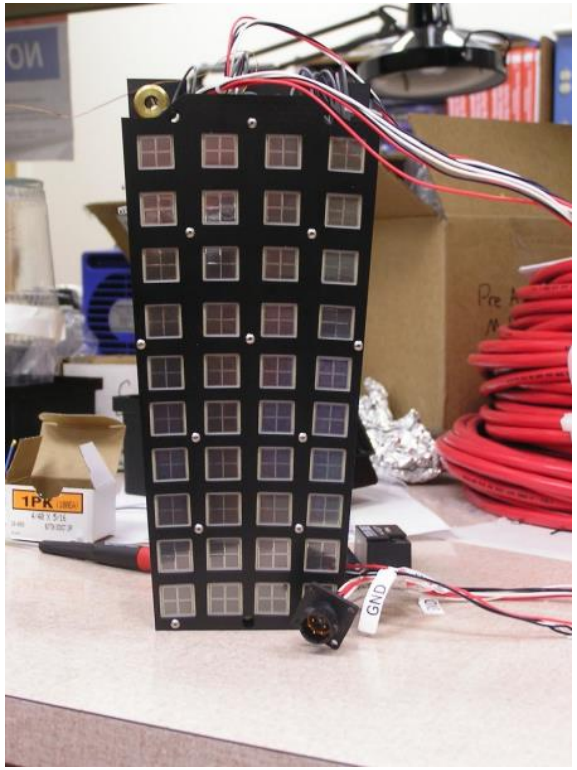
“Baby ” BCAL Progress Report

Maggie Kerr & Jon Zarling

7/11/23



Motivations

GlueX has good experience with EM showers up to about 2 GeV

"Baby BCAL" extends using 3-6 GeV positrons:

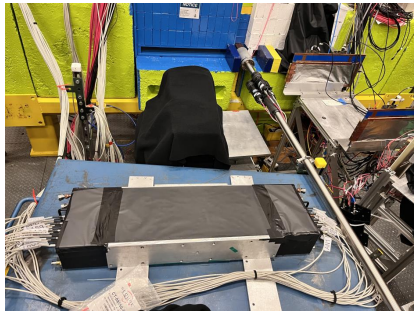
- Prep for future beam tests
- Better constrain constant term in energy resolution
- Extract $N_{p.e.}$ (number of photoelectrons)

Two Setups in JLab Hall D

March e^+ Beam

- GlueX fADCs and DAQ
- e^+ energy 3-6 GeV

- Goal: resolution studies & $N_{p.e.}$ extraction
- Upstream hodoscope to measure e^+ energy and trigger
- Largely uncalibrated prior



Fall Cosmics

- GlueX fADCs and DAQ
- Trigger on cosmics

- Goal: better gain determination for low occupancy channels
- Scintillator paddles above/below provide trigger
- Better geometric coverage for calibrations

e^+ Beam Setup

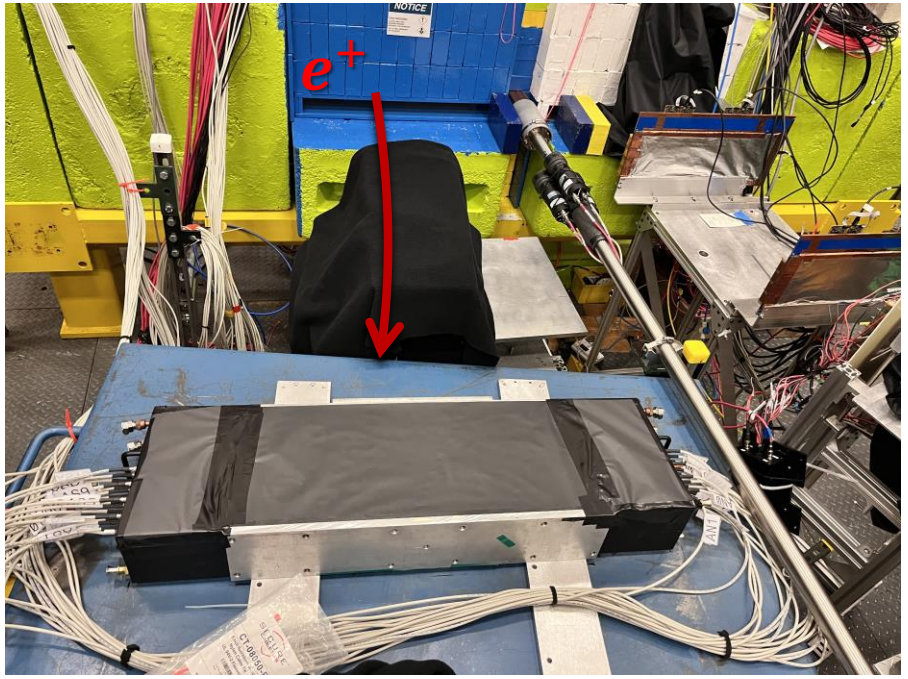
Good source of EM showers with known energy

Essentially identical to GlueX lead SciFi wedge, except 58 cm in length rather than 390 cm

Hall D pair spectrometer:

- e^+ energy roughly 3-6 GeV
- Unfortunately, SciGlass blocks portions
- About 1 kHz event rate BBCAL
- About 12 days (on and off) running

