ECAL-P Mechanical Frame

(technical specification)

Grzegorz Grzelak, Piotr Zbińkowski, Filip Żarnecki

University of Warsaw

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Outline

Mechanical Frame for ECAL-P: Technical Note

- Design assumptions
- Main body of the calorimeter, tungsten plates
- PCB support
- Positioning of the silicon sensors
- Location in the LUXE experiment
- Auxiliary equipment

Mechanical Frame for the LUXE ECAL-P Calorimeter

(technical specification, **preliminary draft ver. 0.3**)

Grzegorz Grzelak, Piotr Zbińkowski, Aleksander Filip Żarnecki

August 31, 2023

- **Draft is ready !** → circulated to the ECAL group
- Following specification is based on the above document

Design Assumptions

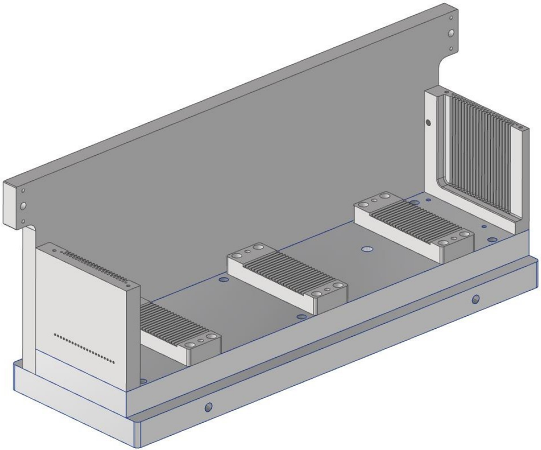
Baseline specification:

- ECAL-P is sampling calorimeter
- 21 1X_0 (3.5 mm thick) tungsten plates as absorber
- 20 layers of CALICE silicon sensors (0.32 mm thick) as active medium
- open architecture (flexible choice of the number and thickness of the absorber plates)
- possible removal/insertion of single detector plane in case of repair/service
- fixture to facilitate gentle insertion/removal of detector planes
- mounting points (nests) of markers for geodesy laser tracker survey
- support for readout cables
- auxiliary equipment for transportation and positioning “on beam”

ECAL-P: mechanical parameters

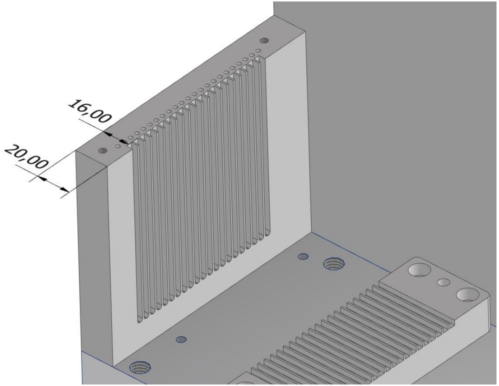
ECAL-P: main frame and combs

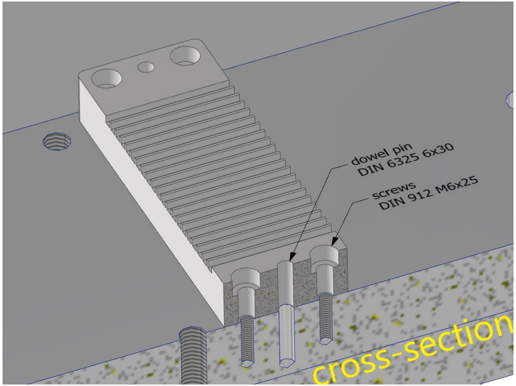
ECAL-P main frame on transportation plate



- duraluminum body of ECAL-P (30 mm bottom plates, 20 mm back-plane) with combs structure for holding 21 tungsten plates and 20 silicon sensor layers in **1 mm gaps**
- flexible “open-architecture”, asymmetric side walls (10 mm sensor distance to the inner ECAL-P edge)

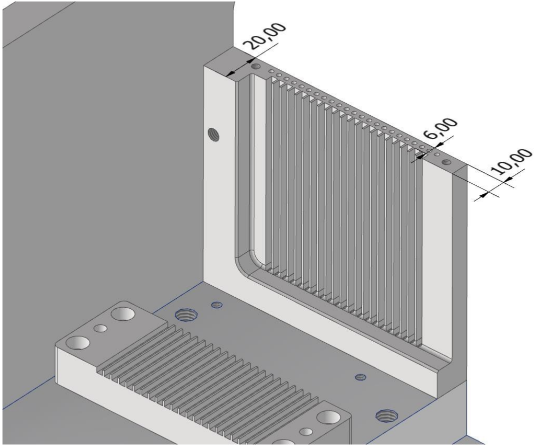
Combs structure (1) : outer wall and bottom

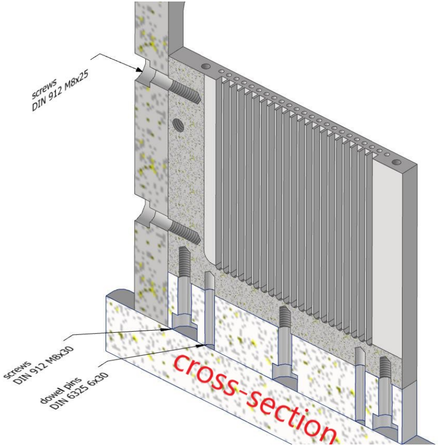




- **dowel pins for precise alignment**, screws for fixing the structure
- ribs: depth 4 mm, thickness 0.8 mm, inner distance 3.7 mm → tolerances of tungsten plates

Combs structure (2) : inner wall (beam-pipe side)

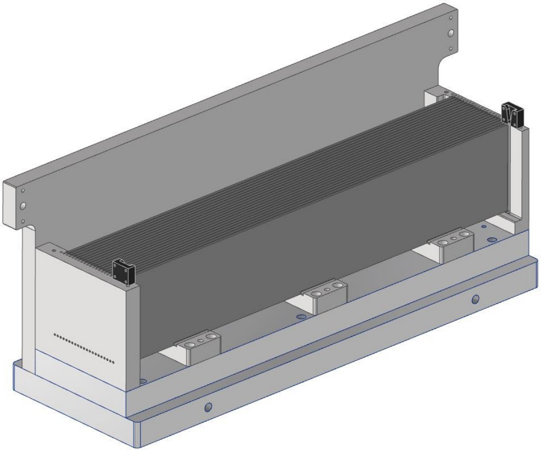




- **dowel pins for precise alignment**, screws for fixing the structure
- ribs: depth 4 mm, thickness 0.8 mm, inner distance 3.7 mm → tolerances of tungsten plates

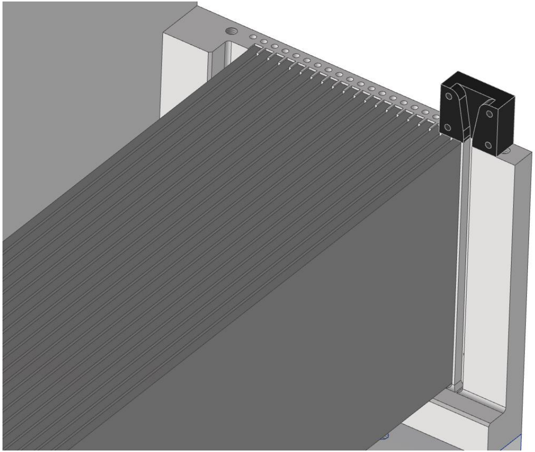
ECAL-P: tungsten plates

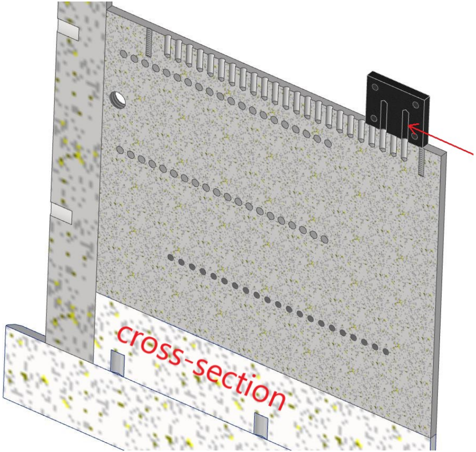
ECAL-P main frame equipped with 21 tungsten plates



