GAmma Reconstruction at a LInear Collider

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Role of photon reconstruction in Particle Flow

Description of GARLIC algorithm

Performance in jet events

Role of ECAL and photon reconstruction in Particle Flow

Particle Flow (PF) relies on (ideally) topologically distinguishing
- individual particle calorimeter deposits in hadronic jets
- allows use of tracker measurements to estimate charged energy
- Main limitation: confusion between charged and neutral energy deposits
  - "confusion term"
- Single particle energy resolution not dominant

Role of ECAL:
- **clean identification of photon energy deposits**
  - **measure this photon energy reasonably well**

- Identify energy deposits due to charged and neutral hadrons
  - (in tandem with HCAL)

- Becomes more difficult in higher energy, more boosted jets
  - Smaller distance between jet particles

Studied in ILD Si-W ECAL
- Sampling ECAL,
  - Tungsten absorber, silicon PIN diode readout

GARLIC
Gamma Reconstruction at a Linear Collider

Photon identification in hadronic jets
in a highly segmented calorimeter

Algorithm

Track veto
Remove hits close to extrapolated tracks

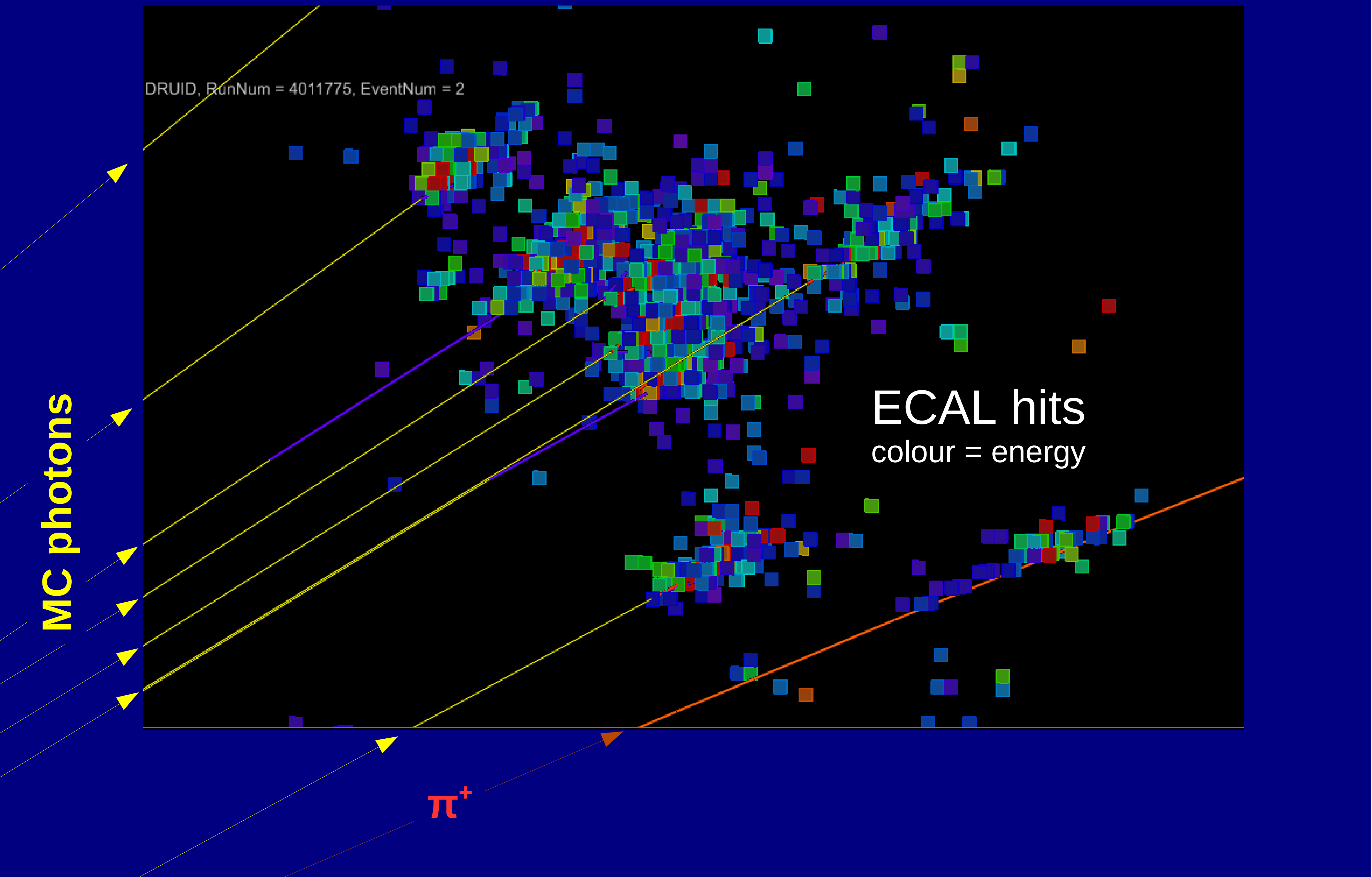
Seed finding
Identify cluster seeds in first part of ECAL

Core building
Build dense core of EM shower

Final clustering
Add nearby hits: “halo” around the core

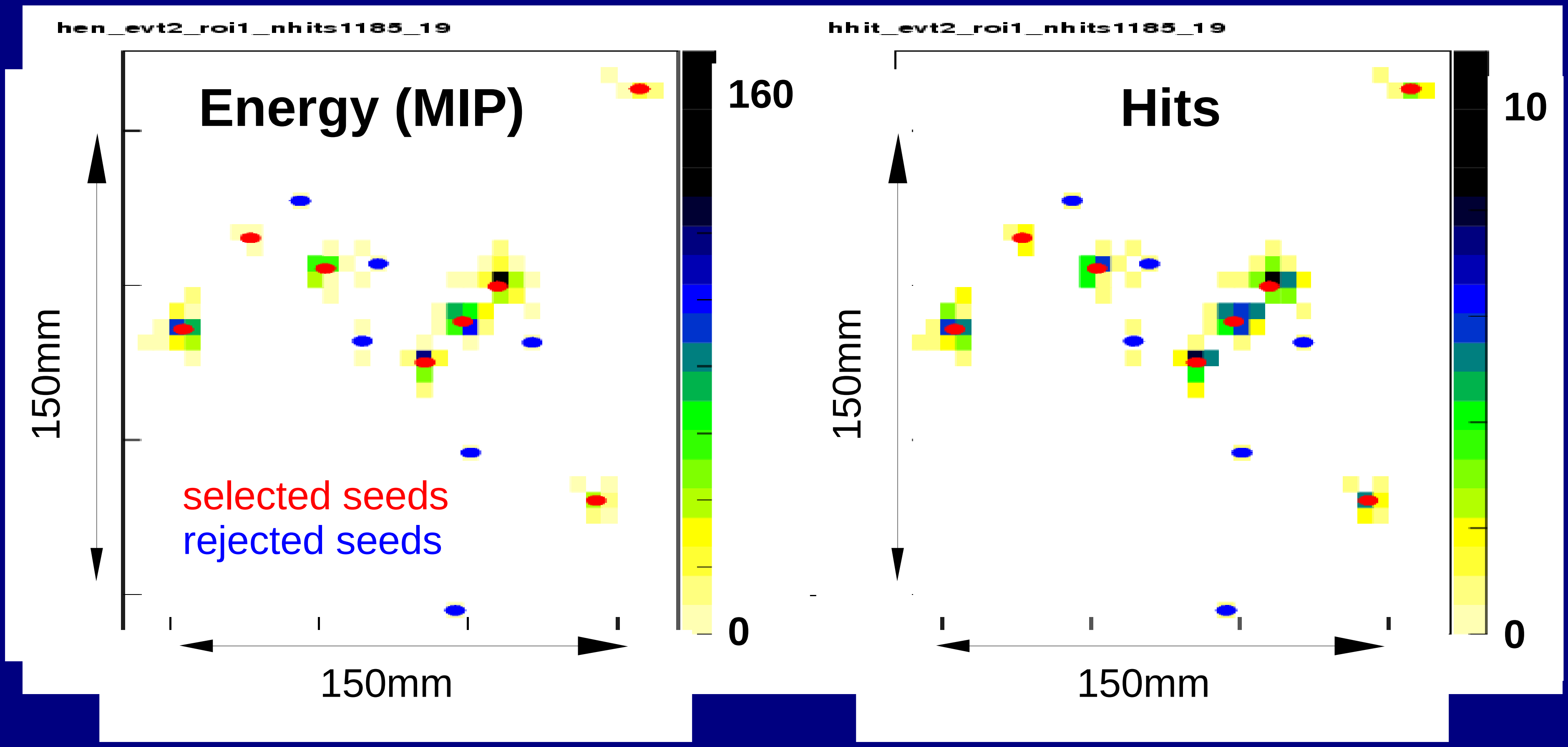
Neural Network identification
Decide if cluster is photon-like

