Status of PFA at Iowa

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Outline

- Recap of the last two talks (July 16, 23)
- Changes this week
- Summary of current performance
- Resolution as function of |cos(θ)|
- Leakage and the muon system

Recap (1)

July 16th:

- Lots of changes to the PFA recently -- most importantly:
  - Short second pass to pick up cluster pieces missed in first pass. Currently using simple cone -- we can do better.
  - Smarter handling of shared hits (hit-by-hit, not en bloc).
  - Trying harder to find structure in hadronic showers
  - Addition to main clustering pass: as well as usual link types (MIP-MIP, MIP-clump, etc), link track seeds to clusters in tight cone downstream of showering point.
  - Share teeny clusters by cone from showering point as well as proximity.
  - Don't drop any hits.

Recap (2)

July 23rd:

- Bugfixes in cone sharing/scoring algorithms (spotted by TJ)
- Corrections to charged hadron calibration.
  - Previously, we treated all track/MIP-like segments as minimum ionizing -- including charged secondaries.
  - Now only do this before the shower.
  - Also introduce rough angular dependence.
- Correction to soft neutral output (avoid E<m)
- Stable version of PFA (v0.32) now includes these fixes.

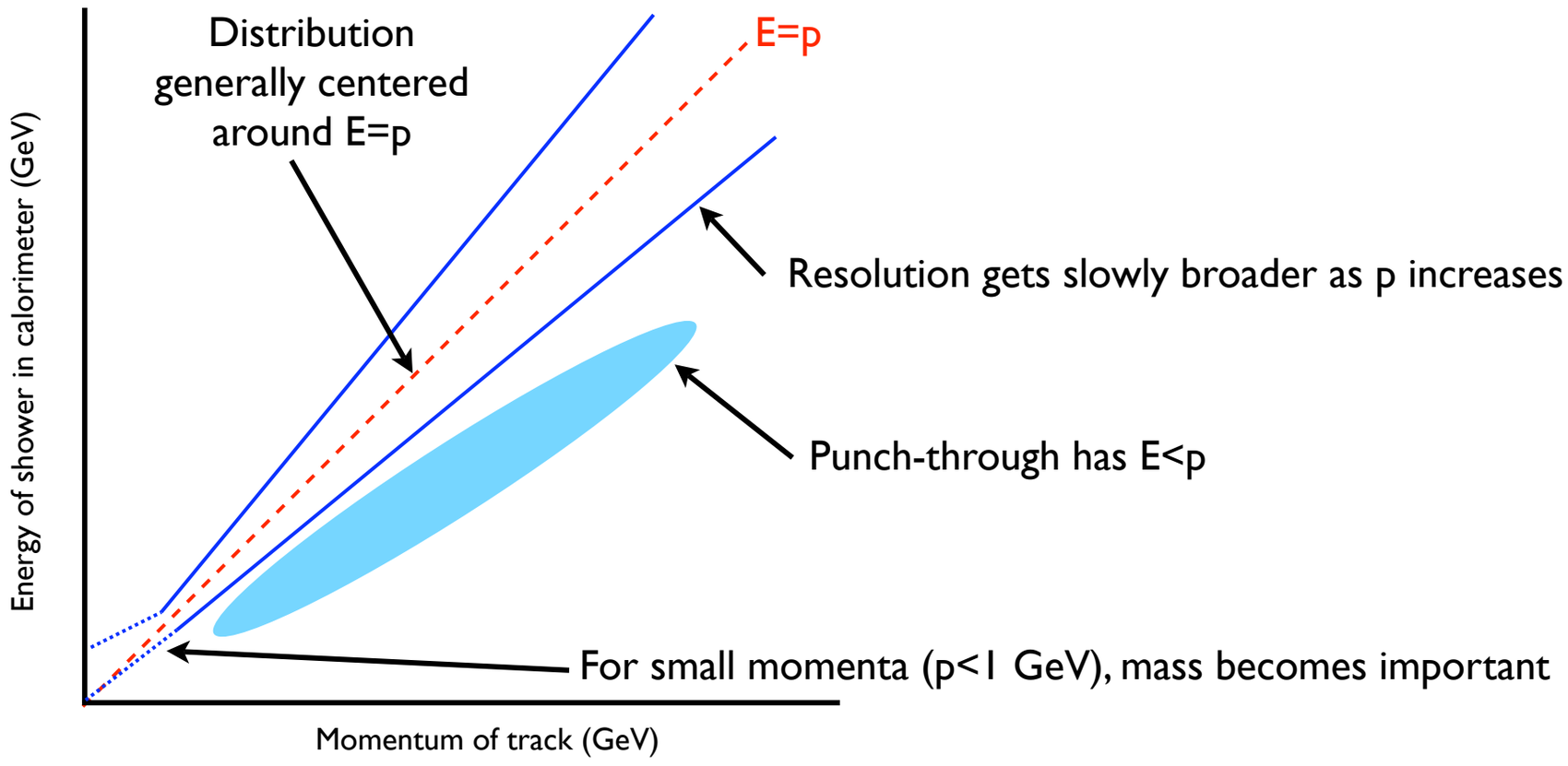
July 23rd:

Recap (3)

Consider tracks for which:

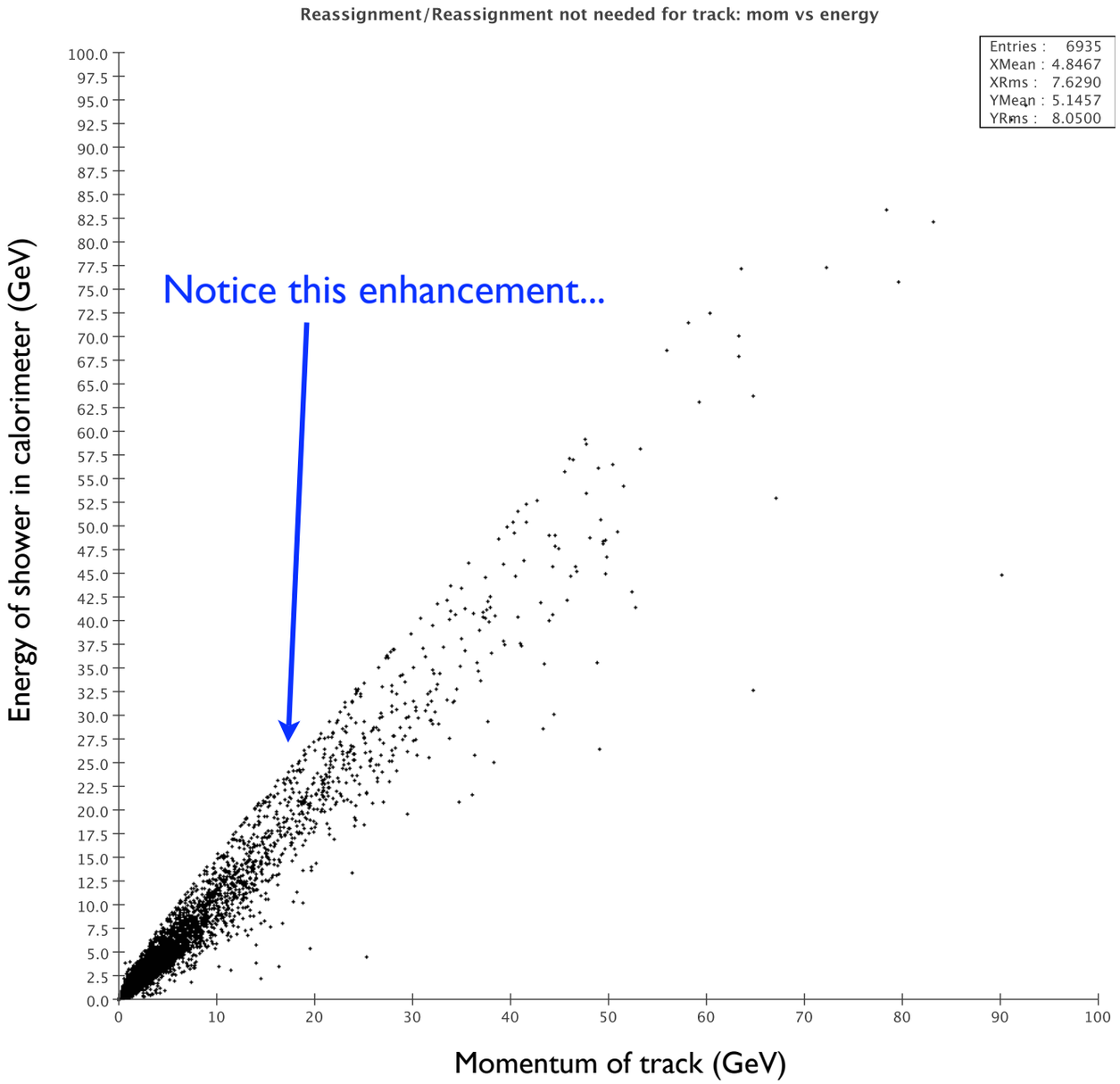
- Not part of a jet (i.e. don't overlap significantly with other charged showers)
- Reassignment is not needed (i.e. E/p passes cut before we get to the final step of reconstruction)

We should expect them to look something like this:



July 23rd: Recap (4)

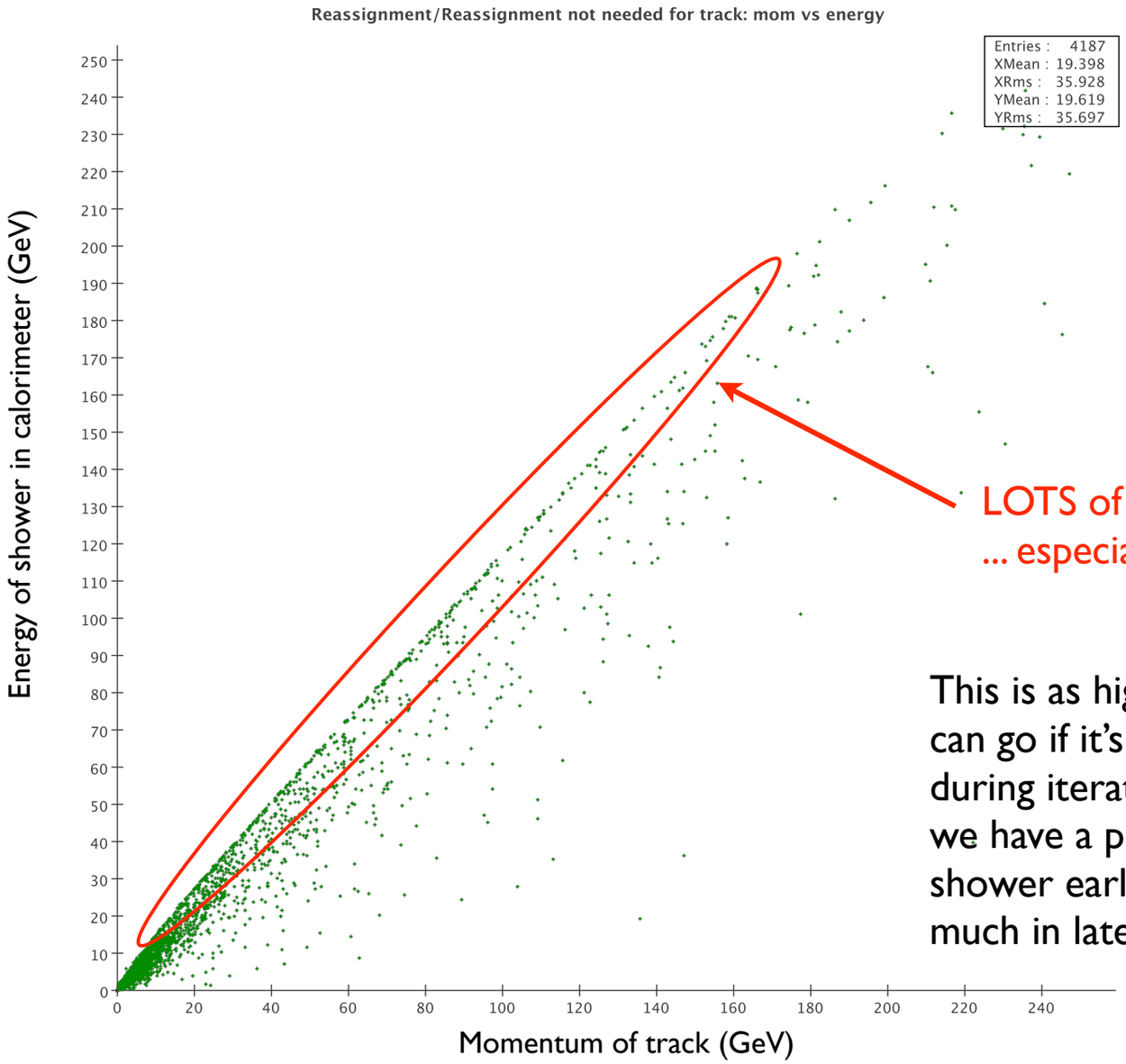
For 200 GeV qqbar events on sid01_scint, things look roughly as we expected:



July 23rd:

Recap (5)

For 500 GeV qqbar events on sid01_scint, there's a clear unexpected feature:



LOTS of events with E=p+2.5σ
... especially at higher momentum.

