

p-type Pad Array R&D Update from NISER, India

Prepared by Ganesh Tambave

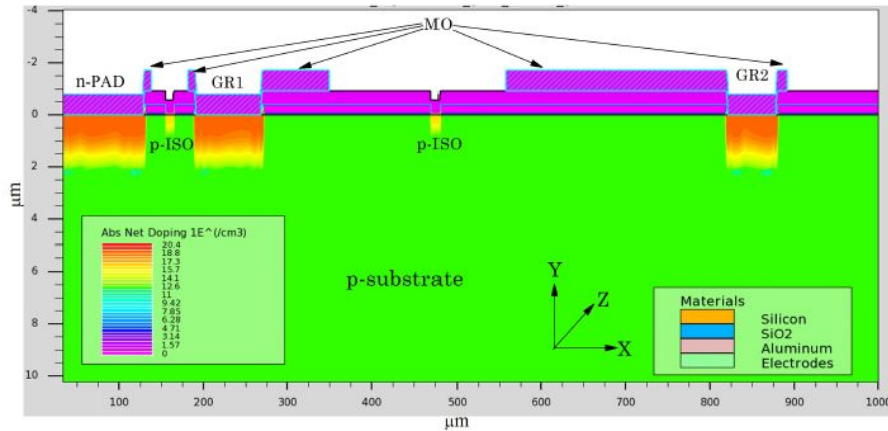
presenting on behalf of NISER FoCal Team

ALICE -India Meeting at VECC, held on 1-4 July 2025

<https://indico.cern.ch/event/1548280/timetable/#20250701>

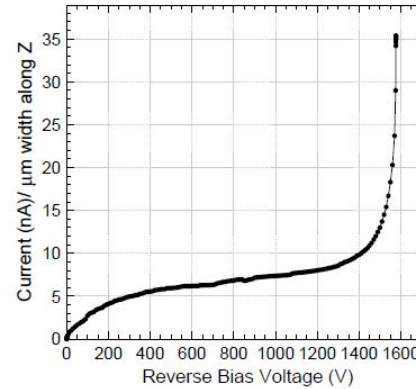
p-type Si pad array (8x9): TCAD Simulations

Doping profile of part of p-type Si pad

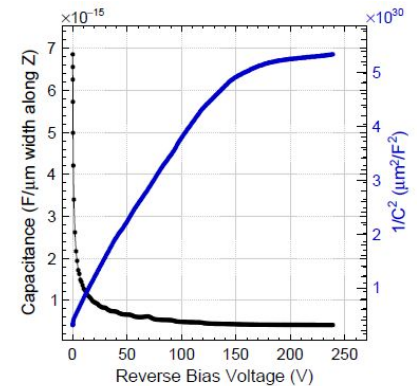


Parts visible in the above scheme:
Two guard rings (GR1, GR2), and p-type isolation regions.
The colour gradient \rightarrow absolute net doping concentration in cm^{-3}

Simulated IV

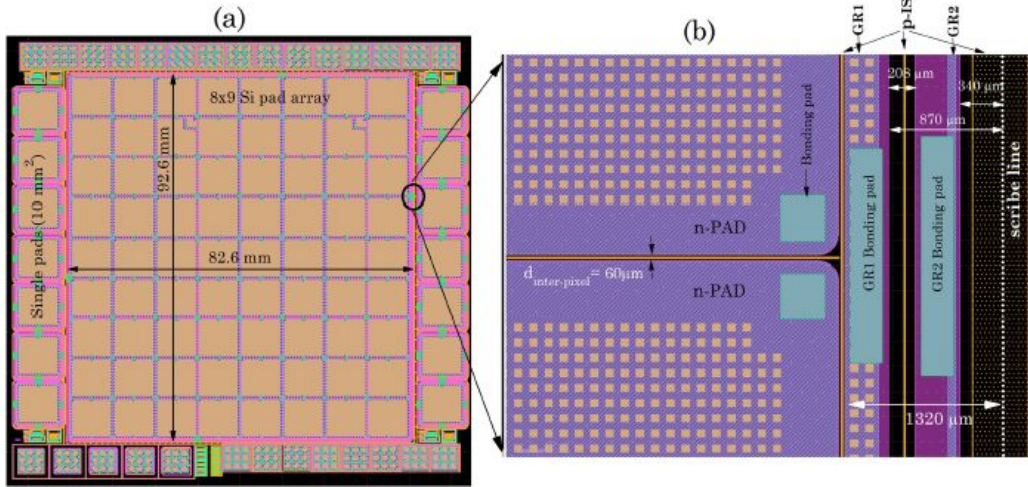


Simulated CV

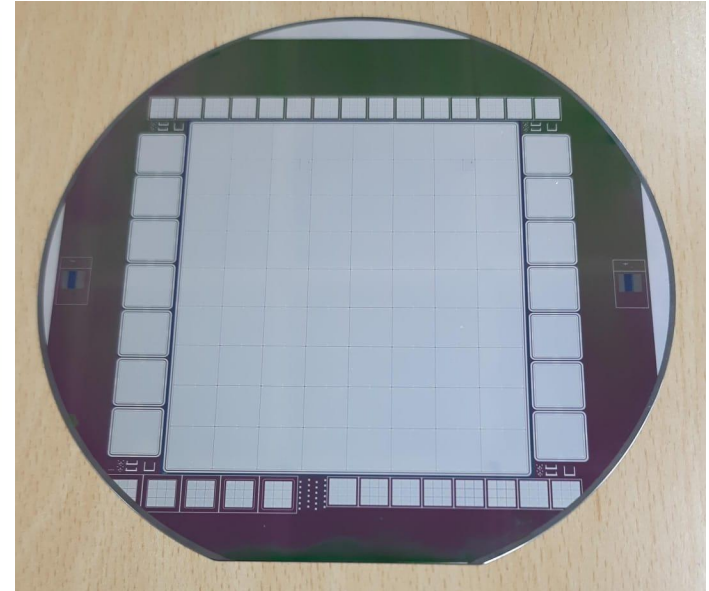


p-type Si pad array (8x9): Mask & Fabricated Detector

Mask layout



Detector at 6-inch wafer level



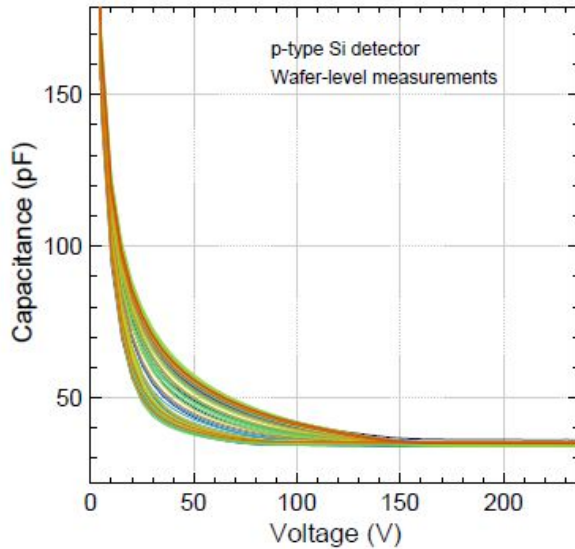
Fabrication is done at
Semiconductor lab (SCL), Chandigarh, India

