Simulation Study for ILD AHCAL

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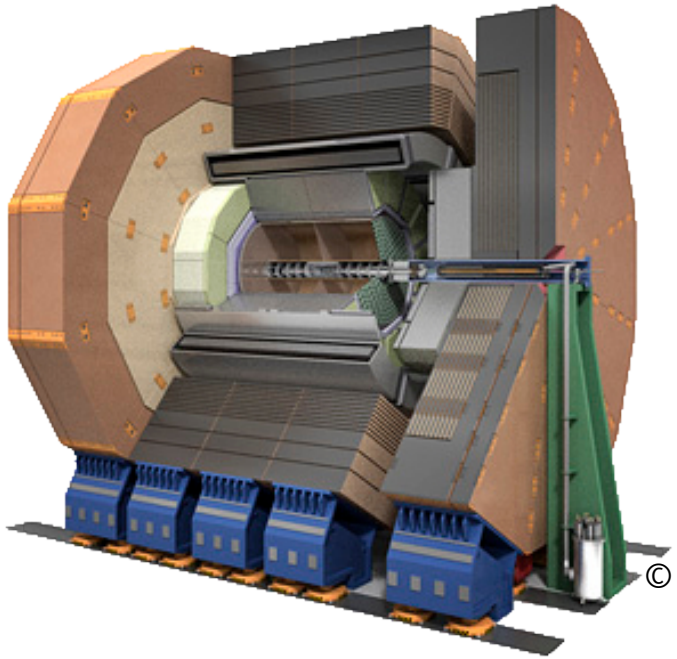
International Large Detector

- Multipurpose detector with vertex detector, tracking detector, calorimeters, muon detectors
- Important feature of ILD is calorimetry based on Particle Flow Algorithm



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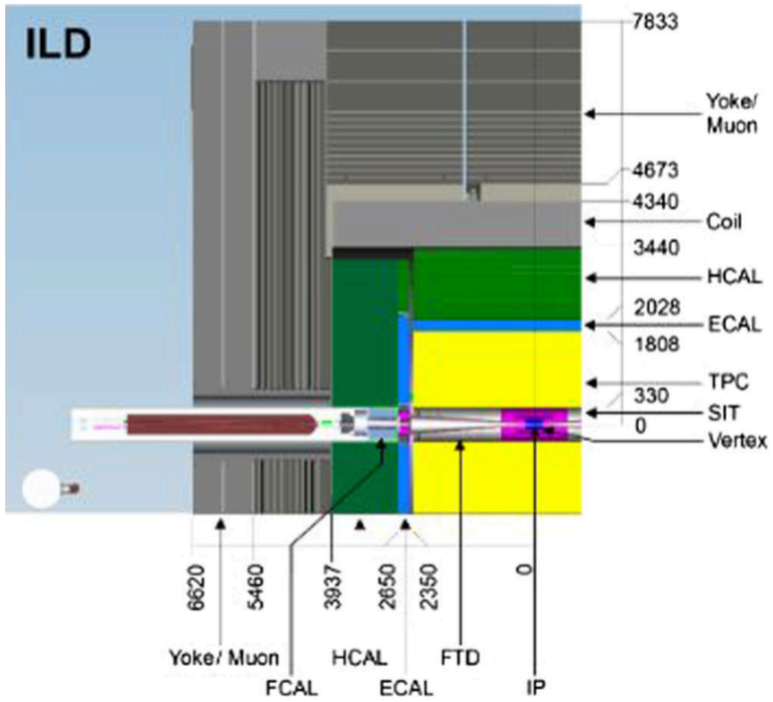
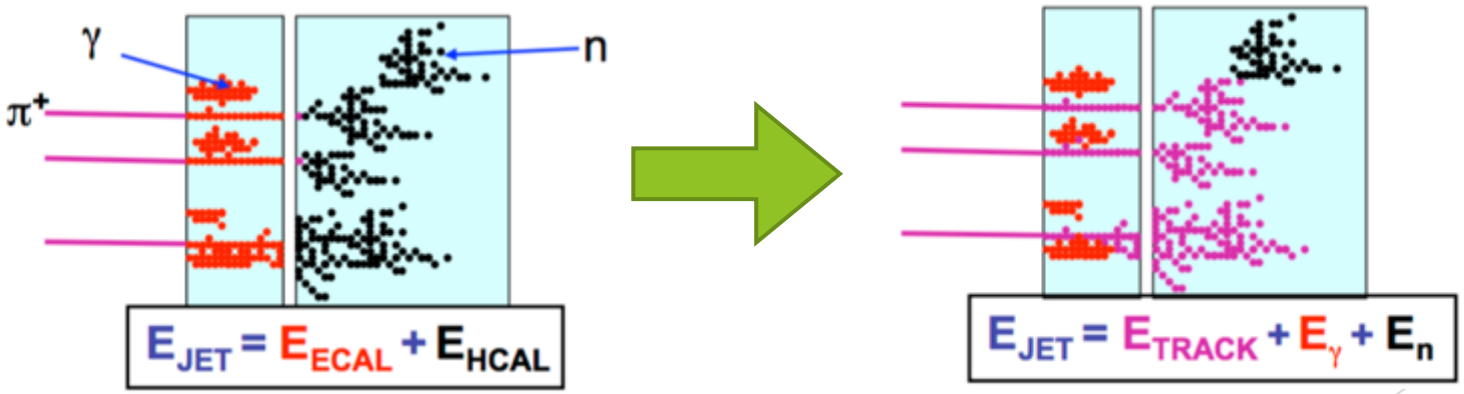
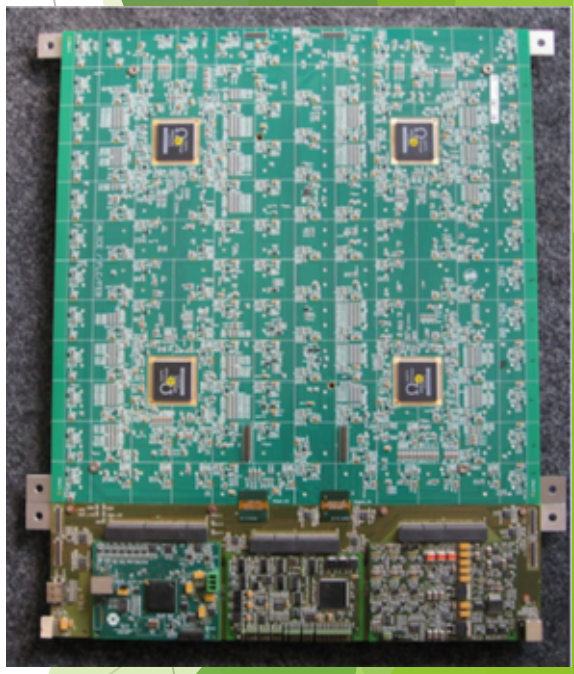