- 21 tungsten absorber plates, 3.5 mm thick, ($1X_0$)
- XYZ size of tungsten plate: $550 \times 100 \times 3.5$ mm^3
- **funnels** to facilitate the insertion of tungsten plates (comb ribs are thin !) $\rightarrow$ see next page

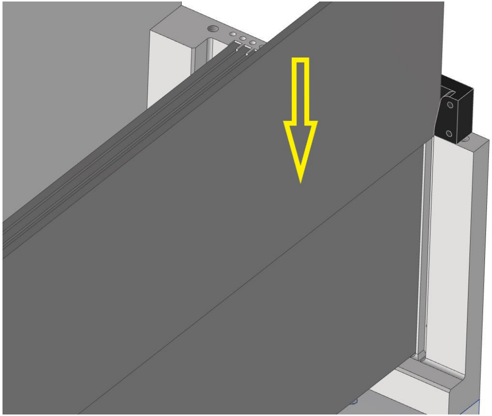
Details of the funnels

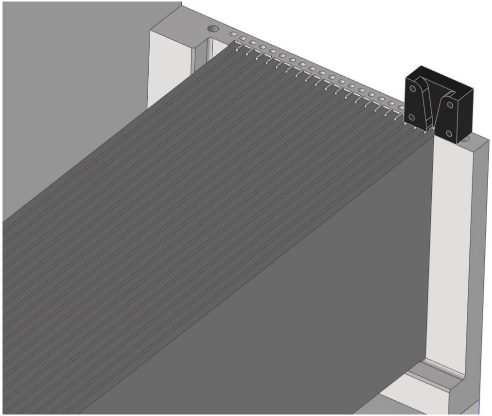




- funnels to guide the tungsten plates and to protect the ribs
- mounted with dowel pins

ECAL-P frame: the funnels in action



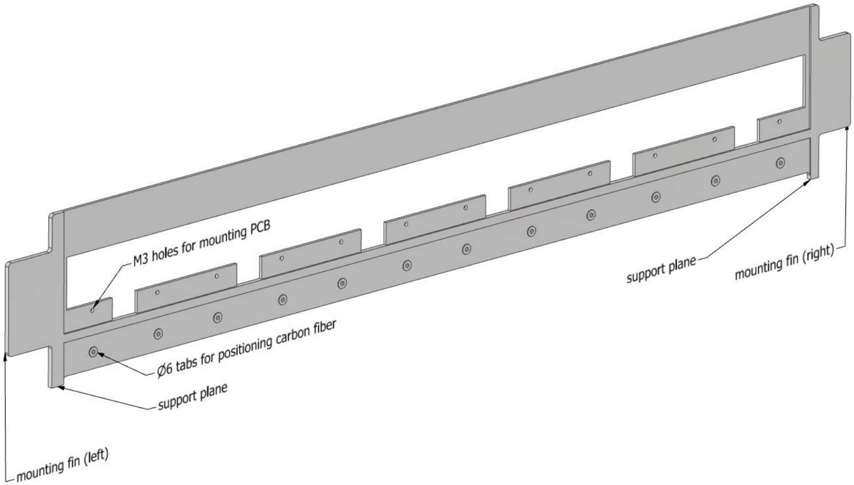


- visualization of the insertion procedure of tungsten plate
- weight of single tungsten plate: $\sim$ 4 kG

ECAL-P: Support for PCB boards and sensors

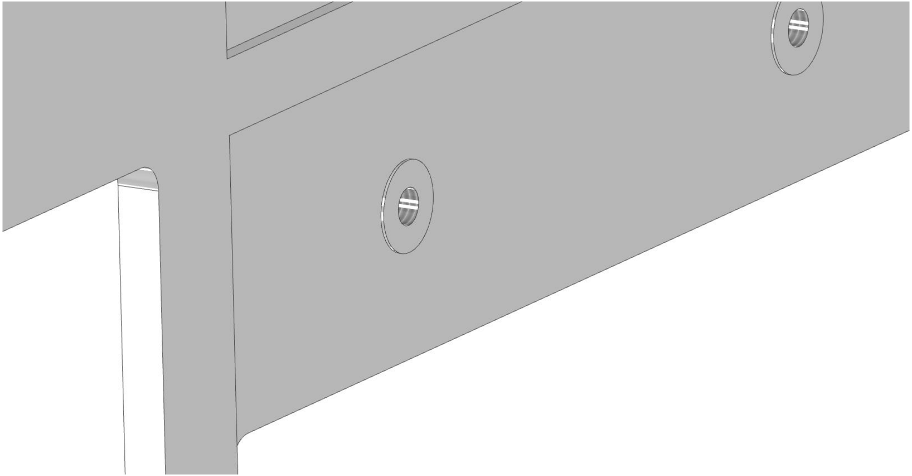
- PCBs will be **not monolithic**, composed of 2 pieces (1 mm thick) $\rightarrow$ **not self-supporting**
- **requires extra mechanical structure** : T-frame made of 3 mm Alu plates ($\sim$ 550 mm) long (!) plus extra machining for fine substructure, **non trivial element !**

T-frame: Support for PCB and Carbon Fiber



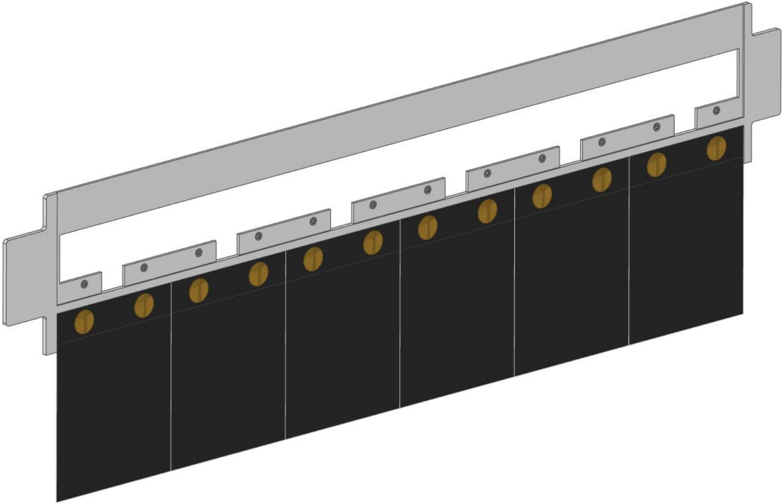
- machined out of 3 mm dural substrate plate
- pins for mounting the PCB boards and positioning the carbon fiber

T-frame: Support for PCB and Carbon Fiber (zoom)



