



TCAD simulation of LGAD

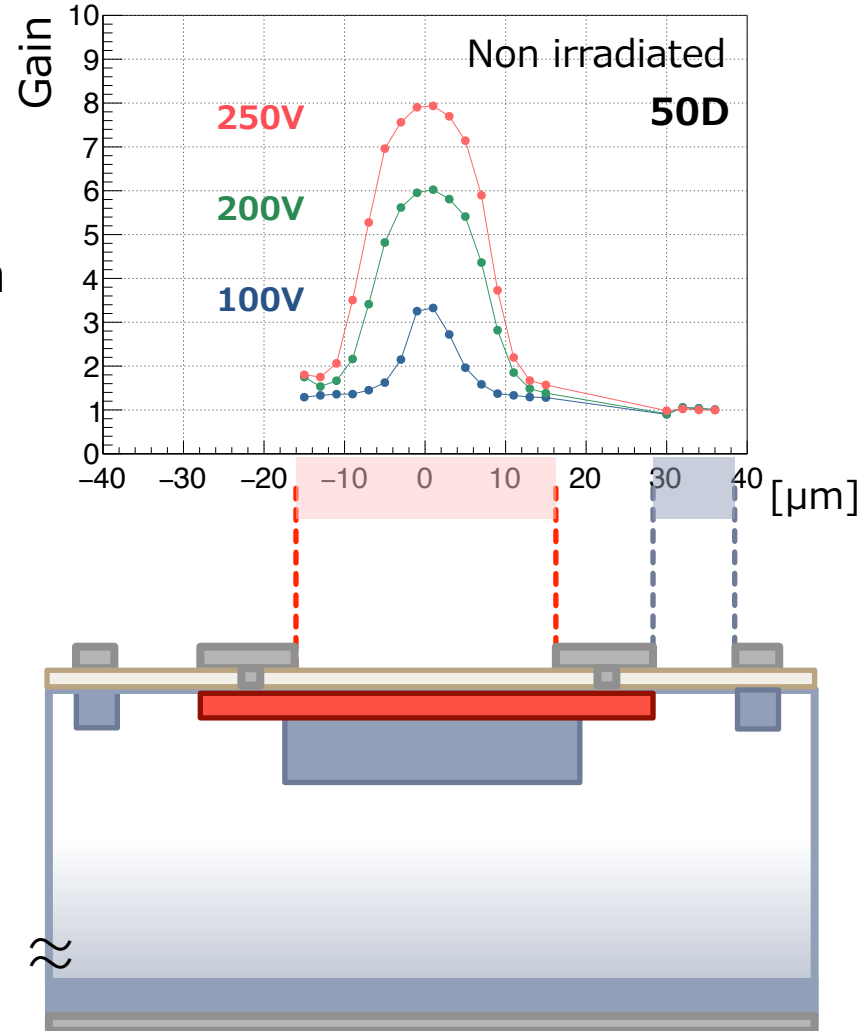
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- Motivation
- Strip Structure
- Electric Field Distribution
- Comparison with measurements
- Electrode Structure Candidate
- Summary

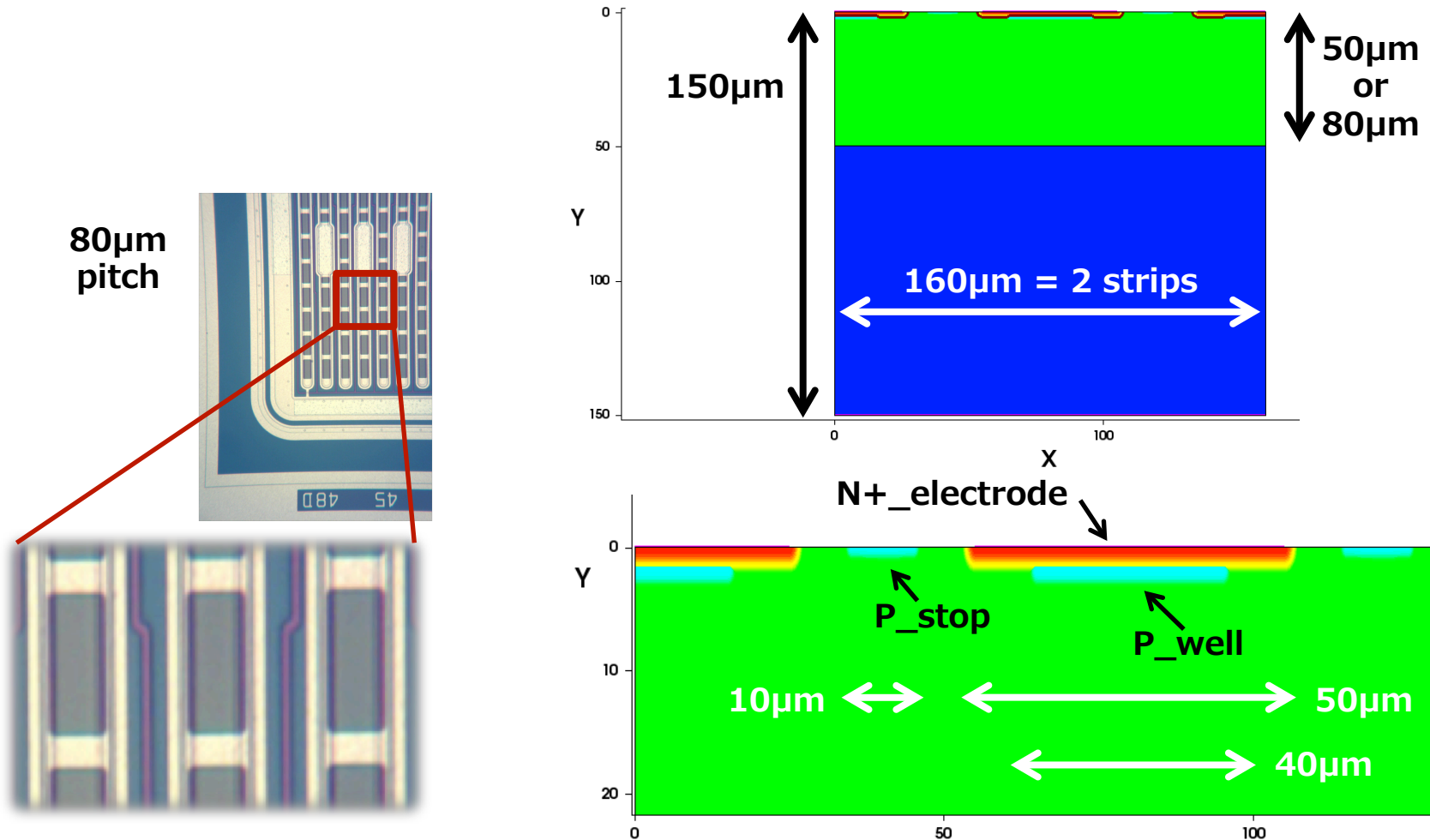
Technology Computer Aided Design

- ❑ Strip LGAD has been tested.
 - ❑ Non-uniformity in gain region
 - ❑ No gain in interstrip region.
- ❑ We need better structure with uniform and sufficient gain.
 - Strip LGAD parameterized in TCAD and validated comparing with measured results.
 - Simulation started for promising candidate structures.



