Particle flow reconstruction for ILD detector model with SDHCAL

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Asian Linear Collider Workshop 2018
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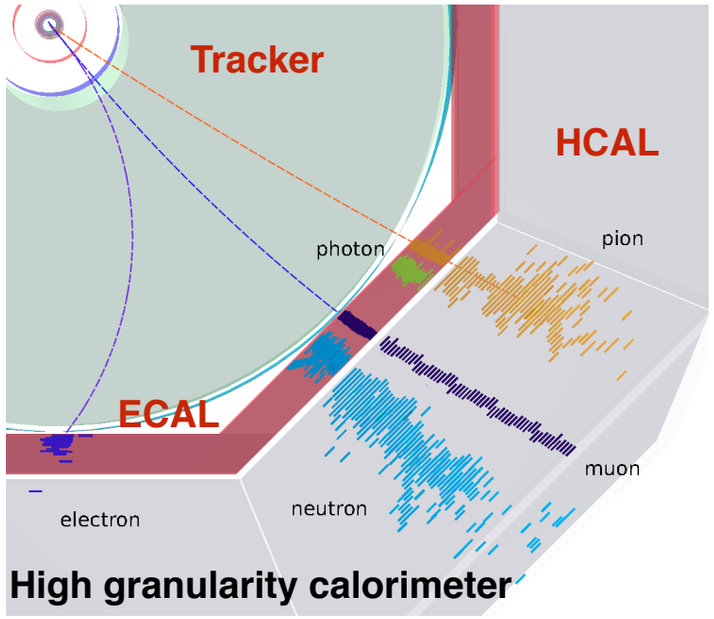
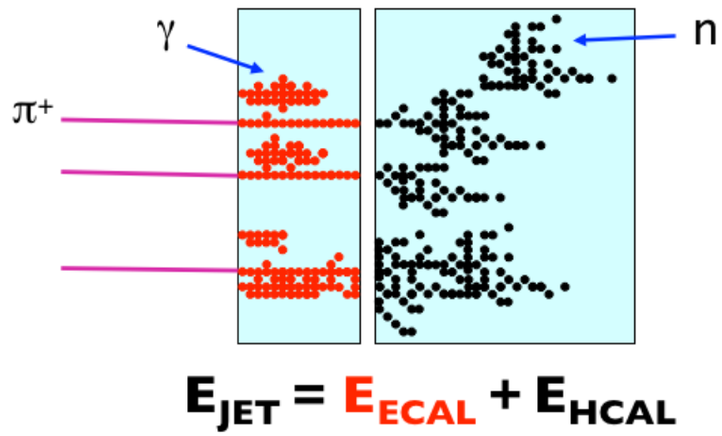
Outline

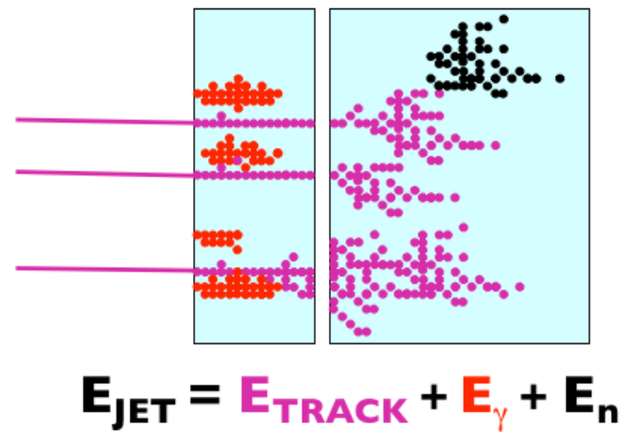
- SDHCAL energy reconstruction
- PFA performance for ILD SDHCAL option
- Status of ArborPFA

Particle flow algorithm

- Particle flow algorithm (PFA): an algorithm that tries to reconstruct individual final state particles from the recorded information by detector.

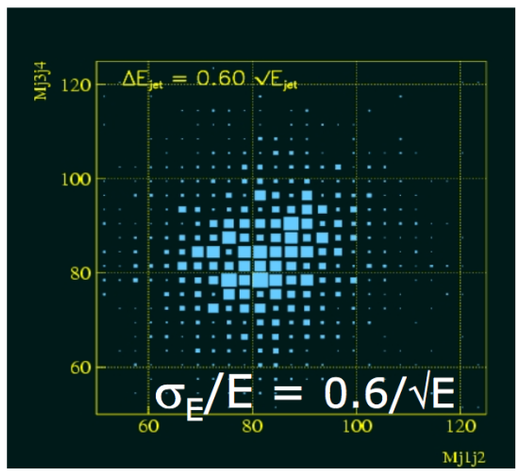


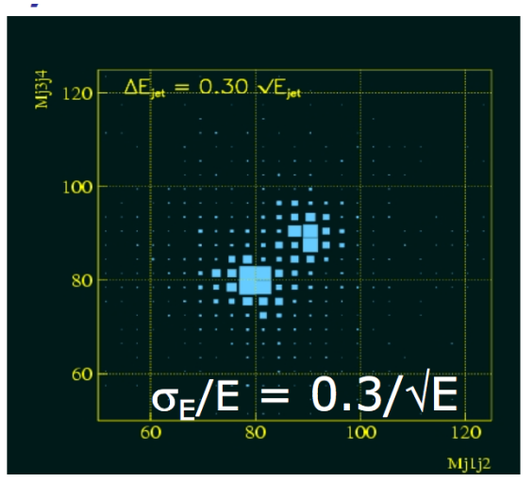




arXiv: 1308.4537

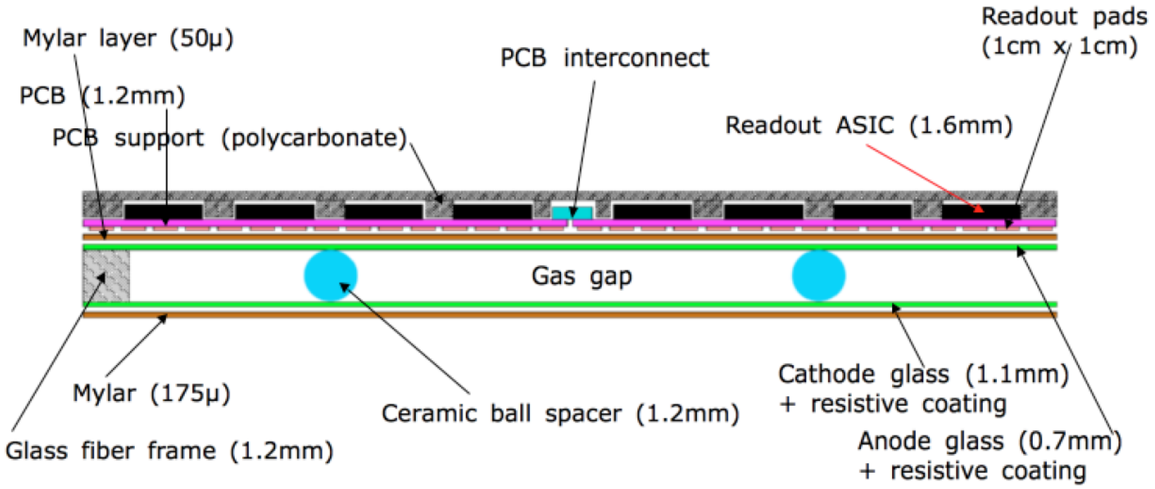
- PFA can make jet reconstruction more accurately
- Types of high granularity HCAL
  - Analog HCAL
  - Digital HCAL
  - Semi-Digital HCAL





- Jet energy resolution at ILC: $\sigma_E/E \lesssim 3.5\%$ in the range of 50 to 500 GeV

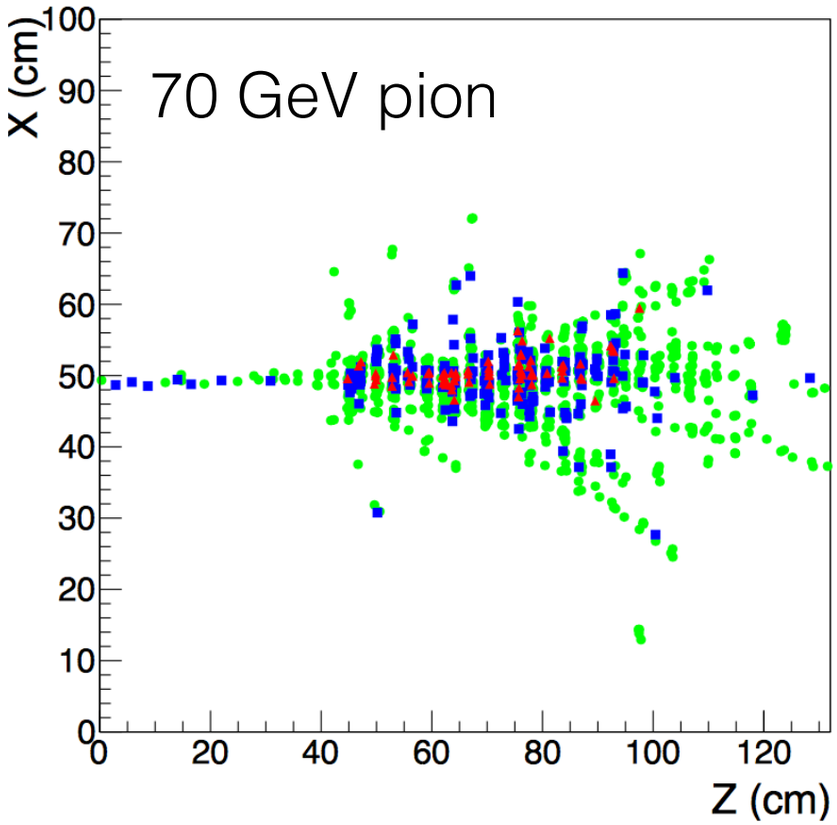
Semi-Digital HCAL



arXiv:1602.02276

- 48 layers, GRPC(1×1 m^2)
- 9216 pads (1×1 cm^2) for each layer
- three thresholds

