ECAL-P Workshop summary

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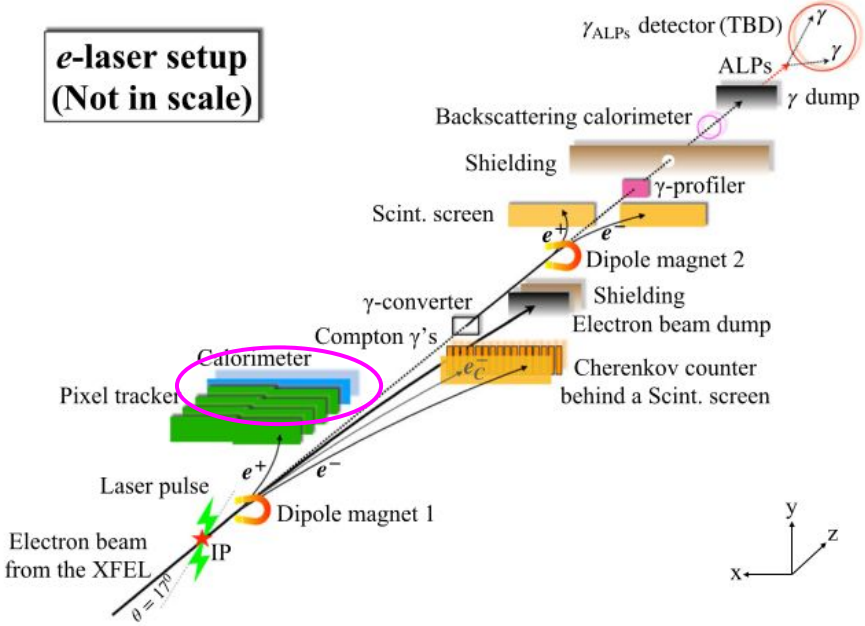
07/10/2025

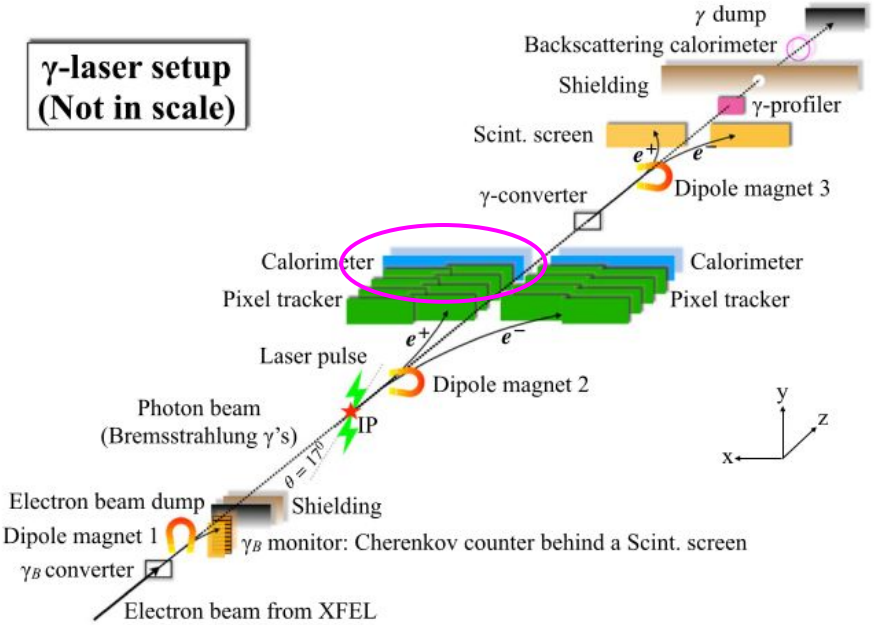
CSIC
Consejo Superior de Investigaciones Científicas
Universitat de València
IFIC Institut de Física Corpuscular
Excelencia Severo Ochoa
Agencia Estatal de Investigación
Gobierno de España
Ministerio de Ciencia, Innovación y Universidades
Generalitat Valenciana
Conselleria de Educación, Universidades y Empleo
Financiado por la Unión Europea
NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
AITANA

LUXE ECAL-P Workshop: Warsaw (Sep 10 – 12, 2025)

