2025 ZERO PROTOTYPES SUMMIT

Advanced tire modeling approach for vehicle behavior validation on low-friction surfaces

Ing. Marco Sbrosi

R&D – Head of Tyre Modelling & Driving Simulator, Pirelli Tyre

Ing. Andrea Sammartino

Project Coordinator Manager, MegaRide

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RESEARCH FRAMEWORK

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

MEGARIDE
APPLIED VEHICLE RESEARCH

Advanced tire modeling approach for vehicle behavior validation on low-friction surfaces

PhD CANDIDATE Matteo Romano

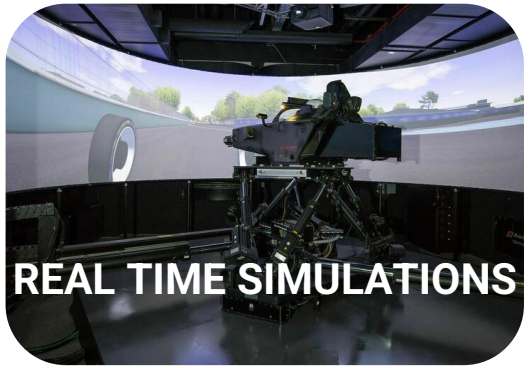
ADVISORS *Prof.* Flavio Farroni
Ing. Marco Sbrosi
Ing. Andrea Sammartino

MEGARIDE TECHNOLOGIES FOR

MEGARIDE®
APPLIED VEHICLE RESEARCH
an official UniNa spinoff company

UniNa Vehicle Dynamics research group

2016 2017 2018 2019 2020 2021 2022 2023 2024



STATE OF THE ART APPROACHES FOR ADVANCED TIRE MODELLING

FLAT TRAC TESTING

TRAILER WET TESTING

VEHICLE WET TESTING

Tire level approaches

REALISM

PRECISION

Vehicle level approaches

	Flat Trac	Trailer	Vehicle (T.R.I.C.K.)
PROS	Precise control of input and ambient conditions	WET asphalt surface	Real tire working conditions
CONS	DRY sandpaper surface	Limited space available on wet surfaces	Indirect tire forces measurement Less controlled ambient conditions

THE PATH TO AN ADVANCED LOW FRICTION TIRE MODEL

FLAT TRAC TESTING

TRAILER WET TESTING

Tire multiphysical model from indoor dry + trailer wet data

RIDEsuite

VEHICLE WET TESTING

Tire multiphysical model from outdoor wet data

RIDEsuite

THE PATH TO AN ADVANCED LOW FRICTION TIRE MODEL

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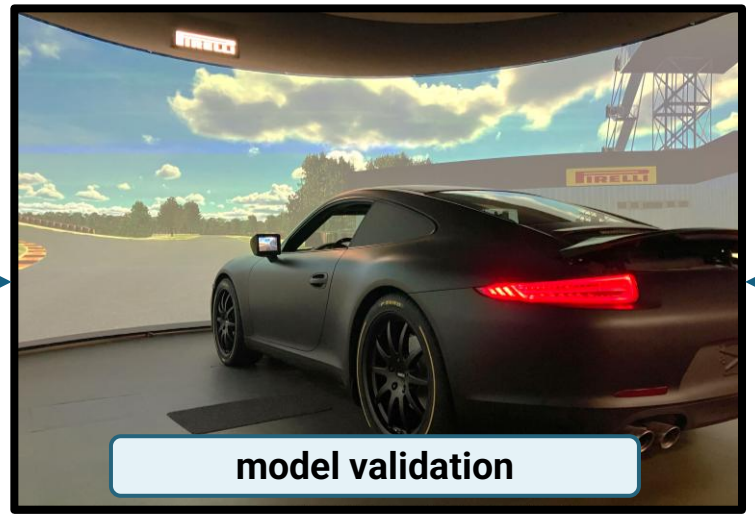
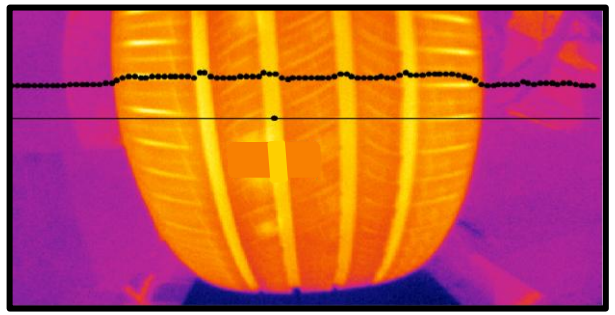
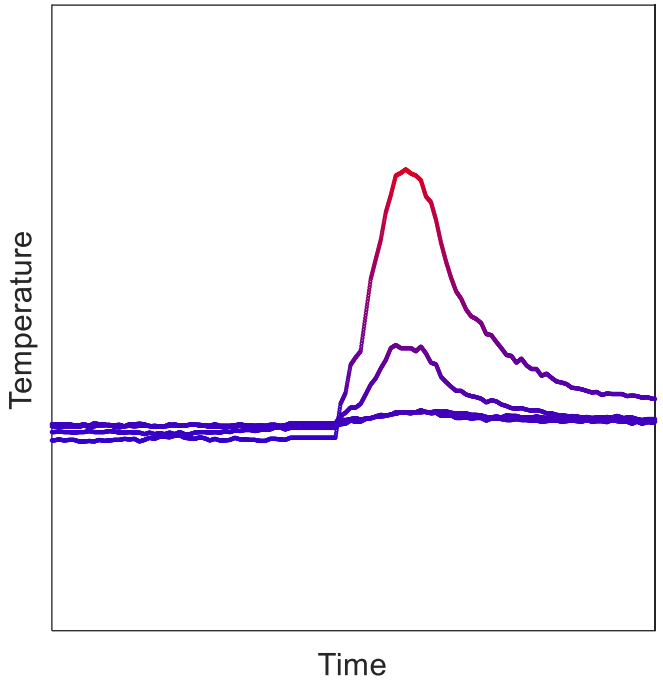


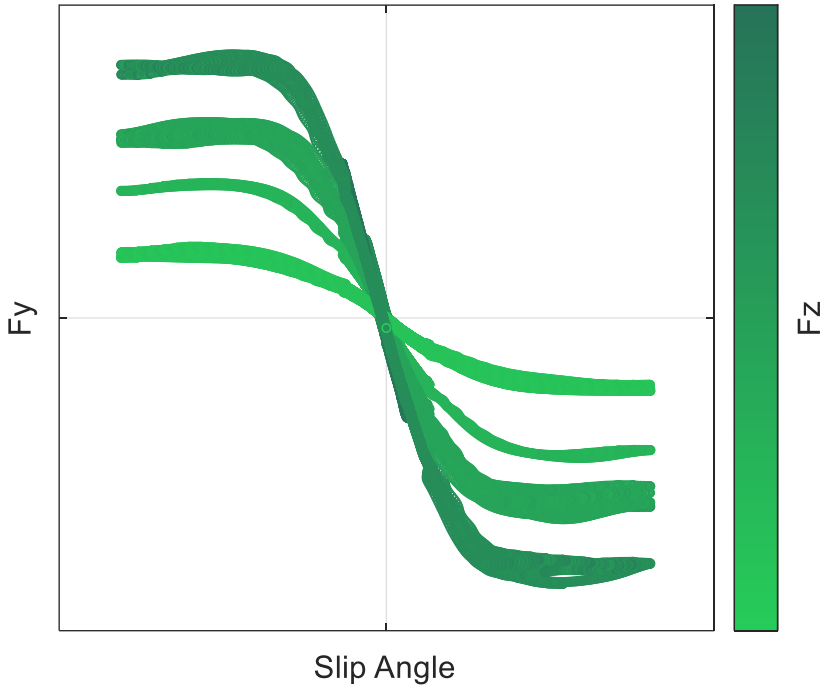
DRIVING SIMULATOR

TIRE LEVEL APPROACH

FLAT TRAC TESTING





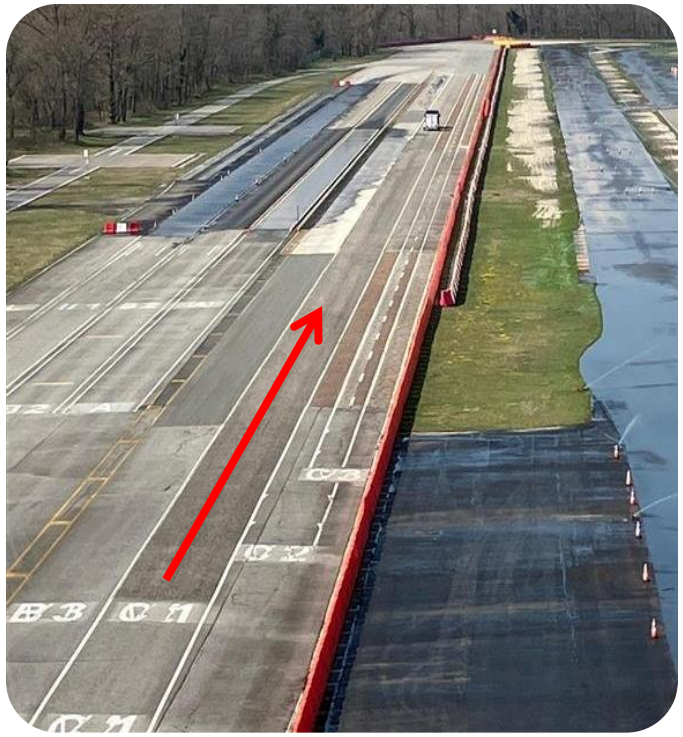


- **full tire characterization**
- **complete thermal setup**
- **dry sandpaper surface**

