# Status of CEPC-AHCAL R&D

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**On behalf of the CEPC Calorimeter working Group**

# OutLine

- Requirements of CEPC-AHCAL prototype
- Optimization of  AHCAL energy resolution and tiles
- Scintillator testing platform and KLauS chips
- summary

# Background introduction

## Requirement

BMR better than 4%

$$\frac{\sigma}{E} = \frac{60\%}{\sqrt{E}} \oplus 3\%$$

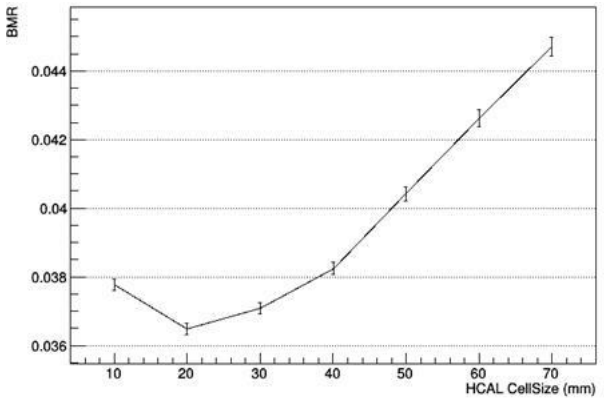
## Structure

- The absorber: 2 cm Stainless steel ($0.12\lambda_I$, $1.14X_0$);
- Detector cell size: 3 cm×3 cm or 4 cm× 4 cm;
- The sensitive detector : Scintillator;
- SiPMs: HMAMMATSU or NDL;
- About 40 sensitive layers, total readout channels:

  11560 (3cmx3cm) , 12960 (4cmx4cm)

- Transverse Dimension:

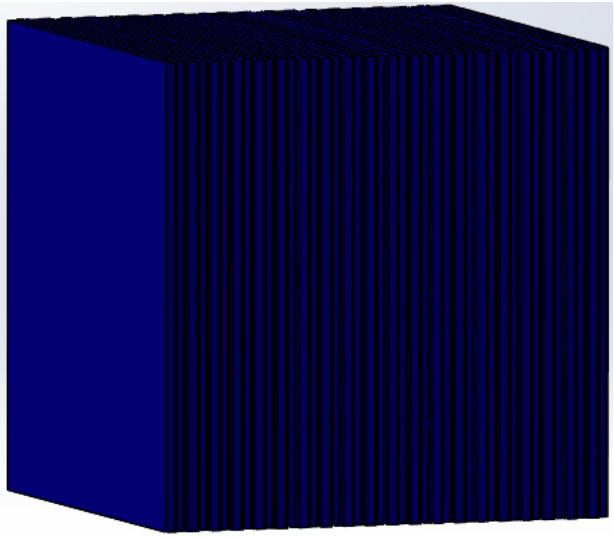
  51 cm*51 cm (3cmx3cm), 72 cm*72 cm (4cmx4cm)



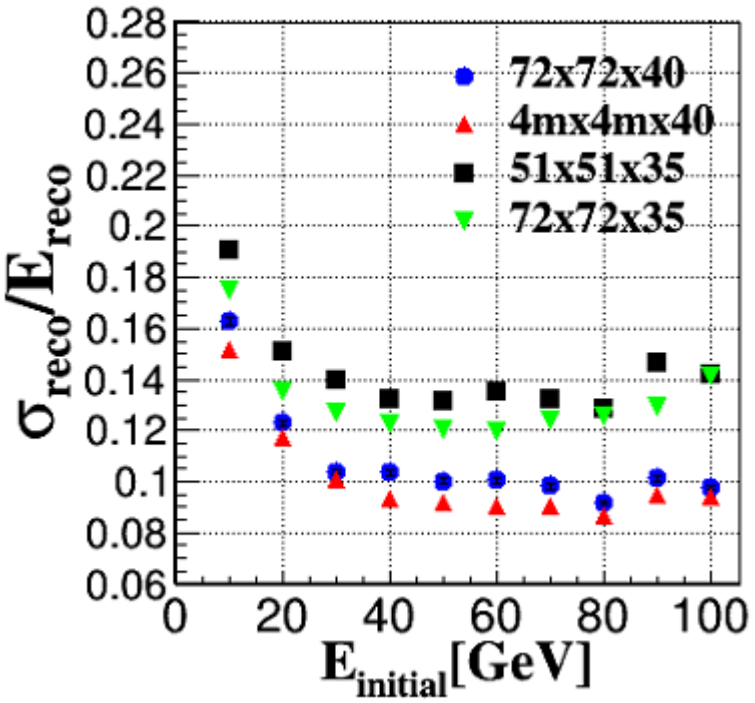

BMR - HCAL Cell Size

BMR: Boson Mass Resolution at di-jet final states

BMR*sqrt(2) = Jet Energy Resolution

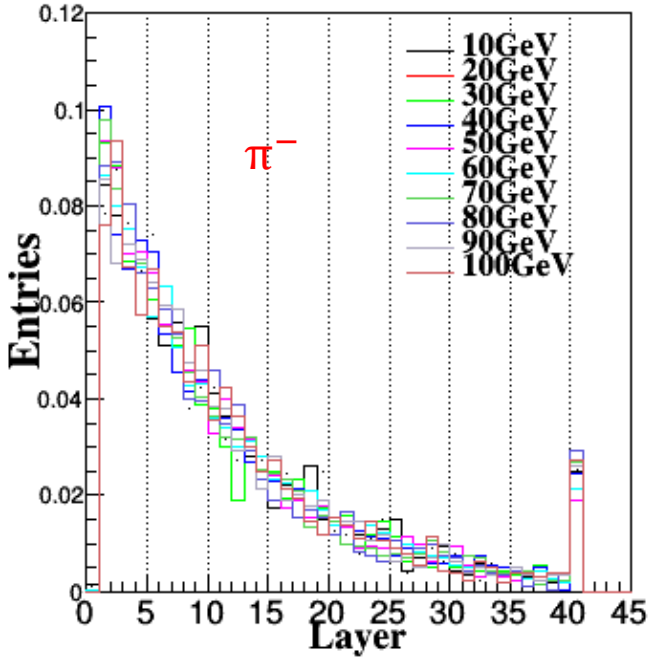


# Energy Resolution




Layer structure:
Sc:3mm,PCB:2mm, Fe :20mm
Incident particle: $\pi^-$

→ Improvement of Leakage energy
→ Shower start finding
→ Efficient events are around 33%