Beam test@CERN, Sep. 2017



SDHCAL Energy reconstruction

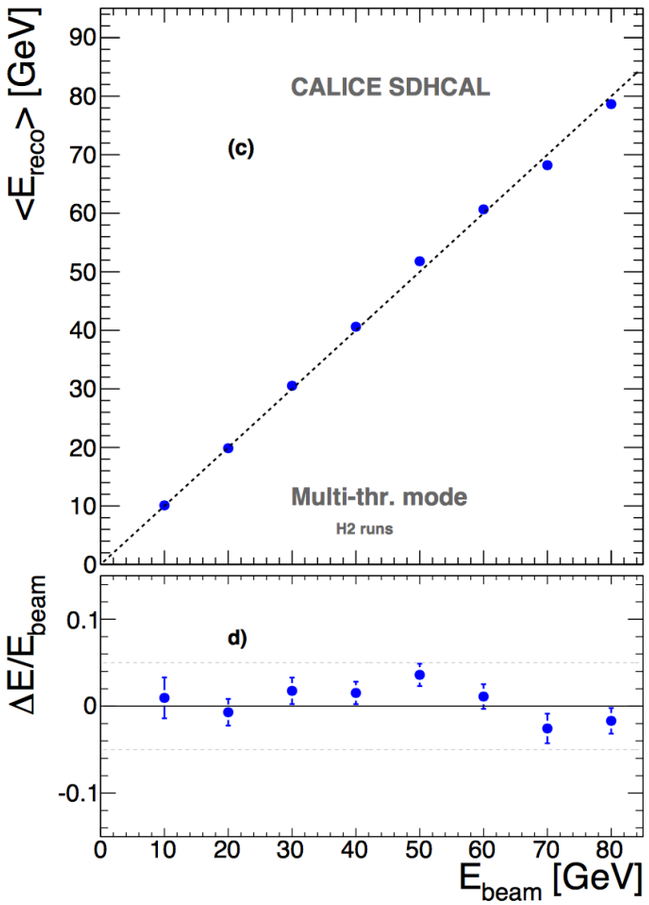
Linear formula

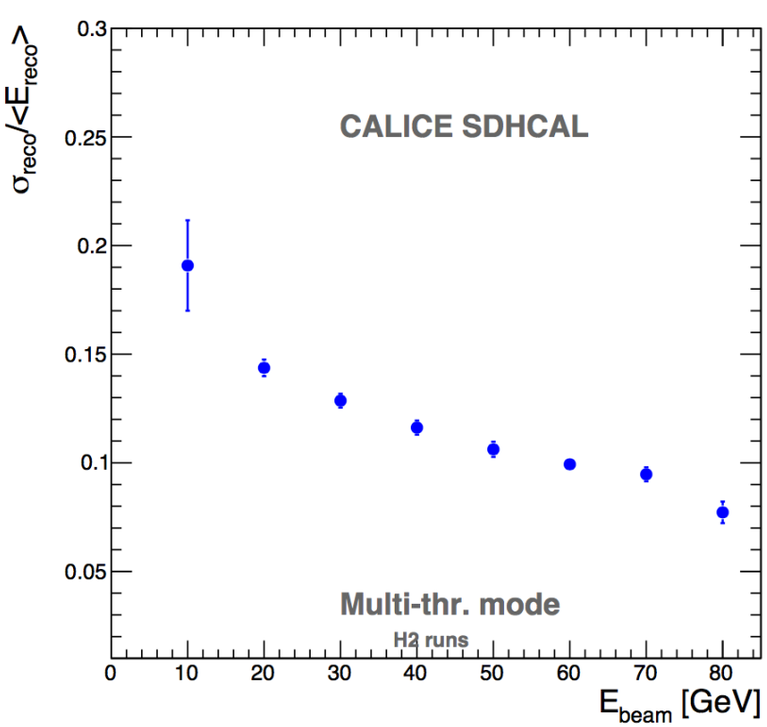
$$E_{rec} = \alpha N_1 + \beta N_2 + \gamma N_3$$

Quadratical formula

$$E_{rec} = (\alpha_1 + \alpha_2 N_{tot} + \alpha_3 N_{tot}^2) N_1 + (\beta_1 + \beta_2 N_{tot} + \beta_3 N_{tot}^2) N_2 + (\gamma_1 + \gamma_2 N_{tot} + \gamma_3 N_{tot}^2) N_3$$

- With the reconstruction by quadratical formula, both test beam and simulation show better linearity and resolution results for SDHCAL.
- And validity of the quadratical energy parametrization method confirmed for overlapped showers (see my talk at LCWS2017)





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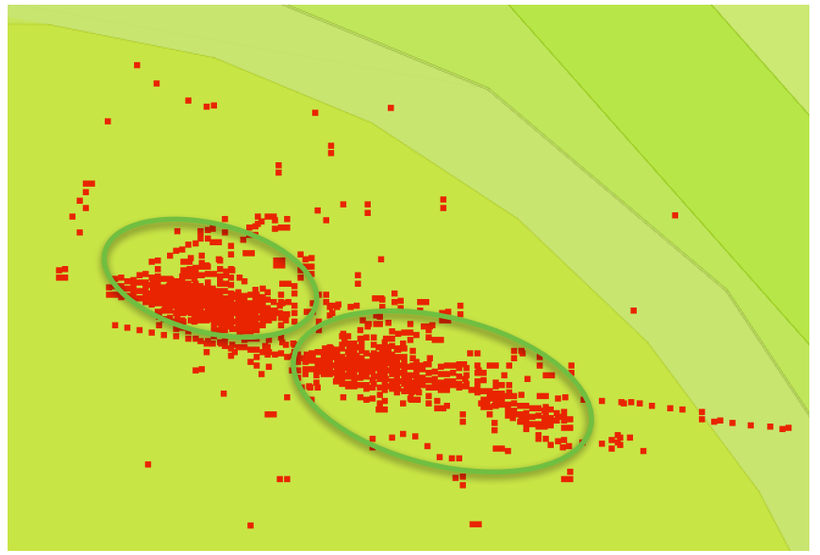
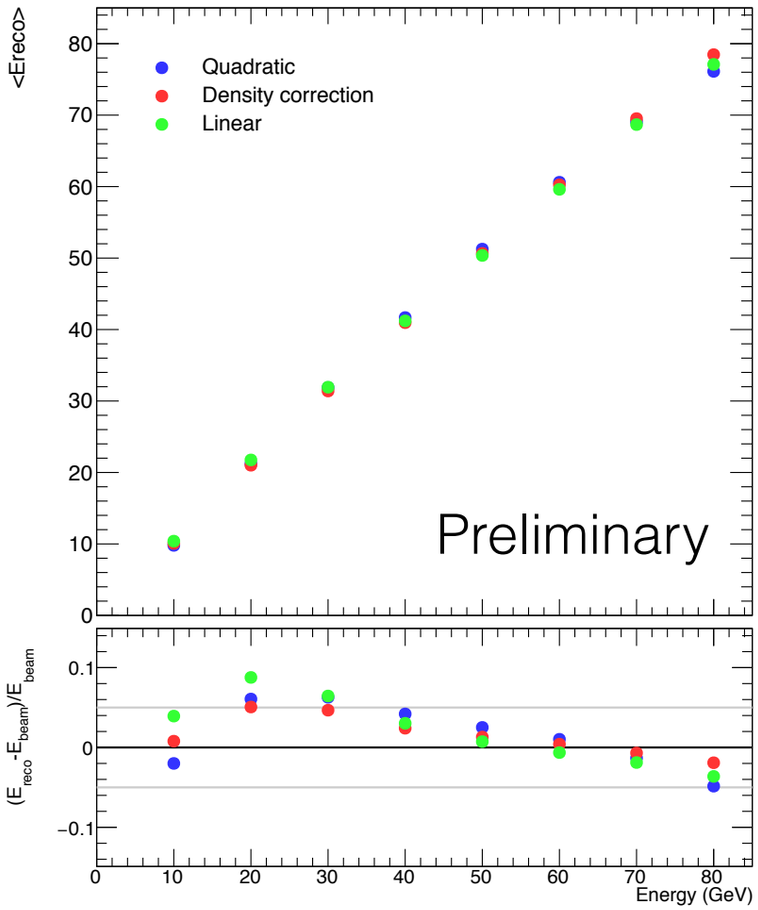
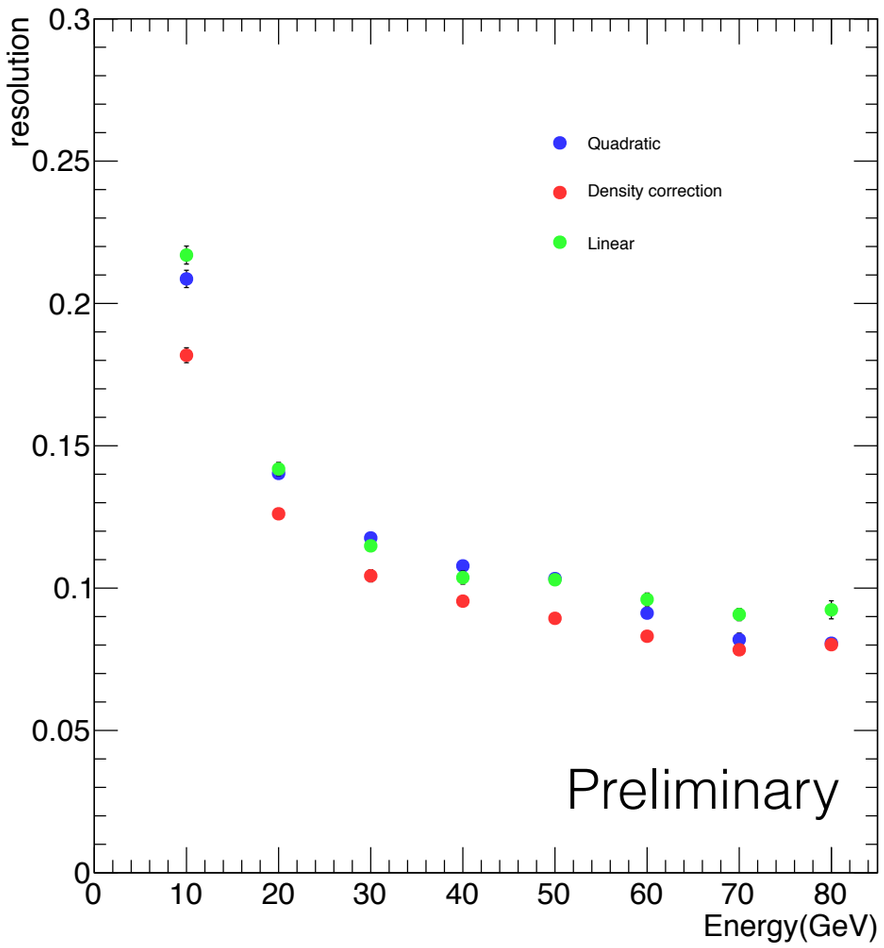


- Clustering stage ?
- Density correction: 9 possible discrete densities for each hit, the idea is similar to software compensation

Calibration

- Calibration of SDHCAL parameters for a ILD model with SDHCAL, **ILD_l5_o2_v02**





- Calibration of all PFA related parameter with **LCCalibration** (Rémi Ete)
  - The weights of hadronic shower in ECAL and HCAL are impactful to our calibration.
  - ECAL and muon detector related parameters keep the same as ILD_l5_o1_v02
  - Parameters of MIP are not used for calculation of hit energy

