

# HBM4VT – WG 2

## Impactor simulation setup

Shaw et al. 2006

# General Overview

## Model Setup

# Impactor tests by Shaw et al. 2006

## Key factors to replicate from PMHS tests:

- HBM in sitting posture
  - Simulation to be performed with occupant model → model is rotated to an upright position
- Positioning of extremities
  - No positioning of the lower extremities → hub is only in contact with thorax
  - Repositioning of upper arm to avoid impactor contact with the upper arm

## Development notes

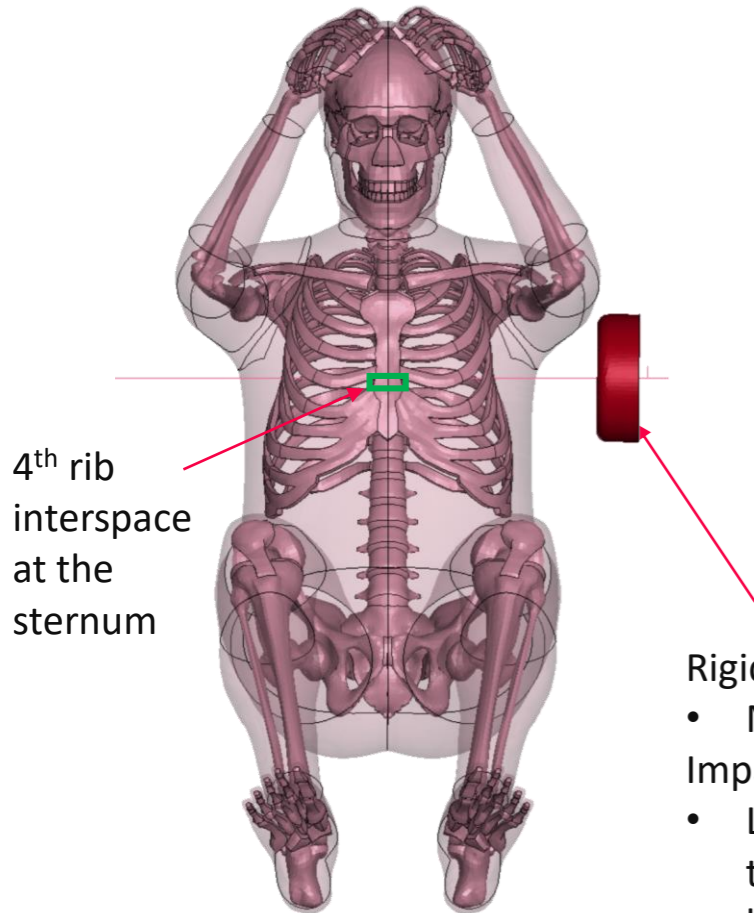
LS-Dyna version used for development:

- R12.2\_217 mpp single precision (R12.2-217-gfcd6dde0c9)
- Time step: dt2ms = -4.44E-4 ms (tssfac = 0.9)

HBMs used in testing:

- THUMS v4.1 50th percentile male

# Simulation setup



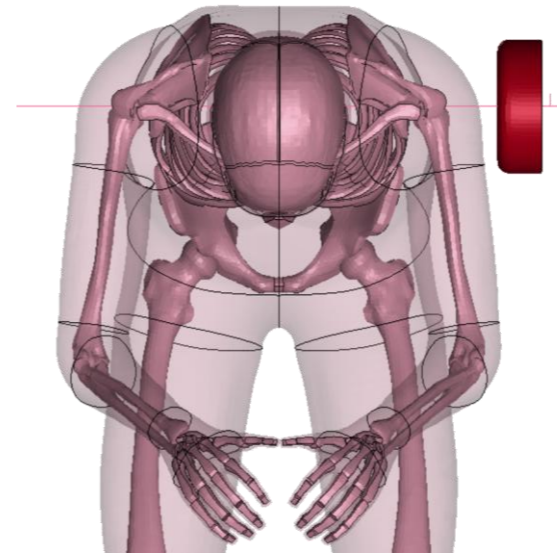
Rigid Impactor

- Mass: 23 kg

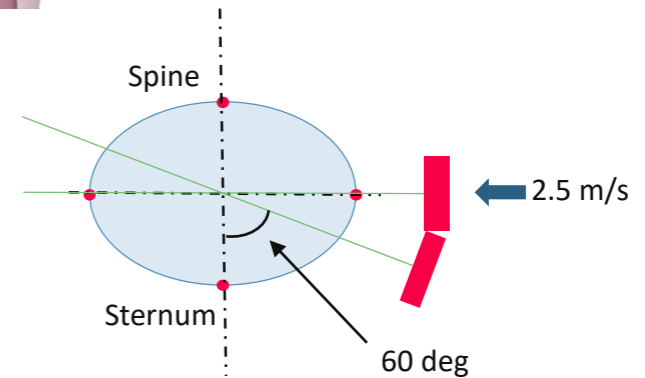
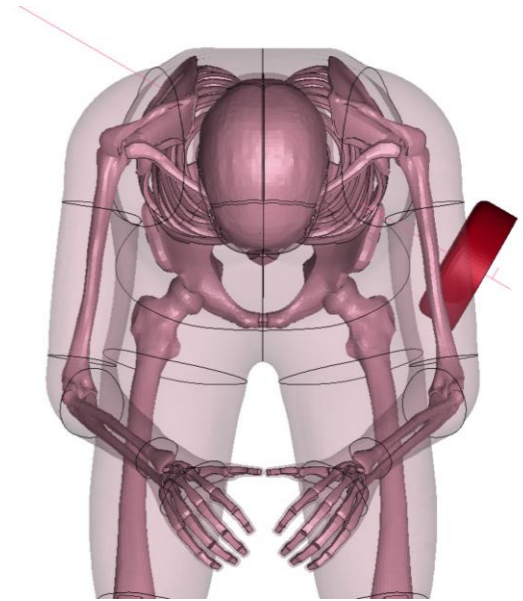
Impact locations:

- Lateral and oblique impact on the thorax at the 4<sup>th</sup> rib interspace level of the sternum

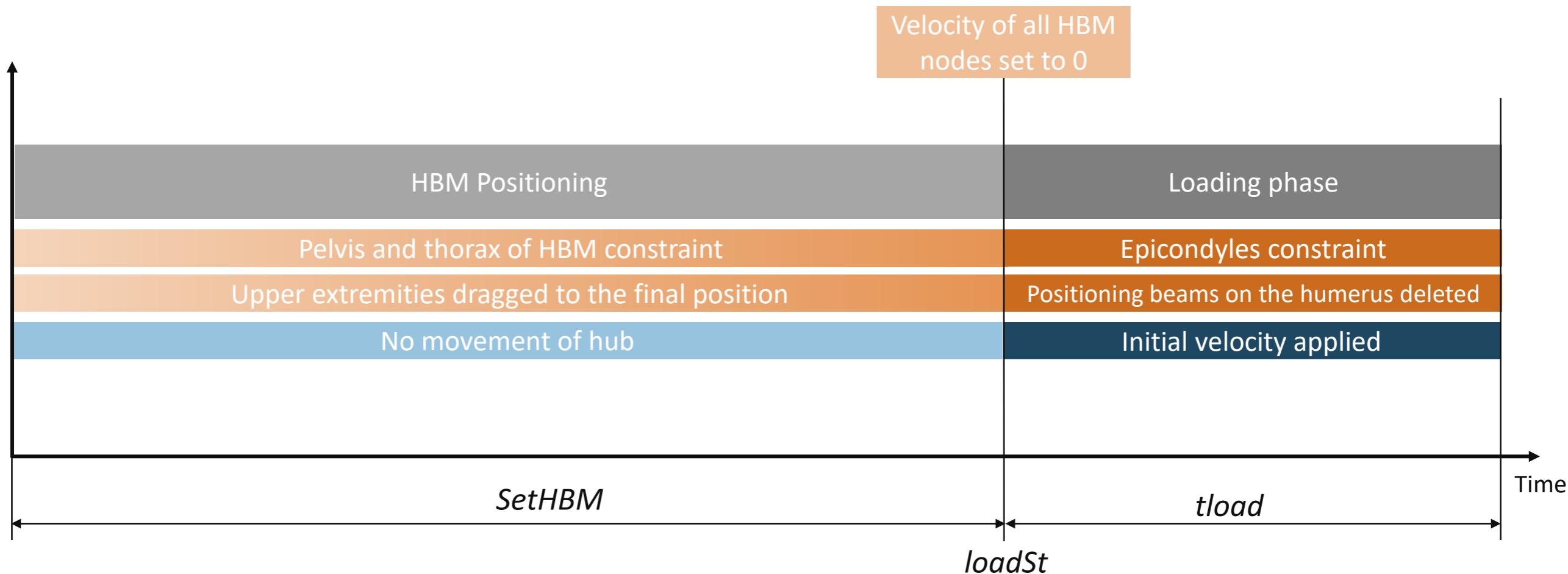
Impact at 90 deg from the mid sternum



Impact at 60 deg from the mid sternum



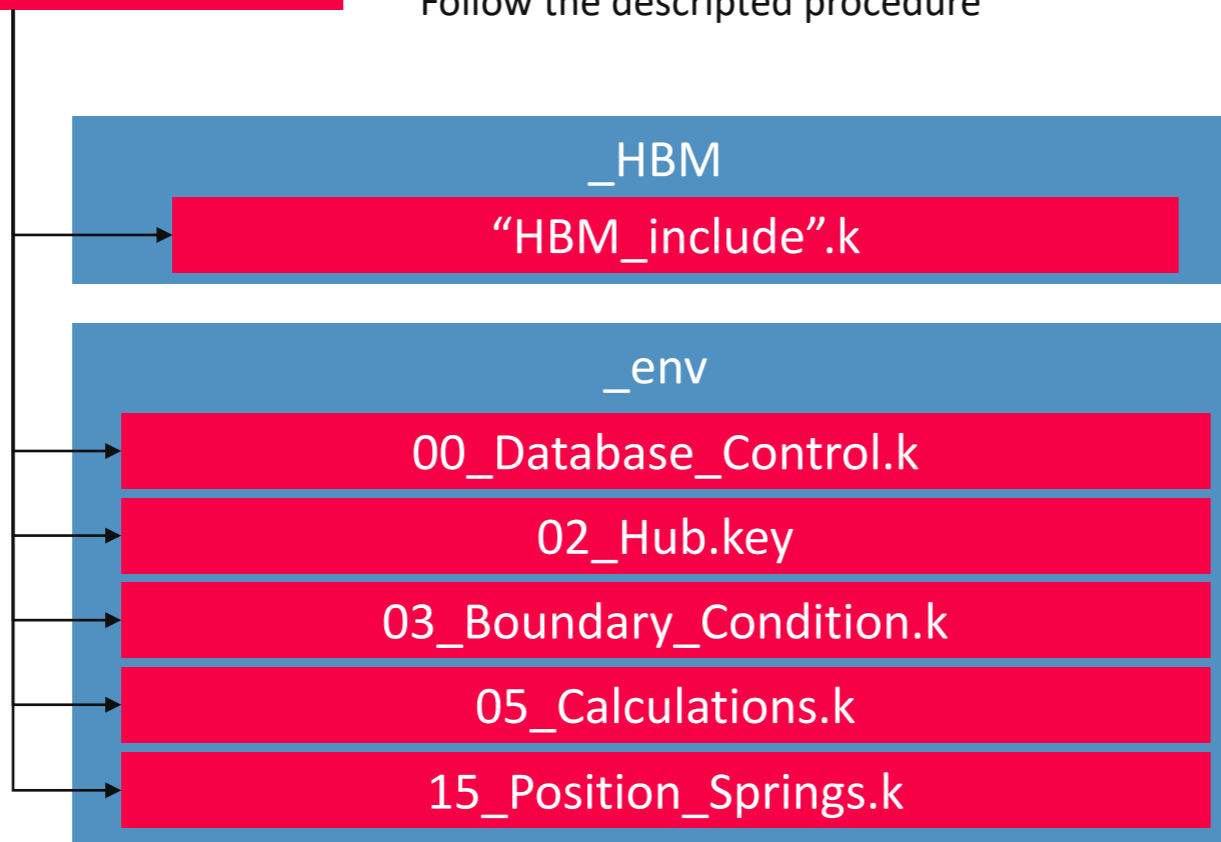
# Simulation phases



# Overview – hub load case

00\_Master\_Hub.k

→ Single file to be changed  
Follow the described procedure



→ Add your HBM-include in the folder „\_HBM“

# Procedure

Setting the parameters

## Set up the include files

- 1) Put the main HBM file in the folder directory "\_HBM"
- 2) Open the main HBM file in a pre-processor
- 3) Open the file 00\_Master\_Hub.k in a text editor
- 4) Define the main HBM file in the I N C L U D E S section
- 5) Follow the instructions from STEP 1 to STEP 8 (following slides)

# Instrumentation requirements

- Note: The required output rate is defined in the file “00\_Database\_Control.k”
  - 10kHz for contact and nodal outputs since CFC filtering is applied in Jupyter notebook
- Update all NODE and OBJECT IDs in the HBM ID-file in “...\data\metadata” accordingly (see THUMS file for example)

## Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary
- 4) Definition of the location where hub contacts HBM
- 5) Definition of the HBM rotations in order to reach target orientation
- 6) Define Nodouts and check for intersections of the HBM to the hub
- 7) Define attachment nodes for positioning beams
- 8) Run simulation and check results

# Overview on stepwise simulation setup (see following slides)

## 1) Definition of the load case

Goal:

- Define the impact angle

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter

## Goal:

- Set factor to scale environment to the unit system of the HBM

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary

## Goal:

- Define sensible HBM contact set

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary
- 4) Definition of the location where hub contacts HBM

## Goal:

- Determine where hub should impact HBM in default HBM position
- Determine the center point of the thorax

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the HBM rotations in order to reach target orientation

## Goal:

- Determine the target orientation of the HBM
- Rotate the HBM based on TB024 sternum angle

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the location where hub contacts HBM
