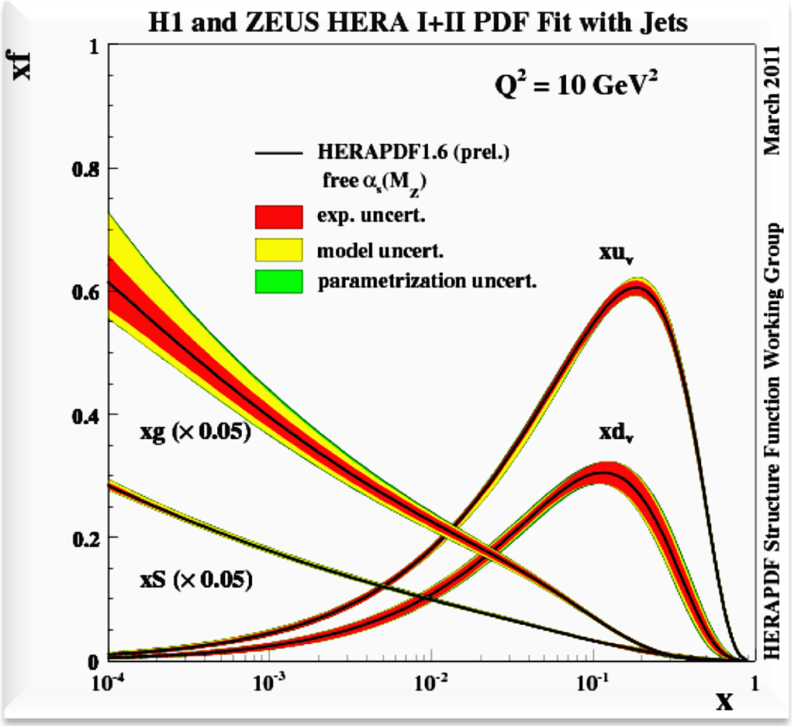
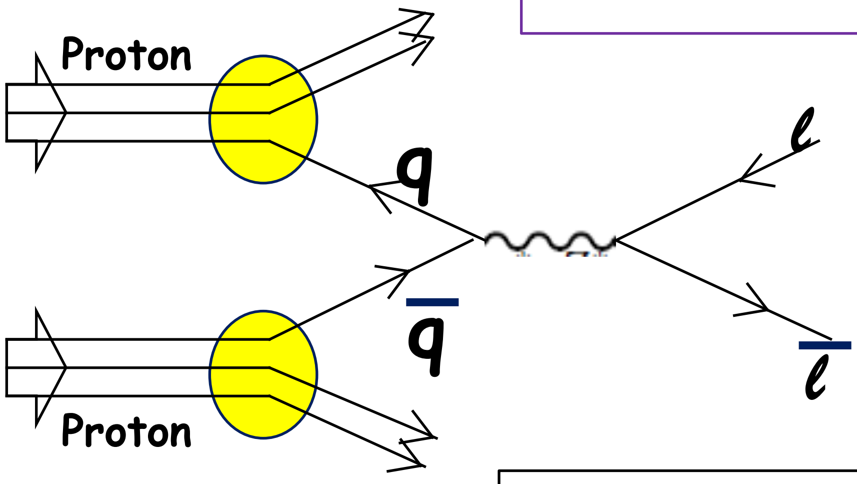
FoCal @ ALICE – Indian participation

Sanjib Muhuri
VECC

- Physics Motivation
- Observable & measurement
- FoCal and Indian participation
- R&D for FoCal-E LGL
- Where are we now !!

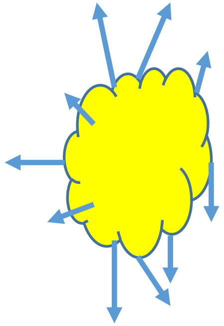
What does the low-x mean?





Particle Production

$$PDF \otimes \sigma(qq \rightarrow qq) \otimes FF$$

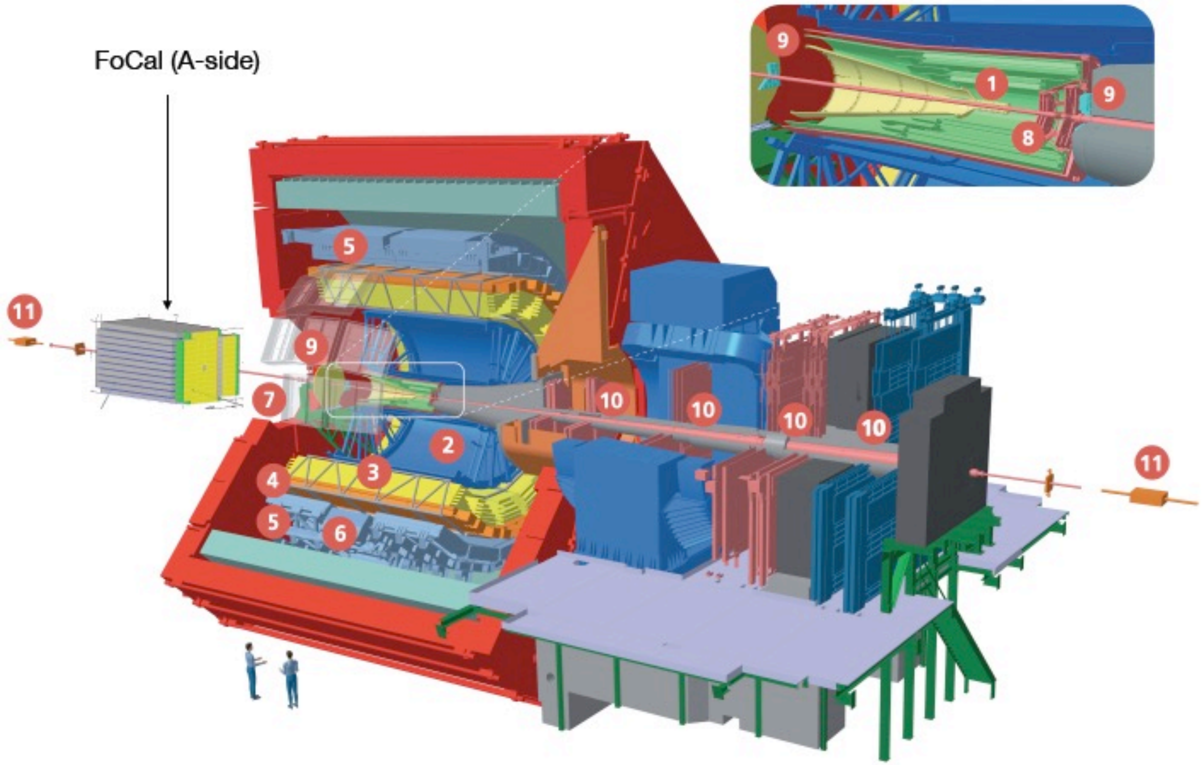


Medium effect

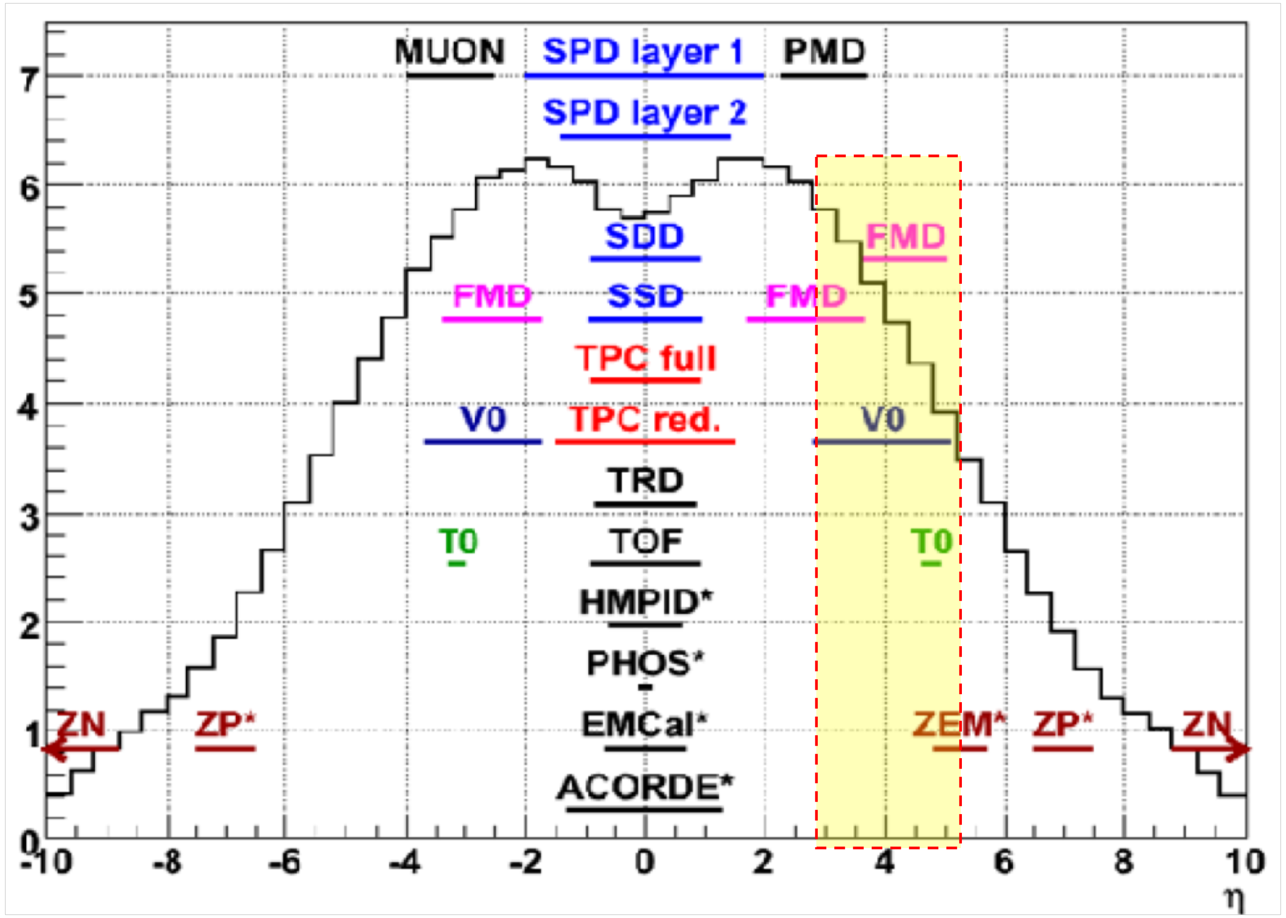
$$x_{1,2} = \frac{2p_T}{\sqrt{s}}\left(e^{\pm y_1} + e^{\pm y_2}\right)$$

Main physics goal: Explore non-linear QCD in regime of saturated gluons at low *Bjorken-x*

ALICE: Present & Possibilities



1. **ITS** | Inner Tracking System
2. **TPC** | Time Projection Chamber
3. **TRD** | Transition Radiation Detector
4. **TOF** | Time Of Flight
5. **EMCal** | Electromagnetic Calorimet
6. **PHOS / CPV** | Photon Spectrometer
7. **HMPID** | High Momentum Particle Identification Detector
8. **MFT** | Muon Forward Tracker
9. **FIT** | Fast Interaction Trigger
10. **Muon Spectrometer**
11. **ZDC** | Zero Degree Calorimeter



Observables

- ✓ Prompt photon measurement
- ✓ π^0, η^0, ω measurement
- ✓ J/Y, Ψ,ϒ measurement

