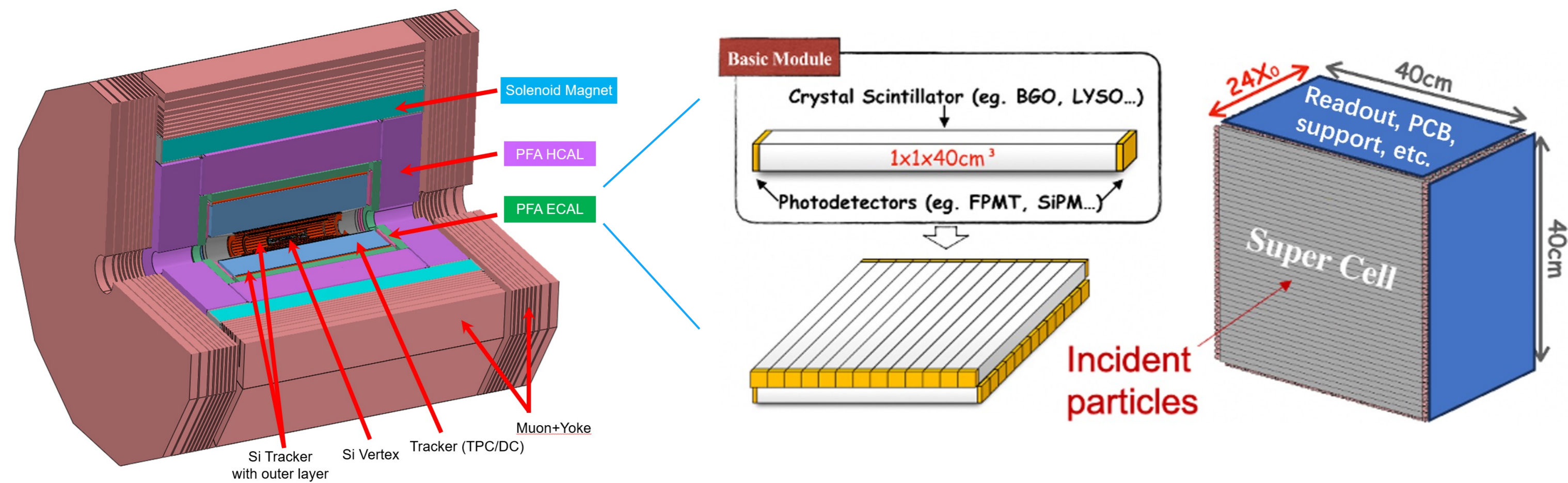


Introduction

- **CEPC: Future lepton collider as a Higgs/EW factory**
 - Precise SM particle measurements & direct BSM search.
 - Detector requirement: PFA-oriented.
 - Jet energy resolution $< 30\% / \sqrt{E}$, Boson mass resolution $< 4\%$.
- **A homogeneous ECAL: orthogonal arranged crystal bars.**
 - Bar size $\sim 1 \times 1 \times 40 \text{ cm}^3$, while reconstruct 5D info (x, y, z, E, T) .
 - EM resolution $\sim 3\% / \sqrt{E}$
 - Main challenges:
 - Hardware: large dynamic range, time measurement, mechanism design.
 - Software: dedicated reconstruction algorithms.



