MEG II 実験の背景事象の抑制に向けた超低物質量RPCの開発と性能評価

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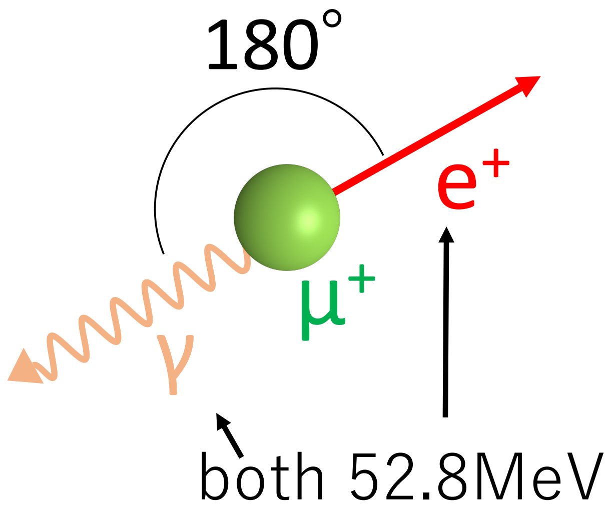
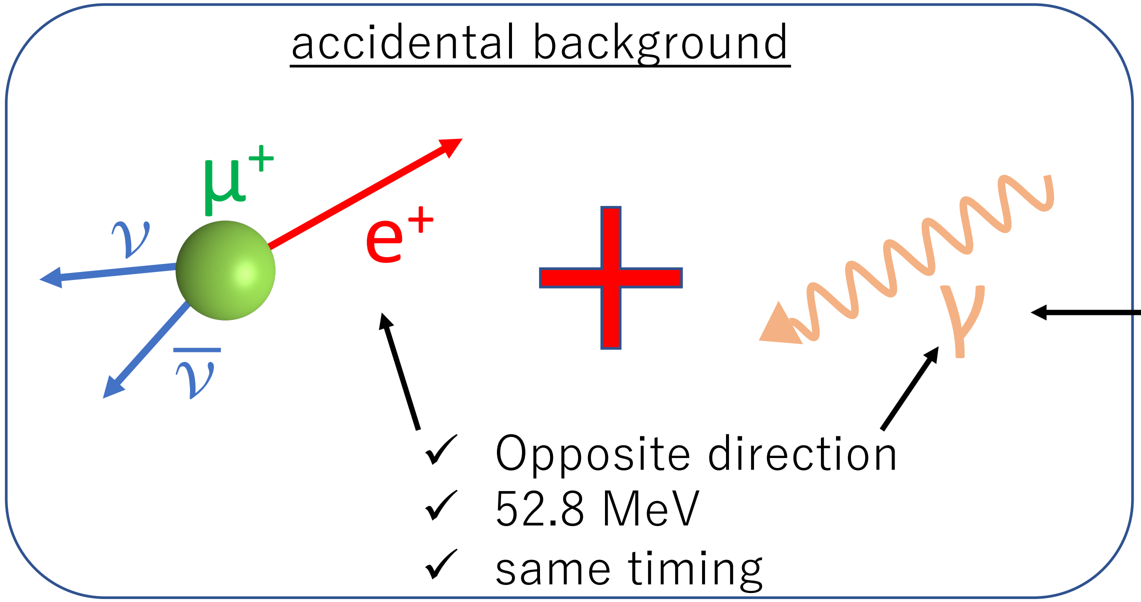
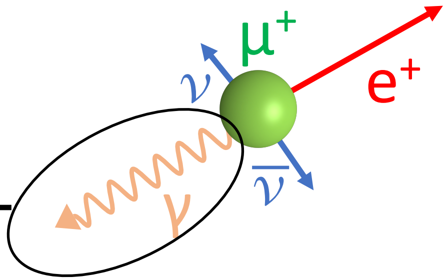
  - ✓ Background identification detectors for MEG II background
  - ✓ RPC with DLC sputtering technique
  - ✓ Required studies for MEG II
- R&D for RPC
- Summary and prospects

MEG II signal and background



- MEG II will search for $\mu \rightarrow e\gamma$ rare decay
  - ✓ Identified by energy, timing and direction of e and γ
- Dominant source of background is accidental coincidence of BG-e and BG-γ mimicking the signal
  - ✓ One of the dominant source of BG-γ is radiative muon decay

