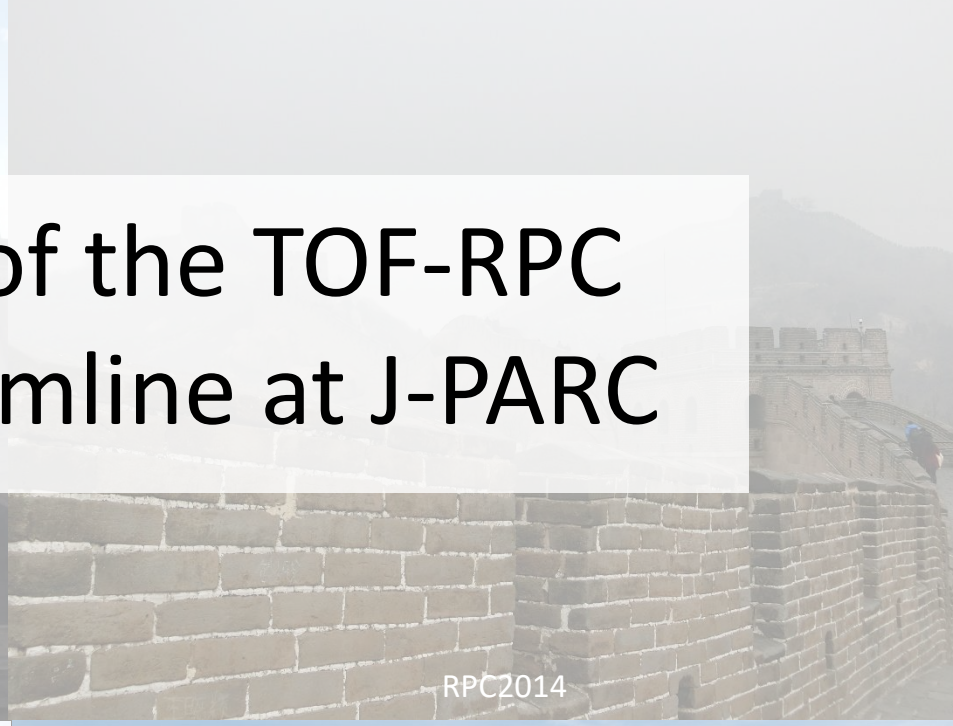
Development of the TOF-RPC for the π20 beamline at J-PARC


RPC2012


RPC2014

RPC2022 @ CERN

2022/9/26

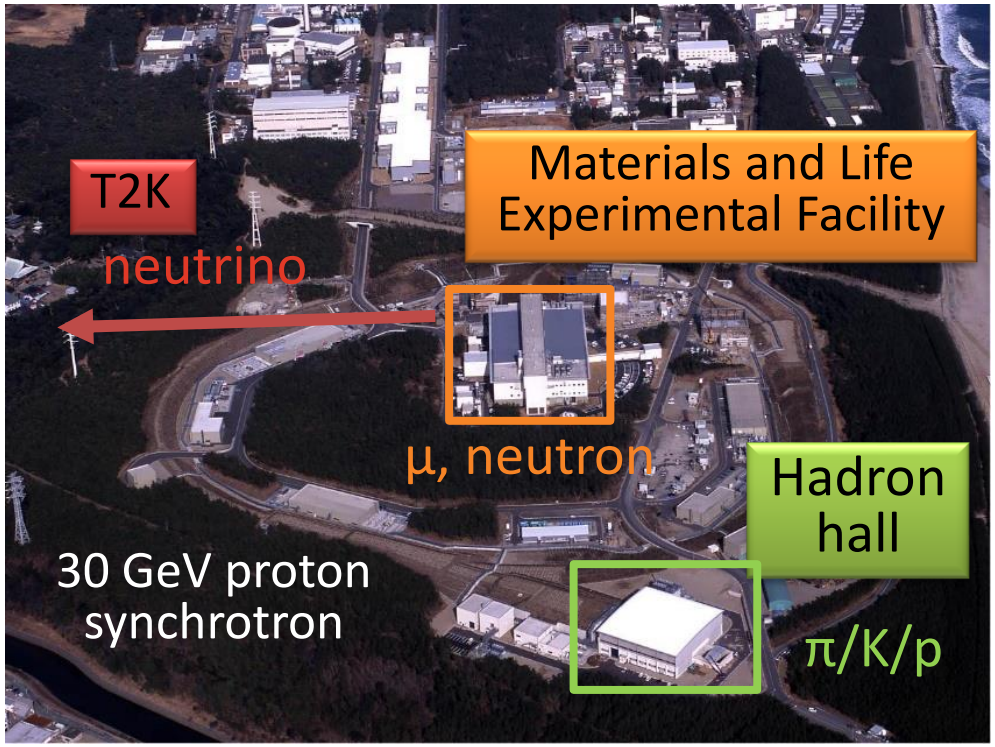
Natsuki TOMIDA (Kyoto Univ., Japan)


