MEG II 実験背景事象抑制に向けた DLC-RPC検出器の開発

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Outline

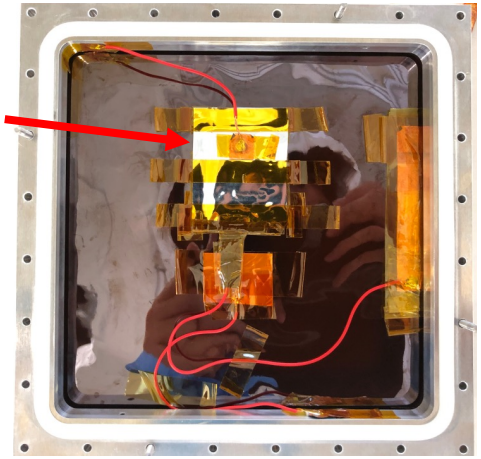
- **Introduction**
- **First Prototype**
  - New structure
  - Changes on electrode
  - Demonstrated performance and problems
- **Investigation for causes of discharge**
- **What we know now?**
- **Summary and prospects**

Introduction

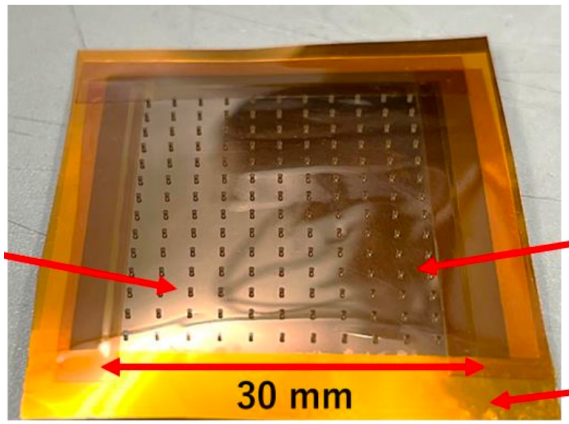
- **Requirements for US-RDC and current status for DLC-RPC**

Contents	Requirements	Current status
Material budget	$< 0.1\% X_0$	$\sim 0.095\%$
Rate capability	$4.0\ \mathrm{MHz/cm^2}$	$1\ \mathrm{MHz/cm^2}$
Radiation-hardness	> 30 weeks	N/A
Detection efficiency	$> 90\%$	$> 40\%$ (with single-layer), $> 90\%$ (calculated)
Timing resolution	1 ns	160 ps
Detector size	ϕ 20 cm	3 cm × 3 cm (active region)

Test bench



Electrode sample with 384 μm spacer



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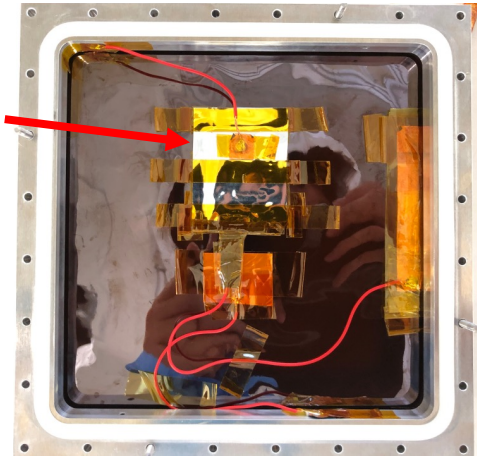

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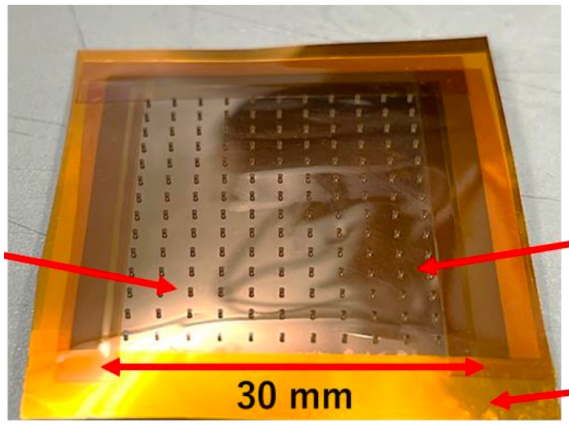
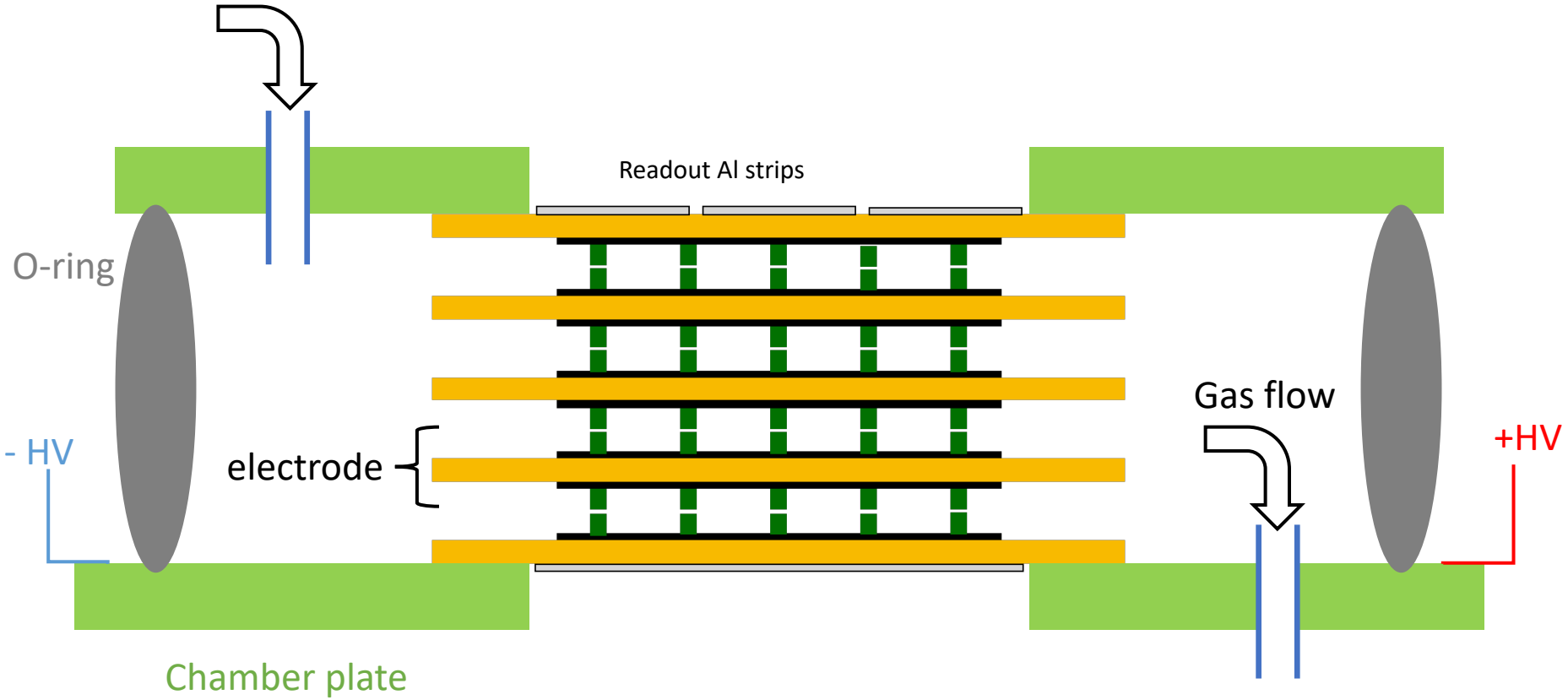