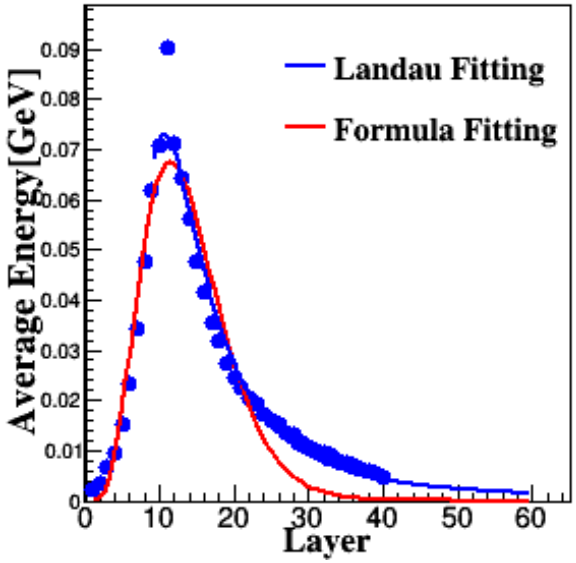



**Fit:** $\frac{a}{\sqrt{E}} \oplus b$

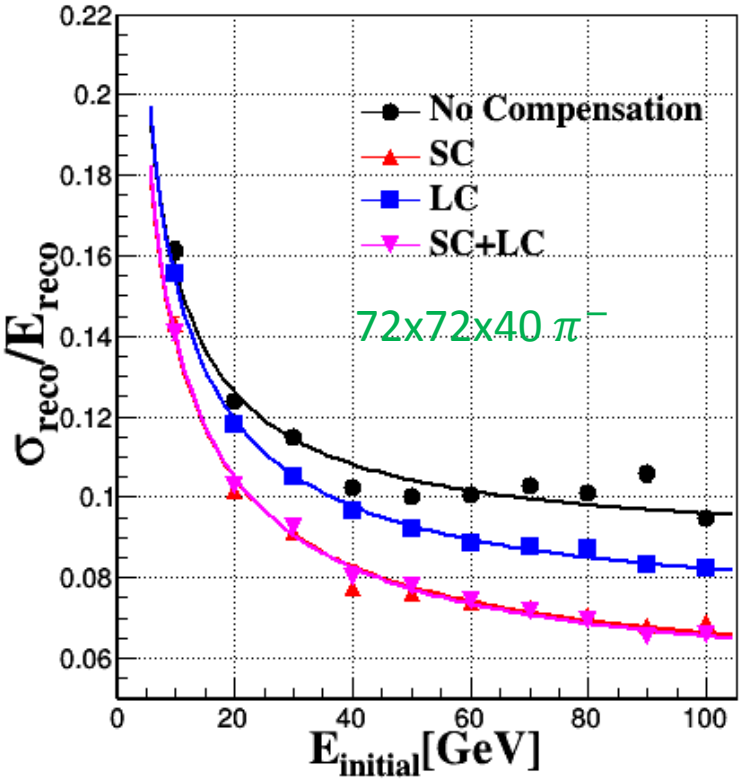
- a=46.1±0.8% b=11.5±0.1%
- a=43.9±0.8% b=10.0±0.2%
- a=42.6±0.6% b=8.0±0.1%
- a=41.5±0.6% b=7.2±0.1 %

# Energy Resolution

## Leakage Energy Compensation




- Event selection:
  A group with the same maximum energy deposition layer
- Tail description:
  Landau or formula function [1]
- Compensation layer:
  Layer>40




Constant term comparison

No Compensation:8.0%

Leakage Energy Compensation : 7.0%

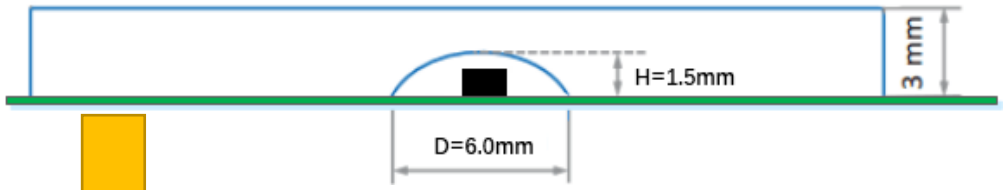
Software Compensation: 5.3%

SC+LC： 4.9%

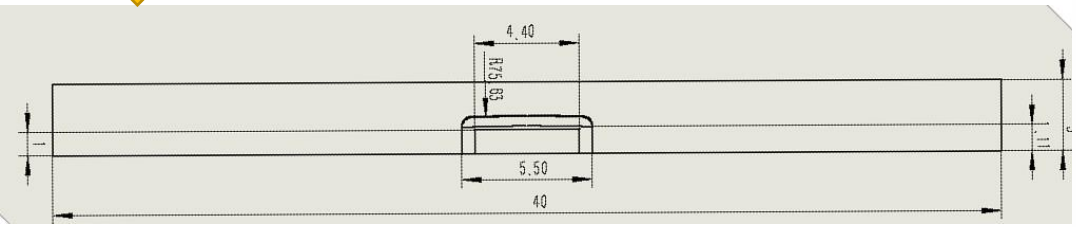
[1] $\frac{dE(x)}{dx} = \frac{E_f \beta^{\alpha+1}}{\Gamma(\alpha+1)} x^{\alpha} e^{-\beta x}$

# AHCAL Tiles

- Old structure of 3cmx3cmx3mm

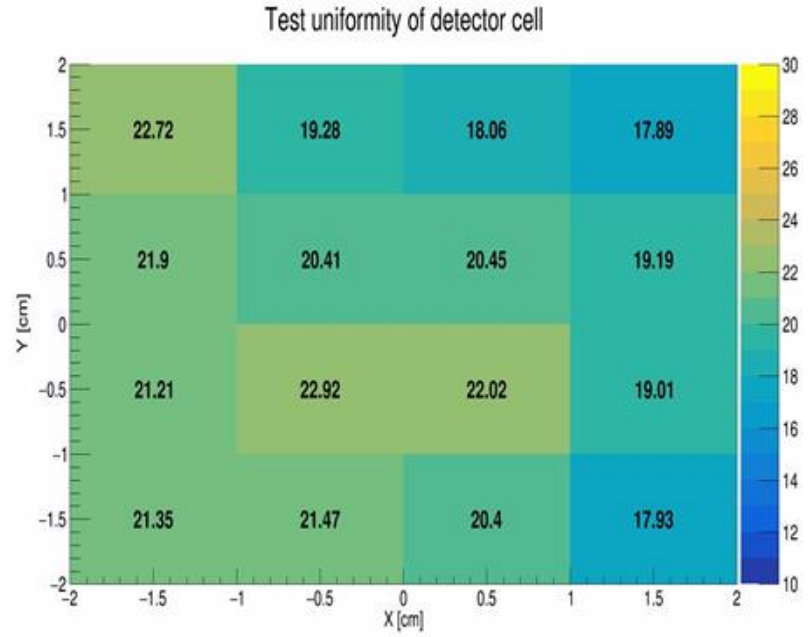



- New structure of 4cmx4cmx3mm




- ✓ Less light output for larger size of tiles
- ✓ Flexible application of NDL SiPMs


- scintillator type: BC408
- SiPMs type:S6N1904-1010-15um
- Breakdown:19.5V
- Overvoltage:4V



