EMCal Optimization Studies for Test Beam and MC

—

Amanda Steinhebel, Jason Barkeloo, Jim Brau

22 September 2016

University of Oregon

EMCal

- Silicon-tungsten imaging calorimeter array
- Located before hadron calorimeter
- 30 alternating layers of tungsten alloy and silicon wafers
  - 1024 13 mm^2 pixels/wafer
  - Half-sized pixels near center of wafer
- KPiX microchip reads output of each pixel
  - Mounted at center of wafer

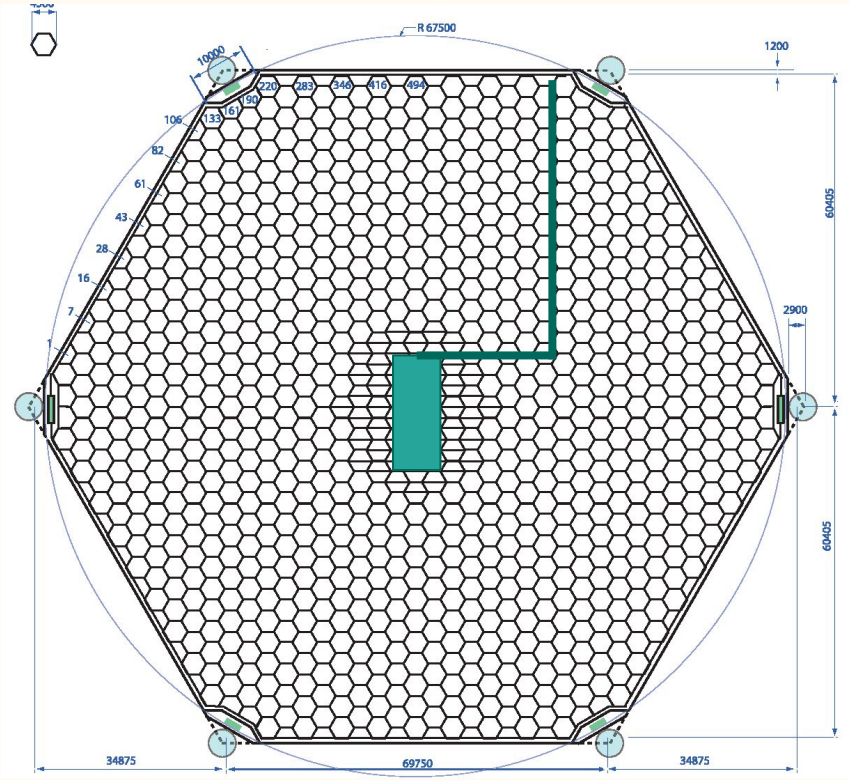
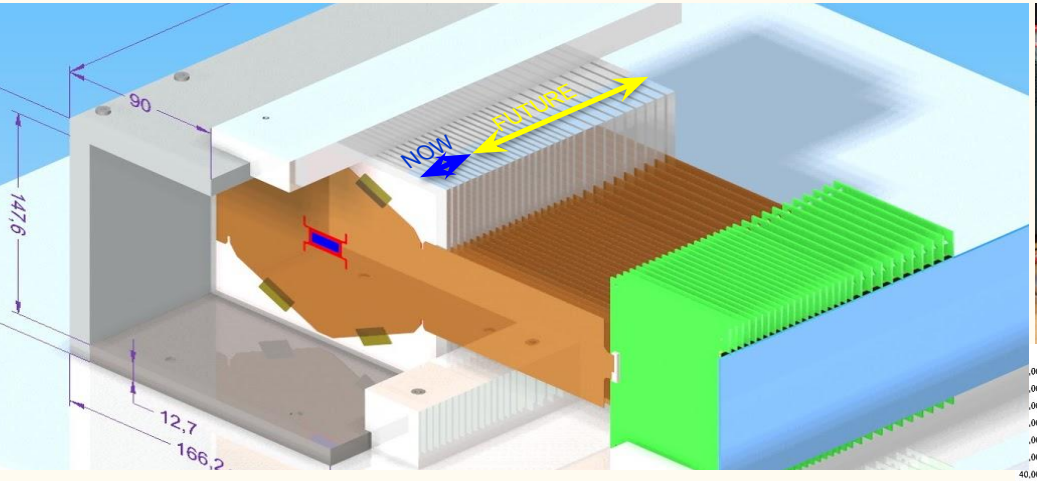
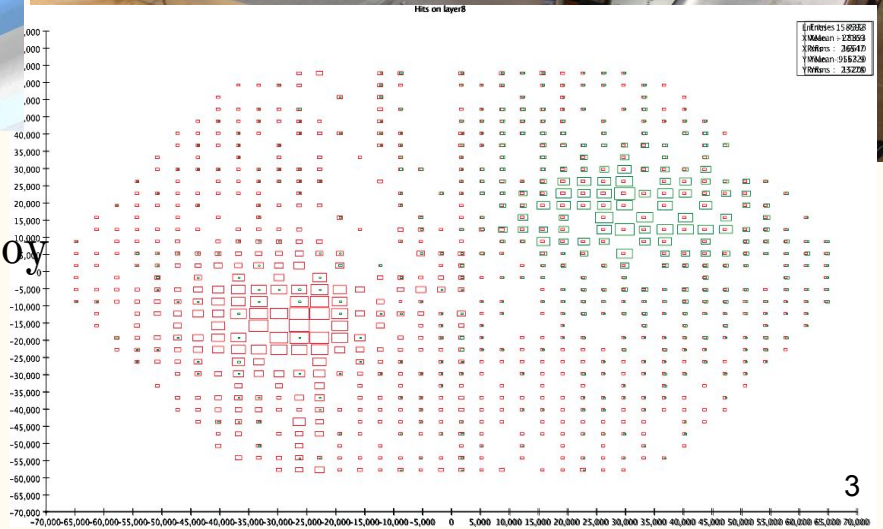


