

The progress of FIT simulation

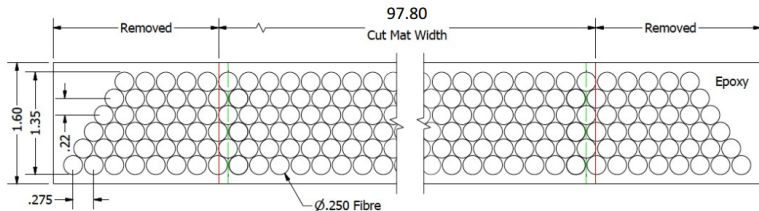
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December 17, 2019

IHEP & UNIGE

- Fast simulation of a single mat & BT
- Simulation of multilayers

FIT Module: Fiber Mat



- Two possible lengths:
1060 mm, 770 mm
- LHCb fiber tracker upgrade
- 6 layers of fibers in each mat
round section, diameter 250 μm
peak emission wavelength: 450 nm
- Mat width: 97.80 mm to match 3 SiPM arrays

FIT Module: SiPM

Multi-cell avalanche photodiodes(APD) operated in Geiger-mode

“LHCb” SiPM

Hamamatsu S13552-HRQ

2 chips/array

64 channels/chip

104 (4x26) pixels/channel

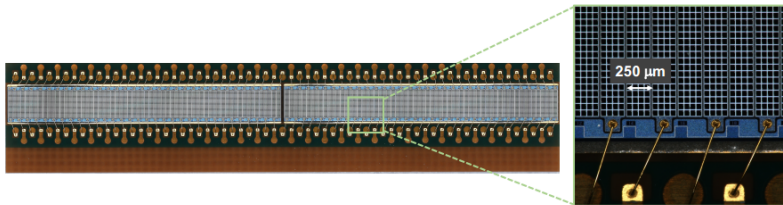
Pixel size: $57.5\mu\text{m} \times 62.5\mu\text{m}$

Channel size: $230\mu\text{m} \times 1625\mu\text{m}$

Gap between channels: 20 μm

Gap between chips: $(220 \pm 50)\mu\text{m}$

Photon detection efficiency 45%



FIT Module: SiPM

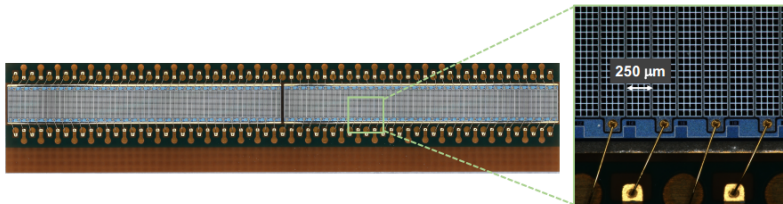
Multi-cell avalanche photodiodes(APD) operated in Geiger-mode

“LHCb” SiPM

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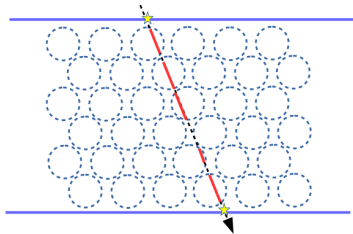
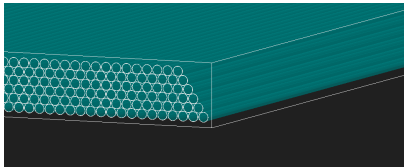
“10 μm ” SiPM

Hamamatsu S13552-10
2 chips/array
64 channels/chip
3749 (23x163) pixels/channel
Pixel size: $10\mu\text{m} \times 10\mu\text{m}$
Channel size: $230\mu\text{m} \times 1630\mu\text{m}$
Gap between channels: 20 m
Gap between chips: $(220 \pm 50)\mu\text{m}$
Photon detection efficiency 15%

