FastSim Study of Energy Resolution Degradation due to Machine Background Pileup

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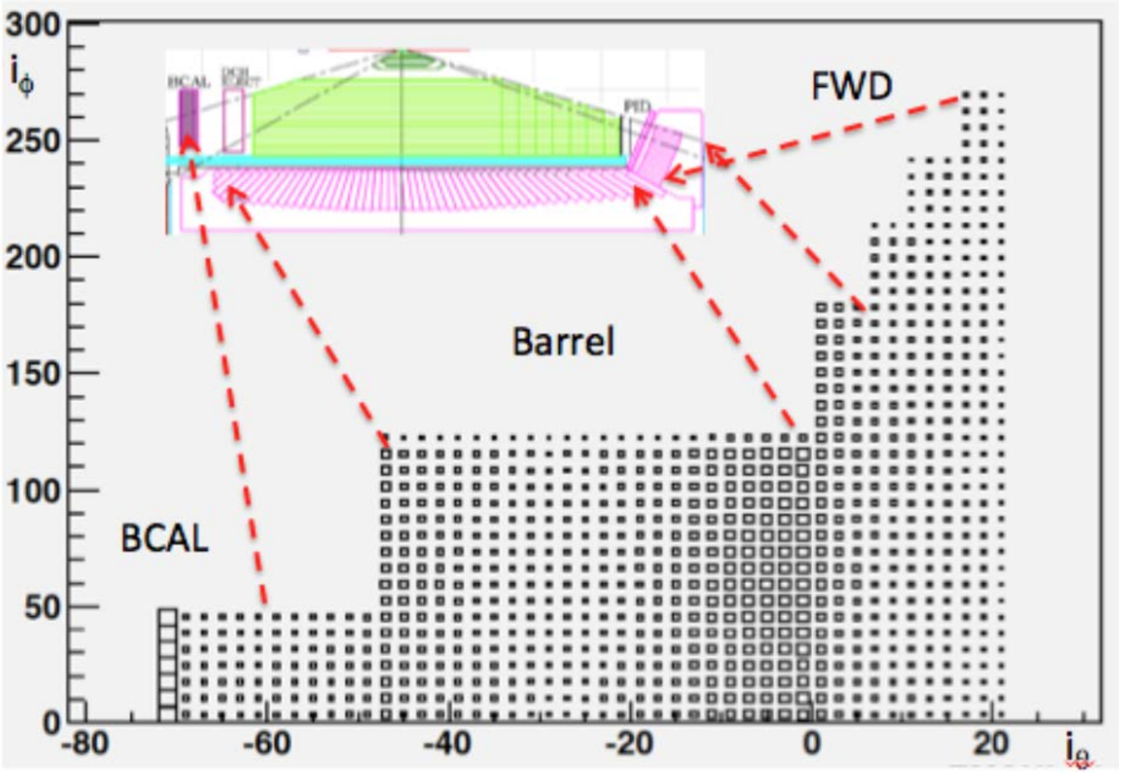
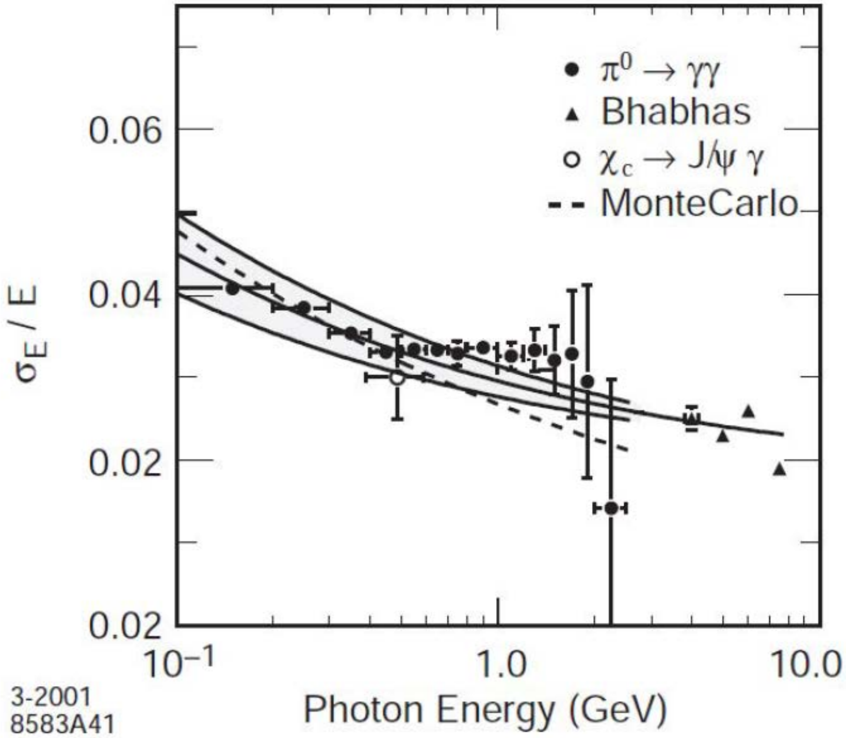
Problem

- Due to the hundred fold increase in luminosity at SuperB, we expect radiative bhabha's to be the dominant machine background.
- Therefore, the degradation in energy resolution due to pileup of machine background must be contained.



Energy Resolution

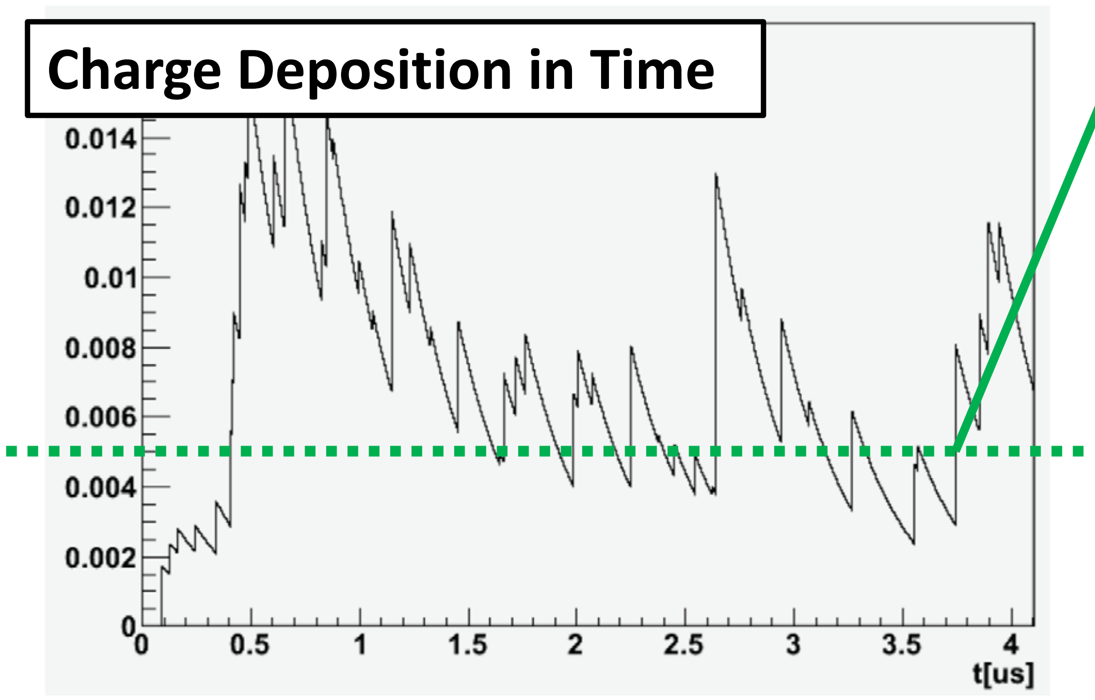
$$\sigma_E = \sigma_{p.e.} \oplus \sigma_{elec} \oplus \sigma_{intrinsic}$$



- The energy resolution of the EMC necessary to achieve SuperB's physics goals should be the same as those at Babar.
- A look at the Babar resolution profile leads us to conclude that pileup should contribute approximately less than 3 MeV at 100 MeV of energy deposition.

Energy Resolution

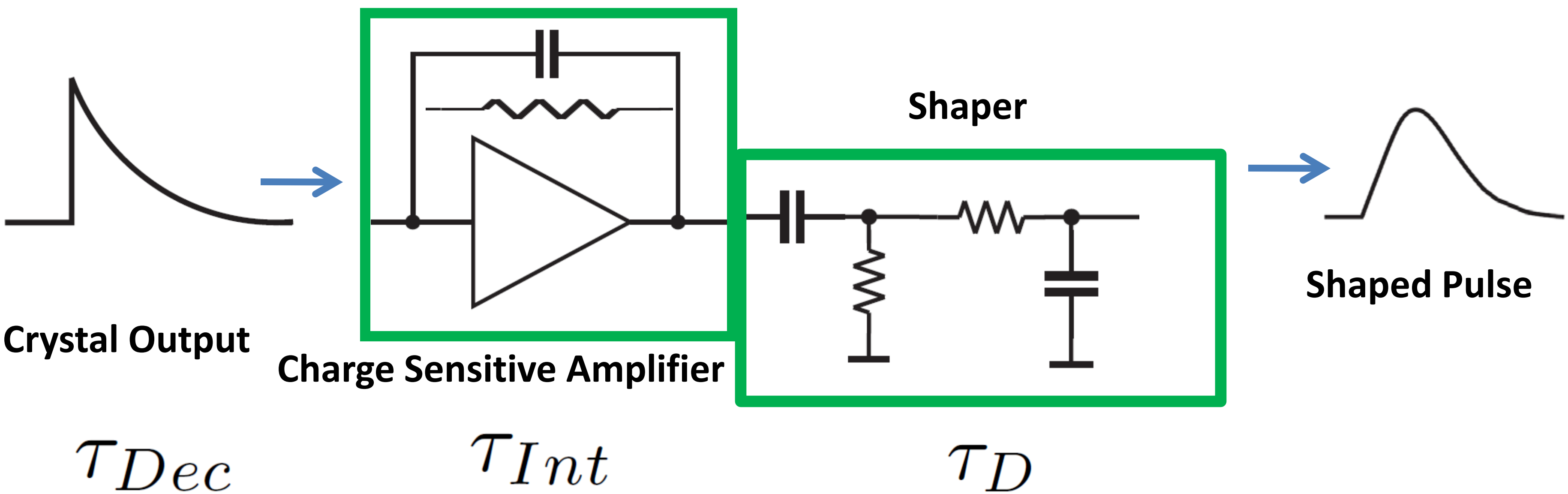
$$\sigma_E = \sigma_{p.e.} \oplus \sigma_{elec} \oplus \sigma_{intrinsic} \boxed{\oplus \sigma_{pedes}}$$



- We can think of the pileup contribution to energy smearing as a pedestal.
- Therefore, this term should be constant as a function of energy deposited.

Signal Amplification and Shaping

- Want to have as little pileup as possible; we can achieve this by shaping the pulse appropriately.
- The pulse passes through different stages. Conceptually:



Toy Study Estimate of Pileups

- From the Bruno FullSim files, we obtain the hit time of the background particles in different regions of the EMC. In fact, this is done for individual crystals for the region(s) of interest.
- For every particle that strikes, we place an exponential with the appropriate height and crystal time constant (T_{Dec}) that represents its energy deposition.
- We then integrate the energy in randomly placed windows of length equal to a preamp integration time of interest (T_{int}).
- We sum together the energy of 5x5 neighboring crystals, and compute their contribution to the energy resolution.

Toy Study Estimate of Pileups

model	T_{dec} (ns)	T_{int} (ns)	central barrel	forward barrel	external FWD	internal FWD
LYSO	50	50	N/A	N/A	0.4	2.6
BGO (short)	300	100	N/A	N/A	0.5	1.4
BGO (long)	300	300	N/A	N/A	2.5	5.8
CsI(Tl) (BaBar)	1300	700	2.4	7.3	N/A	N/A
CsI(Tl) (short)	1300	300	0.6	2.0	N/A	N/A

- This table lists the energy smearing due to pileup in MeV.
- The forward barrel corresponds to the 1st ring in the forward region.
- The central barrel corresponds to the 20th ring.

