

# Development of a Precise Time and Position Resolutions TOF-tracker RPC for the $\pi 20$ Beamline at J-PARC

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Master Student

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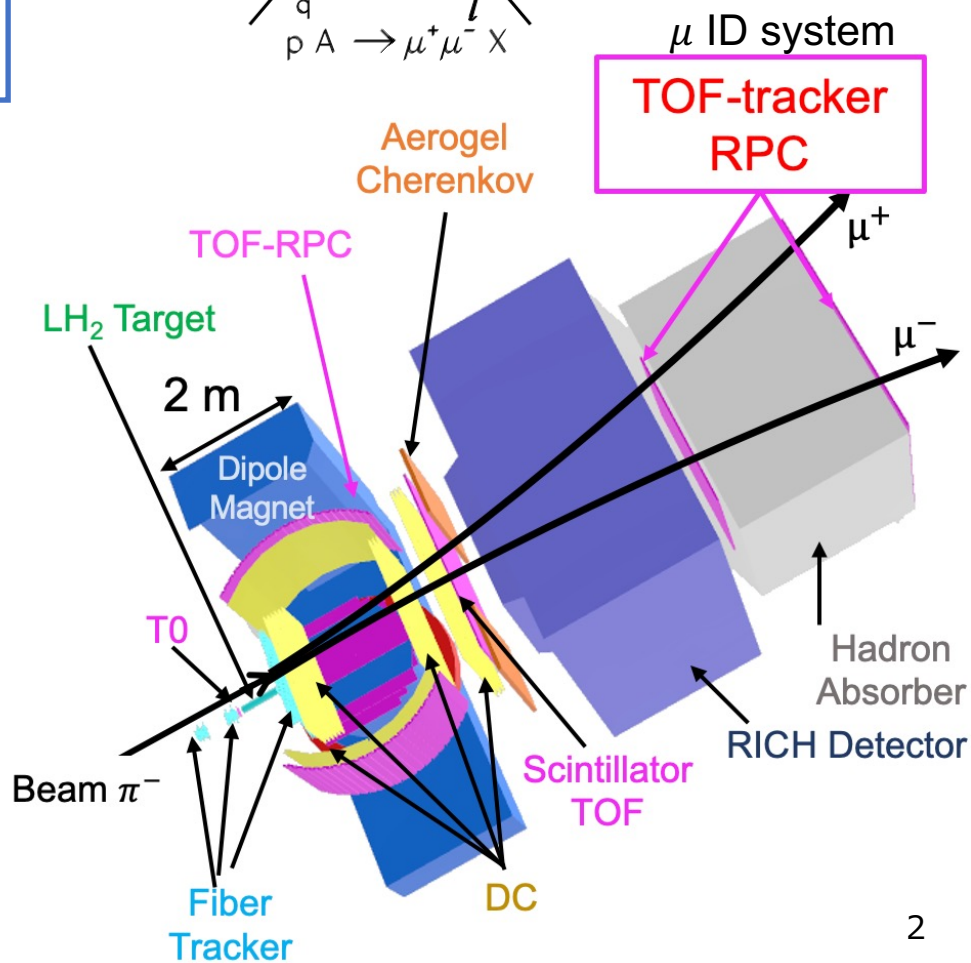
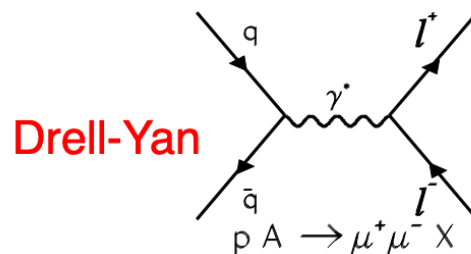
for the J-PARC E50 collaboration

# TOF-tracker RPC for The Nucleon Structure Study

## Nucleon spin crisis

- Quark spin contribution to nucleon spin  
→ approximately **30 %**
- What is the remaining 70 % ?
- Measurement of **the generalized parton distribution function**

@J-PARC  $\pi 20$  Beamline



# TOF-tracker RPC for The Nucleon Structure Study

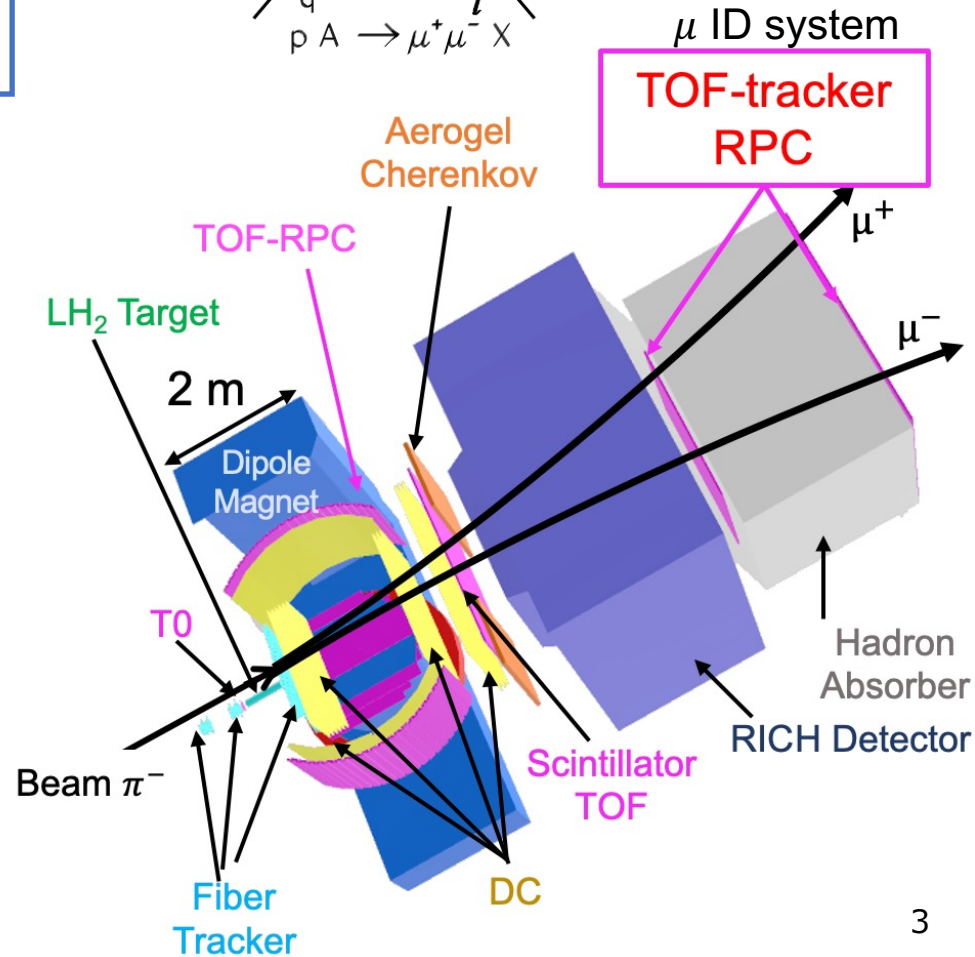
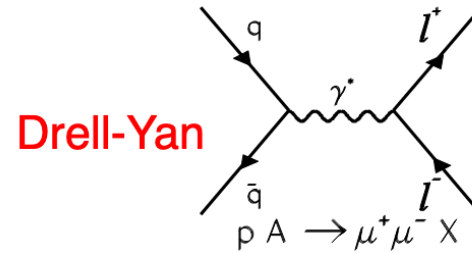
## Nucleon spin crisis

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Exclusive Drell-Yan reaction

$$\pi^- p \rightarrow \gamma^* n \rightarrow \mu^+ \mu^- n$$

@J-PARC  $\pi 20$  Beamline

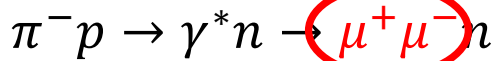


# TOF-tracker RPC for The Nucleon Structure Study

## Nucleon spin crisis

- Quark spin contribution to nucleon spin  
→ approximately **30 %**
- What is the remaining 70 % ?
- Measurement of **the generalized parton distribution function**

