Update for Discrete Readout & MIT Prototype Comparison December 2025 DESY Testbeam

Justin Frantz (Ohio U), EEEMcal Group

ePIC TIC Mtg

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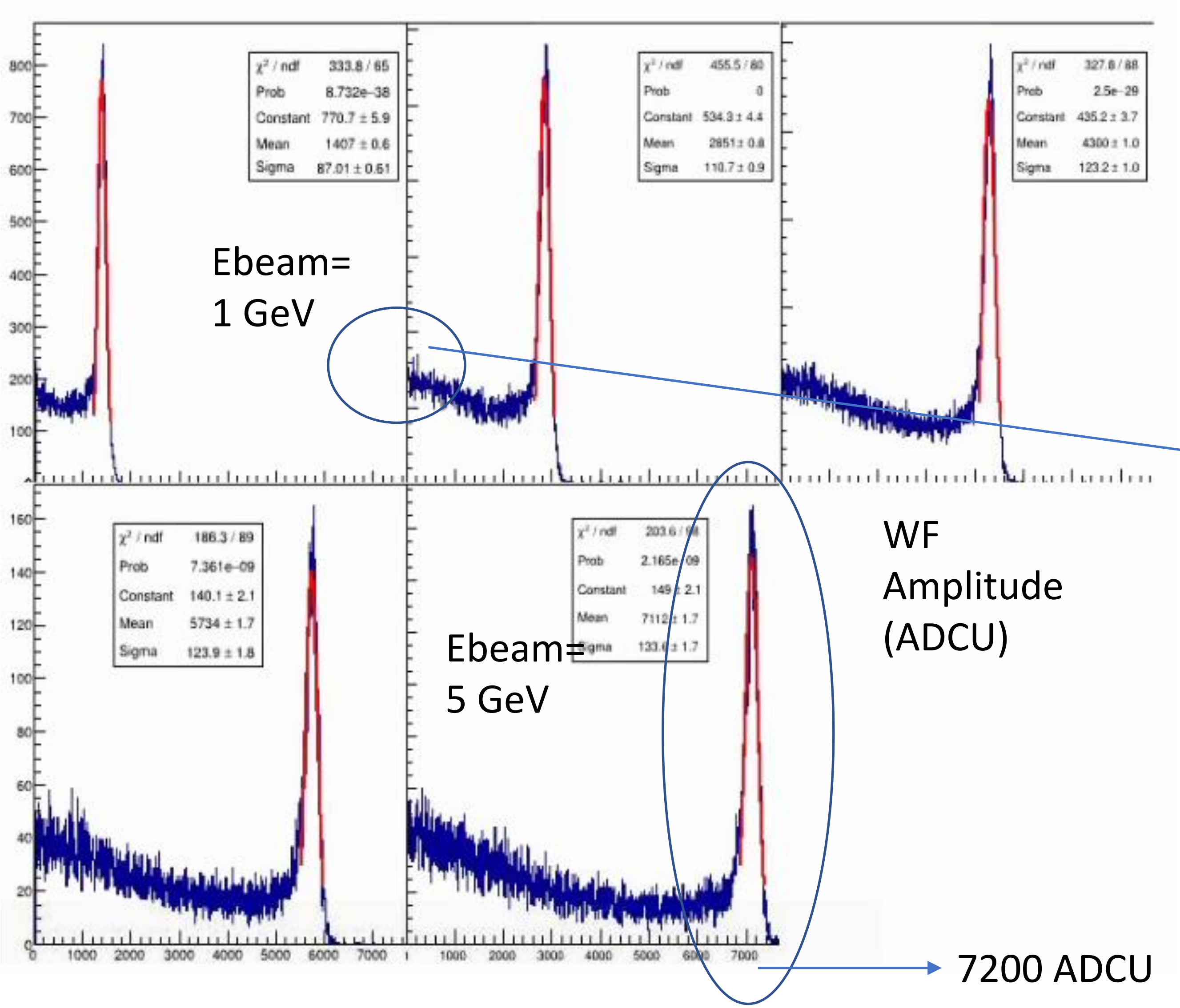
Testbeam December 2025

- Testbeam DESY December 8-22 2025 -- MIT Prototype Dec 9-10 -- Discrete readout/Orsay prototype Dec ~11-12
  - Two Scintillator trigger → Two 16-Ch 250 MHz Caen V1725s Waveform digitizers / core software provided by MIT – **Milner/Hasell/Cline**
  - Readout by same siPM's as HGCROC – diff amp boards
  - DESY T24 TB area : 1-5 GeV electron energies

- Goals for DISCRETE (Compared to Feb/March 2025)
  - 1) DISCRETE Readout : try stabilization of bias voltage of individual channels/channel current monitoring, understand backgrounds better
  - (Get resolution measurements)
  - 2) MIT Prototype : Get Better Measurements for understanding instrinsic beam resolutions and backgrounds
  - Improve crystal siPM mounting for poor light coupling
- Tight schedule took most data ~1.5 days (helped by February 25 experience)
  - MIT Prototype/DISCRETE: J. Crafts, D. Hassell, G.Visser, and J. Frantz

Feb 2025 : Amplitude Distributions –BACKGROUND!



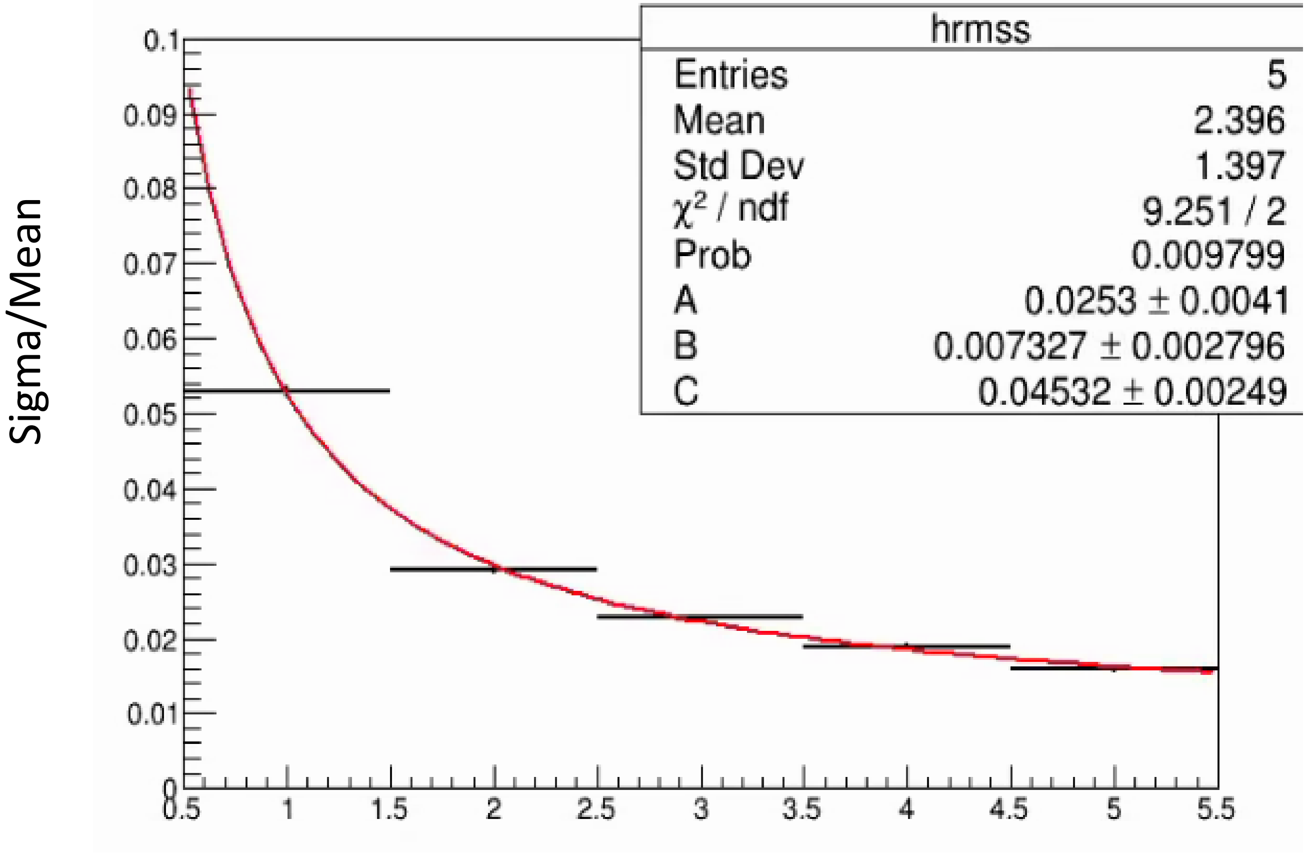
REMINDER FEB. RESULTS:

Mysterious background / low energy tail

Eventually was subtracted, but still uncertainty on residual effects.

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

- Resolution fit needed a 1/E term   -- meaning?
- Remember but we didn't know what the intrinsic BEAM energy spread was



Reso Fit form

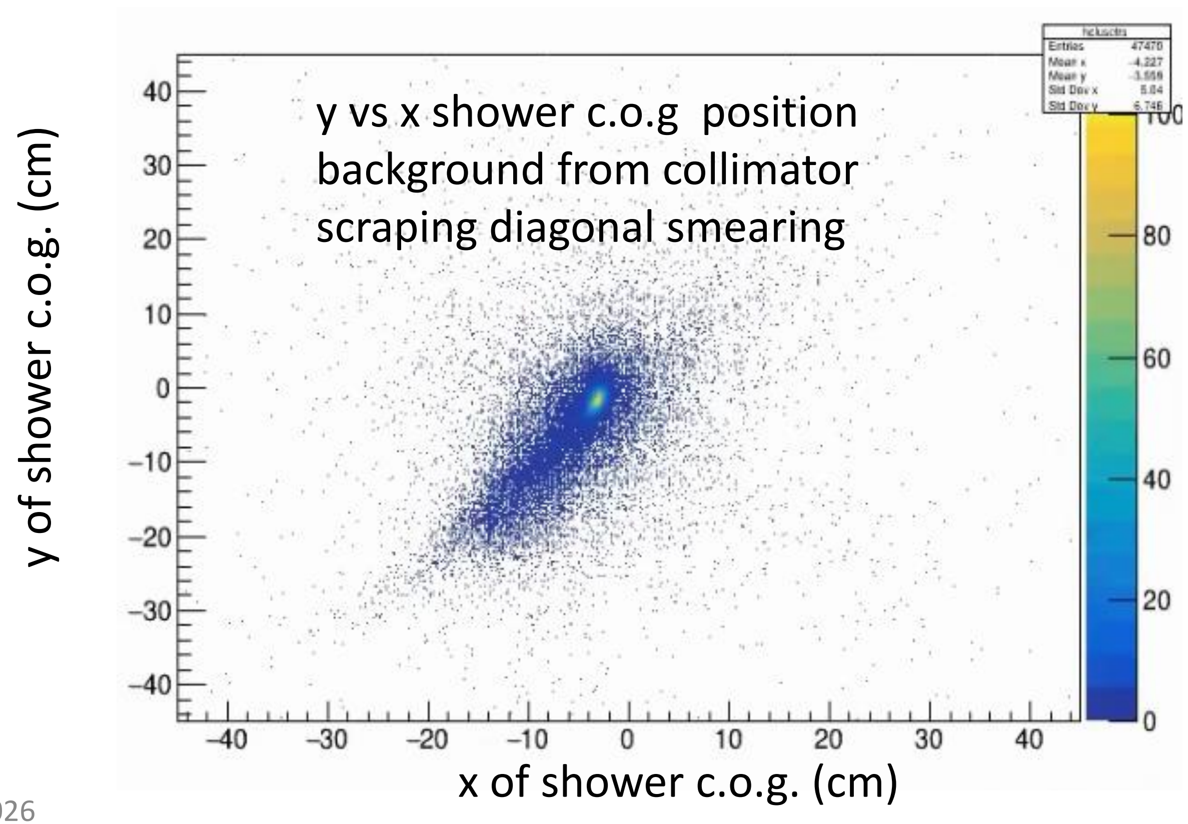
: **$A\%/\sqrt{E} \oplus B\% \oplus C\%/E$**

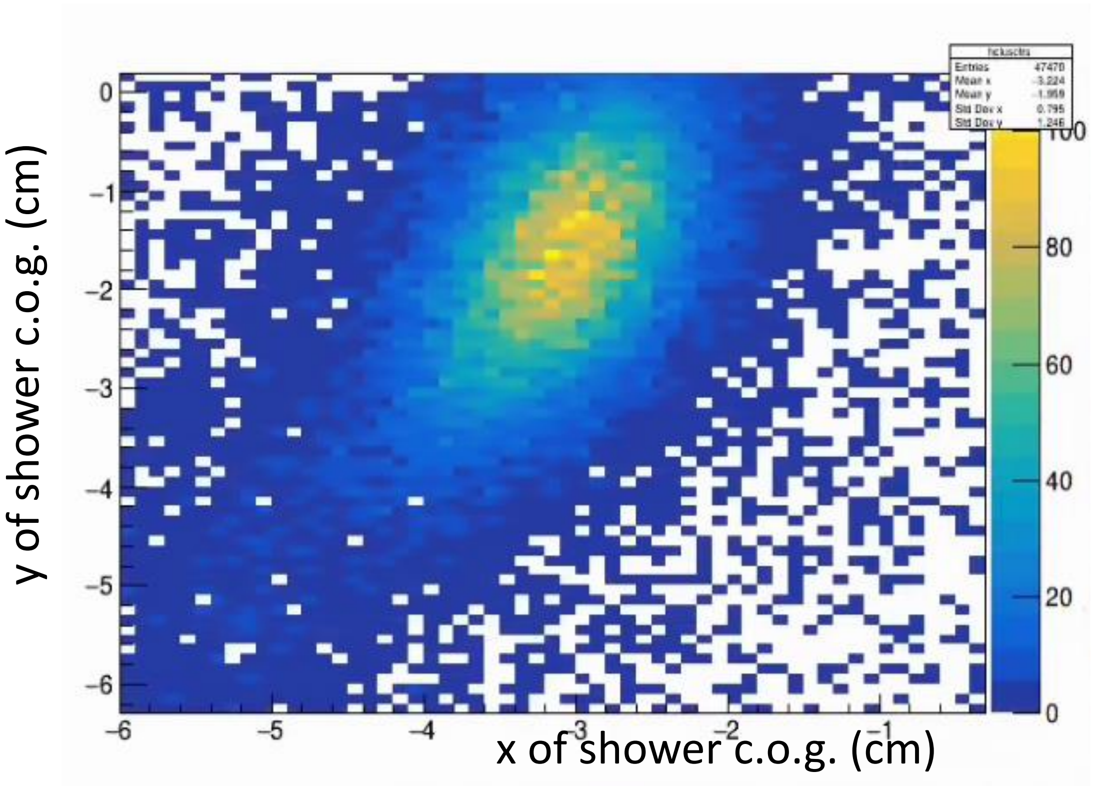
- A term 2.5%
- B term (floated) 0.7%
- **Noise term 4.5%/E. Large :**

