Efforts in Particle Flow

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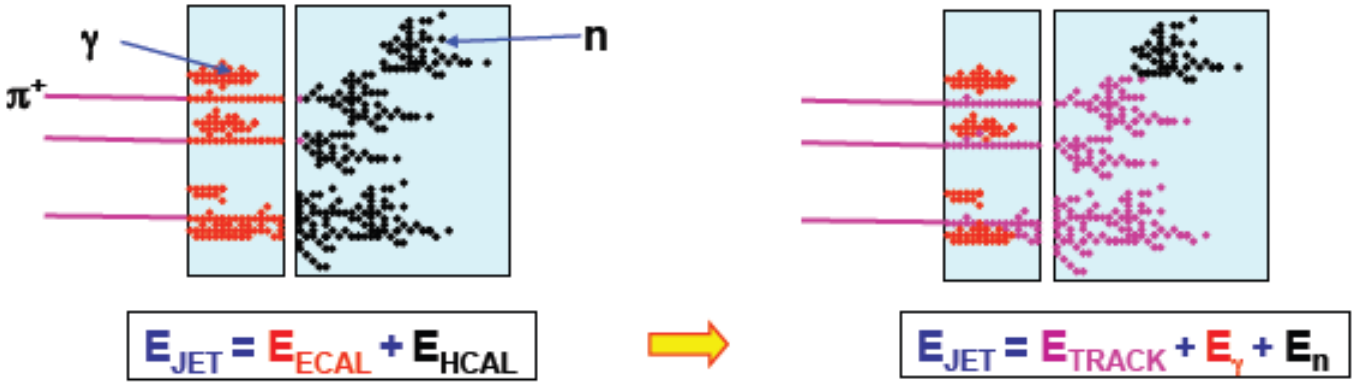
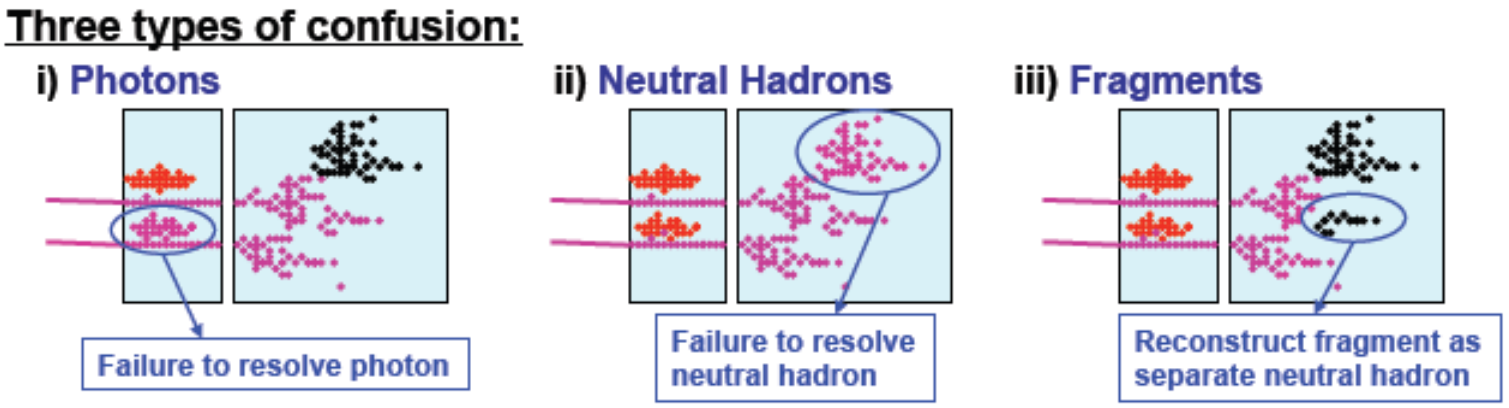
Particle Flow

- Jet energy is traditionally measured with the ECAL and HCAL. This limits the jet energy resolution (intrinsic HCAL resolution).
- Typical jet content: 60% charged hadrons, 30 % photons and 10 % neutral hadrons
- Particle flow aims to measure the energy of individual particles in the most optimal subdetector to improve the resolution;
  - Charged hadrons in the tracker
  - Photons in the ECAL
  - Neutral hadrons in the HCAL



