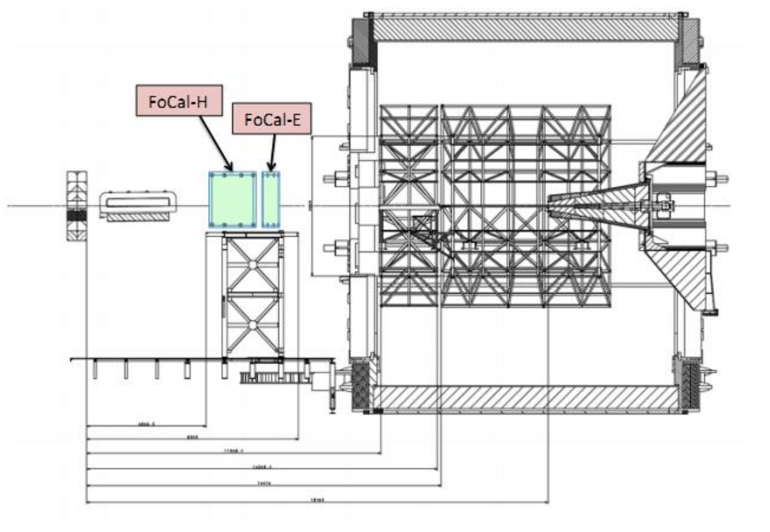
Forward High Granularity Electromagnetic Calorimeter Prototype(FoCal)

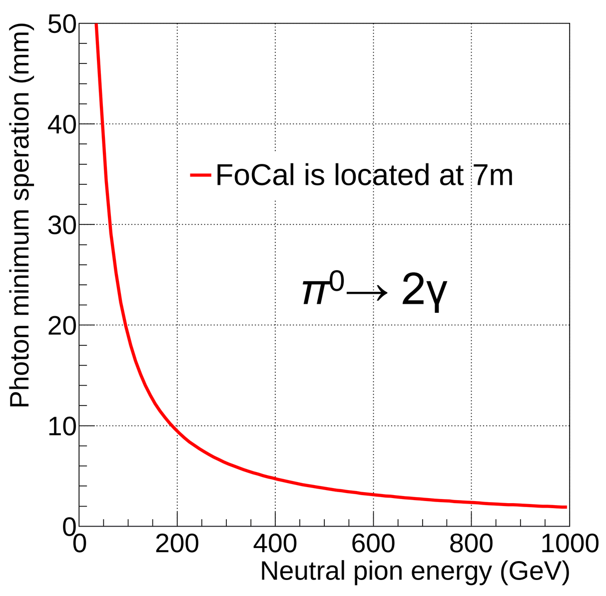
Hongkai Wang for the ALICE-FoCal Collaboration
Utrecht University

Motivation

- What is FoCal ?
  - A forward calorimeter for measurement of forward direct photons at the LHC.
  - Upgrade proposal in ALICE during LS3.
- Main goal :
  - Decisive probe of gluon-density saturation at small Bjorken-*x*.
- Golden Measurements:
  - Direct photon p_T distributions in pp and p-Pb, probe Bjorken-*x* down to ~10^{-5} .
  - p_T range from a few GeV/c up to 100 GeV/c .
  - Pseudorapidity range 3.5< η <5.



Schematic view of the proposed installation position of FoCal in ALICE



Requires

High-granularity detector

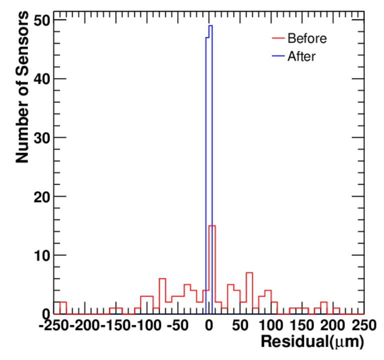
- Discrimination between direct photons and photons from π^0 decay at high energy, small opening angle from π^0 decay.
- 3D shower shape analysis.

