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Preventing Lateral Sliding in Curves

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Preventing Lateral Sliding in Curves
Motivation for Research Project Focusing on Safe Cornering

Motorcycle Stability Control (MSC)

- Safe braking and accelerating
- Homogenous, slightly varying friction

One challenging situation left

- Sliding wheels due to high friction changes
- **New** safety intervention **concept needed**

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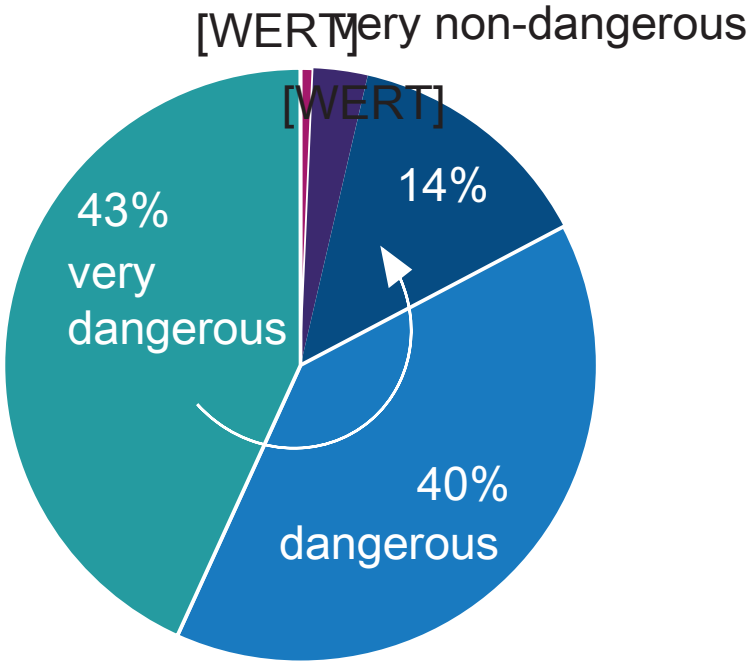
Motivation for Research Project Focusing on Safe Cornering

User Survey

- 500 active riders (>2000km/y)
- **Sudden friction change while cornering**
  - Situation **feared** by 83% of riders
  - 5% experienced already **low/high side**
  - Sliding mitigation system **most favoured** one (Realization not specified)



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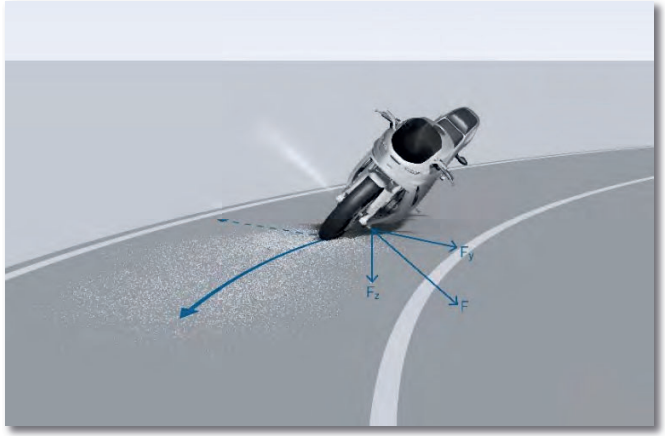
Preventing Lateral Sliding in Curves
Principle

- Generation of lateral **repulsion force** by **exhausting gas stream** to compensate low lateral tire force

- Repulsion force $F(t)$ „pushes“ sliding wheel/bike back
  - Bike **stays on** desired **track**
  - Temporary intervention
  - No control of roll angle

- Addressed situations
  - μ-patches (gravel-, oil patch)
  - ABS-braking over μ-jump



