Simulation Study for ILD AHCAL

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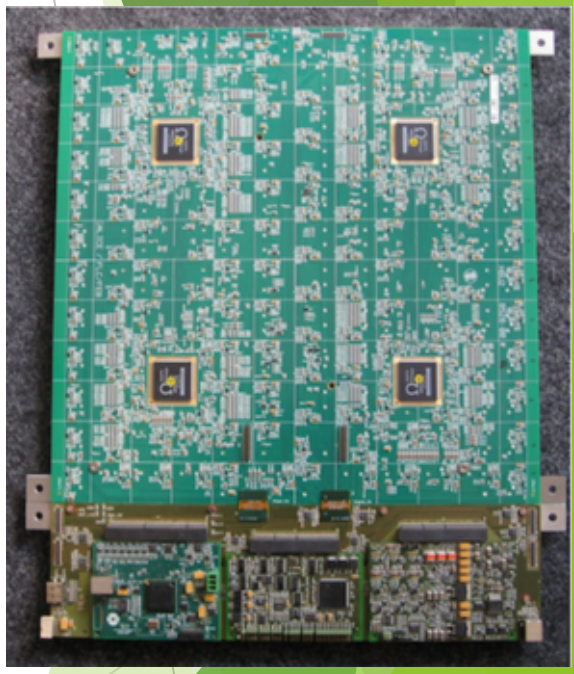
Design of ILD HCAL

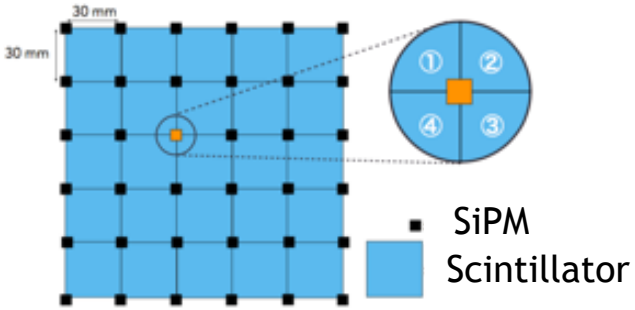


- Current design of ILD HCAL : 48 absorbers and 48 active layers alternately
- The active layers are aligned 30mm x 30mm scintillator tiles with SiPMs at the center of the tiles
- The enormous amount of signals from SiPMs are managed by HCAL Base Unit, 12 x 12 SiPMs and 4 ASICs combined

- Some other detector designs for mass production and performance improvement

megatile

-> Possible increase of optical crosstalk



4 corner readout

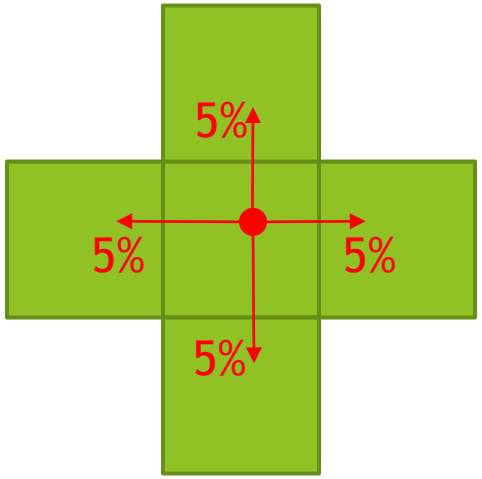
Optical Crosstalk

- 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

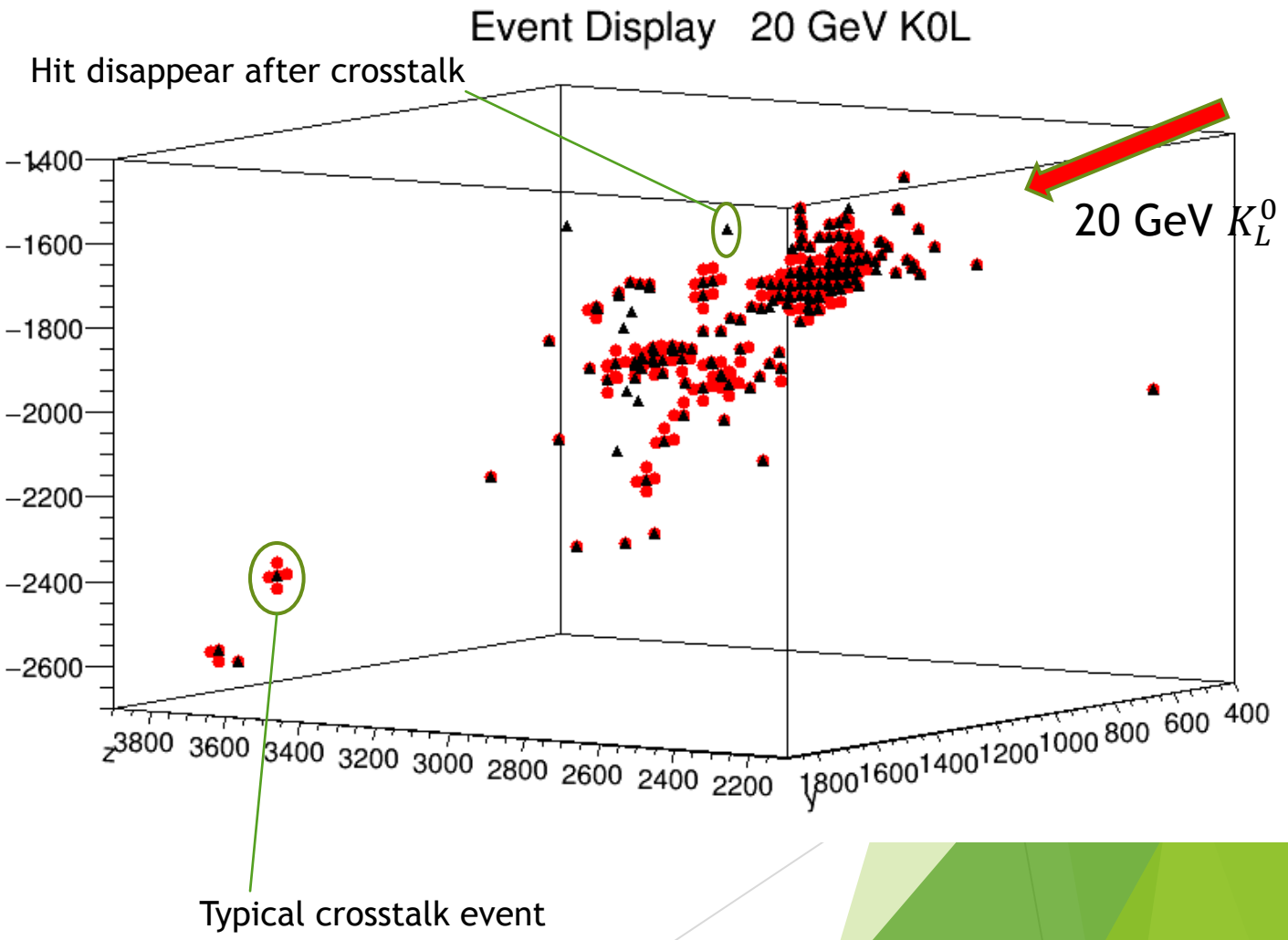
Generating Crosstalk in Simulation

- 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
- We are now grasping general tendency with including extreme cases (up to 20% to each neighboring tile)



