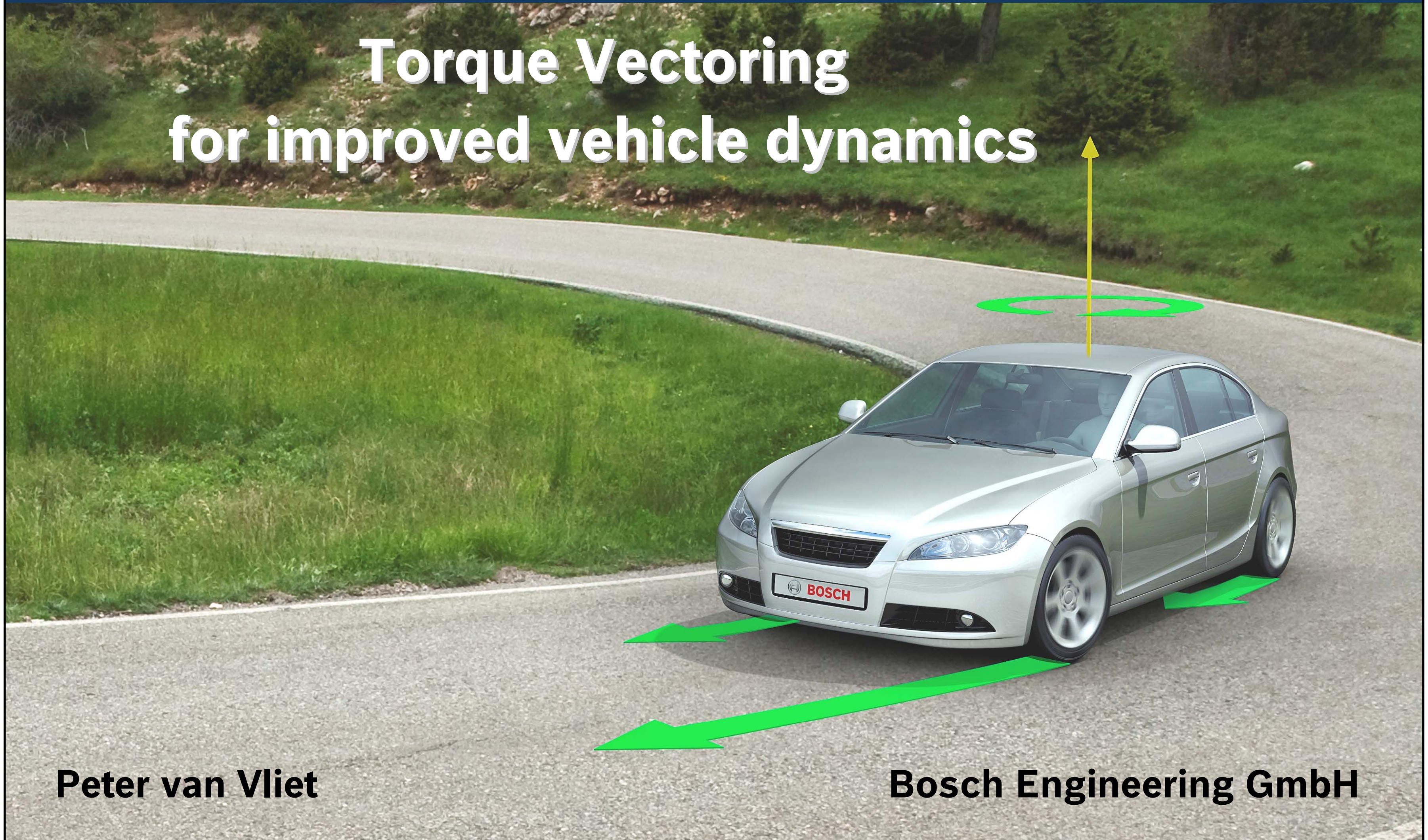
Vehicle Dynamics EXPO

Stuttgart, June 22nd 2010

Torque Vectoring for improved vehicle dynamics



Peter van Vliet

Bosch Engineering GmbH

Bosch Engineering GmbH

Combustion Engines	**Vehicle Dynamics**	EE-Integration	Motorsport	Sensor-Systems

- ▶ 100 % subsidiary of Robert Bosch GmbH
- ▶ established in 1999, approx. 1400 employees
- ▶ customized solutions based on Bosch products

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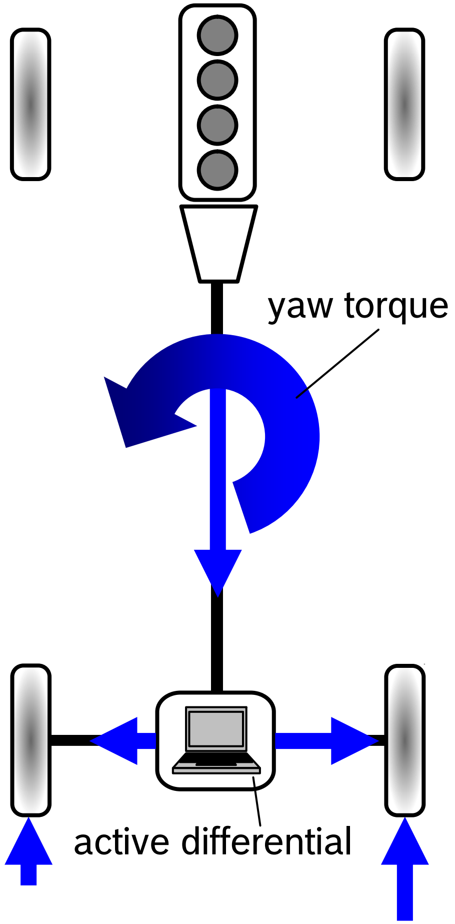
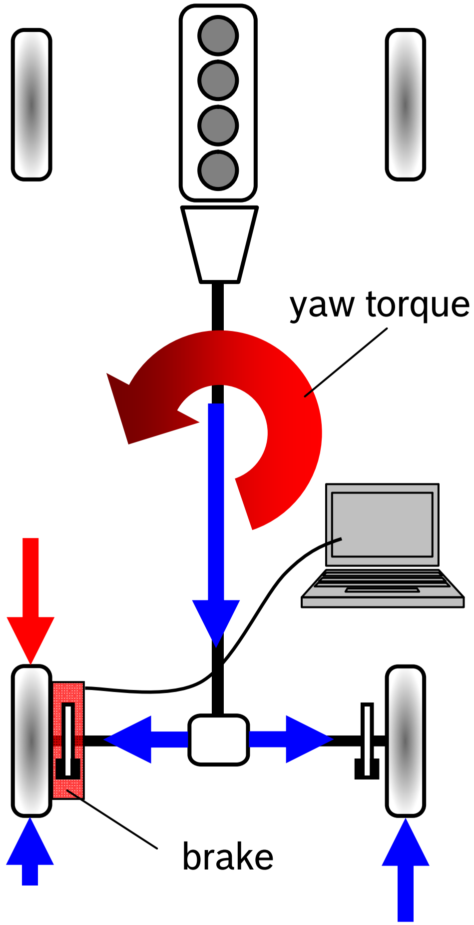
Torque Vectoring – Actuators