First Prototype



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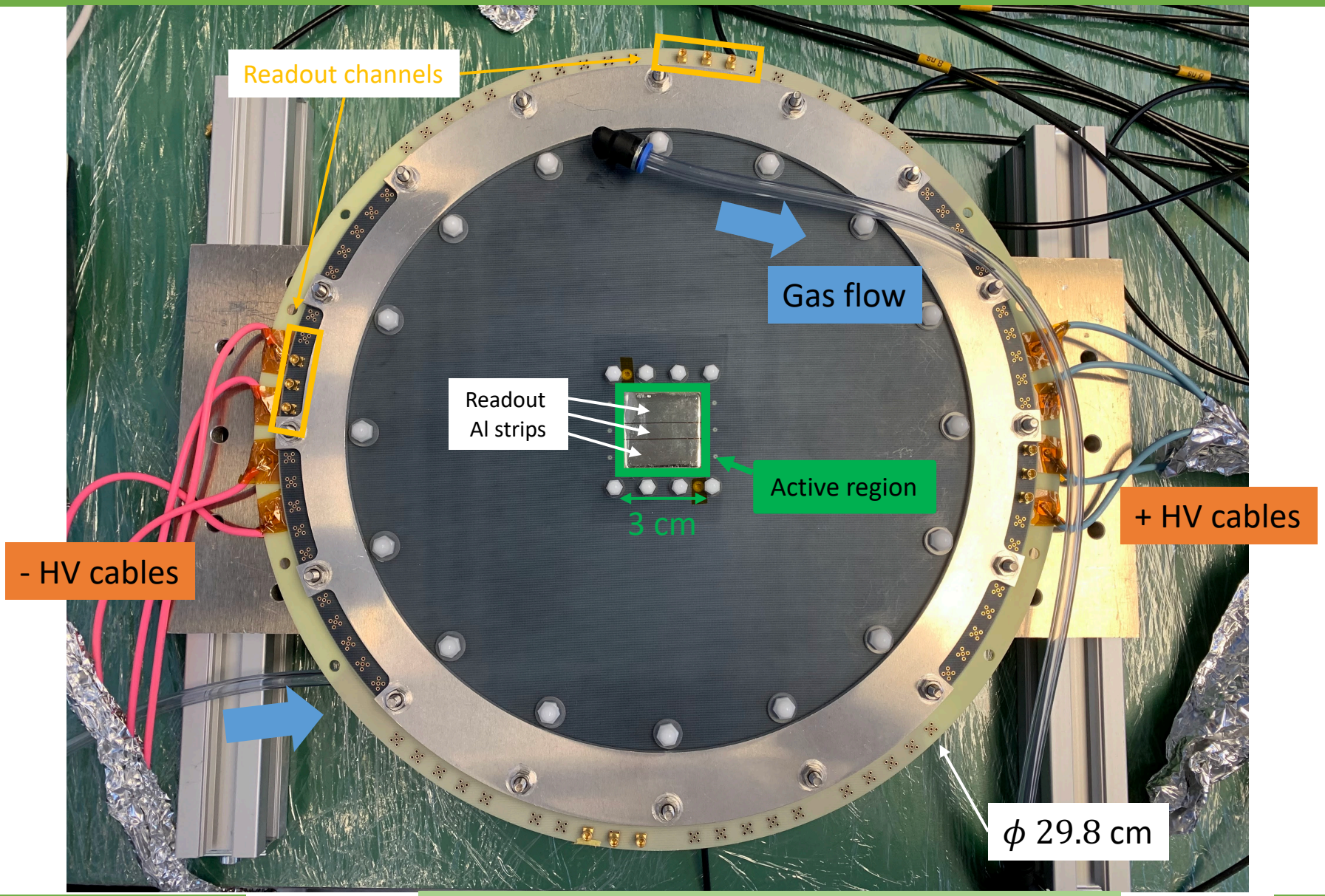