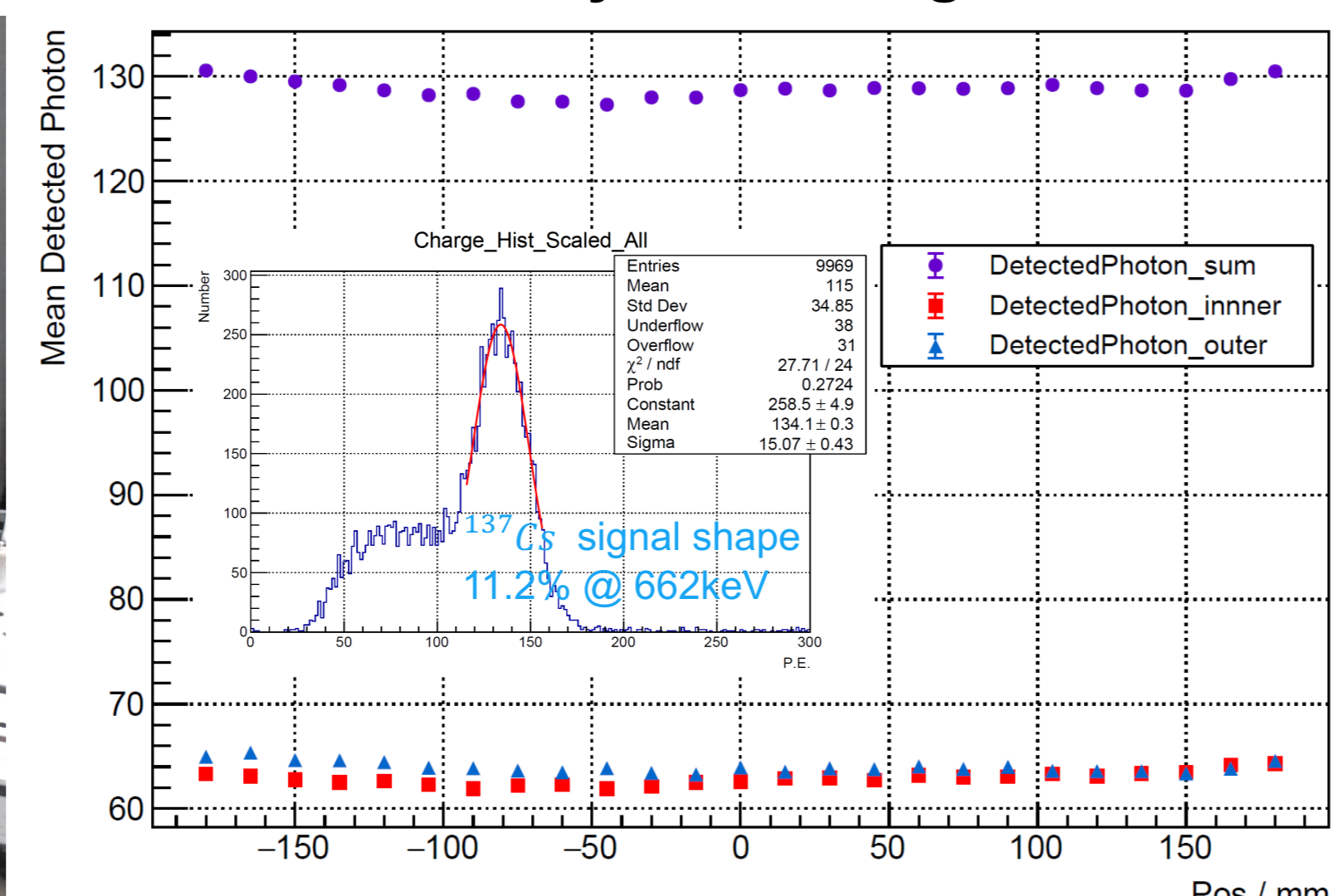