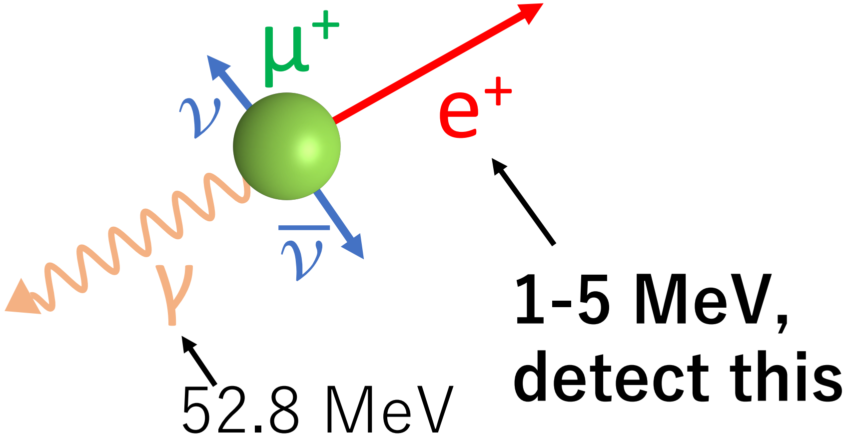




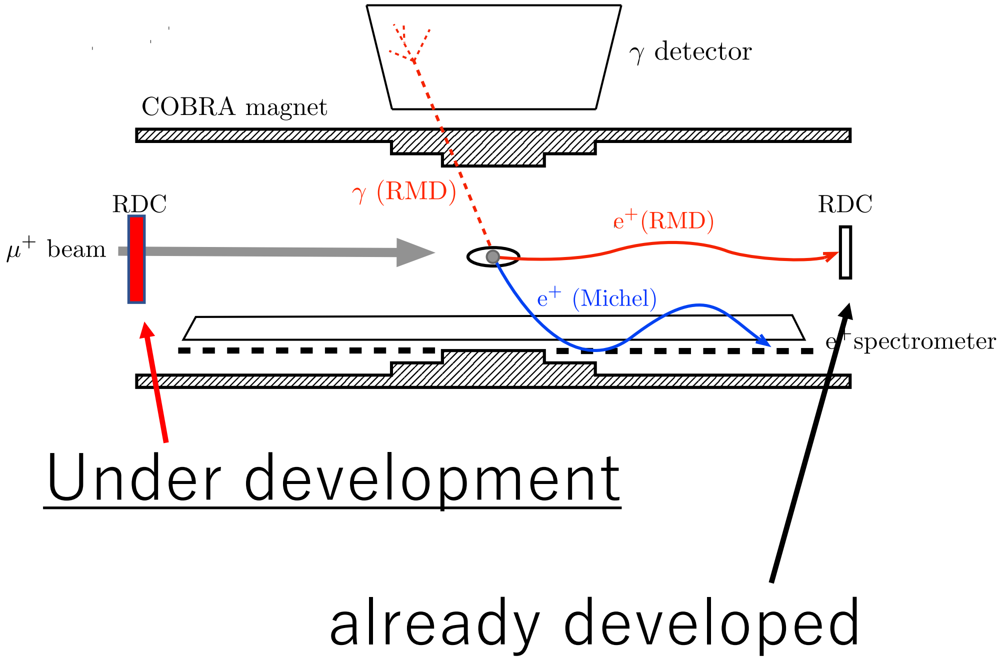
radiative muon decay is one of the source of γ

Background identification detector

- New detectors to identify BG-γ from radiative muon decay will be installed for further sensitivity improvement
  - ✓ Detect low energy positron (1-5MeV) accompanying BG γ (~53MeV)



- Planned to be installed to 2 sites
  - ✓ Upstream and downstream of the target
  - ✓ Upstream one is under development → Today's talk



Upstream BG identification detector

- Difficulty of upstream detector is the μ beam(100MHz) passing through the detector

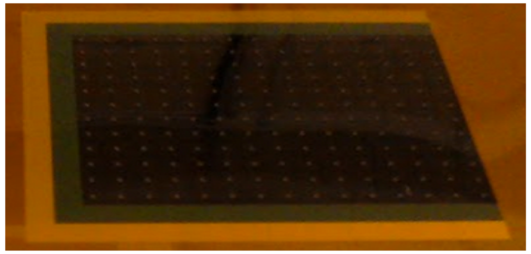
<u>Requirements for upstream detector</u>

1. Detection of 1-5MeV positron
2. Timing resolution : ~1ns
3. Rate capability and radiation hardness (100MHz of ~21MeV/c muon, 60week run)
4. material budget: $< 0.1\%$ of X_0
5. detector size of 20 cm diameter

- Candidate: RPC using electrodes based on Diamond Like Carbon (DLC)

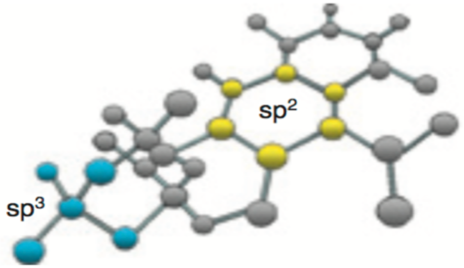
RPC based on DLC

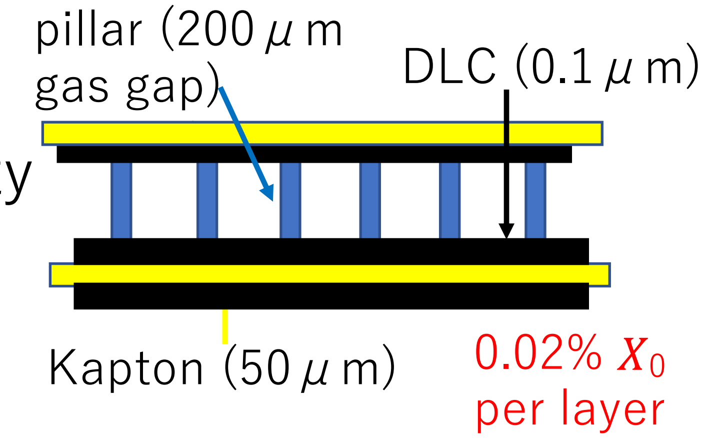
- RPC: gaseous detector with resistive electrodes parallelly placed
  - ✓ R134a based gas with iso-butane & SF6 quencher
  - ✓ Gas gap is typically several hundred μm



resistive plate
made of DLC film

- We use electrodes fabricated by sputtering DLC on 50μm Kapton films
  - ✓ DLC: high-resistive material made of carbon (mixed structure of sp^2 bond and sp^3 bond)
  - ✓ Advantage of DLC: low material & adjustable resistivity
  - ✓ Technology developed by Kobe University





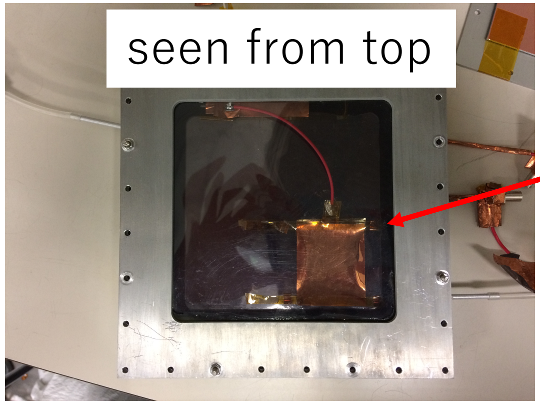
Required studies

- Design parameters to be optimized
  - ✓ Gap thickness
    → determines timing resolution and detection efficiency
  - ✓ Resistivity of electrode surface
    → determines rate capability of the detector
  - ✓ Readout structure
    → affects pileup probability, timing resolution

