Cluster finding in CALICE calorimeters

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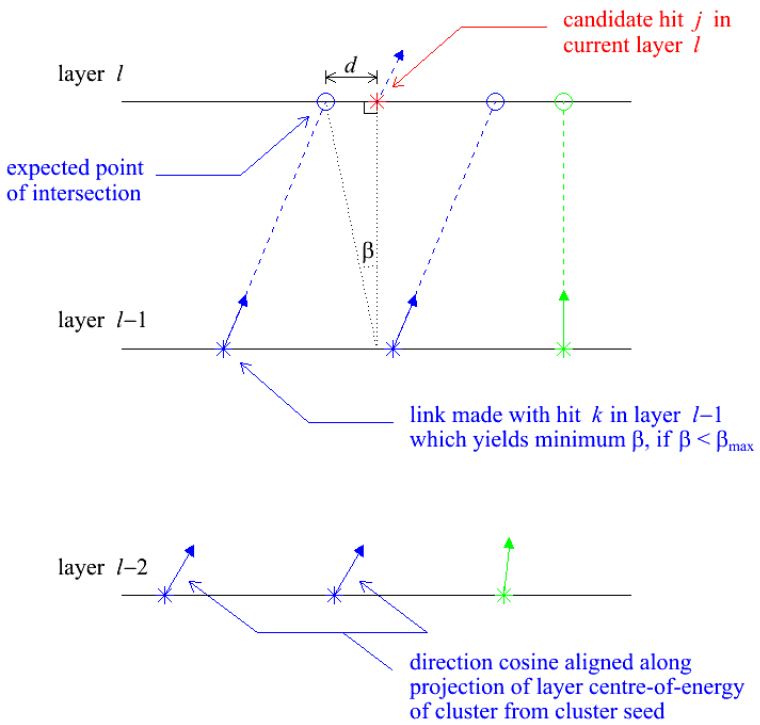
Motivation

- Desire for excellent jet energy resolution at future LC
  - $\Rightarrow$ calorimeter needs to be highly granular to resolve individual particles within jets;
  - $\Rightarrow$ calorimeter will have tracker-like behaviour: unprecedented;
  - $\Rightarrow$ novel approach to calorimeter clustering required.
- Aim to produce a flexible clustering algorithm, independent of ultimate detector configuration and not tied to a specific MC program.
- Develop within an LCIO-compatible framework
  - $\Rightarrow$ direct comparisons with alternative algorithms can be made straightforwardly.

Order of service

- Tracker-like clustering algorithm in outline.
- Generalisation of the full detector geometry.
- Application to single-particle cluster reconstruction.
- Application to multi-particle cluster reconstruction:
  - Z event at 91 GeV (W-Si Ecal, Fe-RPC Hcal);
  - W^+W^- event at 800 GeV (W-Si Ecal, Fe-RPC Hcal).
- Summary and outlook.

Tracker-like clustering algorithm in outline

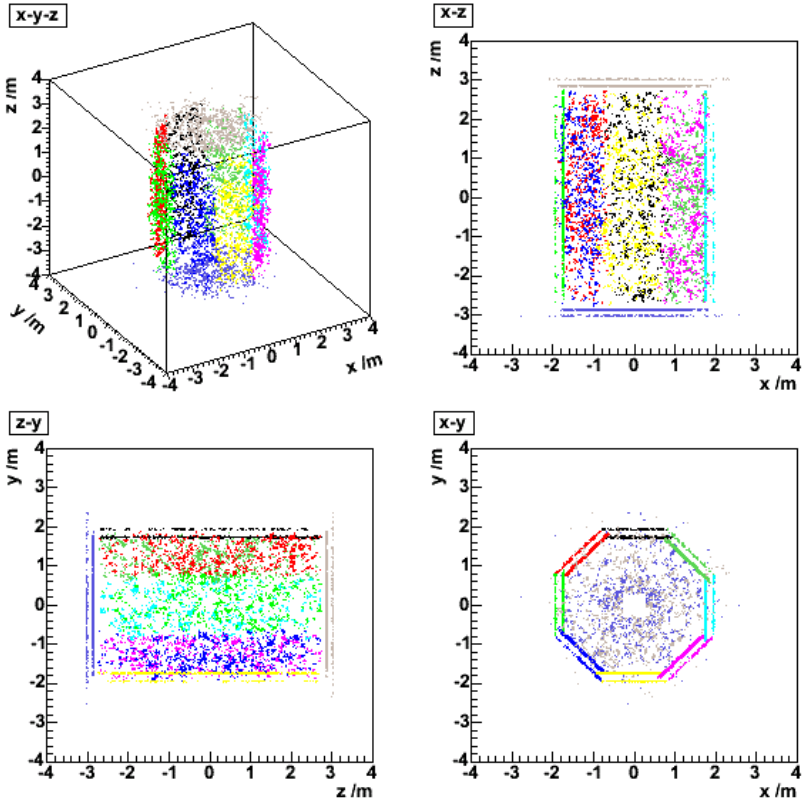


- Sum energy deposits within each cell.
- Retain cells with total hit energy above some threshold (⅓ MIP; adjustable).
- Form clusters by tracking closely related hits layer-by-layer through calorimeters:
  - for a given hit j in a given layer l, minimize the angle β w.r.t all hits k in layer l–1;
  - if $\beta < \beta_{max}$ for minimum β, assign hit j to same cluster as hit k which yields minimum;
  - if not, repeat with all hits in layer l–2, then, if necessary, layer l–3, etc.;
  - after iterating over all hits j, seed new clusters with those still unassigned;
  - calculate centre-of-energy of each cluster in layer l;
  - assign a direction cosine to each hit along the line joining its clusters' seed (or {0,0,0} if it's a seed) to its clusters' centre-of-energy in layer l;
  - propagate layer-by-layer through Ecal, then Hcal;
  - retrospectively match any backward-spiralling track-like cluster fragments with the forward-propagating cluster fragments to which they correspond using directional and proximity information at the apex of the track.