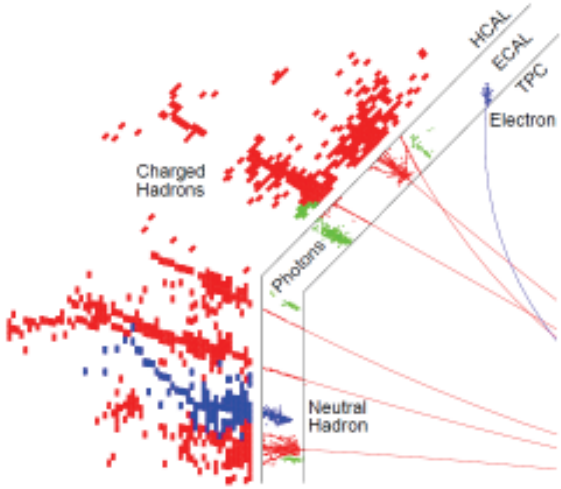
Particle Flow (2)

- Particle flow is a full detector concept involving both trackers and calorimeters.
- Highly granular calorimeters are needed to resolve energy deposits from different particles -> Important contribution from France in the R&D
- Sophisticated reconstruction software is needed to identify individual particles in the calorimeters -> France should contribute to show the full potential of the French R&D options
  - Confusion term determines the resolution – separate charged and neutral particles

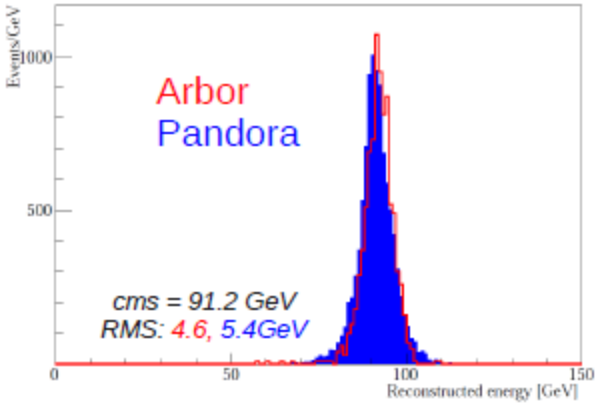


PandoraPFA

- The particle flow concept has been applied in the PandoraPFA algorithm (arXiv:0907.3577) it achieves a resolution of 3% in W Z separation for the baseline ILD detector
- In case of “perfect PFA” a performance gain of 2 is possible -> reduce the confusion term
- Would be good to have an alternative implementation
  - Already existing are
    - ARBOR (track fitting, constructing showers from a pattern of bushes Manqi Ruan & Henri Videau)
    - GARLIC (photons reconstruction, Daniel Jeans, Jean-Claude Brient & Marcel Reinhard, arXiv:1203.0774)
- Jet energy resolution requirements depend on the physics channels to be studied
- Possible design changes in ILD will put more stringent requirements on the resolution(radius reduction) and performance might change with different calorimeter techniques
- High granularity calorimeters offer the opportunity for e.g. tracking and classification

