International Center for
Quantum-field Measurement Systems for
Studies of the Universe and Particles
WPI research center at KEK

Measurement on Prototype of Double-Sided 3D Sensors Produced by CNM

Chuan Liao[1,2], Christopher Betancourt[1,2], Daniela Bortoletto[1,2,3], Manabu Togawa[1,2], Koji Nakamura[1]

1. High Energy Accelerator Research Organization(KEK)

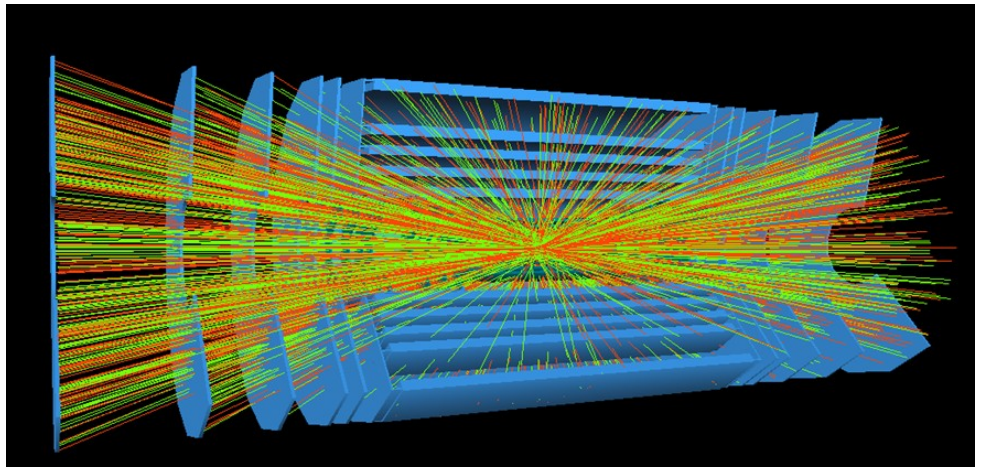
2. International Center for Quantum-field Measurement Systems for Studies of the Unverse and Particles (QUP)

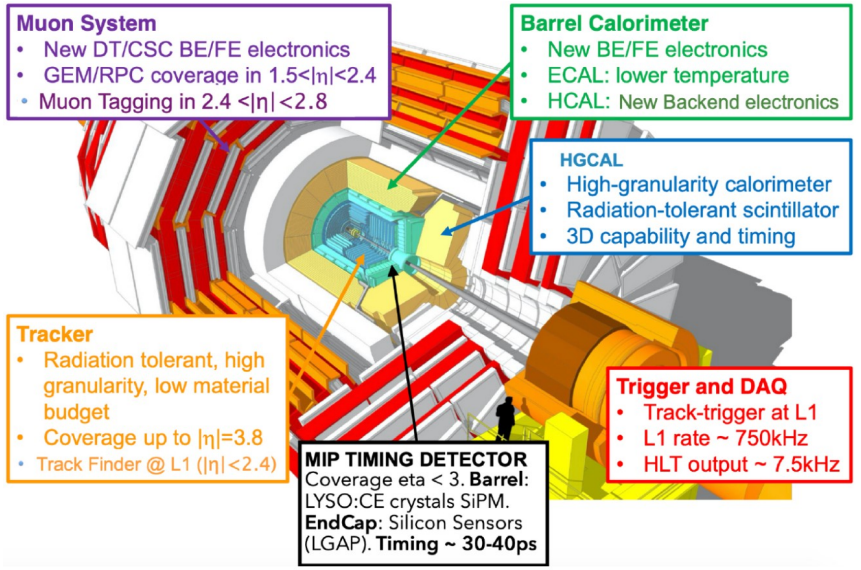
3. Department of Physics, University of Oxford, UK

Outline

- Motivation
- Sample information
- Simulation
- Experiment
- Next Plan

Motivation





High particle rate for LHC upgrade:
up to 200 p-p collisions per bunch crossing in collision experiment;
Higher luminosity