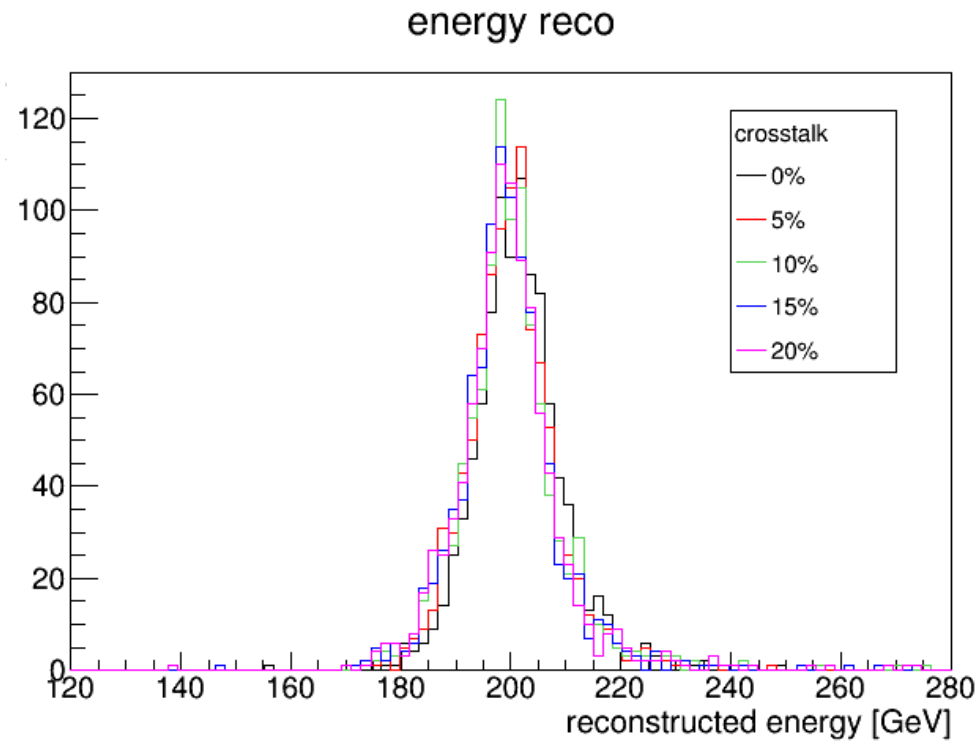
Event Display with Single Particle

- 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

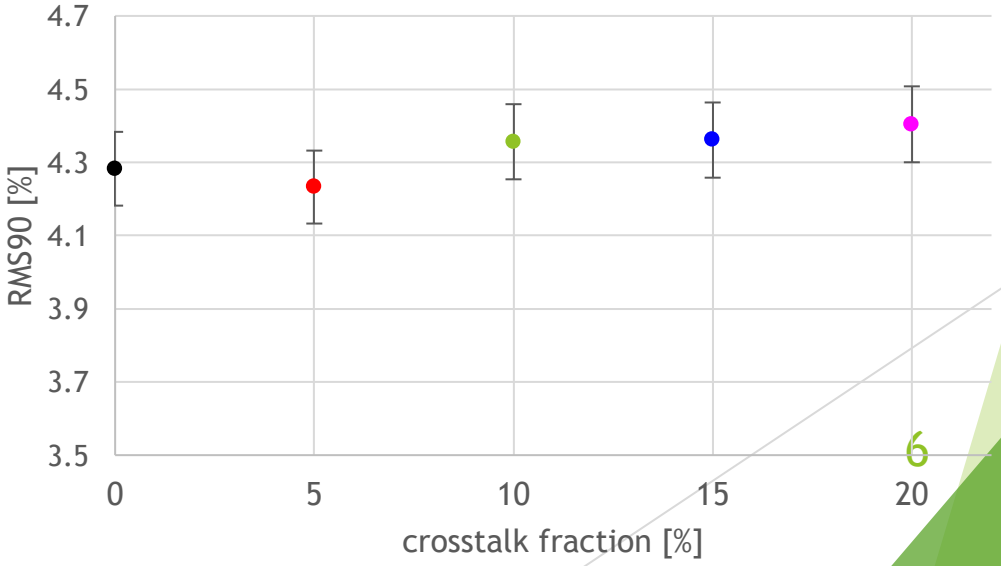


Jet Energy Resolution

- $e^+e^- \rightarrow q\bar{q}$ with 200 GeV center-of-mass energy
- Sum of energies of two jets is reconstructed
- Energy reconstruction is well functioning (distributed around 200 GeV)



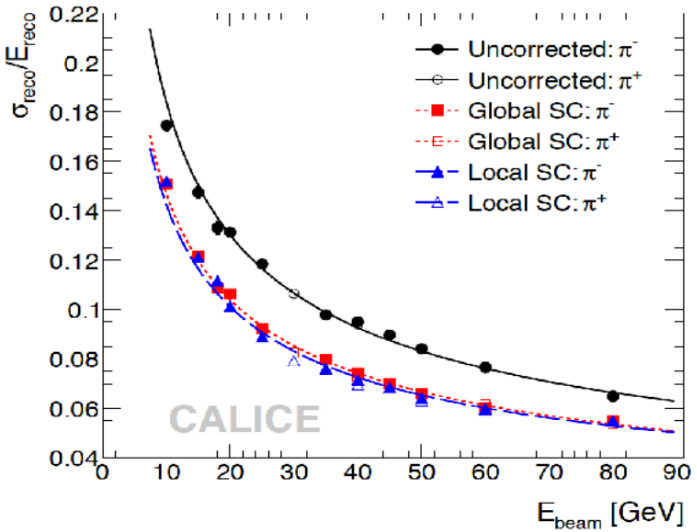
$\sigma_j/E_j = \sqrt{2}\sigma_{jj}/E_{jj}$

