Dependence of MIP signal amplitude on bias voltage

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Brief introduction

- For diploma thesis, I surveyed dependence of MIP signal amplitude on bias voltage.

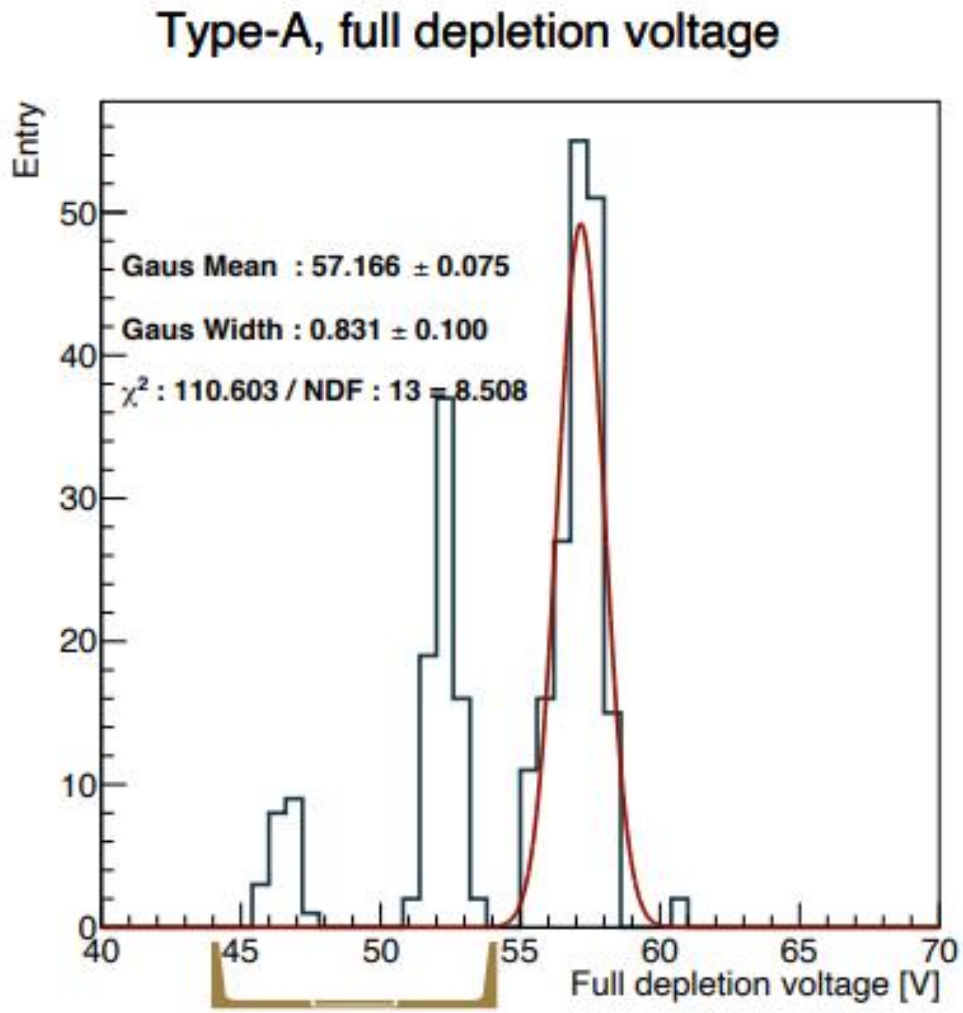
- Focusing on the structure of depletion area.

Assumption

- The signal of INTT is assumed to be **V=Q/C**.
- Q is the amount of charge excited by particles.
- C is the capacitance of INTT silicon.

- The bias voltage dependence of the capacitance was measured by Hamamatsu.

- It suggests that MIP amplitude is constant over 50V.

