# Soft Handling evaluation through Dynamic Simulator


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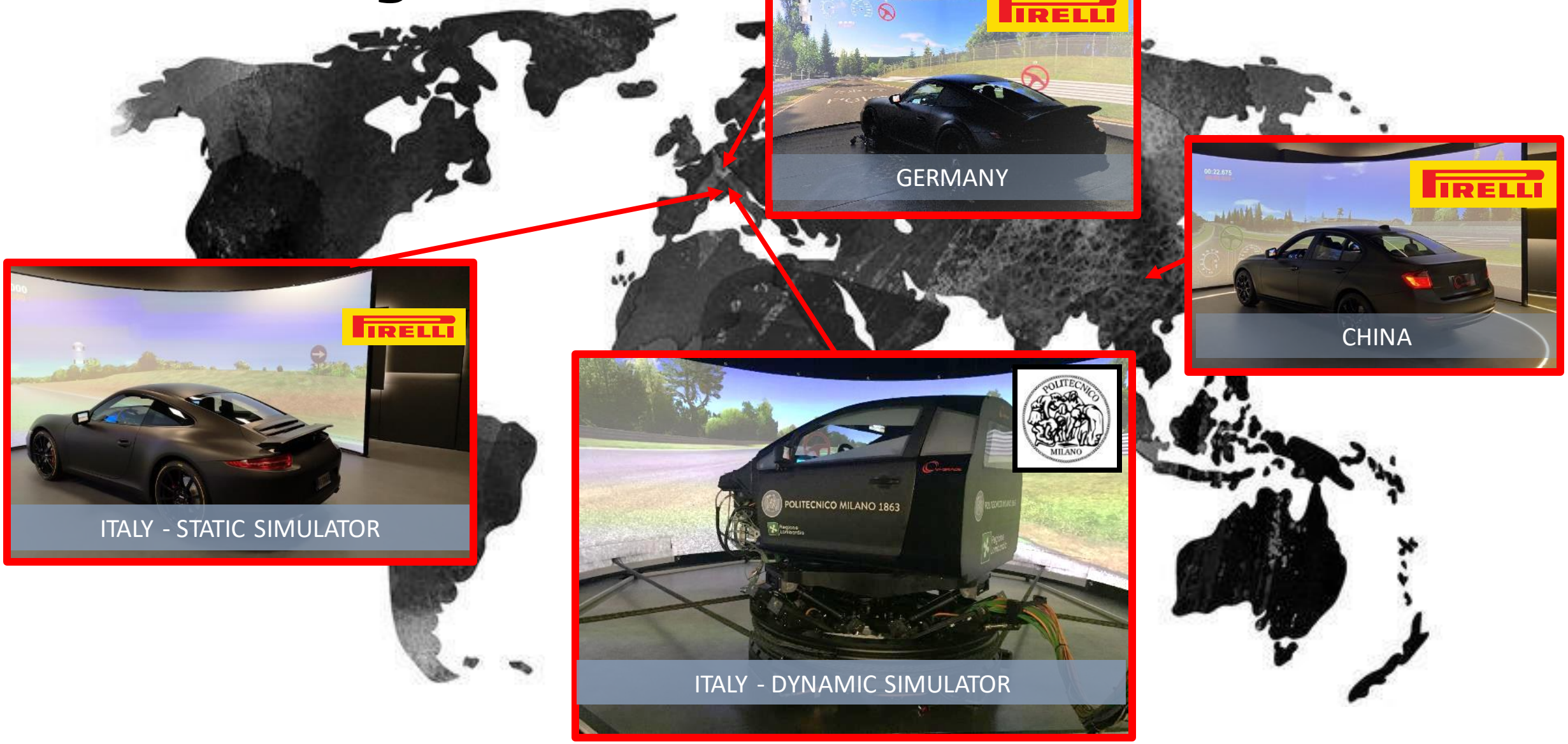
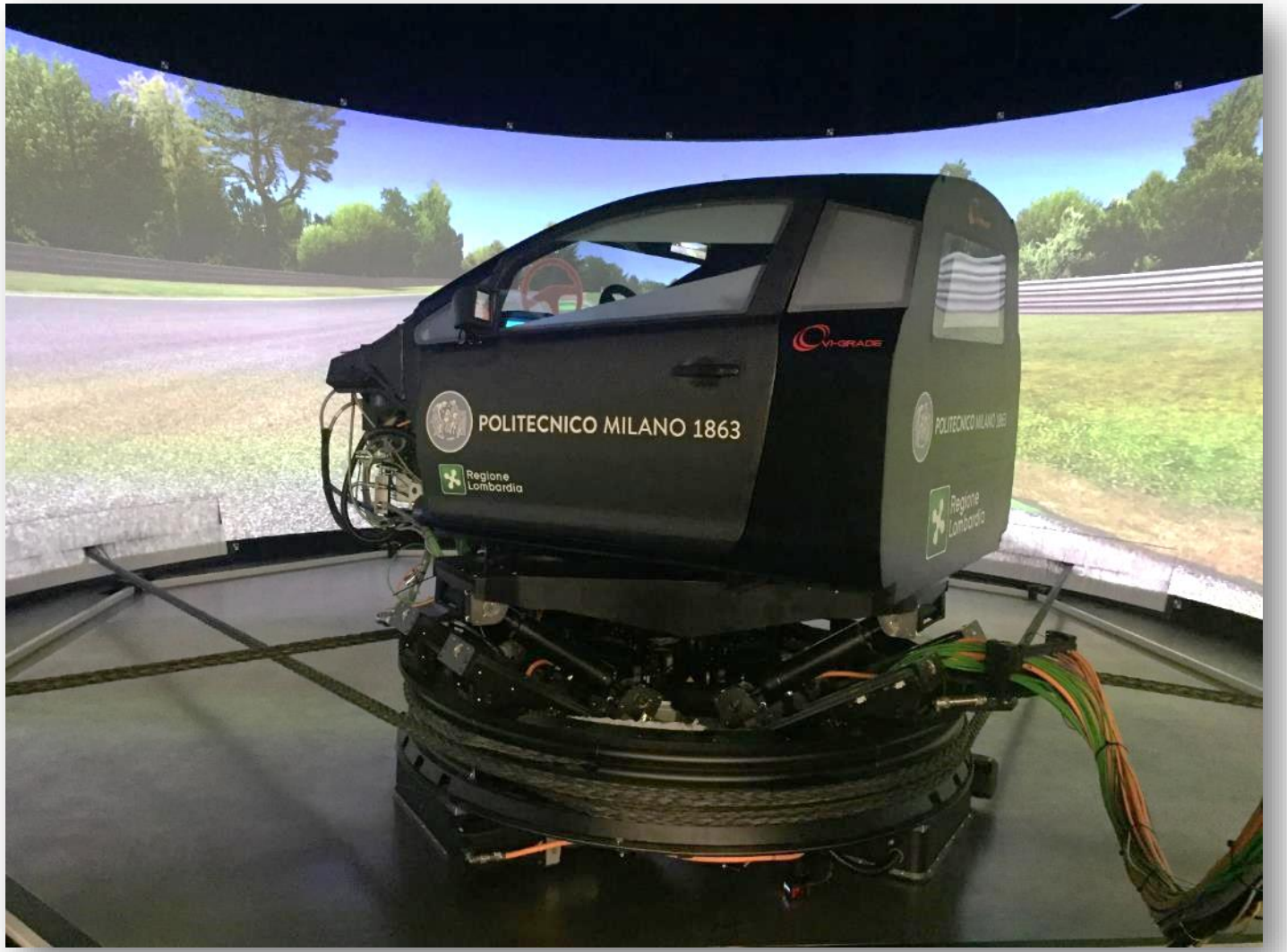
Thursday, May 25, 2023

