Cal Cluster ID
an approach to Eflow

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LCD Cal Video Mtg, 7/22/02

Thank you

- Ron Cassell has made many essential contributions to this project.

Outline

- This is very much a work in progress.
- Describe the approach
- Apply to single particle events
- Apply to signal events
- Things to do.
- Conclusions.

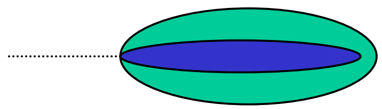
Approachs to Eflow

- Subtractive – identify hits/clusters ($p^{\pm}$) to be ignored, what's left is neutrals.
- Positive ID – Directly identify origin of each cluster by its characteristics.

How gammas shower

- Lots of pair production, bremsstrahlung, Comptoms and copious ionization.
- Results in uniform cigar shaped compact shower with a declining energy density outward from the shower axis more than one cell wide.
- Shower initiates early in cal and is not very deep (contained in EM Cal).

Gamma shower cartoon



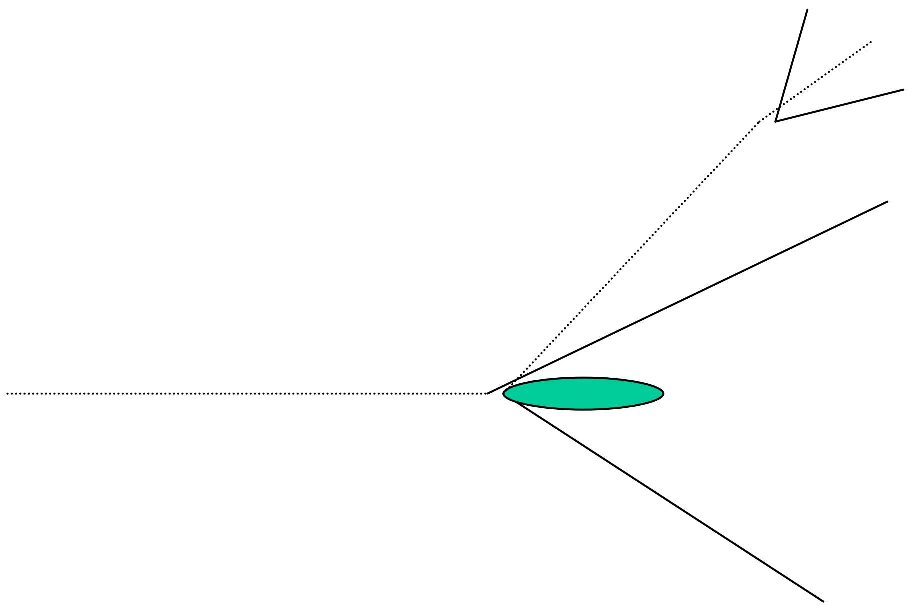
How hadrons shower 1

- Charged hadrons travel many layers before interacting leaving a track-like, one cell width minI trail of hits.
- Neutral hadrons travel many layers before interacting but have no hit trail.

How hadrons shower 2

- Hadrons interact with nuclei producing outgoing hadrons, mostly pions.
- ~1/3 of outgoing hadrons are p^0s which immediately decay to gammas most of the remainder are $p^{\pm}$.
- Sometimes a low energy neutron is knocked out.
- Incoming hadron may survive and continue.

Neutral hadron shower cartoon



Contiguous hit (“simple”) clusters

- Form clusters from cal hits by assigning two hits to the same cluster if they are adjacent.
- Adjacent means one hit is in one of the (3x3x3-1=)26 adjoining cells of the other.
- Iterate over all hits to form contiguous hits clusters.

Cluster energy tensor

- Form a tensor of hit locations and energy per hit. Identical to an inertia tensor.
- Tensor is symmetric and has three principal axes and associated eigenvalues.
- Eigenvalues describe shape.
- Smallest eigenvalue goes with axis that points along direction of shower.

Gamma cluster characteristics

- No fragments
- Cluster axis points back to gamma origin.
- Energy is close to axis.
- Begins near front of EM Cal.
- Uniform cigar shape.

Hadron cluster characteristics

- May have fragements.
- If charged, has minI trail beginning in first layer.
- A large spread out extend object.
- If neutral with no large fragment it will point back towards origin.

Fragment cluster characteristics

- May have second level fragments.
- Initiated by a neutral (may also be artifact of "errors" in contiguous hit matching, ie, across inter-calorimeter gaps, dead cells or charged particle traversing a cell without touching active element.)
- Generally don't point back to IP, but otherwise like a neutral hadron cluster.

First test of the model

- Three datasets of 1000 single particle events.
  - piminus, gamma, and K0L
  - 1-50 Gev momentum
  - In barrel, within 45^{o} of perpendicular to beam
- Make contiguous hit clusters
  - Ignore clusters with energy < 0.5 GeV
  - Treat most energetic cluster as primary deposition
  - Treat second most energetic cluster as fragment.
- Test both primary and secondary cluster
  - Is it a gamma, piminus, K0L, and/or fragment?

ID result:

gamma piminus K0L fragment

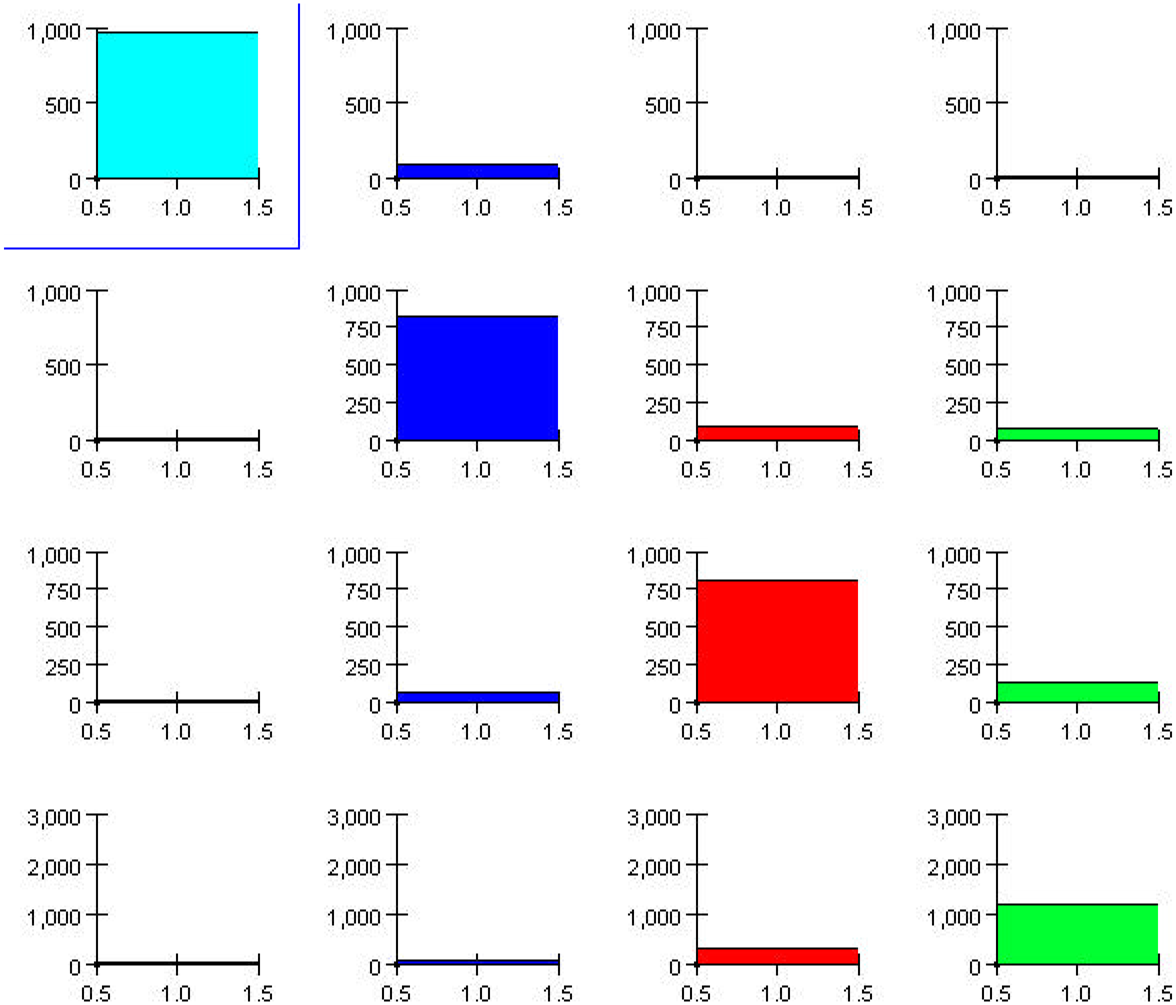
Input:

gamma

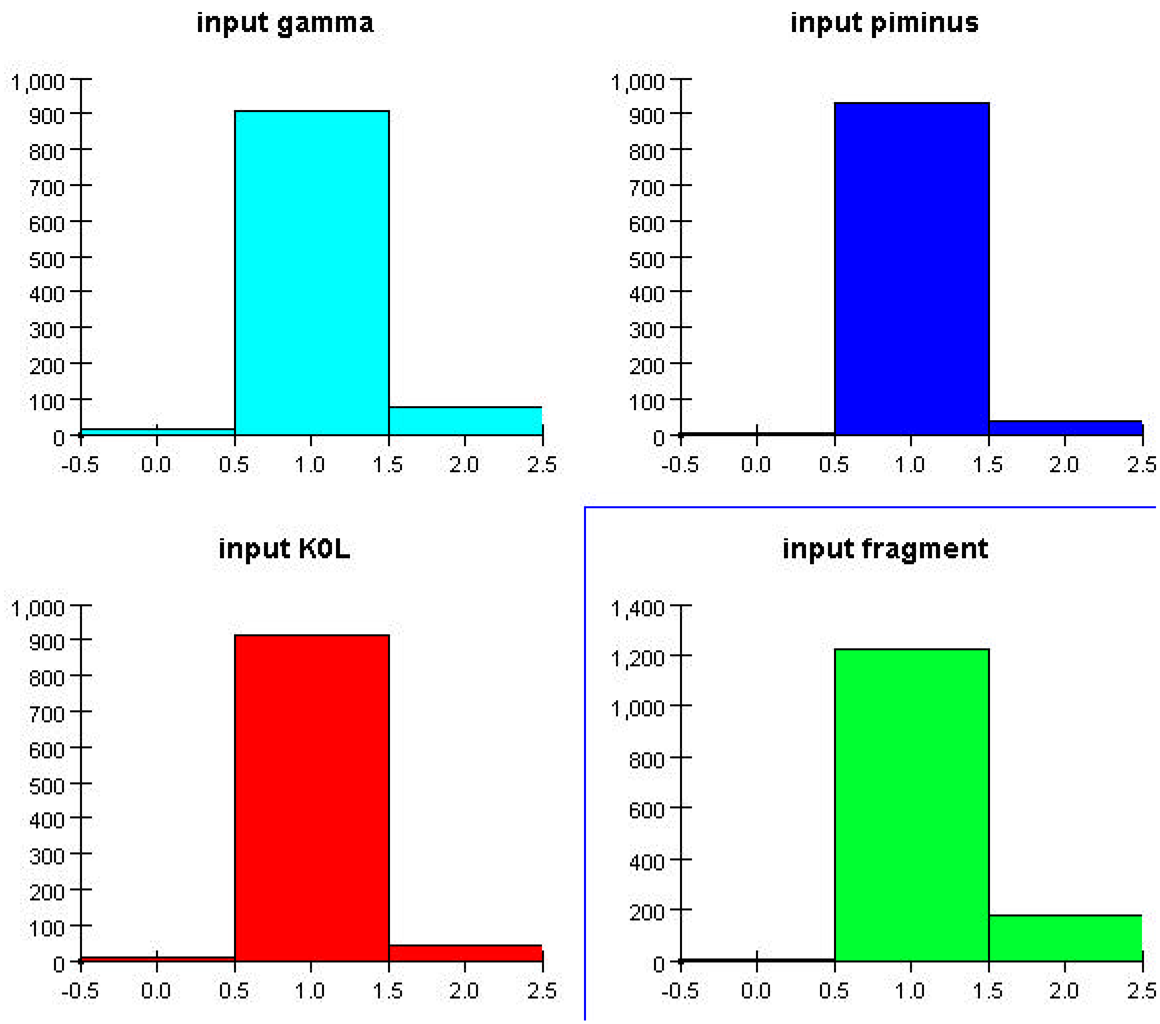
piminus

KOL

fragment

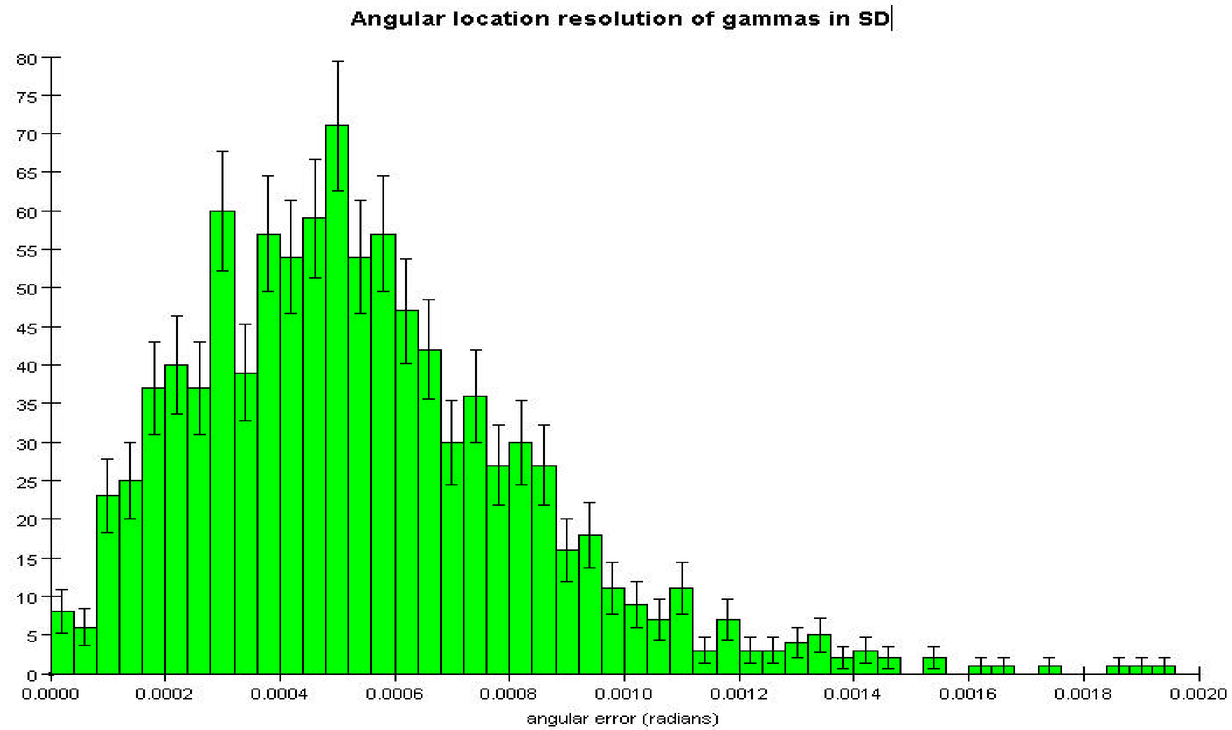


Multiple ID rates

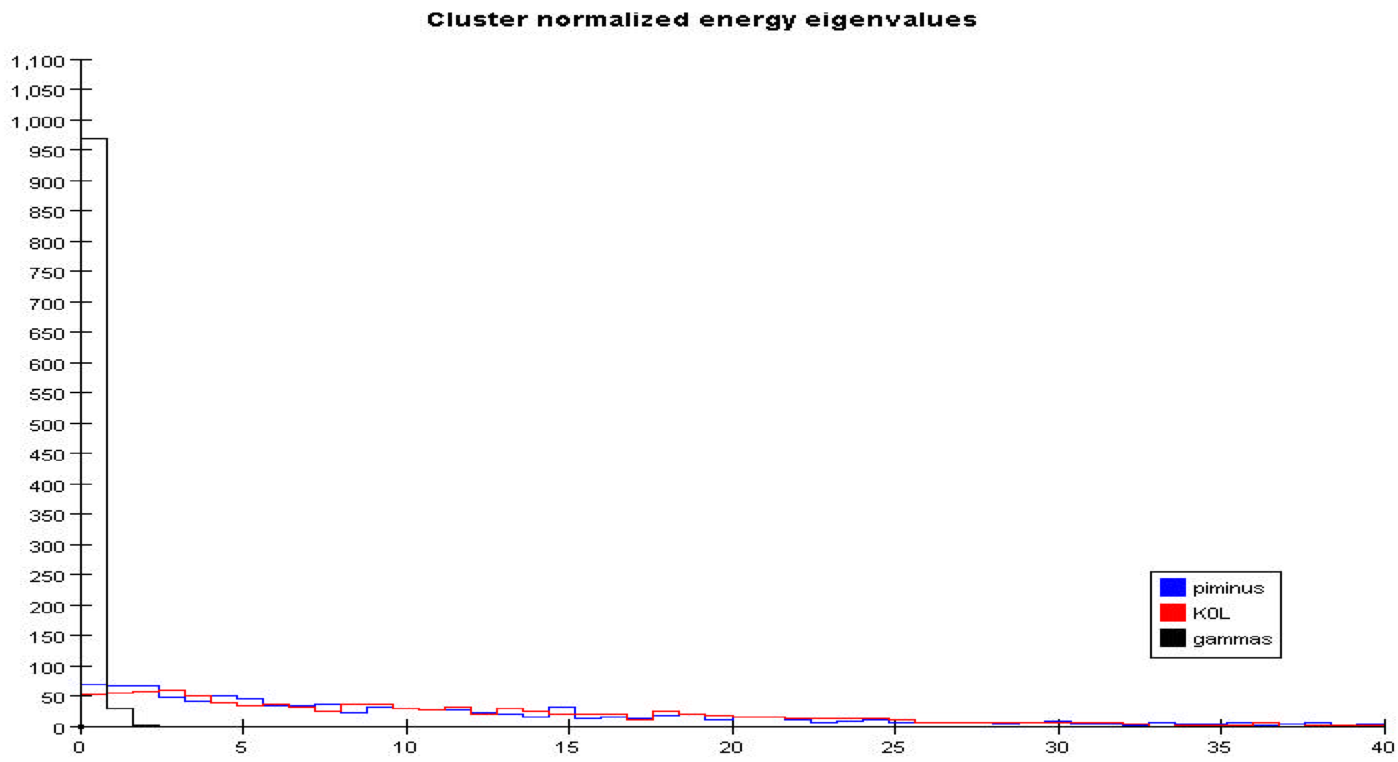


