Reconstruction in a Segmented Calorimeter

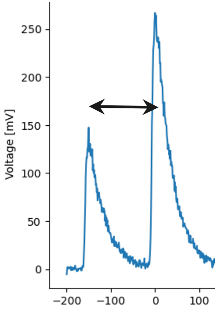
Omar Beesley

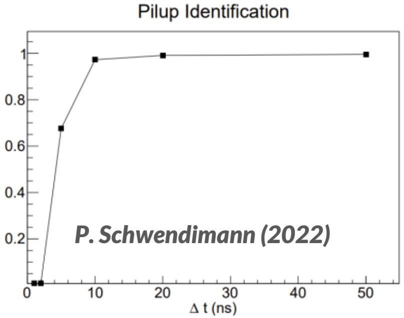
Current Calorimeter Reconstruction

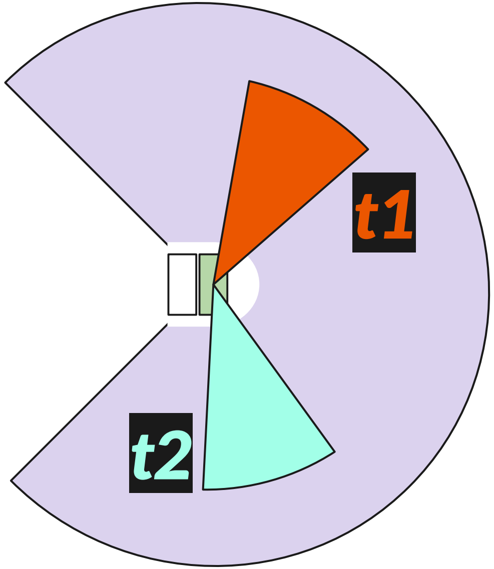
|t1-t2| < 10 ns → Pileup

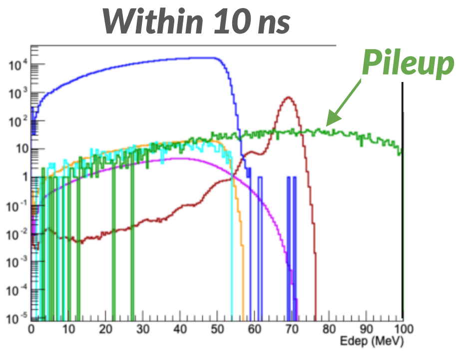
|t1-t2| > 10 ns → Not Pileup

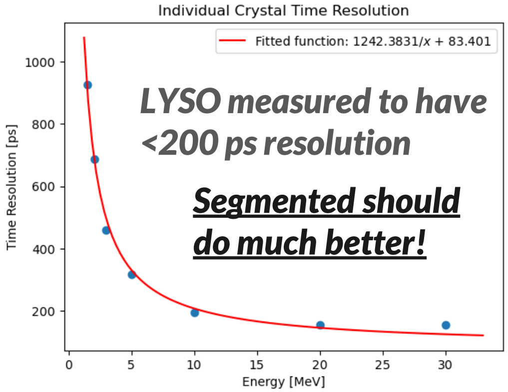
Move templates closer together until fitter can't find two pulses







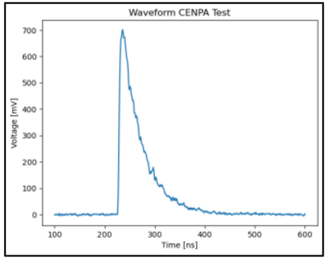


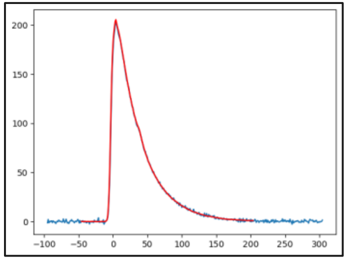


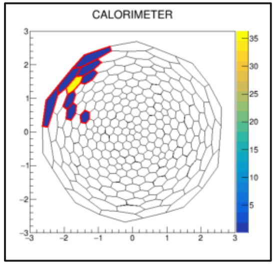
Implementation of LYSO Detector Response