FastSim: Simulation Flow

EvtGen: Shoot single Photon of specified energy in the EMC forward barrel.
Background Frame: Import from ROOT files.
Cuts:
1. **z coordinate of particle creation.**
2. **Minimum KE of particle.**

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→

Try to make clusters for every SimTrk.
Cuts:
1. **L1 trigger threshold.**
2. **Crystal threshold.**
3. **Windowing algorithm.**

Attempt to split / merge clusters from different SimTrks.

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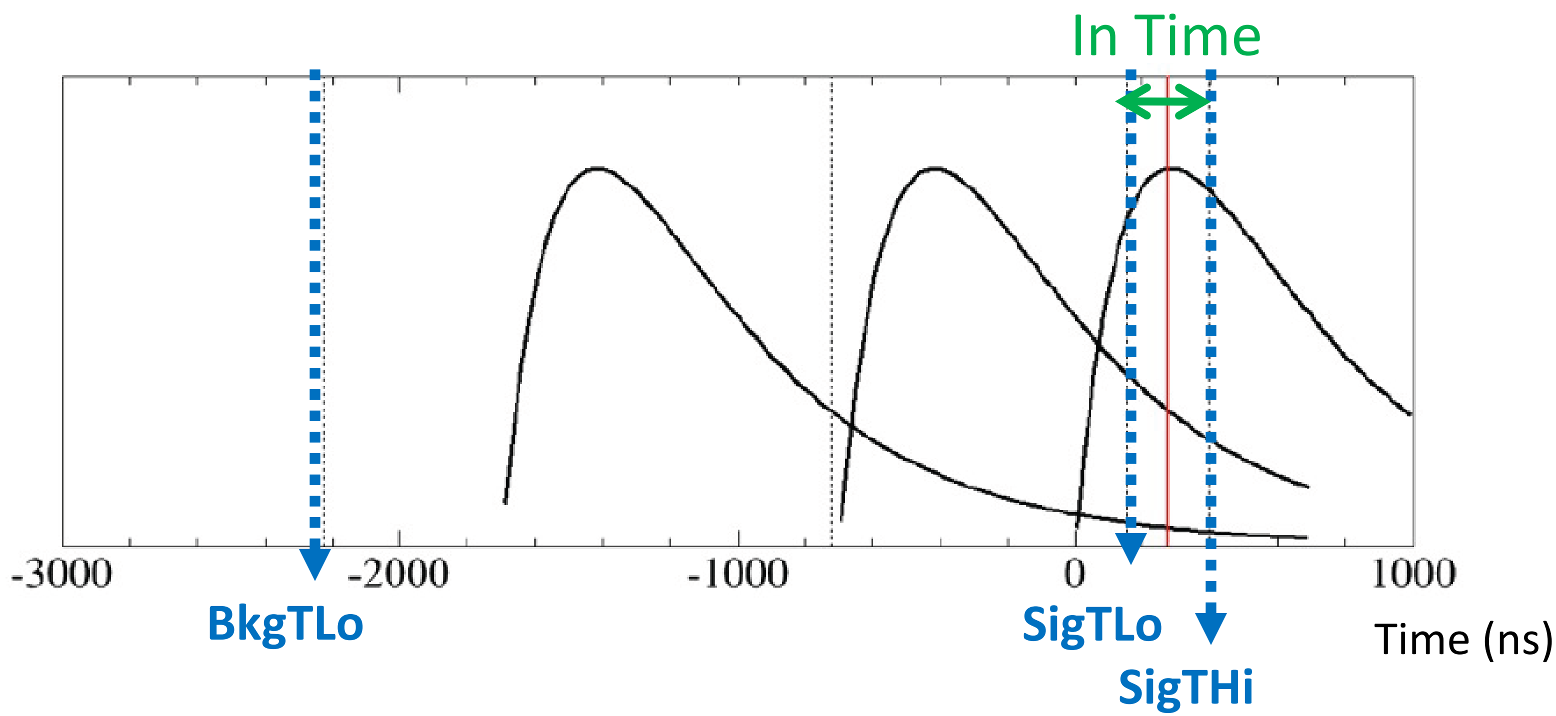
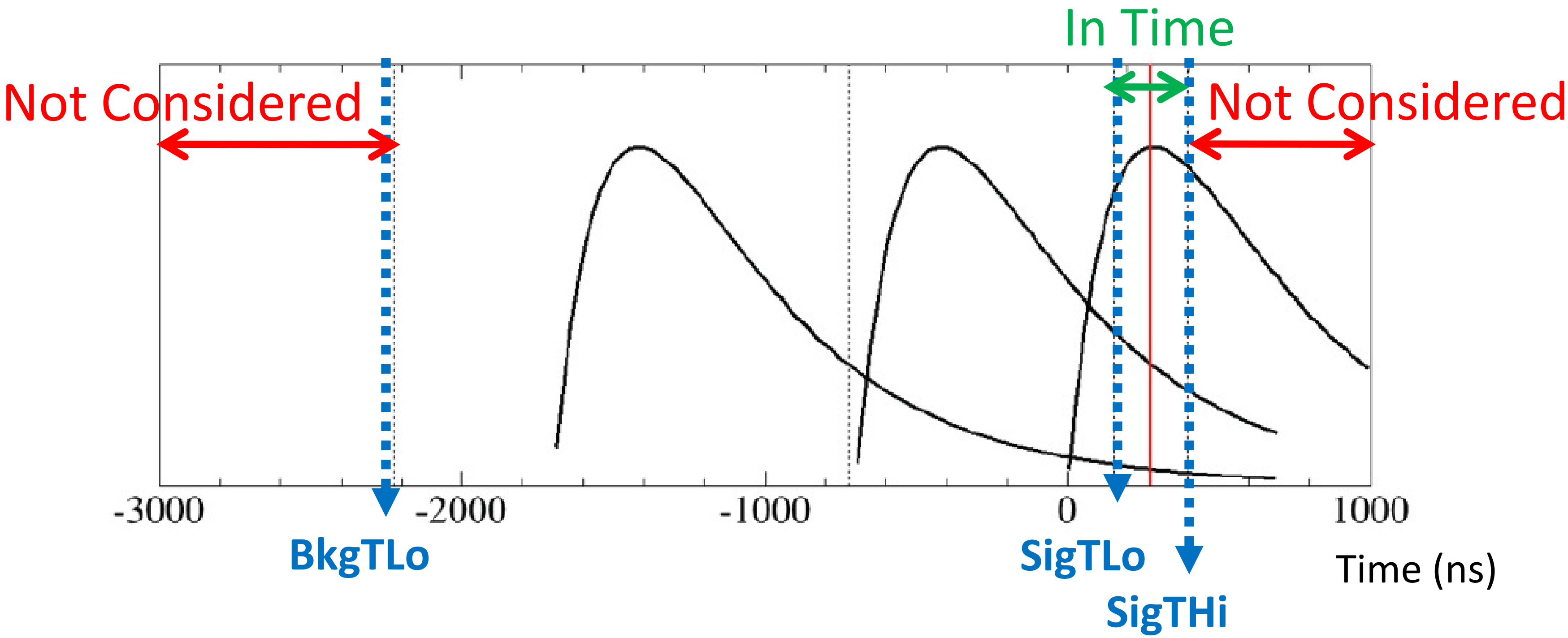
Noise cleanup.
Cuts:
1. **Low energy digis removed. (currently not in my jobs)**
2. **"Out of time" clusters removed.**
3. **Only clusters with energy above a threshold are kept.**

Windowing Algorithm



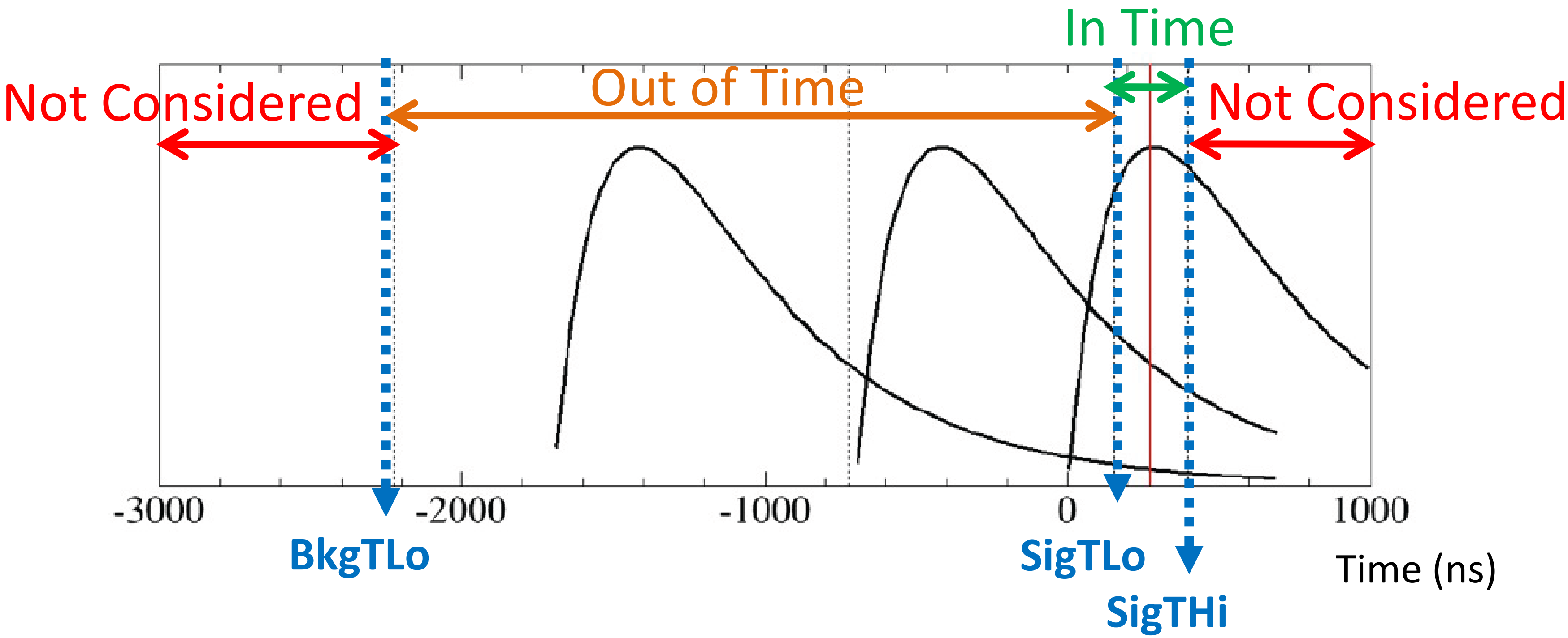
- Cluster with arrival time assigned in the **green region is kept**.

Windowing Algorithm



- Cluster with arrival time assigned in the **green region is kept**.
- Particles arriving in **red region is not considered**.