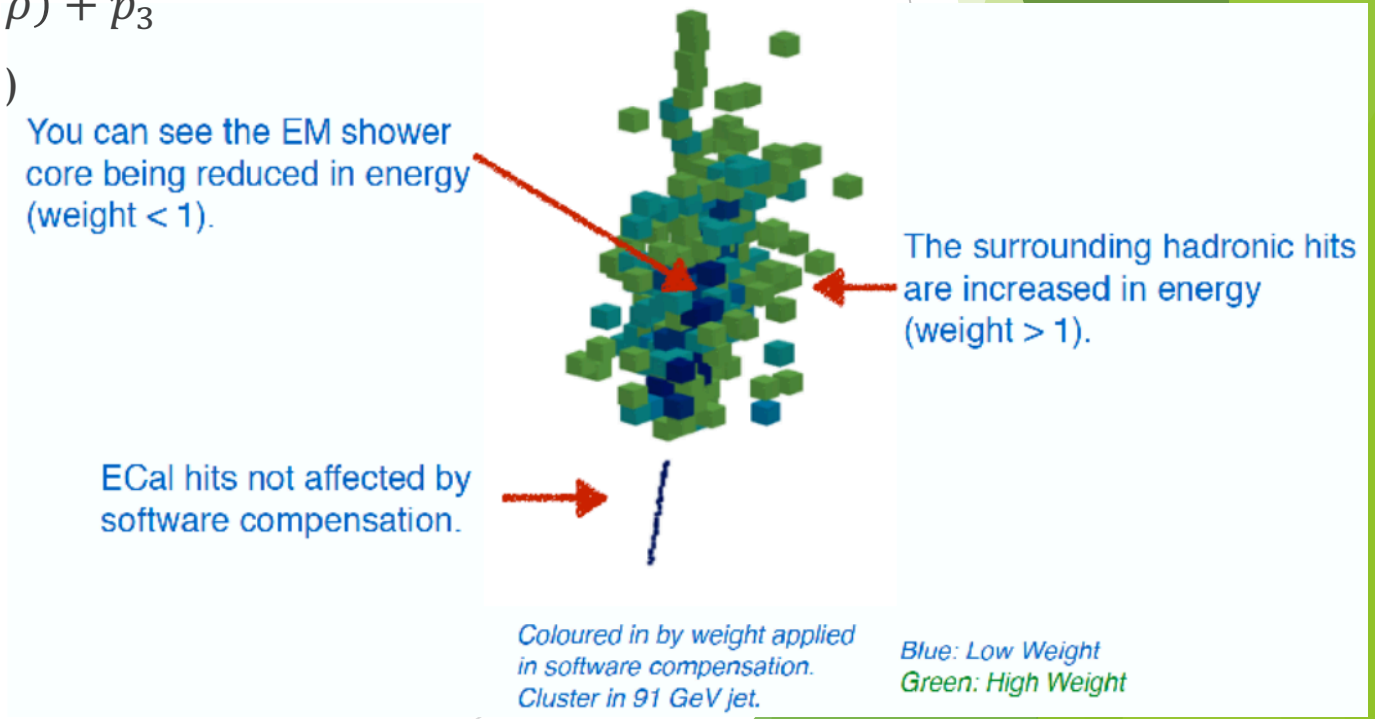


Software Compensation

- EM shower and hadronic shower are different in their detectable energies
- Compensate the difference by applying weights for different energy density
- $$\omega(\rho) = p_1 \cdot \exp(p_2 \rho) + p_3$$
  - (with energy dependent parameters p_1, p_2, p_3)

Single particle resolution with SC

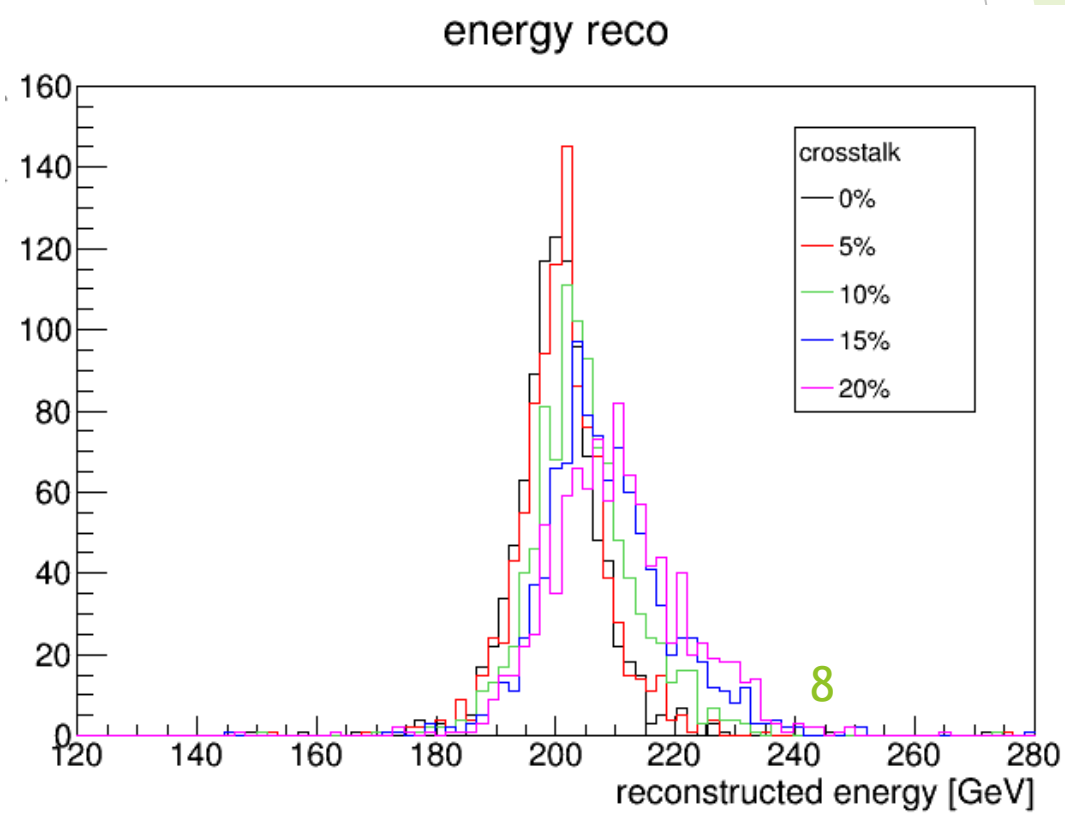




Jet Energy Resolution with SC

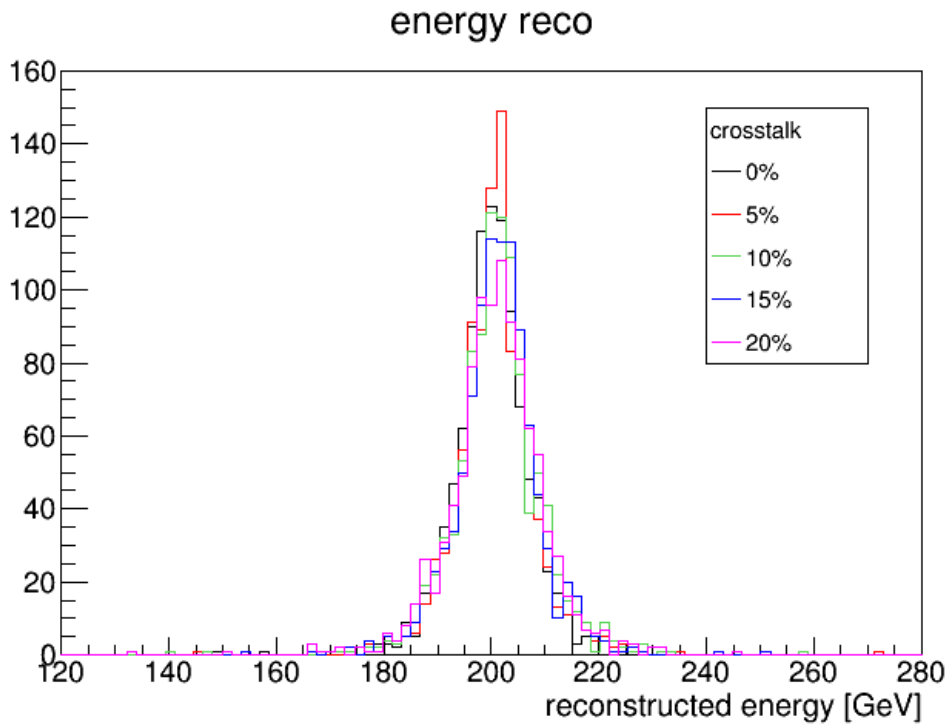
- $e^+e^- \rightarrow q\bar{q}$ with 200 GeV center-of-mass energy
- With the software compensation, reconstruction get worse as the optical crosstalk increase

- Reason:
- Hit energy is spread out to neighboring tiles, so the energy density reduced and SC overweight the energy