BikeSim simulation

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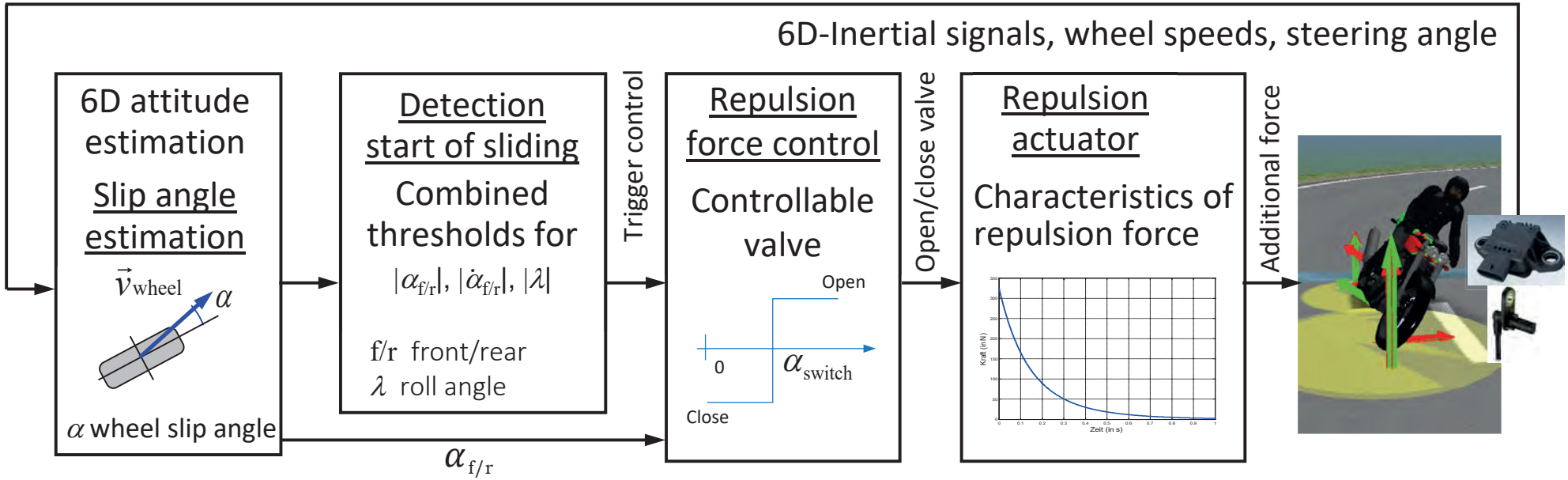
Control Loop



Intervenes only in case of an unpreventable crash

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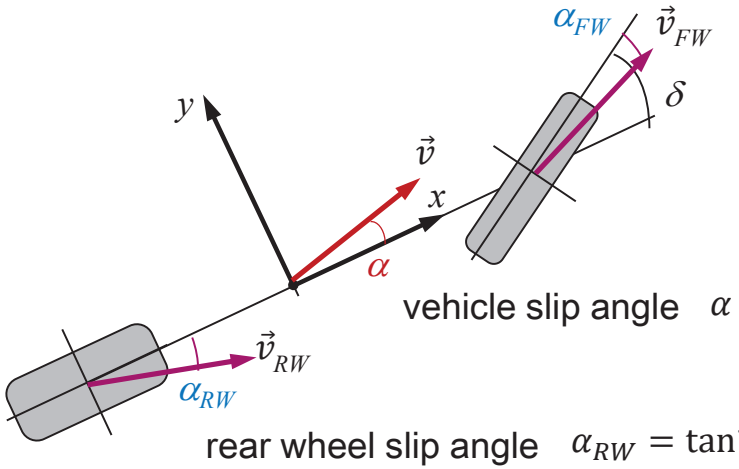
Slip Angle Estimation

front wheel slip angle $\alpha_{FW} = \tan^{-1}\frac{v_y^{FW}}{v_x^{FW}} - \delta$

