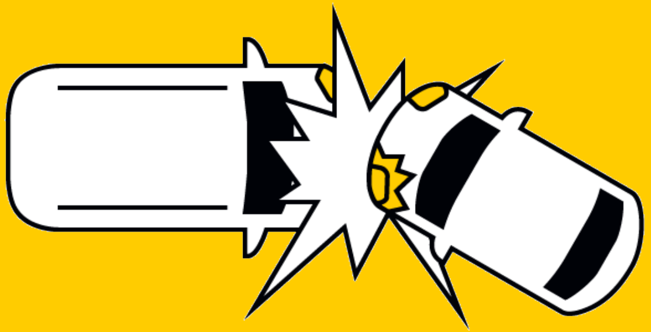
ADAC

Investigation of Active Pedestrian Protection Systems using the Biofidelic Dummy and Component Tests

ADAC Technik Zentrum Landsberg

David Altkofer

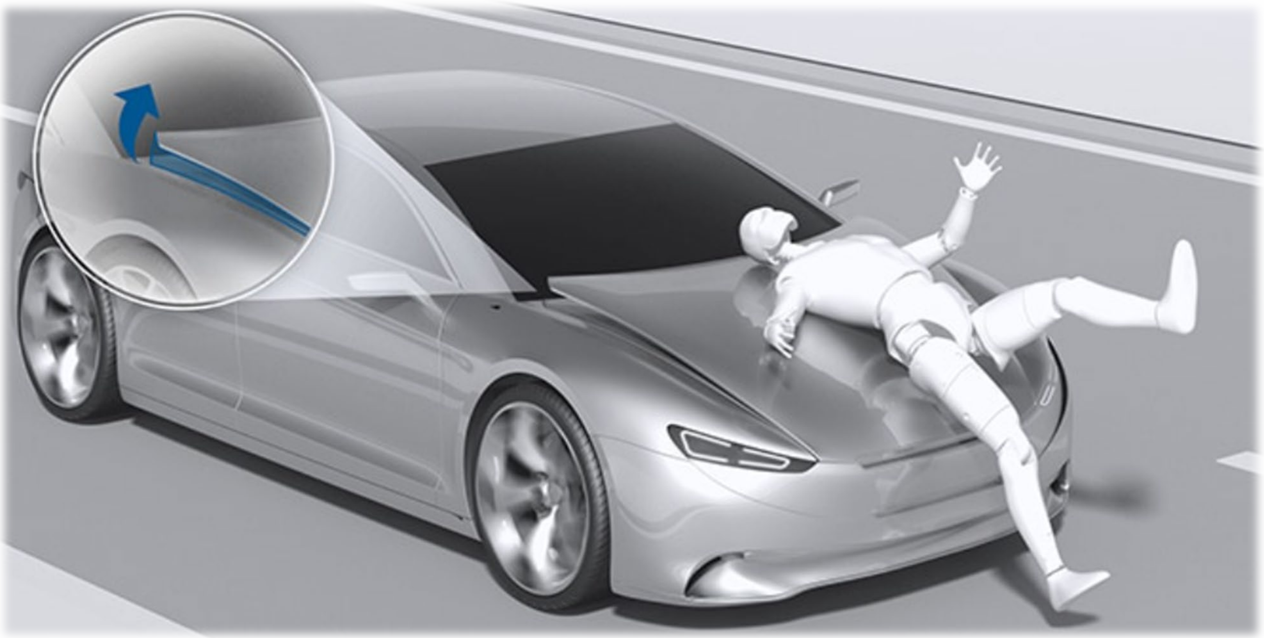


Agenda

1. **Motivation**
2. **Investigation of the potential of reversible active bonnet systems**
   - **2.1 Results of Full-Scale-Tests**
   - **2.2 Results of Component-Tests**
3. **Comparison**
4. **Activation of reversible bonnets**
5. **Integration into consumer protection projects**

1. Motivation

- goal: use deployable bonnets in conjunction with ADAS and avoid contact based sensors
- more time until collision means more time to take action (e.g. more distance)
- more safety potential for VRUs
- main problem is the irreversibility which leads to false-positive-risk



→ not applicable with ADAS sensors

→ remedy: reversible mechanism (e.g. hood lock)

1. Motivation

aims of the project

- investigate the safety potential for VRUs using a reversible mechanism for deployed bonnets

- therefor comparison with three bonnet configurations
  - reference ⇒ closed bonnet
  - state of the art ⇒ rear deployed
  - front deployed ⇒ deployment using the hood lock mechanism

- testing in full-scale-tests with a biofidelic crashtest dummy and the established test specimens

- generating recommendations / proposals

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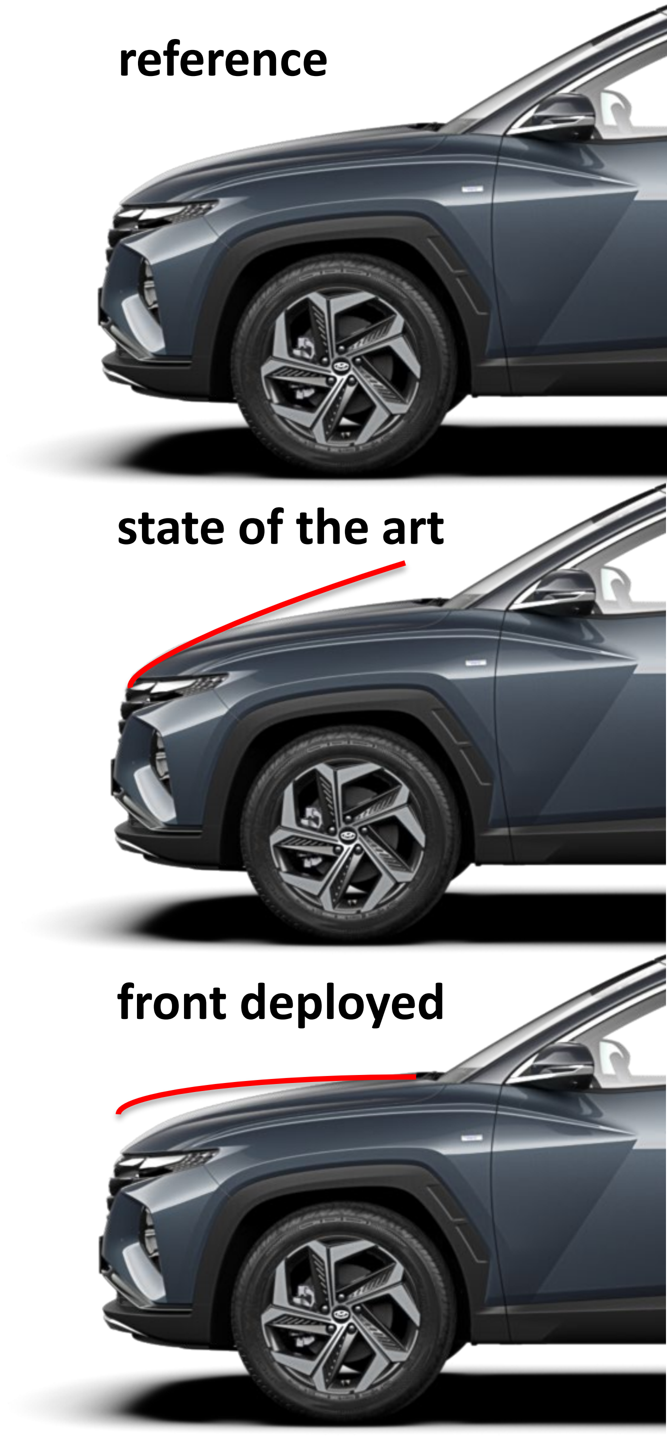
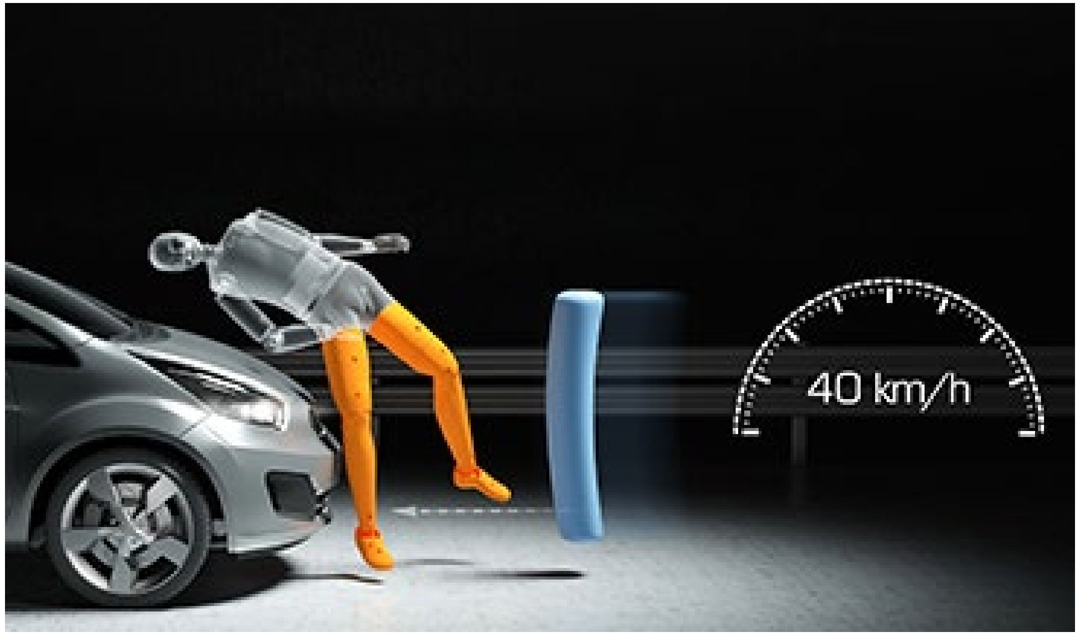
2. Testing with deployable bonnets

Konfiguration	Test Specimen / Dummy	Testnumber
Full-Scale-testing		
Reference	Primus breakable	PP4223AAFR
State of the Art	Primus breakable	PP4523AAFS
Front Deployed	Primus breakable	PP5123AAFF
Component-testing		
test series for comparison with Full-Scale-tests		PP0224AAC1
Reference	Adult Head	AACAR08+0
	Upper Leg	AACUR+0
	aPLI	AACLR+0
State of the Art	Adult Head	AACAS08+0
	Upper Leg	AACUS+0
	aPLI	AACLS+0
Front Deployed	Adult Head	AACAF07+0
	Upper Leg	AACUF+0
	aPLI	AACLF+0
test series for further evaluation		PP0224AAC2
Reference	Child Head	AACCR01+5
		AACCR04-7
State of the Art		AACCS01+5
		AACCS04-7
Front Deployed		AACCF01+5
		AACCF04-7



2. Testing with deployable bonnets

https://www.euroncap.com/en/car-safety/the-ratings-explained/vulnerable-road-user-vru-protection/head-impact



Adult / Child Head

Upper Legform

aPLI

2. Testing with deployable bonnets

modifications

lifting the rear edge by modified hinges

- ➢ generating 100mm at WAD1700

lifting the leading edge by compression springs (total rate: 80N/mm)

