The plastic scintillator detector of HERD

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IHEP

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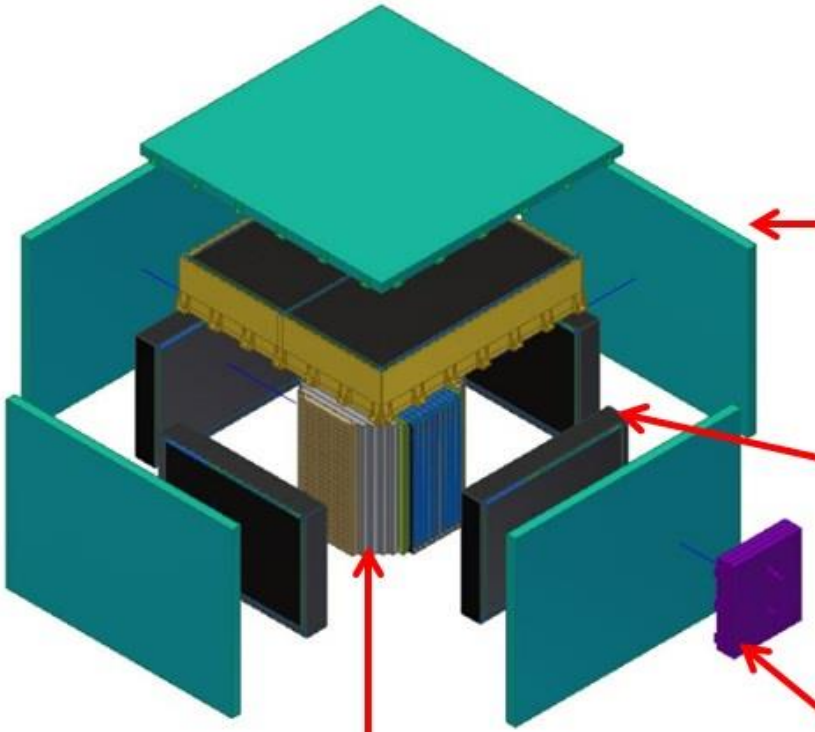
Structure of the HERD detector



PSD, six sides
LE Gamma identification（0.5GeV < Edep <10 GeV）
Charge

STK(SSD),five sides
Trajectory
Gamma tracking
Charge

TRD
TeV proton calibration

LYSO array
Trigger sub-system
ISCMOS sub-system

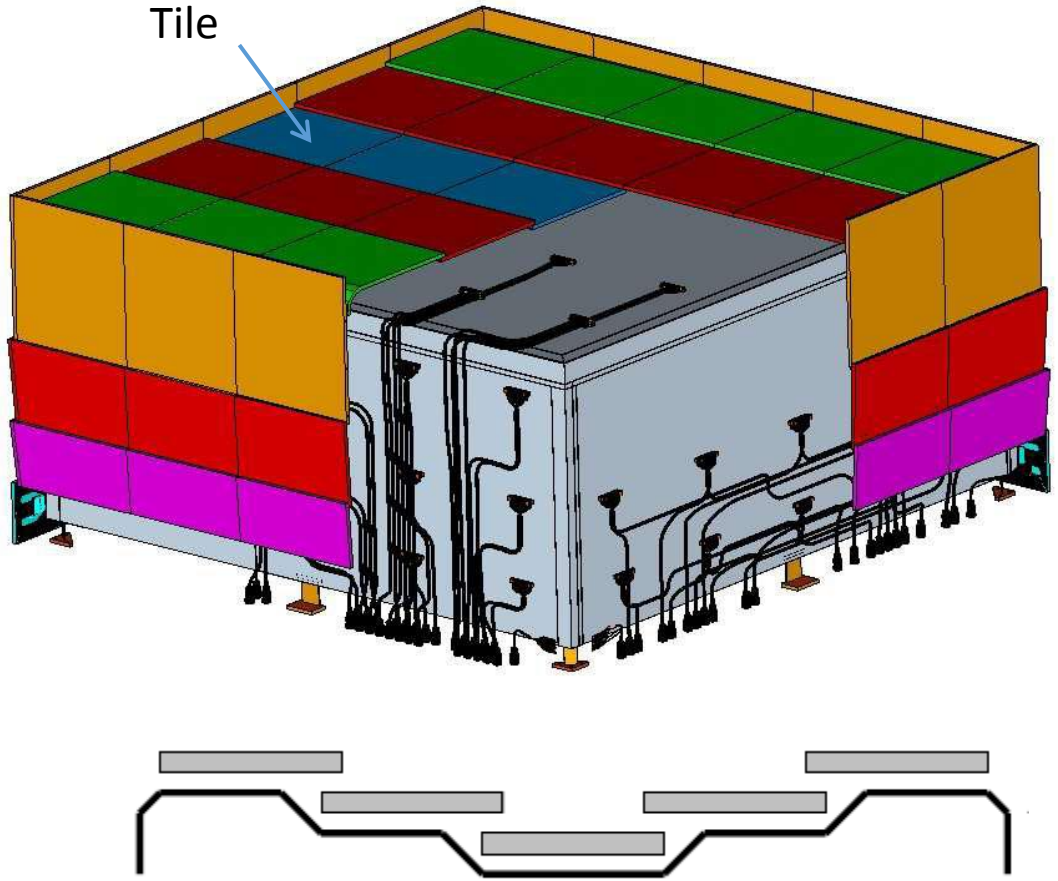
CALO, 3-d
e/G/CR energy
e/p discrimination