Reso 1GeV :0.0529
Reso 2GeV :0.0290
Reso 3GeV :0.0228
Reso 4GeV :0.0189
Reso 5GeV :0.0158

Collimator discovery → Source of Low E Bkg

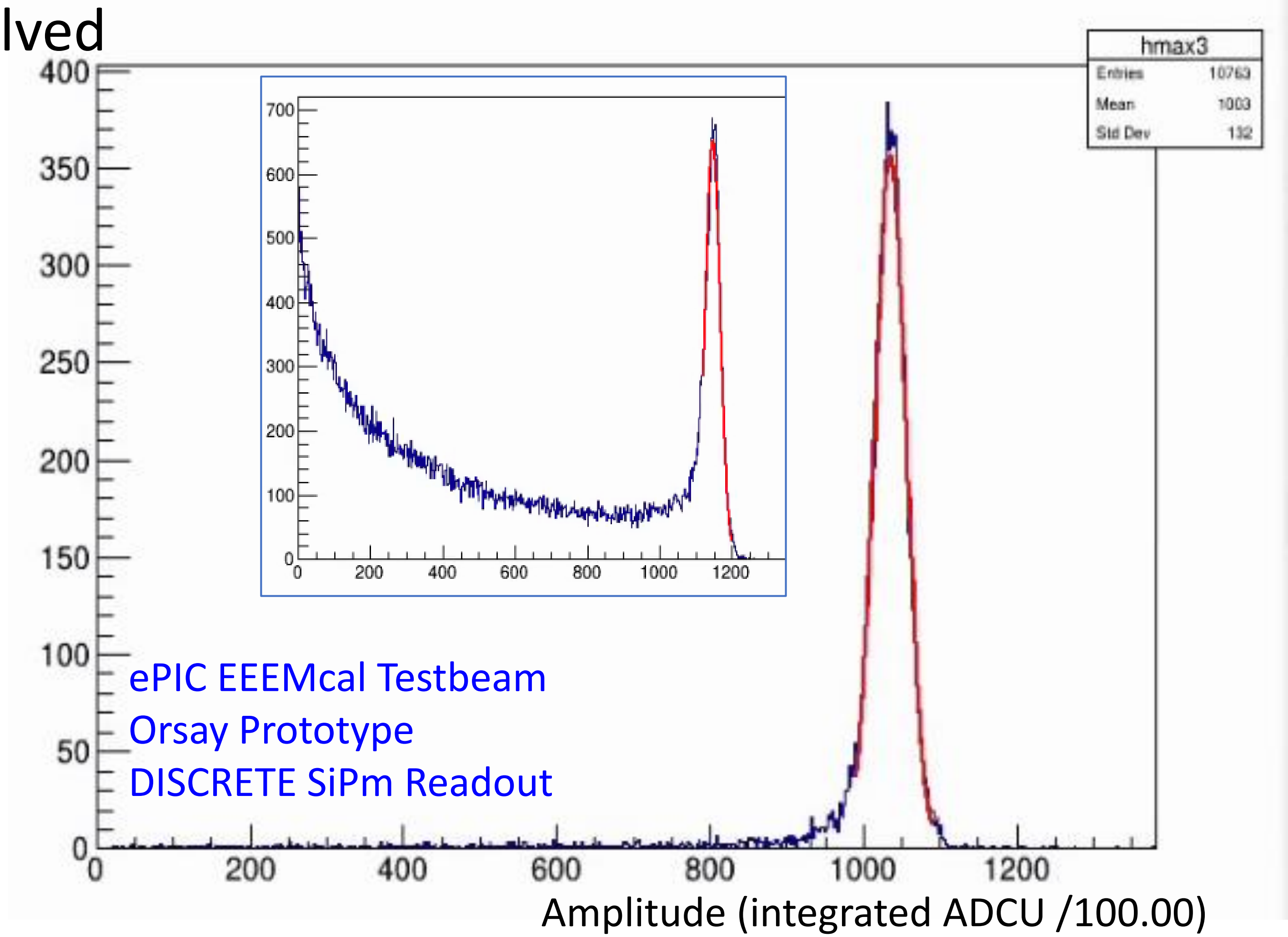
- Within < 1 day after our ~1.5 day data-taking was finished analysis of our data allowed us to deduce low E bkg caused by DESY/local collimators layout/combinations
- Fixed for HGCROC running based on first looks at our data
- Although our data was already taken we can make an **offline cut based onshower center of gravity (E C.O.G.) which completely cleans up**





Cleaned up E=4GeV with offline cut

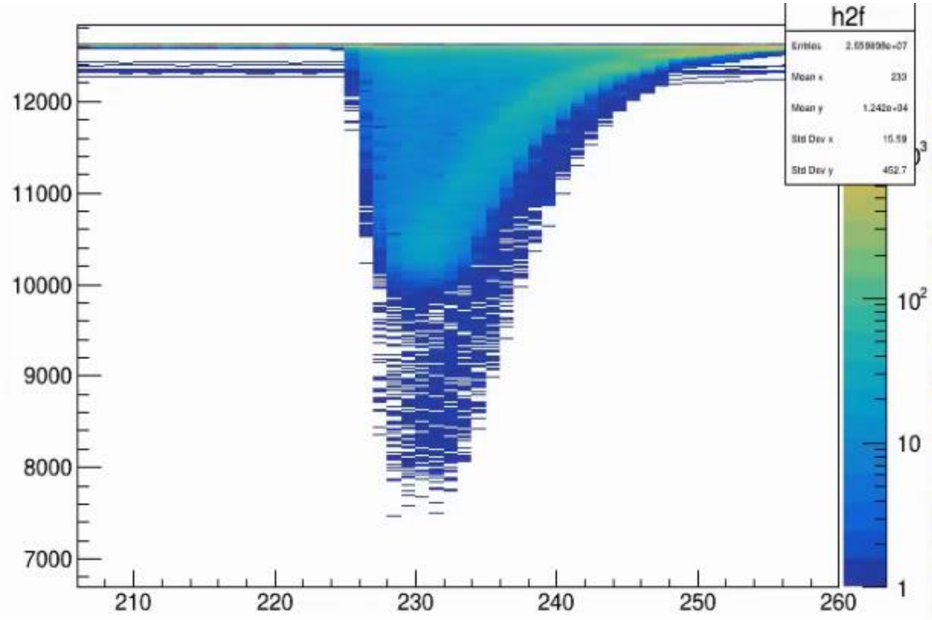
- ~Near-complete clean up (full prototype 4 GeV Amplitude distribution). Cut value does not alter peak widths themselves but makes analysis easier.
- One mystery solved



