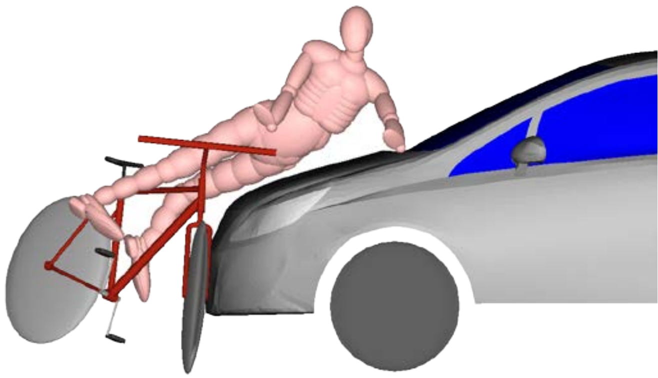
3rd International Cycling Safety Conference - ICSC 2014

Analysis of Cyclist Kinematics in Car Impacts considering different Vehicle Fronts, Collision Speeds, Body Heights and Impact Constellations

Gothenburg, November 18th 2014



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Agenda

- Introduction
- Simulation Models & Impact Scenarios
- Simulation Results
- Conclusions

Introduction

fka

- **Basic data:**
  - > Founded in 1981 as a spin-off from the Institute for Automotive Engineering (ika) of RWTH Aachen University
  - > Together with cooperation partner ika access to a total staff of approx. 420 employees
  - > Automotive customers from Europe, USA and Asia

Innovation Topics

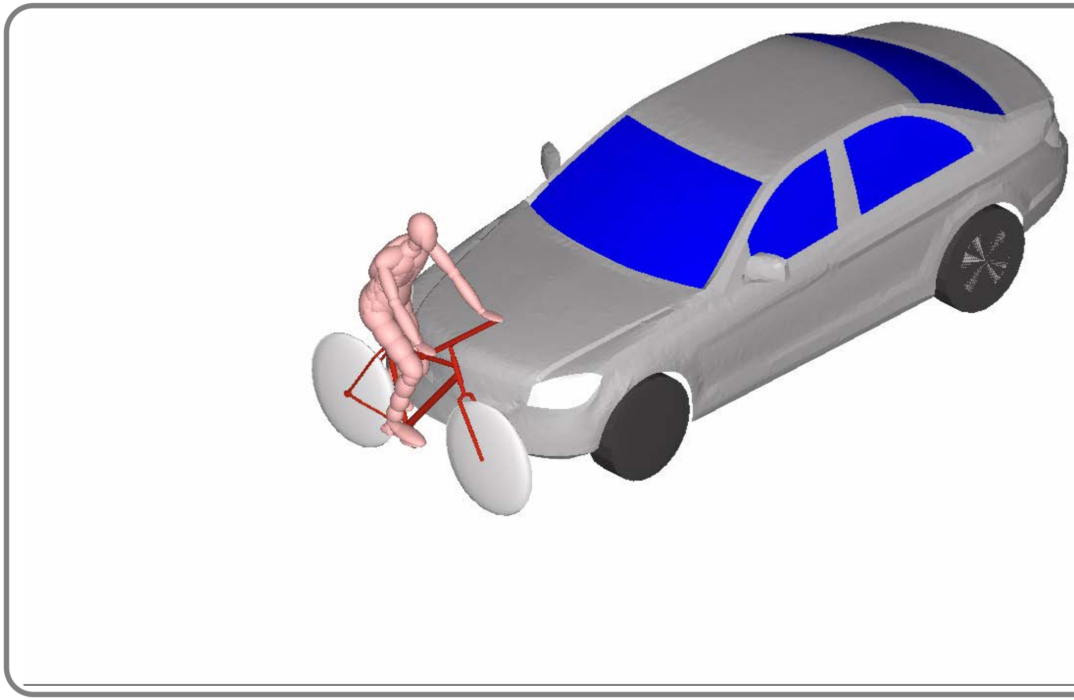
> Energy Efficiency

> Safety

> Driving Pleasure

Introduction
Simulation Study

- **Research objective:**
  - > A simulation study has been carried out in order to analyse the kinematics of cyclists in car accidents for a wide range of impact constellations
  - > Goal of the study is to provide a comprehensive overview of head impact locations, velocities and angles by consideration of different:
    - → Vehicle front geometries
    - → Cyclist models
    - → Pedal positions
    - → Impact scenarios
    - → Vehicle speeds
  - > Simulations have been conducted with MADYMO multi-body solver