Superb gamma location resolution

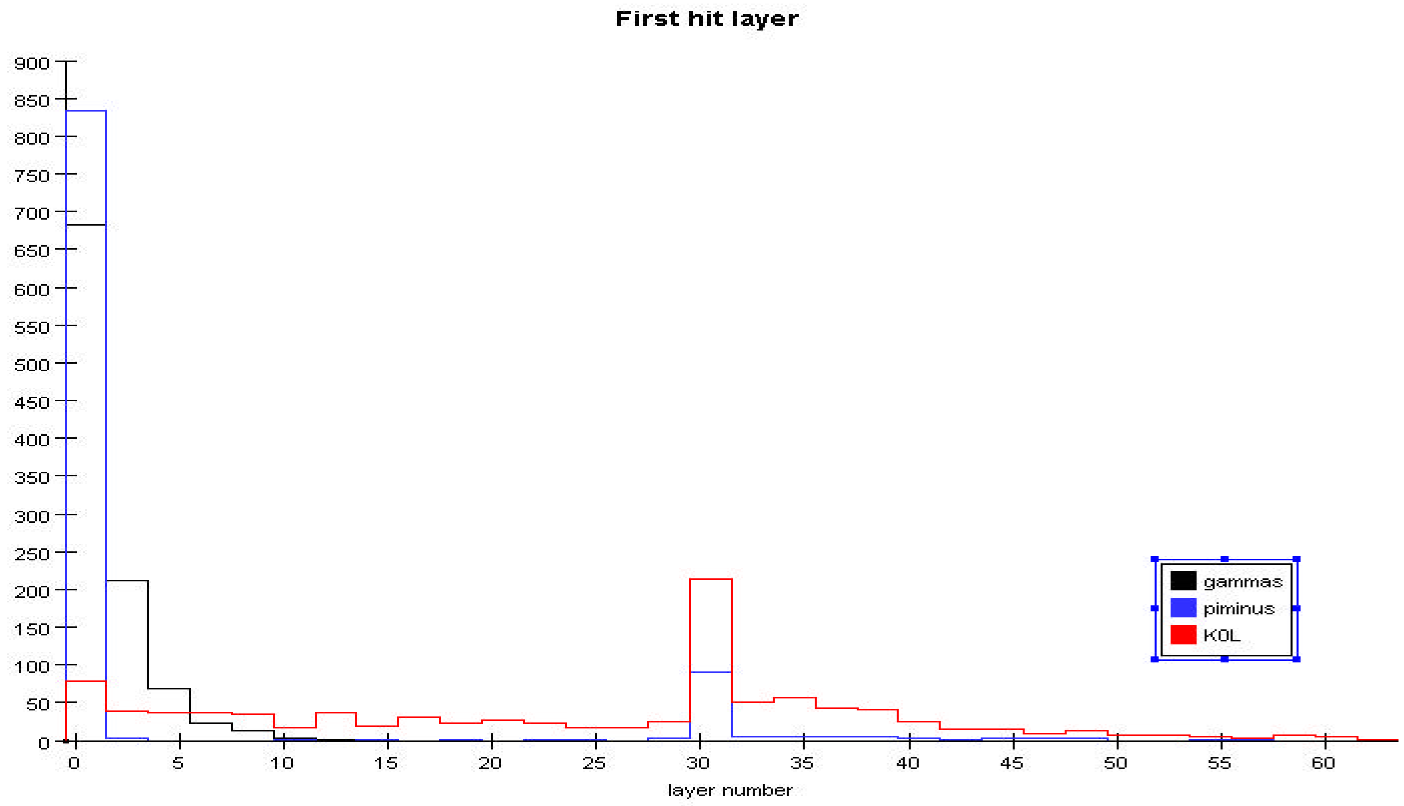
Resolve gamma direction to ~1/6 cell size using center of energy of hits