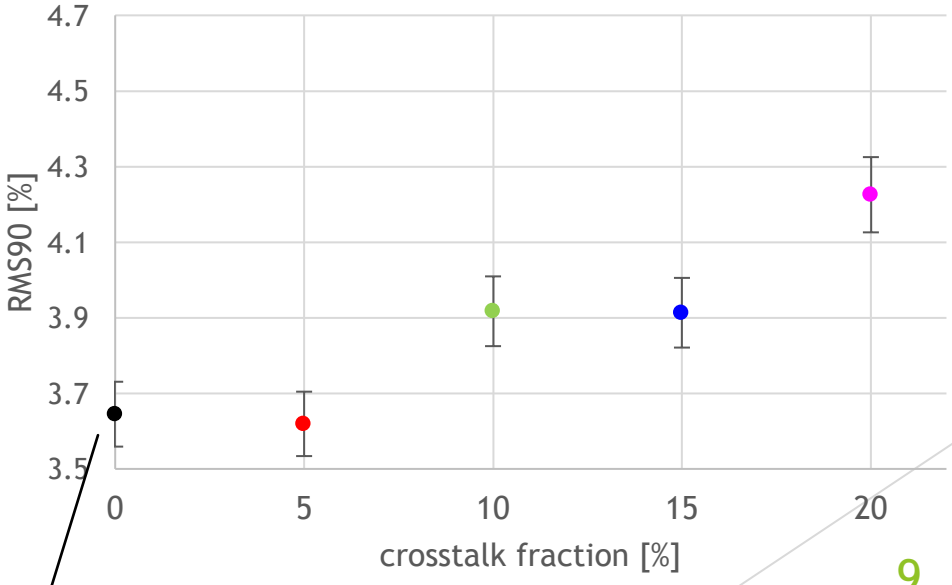


Jet Energy Resolution with SC

- Simply modified calibration constants for HCAL to adjust energy reconstruction
- The resolution gets worse by increasing the optical crosstalk



$$\sigma_j/E_j = \sqrt{2}\sigma_{jj}/E_{jj}$$

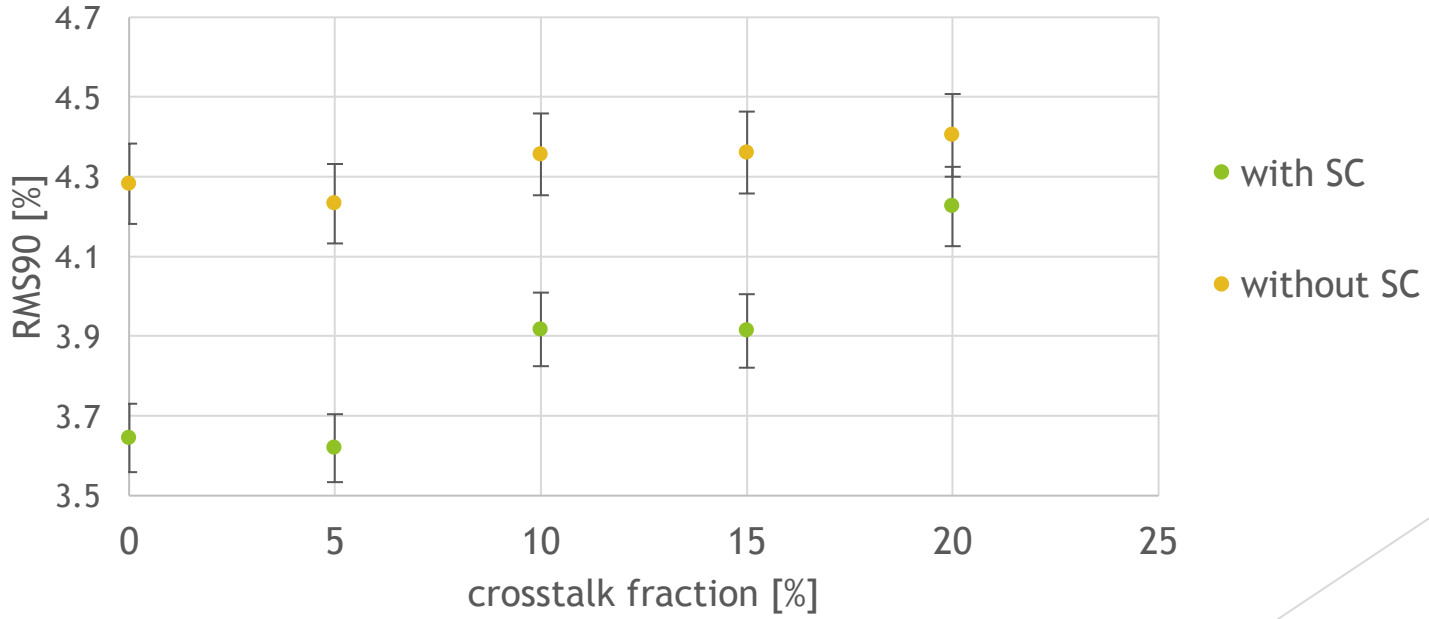


Resolution without crosstalk is slightly worse than standard analysis
-> Under investigation

Jet Energy Resolution

- The energy resolution with and without software compensation
- Including software compensation, the resolution is improved
- But software compensation is affected by the optical crosstalk

$$\sigma_j/E_j = \sqrt{2}\sigma_{jj}/E_{jj}$$



Summary & Prospects

- Without software compensation, even extreme crosstalk do not generally affect the resolution

- Software compensation is to change weight by each hit's energy density for resolution improvement
- Performance of software compensation is affected only when optical crosstalk is extremely large (>~5%)
- Re-optimization of software compensation may mitigate the worsening of the resolution

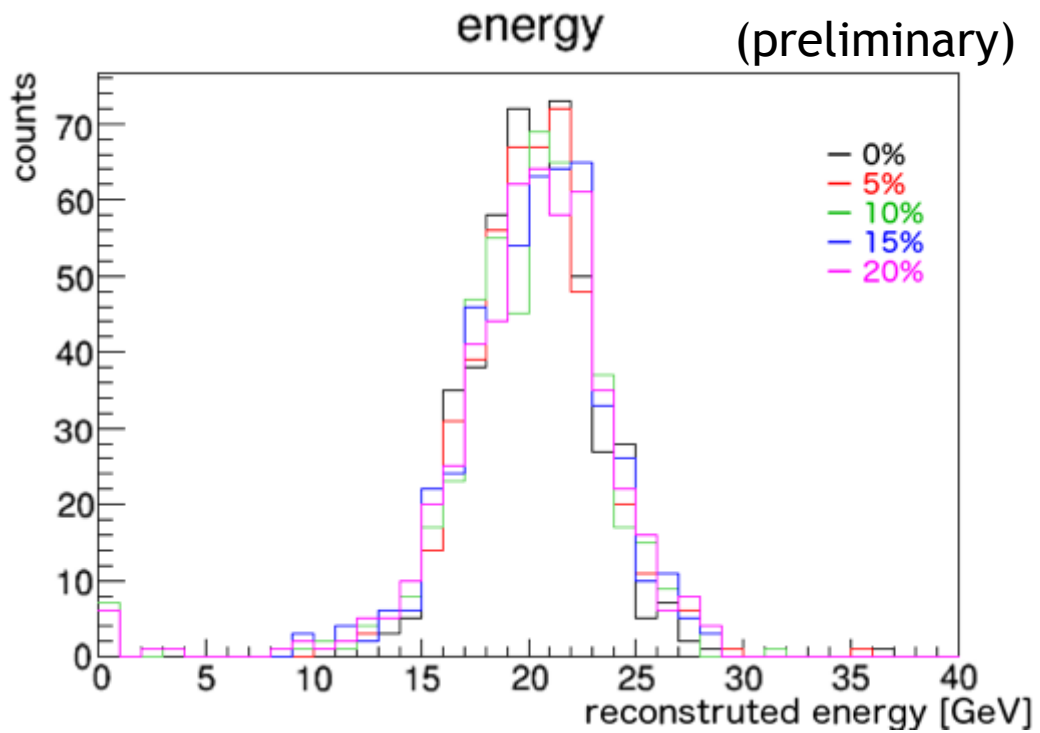
- See the effect of more moderate crosstalk value in detail
- Study the energy resolution of various jet energies
- Optical crosstalk with random proportions (depending on hit position in a cell)
- Optical crosstalk to farther tiles (not only 4 neighbors but 8 or 12)

