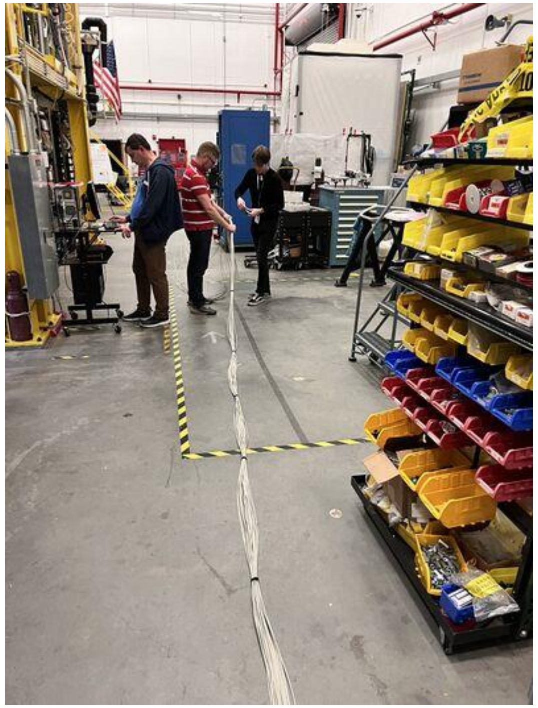
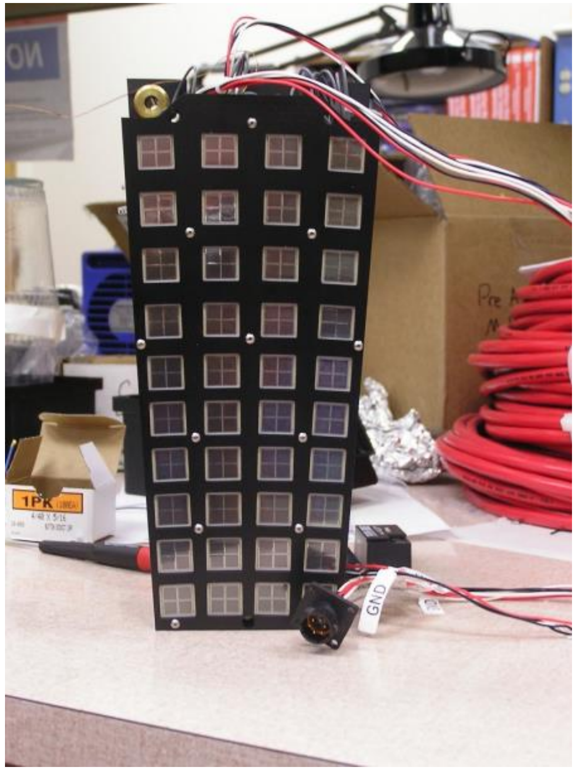
“Baby ” BCAL Progress Report





Jon Zarling

7/11/23

Motivations

GlueX has excellent experience with EM showers up to about 2 GeV using Pb-SciFi

“Baby BCAL” extends using 3-6 GeV positrons:

- Initial energy measured known
- Better constrain constant term in energy resolution
- Aids in extracting $N_{p.e.}$ (number of photoelectrons)
- Full waveforms also stored during portions of data taking

The Baby BCAL in Hall D

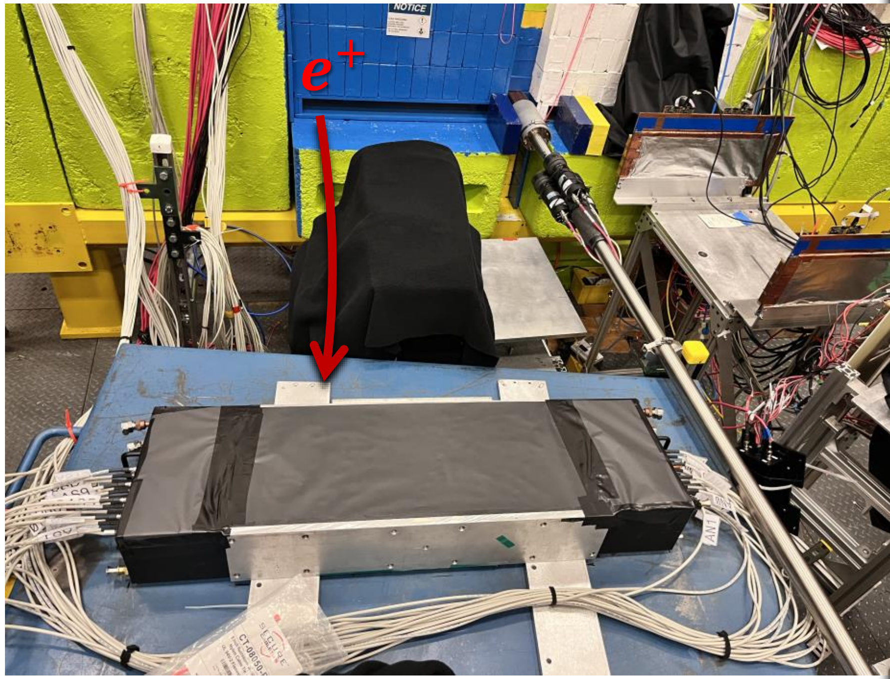
Essentially identical to GlueX lead SciFi wedge, except 58 cm in length rather than 390 cm

Hall D pair spectrometer:

- e^+ energy roughly 3-6 GeV
- Precise energy tagging
- Provides trigger

Good source of EM showers with known energy

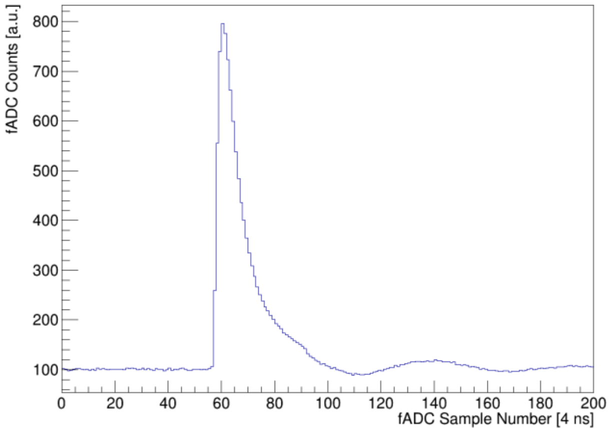
View from above



Segmentation and Readout

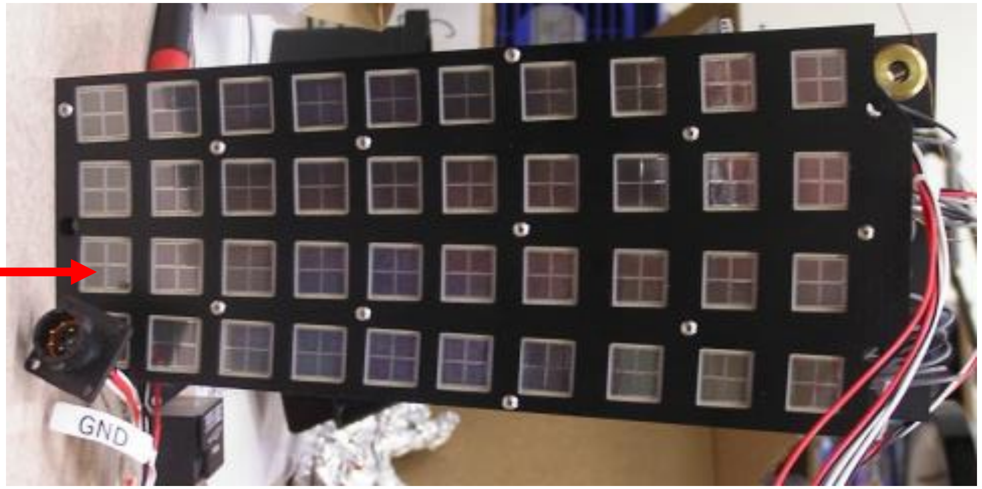
Flash ADC readout

- 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

e^+



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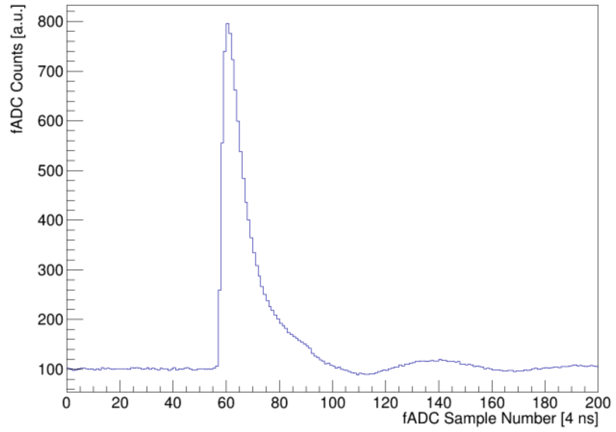


Two-ended readout:

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

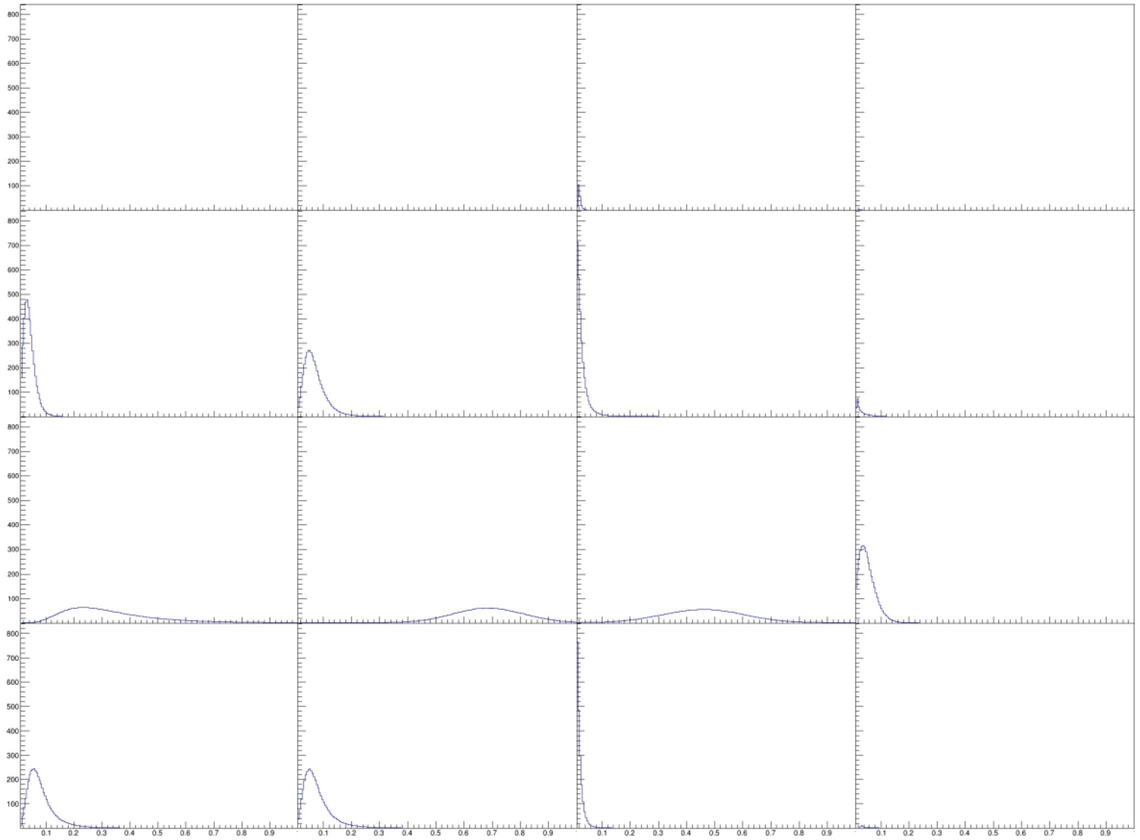
View from side

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

Showers in Baby BCAL

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

e^+ →



Channel energy (GeV)

