MEG II実験における バックグラウンド抑制のための 超低物質量高速RPCの開発

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  - ✓ Background detectors for MEG II background
  - ✓ RPC with DLC sputtering technique
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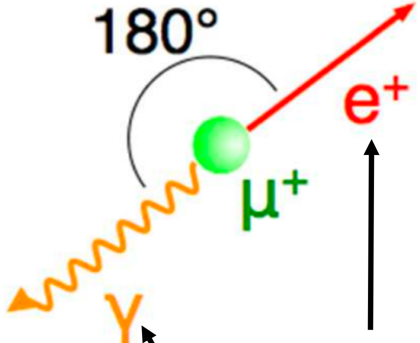
- R&D for RPC
- Summary and prospects

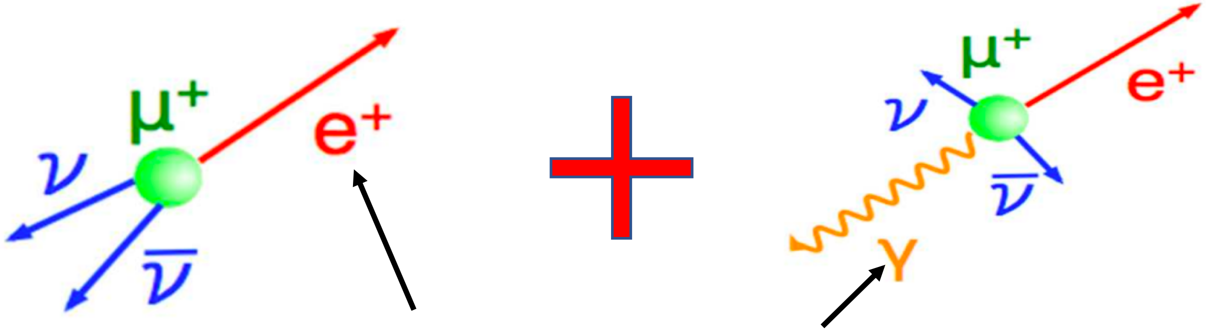
MEG II signal and background



both ~53MeV

- In the $\mu \rightarrow e\gamma$ event (MEG II signal), γ and positron are emitted in the opposite direction w/ ~53MeV

- One of the source of BG γ is $\mu \rightarrow e\gamma\nu\overline{\nu}$
  → When γ coincide with positron from $\mu \rightarrow e\nu\overline{\nu}$ (Michel), this event becomes accidental background