Particle Flow Algorithm

- ILD is going to make use of Particle Flow Algorithm (PFA) for jet energy resolution improvement
- Hadron jets consist of many neutral and charged hadrons, photons, leptons
- PFA is to distinguish each particle in a jet and measure the particle energies with the most appropriate detector
- Cover the rather poor resolution of HCAL with ECAL and tracking detector
- The calorimeter must have high granularity for particle separation



Design of ILD AHCAL

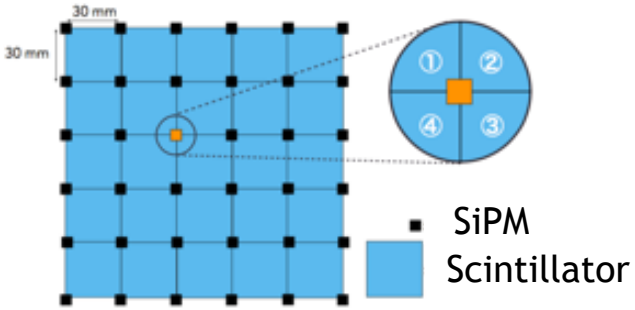


- Current design of ILD AHCAL : 48 absorbers and 48 active layers alternately
- The active layers are aligned 30mm x 30mm scintillator tiles with SiPMs at the center of the tiles
- The enormous amount of signals from SiPMs are managed by HCAL Base Unit, 12 x 12 SiPMs and 4 ASICs combined

- Some other detector designs for mass production and performance improvement

megatile

-> Possible increase of optical crosstalk



4 corner readout

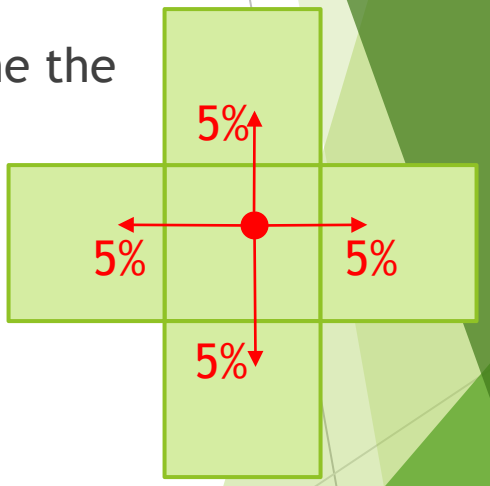
Optical Crosstalk

- Optical crosstalk in the standard type design is expected to be a few percent or lower
- It could be higher for some of the alternate designs
- The effect of the crosstalk on the overall calorimeter is not fully studied yet