Geometry generalisation (1)

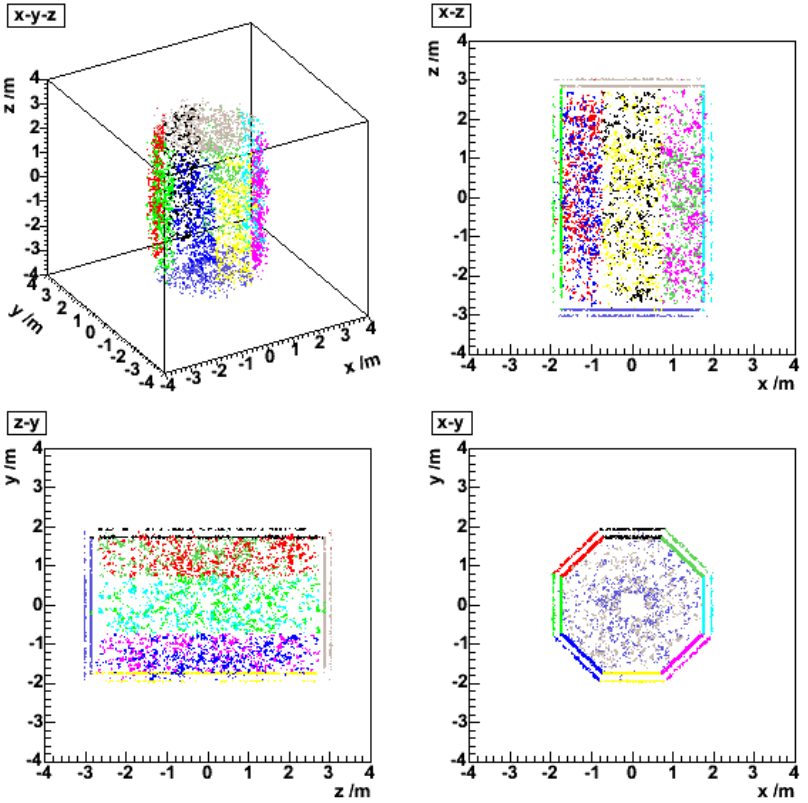
Layers

- Layer index changes discontinuously at:
  (i) Ecal barrel stave boundaries;
  (ii) barrel/endcap boundaries.



Pseudolayers

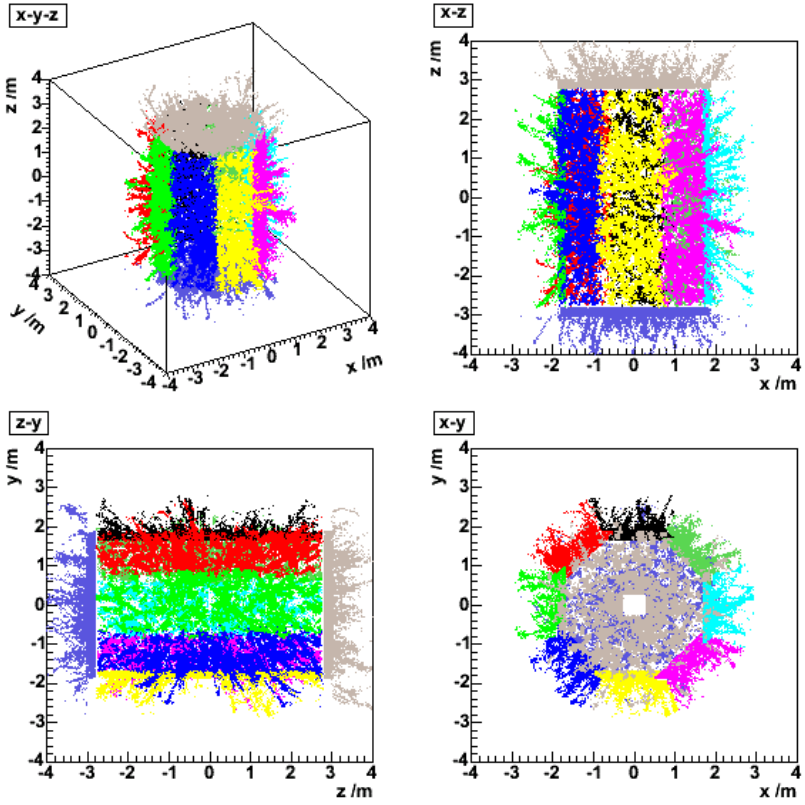
- Define “pseudolayers” as surfaces of coaxial octagonal prisms ⇒ discontinuities removed; pseudolayer indices vary smoothly.



Geometry generalisation (2)