High time resolution
High radiation hardness

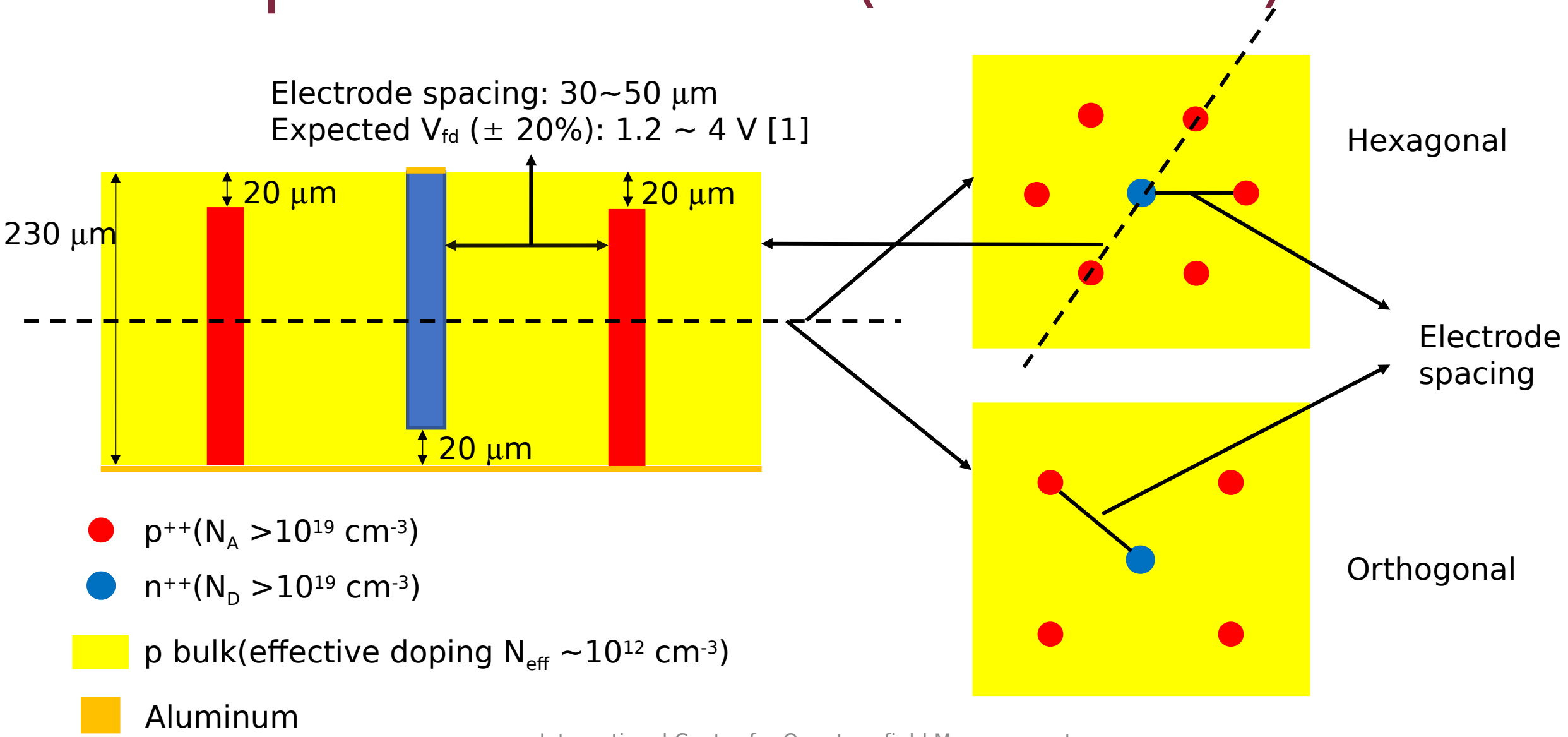
To meet those requirements, several detectors were developed for different layers

EndCap - Low gain avalanche detectors (LGADs)

Inner layer - **3-D detector**: higher radiaition tolarance, the time resolution can reach 10 ps according to [1]

[1] G M, Cossu and A, Lai. JINST 2023, 18(01): P01039.

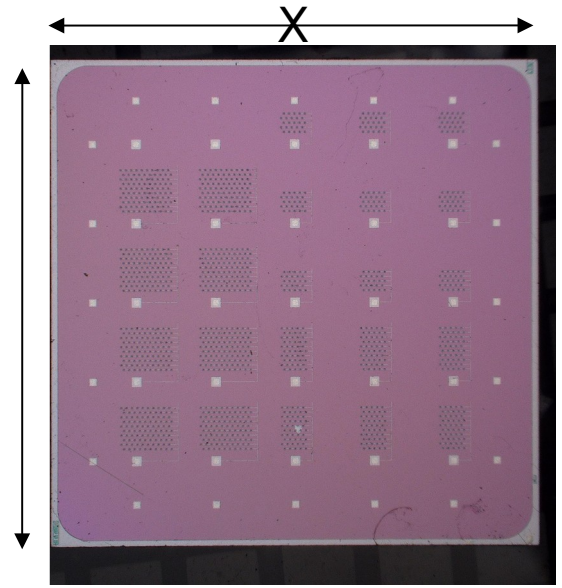
Sample Information (schematic)



[1] Z, Li. NIM-A, 2011, 658, 90-97.