Exclusive Drell-Yan reaction



Identification

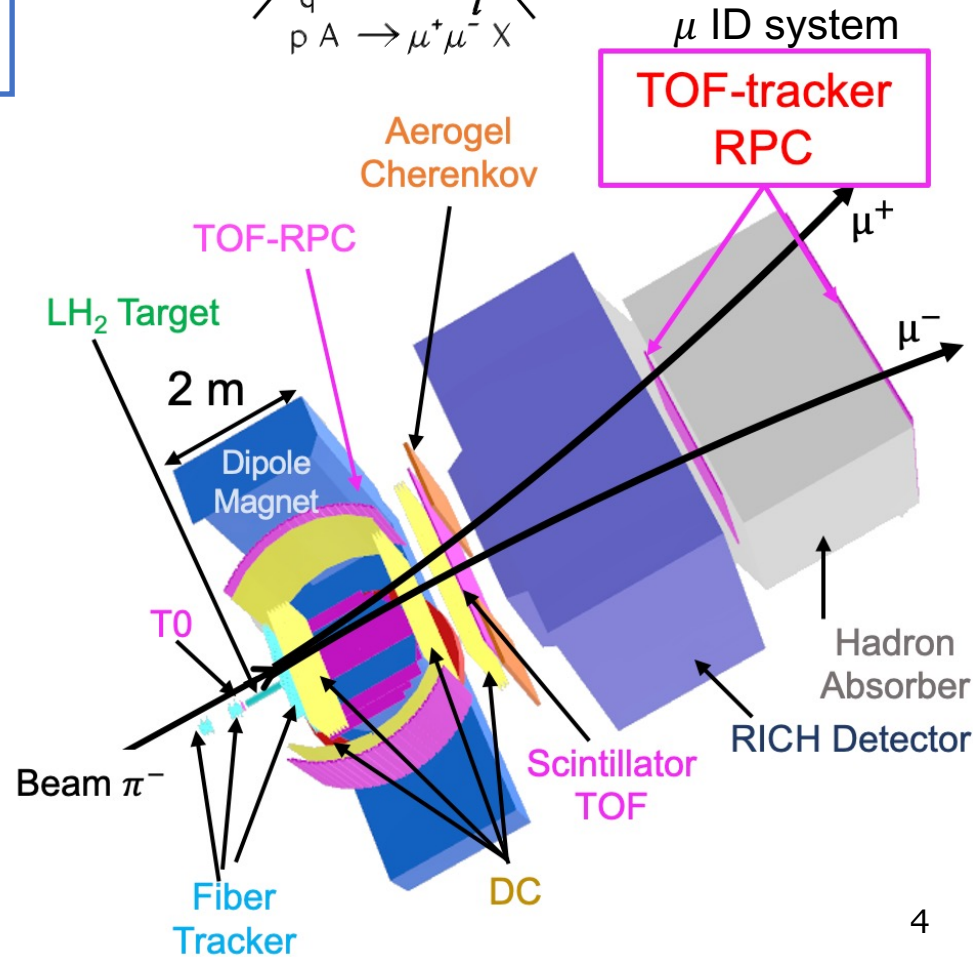
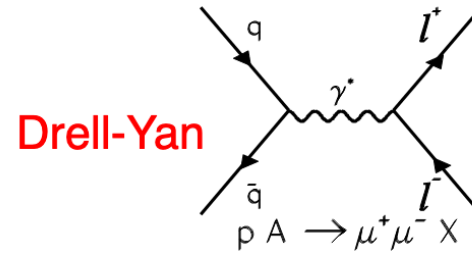
## TOF-tracker RPC

Remove background muons from decays in flight of kaons and pions

### Upstream muon detector

- Size : 1.8 m × 2.4 m
- Efficiency : more than 99 %
- Time resolution : ~100 ps
- **Position resolution :  $\sigma \sim 1$  mm**

@J-PARC  $\pi 20$  Beamline



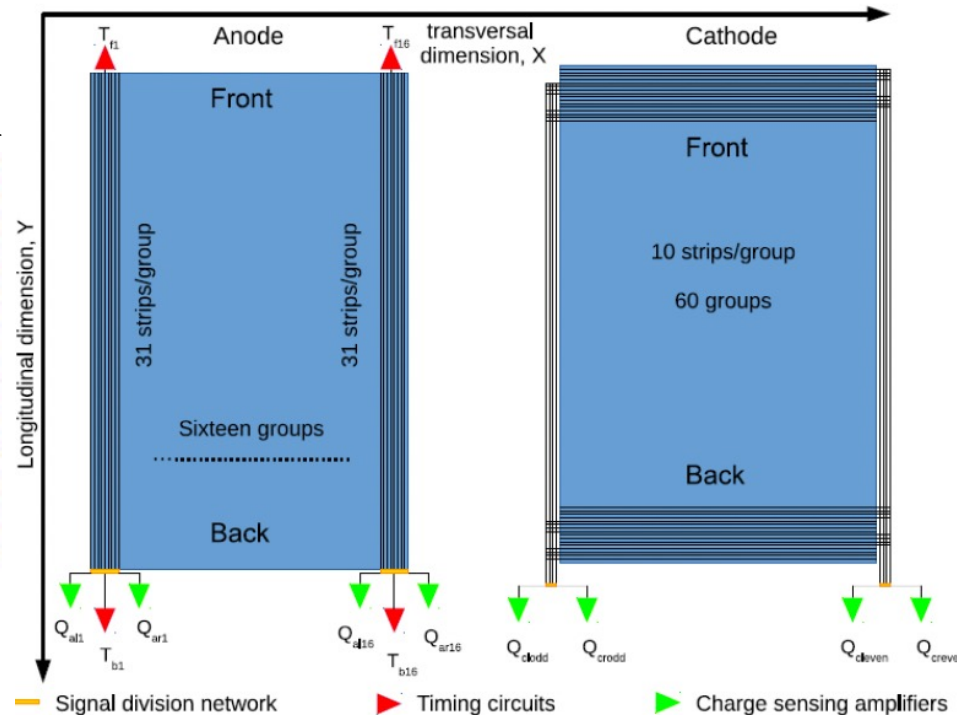
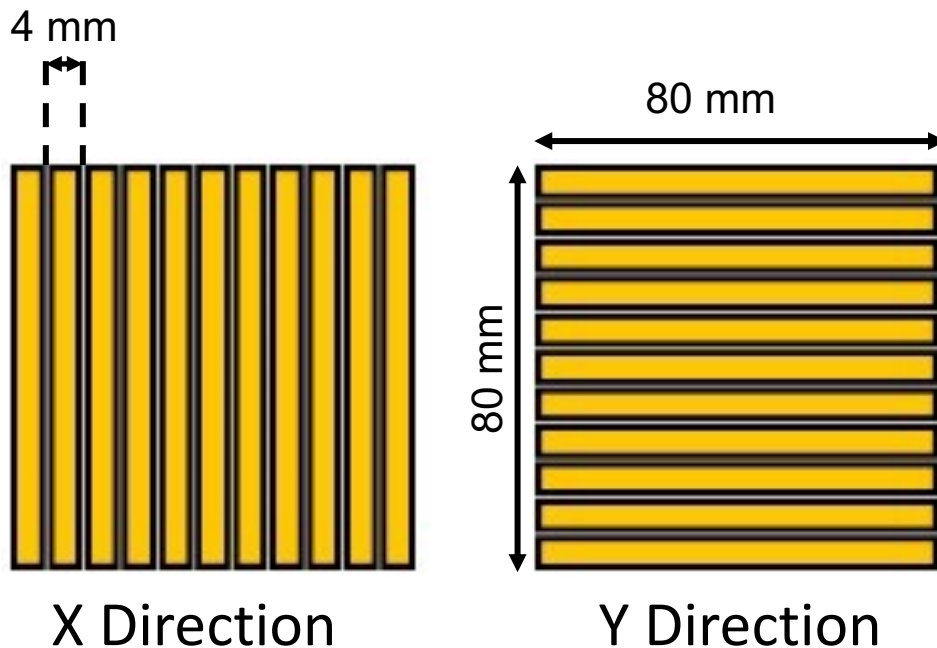
# TOF-tracker RPCs Developed so far

## Small TOF-tracker RPC JINST7(2012)P11012

- 80 mm × 80 mm
- Strip pitch : 4 mm
- The orientation of the top and bottom readout strips was rotated by 90 degrees
- Read out channel by channel
- Time resolution : ~80 ps
- Position resolution : 40~70 μm

