Efforts in Particle Flow

& Simulation

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sur les slides de Naomi van der Kolk (LAL, LLR)

Présentation aux JCL IRFU/CNRS

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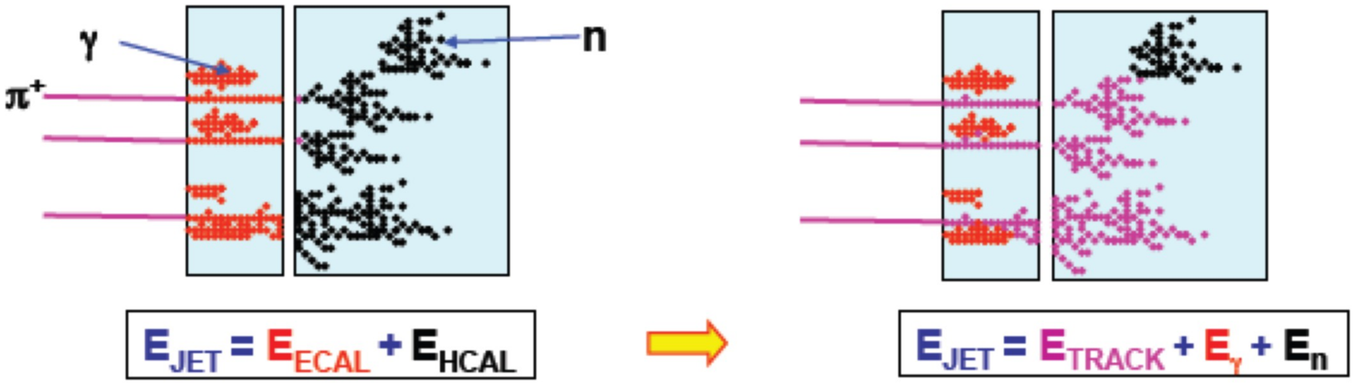
Particle Flow

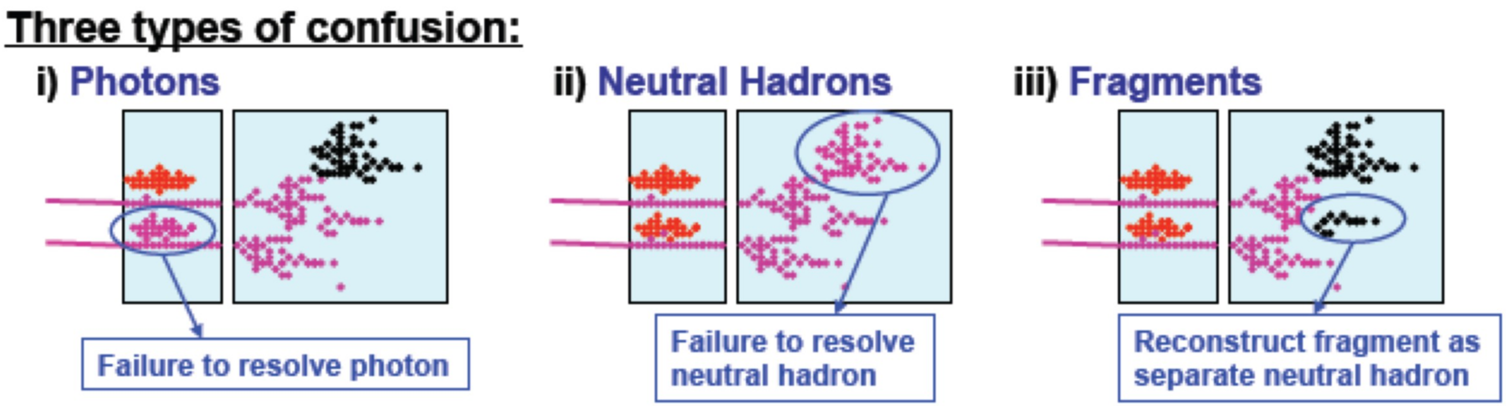
- Jet energy is traditionally measured with the ECAL and HCAL.
  This limits the jet energy resolution **[JER]** (intrinsic HCAL resolution).
- Typical jet content: 60% charged hadrons, 30 % photons and 10 % neutral hadrons
- Particle flow aims at measuring the energy of individual particles in the most optimal sub-detector to improve the resolution;