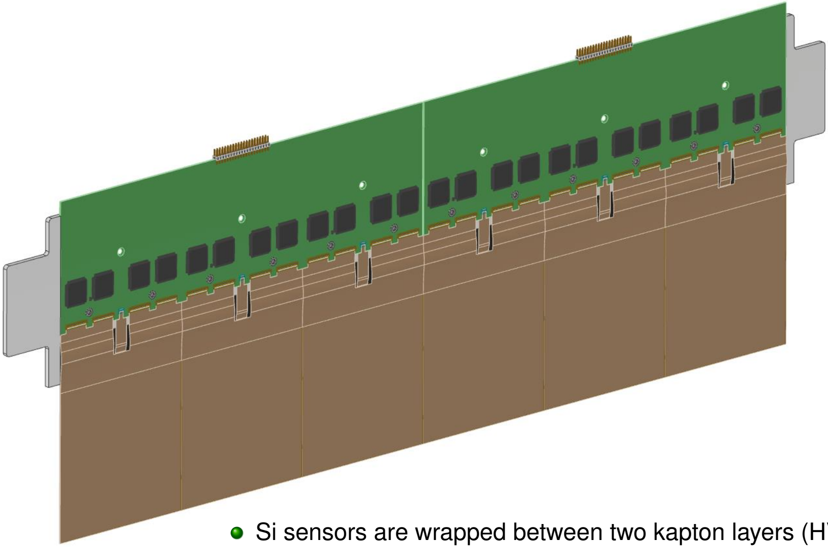
- zoom on the pin (positioning) with the threaded hole (screw mounting)

T-frame with Carbon Fiber: support for Si sensors and kapton



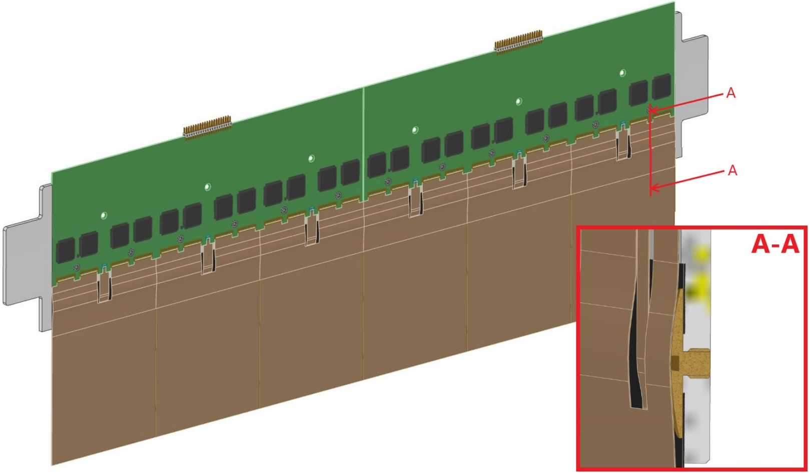
- 0.2 mm thick Carbon Fiber (CF) structure mounted with flat screws
- modular structure: 6 CF pices for each CALICE Si sensor (see next pages for dimensions)

T-frame with Carbon Fiber and PCB + kapton



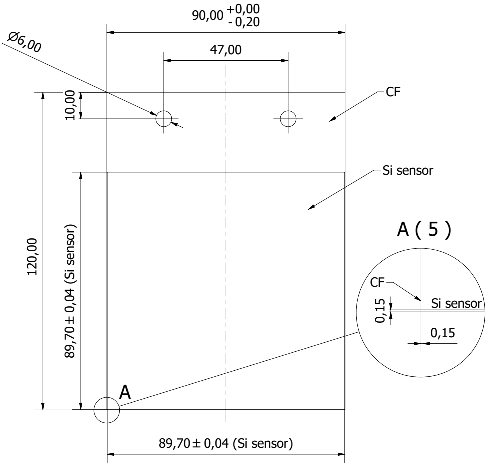
- Si sensors are wrapped between two kapton layers (HV and charge readout)
- some “wrinkles” on the signal kapton (next page)

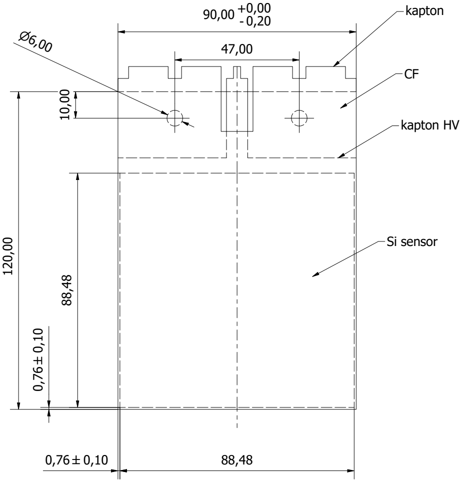
T-frame with Carbon Fiber and PCB + kapton



- Si sensors are wrapped between two kapton layers (HV and charge readout)
- screws extend 0.6 mm above the surface: not in collision, kapton flexible enough (?)

Carbon Fiber + Si sensor + kaptons : dimensions (dead space between sensors)