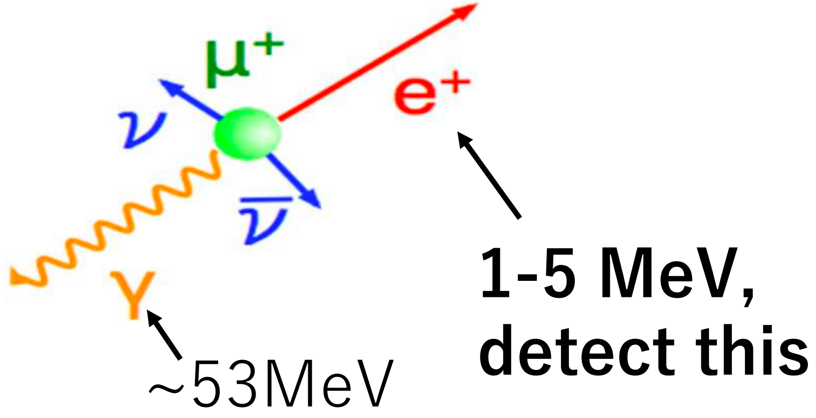


→ Accidental BG

both ~53MeV, accidentally
in the opposite direction
at the same time

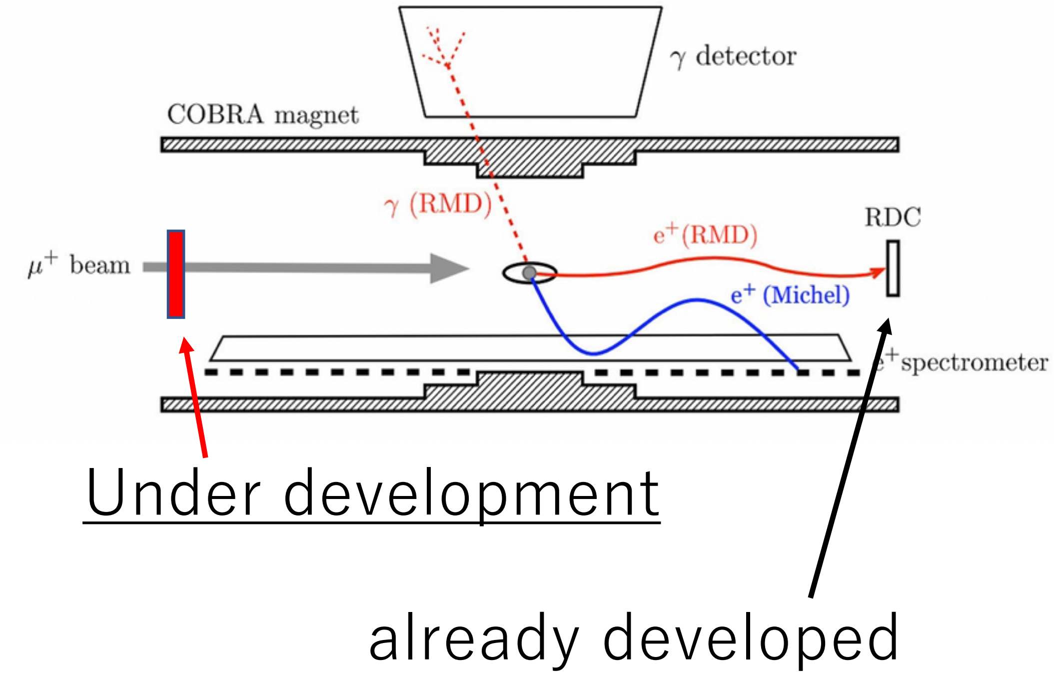
Background detector

- Strategy for BG identification
  - ✓ Detect low energy positron (1-5MeV) accompanying BG γ (~53MeV)



<u>Requirements for new BG detector</u>

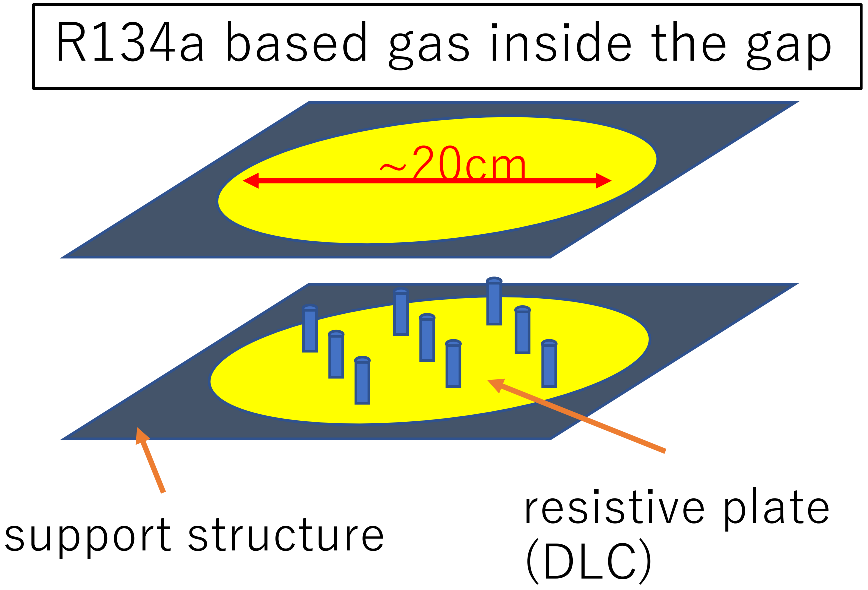
1. Detection of 1-5MeV positron (~MIP)
2. Timing resolution : ~1ns
3. Rate capability to cope with $4\text{MHz}/cm^2$ ~21MeV/c muon beam
4. material budget: $< 0.1\%$ of X_0
   → so as not to degrade muon beam
5. radiation hardness



➡ Candidate: Resistive Plate Chamber (RPC)

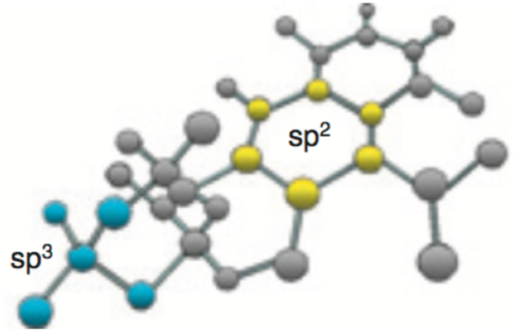
RPC with DLC sputtering for MEG II

- Resistive Plate Chamber (RPC)
  - ✓ Two resistive (to suppress self-discharge) electrodes are put face to face
  - ✓ R134a based gas with iso-butane & SF_6 quencher



- Following structure is considered
  - ✓ Possibility of segmentation
  - ✓ DLC (Diamond Like Carbon) sputtering technique is used to form the resistive electrodes (Instead of glass)

- Diamond Like Carbon
  - ✓ High resistivity with mixed structure of sp^2 bond and sp^3 bond of carbon
  - ✓ Low material budget (DLC thickness: ~0.1 μm)