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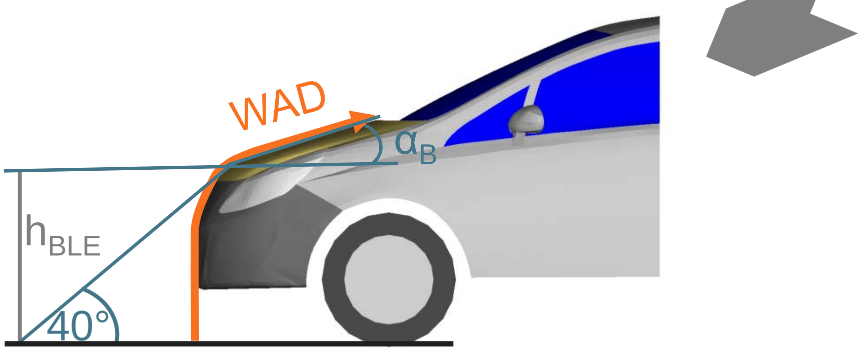
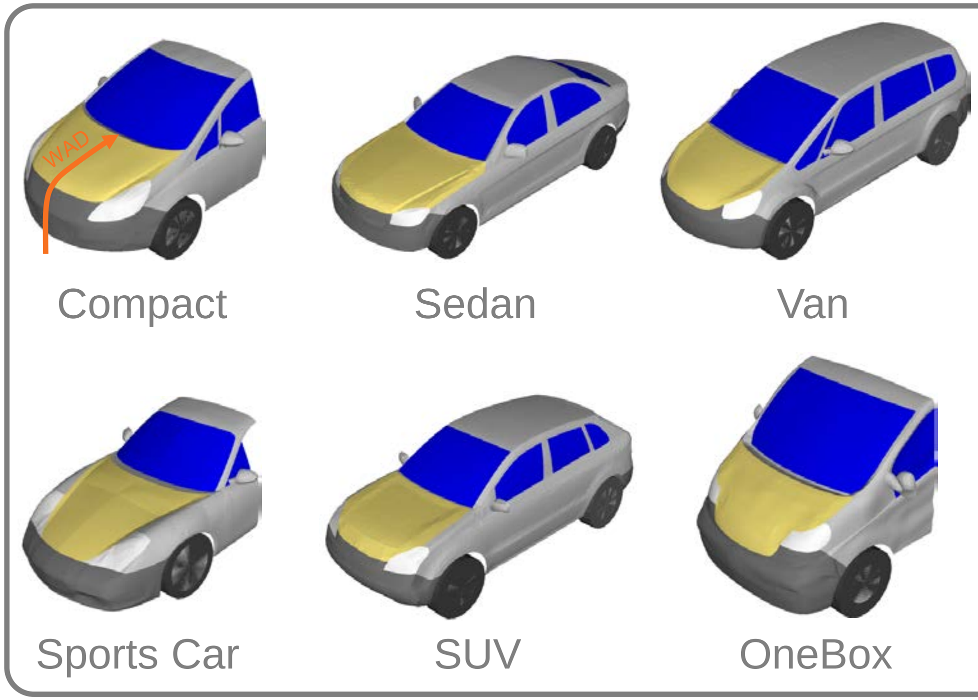
Simulation Models & Impact Scenarios
Vehicle Models

- **Six vehicle class representatives:**
  - > Influence of six real passenger car fronts, all representing different vehicle classes, on cyclist kinematics is examined
  - > Three geometrical parameters used for classification:
    - ➔ Height of bonnet leading edge (h_{BLE})
    - ➔ Wrap around distance (WAD) up to the bonnet rear edge
    - ➔ Bonnet angle (α_B)





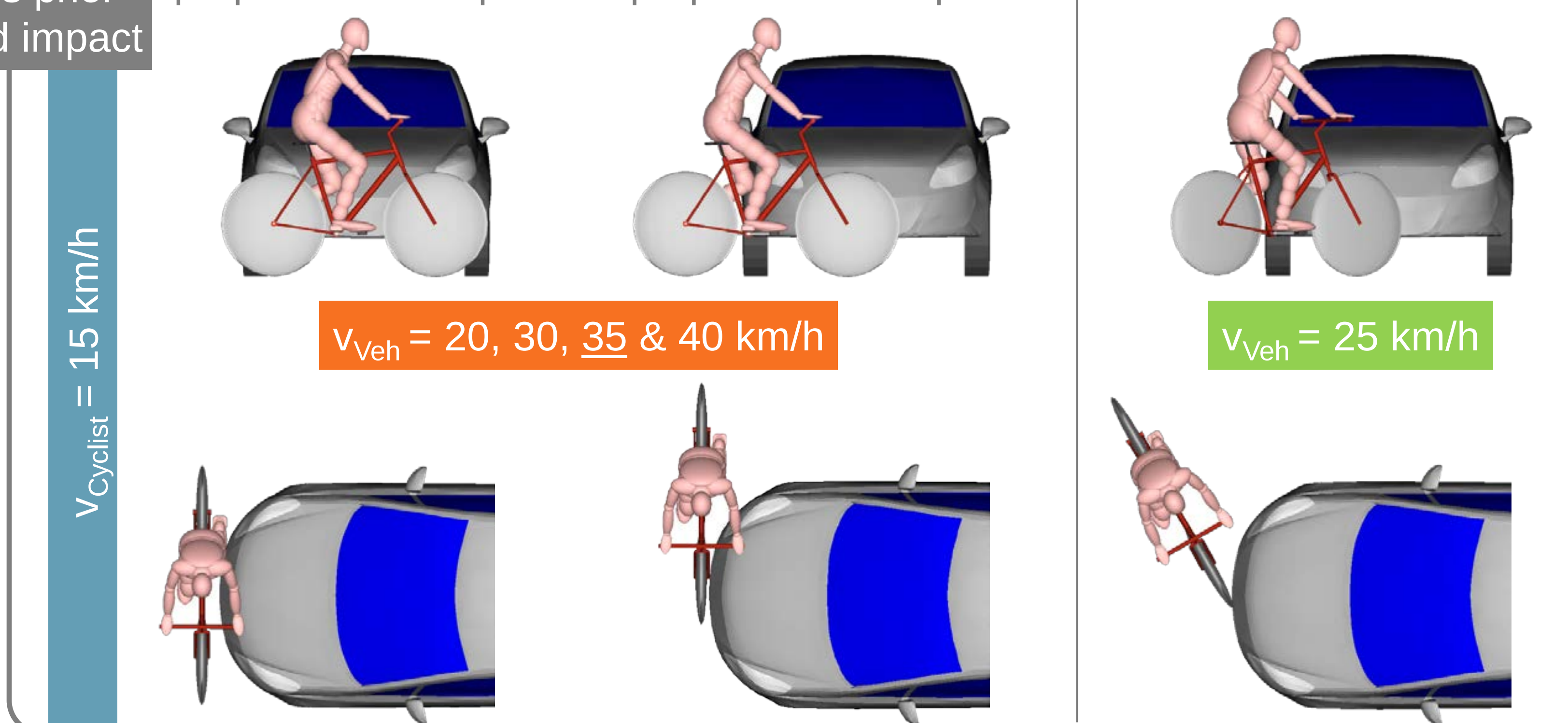
Simulation Models & Impact Scenarios

Impact Scenarios

- **Two perpendicular (crossing) scenarios & one oblique scenario:**
  - > Based on accident research data ➔ Perpendicular scenarios: $v_{Veh,\ Basis}$= 35 km/h
  - > Oblique scenario represents impact constellation with a turning car