- ➢ generating 40mm

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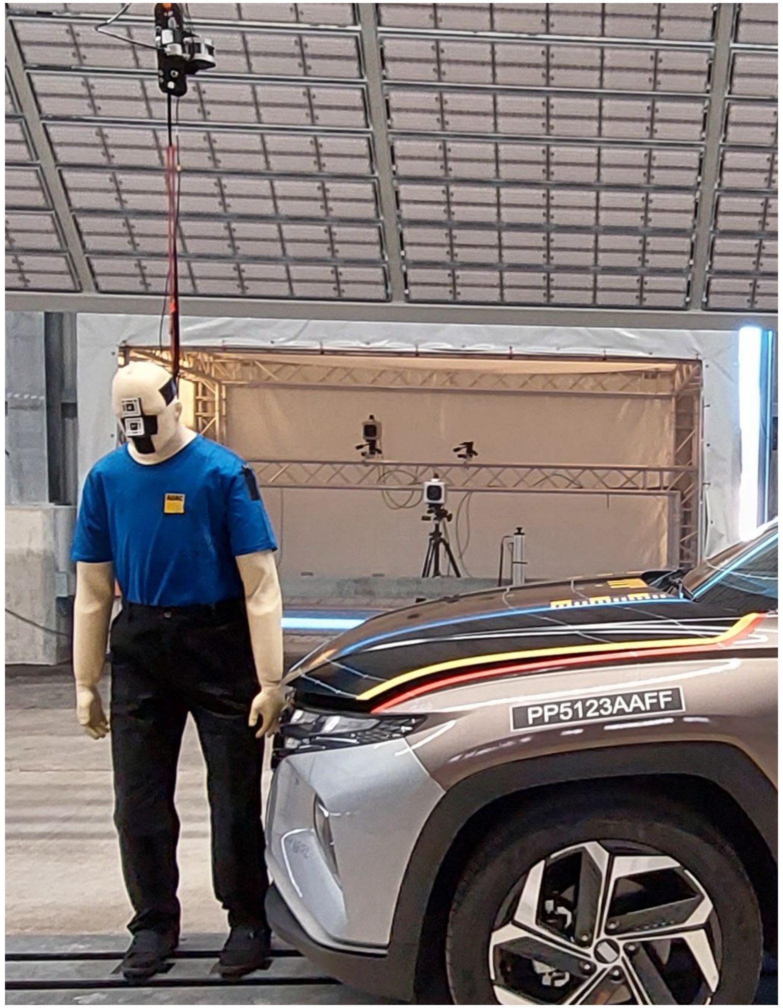
2.1 Full-Scale-testing

biofidelic crashtest-dummy „Primus breakable“

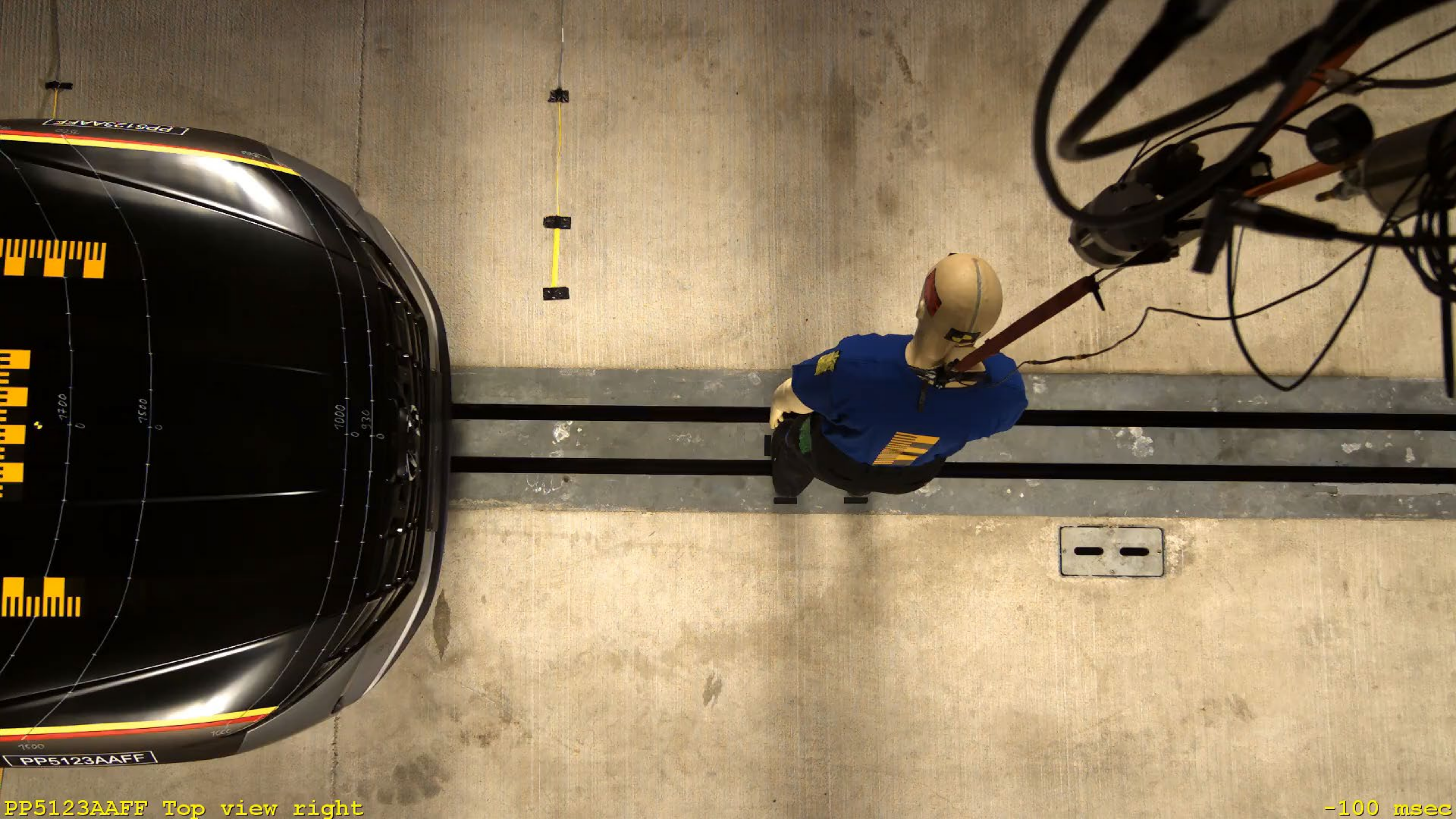
- anthropomorphic manikins are subject to the compromise between durability and biofidelity
- focus on biofidelity
- replacement materials for bones, muscles, tendons, ligaments, ...
- technical obduction after a crash
- acceleration sensors in head, chest and pelvis

2.1 Full-Scale-testing

positioning of the dummy




PP4523
PP4523AAFS Left
-020 msec



PP5123AAFF
PP5123AAFF
PP5123AAFF Top view right
-100 msec


PP5123AAFF Onboard driver view
-200 msec

2.1 Full-Scale-Testing

evaluation - Injury criteria

criterion	reference	state of the art	front deployed	limit values
Head: HIC_{15}	3.707	4.037	5.688	700
Head: a_{3ms}	99g	210g	122g	80 g
Head: $a_{res,\,max}$	377g	356g	536g	300 g
Head: $BrIC$	1,17	1,07	1,07	1,0
Head: $\ddot{\alpha}_{res,\,max}$	13.584rad/s²	16.266rad/s²	18.435rad/s²	1.800 ... 7.500 rad/s²
Chest: a_{3ms}	29g	30g	33g	40 ... 60 g
Chest: $a_{res,\,max}$	33g	61g	57g	80 g
Pelvis: a_{3ms}	44g	40g	56g	50 ... 80 g
Pelvis: $a_{res,\,max}$	189g	181g	310g	80 g

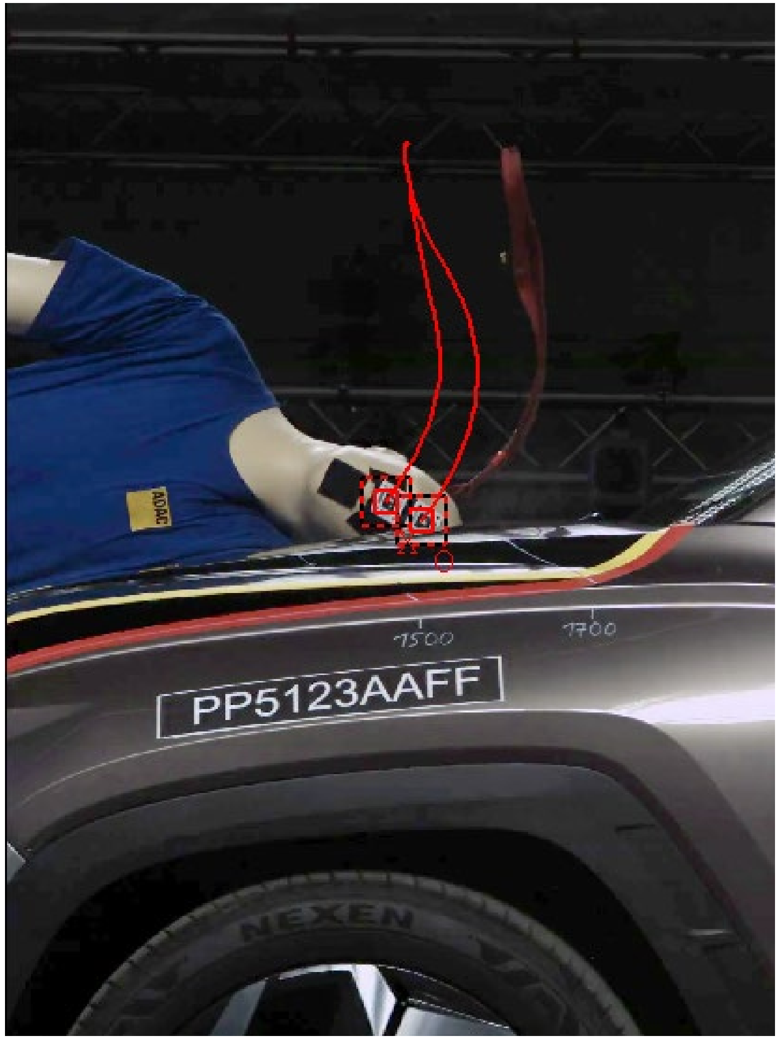
➔ key message: no improvement by the bonnet deployment