Showers in Baby BCAL

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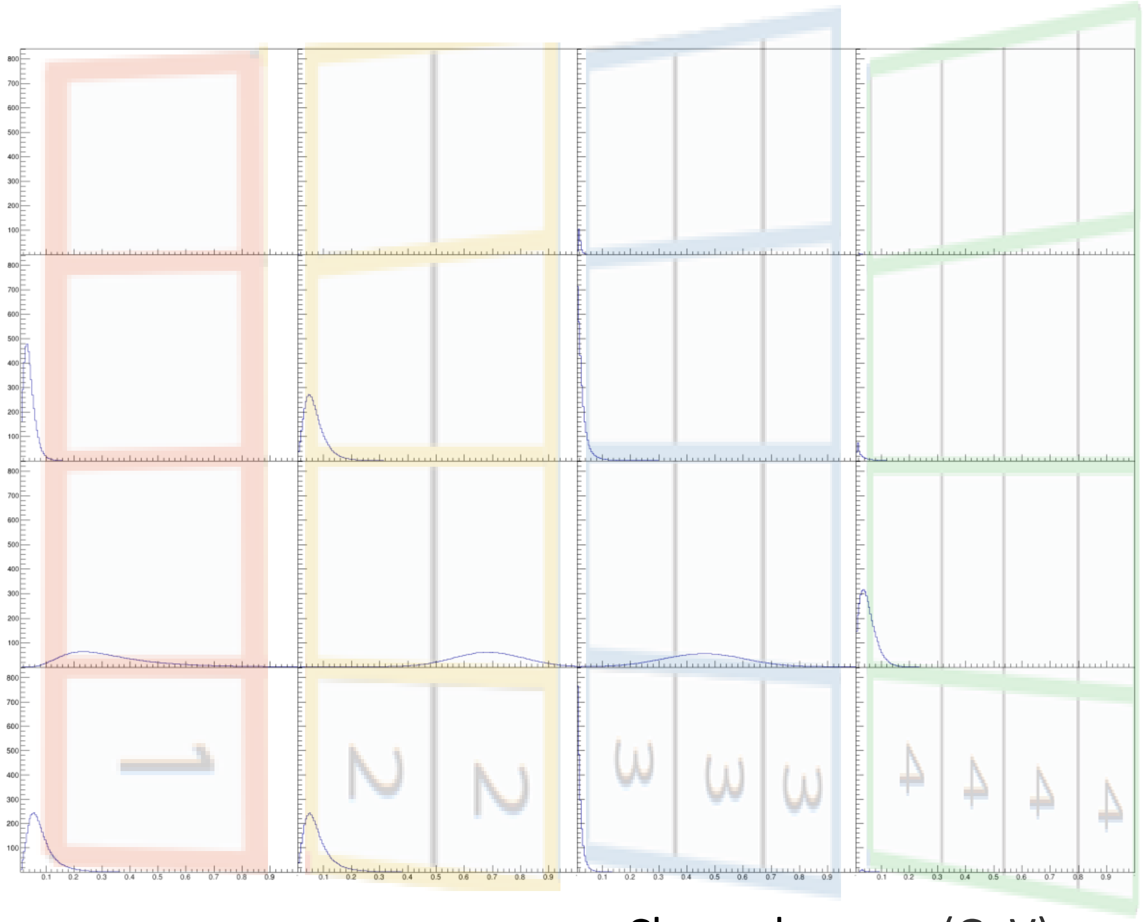
e^+ →