No deceleration of vehicle models prior to primary head impact

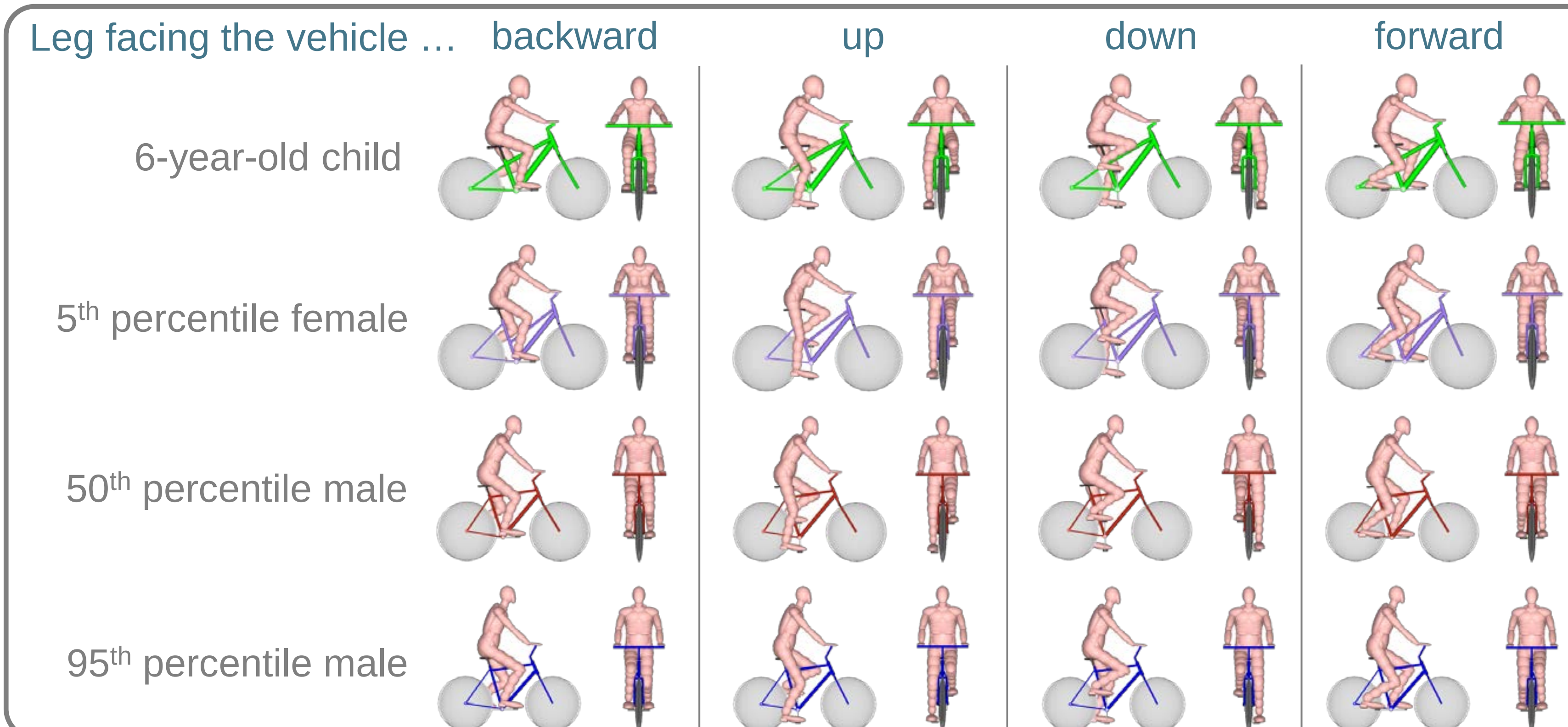
Central perpendicular impact	Outer perpendicular impact	Oblique scenario