Truth energies/times → Waveforms → Fitted waveforms (reconstructed energies/times) → Calorimeter clusters

```
True Hit Energy:  15.087931632995605
True Hit Time:  4801.29052734375

True Hit Energy:  7.043130874633789
True Hit Time:  4801.31982421875

True Hit Energy:  1.0506820678710938
True Hit Time:  4801.35302734375

True Hit Energy:  0.7235432863235474
True Hit Time:  4801.38818359375

True Hit Energy:  0.7524951100349426
True Hit Time:  4801.380859375

True Hit Energy:  0.421333372592926
True Hit Time:  4801.4453125

True Hit Energy:  0.9610615968704224
True Hit Time:  4801.349609375

True Hit Energy:  2.3206822872161865
True Hit Time:  4801.234375
```

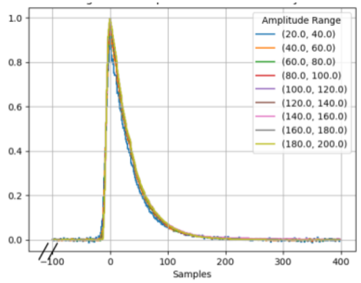




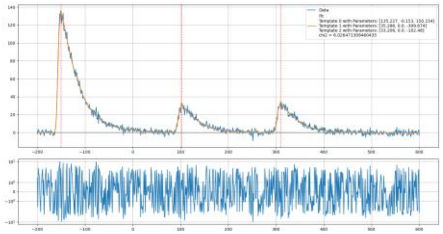


A Waveform Generator from LYSO Waveforms

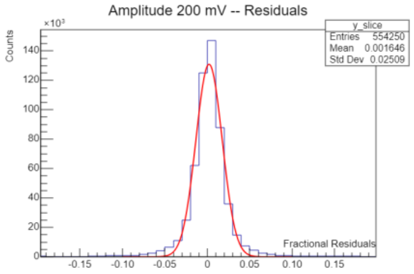
1. ***Templates built from testbeam waveforms across PIONEER energy scale***



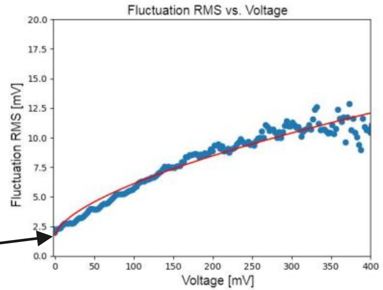
2. ***Waveforms are fit with templates and residuals are recorded as a function of voltage***



3. ***Residual distributions at each voltage are fit to quantify voltage dependent fluctuations***



4. ***Fluctuation size is fit as a function of voltage to obtain a two parameter waveform model***



