Update for Discrete Readout & MIT Prototype Comparison December Testbeam Analysis

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ePIC Collaboration Calib Cross Cutting WG

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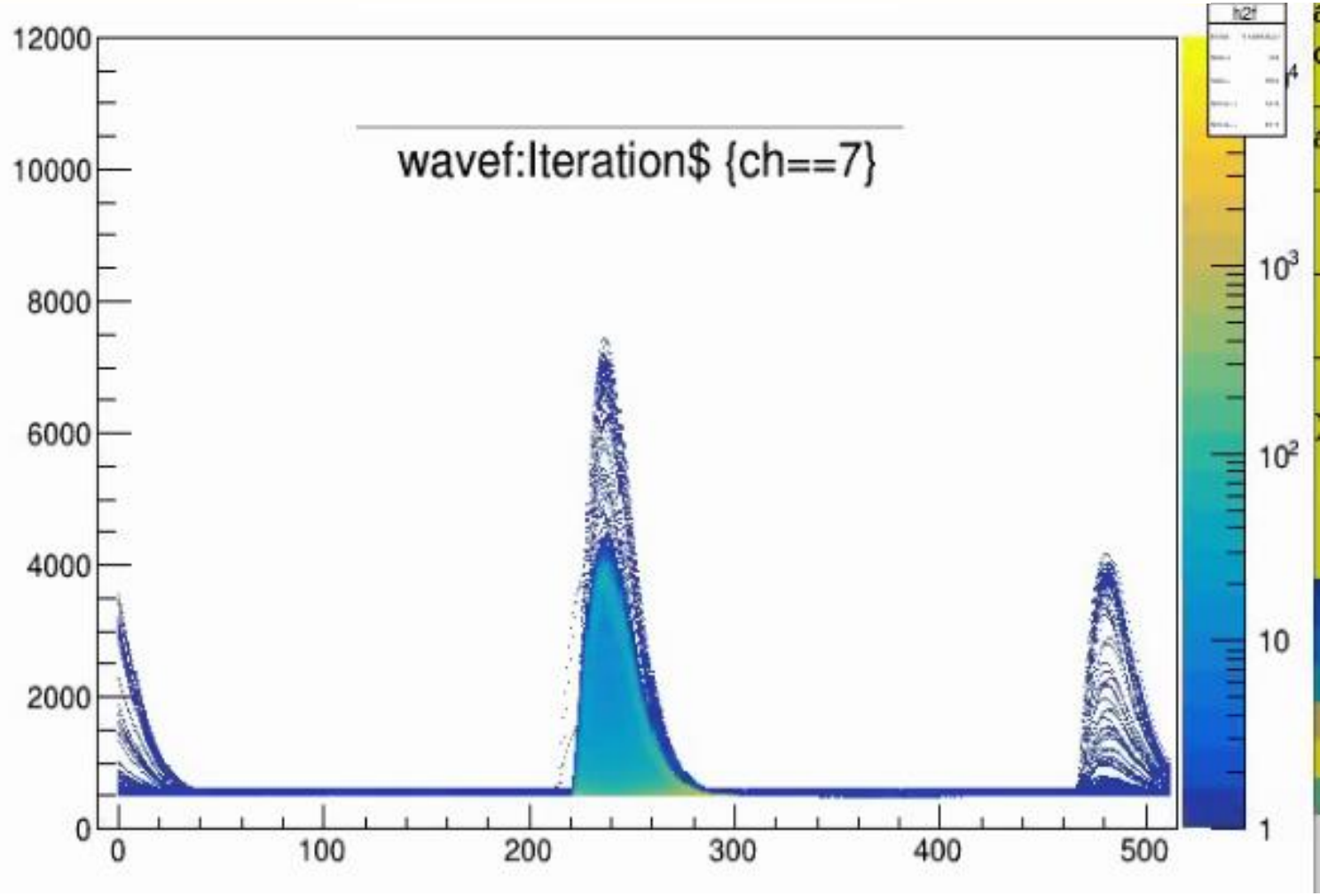
Testbeam December 2025

- Testbeam DESY December 8-22 2025 -- MIT Prototype Dec ~9 -- Discrete readout/Orsay prototype Dec 10-12
  - Two Scintillator trigger → Two 16-Ch 250 MHz Caen V1725s Waveform digitizers / core software provided by MIT – **Milner/Hasell/Cline**
  - Readout by same
  - DESY T24 TB area : 1-5 GeV electron energies

- Goals (Compared to February/March 2025 visits):
- 1) Further develop CaloROC readout (see CaloROC workshop)
- - 2) DISCRETE Readout : try stabilization of bias voltage of individual channels/channel current monitoring, understand backgrounds better
  - (Get resolution measurements)
- 3) MIT Prototype : Get Better Measurements for understanding instrinsic beam resolutions and backgrounds

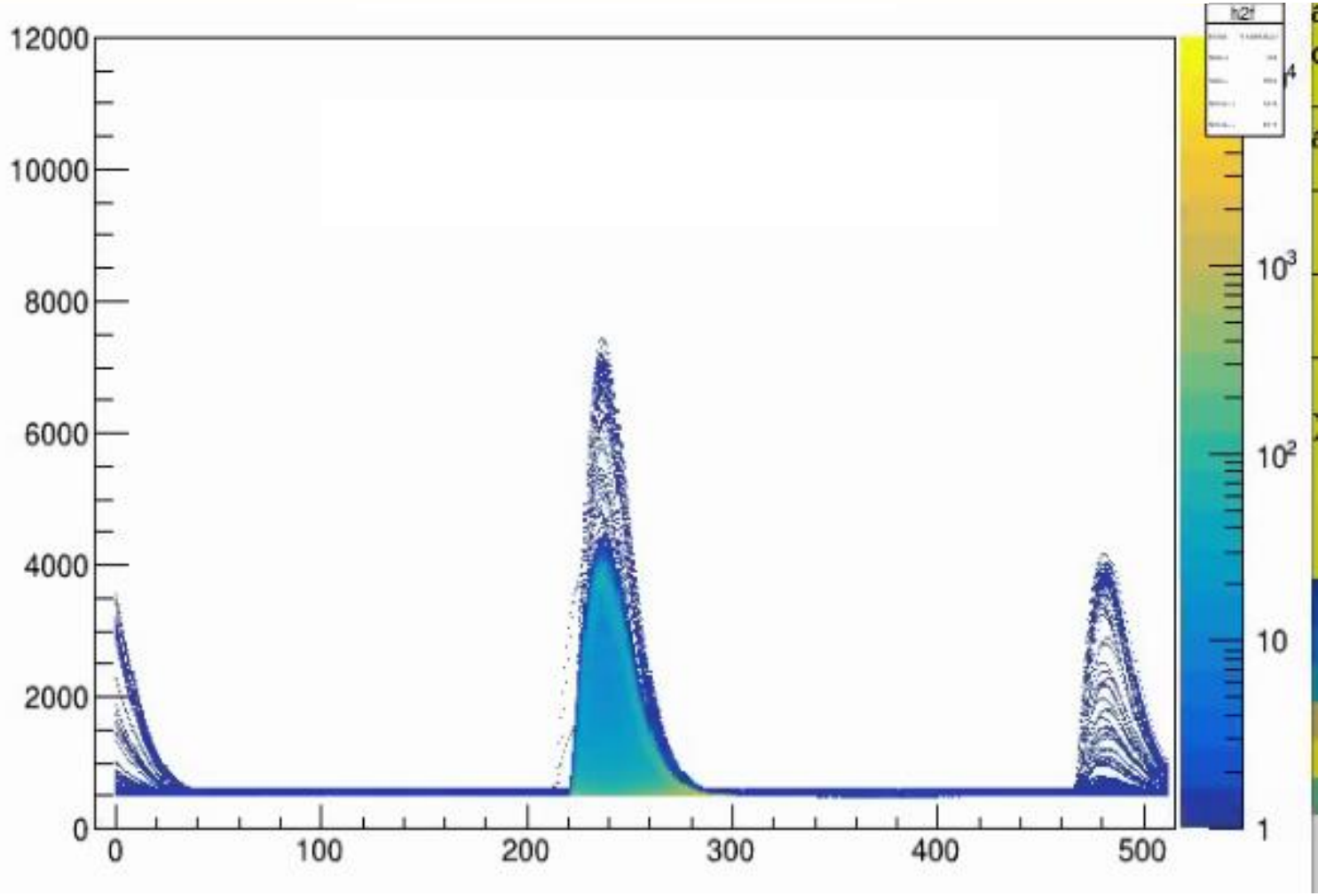
Caen v1725 Wave forms

- Same as last year
- ~full dynamic range 2^14 = 16K, new baseline set at ~500, but is a rough setting and changes for each channel by +- 100's ADC U's
- ~250 pre-samples (Caen setting)
- Max 1024 samples taken (750 signal + post)
- This analysis only looked at first 512 samples.
- Signal around sample # = 230