+ Strip Sensor Structure

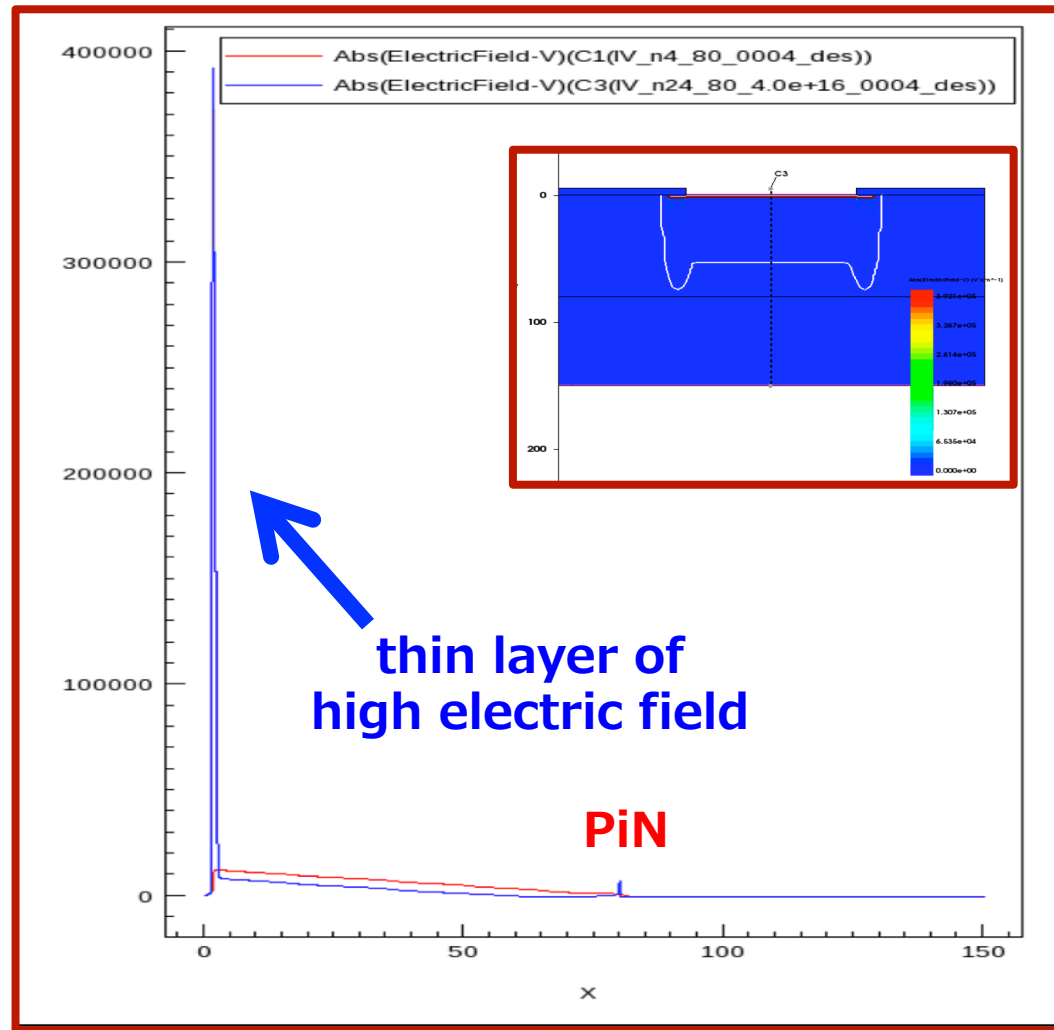
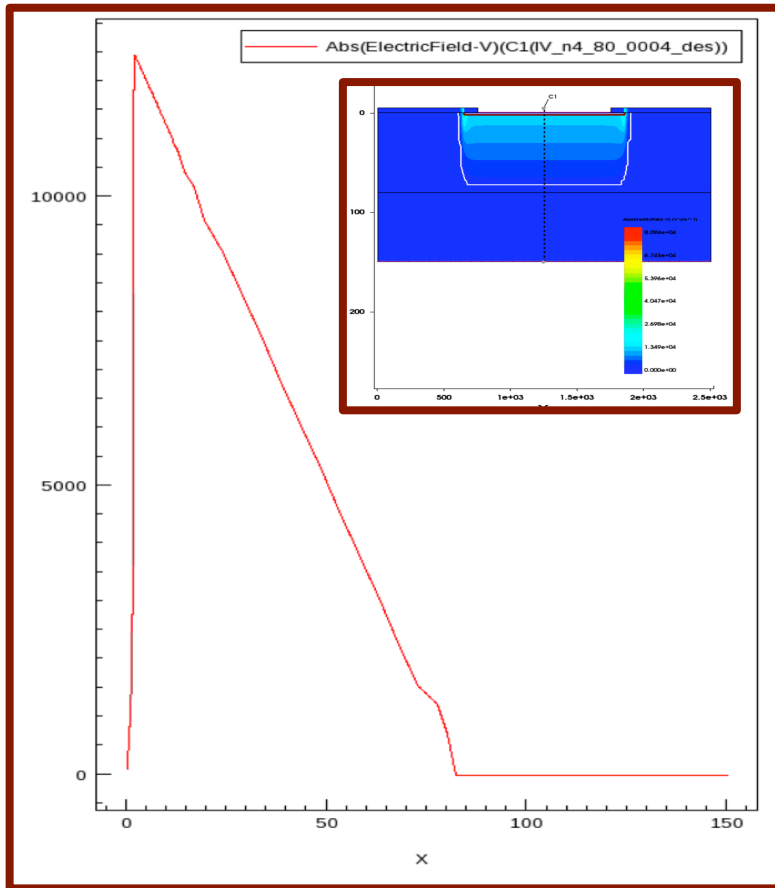
- Concentration information not available from HPK. The concentrations and physical dimensions in TCAD are just best estimates.



+ Electric Field Distribution

LGAD PD

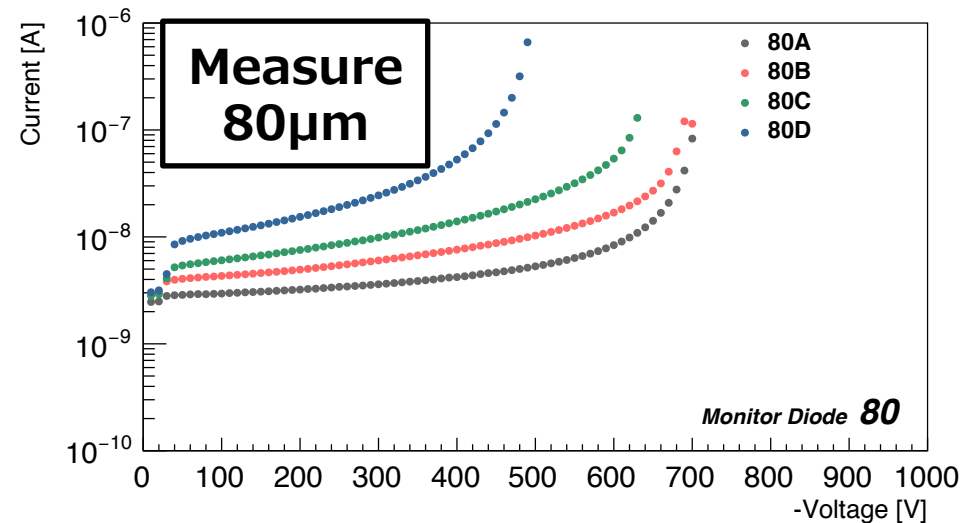
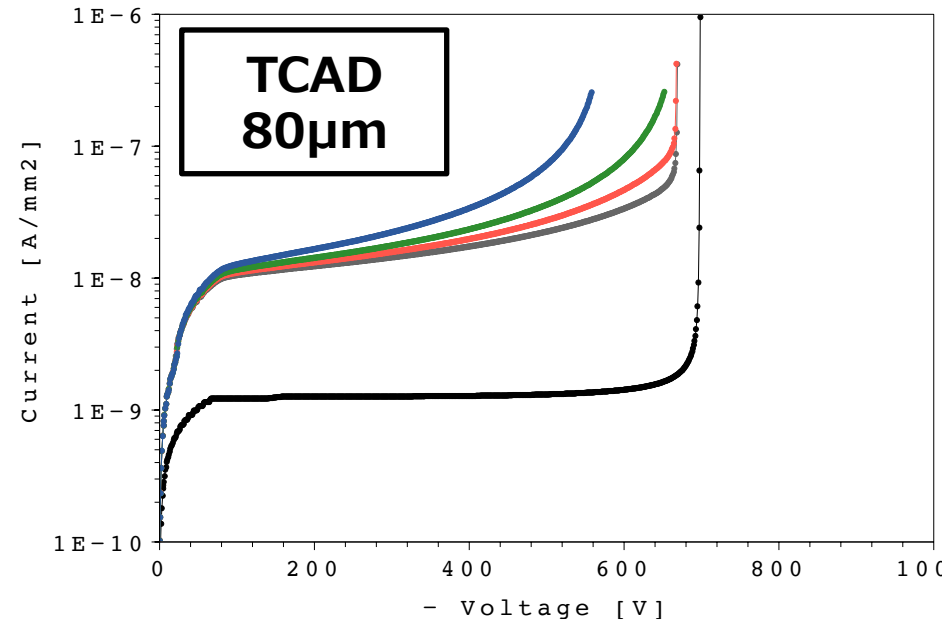
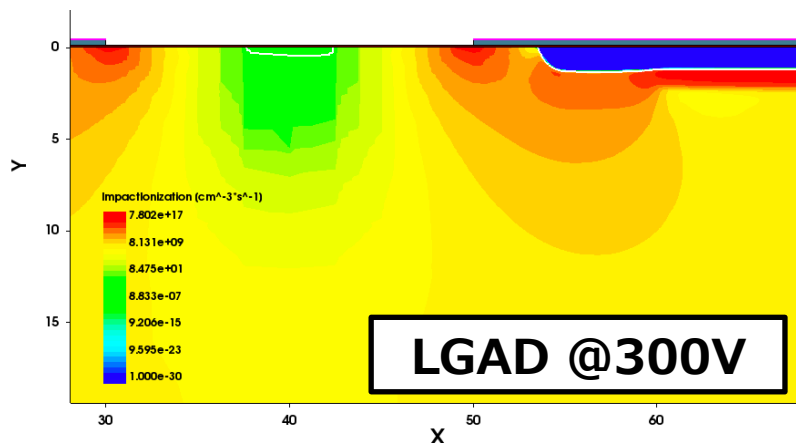
PiN



IV Curve

TCAD

- PiN (Black line) and LGAD (colors for different p+ concentration) with same electrode structure (other than p+ implant) should break at a similar voltage.
- Impact Ionization occurs underneath the aluminum edge.