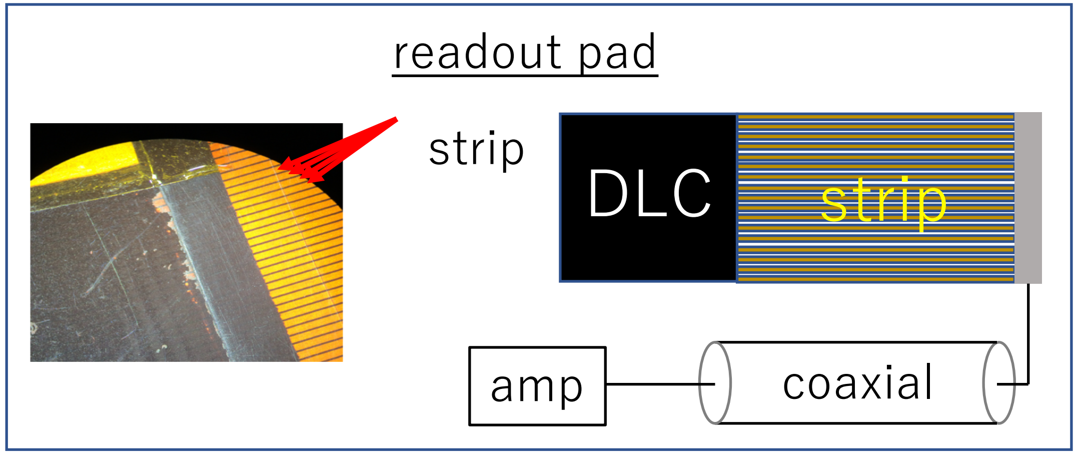


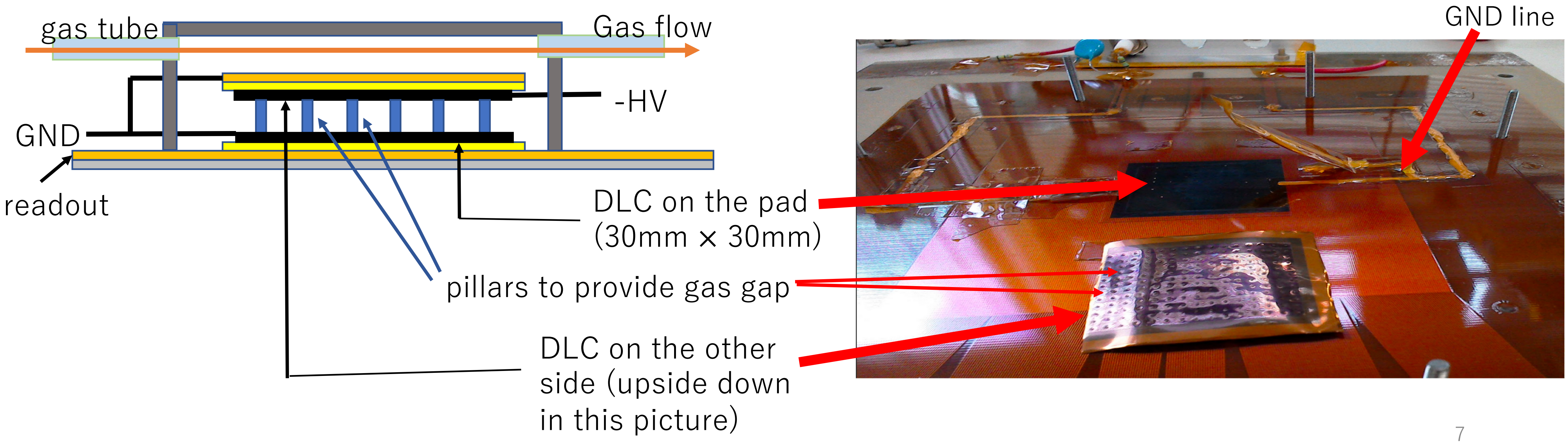
Contents

- Introduction
- R&D for DLC-RPC
  - ✓ Structure
  - ✓ Previous study & upgrade
  - ✓ Result of rate capability measurement & problem of amp speed
  - ✓ Fast amp trial & its other problem
- Summary and prospects

Structure

- **It is not a final design**
  - ✓ Not optimal readout system
  - ✓ Used to check operation and rate capability
  - ✓ R134a based gas was used if no remark is made