Image: Craig Gallagher

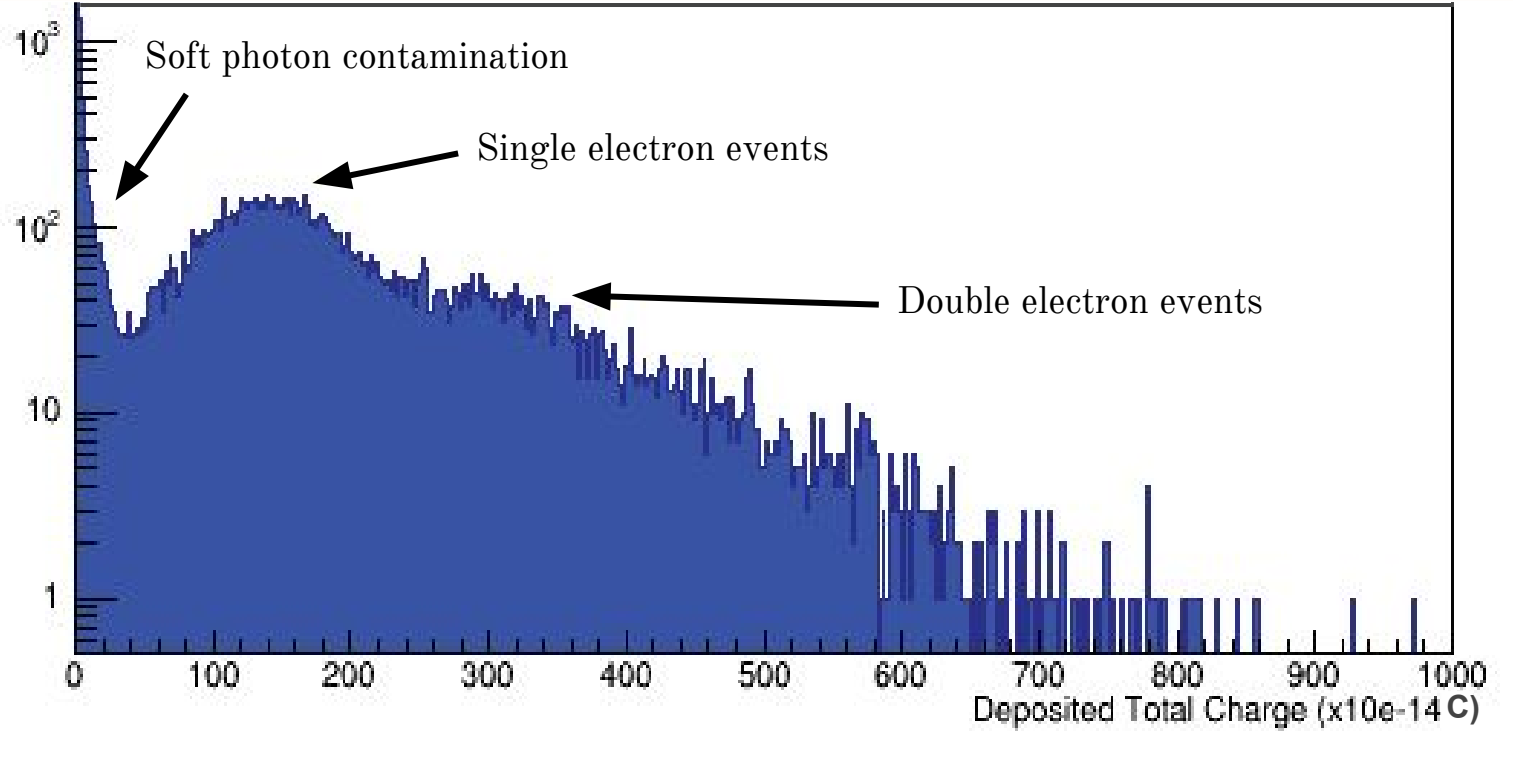
SLAC Test Beam





- Run in 2013
- 9 alternating layers silicon/tungsten alloy
- 12.1 GeV beam
- Can run W- or Si-first
- Simulated with Geant4

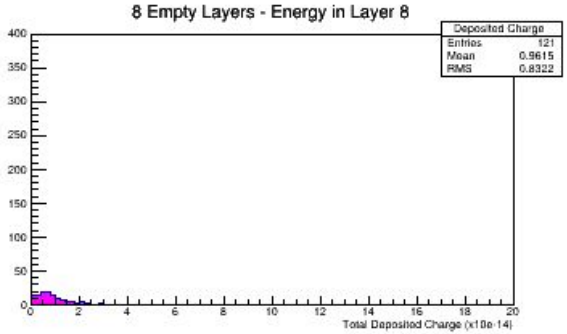
Test Beam Data Cleaning - Silicon first runs

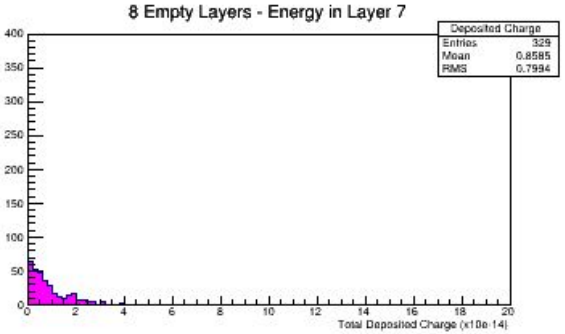


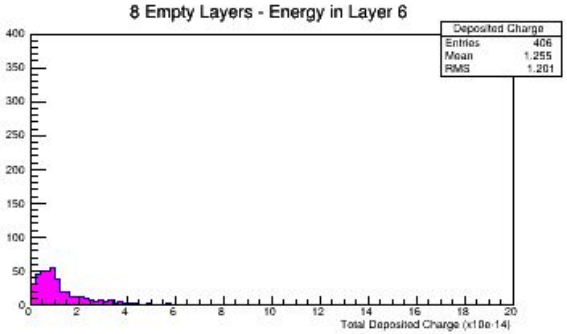
Clean Out Contaminants without Energy Cut

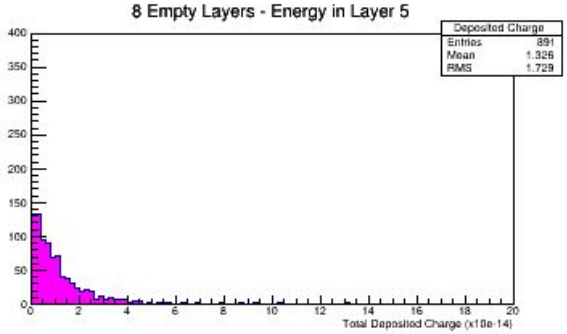
- Want to remove contaminants without eliminating low energy electron events
- Found not all events deposited in all layers
  - ~45% of events deposit in only one layer
  - See slide 6 showing which layer has deposited energy for events that only deposit in one layer
  - For Si-first test beams runs, beamline goes from layer 8 → 0
- Developed algorithm to categorize showers
  - Weig $\mathcal{E}$ each deposit by layer number
    - Beamline: layer 1 → 9
    - L = layer
    - L = deposit energy
  - Insert 5x10e-14C (MIP) to any empty layer
  - See slide 7 for the statistics and cut

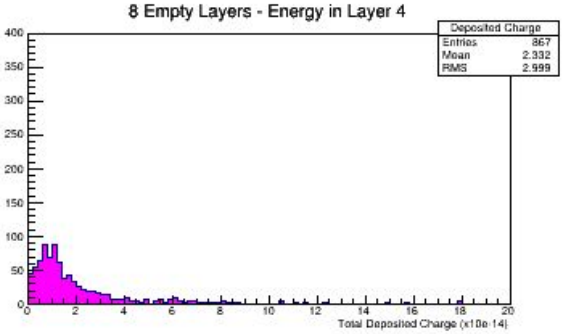
$$\frac{\sum_d L_d^2 \mathcal{E}_d}{\sum_d \mathcal{E}_d}$$