2.1 Full-Scale-testing

head velocity

PP4523AAFS

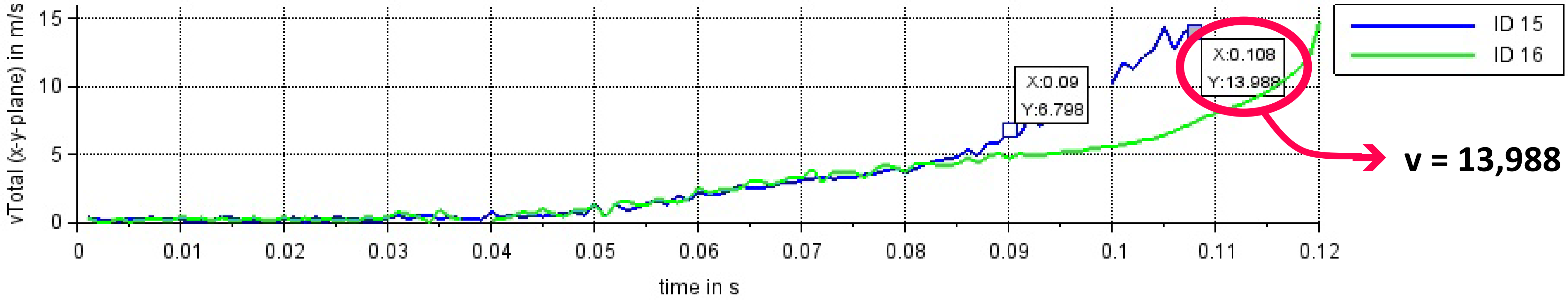
PP5123AAFF



2.1 Full-Scale-Versuche

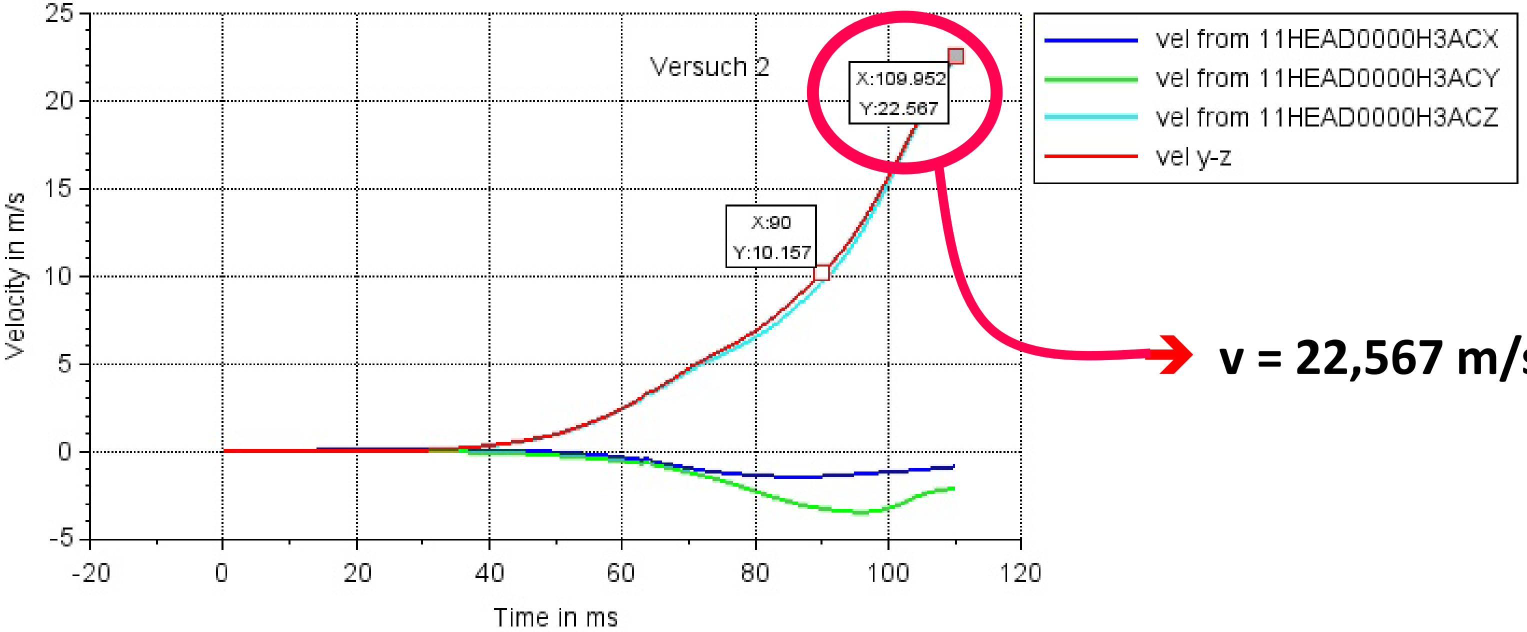
evaluation – head velocity shortly before collision

6D-Tracking



v = 13,988 m/s

integration



v = 22,567 m/s

!

comparison:

v_t = 11,11 m/s

(40km/h)

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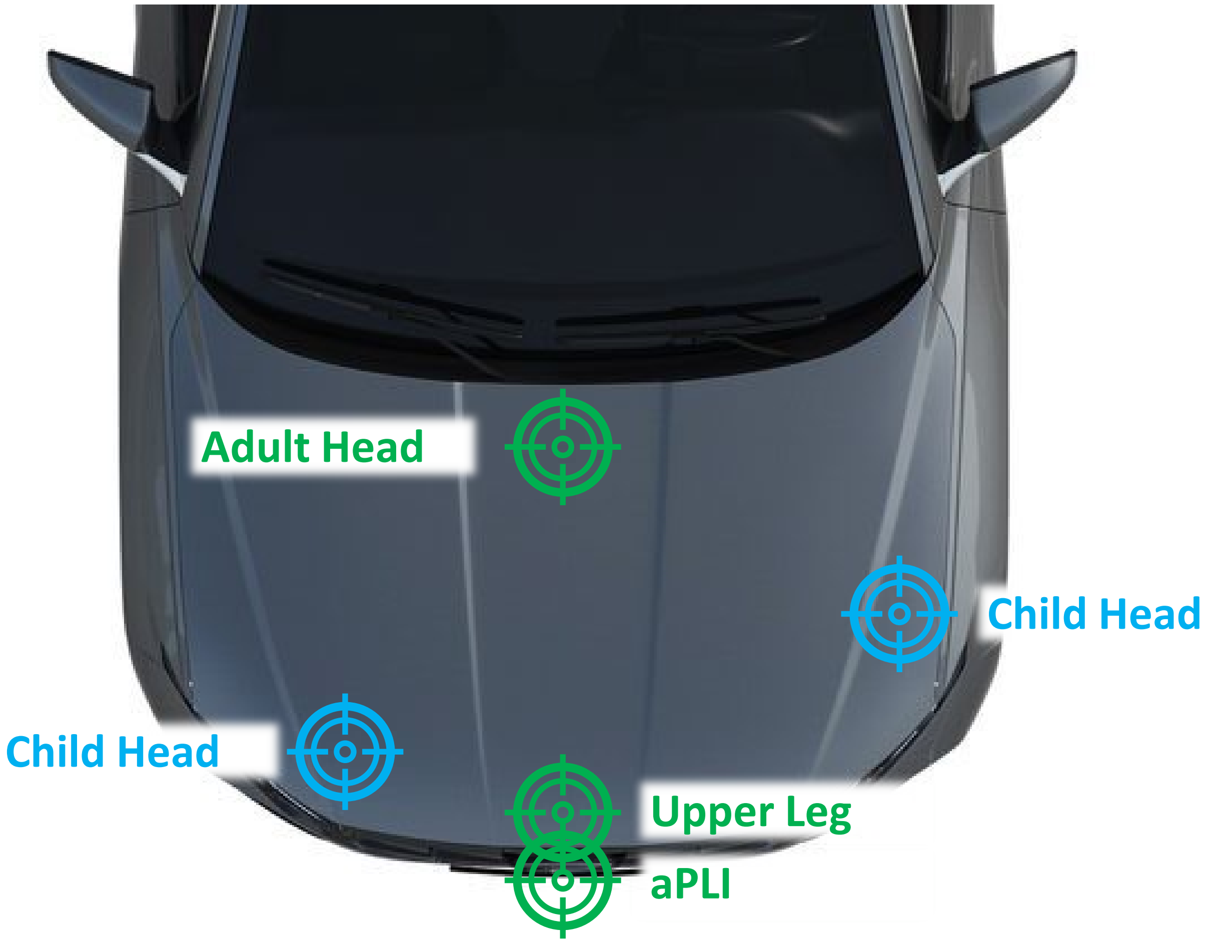
2.2 Component-Tests