Contents

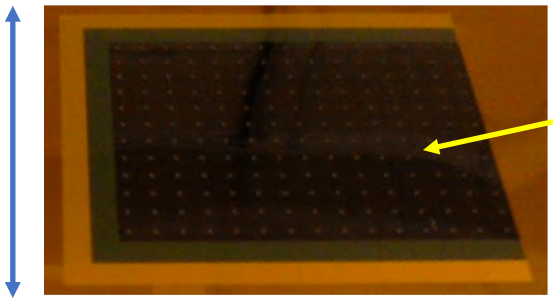
Prototype design

- Performance study is conducted using 4cm×5cm size plate
  - ✓ DLC films are put face to face with a gap of 200 μm
  - ✓ Single layer



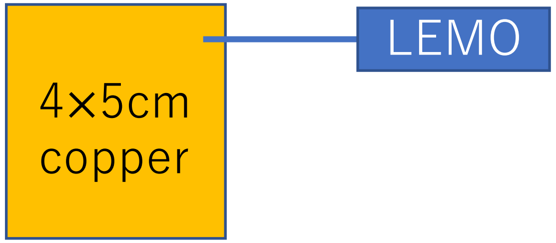
5cm

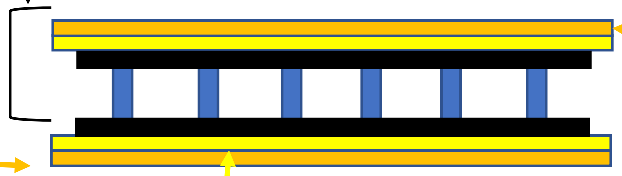
4cm



- DLC sputtered on the front side
- 200 μm pillars are attached on the DLC film

4cm × 5cm copper is attached for readout on the reverse side

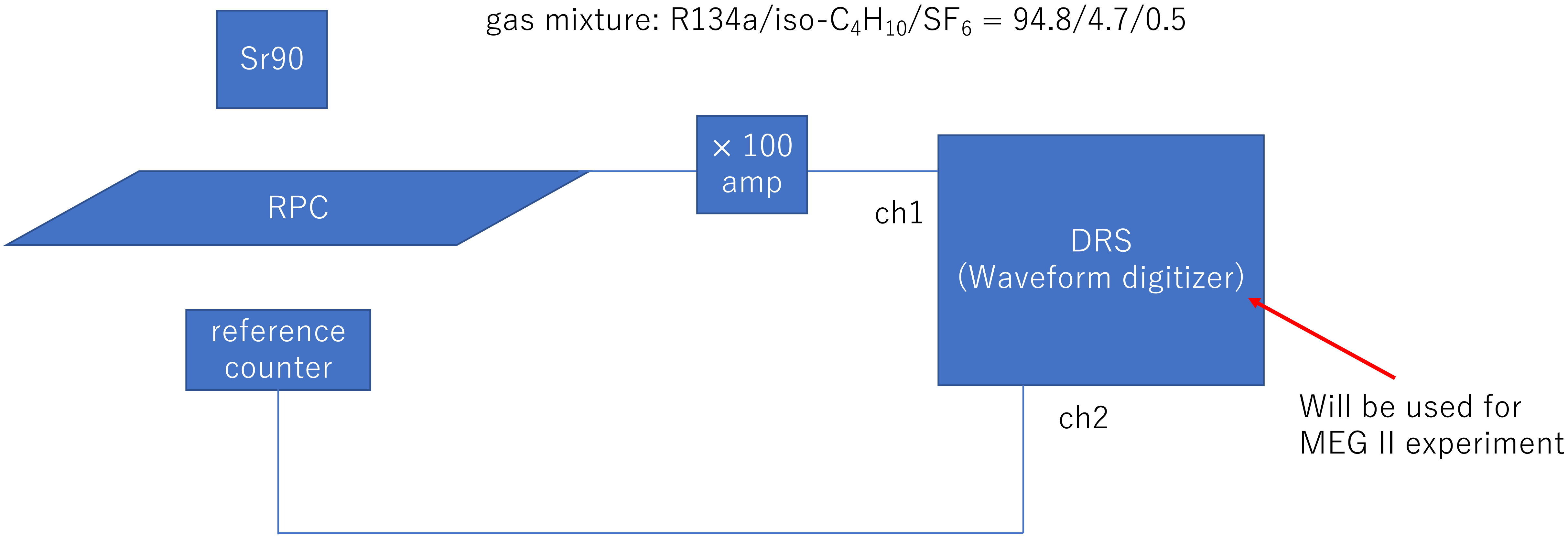




readout

Kapton (50 μm)

