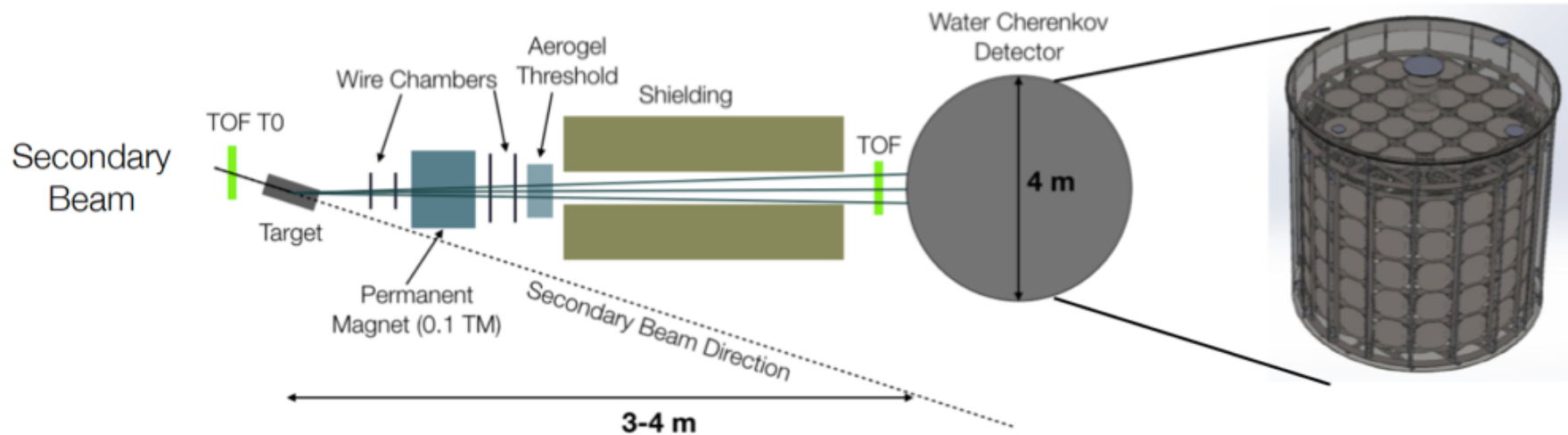


RPC for TOF at WCTE

Roger Wendell
Kyoto University
WCTE Collaboration Meeting
2021.11.29

WG: Megan Friend (KEK), Natsuki Tomida (Osaka U. RCNP), R.W.