Track Based Alignment

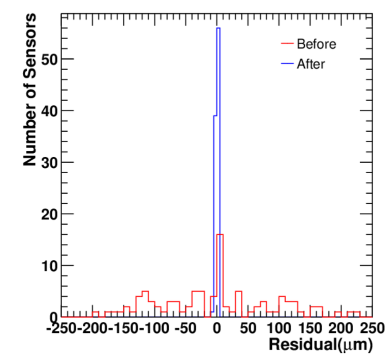
- The MIP(Minimum Ionizing Particles) can be detected and tracked in detail.
- Particle deposits energy in pixel and generates charge, if the charge is above threshold it generates a hit, hits generated by the same particle form a cluster.

$$X_{new} = X_{old}\cos\theta + Y_{old}\sin\theta + \Delta X$$
$$Y_{new} = Y_{old}\cos\theta - X_{old}\sin\theta + \Delta Y$$

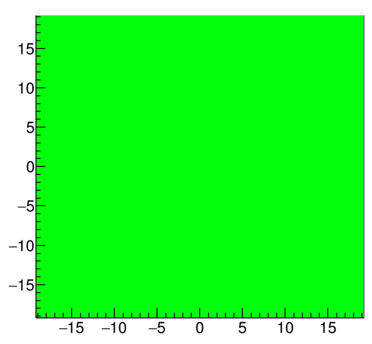
- The assembly of the detector has an accuracy of the positions of 0.2mm.
- Alignment procedure has in total 283 degrees of freedom.
- The cosmic muon data were used in the alignment.
- Iteration until convergence is reached
- After alignment, the residuals are better than 10μm.



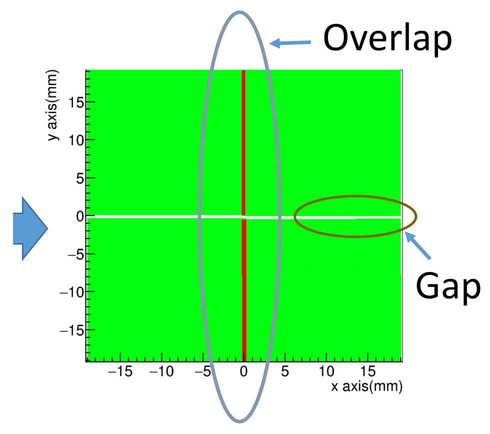
P_{Fit}-$P_{Cluster}$ (Residual)distribution in x direction



P_{Fit}-$P_{Cluster}$ (Residual)distribution in y direction

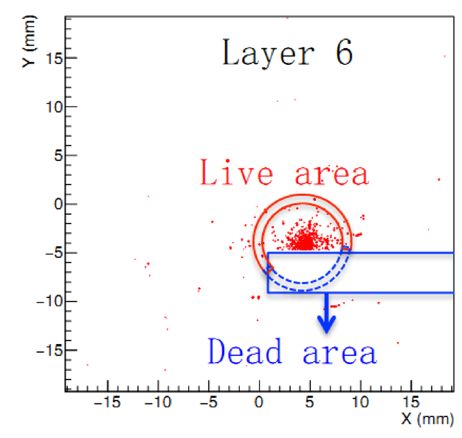


A layer before alignment



A layer after alignment
(Overlap and gap are reconstructed)

Sensitivity Calibration and Dead Zone Correction



$$N = \sum_{i=0}^{3} c_i \int_0^{1.92} 2\pi r \rho_i(r)\,dr$$

c_i is the sensor sensitivity factor
$\rho_i(r)$ is the hit density at distance to the shower axis r

ρ(r) → Normalization → ρ(r)·S → The number of hits in this ring → accumulation → The number of hits in this layer

Two steps :

- Normalize the sensitivities in same layer.
- Correct again to match the shower development longitudinally.

Shower Center Determination

Rough shower center determination → Fine sensor selection → Refine position from power-law weighted mean

$$X_{rough}(3,4) = \frac{\sum_{j=0}^{N-1} x_j}{N}$$

Barycenter of N hits in layer 3 and 4

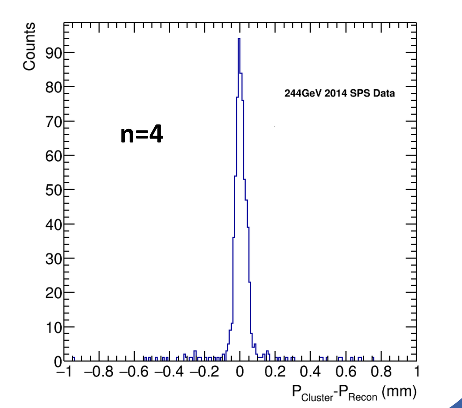
$$w_i = \sum_L R_{l,i}\ (R_{l,i} = 0\ or\ 1)$$

w_i is the sum over the layers in the same pixel region i
$R_{l,i}$ is the response of the pixel in region i in layer l

