Prospects of the EIC India group

Shuddha

On behalf of

EIC India group

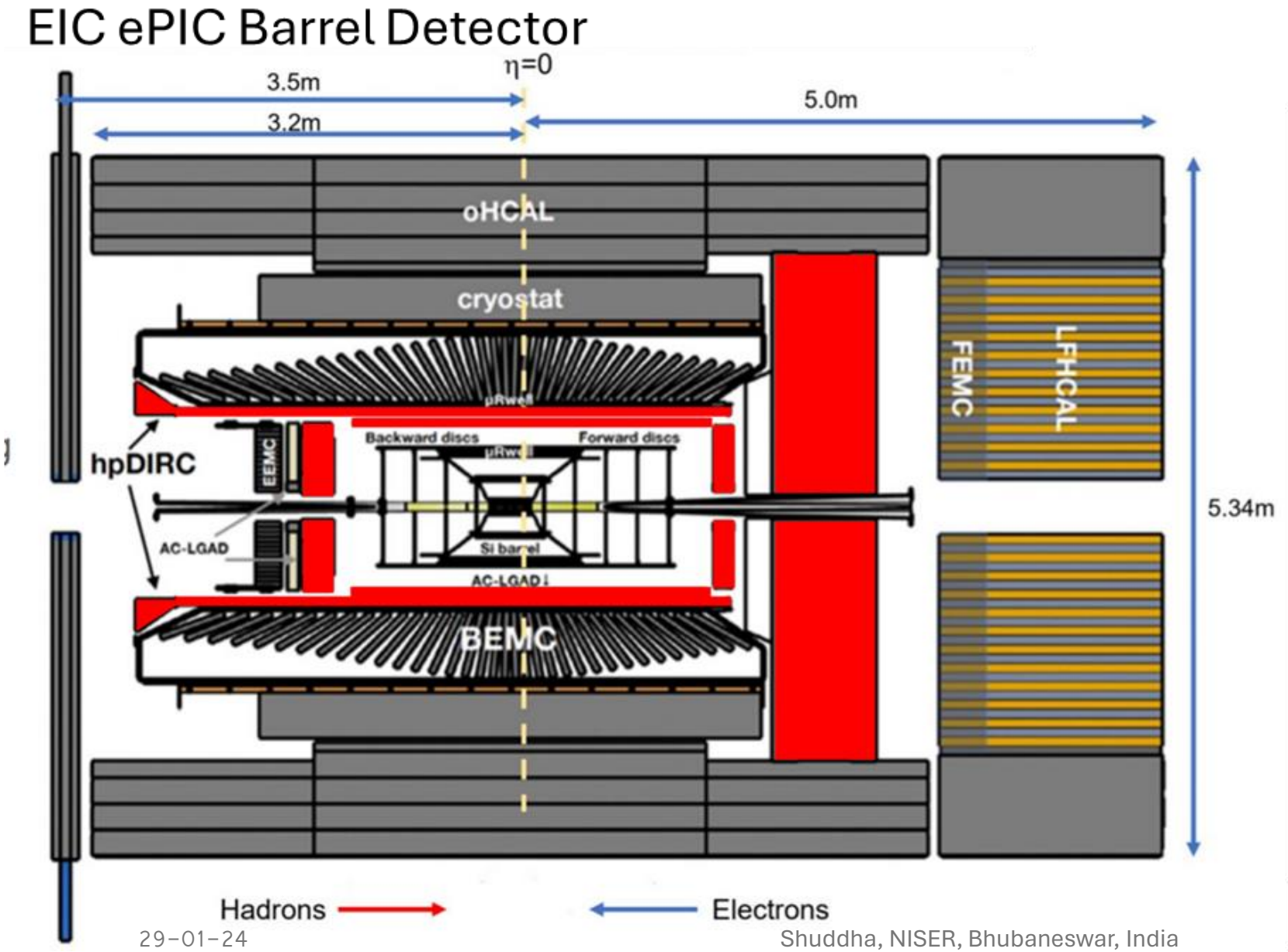
Outline

- EIC India Collaboration and interest
- RICH (Radiator Studies and SiPM)
- Calorimeter experience
- AC – LGAD test setup
- Software Interests
- Conclusion

Indian Institutes interested in ePIC at EIC

- 18 Institutes from all around India have shown interest. Two more are willing to join.
- Interests in hardware as well as in software activities.
  - **PID.**
  - **Calorimeter.**
  - **ToF.**
  - **Simulation studies.**

Indian Interest in ePIC



- Calorimetry
- Particle ID
  - ToF: LGAD
  - dRICH: Radiator characterization and SiPMs
- DAQ/DCS and Slow Control Software
- Simulation studies

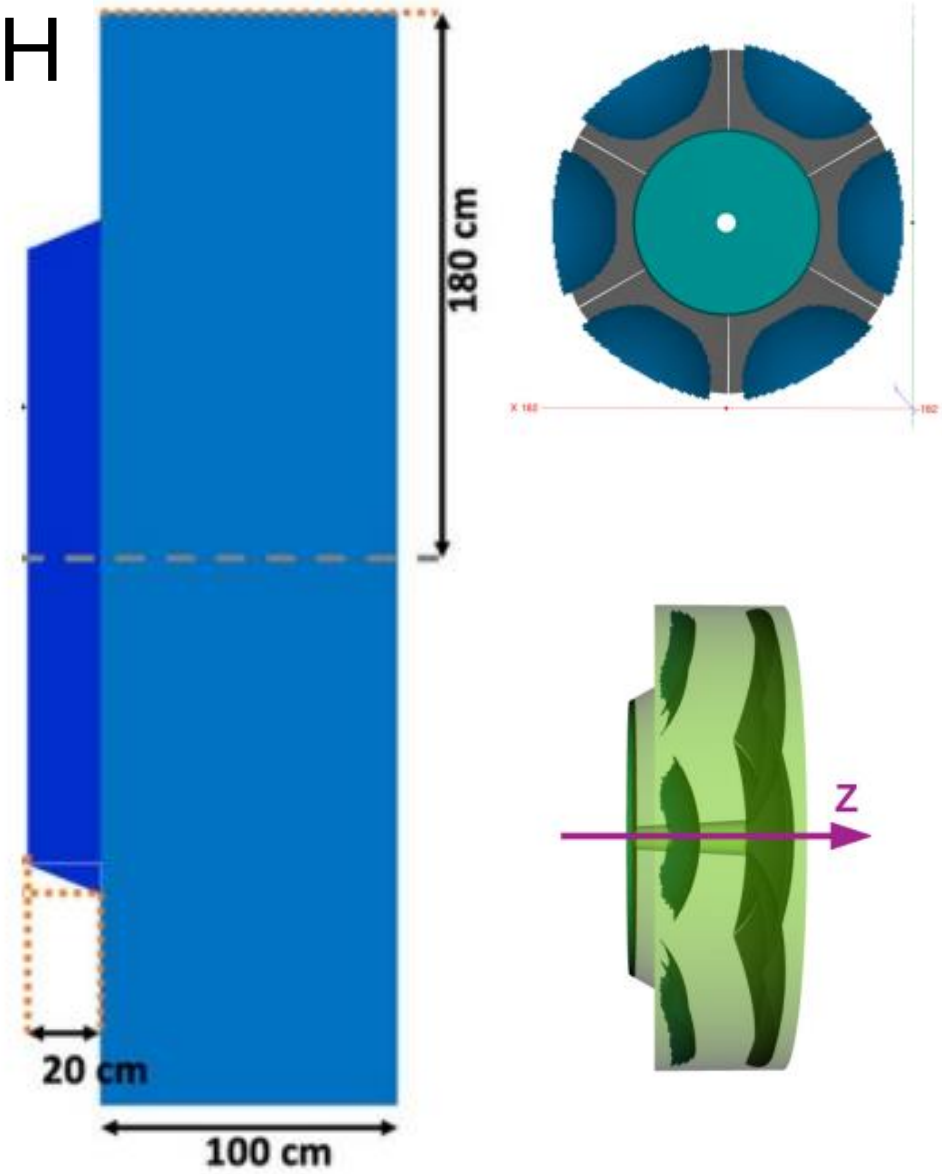
dRICH Requirements

- **Requirements**
  - **Wide acceptance:** $(1.5 < |\eta| \leq 3.5)$
  - **High momentum coverage: upto** $50\ GeV/c$ $\pi - K$ separation.
  - **Dual Radiator RICH: (Aerogel n~1.02 + C_2F_6 gas n~1.0008)**
- **Large photo sensor surface to be covered in magnetic field.**
  - **Choice of Photo Sensor is SiPMs due to more number of detected photons.**

