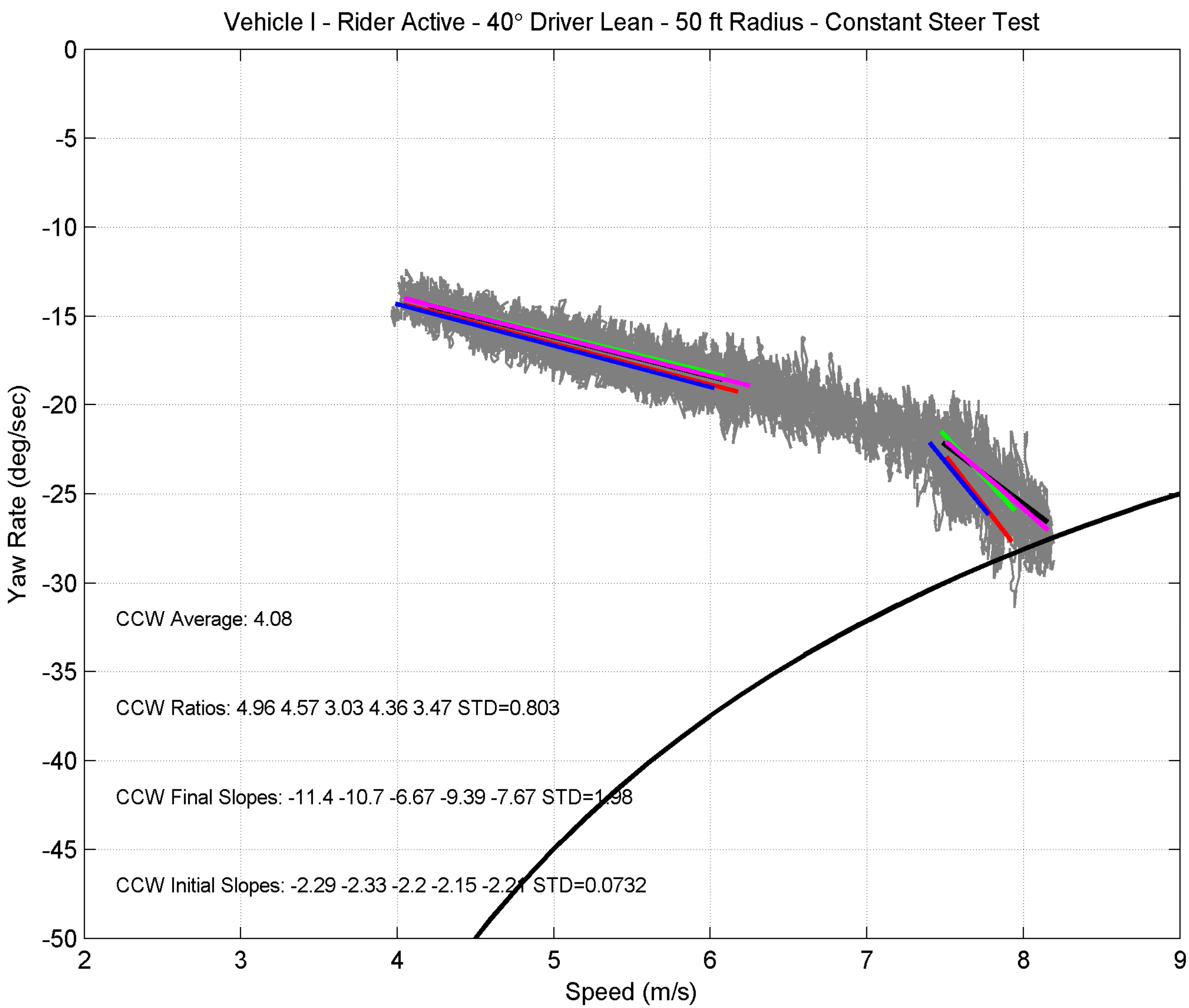


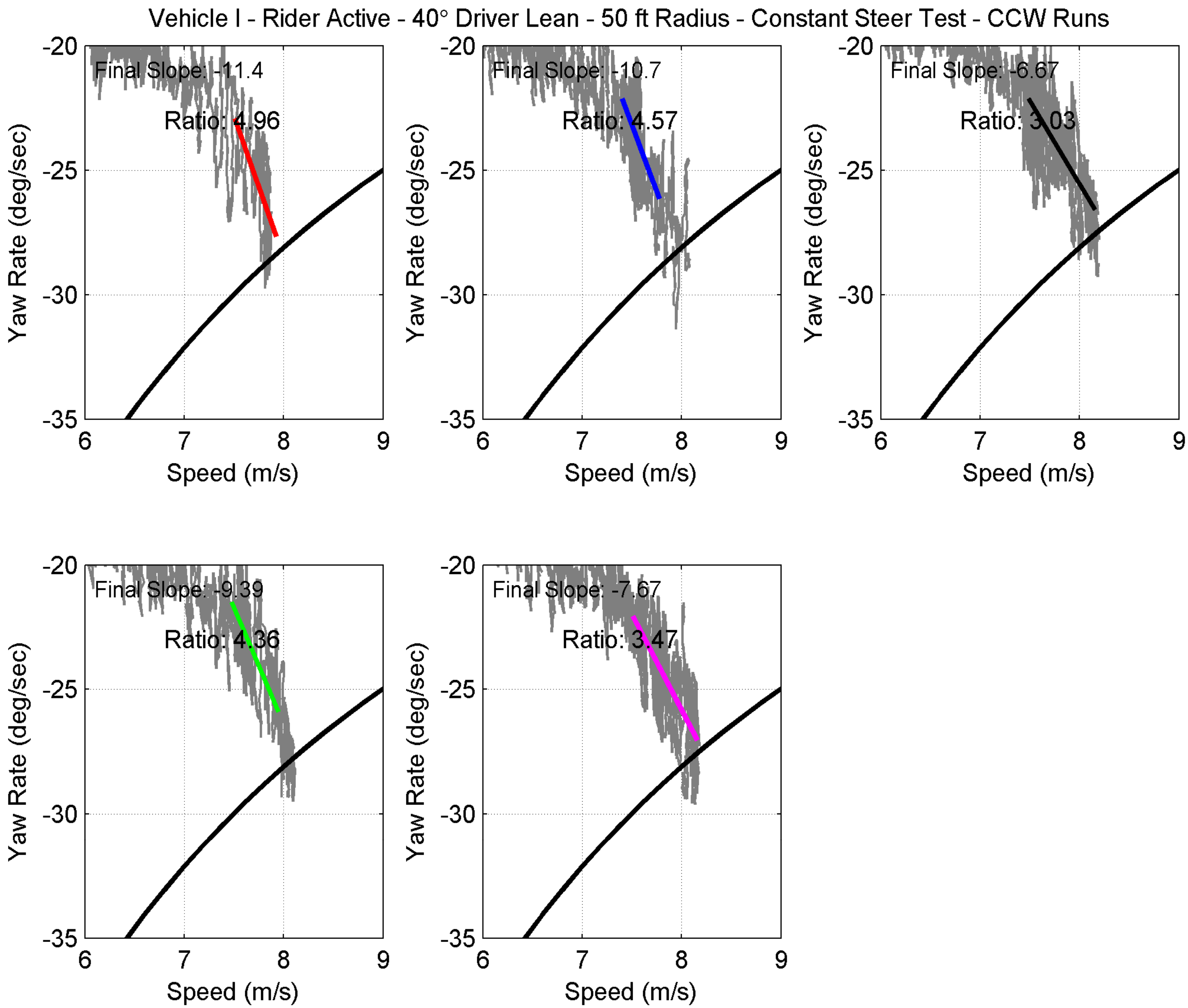
Vehicle I - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs




Vehicle I - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

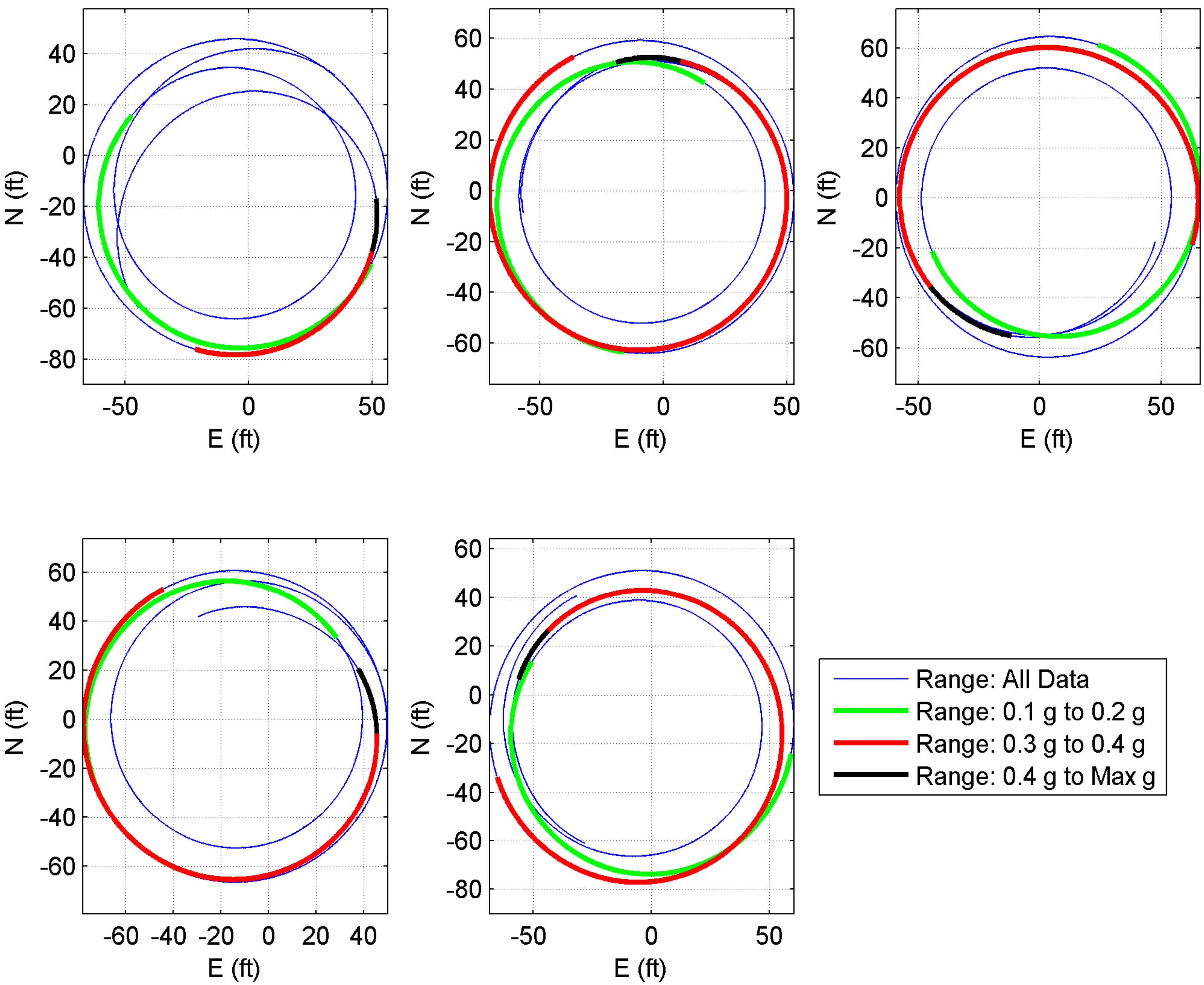

Vehicle I - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8
9

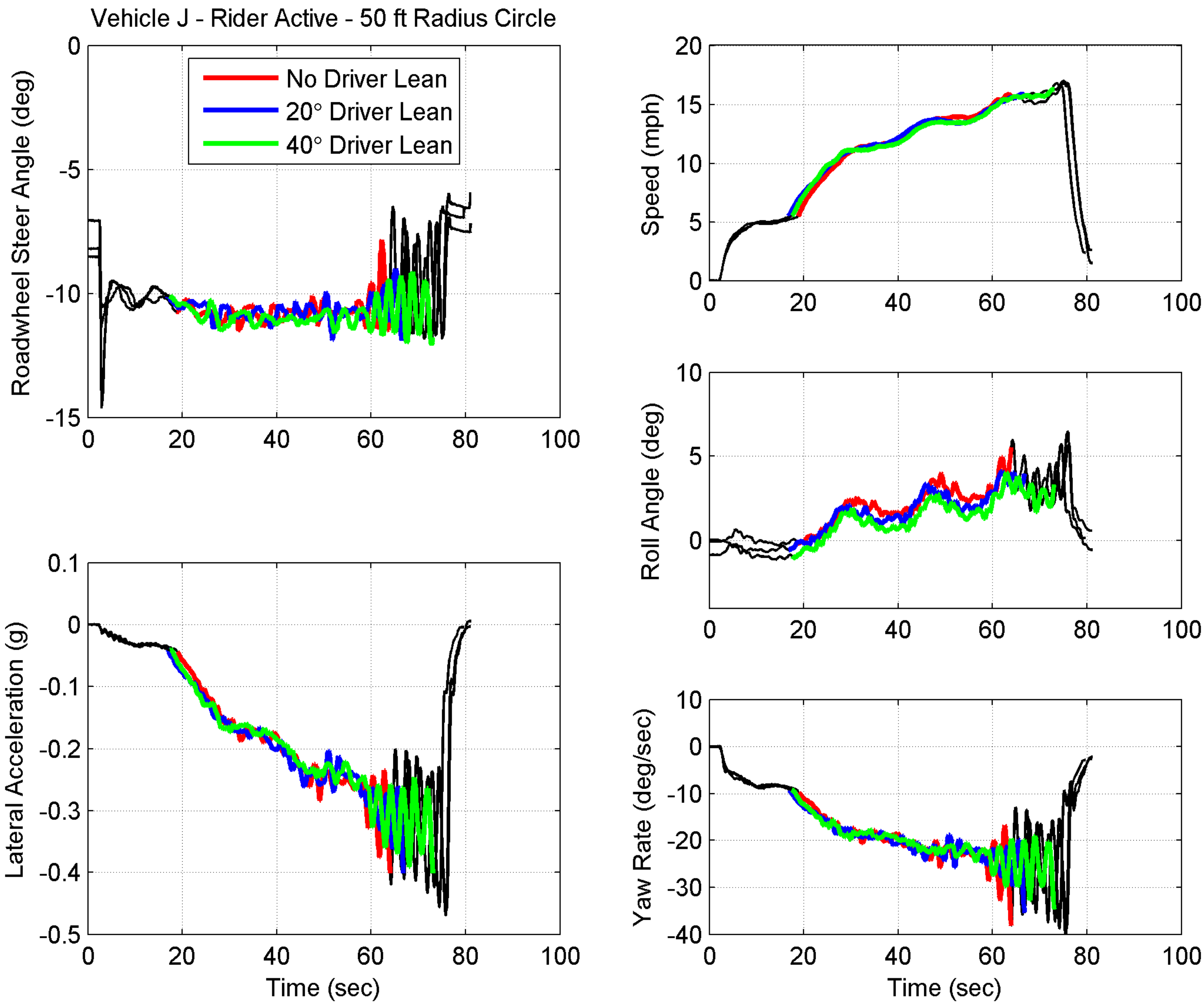

Vehicle I - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
CCW Average: 4.08
CCW Ratios: 4.96 4.57 3.03 4.36 3.47 STD=0.803
CCW Final Slopes: -11.4 -10.7 -6.67 -9.39 -7.67 STD=1.98
CCW Initial Slopes: -2.29 -2.33 -2.2 -2.15 -2.21 STD=0.0732

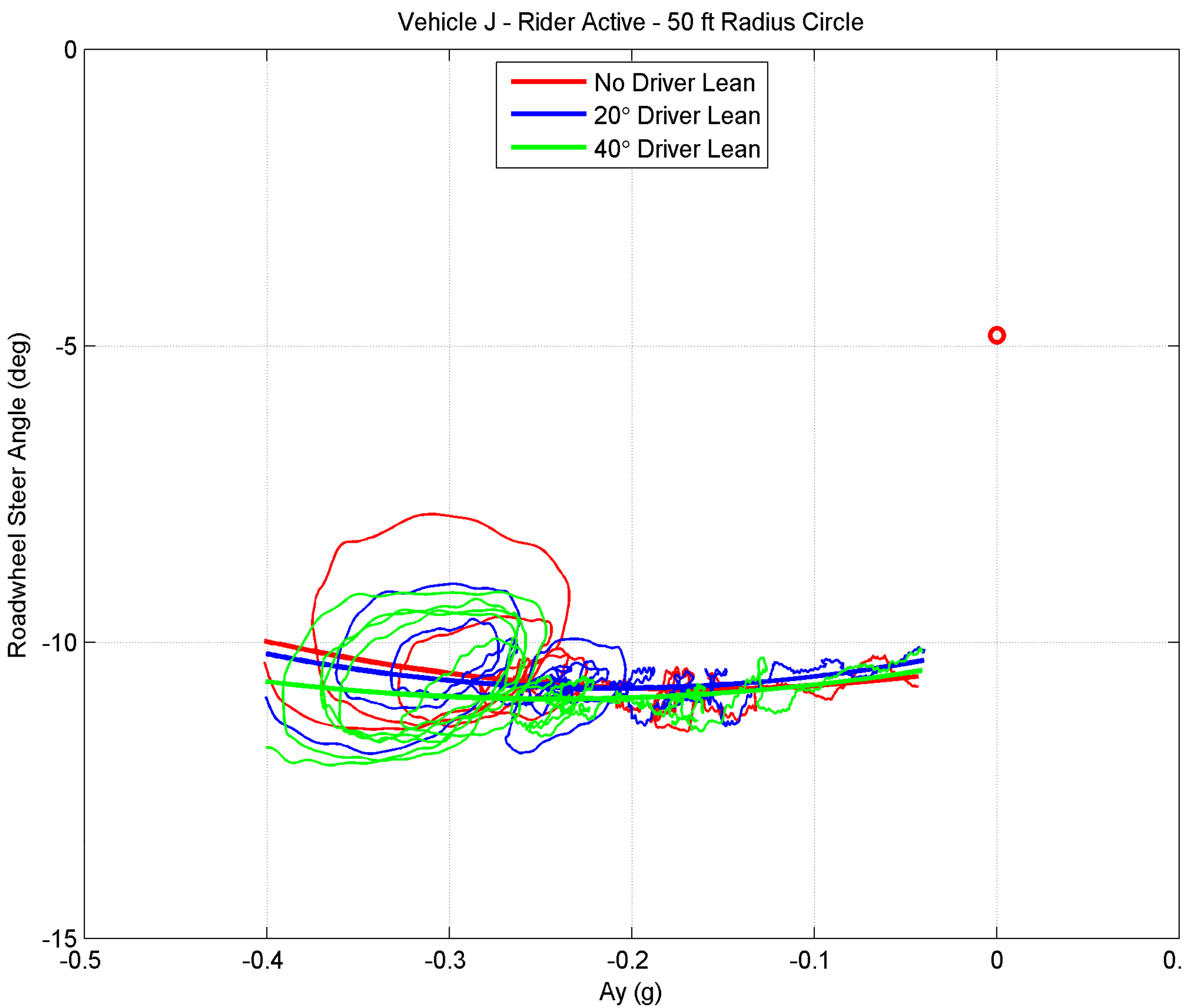


Vehicle I - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -11.4
Ratio: 4.96
Final Slope: -10.7
Ratio: 4.57
Final Slope: -6.67
Ratio: 3.03
Final Slope: -9.39
Ratio: 4.36
Final Slope: -7.67
Ratio: 3.47
Yaw Rate (deg/sec)
Speed (m/s)
-20
-25
-30
-35
6
7
8
9

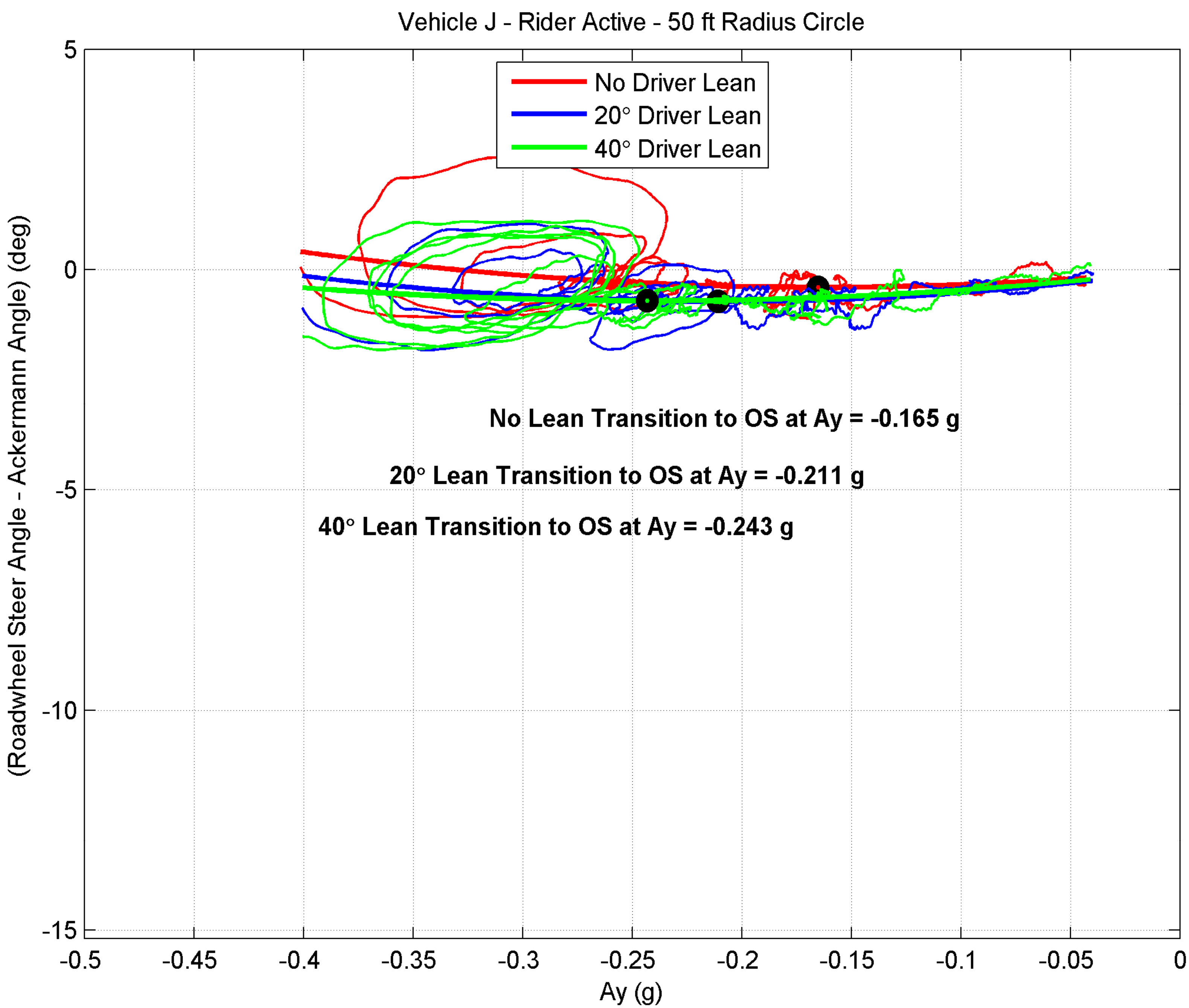
Vehicle I - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



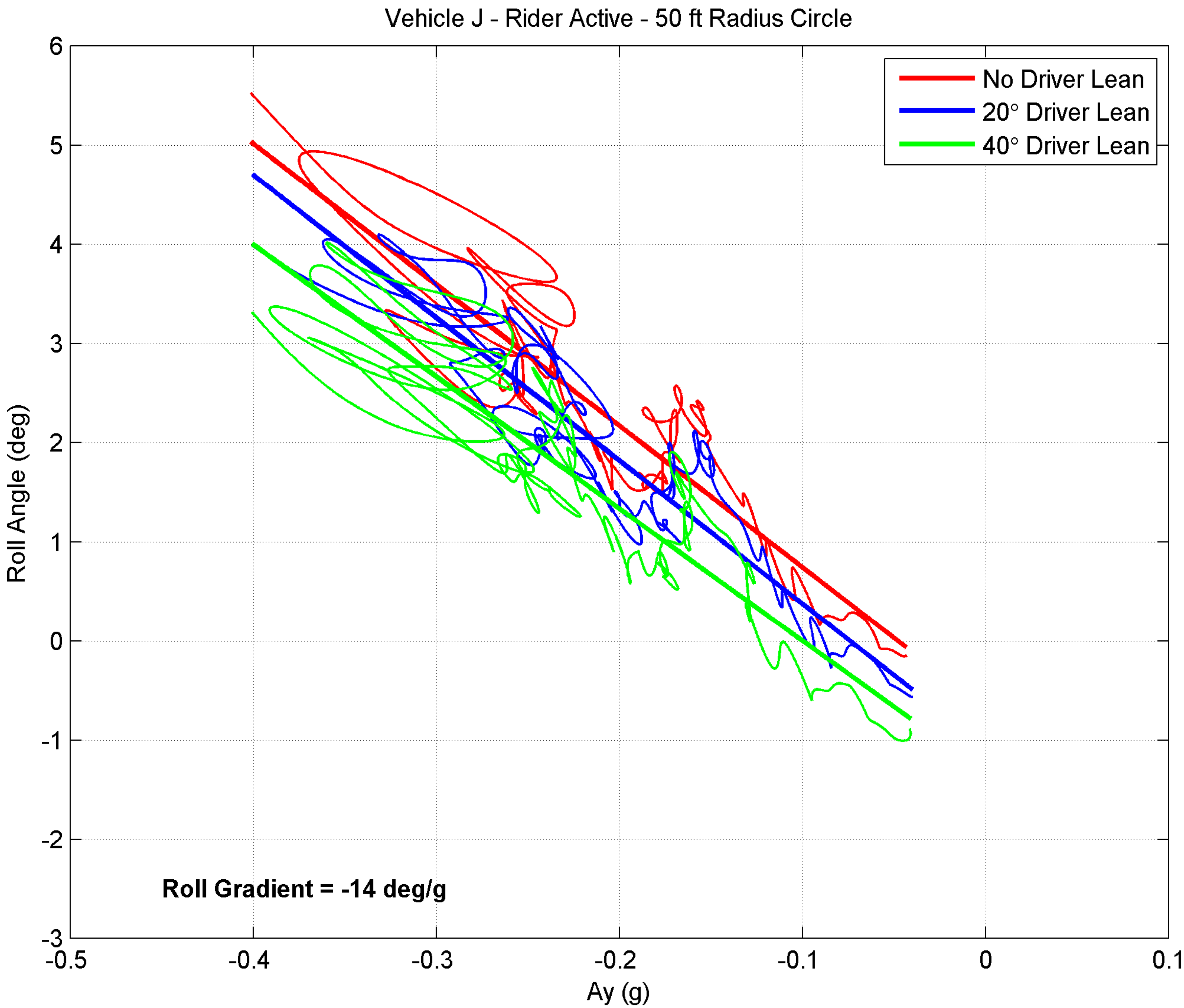

Vehicle J - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



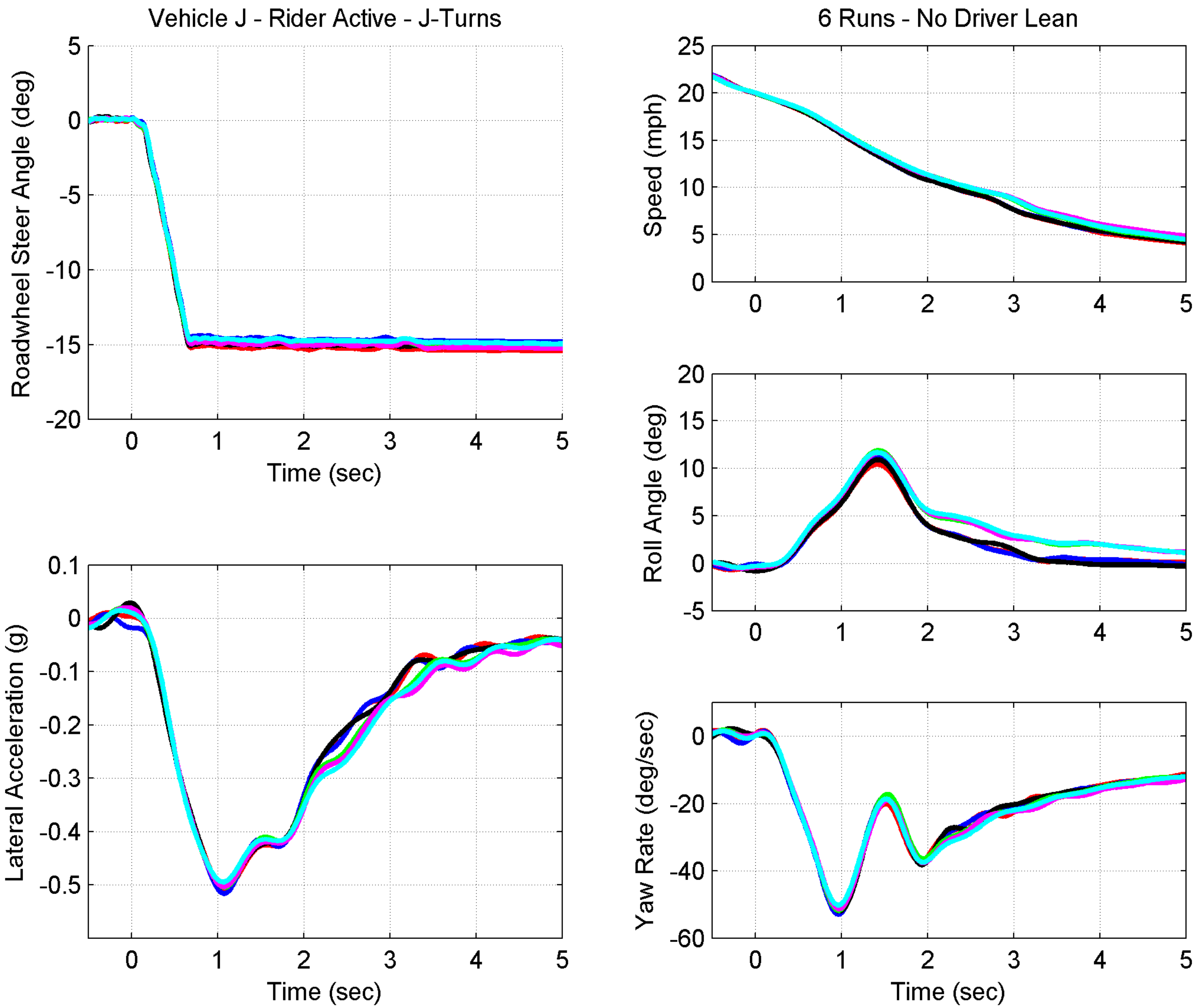
Vehicle J - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)

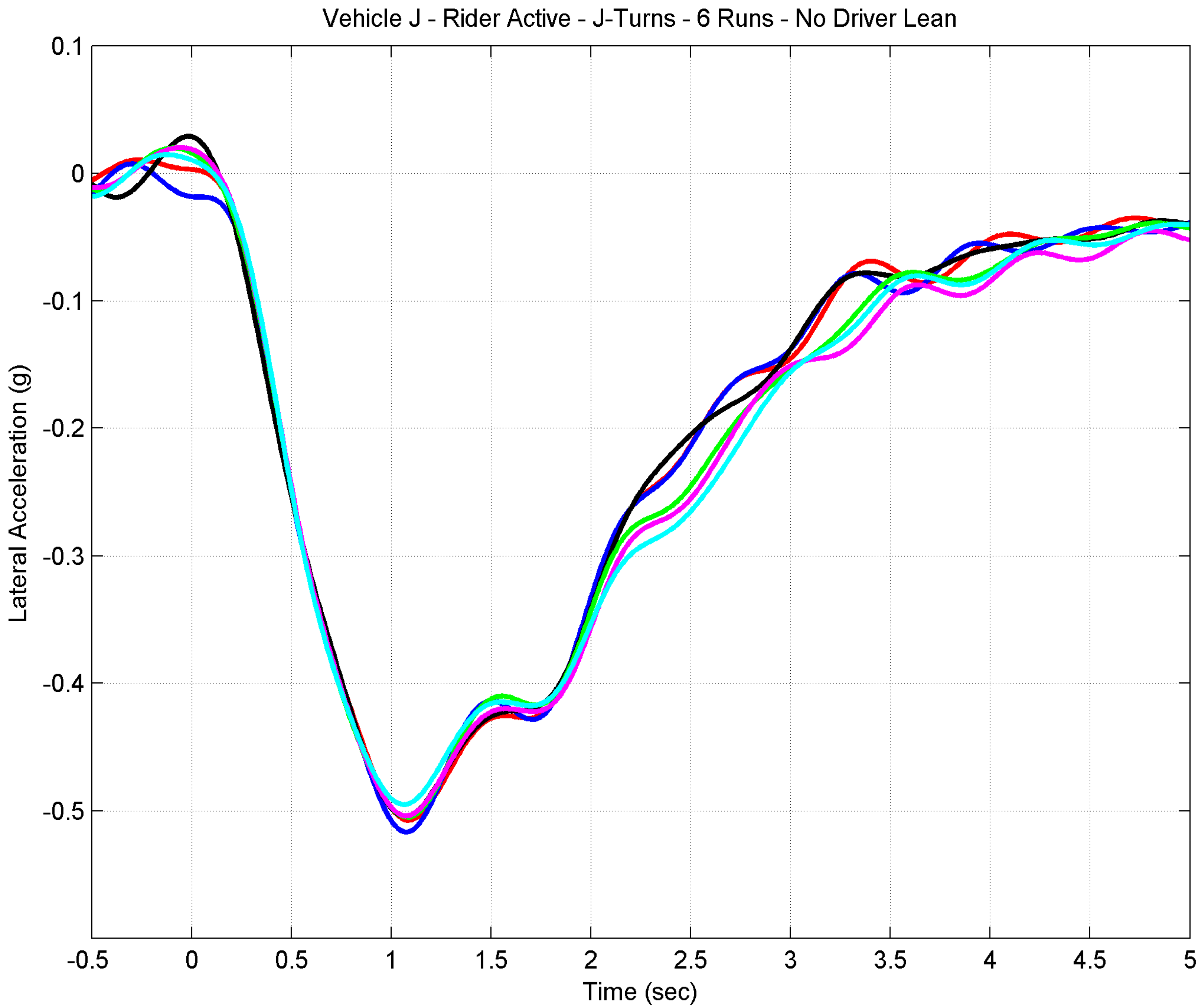


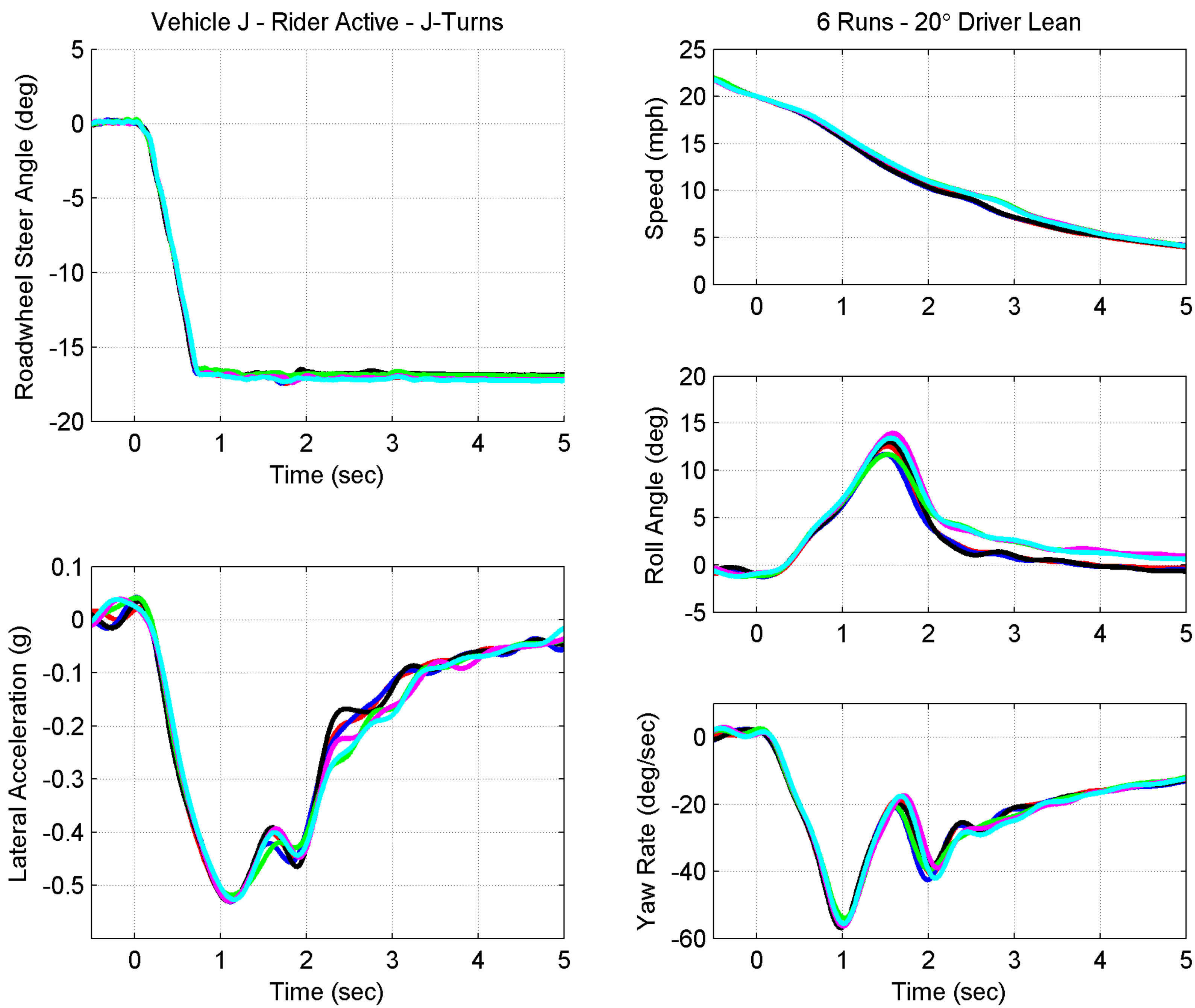
Vehicle J - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.165 g
20° Lean Transition to OS at Ay = -0.211 g
40° Lean Transition to OS at Ay = -0.243 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

