CEPC AHCAL Progress

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Outline

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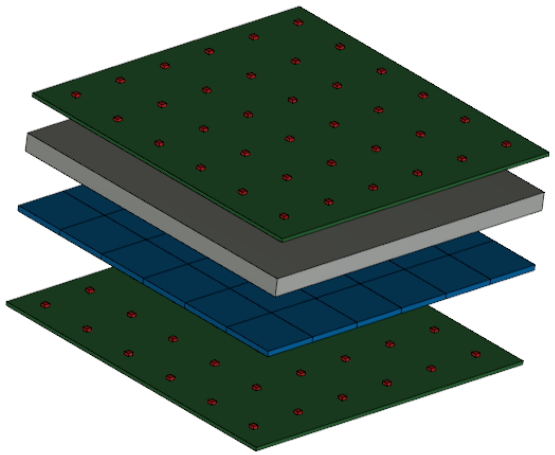
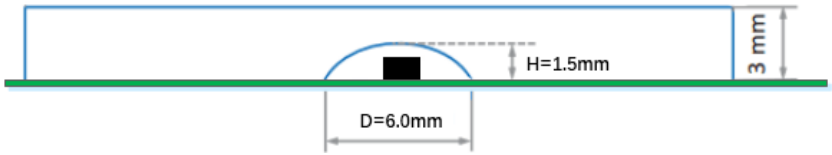
- Introduction
- Cell size optimization
- SiPM simulation
- Studies on AHCAL active cell: scintillator tile and SiPM
- Scintillator tile wrapping machine
- Summary

Introduction

- AHCAL is one HCAL option for CEPC
- Active medium: scintillator, absorber: steel
- SiPM-on-Tile configuration

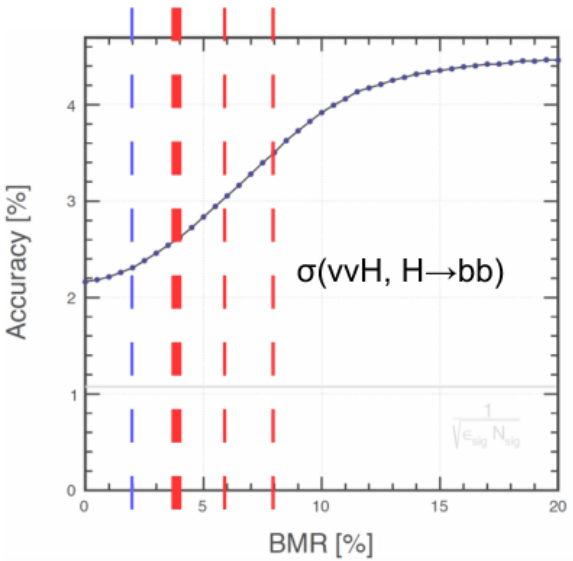


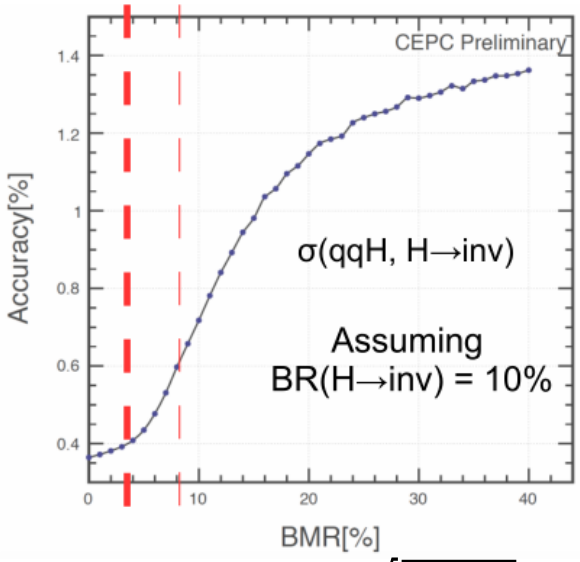


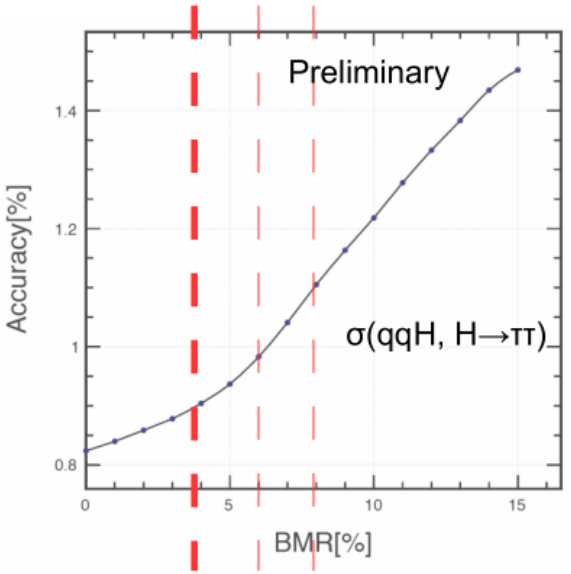
- The AHCAL task in the MOST2 CEPC R&D project
  - to validate the CEPC AHCAL option by designing, building and testing a full AHCAL prototype