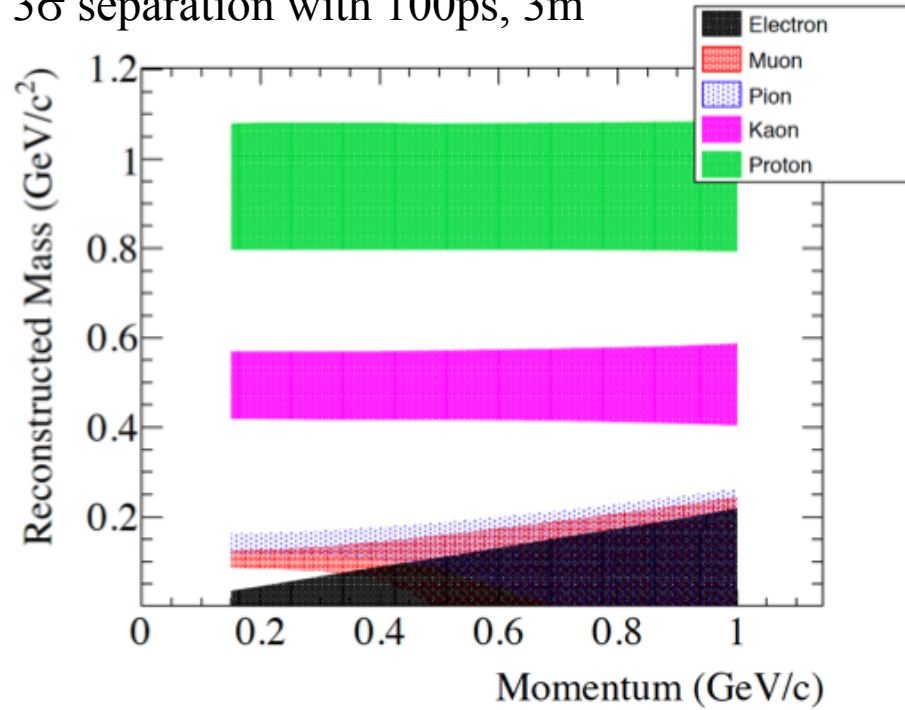
Introduction



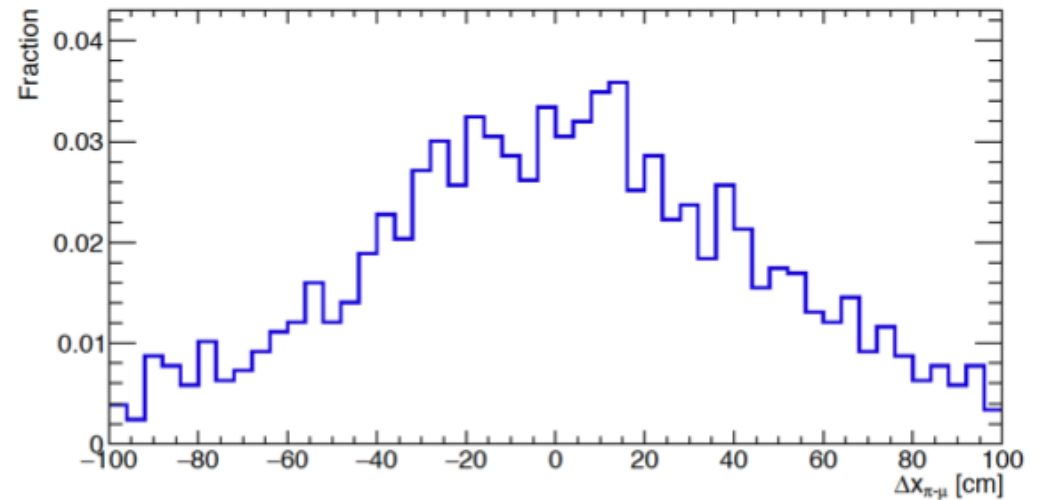
- Discuss requirements, design ideas, construction method, and costs for WCTE TOF
- Based largely on work currently underway for the EMPHATIC (hadron production) and J-PARC E50 (Charmed Baryon Spectroscopy) experiments
 - Already realized large area (230mm x 940mm) Multi-stack, Multi-gap RPCs with ~60 ps resolution
 - E50 is currently working on a design similar to what we would like for WCTE