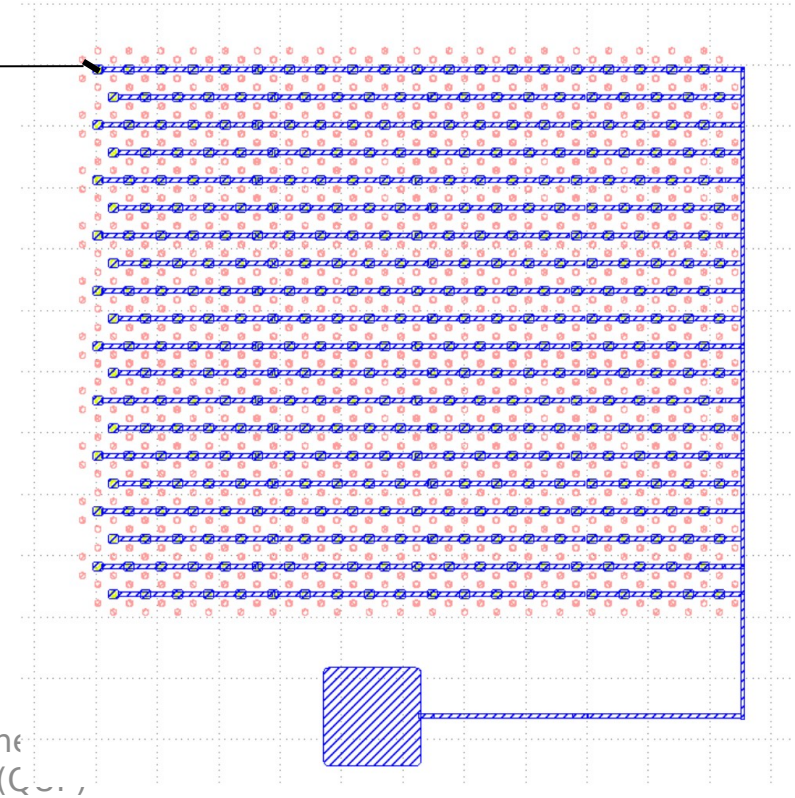
Sample Information

$A\ (mm^2) = X*Y$



3-D sensors	Thickness (μm)	A (mm^2)	Electrode spacing(μm)	V_{fd} (V)
Altiroc-A	230	8X8	50	2
Altiroc-B	230	8X8	30	1.5
Altiroc-C	230	8X8	50	2
Altiroc-D	230	8X8	30	1.5
Altiroc-E	230	8X8	50	2
1-X	230	4X4	55	2
2-X	230	4X4	50	2
4-X	230	4X4	30	1.5
5-X	230	4X4	30	1.5
6-X	230	4X4	30	1.5
7-X	230	4X4	30	1.5

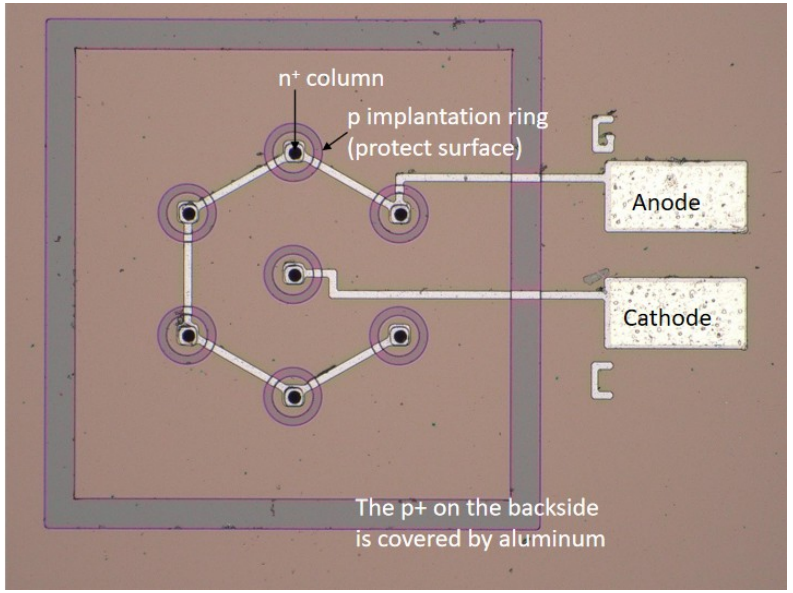
Electrode spacing



Each wafer contains 25 single cells, and over 300 cells will be investigated

Research Plan

3D sensors



Focus:

1. Impurity doping?
2. Geometric configuration?
3. Electronic readout?

Investigation methods

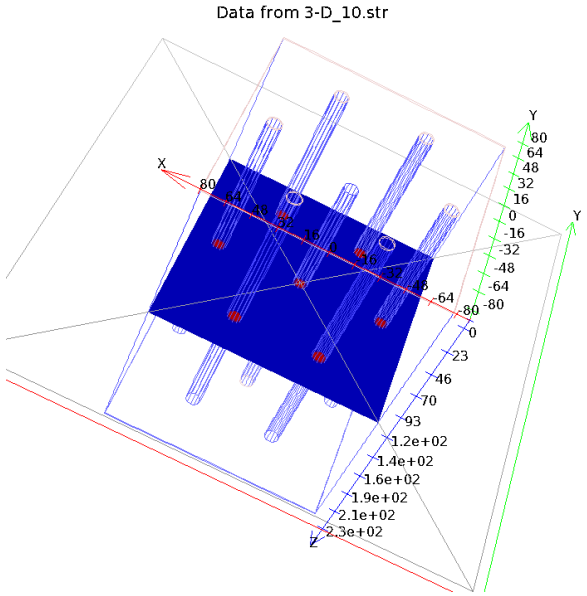
TCAD
Geant4
Simulation

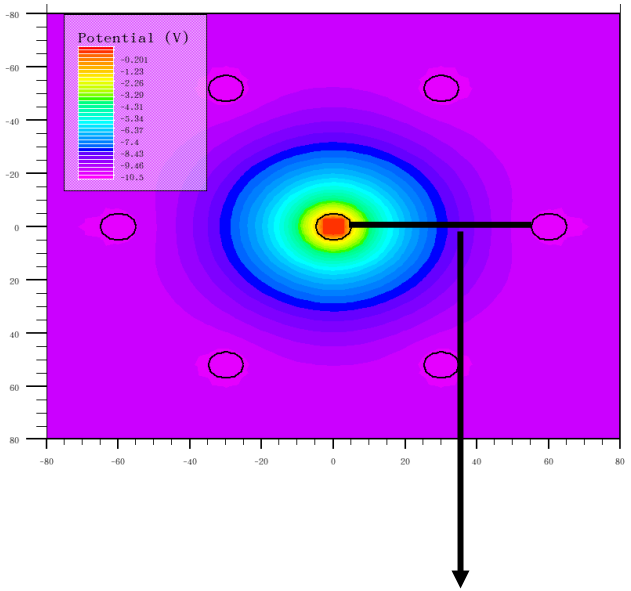
Before and after irradiation

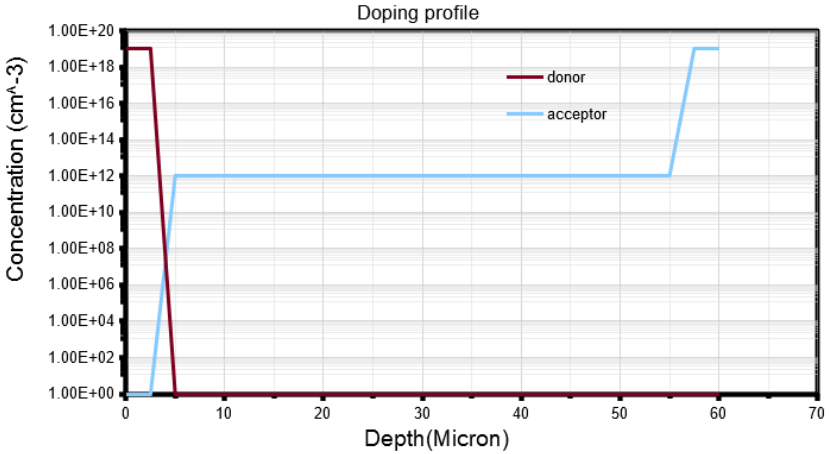
I-V
C-V
Timing
Experiment

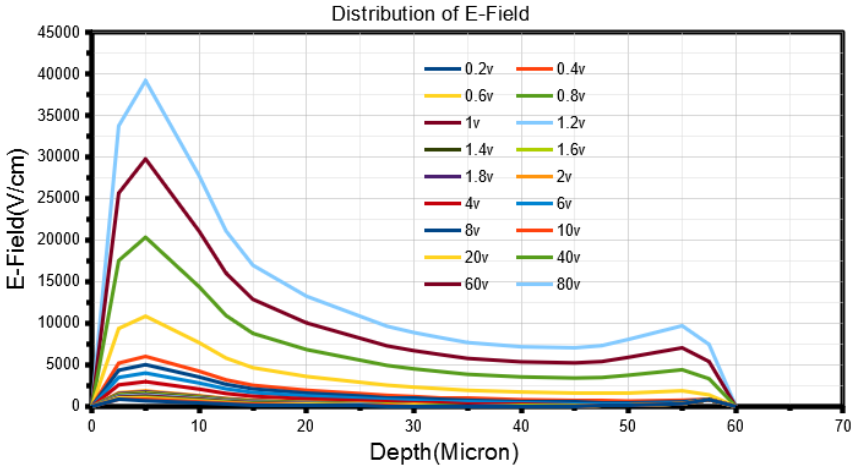
Theoretic model → New 3D detector prototype test