- 6) Define Nodouts and check for intersections of the HBM to the hub**
  - Define nodes for evaluation
  - Offset hub if there is intersection

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the location where hub contacts HBM
- 6) Define Nodouts and check for intersections of the HBM to the hub
- 7) Define attachment nodes for positioning beams**
  - Define how extremities are moved during positioning

# Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
- 2) Definition of global parameter
- 3) Define ID for contact sets and ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the location where hub contacts HBM
- 6) Define Nodouts and check for intersections of the HBM to the hub
- 7) Define attachment nodes for positioning beams
- 8) Run simulation and check results

# STEP 1

## Definition of the load case

Define impact angle

- Imp\_90: set to 1 for 90 deg impact (set other parameter to 0)
- Imp\_60: set to 1 for 60 deg impact (set other parameter to 0)

---

	Velocity [m/s]
90 deg impact	2.5
60 deg impact	2.5

---

## STEP 2

# Definition of global HBM parameter

Define the scale factors depending on the unit system of the HBM

- U\_Scal: 0.001 for unit system t-mm-s
  - U\_Scal: 1 for unit system kg-mm-ms
- The testbed environment will be scaled by *UScal* to the preferred unit system

Define the correct unit system in the Jupyter notebook

- ms\_mm\_kg
- s\_mm\_ton

**Attention: all parameters in the main key file need to be defined in the unit system kg-mm-ms**

## STEP 3

# Define ID for contact sets and ID offset if necessary

Define the part set of the HBM

- $P\_hbm$ : ID of the set including all HBM parts  
→ This part set will be damped

Define the part set of all skin parts of the HBM

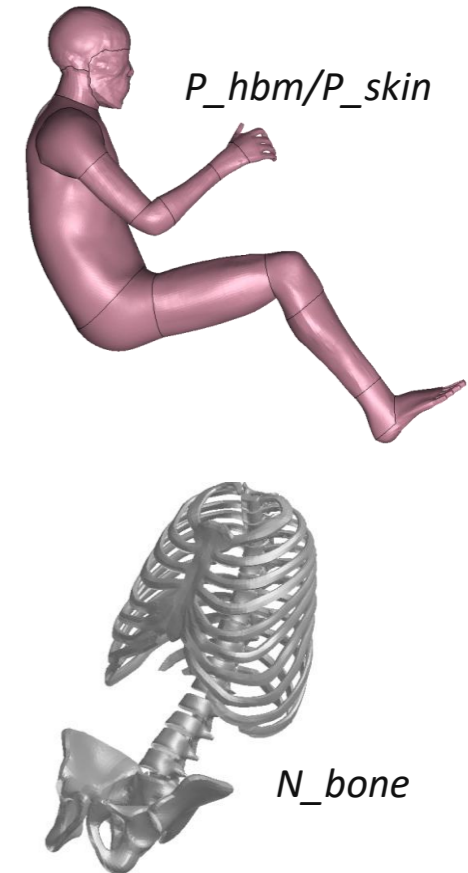
- $P\_skin$ : ID of the set including all skin parts  
→ This part set will be in contact to the impactor

Define the node set including several nodes on the bones of the pelvis, the thorax, and the spine (e.g. choose three nodes per bone, not all nodes of a bone are required to be constrained)

- $N\_bone$ : ID of the set including nodes on bones of pelvis, spine and ribs  
→ This node set will be constrained till the point when the hub comes in contact with the HBM (do not choose nodes belonging to rigid materials or rigid bodies)

If the test setup shares node IDs with HBM, define an ID offset for the HBM

- $IDoff$ : default: 0.



