A New Topologic Particle Flow Algorithm

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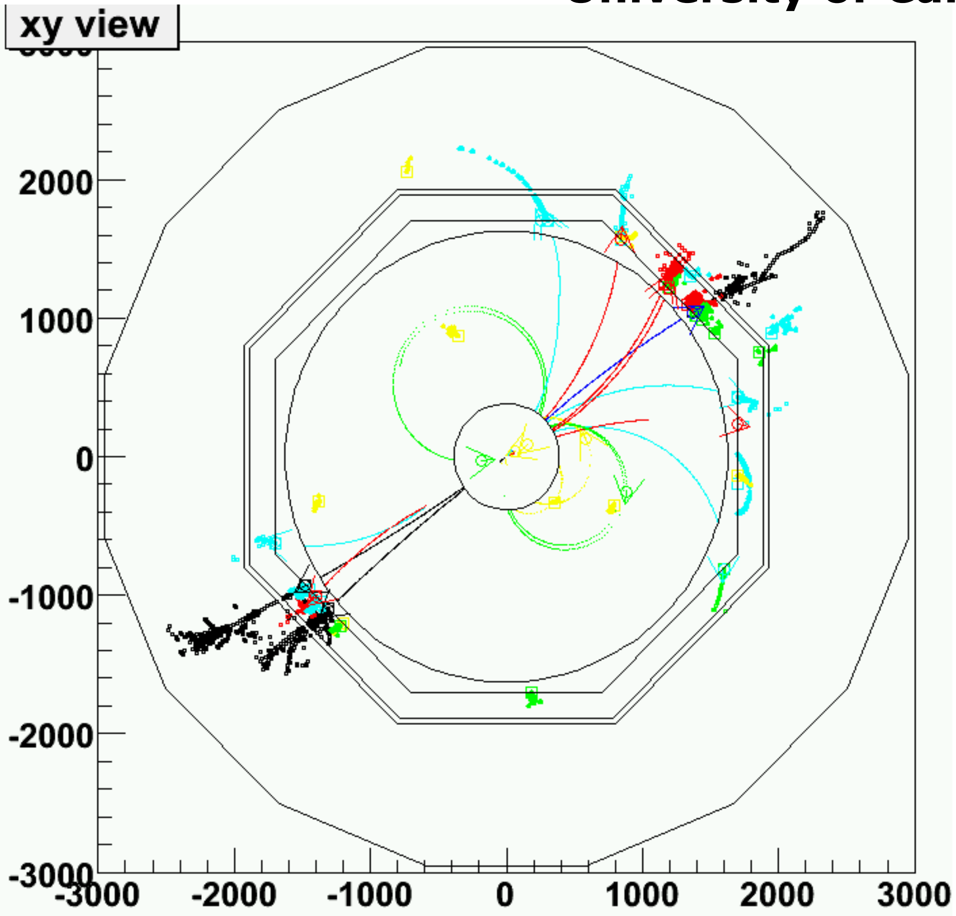


This Talk:

- ★ Philosophy
- ★ The Algorithm
- ★ First Results
- ★ Conclusions/Outlook

❶ Philosophy

★ Try to develop “generic” PFA which will take advantage of a high/very high granularity ECAL

★ Clustering and PFA performed in a single algorithm

★ Aim for fairly generic algorithm:

- very few hard coded numbers
- use GEAR to get basic geometry

★ Use tracking information to help clustering

★ Initial clustering is fairly loose

⇨ ProtoClusters

★ ProtoClusters are then linked together…

★ Clusters linked to tracks at a number of levels

+ build on what exists in MARLIN framework:

✦ GEAR (Frank G)

✦ Marlin Simple Digitisation

✦ Track finding/fitting : TrackCheater (Alexei R.)

✦ PFA Utility classes, e.g. Helix class for track extrap. (Alexei R.)

❷ The Algorithm

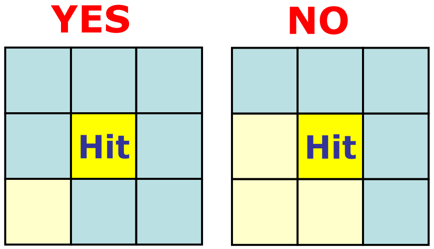
Overview:

- ★**Preparation**
  - ★**Isolation cuts, hit ordering, track quality**
- ★**Initial clustering to form ProtoClusters**
  - ★**ProtoClusters are heavyweight object:**
    - ★ **collection of hits**
    - ★ **know how to grow (configured when created)**
    - ★ **information about shape, direction, isPhoton,…**
    - ★ **+much more…**
- ★**Cluster association/merging**
  - ★**Tight Topological linking of clusters**
  - ★**Looser merging of clusters**
  - ★**Track-driven merging**
- ★**PFA**
  - ★**Final track-cluster matching**