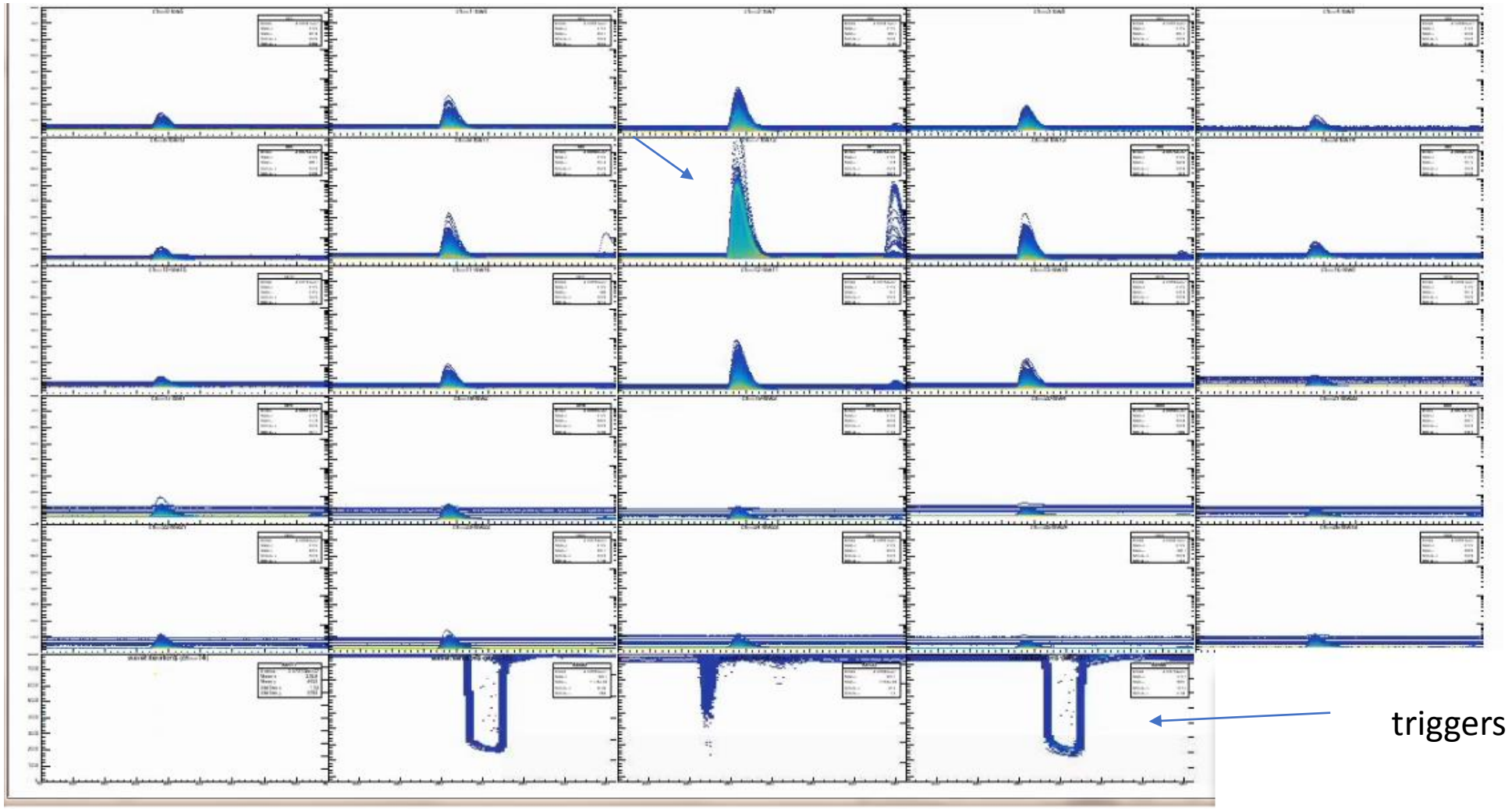
Wave forms --> Amplitudes

- For December data, slightly changed the pedestal subtraction and using integration of the waveforms rather than peak max
- First thing I did was compare directly reanalysis of old data vs new to see if there was improvement
  - Generally resolution was improved
- Preliminarily we saw less noise in most channels. (to be confirmed)



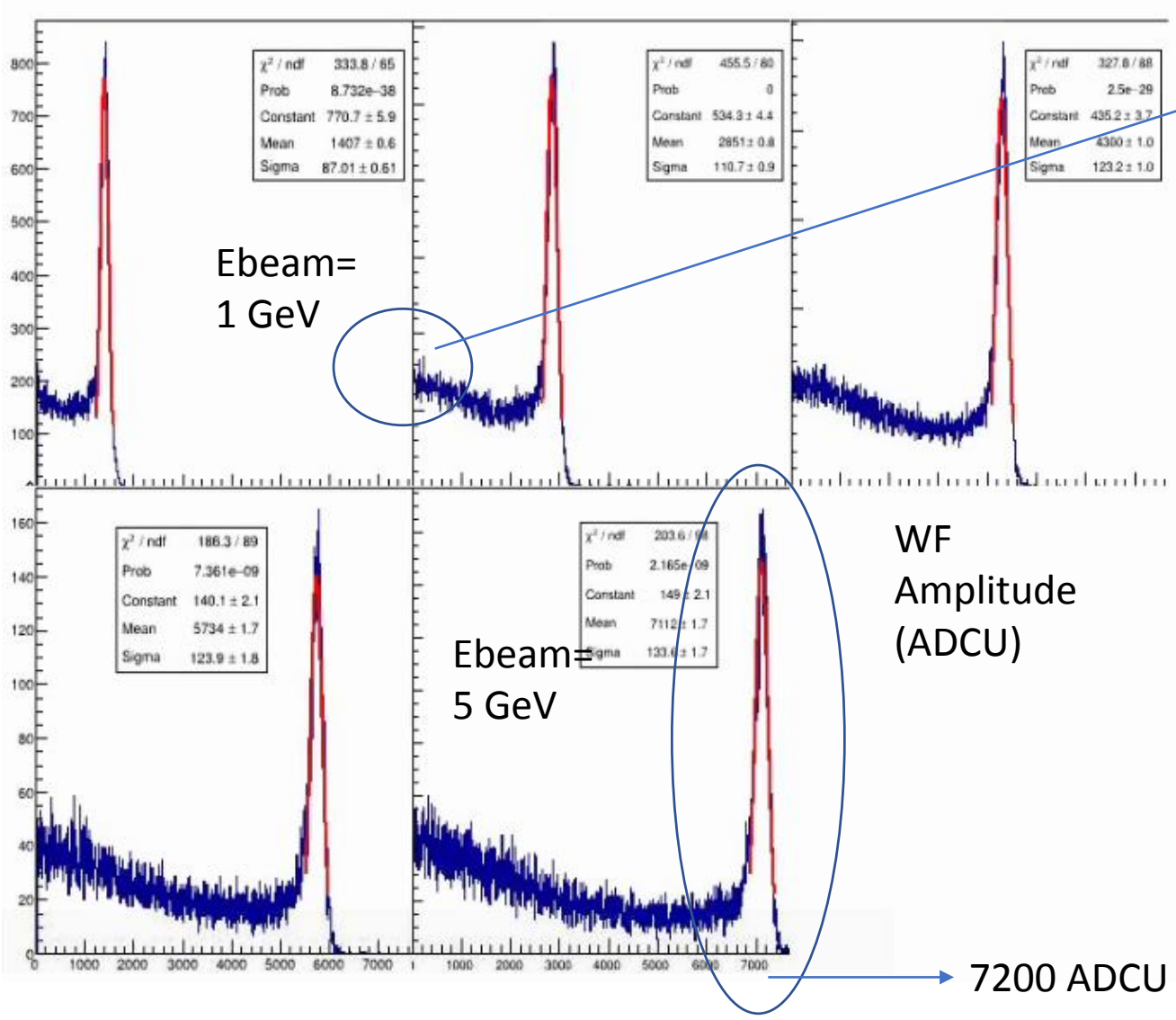
All Channels

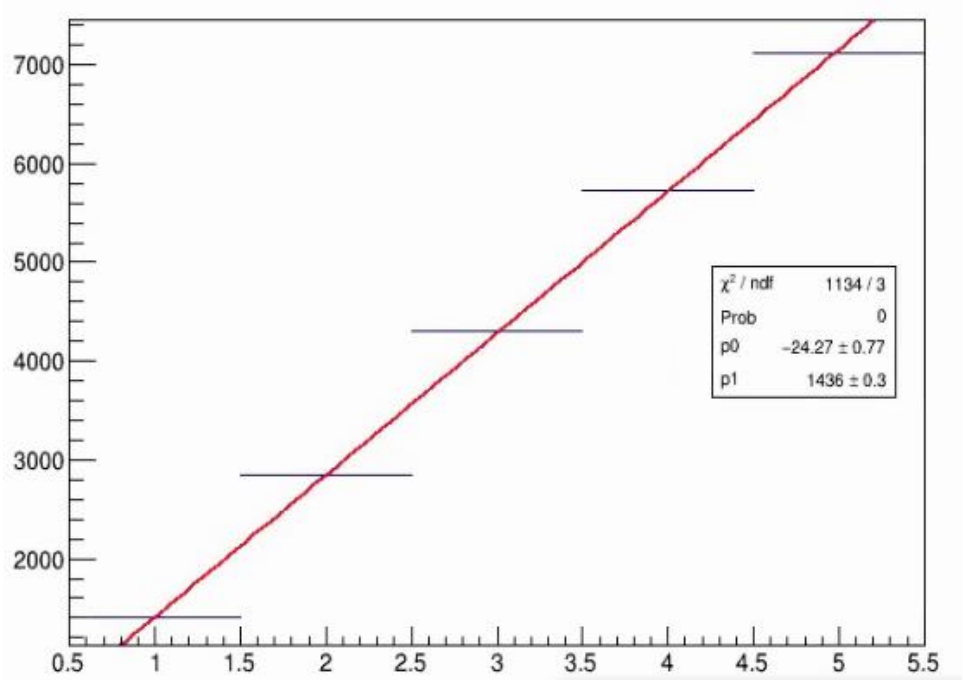
- Example file from ~4 Gev center crystal “12