Dense portion of 250 GeV jet in ILD SiW ECAL

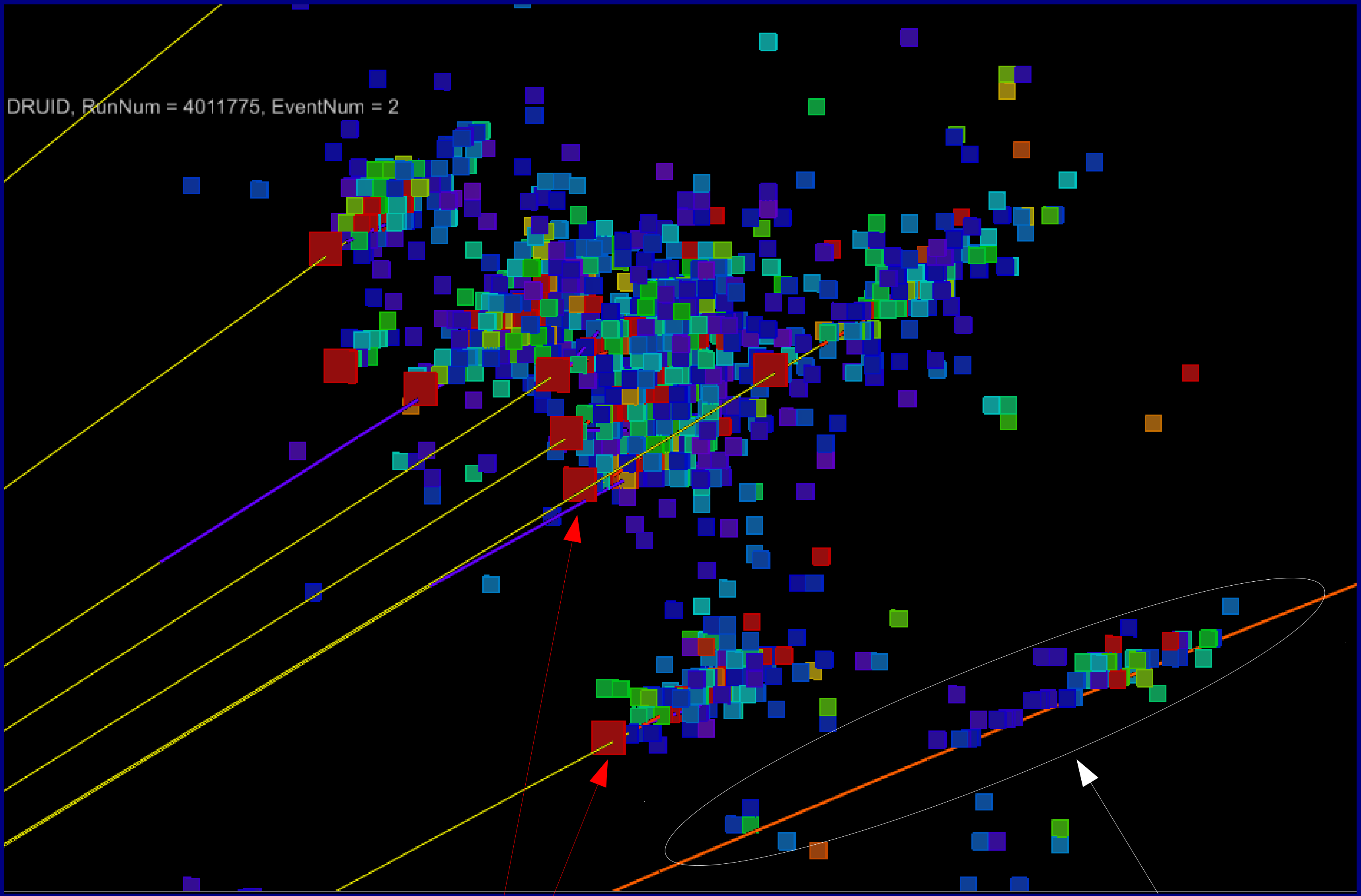


Project hits from first 10 X_0 onto ECAL front face

simple nearest neighbour clustering
cluster seed candidates
requirements on energy and number of hits