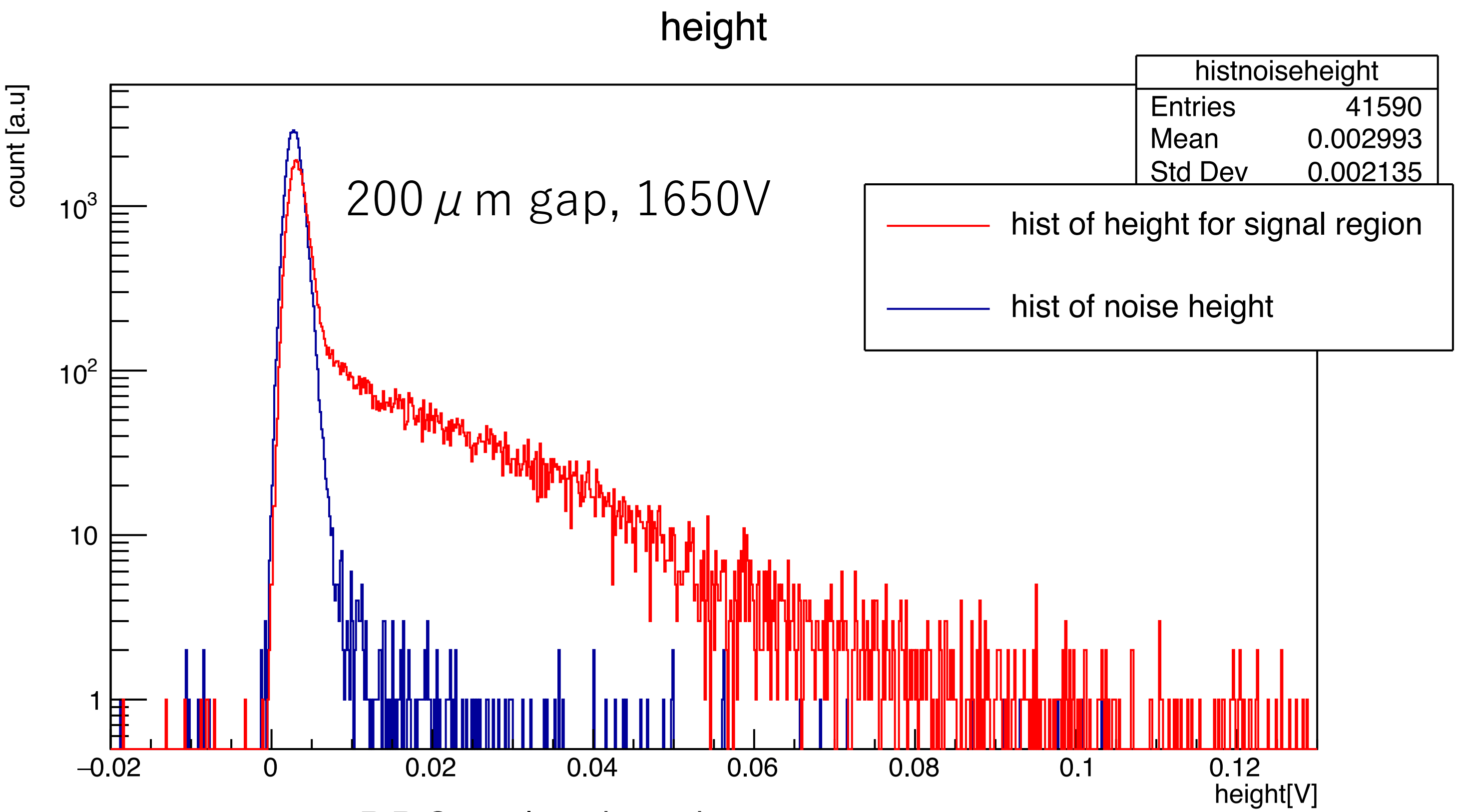
Setup for performance measurement



Detection efficiency and timing resolution are measured in this setup

Performance: efficiency

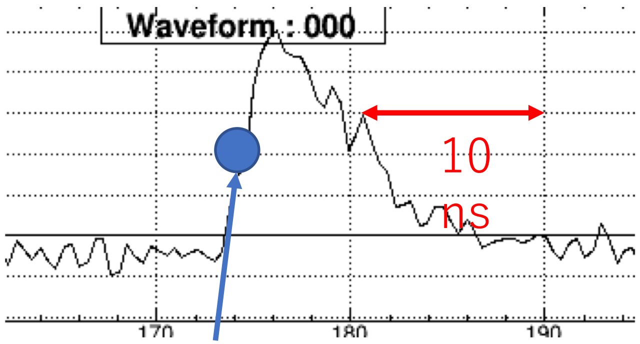
- Efficiency : 23 %
  ✓ 9mV pulse height threshold is set considering the noise level



