Simulation Study for ILC HCAL

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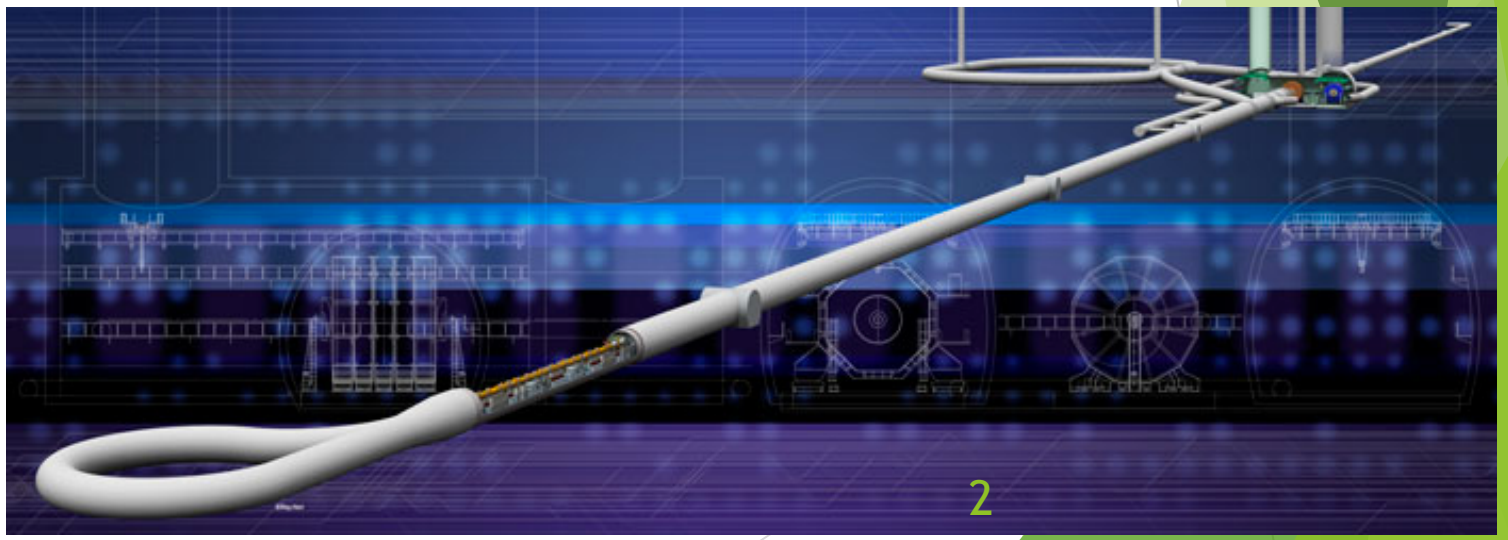
International Linear Collider

- International Linear Collider (ILC) will be the world's largest e^-e^+ collider
- Candidate site is Kitakami mountains in Iwate, Japan
- Similar to and complementary with LHC, ILC is going to do researches on Higgs, top quark and so on in order to find New Physics



kek.jp

International Large Detector

- For ILC, there are mainly two detector designs
- International Large Detector (ILD) and Silicon Detector (SiD)
- Both are multipurpose detector with tracking detector, calorimeters, muon detectors
- Important feature of both ILD and SiD is calorimetry based on Particle Flow Algorithm
- Most Japanese ILC researchers are working on ILD

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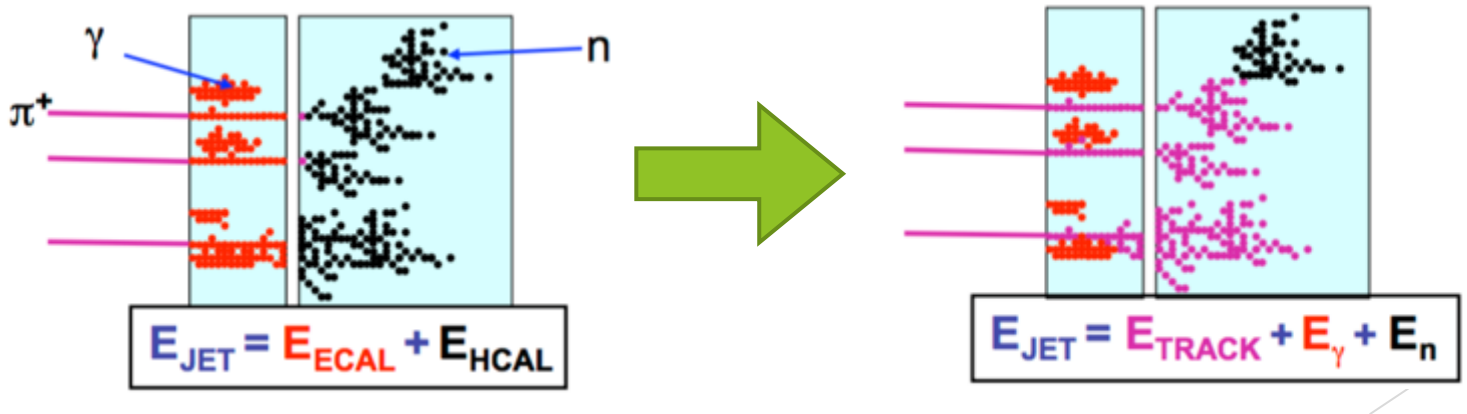
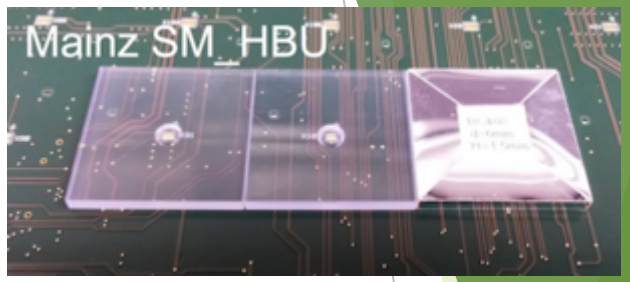
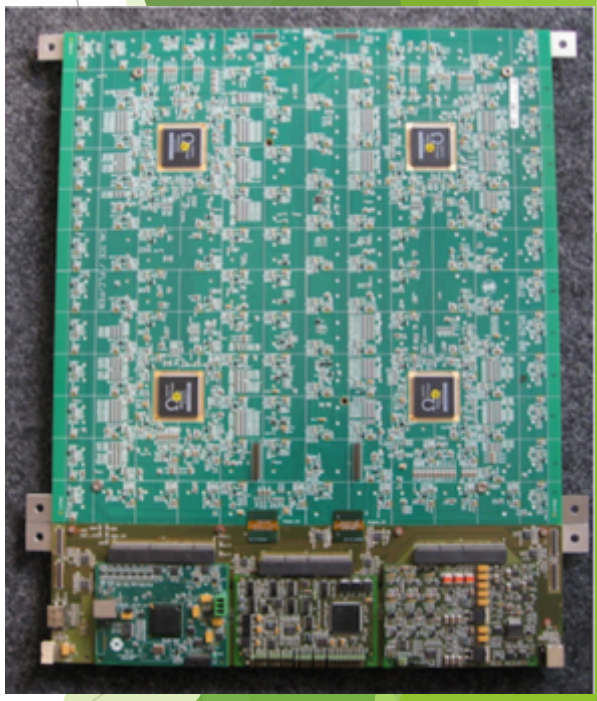
Particle Flow Algorithm