Requirements

3σ separation with 100ps, 3m

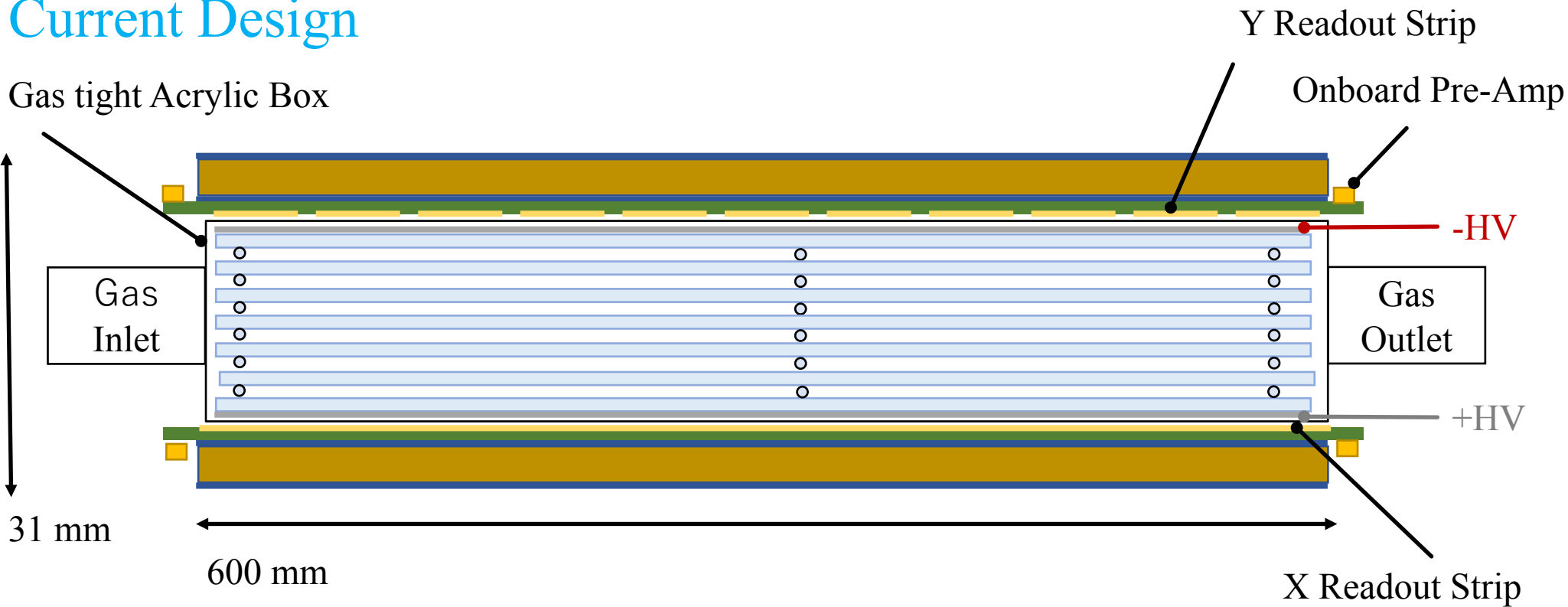


$\Delta(\mu$ and extrapolated π hit positions)



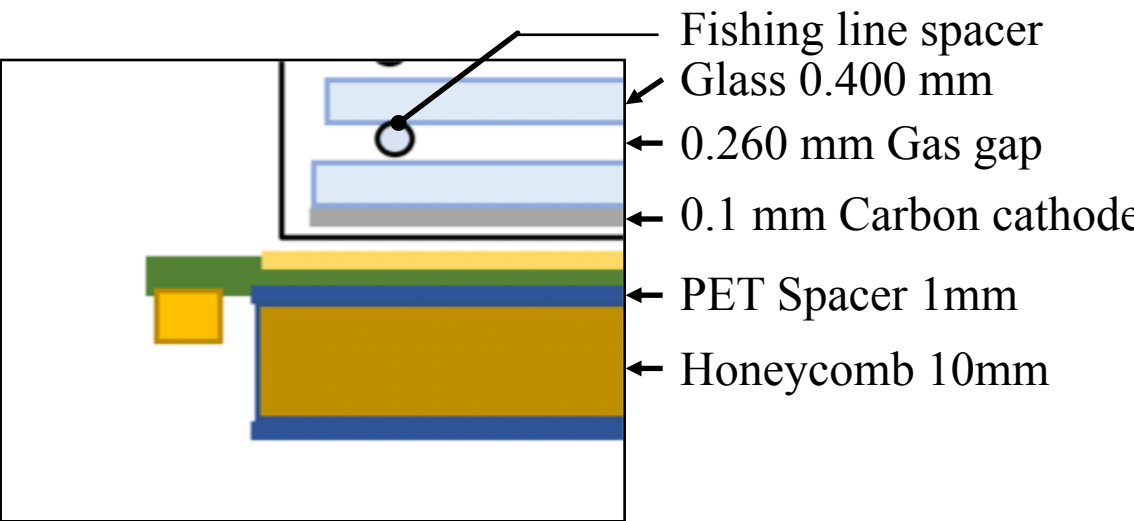
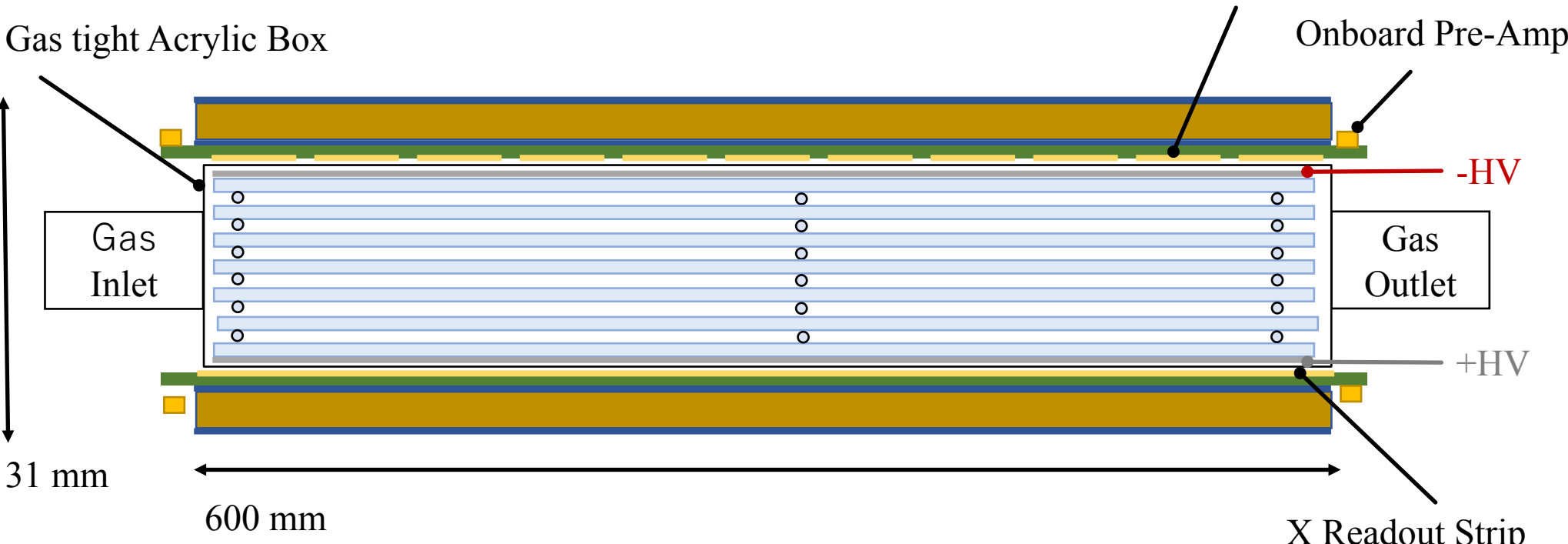
- Large size : At least 60cm x 60cm to cover beam spot
- ~ 100 ps resolution for beam particle PID
- Segmentation for decay-in-flight $\pi-\mu$ separation