Charged hadrons in the tracker; Photons in the ECAL; Neutral hadrons in the HCAL



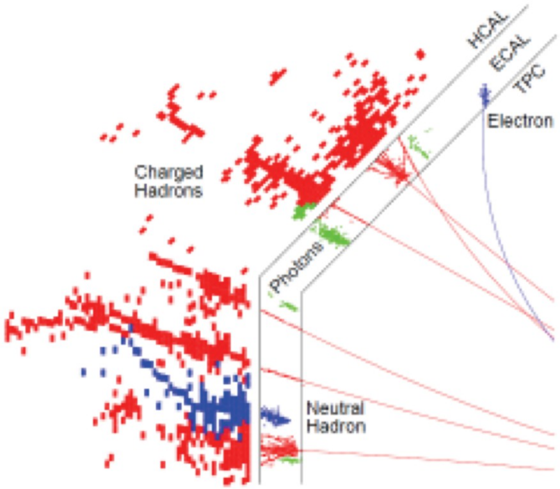
Particle Flow (2)

- 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 there solution – separate charged and neutral particles

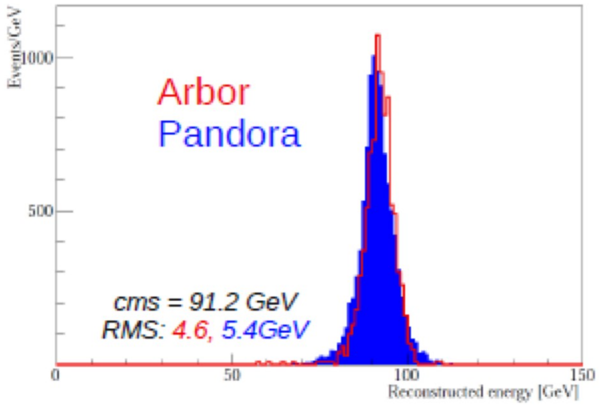


PandoraPFA

- The particle flow concept has been applied in the PandoraPFA algorithm (arXiv:0907.3577) ; it achieves a resolution of 3% needed for W/Z separation for the baseline ILD detector.
- In case of "perfect PFA" a performance gain of 2 is possible → reduce the confusion term
- but PandoraPFA optimised on ILD baseline (SiW ECAL + AHCAL 3×3 cm^2 in TESLA geom).
- Would be good to have an alternative implementation
  - Already existing pieces are
    - ARBOR (track fitting, constructing showers from a pattern of bushes Manq iRuan & Henri Videau)
    - GARLIC (photons reconstruction, Daniel Jeans, Jean-Claude Brient & Marcel Reinhard, arXiv:1203.0774)
- JER 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

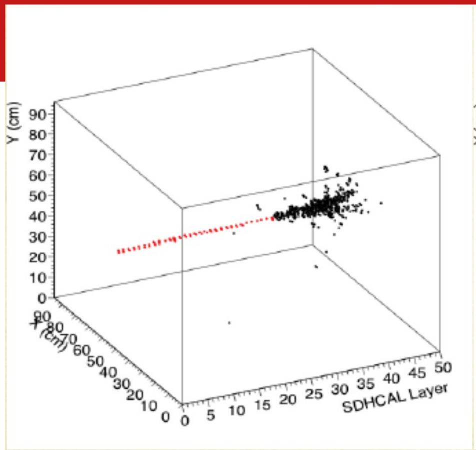


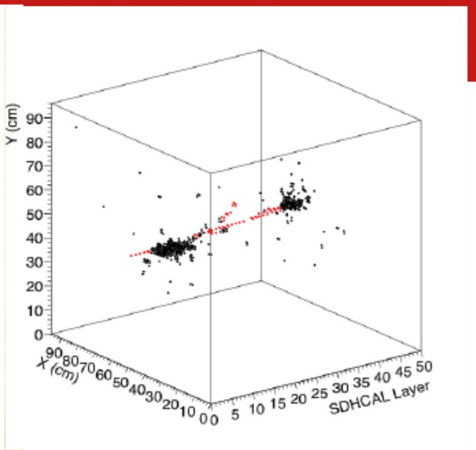
Typical topology of a simulated 250GeV jet in CLIC ILD