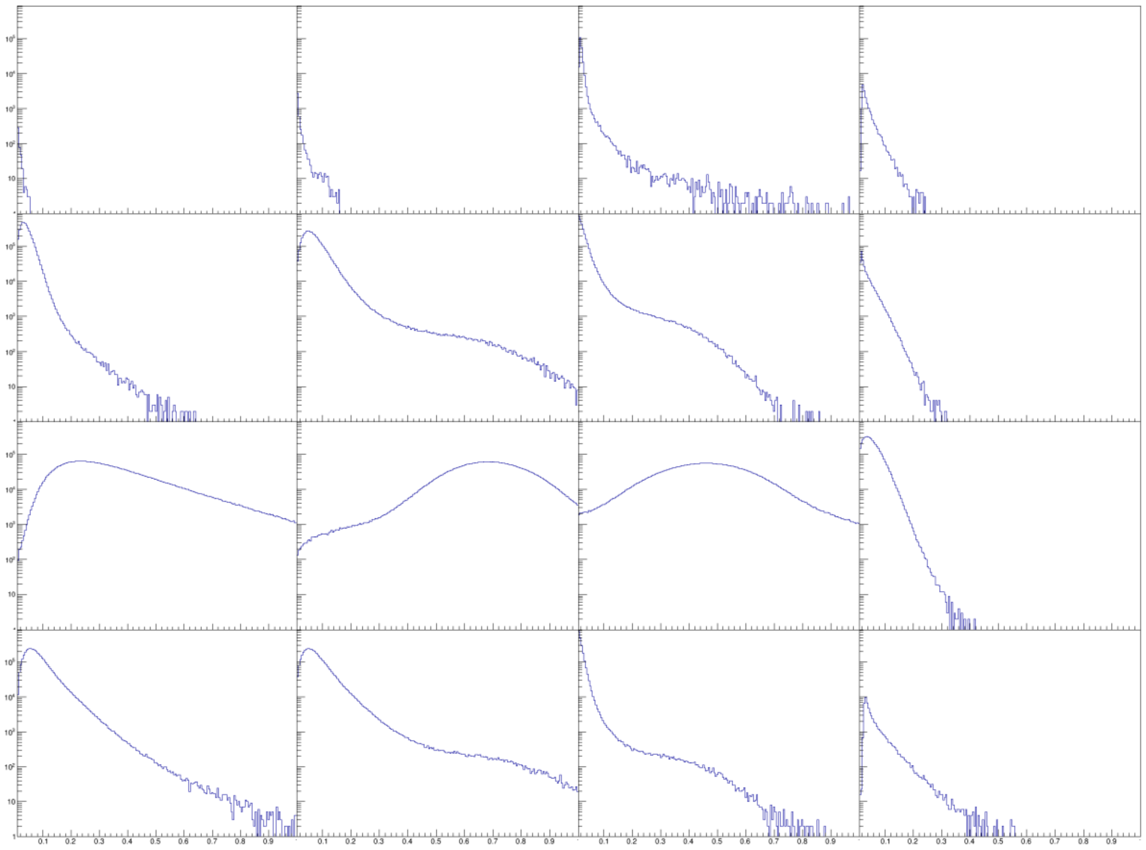


Channel energy (GeV)

Showers in Baby BCAL

(log scale)

e^+ →



Channel energy (GeV)

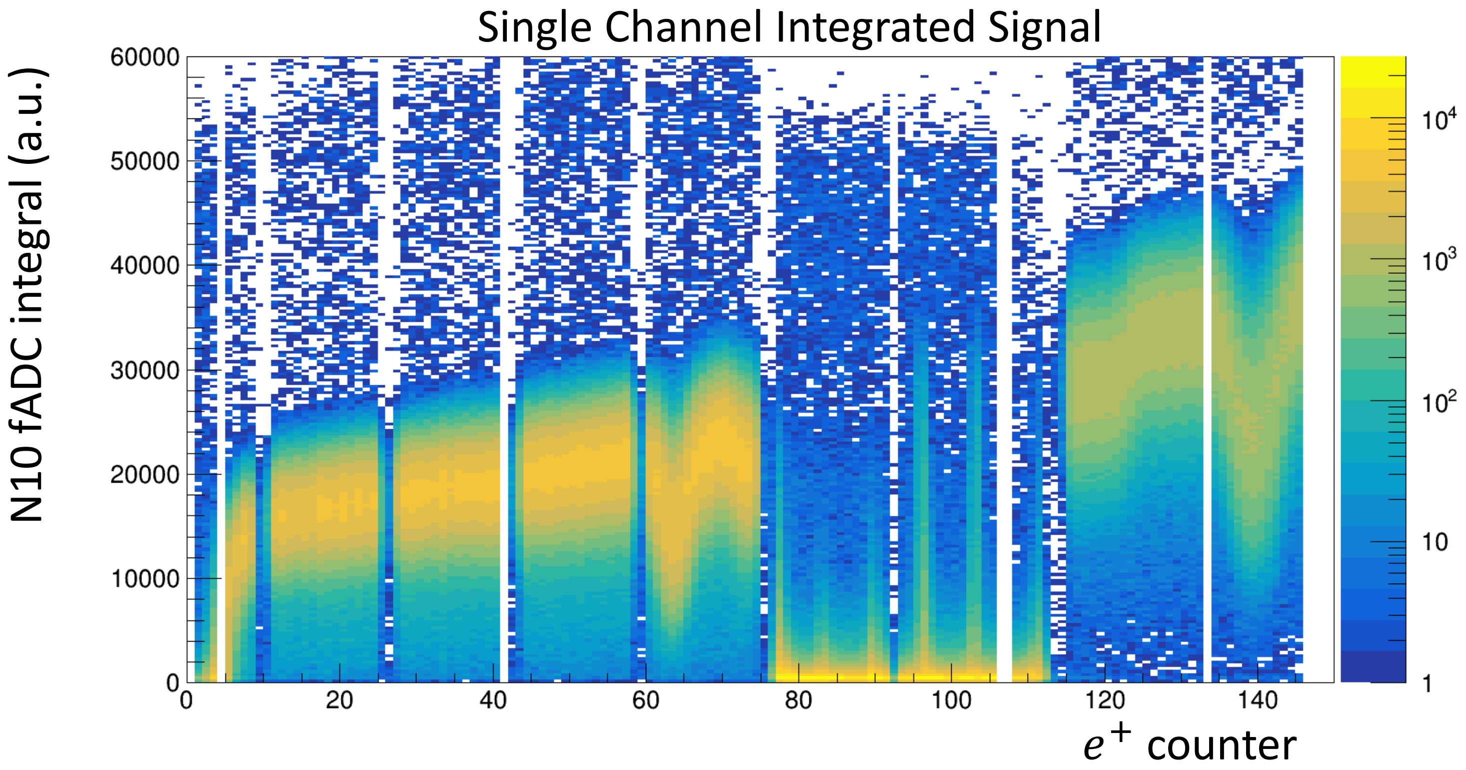
A Few Challenges

- SciGlass shadows the Baby BCAL at some energies

- Calibrations:
  - Not balanced before running
  - Not temperature controlled
  - SiPM overbiases modified over running
  - Some channels rarely have hits above threshold