Calibration parameters

ILD_l5_o1_v02

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ILD_l5_o2_v02

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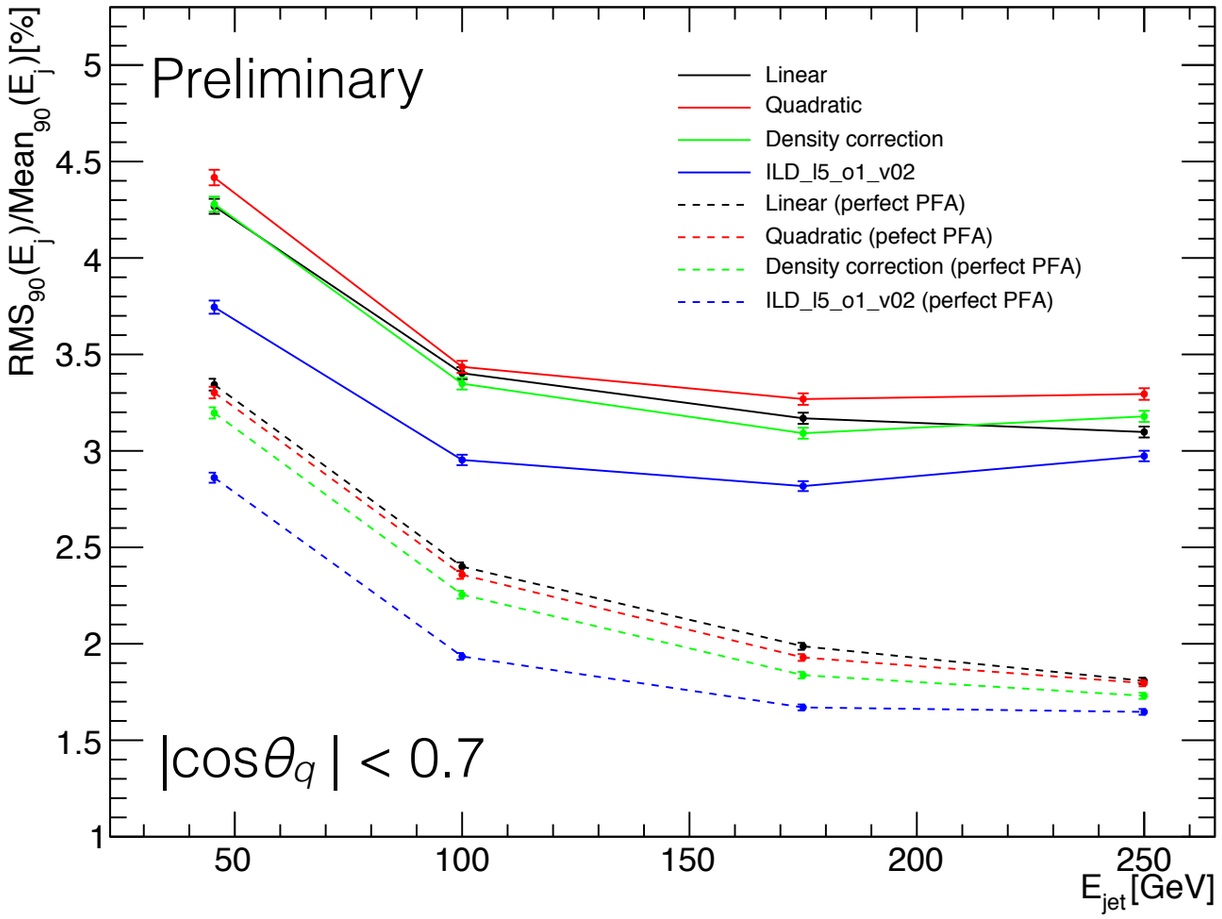
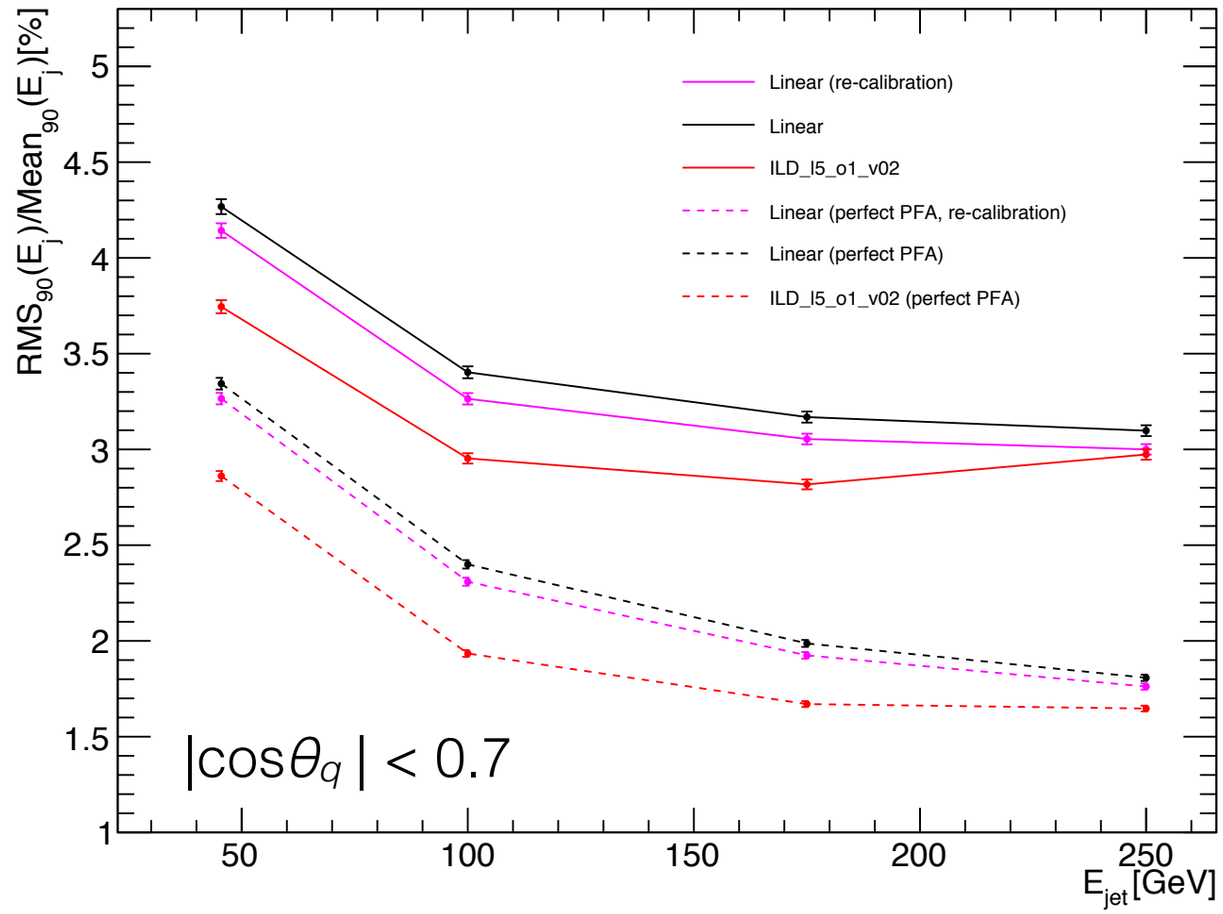
→ 27.2