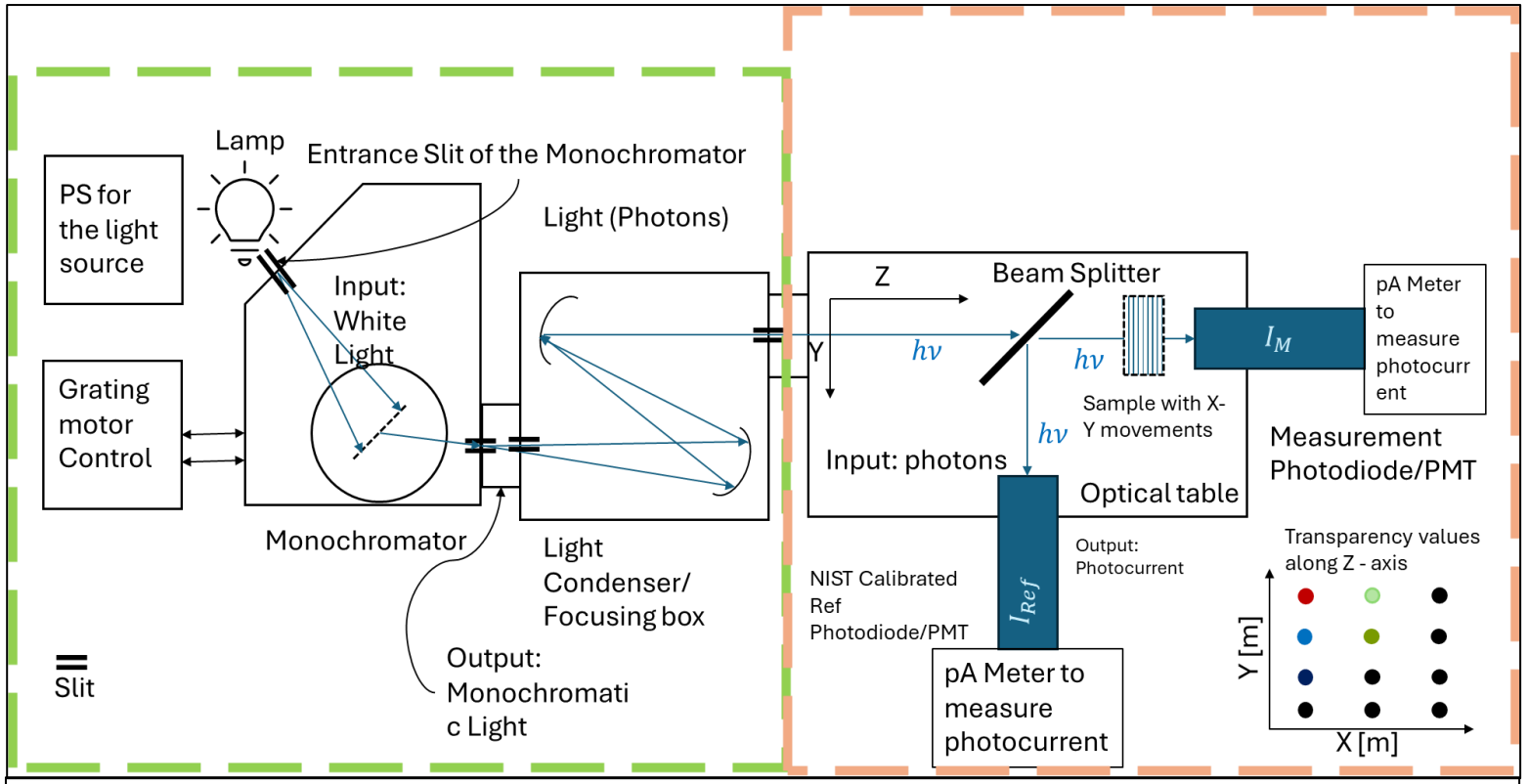
Our Interests

1. **Aerogel characterization**
   - I. **Study of refractive index uniformity.**
   - II. **Transmittance and reflectance studies.**
   - III. Raleigh scattering in UV domain, chromaticity.
   - IV. Aging effects due to water absorption: difference in response between different size and thickness of aerogel blocks.
2. **SiPM characterizations**
   - I. **PDE (normal value ~ 40%).**
   - II. **Dark count Suppression.**
   - III. Timing studies.
3. **Simulation studies.**

dRICH



Typical Aerogel Characterization Setup



Transparency is the ratio of photocurrents with and without the object between the beam splitter and measurement detector ratio.

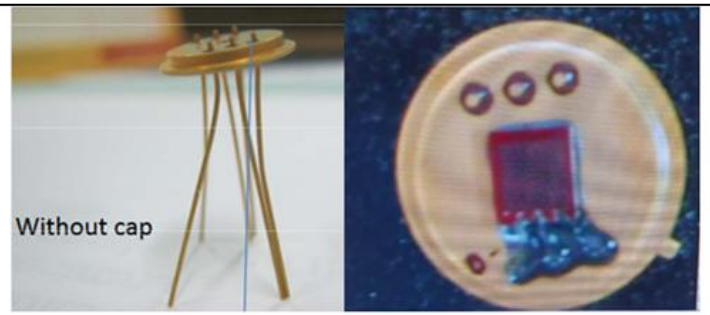
$$Transparency = \left[\frac{\{(I_M - I_{MDC})/(I_{Ref} - I_{RefDC})\}_{With\ Obj}}{\{(I_M - I_{MDC})/(I_{Ref} - I_{RefDC})\}_{WO\ Obj}}\right] \times 100\%$$

- This setup has synergies with ALICE3 pfRICH Aerogel characterization activities.
- Setup is ongoing. It will be ready in the 1.5-year timeline.

SiPMs in India

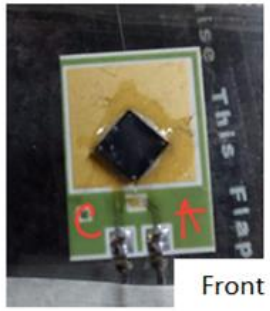
Two semiconductor fabs in India

- Semiconductor Lab (SCL) in Chandigarh, Punjab
- Bharat Electronics Ltd. (BEL) in Bengaluru, Karnataka

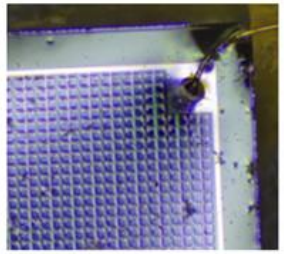


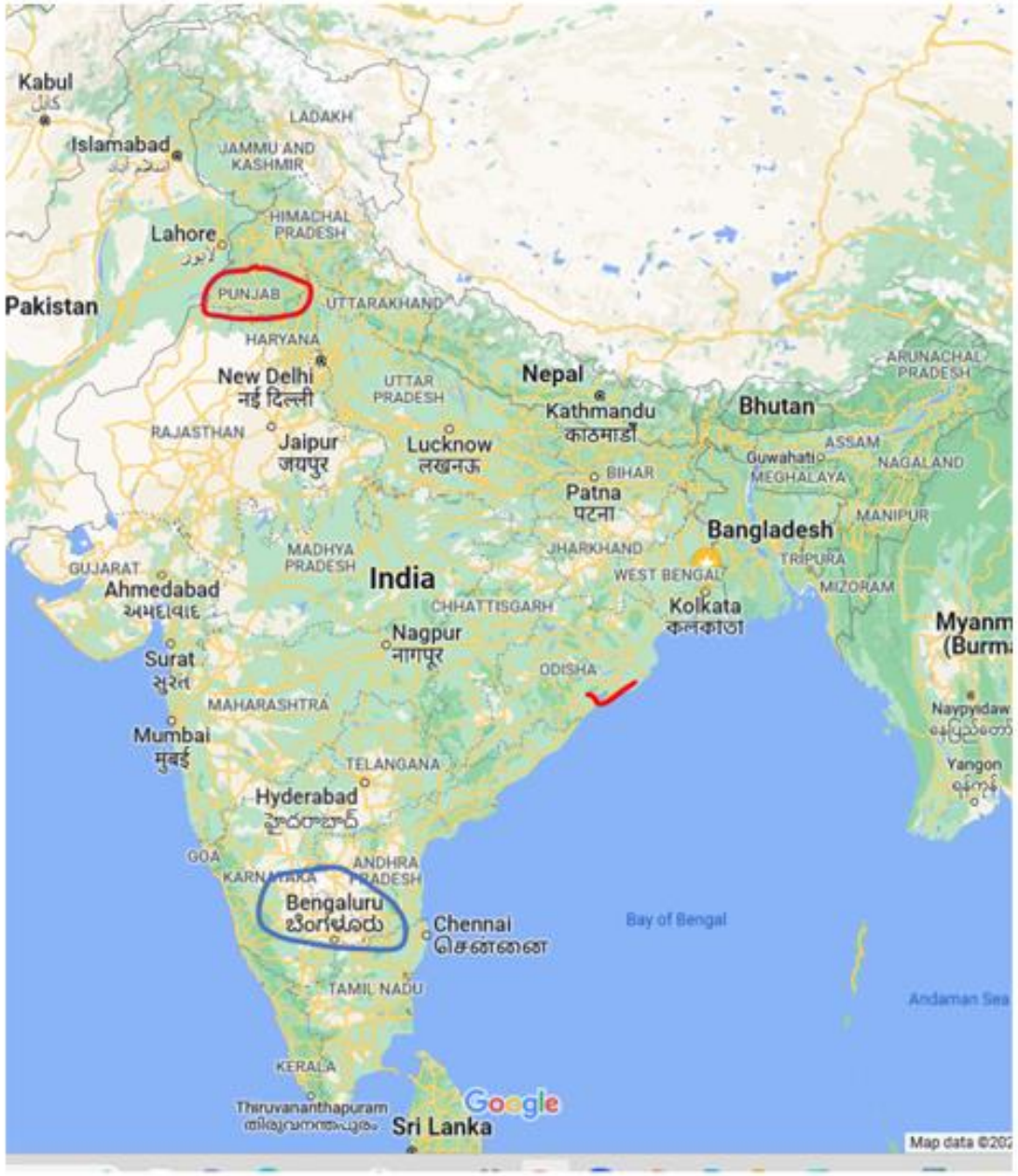
SCL sample
(epi., p-type)