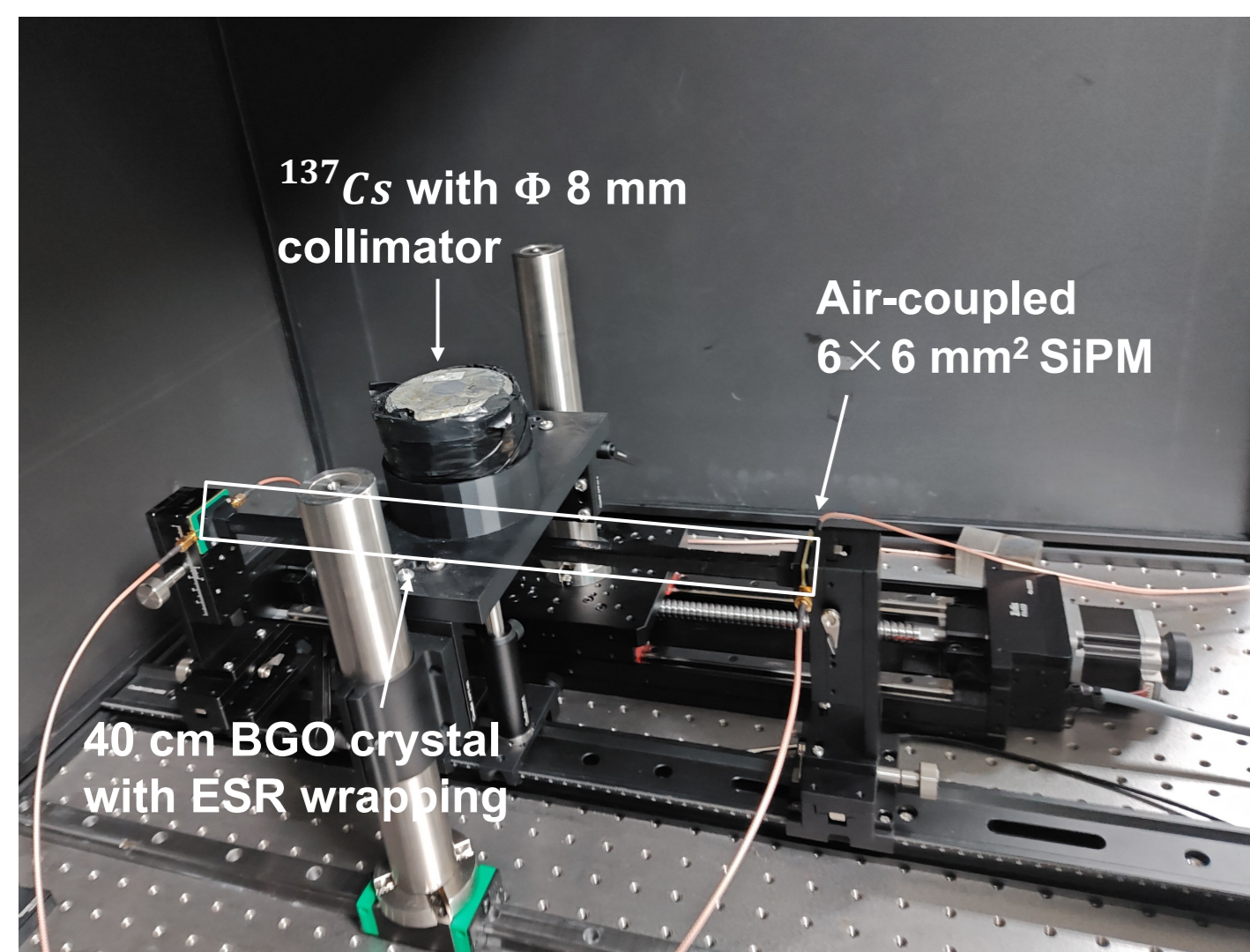
Lab R&D activities