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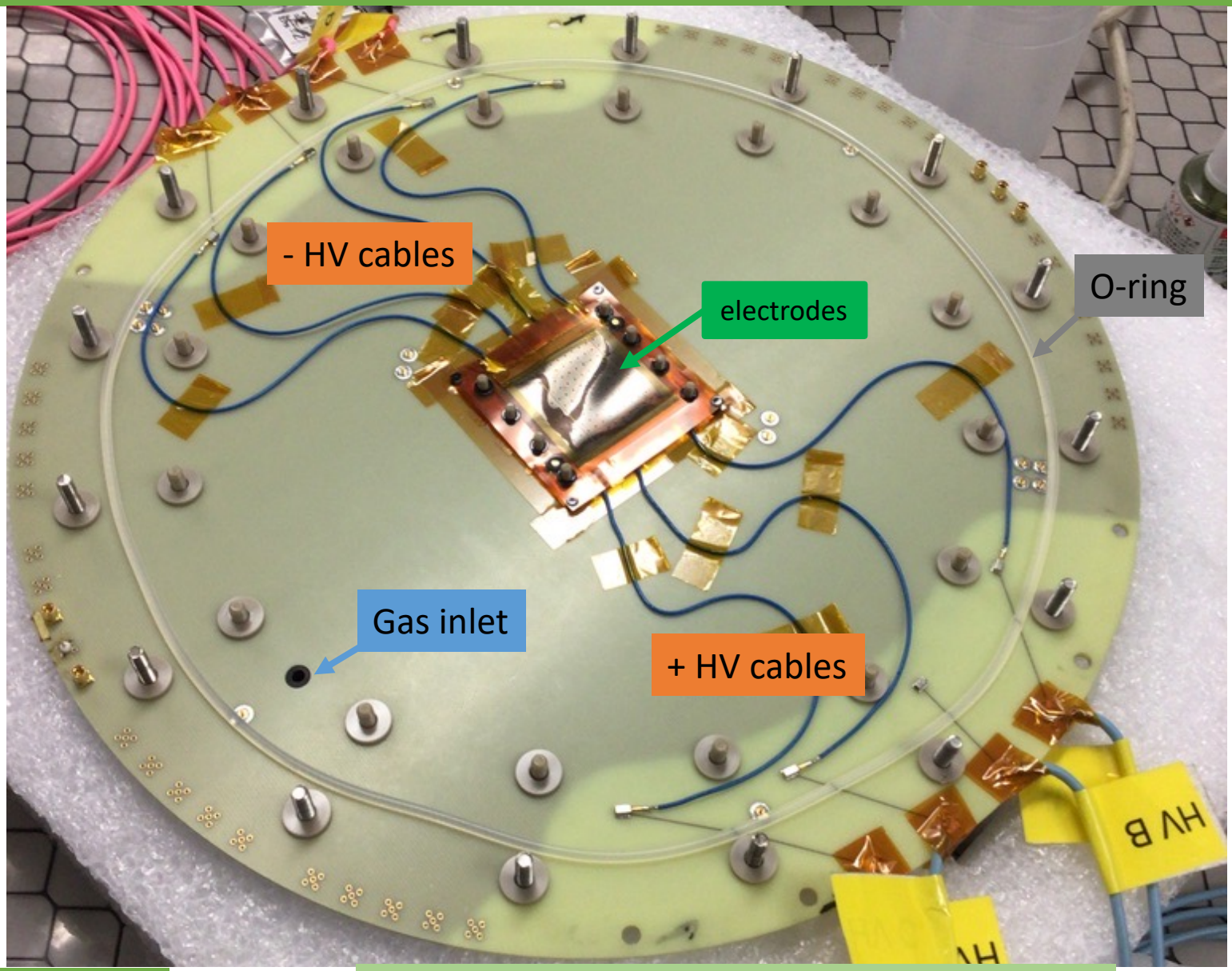
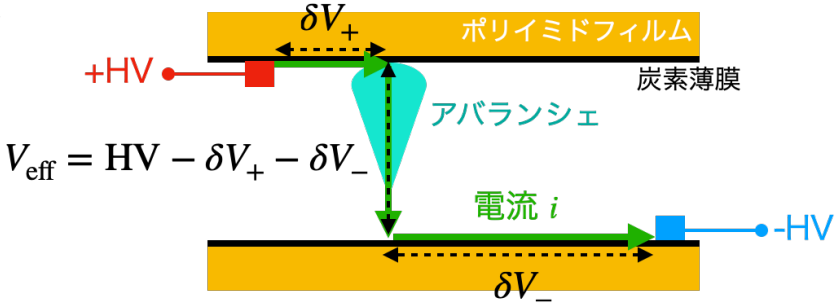