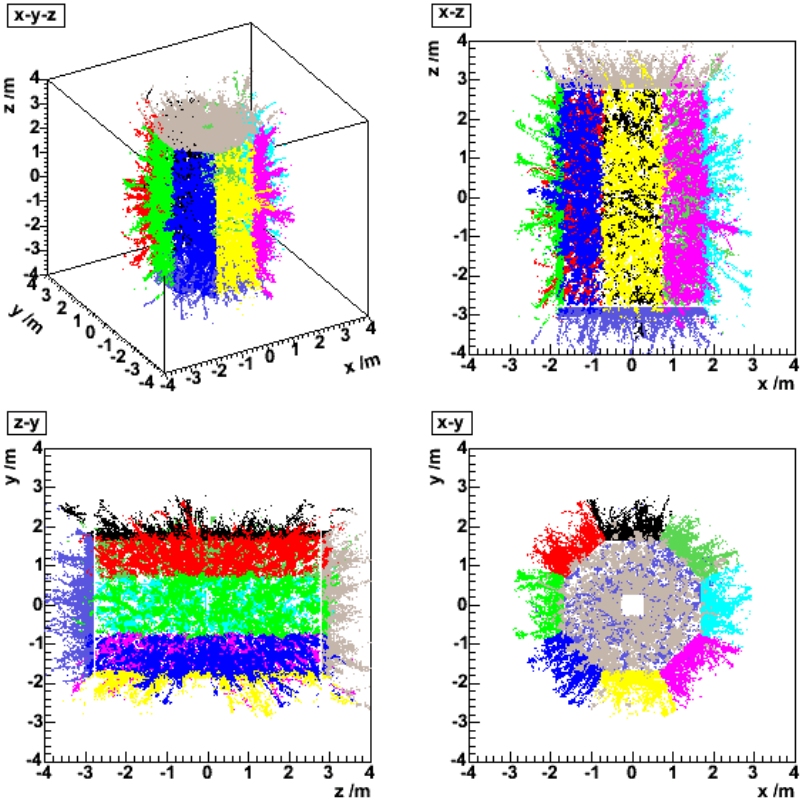
Staves

- Stave = plane of parallel layers



Pseudostaves

- Pseudostave = plane of parallel pseudolayers

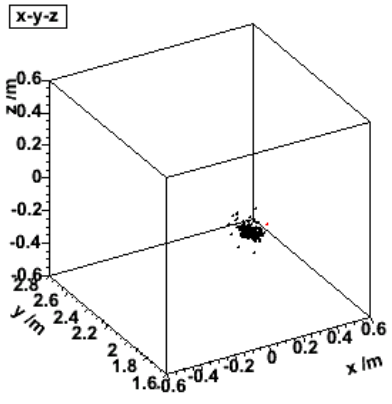


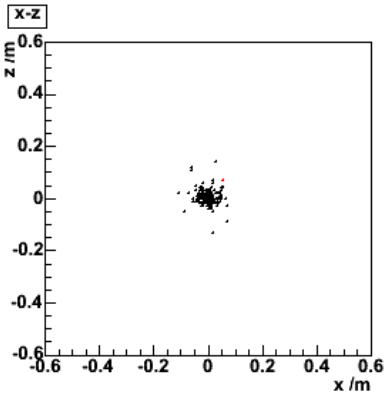
Geometry generalisation (3)

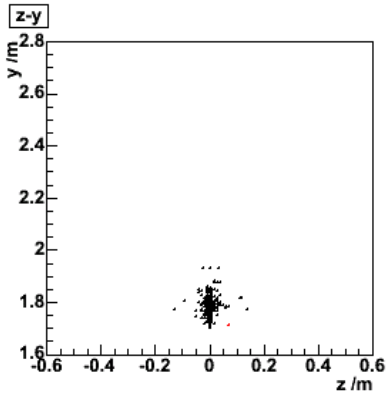
- Clustering algorithm works as described earlier, but with layers replaced by pseudolayers
  - $\Rightarrow$ pseudolayer index changes smoothly;
  - $\Rightarrow$ clusters are tracked with continuity across stave boundaries.
- Pseudolayers/pseudostaves are defined automatically by the intersection of the real, physical layers
  - $\Rightarrow$ only need distances of layers from {0,0,0} and their angles w.r.t. each other to construct these;
  - $\Rightarrow$ idea applies to ANY detector design comprising an *n*-fold rotationally symmetric barrel closed by a pair of endcaps!