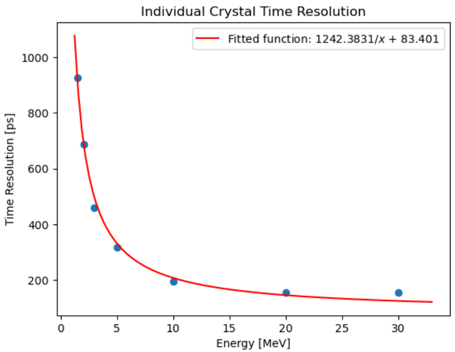
Pedestal noise

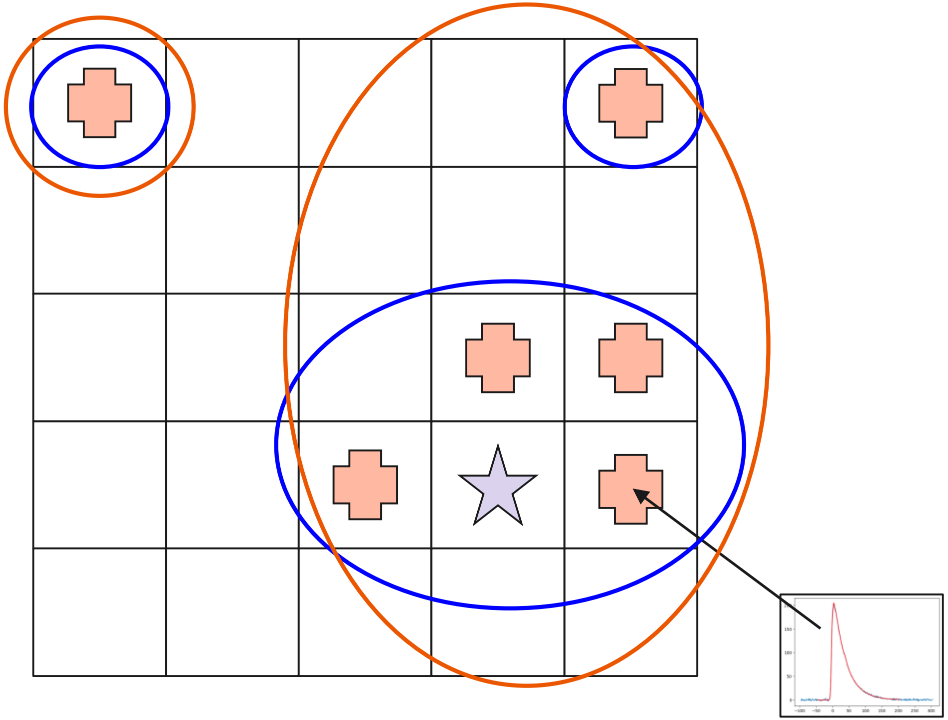
Omar Beesley - University of Washington

Outline of LYSO Clustering Algorithm

Crystal hits within 2.5 R_M that are within 3.5 standard deviations of time resolution – combined to form "***bunches***"

Bunches within 5 R_M that are within 2 standard deviations of time – combined to form "***proto clusters***"

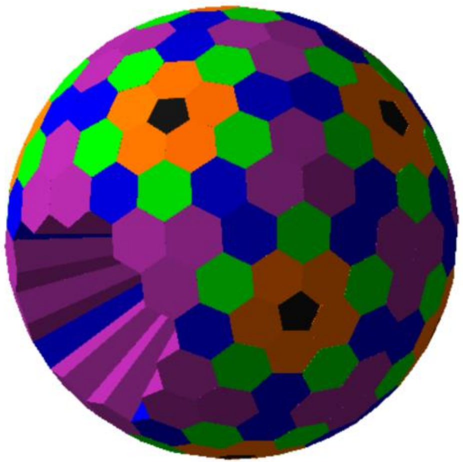


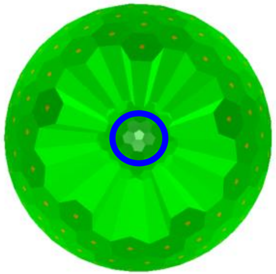


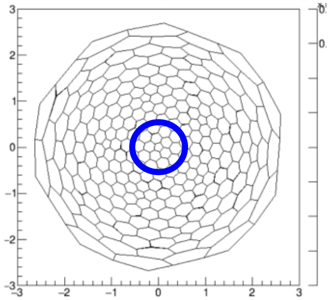
Calorimeter and Beam Setup

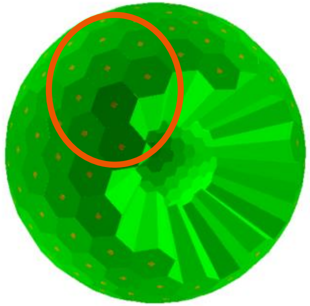
Nominal LYSO inner radius is now 15 cm

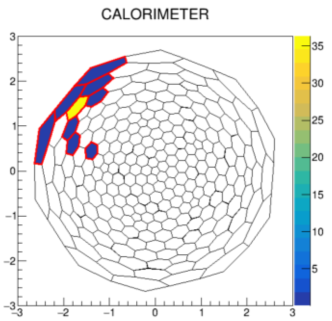
- *Beam of pions with 3e5 rate – forced to decay to muons*