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



Design of ILD HCAL

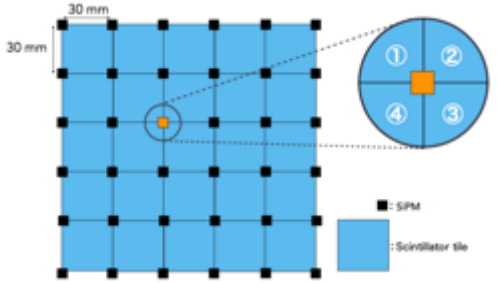




- Current design of ILD HCAL : 48 absorbers and 48 active layers alternately
- The active layers are aligned 30mm x 30mm scintillator tiles with SiPMs at the center of the tiles
- The enormous amount of signals from SiPMs are managed by HCAL Base Unit, 12 x 12 SiPMs and 4 ASICs combined

- Some other detector designs for cost reduction or noise reduction

megatile



4 corner readout

-> Possible increase of optical crosstalk

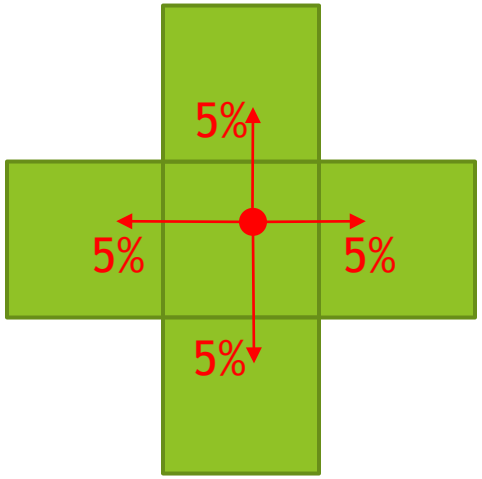
Optical Crosstalk Simulation

- There are some optical crosstalk between scintillator tiles, but the effect of the crosstalk is not fully studied yet
- Estimated optical crosstalk of current design is just a few percent, but in some alternate design it could increase

- 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

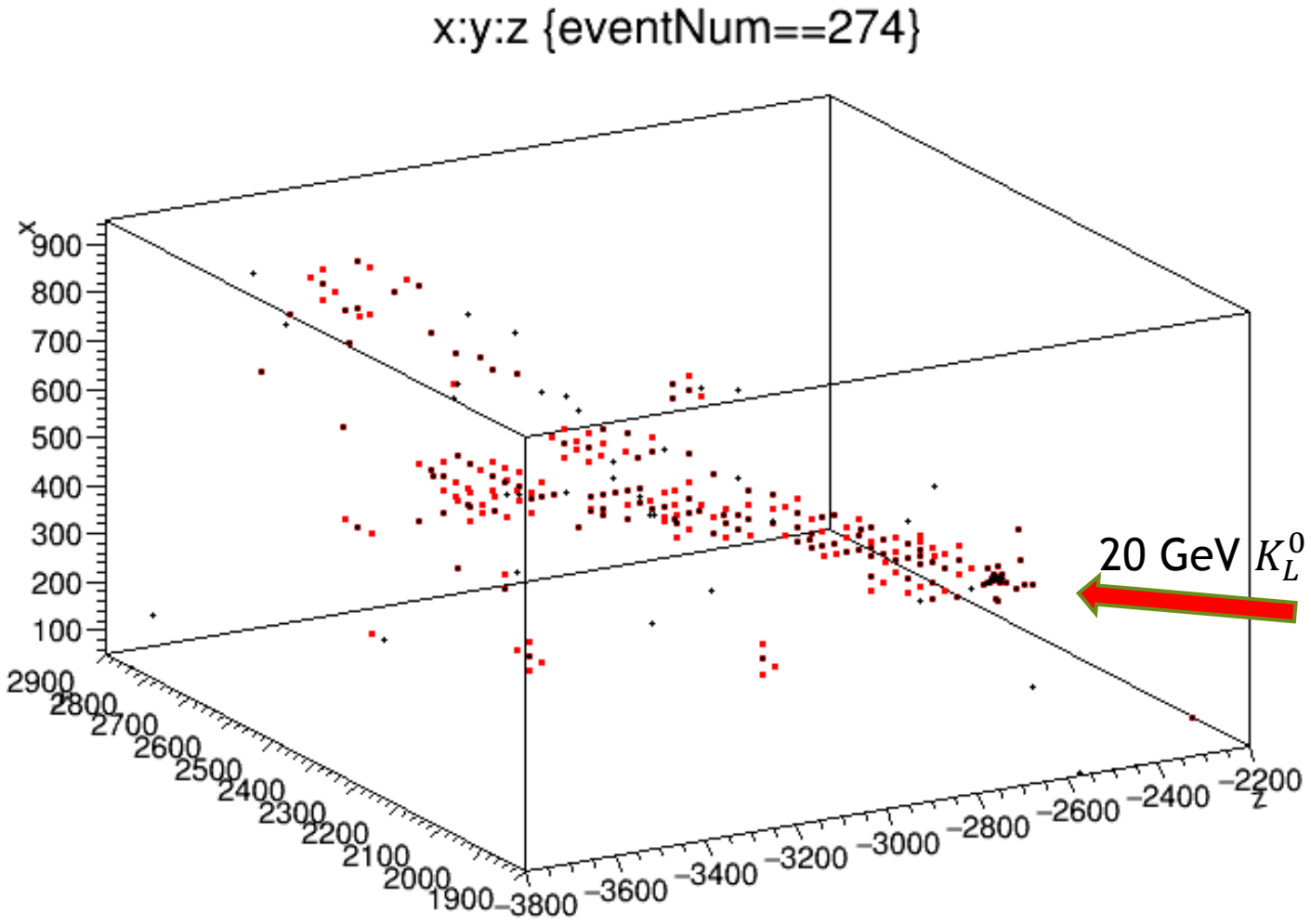
Generating crosstalk in simulation

- 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)