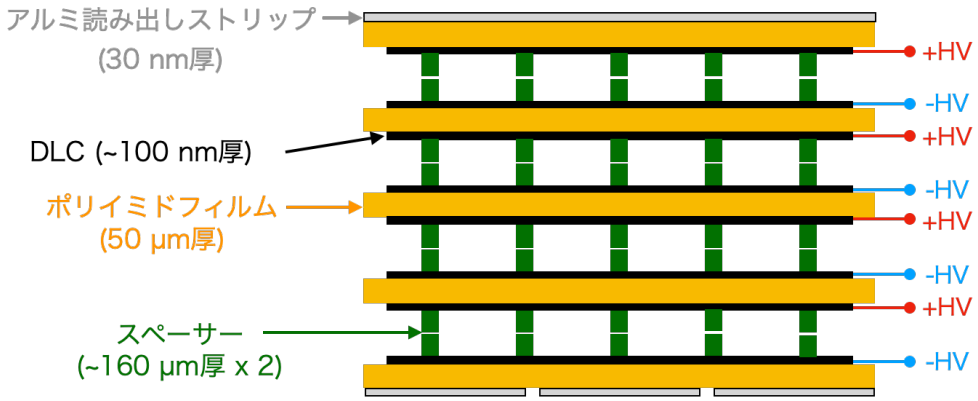
New structure

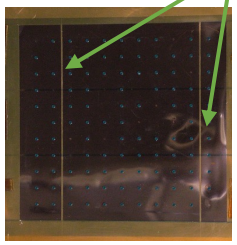
- **Rate capability：New electrodes with conductive strips implemented**
  - Under high-rate environment, steady current flow between the gap and effective voltage decreases
  - Suppress voltage decrease by shortening the distance of current flow on DLC

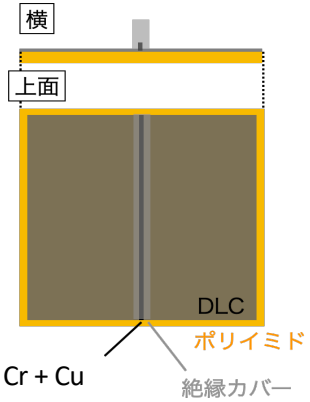
  → Implement conductive strips on DLC
  - Strips are protected by insulation covers to prevent discharge



- **Detection efficiency : stuck to multi-layers**
  - 4 layers for achieving 90% efficiency

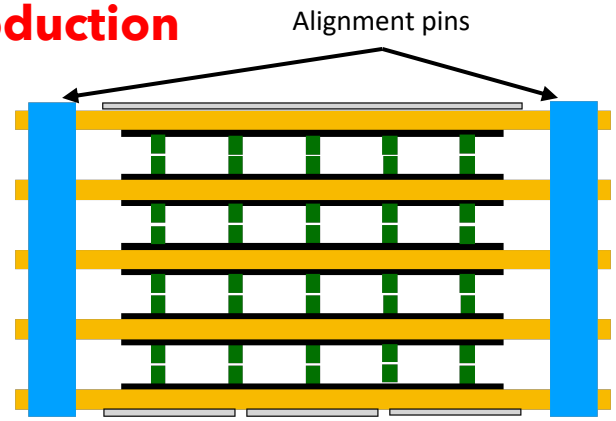


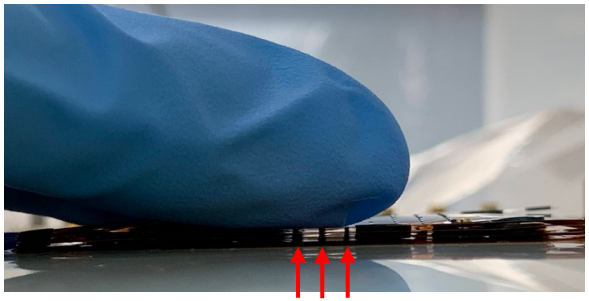




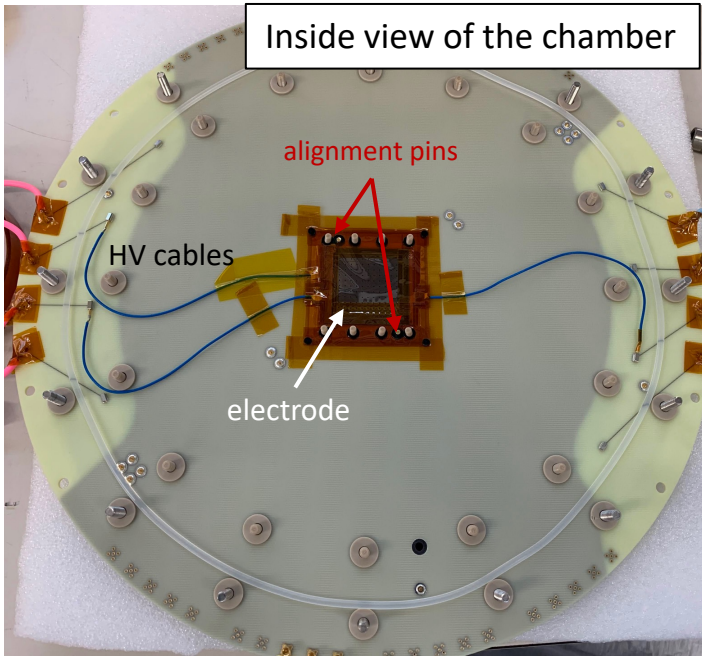
Changes on electrode

- **Spacer material used in prior studies is out of production**
  - Alternative materials in new electrodes
  - Difficult to form spacers of sufficient thickness
  - To make 320 μm gap thickness per layer, 160 μm spacers are stucked
  - Electrodes are fixed by alignment pins so that the spacers are aligned