Current Design



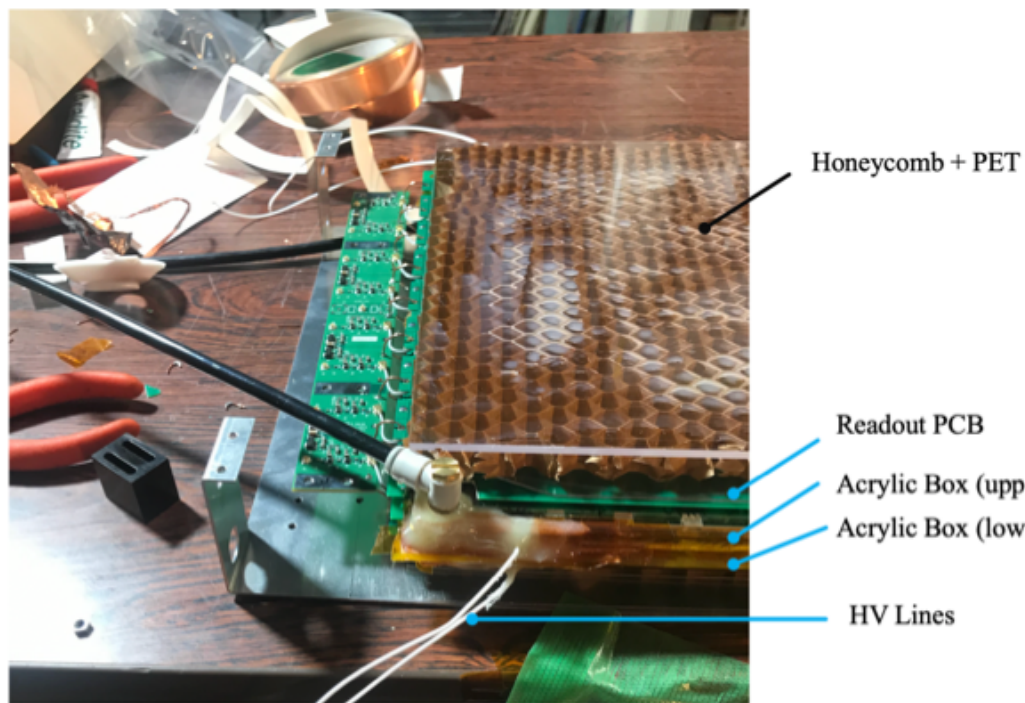
- 600 mm x 600 mm sensitive region
- 2 cm wide readout strips in both X and Y directions
 - Readout on both sides of strips
 - Amplifier gain ~ 300
- HV: Operate at 13.5 kV
- Gas: Operate with 90% R134a, 5% SF6, 5% Butane
 - Investigating reduced SF6 down to 0.5% in favor of more R134a