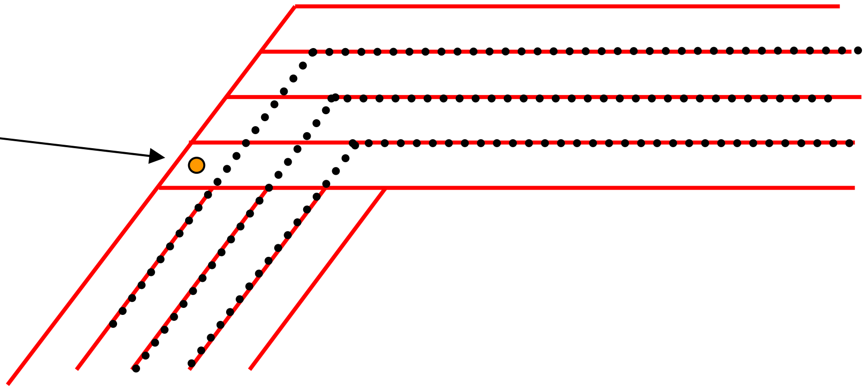
- **In the next few slides will outline what's done in each stage**
  - skip MANY details

Preparation I: Extended Hits

- Create internal **ExtendedCaloHits** from **CaloHits**
- **ExtendedCaloHits** contain extra info:
  - pointer to original hit
  - pseudoLayer (see below)
  - measure of isolation for other hits
  - is it MIP like
  - actual layer (decoded from **CellID**)
  - Pixel Size (from GEAR) – hits are now self describing



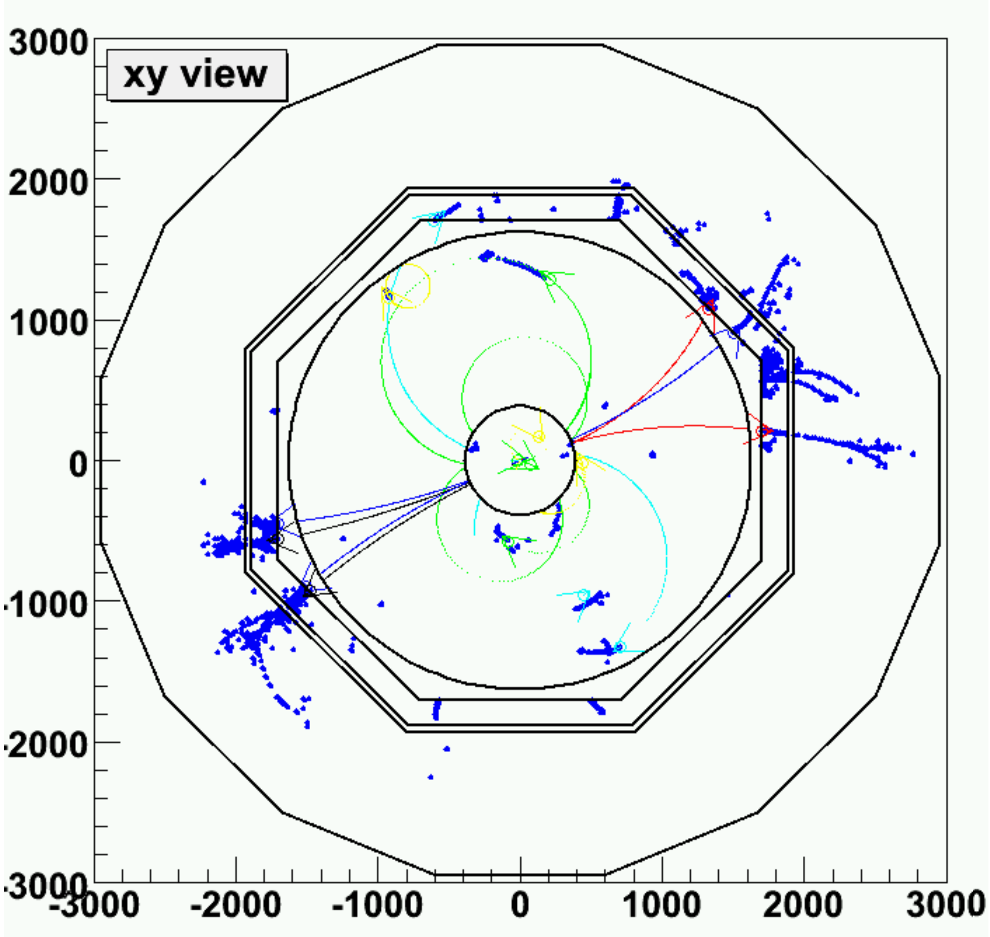
- Arrange hits into **PSEUDOLAYERS (e.g. Chris Ainsley's MAGIC)**
  - **i.e.** order hits in increasing depth within calorimeter
  - PseudoLayers follow detector geometry