The overall PSD efficiency of singly charged relativistic particles >99.9%

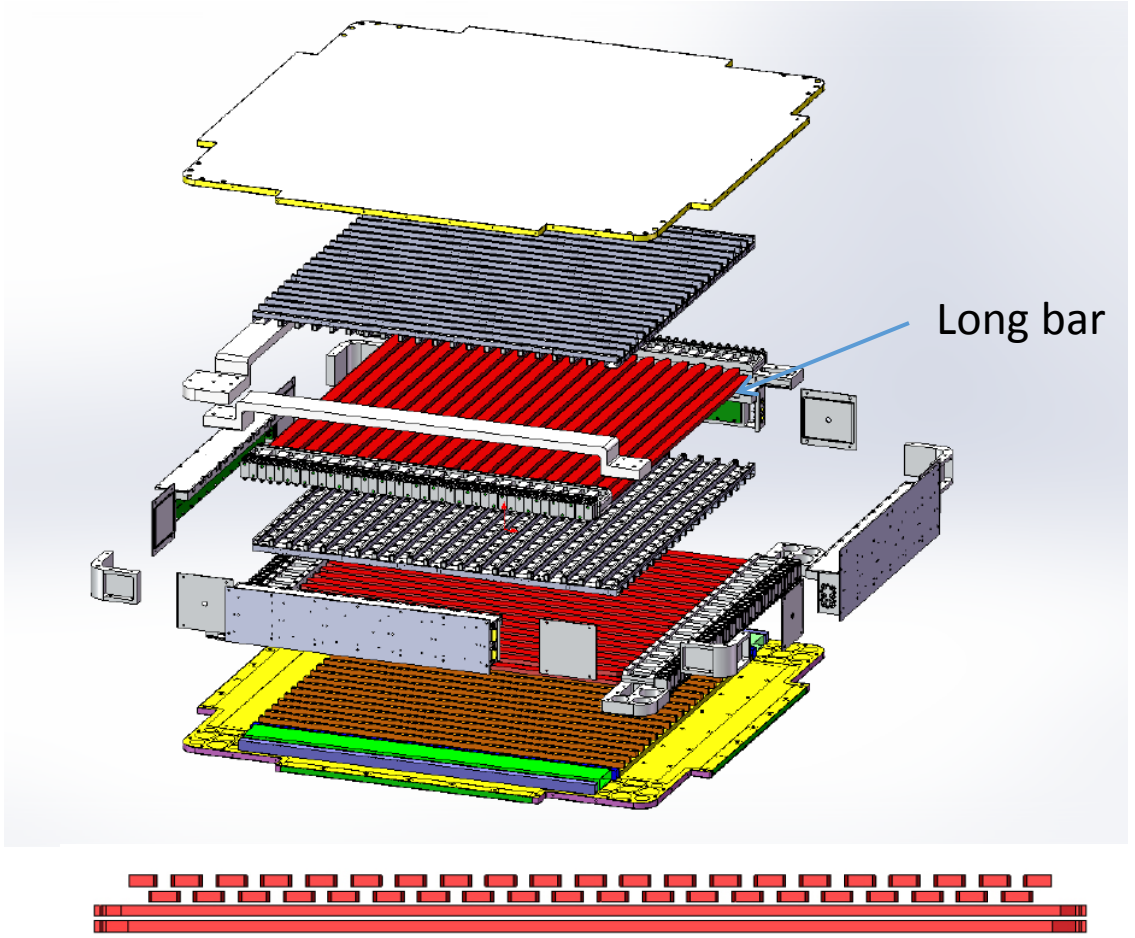
Charge measurement of CRs with Z from 1 to 26

Charge resolution 0.15 c.u. (joined with thin crystal)

Similar design of other projects

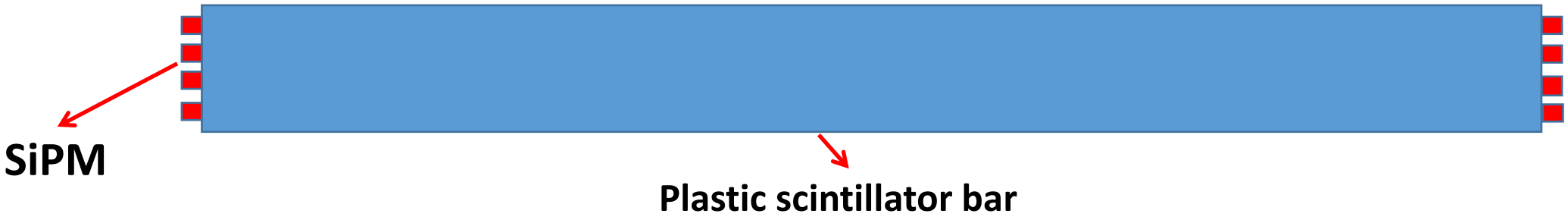


Fermi LAT AntiCoincidence Detector (ACD)



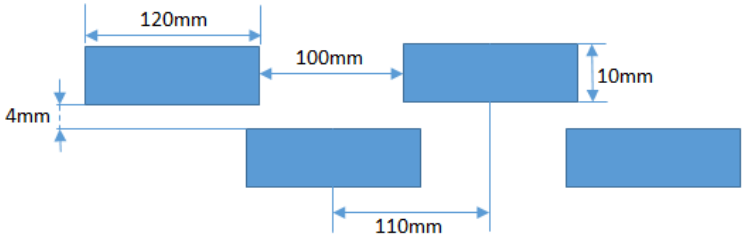
DAMPE PSD

Design of the PSD



The overall PSD efficiency =Charged particle detection efficiency×Charged particle coverage efficiency

The overall PSD efficiency>99.9%(LE photon trigger required)
Charged particle detection efficiency=99.98%(one layer)
Charged particle coverage efficiency>99.92%



Relative position of PS bars

the neighbor bars are overlapped by 10 mm to avoid “dead zone”.