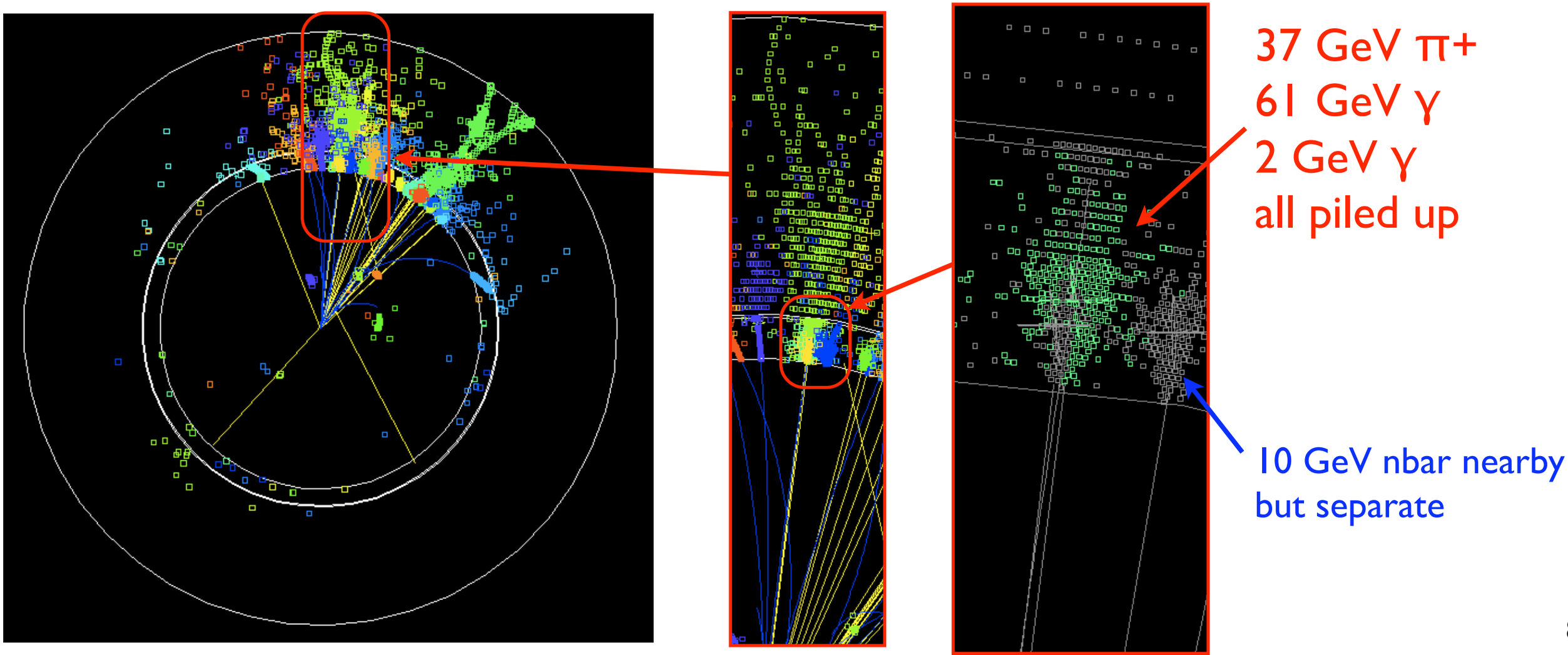
This is as high as the upper bound on E/p can go if it's increased several times during iterative reconstruction. Suggests we have a problem with failing to find shower early on, then grabbing way too much in later stages.

Fix: Don't loosen E/p tolerance if E>p+0.5σ already.

Track seed changes

One of the first steps in the PFA is to extrapolate the charged tracks to the ECAL surface & match them to "seed" clusters. What if that goes wrong?

- Sometimes, track connects to a cluster that is too big ($E_{clus} > p + 3\sigma$). Often due to high-energy track & photon close together. For example:



Track seed changes

One of the first steps in the PFA is to extrapolate the charged tracks to the ECAL surface & match them to "seed" clusters. What if that goes wrong?

- Sometimes, track connects to a cluster that is too big ($E_{clus} > p + 3\sigma$). Often due to high-energy track & photon close together.
- Before, we just absorbed that energy.
- Now: Try to break cluster apart. If that fails, give up & treat as pure (E/M) calorimetry to avoid undercounting.
    - Improvement needed: Do it energy-flow-style, using calorimetry for energy but track for direction.
- Mainly important for higher energies. Affects only a small fraction of tracks, so impact on resolution is not huge.
- We could be smarter about this (e.g. try to pick up MIP as it comes out of the back of the shower).

- Another change: If track connects to leftover hits from a DTreeCluster with structure inside, try connecting to that structure instead.

Other changes

- Leftover hit clusters as track seeds:
  - Preliminary clustering step comes before track-cluster matching.
  - One class of cluster: the leftover hits of a DTree when structure is found inside it (e.g. MIPs, clumps, ...)
  - If track initially connects to those leftover hits, try instead to connect it to one of the pieces of structure.
- Switch from Steve's MIP cluster finder to Tae Jeong's
- Bugfix: One class of output charged particle (those that were seen in tracking system but didn't reach inner face of ECAL) had tracks omitted from the ReconstructedParticle output. Fixed.
- Fix: E/p check was being applied inconsistently.
  - For E<1 GeV, I generally fix σ to 0.7 GeV.
  - But sometimes it was just scaling as $\sqrt{E}$, and getting too small.