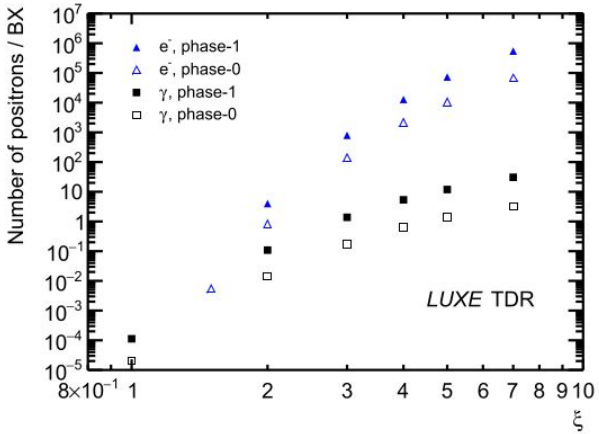
Participating institutes

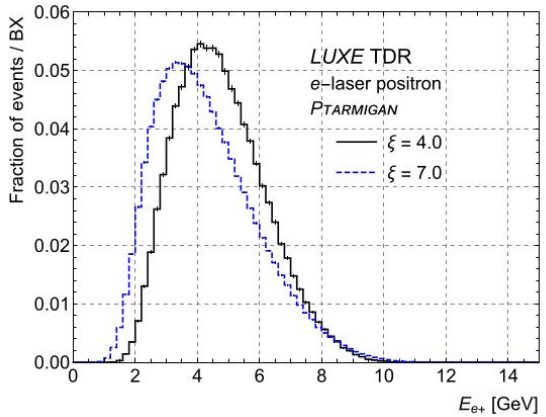
System overview:ECAL-P at LUXE

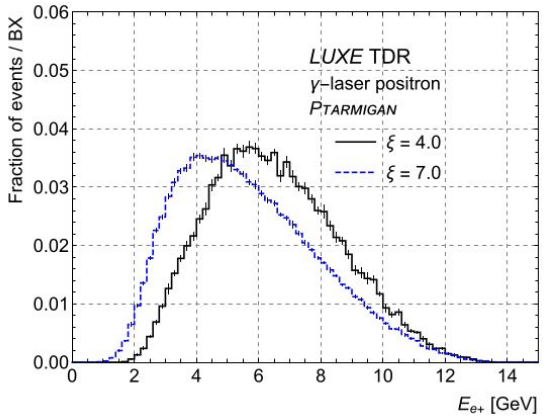


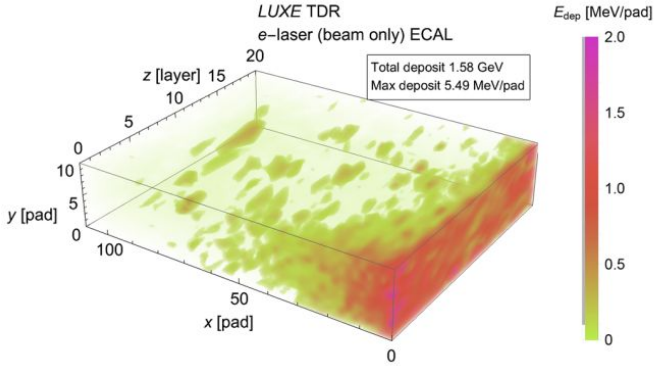


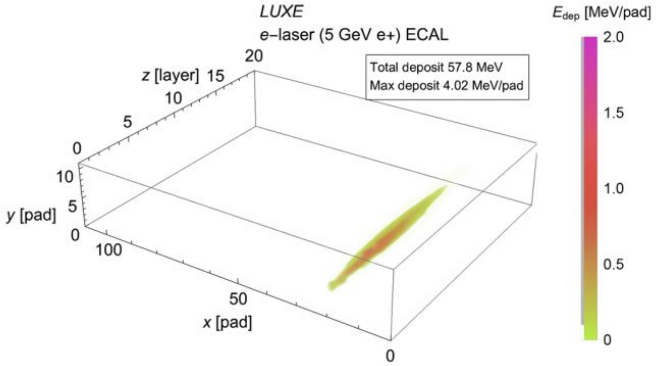
System overview: ECAL-P at LUXE





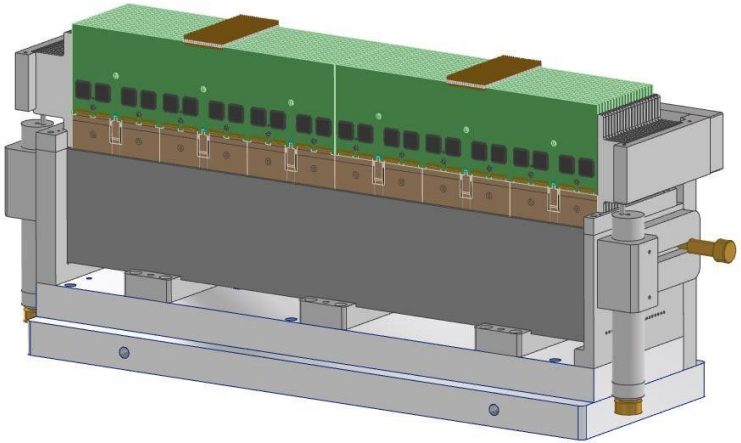






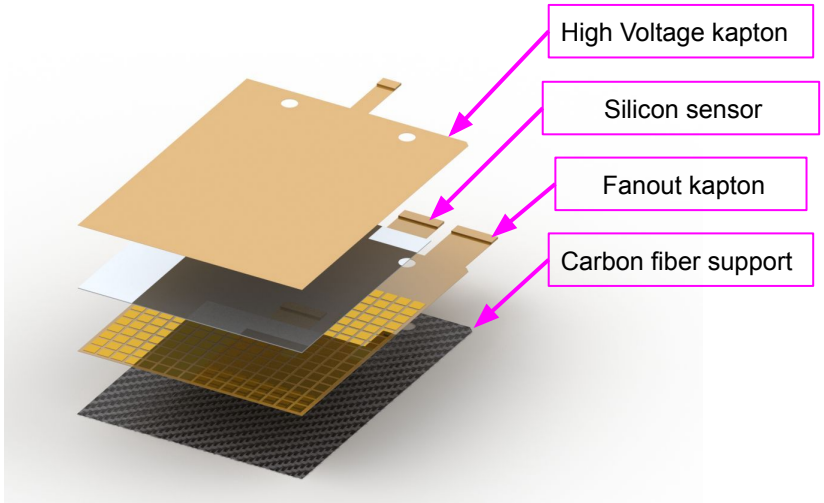
System overview: The ECAL-P design

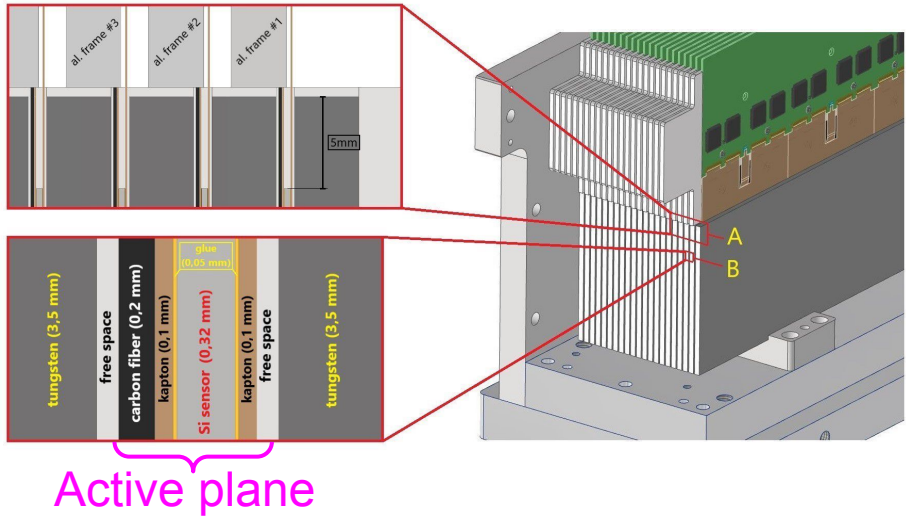
- Highly compact and granular sampling calorimeter
- 21 tungsten plates of 1 X_0 (3.5mm)
- 20 active planes
- 1mm space between W plates for Active plane insertion
- Each plane composed of 6 sensors with 256 pixels of 5.5 x 5.5 mm^2
- Active plane design with fanout PCB keep FEB at the top of the calorimeter



System overview: The ECAL-P design

- Aluminium frames hold active planes and FE electronics
- These planes are inserted in between tungsten plates and frames rest in top