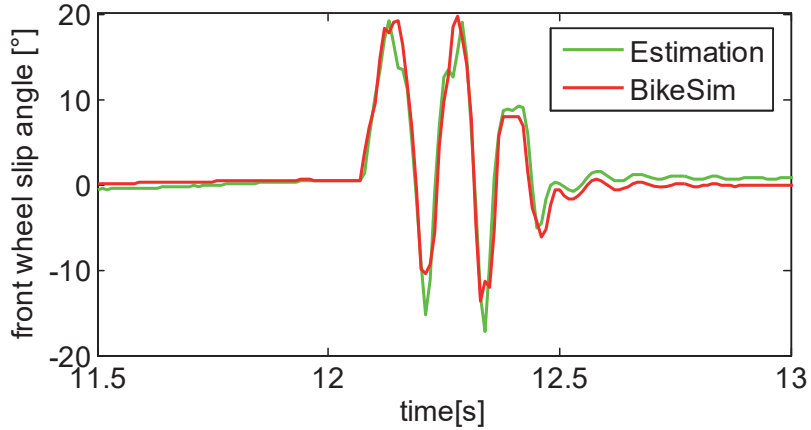


vehicle slip angle $\alpha = \tan^{-1}\frac{v_y}{v_x}$

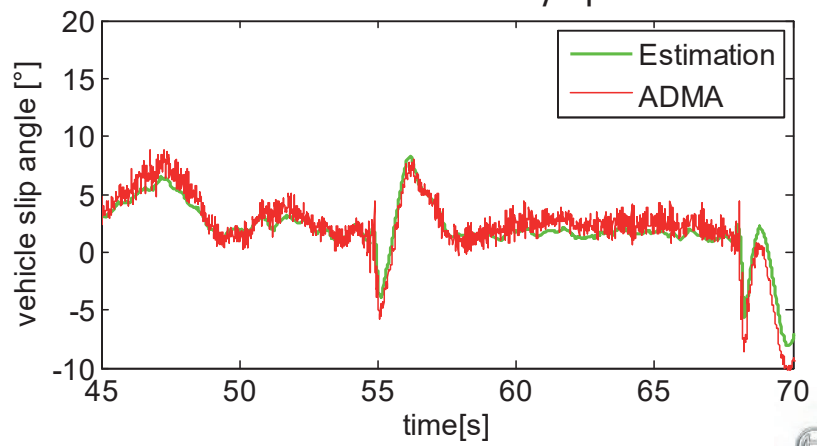
rear wheel slip angle $\alpha_{RW} = \tan^{-1}\frac{v_y^{RW}}{v_x^{RW}}$

- Slip angle estimation integrated into MSC
- 6D inertial and steering angle sensor used

Simulative evaluation: slalom with μ-patch



Measurement evaluation: μ-patch



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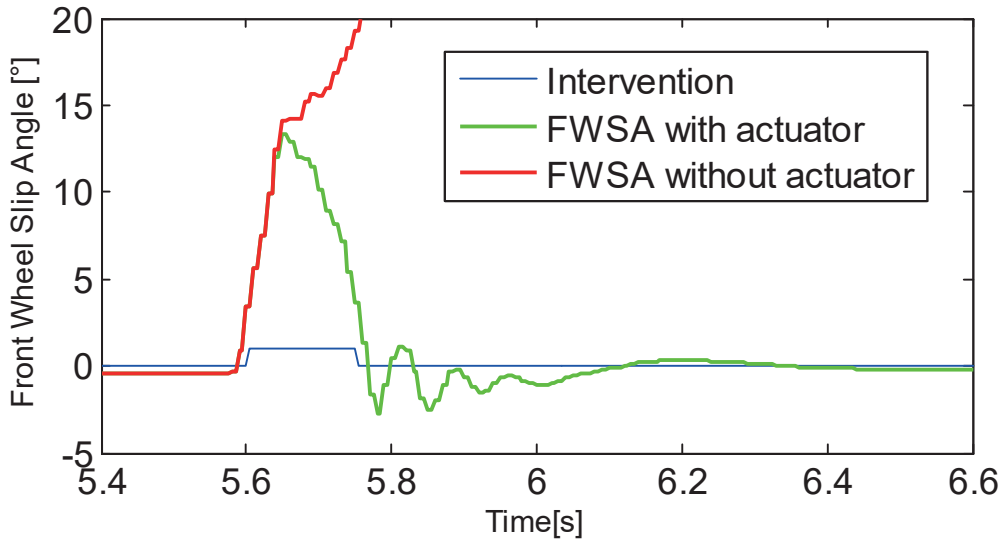
Preventing Lateral Sliding in Curves
Simulation studies