## Large TOF-tracker RPC JINST11(2016)C10002

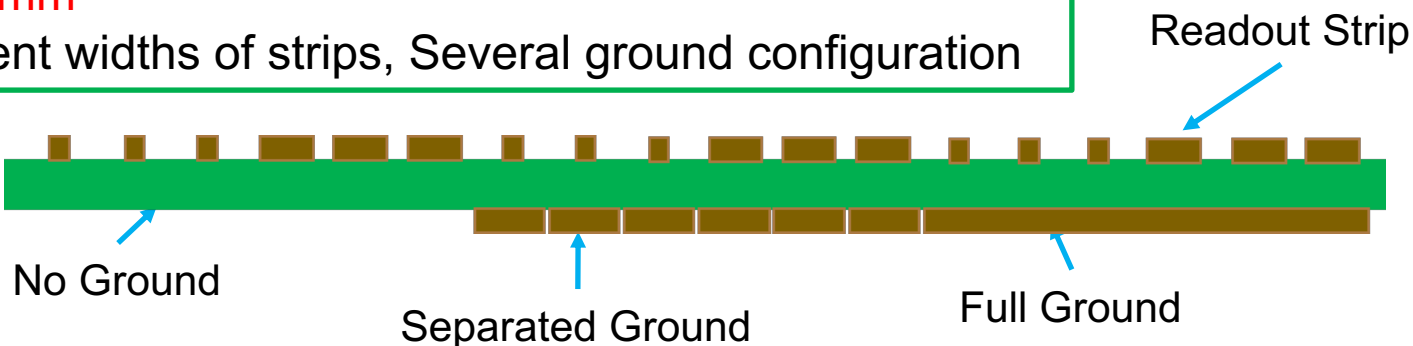
- 1.5 m × 1.2 m
- Strip pitch : 2.5 mm
- The orientation of the top and bottom readout strips was rotated by 90 degrees
- X : group 31 strips, Y : group 10 strips
- Efficiency : 92 % (tracking), 72 % (timing)
- Time resolution : ~150 ps
- Position resolution : 1.3 mm (X), 8.1 mm (Y)



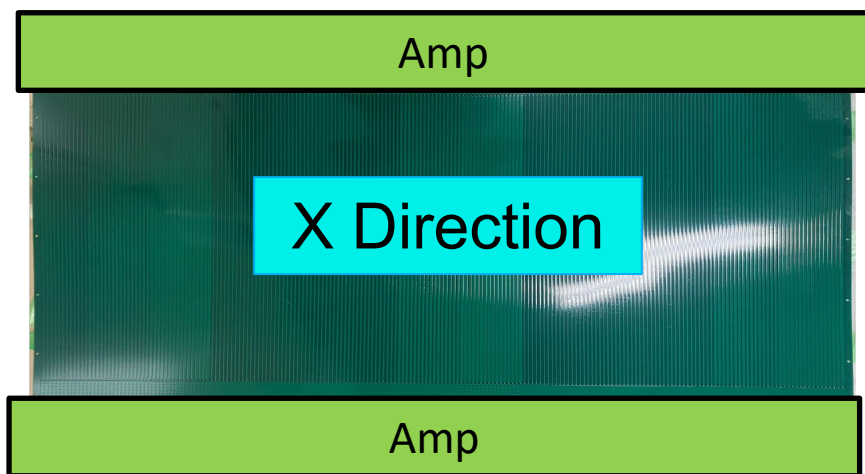
# Prototype TOF-tracker RPC

- Size : 500 mm × 1000 mm
  - The maximum production size of readout board
- Number of gas gaps : 5 gaps, Gas gap : 260 μm
- 1 stack
- Strip pitch : **5 mm**
- Several different widths of strips, Several ground configuration

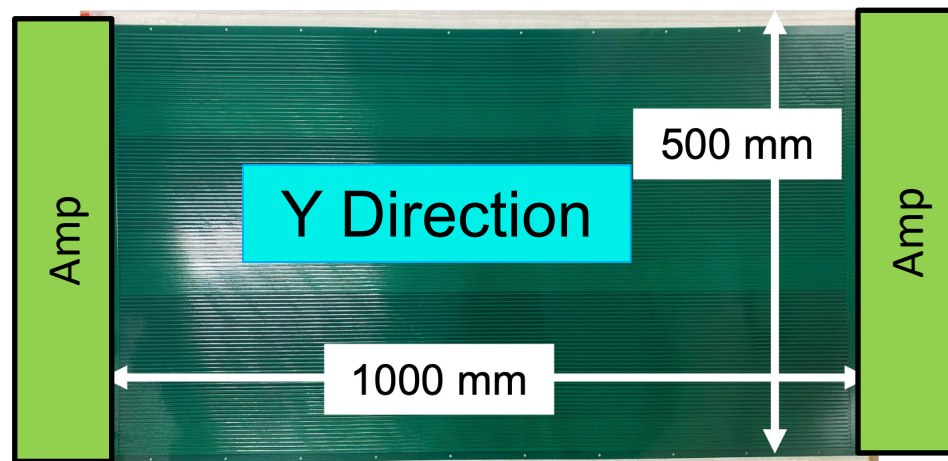
Cross-sectional view of the readout strips



Readout Strip



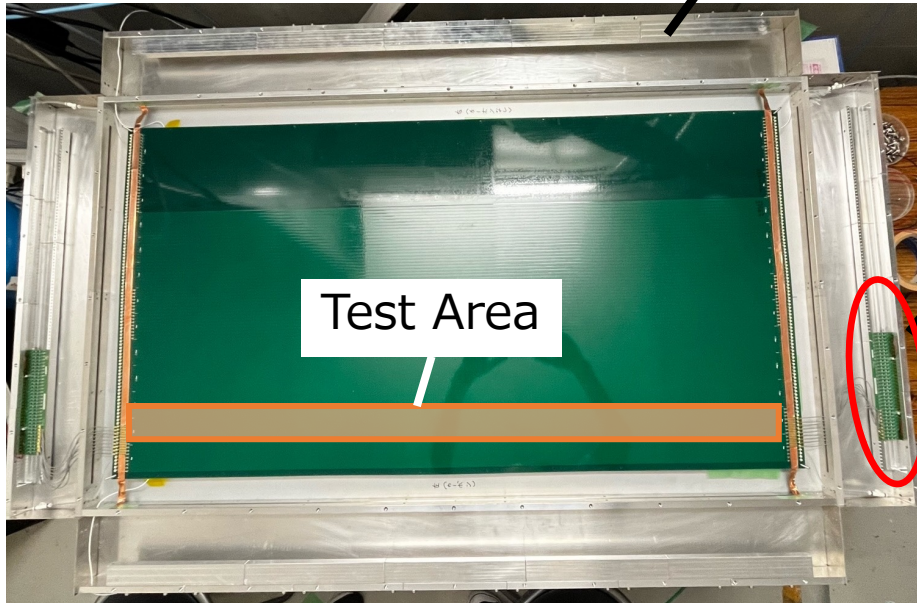
5 mm pitch × 204 strip



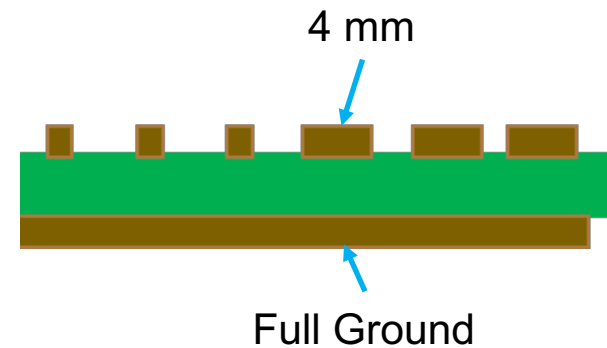
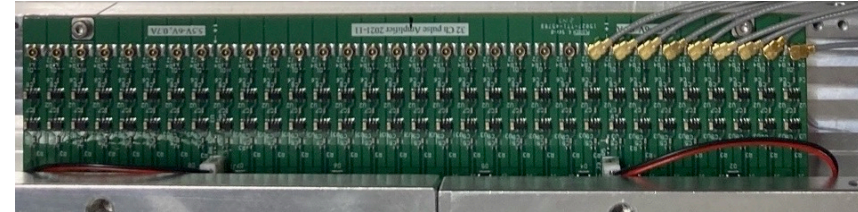
5 mm pitch × 106 strip