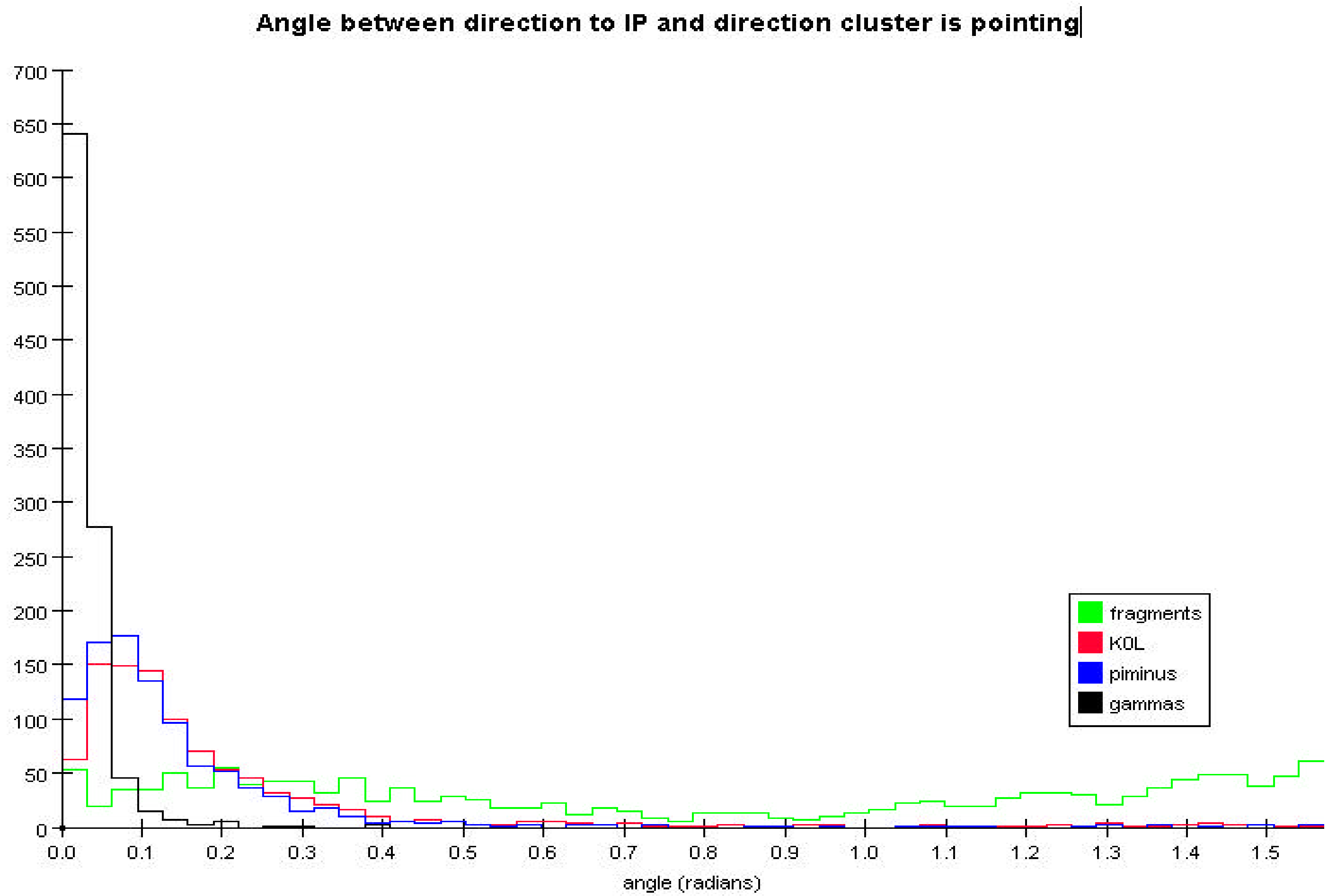
Separating gammas



Separating piminuses



Separating K0Ls



Summary – Single particle study

- Can find gammas with ~100% efficiency and ~few percent fakes.
- Can identify most pions without tracking
- Can identify majority of K0Ls.
- Have only sketched the power of the method.

Important questions

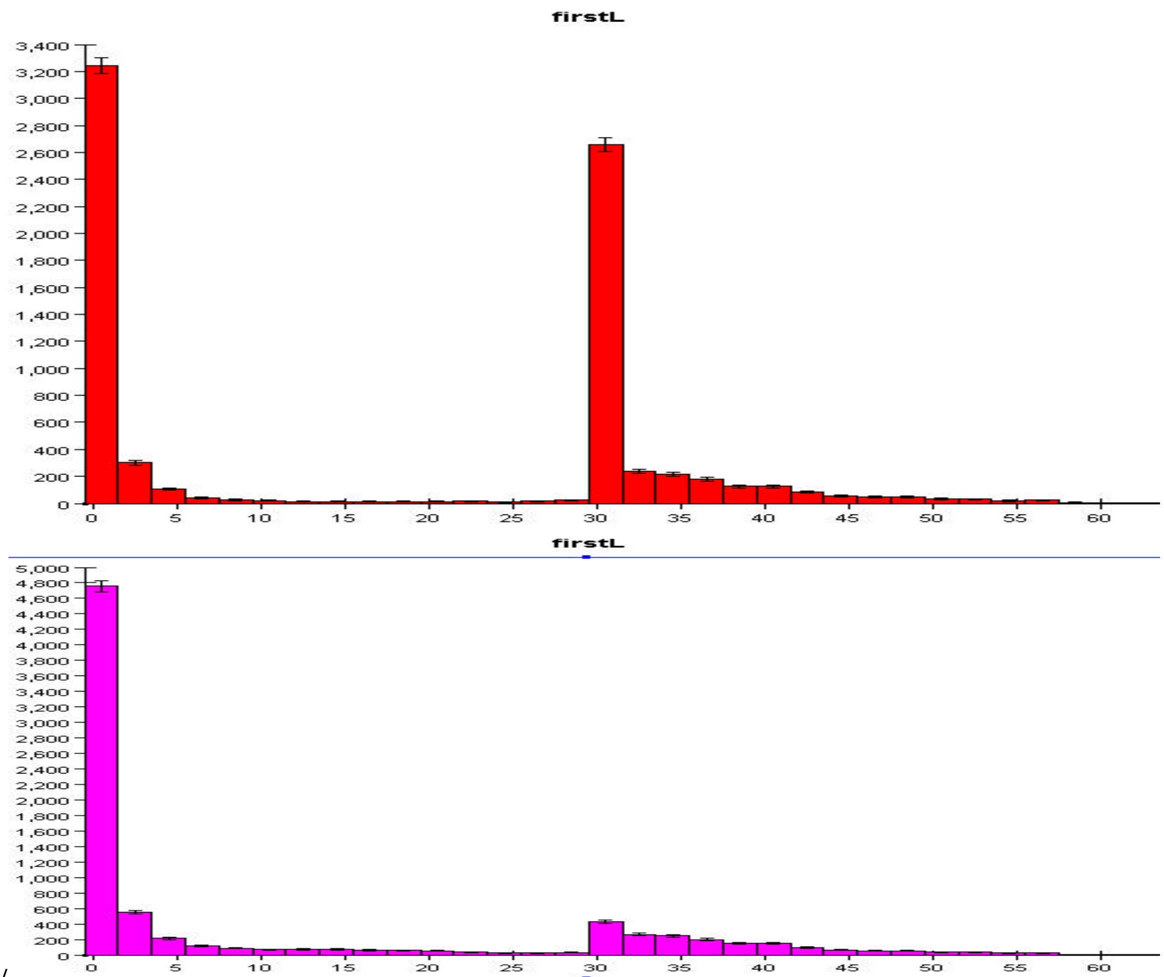
- Connecting clusters across intercalorimeter boundaries.
- Overlapping clusters.

