Proposal for a Definition of the FlexPLI Biofidelic Assessment Interval (BAI)

6th Meeting of Informal Group GTR9 Phase 2
Washington DC, March 19th - 20th, 2012

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Background

- **At the 5th meeting of the IG GTR9-PH2, two proposals related to the definition of the FlexPLI rebound phase were provided by OICA (Doc GTR9-5-08) and ACEA (Doc GTR9-5-30).**
- **No agreement could be found on either proposal**
- **Both proposals do not really address the issue to its full extent.**
- **It was agreed that a new proposal shall be developed until the next meeting. This document reflects the advantages and disadvantages of both above mentioned proposals and presents a new approach.**

Basics

- **Several discussion items are important to consider:**
  - **The need for a distinction between impact phase and rebound phase on the basis of the time-history-curves only and without considering high-speed videos is based on the request for an automatic evaluation.**
  - **The impact phase is not necessarily limited to direct contact of the respective legform part with the vehicle. Furthermore, in case of an automatic evaluation the direct contact will not even be considered.**
  - **If the start of a rebound phase needs to be determined, the determination must not exclude any possible relevant loadings that may have an influence on the pedestrian injury risk.**
  - **In case of excluding impactor loadings before the common zero-crossing phase of the femur and tibia, detailed information about the biofidelity of the impactor during all impact phases would be needed. This information is not (yet) available.**

GTR9-5-08 – OICA Proposal

Proposed Protocol

GTR9-5-08

The following protocol is proposed based upon the results of the investigation for the maximum possible bending moment in the rebound phase using a human model.

Proposal

In the cases where all of the following conditions (1) through (3) apply, tibia bending moment time histories shall be used up to the timing of the local minimum value between the maximum before 30 ms and the maximum after 30 ms. The timing shall be determined using the channel providing the maximum value of the four channels after 30 ms.

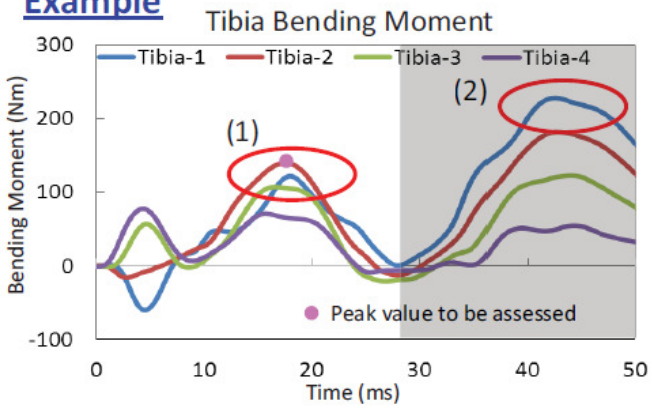
(1) Local peak bending moments are clearly identified before 30 ms[1)]

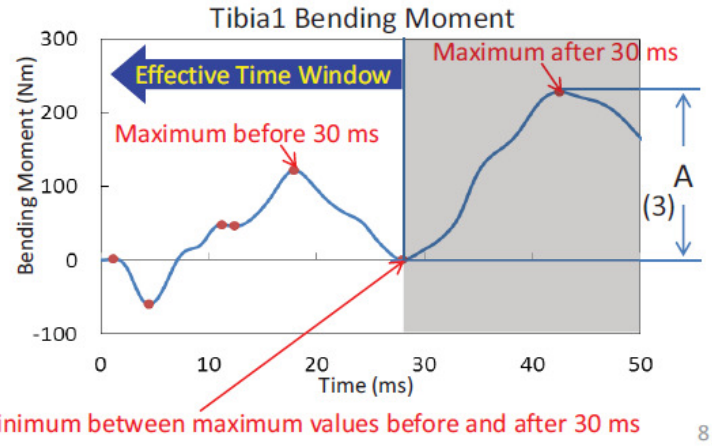
(2) Overall maximum value is determined after 30 ms

(3) Bending moment increase (A) of the channel providing the maximum value of the four channels after 30 ms is greater than 170 Nm

1) Justification provided on the next page

Example





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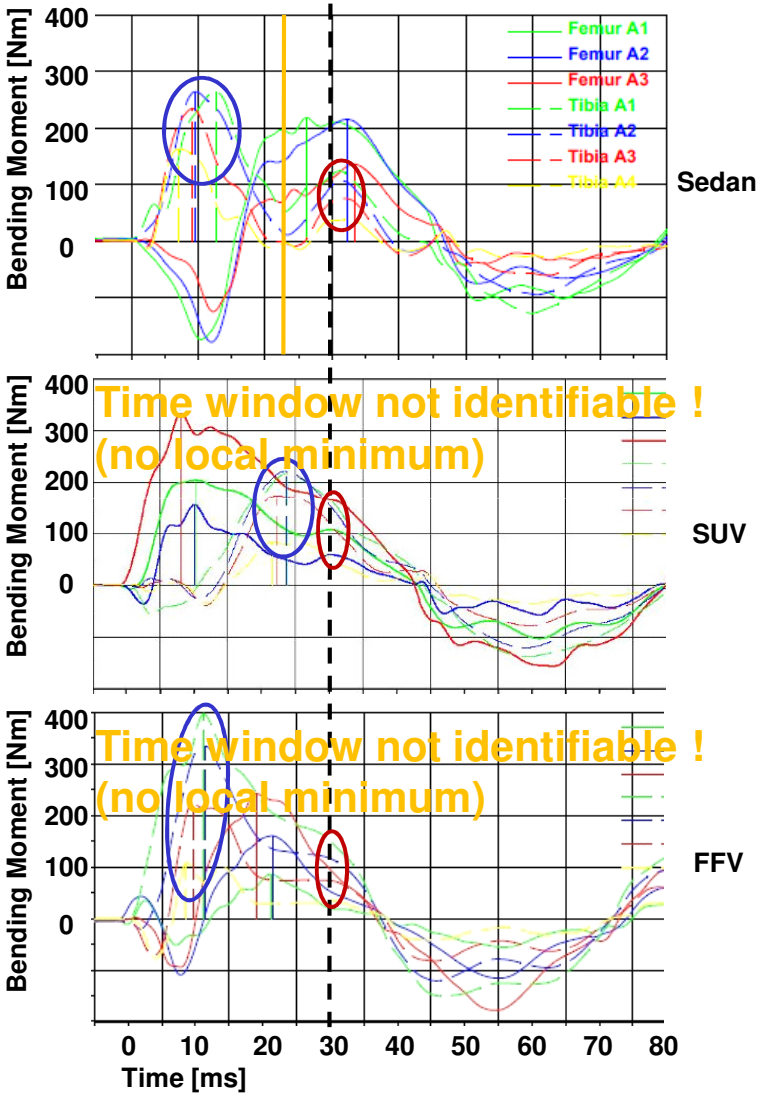
GTR9-5-08 – Trial