Previous study & upgrade

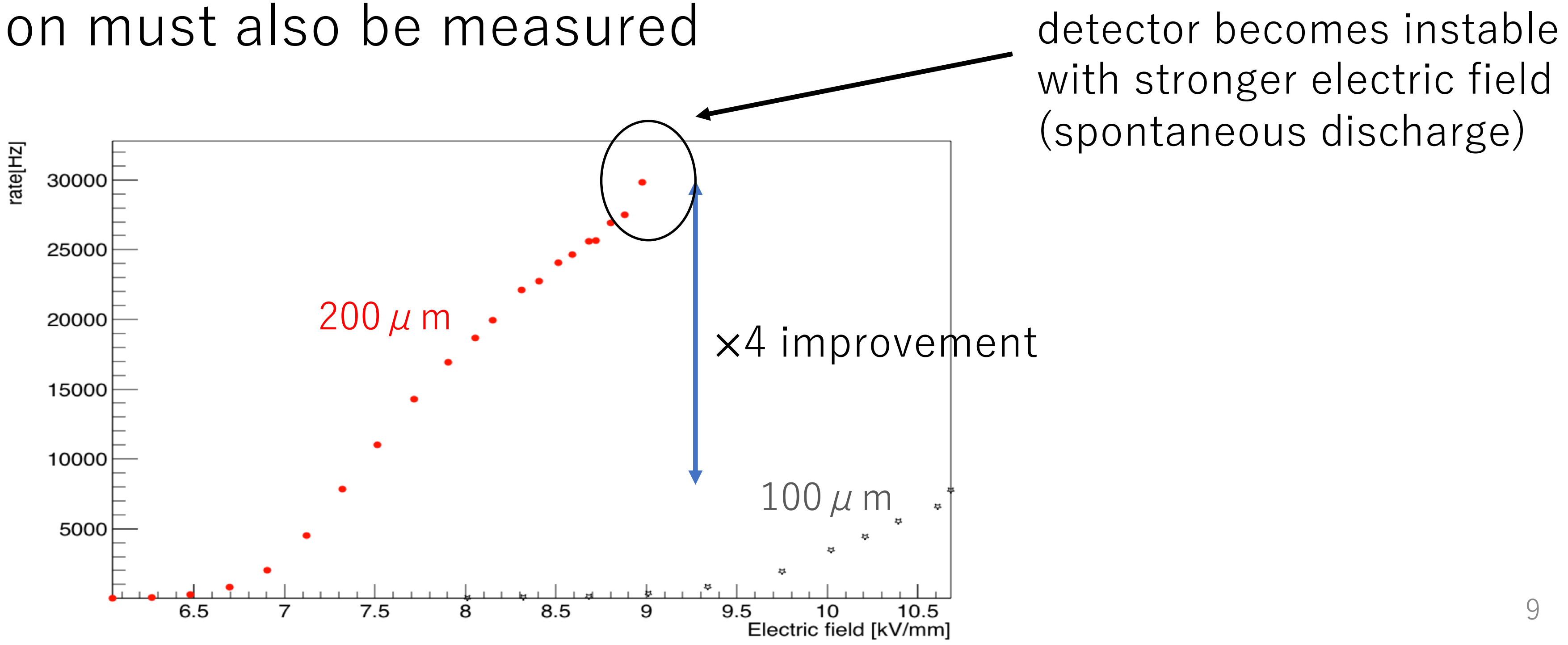
- DLC-RPC was developed by a group of Kobe University
  - ✓ They successfully operated DLC-RPC (2017) with 100 μm gap
  - ✓ Efficiency is not high enough for 100 μm gap: 10 % for 1 layer – 30% for 3 layer
    → In general, thicker gap is used to achieve high efficiency with small number of gap (with thick gap, timing resolution is bad)

- Performance test is required in more detail
  - ✓ Rate capability (started)
  - ✓ Efficiency (only rough comparison)
  - ✓ Timing resolution

- Design upgrade is also required
  - ✓ development of readout system and gas supply
  - ✓ try thicker gap (started, 200 μm is now used)
  - ✓ study on amplifier (started)

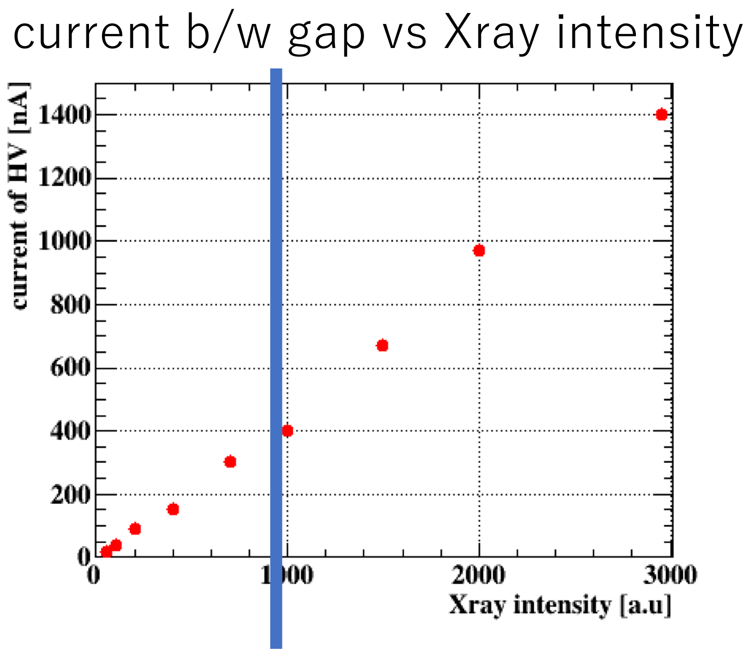
Effect of using thicker gap RPC

- Check the relative difference in achievable efficiency b/w 100 μm & 200 μm setup (Sr90 irradiation)
  - ✓ Compare count rate using the same measurement setup except for the gap (Charge amp + shaper)
  - ✓ But absolute efficiency is not measured
  - ✓ Timing resolution must also be measured



Rate capability test w/ 200μm setup

- In Sep2018 rate capability was tested using intense Xray
  - ✓ Using Ar based gas(R134a based gas was not able to be prepared), charge amp



0.6MHz equivalent intensity (sensitive area ~6cm^2)