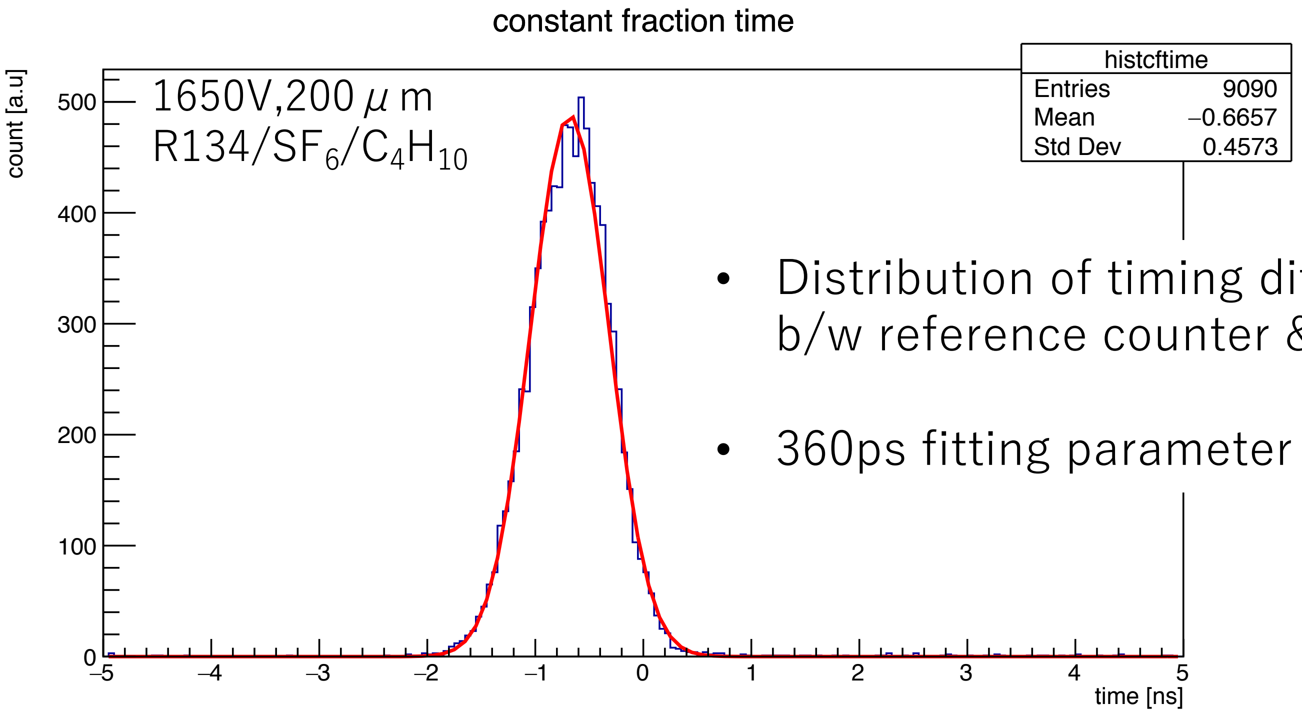
RPC pulse height spectra

Performance: timing resolution

- Timing resolution: 360 ps

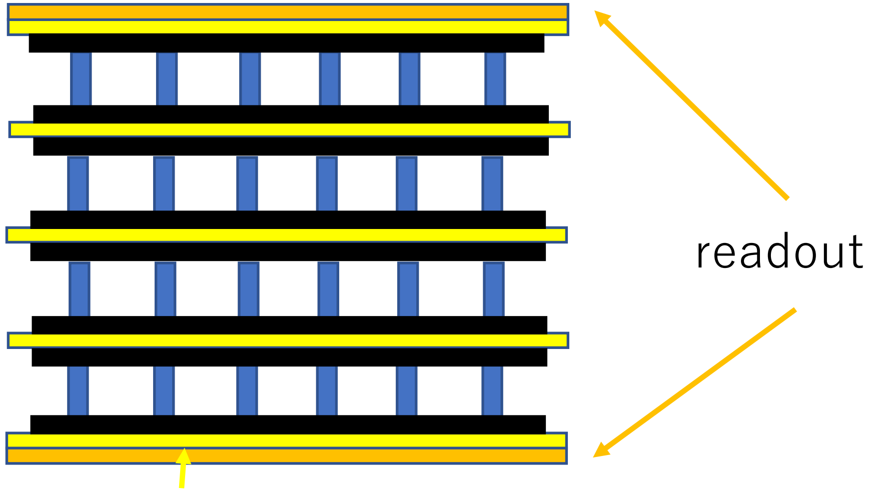


RPC timing is measured at 50% constant fraction



- Distribution of timing difference b/w reference counter & RPC
- 360ps fitting parameter

Required improvements

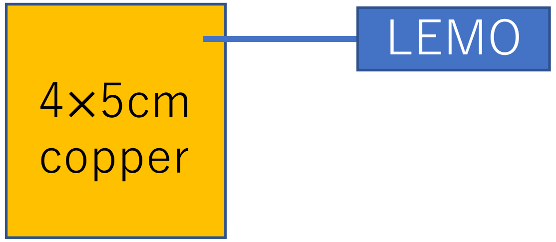


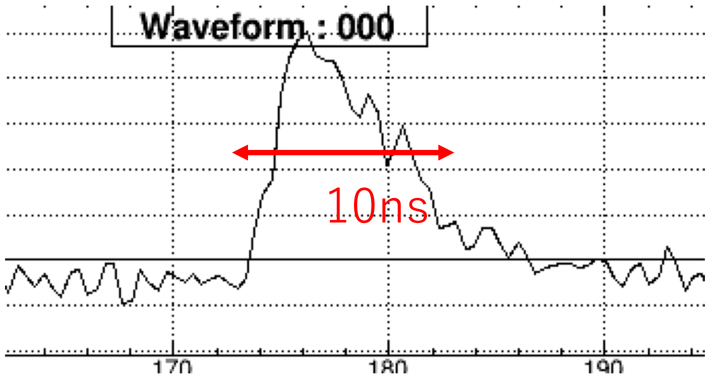
- The readout should be made of Aluminium because copper has large material itself
  (Commercial aluminized Kapton has thin Al layer with non-negligible resistivity, which may cause problem)
- Multilayer RPC is favored to achieve higher efficiency, but the number of layers is 4 at maximum (limited by material budget)
  - ✓ 40 % single layer efficiency is desired (Total 90% efficiency in reach)
- To achieve high rate capability, the readout must be segmented
  - ✓ Strip shape readout is considered

