π^0 reconstruction

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- π^0 reconstruction in Z^0 events
- clustering algorithm for strip calorimeter

jet energy reconstruction

- ILC detector aims to have an excellent jet energy resolution $\sigma(E)/E \sim 30\% / \sqrt{E}$
- allows separation of hadronic W & Z decays
- we use Particle Flow Algorithm to achieve this:
  - tracker to measure charged energy
  - calorimeter for neutral energy

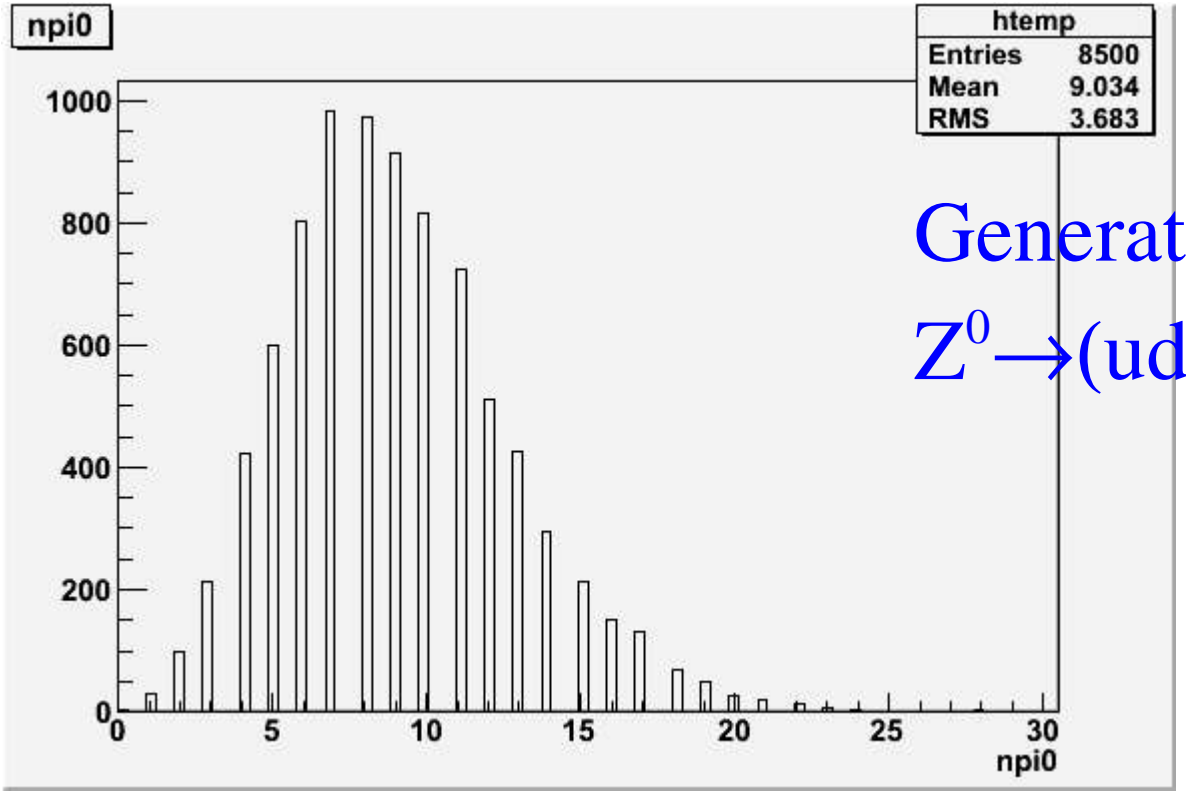
GLD calorimeter

- study tungsten-scintillator sampling calorimeter
  - EM – 33 * (W: 2mm, scintillator: 3mm, gap: 1mm)
  - Molière radius ~ 14mm, X_0 ~ 26 mm
- scintillator segmented into tiles or strips, each read out by Multi Pixel Photon Counter (MPPC)

why identify π^0 ?

- most particles in jets are π
- $\pi^{+/-}$ momenta well measured by tracking system in Particle Flow Algorithms
- π^0 carry significant energy, not measured by tracking system: only calorimeter can measure this
- essential for good jet energy resolution

how many π^0s, what energy?



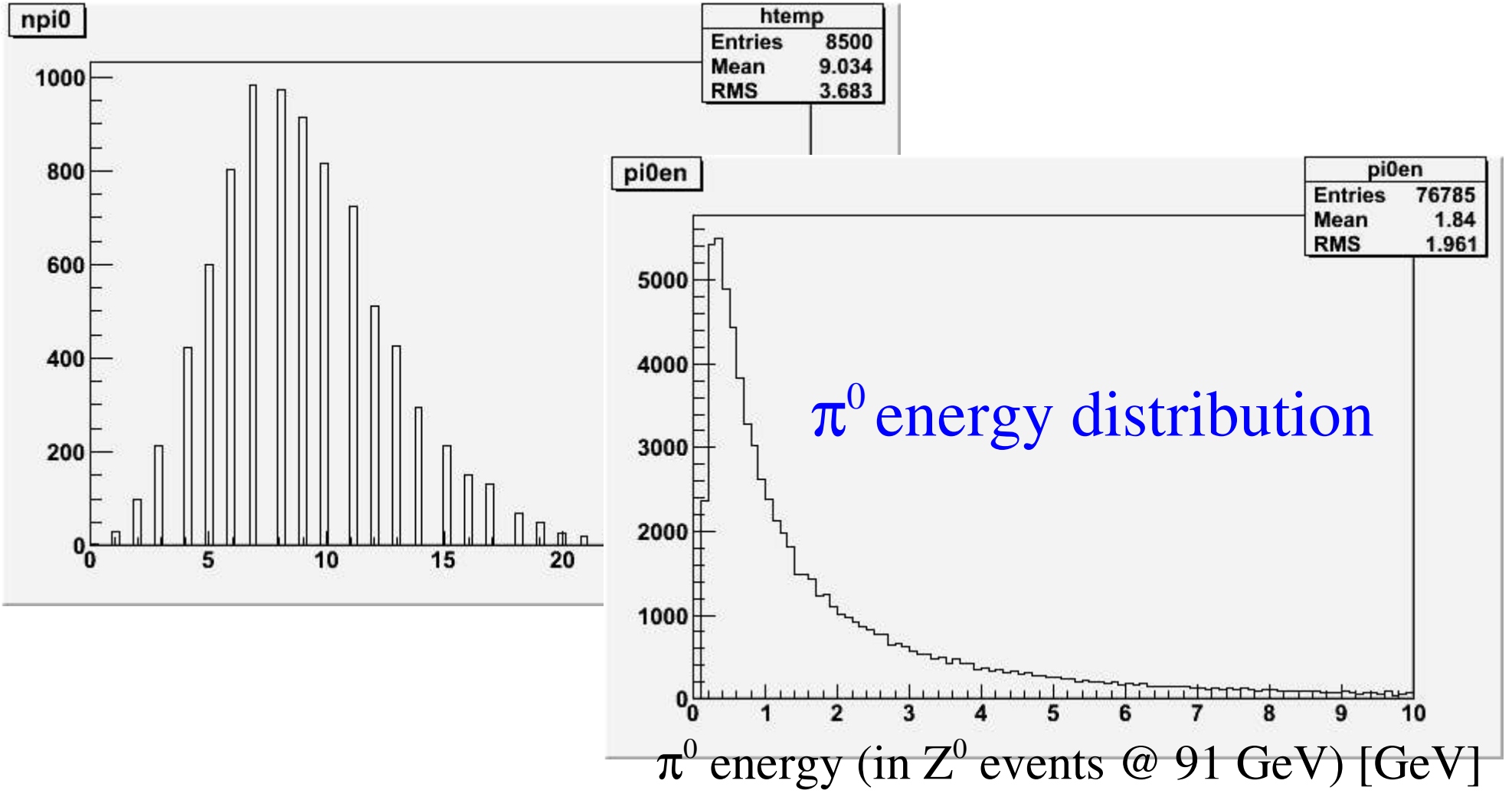
Generator level

$Z^0 \rightarrow$(uds) @ 91 GeV

number of pi0s per Z^0 event

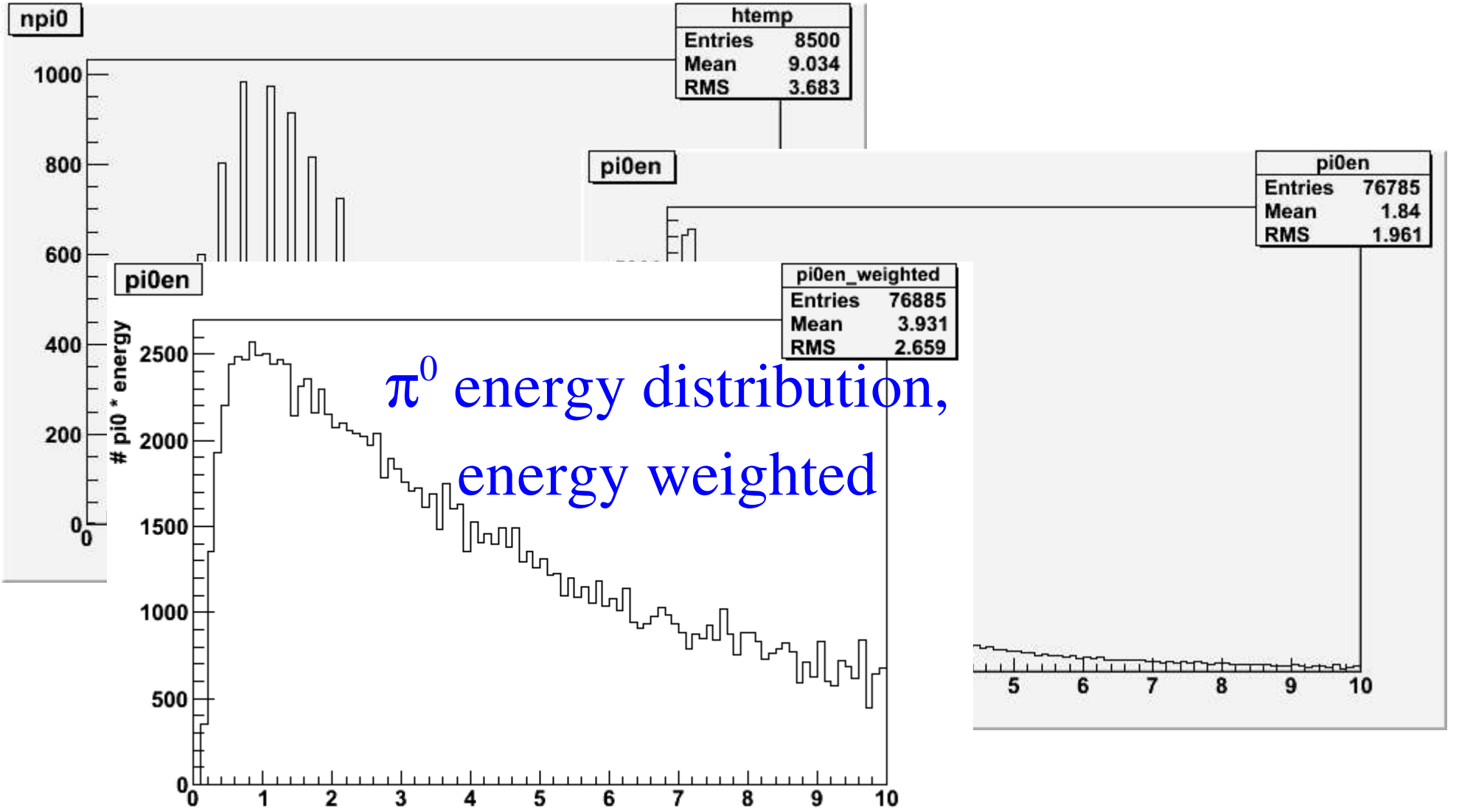
O(10) π^0s per event

how many π^0s, what energy?



