Test and Characterization of a silicon-tungsten calorimeter prototype at SPS-CERN

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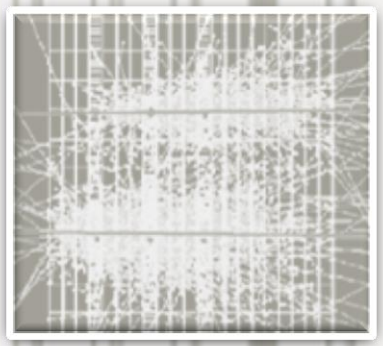
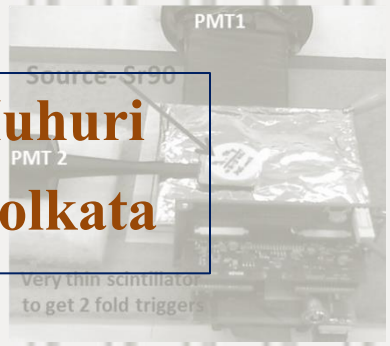
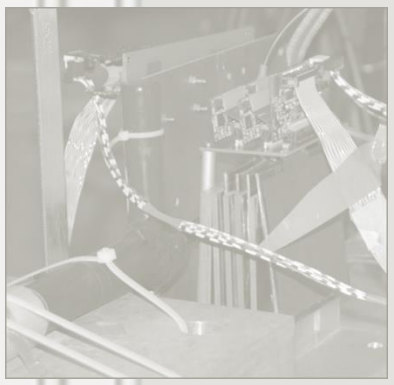
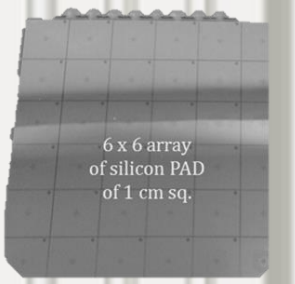
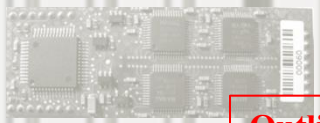
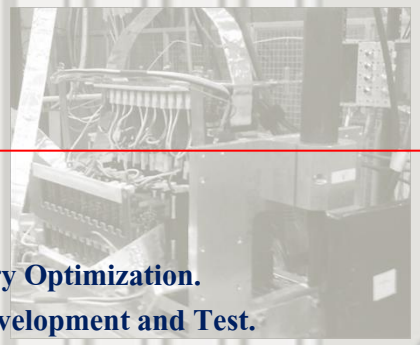












Outline:

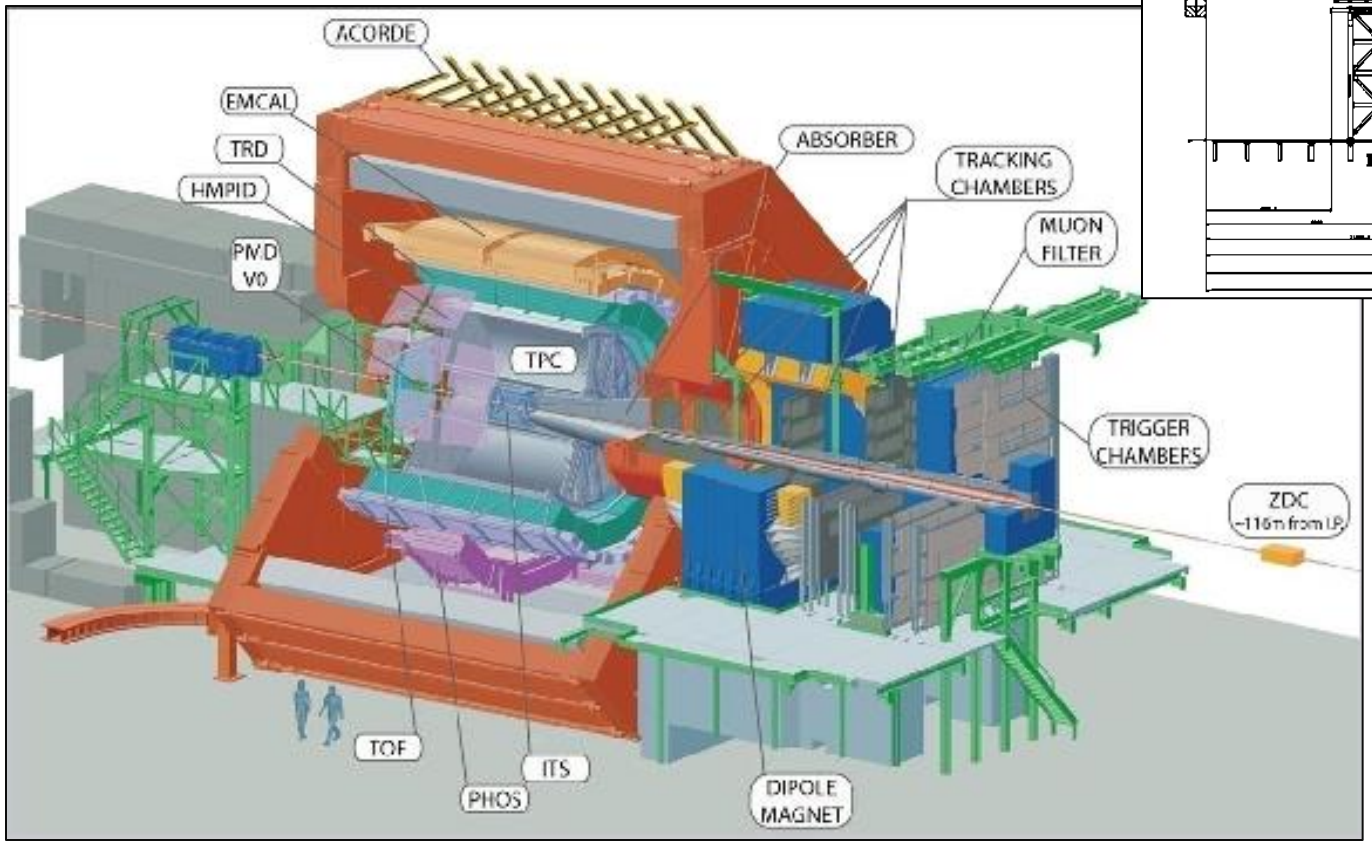
- Physics Motivation
- Design and Geometry Optimization.
- Mini-Prototype : Development and Test.
- Full-Length Prototype: Fabrication and Characterization.
- Summary