Single Channel Over e^+ Energy

- e^+ counter number ~ proportional to e^+ energy
- Some missing or shadowed regions



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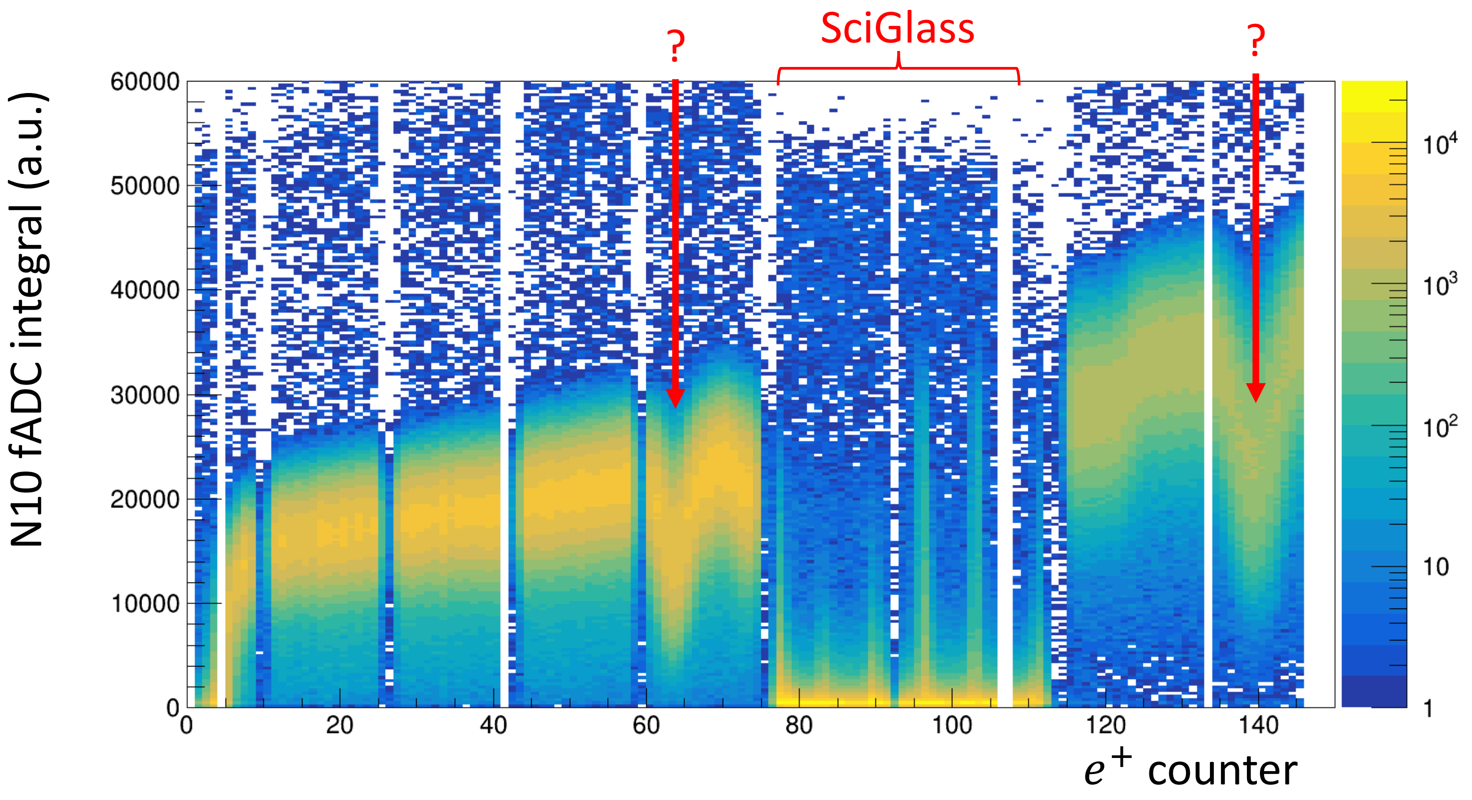
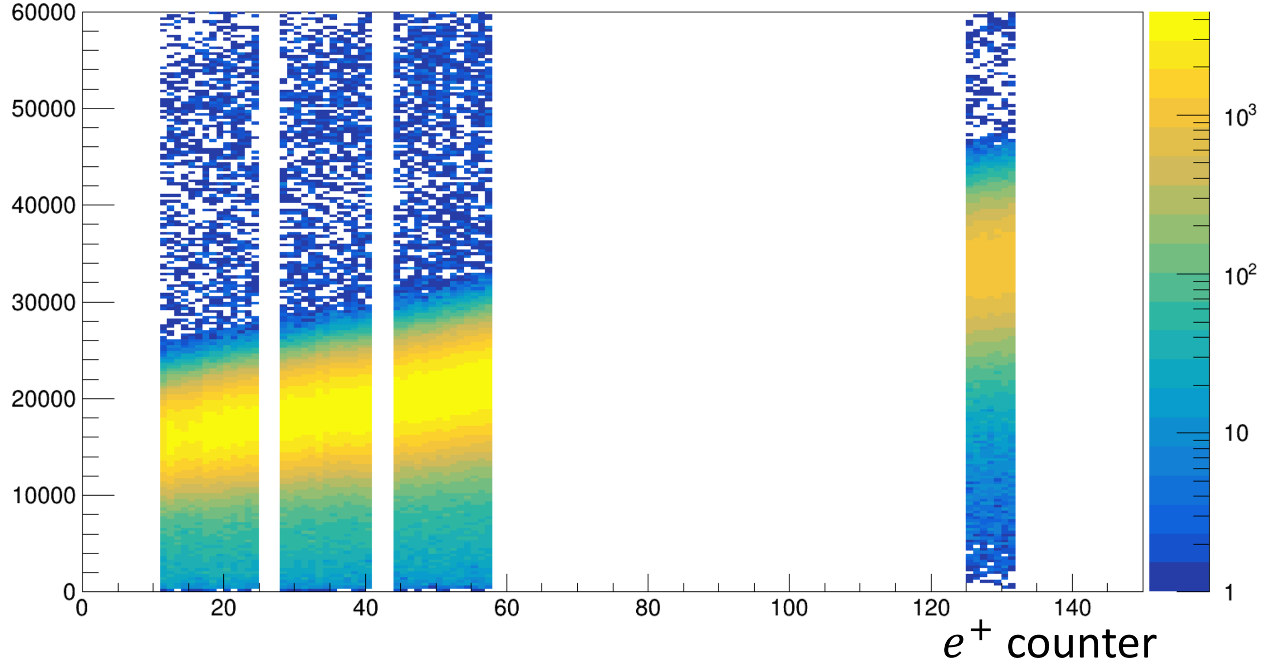


