SCIENCE
PASSION
TECHNOLOGY

# HBM4VT – WG 2

# **Hub simulation setup**

## **Kroell** et al. 1971

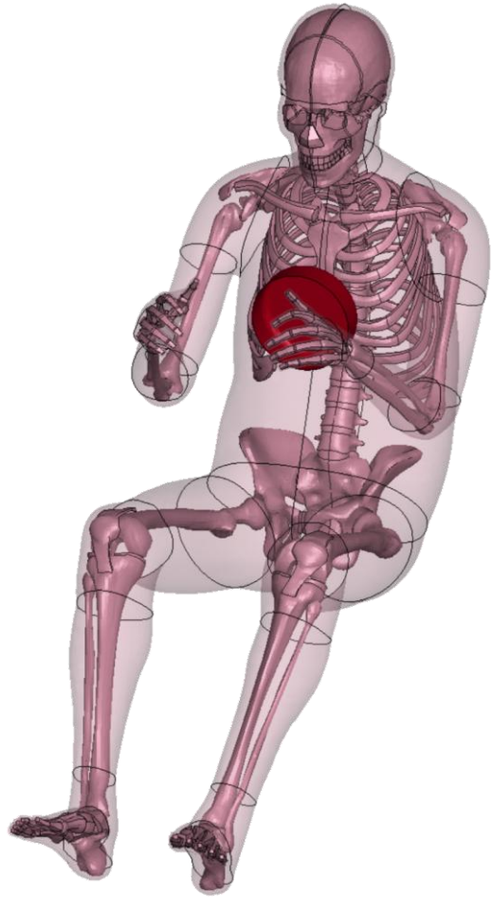
# General Overview

## Model Setup

# Hub test by Kroell et al. 1971

## Key factors to replicate from PMHS tests:

- HBM in the seated position
  - Simulation can be performed also with HBM in occupant model posture → model is rotated such that the angle between the AC & T1 is 90deg to the sagittal axis (which is more erect)
- No HBM re-positioning
  - Re-positioning of the upper and lower extremities not required, as the response of thorax is only considered



# 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)

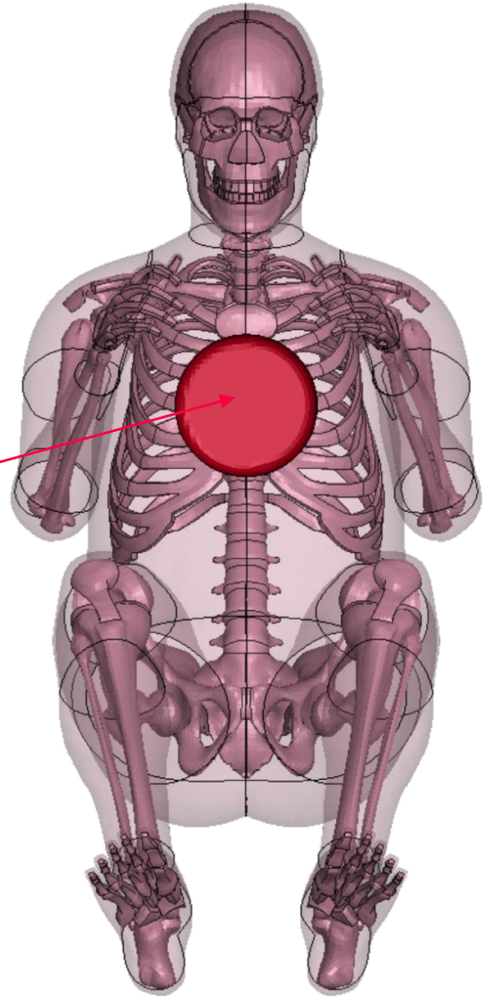
## HBMs used in testing:

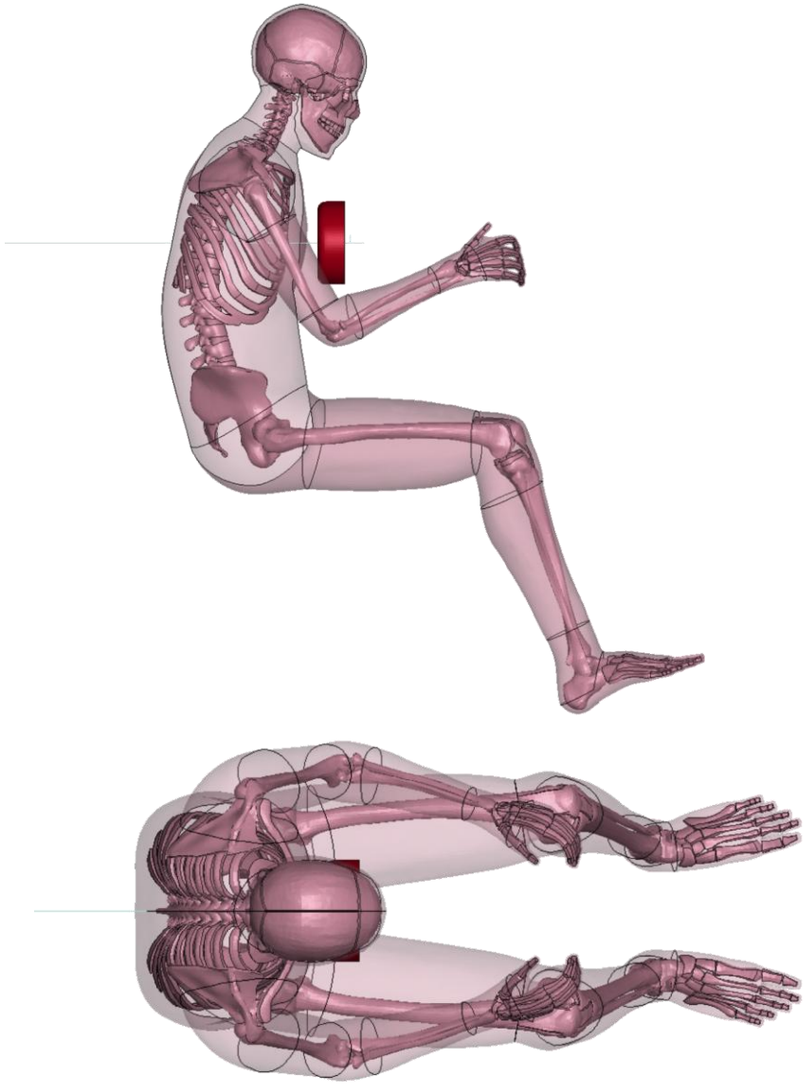
- THUMS v4.1 50th percentile male
- VIVA+ v1.1.0 50th percentile female