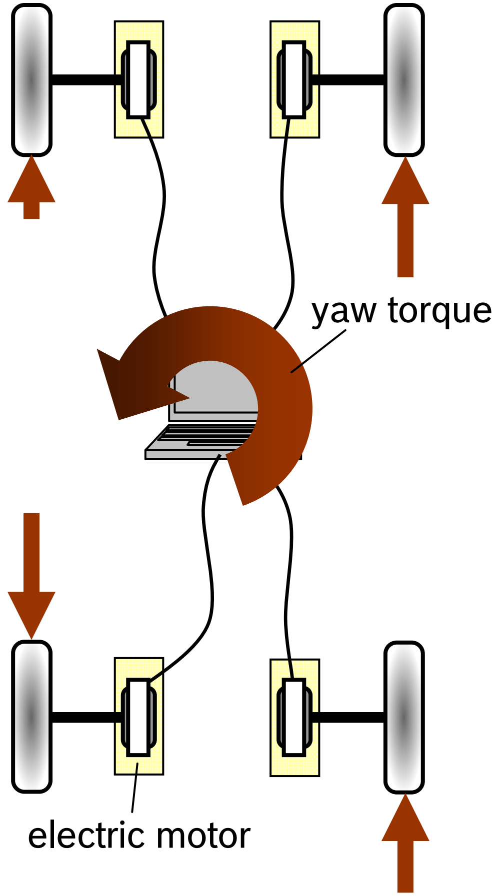
Differential



Brake



E-Motors



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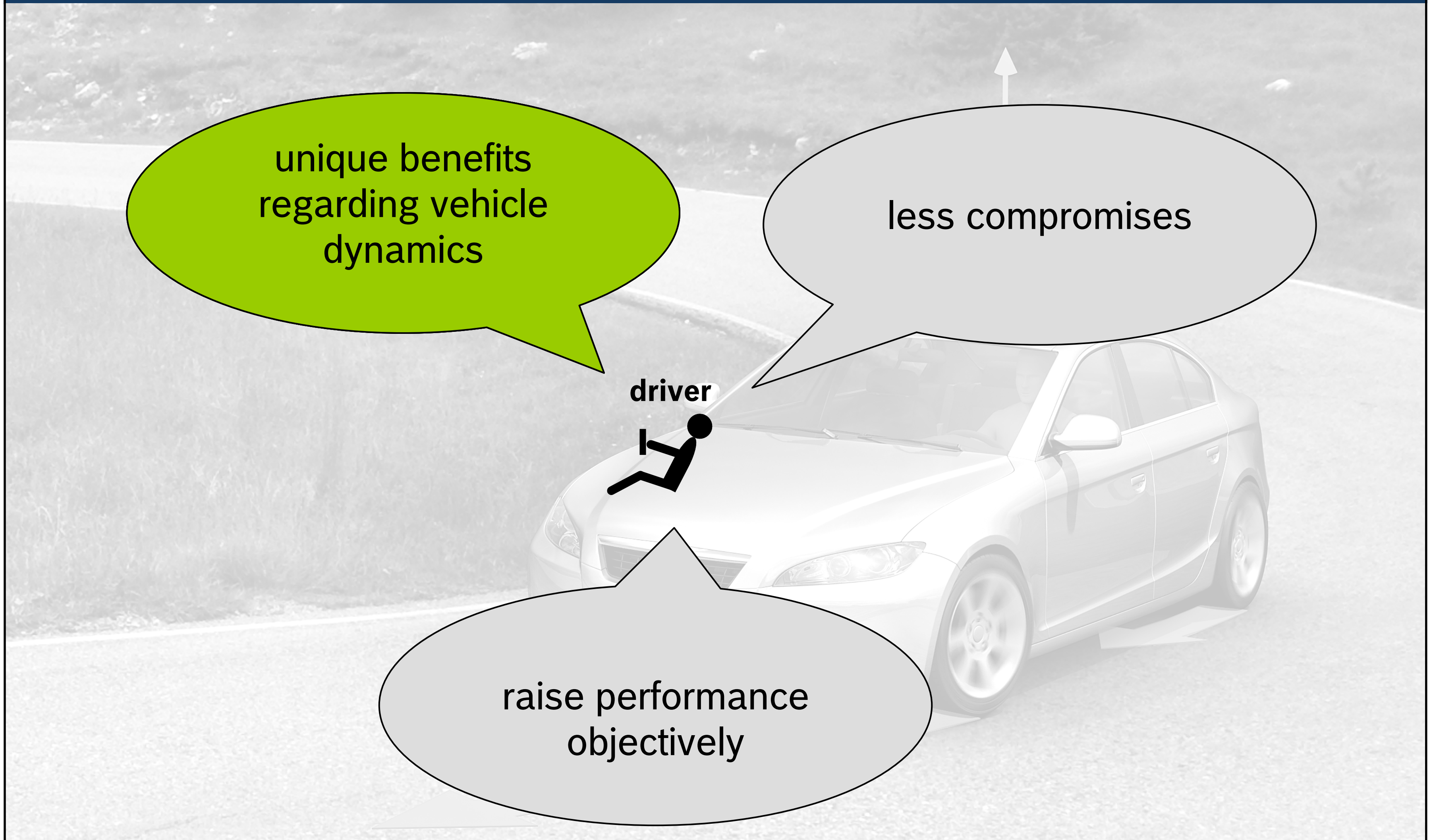
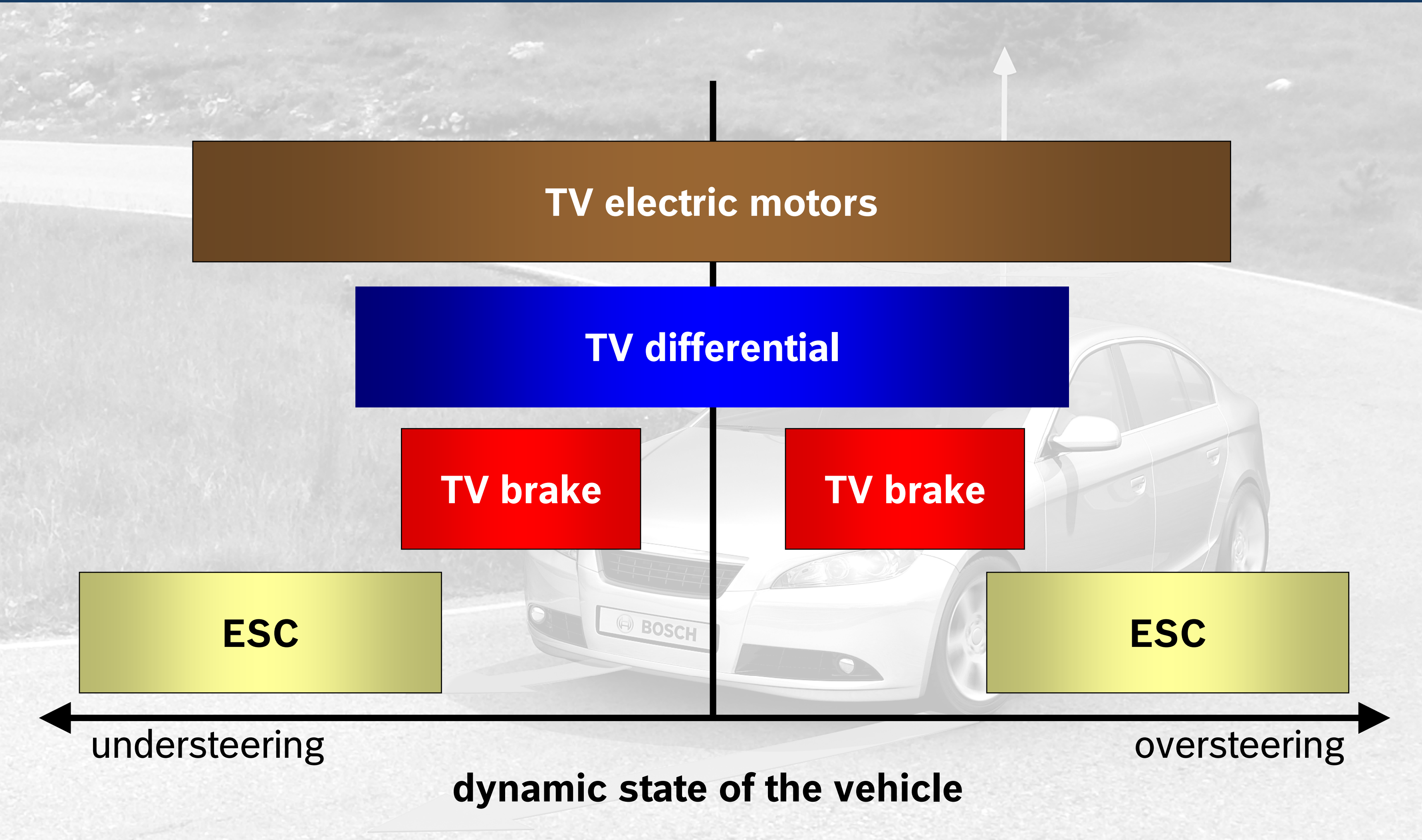