Jet energy resolution

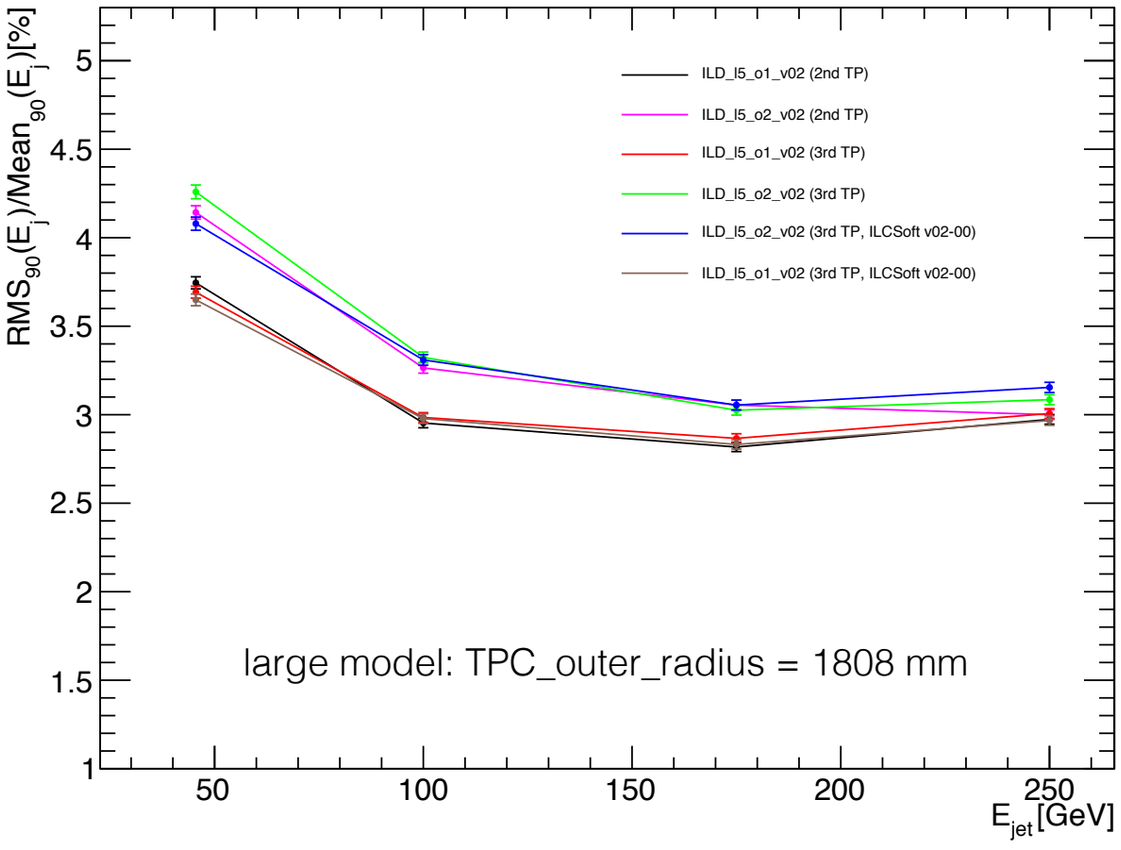




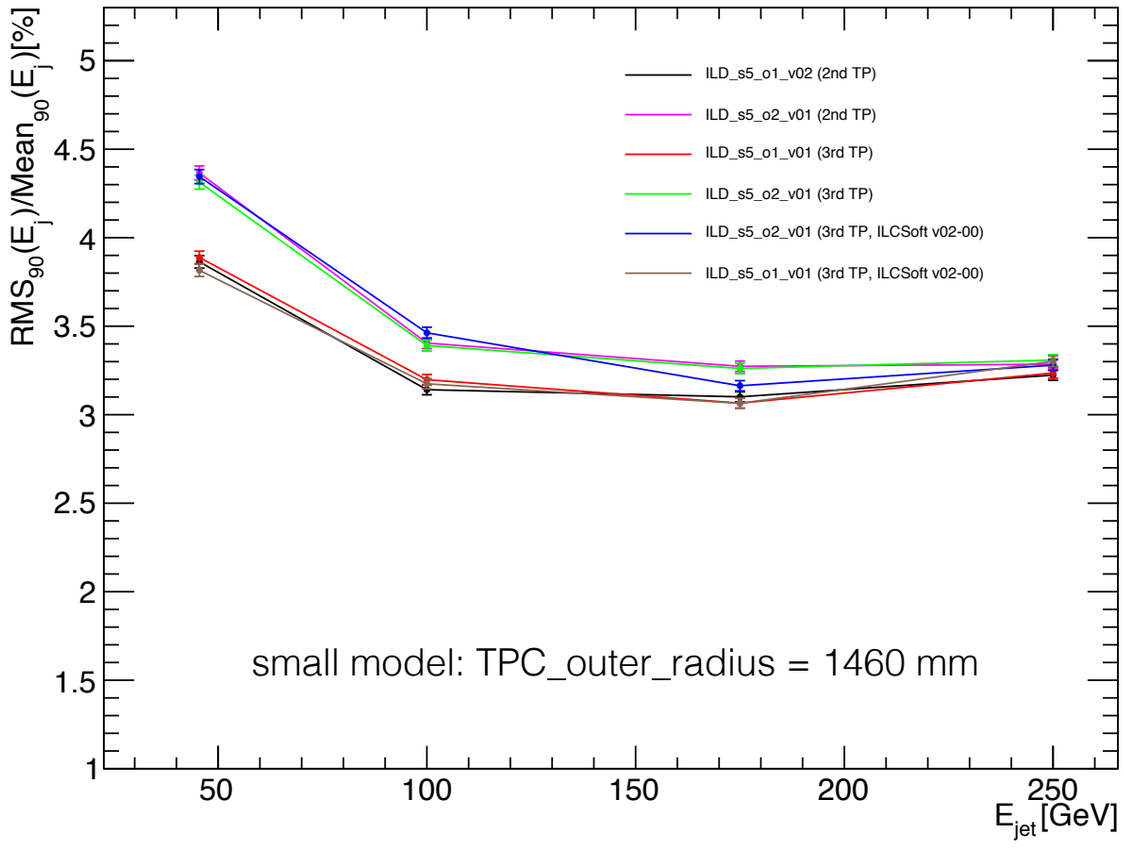
- Particle flow reconstruction is done by PandoraPFA
- Quadratic parametrization and density correction may have better JER than linear parametrization. We need to make a re-calibration for these two methods.
- After a re-calibration to PFA parameters under the case of linear parametrization, it even shows better JER result.

JER in test production

- Results for different ILD models, test productions and ILCSoft versions
  - ILD_l/s5_o1_v02 calo: SiW ECAL + AHCAL
  - ILD_l/s5_o2_v02 calo: SiW ECAL + SDHCAL
  - uds samples, simulation and reconstruction done by ILD software working group