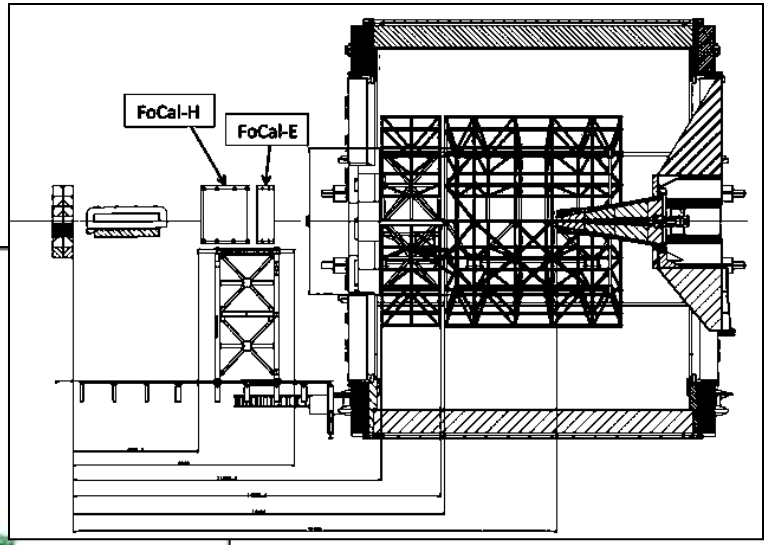
Physics Motivation:

- ✓ **Test of pQCD prediction (pp collisions)**
  - ✓ Particle production
  - ✓ Effect of small-x contribution
- ✓ **To probe the initial condition (p-A collisions)**
  - ✓ Gluon density at small-x (down to 10^{-5} to 10^{-6})
  - ✓ Study of Color Glass Condensate
- ✓ **To probe the final state effects (A-A collisions)**
  - ✓ Opacity of medium: gamma-jets correlations.
  - ✓ Parton energy loss in dense partonic matter.

Design and Geometry Optimization:

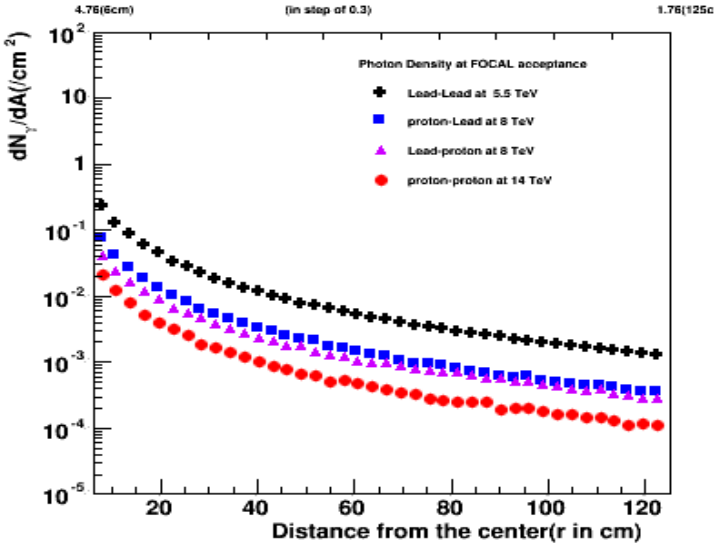
ALICE Experimental Set-up

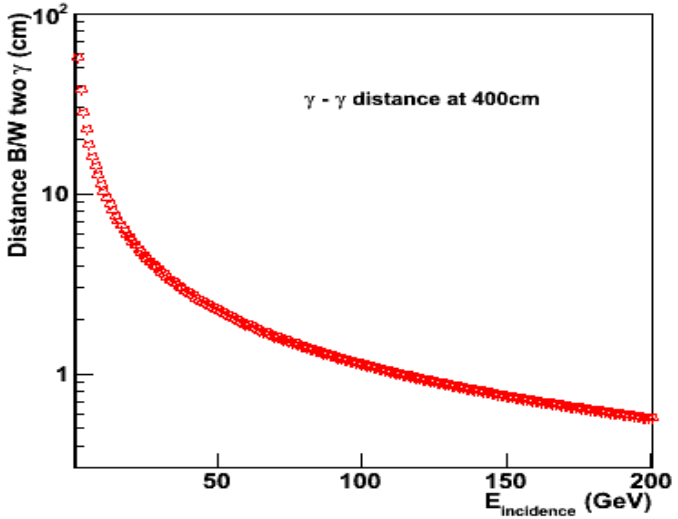




FOCAL in ALICE

Design and Geometry Optimization:





Distance from IP in ALICE: 7 m

Radial distance

Inner: 6 cm (limited by beam pipe)