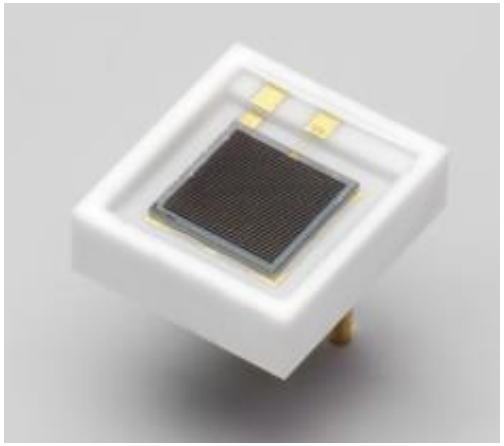
The dimension of Plastic scintillator bar:
Top:170cm×12cm×1cm(16 pieces)
Sides:120cm×12cm×1cm(60 pieces)
Bottom: TBD
All dimension will be optimized in the further (simulation&structure).
The material of Plastic scintillator bar: EJ-200(Fermi LAT&DAMPE application)

Design of the PSD

At each end of PS, 4 redundant SiPMs attached to readout as 2 low range signals and 2 high range signals

Item	Low range	High range
Effective area	6mm×6mm	3mm×3mm
Pixel number	57600	90000
Pixel pitch	25um	10um
PDE@425nm	25%	11%
Gain@typical	7e5	1.35e5
Charge number(Z)	1-6	5-26
P.E. number	50-3600P.E.	138-3036P.E.
Charge	5.6-403pC	2.98-66pC
Candidate	S13360-6025CS	S12572-010C

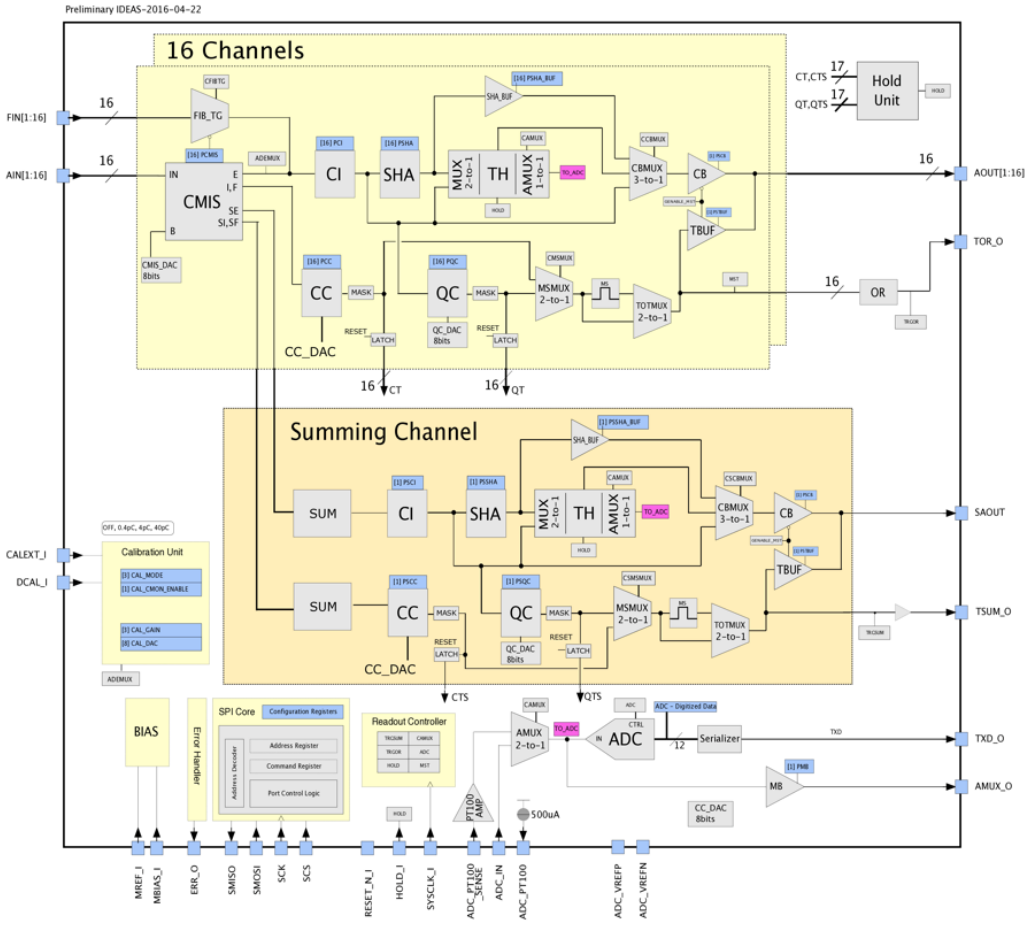
S13360-6025CS



S12572-010C

Quenching factor 0.4
Double redundancy are considered
The gain may be optimized to improve the SNR

Readout of the SiPM



IDE3380 ASIC Architecture

Trigger timing pulse generated in a faster current comparator
16 current sensitive inputs (≤ 16 nC)
Automatic 12-bit digital readout
SEL/SEU radiation hardened

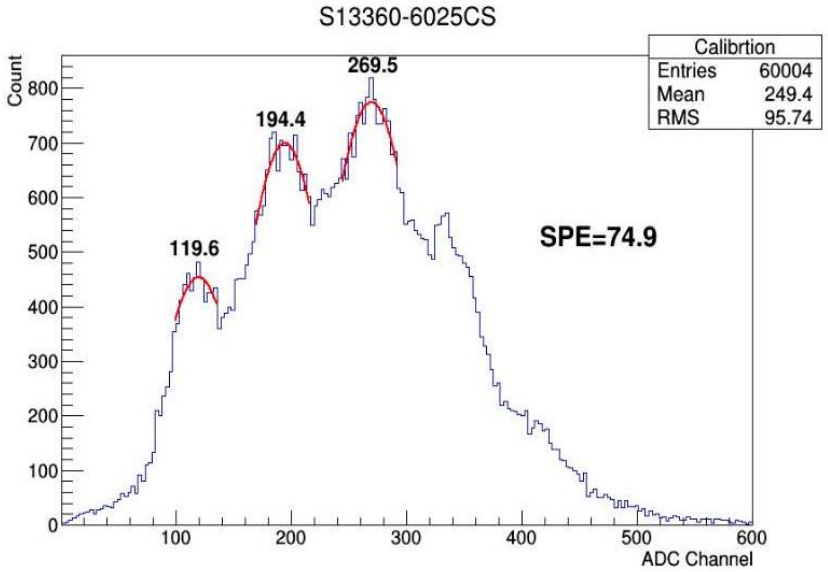
4 SiPMs at single end of PS bar connect to one ASIC.
4 ch. are active, other 4 ch. back up, left 8 ch. are shuted off.
The total number of ASIC is 152(only five sides)
The ASIC number that readout SiPMs in the bottom will be calculated subsequently