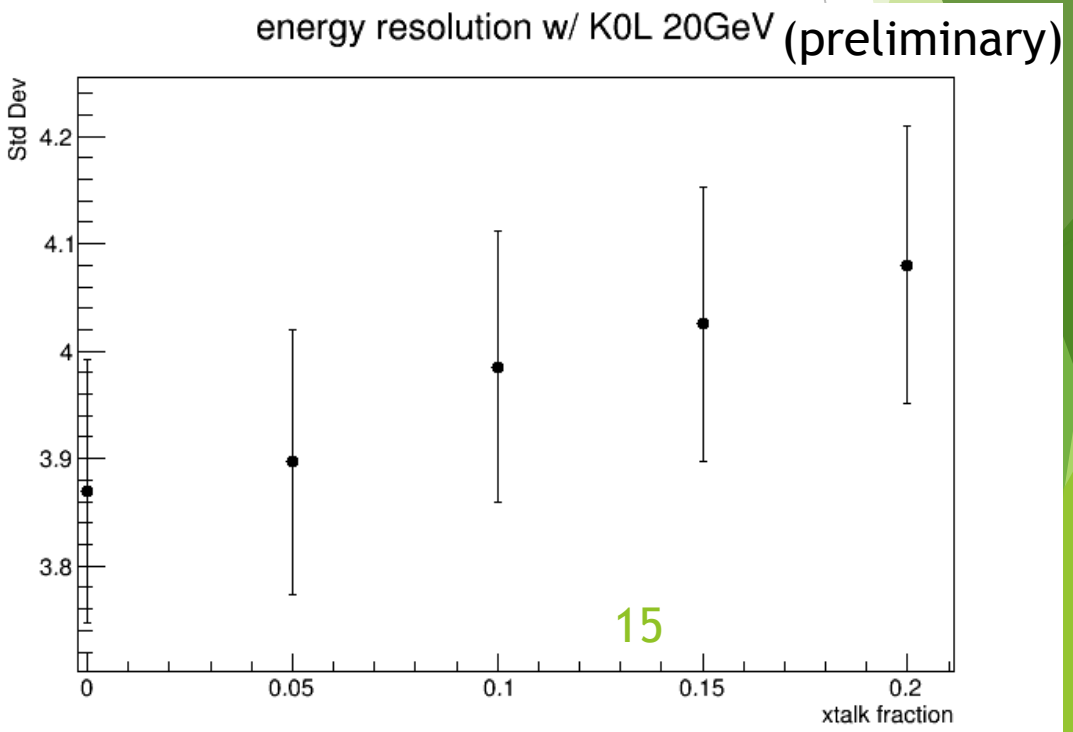
THE END

Backups

Single particle energy resolution

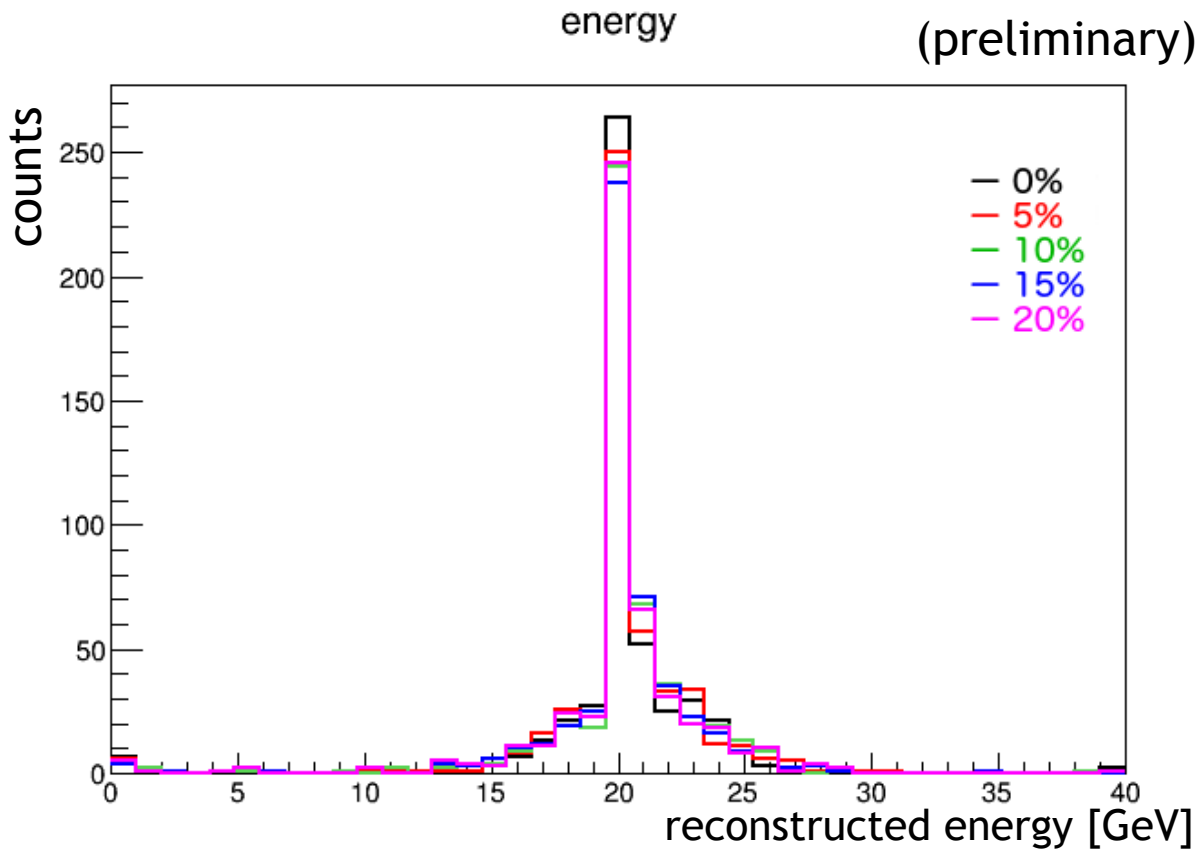
- The reconstructed energy of neutral hadron (K_L^0, 20GeV)
- The mean value of the reconstructed energy changed by increasing the crosstalk, so I made some calibration to modify
- The resolution is gradually getting worse as the crosstalk increases