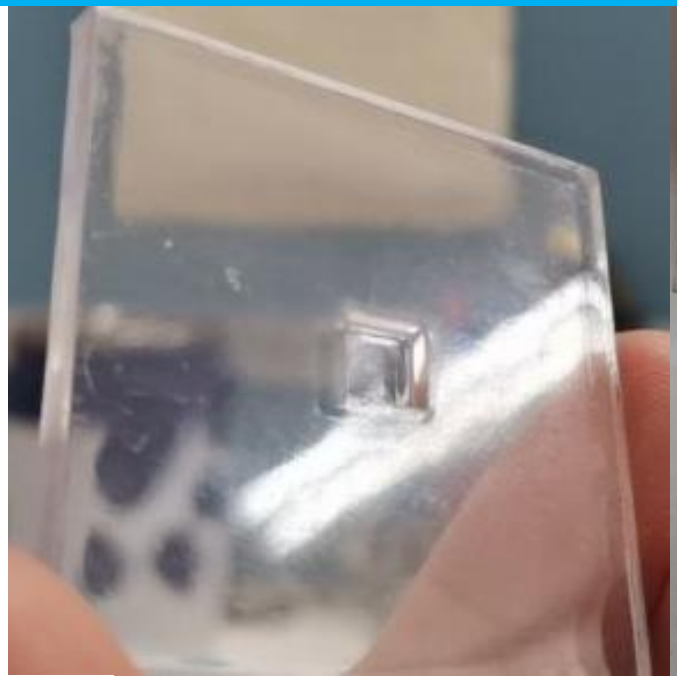

- scan step size:1cm
- Mean=20.4
- mean deviation : ±12%

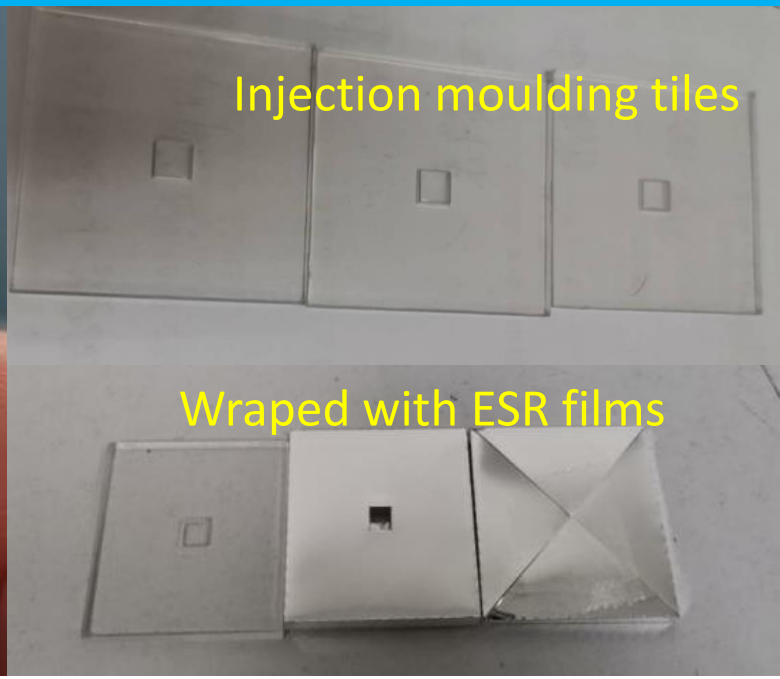
# AHCAL Tiles

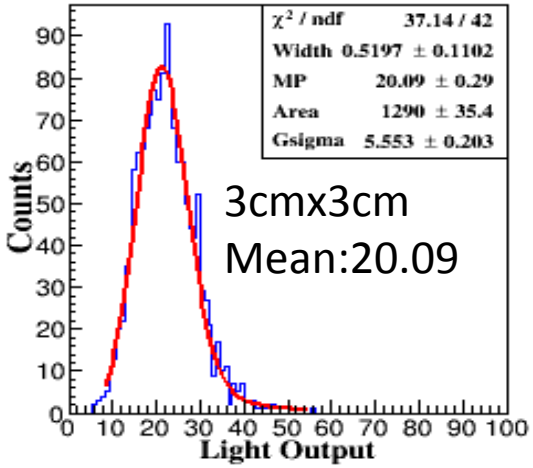
Injection craft:

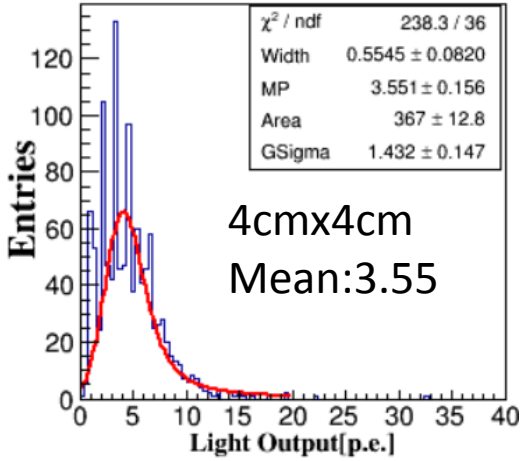
- Massive production
- High efficiency
- Consistency

- Tile Dimension: 4cmx4cmx3mm
- Cavity Dimension: 5.1mmx5.1mmx1.6mm





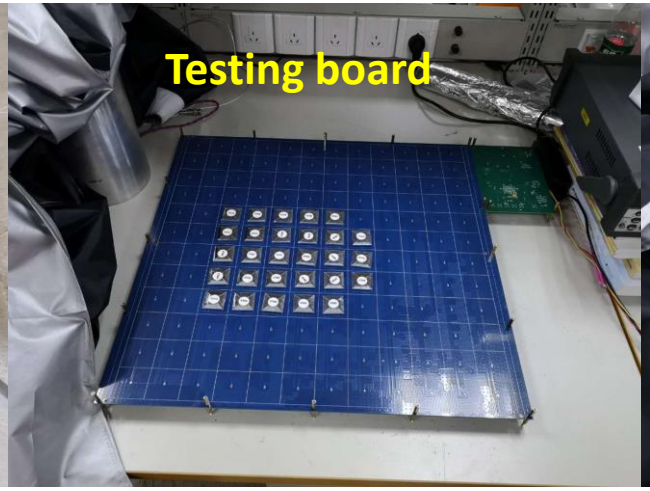



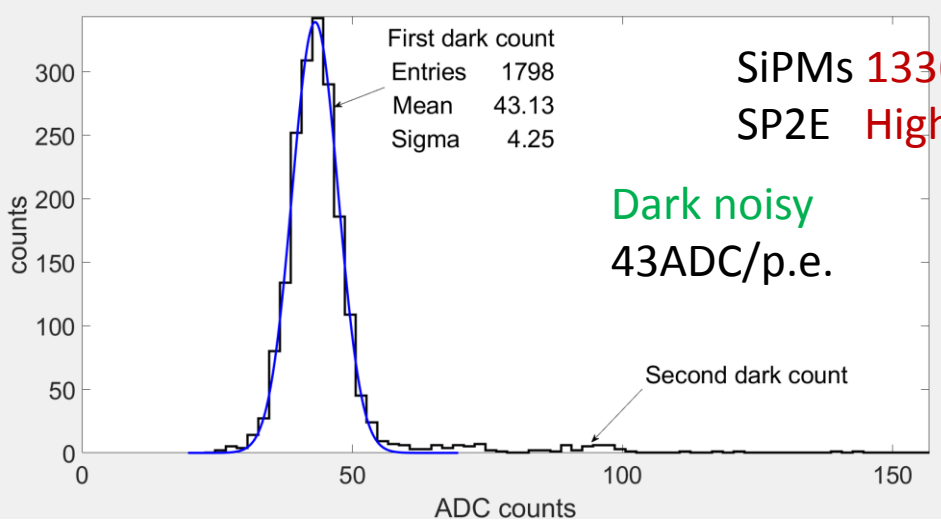

- The first batch of PS tiles
  Low light output.
- Improvement
  Ratio of solute and solvent
  Time of mixing