Photon production

Decay photons

- π^+, π^-, π^0
- η^0, η
- ω
- J/Ψ

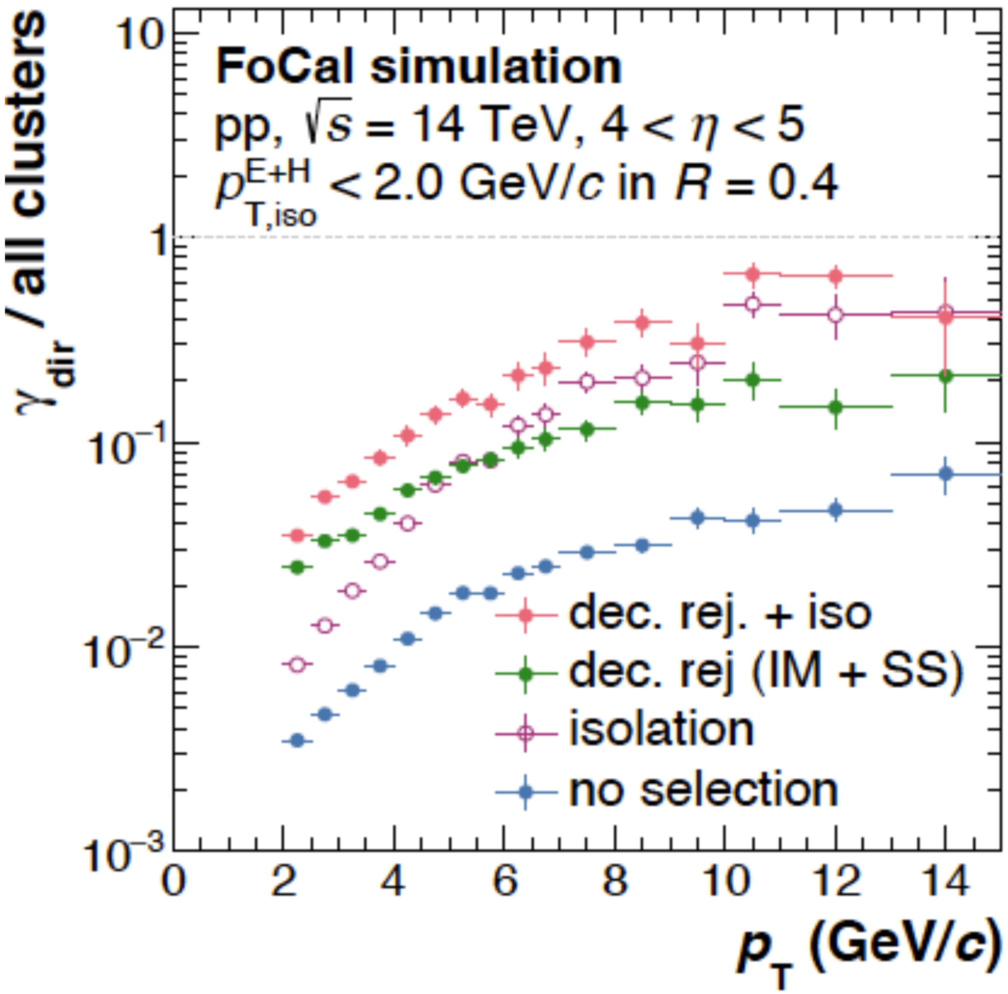
Direct photons

- Compton
- Annihilation
- Bremsstrahlung
- Fragmentation

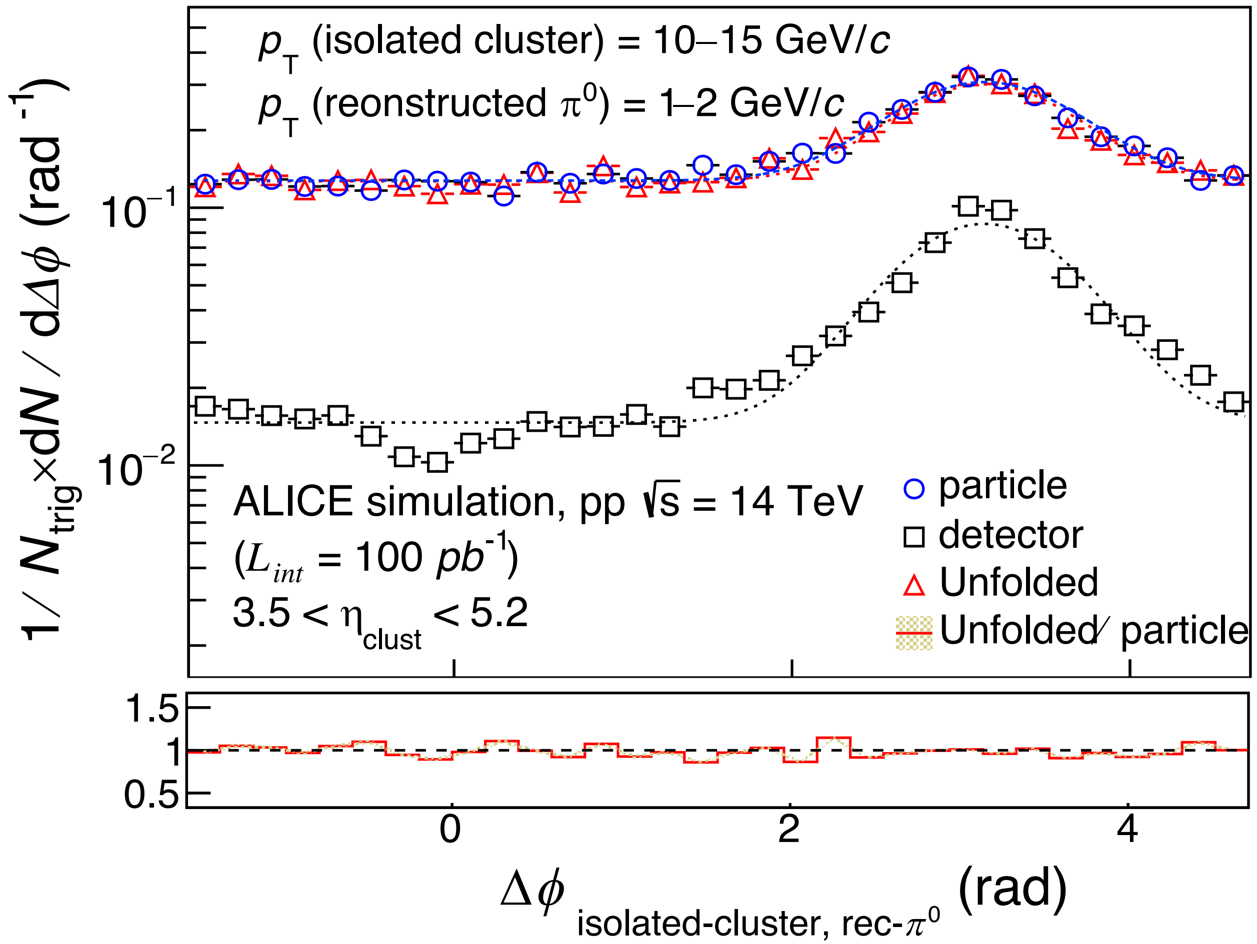
Challenge is to differentiate these photons from each other.

Performance

India



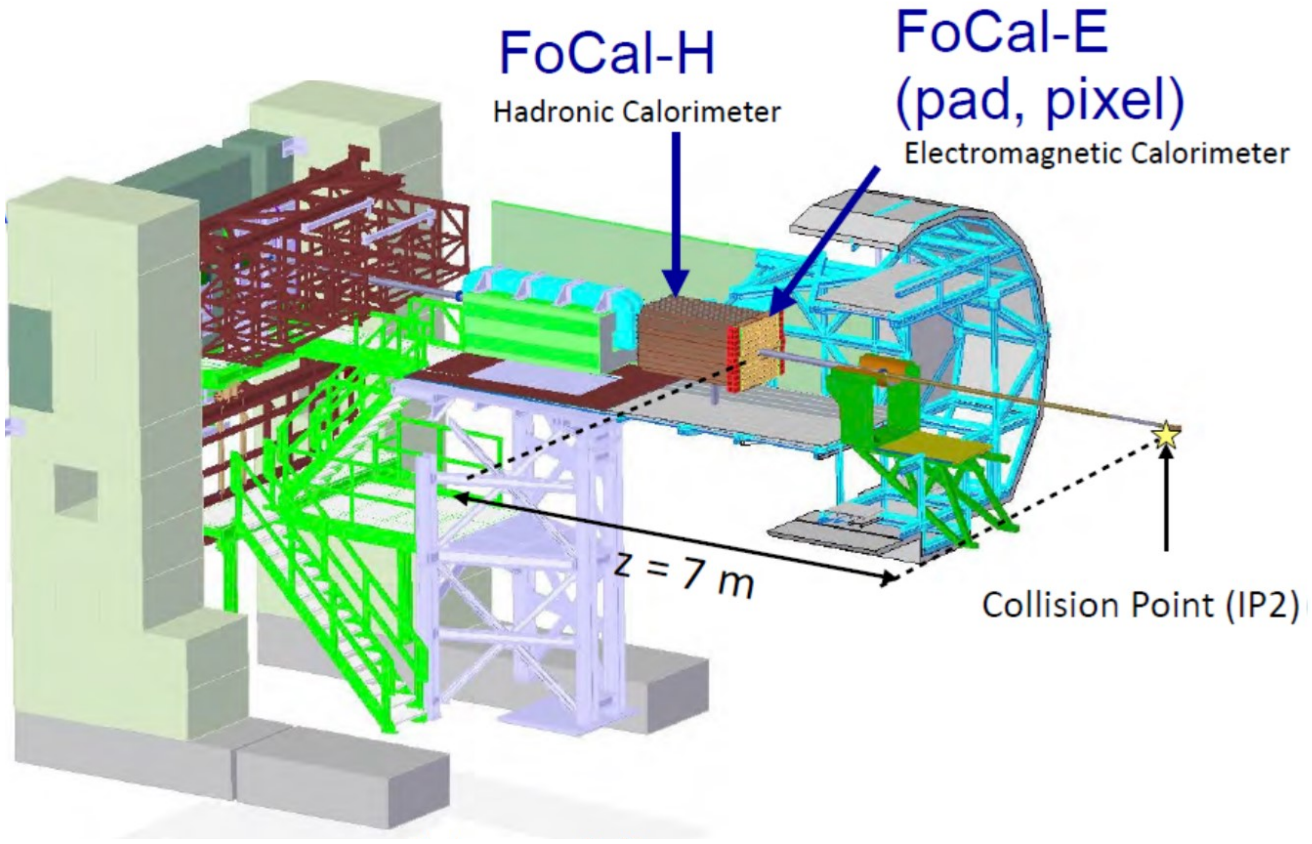
Estimation of prompt signal photon with respect to all clusters