unique benefits regarding vehicle dynamics
less compromises
driver
raise performance objectively

Torque vectoring – range of action



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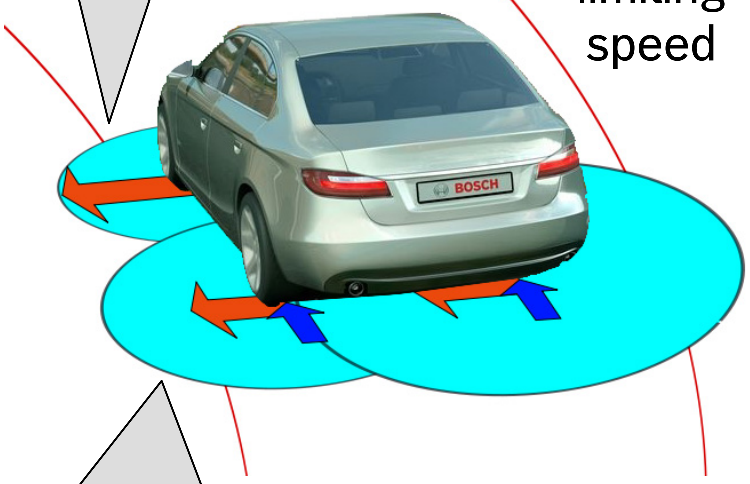
Raise the limiting cornering speed