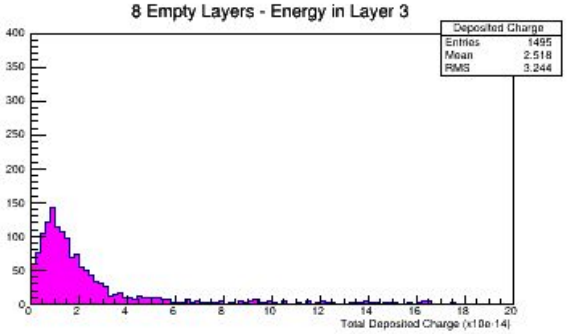

8 Empty Layers - Energy in Layer 8
Deposited Charge
Entries 121
Mean 0.9615
RMS 0.8322
Total Deposited Charge (x10e-14)

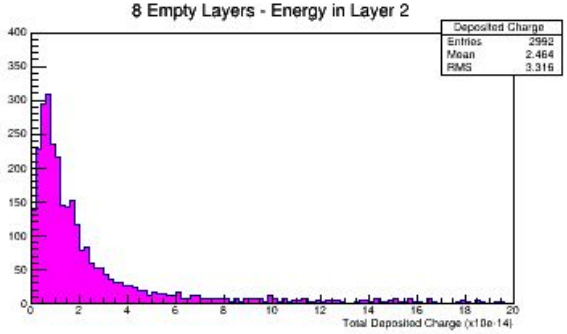

8 Empty Layers - Energy in Layer 7
Deposited Charge
Entries 329
Mean 0.8585
RMS 0.7994
Total Deposited Charge (x10e-14)

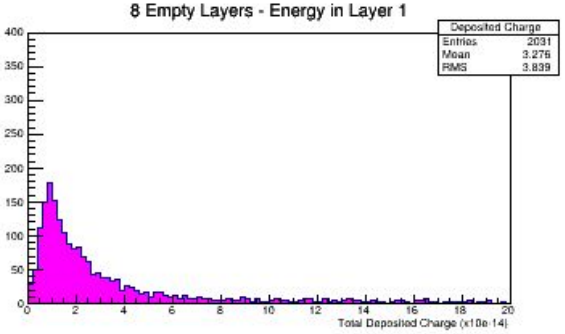

8 Empty Layers - Energy in Layer 6
Deposited Charge
Entries 406
Mean 1.255
RMS 1.201
Total Deposited Charge (x10e-14)

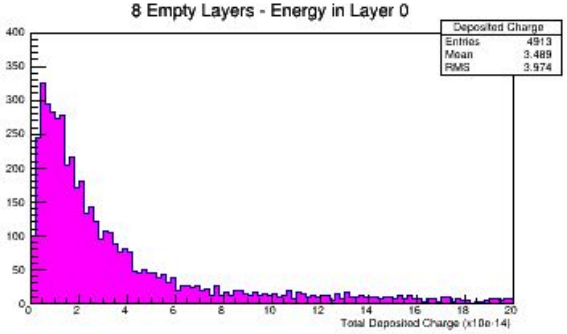

8 Empty Layers - Energy in Layer 5
Deposited Charge
Entries 891
Mean 1.326
RMS 1.729
Total Deposited Charge (x10e-14)

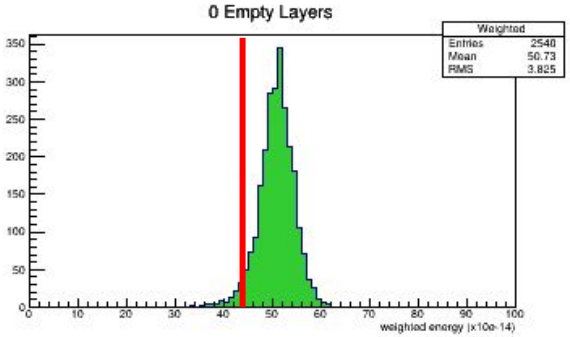

8 Empty Layers - Energy in Layer 4
Deposited Charge
Entries 867
Mean 2.332
RMS 2.999
Total Deposited Charge (x10e-14)

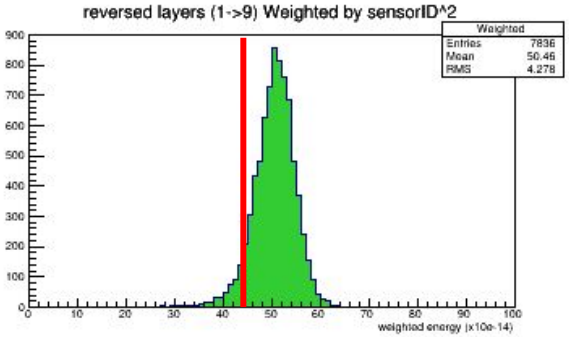

8 Empty Layers - Energy in Layer 3
Deposited Charge
Entries 1495
Mean 2.518
RMS 3.244
Total Deposited Charge (x10e-14)

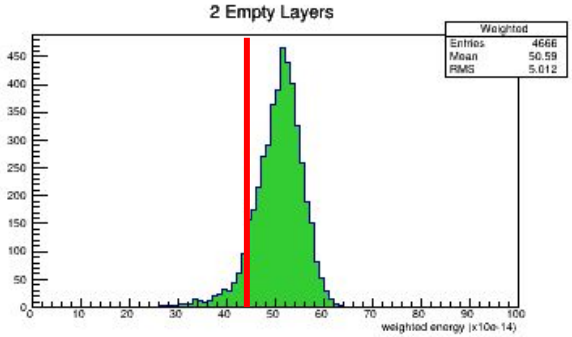

8 Empty Layers - Energy in Layer 2
Deposited Charge
Entries 2992
Mean 2.464
RMS 3.316
Total Deposited Charge (x10e-14)

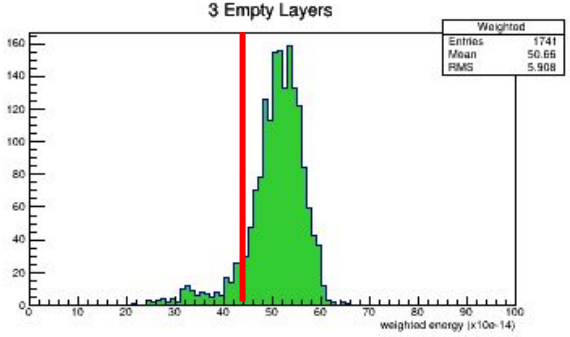

8 Empty Layers - Energy in Layer 1
Deposited Charge
Entries 2031
Mean 3.275
RMS 3.839
Total Deposited Charge (x10e-14)

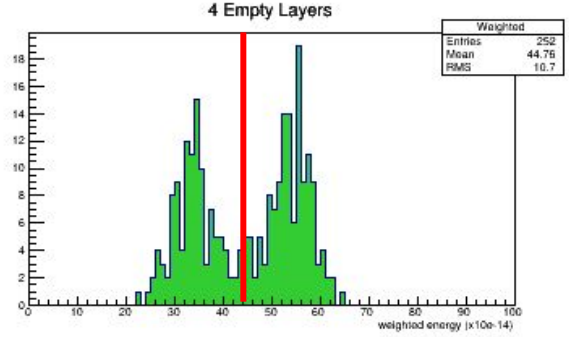

8 Empty Layers - Energy in Layer 0
Deposited Charge
Entries 4913
Mean 3.489
RMS 3.974
Total Deposited Charge (x10e-14)

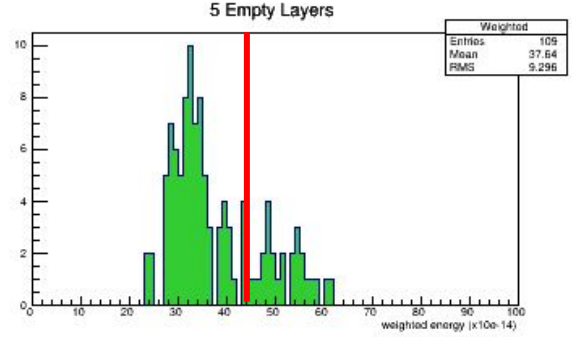

0 Empty Layers
Weighted
Entries 2540
Mean 50.73
RMS 3.825
weighted energy (x10e-14)

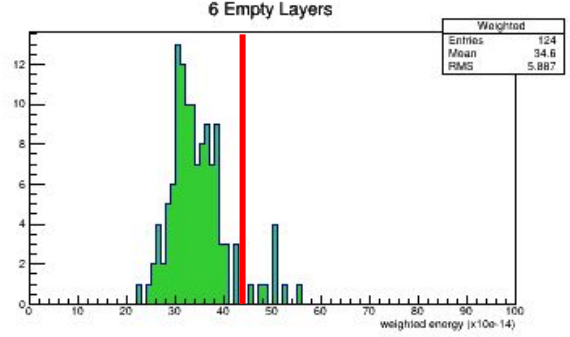

reversed layers (1->9) Weighted by sensorID^2
Weighted
Entries 7836
Mean 50.46
RMS 4.278
weighted energy (x10e-14)