Readout test: signal waveform

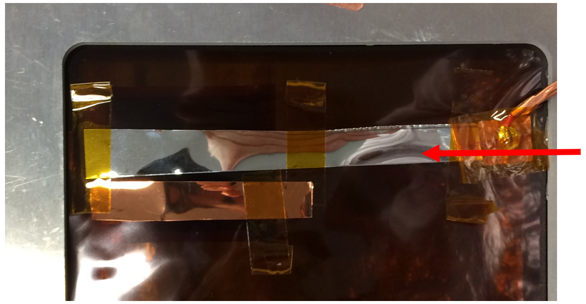
- Strip shaped Al readout is tested

①

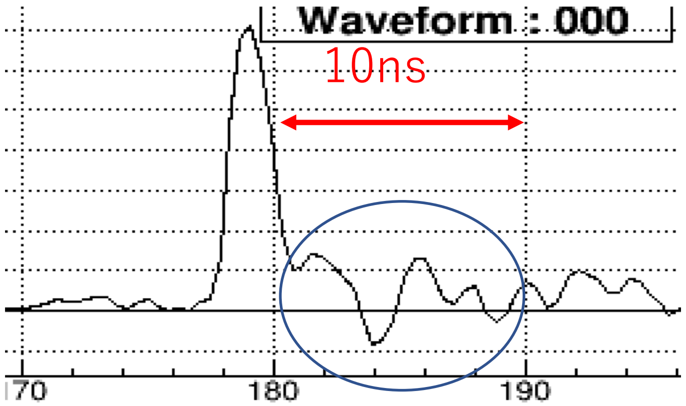




②



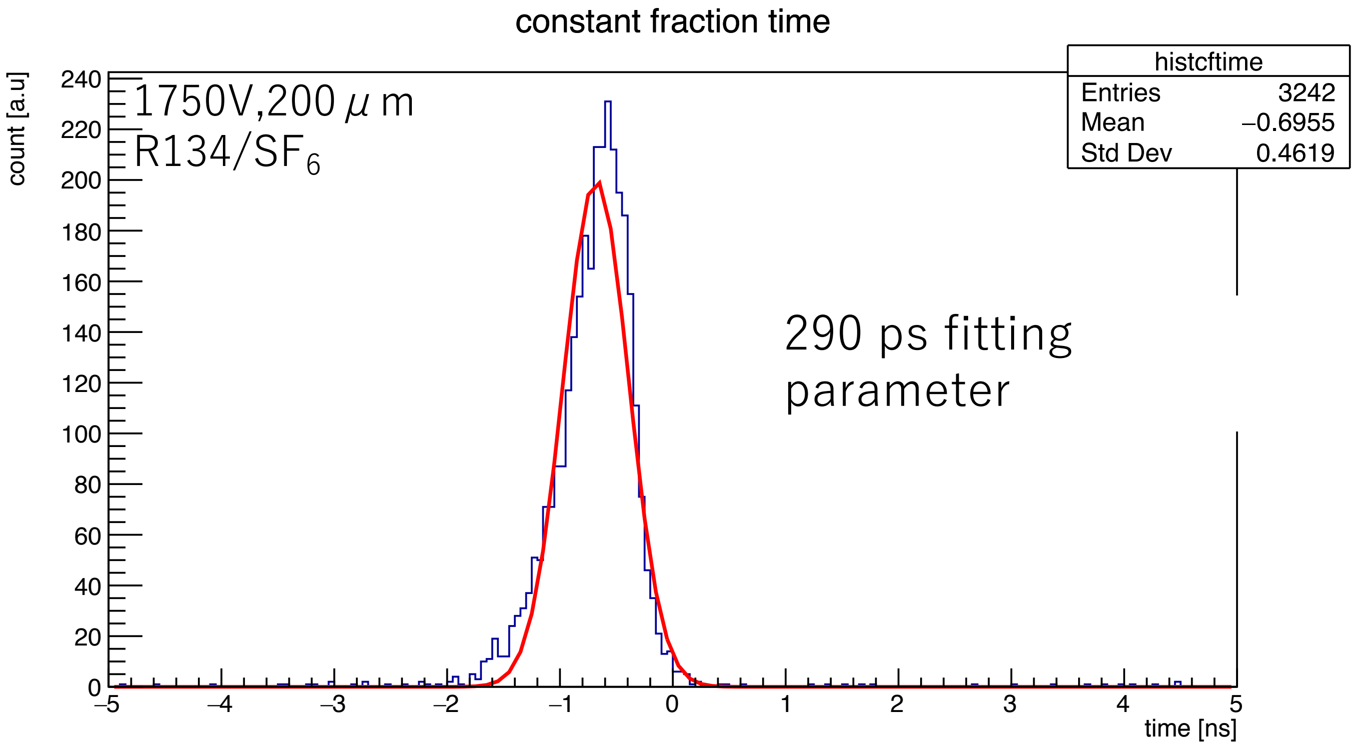
1×10cm
Aluminium
(100nm thickness)



- No problem in the signal waveform

Readout test: timing resolution

- Timing resolution: 290 ps
  - ✓ Asymmetry of the distribution is not understood



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- R&D for RPC based on DLC electrodes
- Summary and prospects

Summary

- 23% efficiency is achieved with single layer 200 μm gap RPC
  → It has not reached the goal of 40% for single layer setup

- Timing resolution is 300-400ps for 200 μm
  - ✓ Better than the requirement
    (dependence on readout scheme is also found)
  - ✓ It may be worsened when wider gap is used

- It has been demonstrated that Aluminium readout works
  → 0.1% X_0 requirement can be achieved (not completed)

Prospects

- Performance with larger gas gap (400-500um) to be measured

Pros	Cons
• better efficiency	• higher operating voltage • worse timing resolution

currently 360ps → acceptable to some extent

- Further studies on readout configuration is required
  - ✓ To pickup the narrow signal shape and suppress reflection of signal
→ important to suppress pileup b/w positron and beam μ
  - ✓ To understand the dependence of timing measurement on the readout