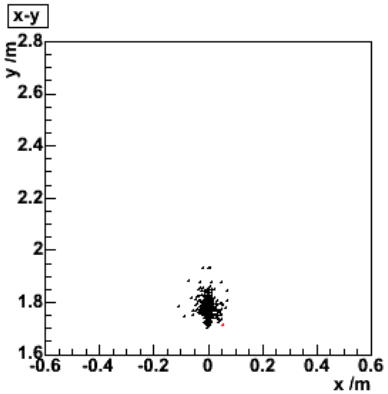
Single-particle reconstruction

15 GeV e^-

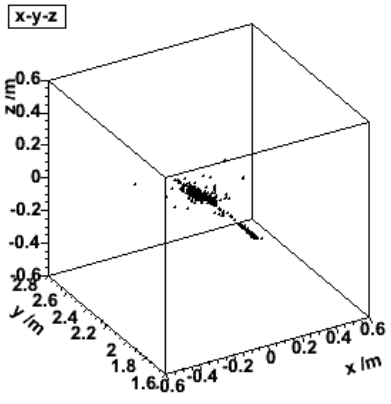


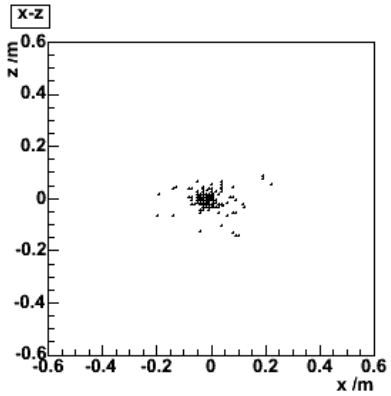


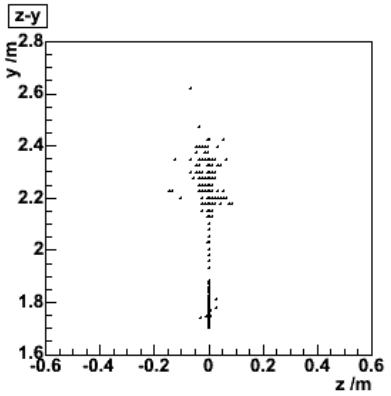


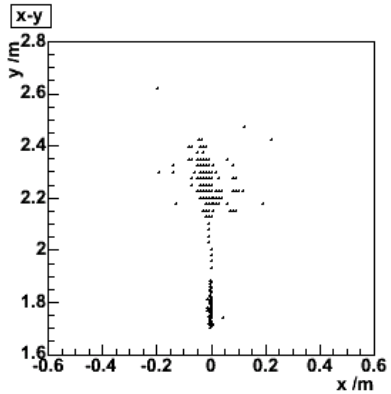


15 GeV π^-



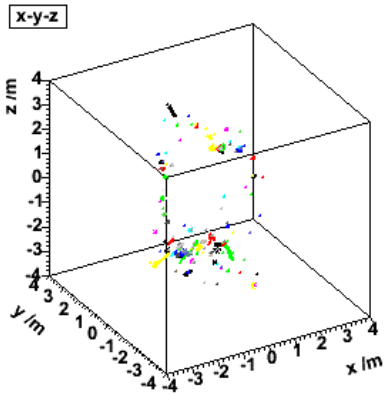


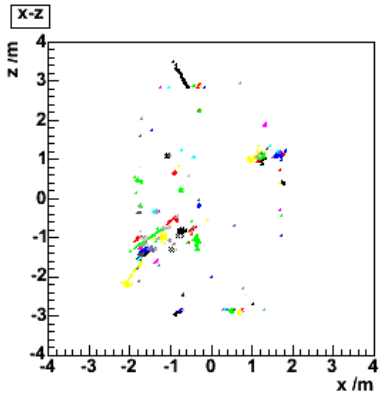


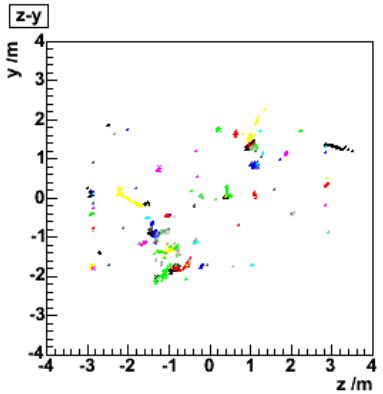


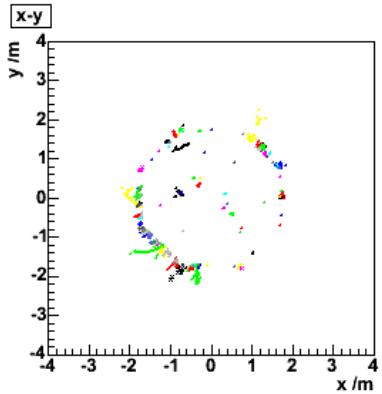
91 GeV Z event: Full detector

Reconstructed clusters

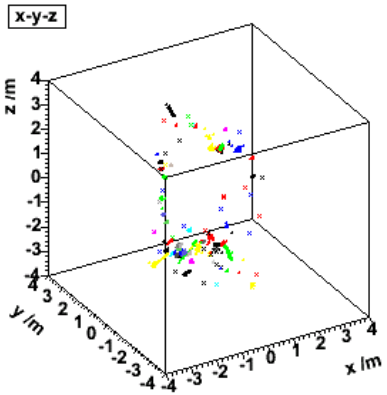


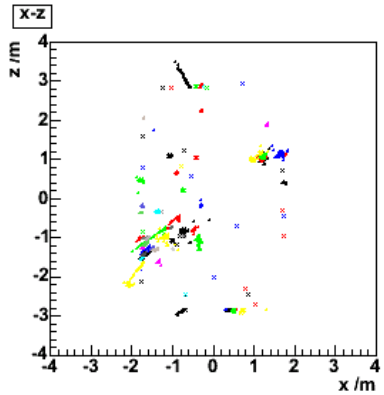


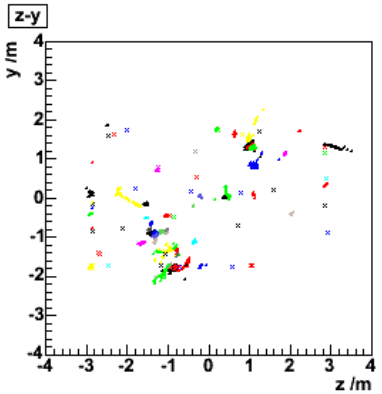


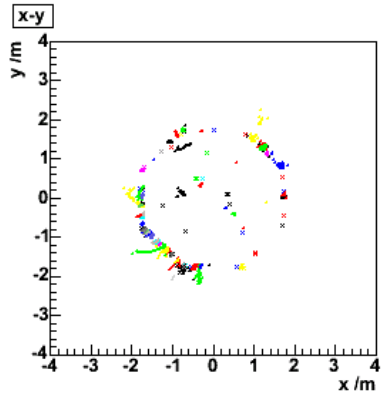


True particle clusters



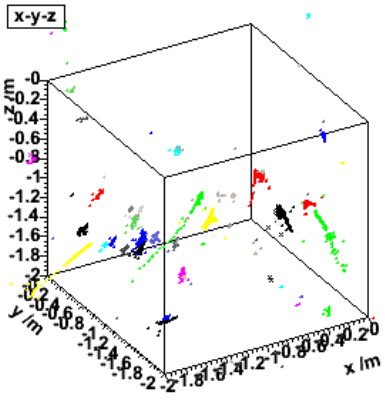


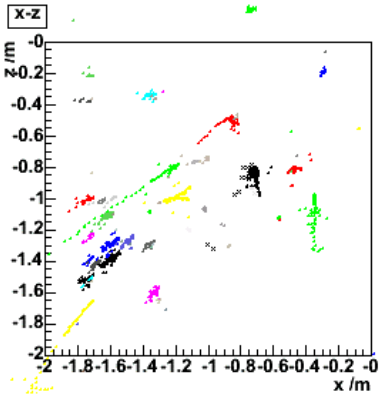


