Cluster finding in CALICE calorimeters

Chris Ainsley

University of Cambridge, UK

<ainsley@hep.phy.cam.ac.uk>

LCWS 04: Simulation (reconstruction) parallel session
20 April 2004, Paris, France

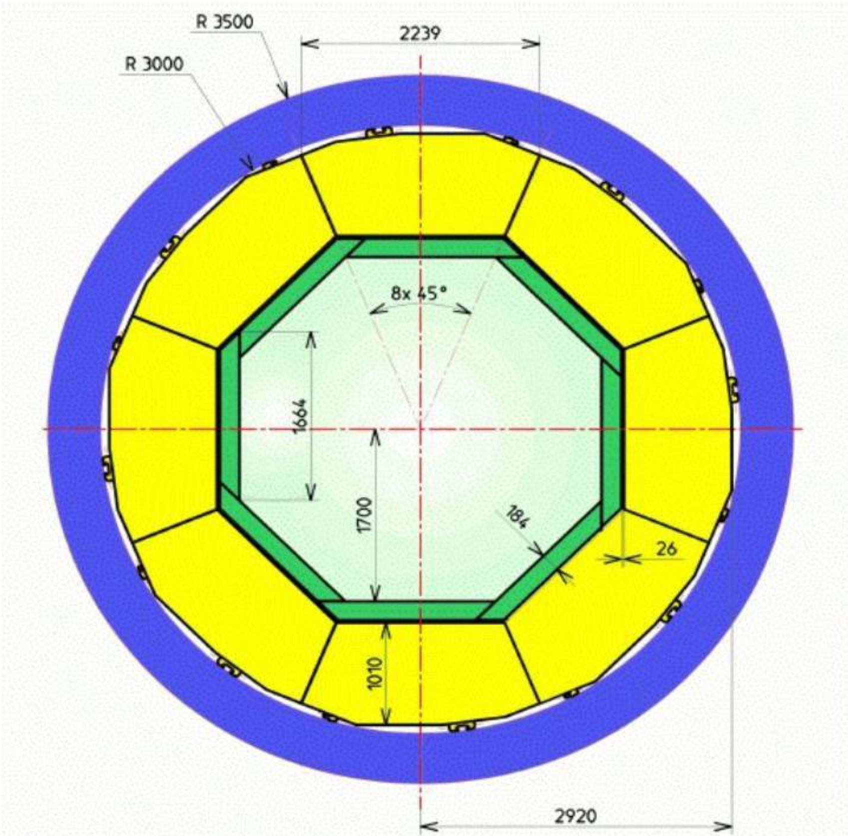
Motivation

- Desire for excellent jet energy resolution at future LC
  - ⇒ calorimeter needs to be highly granular to resolve individual particles within jets;
  - ⇒ calorimeter will have tracker-like behaviour: unprecedented;
  - ⇒ 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
  - ⇒ direct comparisons with alternative algorithms can be made straightforwardly.
- Test with CALICE calorimeters (TESLA TDR) simulated by Mokka.

Order of service

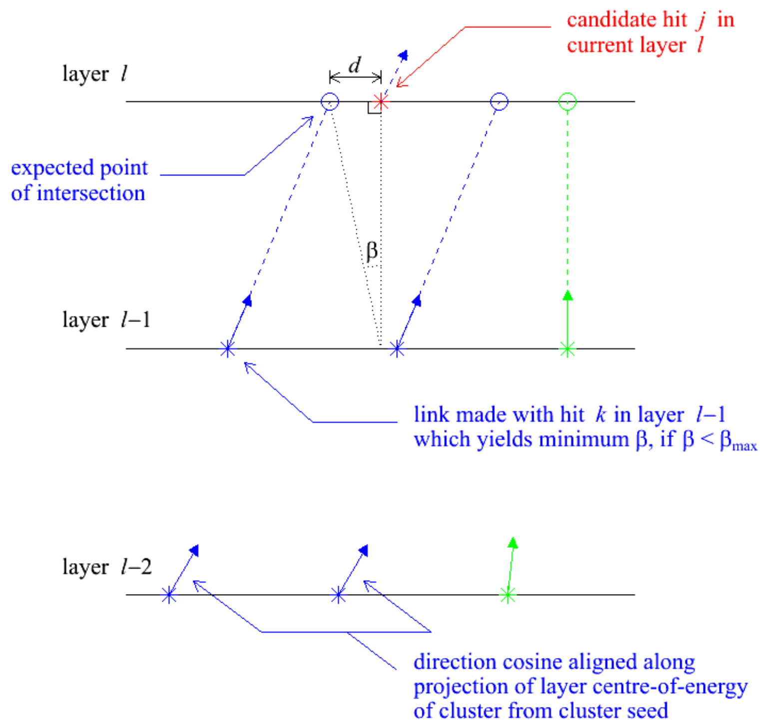
- Overview of CALICE geometry.
- Algorithm in outline.
- Application to single-particle cluster reconstruction.
- Application to multi-particle cluster reconstruction:
  - in the full barrel;
  - in selected segments
    - assessment of performance (how best to do this?).
- Summary and outlook.