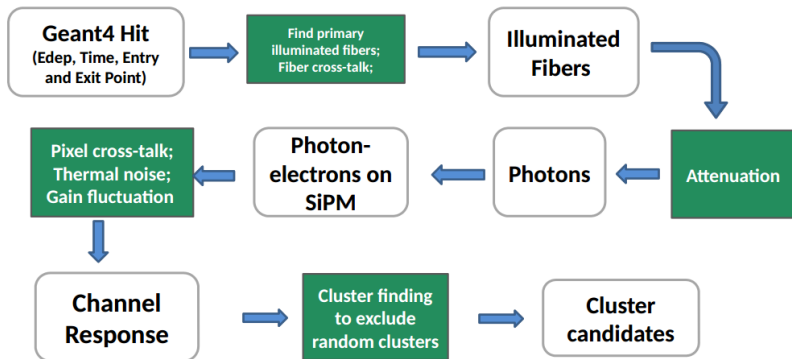


Fast simulation for a single mat

- Fiber matrix is replaced by a thin flat strip;
- Particles pass through the fiber mat that is defined as sensitive detector(“MatSD”);
- Energy deposit, time, entry and exit coordinate are recorded in “MatHit”;
- A digitization process converts energy into photoelectrons;
- The same clustering algorithm as the actual data processing is applied

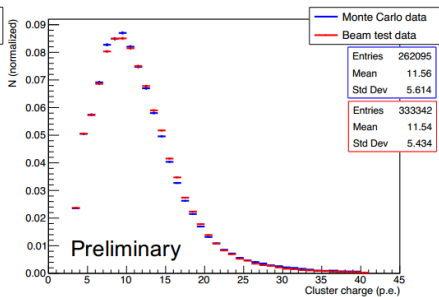
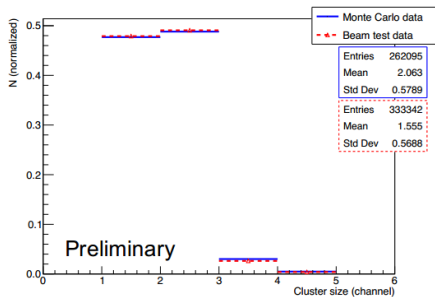


Digitization Flow



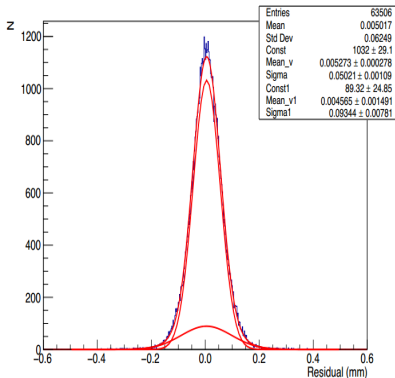
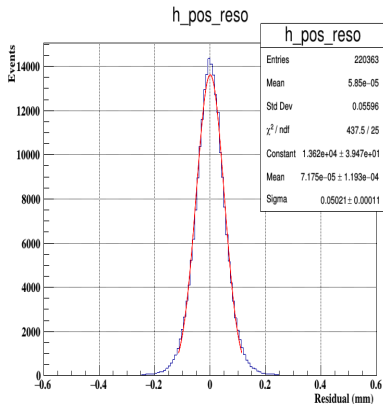
Simulation results

400GeV proton, normal incidence
Cluster charge and cluster size



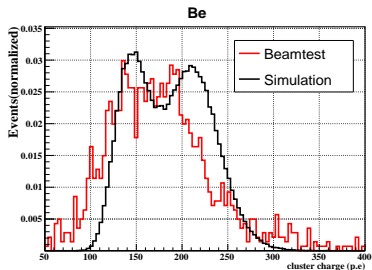
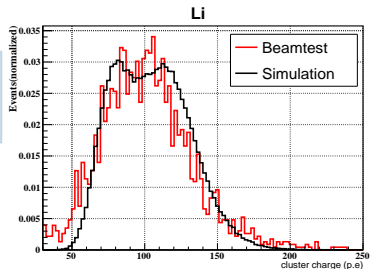
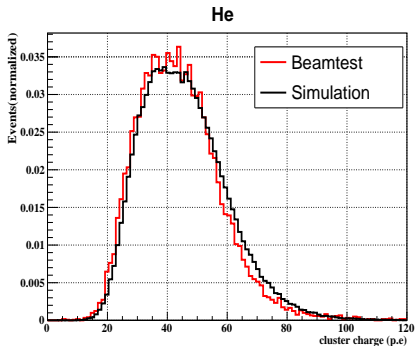
Simulation results