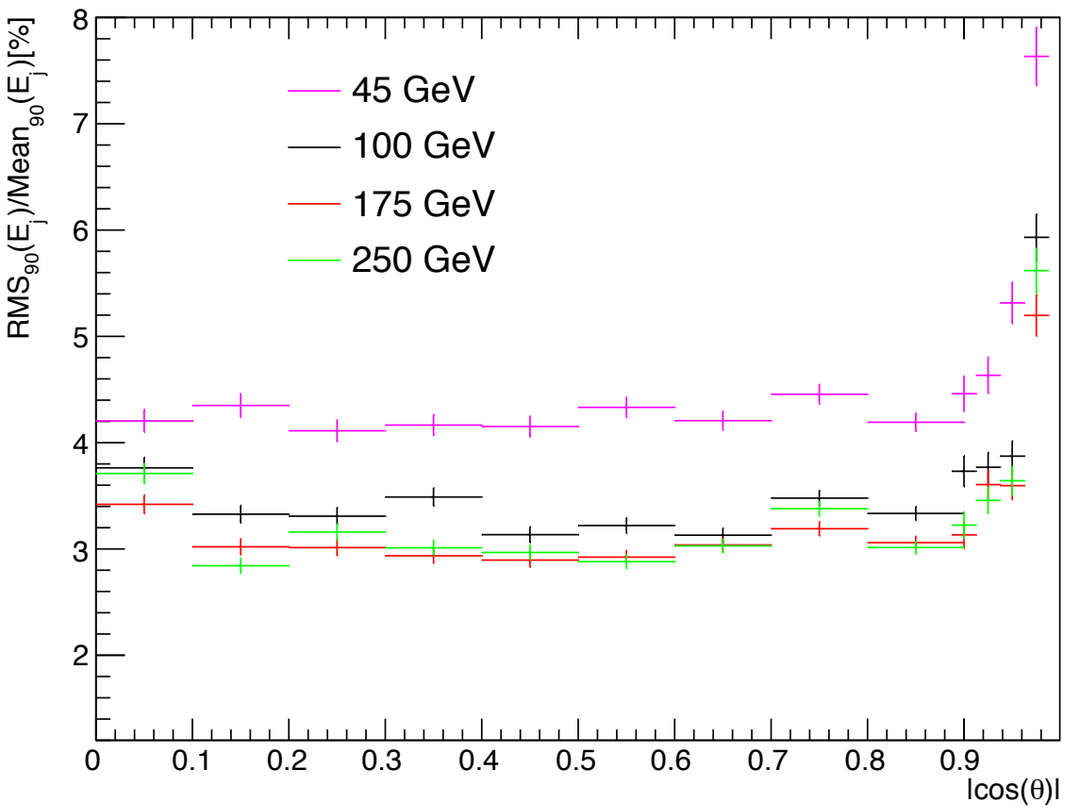
large models



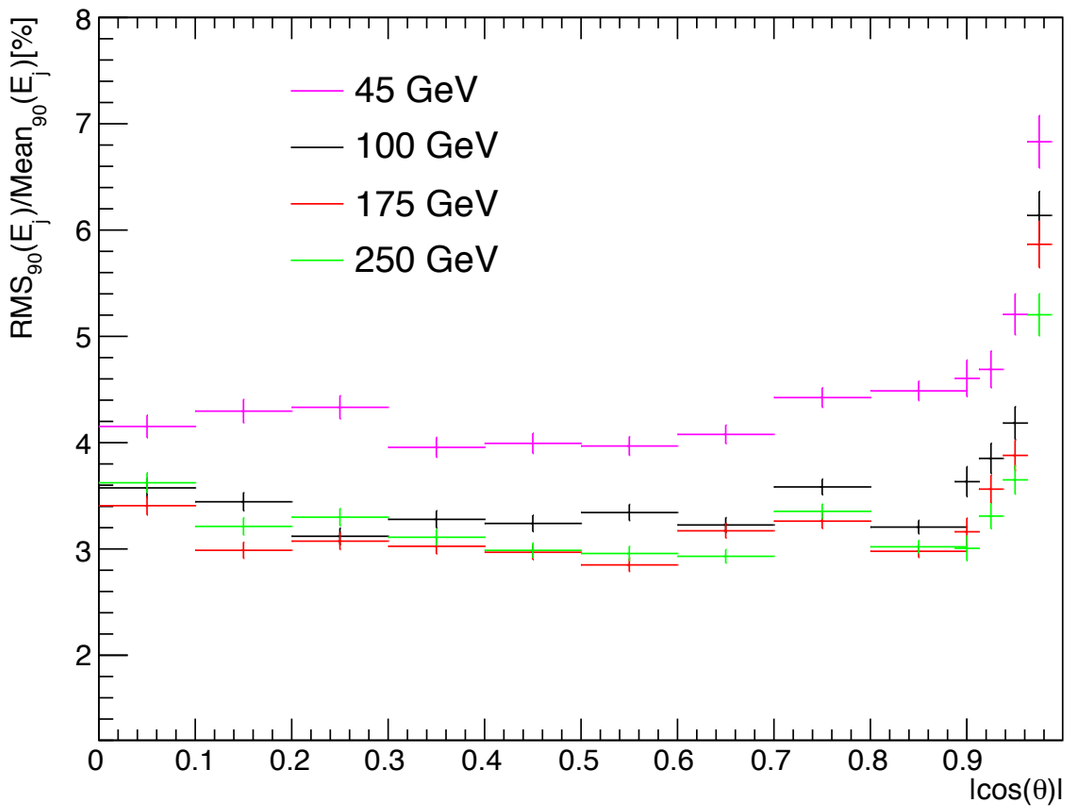
small models

JER vs. polar angle

ILD_l5_o2_v02



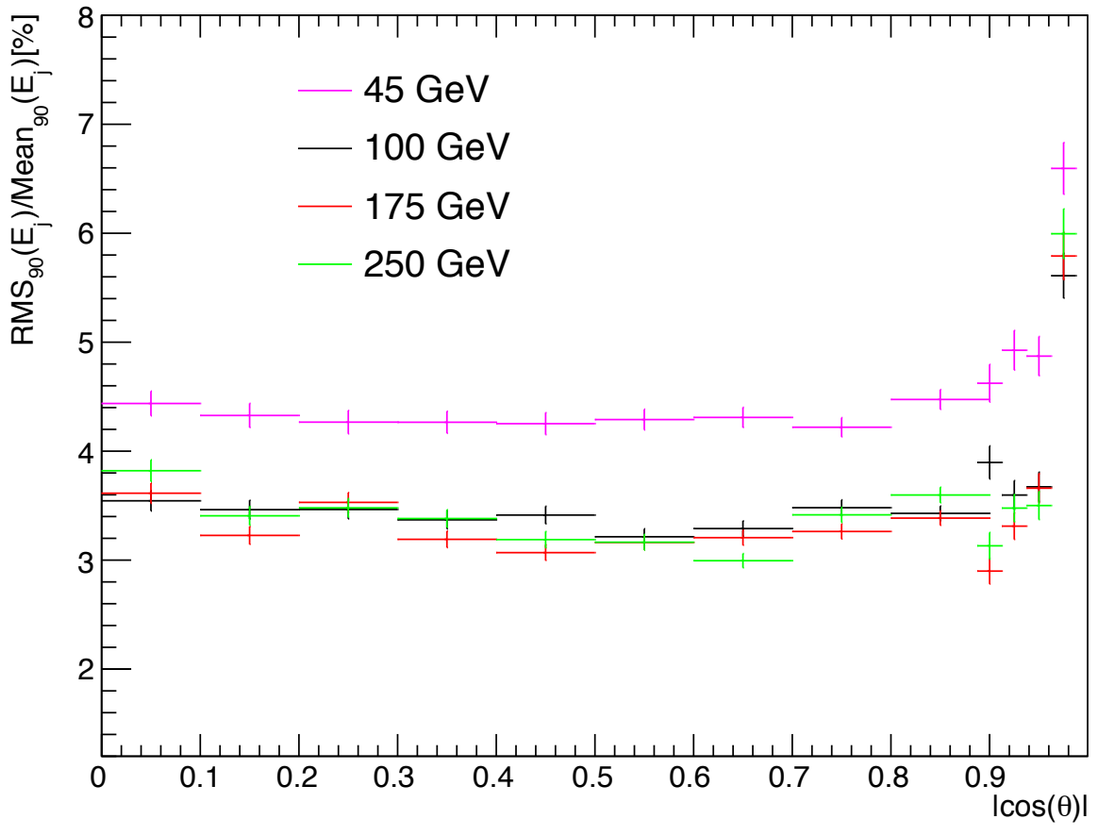
ILCSoft v01-19-06



ILCSoft v02-00

JER vs. polar angle

ILD_s5_o2_v02



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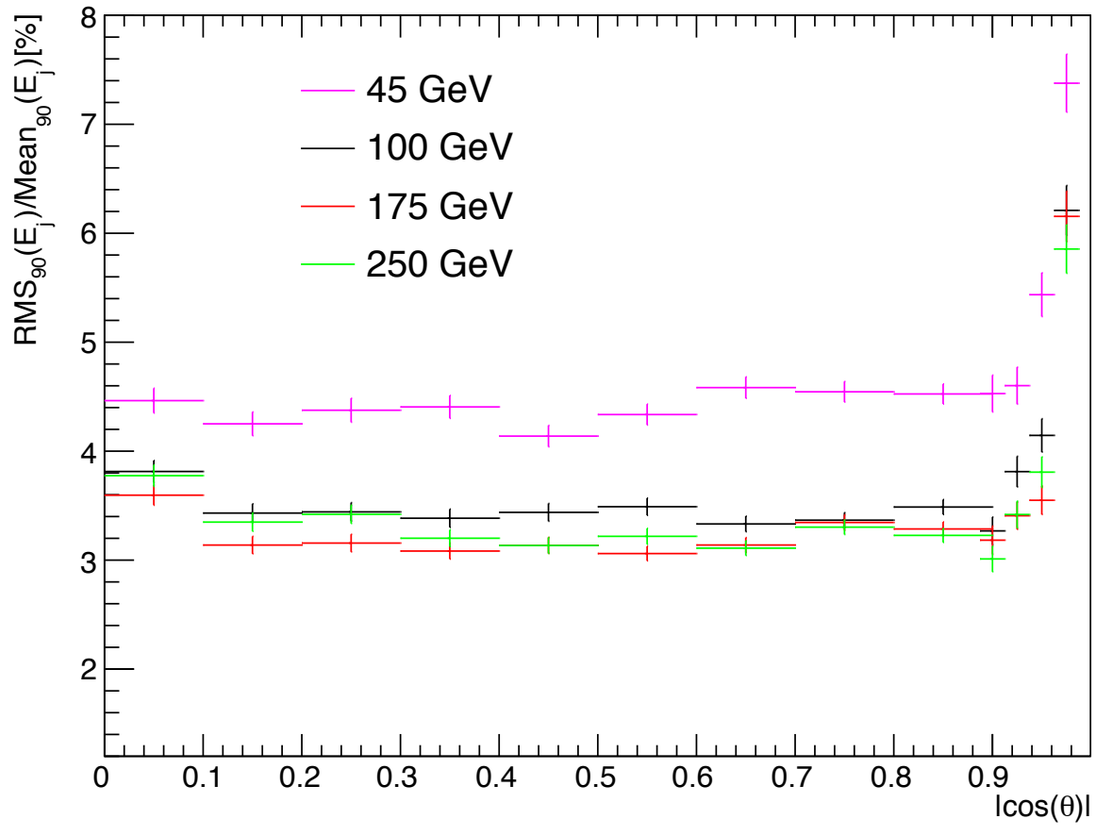
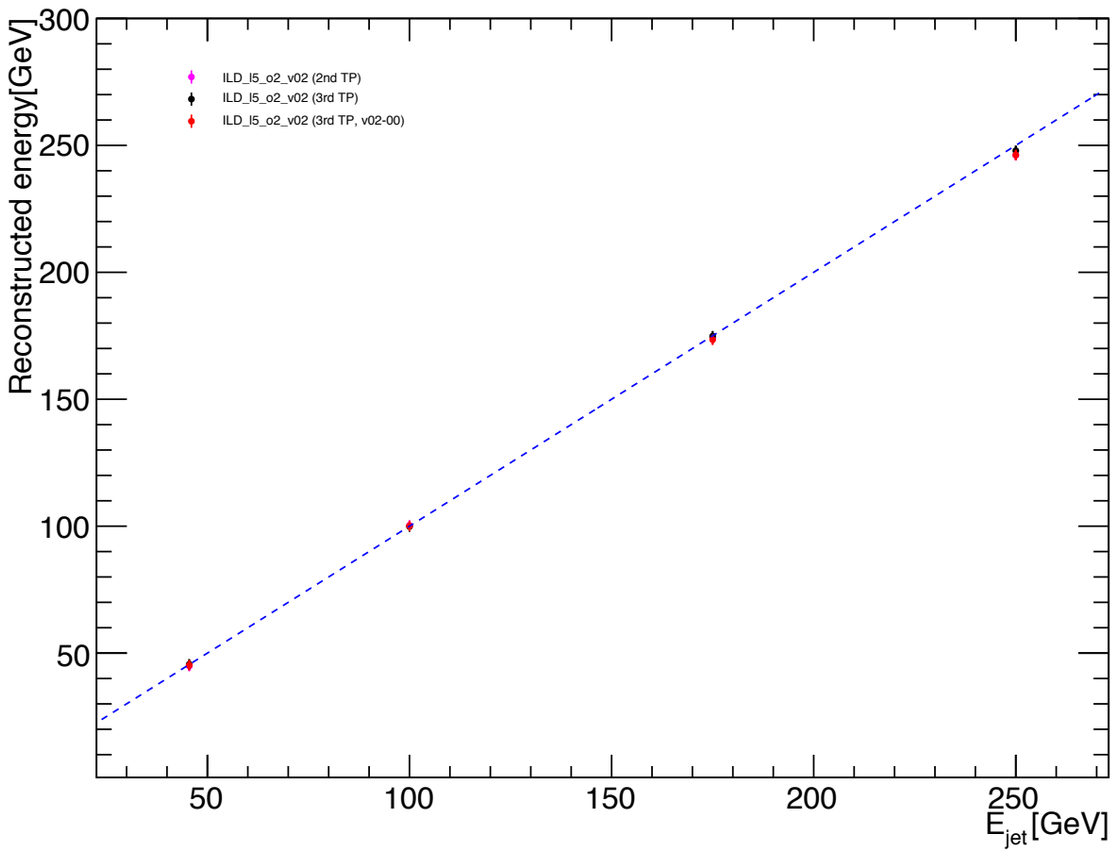
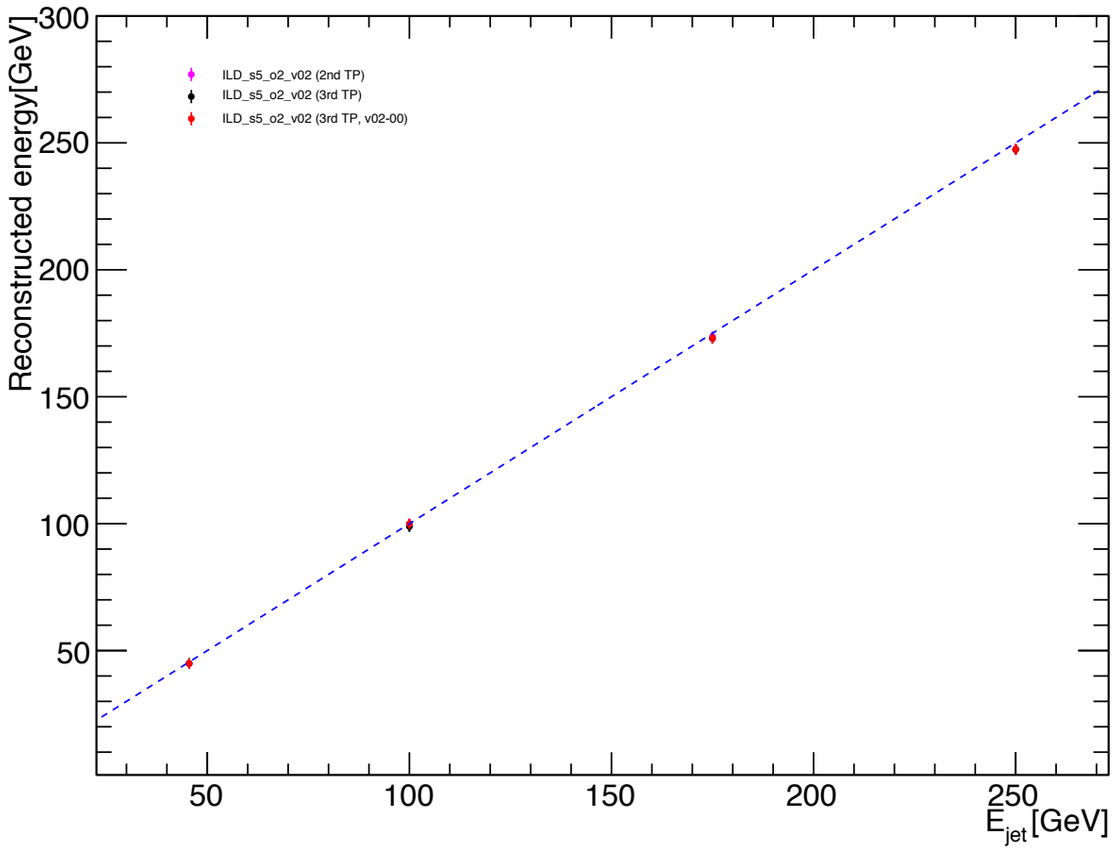