View from above



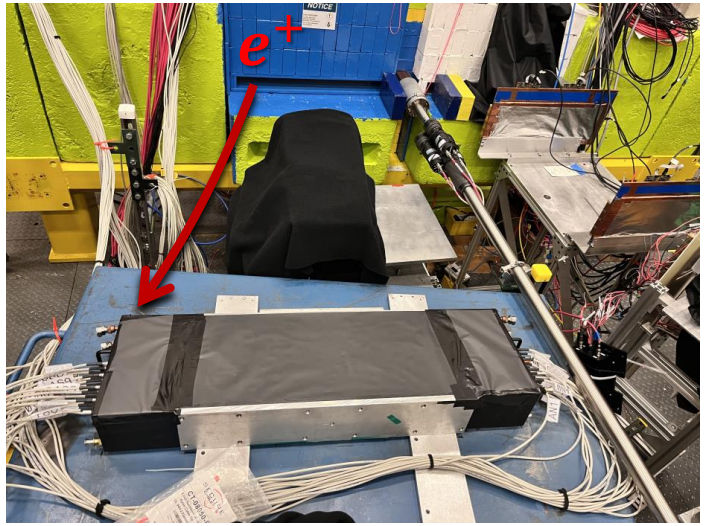
Baby BCAL Gains

- Minimize $F = \sum_i^{events} \left(E_i^{BCAL} - E^{PS} \right)^2$

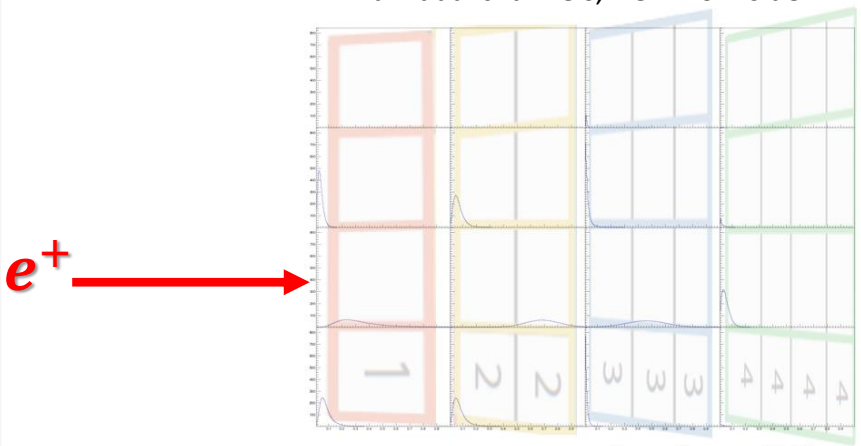
  E^{BCAL} is sum of north and south readouts
  $E^{BCAL} = \sum_j^{16} c_j \left(A_j^N + A_j^S \right) = \sum_j^{16} c_j \, A_j^{sum}$

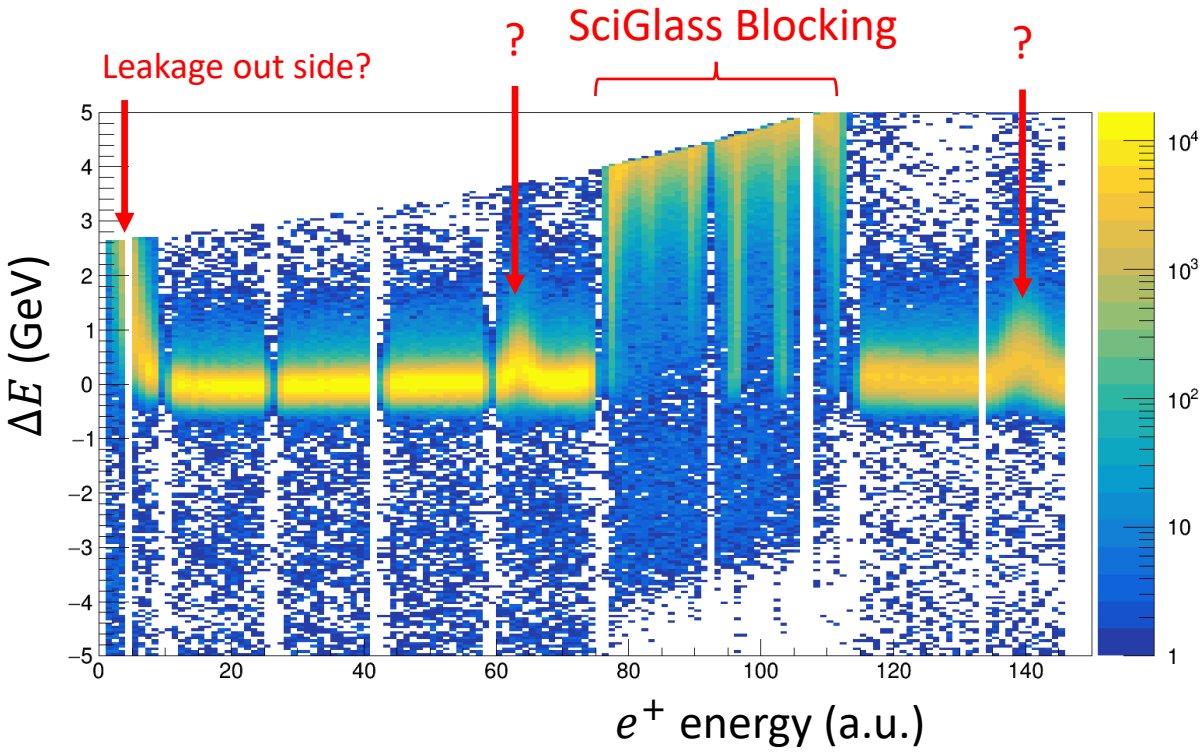
- Calculate c_k with $\frac{\partial F}{\partial c_k} = 0$
- Math in backup slides

Baby BCAL Readout (e^+ Beam)



