Simulation Study on Optical Crosstalk for AHCAL

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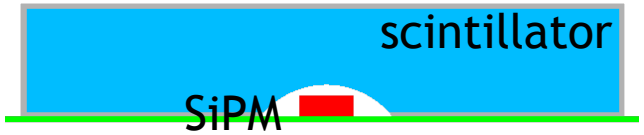
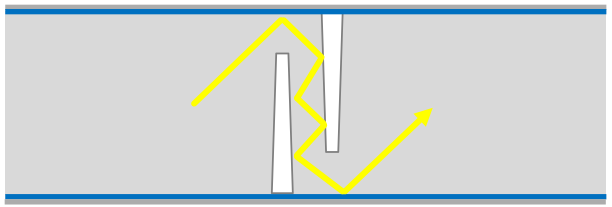
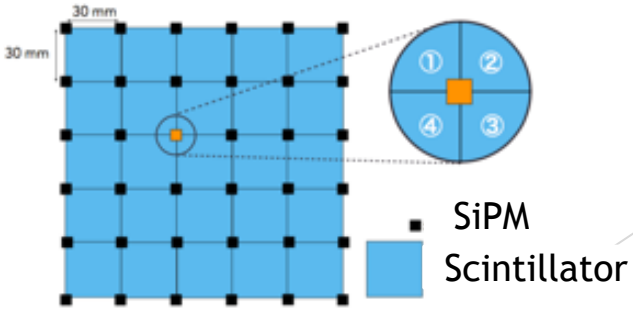
Possible Increase of Optical Crosstalk



- Baseline design of AHCAL :
  - The active layers are aligned 30mm x 30mm scintillator tiles with SiPMs at the center of the tiles
  - Each tile is wrapped with reflector foil individually
  - The optical crosstalk between tiles is estimated to be a few percent or lower
- Some other detector designs for mass production and performance improvement



megatile



4 corner readout

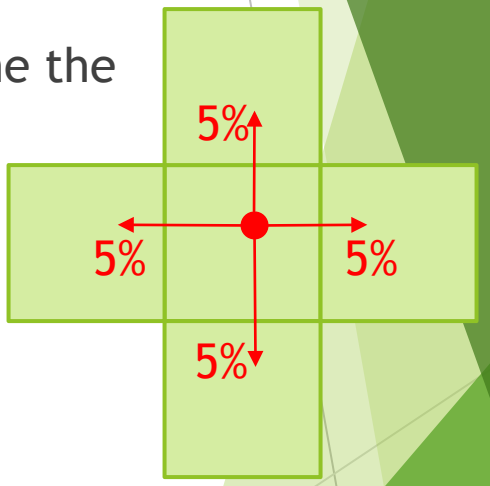
-> Possible increase of optical crosstalk

Objectives

- Simulate the effect of crosstalk on the calorimeter performance
  - Jet energy resolution
  - Particle separation
- Define the upper limit of crosstalk to retain the target resolution

Generating Crosstalk in Simulation

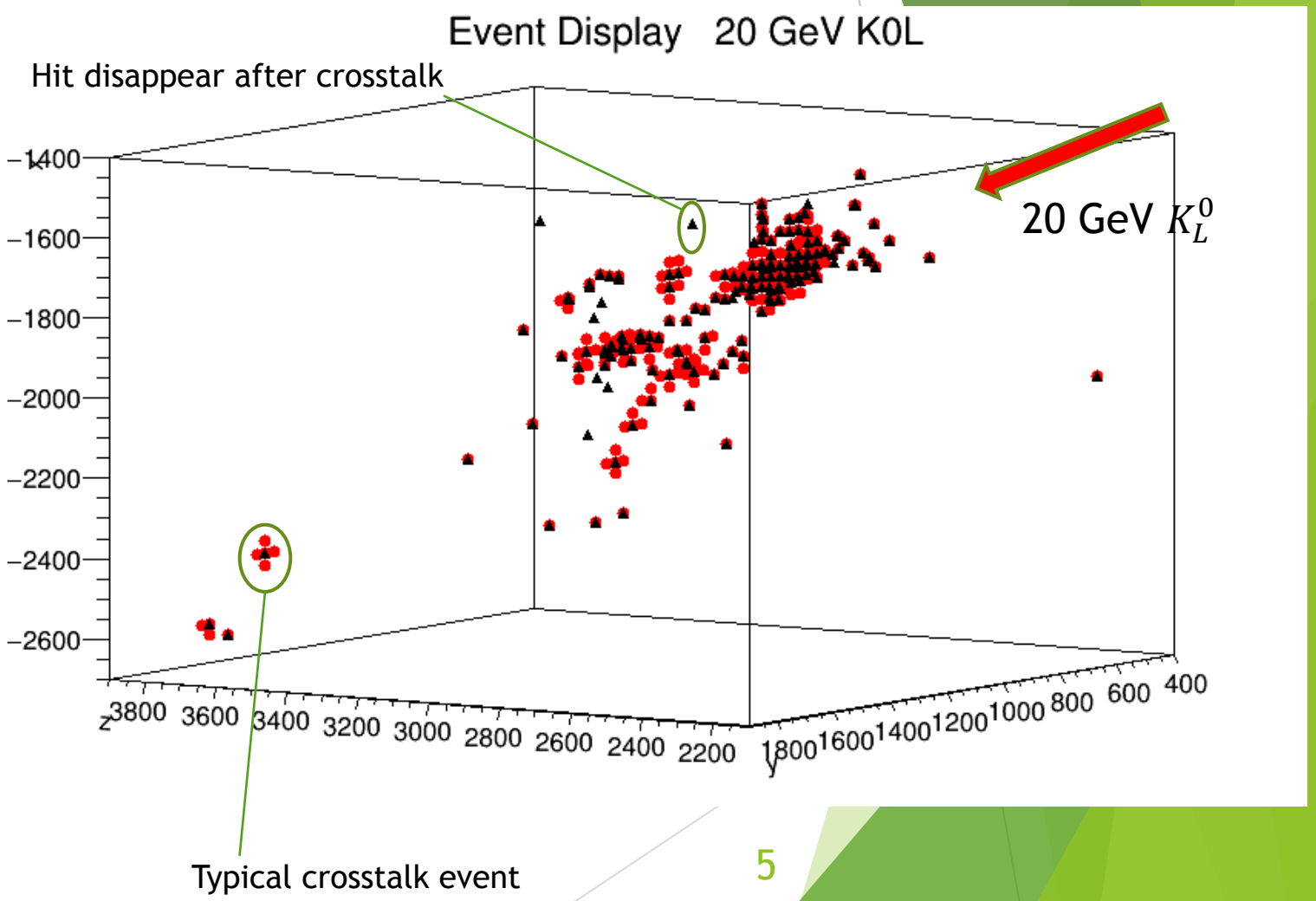
- For each energy deposit on scintillator tile, give some fraction of energy to neighboring tiles
- If there is already existing energy deposit on the neighboring tile, combine the original energy and the crosstalk energy
- Each energy deposit is digitized with threshold of 0.5 MIP