- **Local peak bending moments are clearly defined before 30 ms**
  - ✓ **Sedan ➔ pass**
  - ✓ **SUV ➔ pass**
  - ✓ **FFV ➔ pass**
- **Overall maximum value is determined after 30 ms**
  - – **Sedan ➔ fail**
  - – **SUV ➔ fail**
  - – **FFV ➔ fail**
- **Bending moment increase (A) of the channel providing the maximum value of the four channels after 30 ms is greater than 170 Nm**
  - – **Sedan ➔ fail**
  - – **SUV ➔ fail**
  - – **FFV ➔ fail**

Start of rebound phase ?



GTR9-5-08 – Discussion

- **This procedure obviously is quite complex and covers not all cases.**
- **As demonstrated, in several cases an unlimited time window including actual rebound impactor movement would be considered for the tibia bending moment assessment. This could lead to incorrect measurement interpretations and maxima determinations even during a possible rebound phase.**
- **To ensure a correct assessment during an automatic evaluation the procedure must cover all possibilities.**
- **Besides, considering only the tibia bending moments may lead to a wrong determination of the rebound phase starting point**
- **The determination of the rebound phase is based on maximum values *during* the rebound phase whereas the whole rebound phase is assumed not to give realistic and reproducible measurements.**

GTR9-5-30 – ACEA Proposal

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European Automobile Manufacturers Association

GTR9-5-30

Discussion of the Rebound Issue

Current TEG Proposal (TEG-128):

Document TEG-128 (11 TEG Meeting in April 2010)

Biofidelic response of
(contact to vehicle) un

Biomechanical assess
phase is not recomme

Rebound phase was p

All max.values should
(to be determined

European Automobile Manufacturers Association

GTR9-5-30

Discussion of the Rebound Issue

ACEA proposal:

Distinguish between rebound phases for ligament elongations and bending moments

Rebound for tibia measurements is indicated by the first zero-crossing of T1, T2, T3 or T4 after the first maximum.

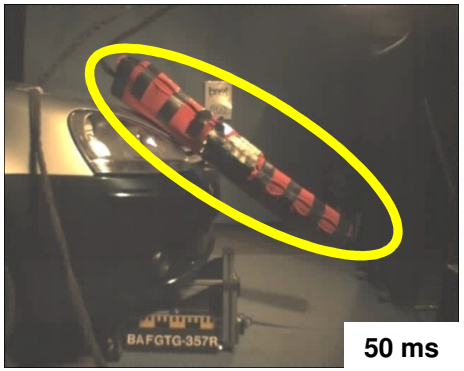
Timing of zero-crossing can be easily and automatically derived from time-history-curves and is more precise than film analysis

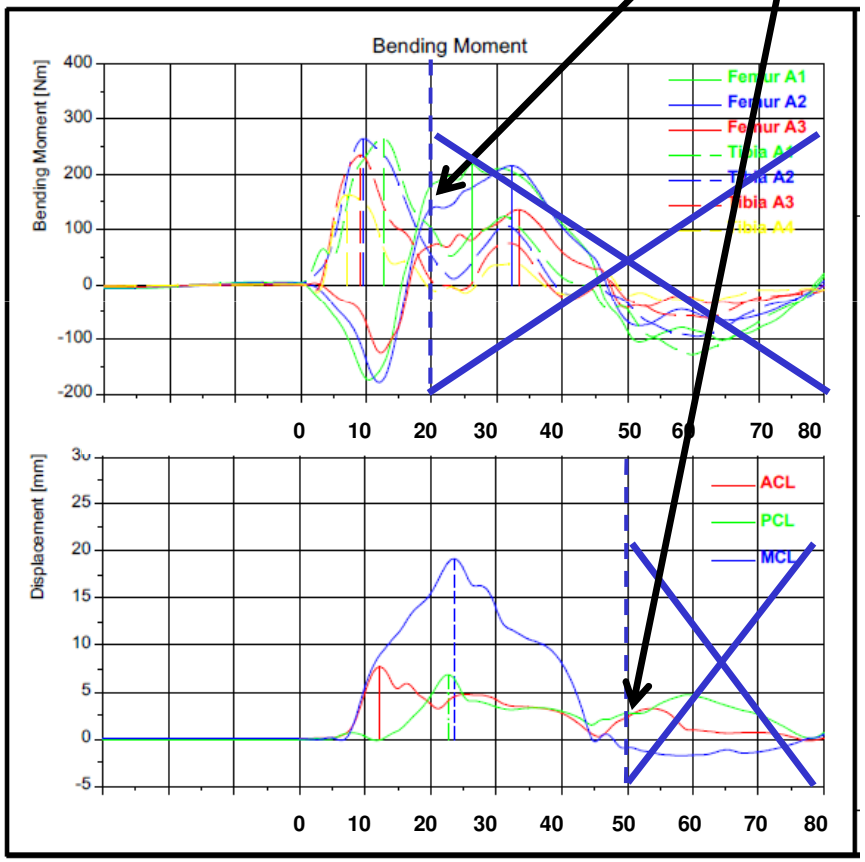
Rebound for ligament measurements remain as proposed by the TEG recommendation (50ms)

5. IG GTR9-PH2
05.-06.12.2012, Bergisch Gladbach, Germany

GTR9-5-30 – Case study (I): Sedan

Rebound ?