# Pirelli driving simulators



# POLIMI dynamic Driving Simulator




- 1st installation of VI-Grade DIM400
- Movement through cables, allowing
  - Increased workspace (6x6 m platform)
  - Decoupling between yaw and translations throughout the entire workspace
- The laboratory was created thanks to a substantial investment from the **Government of the Lombardy Region**
- The project has been promoted by the **Lombardy Mobilitv Cluster**

Regione Lombardia

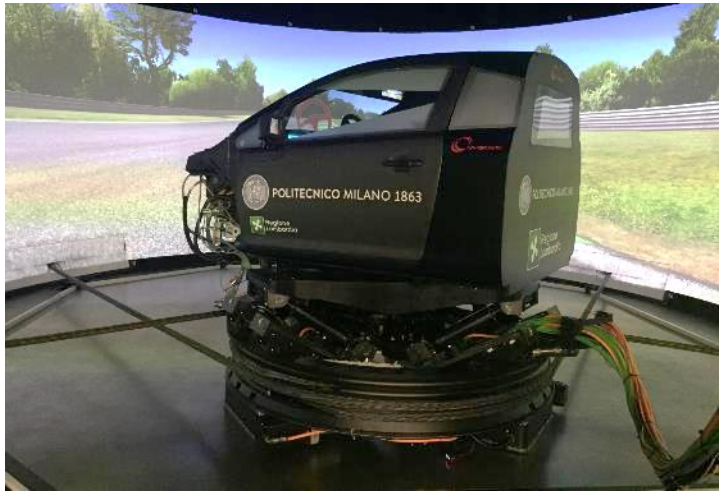
CLM
Cluster Lombardo della Mobilità
Lombardy Mobility Cluster

# POLIMI dynamic Driving Simulator

**On going research activities of the Department of Mechanical Engineering**


- **ADAS/Autonomous driving**
  - Development and subjective testing of control logics for ADAS and Autonomous driving systems
  - AI@Edge project: development and testing of connected-vehicles control logics (scenarios developed using Vi-WorldSim + Sumo as traffic engine
- **Smart roads**
  - Controlling road signals according to road conditions, e.g.: variable speed limit according to side wind speed
- **Expanding measurement set-up**
  - Dynamometric steering wheel, on board cameras
  - EEG cooperation with DEIB (Bioengineering research area)
  - Psychometrics (cooperation with San Raffaele University)


- **Cooperation with Pirelli**
  - Subjective analysis of Soft handling with DIM400