Other readout chips are also investigated.
For example: OMEGA CITIROC ASIC

A small size prototype of PSD

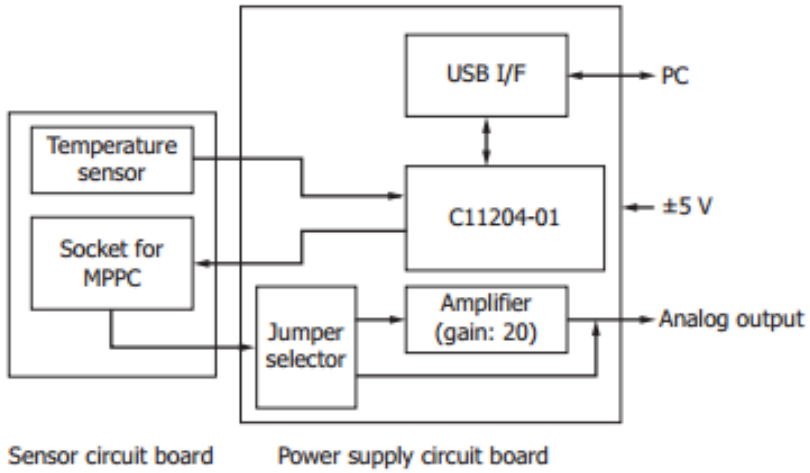
SiPM

Plastic scintillator bar:　120cm×12cm×1cm



Calibration of SiPM

C12332-01



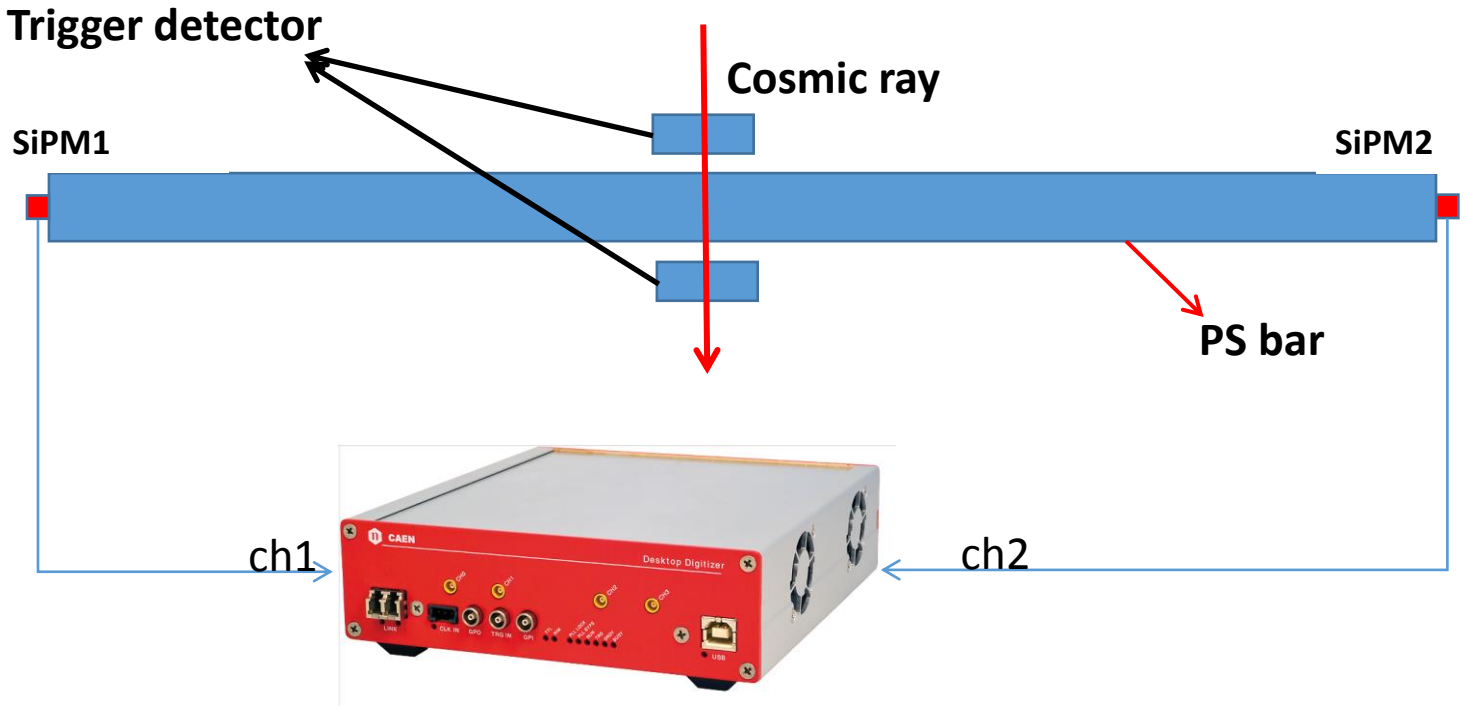
Block diagram of C12332-01

C12332-01 : a evaluation circuit for SiPM, contains:

・A high-accuracy, high-voltage power supply that provides the operating voltage for SiPM.