- Simulate dijet events from quark pairs in DD4hep ILD model (ILD_l1_v01)
- Apply 1-20 % crosstalk and reconstruct with Particle Flow Algorithm

Event with crosstalk

- Single neutral kaon injection
- Black : before applying crosstalk
- Red : after applying 10% crosstalk
- The shower get vague, and some hit energies fall below threshold



Previous Study

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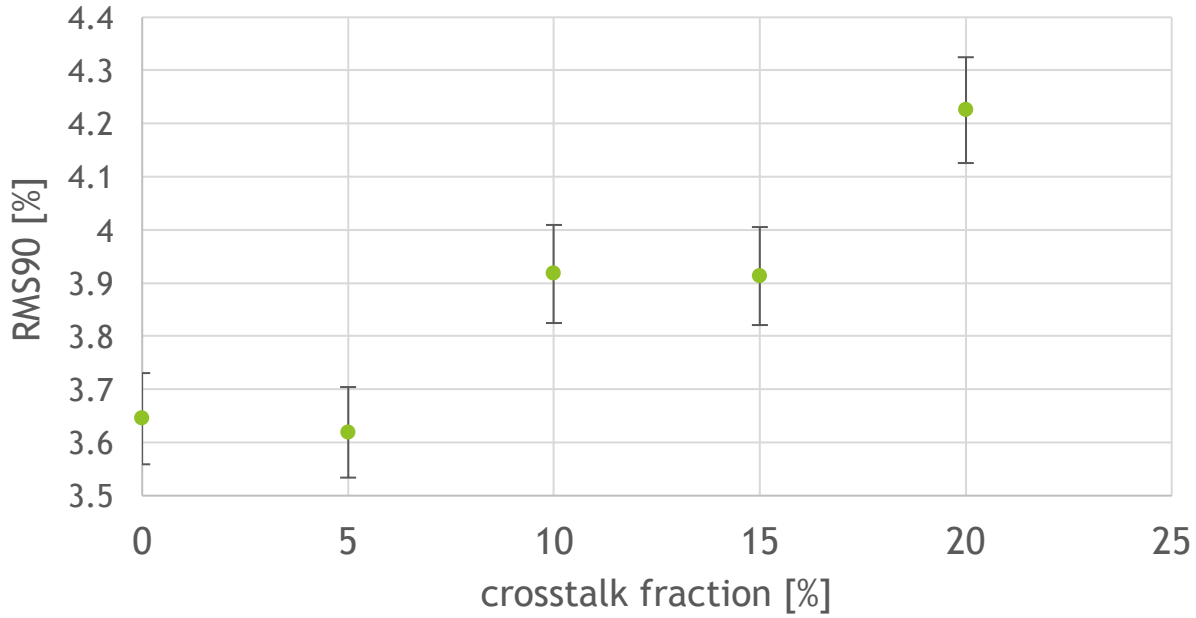
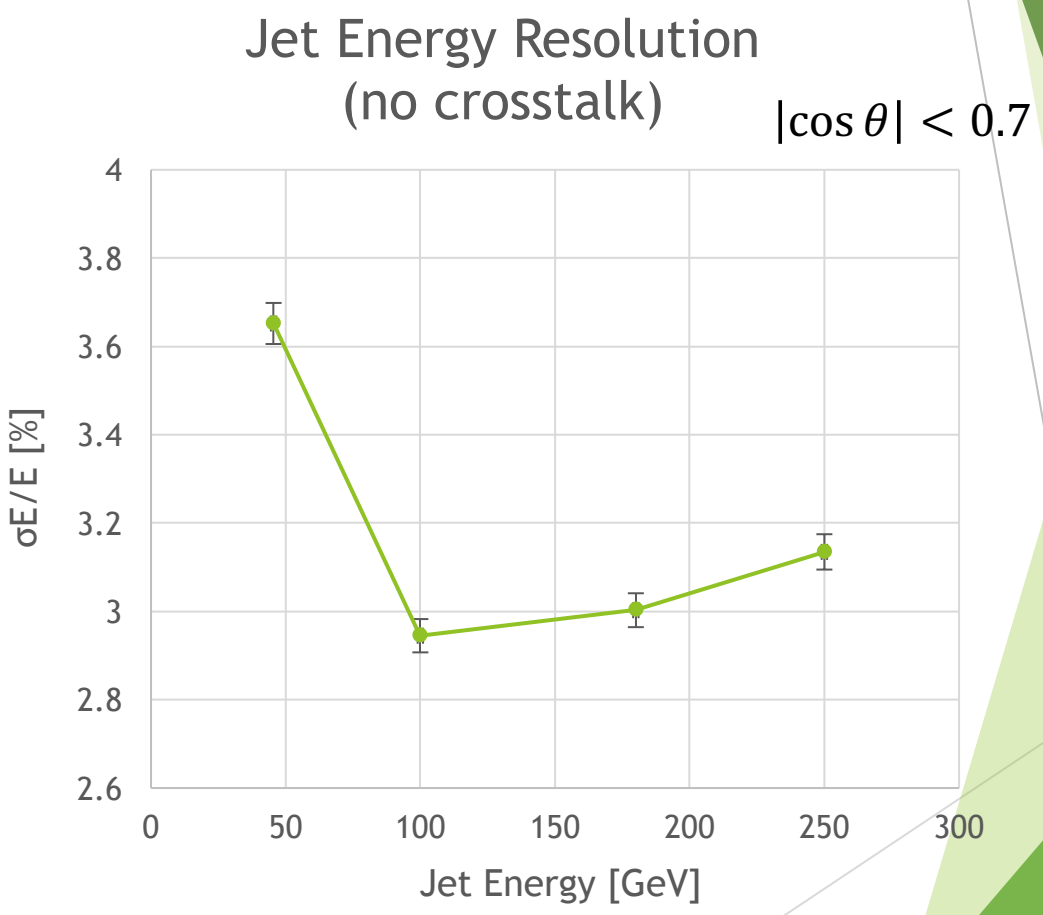
- General tendency of JER getting worse as crosstalk increase was seen
- Though the JER at 0% crosstalk was worse compared to standard JER study (~ 3%)
- Investigated the reason and did it again