Optimization based on BMR

- 1/3 of Higgs events have 2jets : hadronic decays of bosons
- The requirement from benchmark physics processes on boson mass resolution(BMR) : 4%
- Calorimeter cell size and number of readout layers should be optimized in terms of BMR







$$\text{Accuracy}=\frac{\sqrt{S+B}}{S}$$

Simulation Setup

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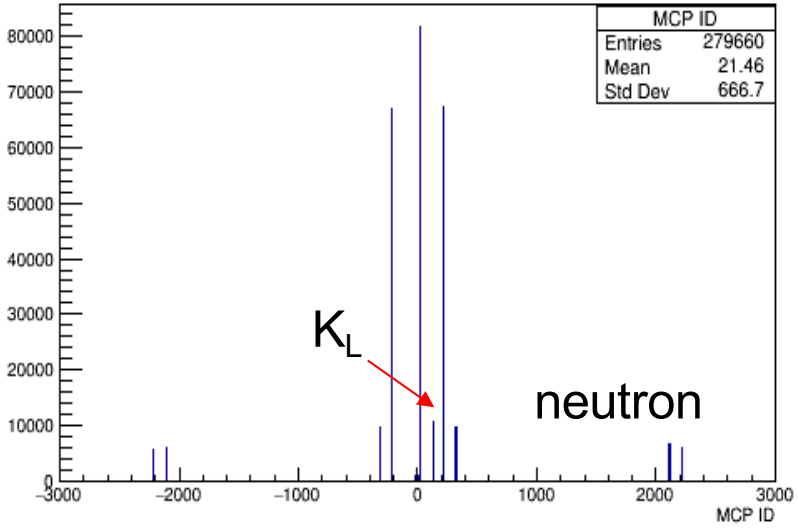
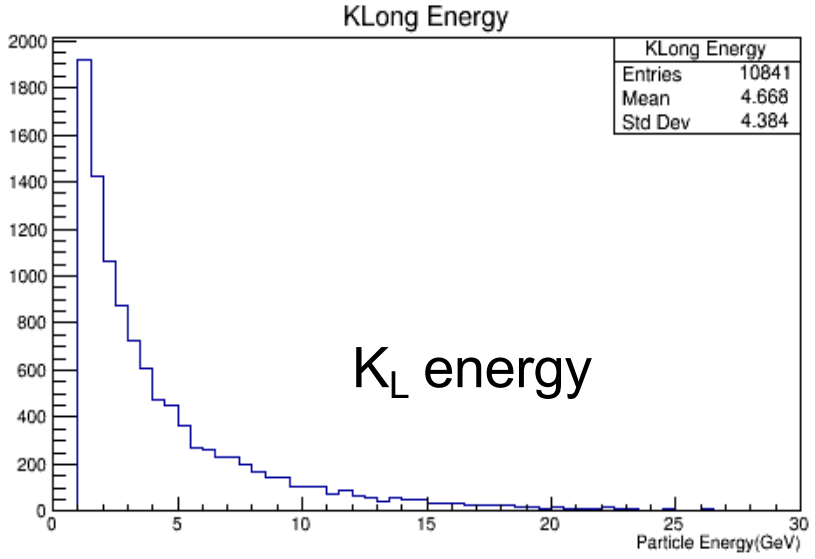
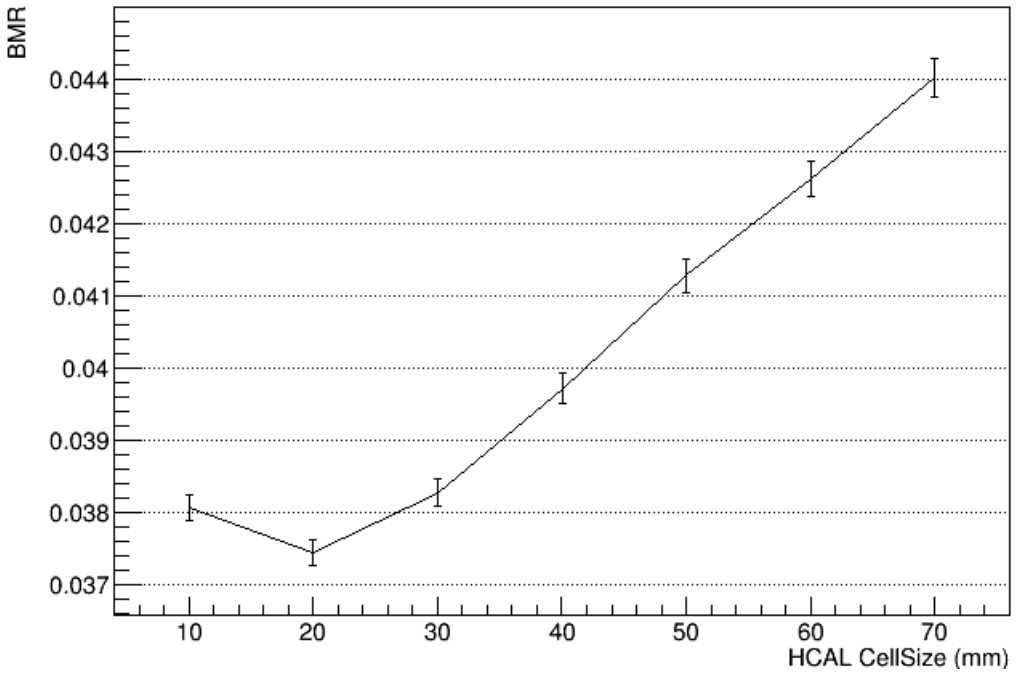
- CEPC V4 geometry
  - Tracker, Si-W ECAL, Sci-Fe HCAL
- Evaluate BMR with vvH→gluon+gluon
  - K_L is the largest in number in neutral hadrons
  - K_L energy mostly below 30 GeV