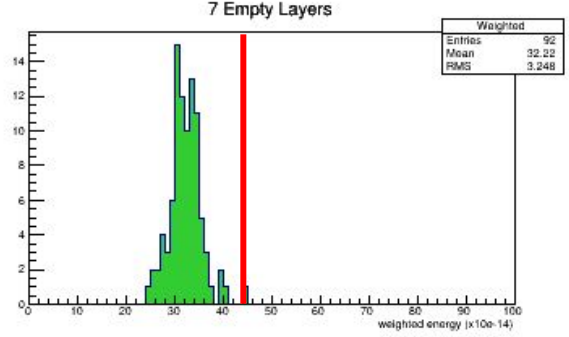

2 Empty Layers
Weighted
Entries 4666
Mean 50.59
RMS 5.012
weighted energy (x10e-14)

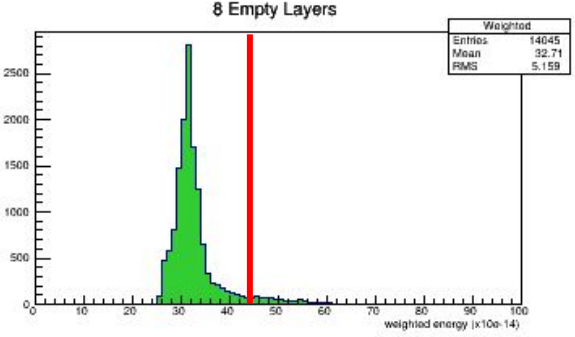

3 Empty Layers
Weighted
Entries 1741
Mean 50.66
RMS 5.908
weighted energy (x10e-14)


4 Empty Layers
Weighted
Entries 252
Mean 44.76
RMS 10.7
weighted energy (x10e-14)


5 Empty Layers
Weighted
Entries 109
Mean 37.64
RMS 9.296
weighted energy (x10e-14)

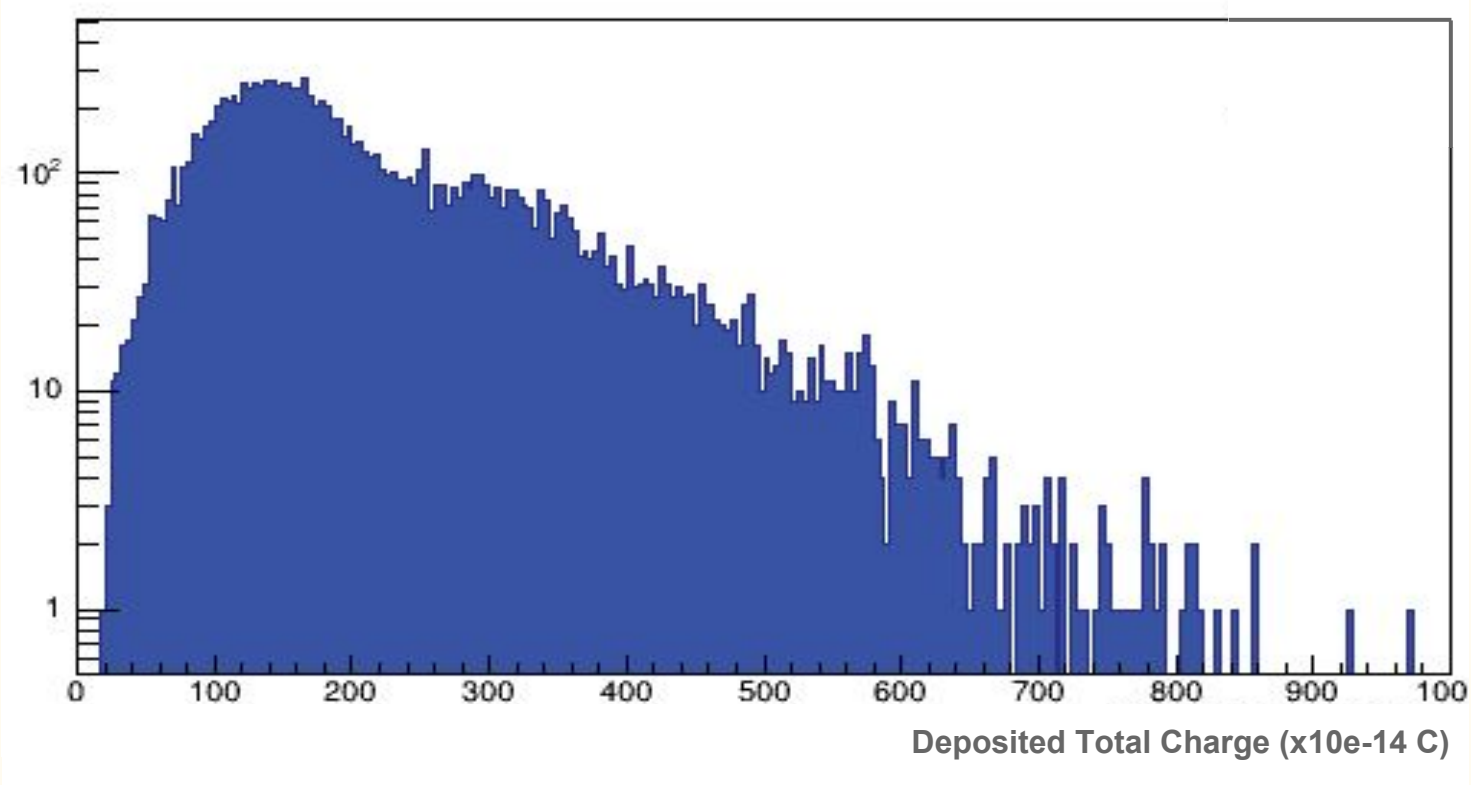

6 Empty Layers
Weighted
Entries 124
Mean 34.6
RMS 5.887
weighted energy (x10e-14)


7 Empty Layers
Weighted
Entries 92
Mean 32.22
RMS 3.248
weighted energy (x10e-14)


8 Empty Layers
Weighted
Entries 14045
Mean 32.71
RMS 5.159
weighted energy (x10e-14)

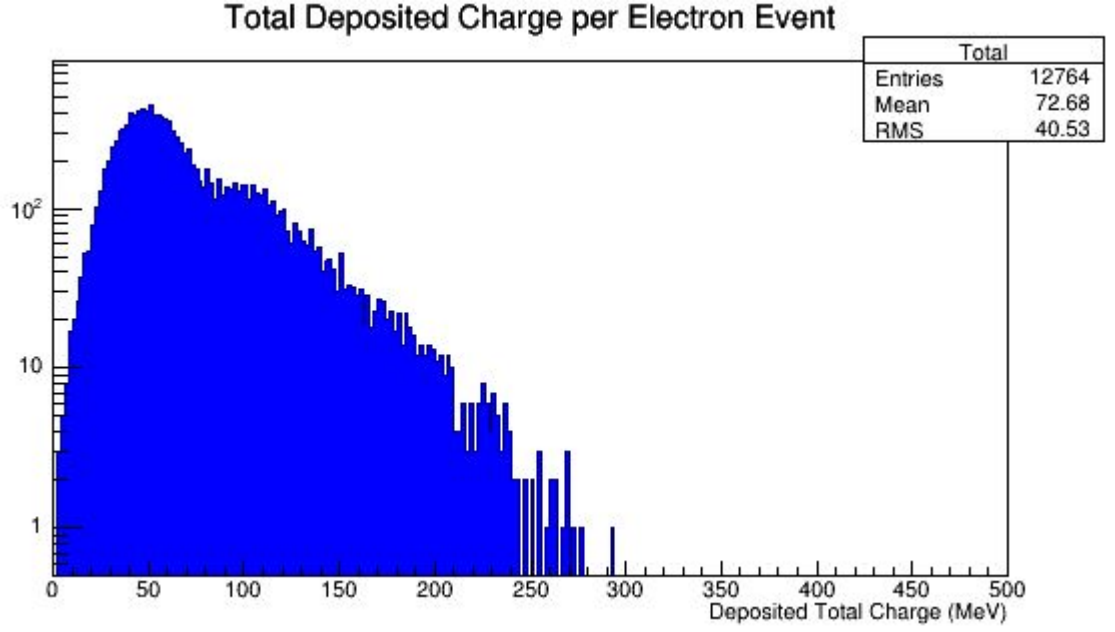
Test Beam Data Cleaning

Remove ~50% of total events (soft photons)