Spatial resolution



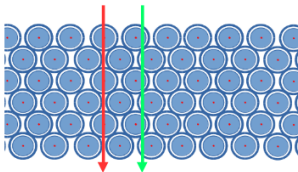
Simulation results

Cluster charge spectrum of
He, Li, Be

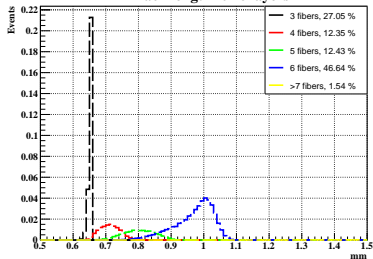


The uniformity of fiber mat

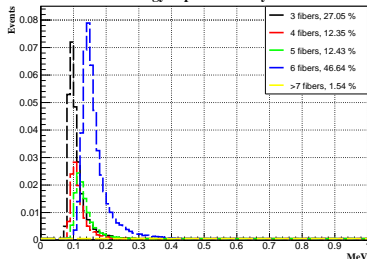
Normal Incidence



Track length for 6 layers

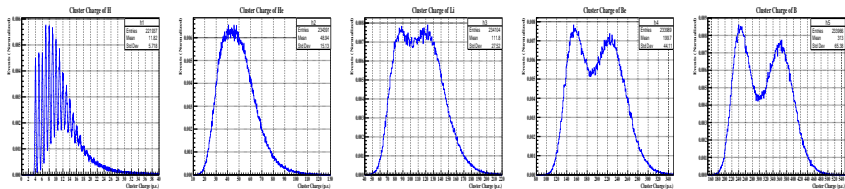


Energy deposit for 6 layers

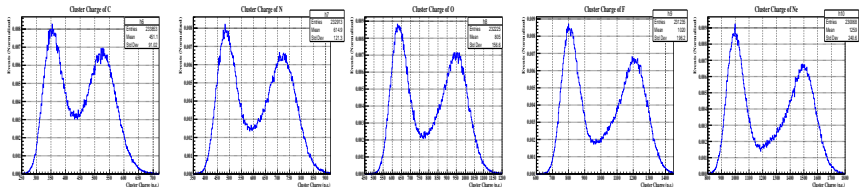


The uniformity of fiber mat

proton \rightarrow *B*:



C \rightarrow *Ne*:



Multilayer Simulation

Motivation:

the charge measurement capability of FIT

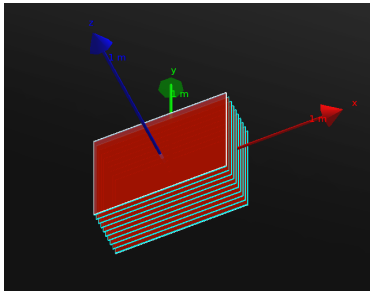
Simulation setup

Geometry:

- 10 XY layers ($77 \times 77 \text{ cm}$)
- Each layer has a 200 μm position fluctuation

Particle:

- Isotropic source
- Proton \rightarrow Fe
- Energy: 10 GeV/n



Multilayer Simulation

Simulation setup

Geometry:

- 10 XY layers ($77 \times 77 \text{ cm}$)
- Each layer has a 200um position fluctuation

Particle:

- Isotropic source
- Proton \rightarrow Fe
- Energy: 10 GeV/n

Event selection

- Incident angle ($< 45^\circ$)
- Particle hit all the interested layers
- Cluster size (< 50 channels, to exclude huge cluster)
- Cluster charge thresholds (low and high cut)

- Quenching effect (from DAMPE PSD)

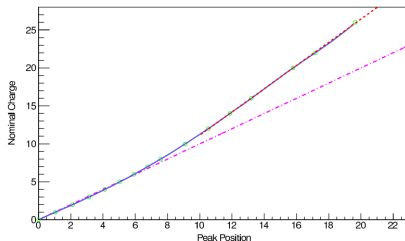


Fig. 15 Peak positions obtained from a reconstructed charge spectrum versus charge numbers (open circles). The solid line and dotted line present the constructed third-order spline function and the fitted linear function, respectively, the dash-dotted line is the bisector (ordinate = abscissa) as a reference.

