First Results Discrete Readout Testbeam Analysis

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EEEMcal Testbeam Ana Update 1

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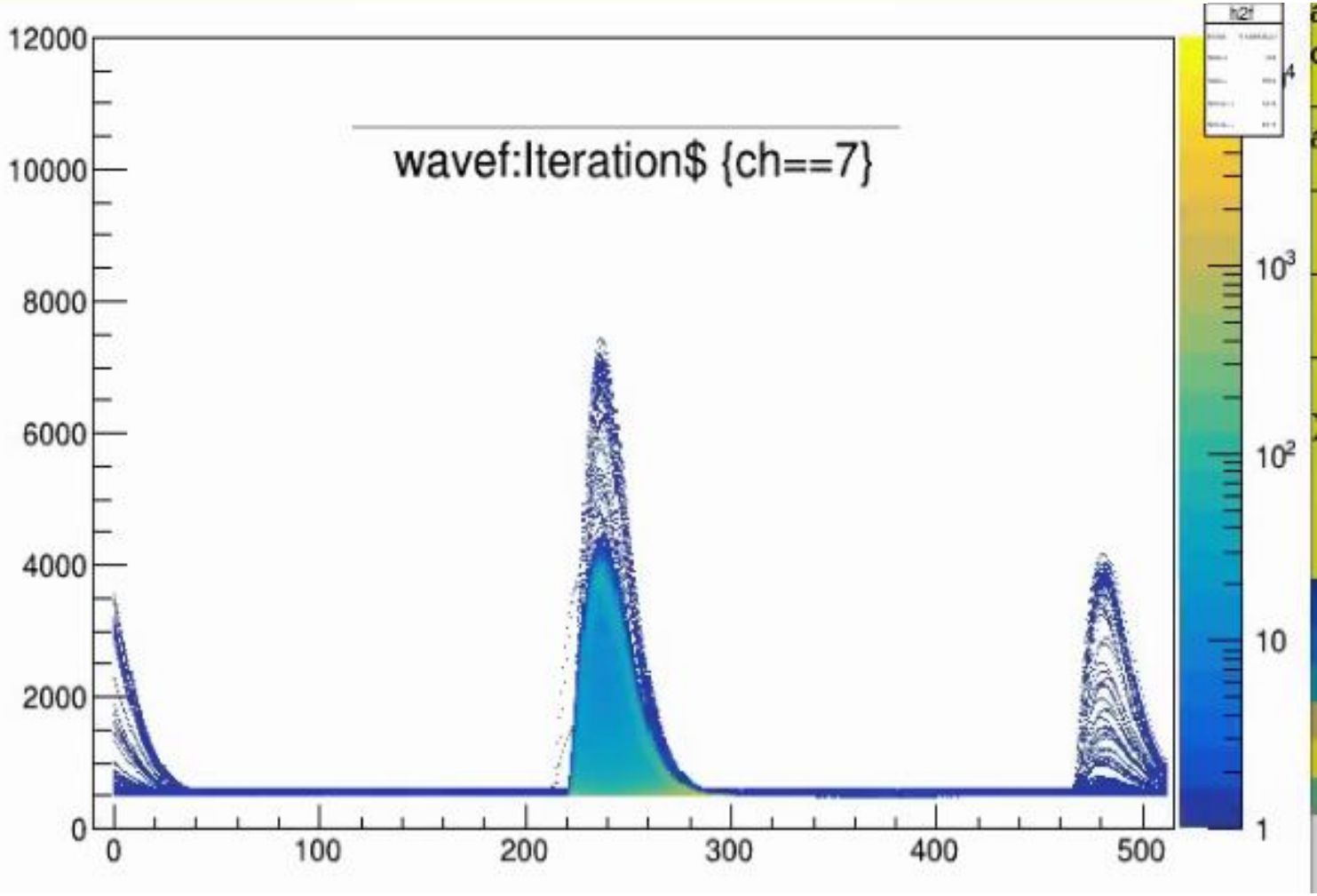
Testbeam

- Testbeam DESY Feb 17-Mar2 Discrete readout
  - Two Scintillator trigger → Two 16-Ch 250 MHz Caen V1725s Waveform digitizers / core software provided by MIT – Milner/Hasell/Cline
  - DESY T21 TB area : 1-5 GeV electron energies
- Most data taken with 2x2 mm collimator →
  - Expect Ebeam uniformity to be better than DESY quoted RMS of ~157 MeV
  - This analysis confirms that
- Full data taken Fri/Sat ~2/21 Found that Beam energies 4,5 GeV were saturated due to baseline/pedestal setting on Caen's too high (previously set for negative pulses)
- Slightly abbreviated second data set taken Monday 2/24 "v2ohio"
- Data from both sets can't necessarily be mixed amongst maybe other reasons since daughter pre-amp boards (which are not individually labled) are attached to randomly different siPM boards.
  - Possible, if preamp board does not affect calibration much
  - **THIS ANALYSIS : v2ohio SECOND data set only**

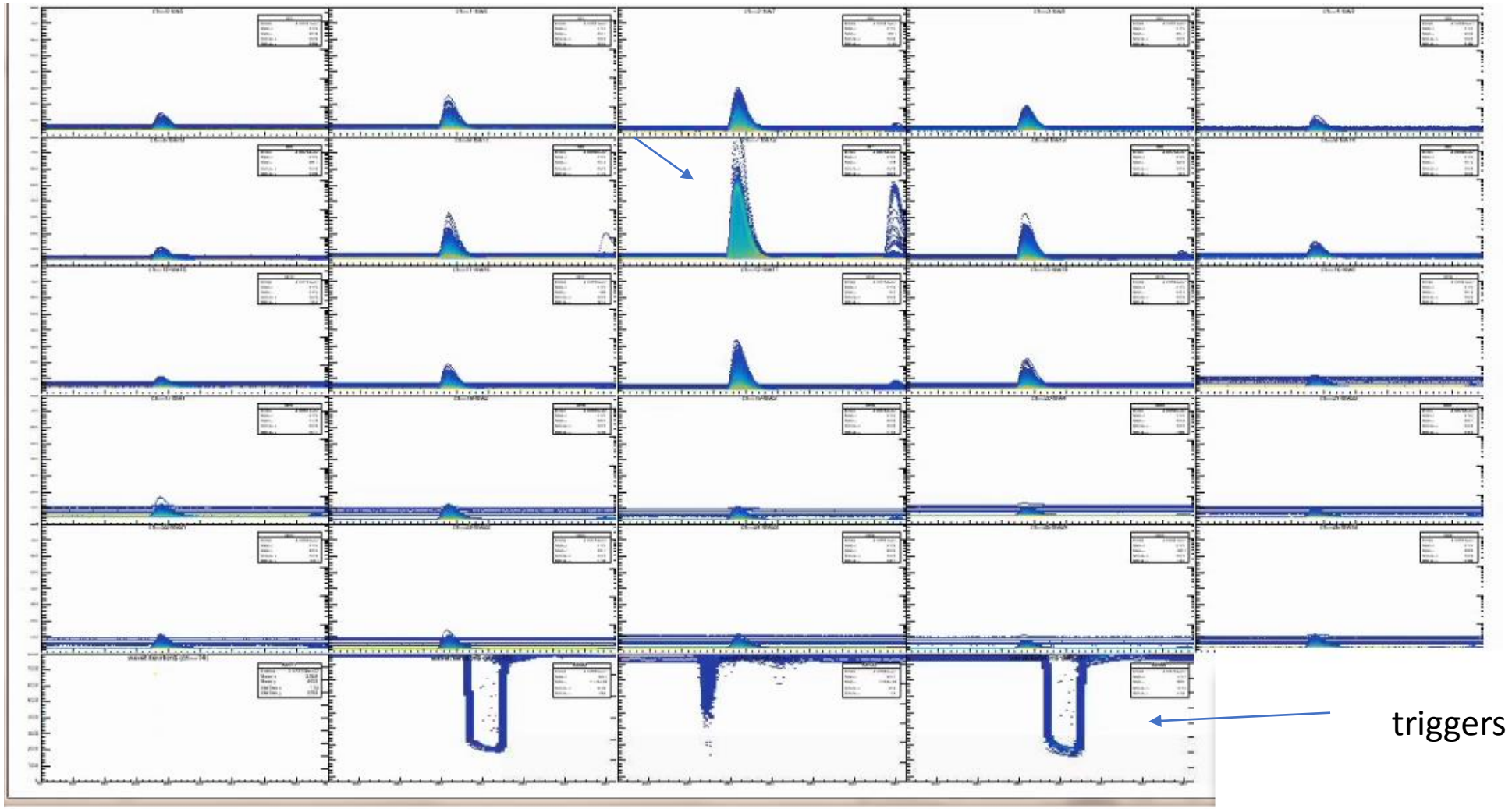
Wave forms

- Second v2ohio set: ~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
- Other wf's appear small % of time



Time stability across all channels

- Example file from ~4 Gev center crystal “12” [13 in Orsay convention] for us this is Caen channel **7** out of 32



Layout of Daq Channels

Basic idea crystal→16-ch digi board mapping: put central core (yellow box) all on same board (b1) in case of 2-board synchronization issues

Originally on 2/20: those in yellow box:
these 15 are on the left v1725s in increasing numerical order from top of board to bottom

crys#-bV70ch# ; crys#-bV69ch#/absCh#

5-0 0-0/16
6-1, 1-1 /17
7-2 … 4-4/20
8-3, 20 – 5/21
9-4, 21-6/22
10-5 22-7 /23
11-6 23-8 /24
12-7 24-9 /25
13-8 …
14-9 trigger logic signal:-15/31
15-10
16-11
17-12
18-13
19-14
trigger logic signal -15

the right column is crystals going into board 2 (v69) going into the boards ch # first relative to itself, then after the "/", the ch# in the software system convention which has channels going from 0-31, 0-15 b1, 16-31 b2 ie crystal 23 is is readout by ch 8 on b2 (bV69(

Map of crystals in Caen/Discrete Cable System

4	9	14	19	24
3	8	13	18	23
2	7	12	17	22
1	6	11	16	21
0	5	10	15	20

Note Orsay group refers to crystal locations with +1 of the above numbers on the map – (ie. lower left is 1 going up 2,…)

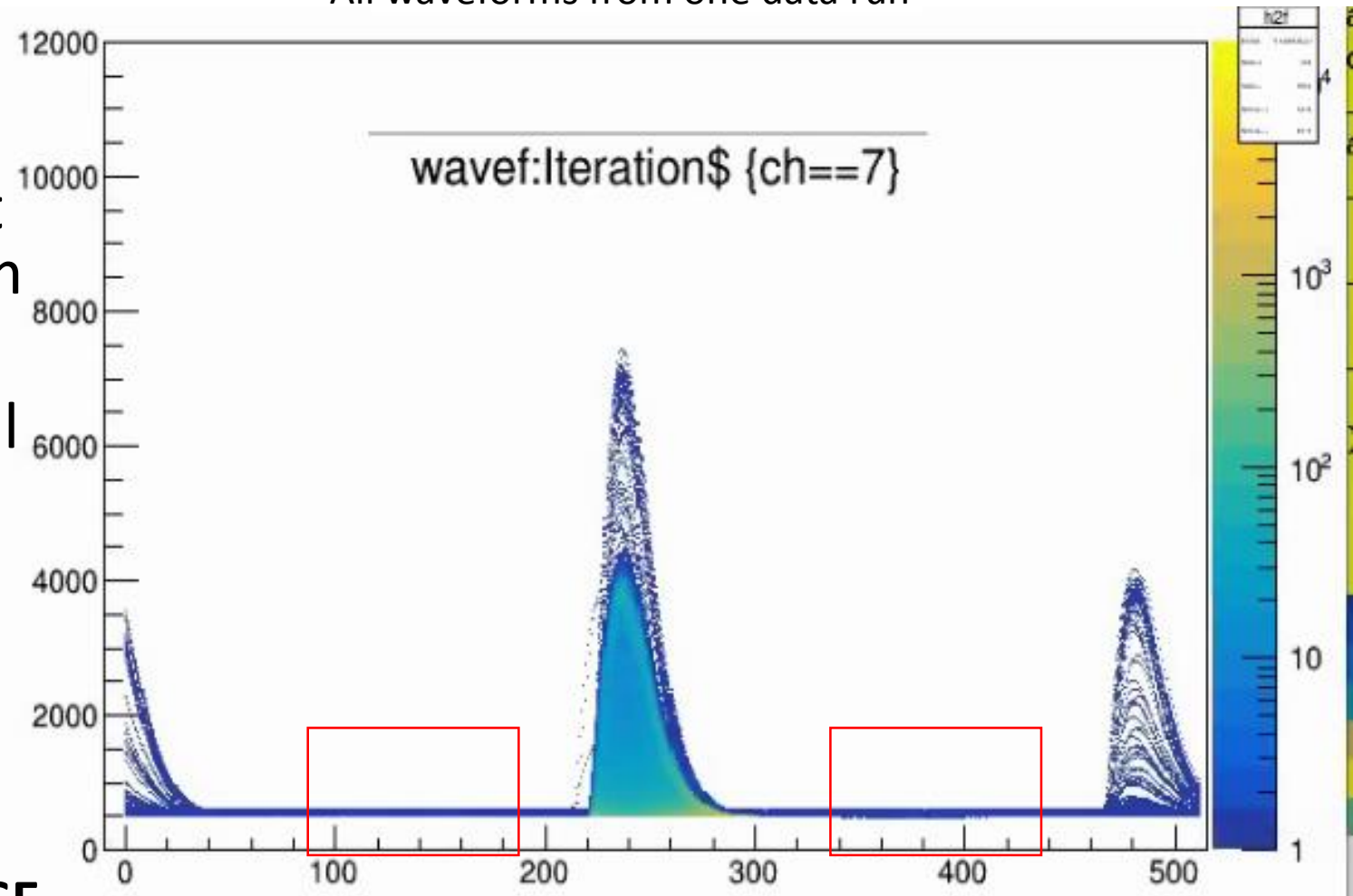
Starting on 2/21/25 we decided to also put copies of the analog trigger signal in both boards to allow 2-board synchronization checks.
-So we moved only crystal 19 over to board 2 (bV69) (ch10) and put both copies of analog trigger signals in ch 14
-THIS IS CONFIG ALL DATA WAS TAKEN WITH EXCEPT TESTING THURS NIGHT