Cross-section through the CALICE barrel calorimeters



- TESLA TDR barrel geometry:
  - 8 identical octants (number 1 at 12 o' clock, running anti-clockwise to number 8);
  - 40 layers of W-Si in Ecal (green);
  - 40 layers of Fe-Scintillator in Hcal (yellow);
  - 1x1 cm^2 sensitive cells in both Ecal & Hcal.

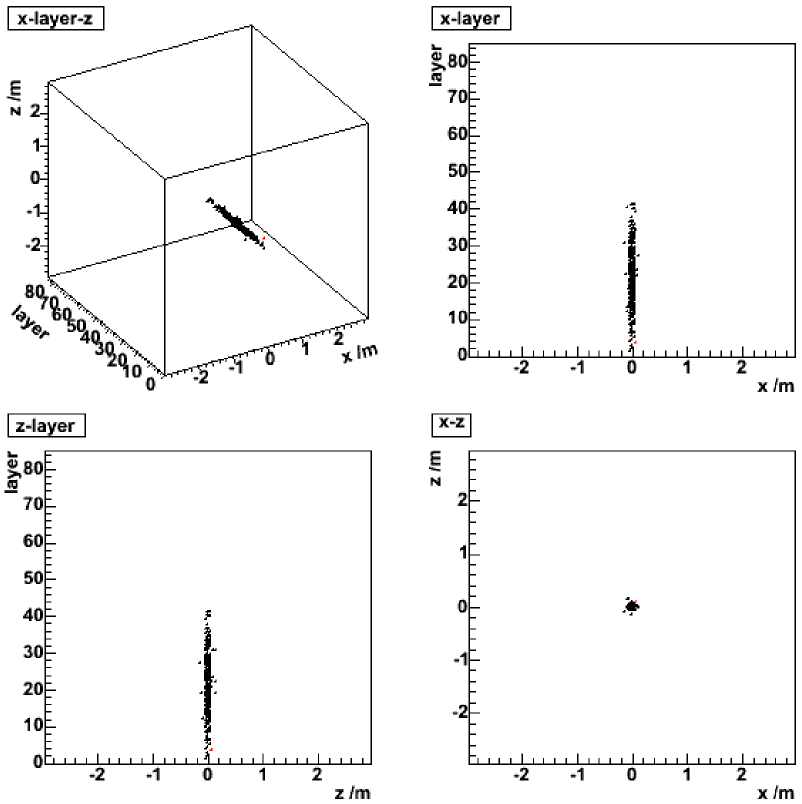
Algorithm in outline



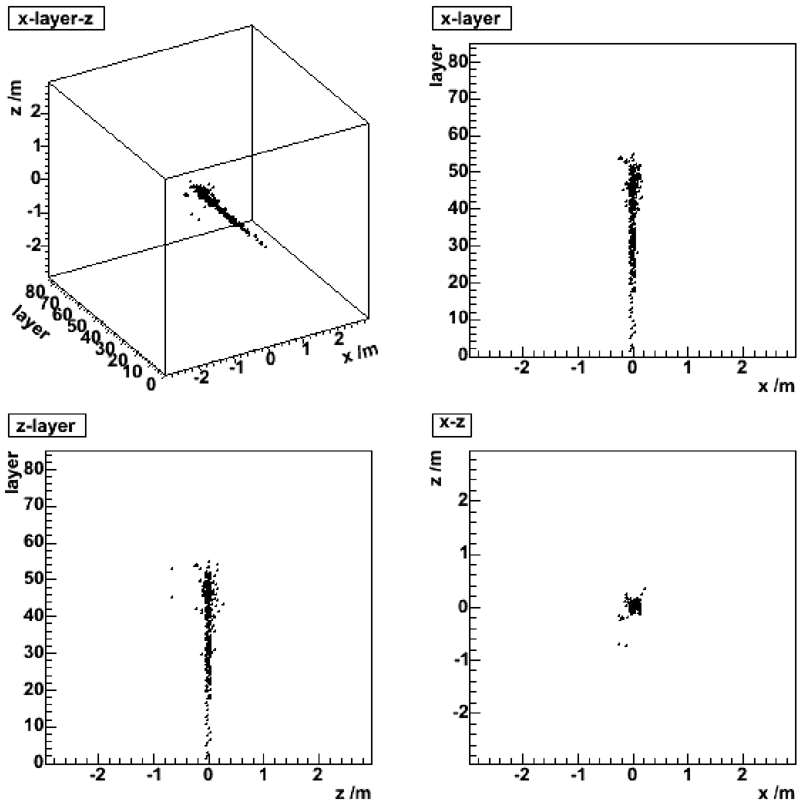
- Sum energy deposits within each cell.
- Retain cells with total hit energy above some threshold (⅓ MIP).
- Form clusters by tracking closely related hits through calorimeters:
  - for a given hit j in a given layer l, minimize the angle β w.r.t all hits k in layer l–1;
  - if $\beta < \beta_{max}$ 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 through Ecal, then Hcal;
  - do some retrospective tidying up.