"Secret" to solving fragmentation problem

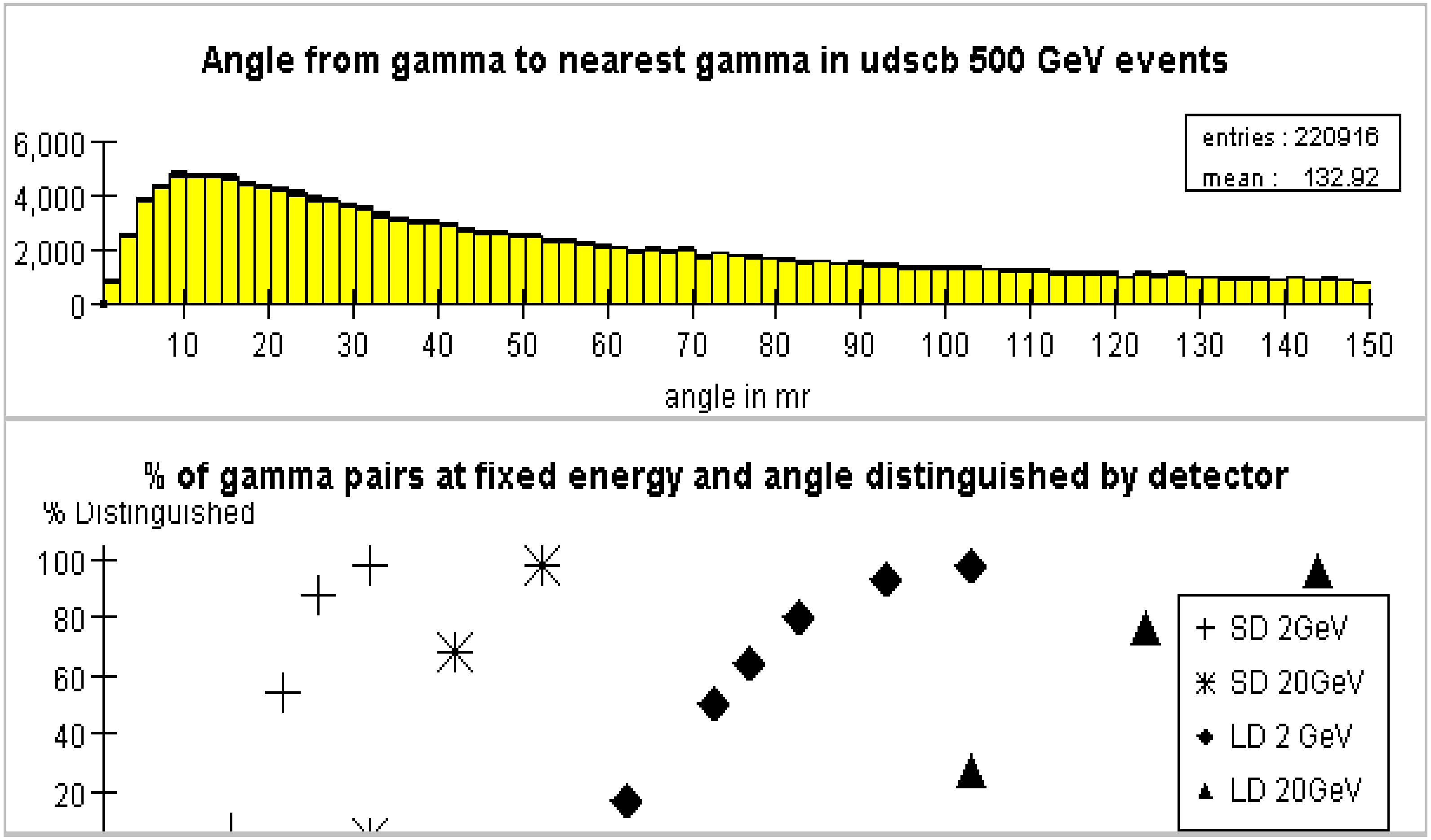
- Combine EM and Had clusters using contiguous hits cluster builder by Ron Cassell.
- Caveat: For the occasional neutral hadron there will be significant fragments but we have a promising technique to find and associate them.

Cal gaps vs no gaps

first hit layer



Isolation of gammas



Overlapping hadron showers?

- Hadron shower somewhat like a spread out spiderweb – long thin lines (pi) with small globs (gammas) at intersection points.
- Two such showers may overlap globally but never actually touch locally.
- (Note: Need to demonstrate this.)

