Development and Beam Test of the CEPC PFA Calorimeter Prototypes

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On behalf of CEPC Calorimeter working group

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Outline

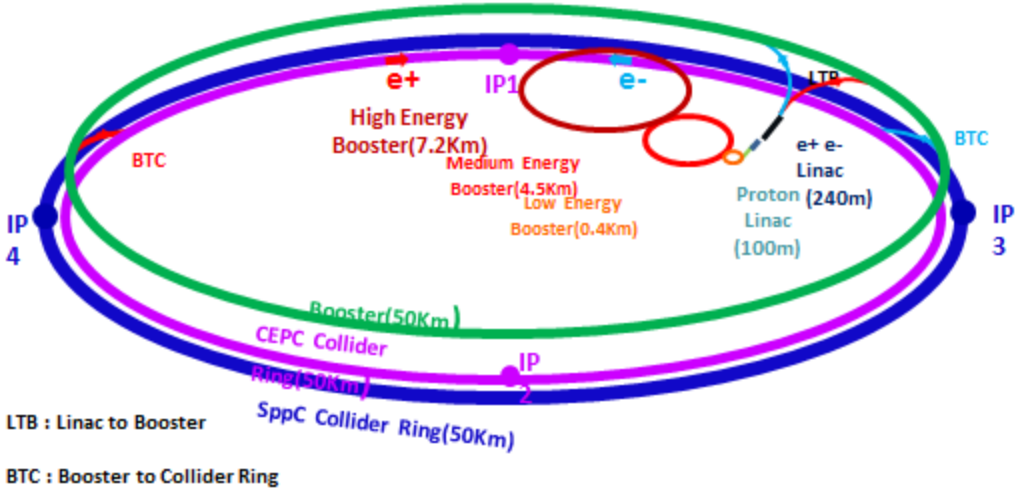
- Motivation
- Calorimeter prototypes introduction
- Beam test at CERN
- Summary

Motivation

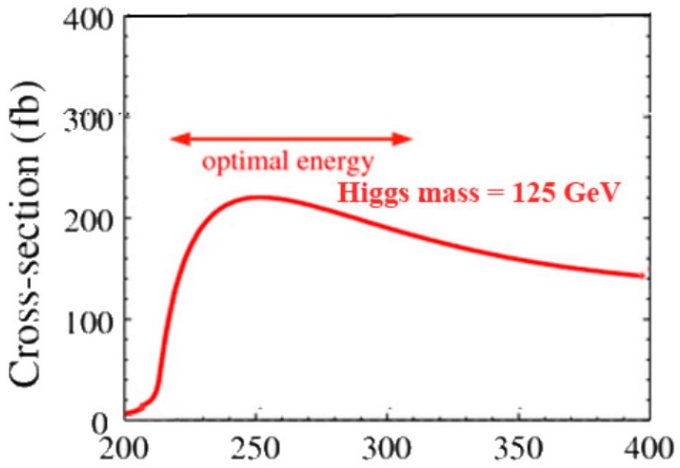
Circular Electron Positron Collider (CEPC)

$E_{cm} \approx 240$GeV, luminosity ~2×10^{34} $cm^{-2}s^{-1}$ can also rum at the Z-pole

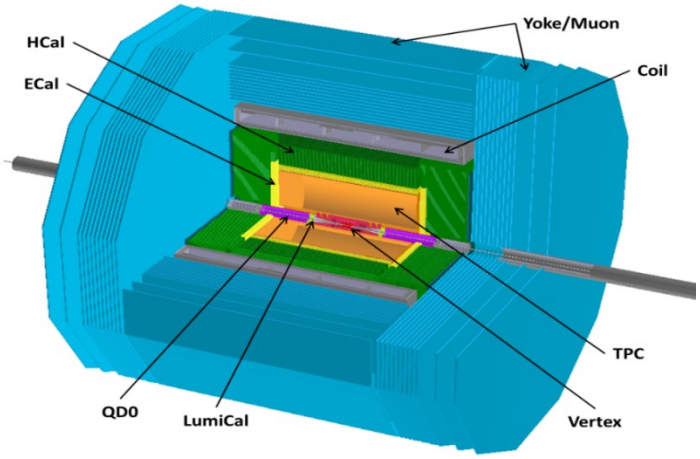
Precision measurement of the Higgs boson (and the Z boson)



$e^+e^- \rightarrow ZH$



Requirements of CEPC Calorimeter



- **ILD-like detector with additional considerations.**

Challenges:

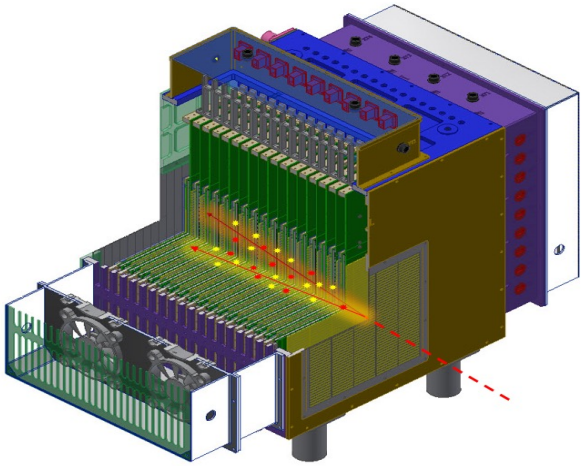
- **Momentum:** $\sigma_{1/p} < 5\times10^{-5}\ \mathrm{GeV}^{-1}$
- **Impact parameter:** $\sigma_{r\phi} = 5 \oplus 10/(p\cdot\sin^{\frac{3}{2}}\theta)\ \mu\mathrm{m}$
- **Jet energy:** $\frac{\sigma_E}{E} \approx 3-4\%$

- The Particle Flow Algorithm (PFA) calorimeter concept was proposed
  - High granularity
  - Good track finding
  - Good energy resolution

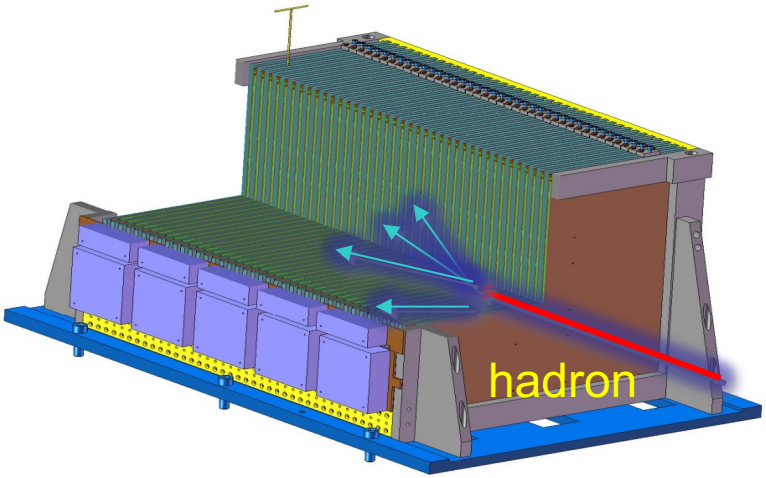
PFA Calorimeter

Sampling Calorimeter

Calo	Sampling No.	Sensitive detector	Absorber	Granularity	Electronics	Absorb length	Energy Resolution	weight
Sci-W ECAL	32	PSD+SiPM	W-Cu	5mm×5mm	SP-2E	22 X_0	16%@ 1 GeV	0.3 T
AHCAL	40	PSD+SiPM	Fe	40mm×40mm	SP-2E	4.6 NIL	60%@ 1 GeV	5.0 T