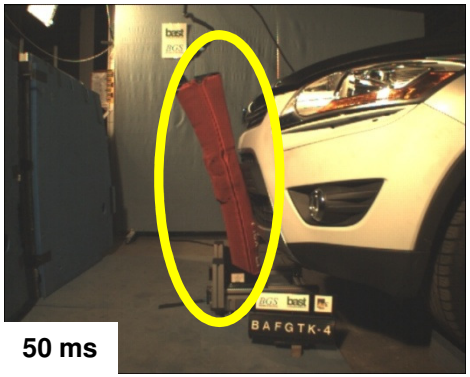


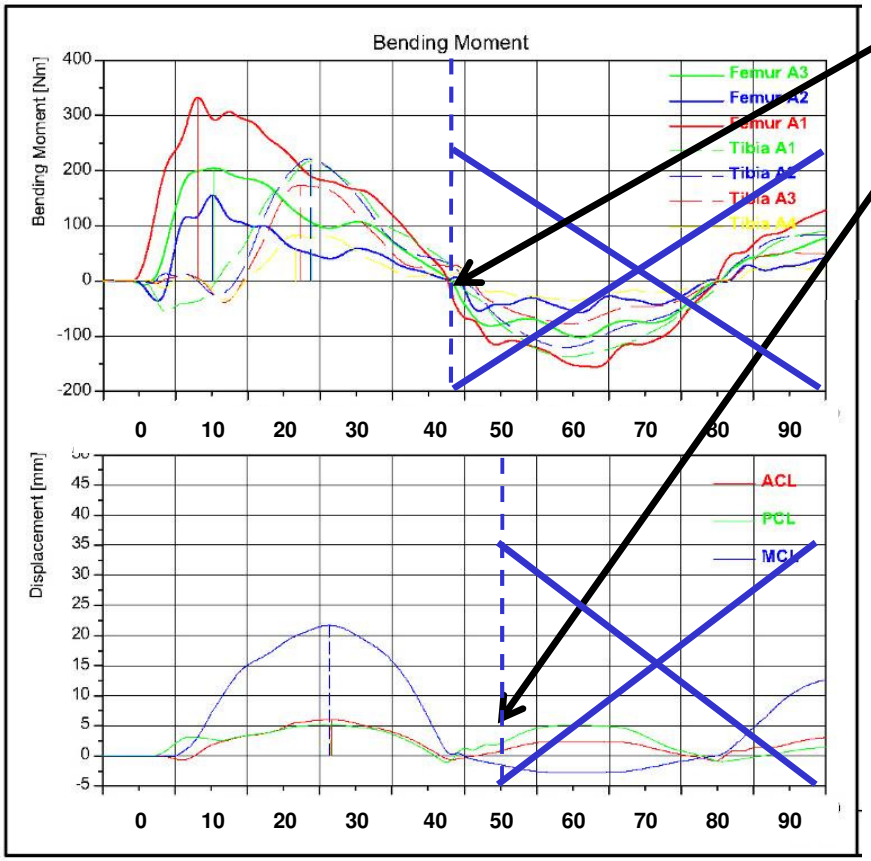


too early !

too late !

GTR9-5-30 – Case study (II): SUV



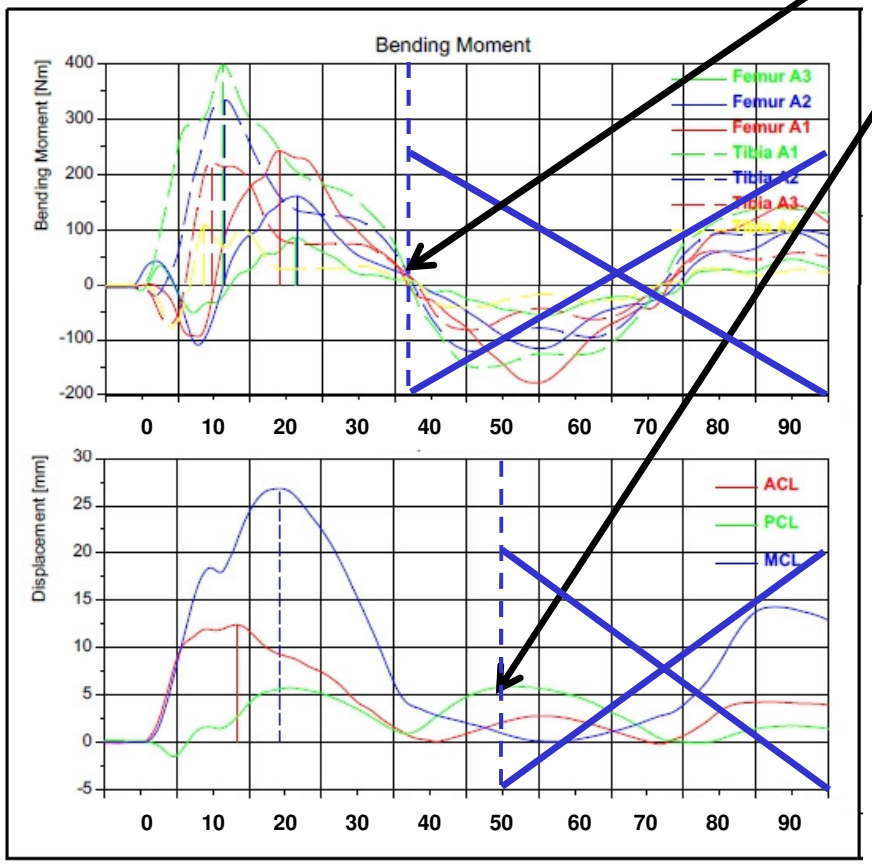


Rebound ?

approx. ok !

too late !