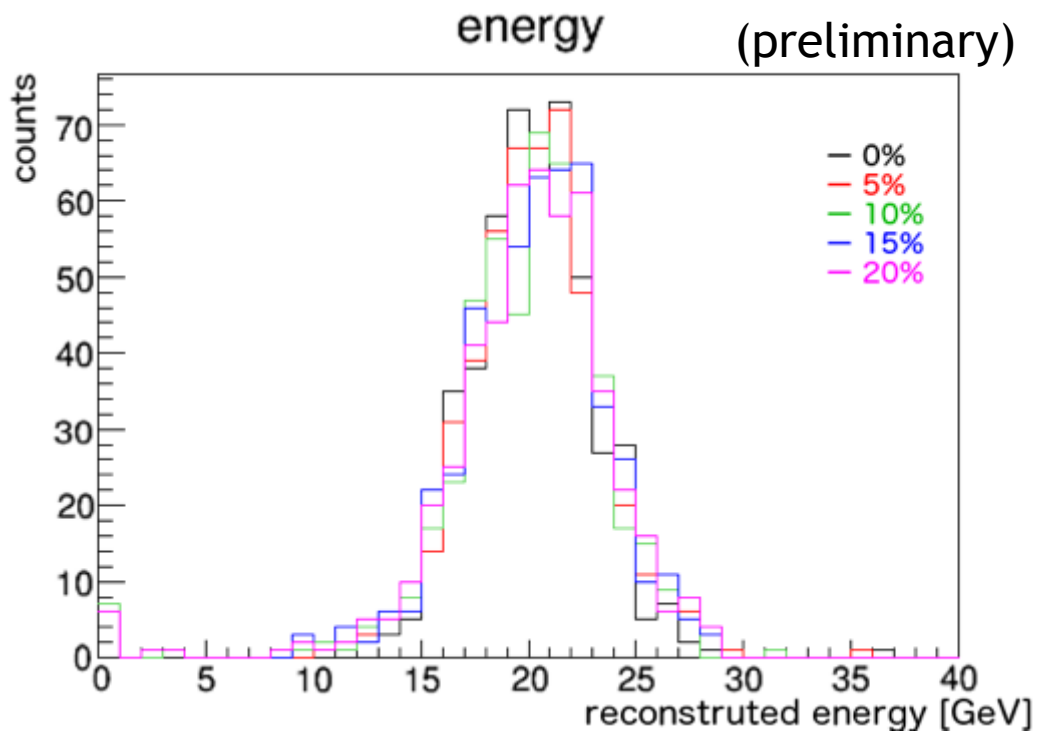
Example

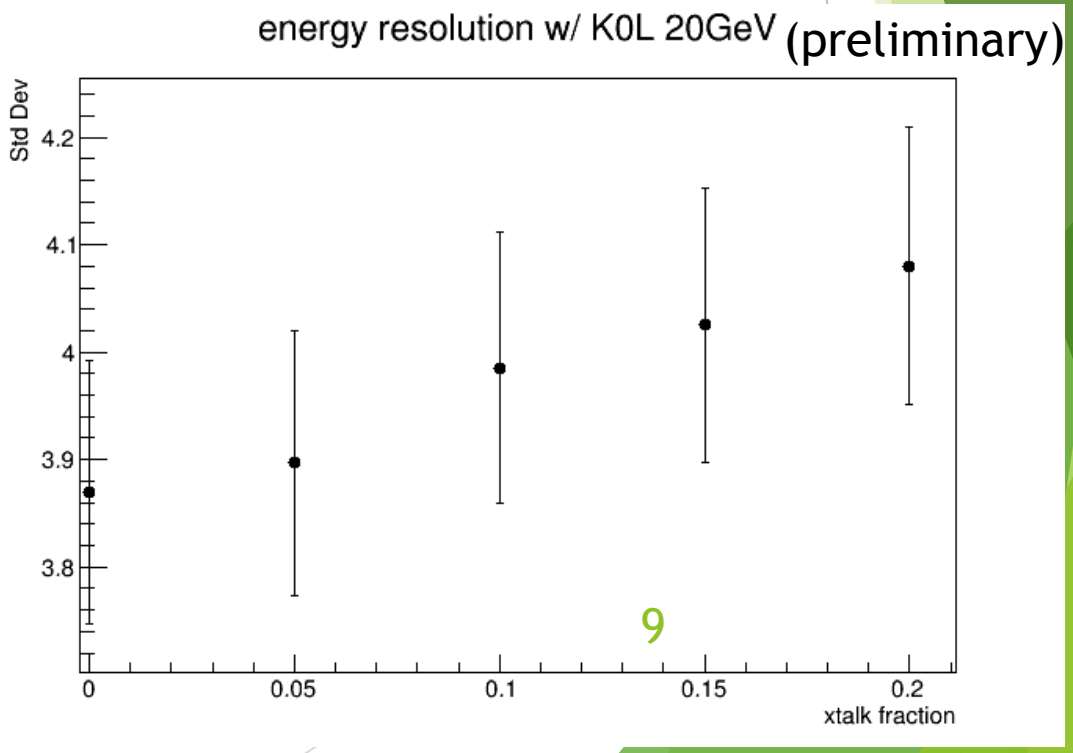
- Example event display
- The black points are the original energy deposit
- The red points are hits after generating the crosstalk