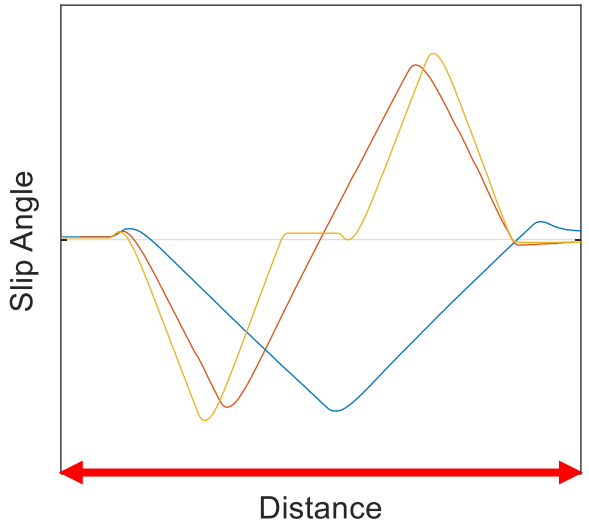
TIRE LEVEL APPROACH

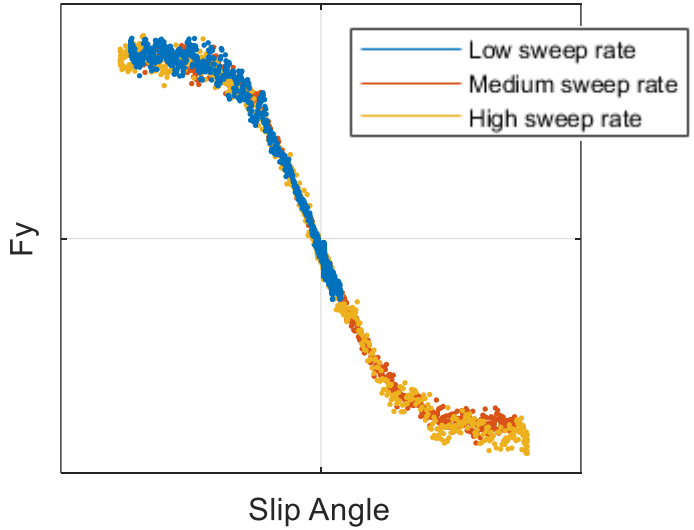
TRAILER TESTING

- possibility to analyze tires interaction with different asphalts
- sufficiently controlled outdoor testing
- possibility to test tires in both dry and wet conditions



- constant speed driving and limited space
- higher sweep rates allow a complete sweep of the slip angle within the available space
- no significant differences in test results when changing the sweep rate

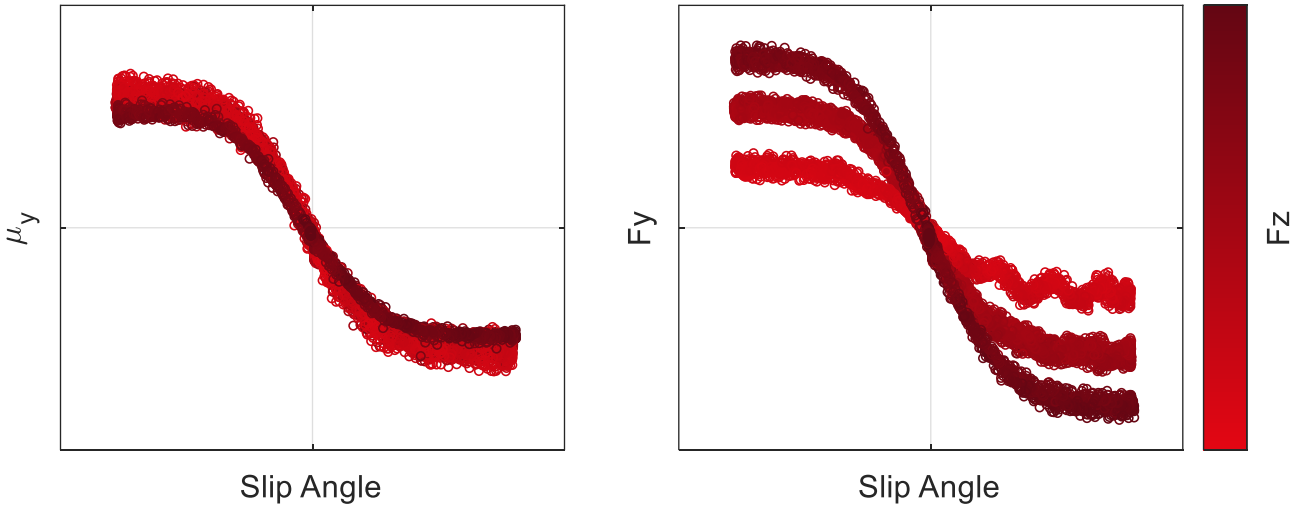




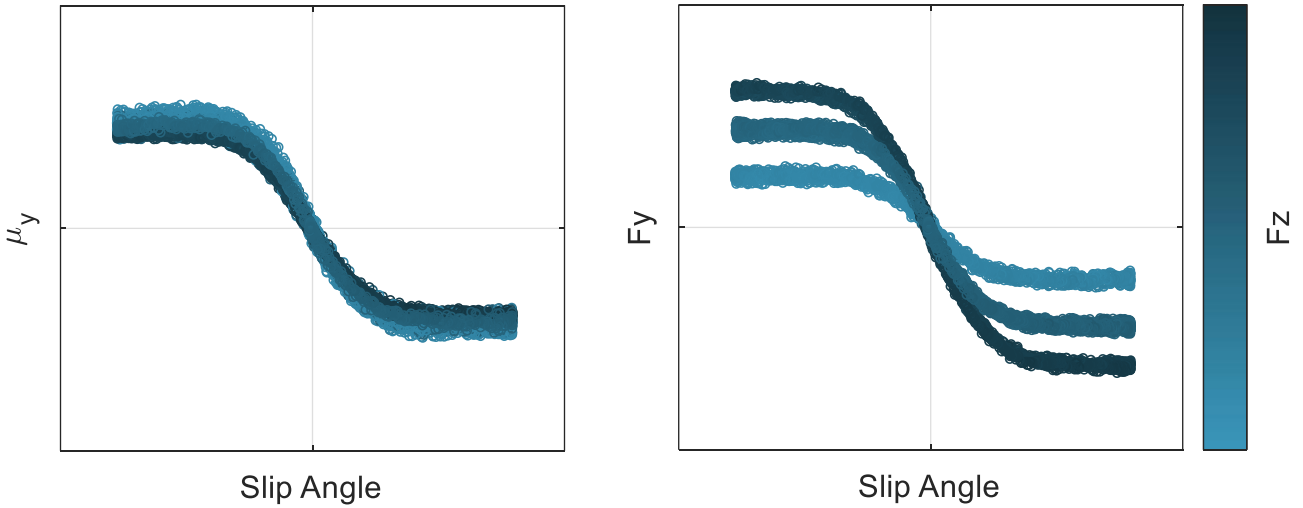
TIRE LEVEL APPROACH

TRAILER TESTING

- **dry asphalt**



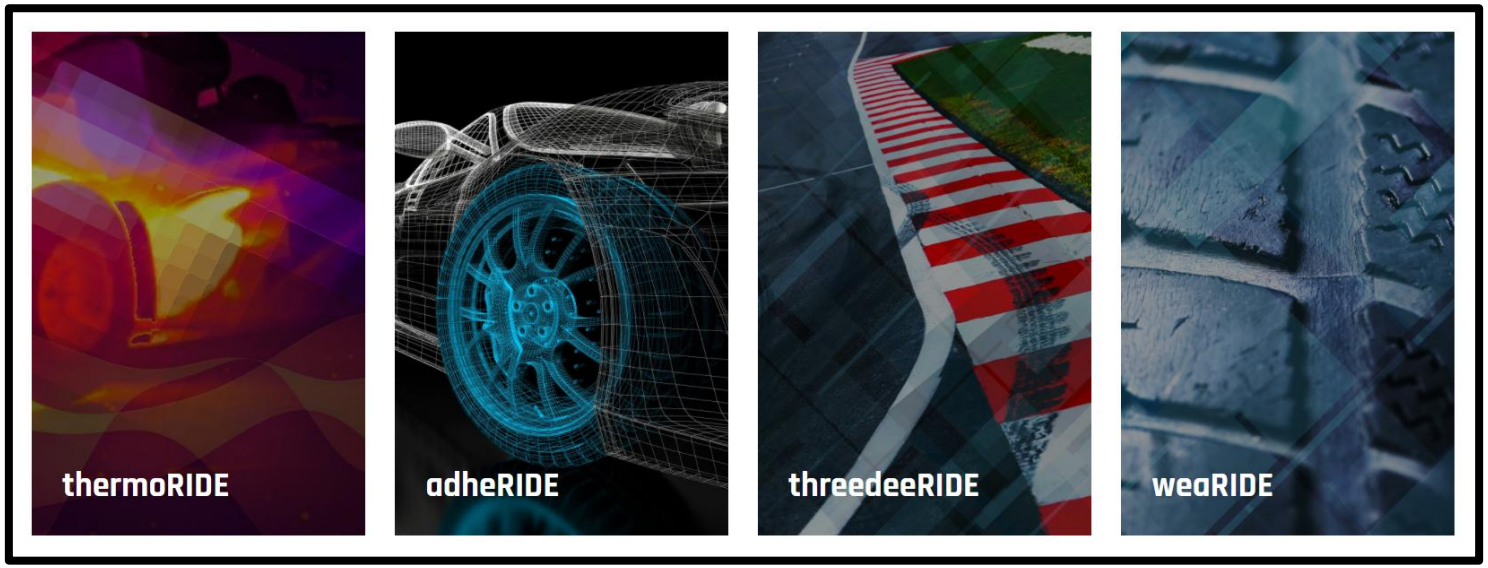
- **wet asphalt**



TIRE LEVEL APPROACH

MEGARIDE RIDEsuite

RIDEsuite



thermoRIDE adheRIDE threedeeRIDE weaRIDE

It comprises four main elements, able to simulate in detail the physical effects characterizing a vehicle interacting with the external environment.