GTR9-5-30 – Case study (III): FFV



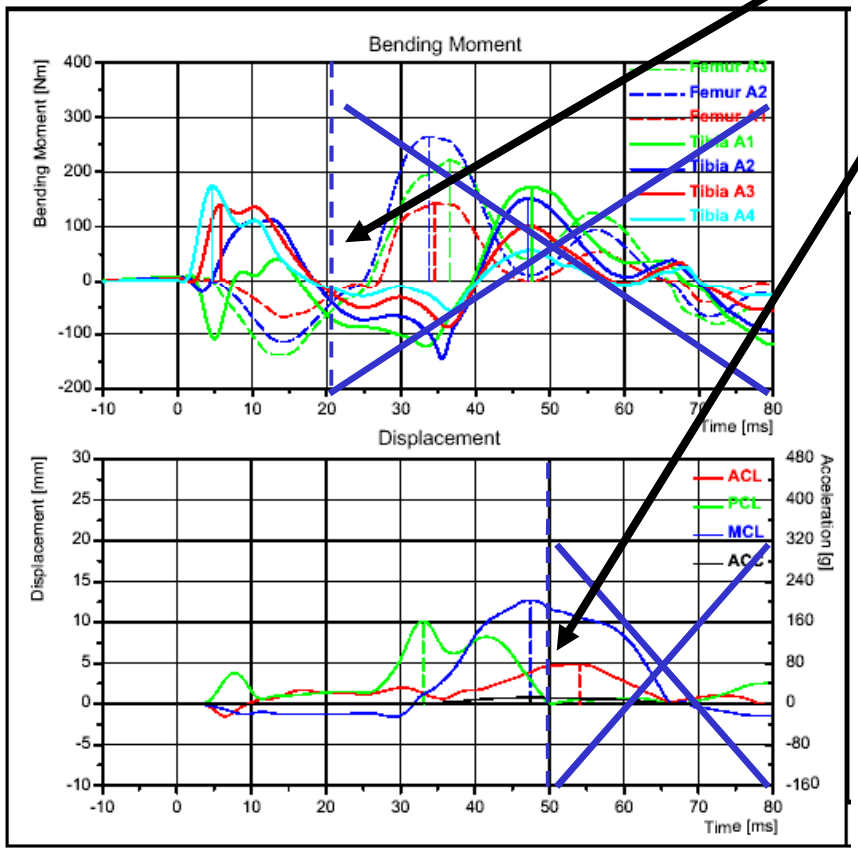
Rebound ?

approx. ok !

too late !

GTR9-5-30 – Case study (IV): Sports car

Rebound ?



too early !

too early !

GTR9-5-30 – Discussion

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- **This procedure distinguishes between tibia moments and knee elongations**
- **The use of the first zero crossing of only one tibia moment can lead to rebound starting points that are too early**
- **The procedure is a pragmatic approach but seems not precise enough: Rebound phase starts too early or too late in some cases.**
- **The use of a fixed time interval (50 ms) is not appropriate because in some cases the maximum loadings occur later.**

Findings

- **The start of the rebound phase is understood as the loss of contact between tibia or knee and the vehicle front. As demonstrated, realistic maximum loadings of pedestrian LE can still occur afterwards.**
- **The rebound phase can only be determined as soon as the entire impactor is in rebound movement, i.e. tibia and femur bending moments must be considered.**
- **Therefore it is not necessary to distinguish between tibia bending moments and knee ligament elongations.**
- **The biofidelic interval is understood as the time interval in which the impactor shows humanlike behaviour in terms of kinematics and loadings.**
- **The timings of the end of the biofidelic interval and the start of the rebound phase are not necessarily identical.**
- **For the benefit of the pedestrians the procedure to determine the biofidelic interval must be defined in a way that no possible maximum loading that could be injurious can be left out.**
- **In case of excluding impactor loadings before the common zero-crossing phase of the femur and tibia, detailed information about the biofidelity of the impactor during all impact phases would be needed (not yet available).**
- **In case of an automatic evaluation the procedure should cover all possibilities.**

BASt proposal

- **Based on the two proposals and these findings, BASt is proposing the definition of the rebound phase (A-5-06) as follows:**

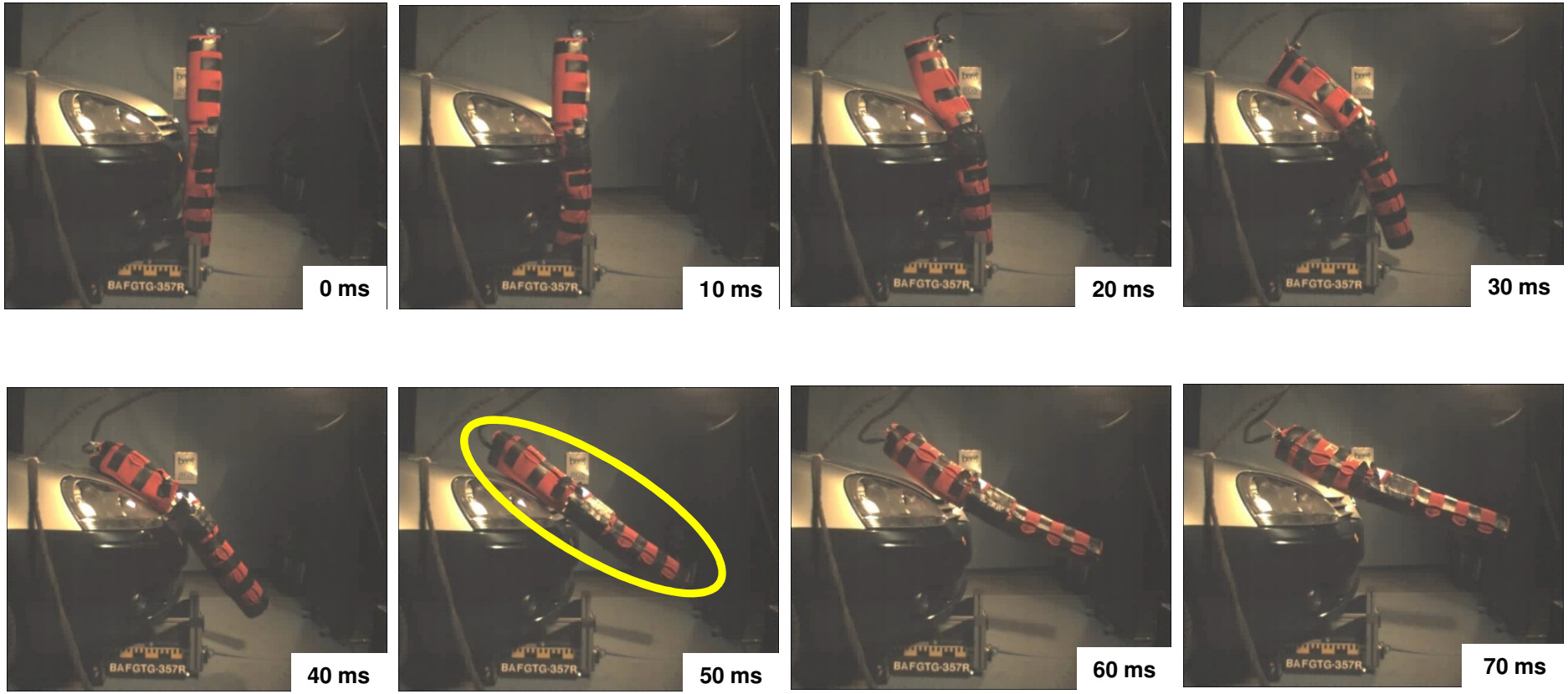
- **The start of the rebound phase is understood as the loss of contact between tibia or knee and the vehicle front. Realistic maximum loadings of pedestrian LE can still occur afterwards.**