MIT Prototype / data

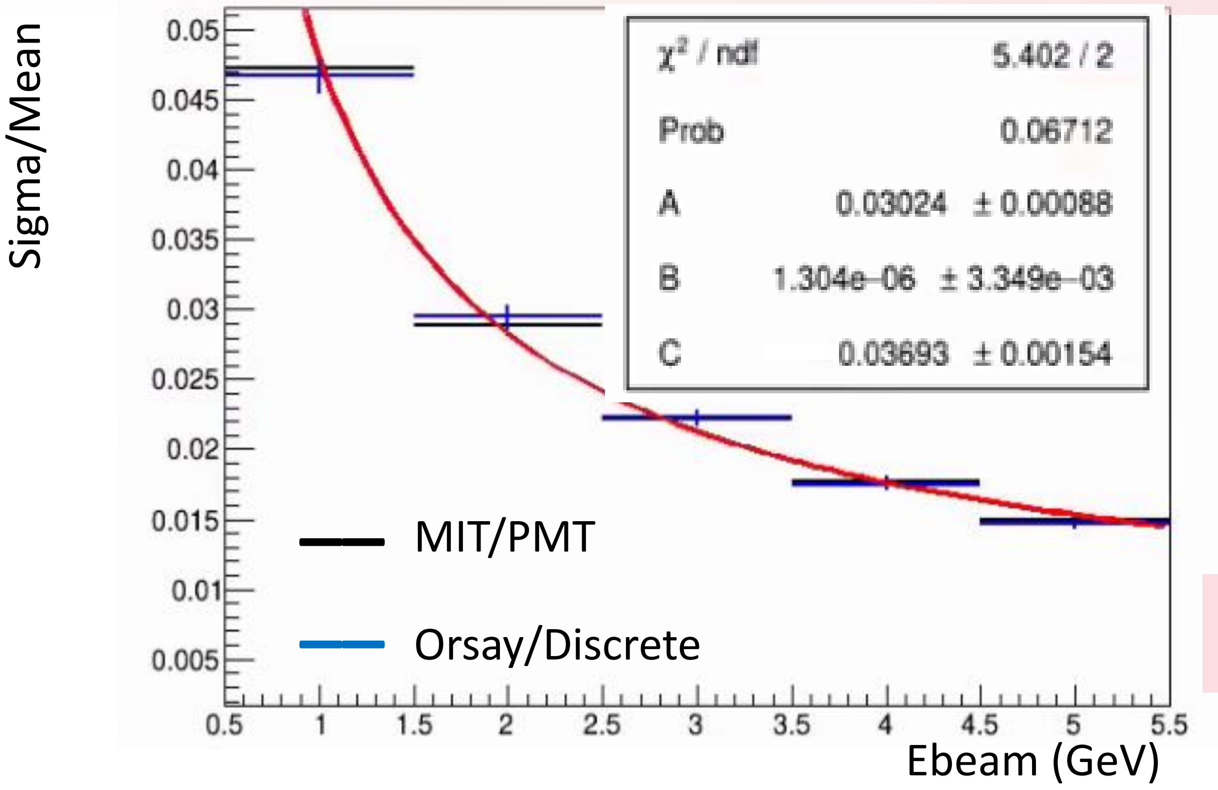
- **IDEA: use known reso alt prototype as cross check → intrinsic beam resolution**
- Joshua Crafts (CUA), Doug Hassell / Gerard: MIT Prototype data –analysis by me using same code as for discrete.
- MIT Prototype:
  - ~Identical PbWO Crystals: PMT/Amplification/Bases NPS@Jlab
  - Cooled to -20 Celsius [in principle better reso than NPS)
  - Negative Pulses →Our siPM is positive pulses.
  - + 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)

PMT Waveforms



- Digitized by same Caen Modules we later used for siPM/Discrete Waveform timing/pedestal subtraction ~ identical
- **Can make SAME C.O.G. cut to clean up low E tail offline**

New Resolutions/Peak Widths siPM vs MIT/PMT



MIT Prototype/PMT	Orsay Prototype/ siPM/Discrete
Reso 1GeV :0.0473	Reso 1GeV :0.0467
Reso 2GeV :0.0288	Reso 2GeV :0.0295
Reso 3GeV :0.0222	Reso 3GeV :0.0223
Reso 4GeV :0.0177	Reso 4GeV :0.0174
Reso 5GeV :0.0149	Reso 5GeV :0.0146

Reso fit: 3%/$\sqrt{E}$ $\oplus$ ~0-1% $\oplus$ 3.7%/E

- **RESULTS ARE SAME WITHIN STATISTICAL ERRORS**
  - Likely both are measuring beam reso limitation → Third prototype test data from March 2025 DESY trip, from Crytur also shows almost identical point by point RMS's. **-- SLIGHTLY better than Feb data.**
- Presumably puzzling rise at low Ebeam is due to intrinsic DESY beam resolution ? – source of 1/E term need in resolution fits previously
- **NEW Question: will we be limited by beam resolution to quote a resolution?**

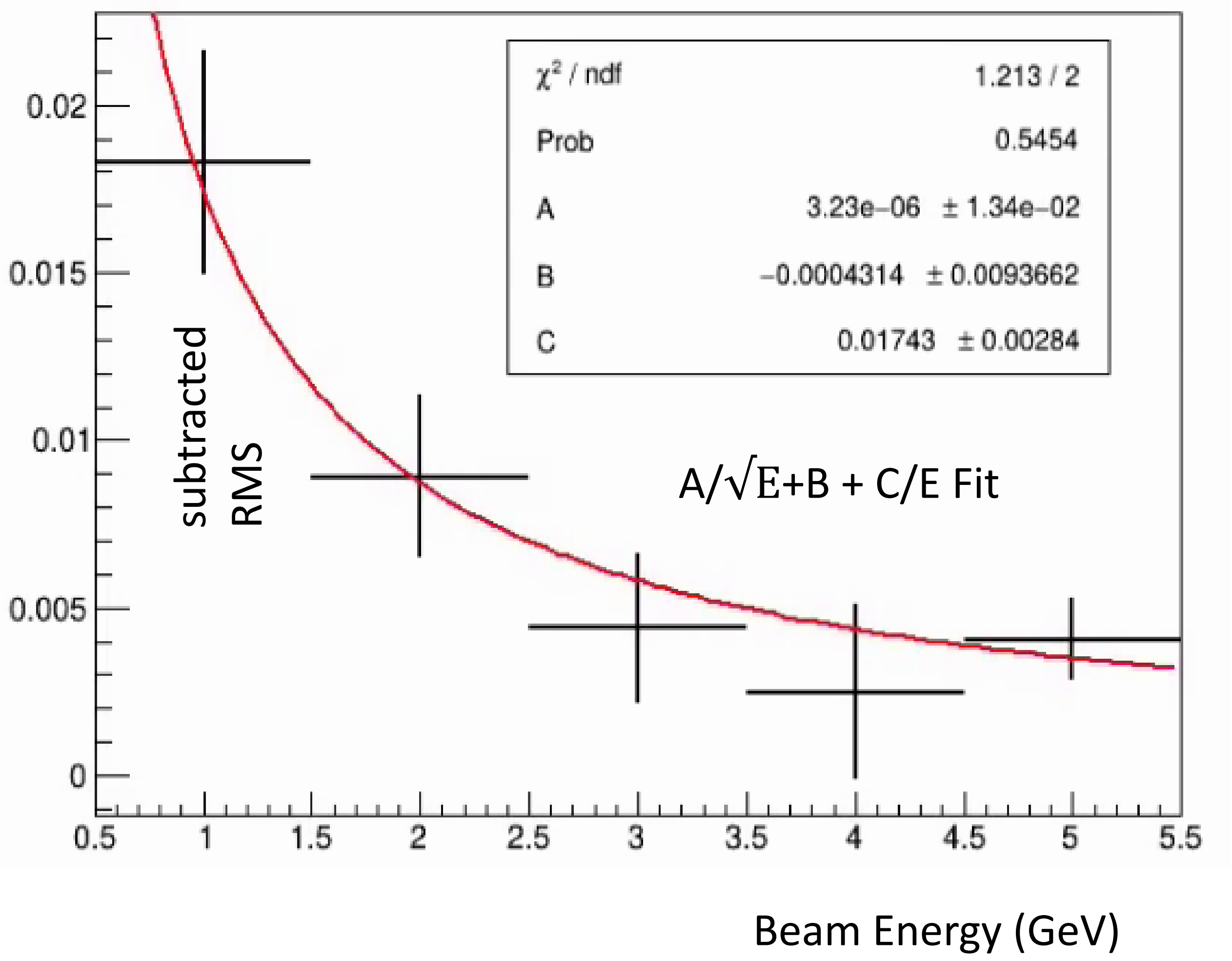
More realistic ePIC performance- 50MHz Mockup