# STEP 4

## Definition of the location where hub contacts HBM

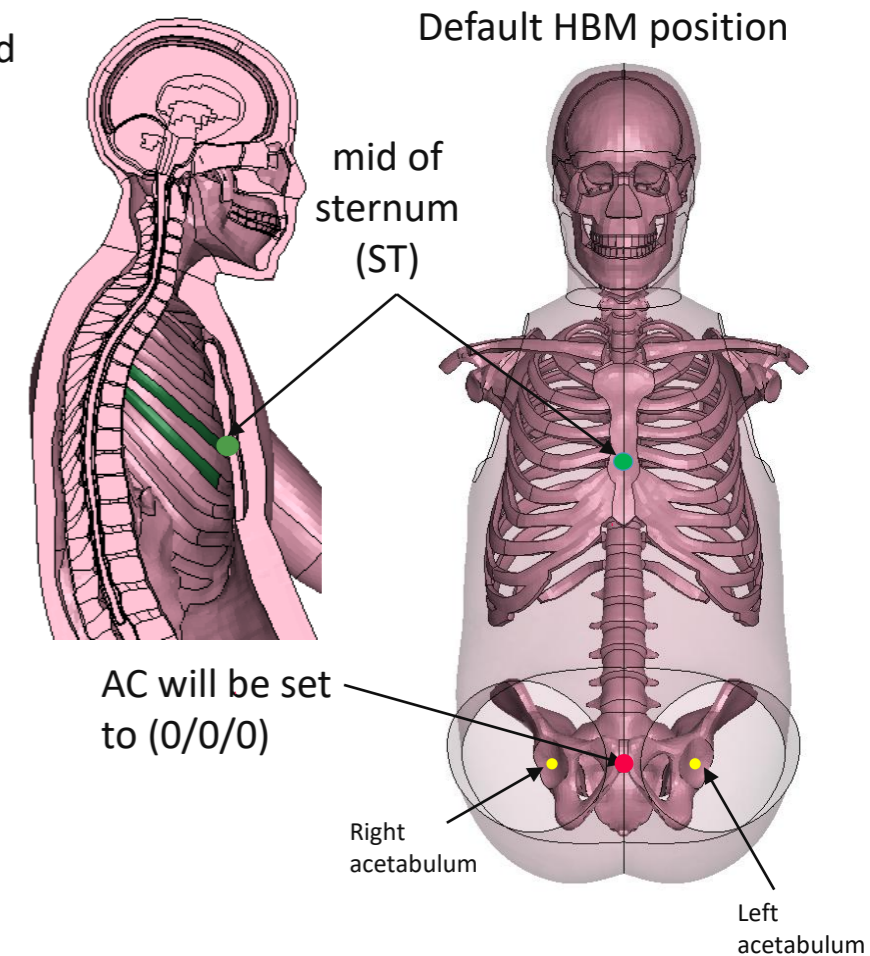
Define the coordinates of the location of the acetabulum centre point (AC) between the left and right acetabulum (in midsagittal plane):

- $x_{AC}$ : x-coordinate of AC in the default HBM position with respect to the global coordinate system
- $y_{AC}$ : y-coordinate of AC in the default HBM position with respect to the global coordinate system
- $z_{AC}$ : z-coordinate of AC in the default HBM position with respect to the global coordinate system

→ The HBM will be transferred so that the AC is at 0/0/0

Define the coordinates of the position of the center of the sternum at the 4th rib interspace in the midsagittal plane

- $x_{ST}$ : x-coordinate of ST in the default HBM position with respect to the global coordinate system
- $z_{ST}$ : z-coordinate of ST in the default HBM position with respect to the global coordinate system



# STEP 4

## Definition of the location where hub contacts HBM

Define the lateral distance between the acetabulum centre (AC) and the most lateral point of the thorax

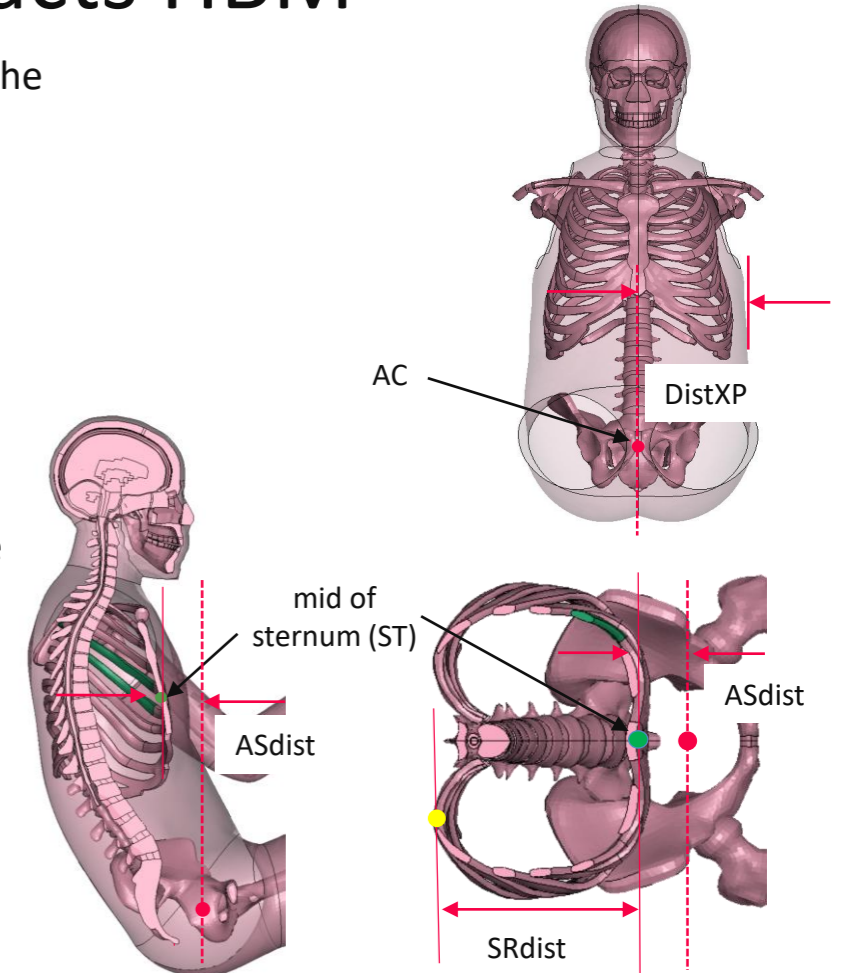
- *DistXP*: distance in lateral direction