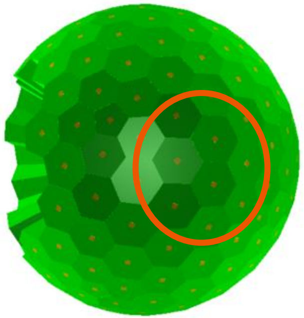


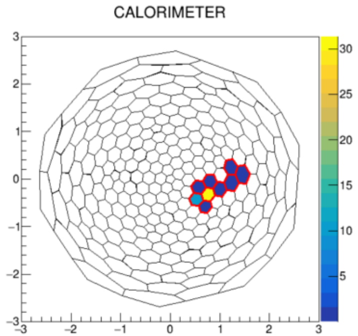






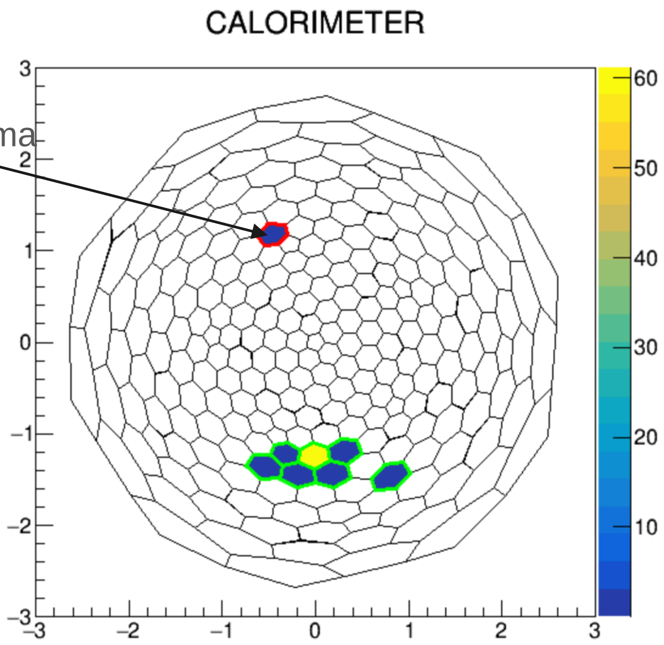




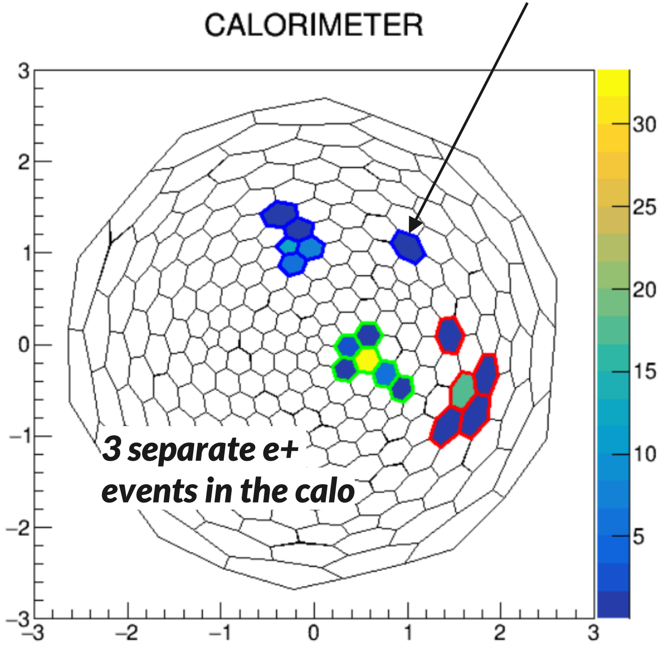


Event Displays

511 keV gamma from albedo

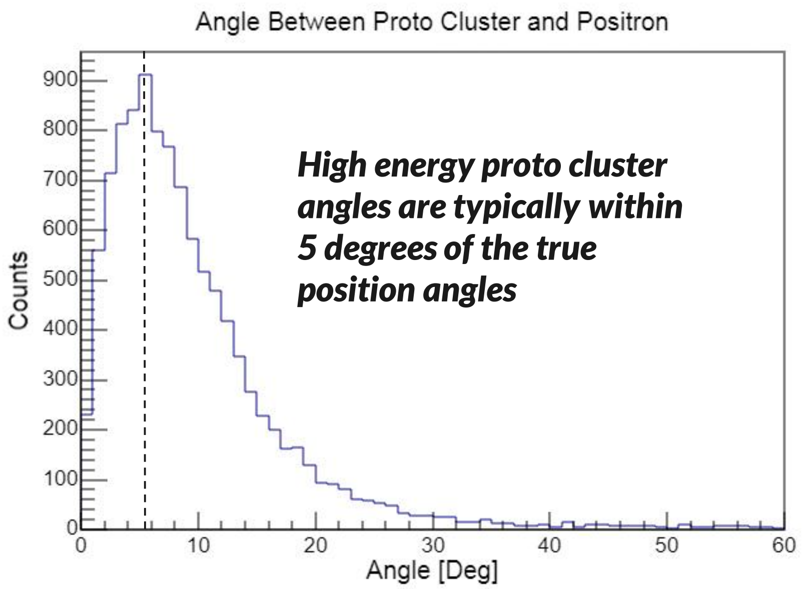


Look 5 R_M to capture 511s

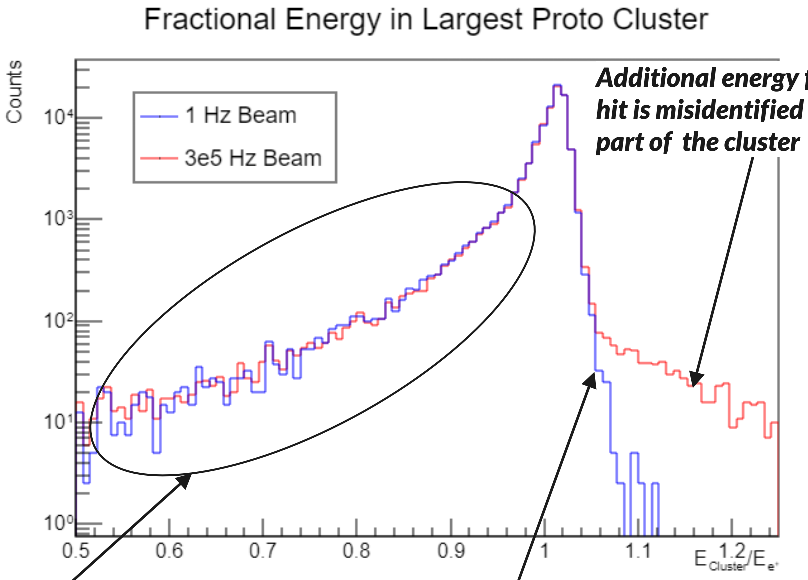


3 separate e+ events in the calo

Proto cluster performance



High energy proto cluster angles are typically within 5 degrees of the true position angles



Additional energy from a 2nd hit is misidentified as being part of the cluster

Highest energy proto cluster misses energy

Uncertainty in reconstructed energy from fitter

Reconstruction from proto clusters to clusters

Simulation outputs proto clusters – user able to do additional reconstruction/merging

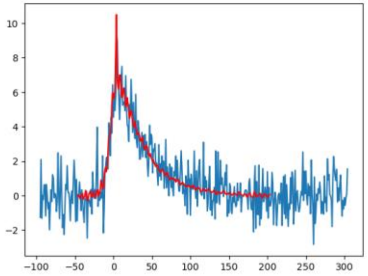
- To classify events using only calo information, energy dependent criterion for timing difference used to combine ***proto clusters*** into ***clusters***
    - Proto clusters above 5 MeV need to be almost exactly time coincident to be merged – rarely merged