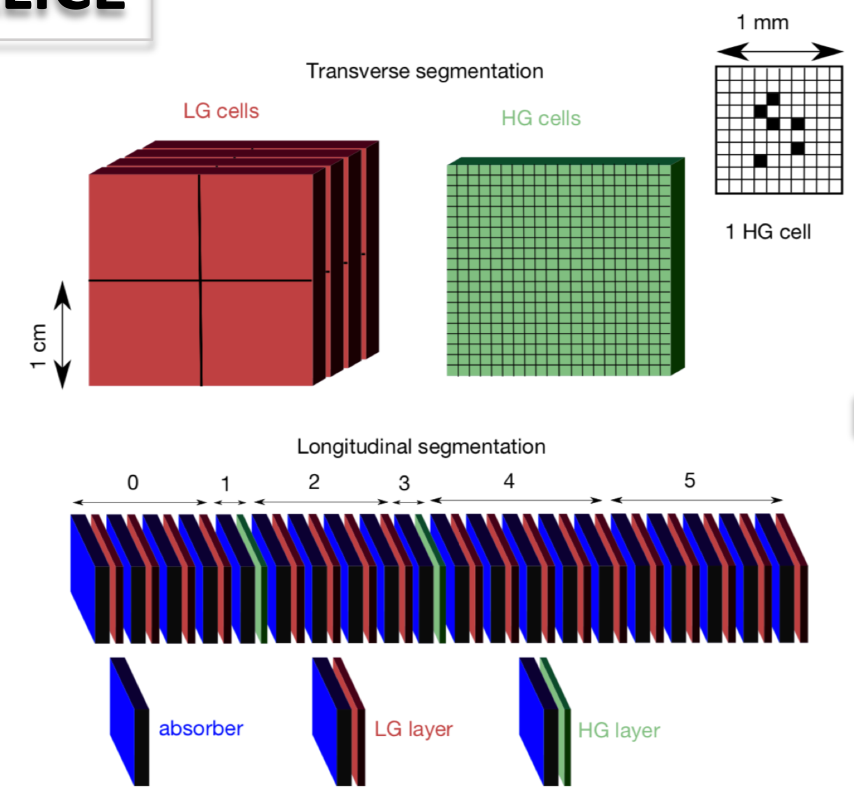


photon-π^0 correlations

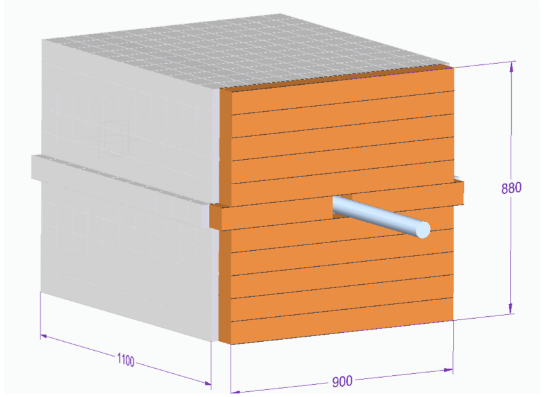
ALICE-PUBLIC-2023-004,

FOCAL @ ALICE





FOCAL-E



FOCAL-H

metal-scintillator with fibres embeded in Cu tubes

- ✓ Location: 7 m from IP
- ✓ Coverage: $3.2<\eta<5.8$
- ✓ Measures: clusters

- ✓ Cross Section: 90 x 88 (cm)
- ✓ Depth: 17 cm
- ✓ Sensor area: 14.3 m^2

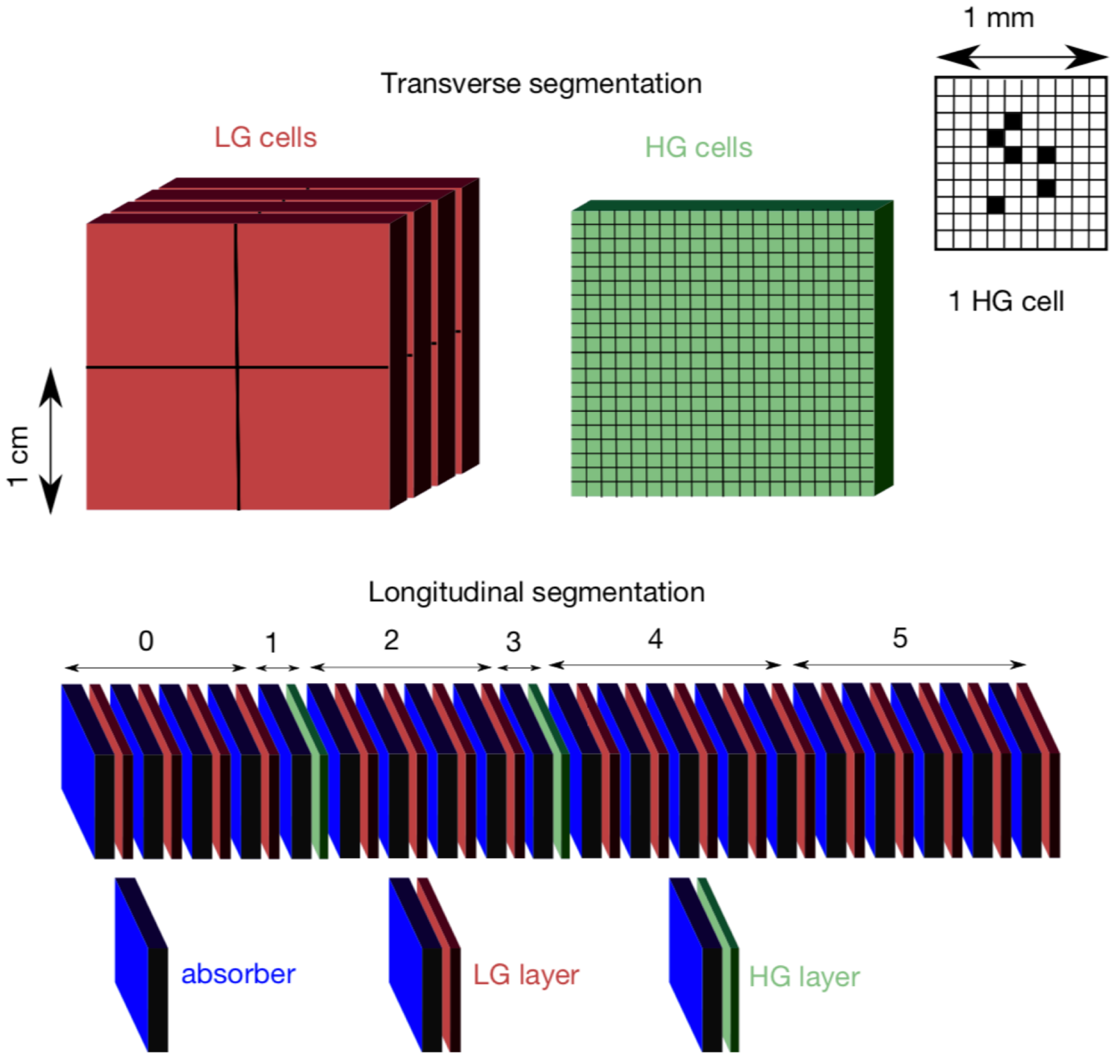
FOCAL - E

FOCAL-E-LGL

Component	Quantity
Sensors	2160
W plates	504
PCB	2160
Cables	432
CBs	120

FOCAL-E-HGL

Component	Quantity
ALPIDEs	8000
Strings	288
RUs	45
Monitoring	45
Power cards	45
FF cables	200
TCs	56
Repeaters	56



FoCal-E consist of a Si+W **sampling** calorimeter with **hybrid design** using **two different Si readout**

Pads (LGL)

Pad layers, with transverse cell sizes of ≈ $1cm^2$

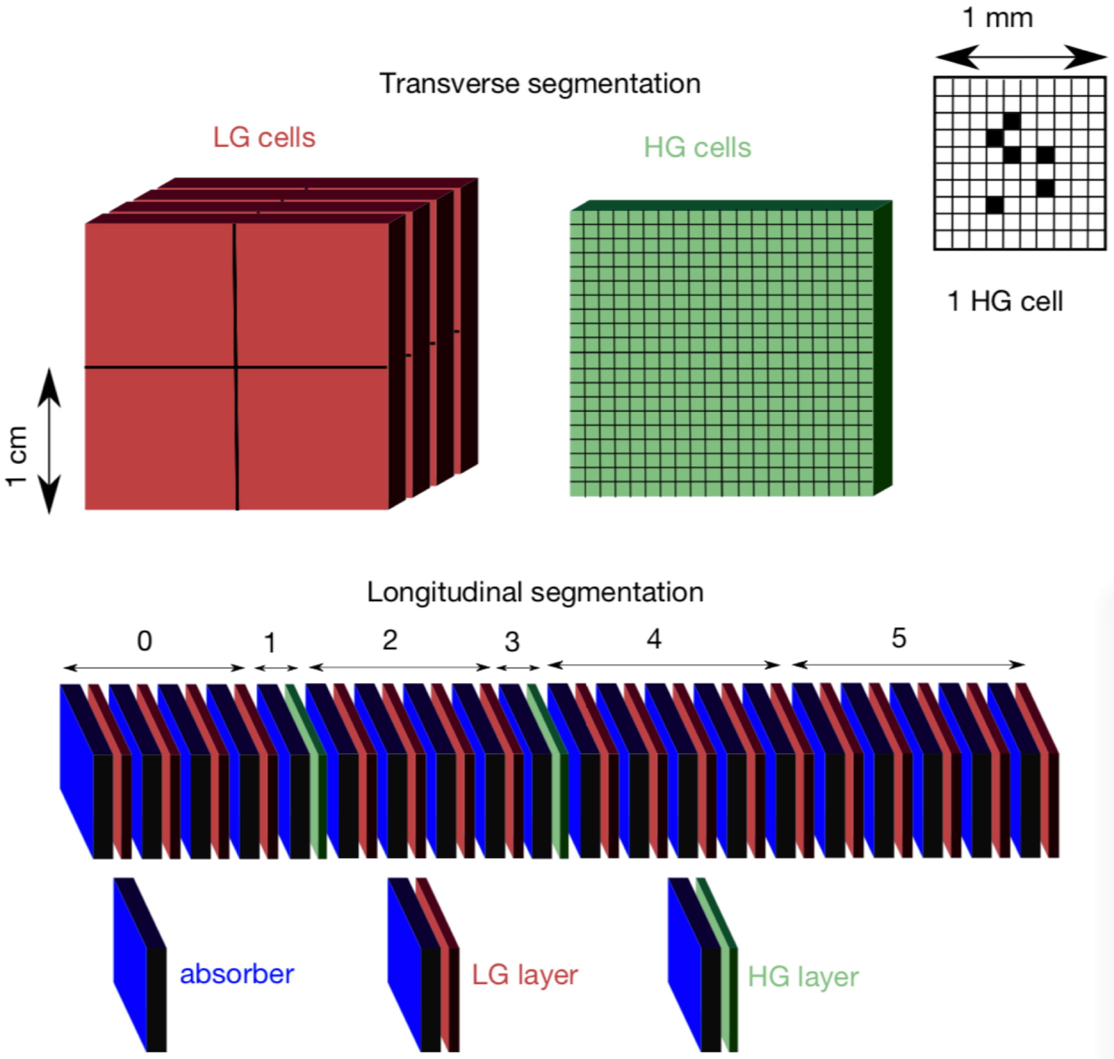
Pixels (HGL)

digital readout and a cell size of ≈ $30{\times}30\mu m^2$

FOCAL - E

FoCal-E (LGL + HGL)

- ✓ Si-W sampling calorimeter
- ✓ 18 LGL (1x1 cm^2)
- ✓ 2 HGL (30x30 m^2)
- ✓ propagating shower!
- ✓ Measure photons and π^0



Indian Participation

FoCal-E-LGL (~30%)

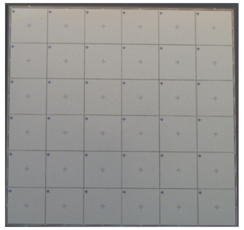
Segmented Silicon detector with 320 μm 6 inch p-type wafer

- ✓ Sensor array: 82 mm x 92 mm
- ✓ FOCAL-E Module 45 x 8 cm^2 (5 wafer side by side)
- ✓ 22 Module (11 on each side of beam line)
- ✓ W-Plate size: 46.5 cm × 8.38 cm × 3.5 mm

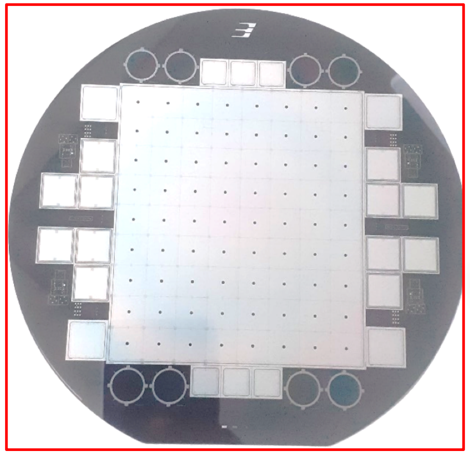
FoCal-E LGL

R & D in India for Silicon Detector array

5 x 5 n-type array



4’ n-type: 6 x 6 array



P-Type

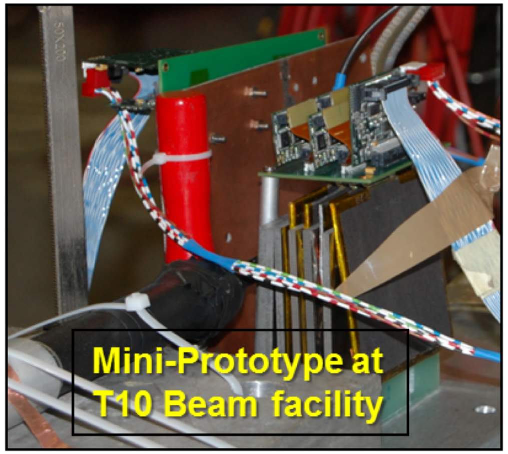
8 x 9 Array

N-Type

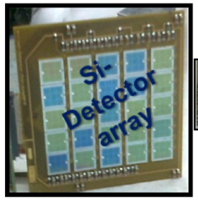
R&D with N-type Silicon detector

Prototypes @ Beam

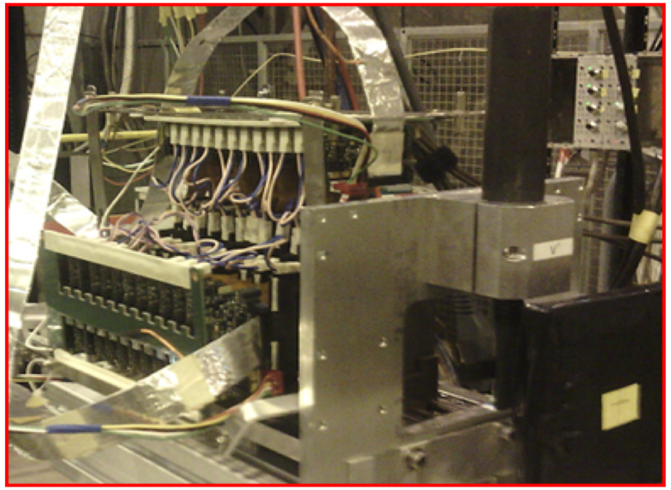
TB2014



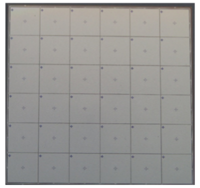
Mini-Prototype

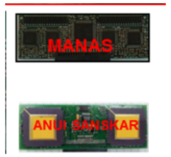


TB2015



Full prototype

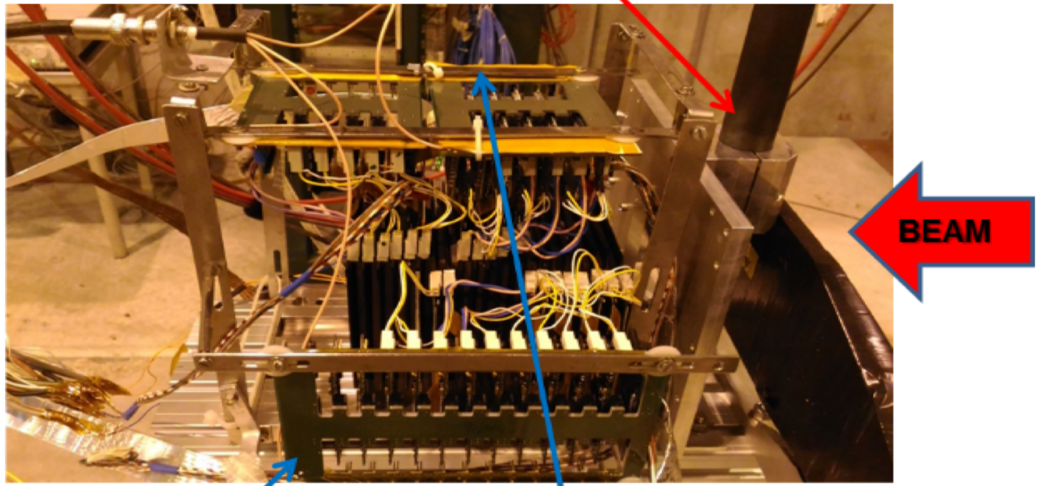




TB2017

6*6 array of 1cm^2 Silicon detector

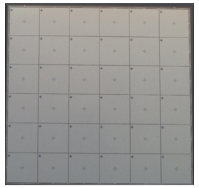
Trigger system consist of P, H, V Scintillator.