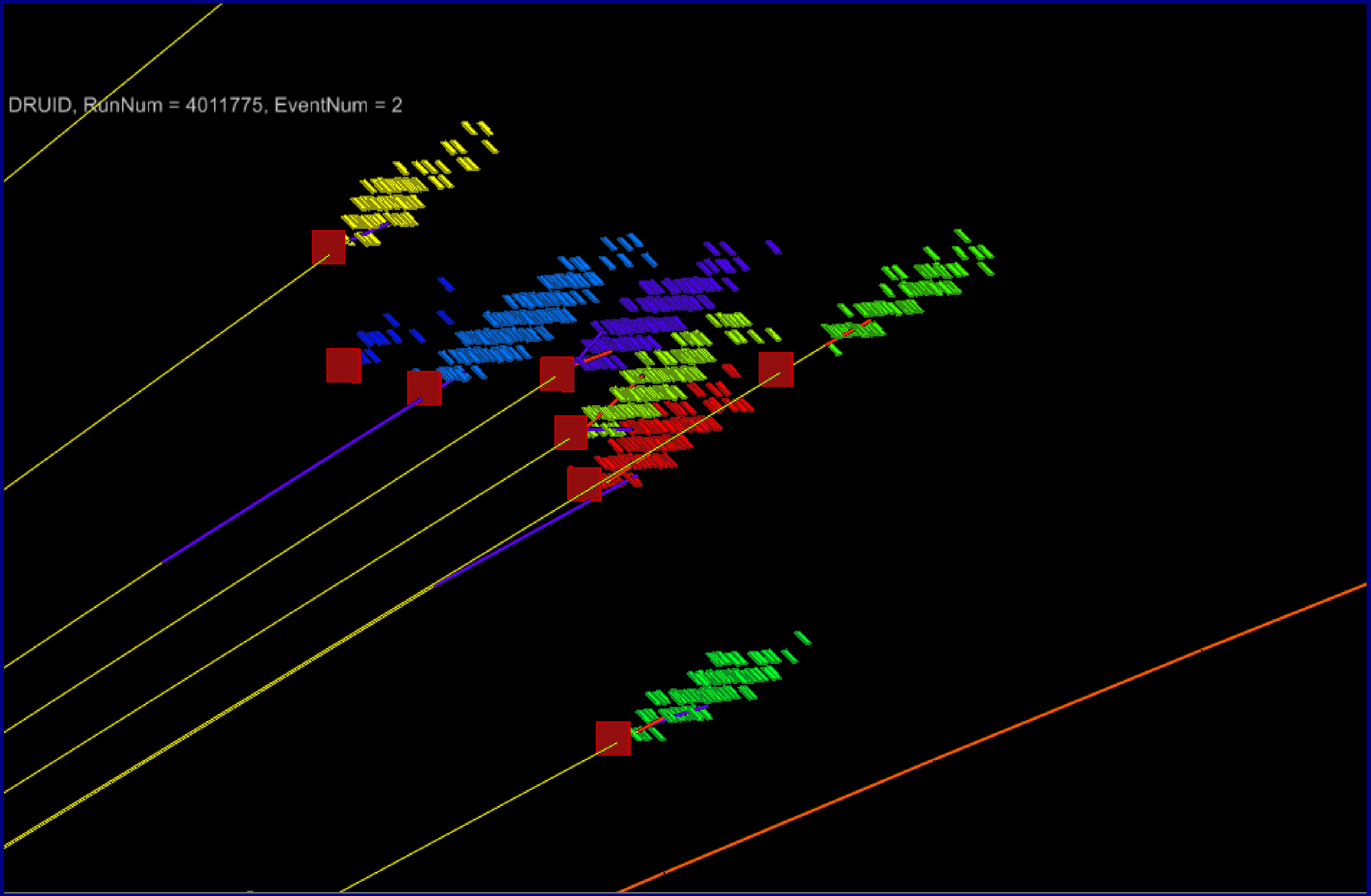


Track veto, seed finding



Core building : radius ~ cell size

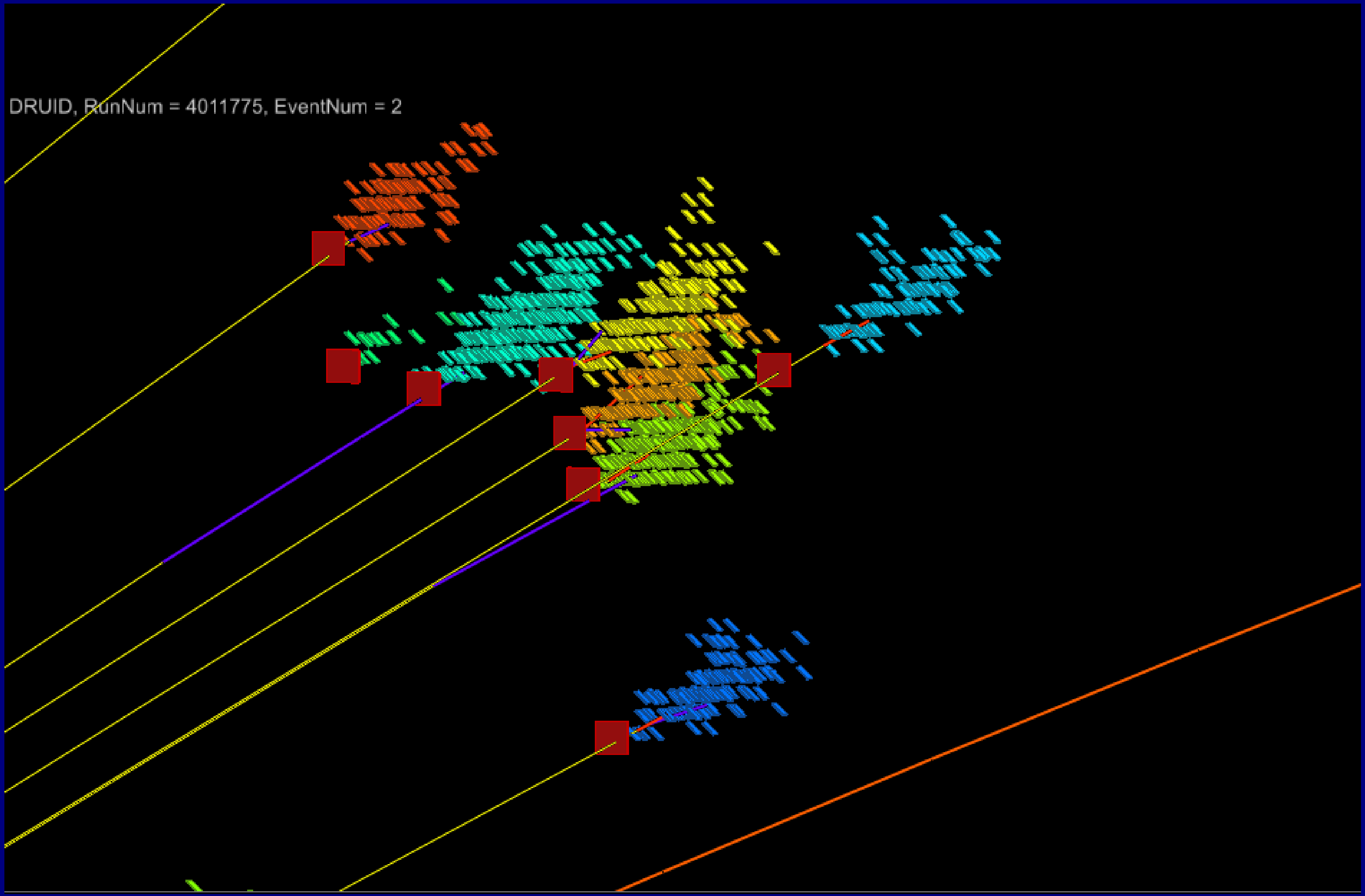
project seed positions into ECAL



High energy core of shower is << Molière radius

Final clustering : radius ~ Molière radius

Add nearby hits to shower cores

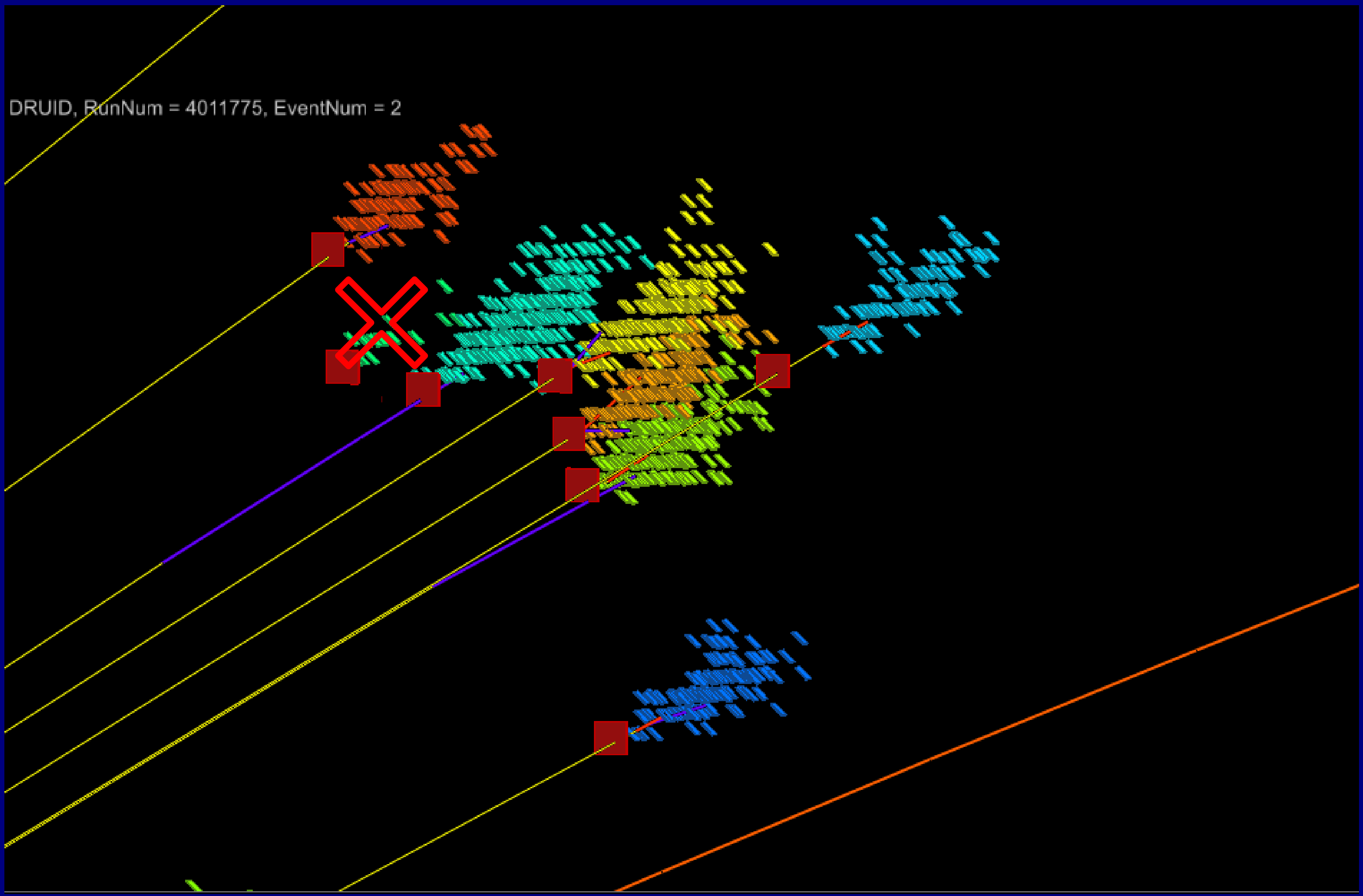


Collect large majority of shower hits

Loosely restrict window size to prevent “eating” nearby showers