Selecting Good Counters

Pick these 38 counters to calibrate channels



Baby BCAL Gains

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

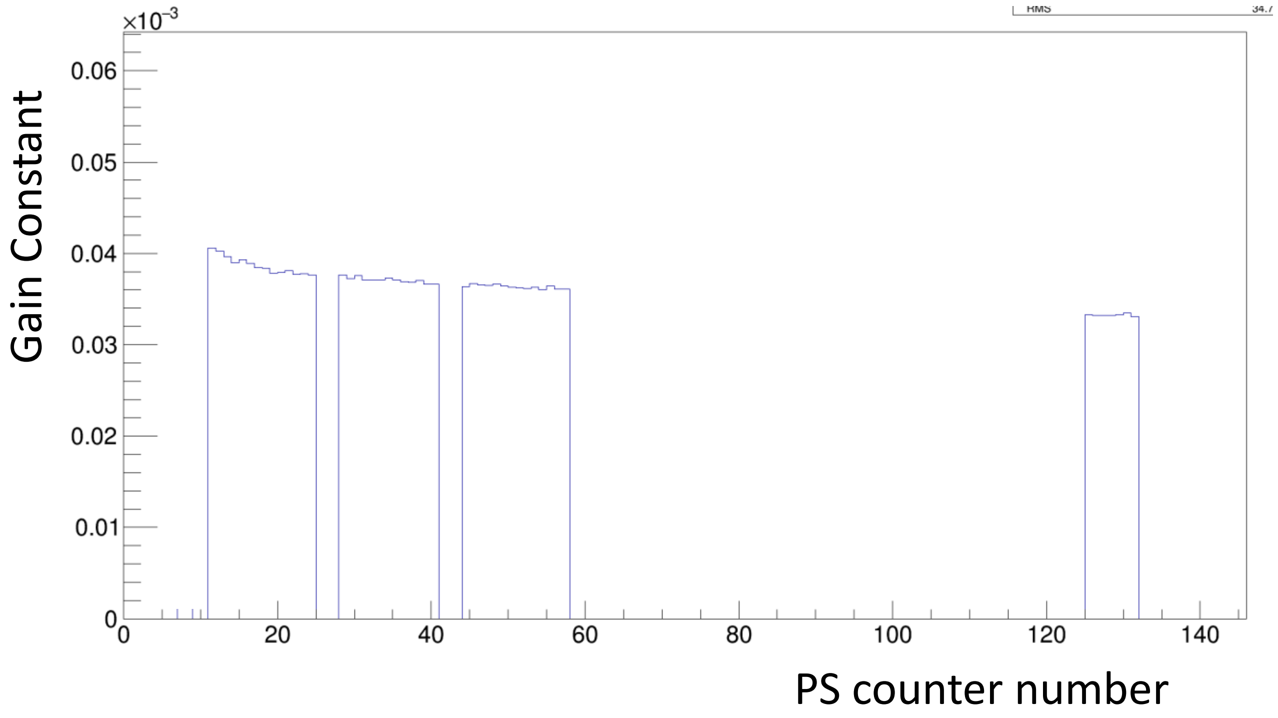
  E^{BCAL} is sum of north and south readouts

  $E^{BCAL} = \sum_j^{16} c_j \left(A_j^N + A_j^S\right) = \sum_j^{16} c_j\, A_j^{sum}$

- Calculate c_k with $\frac{\partial F}{\partial c_k} = 0$
- Math in backup slides
- Compensates for leakage, for better or worse

Single Channel Gain Constant

- North channel 10: most energy deposited here
- Each bin from different 16x16 matrix inversion, totally separate
- Single run, less than 1% of Baby BCAL data