# Prototype TOF-tracker RPC

Aluminum Case



Amplifier

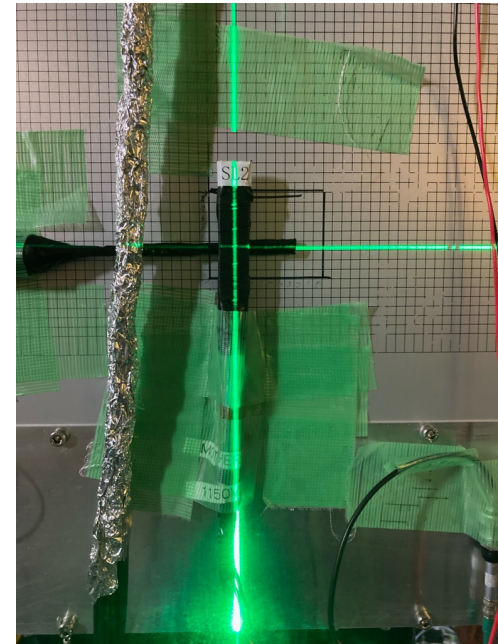
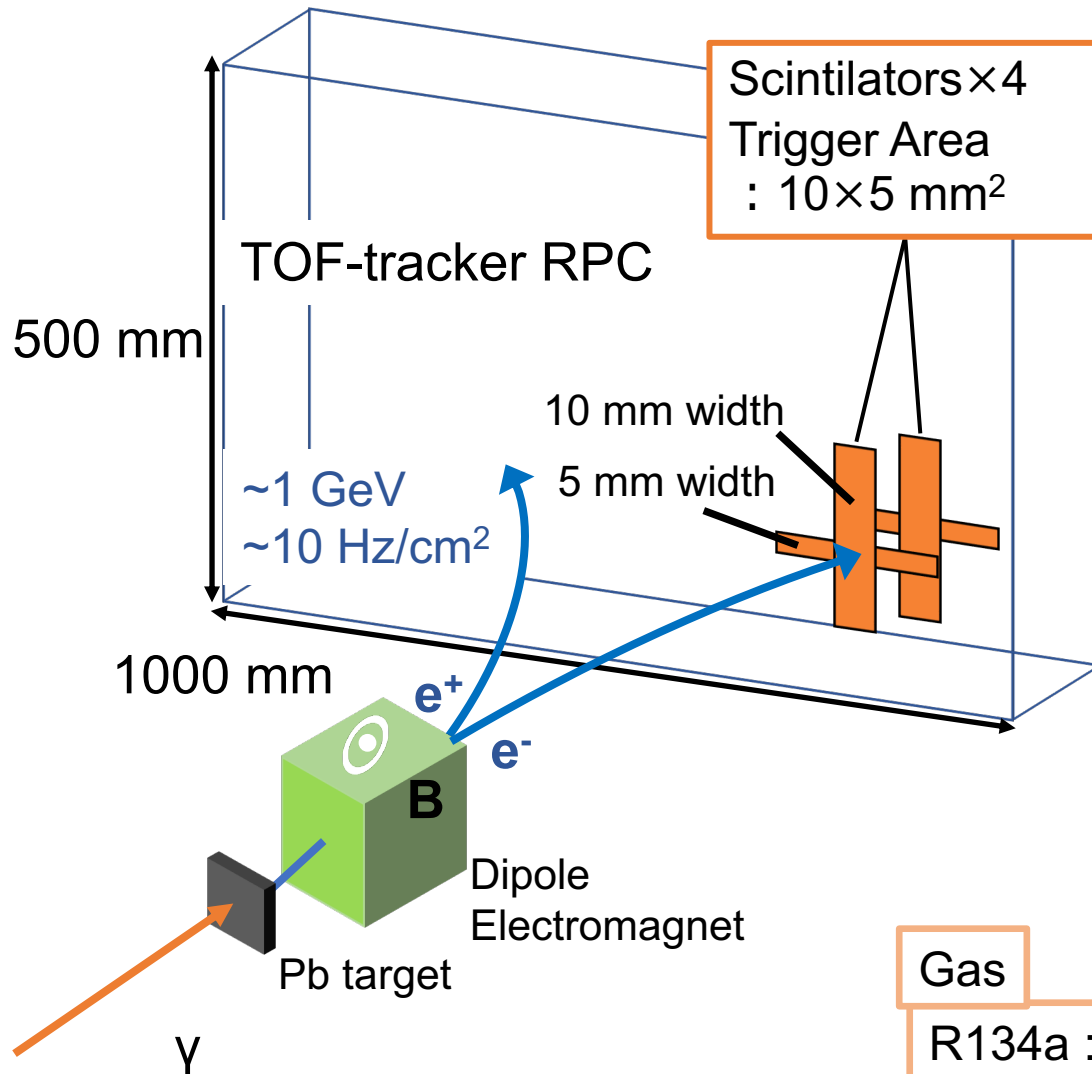


- Amplifier was developed with Academia Sinica in Taiwan (Gain ~ 800 )
- The beam test was carried out with 9 strips (Strip width : 4 mm, Full ground) in Y direction

# Beam Test

@SPring-8/LEPS2 Beamline

## Time resolution evaluation



Start timing of time information  
: RF signal of accelerator  
(Time resolution ~15 ps)

Time resolution of TDC (HUL) ~ 20 ps

Gas

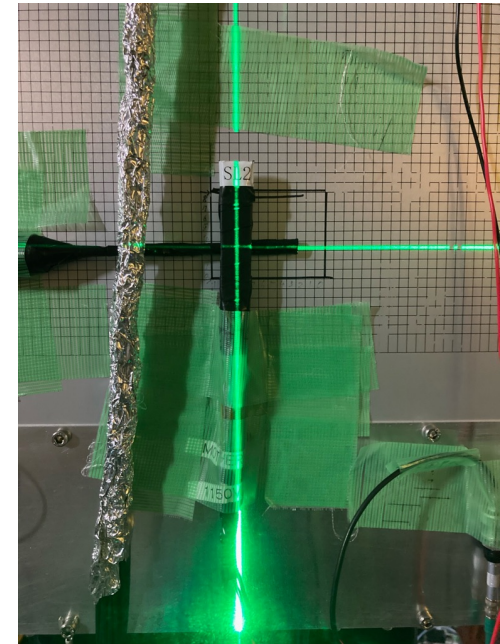
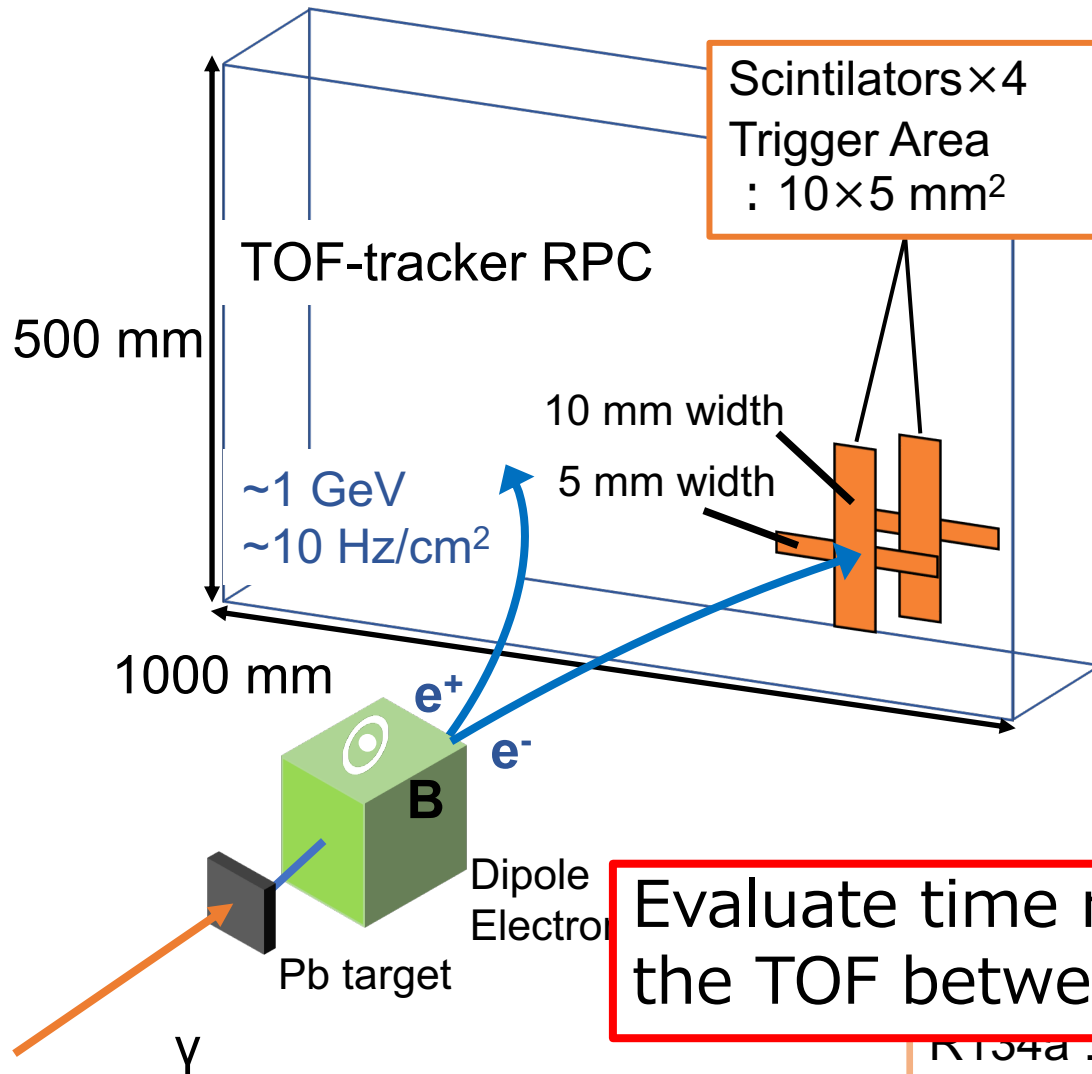
R134a : butane : SF6 = 90 : 5 : 5



