

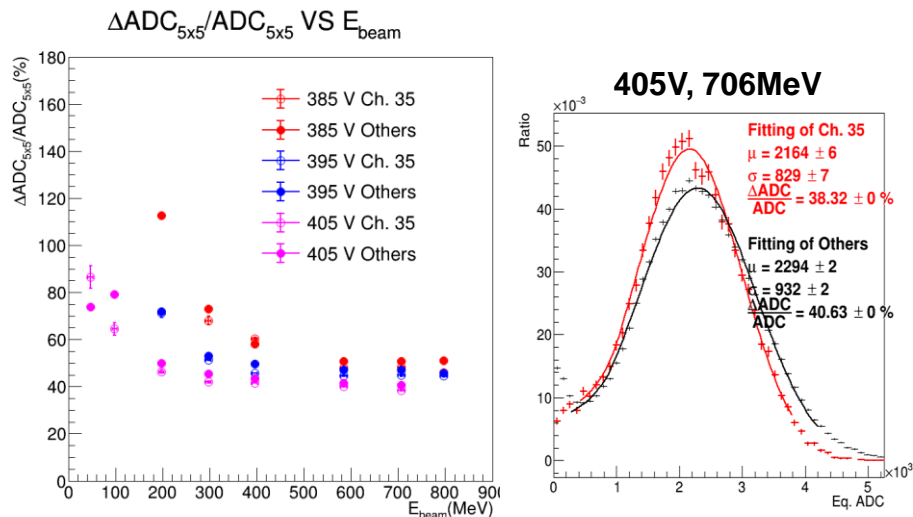


ZDC ECal Test Beam Analysis 20250401

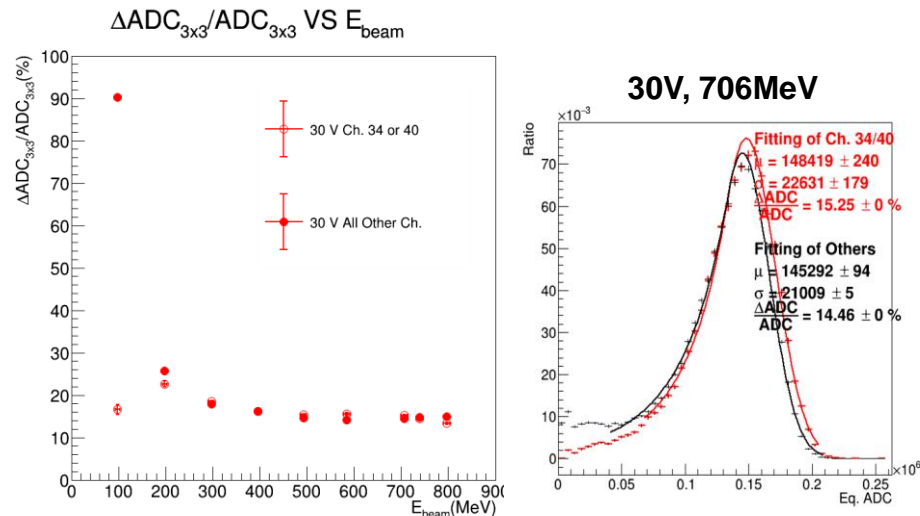
**Wen-Chen Chang, Kai-Yu Cheng, Tatsuya Chujo, Yuji Goto, Chia-Yu Hsieh,
Motoi Inaba, Subaru Ito, Kentaro Kawade, Yongsun Kim, Chia Ming Kuo,
Chih-Hsun Lin, Po-Ju Lin, Rong-Shyang Lu, Jen-Chieh Peng**

Review : Energy Resolution@ EIC-Asia@20250313

LYSO + APD



PbWO4 + SiPM

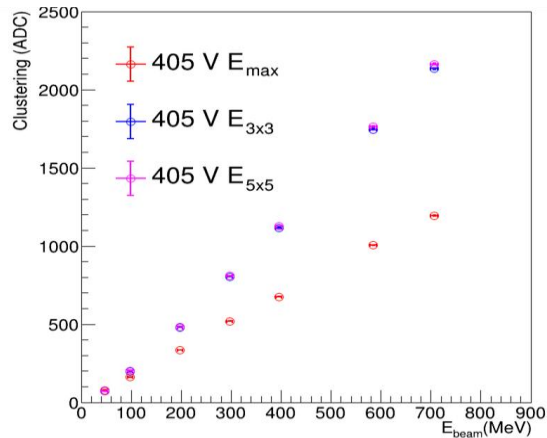


- Preliminary results gave energy resolution for “LYSO + APD” ~40% and “PbWO4+SiPM” ~ 15% before energy regression.
- Tracking only require timing matching here. More strict tracking cut will be applied.

