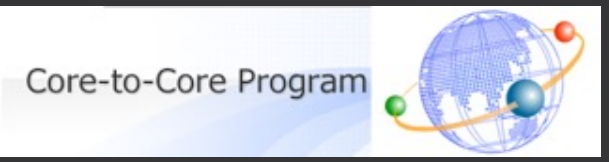

MEG II実験背景事象抑制に向けた DLC-RPC検出器の開発
―新型電極設計の最適化―

李 維遠（東大理）

家城 佳[A], 大谷 航[A], 大矢 淳史, 越智 敦彦[B], 恩田 理奈, 高橋 真斗[B], 潘 晟[A], 山本 健介
他MEG IIコラボレーション
(東大理、東大素セ[A]、 神戸大理[B])

2023年3月23日 (木)
日本物理学会2023年春季大会

Outline

- **Recall**
  - Requirements for US-RDC
  - First Prototype of DLC-RPC
  - Discharge before working point
- **Distortion of electric field**
  - Separating problems
  - Cause of the electric field distortion
  - Spacer Material
  - Distortion cause other than spacer
  - Fixing method
- **Summary and Prospects**

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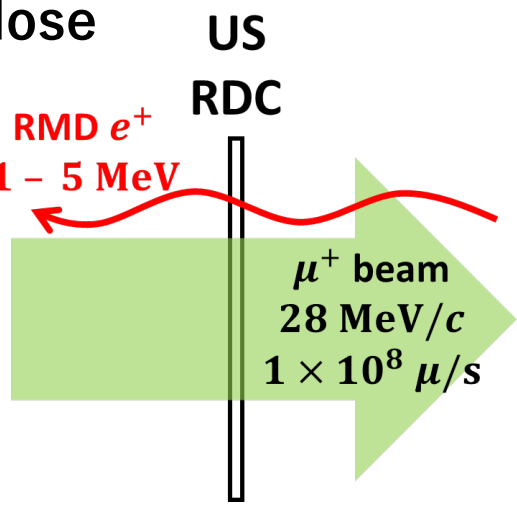
Requirements for US-RDC

- US-RDC needs to detect MIP e^+ from RMD in a low-momentum ($28\ \mathrm{MeV/c}$) and high-intensity ($1\times10^8\ \mu/\mathrm{s}$) muon beam

1.	Material budget:	$< 0.1\%$ radiation length
2.	Rate capability:	$4\ \mathrm{MHz/cm^2}$ of muon beam
3.	Radiation hardness:	$\mathcal{O}(100)\ \mathrm{C/cm^2}$ irradiation dose for > 30 weeks operation
4.	Efficiency:	$> 90\%$ for MIP e^+
5.	Timing resolution:	< 1 ns
6.	Detector size:	20 cm (diameter)

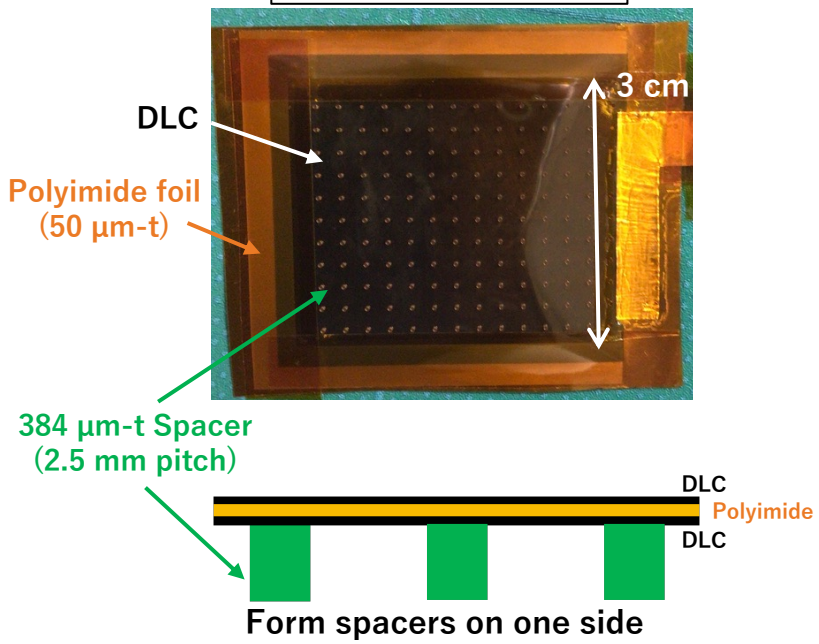
Making the development difficult!



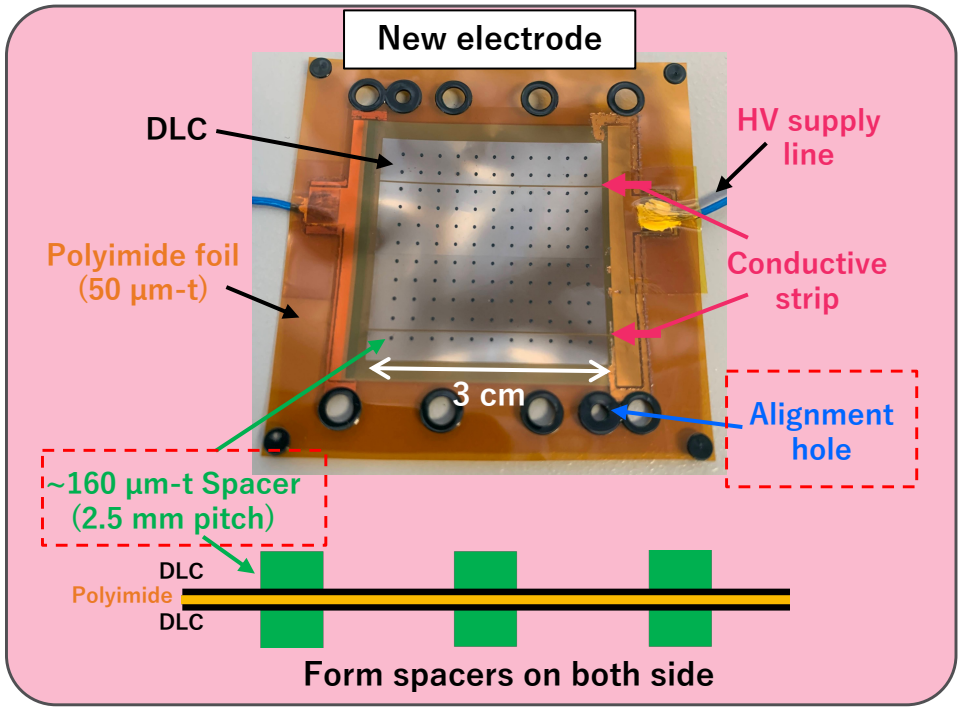
Development of Resistive Plate Chamber (RPC) with Diamond-Like Carbon (DLC) electrodes for US-RDC