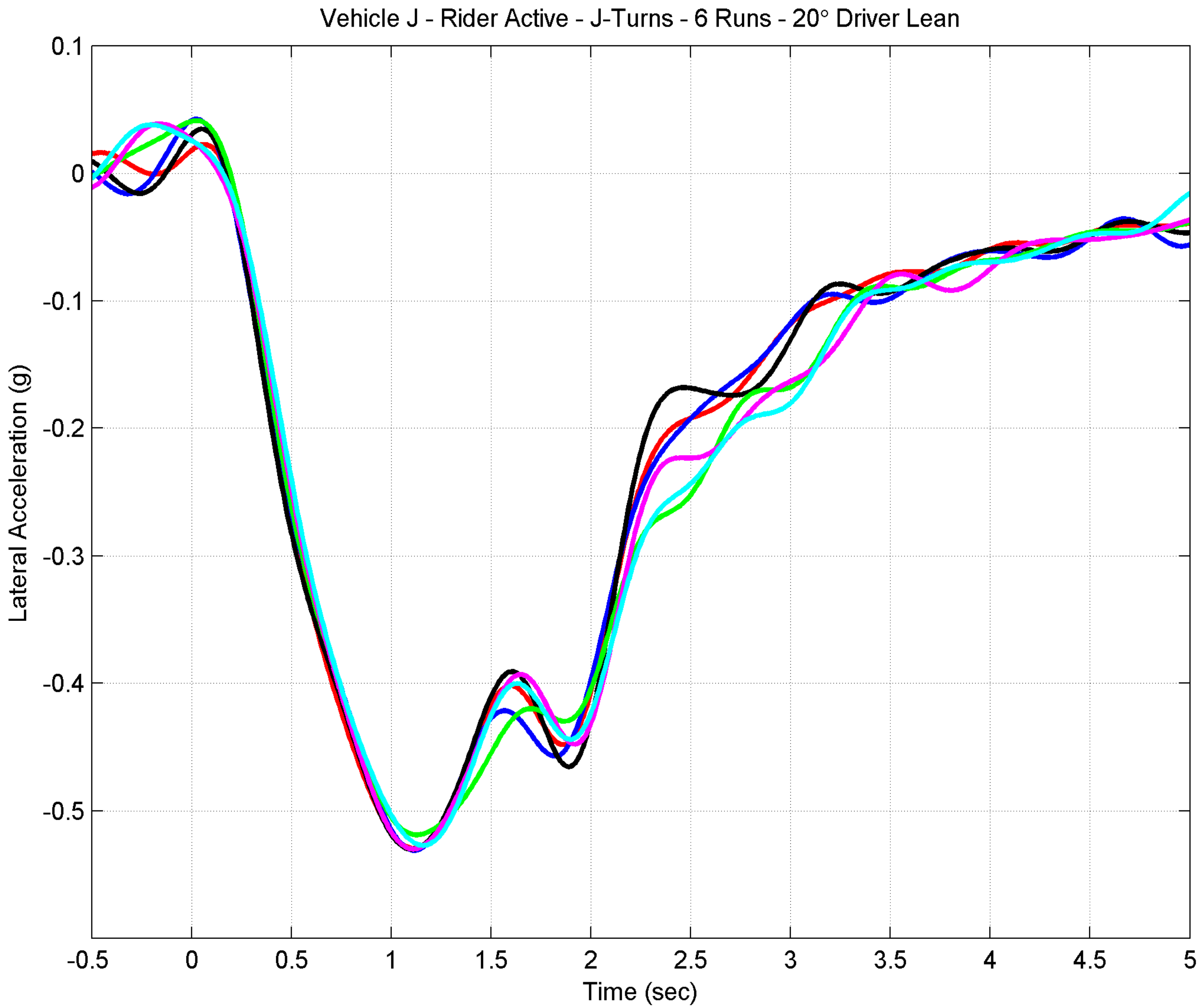


Vehicle J - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Roll Gradient = -14 deg/g

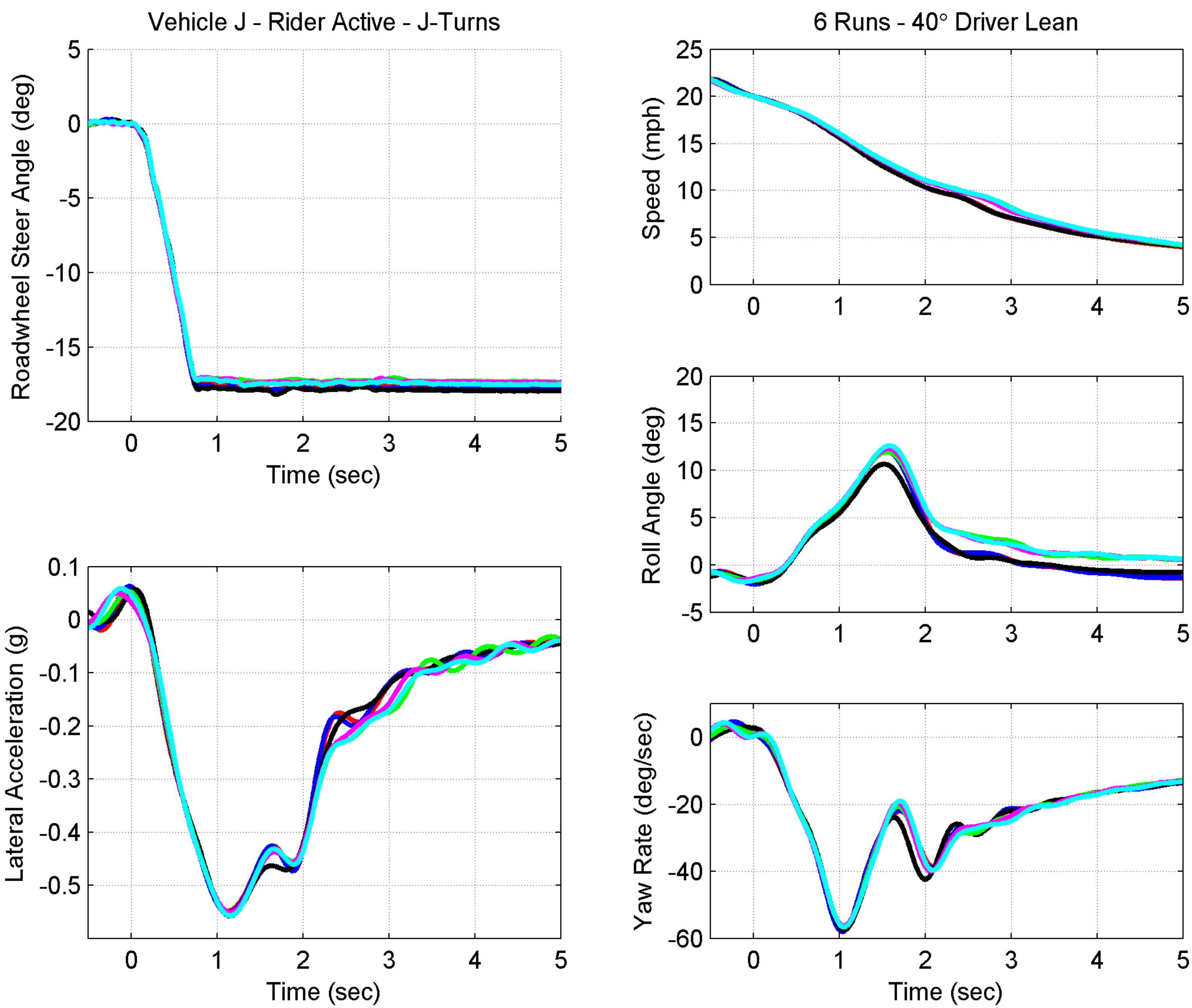

Vehicle J - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

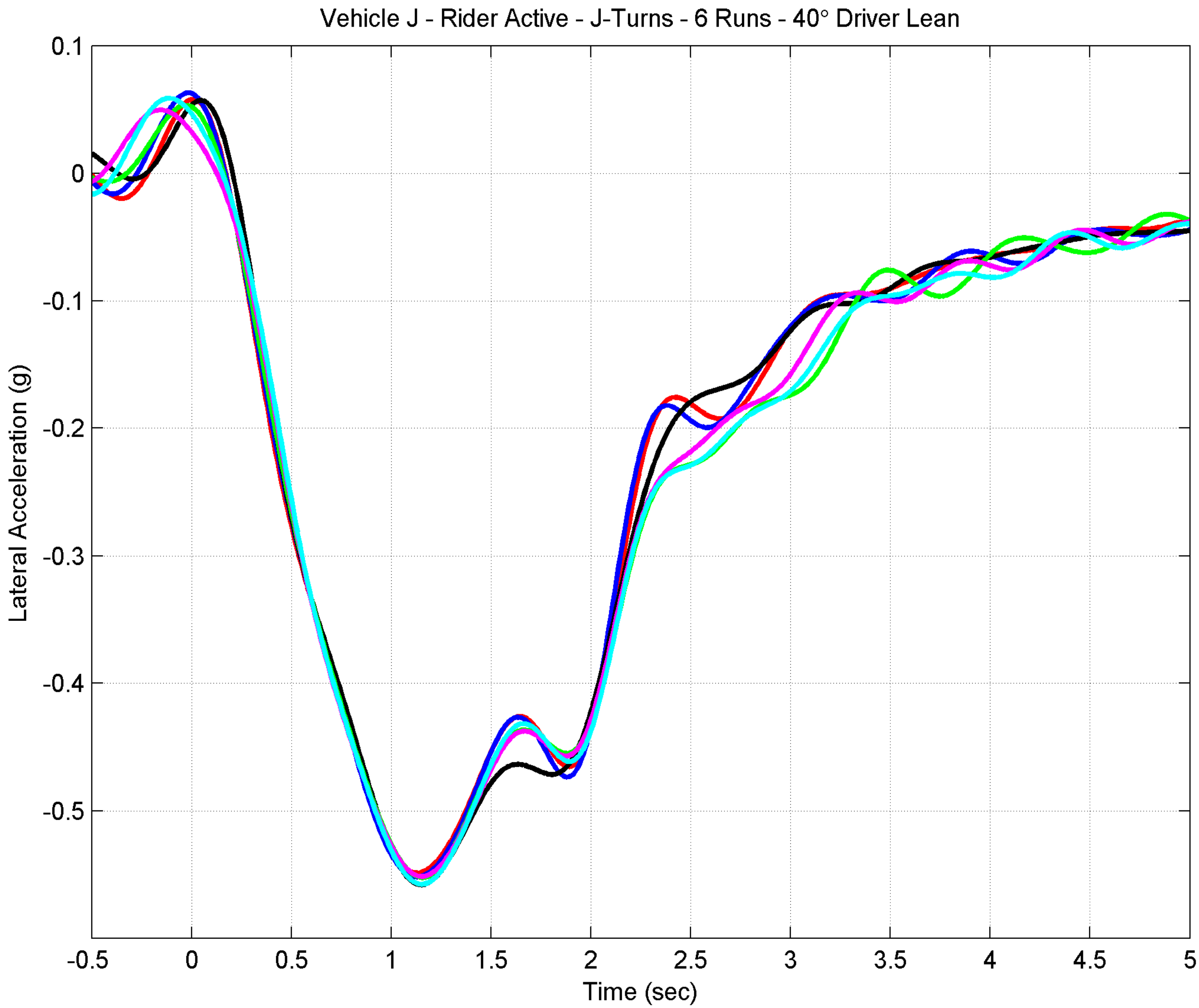

Vehicle J - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle J - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)



Vehicle J - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)


Vehicle J - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Time (sec)
Yaw Rate (deg/sec)
Time (sec)



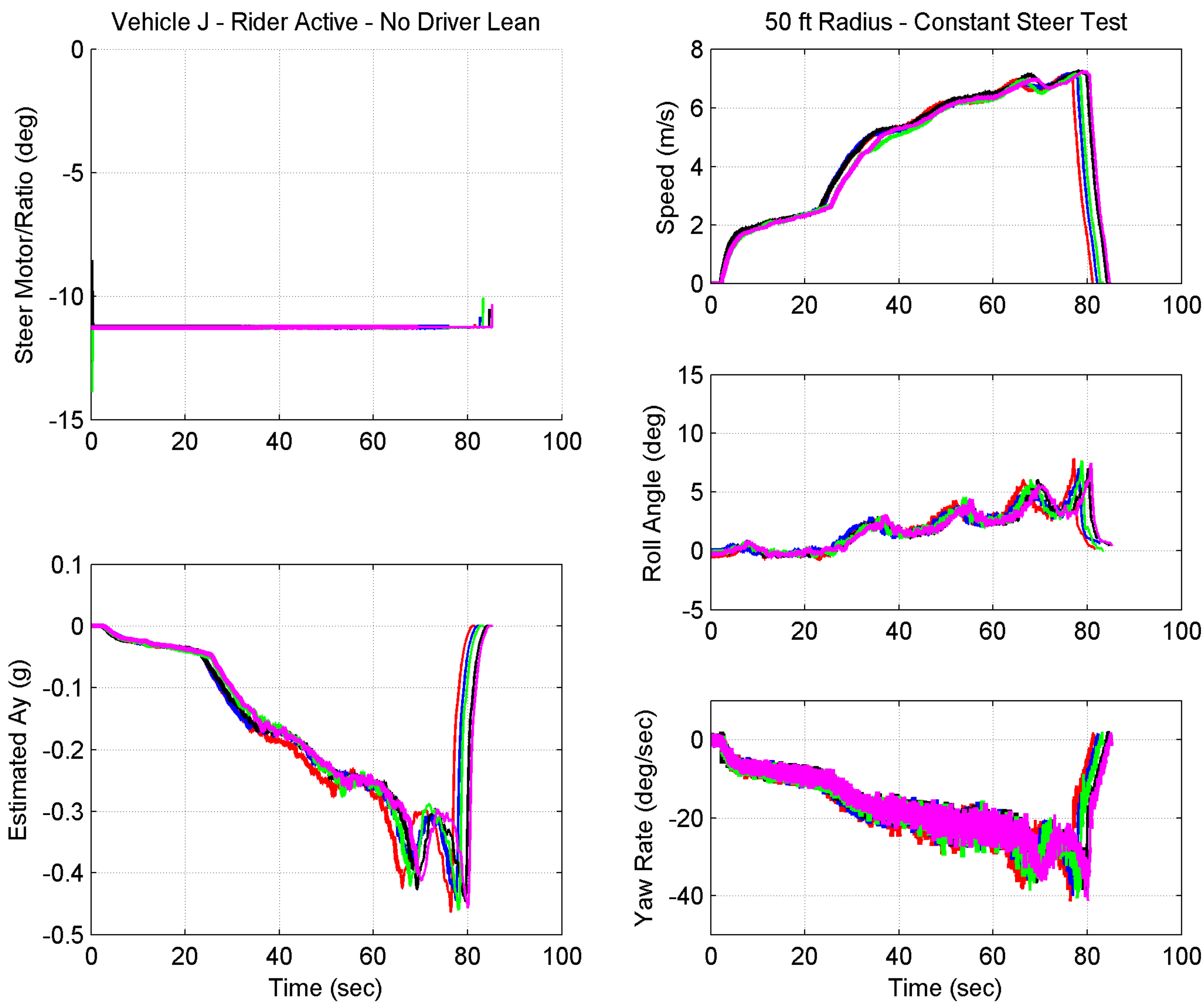
Vehicle J - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle J - Rider Active Results

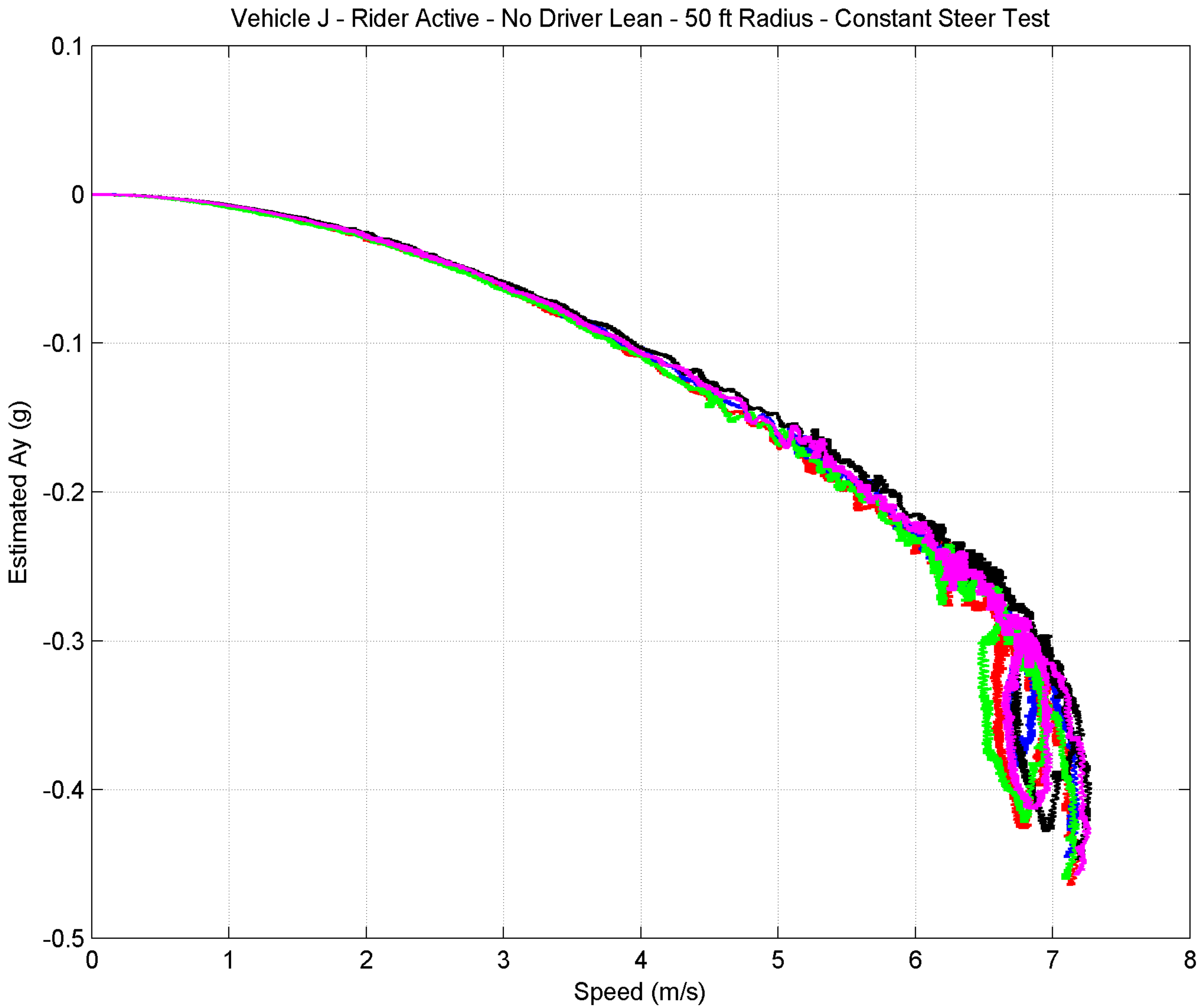
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

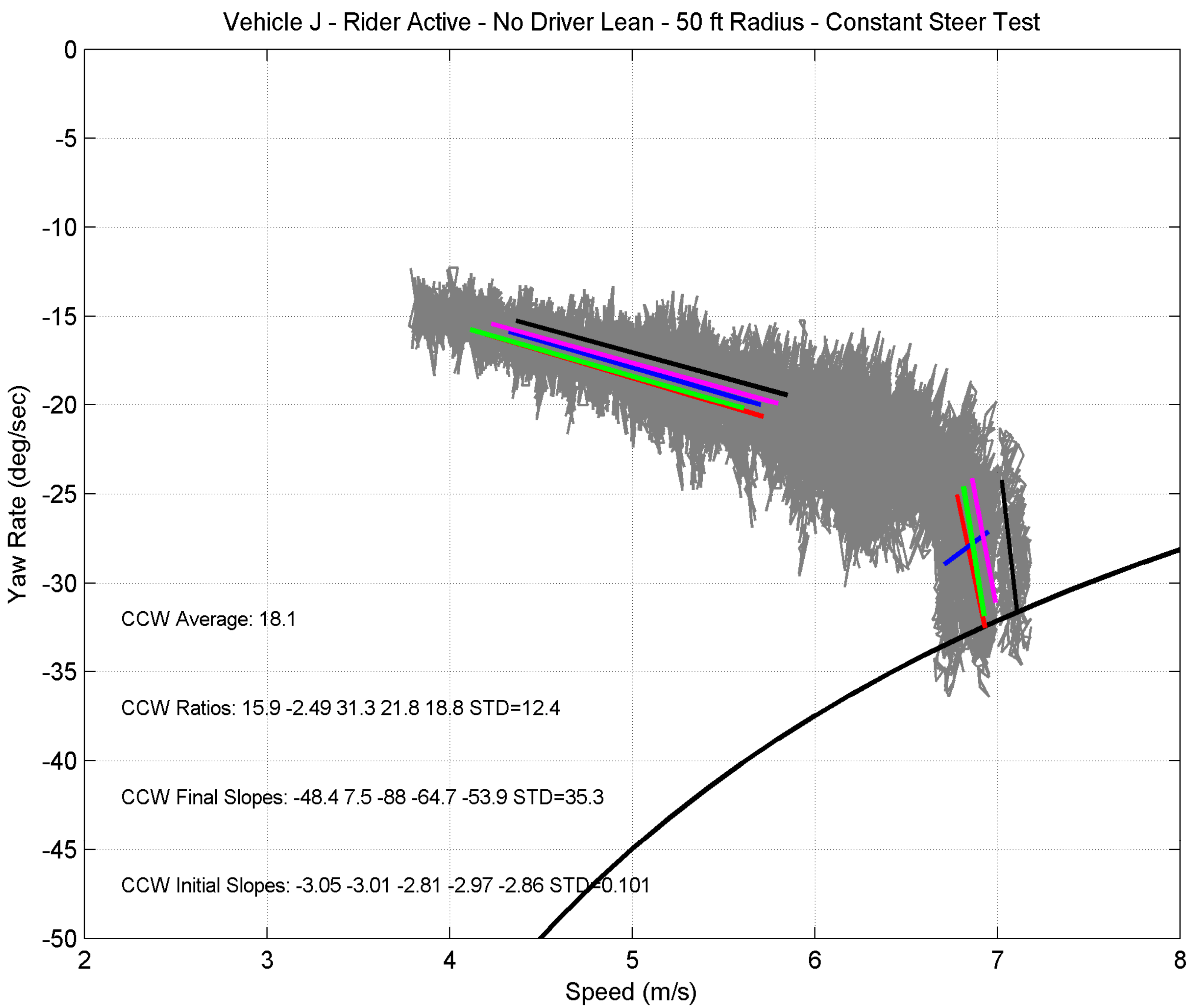
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.507	-0.530	-0.549
	-0.517	-0.531	-0.552
	-0.504	-0.530	-0.558
Mean Value of 3 Runs	-0.509	-0.530	-0.553
Standard Deviation of 3 Runs	0.006	0.001	0.005

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.505	-0.519	-0.553
	-0.504	-0.530	-0.552
	-0.495	-0.527	-0.558
Mean Value of 3 Runs	-0.501	-0.525	-0.554
Standard Deviation of 3 Runs	0.005	0.006	0.003
Average of All 6 Runs	**0.505**	**0.528**	**0.554**

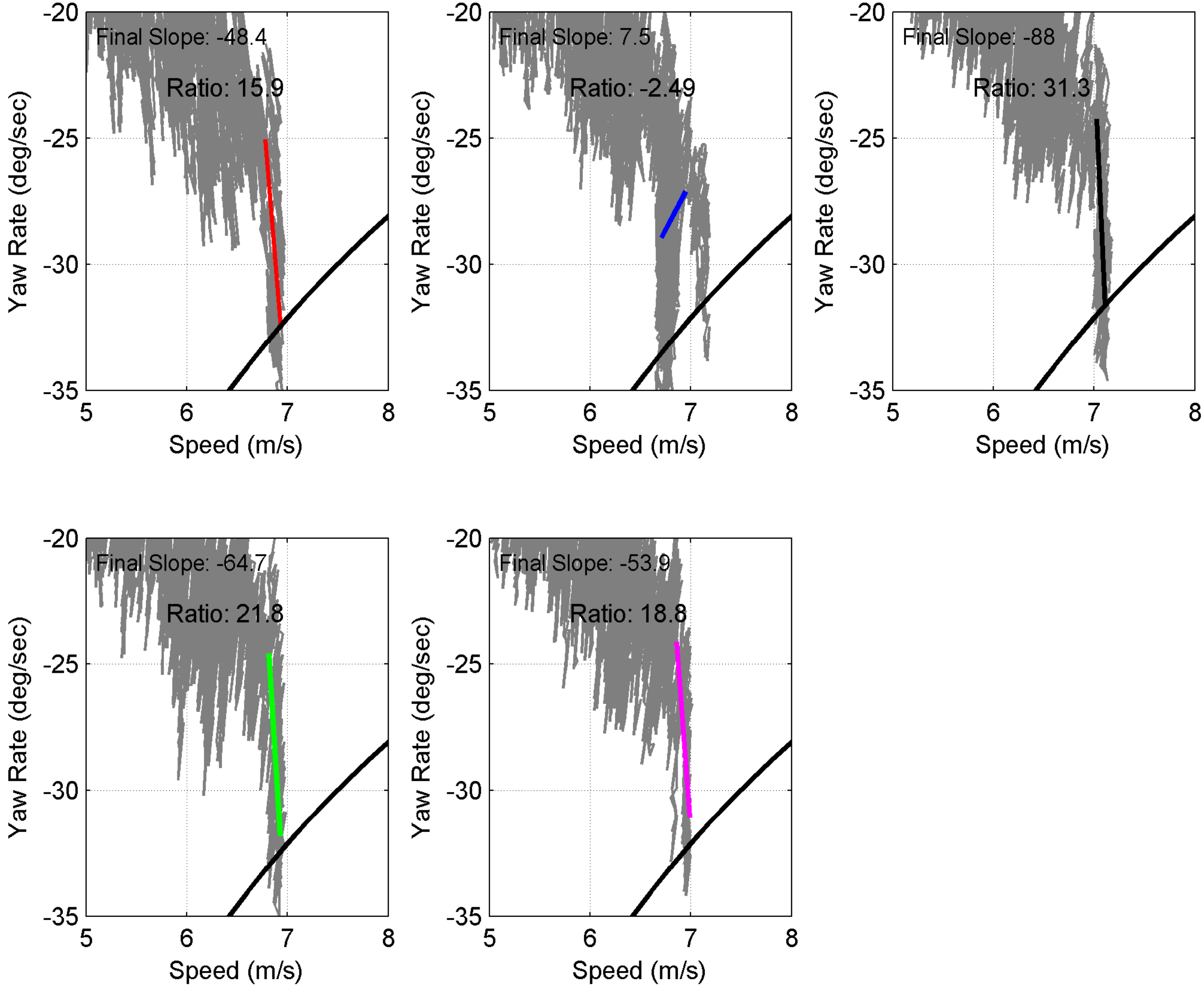


Vehicle J - Rider Active - No Driver Lean
50 ft Radius - Constant Steer Test
Steer Motor/Ratio (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

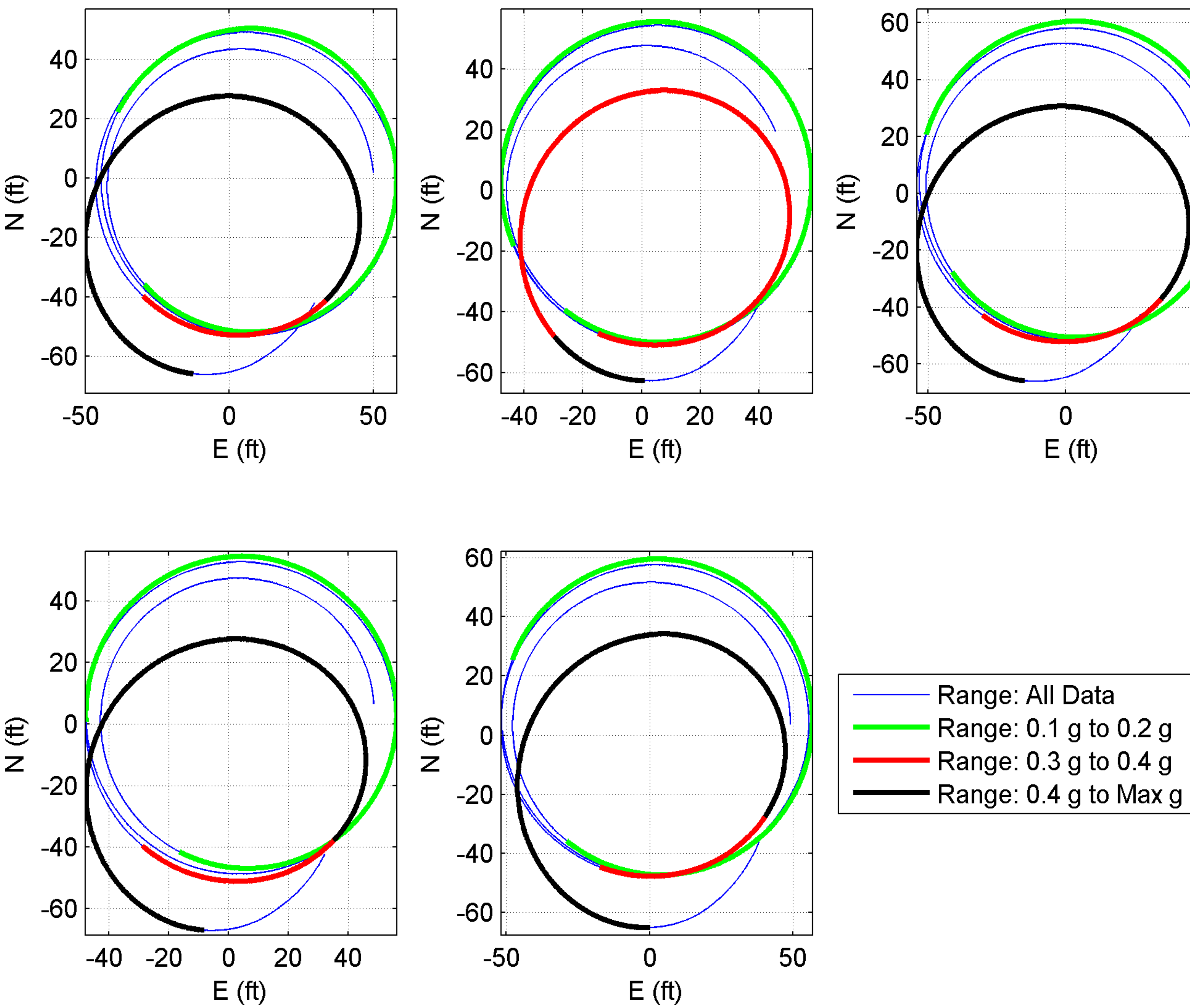

Vehicle J - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7
8

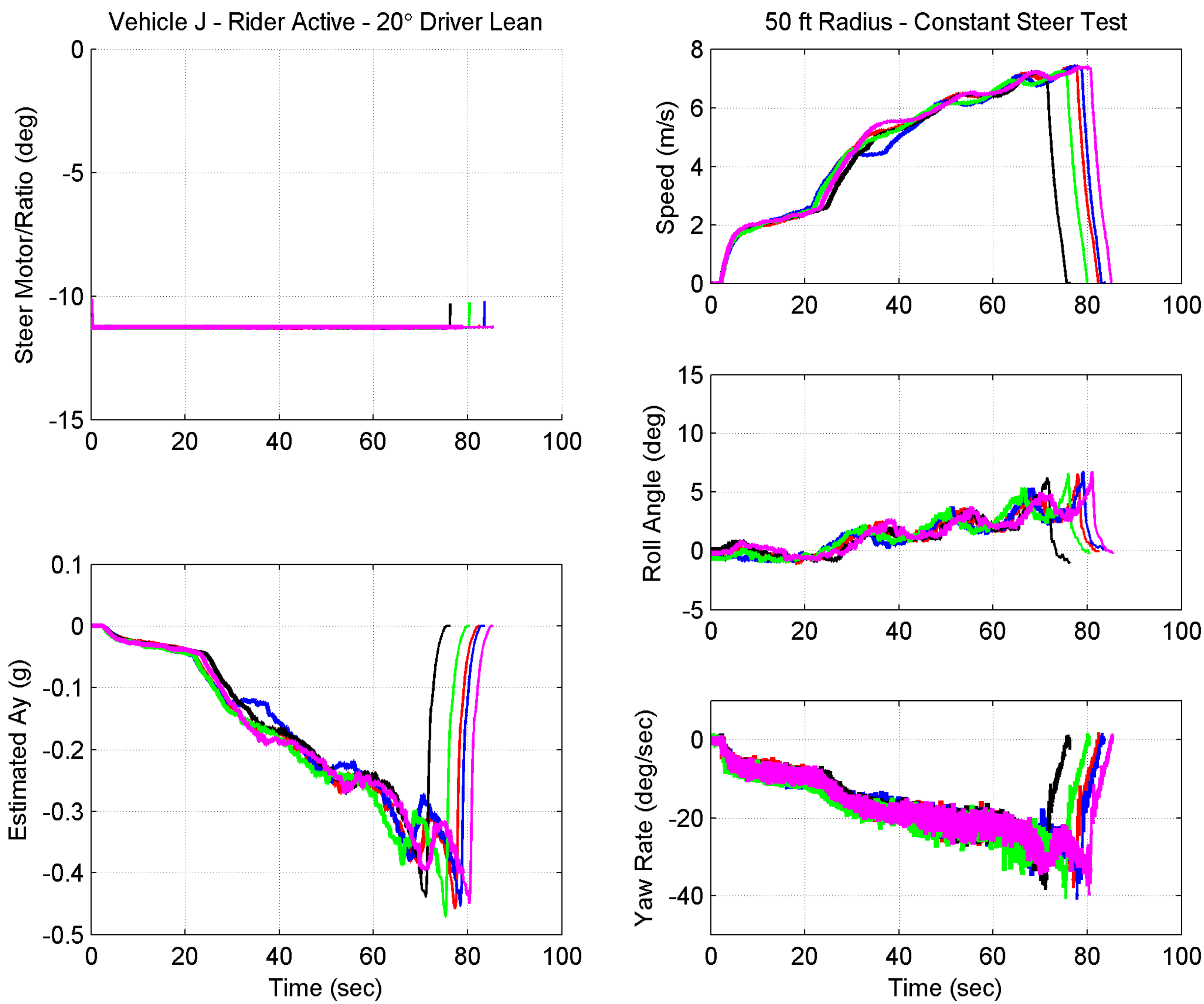

Vehicle J - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
CCW Average: 18.1
CCW Ratios: 15.9 -2.49 31.3 21.8 18.8 STD=12.4
CCW Final Slopes: -48.4 7.5 -88 -64.7 -53.9 STD=35.3
CCW Initial Slopes: -3.05 -3.01 -2.81 -2.97 -2.86 STD=0.101

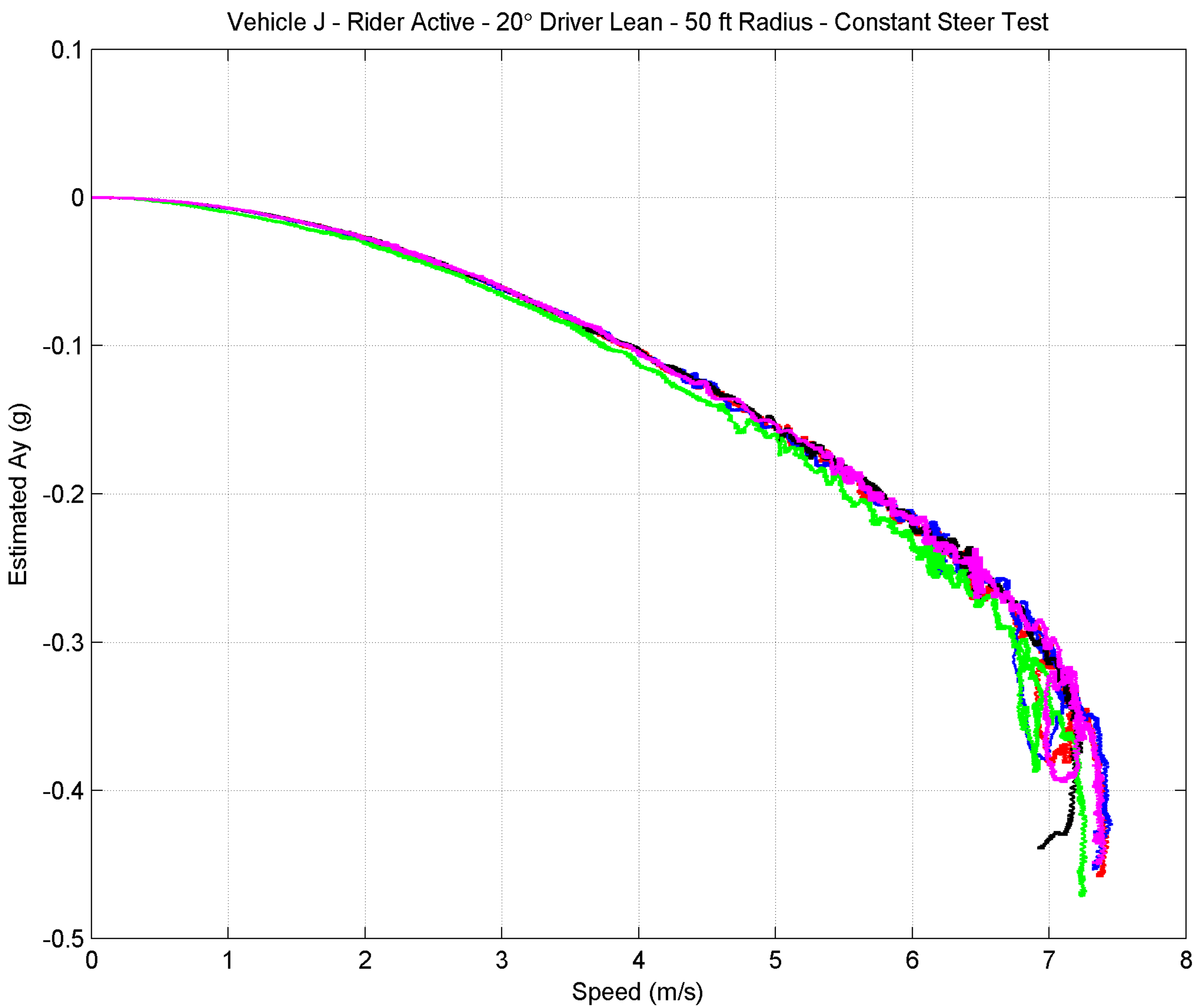
Vehicle J - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



