Perspective on EIC activities in India

Ganesh Tambave
On behalf of EIC-India Group

16.03.2023

EIC-Asia Workshop, RIKEN, Japan

Indian groups participation in HI collision experiments

Active participation in QCD physics experiments:
STAR@RICH, ALICE@LHC, CBM@FAIR and CMS@LHC

Institution	Experiment/Facility	Approx number of persons
Univ. of Jammu	STAR@RHIC, ALICE@LHC, CBM@FAIR	10
Univ. of Panjab	STAR@RHIC, ALICE@LHC, CBM@FAIR	10
Univ. of Rajasthan	STAR@RHIC, ALICE@LHC	2
Inst. of Phy. BBSR	STAR@RHIC, ALICE@LHC, CBM@FAIR	4
NISER, BBSR	STAR@RHIC, ALICE@LHC, CBM@FAIR	12
VECC, Kolkata	STAR@RHIC, ALICE@LHC, CBM@FAIR	15
IIT, Bombay	STAR@RHIC, ALICE@LHC	8
SINP, Kolkata	ALICE@LHC	8
Bose Inst. Kolkata	ALICE@LHC, CBM@FAIR	8
IIT, Indore	ALICE@LHC CBM@FAIR	10
BHU, Varanasi	PHENIX@RHIC, CBM@FAIR	3
AMU, Aligrah	ALICE@LHC, CBM@FAIR	6
BARC, Mumbai	PHENIX@RHIC, CMS@LHC, ALICE@LHC	10
Gauhati Univ.	ALICE@LHC, CBM@FAIR	3
Univ. Calcutta	CBM@FAIR	4
IISER, Tirupati	STAR@RHIC	3
IISER, Berhampur	STAR@RHIC	2
IIT, Patna	STAR@RHIC	2
IIT Madras	CMS@LHC	4
19 Institutes	**RHIC, LHC, FAIR**	**124**

Indian groups contribution in HI collision experiments

Institution	Physics, Detector, Experiment (selected list only)
Univ. of Jammu	Heavy Flavour Physics, PMD, DCS, Trigger, GRID computing, STAR HFT, ALICE-FOCAL, **EIC**
Univ. of Panjab	Fluctuation and correlations, photon multiplicity, nuclei production, BES-II-RHIC, CBM, **EIC**
Univ. of Rajasthan	Anisotropic flow, photon multiplicity
Inst. of Phy. BBSR	Light hadron spectra, PMD, GEM, CBM, **EIC**
NISER, BBSR	Spectra, fluctuations, azimuthal anisotropy, RHIC-BES, CBM-RPC, GEM, ALICE-FOCAL, **EIC**
VECC, Kolkata	PMD, MUCH, fluctuations, correlations, Jet physics, ALICE-TPC, ALICE-FOCAL, CBM-MUCH, CRU, Electronics, Grid Computing
IIT, Bombay	Resonance, fluctuations, correlations, simulations, ALICE-FOCAL, **EIC**
SINP, Kolkata	Muon Spectrometer ALICE, High Level trigger, RAA, J/Psi, Upsilon
Bose Inst. Kolkata	ALICE-TPC upgrade, photon multiplicity, ALICE-FOCAL, CBM
IIT, Indore	Photon Multiplicity, HBT, Freeze-out dynamics, CBM, **EIC**
BHU, Varanasi	Non-photonic electrons PHENIX@RHIC, CBM@FAIR, detector R&D **EIC**
AMU, Aligrah	Heavy-quark Measurements, ALICE-Muon Detector, **EIC**
BARC, Mumbai	Heavy-quark Measurements, Fluctuations and Correlations, jets, UPC, ALICE-FOCAL, GEM, RPC, Electronics
IISER Tirupati and Berhampur IIT Patna	Physics Analysis at RHIC and **EIC**

PMD – Photon Multiplicity Detector, MUCH – Muon Chambers, TPC – Time Projection Chamber

Experimental participation to achieve science goals

Experiments/Facility	Nature of participation and time line
STAR Experiment Beam Energy Scan Phase – II – Relativistic Heavy Ion Collider, BNL, USA	*Data taking and Physics Analysis* ***2014-2024***
Compressed Baryonic Matter Experiment, FAIR facility, GSI, Germany	*Detector for muon identification in CBM (RPC and GEM based)* *Physics Analysis and Data Taking* ***2025 Onwards***
LHC	*Data taking, Physics Analysis* *Detector and Electronics R&D – upgrades coping with higher luminosity and building radiation hard detectors (silicon based).* ***2010 - 2030***

Active participation and significant contribution in
software, data analysis and detector hardware related work

Indian participation in EIC progress

- **International Representative for Steering Committee**: Asmita Mukherjee (IIT Bombay, India)
- Member of "**Diversity and Inclusion Committee**": Asmita Mukherjee (IIT Bombay, India)
- Member of "**Elections and Nominating Committee**": Bedangadas Mohanty (NISER, India)
- Member of "**Integration Committee (ATHENA)**": Bedangadas Mohanty (NISER, India)
- Member of "**Bye laws and Charter Committee**": Bedangadas Mohanty (NISER, India)

- EIC finds place in the Indian "Mega Science Vision (MSV) – 2035" document
- MSV 2035: A roadmap prepared by the Indian Nuclear Physics Community for long term future
- Recommendations for participation in Electron – Ion Collider experiments to address the fundamental questions in nuclear physics and participate in detector development.

EIC physics contribution: Theory Colleagues

- Initiated joint IITB – CFNS (theory) postdoc fellowship (50% funding from CFNS)

SciPost (Selected publication only) SciPost Phys. Proc. 8, 017 (2022)

Sivers asymmetry in inelastic J/ψ leptoproduction at the EIC

S. Rajesh[1*], U. D'Alesio[1,2], A. Mukherjee[3], F. Murgia[1] and C. Pisano[1,2]

$\cos 2\phi_t$ azimuthal asymmetry in back-to-back J/ψ-jet production in $ep \to eJ/\psi$ jet X at the EIC

Raj Kishore, Asmita Mukherjee, Amol Pawar, and Mariyah Siddiqah
Phys. Rev. D **106**, 034009 – Published 10 August 2022

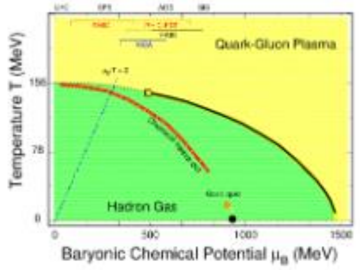
- International workshop on QCD with Electron-Ion Collider (QEIC), January 4-7, 2020, IIT Bombay, Mumbai
- The next workshop QEIC II will be held by IIT Delhi during Dec 18 – 20, 2022. **Everyone here are invited to attend.** https://indico.cern.ch/event/1196913/
- There is a possibility to receive seed funds from DAE and DST for next 3 years → under discussion.

Indian long-range plan – Mega Science Vision 2035 – Nuclear Physics

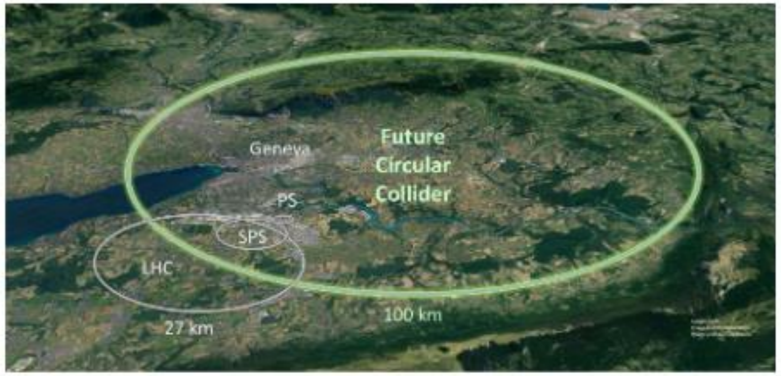
QCD: Recommendations

The study of the emergent properties of QCD matter is one of the most compelling science problems in nuclear physics. It includes mapping the phase diagram of the QCD matter, measuring the properties of the QCD matter subjected to extreme conditions of temperature, pressure, baryon density, electromagnetic fields and angular momentum, finding out the partonic content of a nucleus and the fundamental mechanisms behind the properties of nucleons, such as its mass and spin.

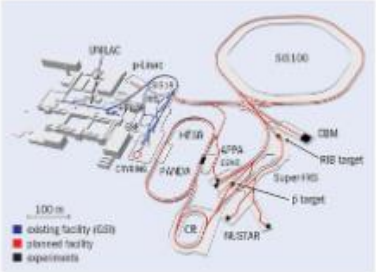
We recommend continued participation in heavy-ion programs at LHC, RHIC and FAIR, the collision energies of which, only when taken together, allow to map the QCD phase diagram. While the CBM experiment, which is under construction at FAIR, should be the focus for the high-energy nuclear collisions in the near future, we also recommend participation in the upcoming Electron-Ion Collider experiments to address the fundamental questions in nuclear physics.

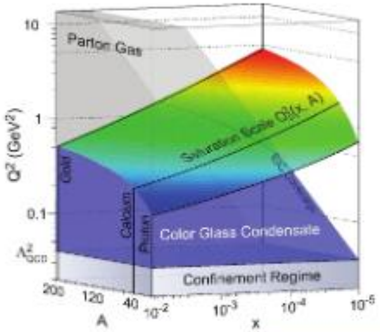


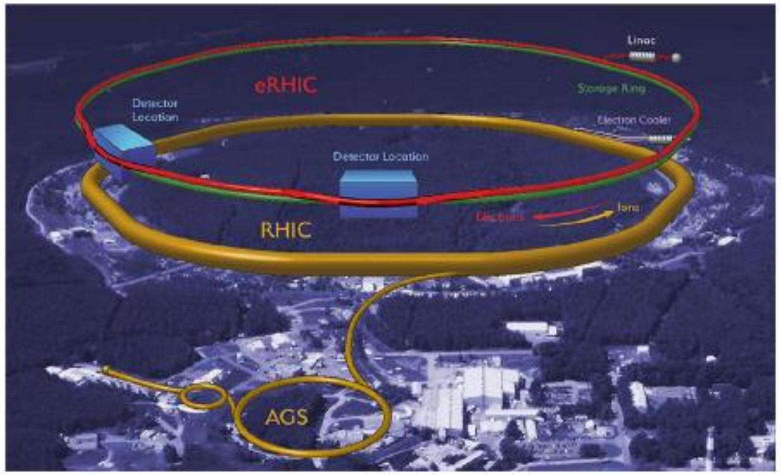
What are the phase structures of Quantum Chromodynamic (QCD) matter?



How do the strong interactions amongst quarks and gluons inside the nucleons result in confinement and collectively result in their properties such as mass and spin?







How does a nucleus look in terms of its partonic content? Does the gluon density saturate to gluonic matter of universal properties?

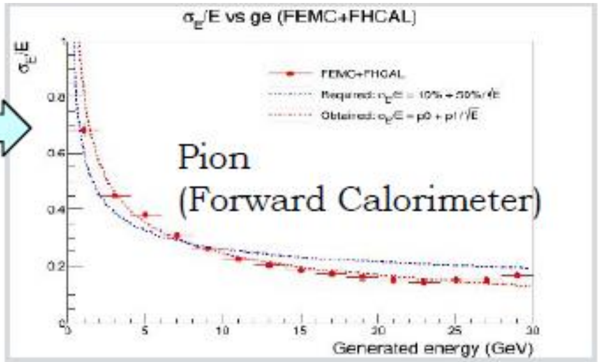
Indian Institutes interested in EIC

SI NO.	Institute Name
1	Banaras Hindu University
2	Central University of Haryana
3	Central University of Karnataka
4	Central University of Tamil Nadu, Thiruvarur
5	Goa University
6	Indian Institute of Science Education and Research, Berhampur
7	Indian Institute of Science Education and Research, Tirupati
8	Indian Institute of Technology Bombay
9	Indian Institute of Technology Indore
10	Indian Institute of Technology Madras
11	Indian Institute of Technology Patna
12	Institute of Physics
13	Malaviya National Institute of Technology Jaipur
14	National Institute of Science Education and Research
15	Panjab University
16	Ramakrishna Mission Residential College, Narendrapur, Kolkata
17	Tata Institute of Fundamental Research
18	University of Jammu

18 Indian Institutes have shown interest to participate and contribute in both in software and hardware work for EIC – EPIC

EIC India – Software contribution: Benchmarking

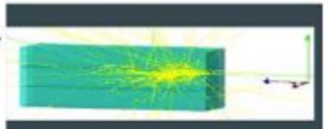
Fun4ALL (PU, IITI) : Parameterization of energy resolution of Calorimeters



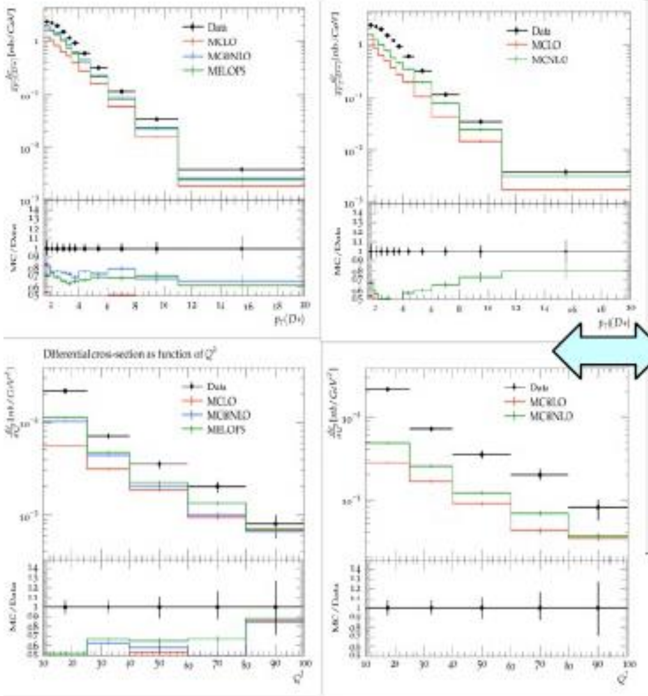
$\sigma_E/E = 2\% + 83\%/E$

Escalate-ML (IITI): Create a framework that read and write generated particle interaction events

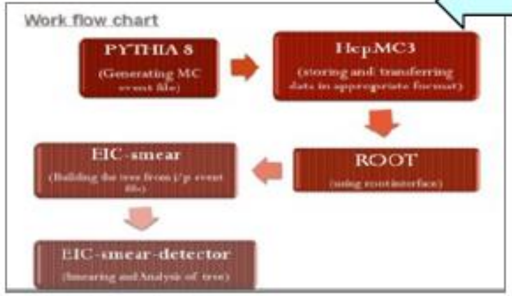
The Setup



Hits in a 3x3 calorimeter are simulated using g4e. ADC values(in MeV) of hits are recorded for each cell. These adc values correspond to the energy deposited in the cell.