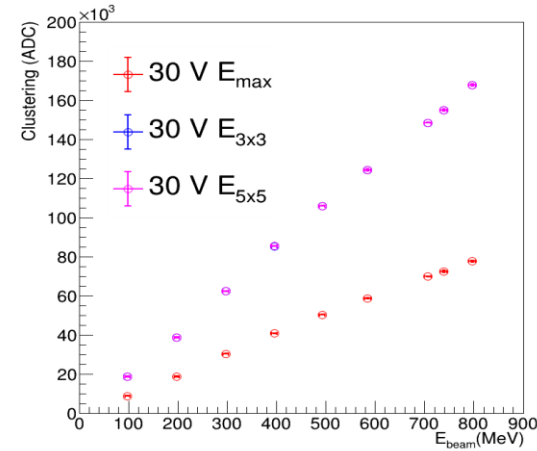
Clustering

ADCsum
mean

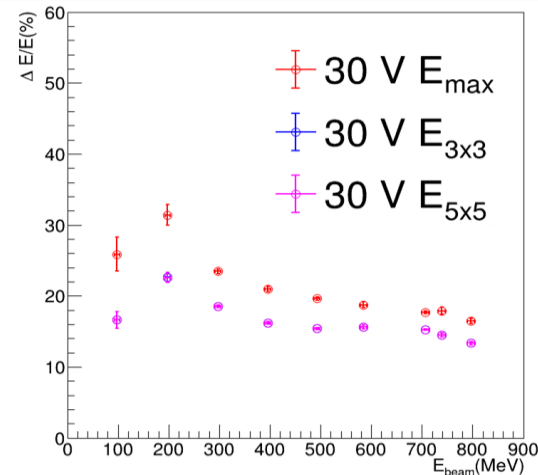
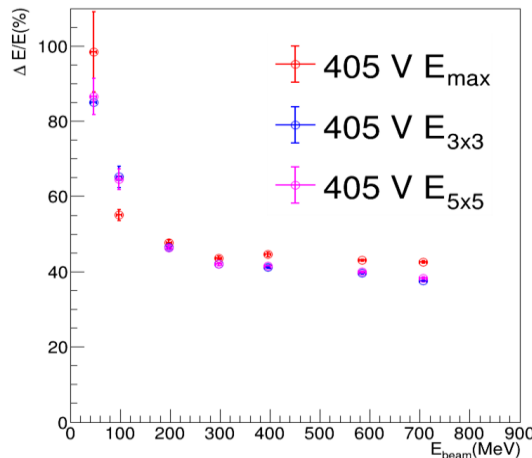
LYSO + APD



PbWO4 + SiPM

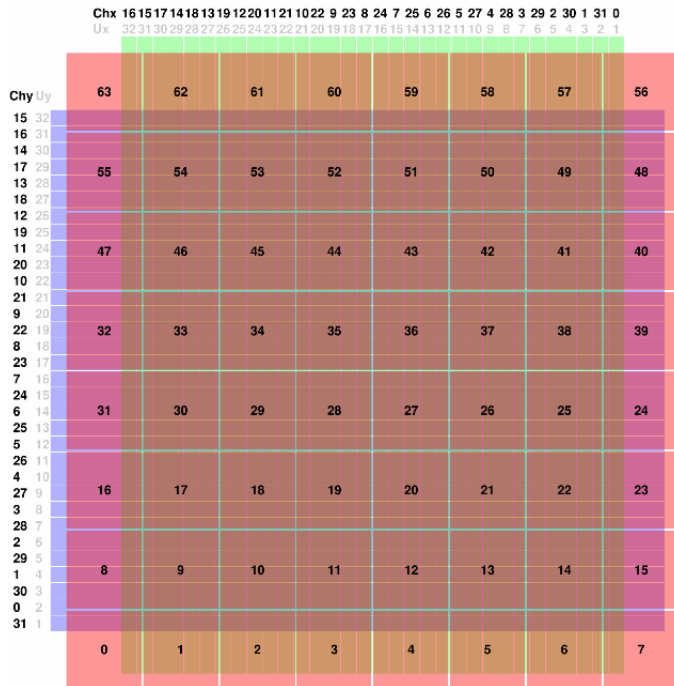


ADCsum
sigma/mean

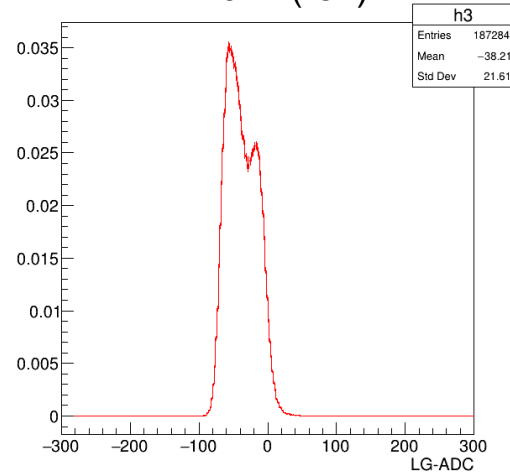


- No obvious difference between 3x3 and 5x5 for both systems.
- For LYSO + APD, energy resolution of E1x1 ~ E3x3 ~ E5x5. Hardware threshold setting is probably too high.

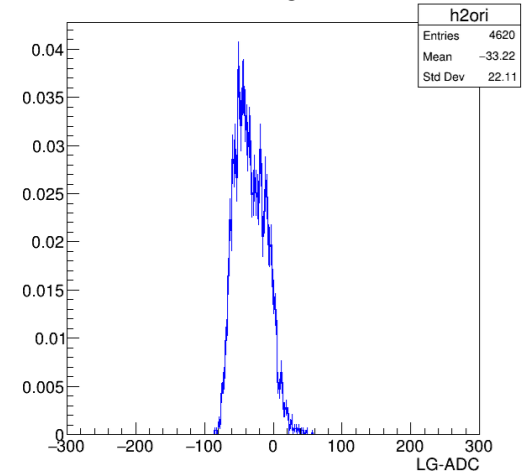
Beam Monitor Calibration



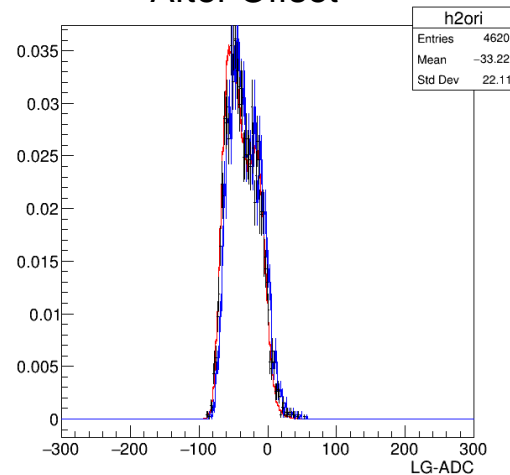
BM2. ch7 (ref.)