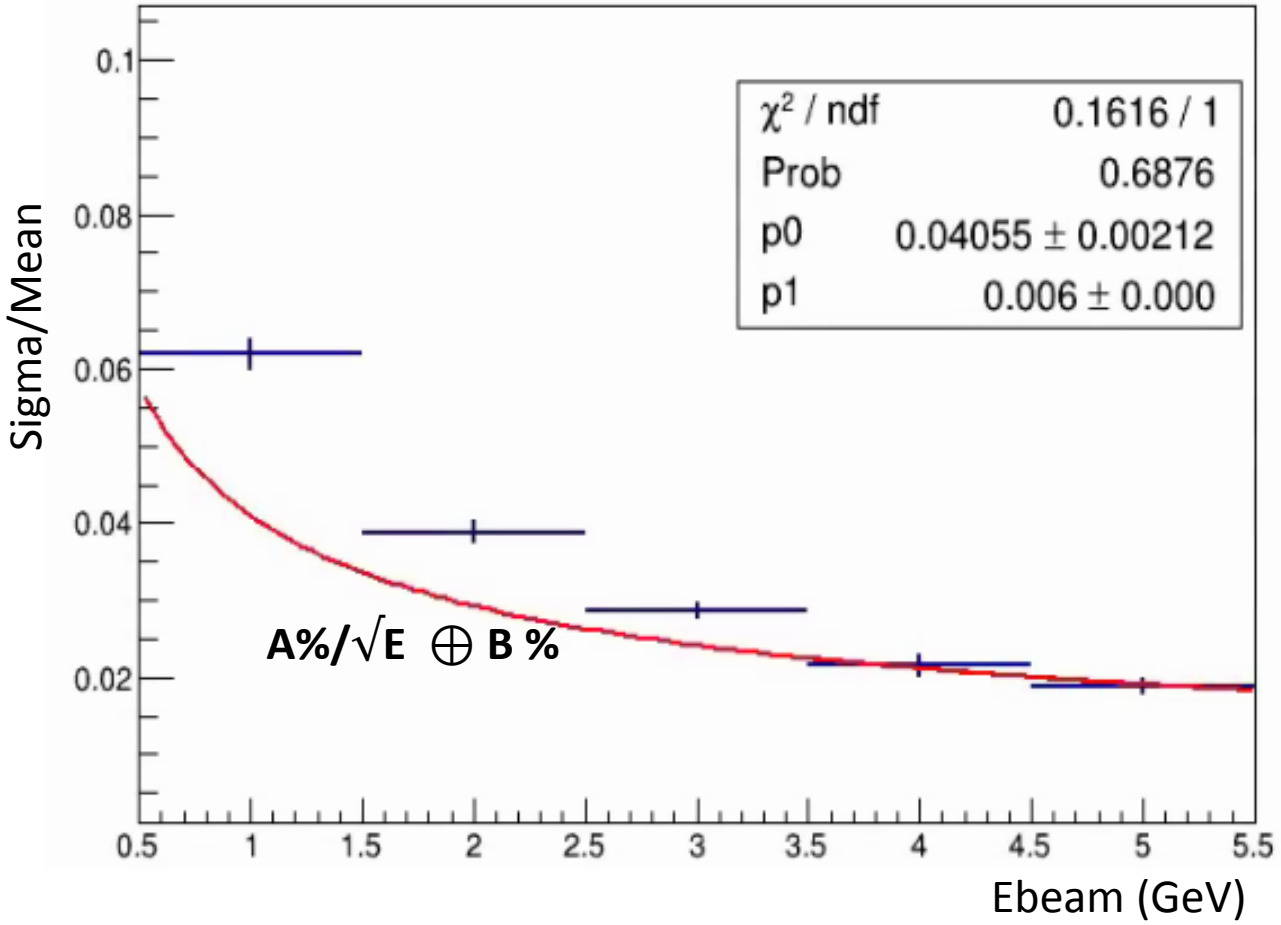
Feb 2025 : Fits / Mean/Calibration –BACKGROUND!

Mysterious background / low energy tail
Eventually was subtracted, but still uncertainty on residual effects





Feb 2025: Full 5x5 Crystal Resolution (Wavefm Max method)



Reso 1GeV :0.0619
Reso 2GeV :0.0388
Reso 3GeV :0.0286
Reso 4GeV :0.0216
Reso 5GeV :0.0188

All energies: much smaller spread than 157 MeV constant DESY-quoted beam spread

less than 2% at 5 GeV

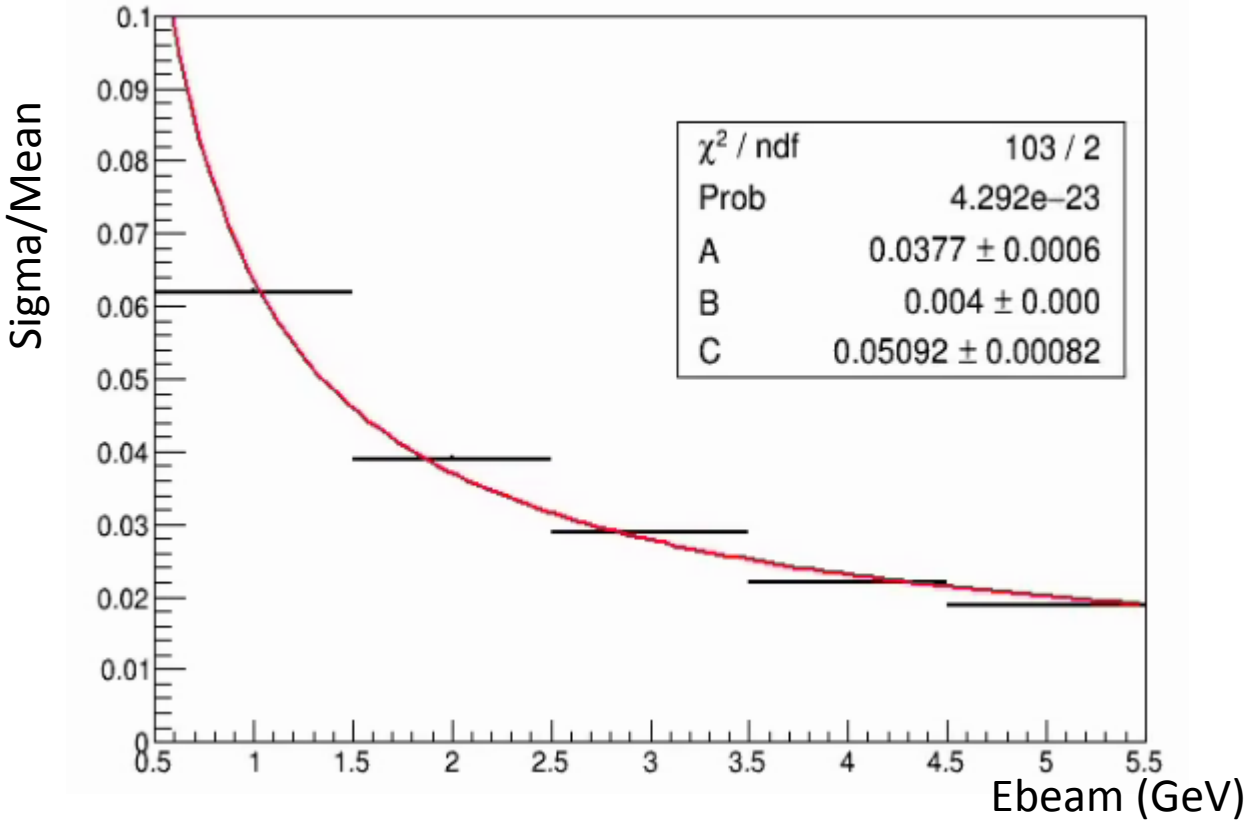
- Standard form does not fit well : **A%/√E ⊕ B %**

Best fit – (not shown)
greatly misses all but middle point

Fits alway want to force B term to be 0. So I always force it to be >= ~half percent

Feb 2025 Alt Fitting – ~4.5-5% / E Resolution Term Meaning

- We had to use an alt functional form for fitting including a 1/E term -- meaning? (Noise?)
  - Remember also though we don't know what the intrinsic BEAM energy spread is : could be as high as 157 MeV → 16 % at 1 GeV? , so it could be that