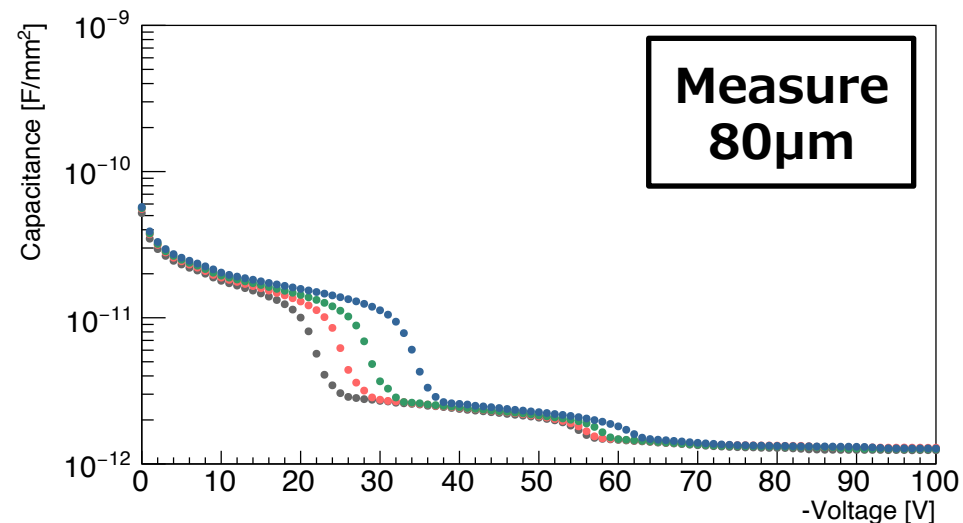
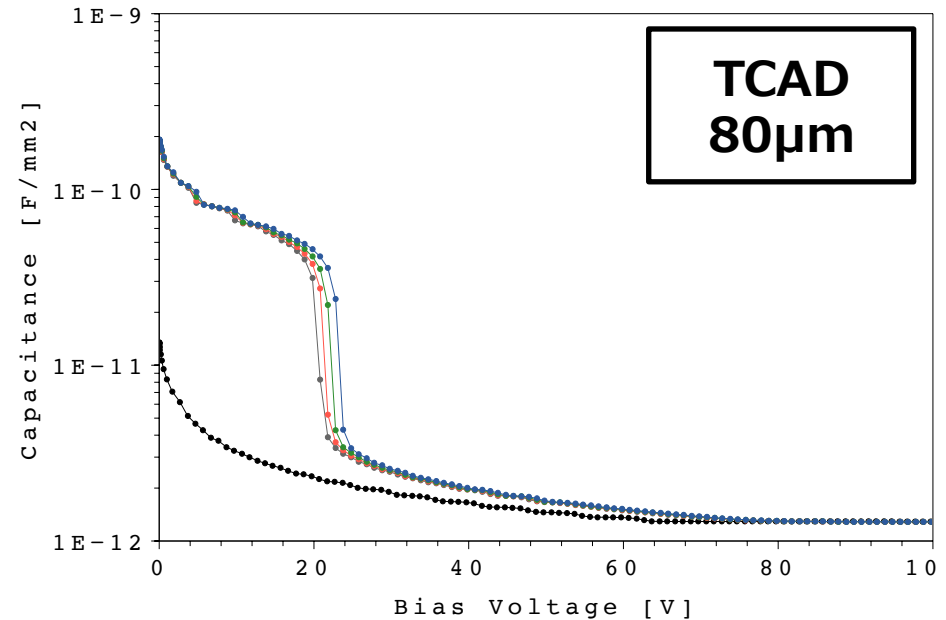
CV Curve

TCAD

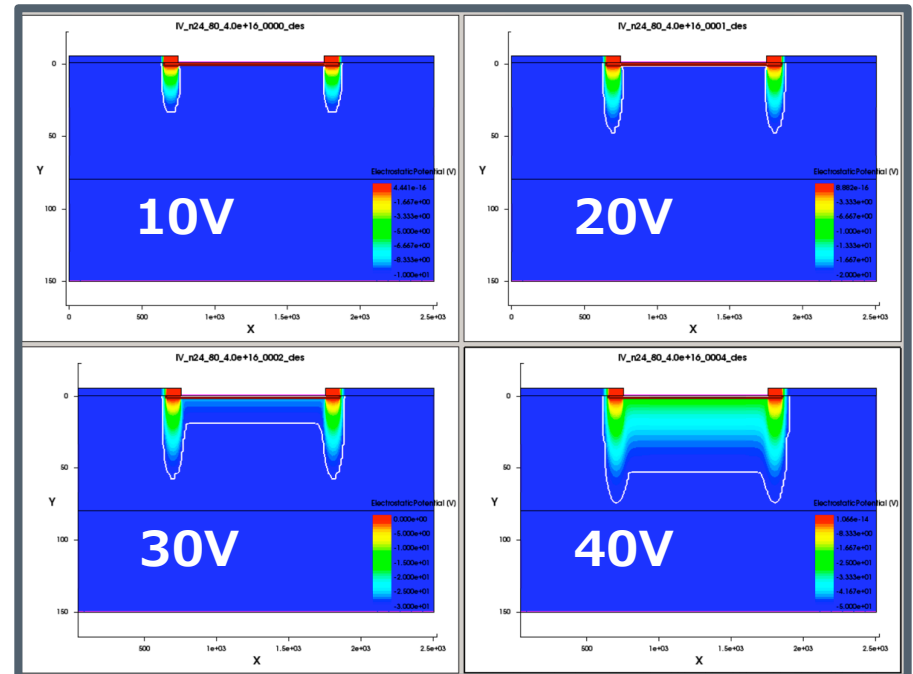
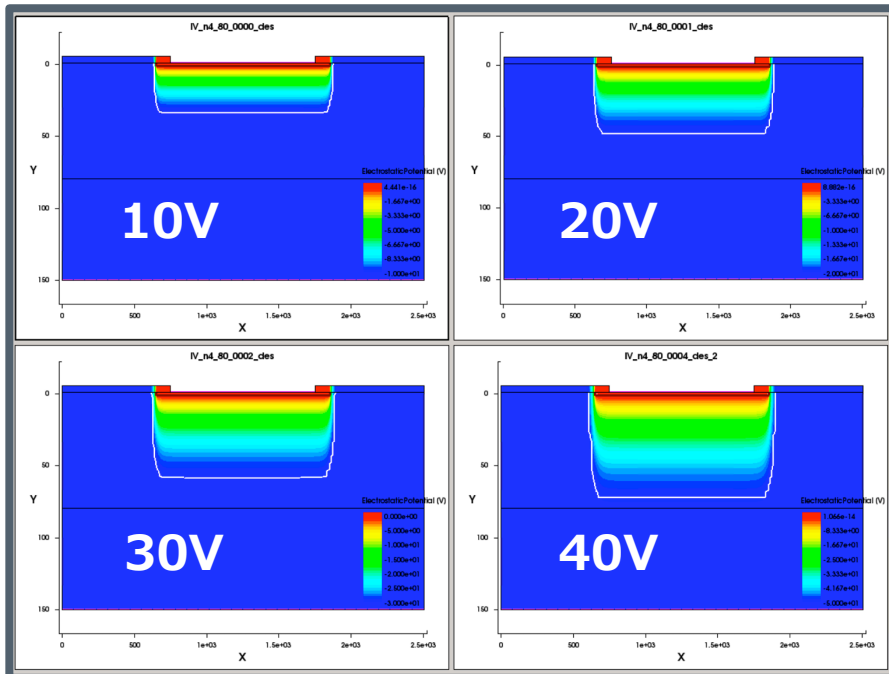
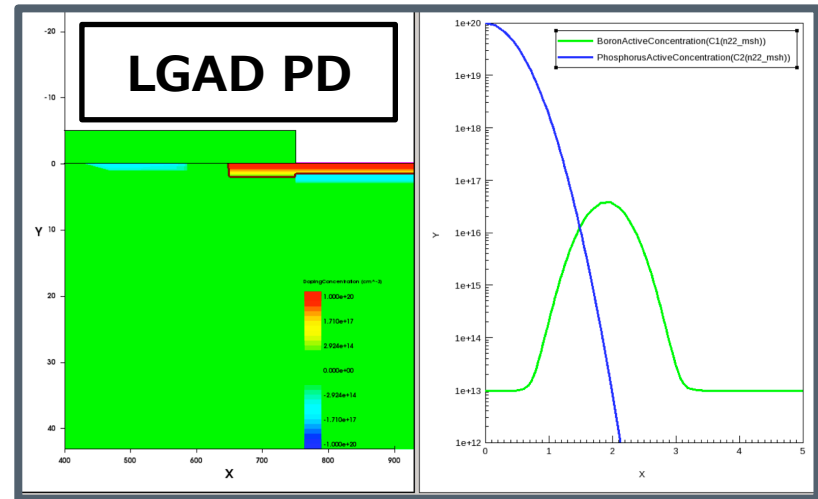
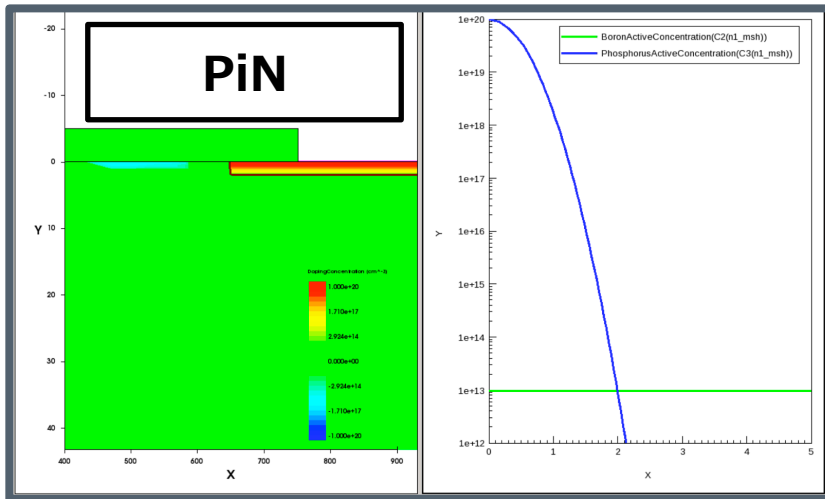
- Difference to PiN is clearly reproduced, caused by p+ layer in LGAD.
- CV curve is roughly reproduced, especially depletion of p+ layer dependence on the concentration.