Single particle energy resolution

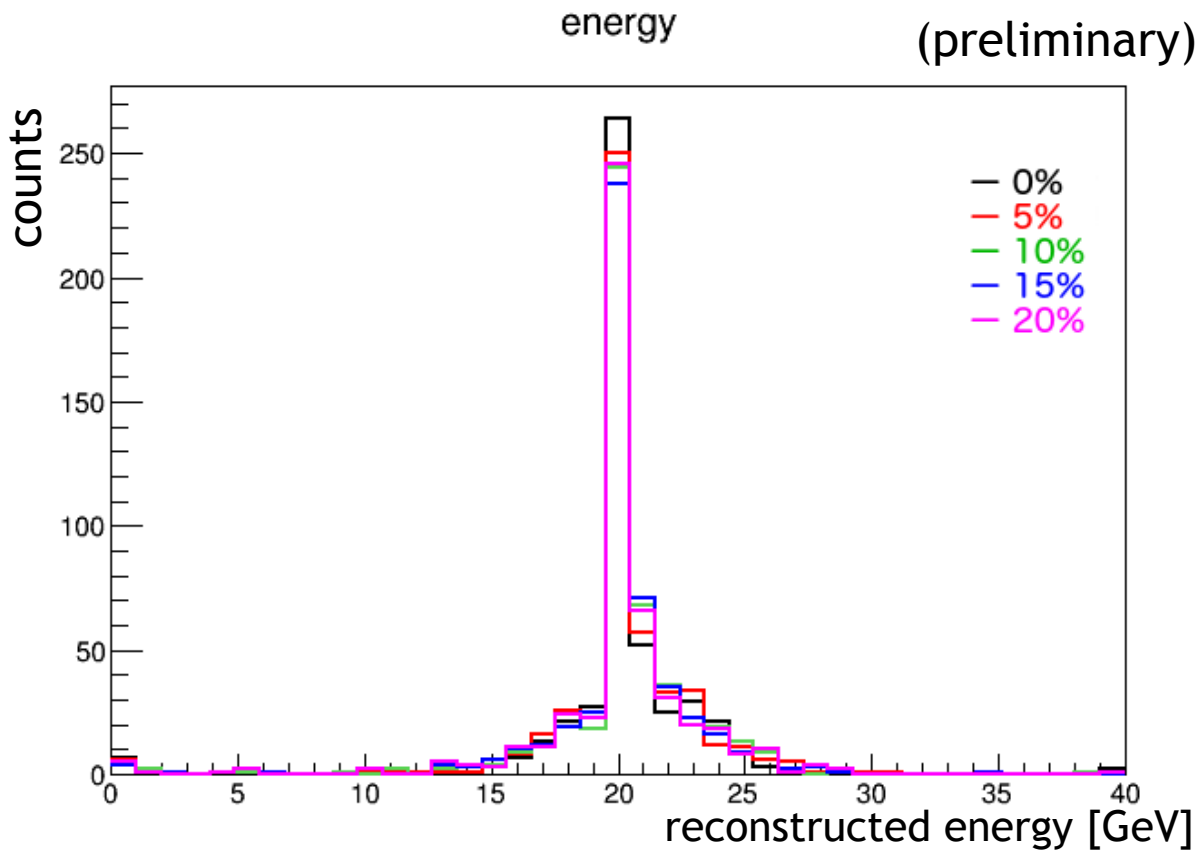
- The reconstructed energy of neutral hadron (K_L^0, 20GeV)
- The mean value of the reconstructed energy changed by increasing the crosstalk, so I made some calibration to modify
- The resolution is gradually getting worse as the crosstalk increases





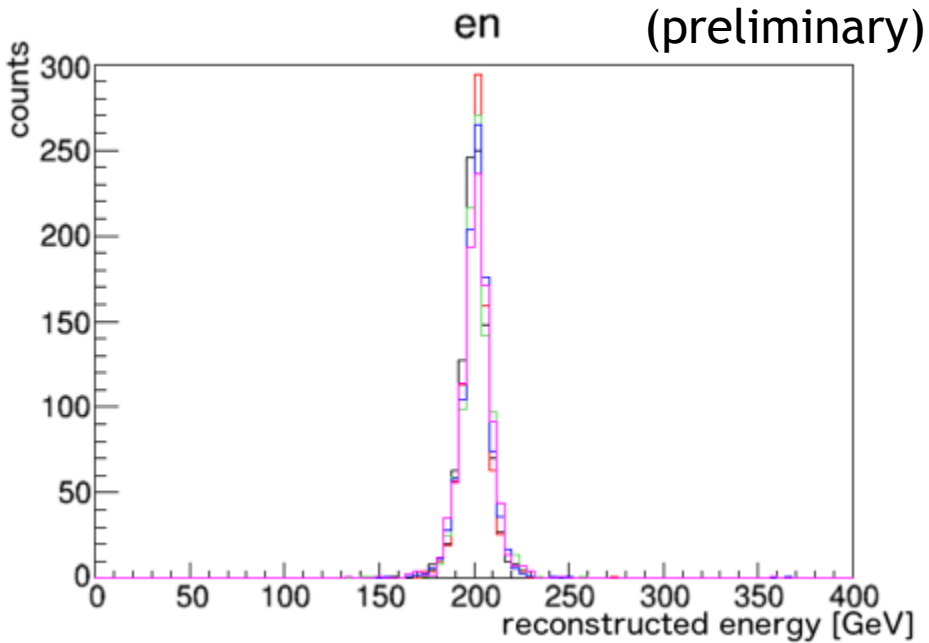
Single particle energy resolution

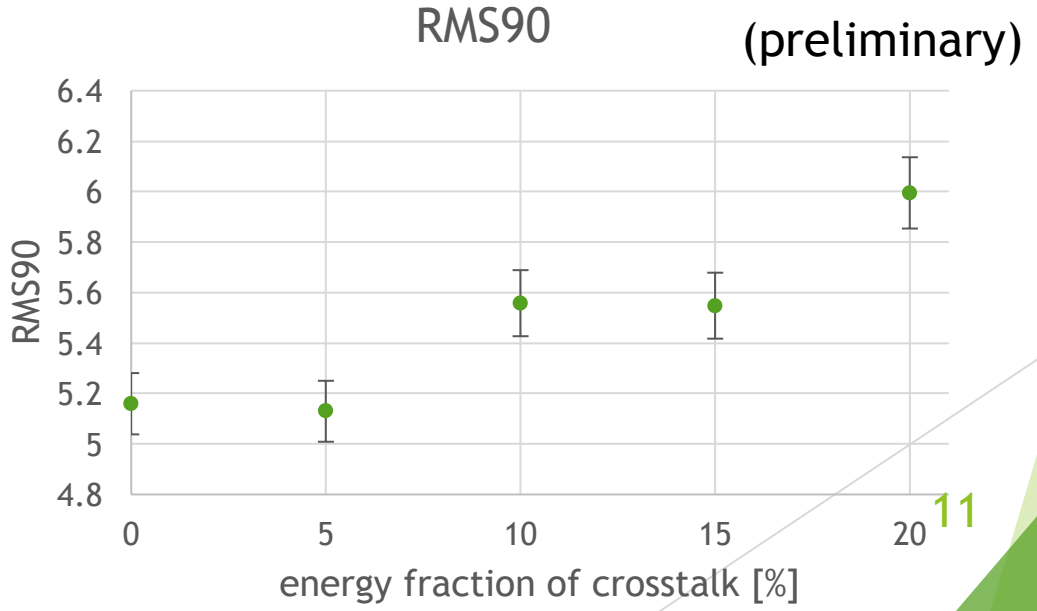
- For charged hadron (π^+), energy is mainly reconstructed by tracking detector, therefore the reconstruction is much better than neutral



Jet energy resolution

- $e^+e^- \rightarrow q\bar{q}$ with 200 GeV center-of-mass energy
- Energy reconstruction is well functioning (distributed around 200 GeV)
- The energy resolution is getting worse as same as neutral hadron case