# AHCAL scintillator testing platform

**STP of AHCAL** Quickly check the uniformity among detector cells

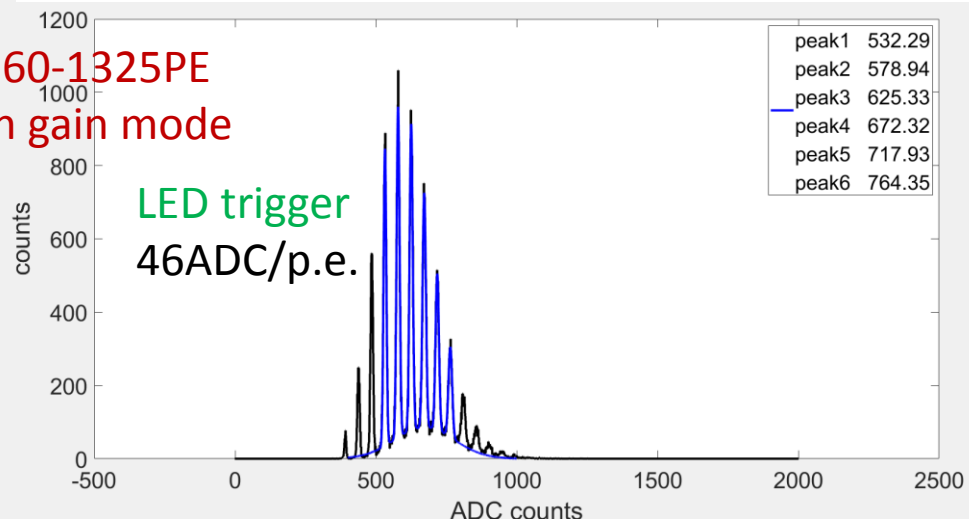








SiPMs 13360-1325PE
SP2E High gain mode

Dark noisy
43ADC/p.e.




LED trigger
46ADC/p.e.

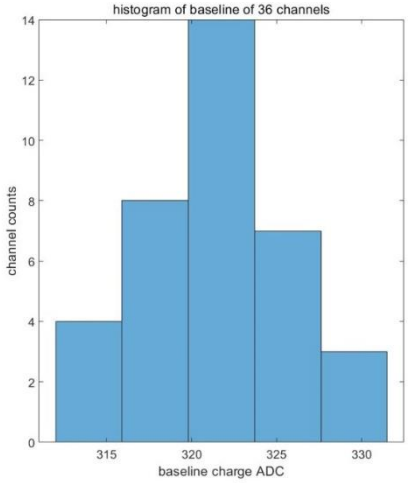
# KLauS chips

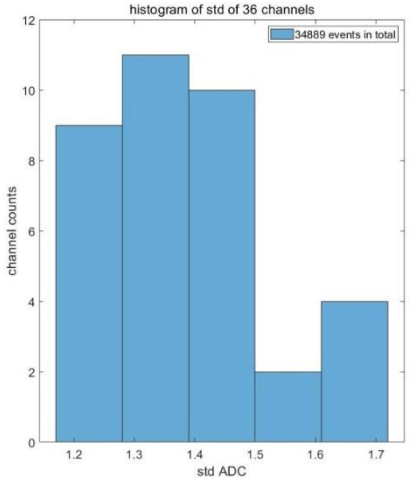
SP2 and KLauS

- Used in AHCAL
- By Omega, University Heidelberg
- Transistor 180nm （SP2 350nm）
- Power consumption：full operation 3.6mW
  sum = 3.6mW * 36 chns = 130mW （SP2 ≈300mW）
- Auto/Ext Trigger
- 36 channels
- Dynamic Range：450pC （SP2 320pC）
- Pe/Noise Ratio = 35 （SP2 11）
- ADC：10/12bits
- 4 Gain modes (SP2 2 gain modes)
- Dead time 500ns (SP2 ~ms)

✓ The KLauS testing board can work now.