Neural Network-based selection:

reject clusters which don't look like photon showers

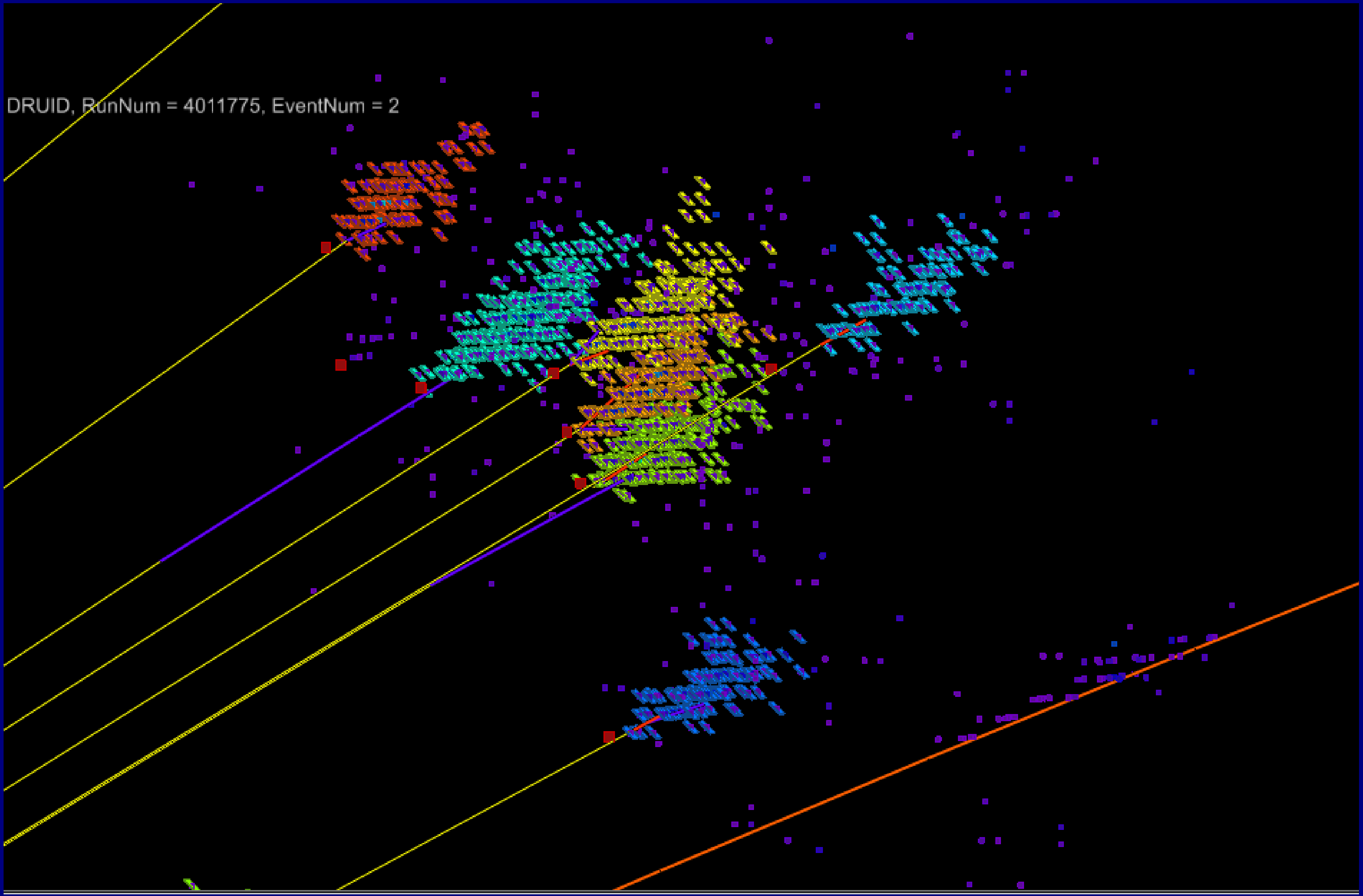


more details later...

Some hits due to photons are left unclustered:

Far from shower core,

contain minimal information on photon energy



Cluster properties : neural network inputs

- Angle between main cluster axis and cluster-IP direction

- Mean shower depth (energy weighted)