Not to scale



BEL sample:
(Non-epi, n-type)





SiPMs in India

Sr. No	Parameter (targeted by design)	Specifications		
		BARC/SCL	SCL	BEL
1	Effective active area (mm^2)	1.5 x 1.5 & 3 x3	1.5 x 1.5	3.3 x 3.3
2	Micro-cell count	676 & 2704	1156	4836
3	Micro-cell size	50 x 50 μm^2	35 x 35 μm^2	
4	Micro-cell fill factor	20% & 75%	61%	55%
5	Capacitance (Cathode - anode)	1000 pF	~330 pF	~100pF/cell and (500 pF @25.5V)
6	Recharge time constant	120 ns – 150 ns	-	-
7	Spectral response range	350 nm – 900 nm	-	350 nm – 900 nm
8	Peak sensitivity wavelength	~ 500 nm	-	420 – 450 nm
9	Photon detection efficiency	-	-	-
10	Breakdown voltage (V_{BD})	22 V	18 V	23 V
11	Overvoltage range (OV)	2 V – 3 V	2.5 V	2 V – 5 V
12	Dark count rate	~ 500 kHz (@ V_{BD}+2.0 V and 0.5 p.e. thr.	20 Hz/ μm^2 at 1V OV	-
13	Gain	2 x 10^6 @ V_{BD}+1V	~ 10^6	~5.2 x 10^5 @V_{BD}+2V
14	V_{BR} temp. coefficient	20.0 mV/°C	15.0 mV/°C	-
15	Package type	LCC* 16, 20 pin	TO-8/6 pin	On PCB
16	Package dimension	~ 3.5 x 3.5 mm^2		
17	Dark current	< 5 nA/cm^2 @ 20V	< 10 nA/cm^2	-
18	Quenching resistor (R_q)	300-500 kΩ	360 kΩ	R_{sq} = 6.6 kΩ and R_q = ~ 32 MΩ
19	Cross-talk	< 5 % @V_{BD}+2.0 V	-	-

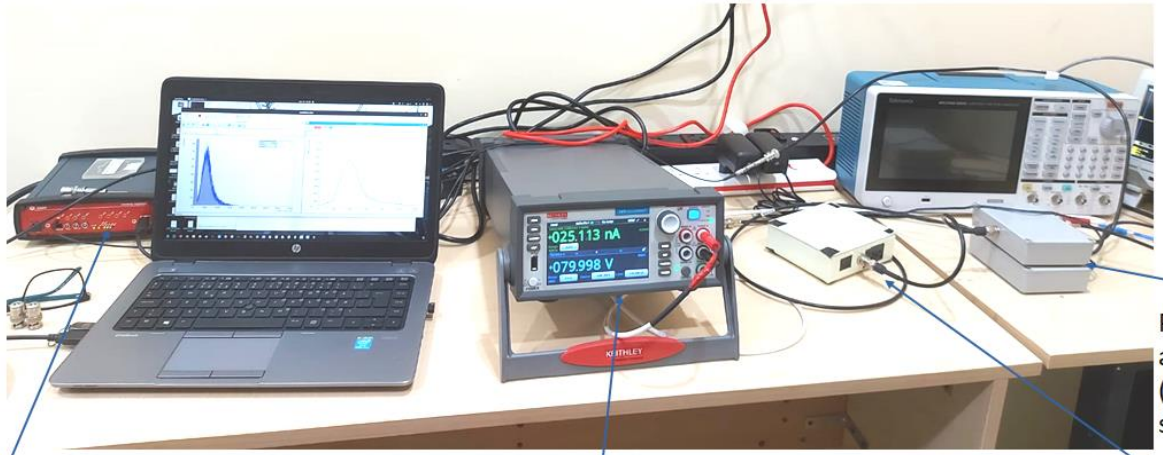
*Lead-Less Chip Carriers (LCC)

Sl No.	Sensitive area – 3 $mm \times 3$ mm, Pixel size – 50 $\mu m \times 50$ μm		
	Properties	On Semiconductor C – Series 30050	SCL Sample
1	Breakdown Voltage	24.2 V	22.0 V
2	No of Pixels	2668	2704
3	Fill factor	72%	75%
4	Gain	6×10^6 @ $V_{BD} = +2.5\ V$	~2×10^6 @ $V_{BD} = +1.0\ V$
5	Temperature dependence of V_{BD}	21.5 $mV/°C$	20.0 $mV/°C$
6	Capacitance (Cathode - Anode)	920 pF	1000 pF
7	Dark count rate	@ $V_{BD} = +2.5\ V$ Typ. 300 kHz	@ $V_{BD} = +2.0\ V$ Typ. 500 kHz
8	Cross Talk	@ $V_{BD} = +2.5\ V$ 10%	@ $V_{BD} = +2.0\ V < 5\%$

- Specifications are similar to some commercially available SiPMs

SiPM test setup at NISER

Test setup @ NISER: Few channels



Preamp (cremat 110) and Shaping amplifier (cremat 200) with shaping time 100 ns

CAEN Digitizer (DT5730) 8 ch, 14 bit resolution, 500 MS/s sampling rate, 2Vpp dynamic range With DPP firmware

Detector bias supply (Keithley 2470 SMU)

SiPM inside the detector box

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LED Driver available at NISER

SP5601

LED Driver

Request a quote

Manual Downloads

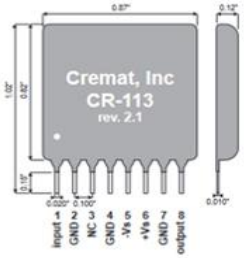
Features

- Pulse width: 8 ns
- LED color: violet (400 nm) 1500 mcd
- Pulse generator: internal/external
- Optical output connectors: FC
- Optical fiber included
- Dimension: 79 x 42 x 102 mm³ (WxHxD

- Cremat fast preamp order in process

Detector coupling

The CR-113-R2.1 can be used either in a direct coupled (DC) mode or an AC coupled mode. If the detector current exceeds