- No saturation in current b/w gas gap vs X ray intensity

→ no saturation expected at least up to 0.1MHz/cm^2

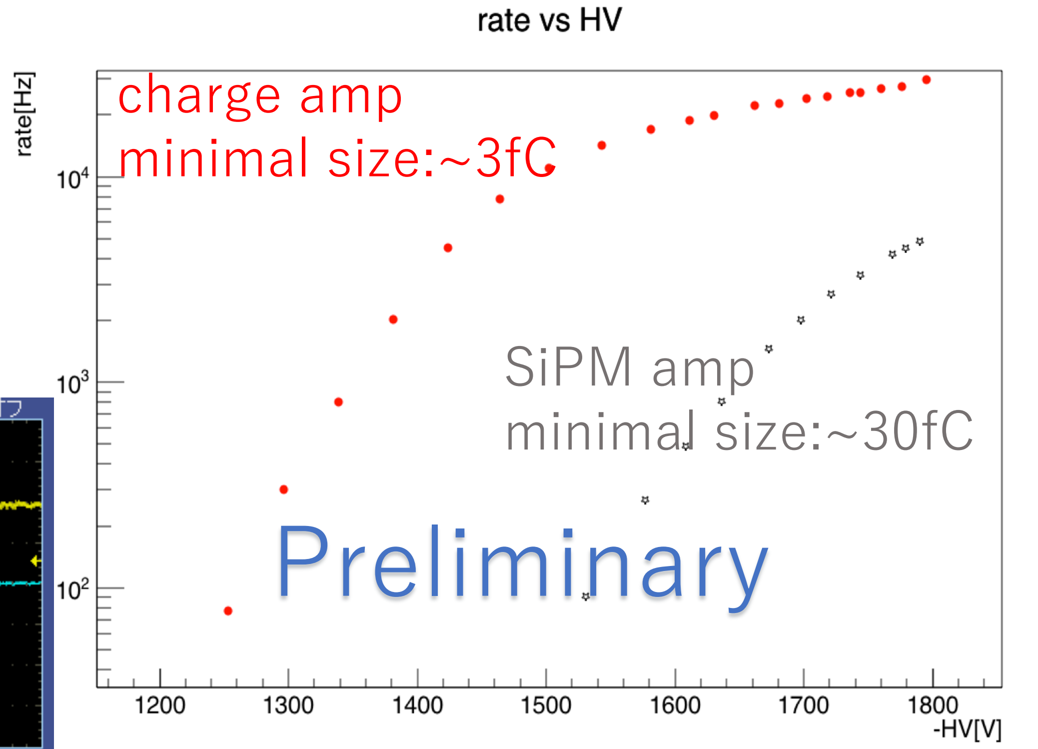
- Count rate was not completely measured because charge amp (ORTEC 142IH) was slow

→ Tried another amplifier (SiPM amp developed in PSI: fast response DC to ~2GHz bandwidth current amp) after this test

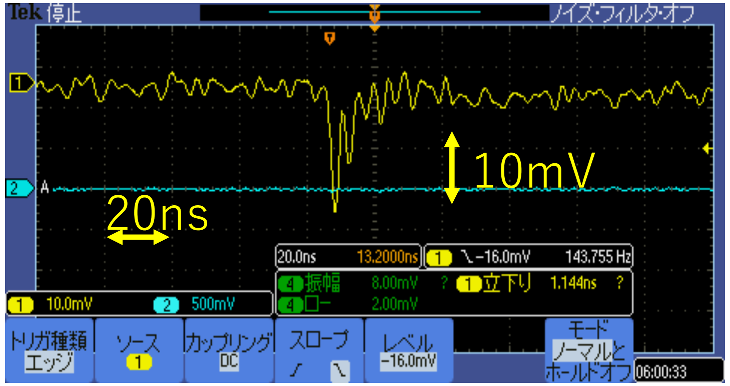
Comparison of amplifier

- Setup: 200μm gap, Sr90,R134a gas
  - ✓ Compared SiPM amp & charge amp with this setup
- SiPM amp is faster, worse S/N
  - → Small signal cannot be seen; It will deteriorate efficiency
- Need further improvement for amp

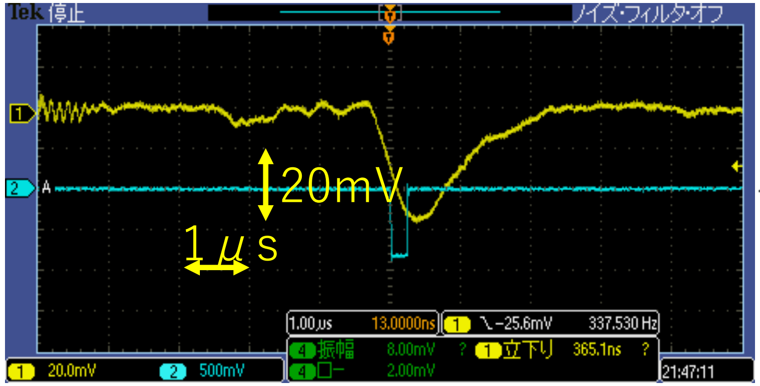
	SiPM amp	charge amp
S/N	bad	good
pulse width (w/ RPC)	~10ns	1μs



SiPM amp



charge amp



Summary and Prospects

- 200 μm gap DLC-RPC is tested
  - ✓ We checked rate capability of at least 0.1MHz/cm^2
  - ✓ Efficiency seems improved from 100 μm setup

- Further development of DLC-RPC for MEG II
  - ✓ Reduce material budget of readout

- More study on amp is required
  - ✓ Good S/N & high speed amplifier is the requirement