# Beam Test

@SPring-8/LEPS2 Beamline

## Time resolution evaluation

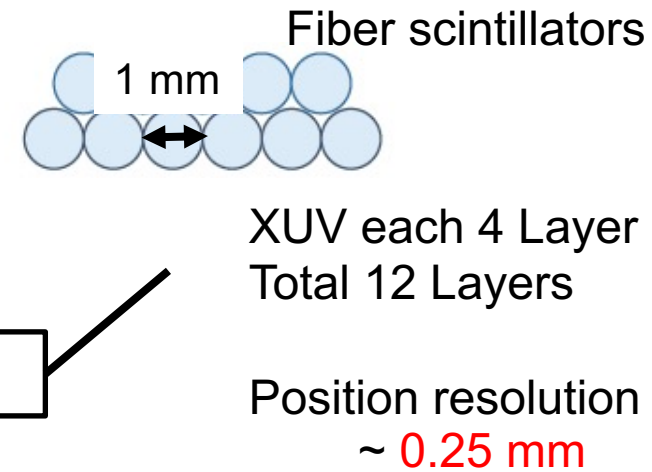
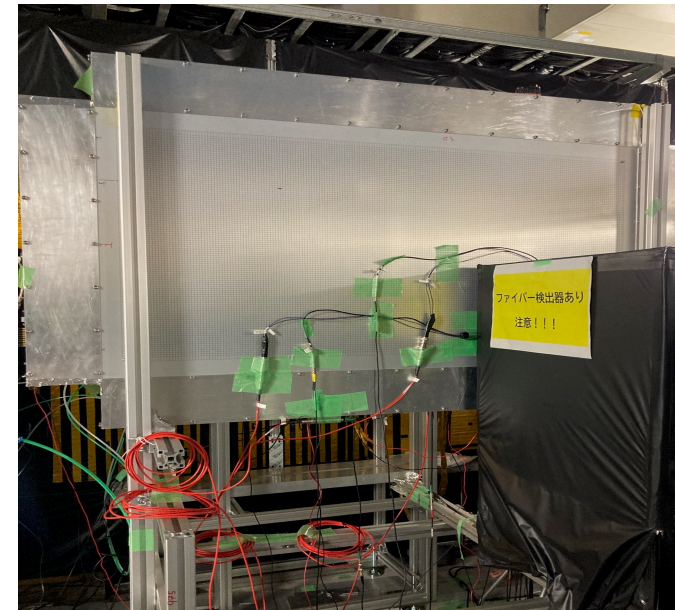
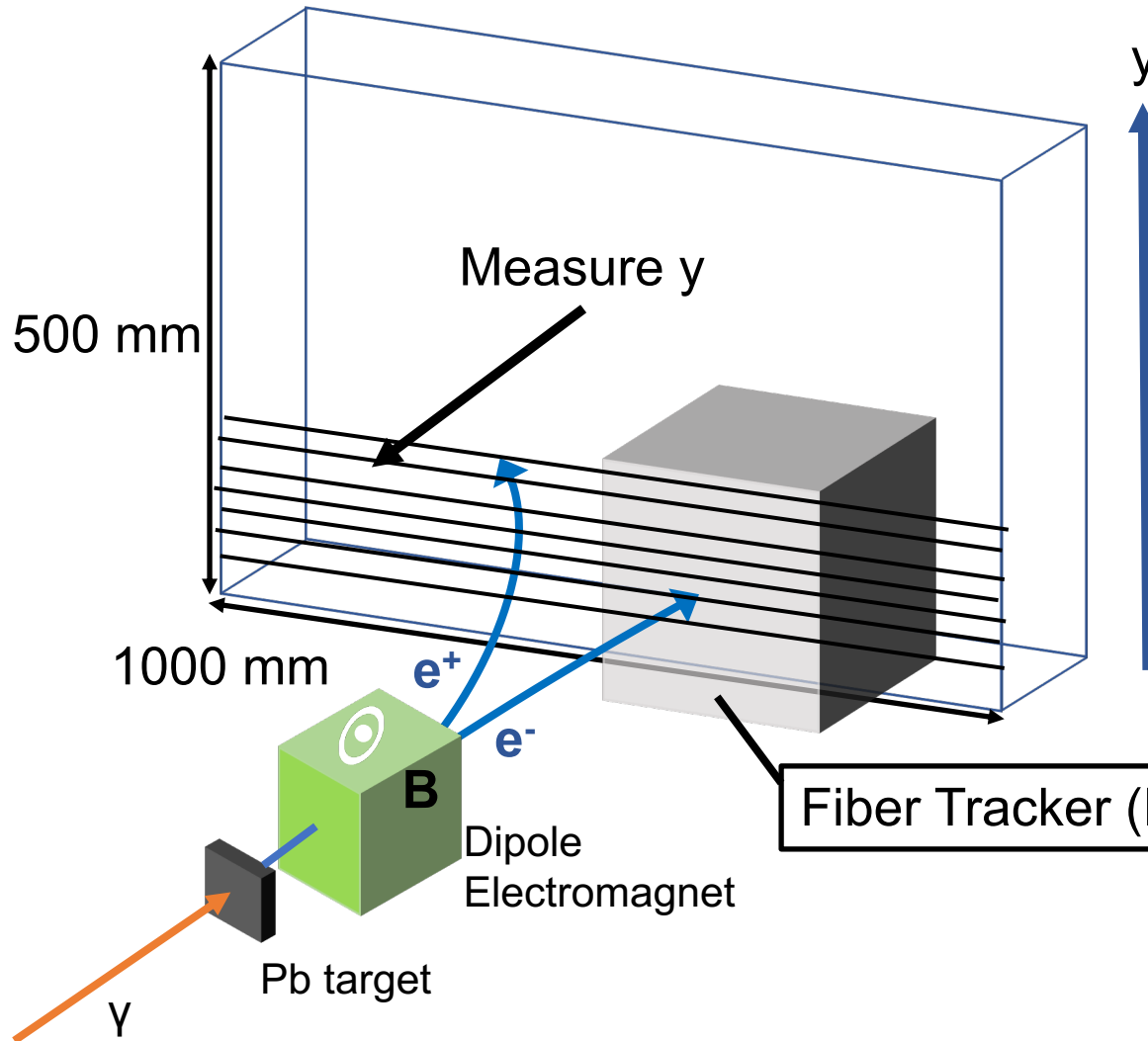


Start timing of time information  
: RF signal of accelerator  
(Time resolution ~15 ps)