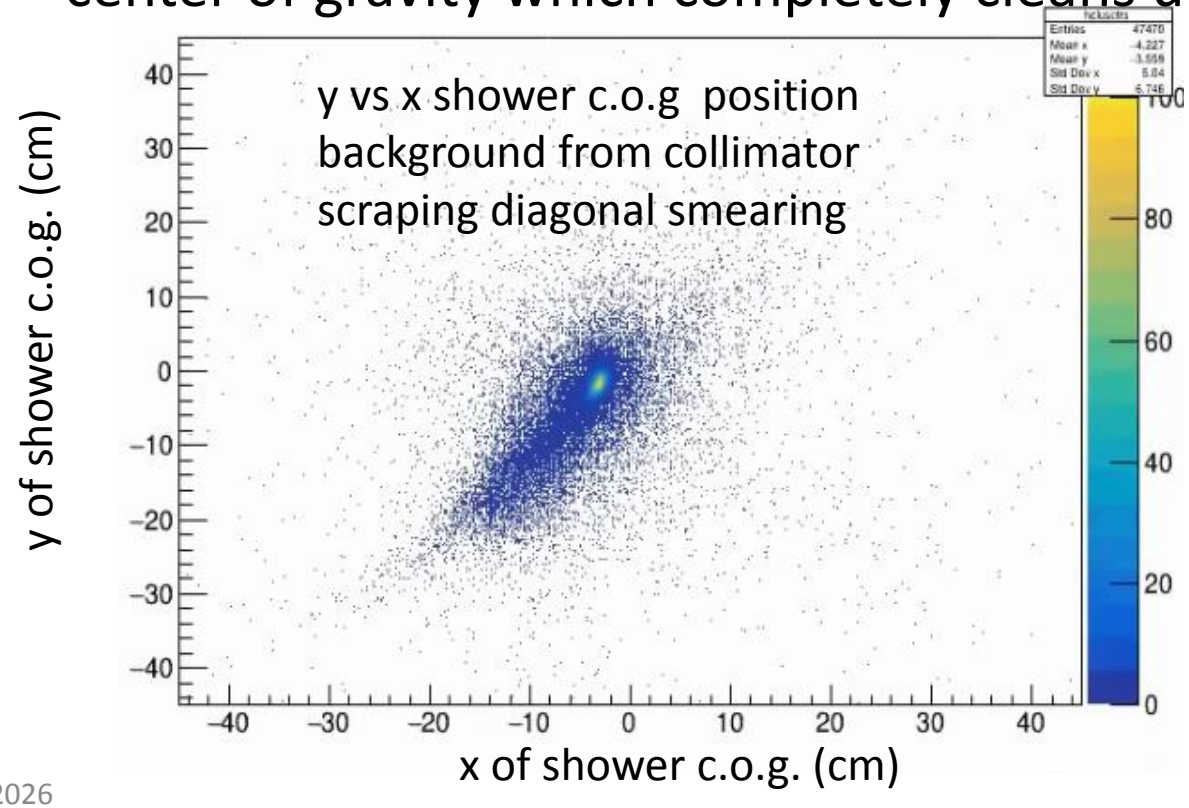
Alt Fit form

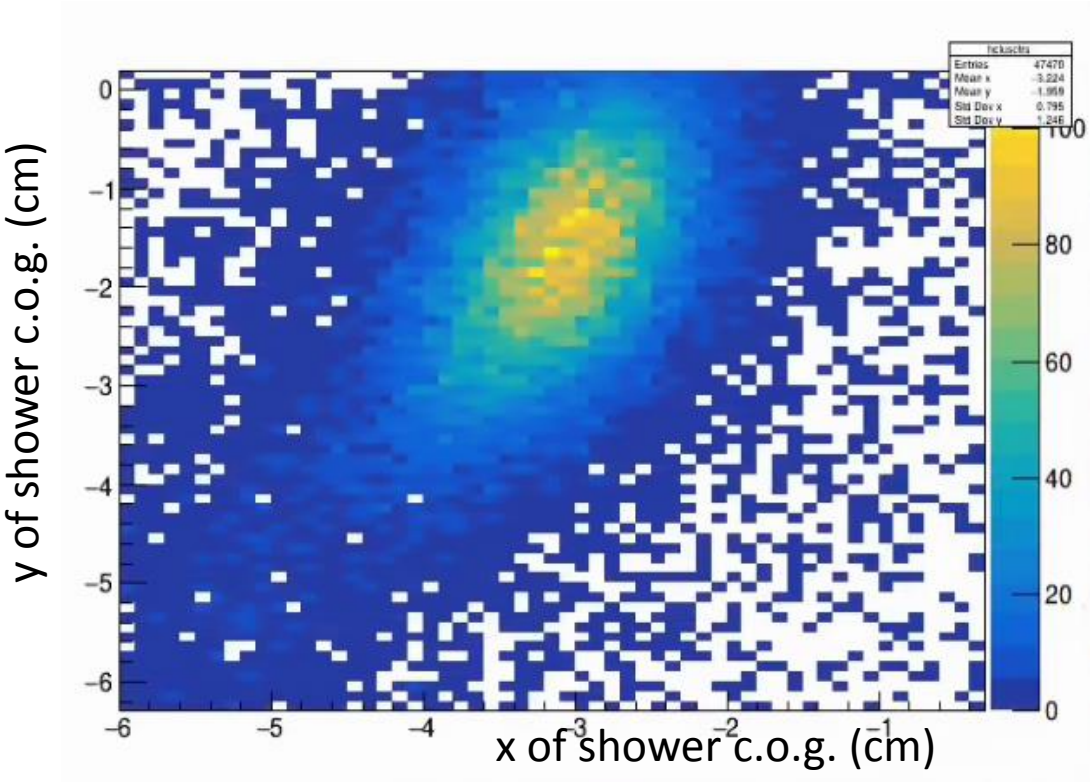
: **$A\%/\sqrt{E} \oplus B\% \oplus C\% / E$**

Many fits and methods were tried these were not FINAL results from February
3%/sqrt(E) + ~0-1%

Collimator discovery → Source of Bkg

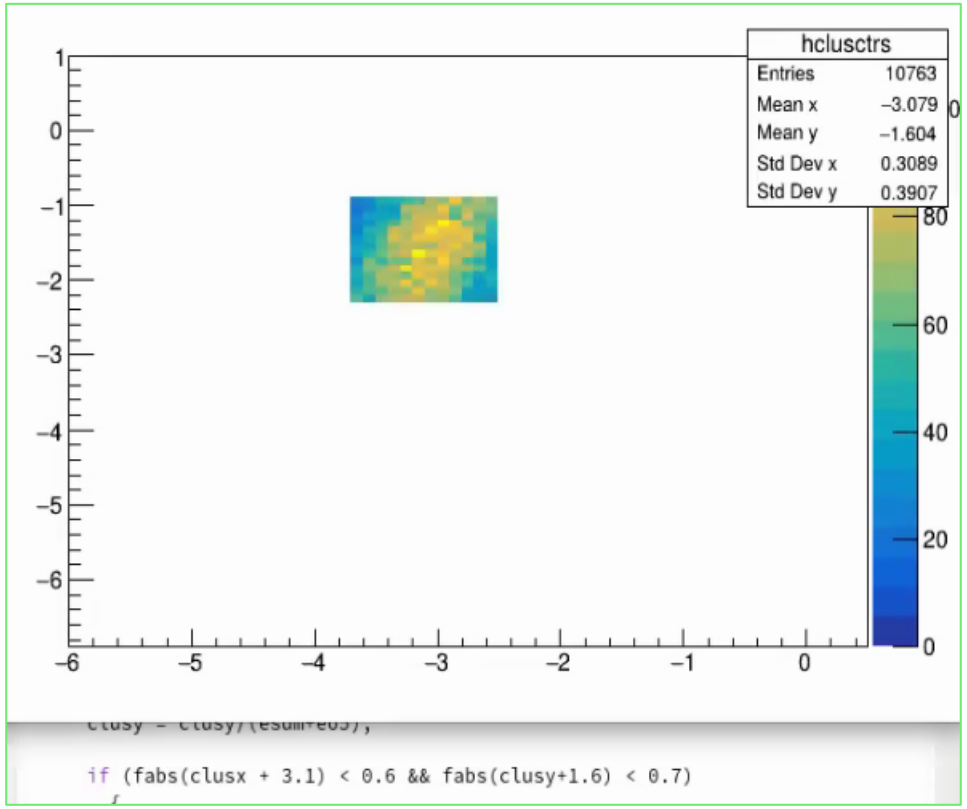
- After Gerard's suggestion to try 5x5 collimator and saw improvement, it was discovered background was caused by DESY/local collimators layout/combinations
- Fixed for Caloroc running based on first looks at our data
- Although our data was already taken we can make an offline cut based shower center of gravity which completely cleans up