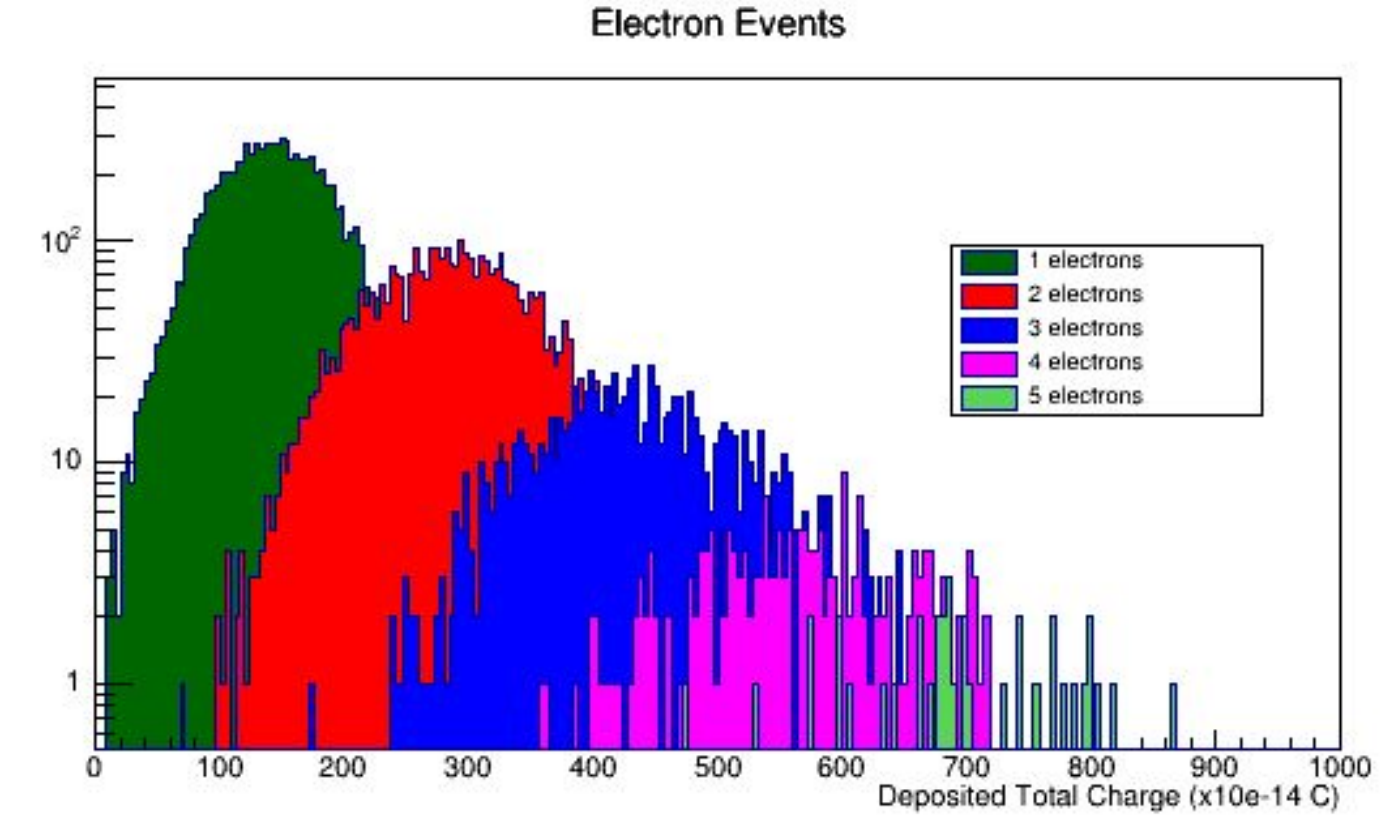


Geant4 MC Optimization

- 8000 single-electron events aimed at center of wafer
- Gaussian smear and shift off center
- Poisson distribution for up to 5-electron events
- Randomly remove 10% of pixels from each layer to account for inactive pixels
- Done to model test beam data

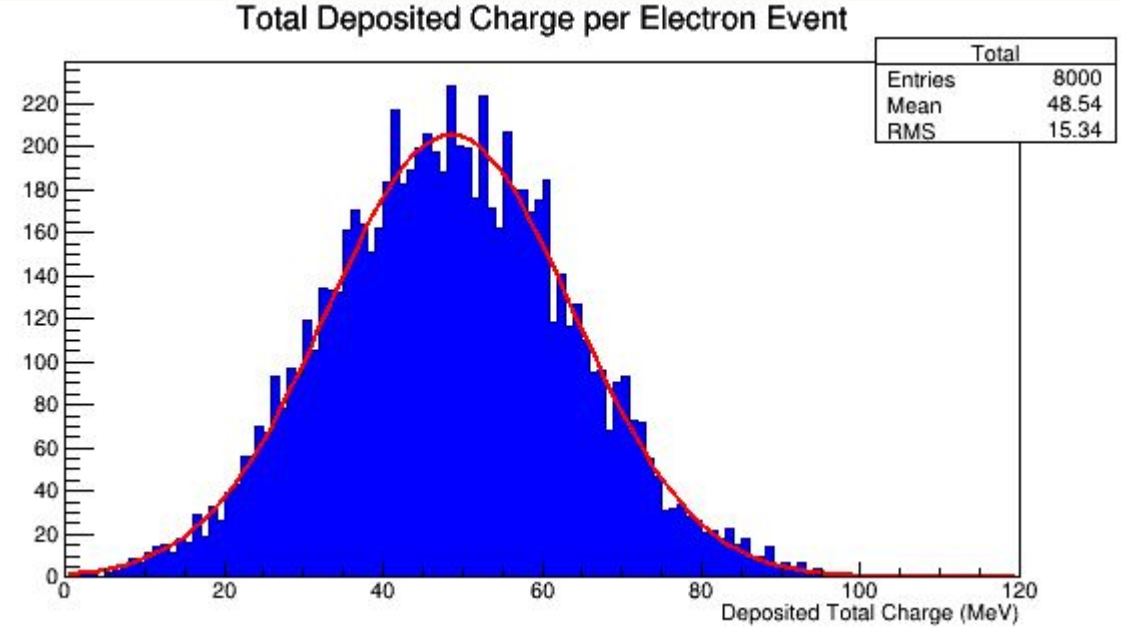


MC Total Energy from Multiple Electron Distribution



Geant4 Single Electron Distribution

- Single electron events have a Gaussian distribution
  - $\sigma = 15.37$ +/- 0.13
  - $E_0 = 48.44$ +/- 0.18
- Simulation underestimates spread of distribution - may need to broaden Geant4



Fitting Function

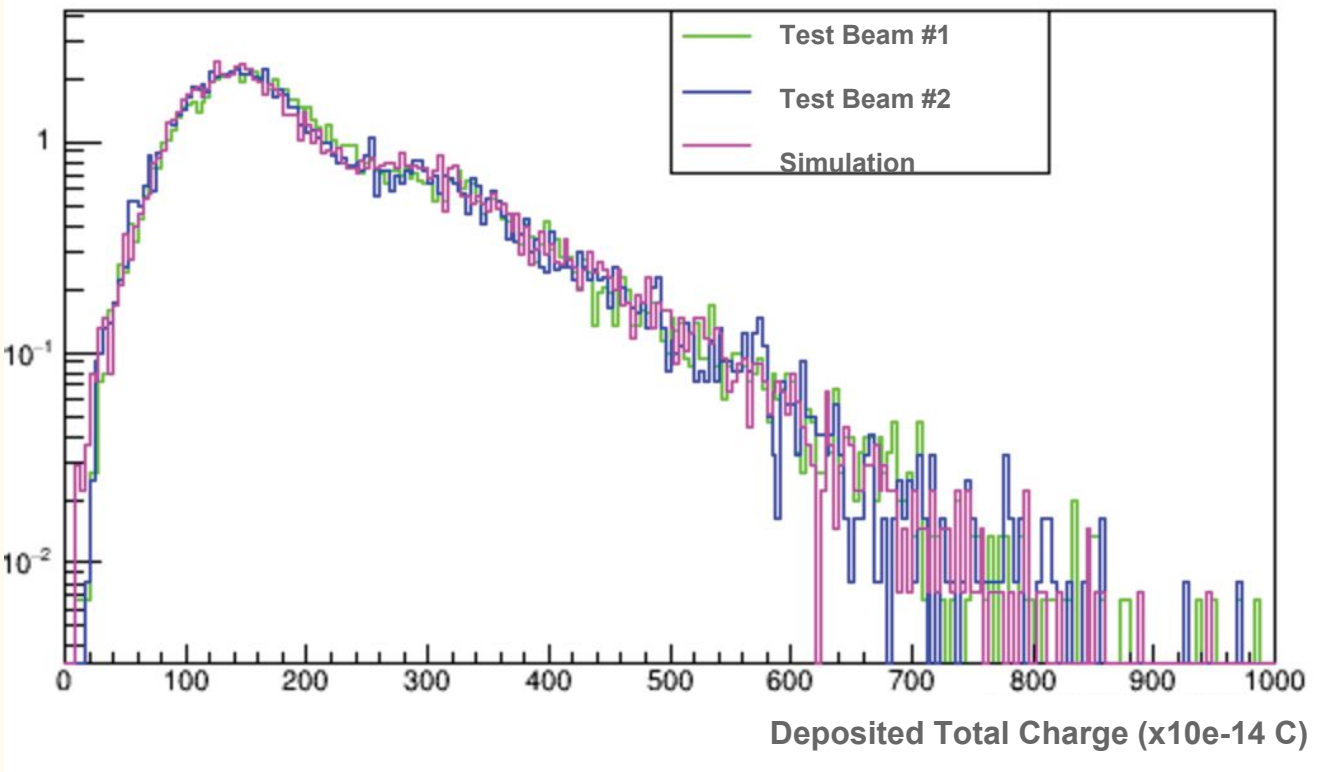
- Need to optimize three parameters
  - Scaling a (should be identical for both orientations)
  - Electron Poisson distribution $<n>$
  - Difference in spread of simulated vs experimental single electron spectrum σ
    - experimental RMS > simulated RMS
- Fitting function:

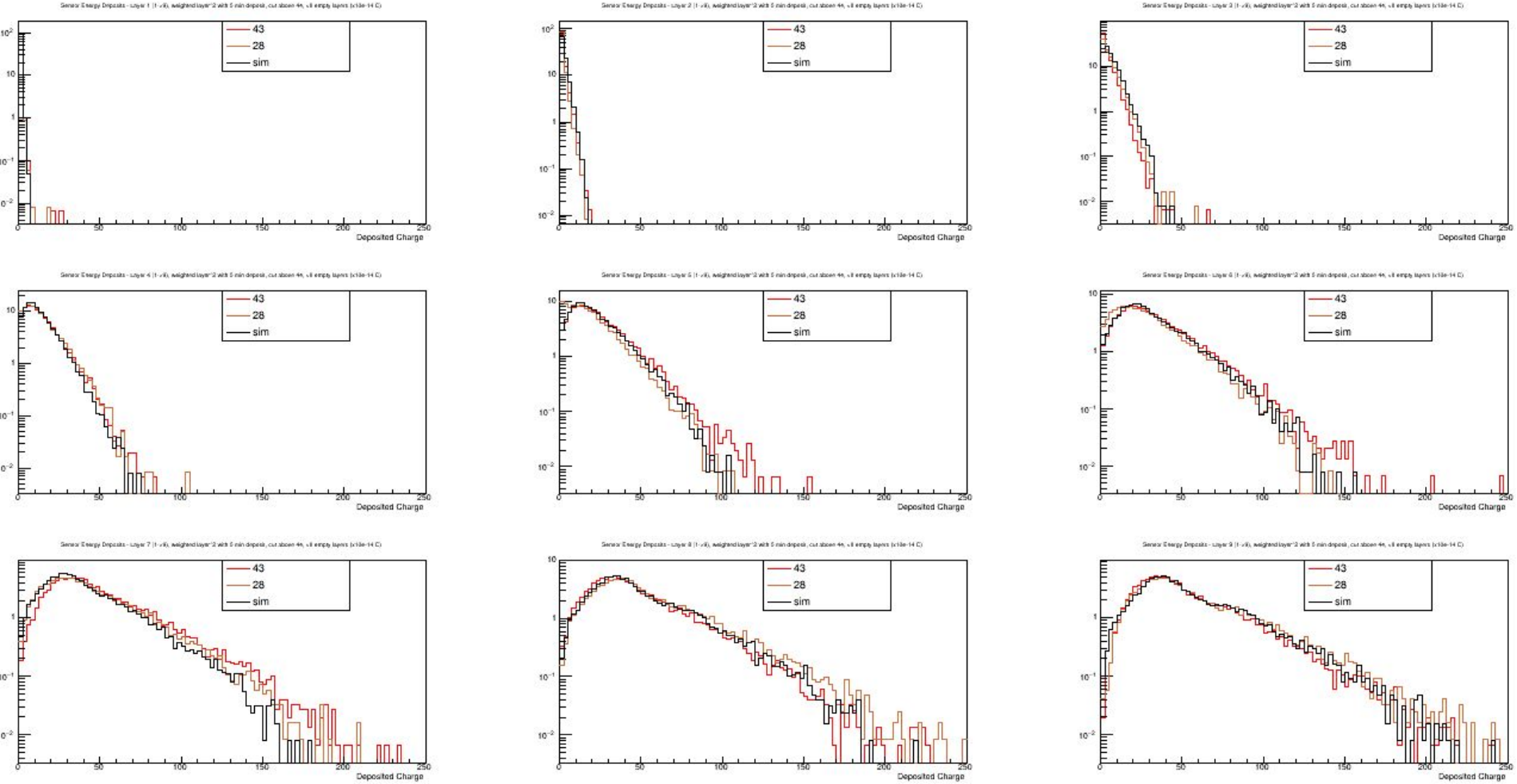
$$D(E) = \sum_{n=1}^{\infty} P(n, \langle n \rangle) \mathcal{E}\left(E, anE_0, a^2 n(\sigma_{MC}^2 + \sigma^2)\right)$$

$$P(n, \langle n \rangle) = \frac{\langle n \rangle^n e^{-\langle n \rangle}}{n!\left(1 - e^{-\langle n \rangle}\right)}$$

Experiment Agrees with Simulation

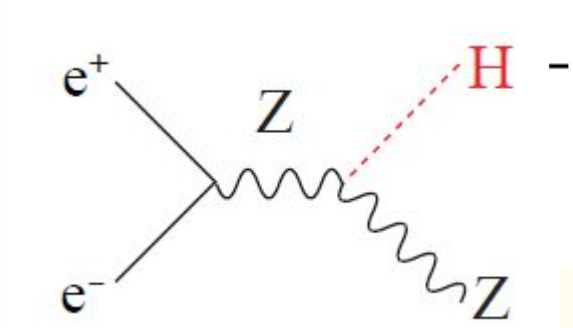
- Normalized to 100 events
- Conversion factor: 2.9575 MeV = 1x10e-14 C
  - Found from fitting function (a)
- $n = 0.8725$
- $\sigma = 0$

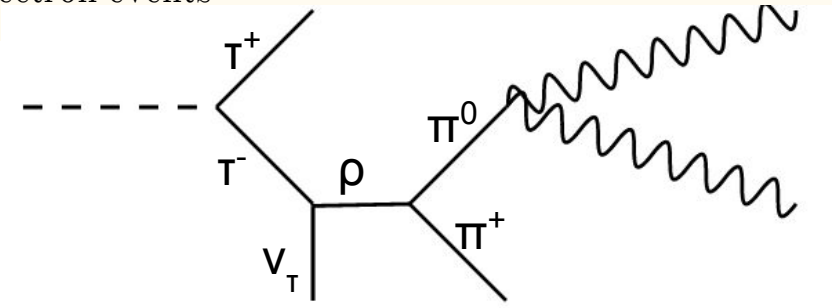



43
28
sim
Deposited Charge

Electron Counting Efficiency

- Want to use full ILC for precise measurements
  - Ex: Higgs mass, Higgs branching ratios
- Higgstralung decay ⇒ two close photons
  - Want to be able to distinguish
- Use current detector setup to identify nearby showers
  - Previous algorithm = ~88% correct at counting electrons
  - Especially interested in 2-electron events