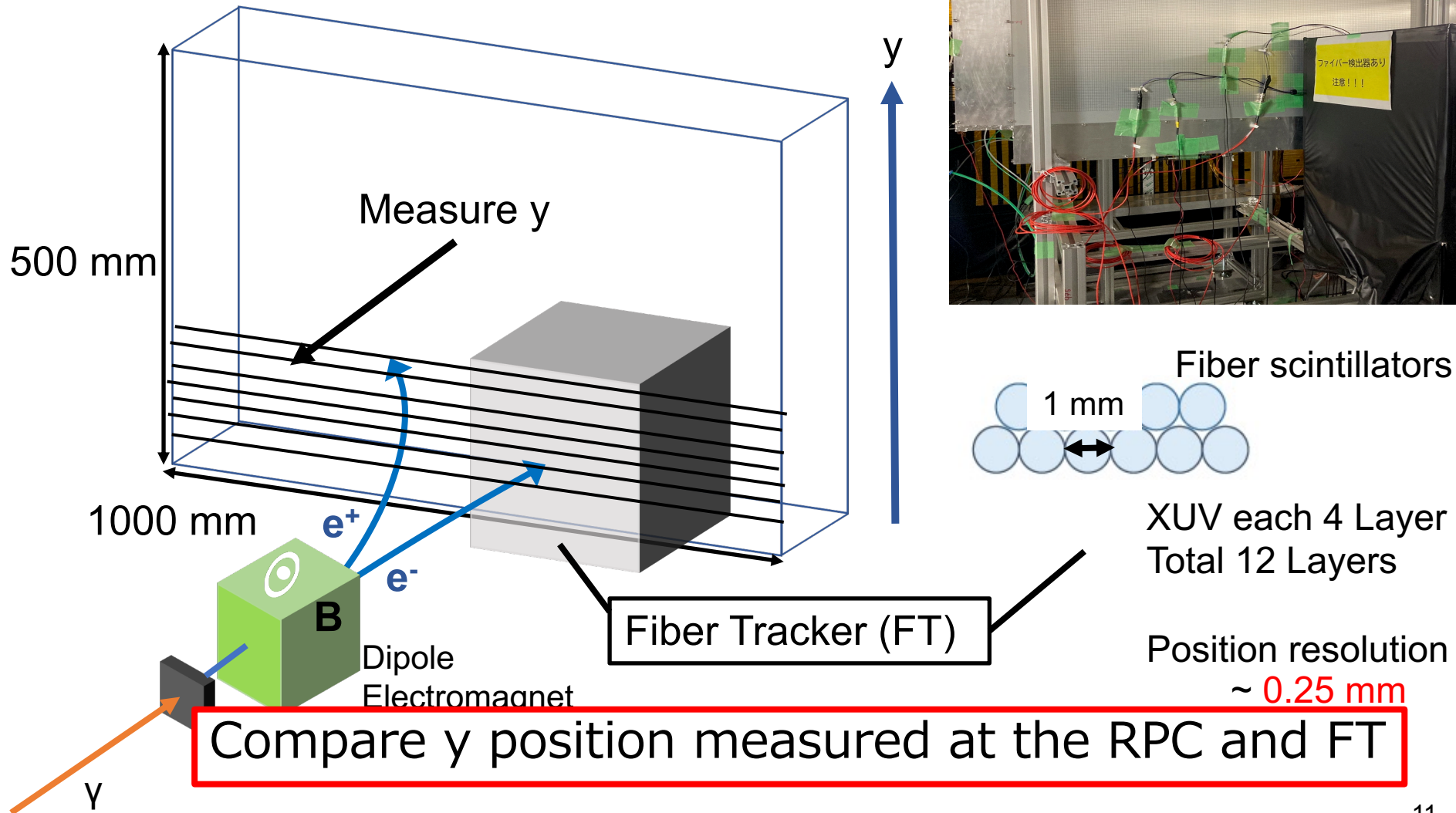
Time resolution of TDC (MUL) ~ 20 ps

Evaluate time resolution from  
the TOF between RPC and RF

## Position resolution evaluation



## Position resolution evaluation

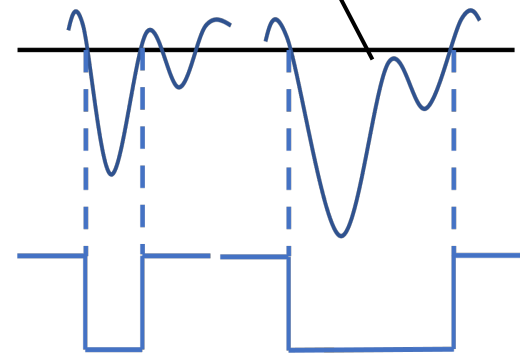


# Time Walk Correction

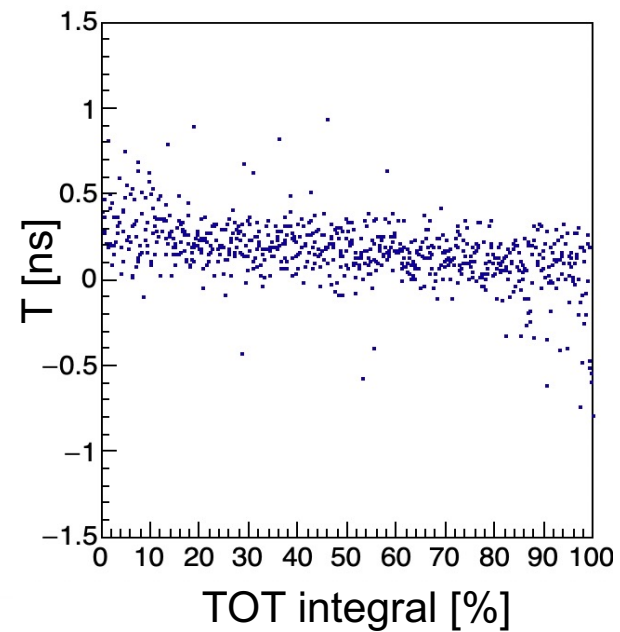
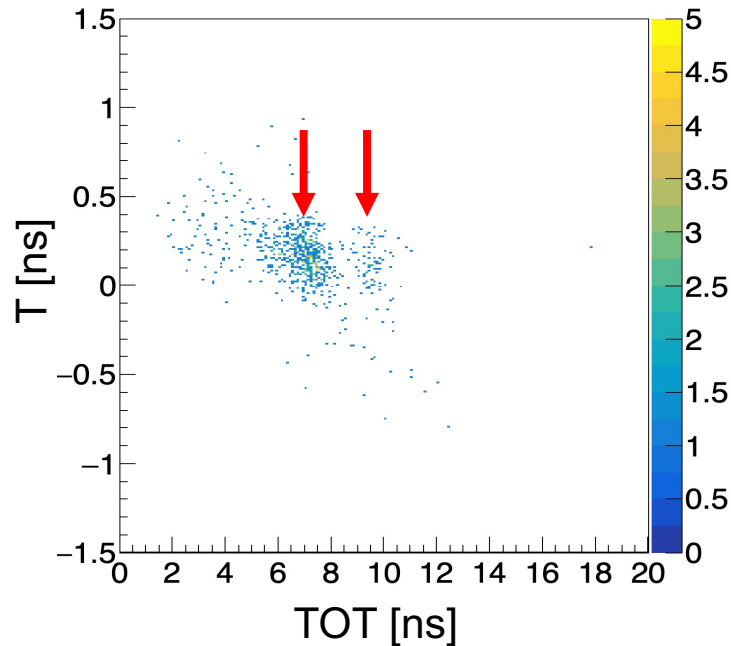
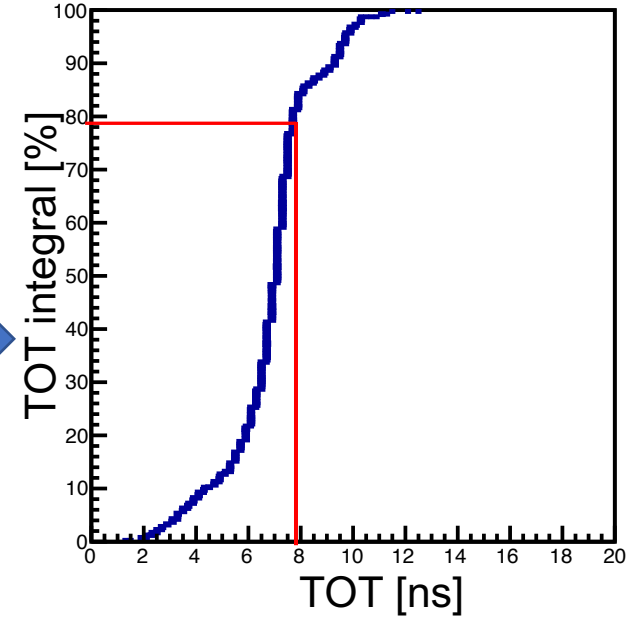
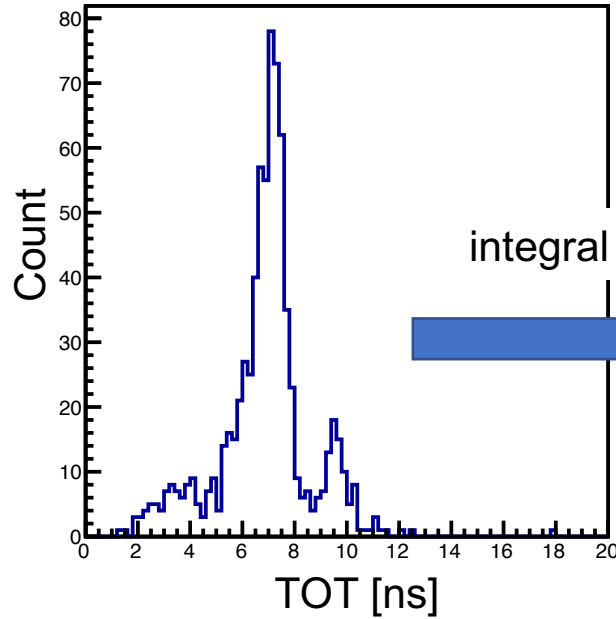
BES-III RPC  
JINST 12 C01012 (2017)