MC-data Validation (IITB, IITM, Goa Univ.): Study the global properties of hadronic final states in DIS events and other observables at EIC energies using different event generators.

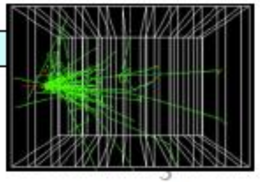


EIC Smear (IITP, IITM, MNIT): Get the smearing for fast-simulation and from Geant4, develop unit tests for the repository using Catch2

Project EAST (IITB, IITM, Goa Univ.): Develop a HepMC3 interface to read event record and pass the information to Geant4

Barrel Imaging Calorimeter (ATHENA): Optimization of Clustering Parameters (PU)

dRICH (NISER): Photo-sensors optimization simulation with JUGLER

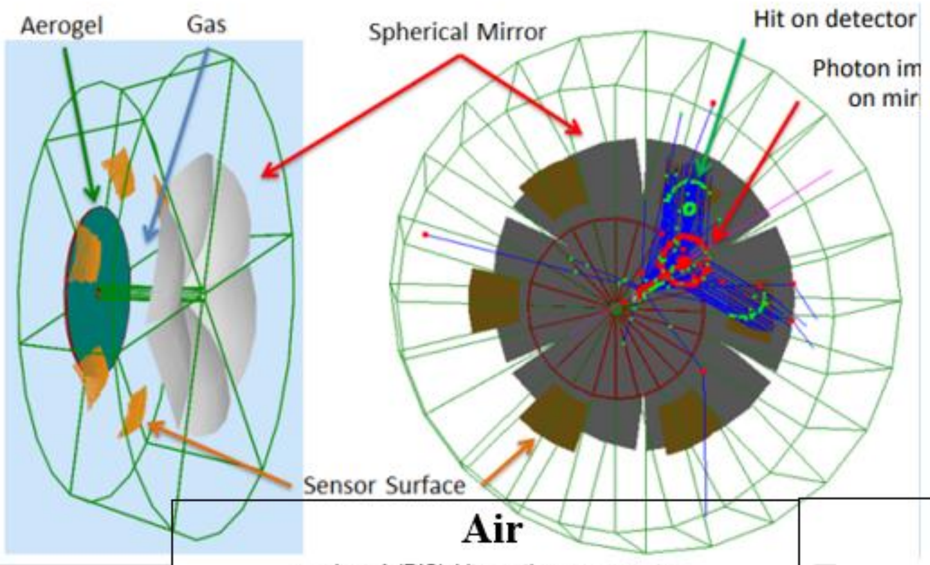


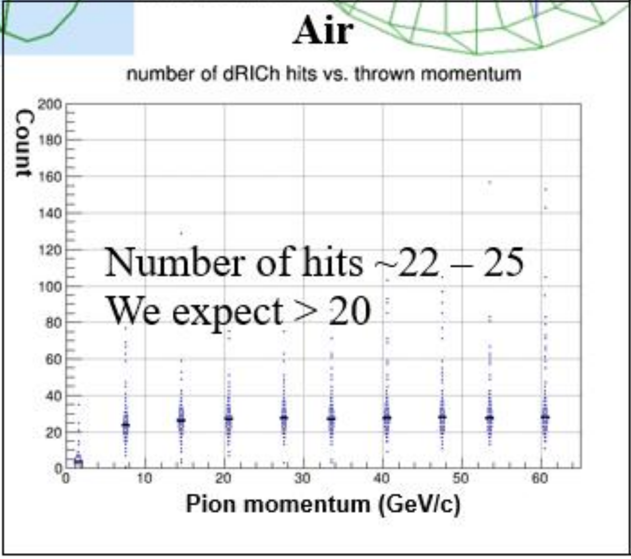
EIC India – Software contribution: Benchmarking

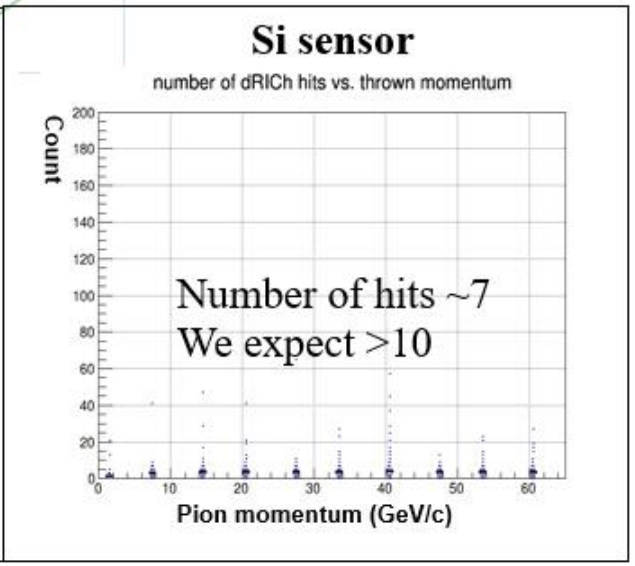
EIC Simulation effort @ NISER

dRICH detector system →	Radiator, mirror, and other component
Transport of particle through dRICH →	Particles are transported trough detector material
Sensors for photons →	Detector for single photon detection
Photon hits on sensor →	Hits on Sensor

Simulation goal is to implement the realistic sensor material and check the number of photons for given incident particle and given momentum







Work by Ajit Kumar Post Doctoral Fellow

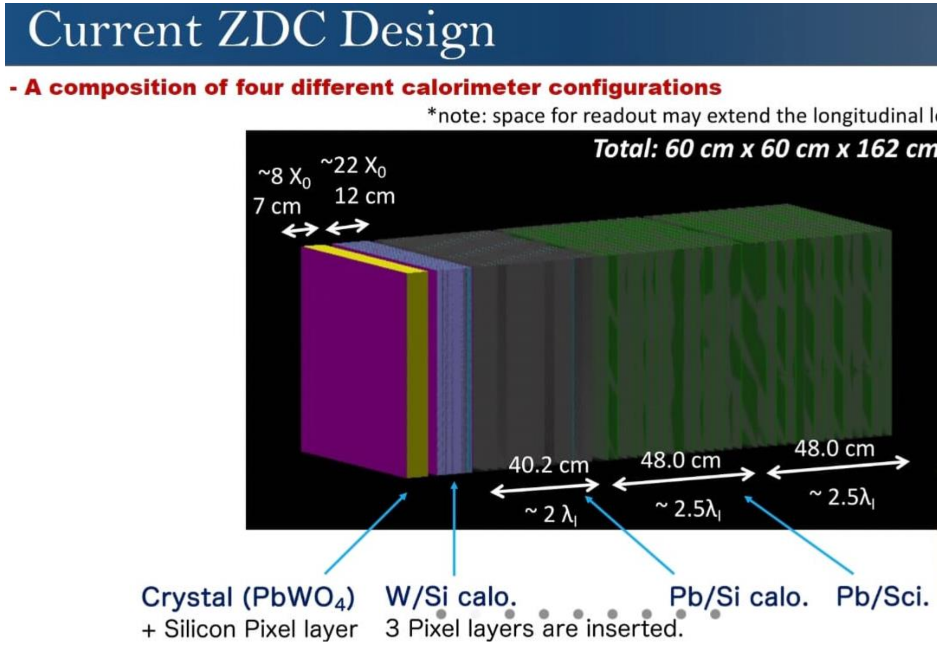
EIC-India collective research Proposal
Detailed Project Report (DPR)

- All the interested Indian institute are working on the proposal together to our major funding agency in India, plan to submit in coming four months
- Hardware contribution/R&D is most important part of our proposal, the idea is to request money initially for R&D (2 - 3 years) and upon successful completion of R&D apply for mass production
- Funding agency strictly wants us to spend money locally (favours in-kind contribution), however there is some scope to purchase imported test equipment

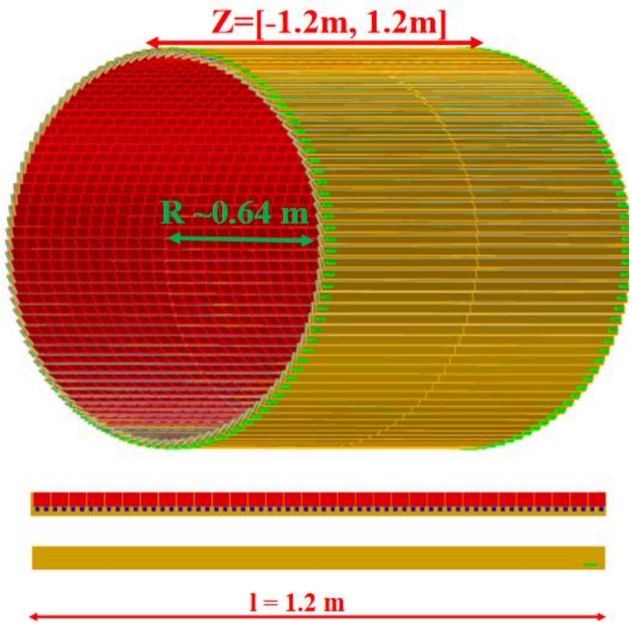
Our Interest in ePIC detector system

Interests are based on what is possible to do in India

1. dRICH/hpDIRC (SiPM R&D) and
2. Zero Degree Calorimeter (p-type Si pad arrays and/or SiPM based calorimeter in ZDC)
3. Also some interest on Time of Flight (AC-LGAD R&D) – R&D level
4. Interest expressed to contribute in DAQ and slow control



Barrel ToF Design



Regular attendance in PID and LGAD consortium weekly meetings, exploring possibilities for contribution

Proposed possible contributions

- If the proposal is successful, as the recommendation is to spend money locally; we plan to propose design, fabrication and testing of SiPM’s and p-type pad arrays (also some R&D on AC-LGAD’s) in India, the major cost would be to purchase of p-type epitaxial wafers and photomask
- The work would include TCAD device and process simulations, fabrication
- Qualification studies: Borrow/purchase readout ASIC and related DAQ
- Contribute in test beam experiments, data analysis etc.
- ePIC ZDC, RICH, ToF System commissioning and integration (in later stages)
- There are many other aspects where we could contribute later like, producing evaluation board PCB or ASIC carrier board PCB in India. The cost is very competitive to others. Any other work like production of cooling, mechanical structures is possible

SiPM, p-type Pad arrays, and AC-LGAD: Fabrication

- In discussion with design engineers from semiconductor Fabs in India
- Indian semiconductor fabs are experienced in silicon detector fabrication (SiPM, Pad arrays) as well as in readout ASIC (ROIC) chip fabrication
- They have capability of fabrication on 6’’ and 8'' wafer and 180 nm process technology and also aim to acquire smaller process nodes (65 nm, 28 nm) in near future
- The preparation of the design specification for p-type pad array, SiPM, AC-LGAD is ongoing
- Seeking help from subject experts from collaboration for AC-LGAD fabrication (not done before)
- Possibility to fabricate readout ASICs in Indian fab
- In addition, our Fabs showed interested to cooperate in mass production

Available infrastructure and detector R&D:

Si Fabs and their expertise

1) Semiconductor Lab (SCL), Mohali
2) Bharat Electronics Limited (BEL), Bangalore

Semiconductor Lab (SCL), Mohali - Capabilities

- Process and fabrication

- Design

- Testing

- Packaging and assembly

- Reliability and quality assurance

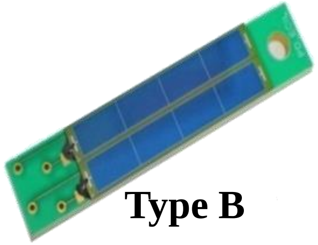
https://www.scl.gov.in/

Future roadmap

Sr. No.	Technologies	2021-22	2022-23	2023-24	2024-25
1.	**Establishment of GaN Technology for Detectors & High Power Devices**				
2.	**SiGe Bi-CMOS for High Speed Devices**				
3.	**Detectors:** including Back side illumination in full spectrum range with compound semiconductors				
4.	**Higher Technology Node (65nm/45nm/28nm)**				

SCL background - detectors and ASICs

Photodiode Detectors for X-Ray Systems



Type A

- No of pixels: 16
- Pixel size: 3.2mm × 1.4mm
- Pixel pitch: 1.5 mm
- Chip size: 3.2mm × 24mm

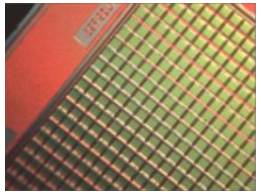
Type B

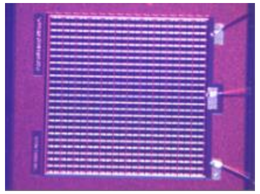
- No of pixels: 1
- Pixel size: 3cm × 0.4cm
- Pixel pitch: 1.5 mm
- Chip size: 3.5cm x 0.5cm

- Dark current: < 0.5nA @1V
- Responsivity - 0.3 A/W at wavelength of 540nm

Silicon Photo Multipliers (SD31xx-0Tx)

- Pixel architecture: N+/P well diode with Virtual Guard Ring
- Quenching type: Passive (~350kOhm) Quenching resistor:- Poly-silicon
- Isolation between pixels: Shallow trench isolation (0.38um deep)
- Break-down Voltage (VBD) : 22V
- Excess Bias: +2.5V
- Recovery Time: 100ns
- Leakage Current: <5nA/cm2 (at 20V & RT)
- Peak Wavelength: 510nm
- Gain: 5E5 to 1E6





BARC - Charged Particle Detectors

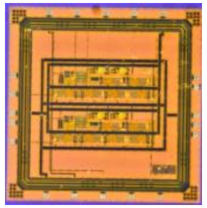
- Area: 450 sq. mm
- Reverse leakage current: <1nA @ 100V

BARC CPD (TOP VIEW)

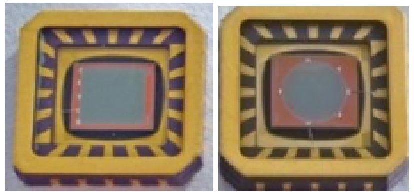
VECC ASICs

Granular charged particle Multiplicity filter Detector Array (GMDA) and NFM (Neutron Flux Monitor)

	GMDA	NFM
Detector Type	96 CSI(Tl) with PIN	Boron Trifluoride (BF3)
Electronic Resolution	<1% of dynamic range	<1% of dynamic range
Sensitivity	5mV/fC (CSA); 2.5mV/fC(shaper)	2mV/fC (CSA); 1mV/fC(shaper)
Linearity	<1%	< 1%
No of Channel	8	2



SiPM Fabricated at SCL, Mohali

	SILICON PHOTOMULTIPLIER	
SCL Part No.	SD31XX-0TX	

PRODUCT DESCRIPTION:

Silicon Photomultiplier is a novel, high gain, single photon sensitive sensor. It consists of parallel array of identical and independent avalanche photodiodes pixels, with each pixel diode connected to bias voltage supply through a series resistor (~few hundred kilo Ohms).
Device are available in:

- 1.5 x 1.5 sq. mm (pixel size 50um x 50um & 10um x 10um)
- 3 x 3 sq. mm (pixel size 50um x 50um & 10um x 10um)
- 3mm circular diameter

FEATURES:

- Breakdown Voltage (BV): 22 V
- Over-Bias voltage: 2V (max)
- Temperature coefficient of BV: 22mV/°C (Temperature Range :-243to 323 K)
- Total leakage current :<5nA/cm2 (at 20 V)
- Dark count rate: 350 to700kHz (3*3 sq mm) &
  370 to 500 kHz (1.5*1.5 sq mm)
- Recovery time: 100ns
- Geometrical Fill factor: 70% for 50 um pixel size & 15% for 10 um pixel size SiPMs

Silicon Photo Multipliers (SD31xx-0Tx)

Pixel architecture: N+/P well diode with Virtual Guard Ring

Quenching type: Passive (~350kOhm) Quenching resistor:- Polysilicon

Isolation between pixels: Shallow trench isolation (0.38um deep)

Break-down Voltage (VBD) : 22V

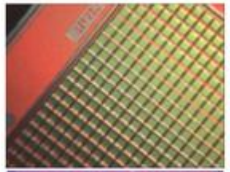
Excess Bias: +2.5V

Recovery Time: 100ns

Leakage Current: <5nA/cm2 (at 20V & RT)

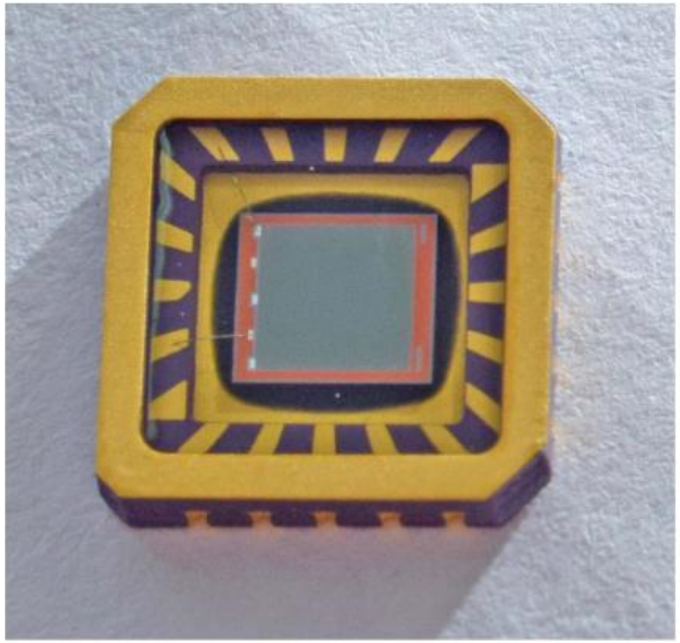
Peak Wavelength: 510nm

Gain: 5E5 to 1E6

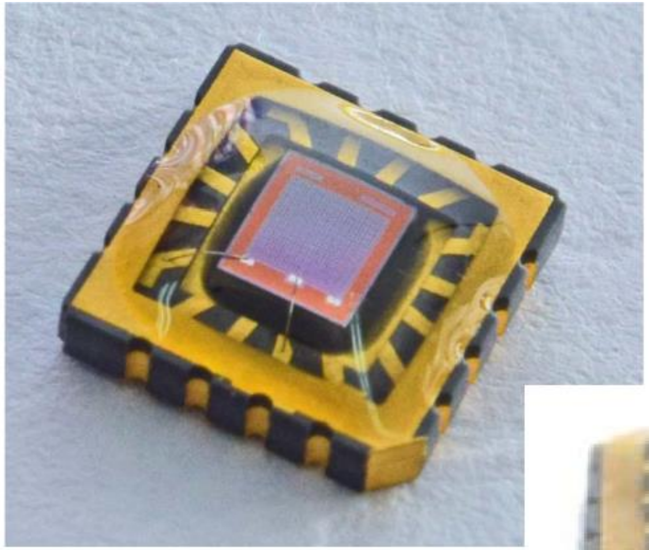


[Ref1] product no. 65: https://www.scl.gov.in/productsSCL.html

SiPM Fabricated at SCL, Mohali



Size: 1.5 x 1.5 mm^2
Pixel size: 35 x 35 μm^2
No of pixels: 1156



- Standard low voltage 180nm CMOS baseline process was adopted for realizing SPADs
- Some test samples are available

[Ref] product no. 65: https://www.scl.gov.in/productsSCL.html

SiPM Fabricated at SCL, Mohali: Test results

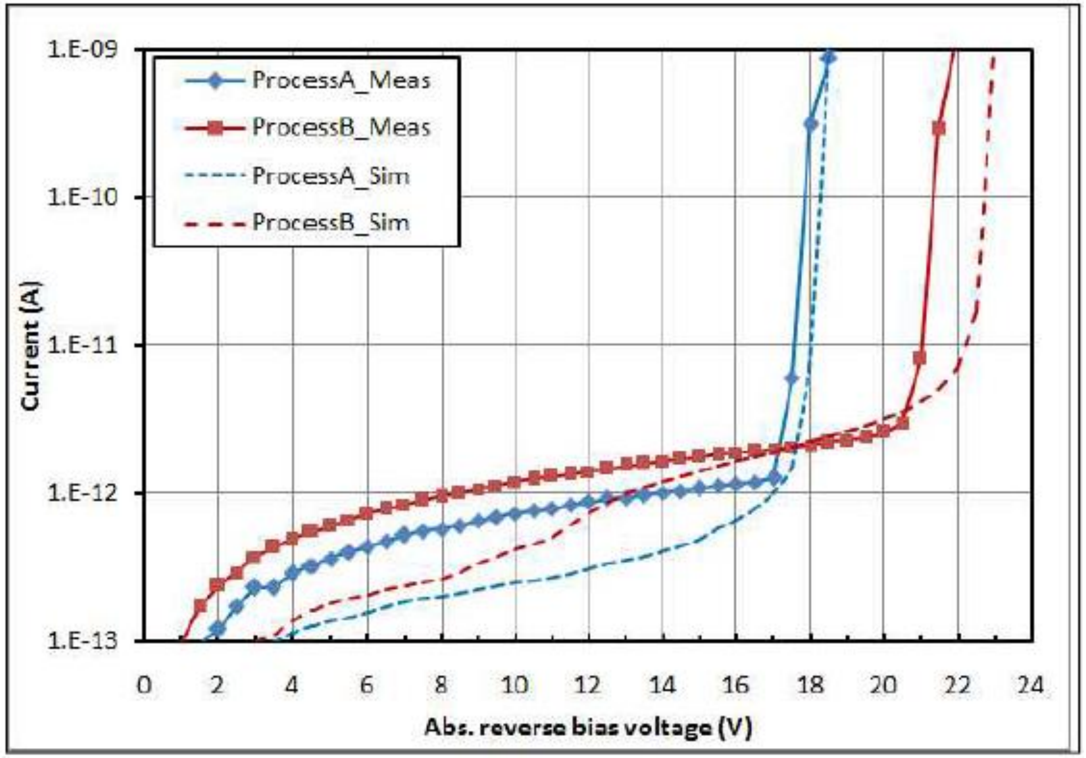


Fig. 6. Reverse I-V TCAD simulated Vs measured on silicon.

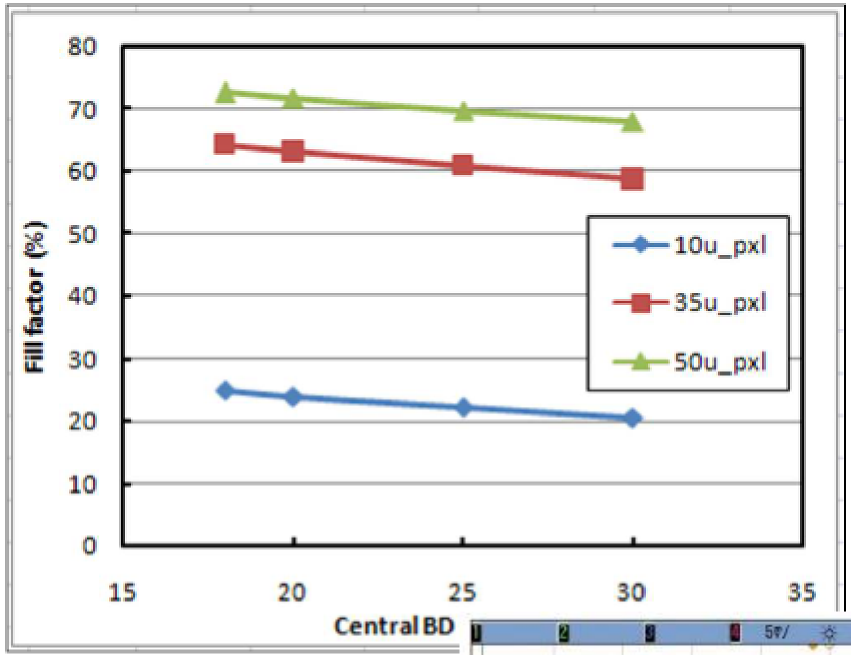
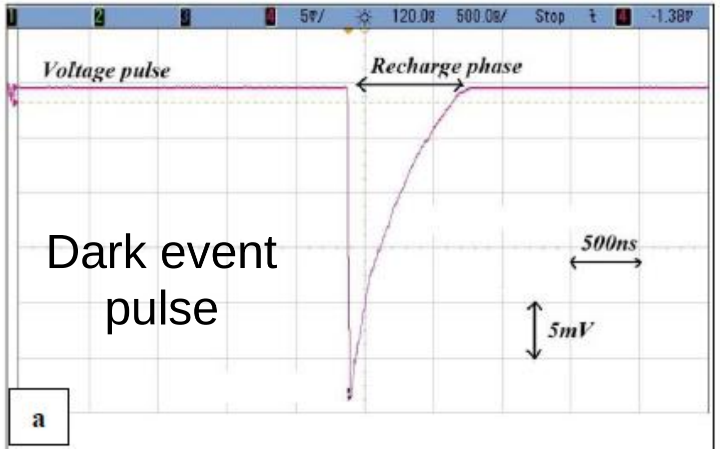


Fig. 9. Fill factor roll-off w.r.t central br



[Ref] A. Yasser et.al, "Fabrication and Electrical Measurements of CMOS-integrated GM-APDs and Test Structures in 180nm CMOS Technology Platform," 2022 IEEE 19th India Council International Conference (INDICON), Kochi, India, 2022, pp. 1-4, doi: 10.1109/INDICON56171.2022.10040143.

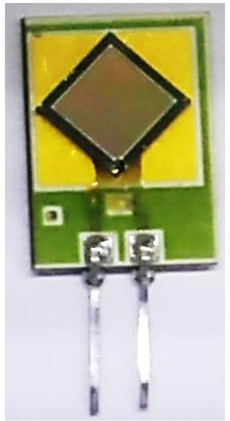
SiPM Fabrication
at Bharat Electronics Limited (BEL), Bangalore, India

BEL: working on the design and fabrication of SiPM on non-epitaxial structures

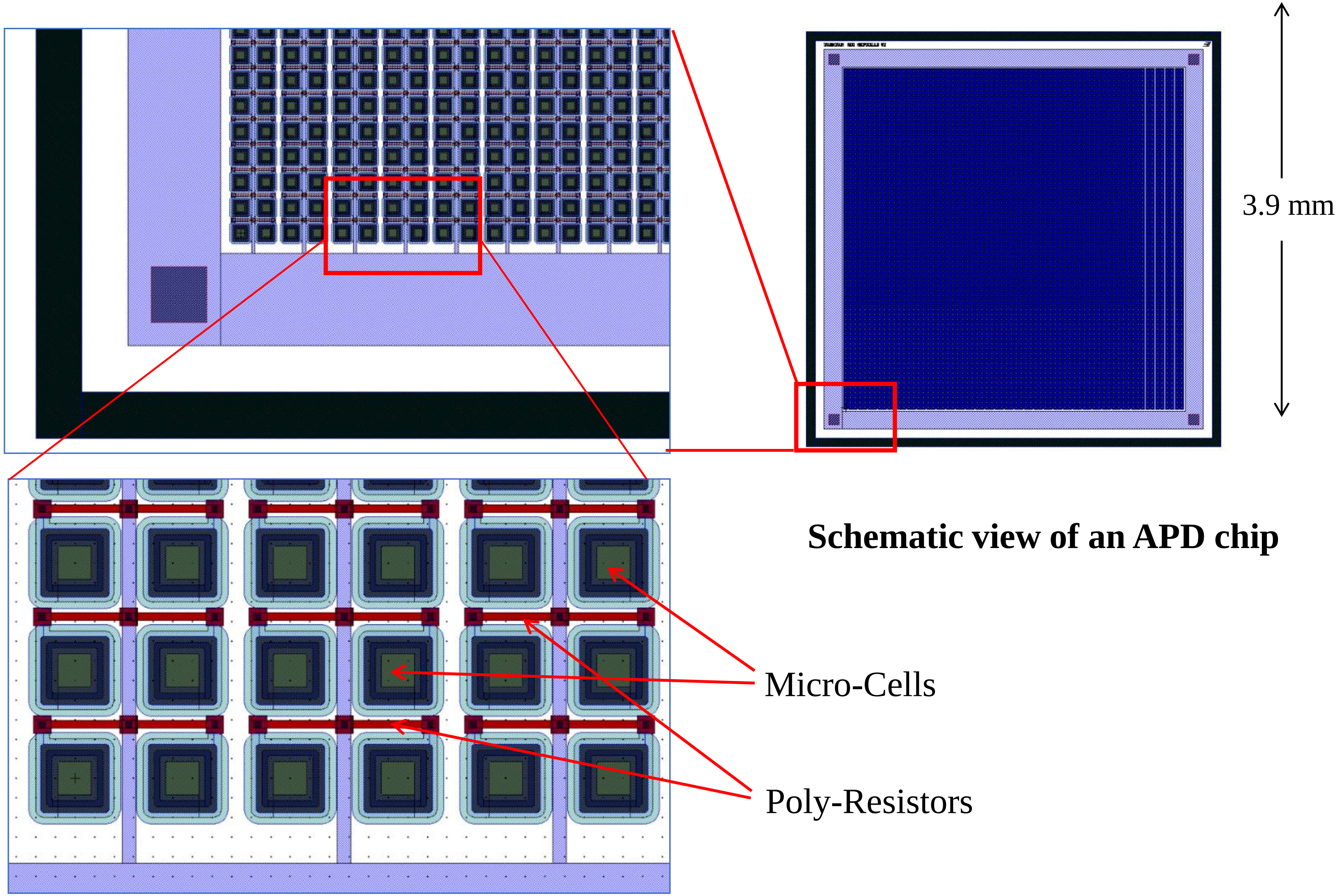
Targeted Technical Specification for Internal proactive development of SiPMs