RPC2016

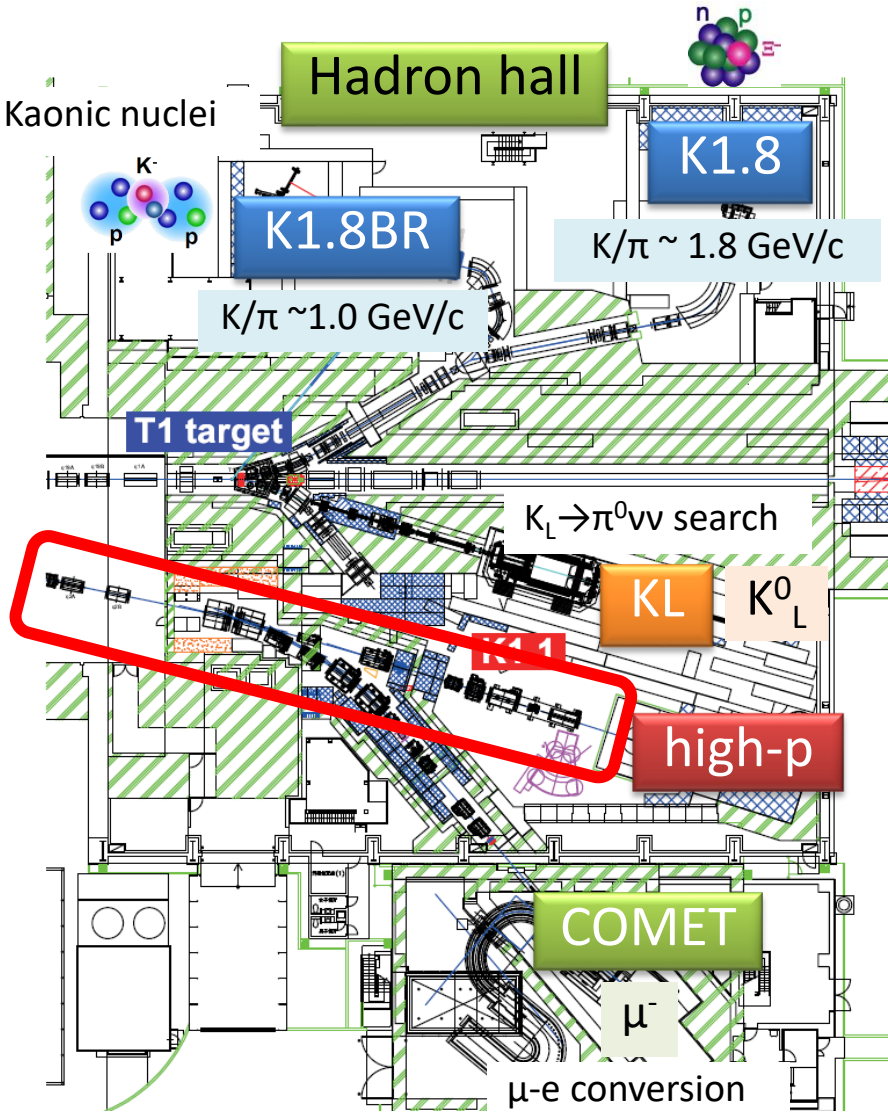

CERN2010

J-PARC / π20 beamline

Japan Proton Accelerator Research Complex 2010-



high-p beamline



2020- : **30 GeV primary proton beam**

⇒ Study of Φ meson mass in nucleus : p + A → Φ + X

202?- : **Secondary π/K/pbar beam : π20 beam line** >10^7/s, Δp/p～0.1% (RMS)

π20 spectrometer

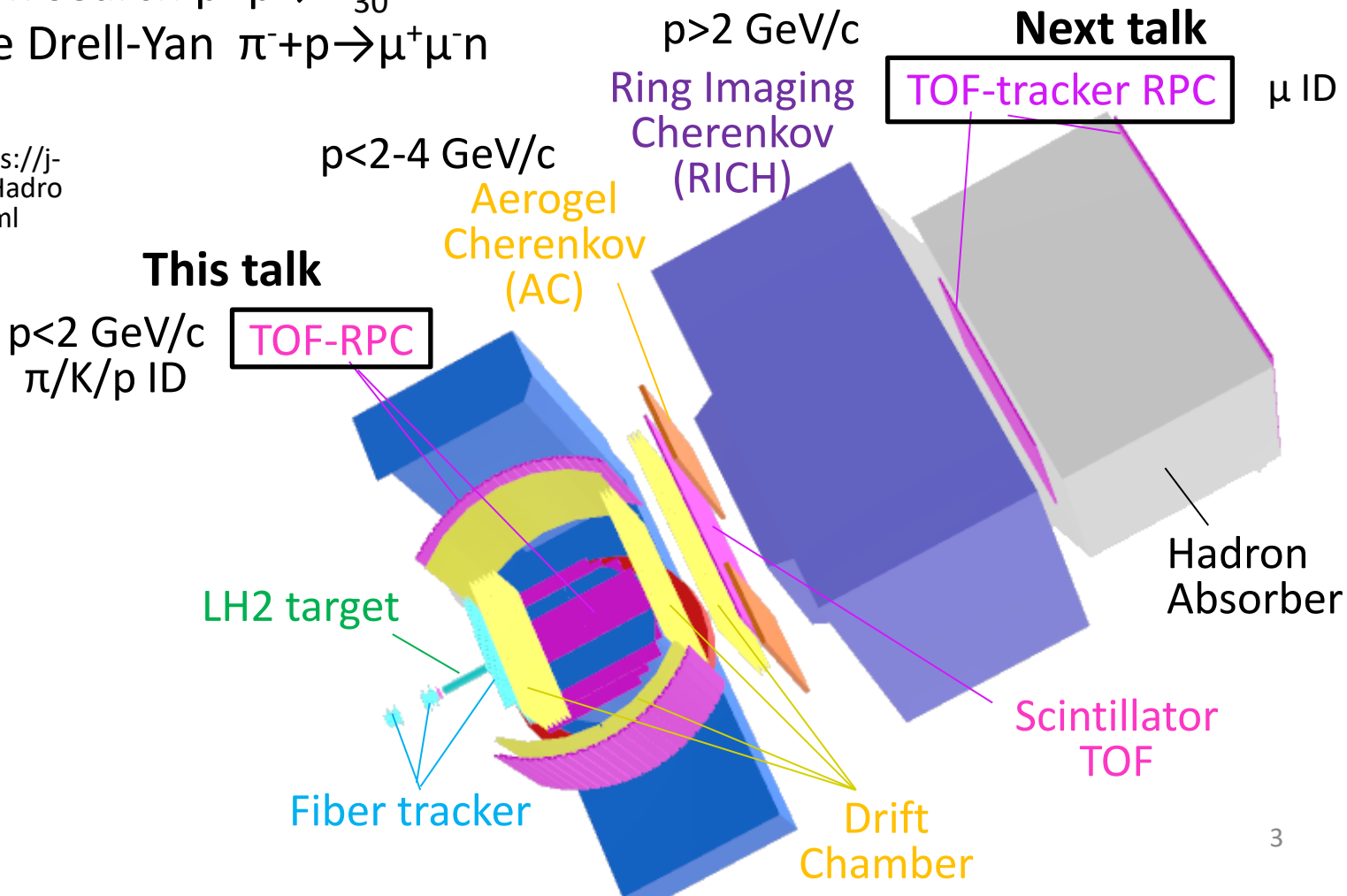
Multi purpose spectrometer | Trigger-less DAQ