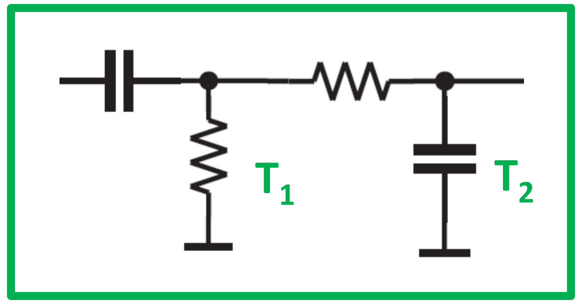
Windowing Algorithm



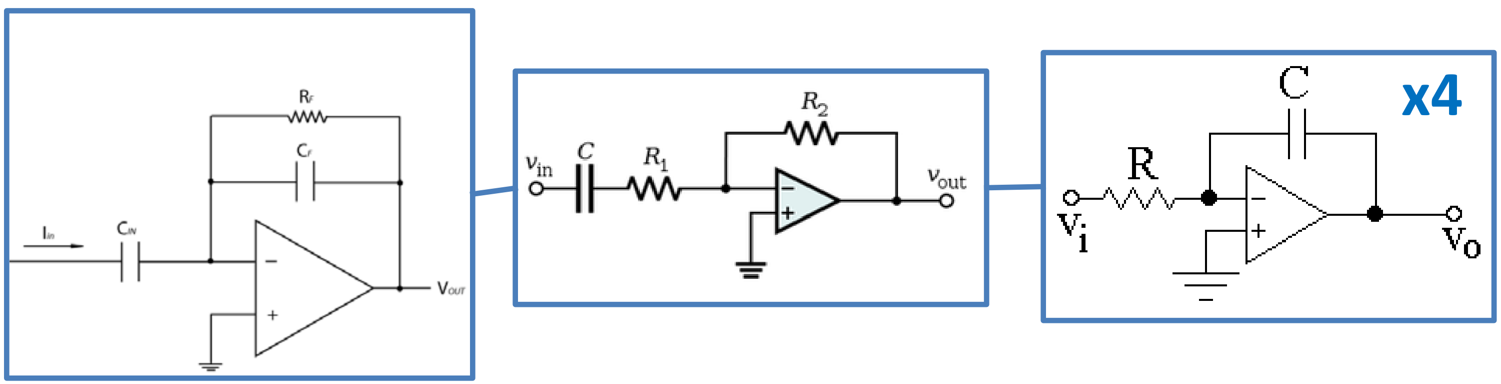
- Cluster with arrival time assigned in the **green region is kept**.
- Particles arriving in **red region is not considered**.
- Particles in the **orange region contributes to pileup, but clusters with time assigned in this region are rejected.**

FastSim Preamp Model

Before:

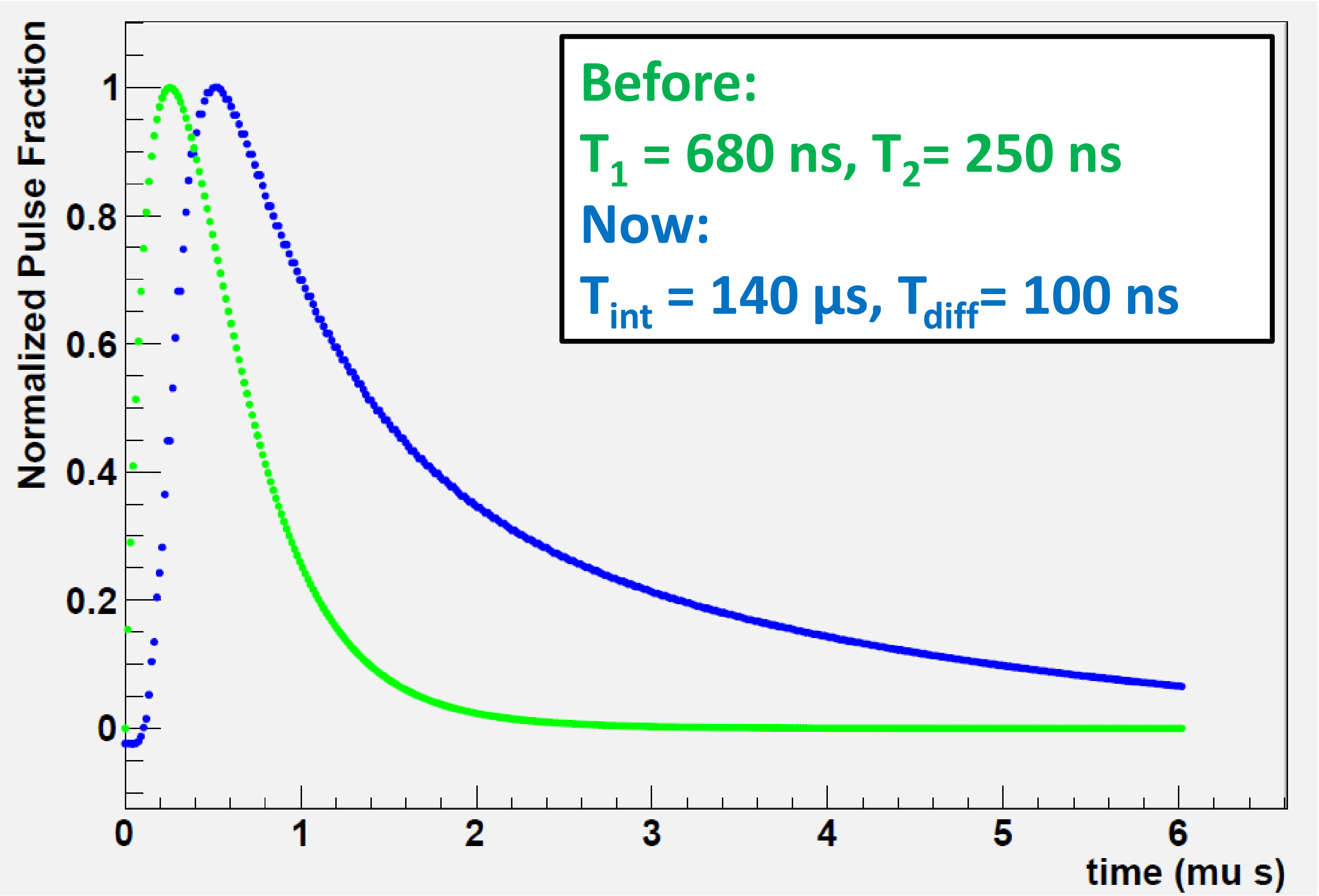


Now (Conceptually):



- SPICE simulation (**Luigi Recchia** and **Valerio Bocci**) generates a lookup table of the shaper output.
- FastSim reads in the lookup table to get the pulse shape.

FastSim Preamp Model



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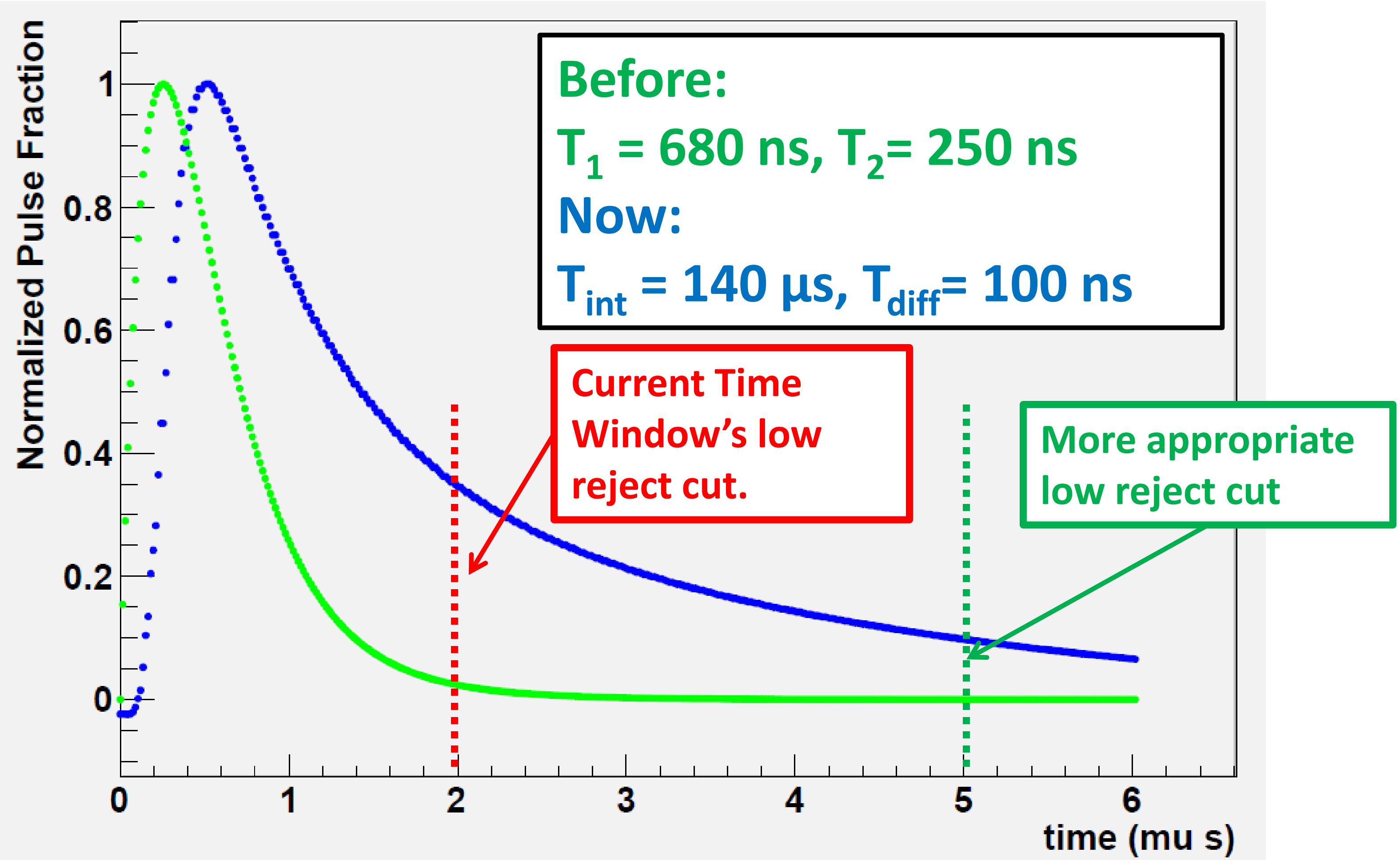

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FastSim Job Configuration

- Background Frame:
  - Bunch crossing: 200 MHz.
  - **Window length of 2μs**. ~400 bunch crossings.
- Background frame particle cuts:
  - Z coordinate of creation (in cm): $-300 < z < 200$
  - **Minimum Energy: 10 MeV**
- Preamp Model:
  - 140 μs of integration time.
  - **100 ns of shaping time.**
- Cluster formation cuts:
  - **L1 threshold: 0.1 MeV**
  - **Crystal Threshold: 0.01 MeV**
- Time window:
  - BkgLo: -25 μs (this is irrelevant because it is limited by window length)
  - SigTHi: 120 ns
- Noise Cleanup:
  - Remove Out of Time.
  - Keep clusters with energy above 10 MeV, and highest energy digi above 1 MeV.
- Generate single photons at various energies and shoot them in the forward barrel region. Generated 50000 events for signal only, 1000 events for sig + bkg.

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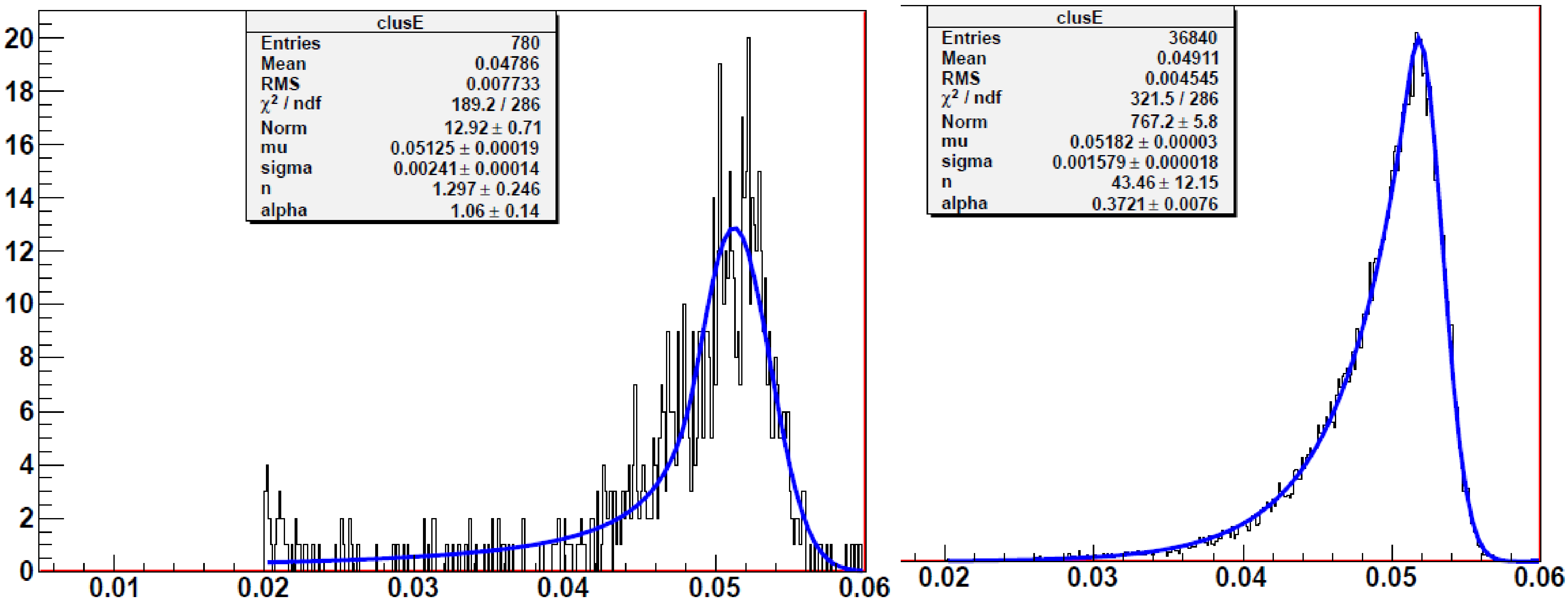
Can't implement all the changes we would like because it would take way too long to run!!