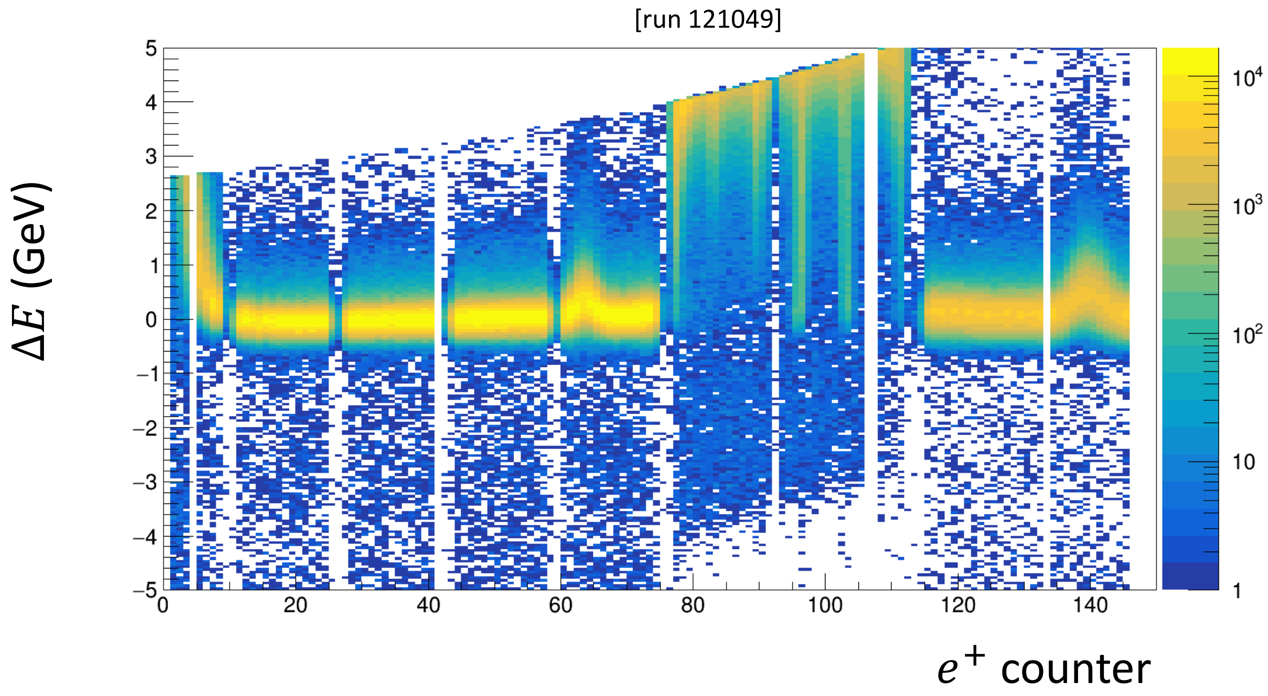


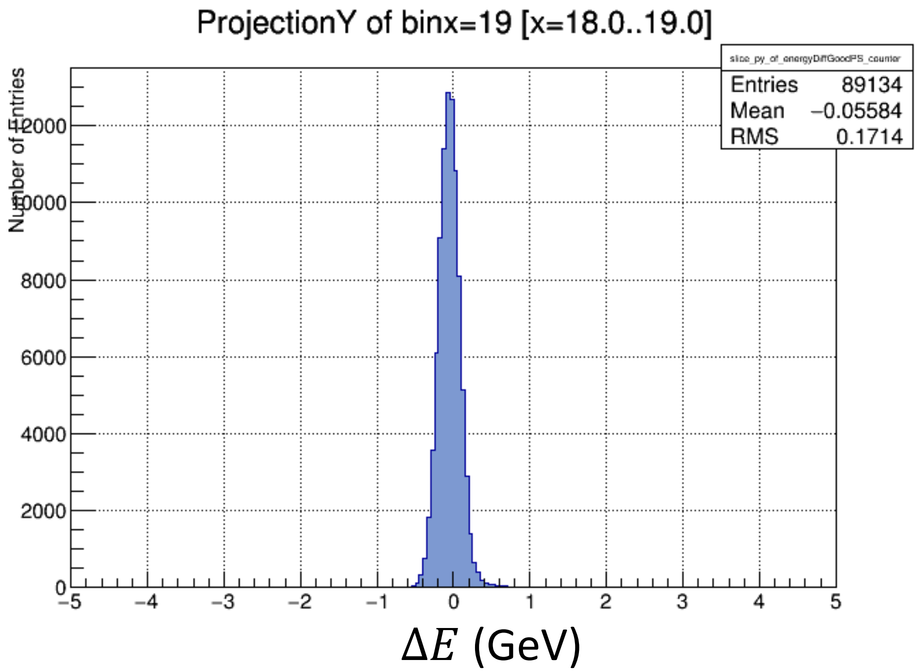
Results

- Plot $\Delta E = E_{tag} - E_{BCAL}$
- Appears good in non-shadowed regions

Positrons around 3.35 GeV/c

- BCAL NIM: **0.15** GeV ($= \frac{\sigma_E}{E} = \frac{5.2\%}{\sqrt{E}} \oplus 3.6\%$)
- Here: about **0.17** GeV