Define the sagittal distance between the acetabulum centre (AC) to the mid of the sternum at the fourth rib interspace

- *ASdist*: sagittal distance

Define the sagittal distance between the mid of the sternum at the fourth rib interspace to the most posterior point on the ribcage

- *SRdist*: sagittal posterior distance



# STEP 5

## Definition of the HBM rotations to reach target orientation

Check the actual HBM orientation and compare to target orientation as illustrated

Define the flag for all axes:

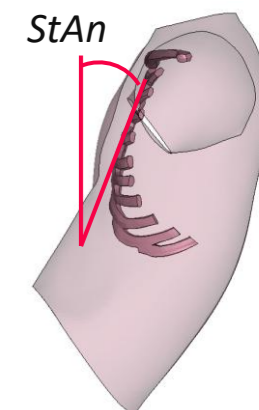
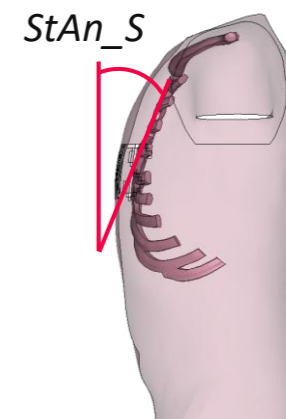
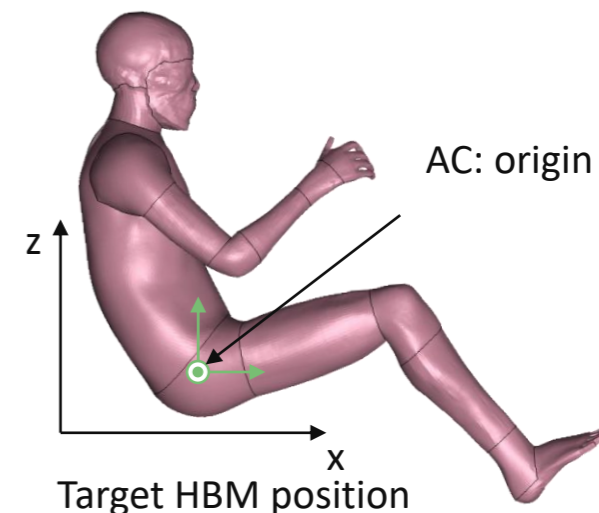
- $x_{rt}$ : "1" for correct axis orientation and "-1" to rotate the model 180deg about the x axis
- $y_{rt}$ : "1" for correct axis orientation and "-1" to rotate the model 180deg about the y axis
- $z_{rt}$ : "1" for correct axis orientation and "-1" to rotate the model 180deg about the z axis

→ HBM will be rotated to reach target orientation

Measure the sternum angle between the center of attachment of 4th to 2nd rib relative to frontal plane

- $StAn$ : angle in default posture of HMB used here (insert a positive value)
- $StAn_S$ : angle in default posture of corresponding HBM in TB024 (insert a positive value)
  - If the used HBM is already in standing posture, define both angles as 0 and no rotation is applied to the hub
  - If no standing posture of the HBM is available, define both angles as 0 and no rotation is applied to the hub

→ The HBM will be rotated in a way so that the HBM reaches an erect posture similar to the TB024 posture



# STEP 6

## Define Nodouts and check for intersections of HBM to the hub

Save this file (00\_Master\_Hub.k) and open it in a pre-processor

IF the hub has intersections to the HBM thorax, adjust the hub offset

- $H_{offy}$ : distance in y (positive value: hub moves away from HBM)

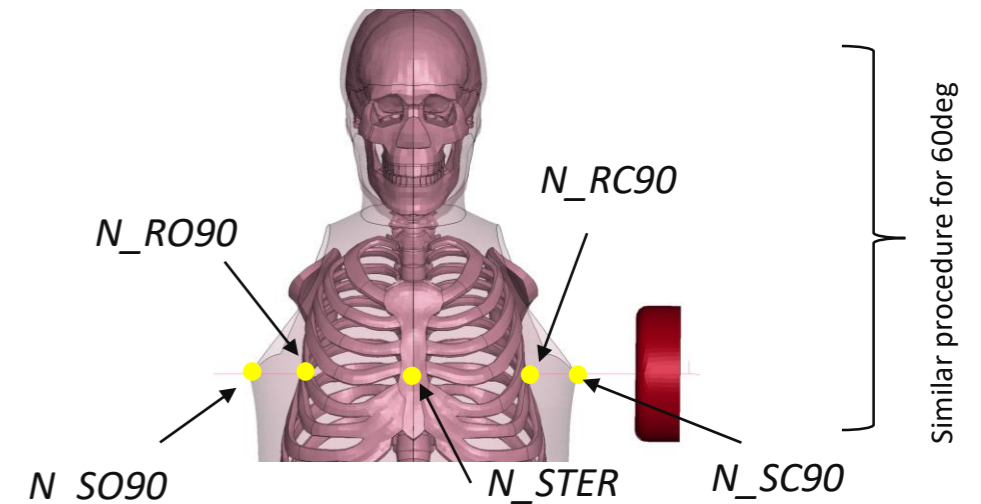
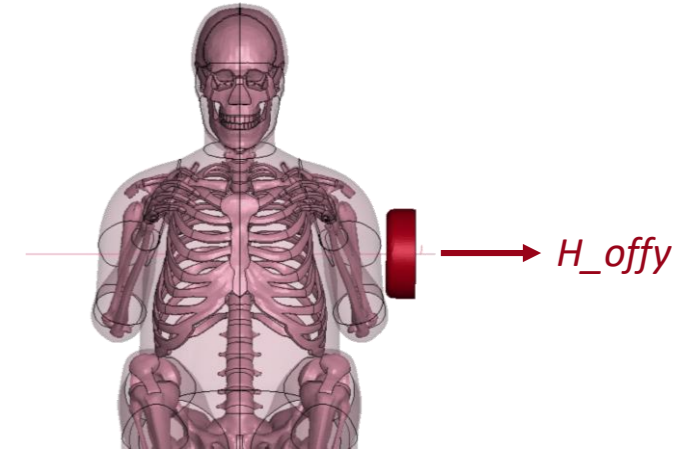
Note: Keep a clearance between hub and HBM of at least 20mm to facilitate filtering of the force signal in the assessment notebook