Simulation (TCAD-silvaco)









Simulation for single cell (V = -10 V)

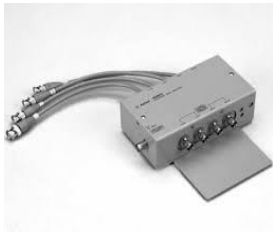
Cutline for extract curves:
E-field–Depth
Doping-Depth

Simulation details:

Carrier lifetime: 1e-4 s
SRH recombination model
Band to Band tunneling (Hurkx model)
Electrode spacing = 50 μm
N_{eff} = 1e12 cm^{-3}

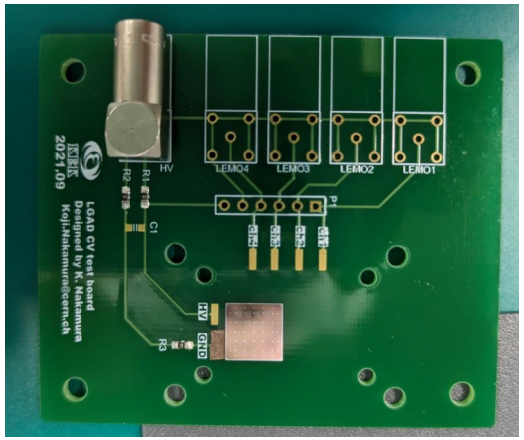
Experiment(IV/CV)