Cell-size optimization

- A cell-size of 40 mm can meet the requirement of 4% BMR



SiPM Modeling

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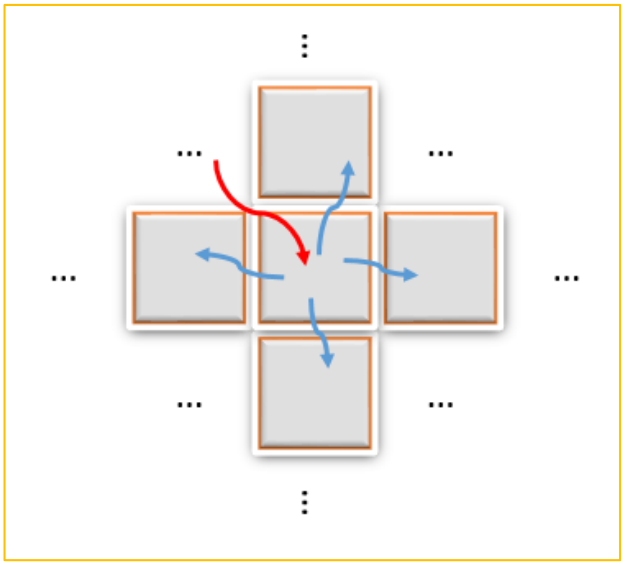
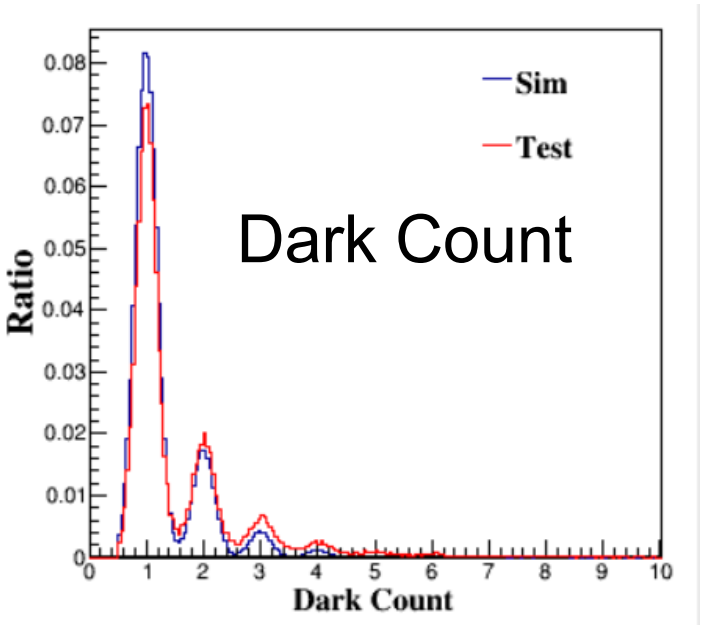
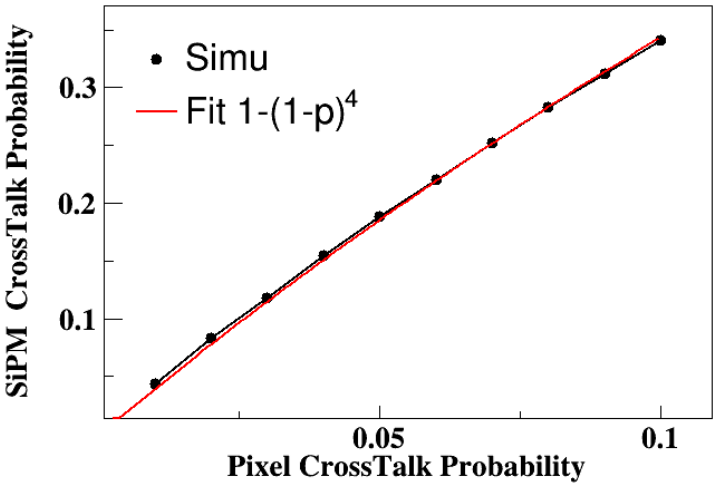
- A SiPM is composed of many pixels each functioning as an avalanche photodiode
- The photons produced in an avalanche occurring in a pixel can propagate to adjacent pixels triggering avalanche in more pixels.