Photos received from SCL, Mohali

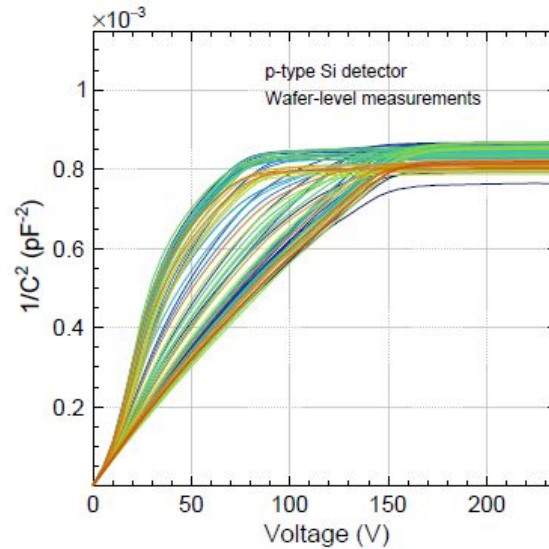
Measured IV & CV Curves

1st batch
wafer - NP#5

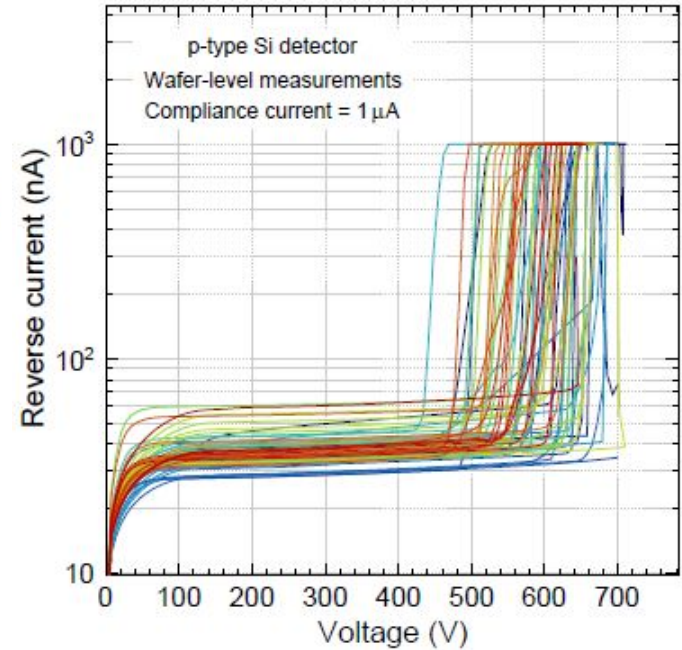
CV curve



$1/C^2$ vs. V curve



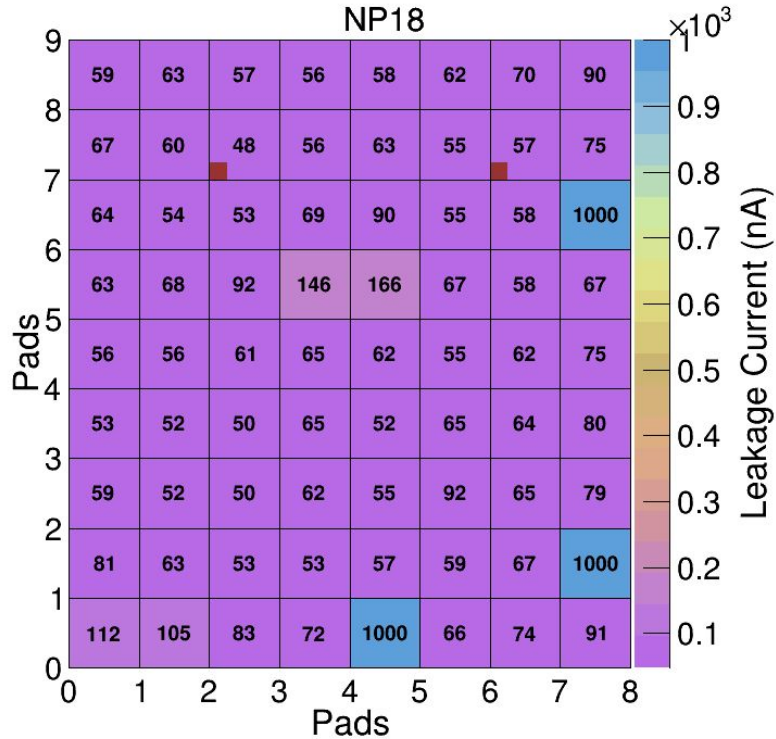
IV curve



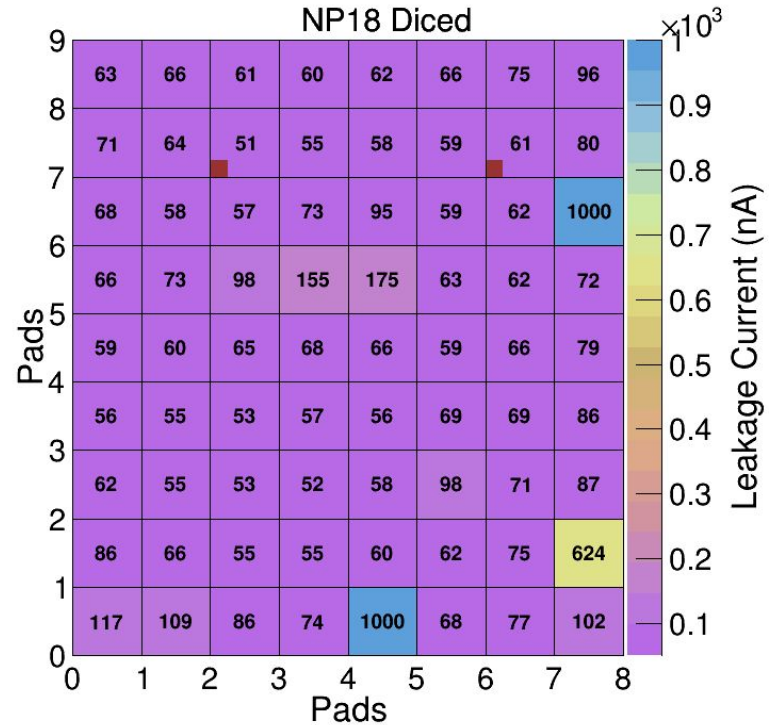
Before and After Diced Comparison

2nd batch
wafer - NP#18

IV before diced



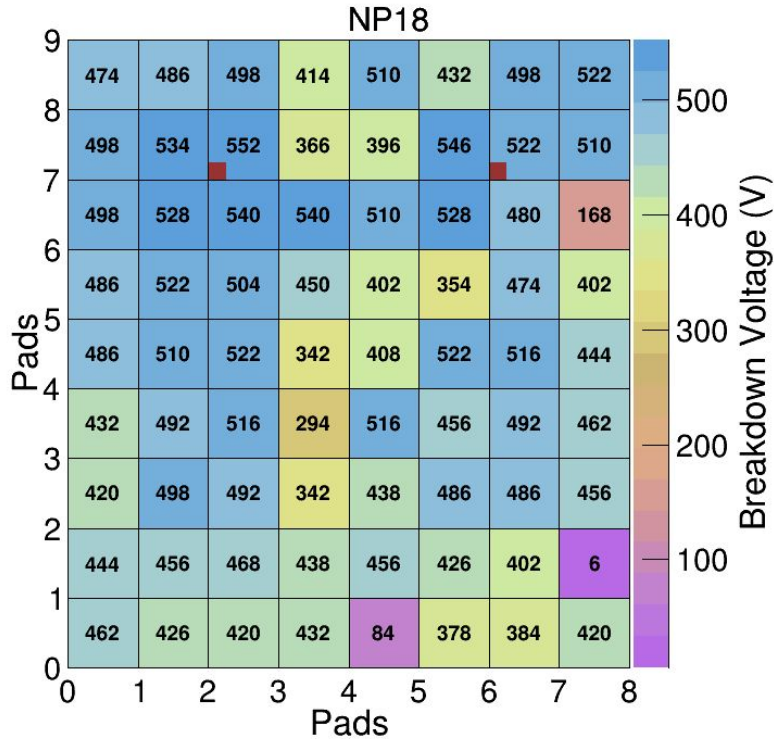
IV after diced



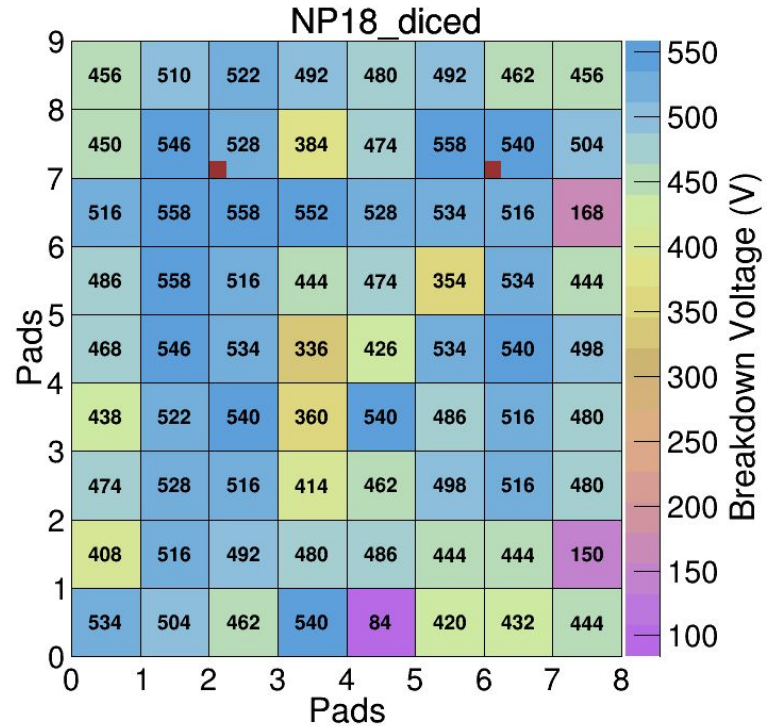
Before and After Diced Comparison

2nd batch