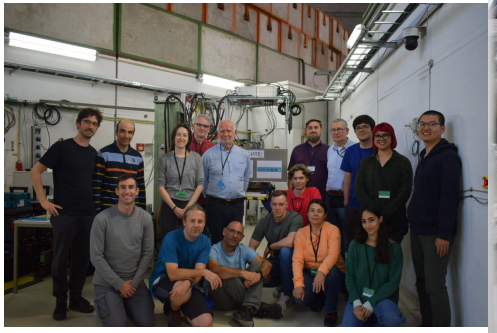


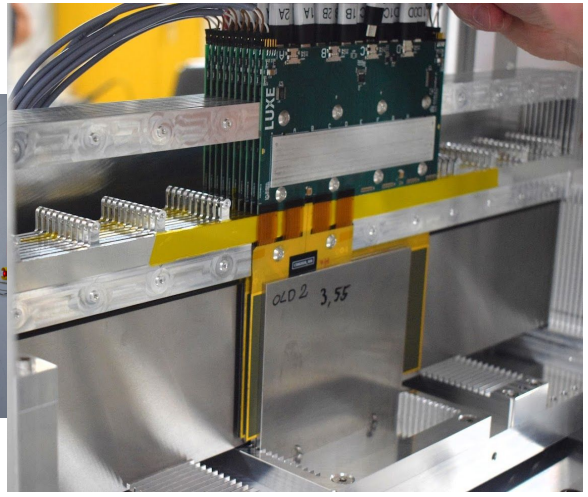


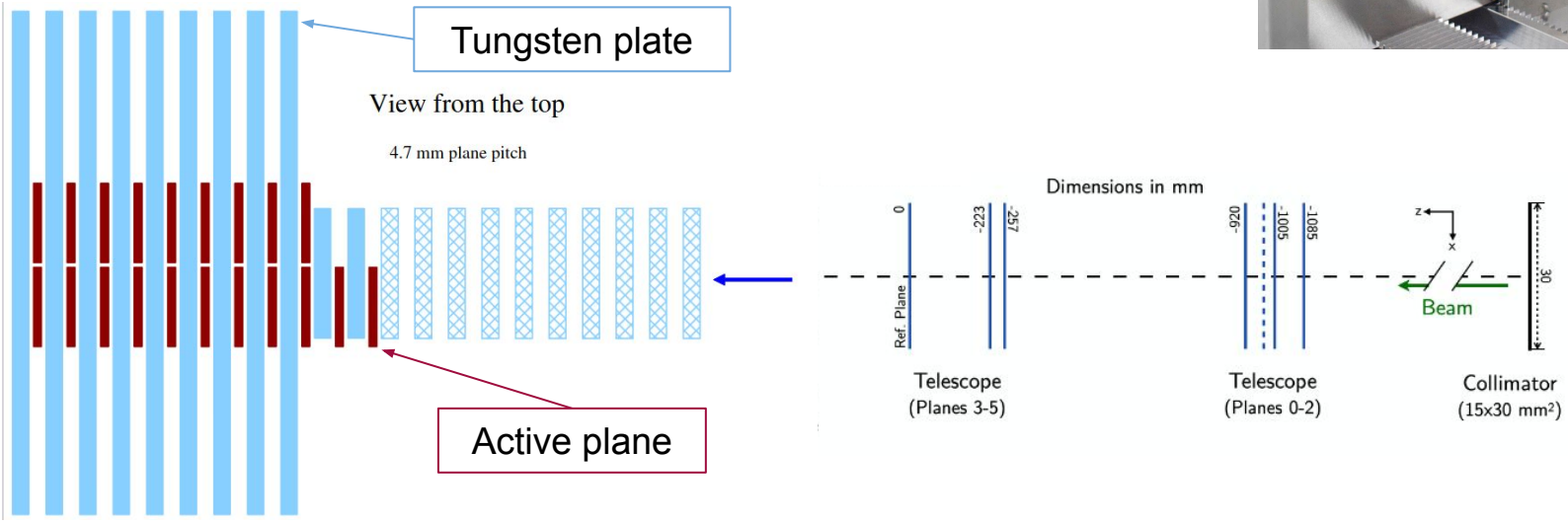
TB2025: Preparation, experience and future plans

Testbeam 2025 at DESY

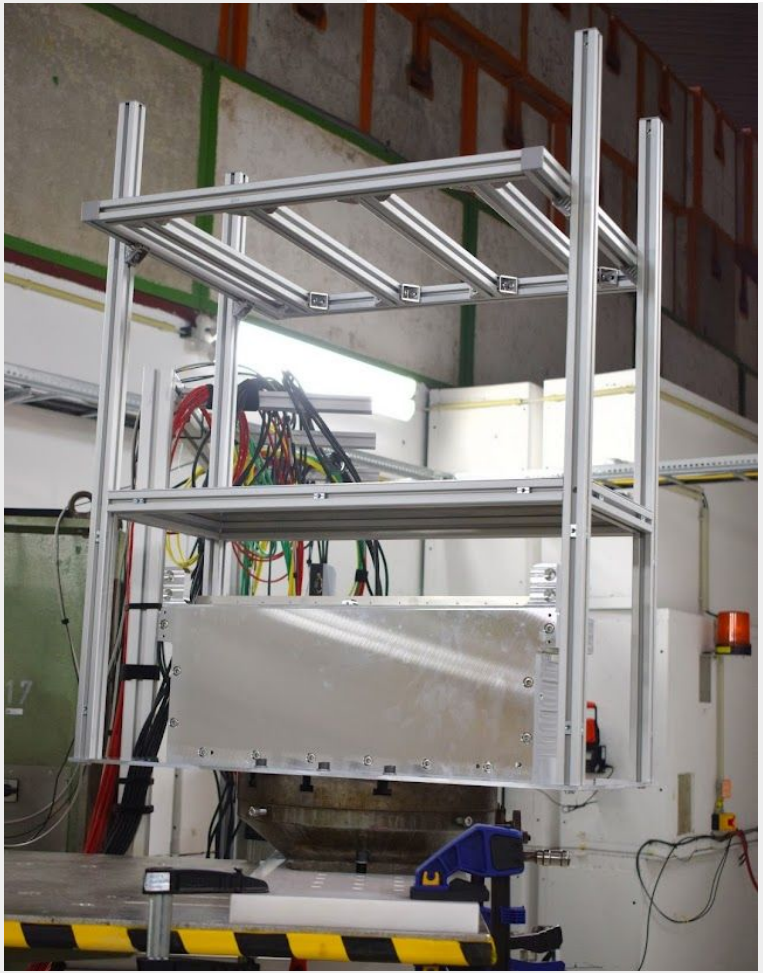
- 382M Events in total with energies from 1 to 5 GeV
  - Tracker mode (no absorber)
  - 9 X_0
  - 11 X_0
    - XY Scan
    - -15 to 15 degrees runs
  - 15 X_0
  - 18 X_0
  - 21 X_0





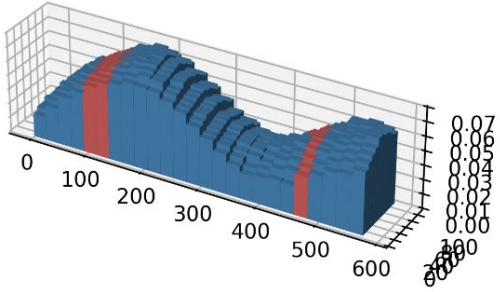


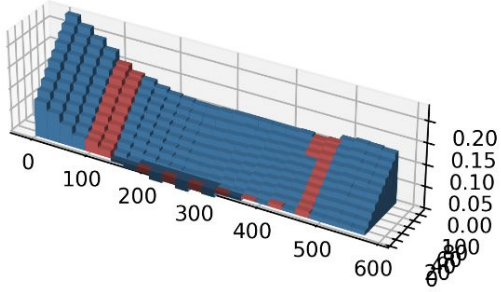
Mechanics



Mechanics: Tungsten plates

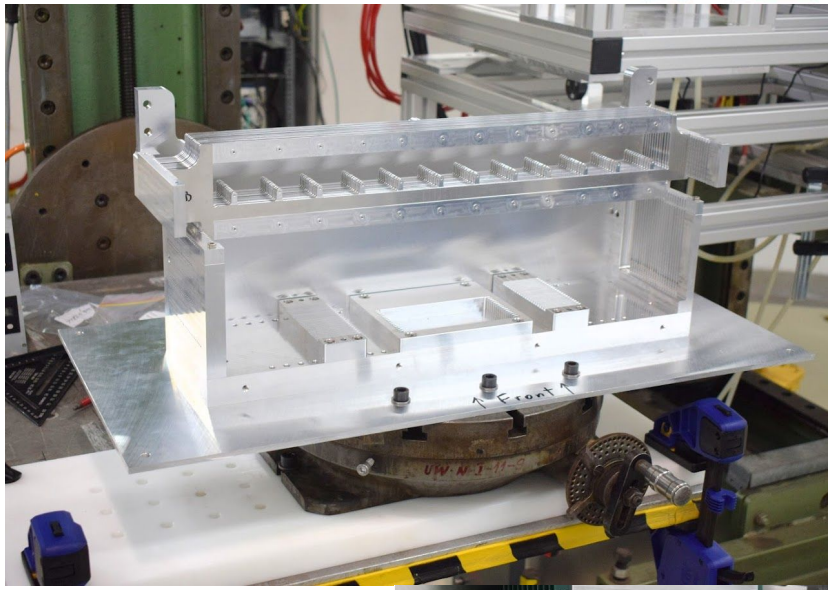
- 9 plates size 55cm x 10cm x 3.55mm
  - 6 plates from two Chinese companies
  - 3 new plates received during TB from German company
- CMM measurements on the 6 Chinese plates results
  - Planarity varies up to ~150 μm
  - Thickness deviations ~50 μm and up to ~200 μm
- During TB: All 9 plates fit in the combs without any problem
- Planned: detailed metrology on new German plates