Simulation Models & Impact Scenarios

Cyclist Models & Pedal Positions

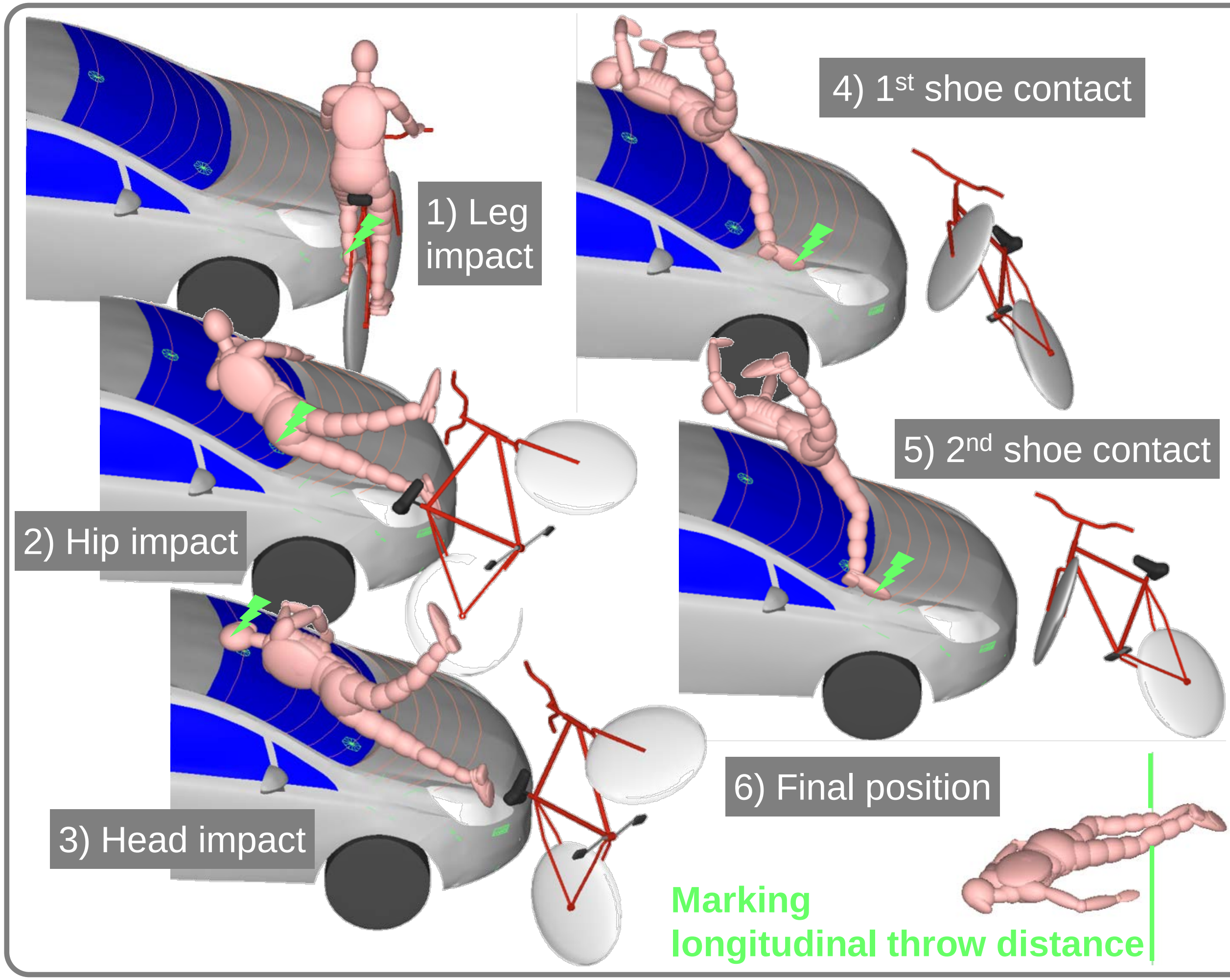
- **Four cyclist models & four pedal positions:**
  - Cyclist models cover a wide spectrum of possible cyclist statures
    - ➔ Size-specific bicycle model with MADYMO Ellipsoid Pedestrian Model placed on top
  - Pedal position has decisive effect on cyclist kinematics



Simulation Models & Impact Scenarios

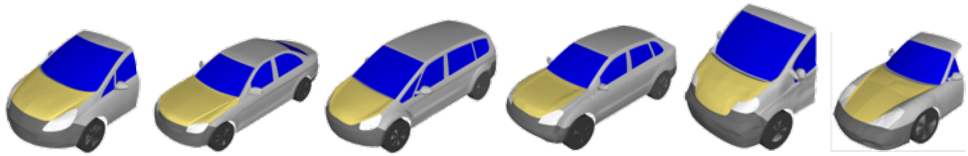
Validation of Simulation Models & Parameters

- **Reconstruction of a real accident (GIDAS database):**
  - Vehicle model
    - ➔ Compact
    - ➔ Average decelera-tion: 5 m/s^2
    - ➔ Inclined by 1.5°
    - ➔ Speed: 35 km/h
  - Cyclist model
    - ➔ 50%-male
    - ➔ Case specific bicycle model
    - ➔ Speed: 13 km/h
  - Impact locations of hip and head as well as final position of cyclist could be re-produced well

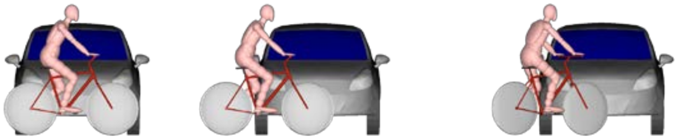


Simulation Models & Impact Scenarios
Overview

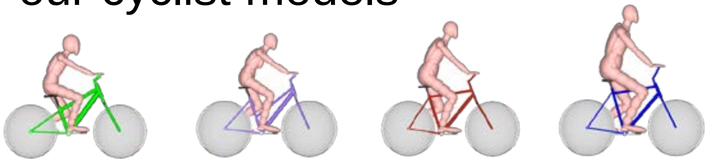
- **Number of simulations:**
  - Six vehicle models



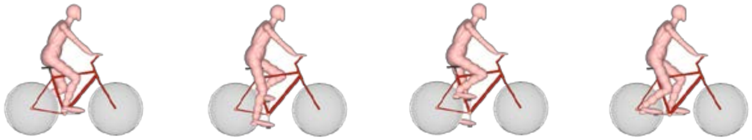
  - Three scenarios & four vehicle speeds (no speed variation for oblique scenario)