First Prototype of DLC-RPC

Previous electrode

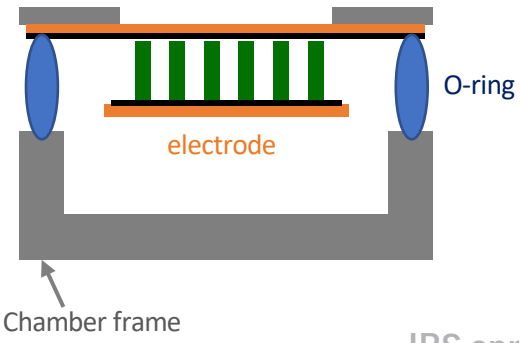


New electrode

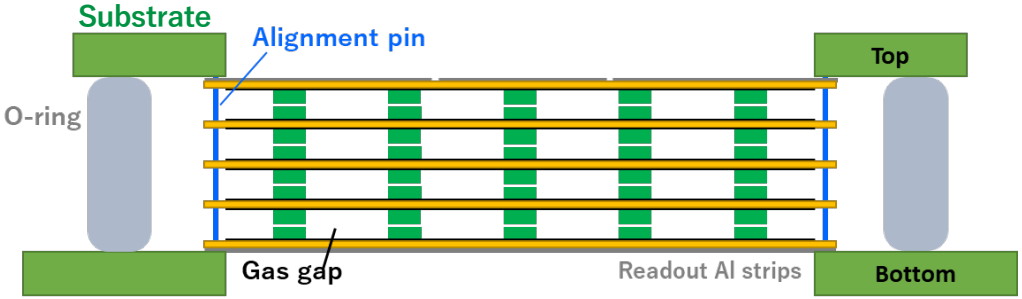


Cross-section scheme

Testbench

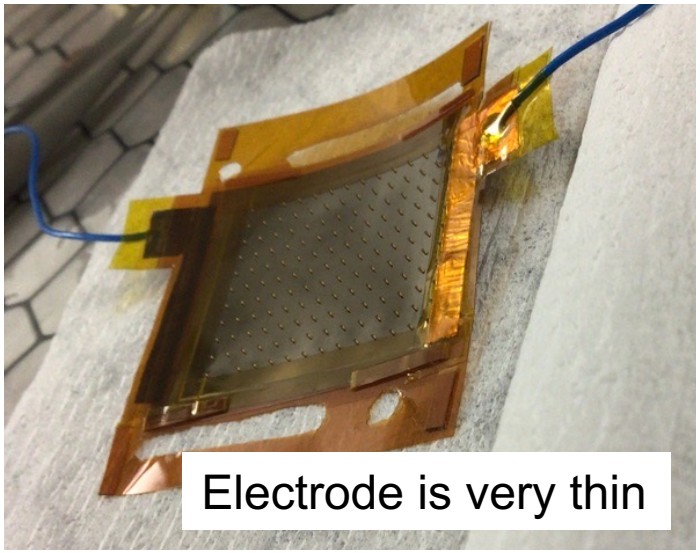


First Prototype



Discharge before working point

- **What are the suspicious causes of discharge for DLC-RPC?**
  - **Insufficient discharge quench capability around conductive strip**
    - **Details presented by Masato at last talk (23pT2-5)**
  - **Distortion of electric field (this talk)**
    - **Electrode for DLC-RPC is mainly made of 50 μm-thick polyimide foil**
    - **→ The structure is mechanically weak and very easy to be distorted**
    - **If electrode being distorted, that will be the weak point and cause the discharge**



Outline

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  - Spacer Material
  - Distortion cause other than spacer
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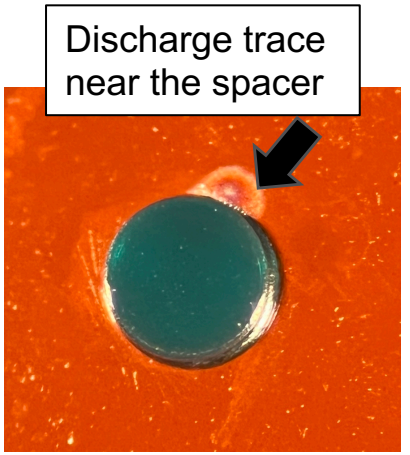
Distortion of electric field

- **Separating problems: lack of quench vs distortion of electric field**
  - Discharge around places other than conductive strip observed in the new electrode
  - Discharge caused by quench problem should be happened around conductive strip

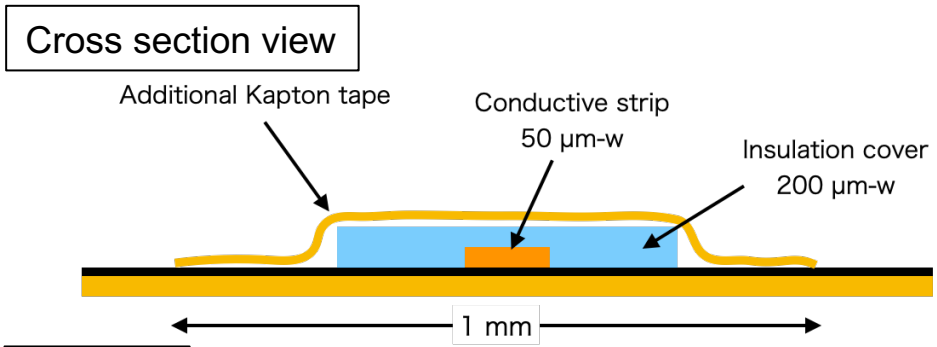
    → other causes?