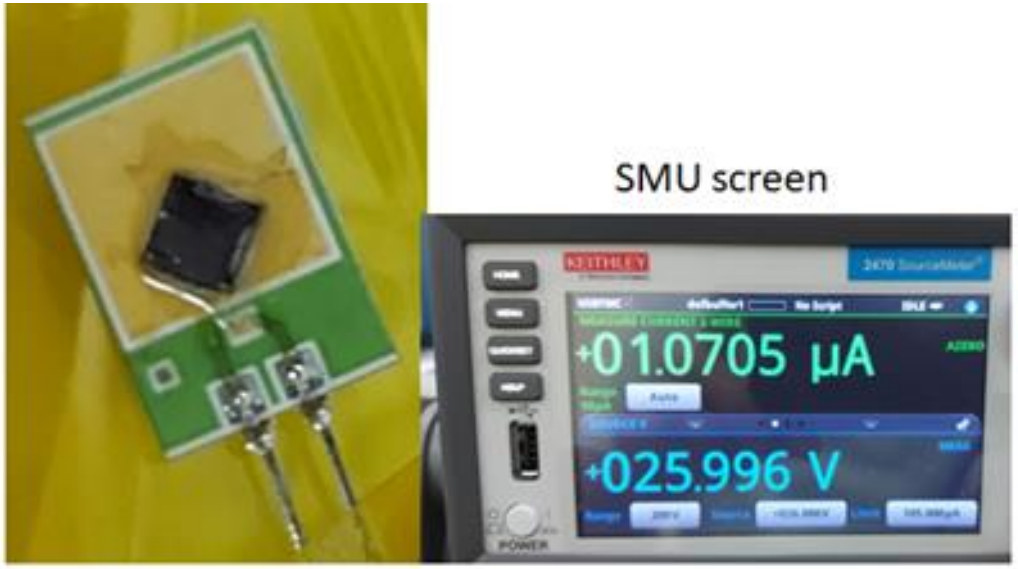
CAEN PETIROC based DAQ

- PETIROC-based test setup is at NISER
- CITIROC DAQ is under procurement

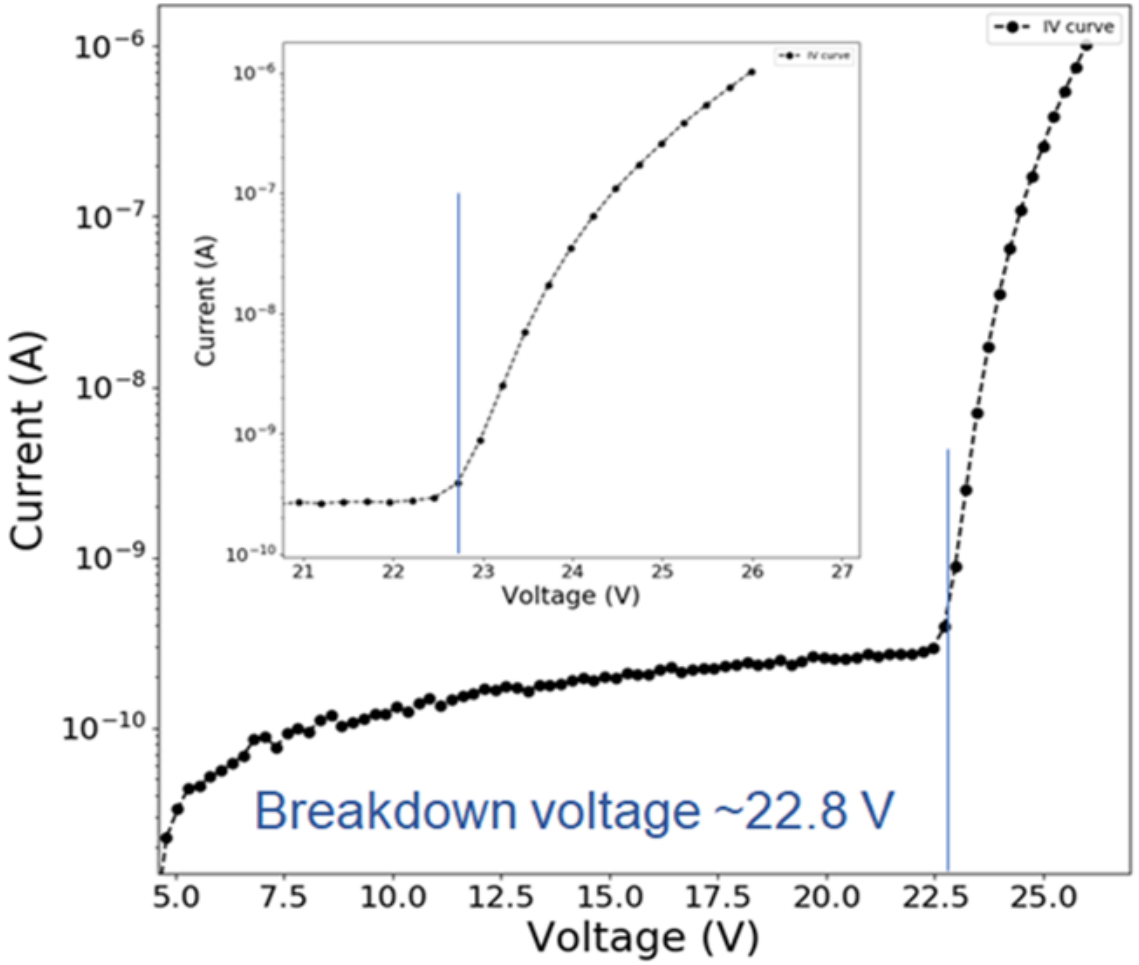
SiPM test results:

BEL Sample

- SiPM fabricated in CMOS 180 nm process
- SiPM was mounted on DIP package
  - Pixel size: $35 \times 35\ \mu m^2$;
  - Effective area: $3 \times 3\ mm^2$;
  - No. Of Cells: 4836;
  - Fill Factor: 55%; and
  - Breakdown voltage: $\sim 23\ V$;



- Connected in Reverse bias mode
- Reverse voltage applied using Keithley 2470
  - Sweep: 0 to 26 V with (0.25 V step)

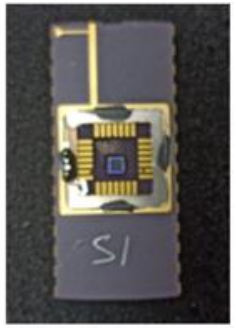


SiPM test results:

SCL Sample

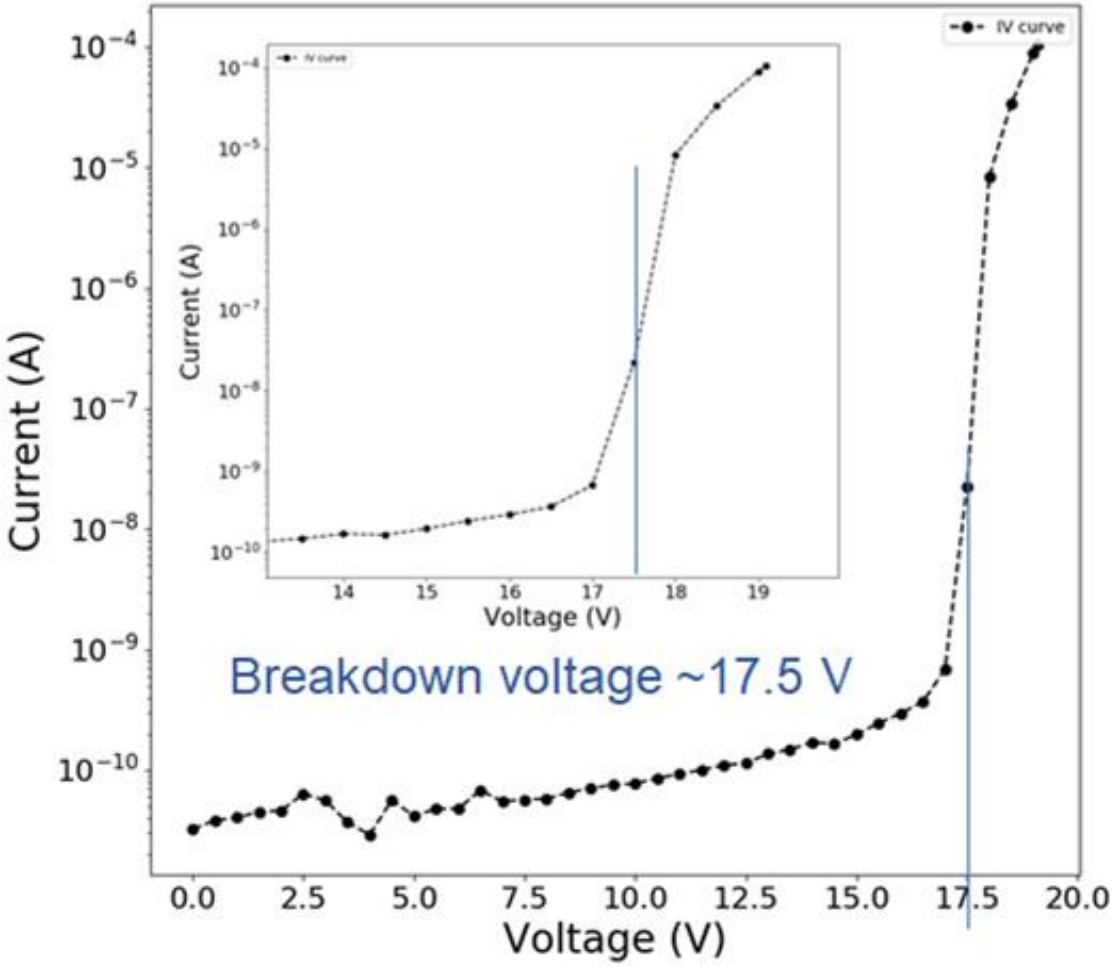
- SiPM fabricated in CMOS 180 nm process
- SiPM was mounted on DIP package
  - Pixel size: $35 \times 35\ \mu m^2$;
  - Effective area: $1.5 \times 1.5\ mm^2$;
  - No. Of Cells: 1156;
  - Fill Factor: 61%; and
  - Breakdown voltage: $\sim 17.5\ V$;