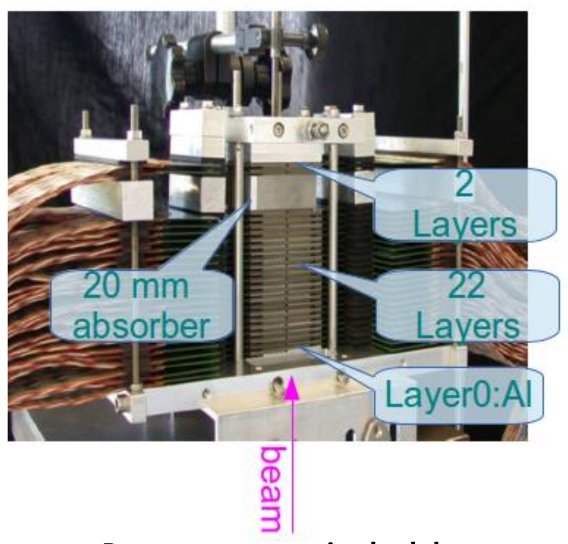
$$X_{refine} = \frac{\sum_i w_i^n x_i}{\sum_i w_i^n}$$

n is the index of the power law weight

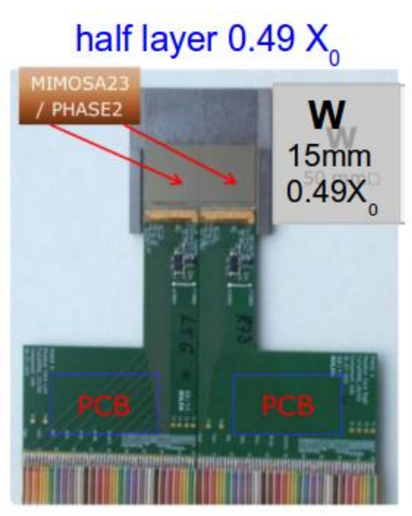
Precision of shower center determination



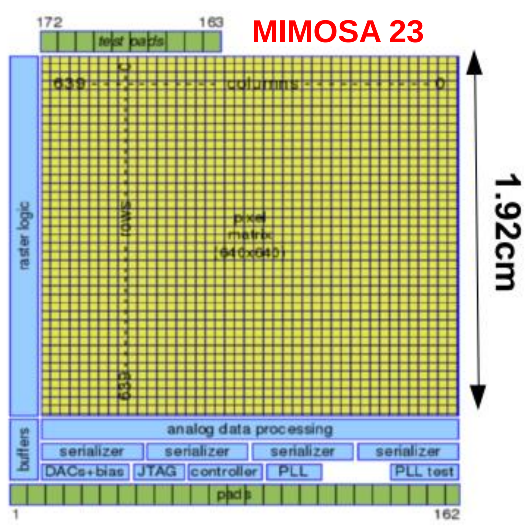
FoCal Prototype Design



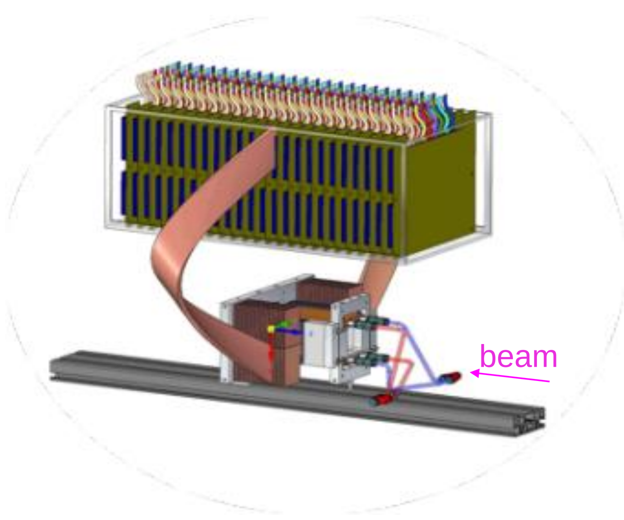
Prototype setup in the lab



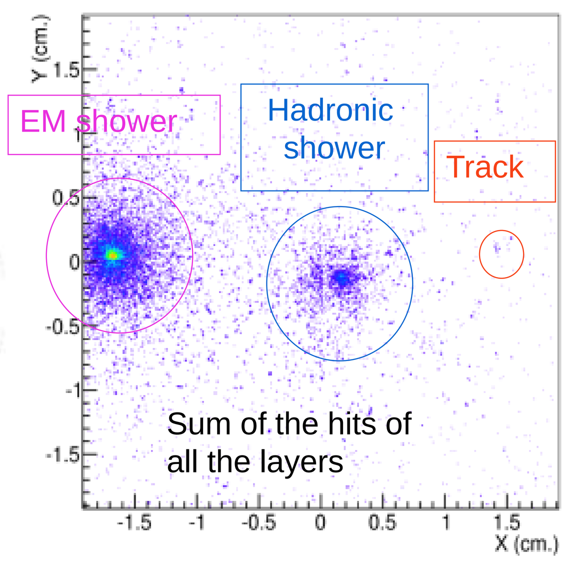
Half layer with W absorber and two sensors including PCBs