wafer - NP#18

Breakdown Voltage (BV) before diced



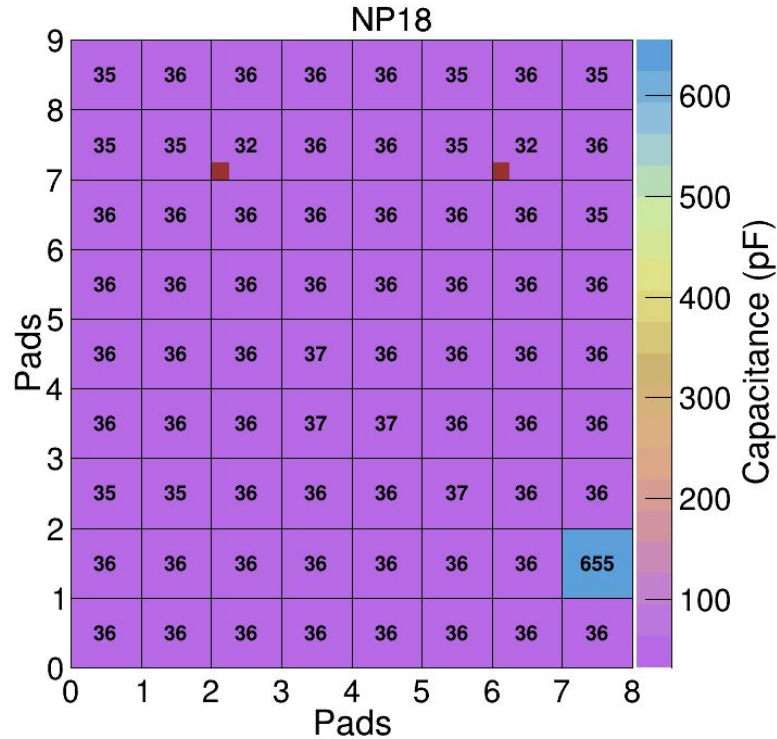
BV after diced



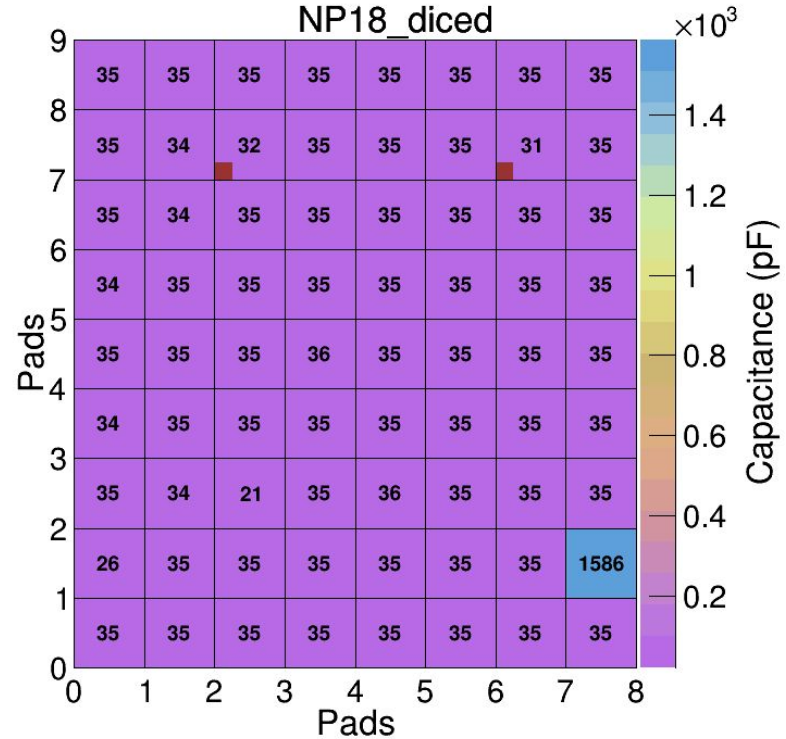
Before and After Diced Comparison

2nd batch
wafer - NP#18

CV before diced



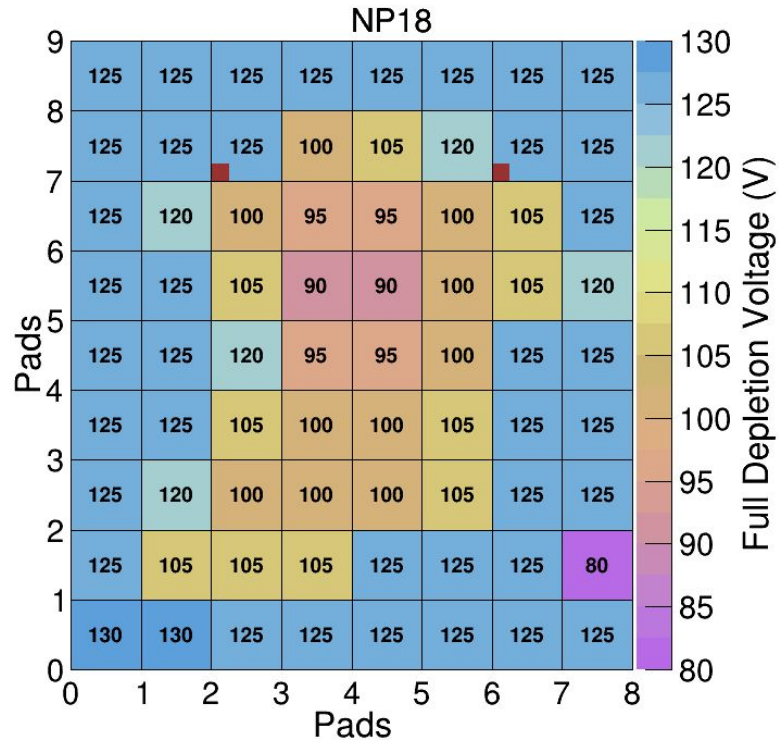
CV after diced



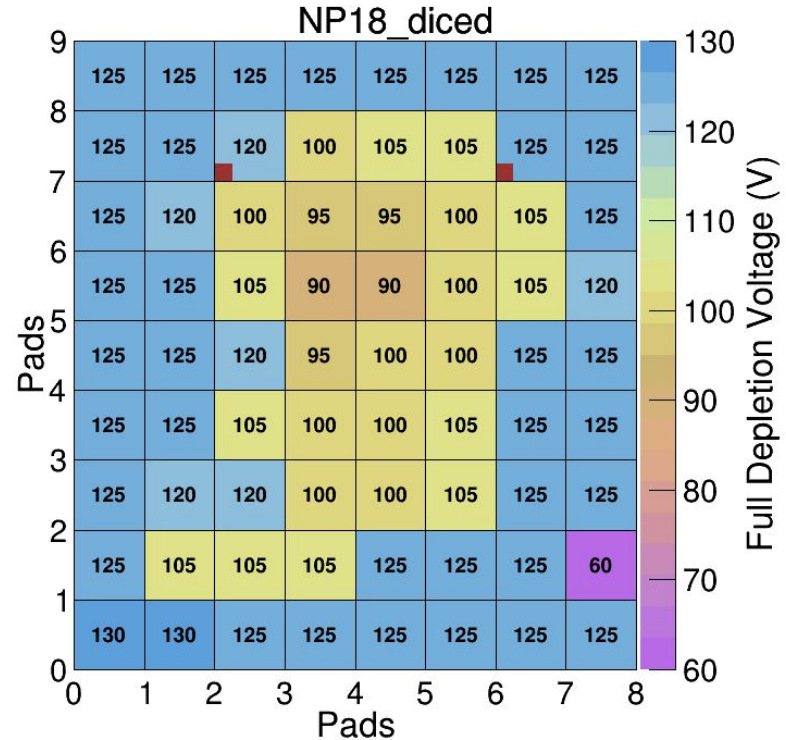
Before and After Diced Comparison

2nd batch
wafer - NP#18

Full Depletion Voltage (FDV) before diced

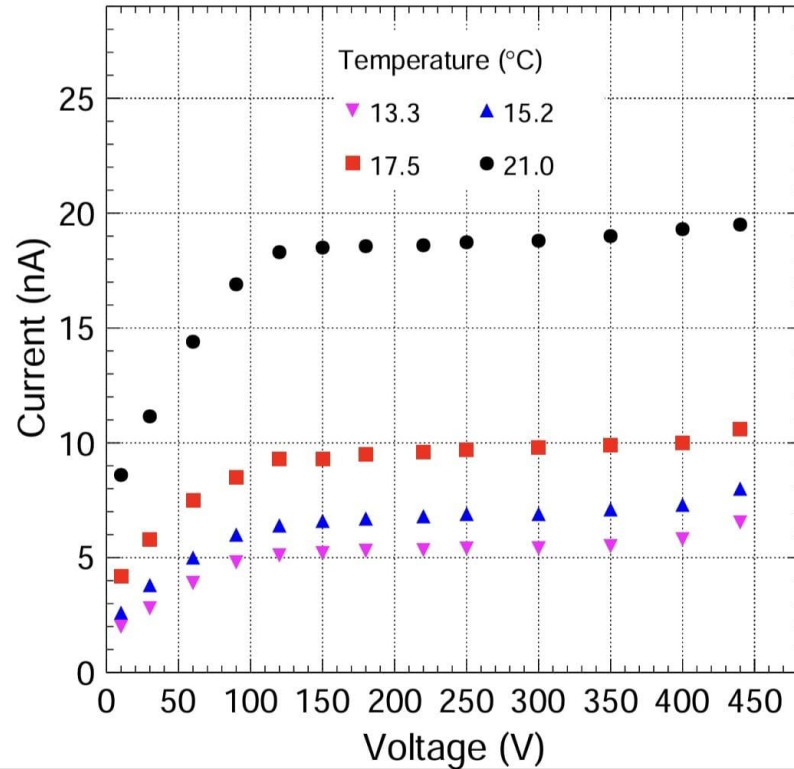


FDV after diced



I-V Curve with change in Temperature