Outer: 80 cm

Rapidity Coverage

$2.5<\eta<5.5$

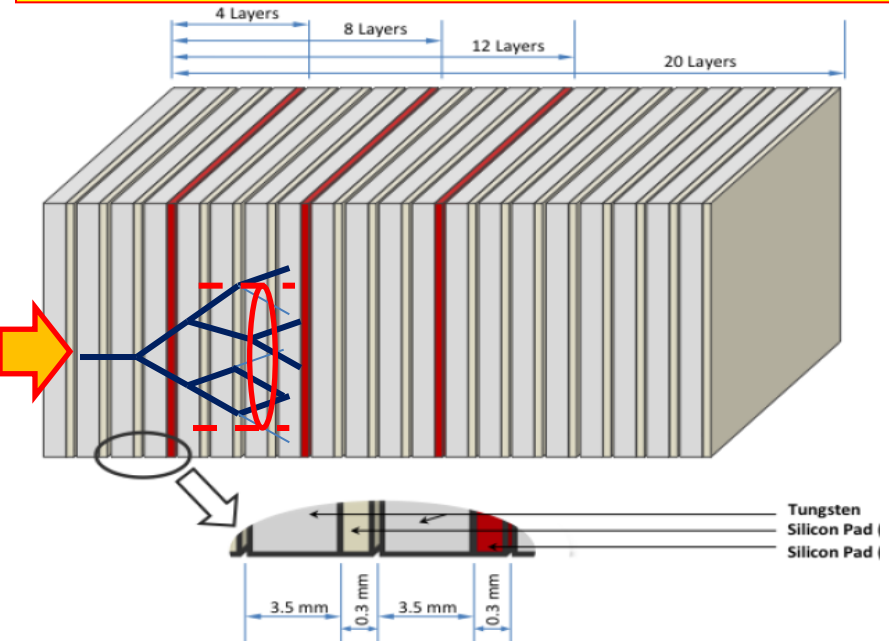
P_T range of particle detection

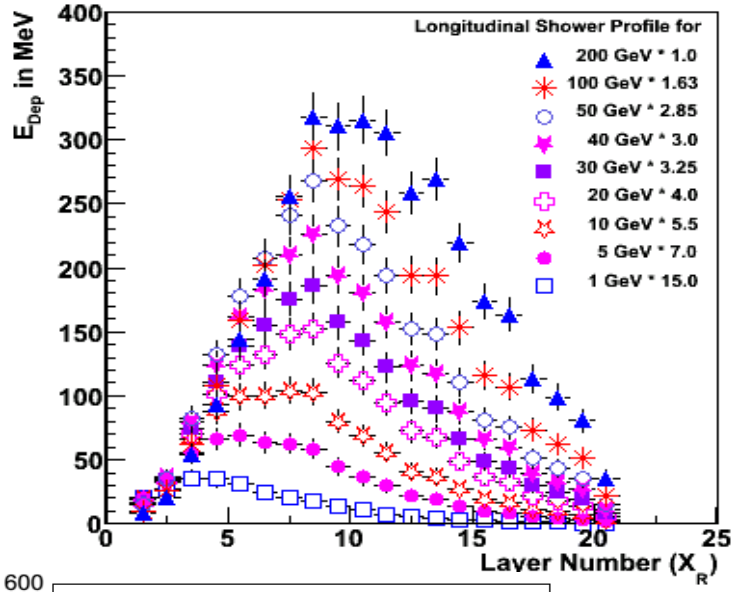
Up to 20 GeV/c

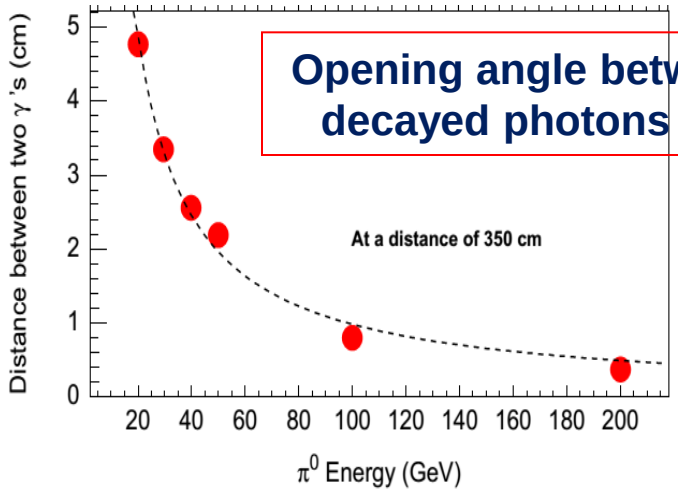
Choice of Configuration

- ✓ **Sampling type Hybrid Calorimeter**
- ✓ **Detector : Silicon(1 cm^2 and 1 mm^2)sensors**
- ✓ **Absorber/Convertor : Tungsten**

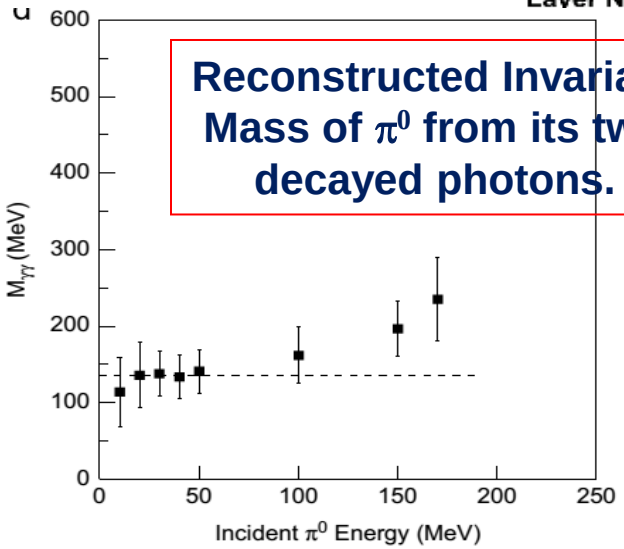
Design and Geometry Optimization:







Opening angle between two decayed photons from π^0



Reconstructed Invariant Mass of π^0 from its two decayed photons.

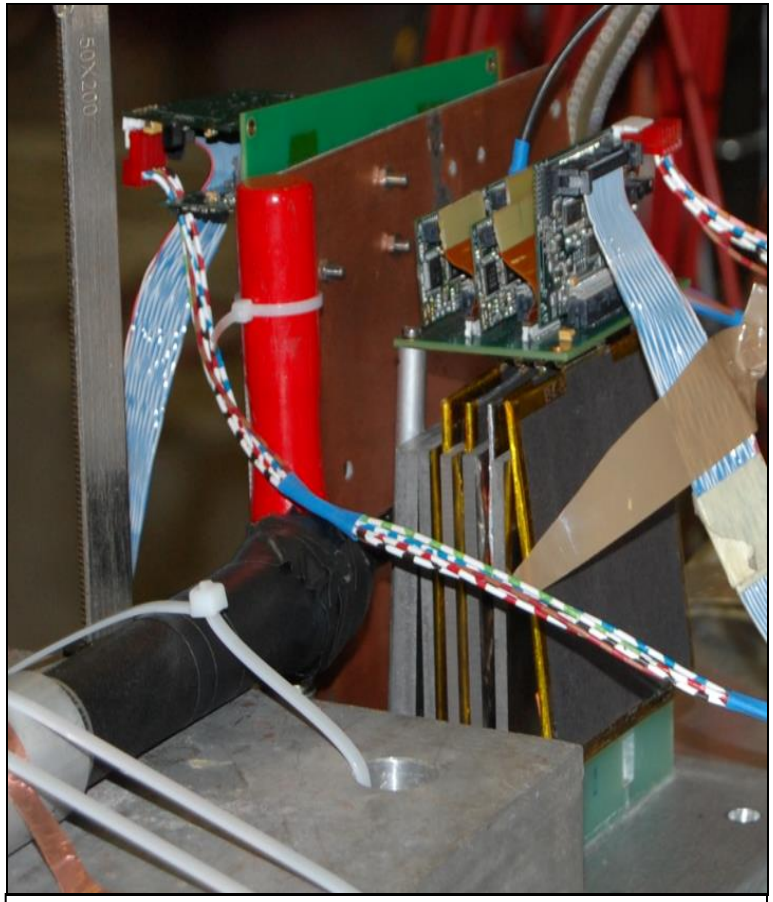
SM et all, NIMA A681 (2012) 34-43

Design and Geometry Optimization:

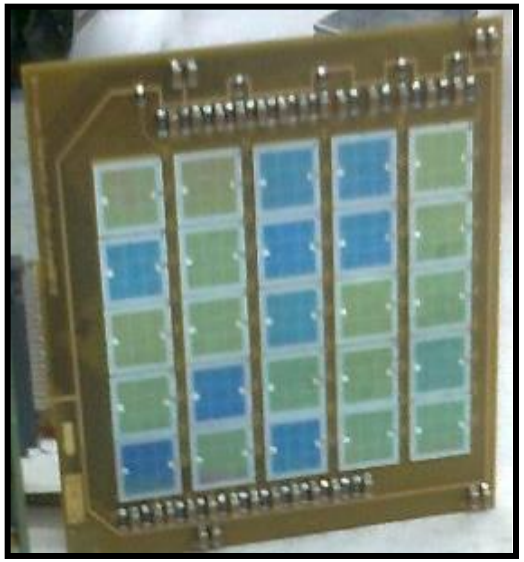
Challenges

- **Measurement of physics observables**
  - Measurements of Direct photons, Decayed photons and their disentanglement.
- **Development of calorimeter**
  - 1cm*1cm silicon pad sensors
    - Reading each and every channels individually.
  - Requirement of large dynamic readout electronics.
  - Development of data acquisition system

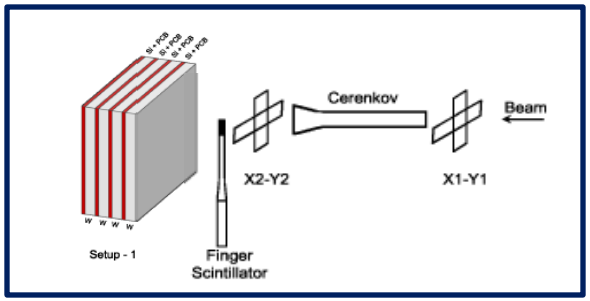
Mini-Prototype: Development and Test.

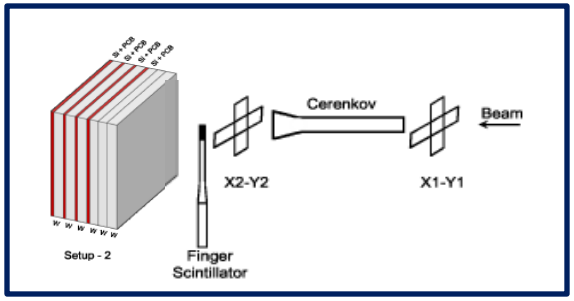


Mini-Prototype at T10 Beam facility



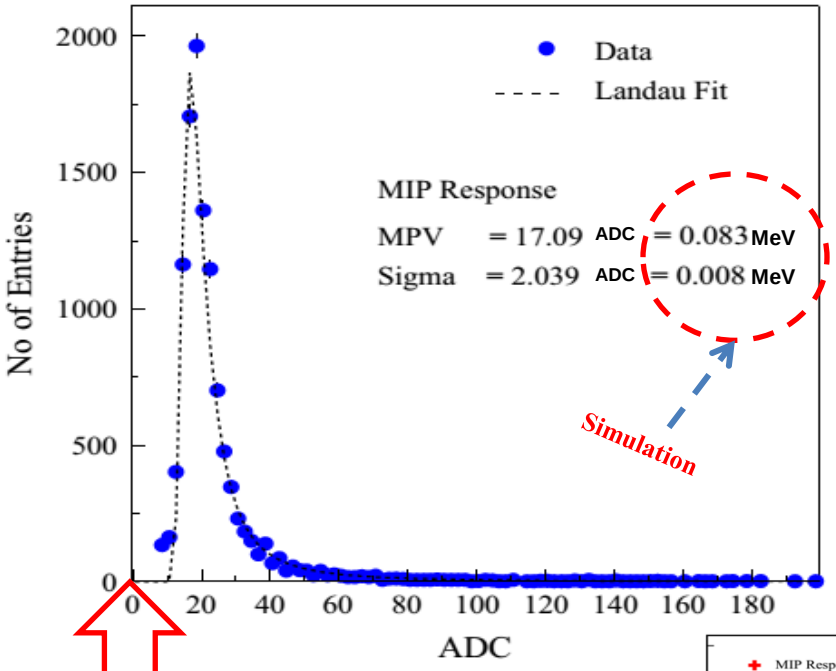
Si-Detector array

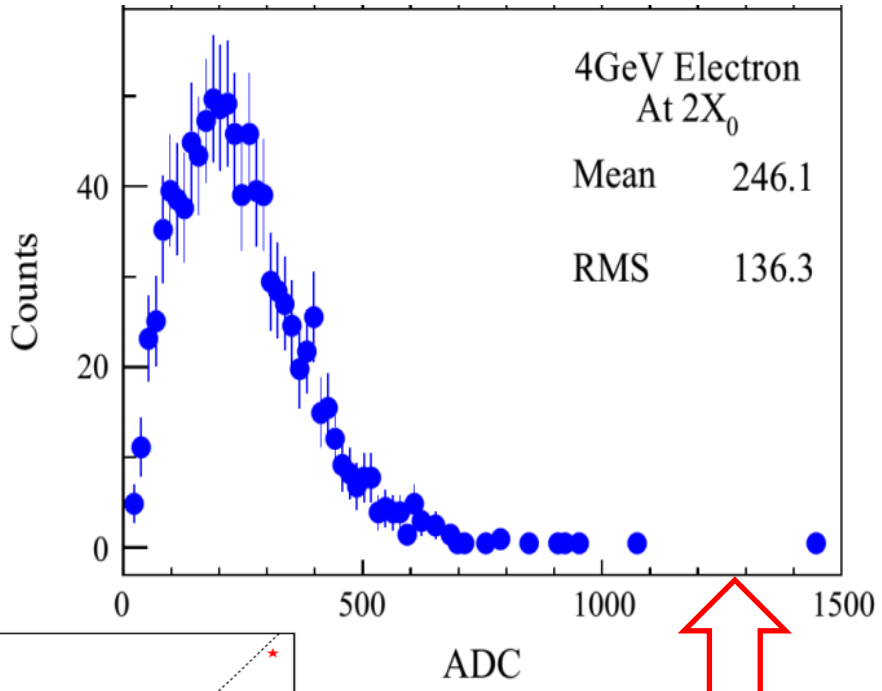




Two set ups used to extend the depth to 6th radiation length with four available detector plane.