- **Uniformity scan for 40 cm BGO crystal bar**

- An automated crystal scan platform.
- Good uniformity along a single bar: $\sim 2.5\%$

Scan platform with ^{137}Cs source

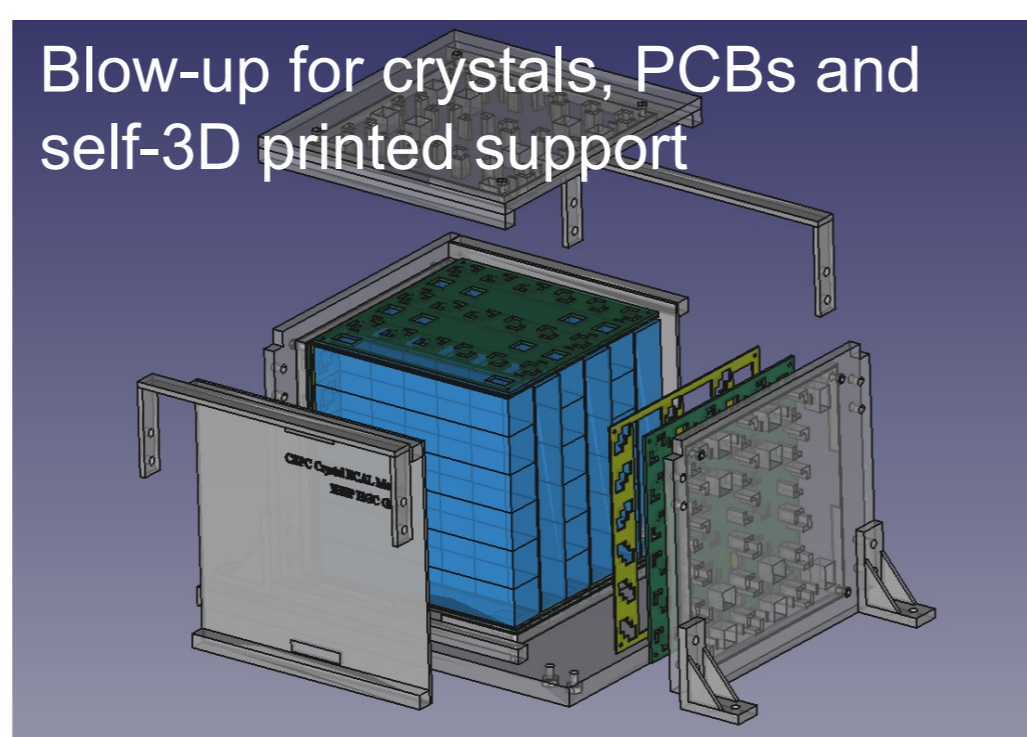
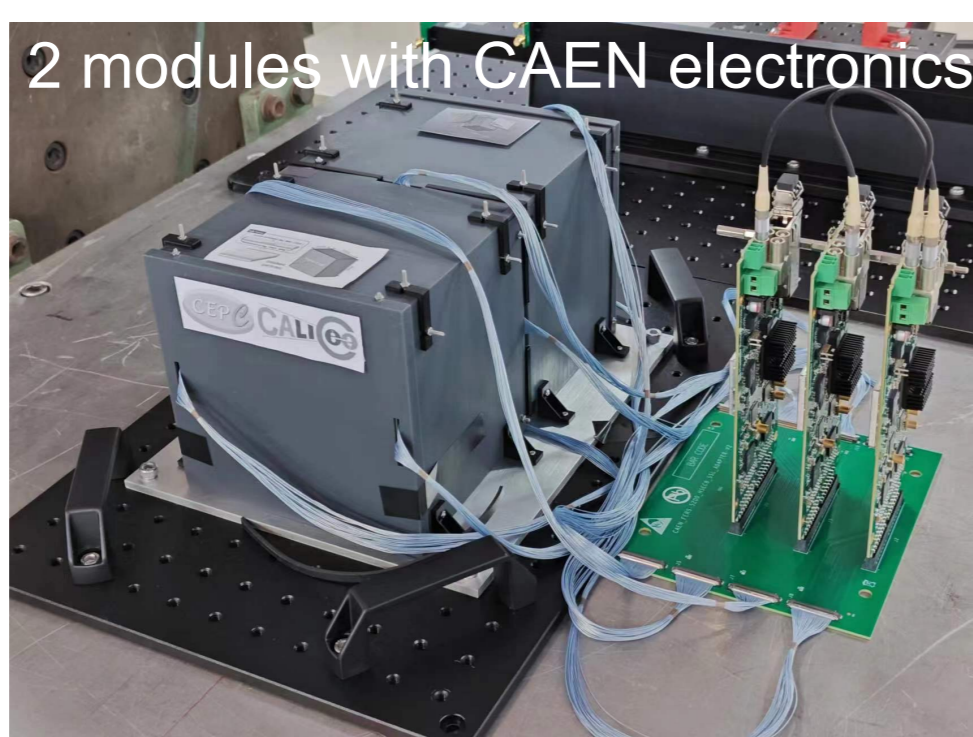
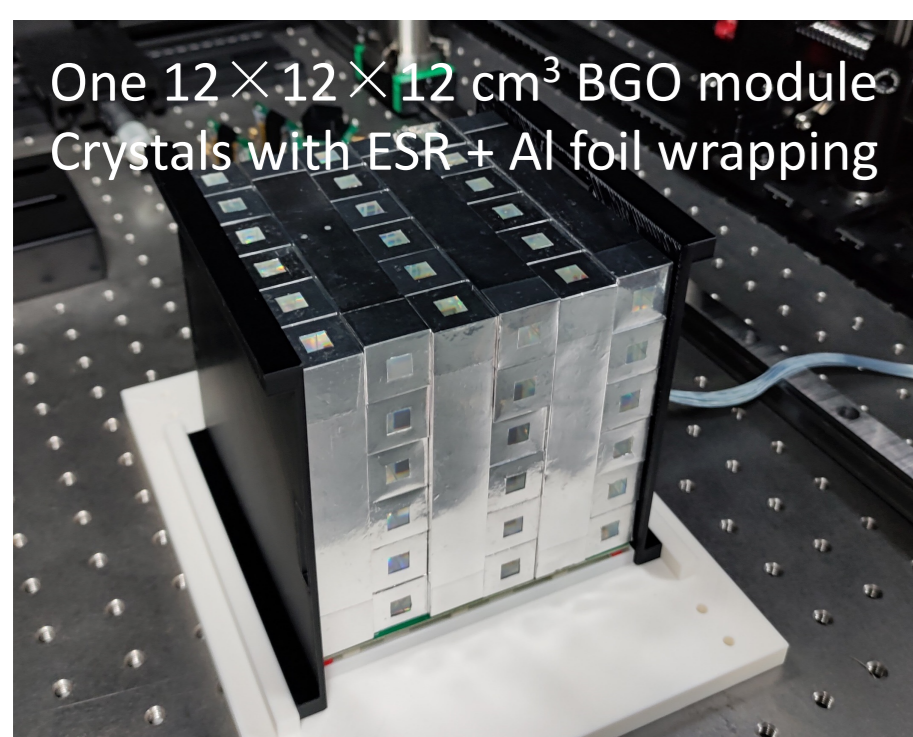
Uniformity scan along bar