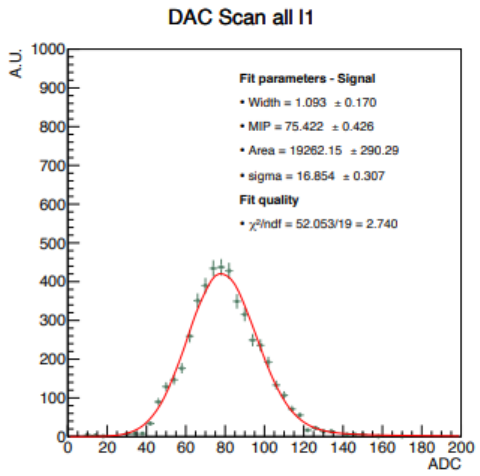


200519_S…datasheet

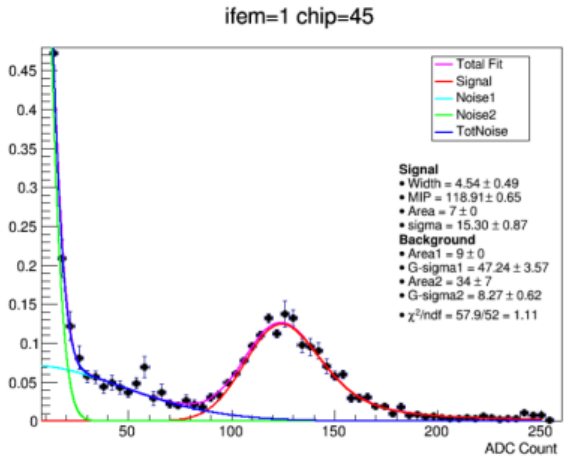
Test beam

- The MIP channel differs from 80 to 120

Testbeam2021, 50 V
Positron beam, 1 GeV



Testbeam2019, 100 V
Proton beam, 120 GeV

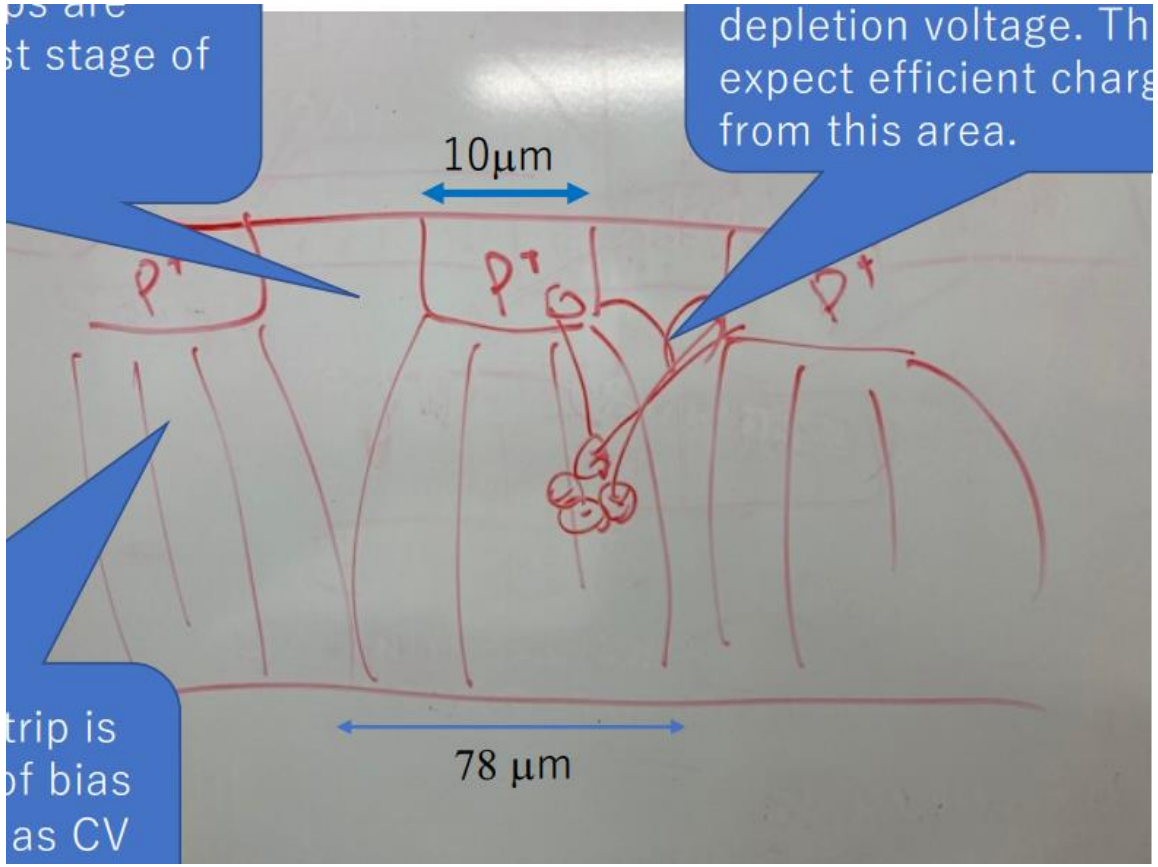


The peaks are different
Original though : because of the difference of the supplied voltage

Graphs made by Mr. Cheng-Wei Shih

Hamamatsu's opinion

- Hamamatsu Photonics said that
- "There may be some instability of depletion area between strips even if the measured capacitance is constant".