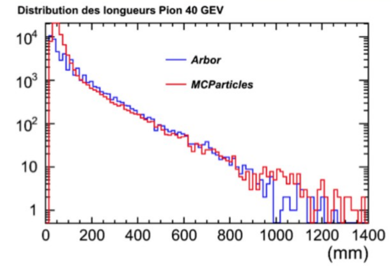


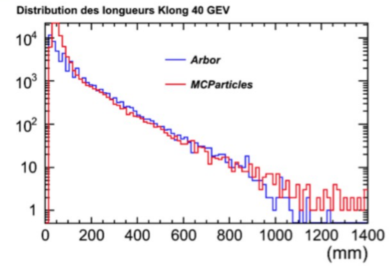
Identifying tracks in calorimeters

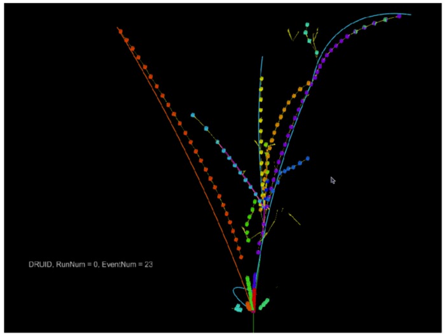
- Calorimeter tracks can be used to
  - identify charged particles (→ reduce fluctuations)
  - better follow in shower particles (→ reduce confusion)
  - better estimate the shower leakage (~10% in 3.5T, L≥20cm)
  - improve MC models
- The Hough transform is ideally suited to detect geometrical shapes like straight lines and circles
  - Has been applied to SDHCAL test beam data
    (Presented at LCWS by Imad Laktineh) (with no B field)
  - Has been applied to Si-W ECAL test beam data
    (Felix Fehr CALICE ANALYSIS NOTE 23a)
- Alternative methods:
  - "by hand" Layer by layer follow-up
    (recent paper on tracks from CALICE in AHCAL)
  - Fit on ARBOR Branches
- With respect to improving PFA tracks can determine the start of the shower and connect energy deposits belonging to the same prime shower