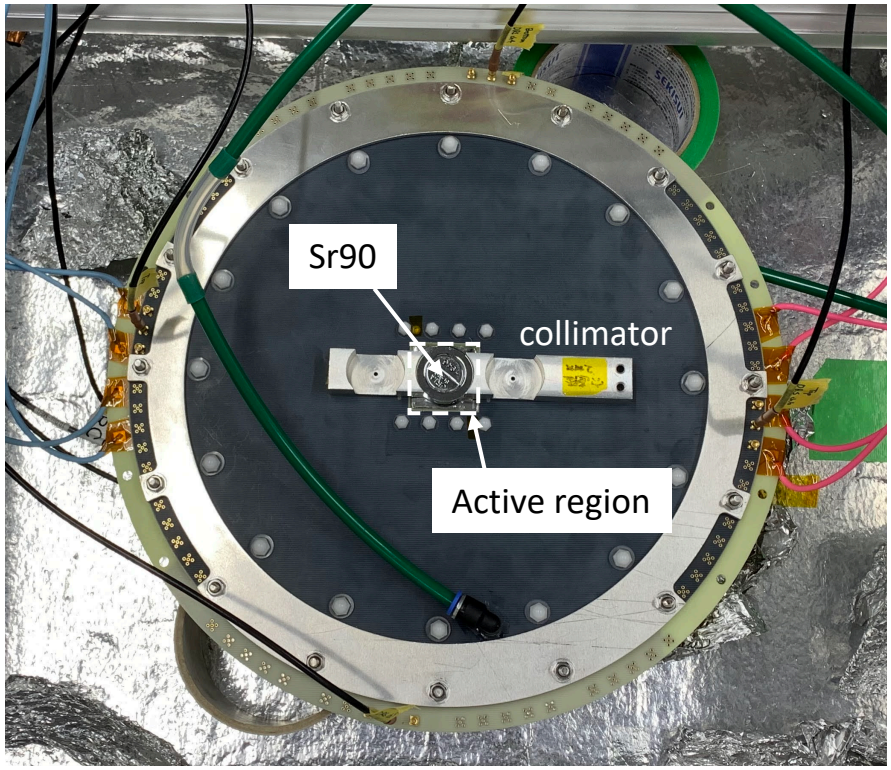


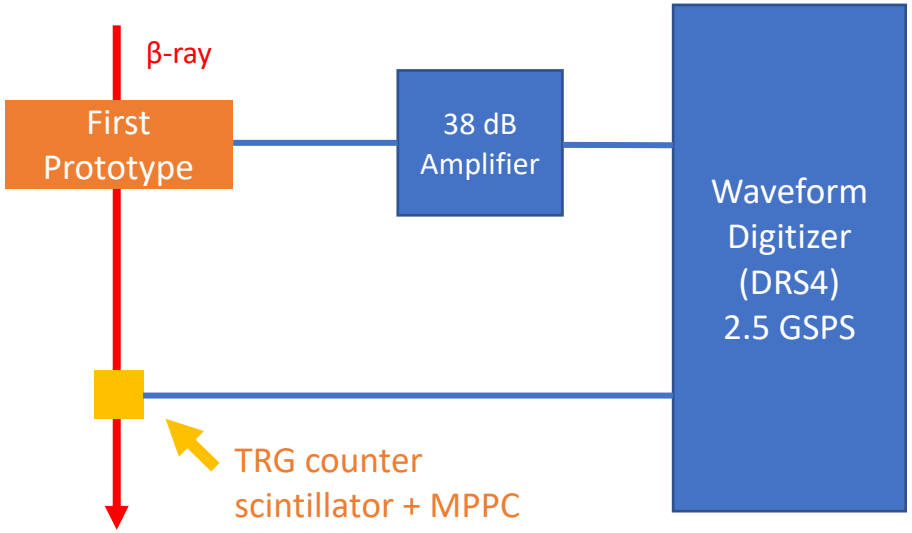
Spacers are aligned by alignment pins



	Prior electrode	New electrode
Thickness of spacer	384 μm	160 μm
Spacer existing face	Only anode	Both anode and cathode
Conductive strip	×	○