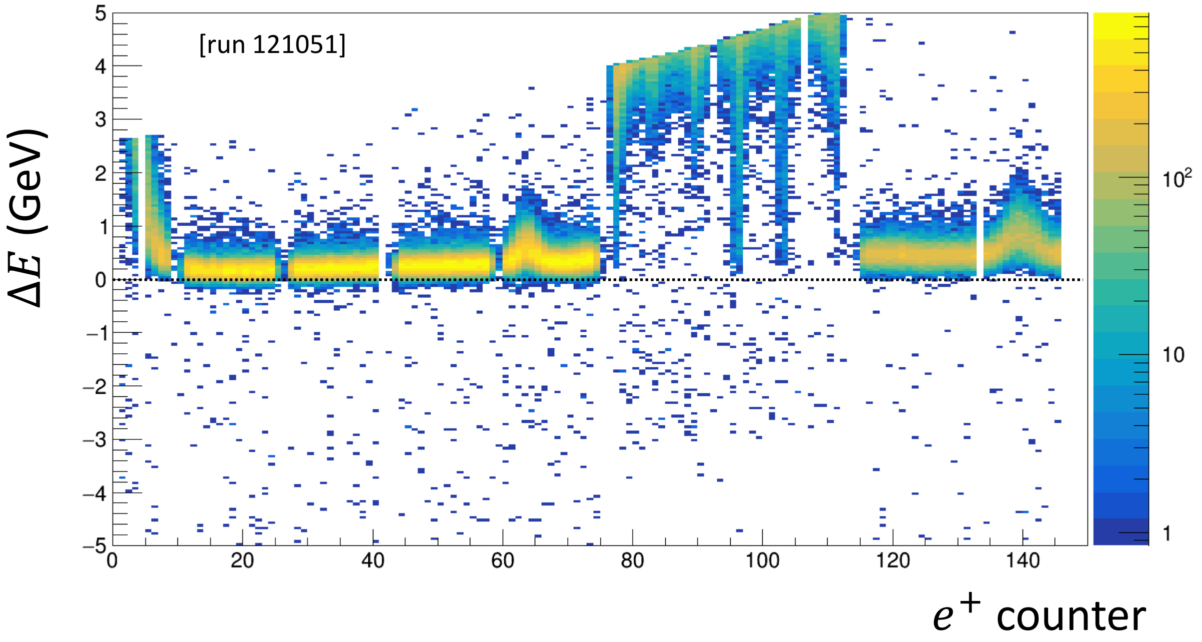




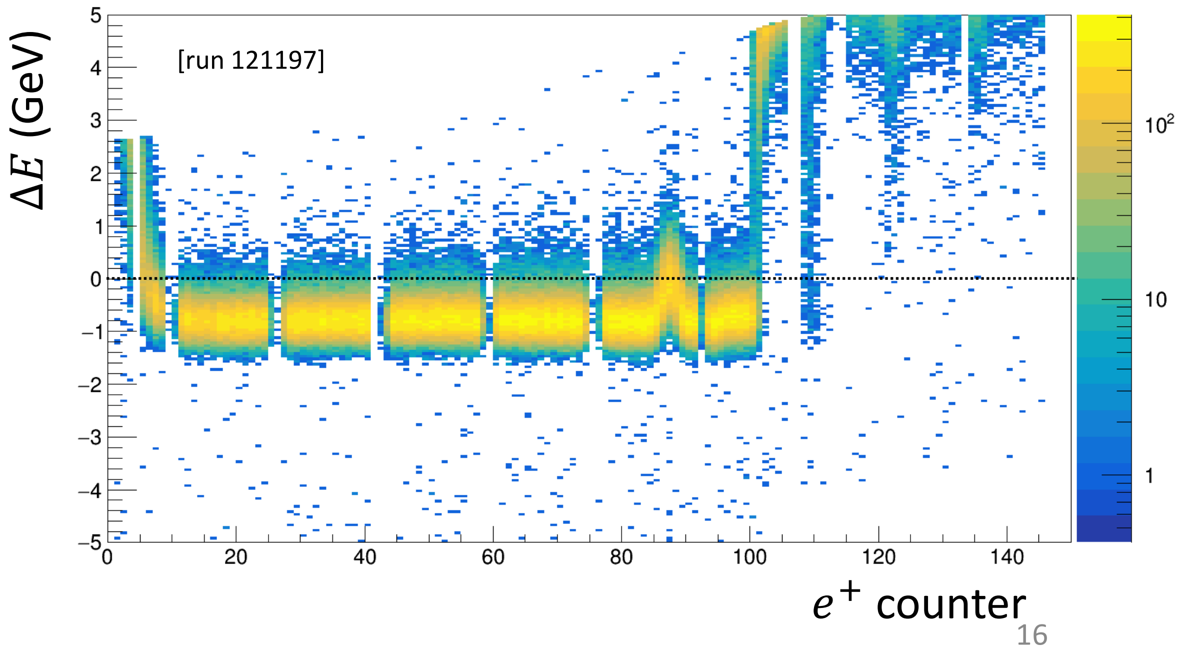
Results

Apply calibration constants to data taken later…

Four hours later: E_{BCAL} too small

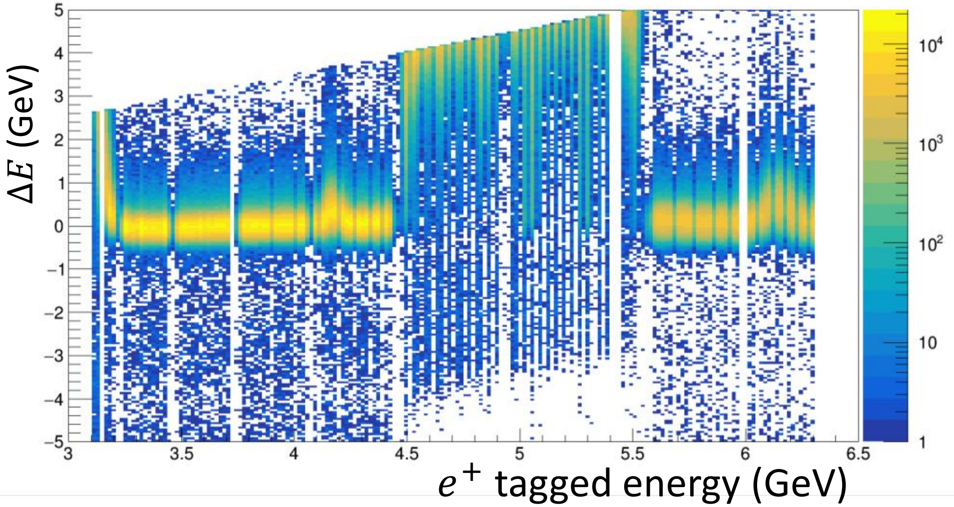


Ten days later: E_{BCAL} too large
(also SciGlass was moved a bit)



Summary

- Baby BCAL may be a little fussy
  - Calibration procedure should pacify
- Swimming in data (few hundred million showers)
- Observed/expected resolutions match to ~ 15%
- Ready to explore!



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