Calibration of the DAMPE Plastic Scintillator Detector and its on-orbit performance <https://arxiv.org/abs/1810.09901v1>

Data flow

- Quenching effect (from DAMPE PSD)
- Channel saturation

$$N_{firedpixel} = N \left(1 - e^{-\frac{N_{pe}\epsilon}{N}} \right) = 3749 \left(1 - e^{-\frac{N_{pe}\epsilon}{3749}} \right)$$

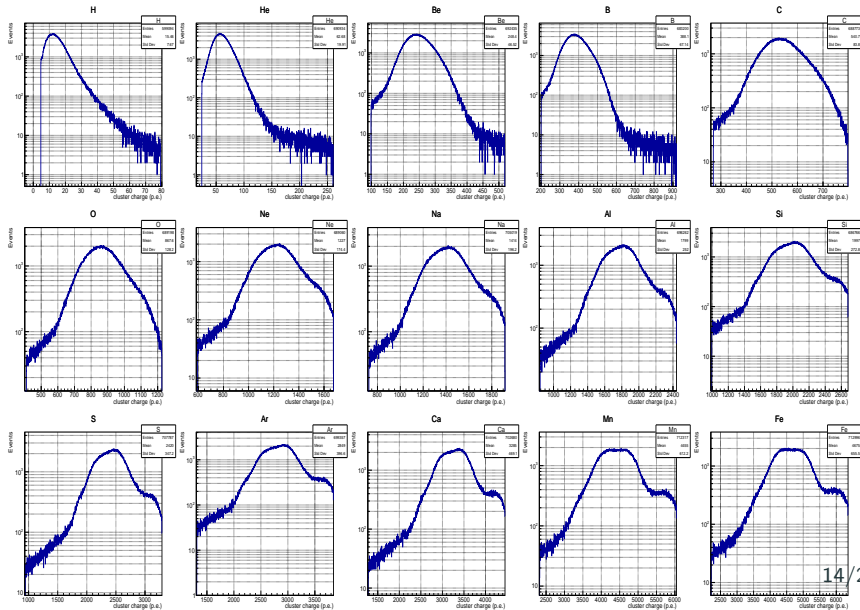
- Attenuation factor

$$a(l) = F_s e^{-\frac{l}{\lambda_{short}}} + (1 - F_s) e^{-\frac{l}{\lambda_{long}}}$$

Both the X and Y layers belonging to the same x-y pair must have valid clusters.

- Angle correction $\sim \cos\theta$

Results - Cluster charge spectrum of a single layer



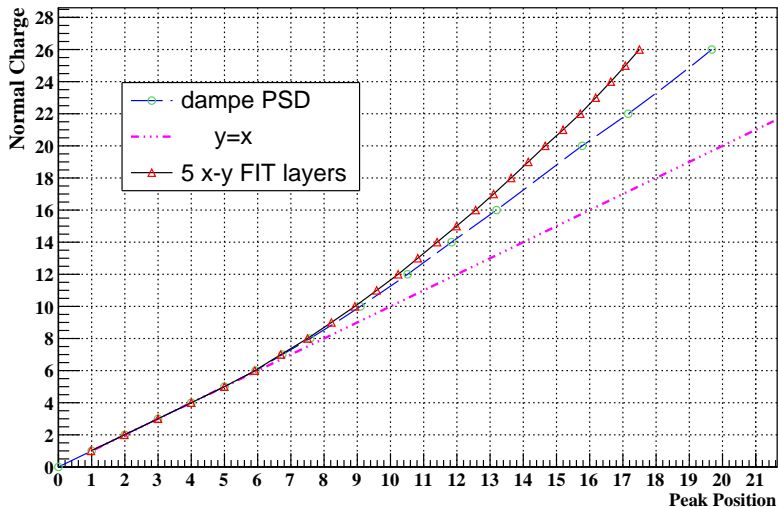
Truncated average of multilayer

- Take the largest cluster of each layer as the corresponding physical hit;
- If the layer cluster charge exceeds the threshold range, this layer will be marked as invalid.
- Calculate the average of all valid signals