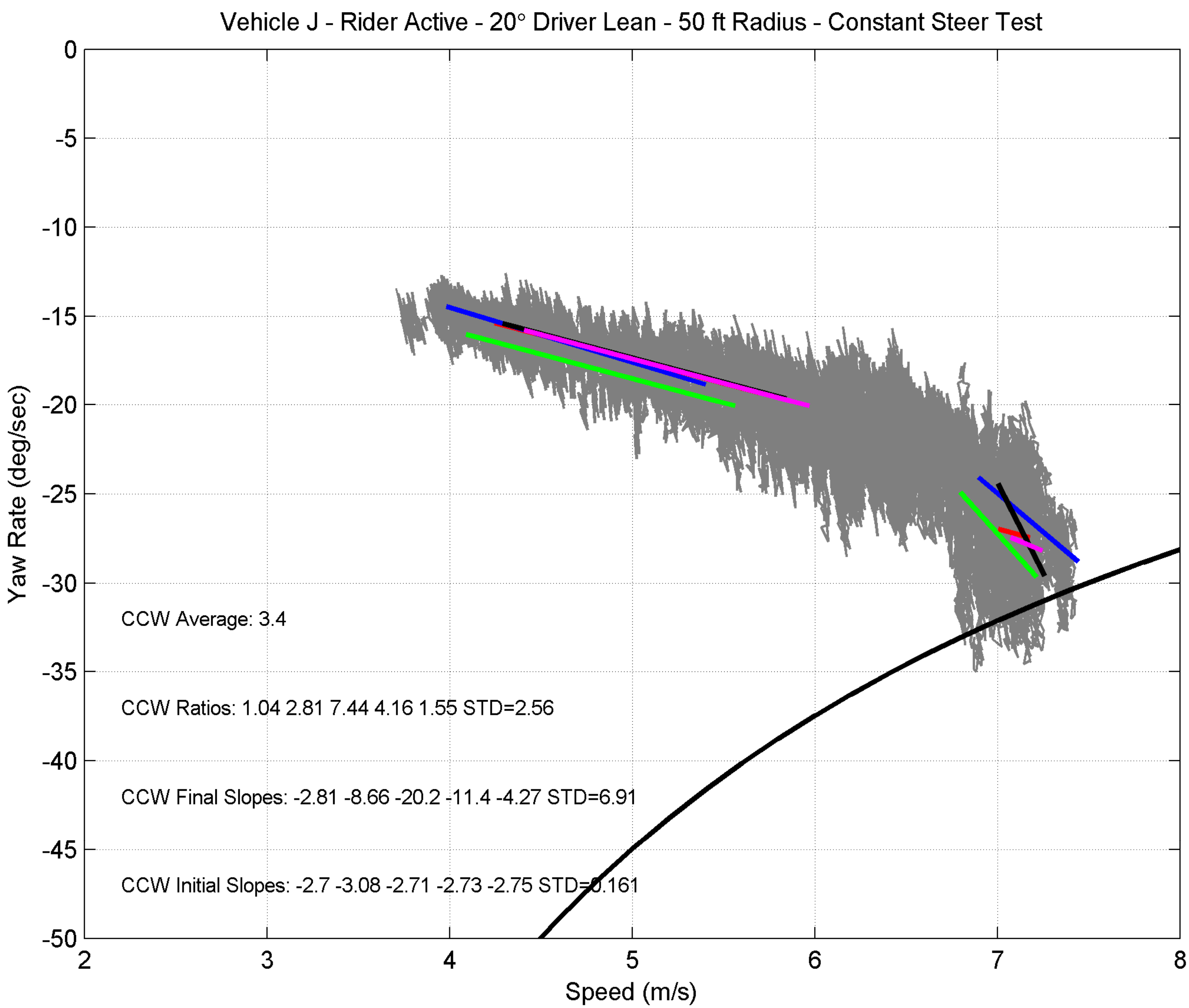
Vehicle J - Rider Active - No Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs



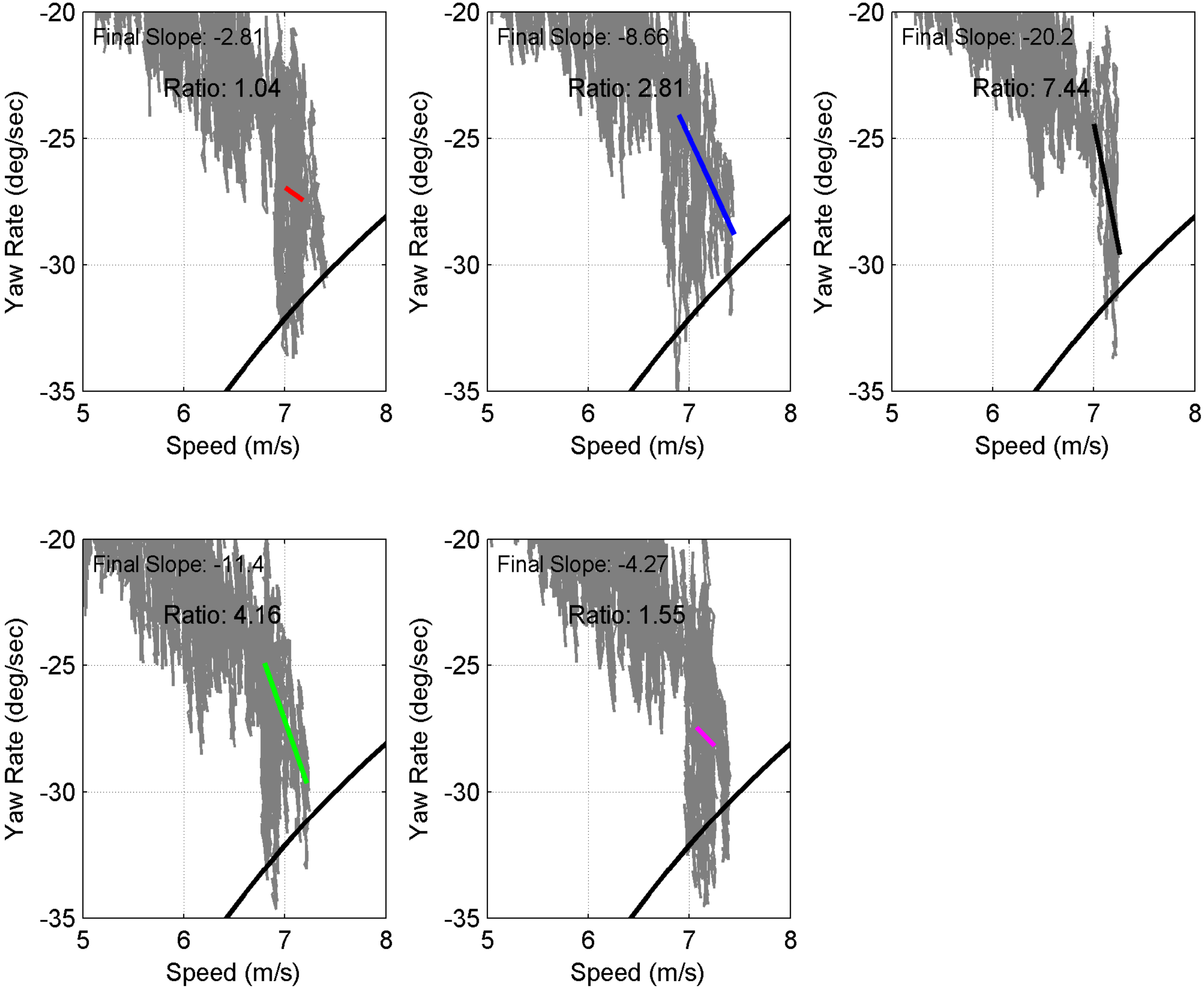

Vehicle J - Rider Active - 20° Driver Lean
50 ft Radius - Constant Steer Test
Steer Motor/Ratio (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



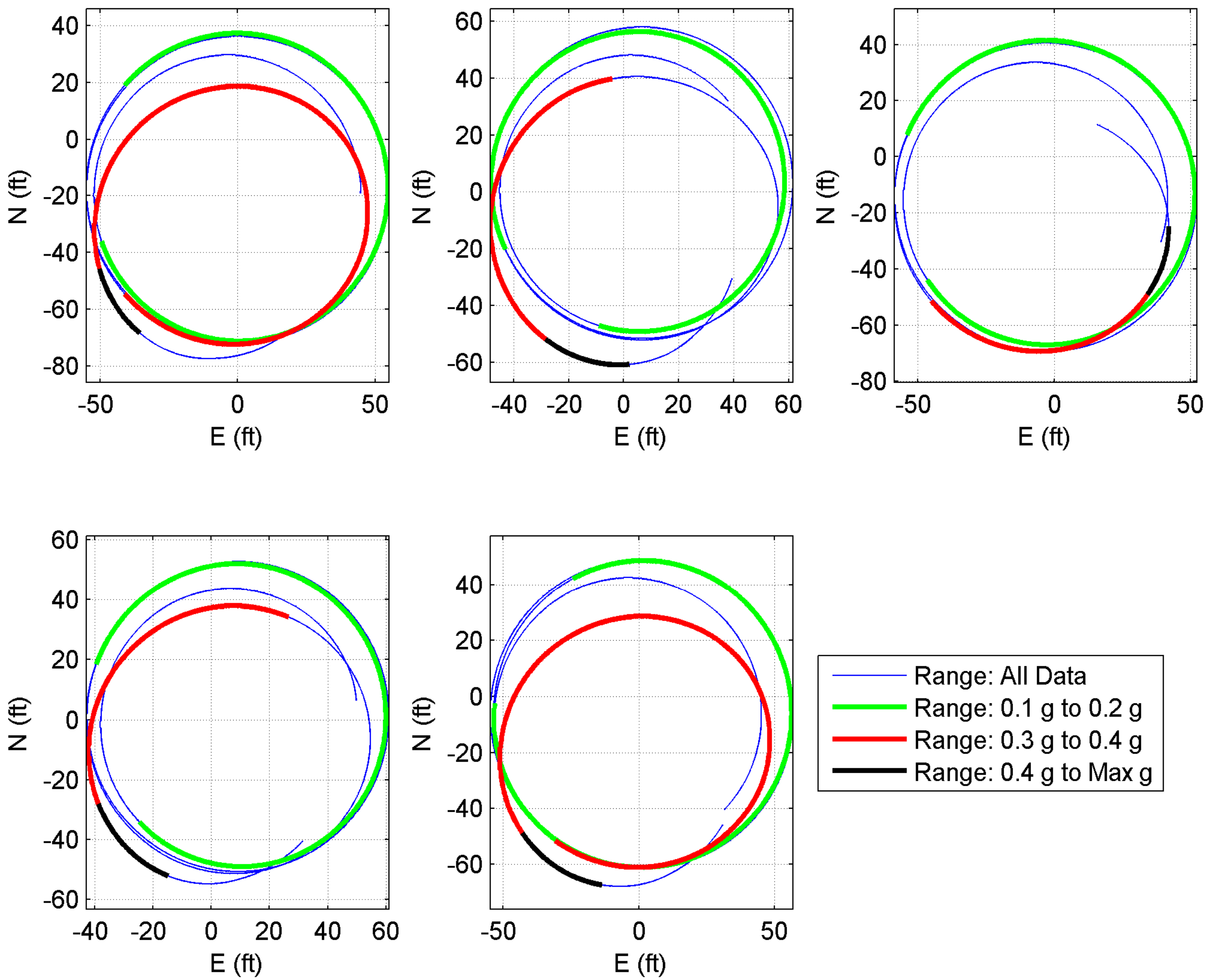
Vehicle J - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
7
8
Speed (m/s)

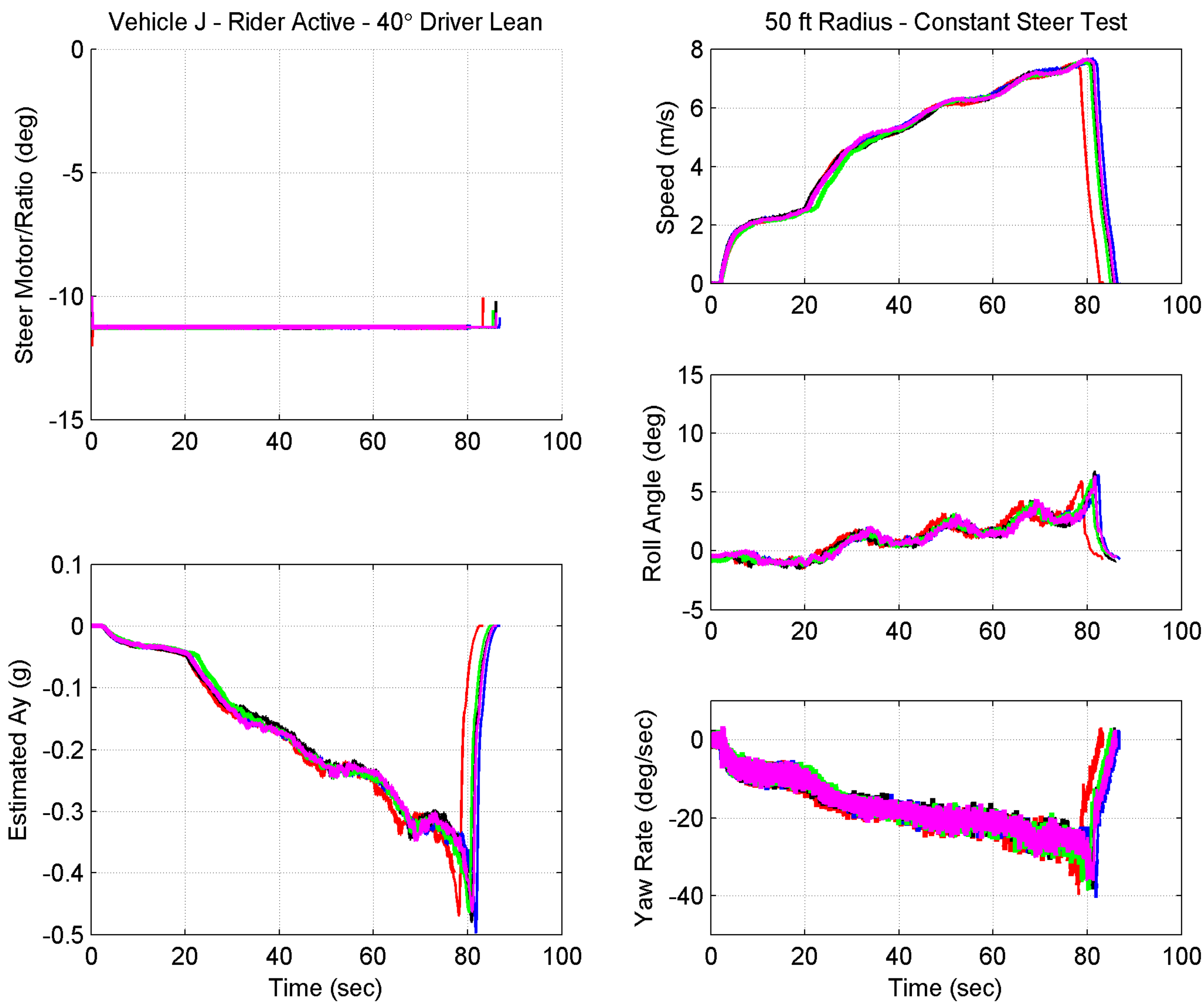

Vehicle J - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
CCW Average: 3.4
CCW Ratios: 1.04 2.81 7.44 4.16 1.55 STD=2.56
CCW Final Slopes: -2.81 -8.66 -20.2 -11.4 -4.27 STD=6.91
CCW Initial Slopes: -2.7 -3.08 -2.71 -2.73 -2.75 STD=0.161

Vehicle J - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

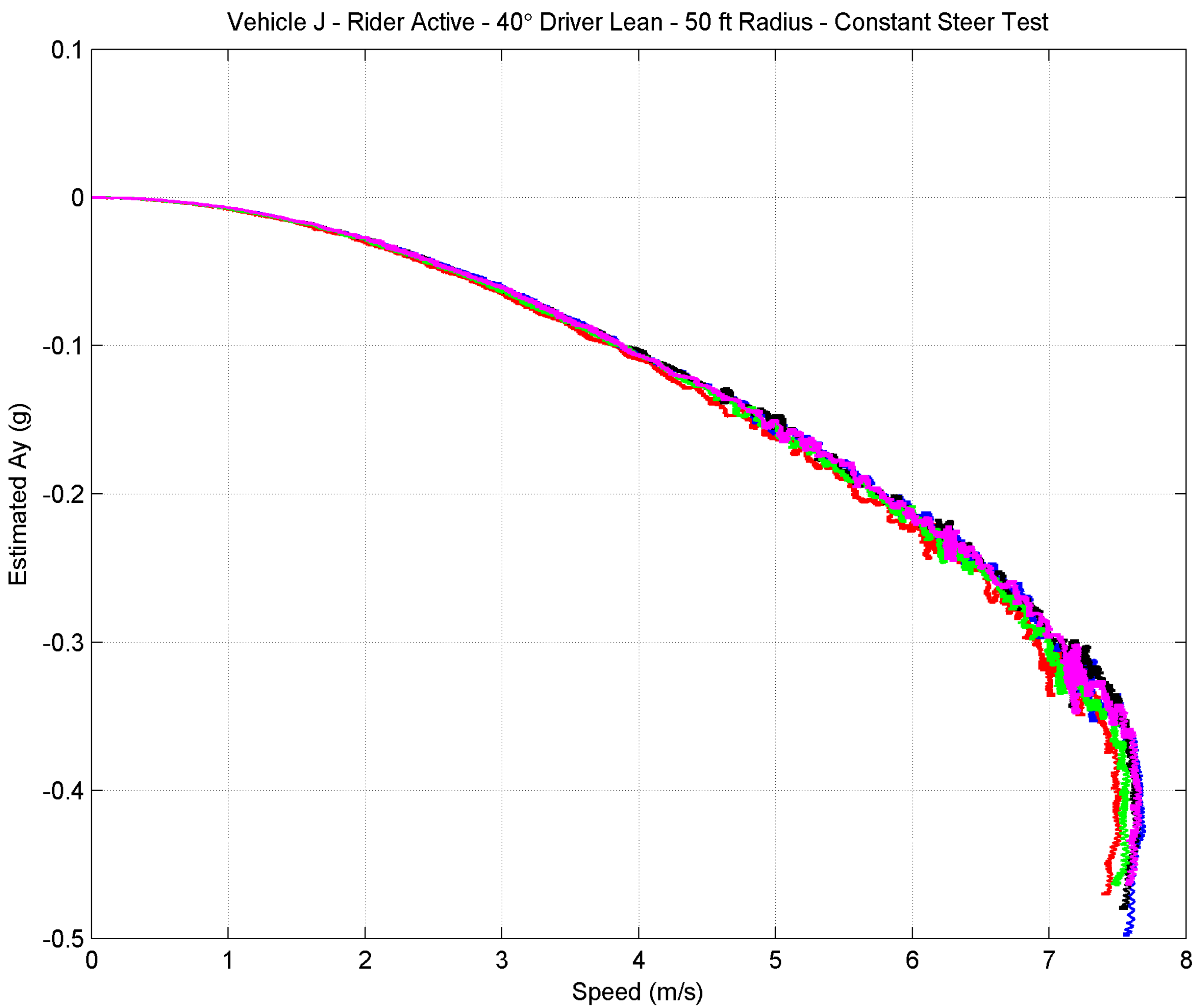


Vehicle J - Rider Active - 20° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs

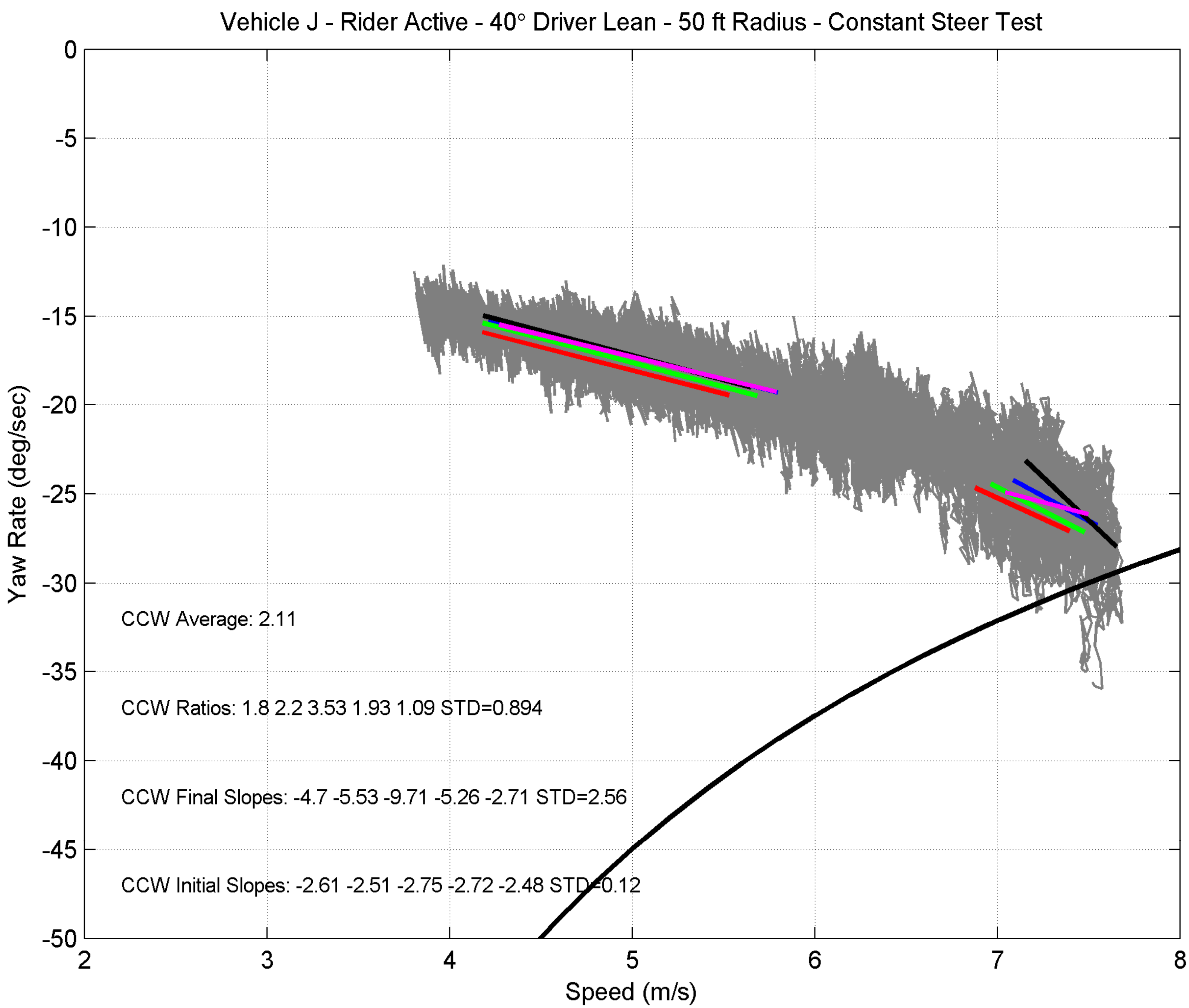


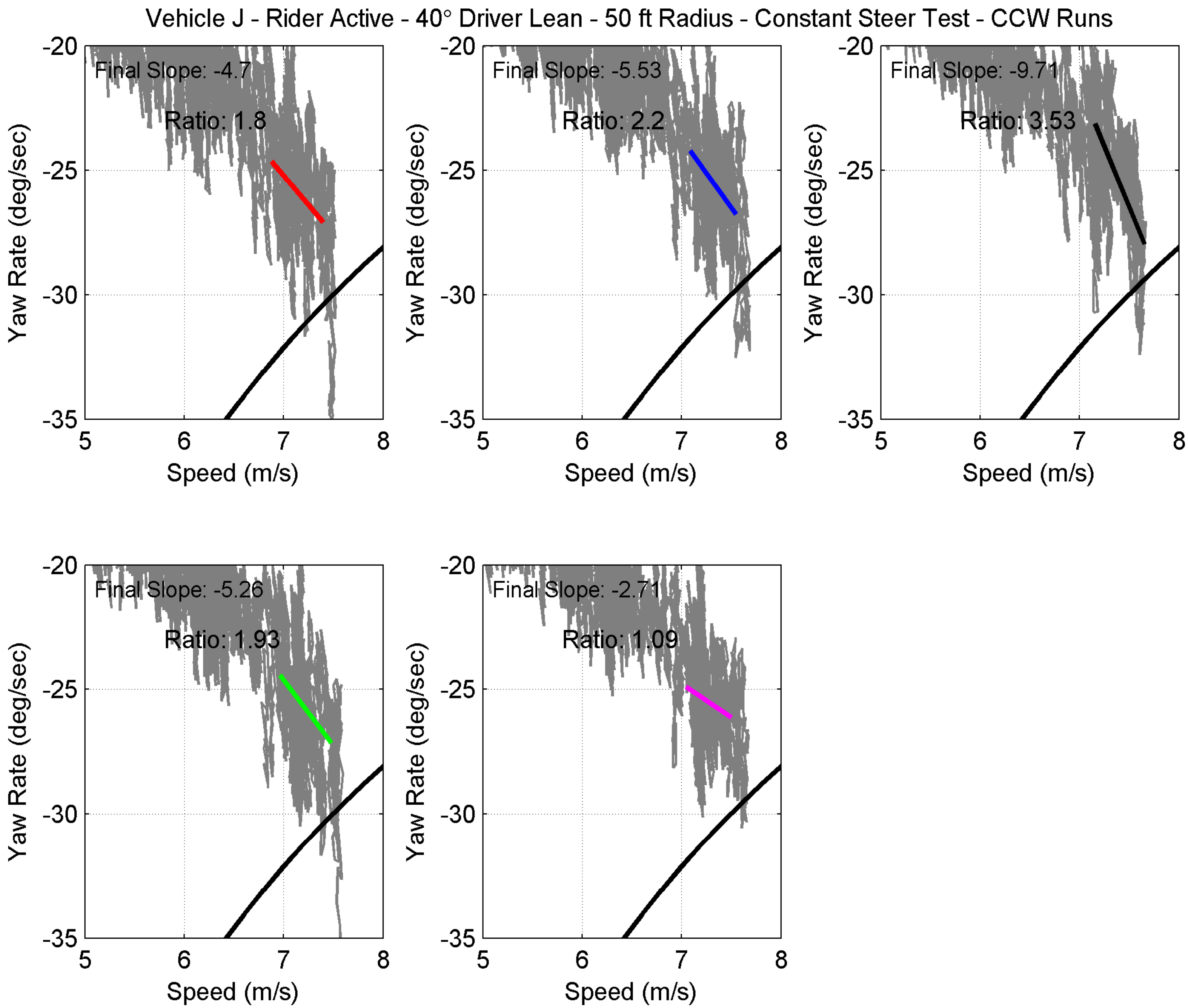


Vehicle J - Rider Active - 40° Driver Lean
50 ft Radius - Constant Steer Test
Steer Motor/Ratio (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

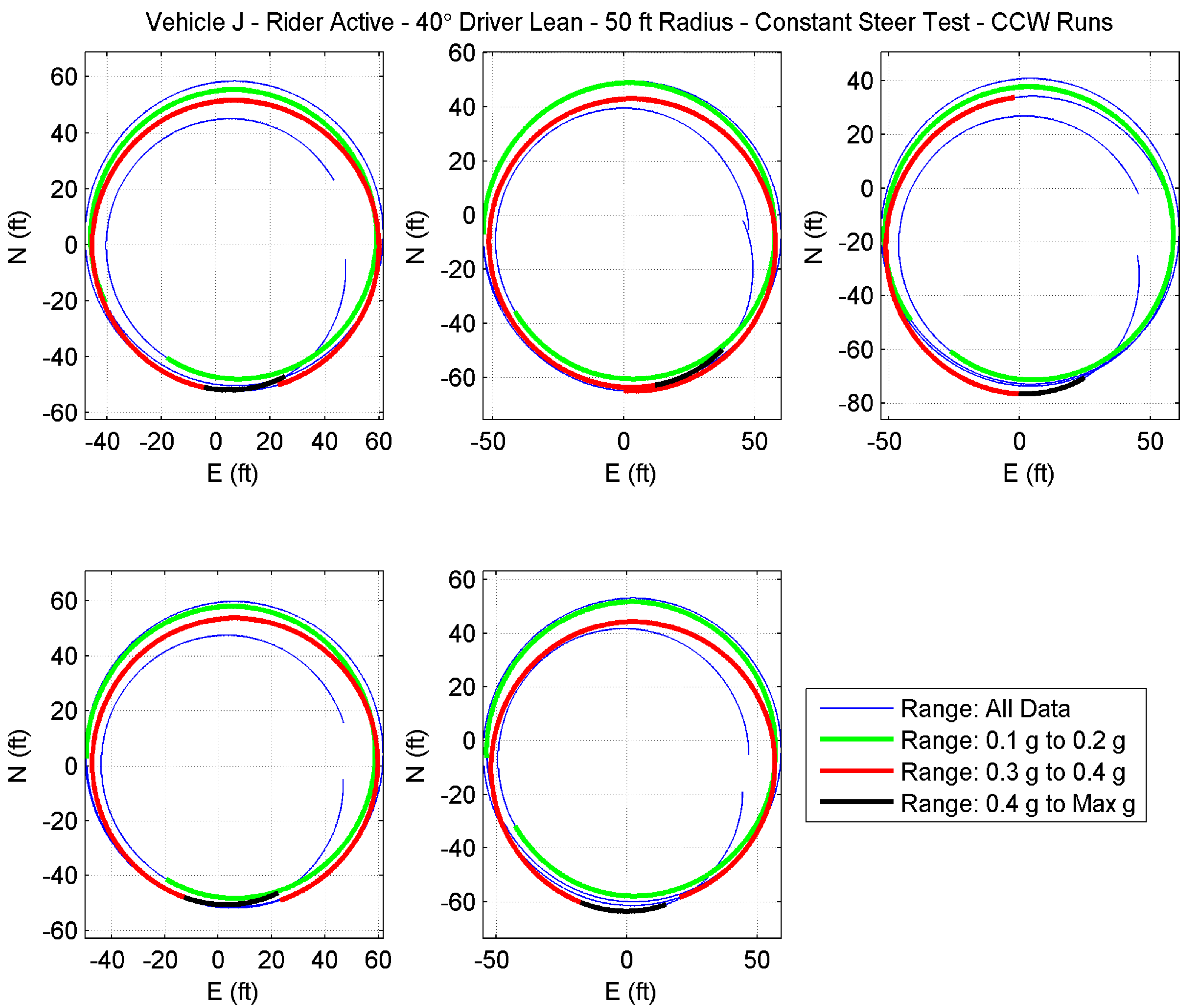


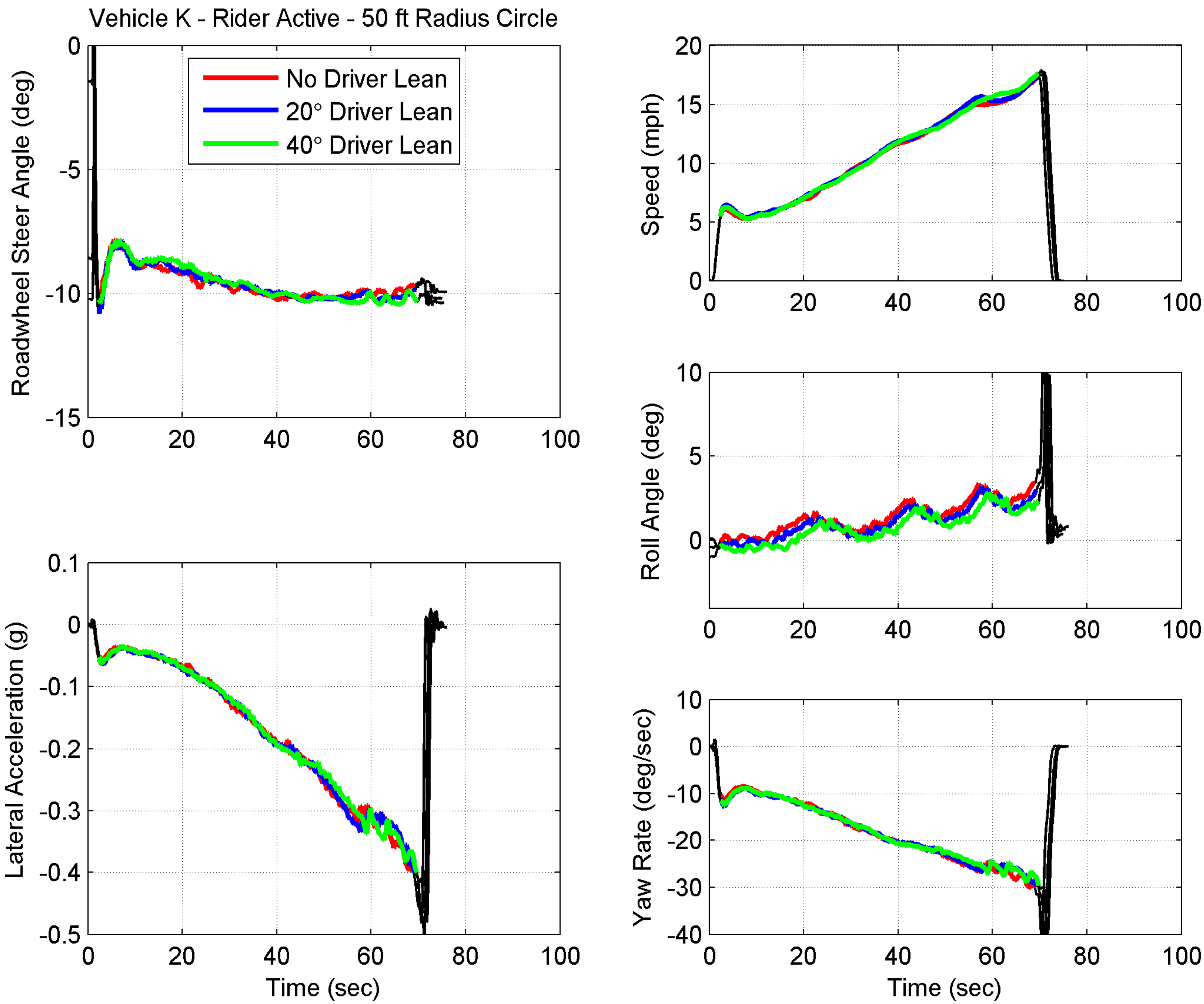
Vehicle J - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
7
8
Speed (m/s)


Vehicle J - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
3
4
5
6
7
8
CCW Average: 2.11
CCW Ratios: 1.8 2.2 3.53 1.93 1.09 STD=0.894
CCW Final Slopes: -4.7 -5.53 -9.71 -5.26 -2.71 STD=2.56
CCW Initial Slopes: -2.61 -2.51 -2.75 -2.72 -2.48 STD=0.12

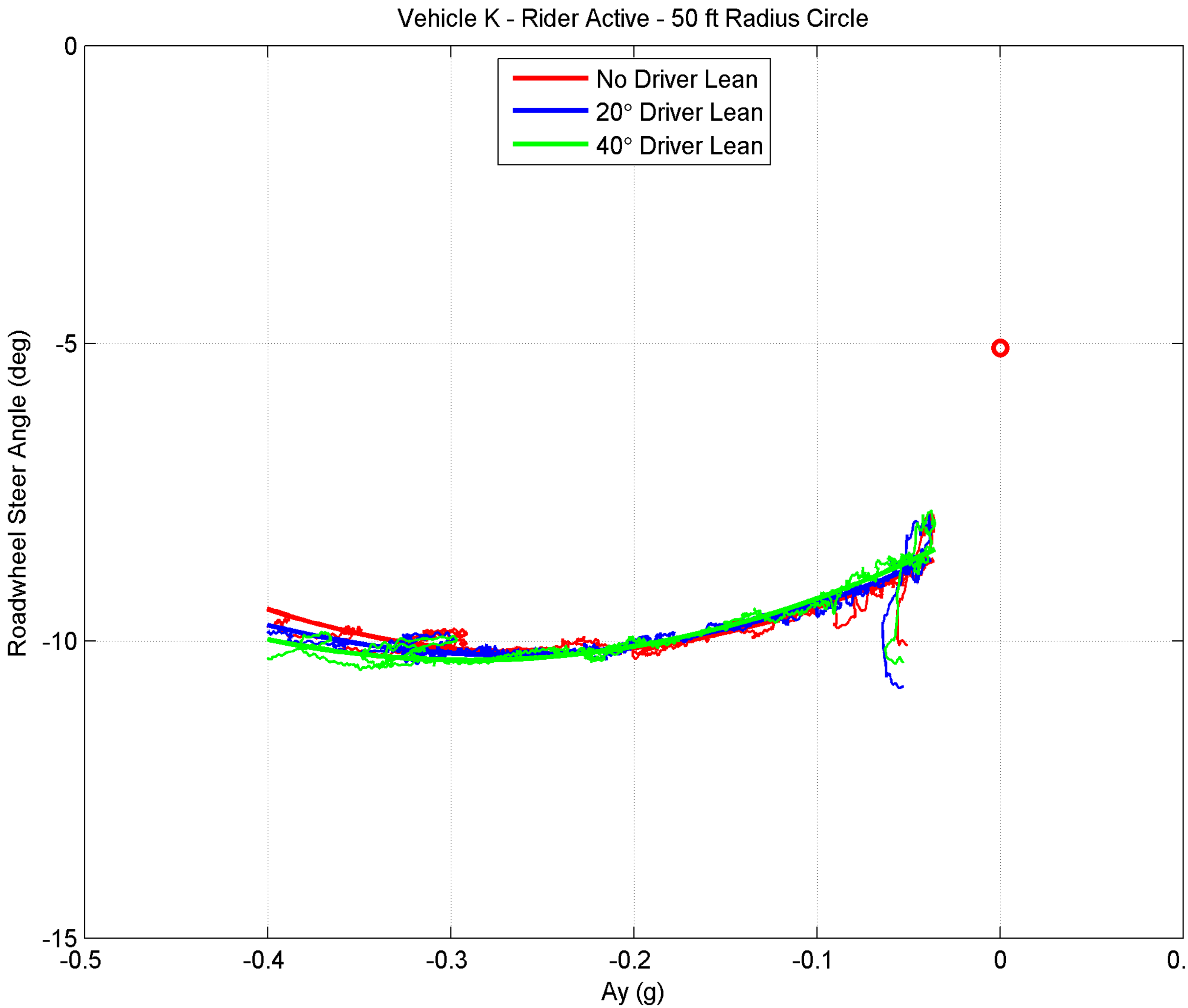


Vehicle J - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -4.7
Ratio: 1.8
Final Slope: -5.53
Ratio: 2.2
Final Slope: -9.71
Ratio: 3.53
Final Slope: -5.26
Ratio: 1.93
Final Slope: -2.71
Ratio: 1.09
Yaw Rate (deg/sec)
Speed (m/s)

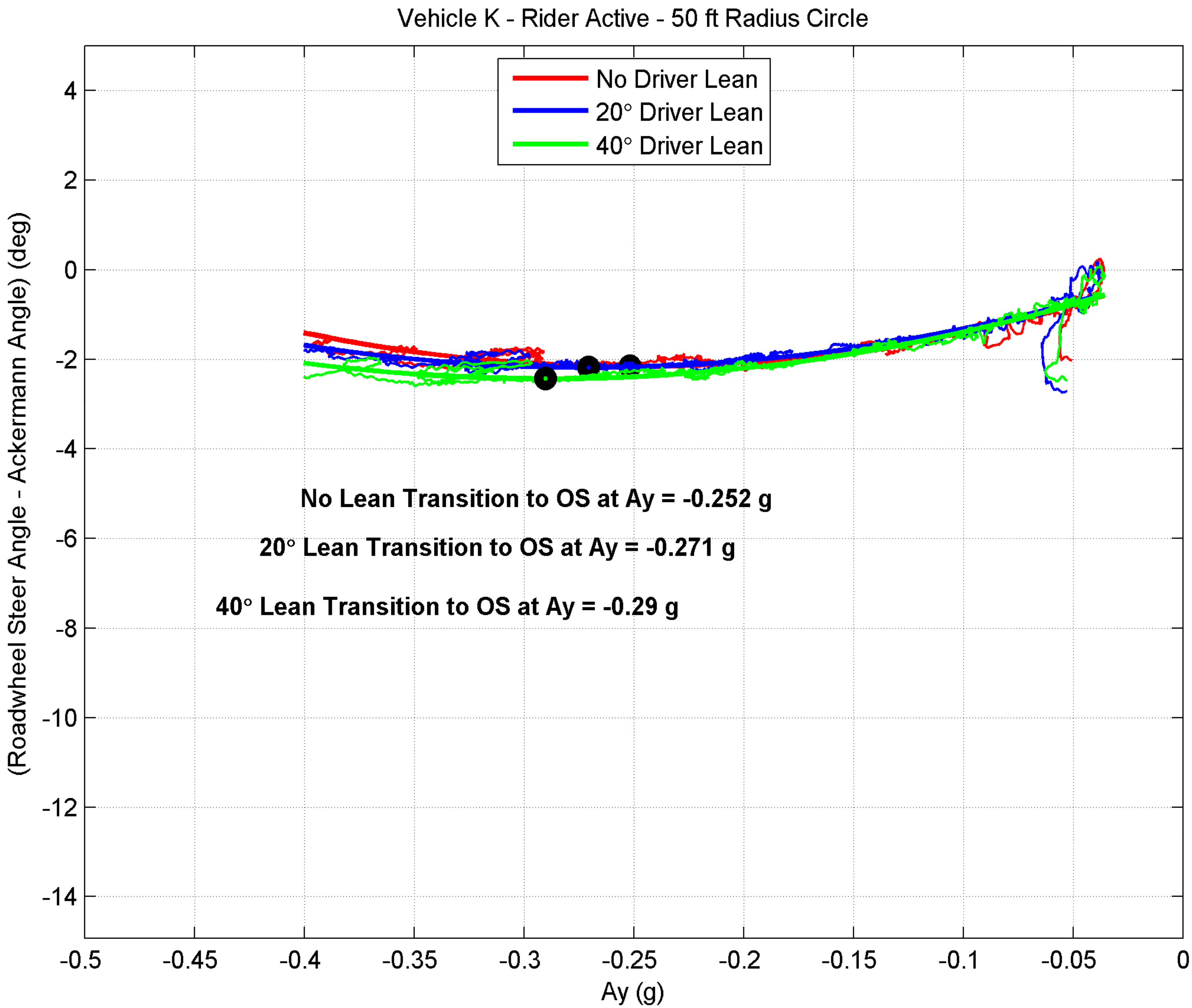

Vehicle J - Rider Active - 40° Driver Lean - 50 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g