- Objectives :
- Simulate the effect of crosstalk on the final result
  - Jet energy resolution
  - Particle separation
- Define the upper limit of crosstalk to get fine resolution

Generating Crosstalk in Simulation

- For each energy deposit on scintillator tile, give some fraction of energy to neighboring tiles
- If there is already existing energy deposit on the neighboring tile, combine the original energy and the crosstalk energy
- Each energy deposit is digitized with threshold of 0.5 MIP



- Simulate dijet events from quark pairs in ILD model (ILD_l1_v01)
- Apply 1-20 % crosstalk and reconstruct with Particle Flow Algorithm

Analysis Optimization

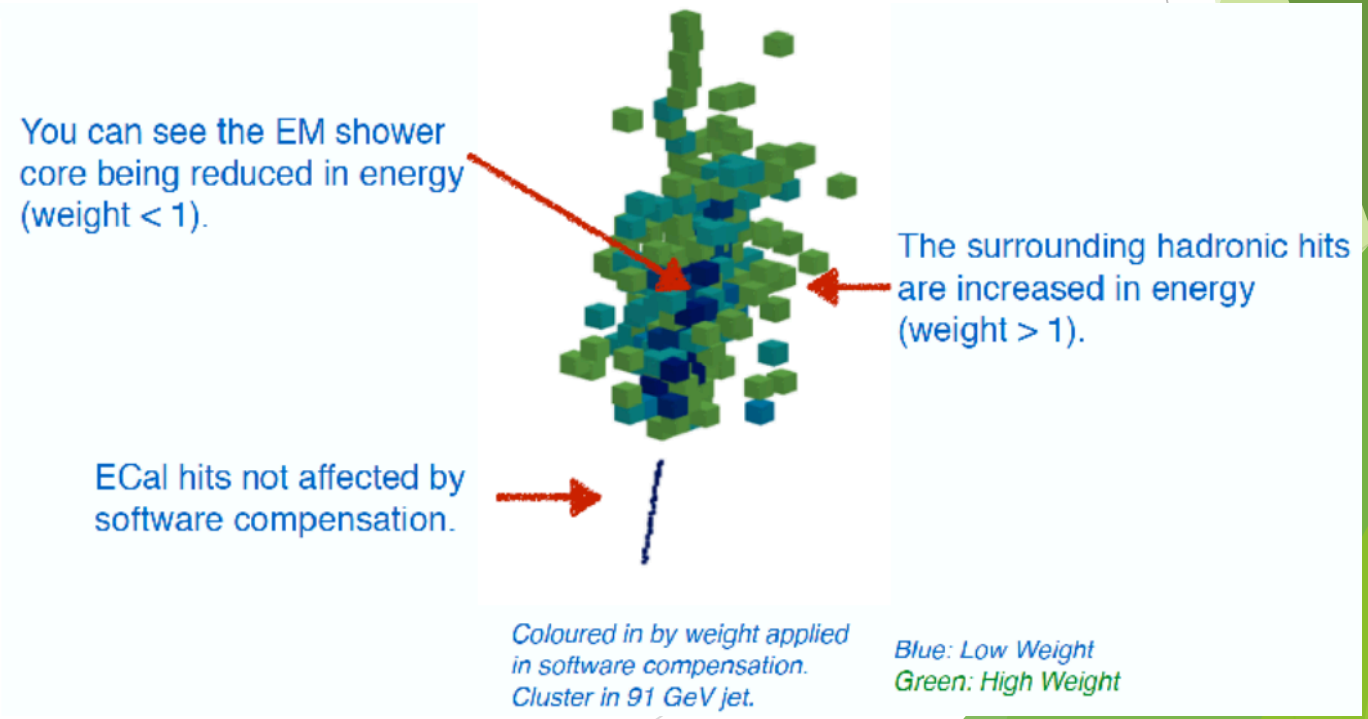
- Pandora Particle Flow Algorithm has to be finely optimized
- Calibration Constants
  - MIP responses
  - Reconstruction constants
  - EM/Hadronic shower type correction
- Optimize using muon/photon/kaon beams with already known energy