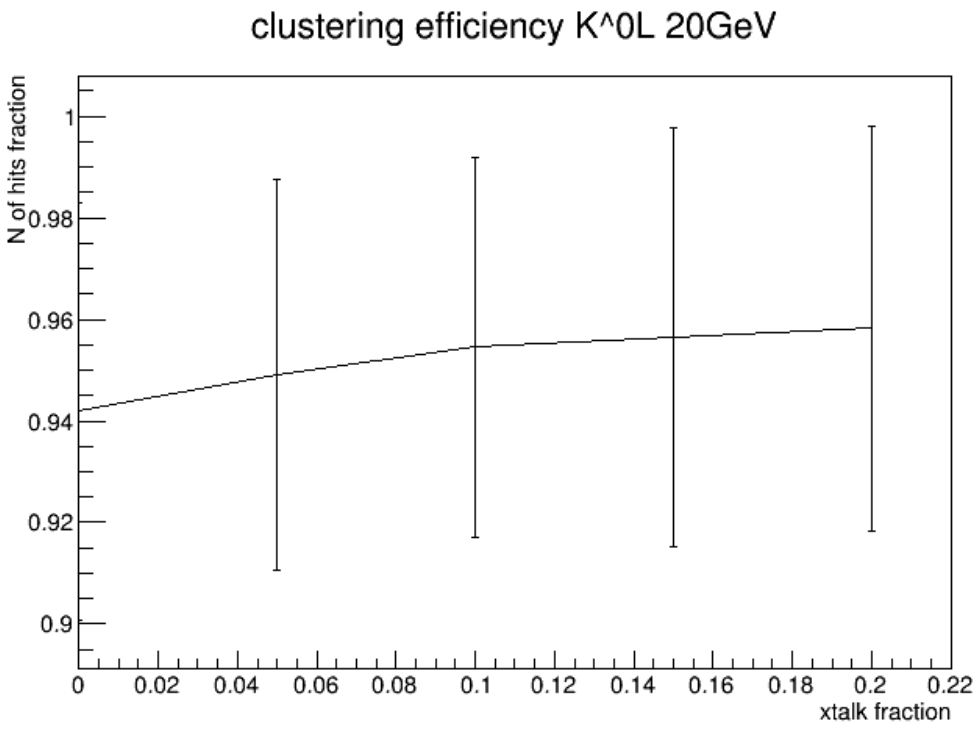


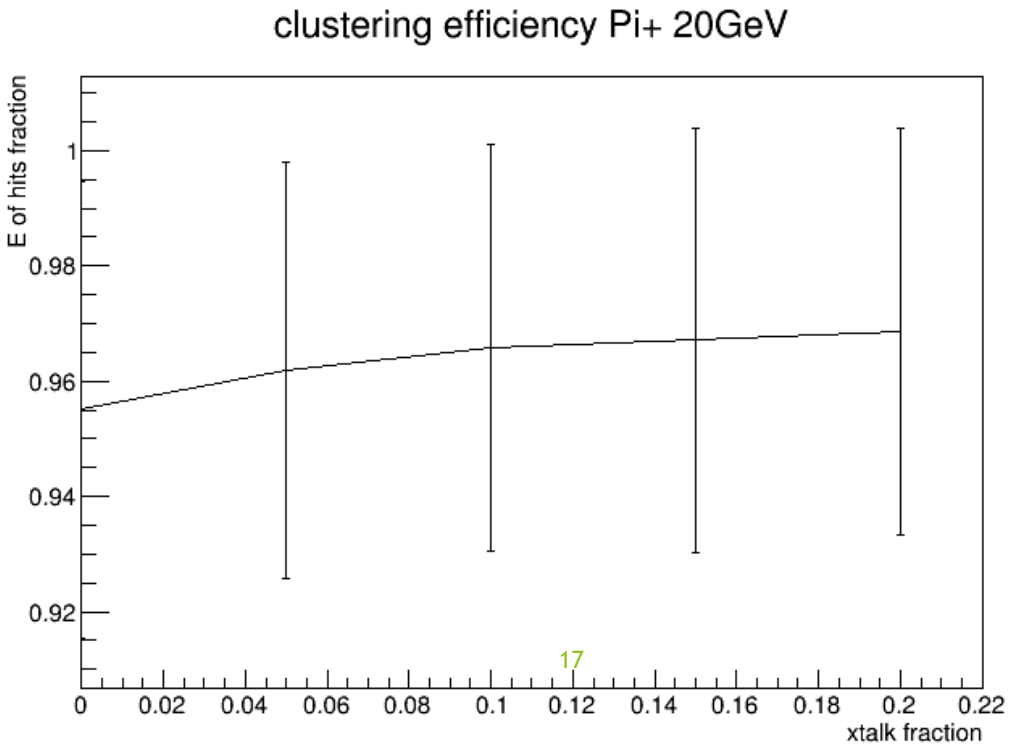


Single particle energy resolution

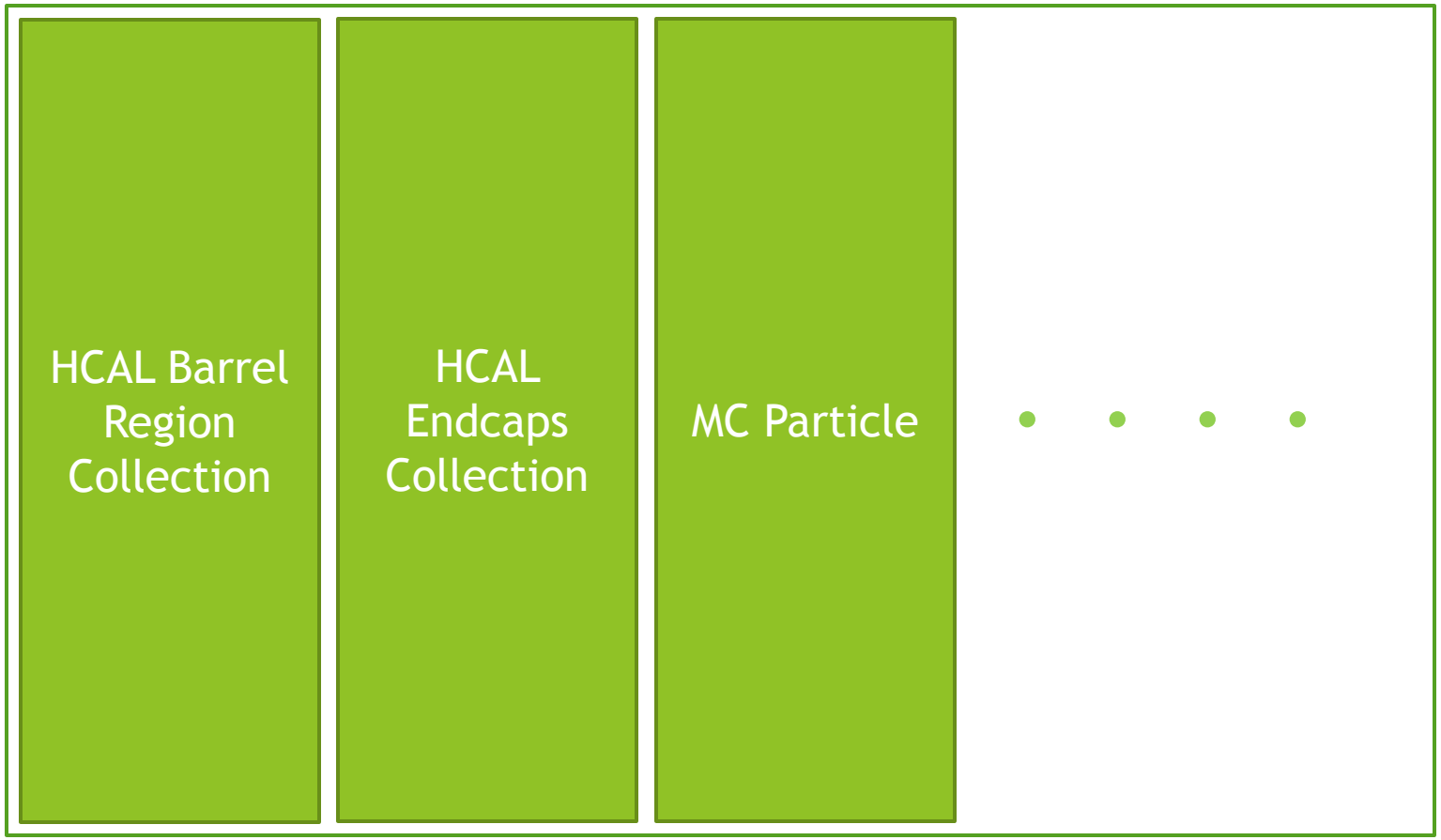
- For charged hadron (π^+), energy is mainly reconstructed by tracking detector, therefore the reconstruction is much better than neutral