After (2/21/2025-?)
5-0 0-0 /16
6-1, 1-1 /17
7-2 … 4-4/20
8-3, 20 – 5/21
9-4, 21-6/22
10-5 22-7 /23
11-6 23-8/24
12-7 24-9/25
13-8 19-10/26
14-9
15-10 trigger analog signal:-15/31
16-11 trigger logic signal:-15/31
17-12
18-13
trigger analog signal -14
trigger logic signal -15

Wave forms → Amplitude

- Several schemes tried , not much variation with any scheme
- E.g. initially used wf Max without pedestal sub (subtracted ped sum over all channels at end)
- Then subtracted average pedestal
- Final results using wf by wf pedestal subtraction and:
  - 1) Finding max sample in pulse region (220-~300)
  - 2) Integrating wf pulse region (~200,300)
  - **Method 2 performs slightly <u>WORSE</u> but pretty consistent– see later slides**

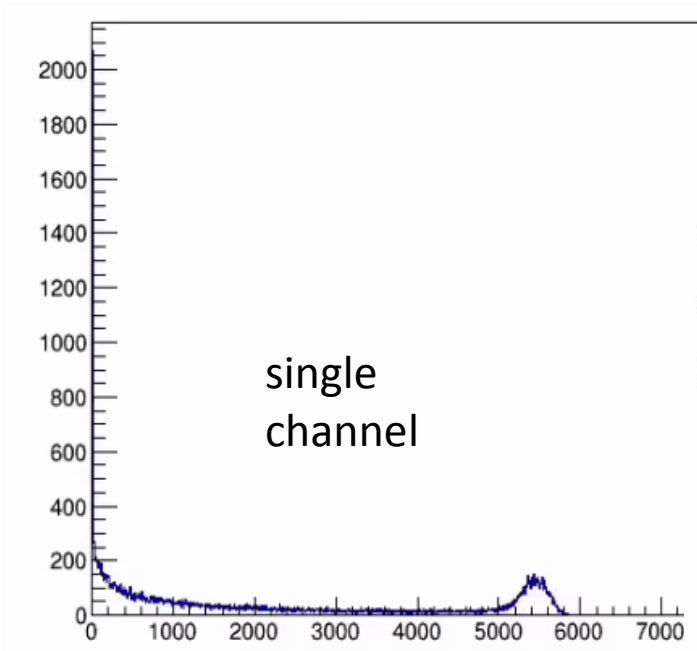
All waveforms from one data run

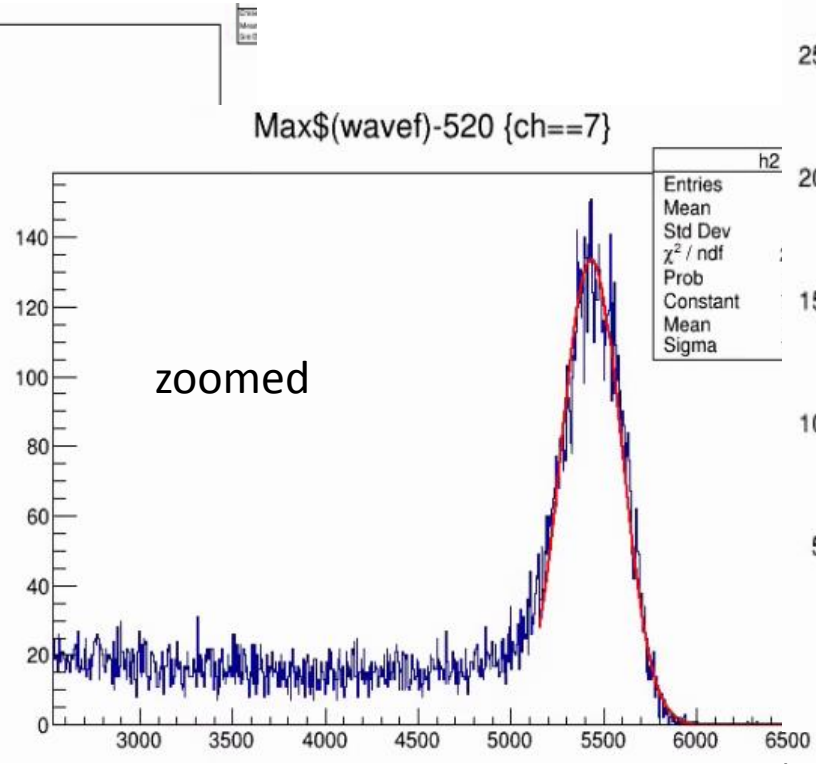


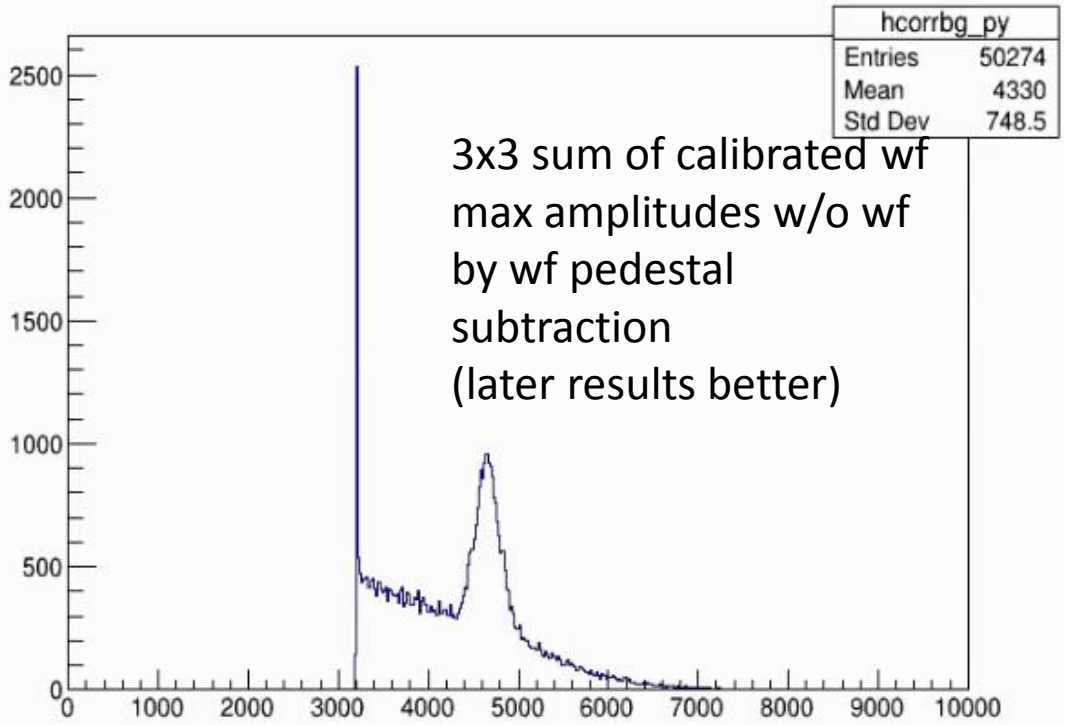
pedestal value from 80 samples before and after pulse region (160 samples total)

Wf Amplitudes→ Distributions

- The distributions for each data run (energy) of wf amplitudes (max's or integral) are plotted, peak is found and fitted to find peak locations (for calibration/ adc->E) and widths (for resolutions)
- A simple Gaussian is always used for this fit. Twice fit, 2nd fit uses 2 sigma range from first fit. - 2sigma "core" resolutions







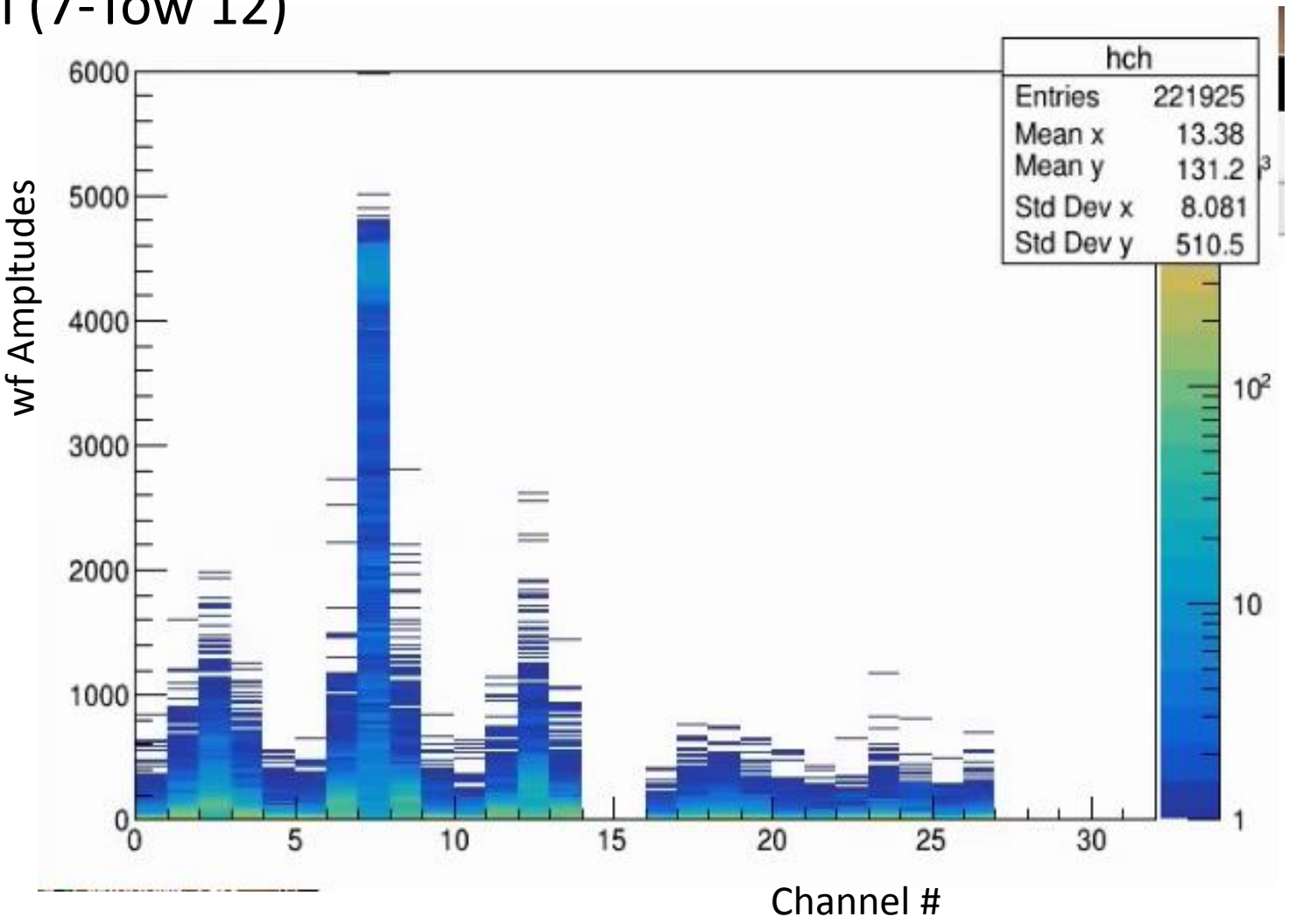
Other Details

- Some other details are discussed at end of these slides, **after** the results are shown
- Such as
- Calibration
  - Beam was scanned over all towers/crystals, centered in each crystal, for calibration. (25 Runs one for each tower and one energy)
  - Mean peak location in wf amp distribution for each tower is found, calibration adjusts energies for each crystal so peak is always in same location
- Syncing
  - The Caen Sends Up Each Channel one at a time with a timestamp. All fired channels with same timestamp are from same trigger. Channels usually come in groups of 16 (one for each board) but boards but board order frequently changes. And maybe not always coming in board groupings, possible some channels never come for small amount of triggers.
  - 32 Channels from each trigger need sync'd
  - Syncing code tested in some different ways, it is almost certainly robust enough for now, might need some further improvement

Amplitudes from Each Channel

- Fitting for resolution is done for :
- Center Crystal Single Channel (7-Tow 12)
- 3x3 Around/Incl Center
- Full 5x5

- In the later cases, each sync'd "event"/trigger—
-- group of syncd32 channels
-- have their amplitudes added together