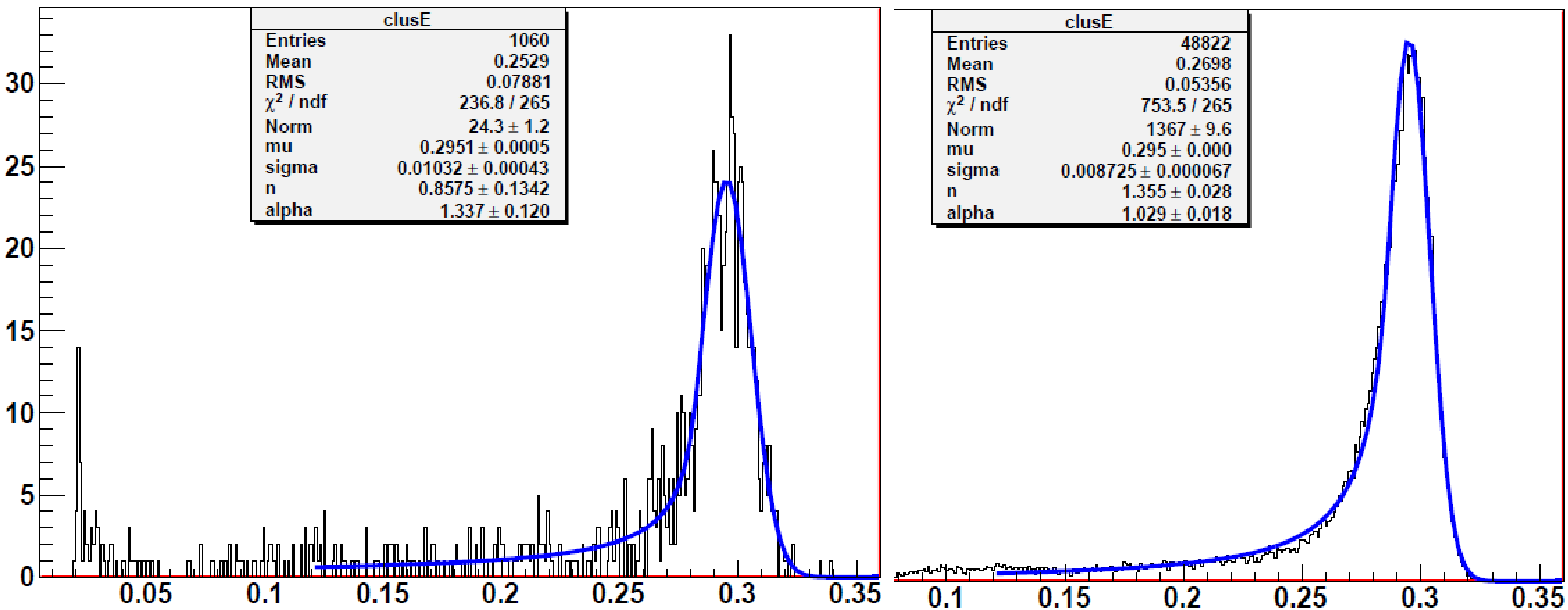
More on this in later section.

Crystal Ball Fits to Cluster Energy



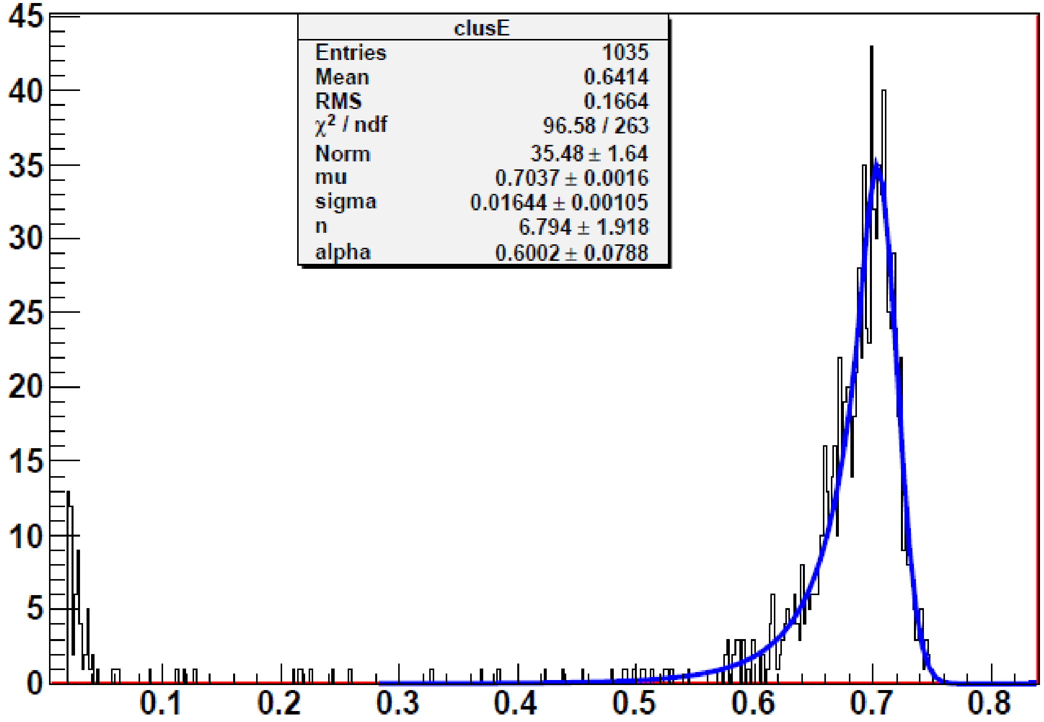
- Generated Photon Energy: 50 MeV.
- Left: Sig + Bkg, Right: Sig only.

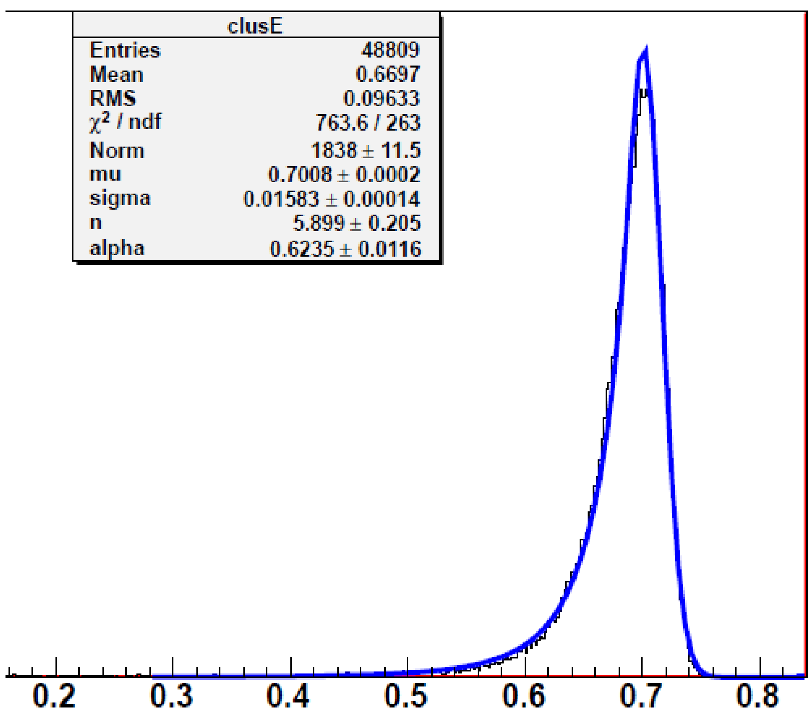
Crystal Ball Fits to Cluster Energy



- Generated Photon Energy: 300 MeV.
- Left: Sig + Bkg, Right: Sig only.