R. Honda et al., PTEP 123H01 (2021)

- Charmed baryon spectroscopy $\pi^-+p\rightarrow D^{*-}+Y^{*+}$
- Ξ baryon spectroscopy $K^-+p\rightarrow K^++\Xi^{*-}, K^{0*}+\Xi^{*0}$
- Di-baryon search $p+p\rightarrow D_{30}$
- Exclusive Drell-Yan $\pi^-+p\rightarrow\mu^+\mu^-n$

and others

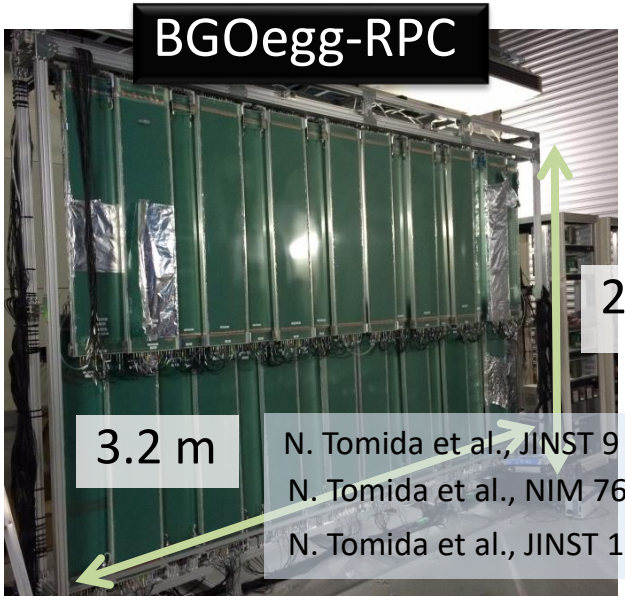
Proposals/LoIs : https://j-parc.jp/researcher/Hadron/en/Proposal_e.html



π20 TOF-RPC

Requirements

- 1.6-m long
- Wide strip
  (less number of TDC channels)
- 60 ps time resolution
- 99 % efficiency
- Slewing correction using
  Time-Over-Threshold (TOT)



Based on LEPS2/BGOegg-RPC

Discontinued items
- preamp chip
- carbon tape for electrode

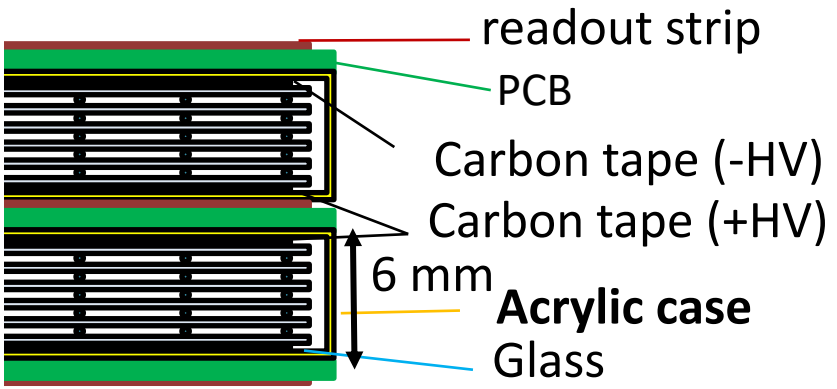
Amp instability
- Amp was inside of gas volume