testpoints

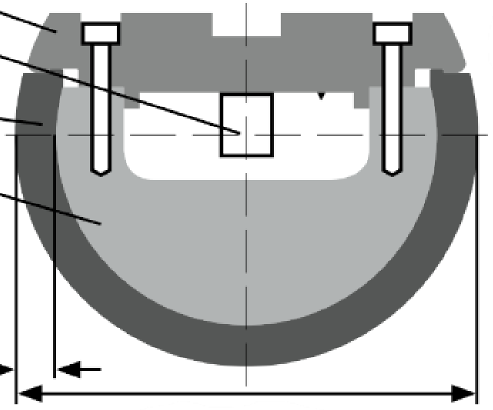


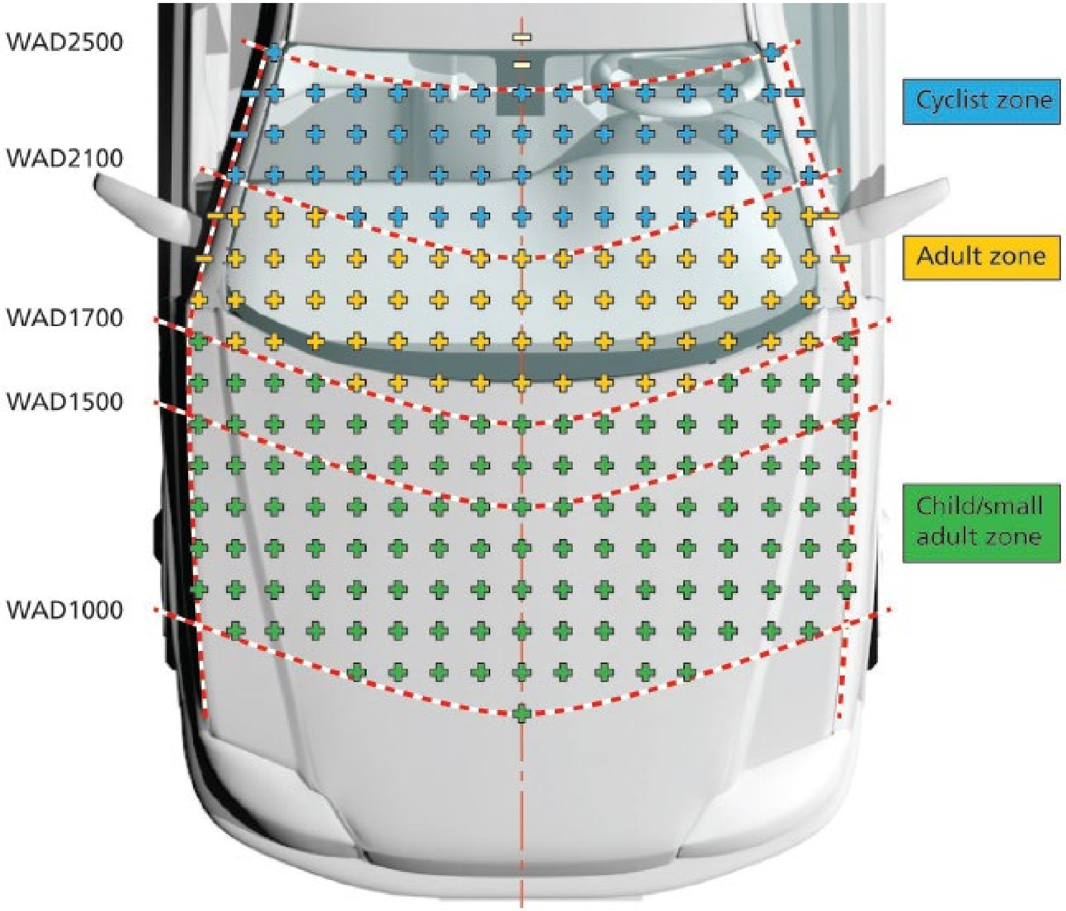
two different test series

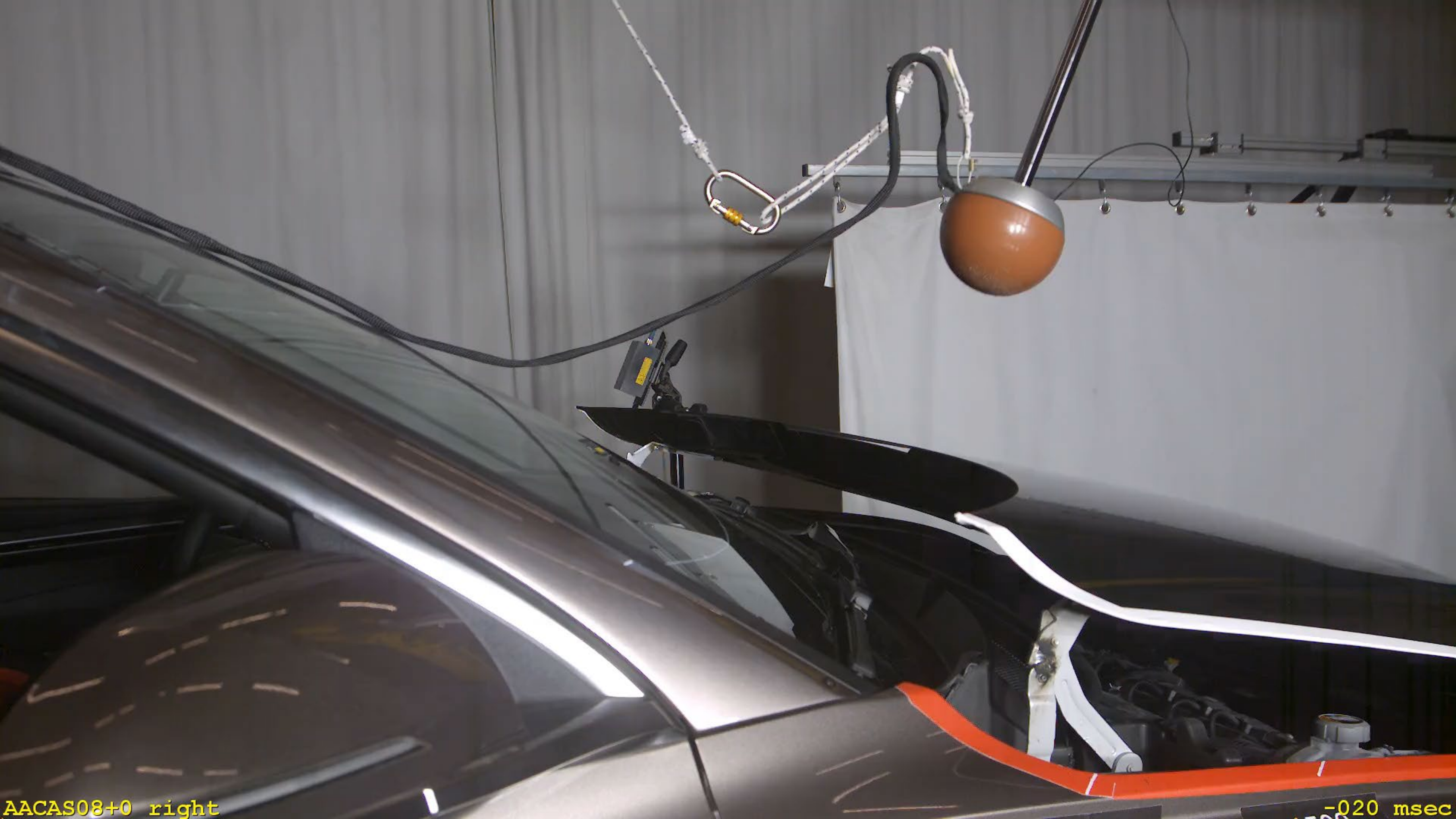
- **PP0224AAC1**
  comparison with Full-Scale-Tests
- **PP0224AAC2**
  investigating the added value for smaller VRUs

2.2 Component-Tests

Adult & Child Head






AACAS08+0 right
-020 msec

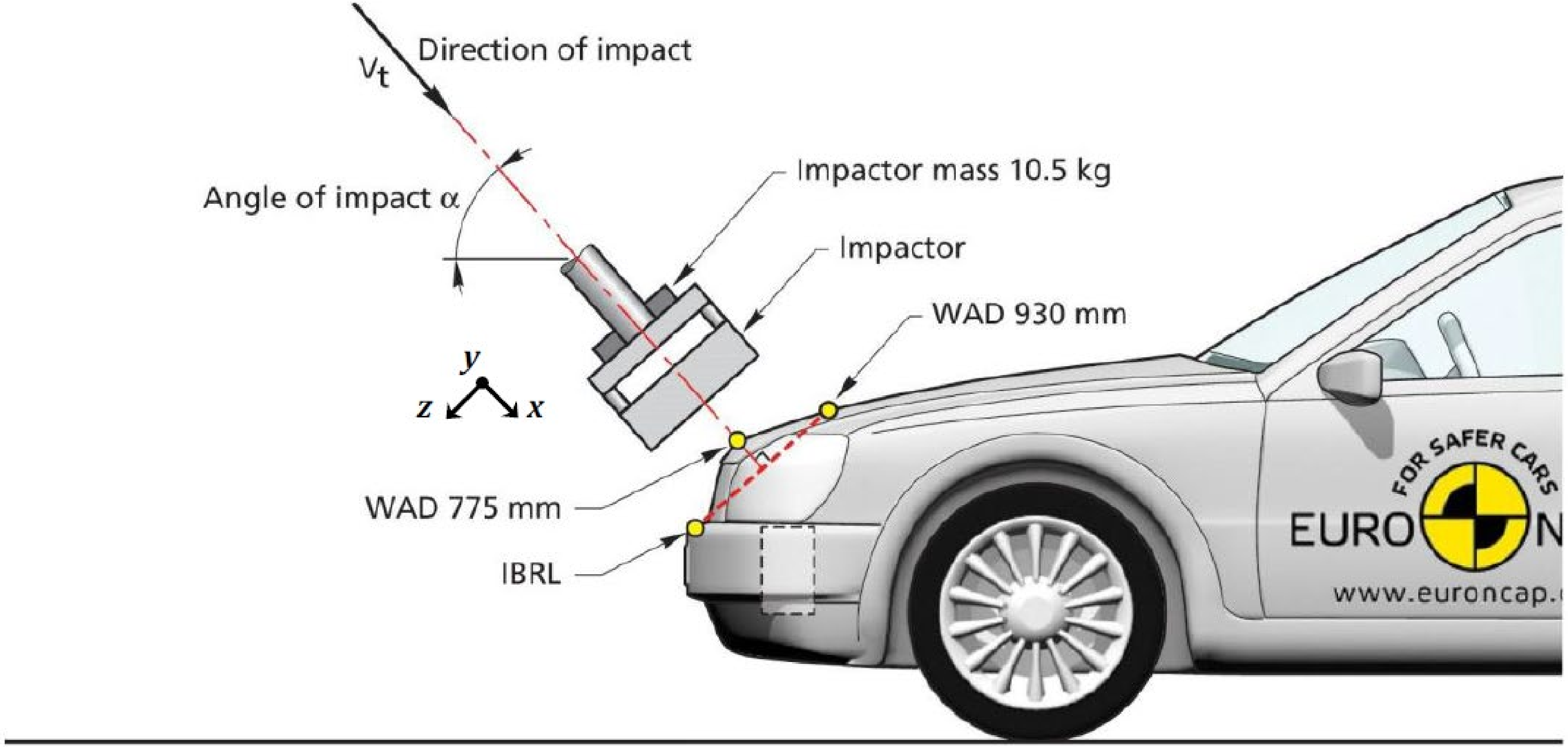
2.2 Component-Tests

Upper Legform

$$v_t = \sqrt{\frac{2En}{10{,}5kg}}$$

$$En = 0{,}5 \cdot m_n \cdot v_c^2$$

$$v_c = v_0 \cdot cos(1{,}2\alpha)$$



https://www.euroncap.com/en/for-engineers/protocols/vulnerable-road-user-vru-protection/

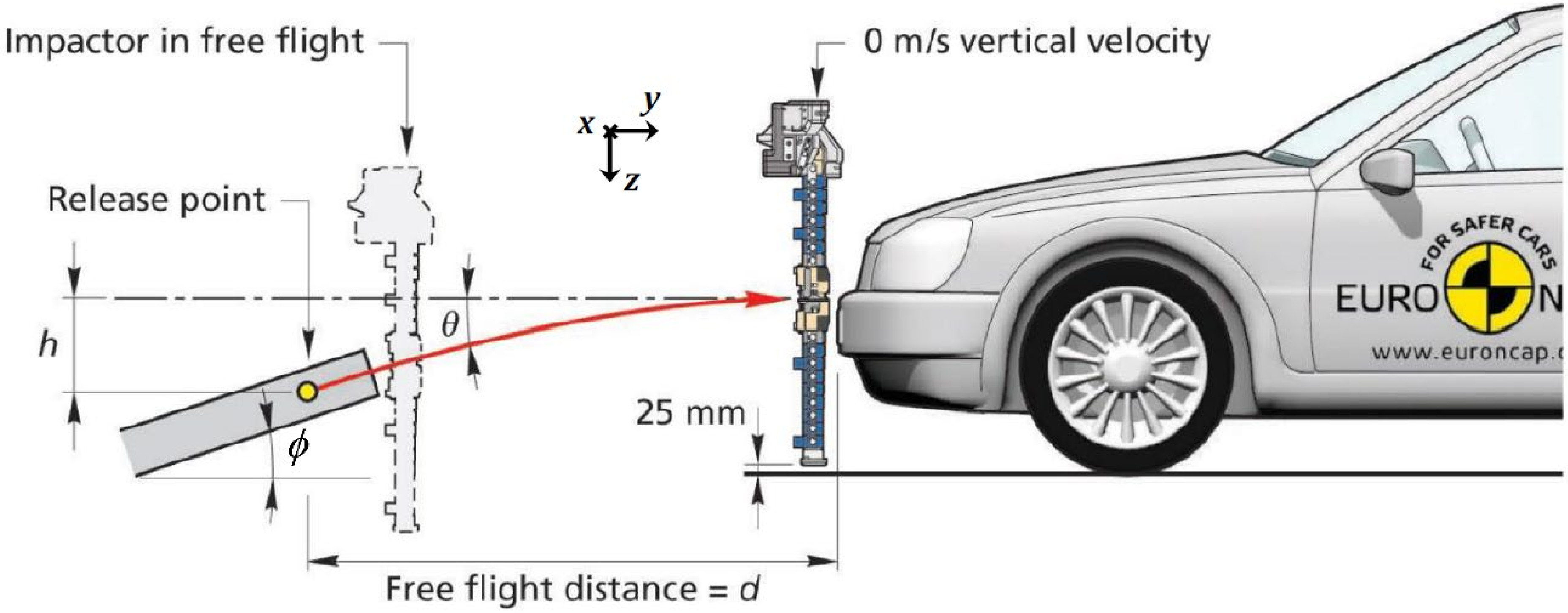

1000
AACUF+0 right
-020 msec

2.2 Component-Tests

Advanced pedestrian legform impactor

$$h = \frac{g\,d^2}{2{v_t}^2}$$

$$\phi = \tan^{-1}\left(\frac{gd}{{v_t}^2}\right)$$




1500
P0224AAC1
1000
755 mm
AACLF+0 right
-100 msec

2.2 Component-Tests

evaluation of test series PP0224AAC1 (comparison with full-scale-tests)

criterion	reference	state of the art	front deployed	limit values
AH: HIC_{15}	*698*	*267*	*428*	*650 ... 1.700*
AH: a_{3ms}	*90g*	*75g*	*79g*	*80 g*
AH: $a_{res,\ max}$	*123g*	*94g*	*139g*	*300 g*
UL: $F_{ges,\ max}$	*5.886N*	*4.871N*	*4.297N*	*5 ... 6 kN*
aPLI: $M_{B,\ Femur,\ max}$	*376Nm*	*382Nm*	*419Nm*	*390 ... 440 Nm*
aPLI: $l_{MCL,\ max}$	*28mm*	*30mm*	*26mm*	*27 ... 32 mm*
aPLI: $M_{B,\ Tibia,\ max}$	*255Nm*	*297Nm*	*280Nm*	*275 ... 320 Nm*
total points	***2,670***	***3,366***	***3,317***	