Keysight 2470 Source meter

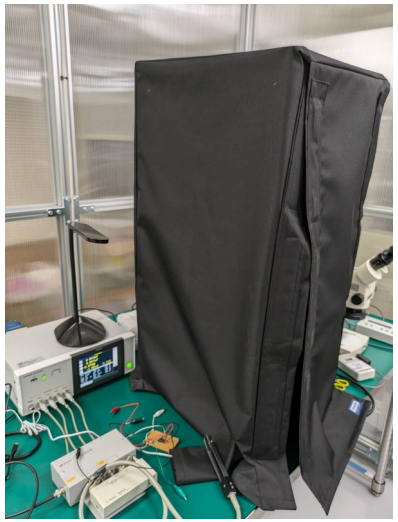


Keysight 16065C adaptor

Keysight IM3536 LCR meter

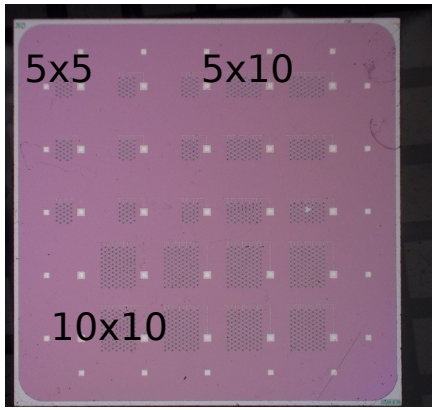


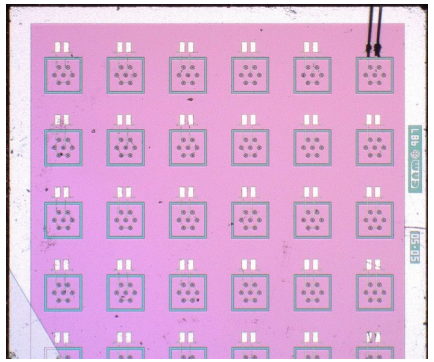
I/V, C/V testing PCB

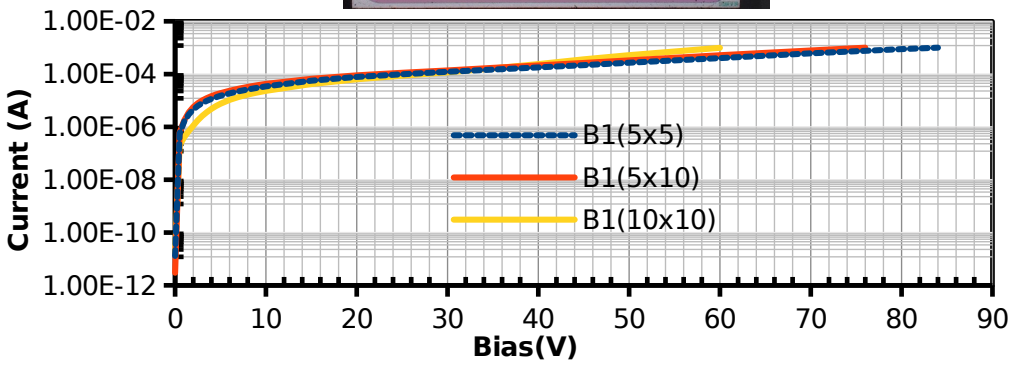


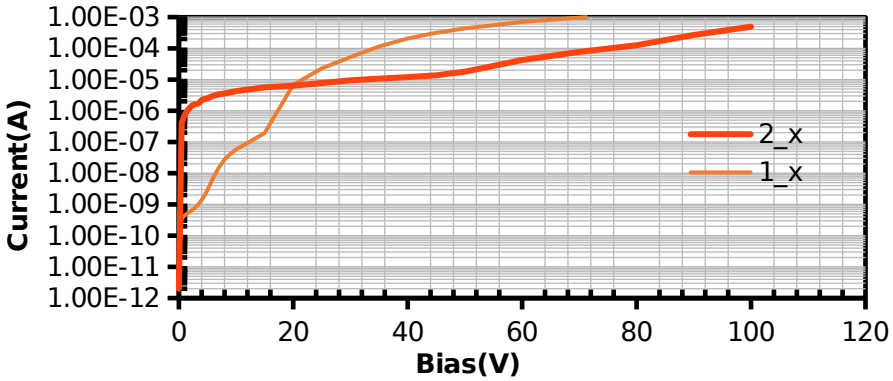
Measurement station

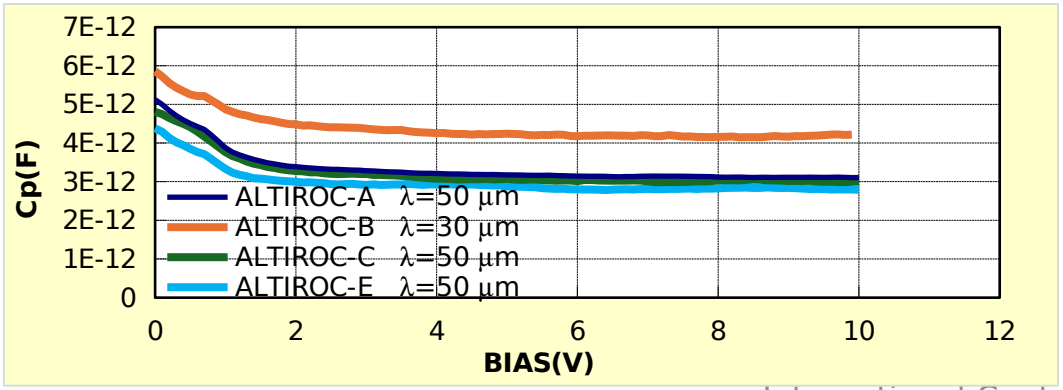
Experiment(IV/CV)