- All previous results (MIT/PMT and siPM/Discrete) are sampling at the full rate of the Caen v1725's → 250 MHz/4 ns intervals
- Use only 1 out of every 5 samples (50 MHz) as first model of realistic ePIC performance w/ flash ADC/discrete type option
- Results (Red) : <= 0.3% worsening
- TODO: Worsen PEDESTAL Calc (using ~80 samples now 16), thesholds, etc.

250 MSPS	50 MSPS
Reso 1GeV :0.0467	Reso 1GeV :0.0504
Reso 2GeV :0.0295	Reso 2GeV :0.0305
Reso 3GeV :0.0223	Reso 3GeV :0.0227
Reso 4GeV :0.0174	Reso 4GeV :0.0177
Reso 5GeV :0.0146	Reso 5GeV :0.0153

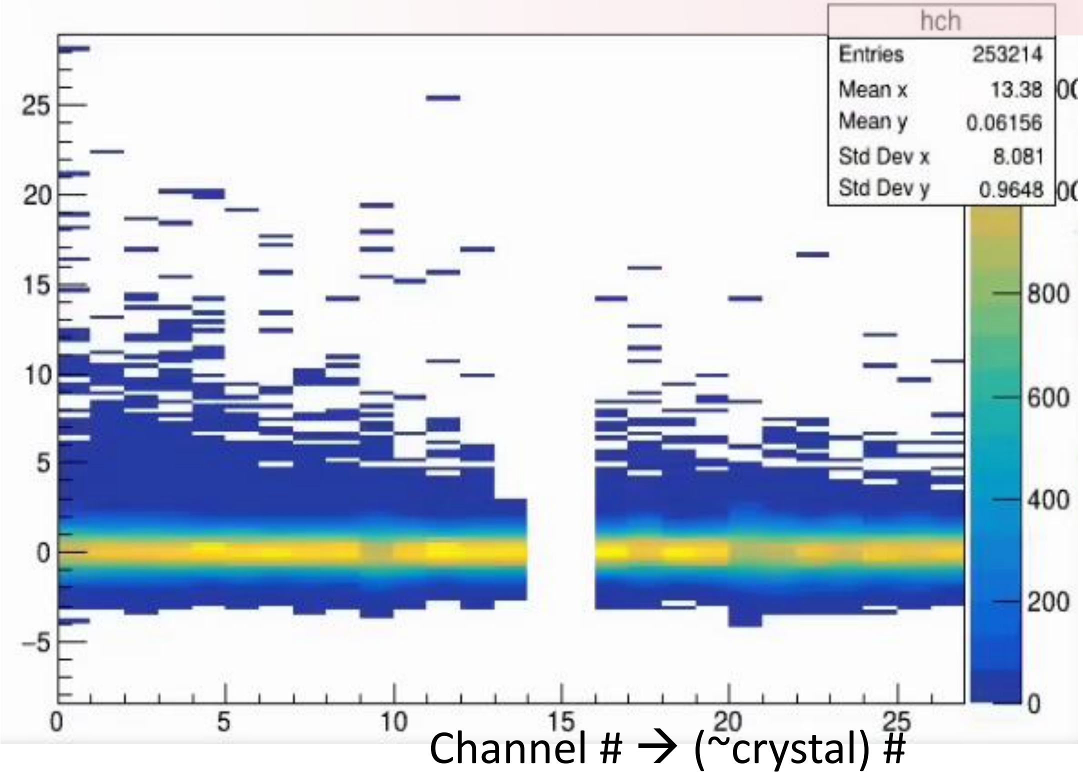
Residual Subtraction after Beam Resolution

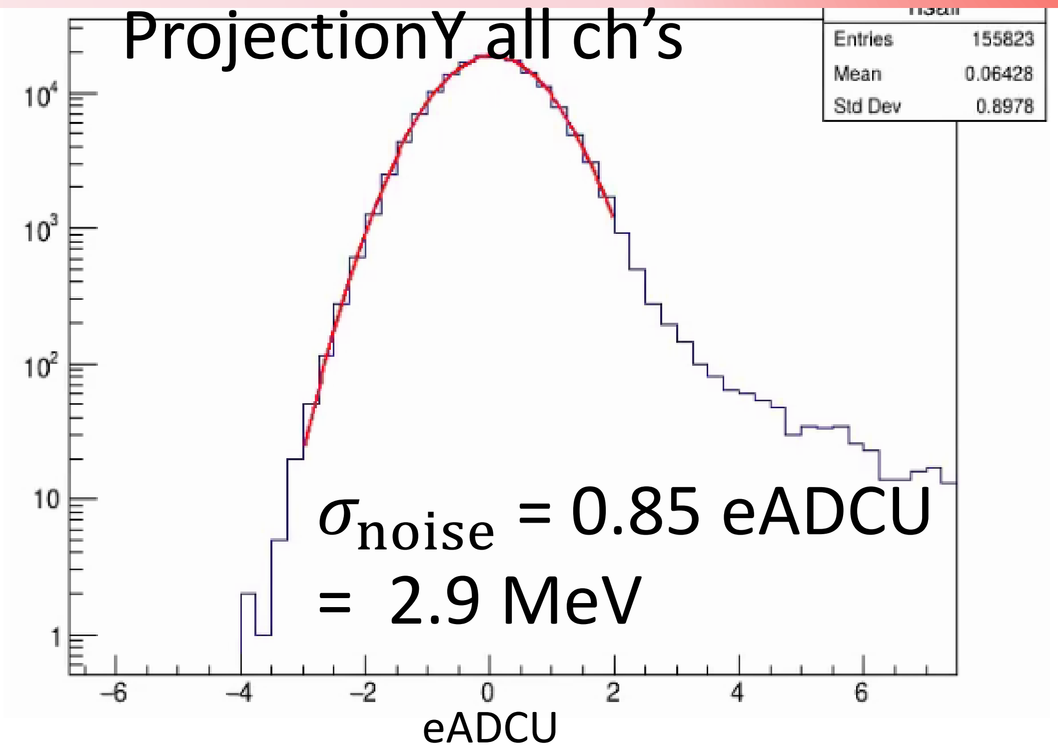
- **IDEA: Use MIT Data as intrinsic beam mom resolution, subtract it**
- Essentially just the quadrature difference of the two sets of points on the previous slide : 250 MHz should have better resolution than these 50MHz → Upper bound for resolution widths ?
  - 1.7 % @ Ebeam 1GeV to 0.5% at high Ebeam
- Pure 1/ E Noise fit works best (other parameters floated, remain negligible)–make sense as electronics noise?