without torque vectoring
- understeering setup -

front axle reaches the limit first

60
limiting speed

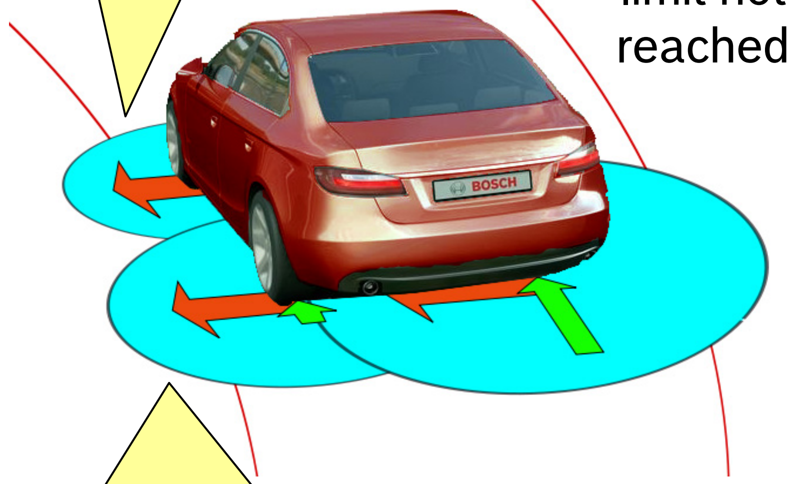


friction potential is **not** utilized completely

with torque vectoring
- neutral -

yaw torque reduces lateral slip at front axle

60
limit not reached



increased usage of friction potential at rear axle

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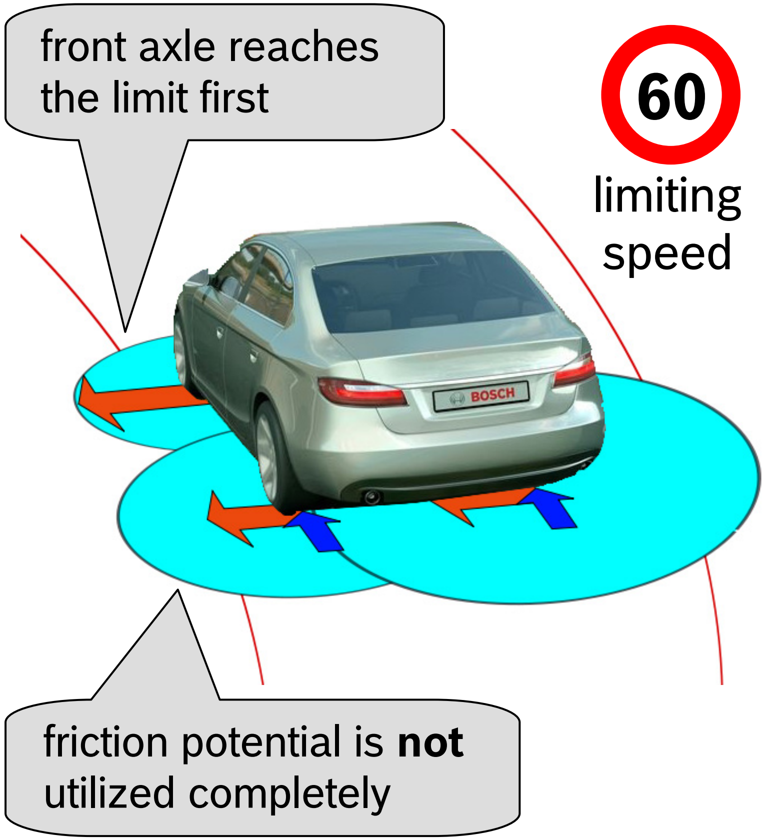
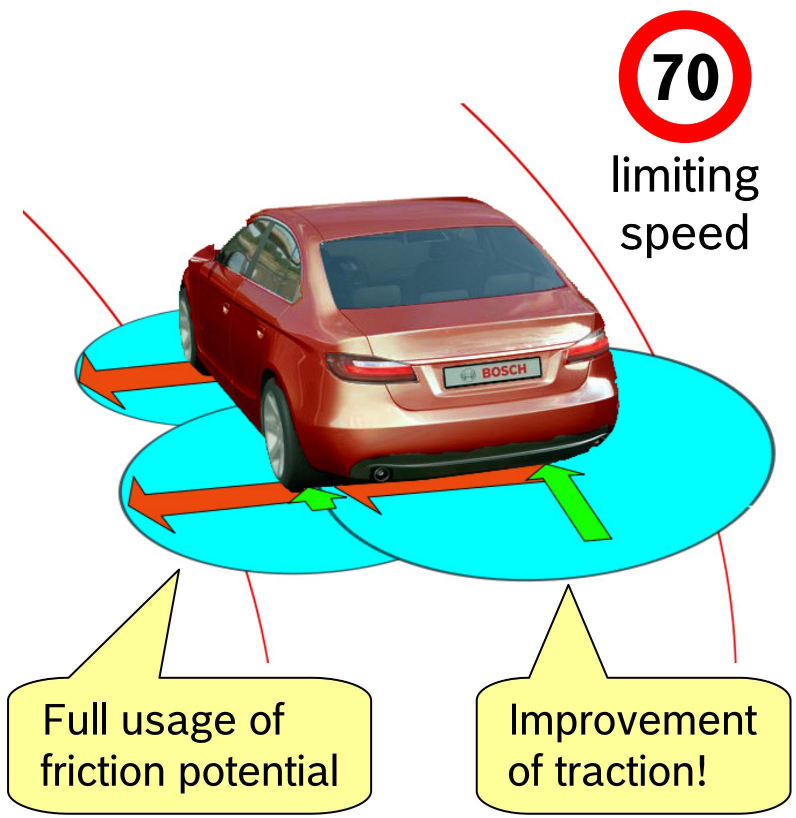
Raise the limiting cornering speed

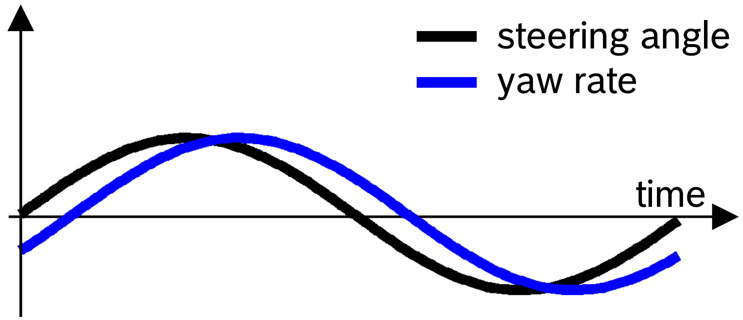
without torque vectoring - understeering setup -	with torque vectoring - neutral -