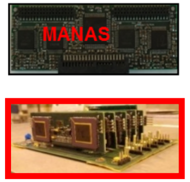


BACK-PLANE PCB for MANAS CHIP

BACK-PLANE PCB for ANUINDRA CHIP

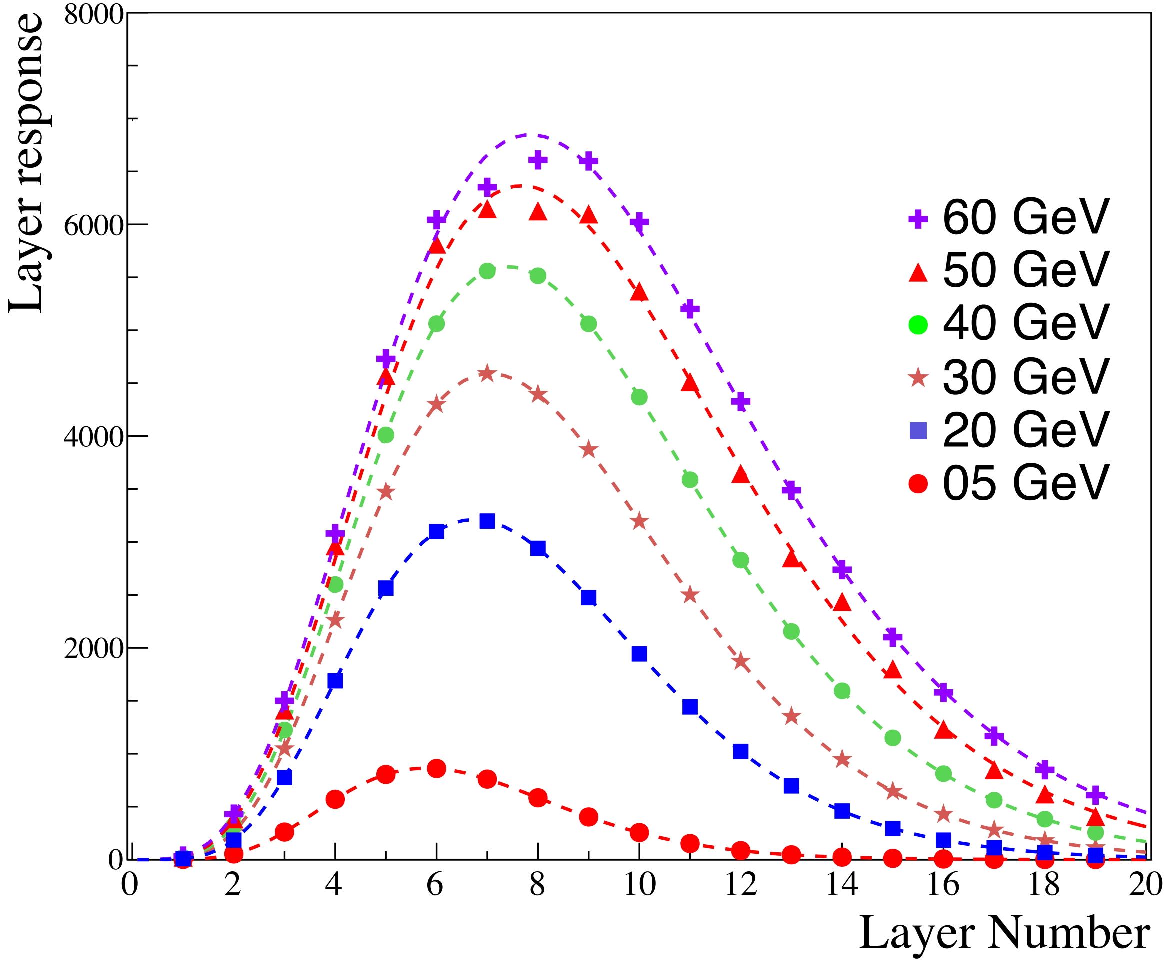
Full prototype + Advanced ASIC





Calorimeter performances

(2021) Springer Proceedings in Physics, vol 261
https://doi.org/10.1007/978-981-33-4408-2_116

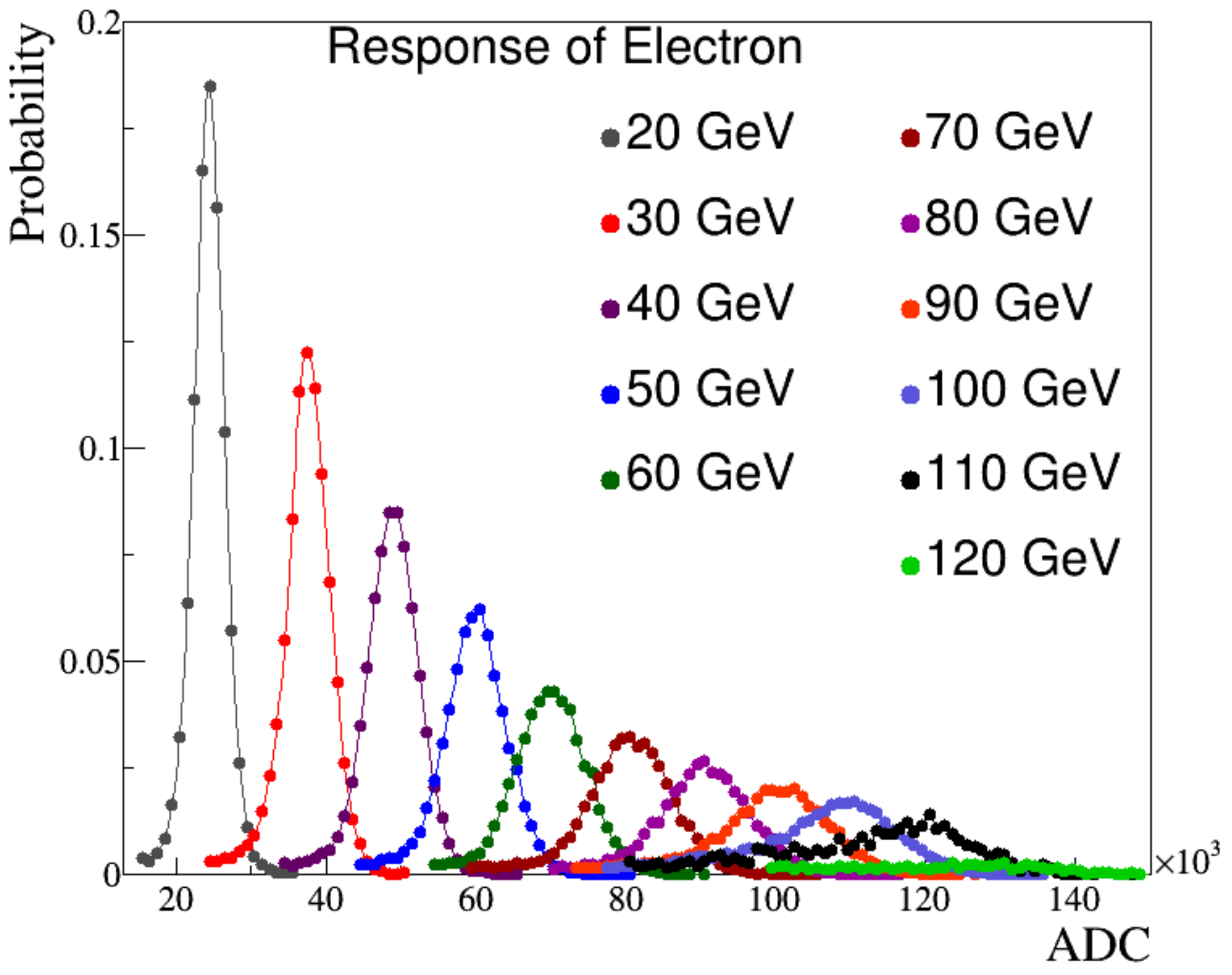


$$\frac{dE}{dt} = \frac{E_0\beta(\beta t)^{(\alpha-1)}e^{-\beta t}}{\Gamma(\alpha)} \approx E_0(t)^{\alpha}e^{-\beta t}$$