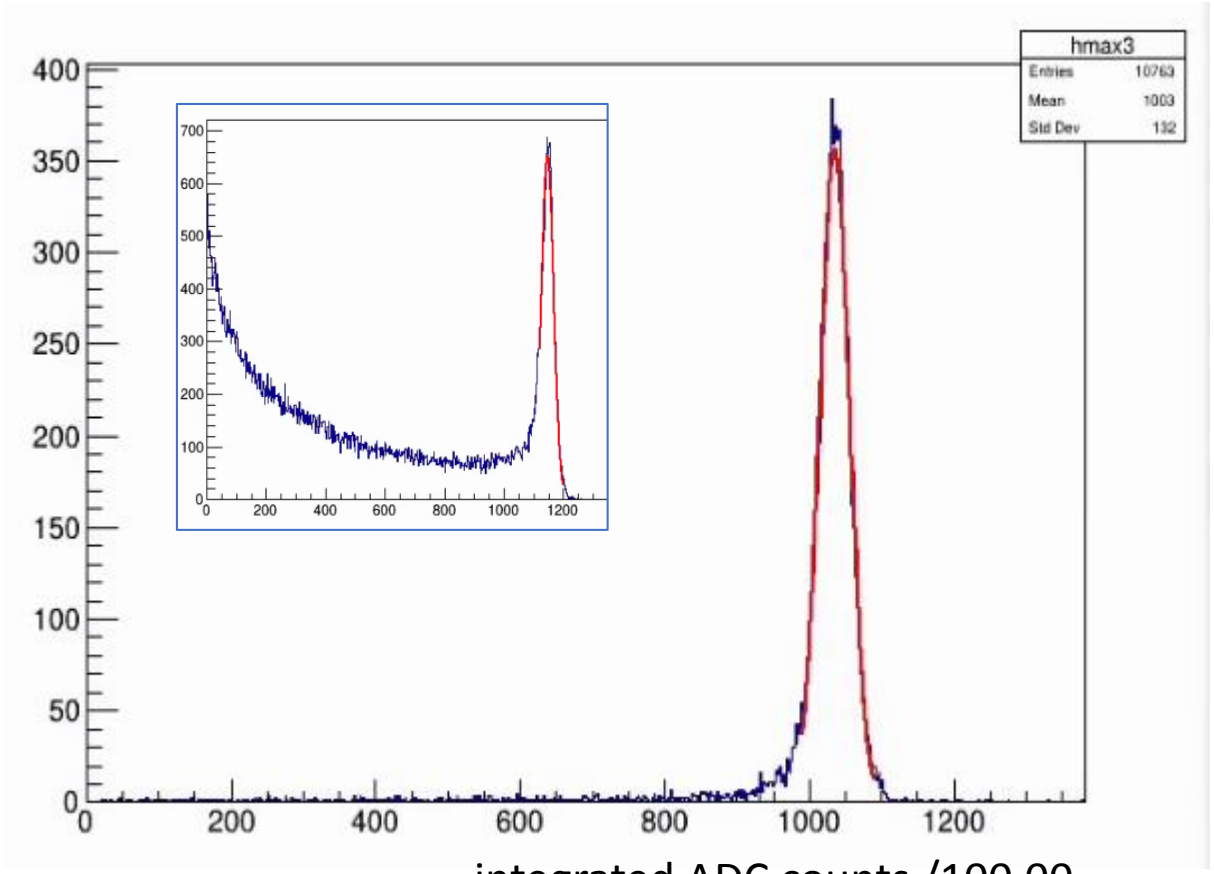
Cut used

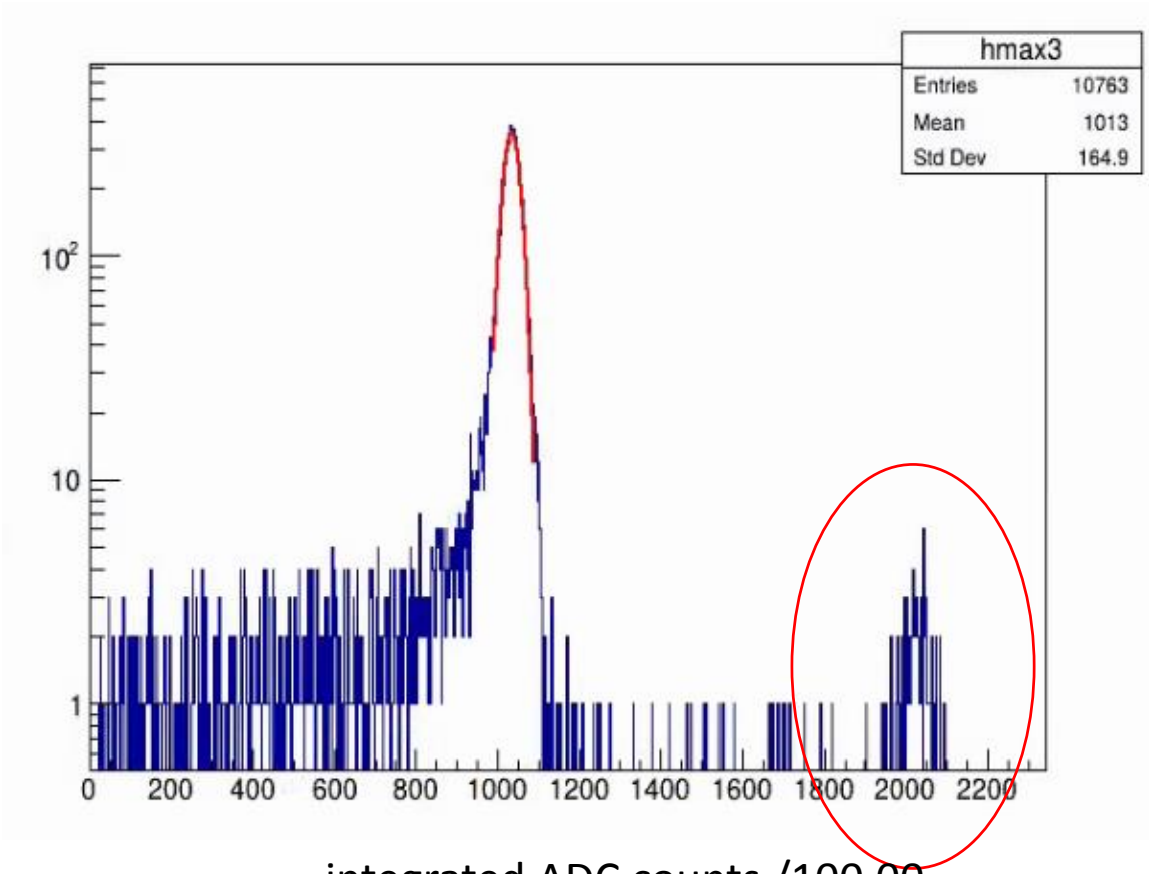
- For now just using simple rectangular box cut



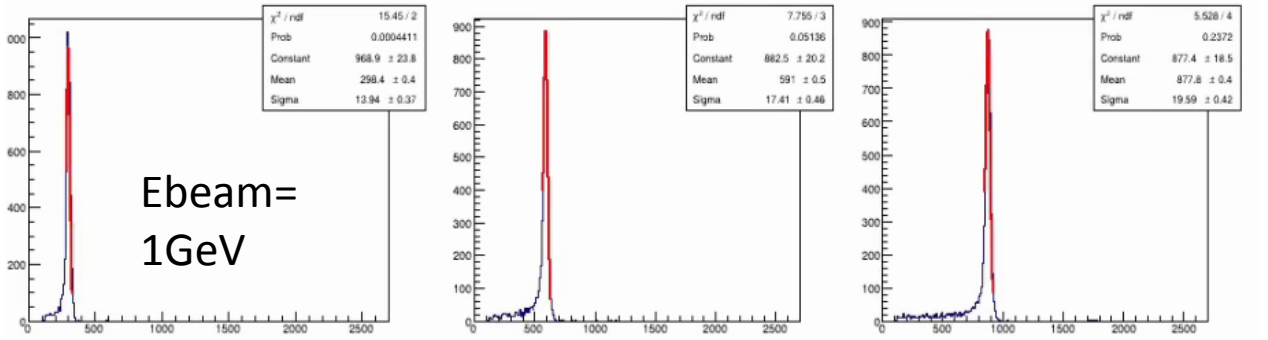
Cleaned up E=4GeV with cut

Second peak at 2 Ebeam (8 GeV) due to 2 electrons in bucket which happens at 1% rate! we didn't notice last year but the DESY documentation confirms it should be there.

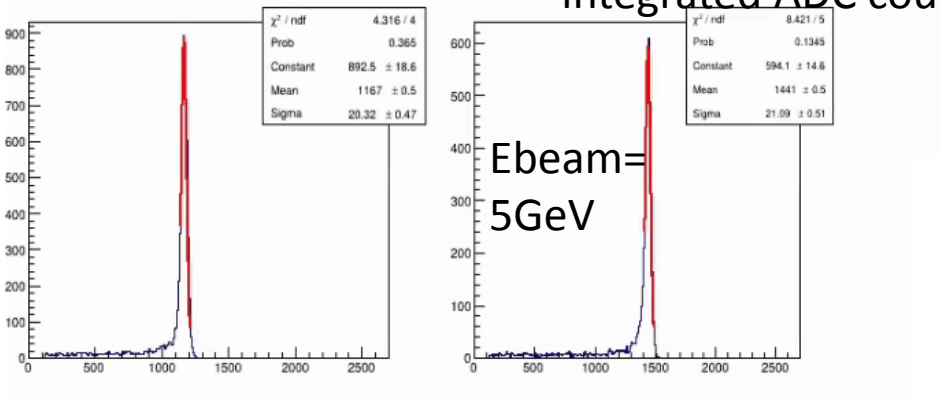


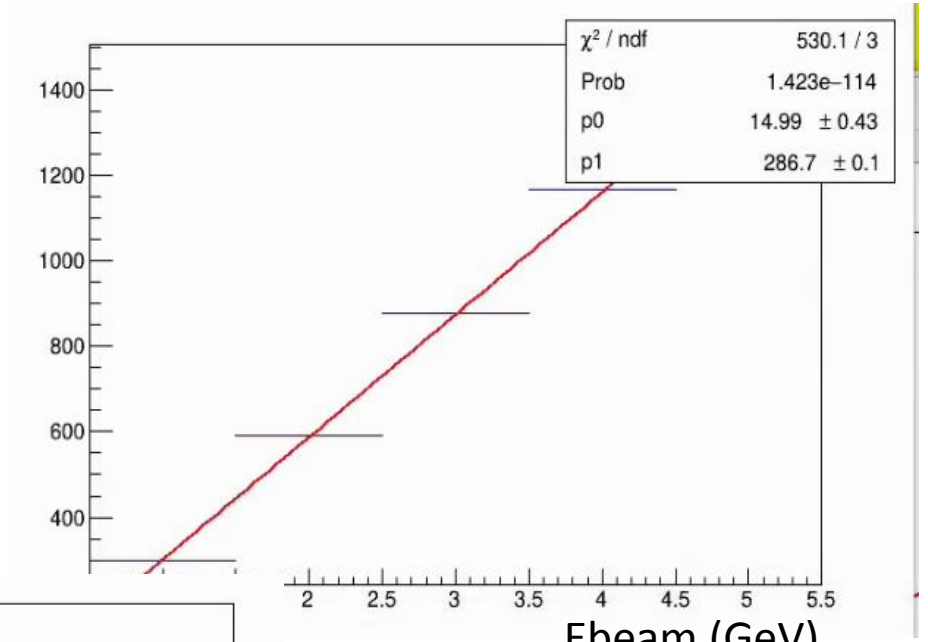


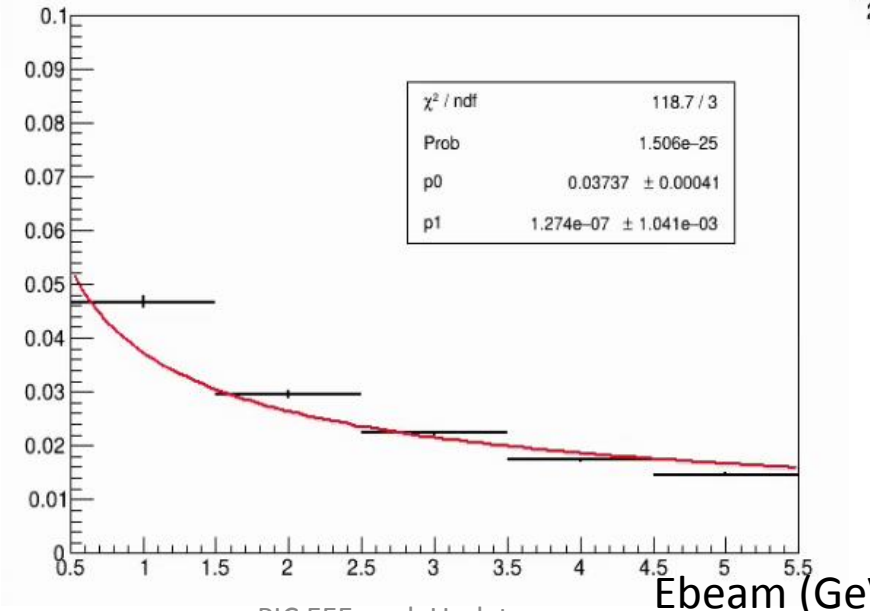
Orsay / siPM DISCRETE data, using only same Ebeam values as February