Need further understanding of

- p+ dose and profile
- strip dimensions
- p-stop structure
-



+ Depletion Process



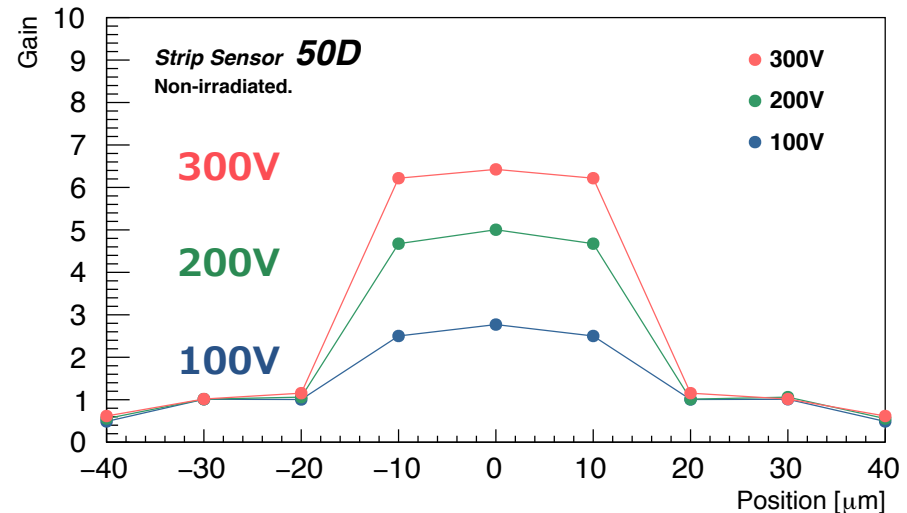
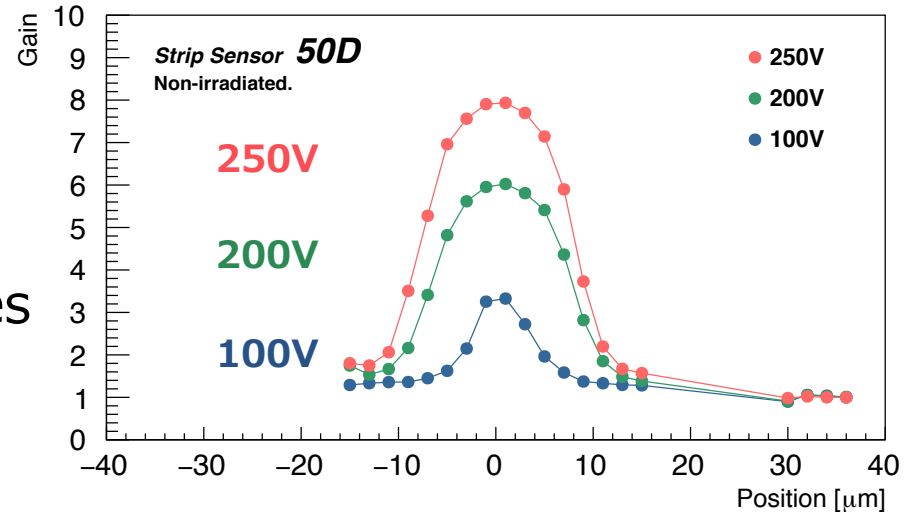
+ Comparison with Measurements

Charge Collection Profile

Measure

TCAD

- Place charges uniformly along vertical track (mimic MIP).
- Profile is reproduced.
- Gain drop towards electrode edges is due to insufficient field.



Candidate for Uniform Gain

NORMAL

No gain in interstrip region.

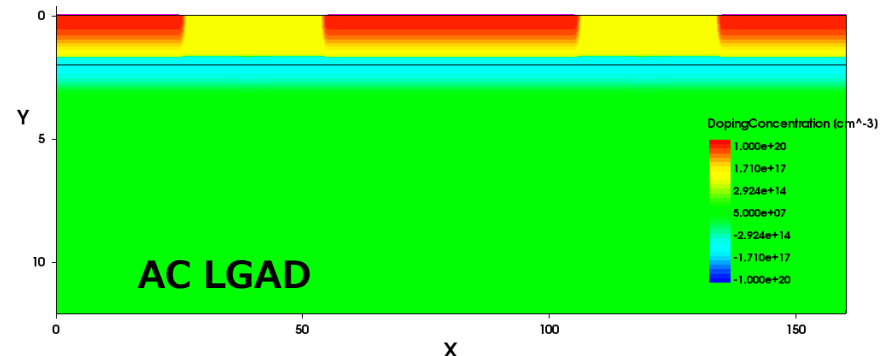
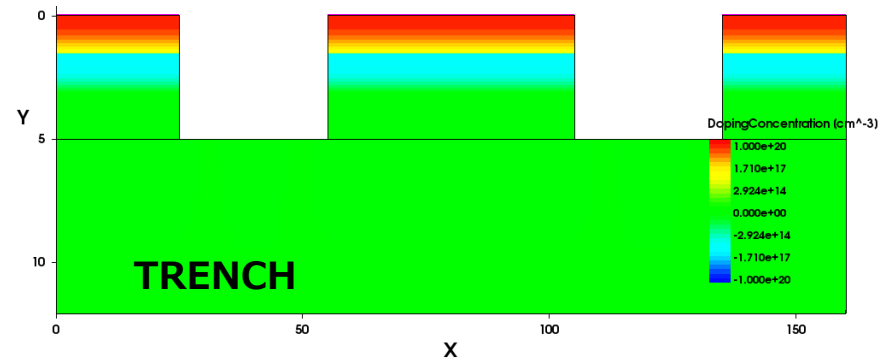
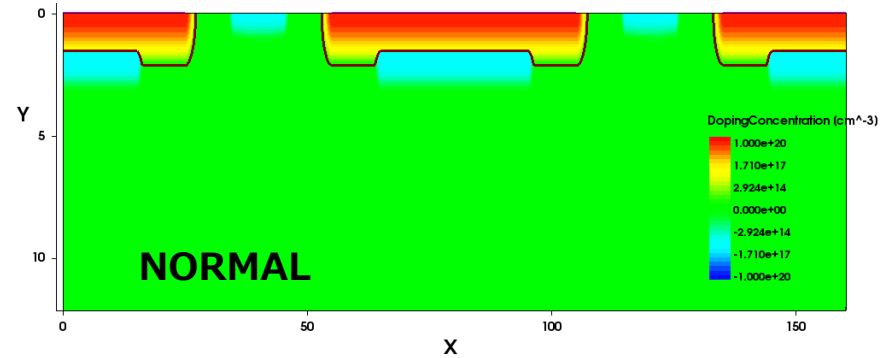
TRENCH

Strip isolation is achieved by (deep) trench. Depth and width need optimized.

AC LGAD

Avalanche generated at \sim uniform np junction layer. Signal read out by AC coupling. Concentration of n+ layer needs optimized.

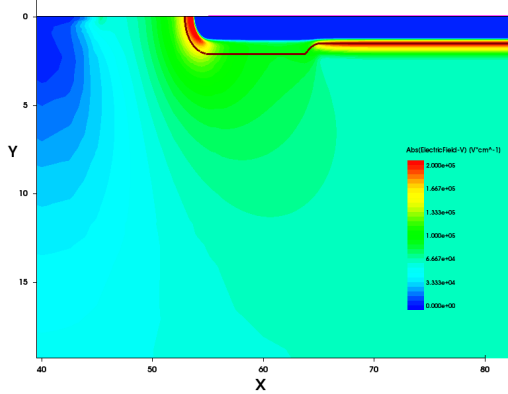
Optimization with TCAD is underway.