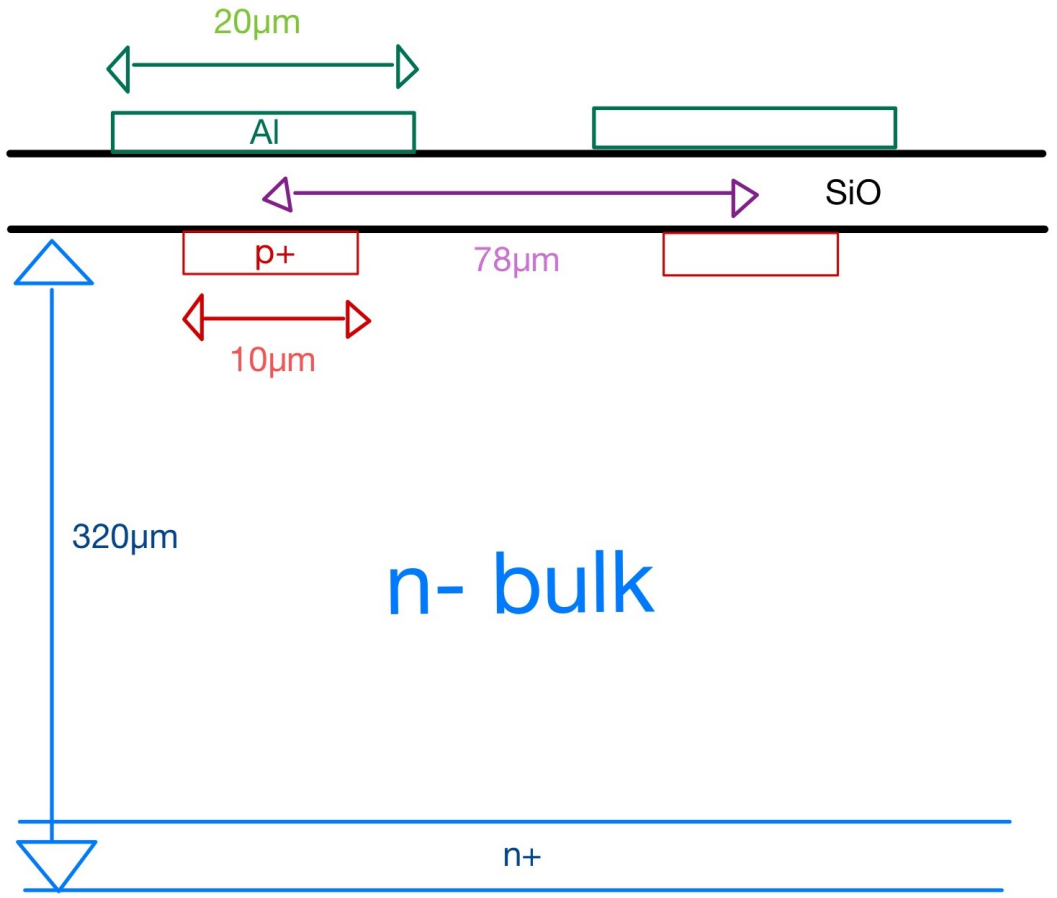
Software for simulation

- Technical CAD (TCAD)
- According to my research, some other groups (e.g. LHC) using this software for simulating a silicon detector.

- Thanks to Mr. Koji Nakamura in KEK, I can use TCAD.

Modeling

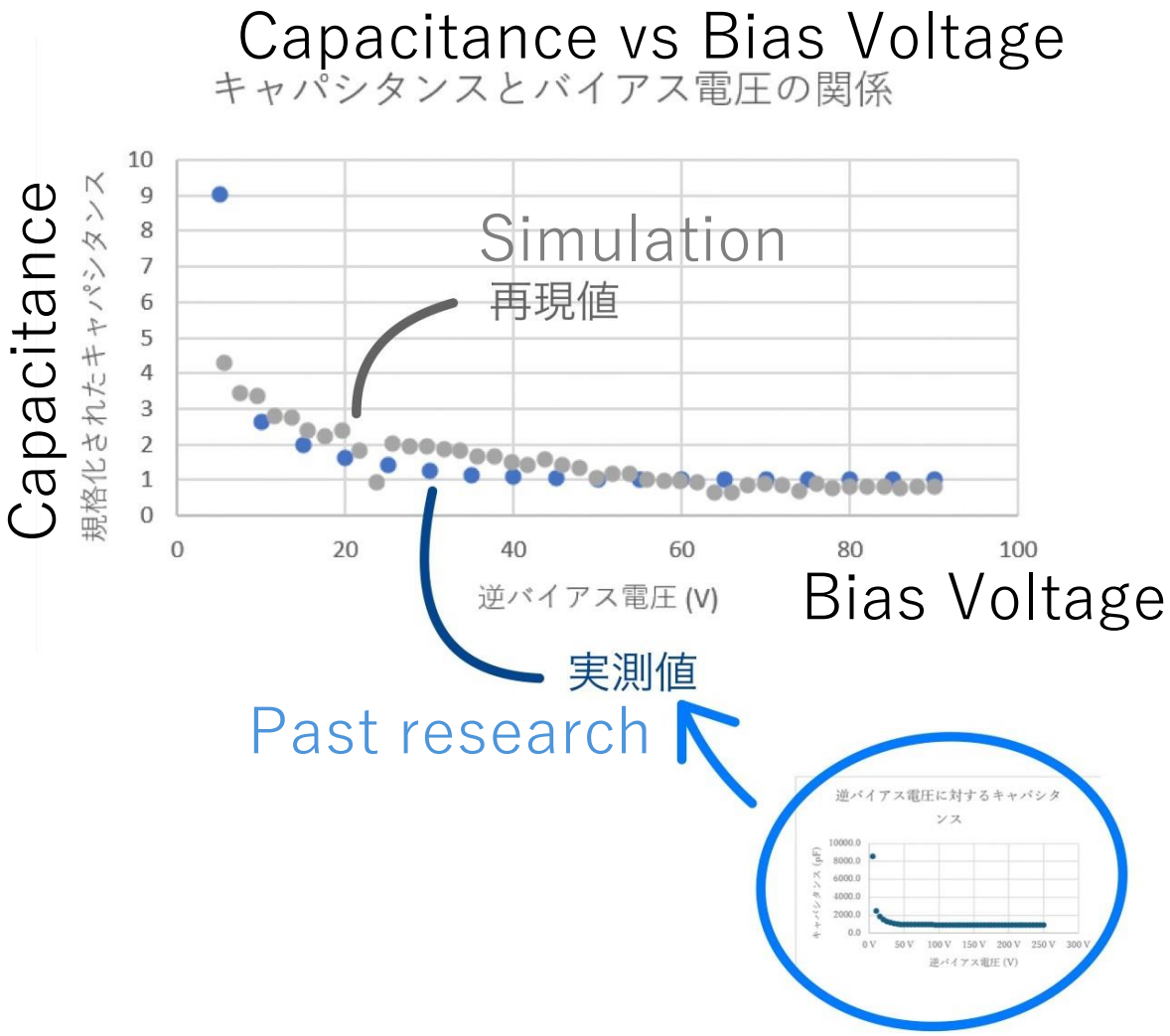
- These measurements is from Hamamatsu's catalogue