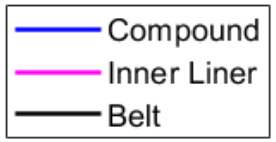
TIRE LEVEL APPROACH

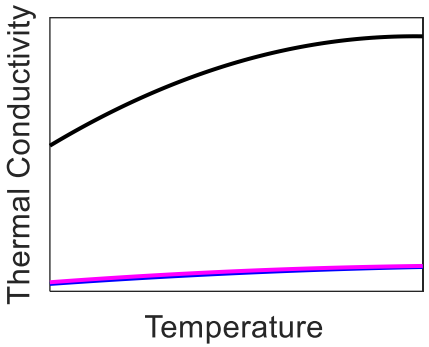
TIRE DIGITALIZATION

- **non-destructive procedures to get tire thermal and structural properties, input of the model**

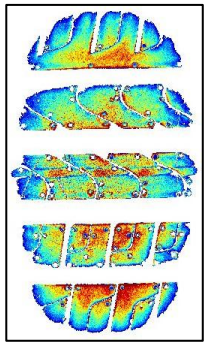
thermoRIDE

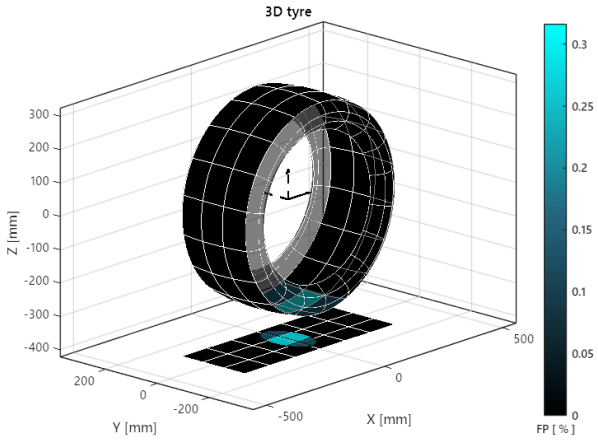
Thermal characterization





Structural characterization



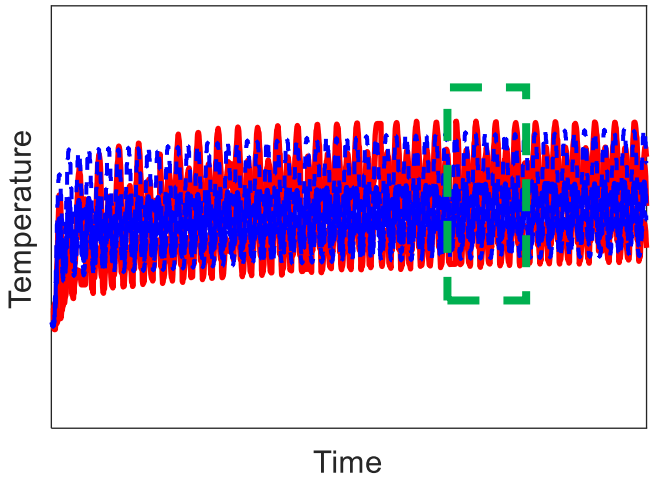


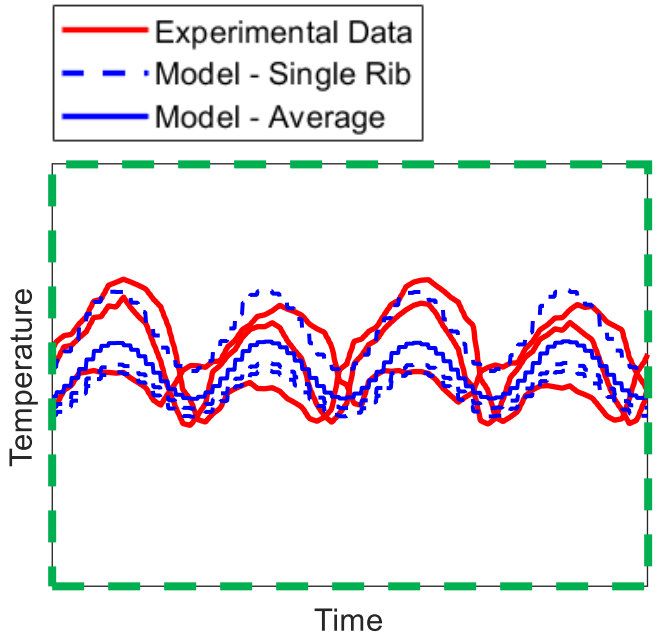
TIRE LEVEL APPROACH

TIRE DIGITALIZATION

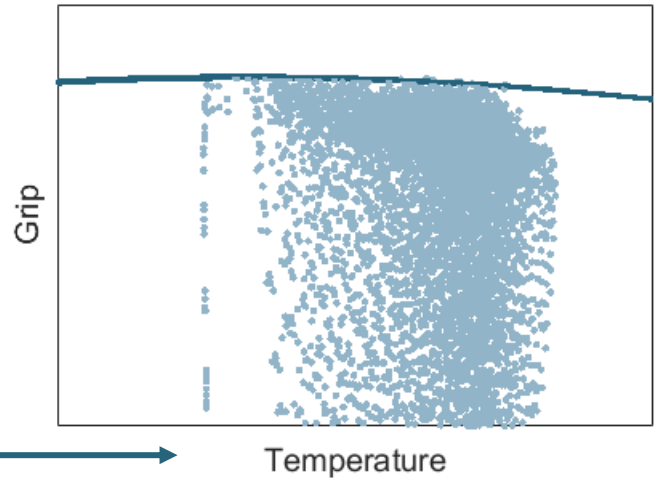
- initial calibration towards flat trac data
- the thermal model even provides inner layers temperature, deeply connected to tire dynamic behavior

thermoRIDE adheRIDE





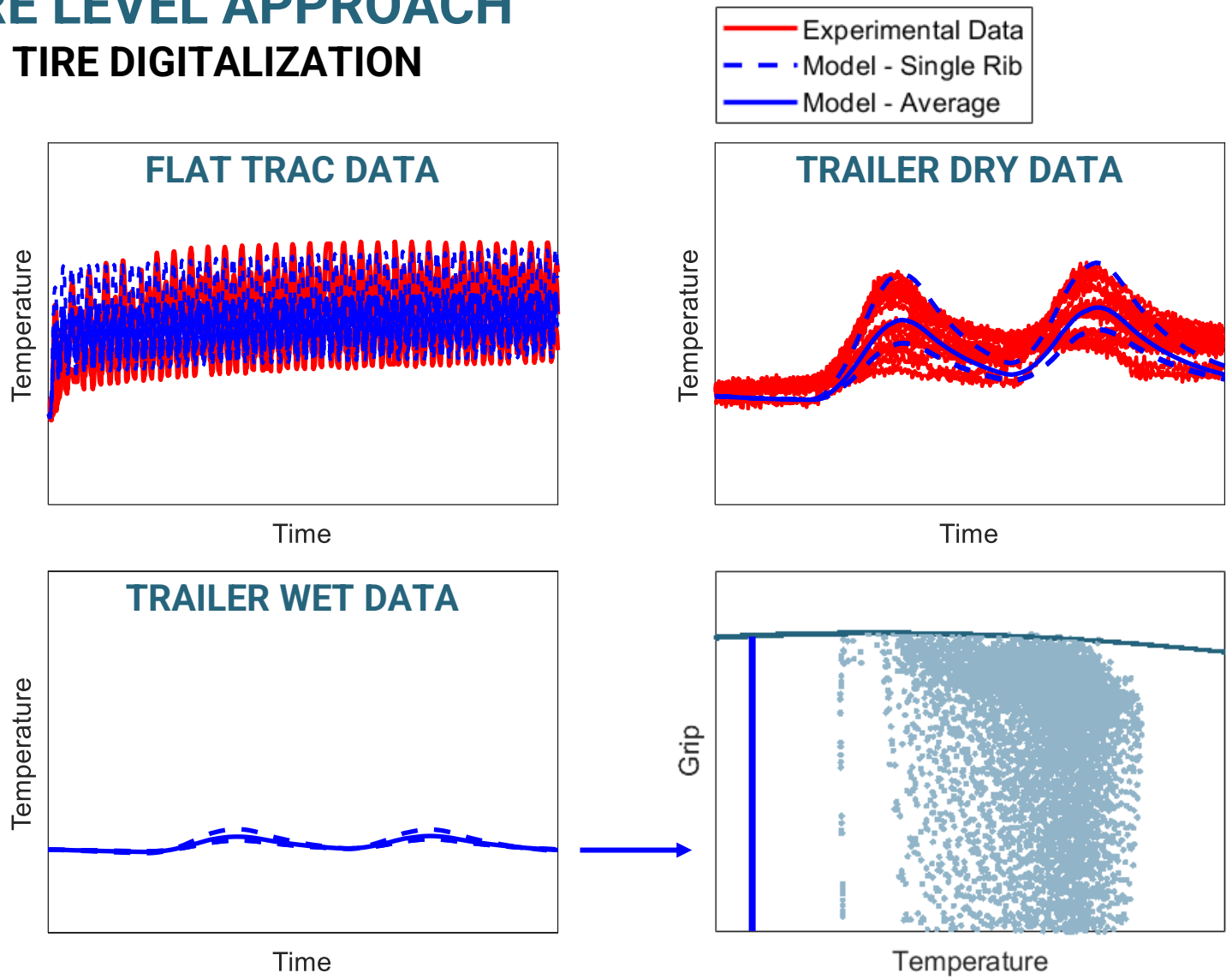
weighted average of inner layers temperature