➔ key message: improvement by the bonnet deployment

2.2 Component-Tests

evaluation of test series PP0224AAC2 (Child Head)

testpoint	criterion	reference	state of the art	front deployed	limit values
radiator support	HIC_{15}	1765	721	686	650 ... 1.700
	a_{3ms}	149g	83g	83g	80 g
	$a_{res,\,max}$	226g	139g	126g	300 g
transition to fender	HIC_{15}	1659	660	865	650 ... 1.700
	a_{3ms}	148g	85g	83g	80 g
	$a_{res,\,max}$	171g	104g	106g	300 g
total points		2,920	4,866	4,817	

➔ key message: improvement by the bonnet deployment

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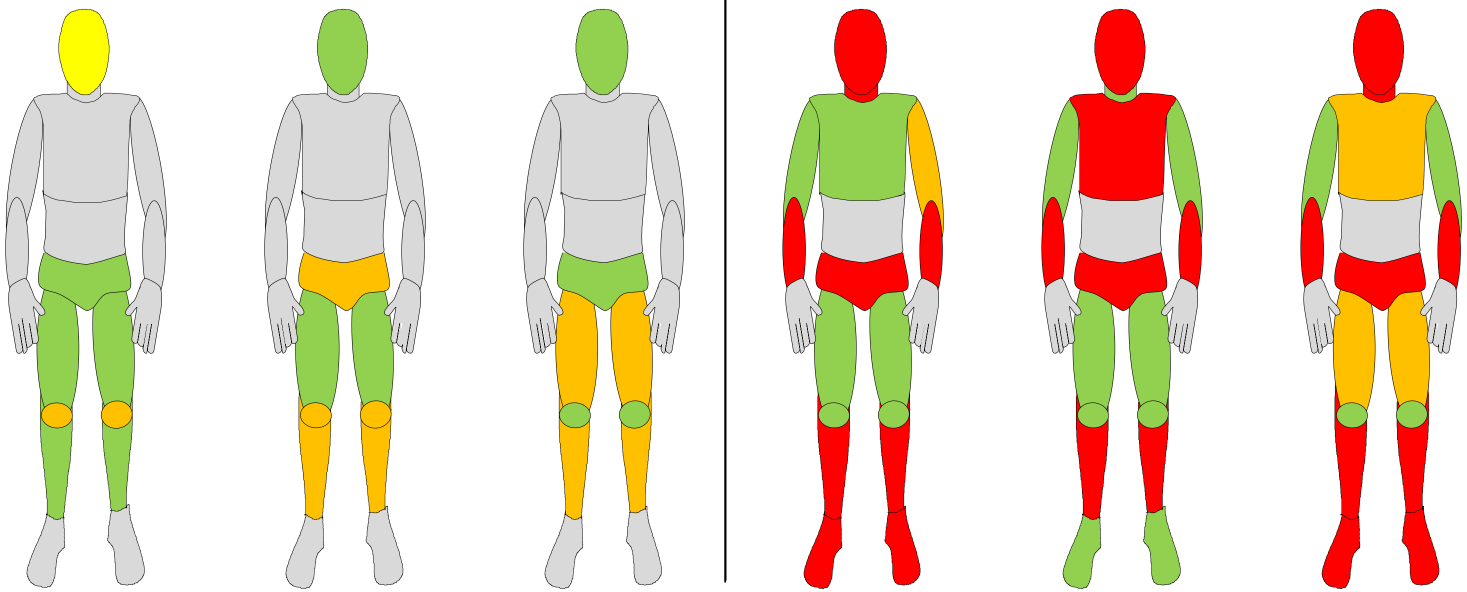
3. Comparison

Primus breakable

vs

AdultHead & aPLI



body region	criterion	component-tests: reference	component-tests: state of the art	component-tests: front deployed	full-scale-tests: reference	full-scale-tests: state of the art	full-scale-tests: front deployed
Head	HIC_{15}	*698*	*267*	*428*	*3.707*	*4.037*	*5.688*
Neck	injury	-	-	-	torsion cs	no injury	deformation cs
Chest	a_{3ms}	-	-	-	*29g*	*30g*	*33g*
	injury	-	-		no injury	vertebra fracture	rib fracture
Upper arm	injury	-	-	-	shoulder disl.	no injury	no injury
Lower arm	injury	-	-	-	fracture	fracture	fracture
Pelvis	a_{3ms}	*48g*	*50g*	*48g*	*44g*	*40g*	*56g*
	injury	-	-	-	fracture	fractures	fractures
Femur	M_B / injury	*376Nm*	*382Nm*	*419Nm*	no injury	no injury	skin rupture
Knee	l_{MCL} / injury	*28mm*	*30mm*	*26mm*	no injury	no injury	no injury
Tibia	M_B / injury	*255Nm*	*297Nm*	*280Nm*	fracture	fracture	fracture
Foot	injury	-	-	-	fracture	no injury	fracture

3. Comparison

critical view & findings

- according to the dummy, head-velocity and loads are many times higher than assumed
  - ➔ pedestrian-vehicle collision has complex kinematics, in particular due to
    - body posture and biofidelity of the dummy
    - front design of the test vehicle
- test specimens can only partially represent pedestrian-vehicle collision
  - ➔ deformation by upper body is not represented
- basically, according to component tests, great potential of the active hoods

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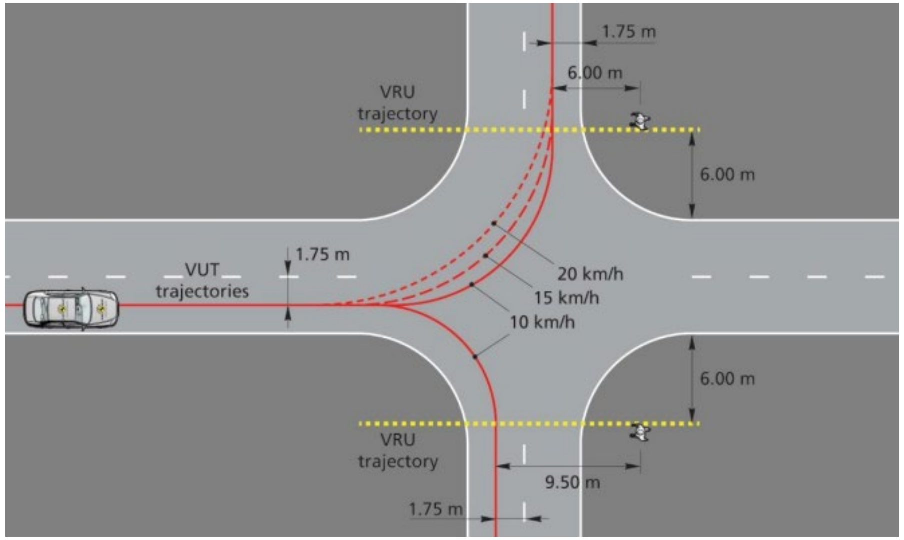
Activation of reversible bonnets

- be in place before the impact
- Should give benefit to ADAS systems
- Close the gap of active and passive systems
- Scenarios more demanding than ADAS functions
- Benefit in passive safety testing in deployed mode

Possible Scenarios

- crossing and junction pedestrian and cyclist
- Obstruction near side child
- Stability, scenarios, such as different pedestrian types



Summary

- Pre-crash triggered APP systems should be encouraged. Suitable systems may then qualify for testing in the deployed position.

- There must be common level of stringency between the requirements of contact systems and pre-trigger systems.

  - Hardest to detect pedestrian approach required
  - Functionality in the most challenging scenarios
  - Bonnet deflection due to body loading
  - Robustness required in pre-crash scenarios
  - Fully deployed before impact
  - Speeds up to 45kph for robustness reasons

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4. Conclusion

recommendations / proposals

- more testing with varied constellations to validate the results!!!
- in the future, headforms could be tested with different speeds (analogue to the angle) depending on vehicle segment respectively the test area
- extend the scope of tests by full-scale-testing
  - → to validate the loads on VRUs
  - → to validate the numerical simulations (HIT vs. WAD)
  - → in the future: to validate the fully deployed hood triggered by ADAS before impact with VRU
- additional points for robustness
  - → direct blinding of the systems by headlights when driving at night
  - → disguising the dummies

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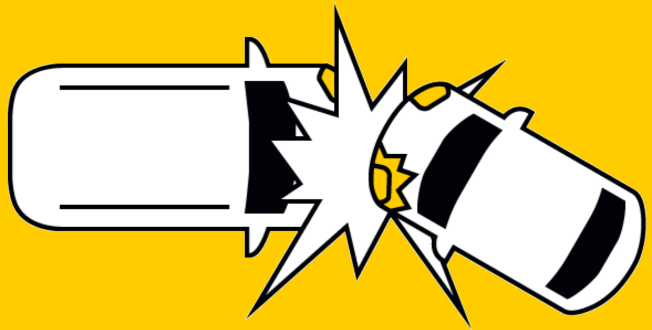
Thank you for your attention

Questions?