ILCSoft v02-00

Linearity



ILD_l5_o2_v02

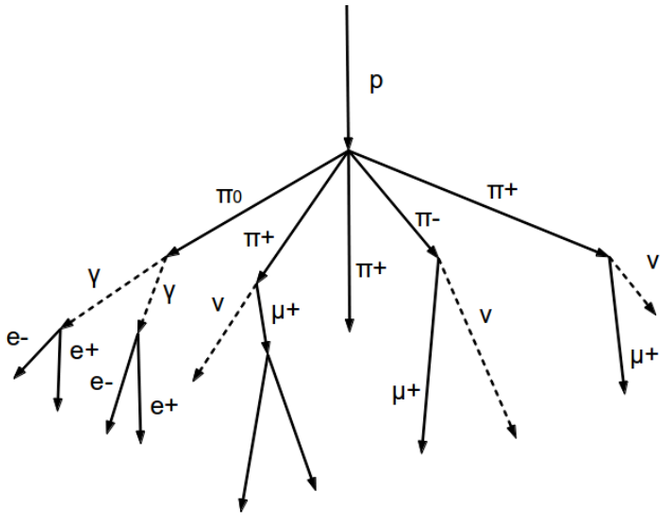


ILD_s5_o2_v02

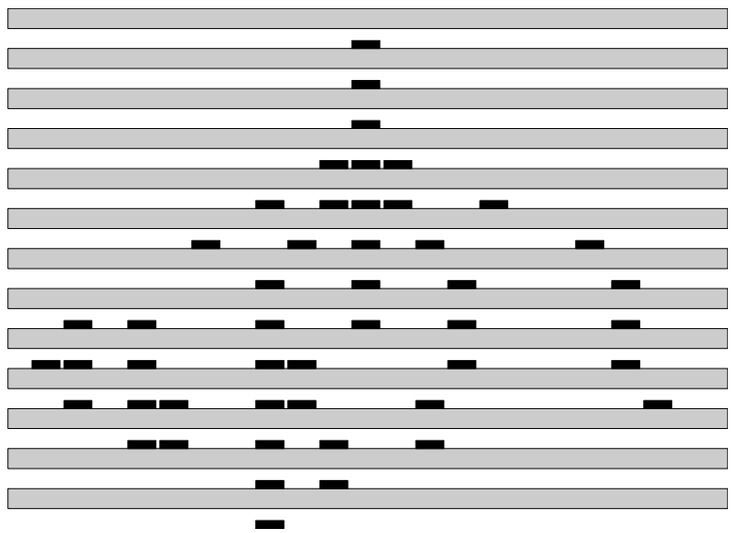
- No abnormality is observed during the evolution of ILCSoft and test production.
- Physics study is ongoing based on the simulation and reconstruction of latest ILCSoft release, v02-00 (see Guillaume's talk on Monday)

ArborPFA

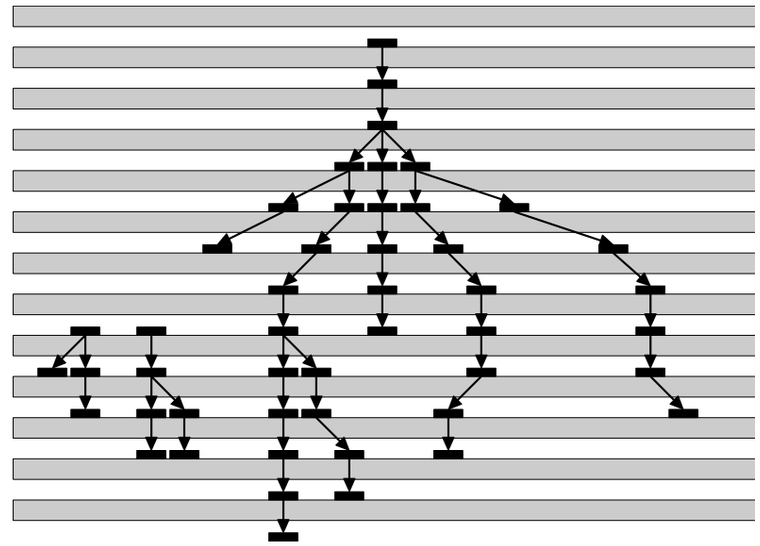
- ArborPFA: it is another code to implement the concept of particle flow algorithm for ILD.
- Use Arbor as the algorithm for clustering the hits in calorimeter with tree topology (H. Videau, M. Ruan, arXiv:1403.4784)



Hadronic shower



Hits in calorimeter



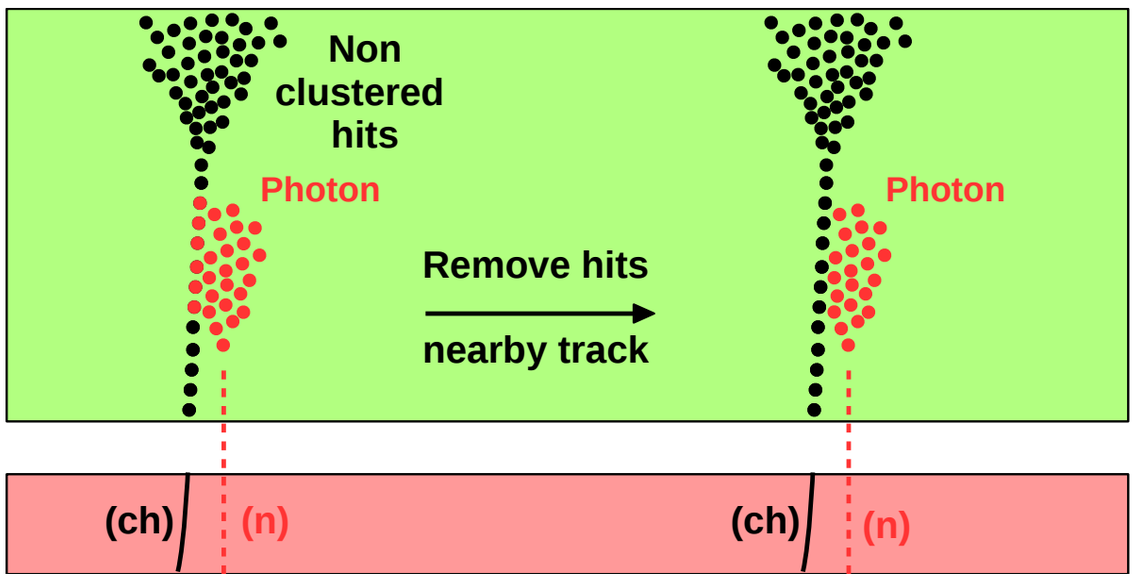
Clustering by Arbor

- PandoraSDK as framework
  - Algorithms developed using the Pandora SDK [arXiv:1506.05348]
  - Multi-algorithm approach and reclustering motivated by Pandora PFA [arXiv:0907.3577, 1209.4039]
  - https://github.com/PandoraPFA

Photon reconstruction

- Preparation of the event
  - CaloHits, tracks
  - Identification of V_0, kink and prong

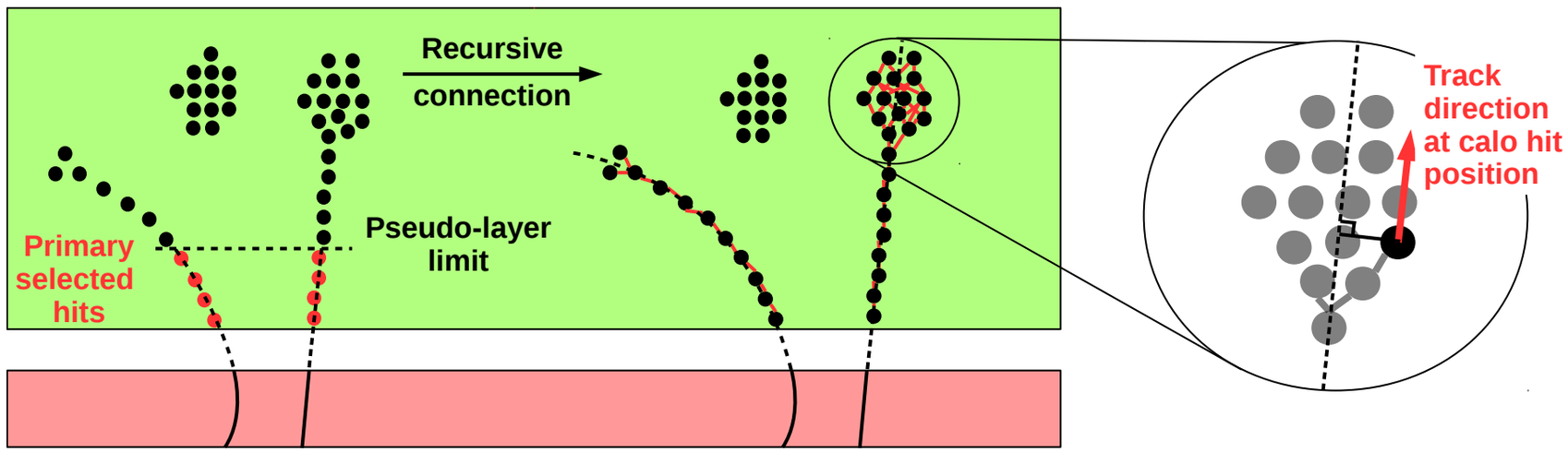
- Reconstruction of photons
  - Clustering in ECAL
  - Remove hits from nearby track



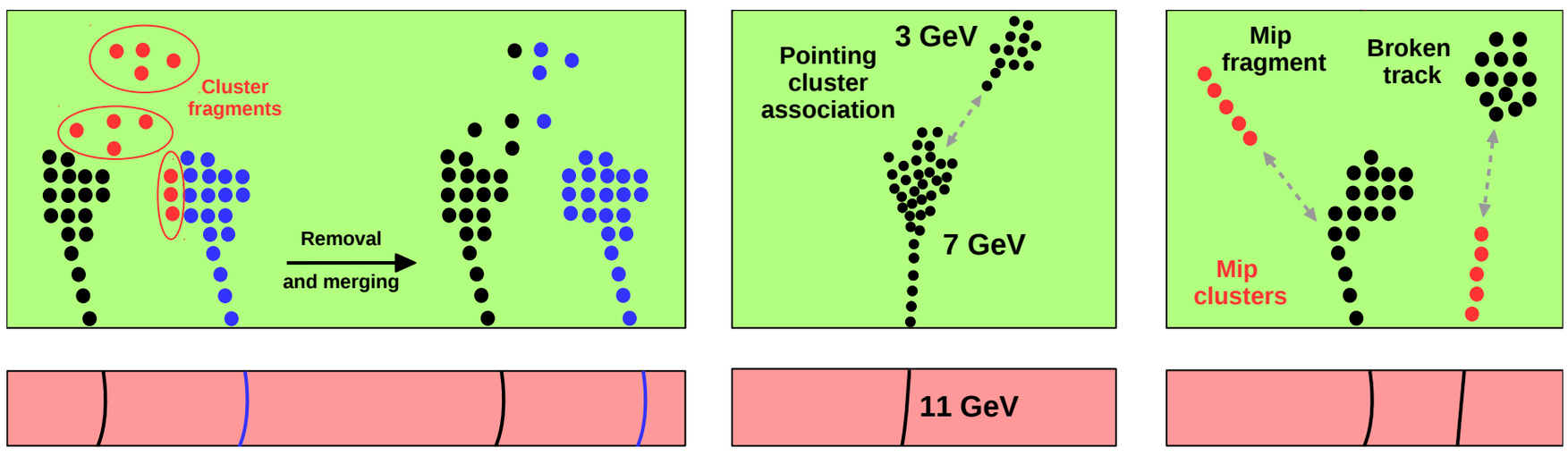
Note: a track-cluster association algorithm is necessary even at this stage.