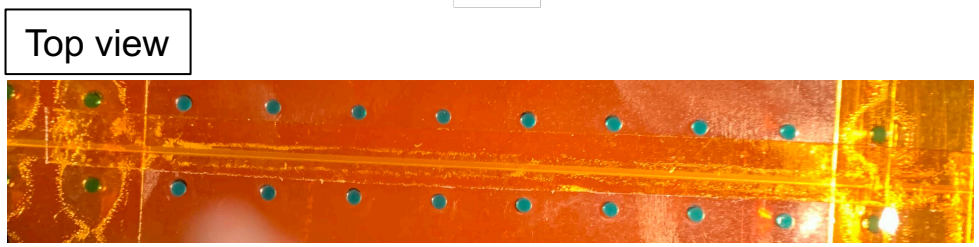


Operation test by masking the conductive strip by Kapton tape

- Original insulation cover (200 μm) : discharge at 2200 V
- Additional Kapton tape (1 mm) : discharge at 2100 V

→ <u>No improvement</u>



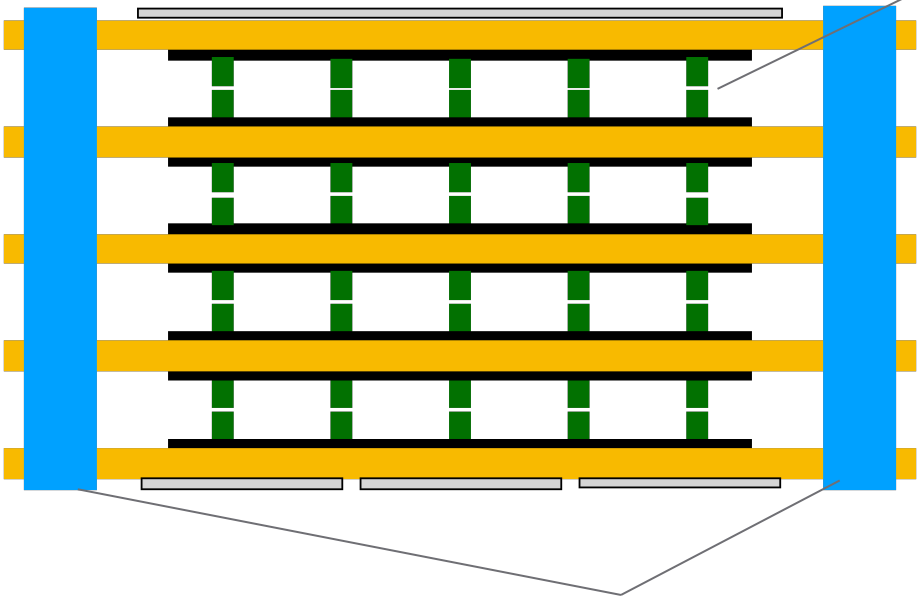


Distortion of the electric field may also playing a big role

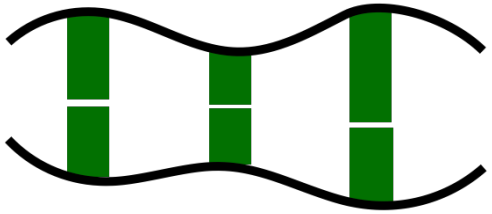
Distortion of electric field

➢ Cause of the electric field distortion

- Electric field is made by electrodes and spacers
  → Cause of the distortion must be either or both of electrode and spacer



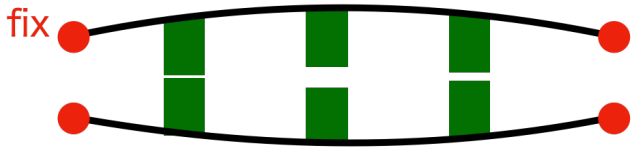
1. Spacers



Spacers defines the gap thickness → the profile of the spacers directly affects the quality of gap thickness uniformity

2. Alignment pins

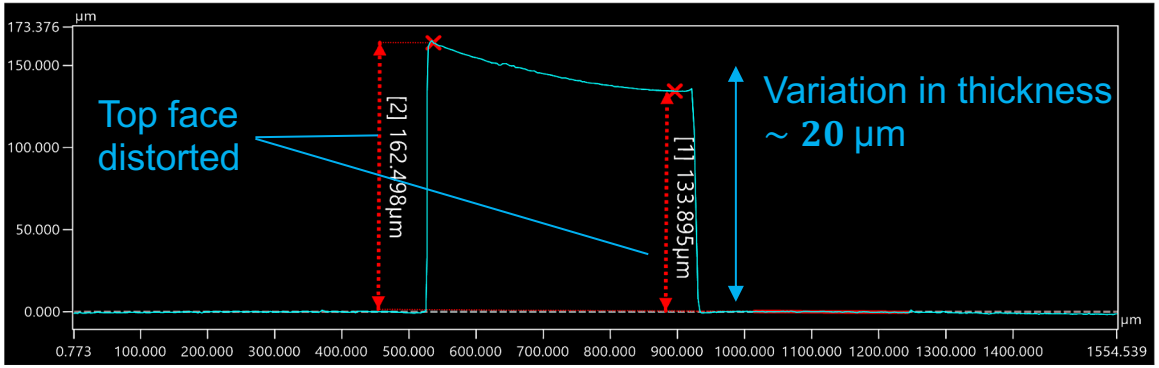
Fixing method defines the flatness of the electrodes → Pins for the alignment of the spacers



Distortion of electric field (1)

➢ Spacer Material

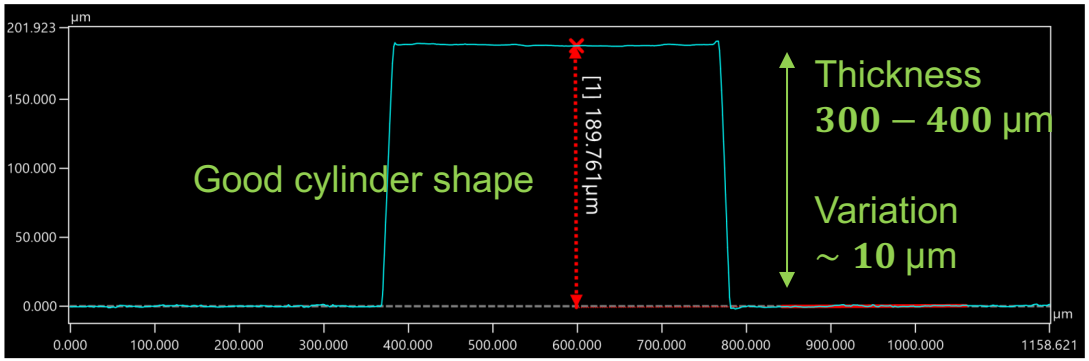
Side view of the spacer on the new electrode (measured by laser microscope)



- Variation in thickness <u>between different spacers</u> : ~ **20** μm
- Distortion in top face of spacers
- Misalignment of spacers

→ all of these contribute to the un-uniformity of gap thickness which causes distortion of electric field

Side view of the spacer* on the previous electrode



*same material on the previous electrode but ~190 μm thickness

✓ An alternative material for the spacer is needed

- Current best candidate : Dryresist by Tokyo Ohka Kogyo (TMMF series)
- Spacer formation test is now underway