Sl. No.	Parameter	Value
1	Number of Pixels	4 x4
2	Pixel Active area	3 mm x 3 mm
3	Number of microcells	4774
4	Size of microcell	35 micron x 35 micron
5	Typical Quench Resistor Value	200 kΩ to 300 kΩ
6	Typical Breakdown Voltage (VBR)	25 Volt
7	Typical Operating/Bias Voltage Range	(VBR + 1 Volt) to (VBR + 5 Volt)
8	Typical microcell Gain	3 x 10^6 @ VBR+2.5 Volt @ RT
9	Device Light Sensitivity Range	300 nm to 800 nm, with peak sensitivity @ 400nm.
10	Rise time	~ 1 ns @ VBR + 2.5 Volt
11	Capacitance (anode to cathode)	850 pF @ VBR + 2.5

Test samples fabricated in year 2020



SiPM Fabrication at BEL, Bangalore, India: Mask Layout of SiPMs die

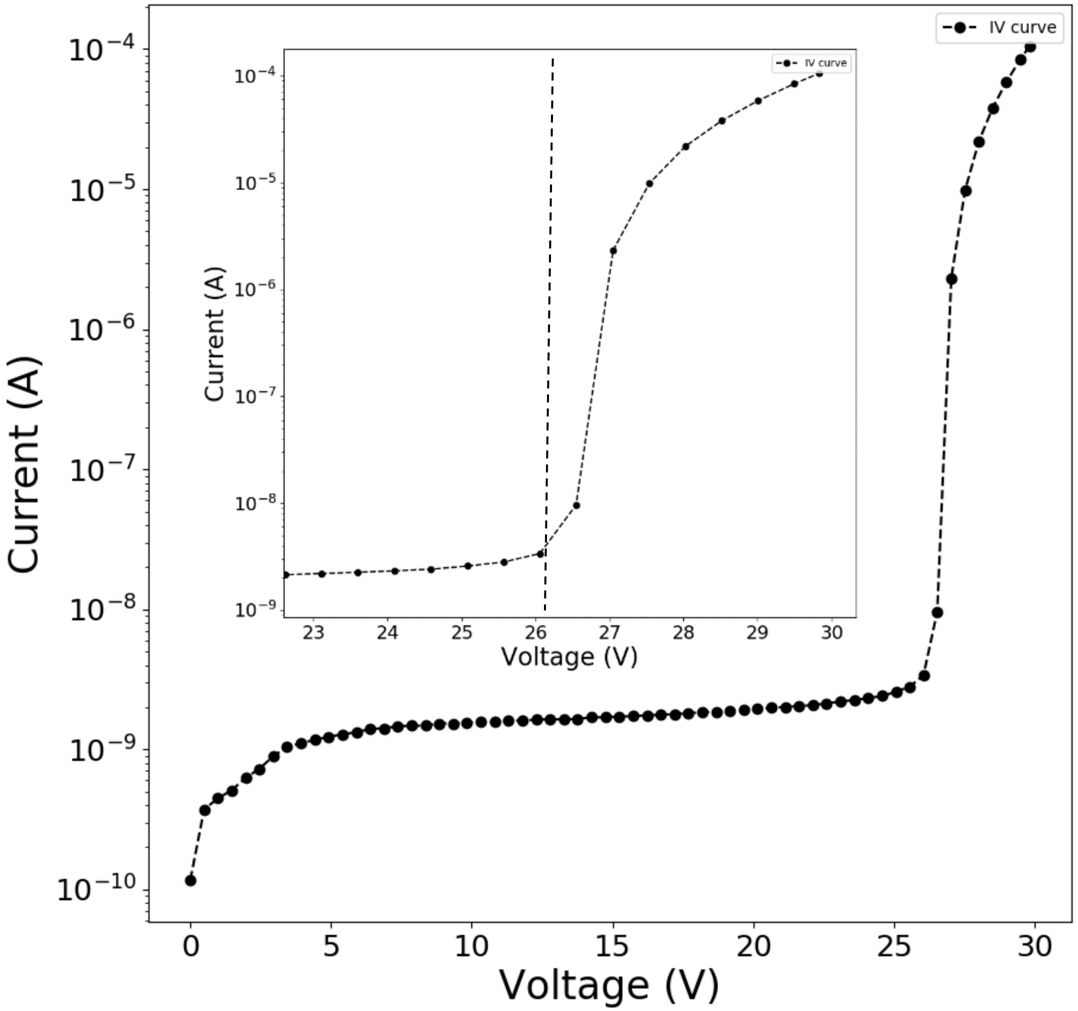


SiPM tests done @ NISER

- SiPM was mounted on a PCB
- Connected in Reverse bias mode
- Reverse bias voltage applied using Keithley 2470
  - ➢ sweep: 0 to 28 V (0.5 V step)

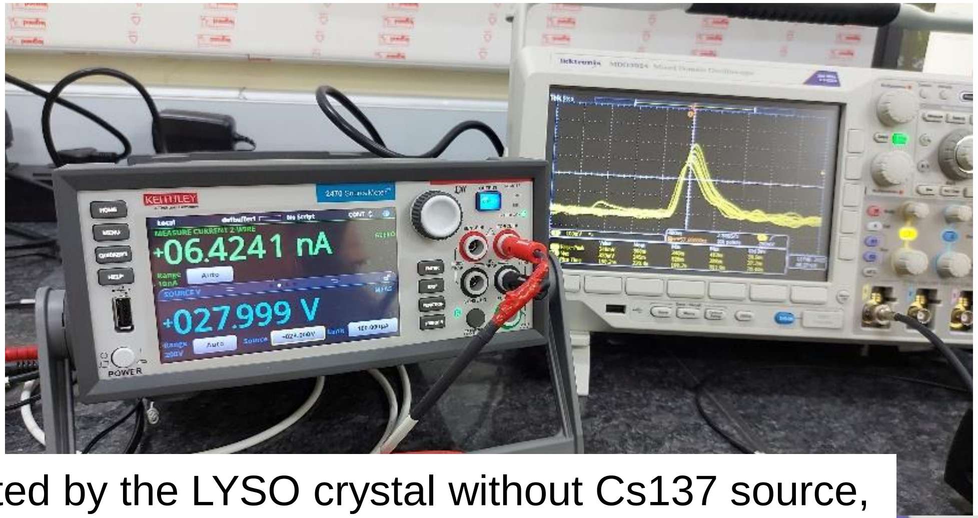
SiPM
3x3 mm^2

I-V curve: Breakdown voltage ~26 V

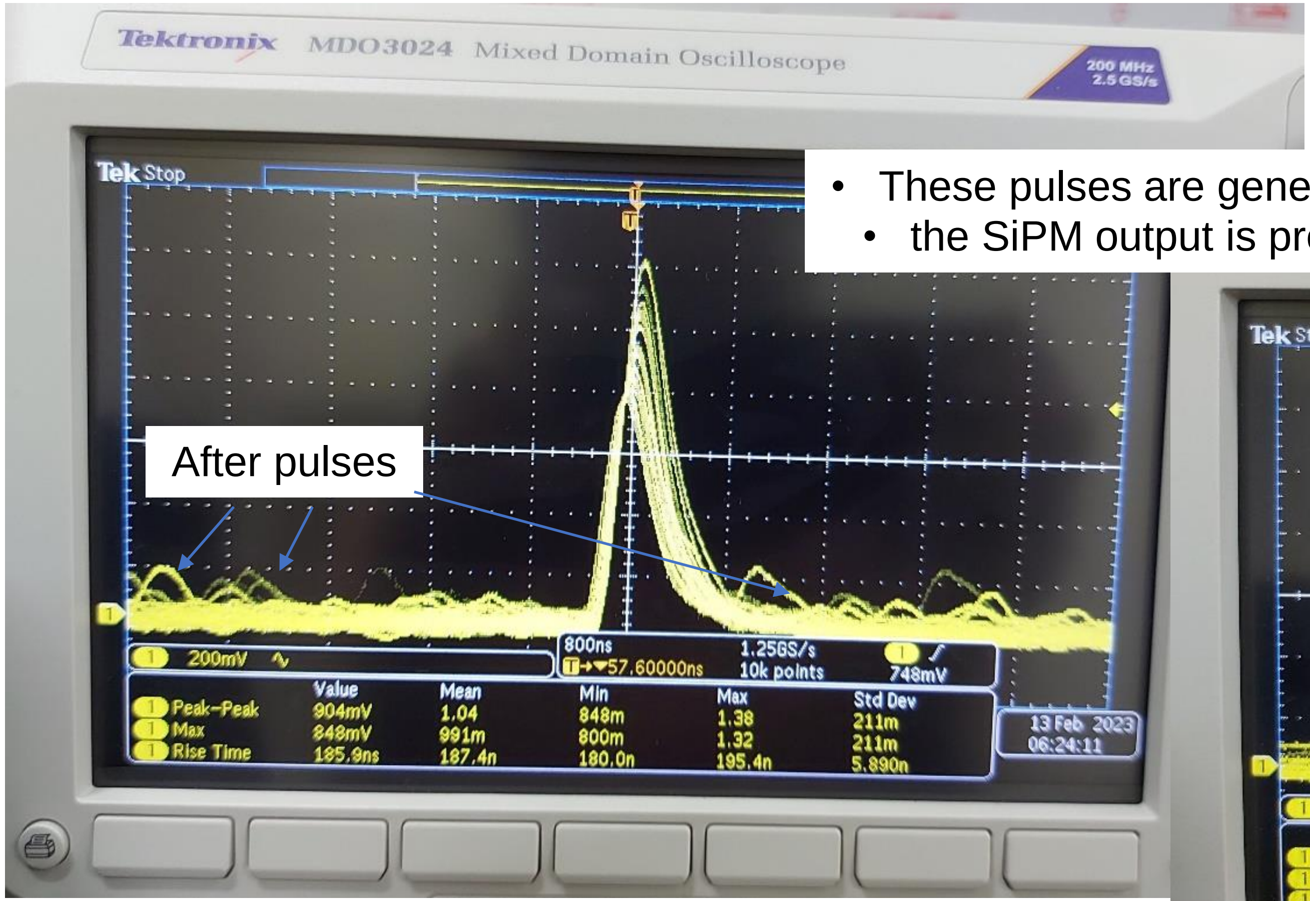


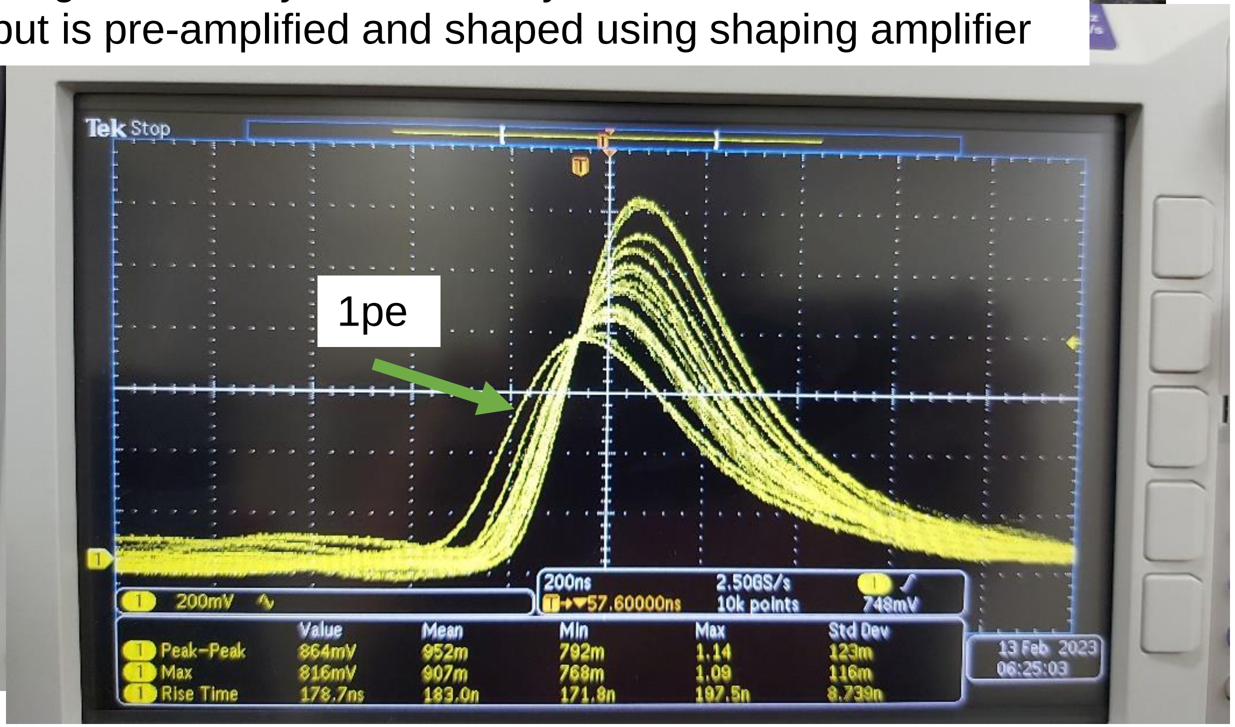
SiPM tests done @ NISER

- SiPM was coupled to LYSO crystal
- Setup operated at 28 V reverse bias



- These pulses are generated by the LYSO crystal without Cs137 source,
- the SiPM output is pre-amplified and shaped using shaping amplifier





Single photo e- pulses and after-pulses are visible

Available infrastructure and detector R&D:

pad array development (ALICE FoCAL R&D)

FoCal-E R&D in India - past

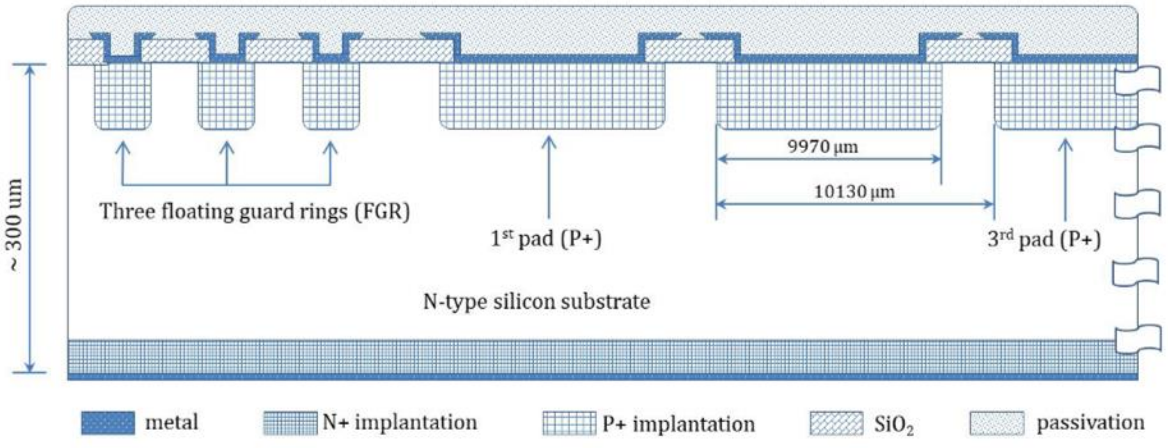


Figure 2. Cross-section of the silicon pad sensor: three pads with the peripheral region (Distances are not to scale).