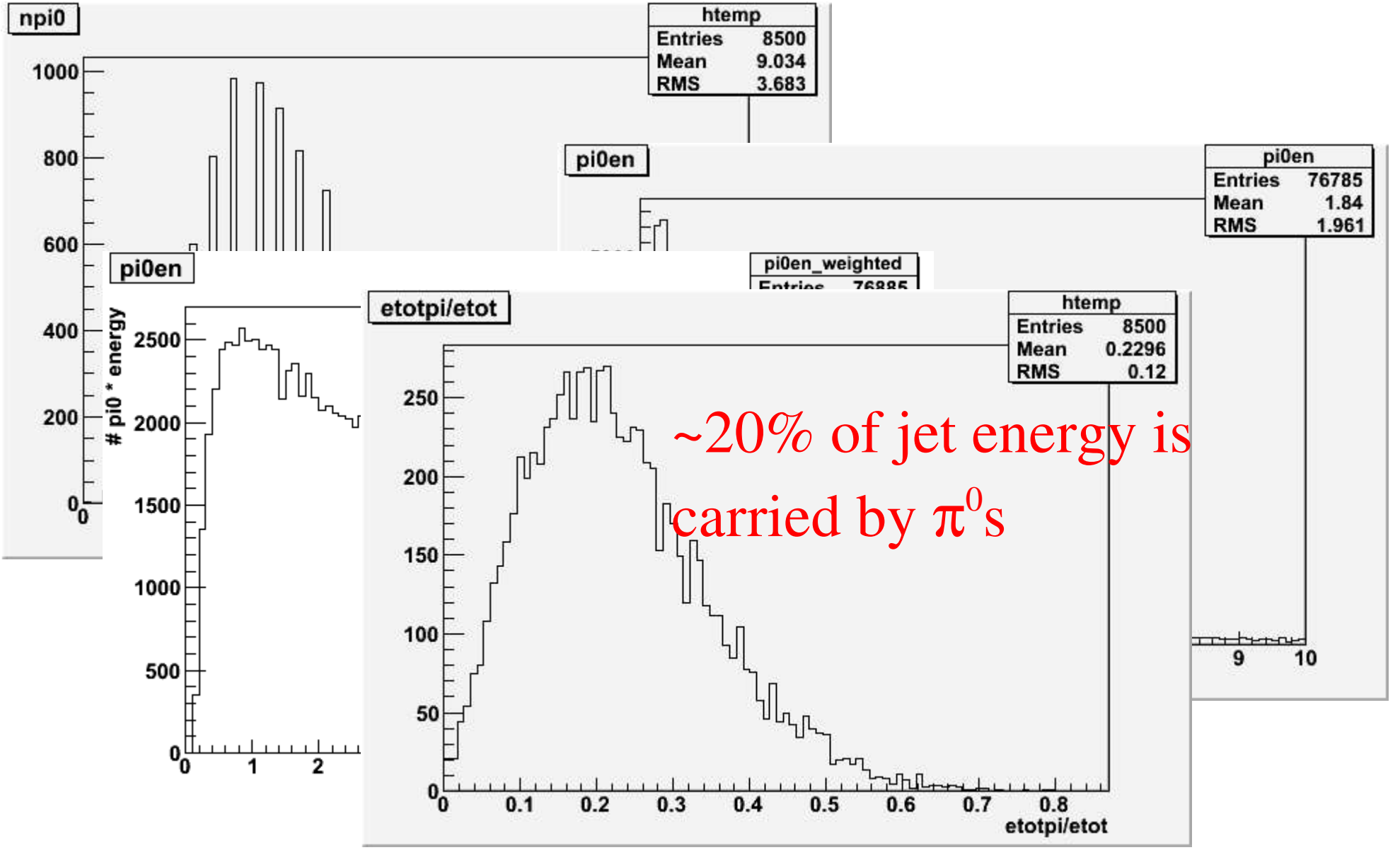
most π^0 have a low energy, average <2 GeV

how many π^0s, what energy?



most energy deposited by low energy π^0

how many π^0s, what energy?

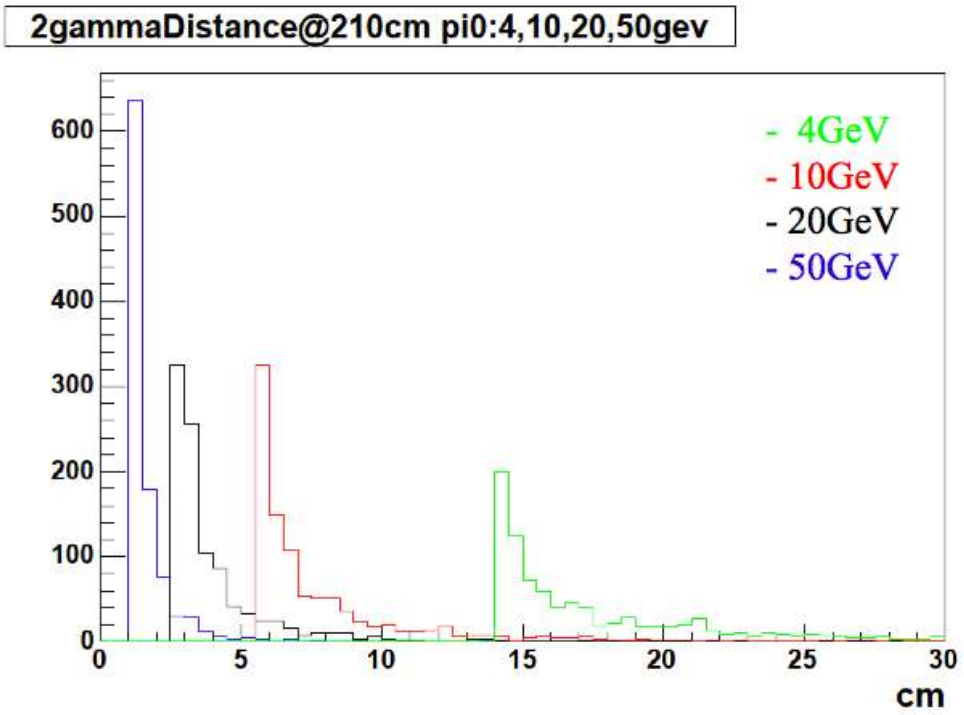


fraction of jet energy carried by π^0s

π^0s in jets

- low energy π^0s, carry significant fraction of jet energy
- low energies measured with low precision

measurement of π^0 energies
significant contribution to
energy resolution
if we can correctly identify
π^0 decays, can use kinematic
fit to improve overall jet
energy resolution



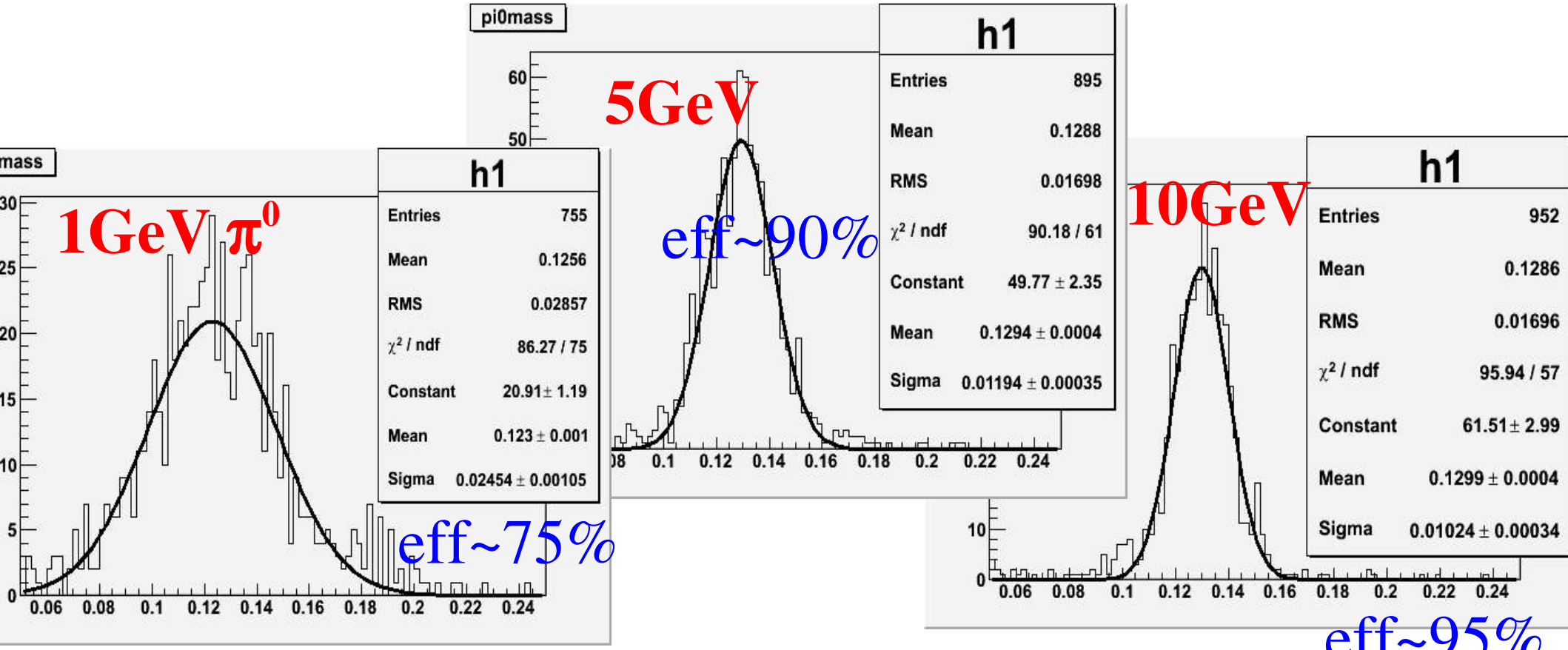
2 γ separation @ R = 210 cm

Nearest Neighbor clustering in cell calorimeter

- study design with 1x1cm scintillator tiles
- current clustering based on “nearest neighbors”
  - find groups of hit calorimeter cells which are each other's neighbors: small cluster
- combine nearby small clusters: EM clusters
- identify EM clusters as photons using likelihood based on shower shape, TOF...

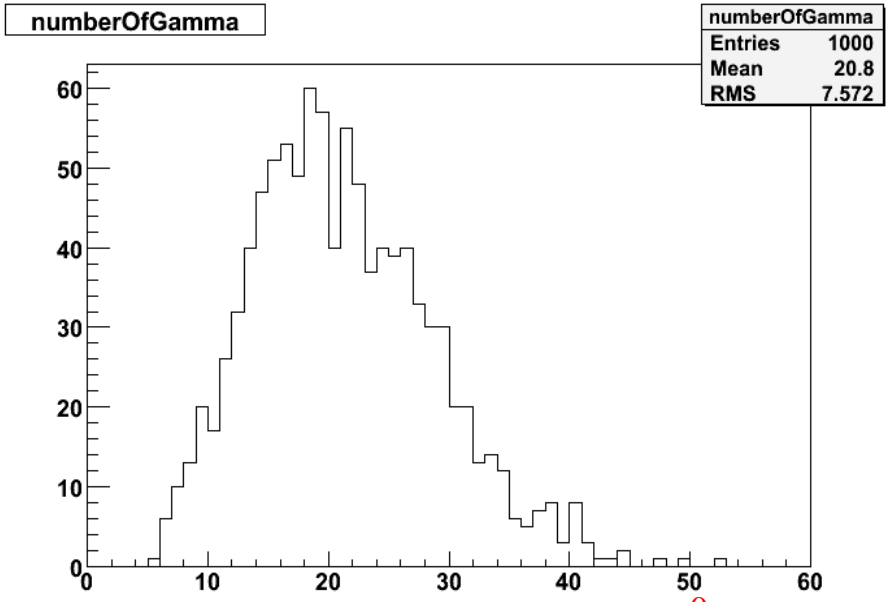
π^0 mass resolution

- in single π^0 events, find two most energetic identified photons
- plot invariant mass, extract mass resolution
- measure resolution as function of π^0 energy