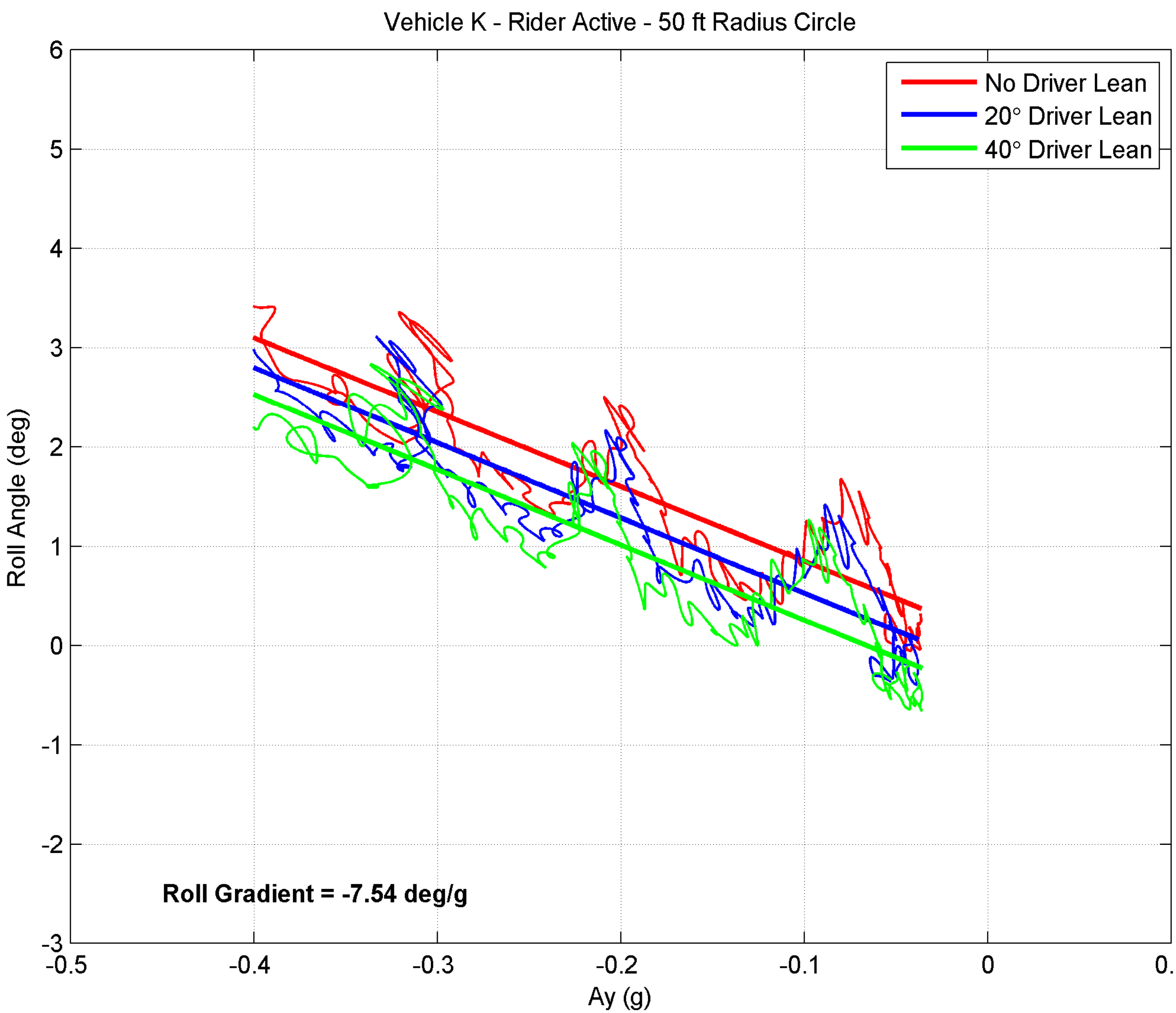
Vehicle K - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

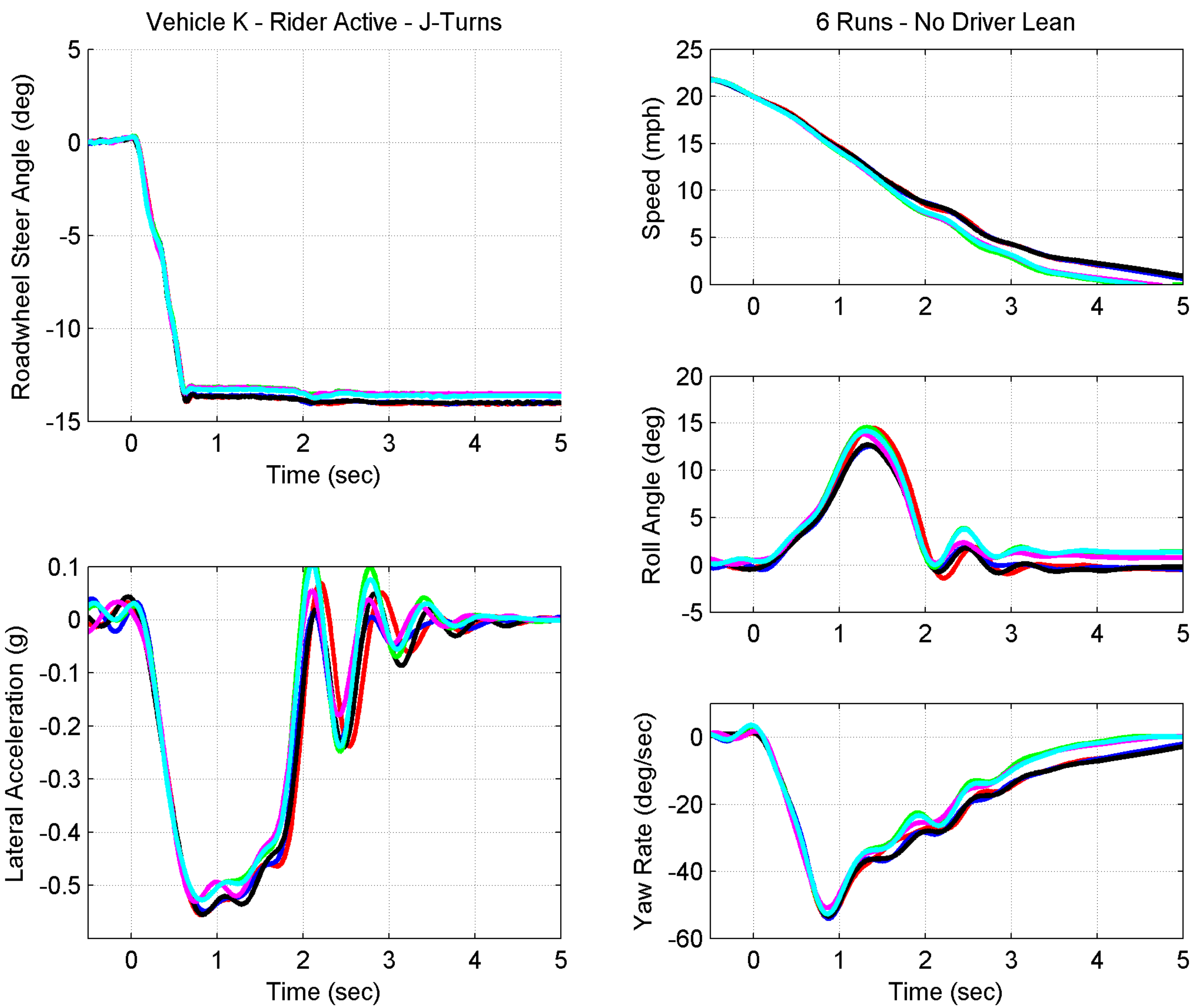


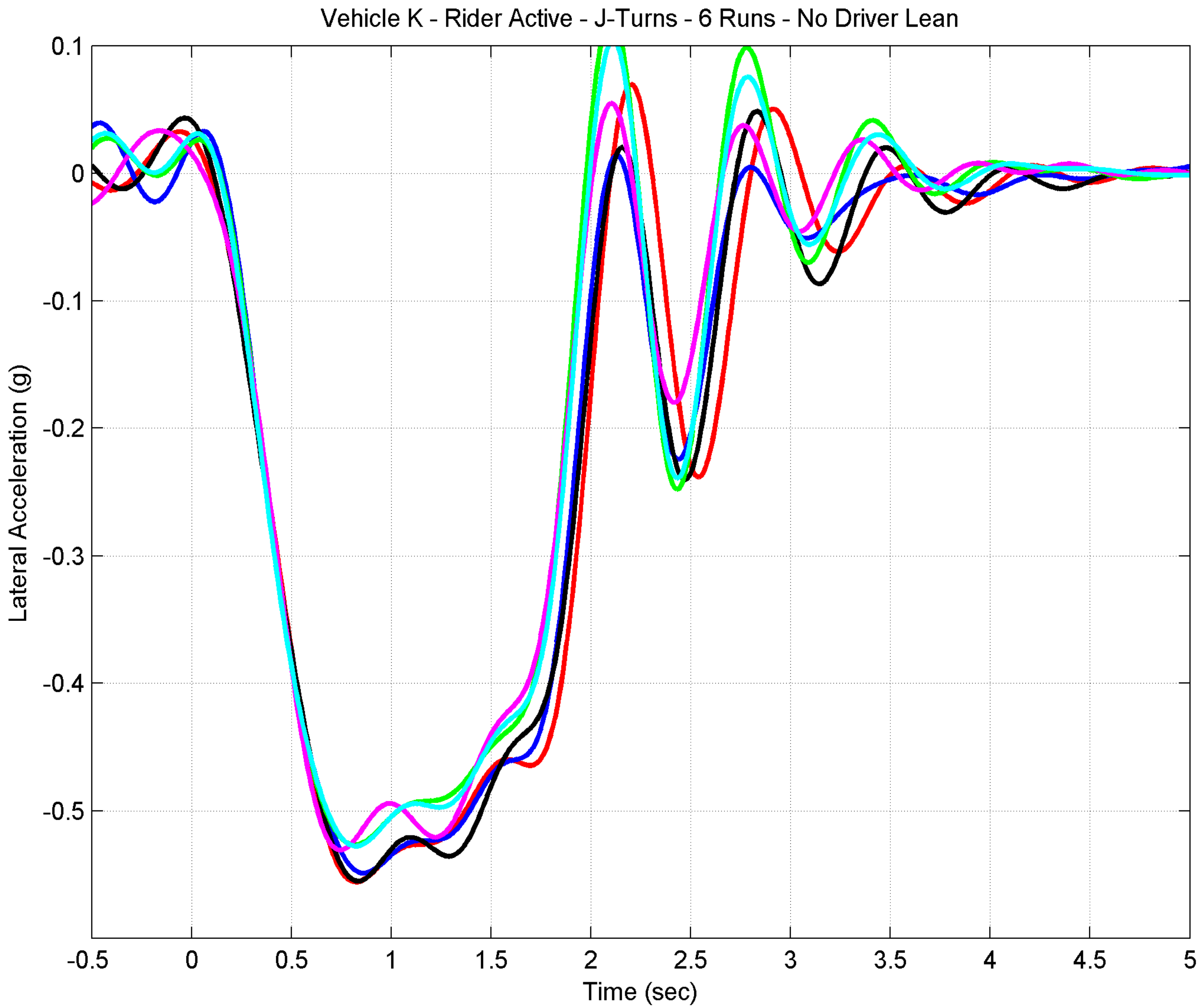
Vehicle K - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)

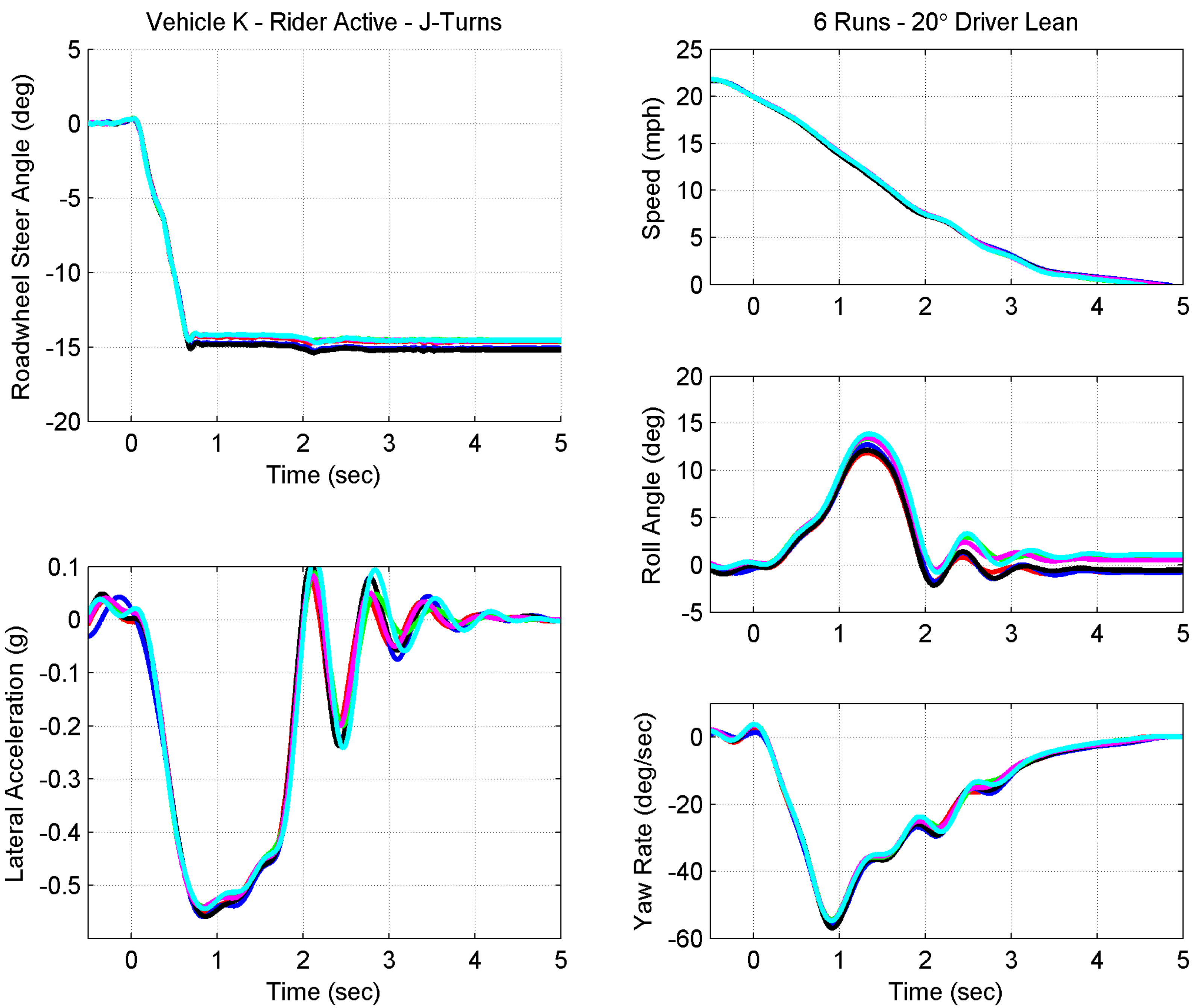


Vehicle K - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
No Lean Transition to OS at Ay = -0.252 g
20° Lean Transition to OS at Ay = -0.271 g
40° Lean Transition to OS at Ay = -0.29 g
(Roadwheel Steer Angle - Ackermann Angle) (deg)
Ay (g)
4
2
0
-2
-4
-6
-8
-10
-12
-14
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0

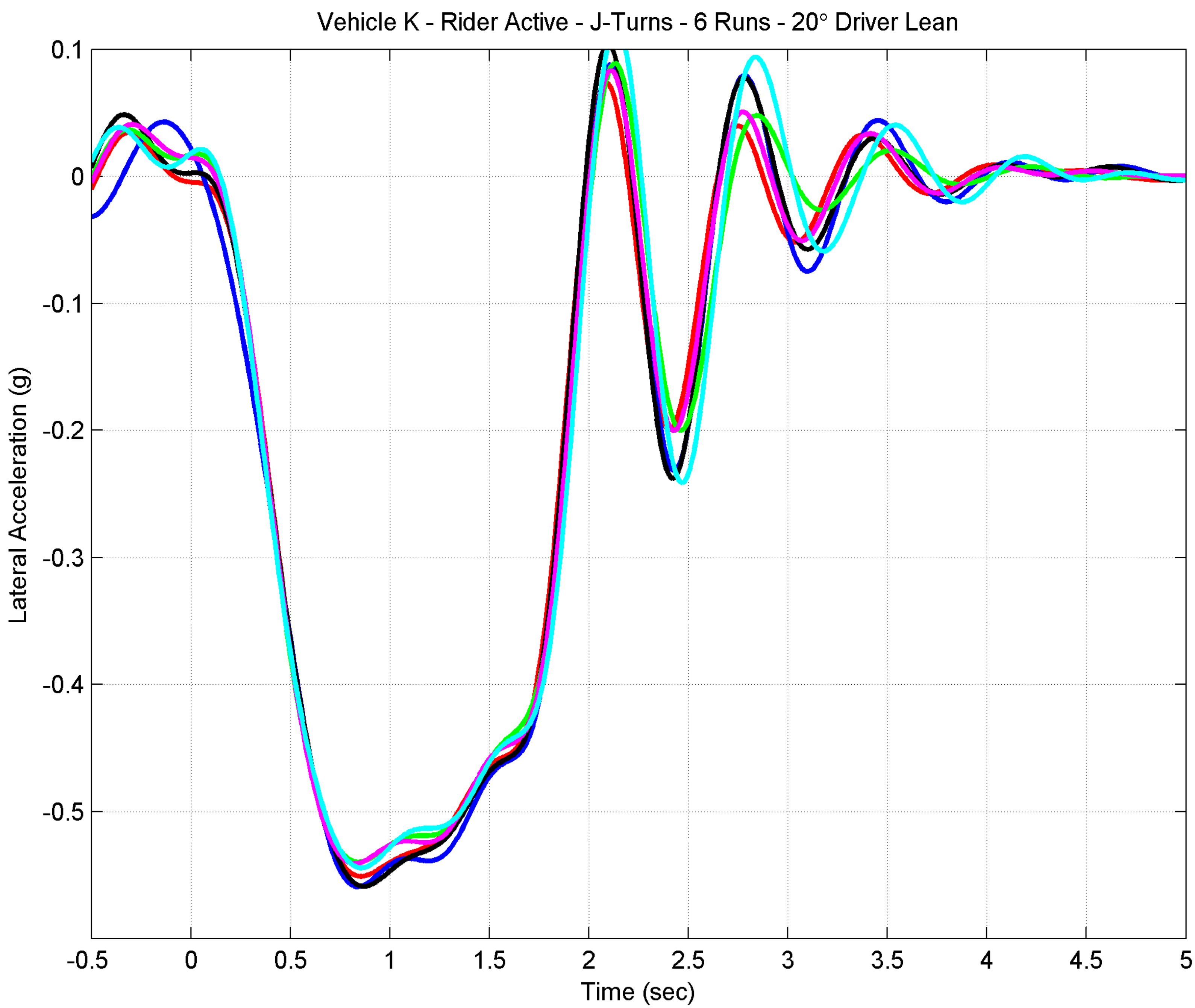

Vehicle K - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
Ay (g)
Roll Gradient = -7.54 deg/g
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

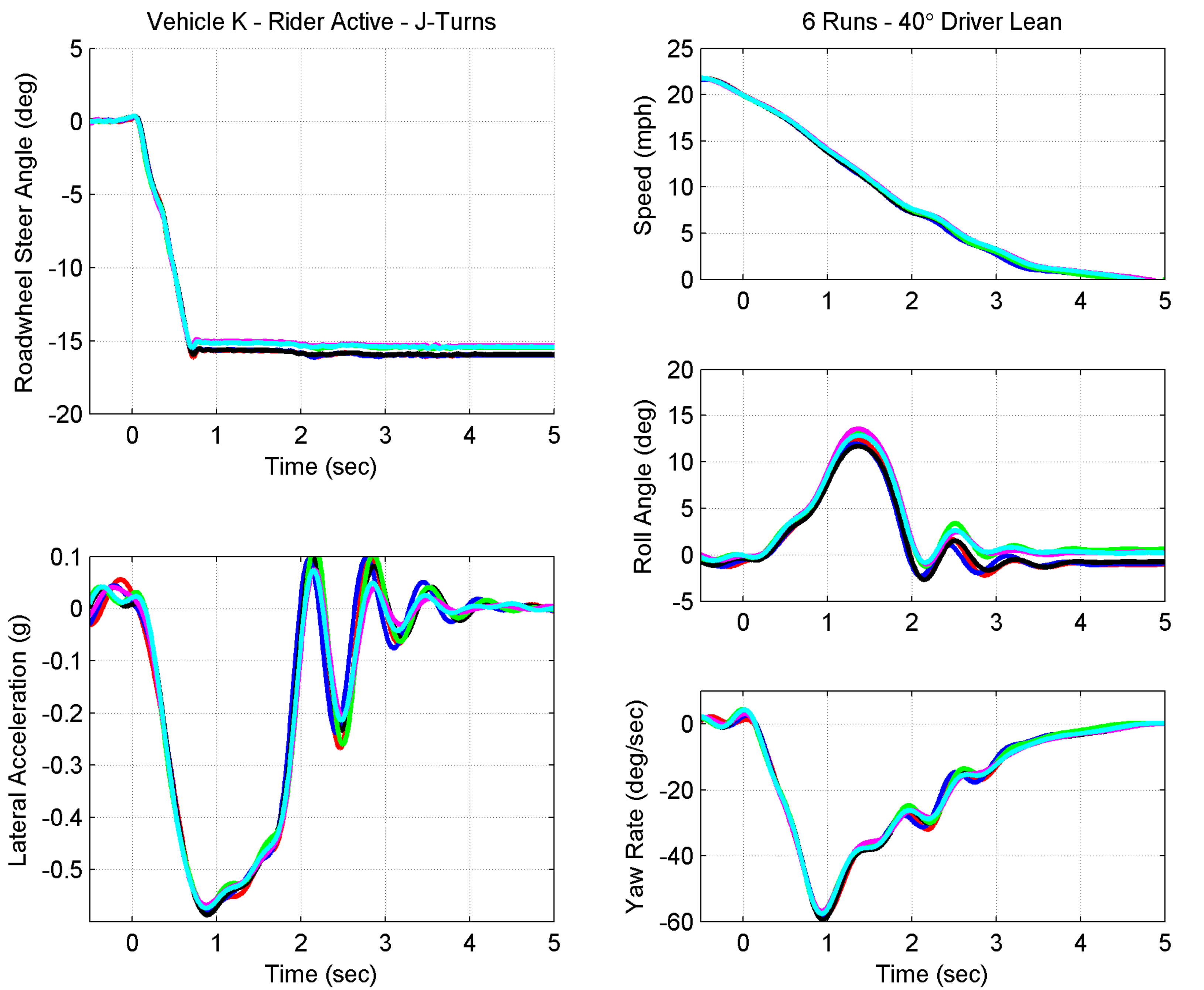

Vehicle K - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)

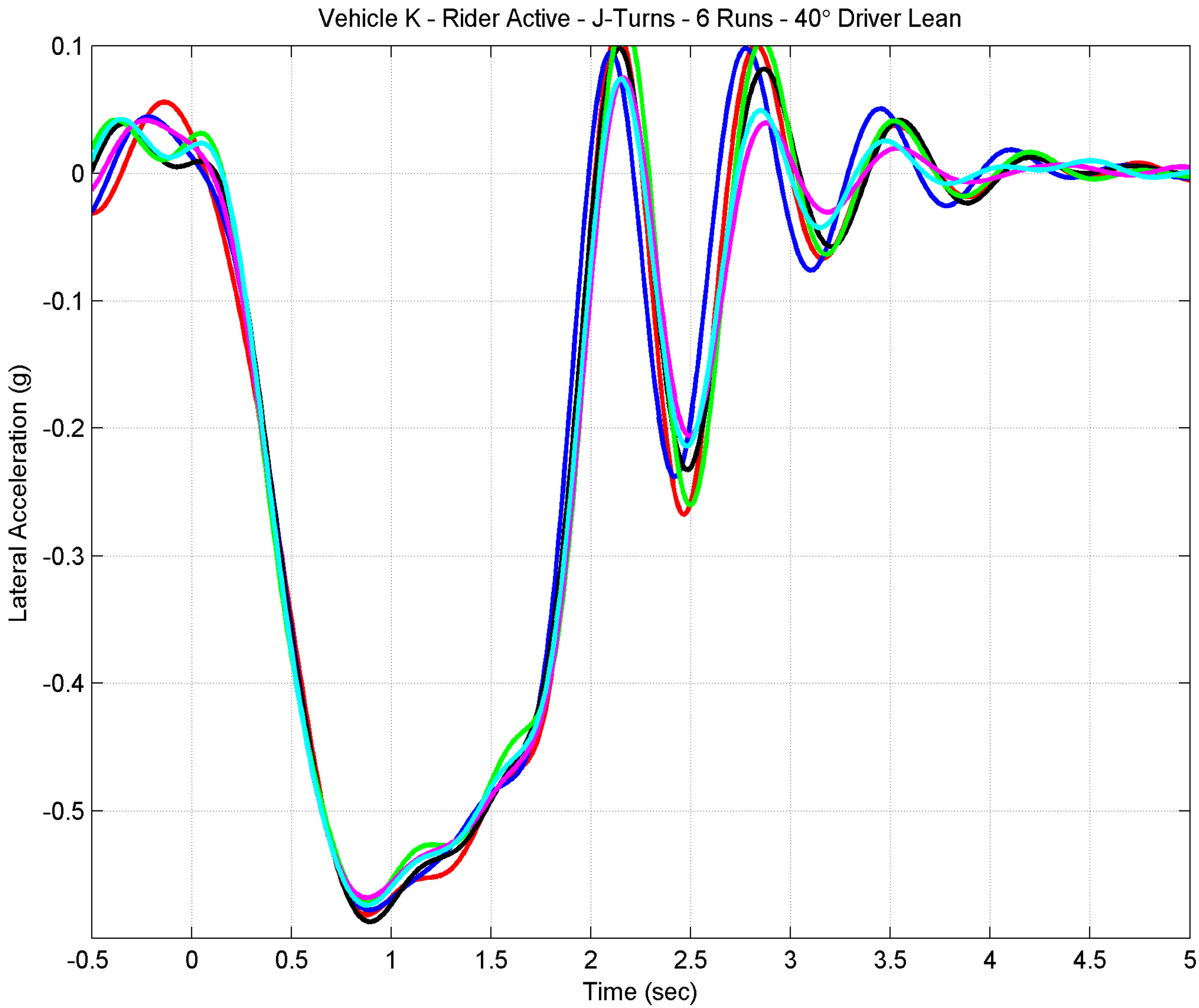

Vehicle K - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



Vehicle K - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle K - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
Time (sec)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Vehicle K - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



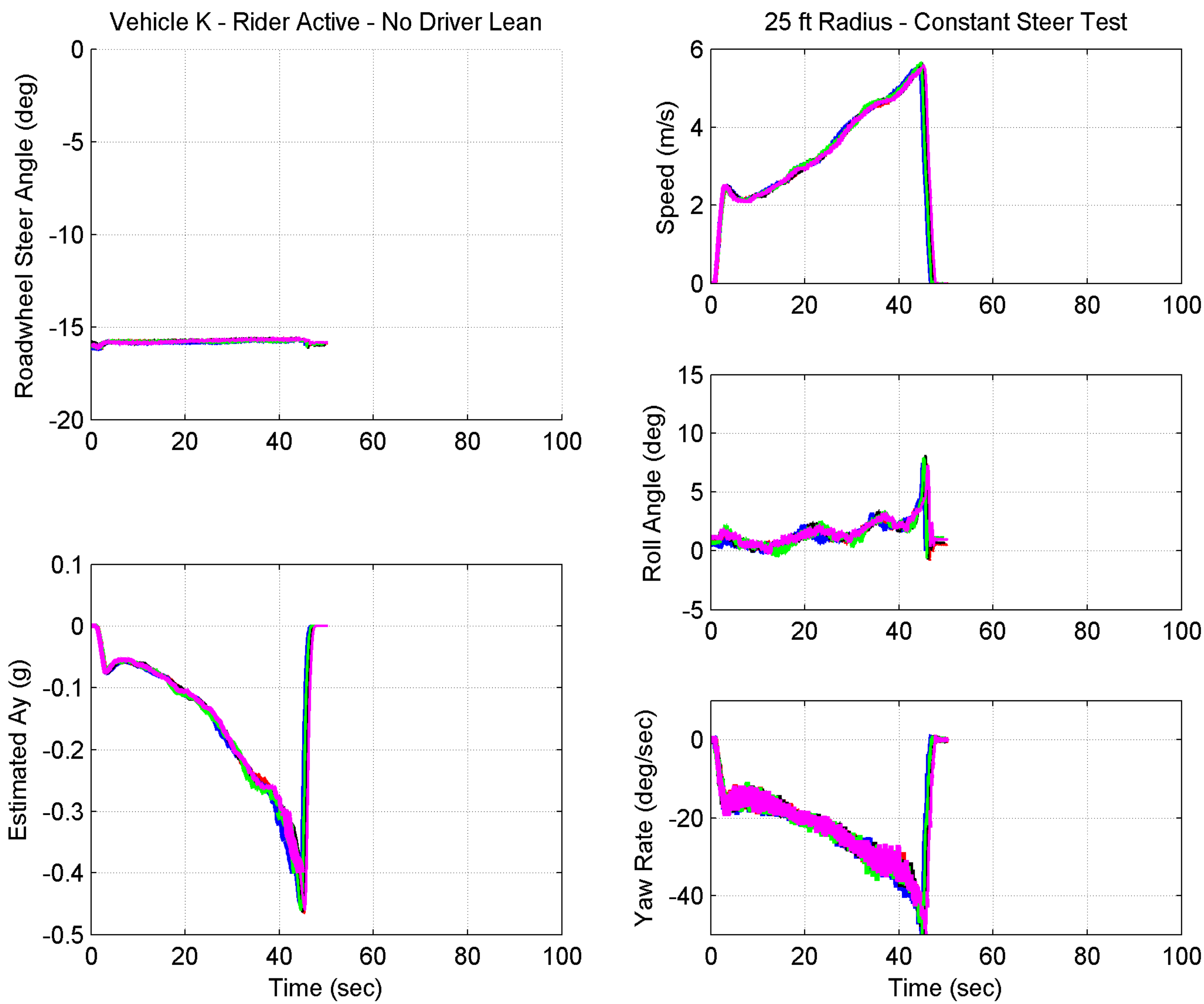
Vehicle K - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Time (sec)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Vehicle K - Rider Active Results

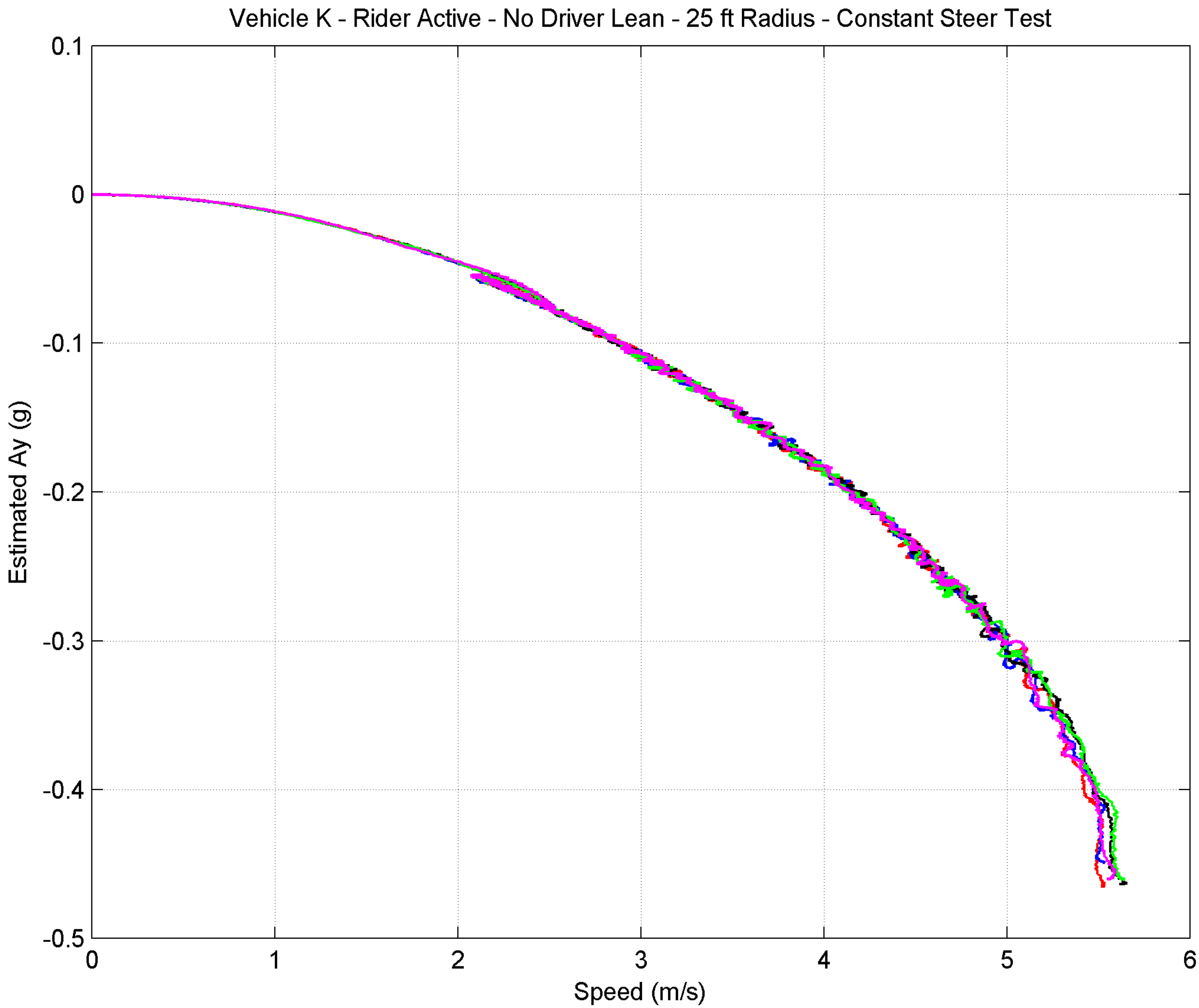
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.556	-0.551	-0.582
	-0.549	-0.559	-0.578
	-0.550	-0.559	-0.587
Mean Value of 3 Runs	-0.552	-0.557	-0.582
Standard Deviation of 3 Runs	0.004	0.005	0.005

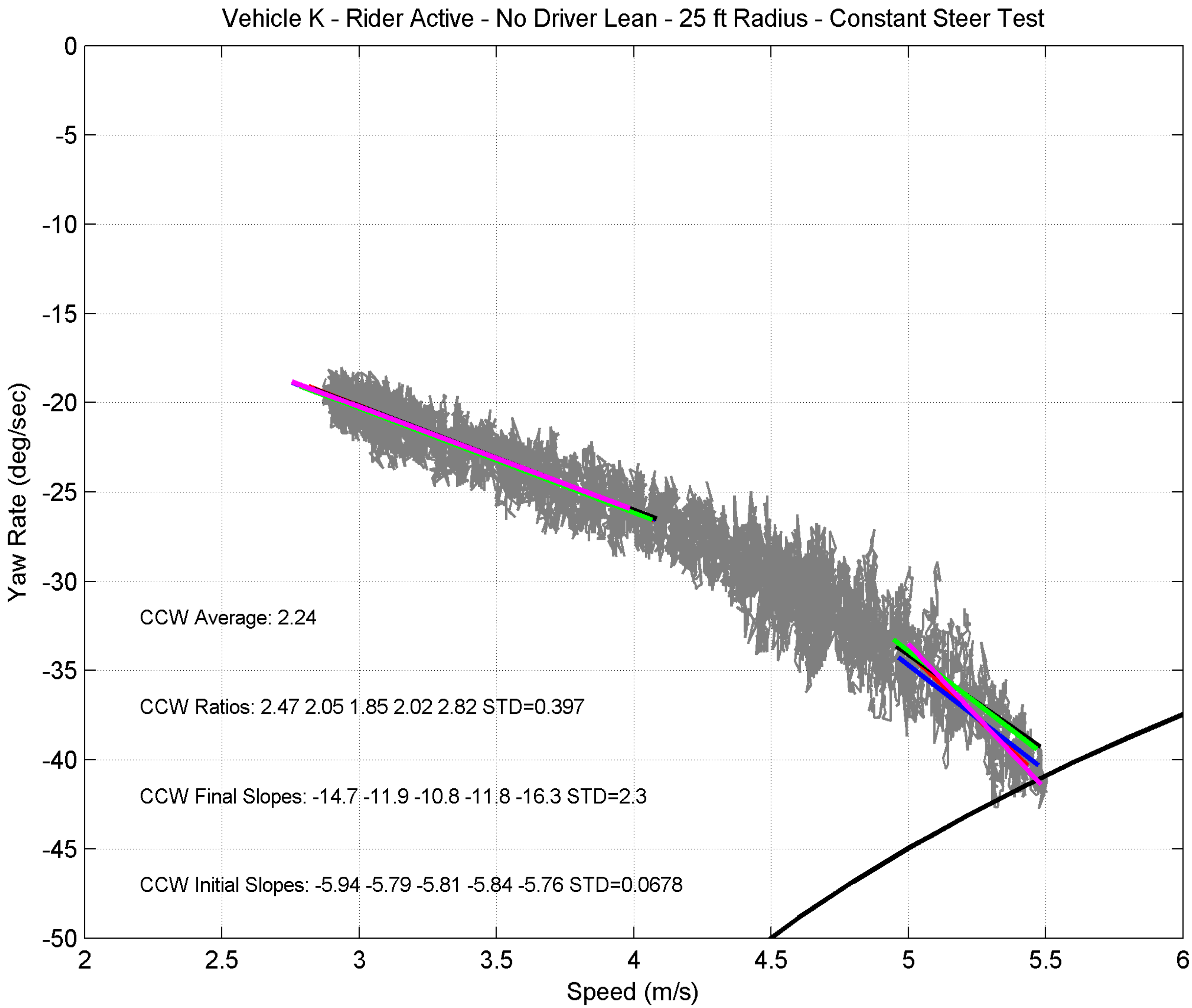
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.527	-0.540	-0.572
	-0.531	-0.541	-0.568
	-0.528	-0.545	-0.574
Mean Value of 3 Runs	-0.529	-0.542	-0.572
Standard Deviation of 3 Runs	0.002	0.002	0.003
Average of All 6 Runs	**0.540**	**0.549**	**0.577**