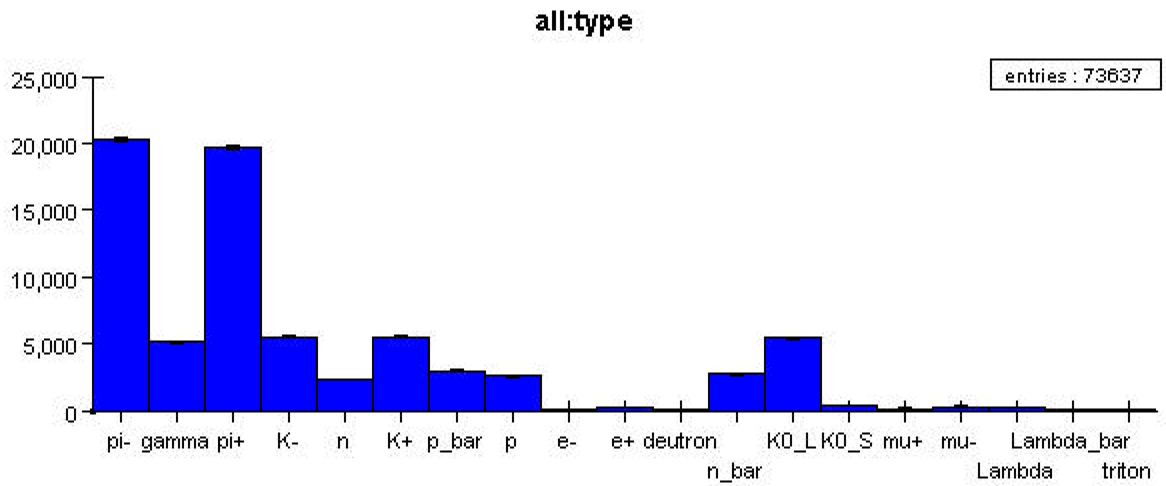
Now apply to signal events

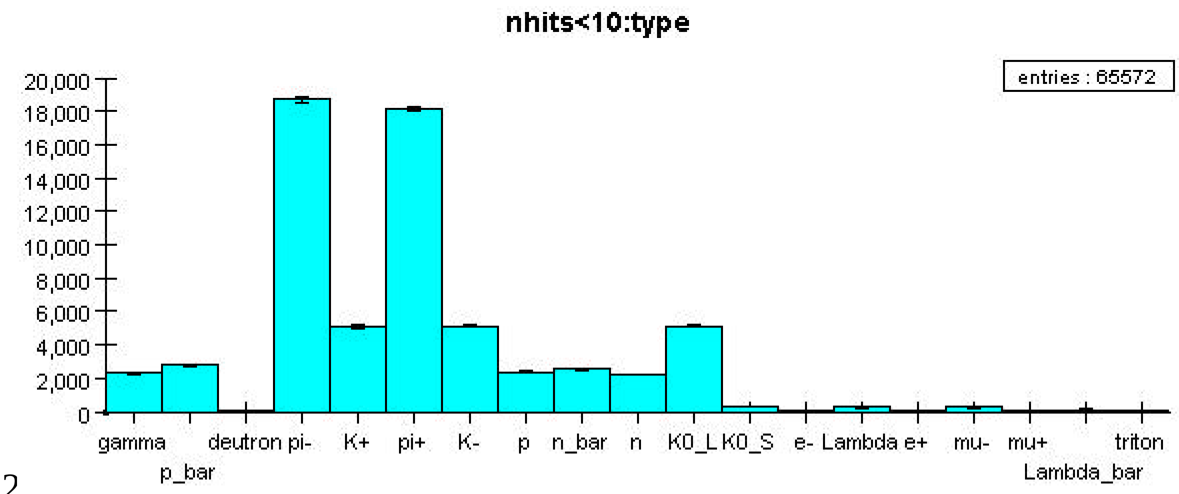
- Important differences between single particle events and signal event tests.
- In single particle tests assumed uniform 1-50 GeV. No too bad for K0L or neutron but not too good for gamma and charged pions.
- Also assumed equal number of each type of particle in single particle test. They differ by an order of magnitude in signal events.

Cuts

- Nhits/cluster > 10
- Only barrel clusters
- Raw energy > 0.002 for gamma study
- Raw energy > 0.015 for hadron study

Nhits cut


all:type
entries : 73637
25,000
20,000
15,000
10,000
5,000
0
pi- gamma pi+ K- n K+ p_bar p e- e+ deutron
n_bar
K0_L K0_S mu+ mu- Lambda_bar
Lambda triton


nhits<10:type
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20,000
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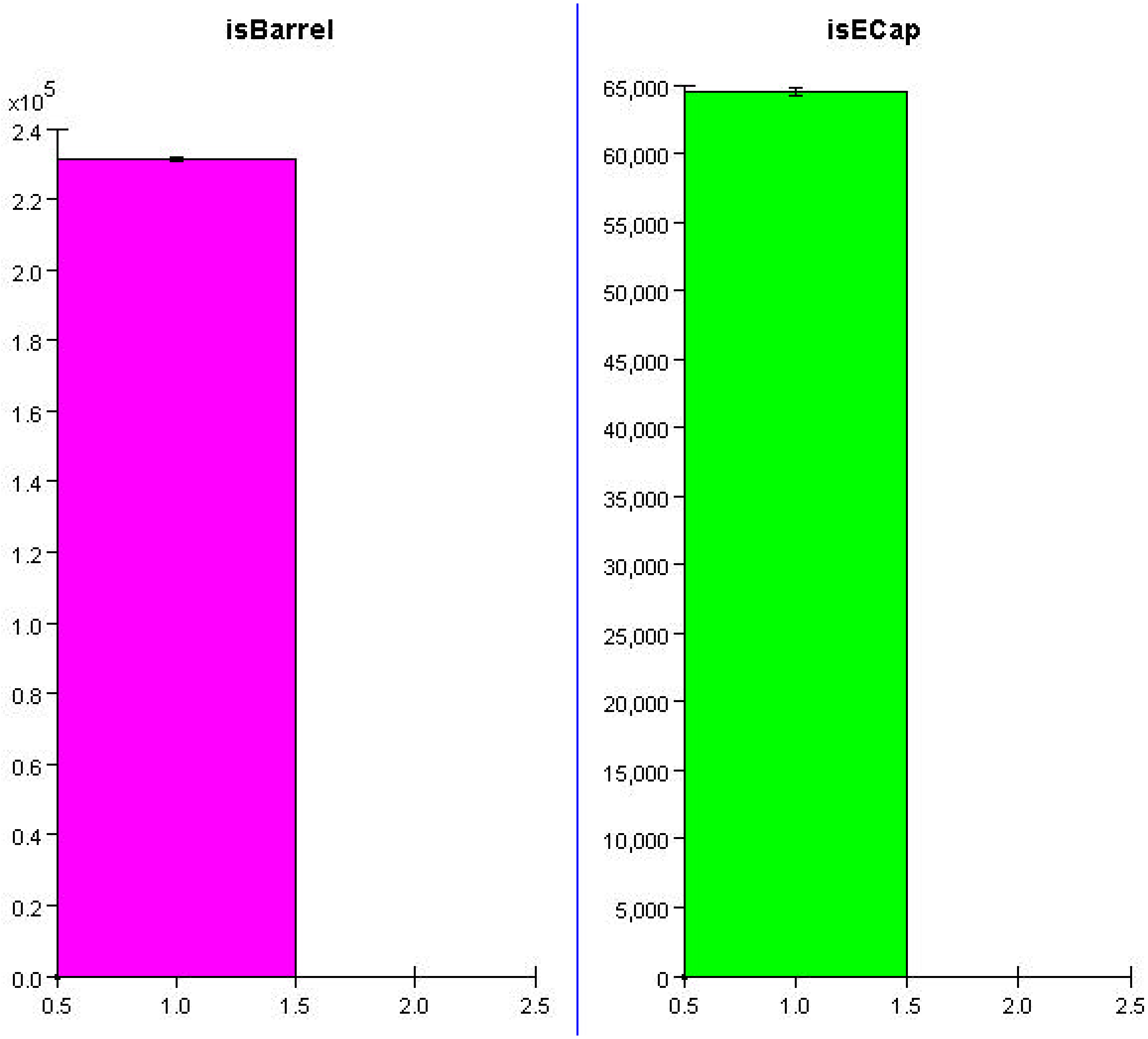
gamma deutron pi- K+ pi+ K- p n_bar n K0_L K0_S e- Lambda e+ mu- mu+ triton
p_bar
Lambda_bar