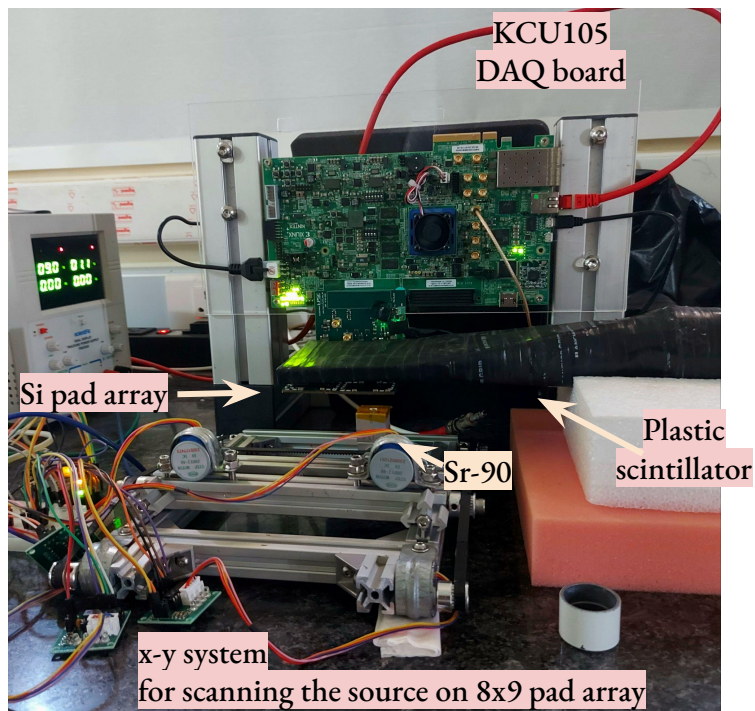
1st batch
wafer - NP#5



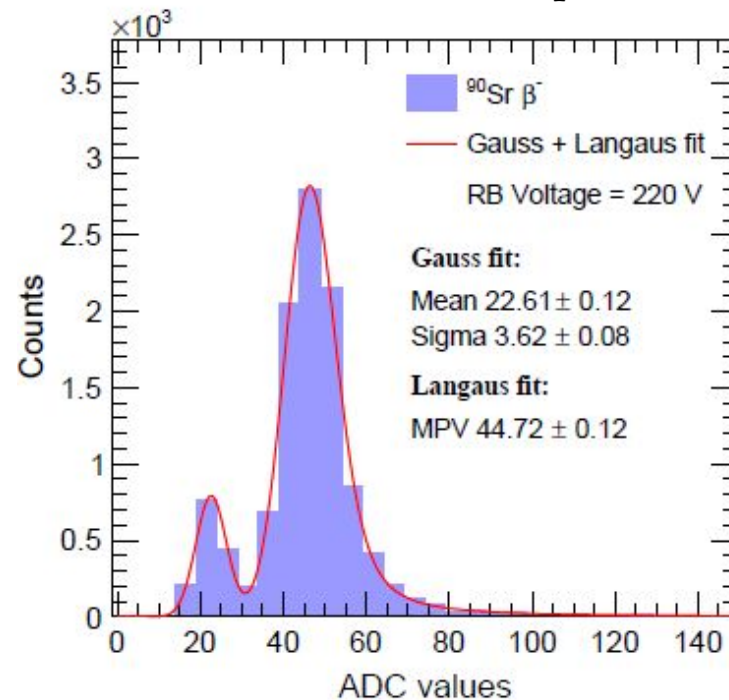
Test with HGCROCV2 chip at NISER

1st batch
wafer - NP#5

Test setup at NISER Si lab



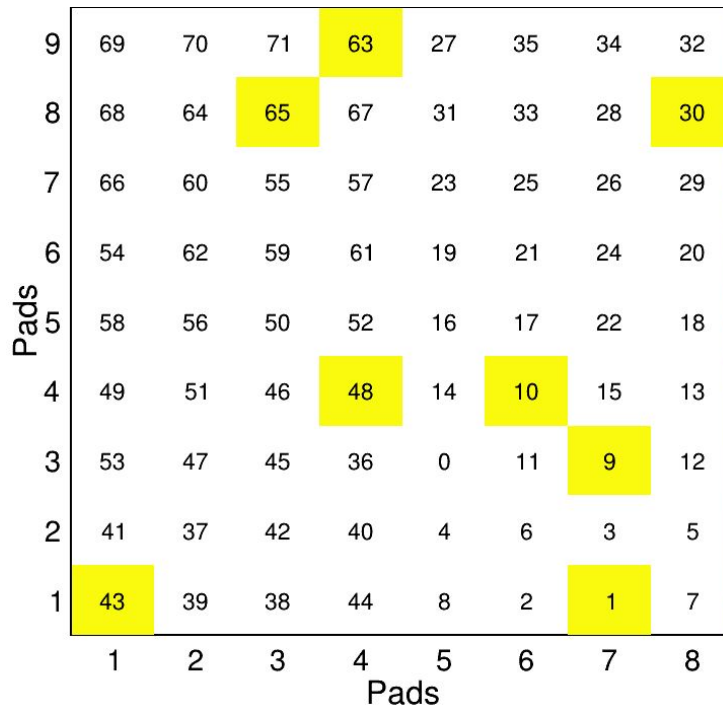
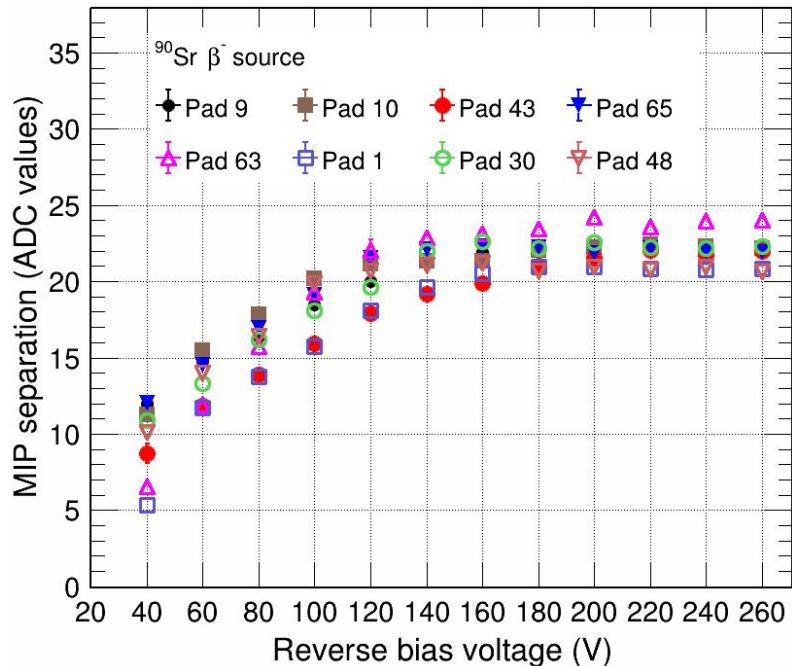
Sr90 e- source: MIP spectrum



Test with HGCROCV2 chip at NISER

1st batch
wafer - NP#5

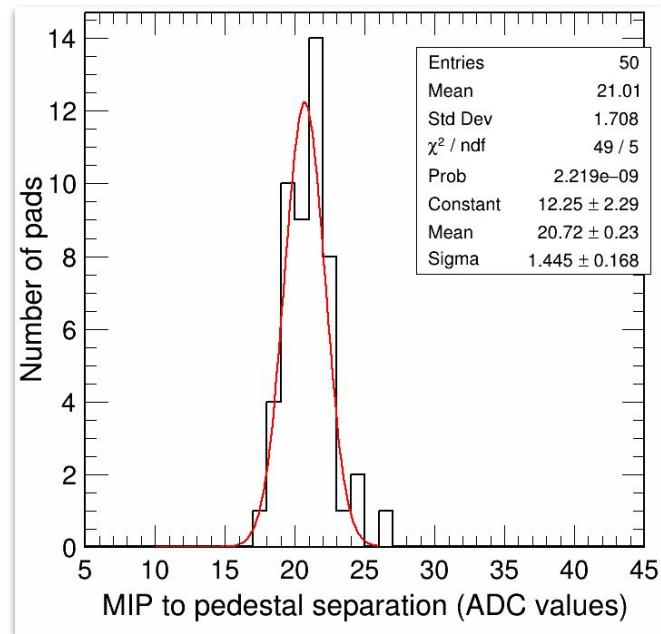
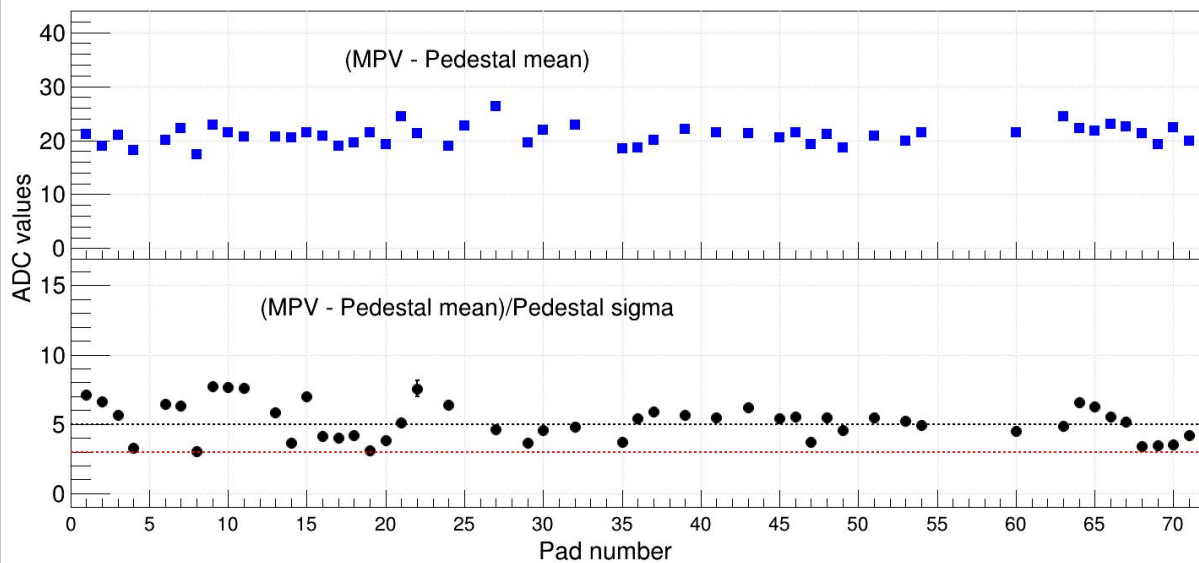
Sr90 e- source: voltage scan @ diff. Positions on array