Charge measurement : ADC → TDC

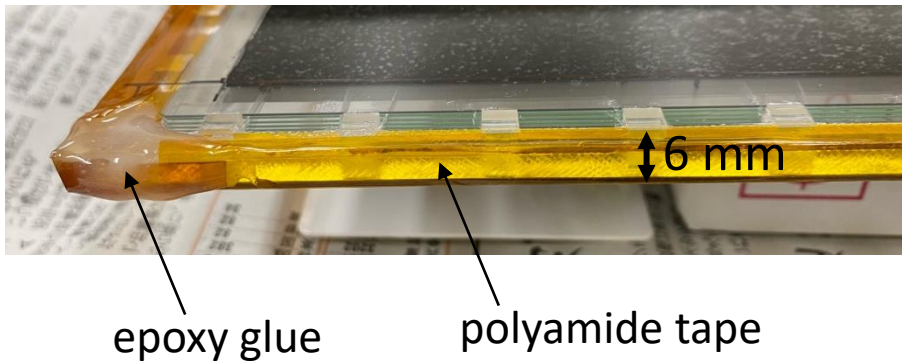
Test items

- New amp
- New carbon electrode
- Easier gas tight/amp connection
- Time walk correction using
  Time-Over-Threshold (TOT)

Prototype 1-m TOF-RPC

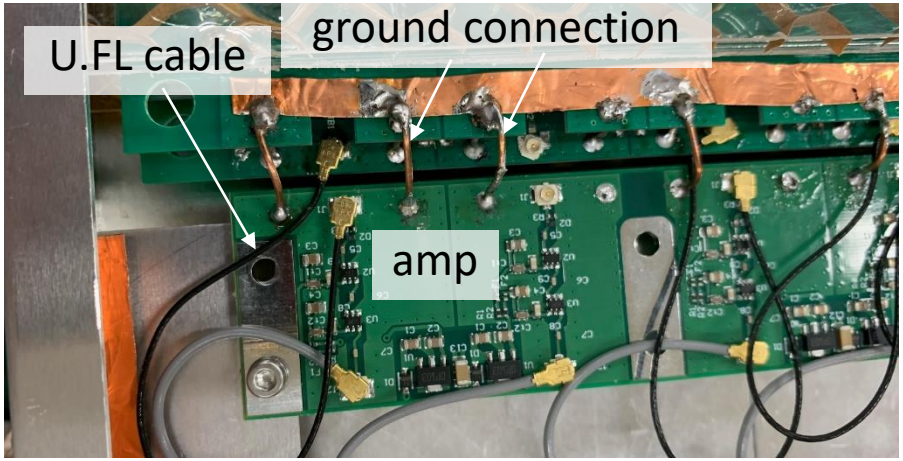


- 260 µm x 5 x 2 gaps
- 25 mm x 1000 mm x 8 strips
- Ordinary carbon : T-9188 (EEEC co.) remaining pieces



- Gas tight using **acrylic cases** : preamps are outside of gas volume (SHiP-RPC design)

A. Blanco et al., JINST 15 C10017



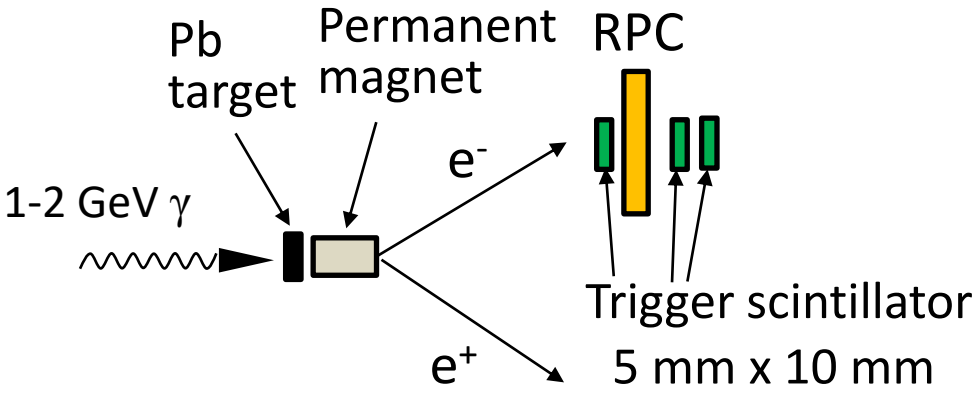
- U.FL (coaxial) connectors between readout strip & amp
- Customized amp (gain ~800)
- Customized discriminator (without stretcher)

N. Tomida et al., JINST 9 C10008 (2014)

(developed in Academia Sinica in Taiwan)