SiPM sample on DIP



SMU screen

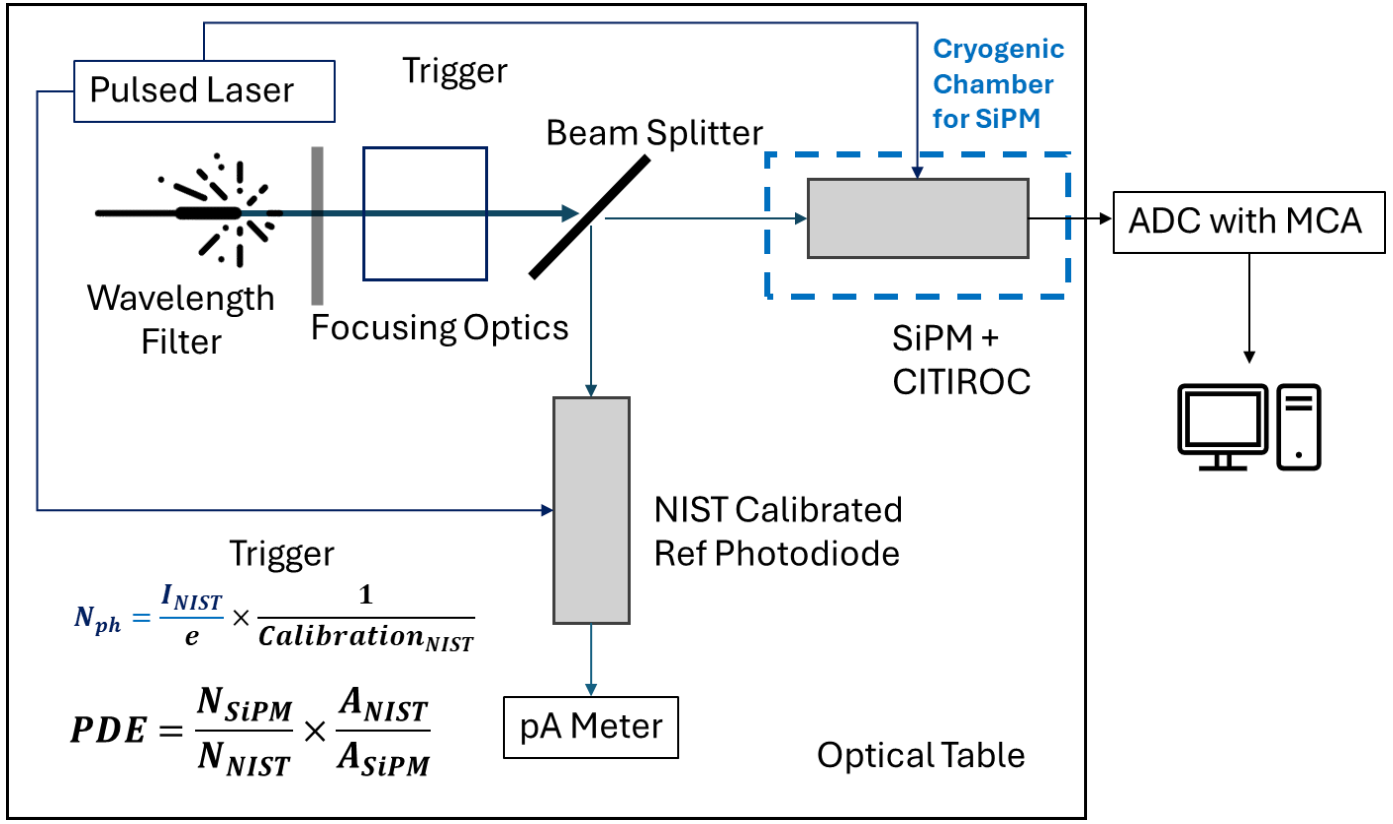
- Connected in Reverse bias mode
- Reverse voltage applied using Keithly 2470
  - Sweep: 0 to 20 V with (0.5 V step)



SiPM in India: Future Setup

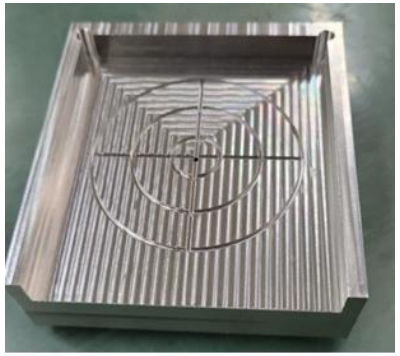
- Photo Detection Efficiency (PDE) measurement setup under preparation.
- New designs and ideas are under way as this work is in synergies with ALICE3 barrel pfRICH activities.

Possible SiPM characterization setup

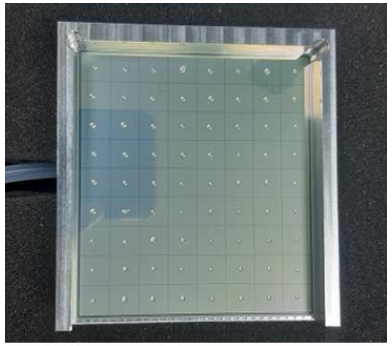


Si PAD Array detector in India

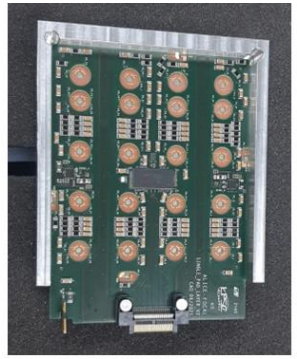
- India is currently part of Alice FOCAL upgrade and developing Si PAD Array detectors.
- Currently n – type 8×9 Si pad arrays are fabricated in BEL, Bengaluru, India and has been tested in the lab and in Test Beam facility at CERN



Jig, holds detector with vacuum



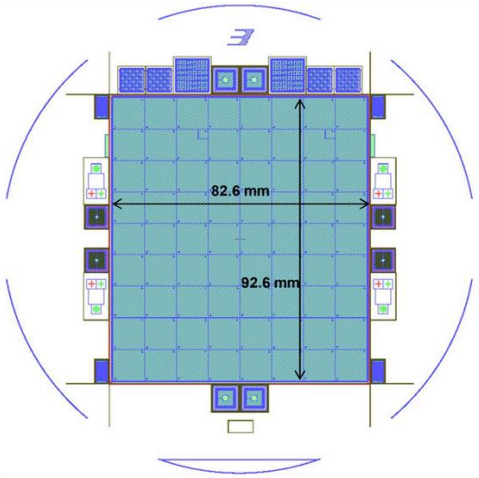
Detector in jig
Then add glue dots at the center of each pad