Required :

- Form enough thickness : 300 – 400 μm
- Less variation in thickness : ~ 10 μm
- Good cylinder shape (uniform thickness in single spacer)

However, this may not a technical problem, but largely a commercial problem

Distortion of electric field (2)

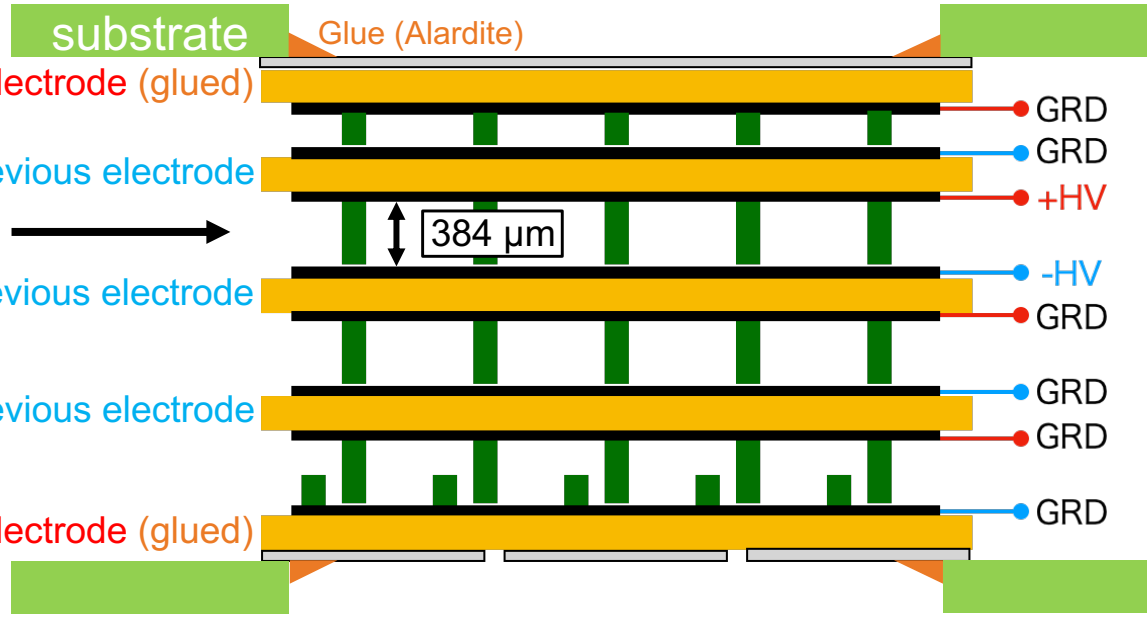
- **Distortion cause other than spacer**
  - Remove the impact of new spacers and conductive strip
    - Test using previous electrode in First Prototype
    - The performance of previous electrode has been demonstrated in testbench
  - Still can't apply HV to working point

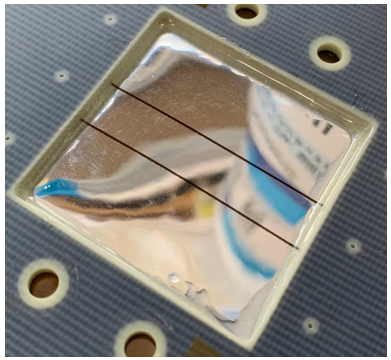
  → There are problems other than spacers

		Previous electrode	New electrode
Spacer	Thick ness	384 μm	160 μm
	Face	Only anode	Both anode and cathode
Conductive strip		×	○

Abnormally large current before working point!

Test at this layer →

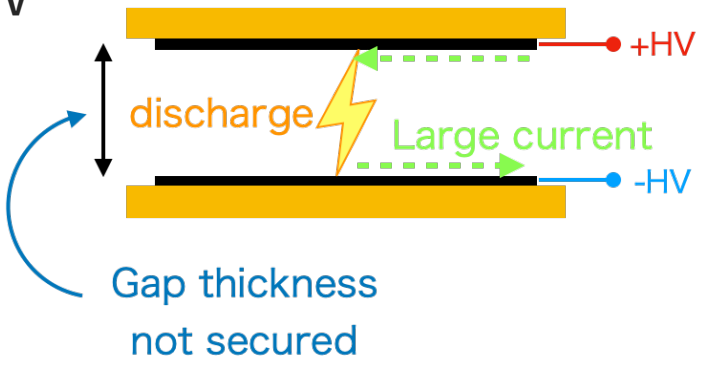




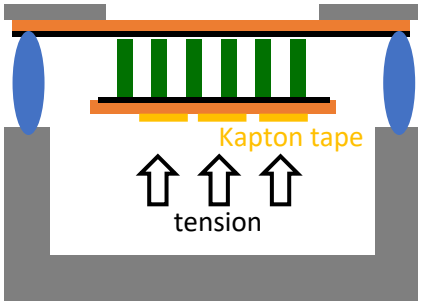
Distortion of electric field (2)

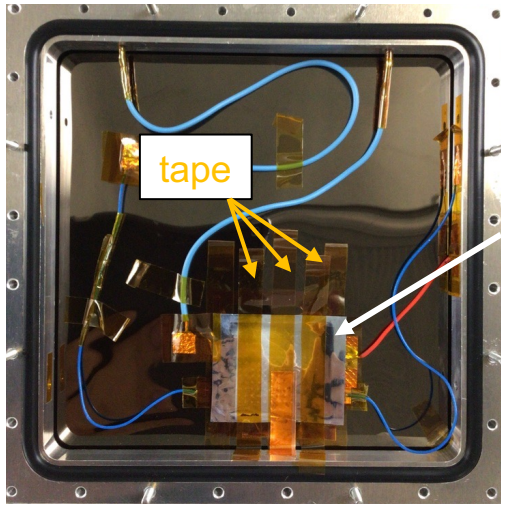
➢ Distortion causes other than spacer

- Previous electrode in <u>testbench</u>
  → Good operation : ~ 60% detection efficiency at 2800 V
- Previous electrode in <u>First Prototype</u>
  → **Abonormally large current before working point**
  - This result suggests there are continuous small discharges between the gap
  - Discharges before working point means that the gap thickness is not secured
  - What's the difference between First Prototype and testbench other than electrode?