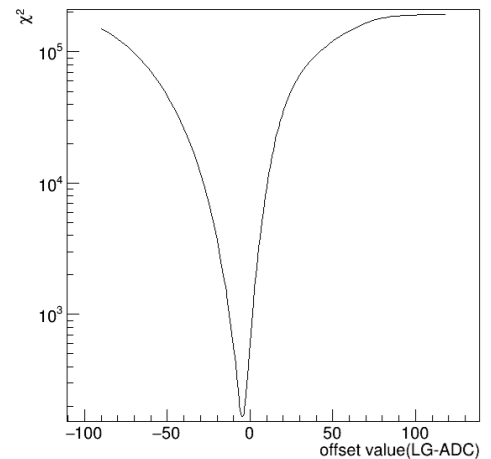
BM2. ch1



After Offset



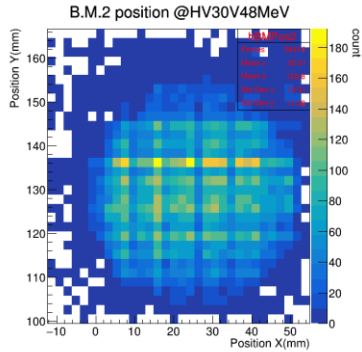
Offset



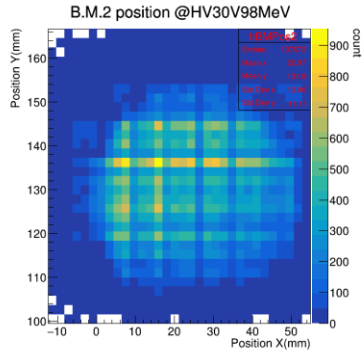
ADC distribution of all channels are offset to alignment with the central channel (ex, ch7 of BM2).

Beam Profile of BM2 (1st Layer)

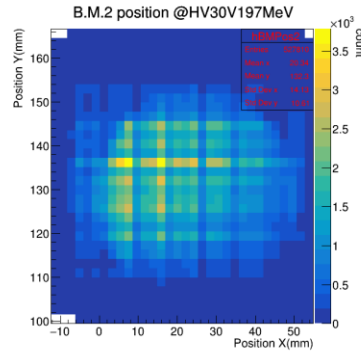
98 MeV



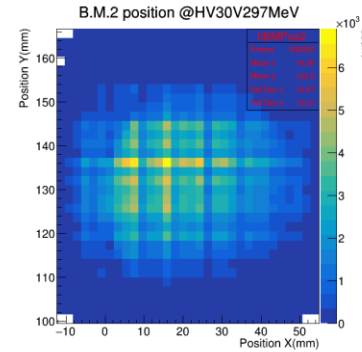
197 MeV



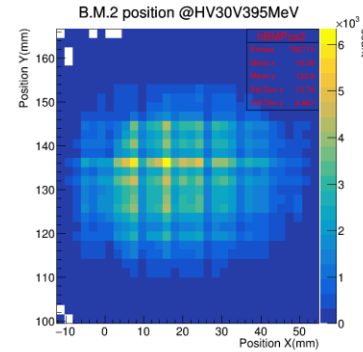
297 MeV



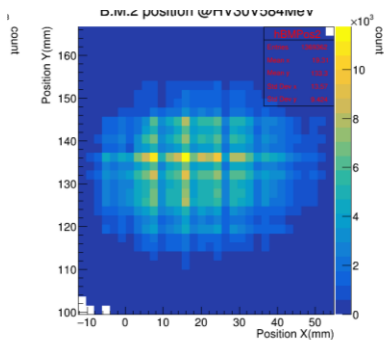
395 MeV



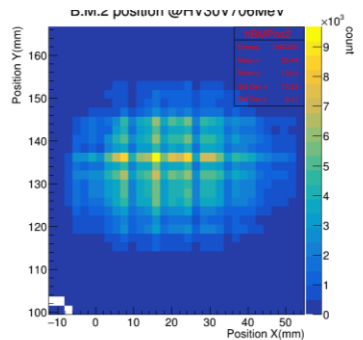
492 MeV



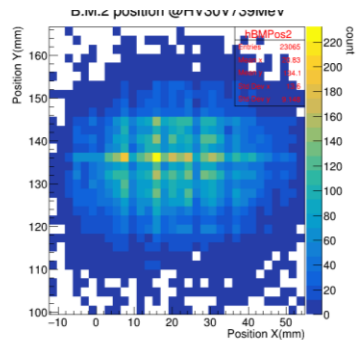
584 MeV



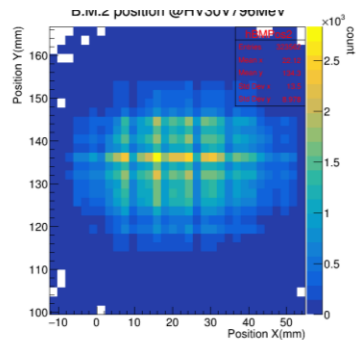
708 MeV



739 MeV



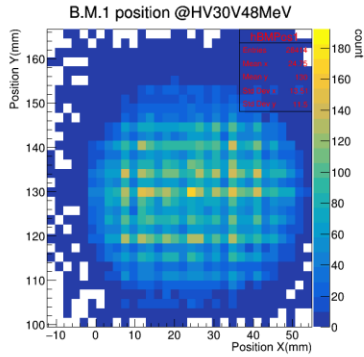
796 MeV



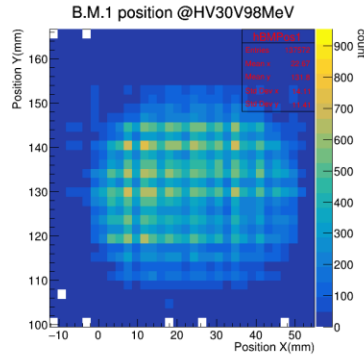
- How to draw beam profile?
 - 0) ADC offset calibration channel by channel.
 - 1) Find the x/y position by ADC weighted method.
 - 2) Beam position = (x_weighted, y_weighted)