Modeling

- A problem of INTT modeling is the unknown dopant concentration.

- It was decided by approximating C-V dependence as past research.

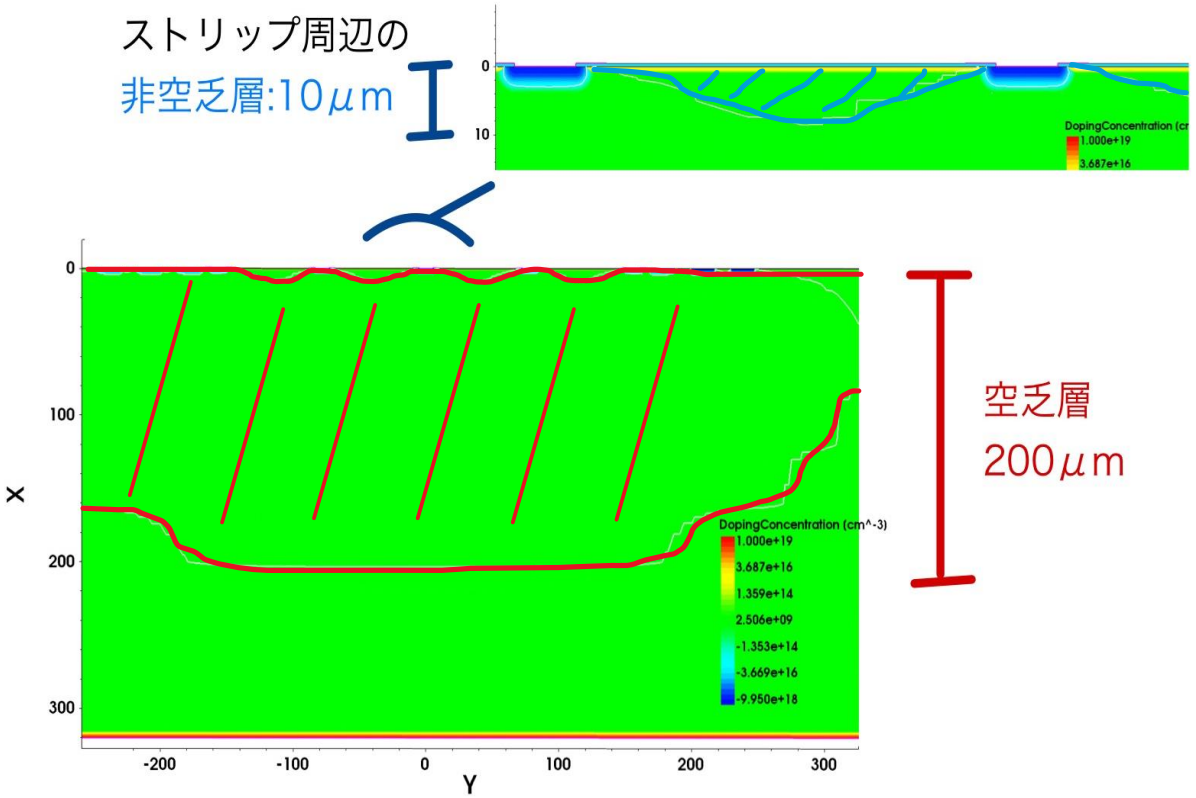


Result : Fully depleted voltage

- The almost area was depleted in 50 V.