Beam tests

- **Prototype module development**

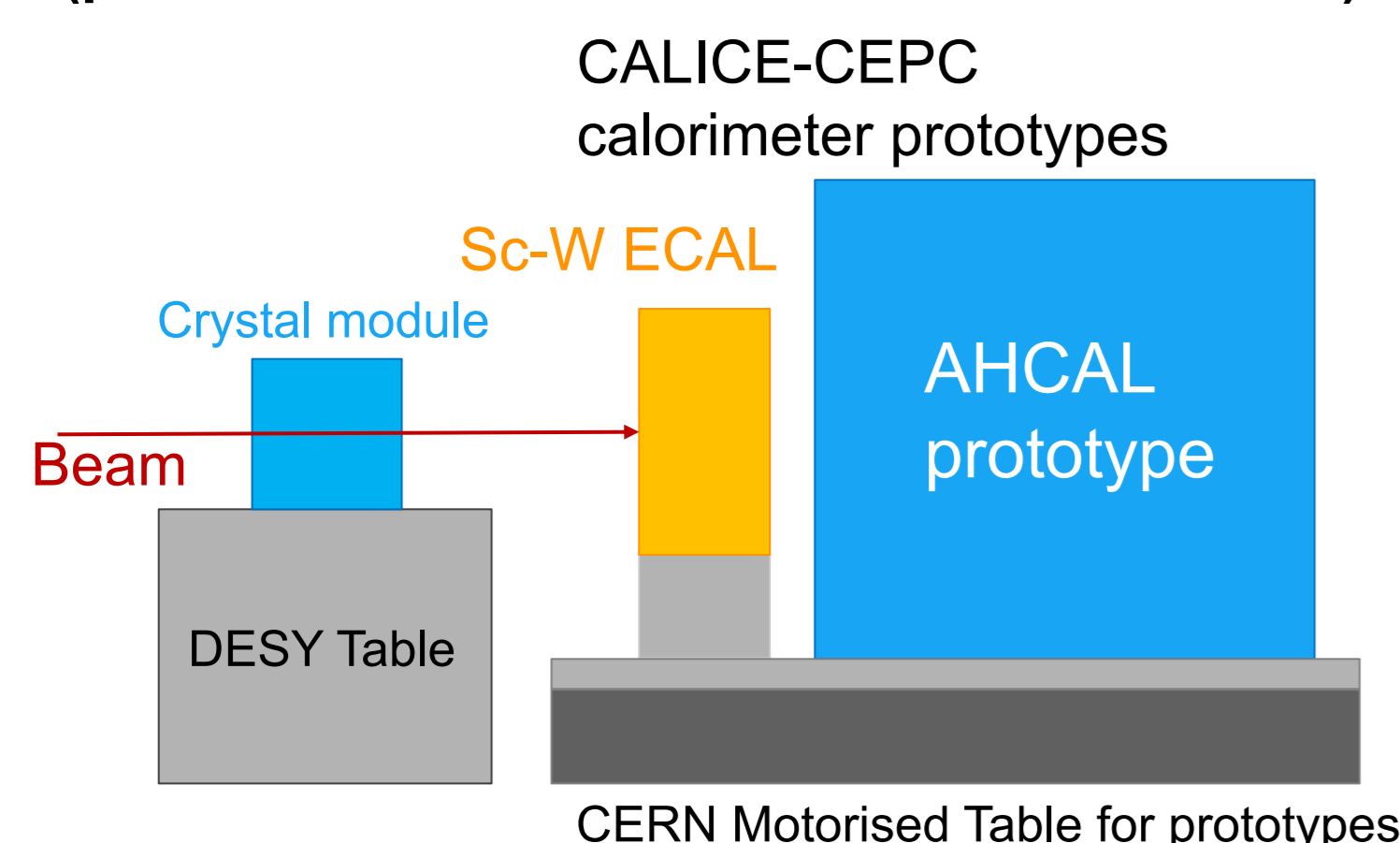
- 2 $12 \times 12 \times 12 \text{ cm}^3$ crystal modules with $2 \times 2 \times 12 \text{ cm}^2$ BGO bars.
- Readout: $3 \times 3 \text{ mm}^2$ SiPMs with 10/15 μm pixel, two-side readout.