$$\bar{Z} = \frac{1}{n-2} \left[\sum_{i=1}^n Z_i - (Z^{Max} + Z^{Min}) \right]$$

- Fit the spectrum of \bar{Z} , get mean value

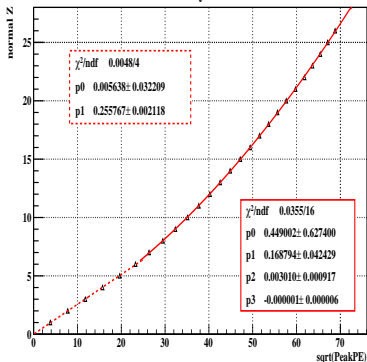
Results - Linearity



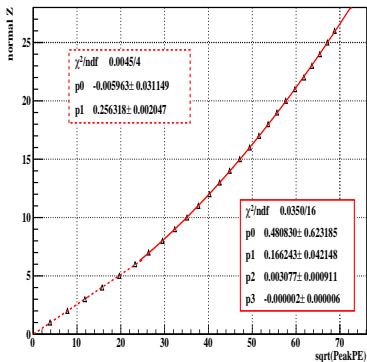
Results - Sqrt(cluster charge) vs Normal Z

charge correction

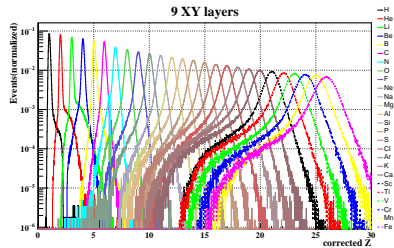
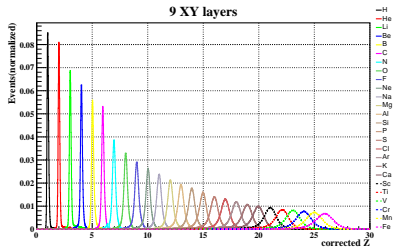
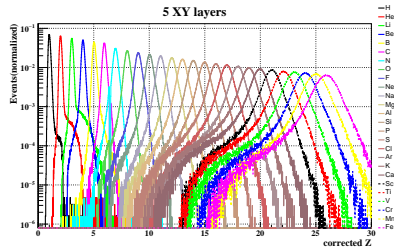
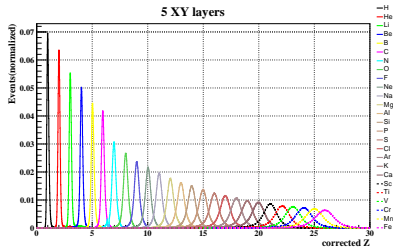
5 XY layers