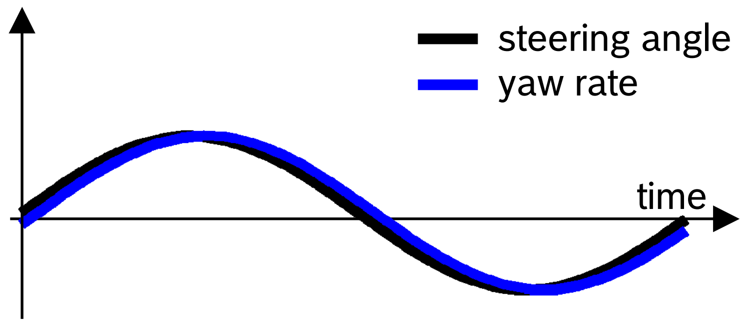


Virtual reduction of the moment of inertia

without torque vectoring



with torque vectoring



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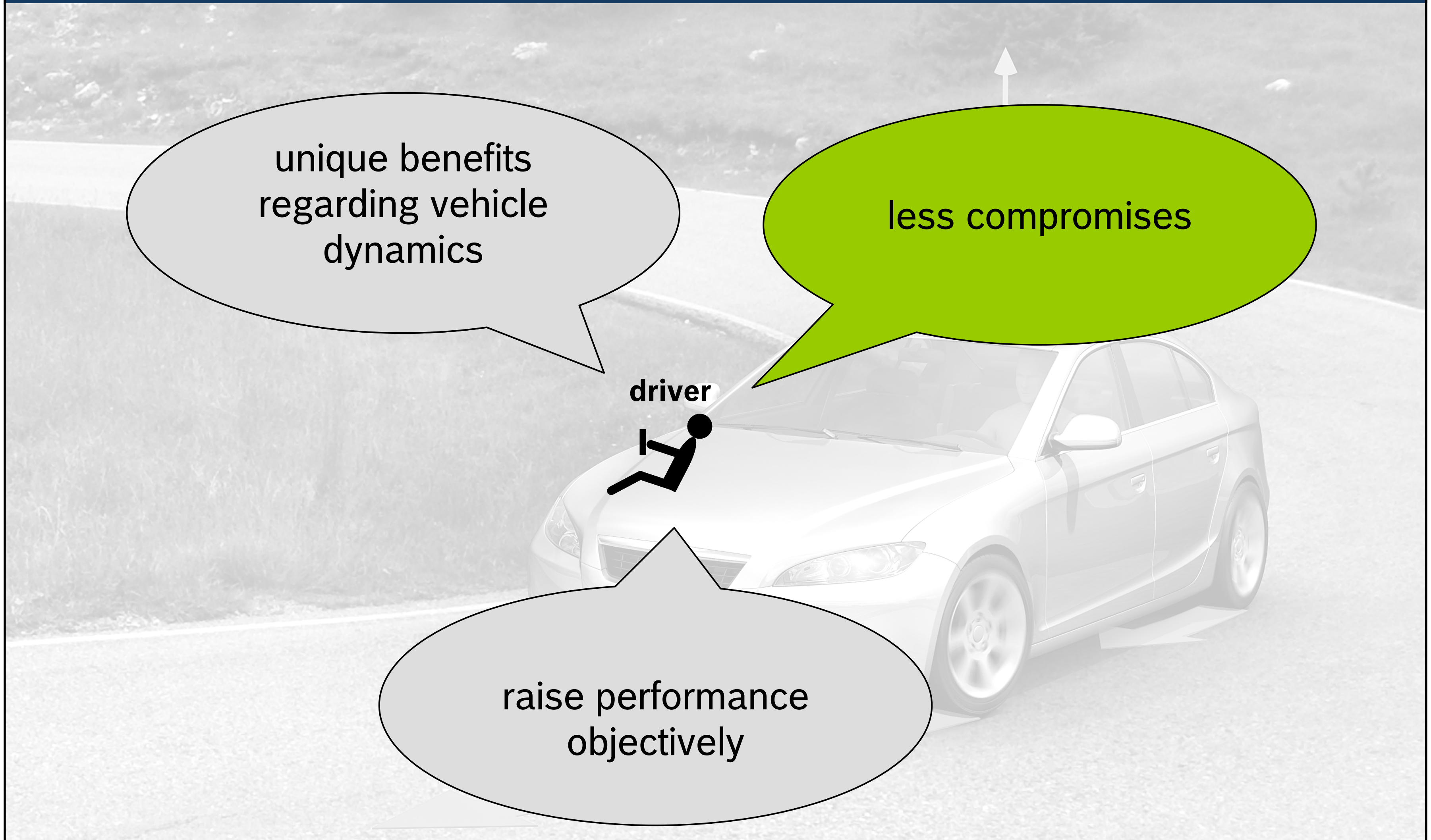

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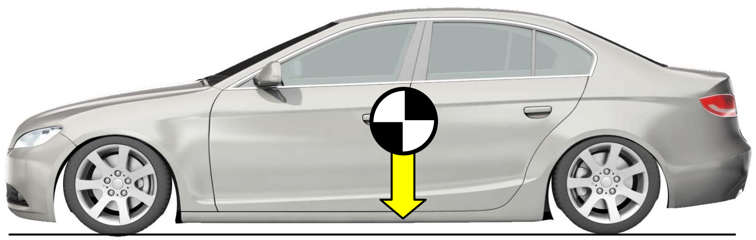
Torque vectoring alternatives

lower center of gravity



Benefit

- less load transfer improves traction and agility

Compromises

- chassis needs to be adapted
- stiffer springs affect comfort
- less ground clearance

torque vectoring

Benefits

- torque vectoring does not affect driving comfort
- chassis tuning can be focused more on aspects like comfort and stability, since agility and traction are already improved

Torque vectoring alternatives

increased camber angle at front wheels

Benefit

- more grip at front axle: increased agility

Compromises

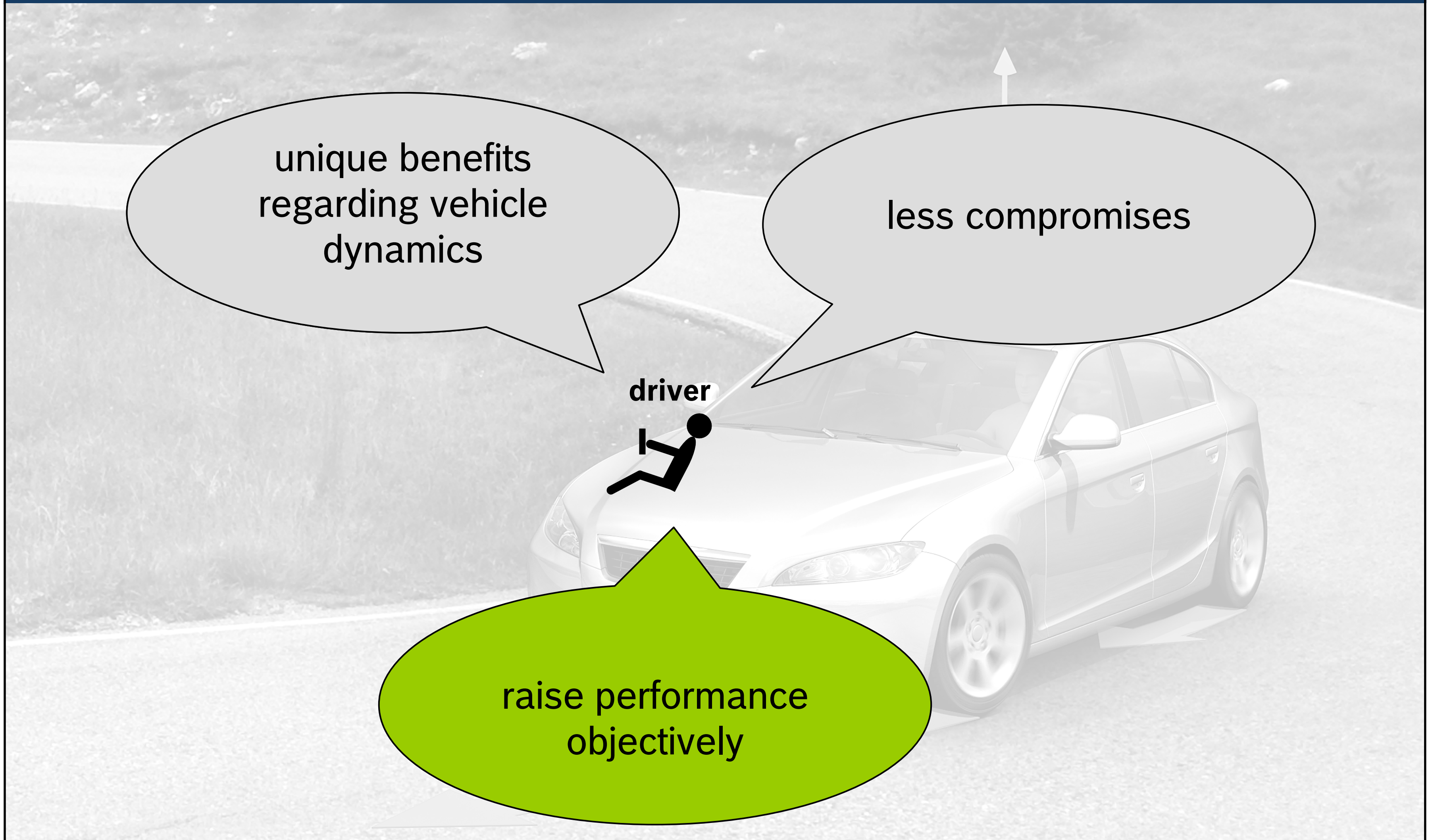
- loss of driving stability at high speeds
- no vehicle dynamics control
- tire wear