TIRE LEVEL APPROACH

TIRE DIGITALIZATION

- calibration refinement of thermal model towards trailer data
- exploited model predictivity in wet conditions by changing boundary conditions



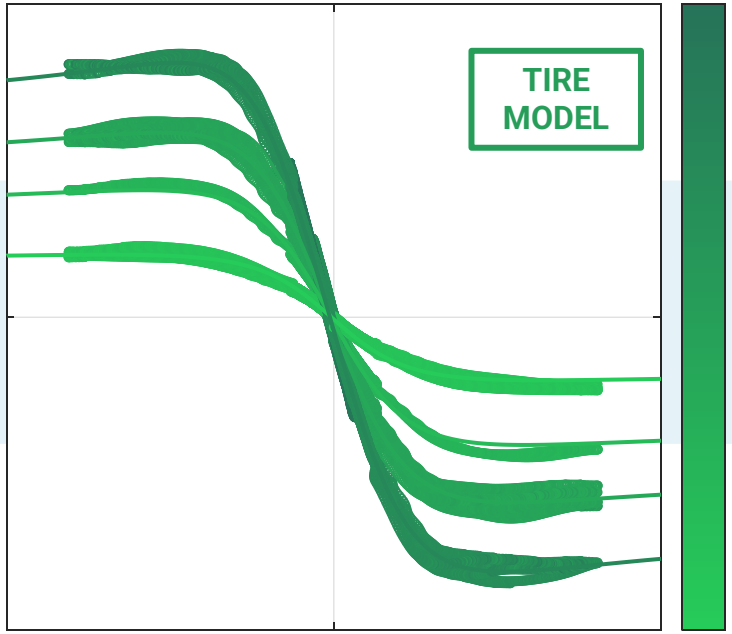
temperature and its effect on tire dynamics in wet conditions were estimated

thermodynamic effect was separated from performance drop due to interaction with water

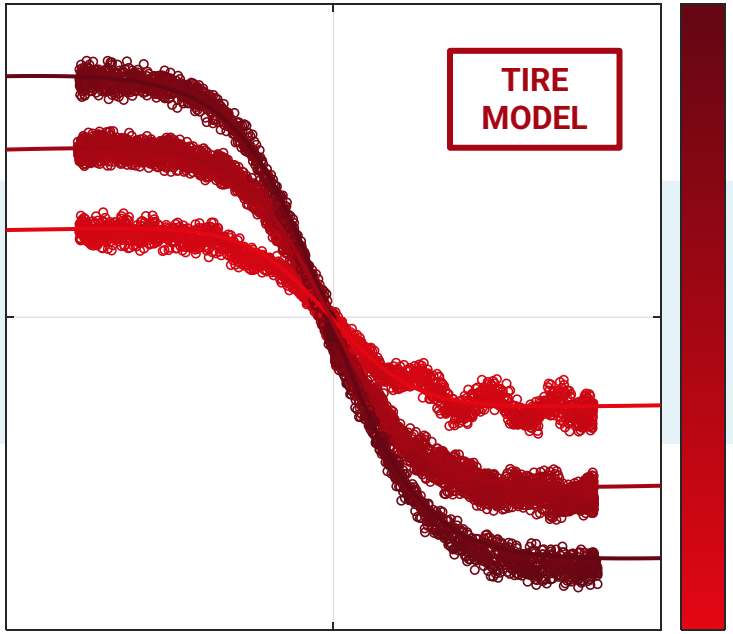
TIRE LEVEL APPROACH

TIRE DIGITALIZATION

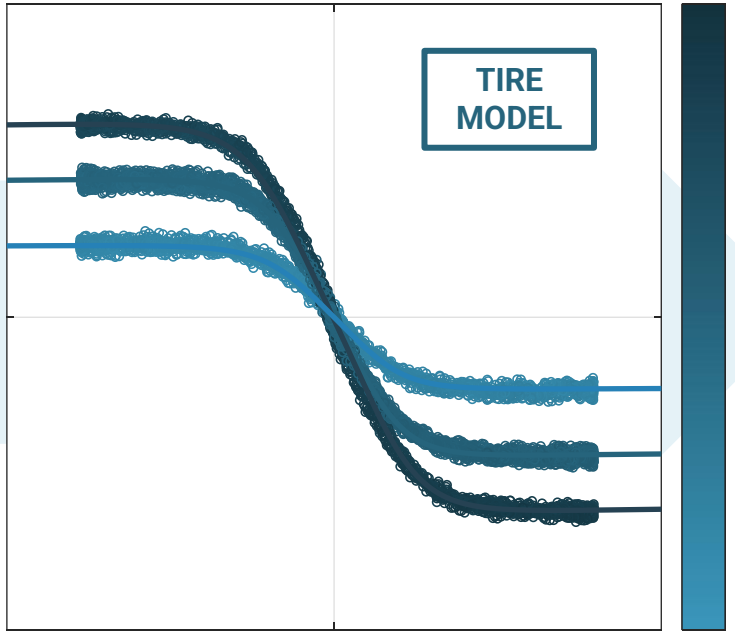
FLAT TRAC DATA



TRAILER DRY DATA



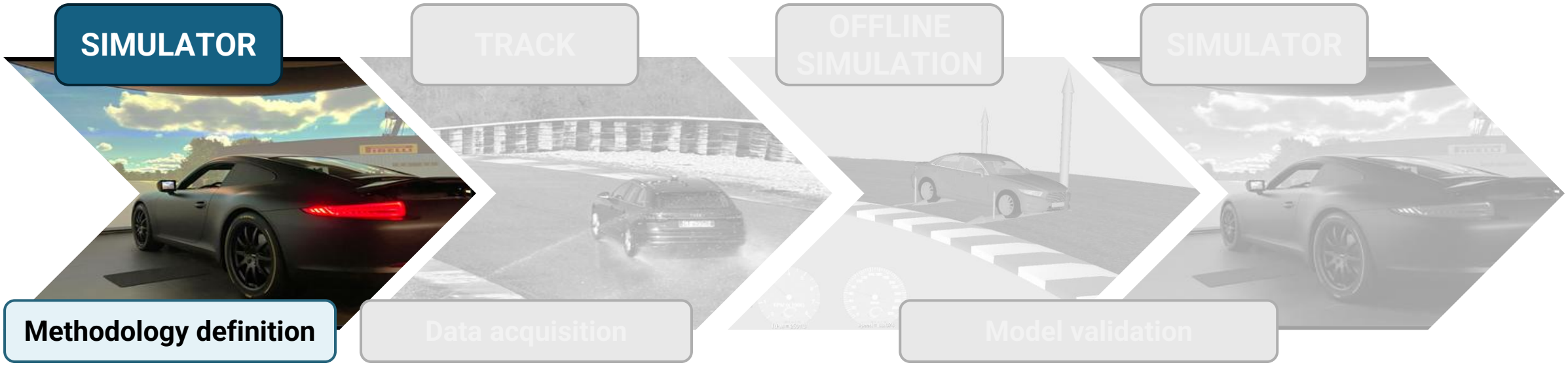
TRAILER WET DATA



Since a multiphysical tire model was calibrated, temperatures and their effect on dynamics were estimated. Therefore, the dry dynamic model can be scaled accounting only for the effect of the interaction between the tire and the water, separating it from the thermodynamic effect.