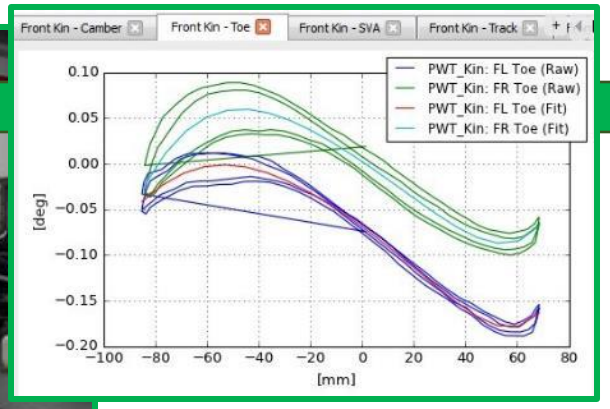
# Dynamic Simulator - Research activity

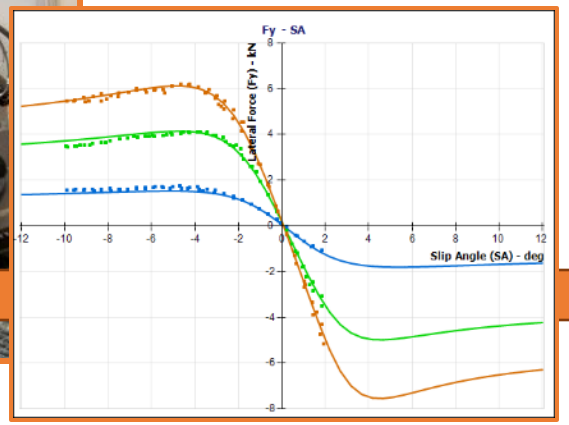
## PROJECT GOAL

Evaluation of Dynamic Simulator technology to assess tyre handling behavior

## STEP 0: Case Study Definition

# Measurements and models creation



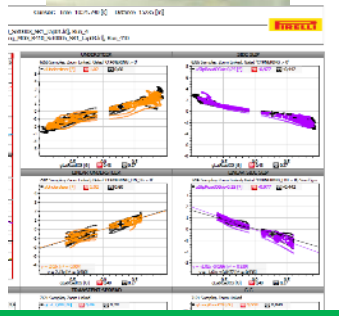

K&C tests

Damper tests

Inertia measurement

Build **ViCRT** model

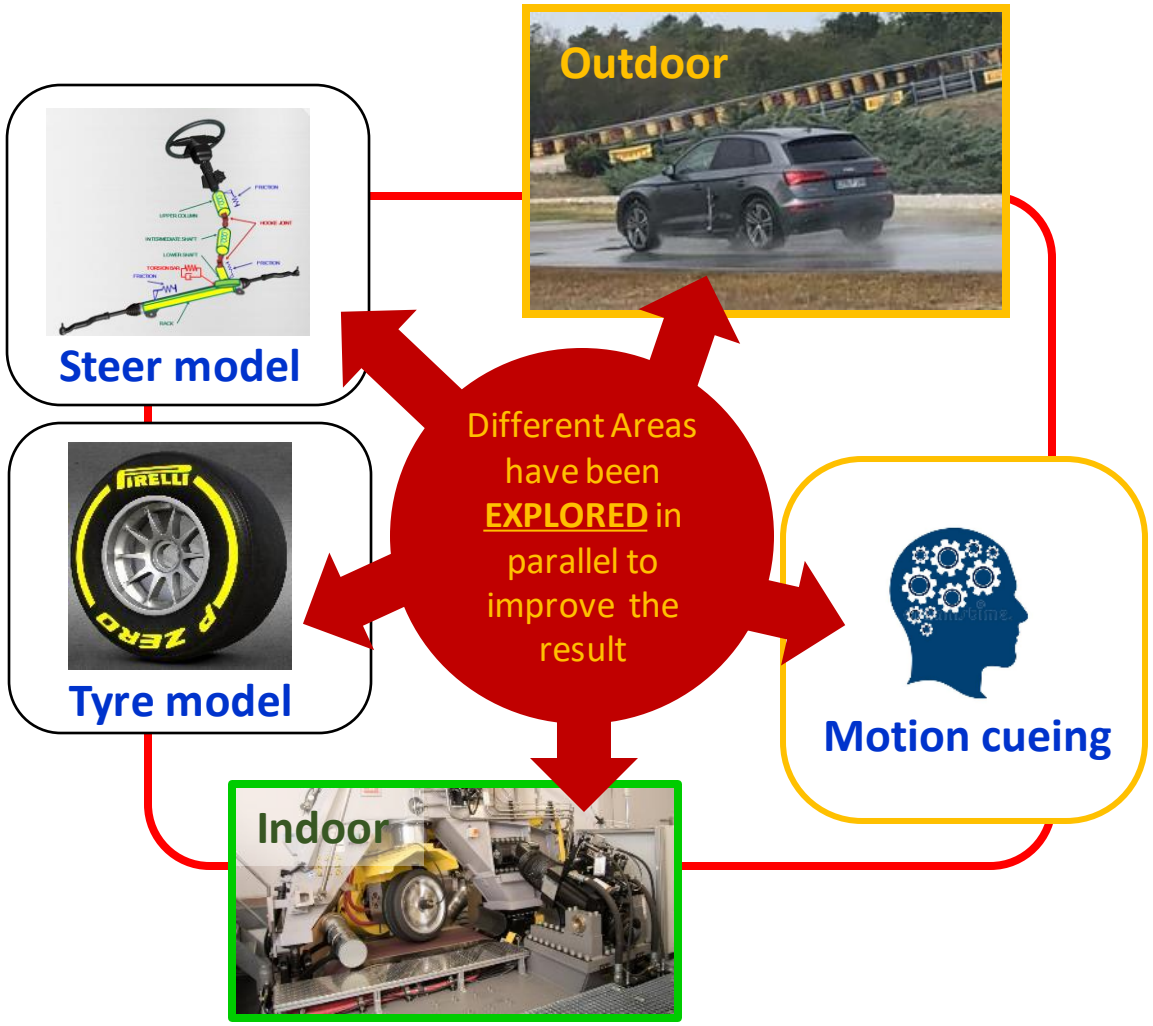
Validation of vehicle+tyre

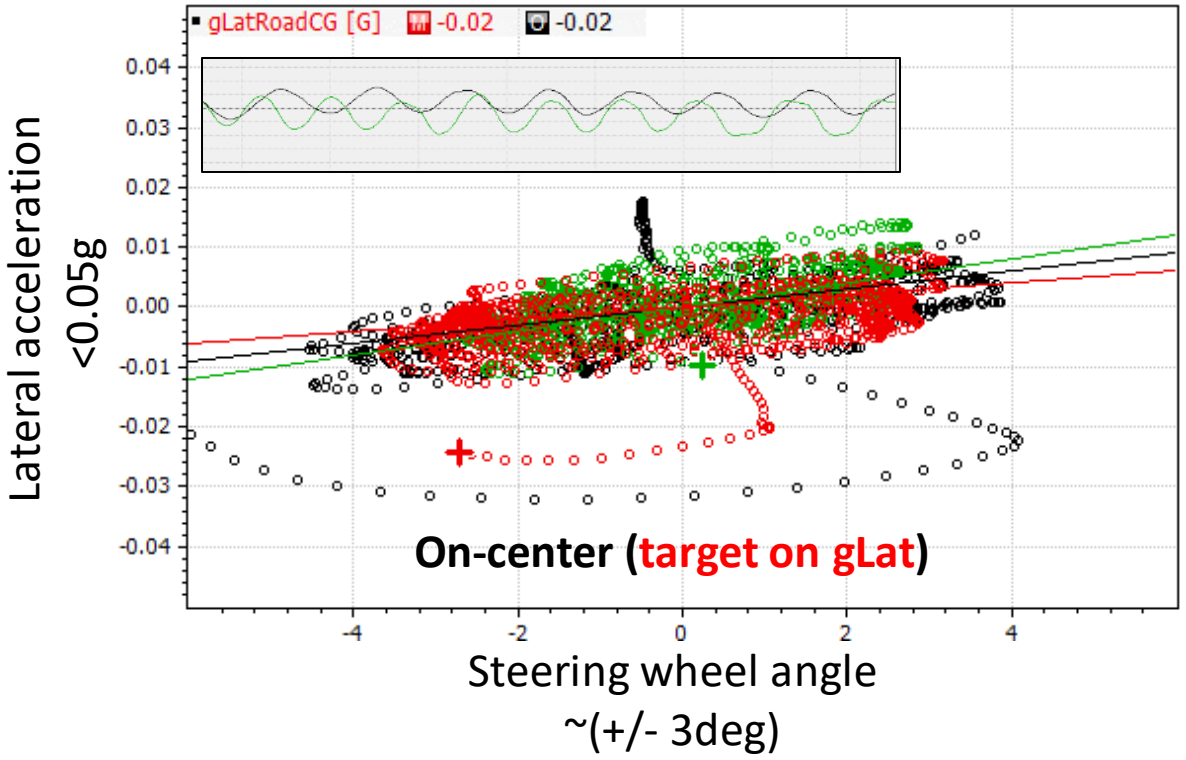
# Subjective test on Dynamic Simulator

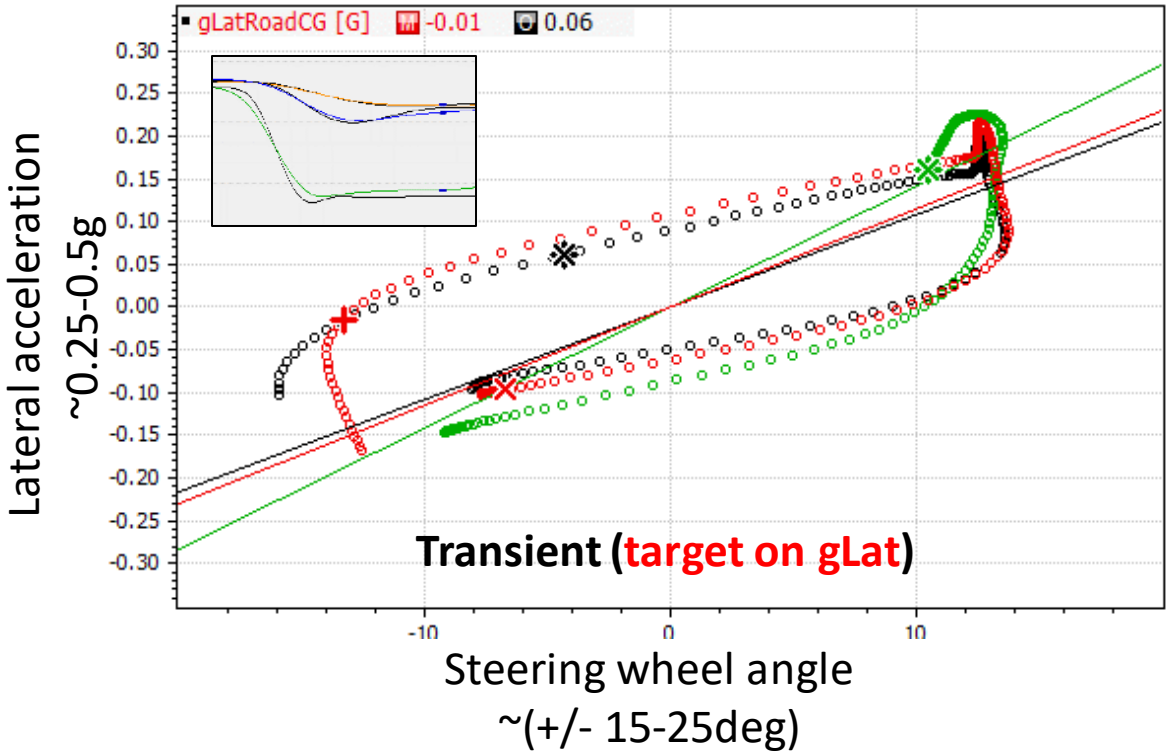
## First Feedback

- **On-center** response feels too much responsive with small delay compared to outdoor.
- **Soft HDL** : Difficult to rate tire **transients** and tires **linearity** of vehicle in soft handling manoeuvers due to cueing “wash-out”.
- **Hard handling**: Comparable with Static Simulator