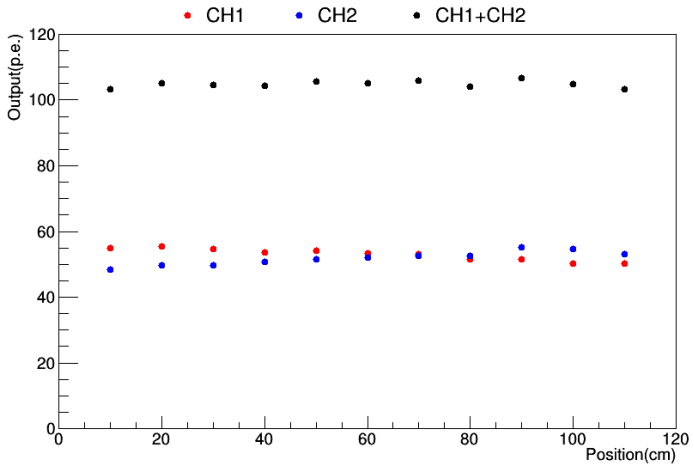
・A temperature compensation function that constantly optimizes the SiPM operation even in environments with varying temperatures.

Position uniformity test

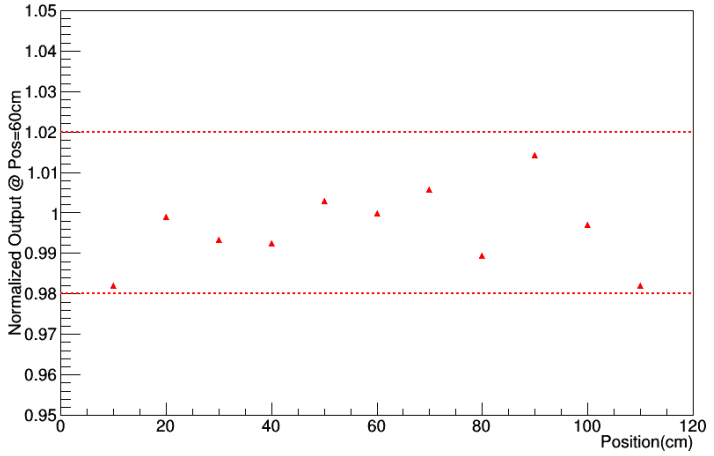


Test diagram

DT5751-Desktop Digitizer:10 bit 2GS/s-1GS/s ADC

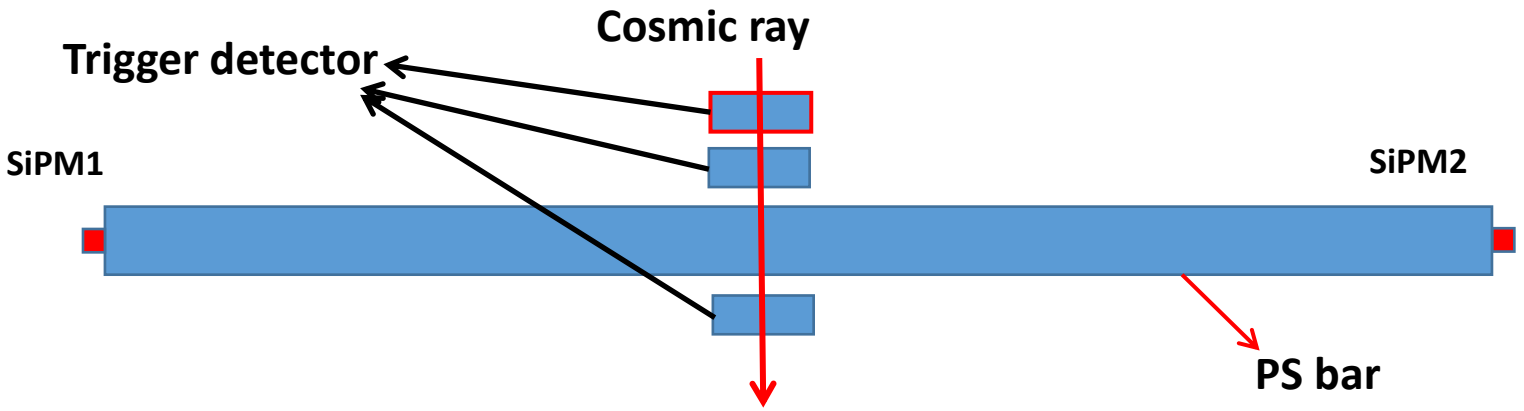


Distance from Ch2 (cm)