Secondary particle generation at smaller depth

Falling part of the profile due to collisional losses at larger depth

TB2017



Calorimeter performances

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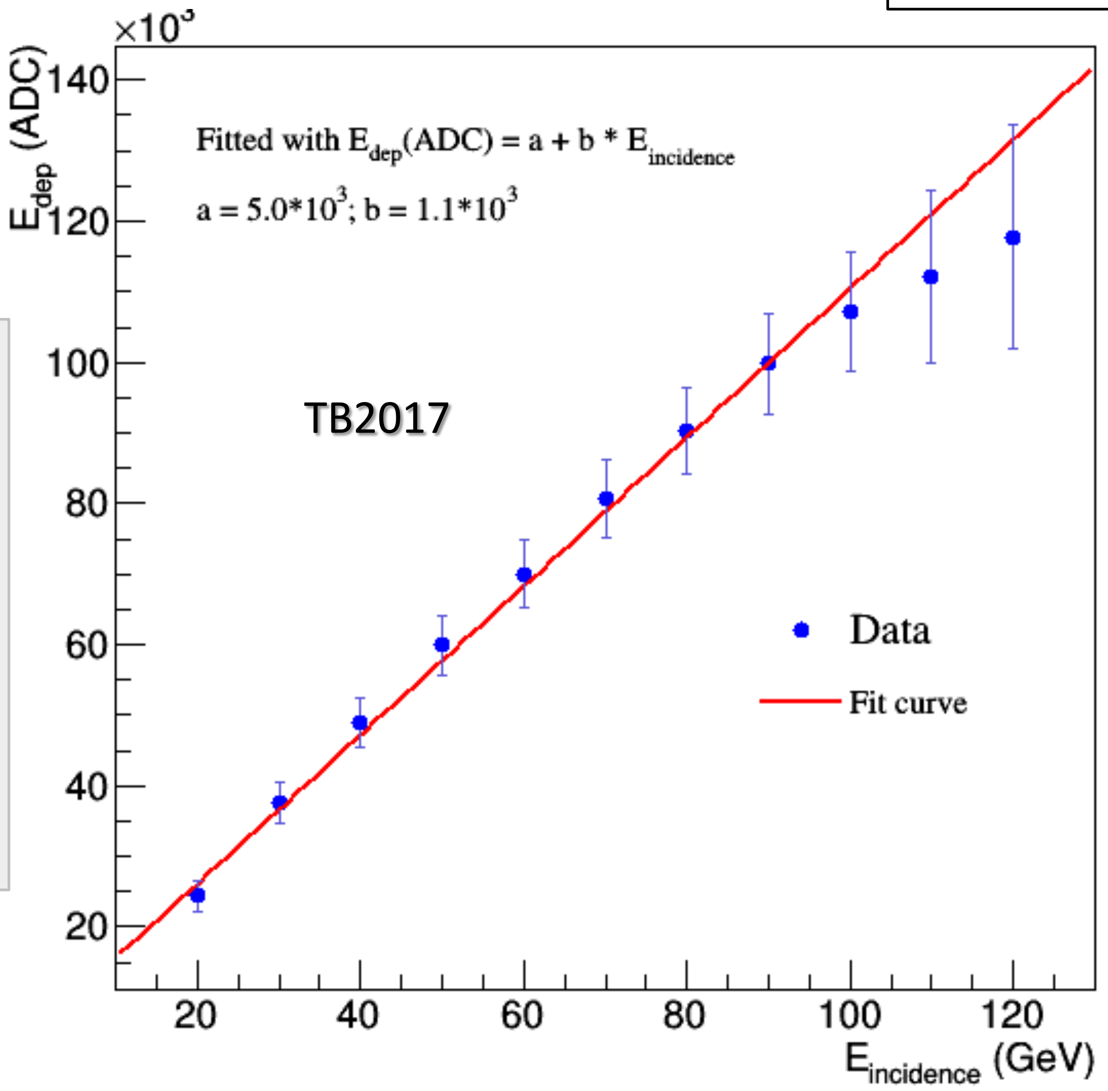
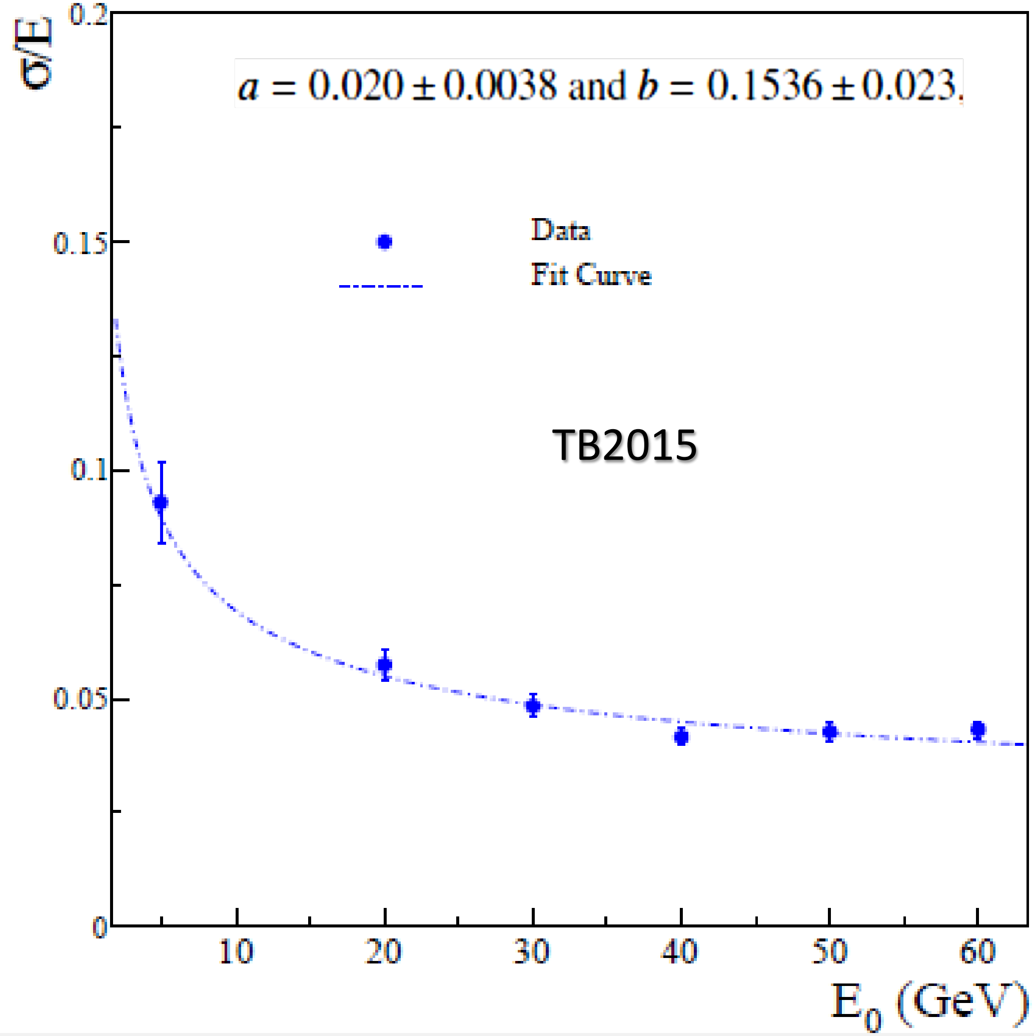
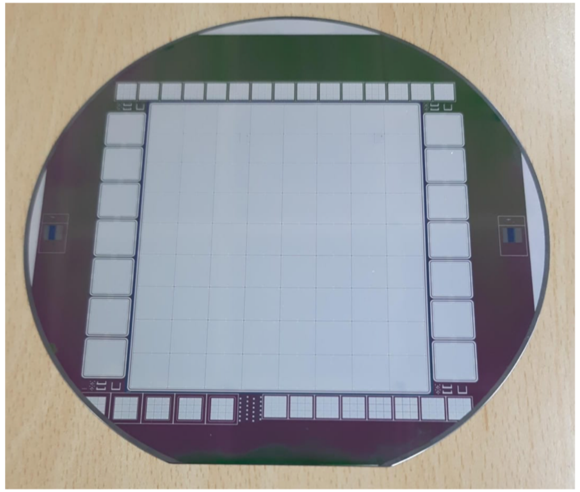


Energy Resolution can be expressed as

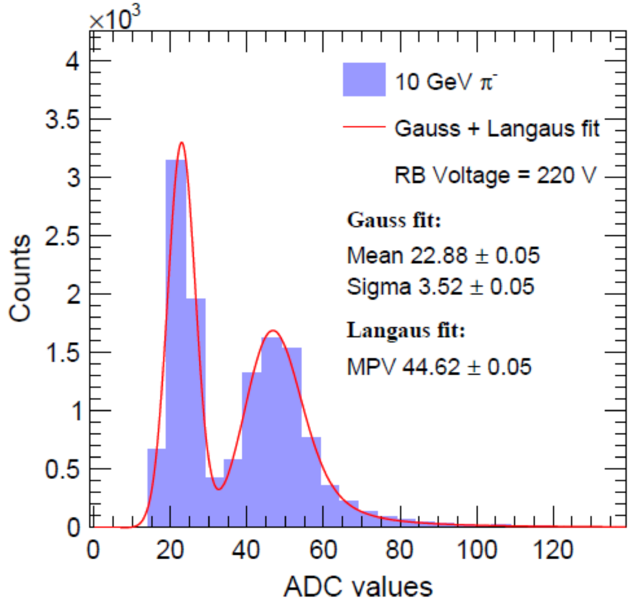
$$\frac{\sigma}{E} = a + \frac{b}{\sqrt{E}} + \frac{C}{E} + \vartheta(E)$$



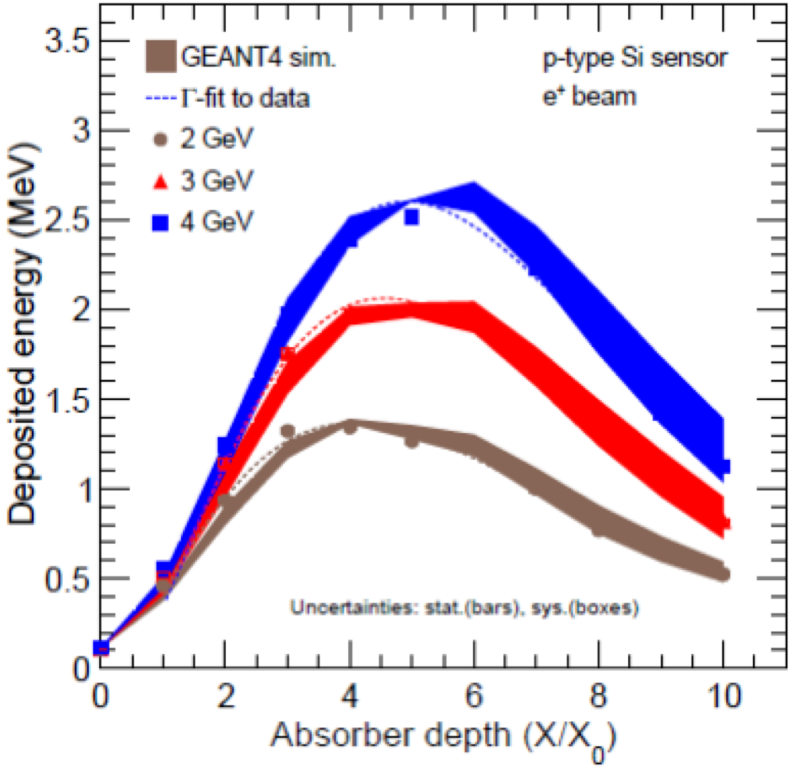
TB2024 CERN-PS



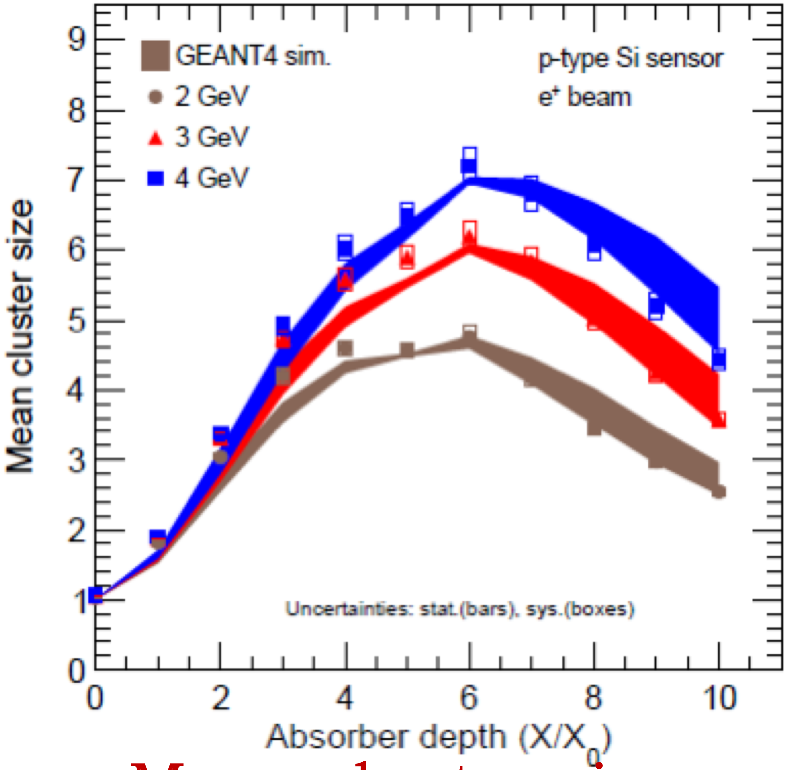
Pad array on the 6-inch Si wafer



10 GeV π- MIP signal in detector



Longitudinal shower profile



Mean cluster size distribution

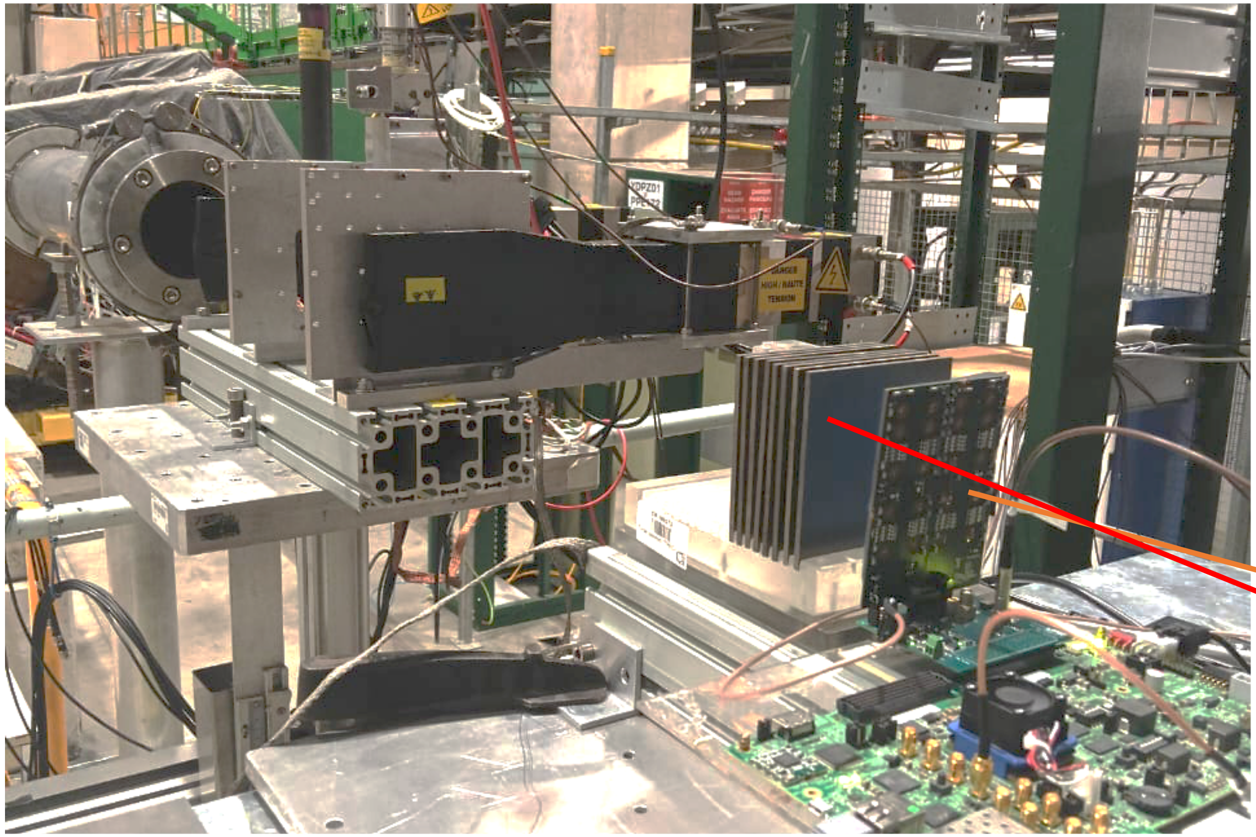
Systematic uncertainties - evaluated by varying the absorber depth by 5%, accounting for any unaccounted upstream material, shower profiles and mean cluster sizes are as expected.