Schematic of MIMOSA sensor



Schematic view of prototype with two readout cables connected

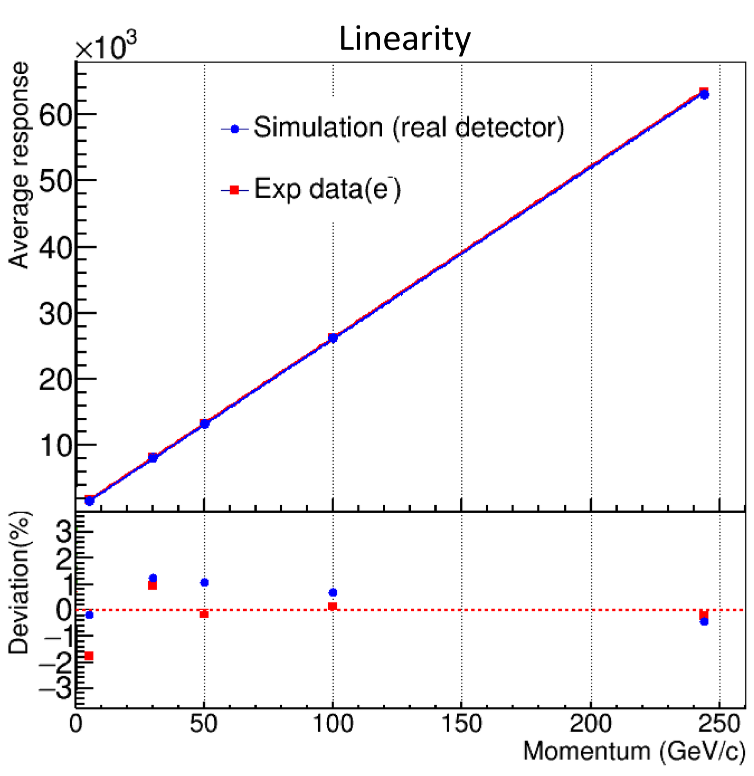


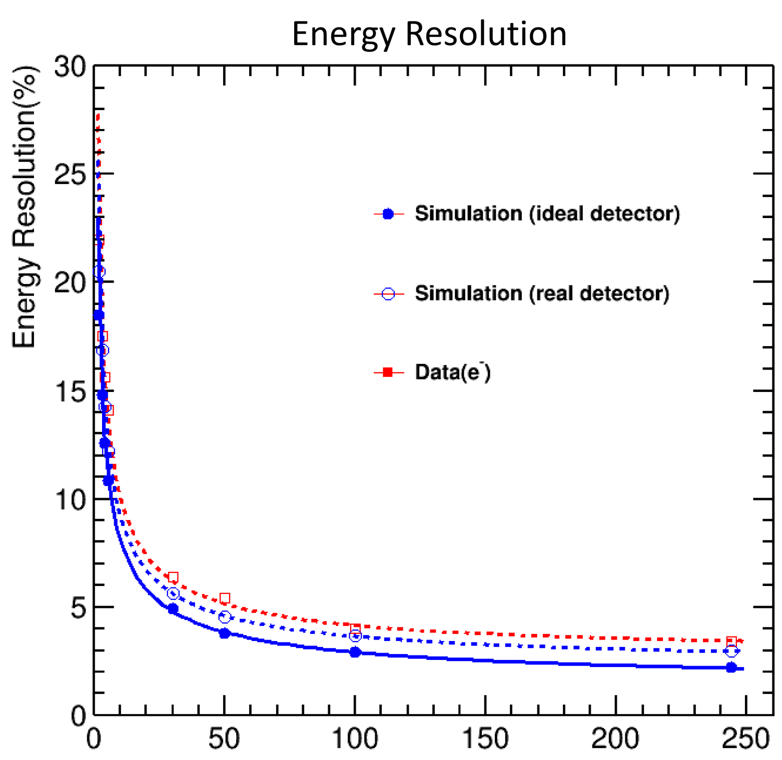
Transverse distribution of hits for different types of interactions