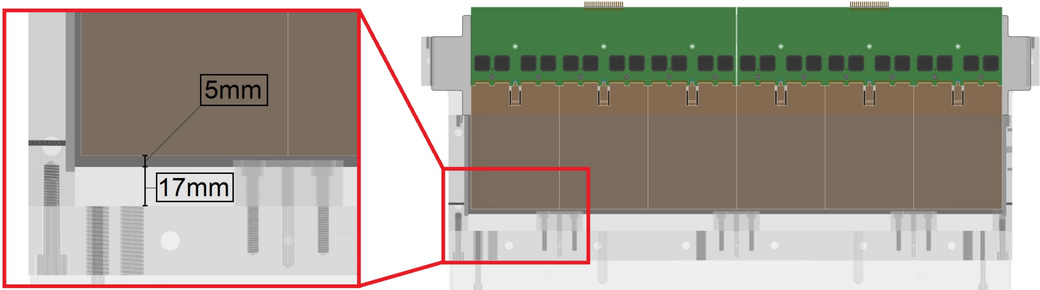
- physical Si sensor size
- CF + Si

- active Si sensor area
- CF + Si + 2 kaptons

ECAL-P: Internal structure

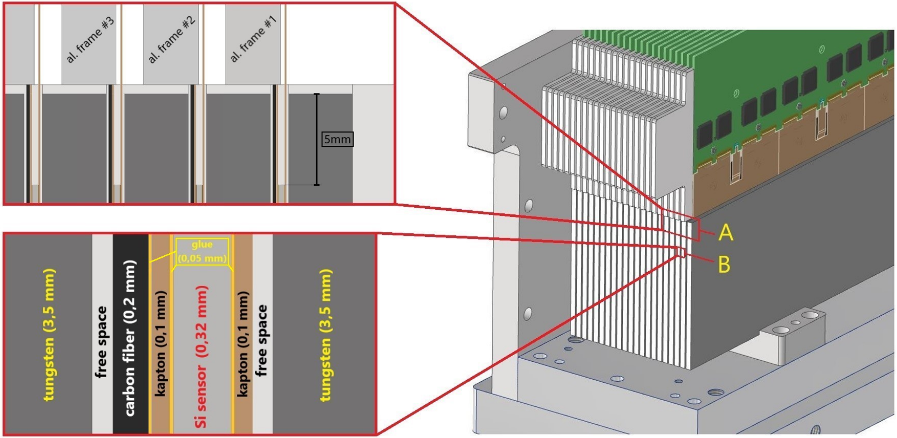
ECAL-P: Sandwich structure

Tungsten / sensors clearance



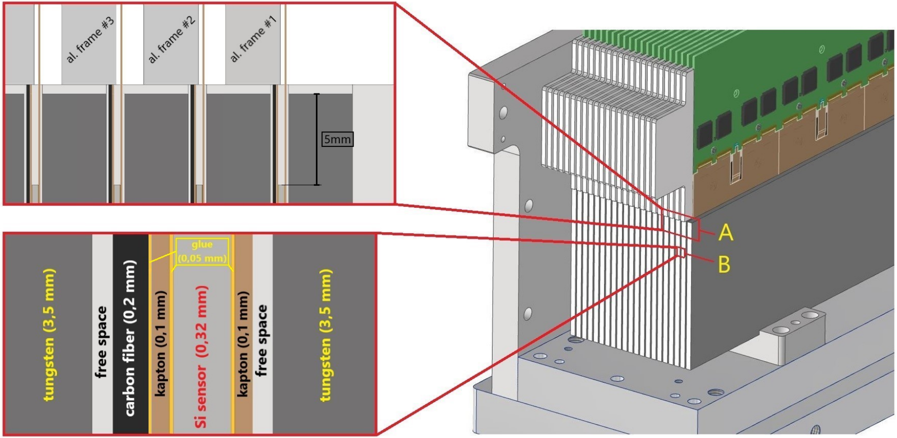
- XY tungsten size: 550 $\times$ 100 mm^2, XY fiducial surface of 6 sensors: 540 $\times$ 90 mm^2
- 5 mm margin around tungsten plate $\rightarrow$ fitting into the 4 mm ribs (+ 1 mm safe clearance)
- 17 mm distance between tungsten plates and the "floor" level $\rightarrow$ monitoring the insertion process
- can be used to control the alignment of carbon fiber planes

ECAL-P Sandwich structure: gaps tolerances, tungsten plates (1)



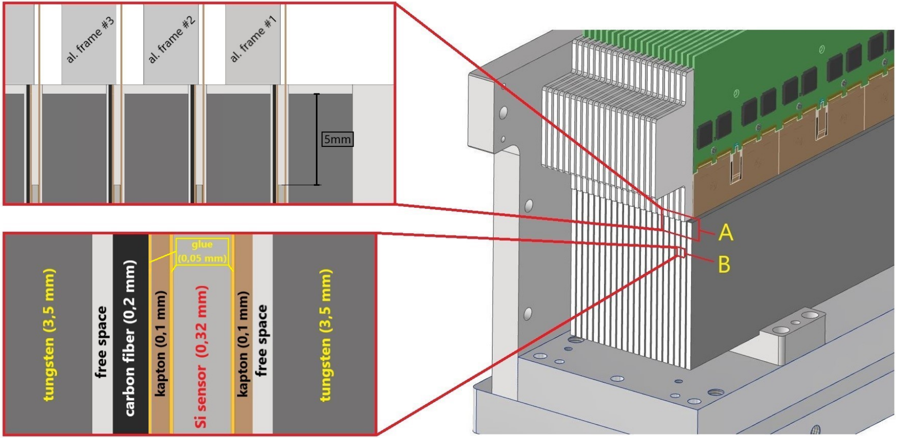
- 320um (Si) + 200um (2 layers kapton) + 200um carbon fiber support + $\sim 3 \times 50$um glue = 870 um
- only $\sim$ 100um "spare space" out of **1 $\pm$ 0.1 mm gaps**: where can we spare on the thickness ?
- tolerances on tungsten plates: 50um (thickness) + 50um (flatness over 55cm) **is it doable ?**

ECAL-P Sandwich structure: gaps tolerances, tungsten plates (2)



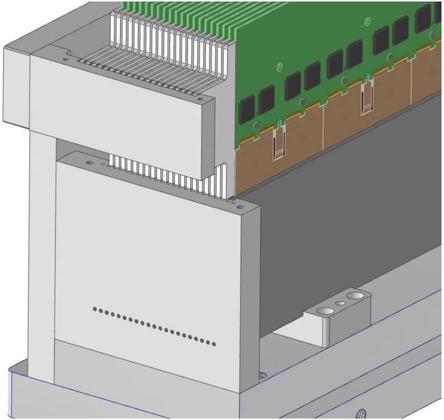
- 320um (Si) + 200um (2 layers kapton) + 200um carbon fiber support + $\sim 3 \times 50$um glue = 870 um
- only $\sim$ 100um "spare space" out of **1 $\pm$ 0.1 mm gaps**: where can we spare on the thickness ?
- **NOTE: 50um for conductive glue is too optimistic ! (150um ?)**

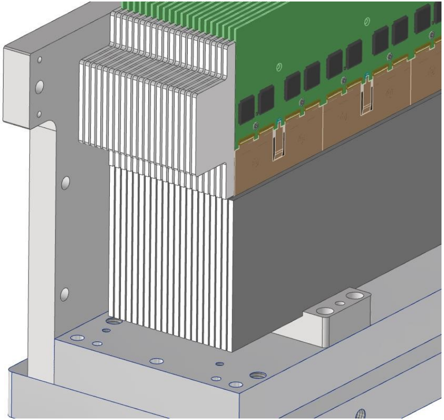
ECAL-P Sandwich structure: gaps tolerances, tungsten plates (3)



- 320um (Si) + 200um (2 layers kapton) + 200um carbon fiber support + $\sim 3 \times$ 50um glue = 870 um
- only $\sim$ 100um "spare space" out of **1** $\pm$ **0.1 mm gaps**: where can we spare on the thickness ?
- **breaking news: each layer encapsulated into Faraday cage ? (copper plate in kapton, 100um ?)**

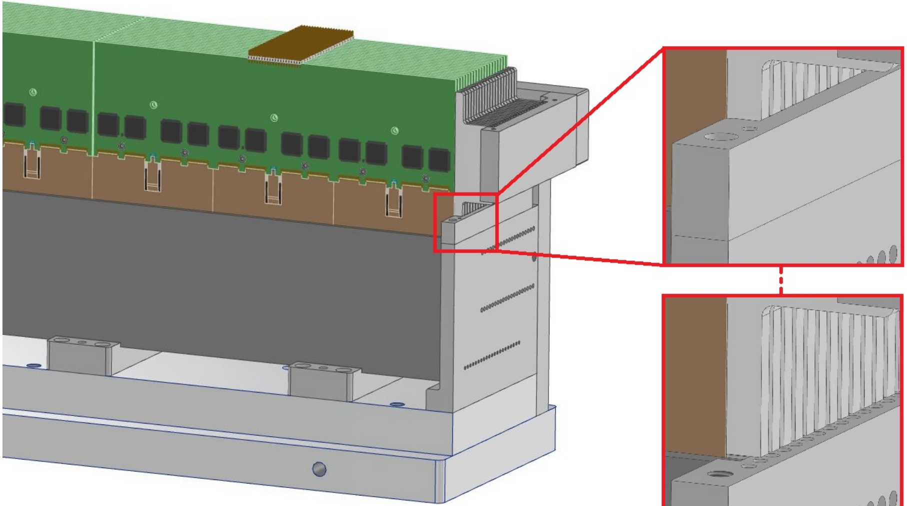
ECAL-P: Support for PCB boards (cont.)