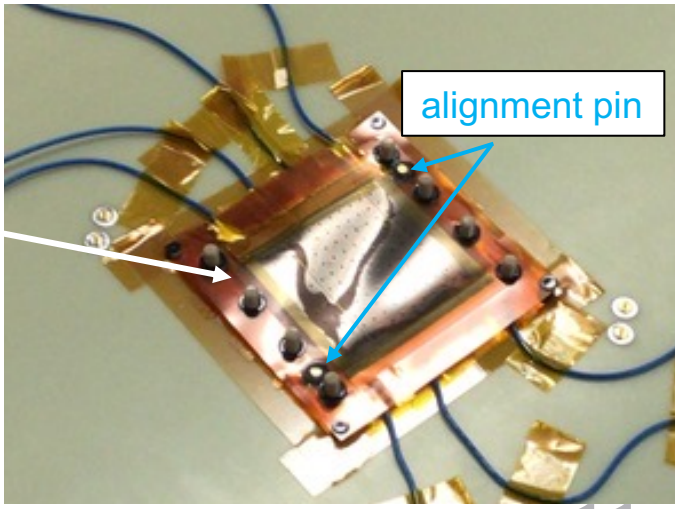


Testbench



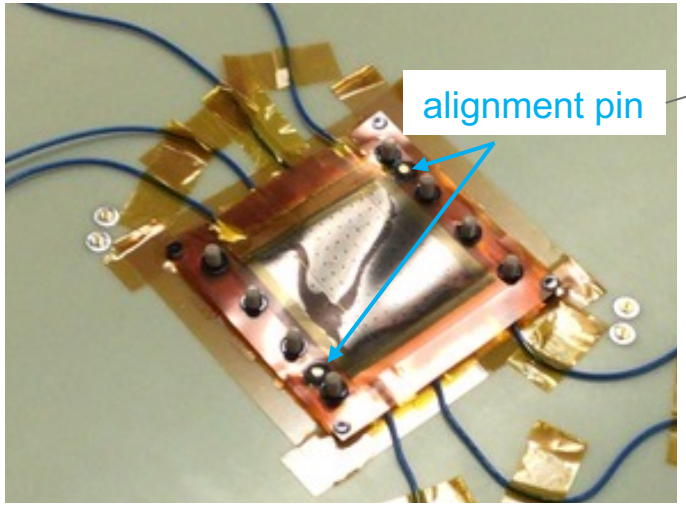


First Prototype



Distortion of electric field (2)

- **Fixing method of electrode**



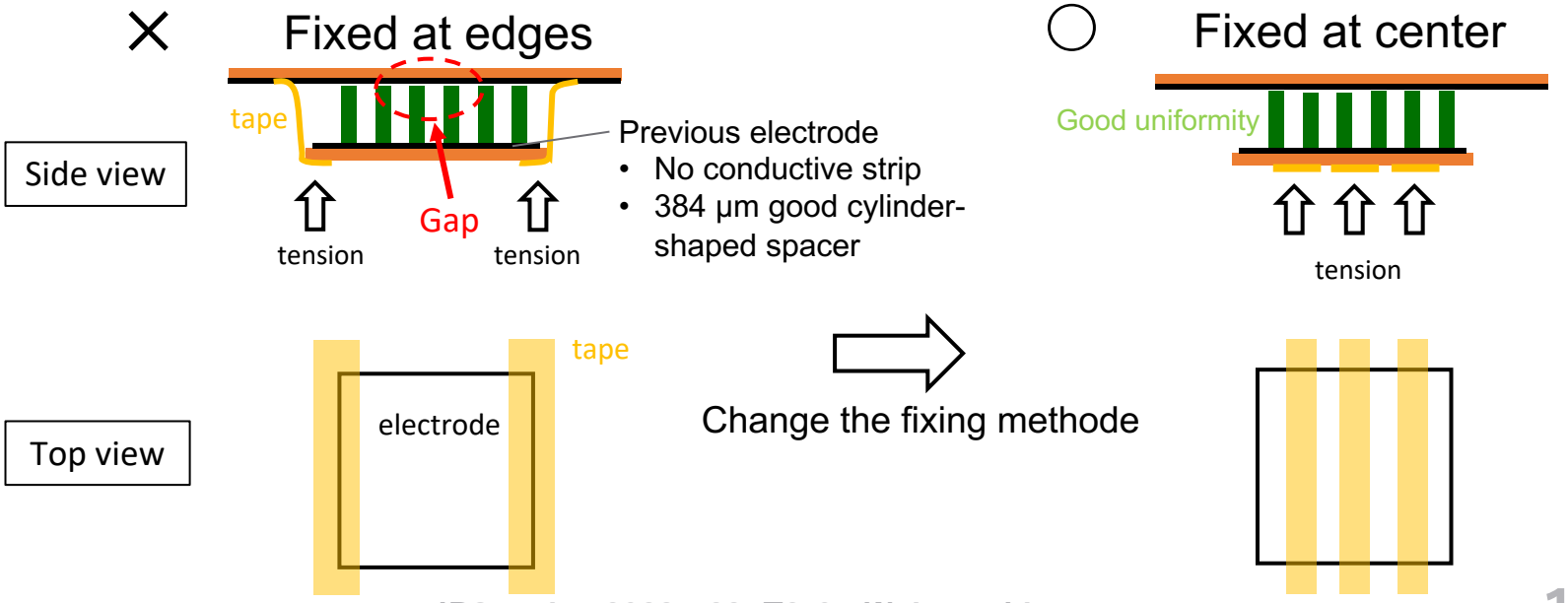
Electrodes are fixed by alignment pins at the edges

→ See if the fixing method is appropriate

Compare the fixing method using previous electrode in testbench

- Edges vs Center
  - Edges : discharge before WP
  - Center : good operation

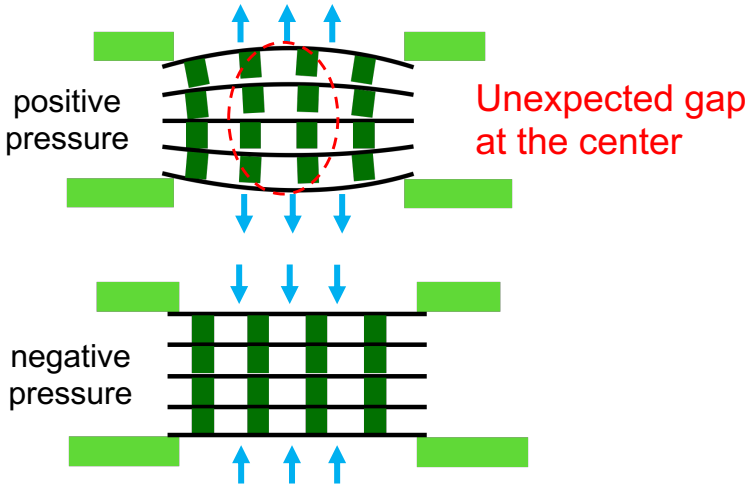
→ **Current fixing method seems not appropriate**