Individual channels, view from side





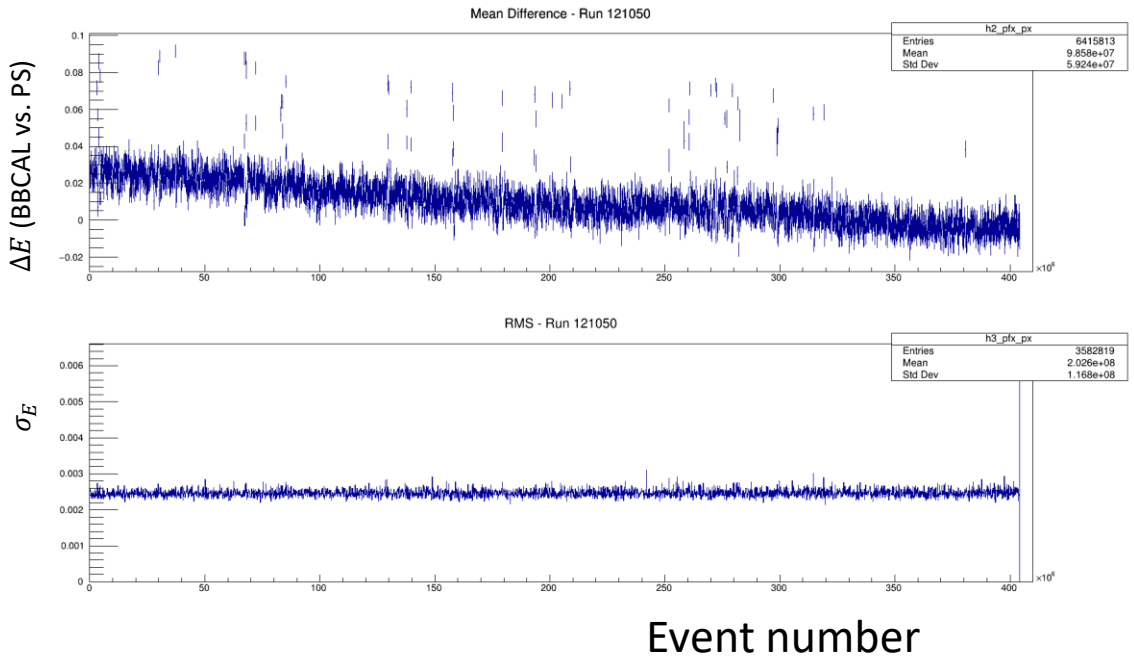
Quality Checks

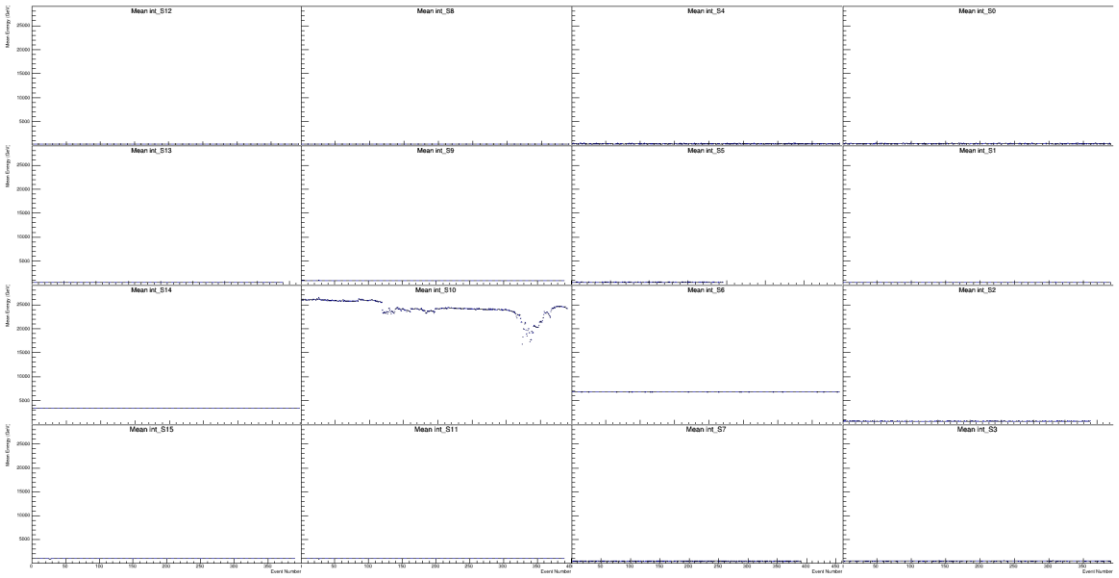
Within run (one run ~ 2 hours)

- Check individual channel stability
- Check overall energy stability

Broad features:

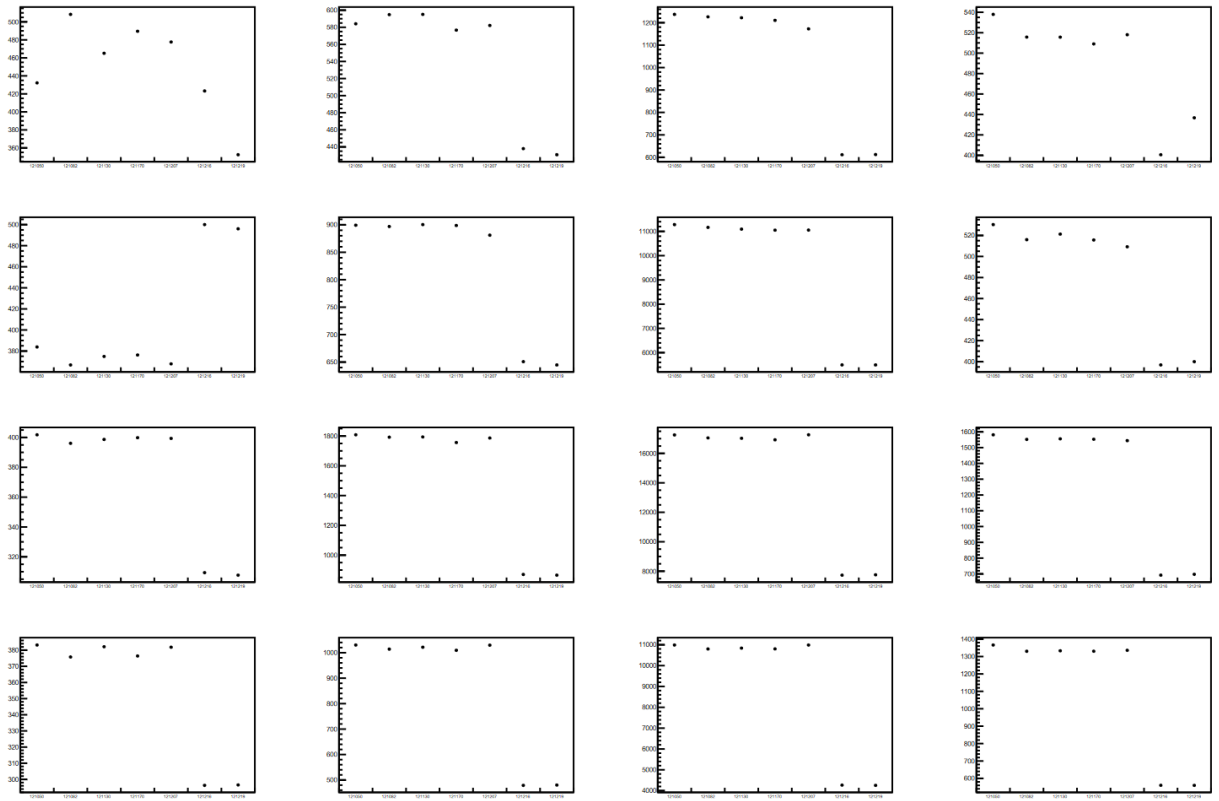
- Larger time dependence just after hall closing (temperature drift?)
- Slow time dependence later (probably ok)
- One very jittery channel shows up after first few runs, continues through end of data taking
  (unfortunately, corresponds to 40% of total energy deposition)