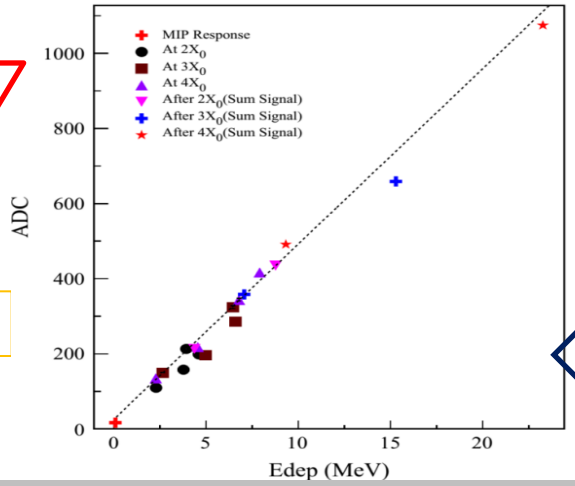
Mini-Prototype: Development and Test.





Response of Pion to understand the MIP behavior

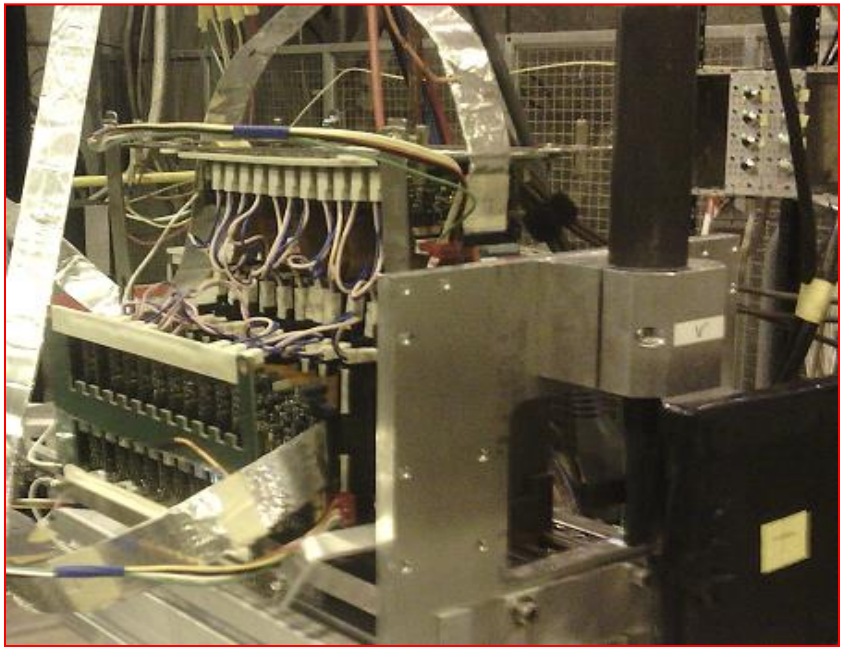
E_{dep} by EM-Shower initiated by electron within prototype



Conversion Curve Expt Vs Simulation

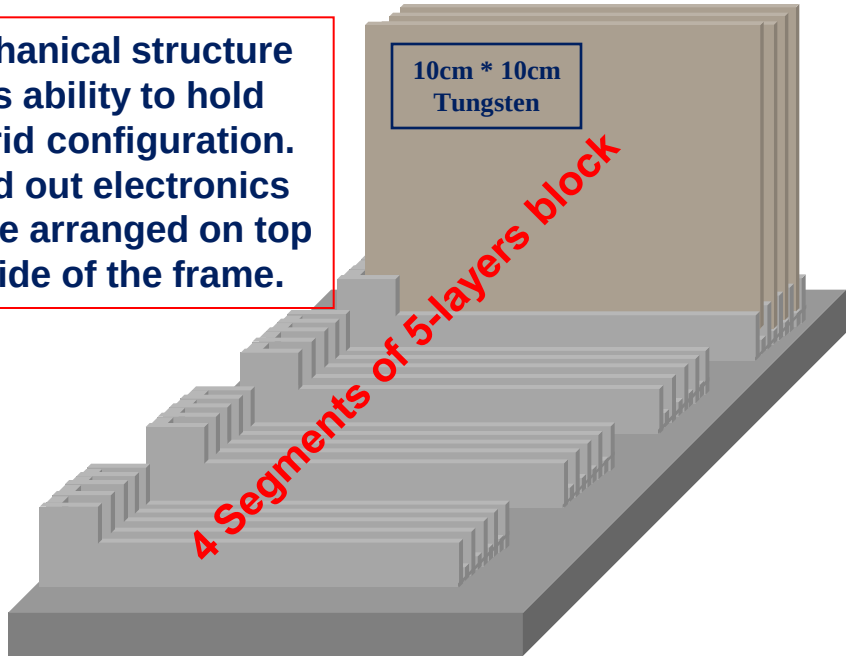
SM et all, NIMA A764 (2014) 24-29

Full-Length Prototype: Fabrication and Characterization

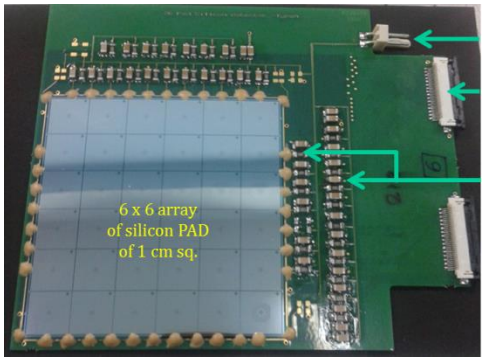


19-Layer prototype calorimeter at SPS

Mechanical structure has ability to hold Hybrid configuration. Read out electronics can be arranged on top or side of the frame.