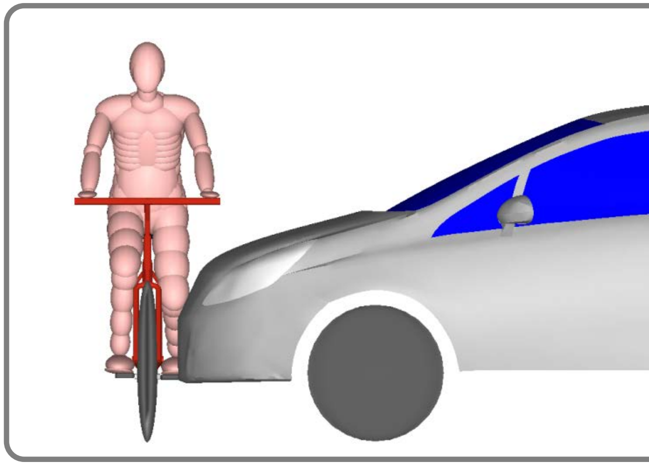
  - Four cyclist models



  - Four pedal positions



  - **864 simulations**



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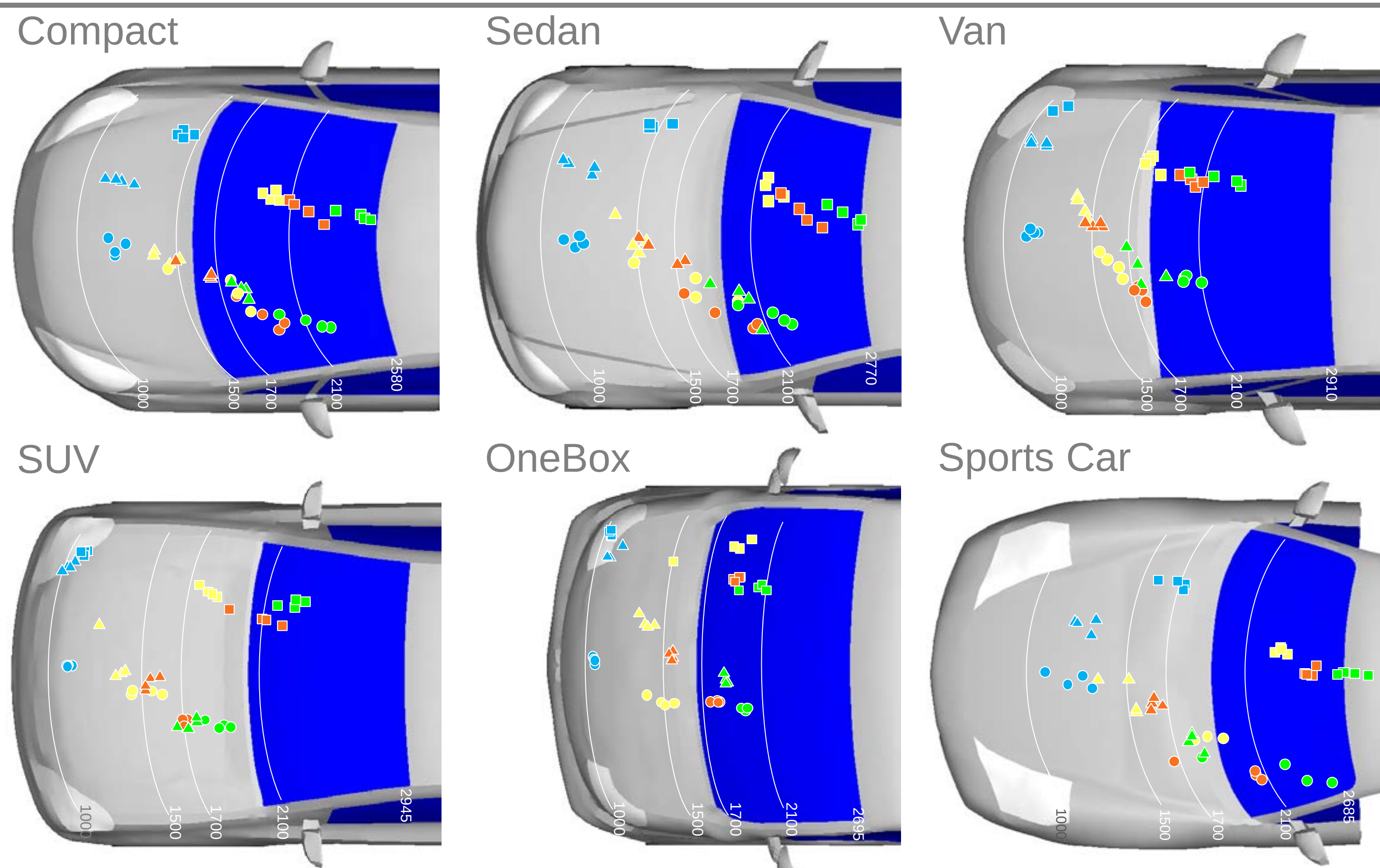
Simulation Results

Head Impact Locations

- **Head impact locations differentiated by scenario & cyclist model:**
  - > Impact area can reach until roof leading edge, for sports car even beyond

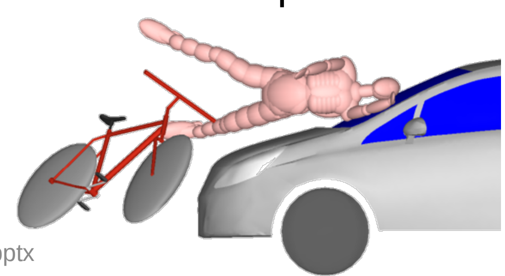
<u>Central & outer perpend. impact:</u>
v_{Veh} = 35 km/h
<u>Oblique scenario:</u>
v_{Veh} = 25 km/h