Current Design



- Most parts are either commercially available or relatively easy for companies to produce
- Housed within an aluminum case (not shown)
- Gas is contained entirely within acrylic volume
 - $\sim 3.6 \times 10^7 \text{mm}^3$

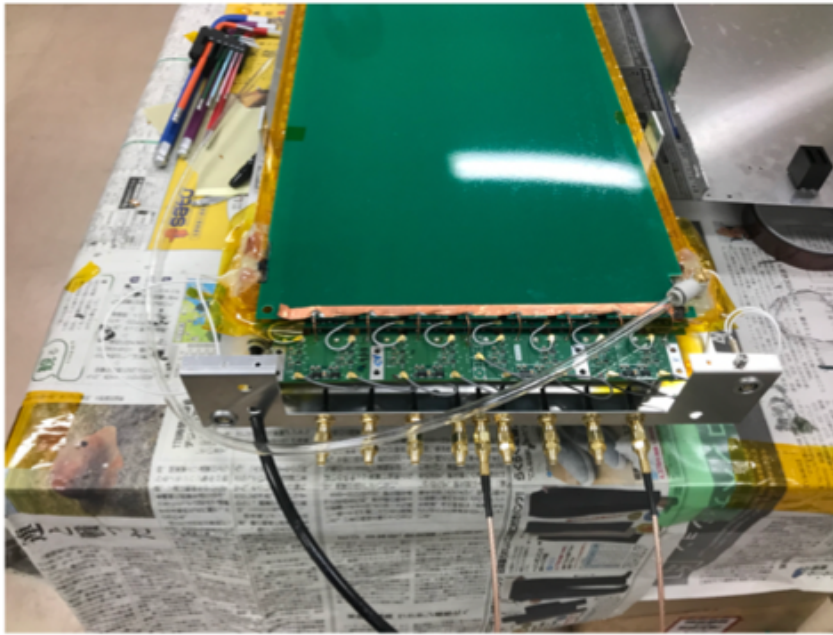
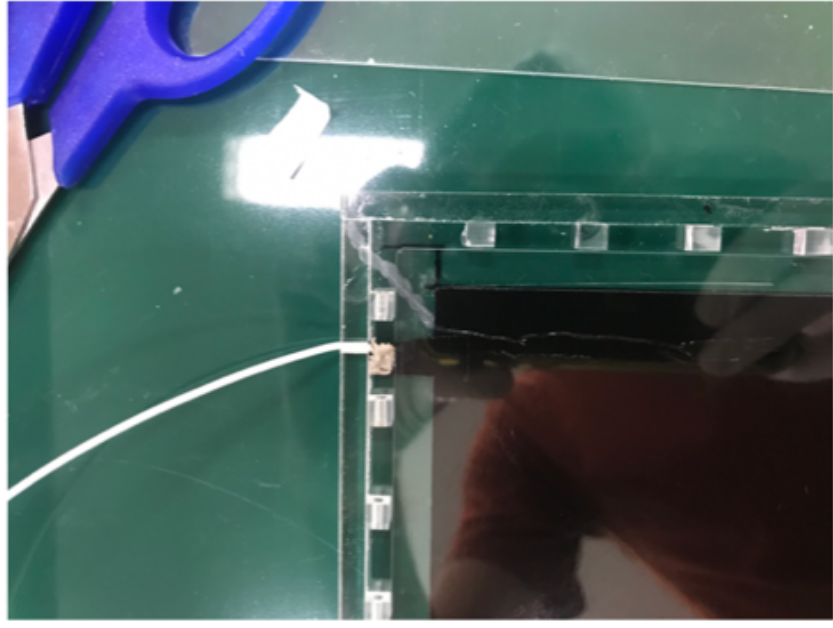
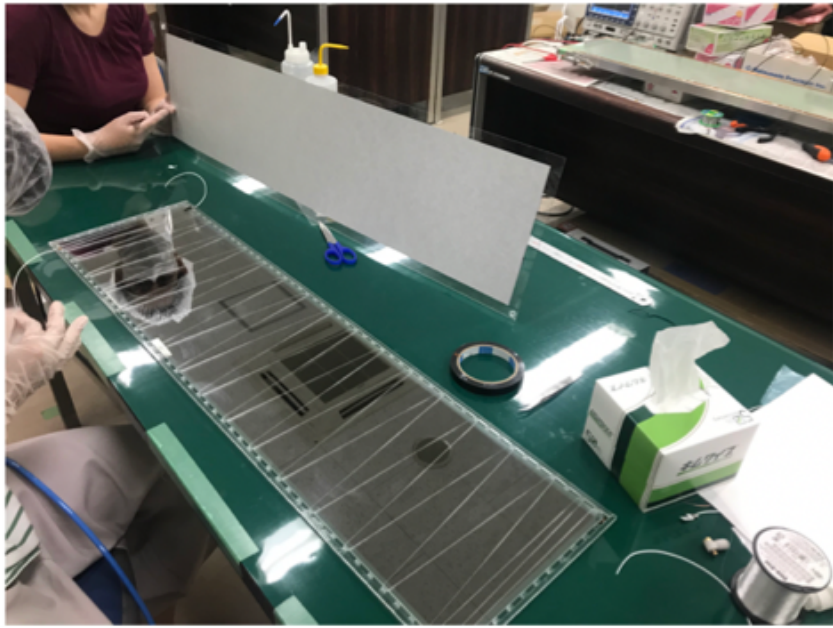
Construction: EMPHATIC RPC