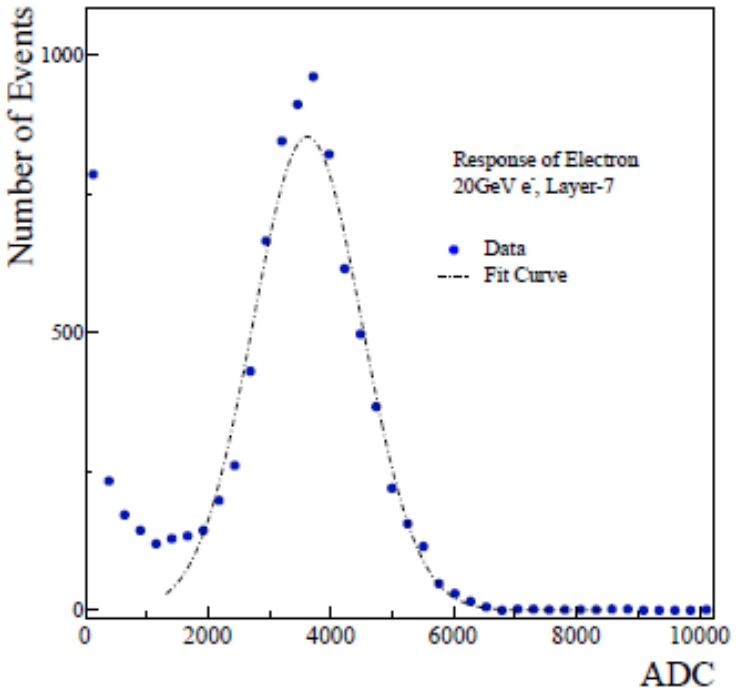


6*6 array of 1cm*1cm Silicon detector on a single wafer

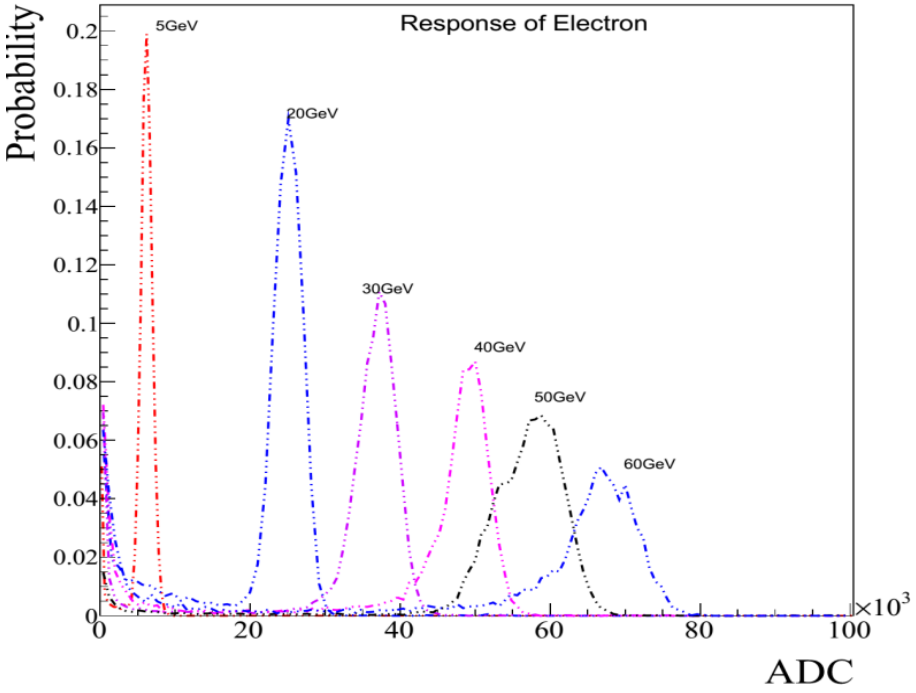


- Break down voltage > 500 Volts
- Leakage current ~ 10nA/cm2
- Capacitance at full depletion ~40pF/cm2
- Full depletion voltage 40 volts
- Dead space b/w 1 cm^2 pads ~ 110um
- Cross Talk probability ~ 10%
- Depletion width ~ 300um