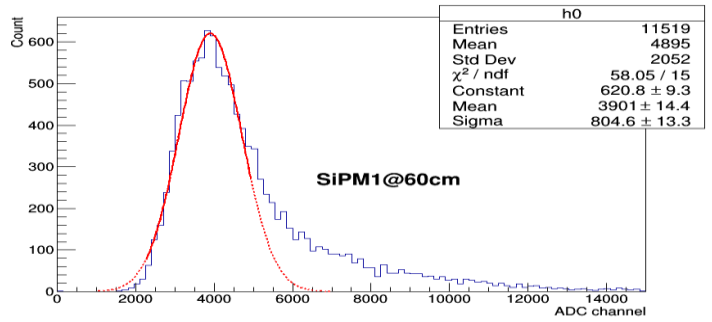
Normalized result of CH1+CH2

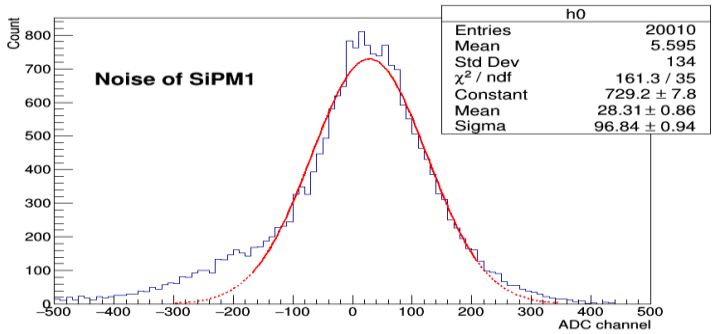
Detection efficiency test

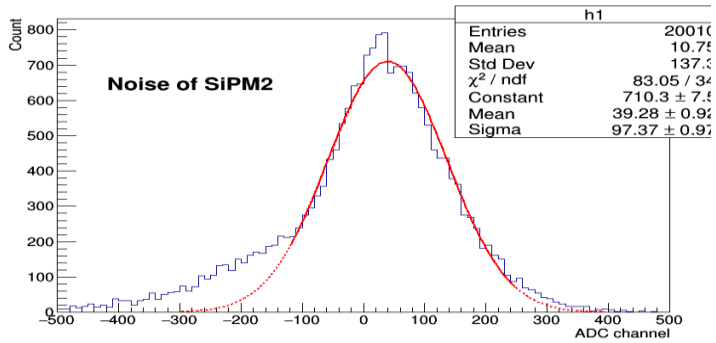


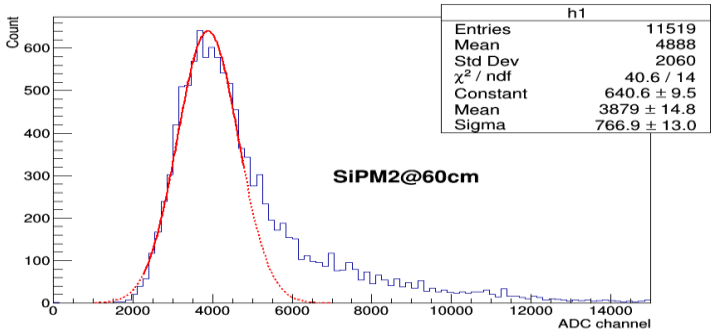
Test layout

The detection efficiency with 2 SiPMs readout is 99.98%