# Simulation setup

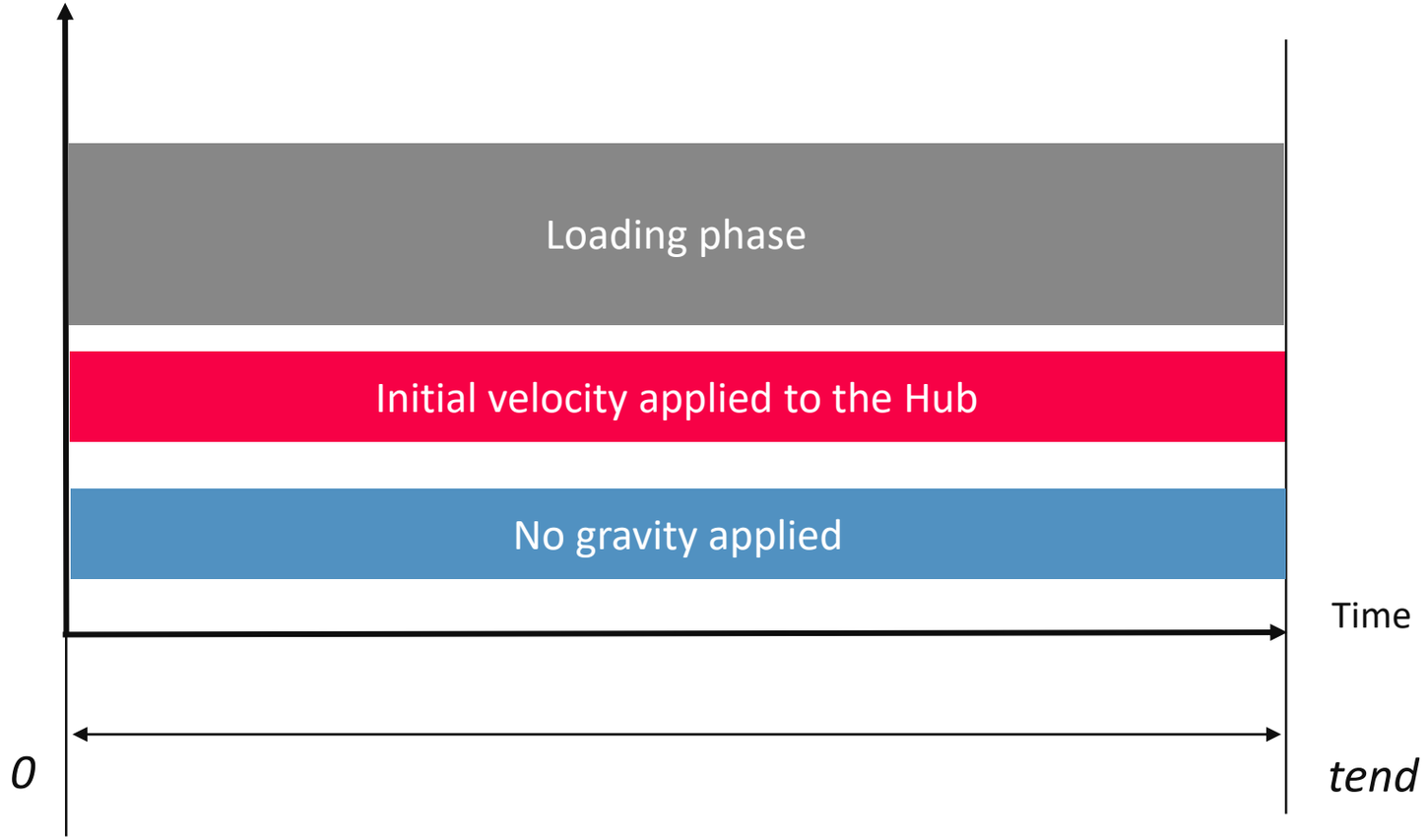
Rigid hub
- Mass: 23.4 kg

Impact location
- at the center of the sternum between the fourth rib interspace

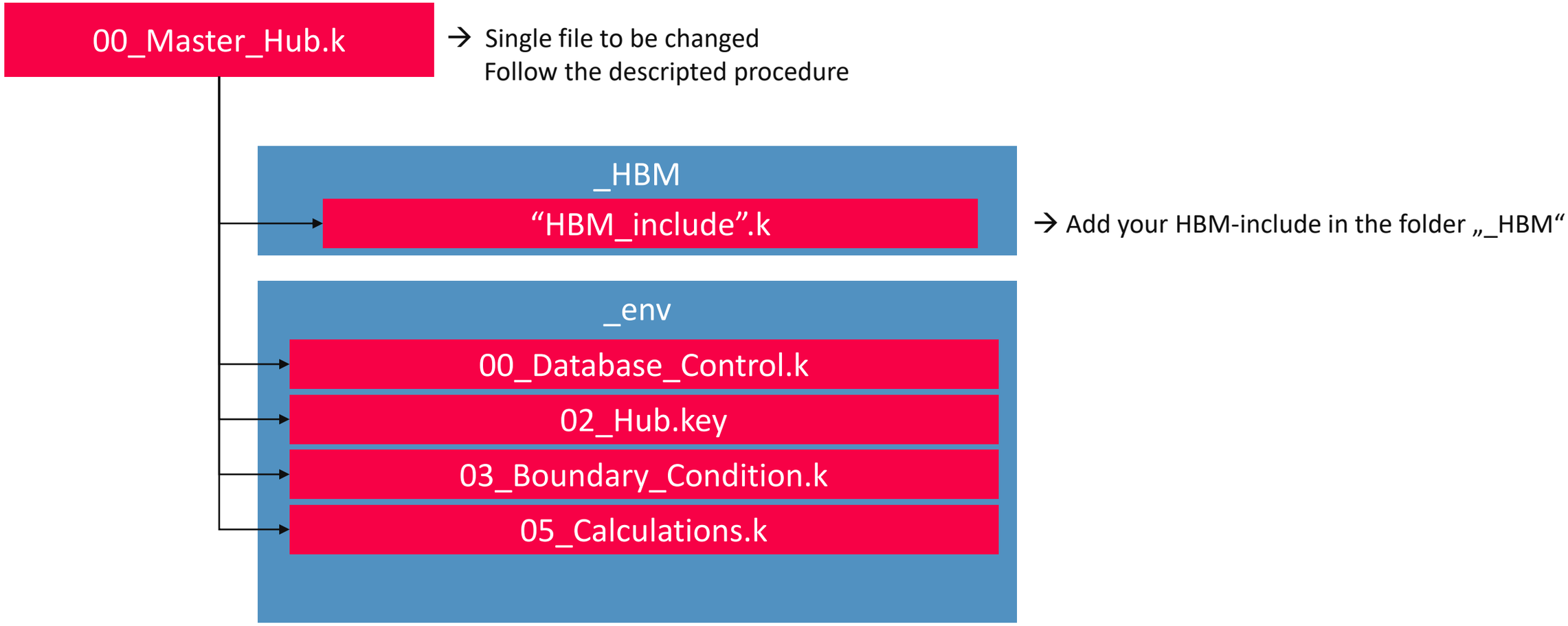




# Simulation phases



# Overview – hub load case



# 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 7 (following slides)

# Instrumentation requirements

- Equip your HBM with the required output
  - Strains in cortical bones of ribs

- 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) Run simulation and check results

# Overview on stepwise simulation setup (see following slides)

## 1) Definition of the load case

Goal:

- Define the impact severity

# 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
- Localise points where hub should impact HBM in default HBM position

# 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 to reach target orientation

Goal:

- Determine the target orientation 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
4) Definition of the HBM landmarks & rotations to reach target orientation
5) **Definition of the location where hub contacts HBM**

Goal:

- Define the impact location