photon-photon invariant mass

π^0 finding in Z^0 events, kinematic fit

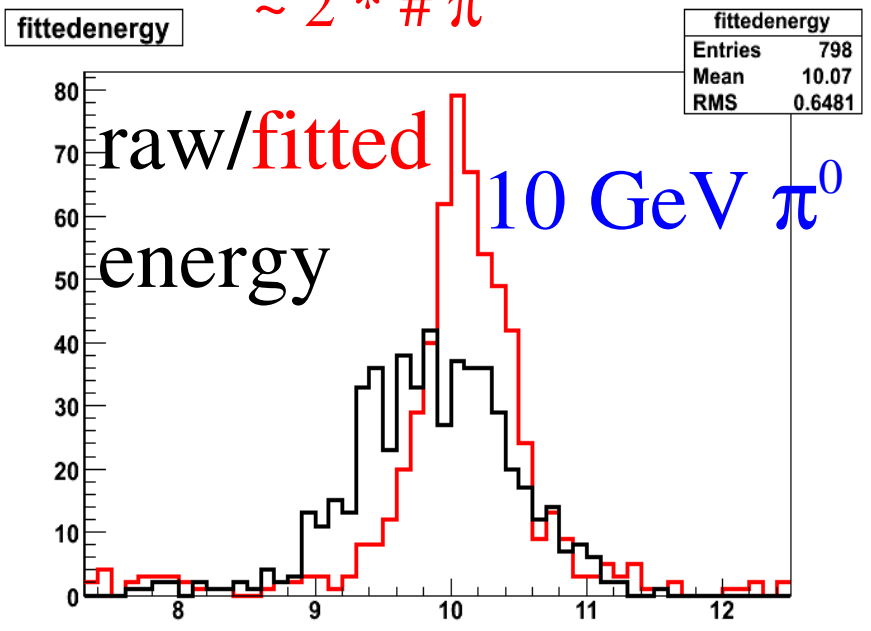


identified photons per Z^0 event

~ 2 * # π^0

1GeV π^0

raw/fitted energy

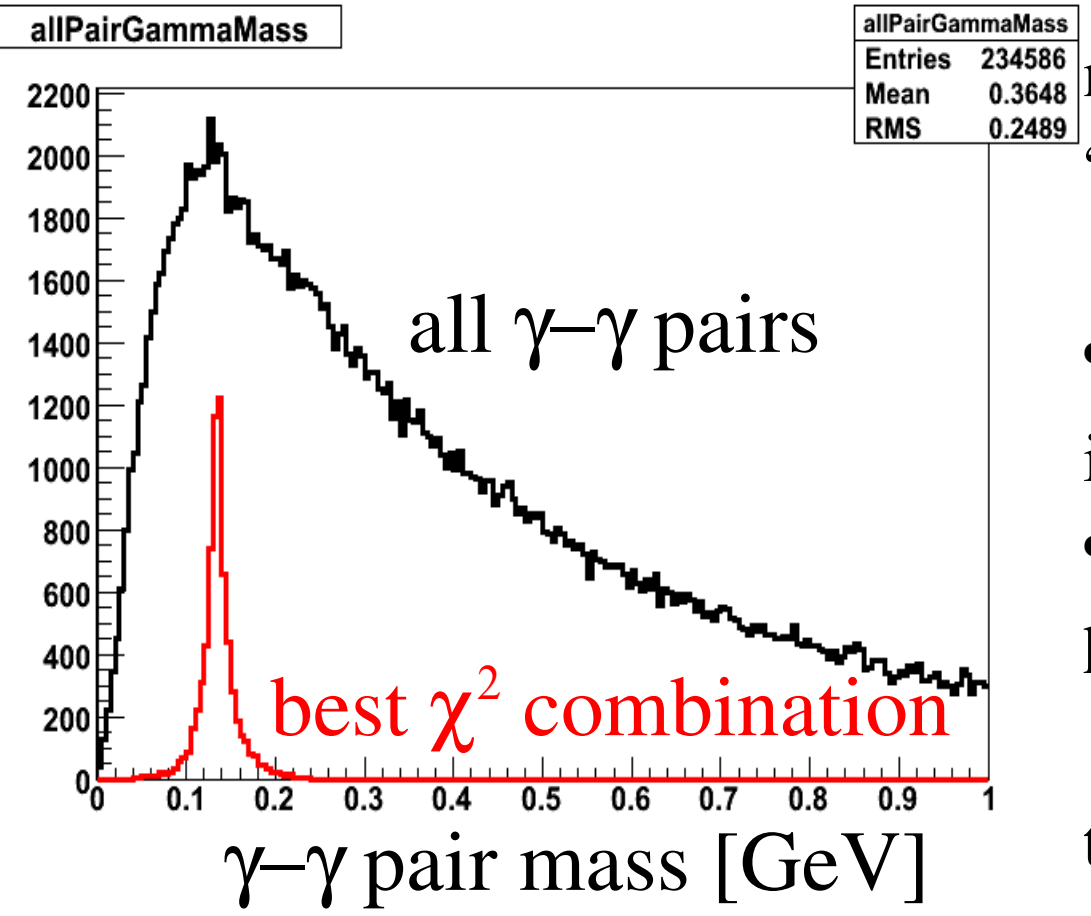


effect of kinematic fit in single π^0 events:

- vary photon energy
- impose $m_{\gamma\gamma} = m_{\pi 0}$

π^0 finding in Z^0 events

- identify pairs of photons from π^0:
  - order all pairs of photons in
    - $\chi^2 = (\text{mass}(\gamma\text{–}\gamma) - m_{\pi 0})^2 / \text{mass resolution}^2$
  - starting from lowest, assign partners until all used



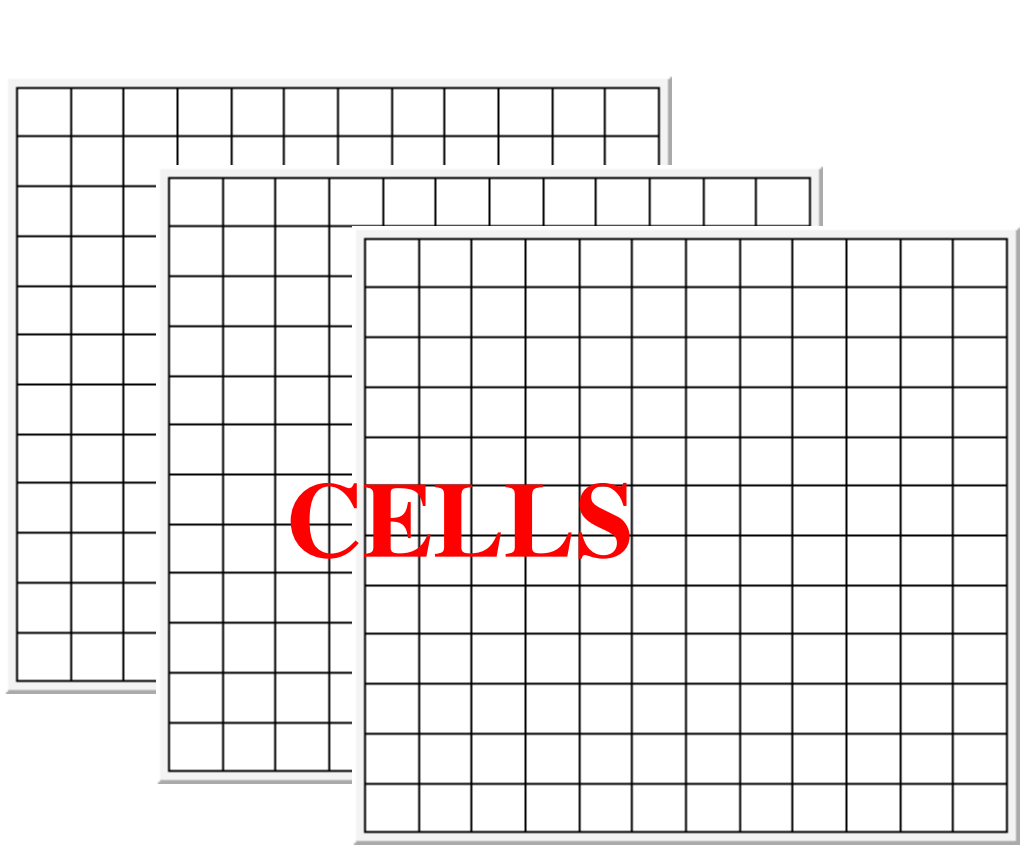
nice peak, maybe too many "accidental" photon pairs?

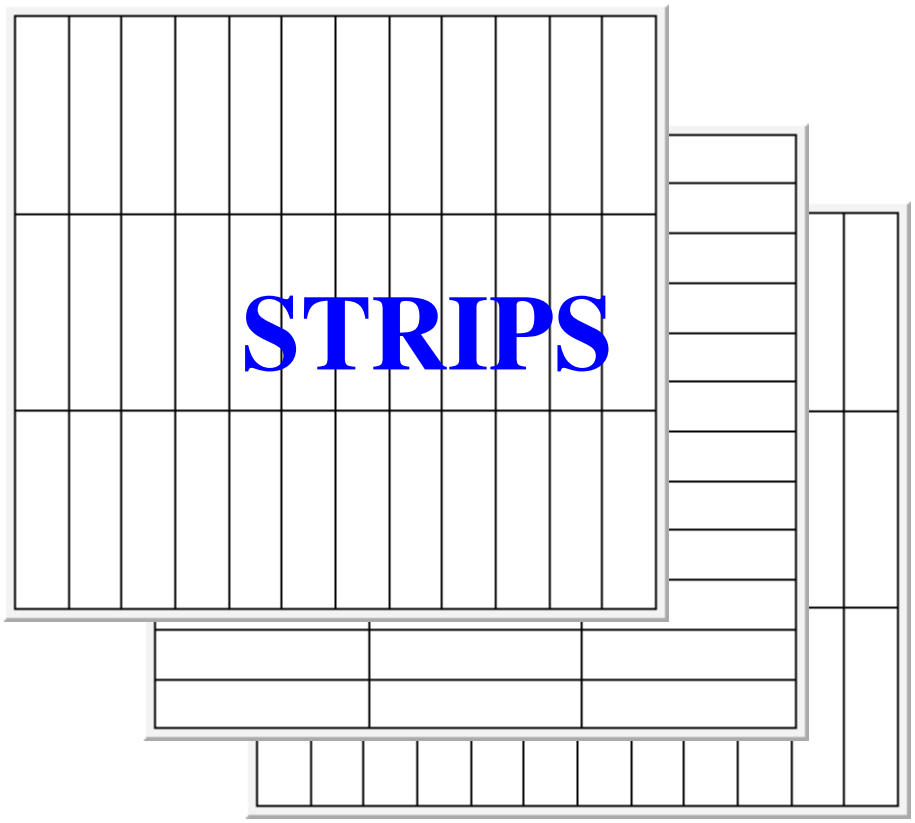
- for true π^0 events, kinematic fit will improve energy resolution
- for accidental pairs, kin. fit will harm

tighter photon selection may help?

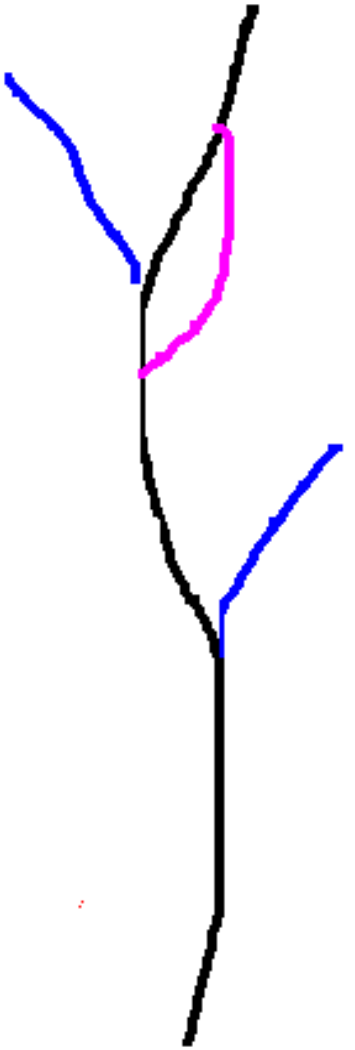
cells & strips

- baseline design has 1*1cm scintillator tiles
- can long strips (1*X cm), give similar performance?
- “stereo calorimeter”: alternating strip directions



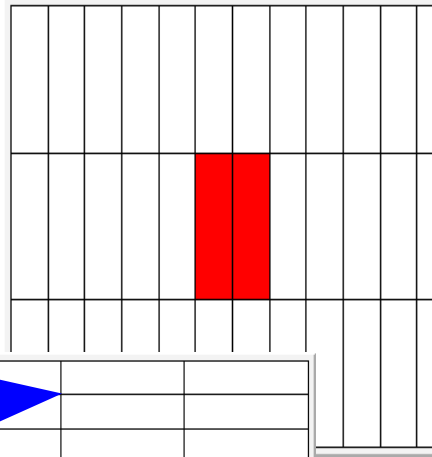


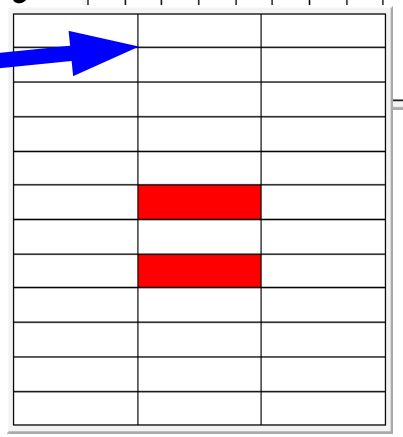
calorimeter “tracking”