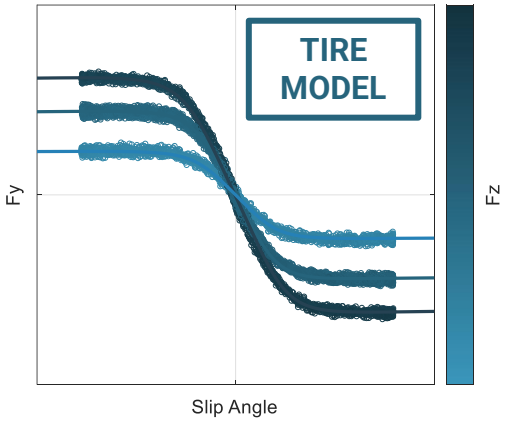
VEHICLE LEVEL APPROACH

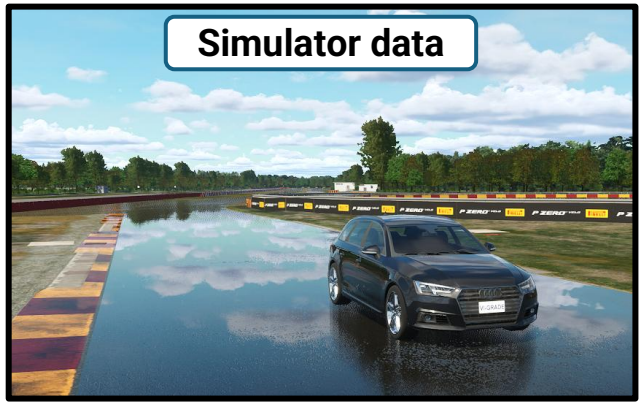
VEHICLE LEVEL APPROACH



VEHICLE LEVEL APPROACH

Pi.S.T.A.: TEST SESSION MANAGEMENT





Pirelli Standard Test Acquisition

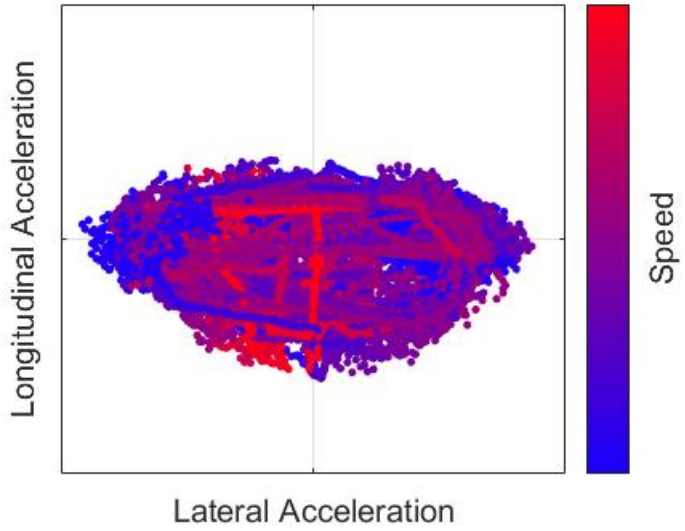
Metadata link

Data Conversion to Standard

PTD

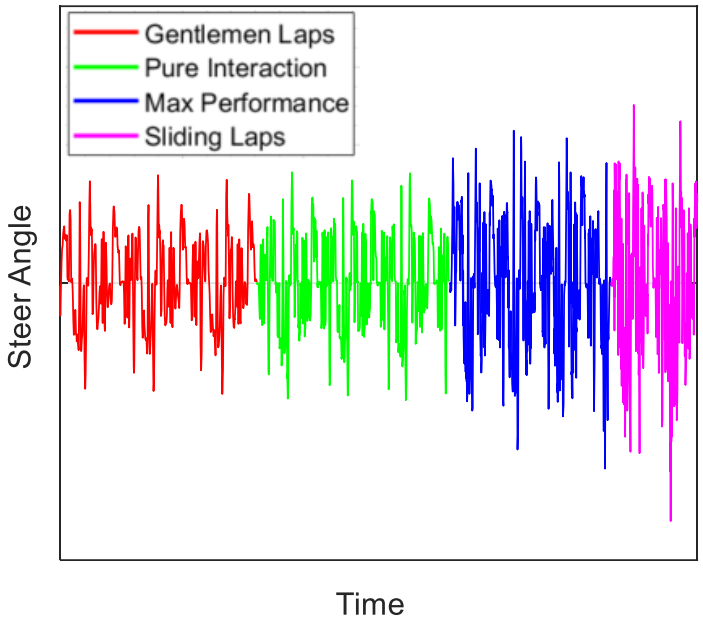
Pirelli standard data

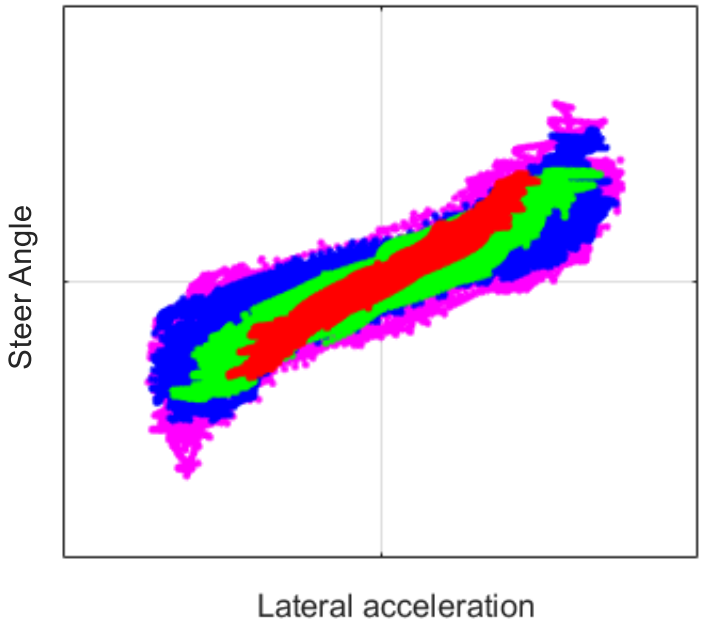
- **driver training to practice planned maneuvers**
- **check of available track space and test duration estimation**
- **post-processing preview to check data quality and methodology effectiveness**

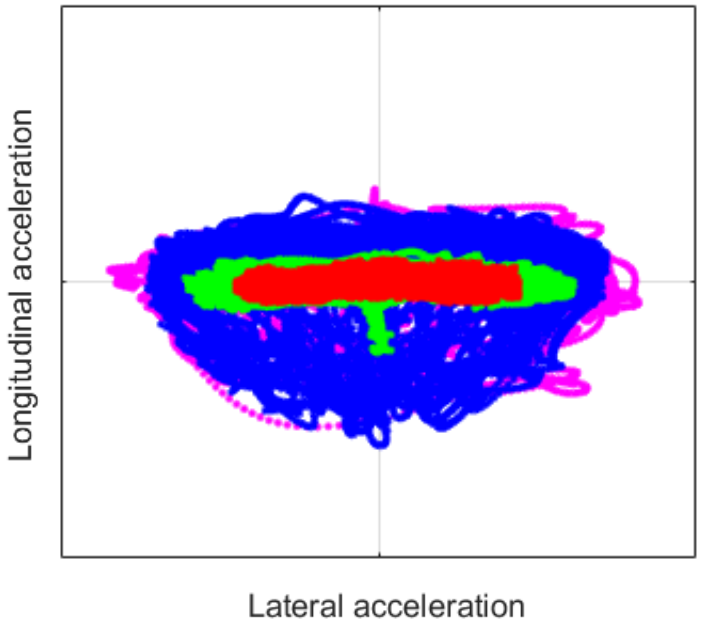


VEHICLE LEVEL APPROACH

TEST MANEUVERS







TRACK LAPS

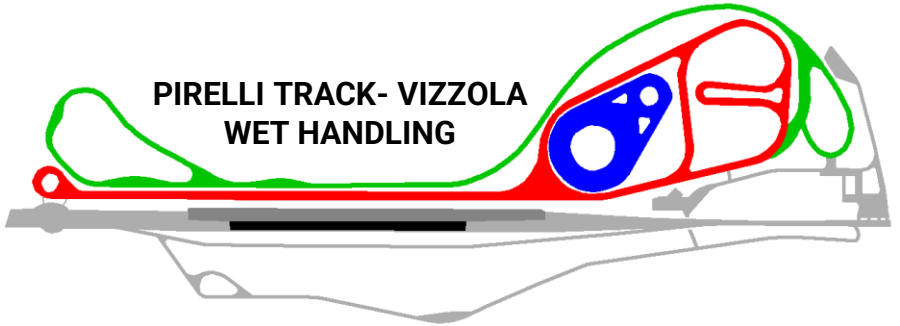
- **Gentlemen driving – linear range**
- **Pure interaction – pure conditions' maximum grip**
- **Max performance – combined range**
- **Sliding – unstable non-linear range**

VEHICLE LEVEL APPROACH

VEHICLE LEVEL APPROACH

OUTDOOR VEHICLE TESTING

- obj maneuver practiced at the driving simulator were replicated on track by the same driver
- proper outdoor instrumentation and CAN-bus signals data set
- various vehicle load conditions were tested



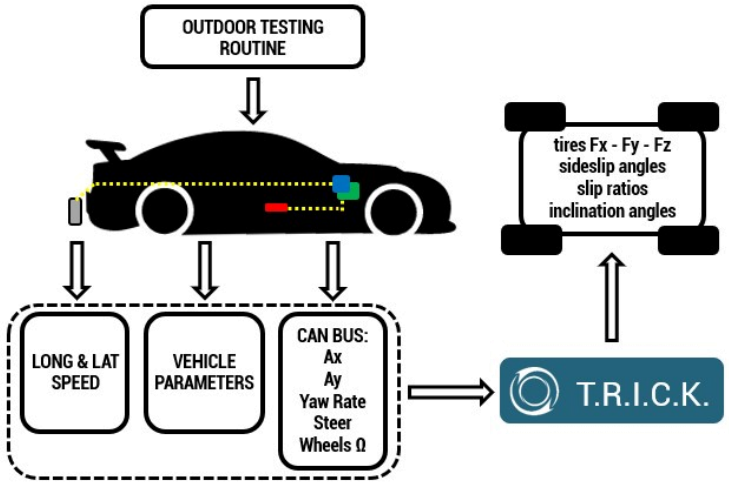
PSTA — Pirelli Standard Test Acquisition

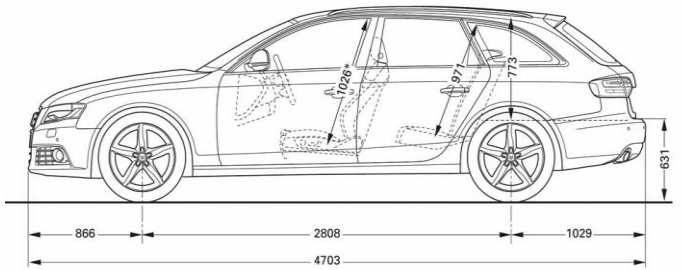
PTD
Pirelli standard data

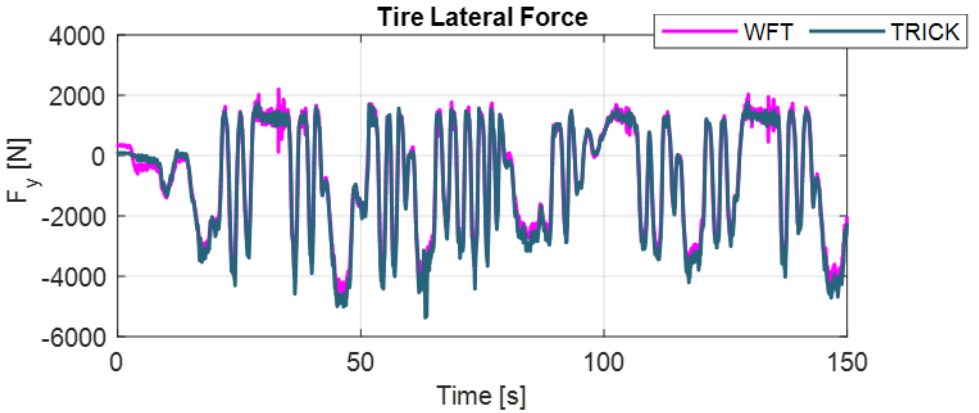
VEHICLE LEVEL APPROACH

T.R.I.C.K.