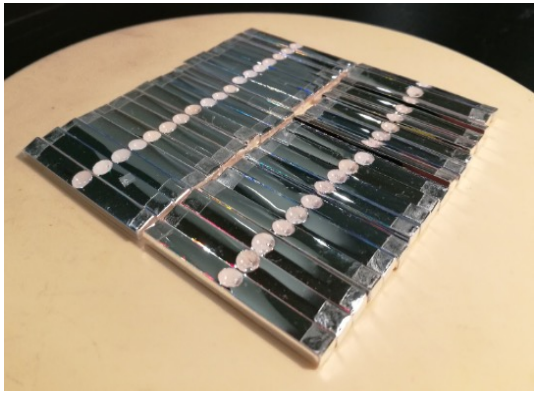
Sci-W ECAL



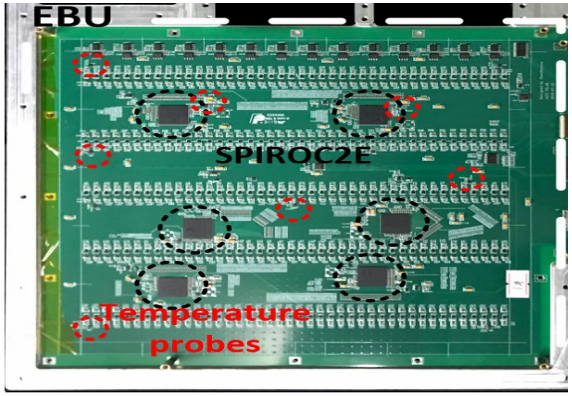
AHCAL

Sci-W ECAL

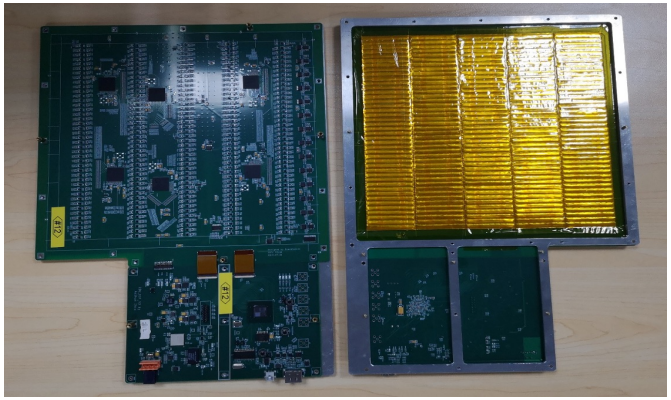
scintillators



EBU



Sensitive layer

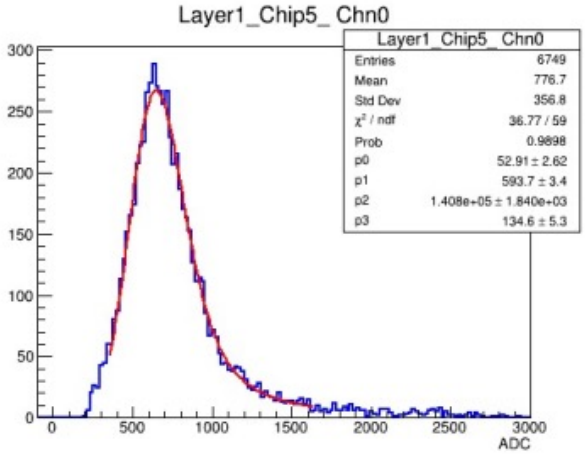


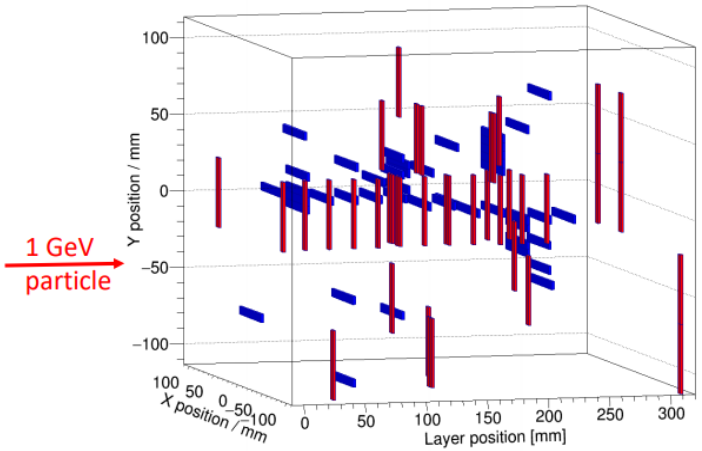
Super-Layers

ECAL structure

Sci-W ECAL

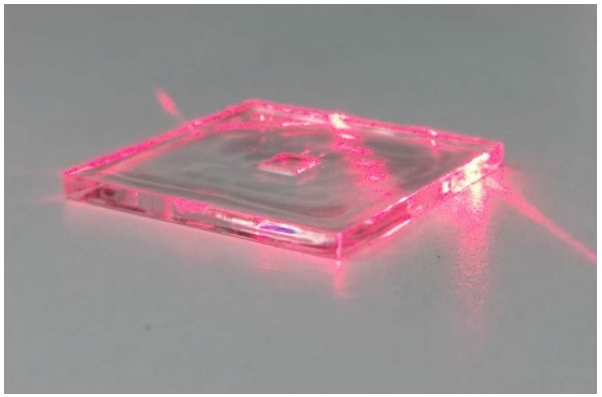
- Sci-W ECAL has been developed two years ago.
  - 32 sensitive layers, and sensitive area is ~ 22cmx22cm
    - Each layer has 210 sensitive cells
    - Cell size is 5 mm x 45 mm



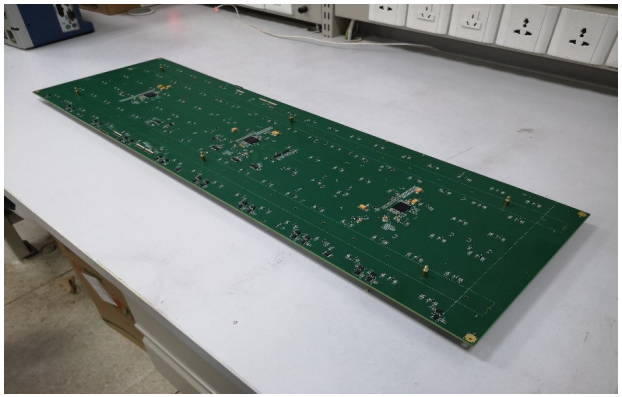


AHCAL

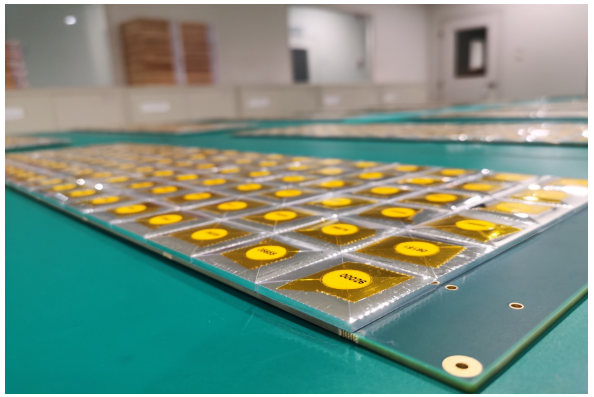
Scintillator

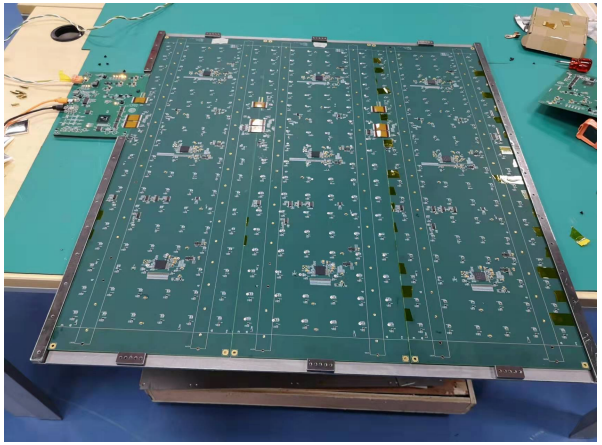


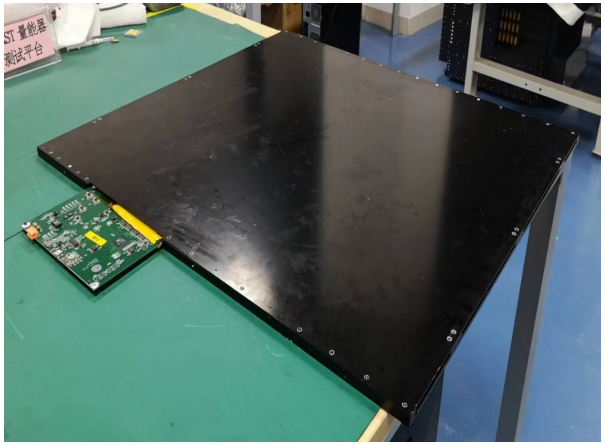
HBU

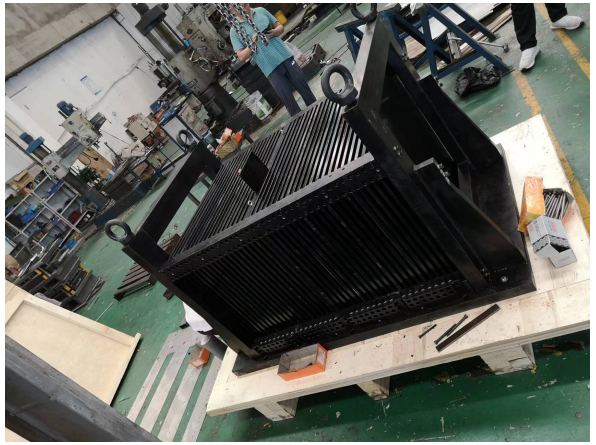


Sensitive layer







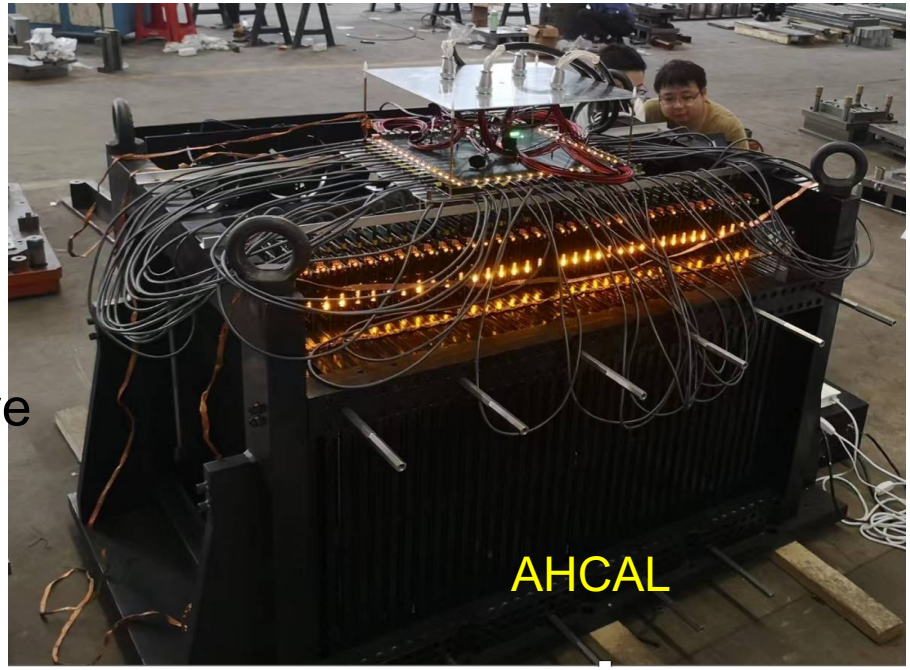


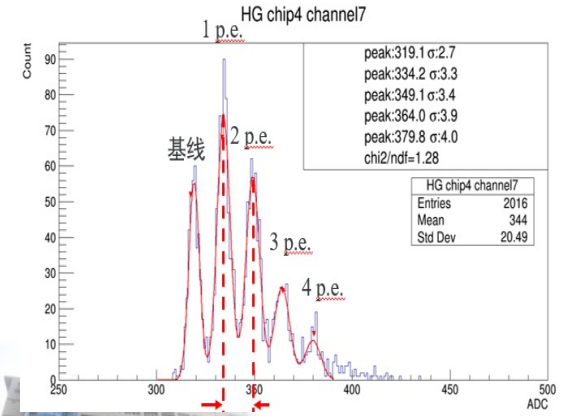
sensitive layer cassette

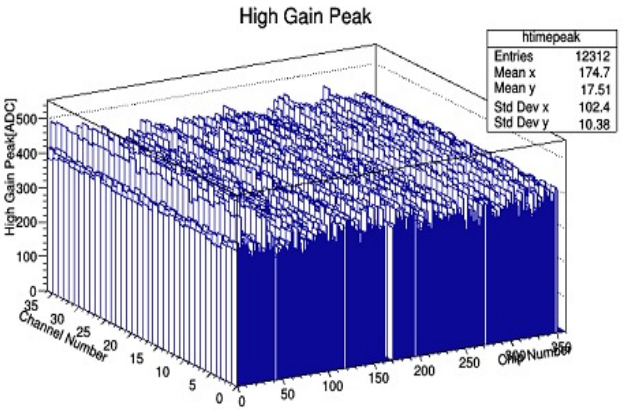
Calorimeter structure

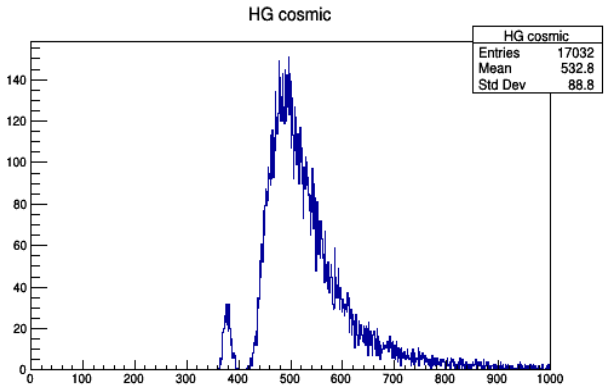
AHCAL

- The AHCAL was assembled this summer
  - It has 39 iron absorbers
    - Absorber: 20 mm iron
  - 40 sensitive layers, and sensitive area is ~ 72 cm x 72 cm
    - Each layer has 324 sensitive cells
    - Cell size is 40 mm x 40 mm