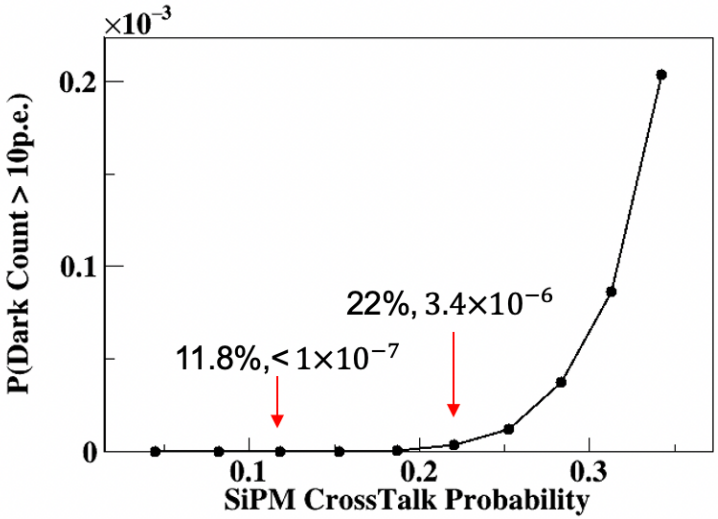




SiPM Cross-talk

- Two cross-talk probabilities:
  - Pixel cross-talk probability: cross-talk probability between adjacent pixels
  - SiPM cross-talk probability: possibility that dark count signal is larger than 1.5p.e.
- Dark count signal distribution is determined by pixel cross-talk probability and SiPM amplitude resolution
- Number of pixels only affects dark count rate with no impact on dark count signal distribution.