- Performance test will be done in 2019
  - ✓ Rate capability, timing resolution, effect on muon beam, efficiency

BACK UP

Summary of previous study in Kobe (2017)

- 100 μm gap DLC-RPC is developed
  - ✓ 1 layer- 3 layer
  - ✓ Make use of readout pad for micromegas
  - ✓ charge amplifier was used

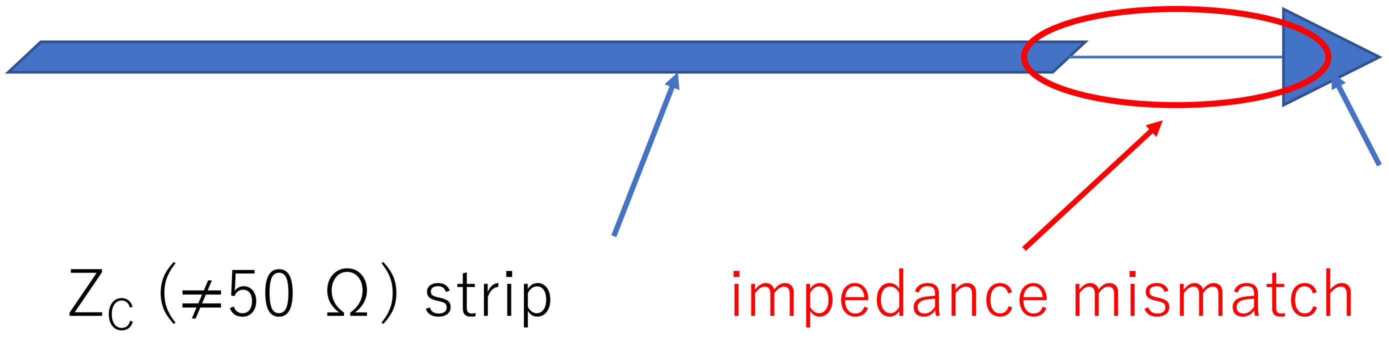
- Their result on efficiency was not high enough
  - ✓ 10 % for 1 layer – 30% for 3 layer
    → need more gap to achieve better efficiency (?)

Detector candidates

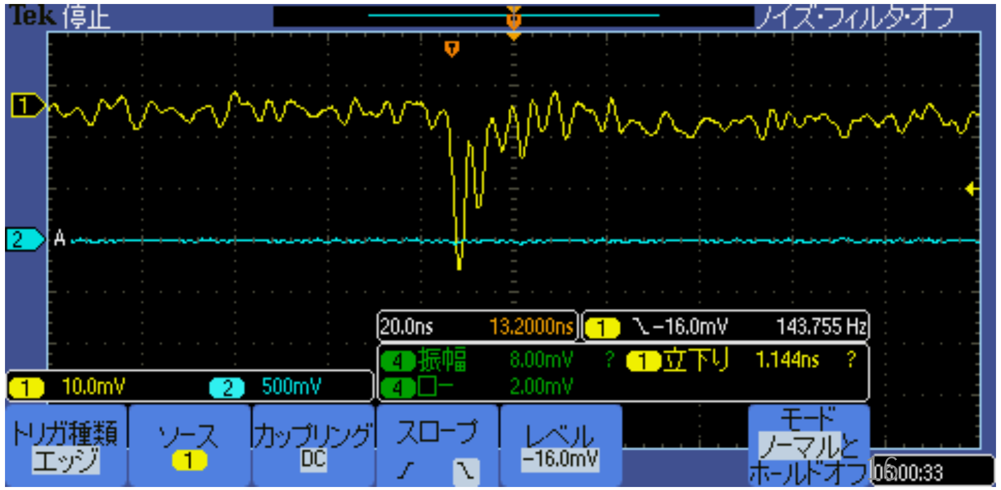
- Scintillator: Plastic scintillator fiber has been studied. Not promising due to limited radiation hardness
- Silicon detector: Under investigation
- Gas detector: We are developing Resistive Plate Chamber applying DLC sputtering technique

Signal shape with PSI amp

- Reflection-like signal shape is observed
  - ✓ Reports from other groups suggest reflection at the end of the strips