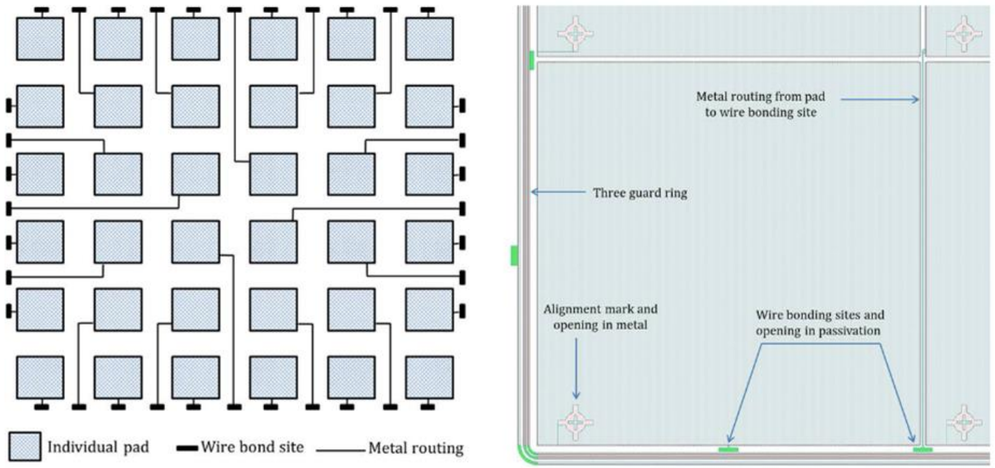
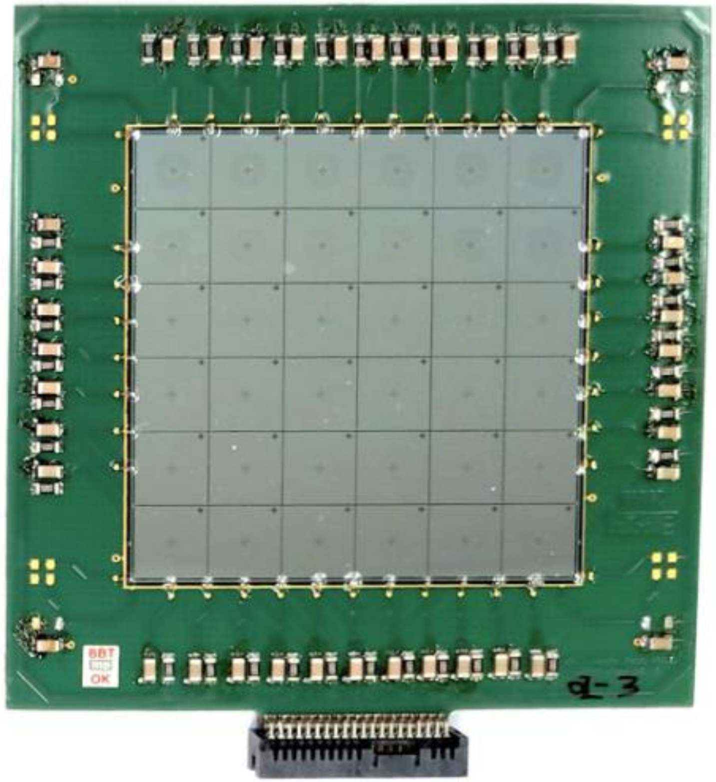


Figure 1. (left panel) Routing scheme in a single metal from individual pad to wire bond sites (Distances are not to scale), (right panel) Detailed corner view of the 6x6 silicon pad array.

6 cm x 6 cm



Design of 6x6 n-type detector developed by BEL, Bangalore

Ref: S. Mukhopadhyay et al "Development and characterization of a large area silicon pad array for an electromagnetic calorimeter", 2021 JINST 16 P09026

FoCal-E R&D in India - past

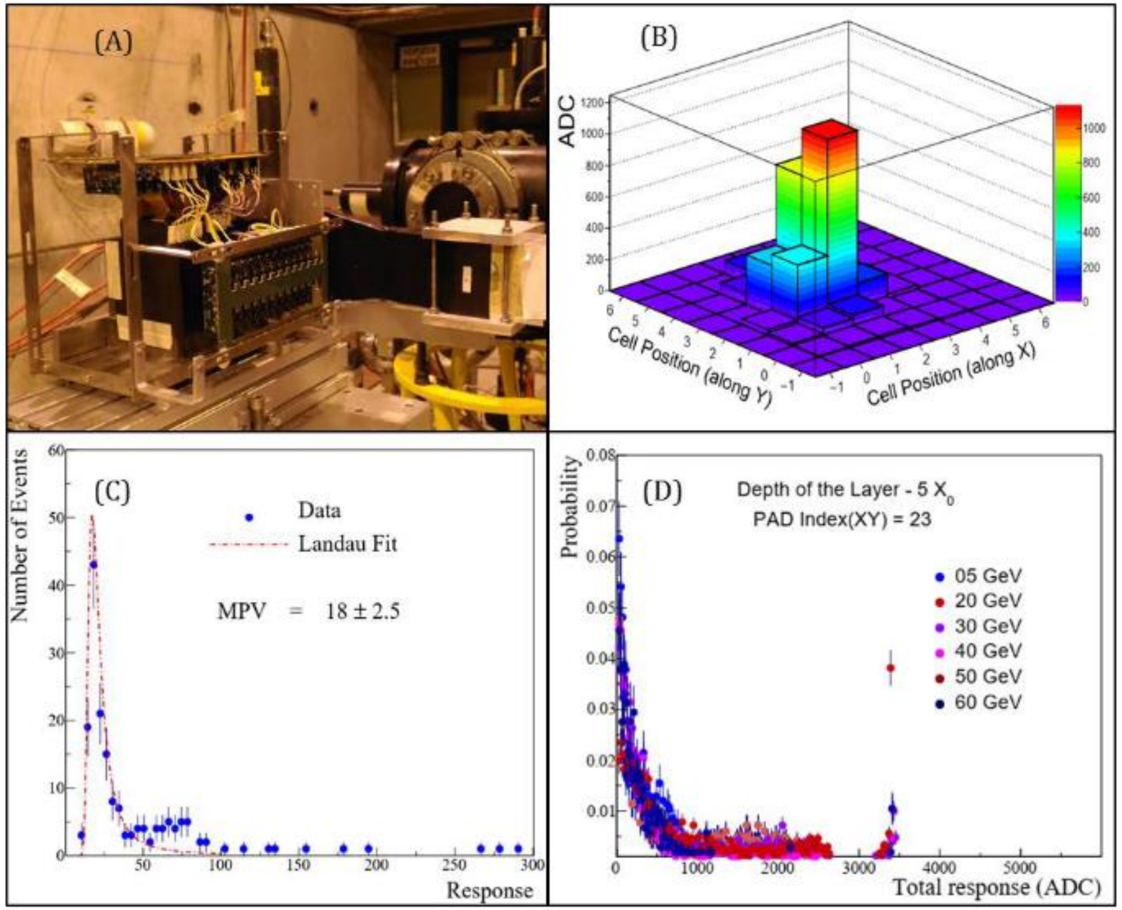
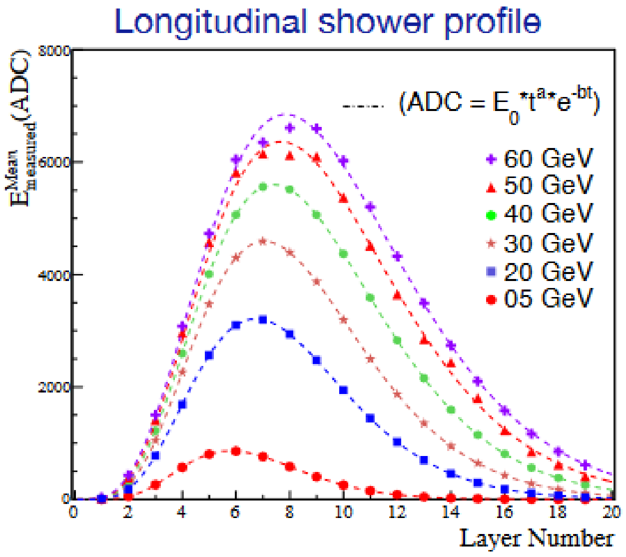
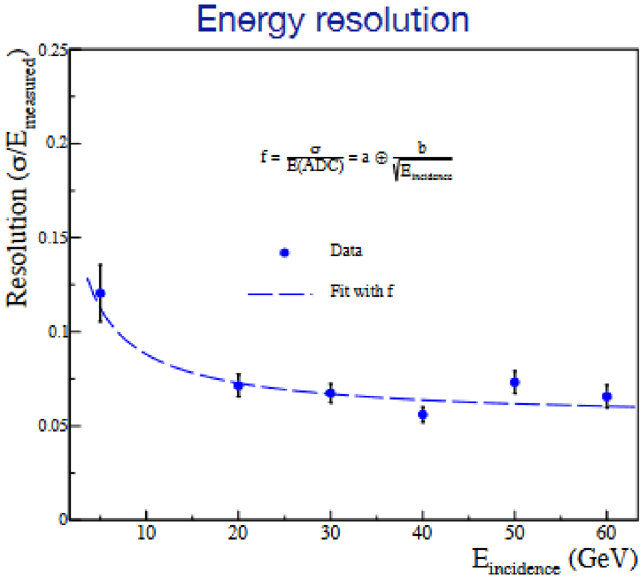
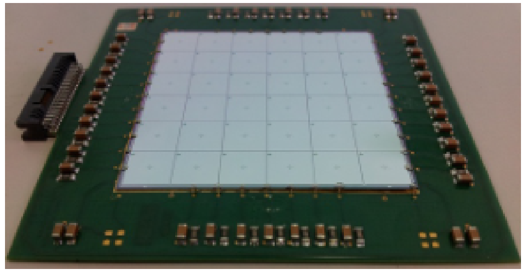


Figure 11. (A) Experimental setup at SPS-CERN. (B) 3-D plot showing the energy deposition in terms ADC count for different pads in a particular sensor layer (layer eight among the 19 layers) in response to t electron beam of 30 GeV incident energy. (C) The typical response of a pad in a particular sensor layer 120 GeV pion beam (MIP) [15]. (D) Response of pad 23 (array coordinate 2,3) of the sensor situated in t 8th layer for a wide range of incident energies of the incoming electron beam.

VECC/BARC prototypes: MANAS readout







PS + SPS test beam energy resolution:

$$\frac{\sigma}{E} = \frac{15.36\,\%}{\sqrt{E}} \oplus 2\,\%$$

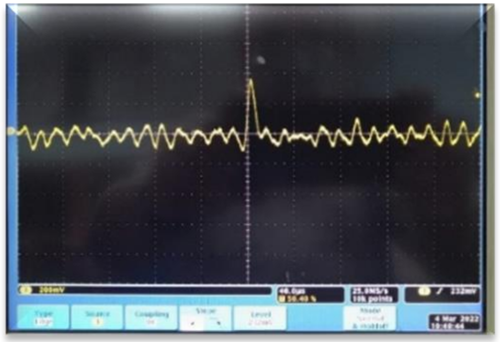
NIM A 764 (2014) 24

JINST 15 (2020) 03, P03015

Ref: S. Mukhopadhyay et al "Development and characterization of a large area silicon pad array for an electromagnetic calorimeter", 2021 JINST 16 P09026

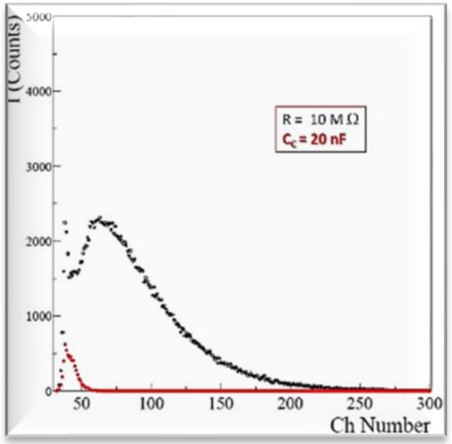
p-type single pad results

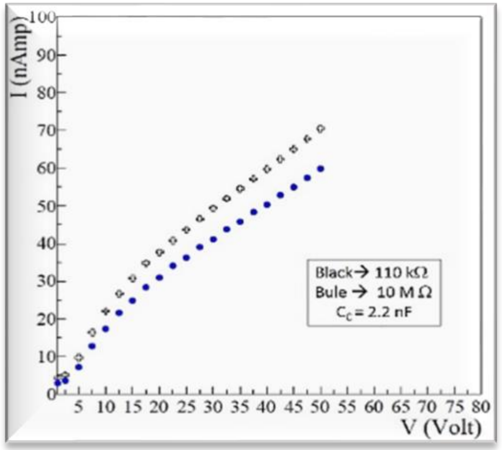
1x1 cm^2
p-type pad detector



Response to
Sr^{90} - beta source

Signal from the p-type silicon detector with (blue) and without (red) beta source.