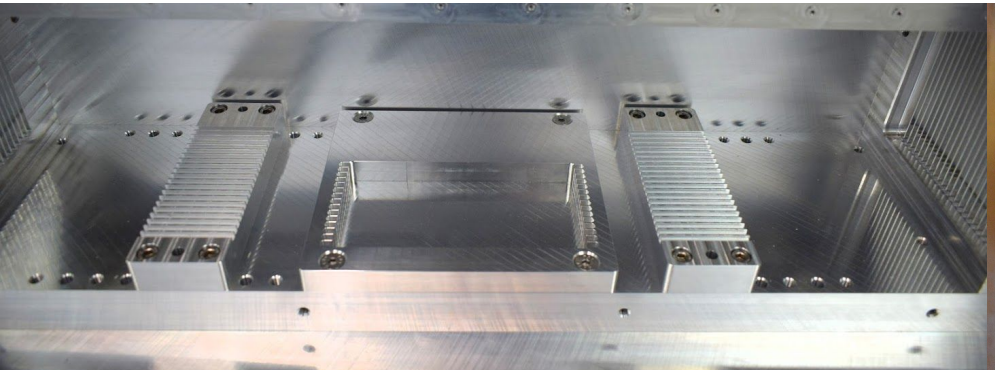


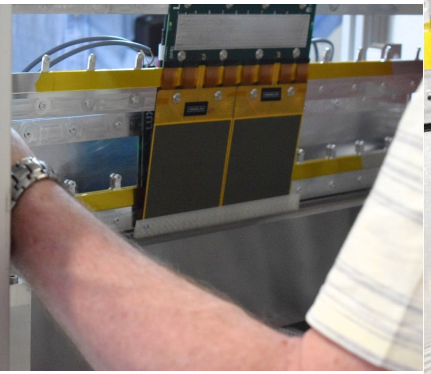


Mechanics: Frame

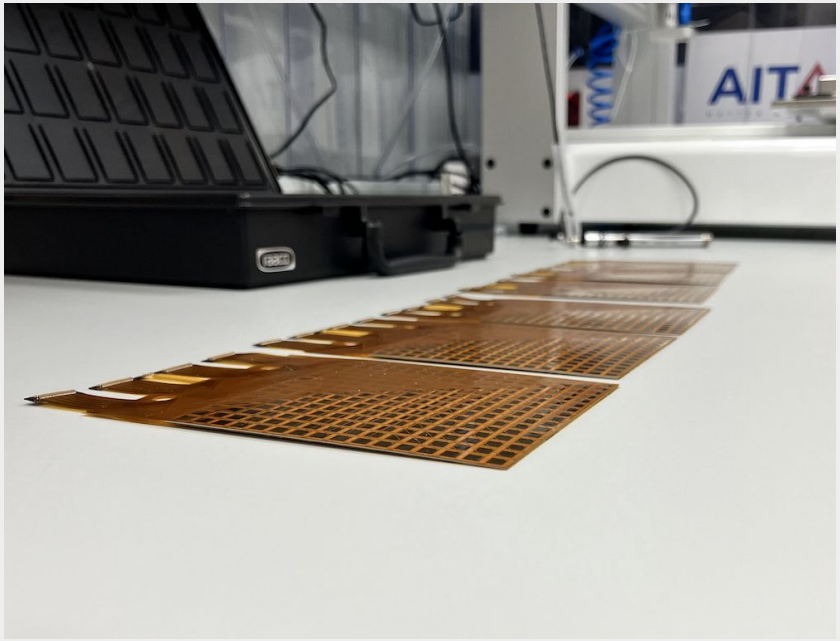
- Status and TB experience
  - 1mm gap between W Plates was relaxed to **1.2 mm** for testbeam 2025
  - Support combs for old (narrower) W plates
  - All sensors were inserted with ease by experts after some practice
- Future plans
  - Go back to planned compactness of **1 mm** gaps





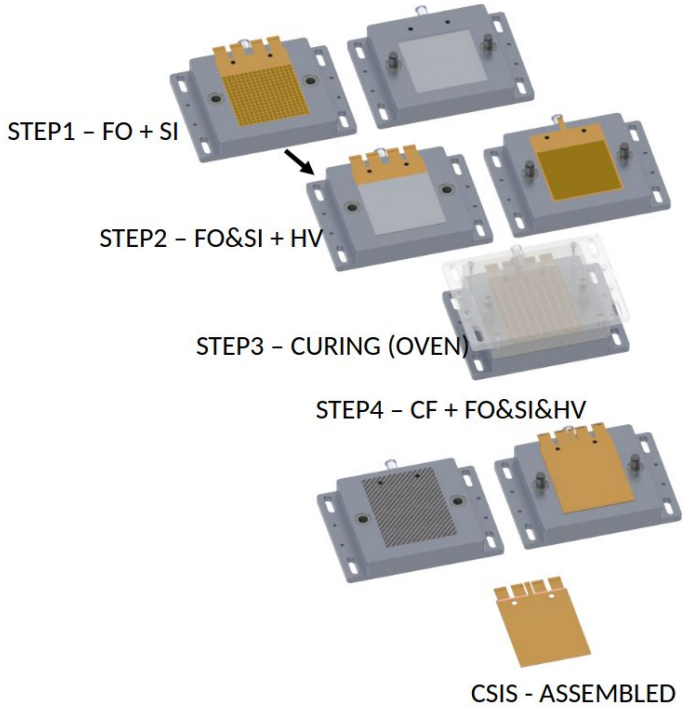


Active planes



Active plane: assembly

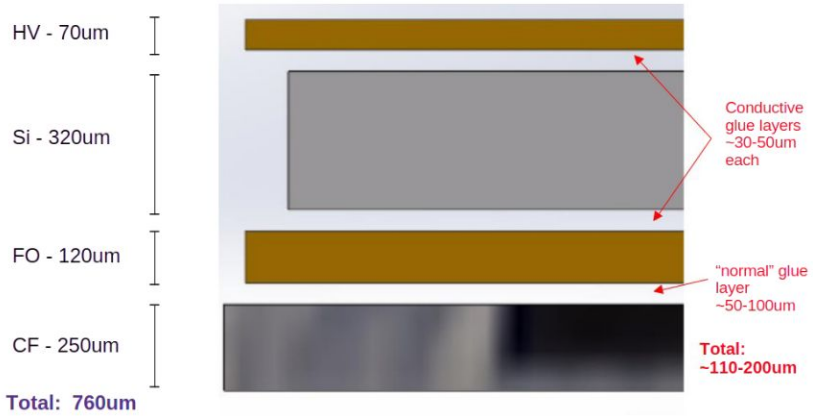
- Methodology for 2025 production



- Glue depositing 3D Robot
- Two conductive glue types used
  - H20E – from EPOTEK (Two-component)
  - TDS-9410 – from MG-Chemicals (monocomponent)
- Two non-conductive glue types(CF to FO)
  - Silicone
  - 5 μm thick Double sided tape
- 2025 production experience
  - Procedure mastered by the group (IFIC)
  - No major problems
    - 4 missing glue dots out of 6400 total