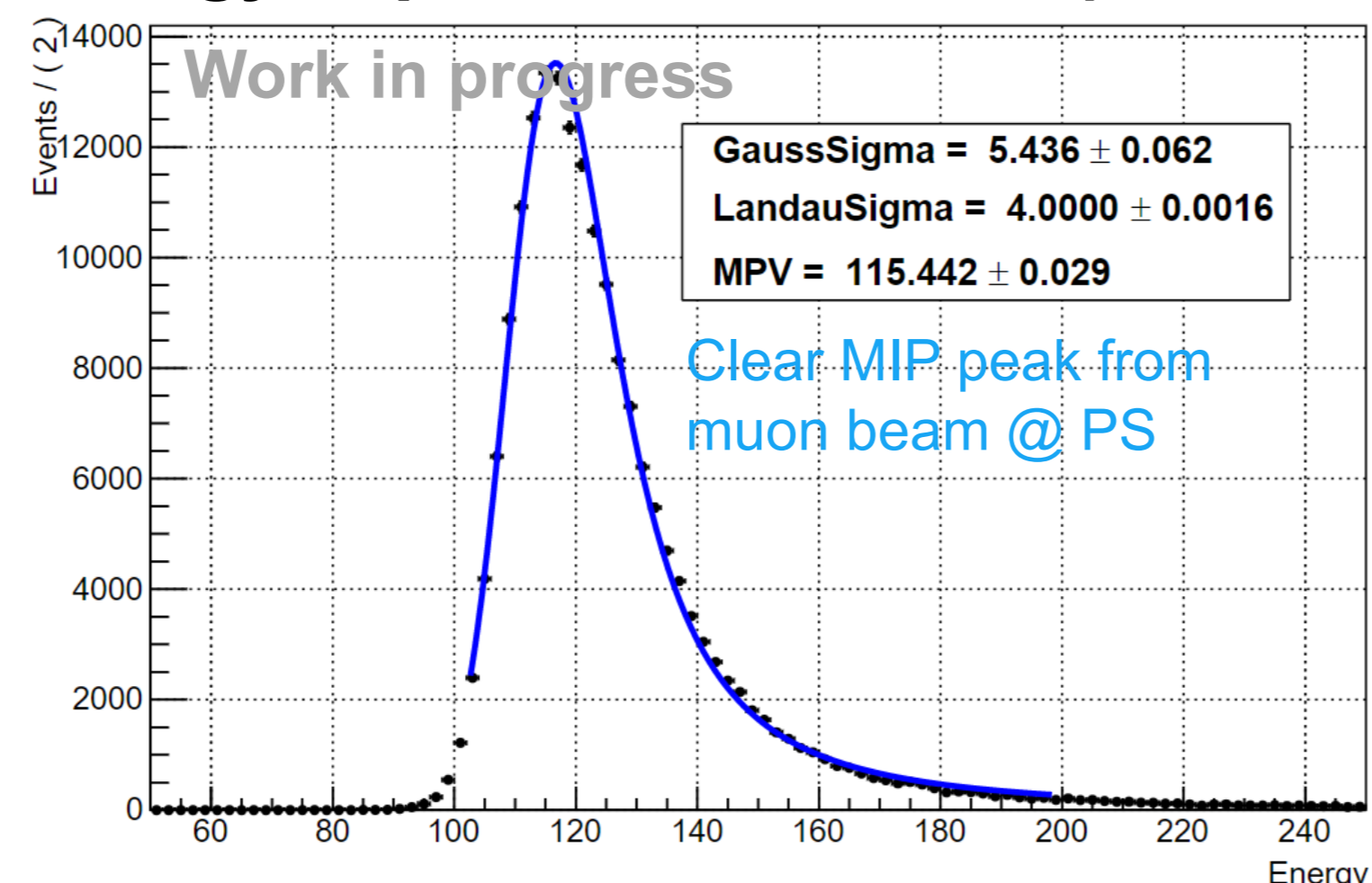
- **MIP signal in CERN muon beam test (1st module only)**

- Beam test @ PS T9 for MIP signal and calibration.
- Got successful commissioning and clear MIP peak from 1st module.
- EM resolution: need better understanding on MC digitization.