Performance table

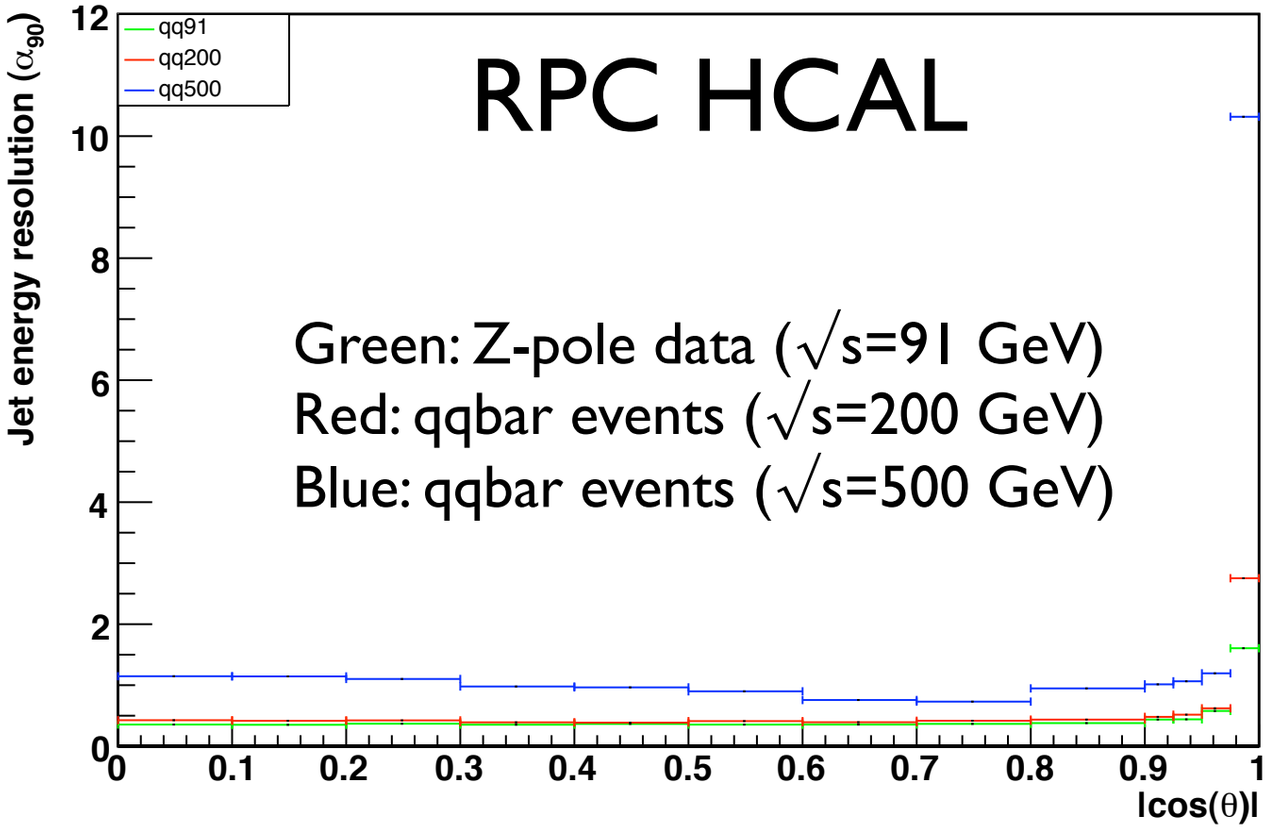
Quoting mean$_{90}$ ± rms$_{90}$ in GeV:

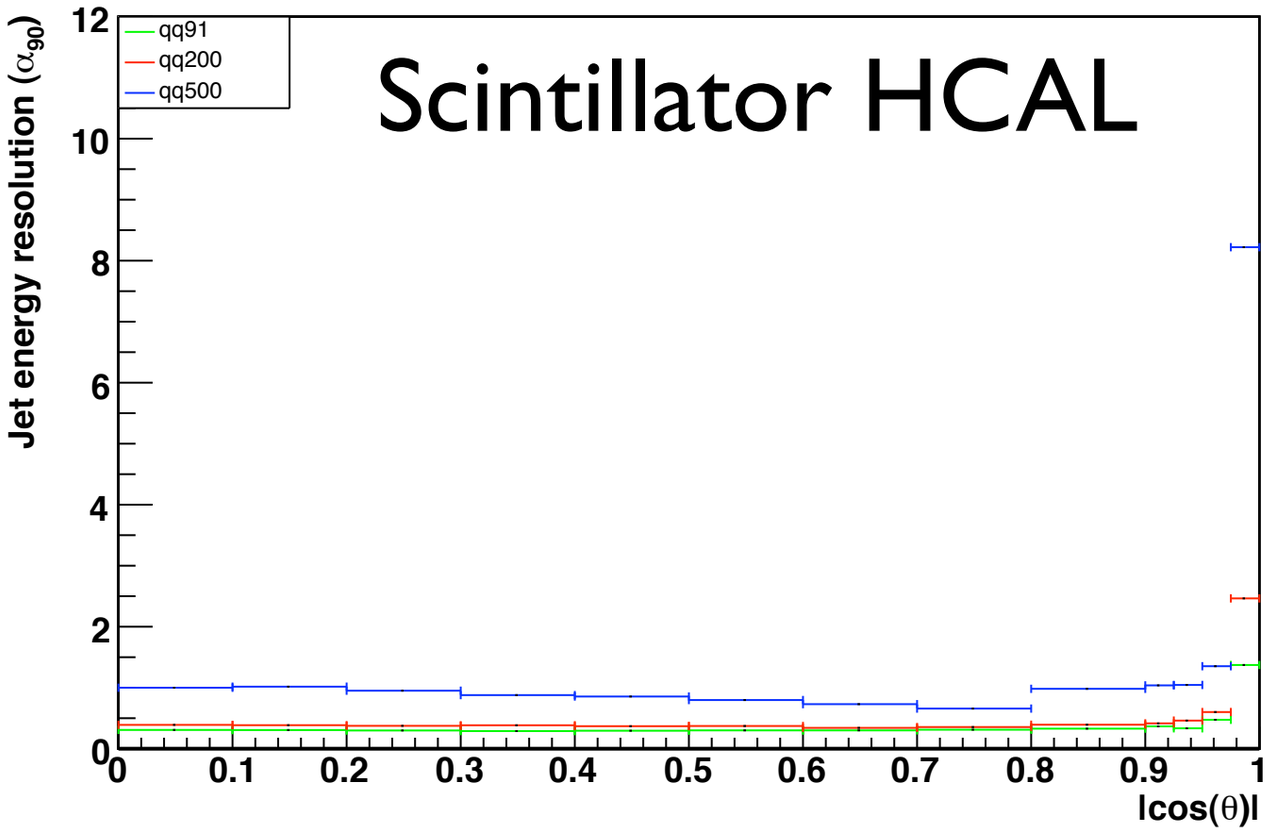
	ZZ mass resolution (GeV)		qq200 energy resolution (GeV)		qq500 energy resolution (GeV)	
	sid01_scint	sid01	sid01_scint	sid01	sid01_scint	sid01
July 14 (#297)	-0.92 ± 3.76 (ΔM/M=4.2%)	-0.87 ± 4.15 (ΔM/M=4.6%)	-3.45 ± 5.69 ($\Delta E_{jet}=40.6\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=4.1% E_{jet})	-2.69 ± 6.32 ($\Delta E_{jet}=45.0\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=4.5% E_{jet})	-15.37 ± 21.29 ($\Delta E_{jet}=97\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=6.2% E_{jet})	-14.91 ± 24.07 ($\Delta E_{jet}=109\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=7.0% E_{jet})
July 23 (#329)	+0.36 ± 3.56 (ΔM/M=3.9%)	+1.34 ± 4.04 (ΔM/M=4.4%)	-0.99 ± 5.20 ($\Delta E_{jet}=36.9\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=3.7% E_{jet})	+1.02 ± 5.82 ($\Delta E_{jet}=41.0\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=4.1% E_{jet})	-6.08 ± 19.07 ($\Delta E_{jet}=86\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=5.5% E_{jet})	-3.08 ± 21.55 ($\Delta E_{jet}=97\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=6.1% E_{jet})
Track seed changes (#347)	+0.61 ± 3.57 (ΔM/M=3.9%)	+1.66 ± 4.02 (ΔM/M=4.3%)	-0.38 ± 5.23 ($\Delta E_{jet}=37.0\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=3.7% E_{jet})	+1.59 ± 5.79 ($\Delta E_{jet}=40.8\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=4.1% E_{jet})	-5.90 ± 19.08 ($\Delta E_{jet}=86\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=5.5% E_{jet})	-2.76 ± 20.94 ($\Delta E_{jet}=94\%\sqrt{E_{jet}}$) ($\Delta E_{jet}$=6.0% E_{jet})

Track seed changes affect only a small fraction of showers -- effect is in the noise.
Helps for RPCs at 500 GeV, though.