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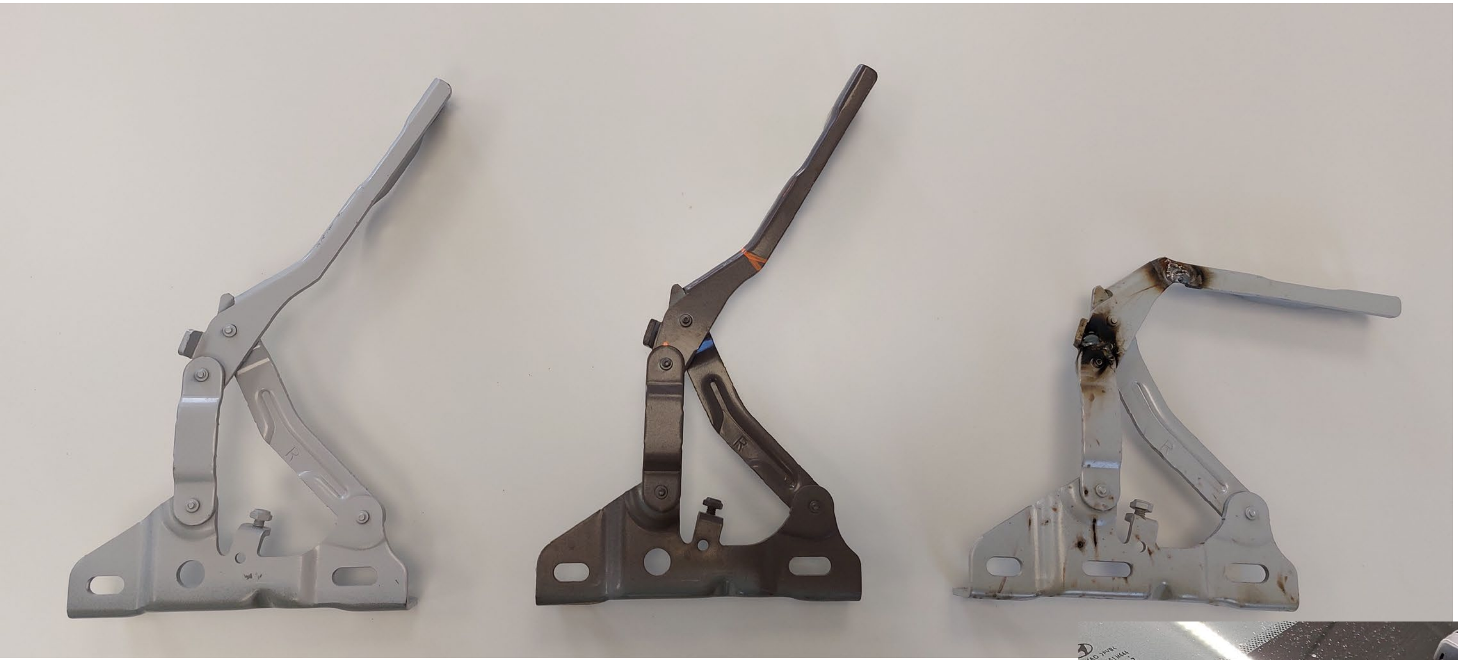
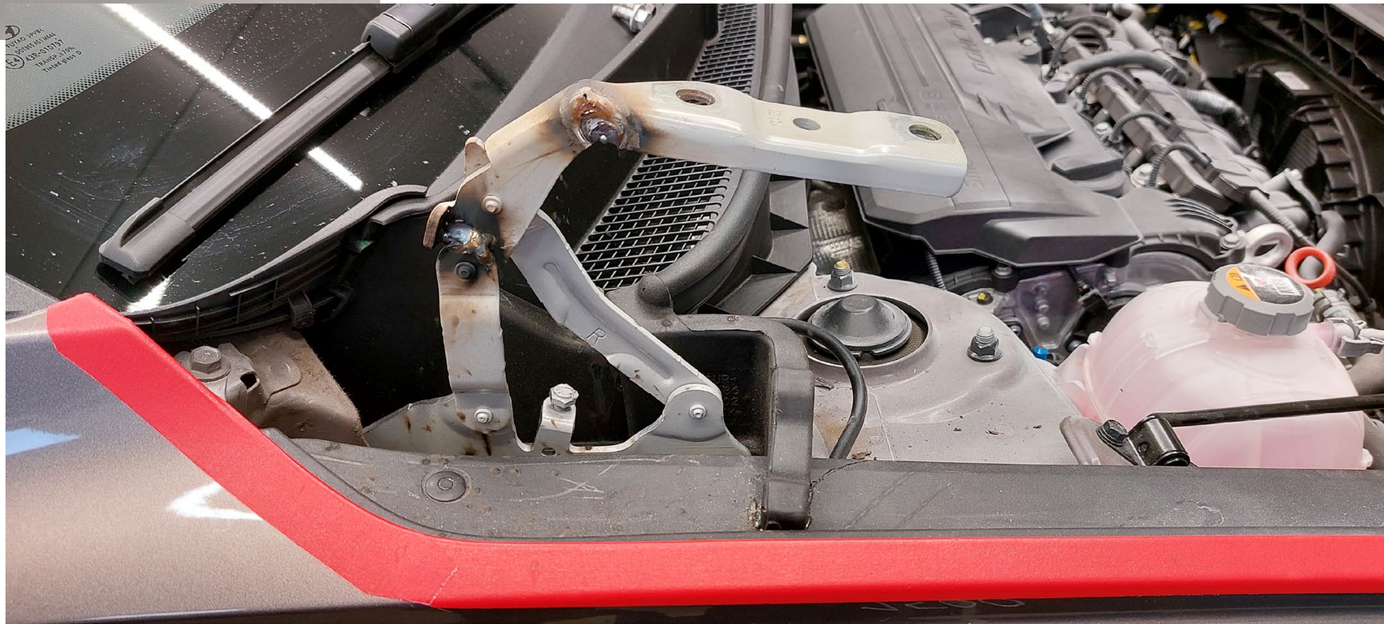
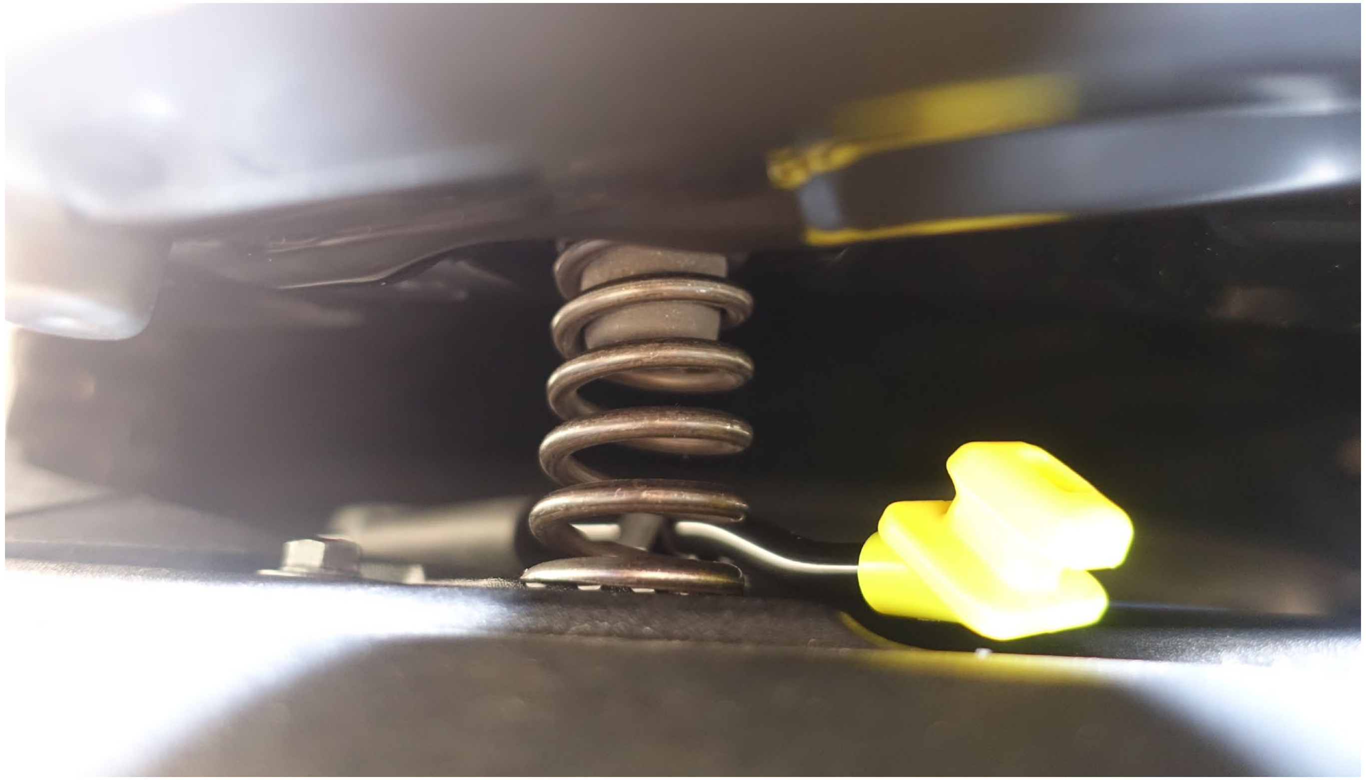
Modified hinges