Define the node IDs which have to be tracked

- $N_{SC90}$ : Node ID on outer skin on the beam axis on the hub side at 90deg
- $N_{RC90}$ : Node ID on the lateral end of the rib on beam axis on the hub side at 90deg
- $N_{SC60}$ : Node ID on outer skin on the beam axis on the hub side at 60deg
- $N_{RC60}$ : Node ID on the lateral end of the rib on beam axis on the hub side at 90deg
- $N_{SO90}$ : Node ID on outer skin on the beam axis opposite to the hub at 90deg
- $N_{RO90}$ : Node ID on the lateral end of the rib on beam axis opposite to the hub at 90deg
- $N_{SO60}$ : Node ID on outer skin on the beam axis opposite to the hub at 60deg
- $N_{RO60}$ : Node ID on the lateral end of the rib on beam axis opposite to the hub at 60deg
- $N_{STER}$ : Node ID on the mid sternum at the fourth rib interspace

→ \*DATABASE\_HISTORY\_NODE will be generated for these nodes

**Important!!** Update these NODE IDs in the HBM\_ID.def file in data\metadata accordingly



# STEP 7

## Define attachment nodes for positioning beams

Define the node IDs for the landmarks to be positioned

R = right, L = left

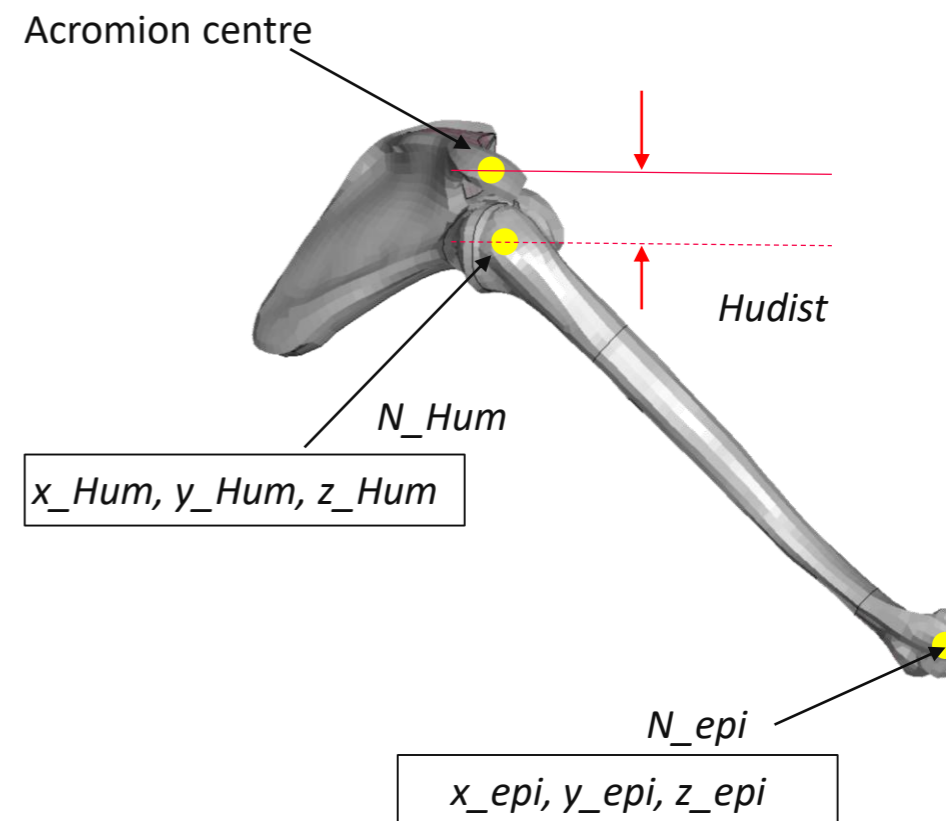
- $N\_epiL/N\_epiR$ : Node at mid of epicondyle
- $N\_HumL/N\_HumR$ : Node at humerus center

Define the coordinates of landmarks in updated "00\_Master\_Hub.k" file

- $X\_epiL/X\_epiR$ : x-coordinates of the mid epicondyle
- $Y\_epiL/Y\_epiR$ : y-coordinates of the mid epicondyle
- $Z\_epiL/Z\_epiR$ : z-coordinates of the mid epicondyle
- $X\_HumL/X\_HumR$ : x-coordinates of the mid epicondyle
- $Y\_HumL/Y\_HumR$ : y-coordinates of the mid epicondyle
- $Z\_HumL/Z\_HumR$ : z-coordinates of the mid epicondyle

Define the vertical distance between the humerus centre and the acromion center

- $Hudist$ : distance between humerus centre and acromion center



# STEP 8

## Run simulation and check results

Check the d3plot and adapt the parameters if needed:

If the upper arms do not reach the target position:

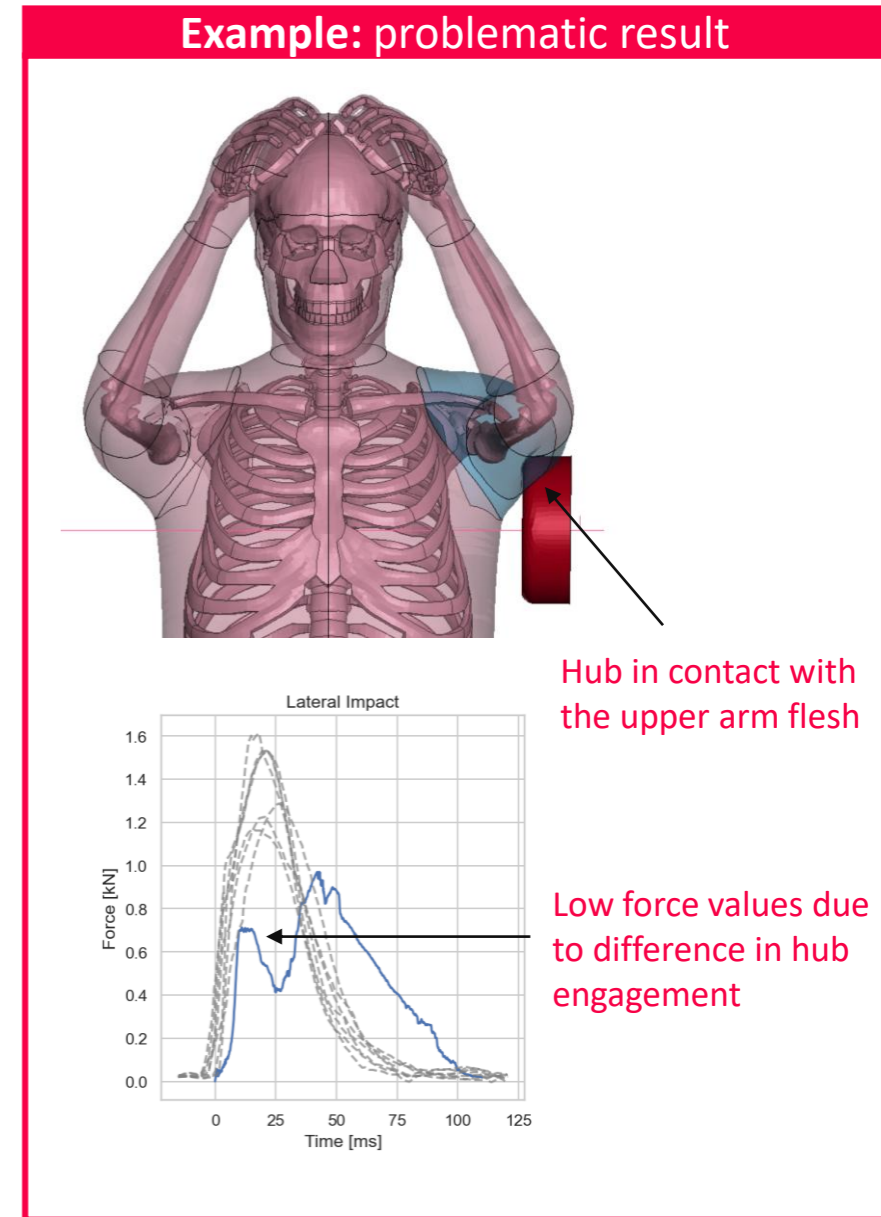
- Option A: change settling duration
  - *SetHBM*: duration of HBM positioning phase (default: 350ms)
- Option B: increase tension force in positioning beams
  - *Fbeam*: tension force in positioning beams (default: 0.2kN)

Check the impacting location after positioning simulation

- If the hub comes in contact with the upper arm flesh or if the resultant loading of the hub is undesirable, move the hub downwards in the vertical axis (see example on the right-hand side)
- *H\_offz*: Hub offset in the vertical axis; positive value = hub moves downwards  
*(Refer the following slides for a detailed trouble shooting guide)*