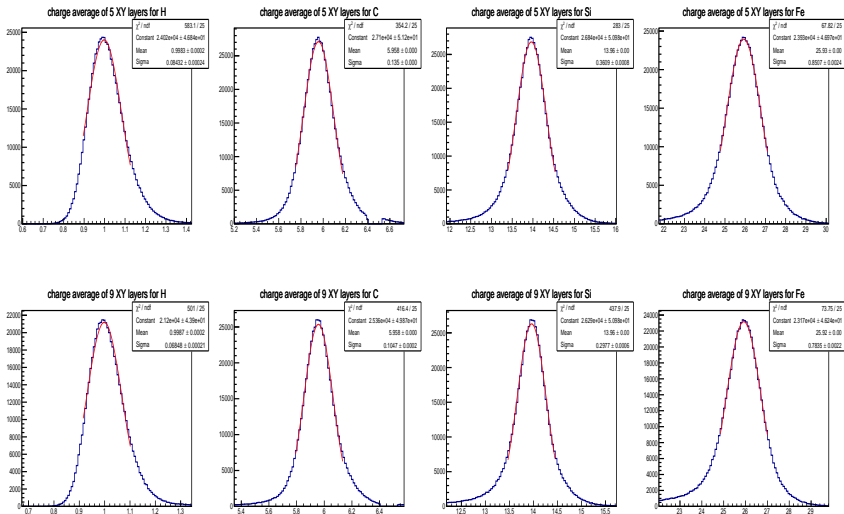
9 XY layers



Results - Spectrums of corrected Z

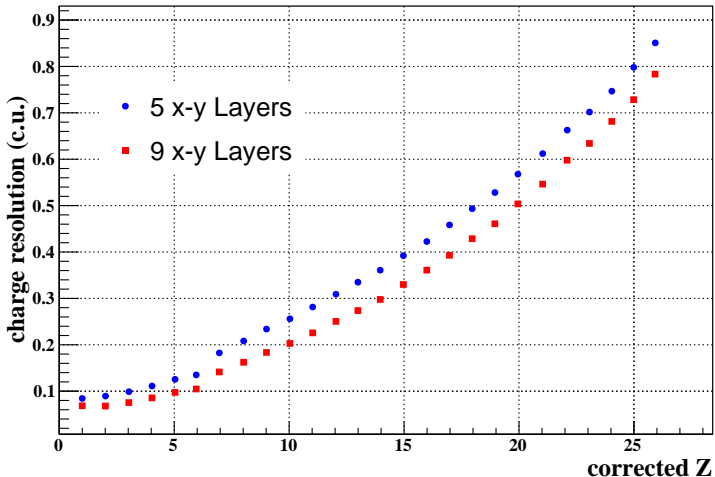


Results - Spectrums of corrected Z



Results - Charge resolution

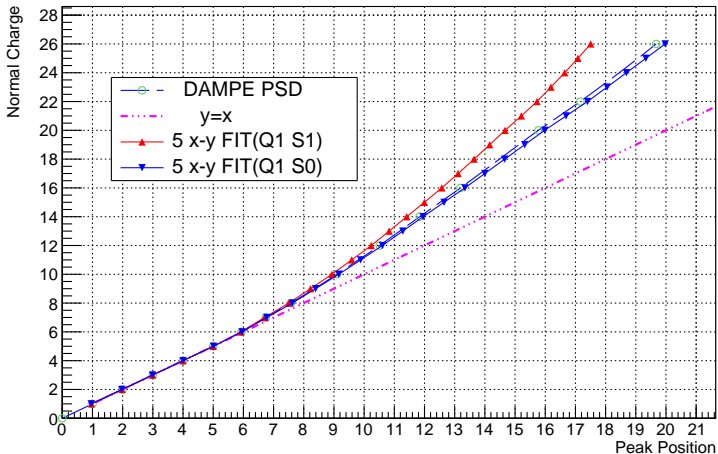
Charge resolution of multi FIT layers



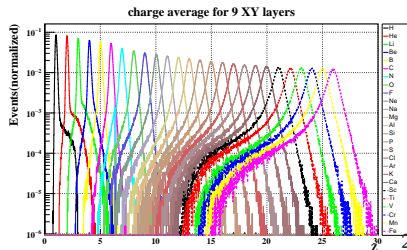
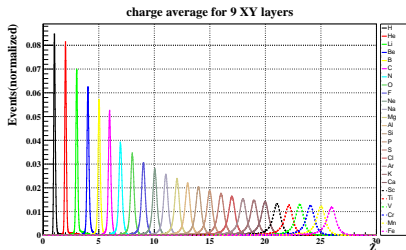
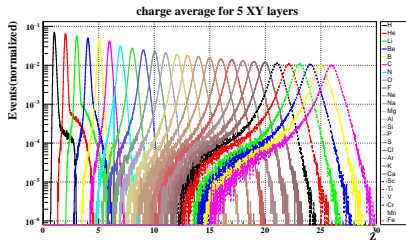
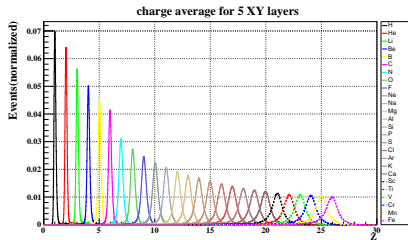
Remove the limit of channel saturation