- Hit in early layer
- But high PseudoL

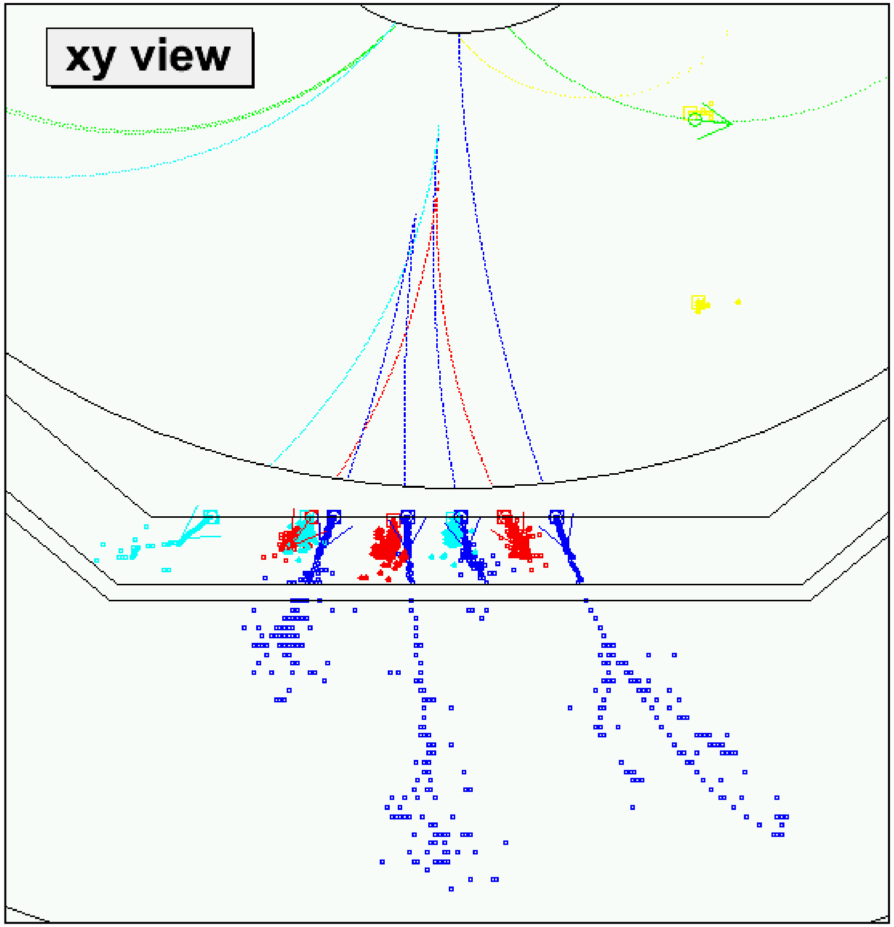
Preparation II: Isolation

- ★Divide hits into isolated and non-isolated
- ★Only cluster **non-isolated** hits
- ★"Cleaner"/Faster clustering
- ★ Significant effect for scintillator HCAL



- ✦ Removal of isolated hits degrades HCAL resolution
- ✦ <u>**e.g. D10scint:**</u>
  50 %/√E/GeV →
  60 %/√E/GeV

Preparation III: Tracking



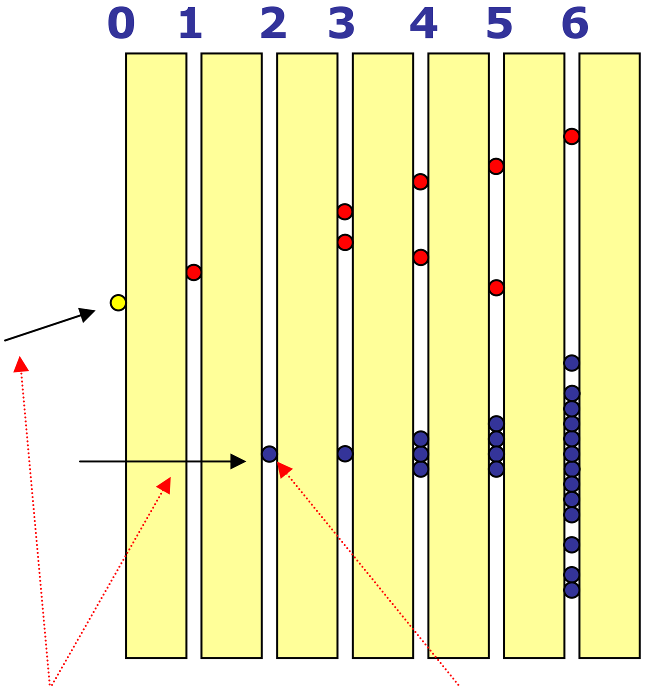
- ★Use MARLIN **TrackCheater**
- ★Tracks formed from MC Hits in **TPC/FTD/VTX**
- ★ HelixFit (Alexei R) ⇒ track params
- ★ Cuts (primary tracks):
  - ♦ $|d_0| < 50$ mm
  - ♦ $|z_0| < 50$ mm
  - ♦ >4 non-Si hits

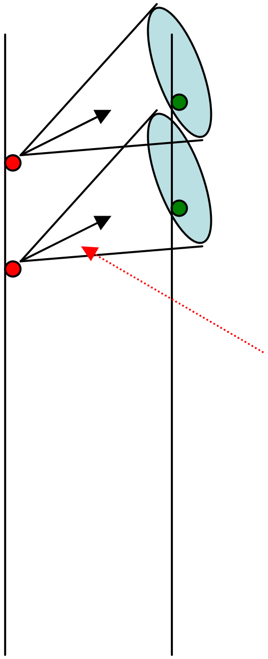
+ V_0 and Kink finding:

- ✦Track resolution better than cluster
- ✦Improves PFA performance by ~2 %

Clustering

- ★ Start at inner layers and work outward [similar to C. Ainsley's MAGIC]
- ★ Associate Hits with existing "ProtoClusters"
- ★ If multiple clusters "want" hit then Arbitrate
- ★ Step back **N** layers until association
- ★ Then try to associate with hits in current layer (M pixel cut)
- ★ If no association made form new ProtoCluster
- ★ IF _trackSeededClusters then tracks used to seed clusters





