Detector R&D of the Forward Calorimeter with PAD readout for the ALICE upgrade

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・FoCal project

・Introduction

FoCal(Forward Calorimeter) is a project under study within the ALICE Collaboration for a possible upgrade during the LHC Long Shutdown 3(2024).
FoCal has two components : FoCal-E and FoCal-H and would be installed 7m from collision point as shown in Fig.1.
The main goal of FoCal is the identification of direct photons and decay photons in pp, p-Pb and Pb-Pb collision.

・Motivation

- to study the initial state of nuclear collisions at high energy.
- measurement of direct photon at large rapidity to test a gluon saturation i.e. Color Grass Condensate

・Components

- Electromagnetic Calorimeter : FoCal-E
- Hadron Calorimeter : FoCal-H

・Acceptance

- 3.3 < η < 5.3

・Observables

- π0 → 2γ
- direct(isolated) photons] ←FoCal-E subject
- J/Ψ (under study)
- Jets (under study)

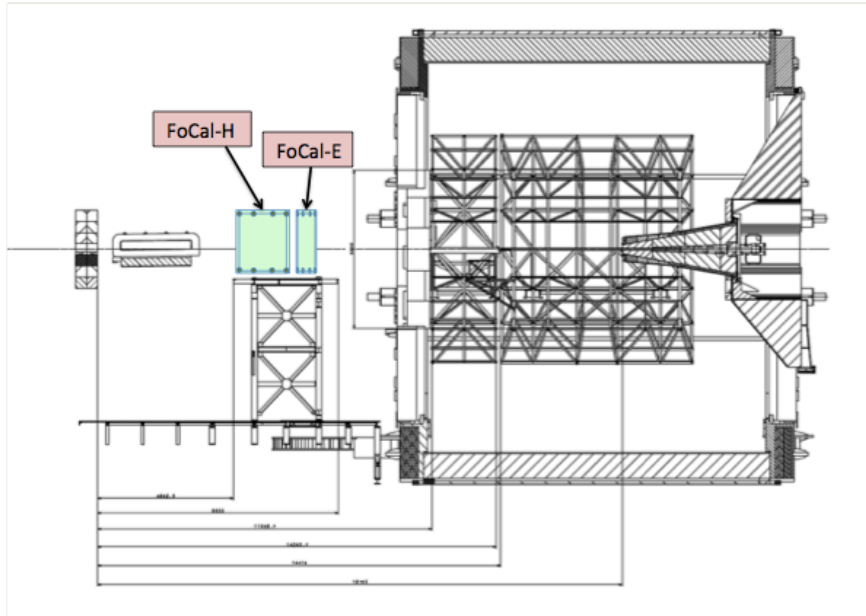

Fig.1 : Installation plan of Forward Calorimeter

・FoCal-E strawman design

FoCal-E is an electromagnetic calorimeter consisting of the tungsten and silicon sensors with a sandwich structure(Fig.2).

・W/Si sandwich calorimeter
- W absorber + Si sensors
  Moliere radius : R_M = 9.3mm
  Radiation length : X_0 = 3.5mm

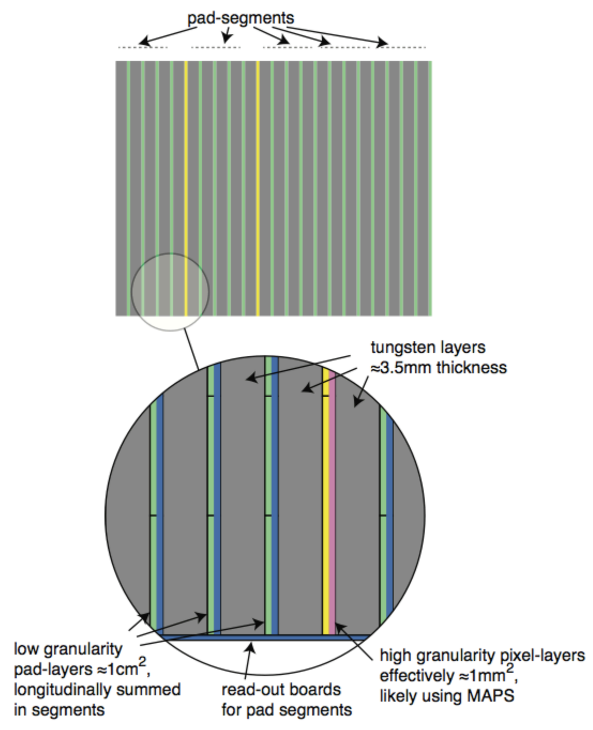

Fig.2 : FoCal-E strawman design(yellow : HGL, green : LGL)