Q1 means quenching effect is added

S0 means no channel saturation

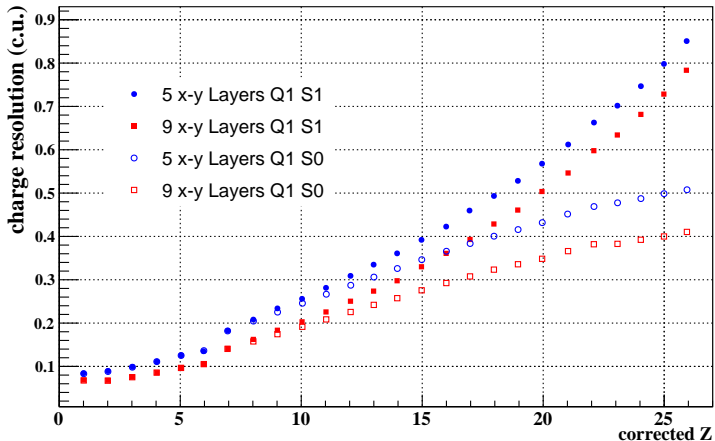


Spectrums of corrected Z(Q1 S0)



Results - Charge resolution

Charge resolution of multi FIT layers



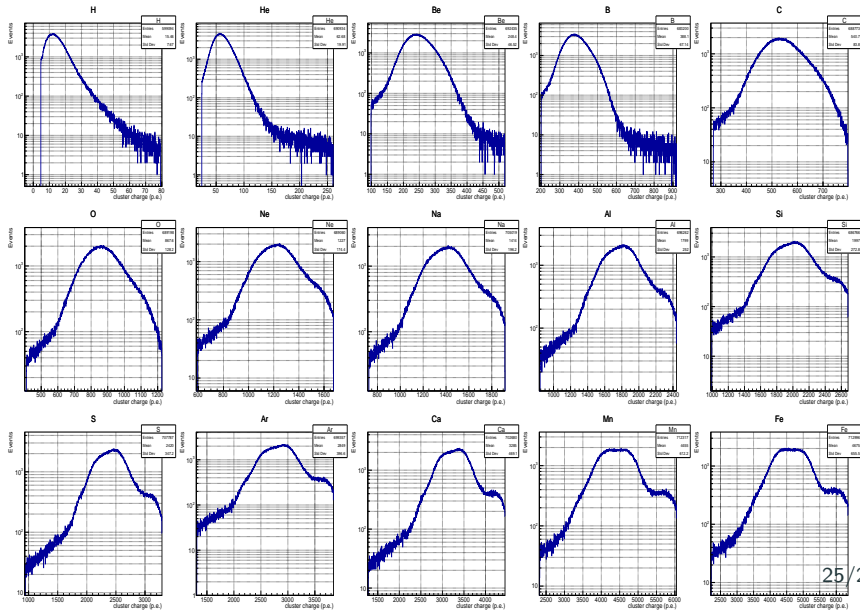
Summary and outlook

- A fast simulation of a single fiber mat module with “ $10\mu\text{m}$ ” SiPM has been done.
- For protons and He, the simulations agree well with BT.
- For other nuclei, further optimization is needed.
- The preliminary overall simulation of the lateral FIT has been completed, and the module simulation will be added into the overall simulation later.

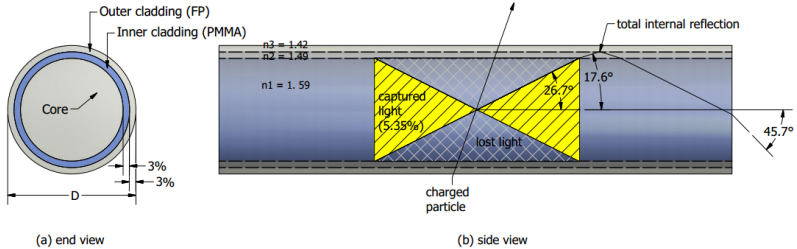
- ▷ A Multilayer simulation has been constructed, and a simple charge reconstruction algorithm was applied to study the charge measurement capability of FIT.
- ▷ More Improvement of charge measurement capability needs to be studied: multipoint fitting instead of the current truncated average

Thanks for your attention!

Results - Cluster charge spectrum of a single layer



backup -Fiber



Clustering algorithm

The signal created by a particle crossing a fibre mat is dispersed over several detector channels.

An algorithm is applied to assemble all signal to a cluster.

The centre-of-gravity(cog) of this cluster is the best estimate of the hit position.