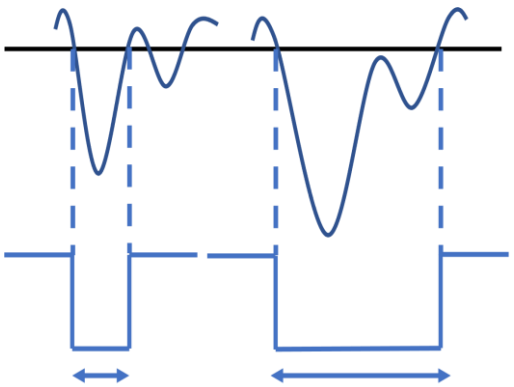
Beam test

- LEPS2 beam line @ SPring-8 Japan

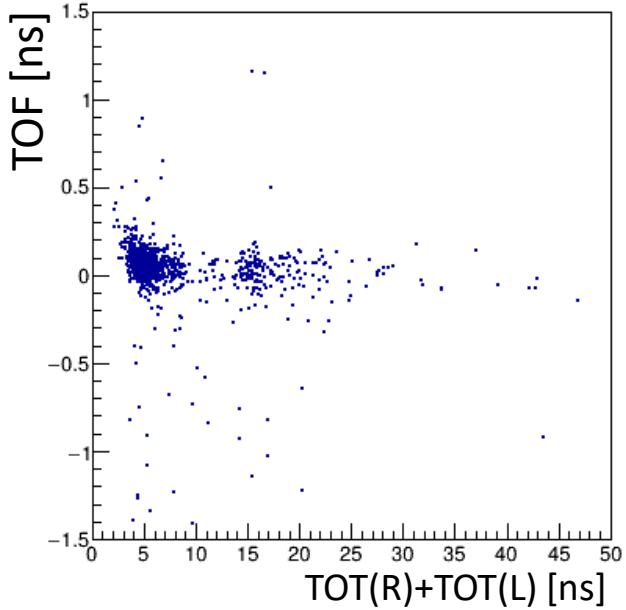


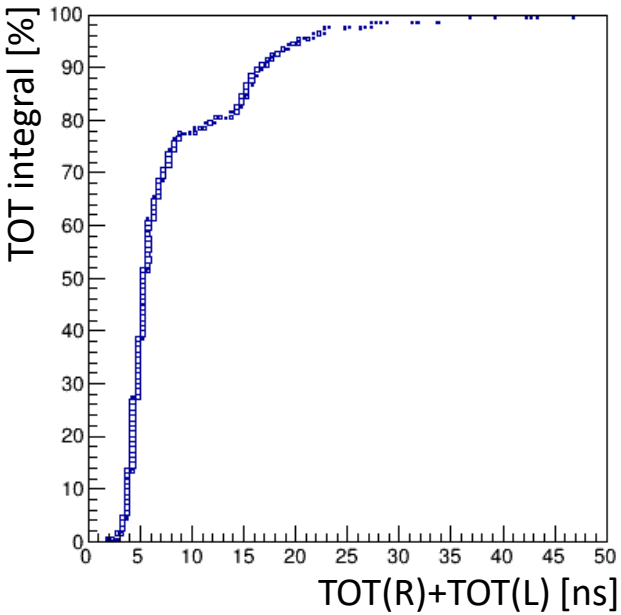
- TOF
  - Start : Accelerator RF signal σ ~ 14 ps (beam bunch width)
  - Stop : RPC
- HR-TDC developed by KEK E-sys (will be used @ π20 beamline)
  - σ ~ 20 ps
  - Minimum interval of leading/trailing edge : ~1 ns
    => TOT measurement without stretcher ⇔ NINO ASIC (10 ns stretcher)
- Gas R134a:butane:SF_6 = 90:5:5