15 V

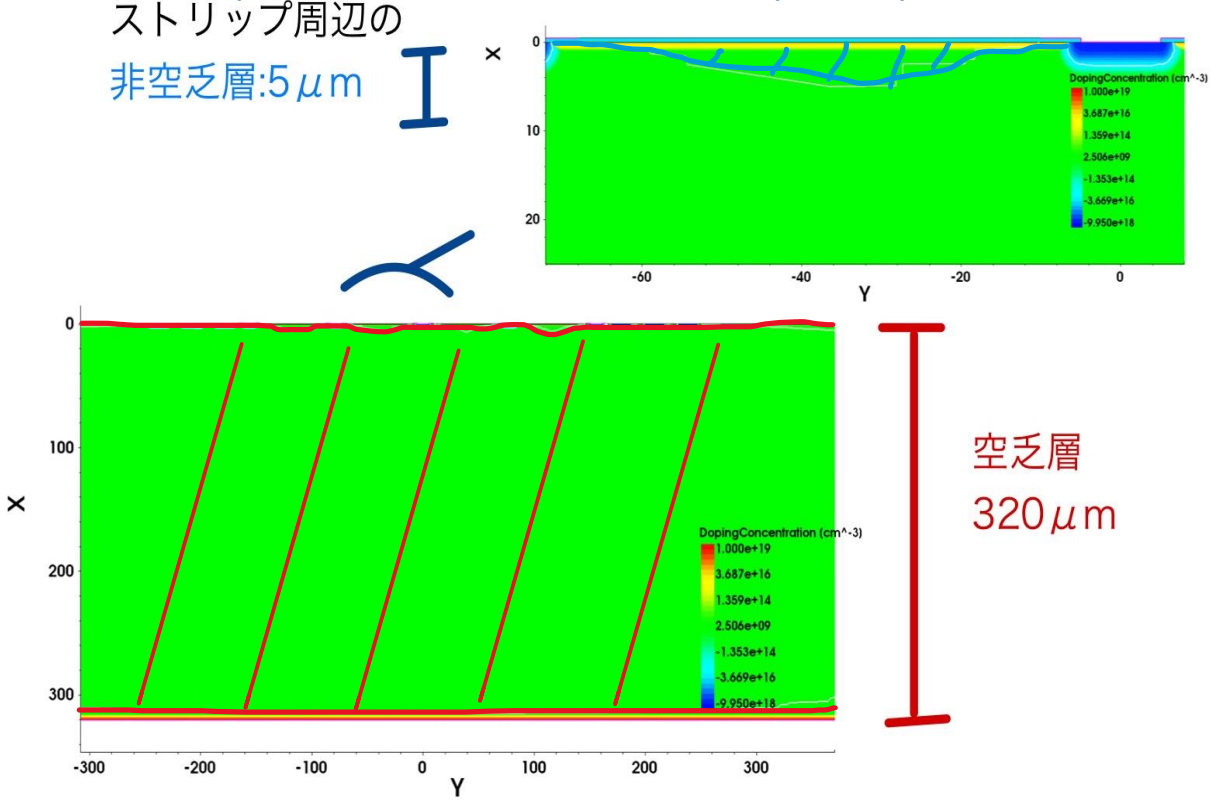
Not depleted area between strips : 10 μm



The depth of depletion : 200 μm

50~100 V

Not depleted area between strips : 5 μm



The depth of depletion : 320 μm

Result : Process of depletion

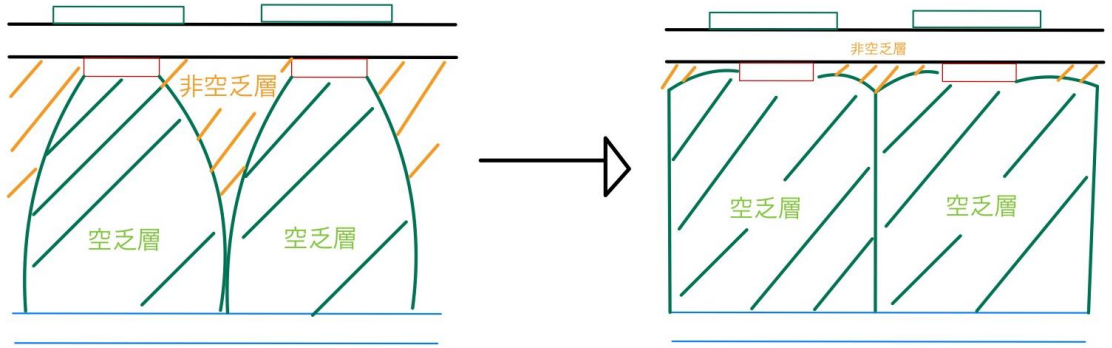
- The depletion area between strips is created much faster than the depletion area toward the depth (n-bulk).