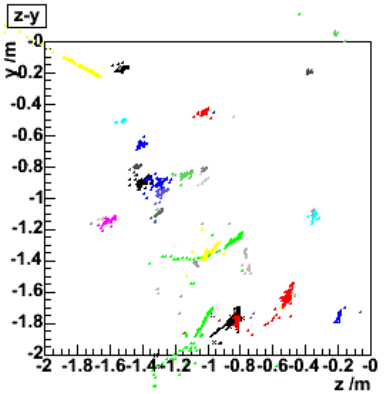


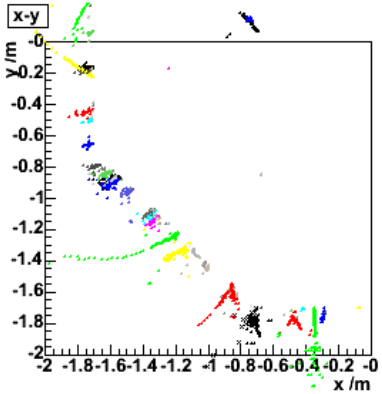
91 GeV Z event: Zoom 1

Reconstructed clusters

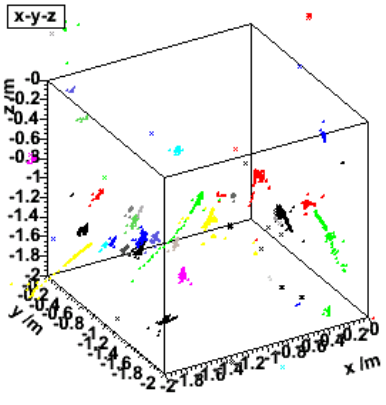


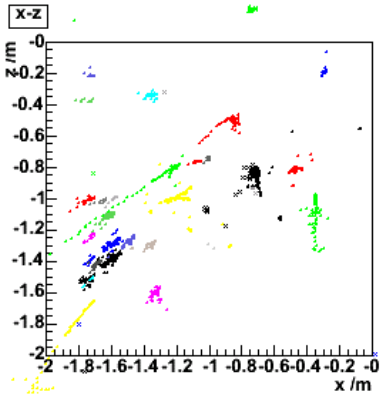


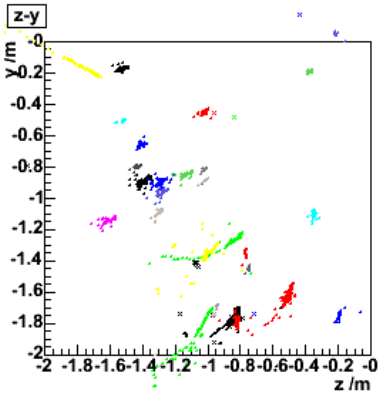


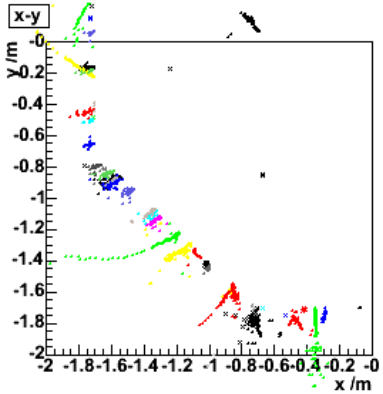


True particle clusters



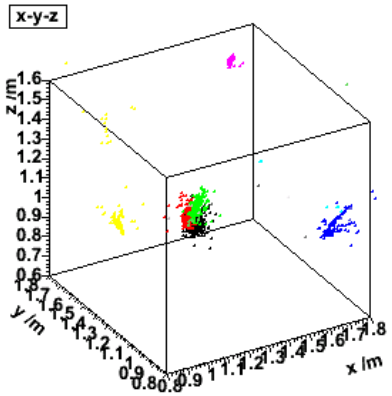


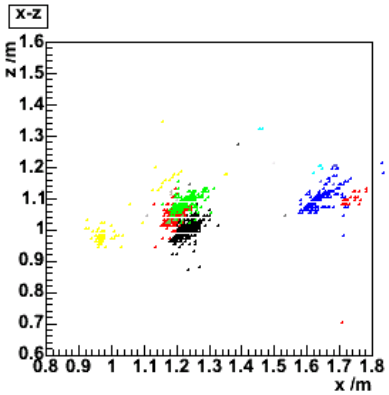


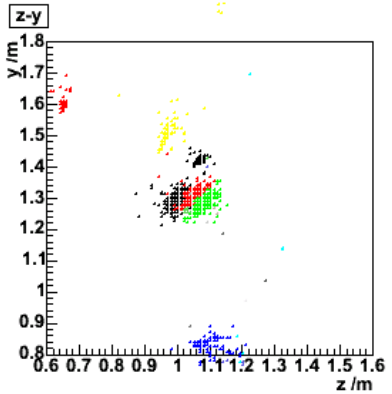


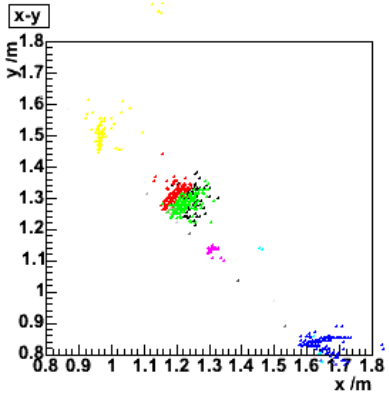
91 GeV Z event: Zoom 2

Reconstructed clusters

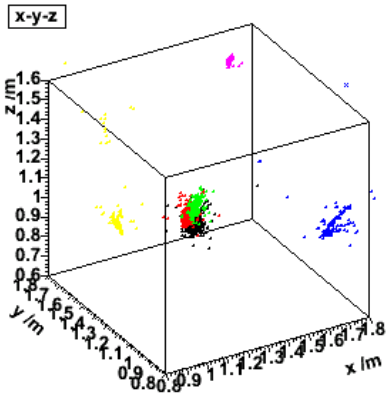


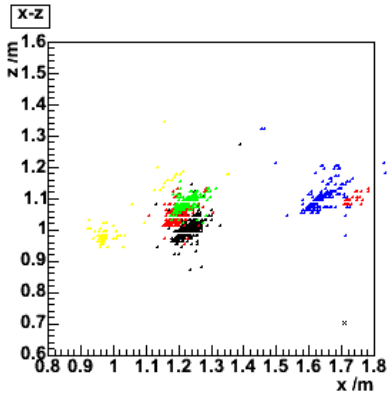


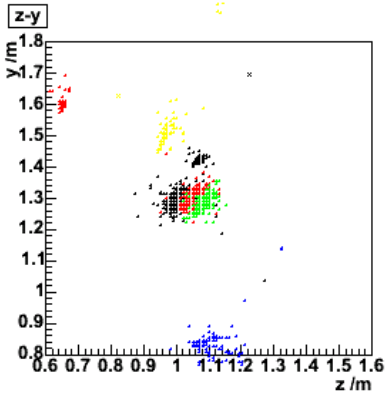


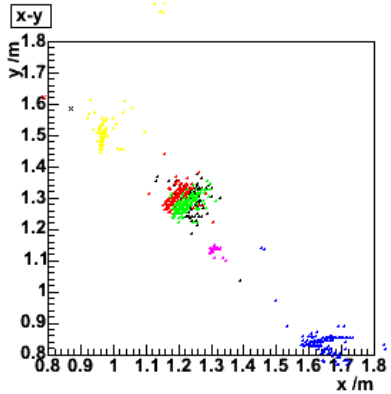


True particle clusters



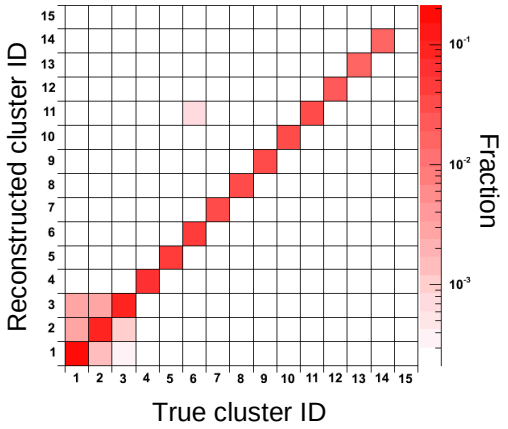