Supporting Table

- The supporting table for calorimeter beam testing
  - The table can support ECAL and AHCAL at the same time
  - The horizontal movement distance is ±20 cm, and the up and down movement distance is ±15 cm

Supporting table

AHCAL on this table

Beam test

- Two weeks of high-energy particle beam test at H8 of SPS
  - The H8 beam line is a high-energy, high-resolution secondary beam line.
  - The maximum momentum that can be transported in the experiments is 400 GeV/c protons
  - or secondary mixed hadron beams within the range 10-360 GeV/c.
  - the electron beams with variable purity (10 – 99 %) are also possible. The maximum Δp/p acceptance of the line is 1.5%.

SPS: October 2022

schedule issue date: 30-May-2022 Version: 1.10

		Mon 26 Sep	Tue 27 Sep	Wed 28 Sep	Thu 29 Sep	Fri 30 Sep	Sat 1 Oct	Sun 2 Oct	Mon 3 Oct	Tue 4 Oct	Wed 5 Oct	Thu 6 Oct	Fri 7 Oct	Sat 8 Oct	Sun 9 Oct	Mon 10 Oct	Tue 11 Oct	Wed 12 Oct	Thu 13 Oct	Fri 14 Oct	Sat 15 Oct	Sun 16 Oct	Mon 17 Oct	Tue 18 Oct	Wed 19 Oct	Thu 20 Oct	Fri 21 Oct	Sat 22 Oct	Sun 23 Oct	Mon 24 Oct	Tue 25 Oct	Wed 26 Oct	Thu 27 Oct	Fri 28 Oct	Sat 29 Oct	Sun 30 Oct
Week		39							40							41							42							43							
Machine																																				
North Area	T2 - H2	Calice Sdhcal	A. Ariga PPE172 NA65						D. Lazic PPE172 CMS HGCAL							Y. Itow PPE172 LHCf							H. Schindler PPE172 LHCb ECAL														
	T2 - H4	V. Gninenko PPE134+PPE144 NA64e							EB. Holzer Place-holder														M.R. Jäkel, E. Oliveri PPE134, PPE154 GIF RD51													
	T4 - H6 main user	CMS PIXELS	A. Rummler PPE146 ATLAS ITK PIXEL						A. Rummler PPE156 ATLAS AFP							Dannheim Dao PPE156 MONO LITH							E. Figueras RD50							H. Danielsson PPE136 NA62						
	T4 - H6 parallel user	EP hybrid	A. Rummler PPE146 ATLAS AFP BCM						A. Rummler PPE146 ATLAS ITK PIXEL							V. DaoD. Dannheim PPE146, PPE156 ATLAS MALTA EP PIXEL							H. Danielsson PPE136, PPE146 NA62 ATLAS HGTD							EP hybrid ATLAS HGTD E. Gkougkousis PPE136, PPE146						
	T4 - H8	UA9 Totem	W. Scandale PPE128 UA9						H. Schindler, N. Neri PPE128, PPE138, PPE158, PPE168 LHCb CMS MTD (SLEDOM)														J. Liu, E. Scomparin 158 or 168, PPE138 Calice ScW ECAL NA60+													

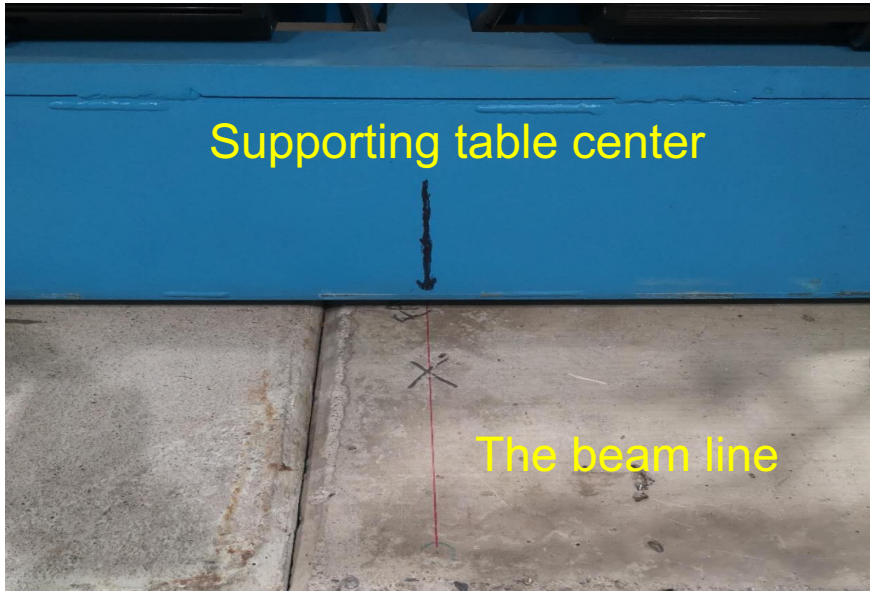
Transport

- In the middle of Sep. The detectors were sent to CERN from Hefei. The total weight is 10.6 tons.
- On Oct. 14, the detectors arrived at CERN.