2023 CERN beam test overview (parasitic run with CALICE-CEPC calorimeter)

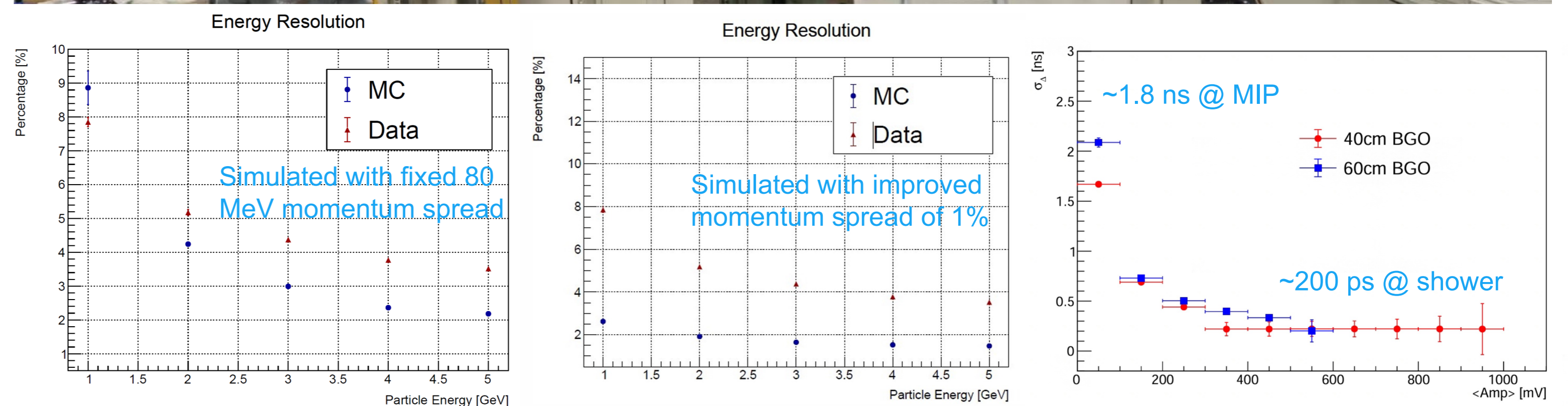
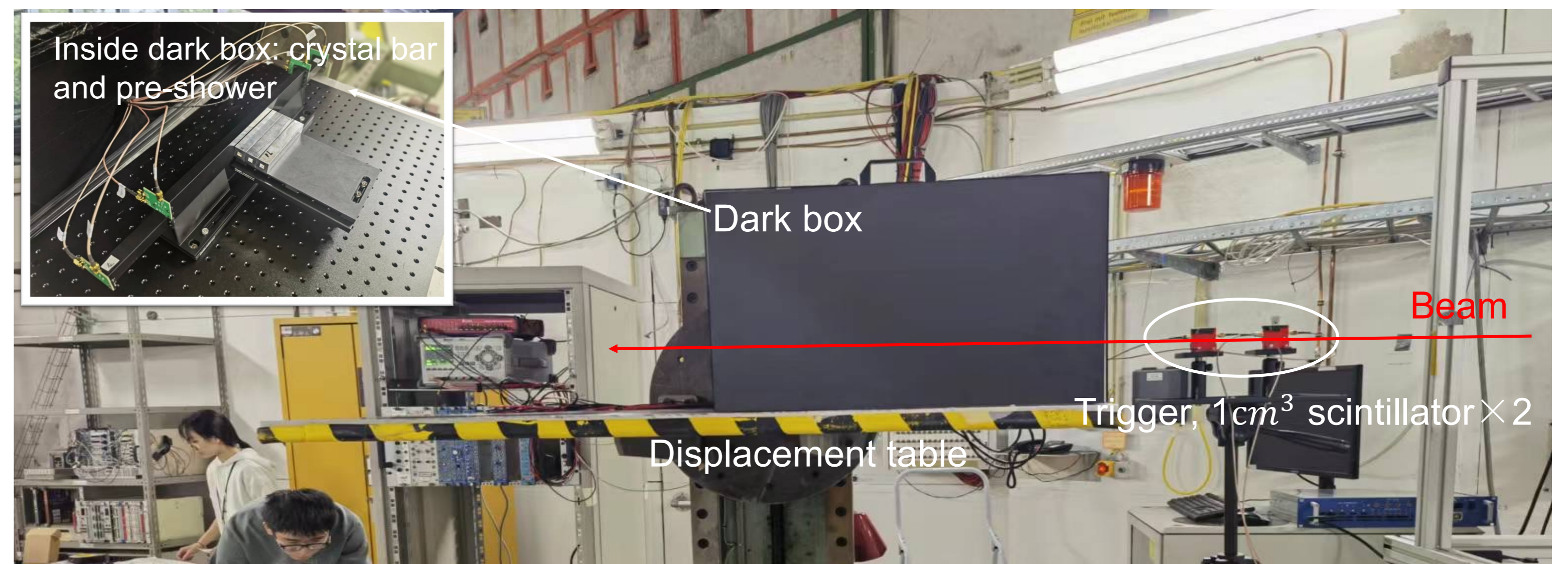


Energy deposition in 10 GeV μ^- beam



- **DESY beam test with 1~5 GeV electrons @ TB 22**

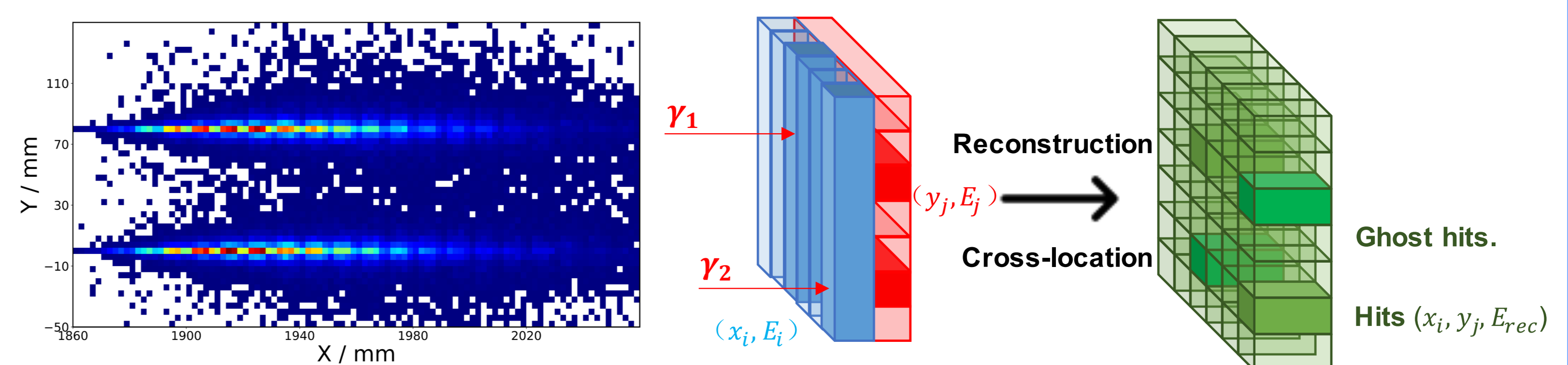
- Energy response: influenced by beam momentum spread.
- Timing response:
 - MIP level: $\sim 1.8 \text{ ns}$.
 - Shower level (with pre-shower): 0.2 ns .