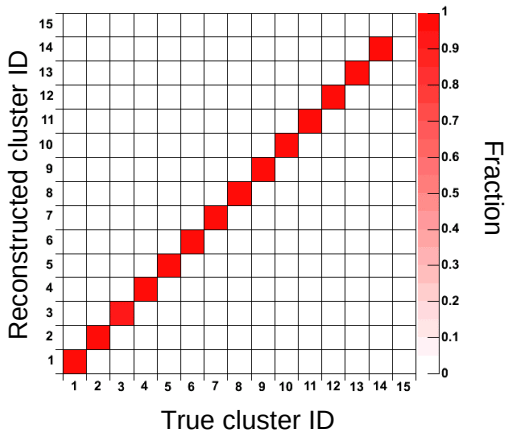


91 GeV Z event: Performance

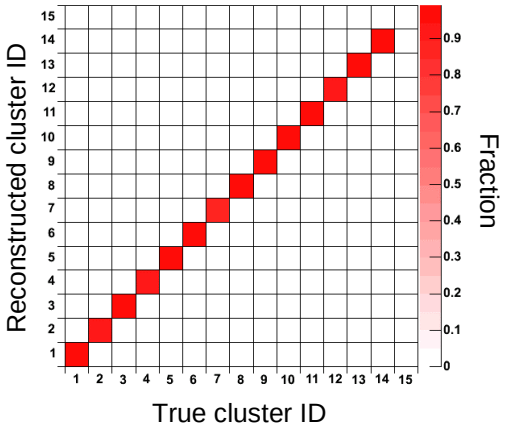
Fraction of event energy in each true-reconstructed cluster pair



Fraction of reconstructed cluster energy in each true cluster



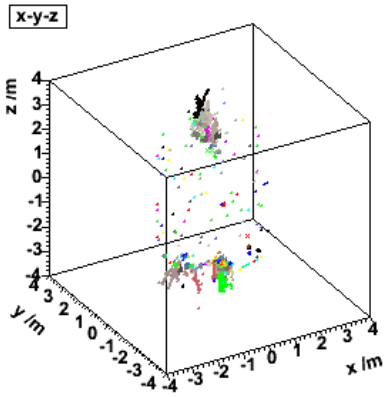
Fraction of true cluster energy in each reconstructed cluster

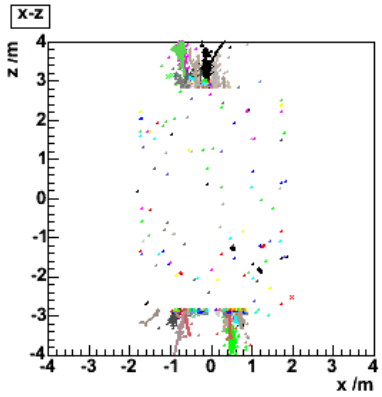


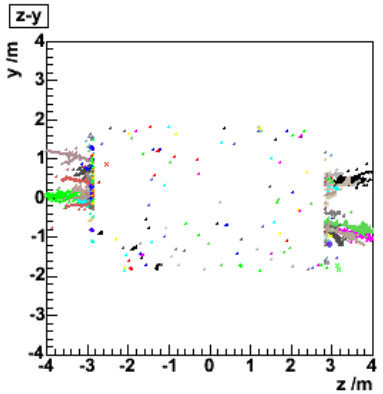
- 15 highest energy reconstructed and true clusters plotted.
- Reconstructed and true clusters tend to have a 1:1 correspondence.
- Averaged over 100 Z events at 91 GeV:
  - 87.7 ± 0.5 % of event energy maps 1:1 from true onto reconstructed clusters;
  - 97.0 ± 0.3 % of event energy maps 1:1 from reconstructed onto true clusters.