Time walk correction

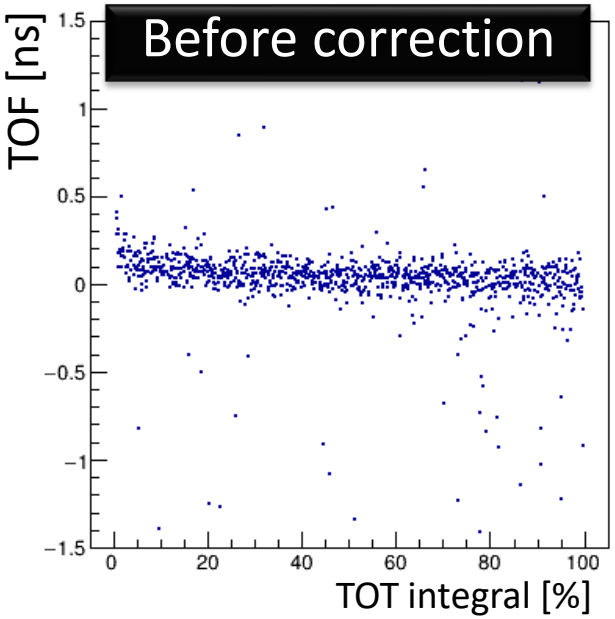


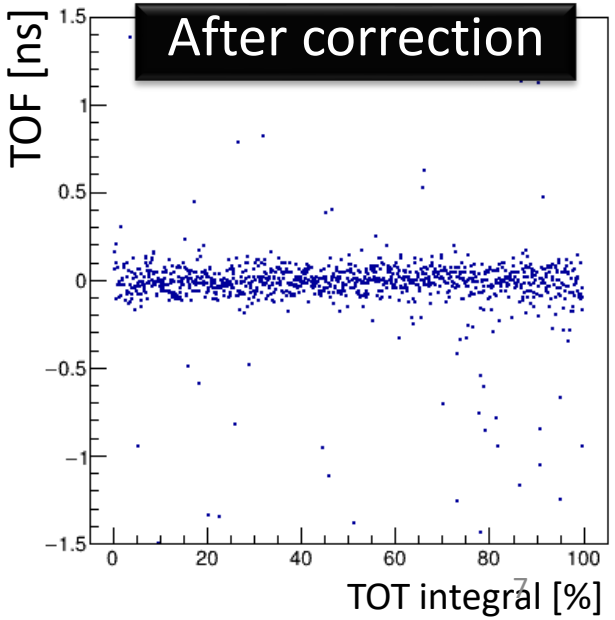
Time-Over-Threshold



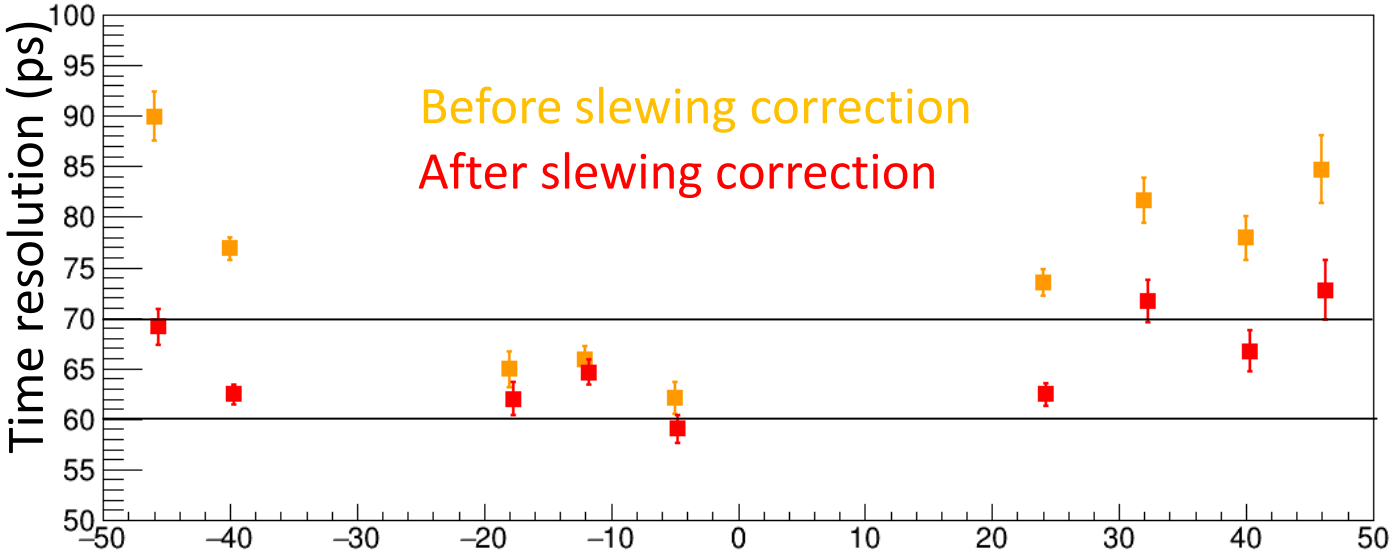


- Multi peak TOT distribution because of signal reflection at the end of strips
- Use “TOT integral” in R.X. Yang et al., JINST 12 C01012 (2017)
- **Worked well without stretcher**