Also ~consistent w/ ch.by ch. noise from pedestal run: [See next slide]
sqrt(25)* 2.9MeV = 14.5 MeV vs 17.4 MeV @ 1 GeV in above plots

Pedestal Run → Noise → for 50 MHz Sampling





- Units of y –axis (all "amplitude"s) are in integrated ADCU's /20 → effective ADCU "eADCU"
- Calibration is 286.7 eADCU per GeV → Noise = ~2.9 MeV for each channel (projection all channels)
- 250 MHz Sampling both Orsay/SiPM & MIT Prototype : 1.5 MeV noise.

Conclusions

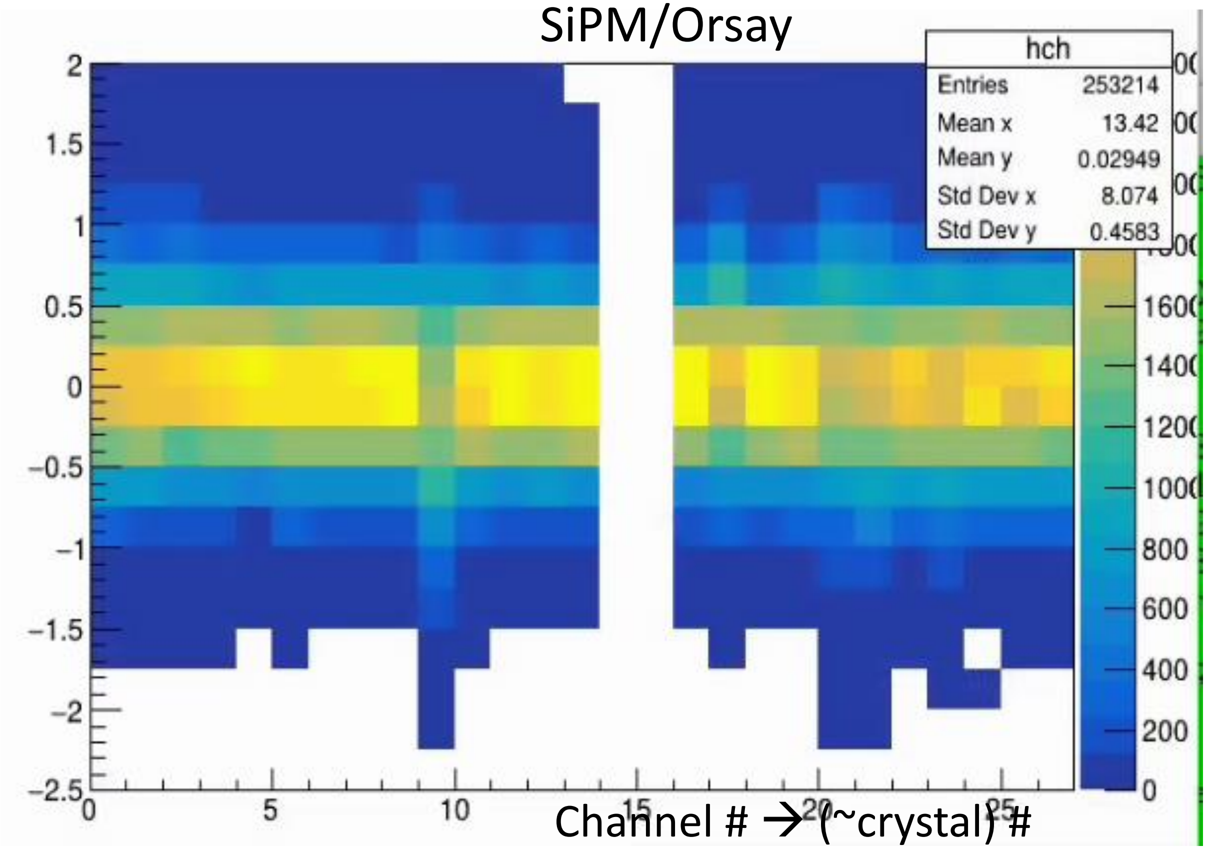
- Many improvements – better resolutions, smaller noise, fixed low energy tail background, multiple prototypes tested successfully with usable data
- Need further analysis to see if we can quote a resolution that is not limited by the intrinsic beam resolution
- Can characterize background
- More Energy 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 extrapolate resolution?

Backup

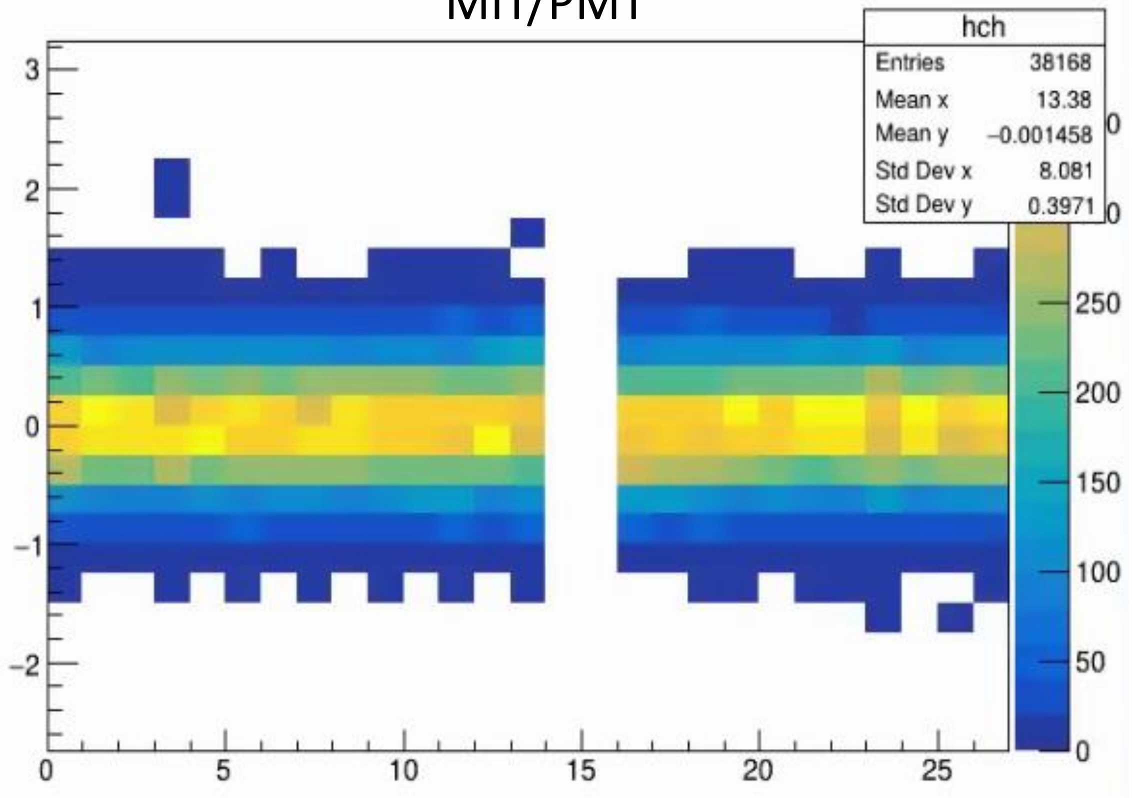
Noise in 250MHz siPM Orsay and MIT/PMT

- With full 250 MHz sampling, chbych noise about half is big (~1.5 MeV)
- MIT/PMT readout actually shows 1.6 MeV noise – in a Pedestal run I found → not sure conditions (cleaner) were same as for Orsay/siPM