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



Previous Study

- What was the problem?
- Software version had some problems with the reconstruction
  - Updated the version
- Standard JER only uses barrel events
  - See barrel events only
- Achieved compatible result with standard JER study

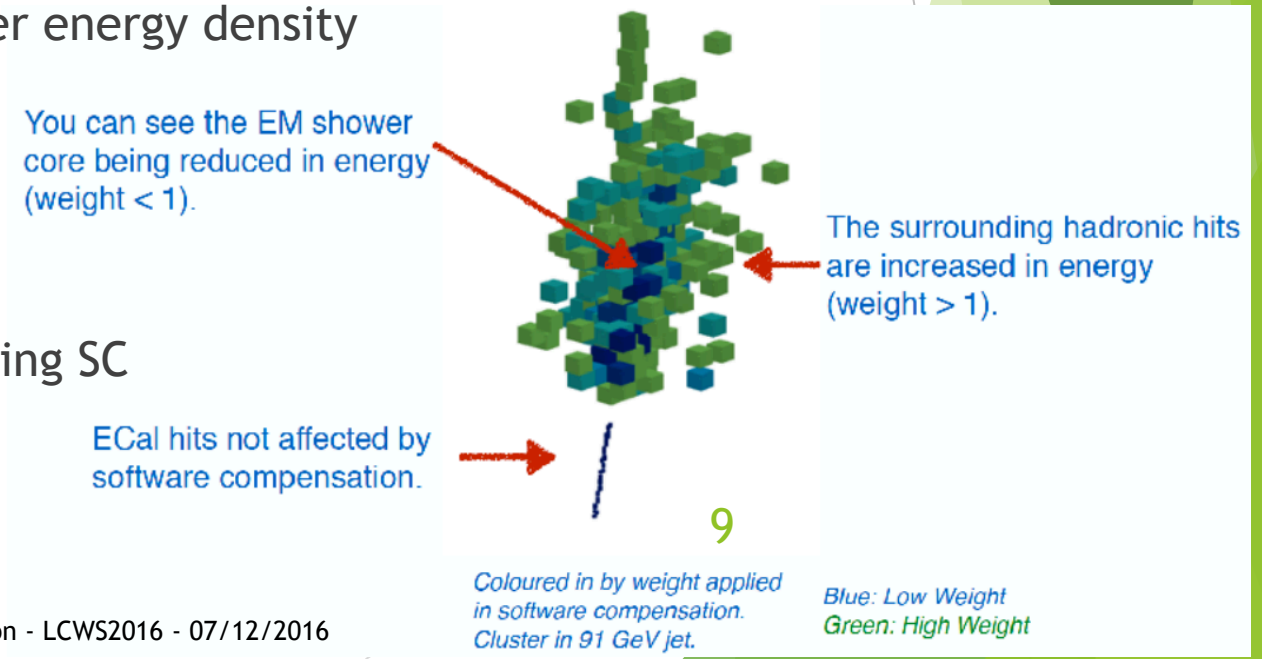


Analysis Calibration

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

Software Compensation

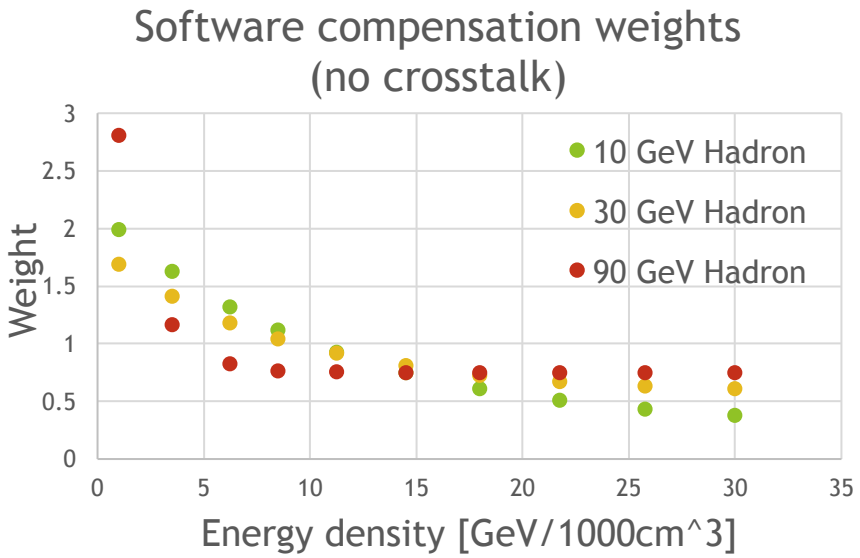
- There are some EM components in hadronic shower and the fraction of EM components differs from event to event
- The detection efficiency differs between EM and hadronic components
- Efficiency compensation is necessary for accurate reconstruction
- EM component is distinguishable for its higher energy density
- Apply more weight on the hadronic component than on the EM component
- Generally resolutions improve by ~20% applying SC

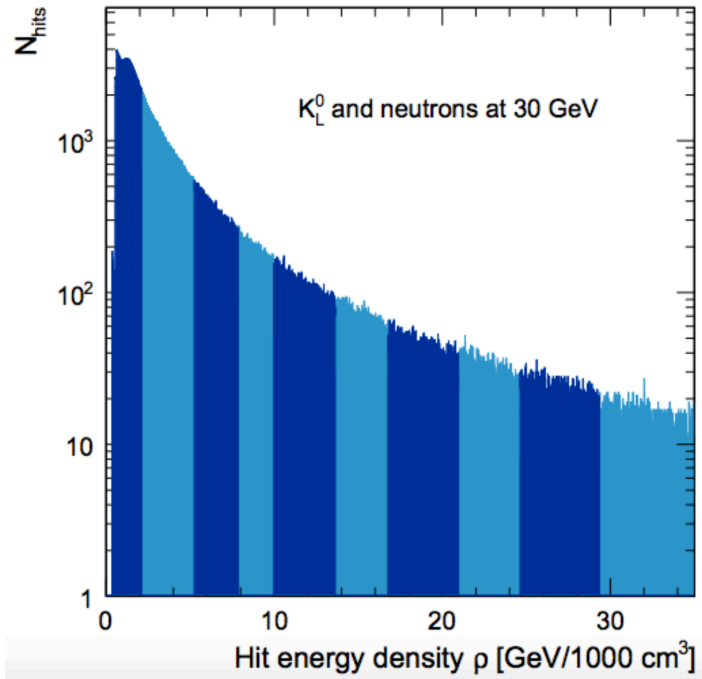


Software Compensation

- 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
- The optimization for crosstalk events is proceeding with cooperation of Steven Green