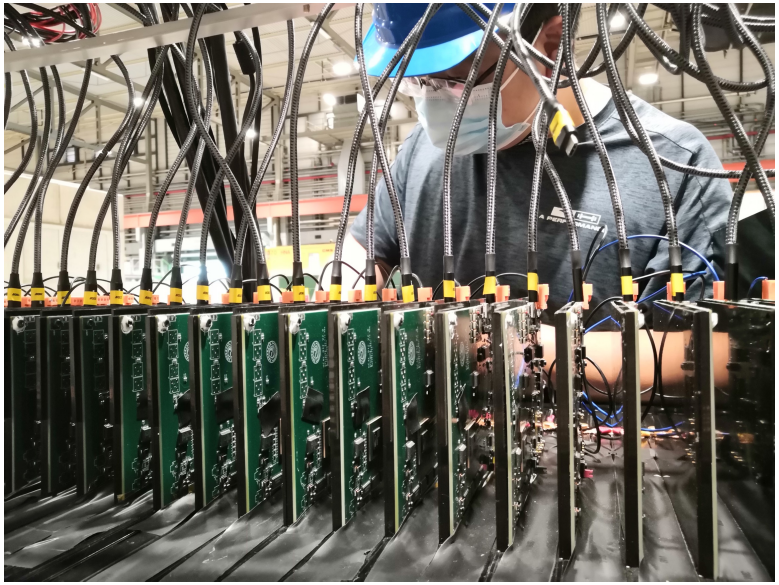
Hefei, 15/9

CERN, 14/10

Install the detectors in beam area

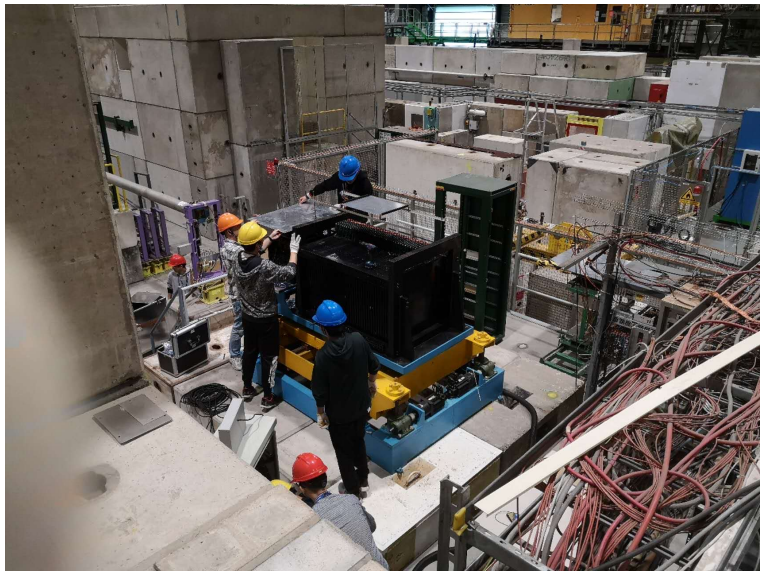


Install the detectors in beam area



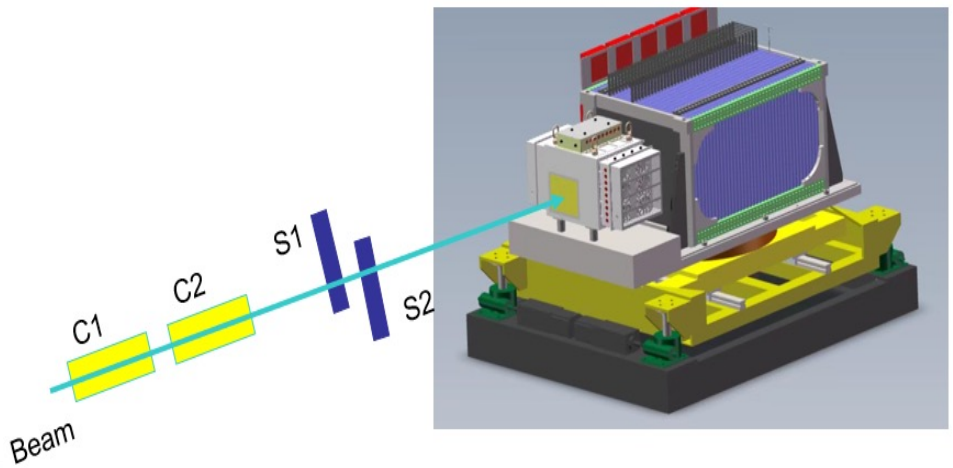
Trigger

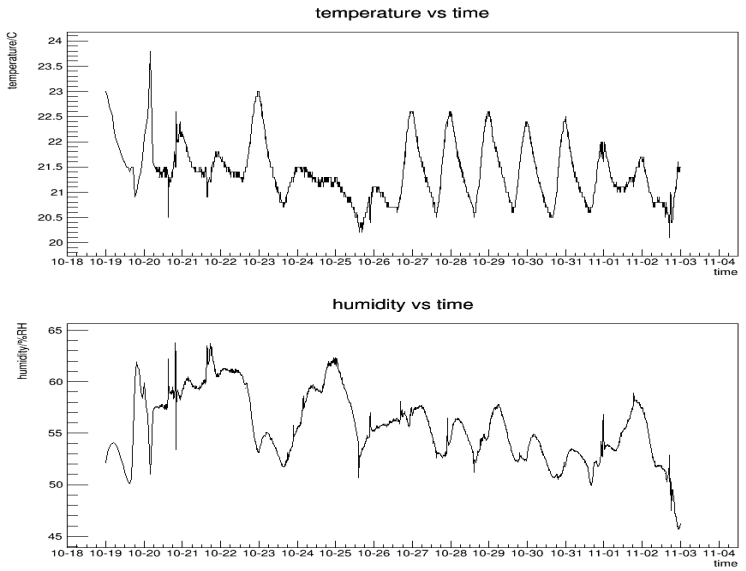
alignment



Beam test

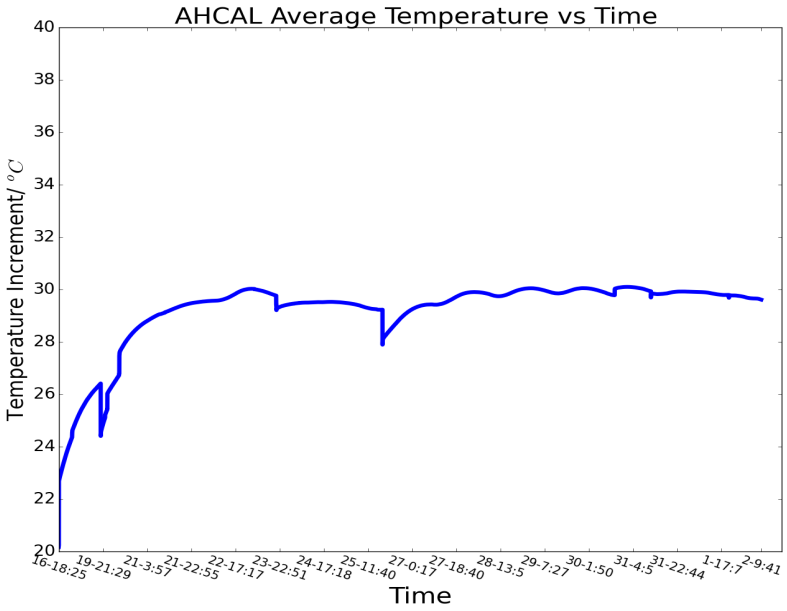
- We tested calorimeter with mu+, pi+, positron
  - Muon+
    - 160 GeV/c, 108 GeV/c
  - Pion+
    - 10 - 120 GeV/c, one million per point
  - Positron
    - 10 - 120 GeV/c, 100 thousand per energy point





AHCAL test

- First of all, we tested AHCAL independently
- The internal temperature of AHCAL rose slowly in the first three days of the test and then tended to be stable

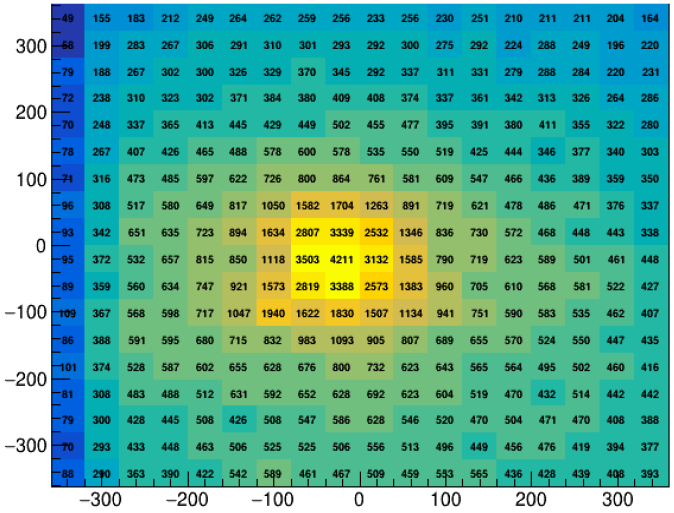


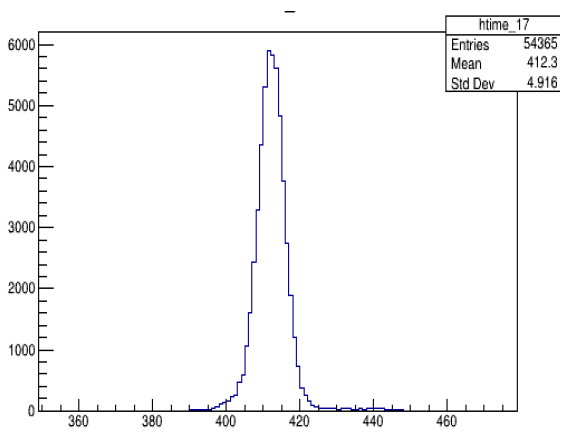
Temperature of AHCAL

AHCAL Test with Mu+

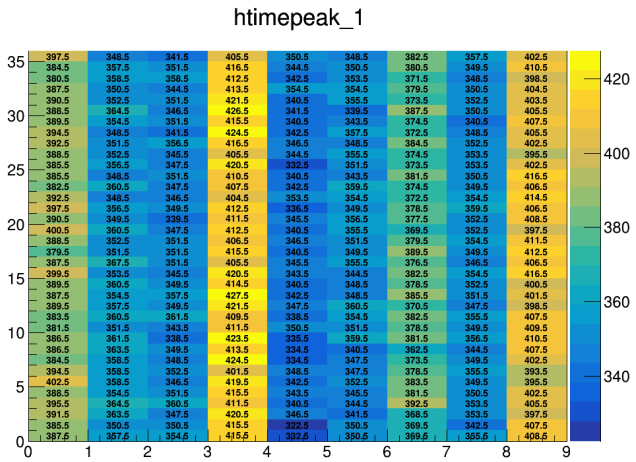
- The energy reference should be taken from MIPs which could be calibrated using high energy muons
- Muon halo mode with 160 GeV/c
- The halo size is about 10 cm x10 cm

Hitting map

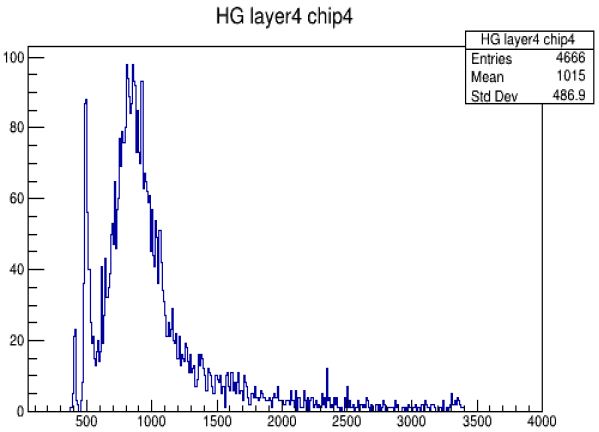




Pedestal



Pedestal Position

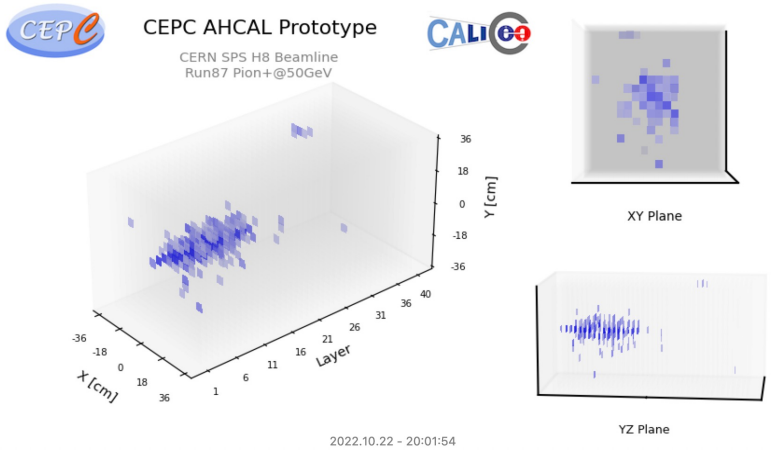


MIPs

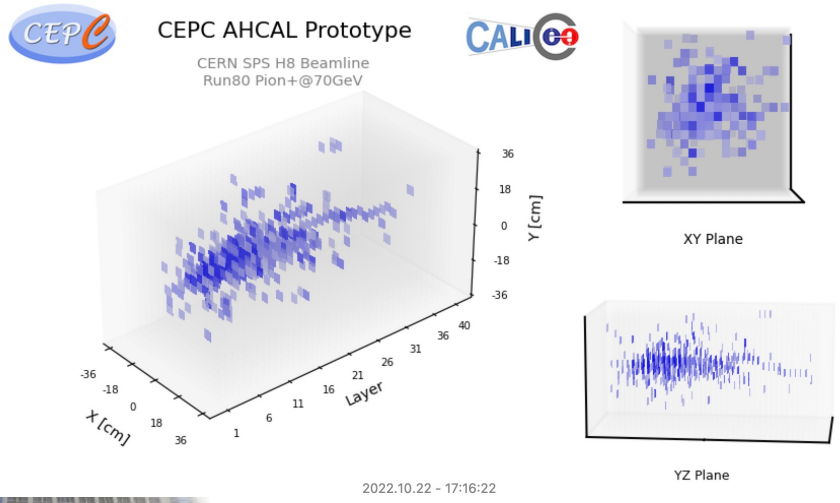
AHCAL Test with pion+

- The energy response of AHCAL was studied by pions
- In the past week, we tested AHCAL independently by pion beams