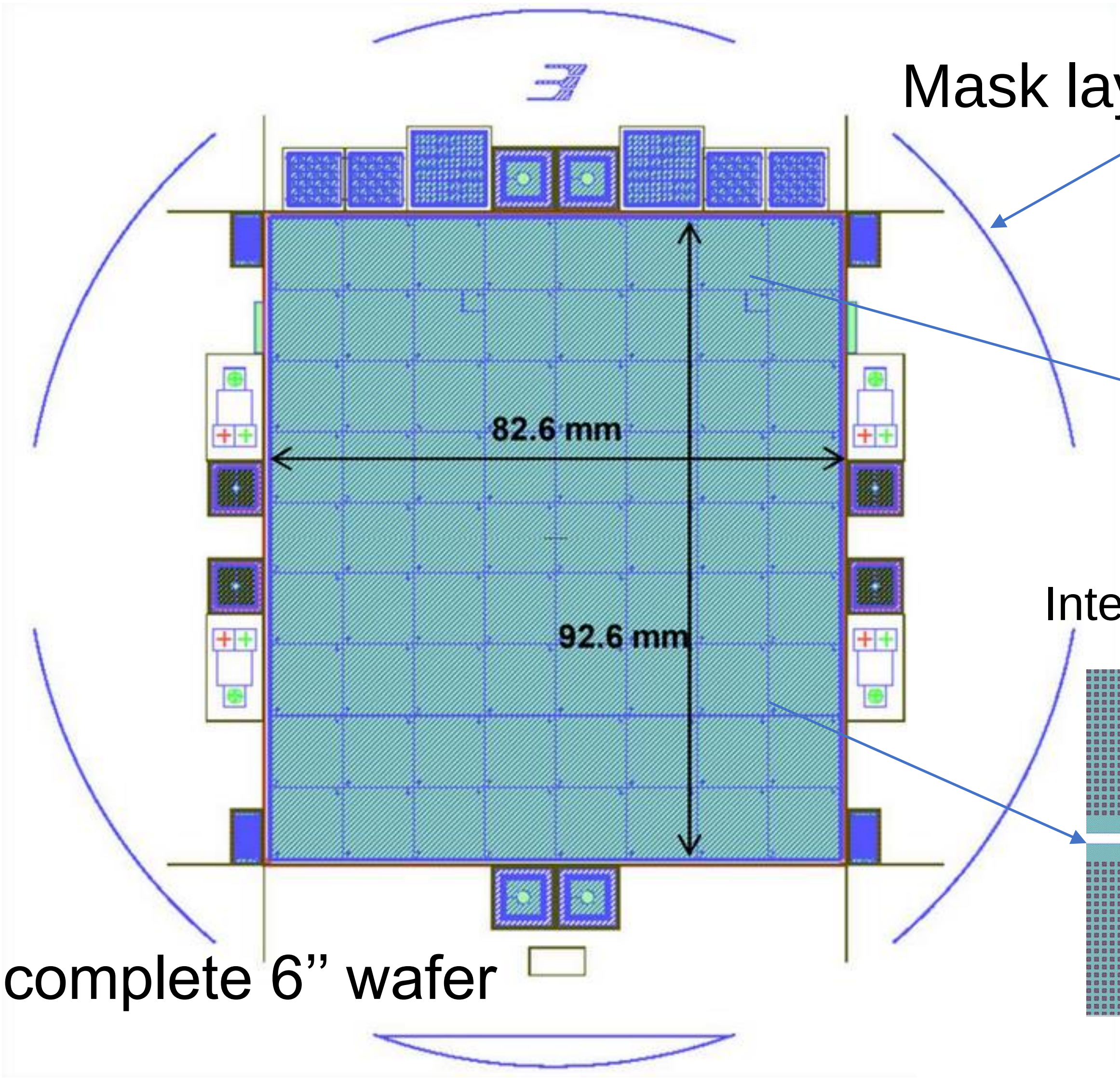
I-V characteristics for different resistances and coupling capacitances

Radiation damage study was done at VECC-K130 cyclotron. The data are being analyzed. The dose, irradiate did not damaged the response in terms of I-V. Next experiment with higher dose is planned.

Ref.: Slide from Sanjib Muhuri, VECC

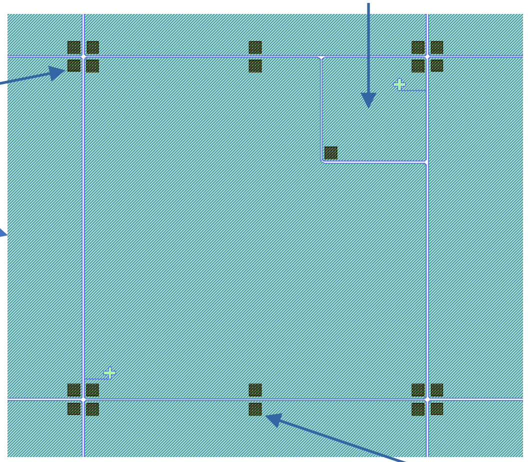
ALICE FoCal-E R&D in NISER – n-type

Mask layout design of 8x9 pad array

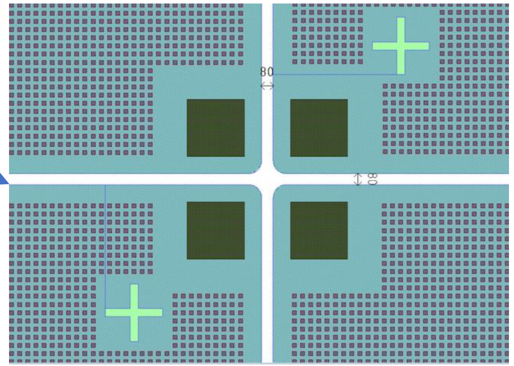


complete 6'' wafer

one pad (1x1 cm^2)



Inter-pad distance (80 μm)



Ref.: All the Mask layout images are taken from slides of **Indian Fab Engineer, BEL, Bangalore**

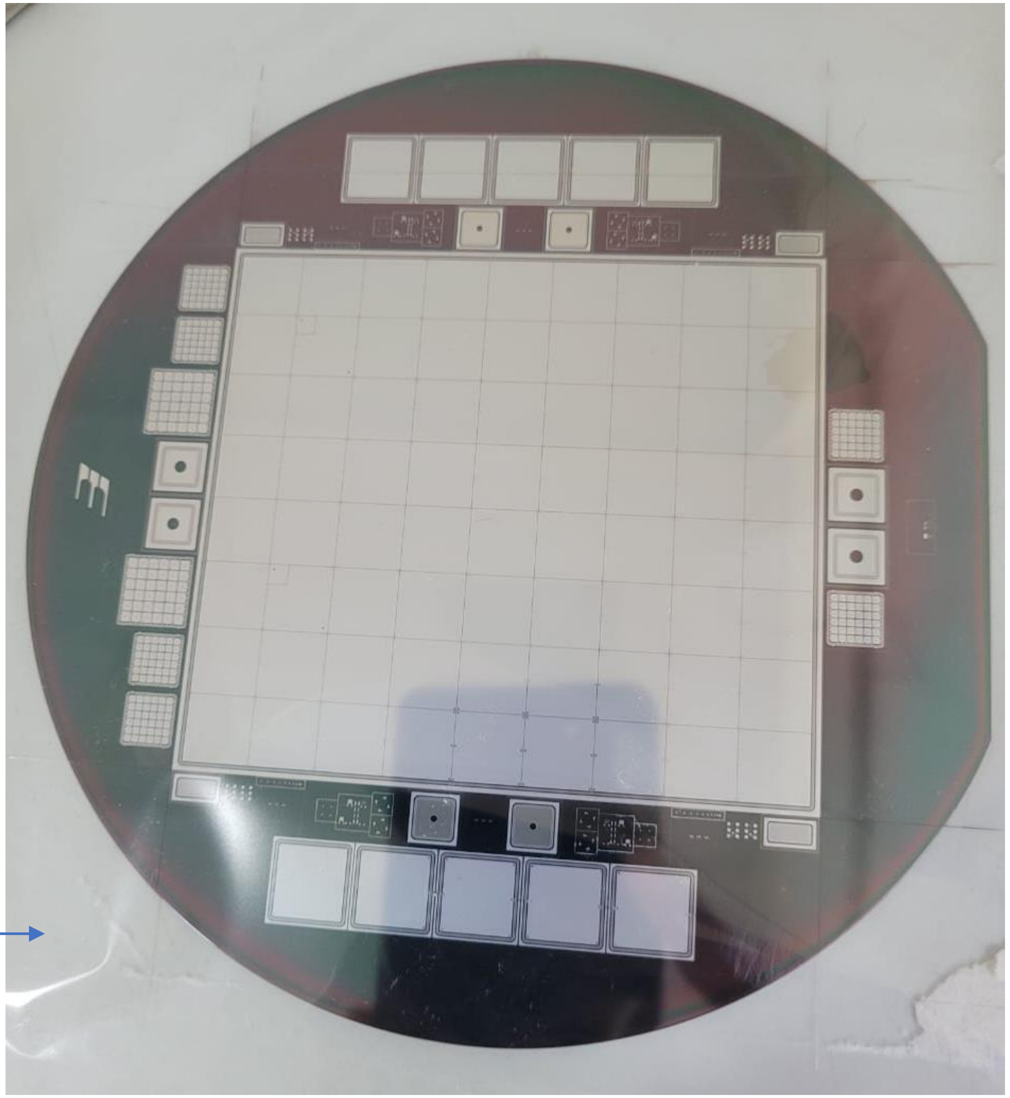
25 n-type 8x9 pad array detector ready by March 2023

ALICE FoCal-E R&D in NISER – n-type

8x9 n-type pad array fabricated on dummy wafer

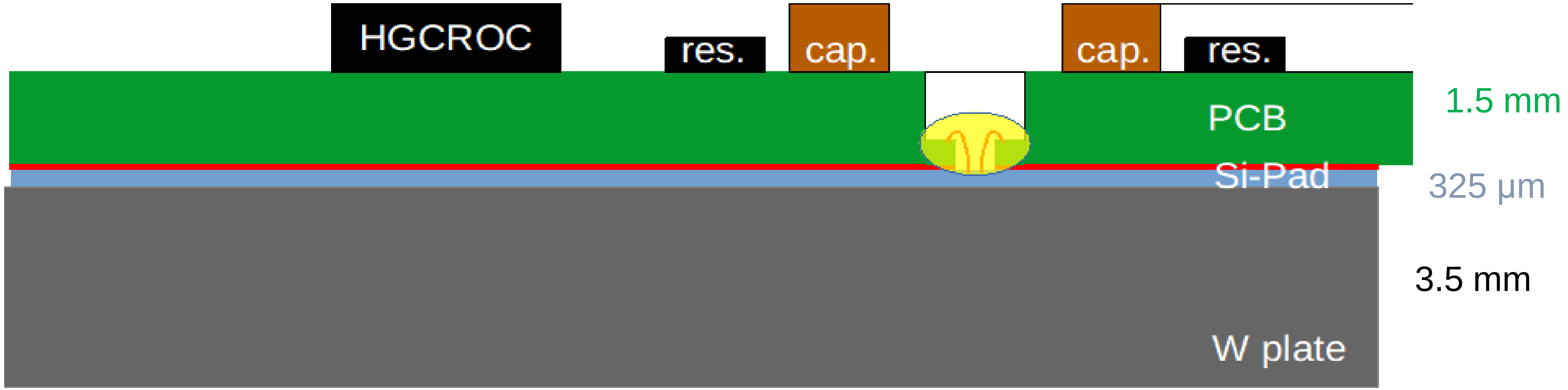
- Dummy wafer is 6'' dia with all processes done
- Resistivity is 4 - 11 Ω.cm, thickness 675 μm
- It will look exactly like a finished product wafer

Fabricated in Jan.2023
at BEL, Bangalore, India



ALICE FoCal-E R&D in NISER – n-type

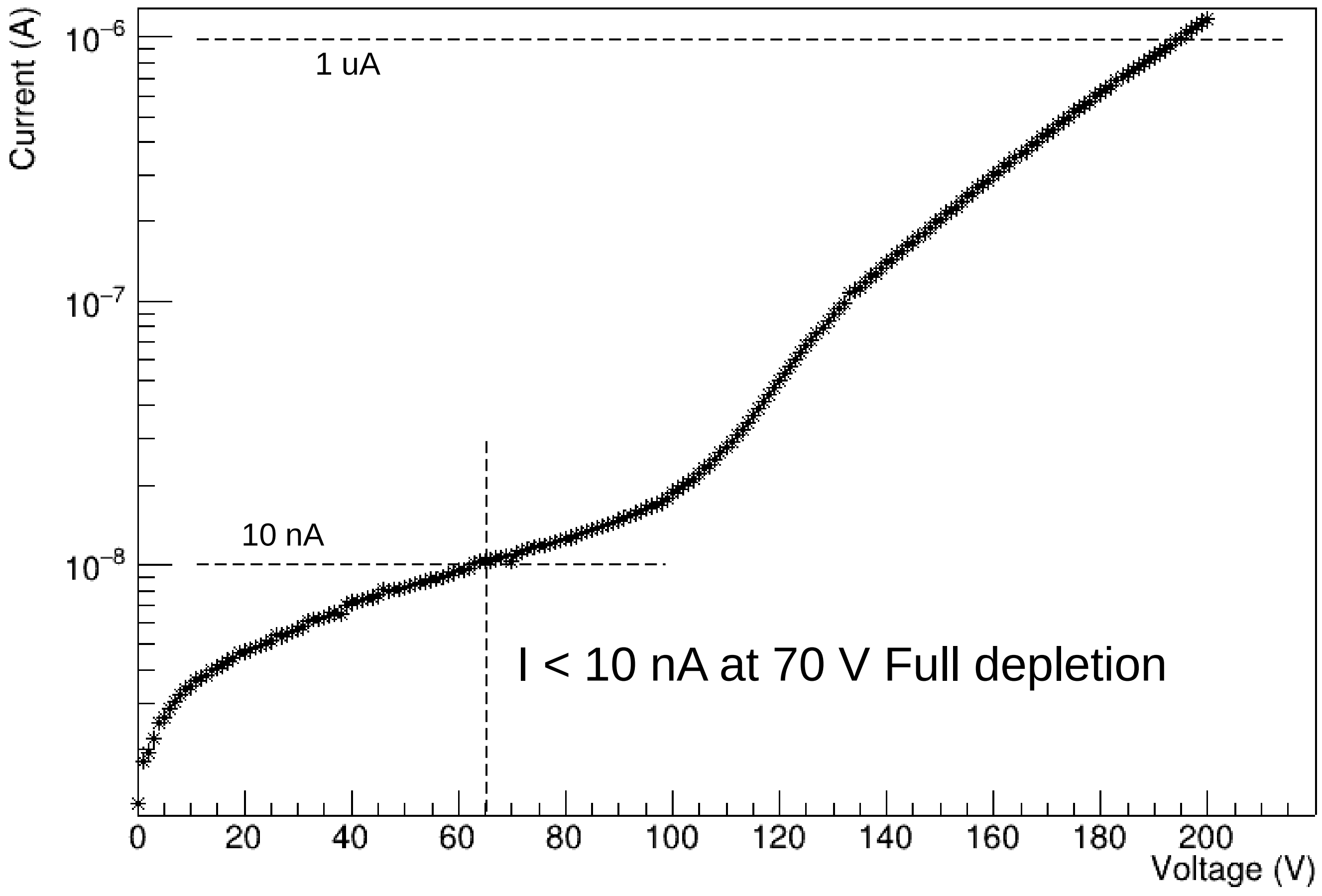
Single pad array assembly with Front-end Electronics