Test with HGCROCV2 chip at NISER

1st batch
wafer - NP#5

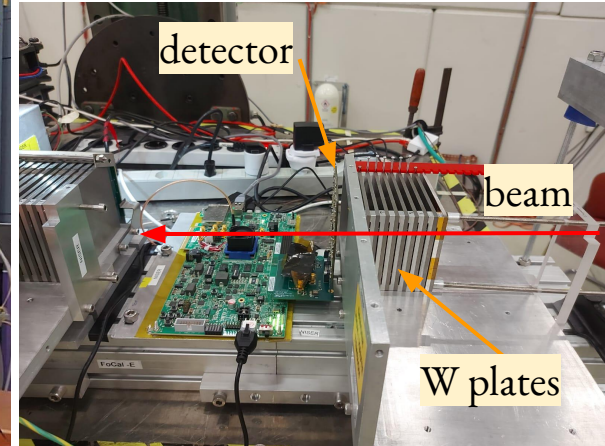
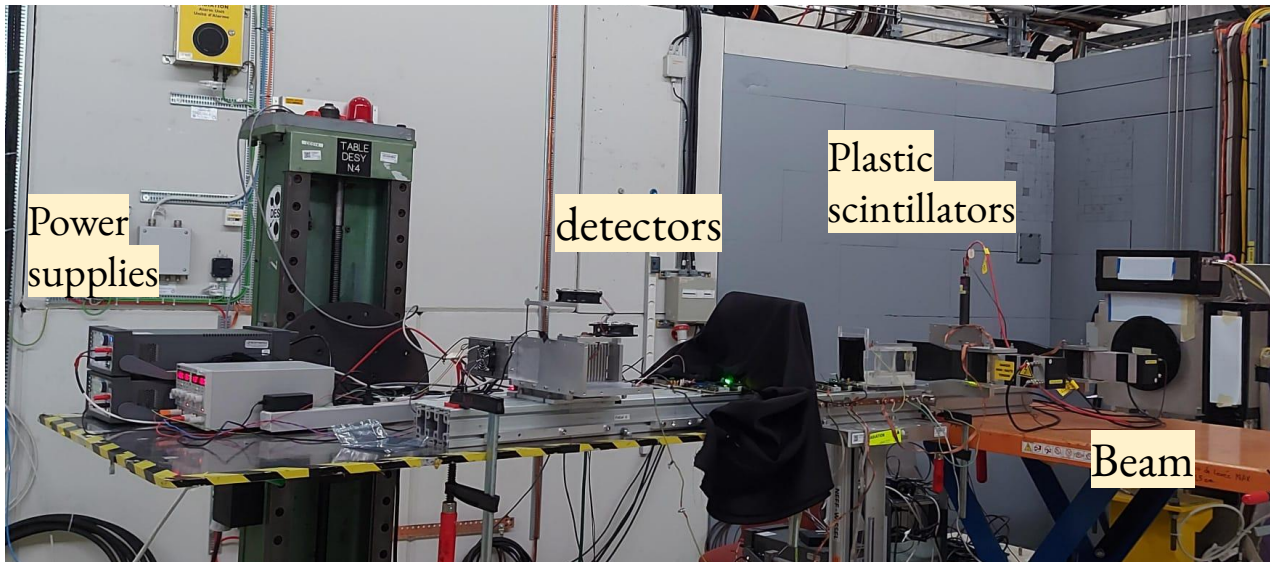
Sr90 e- source: Position Scan



Most of the pad cells show Sr90 signal, electronics noise need to be reduced further

P-type (NISER/SCL) pad array test at PS, CERN (30 Oct. to 6 Nov. 2024)

1st batch
wafer - NP#5



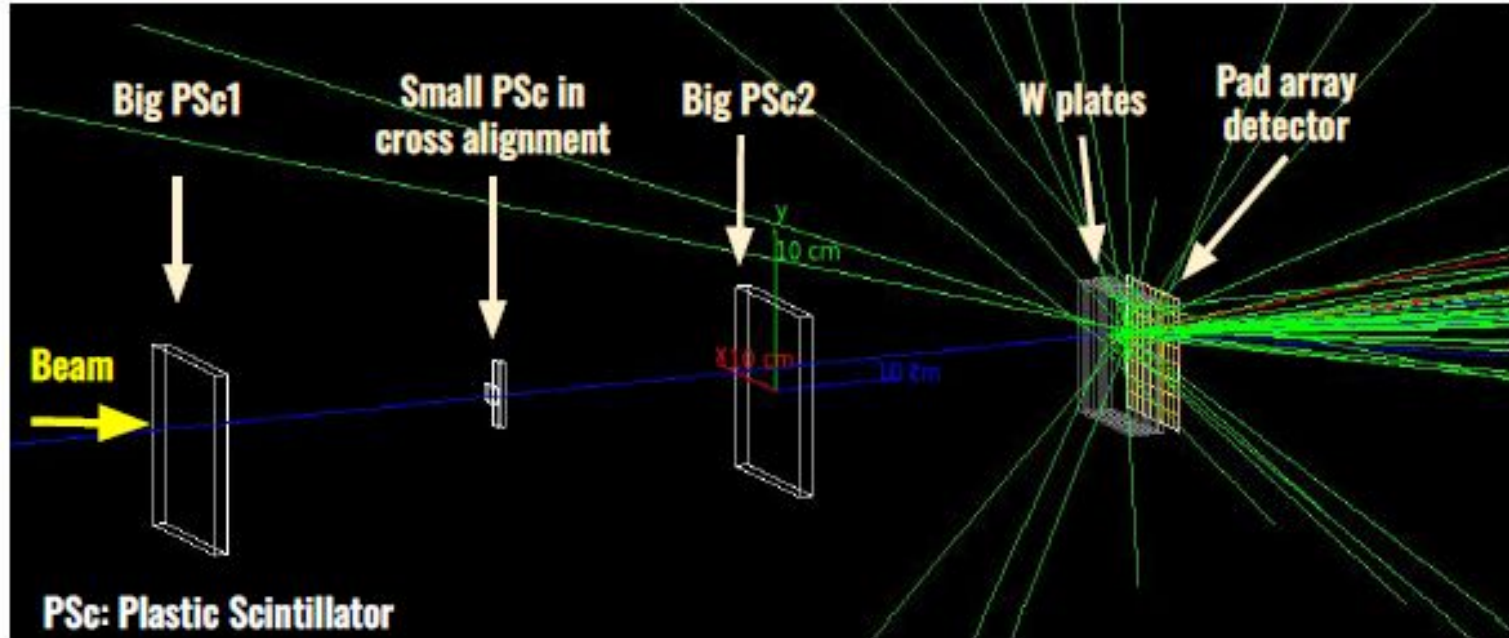
π^- (10 GeV):

- Voltage scan & Position scan of pad cells of 8x9 p-type detector

e^+ beam (2 GeV - 4 GeV):

- Shower profiles using W plates in-front of the detector

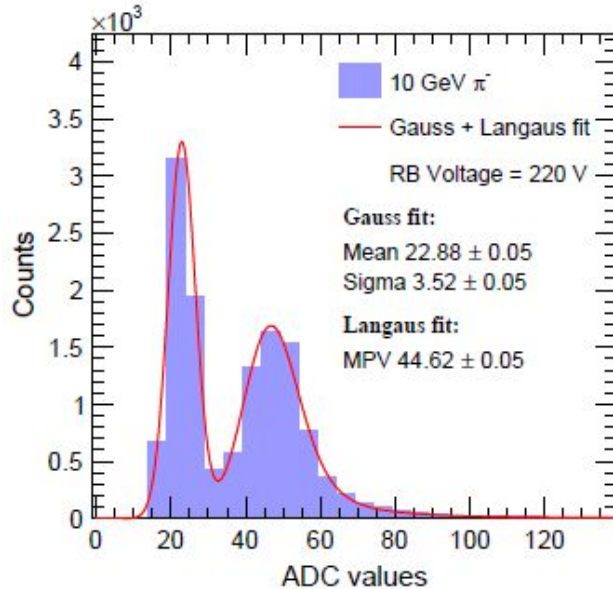
P-type (NISER/SCL) pad array: Geant4



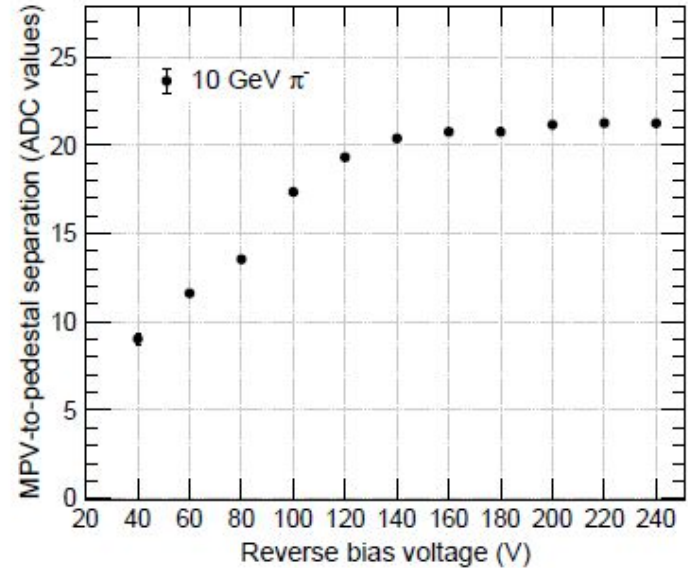
P-type (NISER/SCL) pad array: 10 GeV pion