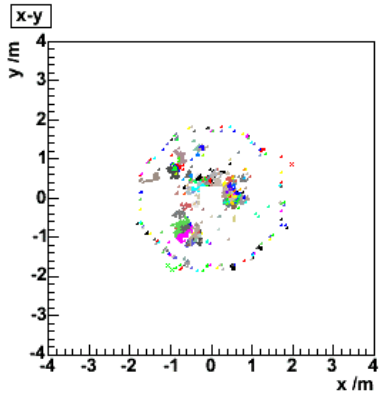
800 GeV W^+W^- event: Full detector

Reconstructed clusters

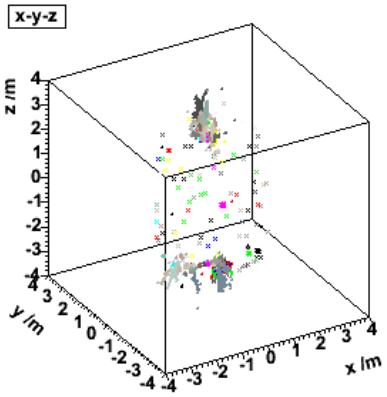


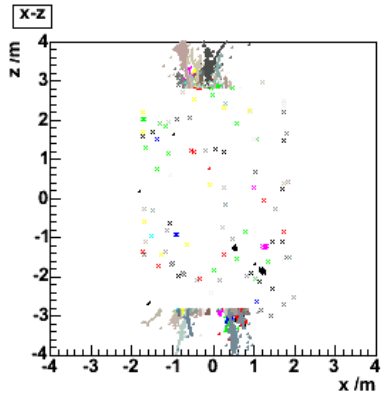


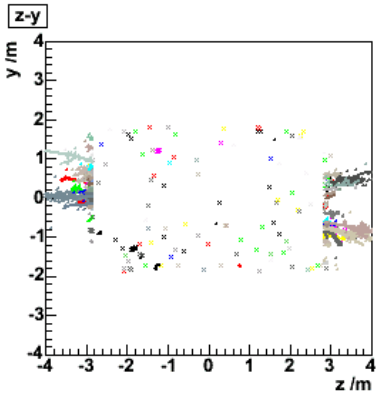


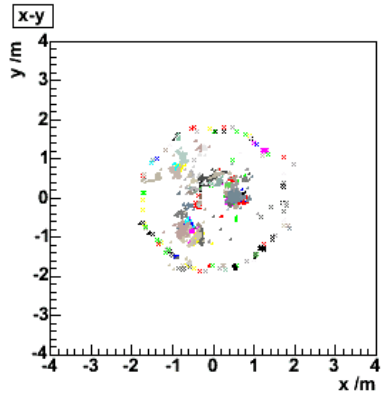


True particle clusters



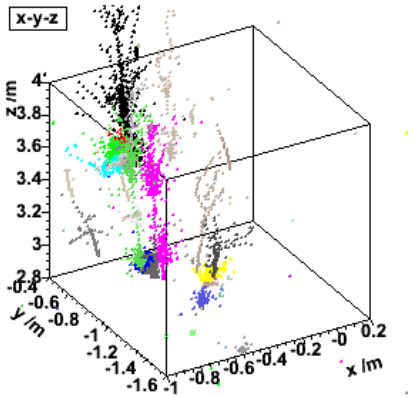


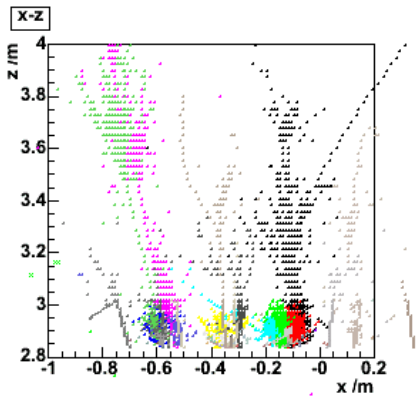


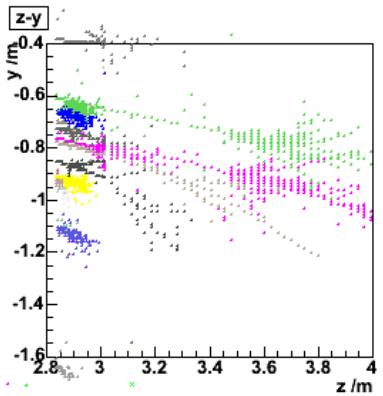


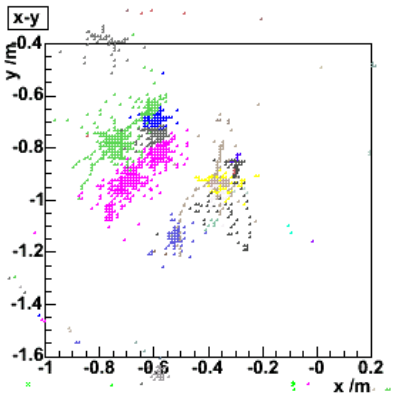
800 GeV W^+W^- event: Zoom 1

Reconstructed clusters

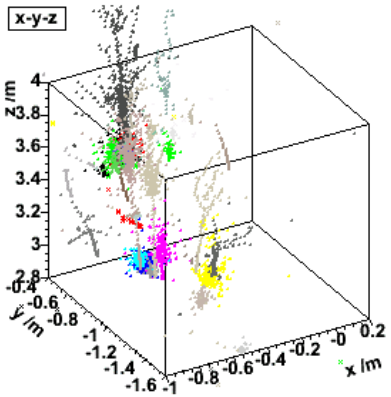


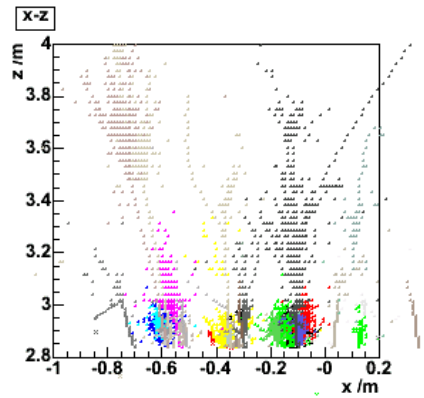


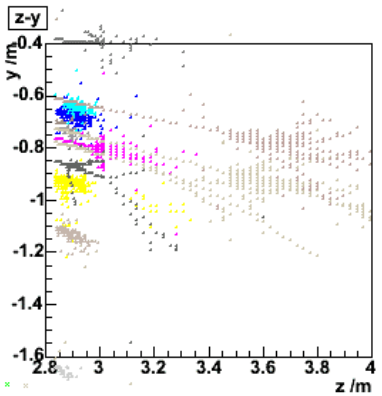


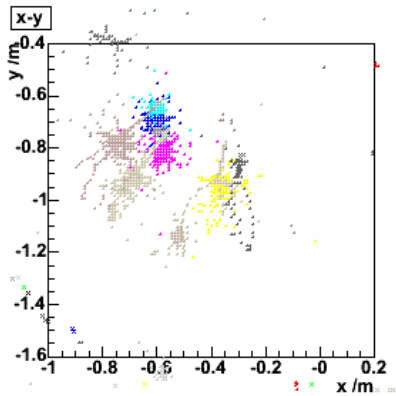


True particle clusters



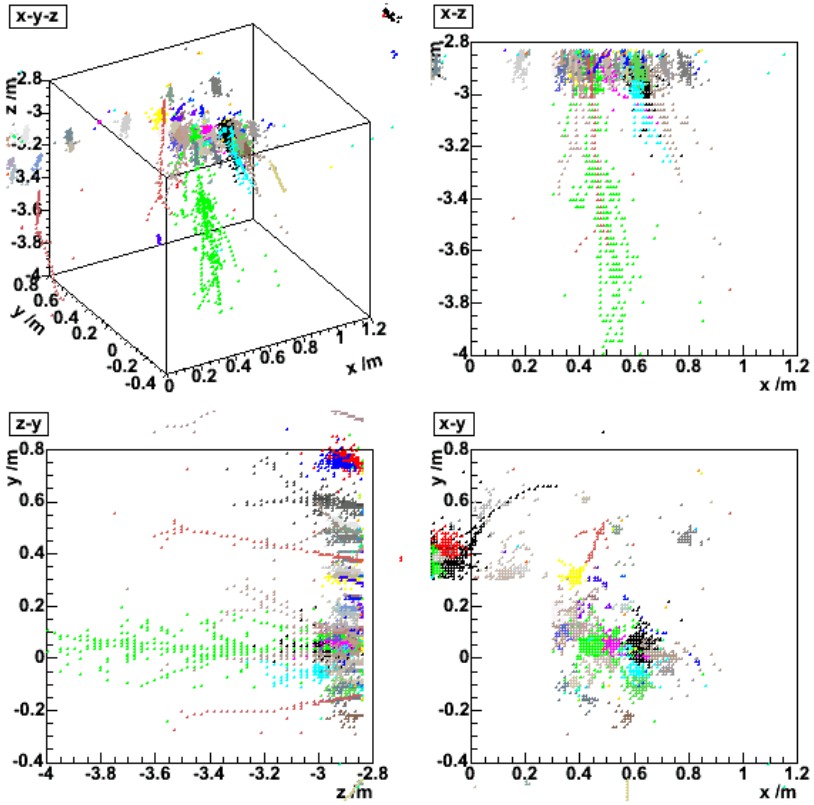




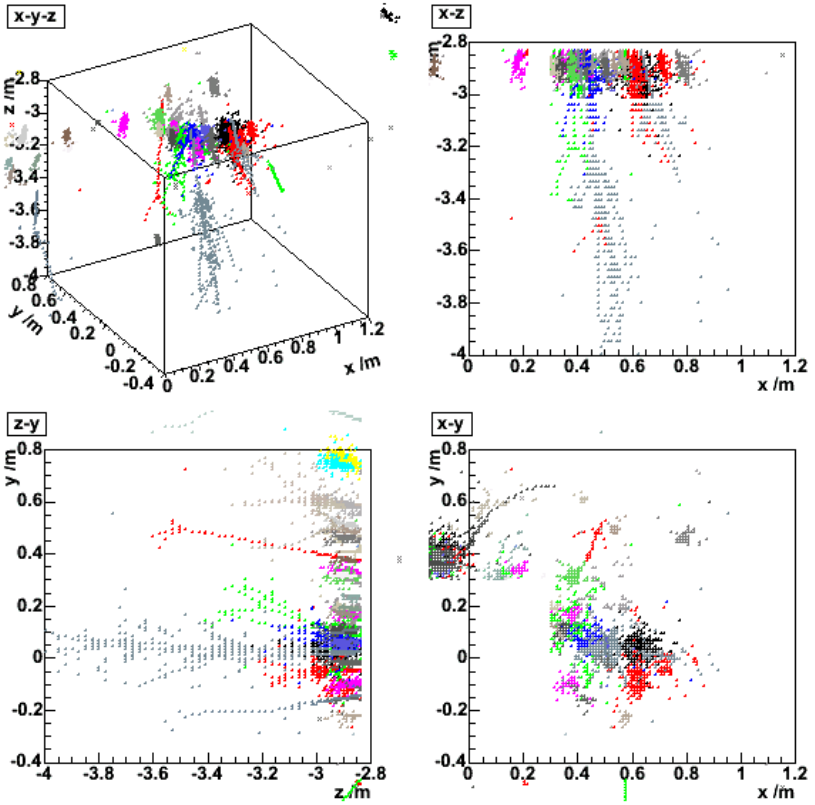


800 GeV W^+W^- event: Zoom 2

Reconstructed clusters

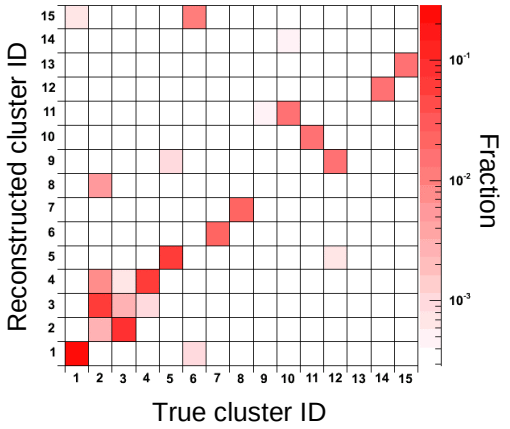


True particle clusters

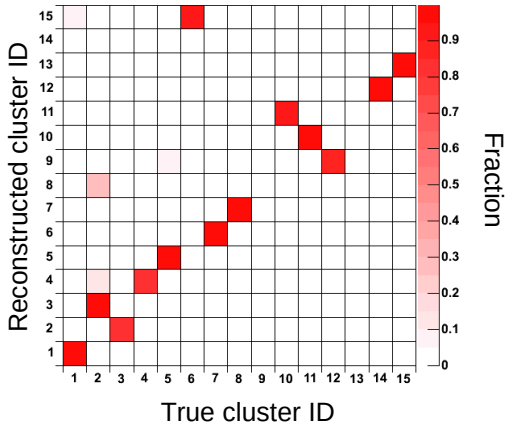


800 GeV W^+W^- event: Performance

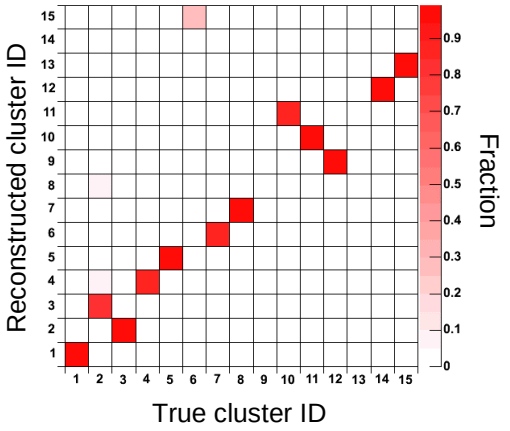
Fraction of event energy in each true-reconstructed cluster pair



Fraction of reconstructed cluster energy in each true cluster



Fraction of true cluster energy in each reconstructed cluster



- 15 highest energy reconstructed and true clusters plotted.
- Reconstructed and true clusters tend to have a 1:1 correspondence.
- Averaged over 100 W^+W^- events at 800 GeV:
  - 83.3 ± 0.5 % of event energy maps 1:1 from true onto reconstructed clusters;
  - 80.2 ± 1.0 % of event energy maps 1:1 from reconstructed onto true clusters.

Summary & Outlook

- R&D on clustering algorithm for calorimeters at a future LC in progress.
- Approach mixes tracking and clustering aspects to utilize the high granularity of the calorimeter cells.
- Starts from calorimeter hits and builds up clusters – a “bottom up” approach (cf. “top down” approach of G. Mavromanolakis).
- Can be applied to any likely detector configuration

  $\Rightarrow$ straightforward to try out alternative geometries.
- Works well for single-particles events.
- Good performance for 91 GeV Z events.
- Encouraging signs for 800 GeV W^+W^- events.
- Runs in the LCIO (v.1.0) framework: hits collection $\rightarrow$ clusters collection (awaiting next version to make full use of cluster object methods)

  $\Rightarrow$ straightforward to try out alternative algorithms.