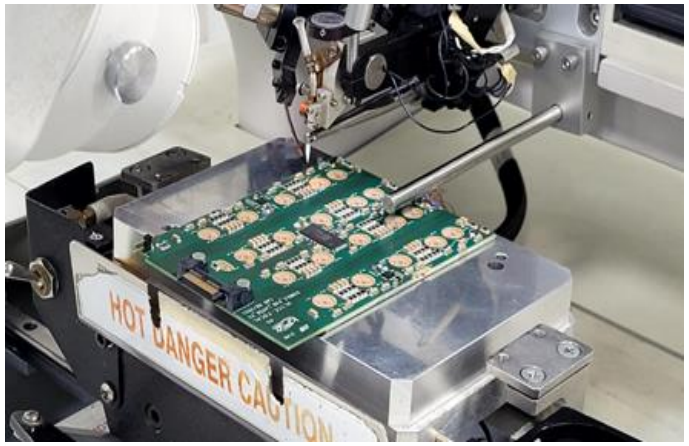


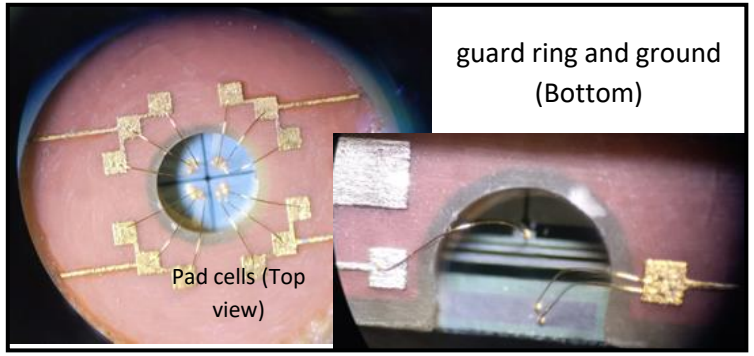
Place PCB on top of the detector and add some weight and keep it overnight

- Wafers glued to PCB
- Used automated wire bonding (~250 wire bonds per detector)
- The jig was kept at 90 degree C while wire bonding

High resistivity (~7kohm.cm), ~325 um thick Si wafer

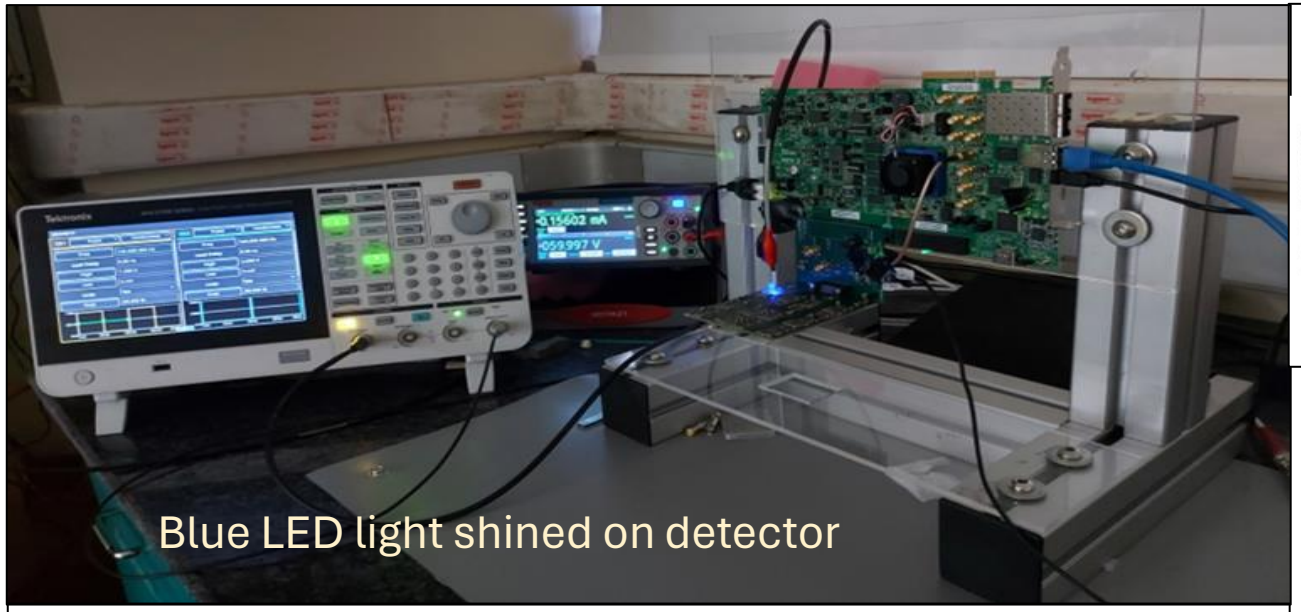


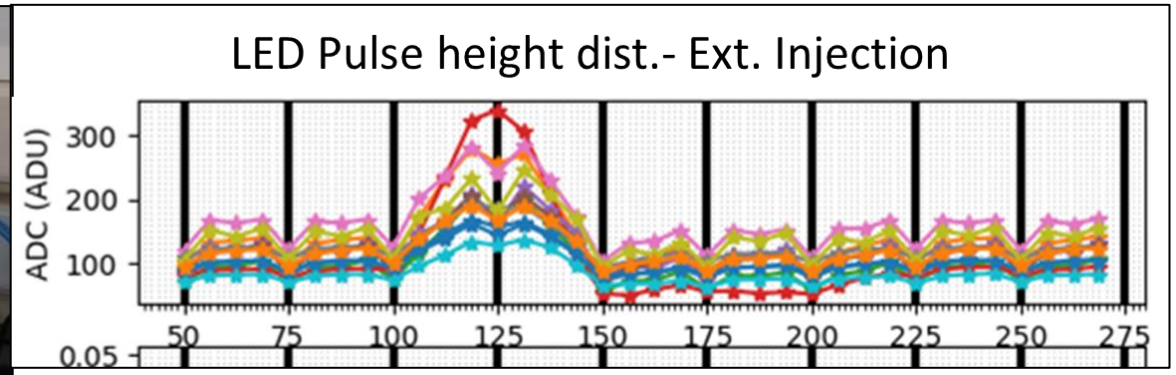




Si pad array detector readout printed circuit board fabricated by Micropack Private Limited, Bangalore, India

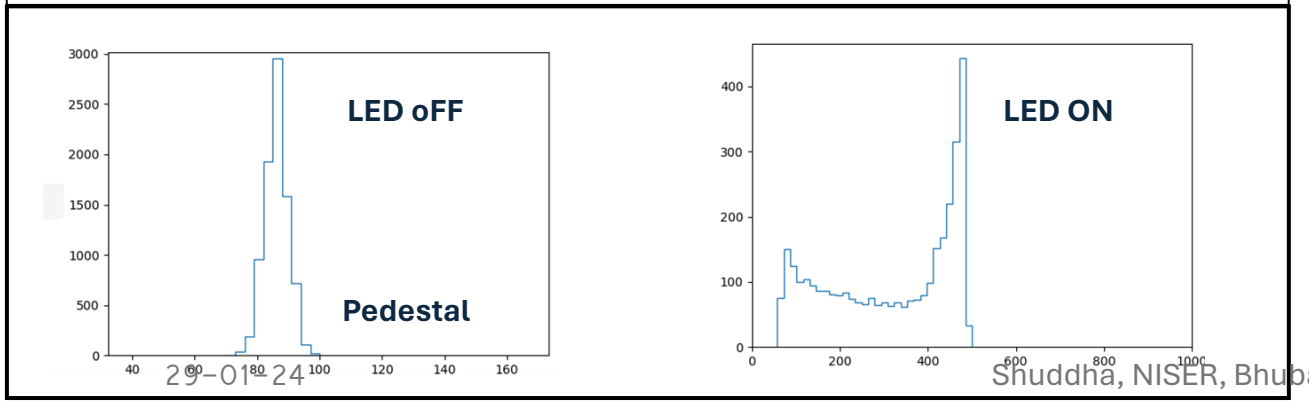
Si PAD Array detector in India: Lab tests at NISER