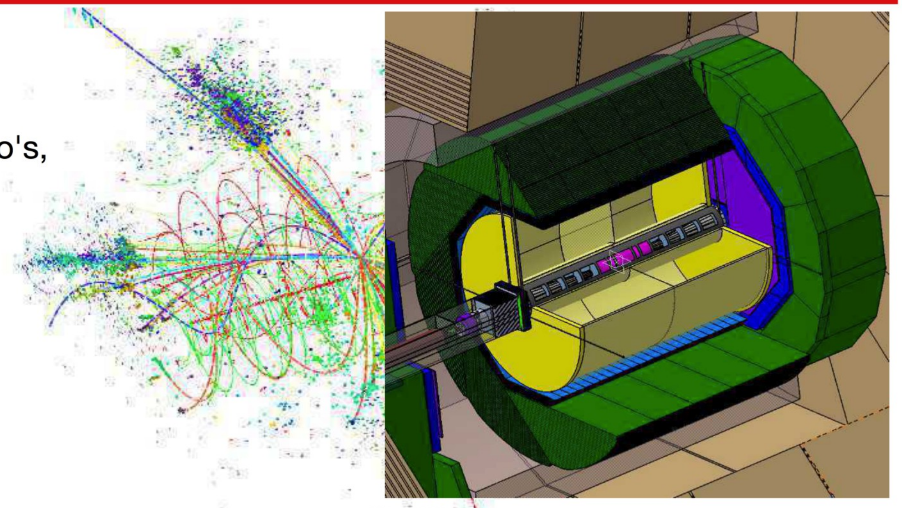


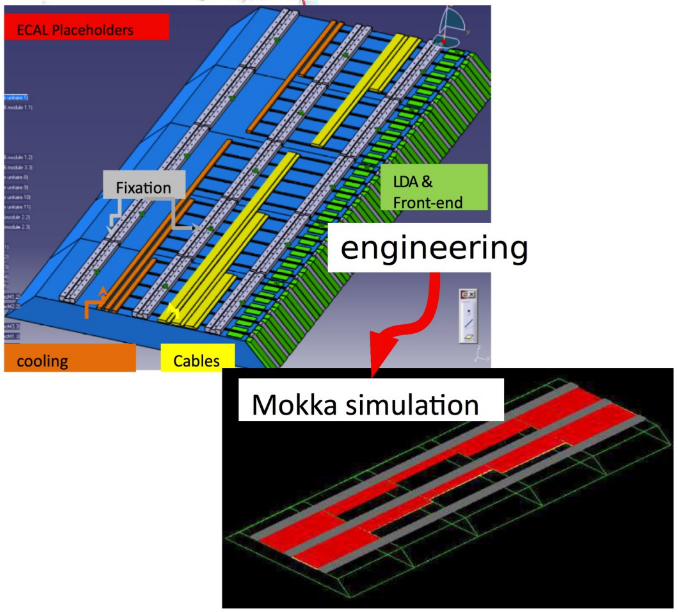


MC model (Mokka)
MC Objects
Events Display
Reconstruction

MC models & digitizers

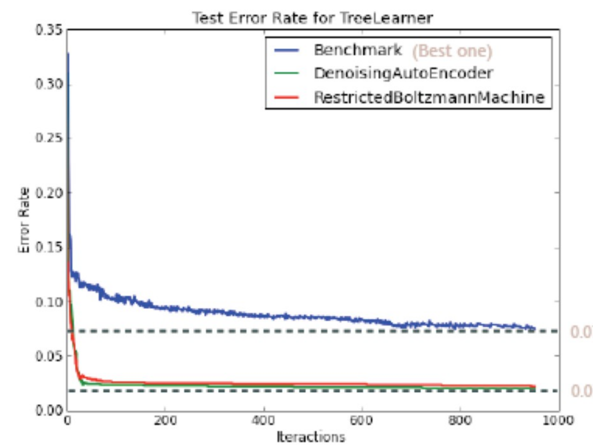
- Mokka:
  - Parametrized model of ILD (and CALICE TB setup: proto's, beam line)
    - R_{VTX}, Half_Z (VTX), N_{layers}, N_{disks}, …
      - ⇒ Ncells in I,j for all VTX dets
    - TPC Half-z, R_TPC, ECAL wafer, ECAL & HCAL Cell_size, N_{layers} in ECAL & HCAL)
      - ⇒ ZECAL, RECAL, Ncells in I, j
        - ⇒ Z HCAL, R HCAL
          - ⇒ R Coil
            - ⇒ Yoke
  - Central DB for geom + Drivers ⇒ Steering + GEANT4 code
  - Used for the ILD simulations (ILC & CLIC): ex. DBD production
  - Support (LLR ➘): historical
- DD4HEP: parametrised model for geom (TGeo + XML/Python drivers)
  - Improved calc time (part trajectory intercept with volume boundaries
  - Being developed in AIDA





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 SiW ECAL pion test beam data together with the App Stat group (B. Kegl) at LAL
- Methods:
  - Generative model (Geant4 parameterization) likelihood fitting of data
  - Direct approach using neural networks or boosted decision trees
- 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

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
- Data is there:
  - SDHCAL CERN TB data
  - ECAL Phys.; ECAL Phys + DHCAL (US; FNAL TB Data)
  - Simulation: ILD (with B field)
- A coordinated effort in France is mandatory
  - ANR ARTIC ? LAL(×2), LLR, IPNL

Long road ahead…

- Improvements toPandoraPFA
  - (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

Example of Information flow....