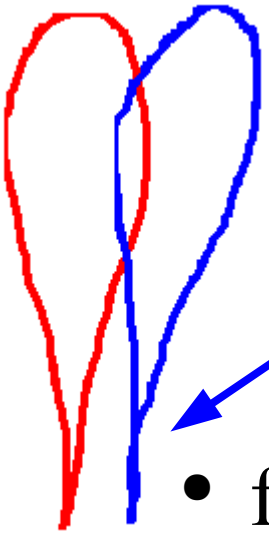


- recently started developing new algorithm
  - still rather preliminary
- “tracking” in calorimeter
- can see detail of shower development
- very large multiple scattering term (!)
  - can't fit to helix....
- study in single photon/π^0 events @ 1/10/50 GeV, various strip lengths

stereo strip calorimeter

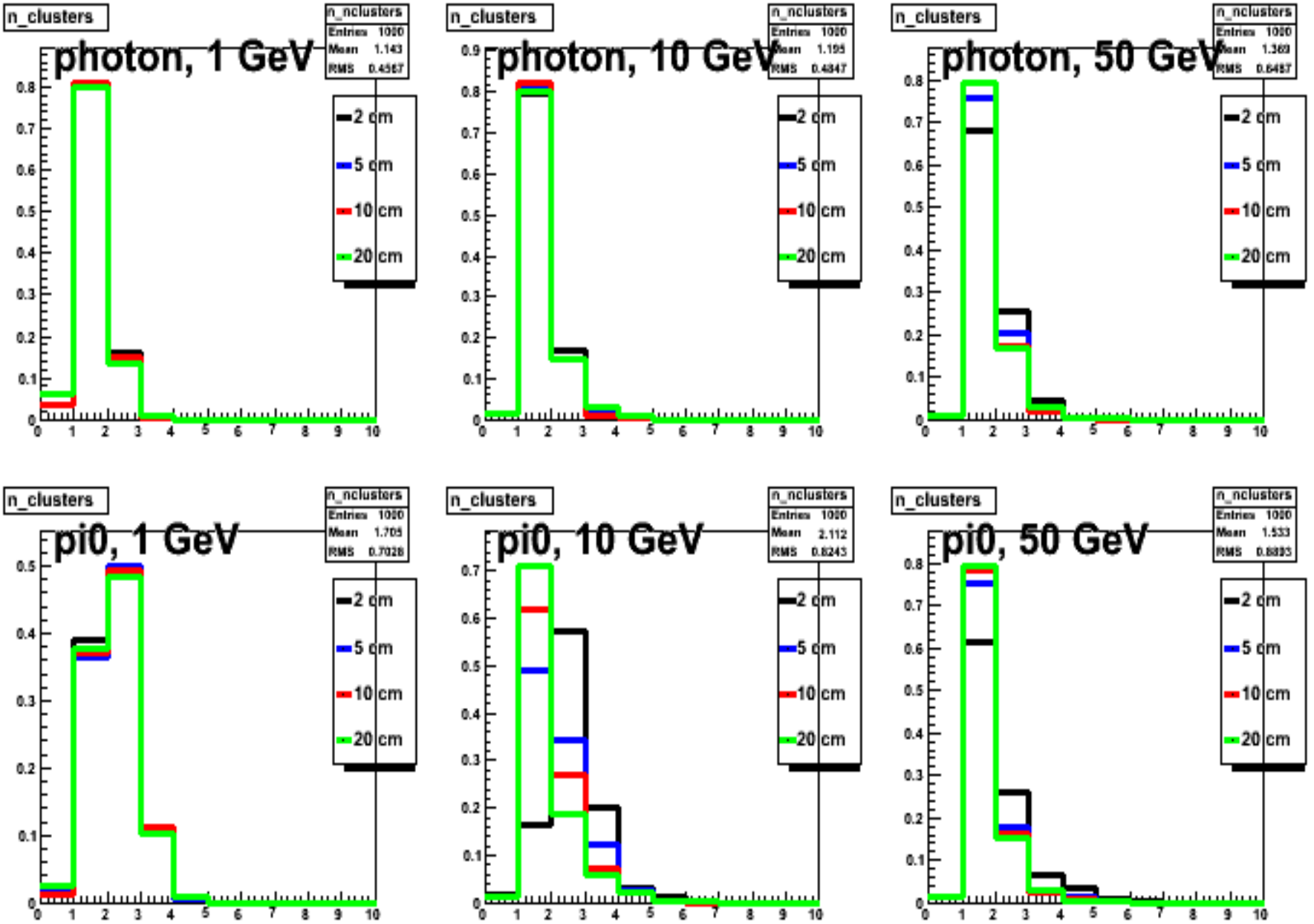






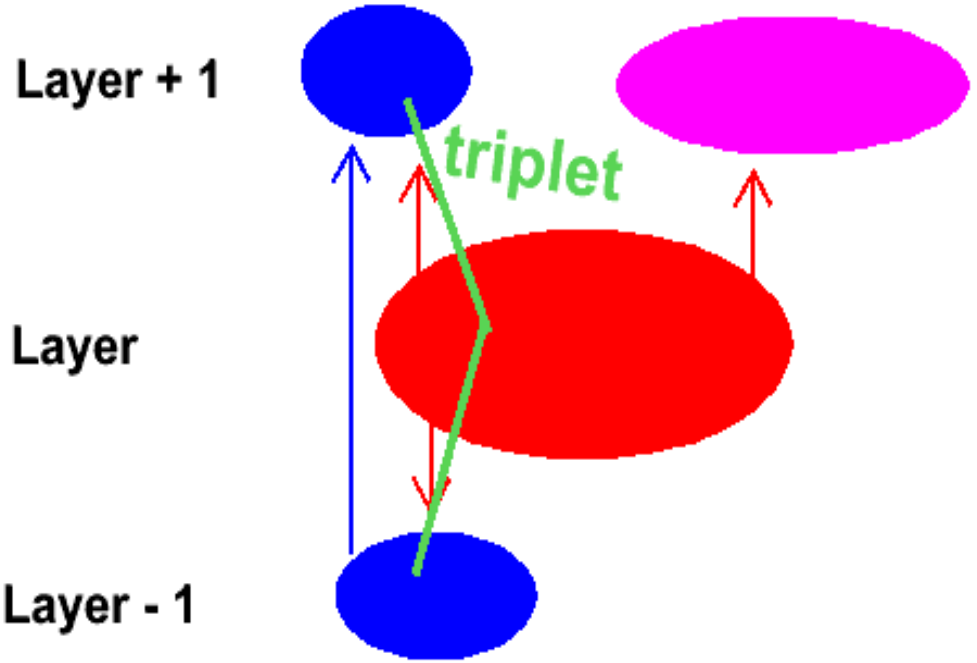
- sometimes nearby clusters resolved only
  - in layers of one polarity
  - early in the shower development
    - (also true for cell calorimeter)
- first make "large clusters" of hits using simple Nearest Neighbor (NearN) algorithm
- then cluster hits in each layer separately (NearN)
  - gives a number of clusters in each layer
  - "single-layer clusters"

"large clusters": single photon/π^0 events



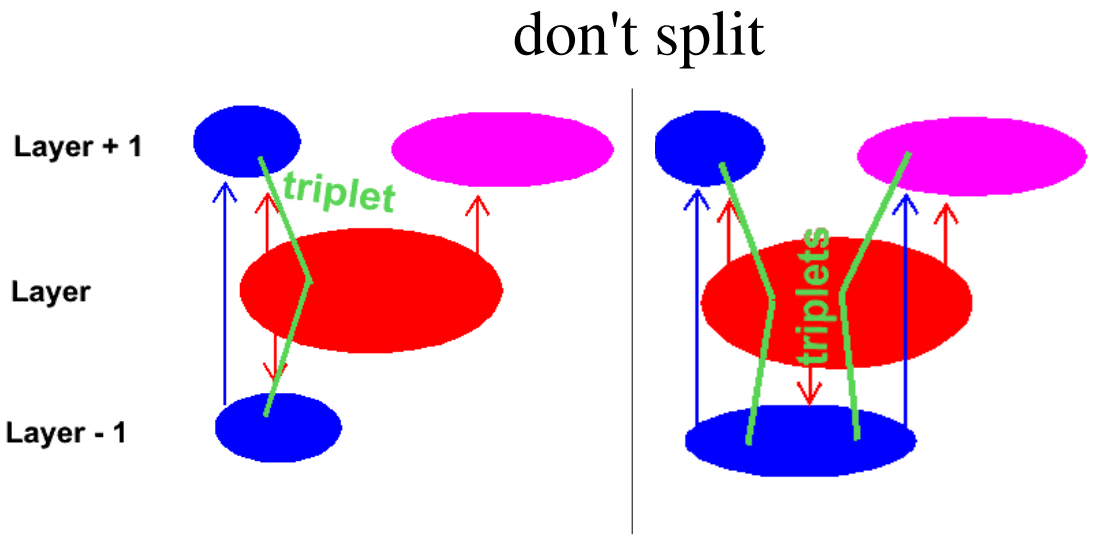
cluster “triplets”

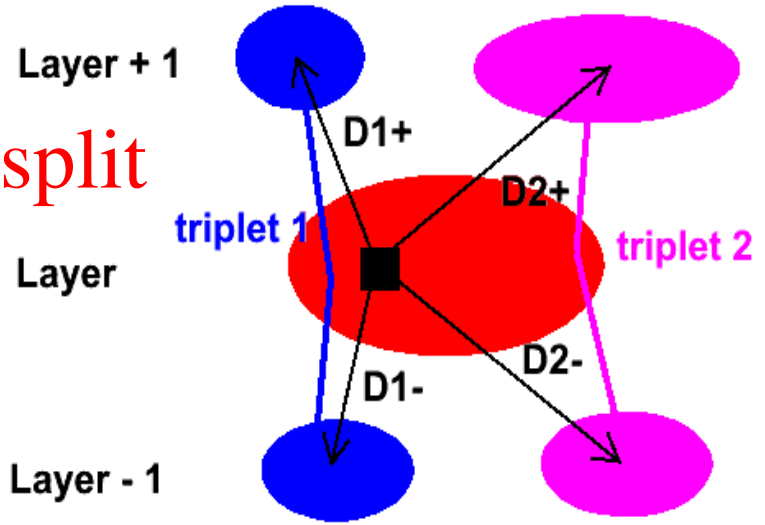
- cluster in layer “X”
- neighboring clusters in layers (X ± 1)
- if clusters in X+1 and X-1 are also neighbors, a “triplet”



cluster splitting

- clusters may be resolved in only one polarity in strip calorimeter
- split clusters which are the central member of two otherwise different triplets
- split cell-by-cell, according to distance to adjacent layer clusters