- Optimization for events with crosstalk had some problem, and is still on going

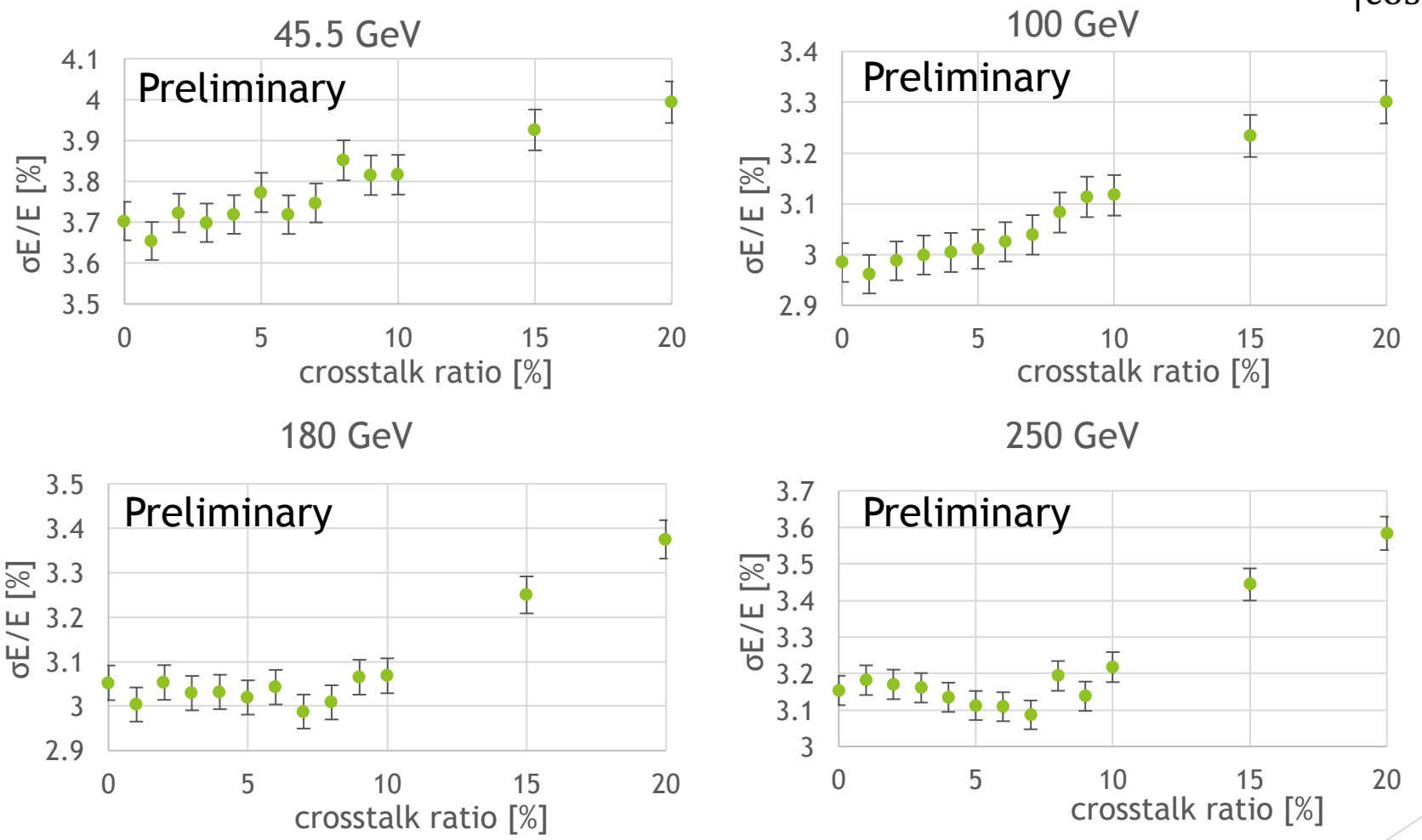
Software Compensation Training

- The software compensation training needs 10 – 100 GeV neutral hadrons
- The optimization is conducted by minimizing chi square function

- Bug: one energy correction of Pandora “CleanClusters” was not included in software compensation training script
- Remi Ete has found and fixed this bug, so the training should work fine