# 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 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

Goal:

- Define nodes for evaluation
- Move hub to avoid intersections to 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
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# STEP 1
# Definition of the load case

Define impact severity

- LS: set to 1 for low speed (set other parameter to 0)
- HS: set to 1 for highest speed (set other parameter to 0)

| | **Velocity [m/s]** |
|---|---|
| Low speed (LS) | 4.3 |
| Highest speed (HS) | 6.7 |

# 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

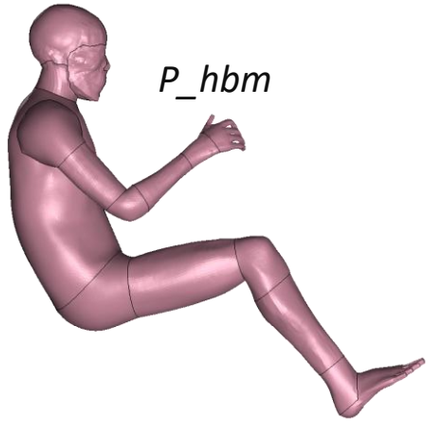
- ms_mm_kg
- s_mm_ton

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




Define the part set of all skin parts of the HBM

- *P_hski*: ID of the set including all skin parts except the head of the HBM

→ This part set will be in contact to the testbed


IF the testbed shares node IDs with HBM, define an ID offset for the HBM

- *IDoff*: default: 0.

# STEP 4

## Definition of the HBM landmarks and rotations to reach target orientation

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

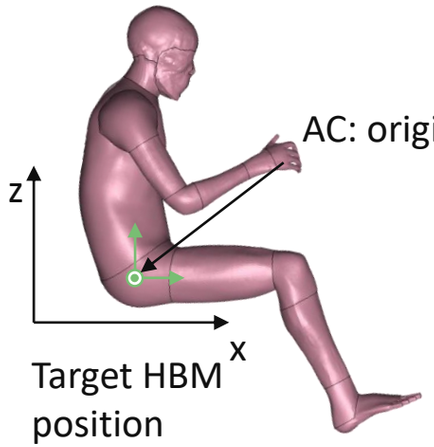
→ The HBM will be transferred so that the AC is at 0/0/0