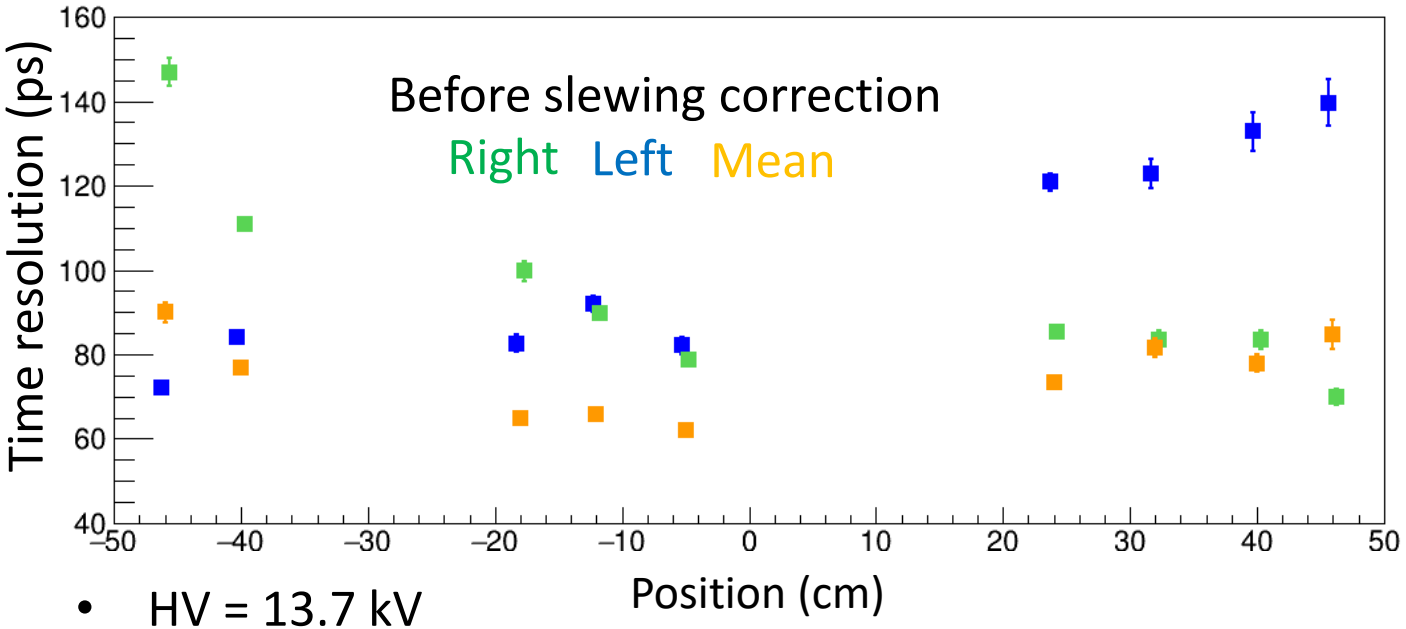


Time resolution



Good resolutions in all positions

60～70 ps

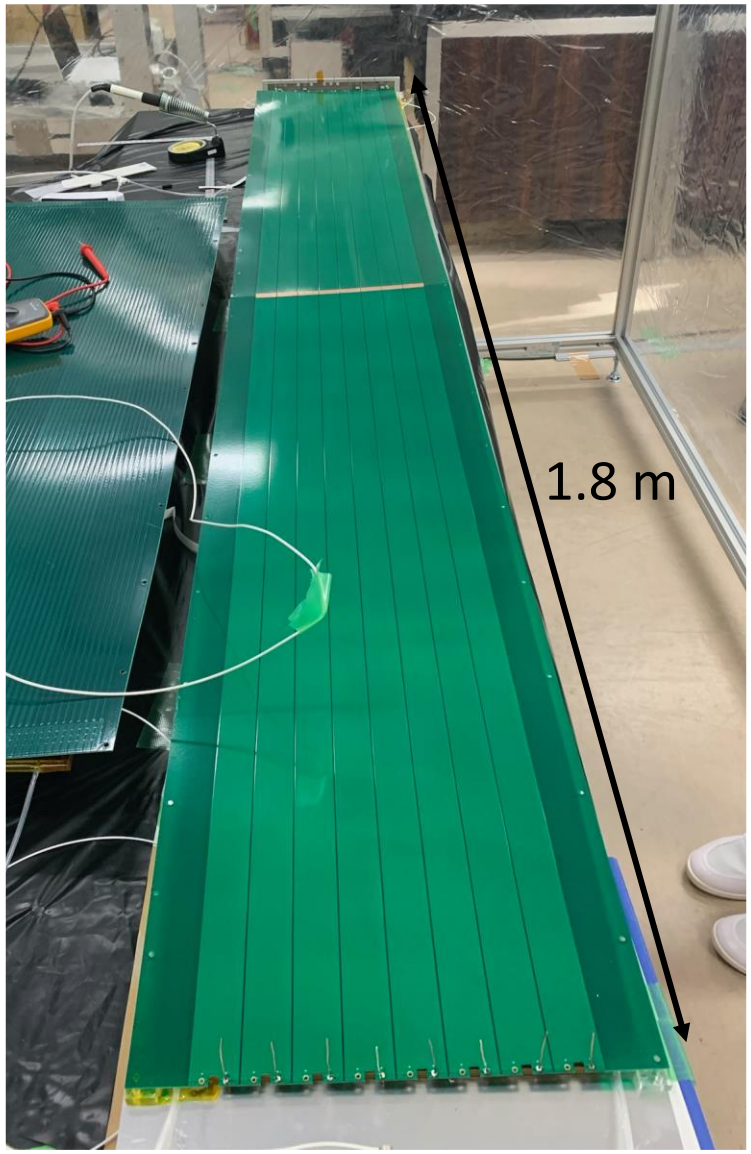


Worse resolution at single end with longer propagation length

test with lower threshold

- HV = 13.7 kV
- V_{th} = -140 mV

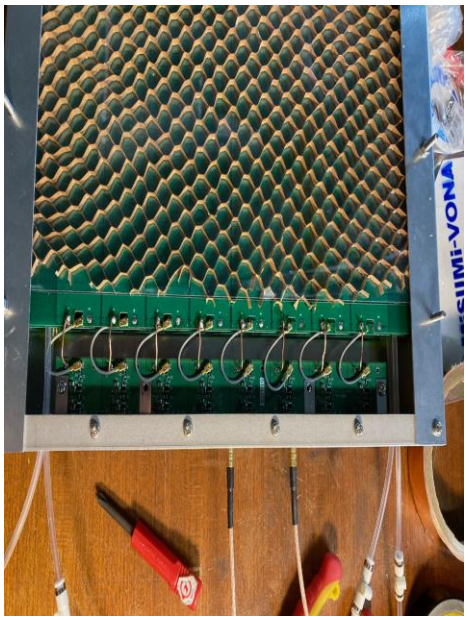
Prototype 1.8-m RPC

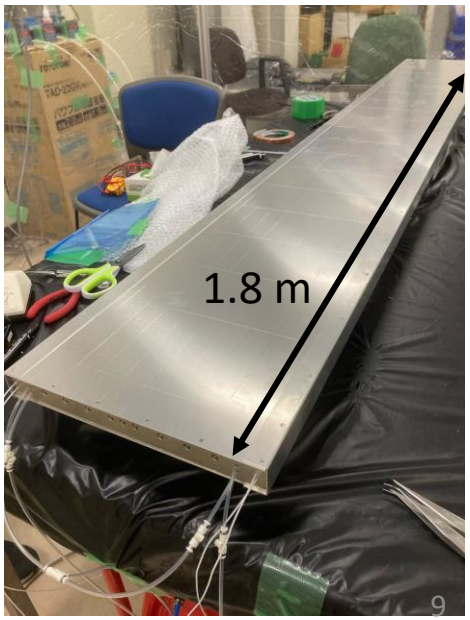


- Same configurations as 1.0-m prototype
- Connect two 0.9-m long readout strip boards/glasses (LEPS2 2-m RPC design)

K. Watanabe et al., NIM 925 (2019) 188

- Different impedance matching resistors in difference strips for matching test
- New carbon electrode