Simple cone algorithm based on current direction + additional N pixels

Cones based on either:
initial PC direction or
current PC direction

Initial cluster direction

Unmatched hits seeds new cluster

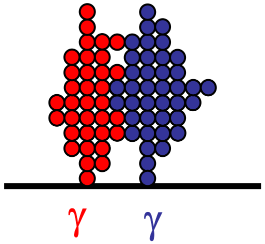
Cluster Association

- By design clustering errs on side of caution
  i.e. clusters tend to be split
- **Philosophy:** easier to put things together than split them up
- Clusters are then associated together in two stages:
  - 1) Tight cluster association - clear topologies
  - 2) Loose cluster association – catches what's been missed but rather crude

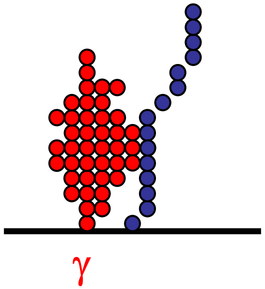
Photon ID

- Photon ID plays important role
- Simple "cut-based" photon ID applied to all clusters
- Clusters tagged as photons are immune from association procedure – just left alone

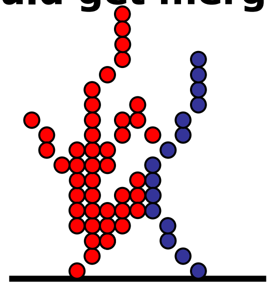
Won't merge



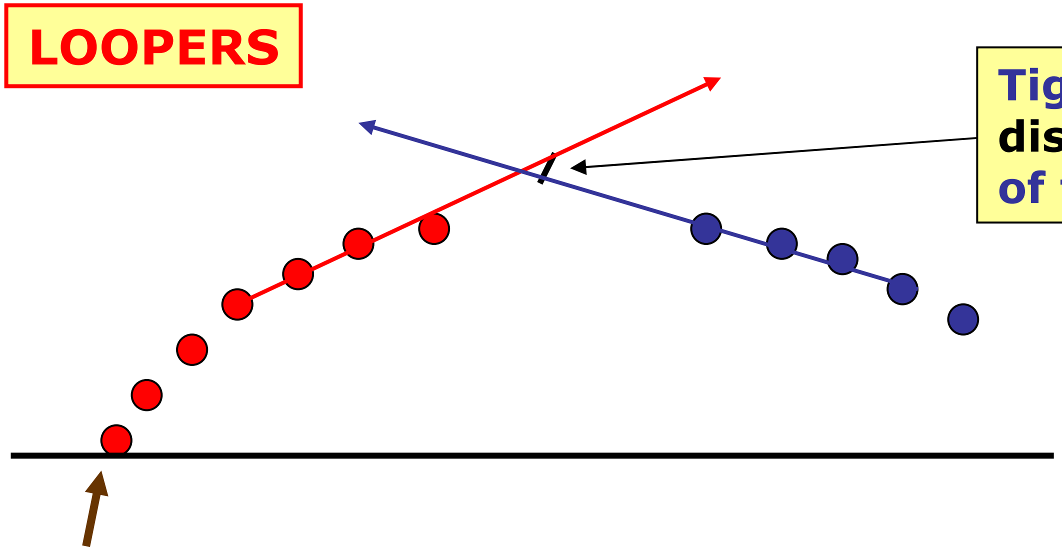
Won't merge



Could get merged

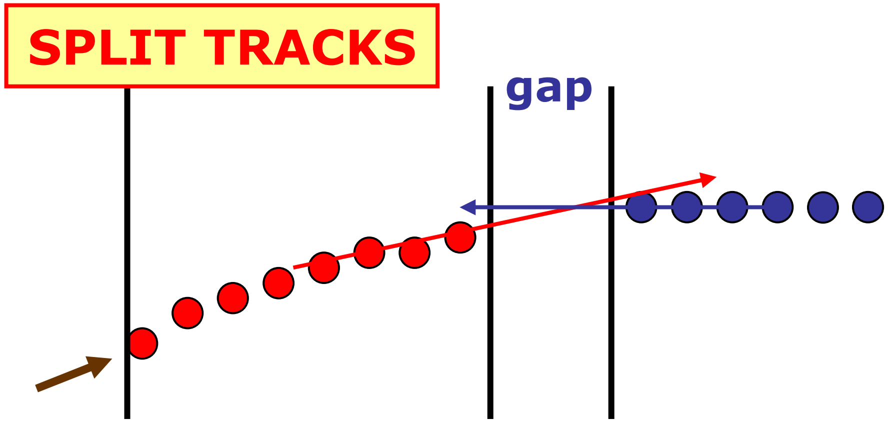


Cluster Association I : track merging



LOOPERS

Tight cut on extrapolation of distance of closest approach of fits to ends of tracks