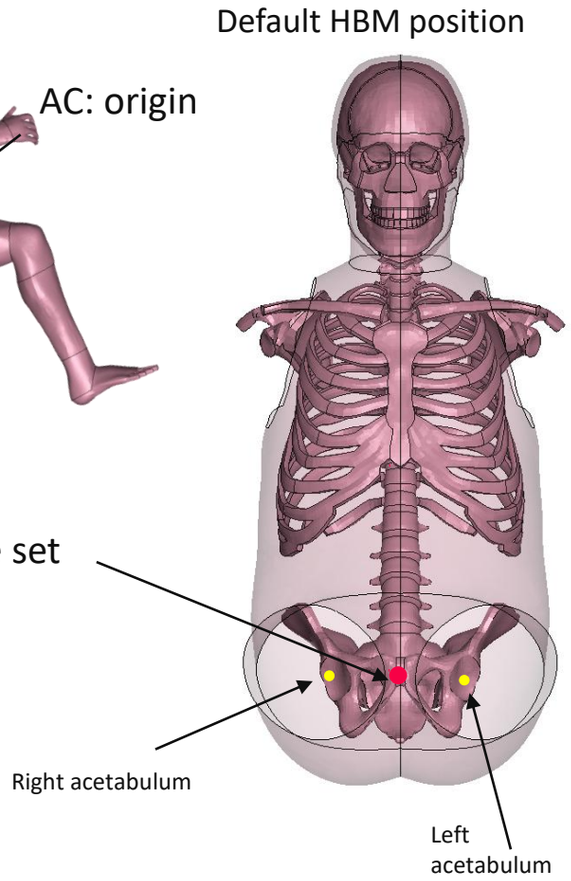
Check the actual HBM orientation and compare to target orientation as illustrated

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



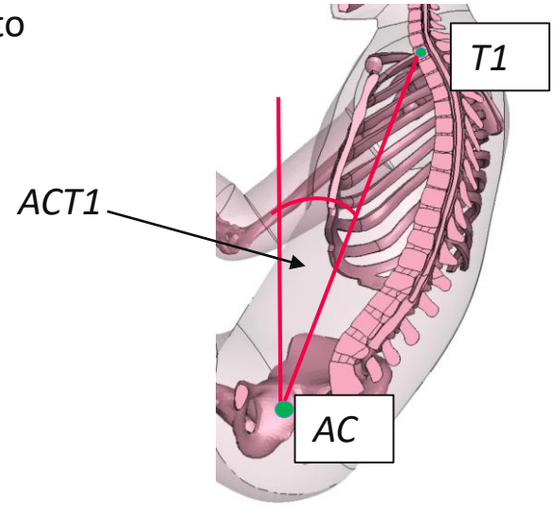



# STEP 4
# Definition of the HBM landmarks and rotations to reach target orientation

Measure the angle between the Acetabulum Centre(AC) to the mid T1 vertebrae relative to frontal plane

- *ACT1*: angle between AC and thoracic vertebrae (T1)