SiPM/Orsay

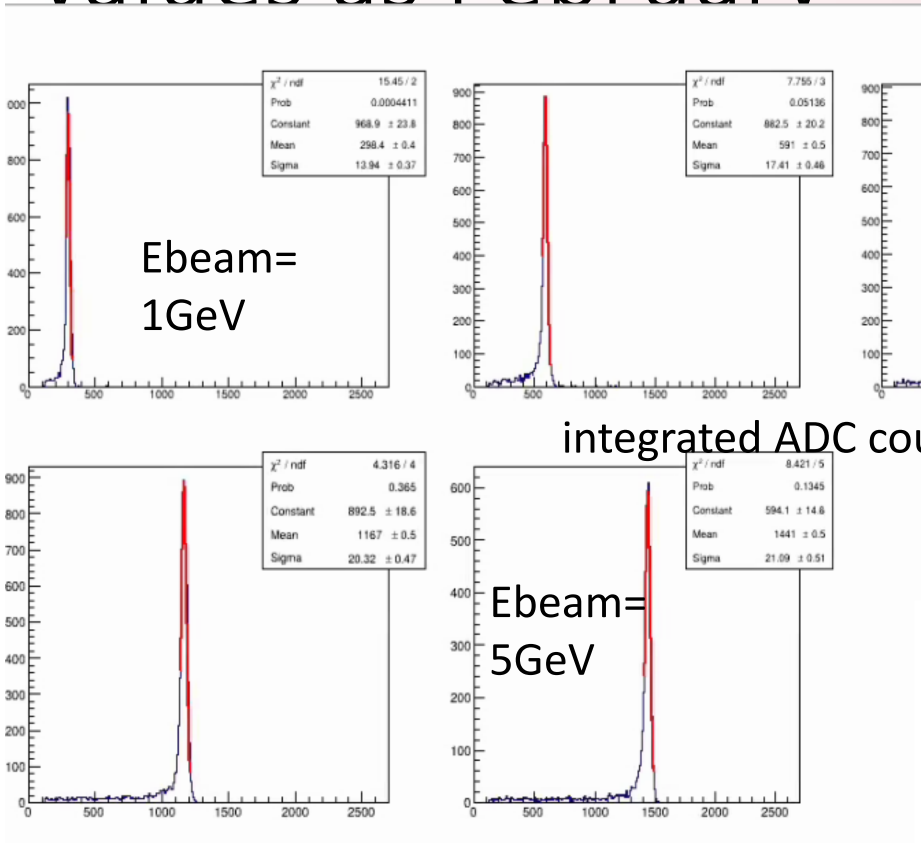


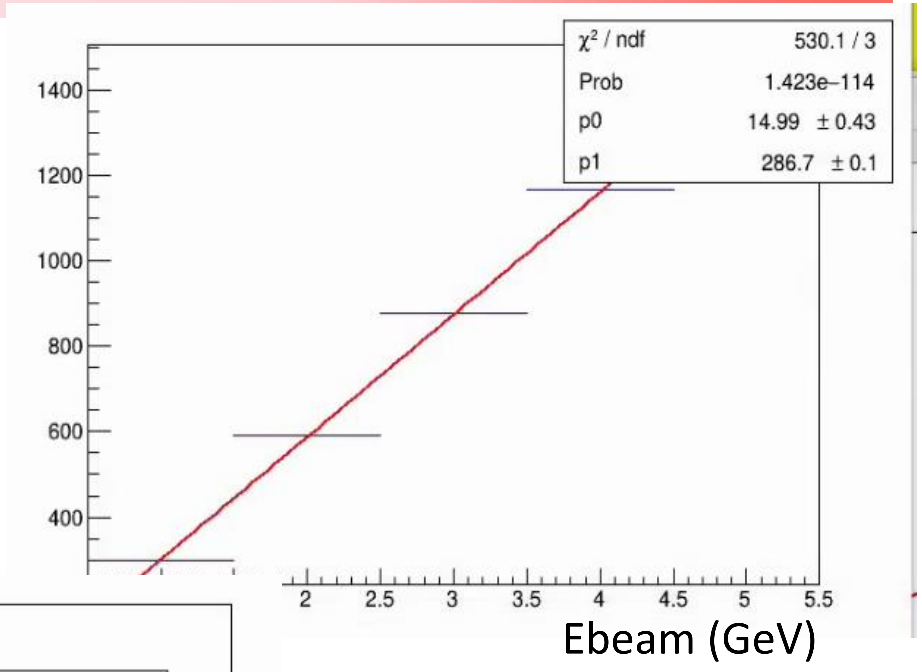
MIT/PMT



Channel # → (~crystal) #

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





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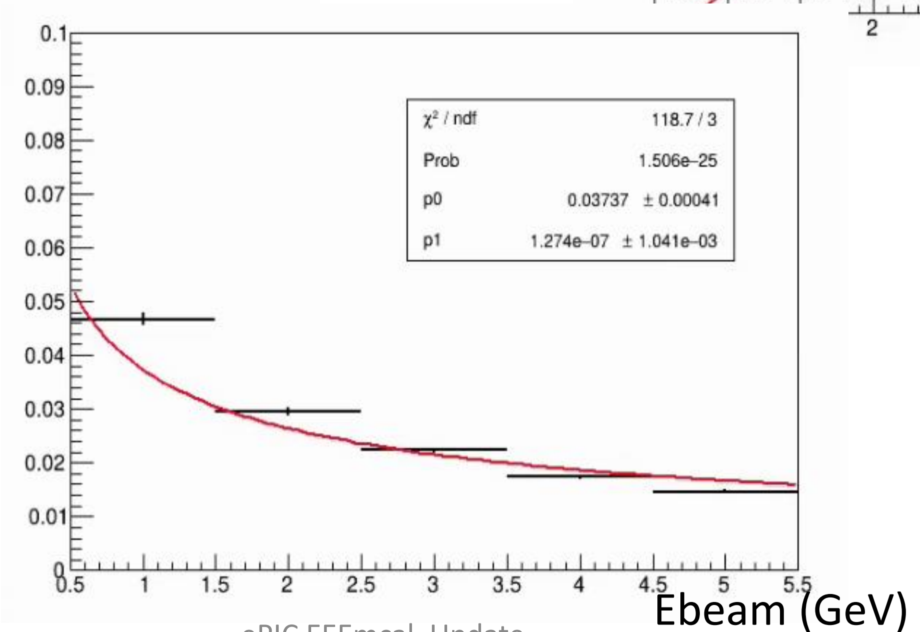