Ref. Sawan et al. (G. Tambave), https://arxiv.org/pdf/2508.06100, Submitted to JINST.

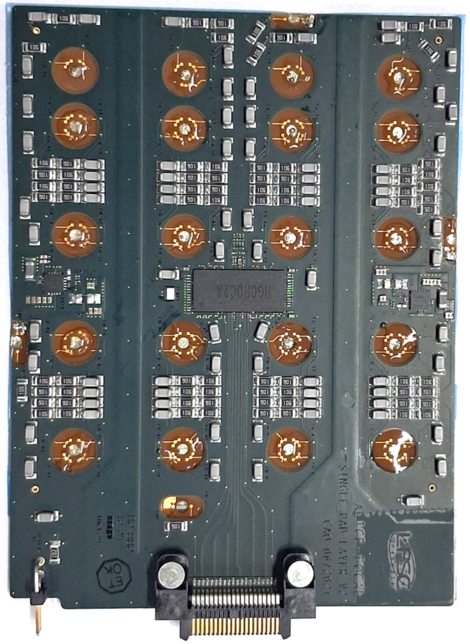
R&D with P-type Silicon detector

VECC-BEL

TB2025



8 x 9 array



Detector array

Absorber Stack

Detector test @ CERN-SPS

8 x 9 P-type Silicon detector array

Set-Up

P-Type silicon detector array with Tungsten absorbers

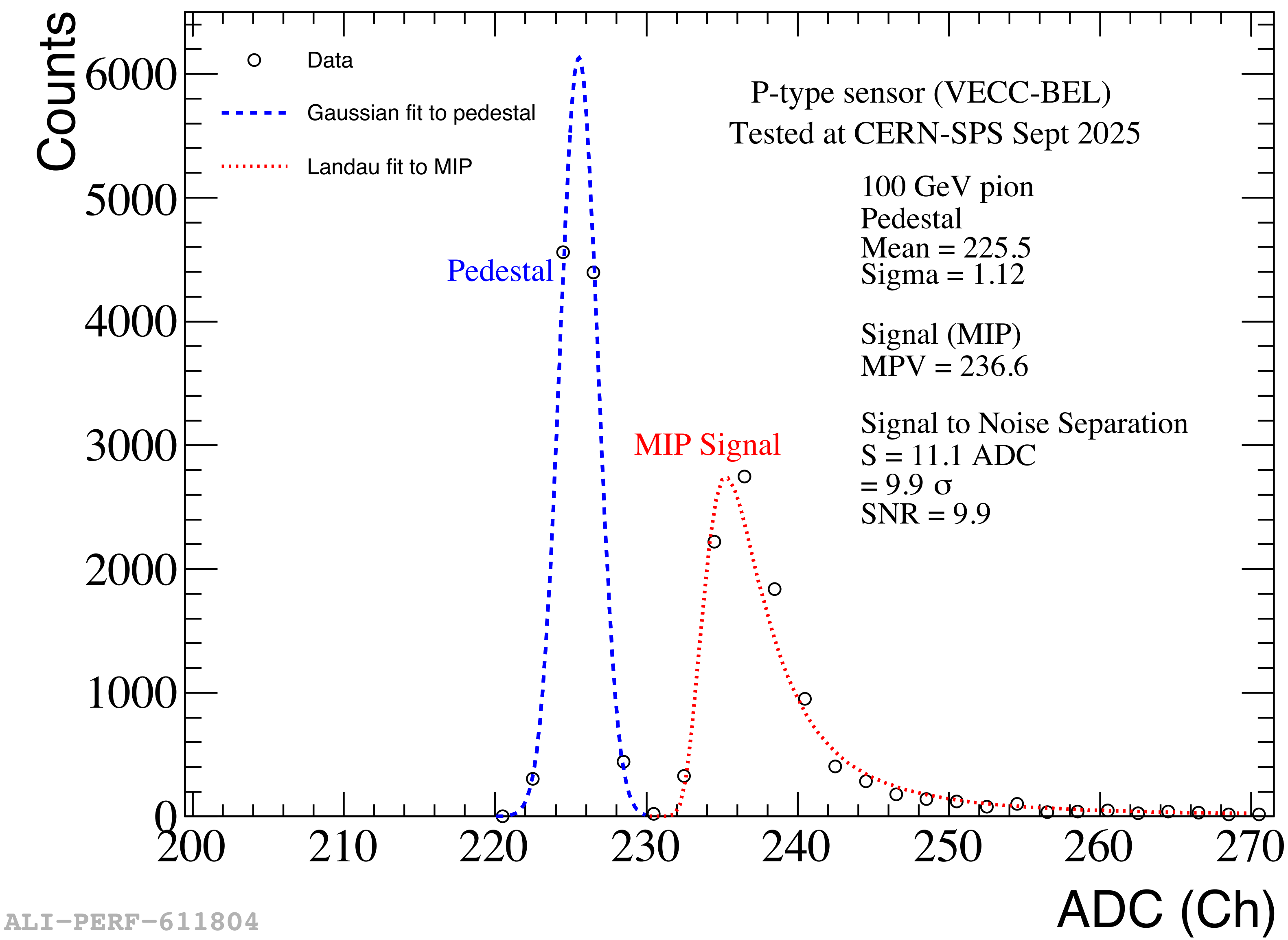
Objectives

1. Noise to MIP separation
2. Scan of the full array with pion
3. EM-Shower signal reconstruction

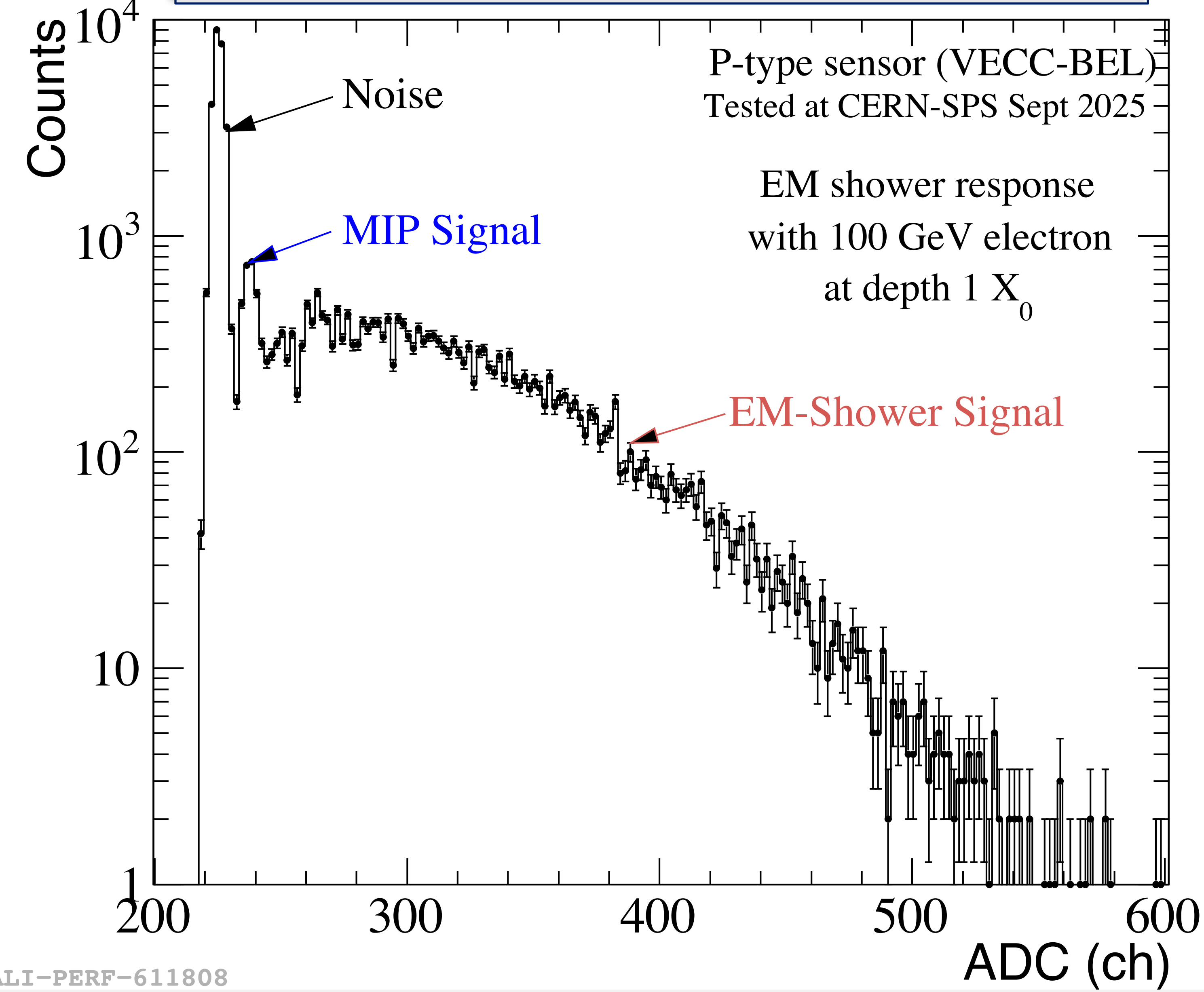
Beam and Energy

1. 100 GeV π^+
2. 20 GeV e^-
3. 40 GeV e^-
4. 50 GeV e^-
5. 60 GeV e^-
6. 70 GeV e^-
7. 80 GeV e^-
8. 90 GeV e^-
9. 100 GeV e^-
10. 120 GeV e^-
11. 150 GeV e^-
12. 180 GeV e^-
13. 200 GeV e^-
14. 250 GeV e^-
15. 300 GeV e^-

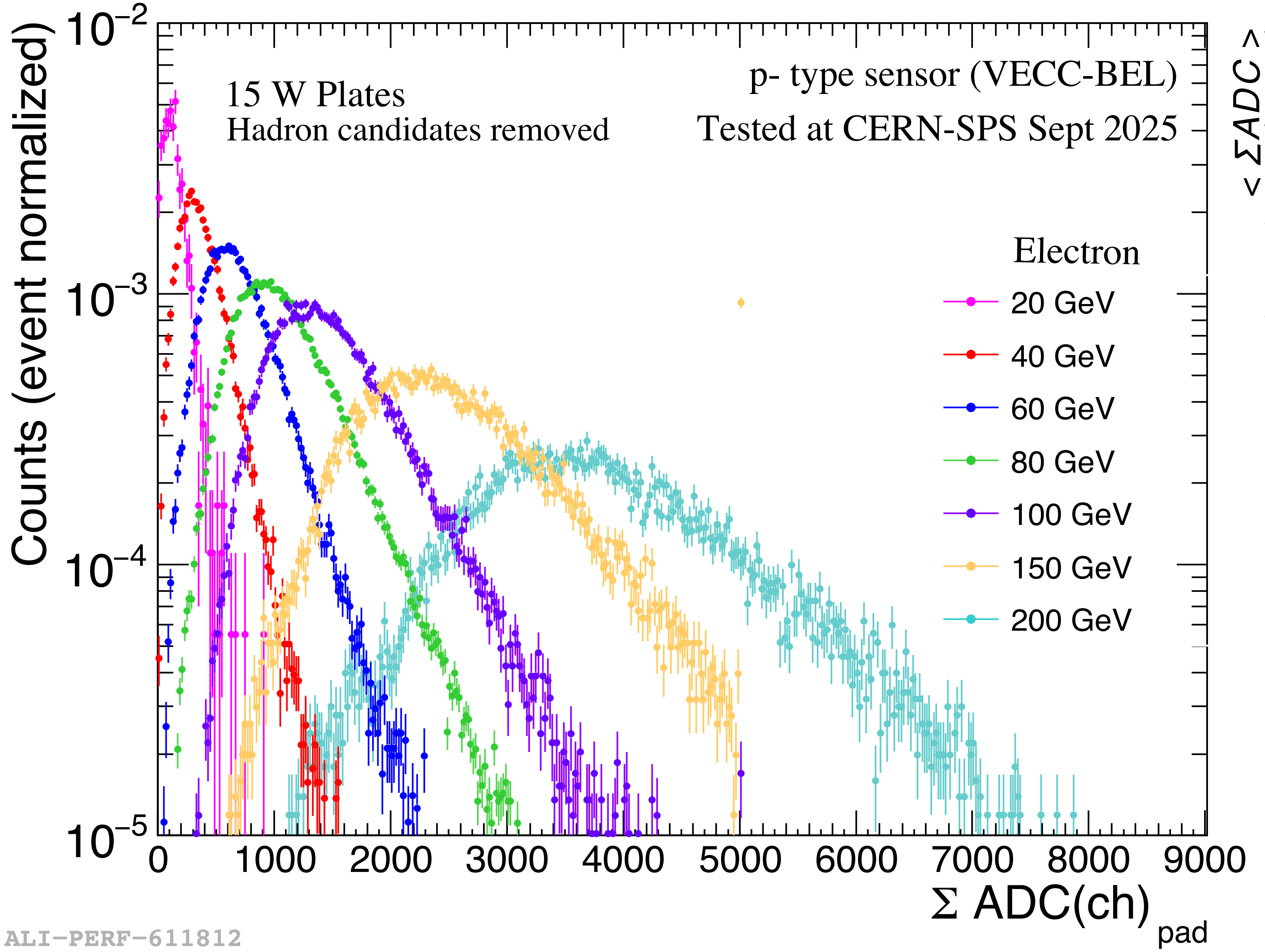
MIP response with 100 GeV pion (+)