→ The HBM will be rotated in a way such that it maintains an erect posture



# STEP 5
# Definition of the location where hub contacts HBM

**Save the file “00_Master_Hub.k” and open it in a pre-processor**

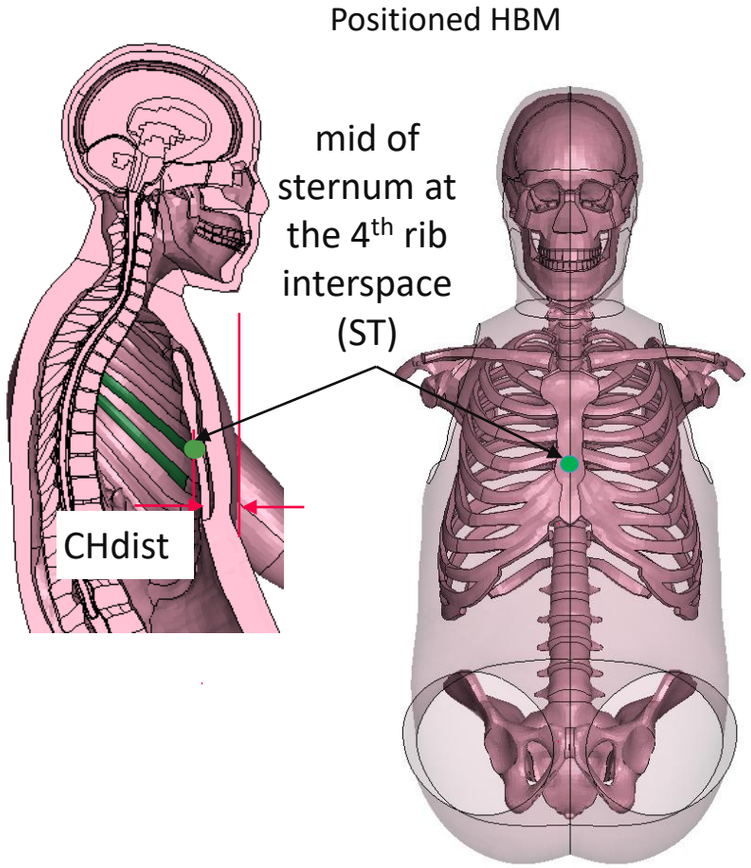
Define the coordinates of the position of the mid of the sternum at the 4th rib interspace in the midsagittal plane

- *x_ST*: x-coordinate of ST in the positioned HBM with respect to the global coordinate system
- *z_ST*: z-coordinate of ST in the positioned HBM with respect to the global coordinate system

Define the distance between ST and the most anterior point on the chest

- *Chdist*: distance in anterior direction

→ The hub will be positioned at the mid of sternum at 4$^{th}$ rib interspace



# STEP 6

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

**Save the file “00_Master_Hub.k” and open it in a pre-processor**

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

- *H_off:* distance in x (positive value: hub moves away from HBM)

Note: Keep a clearance between hub and HBM of at least 35mm to facilitate filtering of the force signal in the assessment notebook

Define the node ID of the closest node on the outer skin, where the beam axis “punctures” the skin

- *N_SKIN*: Node ID on the outer anterior skin on beam axis

Define the node ID of the closest node on the sternum, where the beam axis “punctures” the ribcage

- *N_STER*: Node ID on sternum on beam axis/mid sternum at 4$^{th}$ rib interspace

Define the node ID of the closest node on the anterior side of the spine, where the beam axis “punctures” the thoracic vertebrae

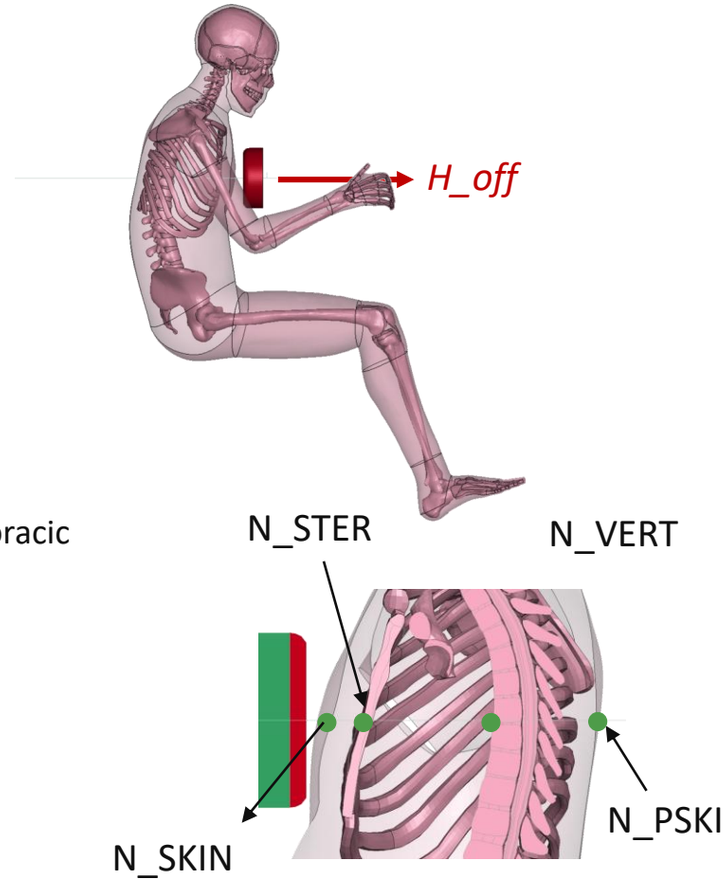
- *N_VERT*: Node ID on thoracic spine on beam axis