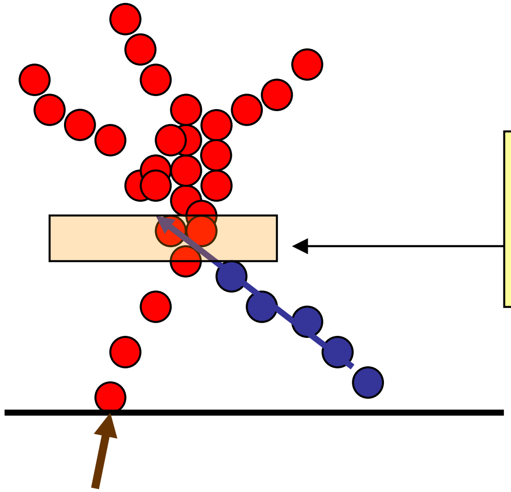


SPLIT TRACKS

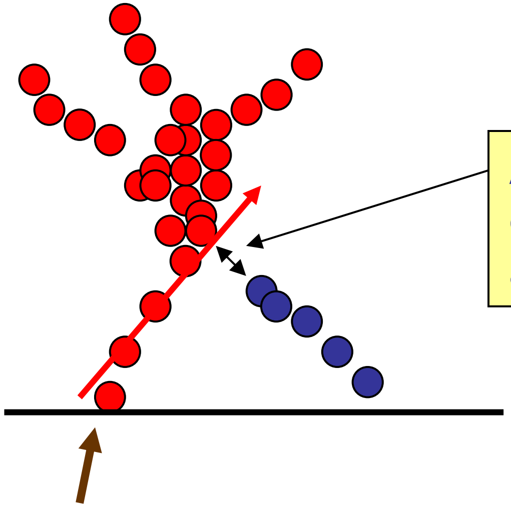
Tight cut on extrapolation of distance of closest approach of fits to end of inner tracks and start of outer track

Cluster Association II : Backscatters

★ **Forward propagation clustering algorithm has a major drawback: back scattered particles form separate clusters**



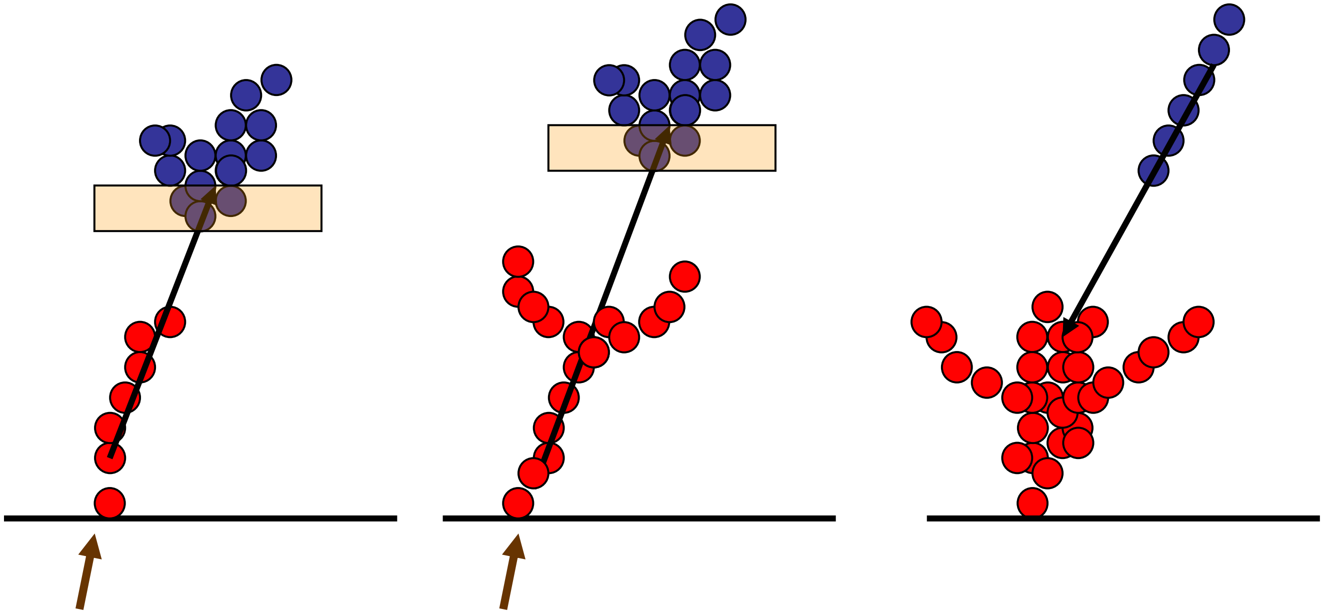
Project track-like clusters forward and check distance to shower centroids in subsequent N layers



Also look for track-like segments at start of cluster and try to match to end of another cluster

Cluster association III : MIP segments

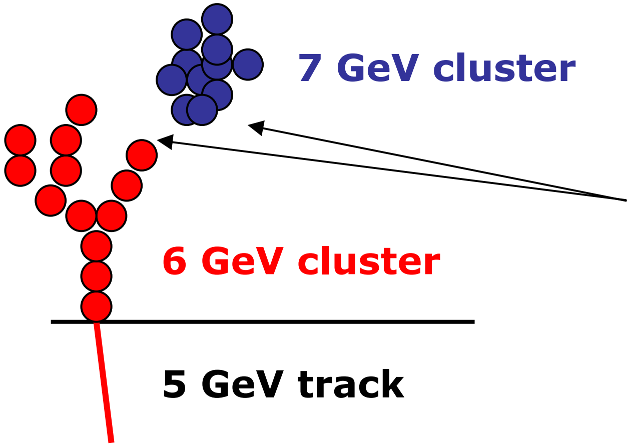
- ★ **Look at clusters which are consistent with having tracks segments and project backwards/forward**



- ★ **Apply tight matching criteria on basis of projected track [NB: + track quality i.e. chi2]**

Cluster Association Part II

- Have made very clear cluster associations
- Now try "cruder" association strategies
- BUT first associate tracks to clusters (temporary association)
- Use track/cluster energies to "veto" associations, e.g.