- **The biofidelic assessment interval (BAI) of the FlexPLI is defined as the timing of the last zero crossing of all femur and tibia segments after their first local maximum, within their common zero crossing phase.**

- **The BAI is identical for all bone segments and knee ligaments.**

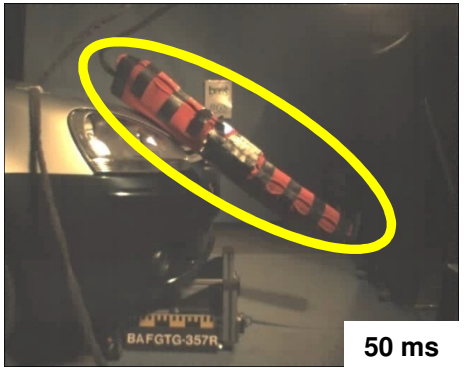
- **In case of not all bending moments having a zero crossing during the common zero crossing phase, the time history curves are shifted downwards until all bending moments are crossing zero. The downwards shift is done for the determination of the BAI only.**

BASt proposal – Case study (I): Sedan

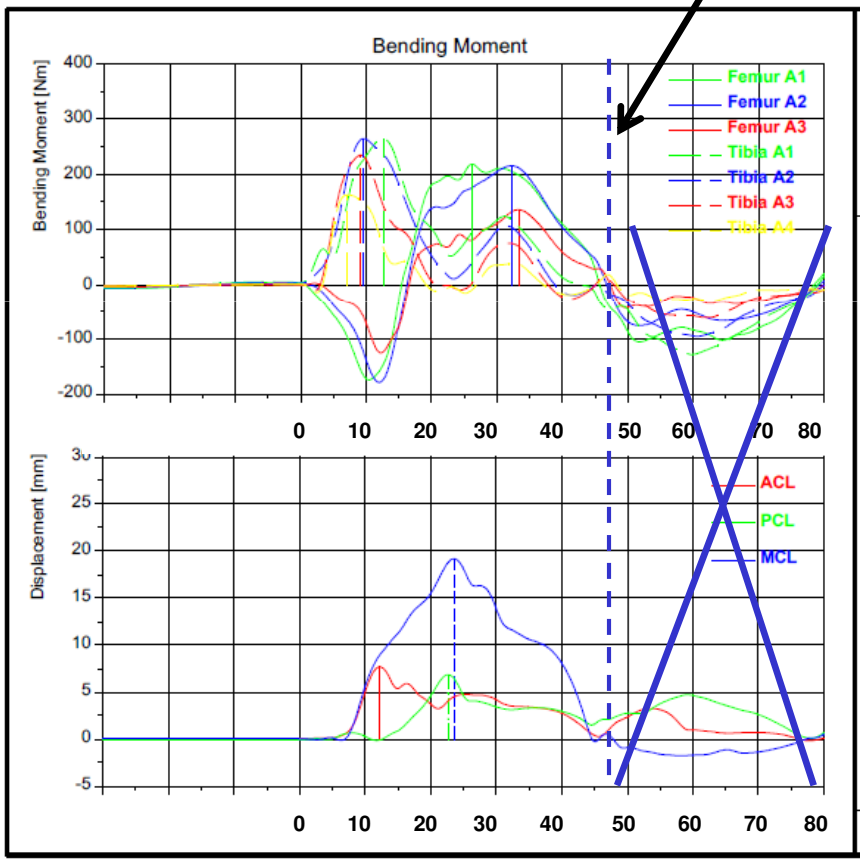


Entire impactor left BAI

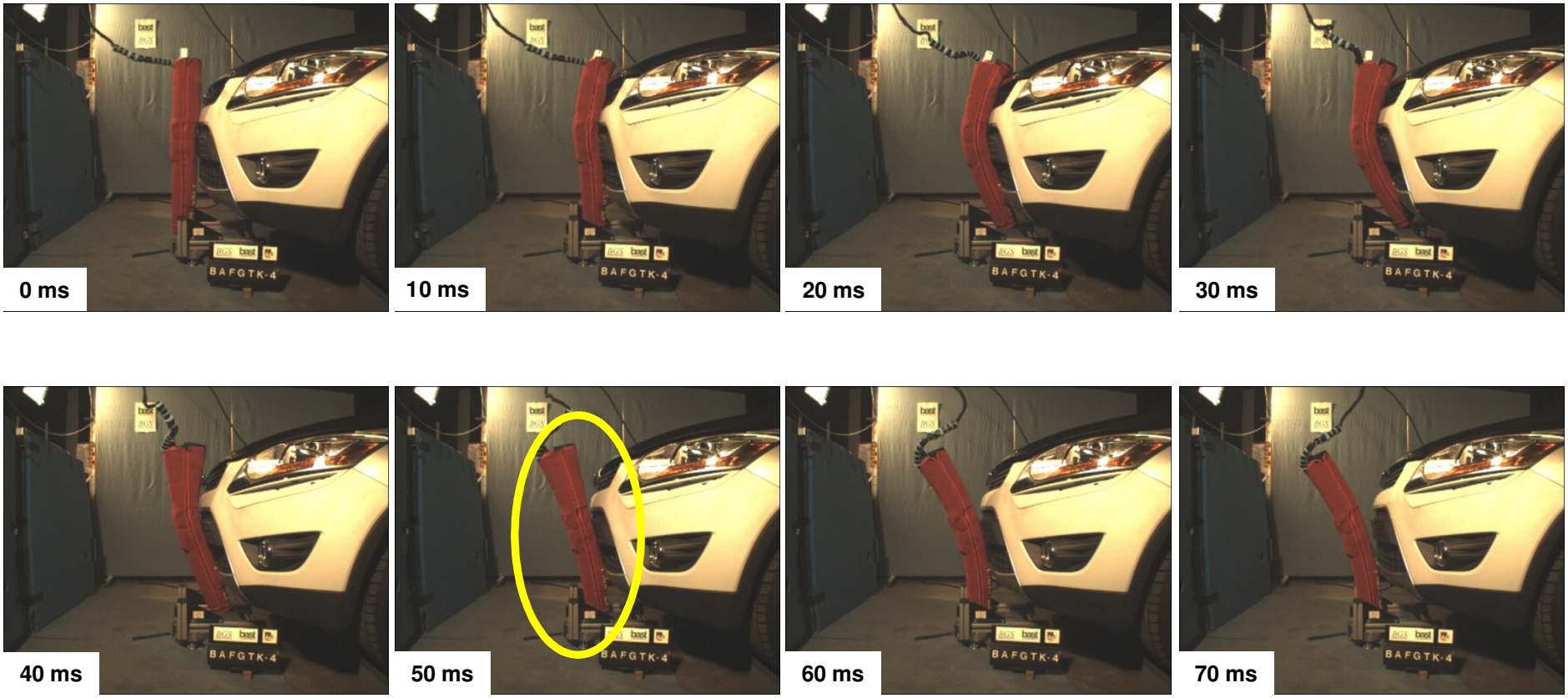
BASt proposal – Case study (I): Sedan



Entire impactor left BAI



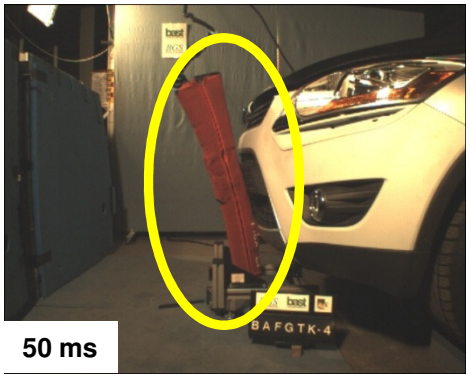
BASt proposal – Case study (II): SUV

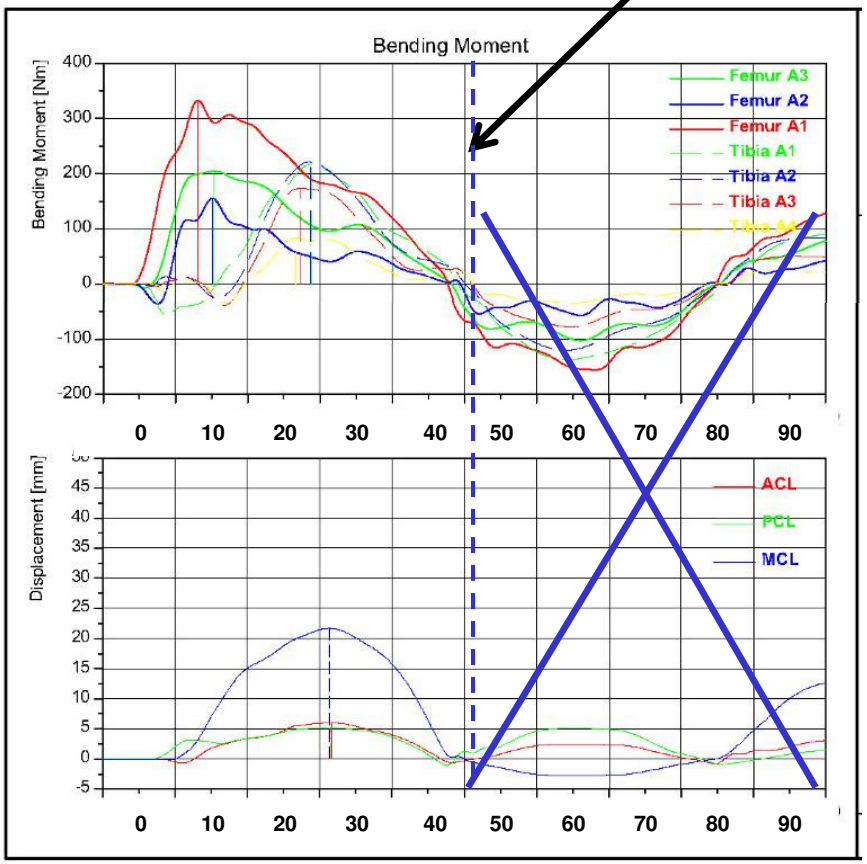


Entire impactor left BAI

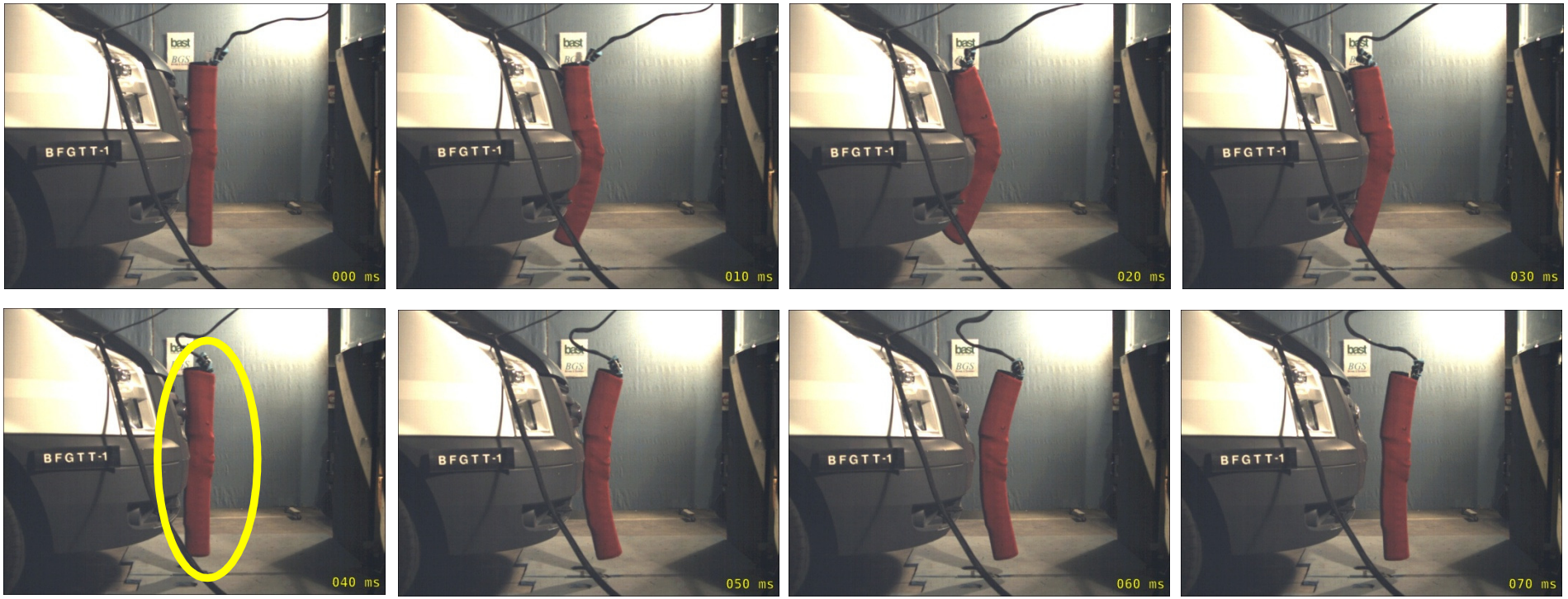
BASt proposal – Case study (II): SUV

Entire impactor left BAI





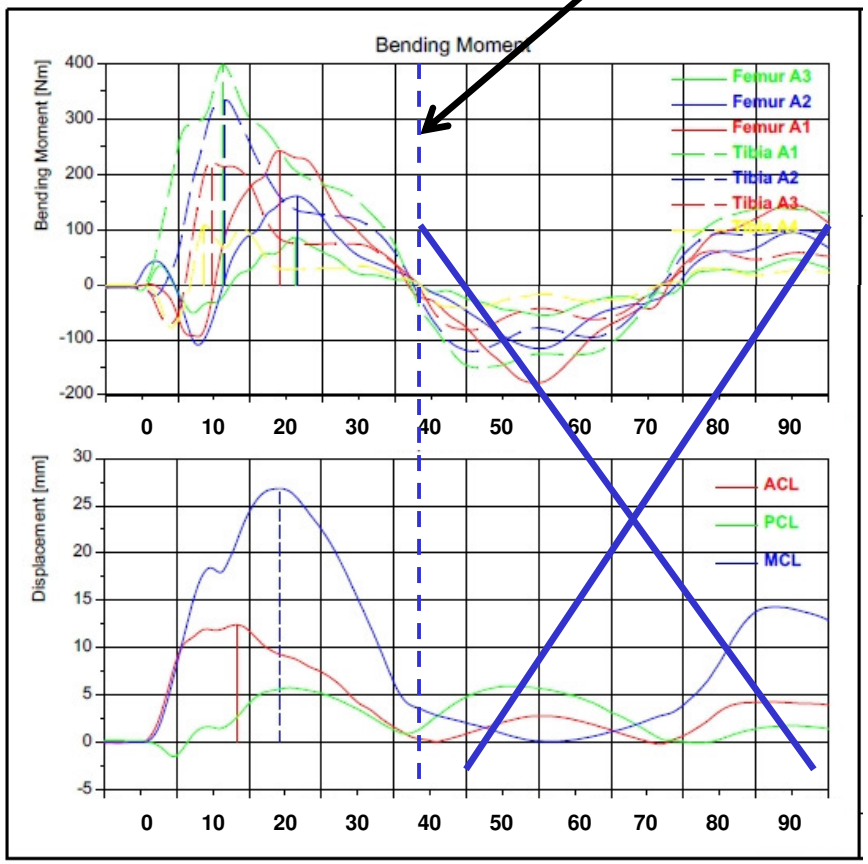
BASt proposal – Case study (III): FFV



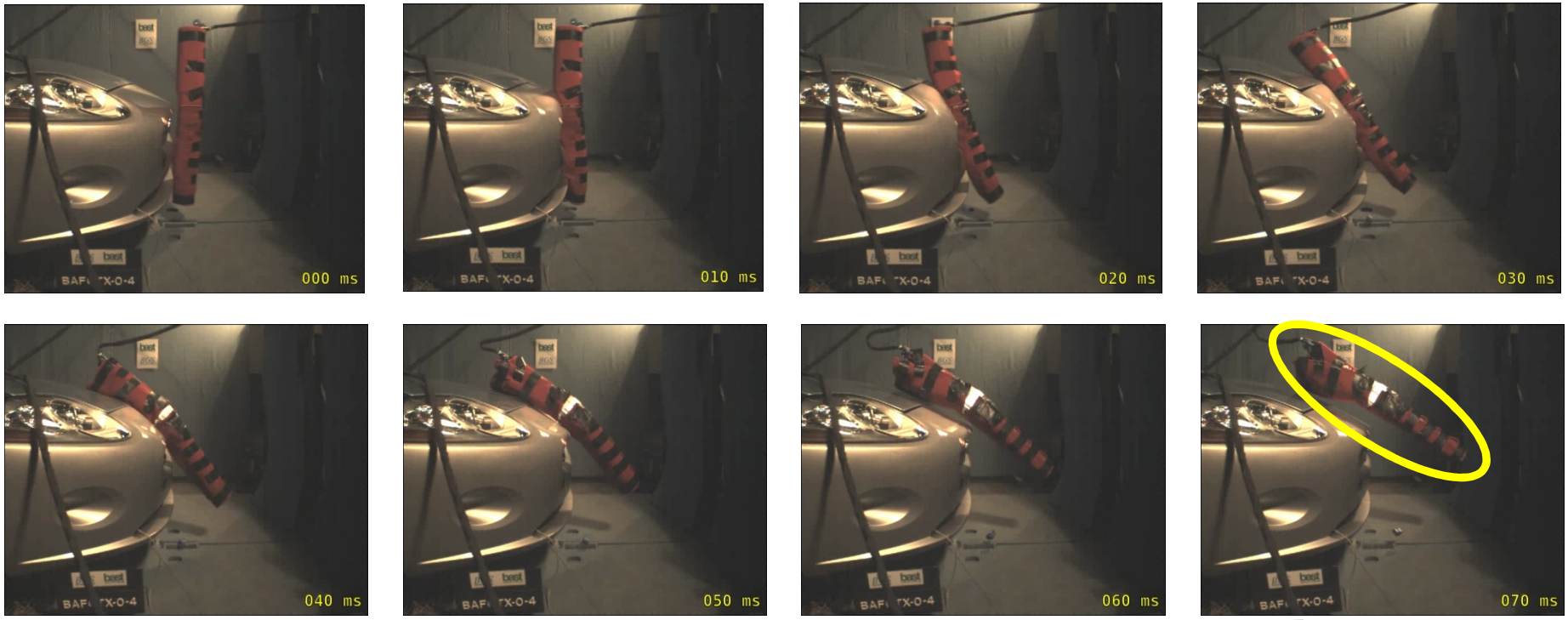