integrated ADC counts /100.00





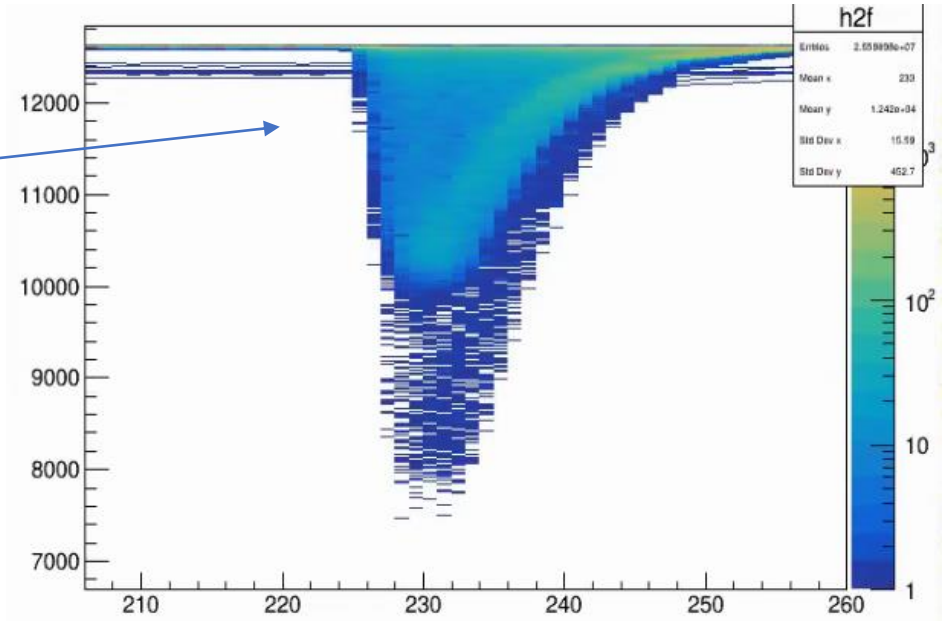


Reso 1GeV :0.0467
Reso 2GeV :0.0295
Reso 3GeV :0.0223
Reso 4GeV :0.0174
Reso 5GeV :0.0146

Resolutions slightly better (widths are ~0.5% lower)
~4.5% / E Extra Noise Term needed
(Several ways to fit only one shown)

MIT Prototype / data

- Joshua Crafts (CUA) & Doug Hassell sent me/us the MIT Prototype data
- I analyzed it to same point as discrete results shown last wk– results look good!
- Shown here are “all” Waveforms overlaid for one Ebeam = 1 GeV file
- MIT Prototype:
  - ~Identical PbWO Crystals
  - Cooled to -20 Celsius [in principle better than NPS)
  - PMT’s (Negative Pulses) – (NPS’s?)
  - + better “ACTIVE” bases than Feb ‘25
    - Performance normal – i.e. linear response etc.
    - As we will see, other than waveforms being negative, it’s hard to distinguish further extracted data from siPM + discrete readout--all checks so far look similar (albeit lightly checked)

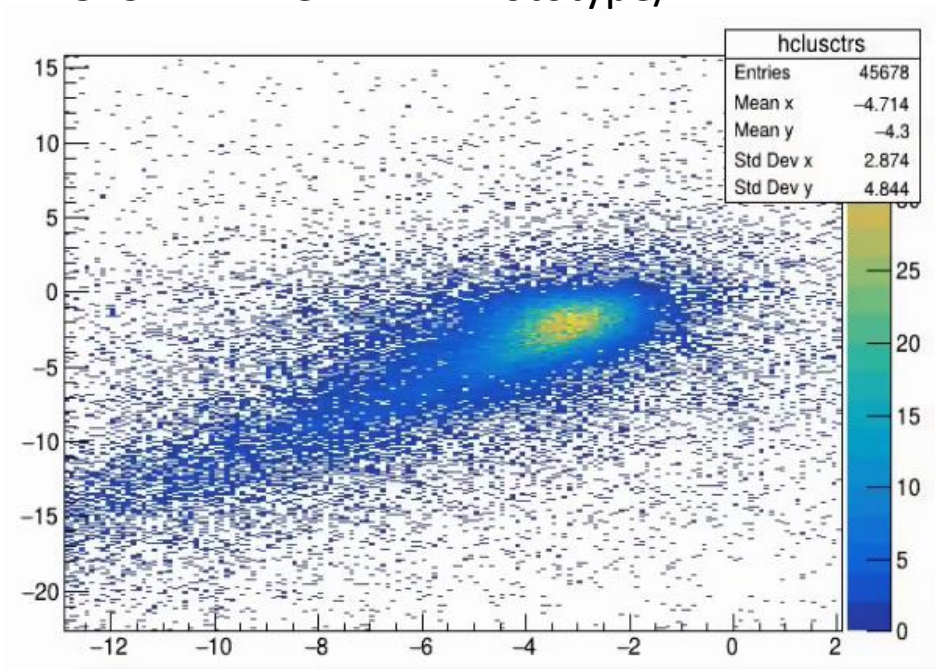


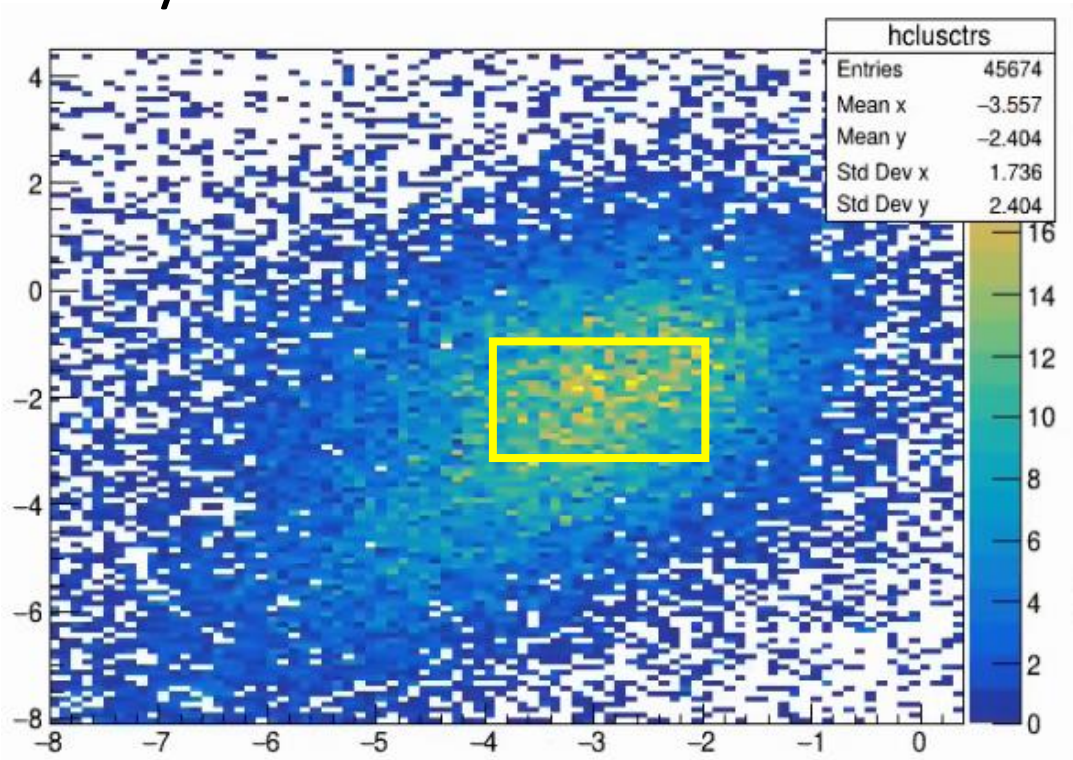
- Digitized by same Caen Modules we later used for siPM/Discrete
- Even waveform timing almost identical
- Used ~exactly the same pedestal subtraction scheme (ped region/integration region) but **ped minus sample** rather than **sample minus ped**.

Same “cluster” E c.o.g. trick to cut collimator low E tail bkg

- Geometric location of shower c.o.g. avg center almost the same different in x by only ~0.5 cm (Q crystal size /spacing ~same)
- Width’s are possibly wider
- Used very similar rectangle box cut to siPM/discrete ana