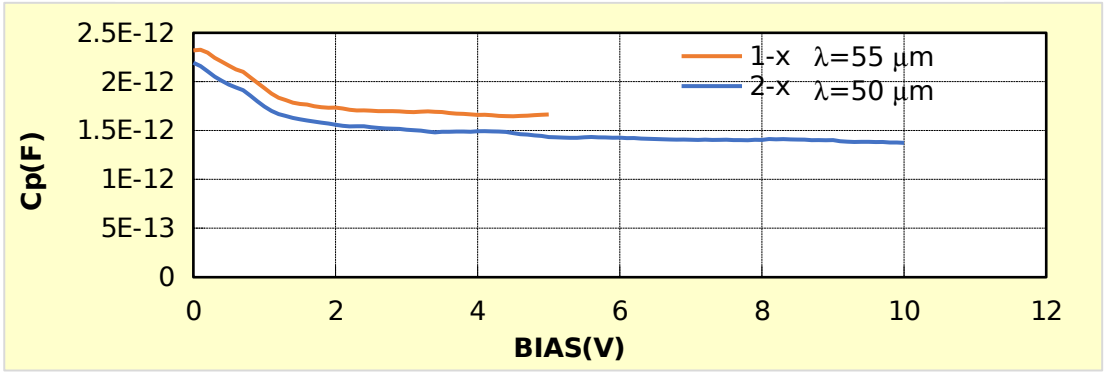




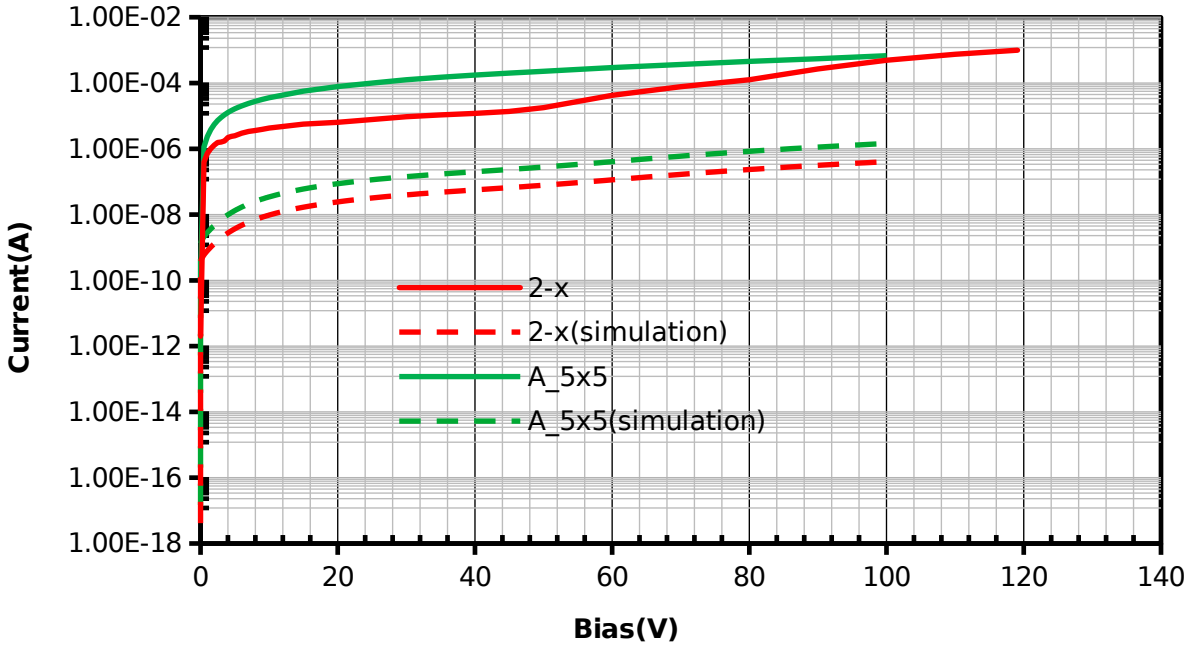


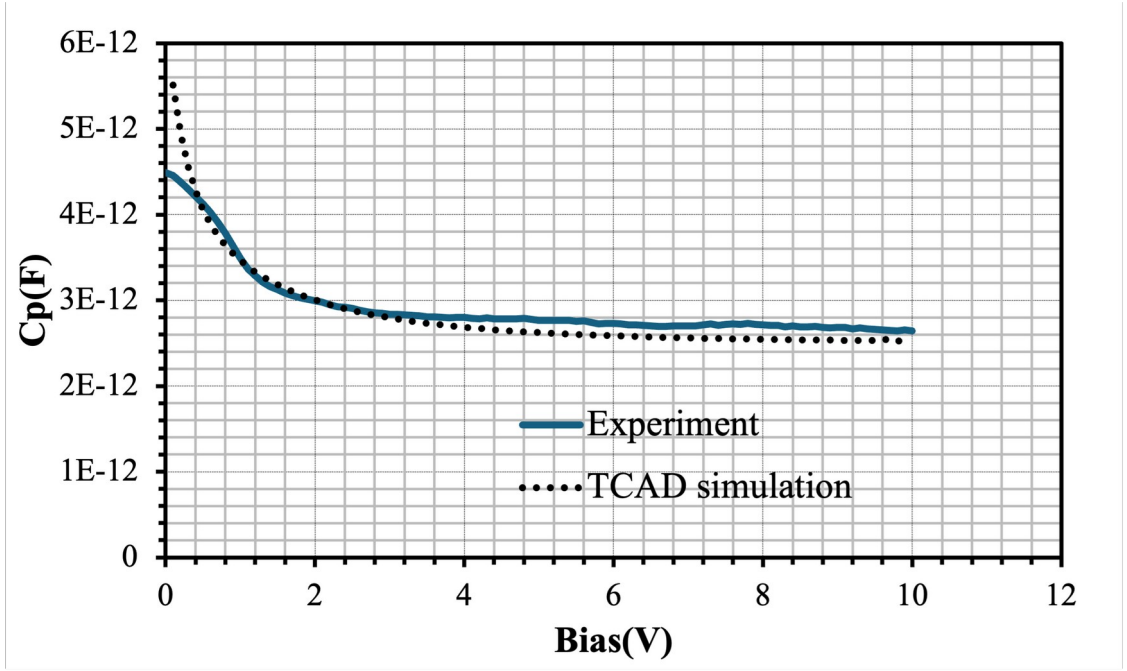






Simulation and Experiment





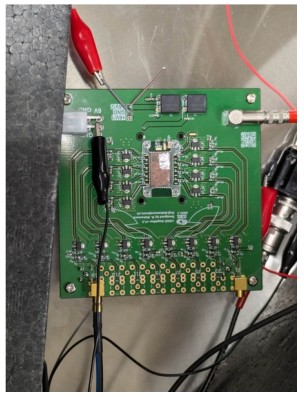
The tendance of leakage currents are similar with measurements

The C-V measurements appear reliable

The I-V behaviour cannot be explained yet. Possible reasons could include:
Experimental setup issues?
Surface effects?
Tunnelling effects in high electric field?

Experiment(Initial test and setup using a beta source)

Beta source with an activity of 3.7 MBq and a maximum particle energy of 0.8 MeV