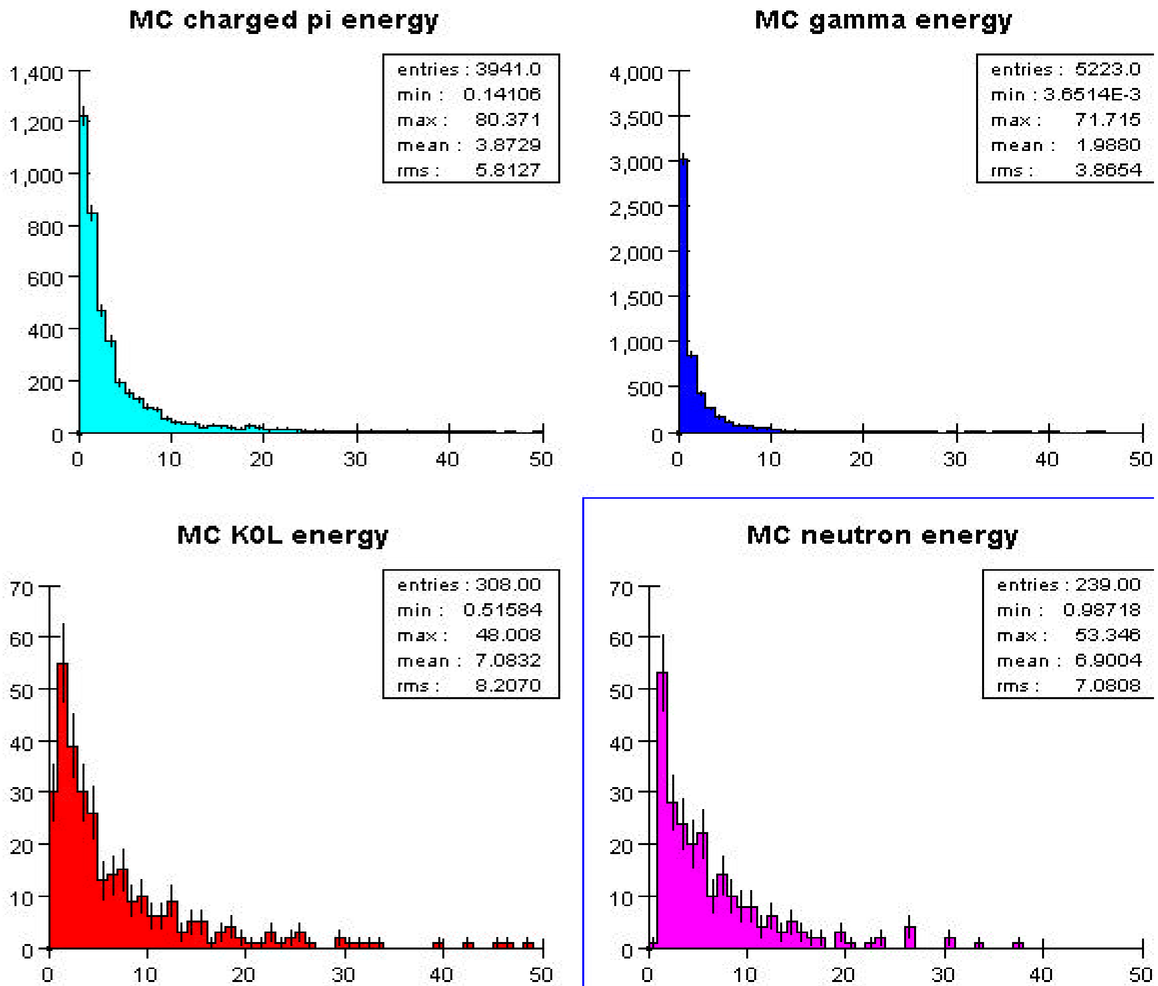
Barrel vs Ecap #clusters



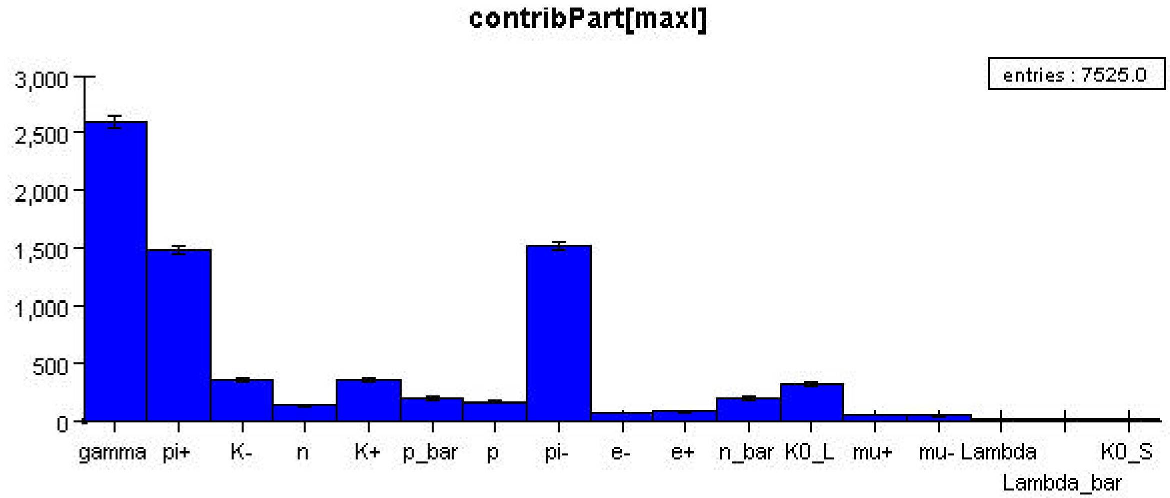
Problems making contiguous hits clusters

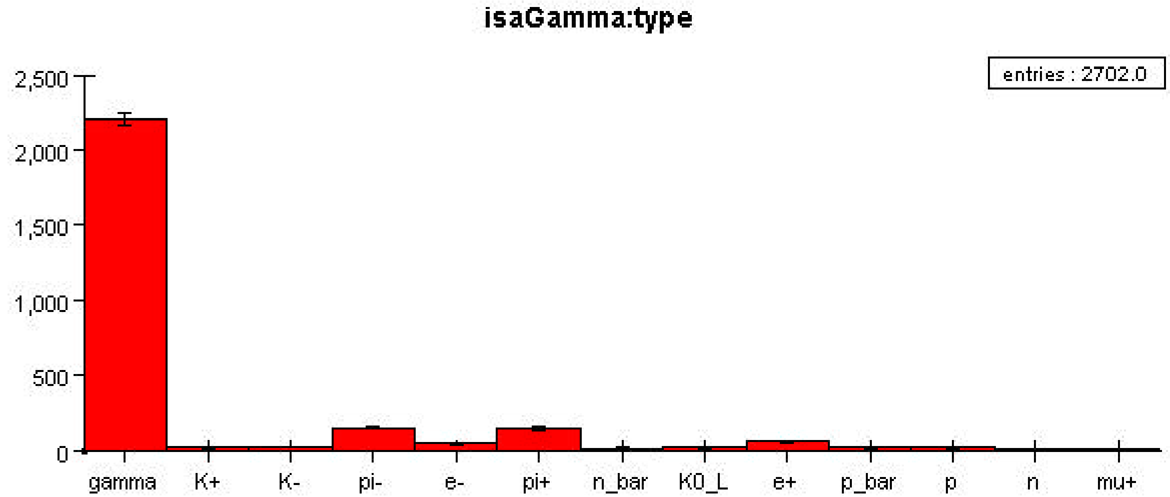
- Above we have encountered two important problems in correctly linking clusters by contiguity of hits:
  - logically connecting clusters in different cal detectors
  - the physical gap between cal detectors
- Ron Cassell is making excellent progress on these issues – ask him to give a talk!