clustering efficiency K^0L 20GeV
N of hits fraction
1
0.98
0.96
0.94
0.92
0.9
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
xtalk fraction


clustering efficiency Pi+ 20GeV
E of hits fraction
1
0.98
0.96
0.94
0.92
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
xtalk fraction

Event (generated by a simulator)



Collection contents

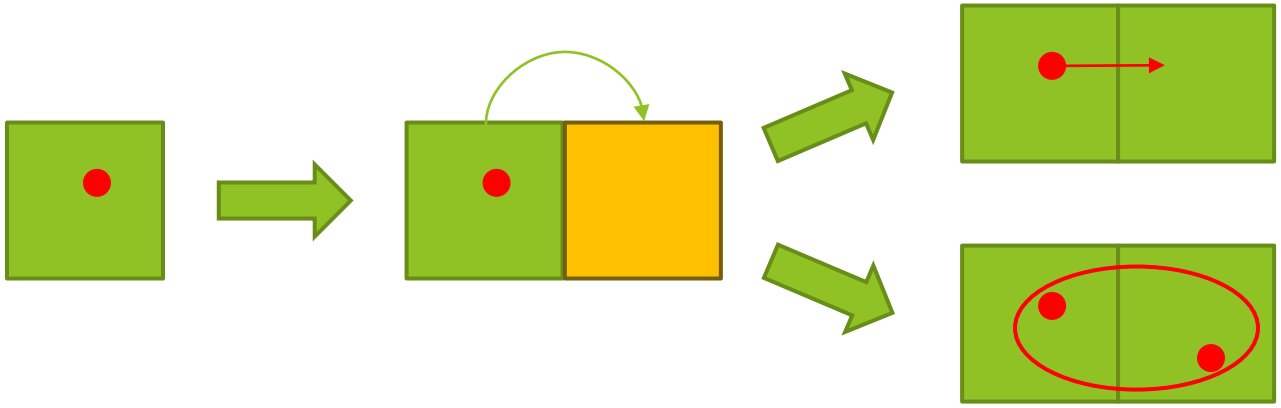
HCAL Barrel Region Collection

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

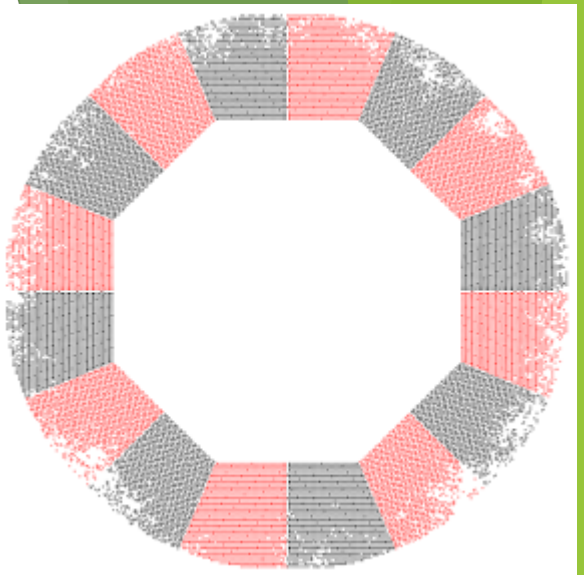
$\times$ nHits

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

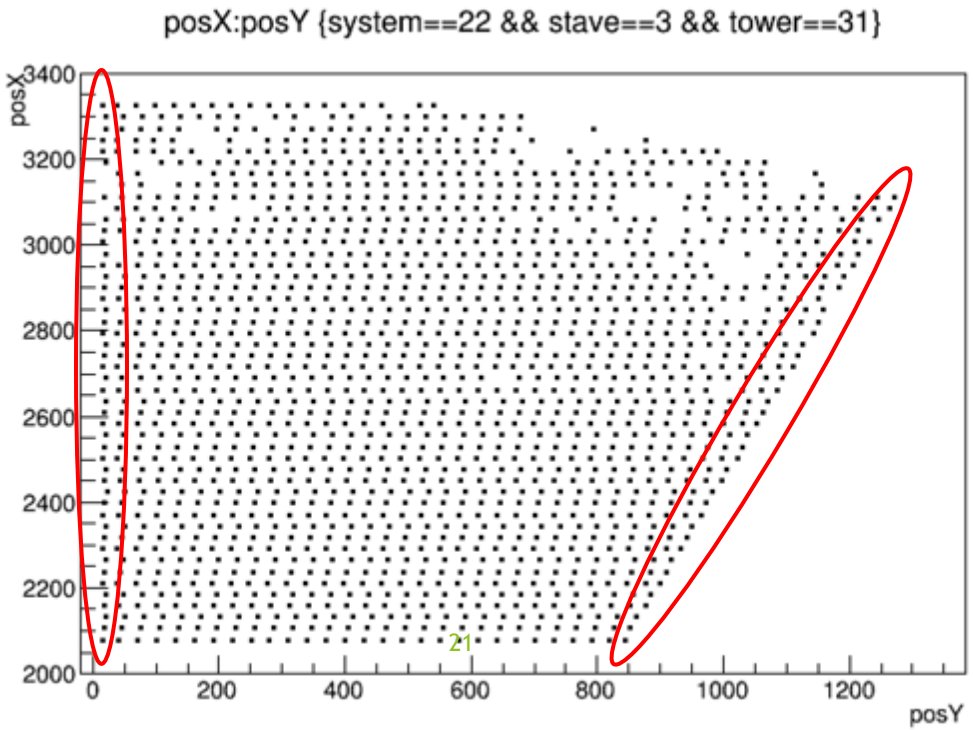


Some difficulty

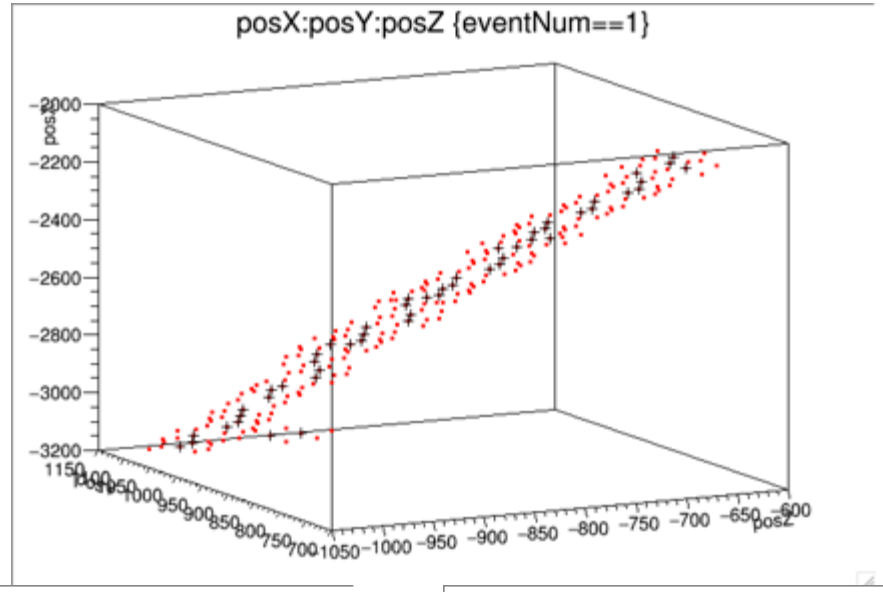


- The spatial position of neighboring cell was not obvious
  - For example, in HCAL Barrel, the distance along the x-y surface is 30 mm
  - but the distance along the z axis is 30.3248 mm
  - Also the at the both edge of each module, some irregular
  - value is appearing (a bit shorter than 30 mm)