- basic concept is to use the vehicle as a “moving lab”
- experimental signals processed by an accurately parameterized vehicle model
- needs only standard on-board sensors and eventual additional instrumentation for the speed components measurement
- validated through the years with WFT data





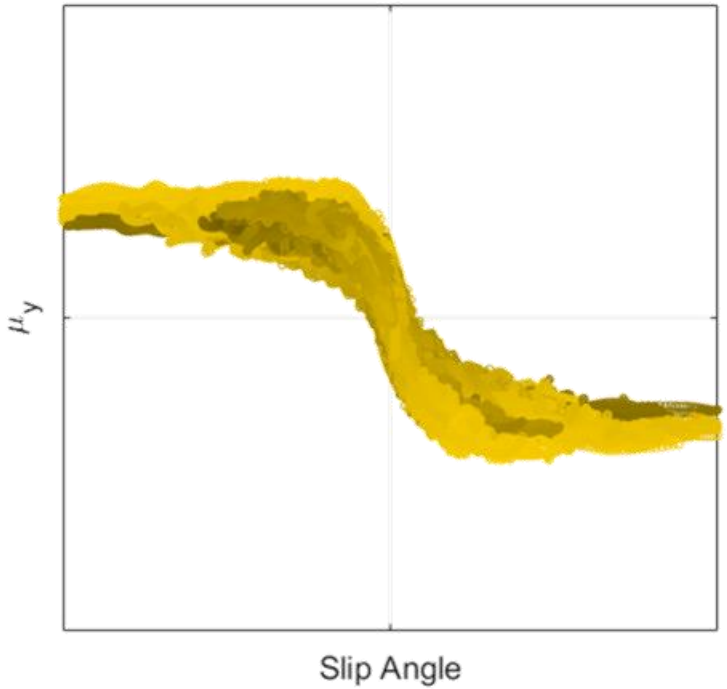


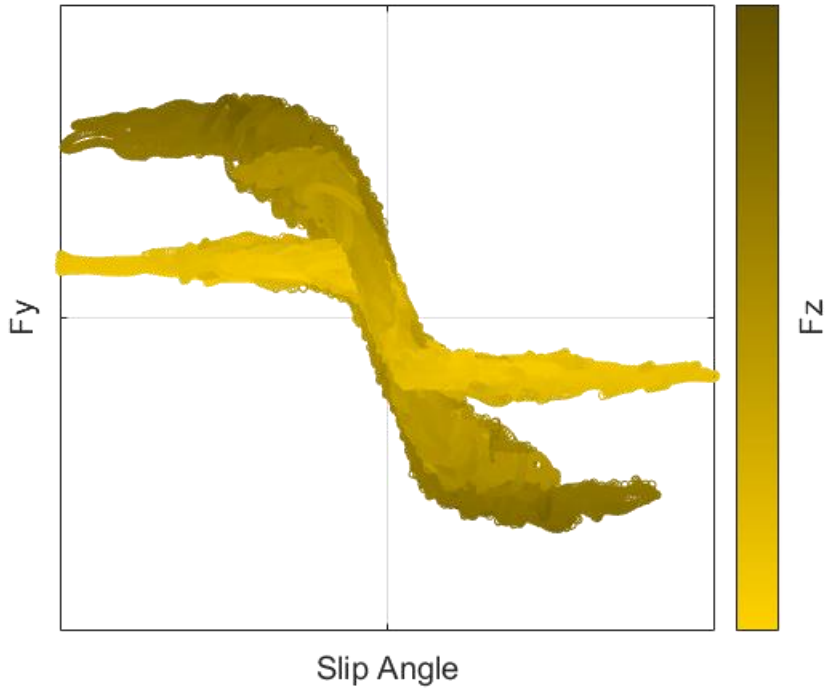
VEHICLE LEVEL APPROACH

T.R.I.C.K.

- additional output channels:
  - tires forces
  - tires slip indices
  - tires inclination angles
  - …

- tire-road interaction characterization in real working conditions

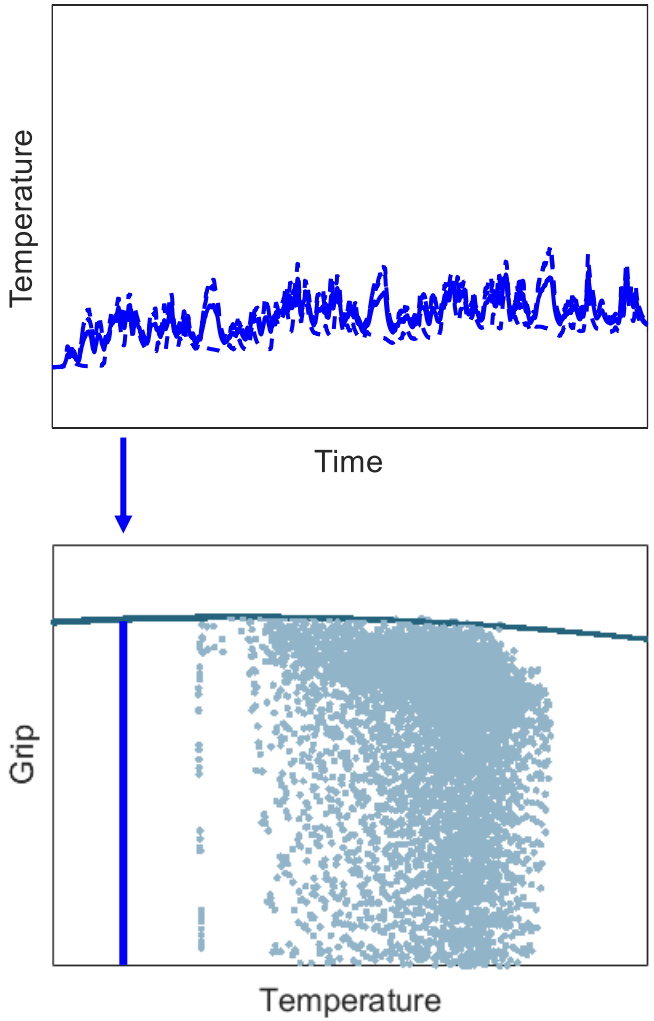


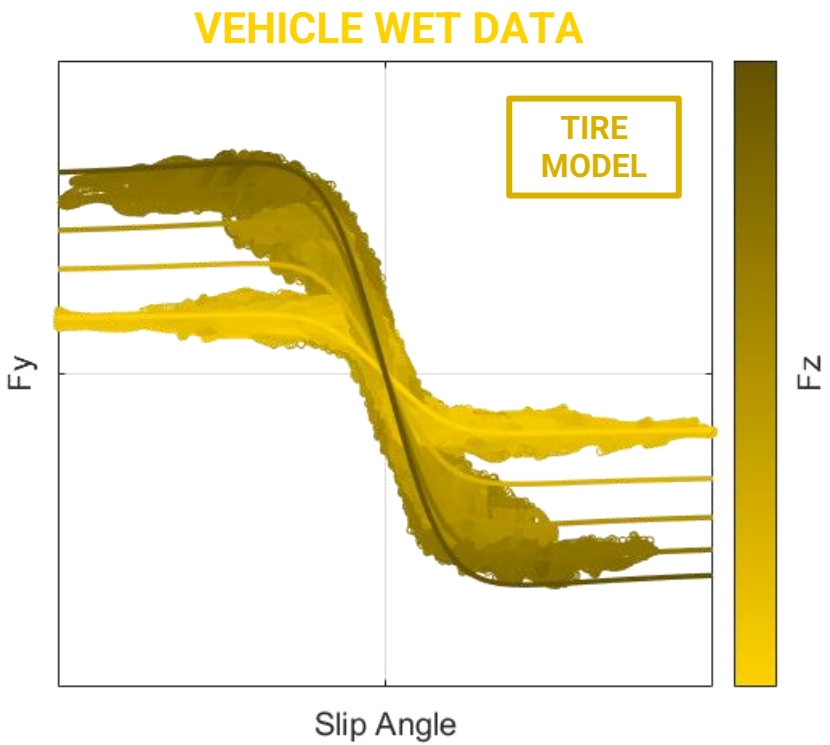


VEHICLE LEVEL APPROACH

TIRE DIGITALIZATION

- **thermal model used to estimate temperature in wet conditions and related effect on tires dynamic behavior**
- **a new low friction parameters' set can be identified based on vehicle handling data**