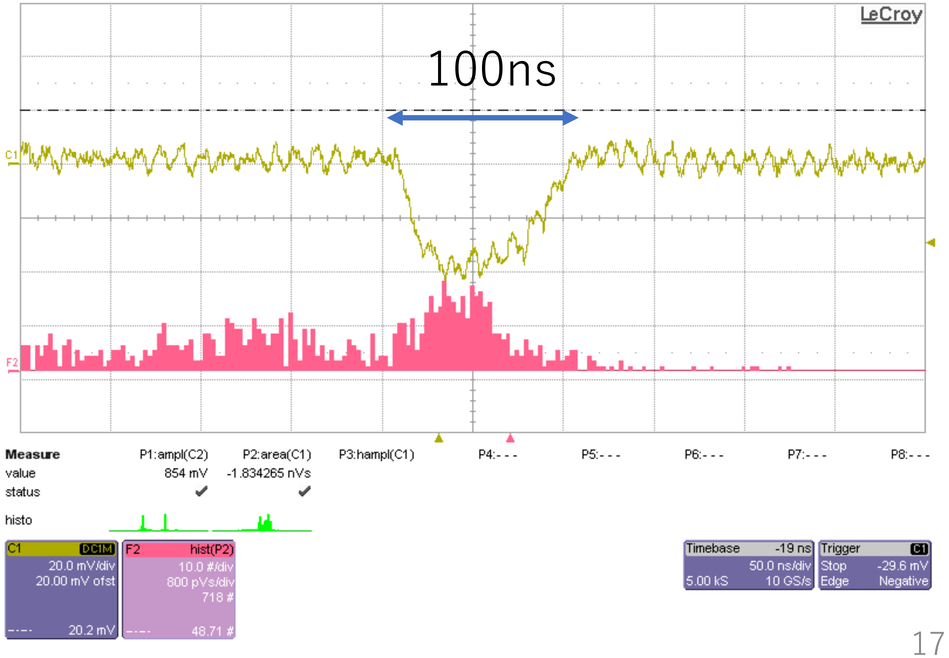
- Study on readout strip is required



Gas type

- 2 types of gas have been tried
  - ✓ Freon (R134a) based gas (standard for RPC, but requires equipment to treat iso-butane quencher): R134a/iso-C4H10/SF6 ~ 94.8/4.7/0.5
  - ✓ Ar based gas (This was used when Freon based gas was not available): Ar/CO_2 ~ 93/7

- Ar based gas is not desirable
  - low count rate
  - slow signal

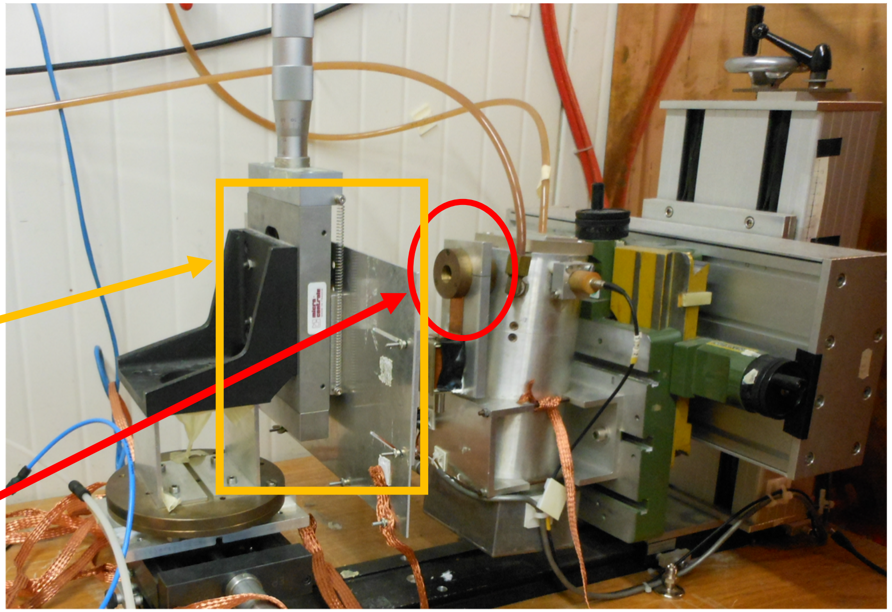


Rate tolerance test

- Rate tolerance test using X-ray generator: @RD51 lab in CERN
  - ✓ 200 μm gap
  - ✓ 10MΩ surface resistivity plate
  - ✓ 93% Ar, 7% CO_2 gas mixure
    (standard RPC gas could not be used :
    it is flammable)

RPC was put here

Xray come out from here



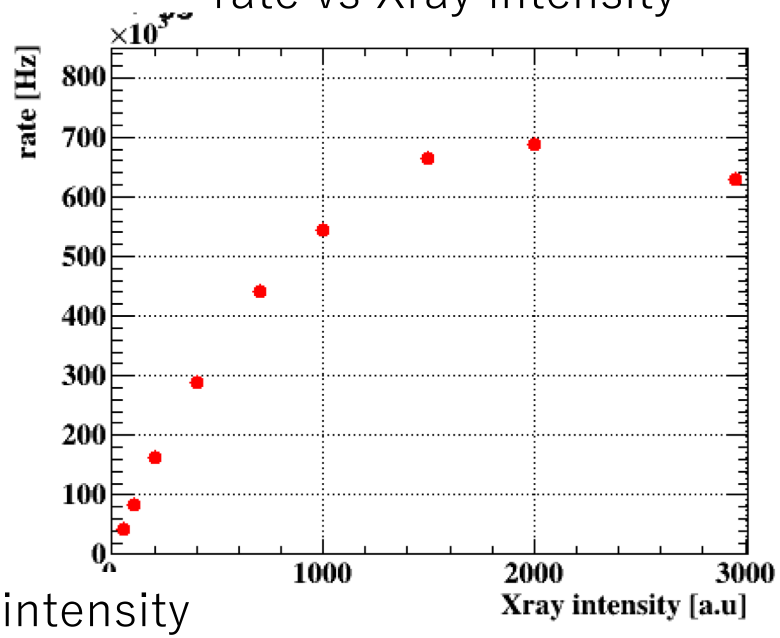
- Signal rate was measured changing the intensity of Xray
  - ✓ charge Amp + pulse shaper (ORTEC 142IH + ORTEC474)
  - ✓ counting was done w/ discriminator + scalar