Green : Depleted

Orange : Not Depleted

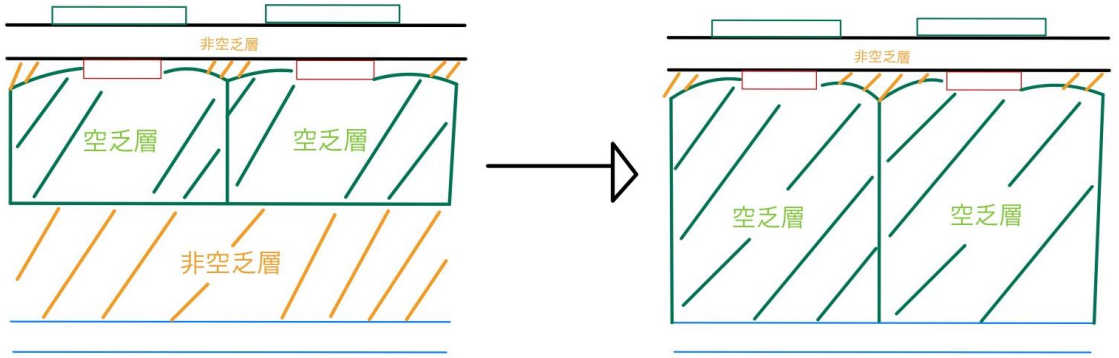
Assumption

事前の予想



実際の結果

Simulation



Hamamatsu's opinion

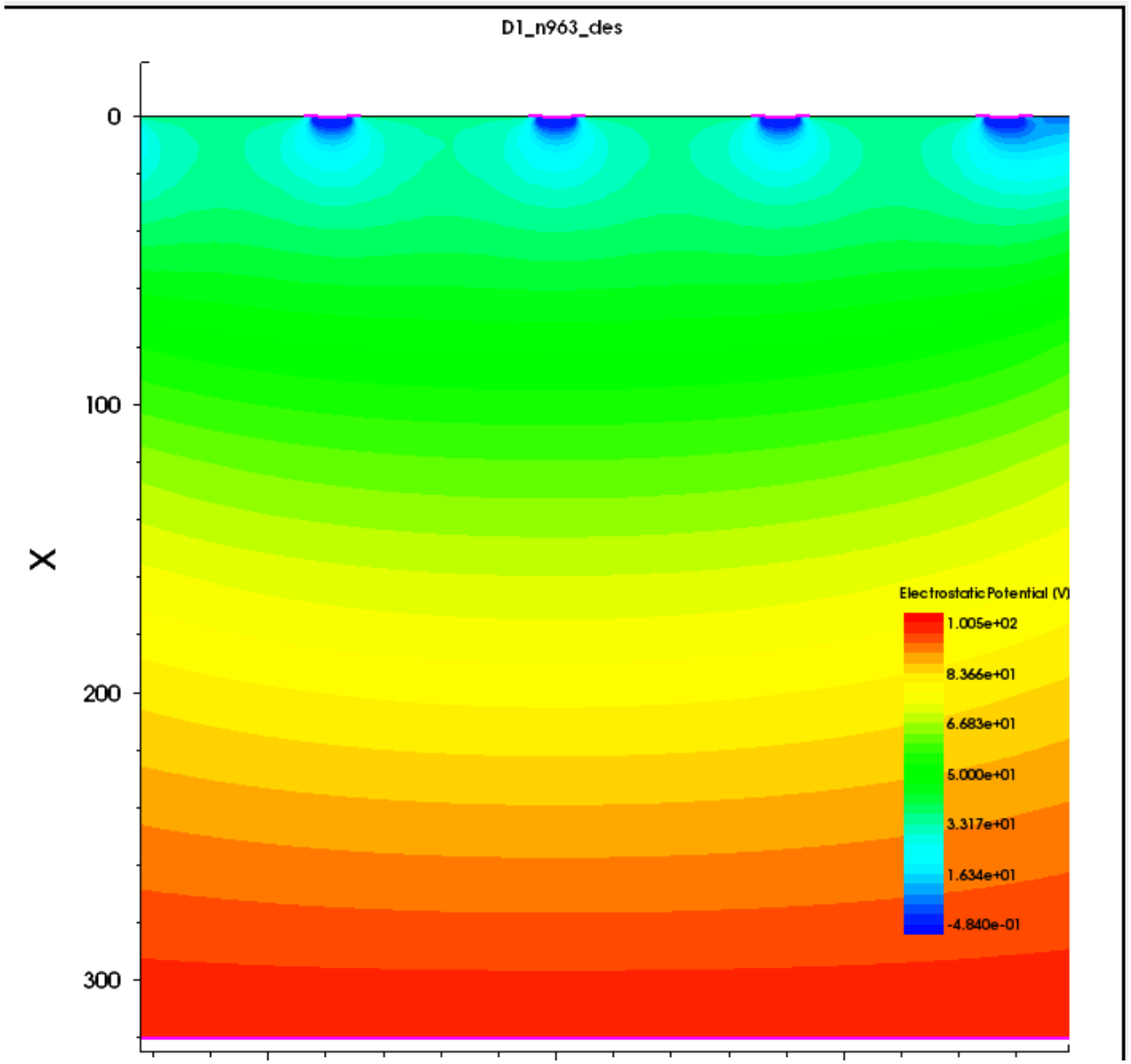
- I sent this simulation result to Hamamatsu Photonics and received some comments.