Active plane thickness

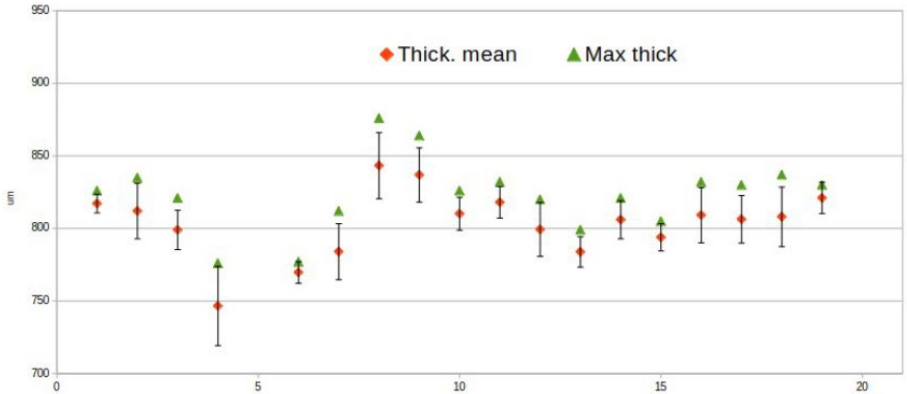
- Expected: ~870-960 µm
  - Most variation in CF Thickness



- Achieved: ~750-870 µm
  - 4 combinations of conductive and non-conductive glue

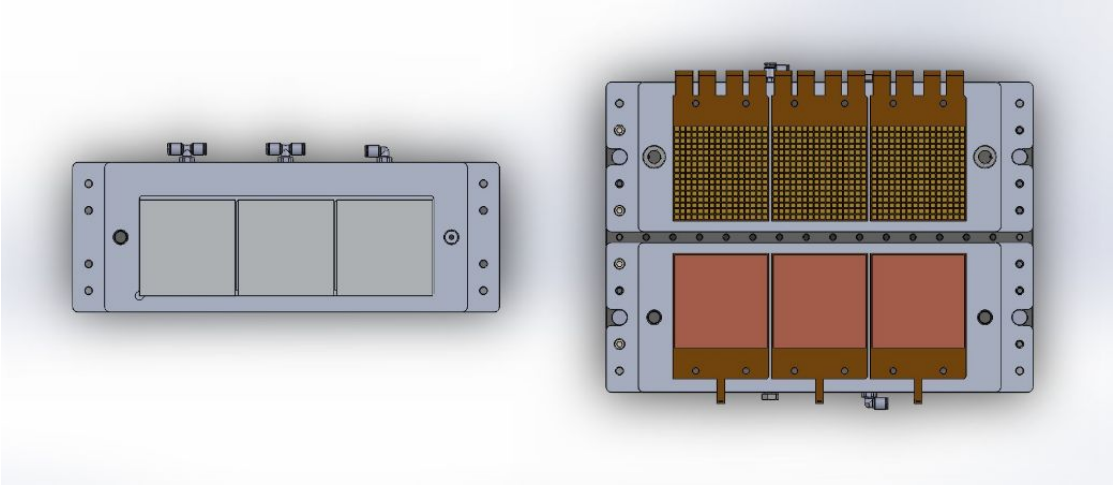
2025_001	DOWSIL+H20E	2025_011	DOWSIL+H20E
2025_002	DOWSIL+H20E	2025_012	DOWSIL+H20E
2025_003	DOWSIL+H20E	2025_013	DOWSIL+H20E
2025_004	3MDST+H20E	2025_014	DOWSIL+H20E
2025_005	3MDST+H20E	2025_015	DOWSIL+H20E
2025_006	3MDST+H20E	2025_016	DOWSIL+H20E
2025_007	3MDST+MG9410	2025_017	DOWSIL+H20E
2025_008	DOWSIL+MG9410	2025_018	DOWSIL+H20E
2025_009	DOWSIL+MG9410	2025_019	DOWSIL+H20E
2025_010	DOWSIL+H20E	2025_020	DOWSIL+H20E

Measured thickness of CSIS2025

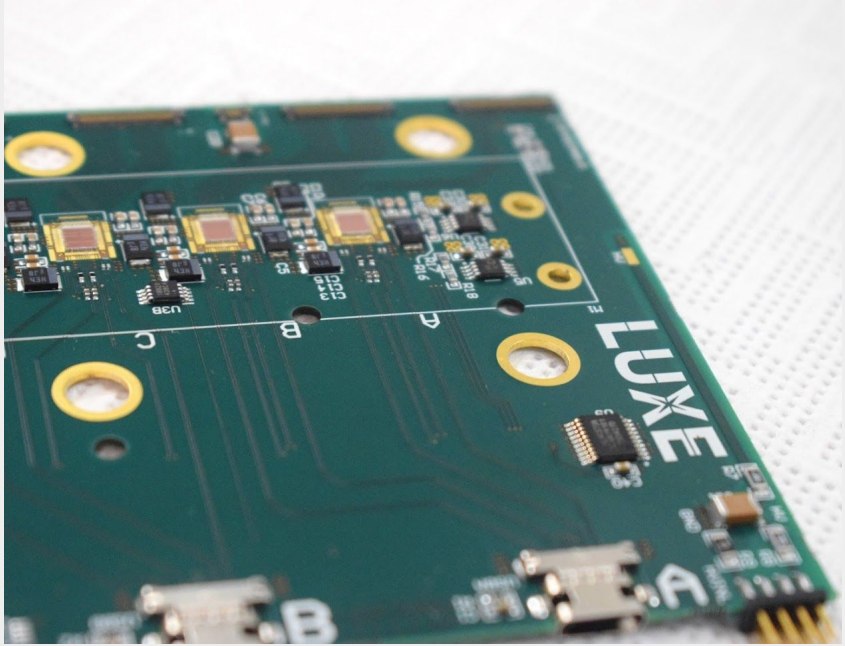


Active planes: Future plans

- Future plans:
  - Idea for new Thicker HV Kapton design to replace the role of carbon fiber
  - New jigs to speed up productivity
    - 3 planes at the same time
    - ~12 planes a day or a more relaxed schedule. Before ~4 planes a day with long workday