torque vectoring

Benefits

- agility improvements are situation dependent (sensor information)
- agility at low speeds, simultaneously stability at high speeds
- adaptive control on dry or wet asphalt and low-µ

Contents


unique benefits regarding vehicle dynamics
less compromises
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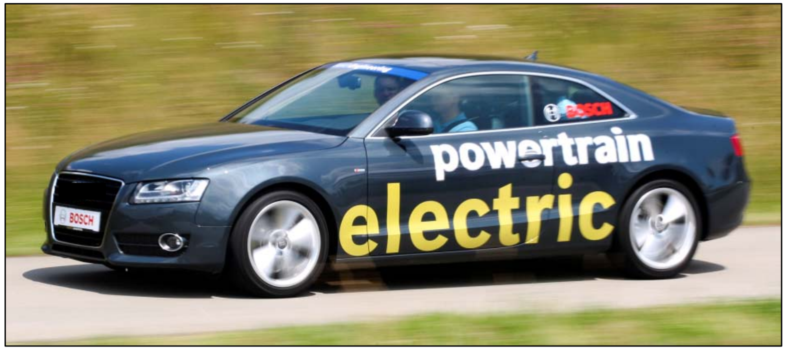
raise performance objectively

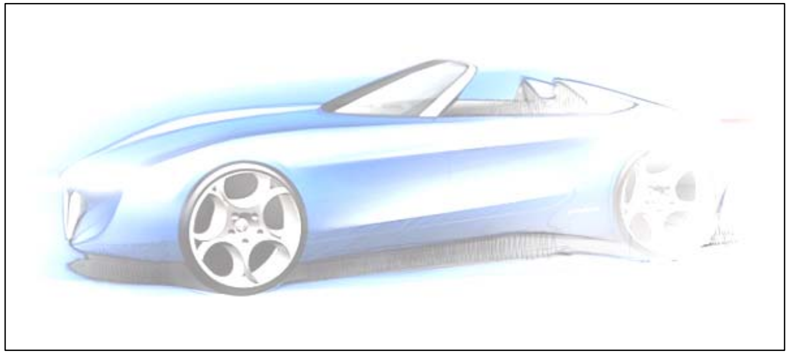
Experimental results – TV e-motors and TV-brake

Coupé (Bosch Engineering)



- torque vectoring actuator: **4 e-motors**
- total power: **4 x 60 kW**
- maximum wheel torque: **700 Nm**
- acceleration 0-100 km/h: **ca. 7 s**
- maximum speed: **130 km/h**
- weight: **1970 kg**
- battery capacity: **45 KWh**

Sports car (OEM)



- torque vectoring actuator: **brake** 
- combustion engine power: **> 350 kW**
- maximum speed: **> 250 km/h**
- weight: **ca. 1550 kg**
- driven wheels: **rear axle**

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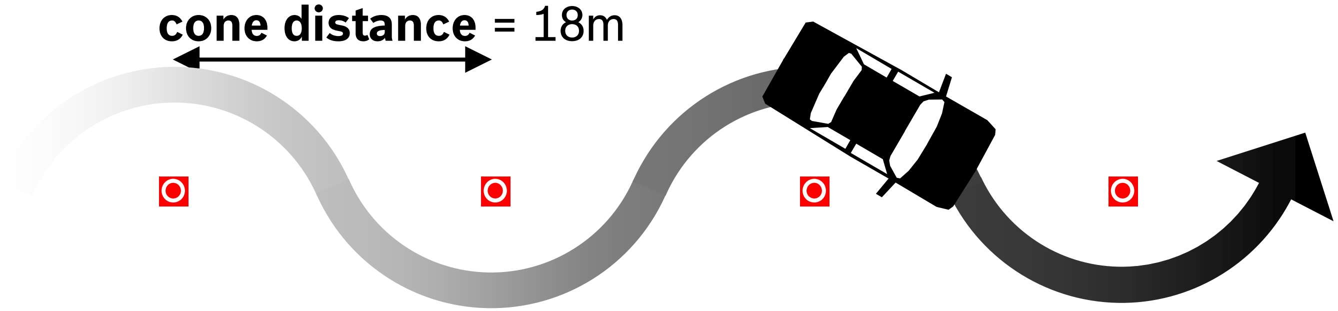
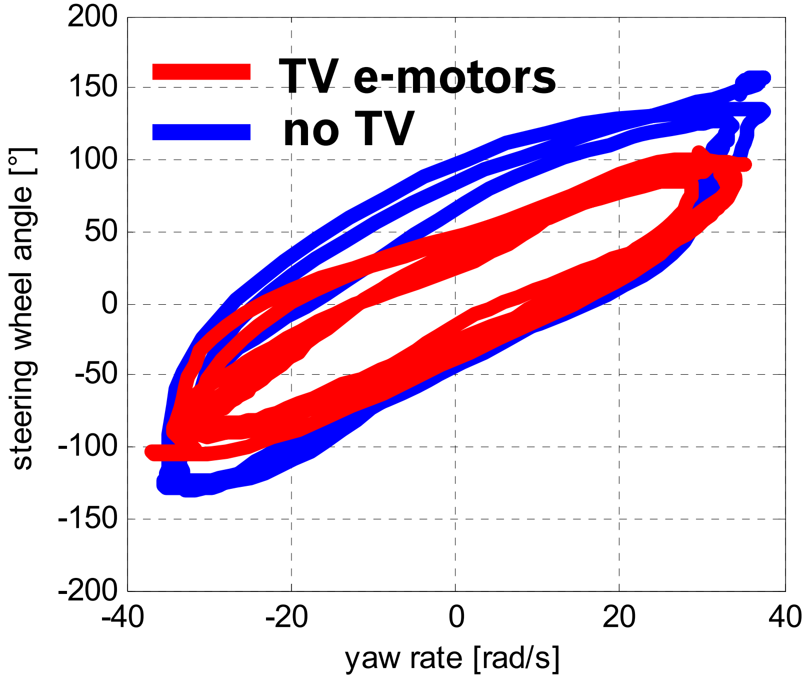
Experimental results – E-motors – slalom course