SiPM dark-count rate

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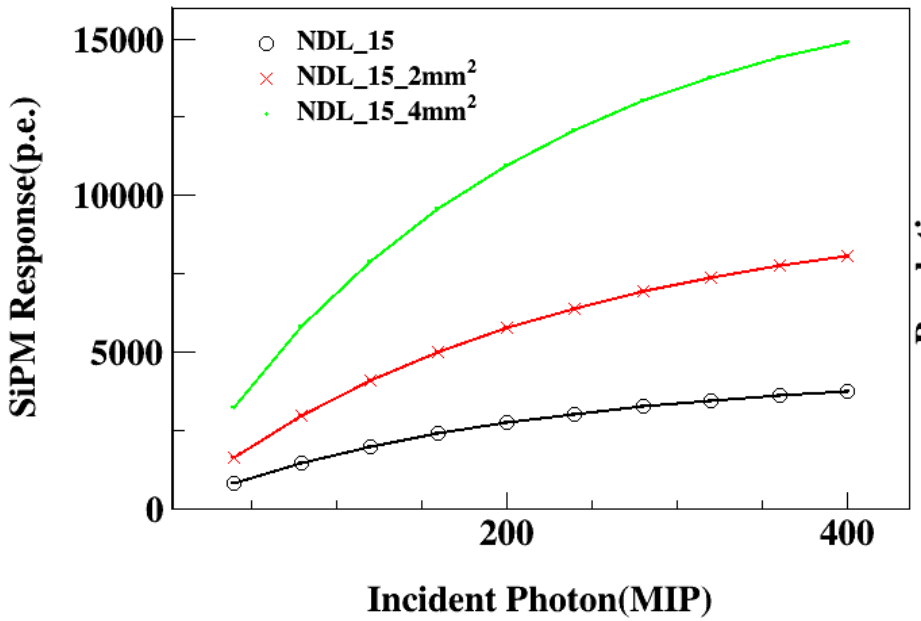
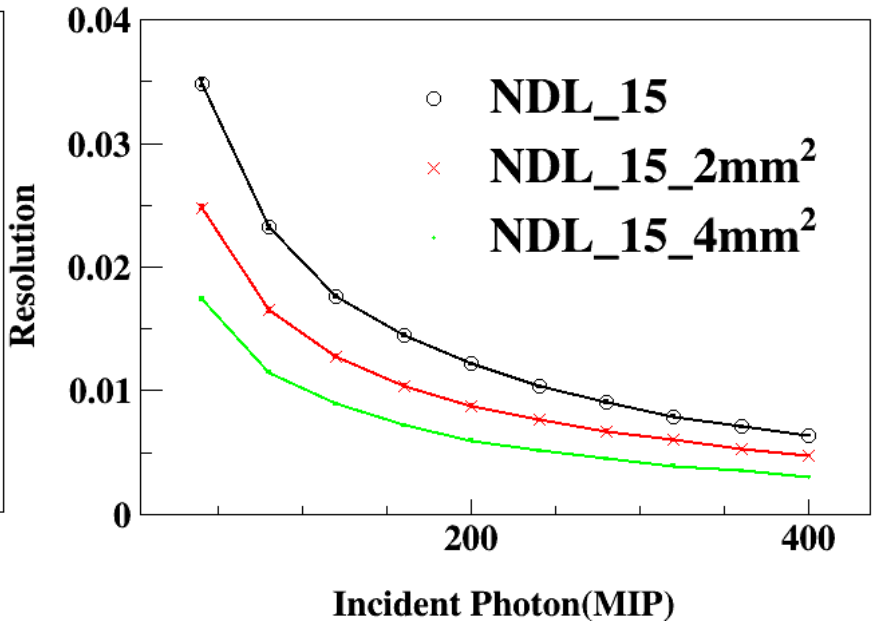
- Dark Count rate of a single SiPM for over 10p.e. :
  - S12571-15: 0.7Hz
    - SiPM cross-talk probability:22%
    - Dark count rate (>= 1.5 p.e.) : 200K
  - NDL-15um:<0.043Hz
    - SiPM cross-talk probability: 11.5%
    - Dark count rate (>= 1.5 p.e.): 425K for $1mm^2$ active area
  - A single layer of AHCAL prototype with $0.7m \times 0.7m$ (324 NDL-SiPM / layer) : 14 Hz

Response of SiPM with different sizes

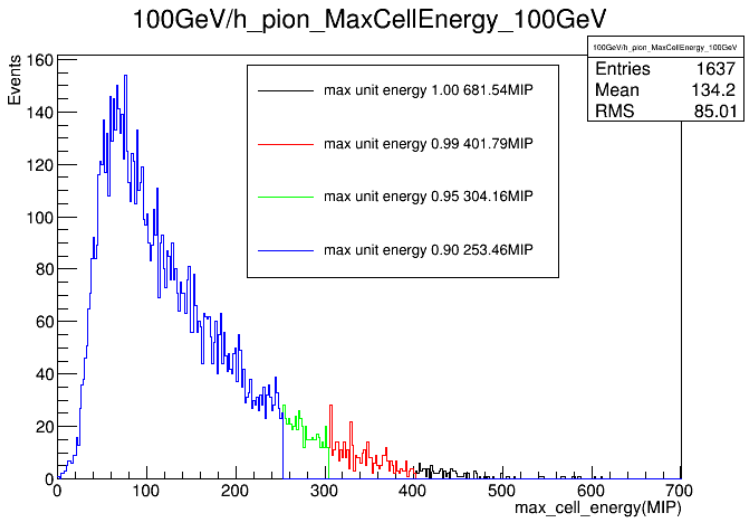
- NDL-15um: $1\text{mm}\times1\text{mm}$, $1.3\text{mm}\times1.3\text{mm}$ and $2\text{mm}\times2\text{mm}$
  - PDE: 35%, Gain: 3.7×10^5
  - SiPM cross-talk probability:11.5%
  - Number of pixels and light yield both proportional to SiPM size





Required dynamic range

- Physics requirement: 400MIP from 100GeV K_L, too much overestimated. Needs to be re-evaluated in a more sensible way.
- A larger SiPM implies a larger maximum input charge for readout electronics. This has to be considered when making a choice of SiPM.