Software Compensation

- There are some EM components in hadronic shower
- The detection efficiency differs between EM and hadronic components
- To distinguish EM component, energy density is clear and easy way
- EM component is great

  in the energy density

- Apply more weight on the hadronic component than on the EM component

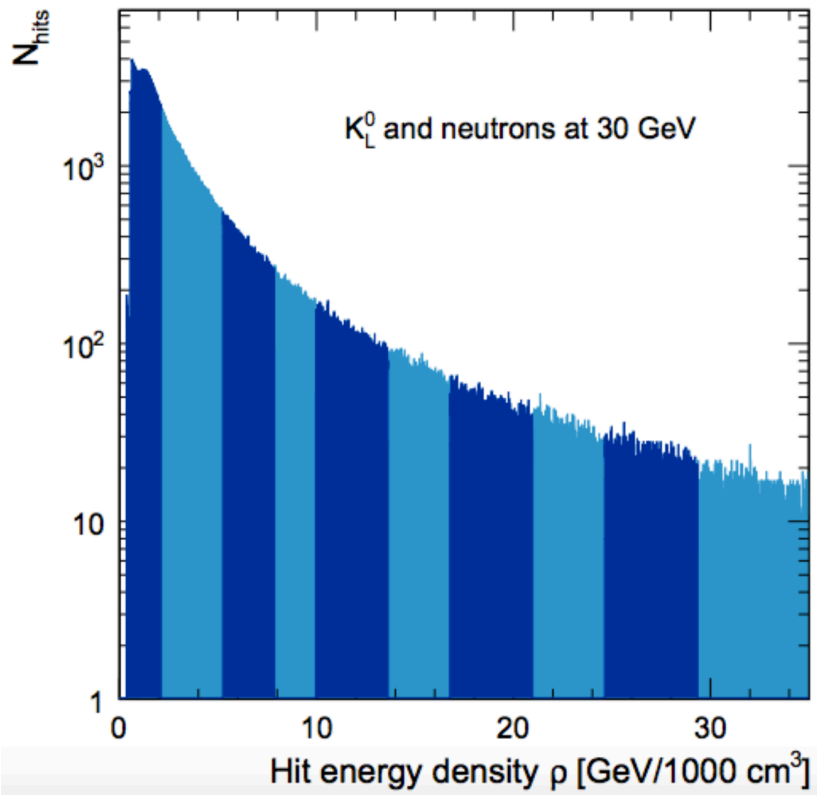


Software Compensation

- Apply weight calculated as:
- $$\omega(\rho) = p_1 \cdot \exp(p_2\rho) + p_3$$

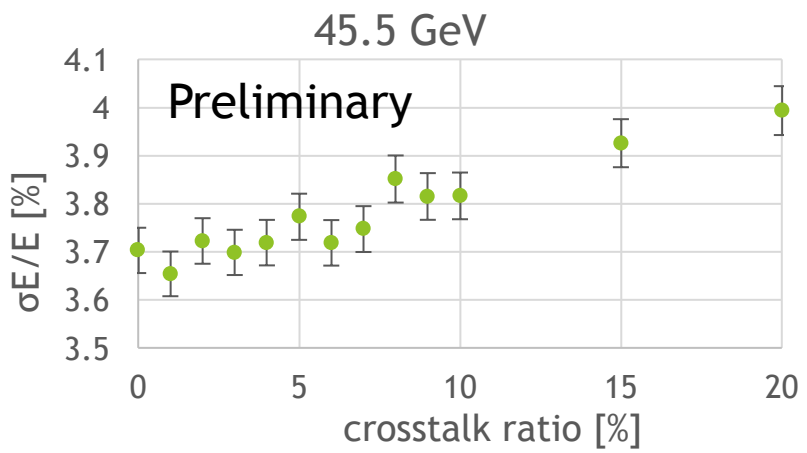
$$p_1 = p_{10} + p_{11}\times E + p_{12}\times E^2$$
$$p_2 = p_{20} + p_{21}\times E + p_{22}\times E^2$$
$$p_3 = \frac{p_{30}}{p_{31} + e^{p_{32}\times E}}$$