Demonstrated performance and problem



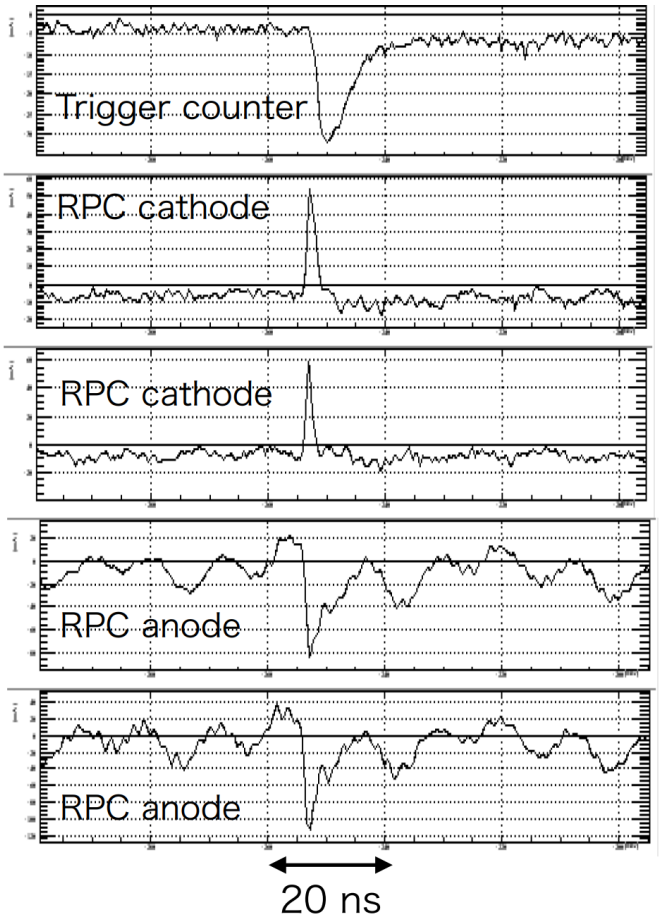


Performace

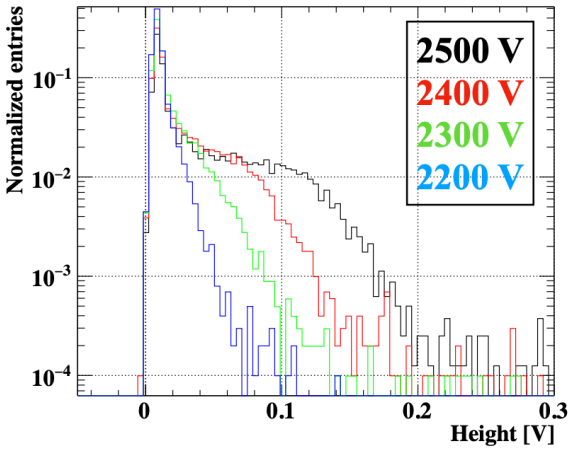
- **Detection efficiency : 46% @2500 V, thr = 20 mV ***

※ just at one specific layer out of 4 layers

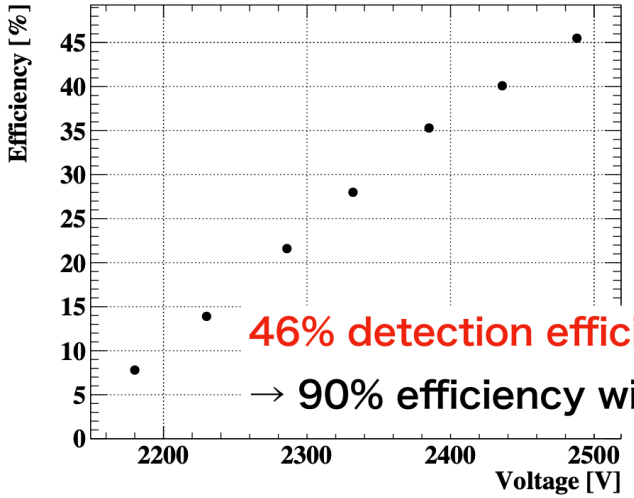
Event display



Pulse height spectra



Efficiency vs voltage



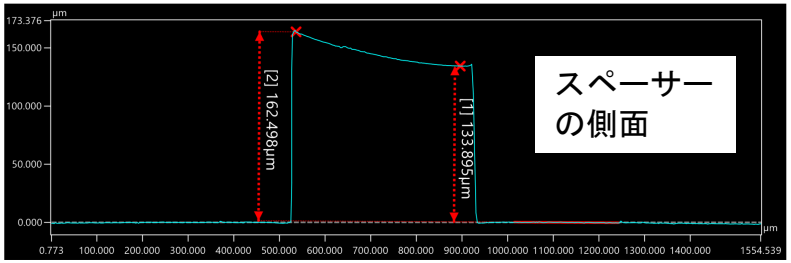
46% detection efficiency with single layer

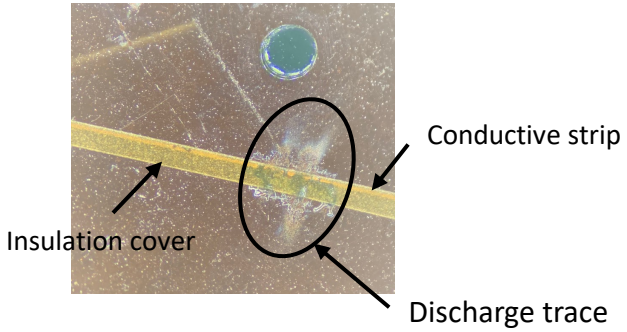
→ 90% efficiency with 4 layers $(1-(1-\epsilon_1)^4)$

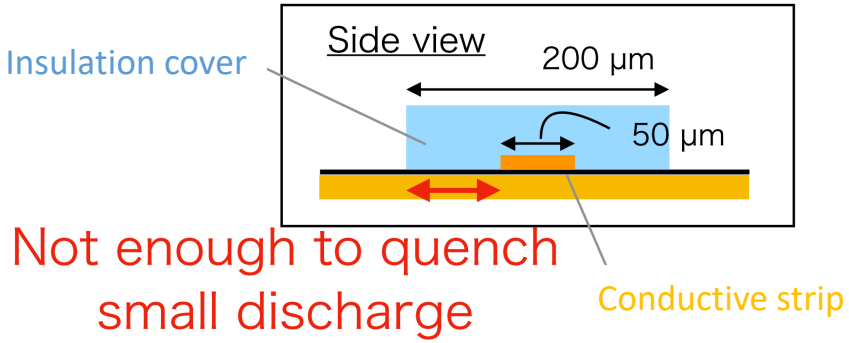
*: 山本健介他、「MEG II実験背景事象削減に向けた高レート耐性DLC-RPCの高抵抗電極の開発」、日本物理学会2022年秋季大会、岡山理科大学、2022年9月