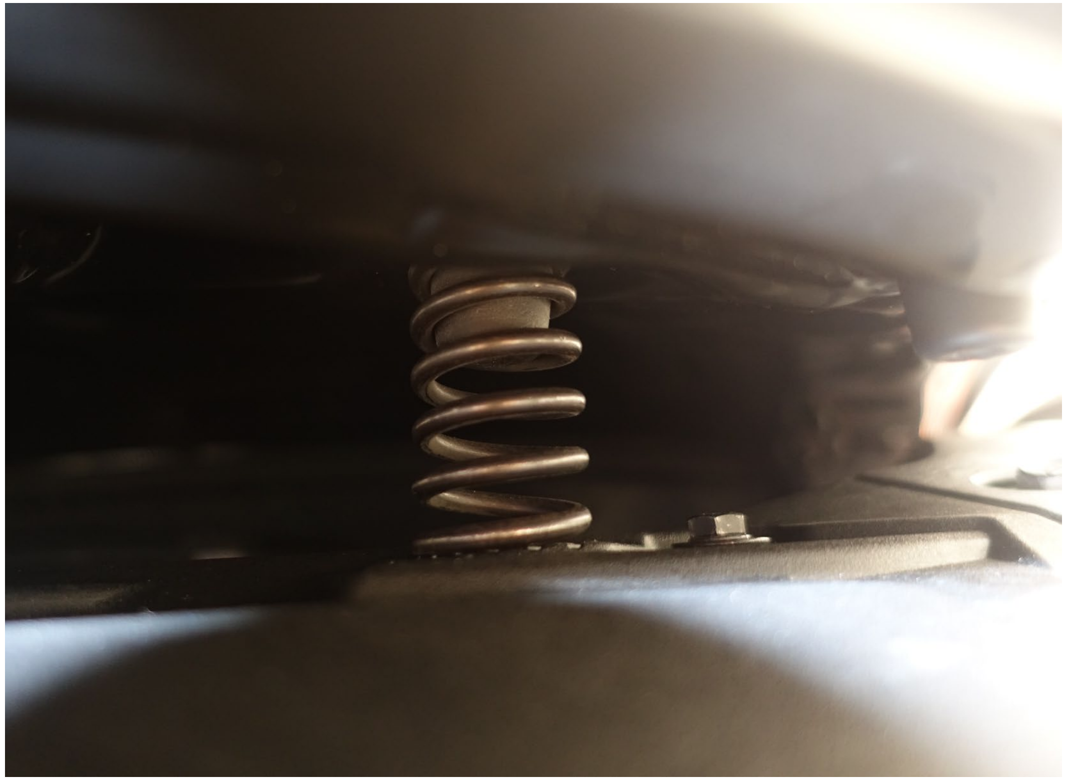




State of the Art

Compression springs





Front deployed

Dummy positioning

Dummy positioning

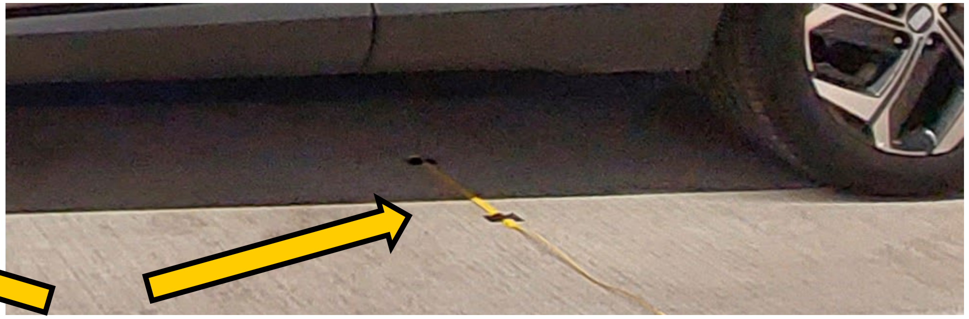
Crash Area

Crash Area


PP4523AAFS
PP4523AAFS Front
-020 msec

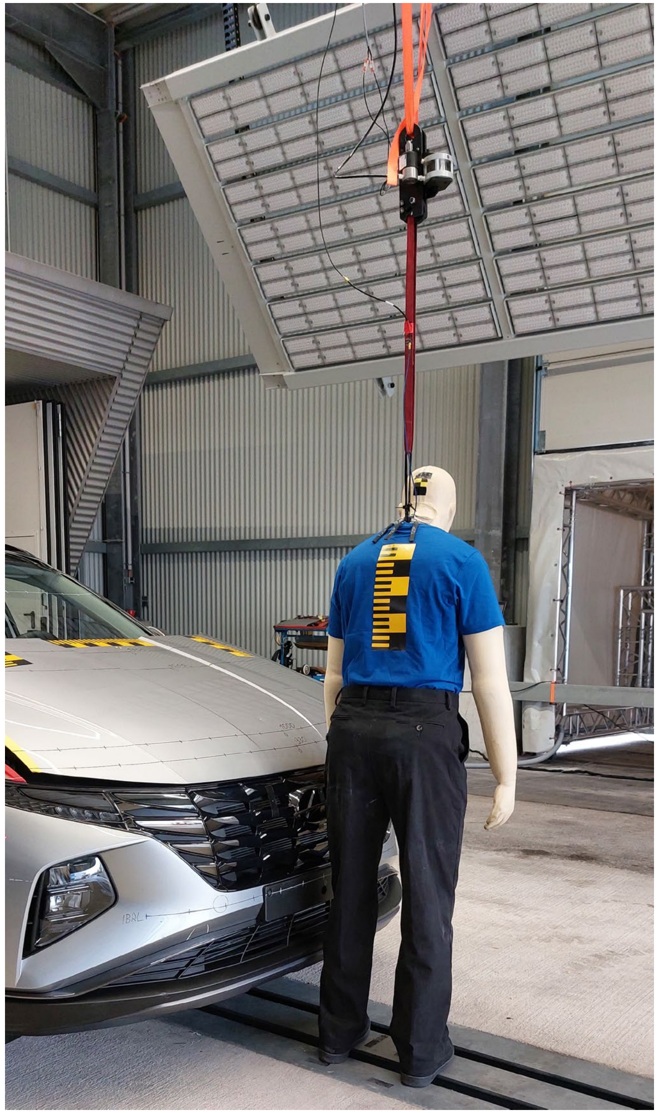
Hanging set up

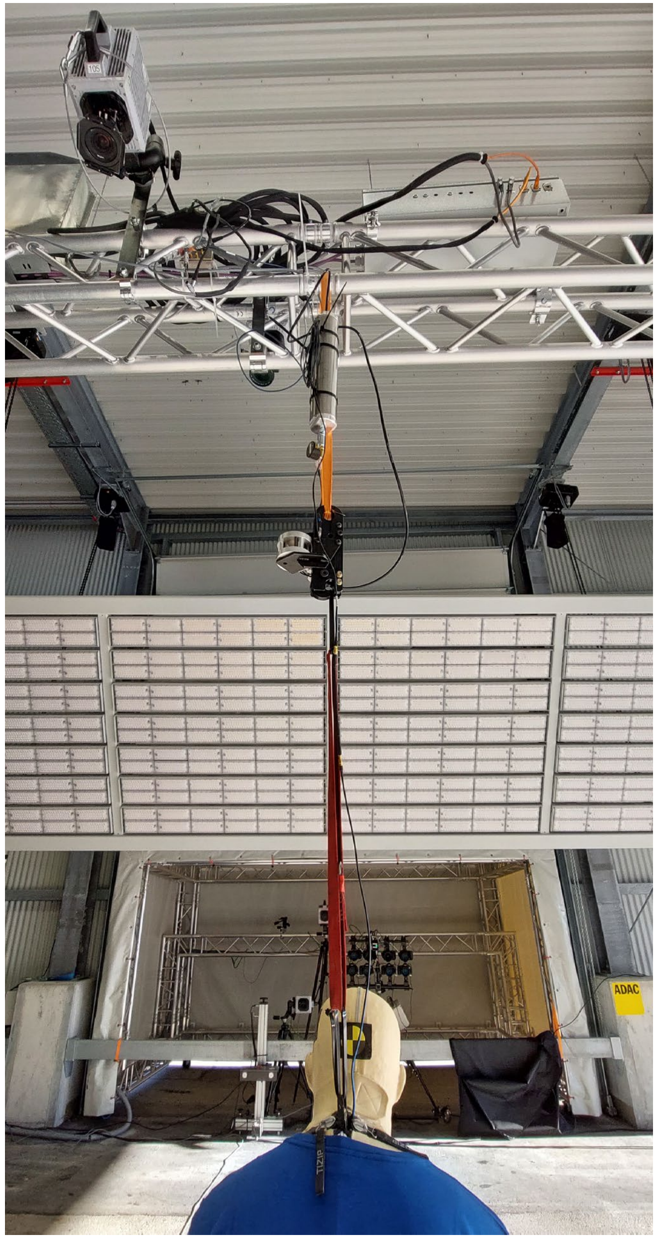
triggering signal



pneumatic reservoir is discharged
→ hook opens
→ dummy falls

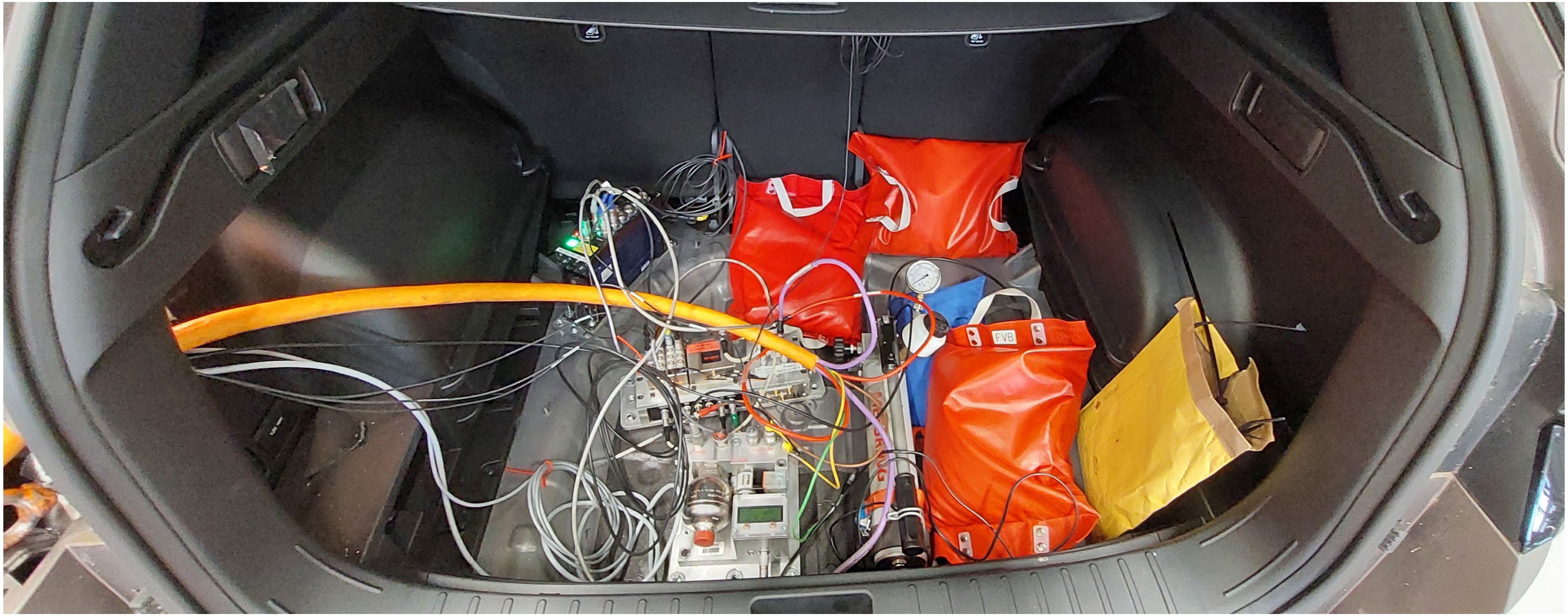
Hanging set up





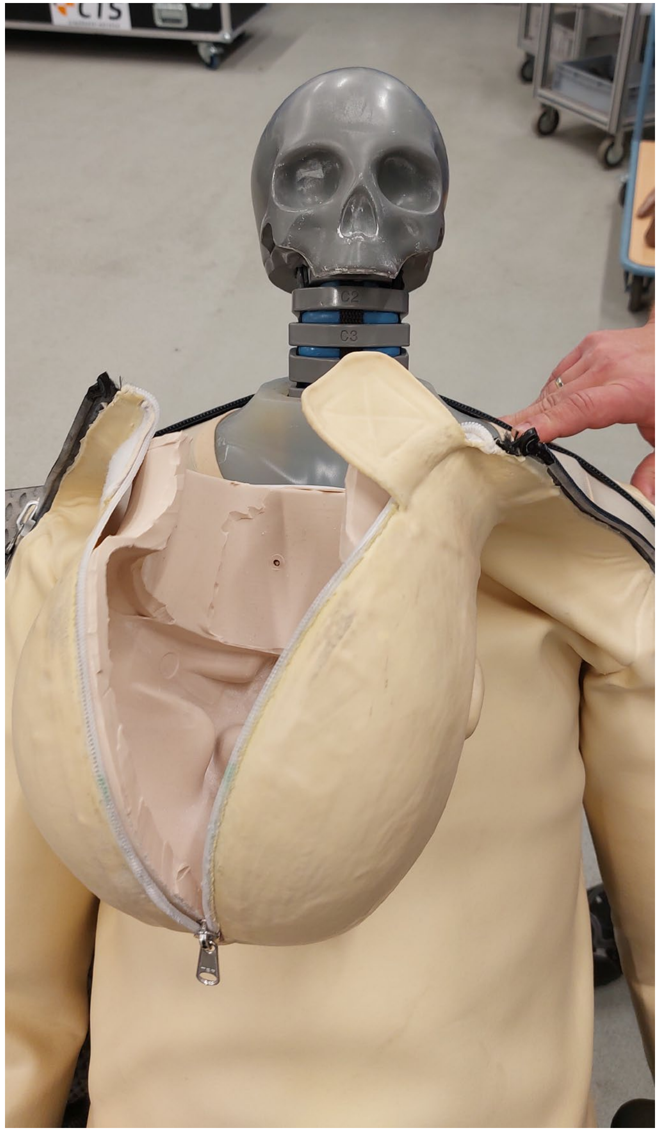
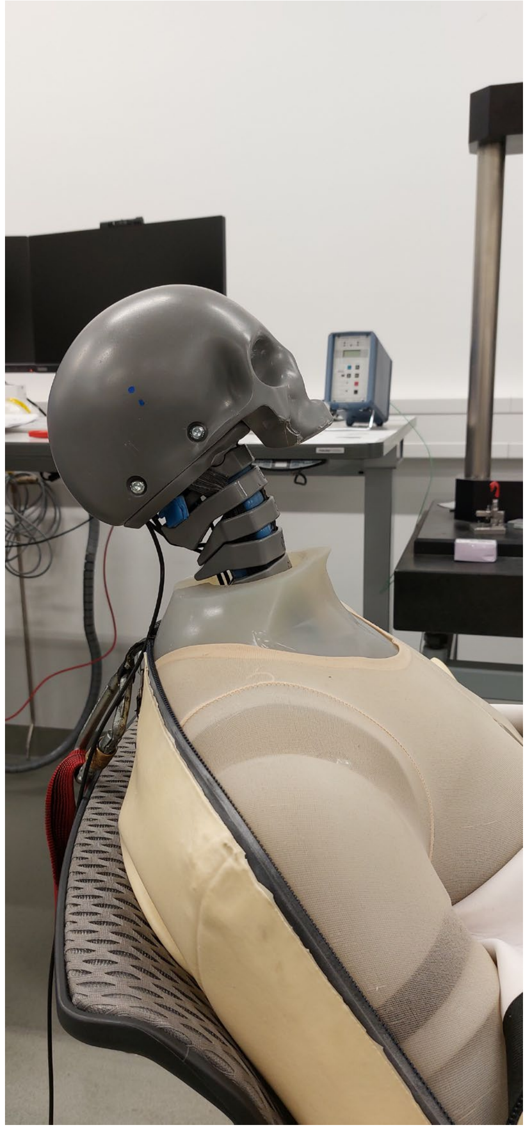
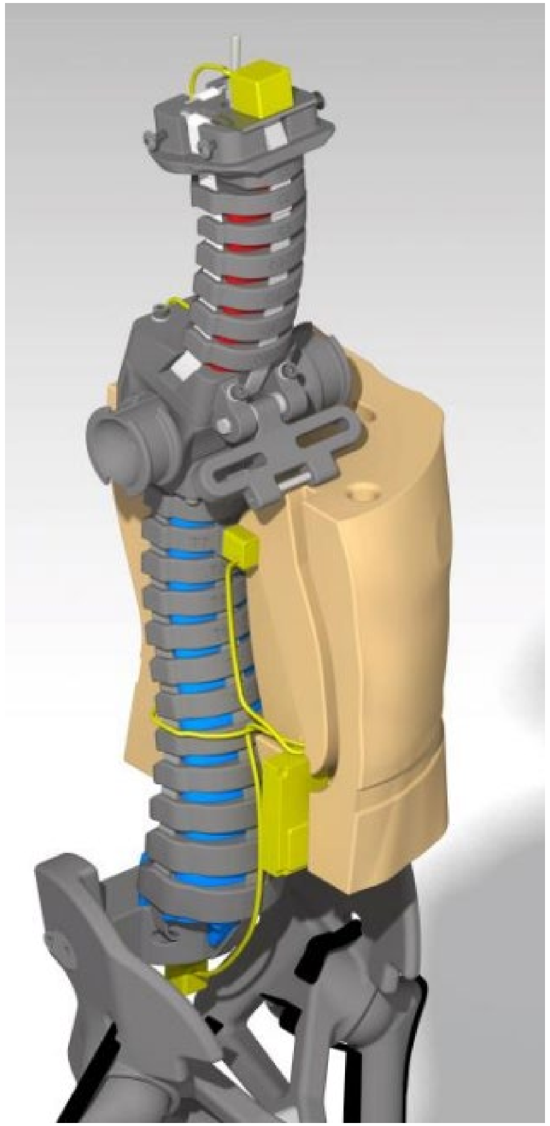
Test Vehicle Interior