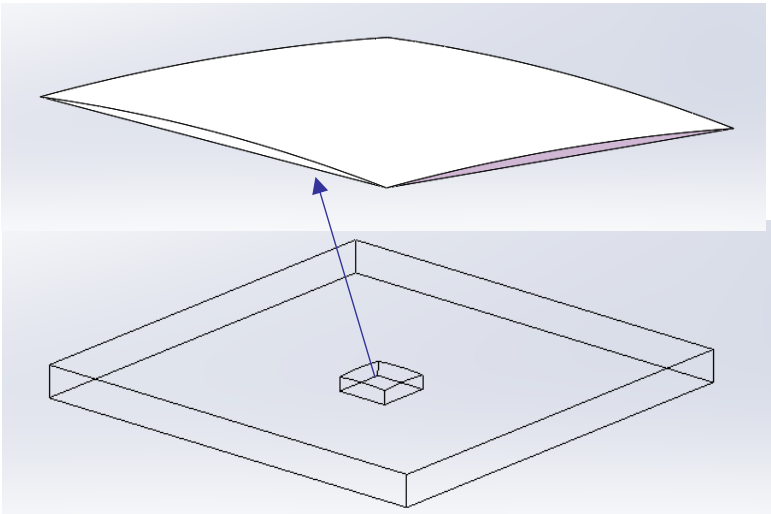


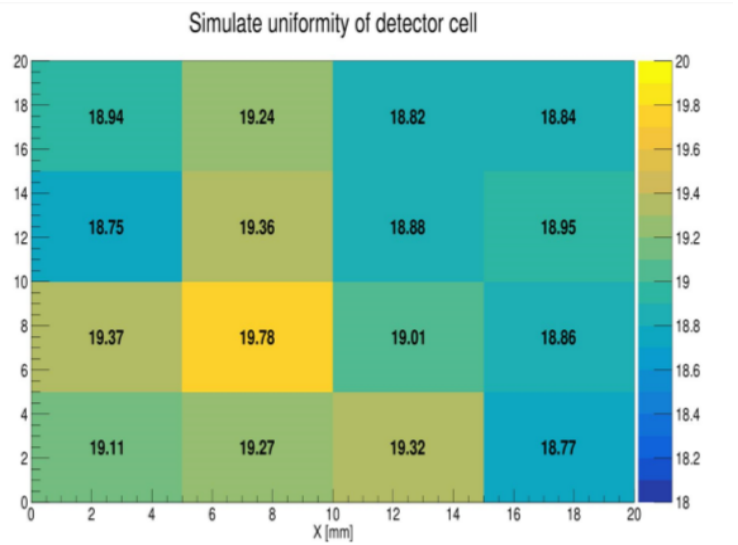
Max Cell Energy for 100GeV KLong

Redesign of scintillator tile

- Given the optimized cell-size of 4cm*4cm, the AHCAL active cell needs to be redesigned to accommodate the change from 3cm*3cm to 4cm*4cm

the central cavity in the new design : 5mmx5mmx1.5mm





mean=19.0794
Max mean deviation value=3.7%
uniformity≤5.4%

The light yield decreases significantly for the size expansion. Need to get back the light yield loss → use larger SiPM