Energy distributions in tt events



Gamma finding

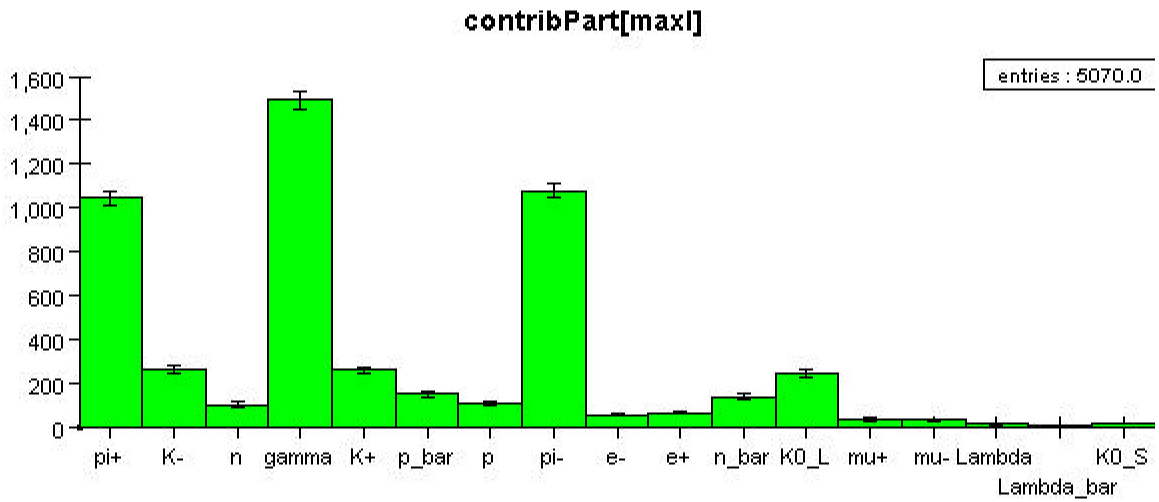


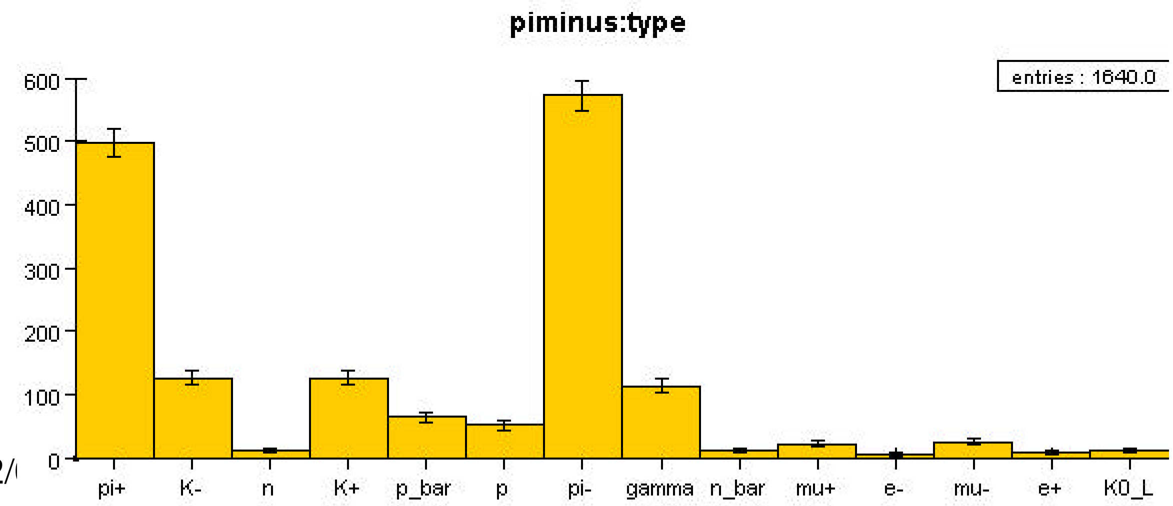


Effect on gamma efficiency

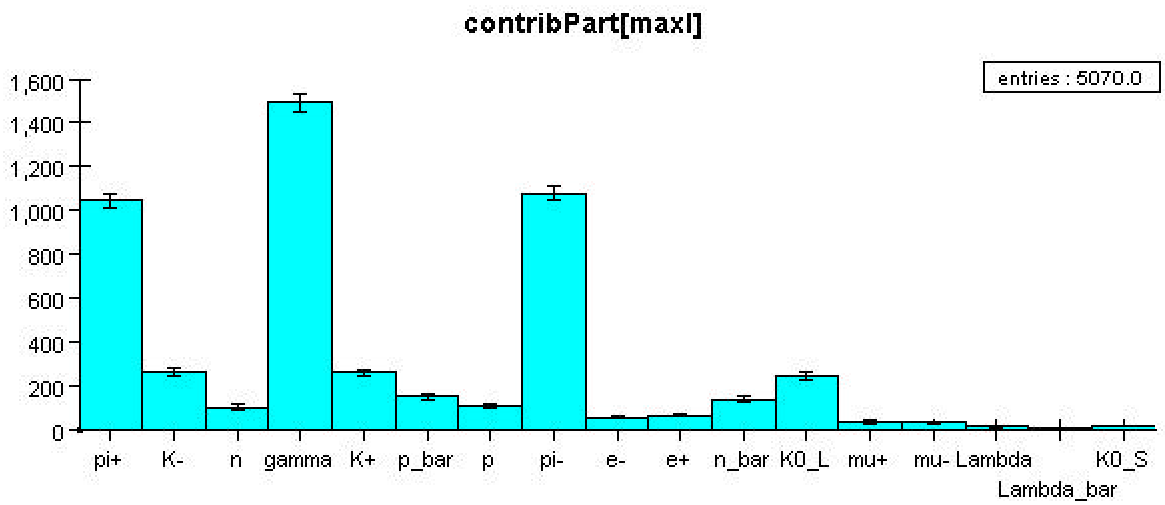
- In the single particle events the missed gammas tended to be low energy.
- In signal events most gammas are very low energy.
- Thus, the gamma efficiency for low energy gammas is down a great deal.
- More work on cuts required.

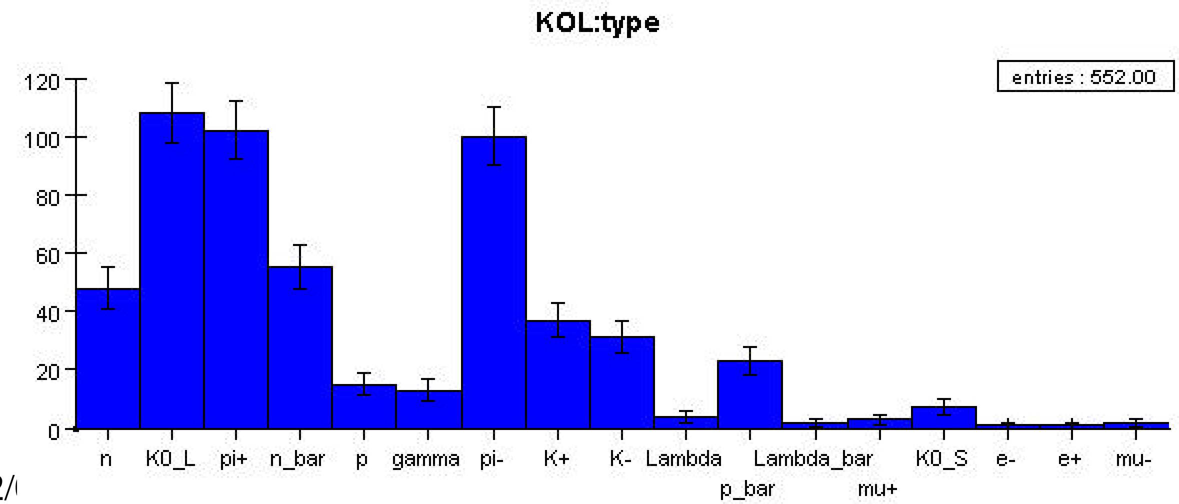
Charged hadron finding





Neutral hadron finding





Effect on K0L purity

- In single particle events test 1000 K0Ls were compared to 1000 piminus.
- In real events the ratio is 1:10.
- The piminus fragments are the K0L fakes, thus the fake rate is up by a factor ~ 10.
- More work required on cuts.

On the other hand

- In both problems with the signal events the additional error introduced is with low energy particles.
- Thus, the impact on overall eflow is not as bad as it appears at first.

A note on cuts

- The cuts used to separate types were chosen in about 2 hours of study.
- Further study of the cuts particularly in special cases, eg, low energy cluster cuts may optimize differently then high energy clusters.
- The space is complex and multidimensional and a neural net will certainly improve things.

Summary signal events

- Results not as amazing as with the single particle events but they are very good.
- There are many options to explore to make improvements.
- This is a work in progress.

Next steps (arbitrary order)

- Many details to cross-check.
- Reconstruct p^0s (dE/E~5%, loc res ~same as $p^{\pm}$.)
- Measure energy of clusters.
- Associate neutral hadron fragments (improve dE/E).
- Combine “gapped” clusters.
- Use neural net to improve results.
- Test on physics measurements.
- Release tools.