- Fraction of cluster energy between 5 and 10 X_0

- Hit energy distribution: mean and RMS/mean

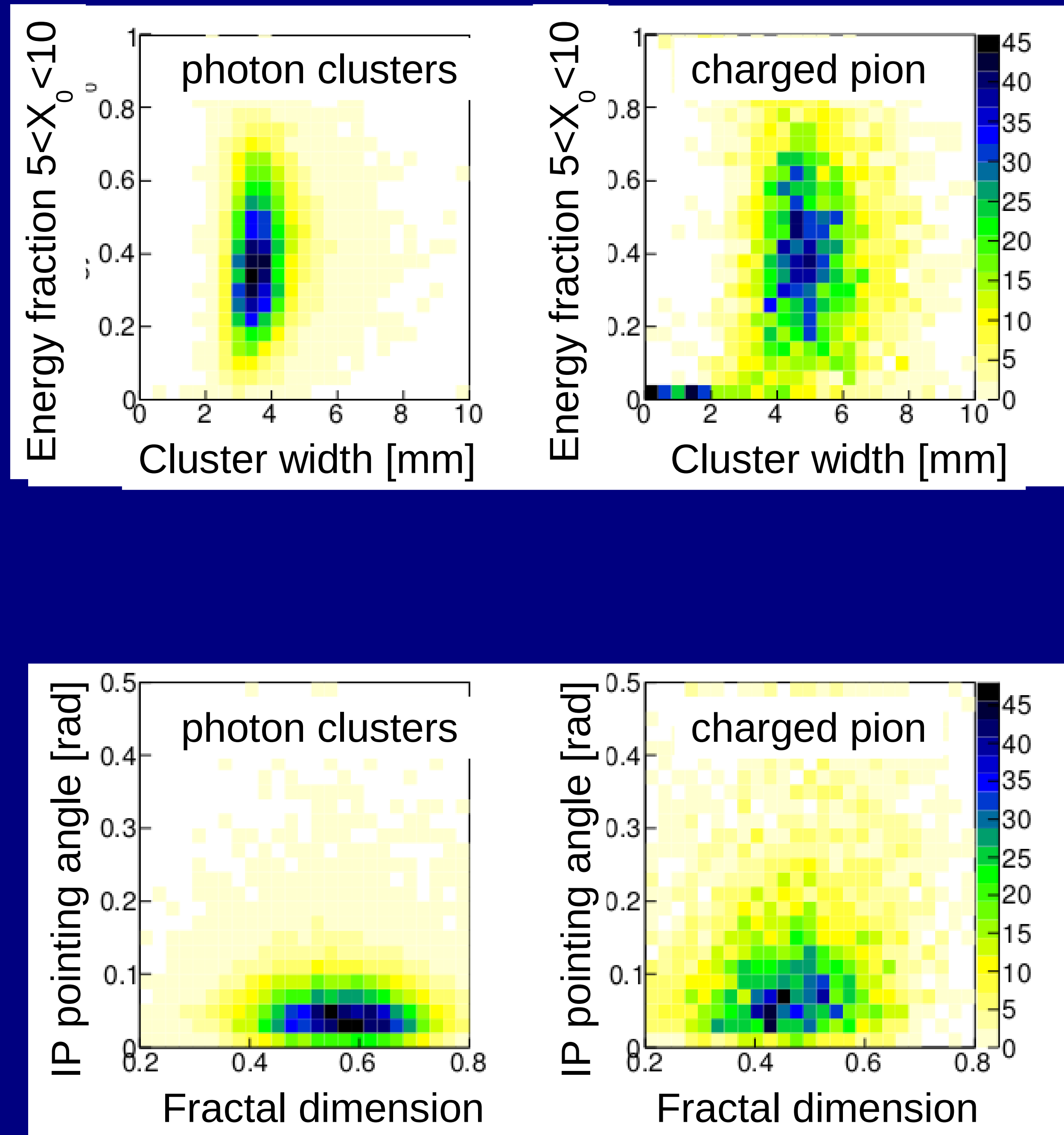
- Fractal dimension: $\log_{10}(N_4/N_1) / \log_{10}(4)$
  - N_1 = number of hits in cluster
  - N_4 = number of hits when 2x2 cells are combined
  - Sensitive to transverse hit density

- Minimum transverse cluster width

If a nearby track:
  - Distance to nearest track extrapolation
  - Angle between track and cluster directions

Trained using mix of 2- and 4-quark events generated at 500 GeV centre-of-mass
  separate trainings in 6 energy bins,
    and for clusters close to (or far from) track