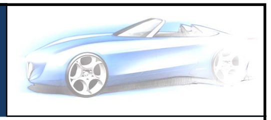


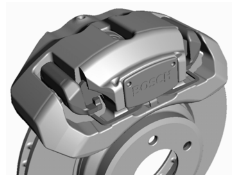
Speed difference
several attempts to find out maximum drive-through speed

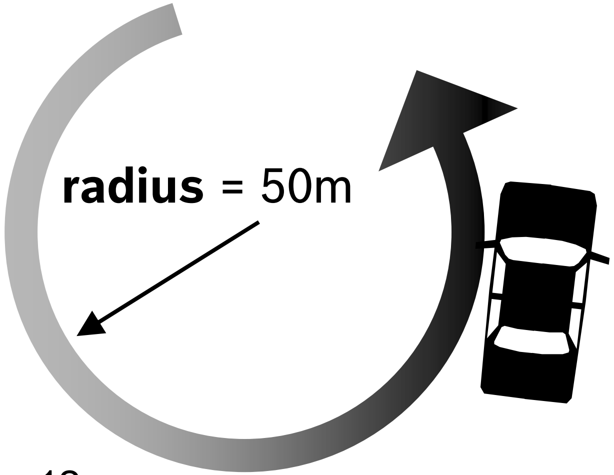
TV e-motors:	70 km/h
no TV:	66 km/h



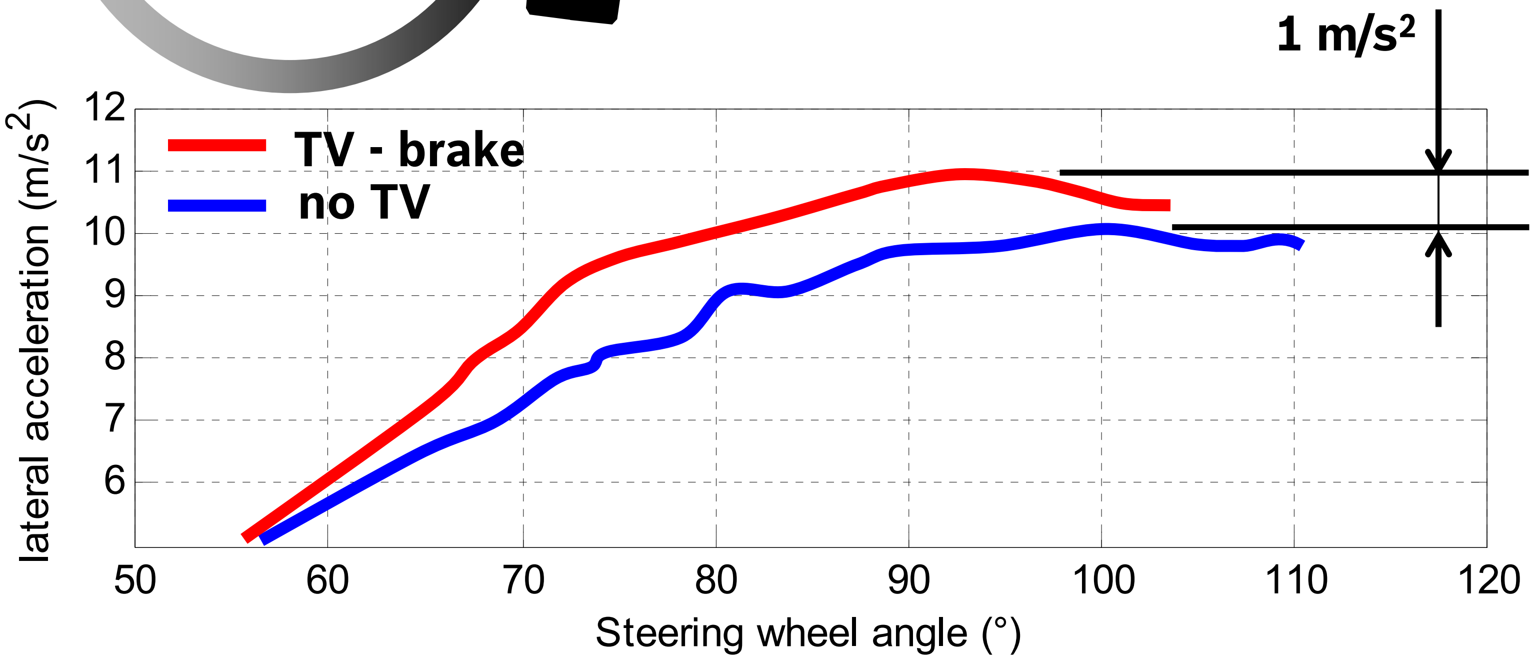
Experimental results – brake - skid pad testing