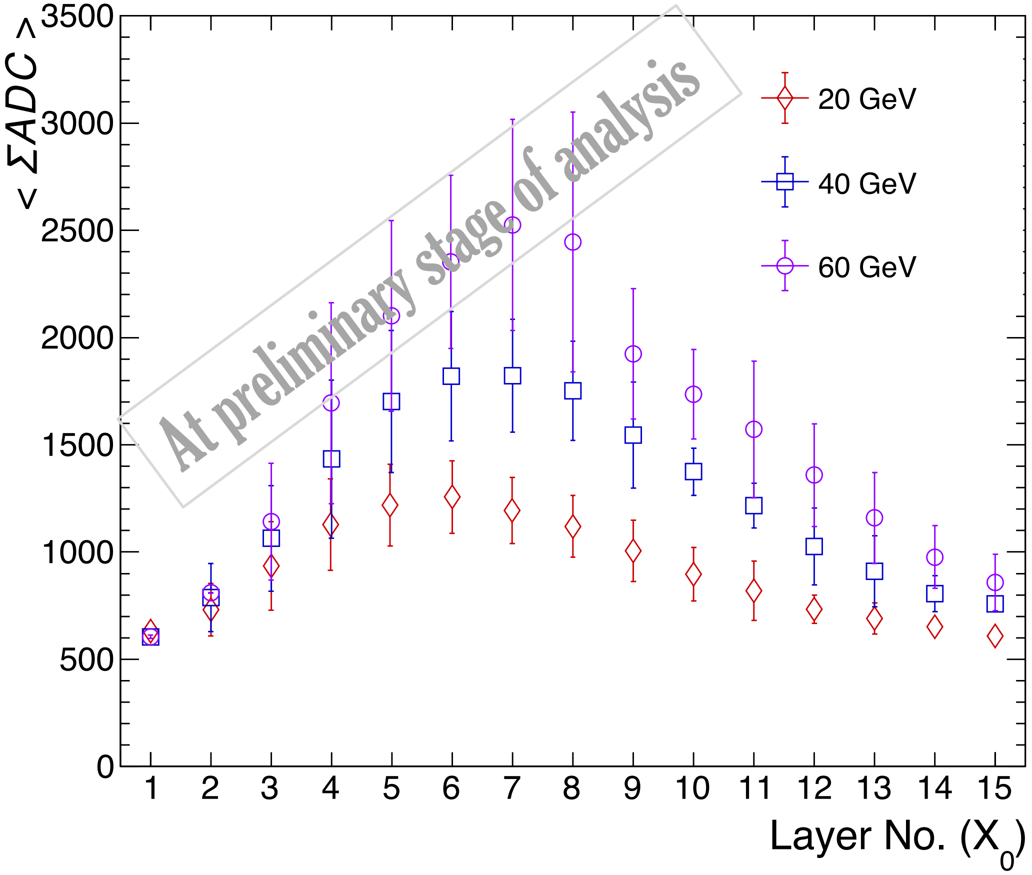


EM-Shower response with 100 GeV electron



EM-Shower Reconstruction



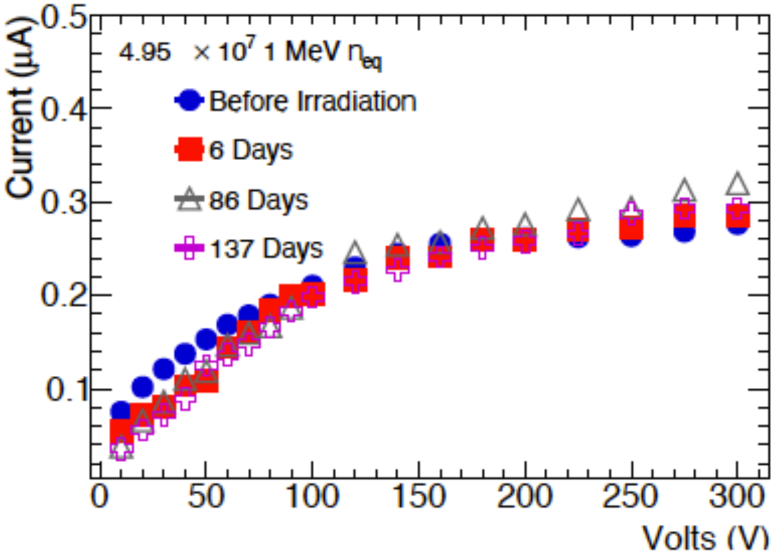


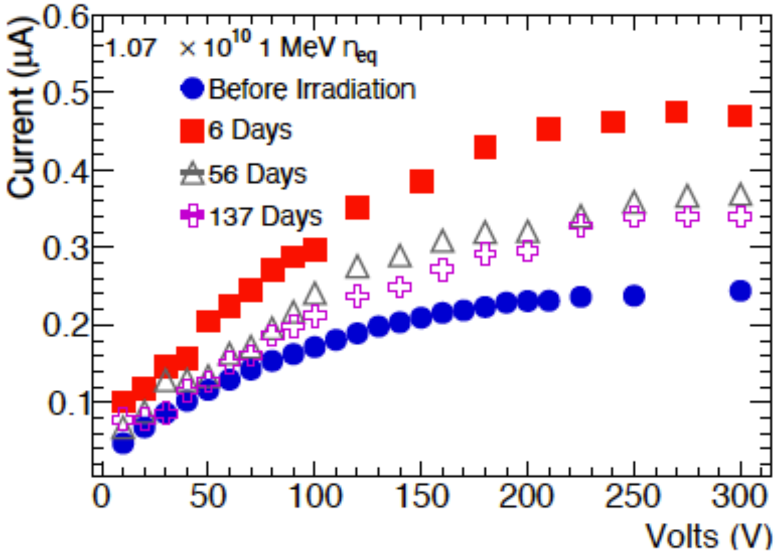
Radiation hardness Test (Test detectors)

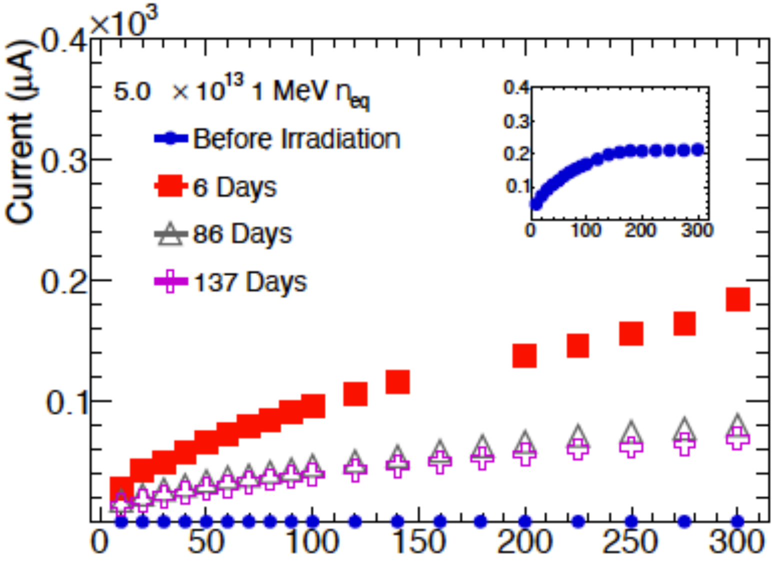
The test detectors from the same wafer were irradiated to different 1 MeV neutron equivalent doses

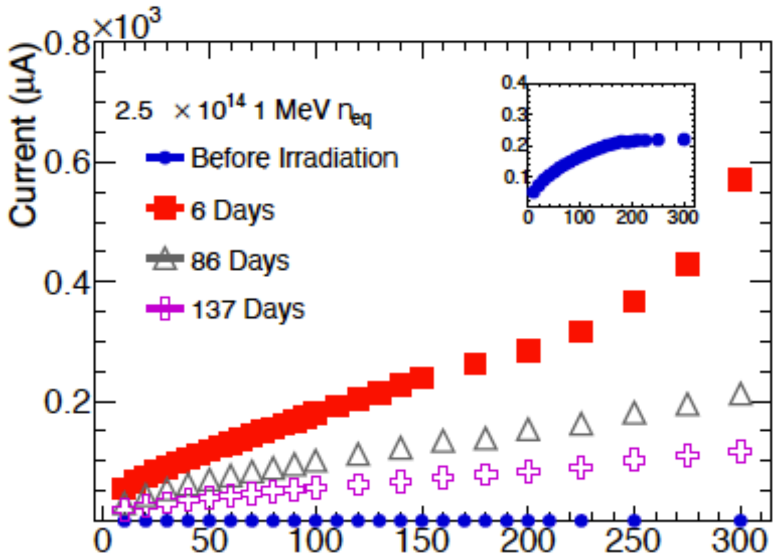
Detector performances before and after the irradiation were measured.

Details can be found in the poster by Anup K. Sikdar.





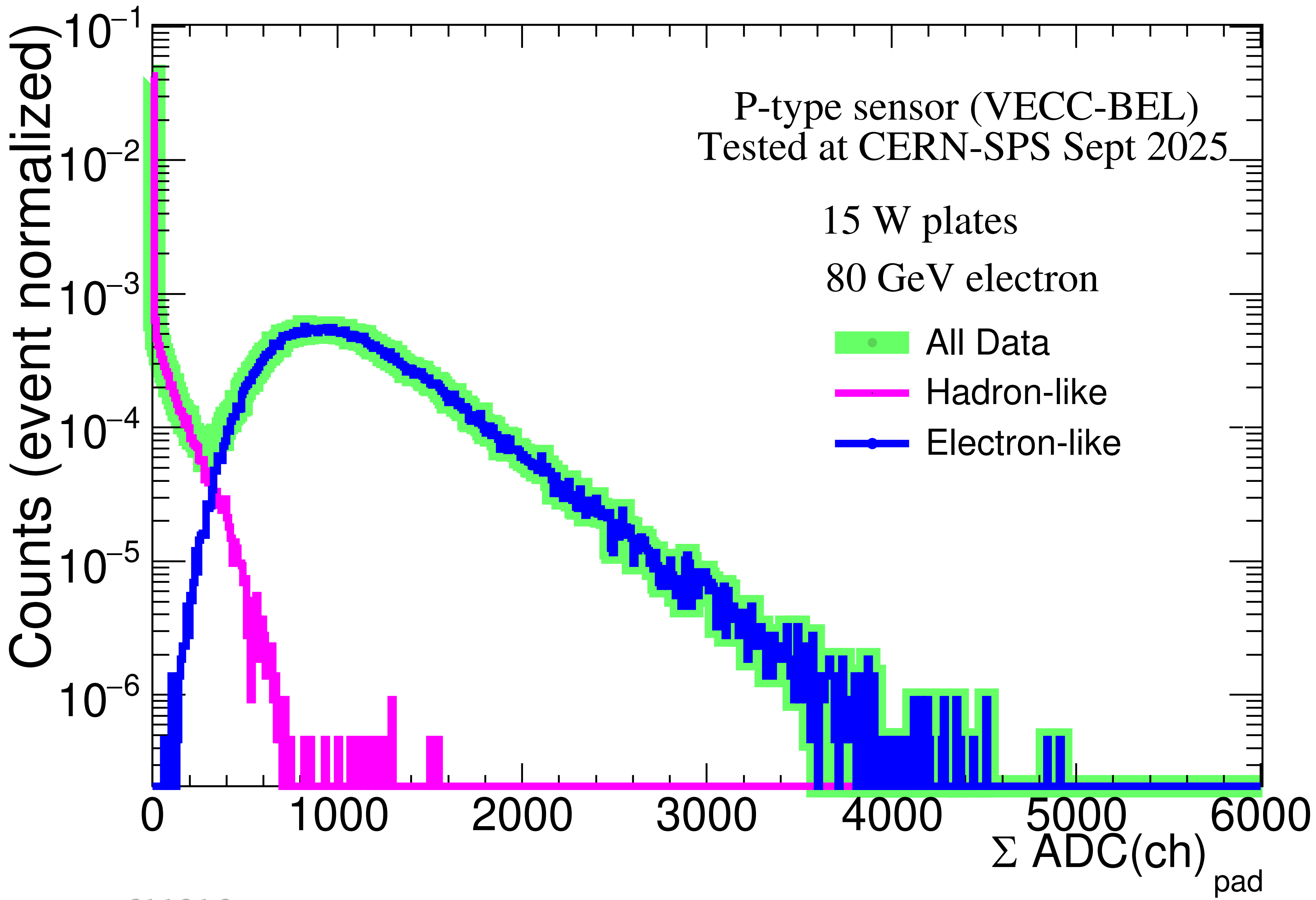




Summary

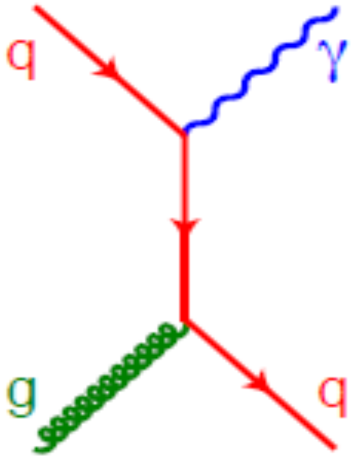
- ✓ Brief accounts of the physics and observables.
- ✓ Capabilities of the ALICE with FoCal at small-x
- ✓ FoCal
- ✓ Indian efforts towards FoCal-E-LGL