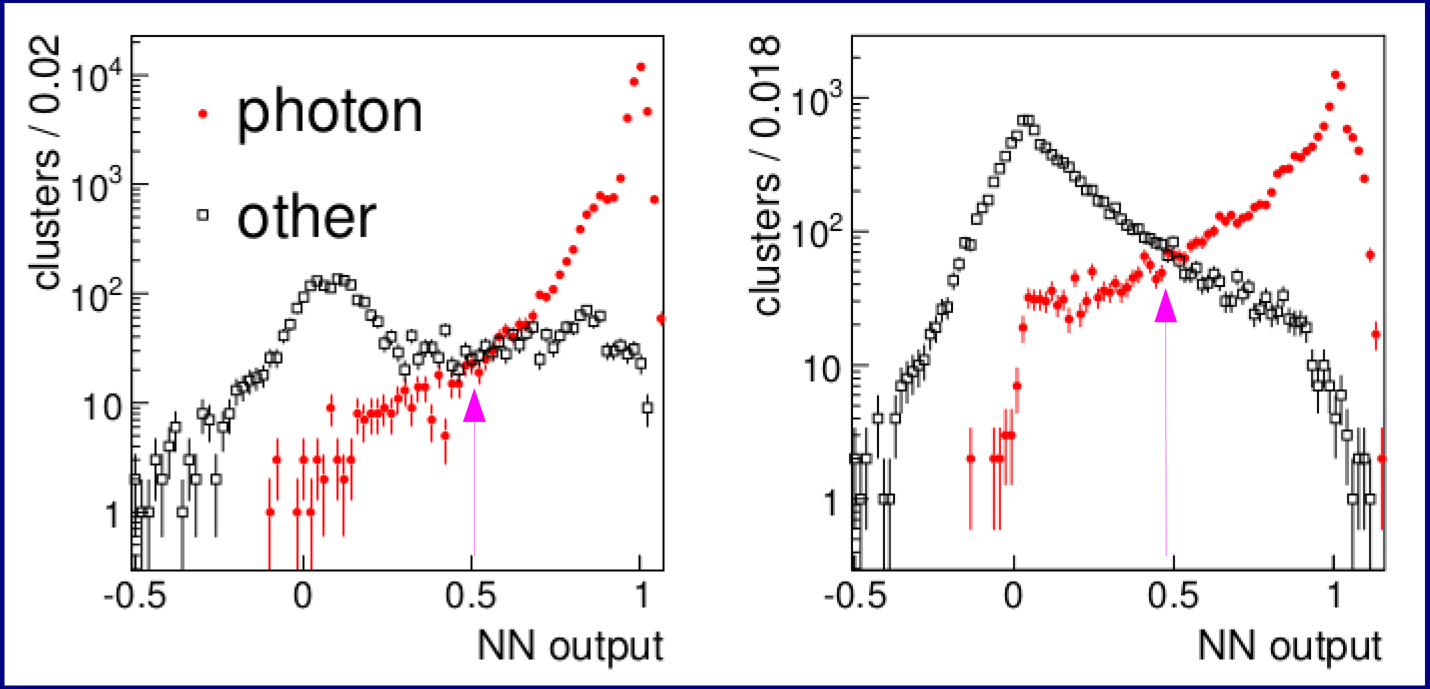
Example of some NN input variables



1->3 GeV clusters reconstructed in 500 GeV 4-quark events

Example of NN output, 1 < $E_{cluster}$ < 3 GeV

Clusters far from track | clusters near to track



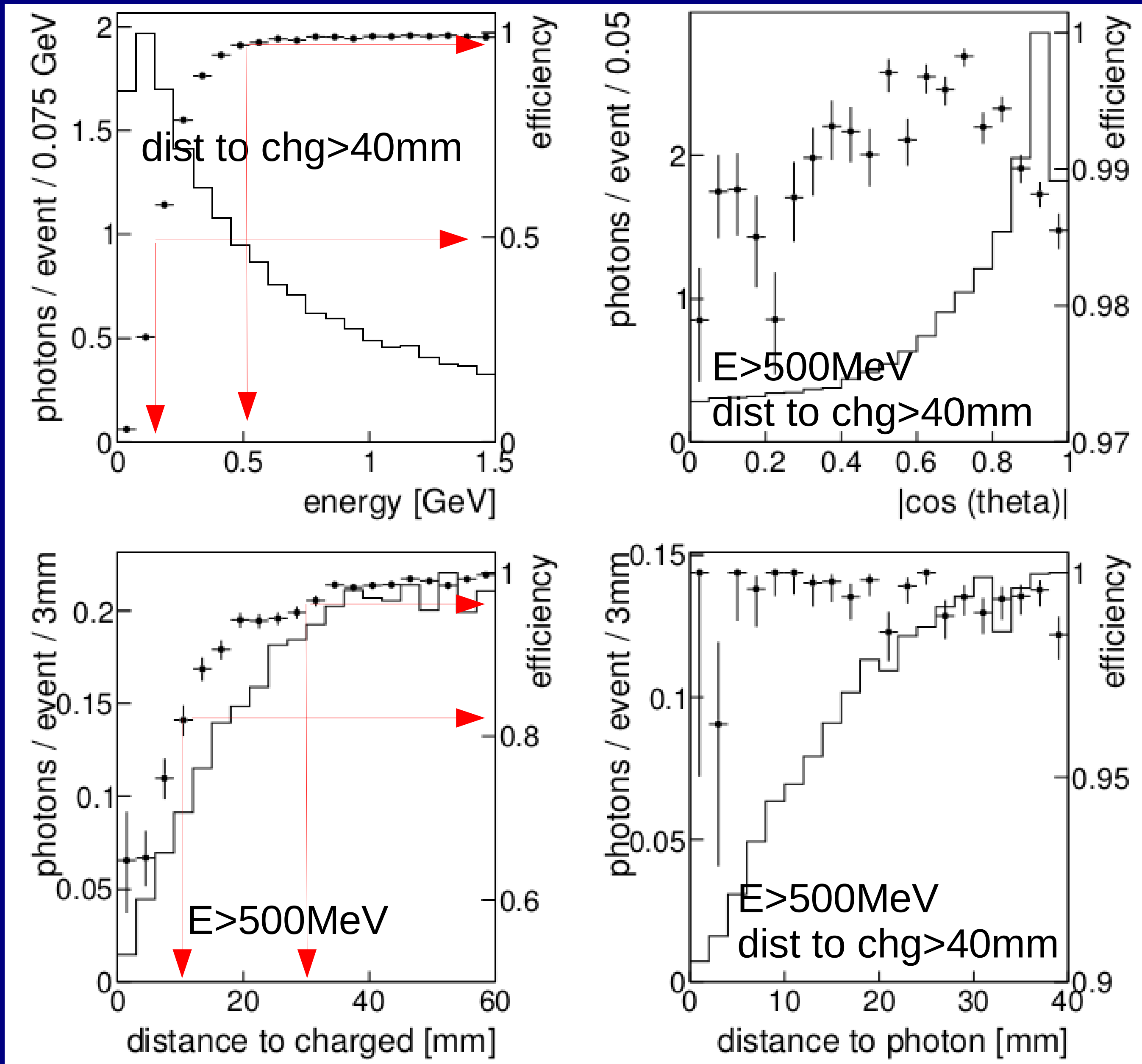
Rather clean separation possible

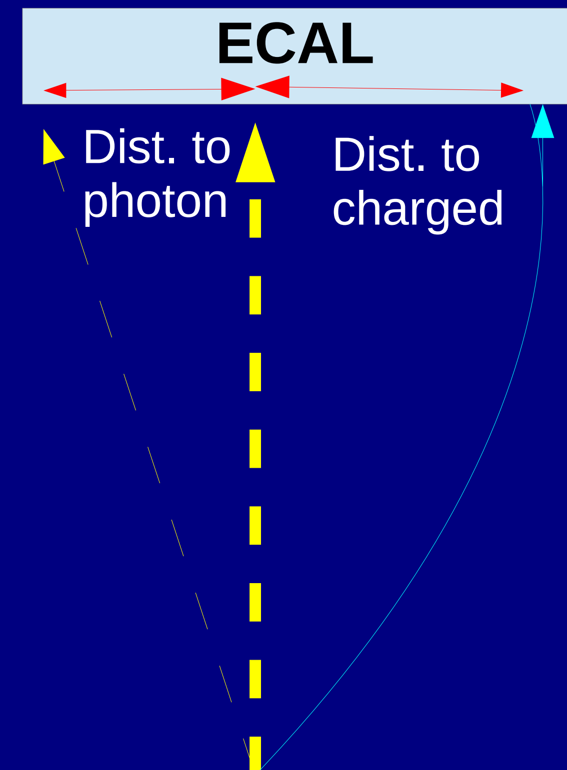
apply cut at 0.5

Performance

Estimated in jet events: 4-quark events
at a centre-of-mass energy 500 GeV

Photon distributions and GARLIC efficiency in 500 GeV e+e- -> 4 light quark events





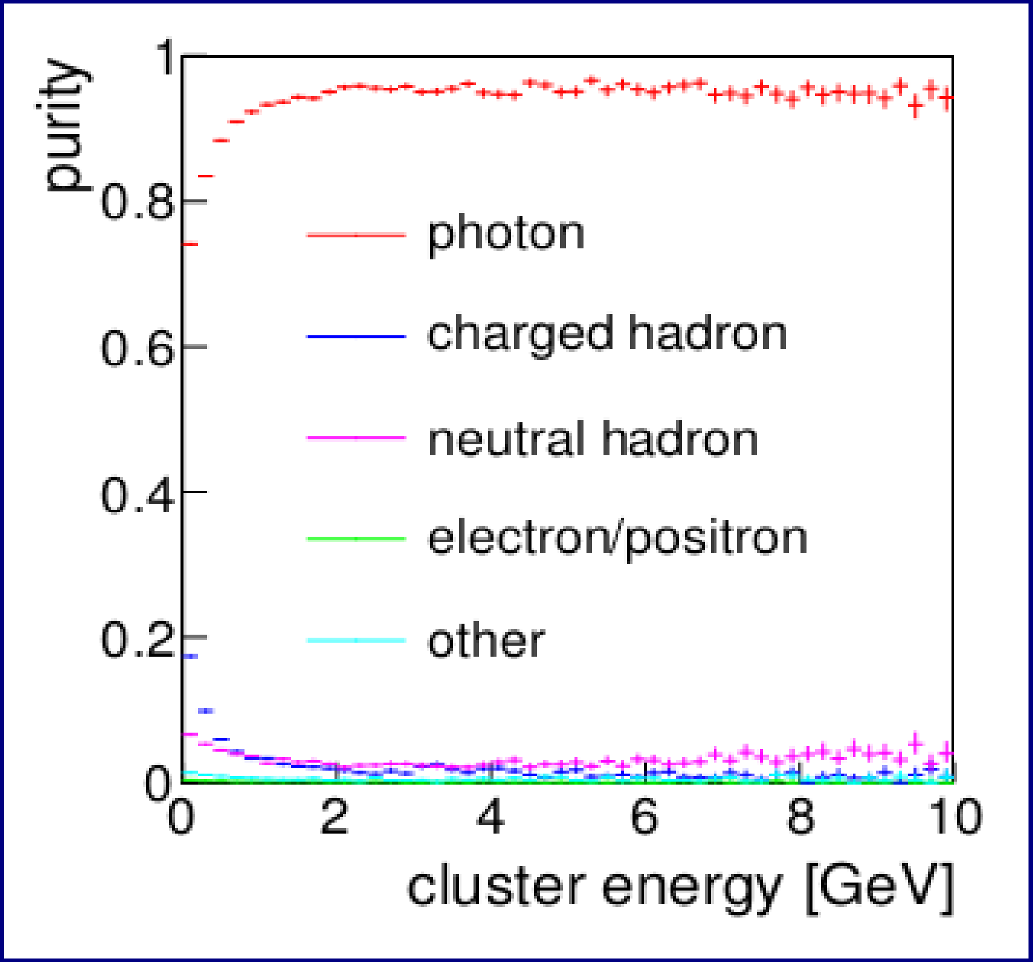
Efficiency falls at low energy (<500 MeV) <--- these photons give only a small fraction of total

and when close (<3cm) to charged particle at ECAL <--- rare, except in very high jet energy

Otherwise, efficiency ~99%

Purity of identified clusters

What fraction of clustered energy is due to which particle species?