Distortion of electric field (2)

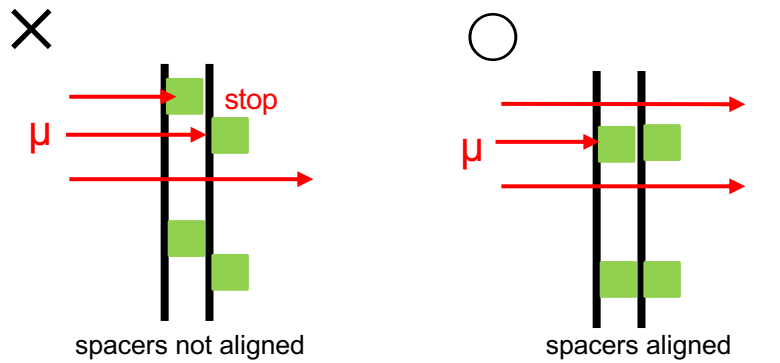
- **Fixing method of electrode**
  - **Pressing the electrode at the center seems important**
  - **Don't want to put extra material in the active region to fix the electrode**

  → Pressing the gap by air pressure difference is the solution

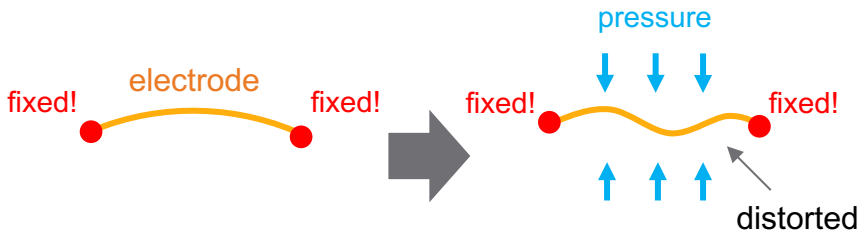


  - **Spacer alignment is still a matter**
    - **muons can't pass through the spacers**
    - **misalignment of the spacers makes more muons to stop**

  → Something like alignment pin to determine the position of electrode is still needed



We need to understand the following
- **What kind of constraint can be put?**
- **How much misalignment is allowed?**



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  - Fixing method
- **Summary and Prospects**

Summary

- Development on DLC-RPC for US-RDC is ongoing
- First Prototype of DLC-RPC has been constructed, but it doesn't work well
- Investigation for the cause of the problems
  - Not enough quench by resistivity (last talk) investigation ongoing
  - Distortion of electric field
    - Quality of the spacer formation test ongoing
      Variation of the thickness caused by spacers should be less
    - Fixing method of electrodes Investigation ongoing
      Alignment pin at the edges cause distortion
- Study for the cure of the problems will be carried on

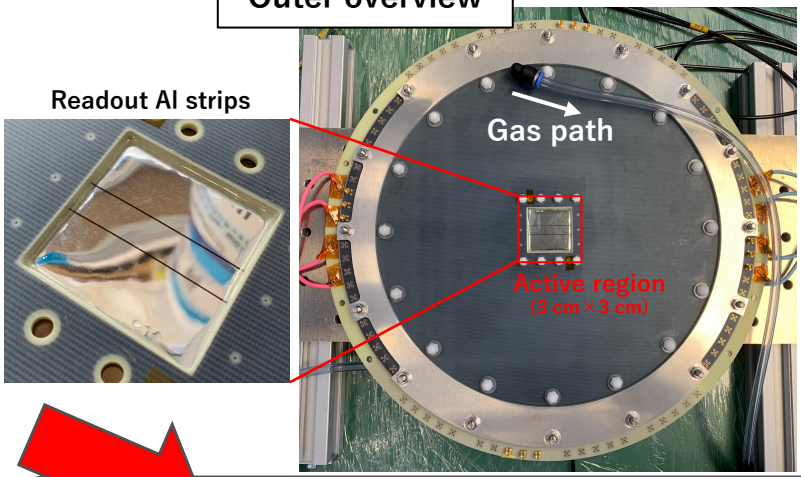
Prospects

- **Study for the uniformity of electric field**
  - Confirm that the alternative spacer material has the good quality
  - Discover how to fix the electrode under negative pressure
    - What kind of constraint can be put on the electrode?
    - How much misalignment of the spacers?
    - Is the misalignment of the spacers acceptable for US-RDC?
- **DLC-RPC as US-RDC**
  - Resolve the problem of electric field distortion and lack of quench on resistivity
  - New structure will be implemented on the next prototype detector
  - Aim to install at 2024 physics run