New Counting Algorithm

- Import files
  - Neighbor geometry of silicon wafer
  - Energy deposits (9 layers of 1024 pixels)
  - True electron number per event
- Collect local maxima of deposits for each layer
- Require same pixel to be a local maxima >3 layers
  - Biases against late forming showers

Counting Improvements

- Assisted by Nick Romig (summer high school student)
- Updated neighbor files in central region
- Disallowed maxima in neighboring pixels
- Still shortcomings
  - Biased against late-developing showers
  - No advantage to high granularity center for test beam

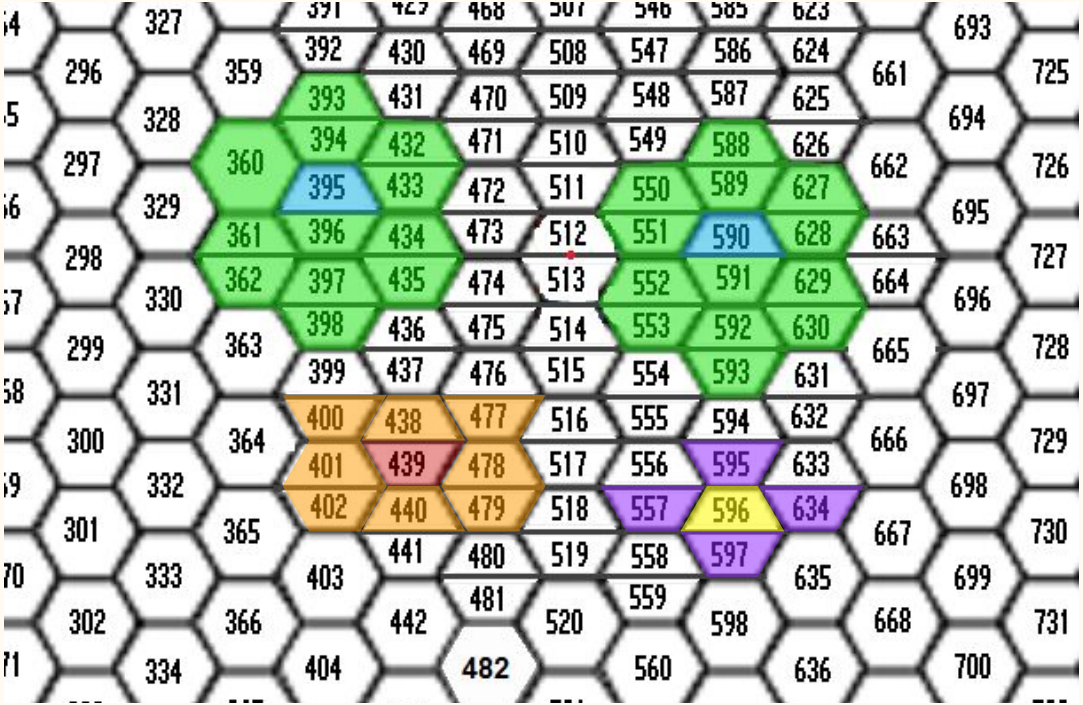
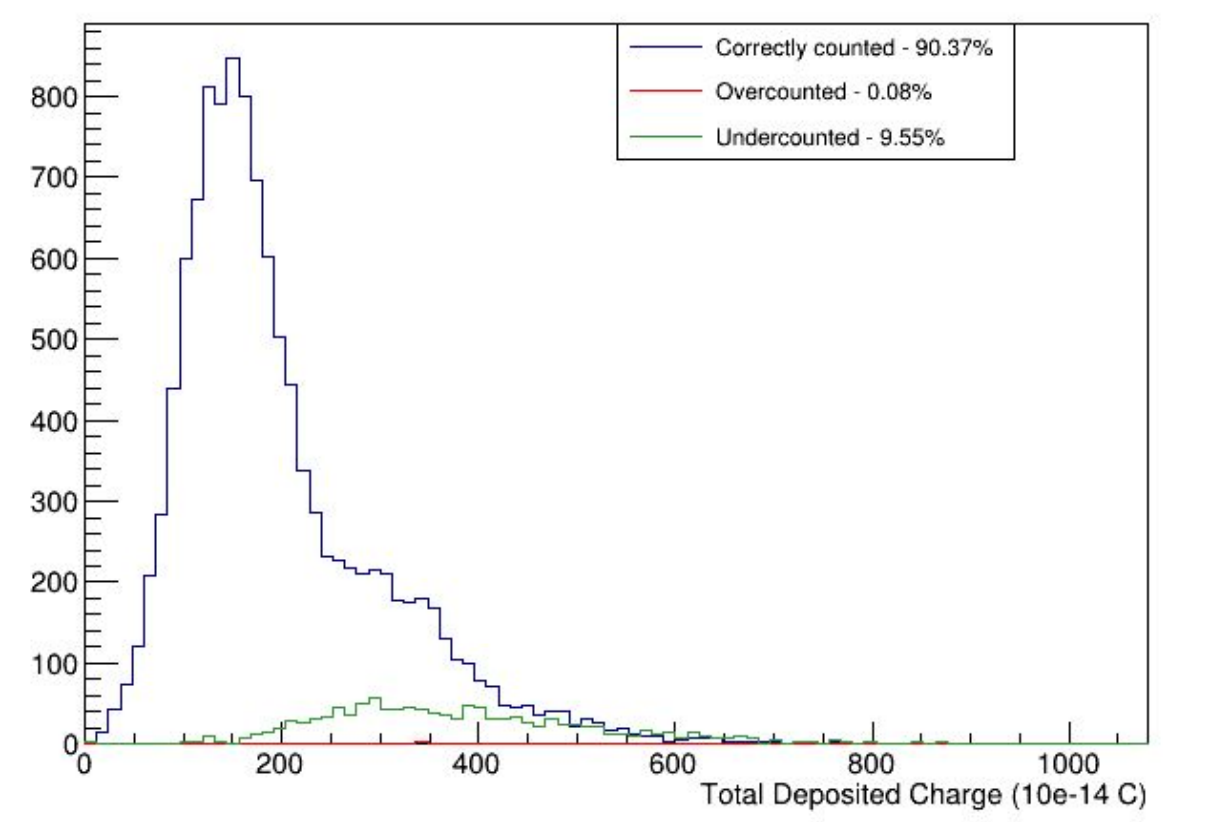
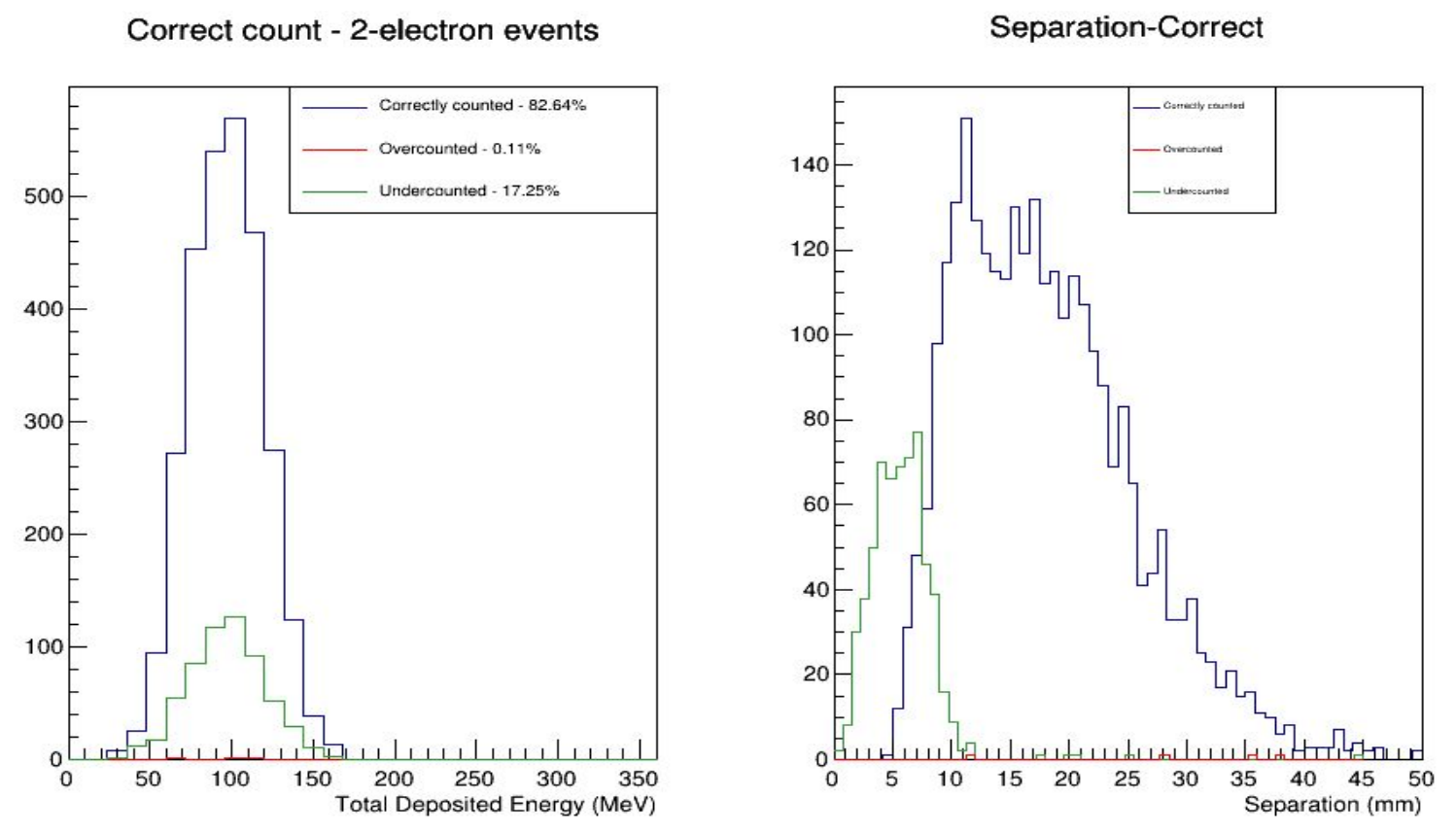