- 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)



Result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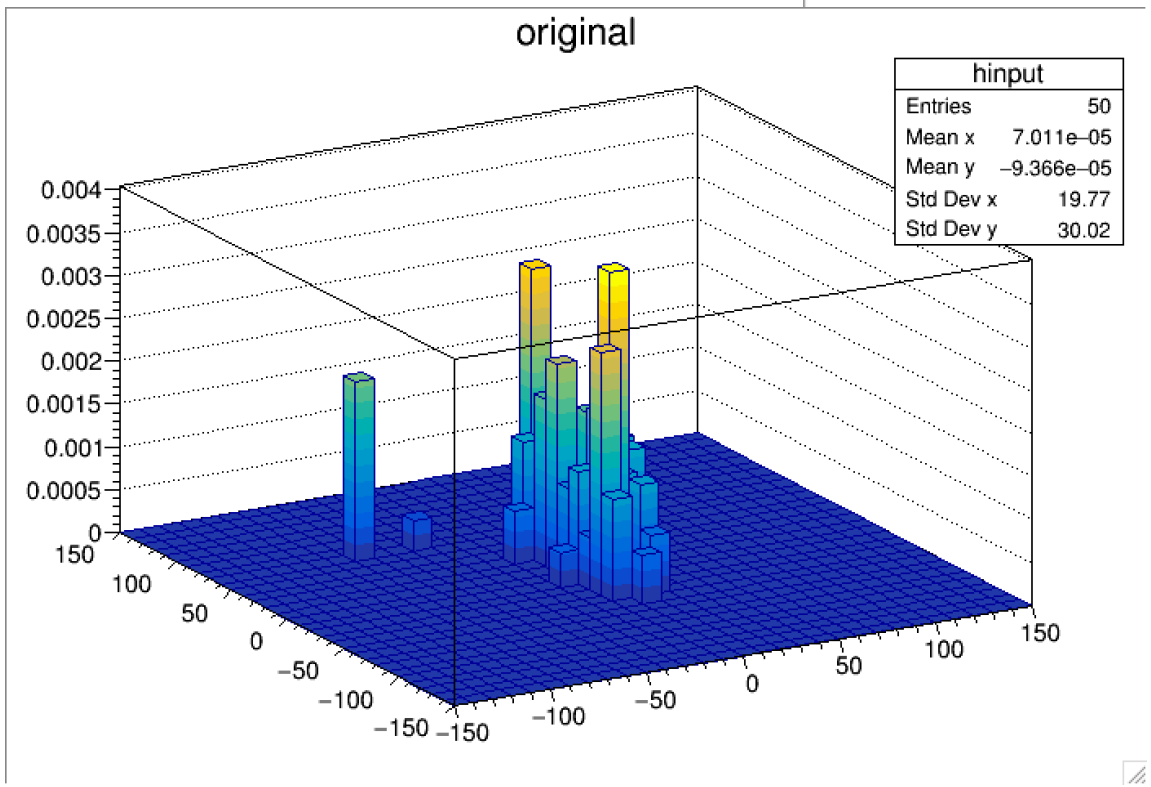
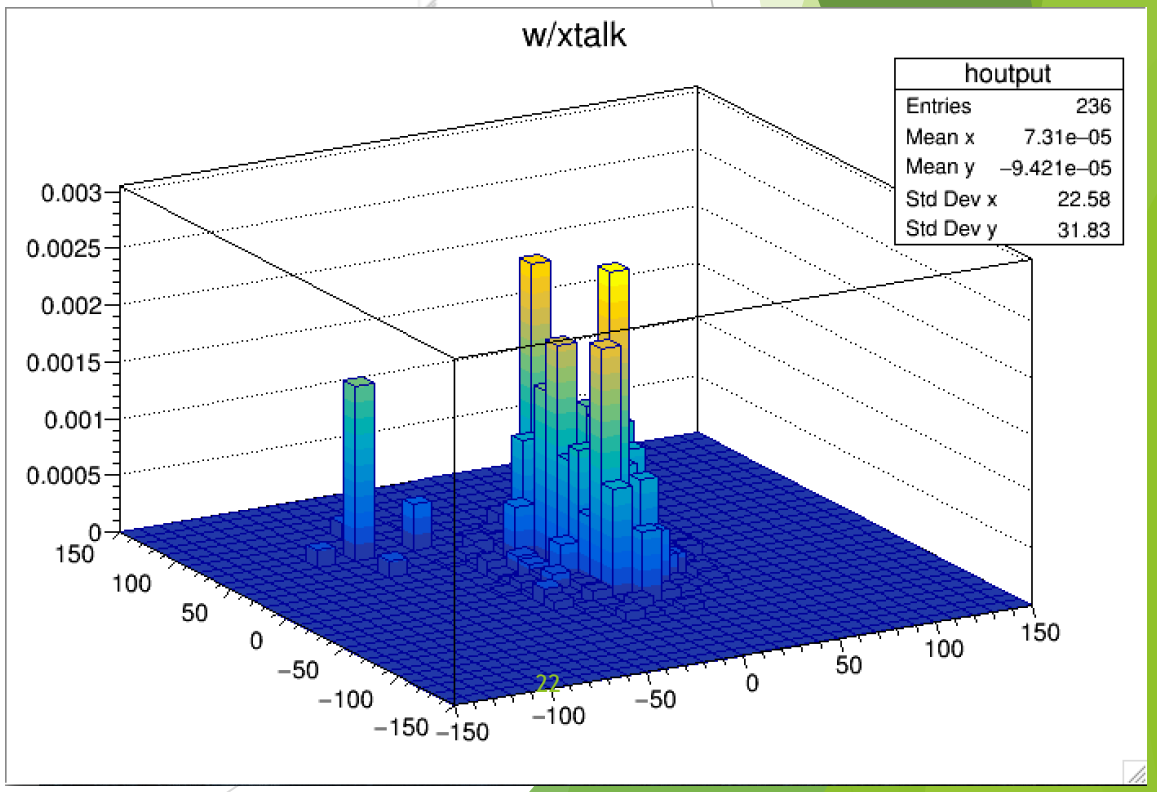
posY
posX
posZ


original
hinput
Entries 50
Mean x 7.011e−05
Mean y −9.366e−05
Std Dev x 19.77
Std Dev y 30.02


w/xtalk
houtput
Entries 236
Mean x 7.31e−05
Mean y −9.421e−05
Std Dev x 22.58
Std Dev y 31.83