・FoCal-E have 2 different module

- Low Granularity Layer(LGL)
  (Fig.3←This is our R&D prototype!!)
  ・1 segment = 4 layers of Si/W
  ・1 layer has 64 PADs(8 × 8)
  ・PAD cell size : 1 × 1 cm^2
  ・signals are longitudinally summed
- High Granularity Layer(HGL)
  ・CMOS-pixel
  ・pixel size : 25 × 25 μm^2
  ・Digital signal are summed in 1 mm^2 cells

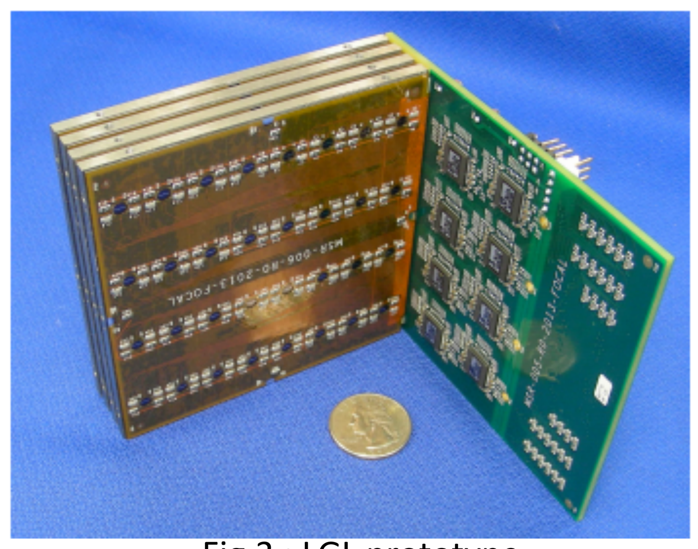

Fig.3 : LGL prototype
(made by Oak Ridge National Laboratory)

・Test beam 2014

・Test beam at PS and SPS

- Test beam at PS beam line on Sep – Oct 2014.
  Beam energy is 2 ~ 10 GeV.
  In PS beam line, we can identify the electron.
- Next, test beam at SPS beam line on Nov 2014.
  Beam energy is 30 ~ 100 GeV.

・Condition and testbench of PS and SPS

PS
- T9 beam line
- Term : Sep – Oct in 2014
- energy : 2 ~ 10 GeV
- beam rate : 〜100 Hz
- gain : high gain(1/1)

Cherenkov : identification of electron

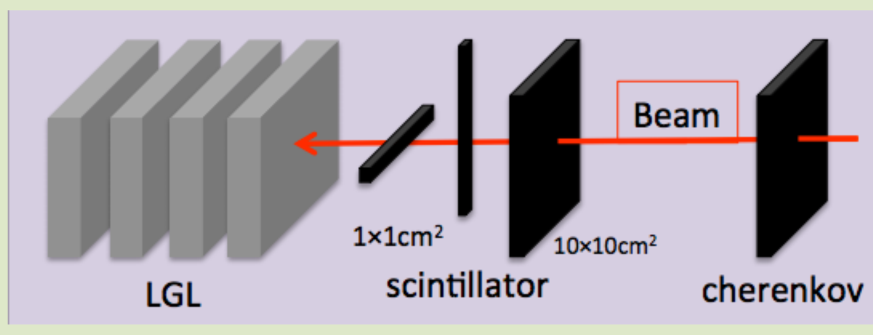

Fig.4 : testbench at PS

SPS
- T4 – H8 beam line
- Term : Nov in 2014
- energy : 30 ~ 100 GeV
- beam rate : 〜300 Hz
- gain : low gain(1/16)

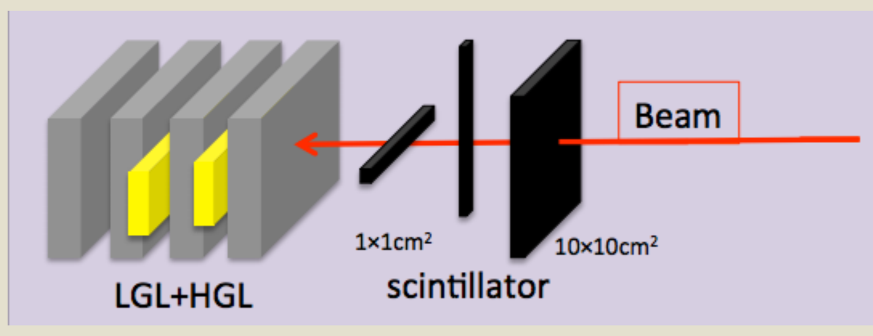

Fig.5 : testbench at SPS

・LGL readout system

We use the APV hybrid board and ADC board, FEC board as electronics of readout(Fig.6).
These electronics is developed by CERN RD51 group.
APV chip have 128 output and sampling speed of APV is 40MHz.
ADC board has simultaneous readout from 8 APV hybrid board for 12 bit ADC and the role of FEC board is to process information from ADC.