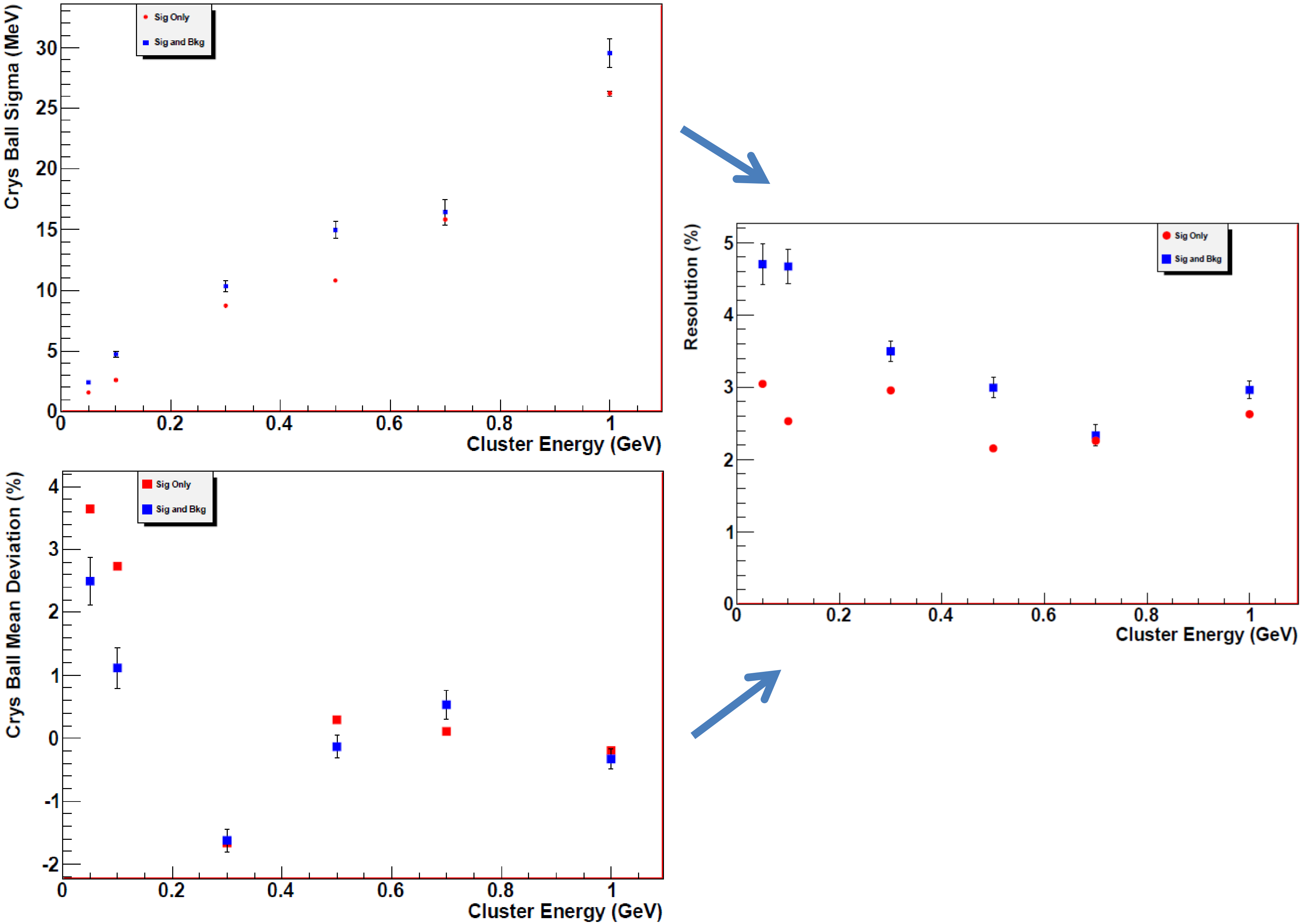
Crystal Ball Fits to Cluster Energy



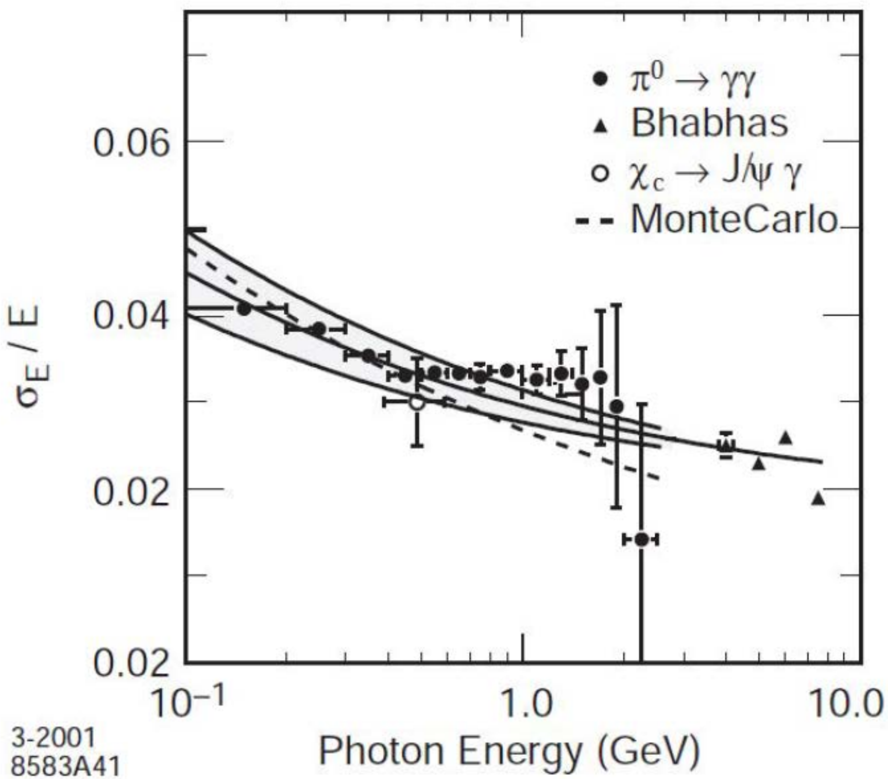


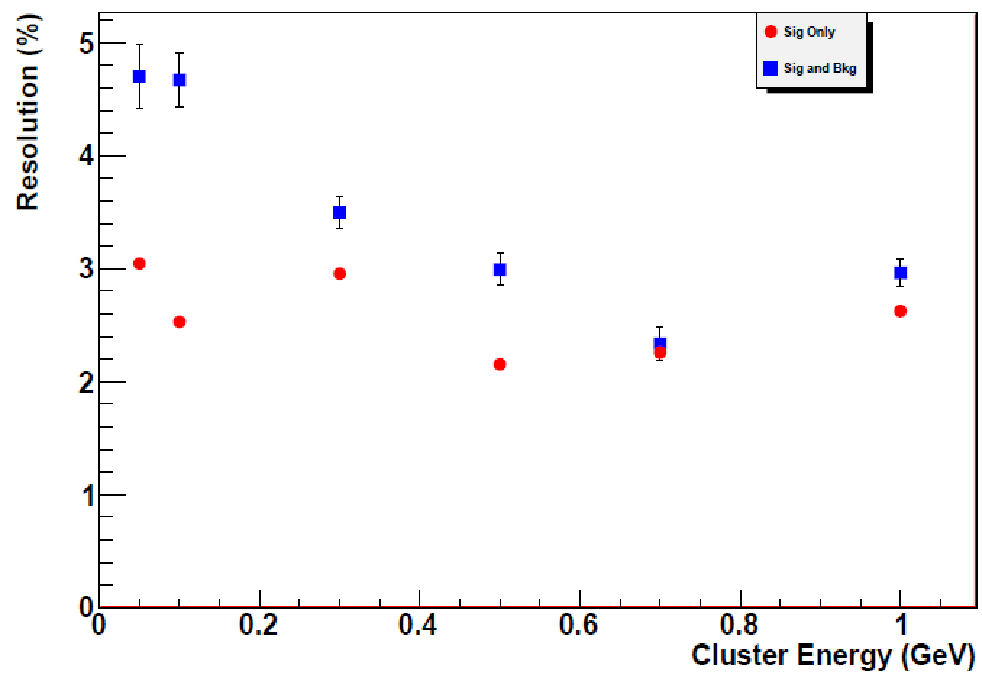
- Generated Photon Energy: 700 MeV.
- Left: Sig + Bkg, Right: Sig only.

Crystal Ball Mean Deviation and Sigma



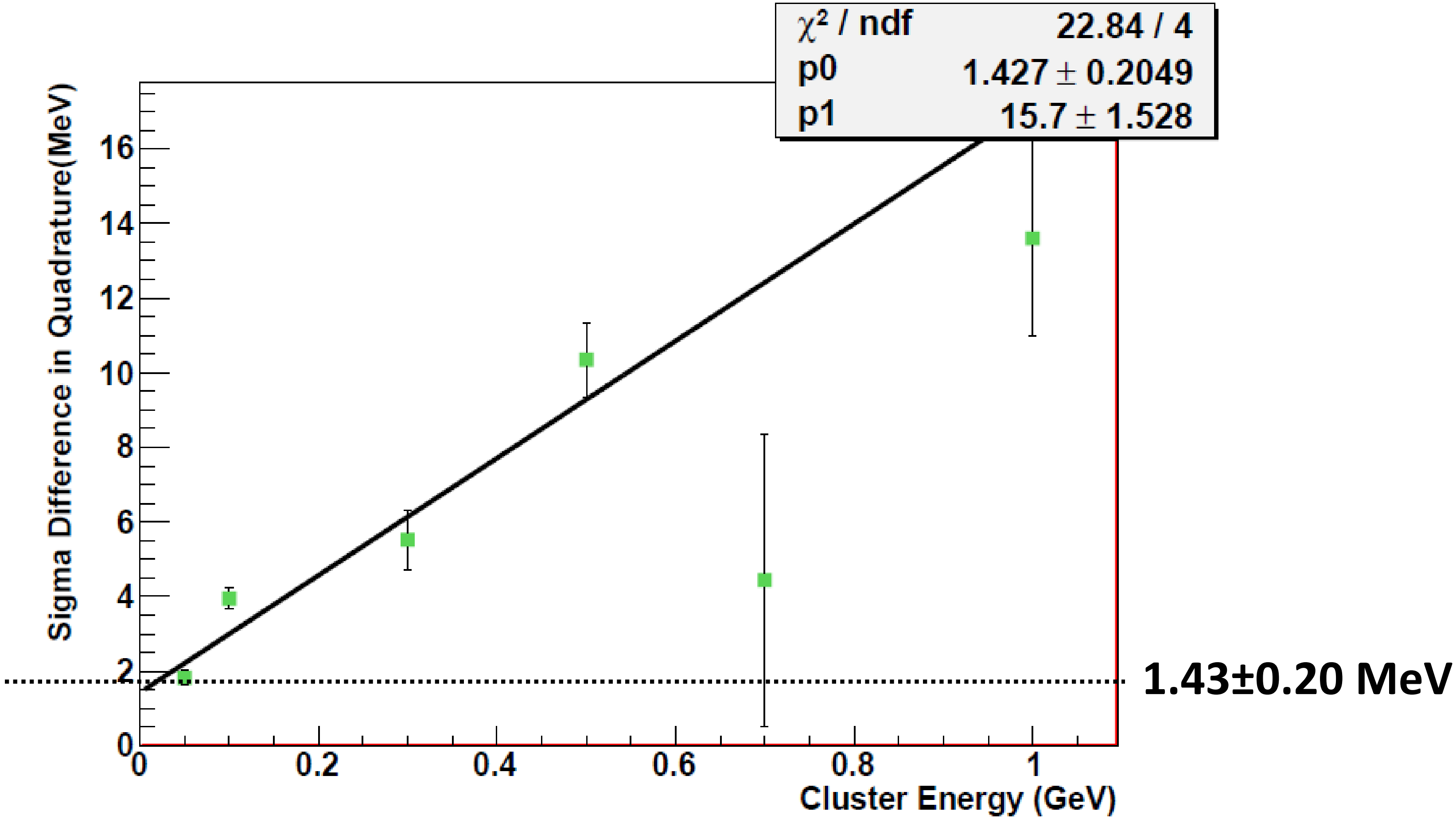
Compare with Babar Resolution





- With the current settings, we are currently at the limit of the Babar requirements.

Results at 10 MeV Energy Cut



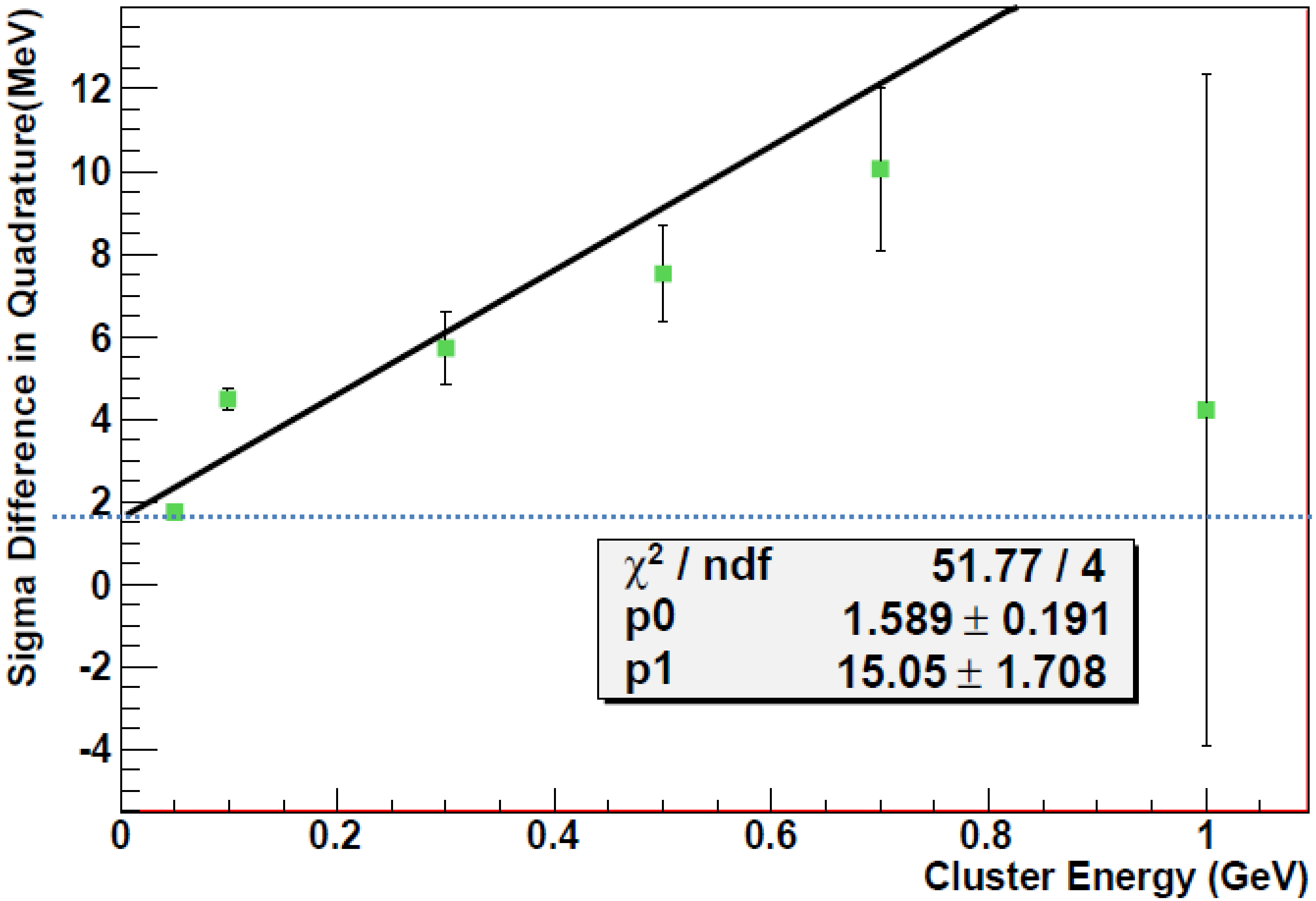
$$\sigma_{pileup} = 15.7E + 1.43 \Rightarrow \boxed{\frac{\sigma_{pileup}}{E} = \frac{(1.57 \pm 0.15)\%}{E}}$$