Jet Energy Resolution with Crosstalk

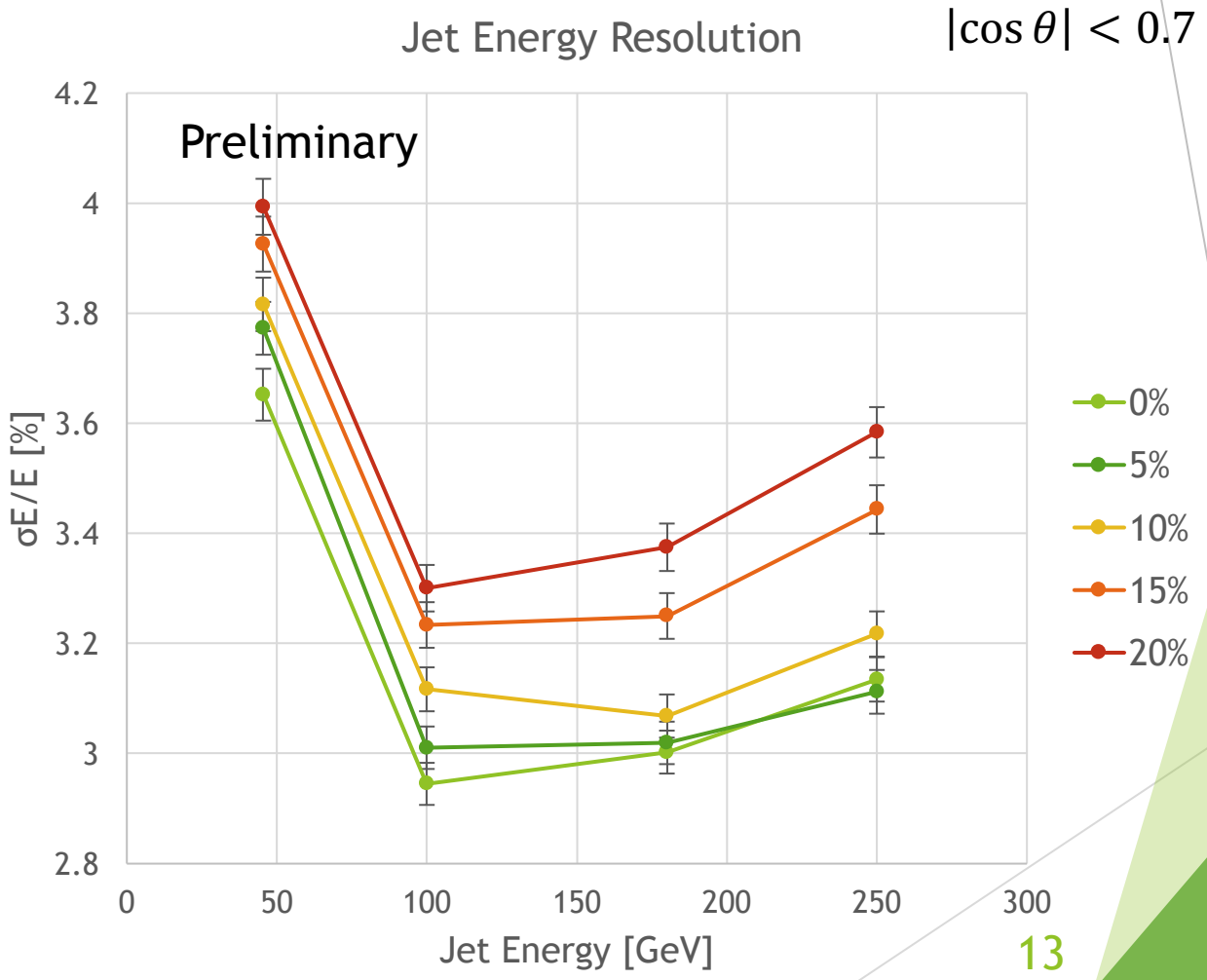
$|\cos\theta| < 0.7$



JER is clearly worse when the crosstalk is extremely high

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

- For some alternative design for ILD AHCAL active layers there might be a significant increase of optical crosstalk between tiles
- Investigated the effect of crosstalk on the detector performance through simulation
- In previous study, the JER was ~20% worse than standard study
  - Solved by updating the software and limiting the events to the barrel part
- Calibration of the analyzer has also done
- As a result, extremely high crosstalk worsen the jet energy resolution, but up to 7% the crosstalk do not much affect