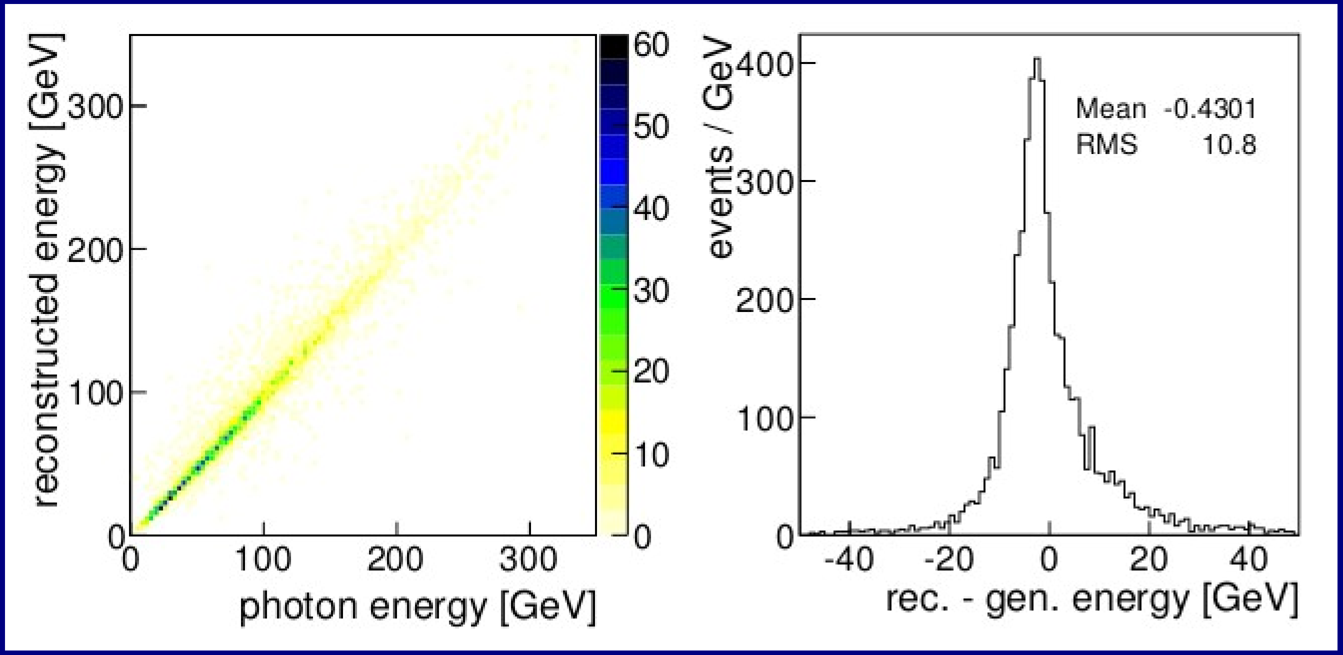
Above ~2 GeV, rather small admixture of non-photon energy

Mostly due to neutral hadrons -> not detrimental to PFA to 1st order

At lower energies, charged hadron contribution becomes non-negligible

Fragments of hadronic showers are misidentified as photons

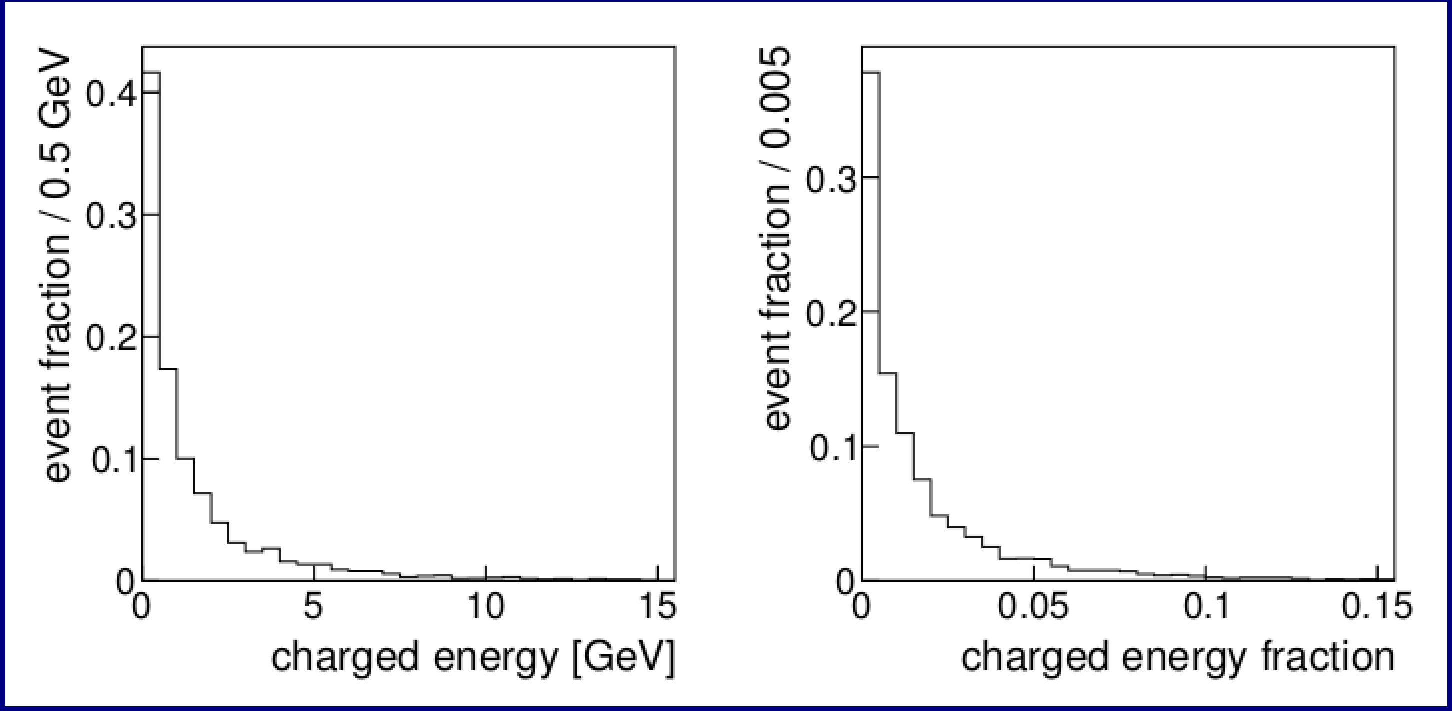
In 4-quark events at 500 GeV, how well is generated photon energy reconstructed?



In same events, how much charged calorimeter energy is mistakenly identified as photonic?