- Variation of force characteristic
  - Variation of intervention point
  - Controlled and uncontrolled gas exhaust
- Intervention strategy developed
- Functional actuator requirements deduced

Comparison: Front wheel slip angle (FWSA) w/o repulsion force, μ-patch



- Red: Increasing slip angle lead to capsize
- Green: Stabilization shortly after intervention

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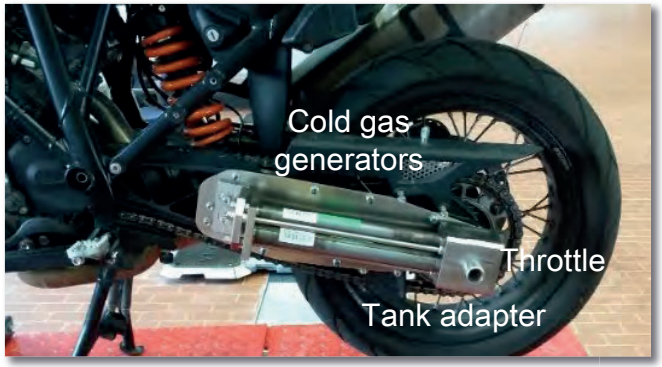
Preventing Lateral Sliding in Curves
Riding Test: Rear Wheel Intervention

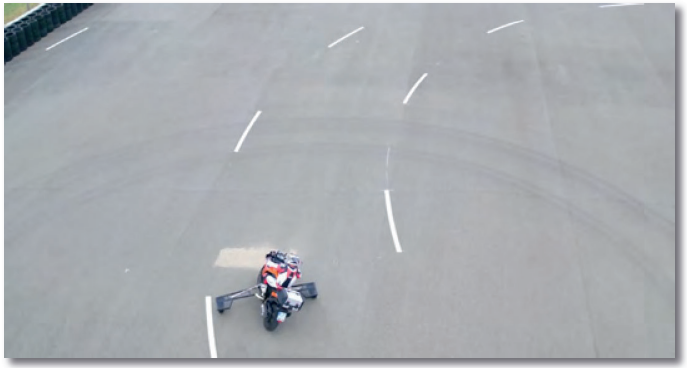
Test actuator

- 3 cold gas generators from passenger car airbags
- Mounted on rear swing arm



Scenario

- Strong rear wheel braking at gravel patch
- MSC active
- Radius r=25m, v0= 45km/h



Results

- Sliding rear wheel captured, no strong change in roll angle
- Rider feedback: “**Magic hand** which pushes you through the curve as if nothing has happened“

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Movie: Rear Wheel Intervention

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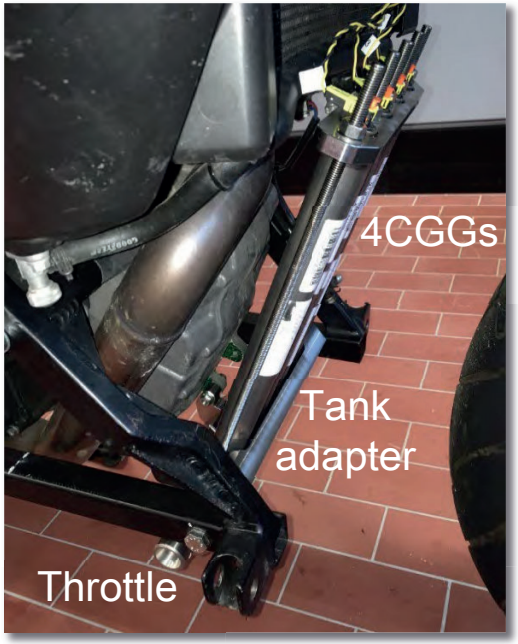
Riding Test: Intervention at Sprung Mass