- **Upper combs** : equidistant positioning of T-frames with PCB boards
- double sided ASIC montage: packages 1.6mm thick
- 1mm (PCB) + 2$\times$1.6 (chips) = 4.2mm out of 4.5 mm free space (3.5mm tungsten + 1mm gaps)

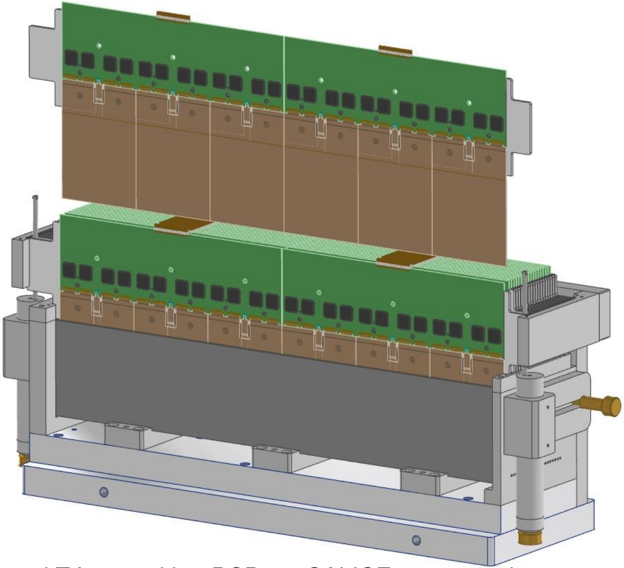
T-frames support: Middle combs



- **Middle combs** : fixing the alignment of T-frames and carbon fiber support

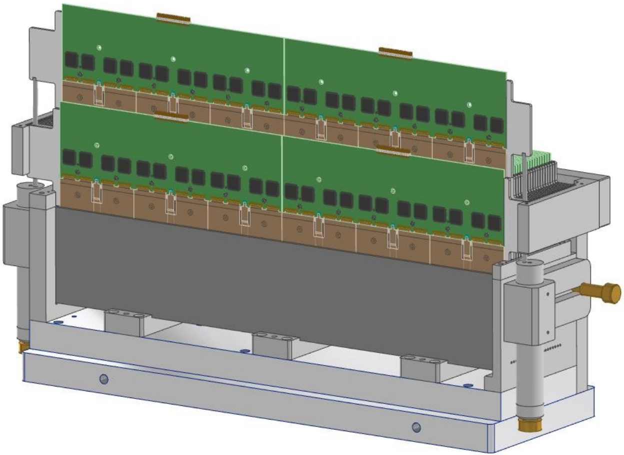
ECAL-P: Placing the PCB boards with sensors

Insertion of PCB boards (1)



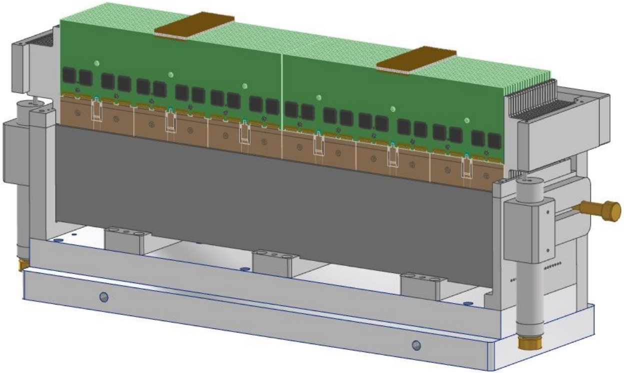
- Fully instrumented T-frame with 2 PCBs, 6 CALICE sensors + kapton on carbon fiber support

Insertion of PCB boards (2)



- Starting position with T-frame supported on vertical bars
- **slow, parallel motion**, counting the number of revolutions on both brass screws

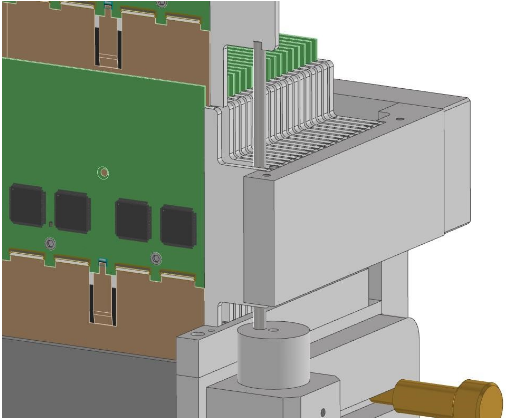
Insertion of PCB boards (3)

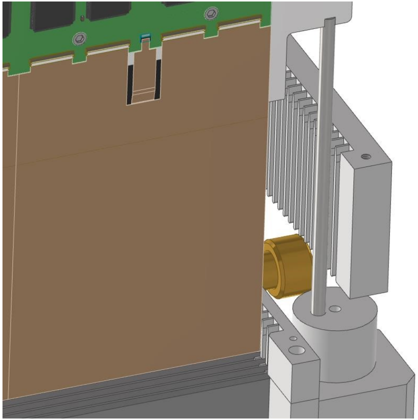


- Final position
- process can be **monitored by small camera** (smart phone) inserted on the calorimeter floor

ECAL-P: Lowering Mechanism

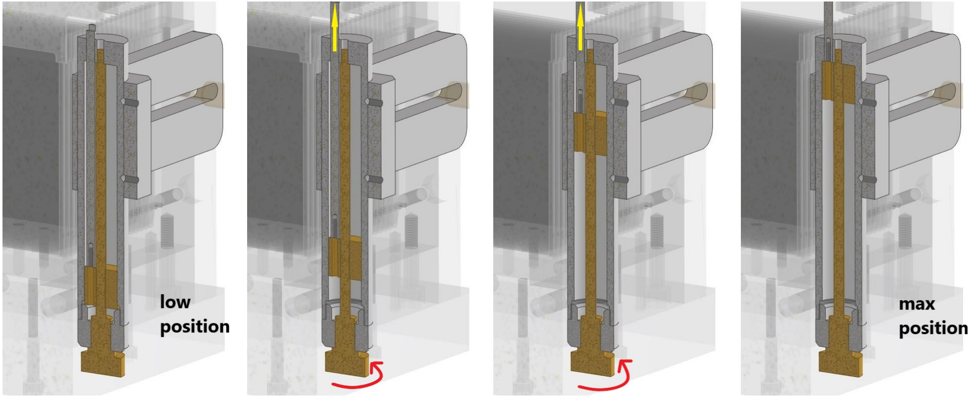
Lowering Mechanism (1)





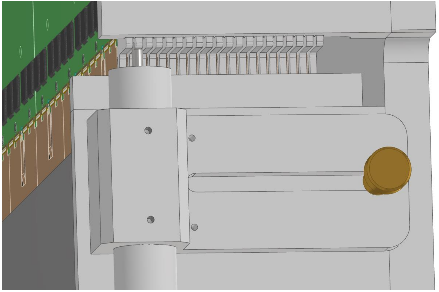
- Details of the lowering mechanism with vertical bars holding the T-frame

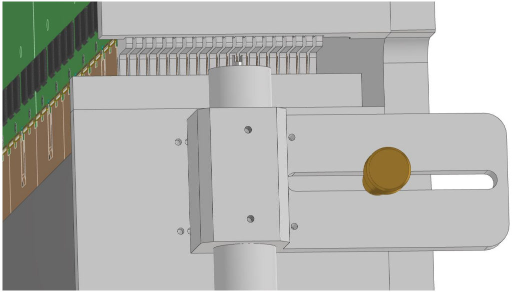
Lowering mechanism (2)



- Lowering/lifting in action
- Threaded piston is driven vertically by rotating the knob
- Vertical position of the knob does not change → can operate on a table