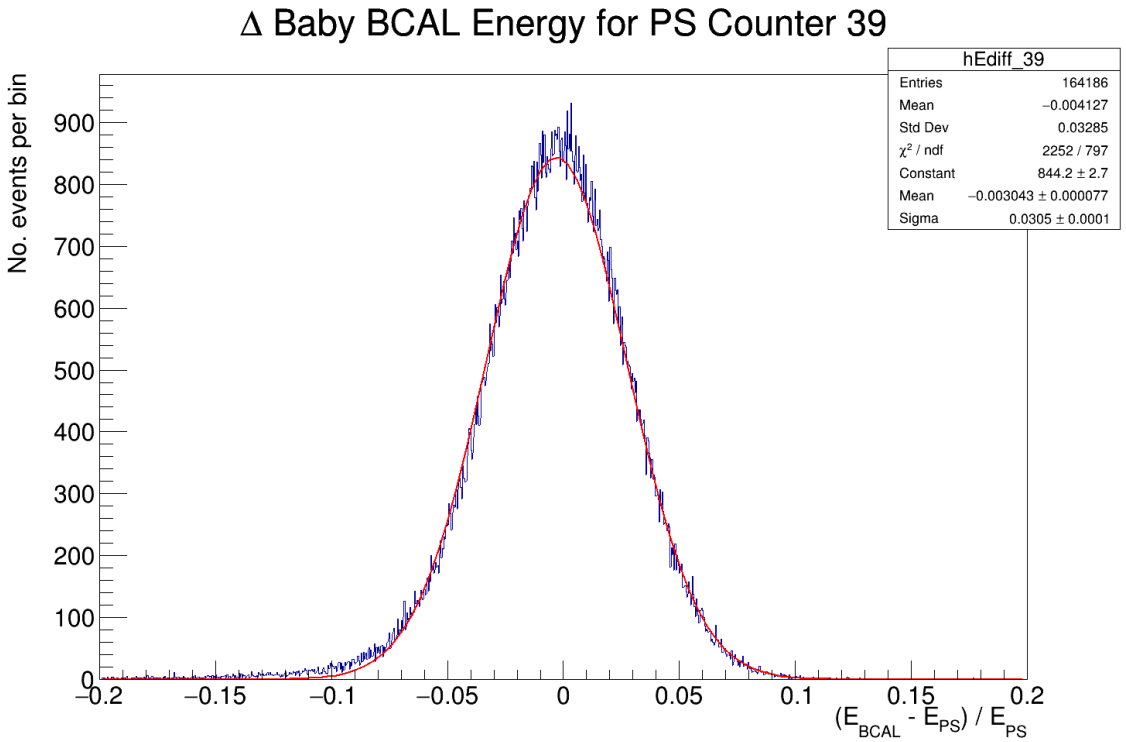
Longer Term Stability

- Check individual channels over 12 day period
- Mostly checking for rad. damage
- Average fADC integral in un-shadowed region
- SiPM bias voltage change for last two points, jump expected



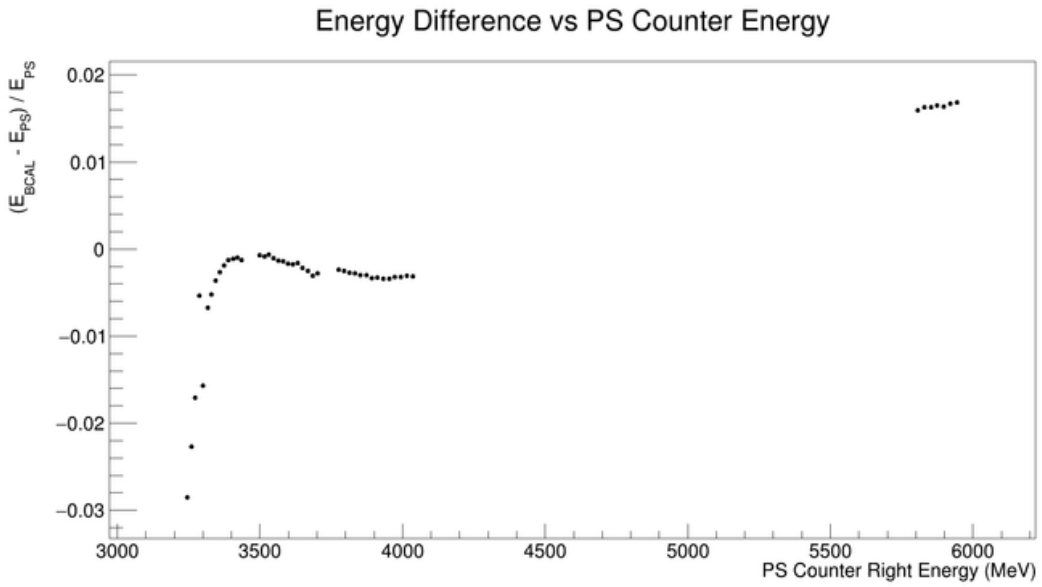
Energy Resolution Extraction

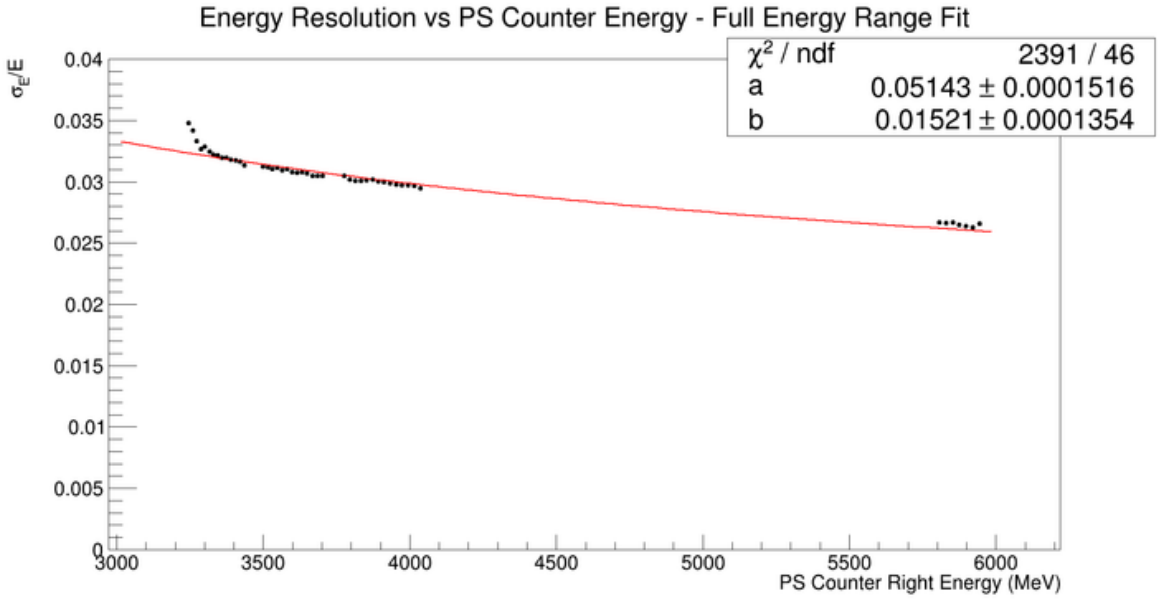
- Fit for single PS counter
  (positrons about ± 10 MeV at most)
- Extract σ_E / E
- Repeat for all good PS counters