- The modeling is almost right.
- The effect of depletion area seems to be small.
- It would be better to concern the diffusion of career and recombination.

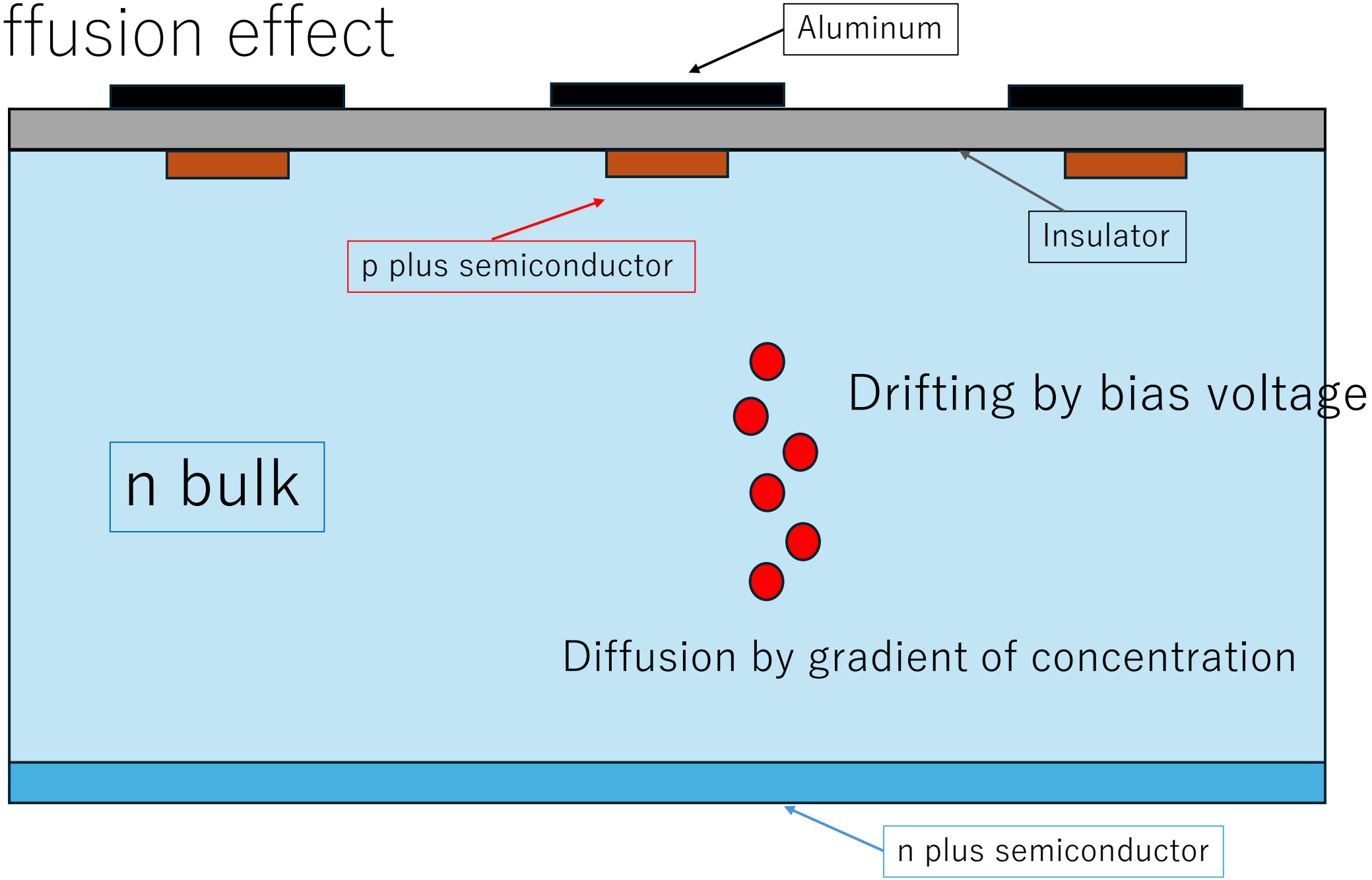
Equipotential surface

Equipotential is almost parallel in most of n-bulk

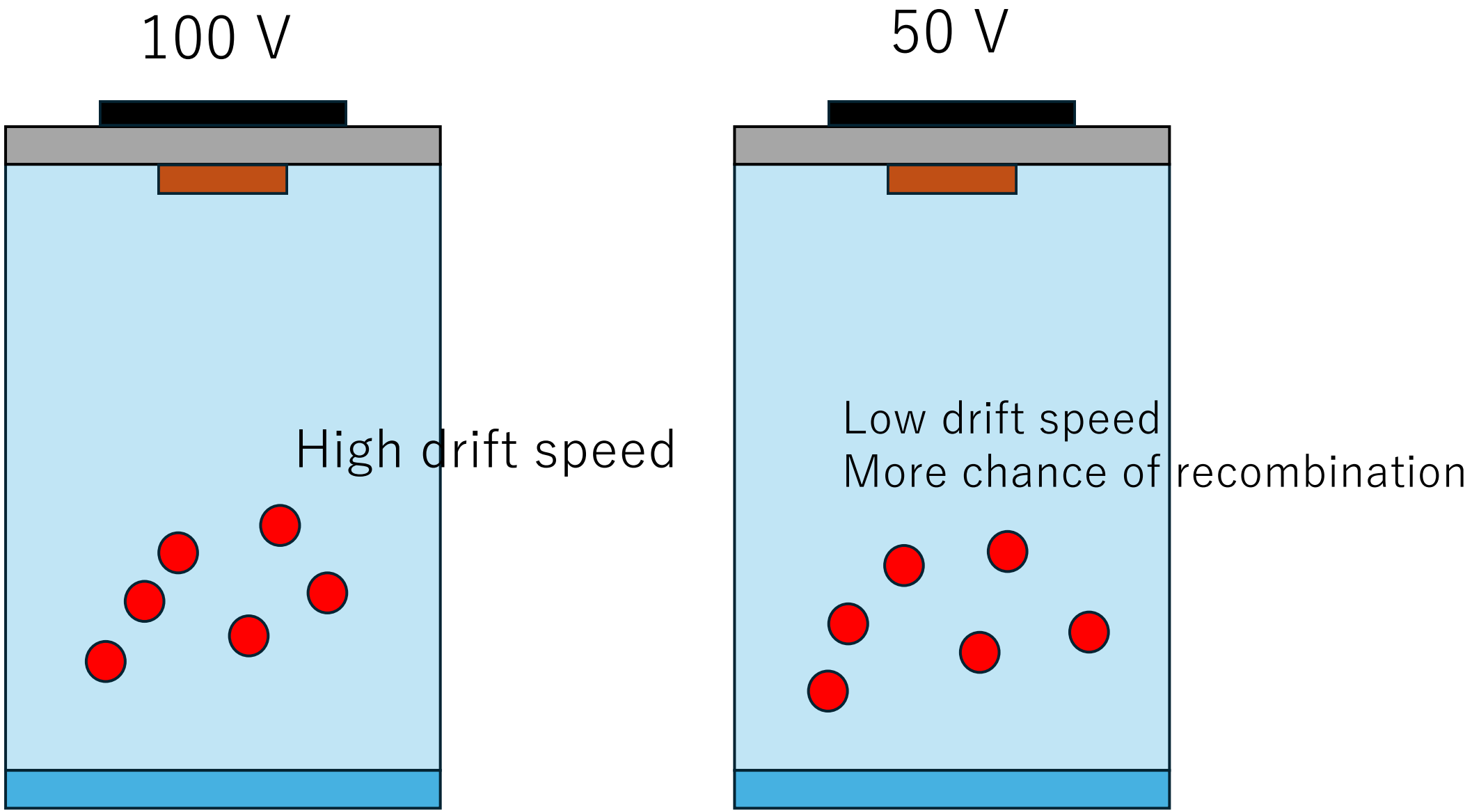
There’s no force toward parallel direction apart from **Diffusion**.



Diffusion effect



Recombination effect



Conclusion

- The effect of depletion area seems to be uniform over 50V.

- But if we lower bias voltage from 100 V, **diffusion** and **recombination** of charge carrier **may** affect the signal amplitude.
- →the lower the bias voltage, the wider a cluster size due to **diffusion**. As a result, pulse height of central strip will be smaller.
- →Also, the slower drift speed may end up with losing charge by **recombination** effect.

- I will compare cluster size between 2019 and 2021 beam tests to verify the diffusion effect.
- But I have no idea how to verify recombination effect by data.

In addition to that

- The result of test beam is still suspected that there’re some mistakes of setting even if those two data was checked many times.