$\pi$ 20 DAQ : Only TDC

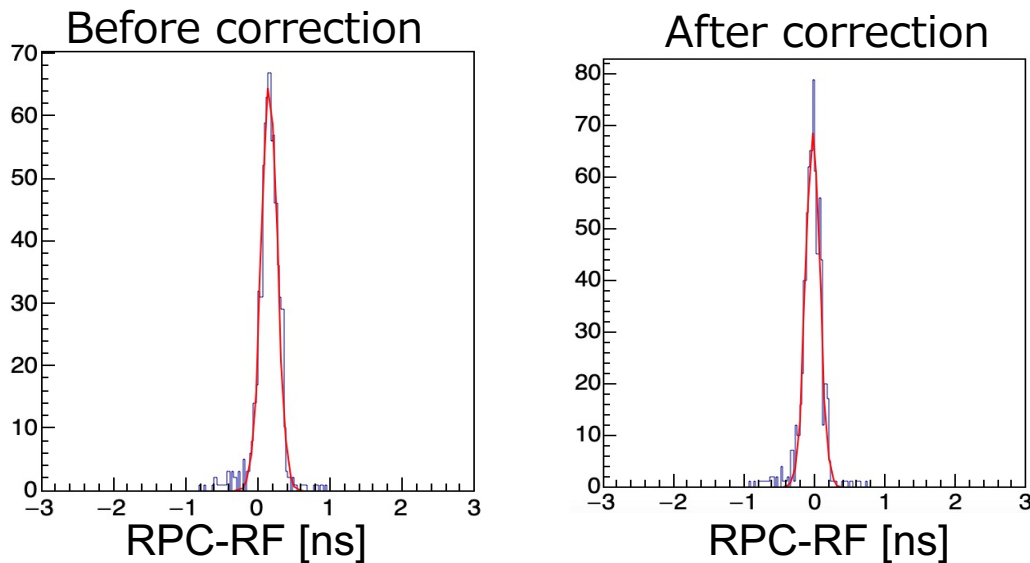
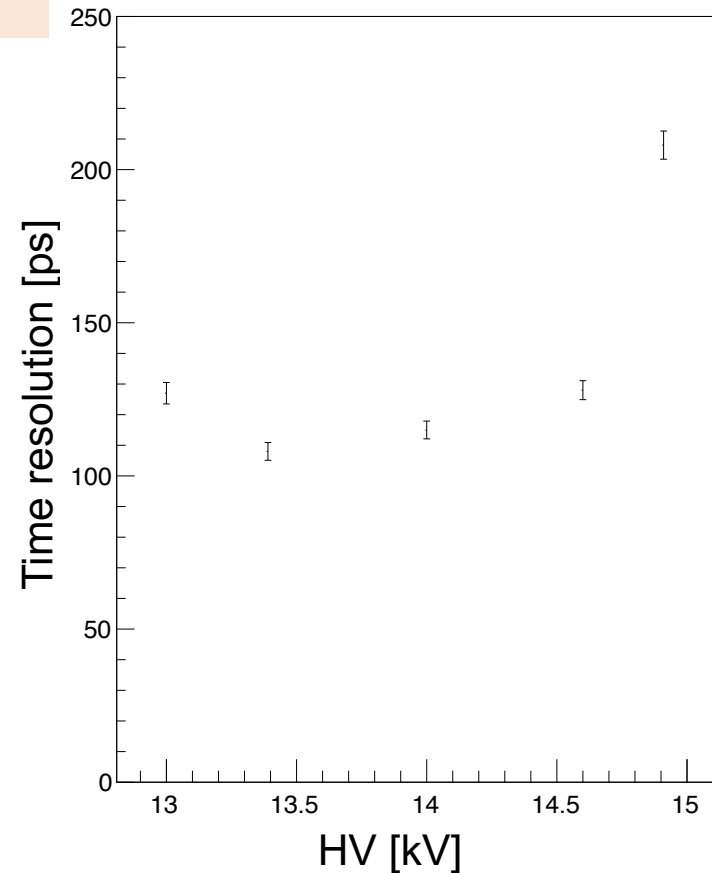
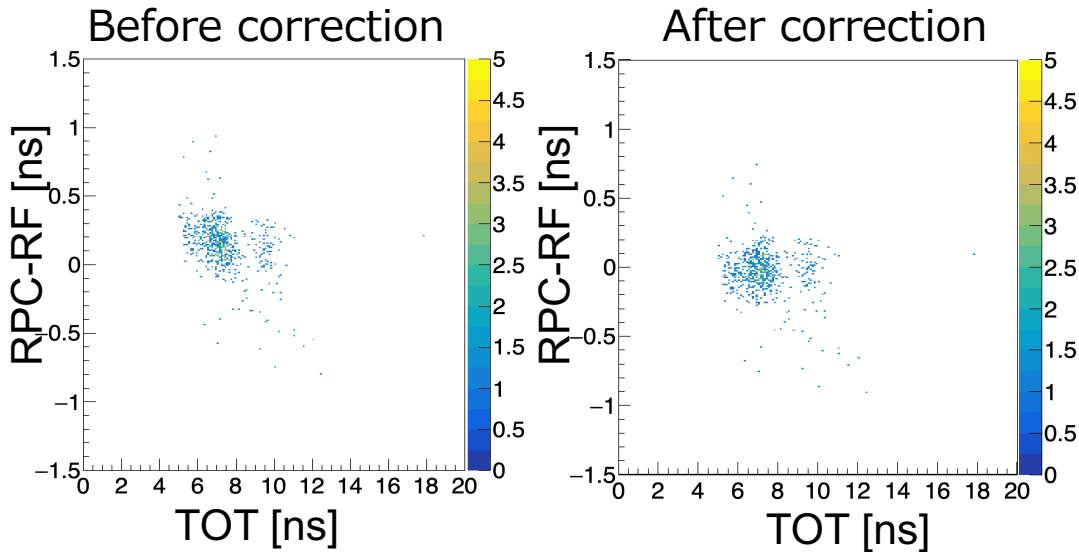
Discriminator  
Threshold



Time Over  
Threshold (TOT)



# Time Resolution



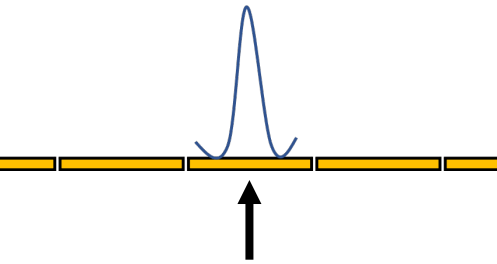
Time resolution  
:  $113 \pm 4$  ps

Time resolution  
:  $103 \pm 3$  ps

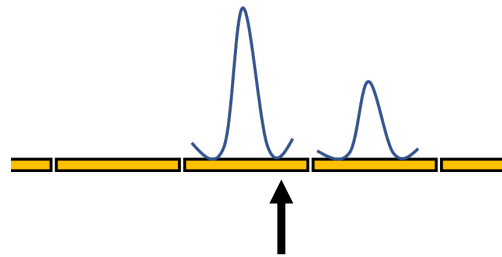
- Achieved required resolution (100 ps)
- Time resolution is the best at around 13.5-14 kV
- Similar voltage dependence to that of conventional TOF-RPCs