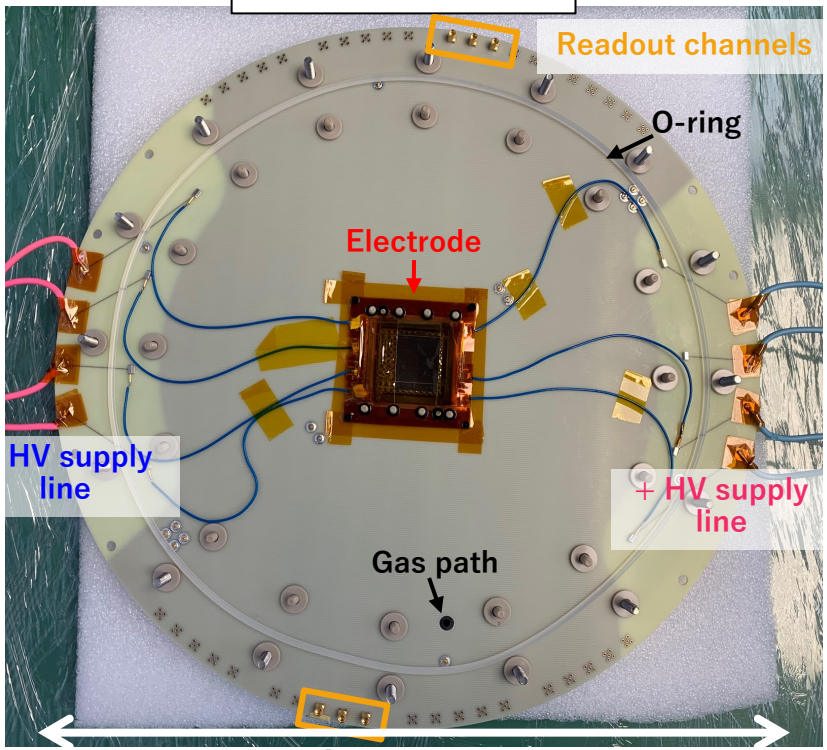
Backup

First Prototype of DLC-RPC

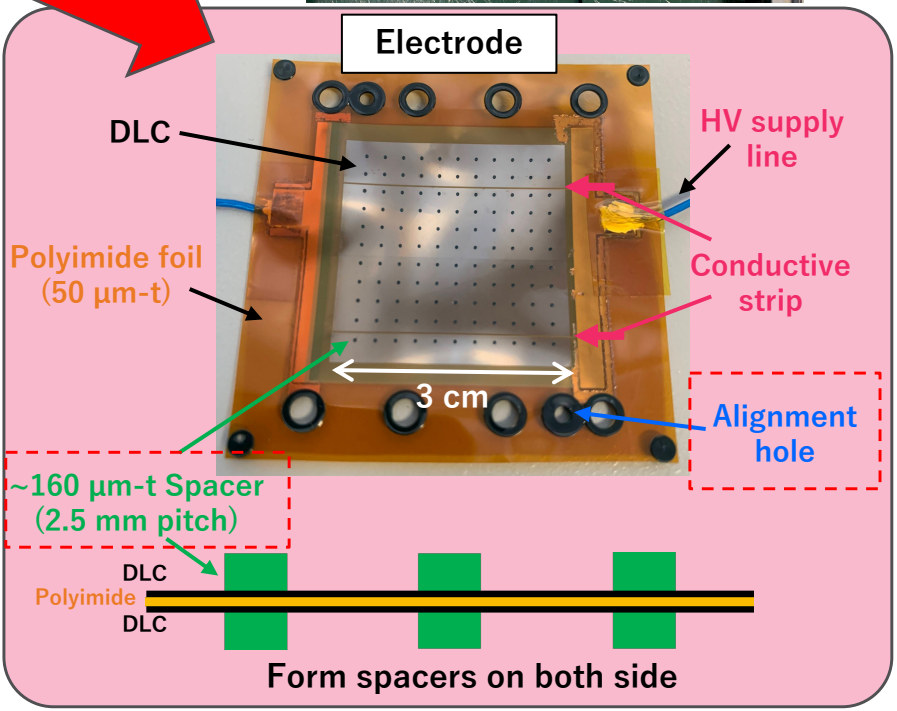
Outer overview



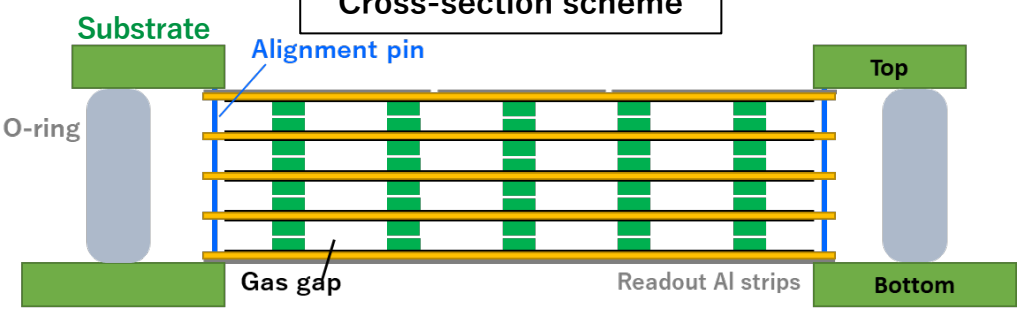
Internal overview



Electrode



Cross-section scheme



Today's talk

- The problems surfaced due to operation at negative pressure
  - Insufficient discharge quench capability
    - Unable to suppress the development of discharges

    ➡ Details presented by Masato at last talk (23pT2-5)
  - ✓ Distortion of electric field
    - Causes excessive development of gas avalanche

    ➡ Details will be presented at this talk (23pT2-6)
- Estimate of performance expected from actual detector
  - Considering the structure of the detector

  ➔ Details will be presented by Kensuke at next talk (23pT2-7)

Distortion of electric field

- **Fixing method : outermost layer electrode**

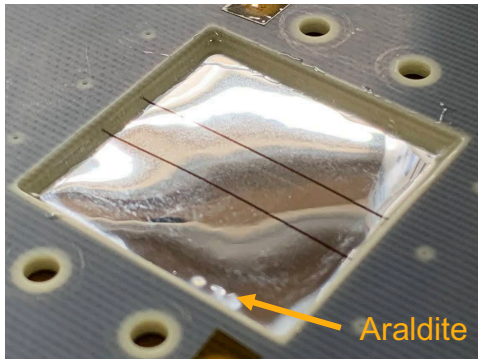
  We don't want to have any space between outermost layer electrode and substrate for gas tight

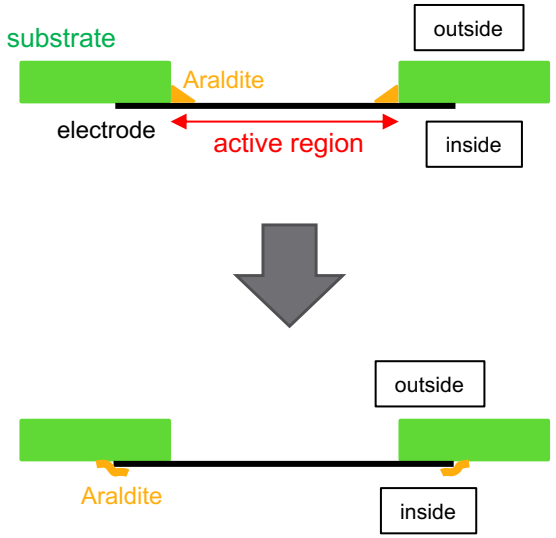
  - **Currently, electrodes are glued by Araldite around the active region**
  - **However, outermost layer seems not flat**

  - **In test bench, gas tight between outermost layer and chamber frame was realized by O-ring**
  - **HV cables make it difficult to use this approach in First Prototype**

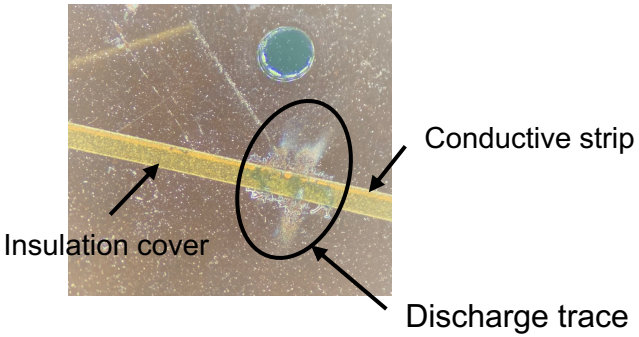
  → Technically, using the glue and tape seems easier to achieve gas tight and flatness of the outermost layer