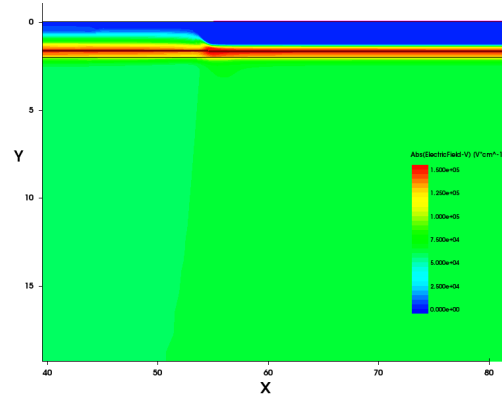
+ Electric Field Comparison @ -300V

11

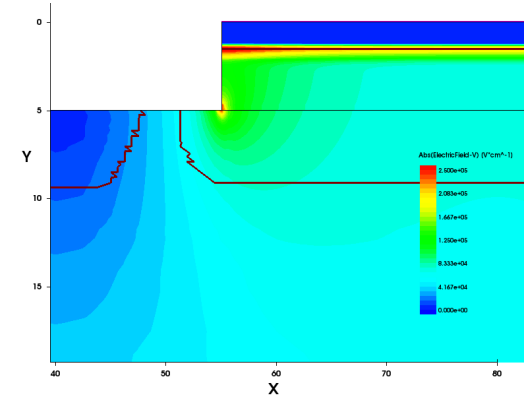
0 ~ 2.0E5 V/cm



0 ~ 1.5E5 V/cm



0 ~ 2.5E5 V/cm

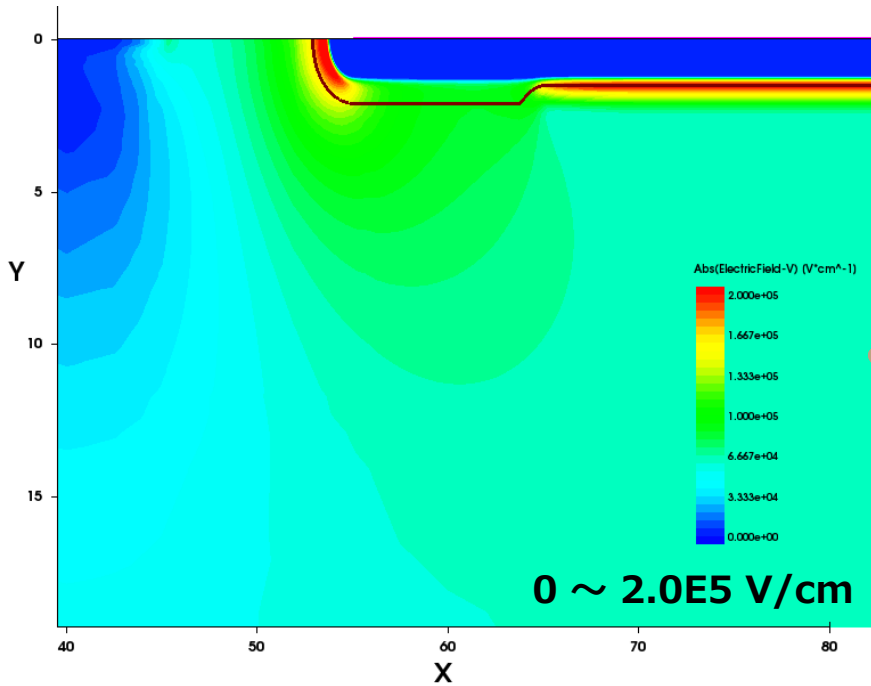


NORMAL

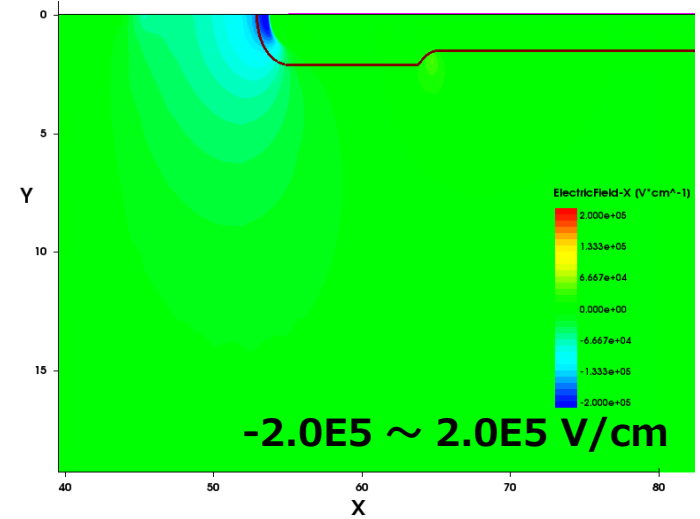
AC LGAD

TRENCH

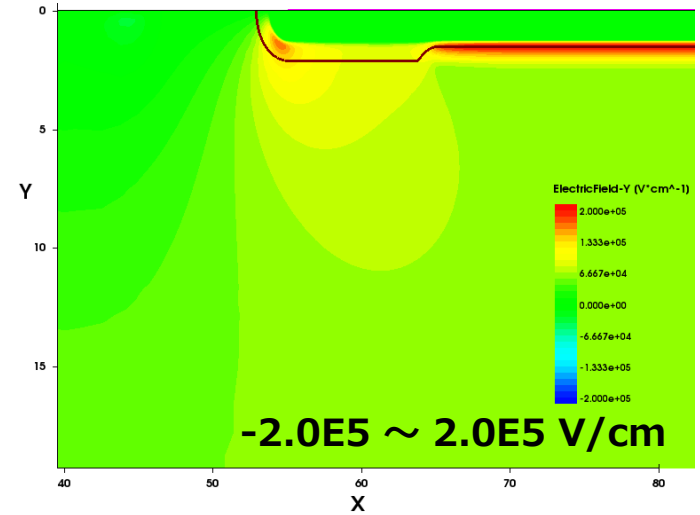
+ NORMAL LGAD E Field @-300V



E_X

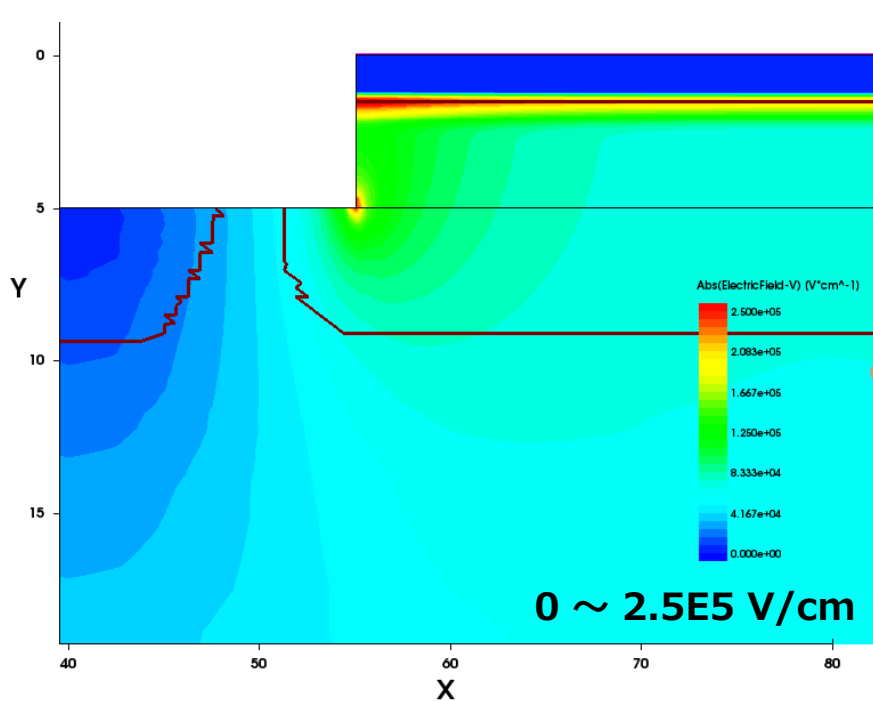
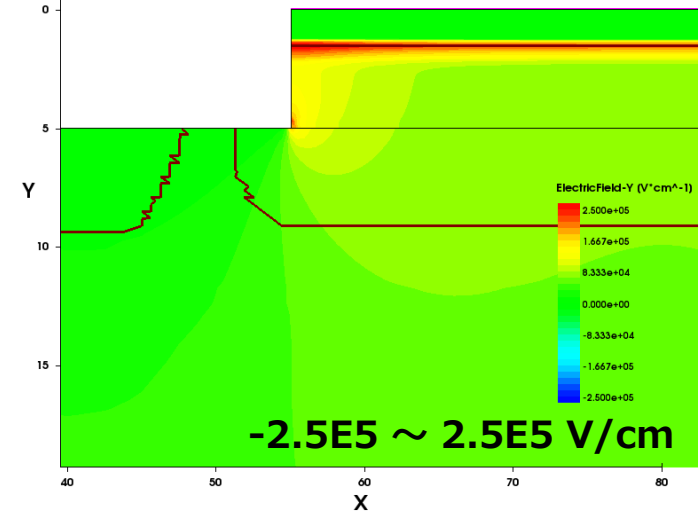
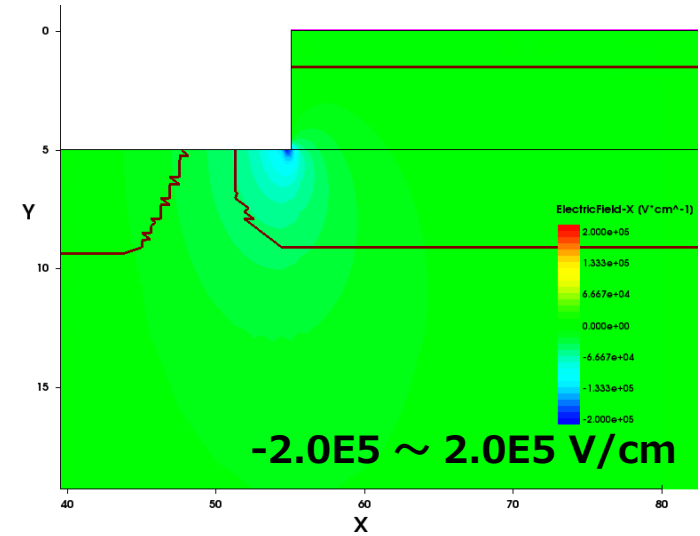