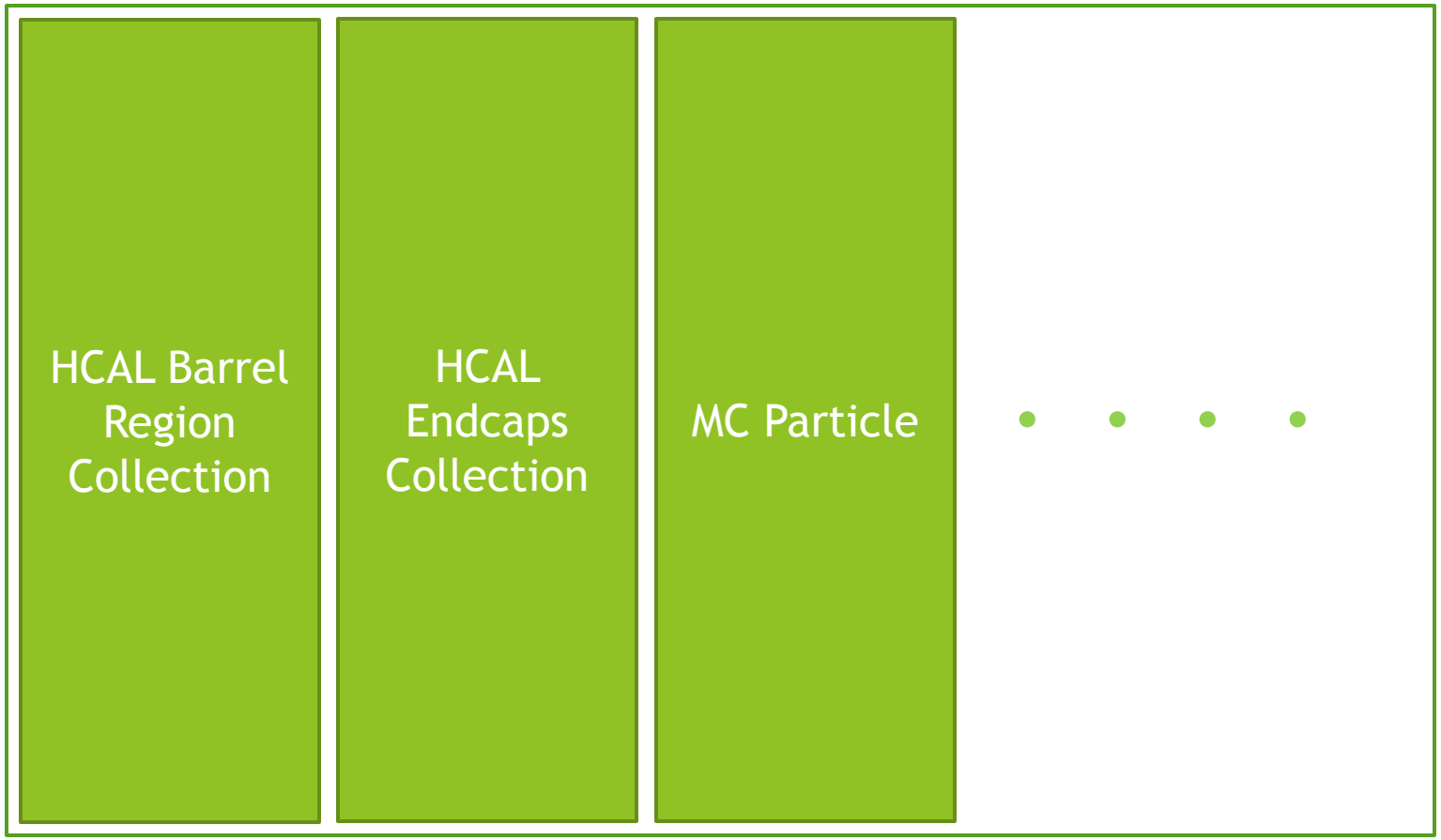
Prospects

- Software compensation training is to be finished soon
- More realistic crosstalk
  - Random crosstalk
  - Depending on particle hit position
  - Secondary crosstalk
- Try to mitigate the effect of crosstalk by improving reconstruction process

THE END

Backups

Event (generated by a simulator)