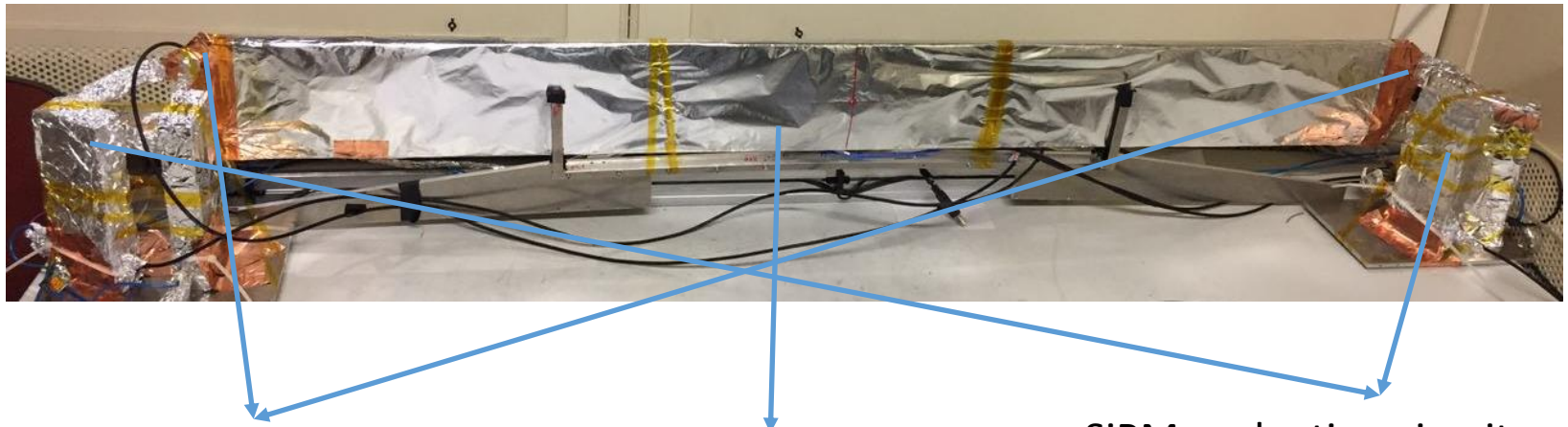




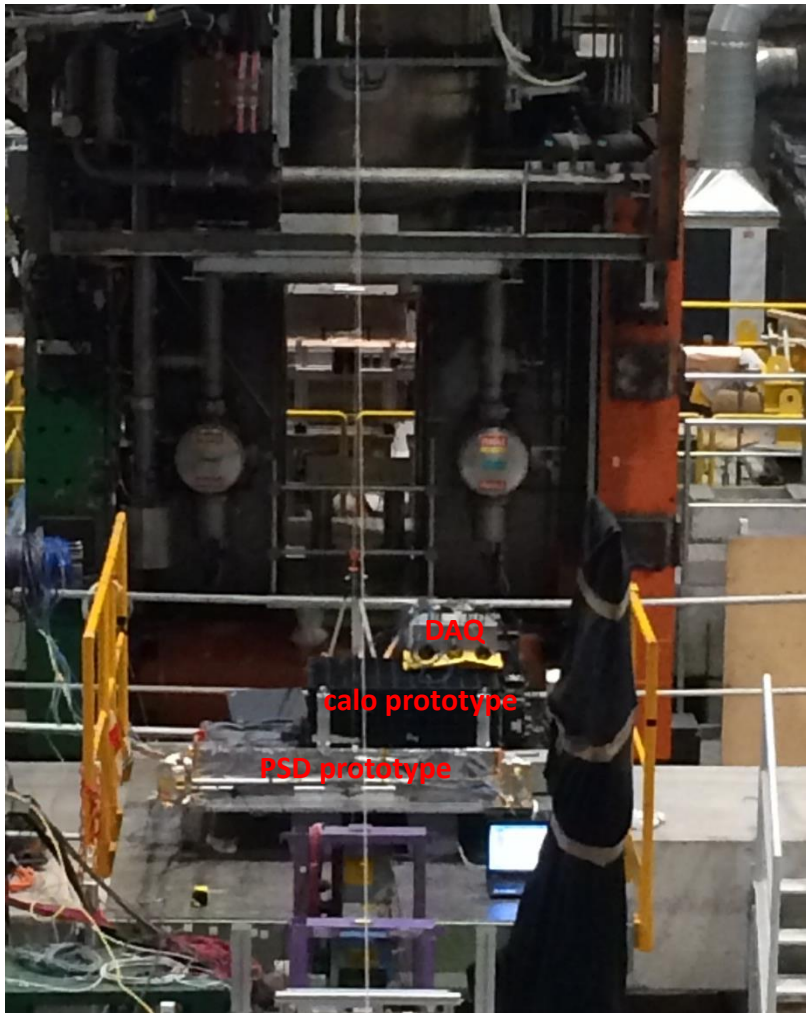




Beam Test

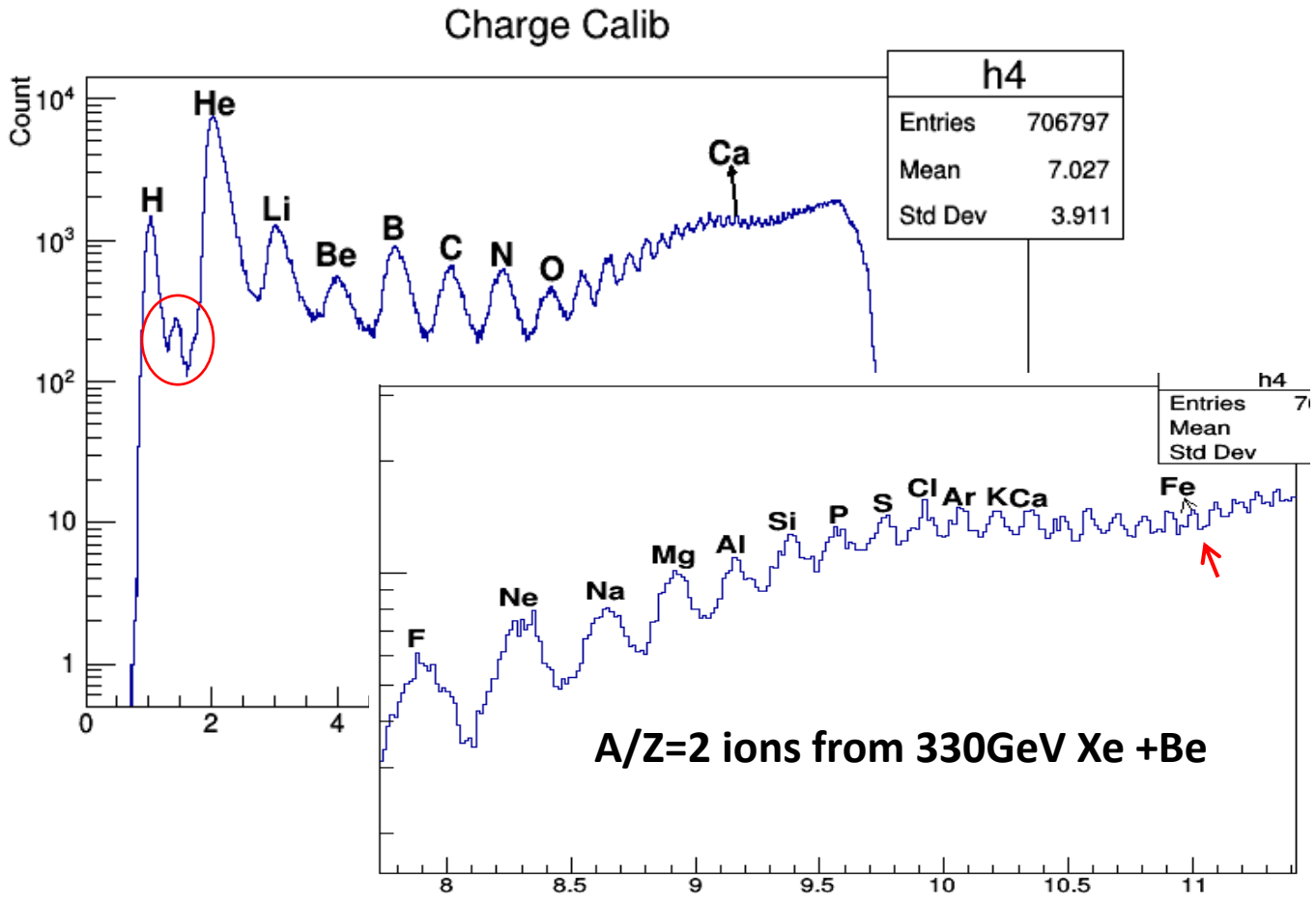


SiPM output recorded by HERD DAQ system.



Experiment layout

Beam Test



Reconstructed charge spectrum

charge resolution σ_z:

$$\sigma_z = \frac{\delta S(Z)}{S(Z) - S(Z-1)}$$

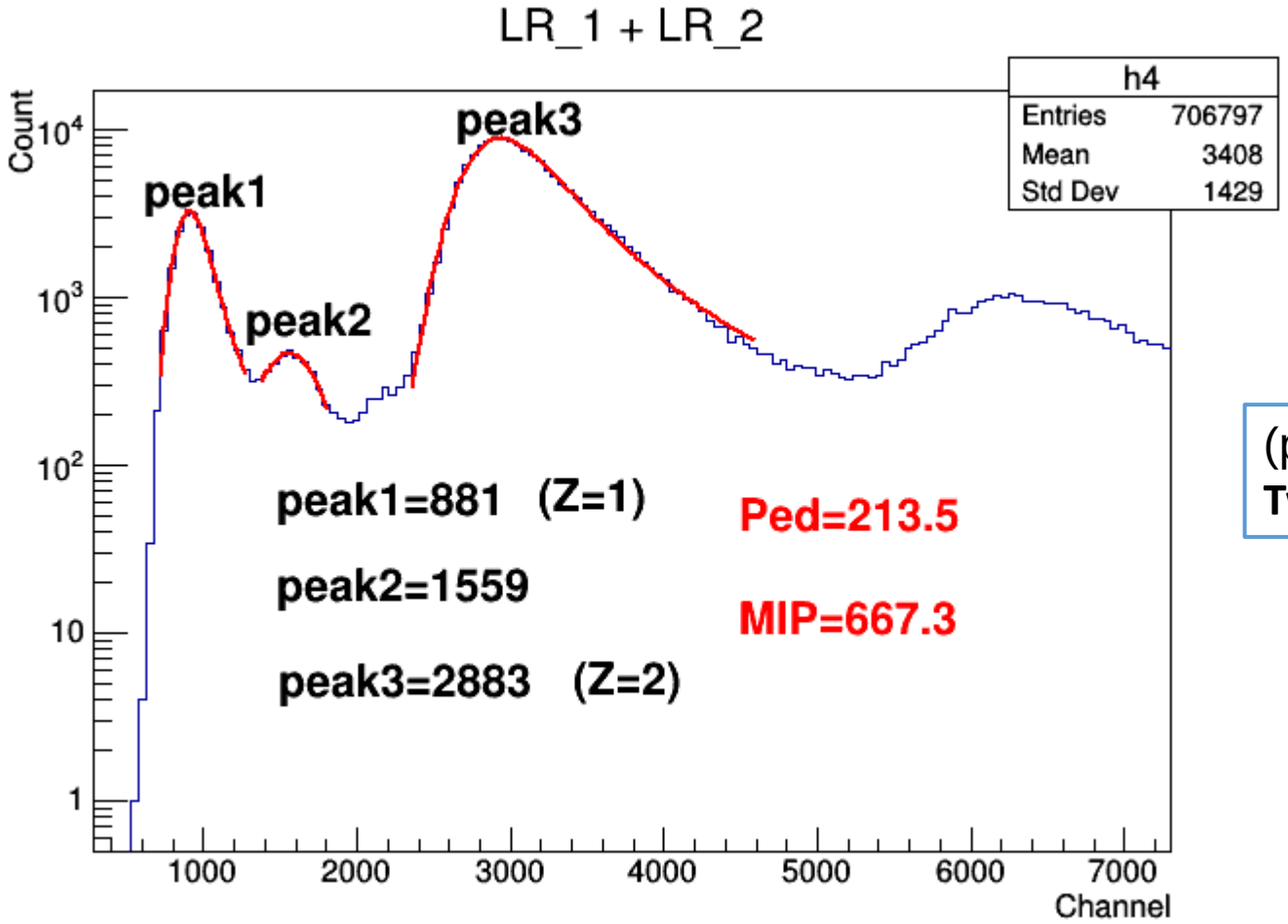
$S(Z)$, $S(Z-1)$: *Mean of the Gaussian*

$\delta S(Z)$: *Standard deviation*

H: $\sigma_{Z=2} = 0.21\ c.u.$
B: $\sigma_{Z=5} = 0.21\ c.u.$
Na: $\sigma_{Z=11} = 0.45\ c.u.$
Ar: $\sigma_{Z=18} = 0.62\ c.u.$
Ca: $\sigma_{Z=20} = 0.71\ c.u.$

The SiPM are saturated from Z=8

Beam Test



Energy spectrum of PSD

(peak2-Ped)/(peak1-Ped)=2
Two proton event

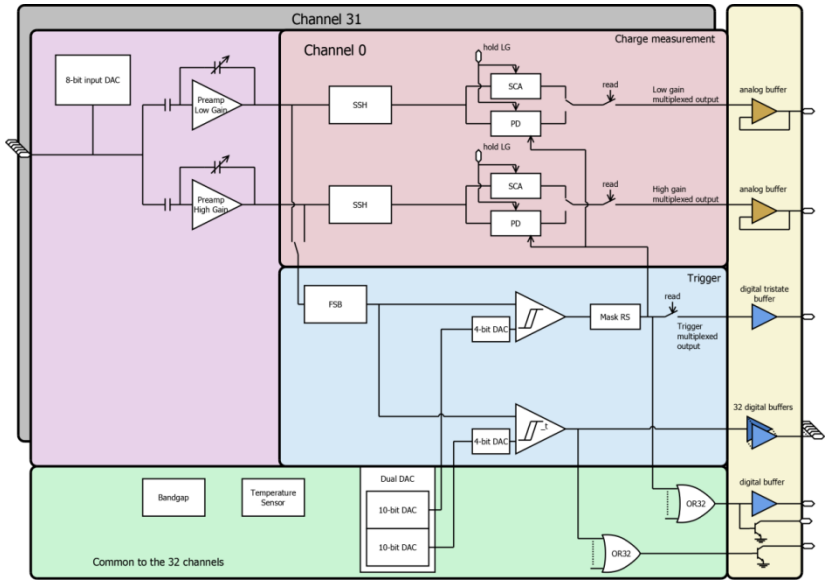
Update of the PSD prototype

Two sizes of SiPM will be attached to each end.
Verify the method of the dual-range design.
A ASIC chip will be implemented(CITIROC or IDE3380?)

The CITIROC ASIC circuit are prepared now.
The joint test between SiPM and ASIC will be carried out.

General ASIC for SiPM readout

- 32-channel readout, charge and trigger outputs (No ADC/TDC)
- Power pulsing
- Individual stage can be turned on or off for various config



CITIROC Architecture

Summary

- PSD was designed preliminary.
- A prototype of PSD was designed and tested in beam line.
- Fragmented ions with Z>26 was clearly seen in the reconstructed energy spectrum from the prototype of PSD.
- The update of PSD prototype is progressing and plan to be tested at CERN in 2018.