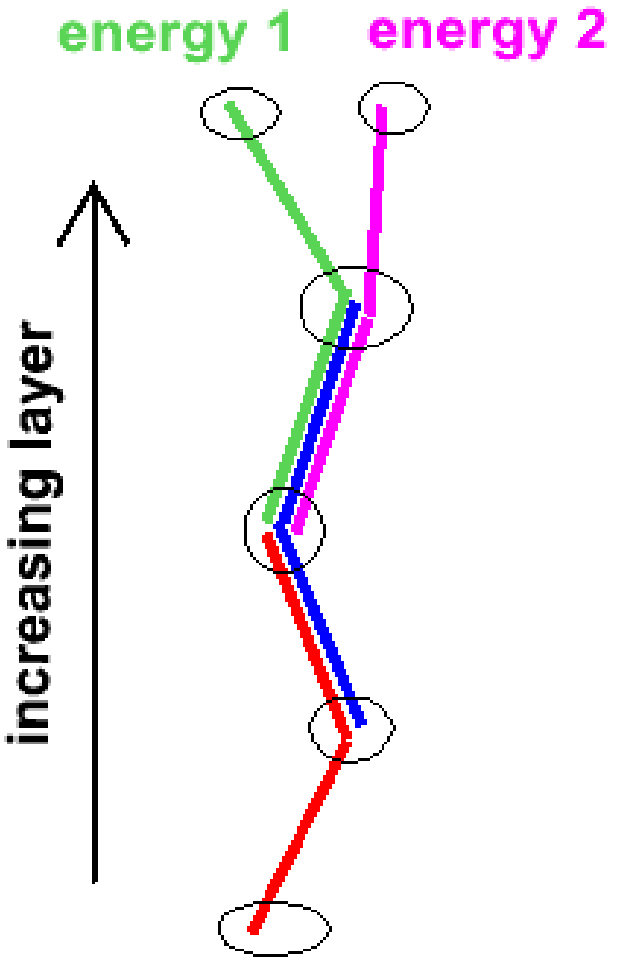




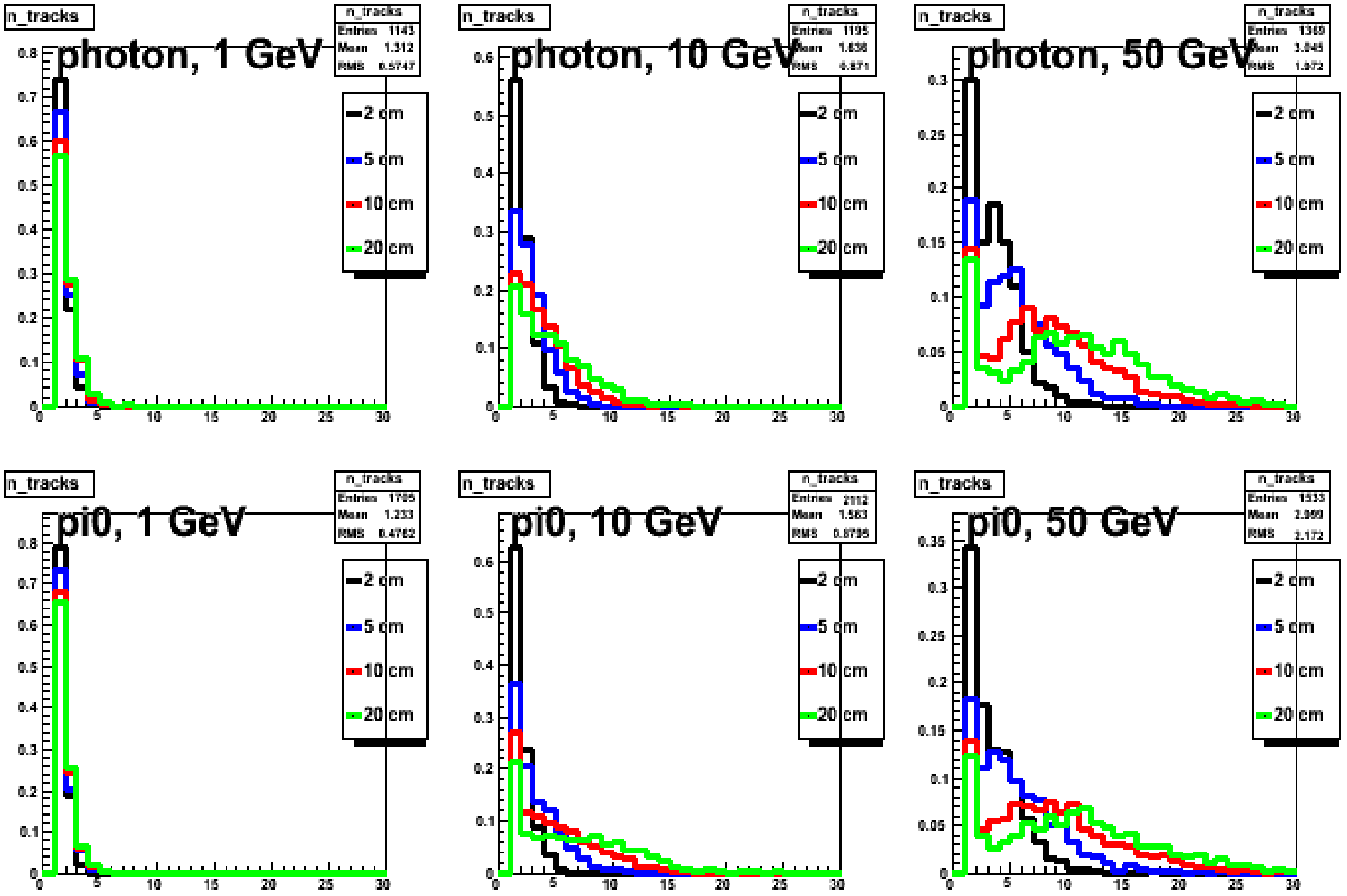
(D1+) + (D1-) < (D2+) + (D2-)

tracking

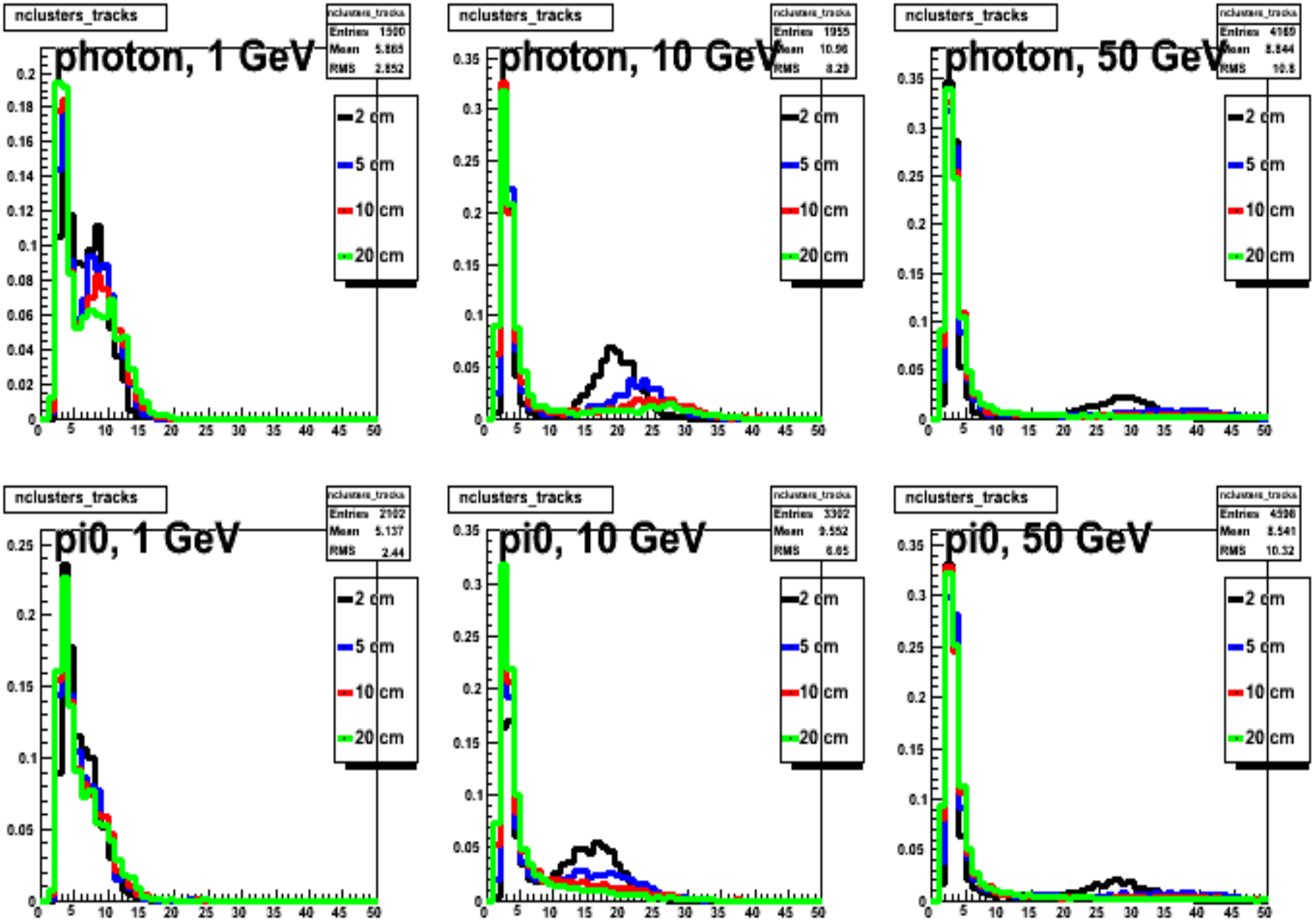
- track by combining triplets
- start from inner layer, look for overlapping triplets
- if more than one candidate, take highest energy
- when track finished, start again from innermost unused triplet



tracks found per “large cluster”

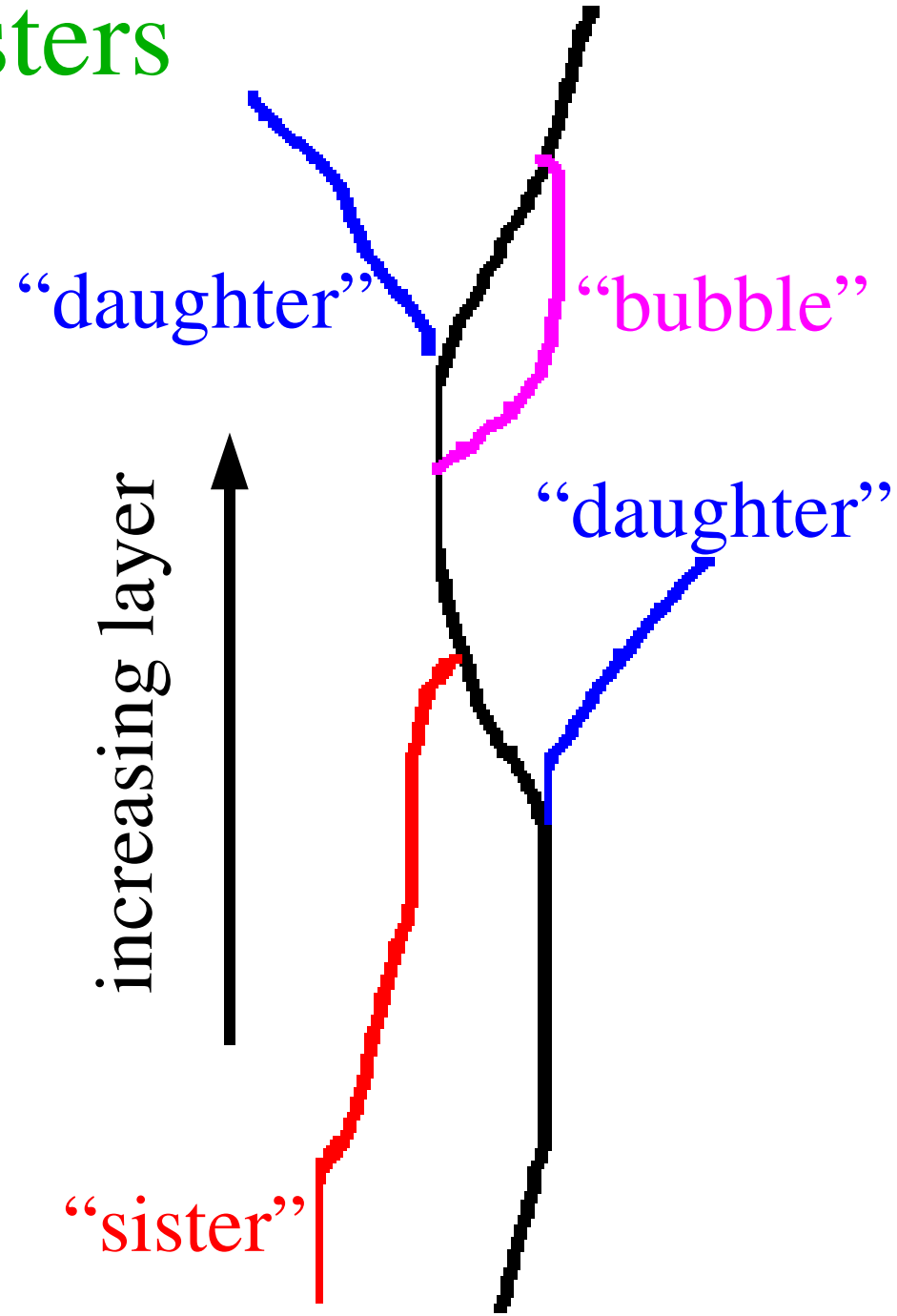


“single-layer clusters” per track



mothers, daughters, sisters

- sometimes tracks meet
  - "daughter" splits off from "mother"
  - "sister" tracks start separate, then merge
  - "bubble" track starts and ends on same "mother"
    - collapse "bubble" onto mother