1st batch
wafer - NP#5

Typical MIP using 10 GeV pion @PS, CERN



MIP separation vs Bias voltage

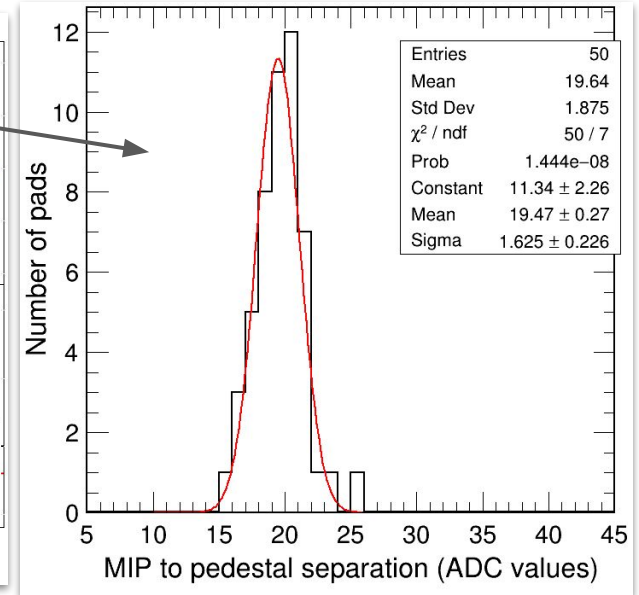
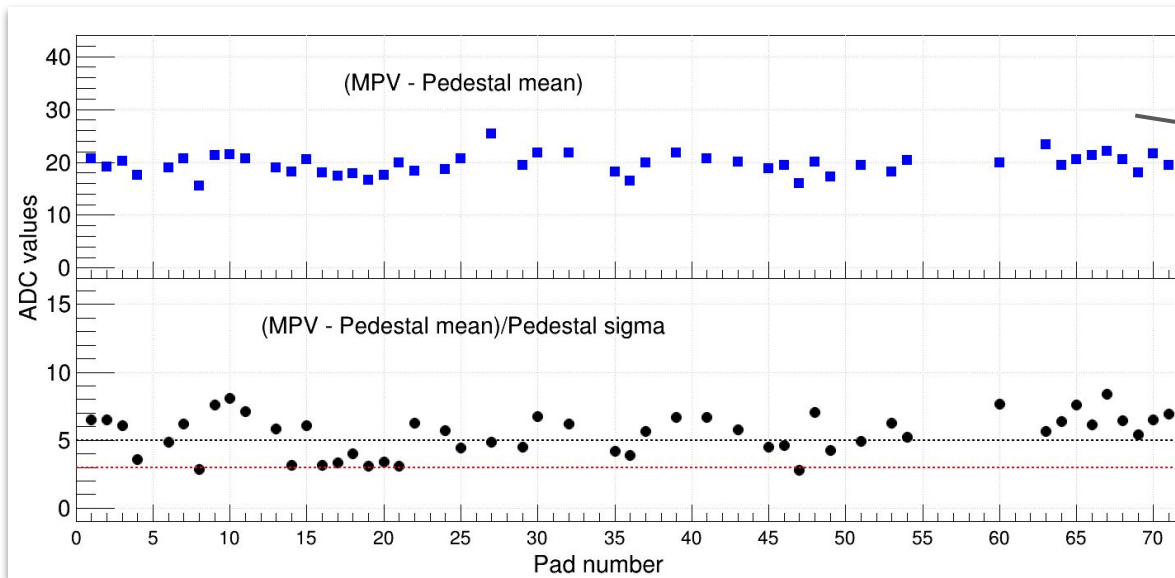


- Observed clear MIP signal using 10 GeV π^-
- Voltage scan confirms the full depletion of the detector ~ 160 V

P-type (NISER/SCL) pad array: 10 GeV pion

1st batch
wafer - NP#5

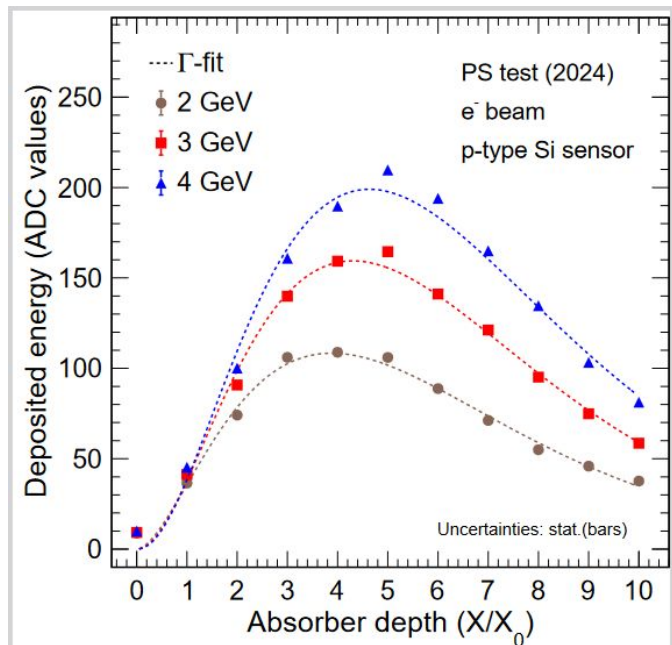
10 GeV pion data: Position Scan



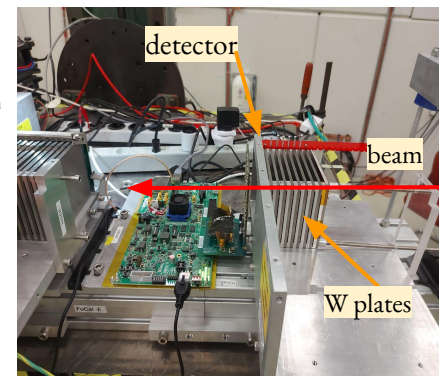
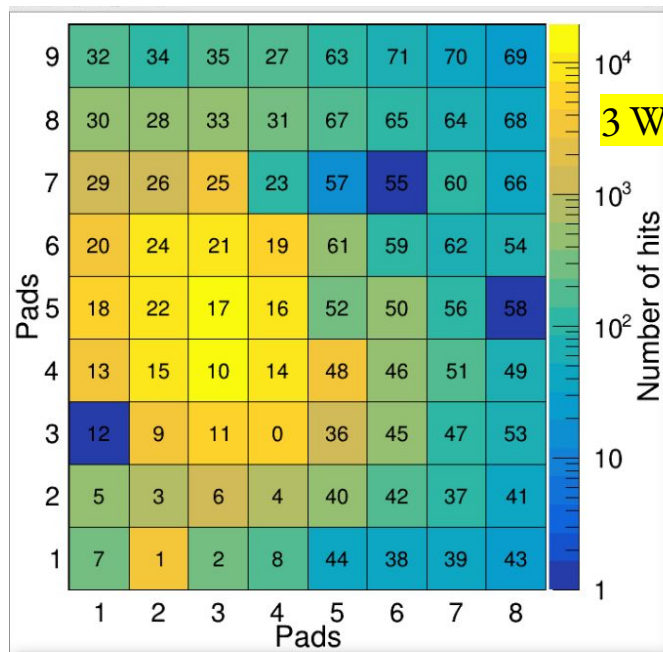
P-type (NISER/SCL) pad array: old results

1st batch
wafer - NP#5

Electron energy loss in detector vs.
radiation lengths (no. w plates in front)