Outline of Results

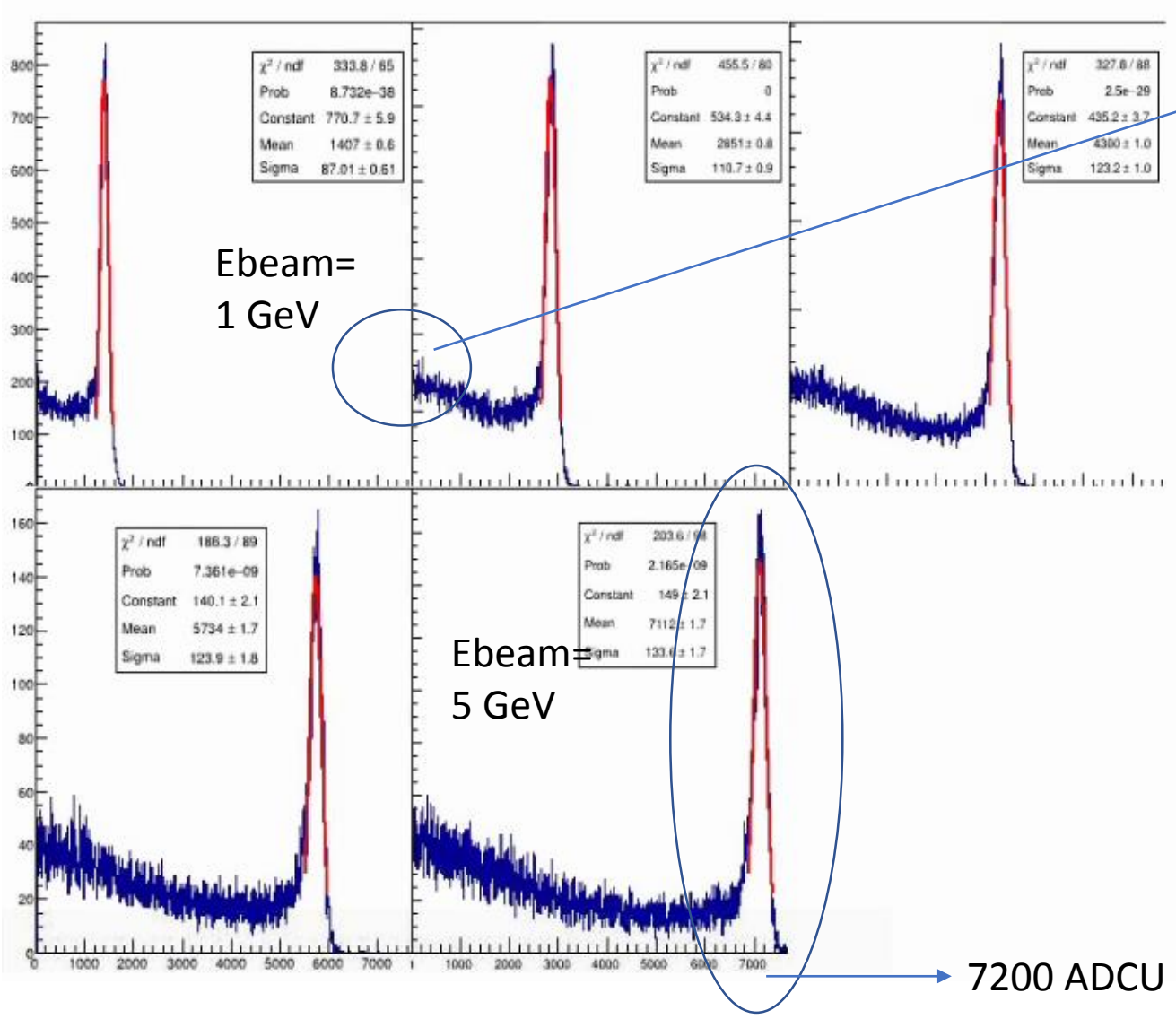
- Below I show:
  - Resolutions for single 1 tow, 3x3, full 5x5
  - Resolution/gain when changing bias voltage to 43.0 V instead of nominal (42.0V)
  - Some little look at very small signal performance / noise

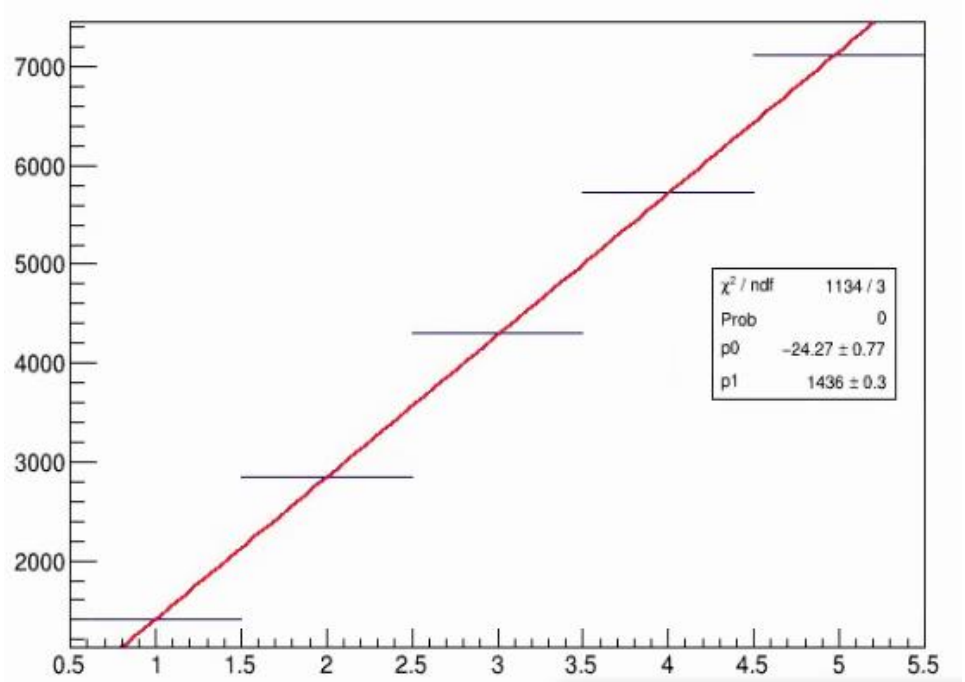
Fits / Mean/Calibration

Even w/ waveform by wf pedestal subtraction E sums still have small pedestal which is subtracted and distribution is shifted left for fits shown

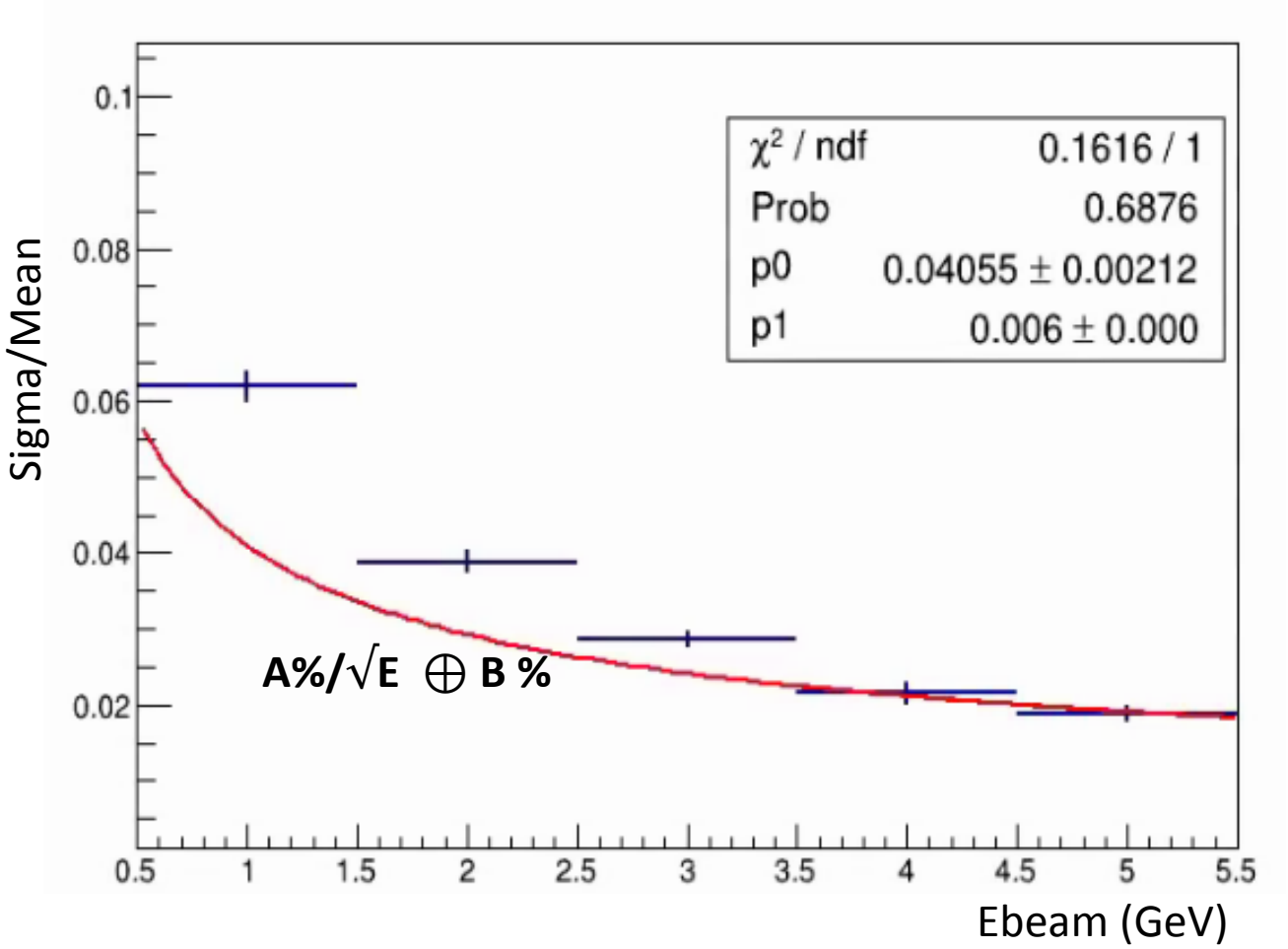
-Sum Pedestal w/ wf-by-wf sub : ~100-200

-Sum Pedestal w/ no ped sub = ~2000-3000





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

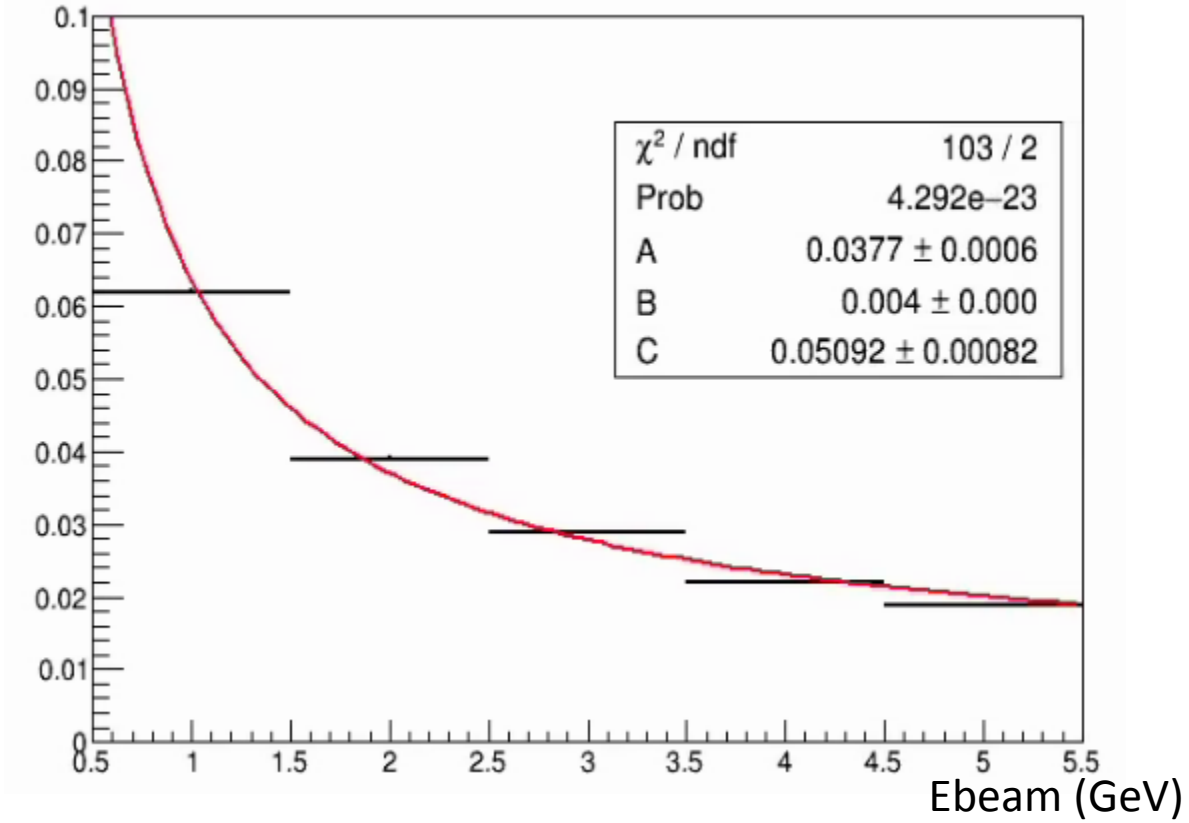
- Standard form does not fit well : **A%/√E ⊕ B %**

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

Alt Fitting -

- For remaining plots I use and 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