Beam Profile of BM1 (2nd Layer)

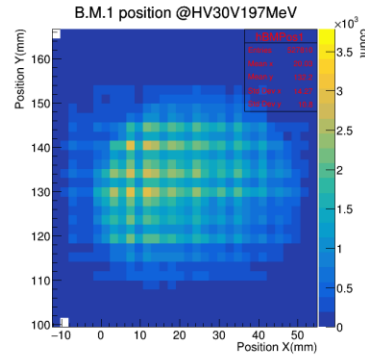
98 MeV



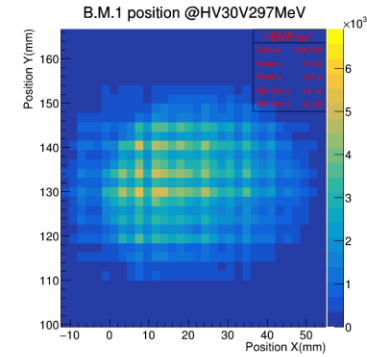
197 MeV



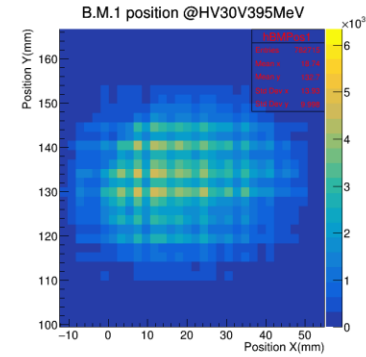
297 MeV



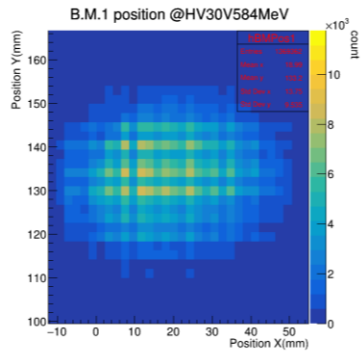
395 MeV



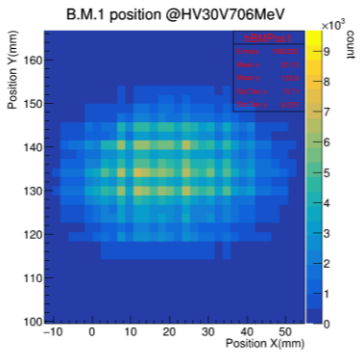
492 MeV



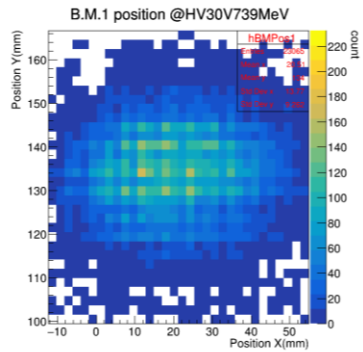
584MeV



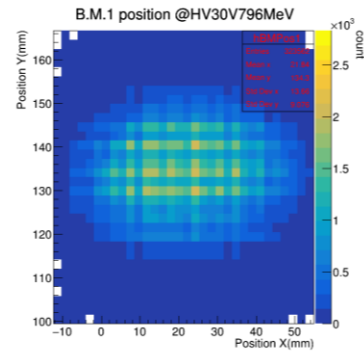
708 MeV



739 MeV

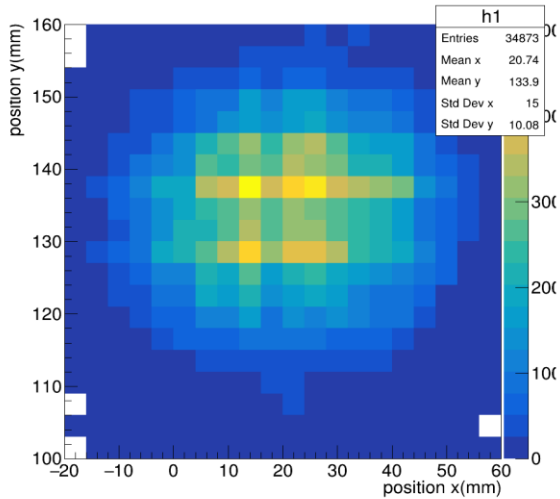


796 MeV

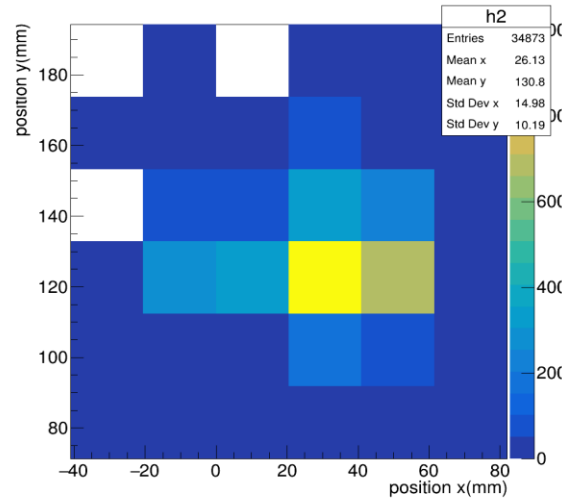


Beam Tracks Projected on PbWO4

Track extrapolation

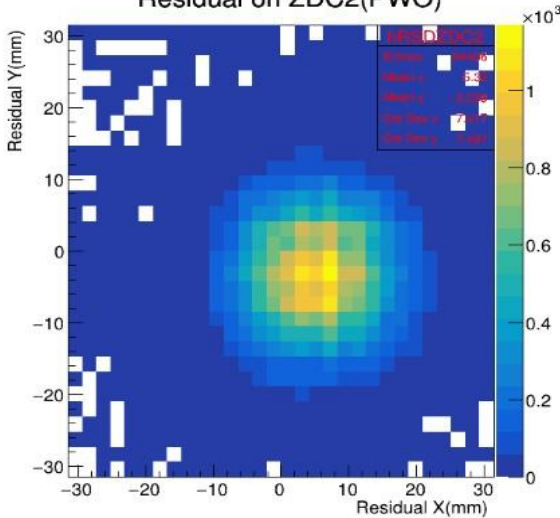


Fired crystal (ADC weighted)