Leakage Revisited

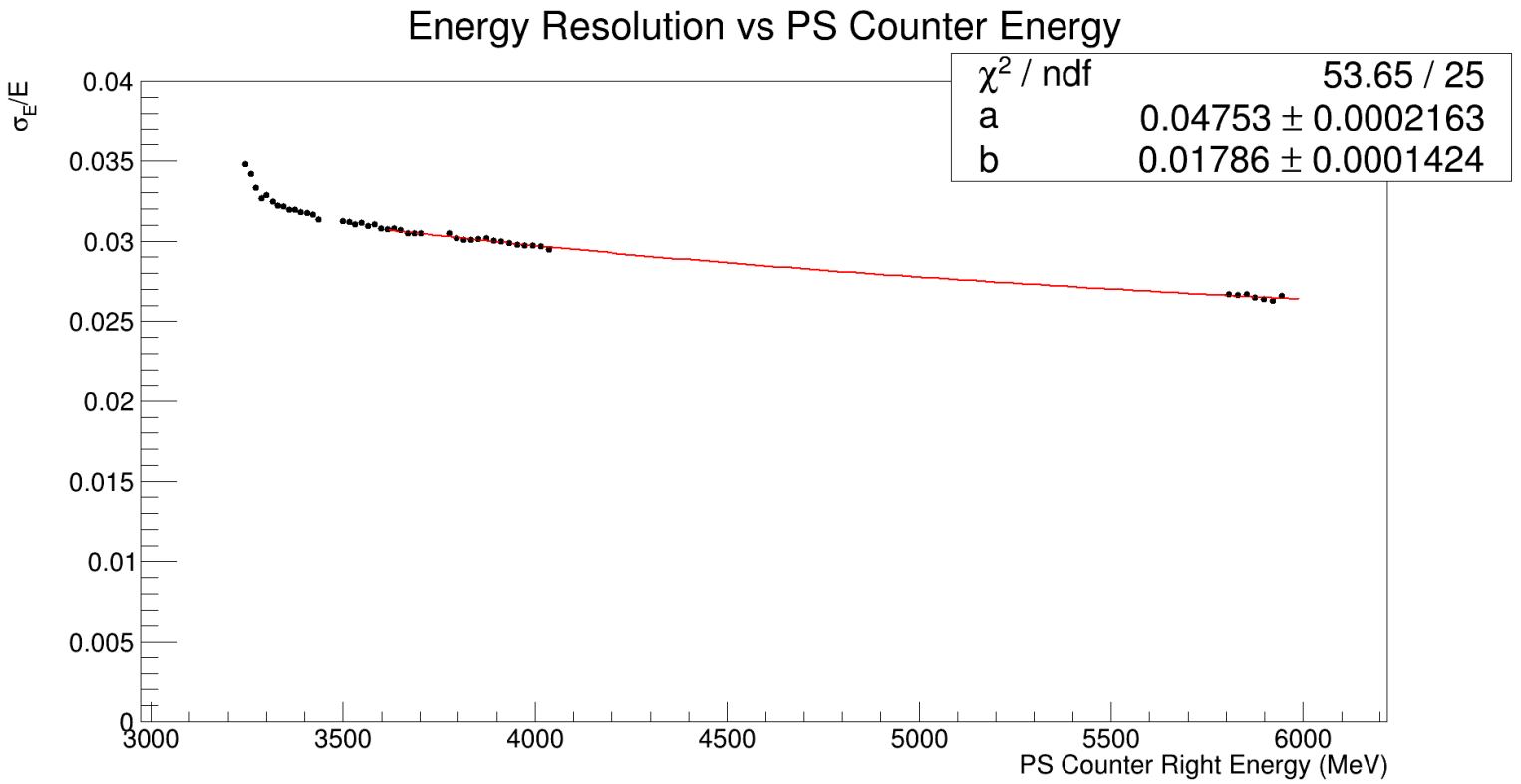
- Difficulty fitting lowest energy points
  - Exclude for today
- Baby BCAL energy also sags here
- Leakage or albedo?





Energy Resolution

$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E(GeV)}} \oplus b.$$



BCAL NIM (2018):

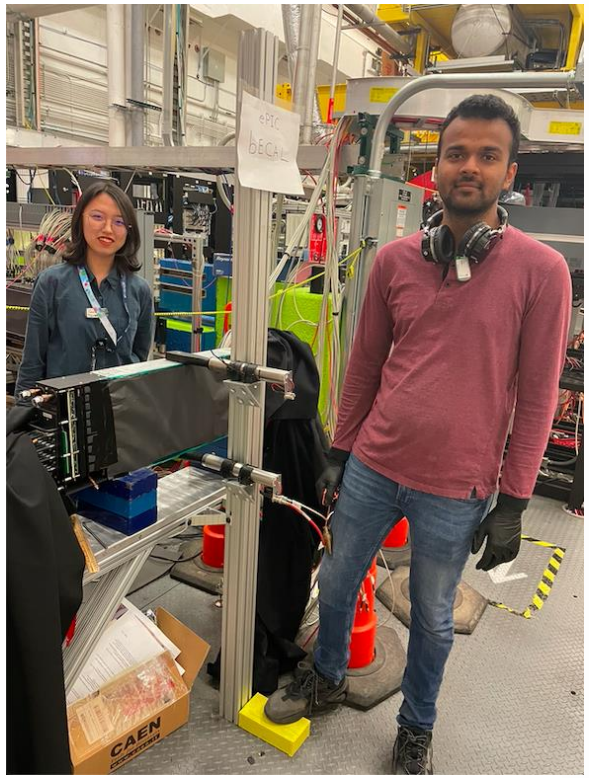
a: 0.052

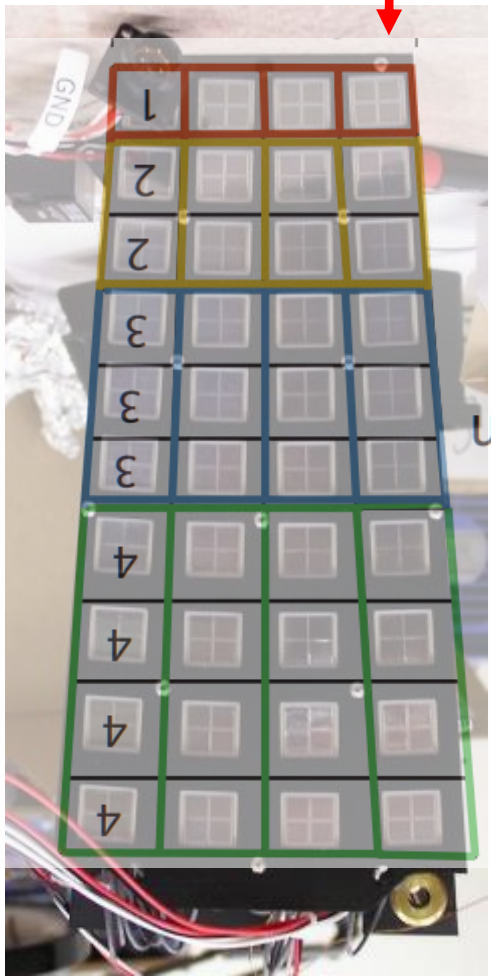
b: 0.036

(measured via symmetric etas in $\gamma p \to \eta\pi^+\pi^-$p)

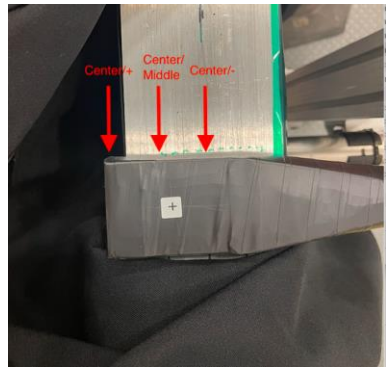
Cosmic Tests

- Unfortunately, e^+ always struck the same spot on the baby BCAL
- Very low occupancy in some channels
- Use MIPs to calibrate?
- Cosmic setup ran from August – October collecting data
  - Close to 30,000 muons collected