Clustering of charged particle

- Track driven clustering

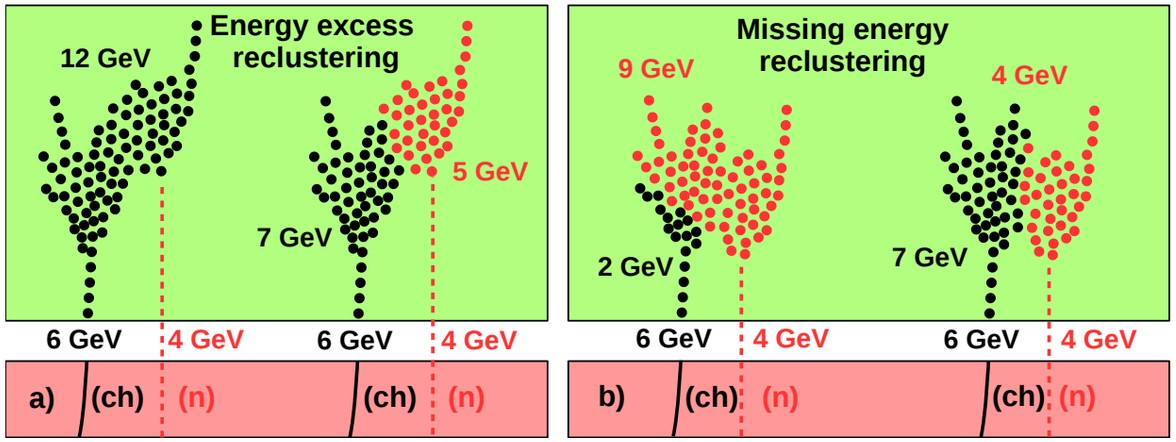


- Topological association for cluster fragments



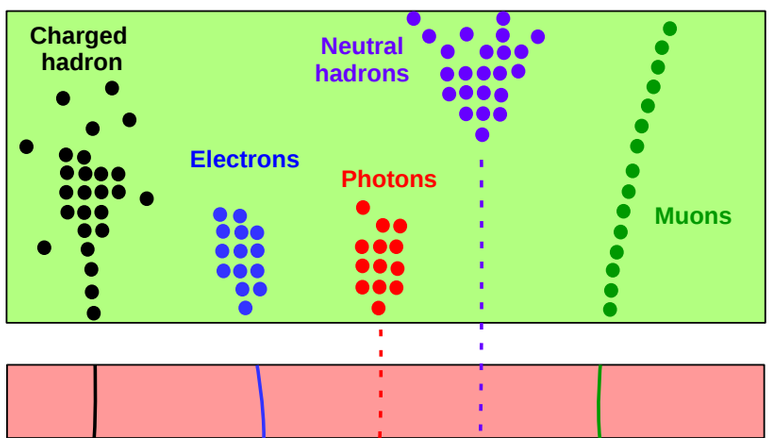
Reclustering and PID

- Reclustering is to correct cluster assignment based on the energy of track in cases of
  - excessing energy
  - missing energy



- Technically, the connector parameters are varied to set different configurations of clusters. So parameters are very important.
- The JER performance current algorithm suffers from this point especially for energetic jet.

- Create particle flow object and identify it



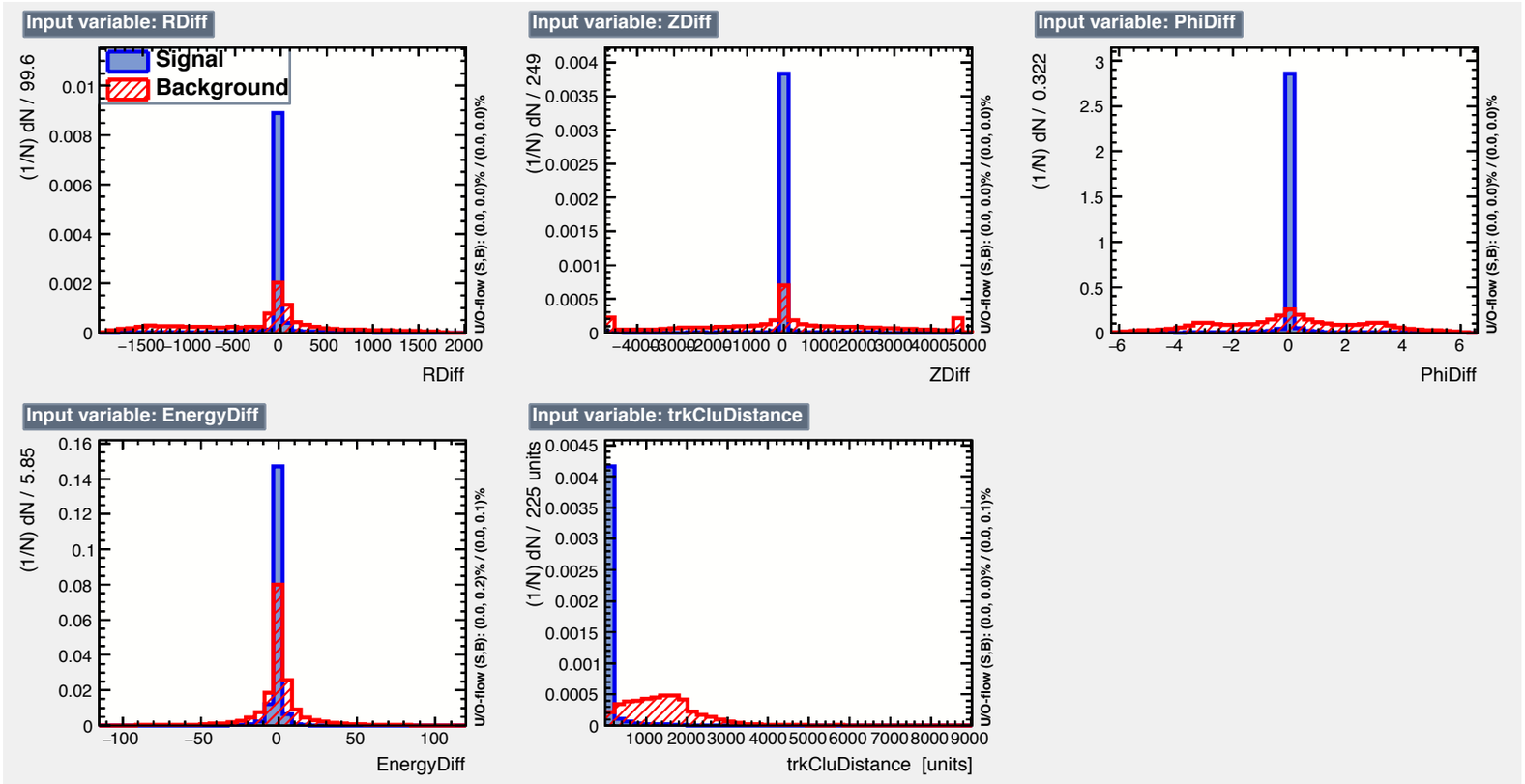
- Track-cluster association algorithm
- PID:
  - Actually also used at photon reconstruction stage
  - Toward to MVA based identification

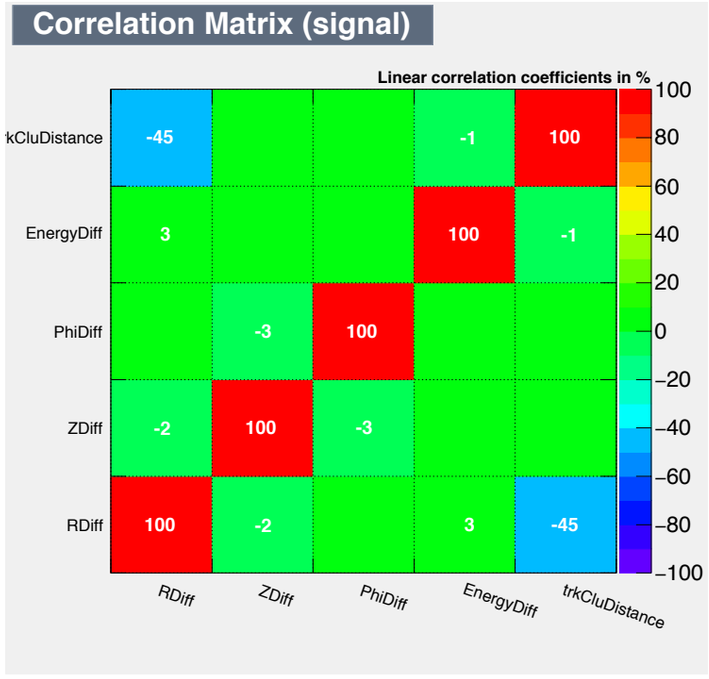
Status

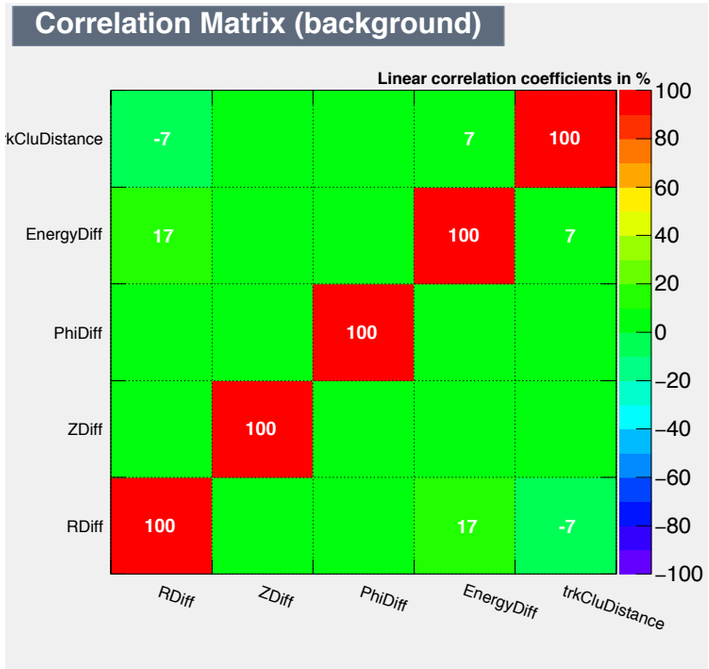
- Take the opportunity of upgrade of ILCSoft (DD4Hep) and test production, and updated the code accordingly to make it work with the latest ILCSoft
  - Use PandoraSDK in the package of ILCSoft (v02-03-00 -> v03-01-00)
  - DDMarlinArbor (from DDMarlinPandora)
  - Testing code with the event samples generated in recent test production.
- Making effort to improve the performance of JER
  - Reclustering is the major problem. But other sub algorithms, such as track-cluster association, clustering, PID, also need to be validated.
  - Currently dealing with track-cluster association
    - cut-based: the distance between helix and cluster, energy
    - MVA: distance, energy, direction

MVA input variables

- Signal: correct association between **reconstructed MarlinTrkTracks** and **perfect clusters**; Background: bad association
  - Perfect clusters is used so that the association can be validated independently of clustering