・Readout electronics : developed by CERN RD51 group
・APV25 hybrid board
- output : 128ch
- sampling speed : 40MHz
・SRS(Scalable Readout System)
- ADC board : 12 bit ADC
  Simultaneous readout from 8 APV hybrid board(Master)
- FEC board : the front-end which processes information from ADC

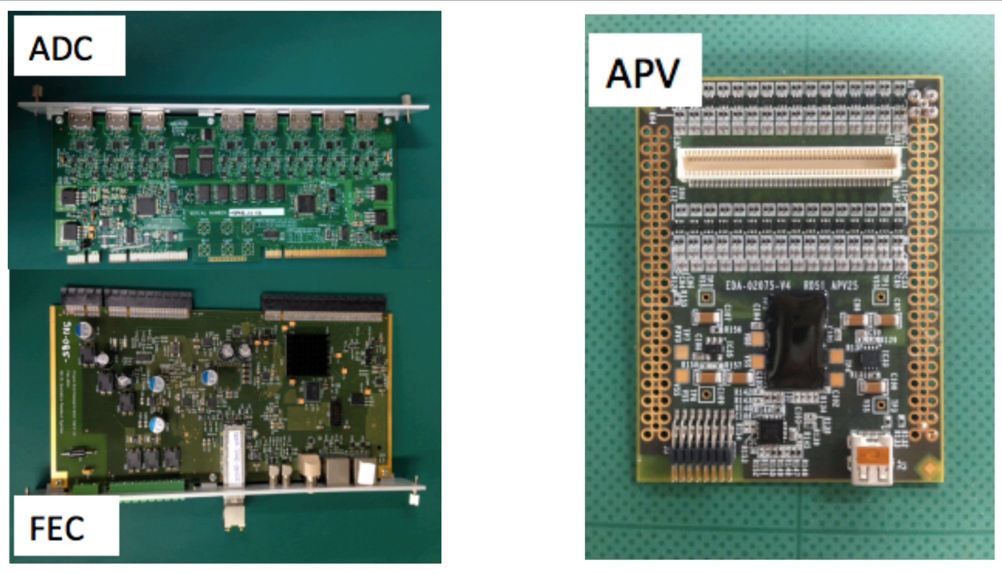

Fig.6 : APV hybrid board and ADC and FEC board picture

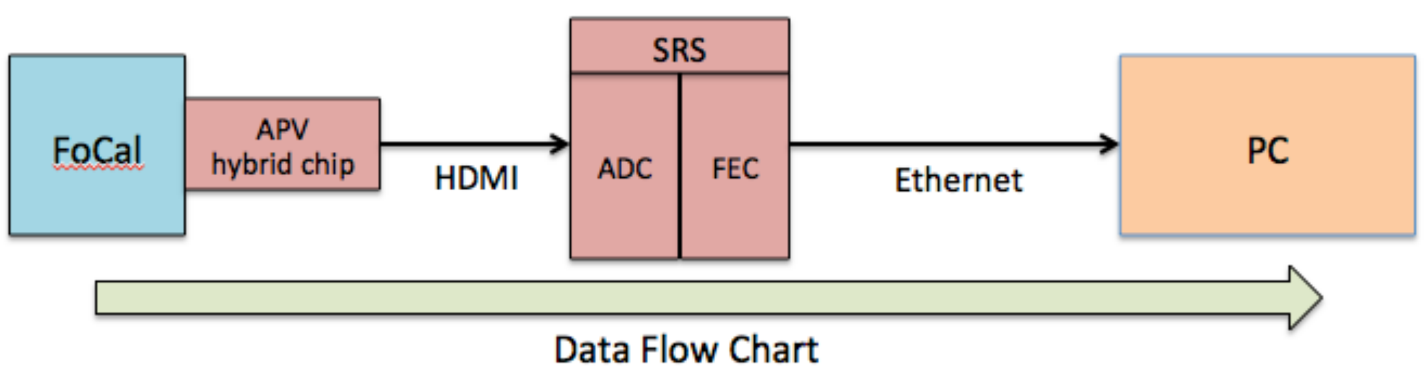

Fig.7 : readout flow chart