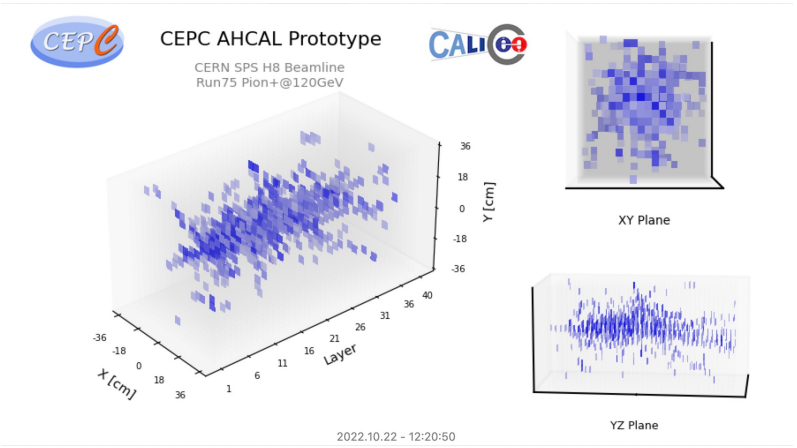
50 GeV



70 GeV

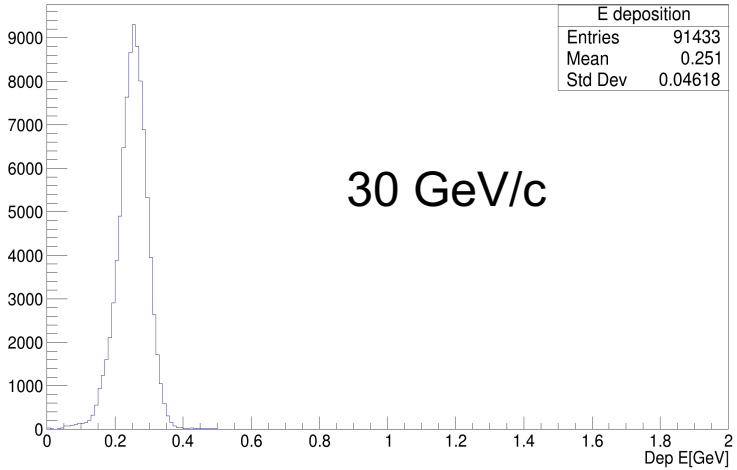


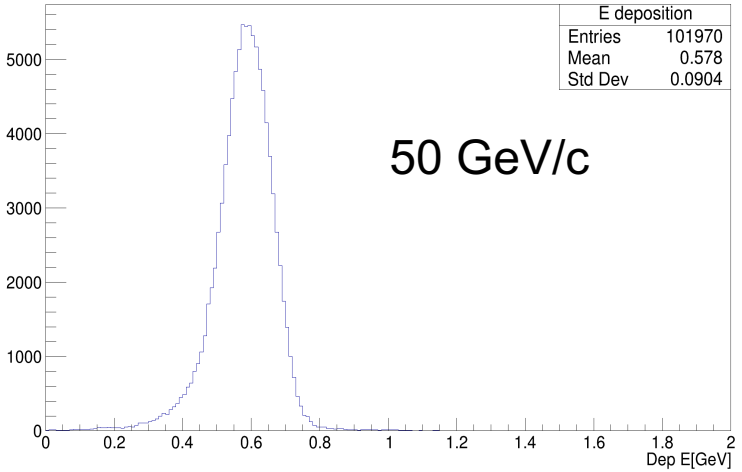
120 GeV

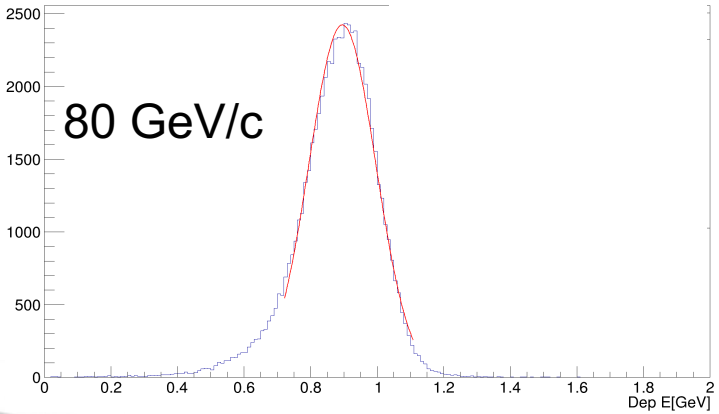


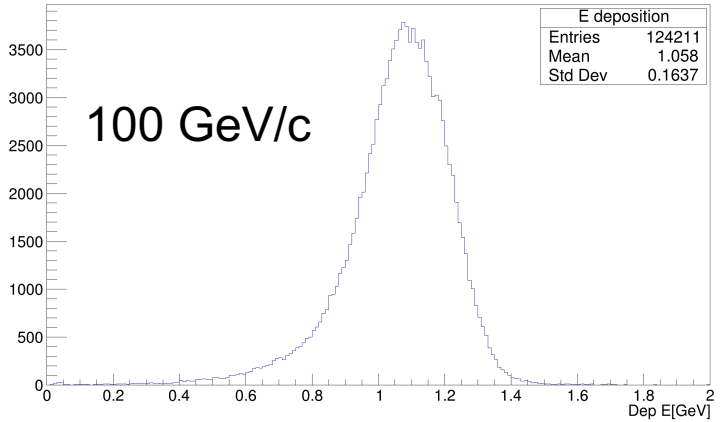
AHCAL Test with pion+

- The energy deposition in sensitive cells



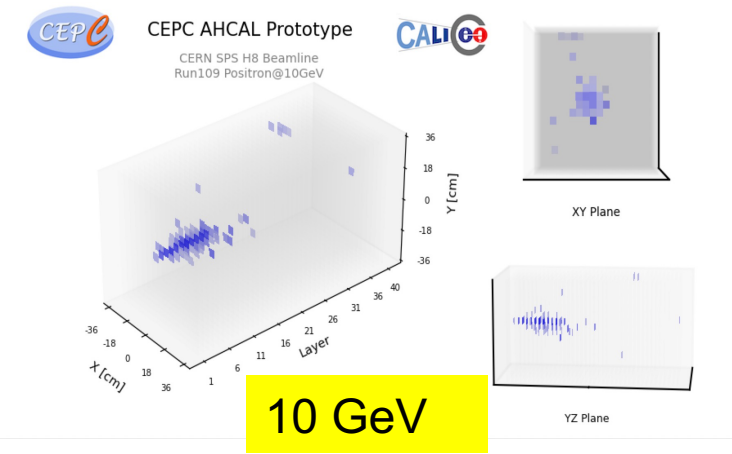


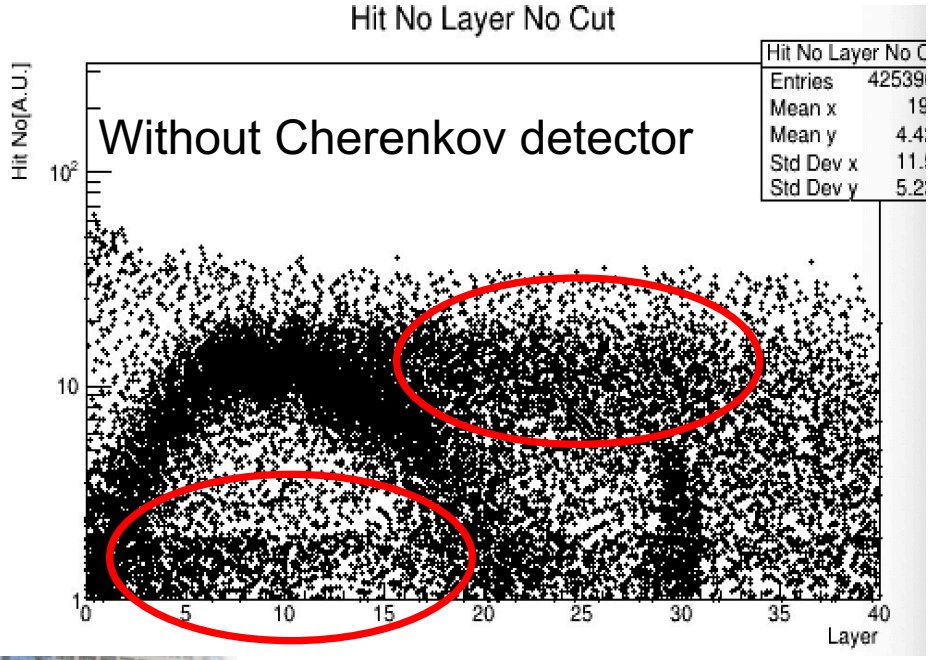


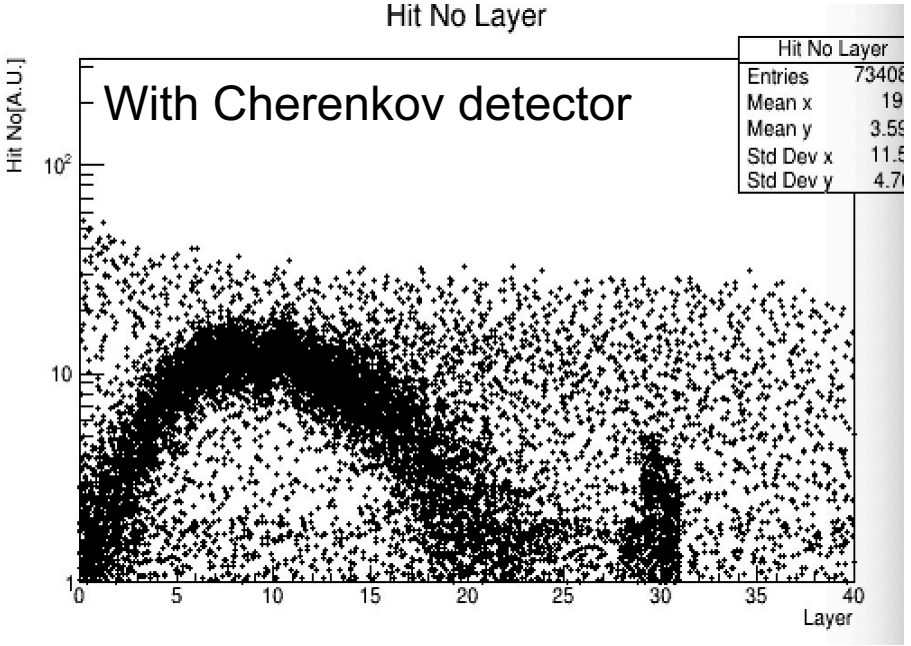


AHCAL Test with positron

- In order to study the AHCAL response to EM shower, the positron were used to calibrate AHCAL