… Cleary something here to be understood
(behavior confirmed by analysis of FWHM)

Background Particles Energy Cut

- The current energy cut for background particles is at 10 MeV. We lose > 99.9 % of the background particles.
- Ideally, we would like to lower it to 1 MeV. In this configuration, we keep > 90 % of the particles.
- However, running FastSim under this configuration will result in about 30 minutes per event… May need to use a batch queue and split the jobs up.
- We can run with a 5 MeV cut instead; this doubles the number of particles load into FastSim, and takes about 10 seconds per event.

Results at 5 MeV Energy Cut



1.59±0.19 MeV

Slightly Higher..

$$\sigma_{pileup} = 15.1E + 1.59 \Rightarrow \frac{\sigma_{pileup}}{E} = \frac{(1.51 \pm 0.17)\%}{E}$$

Caveats and Next Steps (1)

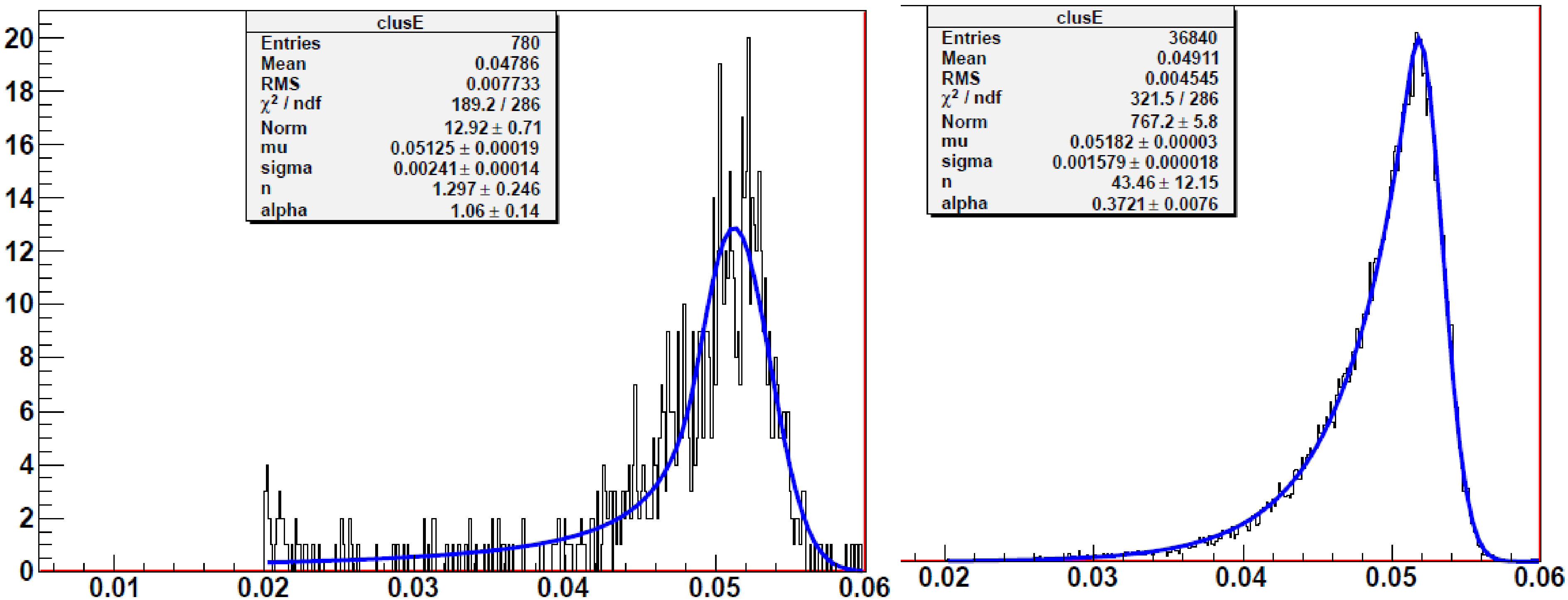
- Understand why the resolution smearing is not constant in Energy.
  - Perhaps related to the lower cuts I made to crystal cutoff. If this is the case, need to extend the code to allow low energy particles to contribute without cutting them out prematurely.
  - Feature of FastSim's cluster forming/merging algorithm?
- Energy cut in background frame particles needs to be moved back to 1 MeV; at 10 MeV, we're losing > 99.9% of the particles.
- Lengthen the background frame to at least 5 μs.
- Lengthen the shaping time in the preamp model from 100 ns to at least 300 ns.
- To run with all the changes above requires a lot of CPU time. Consider running it on a batch queue. Is there one at CNAF?

Caveats and Next Steps (2)

- Understand the hit rate of background particles. When all existing cuts mentioned above were lowered, the hit rate in the EMC is about 50 times lower than what one would expect from an estimate of the background ROOT files.
- The shaper pulse output shape still needs to be agreed upon between the experts.
- Neutron contribution also needs to be included. This must be done after the official FastSim background frame ROOT files are ready.
- Produce the same table as the one in the first few slides that shows pileup in different regions with different integration times.
- Account for the resolution degradation that comes from integrating less charge in the preamp.

Backup

Crystal Ball Fits to Cluster Energy



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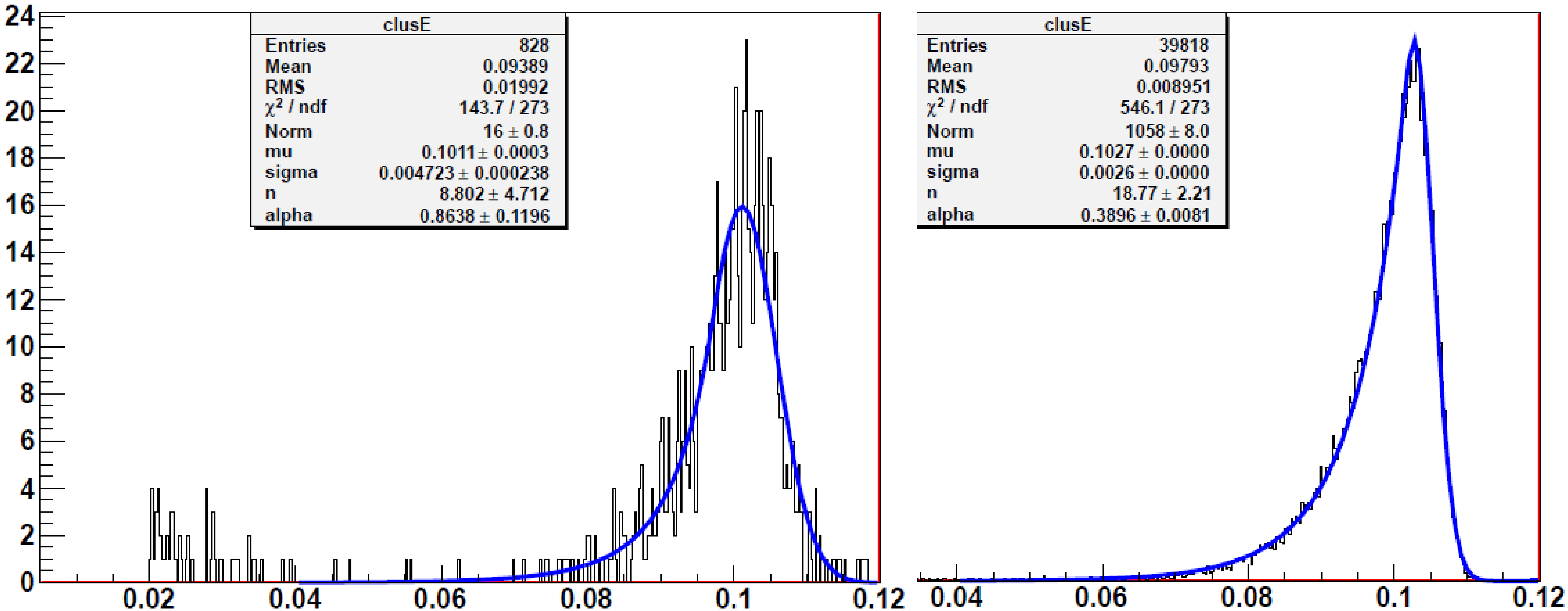
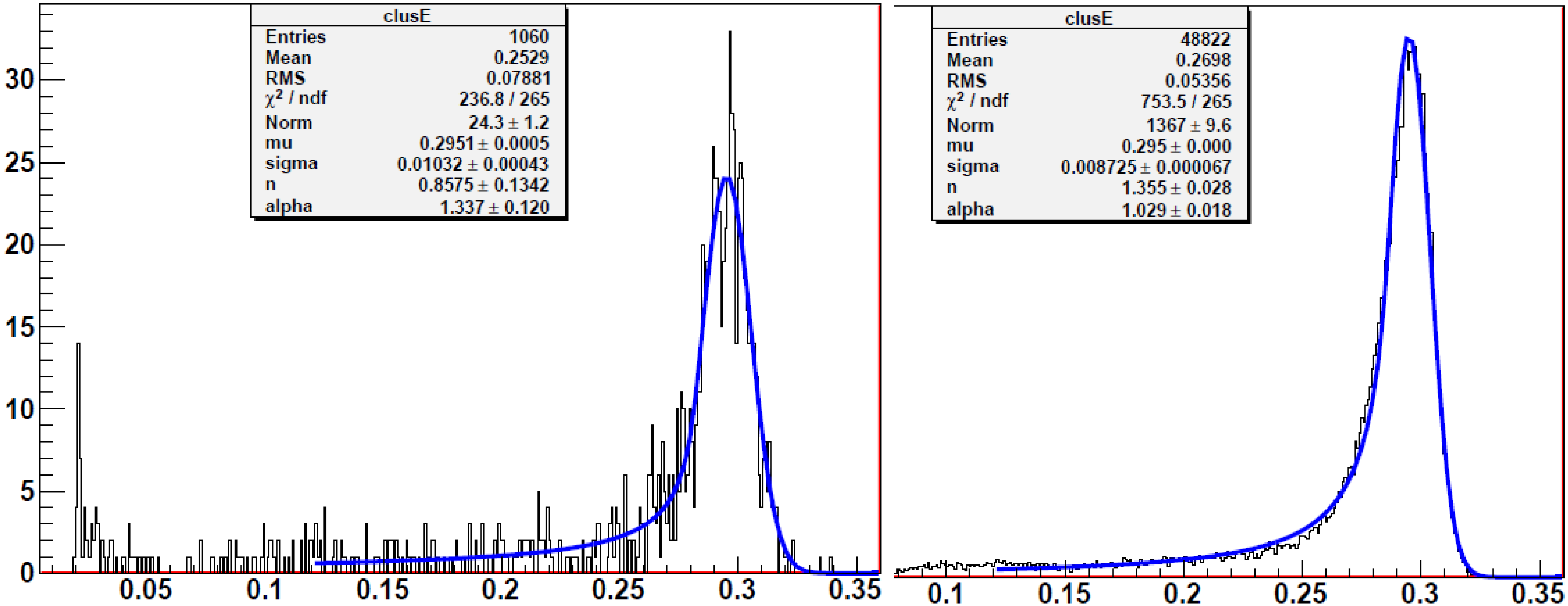
Crystal Ball Fits to Cluster Energy