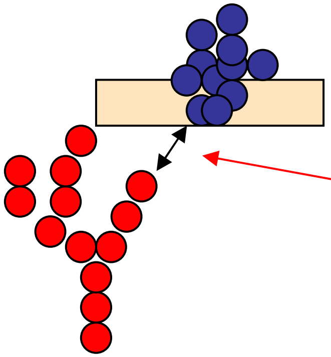


This cluster association would be forbidden if $|E_1 + E_2 - p| > 3\,\sigma_E$

Provides some protection against silly mistakes

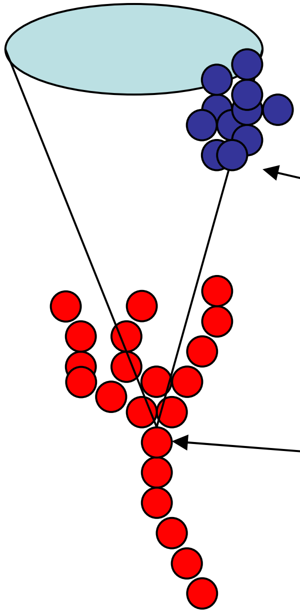
Sledgehammer Cluster Association

Proximity



Distance between hits -limited to first layers

Shower Cone



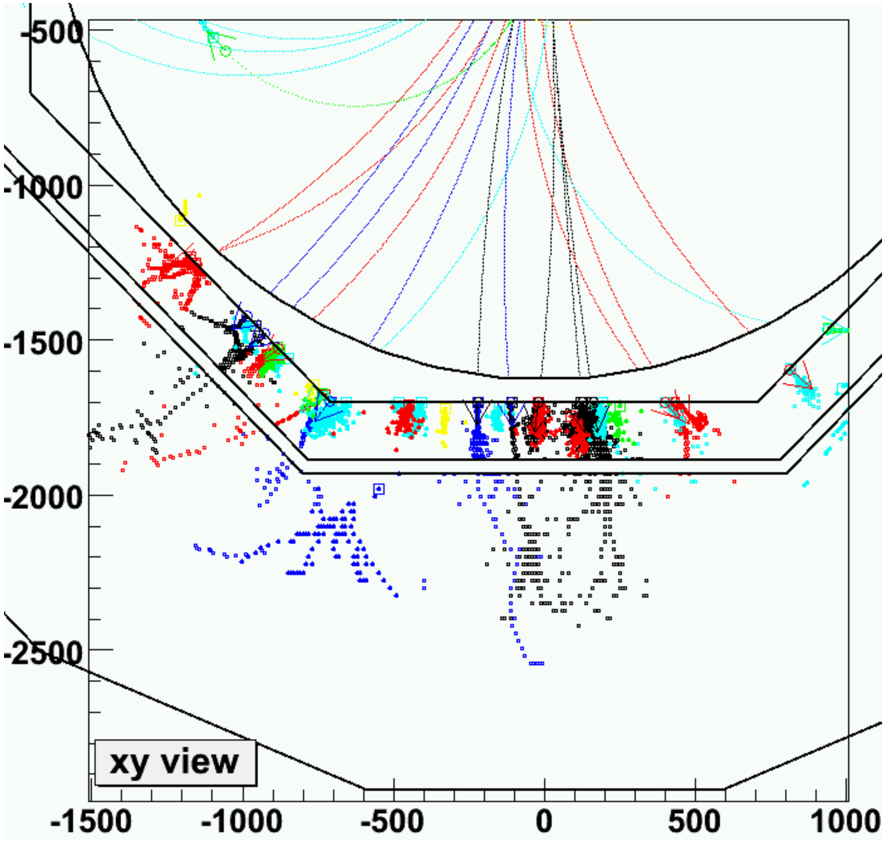
Associated if fraction of hits in cone > some value