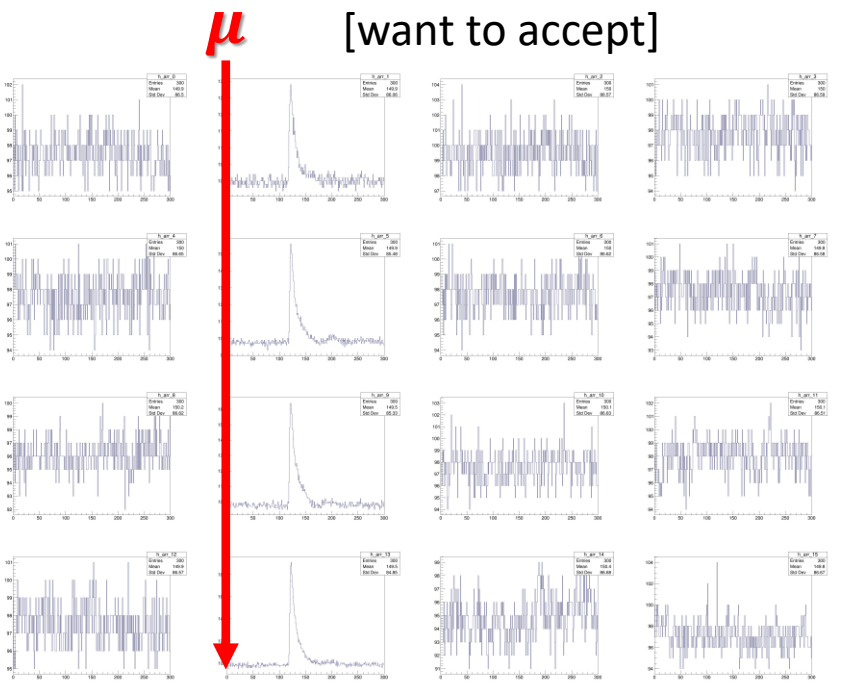




Analysis and Event Selection

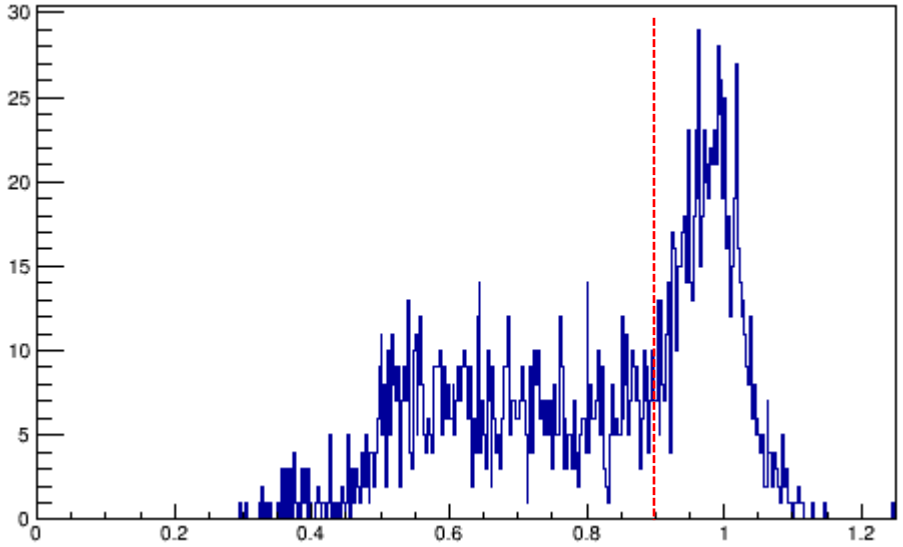


- Match voltage settings during March running
- Paddles ensure that tracks are fairly vertical
- Can still improve with some event selection

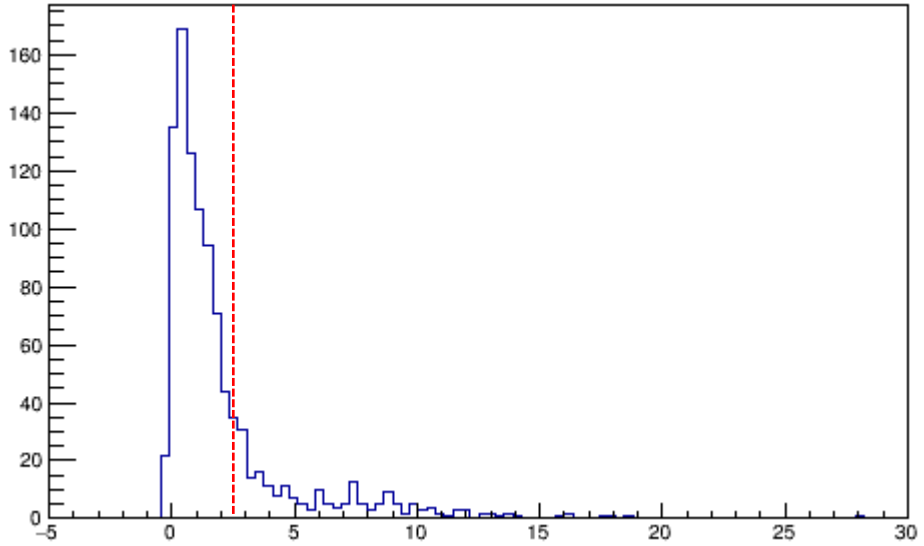


Event Selection, cont.

- Find column with most deposition
  - Require > 90%
- Find largest neighboring top/bottom cell
  - Require this to be very small (< 2.5 ADC units)
- Afterwards: less than $\pm$1.5% length traversed



Fraction of ADC integral sum

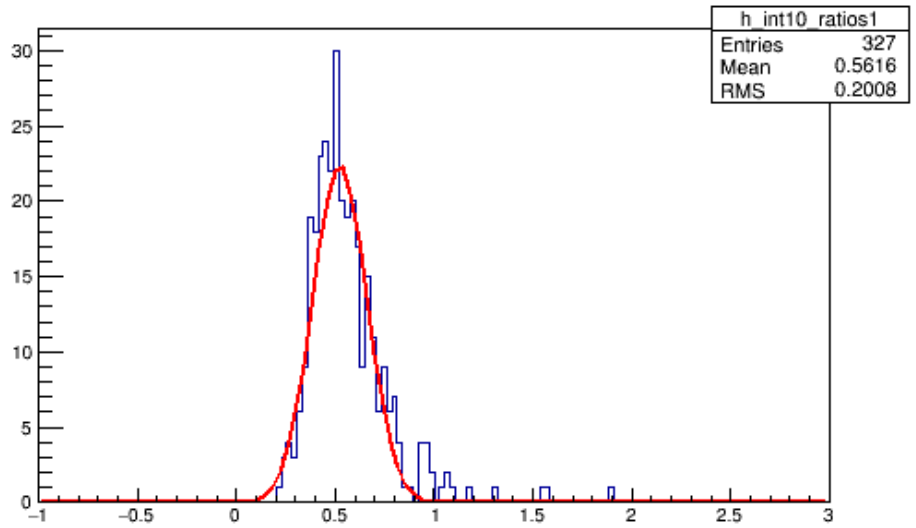


Largest top/bottom neighbor (a.u.)