Collection contents

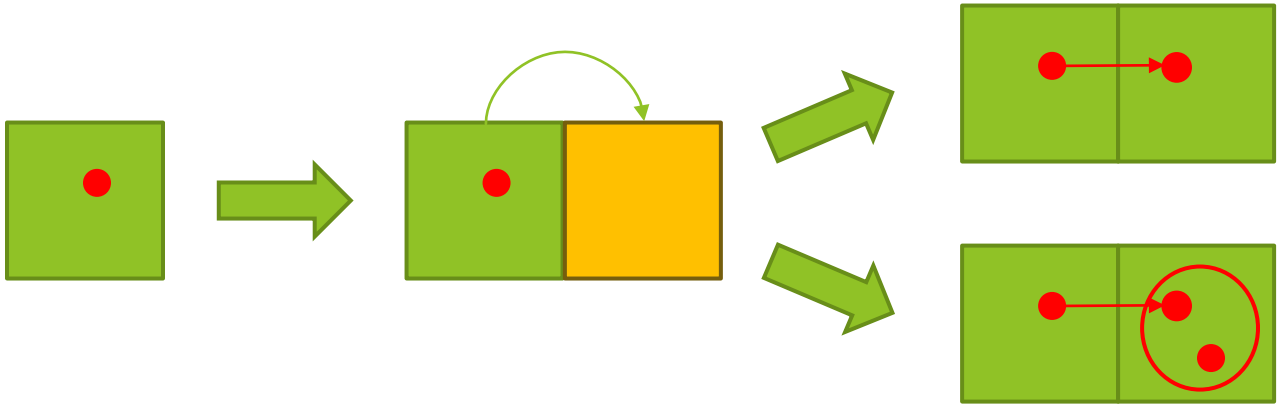
HCAL Barrel Region Collection

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

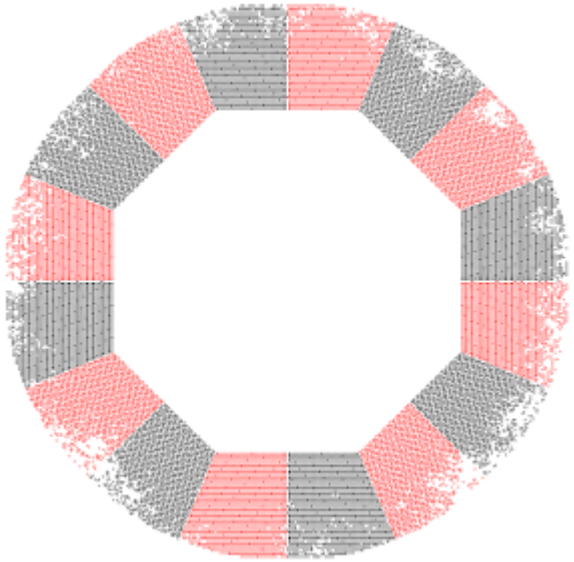
× nHits

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

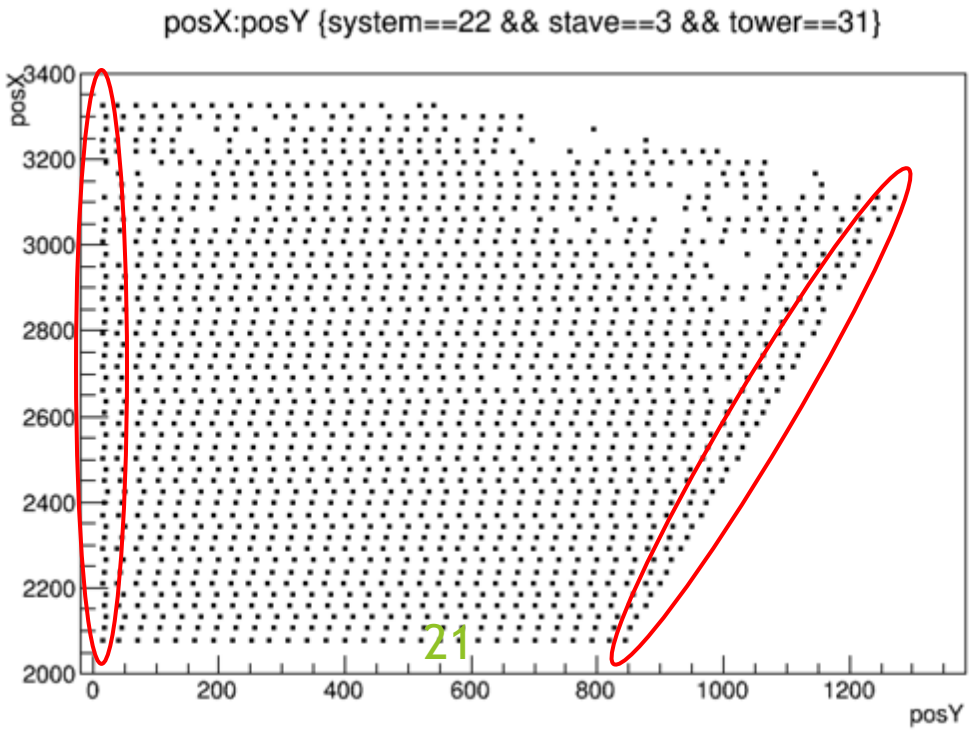


Some difficulty



- 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)

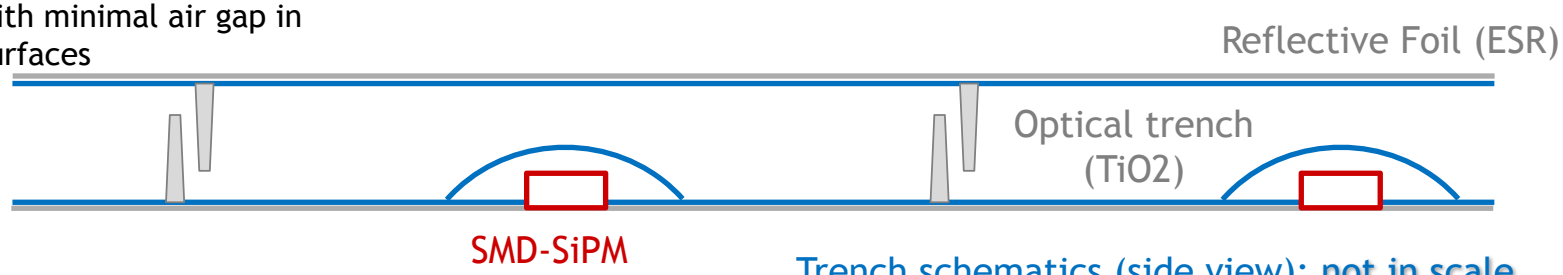
- So I just checked all the spatial alignment of the cells
- and wrote them explicitly in my code
  - (So the code is not stable for detector design changes)