PLOTS ARE FROM MIT Prototype/PMT



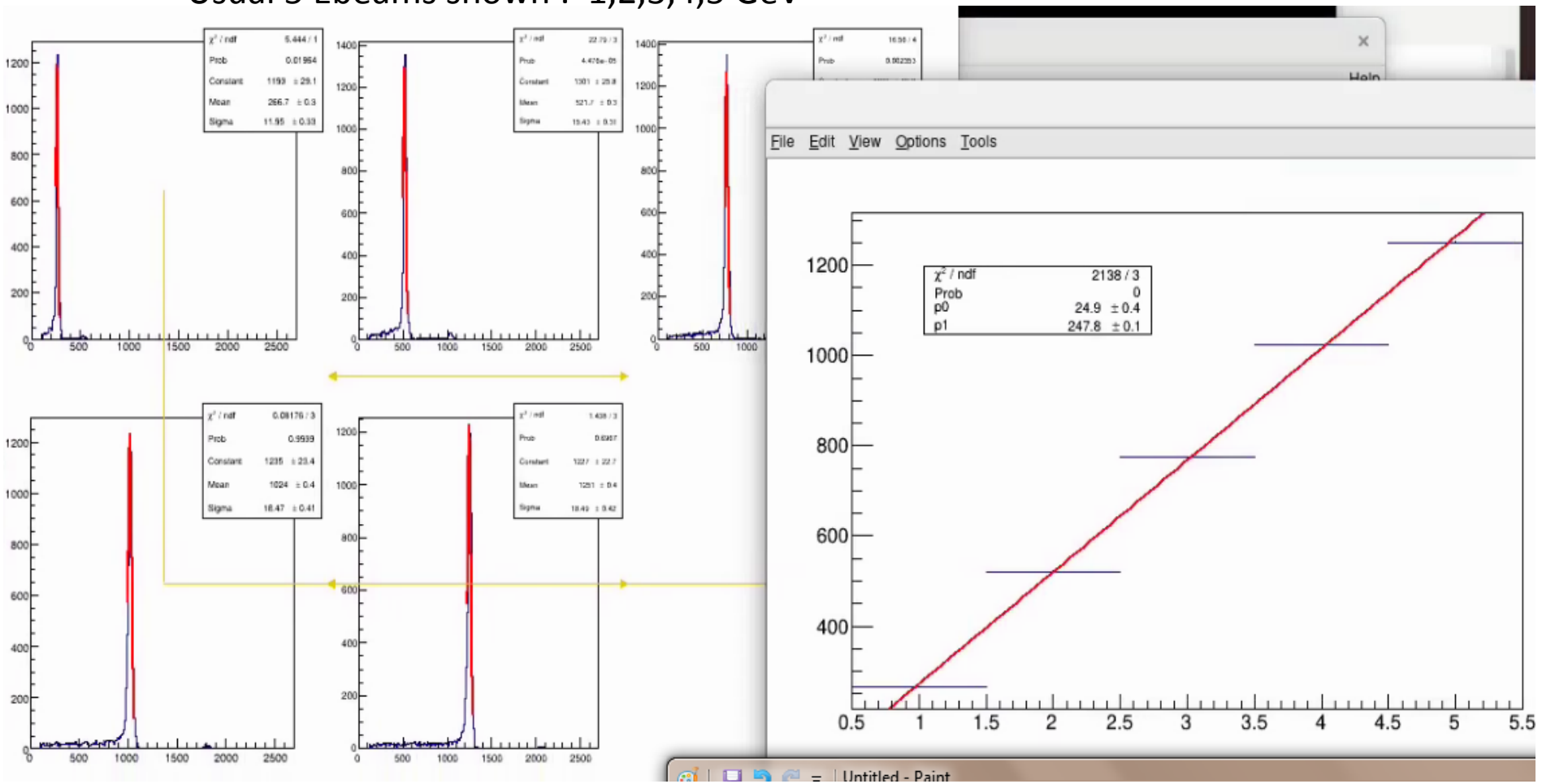


zoomed

MIT Results 1 : Active bases – linearity good

Shown are pulse amplitude distrib's for the full MIT prototype 5x5 sum

Usual 5 Ebeams shown : 1,2,3,4,5 GeV



All looks good
nice and linear– active bases worked well!

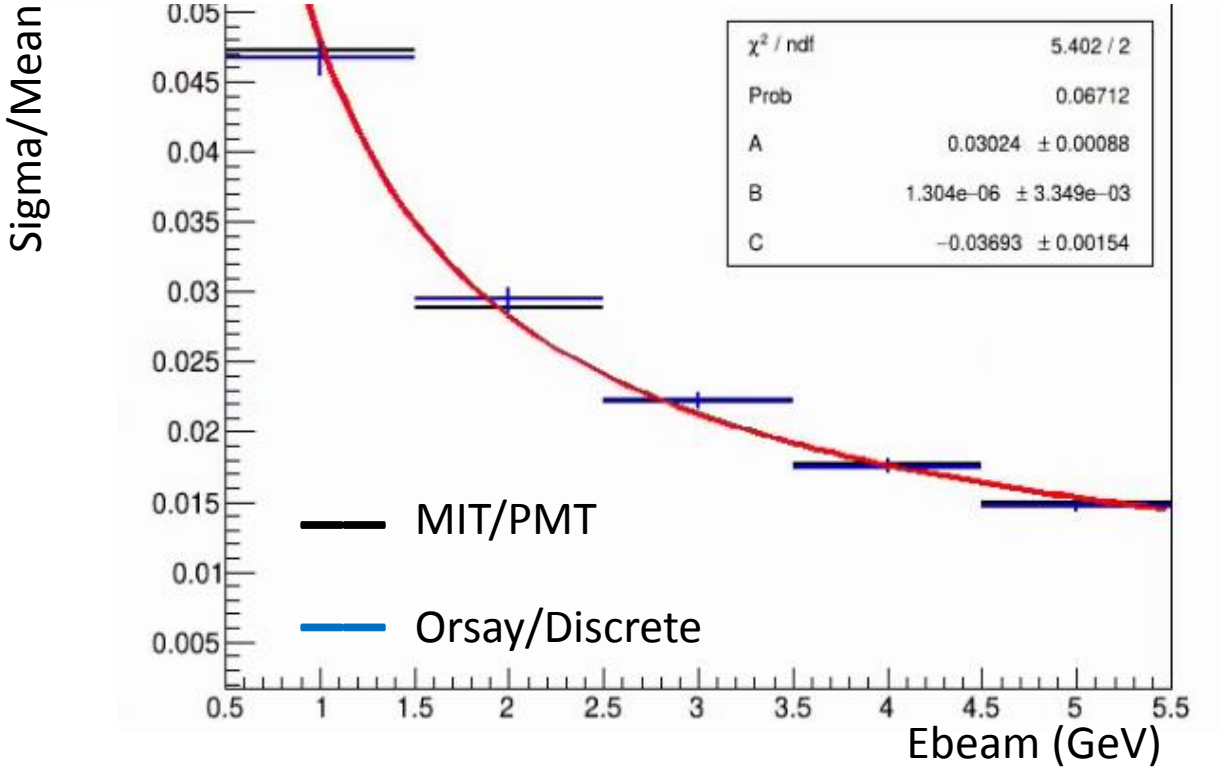
Peaks look VERY similar to siPM/discrete peaks

Not at EXACTLY the same locations – ~20% lower amplitudes

RELATIVE CALIBRATION COMPLETE

(since last week)

1st Results: Comparison of Peak Widths



MIT Prototype/PMT

Reso 1GeV :0.0473
Reso 2GeV :0.0288
Reso 3GeV :0.0222
Reso 4GeV :0.0177
Reso 5GeV :0.0149

Orsay Prototype/ siPM/Discrete

Reso 1GeV :0.0467
Reso 2GeV :0.0295
Reso 3GeV :0.0223
Reso 4GeV :0.0174
Reso 5GeV :0.0146

- **RESULTS ARE SAME WITHIN STATISTICAL ERRORS – Both Measuring beam reso**
- **Presumably puzzling rise at low Ebeam is due to intrinsic DESY beam resolution ? – source of 1/E term need in resolution fits previously**
- **Questions: will we be limited by beam resolution to quote a resolution?**

More realistic ePIC performance- 50MHz Mockup

- All previous results (MIT/PMT and siPM/Discrete) are sampling at the full rate of the Caen v1725's → 250 MHz (every 4 ns)
- For DISCRETE: Use only 1 out of every 5 samples (50 MHz) as first model of realistic ePIC performance w/ flash ADC/discrete type option
  - Each channel/event randomly chooses which starting sample within 5 samples of starting sample (start for previous full 250 MHz results) then uses every 5th sample from there. Pedestal AND Integral BOTH have sampling reduced
- Results (Red) : <= 0.3-0.5% worsening
- Note PEDESTAL Calc probably still too good ? (using ~80 samples now 16)

Reso 1GeV :0.0467
Reso 2GeV :0.0295
Reso 3GeV :0.0223
Reso 4GeV :0.0174
Reso 5GeV :0.0146

Reso 1GeV :0.0504
Reso 2GeV :0.0305
Reso 3GeV :0.0227
Reso 4GeV :0.0177
Reso 5GeV :0.0153

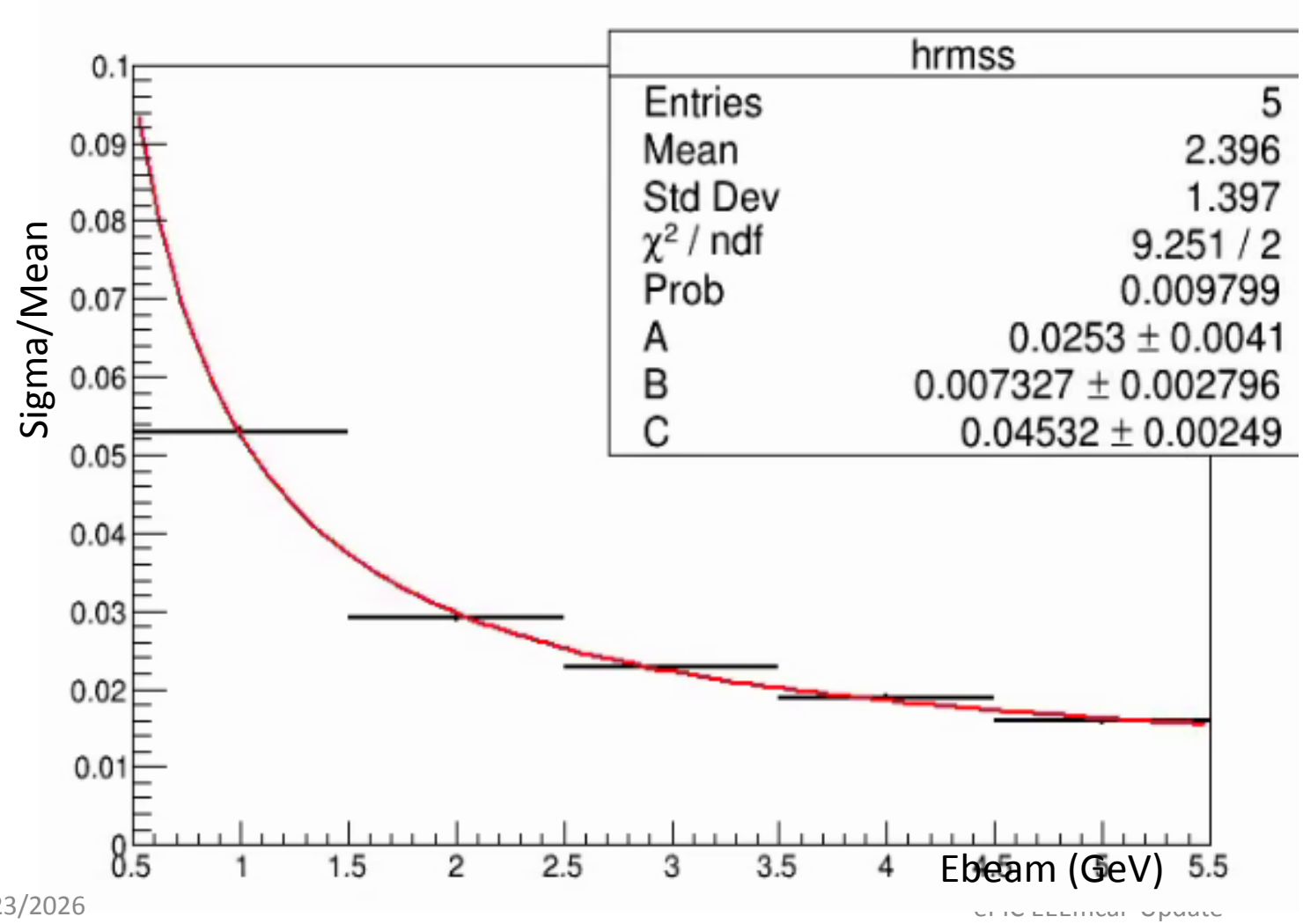
Conclusions

- Many improvements – Smaller noise? Fixed low energy tail background, multiple prototypes tested successfully with usable data
- Need further analysis to see if we can quote a resolution that is not limited by the intrinsic beam resolution
- More Energy points and quite more statistics are available
  - (in principle could even include last February data as well w/ C.O.G cut?
  - Look at more detailed information from subshowers→AI to estimate resolution?
- Can look at individual channel noise and other aspects of the prototype performance even without obtaining a resolution.