Baseline and Std. distribution



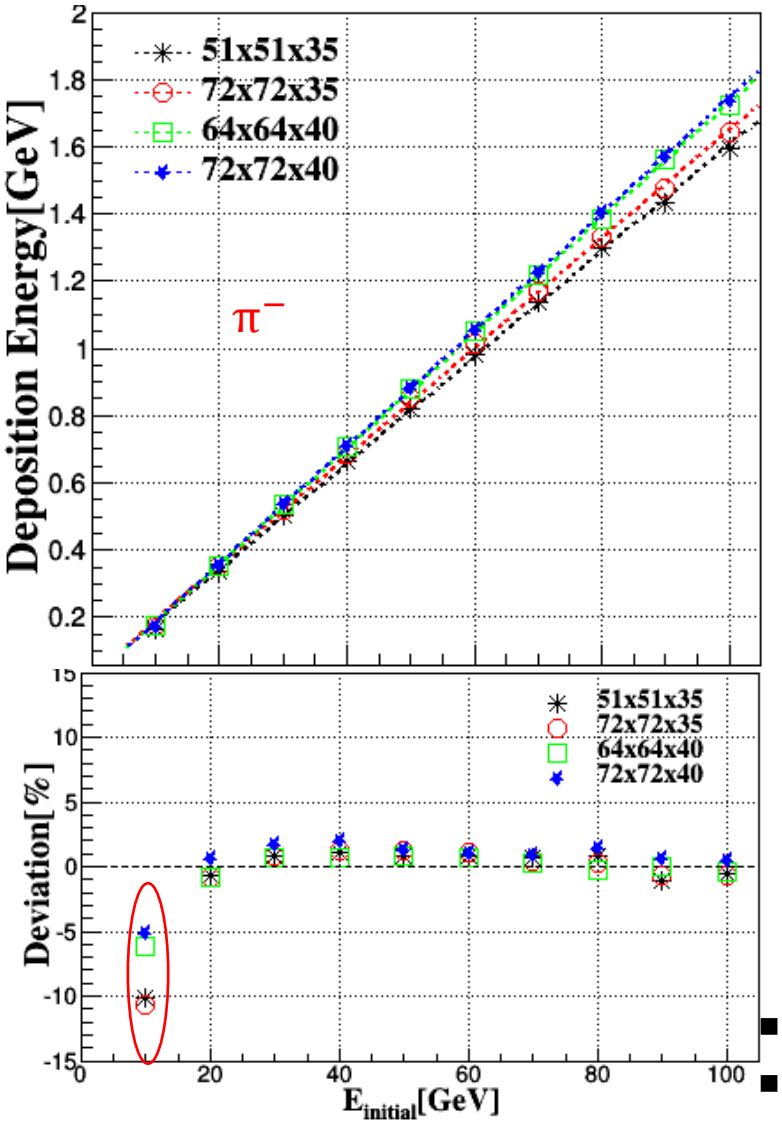



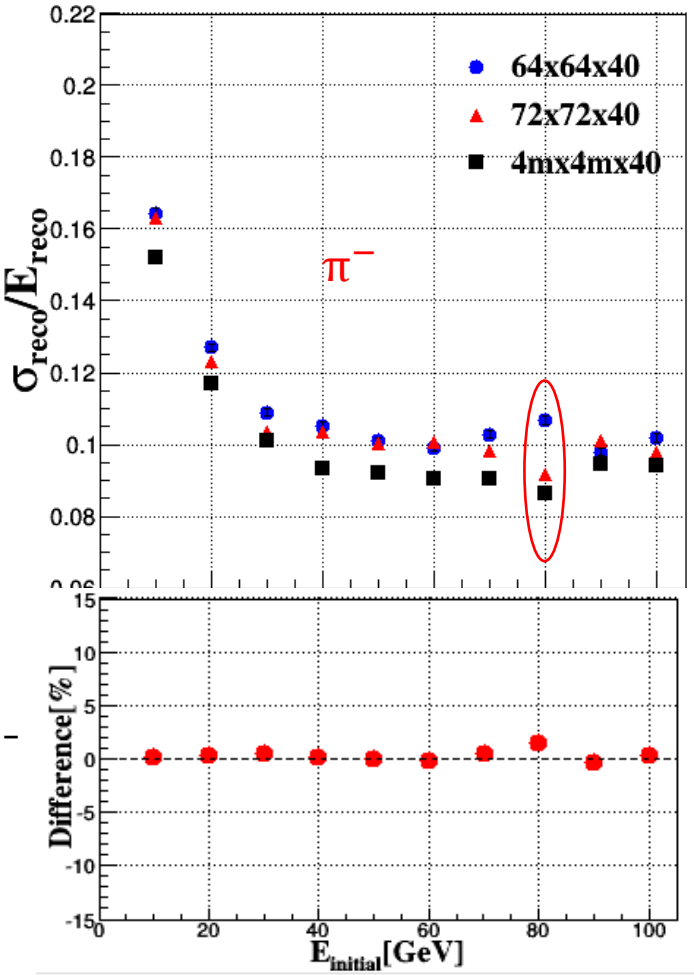
# Summary and plan

- The energy resolution  of AHCAL prototype can be improved by leakage energy compensation algorithm.
- Injection moulding tiles can be produced but light output is low, the craft is optimization.
- Scintillator testing platform have been built up and the batch testing is processing.
- Klaus testing board can work now and some parameters will be measured next.

# Backup

# Performance Different Structure

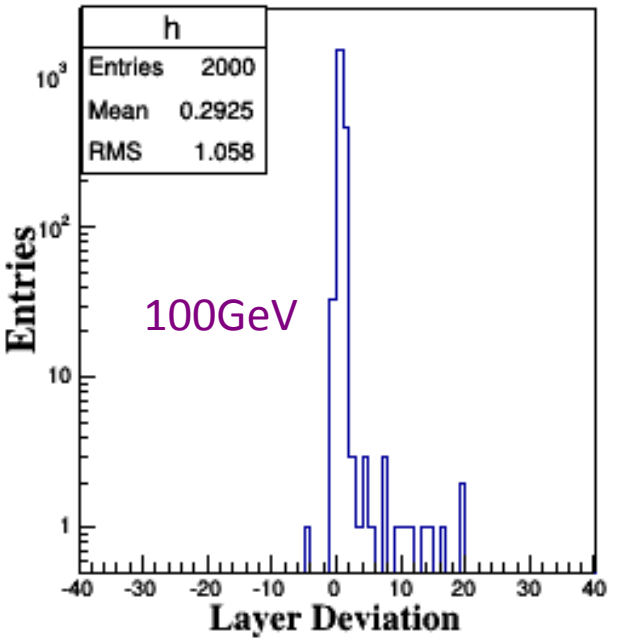


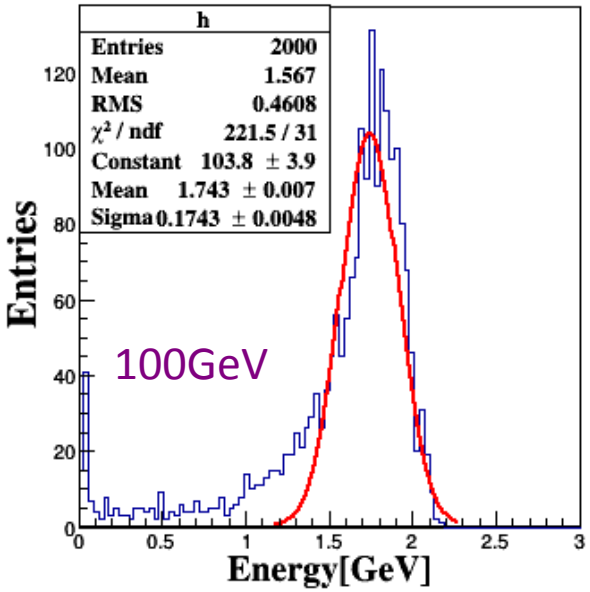



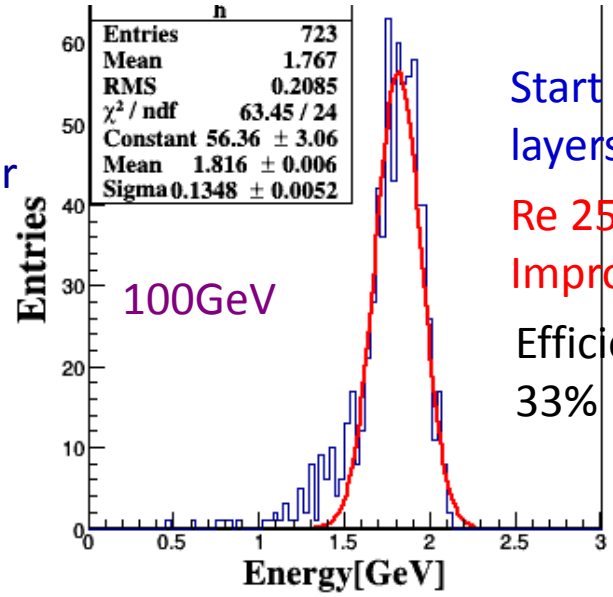

$R_{64x64}$ - $R_{72x72}$

- Nonlinearity 10GeV ➢ Bias of energy distribution
- Fluctuation at 80GeV ➢ Definition of energy resolution

# Performance with Selection




Crosscheak the true layer

Using Information both in stainless steel and scintillator

- Cheak the correction of algorithm
- Over 99% of true Layer deviation ±1 scale of 10GeV to 100GeV
- Long tail disappear with selection
- Gaussian shape within interval

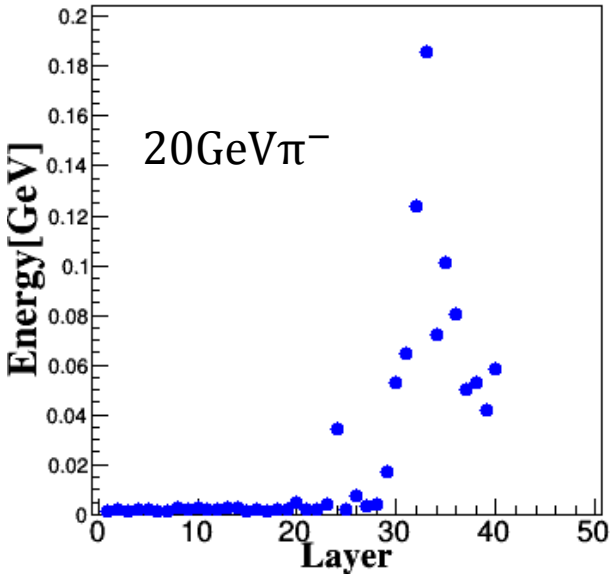
  Mean ±2σ(CALICE fitting range)