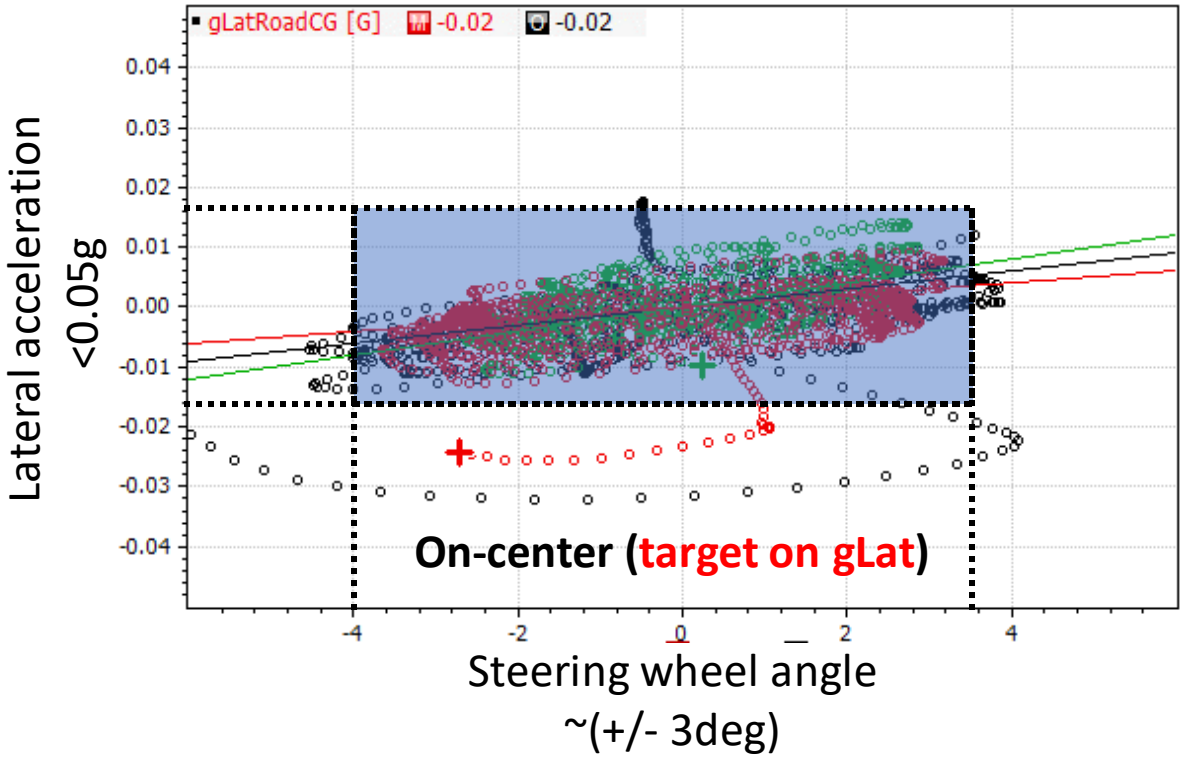
# Outdoor – Soft HDL input levels

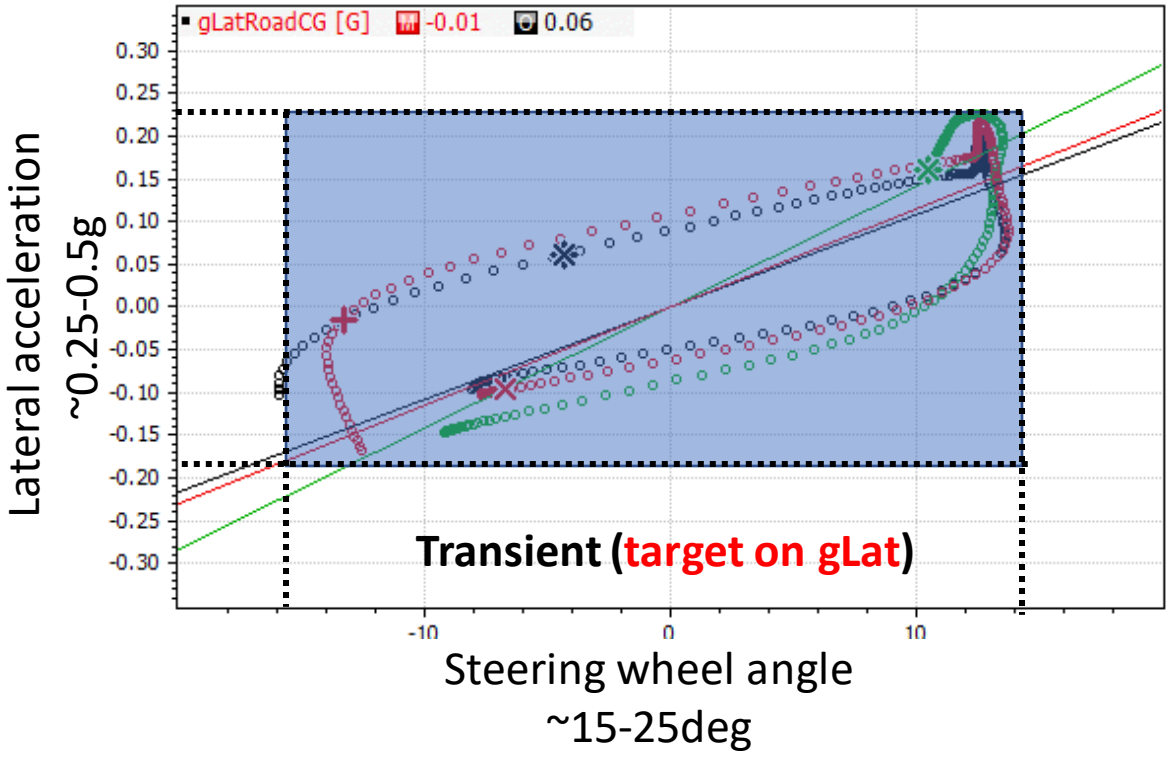



## STRAIGHT LINE SCENARIO

# Outdoor – Soft HDL input levels

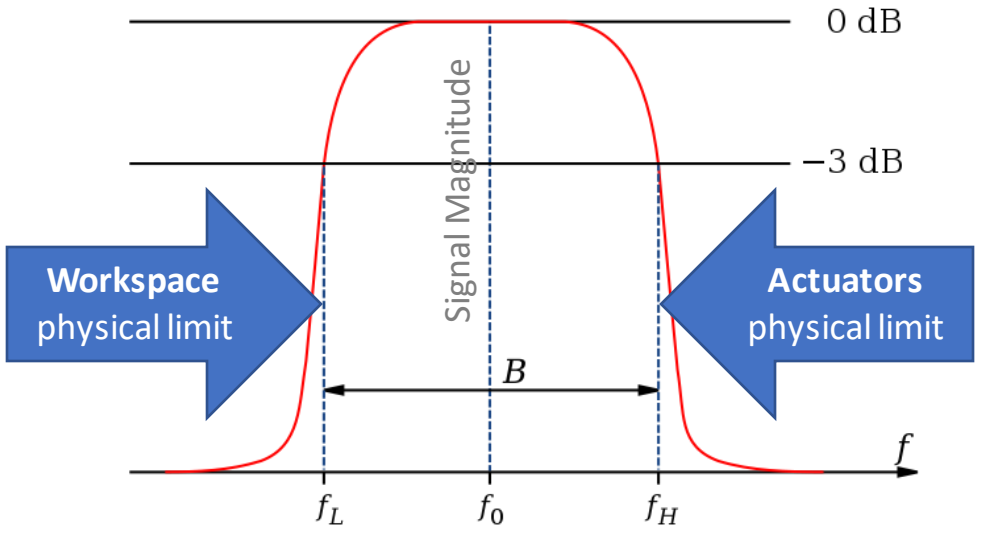



1. Need to focus on **very small tyre inputs** (indoor measurement) and output (motion cueing)
2. Need to replicate with **high fidelity** gain and phase delay between d.o.f. (especially yawrate and lateral accelaration)
3. Importance of **absolute level** of lateral acceleration (is used by the driver as a reference threshold)

# Motion cueing – challenges

Standard Cueing works on simulated Vehicle output as a band-pass filter




**First Feedback**:

- "**Lateral Acceleration vs YawRate build-up** is misleading especially evaluating SoftHandling"
- "**Low frequency** dynamics is not present in the motion (washout), it's difficult to evaluate small input from the car"

# Motion cueing – 1:1 positional cueing development

## TARGETS

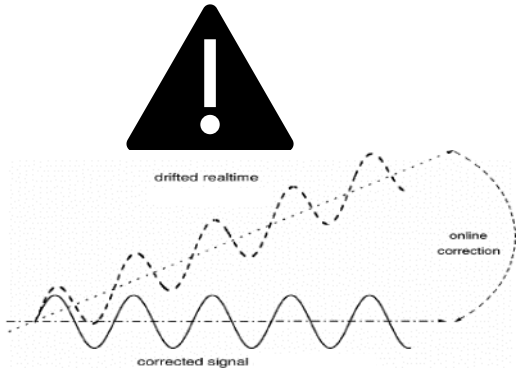
- Increase global GAIN of motion cueing
- Equalize magnitude of all degrees of freedom
- Extend «bandwitdh» of cueing at low freq.