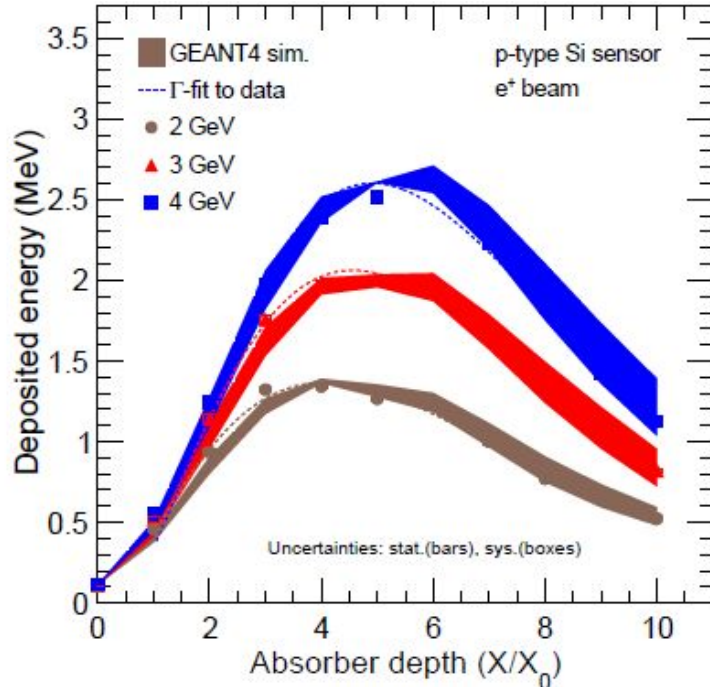


Hitmap: 3 GeV e Shower in P-type
Si pad array with 3 W plates in front

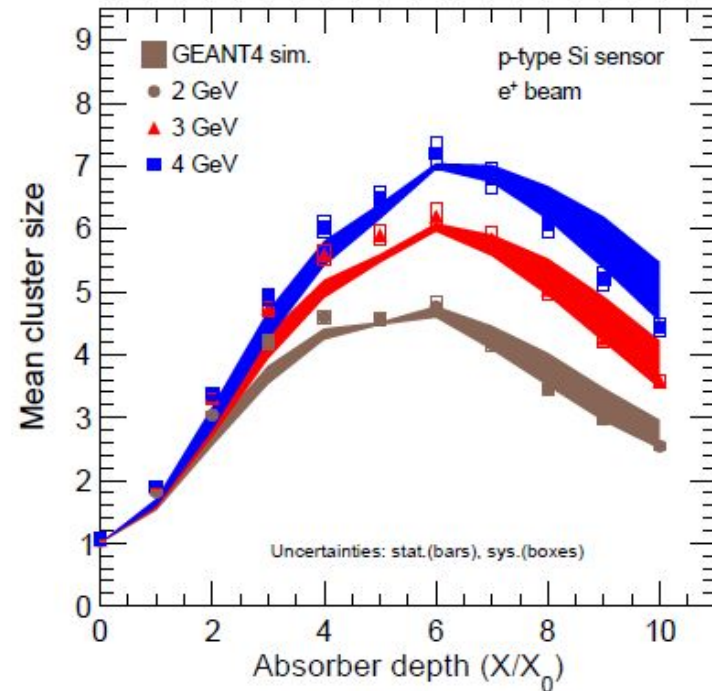


P-type (NISER/SCL) pad array: updated results

Longitudinal shower profile



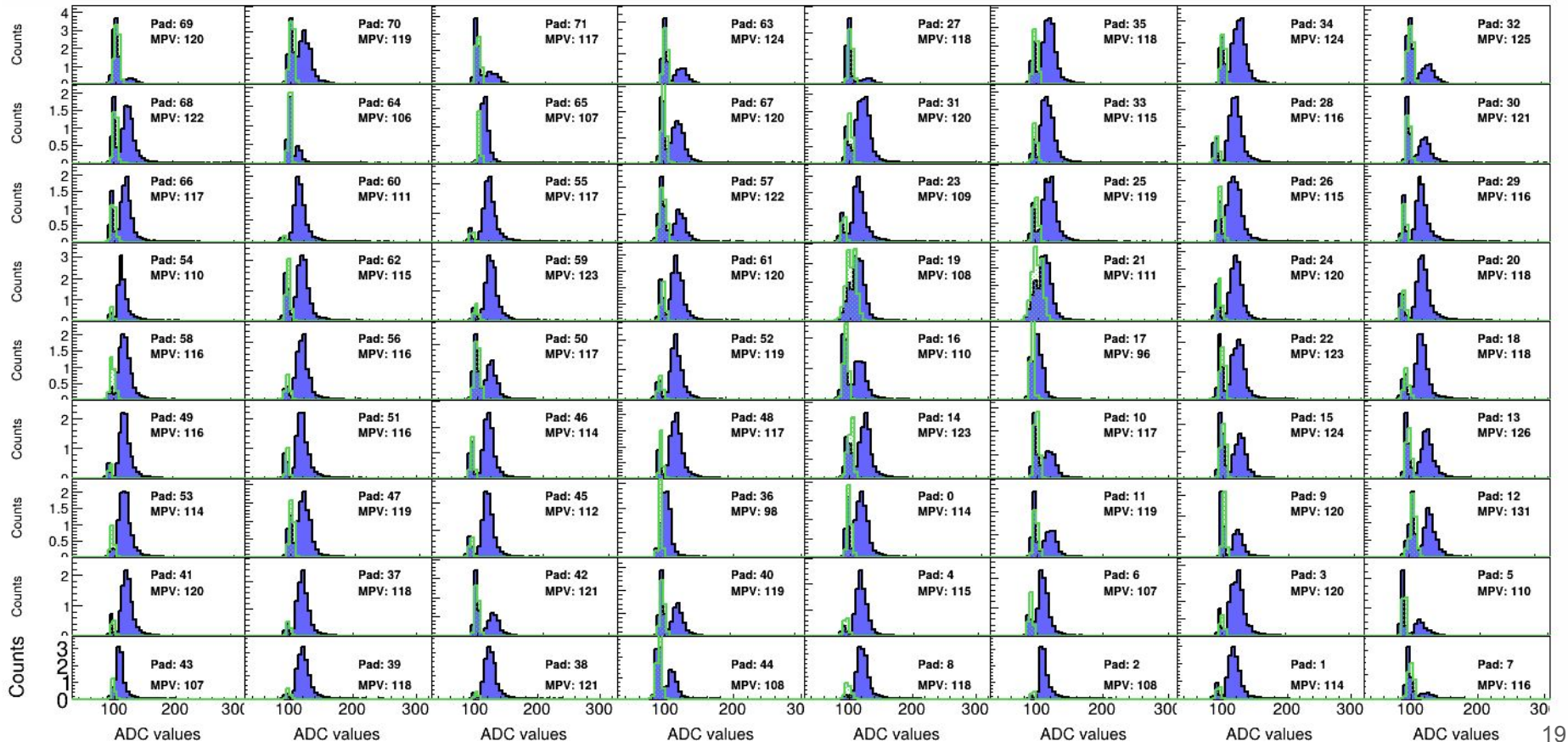
Mean cluster size distribution



- Statistical uncertainties shown with error bars
- Systematic uncertainties shown with boxes for data and bands for simulations is evaluated by varying the absorber depth by 5%, accounting for any unaccounted upstream material

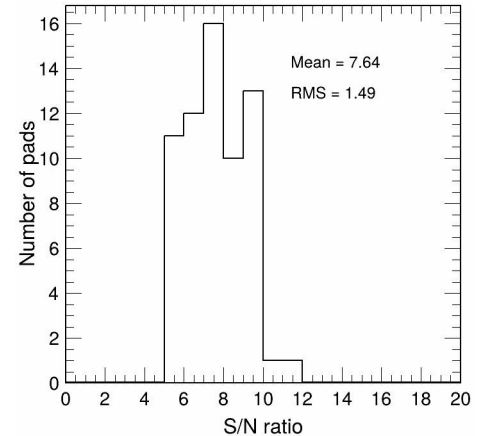
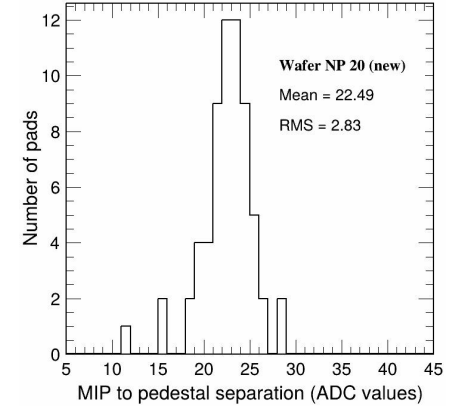
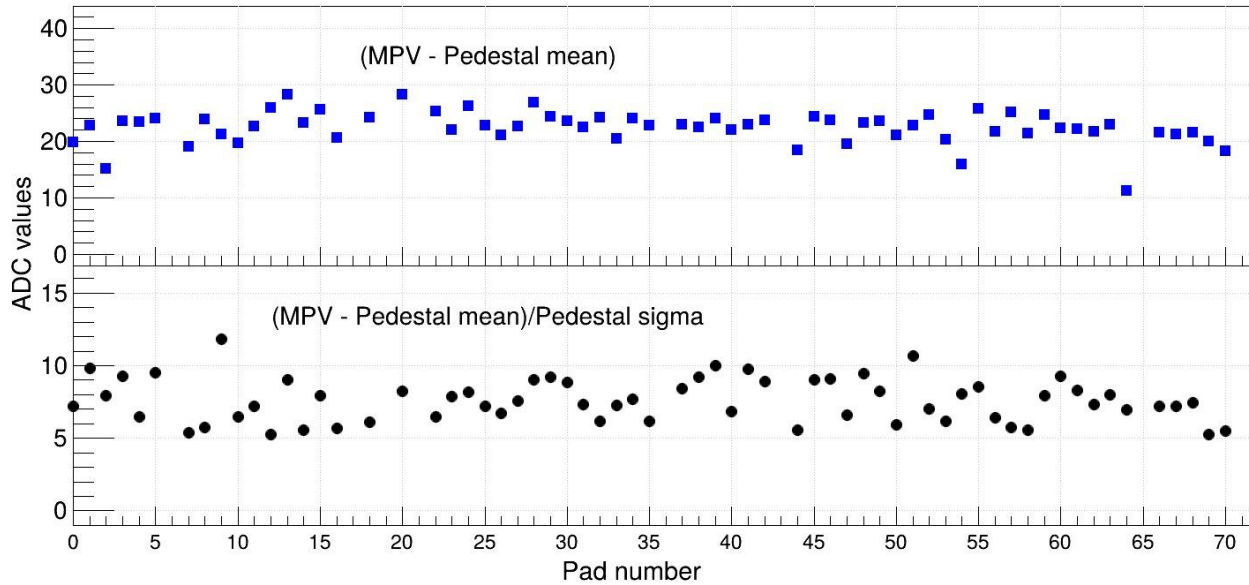
SCL P-type 2nd batch pad array (NP#20) - date 20.05.2025

Sr90 e- source: Position Scan



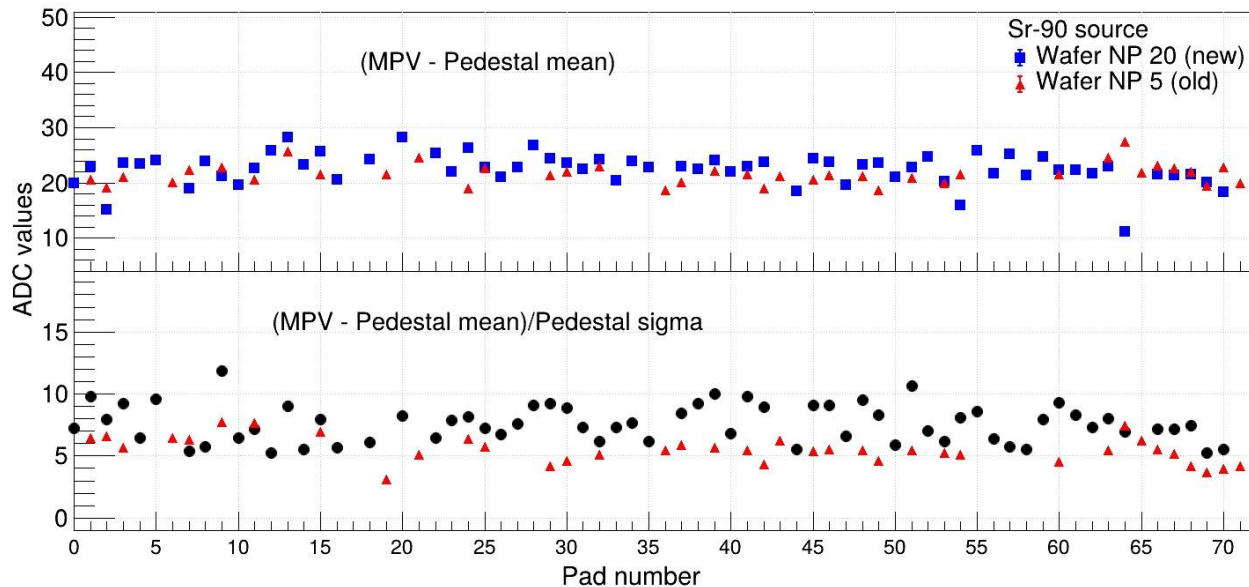
SCL P-type 2nd batch pad array (NP#20) - date 20.05.2025