# Position Resolution (Analysis On-Going)

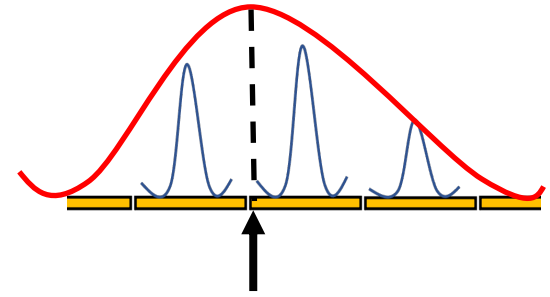
1 strip  
Center of strip



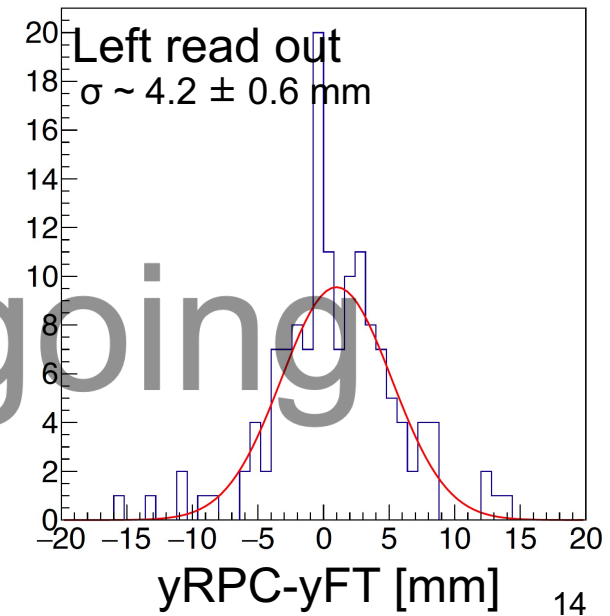
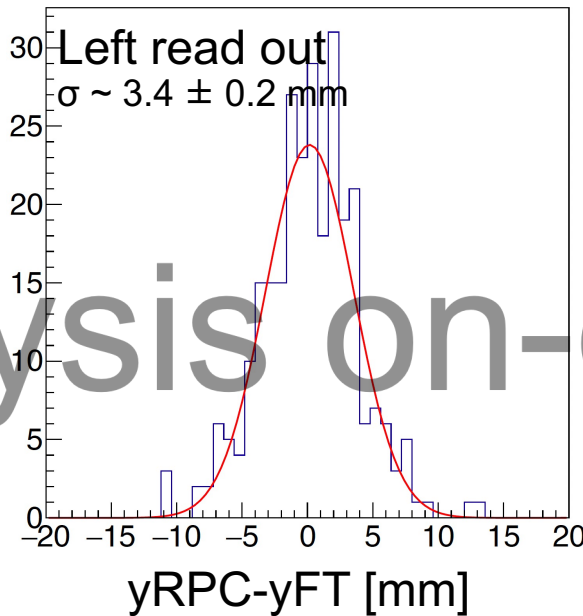
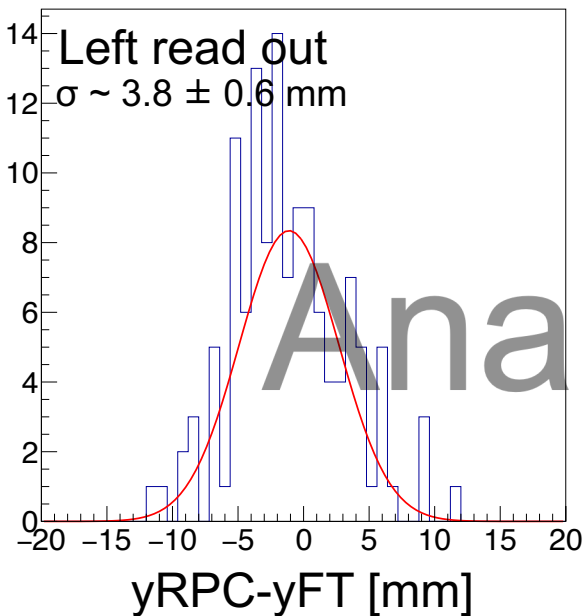
2 strips  
Weighted by pulse height



More than 2 strips  
Fitting with gaussian

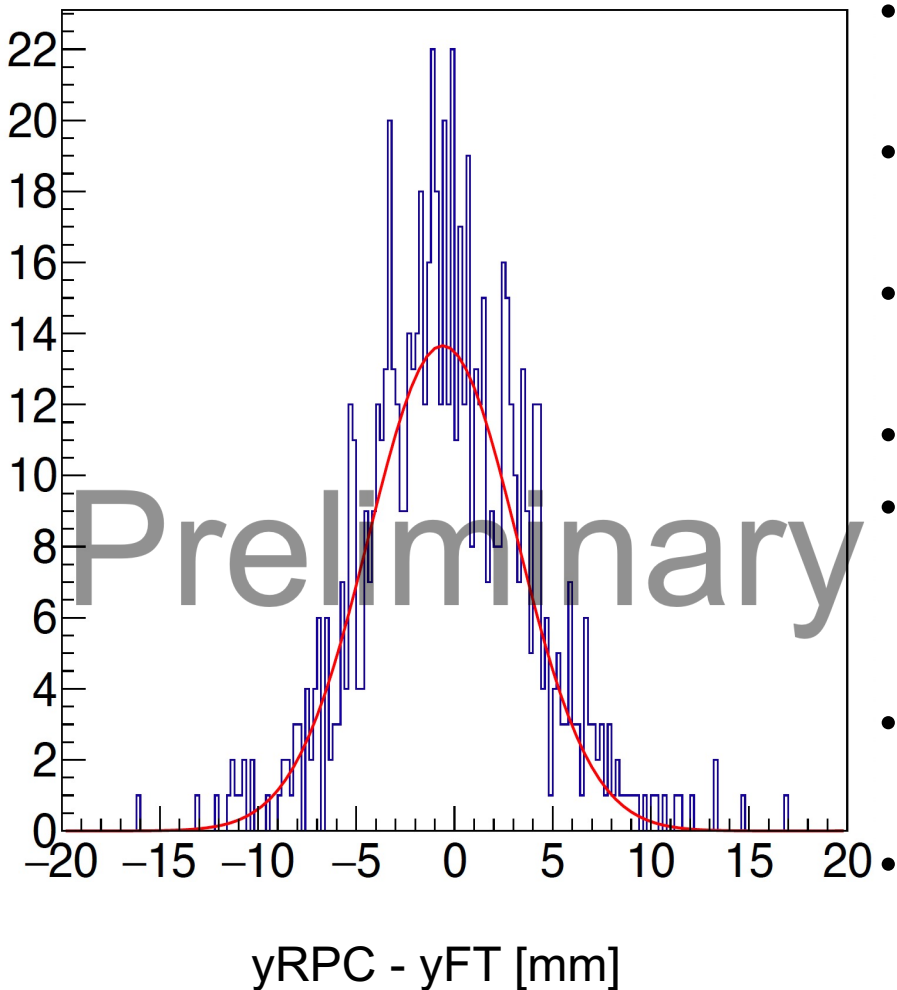


Evaluate Pulse height using TOT integral



Analysis on-going

# Position Resolution (Analysis On-Going)



- Evaluate the hit position in single side
  - Determine the hit position by averaging both sides
  - Position resolution  
 $\sigma \sim 3.8 \pm 0.2$  mm
  - Not achieved required resolution (1 mm)
  - Worth than the expected resolution of single strip hit  
 $\sigma \sim 5/\sqrt{12} = 1.4$  mm
  - We will improve analysis methods of both the FT and RPC
- Efficiency  $97.3 \pm 0.6$  %

# Summary and Future Work

## Summary

- We are developing TOF-tracker RPC for the nucleon structure study experiment at J-PARC
- We have developed the prototype TOF-tracker RPC
  - 500 mm × 1000 mm
  - strip pitch : 5 mm
- We have performed the beamtest of the prototype RPC in SPring-8
  - Efficiency :  $97.6 \pm 0.6 \%$
  - Time resolution :  $103 \pm 3 \text{ ps}$
  - Position resolution :  $3.8 \text{ mm} \pm 0.2 \text{ mm}$ , Analysis on-going

## Future Work

- Increased the number of strips available for readout (amp noise suppression)
- Improvement of analysis method of position measurement