Dedicated PFA algorithms

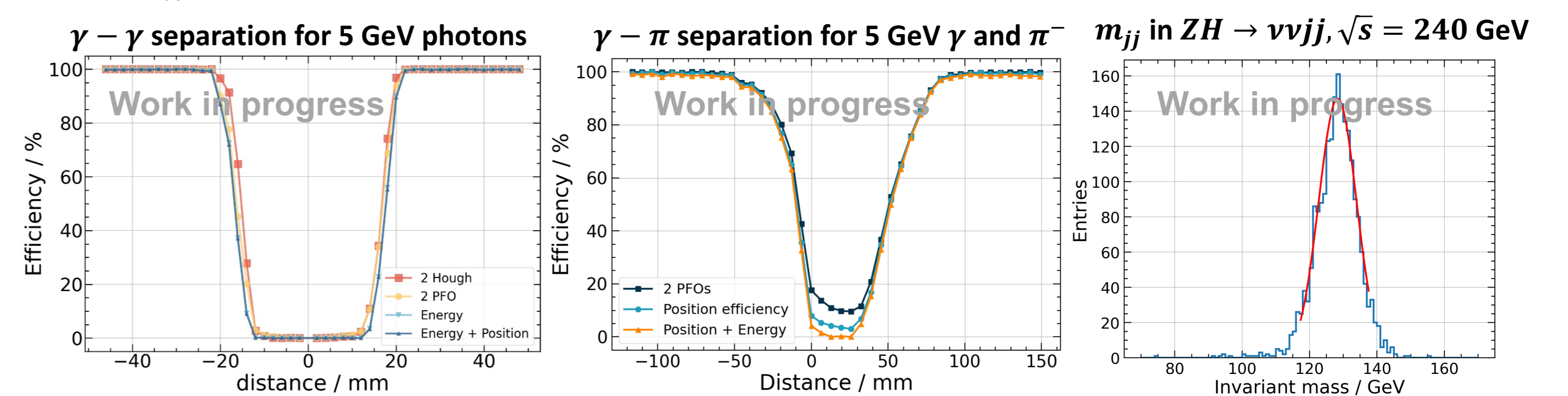
- **Main challenge with traditional PFA**

- Severe energy overlap in crystal: larger R_M and X_0/λ_I .
- Ambiguity in orthogonal arranged bar: $2D \rightarrow 3D$
 - ~ 5 particles in the hottest $40 \times 40 \text{ cm}^2$ module in CEPC.
- A series of pattern recognition algorithms are developed.



- **Performance: studied in CEPC 4th detector**

- Single photon efficiency: $\sim 100\%$ for $> 1 \text{ GeV}$ photon.
- Separation power:
 - $\gamma - \gamma$ separation: 22 mm @ 100% efficiency.
 - $\gamma - \pi$ separation: $50-100 \text{ mm}$ @ 100% efficiency
- Physics performance in $ee \rightarrow ZH \rightarrow \nu\nu + 2\text{jets}$ @ 240 GeV :
 - Reconstruction: truth track + crystal ECAL + plastic scint. HCAL
 - $m_{jj} = 128.3 \pm 5.6 \text{ GeV}$, mass resolution 4.36% .



Conclusions

- **A novel crystal ECAL design for the future lepton collider**

- Extreme EM resolution, timing info available, compatible with PFA.
- Critical issues are studied in system level: mechanics, electronics, integration, etc.
 - Next beam test at CERN PS-T9, June 2024.
 - Possible to provide beam Δp estimation for DESY TB-22.
- Preliminary physical performances with new PFA are promising.

Acknowledgements

- The author would like to present great thanks to the support from CERN and DESY beamtest facilities, CALICE collaboration and CEPC software group, and the financial support from EURO-LAB.