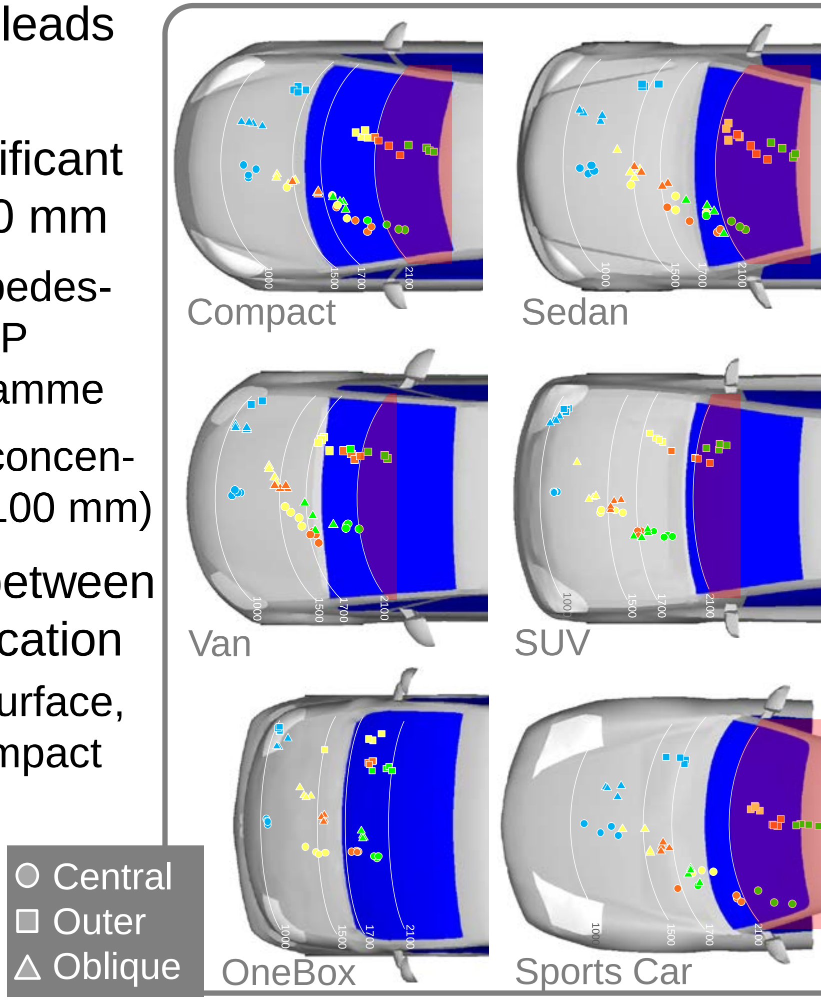
- ○ C6y - Central
- □ C6y - Outer
- △ C6y - Oblique
- ○ F05 - Central
- □ F05 - Outer
- △ F05 - Oblique
- ○ M50 - Central
- □ M50 - Outer
- △ M50 - Oblique
- ○ M95 - Central
- □ M95 - Outer
- △ M95 - Oblique



Simulation Results
Head Impact Locations

- **Head impact locations differentiated by scenario & cyclist model:**
  - > Outer perpendicular impact constellation leads to highest WAD values
  - > Sports Car, Sedan & Compact show significant share of head impacts beyond WAD 2100 mm
    - ➔ Marks end of head test zone defined for pedes-trian protection assessment by Euro NCAP
      - ▶ European New Car Assessment Programme
    - ➔ Safety measures related to head impact concen-trate on defined test area (WAD 1000 - 2100 mm)
  - > Cyclist speed of 15 km/h leads to offset between point of initial contact and head impact location
    - ➔ Diagonal motion of dummy over bonnet surface, with head impact more forward than leg impact