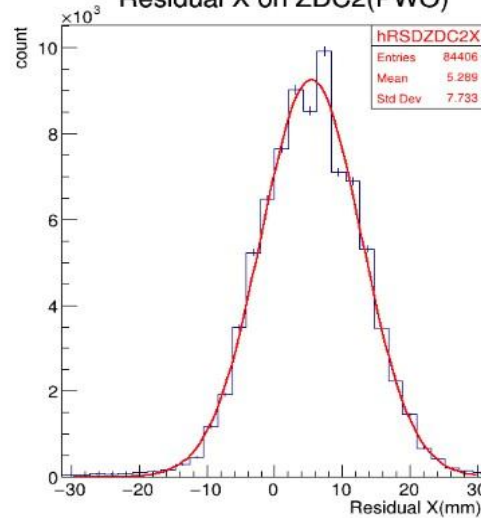


- **Misalignment**
 $X = +5.2\text{mm}$
 $Y = -3.2\text{mm}$
- **Position res. of PbWO4**
(1 pixel = 20mm)
 $\rightarrow \sqrt{7*7 - 2*2} \sim 7\text{mm}$

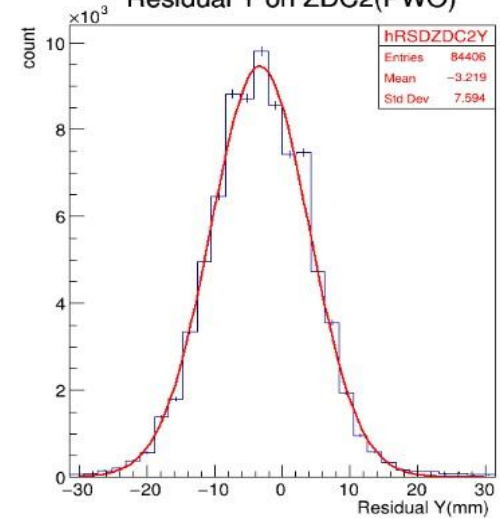
Residual on ZDC2(PWO)



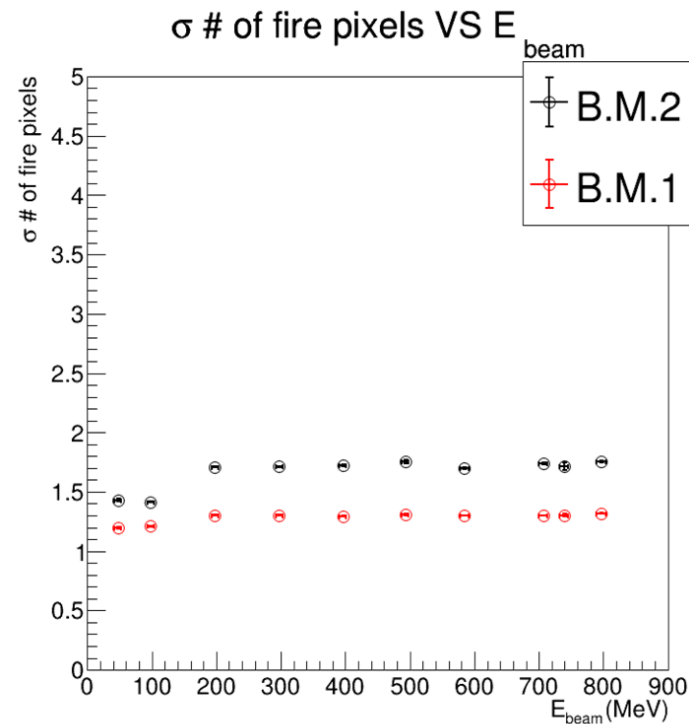
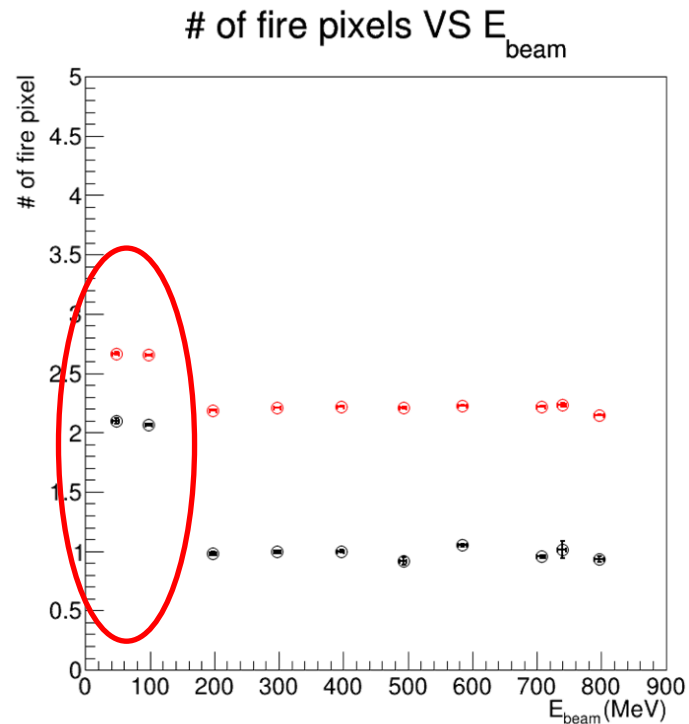
Residual X on ZDC2(PWO)