Single-particle reconstruction

15 GeV e^-

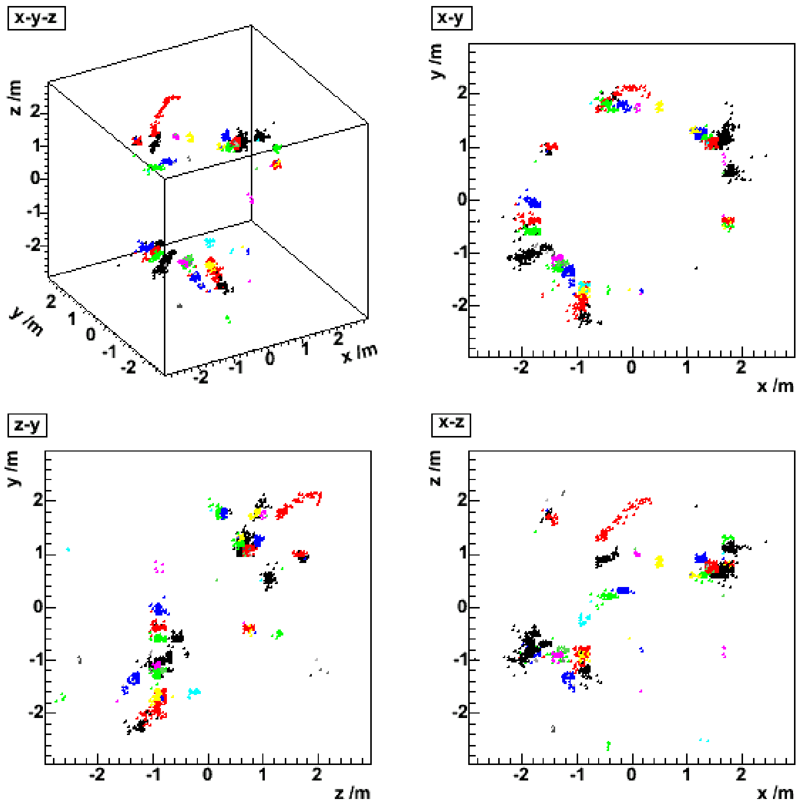


15 GeV π^-

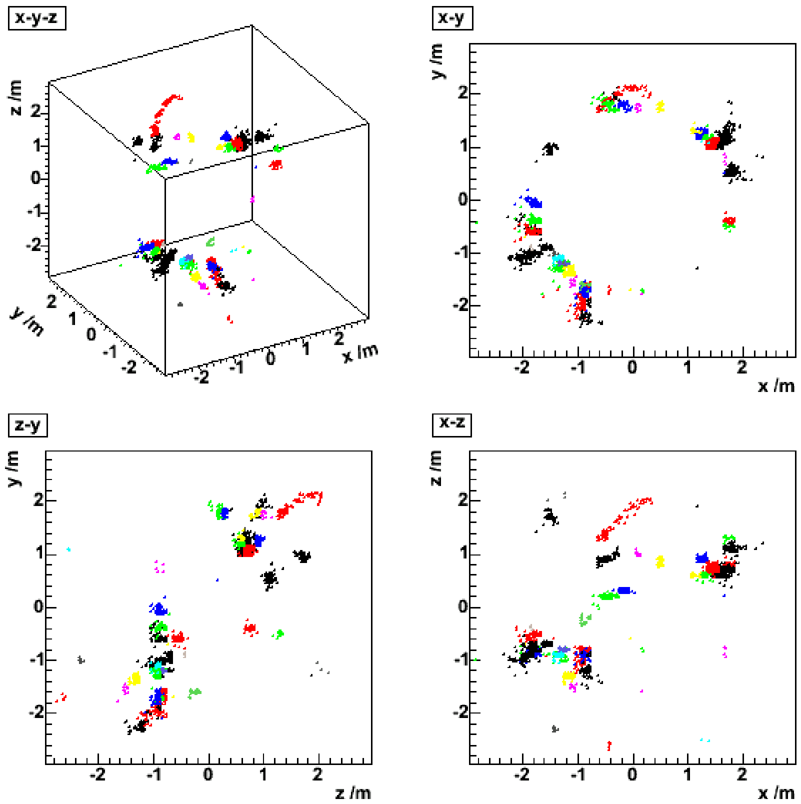


91 GeV Z event: Full barrel

Reconstructed clusters