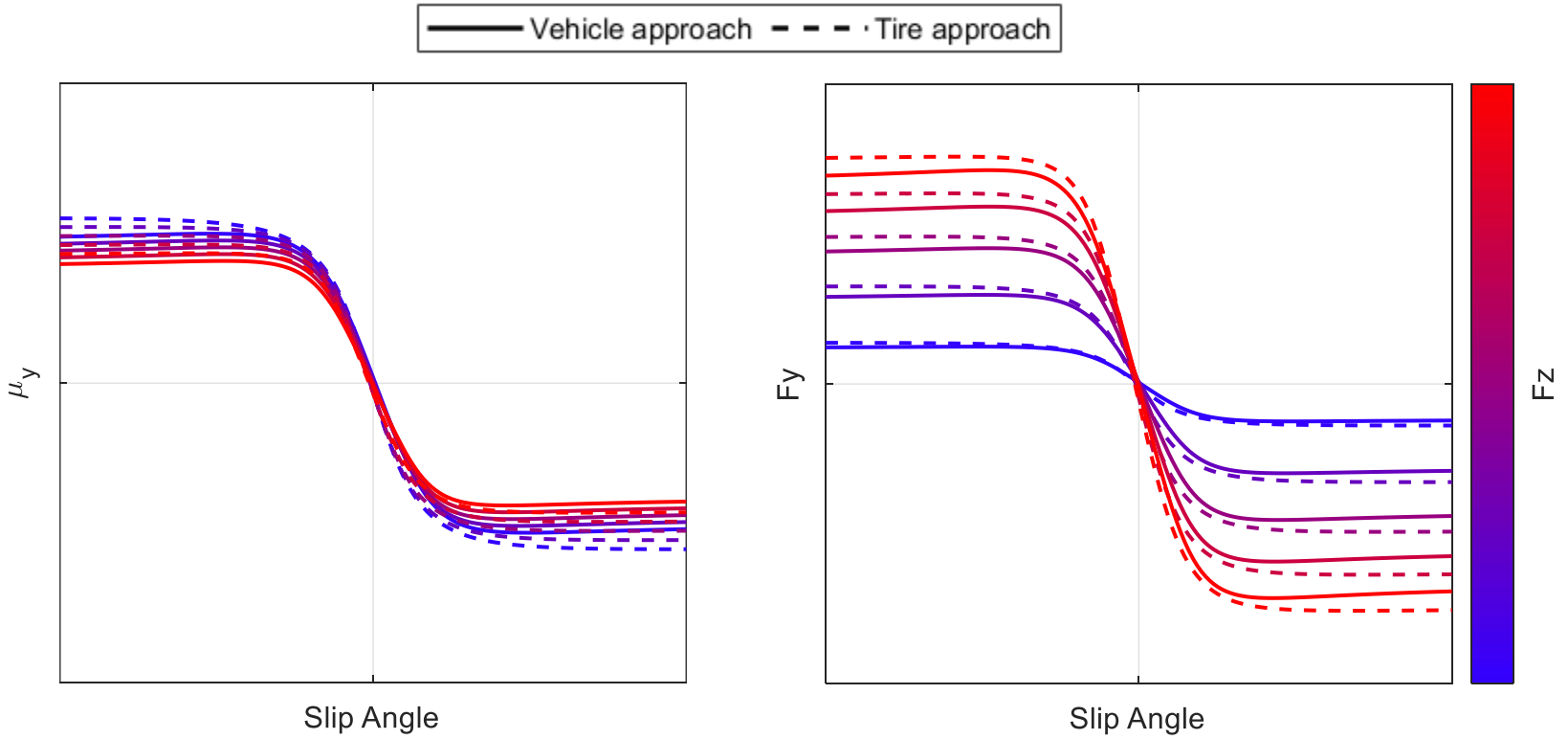




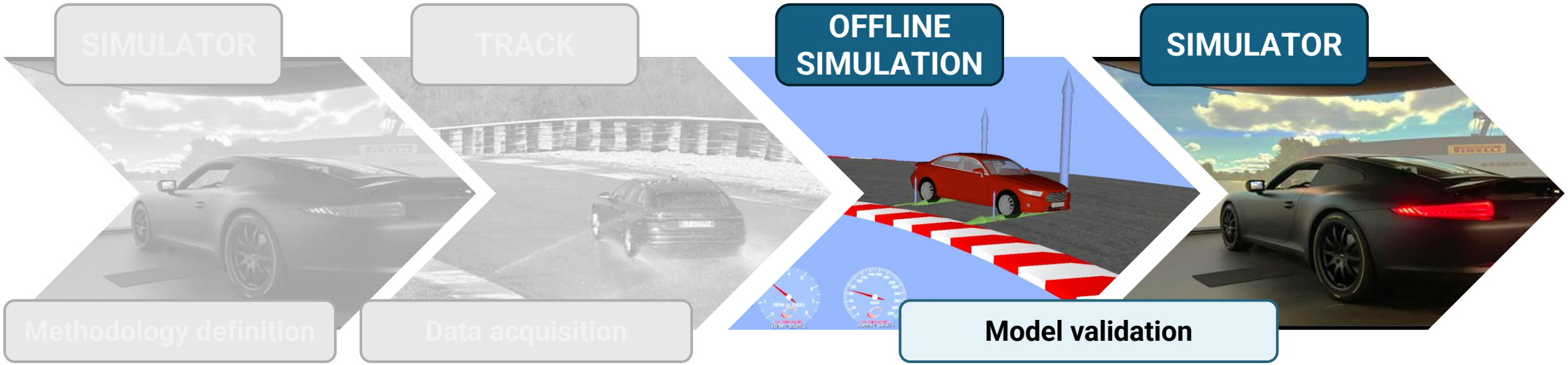
RESULTS ANALYSIS

MODELS COMPARISON

- comparable load effect
- slightly higher level of grip for tire approach model
- less aggressive decay rate for tire approach model



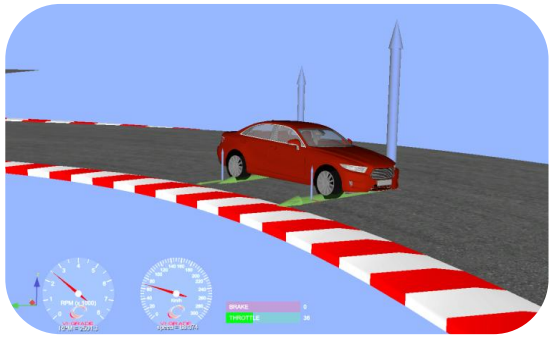
RESULTS ANALYSIS



RESULTS ANALYSIS

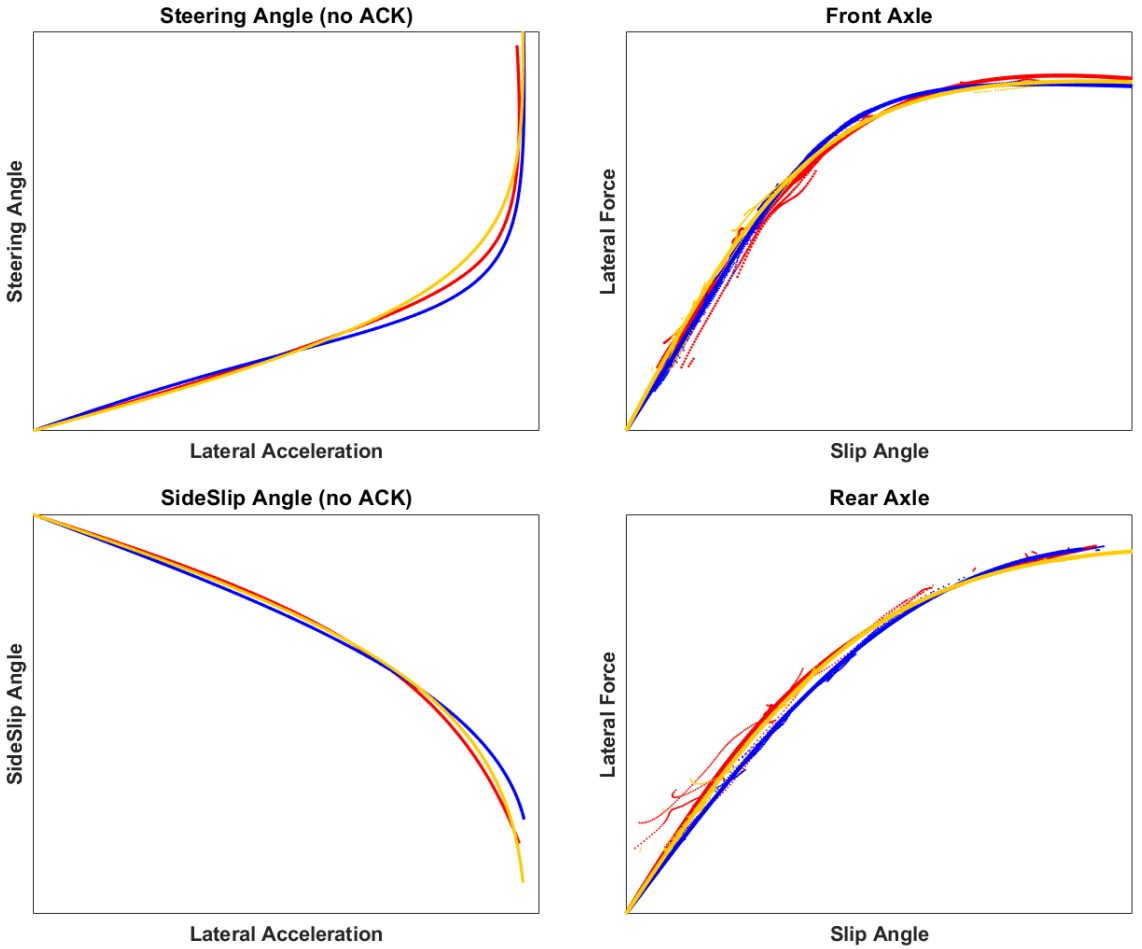
MODELS COMPARISON: OFFLINE SIMULATION

- offline simulations on Vizzola Track have been run to validate both models before the driving simulator
- minor refinement needed on the model built through tire approach to match experimental data