Thanks

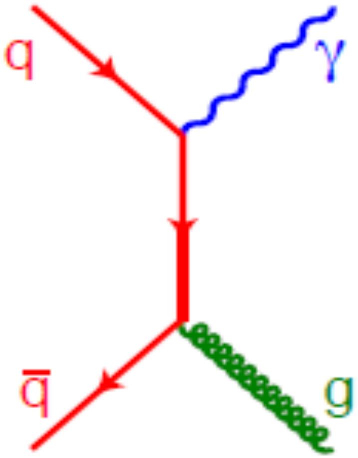


ALI-PERF-611816

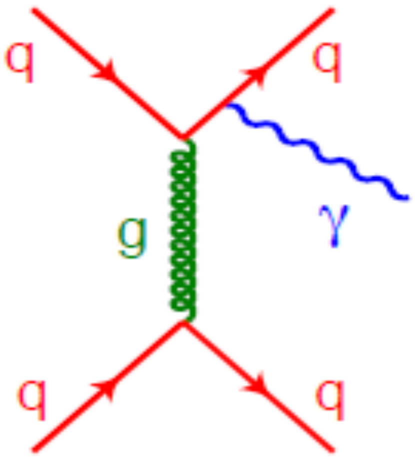
Direct Photon production



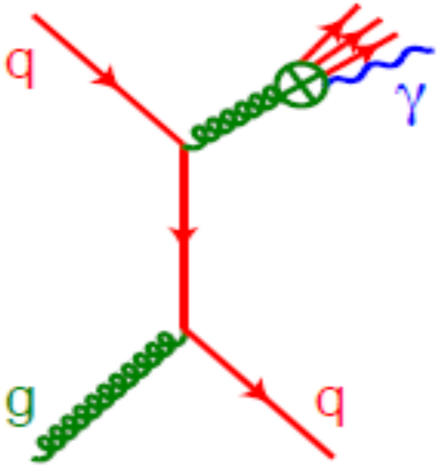
Compton



Annihilation



Bremsstrahlung



Fragmentation

Direct Photons

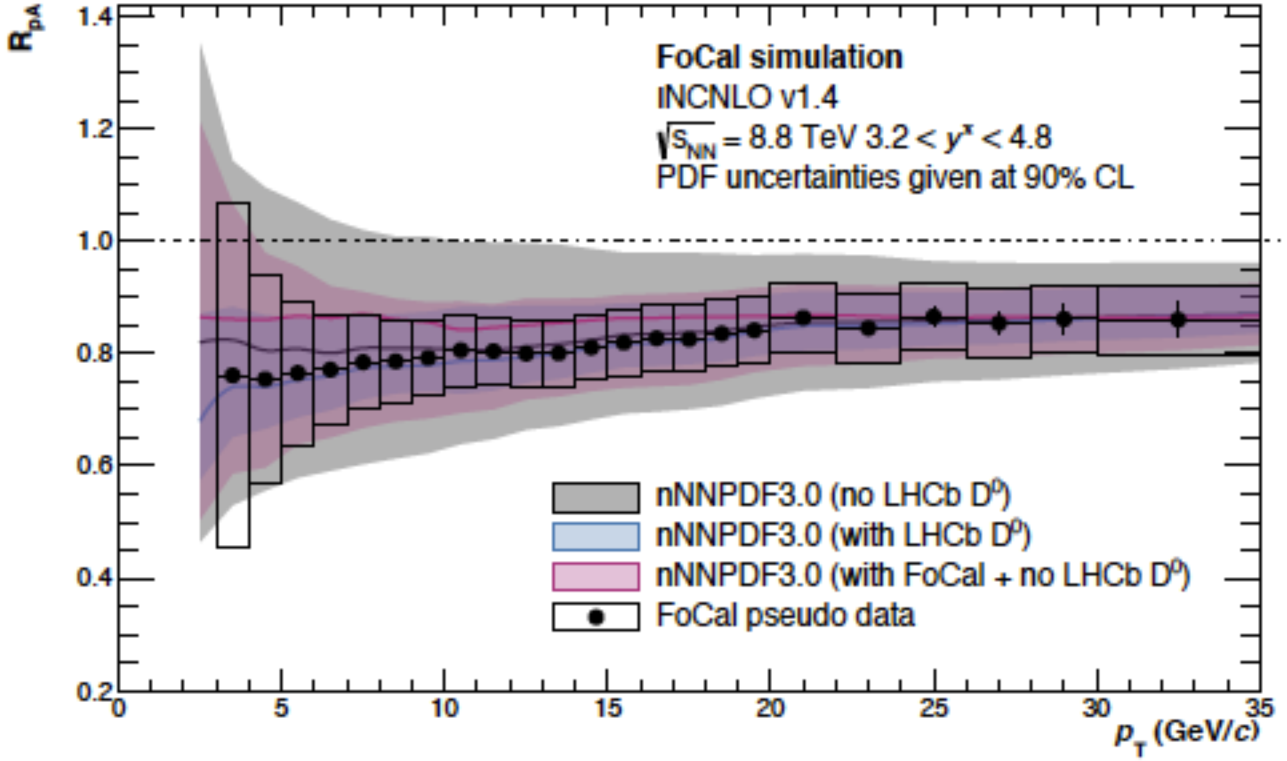
Prompt photon

Fragmented photon

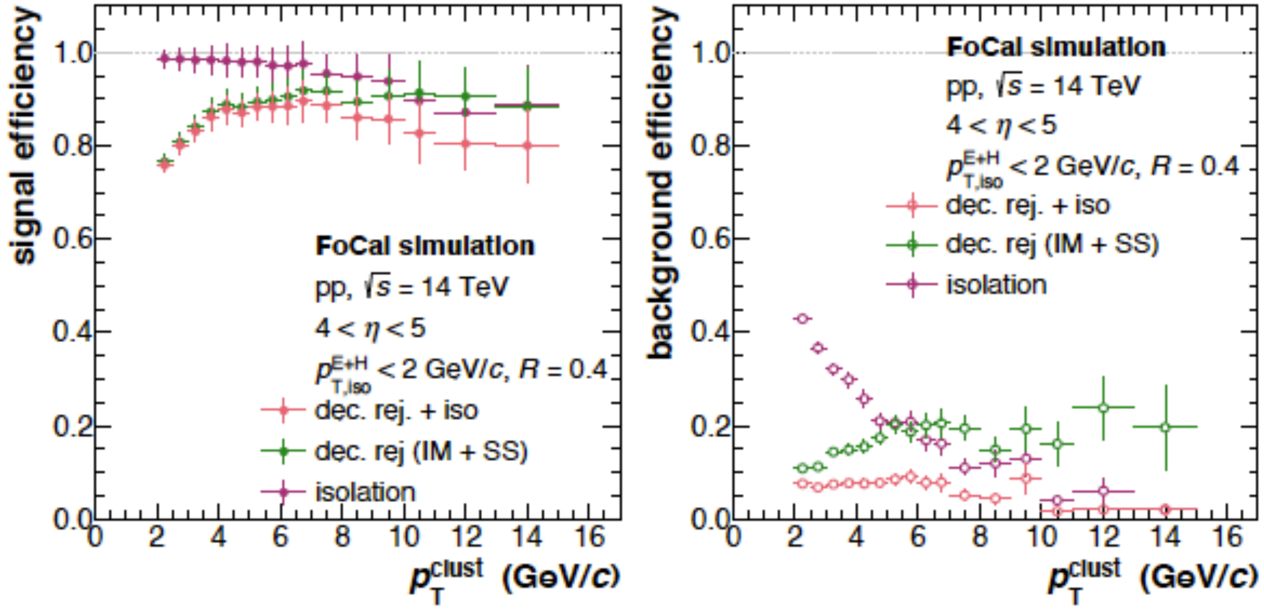
How photons will be measured?

Prompt–photon measurements in the FoCal uses three techniques to enhance the signal contribution.

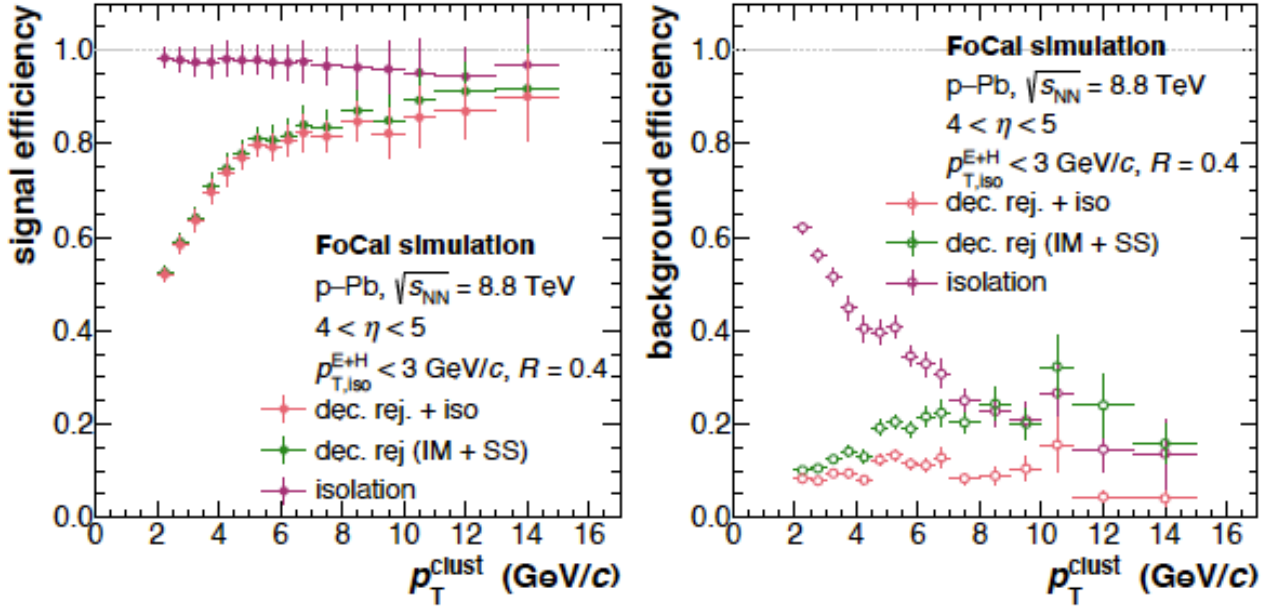
1. **Isolation cut:** measurement of the isolation energy in FoCal-E and FoCal-H in a cone of given radius around the photon candidate, with rejection of candidates with isolation energy above a specified threshold.
2. **Invariant mass technique:** rejection of photons originating from π0 decays using the invariant mass of cluster pairs.
3. **Shower shape:** rejection of elongated clusters originating from decay photons with small opening angle.



- ✓ prompt photons directly produced in hard scattering qg → ϒq.
- ✓ no strong interaction in final state
- ✓ measurement of prompt photon production at forward rapidity in p–Pb coll.



(a) sig. efficiency (pp at $\sqrt{s} = 14$ TeV) (b) bkg. efficiency (pp at $\sqrt{s} = 14$ TeV)



Signal and background photon reconstruction efficiency as a function of cluster pT, for pp collisions at spp = 14 TeV (upper) and p–Pb collisions at sNN = 8:8 TeV (lower). Background rejection is shown for various combinations of decay rejection, isolation, and shower-shape cuts. Low background efficiency and high signal efficiency are desirable.

Performance