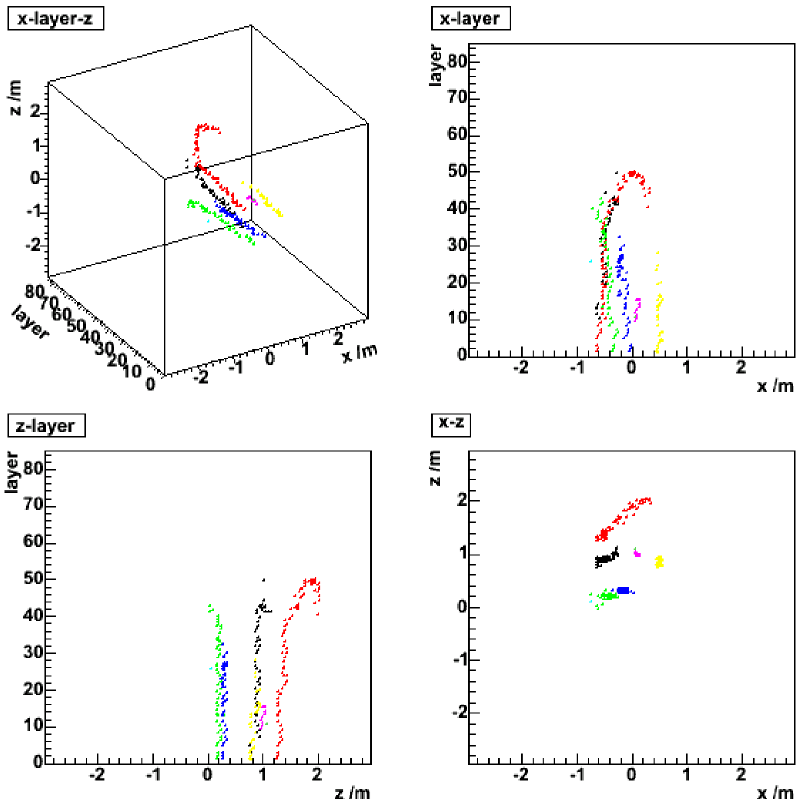


True particle clusters

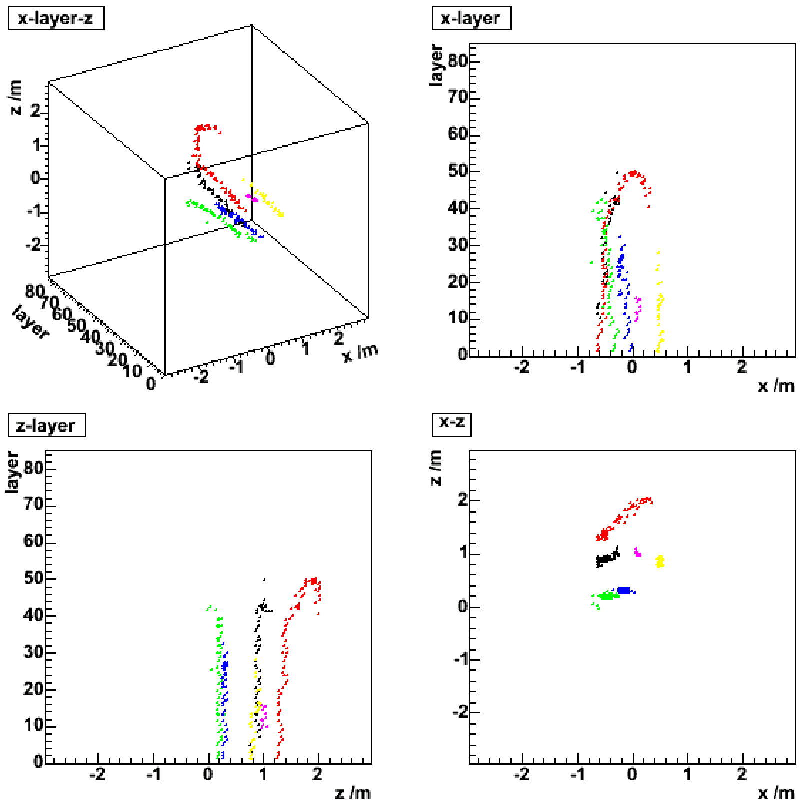


91 GeV Z event: Octant 1

Reconstructed clusters

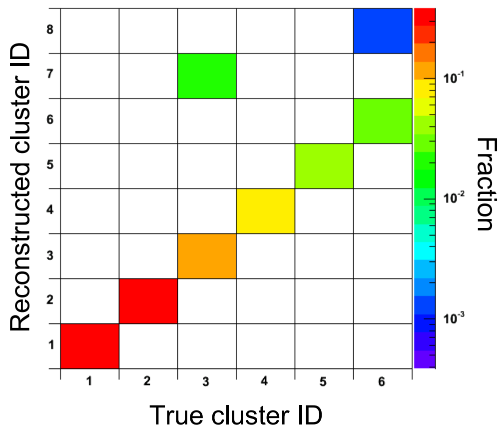