Problems

- **Detector is NOT operating stablely at working point (WP) = 2500 V**
  - 46% detection efficiency is achieved only in a certain area of a certain layer
  - Discharge occurs even at ~ 2100 V when β-ray (Sr90) is irradiated
  - Stable operation at WP and > 40% efficiency in all layers is needed
- **Candidate causes of discharge before WP**
  - Non-uniformity of gap thickness
    - Variation in thickness of spacers：~ 20 μm
    - Distortion in top face of spacers
    - Misalignment of spacers
  - Amplification quenching by resistance
    - Distance between edge of cover and strip
    - Relative misalignment of strip and cover







Investigation of causes of discharge

- **Mounting prior electrode on First Prototype**
  - Spacers are only on anode side and they are uniform thickness of 384 μm
  - No conductive strips

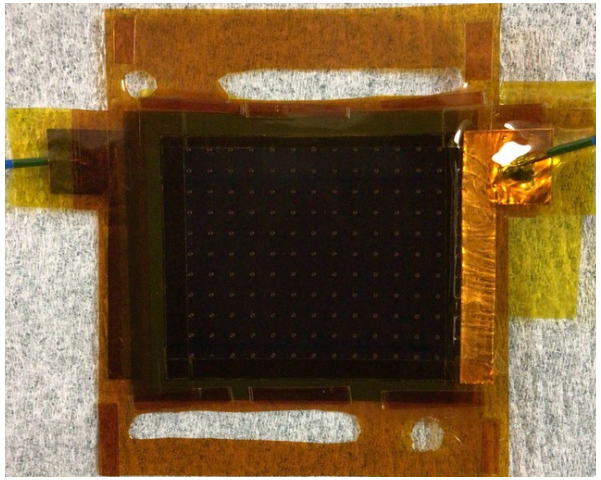
  → Candidate causes of problems on new electrodes are eliminated

- **HV application test**
  - WP for 384 μm gap thickness is about 2700 V
  - Abnormally large current before WP without β-ray
  - Gap thickness is not secured

  → There should be no problem with the electrode itself, as it is the electrode used in the previous study

  → Return to the test bench to test the prior electrodes

Prior electrode



Investigation of causes of discharge

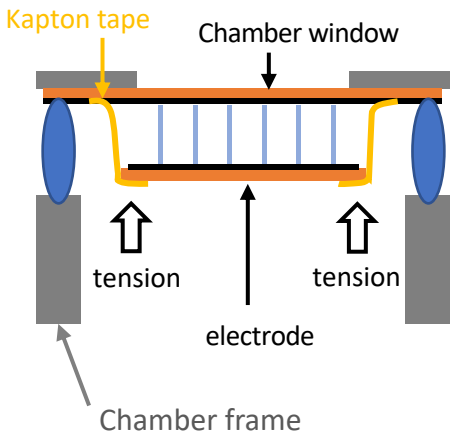
- **Mounting prior electrodes on test bench**
  - Fixing the edges of electrodes by Kapton tape

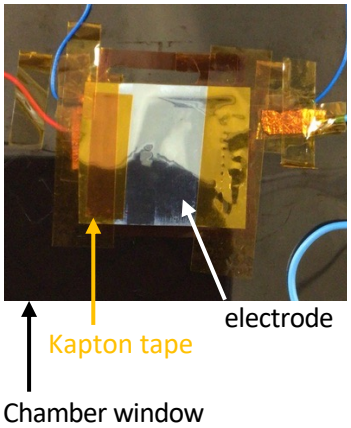
  → the result of HV application test was same as the First Prototype

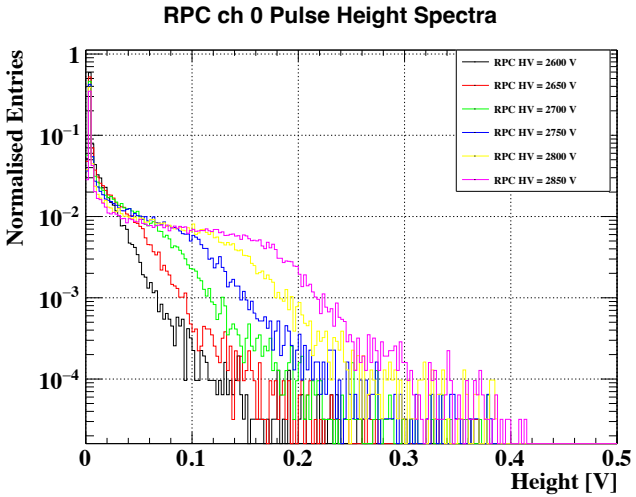
  - More Kapton tape to hold electrode at center
    - 51% detection efficiency at 2800 V, thr = 10 mV

  → the point is making the gap thickness uniform by spacer, just fixing the edges is inappropriate