Shower start identified

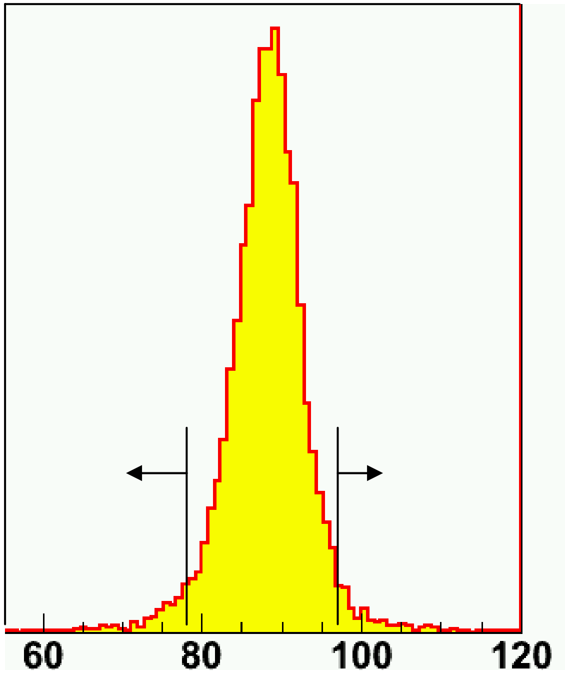
+Track-Driven Shower Cone

Apply looser cuts if have low E cluster associated to high E track

Performance (D10Scint)



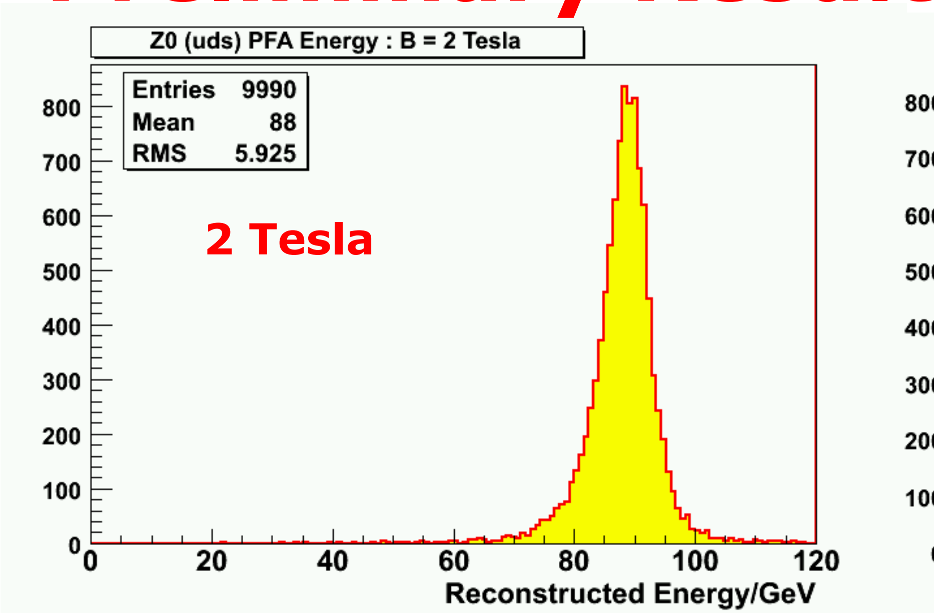
New Figure of Merit:

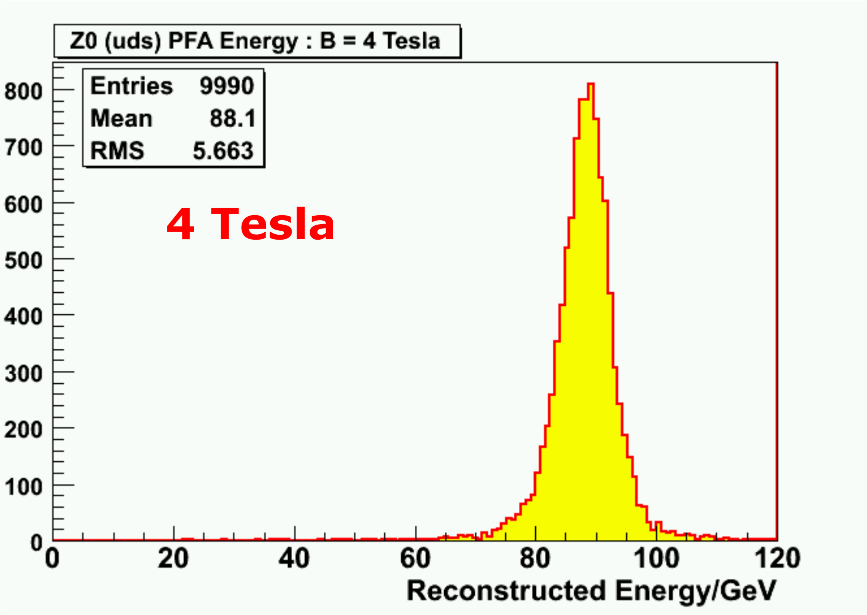


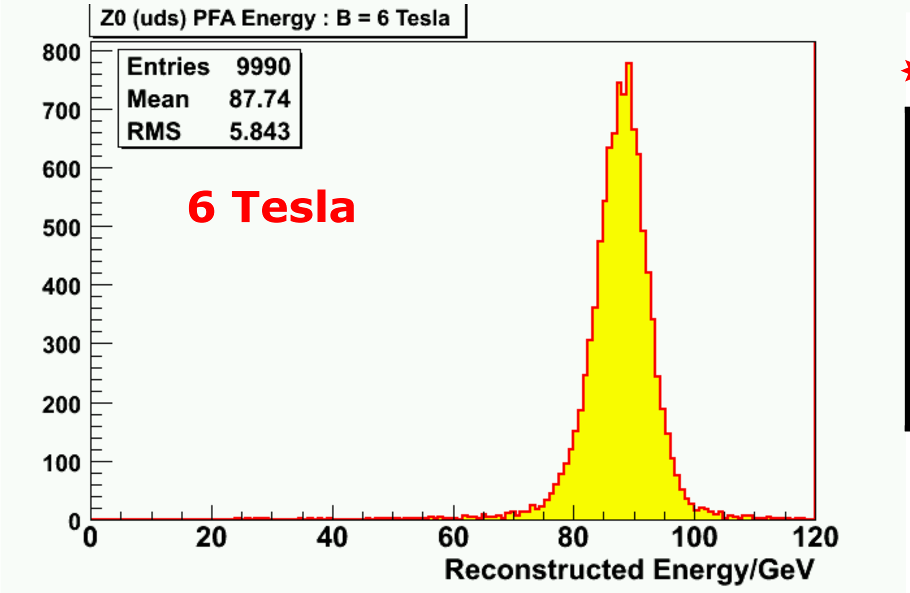
- ★Find smallest region containing 90 % of events
- ★Determine rms in this region

More robust than fitting double Gaussian

Preliminary Results : Z uds events







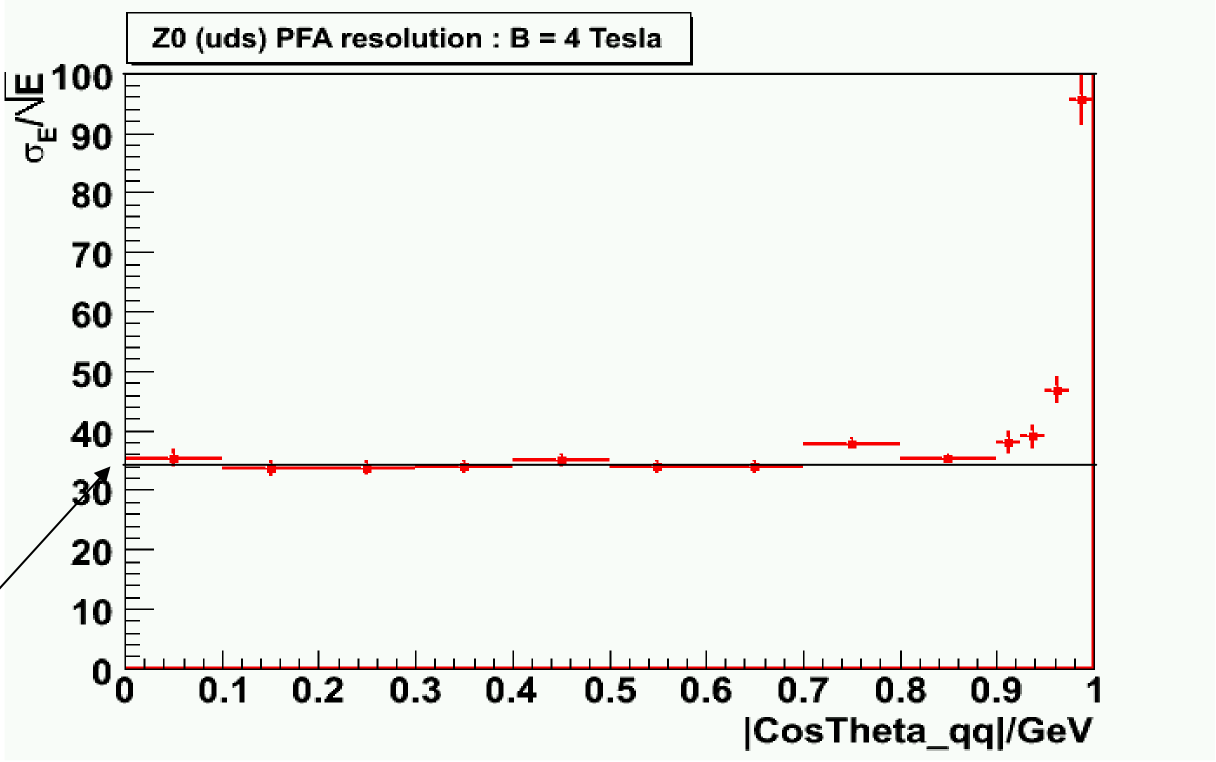
- RMS of Central 90 % of Events

B-Field	$\sigma_E/E = \alpha\sqrt{(E/GeV)}$
2 Tesla	35.3±0.3%
4 Tesla	35.8±0.3 %
6 Tesla	37.0±0.3 %

- only weakly depends on B

Results : Z uds events
Angular dependence

- Plot resolution vs "generated" polar angle of qq system



- In barrel : 34 %/ √E(GeV)

Outlook

- Looks promising - good performance for 91.2 GeV Z events
- Can be improved:
    - algorithm parameters not optimised
    - still a few features (i.e. does something silly)
    - more clever ways of estimating hadronic energy
    - better photon ID…
    - + some new ideas (for high density events)
- Code runs within **Marlin** framework and is nearly ready for release
- First code needs tidying up
    - started with decent OO structure
    - then grew organically…
- Aim to have complete algorithm early next year (January)
- Soon start full simulation detector optimisation studies