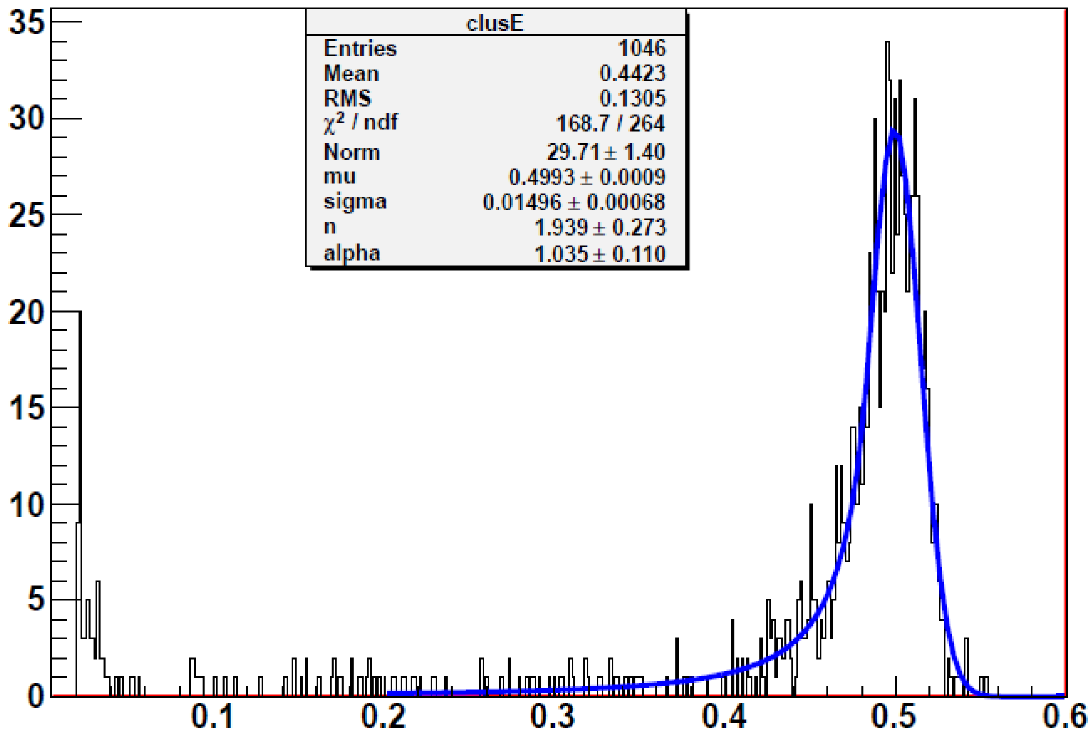
- Generated Photon Energy: 100 MeV.
- Left: Sig + Bkg, Right: Sig only.

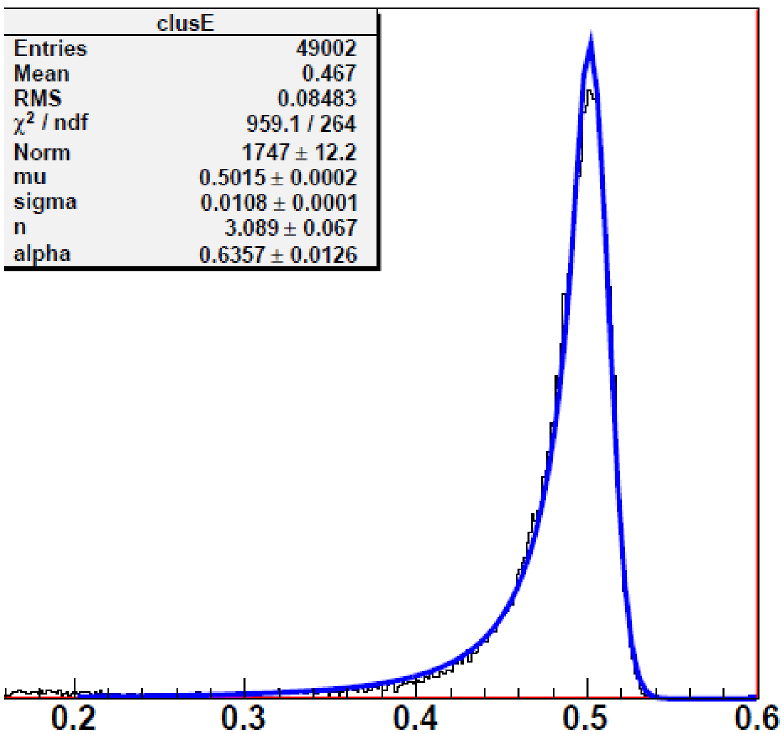
Crystal Ball Fits to Cluster Energy



- Generated Photon Energy: 300 MeV.
- Left: Sig + Bkg, Right: Sig only.

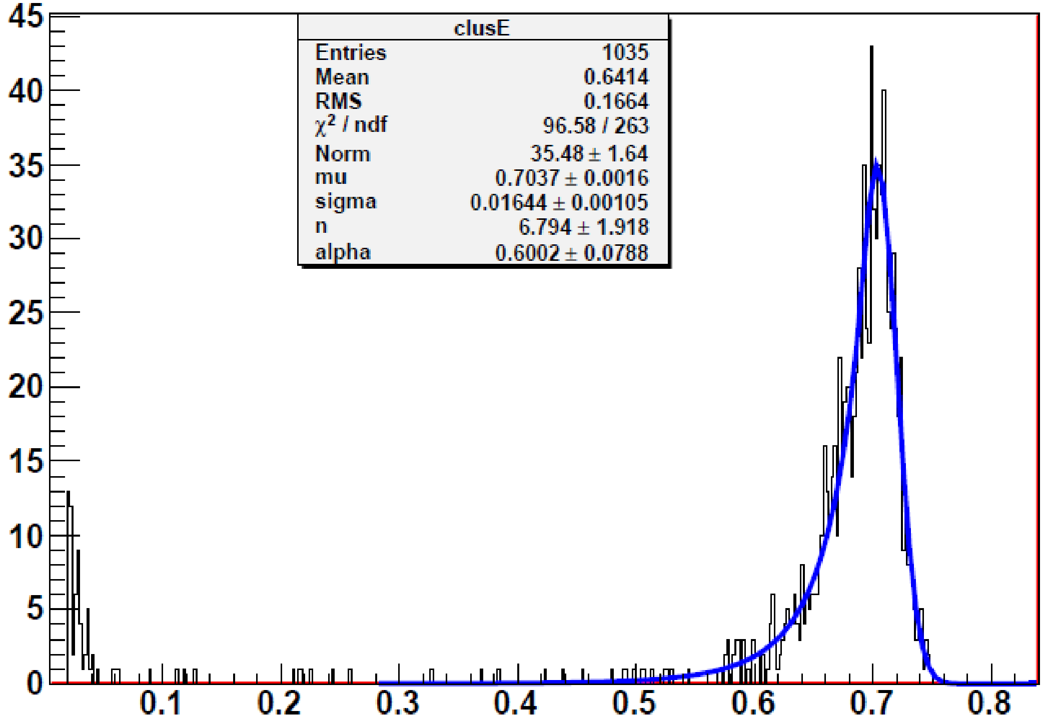
Crystal Ball Fits to Cluster Energy

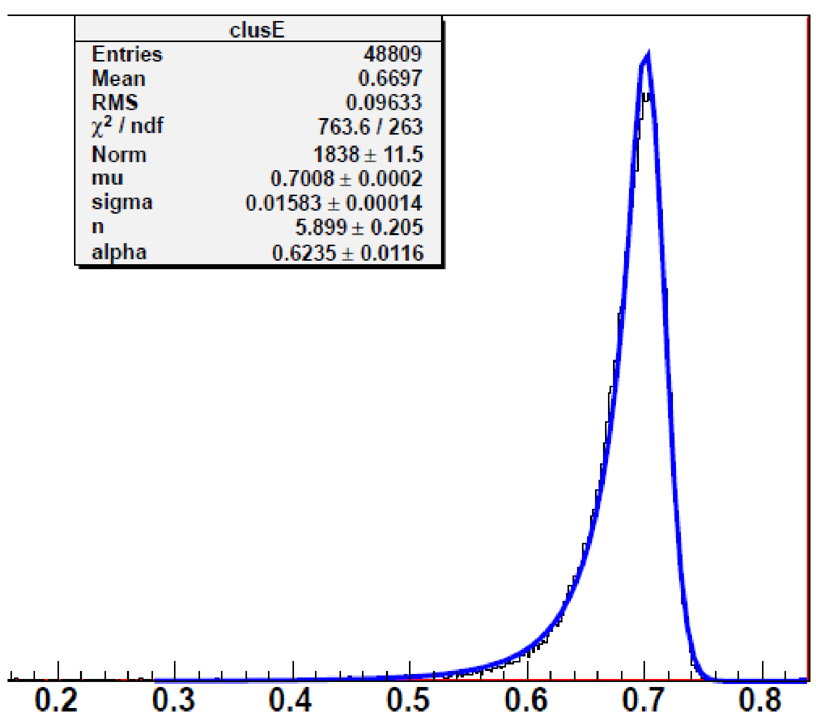




- Generated Photon Energy: 500 MeV.
- Left: Sig + Bkg, Right: Sig only.