## CHALLENGES

Baseframe Space Limitation

Safety (1:1 Accelerations)

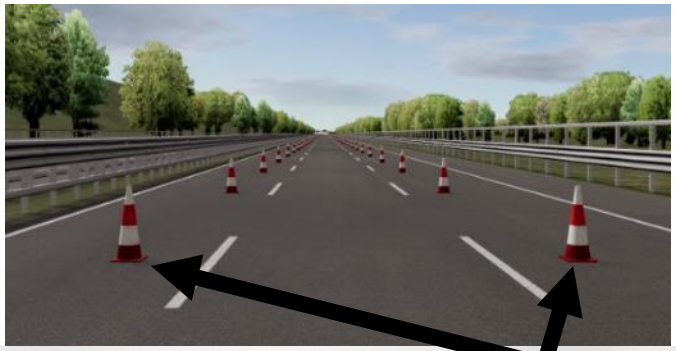
Signals Drift due to double integration of accelerometers




## RESULTS

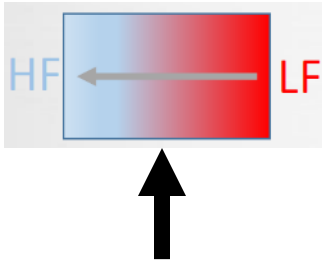
- An **Innovative Positional Cueing** has been developed
- Enabled for the **first time 1:1** SoftHandling manoeuvers
- Custom **Visual and Acoustic warning** have been introduced