・Test beam results

・Energy linearity of PS and SPS

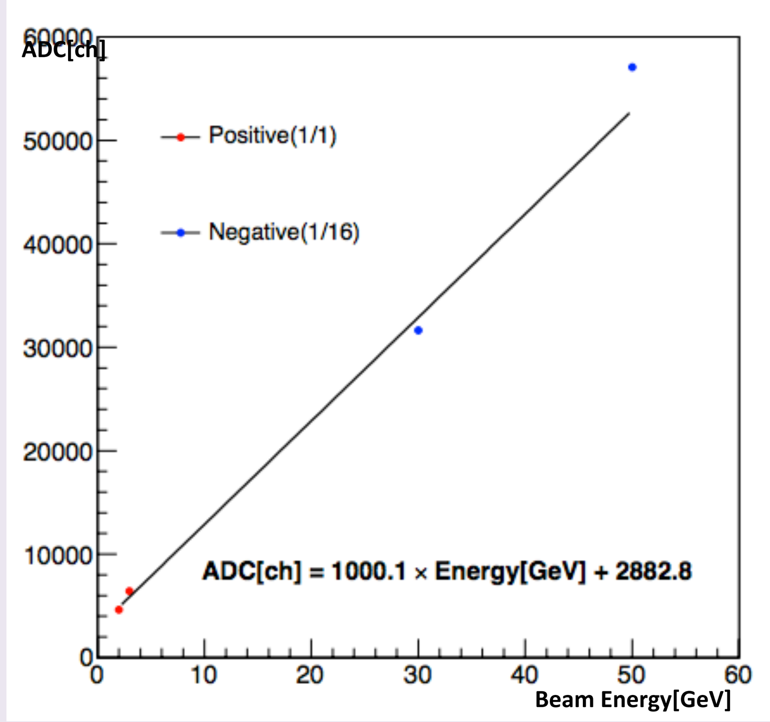

Fig.8 : energy linearity at PS and SPS

We can take the data of 2 & 3GeV at PS and 30 & 50GeV at SPS.

We can see the energy linearity.
Next test beam, cover the other energies.

・Noise measurements

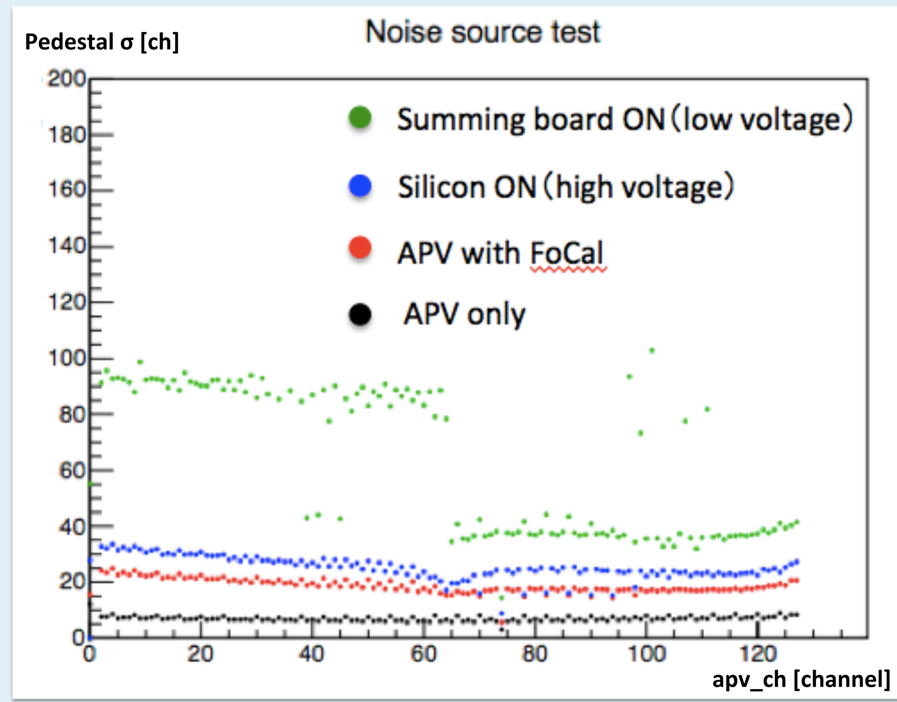

Fig.9 : comparison of noise for each variation

On PS experiment, noise is large.
We try decreasing the noise.