Crystal Ball Fits to Cluster Energy





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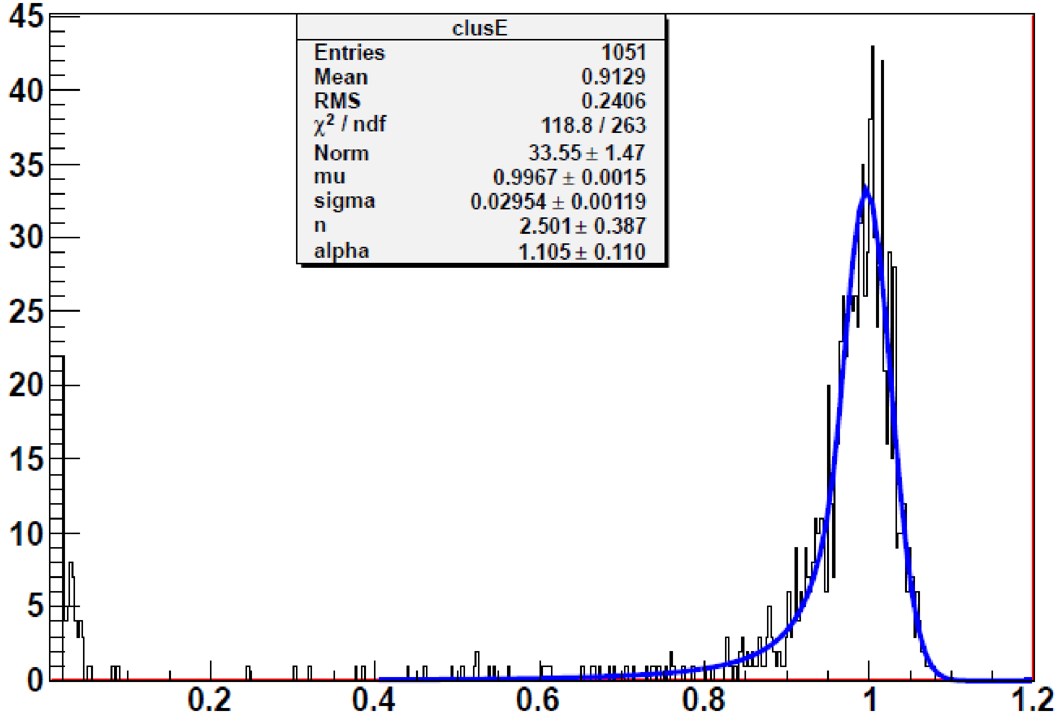
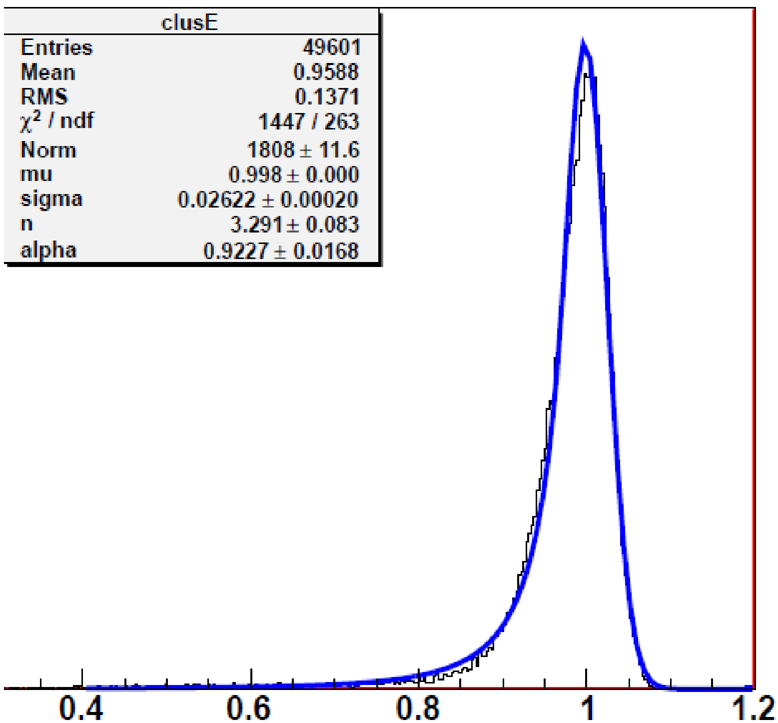
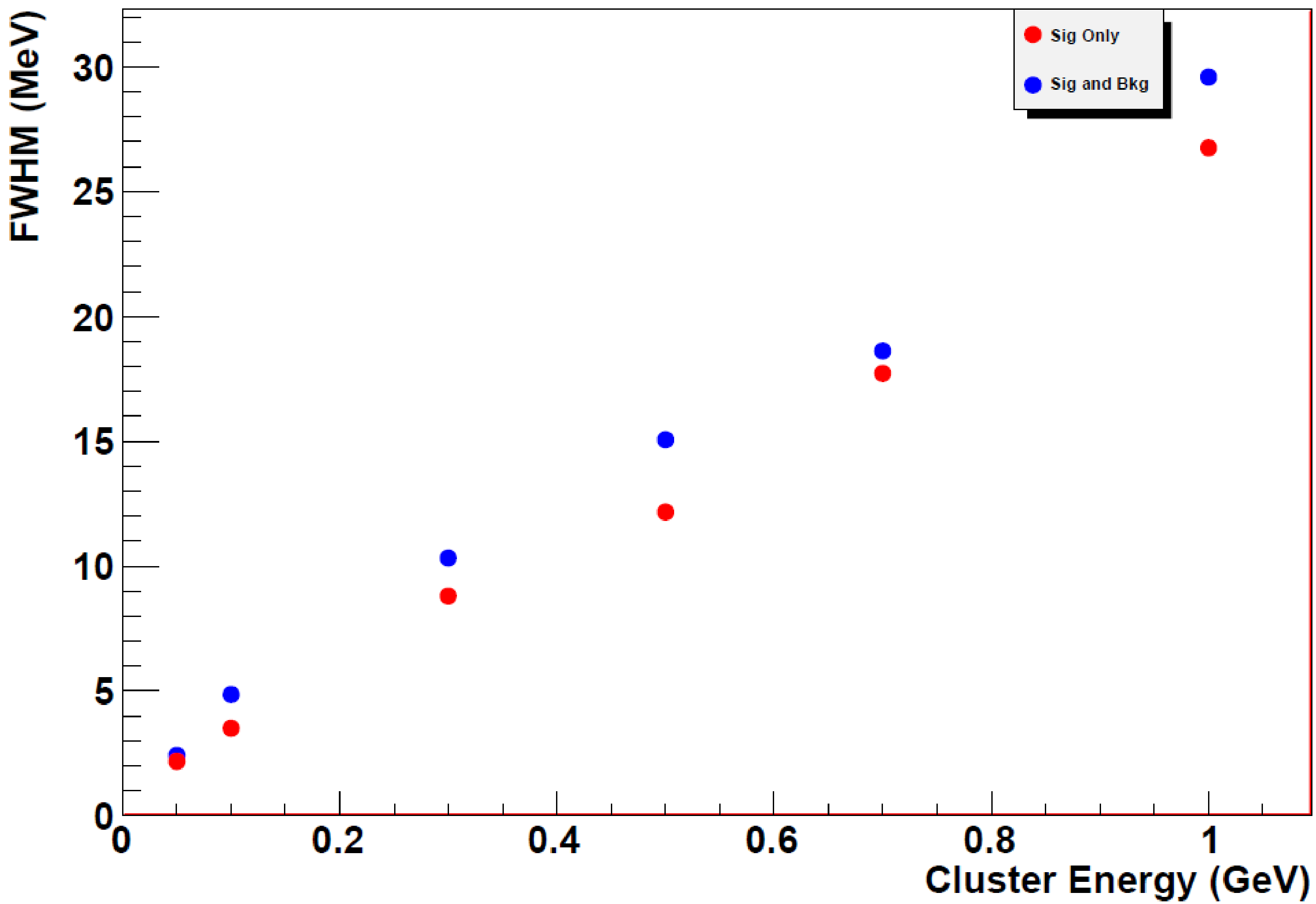
Crystal Ball Fits to Cluster Energy



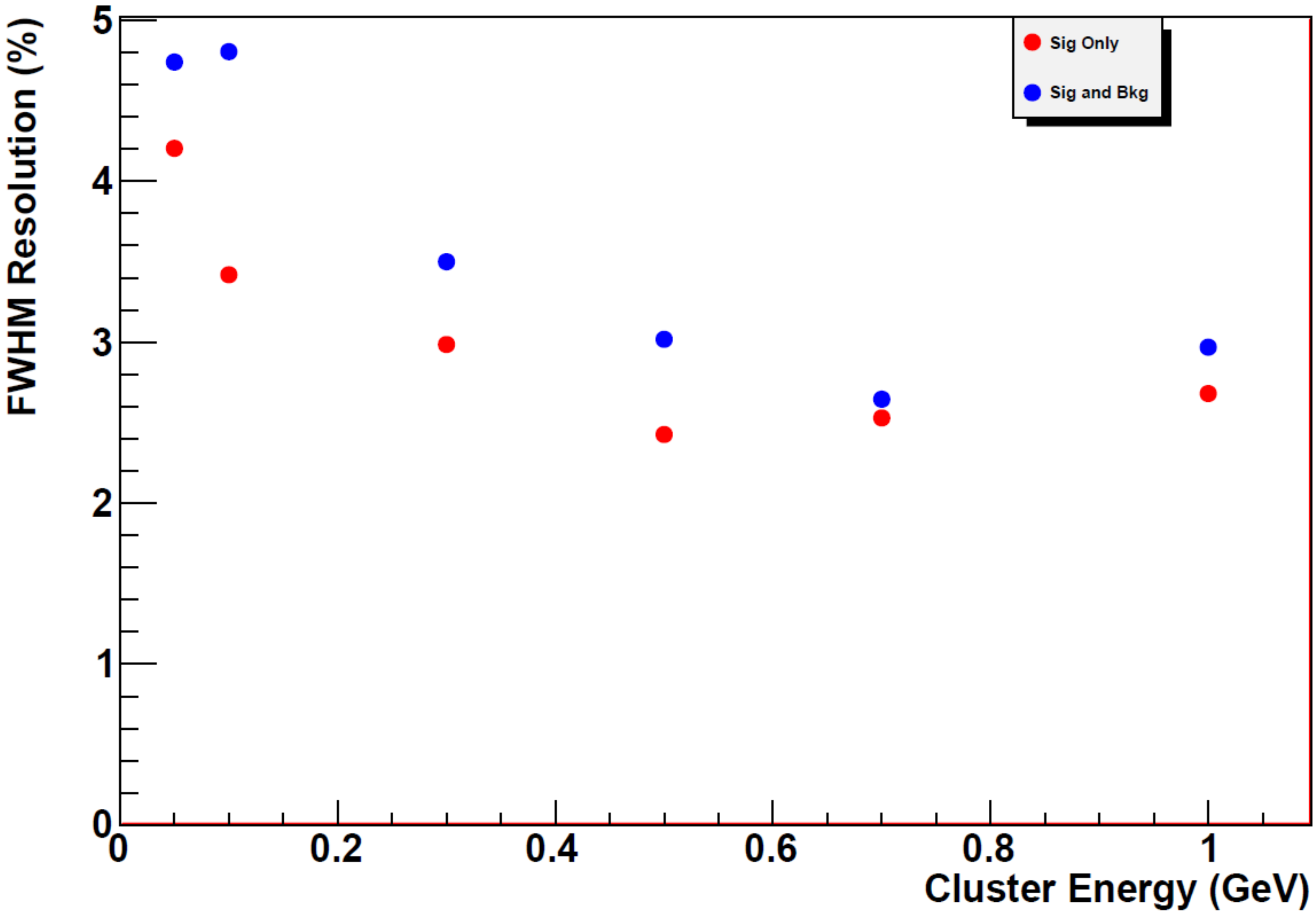


- Generated Photon Energy: 1000 MeV.
- Left: Sig + Bkg, Right: Sig only.

FWHM Converted Sigma

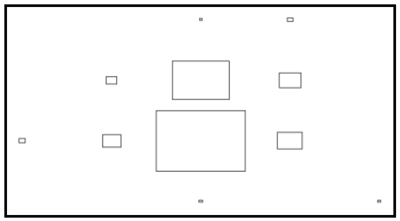


FWHM Converted Resolution



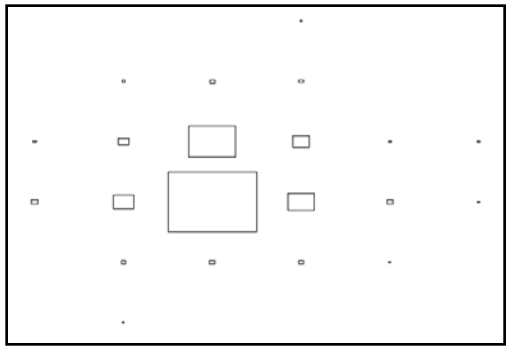
Guess?

50 MeV



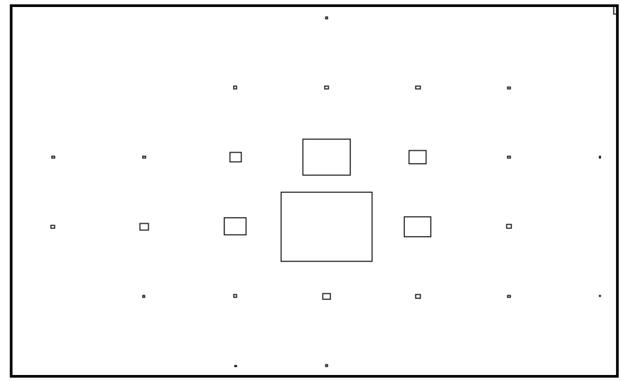
4 x 5

500 MeV



6 x 6

1000 MeV



6 x 7

- Cluster merging depends on whether cluster is connected.
- Therefore, more pileups will be merged if low energy digis are not removed.
- Notice that most of the energy is contained in the center 3x3 crystals anyway, so we should try to raise the digi threshold in the noise cleanup stage.