VI-GRADE ⟷ PIRELLI




**Visual warnings**

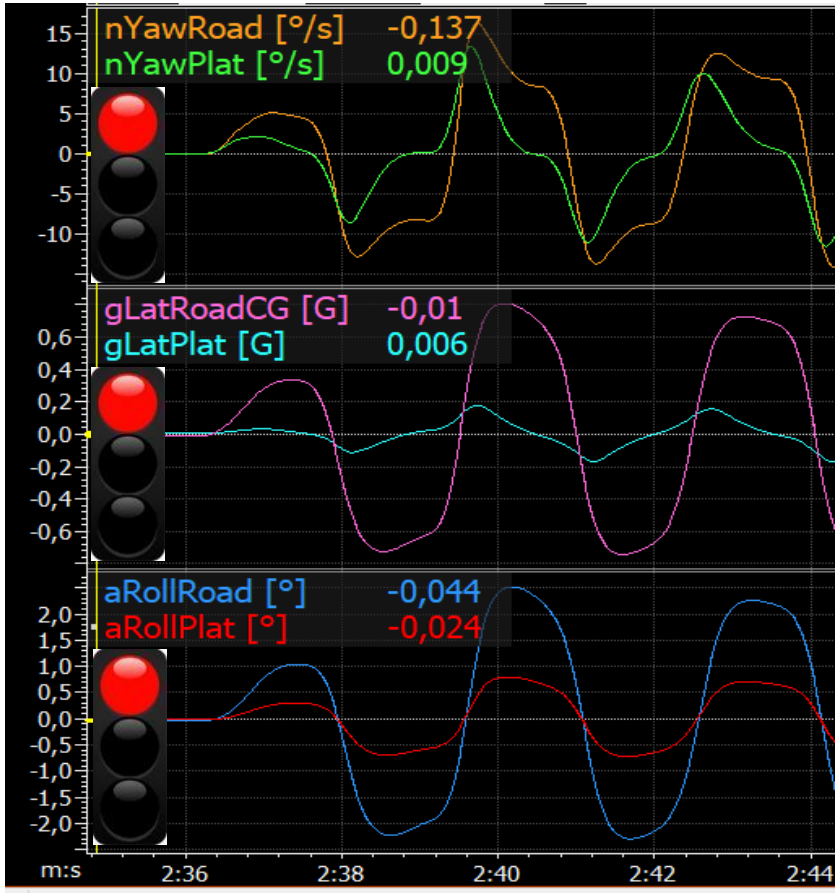
***BEEP***

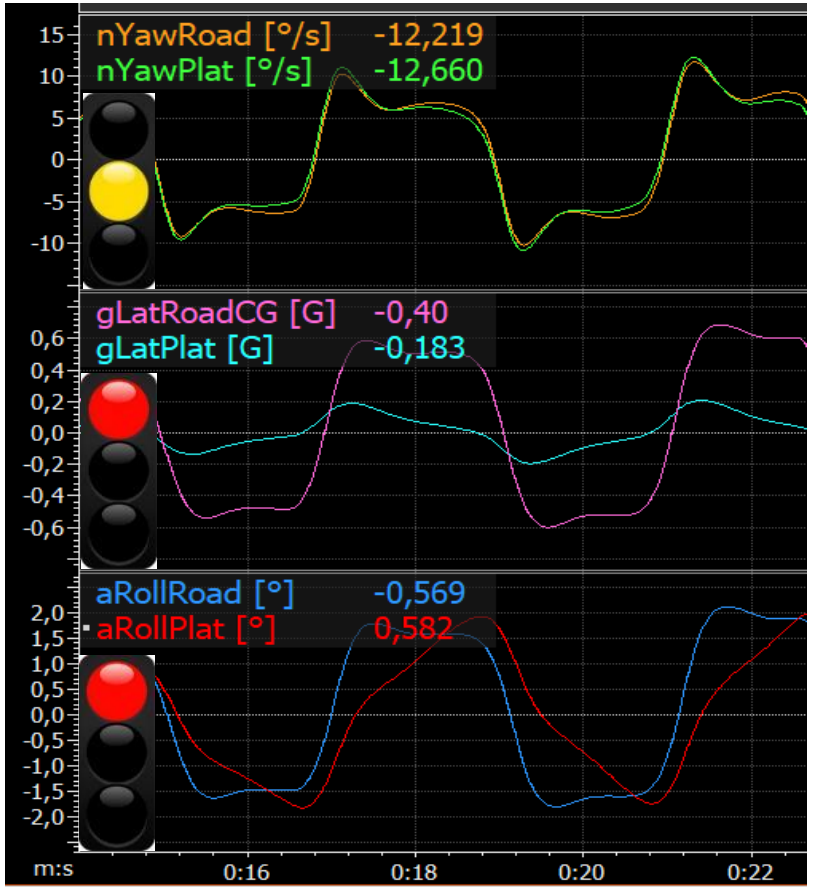


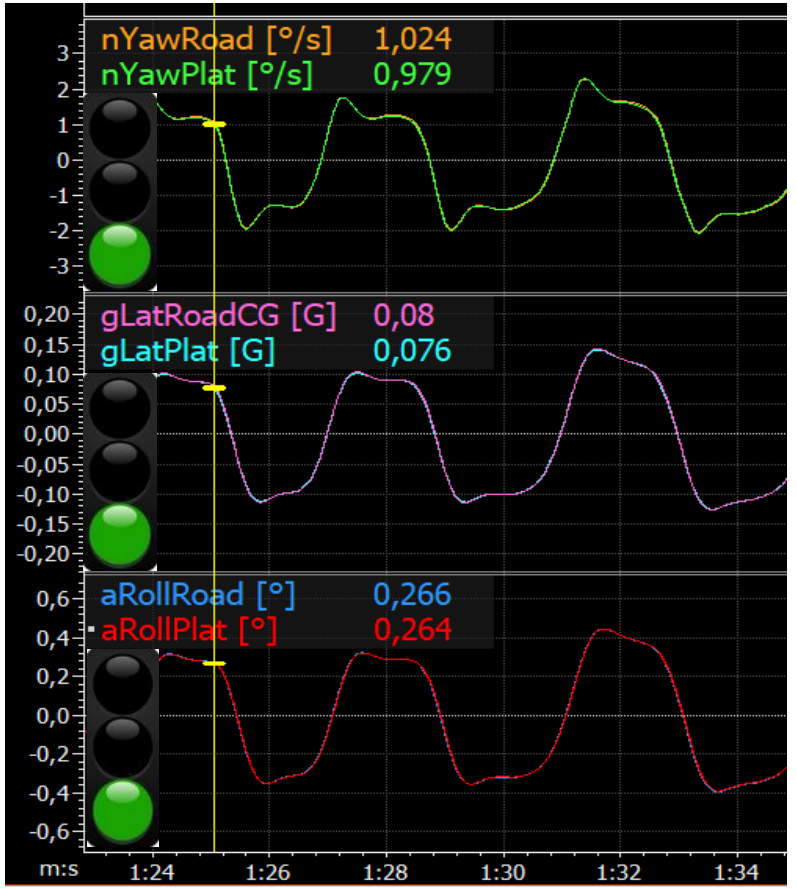

**Acoustic warnings**

# Motion cueing – development

| Initial Cueing | Tuned Cueing | Cueing 1:1 |
|---|---|---|




- Significant **<u>washout</u>** in the final part of the manoeuver (Lateral Acceleration and YawRate).

- **<u>YawRate close to 1:1</u>** scaling
- Still high **<u>washout</u>** on Lateral Acceleration
- Different **<u>magnitude scaling</u>** between dofs

- **<u>1:1 scaling on all dofs</u>** (except Longitudinal)
- Obtained through **<u>co-development</u>** of cueing algorithm with Vi-Grade.

# Motion cueing – development

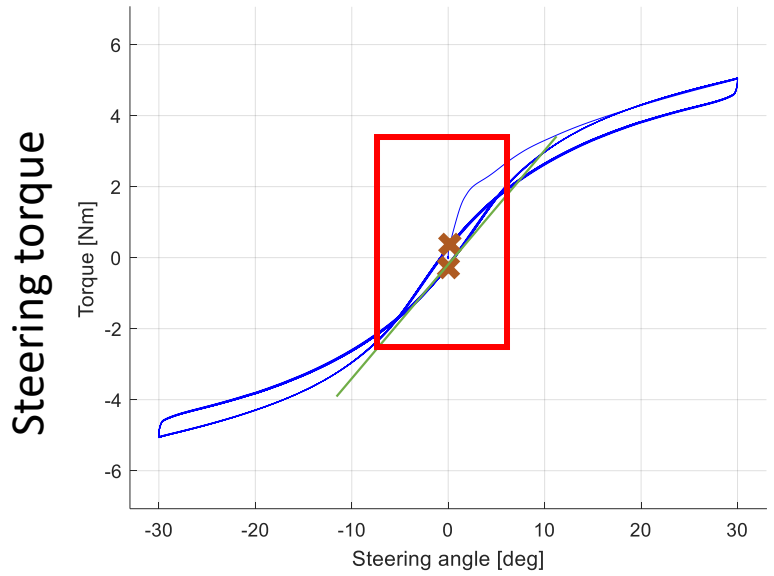
## initial Cueing

## 1:1 Cueing

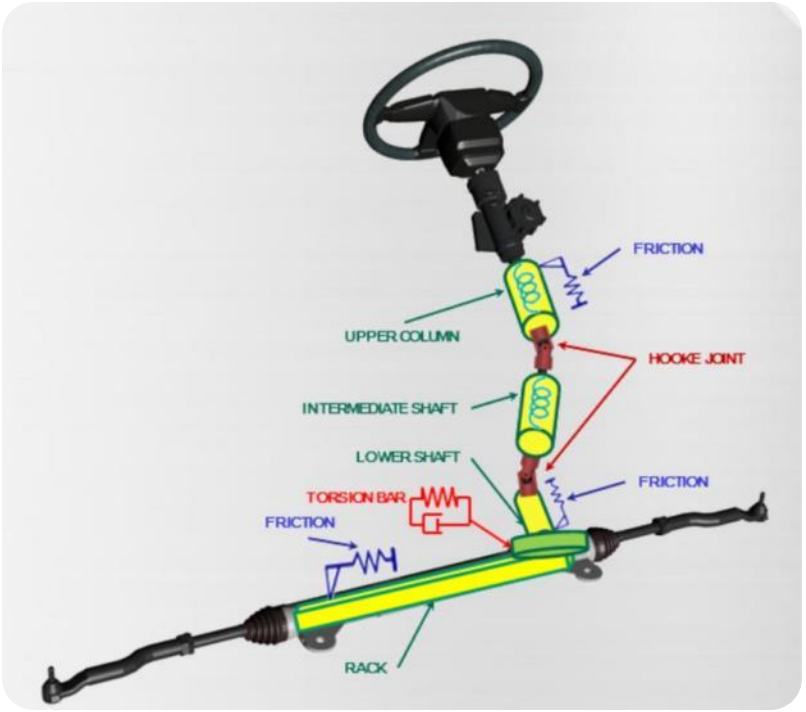
# Steering model

When analysing soft handling, the interest is toward small steer inputs
In this region friction pays a significant role