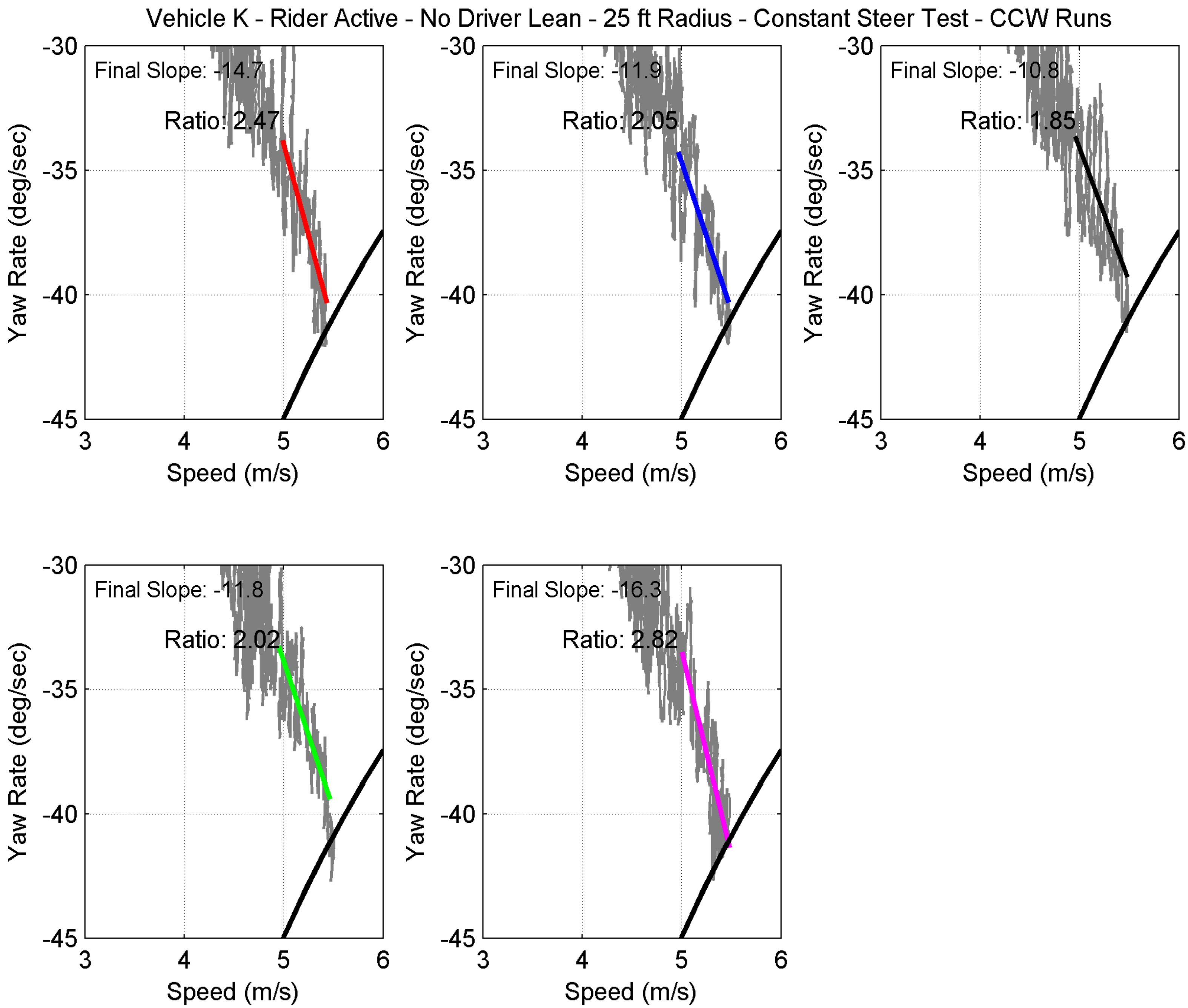
Vehicle K - Rider Active - No Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

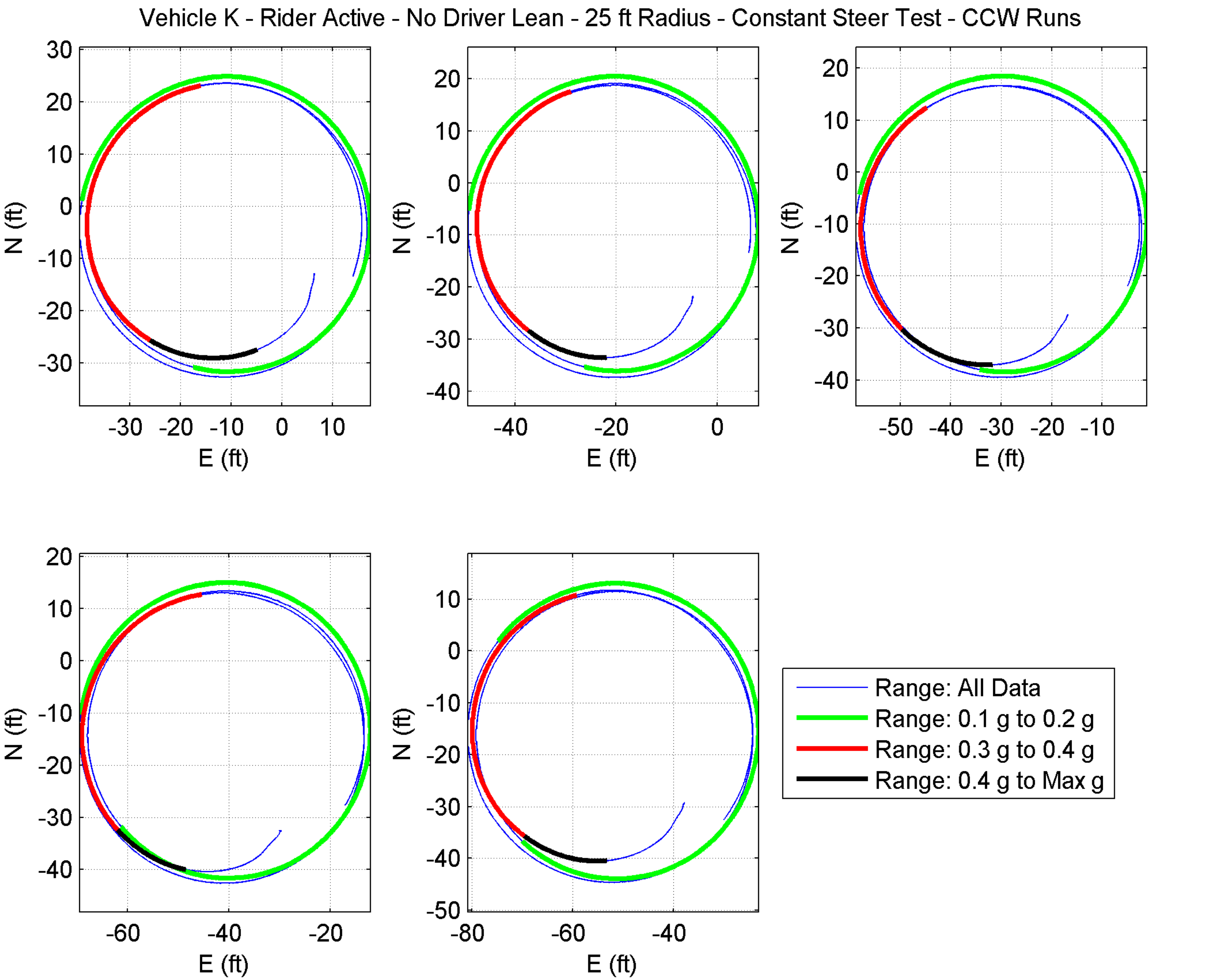


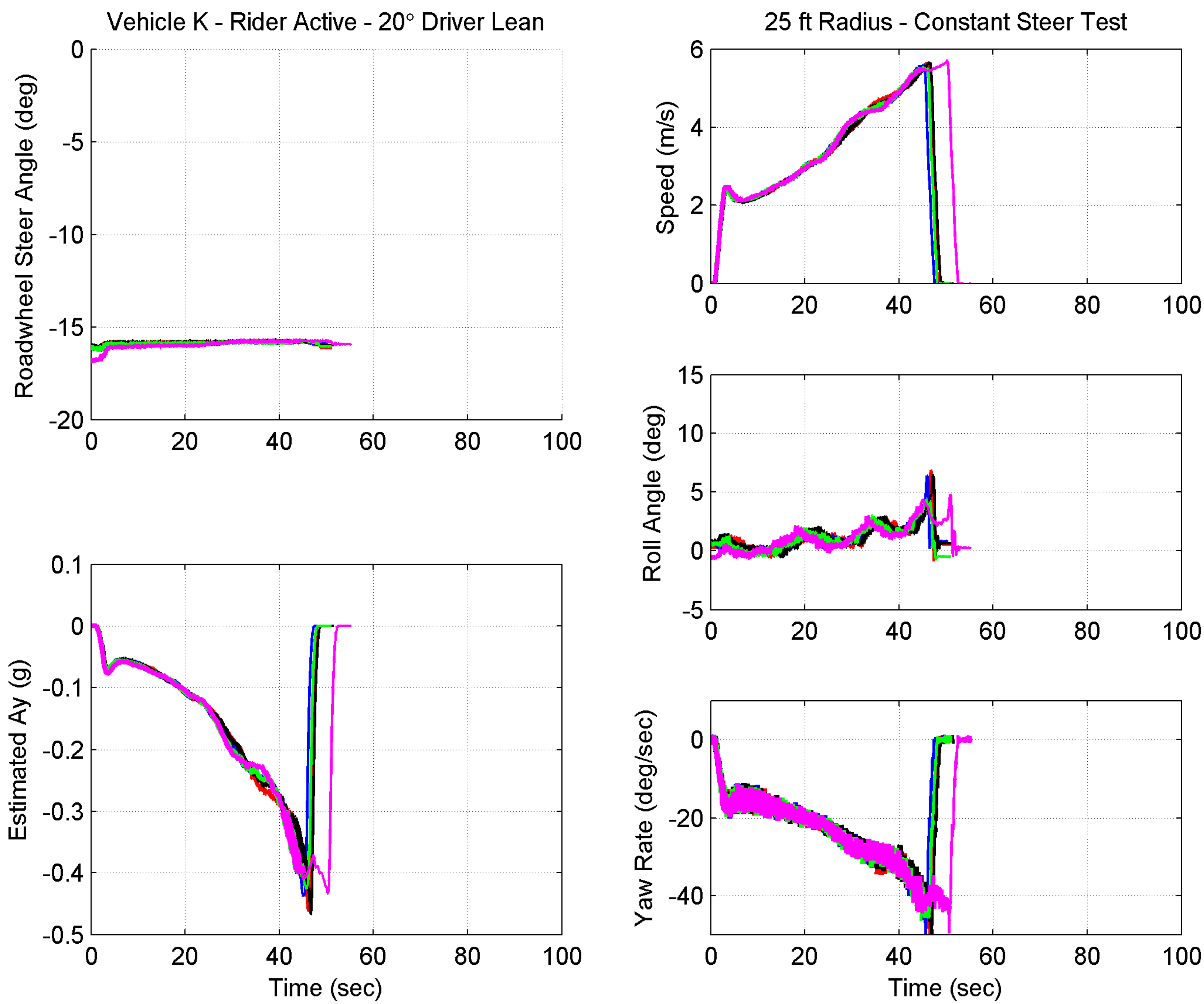
Vehicle K - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6

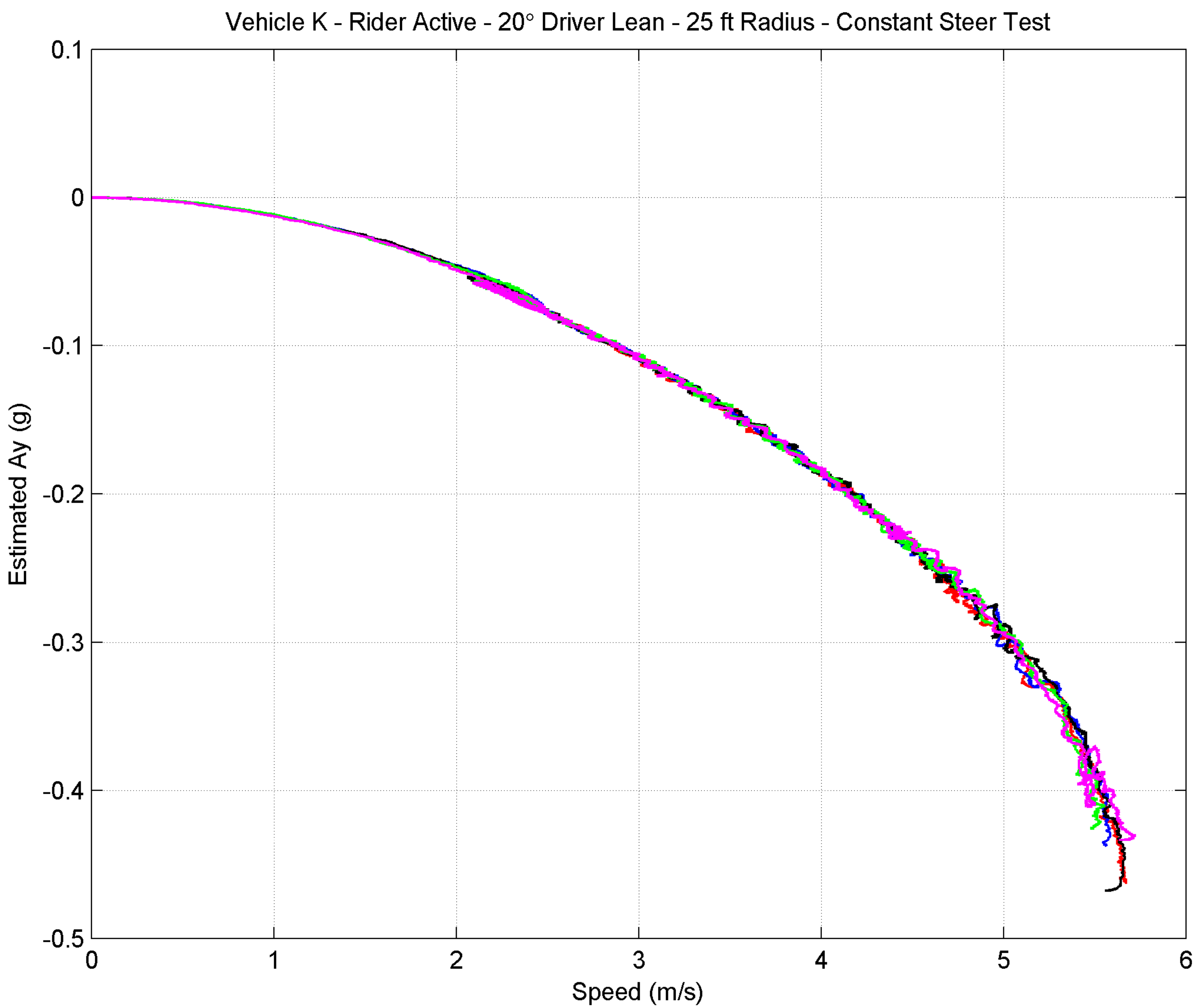


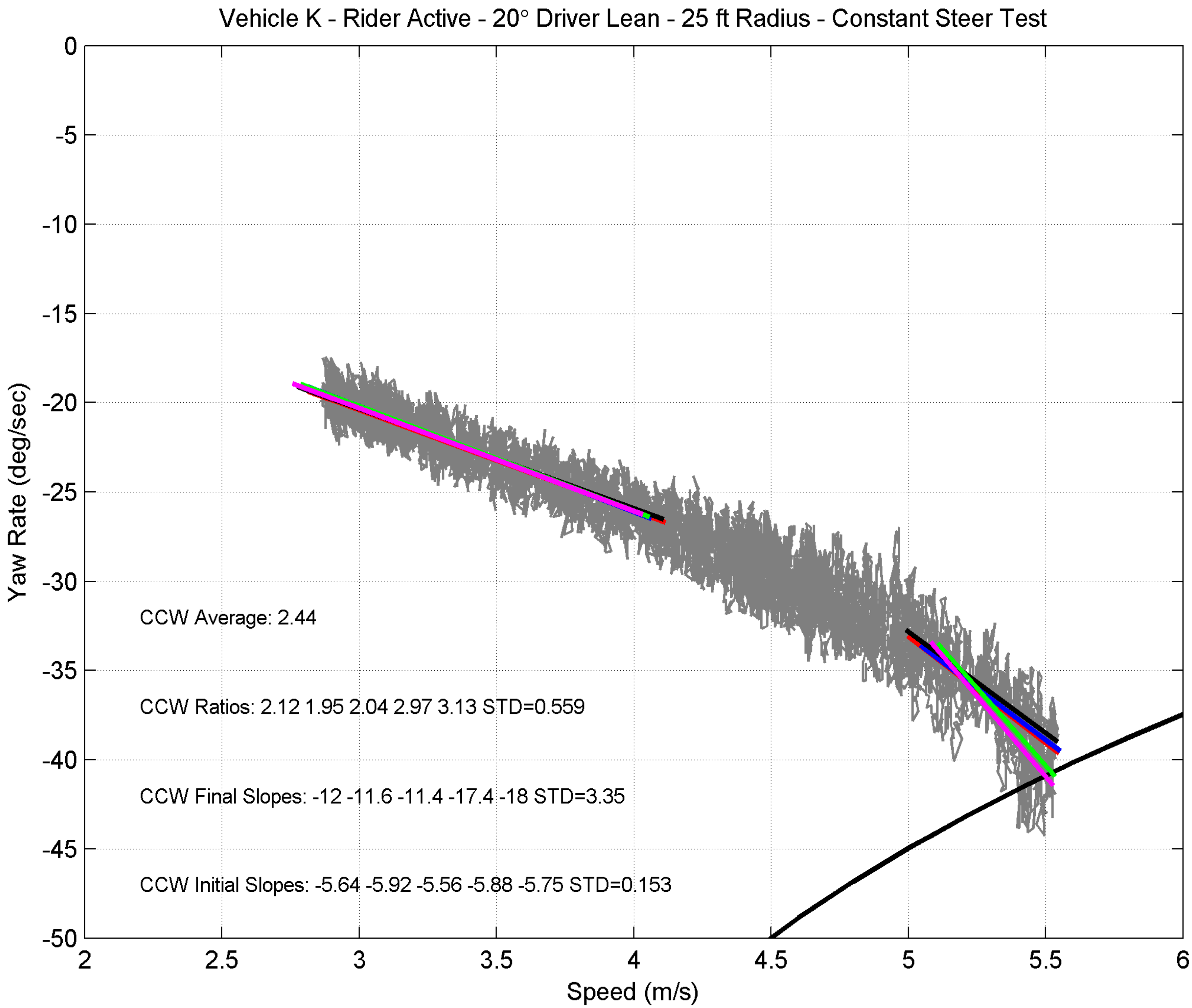
Vehicle K - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
CCW Average: 2.24
CCW Ratios: 2.47 2.05 1.85 2.02 2.82 STD=0.397
CCW Final Slopes: -14.7 -11.9 -10.8 -11.8 -16.3 STD=2.3
CCW Initial Slopes: -5.94 -5.79 -5.81 -5.84 -5.76 STD=0.0678


Vehicle K - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -14.7
Ratio: 2.47
Final Slope: -11.9
Ratio: 2.05
Final Slope: -10.8
Ratio: 1.85
Final Slope: -11.8
Ratio: 2.02
Final Slope: -16.3
Ratio: 2.82
Yaw Rate (deg/sec)
Speed (m/s)
-30
-35
-40
-45
3
4
5
6


Vehicle K - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

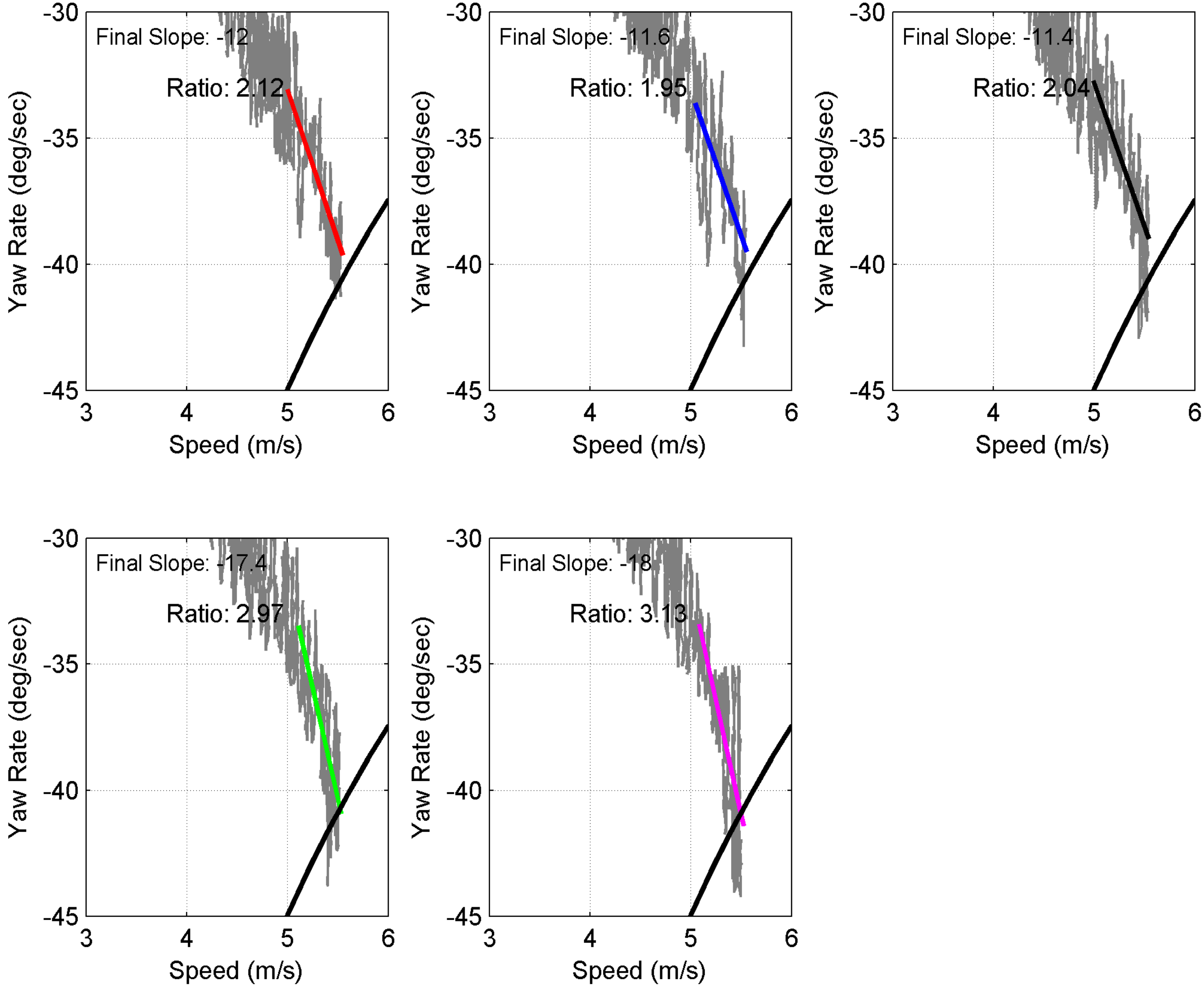

Vehicle K - Rider Active - 20° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle K - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
Speed (m/s)

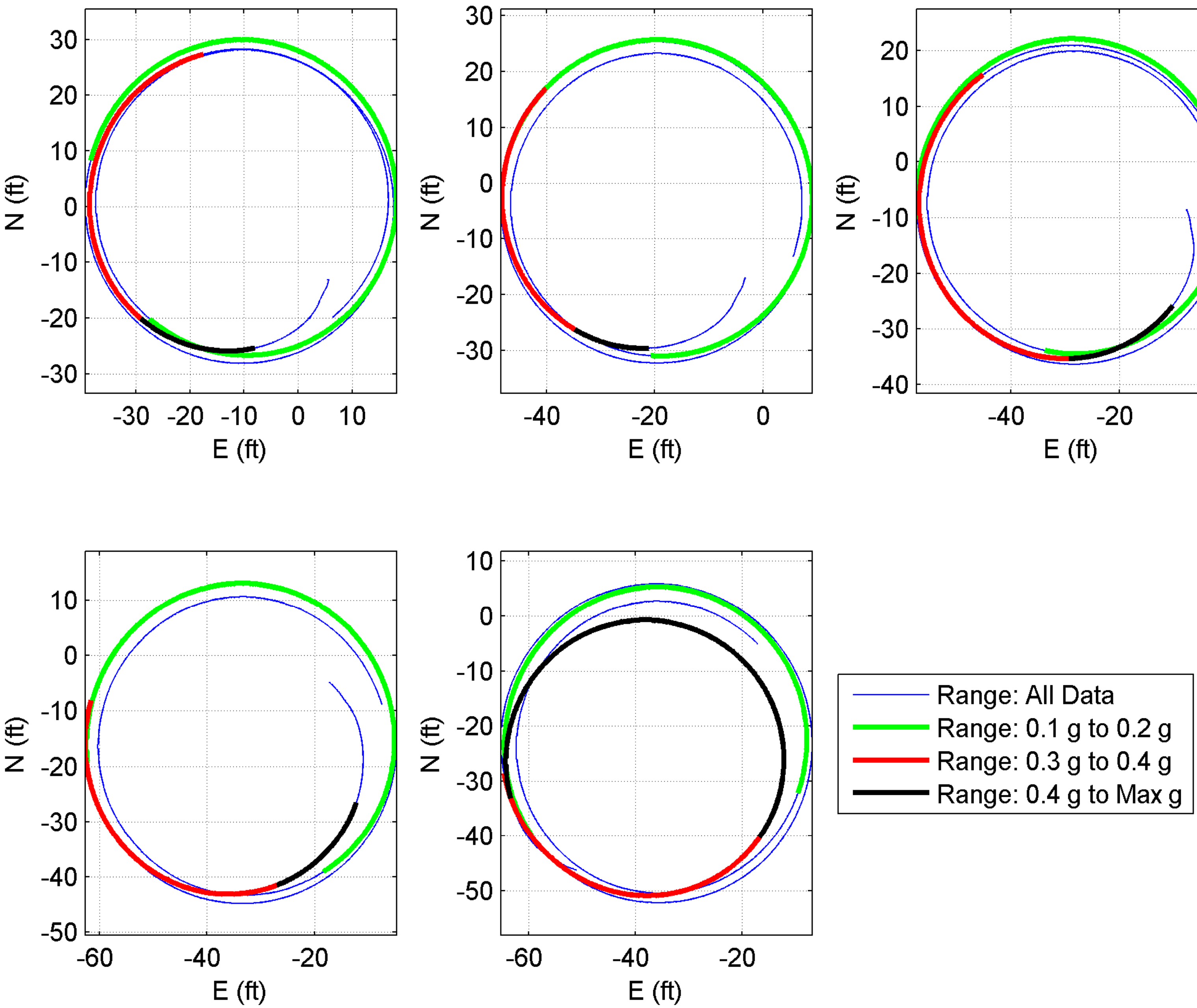


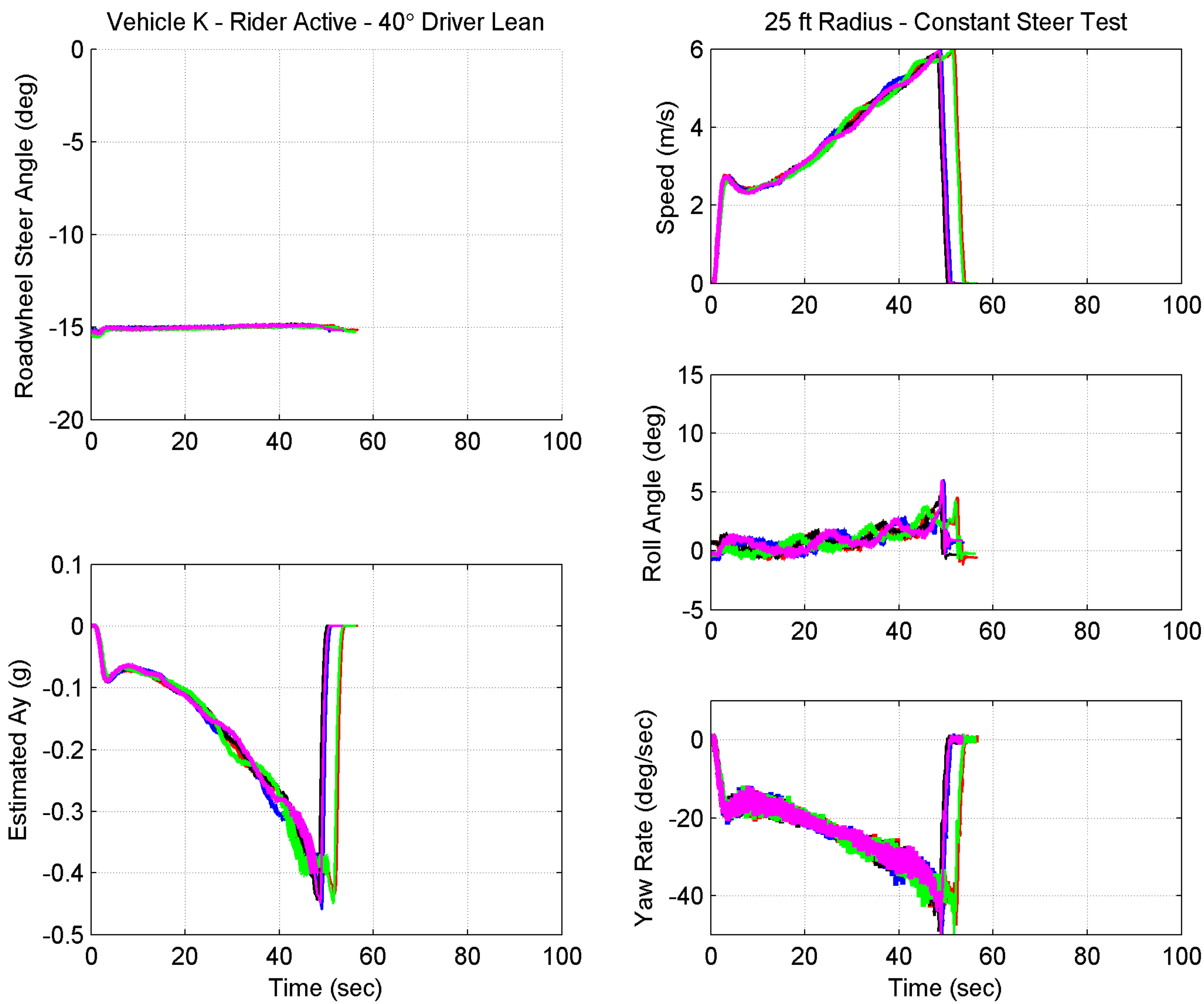
Vehicle K - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
CCW Average: 2.44
CCW Ratios: 2.12 1.95 2.04 2.97 3.13 STD=0.559
CCW Final Slopes: -12 -11.6 -11.4 -17.4 -18 STD=3.35
CCW Initial Slopes: -5.64 -5.92 -5.56 -5.88 -5.75 STD=0.153

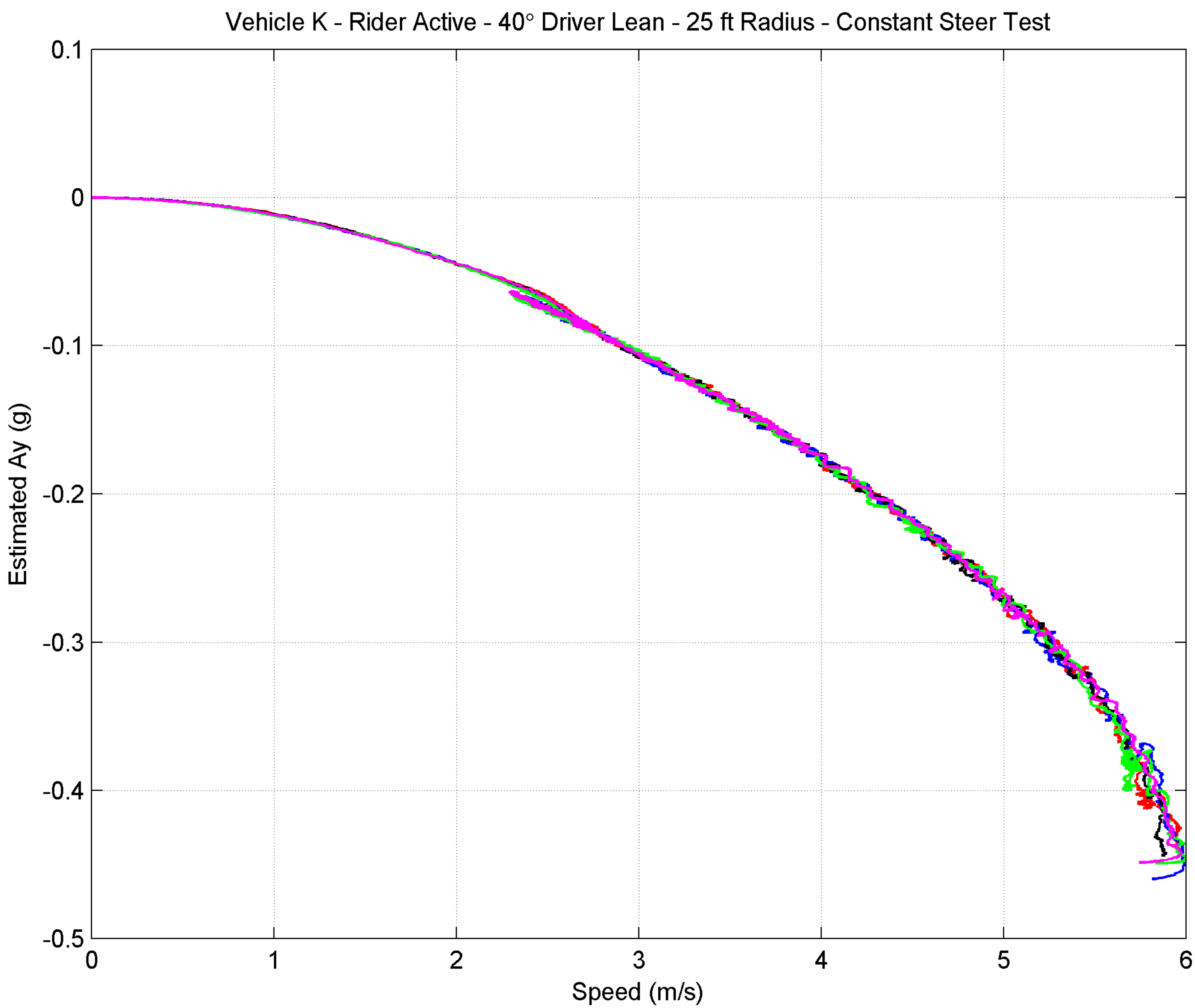
Vehicle K - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

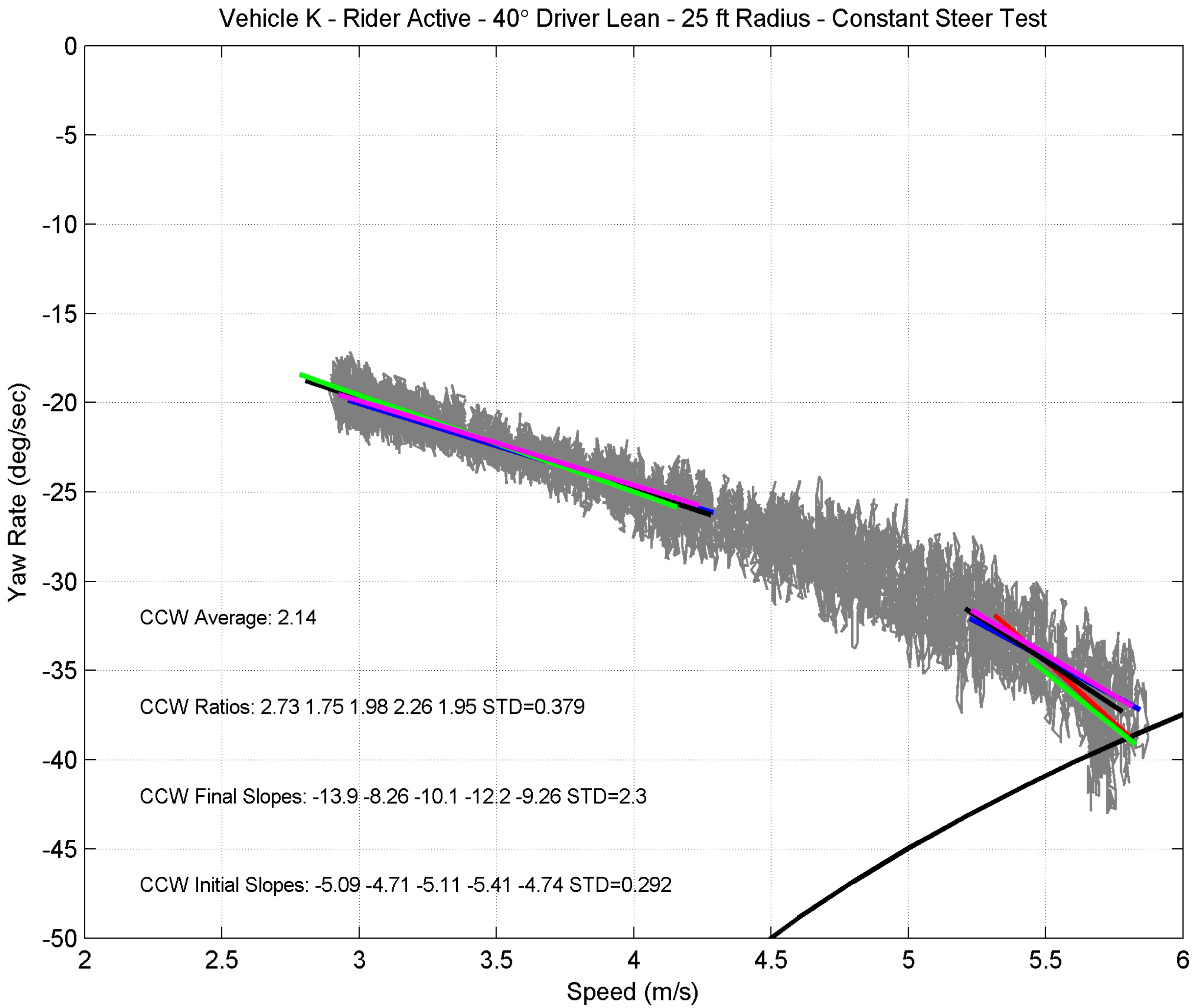


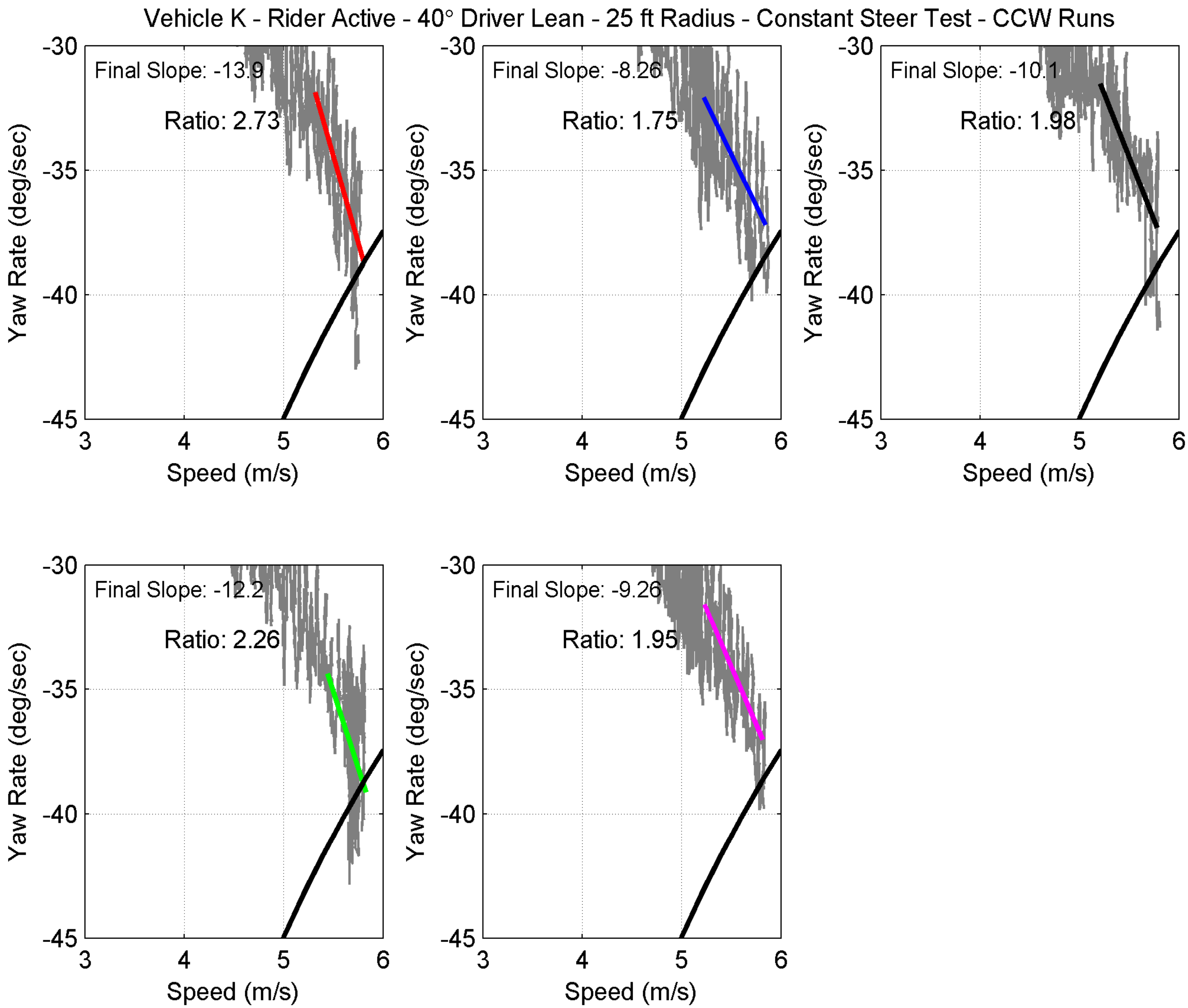
Vehicle K - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs




Vehicle K - Rider Active - 40° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

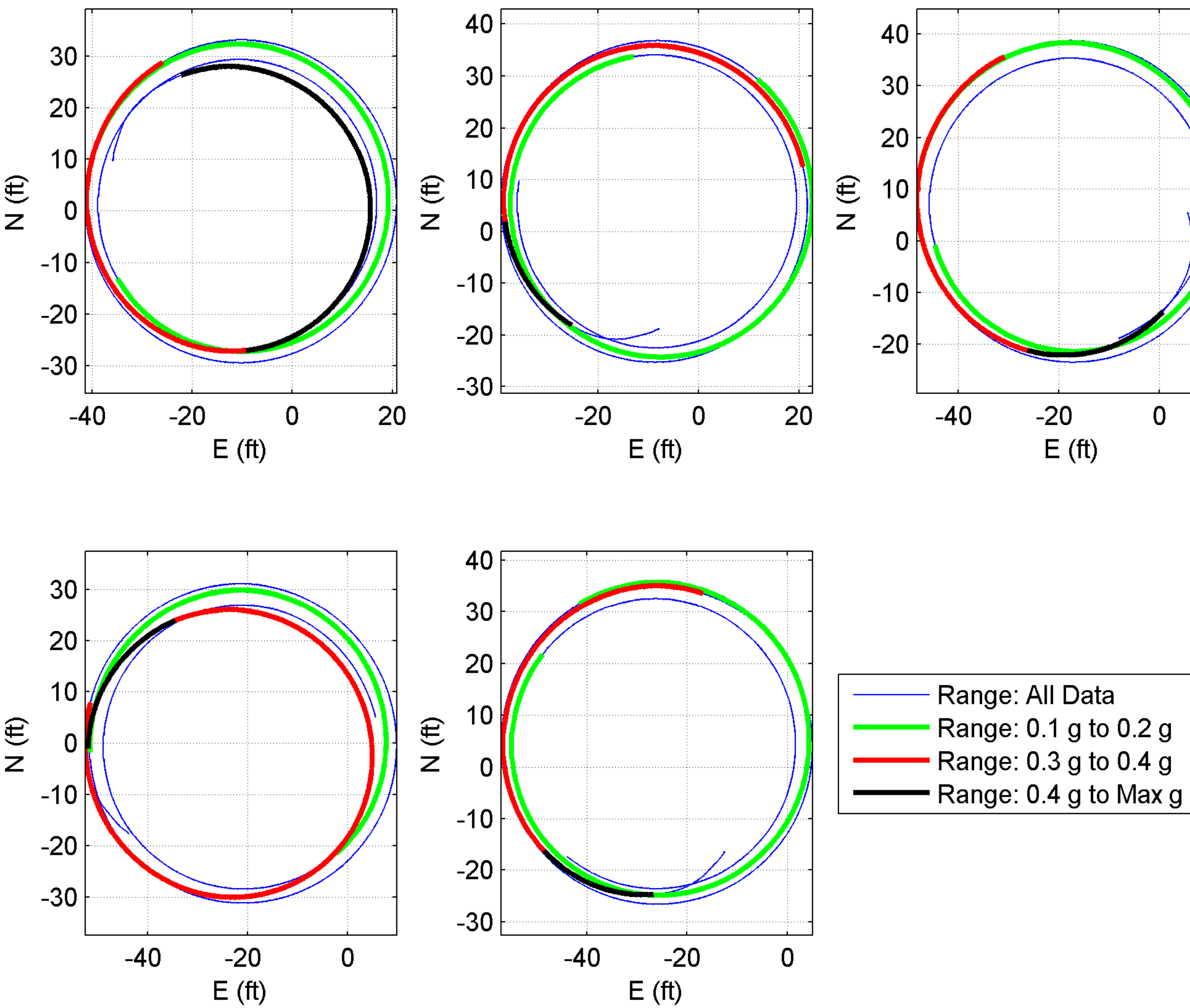

Vehicle K - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
Speed (m/s)

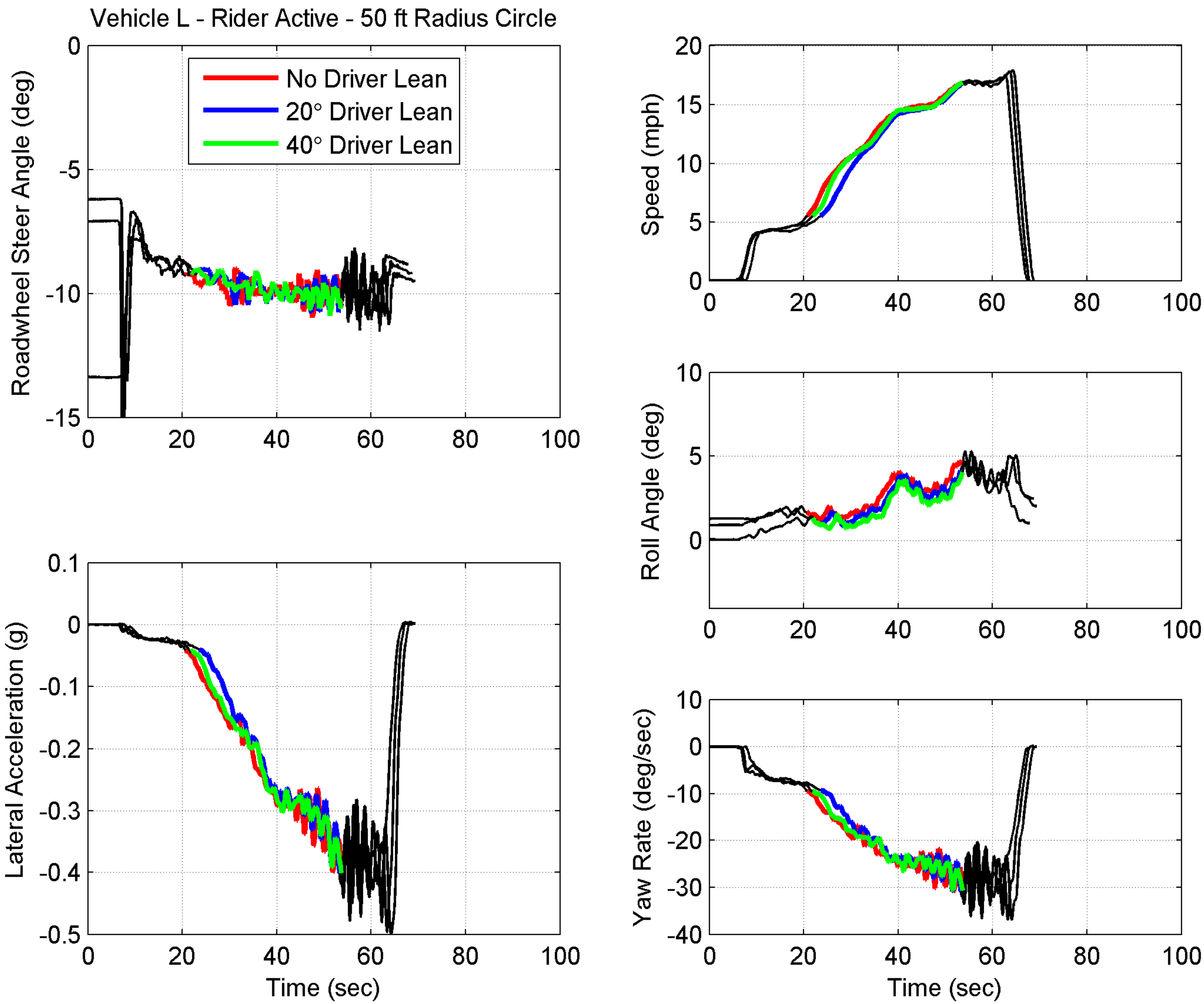

Vehicle K - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
CCW Average: 2.14
CCW Ratios: 2.73 1.75 1.98 2.26 1.95 STD=0.379
CCW Final Slopes: -13.9 -8.26 -10.1 -12.2 -9.26 STD=2.3
CCW Initial Slopes: -5.09 -4.71 -5.11 -5.41 -4.74 STD=0.292



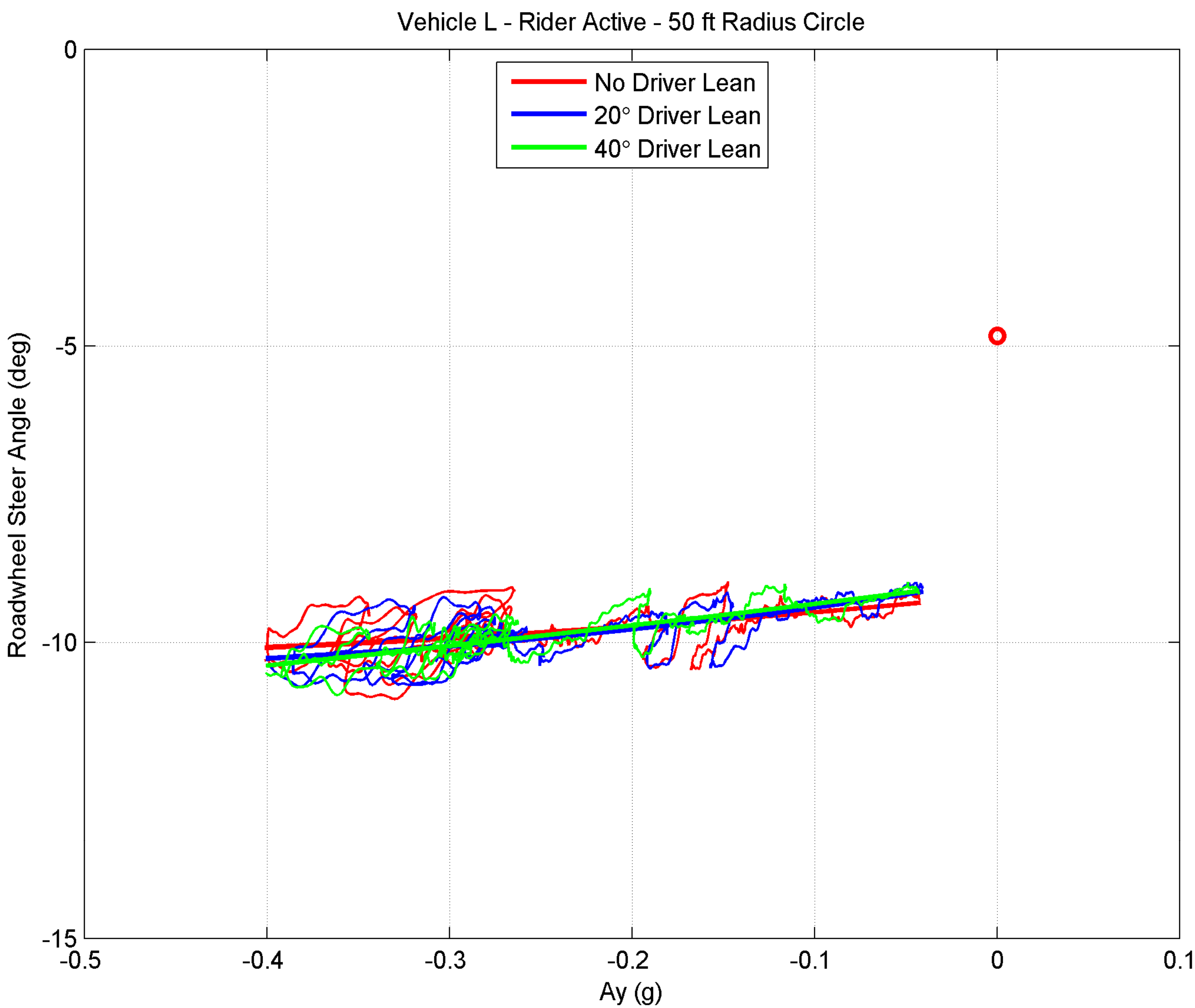
Vehicle K - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -13.9
Ratio: 2.73
Final Slope: -8.26
Ratio: 1.75
Final Slope: -10.1
Ratio: 1.98
Final Slope: -12.2
Ratio: 2.26
Final Slope: -9.26
Ratio: 1.95
Yaw Rate (deg/sec)
Speed (m/s)

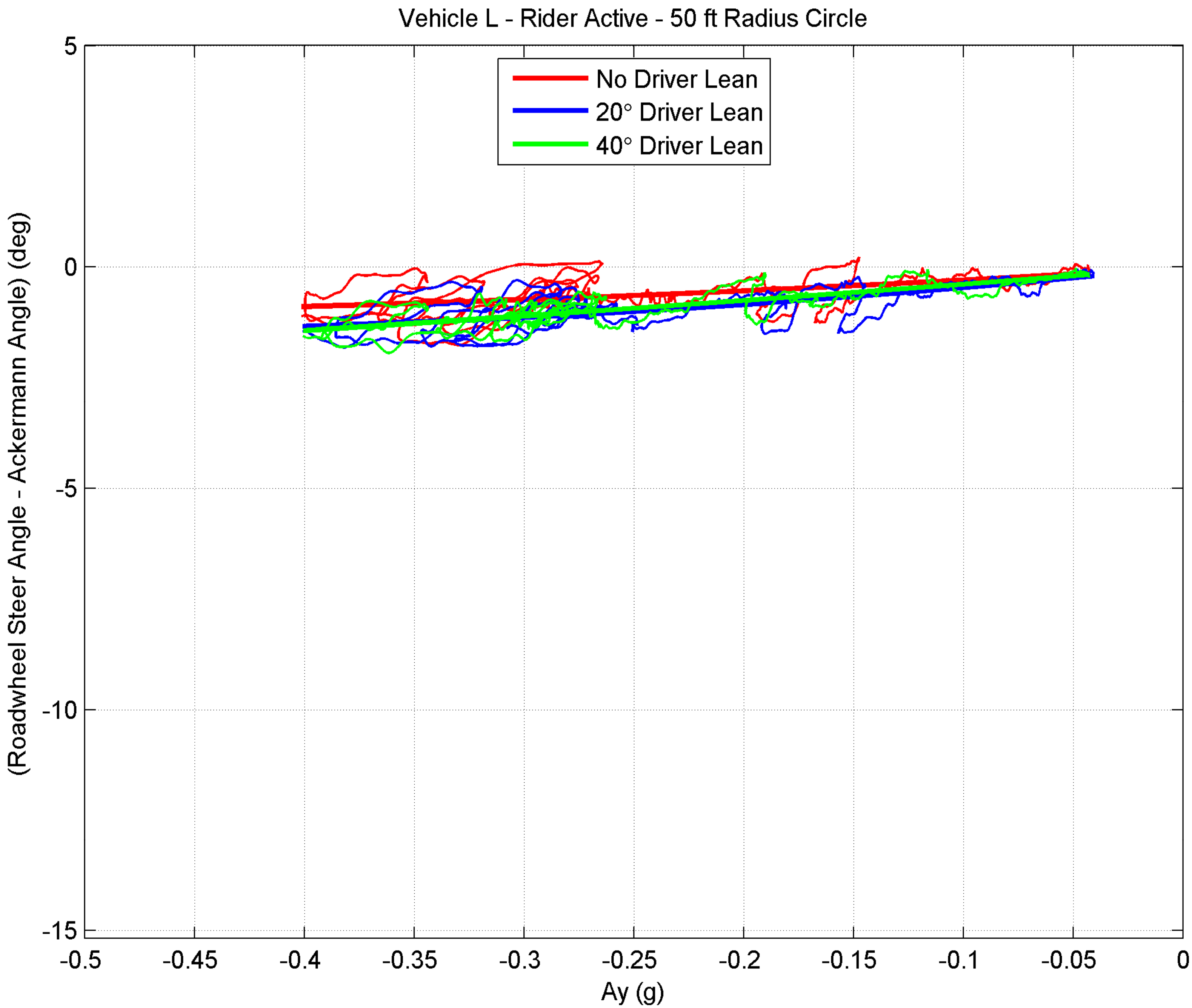
Vehicle K - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

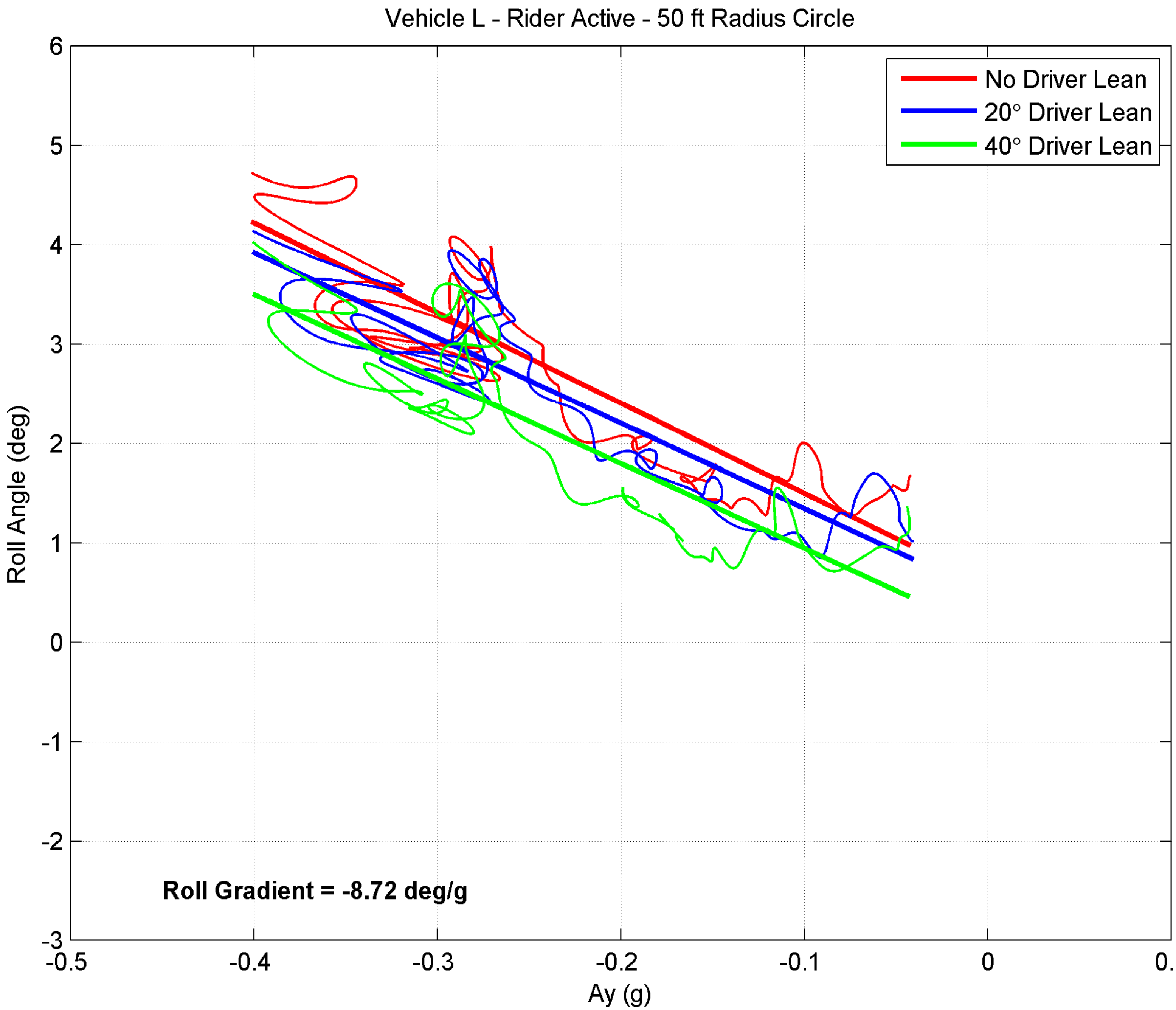




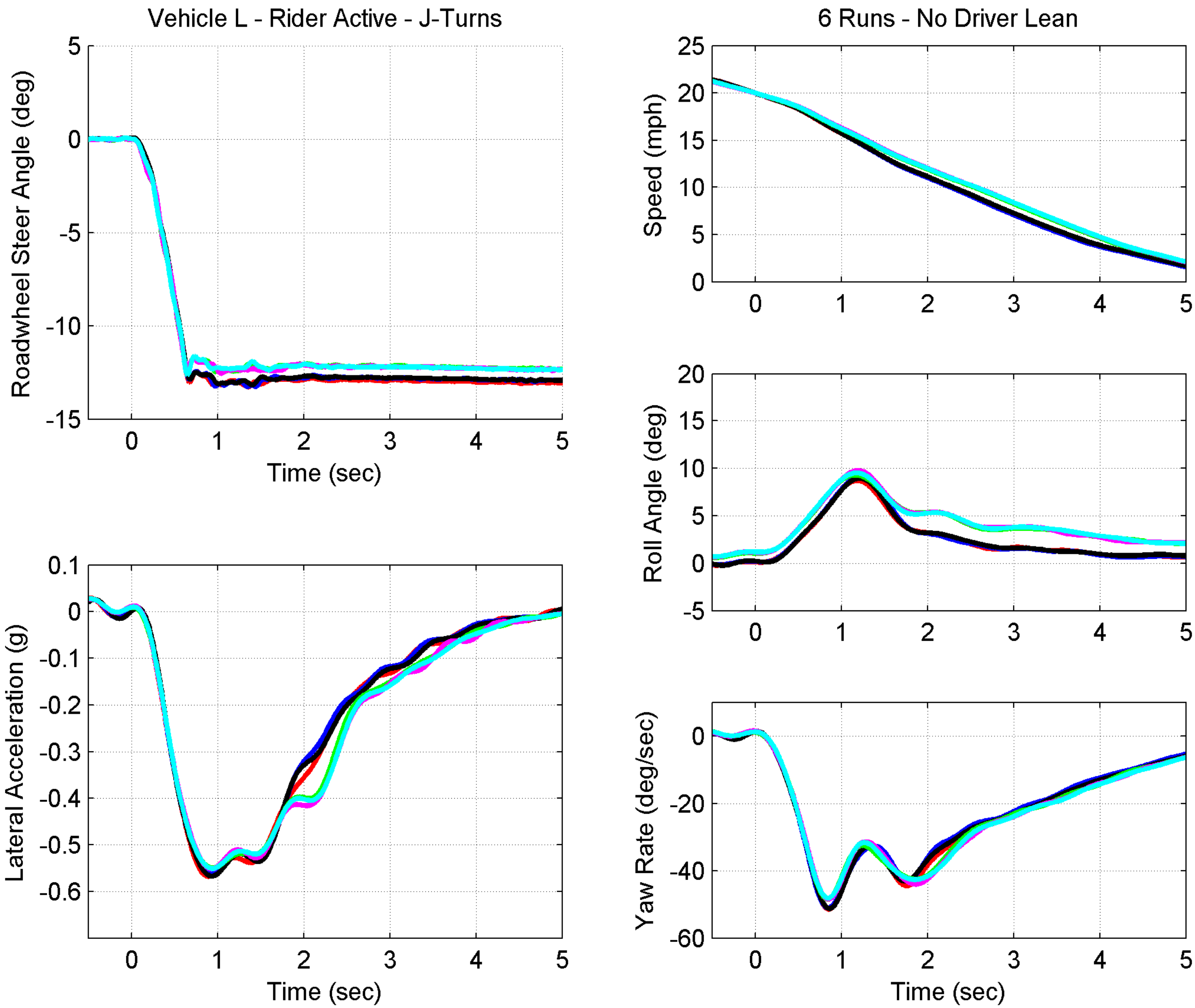
Vehicle L - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

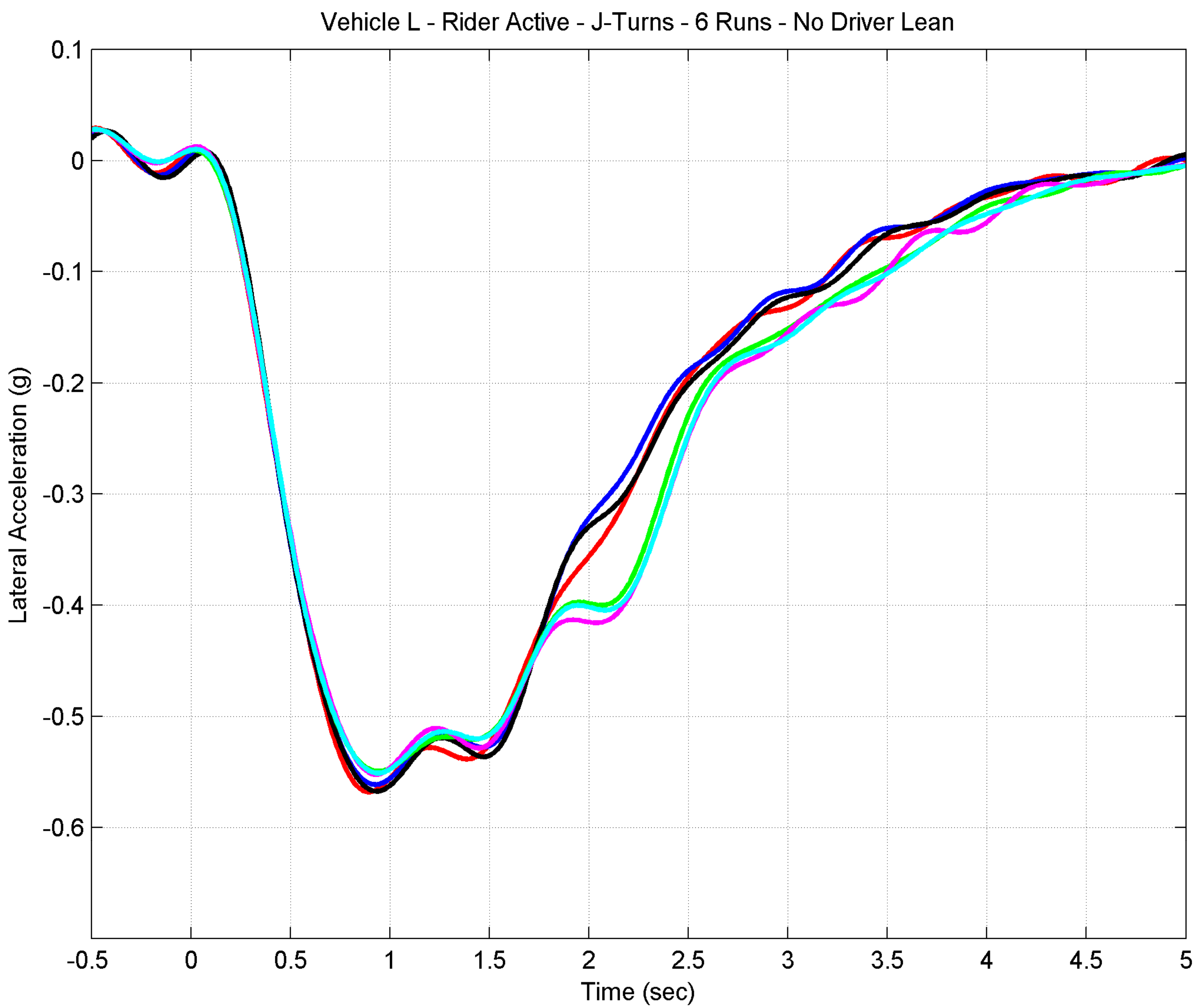

Vehicle L - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)


Vehicle L - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
(Roadwheel Steer Angle - Ackermann Angle) (deg)
5
0
-5
-10
-15
-0.5
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1
-0.05
0
Ay (g)

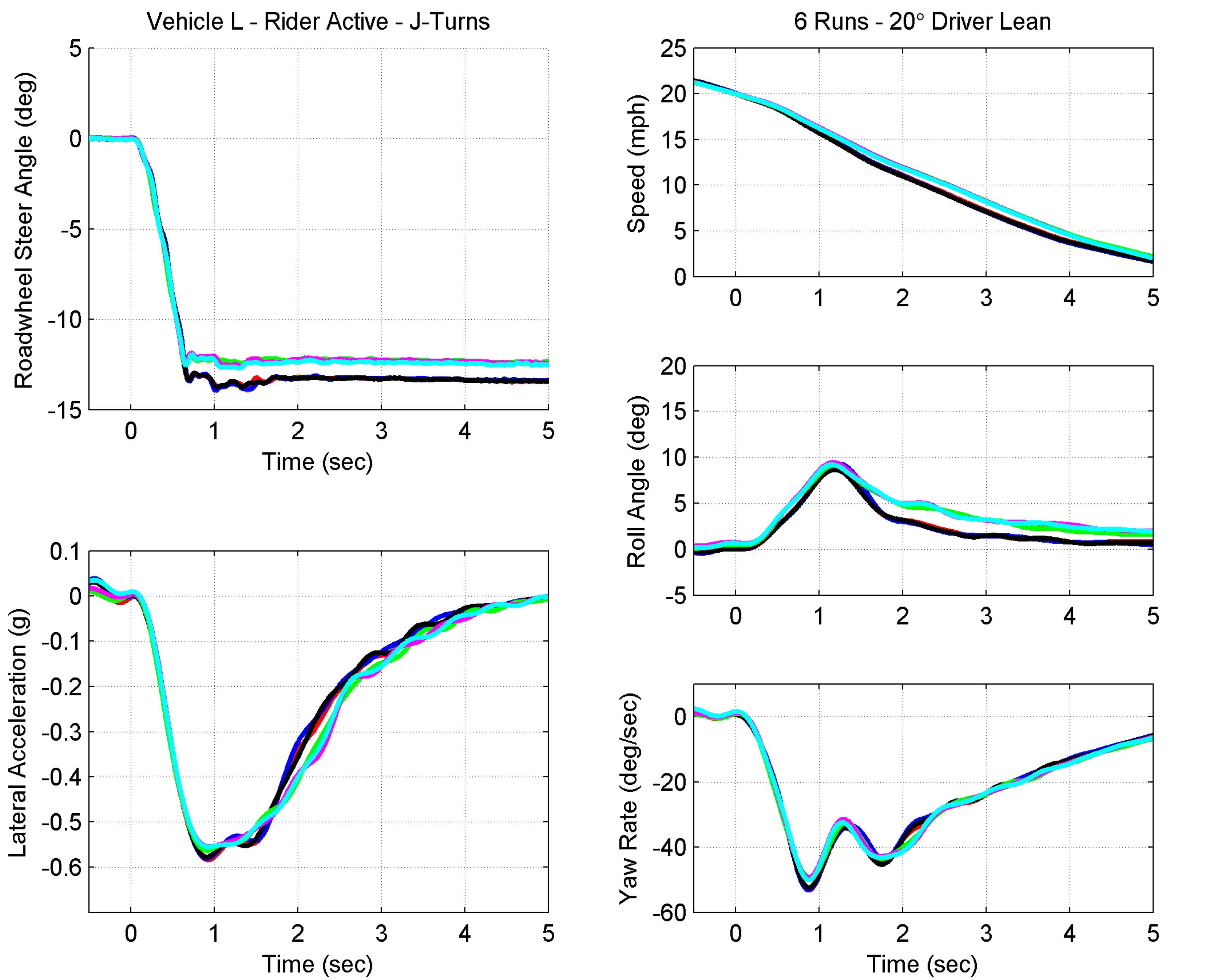


Vehicle L - Rider Active - 50 ft Radius Circle
No Driver Lean
20° Driver Lean
40° Driver Lean
Roll Angle (deg)
6
5
4
3
2
1
0
-1
-2
-3
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
Ay (g)
Roll Gradient = -8.72 deg/g

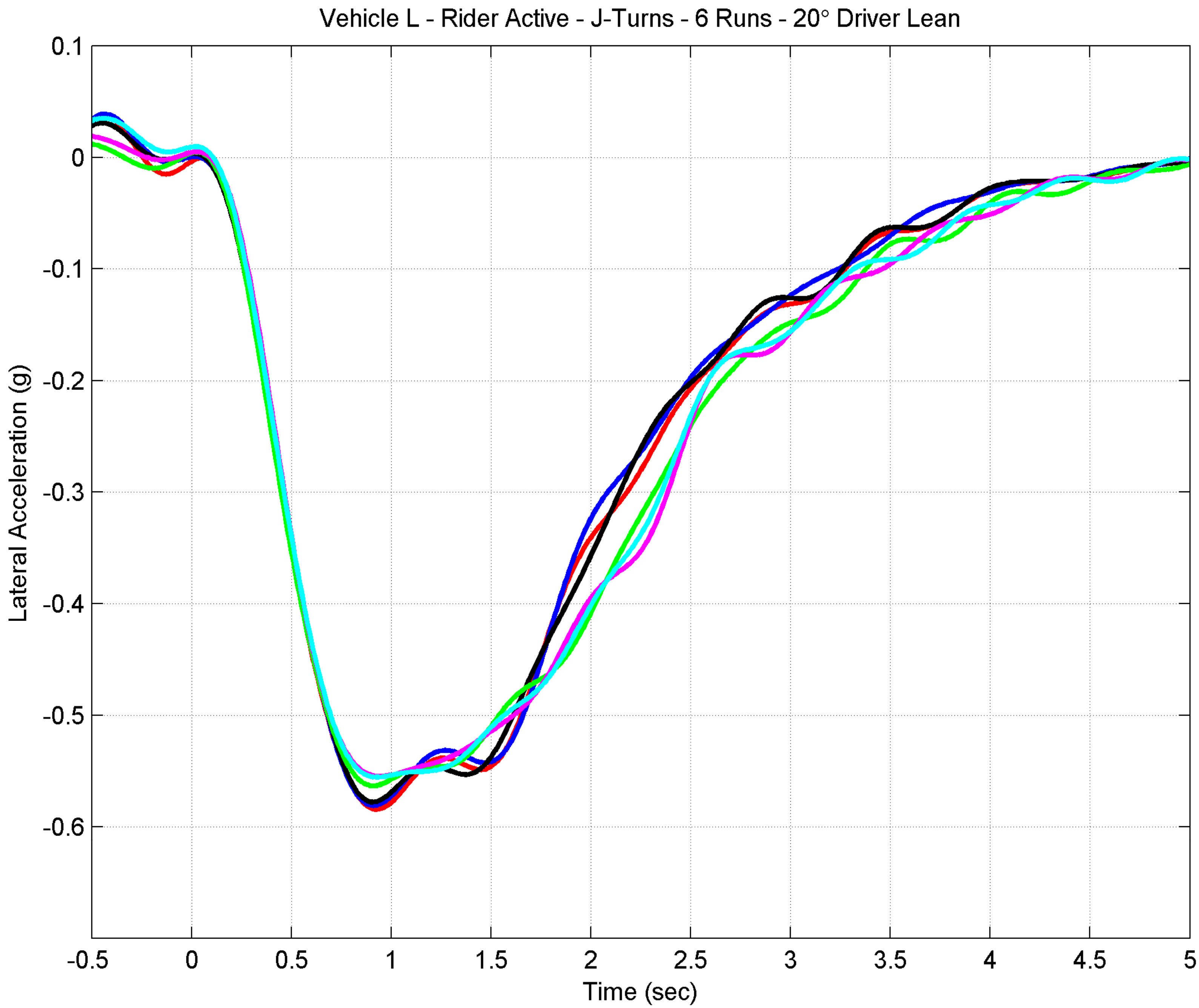

Vehicle L - Rider Active - J-Turns
6 Runs - No Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