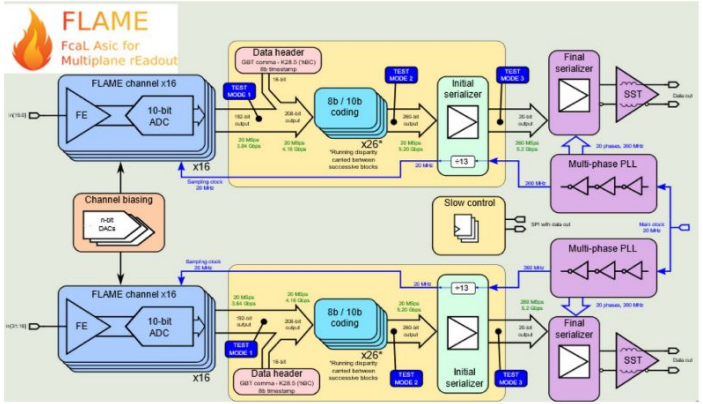


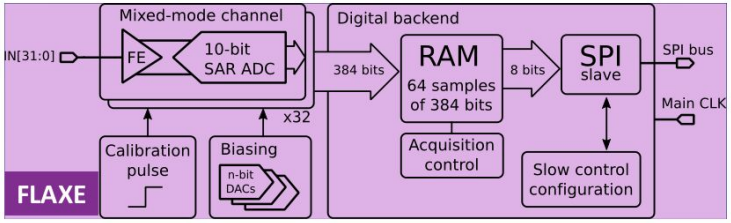
FE and FPGA



FE and FPGA: Overview

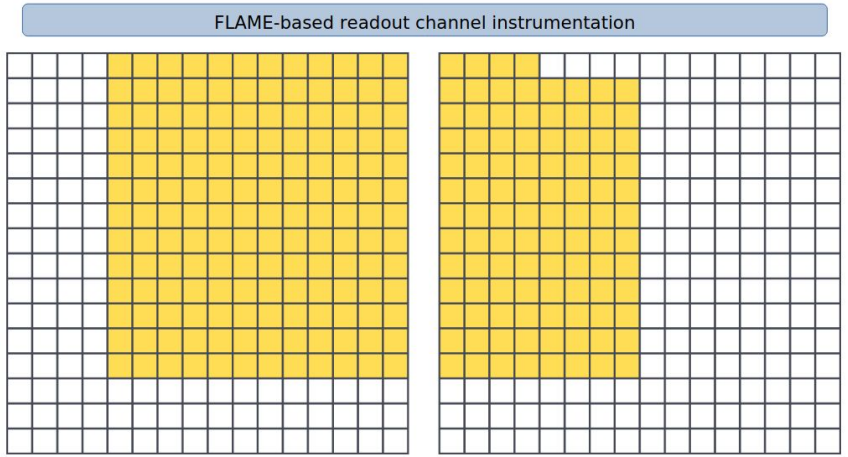
- FLAME ASIC used for TB 2025 due to production failure of FLAXE ASIC
- FLAME Main features
  - 32 channels
  - Analog front end in each channel. CR-RC shaper of 50ns
  - 10 bit ADC at 20 MHz in each channel
  - High speed serializer
- Advantages and Disadvantages:
  - New mechanics, sensors, hybridization process with extensively tested FLAME ASICs
  - Limited amount of available FLAME ASICs and FPGAs for the readout.
  - FEB developed specifically for TB 2025 with FLAME
- Read out with dedicated system based on commercial Trenz TE0808 FPGA. Developed at AGH Krakow





FE and FPGA: TB 2025 experience

- Minor (to the system scale) issues – ASICs communication, HV current variations, module connectors, baseline oscillations.
- Some dead channels and some noisy channels (from ASIC level to sensor level) but negligible to the total number of channels.



- Event rate – up to 2 kev/s
- The system performed well and ran smoothly for six days of (almost) uninterrupted data taking with 11 layers. Equivalent to more than 70 days of single FPGA running constantly

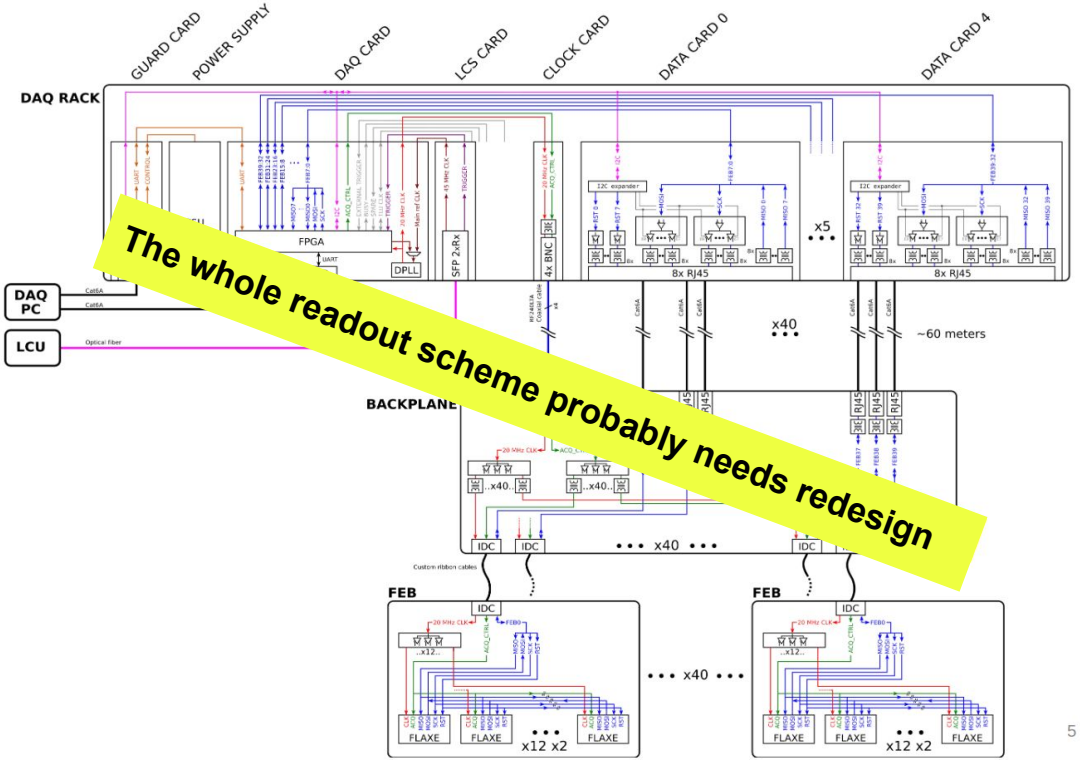
Future plans: Next beam test

- FLAME-based testbeam in 2026
  - Constrained to two tower x 12 layer prototype **or** redesign FEB (not ideal)
  - No concrete plan for this option for now
- Testbeam with FLAXE in the near future
  - FLAXE Production starting this year will be ready ~ middle 2026
  - FEB fabrication, assembly and testing ~4 months
  - Testbeam with FLAXE-based readout → not before 2027
  - No concrete plan for this option until new FLAXE production is tested