Test actuator

- 4 cold gas generators (CGG)
- Mounted on sprung mass



Scenario

- Front wheel ABS-Braking over μ-patch
- MSC active
- Radius r=25m, v0= 45km/h

Results

- Test rider: “Maneuver critical with danger of crash”
- Sliding wheels captured, low-sider prevented

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Movie: Intervention at Sprung Mass

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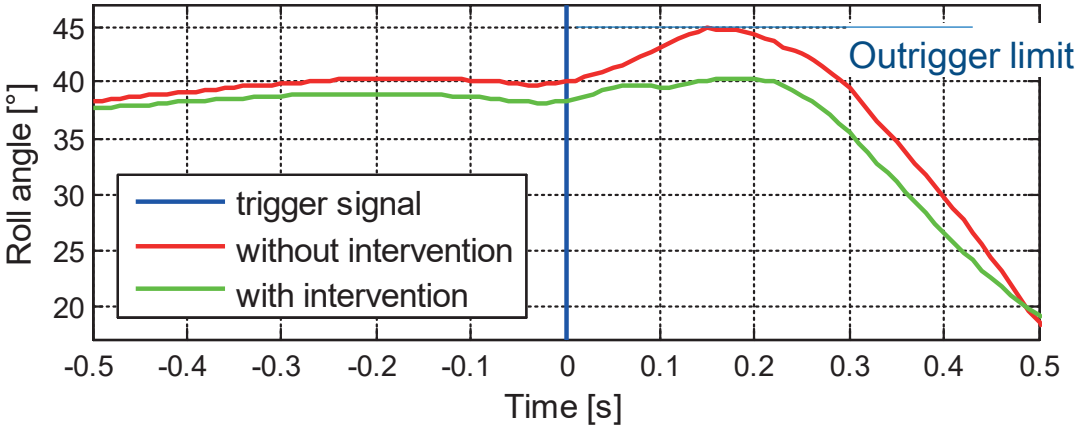
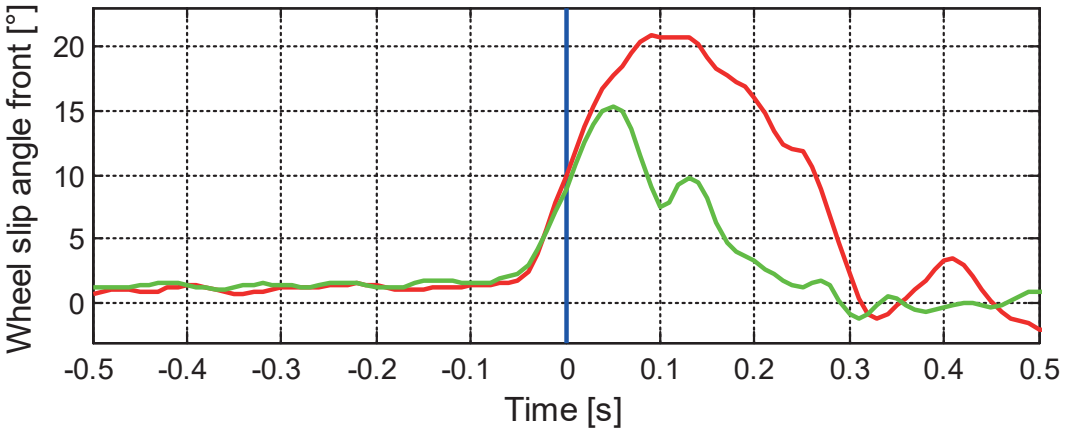
Riding Test: Intervention at Sprung Mass