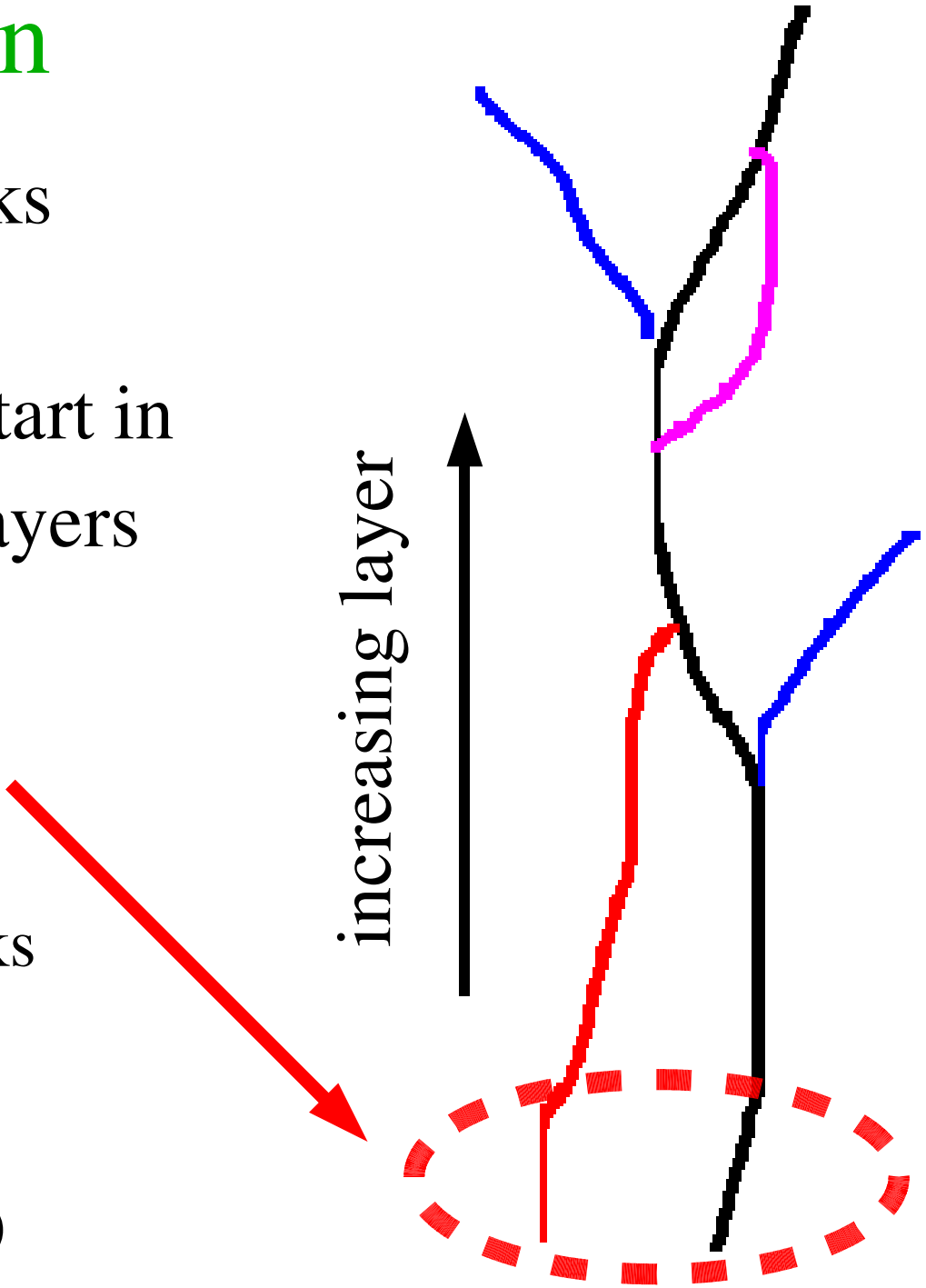
π^0 identification

look at "motherless" tracks

particularly those which start in first few (4) calorimeter layers

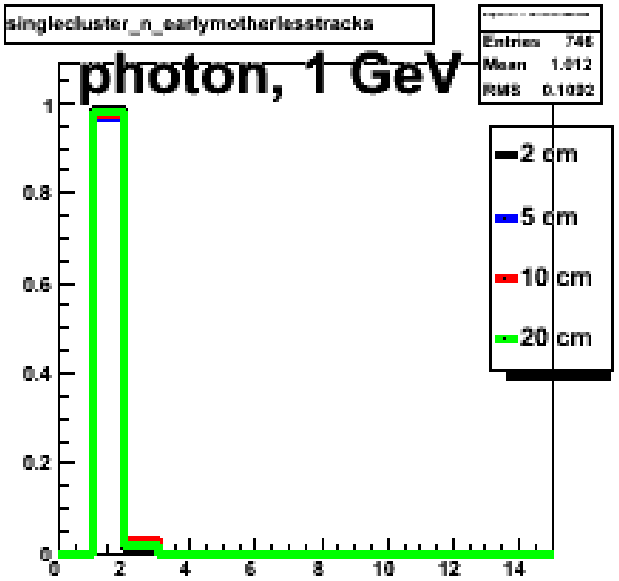
"early motherless tracks"

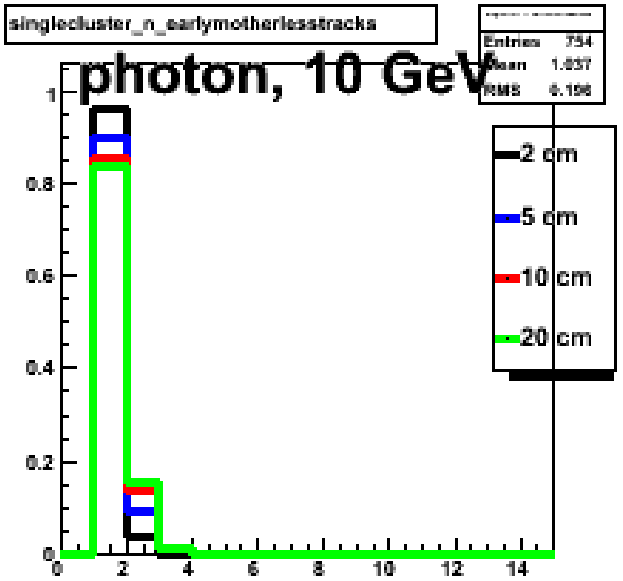
starting position of these tracks should give better measure of position for track matching (now we use centre of cluster)

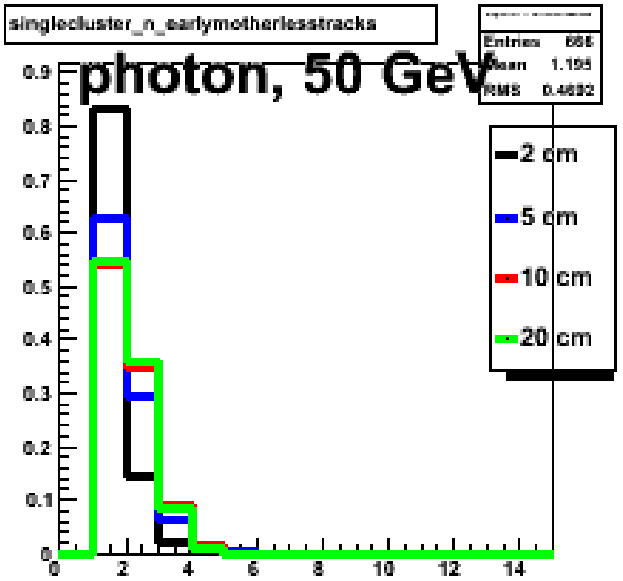


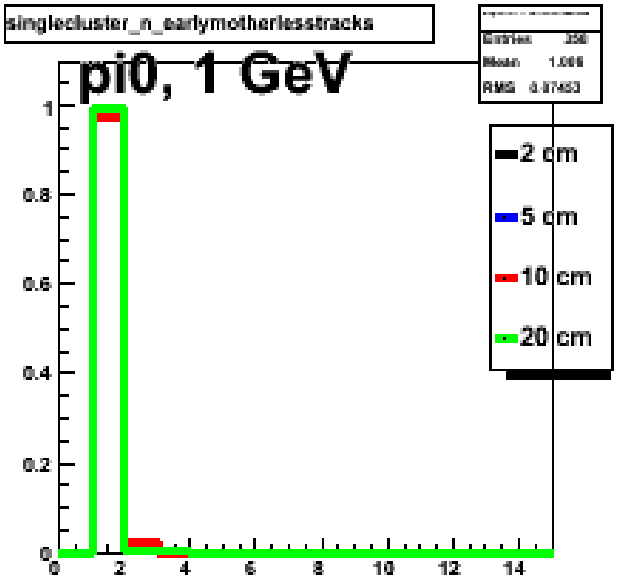
events with single “large cluster”