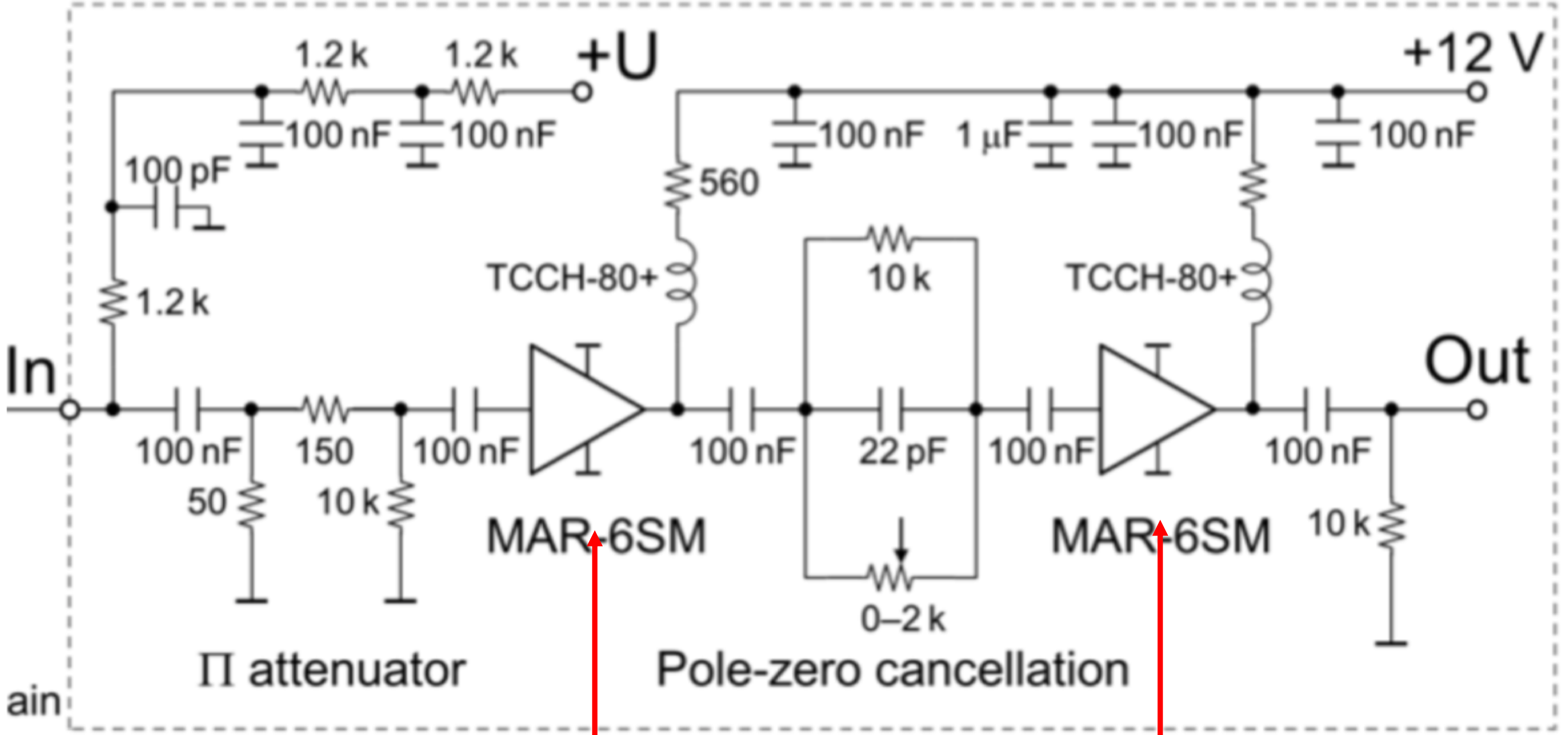
- Rate capability measurement

BACK UP

amplifier

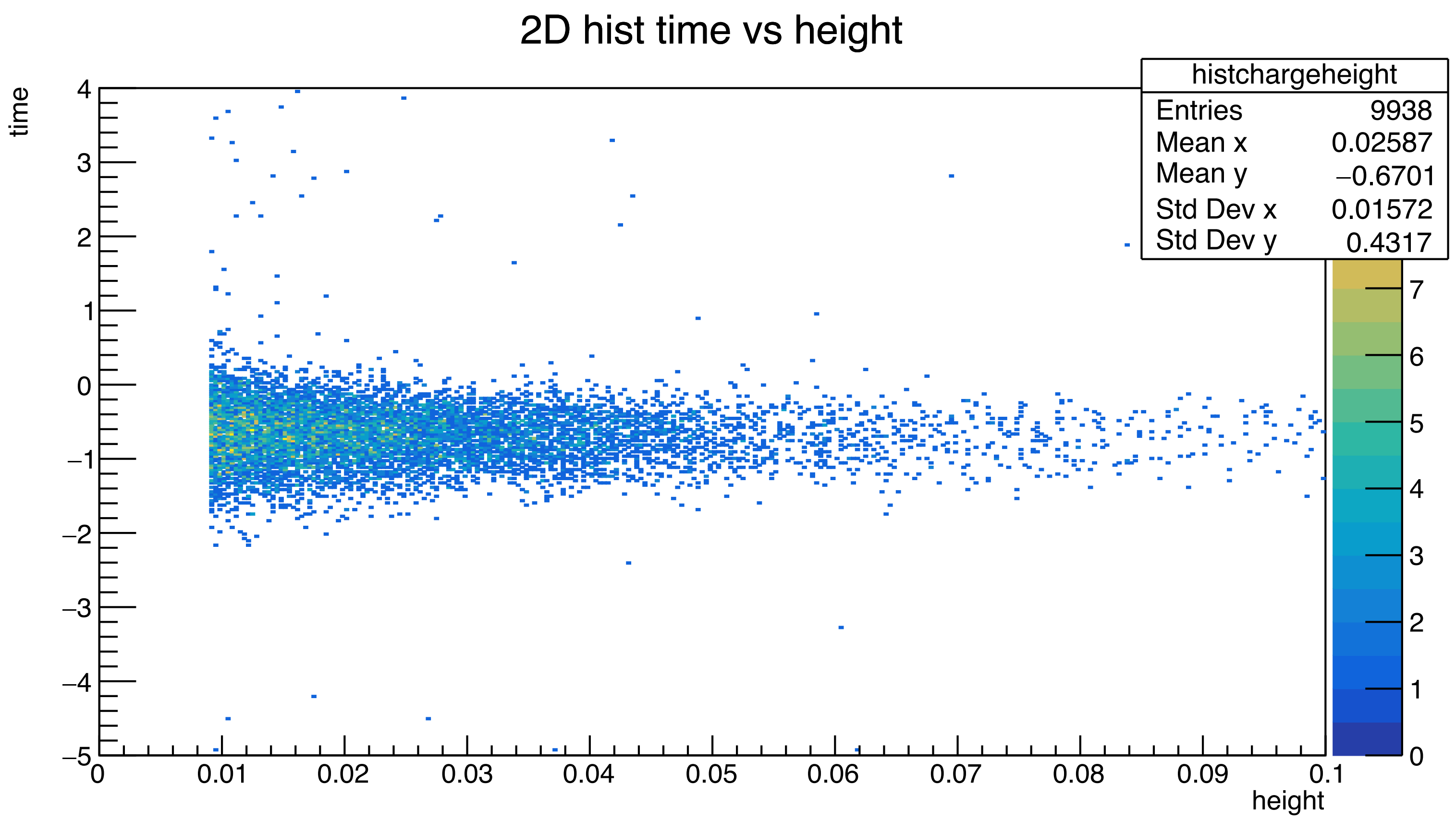
- The circuit diagram of the amplifier used to read signal from the RPC