Start within 5 layers

Re 25% Improvement

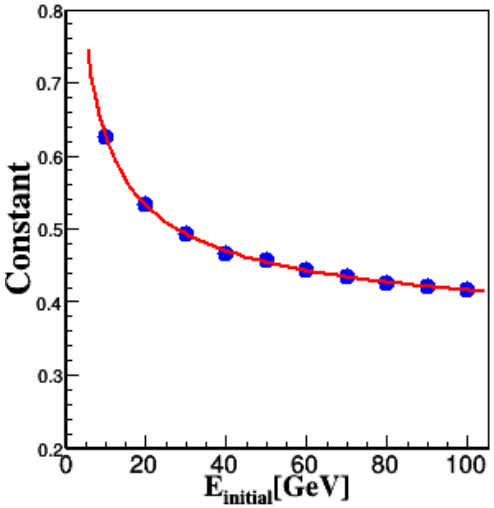
Efficiency 33%

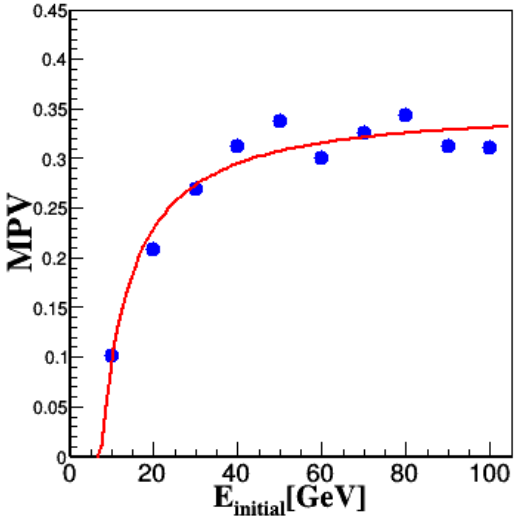
# Events Fluctuation




Fitting parameters: Constant,MPV,Sigma

- Average value from 6 to 20 layers

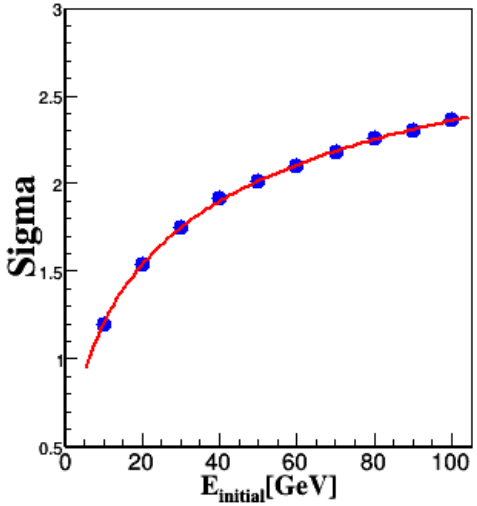


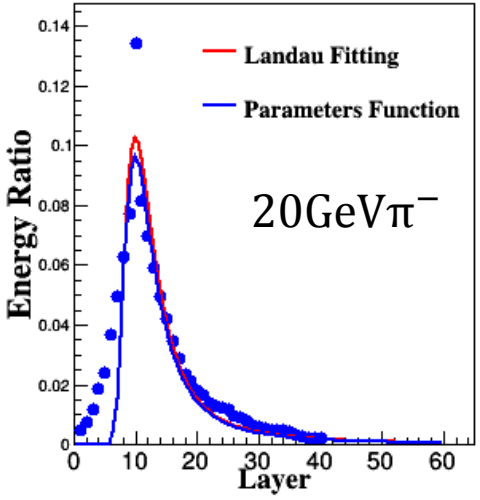




- Maximum energy deposition layer fluctuation
  - ⇒ sum energy for the same start point
- No information about true start point in reality
  - ⇒ sum energy for the same Maximum energy deposition layer
- Divide Events into 40 groups
- Maximum energy deposition layer>5

Fitting function:

$$p_0 + p_1 \times e^{p_2 \times E^{p_3}}$$

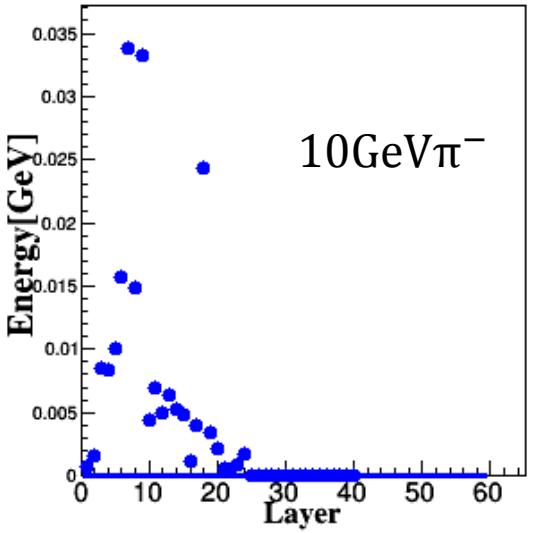


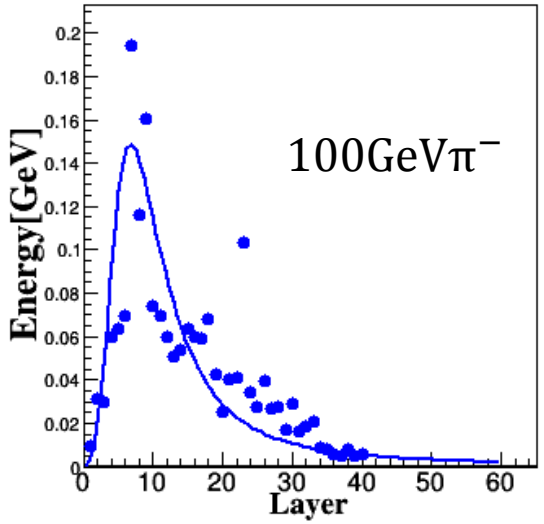
# Leakage Energy Compensation

Reduce the fluctuation of estimate leakage energy

- Average energy deposition in the last 4 layers as estimate energy
- Correct constant term of parameters event by event



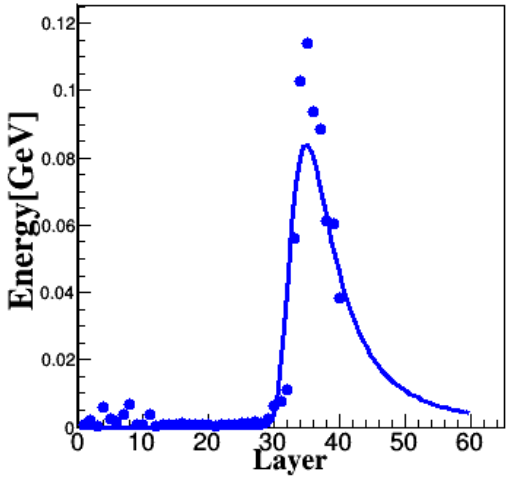

| Energy(GeV) | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|
| MEDL<36 | 97.4% | 95.9% | 96.1% | 96.2% | 95.2% |
| Energy(GeV) | 60 | 70 | 80 | 90 | 100 |
| MEDL<36 | 94.8% | 94.3% | 95.1% | 94.7% | 94.3% |