Residual Y on ZDC2(PWO)

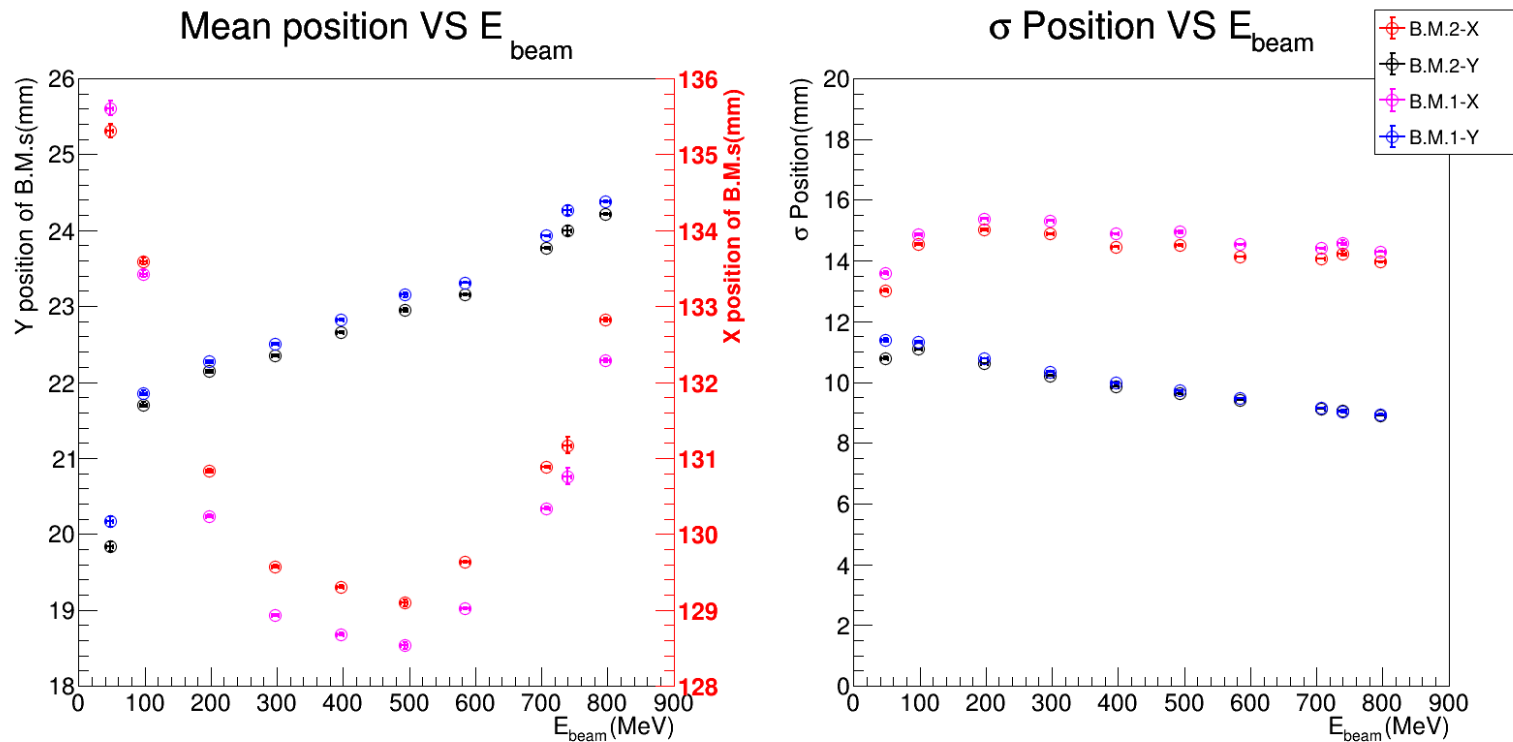


Beam Properties (1) : Hit Multiplicity



- In average, less than 2 strips fired per beam.
- More energy in BM when $E_{\text{beam}} < 200 \text{ MeV}$.