Angular variation

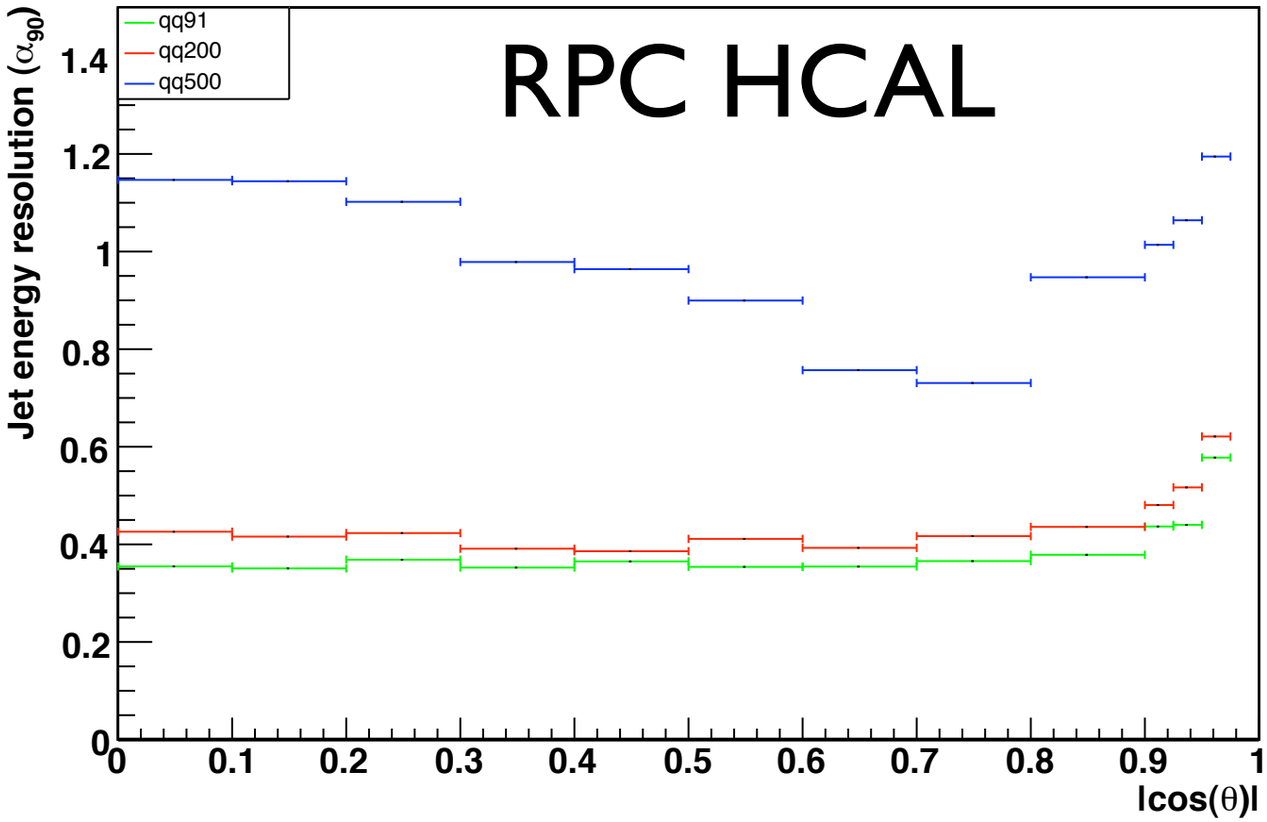
Plotting resolution (expressed as rms_{90} / $\sqrt{E}$) vs cos(θ):