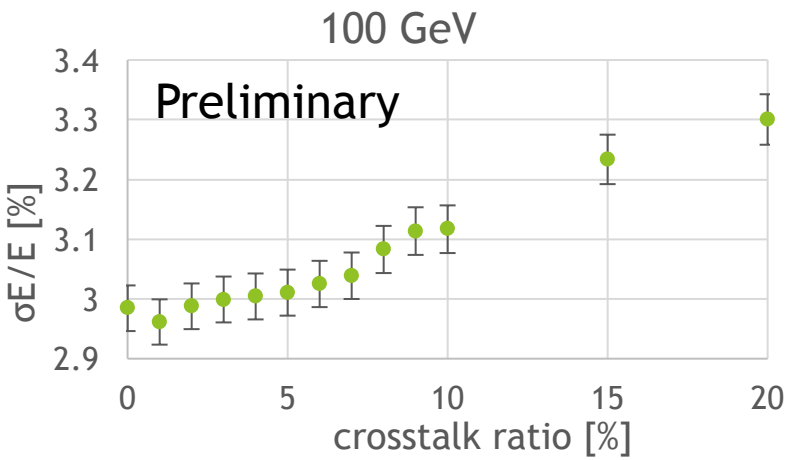
- There are nine parameters to calculate the weight
- These parameters have to be optimized as well

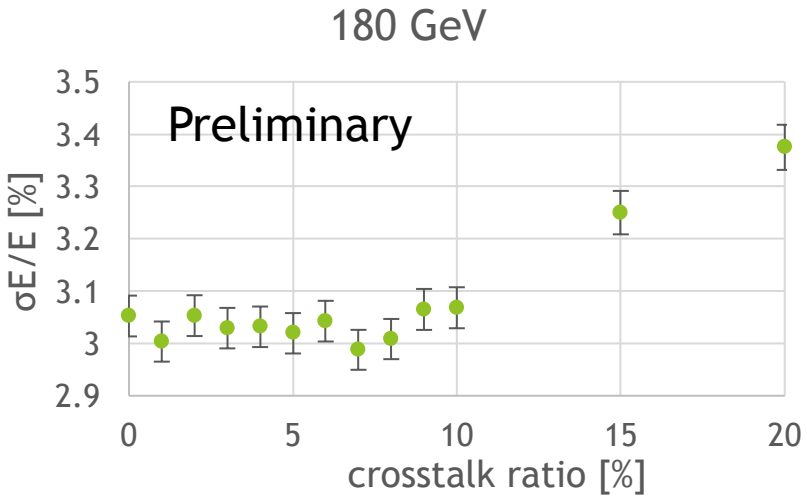


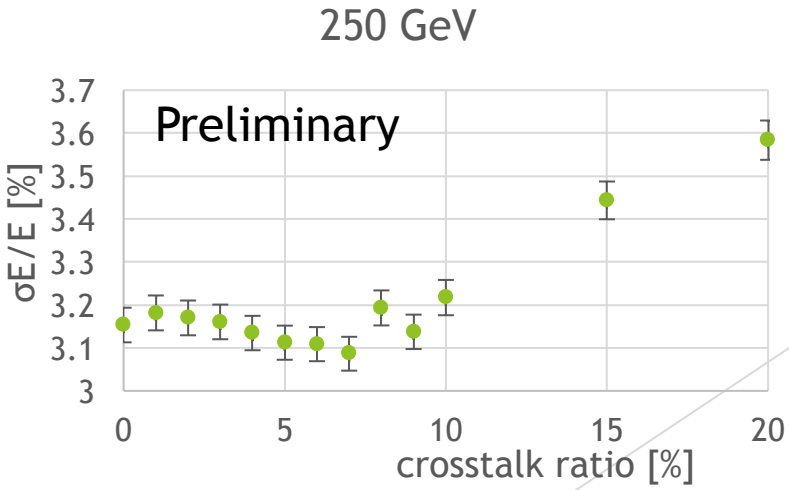
- But this part is still on going and not applied in result this time