Full-Length Prototype: Fabrication and Characterization

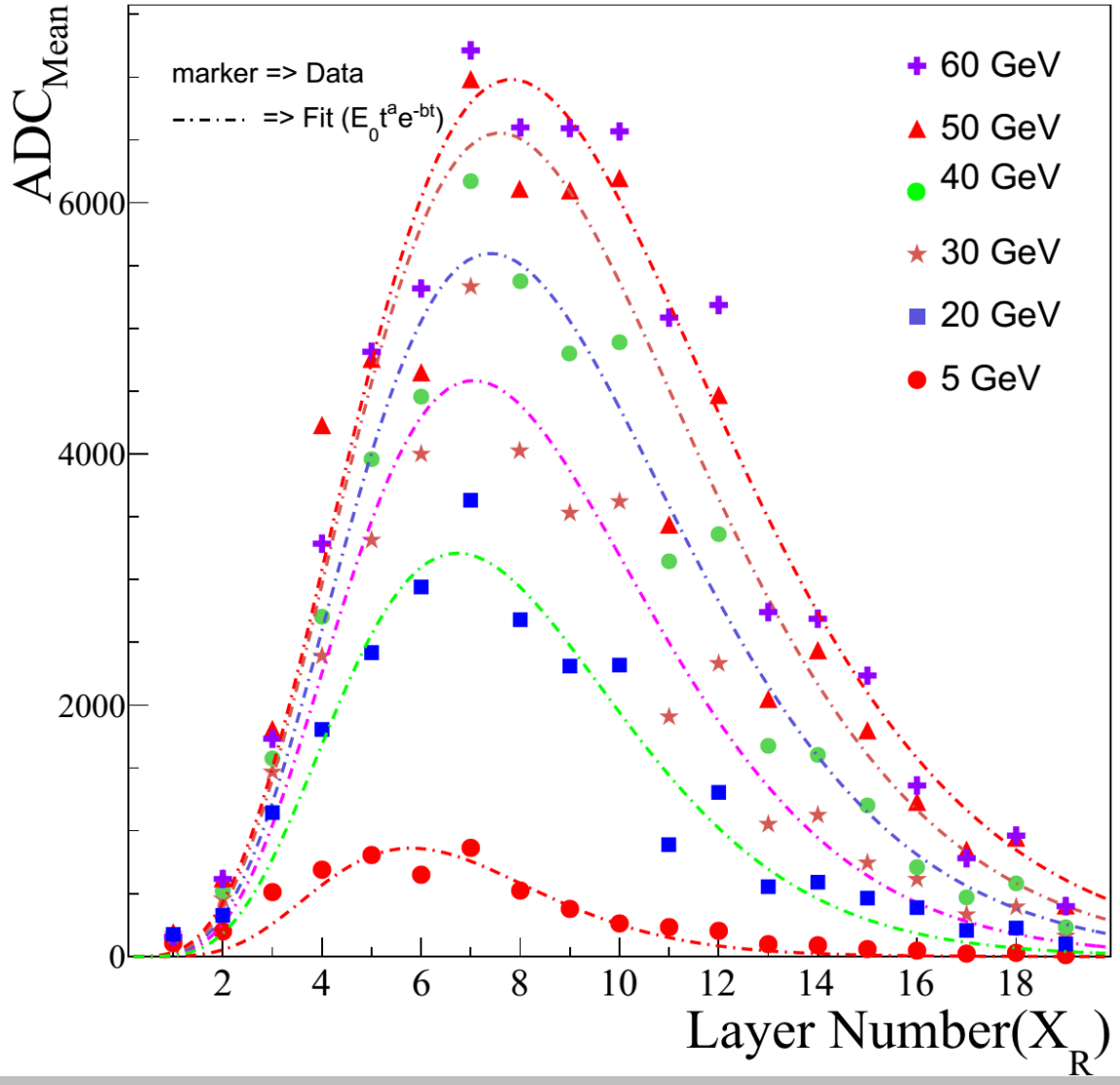


Response of Layer-no-07 of the full-length FOCAL prototype to 20 GeV Electron (Shower). Showed a nicely developed shower with mean ADC 3616.



Reconstruction of energy (ADC) deposited by EM-Shower (electron) within the full depth of the prototype calorimeter for different incident energies.