Large NDL-SiPM

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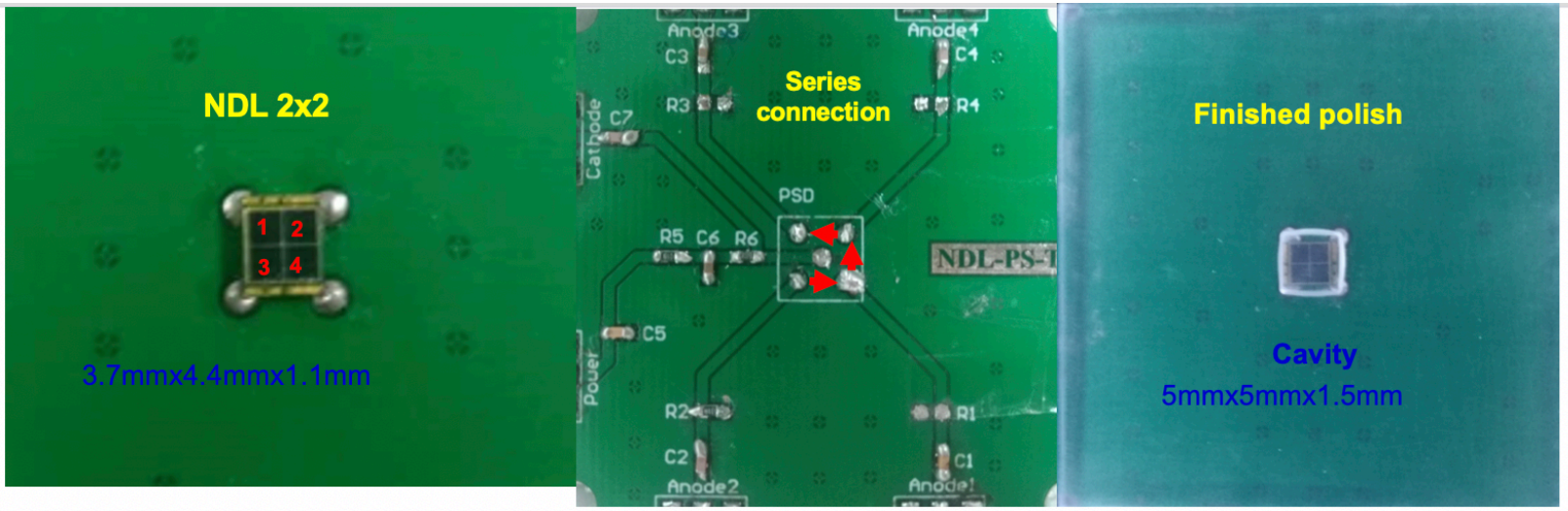
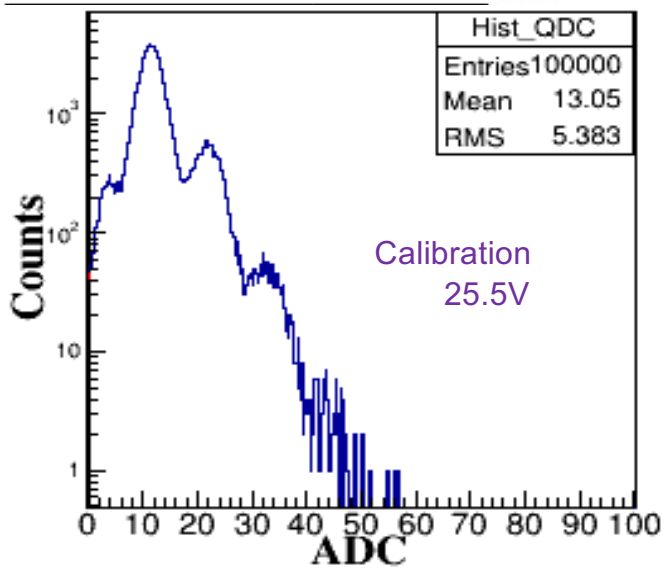
NDL 22-1414B-S



Active area	4x1.3mmx1.3mm
Pixel size	10um
Breakdown	23.7V
PDE@420nm	35%



Light-yield test

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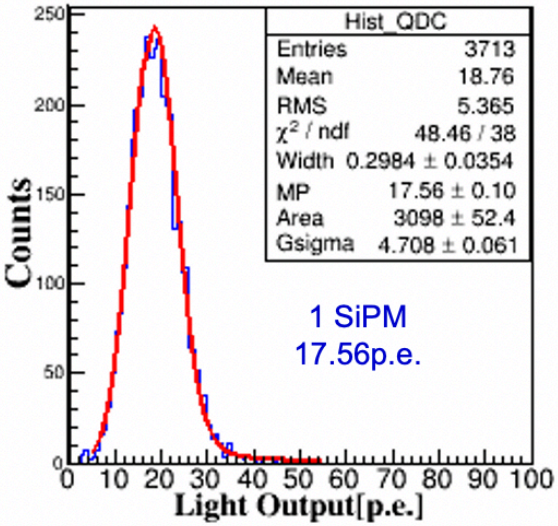