True particle clusters

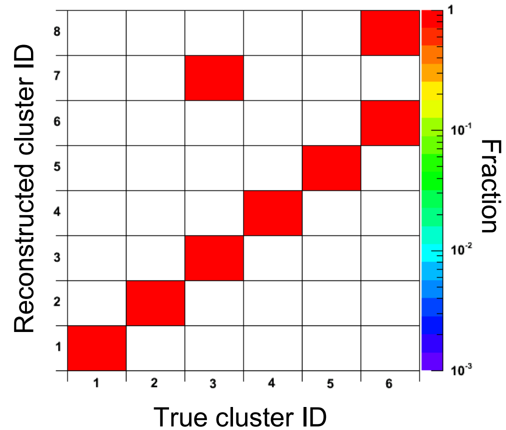


Octant 1: Performance

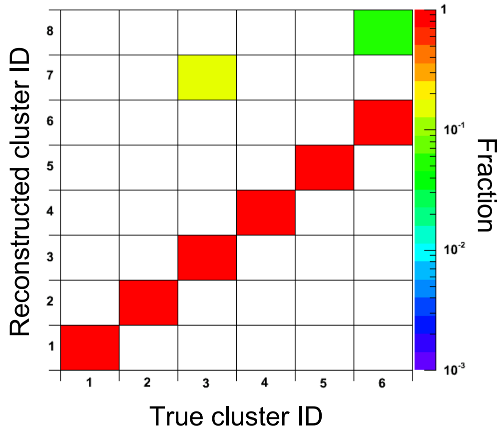
Fraction of octant energy in each true-reconstructed cluster pair