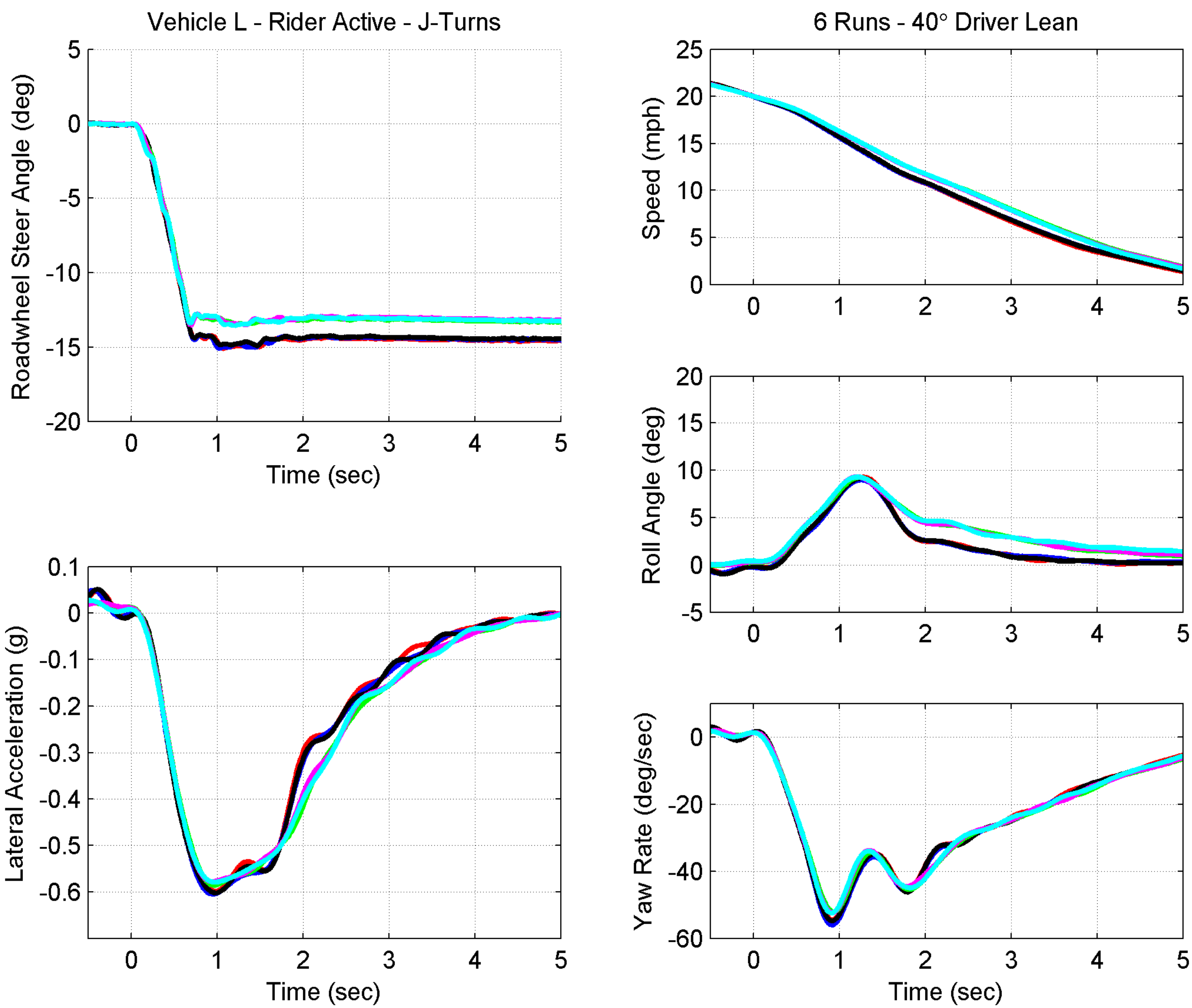
Vehicle L - Rider Active - J-Turns - 6 Runs - No Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Time (sec)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5



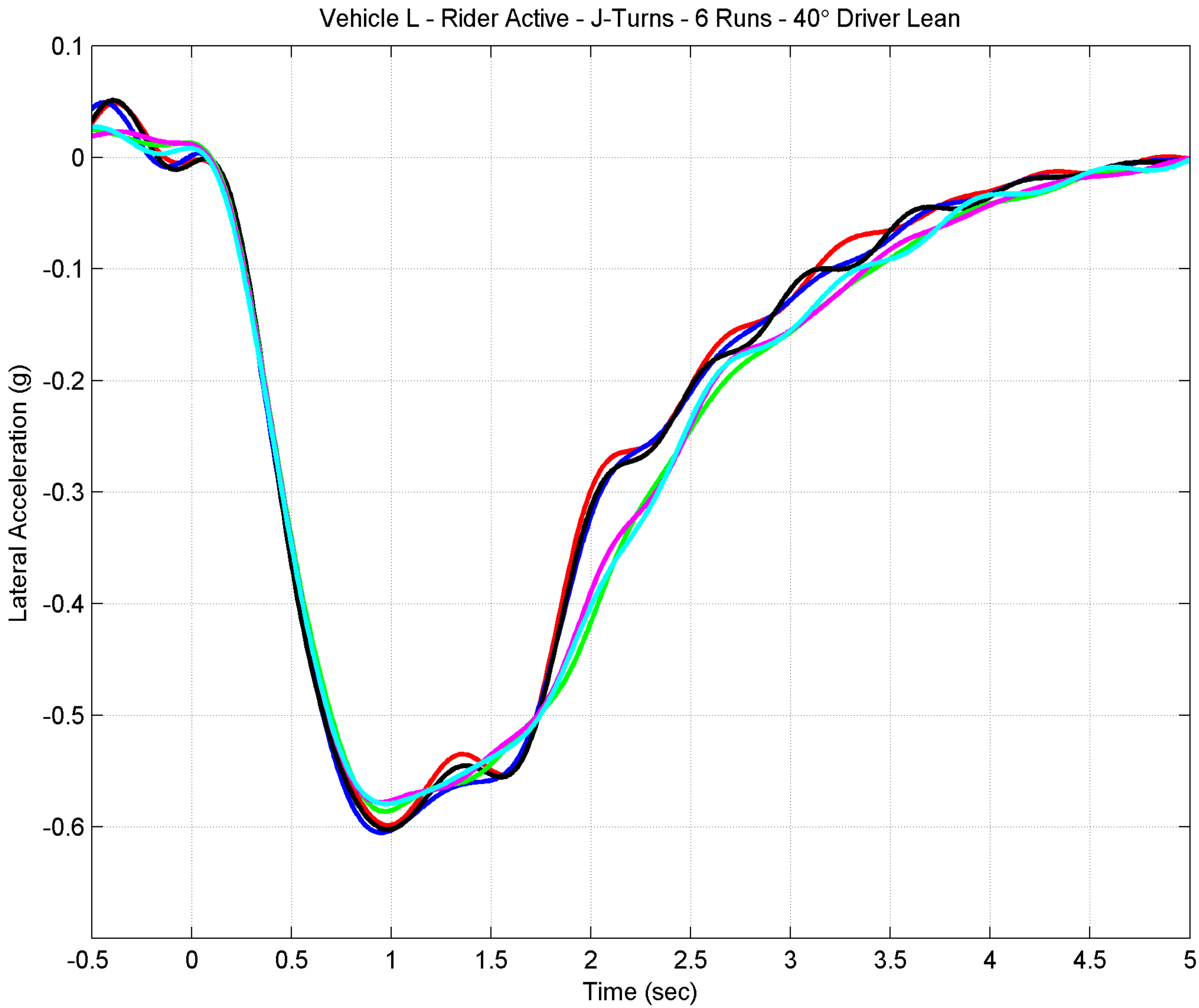
Vehicle L - Rider Active - J-Turns
6 Runs - 20° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)



Vehicle L - Rider Active - J-Turns - 6 Runs - 20° Driver Lean
Lateral Acceleration (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)



Vehicle L - Rider Active - J-Turns
6 Runs - 40° Driver Lean
Roadwheel Steer Angle (deg)
Time (sec)
Speed (mph)
Roll Angle (deg)
Lateral Acceleration (g)
Yaw Rate (deg/sec)

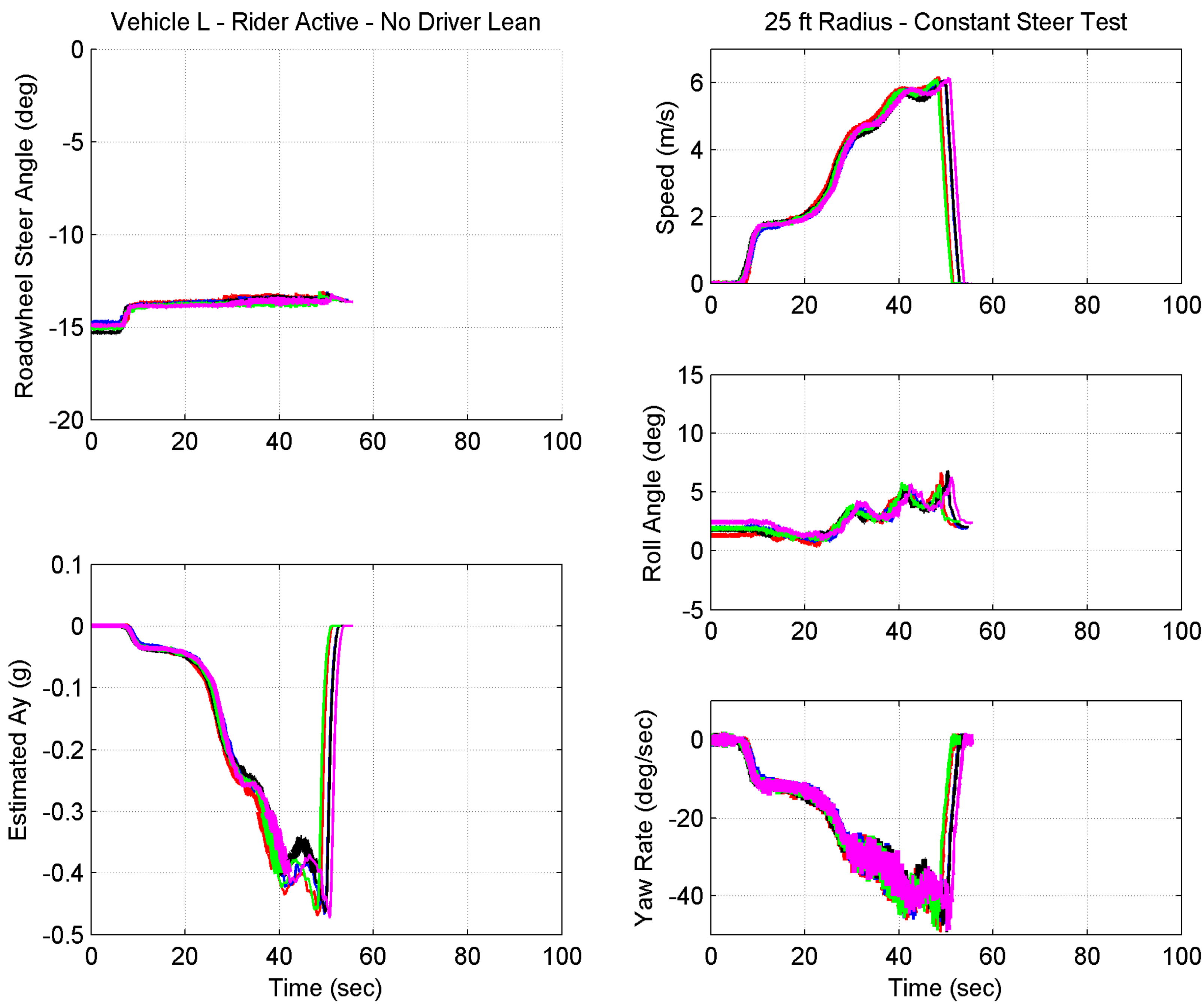

Vehicle L - Rider Active - J-Turns - 6 Runs - 40° Driver Lean
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
Lateral Acceleration (g)
-0.5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (sec)

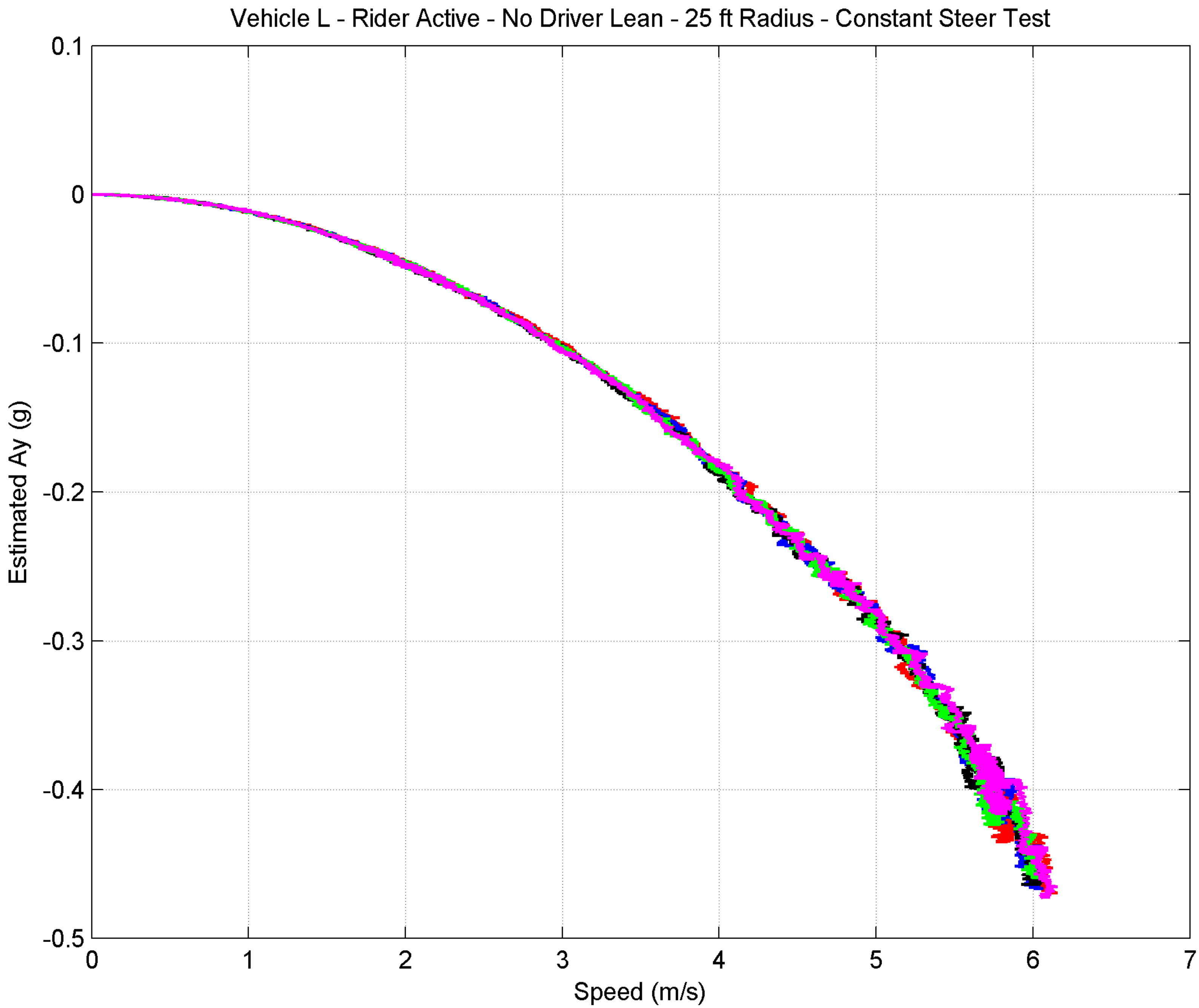
Vehicle L - Rider Active Results

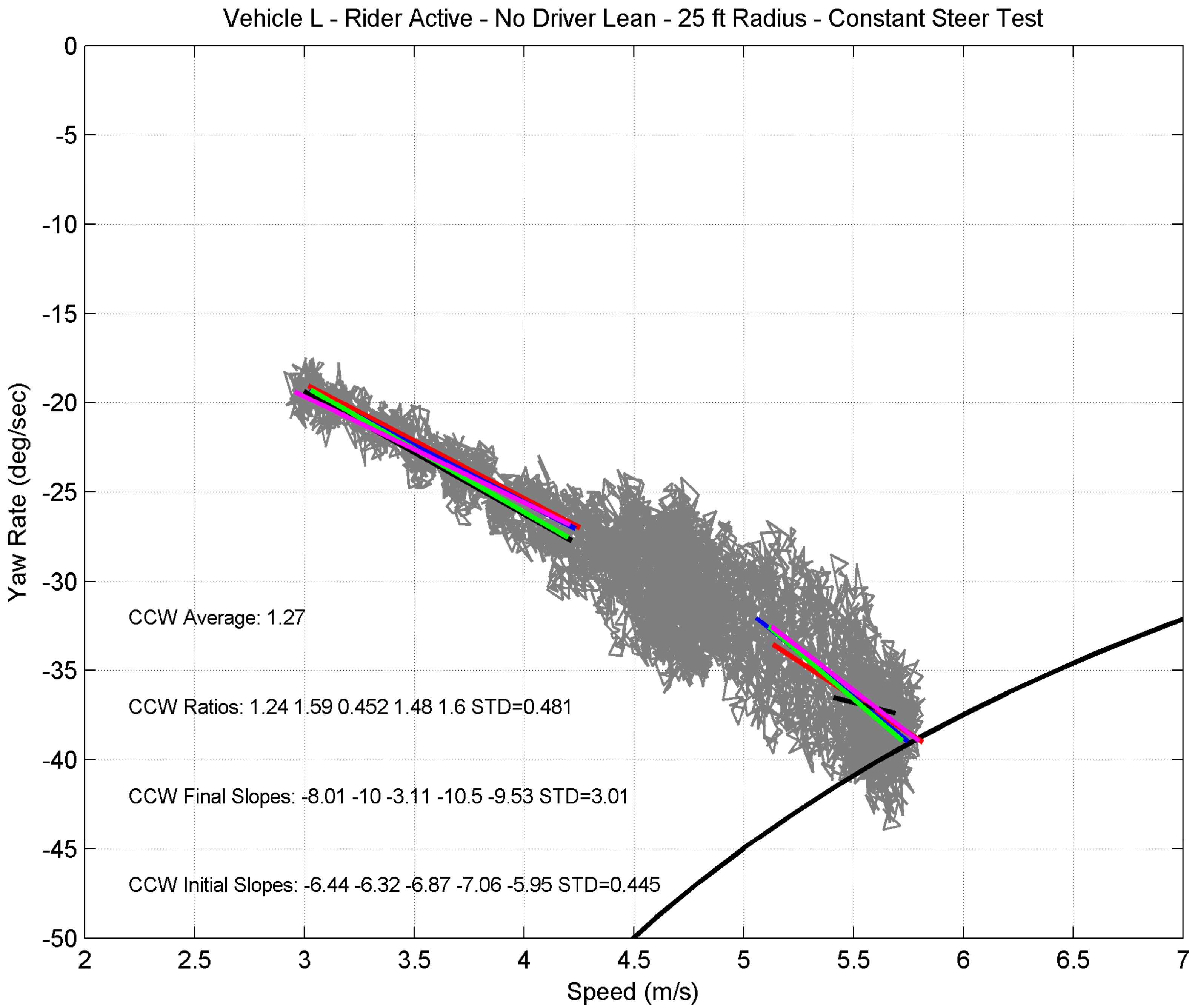
Peak Lateral Accelerations During 2WL J-Turns - All Values in "g's"

	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Northwest Runs	-0.568	-0.584	-0.599
	-0.561	-0.581	-0.605
	-0.567	-0.578	-0.602
Mean Value of 3 Runs	-0.566	-0.581	-0.602
Standard Deviation of 3 Runs	0.004	0.003	0.003

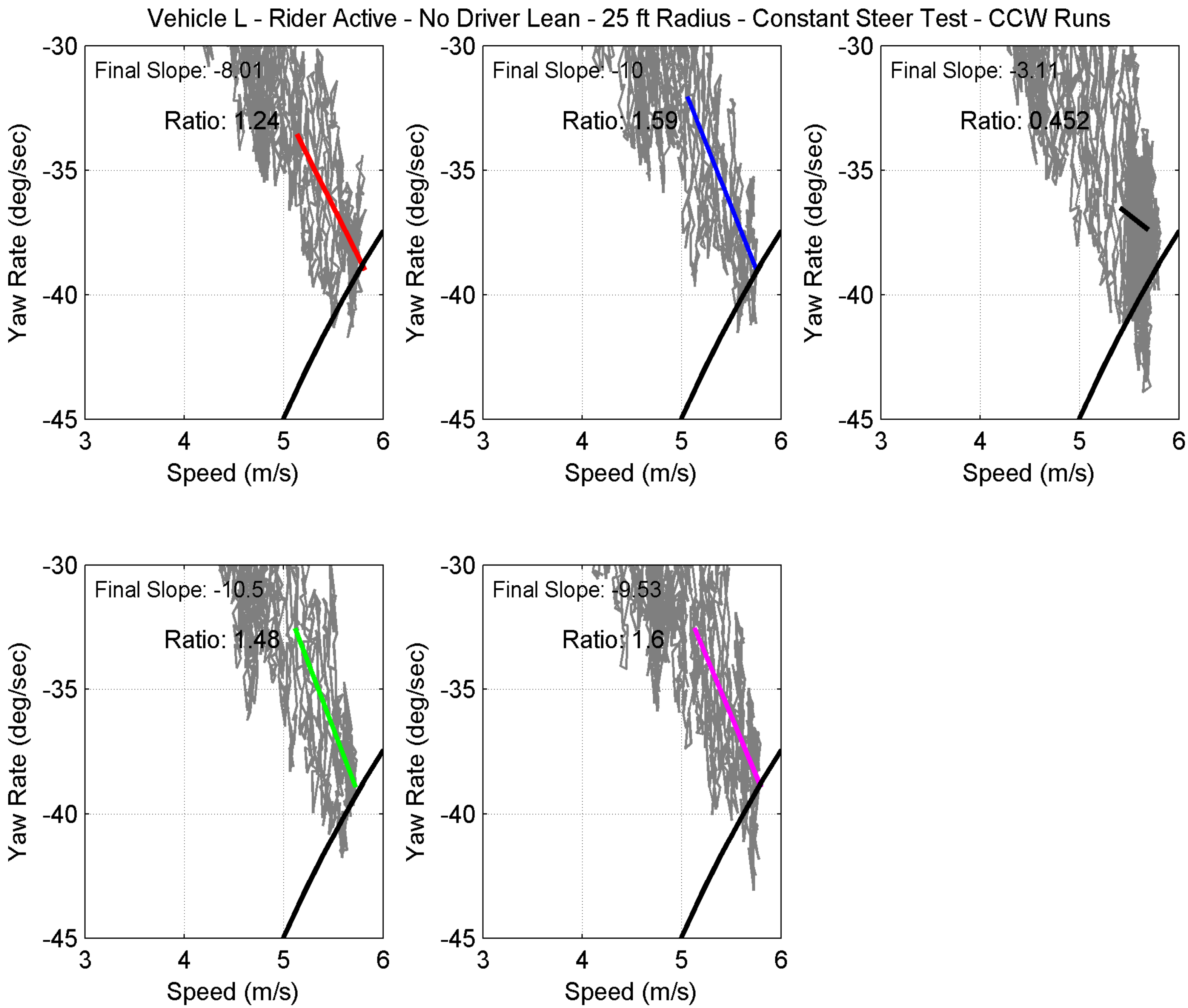
	No Driver Lean	20 deg Driver Lean	40 deg Driver Lean
Southeast Runs	-0.549	-0.563	-0.586
	-0.552	-0.555	-0.578
	-0.551	-0.555	-0.579
Mean Value of 3 Runs	-0.551	-0.558	-0.581
Standard Deviation of 3 Runs	0.001	0.005	0.004
Average of All 6 Runs	**0.558**	**0.569**	**0.592**


Vehicle L - Rider Active - No Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)

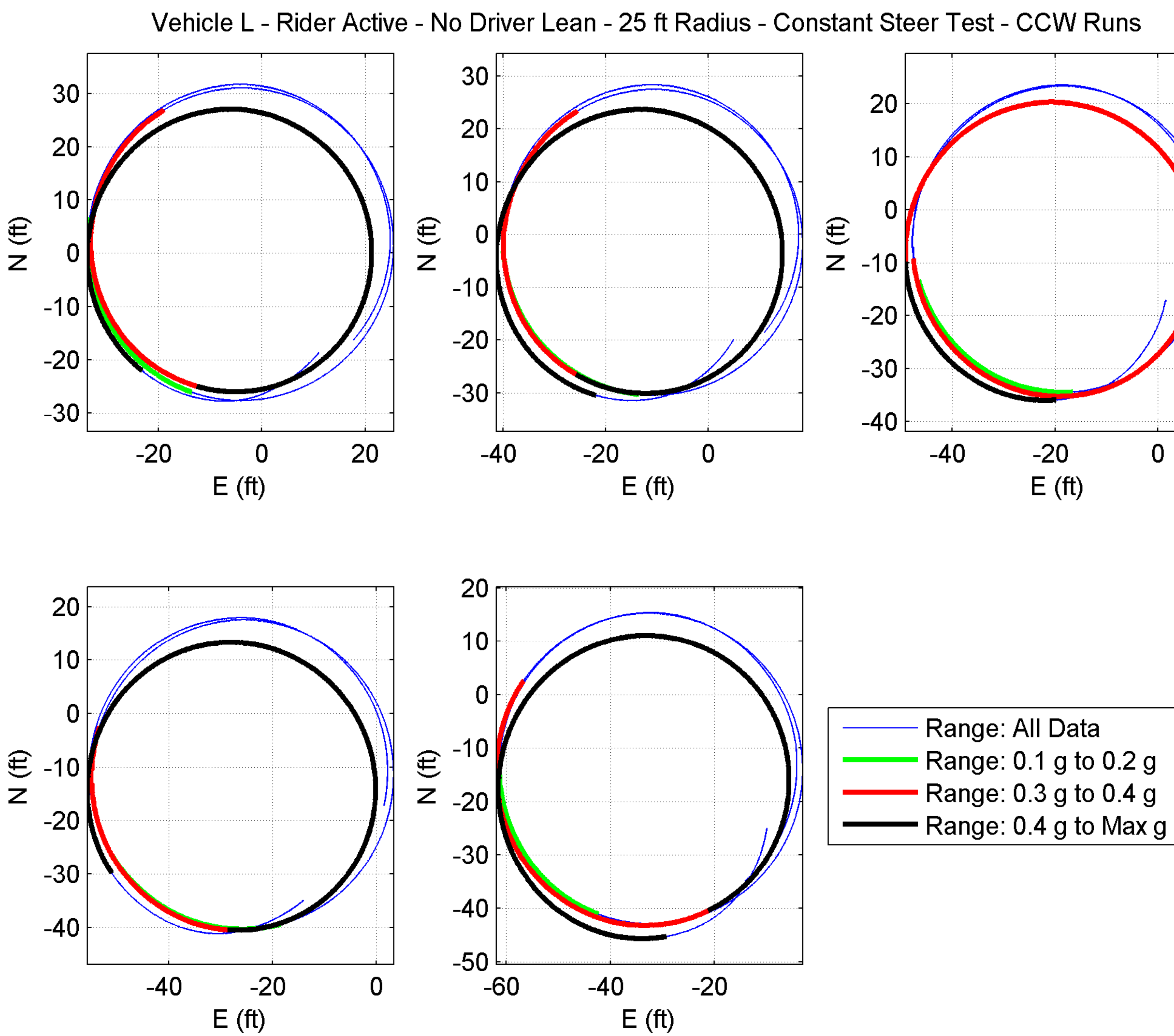

Vehicle L - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Estimated Ay (g)
0
1
2
3
4
5
6
7
Speed (m/s)



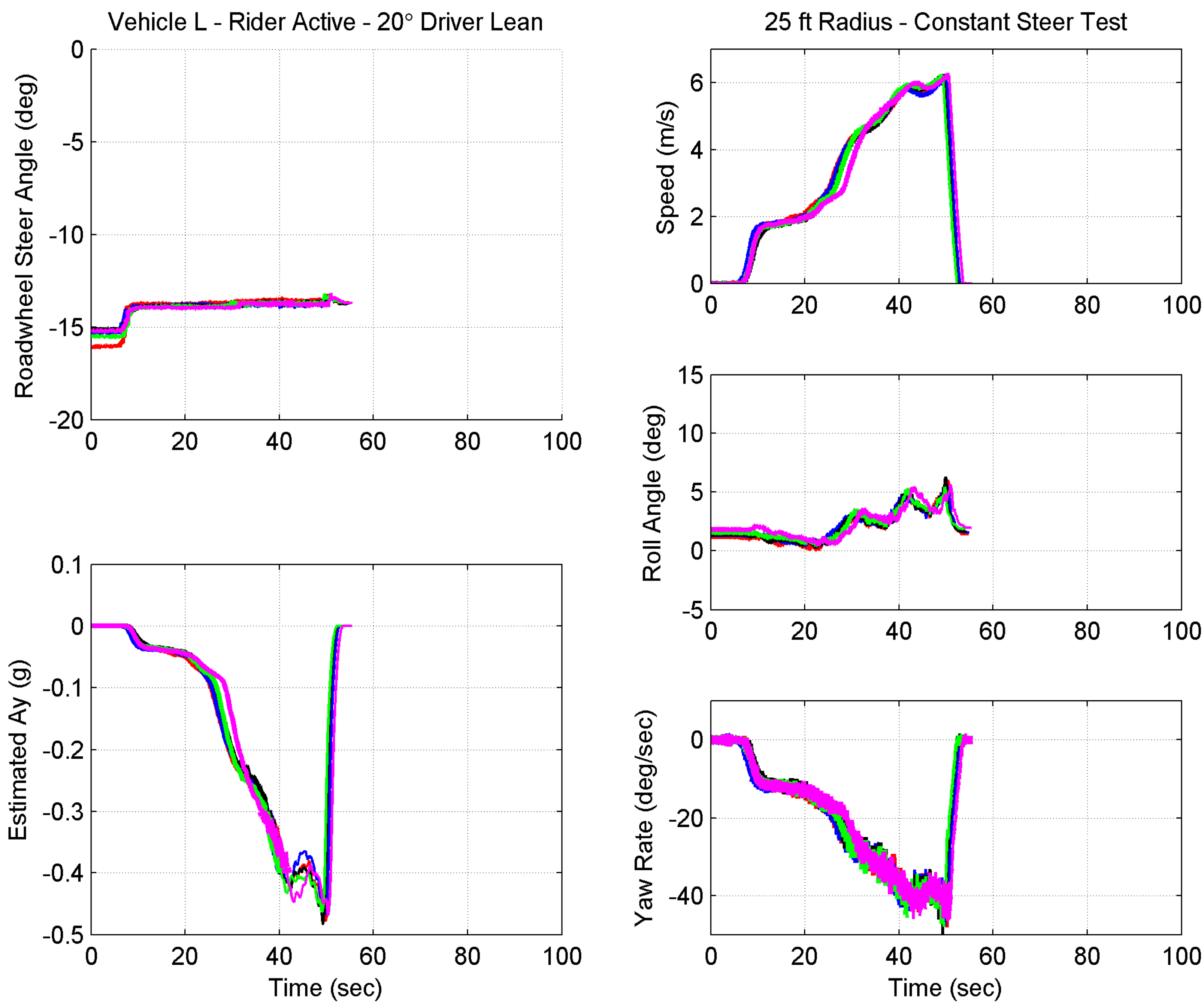
Vehicle L - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
CCW Average: 1.27
CCW Ratios: 1.24 1.59 0.452 1.48 1.6 STD=0.481
CCW Final Slopes: -8.01 -10 -3.11 -10.5 -9.53 STD=3.01
CCW Initial Slopes: -6.44 -6.32 -6.87 -7.06 -5.95 STD=0.445



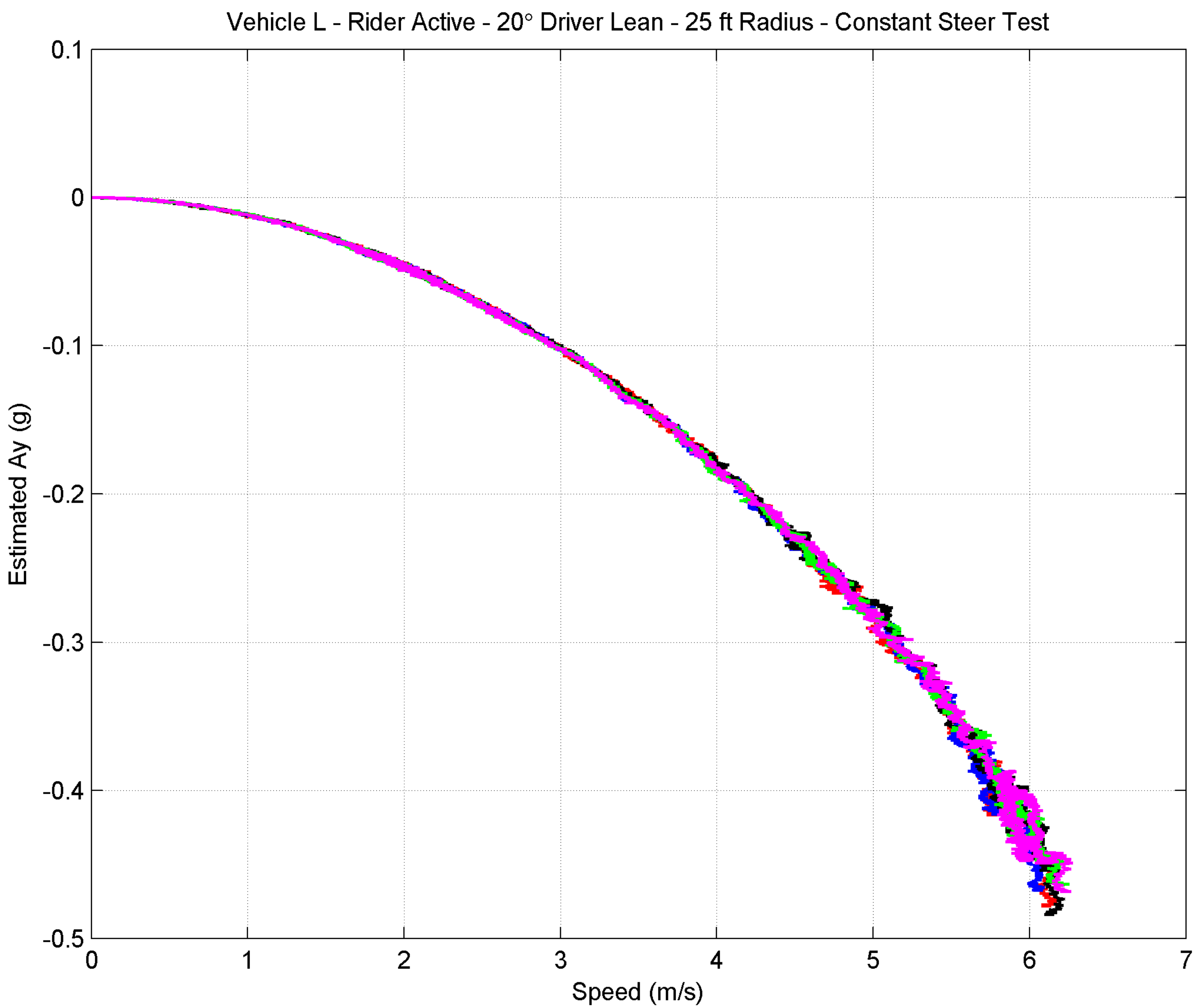
Vehicle L - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -8.01
Ratio: 1.24
Final Slope: -10
Ratio: 1.59
Final Slope: -3.11
Ratio: 0.452
Final Slope: -10.5
Ratio: 1.48
Final Slope: -9.53
Ratio: 1.6
Yaw Rate (deg/sec)
Speed (m/s)



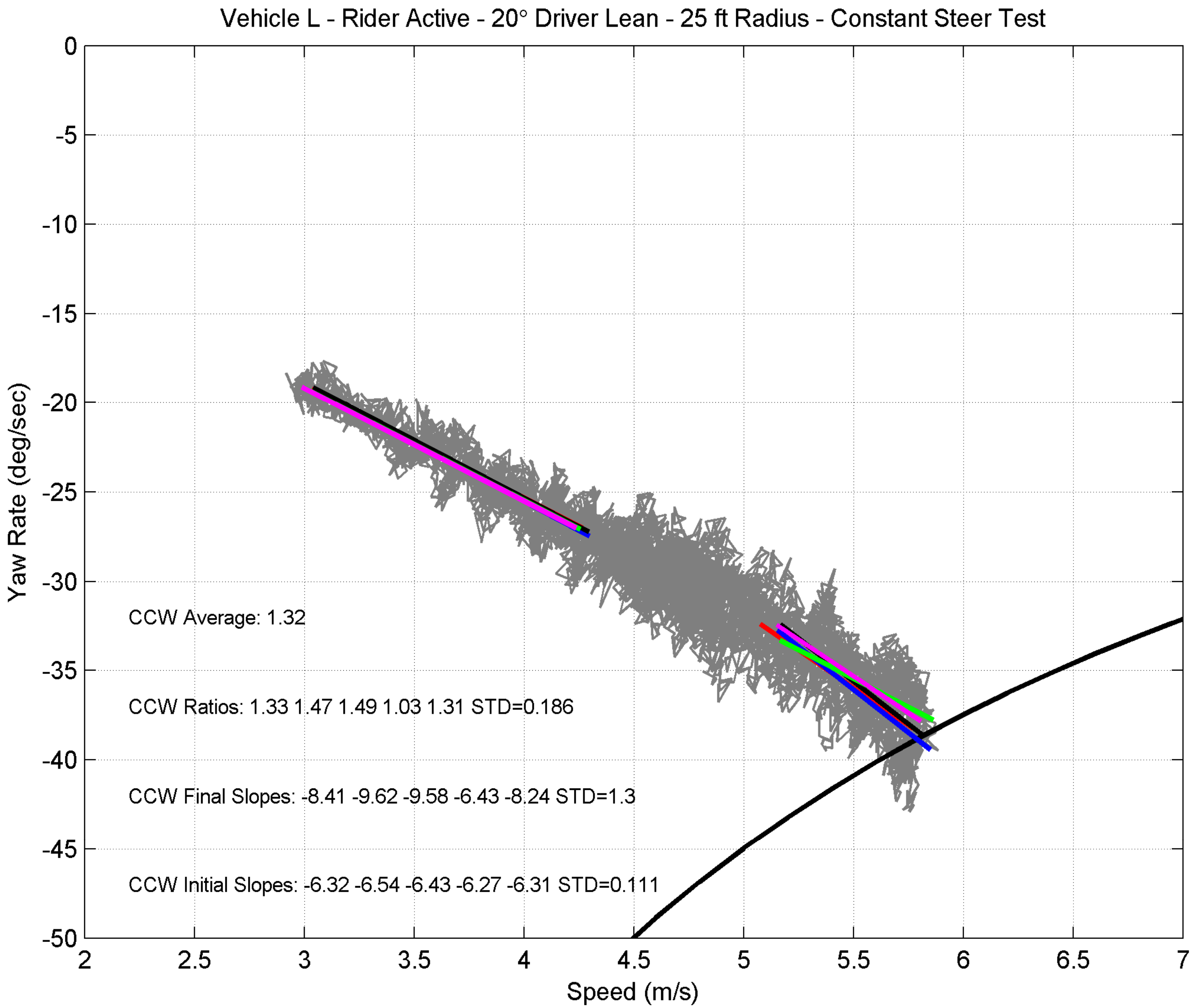
Vehicle L - Rider Active - No Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
N (ft)
E (ft)
Range: All Data
Range: 0.1 g to 0.2 g
Range: 0.3 g to 0.4 g
Range: 0.4 g to Max g