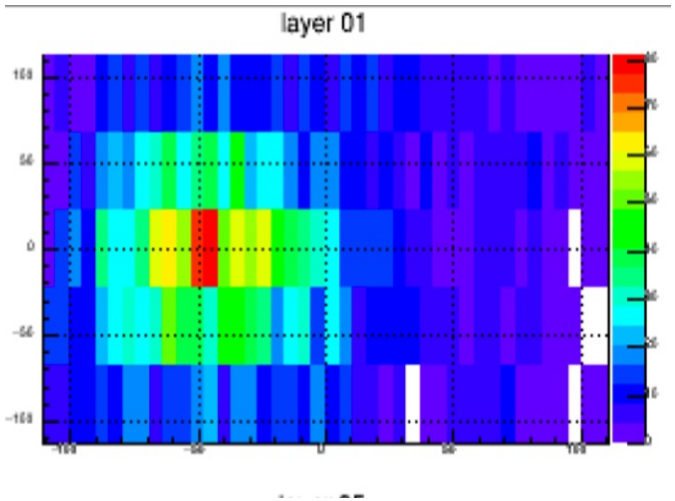


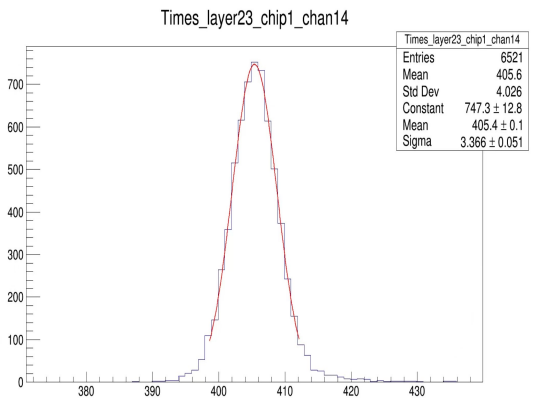


Combined Test

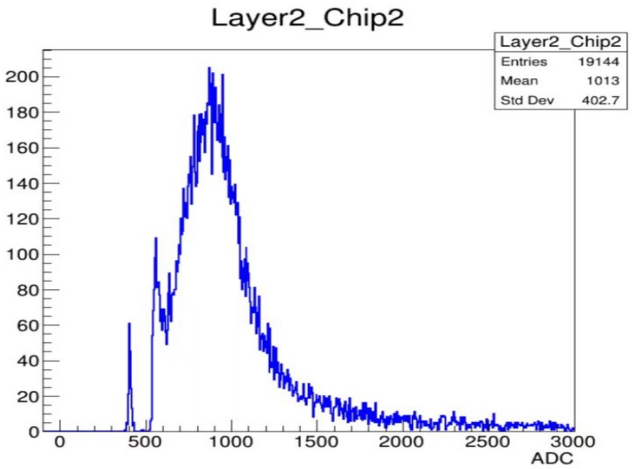
Sci-W ECAL Test with Mu+

- The ECAL also tested using muons with 108 GeV/c
- Different locations were scanned during the test

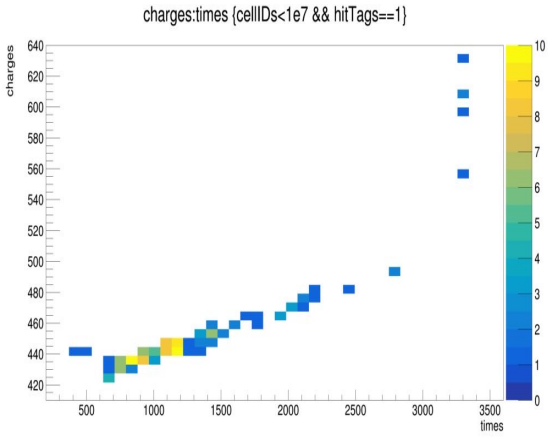




Pedestal



MIPs

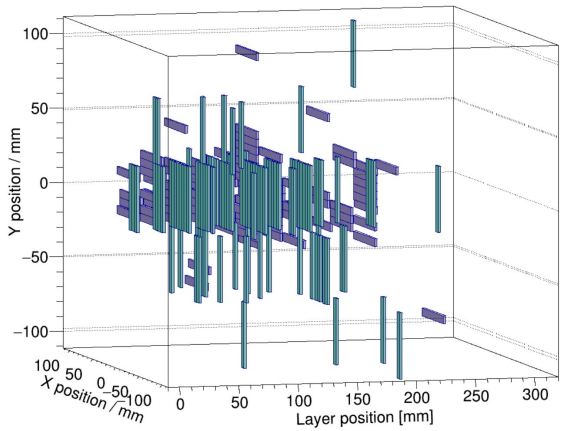


Low – High gain ratio

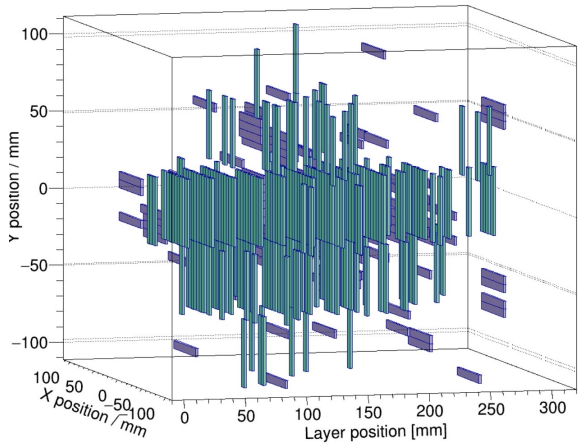
Sci-W ECAL Test with Positron

- The e+ test, also the beam has hadrons.