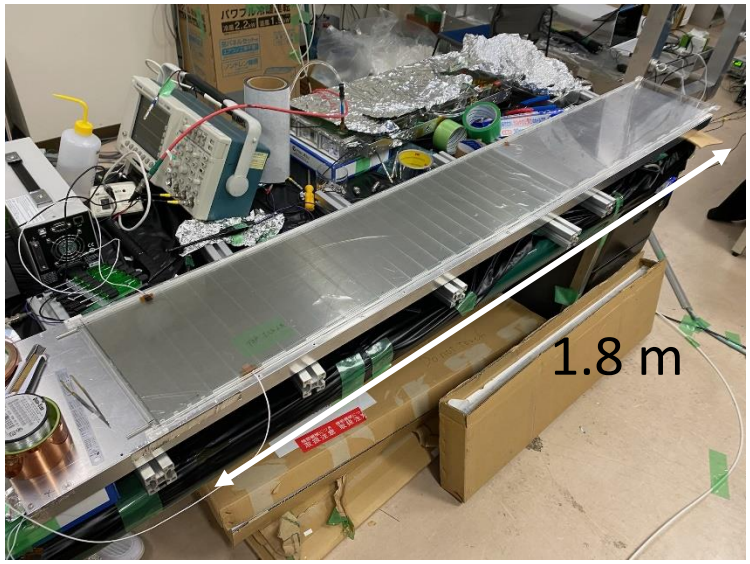




Carbon electrode

MK-APT (Tanimura Co.)

- Worked well with 10 cm x 10 cm TOF-RPC (J.Takahashi master thesis, Tohoku univ. 2020)



No signal observed after a few hours

does not work in large are

SHiP-RPC's carbon ink

Thanks to Dr. Luis Lopes

- Need a skill for a good painting

No signal observed

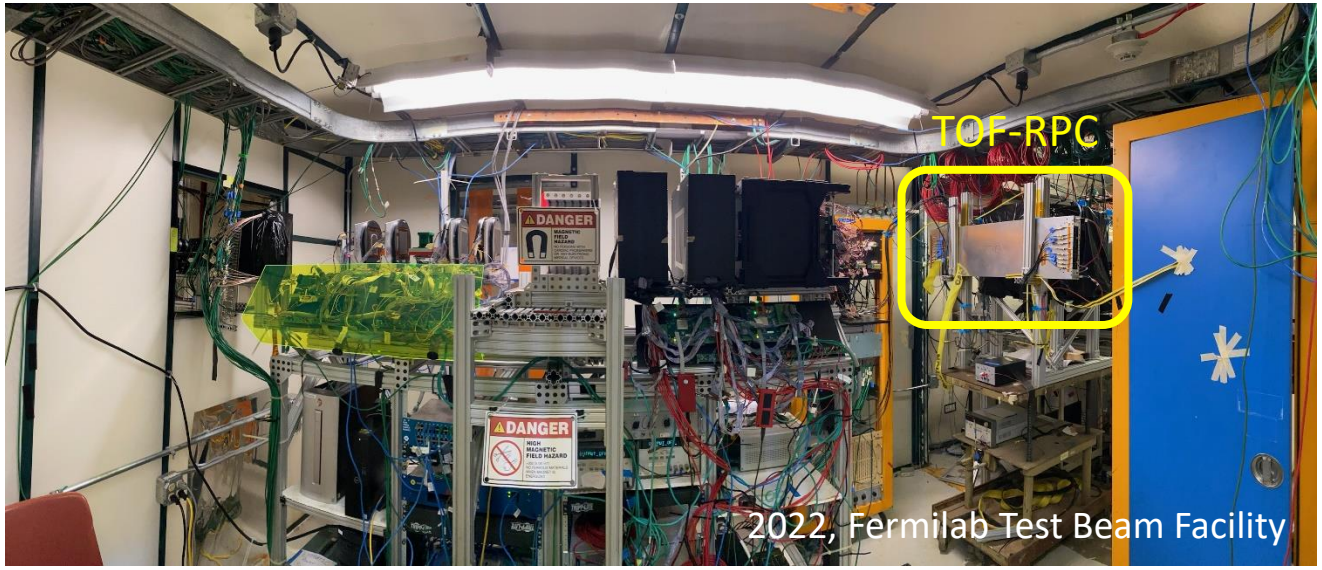
Need a skill up

Japan-Taiwan RPC collaboration

- Common development of preamp, carbon, readout strip, gas tight method

- π20 beam line @ J-PARC
  - **TOF-RPC for K/π ID**
  - **TOFtracker-RPC for μ ID**
- E88 experiment @ J-PARC
  γ+A→Φ+X, Φ→KK
  - **TOF-RPC for p/K/π ID**
- LEPS2 experiment @ SPring-8
  γ+p, γ+d, γ+A
  - **TOF-RPC for p/K/π ID**
- EMPHATIC experiment @ Fermilab
  Hadron measurement for neutrino exp.,
  π+A, p+A (ArXiv 1912.08841)
  - **TOF-RPC for p/K/π ID**

The π20 1-m prototype-RPC is now used for the EMPHATIC phase-1 run



Summary

- High momentum secondary particle beamline (π20 beamline) will be constructed at J-PARC
- 1.8-m long TOF-RPC will be used for π/K/p ID at p<2 GeV/c
- TOF-tracker RPC will be used for μ ID → next talk
- 1-m prototype RPC / amp show good performance : σ_{TOF} = 60~70 ps
- Confirmed that Time-Over-Threshold (TOT) measurement works with KEK Esys HR-TDC without stretcher
- Problem of carbon electrode
- Japan-Taiwan RPC collaboration (J-PARC/SPring-8/Fermilab)