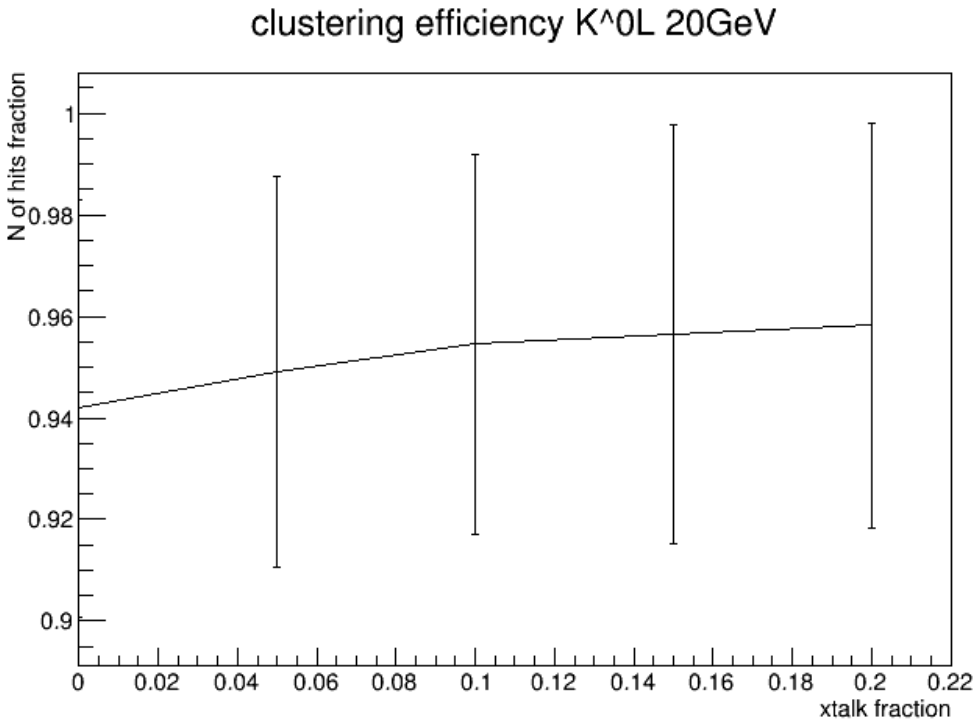


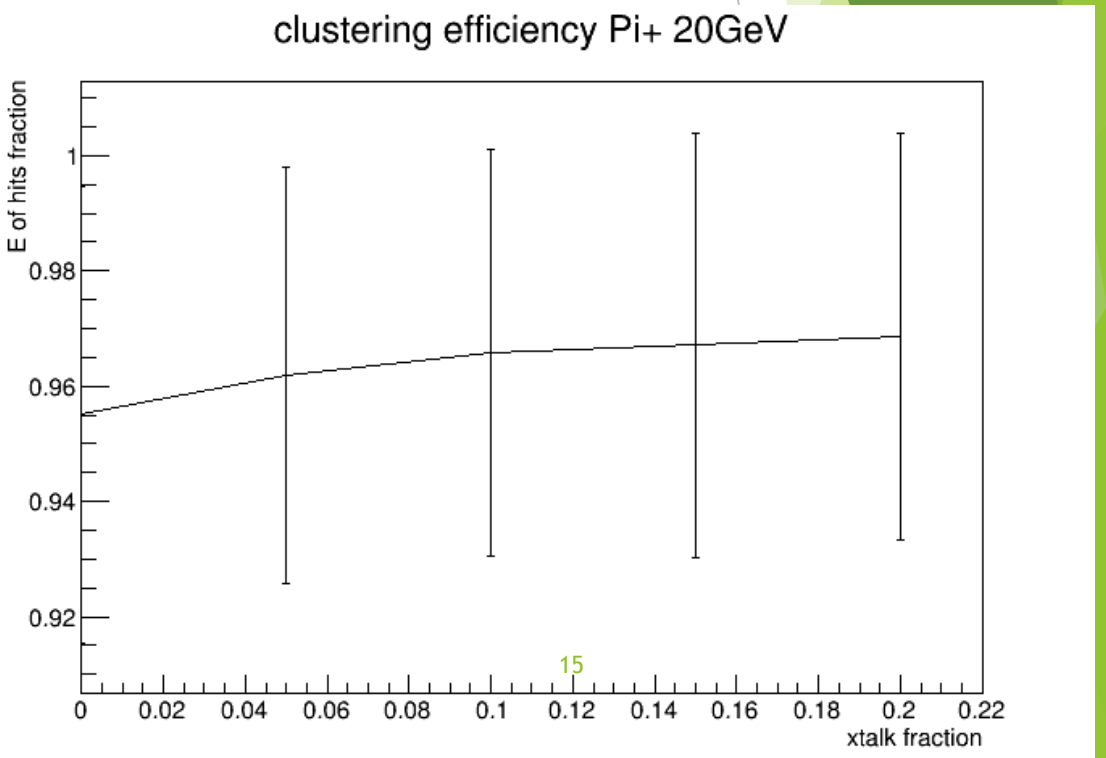
Future Prospects

- We have not yet fully understood exactly what is going on in PFA
- See more details into the jet reconstruction process
- Study two particle system (like $\pi^0 \rightarrow \gamma\gamma$) to see the effect on cluster separation
- Optical crosstalk to farther tiles (not only 4 neighbors but 8 or 12)