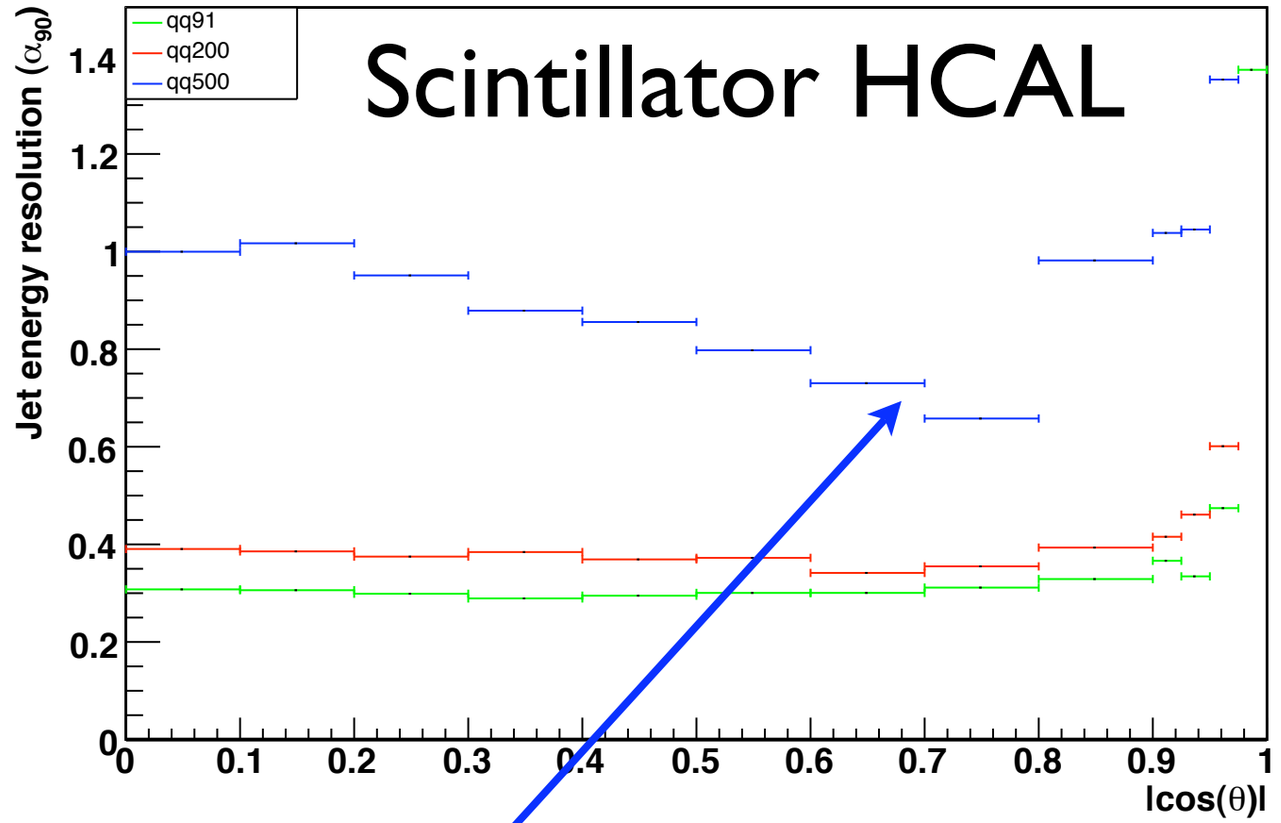




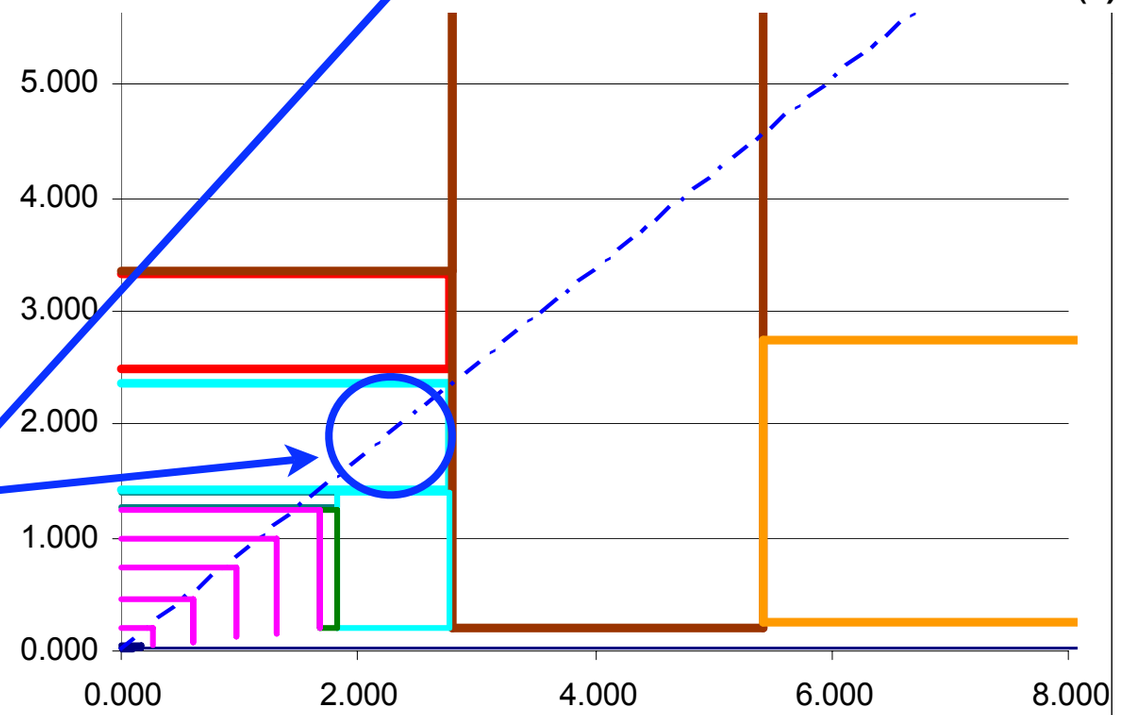
Resolution gets completely lousy for cos(θ)>0.975.
Zoom in on the rest...