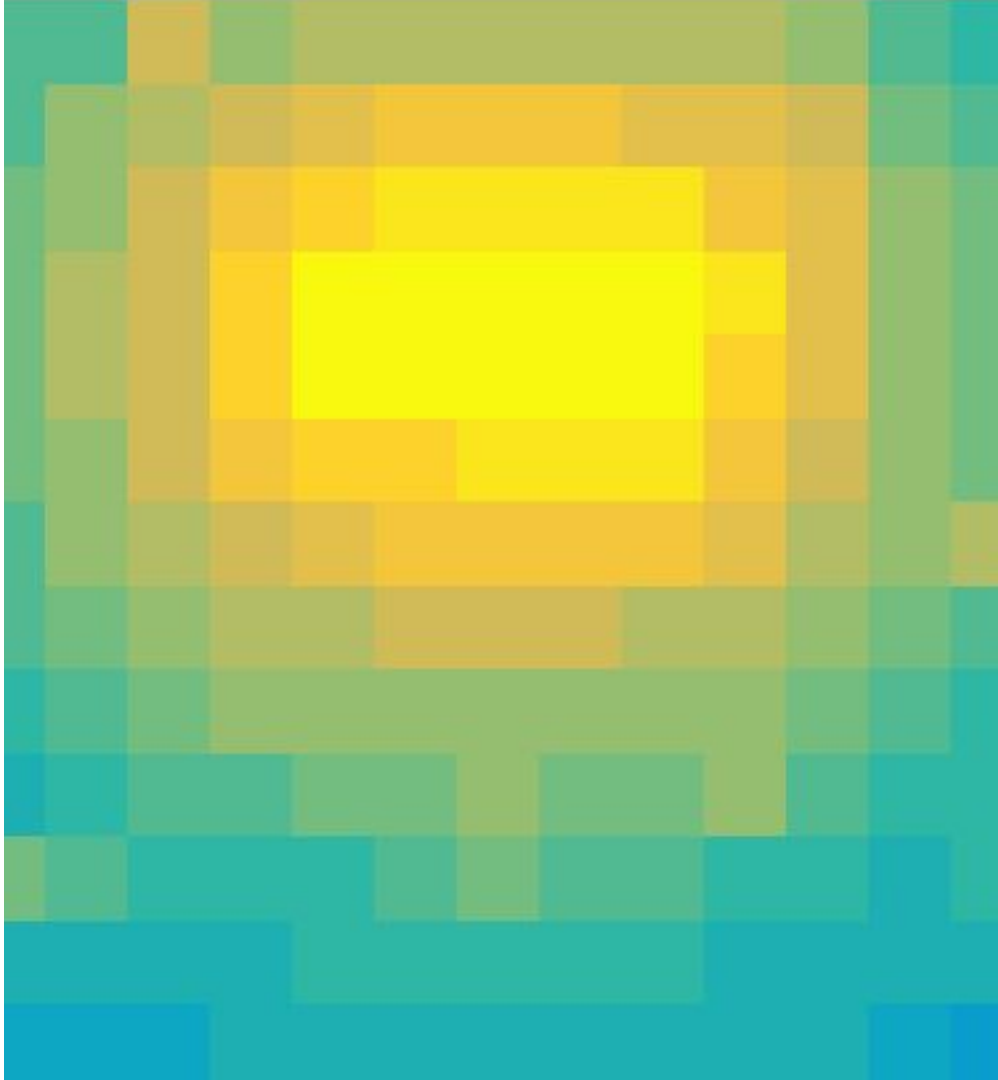
Future plans: LUXE new location

LUXE at XTD8 tunnel:

- Where to put HV and LV supplies?
- Where to locate DAQ system?
- Radiation levels?

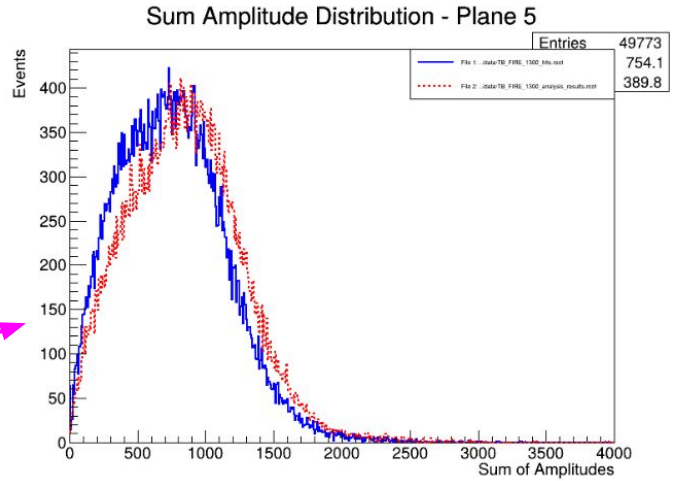


Analysis

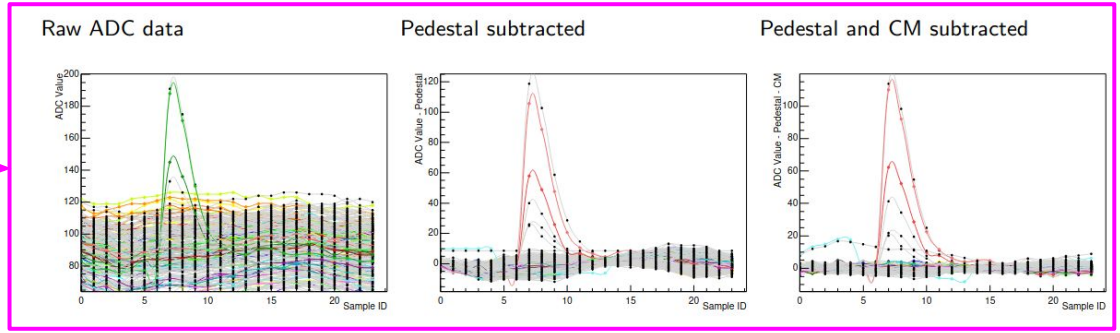


Ongoing: Data integrity and noise analysis

- Data stored during TB 2025:
  - Zero Suppressed (ZS) data calculated signal amplitude and arrival time for triggered channels crucial for on-line monitoring
  - Raw ADC samples for all channels
- Comparison from Zero suppressed on-line data (blue) to preprocessed raw data (red)
  - Some small signals recovered after better noise analyses with raw data



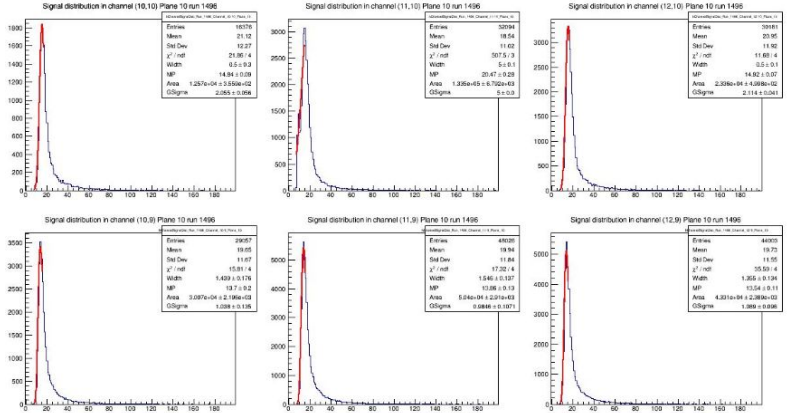
Raw data preprocessing steps

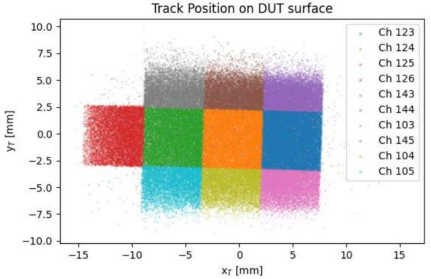


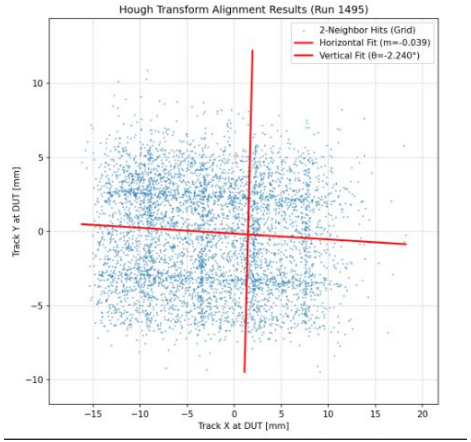
Ongoing: MIP Calibration and DUT+Telescope alignment