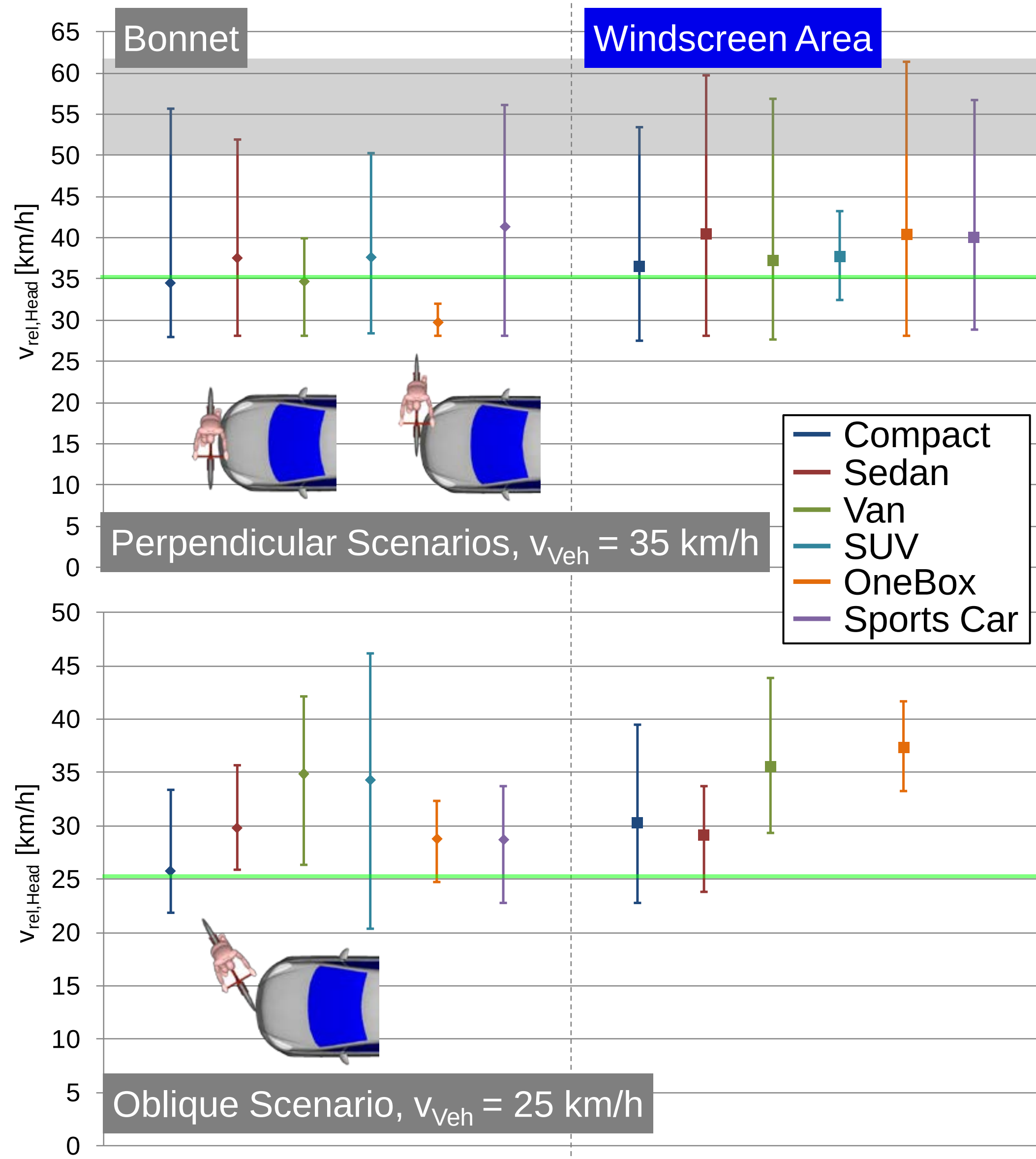




Simulation Results

Head Impact Velocity

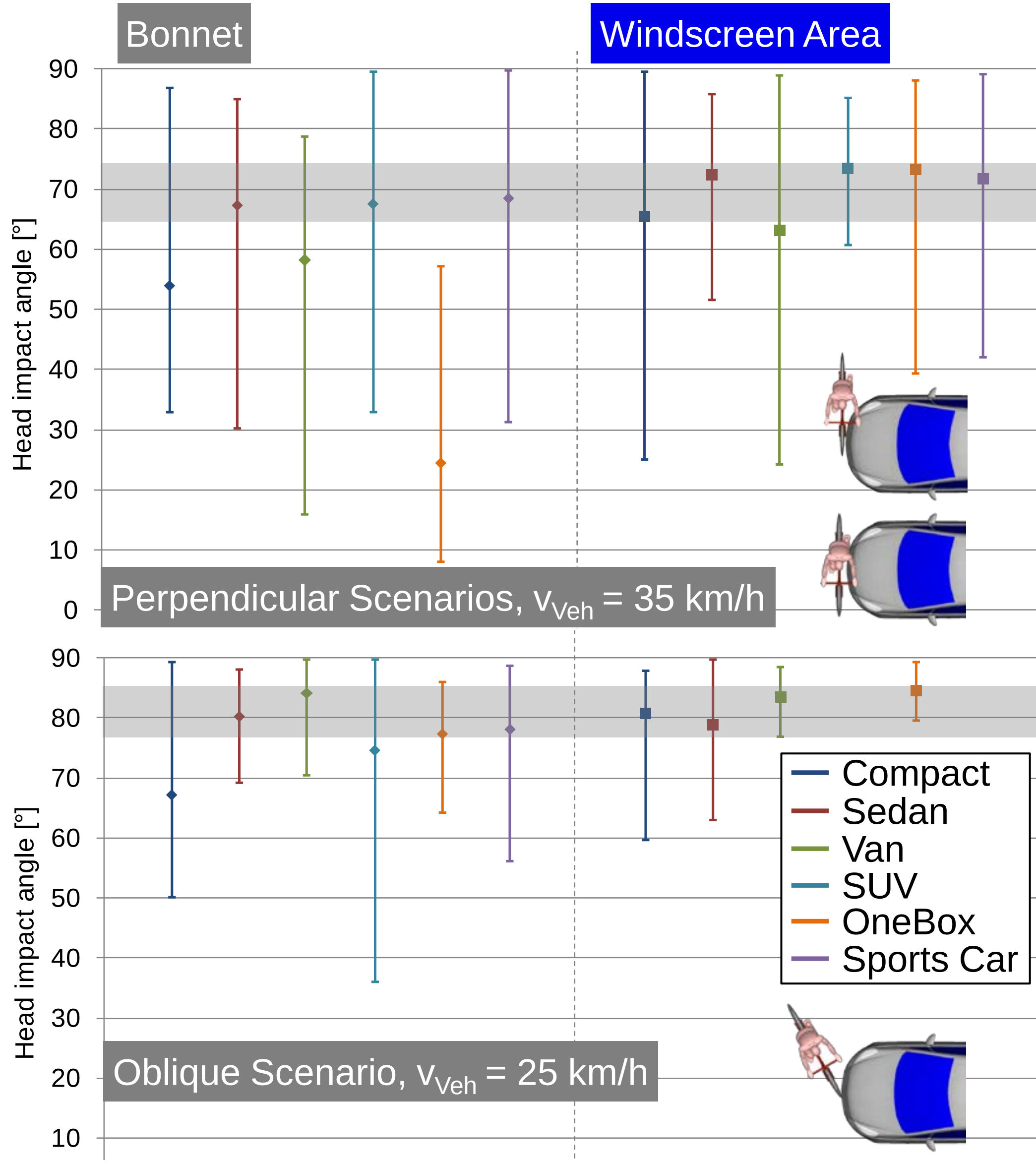
- **Perpendicular scenarios:**
  - > Broad spectrum of impact velocities
  - > Maximum values achieved often lie far above collision speed
    - ➔ $v_{rel,\ Head,\ max}$ = 61 km/h
  - > Even average values usually higher than collision speed
- **Oblique scenario:**
  - > Head impact velocity level again significantly higher than collision speed
    - ➔ $v_{rel,\ Head,\ max}$ = 46 km/h
  - > No head impacts on wind-screen for SUV & Sports Car