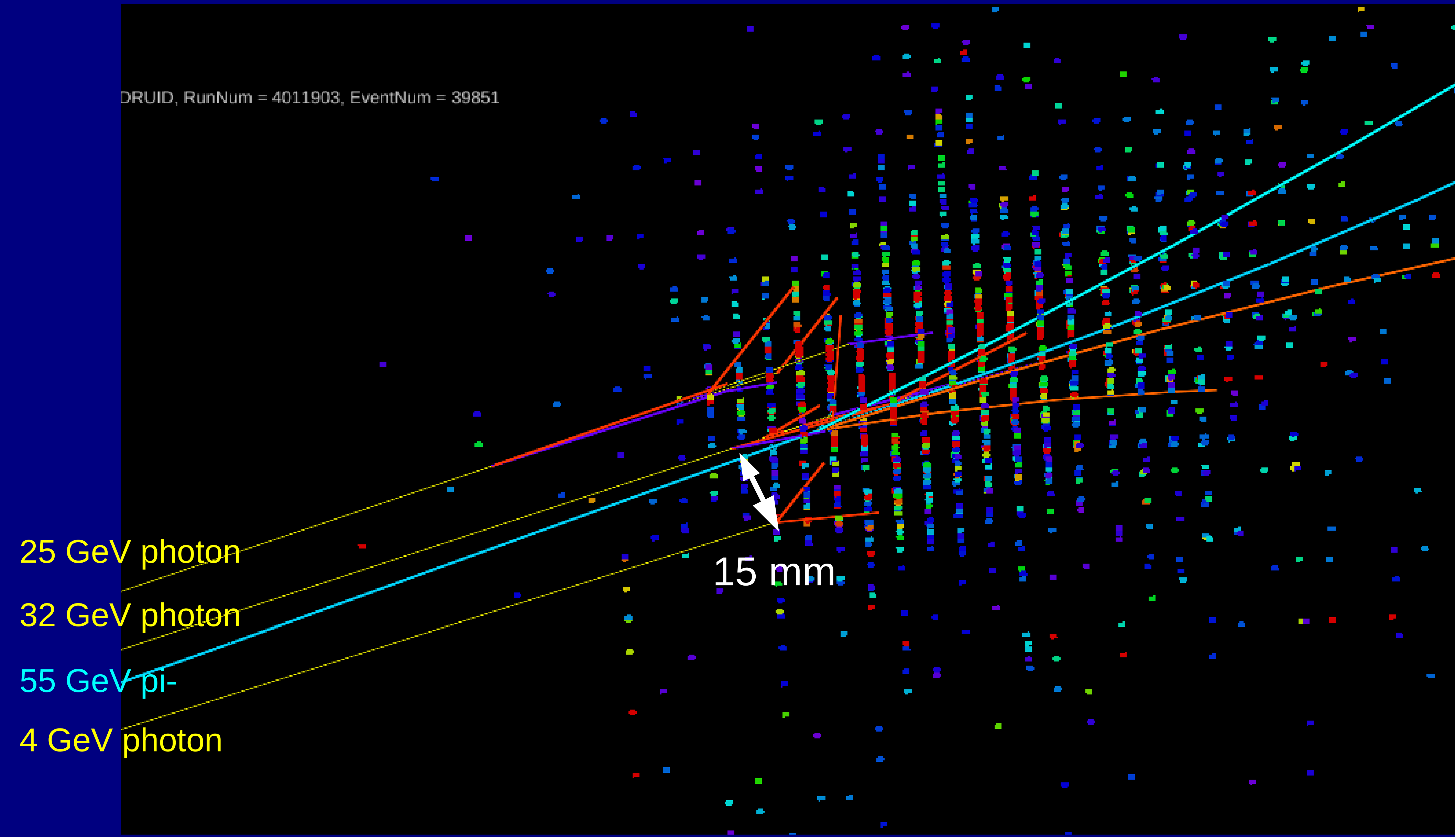
On average, well reconstructed: within a couple of % for ~80% of events

Some tails due to difficult situations in which reconstruction fails



Challenging example (small region of ~125 GeV jet)

3 high energy photons within a few cm of early interacting 55 GeV pi-



In this case GARLIC wrongly collects ~13GeV of pi- hadronic energy pushes event into tails of reconstructed PF energy distribution

Conclusions

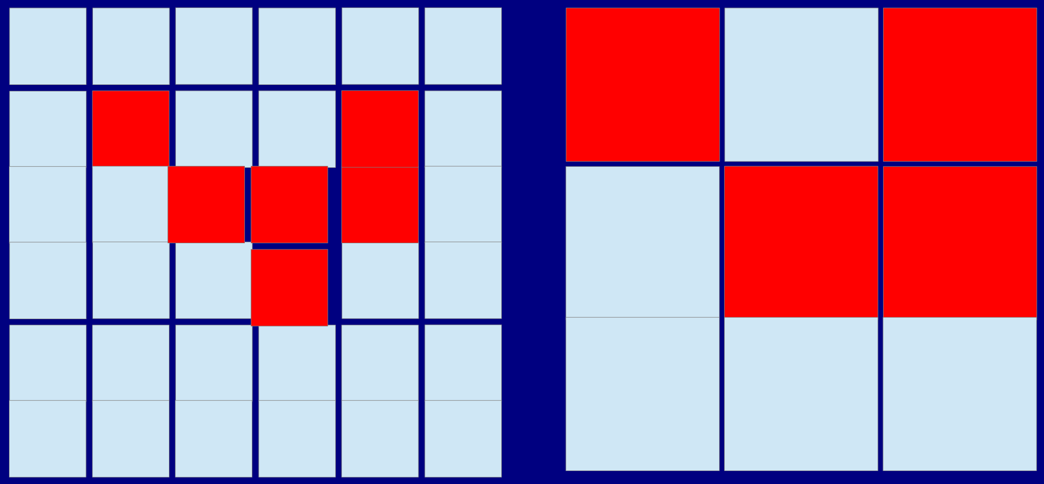
Dedicated photon clustering for Particle Flow in jets

Neural network based selection criteria

Very good performance (efficiency ~99%) for
- photon energies > 500 MeV
- distance of at least ~3cm from nearest charged track

Good performance in jets
- some pathalogical cases give rise to
  - non-Gaussian tails in energy reconstruction

backup

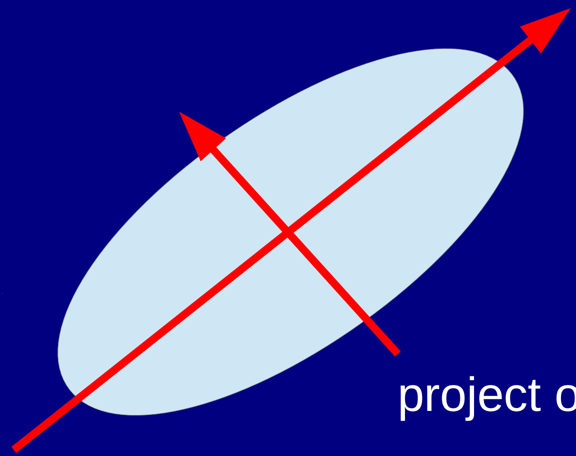


$N_1 = 6$ $N_4 = 4$

Fractal Dimension $= \log_{10}(N_4/N_1) / \log_{10}(4)$

$= \log_{10}(4/6) / \log_{10}(4) =$

Projection of cluster onto plane perpendicular to IP-> cluster centre-of-gravity



project onto minor axis

RMS of this projection

ECAL for particle flow

Large inner radius

allow jet to “spread”, increasing average distance between jet particles

easier to distinguish nearby particles

Small Moliere radius

Smaller single particle showers

Easier to distinguish nearby showers

[Compact depth: small X0

Constrain size & cost of outer detectors, solenoid]

Relatively large lambda

Longitudinal separation between EM and hadronic

Model studied here:

Sampling calorimeter with silicon sensors, tungsten absorber

(for ILD concept: see talks in LC calorimeter session for more details)