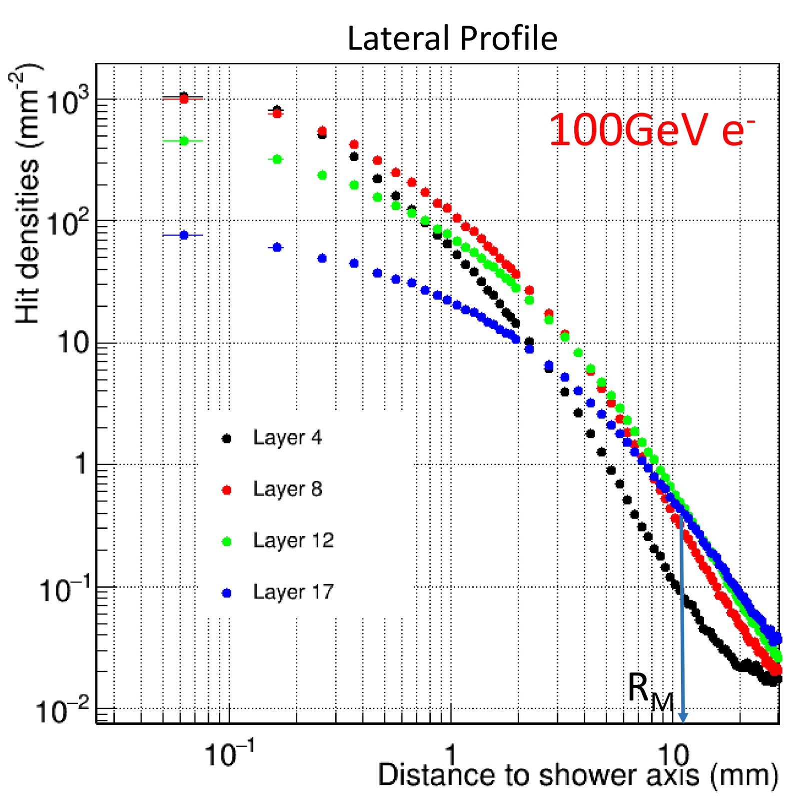
High granularity
CMOS silicon sensor
PHASE2 MIMOSA 23

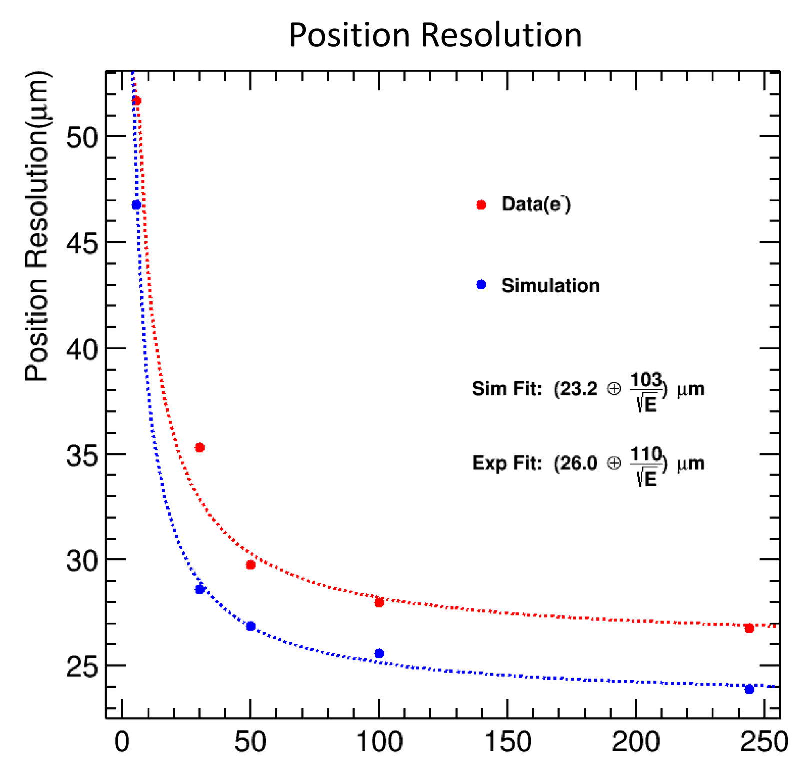
- 640×640 pixels
- Pitch size: 30μm
- 642μs/frame readout
- Rolling shutter

Results and Conclusion









- **Successful proof of principle of particle counting calorimetry.**
  - A high granularity digital Si-W calorimeter prototype for FoCal has been built and tested.
  - Good linearity and reasonable energy resolution have been achieved.
- **Spatial granularity allows unique measurements.**
  - Lateral shower profiles down to few percent **Molière radius** have been obtained.
  - Down to the pixel level position resolution was reached.