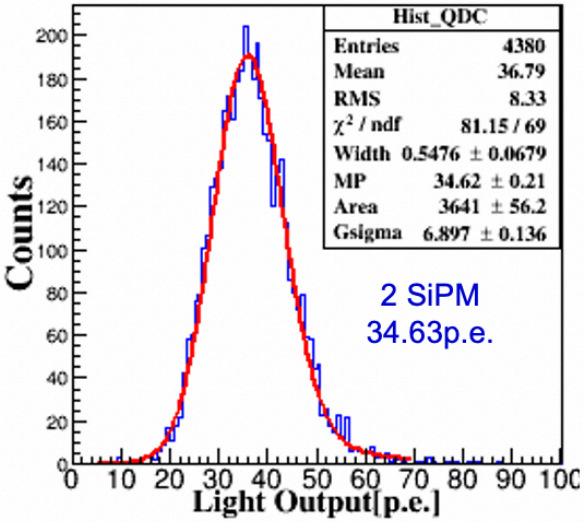

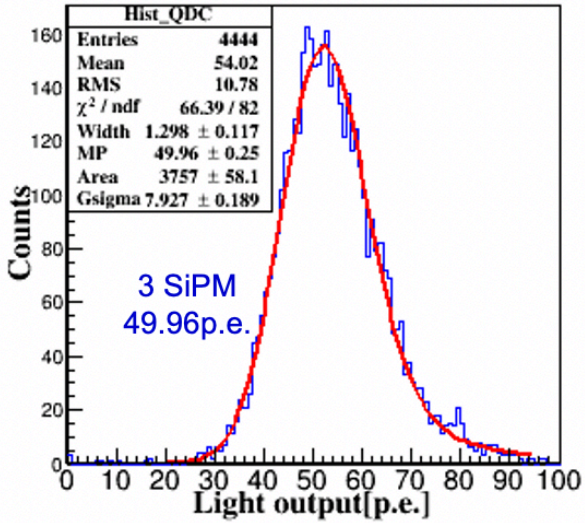

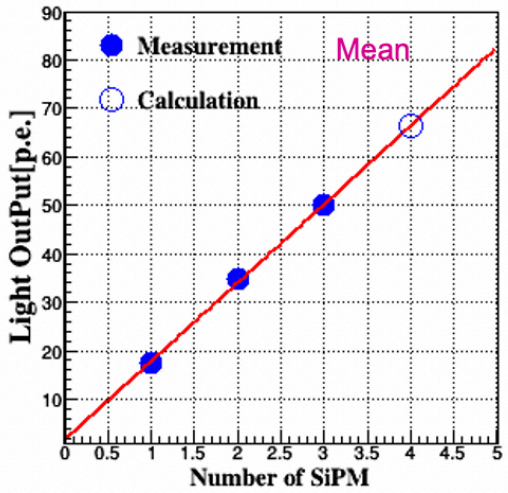

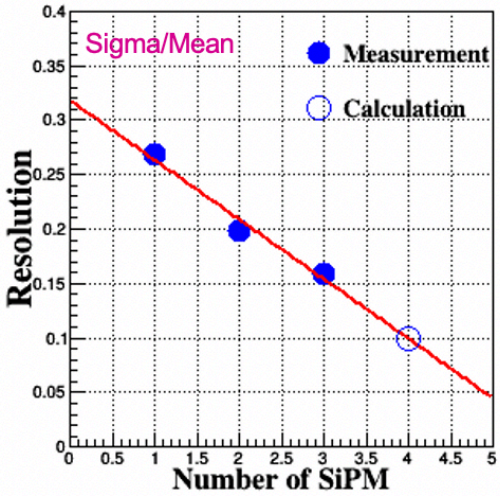

- The SiPM behaved as expected.
- The combination feature of the SiPM also offers us flexibility in adjusting light yield.

Scintillator tile wrapping machine

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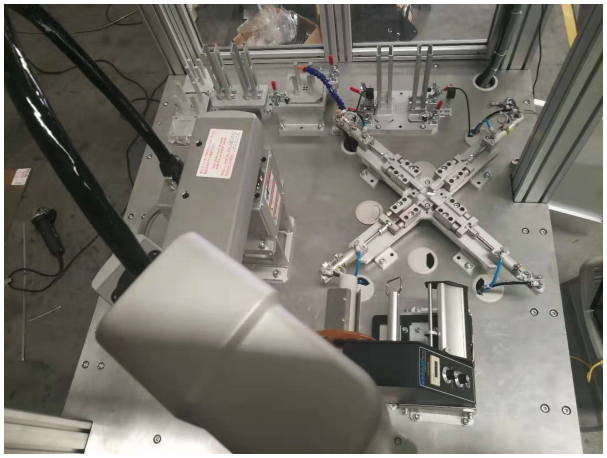

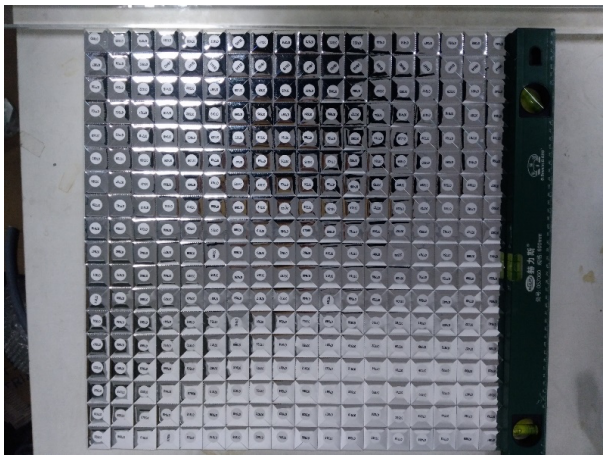

- An auto-wrapping machine has been built and tested.
- Average wrapping time for a single tile: 45 s

Summary

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- The cell size of the CEPC AHCAL has been optimized and the cell geometry has been redesigned following the optimization.
- Large SiPM is needed for the large cell size to compensate for the light yield loss due to the size expansion. One NLD SiPM is being tested as such a SiPM candidate.
- SiPM dark count seems not a big concern above a reasonable threshold.
- Tile wrapping machine is ready for tile batch production.
- Not mentioned in the talk : tile batch testing system is about to finish.