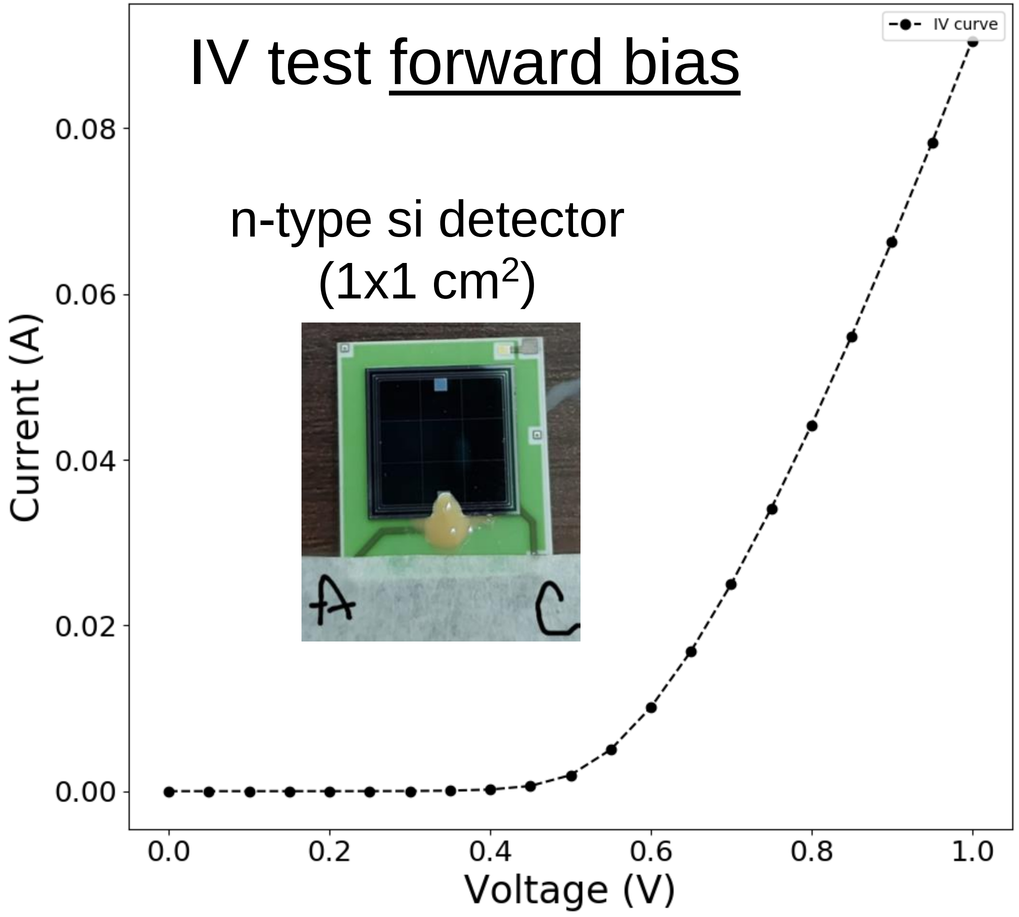


- PCB fabrication and assembly order is given to one Indian company, Assembled PCB will be delivered by May 2023,
- PCB is designed by LPSC Grenoble, France for ALICE FoCal prototype
- NISER will get 25 HGCROC chips from the ALICE FoCal Collaboration

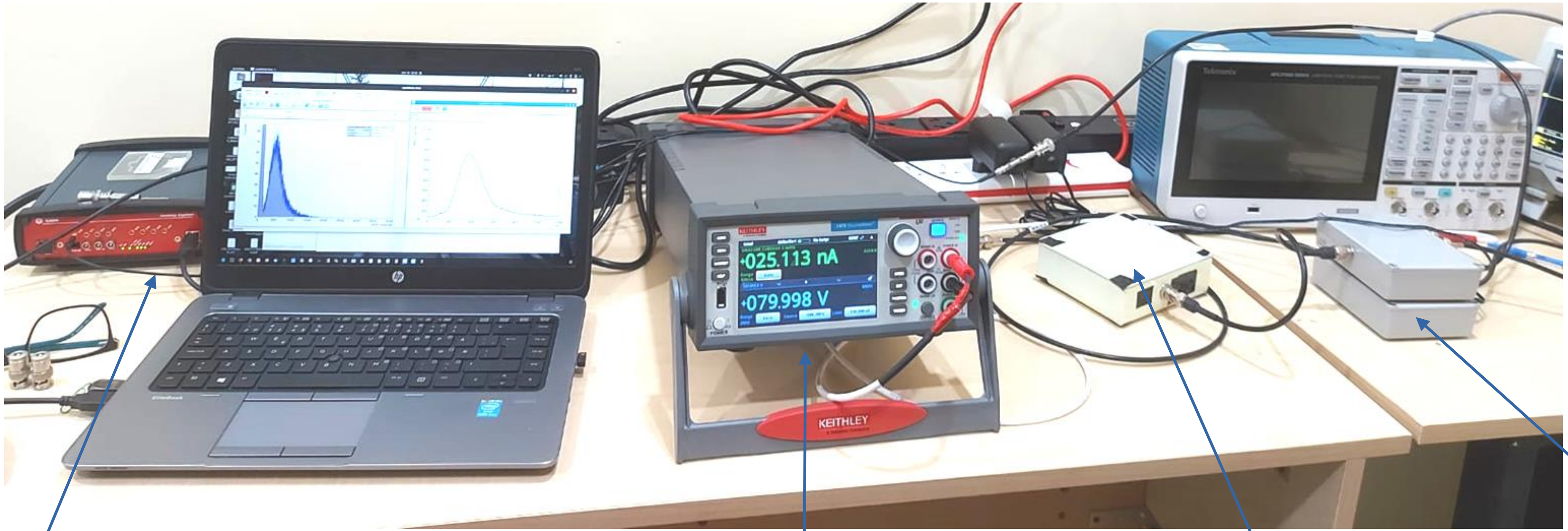
n-type pad – IV test setup

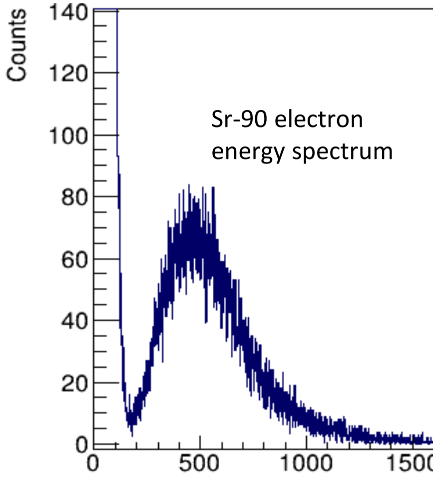
- Used Keithley 2470 source meter unit
- Simple python script sweeps the voltage and measure the leakage current and plots, copy data to file.





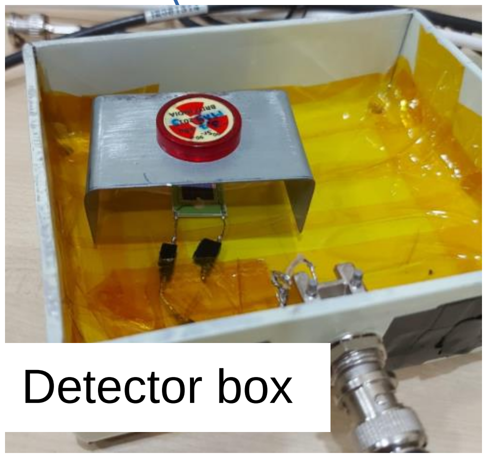
n-type pad – test setup at NISER





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

Detector bias supply (Keithley 2470 SMU)

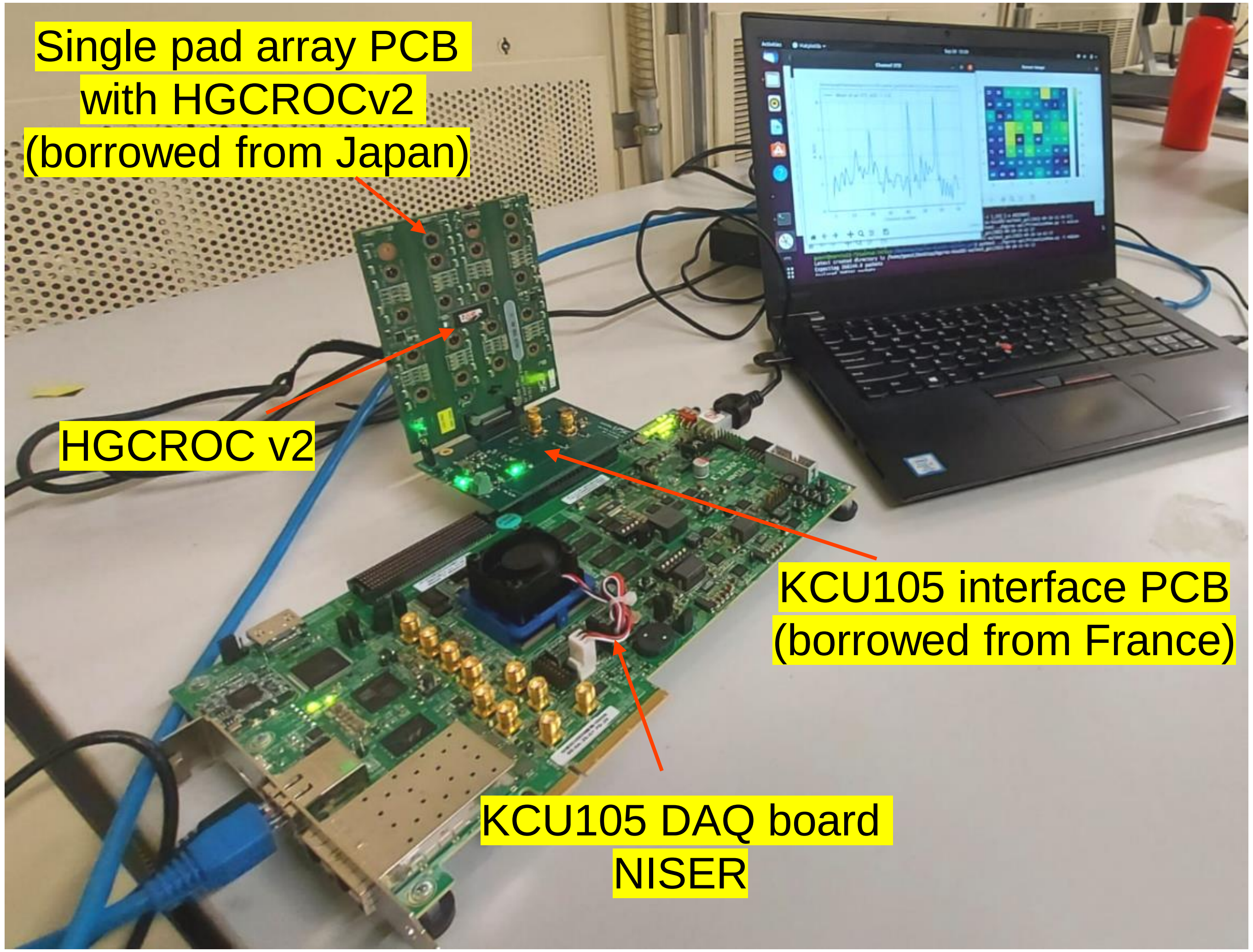


Detector box

Preamp (cremat 110) and Shaping amplifier (cremat 200)

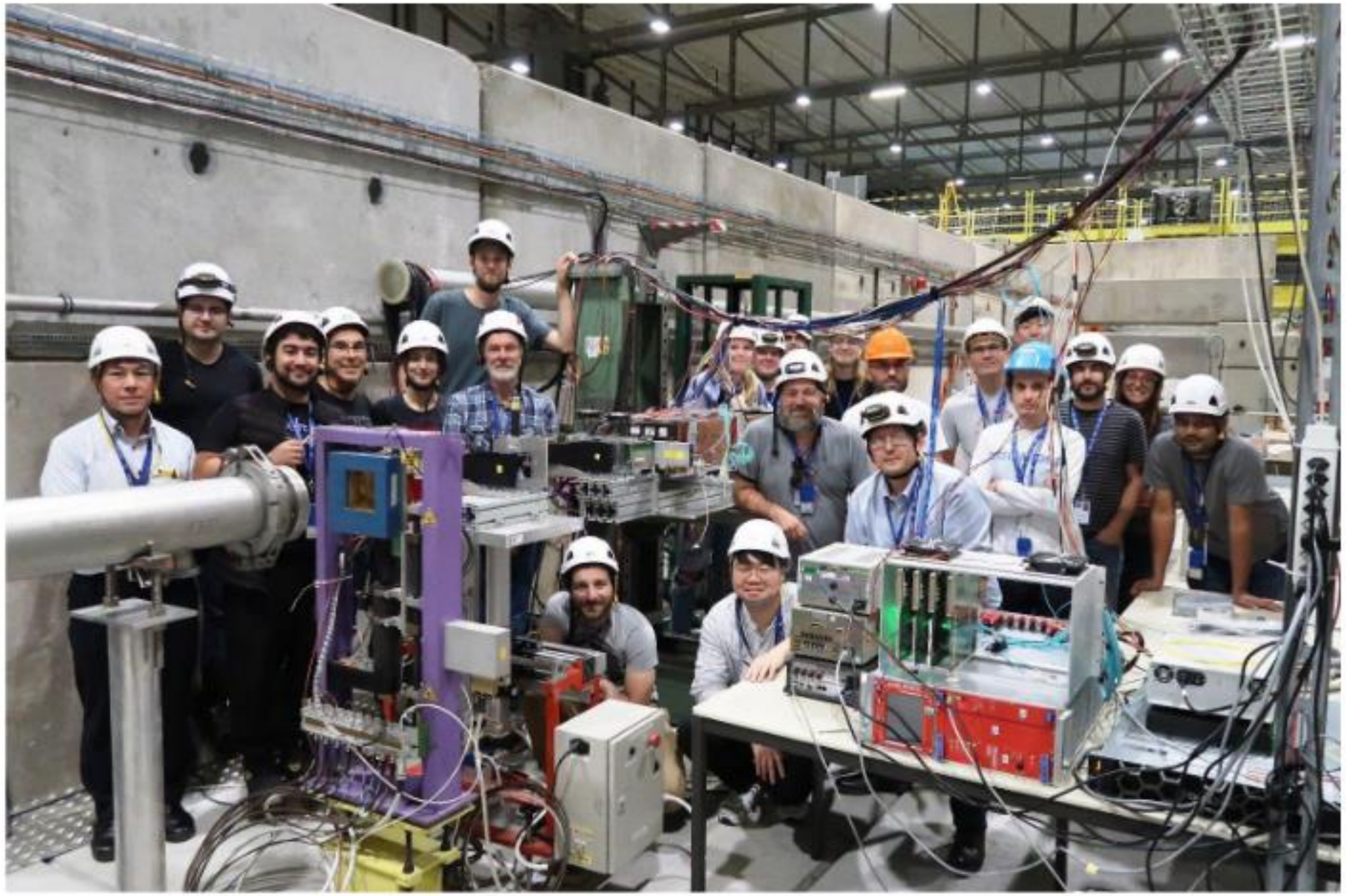
HGCROCv2 – test setup

- Mainly prepared for performance testing of the packaged untested chips before gluing their carrier boards to the detector pad arrays, make sure the KCU105 board works (my motivation!)
- 25 single pad array PCB production is in progress
- Test results in the following slides are produced using a test framework developed by LPSC, Grenoble team