Measuring equipment



Vehicle Marking

Biofidelic Dummy „Primus breakable“

Technical obduction

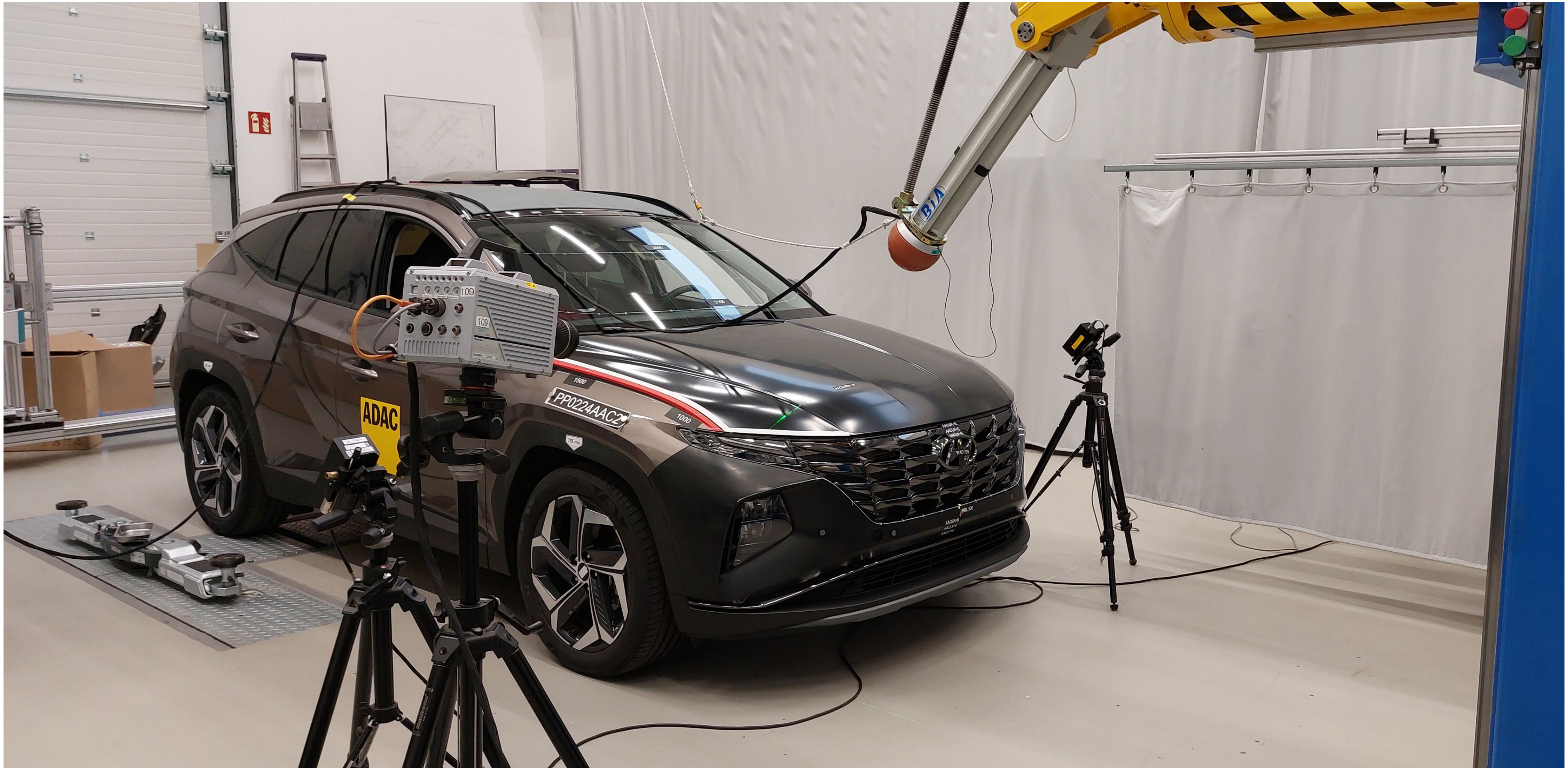
Evaluation - Injury mechanisms

body region	reference	state of the art	front deployed
Head & Neck	- abrasions - torsion der cervical spine	- abrasions	- abrasions - deformation of cervical spine
Upper body & Arms	- fracture of lower arms - shoulder displacement left	- fracture of lower arms - fracture of thoracic vertebra T6 - fracture of ribs L2 & L3	- fracture of lower arms - fracture of rib L3
Pelvis & Legs	- fracture of hip bones - fracture of both tibia - fracture of both ankle joints	- fracture of hip bones - fracture of pubis - fracture of both tibia	- fracture of pubis and sacrum - fracture of hip bones - skin rupture of both legs - fracture of both tibia - rupture of lower leg histoid left - fracture of ankle joints

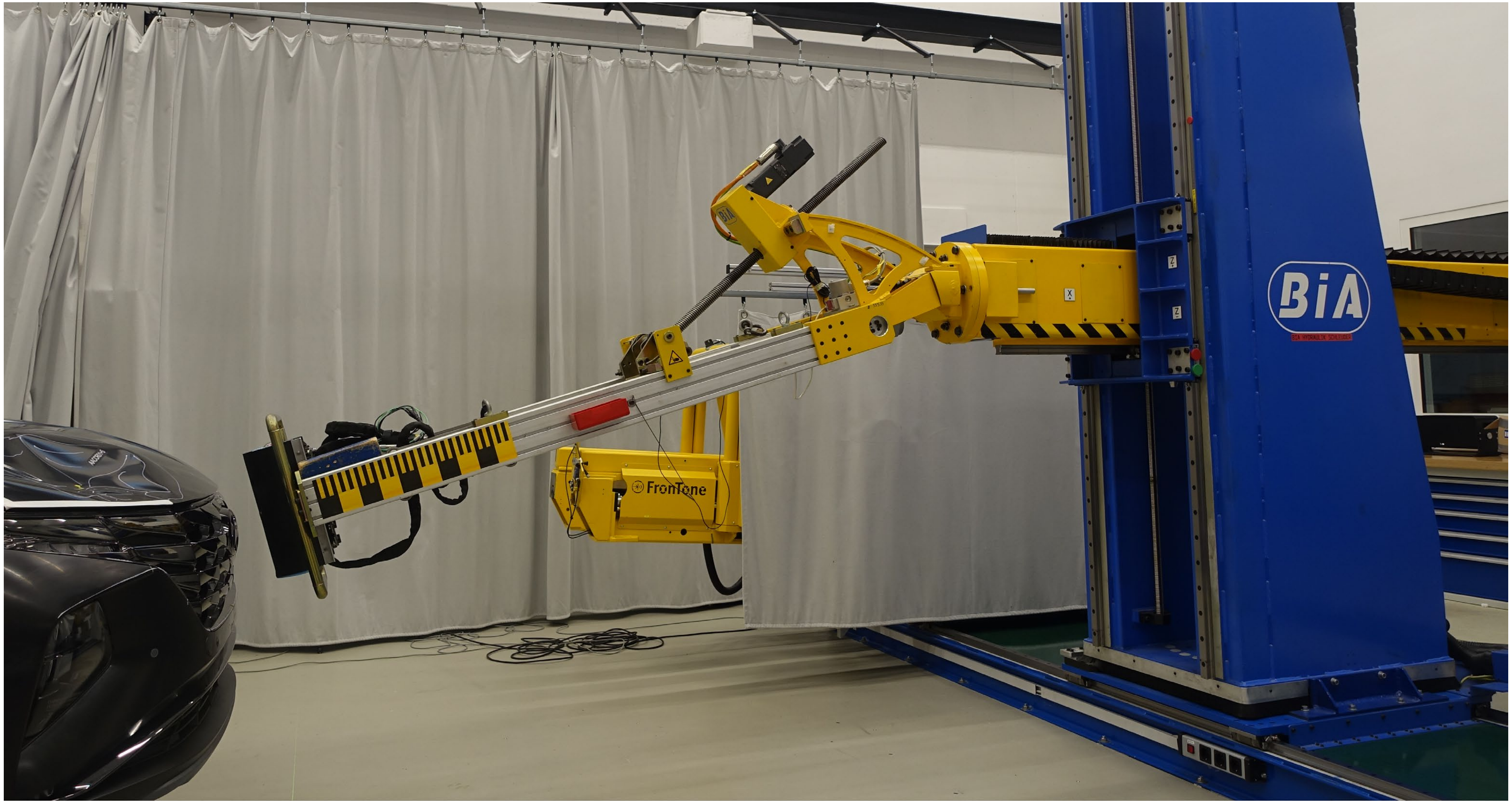
Evaluation – pattern of damage

Crash Area

Headform testing



Upper Legform



aPLI