Image: Craig Gallagher

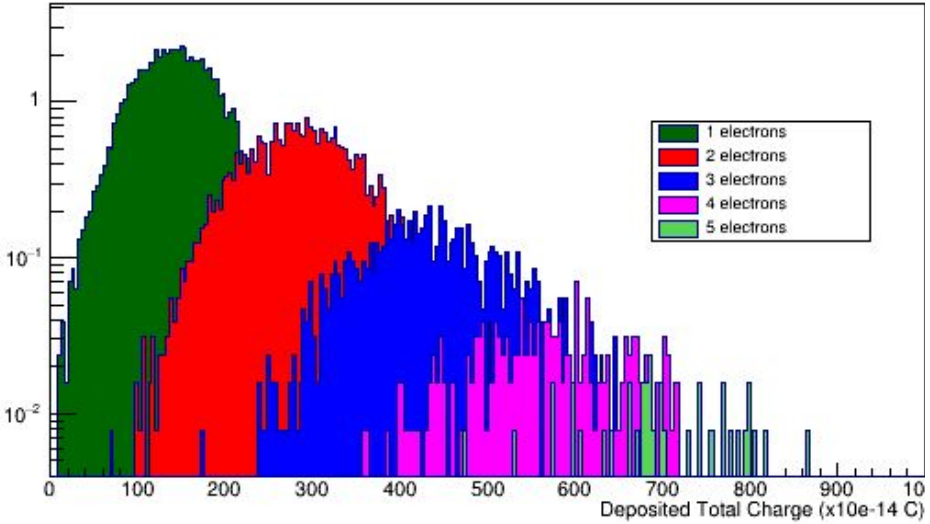
Current Algorithm Counts More Accurately



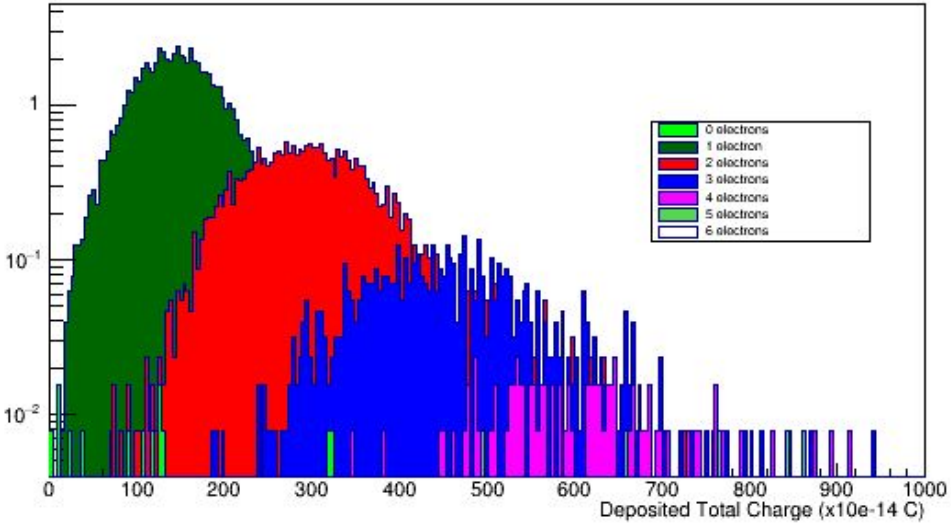
2-Electron Separation Counting



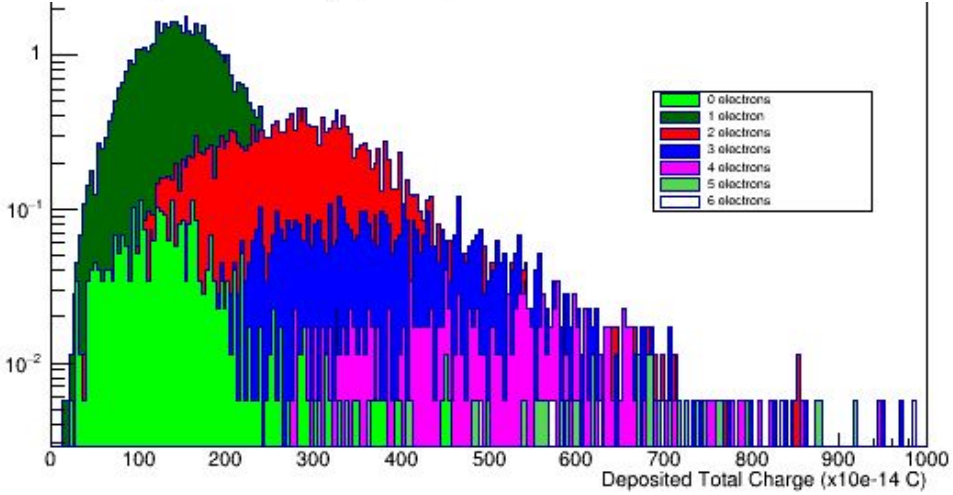
Electron Events -Simulation Truth



Electron Events -Simulation Tagged



Electron Events - Test Beam Tagged



Simulation Tagging Results

		TAGGED					
		0	1	2	3	4	5
TRUTH	1	0.20%	99.80%	0.00%	0.00%	0.00%	0.00%
	2	0.10%	17.20%	82.60%	0.10%	0.00%	0.00%
	3	0.00%	5.40%	36.40%	58.00%	0.20%	0.00%
	4	0.00%	0.90%	16.70%	48.90%	33.00%	0.50%
	5	0.00%	0.00%	7.90%	42.10%	36.80%	13.20%

Future Work

- 87% →95% efficient at counting
- Improve algorithm further to eliminate bias against late showers
- Test algorithm with Higgs decay physics events
  - Familiarize with grid
  - Use yesterday's simulation tutorial

Questions?