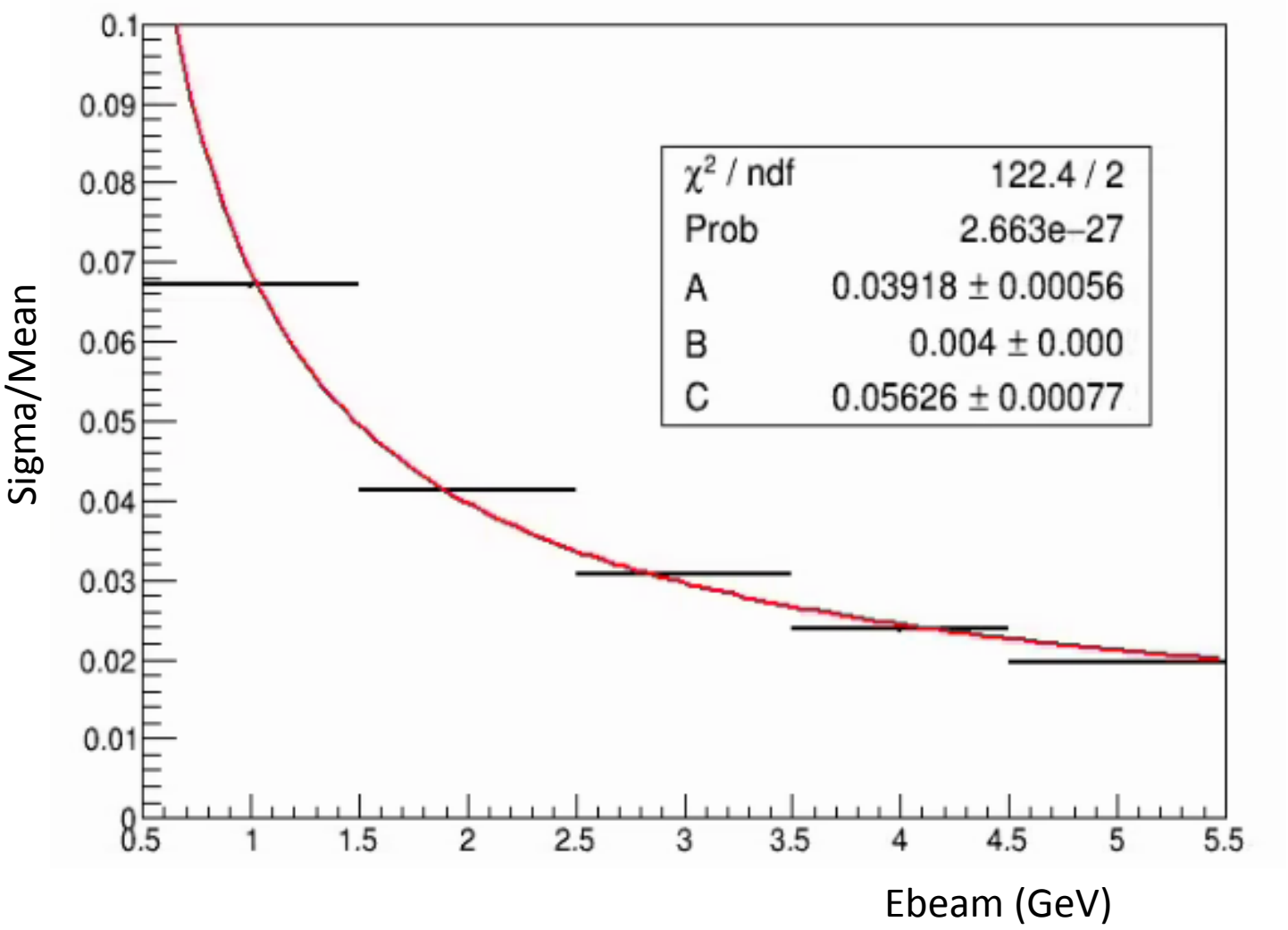
Alt Fit form

: **A%/√E ⊕ B % ⊕ C % / E**

(fixing B term to 0.4% -- does not affect other parameters ~at all, even if forced to 1.5 %ish)

5x5 Resolution Using Integrated WF's

- integration of waveforms instead of max

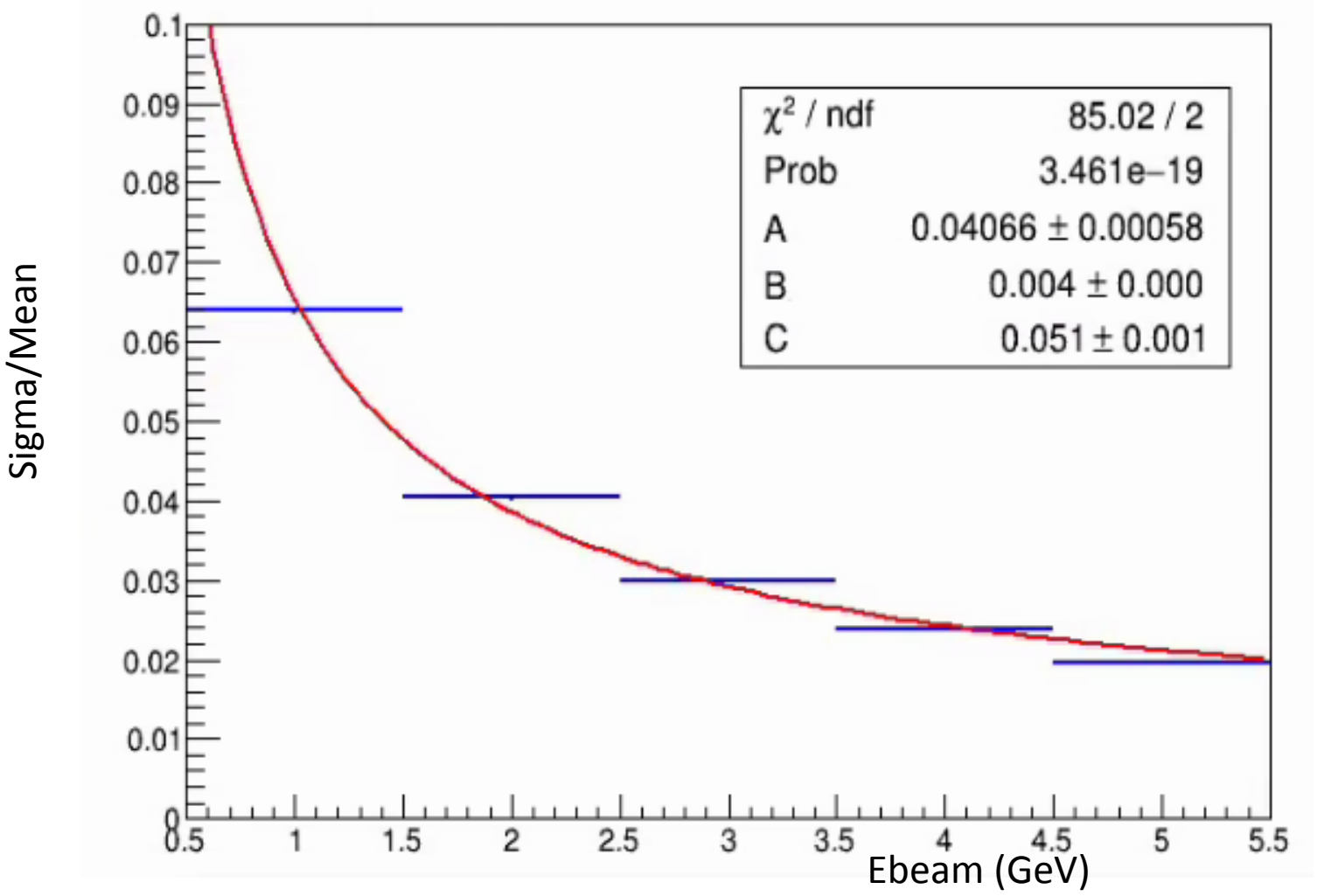


- Almost same, but slightly worse:

Reso 1GeV :0.0671
Reso 2GeV :0.0413
Reso 3GeV :0.0308
Reso 4GeV :0.0237
Reso 5GeV :0.0196

Center 3x3 Resolution

- Resolutions worsen but only slightly by about 0.1- 0.3% larger only

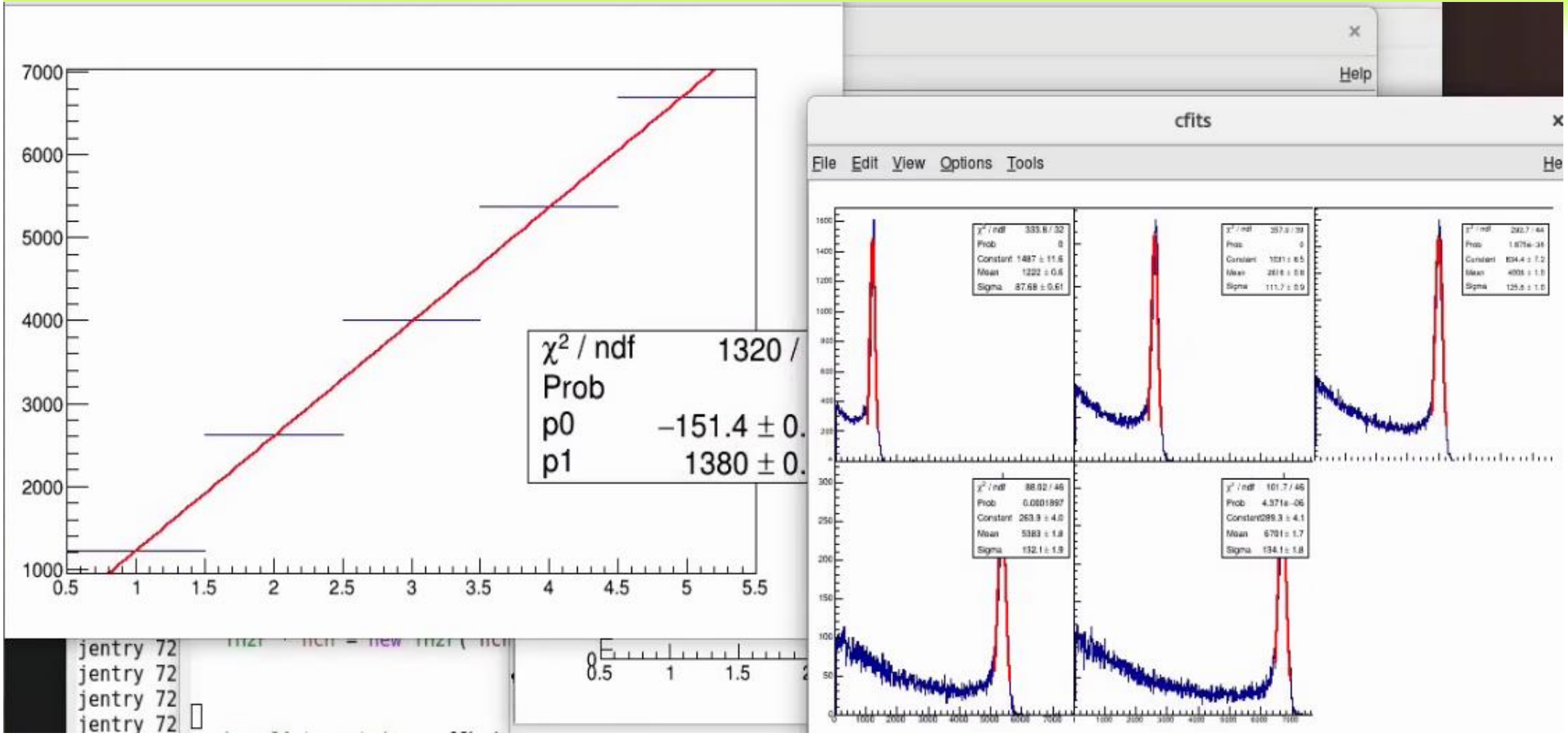


Reso 1GeV :0.0640
Reso 2GeV :0.0404
Reso 3GeV :0.0298
Reso 4GeV :0.0239
Reso 5GeV :0.0196

Expectations ?

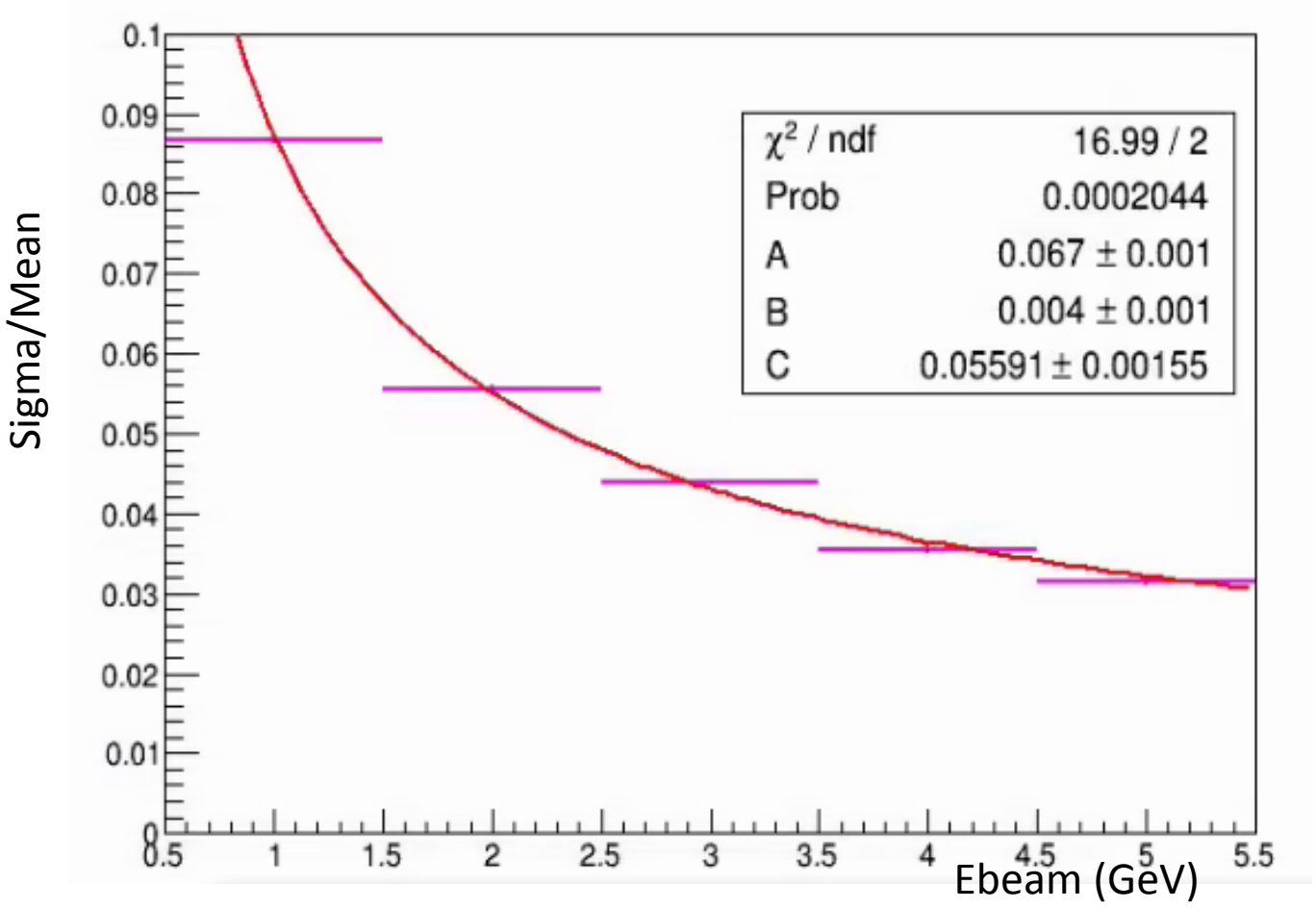
~Consistent (probly) w/ size of outer most 16 tow ring energy sum compared to inner 3x3 (see later slides)

Fits/Means for 3x3



Center Tower Single Crystal Resolution

- Worsens considerably… not 1.3 % at 5 GeV but rather ~3%.