Jet Energy Resolution with Crosstalk



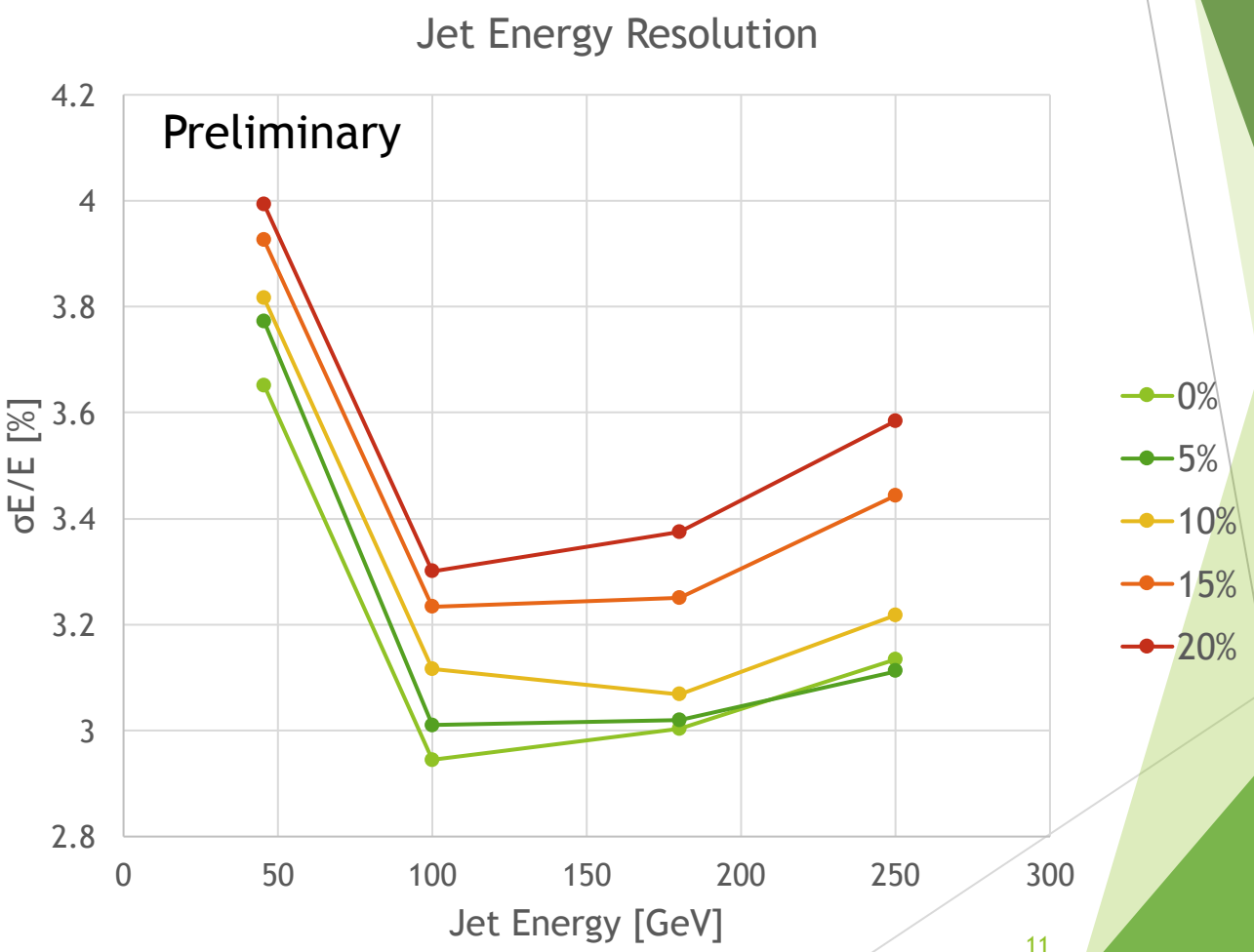






Jet Energy Resolution with Crosstalk

- JER is clearly worse when the crosstalk is extremely high
- But up to 5-7% there seems to be little effect on the detector performance