bunches → ***proto clusters*** → ***clusters***

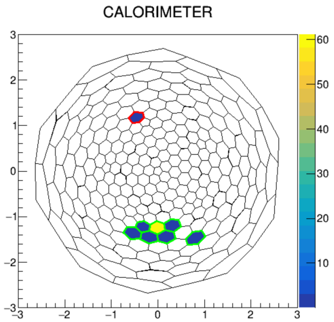
Time Difference	**Overall Efficiency**	**More clusters than e+**	**More e+ than clusters**	**Reasons for inaccuracy**
0-2 ns	86%	0.3%	13.7%	1. Timing limitations 2. Fitter bug 3. Delayed energy deposits
2-10 ns	98%	0.5%	1.5%	1. Delayed energy deposits 2. Fitter bug 3. Timing limitations
Overall <10 ns	95.4%	0.5%	4.1%	

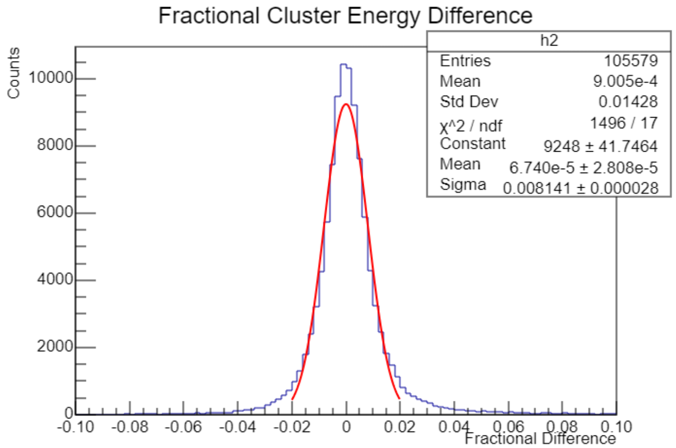
Effect of clustering on calorimeter energy resolution

Uncertainty of reconstructed energy from fit - especially at low energies



Inaccurate clustering of 511s





Add uncertainty in cluster energies to intrinsic calorimeter resolution via quadrature

- ***Reconstruction smears 1.8% resolution to 2%***

Next Steps

- Improve fitter stability and introduce correlated waveform fits
- Implement LYSO intrinsic radioactivity at a Geant4 level
- Optimize clustering for PiBeta
- Train a neural network to classify and cluster events in the calorimeter