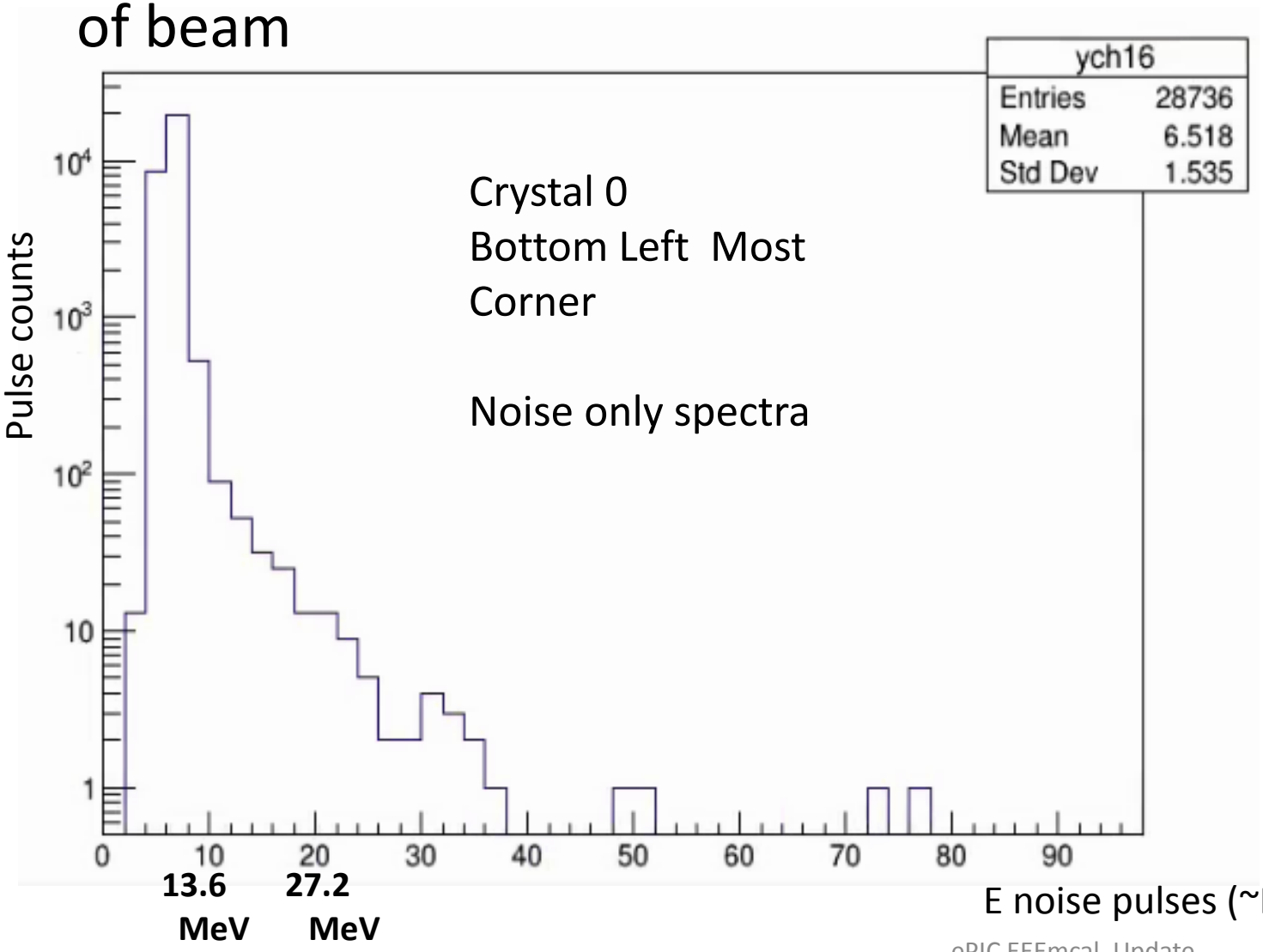


Reso 1GeV :0.0868
Reso 2GeV :0.0557
Reso 3GeV :0.0439
Reso 4GeV :0.0355
Reso 5GeV :0.0314

Energies in Center vs next outer ring of 8 in the 3x3 vs next outer ring of 16 crystals are nicely anti-correlated see later slides

Small Signal Study/Noise

- Took "noise-only" run with triggers firing but prototype lowered out of beam



Probably these boards were not optimized for small noise, but any way look at.

With calibration we can calibrate the x-axis from ADC to MEV

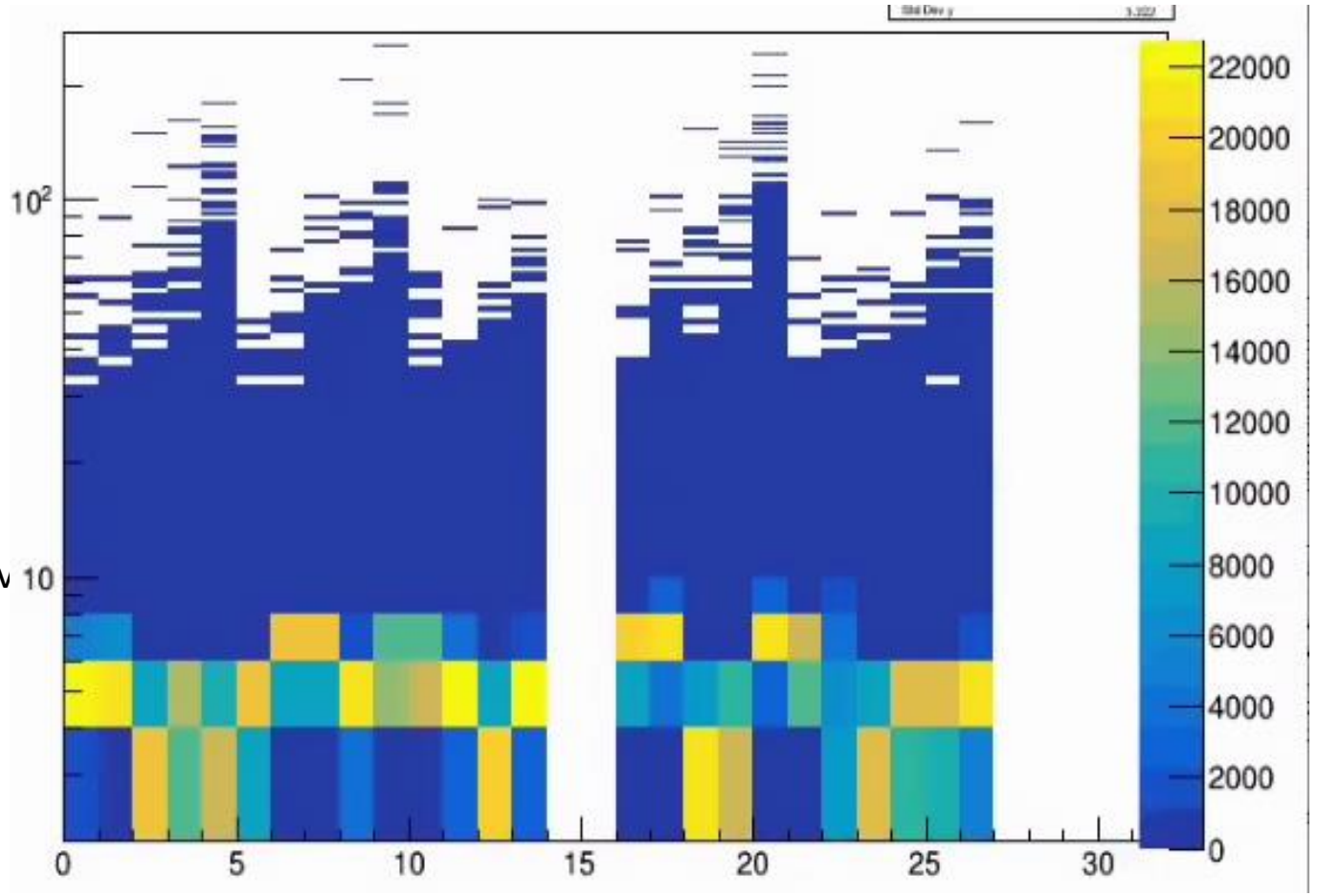
For this I used waveform integration method, calibration is 7.36 "ADCU" per MeV (1 ADC = 1.36 MeV)

*these adcu are 50 times sample adcu for convenience

"Significant" Noise up to ~13.6 MeV.

Small Signal Study/Noise- Chan Comparions

- Took "noise-only" run with triggers firing but prototype lowered out of beam



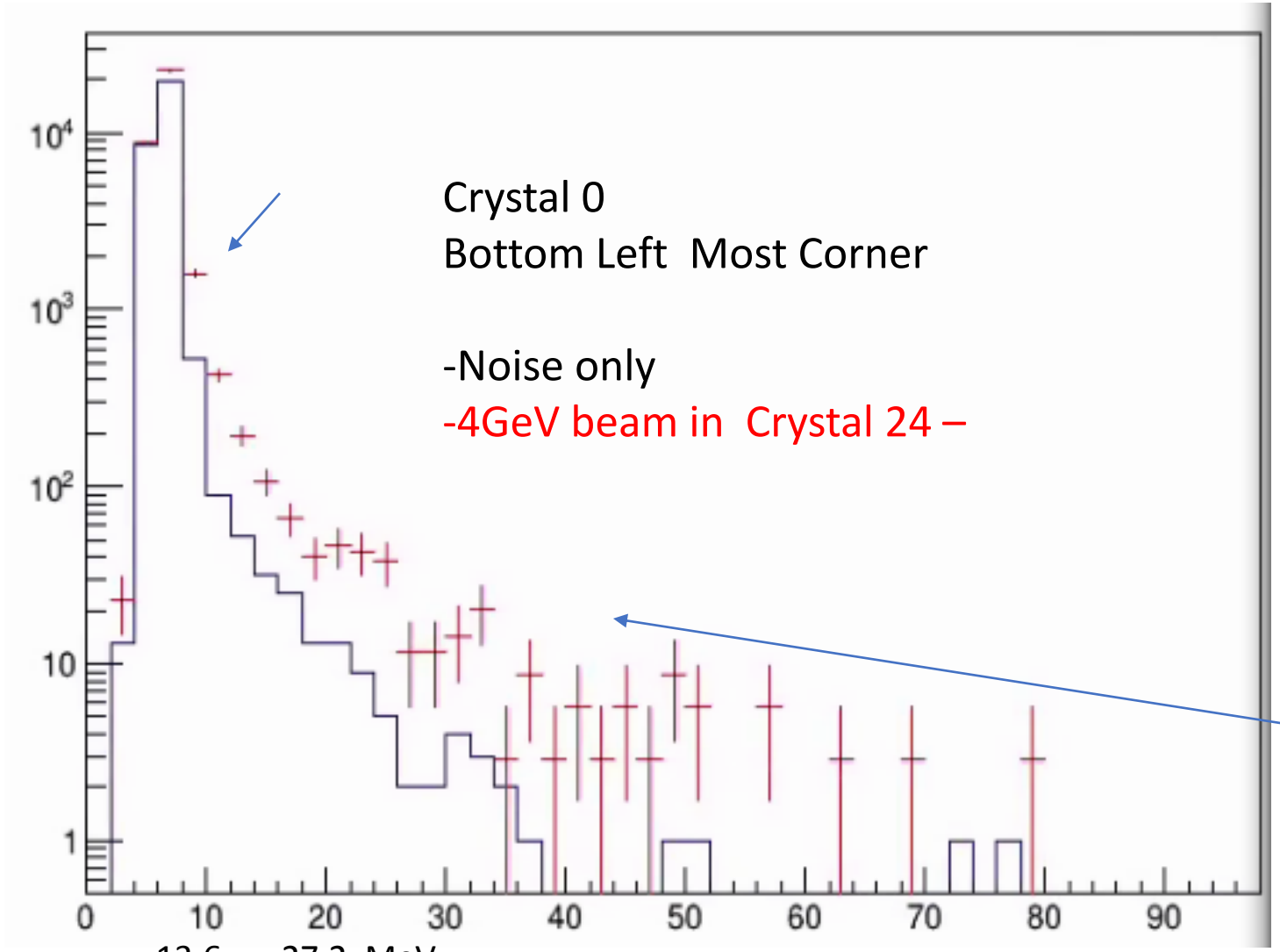
13.6 Mev

~Consistent for all channels

Some have lower e noise

Encouraging? for reducing noise further, already down to ~7-13 MeV → get to 5 MeV