E_Y



Large E_X underneath Al edge

+ TRENCH E Field @-300V

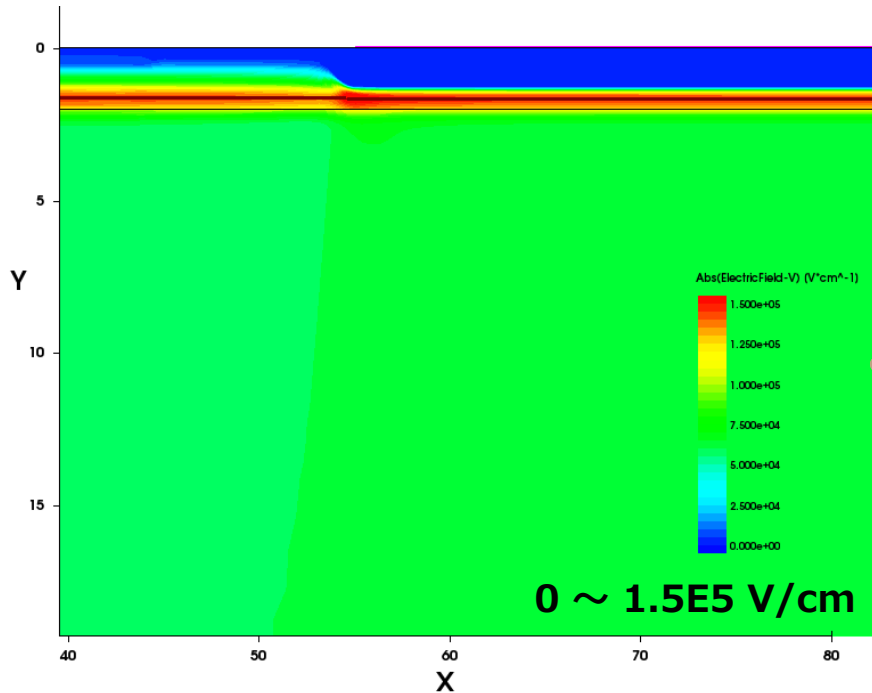
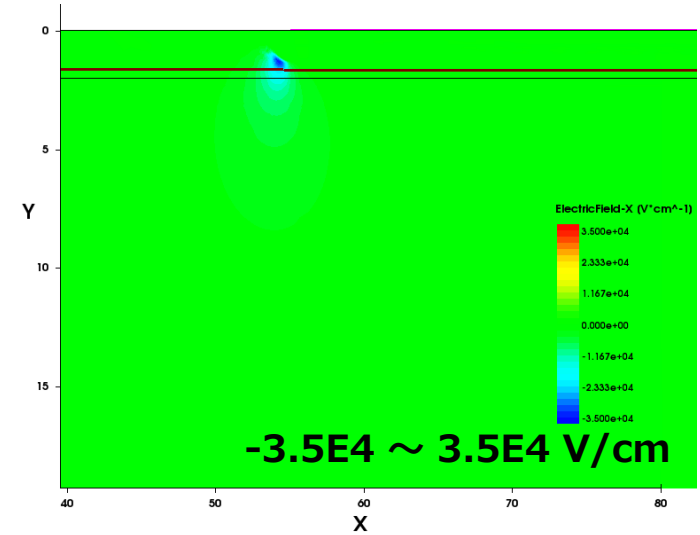
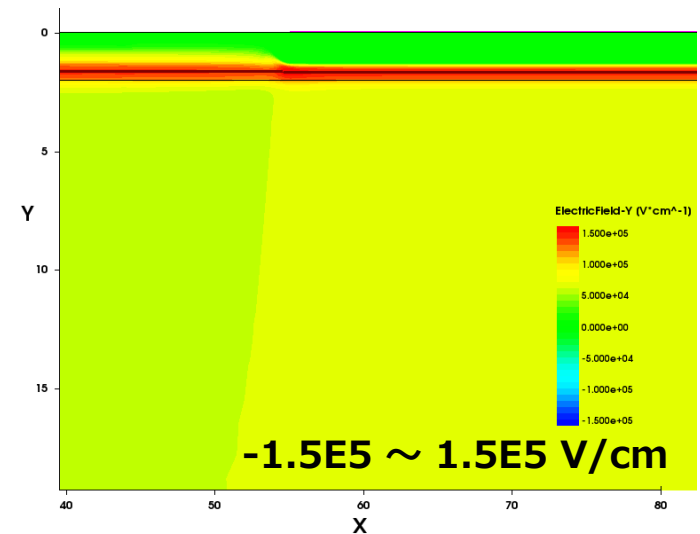
 E_X E_Y 

Large E_X at TRENCH corner

(actual device should have finite R)

Uniform E_Y between TRENCHes

+ AC LGAD E Field @-300V

 E_X  E_Y 

Small $E_X \sim 3.5 \times 10^4 \text{ V/cm}$
Uniform E_Y of $1.5 \times 10^5 \text{ V/cm}$