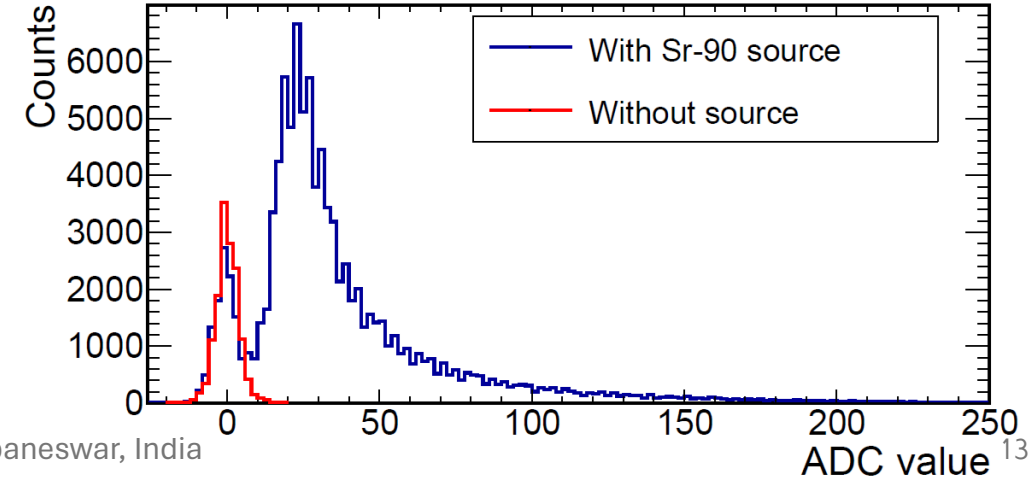




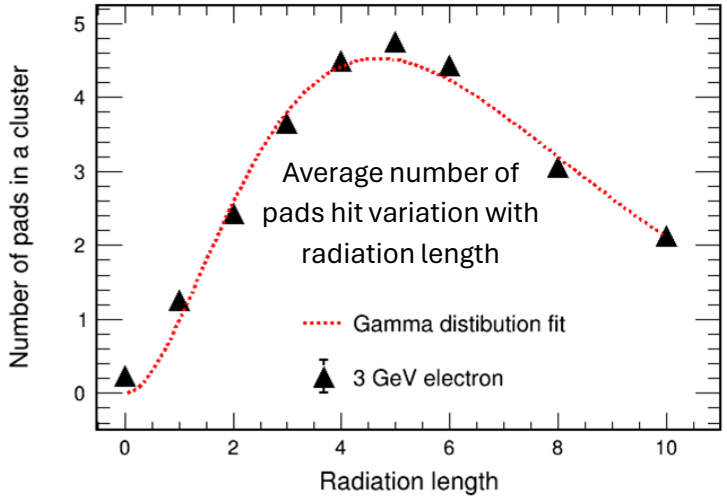
Bias = 75V

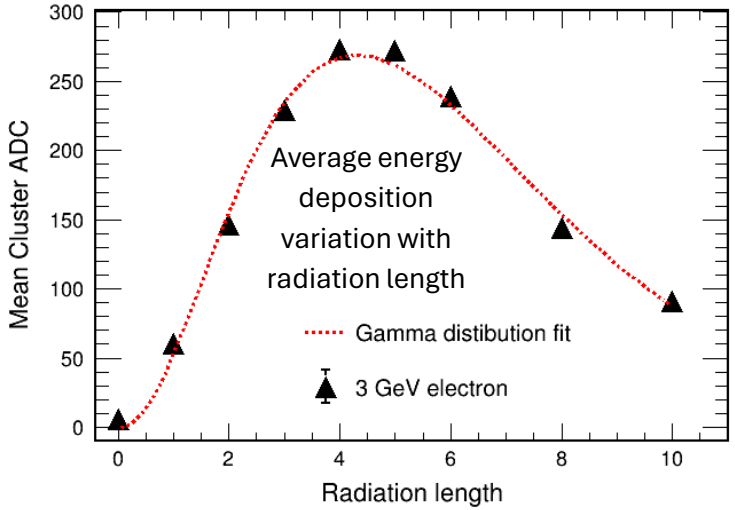
LED pulse amplitude distribution

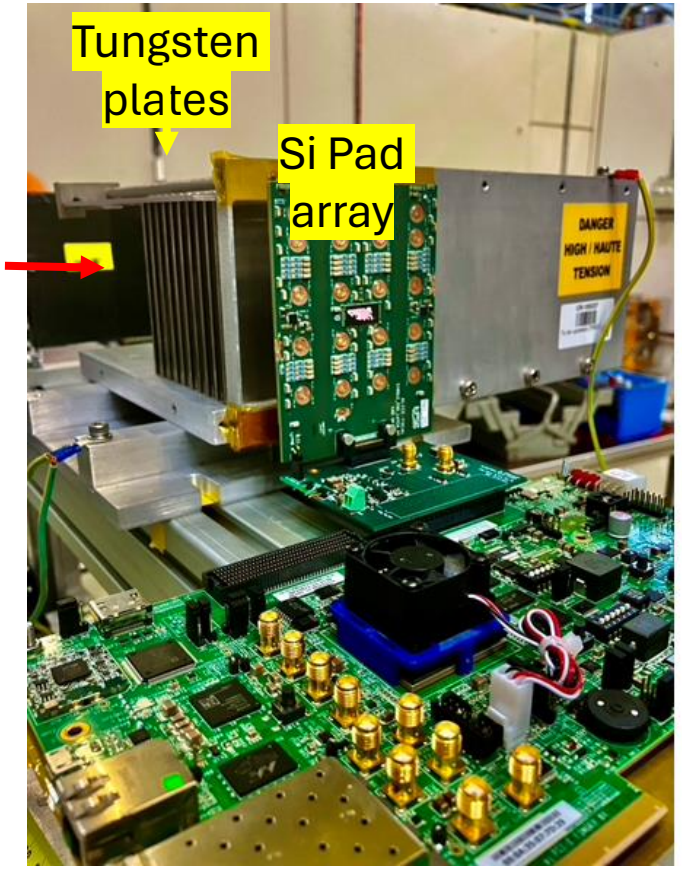




Alice FoCAL test beam at CERN PS T9

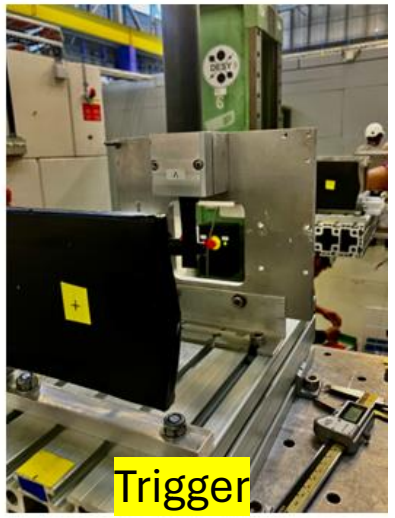


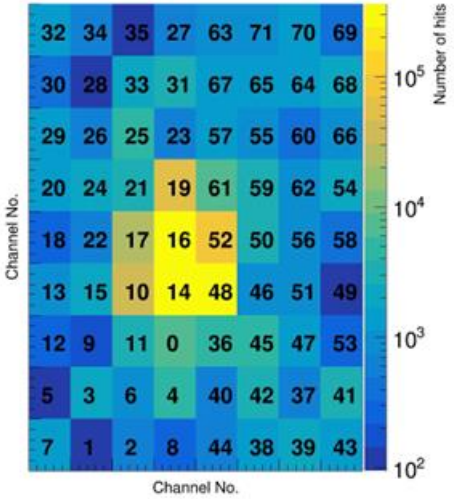




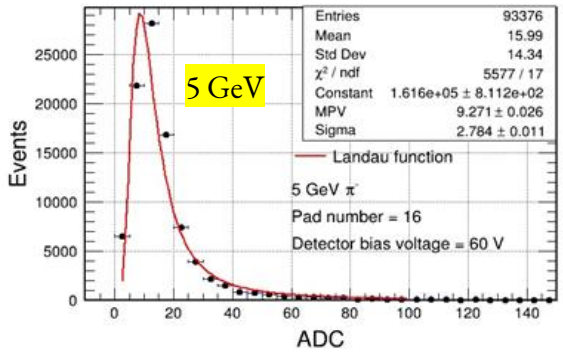
6 days beam time: (11.10.2023 to 18.10.2023)

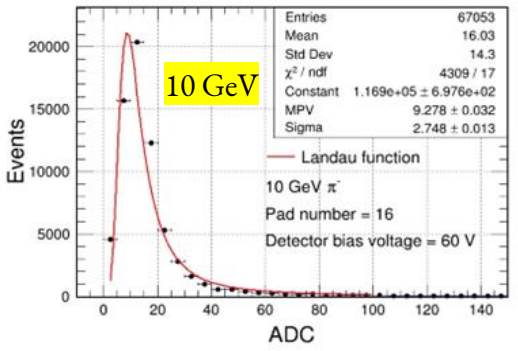
- 5 GeV, 10 GeV and 15 GeV pion(-ve) runs to record MIP response
- Position Scan of each pad element of pad array and Bias voltage scan
- 1- 5 GeV (step of 1) e- beam with Cherenkov trigger 6 to 1 tungsten plates to measure electron