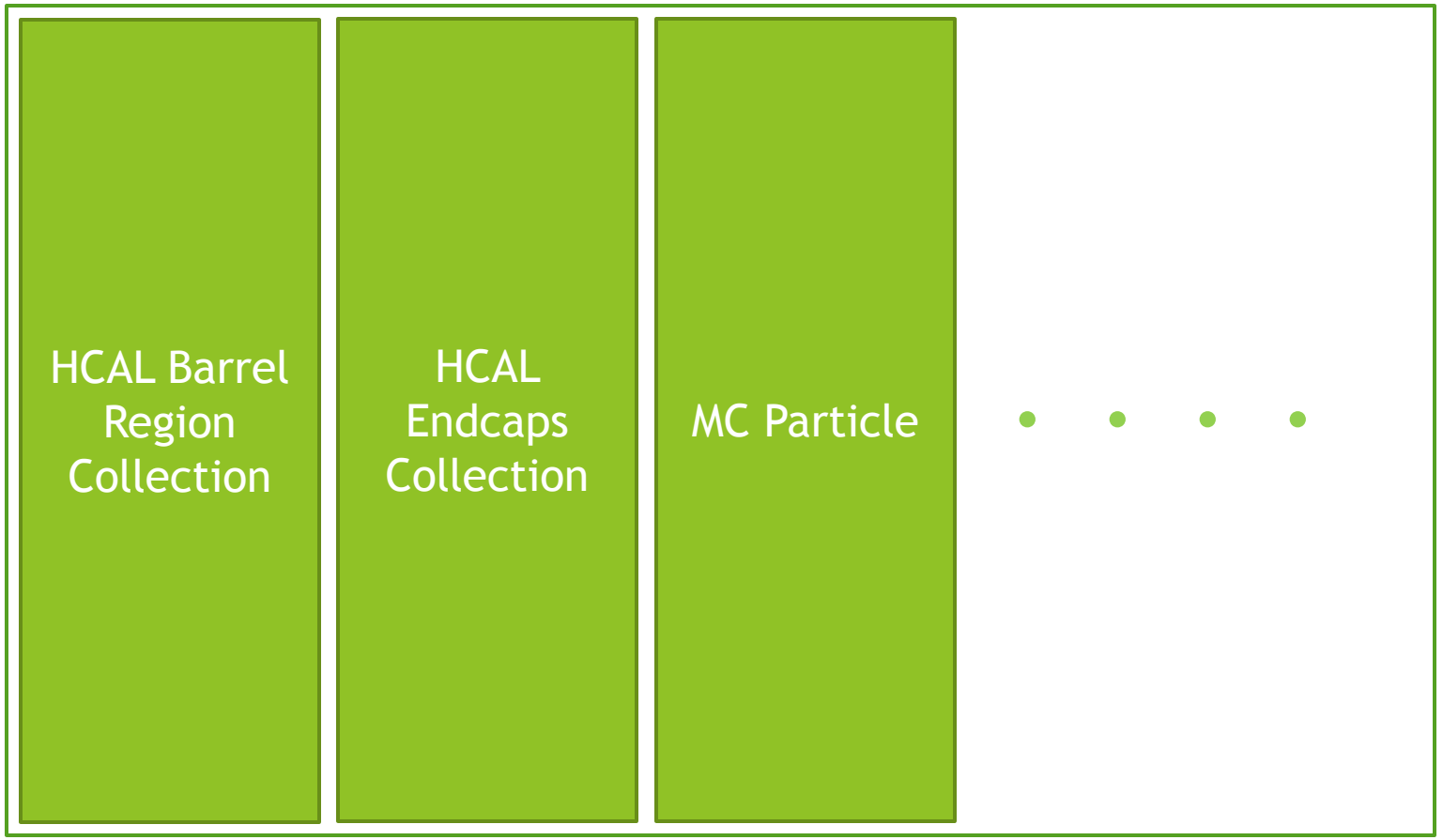
- Develop some method to reduce the effects of crosstalk

Backups

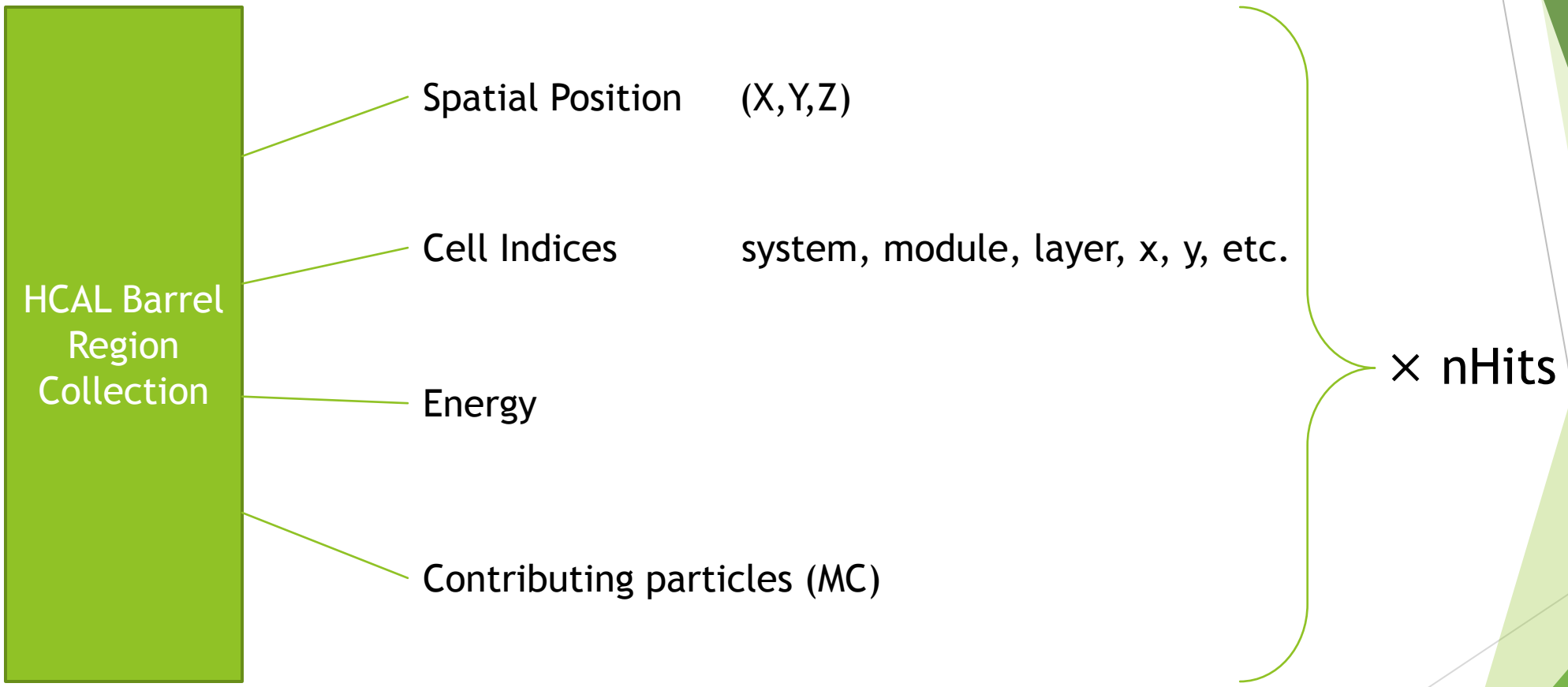

clustering efficiency K^0L 20GeV
N of hits fraction
1
0.98
0.96
0.94
0.92
0.9
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
xtalk fraction


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)