Backup

OLD/ FEB: Full 5x5 E resolution AFTER subtraction

- **THIS SLIDE IS FROM FEBRUARY DATA, EXCEPT BLUE TXT**



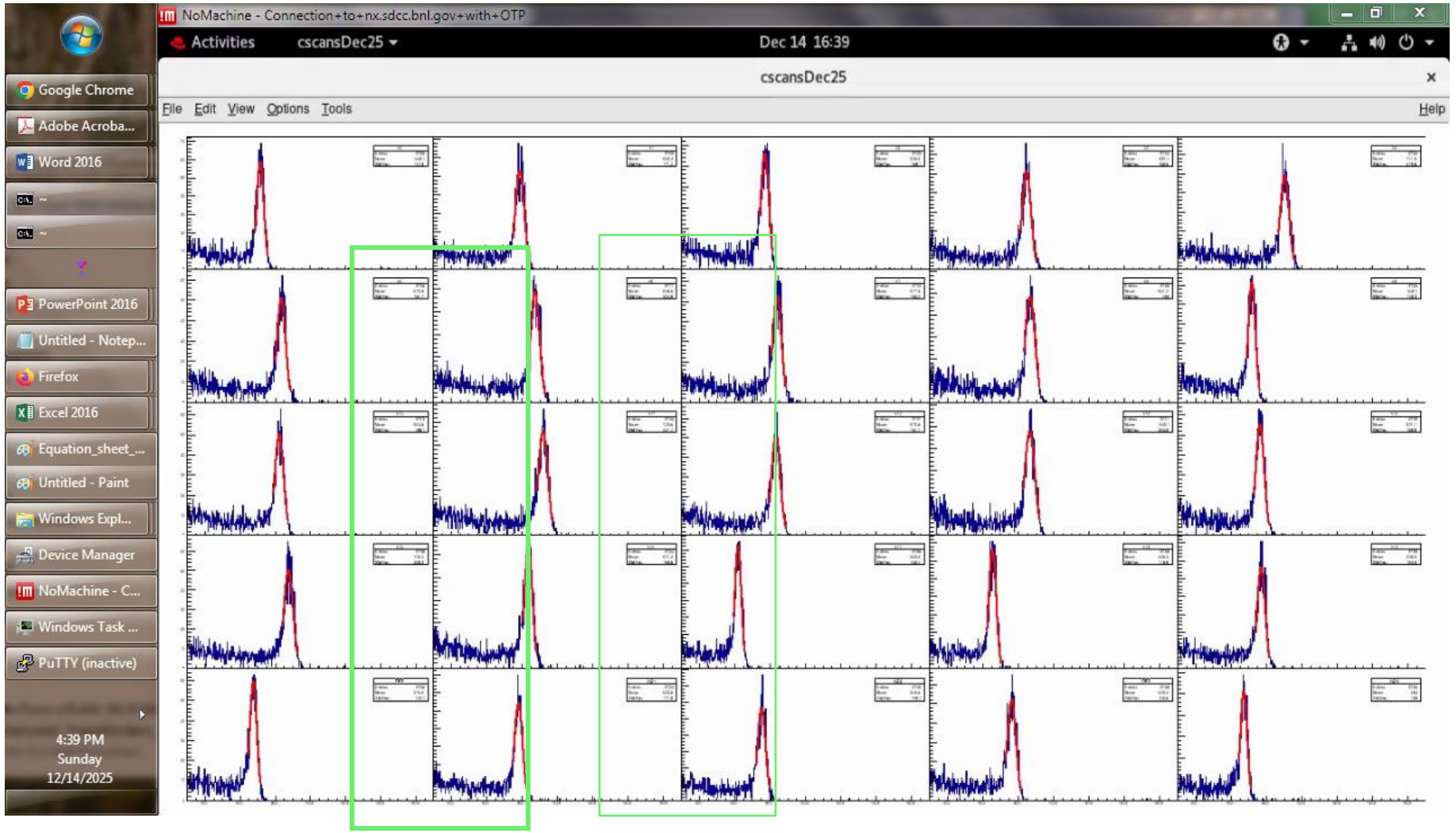
Fit form: **A%/√E ⊕ B % ⊕ C % / E**

- A term 2.5%
- B term (floated) 0.7% reasonable?
  - (raising/fixing B lowers A term)
- **Noise term 4.5%/E. Large : 2nd Mystery**
- Also under investigation
- Size roughly consistent w/ pedestal channel by channel noise

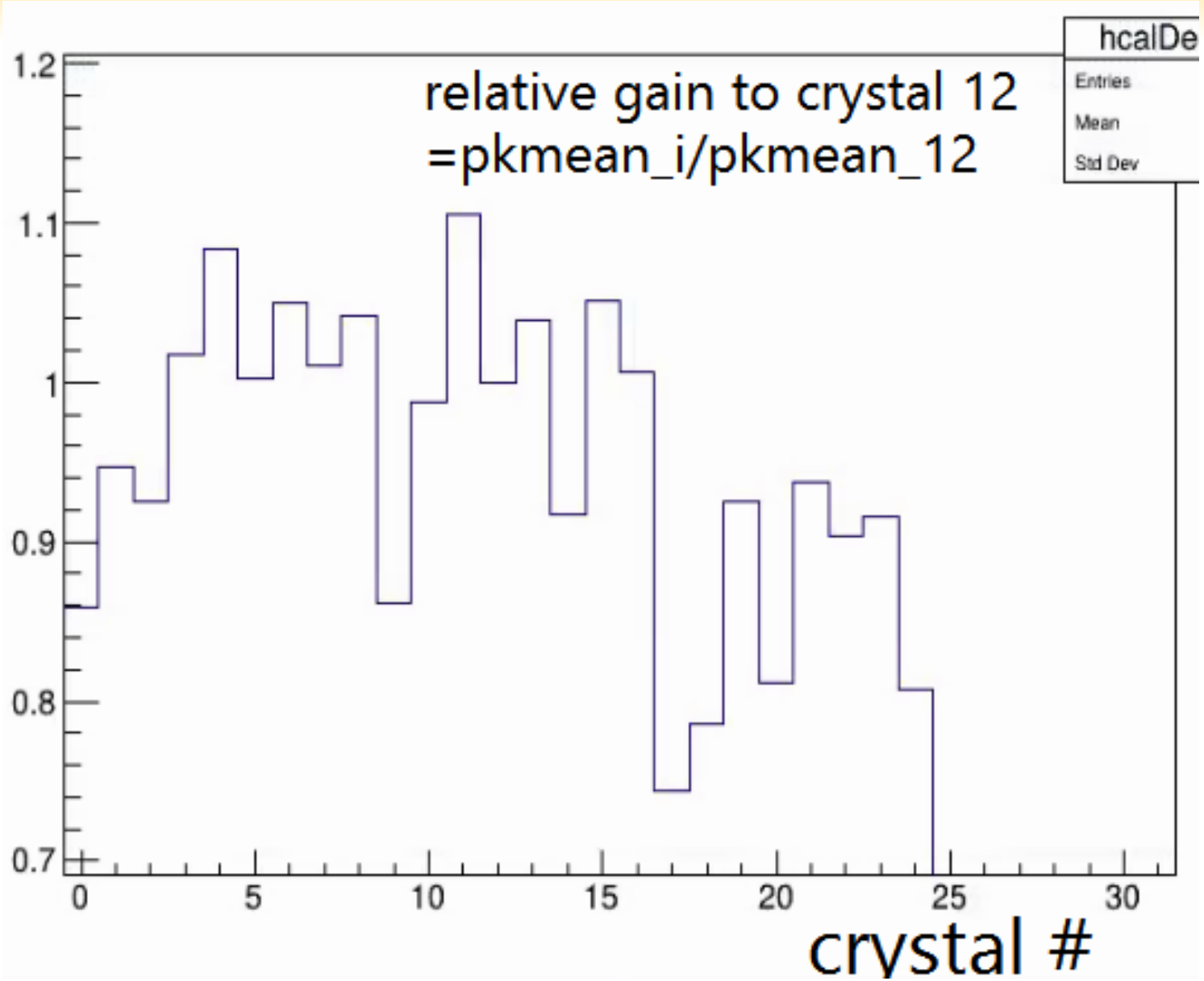
but all behaviors don't hang together

Reso 1GeV :0.0529	Reso 1GeV :0.0467
Reso 2GeV :0.0290	Reso 2GeV :0.0295
Reso 3GeV :0.0228	Reso 3GeV :0.0223
Reso 4GeV :0.0189	Reso 4GeV :0.0174
Reso 5GeV :0.0158	Reso 5GeV :0.0146

Relative calibration fits



Relative calibration



Bigger variation than last year, surprisingly → it was mostly < 10% corrections last year.

This calibration needs a little more variations

Anti correlations