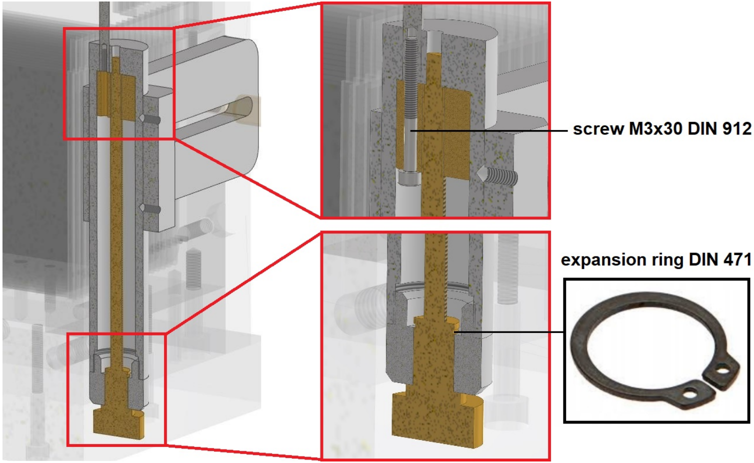
Lowering mechanism (3)





- Navigation between calorimeter slots
- vertical bar hidden in parking position

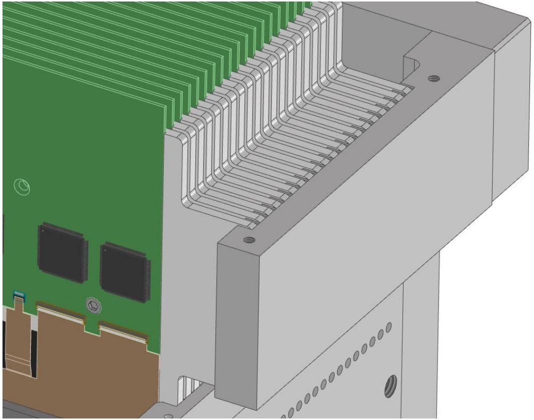
Lowering mechanism (4)

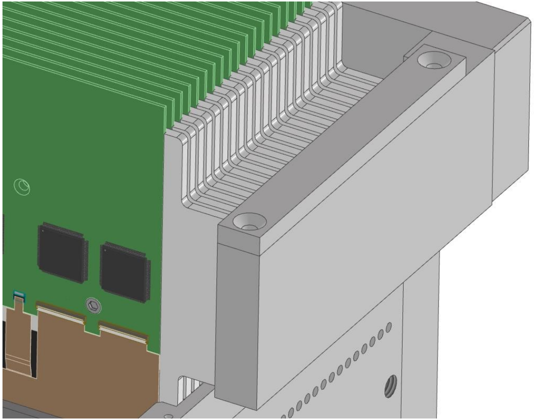


- Details of lowering mechanism: rotation into translation motion

ECAL-P: Removing the mechanical play

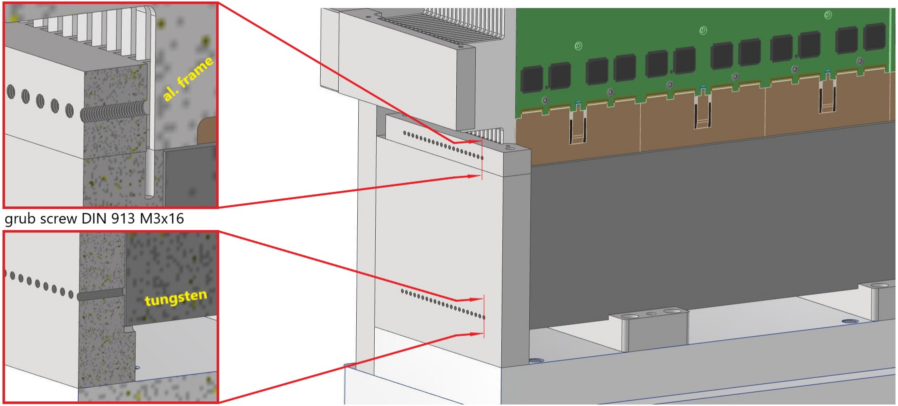
Removing the mechanical play (1) : vertical DOF





- Horizontal cover fixing the T-frames

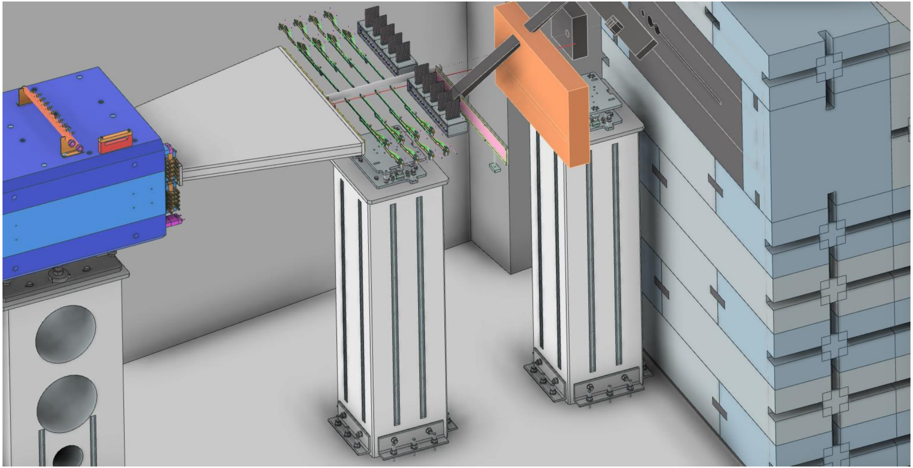
Removing the mechanical play (2) : horizontal DOF



- Set of small screws
- Removing the residual horizontal mechanical play of tungsten plates and T-frames

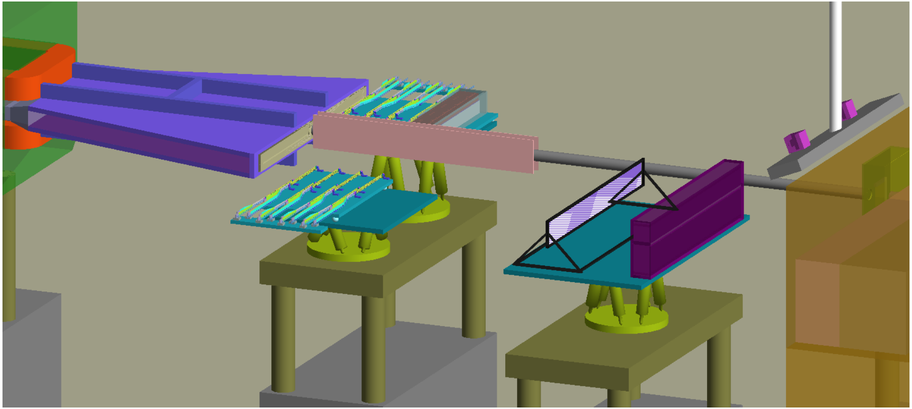
ECAL-P: location/constrains

LUXE hall around IP (1) : CAD view of the being developed interaction area



- ECAL-P standing in the positron arm, just behind the tracker
- beam-pipe $\sim$ 220 cm above the floor level
- only $\sim$ 80 cm free space to the cavern wall