Full-Length Prototype: Fabrication and Characterization

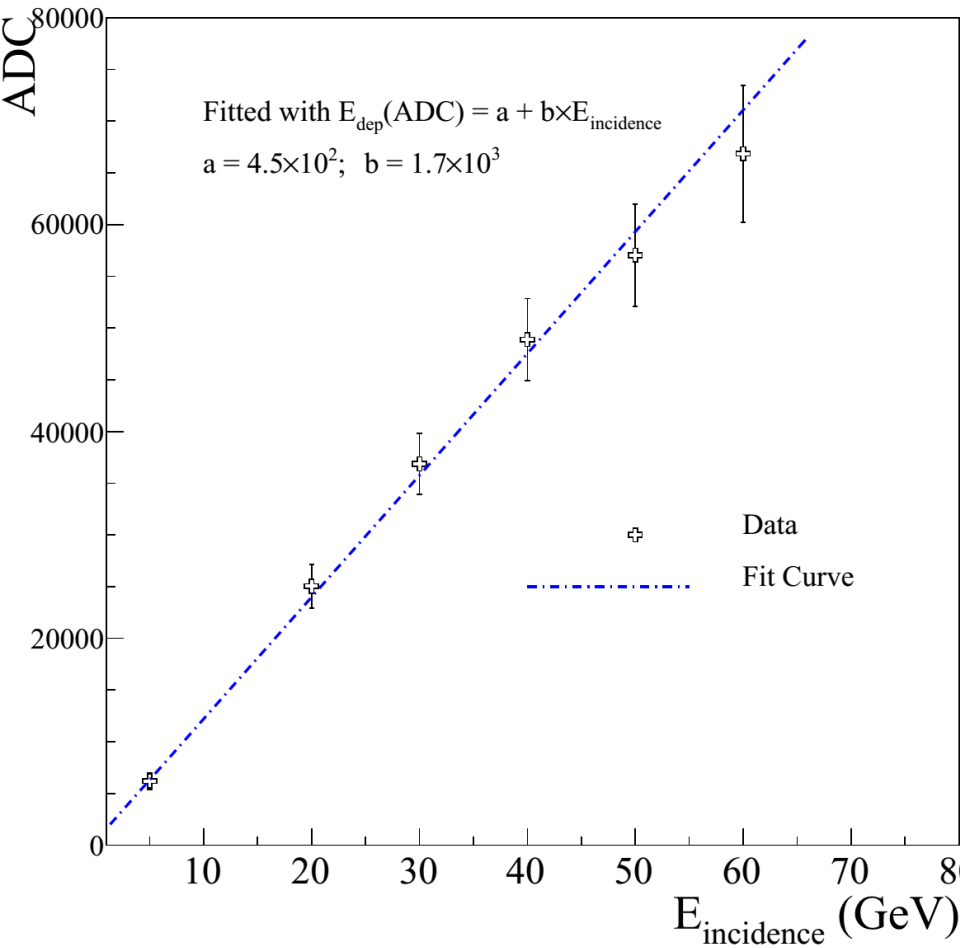


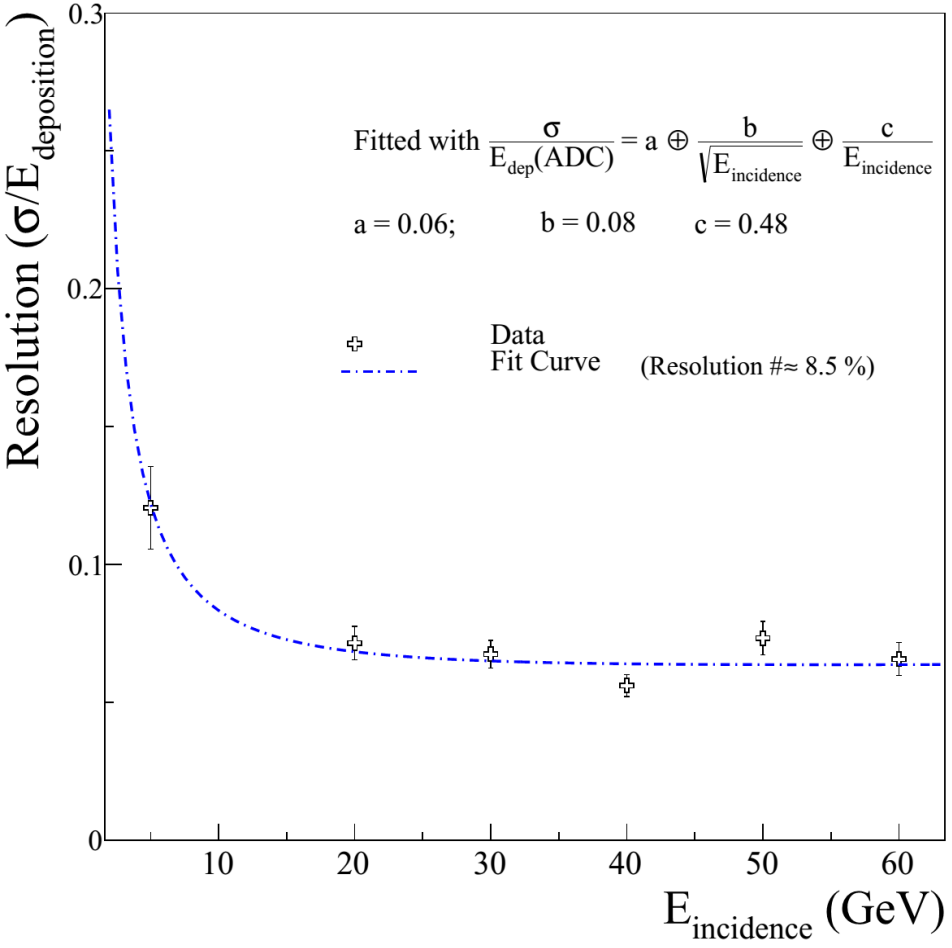
$$\frac{dE}{dt} = \frac{E_0 \beta (\beta t)^{(\alpha-1)} e^{-\beta t}}{\Gamma(\alpha)} \approx E_0 (t)^{\alpha} e^{-\beta t}$$

Secondary particle generation at smaller depth

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

Full-Length Prototype: Fabrication and Characterization





Calibration of measured ADC with respect to incident energy. Found good linearity for range od incident energy probed.

Energy Resolution can be expressed as

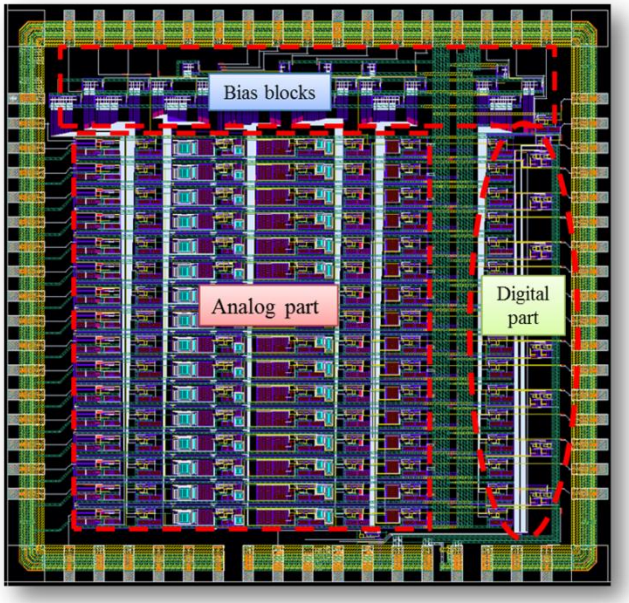
$$\frac{\sigma}{E} = a + \frac{b}{\sqrt{E}} + \frac{c}{E} + \vartheta(E)$$

Summarizing:

- ✓ An exhaustive geometry and physics simulation performed.
- ✓ A mini-prototype test has been done: A proof for the concept.
- ✓ Full depth prototype characterization was done experimentally.
- ✓ Satisfactory calorimeter performances confirmed.

Outlook

- ✓ Saturation effect seen.
- ✓ NEW ASIC ANU-INDRA is ready. Test results are satisfactory at laboratory test.
- ✓ Target: Test of full-depth prototype with the upgraded electronics, May- 2017.



Saturation (signal) Effects: Well taken with large dynamic range (~2.6 pC) compare to previous one (~600fC).

Acknowledgement

Department of Atomic Energy, Govt. Of India.

For **Financial and Technical support in carrying on the R&D.**

Thanks

Time-Line , Budget and Indian contribution for FOCAL R&D

- **First half 2017**: LOI discussion/approval in LHCC.
- **2017-2019:** Converge on realistic design.
- R&D in pixel/pad sensors & readout.

- **2019-2020:** Finalise design
- **2021-2024:** Construction of FOCAL.
- *Test and Installation in ALICE*
- DAQ, DCS , DQM, Analysis software development.

Time-Line , Budget and Indian contribution for FOCAL R&D

COMPONENTS	COST (kCHF)
TUNGSTEN	700
UNIT MECHANICS	500
SILICON SENSORS (PADS)	3100
PAD ELECTRONICS	300
MAPS + ELECTRONICS	1250
CABLES AND CONNECTIONS	200
SUPPORT AND INTEGRATION	1200
COOLING	600
TOTAL DETECTOR COST	7850

~ 60 Cr INR

For Next 3 Years

- R&D on silicon detectors, electronics, integration and manpower
- Possibly construction of Mini-FOCAL as final prototype

For Coming 3 Years
5 Cr INR

India will contribute

- ✓ Half of PAD detectors and associated electronics
- ✓ 1/3 of tungten, mechanics , cables and connections, support and cooling

Institute	Country
Variable Energy Cyclotron Centre, Kolkata	INDIA
Bhabha Atomic Research Centre, Mumbai	INDIA
Nikhef, Amsterdam	Netherlands
Utrecht University, Utrecht	Netherlands
University of Tsukuba, Tsukuba	JAPAN
Center of Nuclear Study, Tokyo	JAPAN
Hiroshima University, Hiroshima	JAPAN
Tsukuba University of Technology, Tsukuba	JAPAN
Nagasaki Inst. Of Applied Science, Nagasaki	JAPAN
Institutes showed Interests	
Universidade de Sao Paulo, Sao Paulo	Brazil
Oak Ridge National Laboratory, Oak Ridge	USA
Jammu University, Jammu	INDIA
IITB, Mumbai	INDIA
IITI, Indore	INDIA
Czech Technical University of Prague, Prague	Czech Republic
University of Jyvaskyla, Jyvaskyla	Finland
University of Texas, Knoxville	USA
Wayne State University, Detroit	USA
University of Bergen, Bergen	Norway

Si-Pad Detectors and Large Dynamic range ASIC.

Si-Pixel Detectors (MAPS).

Si-Pad Detectors. Layer added options

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Thanks a lot for your SUPPORT