Simulation Results

Head Impact Angle

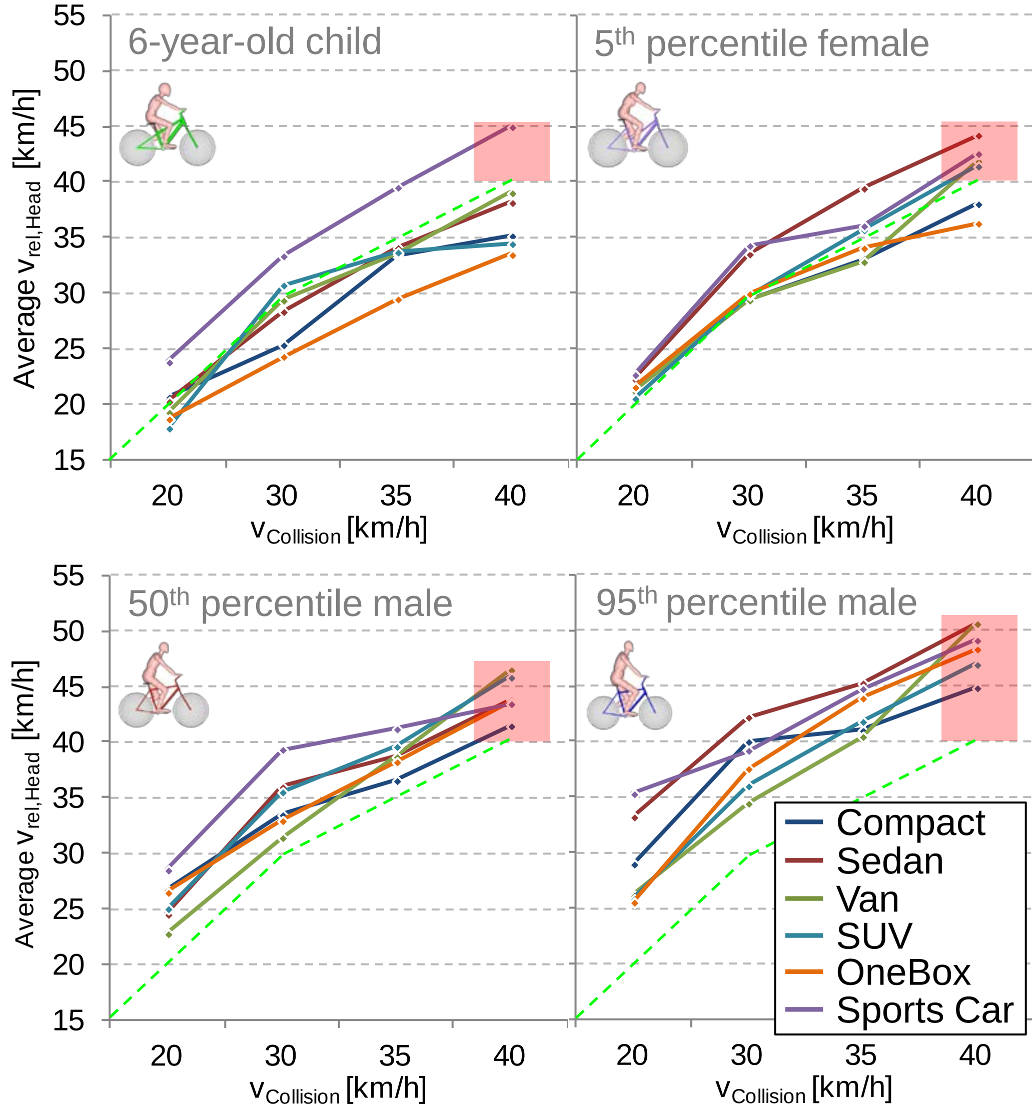
- **Perpendicular scenarios:**
  - > Impact angles reaching from below 20° up to almost 90°
  - > Average values for Sedan, SUV & Sports Car about 70° for bonnet & windscreen area
  - > OneBox with lowest average value for bonnet area (24°) and highest average value for windscreen area (73°)
- **Oblique scenario:**
  - > Angles less scattered & higher
  - > Average values in windscreen area all about 80°
  - > Same applies to bonnet area for most vehicles



Simulation Results

Influence of Vehicle Speed

- **Perpendicular scenarios:**
  - > Four vehicle speeds:
    - ➔ 20, 30, 35 & 40 km/h
  - > Reduction of collision speed leads to forward displacement of head impact locations
  - > Effect less pronounced for front geometries with high bonnet leading edge
    - ➔ SUV & OneBox
  - > Average head impact velocity for 50^{th} & 95^{th} percentile male always above collision speed
  - > Velocity level for cyclist head impact can be considerably higher than existing testing level for pedestrian protection



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Conclusions

- In order to analyse the kinematics of cyclists in car accidents a wide range of impact constellations has been simulated.
- The simulation results reveal an extended head impact area, which can already reach up to the roof leading edge for vehicle speeds of 35 km/h.
- Furthermore, the study shows high values for head impact velocity as well as angle. Even the average values for the head impact velocity usually lie above the collision speed.
- These characteristics of cyclist-passenger car collisions have to be taken into account when developing vehicle related safety measures for cyclists.
- With regard to the high head impact velocities observed within the simulations, a reduction in collision speed by autonomous braking would be one of the most promising safety measures.
- In a next step Polar-II dummy tests with an experimental vehicle will be performed in order to gain further insights into the kinematics of cyclists.
- Those tests will also allow an analysis of the cyclist crash loads for both primary and secondary impact.

Thank you for your attention !

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