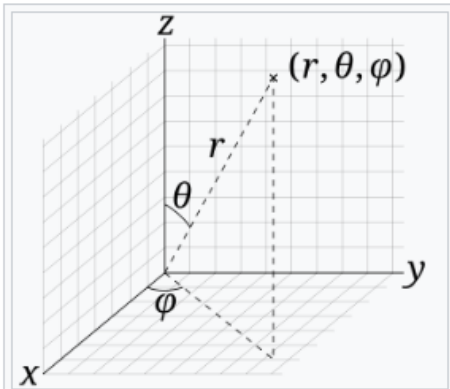
Beam Properties (2) : Beam Width



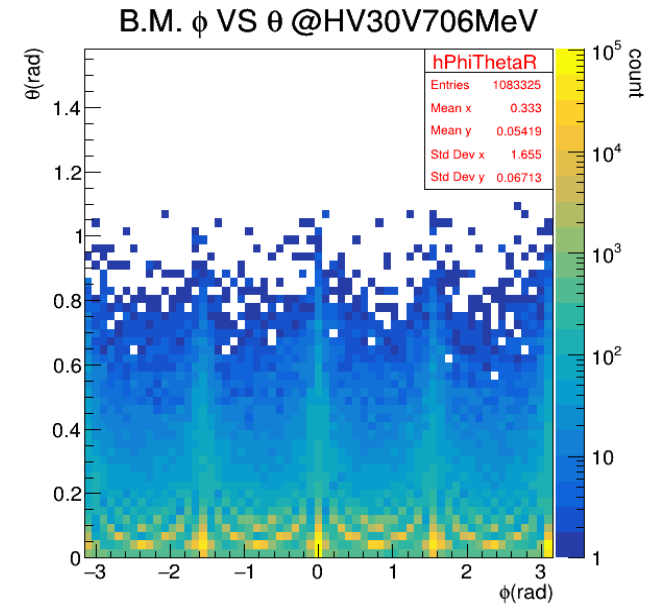
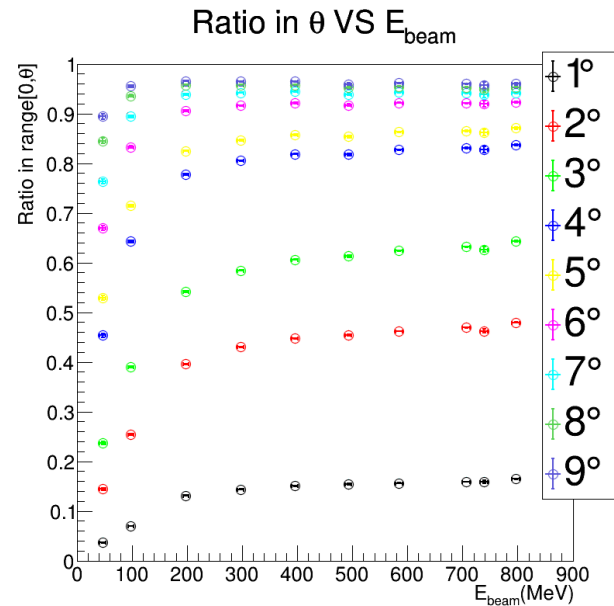
- Beam center constantly shift.
- Wider spread in X-direction.

Beam Properties (3) : Beam Angle

706 MeV

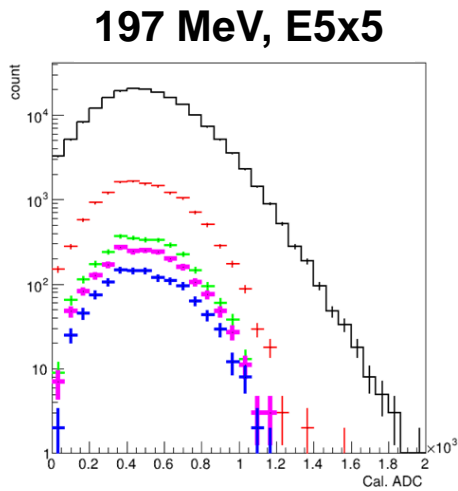


The physics convention.
Spherical coordinates (r, θ, ϕ) as commonly used: (ISO 80000-2:2019): radial distance r (slant distance to origin), polar angle θ (theta) (angle with respect to positive polar axis), and azimuthal angle ϕ (phi) (angle of rotation from the initial meridian plane).
This is the convention followed in this article.

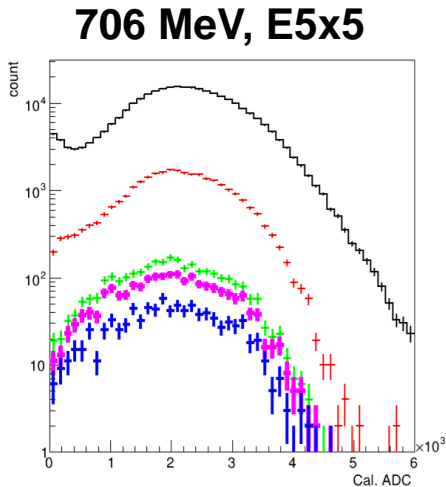
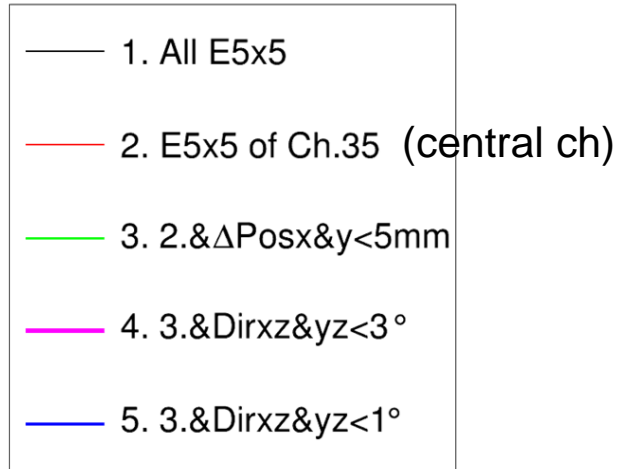
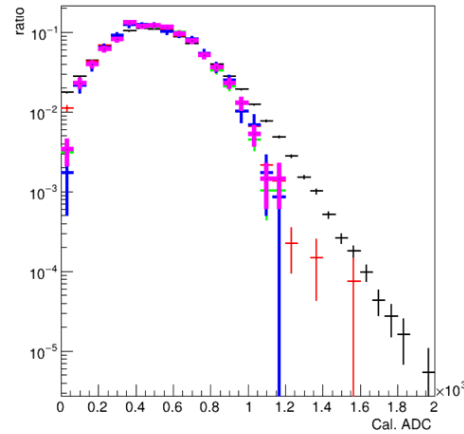


- Spherical coordinate : XY-surface is defined as the BM surface.
- $\theta = 0$ degree = perpendicular to the surface of BM/ZDC.
- Only $\sim 10\%$ beam shoots straightly.
- Most of the beam $\theta < 9$ degree.