NISER Si group and background

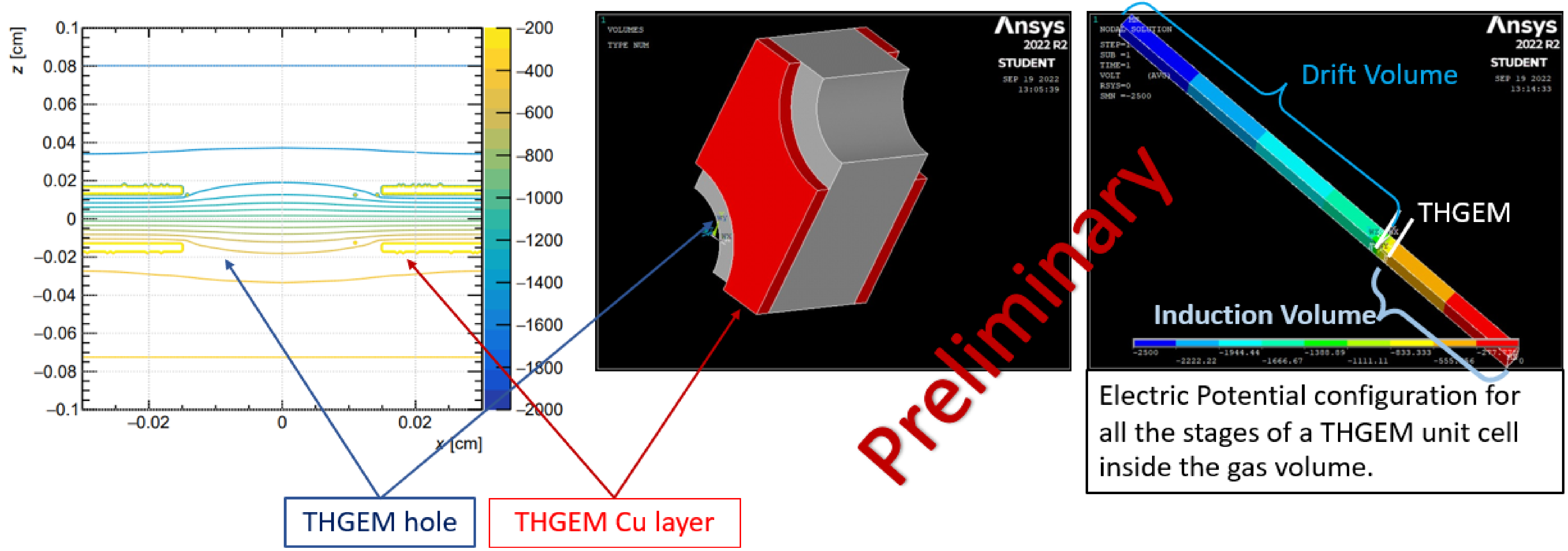
- Team of 6 people: Interested in working on the EPIC-TOF project: two scientists (Ganesh Jagannath Tambave → Si hardware and Mriganka → physics simulations), one electronics engineer (Kirti Prasad Sharma), plus the support staff as mentioned on the last slide.
- The group is currently part of the ALICE FOCAL project
  - Design, development, and production: n-and p-type pad array (8x9) on 6" wafer
  - Qualification studies of pad arrays (lab test, test beam experiments), ordered 25 pads
  - Focal physics simulations
- Dr. Tambave has a background in ALICE TPC upgrade (SAMPA ASIC tests) and ALICE ITS2 upgrade (ALPIDE MAPS tests, system integration), currently working on the ALICE FOCAL project
- 20 m^2 ISO-6 clean room, 40 m^2 workspace for silicon research lab, and various instruments required for detector qualification studies.
- Working on collective funding proposal for EIC – EPIC, includes 18 national institutes in India



FoCAL Test beam at CERN, September 2022.

Simulation of THGEM detector @ NISER

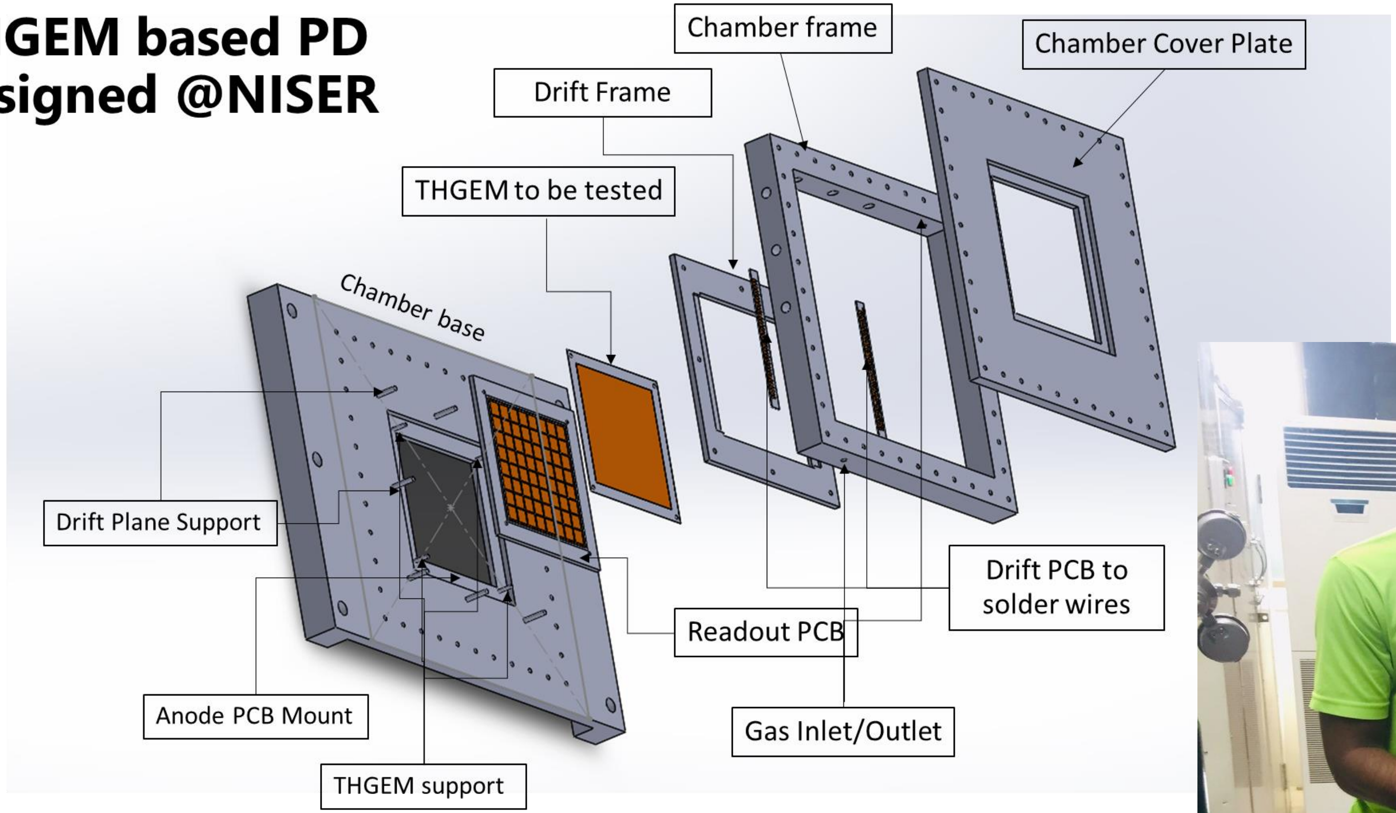
- Field calculation was done by ANSYS and then the results were imported to Garfield++ for further calculations.
- The tool to simulate Electric Field configurations for the available THGEM setup is ready.
- The same tool can be used for simulating new designs.
- Very Preliminary efforts. The tools are getting ready. People are getting trained.

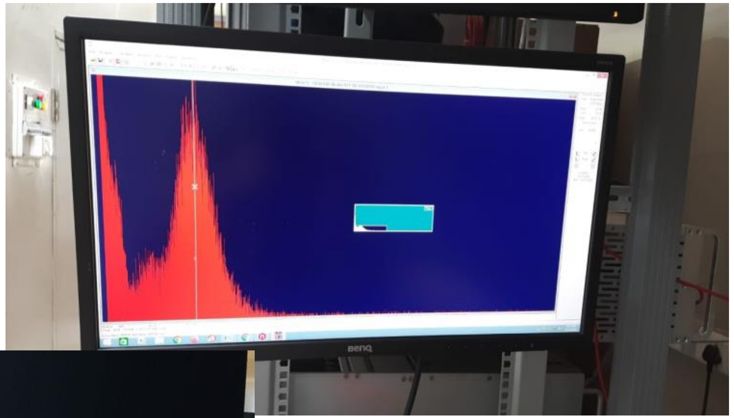


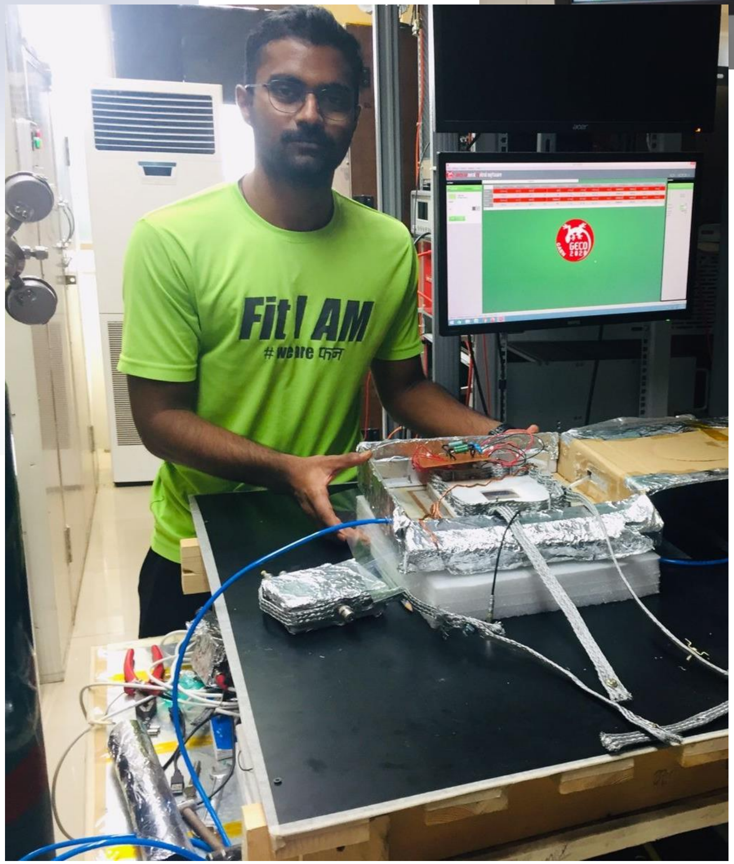
Electric Potential configuration for all the stages of a THGEM unit cell inside the gas volume.

Thick GEM – First results @ NISER

THGEM based PD designed @NISER



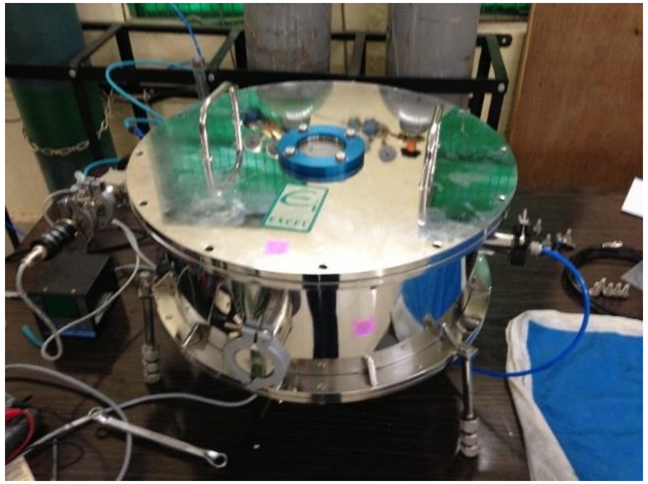




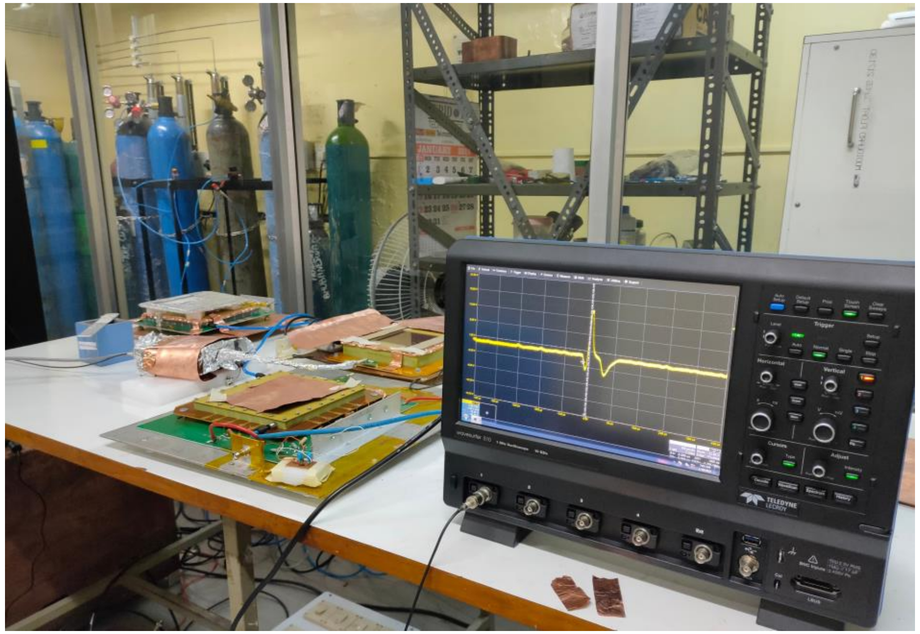
GEM-based photo detector for PID @ BHU and IOP

Photocathodes@BHU:

Conversion of photons into photo-electrons
High QE CsI/KBr/Diamond photocathode may be used.
R & D simulation for Meta-materials for PID application, MPGD test facility



MPGD test setup at IoP Bhubaneswar



Detector R&D facilities @ NISER

Clean room – 20 m^2

Clean room – 20 m^2

Summary

- 18 National Indian institutes have expressed interest to participate in EIC EPIC project
- Nature of contribution is under discussion – in early stage
- Working on collective research proposal – wish to submit during this year
- Contribution on software front has already started and in good progress
- Hardware interests are in ZDC, RICH and ToF (Si detector R&D) – in early stage
  - Experience with SiPM and Pad array fabrication, LGAD – just started
- Experienced community exists in QCD physics experiments and we are open to any possible collaborations

Thank you!