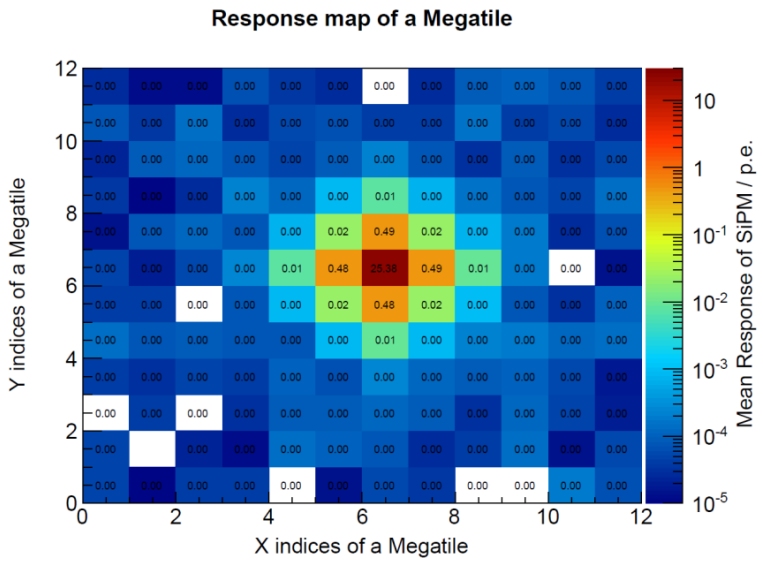
Megatile Recent Study

- According to a simulation with double trenches model, 1.8% crosstalk achieved

Trench parameters are 0.3mm wide, 0.3mm offset with minimal air gap in top & bottom surfaces



Trench schematics (side view): not in scale



Central cell: 25.4 p.e./MIP
Neighboring cell: 0.49 p.e./MIP
Cell-to-cell crosstalk: 1.8 %

Yong Liu, CALICE Collaboration Meeting
Mar. 23, 2017, LLR, Palaiseau

Megatile Prototype

- First prototype with less challenging parameters
  - 3x3 cells, 0.5 mm width 1 mm offset
- Similar MIP response and crosstalk in data and MC