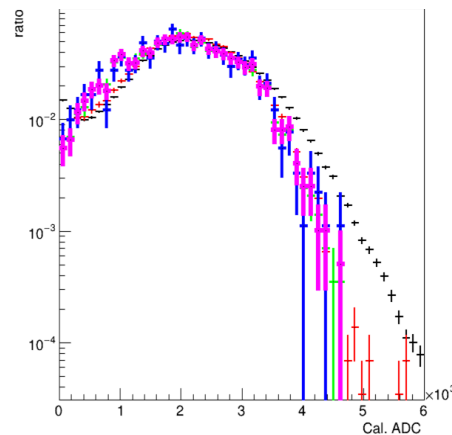
Energy resolution after Cuts (1) : LYSO + APD



197 MeV, E5x5 (Norm)



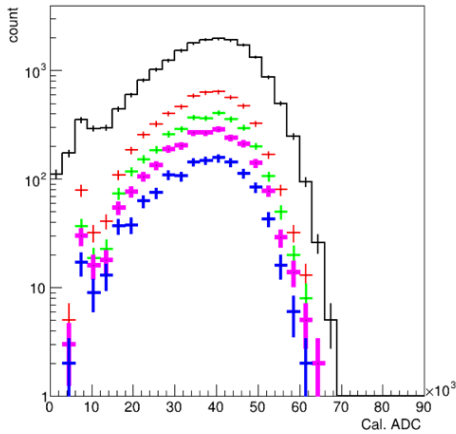
706 MeV, E5x5 (Norm)



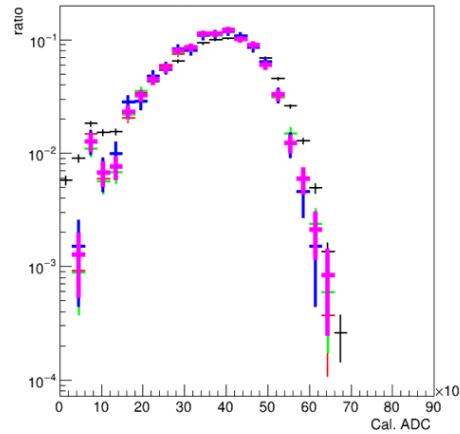
No obvious improvement after cuts/selections.

Energy resolution after Cuts (2) : PbWO4 + SiPM

197 MeV, E5x5

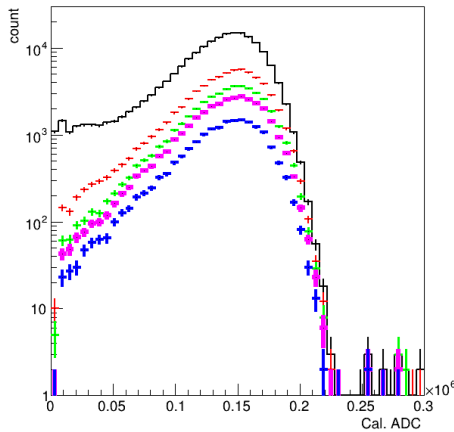


197 MeV, E5x5 (Norm)

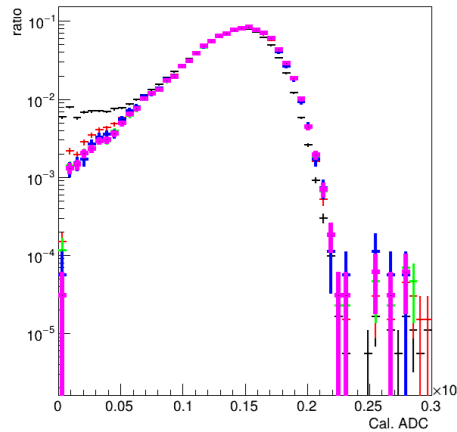


- 1. All E5x5
- 2. E5x5 of Ch.34 v 40 (central ch)
- 3. 2.& $\Delta\text{Posx}\&y < 5\text{mm}$
- 4. 3.& $\text{Dirxz}\&yz < 3^\circ$
- 5. 3.& $\text{Dirxz}\&yz < 1^\circ$

706 MeV, E5x5



706 MeV, E5x5 (Norm)



No obvious improvement after cuts/selections.

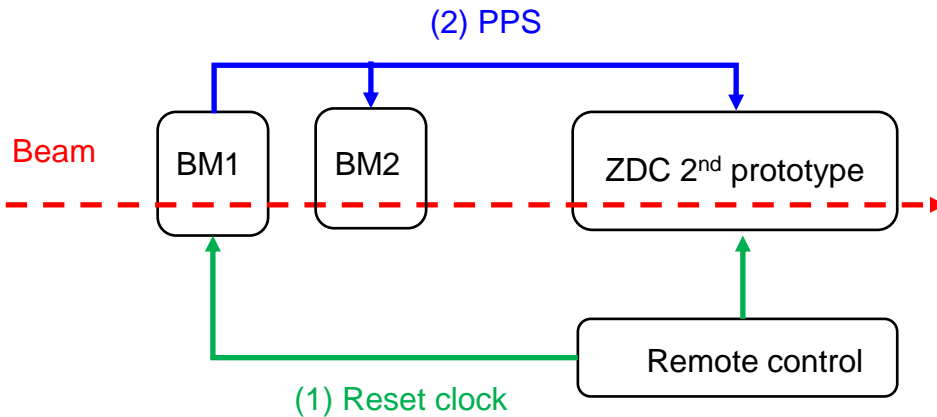
Summary and To Do

- We calibrate beam monitor system and hopefully to improve the energy resolution w/ better beam selection. Unfortunately, the results stay the same : LYSO + APD ~ 40% and PbWO4 + SiPM ~ 15%.
- The threshold setting (hardware-wise) was probably too high during the test beam.
- Next we will try to do energy regression to improve the performance. MC sample is still under preparation. Study of threshold cut is necessary.



Back up

Tracking



- All detectors, including beam monitors and the ZDC ECal prototype, operate in **self-triggered mode**.
 - **Trigger and event matching** are performed offline using **PPS signals**.
- 1) Remote control set commands to reset the clocks : course time (count PPS signals, 20Hz) and fine time (0.24us).
 - 2) The **PPS signal** is distributed from **beam monitor #1** to all other detectors.
 - 3) **Timing matching**: Events are synchronized by ensuring the **same coarse time** and a **fine time difference within 0.24 μ s**, accounting for cable delays.
 - 4) **Position matching** : Not yet implemented, but verified through plots, confirming that tracking appears correct.