When summing board is ON(Low voltage ON), pedestal sigma value is large especially.
→introduction of regulation power supply.
On the other hands, we perform optimization of the GND.

・Shower profile

We use the center of gravity equation to study the shower shape.
By calculating the gap of beam's center of gravity, we can see the shower profile.

The center of gravity equation

s : which LGL
i , j : PAD of x & y axis

$$x^{(s)} \equiv < x^{(s)} > \equiv \frac{\sum_{i,j} ADC_{i,j}^{(s)} \cdot x_i^{(s)}}{\sum_{i,j} ADC_{i,j}^{(s)}} \quad s = 1,2,3,4 \quad i,j = 1,\cdots,8$$

$$y^{(s)} \equiv < y^{(s)} > \equiv \frac{\sum_{i,j} ADC_{i,j}^{(s)} \cdot y_j^{(s)}}{\sum_{i,j} ADC_{i,j}^{(s)}} \quad s = 1,2,3,4 \quad i,j = 1,\cdots,8$$

Shower profile equation

$$d = 0.35 \ln\left(\frac{E_{incident}}{8.11[MeV]} - 0.5\right)[cm]$$

・beam : 2GeV electron
・Longitudinal shower profile
- shower max d (for W) = 19.27mm ← 2nd LGL
・Transverse shower profile
- re-calculate shower center (centroid)
- Moliere radius (for W) : 9.16mm
・longitudinal and transverse shower profiles are consistent with the expectation
- At depth 17.5 – 28[mm], expanse of shower is large

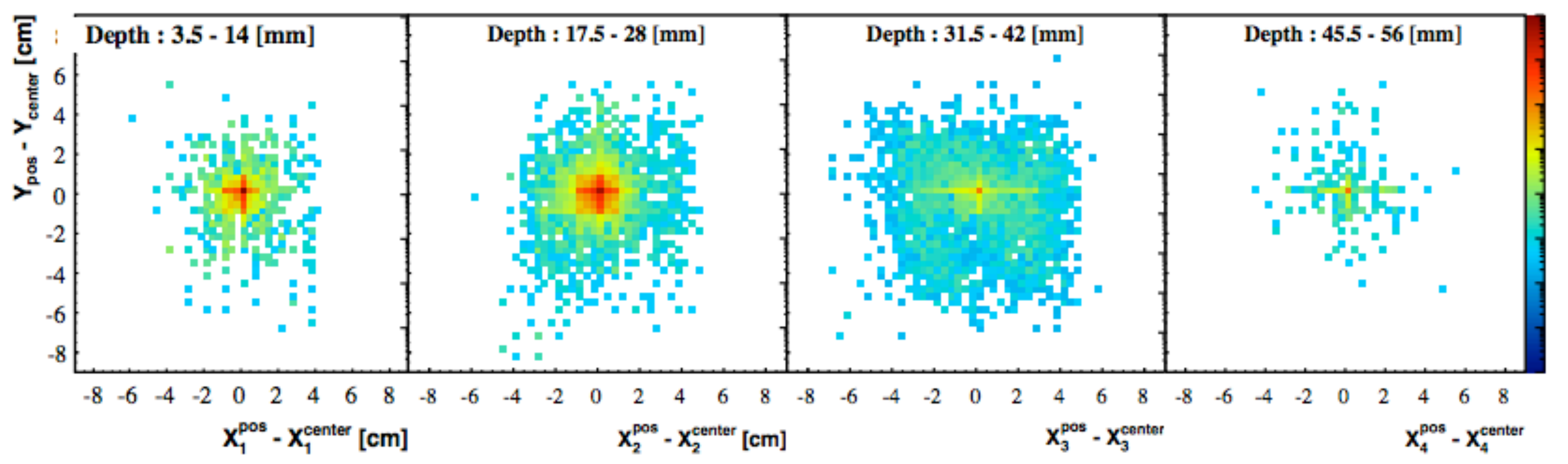

Fig.10 : Gap of center of gravity for the hit

・Summary

- In our first test beam 2014, we were able to see the shower profile and energy linearity.
  - We can see the 2 and 3, 30, 50 GeV beam signal. → Observation of energy linearity.
  - Shower max point is consistent with the expectation. ← 2nd LGL.
  - Optimization carried out to reduce noise level. For example, Optimization of the GND and Introduction of stabilization power supply.

・Outlook

- Second test beam scheduled on Oct – Nov at PS and SPS.
  - completion of energy dependence and resolution for LGL.
- We joined RD51 group and started work of new readout board for new readout system.