Master's Thesis



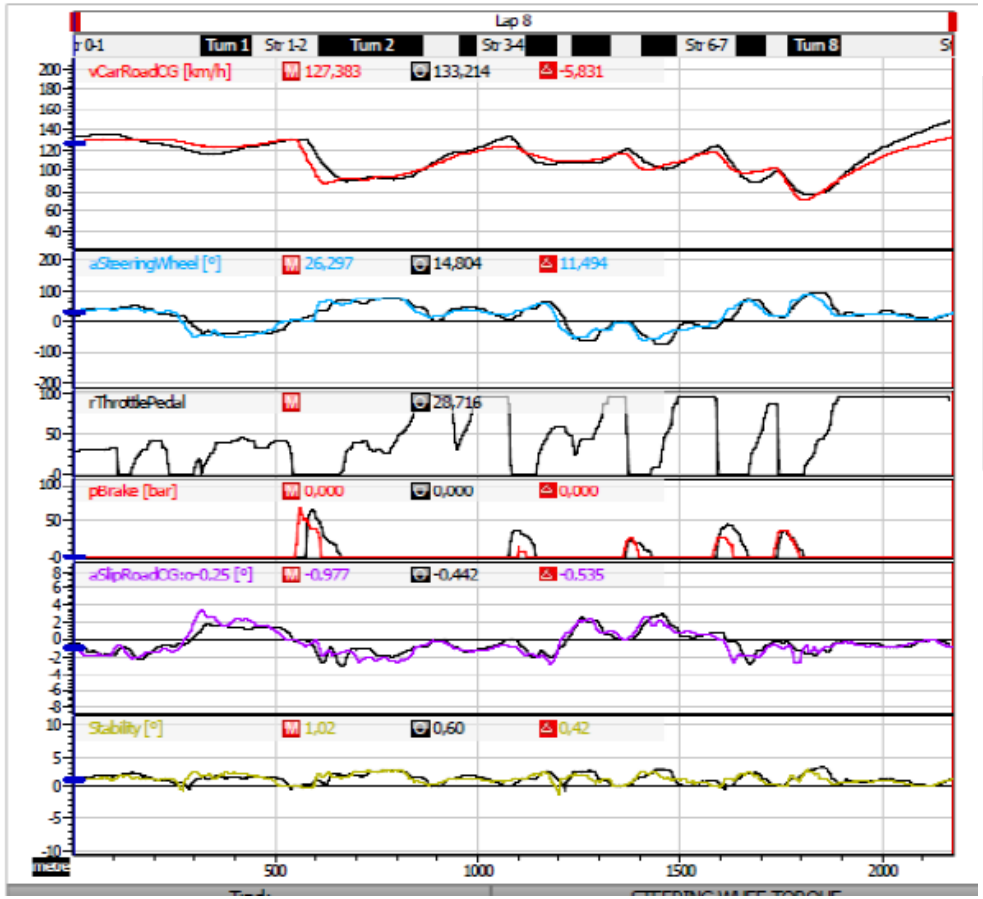

## Advanced steering model



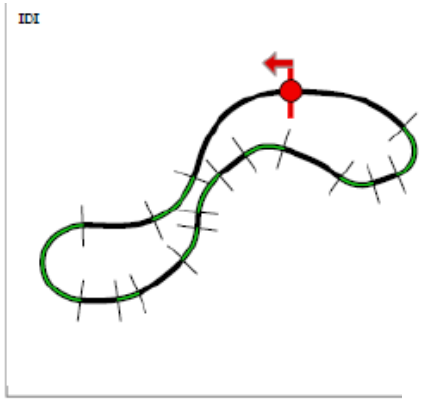

- This model offers enough details to reproduce the steer response
- Identifying the parameters of a such complex model is not an easy task
- Power steering response overlap overlapped with mechanical one

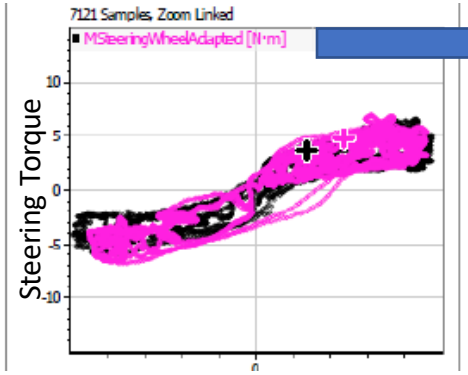
# Steering model identification: standard method

Experimental-Numerical comparison

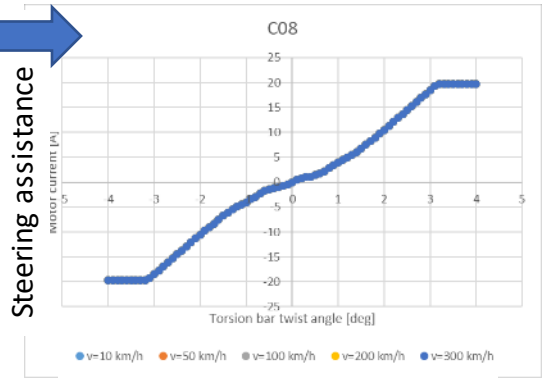



default steering map tuned on track lap data






Lateral Acceleration



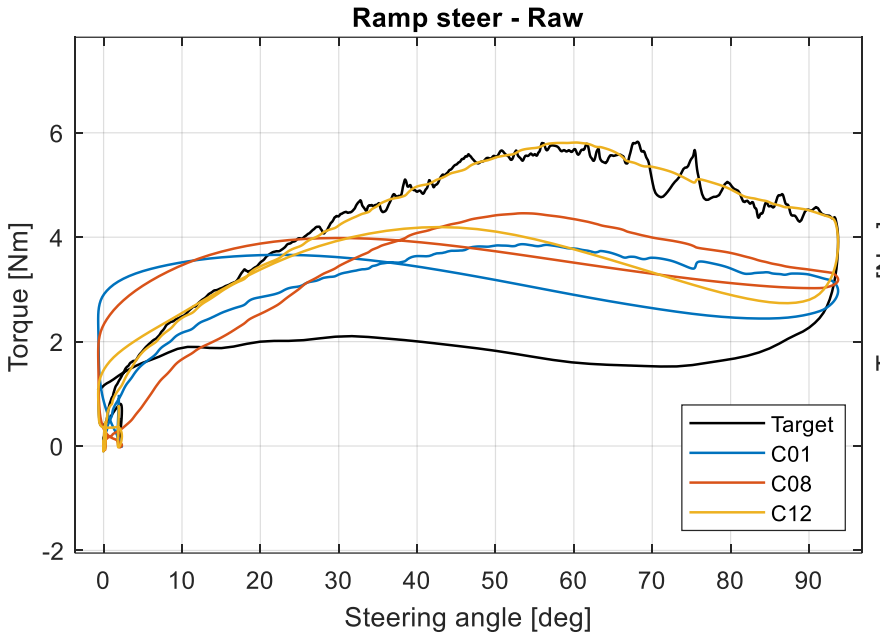

Torsion bar deflection

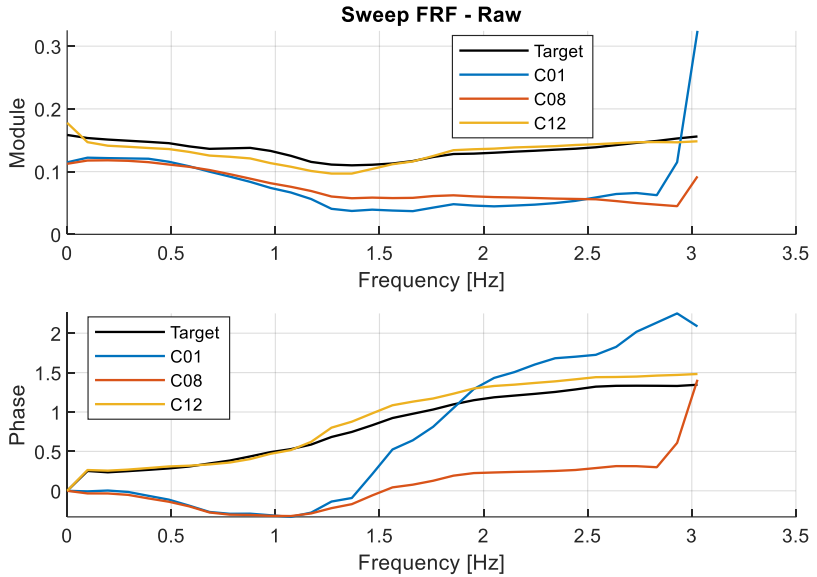
**C08** – Steering model calibrated over a tracklap

This method does not allow to accurately reproduce the response around 0°

# Steering Model Development - Results

| Problem | Solution |
|---|---|
| SWT curves not corresponding with outdoor | Calibration of steering model's parameters starting from outdoor data |
| No SWT around zero | Calibration of powersteering map starting from outdoor data |



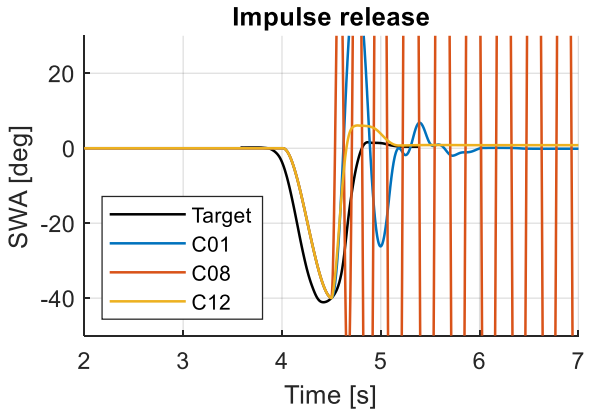

**C01** – Default parameters

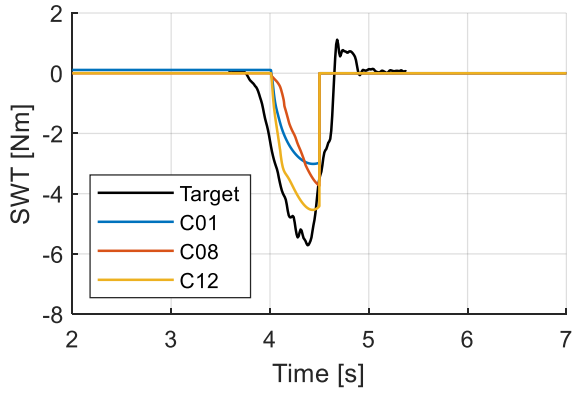
**C08** – Steering model calibrated over a track lap