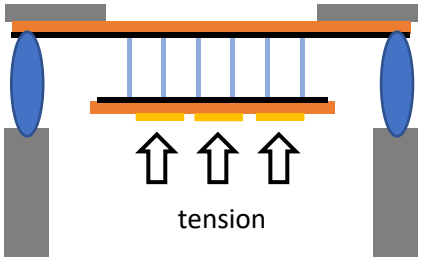
Fixed only at edges

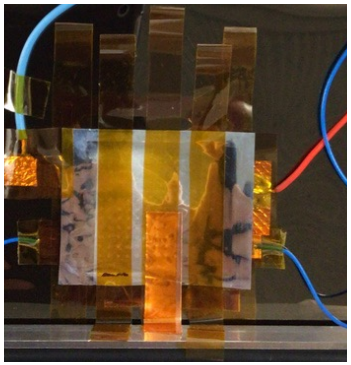






More tapes at center



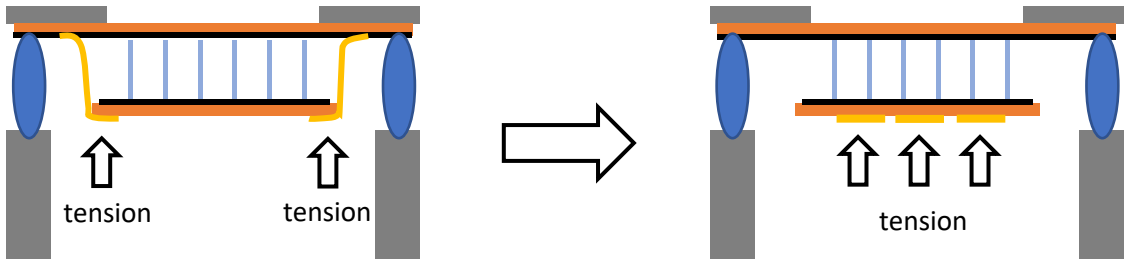


What we know now?

- **For the stable operation of DLC-RPC, following is needed**
  - Uniform electric field formed by uniform gap thickness
    - Electrodes are mainly made of 50 μm polyimide foil, so it is sensitive to any tiny force
    - The thickness of spacers must be the same as possible (less variation)

    → The spacers on new electrodes are inappropriate
    - Hold the active region to the thickness specified by the spacer

    → current method in First Prototype is inappropriate
  - Sufficient insulation cover width to quench large amplification
    - Not sure how much coverage is needed unless the electric field distortion is corrected



Summary and Prospects

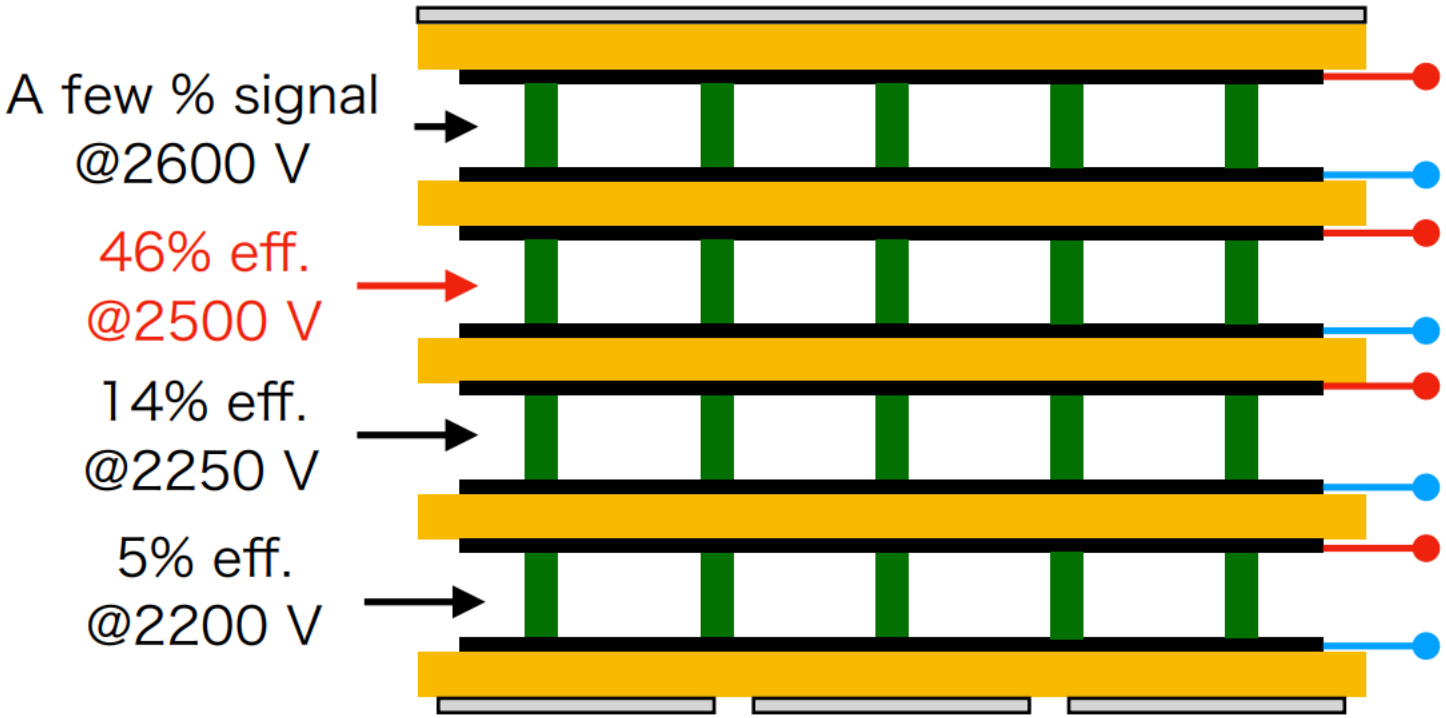
- **Summary**
  - For the further suppression of MEG II experiment background events, development of DLC-RPC as US-RDC is underway
  - First Prototype of DLC-RPC is constructed
  - The performance and problems of First Prototype is clearified through β-ray irradiation test
  - It is now understood that current spacer and electrode fixing methode made it difficult to form a uniform electric field

- **Prospects**
  - Devise a design to form a uniform electric field in a prototype detector
  - Investigation of insulation cover width required for stable operation
  - Production of ~ 360 μm height spacer with a new material
  - Install DLC-RPC in MEG II experiment as US-RDC by 2024 Physics Run

Thank you!!

Back up

Non-uniformity among different layers



Different gap thickness among different layers

Backup