Define the node ID on the posterior skin on the beam axis

- *N_PSKI*: Node ID on the posterior outer skin on the beam axis

→ *DATABASE_HISTORY_NODE will be generated for these nodes

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

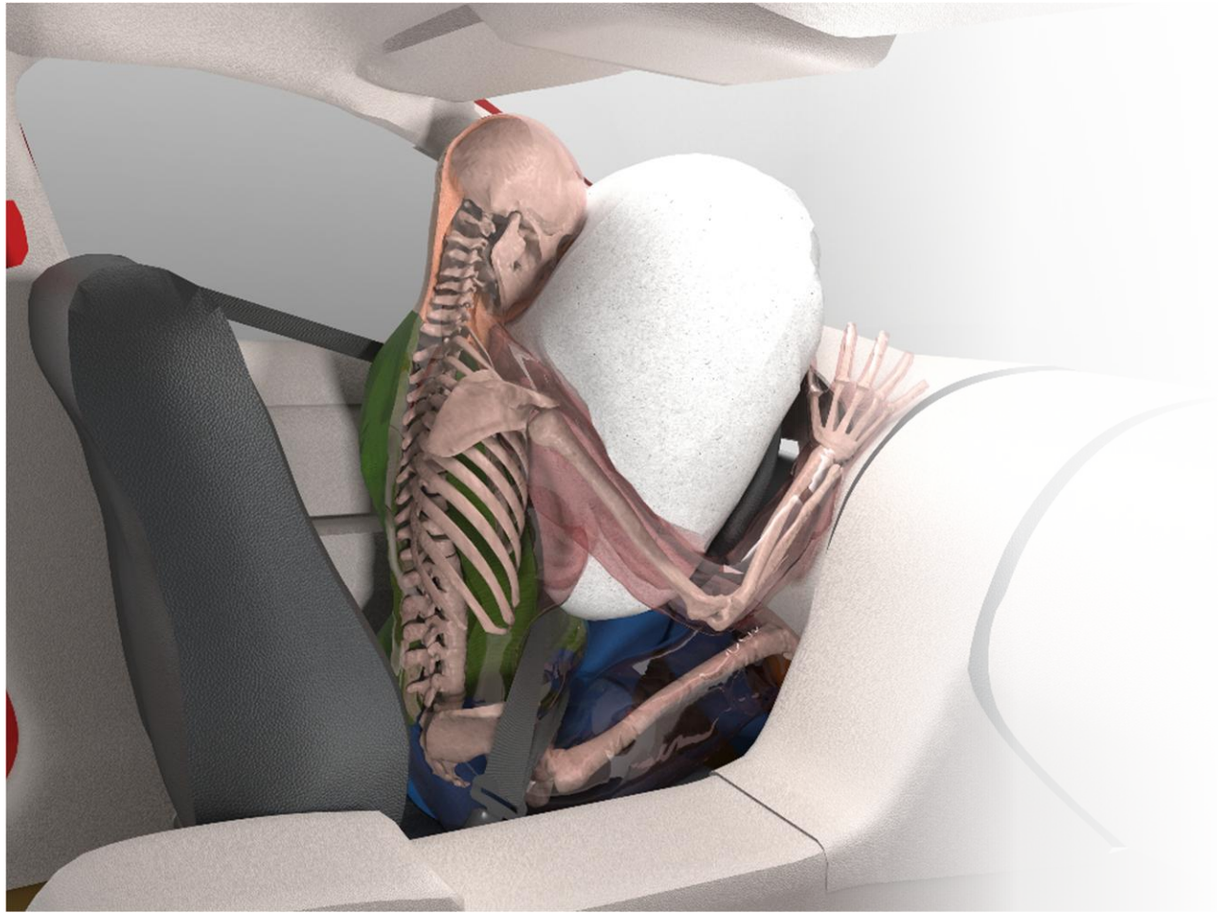


# S T E P  7
# Run simulation and check results

Check the d3plot and evaluate the results in Dynasaur

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

- *Depth*: default: 25



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