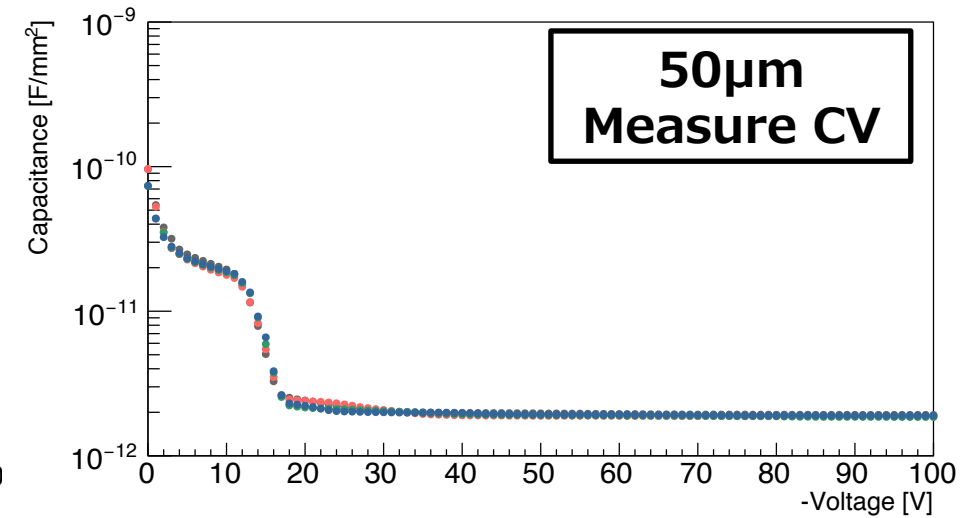
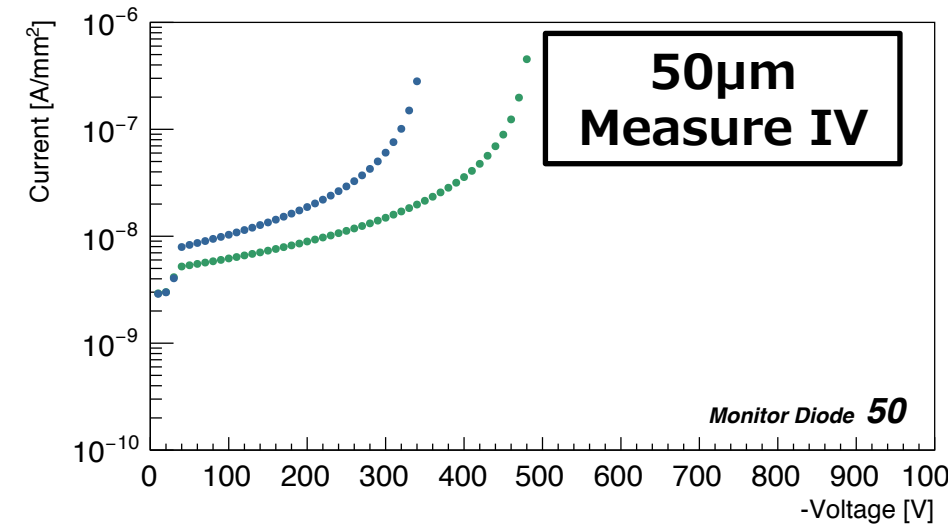
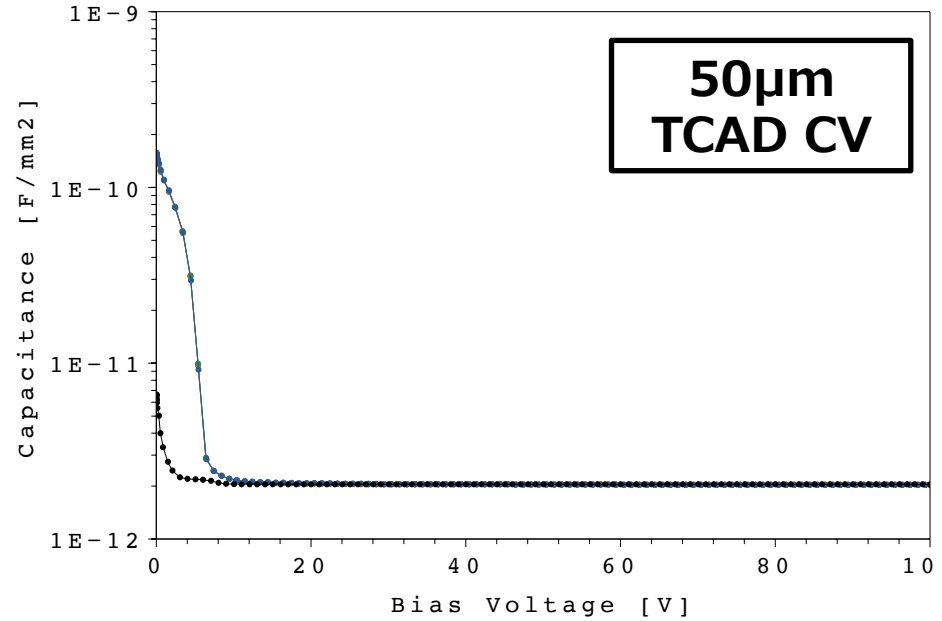
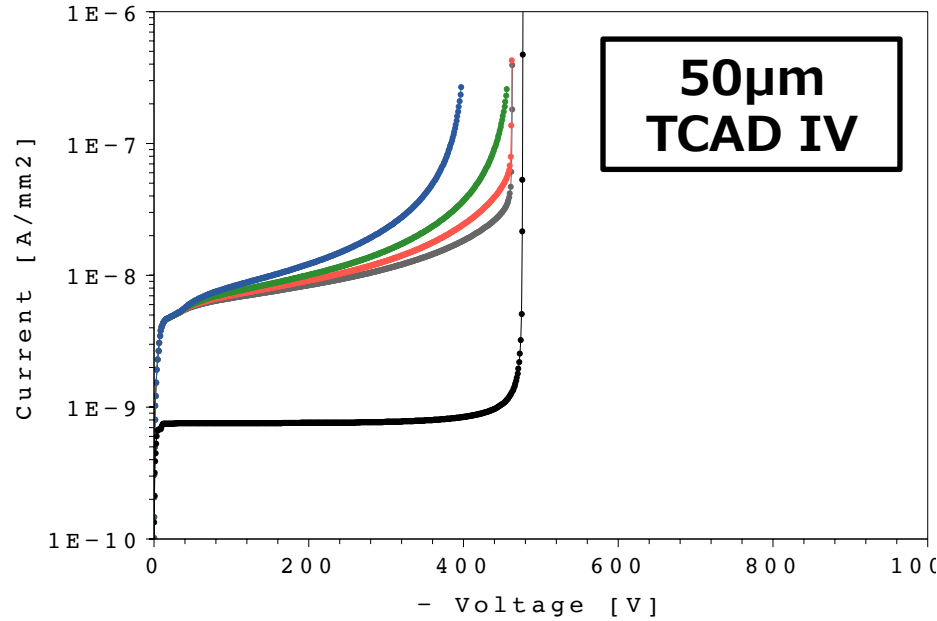
TCAD simulation is performed.

- ❑ Measured results for strip LGAD are used to validate the simulation.
 - ❑ IV & CV are (roughly) reproduced.
 - ❑ Charge collection profile is also reproduced.
- ❑ Started optimization of electrode structure for uniform gain.
 - ❑ Candidates are TRENCH isolation and AC LGAD.

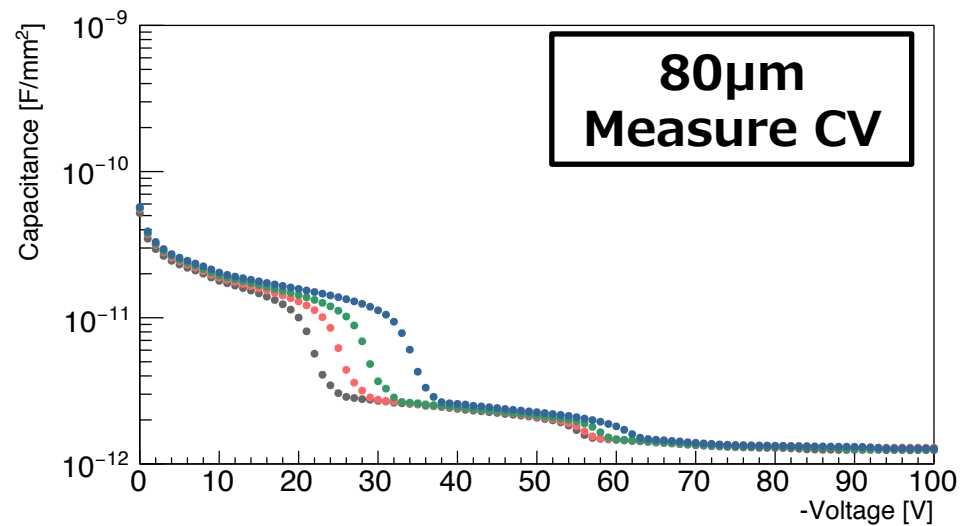
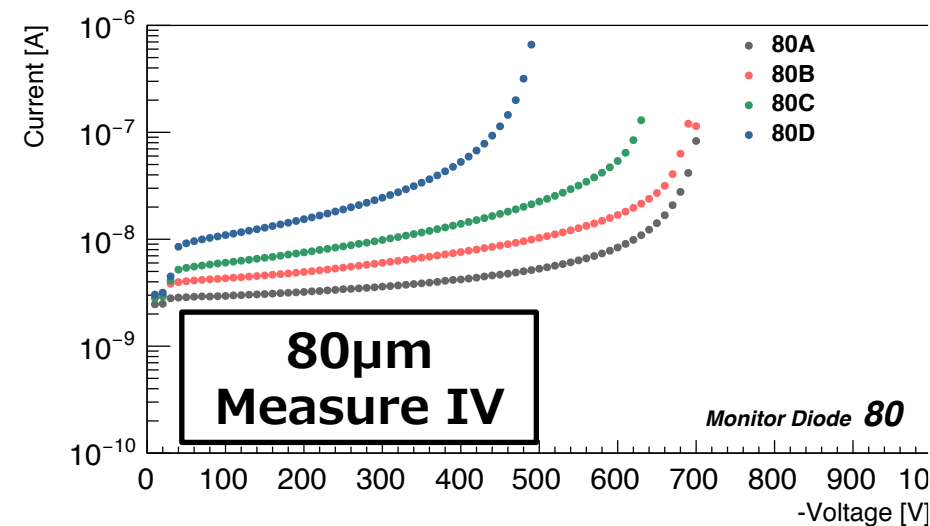
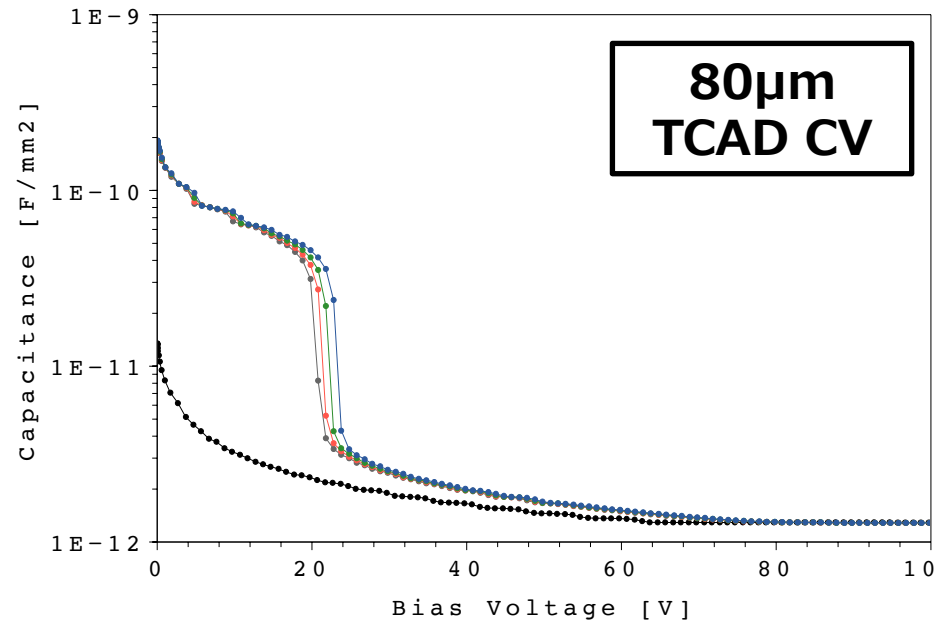
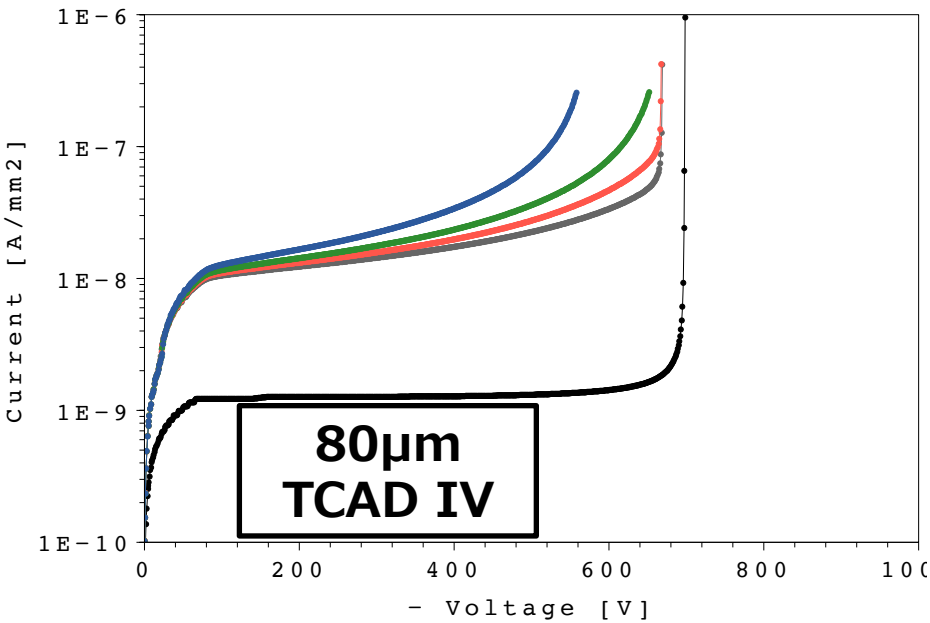