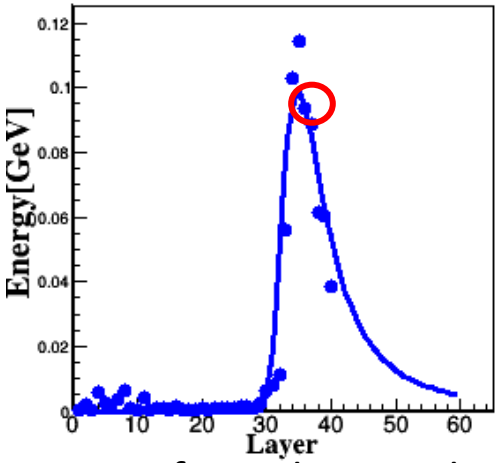



MEDL: maximum energy deposition layer

# Leakage Energy Compensation

Estimate from the last 4 layers



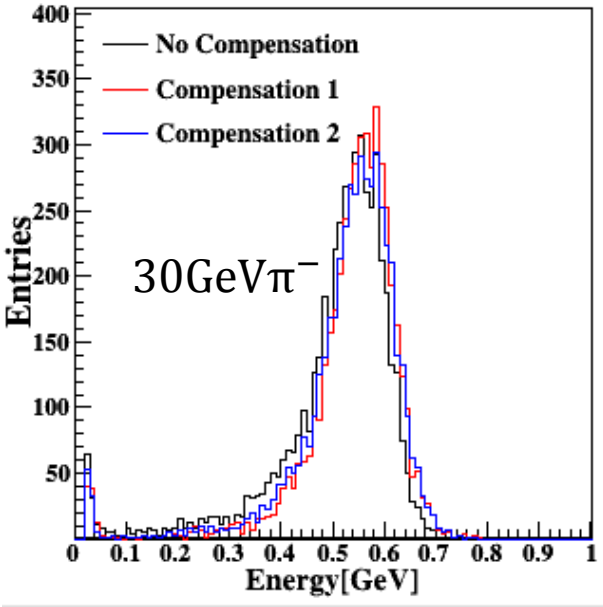



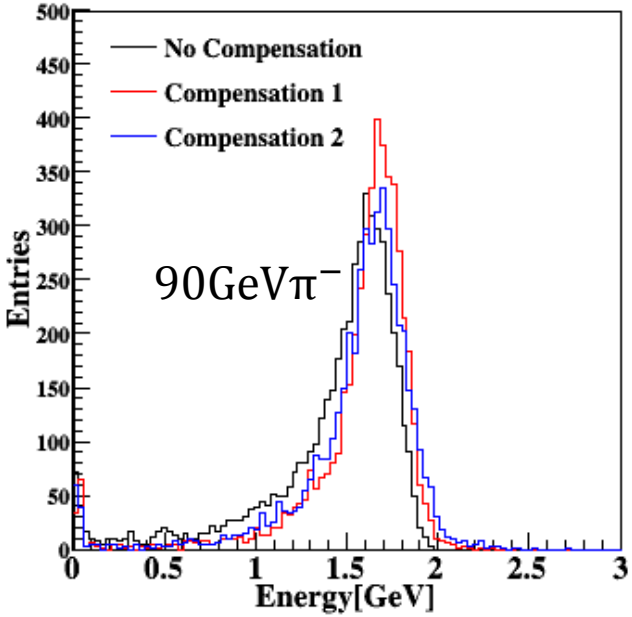

Estimate from the next layer of MEDL

CL:Compensation Layer (Layer>40)

For MEDL above 30

Energy deposition in the last several layer slump obviously




Compensation Condition

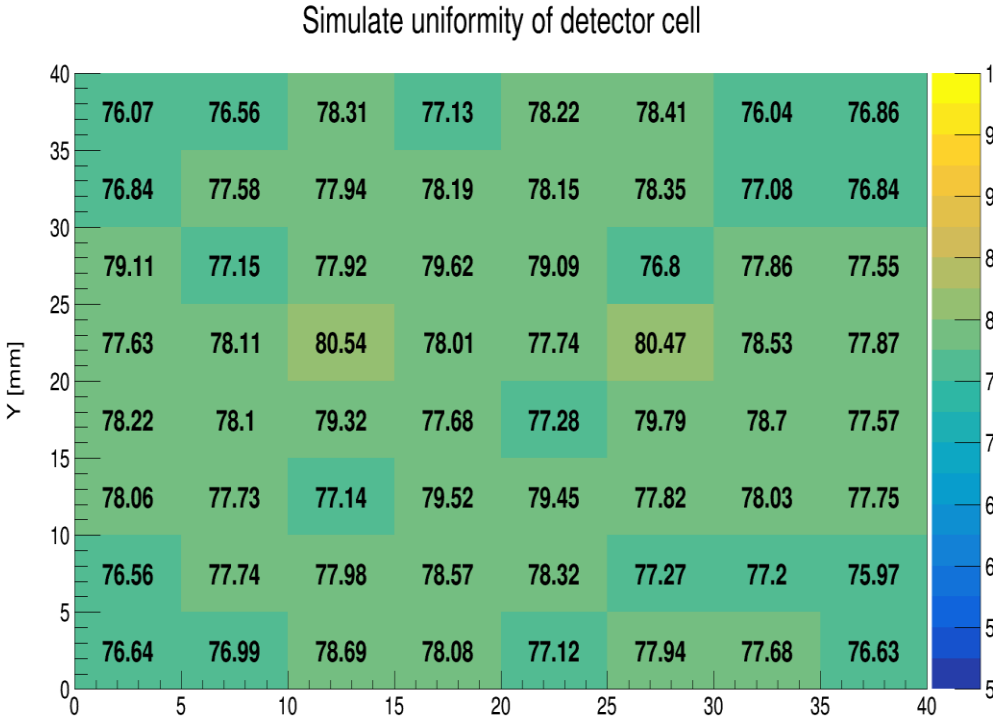
- MEDL >5
- Cut Events( MEDL>35)
- CL=MEDL+35

- Compensation 1: Estimate from the last 4 layers
- Compensation 2: Estimate from the next layer of MEDL
  - Events distribution are closer to Gaussian shape using Compensation 2