Angular variation

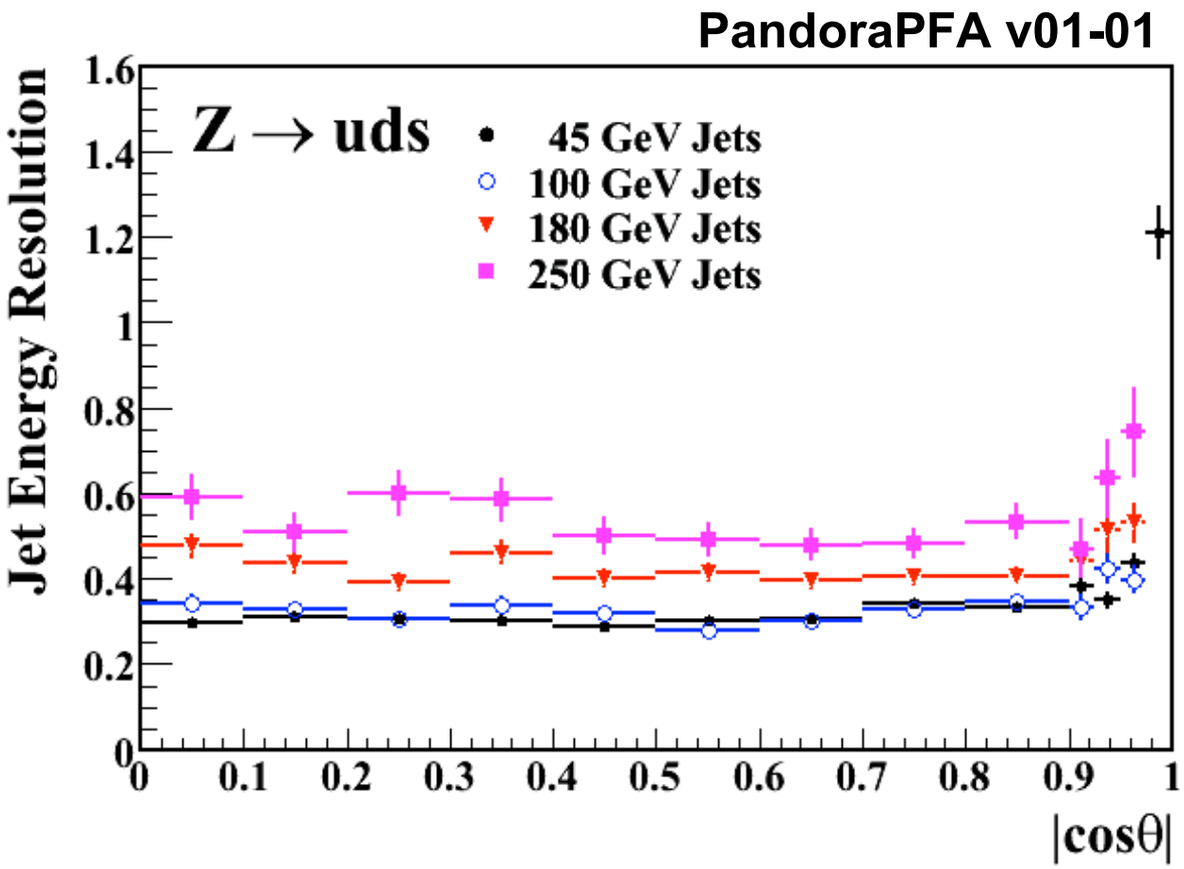


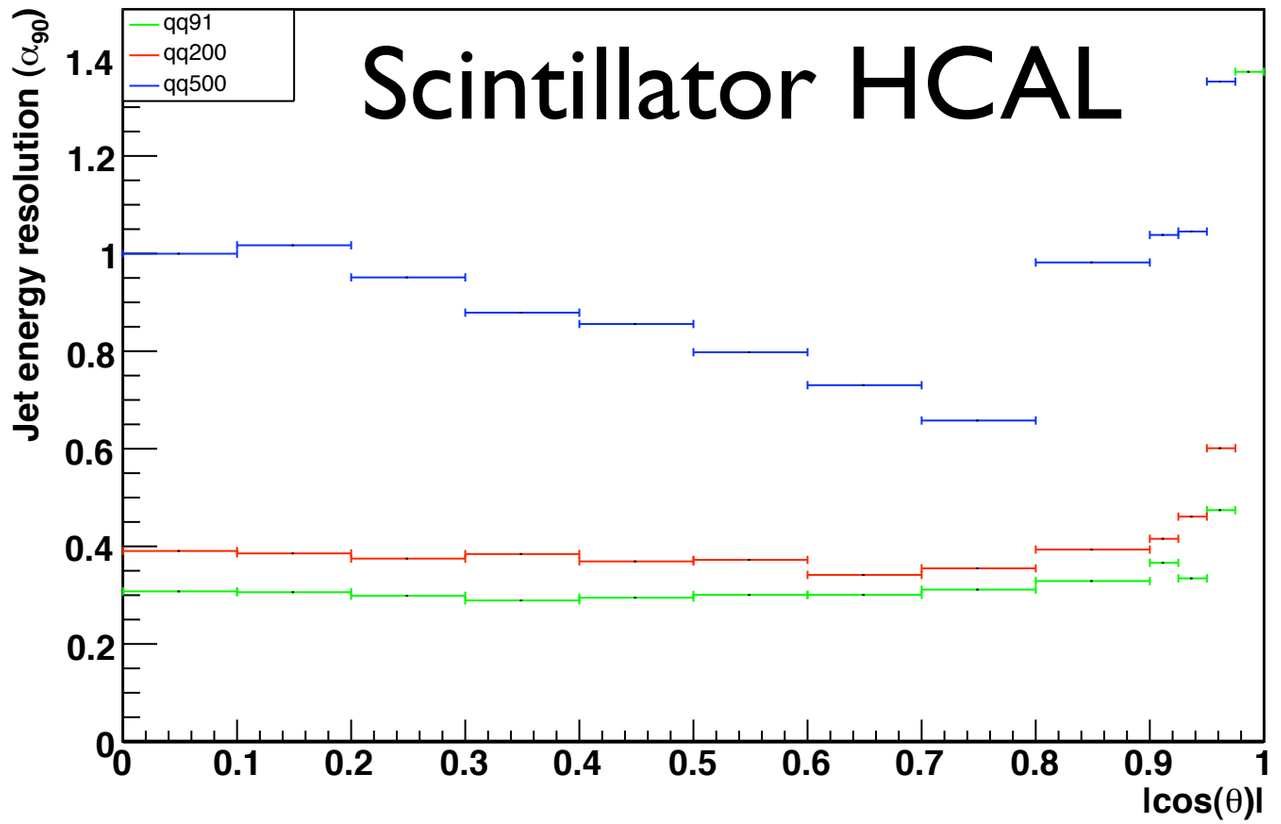


- For all energies, resolution gets worse for $|\cos(\theta)|>0.9$ -- acceptance effects.
- For lower energies ($\sqrt{s}$=91, 200 GeV), distribution is otherwise flat.
- For higher energy ($\sqrt{s}$=500 GeV), resolution is significantly better in overlap region because HCAL is deeper there => showers better contained.