IF contact issues occur, modify DEPTH flag for contact HBM to environment

- *Depth*: default: 25



# Hub comes in contact with the upper arm flesh... What to do?

*(Applicable for both impact angles)*

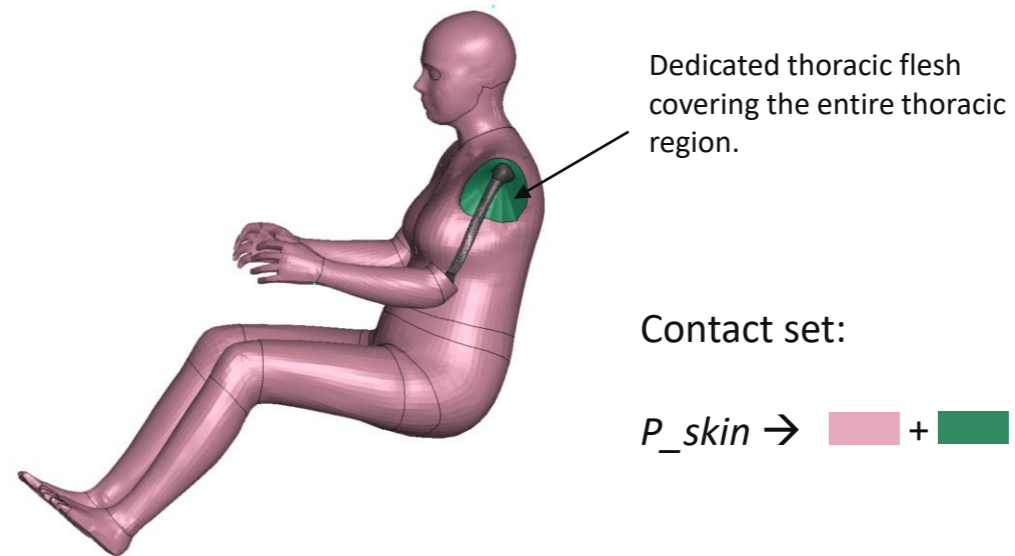
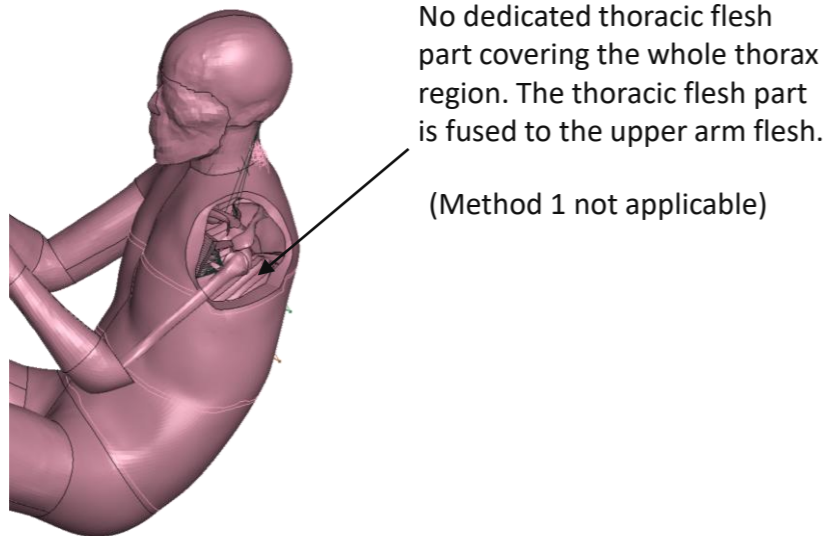
Two methods to address this:

- **Method 1:** By removing the upper arm parts from the contact set (easy way, but not applicable to all HBMs)
- **Method 2:** By moving the impactor downwards

# Hub comes in contact with the upper arm flesh... What to do?

## Method 1: By removing the upper arm parts from the contact set

- Check how the used HBM torso is modeled
  - Certain HBMs do not have a dedicated flesh part (solid) covering the entire thoracic region. E.g.: THUMS. If that's the case, this method is not applicable. Use Method 2.
  - If the used HBM has a dedicated flesh part (solid) covering the entire thoracic region (Eg: VIVA+), remove the skin part corresponding to the upper arm and add the additional thoracic flesh part to the contact set *P\_skin* in S T E P 3 and proceed till S T E P 8.

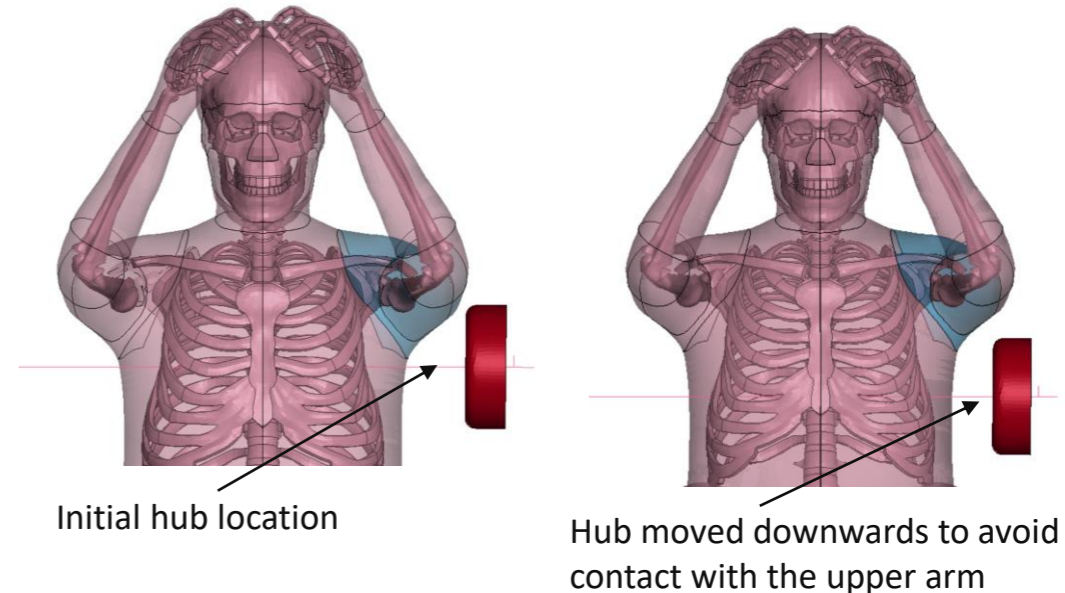


# Hub comes in contact with the upper arm flesh... What to do?

## Method 2: By moving the hub downwards

- Open the *d3plots* in a post-processor
- Estimate how much should the hub be moved downwards in the vertical direction to avoid contact with the upper arm  
Enter this value (in positive) in ***H\_offz*** in S T E P 8
- Estimate also the nodes that would be on the beam axis if the hub is moved\*  
Update these node IDs used for nodouts in S T E P 6 and also in data/metadata
- Run the simulation again and check results

\*TIP:  
It can be difficult to estimate the nodes that would be on the beam axis. Choose nodes approximately, such that they lie parallel to the beam axis within the projected area of the hub.





## Vehicle Safety Institute

Graz University of Technology

Inffeldgasse 13/6

8010 Graz Austria

[www.vsi.tugraz.at](http://www.vsi.tugraz.at)

**Desiree Kofler**

[desiree.kofler@tugraz.at](mailto:desiree.kofler@tugraz.at)

+43 316 873 30350

**Felix Ressi**

[felix.ressi@tugraz.at](mailto:felix.ressi@tugraz.at)

+43 316 873 30363

**Corina Klug**

[corina.klug@tugraz.at](mailto:corina.klug@tugraz.at)

+43 316 873 30329