Fraction of reconstructed cluster energy in each true cluster



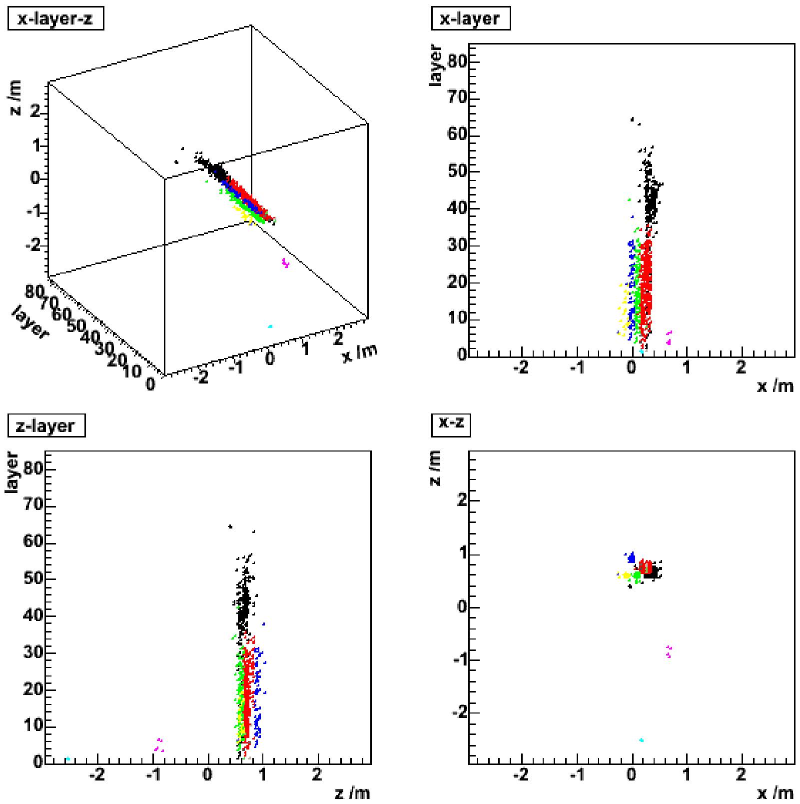
Fraction of true cluster energy in each reconstructed cluster



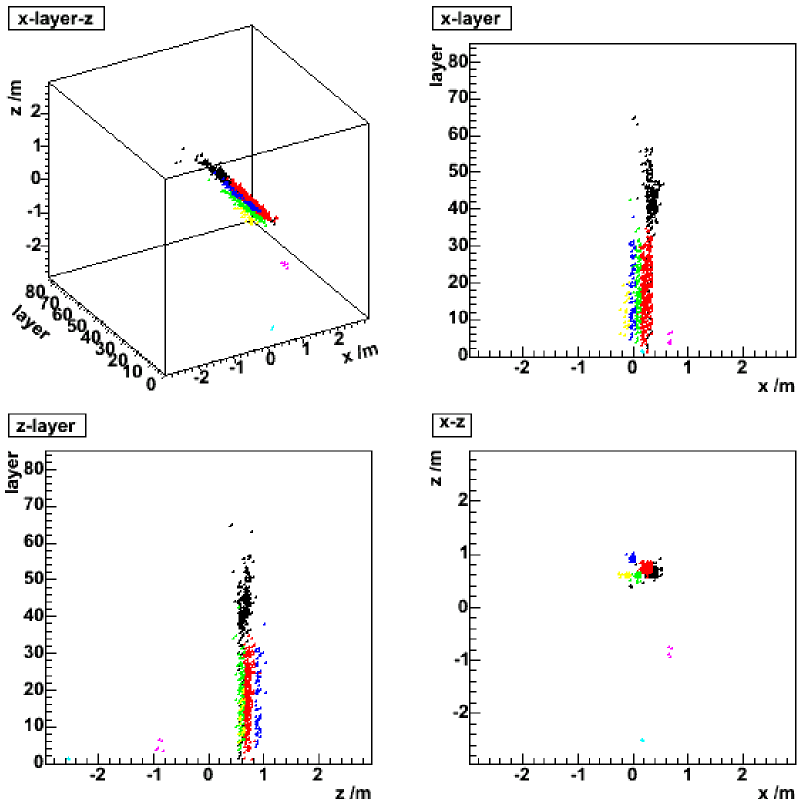
- 97.8 % of octant energy maps from true onto reconstructed clusters (2 clusters broken in reconstruction).
- 100 % of octant energy maps from reconstructed onto true clusters
  ⇒ no misassignments.