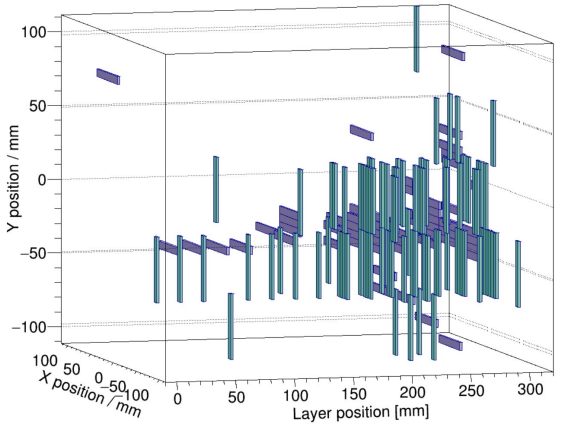
10 GeV e+



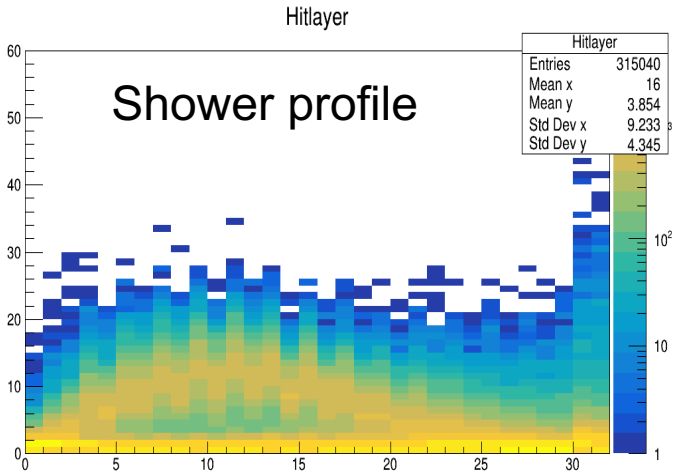
40 GeV e+



10 GeV hadron

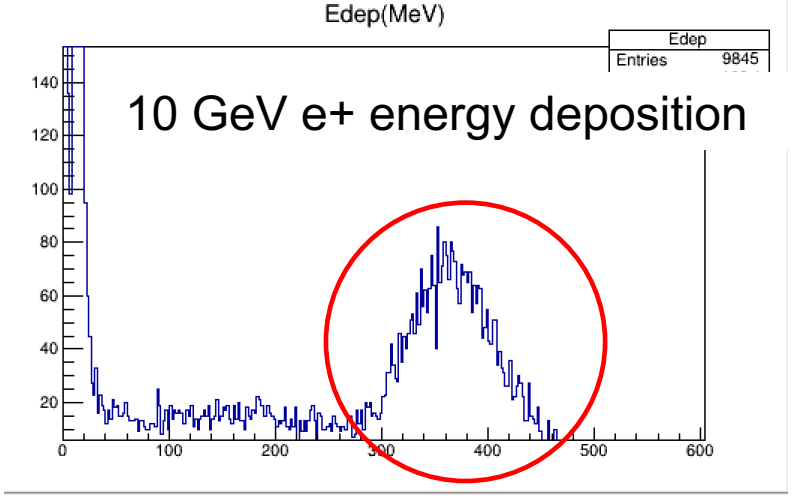


Shower profile



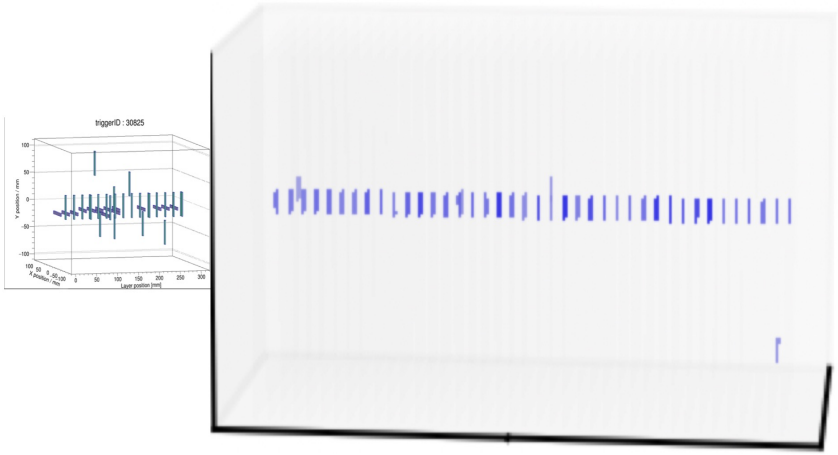
ECAL layer

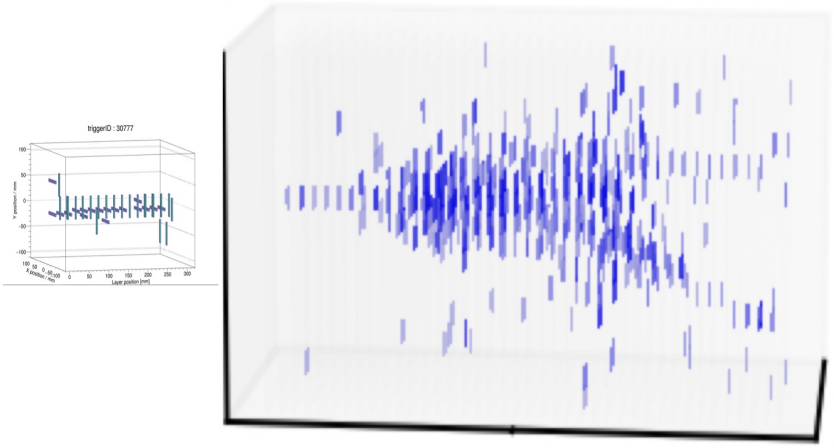
10 GeV e+ energy deposition

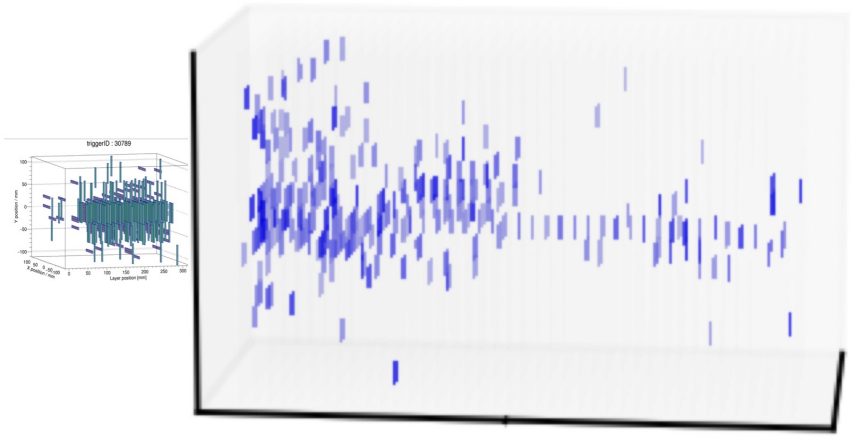


Combined Test with pions

- One of the important things is the combined test for hadrons.
  - The event alignment is an important step
  - Preliminary results show that the events collected by ECAL and AHCAL systems are aligned

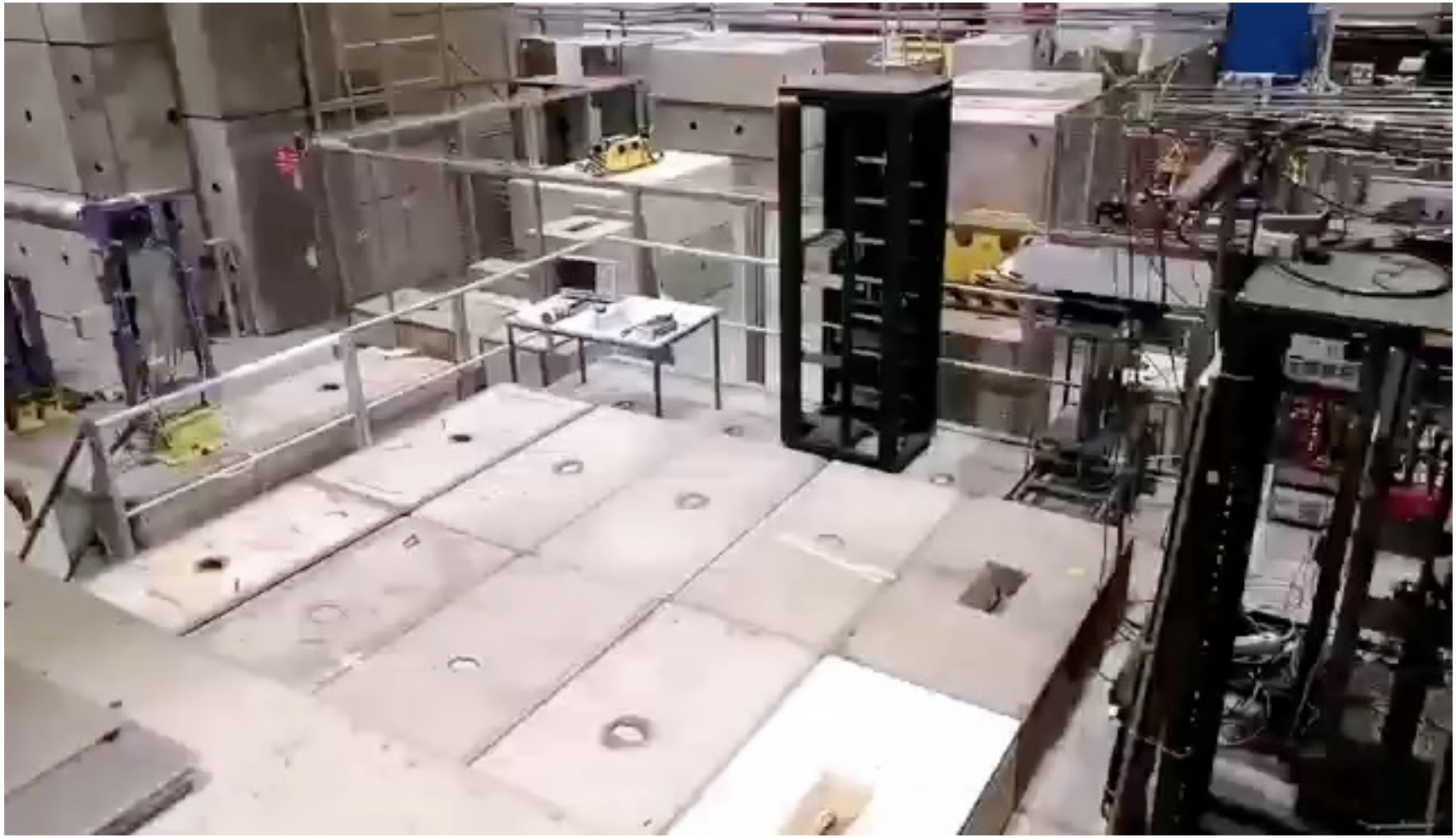






Summary

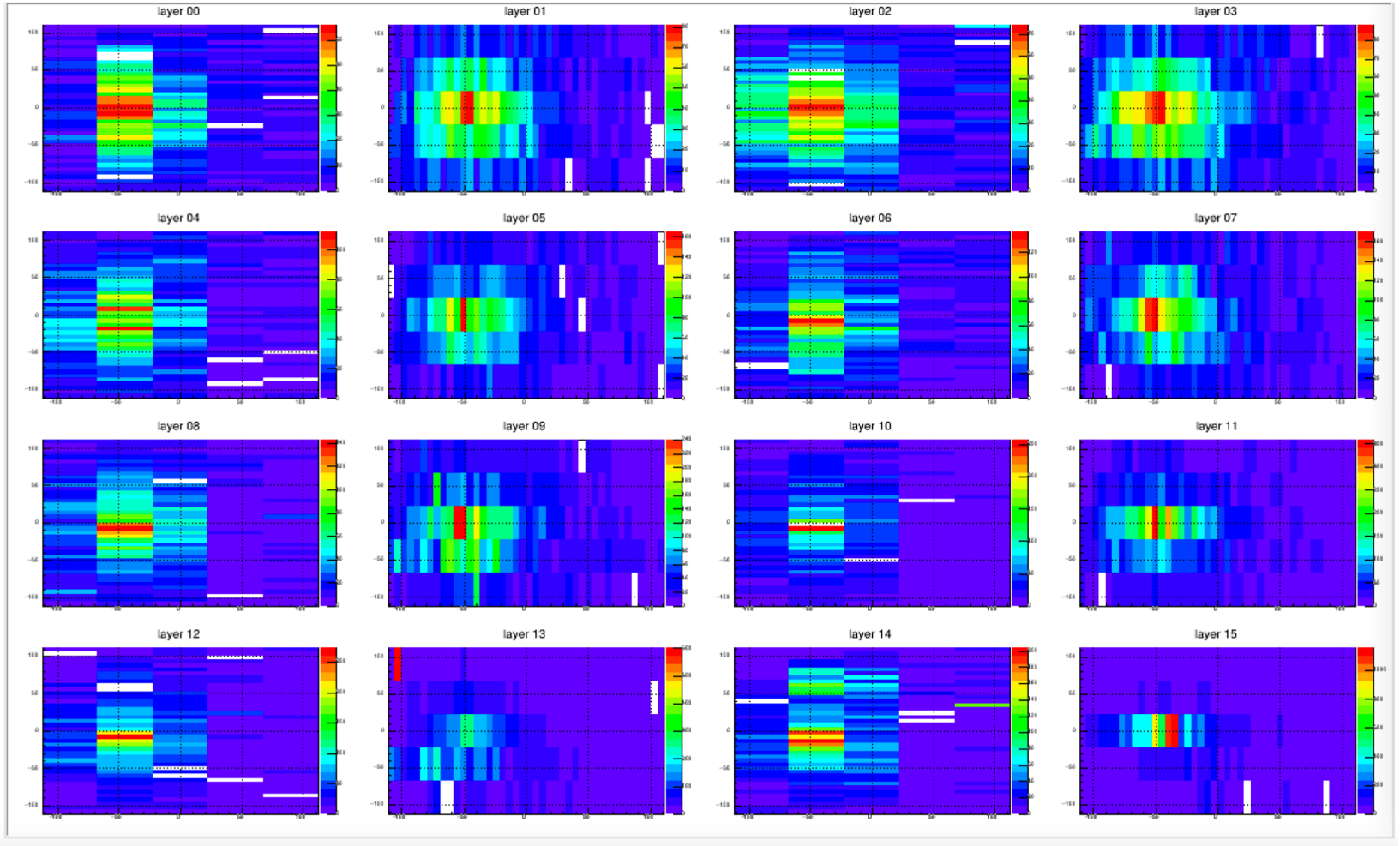
- Both the Sci-W ECAL and AHCAL prototypes were assembled, and tested at CERN last month.
- The two calorimeters has been taking beam test from Oct. 19 to Nov. 2, the preliminary results show the calorimeters work very well
  - The Sci-W ECAL and AHCAL were tested with pions and positrons from 10 GeV/c to 120 GeV/c
  - We collected about 25 million events in this beam test
- We will conduct a detailed analysis of the data to further tap the potential of the data