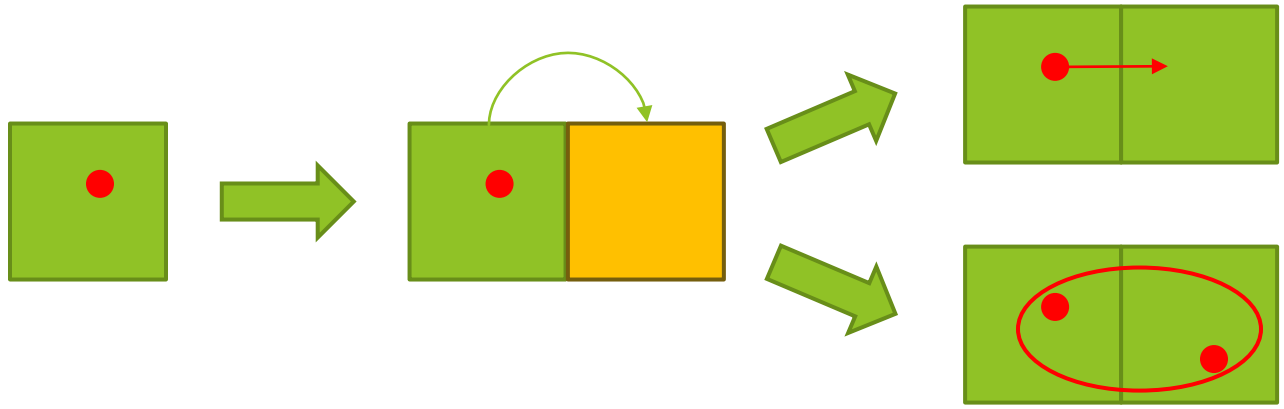


Collection contents

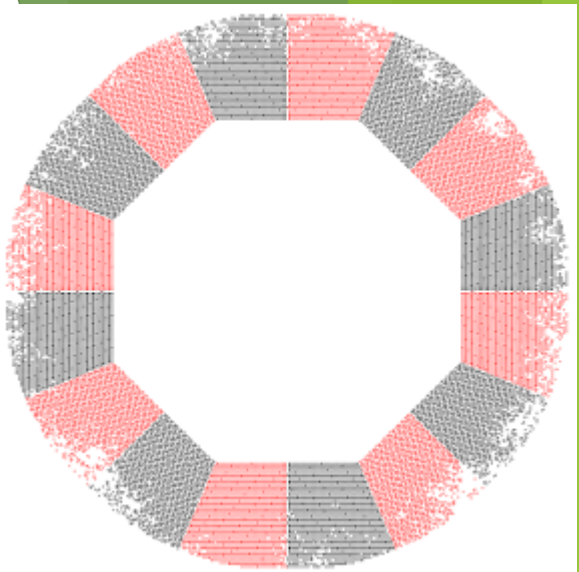


Algorithm

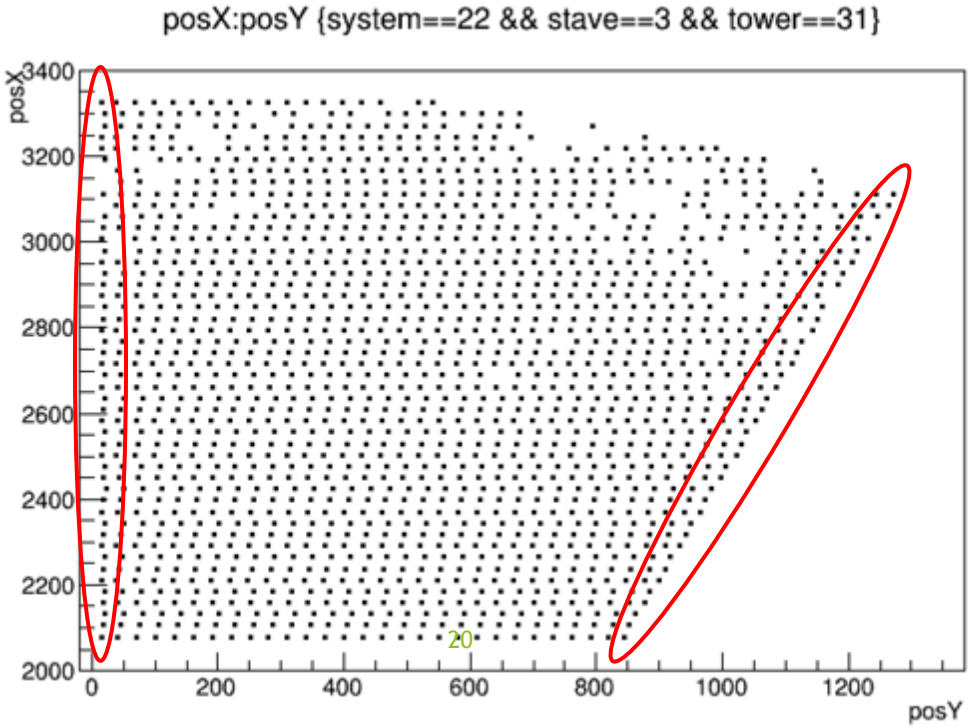
- Take one hit in the event
- Calculate the cell indices and the spatial positions of neighboring cells
- Then, if there is no hit on the neighboring cell, generate a new hit with some energy fraction (like 5% or so)
- And if the neighboring cell already has a hit, add as the form of energy contribution



Some difficulty

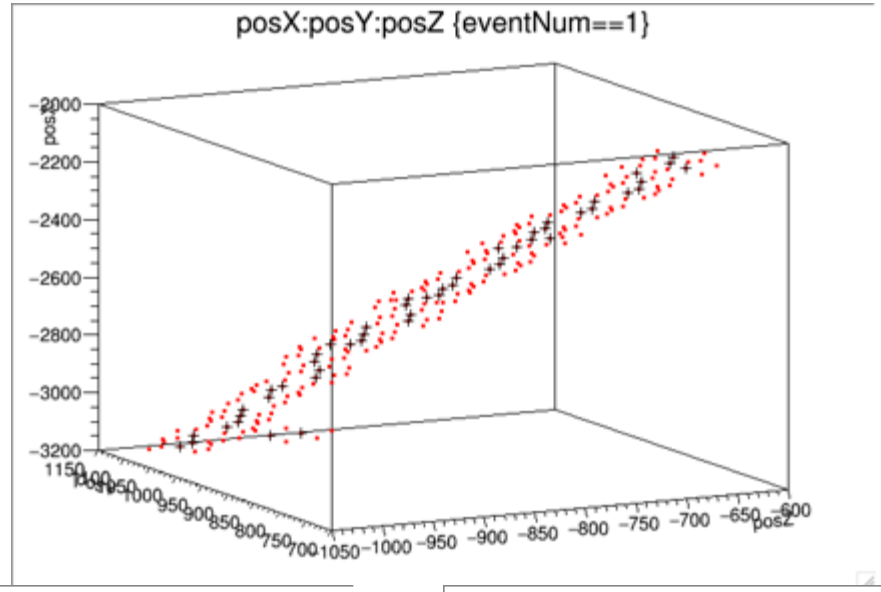


- The spatial position of neighboring cell was not obvious
  - For example, in HCAL Barrel, the distance along the x-y surface is 30 mm
  - but the distance along the z axis is 30.3248 mm
  - Also the at the both edge of each module, some irregular
  - value is appearing (a bit shorter than 30 mm)