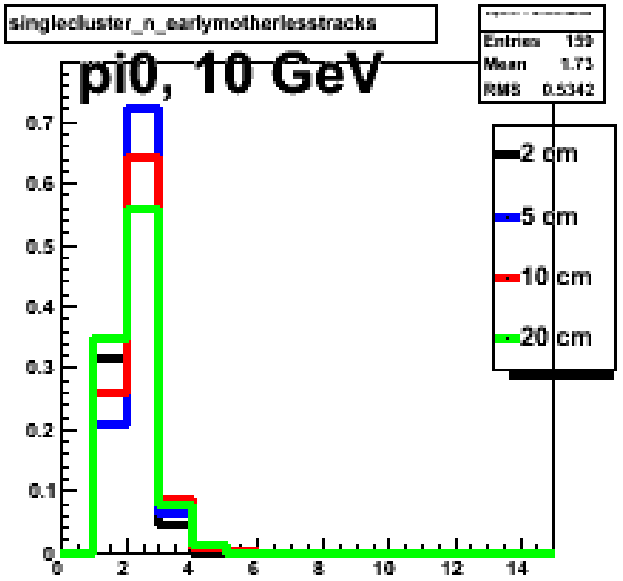
early motherless tracks

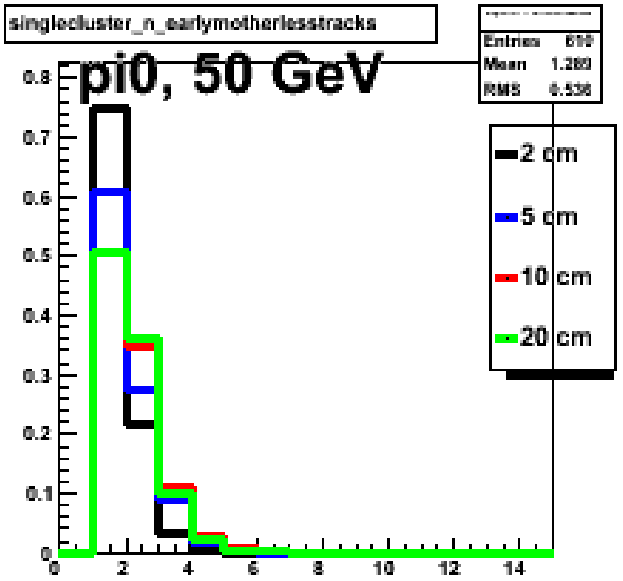




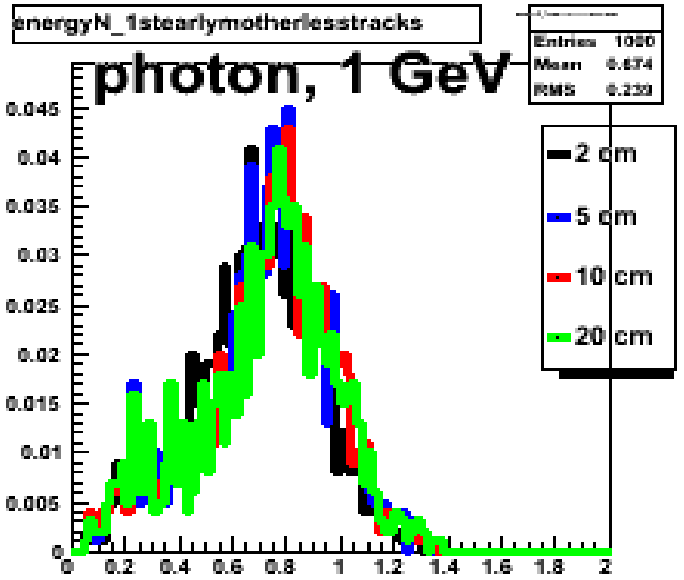


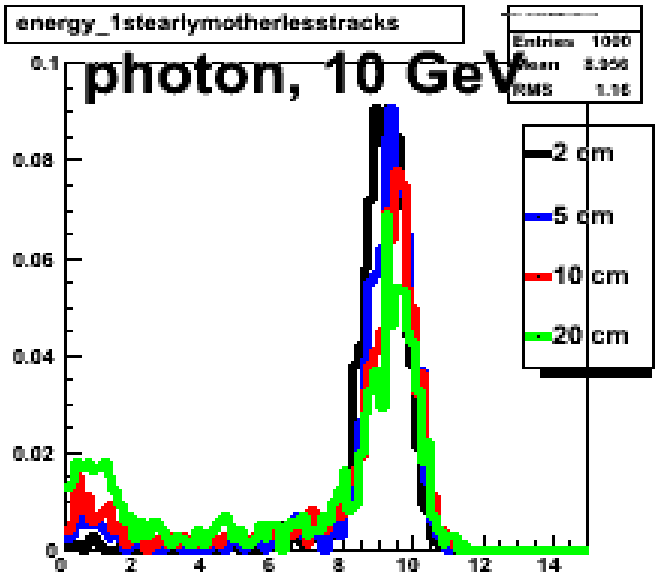


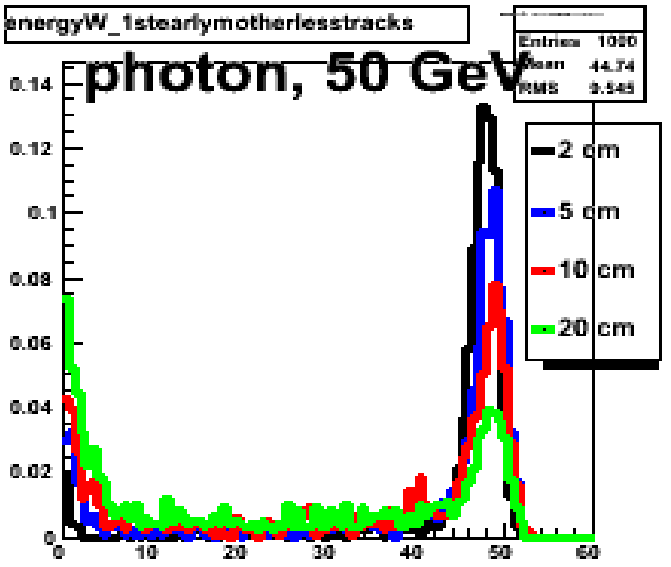


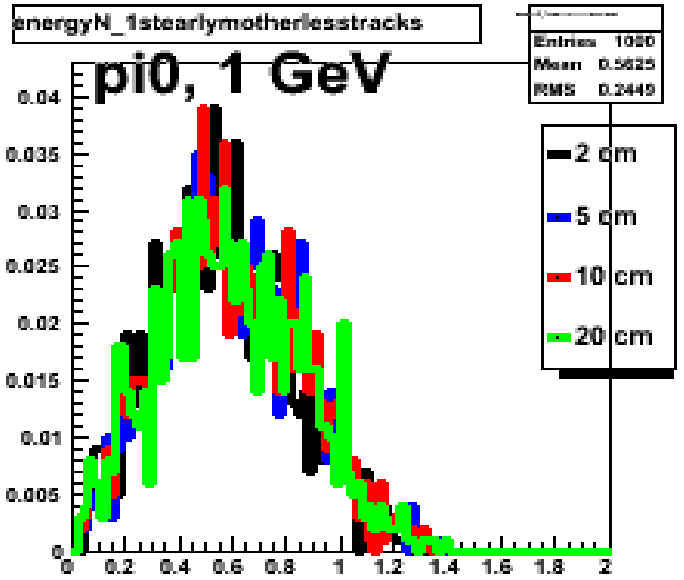


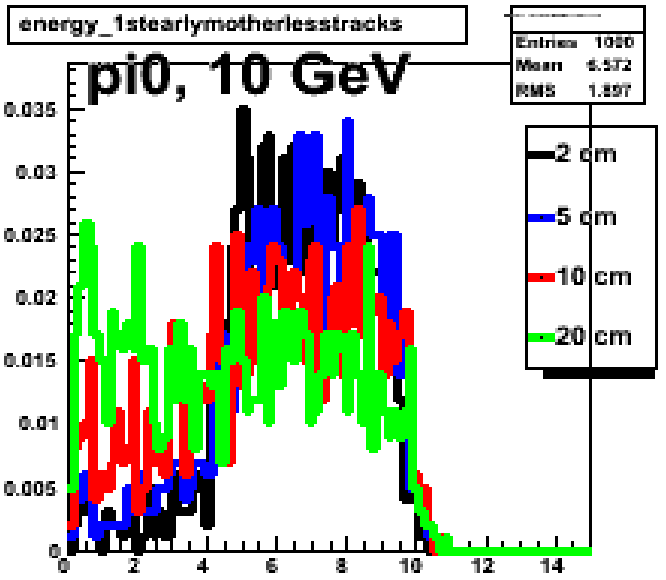
energy of leading "early motherless" track

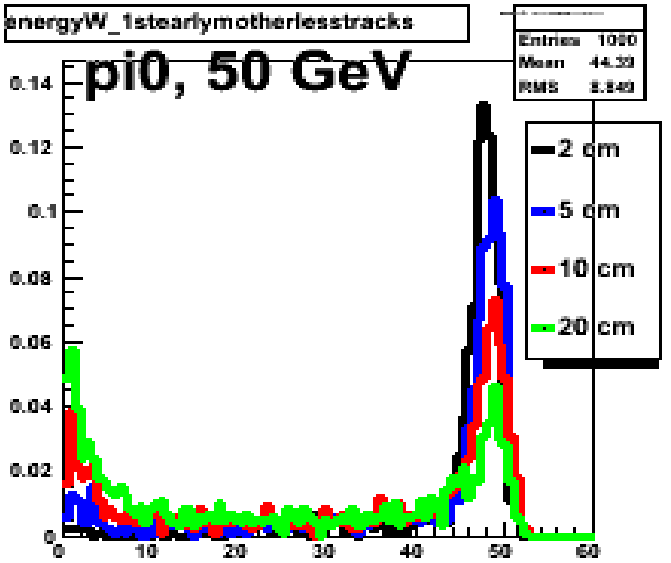












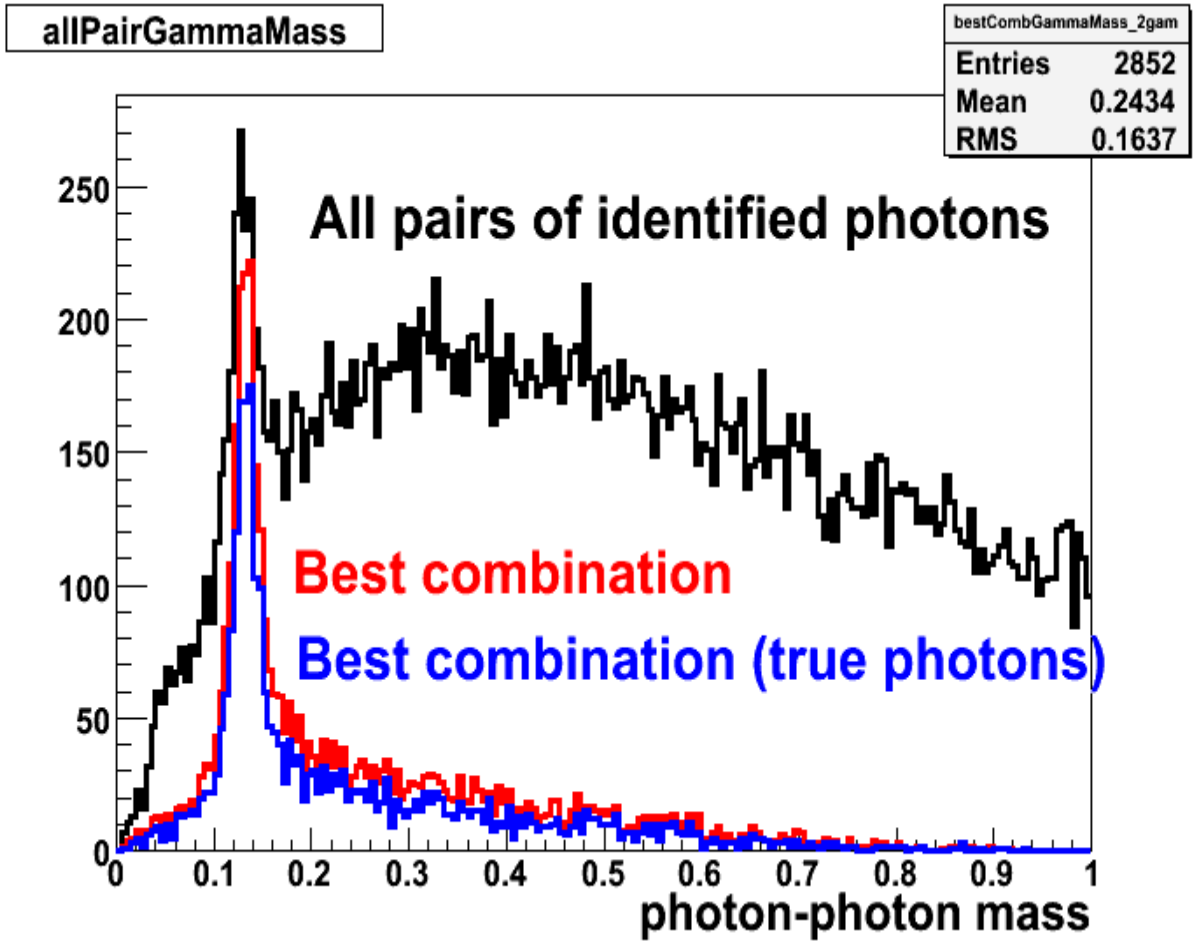
good gamma-π^0 discrimination seems possible up to 10 GeV

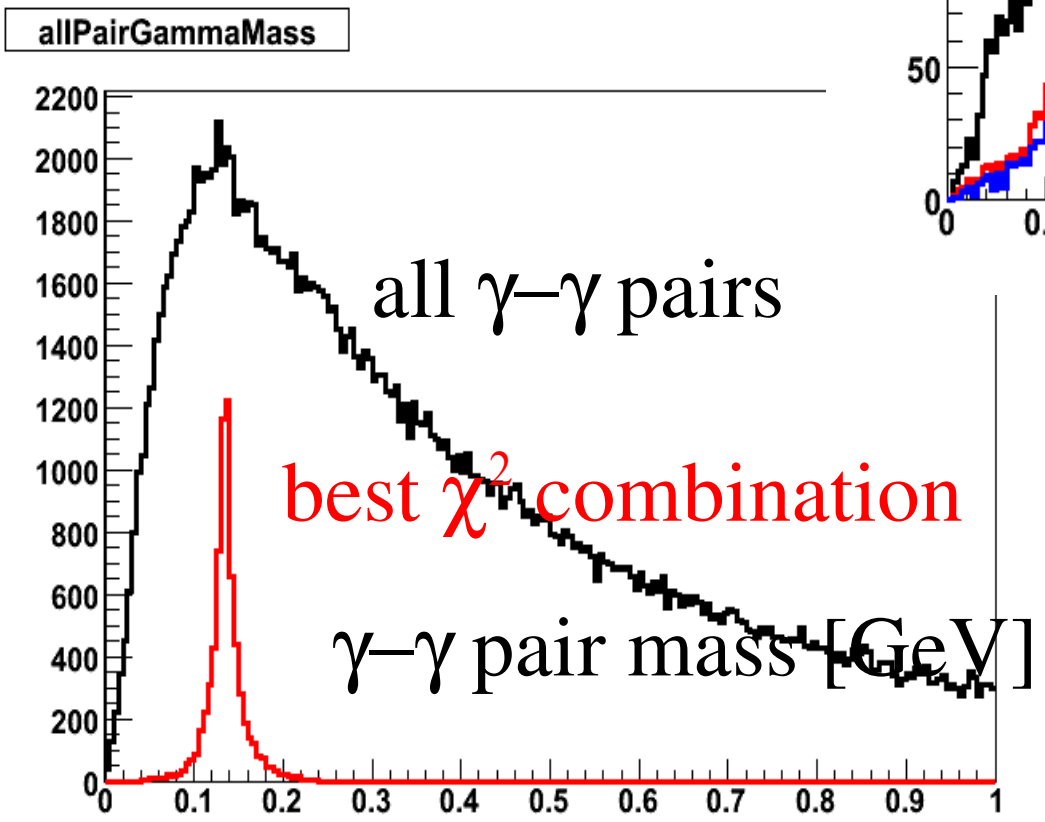
summary, plans

- can find π^0 in jets
  - studying optimal photon efficiency/purity point
- possible to resolve 10 GeV π^0 with O(10)cm strips
- resolving photons from 50 GeV π^0 decay beyond capabilities of 1cm width - also true for 1x1cm cells
  - probably not critical for jet energy resolution: energy quite well measured by calorimeter, so kin. fit will not help much
- maybe shower shape will help distinguish high energy gamma and π^0 showers...