Bonfanti
CALICE
THANKS

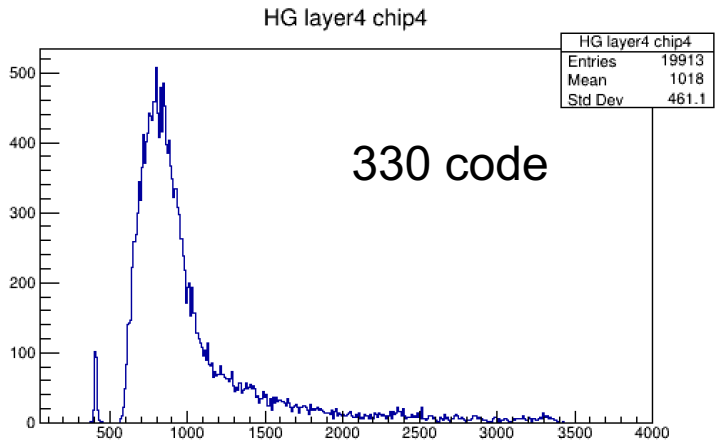
backup

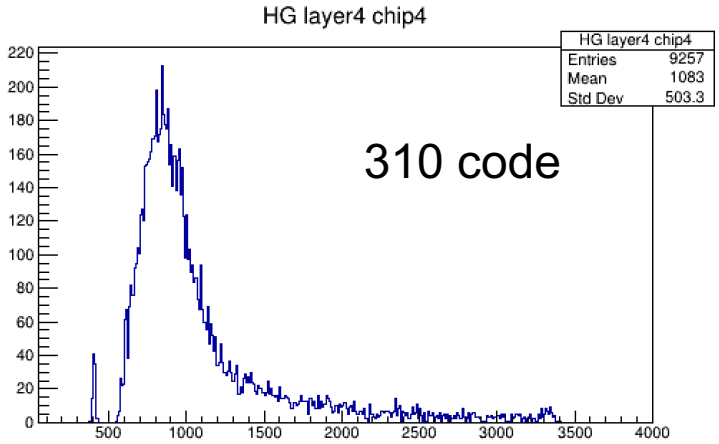
PFA Calorimeter

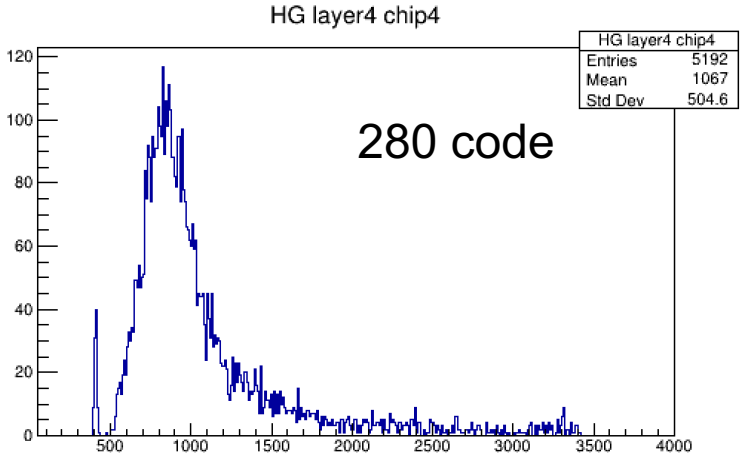


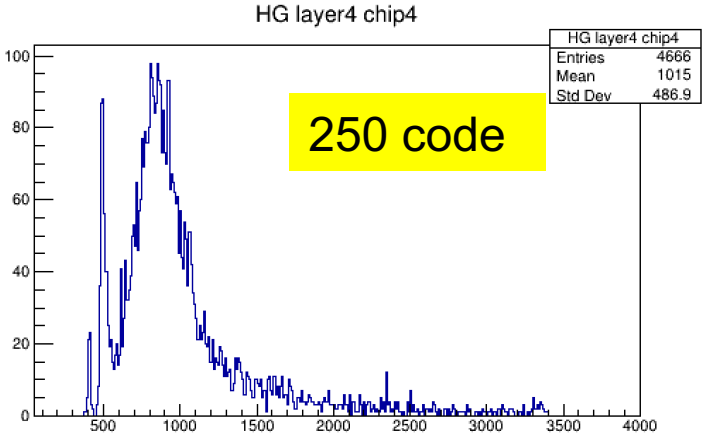
AHCAL Test with Mu+

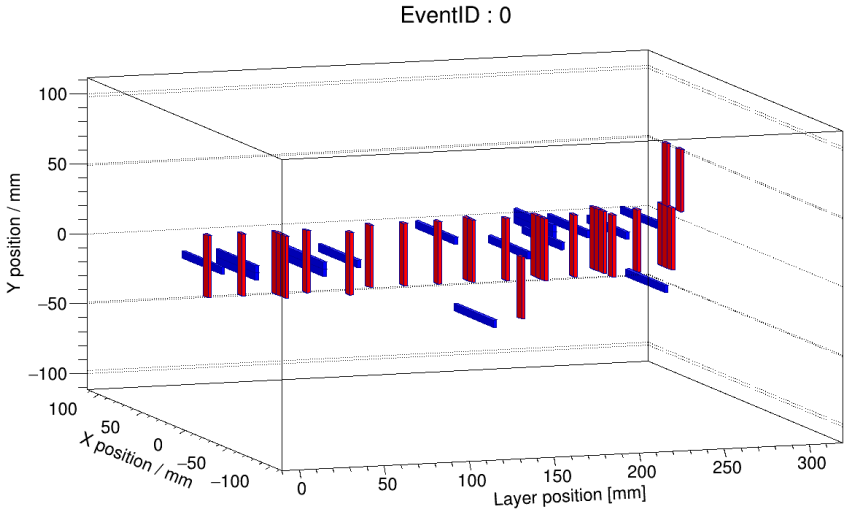
- The thresholds were calibrated using muon beam







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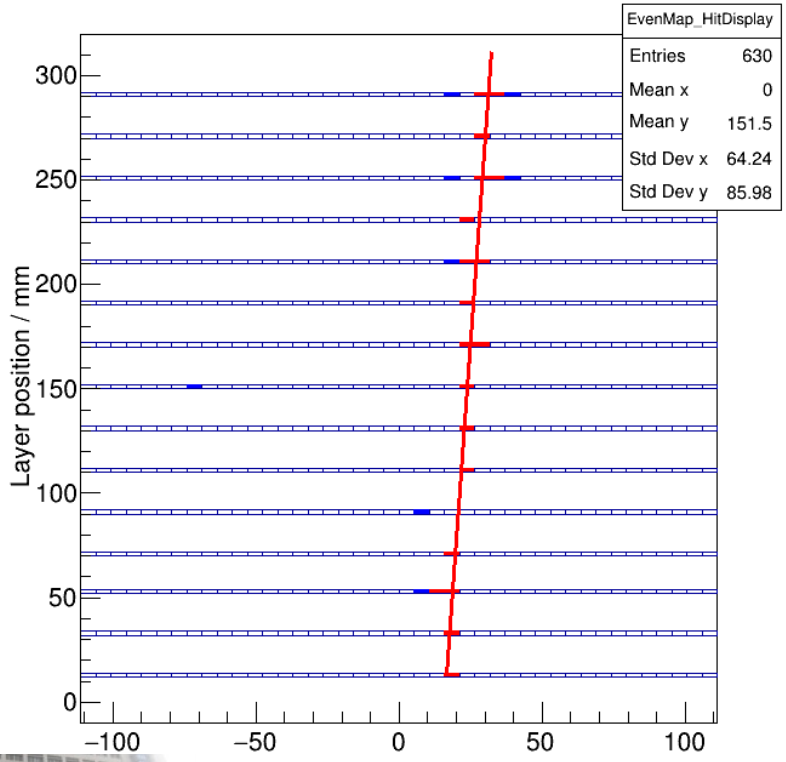
Y position / mm
X position / mm
Layer position [mm]

moun+ 160GeV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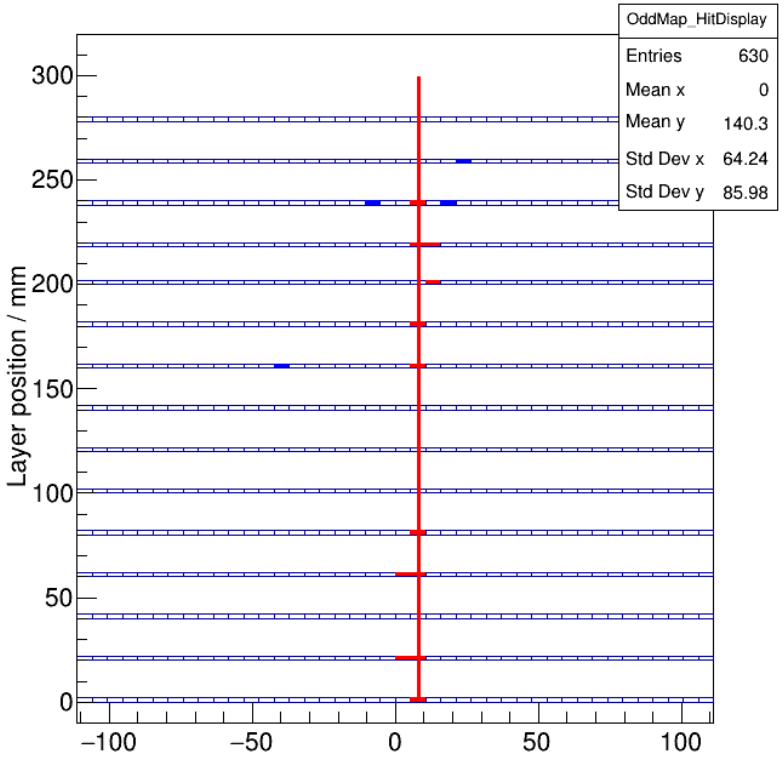
Std Dev x 64.24
Std Dev y 85.98
Layer position / mm


OddMap_HitDisplay
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Mean x 0
Mean y 140.3
Std Dev x 64.24
Std Dev y 85.98
Layer position / mm