- multiphysical tire model accounting for thermal influence used in all simulations

RIDEsuite



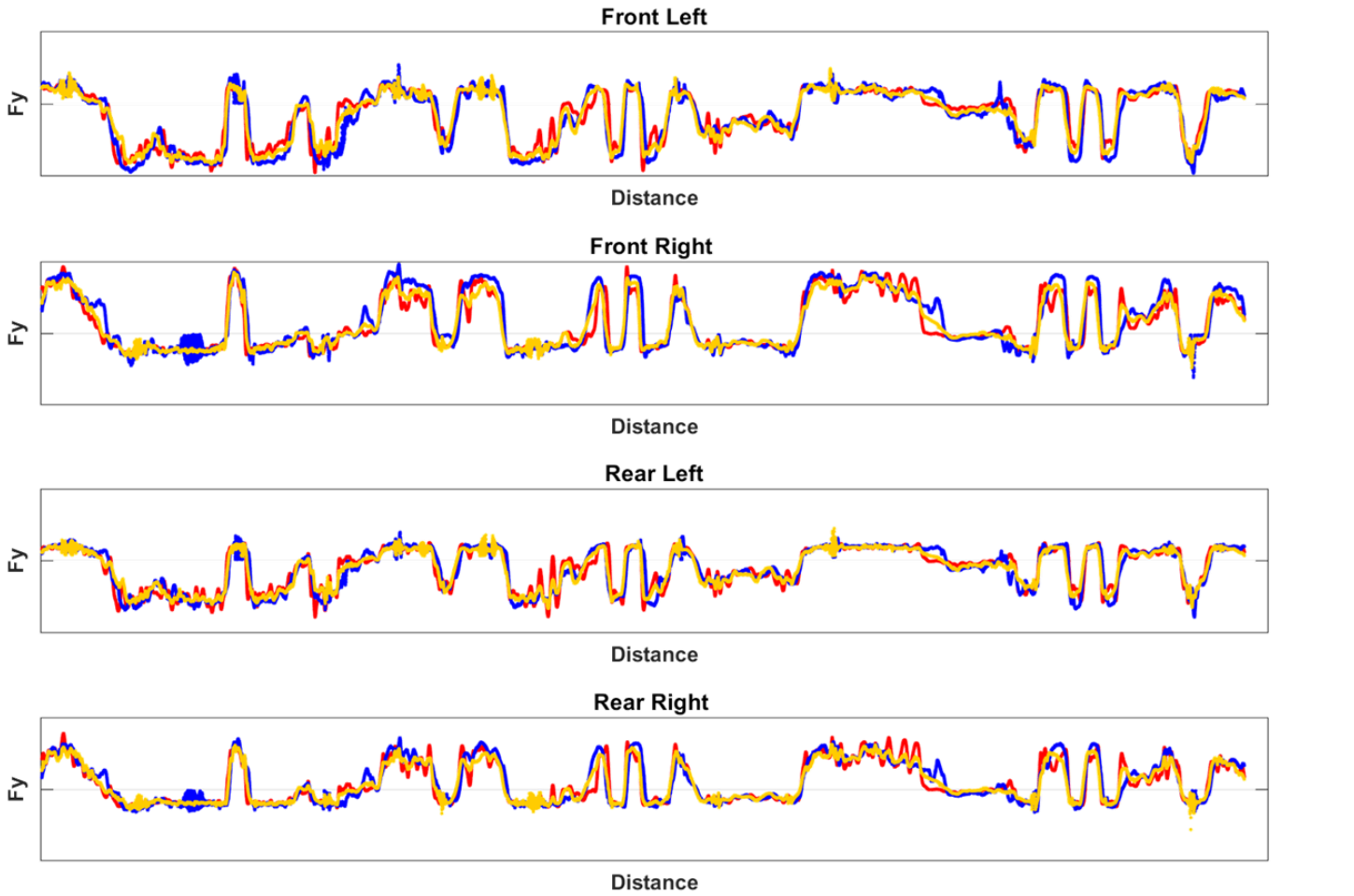
RESULTS ANALYSIS

MODELS COMPARISON: DRIVING SIMULATOR

- good reproduction in terms of tires forces for both approaches

- multiphysical tire model accounting for thermal influence used in all simulations

RIDEsuite



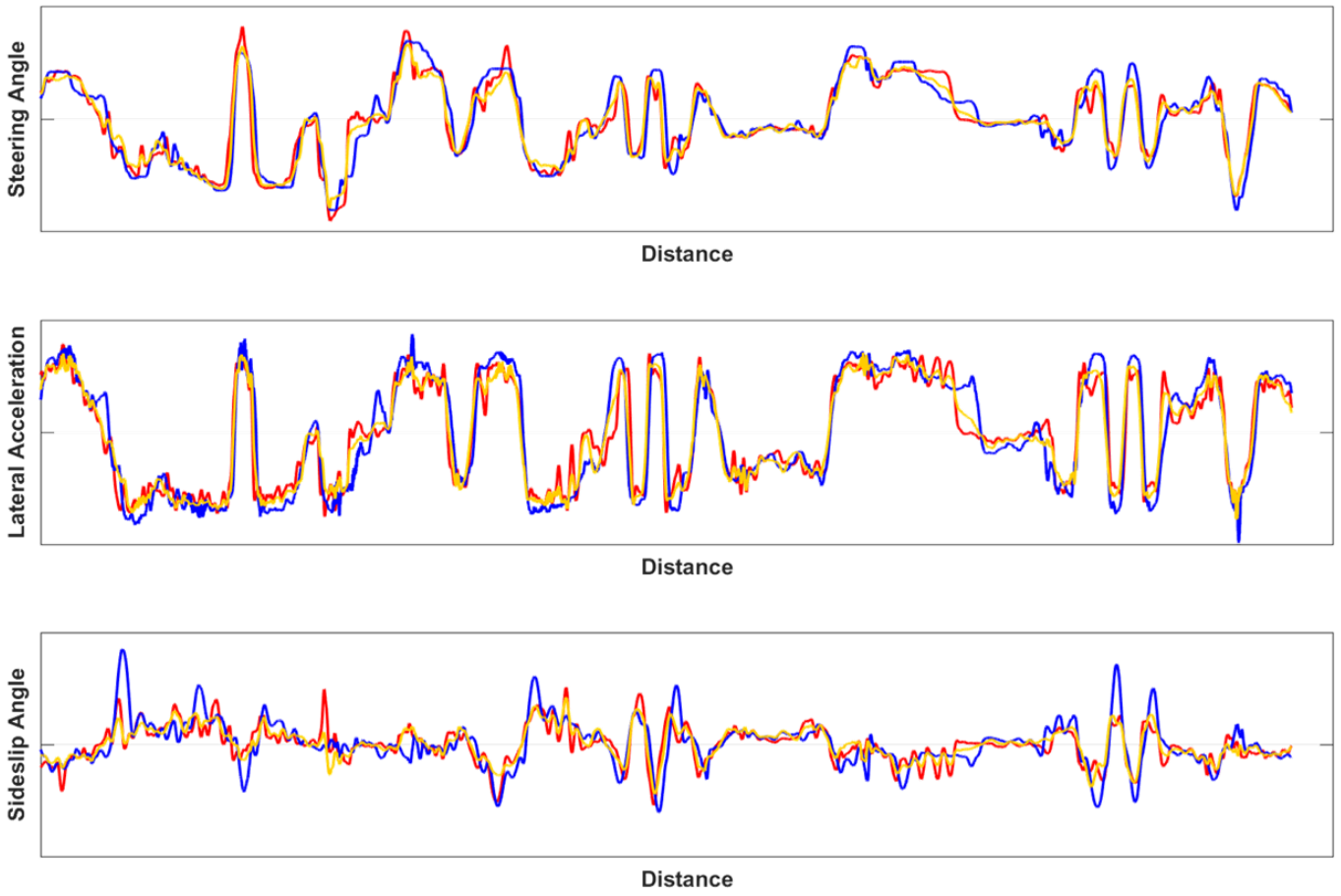
RESULTS ANALYSIS

MODELS COMPARISON: DRIVING SIMULATOR

- slightly higher level of acceleration with tire approach model
- minor differences in sideslip angle

- multiphysical tire model accounting for thermal influence used in all simulations

RIDEsuite



CONCLUSIONS AND FUTURE DEVELOPMENTS

In the present work:

- a comparison between two different experimental approaches have been used to parametrize a **multiphysical** tire model in wet tire conditions
- the **driving simulator** has been used to **train the driver** on a custom test methodology that meets the workspace constraint of the proving ground, **shortening** the effective time spent on real track
- in the validation phase at **driving simulator,** the subjective assessment of the driver highlighted a **highly-realistic tires behavior**

Future developments will be carried on during the **PhD research activity:**

- development of a predictive tire model able to catch the tire behavior on different road surfaces and conditions

THANK YOU

Marco Sbrosi, PhD
R&D – Head of Tyre Modelling & Driving Simulator

Pirelli Tyre S.p.A.
Viale Piero e Alberto Pirelli, 25 -20126 Milano
marco.sbrosi@pirelli.com
www.pirelli.com

Andrea Sammartino
Project Coordination Manager

MegaRide SRL
Via Claudio, 21 - 80125 Napoli (NA)
andrea.Sammartino@megaride.eu
info@megaride.eu
https://www.megaride.eu/