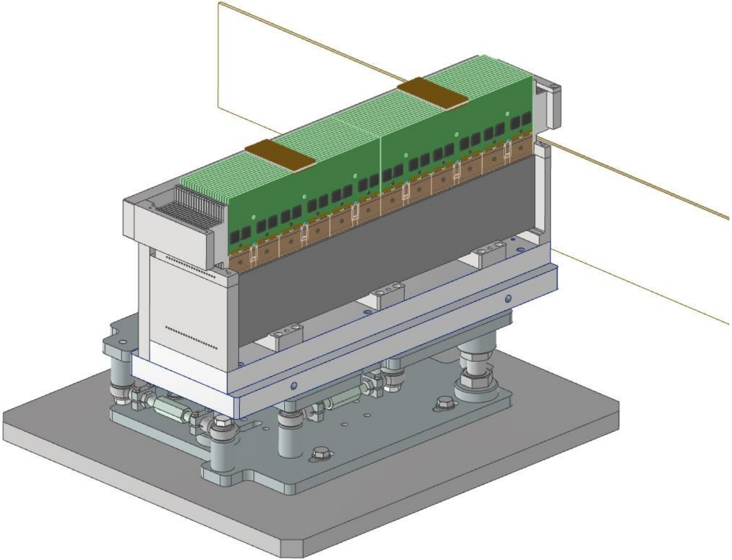
LUXE hall around IP (2) : OLD CAD view



- NOTE: not up to date: schematic CAD view of interaction area
- ECAL-P and Tracker on a separate tables (base-plates) (separate pillars ?)
- behind **shielding** (5 mm thick) tungsten plates ($\sim$ 1000 mm long)

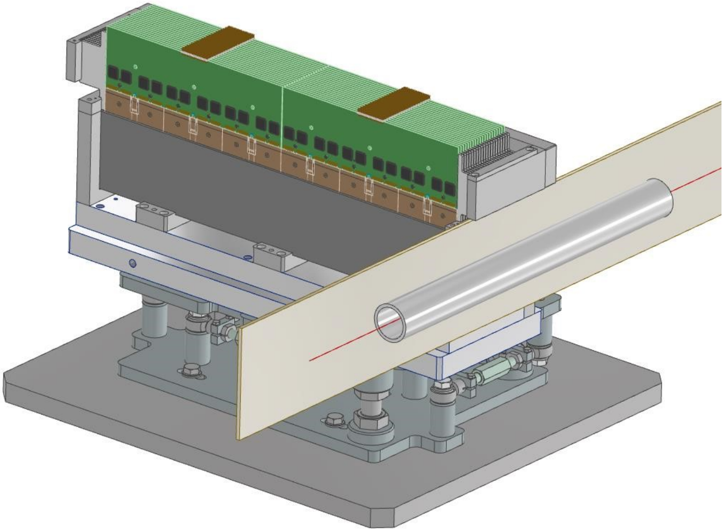
ECAL-P: Position w.r.t. the shielding and beam-pipe

ECAL-P in the LUXE hall (1)



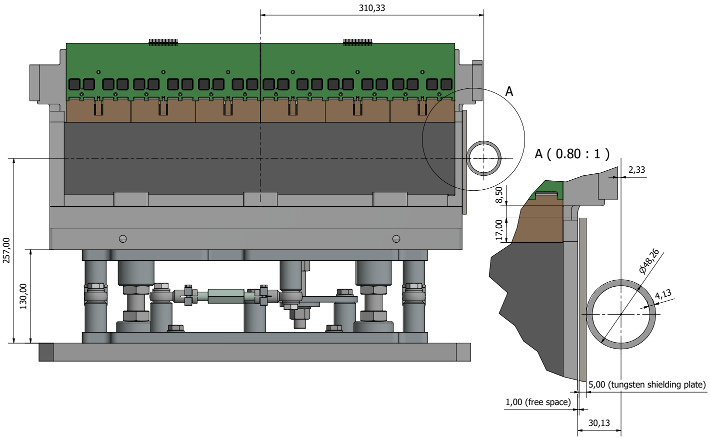
- on concrete pillar, 6DOF optical table ($\pm$5 mm range) and transportation plate, behind the shielding

ECAL-P in the LUXE hall (2)



- ECAL-P Y position of geometrical center aligned to the beam-pipe axis

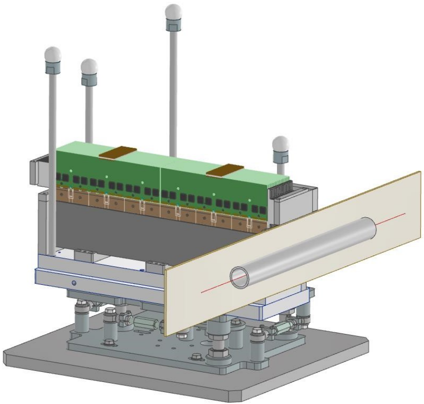
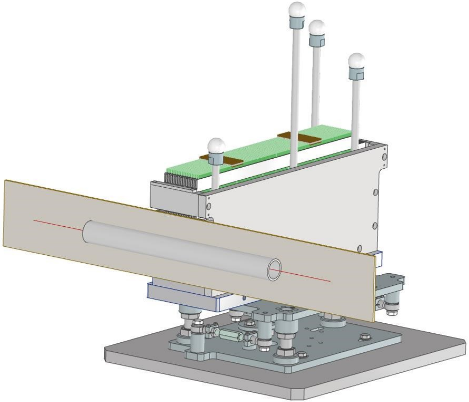
ECAL-P in the LUXE hall (3)



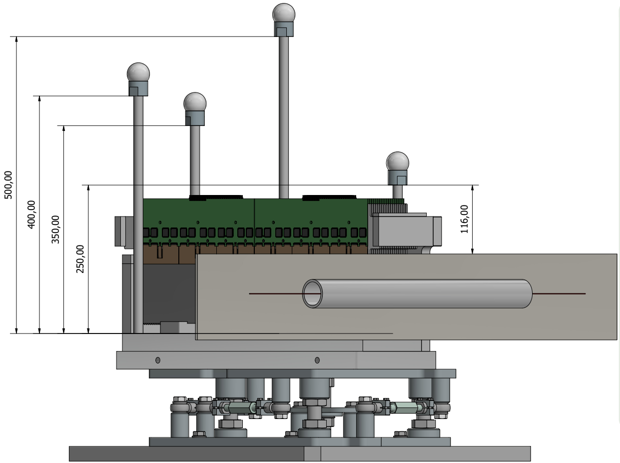
- **1 mm clearance to the shielding**
- using $<$ 50% space above the beam-pipe ($\rightarrow$ ECAL-E)

ECAL-P: Markers for Geodesy Survey

Markers for Geodesy Survey (1)

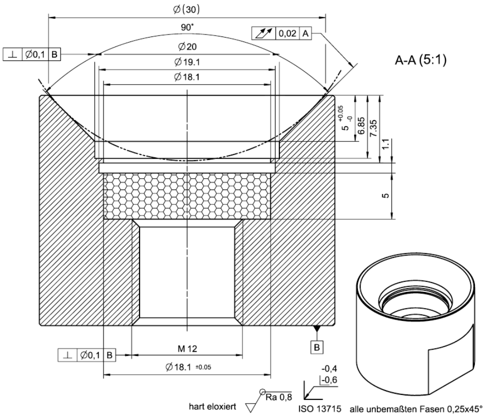



- example location of the nests for the markers (ball mounted retroreflectors / “corner cubes”)
- mounted on vertical bars, **needs verification**: field of view of the laser tracker (?)
- not present during data taking, may be used also during test beam
  (transfer of internal sensors alignment to the outer geometry of the ECAL-P)



- **4 markers on metal bars**, not on common plane (better constrains of DOF), **exact heights TBD**
- (marker closest to the beam-pipe has the lowest possible position above beam-pipe $\sim$ 20 cm)
- attached directly to the ECAL-P main frame
- not in conflict with other components (easy to remove)
- **looking “upwards”** **better reproducibility of position**
- waiting for feedback from Louise and Karsten $\rightarrow$ **field of view of laser tracker ?**

ECAL-P: marker nest for geodesy survey (one of “DESY standards”)