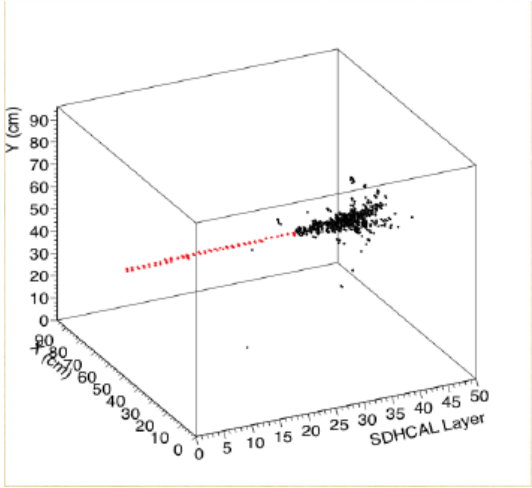


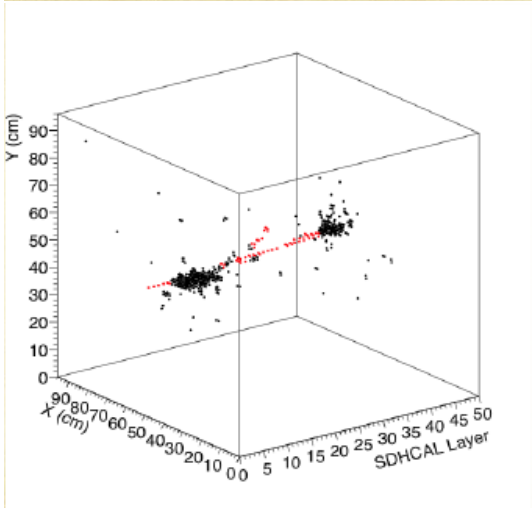
Typical topology of a simulated 250GeV jet in CLIC ILD



Identifying tracks in calorimeters using the Hough transform

- The Hough transform is ideally suited to detect geometrical shapes like straight lines and circles
- Calorimeter tracks can be used to identify charged particles and discriminate between hadrons and electrons, also this can contribute to improving MC models
  - Has been applied to SDHCAL test beam data (Presented at LCWS by Imad Laktineh)
  - Has been applied to Si-W ECAL test beam data (Felix Fehr CALICE ANALYSIS NOTE 23a)
- With respect to improving PFA tracks can determine the start of the shower and connect energy deposits belonging to the same prime shower





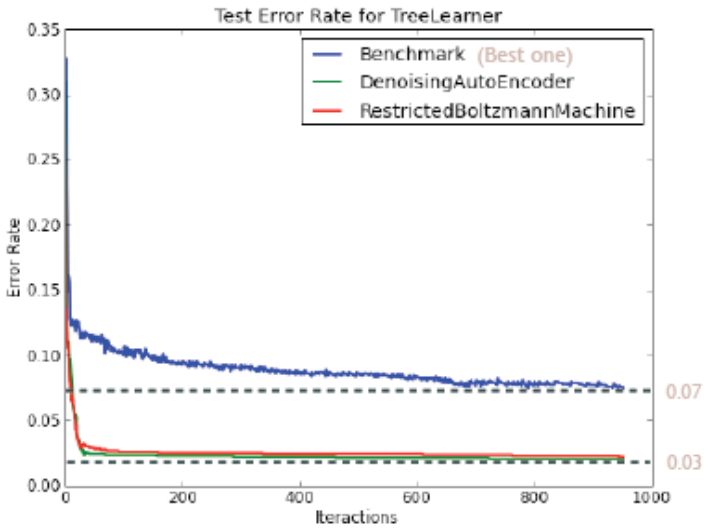
Pattern recognition of full showers

- Apply advanced machine learning techniques to assign each energy deposit to an incoming particle
- Study to classify events started on ECAL pion test beam data together with the AppStat group (B. Kegl) at LAL
- Methods:
  - Generative model (Geant4 parameterization) likelihood fitting of data
  - Direct approach using neural networks or boosted decision trees

Pattern recognition of full showers(2)

- Supervised learning – needs manual input of discriminating features and classes
- Deep learning – relevant features are automatically extracted from the data, then used in supervised learning
  These techniques are used extensively in speech and image recognition
- Promising/Interesting project:
  - PhD student granted from University Paris-Saclay
  - ANR (ARTIC) and P2IO applications submitted

Franck Dubard (AppStat)



Summary

- To reach the physics goals at future colliders highly granular calorimeters are needed as well as reconstruction algorithms to apply PFA
- Combining tracks from the tracker and calorimeter, together with proper assignment of energy deposits to incoming particles, will enable the reconstruction of particles which can lead to improved PFA implementations
- Many ideas and promising new methods to explore in order to improve the application of the PFA and as a results the physics capabilities of future colliders
- A coordinated effort in France is mandatory

Long road ahead…

- Improvements to PandoraPFA
  - (s)DHAL calibration
  - Optimization for (s)DHCAL
  - Improved energy estimation: energy weighting, (s)DHCAL: hit density, AHCAL: energy profile
  - Integrate the GARLIC photon finder into Pandora
  - Tracking and vertexing at low energies
- Track fitting and pattern recognition
- Develop improved PFA
- Explore all the available test beam data
  - Notably the combined ECAL + DHCAL data