Backups

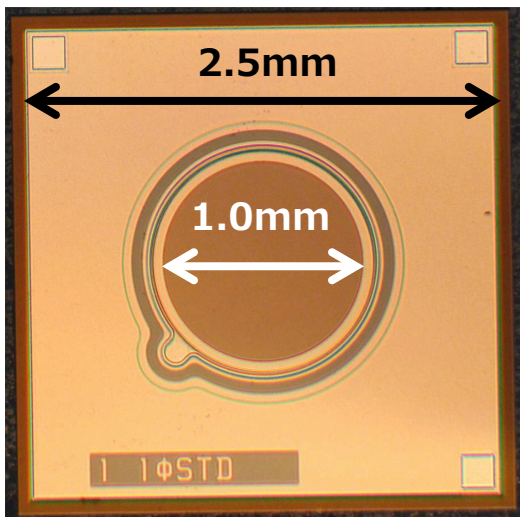
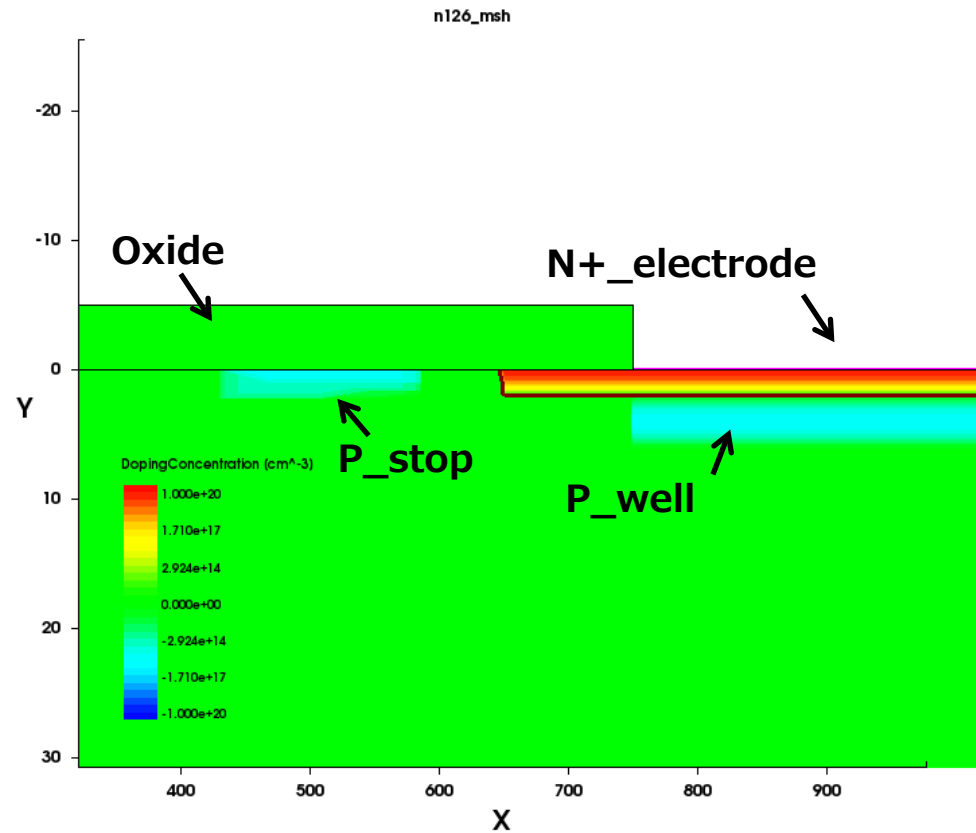
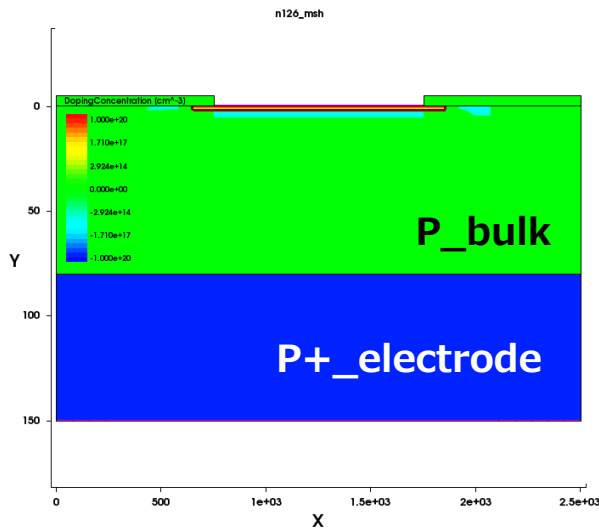
+ Comparison with Measurements



+ Comparison with Measurements



+ Pad Sensor Structure



□ Samples from HPK

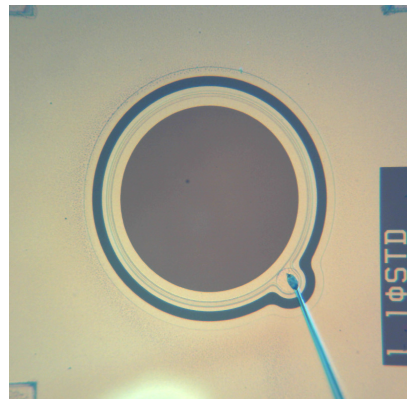
□ Monitor Diode

- Chip Size: 2.5mm × 2.5mm
- Window 1mmφ

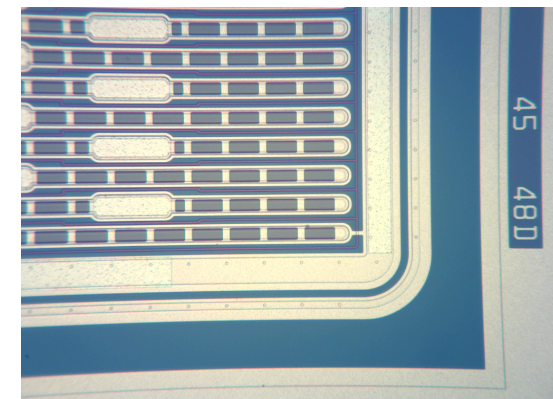
□ Strip

- Chip Size: 6.0mm × 12mm
- Strip Pitch: 80μm

Monitor Diode



Strip



□ Dose of P⁺ layer

- Low to high; A-B-C-D
(HPK confidential)

□ Active thickness

- 50μm or 80μm

Sample Name	P ⁺ Dose Light>dense	Physical Thickness [μm]	Active Thickness [μm]
50A	A	150	50
50B	B		
50C	C		
50D	D		
80A	A		80
80B	B		
80C	C		
80D	D		