Preamp board developed by Koji Nakamura [1]

Vacuum chamber

Initial test on AC-LGADs [1]

For 3D sensors, the pulse from beta particles has not been detected yet

[1] S Kita, K Nakamura, et al., NIMA, vol. 1048, no. 168009

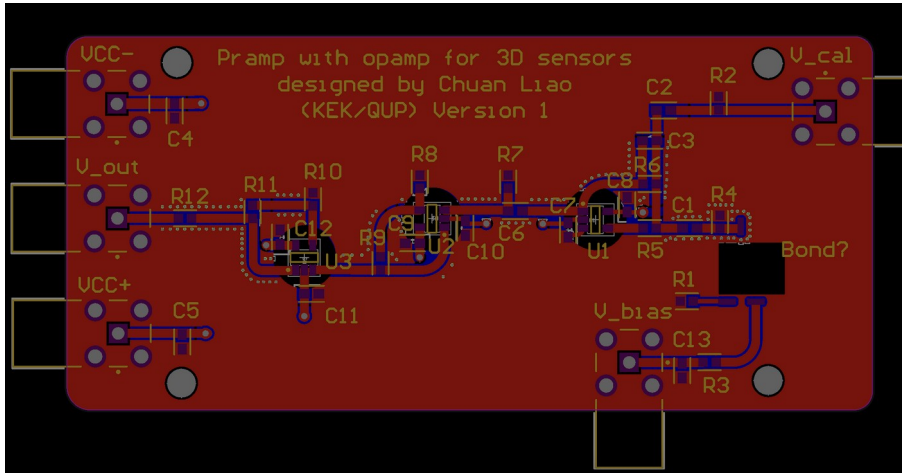
Next plan

Measurements in the ESPEC temperature chamber

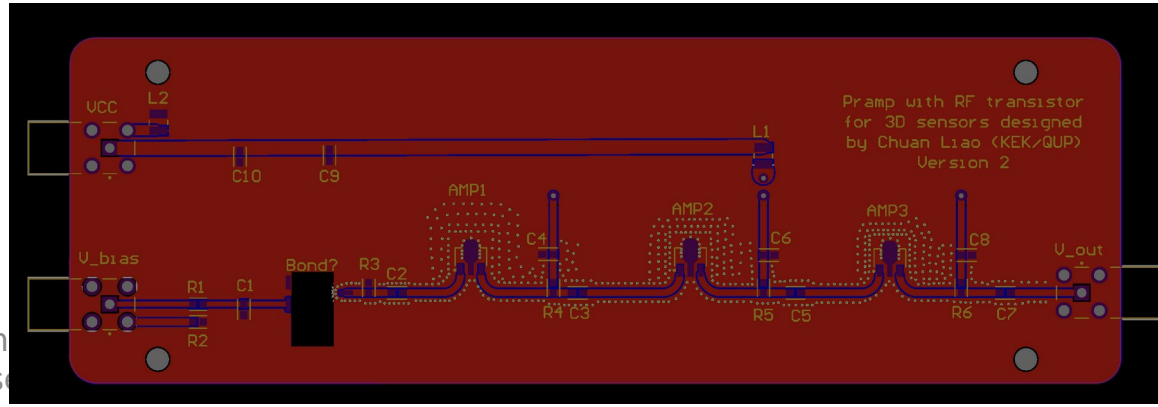
Correct simulation model

Develop a pre-amp board specific to 3D sensors

3-stages amplifier using operational amplifier



3-stages amplifier using RF transistor



End

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