- 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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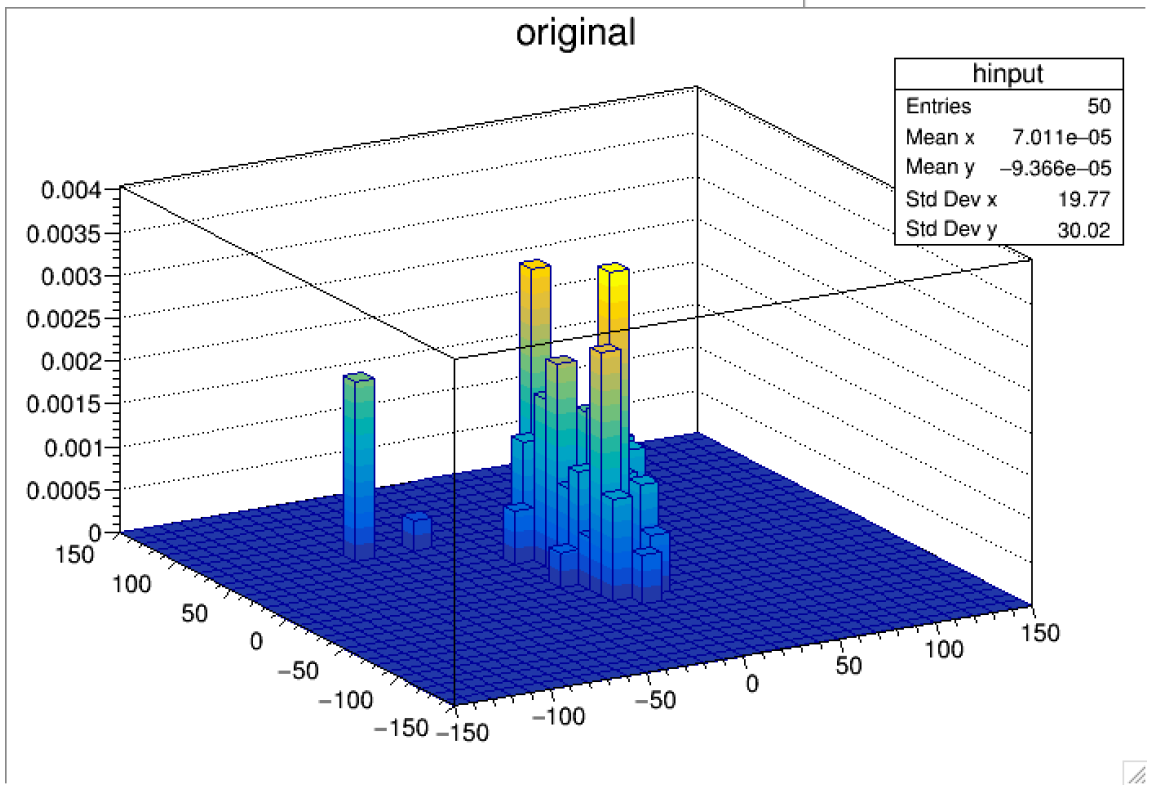
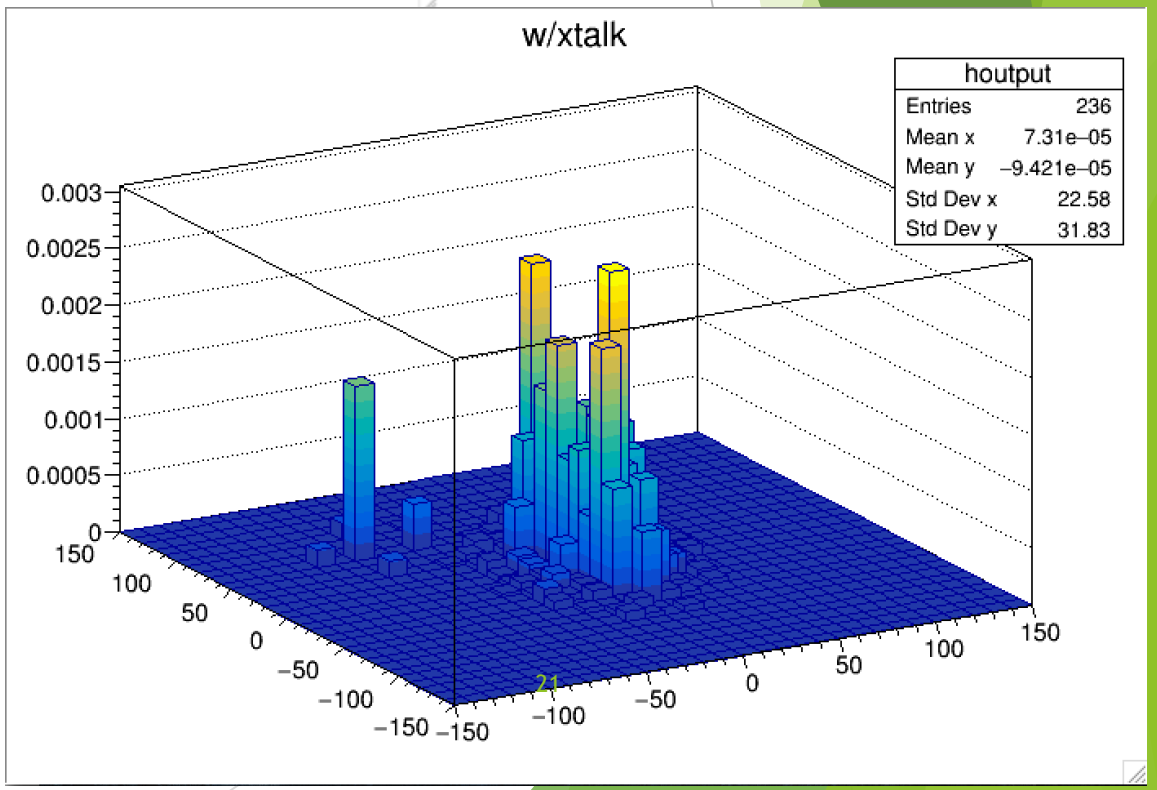
posY
posZ


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

Prospective

- Analyze the hit data including the crosstalk with PFA, and see how much is the result affected by the crosstalk
- Changing the energy fraction of the crosstalk, check the limitation of crosstalk to achieve fine analysis
- Also develop some processor to reduce the effect of the crosstalk