Pandora comparison

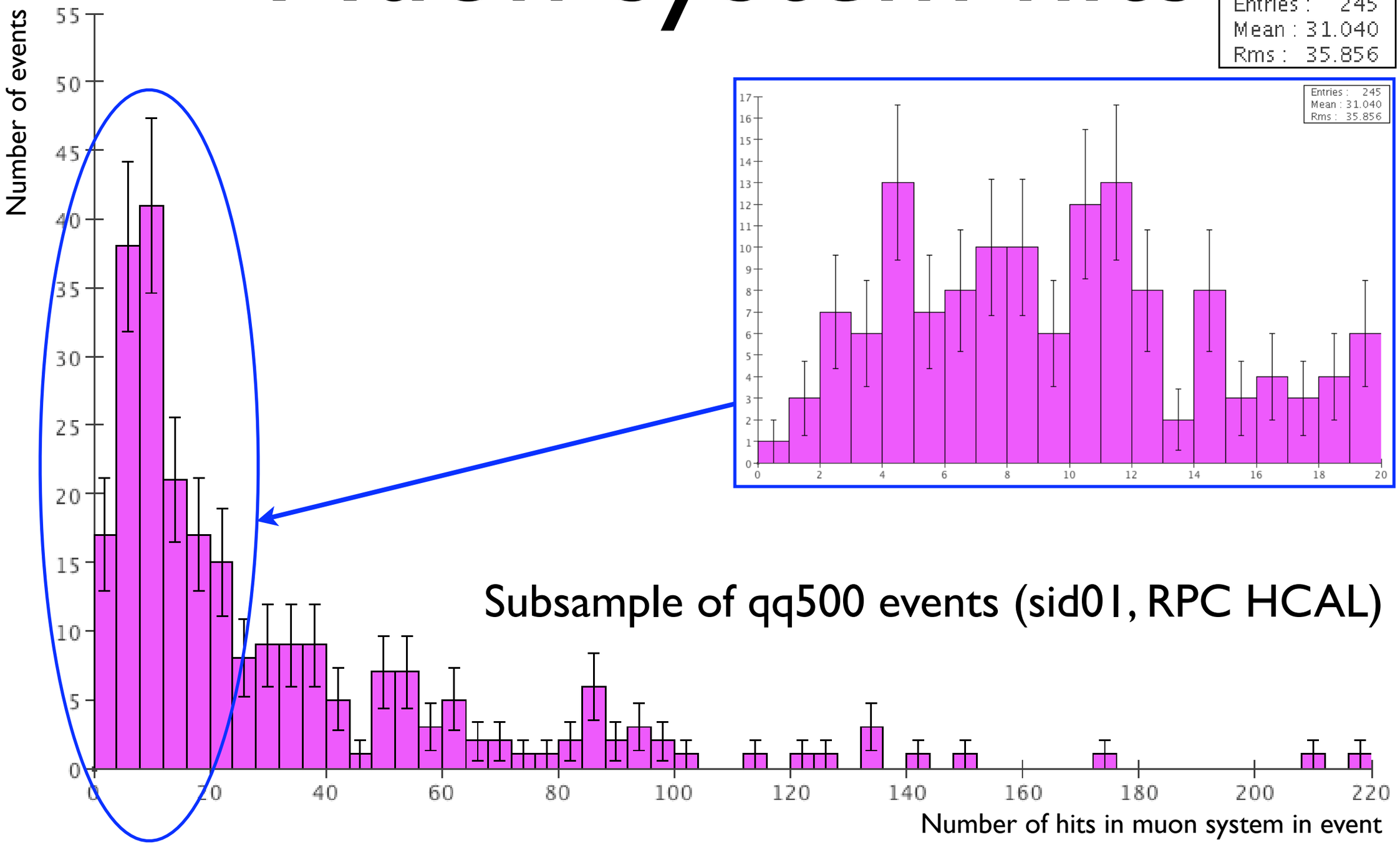




Interesting -- he doesn't see the same dip for $\sqrt{s}$=500 GeV. Perhaps LDC00Sc is already deep enough that all showers are well-contained?

- The longitudinal depth of LDC00Sc is 5.4λ in the barrel and 7.1λ in the endcaps (summing ECAL & HCAL)
- The longitudinal depth of sid01 is roughly 4.5λ for both, I think.

Muon system hits



Almost all events have some muon system hits.
Check resolution separately for events with <20, >=20 hits...

Resolution vs Muon hits

Quoting energy sum $mean_{90} \pm rms_{90}$ in GeV:

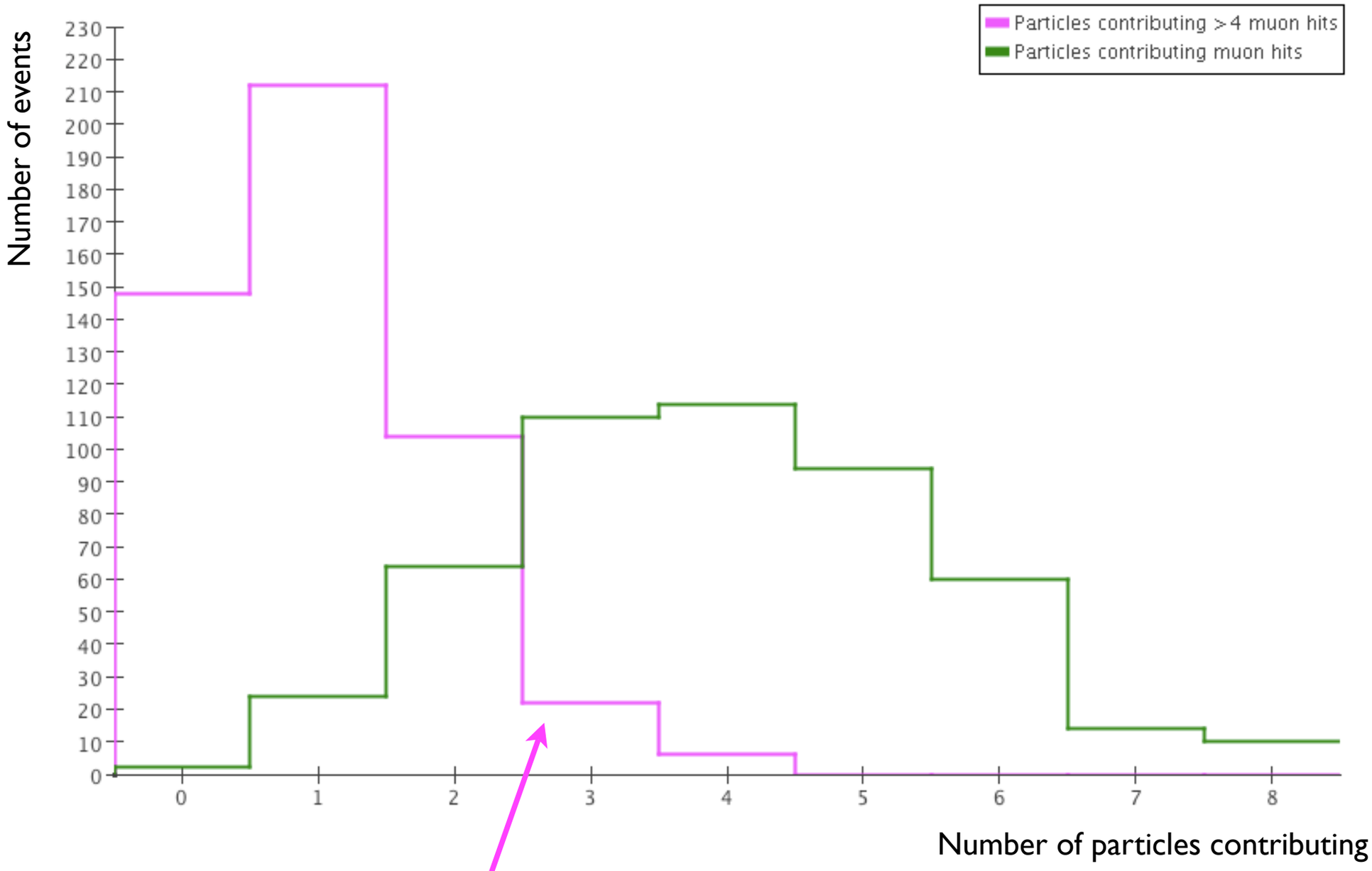
qq500	<20 muon system hits	≥20 muon system hits
sid01 RPC HCAL	+1.55 ± 17.36	-9.46 ± 23.97
sid01_scint Scintillator HCAL	-1.76 ± 15.26	-13.09 ± 22.46

As expected, resolution is much worse when a lot of energy leaks out of the HCAL into the muon system.

Could we recover this energy?

How many different particles contribute?

Looking at MC truth for a subsample of qq500 events (sid01, RPC HCAL)



Mean of only 1.0 particle per event contributing >4 hits in MUCAL.

So we do have a shot at pattern-recognition in MUCAL.

Hard part will be associating the right punch-through shower with MUCAL hits.

(Can get resolution of O(20-30cm) trivially from track, but that won't be good enough.)