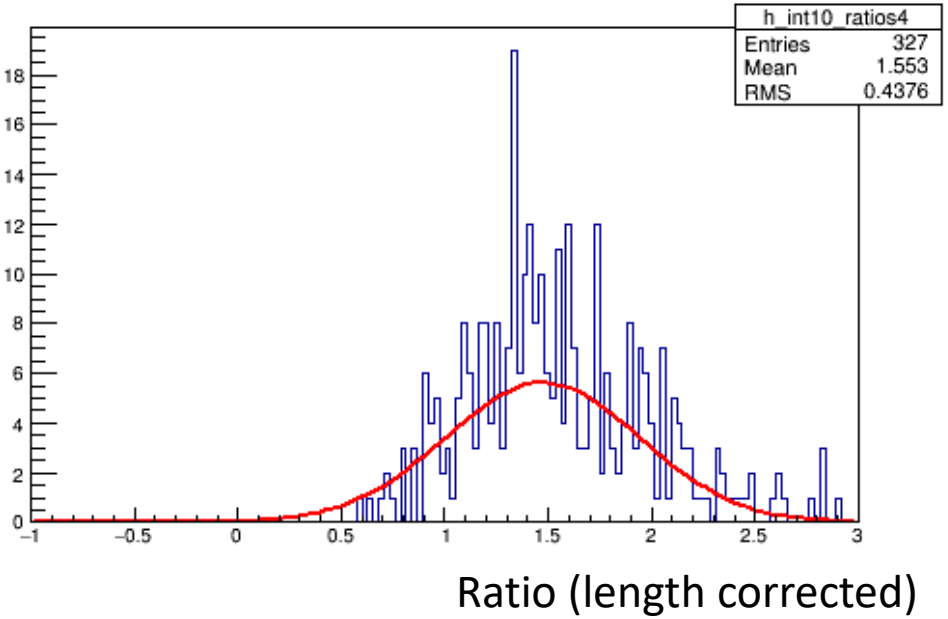
Initial Check

- Check channels that were well determined in March run

North 6 / North 14
Cosmics: **0.524**
March: **0.733**



South 6 / South 14
Cosmics: **1.47**
March: **1.55**



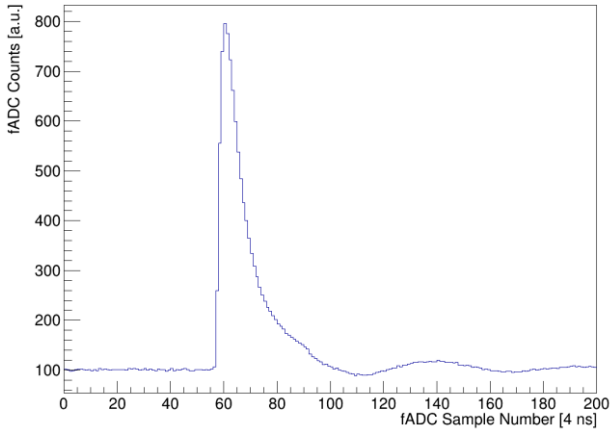
Looking Ahead

- Data quality checks look ok for March data
  - Good blueprint for future beam tests
- Energy resolution extraction:
  - First pass looks good
  - Study correlation between parameters
  - Check with additional runs, voltage settings
- $N_{p.e.}$: next
- Cosmic gains
  - Will attempt to apply to March data, check resolution

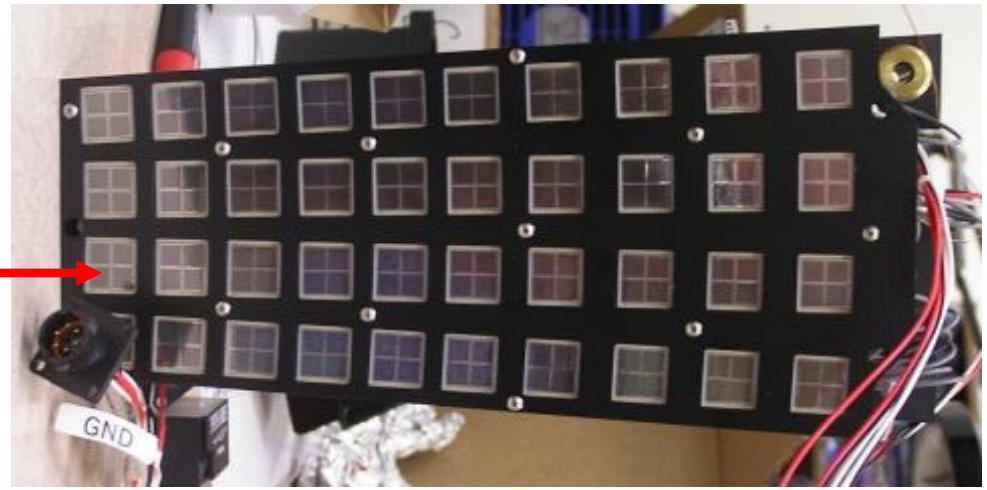
Backup: Segmentation and Readout

Flash ADC readout

- 250 MHz readout frequency (or every 4 ns)
- Up to 200 samples, if storing full waveform
- Some ~ 25 sample integral used otherwise



View from side



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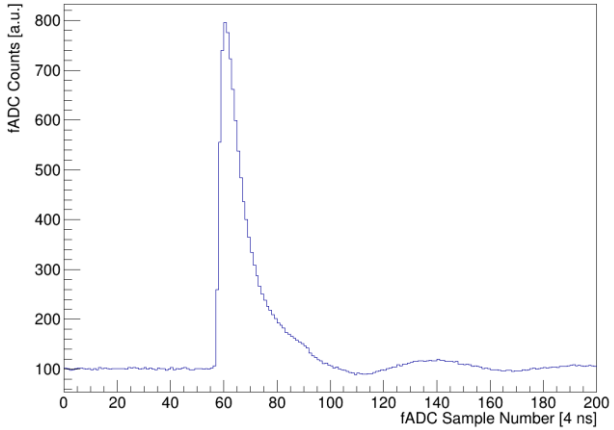
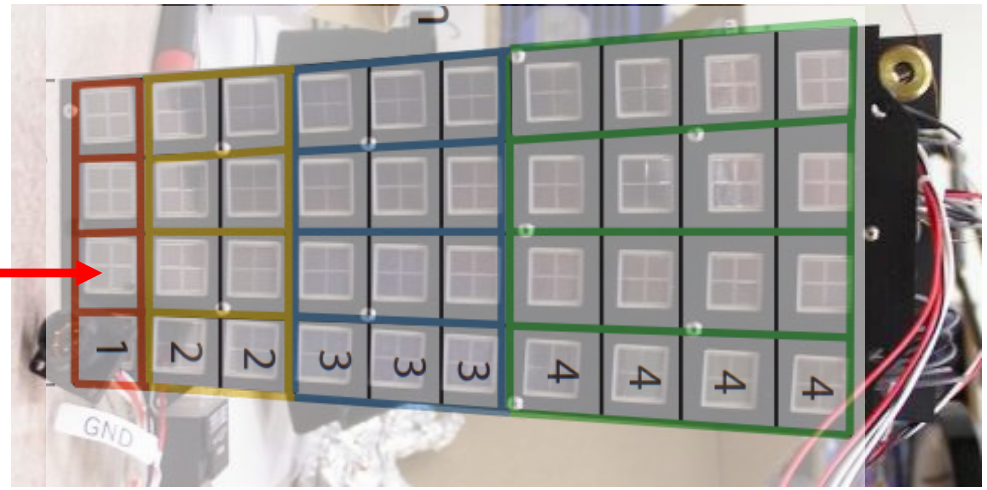