→ Developed to read signal from SiPMs with high amplification gain and fast resposce

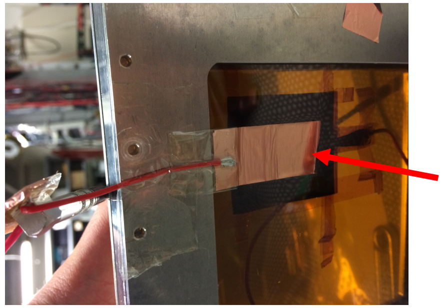


2GHz bandwidth, 20dB RF amplifier

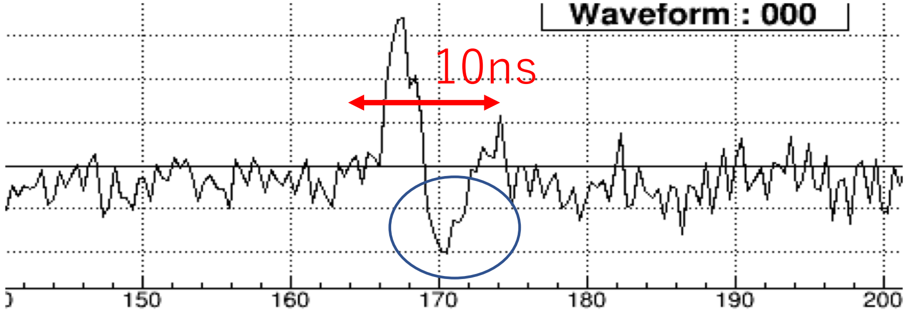
Pulse height and timing relation



Signal shape

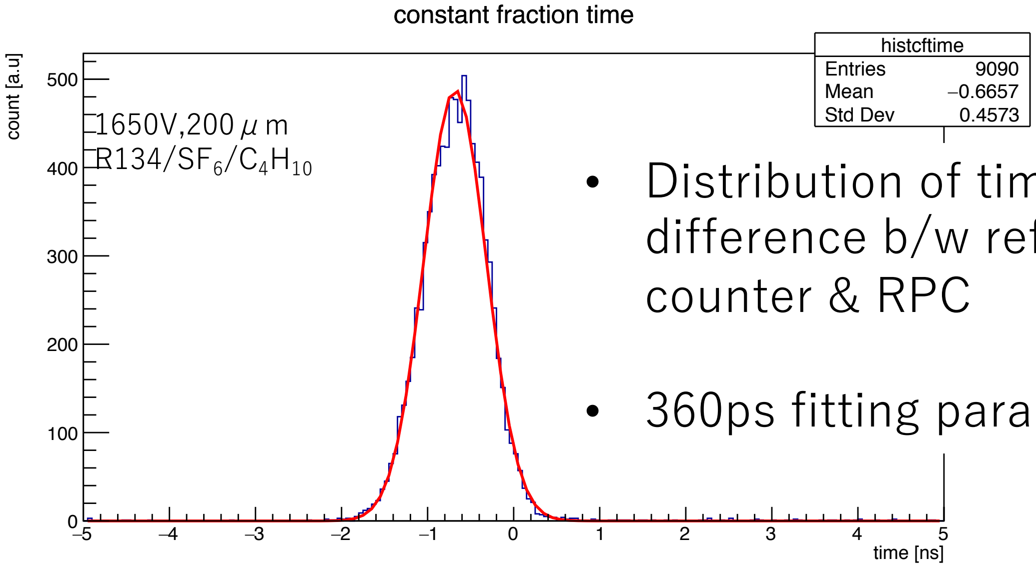


2×4cm
copper



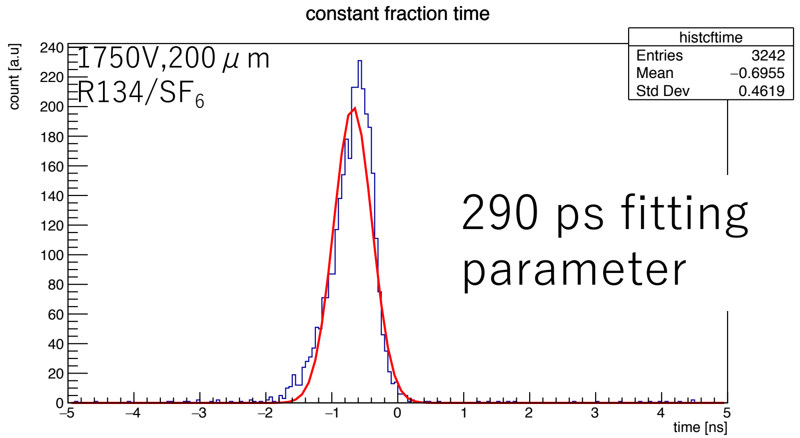
Timing resolution

- For 4cm × 5cm readout setup



- Distribution of timing difference b/w reference counter & RPC
- 360ps fitting parameter

- 1cm × 10cm showed different timing distribution
(This might be unrelated to readout)



290 ps fitting parameter