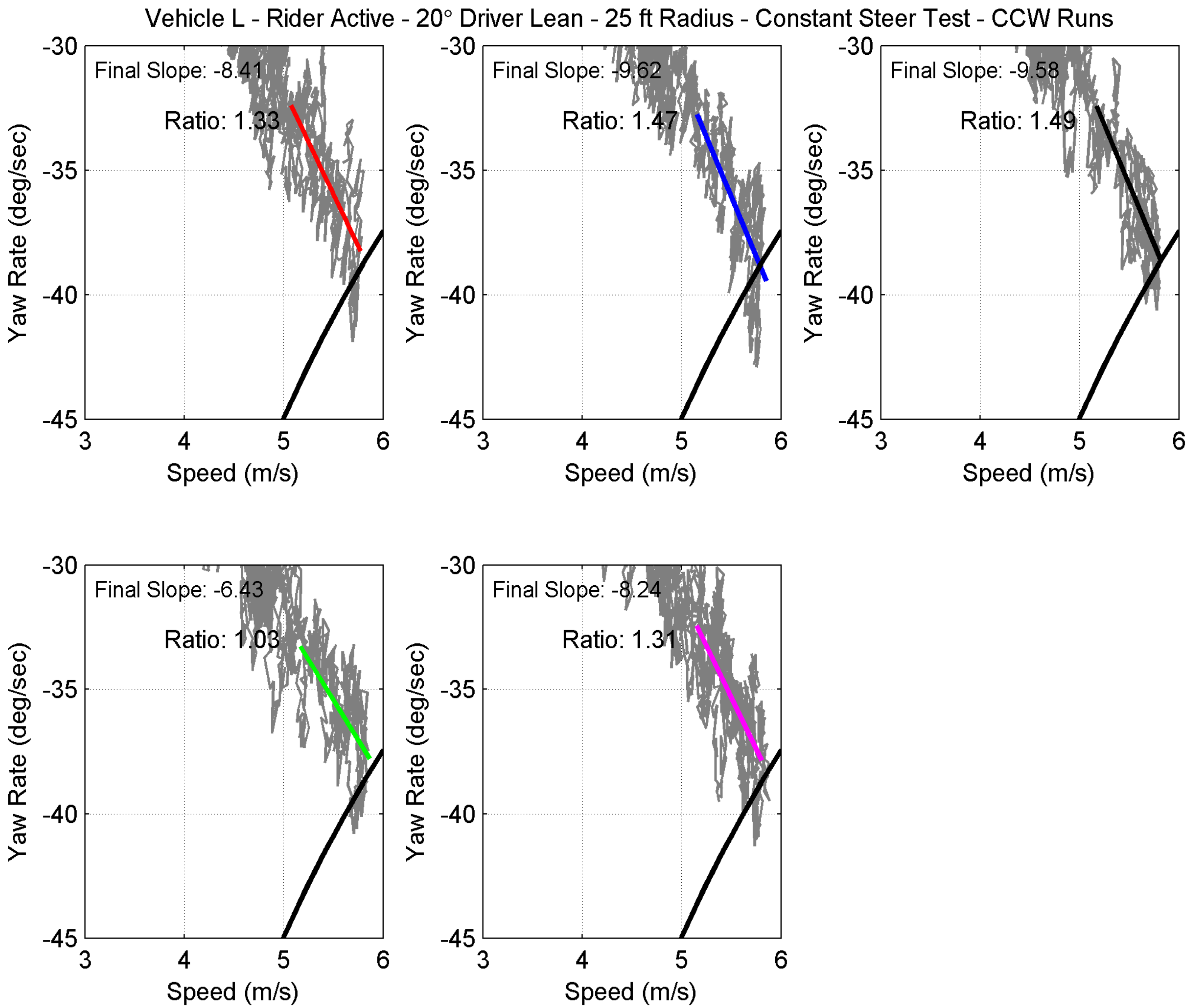


Vehicle L - Rider Active - 20° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
0
-5
-10
-15
-20
0 20 40 60 80 100
Speed (m/s)
6
4
2
0
0 20 40 60 80 100
Roll Angle (deg)
15
10
5
0
-5
0 20 40 60 80 100
Estimated Ay (g)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0 20 40 60 80 100
Time (sec)
Yaw Rate (deg/sec)
0
-20
-40
0 20 40 60 80 100
Time (sec)

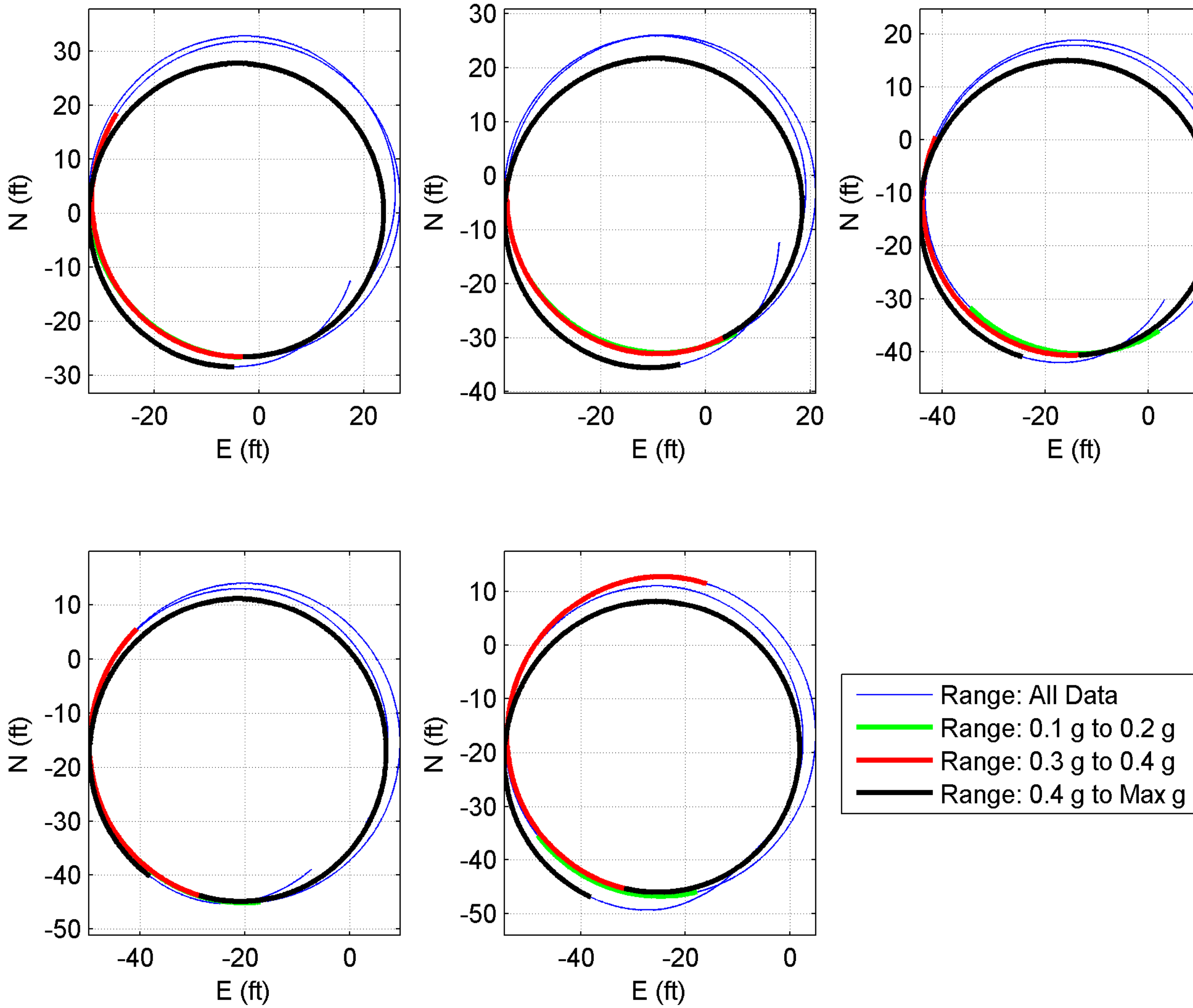


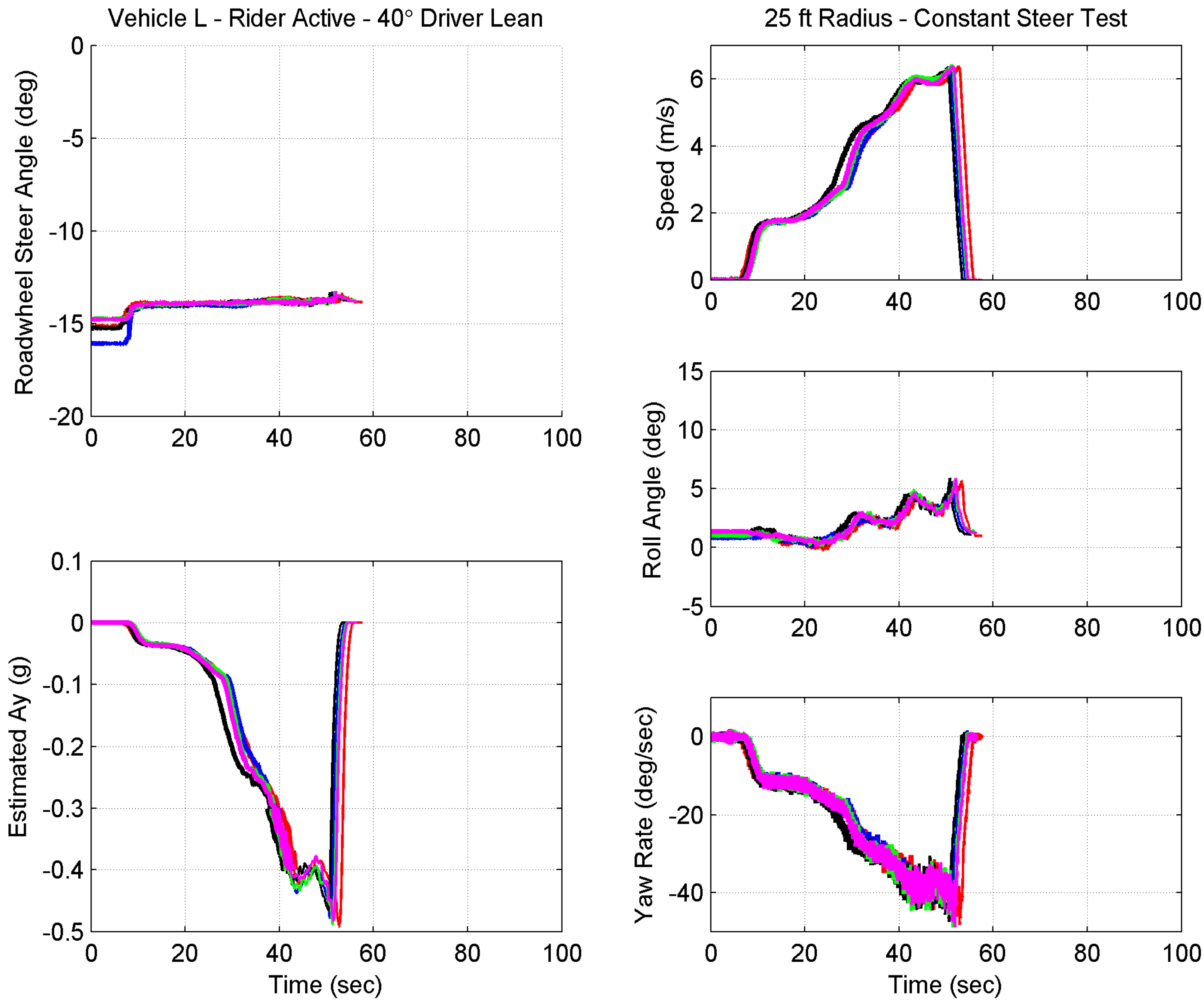
Vehicle L - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7


Vehicle L - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
CCW Average: 1.32
CCW Ratios: 1.33 1.47 1.49 1.03 1.31 STD=0.186
CCW Final Slopes: -8.41 -9.62 -9.58 -6.43 -8.24 STD=1.3
CCW Initial Slopes: -6.32 -6.54 -6.43 -6.27 -6.31 STD=0.111

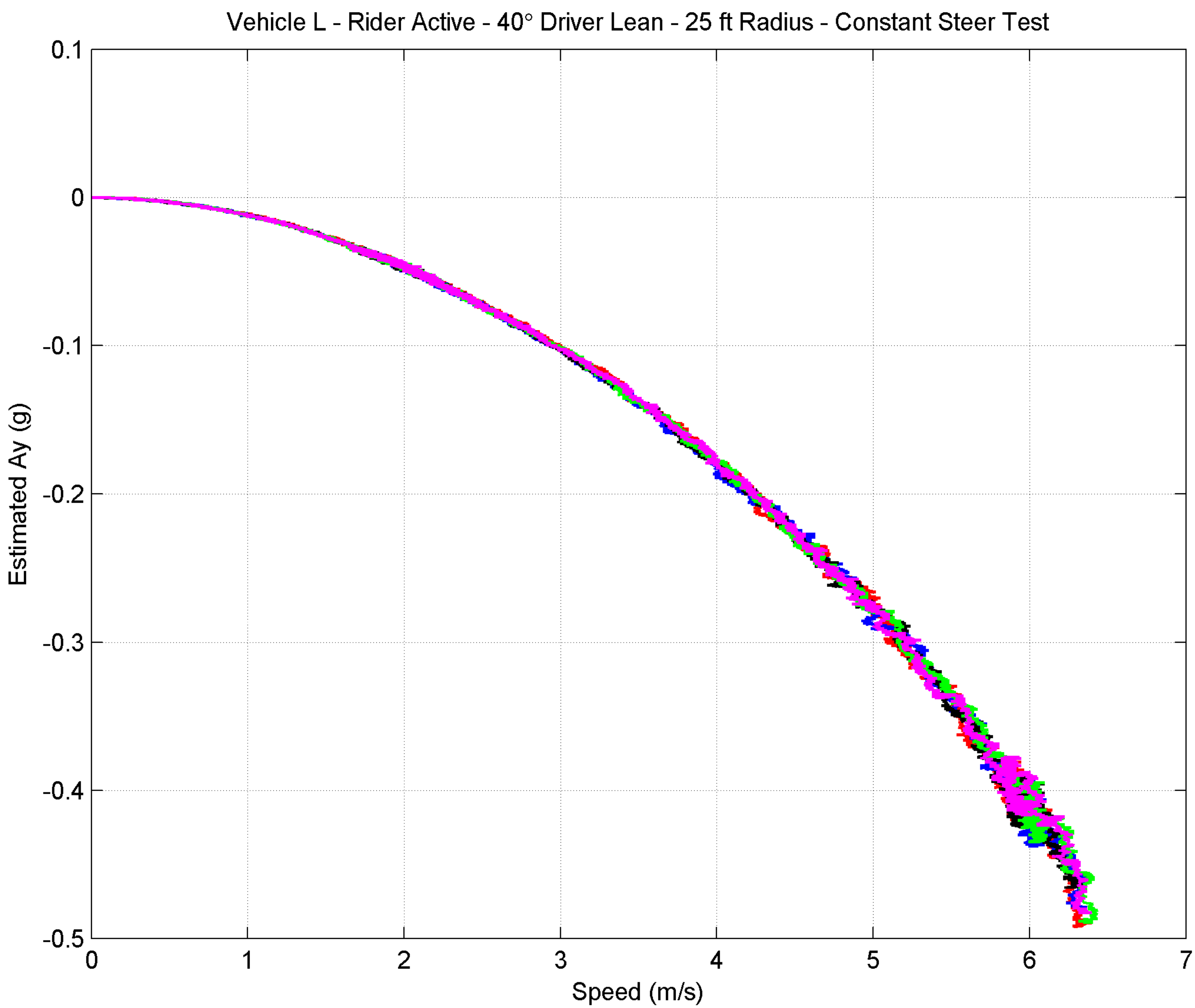

Vehicle L - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -8.41
Ratio: 1.33
Final Slope: -9.62
Ratio: 1.47
Final Slope: -9.58
Ratio: 1.49
Final Slope: -6.43
Ratio: 1.03
Final Slope: -8.24
Ratio: 1.31
Yaw Rate (deg/sec)
Speed (m/s)

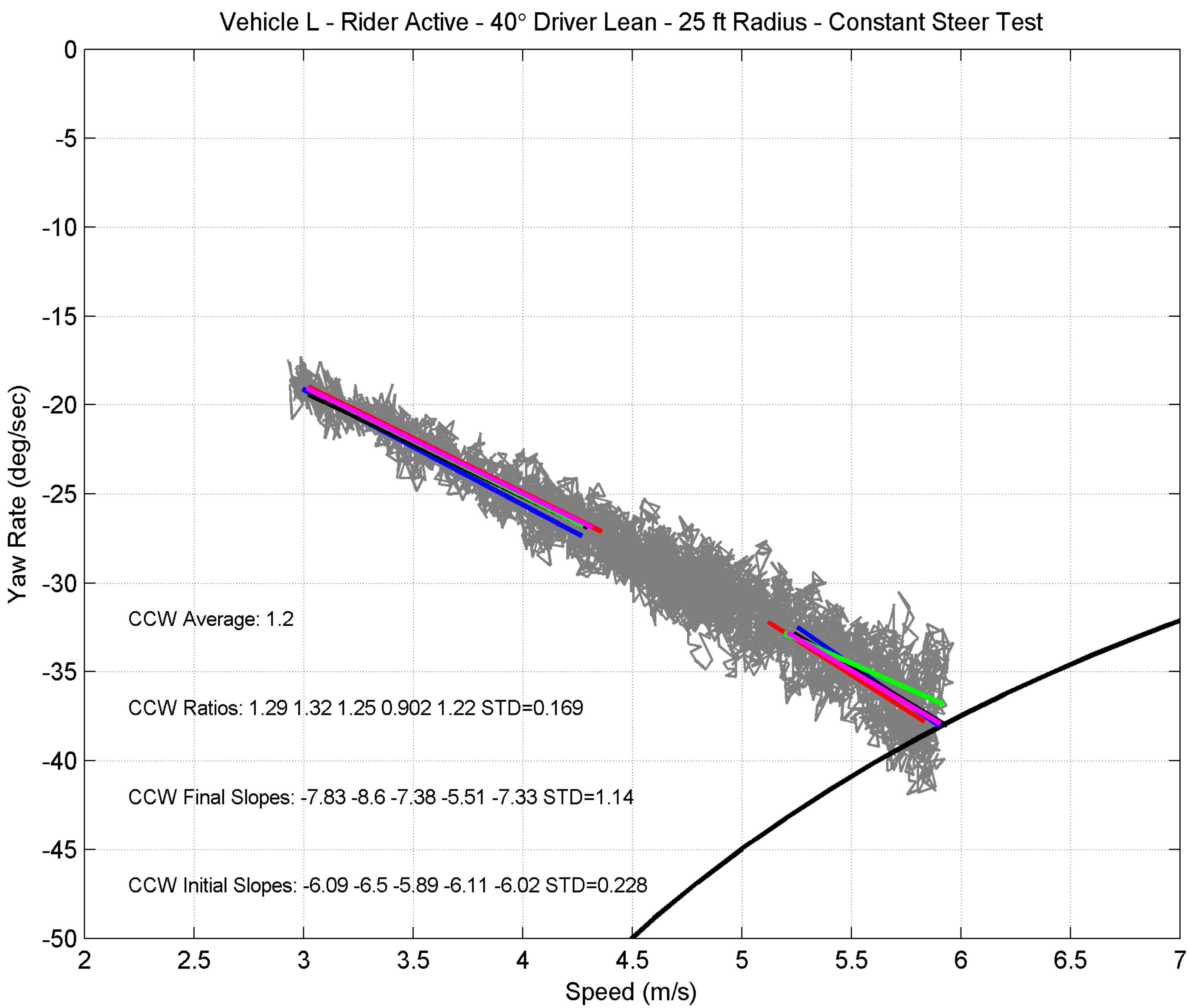
Vehicle L - Rider Active - 20° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

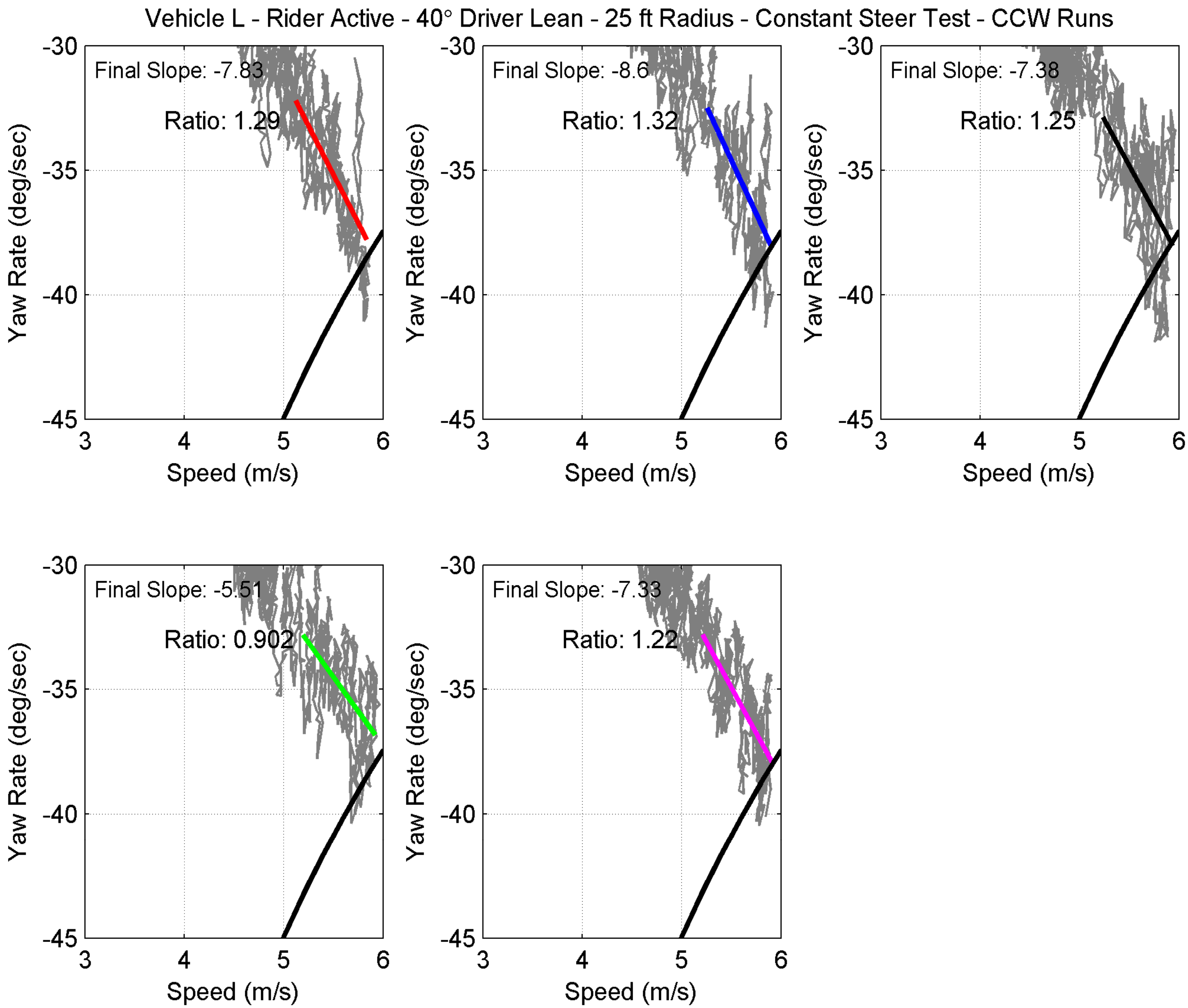




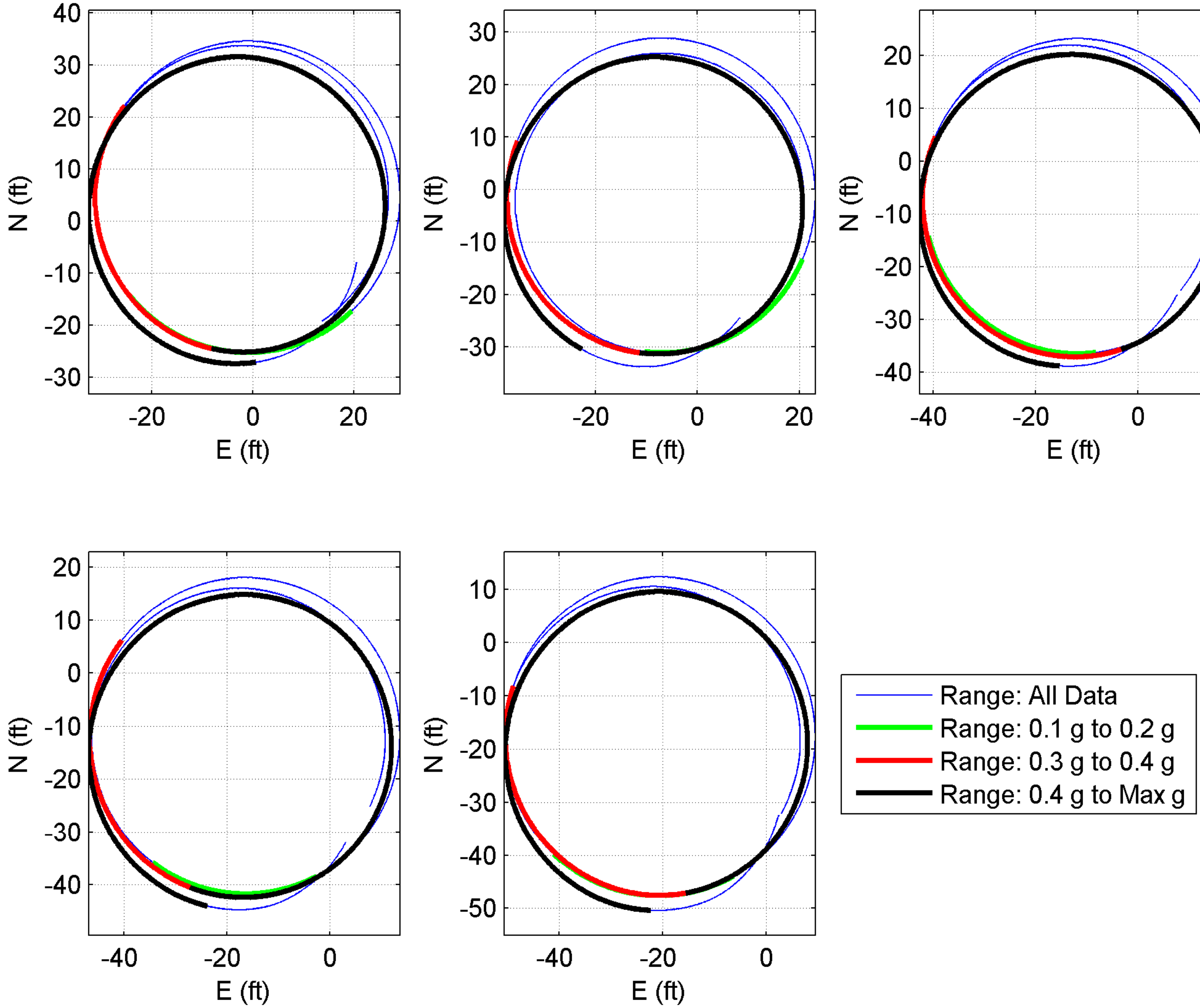
Vehicle L - Rider Active - 40° Driver Lean
25 ft Radius - Constant Steer Test
Roadwheel Steer Angle (deg)
Speed (m/s)
Roll Angle (deg)
Estimated Ay (g)
Yaw Rate (deg/sec)
Time (sec)
Time (sec)


Vehicle L - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Estimated Ay (g)
Speed (m/s)
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
1
2
3
4
5
6
7


Vehicle L - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test
Yaw Rate (deg/sec)
Speed (m/s)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
CCW Average: 1.2
CCW Ratios: 1.29 1.32 1.25 0.902 1.22 STD=0.169
CCW Final Slopes: -7.83 -8.6 -7.38 -5.51 -7.33 STD=1.14
CCW Initial Slopes: -6.09 -6.5 -5.89 -6.11 -6.02 STD=0.228

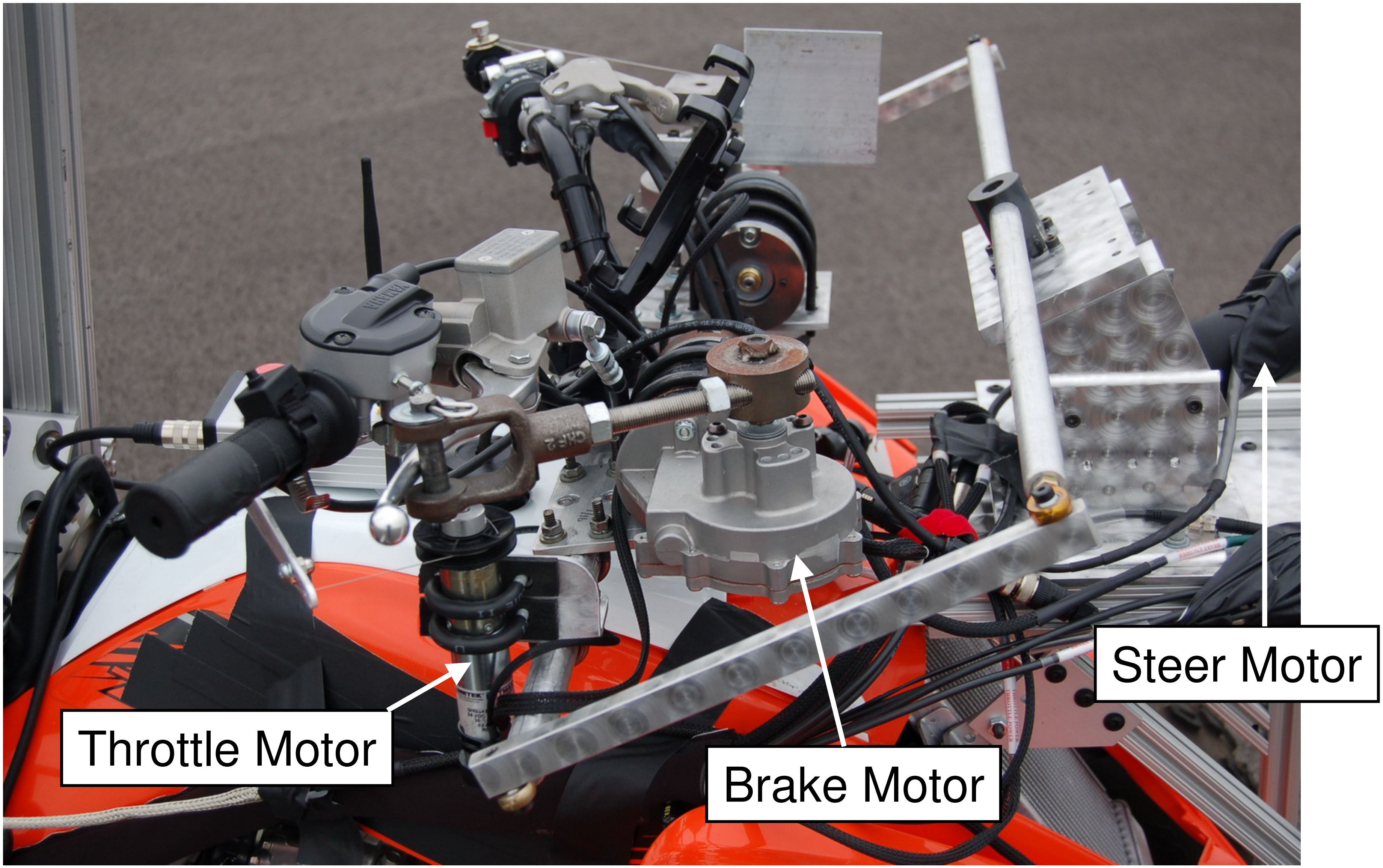

Vehicle L - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs
Final Slope: -7.83
Ratio: 1.29
Final Slope: -8.6
Ratio: 1.32
Final Slope: -7.38
Ratio: 1.25
Final Slope: -5.51
Ratio: 0.902
Final Slope: -7.33
Ratio: 1.22
Yaw Rate (deg/sec)
Speed (m/s)

Vehicle L - Rider Active - 40° Driver Lean - 25 ft Radius - Constant Steer Test - CCW Runs

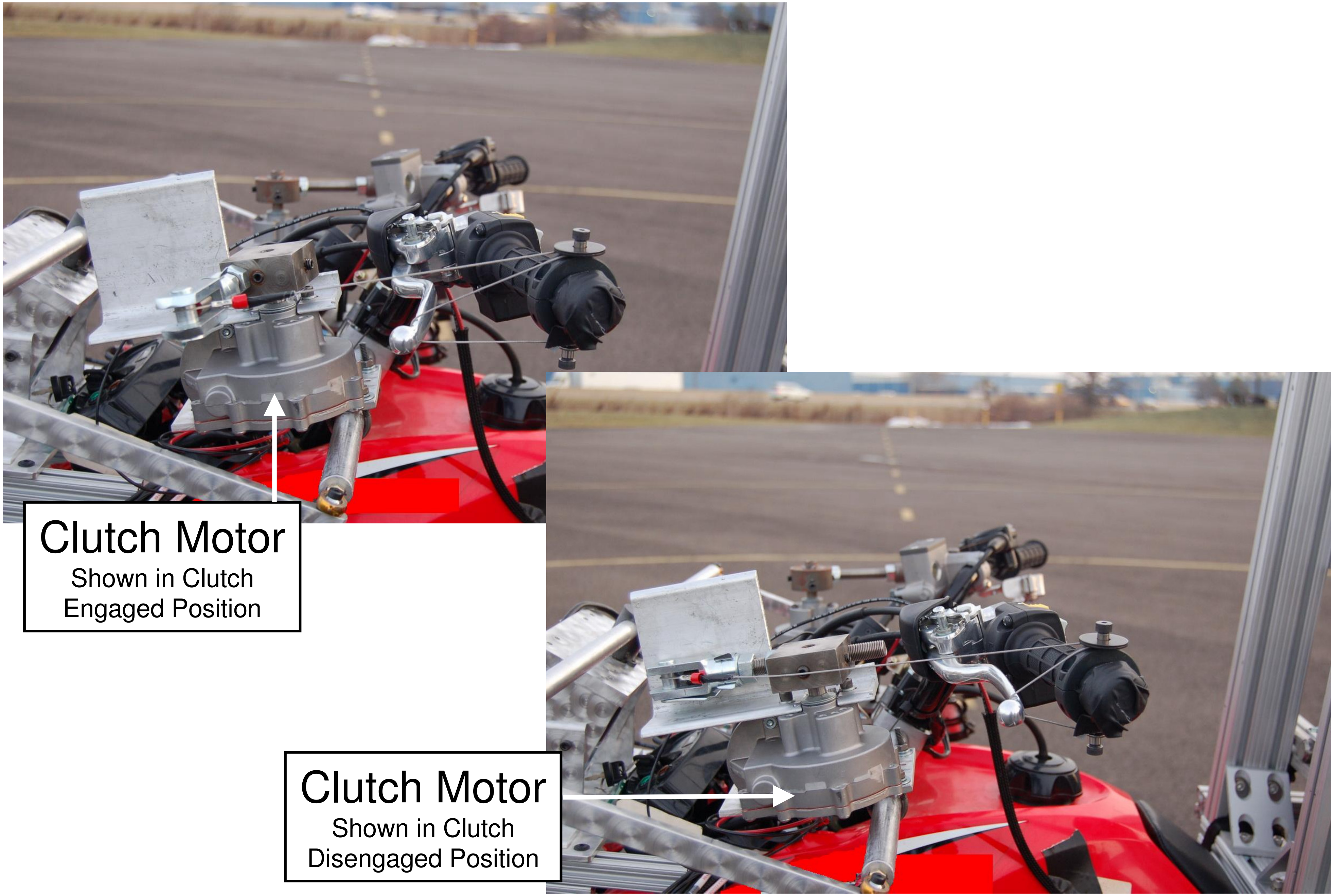


Side View of Test Vehicle in Representative 0° Driver Lean Loading Condition

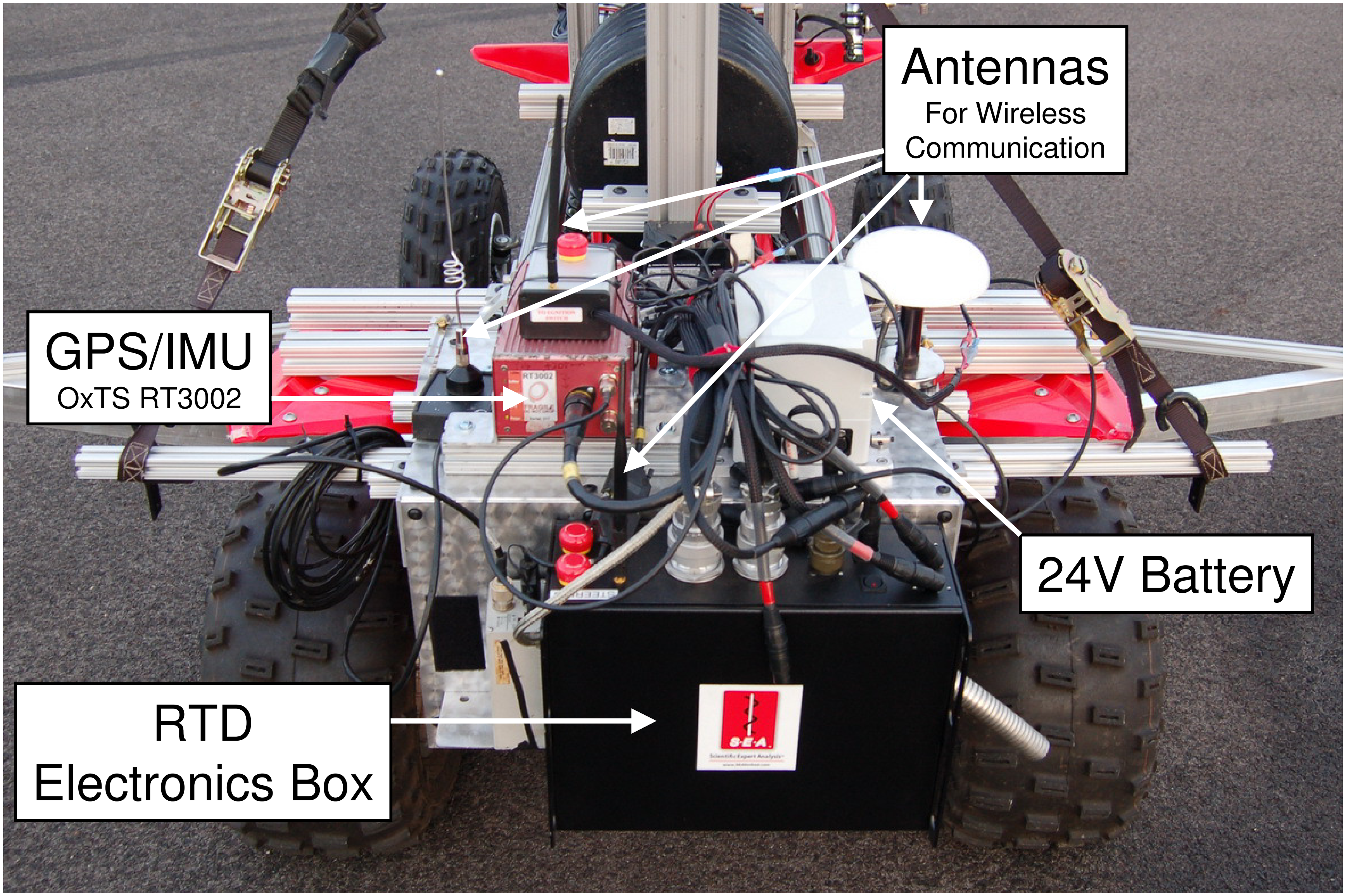
Photographs of SEA ATV Robotic Test Driver (RTD) Components (Throttle, Brake and Steer Motors)



Photographs of SEA ATV Robotic Test Driver (RTD) Component (Clutch Motor)



Photographs of SEA ATV Robotic Test Driver (RTD) Components (GPS/IMU, Control Box, and Antennas)



Photographs of SEA Standard ATV Safety Outriggers

Photographs of SEA Light-Vehicle ATV Safety Outriggers

Photographs of Steering Column Angle Encoder (Left) and Potentiometer (Right)