backups

tight photon selection

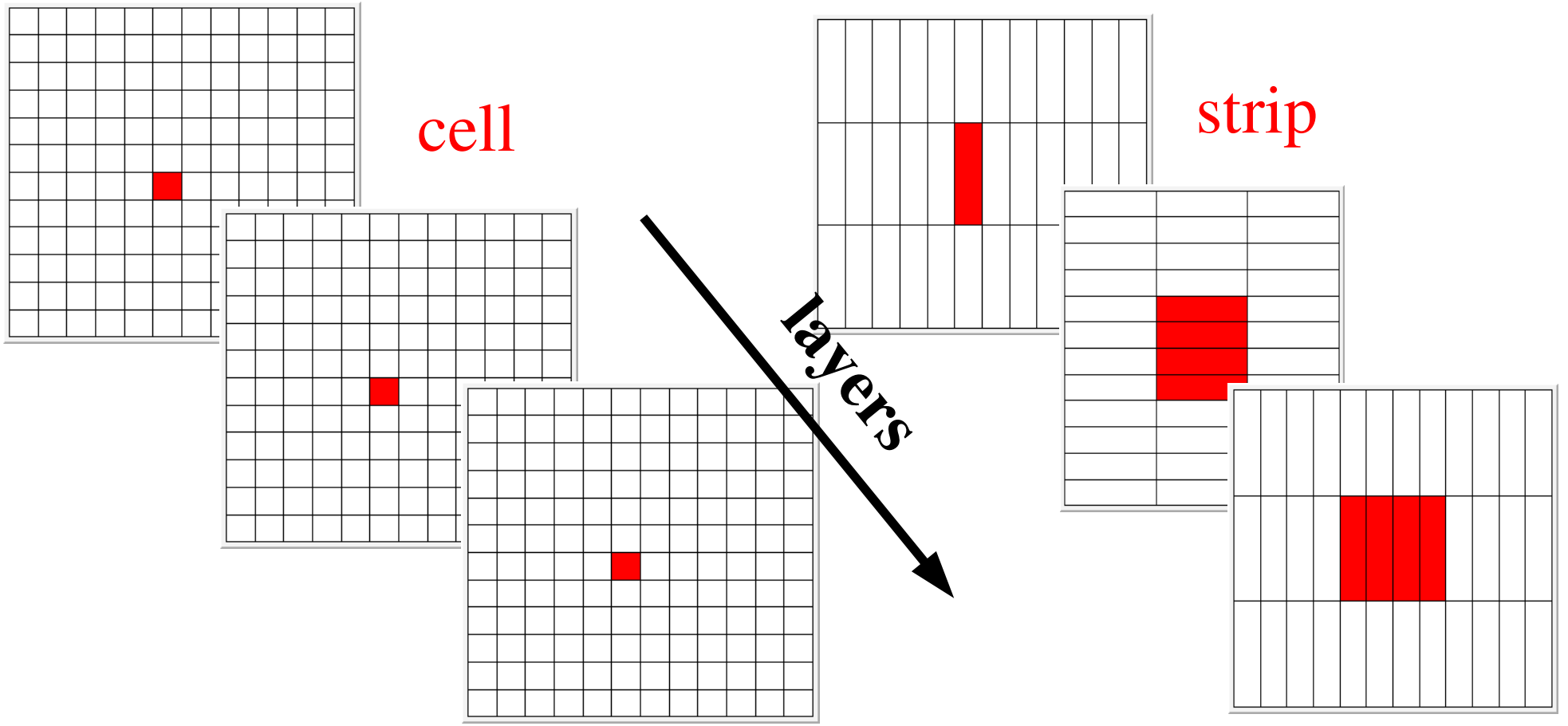




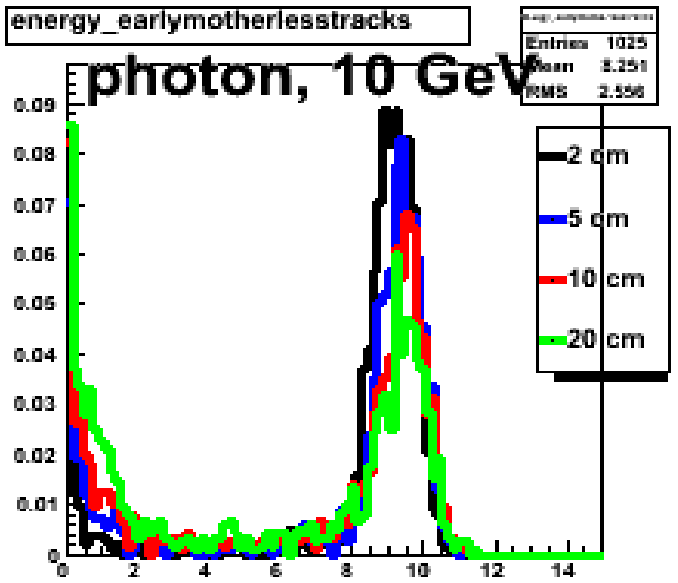
loose photon selection

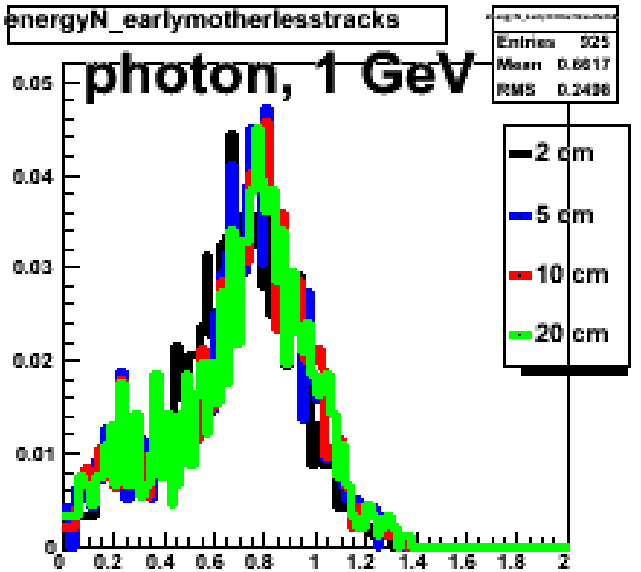
nearest neighbor in strip

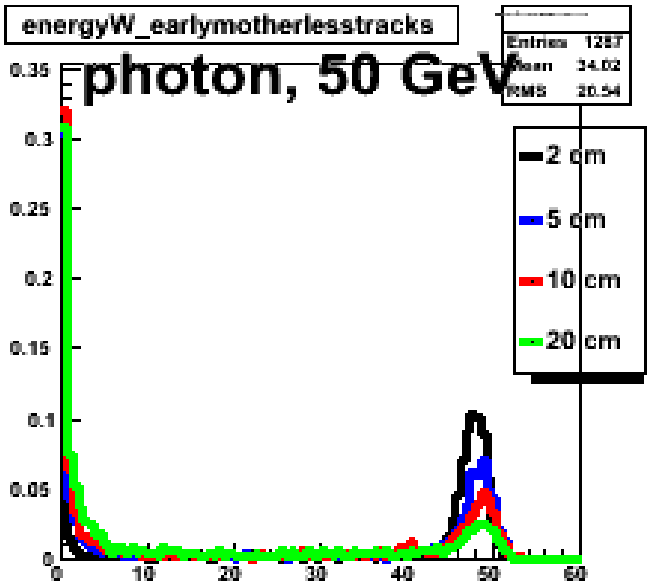
- groups of hit cells which are each other's neighbors
- for long strips, # of nearest neighbors large due to different layer polarisations: lose resolution

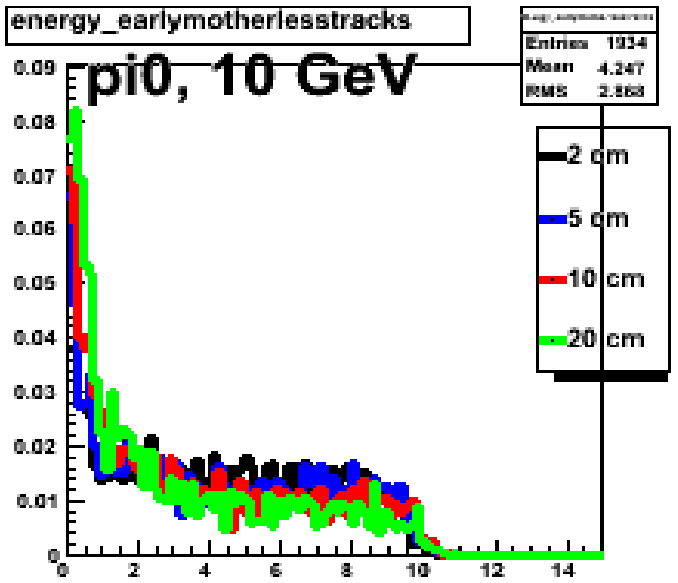


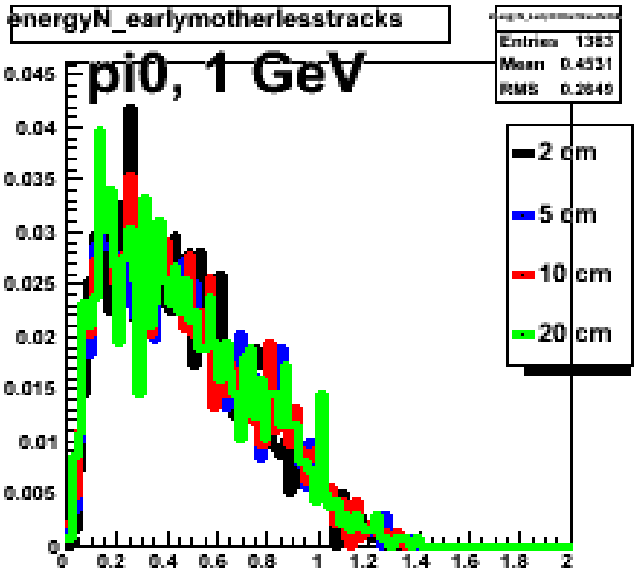
energy of “early motherless” tracks

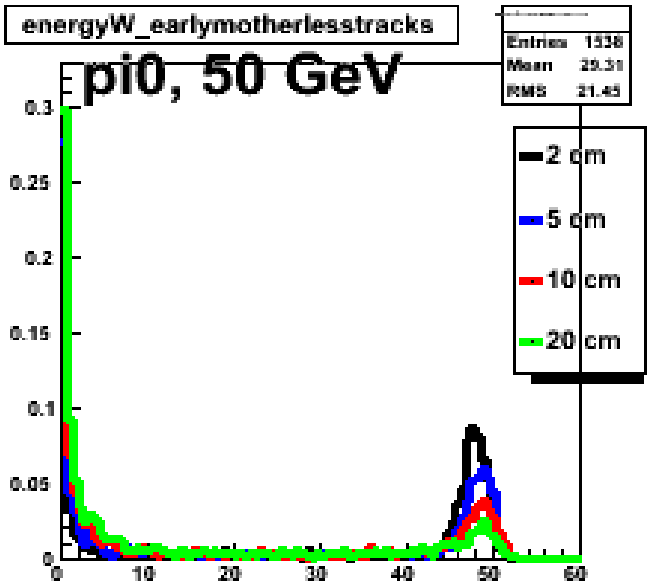












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