Small Signal - Farthest Crystal



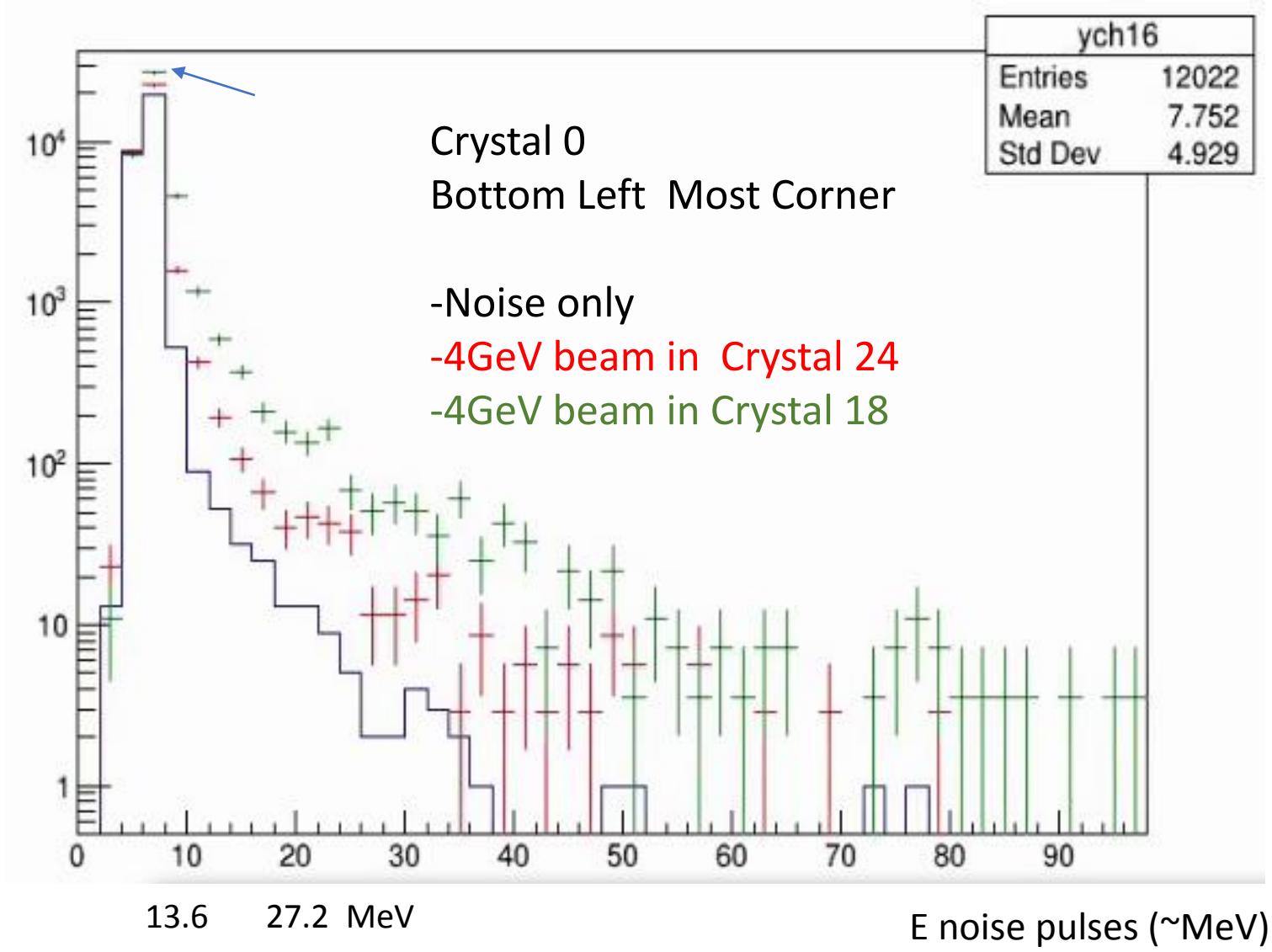
- Red points overlaid:
- Beam pointed at Crystal 24 (upper right most corner)
- (still looking at Tow 0)
- Small Signal Excess?
  - (normed at 2nd point from left- but very close stats there, norm factor ~O(1))
- 3:1 S/B at 11 MeV (9adc)?

4	9	14	19	24
3	8	13	18	23
2	7	12	17	22
1	6	11	16	21
0	5	10	15	20

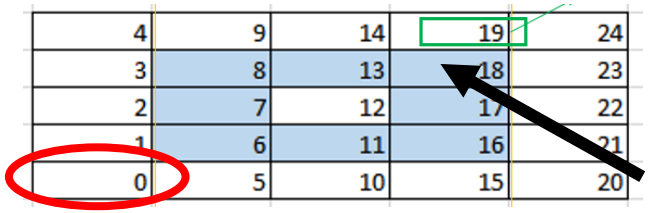
Beam

- Maybe still just changed noise from cross talk?

Slightly closer tower - small signal



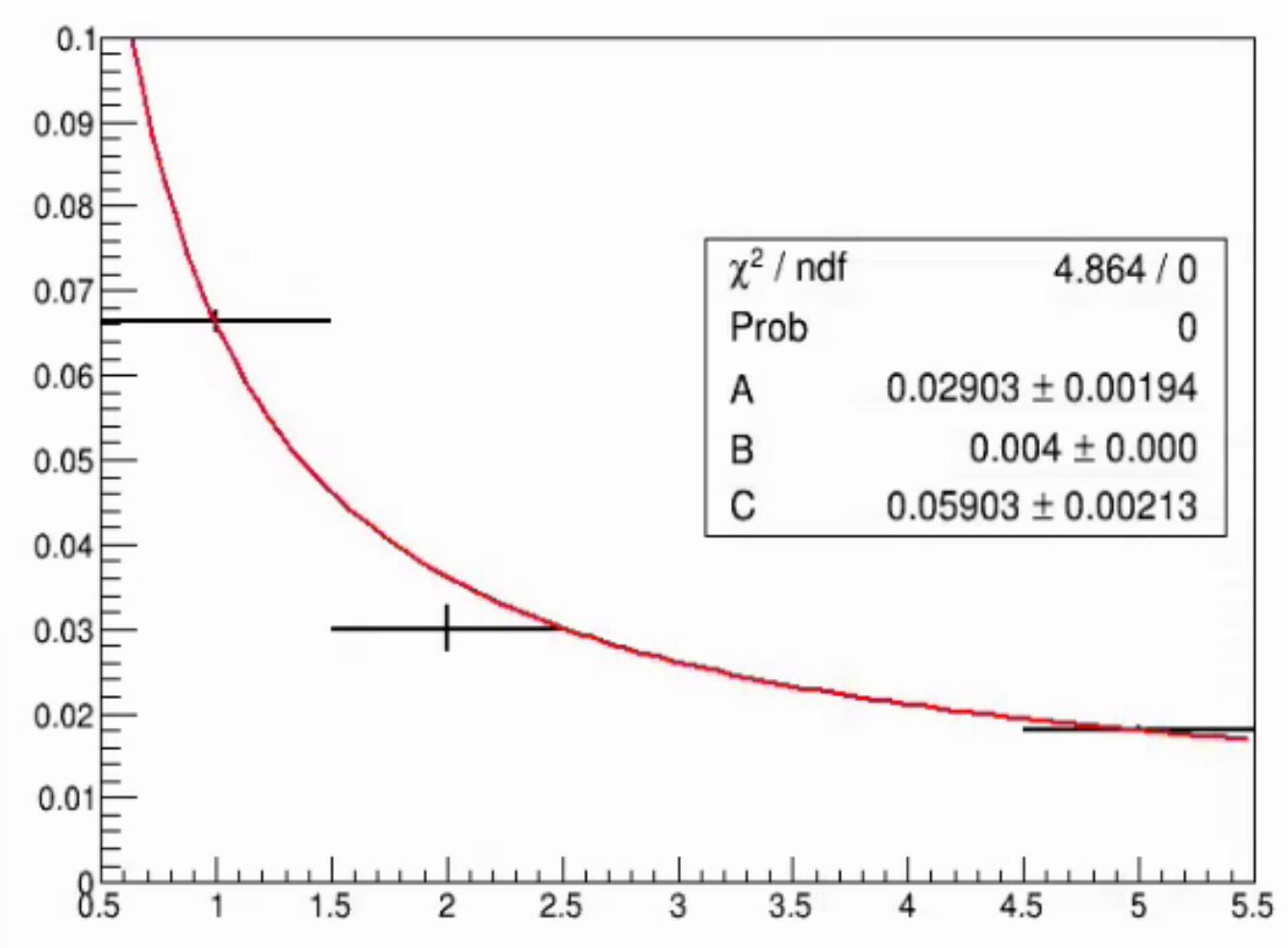
- Additional green points overlaid:
- Beam pointed at Crystal 18 – one diagonal closer
- (still looking at Tow 0)
- Signal Excess (2:1 @ 8 Mev)



- (next one, beam in tow 12 has ~flat high yield going way beyond adc 100)

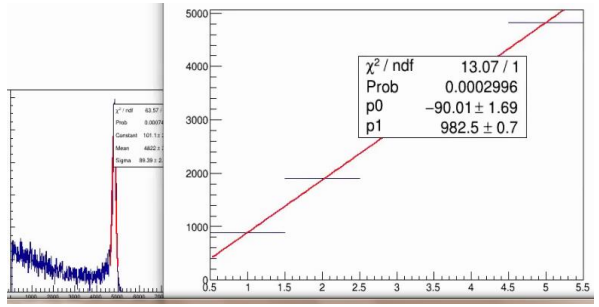
Alt Bias Voltage → We set to 43.0 V.

Took Small run with only 3 energies - Requested by Gerard– Use 43.0 V bias voltage rather than 42.0.



Reso 1GeV :0.0664
Reso 2GeV :0.0300
Reso 3GeV :0.0000
Reso 4GeV :0.0000
Reso 5GeV :0.0181

-Reso results virtually the same
-Gain definitely changes



736 adc/geV @42V → **982 adc/gev @ 43V**

Calibration (Calibration Flattening Away of Crystal-to-crystal Variations)

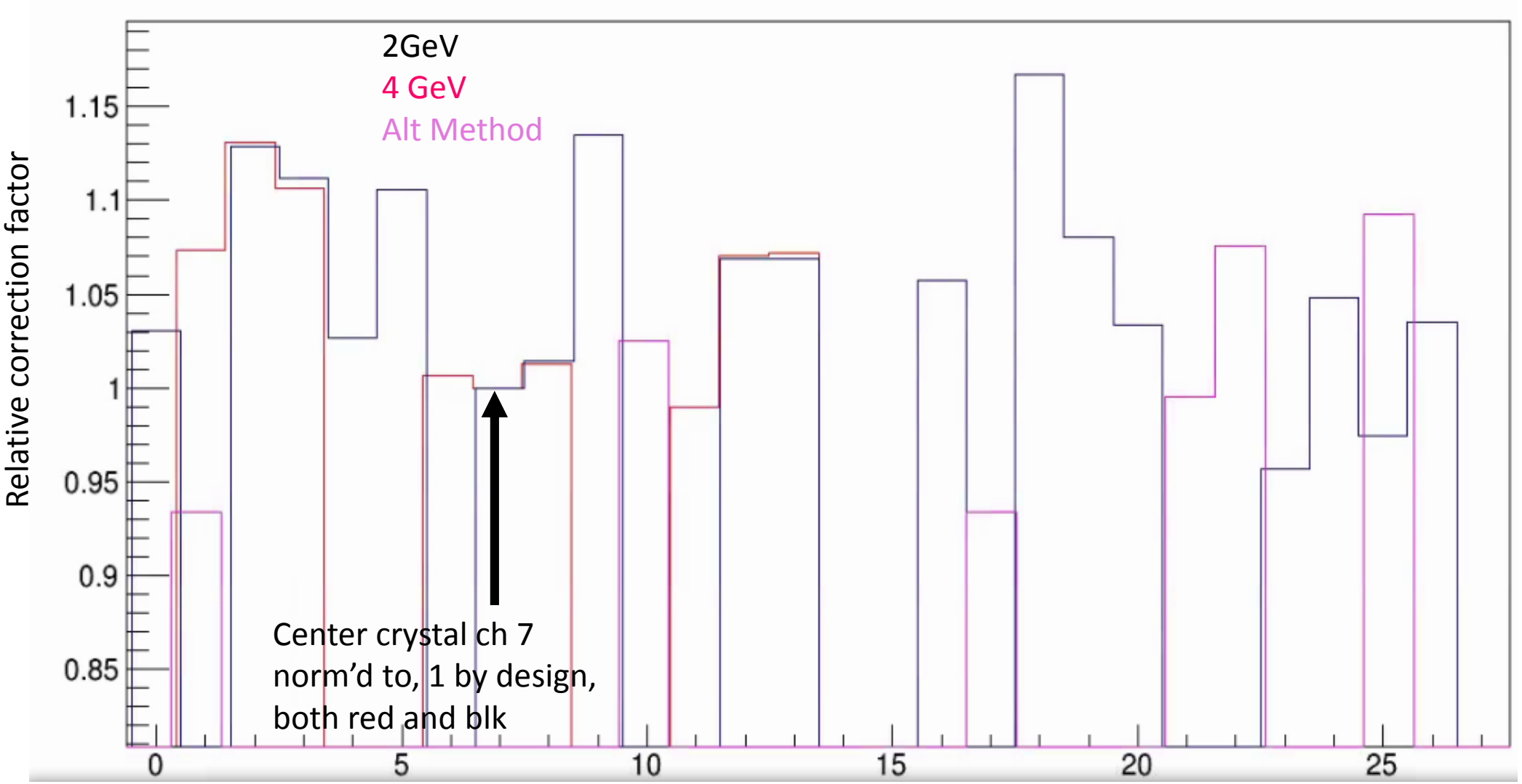
- With v2ohio Second data set more limited calibration data was taken
- 2GeV each crystal center data –some towers were missing (we went to dinner some misunderstanding, should've checked.)

  Relative Cal : Corrs w.r.t Channel 7 --> all tows same calib

- 4 GeV purposely only took central 3x3 plus a few to save time (also used 5x5 collimator for this data, increased data rate by ~8 times ~1 kHz – because it was getting very late on Monday night and I had to leave ~5am Tues morning.
  - (900 Hz "high" rate, ~no effect?)
- ~two towers(/crystals) in outer most ring, use 4 gev diagonal tower away data files for relative/flattening calibration.