Summary & Prospects

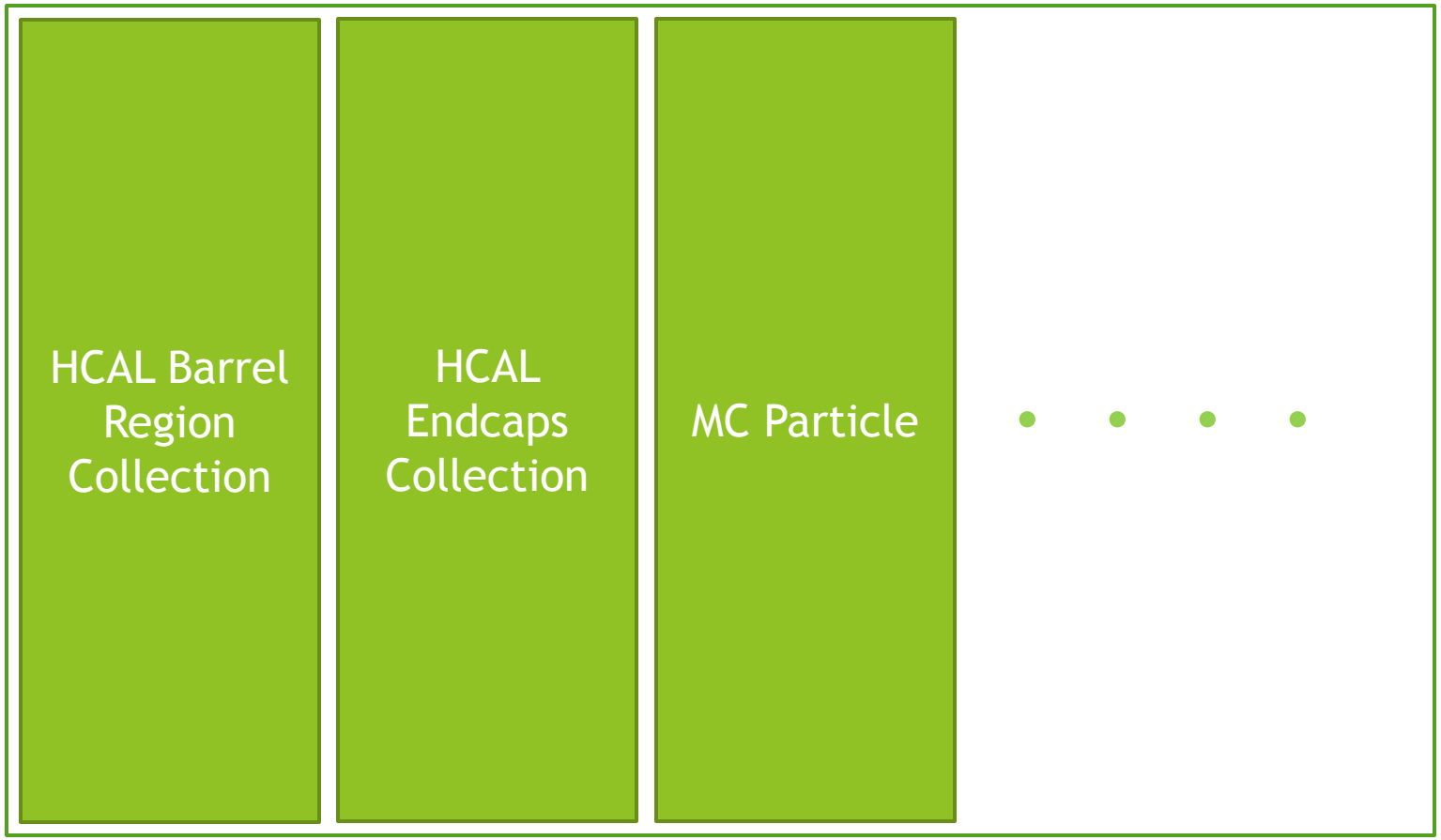
- In ILD AHCAL design there might be a possible increase of optical crosstalk between tiles
- Investigated the effect of crosstalk on the detector performance through simulation
- Extremely high crosstalk worsen the jet energy resolution, but up to 7% the crosstalk do not much affect

- Full optimization of the analysis is still on going (about software compensation)
- More realistic crosstalk (random or/and secondary crosstalk)
- Try to diminish the effect of crosstalk in the software analysis part

THE END

Backups

Event (generated by a simulator)



Collection contents

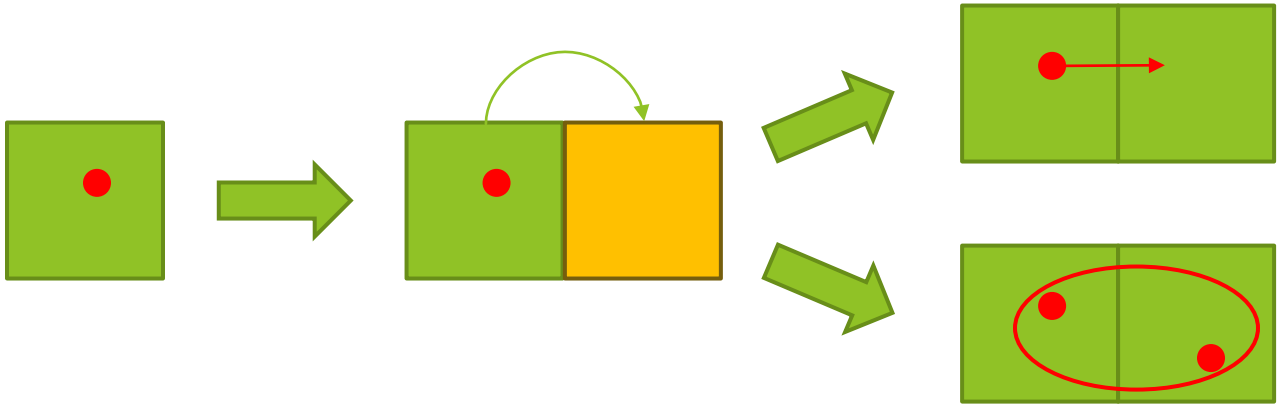
HCAL Barrel Region Collection

- Spatial Position (X,Y,Z)
- Cell Indices system, module, layer, x, y, etc.
- Energy
- Contributing particles (MC)