Tests with outriggers

Green lines: With intervention

- Roll angle kept constant
- Slip angle increase stopped
- Crash prevented

Red lines: Without intervention

- Roll angle increase
- Large slip angle over significant time → Crash

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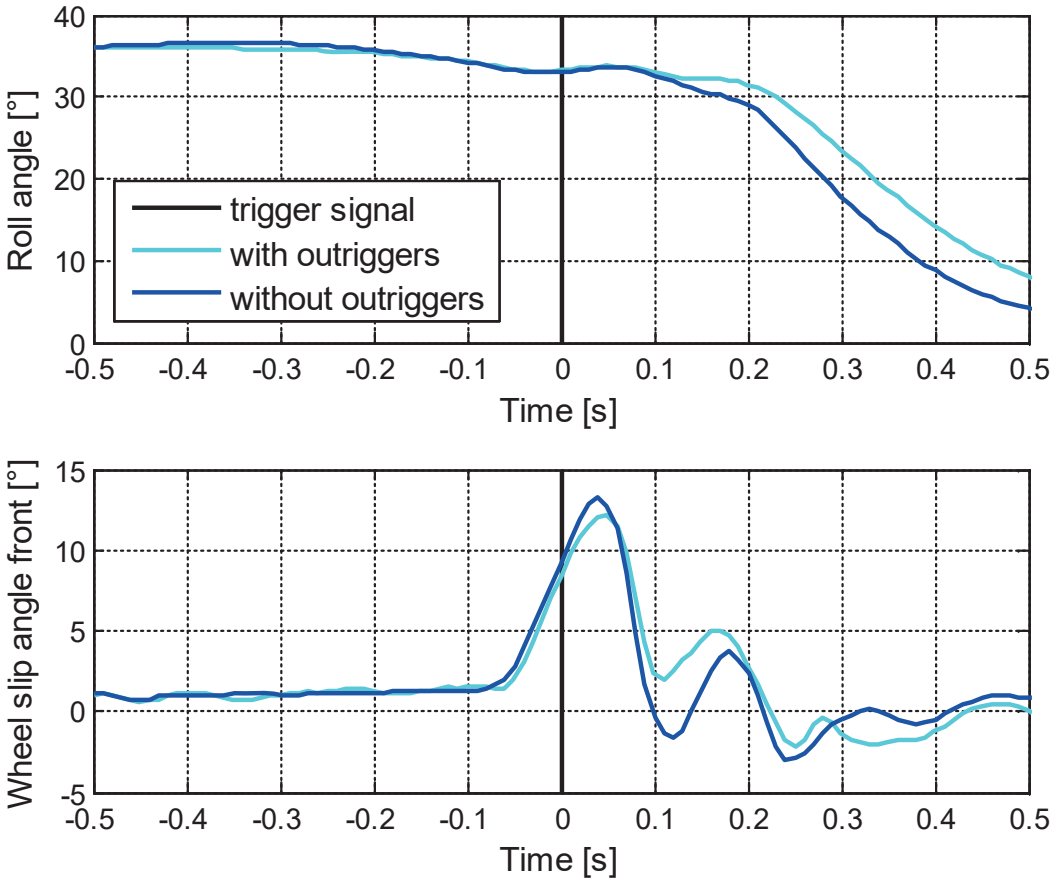
Comparison w/o Outriggers



- Comparable results
  - Roll angel kept constant
  - Slip angle increase stopped, settles
- Clear concept proof by riding tests without outriggers

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Preventing Lateral Sliding in Curves
Conclusion

- Clear concept proof in research phase achieved
- World's first active safety system of that kind
- Simulation based system design
- Reproducible test results

Challenges:

- System design for safe gas emission
- Crash safety, durability
- Bike integration


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