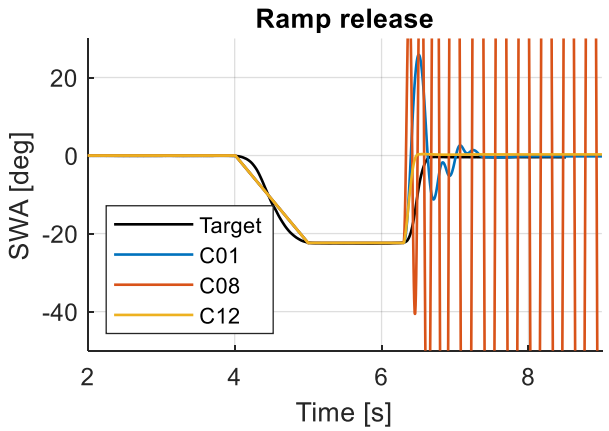
**C12** – Steering model calibrated with objective manoeuvres

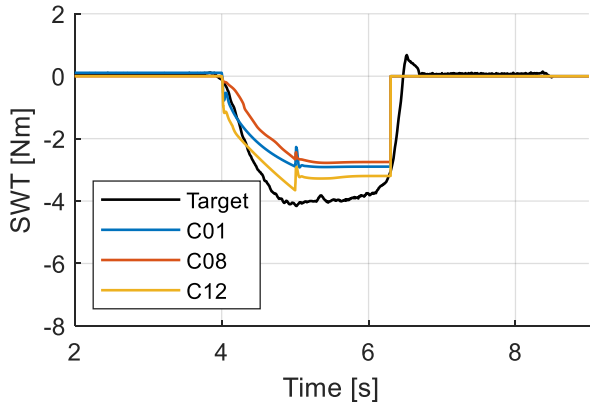
# Steering Model Development - Results

| Problem | Solution |
|---|---|
| Steering system instability at steer release | Calibration of parameters in a combined way (instead of one-by-one) and particular attention to «critical» parameters in comparison with outdoor behaviour |




**C01** – Default parameters

**C08** – Steering model calibrated over a track lap

**C12** – Steering model calibrated with objective manoeuvres

# Conclusions

- An **Innovative Positional Cueing** has been developed which enabled for the **first time 1:1 SoftHandling** manoeuvers.
- A methodology for **Advanced Steering model parametrization** based on outdoor objective data has been developed.
- For Soft Handling evaluation **Cueing 1:1** and tuning of **advanced steering model**, were found to be the **key enabler.**
- The developed methodology lead to improved **consistency** between Simulator and Outdoor **subjective** assessment.

**Drivers Feedback**:

- ***Driver #1****: «…with Cueing 1:1* ***absolutely realistic feeling****. The only cueing that is functional for soft handling evaluation; adequate* ***only for soft handling*** *manouvres as it allows for 1.5 lanes in witdh. This is plenty for the soft handling evaluation, albeit more space would be better…»;*

- ***Driver #2****: «Details of the* ***steering feel are much more noticeable*** *and easier to compare to the real car. i.e. the improved steering model* ***is much more realistic*** *and the torque build up that is often considered "too much" on the static simulator, with the 1:1 cueing is* ***subjectively very similar to the real one****.*

- ***Driver #3***: *«Much better in terms of steering torque and general perception of the vehicle,* ***now it's possbile to investigate on-center****. Chassis movements are now correlated with steering torque feedback. Simulator response is improved and the* ***subjective analysis is now much more significant in relation with real world»***

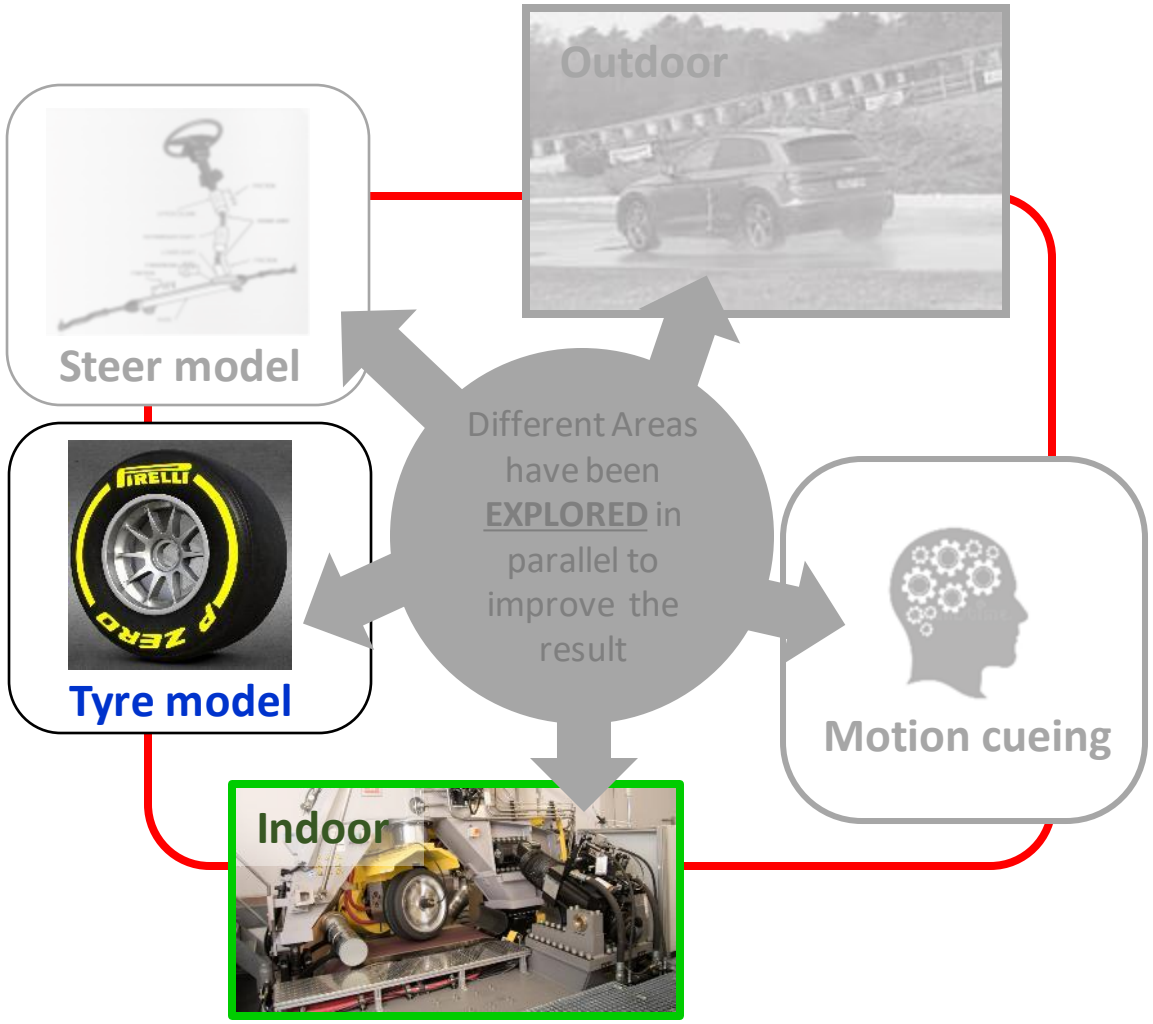
# Next Steps

## Tyre modelling:

- Investigation on the contribution of different **advanced tyre models** on subjective handling, using enhanced Dynamic Simulator setup (1:1 cueing and validated steering model).

## Driving Simulator:

- Improvement of cueing configuration for **hard handling** and **ride** applications.





Thank you for your attention!