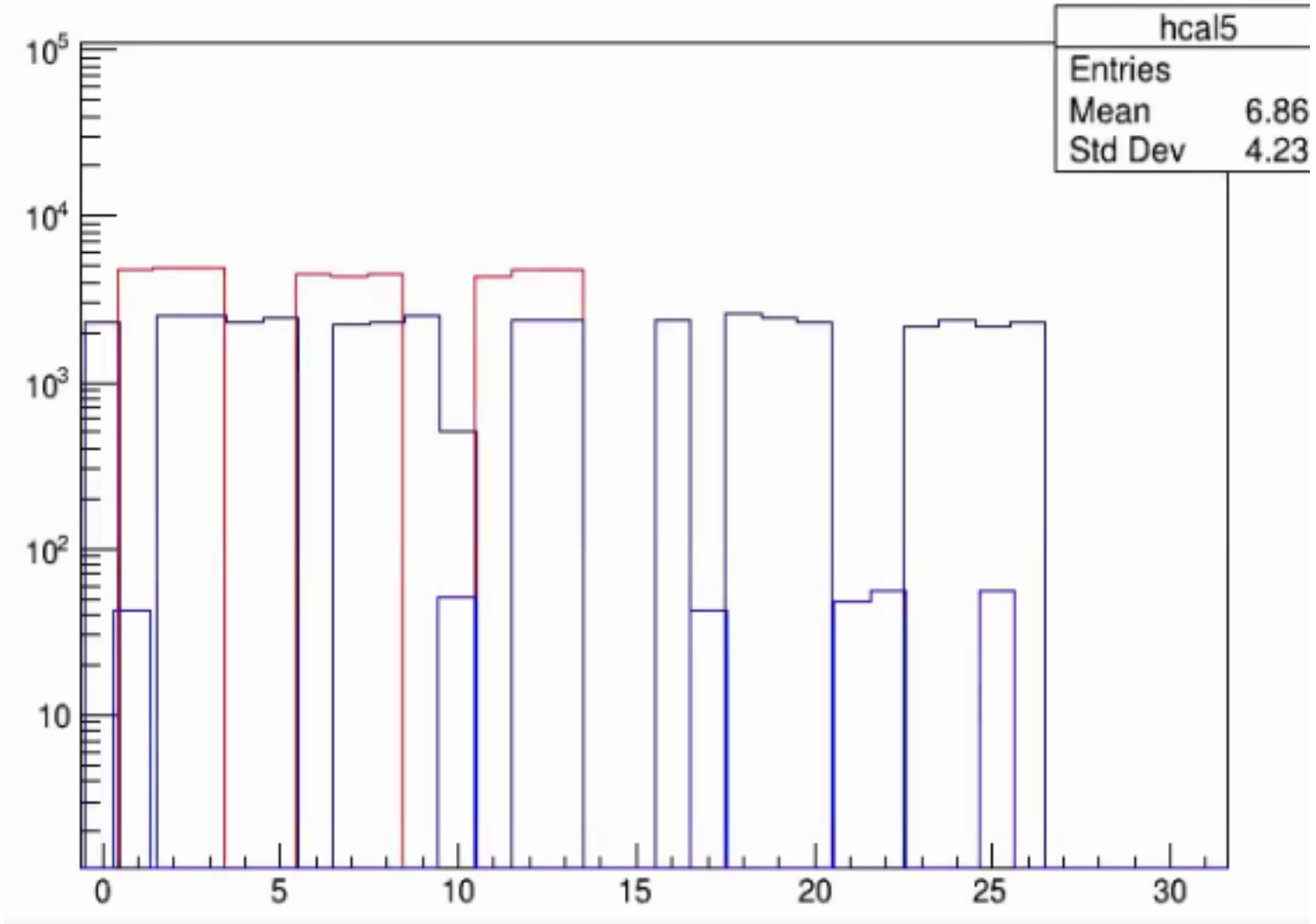
- For cases of good 2 GeV and 4 GeV calib files, relative calibration agrees almost exactly.
  - If calibration is dominated by siPM's only, not preamp daughter boards (which were randomly located differently in v2ohio second data set) first set of calibration data could be used for better calibration

Final relative (flattening) calibration factors



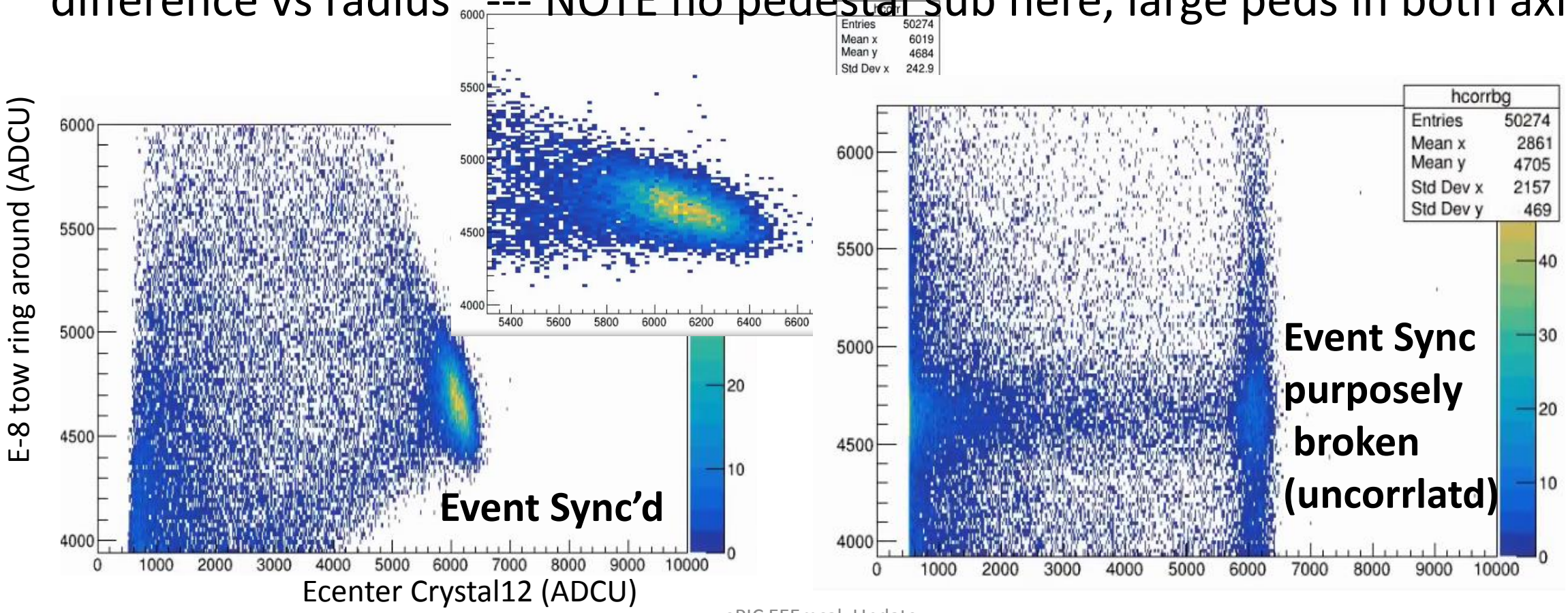
Calibration Fits

- Peak locations from fits that were used - note ch 14 & 15 are trigger channels



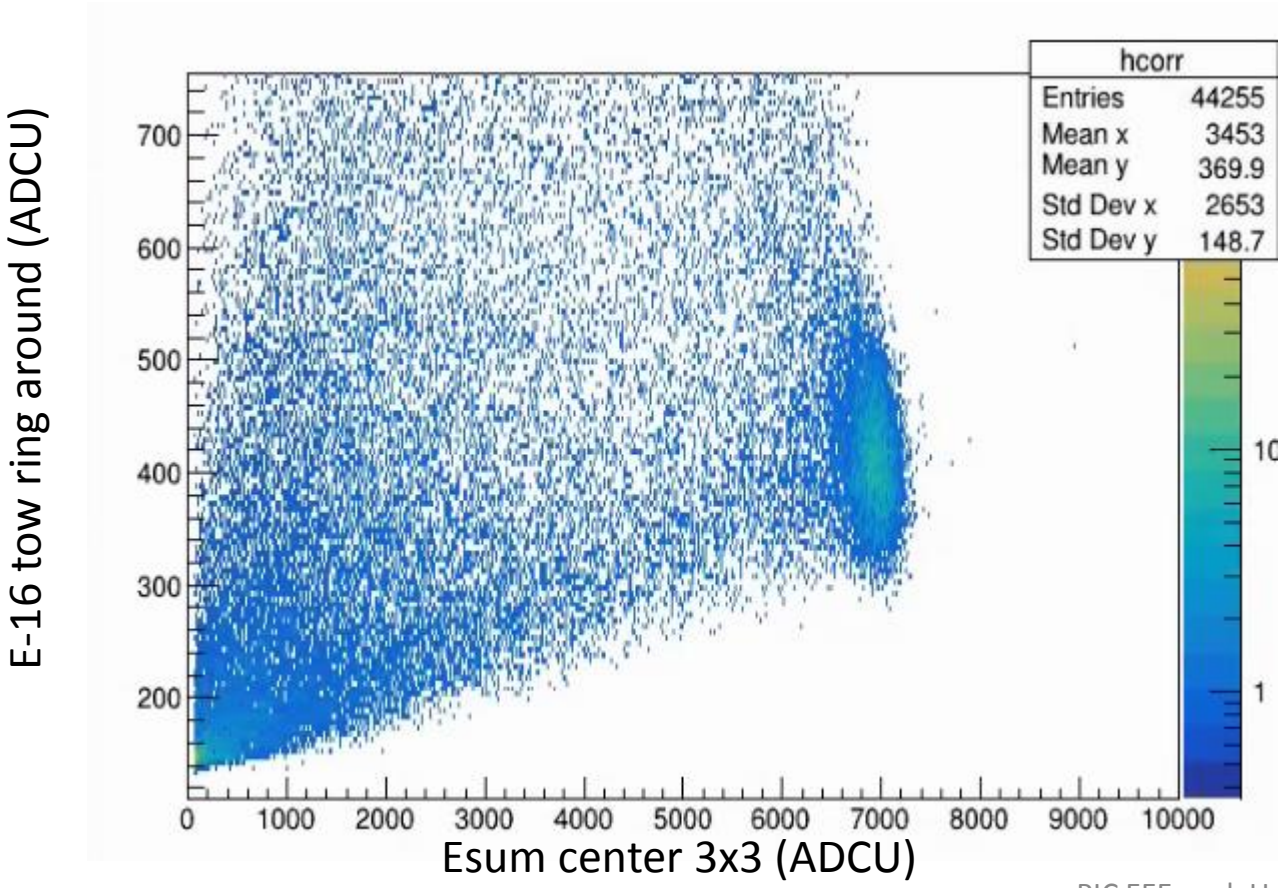
Correlations of Center -> Rings Energy

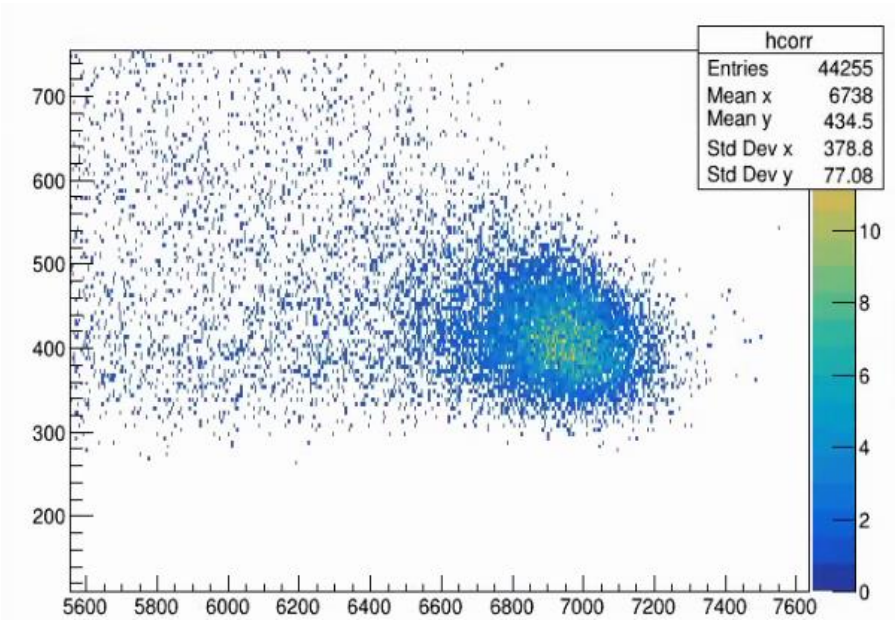
- Mostly to test event syncing, looked at correlations:
- Here: **E center crystal vs bordering 8 towers Esum in next ring outside it**
- Nice anti-correlation as expected – mean show rough comparison of Esize difference vs radius --- NOTE no pedestal sub here, large peds in both axis



Energy (Anti-)Correlation 3x3 to (5x5-3x3)

- Now full wf-by-wf pedestal subtraction→(needed to see this one)
- **E3x3sum vs E sum of 16tower ring boarding outside 3x3** (“r <=1 vs r= 2”)
- Only about on avg ~400 ADCU of E in outer ring vs 7000 in core 3x3