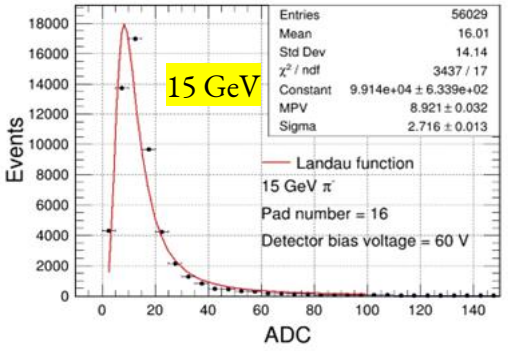




10 GeV pion beam Hit Map



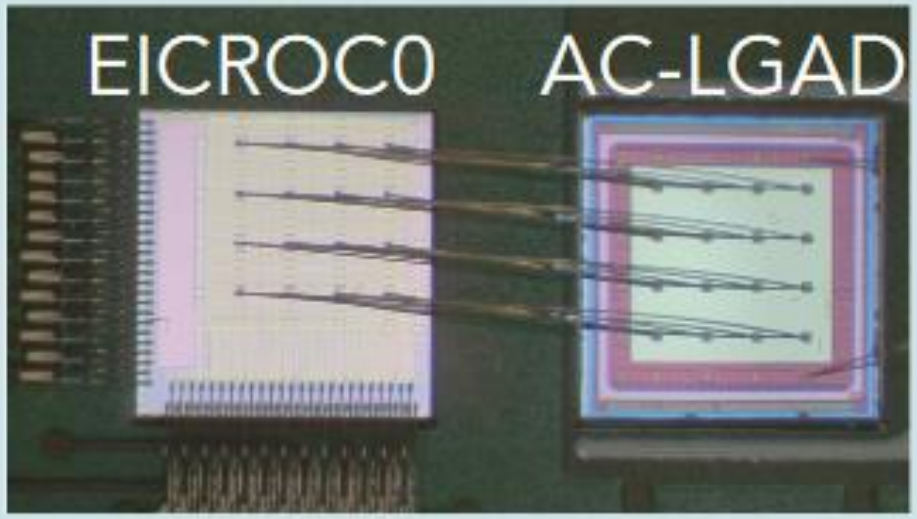




AC – LGADs test setup preparation

- Interested to contribute mostly to test and characterization work of AC-LGADs and readout ASIC (EICROC)
- Plan to purchase test equipment such as,
  - Zynq evaluation board (ZC706), Picosecond laser, high-precision oscilloscope (e.g. LeCroy 9404M-MS 4 GHz, 40 GS/s)
- Earlier experience:
  - SAMPA readout chip for ALICE TPC
  - HGCROCv2 ASIC for ALICE FoCal

Computer ⟺ DAQ board **(Zynq SoC ZC706)** ⟺



DAQ/DCS Slow Control contribution

Crucial input to the DAQ team: Background rates of each detector arising out of various sources.
Used for: Calculating data volumes and corresponding bandwidths

CUK: Estimation of background rates due to synchrotron radiation

Ran simulation for two different setups (with gold and without gold coating) and analyzed the photon and electron counts for a specific beam current.

Results were used in ATHENA white paper to calculate maximum data volumes

Adam, J., et al. *Journal of Instrumentation* 17, P10019 (2022)

Table 7: Maximum data volume by detector.

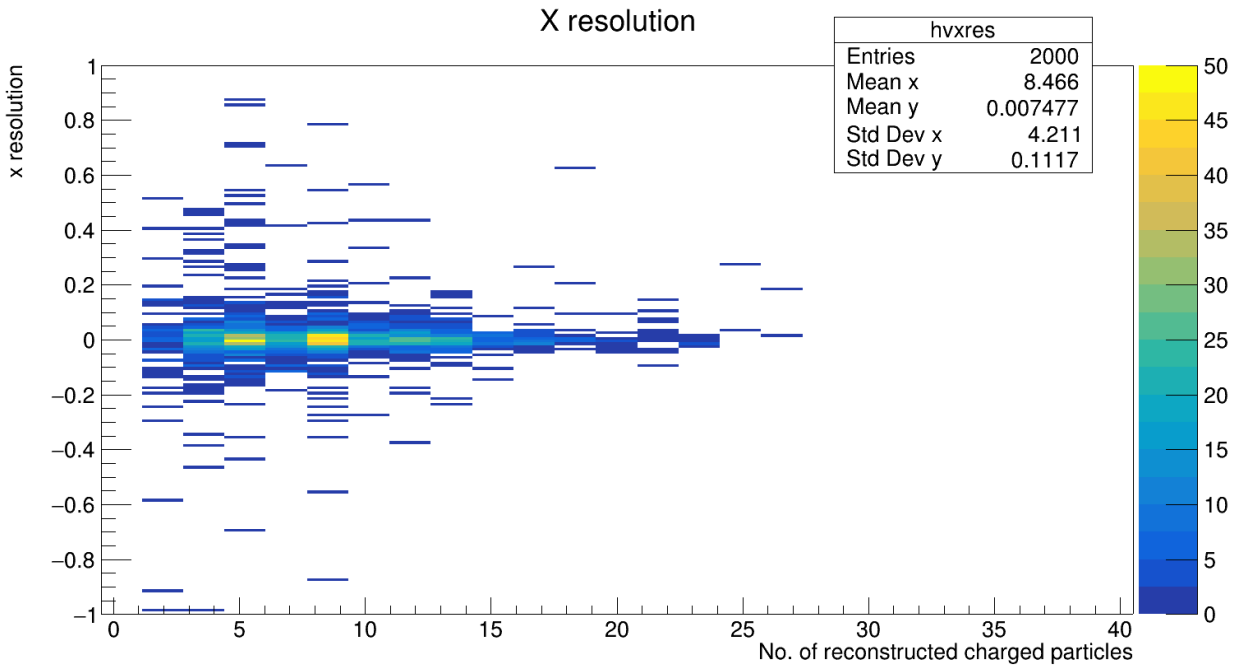
Detector	Channels	DAQ Input (Gbps)	DAQ Output (Gbps)
B0 Si	400M	<1	<1
B0 AC-LGAD	500k	<1	<1
RP+OMD+ZDC	700k	<1	<1
FB Cal	4k	80	1
ECal	34k	5	5
HCal	39k	5.5	5.5
Imaging bECal	619M	4	4
Si Tracking	60B	5	5
Micromegas Tracking	66k	2.6	.6
GEM Tracking	28k	2.4	.5
µRWELL Tracking	50k	2.4	.5
dRICH	300k	1830	14
pfRICH	225k	1380	12
DIRC	100k	11	11
TOF	332k	3	.8
Total		3334	62.9

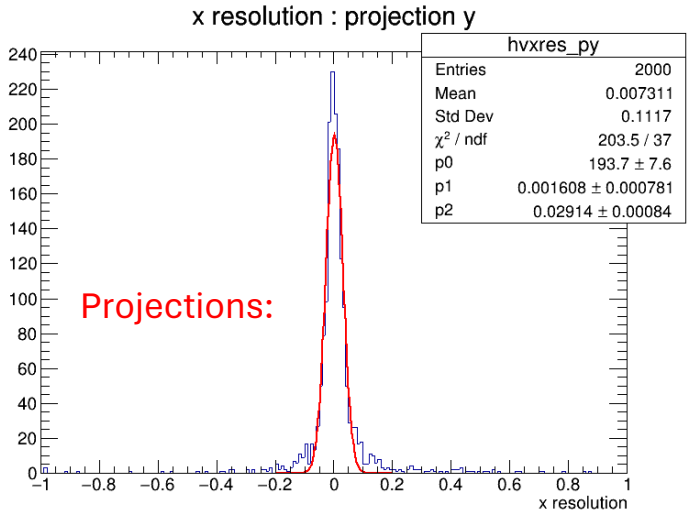
Software/Simulation contribution

Task: Evaluate the vertexing algorithm performance of ePIC

- **Strategy:**
  - Few-track simulation, check single track performances (resolution, efficiency, DCA), then move away from (0,0) in (x,y)
- **Simulation details:**
  - PYTHIA DIS simulation, starting from (0,0,0)
  - Simulated 2000 events:
  - Electron Beam Energy = 18 GeV
  - Proton Beam Energy = 275 GeV
  - $Q^2_{Min} = 10GeV^2$ With Neutral Current

Vertex resolution vs. no. of reconstructed tracks





Work in progress

Suggestions from ePIC management

- **Recently (last week), we received some suggestions from ePIC managements about possible participation topics:**
  - Forward EM Calorimeter.
  - AC – LGAD assembly and test facilities for Forward ToF.
  - dRICH studies.
  - Software for streaming DAQ studies.
- **We are discussing within EIC India about the possible contributions.**

Summary

- Thanks to DAE, DST, and the EIC community for their support.
- EIC India group interests in hardware and software are being defined.
- The funding proposal is in progress.
- The interests are
  - dRICH aerogel characterization
  - SiPM studies for dRICH and Forward EM Calorimeter
  - DAQ/DCS
  - Software and Simulation studies