Two-ended readout:

- 4 SiPM readouts up/down
- 10 SiPMs left/right, some summed pre-readout
- **16 fADC readouts per side** (32 in total)

View from side

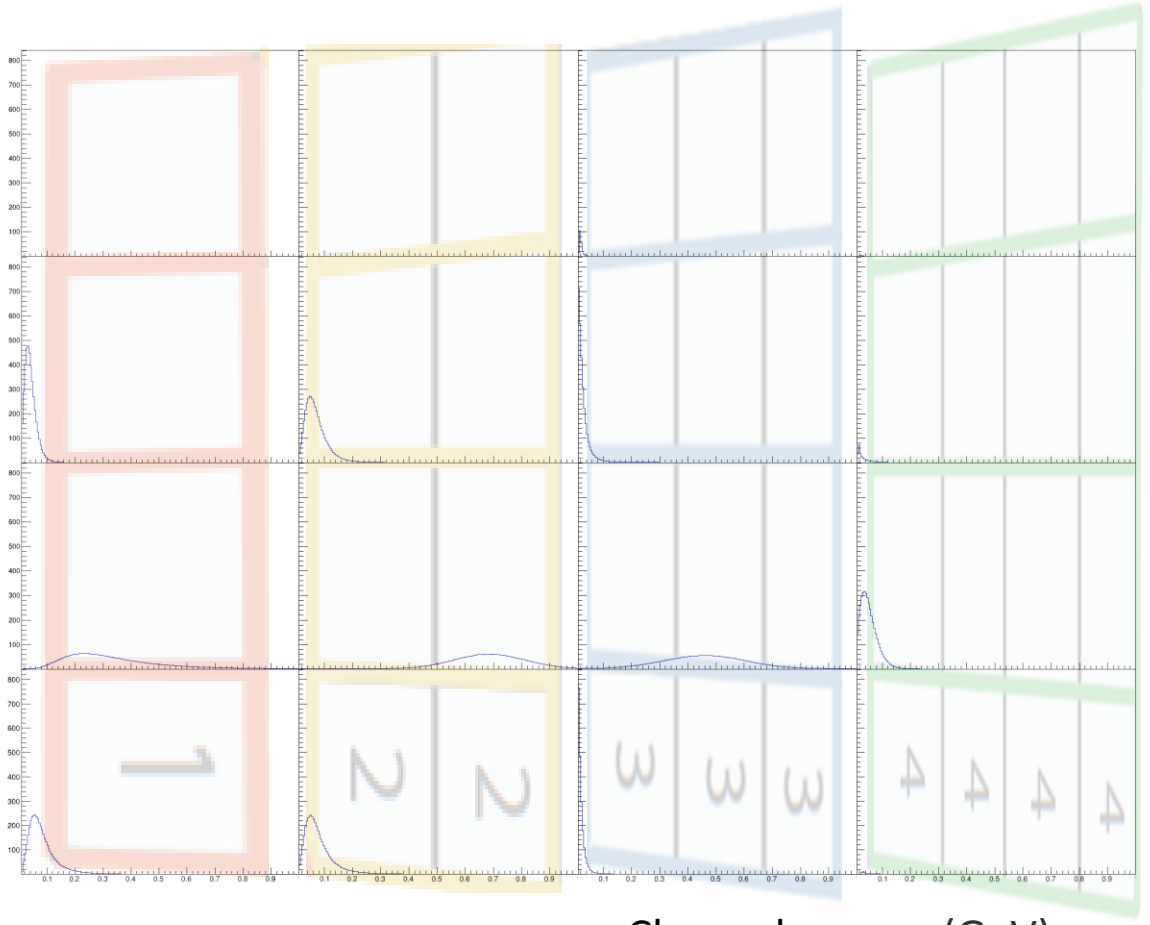


(summation for bottom channels 1, 2, 3, 4)

Backup: Showers in Baby BCAL

- Strikes a little low of center
- Upper left & rightmost layers: very little energy deposited

e^+



Channel energy (GeV)

Backup: Baby BCAL Gains

- Minimize $F = \sum_i^{events} \left(\sum_j^{16} c_j \, A_{ij}^{sum} - E^{PS} \right)^2$
- $\frac{\partial F}{\partial c_k} = 0 = 2 \sum_i^{events} A_{ik}^{sum} \left(\sum_j^{16} c_j \, A_{ij}^{sum} - E^{PS} \right)$
- $\Rightarrow \sum_i^{events} A_{ij}^{sum} E^{PS} = \sum_i^{events} A_{ij}^{sum} \left(\sum_j^{16} c_j \, A_{ij}^{sum} - E^{PS} \right)$

Backup: Baby BCAL Gains

- $\sum_i^{events} A_{ik}^{sum} E^{PS} = \sum_i^{events} A_{ik}^{sum} \left(\sum_j^{16} c_j A_{ij}^{sum} \right)$
  - Define vectors $\mathbf{A_i} = \begin{bmatrix} A_{i0}^{sum} \\ \dots \\ A_{i15}^{sum} \end{bmatrix}$ and $\boldsymbol{C} = \begin{bmatrix} c_0 \\ \dots \\ c_{15} \end{bmatrix}$
- Then in matrix form $\sum_i E_i^{PS} \mathbf{A_i} = \left(\sum_i \boldsymbol{A_i} \boldsymbol{A_i^T} \right) \boldsymbol{C}$
  - Now define $\boldsymbol{W} = \sum_i E_i^{PS} \mathbf{A_i}$, and $\boldsymbol{Z} = \left(\sum_i \boldsymbol{A_i} \boldsymbol{A_i^T} \right)$
- $\Rightarrow \boldsymbol{W} = \mathbf{Z}\,\mathbf{C}$
- Solving for gain constants $\boldsymbol{C}$:
  - $\boldsymbol{C} = \boldsymbol{Z}^{-1}\,\boldsymbol{W}$

Backup: Baby BCAL Gains

- Determine separate north/south
- Let $f_j = \frac{\sum_i A_j^N}{\sum_i \left(A_j^N + A_j^S\right)} \Rightarrow \left(1 - f_j\right) = \frac{\sum_i A_j^S}{\sum_i \left(A_j^N + A_j^S\right)}$

- Final gain factors: $\boldsymbol{c_j^N = \frac{c_j}{2f_j}}$ and $\boldsymbol{c_j^S = \frac{c_j}{2\left(1-f_j\right)}}$