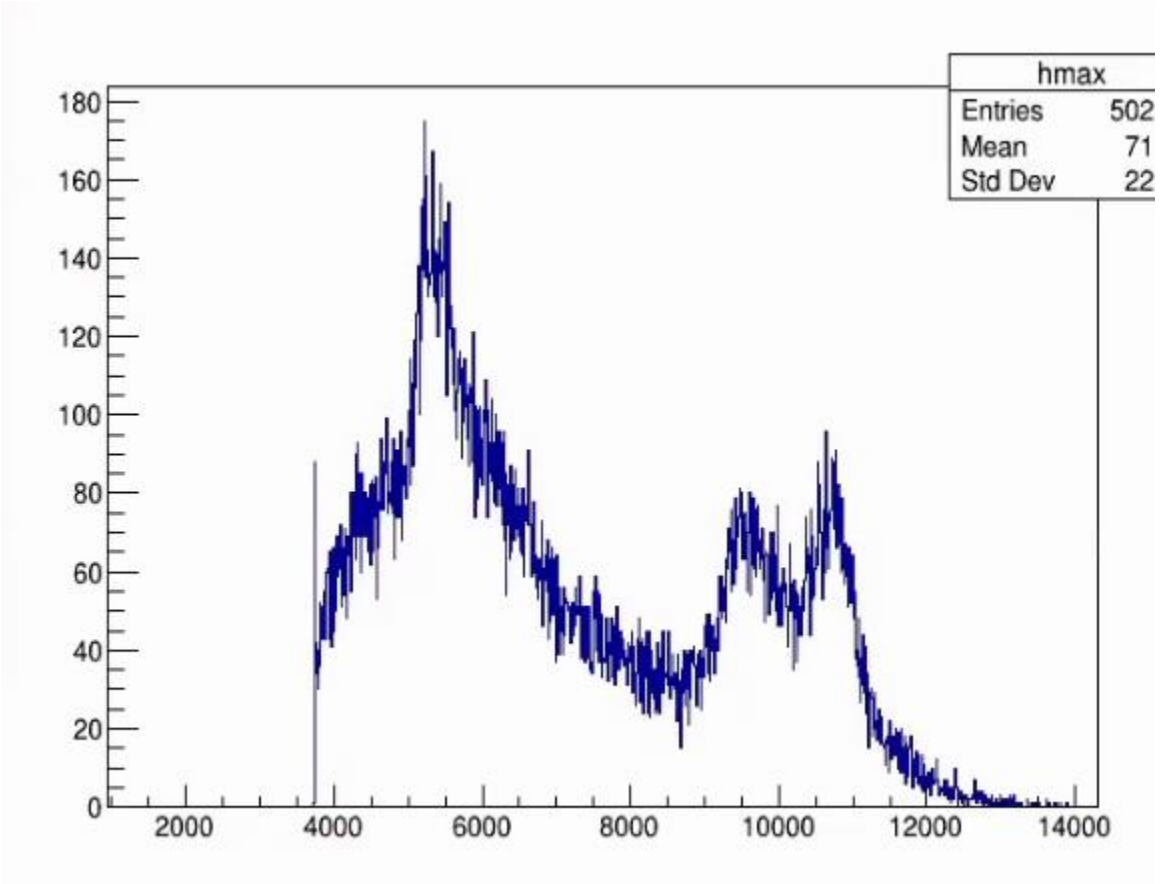




Outlook

- Still more analysis to be done:
- Finer position scan data (fractional tower size shifts), to look at in both data sets.
- Purposely worsen sampling to realistic EIC
- Analyze First data set for anything <= Ebeam 3 GeV (still good for that)
  - Includes very high rate 12x12 m^2 collimater → ~3-5 KHz data
  - better calibration – see if siPM dominated?
  - More detailed fine position scans done, e.g. sampled evenly over entire one tower “all locations” not just center
- …. probably forgetting some things to do too. address your comments

BAckup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Mean 71
Std Dev 22
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2000
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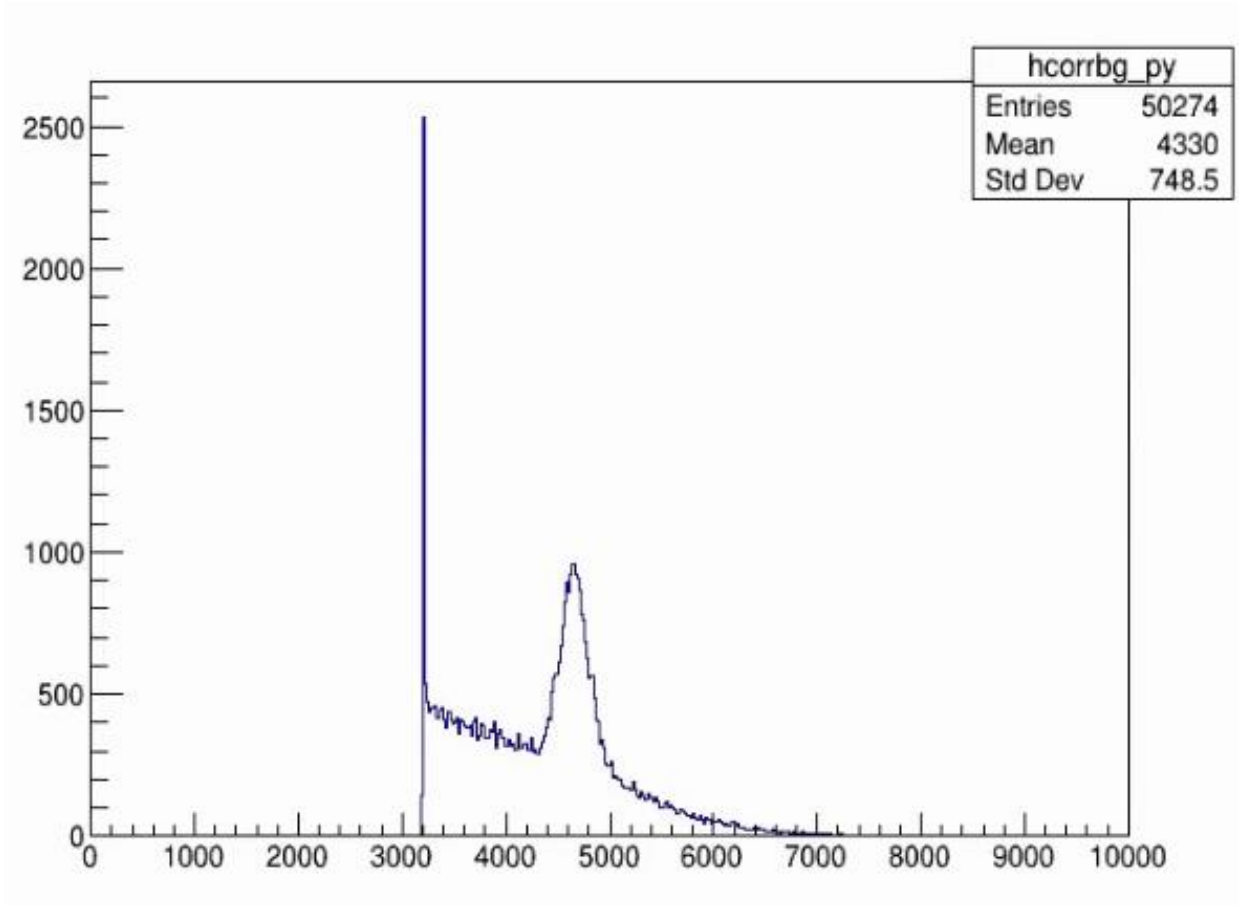
6000
8000
10000
12000
14000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Std Dev 748.5
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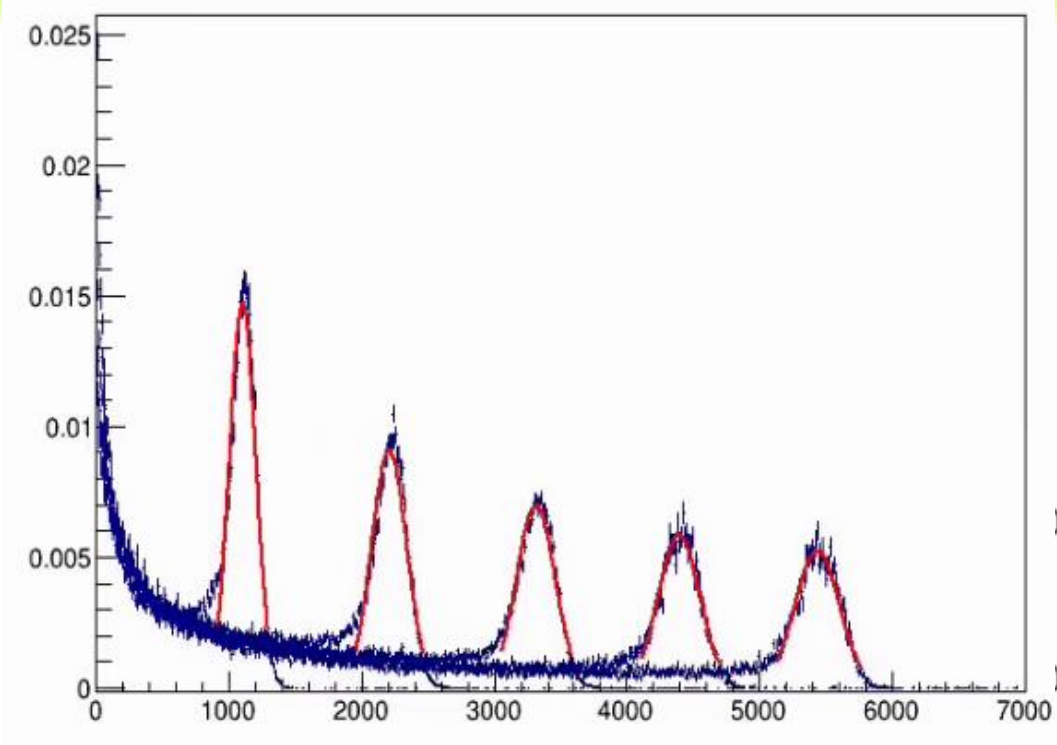
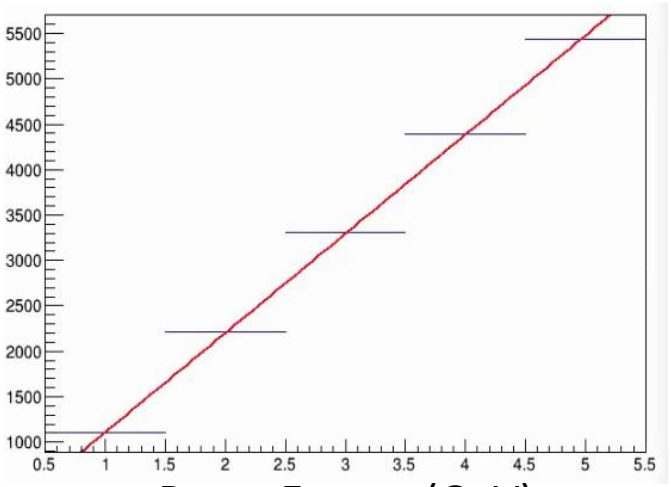
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

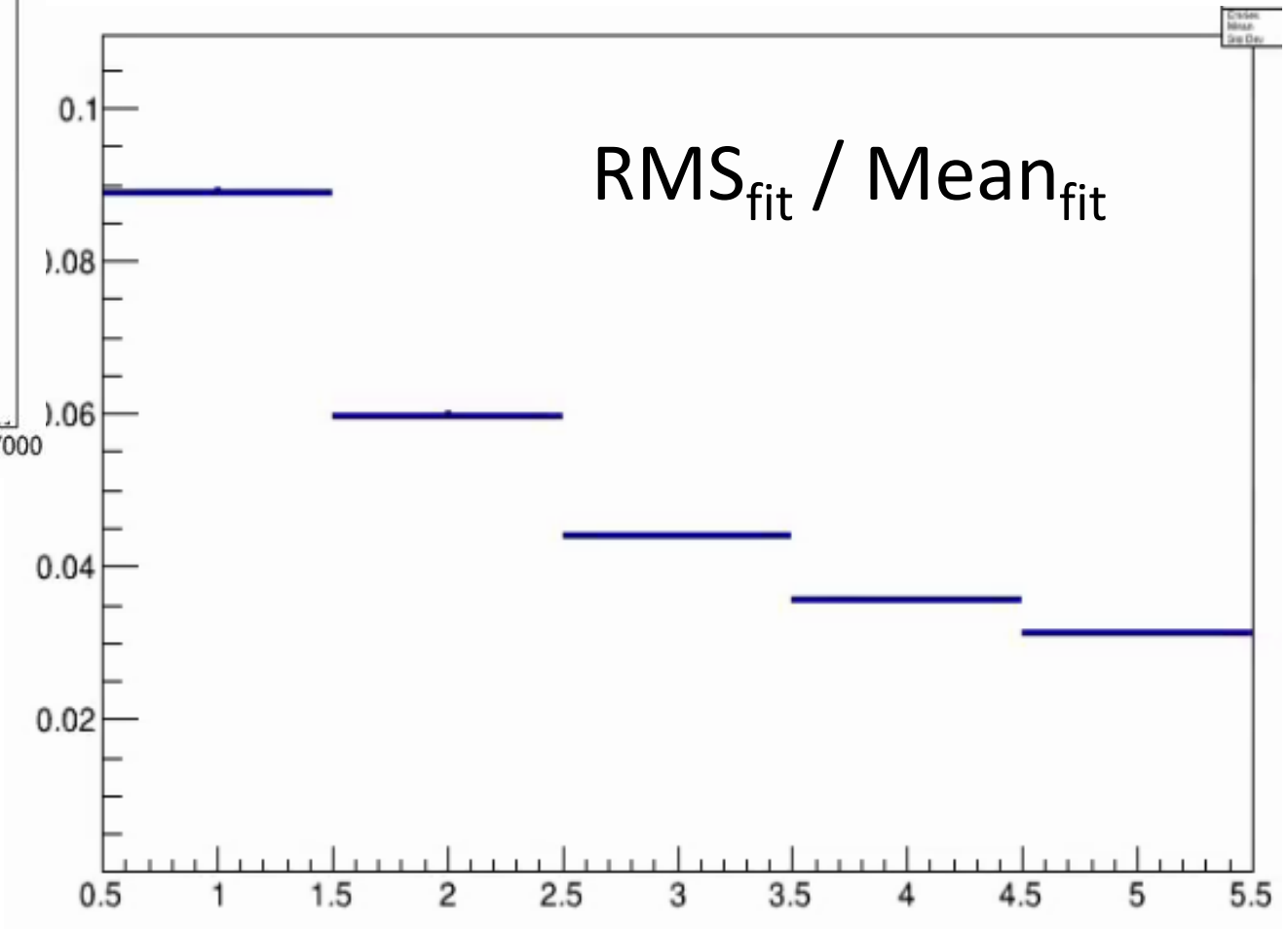
All bins (Single central crystal





Beam Energy (GeV)

- older ana w/ no pedestal sub
- but similar results



Beam Energy (GeV)