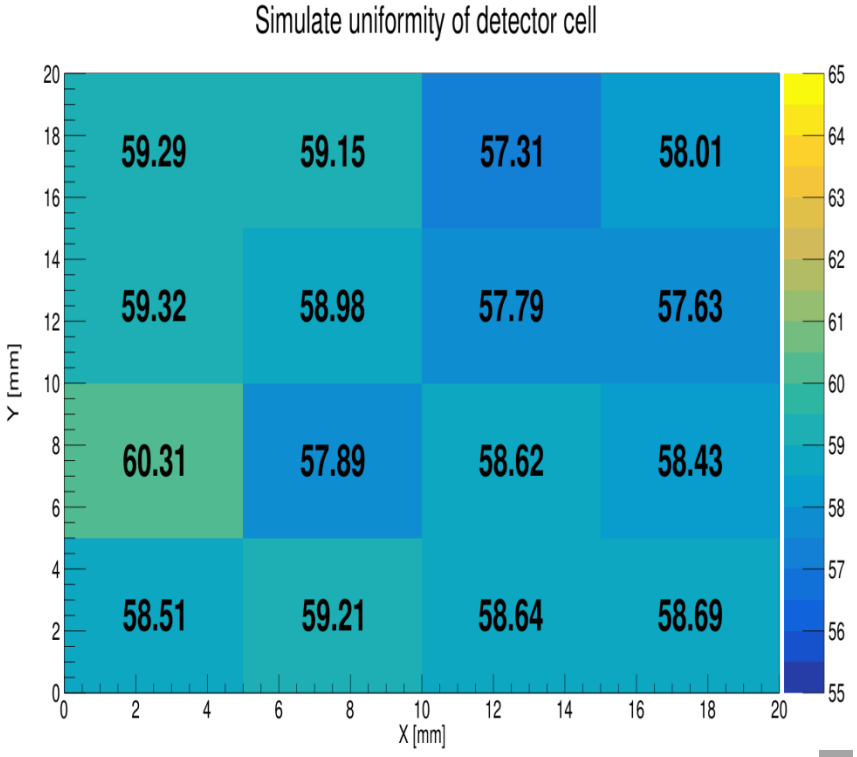
# Simulation of detector cells

Sipm parameters adopted:NDL 1010 series
SiPM size:1.4*1.4*1.mm

Number of SiPM:4 Scan step size:5mm Number of SiPM:3



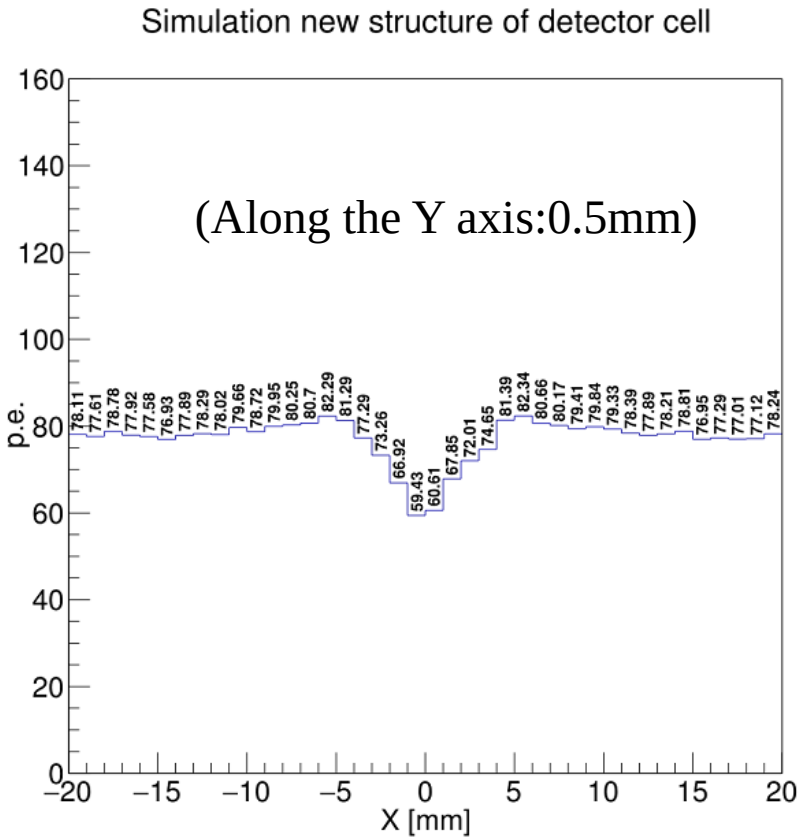

Mean value=77.88 p.e.
Mean deviation max value=3.4%
Uniformity deviation value=5.9%




Mean=58.61 p.e.
Uniformity deviation value=5.12%

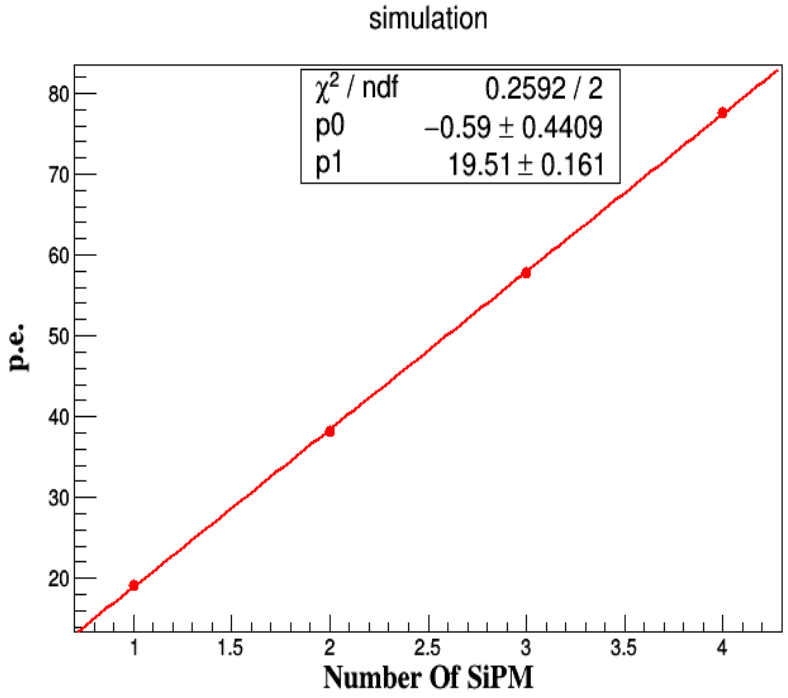
# Simulation of detector cells

Scan step size:1mm




Mean value=76.98 p.e.
Uniformity deviation value=29.8%

p.e. VS Number of SiPM




The p.e. value is proportional to the number of SiPM

# KLauS Chips

Diagram of Control logic

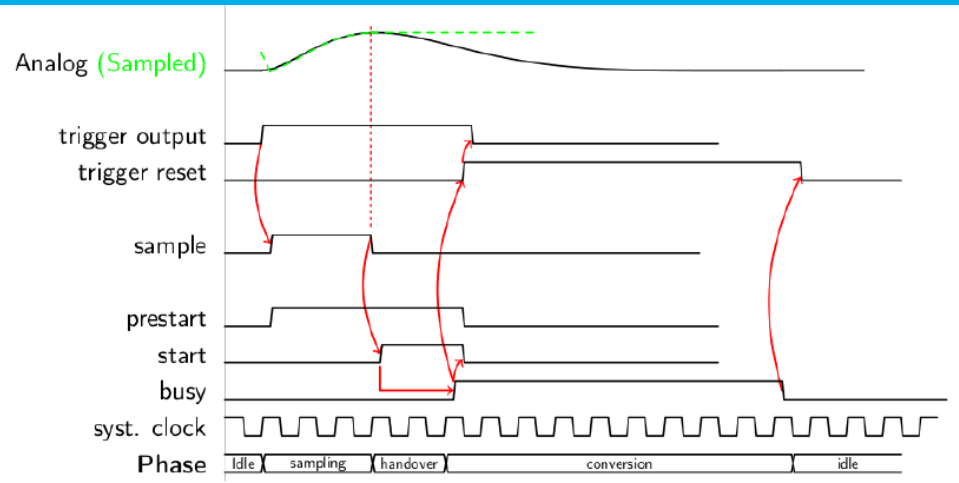



Figure 3.2: Timing diagram illustrating the analog-digital handshake between the hit-logic and the channel control logic.

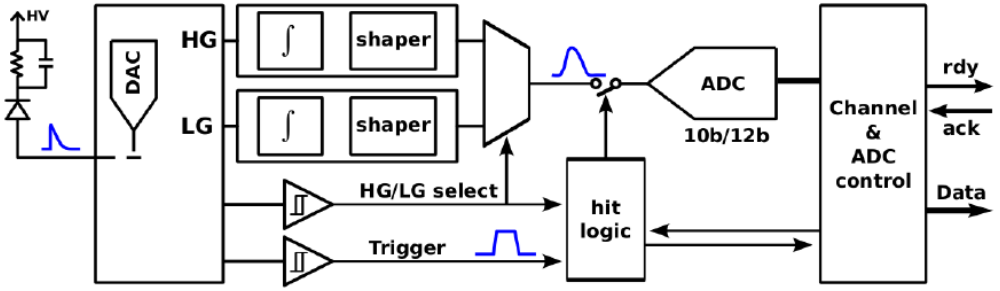



Figure 3.1: Block diagram of the KLauS channel in auto-triggered and auto gain-selection mode.