91 GeV Z event: Octant 8

Reconstructed clusters

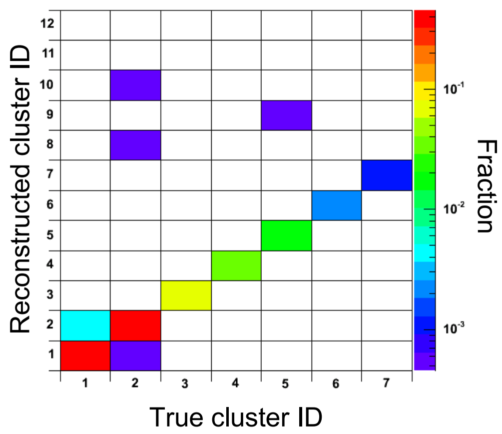


True particle clusters

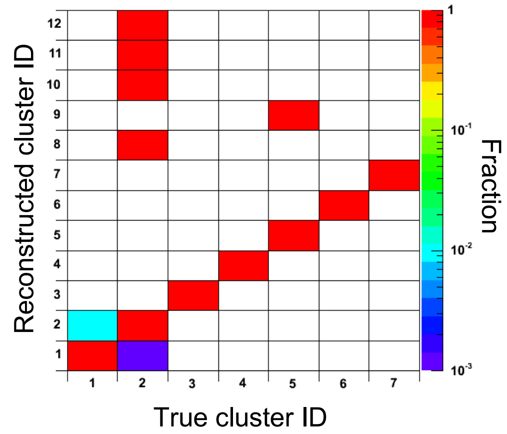


Octant 8: Performance

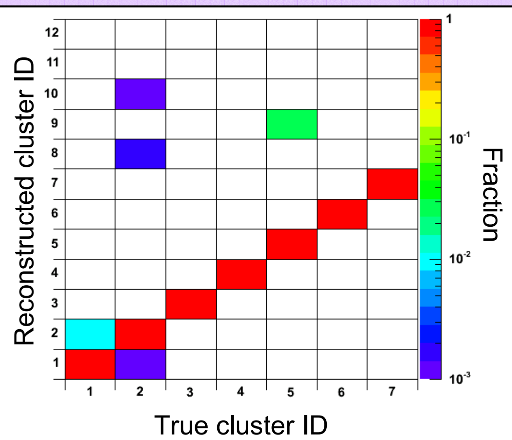
Fraction of octant energy in each true-reconstructed cluster pair



Fraction of reconstructed cluster energy in each true cluster



Fraction of true cluster energy in each reconstructed cluster



- 99.3 % of octant energy maps from true onto reconstructed clusters (3 clusters broken in reconstruction).
- 99.5 % of octant energy maps from reconstructed onto true clusters
  ⇒ almost no misassignments.

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).
- Testing with CALICE geometry.
- Works well for single-particles events.
- Encouraging signs for multi-particle events:
  - Averaged over 100 Z events at 91 GeV
    - 91.1 ± 0.5 % of event energy maps from true onto reconstructed clusters;
    - 94.3 ± 0.3 % of event energy maps from reconstructed onto true clusters.
  - Any better ways of assessing performance?
- Adapt to LCIO framework for easy comparison with alternative (existing and new) algorithms and for application to alternative detector geometries.