Entire impactor left BAI

BASt proposal – Case study (III): FFV

Entire impactor left BAI



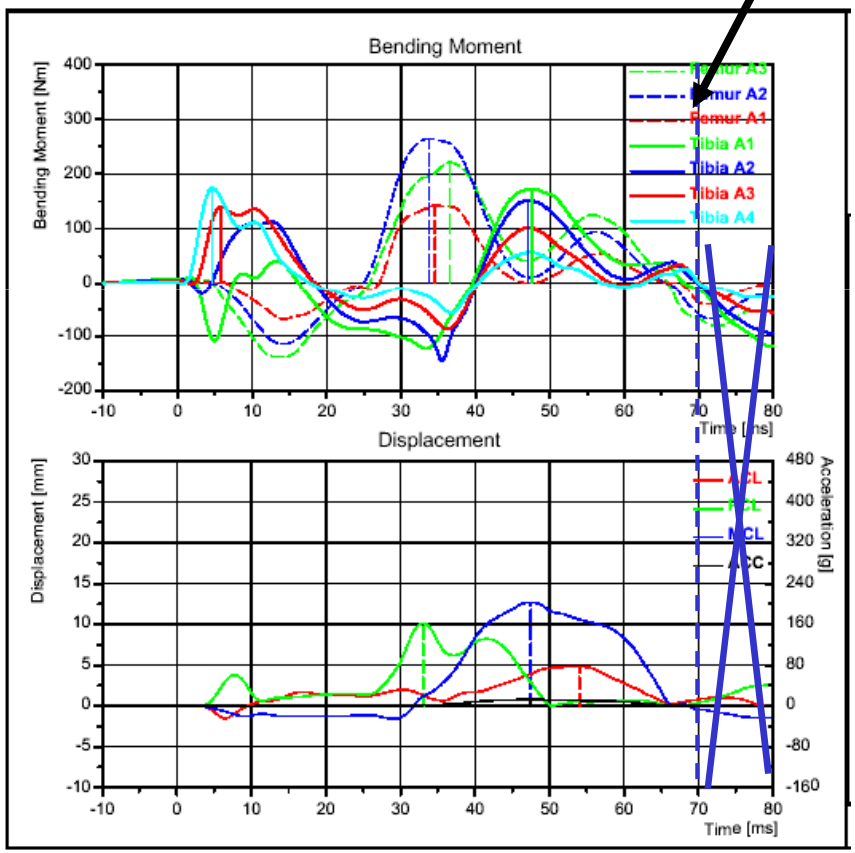
BASt proposal – Case study (IV): Sports car



Entire impactor left BAI

BASt proposal – Case study (IV): Sports car

Entire impactor left BAI



BASt proposal

- **The determination of all FlexPLI peak tibia bending moments and ligament elongations is limited to the biofidelic assessment interval (BAI).**

- **The biofidelic assessment interval (BAI) of the FlexPLI is defined as the timing of the last zero crossing of all femur and tibia segments after their first local maximum, within their common zero crossing phase.**

- **The BAI is identical for all bone segments and knee ligaments.**

- **In case of not all bending moments having a zero crossing during the common zero crossing phase, the time history curves are shifted downwards until all bending moments are crossing zero. The downwards shift is done for determination of the BAI only**

- **BASt proposal covers all cases. The time history curve evaluation until zero crossing ensures that all maxima are taken into consideration.**

- **In case of doubt: For the benefit of the pedestrian !**

Thank you !