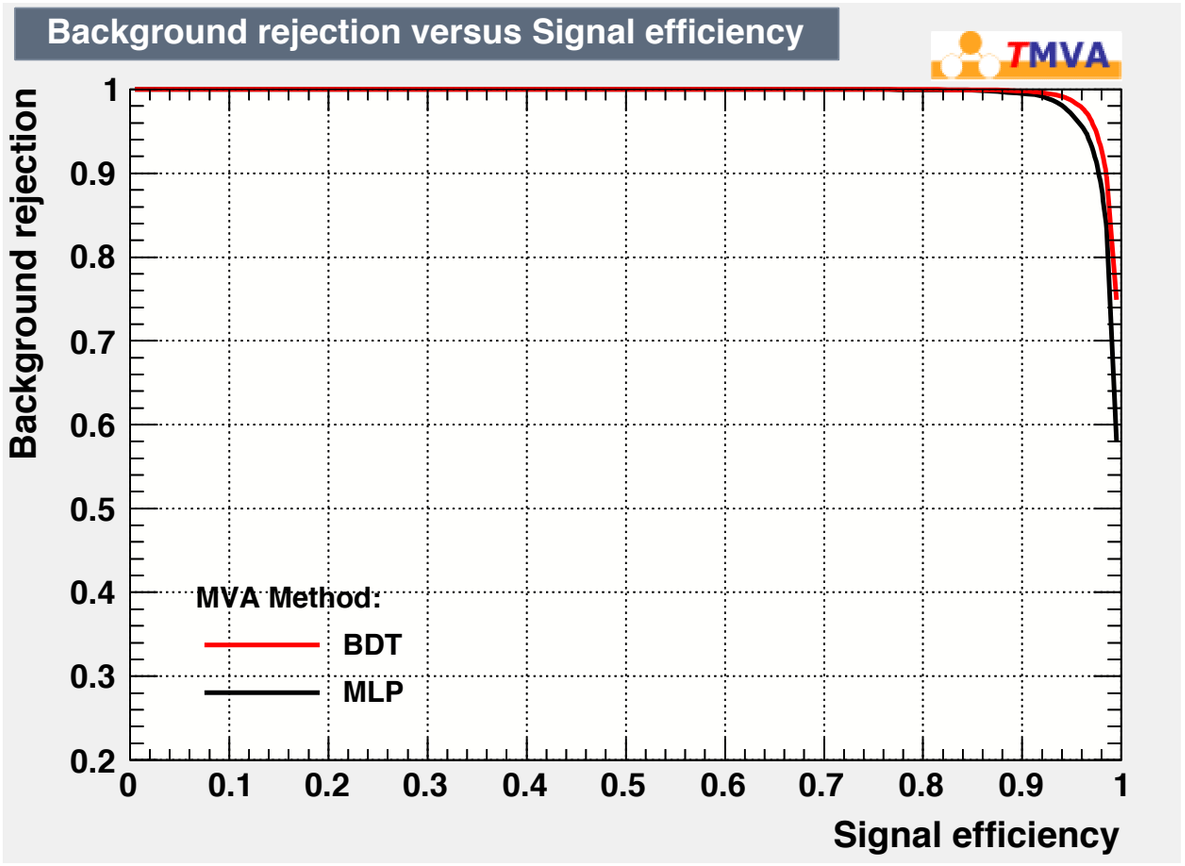


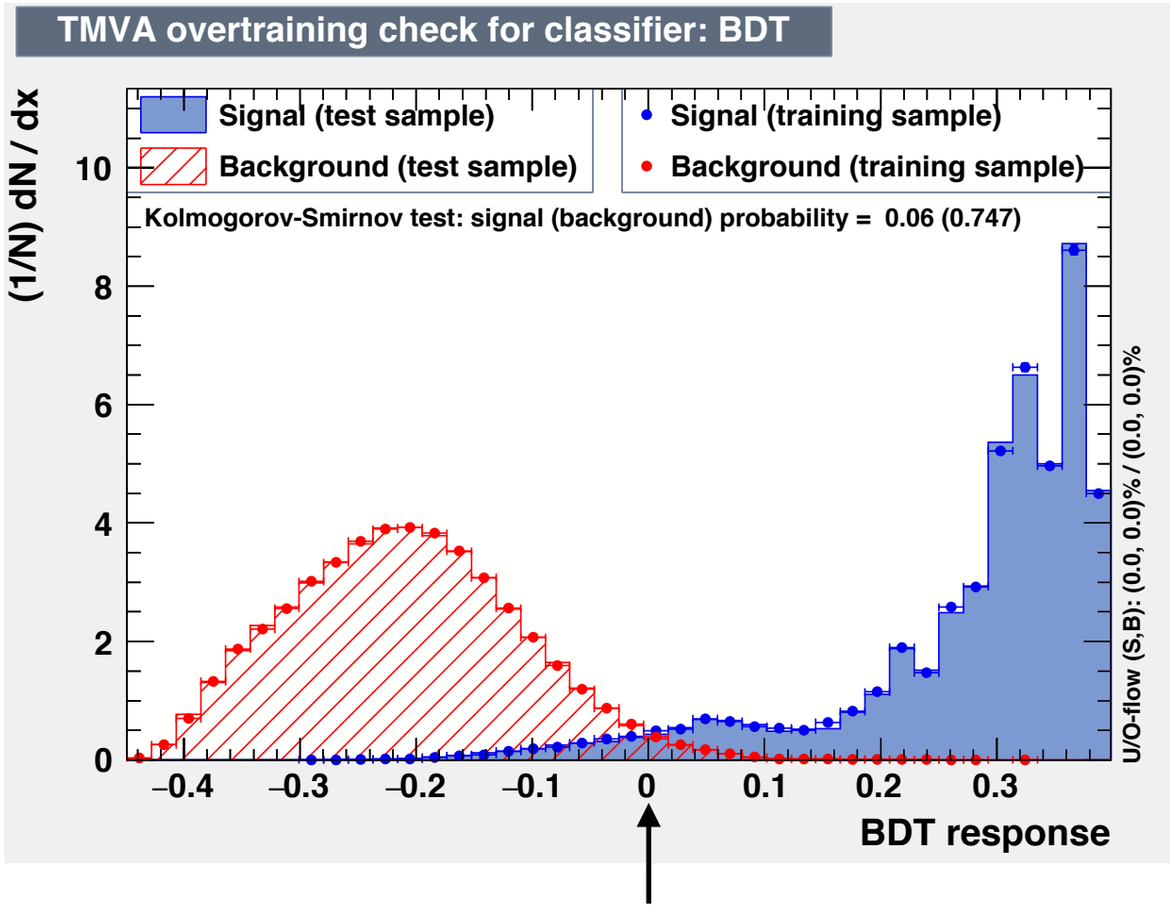




- RDiff, ZDiff, PhiDiff: the difference of cluster and track in the cylindrical coordinate system
- EnergyDiff: energy difference
- trkCluDistance: the distance between helix and cluster COG of inner layers

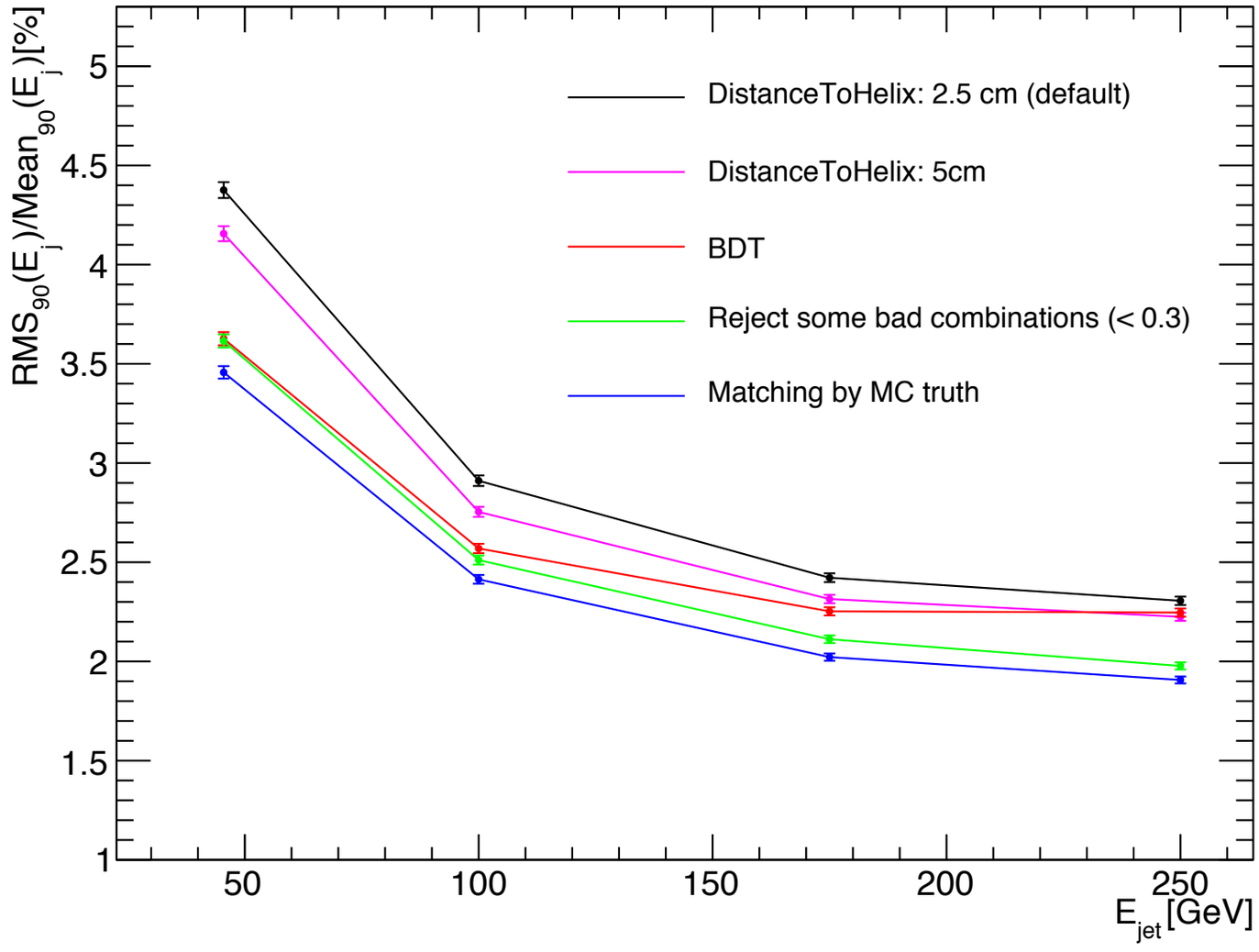
Performance





- The separation seems good, but note that number of background (bad association) could be much larger than signal (correct association).

JER



- It maybe improve the performance for low energy jet.
- Search for new MVA variables to recover the lost information of track and cluster
- Of course, reclustering is the important part, and more difficult.

Summary

- The PFA of ILD model with SDHCAL has been validated
  - Calibration to SDHCAL and PFA
  - The PFA performance keeps stable in the test productions
  - To improve the performance, quadratical parametrization or density correction will be used.

- ArborPFA
  - Updated ArborPFA code with respect to the updates of ILCSoft and PandoraSDK framework.
  - We are trying to solve the found issues in the algorithm. The track-clustering association is improved replacing the cut-based selection by BDT.