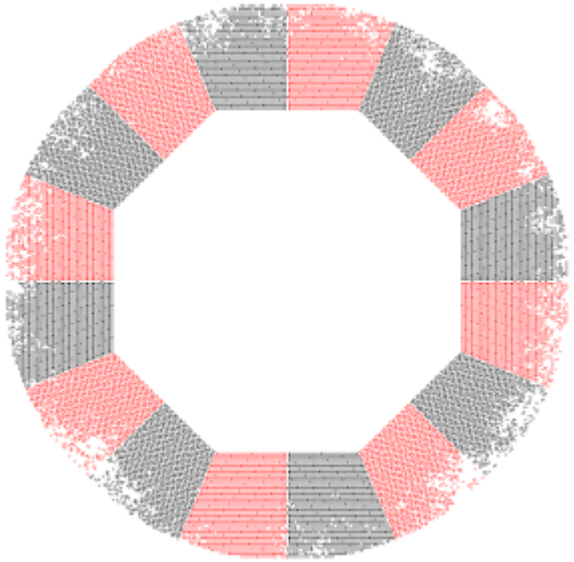
× nHits

Algorithm

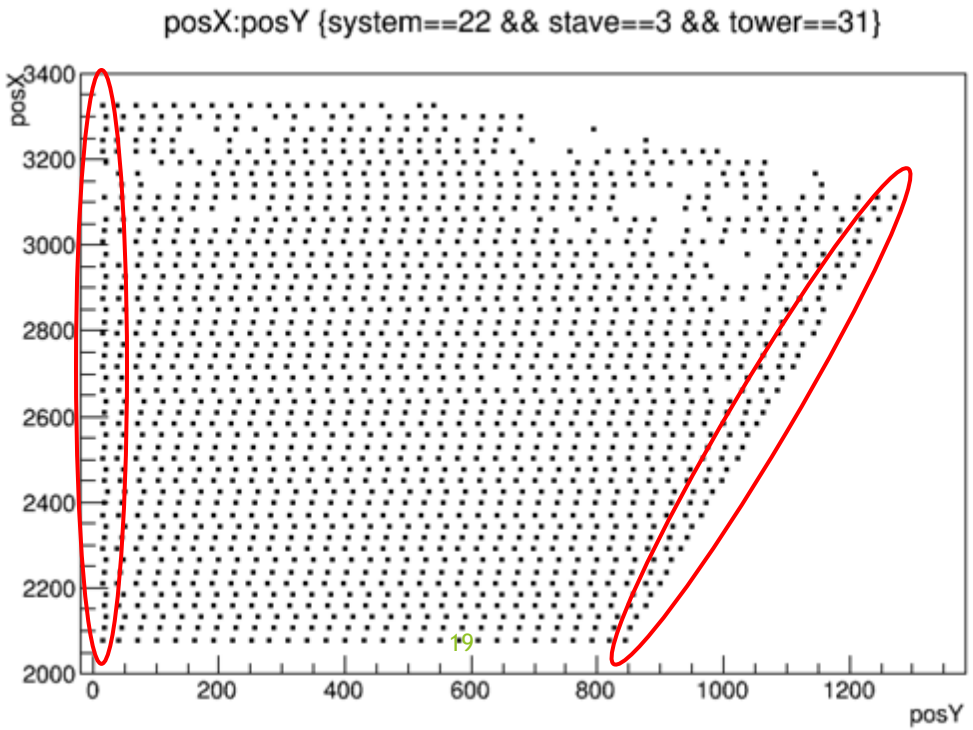
- Take one hit in the event
- Calculate the cell indices and the spatial positions of neighboring cells
- Then, if there is no hit on the neighboring cell, generate a new hit with some energy fraction (like 5% or so)
- And if the neighboring cell already has a hit, add as the form of energy contribution



Some difficulty



- The spatial position of neighboring cell was not obvious
  - For example, in HCAL Barrel, the distance along the x-y surface is 30 mm
  - but the distance along the z axis is 30.3248 mm
  - Also the at the both edge of each module, some irregular
  - value is appearing (a bit shorter than 30 mm)



- So I just checked all the spatial alignment of the cells
- and wrote them explicitly in my code
  - (So the code is not stable for detector design changes)

Event Display with Single Particle

- Inject 20 GeV K_L^0 in ILD
- Simulated in the ILD_l1_v01 detector model
- The black points are the hit positions without crosstalk
- The red points are hits after generating 10% crosstalk