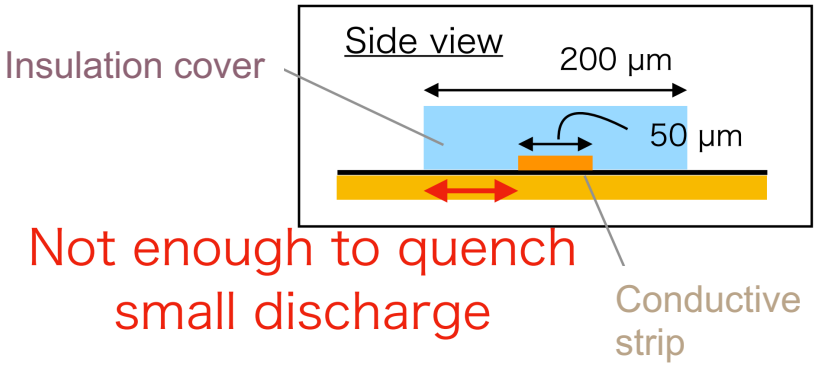
  Problem is that the part making the electrode flat and the part making gas tight is now overlapped.
  → arrange the parts so that different role at different place





Conductive strip and insulation cover

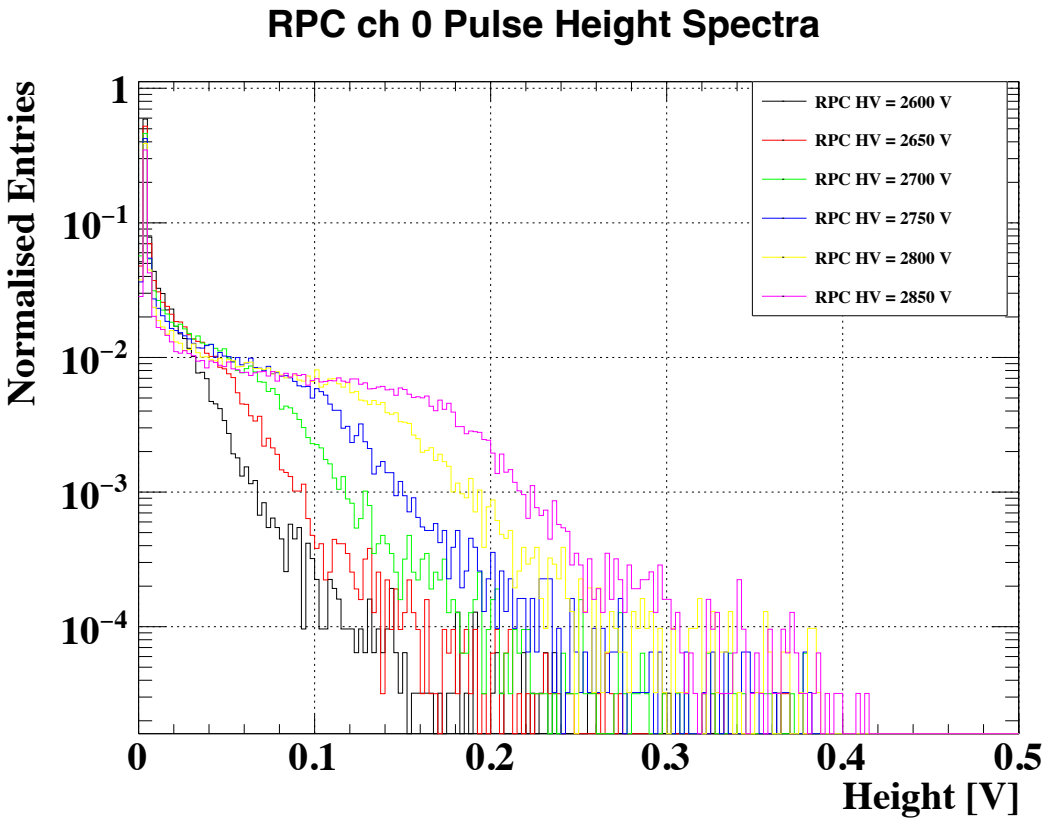




DLC-RPC signal height spectrum

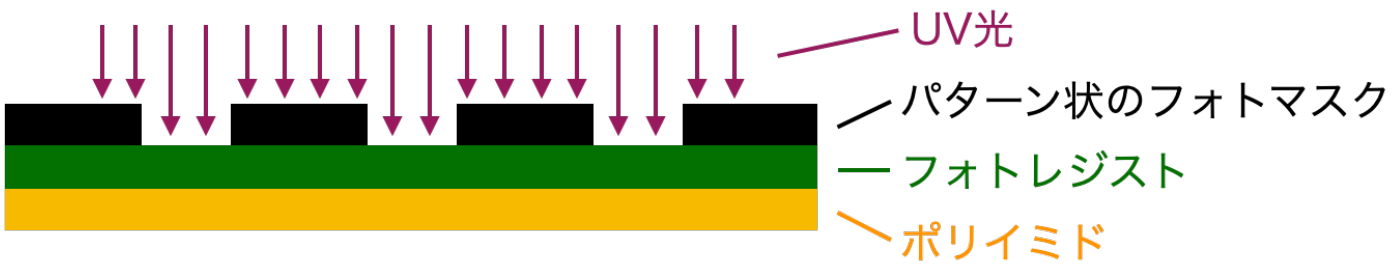
- **Spectrum by fixing at center**

  (testbench, previous electrode)

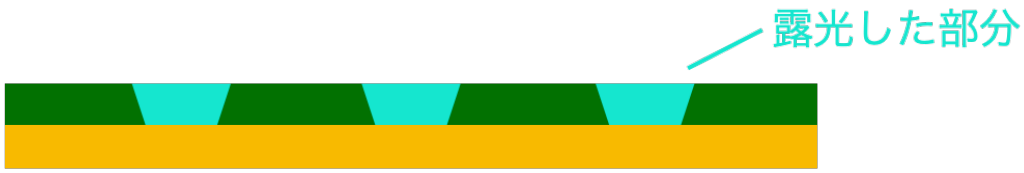


Spacer formation flow

1. マスクをかけて
   UV光で露光する



2. 現像液によって
   非露光領域を溶かす



3. ピラーが完成する

4. 熱硬化する
   (ベーキング)