- Cell-by-cell MIP Calibration (256 channels per plane)
- Alignment of DUT and Telescope → Find entry point of electron to 1st sensor plane

First results with on-line data

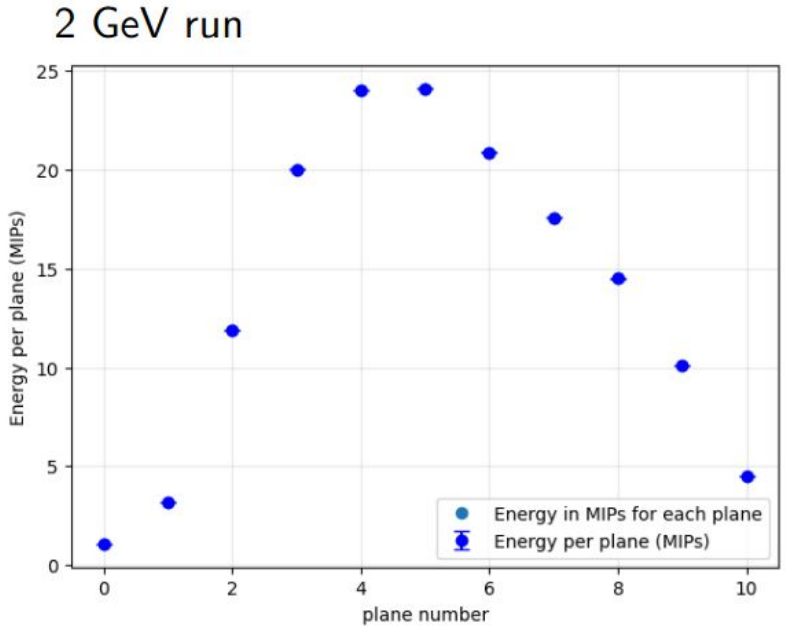


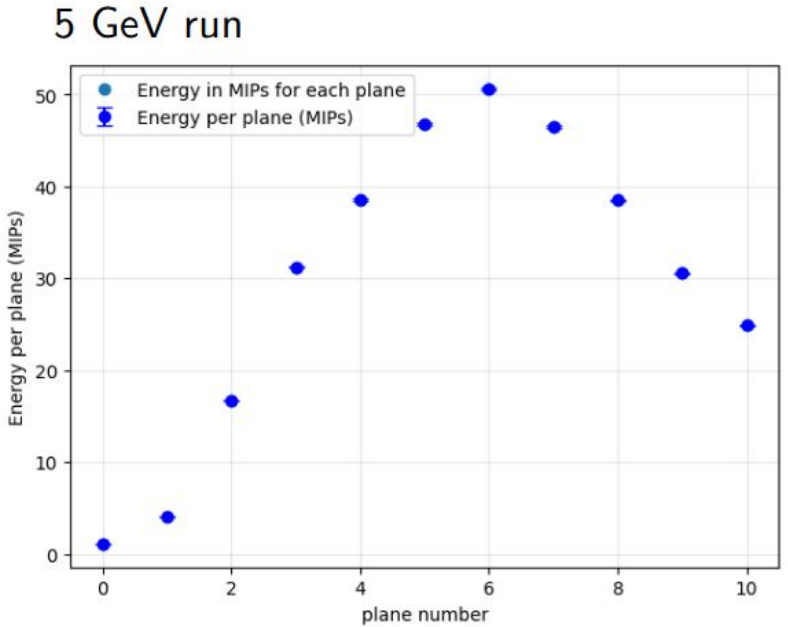




Ongoing: First calorimetry studies with on-line data

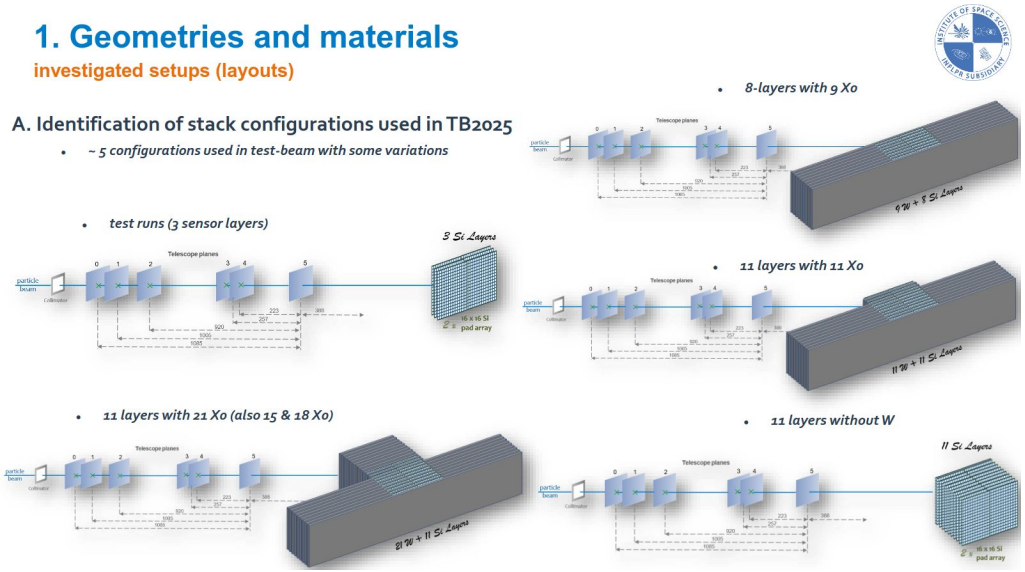
- Longitudinal shower profile

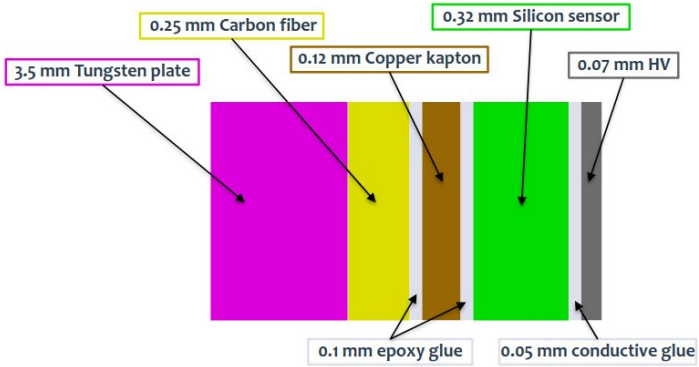




Simulations: Ongoing

- Simulations with Geant4
  - TB 2025 Configurations identified
  - Active plane geometry and sub-layer materials will be applied to Geant4 geometry





Analysis: Future plans

- **Finish preprocessing of data to best achievable quality**
- **Finish DUT+Telescope alignment**
- Calorimetry
  - Energy resolution
  - Linearity
  - Longitudinal profile
  - Transverse profile
- Comparison: Simulation vs TB Data

Conclusions and outlook

- All elements of the detector system met the set requirements and converged into a successful testbeam campaign
- Lots of new data to analyze: 380M events with 5 prototype configurations
- Preliminary analyses started but our priority is to finalize the raw data processing to achieve the best quality
- Next steps in prototyping: Thinner active planes, 1mm gap compactness

Thank you for your attention!