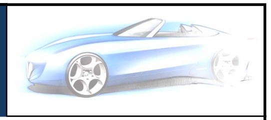


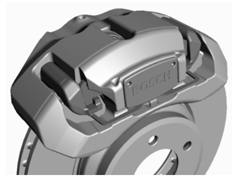


speed
slowly increasing until the vehicle leaves the circular path

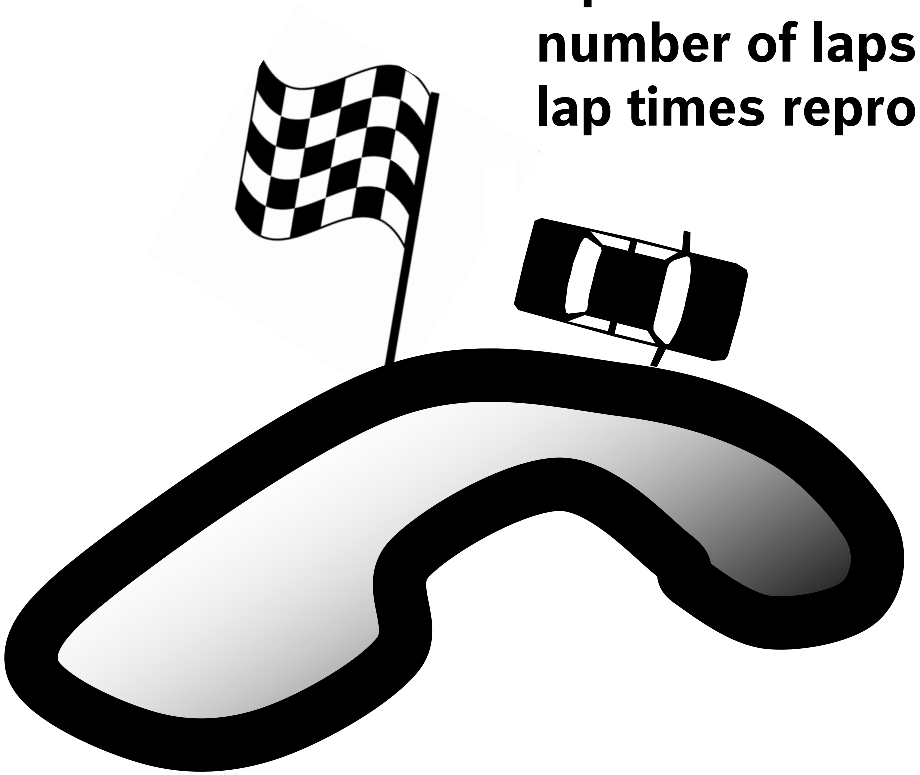


Experimental results – brake – race track driving





lap distance:	2.2km
number of laps:	2
lap times reproducibility:	< 0.2s



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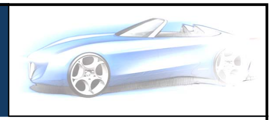
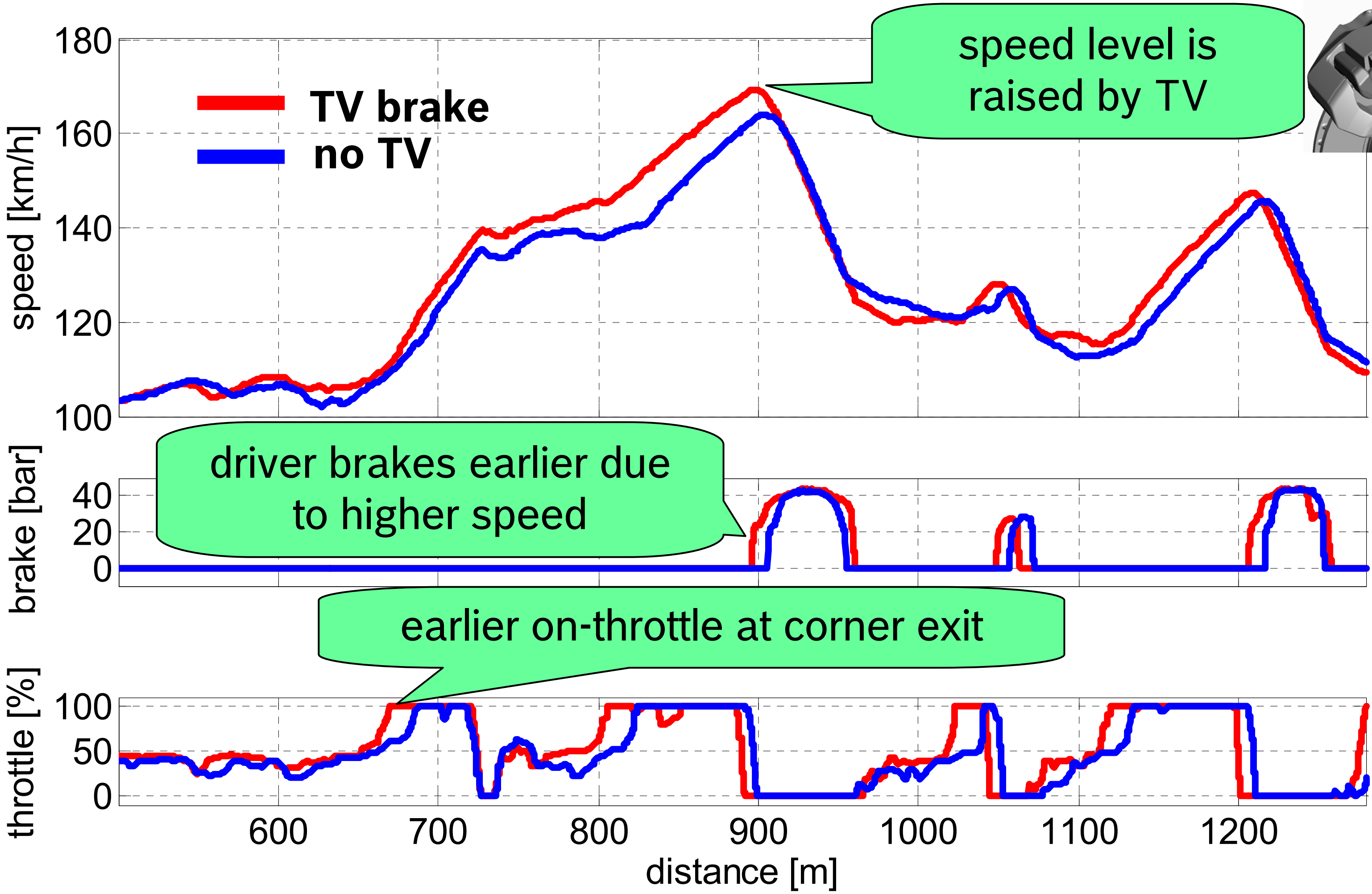
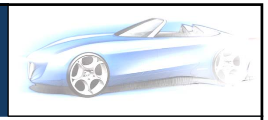
Experimental results – brake – race track driving







Measured improvement of lap times

Lap time reduction lap 1: 1.1 seconds

Lap time reduction lap 2: 0.95 seconds

Lap distance: 2.2 km

Lap time improvement by torque vectoring strongly depends on:

- Chassis setup of vehicle (this case: understeering)
- Engine capacity: possibility to maintain the speed offset after corner exit (this case: > 350kW)
- Capability of the driver to push the vehicle to the limit (this case: world class driver)

Remember that Nordschleife is 21km...

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Torque vectoring

--- An efficient method to improve vehicle dynamics ---

- Improvements in agility, safety, traction
- Chassis tuning without compromising on stability or comfort
- Benefits can be measured objectively
- Proven maturity of brake actuation concept
- Extended opportunities in multi-motor electric vehicles

Thank you for your attention

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