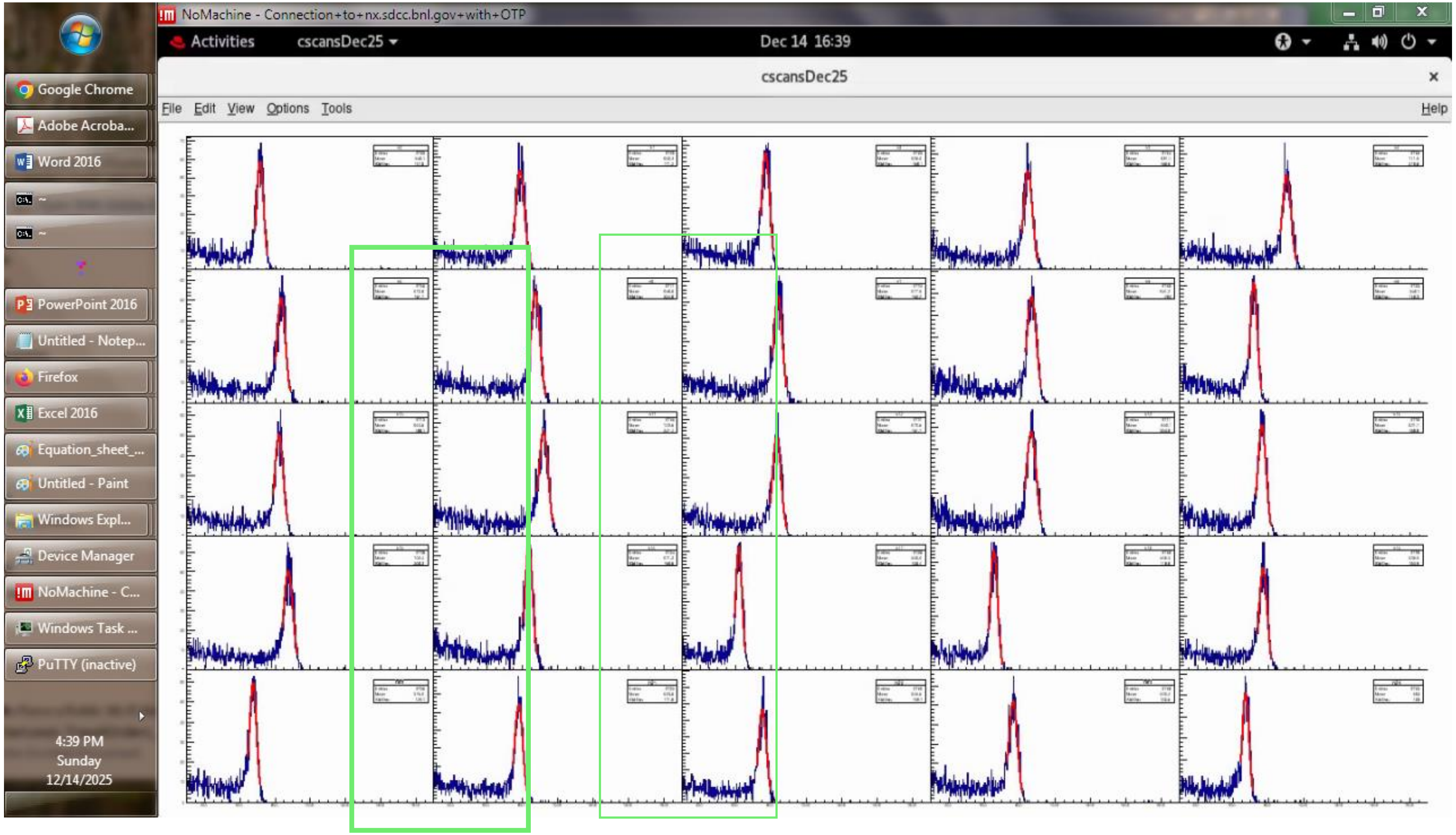
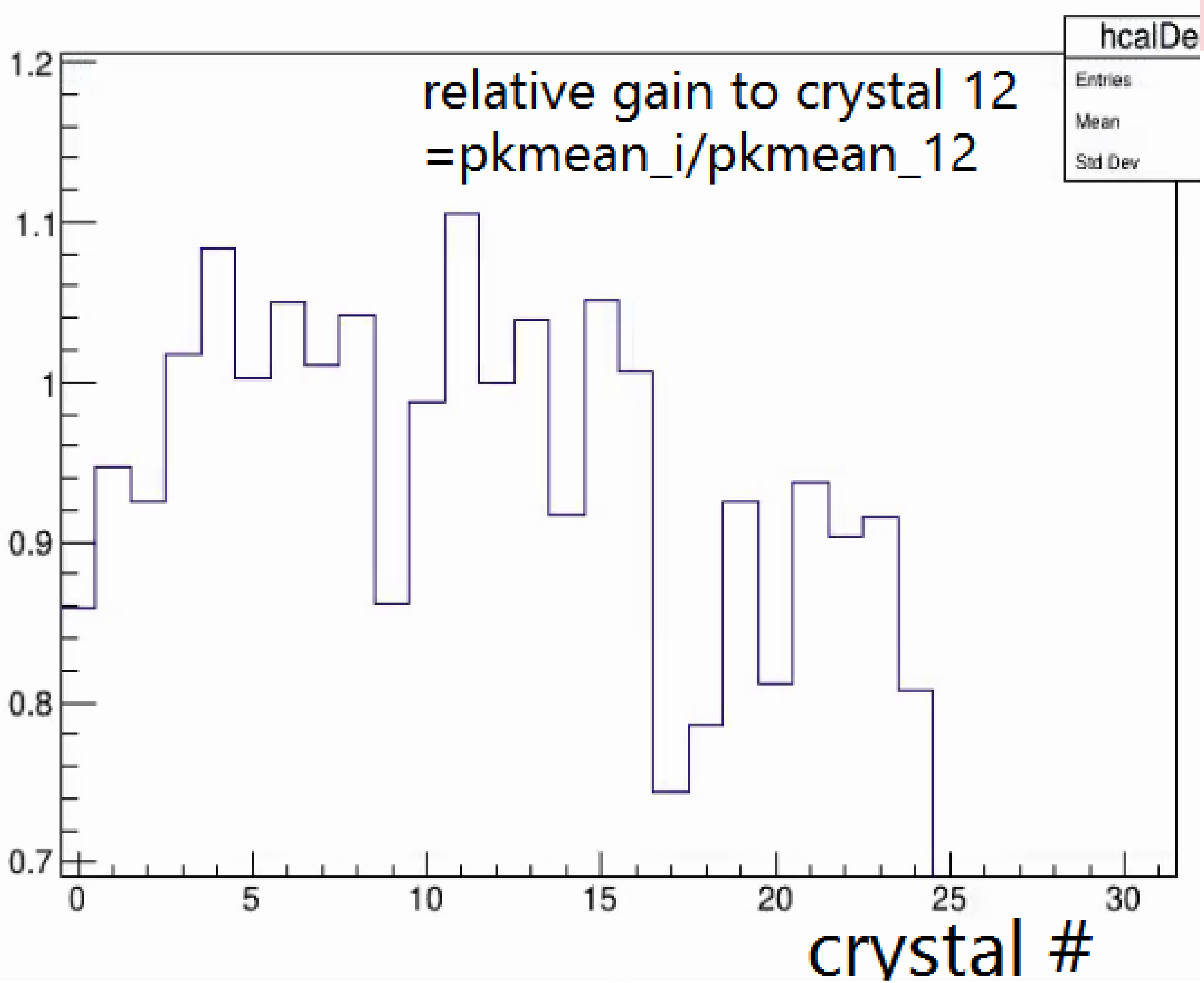


Resolutions slightly better (widths are ~0.5% lower)
~4.5% / E Extra Noise Term needed
(Several ways to fit only one shown)

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