Sr90 e- source: Position Scan



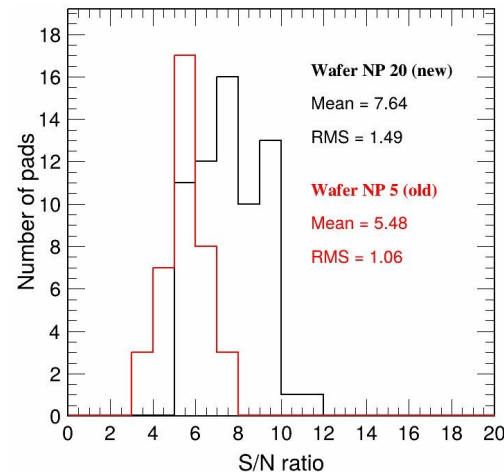
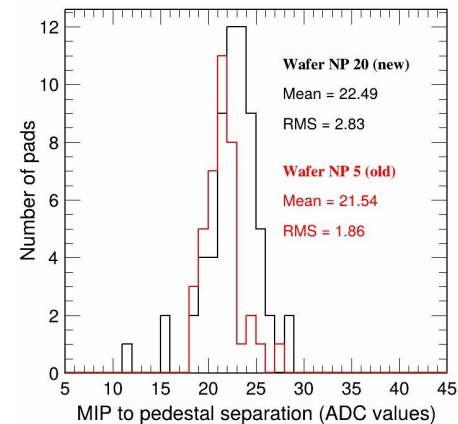
SCL P-type 2nd batch pad array (NP#20) - date 20.05.2025

Sr90 e- source: Position Scan - compared with 1st batch



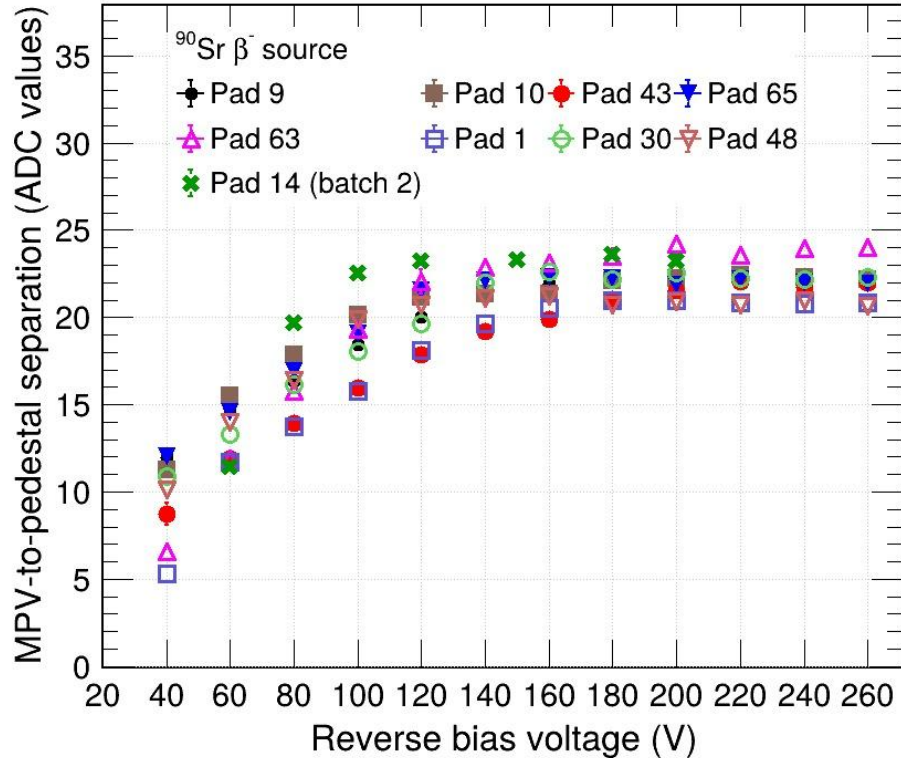
$$\text{S/N ratio} = (\text{MPV} - \text{Pedestal mean}) / \text{Pedestal sigma}$$

Signal-to-noise separation is improved in the new batch of the detectors



SCL P-type 2nd batch pad array (NP#20) - date 20.05.2025

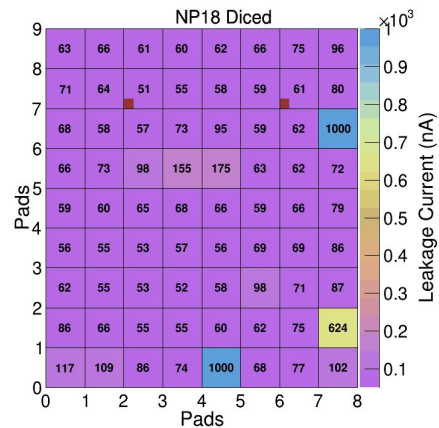
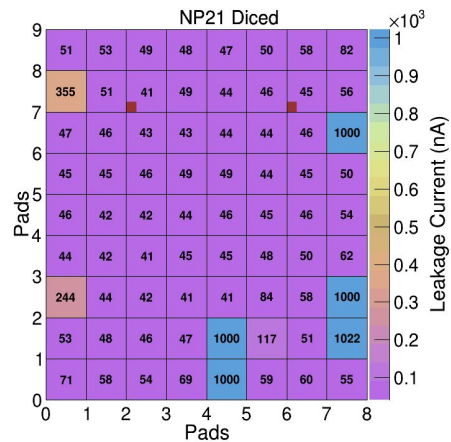
Sr90 e- source: Voltage Scan



SCL P-type samples sent for Radiation hardness test @ PS CERN - date 20.03.2025



IV data of two pad arrays: NP#21 & NP18

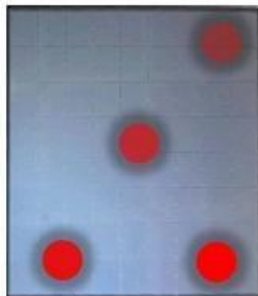


IV of single pad samples

1	Sr. No.	Wafer no.	Site#	I _{lkg} @220 V (nA)	Array_Side
2	1	NP18	L1	63	Left
3	2	NP18	L2	71	Left
4	3	NP18	L4	65	Left
5	4	NP18	L6	110	Left
6	5	NP18	L7	97	Left
7	6	NP18	R1	101	Right
8	7	NP18	R2	19	Right
9	8	NP18	R4	85	Right
10	9	NP18	R6	88	Right
11	10	NP18	R7	90	Right
12	11	NP13	L1	38	Left
13	12	NP13	L2	40	Left
14	13	NP13	L3	37	Left
15	14	NP13	L4	33	Left
16	15	NP13	L5	230	Left
17	16	NP13	L6	39	Left
18	17	NP13	L7	36	Left

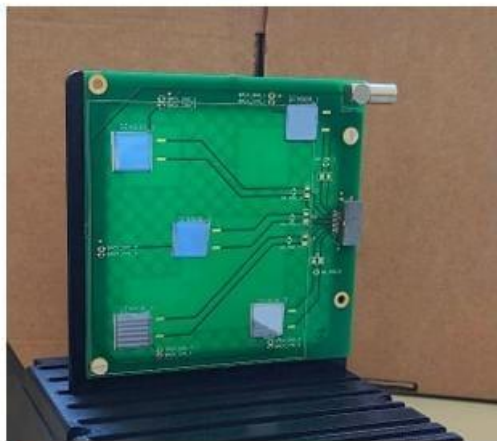


Irradiation campaign 2025 @IRRAD



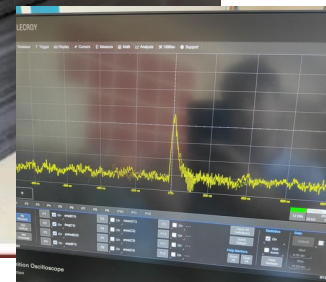
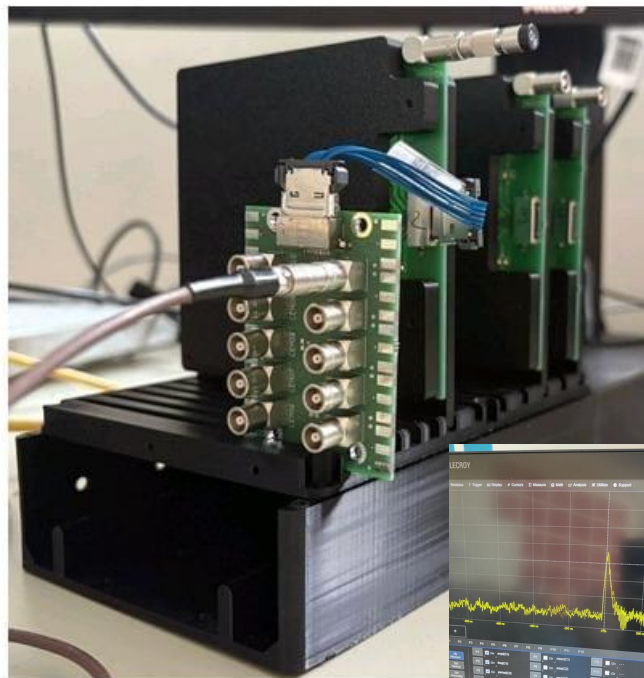
- Full sensors from HPK, SCL and BEL characterized before (IV/CV) and after irradiation IV/CV/MIP).
- Some sensors (>2) irradiated at $7 \cdot 10^{13} \text{ neq / cm}^2$
- Full sensors irradiated in spots:

- Control
- $\sim 10^{11} \text{ neq / cm}^2$
- $\sim 10^{12} \text{ neq / cm}^2$
- $\sim 7 \cdot 10^{13} \text{ neq / cm}^2$
- $\sim 7 \cdot 10^{14} \text{ neq / cm}^2$



1x1 cm² from SCL and BEL ready!
waiting for HPK:

- IV/CV before and after irradiation in progress
- IV monitoring during irradiation



Summary

- Successfully initiated p-type R&D work with SCL
- Detector fabrication so far:
 - 1st batch - fabricated in Sept. 2024, in-beam test completed Nov. 2024, data analysis finalised, documentation completed
 - 2nd batch - fabricated in April 2025, test with Sr-90 completed, several detectors are fabricated and IV/CV test completed - improvement compared to previous
 - 3rd batch - mask design done for improvement to achieve higher breakdown and low leakage current for all the pads