Rate capability: result (detail)

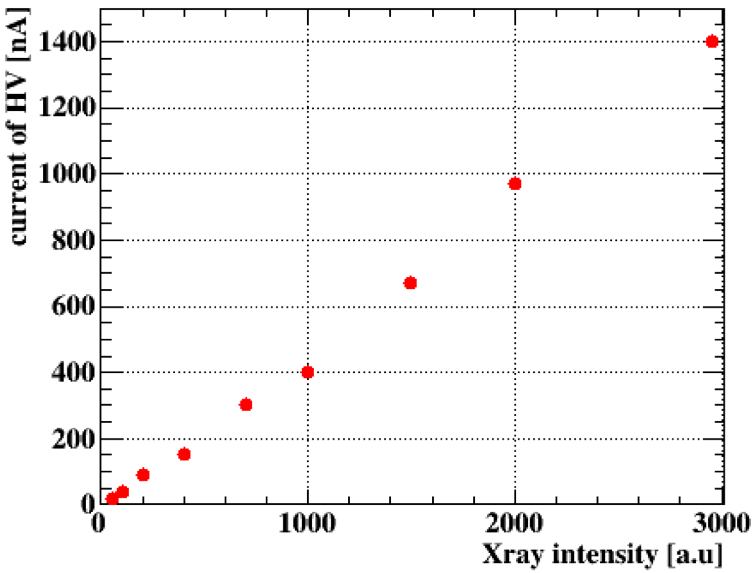
- saturation of rate was observed @ 700kHz
  → Not the limitation of FRPC itself
  (discussed next page)

- no saturation in Xray current b/w gas gap vs intensity graph
  → no saturation expected at least up to $0.1\mathrm{MHz}/cm^2$

rate vs Xray intensity



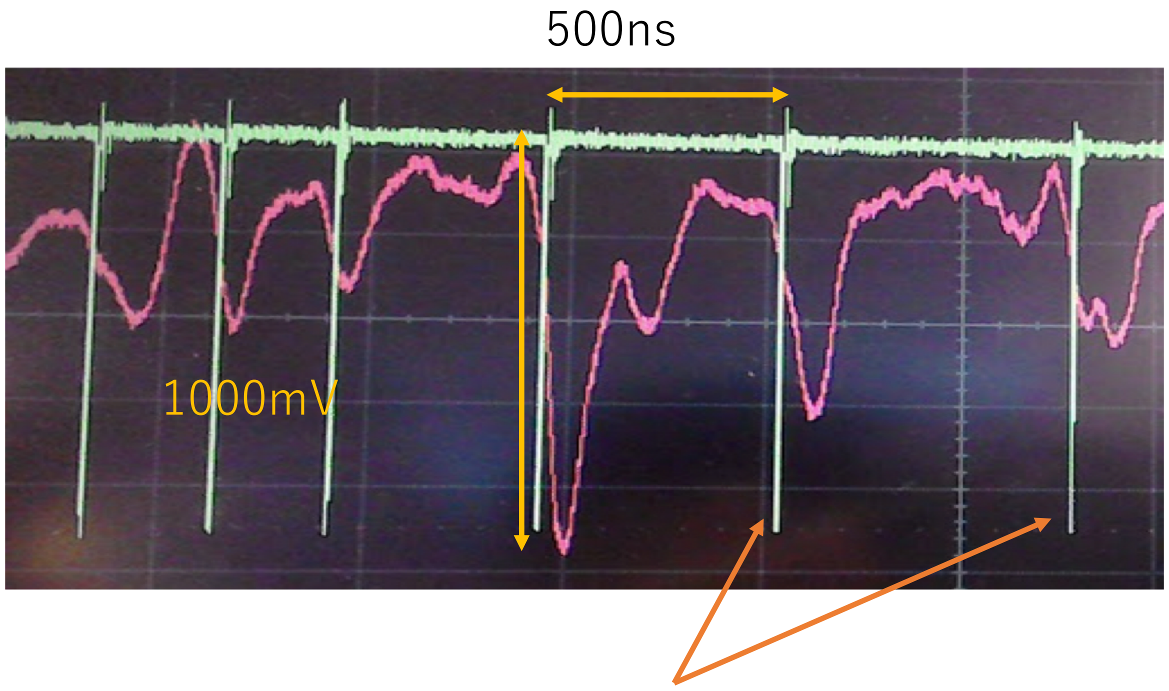
current b/w gap vs Xray intensity



HV: 1092V
air pressure: 968±2 hPa

Rate capability test: slow signal

- The saturation of measured rate was caused by pile up of pulses
  → pulse width: 300ns ⟷ signal rate @ saturation: 700kHz
  ↳ readout electronics was slow



RPC structure

- Electric field is applied between two resistive electrodes
  - ✓ When ionization takes place, both electron and ion drift towards the electrodes
  - ✓ Accelerated electrons cause secondary ionization
    → gas multiplication take place