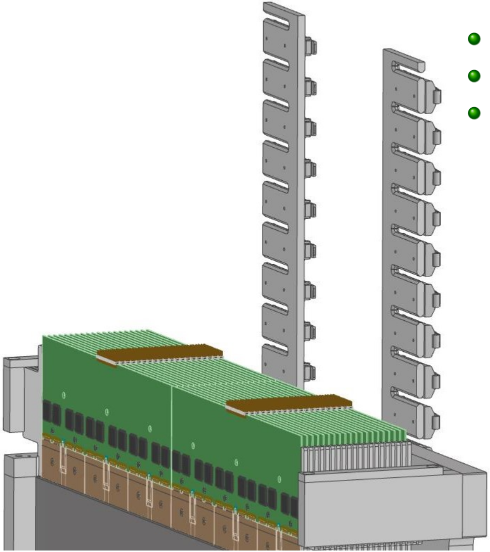


Nest parameters

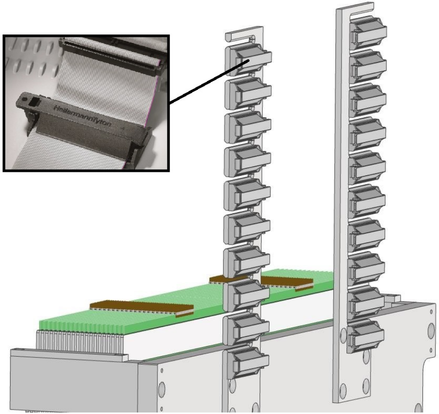
- standard “Messmarkenbasis_12.2.1_Boden”
- nest: 30 mm diameter
- M12 thread & screw
- neodymium magnet $\oslash$ 18 $\times$ 5 mm

ECAL-P: hangers for readout cables

Hangers for readout cables



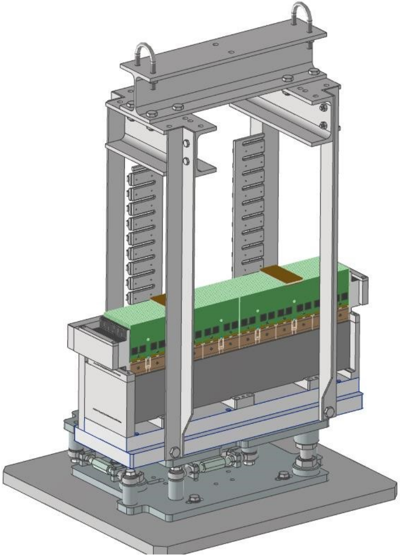
- organizing 40 flex cables: flat ribbon cable mount
- protecting the PCBs and Si sensors from mechanical tension
- each clasp fastening two cables (reduce the hight)



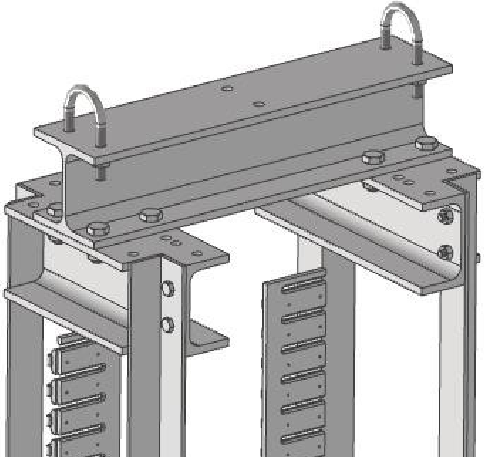
ECAL-P: spider for the transportation

- **rigid self-supporting structure**
- attached to the ECAL-P base-plate with 4 screws
- possible cover/housing (wooden or plastic side walls) for protection during long distance transport

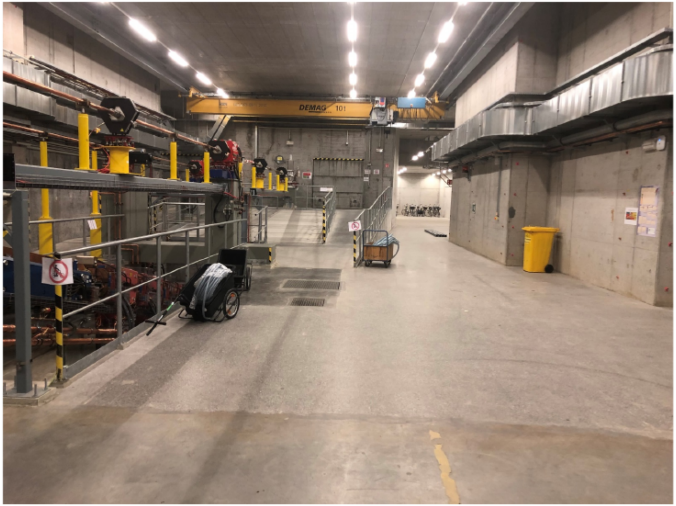
ECAL-P: Spider for the transportation



- To be used with the crane ($\sim$ 100 kG load)



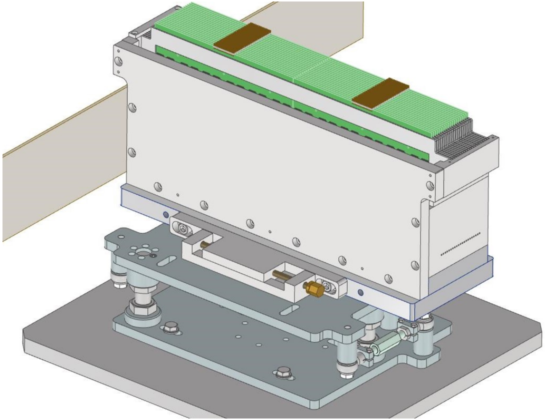
LUXE experimental area: 10 t crane in the cavern

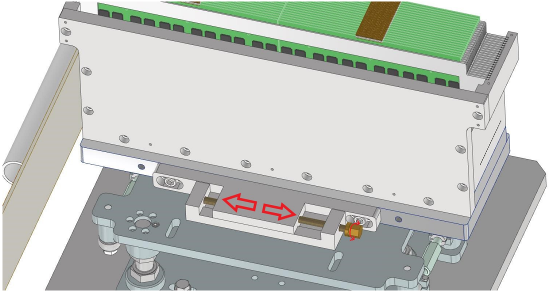


ECAL-P: parking/working position, docking

- **6DOF table has only $\pm$0.5 cm range**
- degrees of freedom are not independent
  (tedious iterative procedure...)
- 6DOF table **adequate for leveling** with beam-pipe and tracker
- but not for moving between working and parking position (few cm in X direction)
- crane not precise enough to define the final position with 1 mm distance to the shielding
- close distance to the beam-pipe (vacuum system !)
- ECAL-P will be to heavy ($\sim$ 100 kg) to adjust it manually...

ECAL-P: moving to the parking/working position and docking





- mechanism to ensure **precise positioning**, 1 mm distance to the shielding
- mounted to the holes in the transportation plate after removing the spider, range $\sim$ 20 mm
- requires additional mounting holes in the 6DOF optical table (still TBD)

ECAL-P: Rotary Table

Rotary Table for ECAL-P

- Collecting test beam data at various angles, 1 deg precision, controlling the leveling (?)

Conclusions/Plans

- Technical note on ECAL-P mechanics is ready $\rightarrow$ technical specification
- After "proof-reading" within the ECAL group will be published to the LUXE Collaboration
- NEXT STEP: build and test the prototype (of crucial components)
- applied for funding of the prototype (local UW grant),
  decision end of September, ($\sim$ 20 kEuro if successful)

Thank you for the Attention !