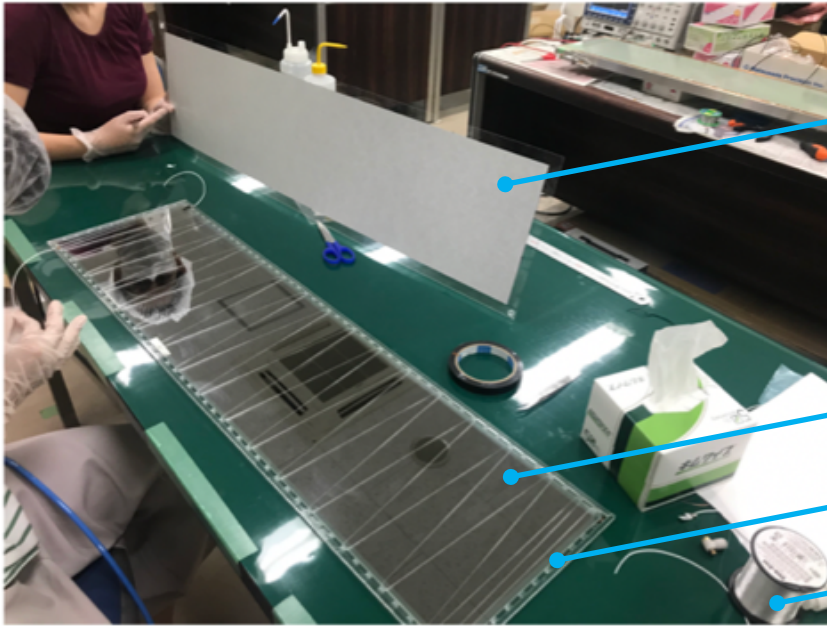
- The following is based on experience building EMPHATIC RPC (230x940mm²)
- Can be assembled by hand by students and staff without too much trouble
- Total cost per RPC ~ USD 5k
 - Including amplifiers and discriminators
- Takes O(1) week to construct once all materials are in hand

Material	Production	Comment
Readout PCBs	Chinese Company via Tsinghua U.(Beijing)	U.FI readout, Taiwan Design
Acrylic Case	CI Industries (Japan)	Gas tight frame (except lid)
Glass	Mitsuru Kougyou (Japan)	Soda glass, 0.4m T
Amp. + Fast Discr.	Academica Sinica (Taiwan)	Electronics engineer
Aluminum Case	Suzuno (Japan)	1mm T
Carbon Tape	EEEEC Engineering (Japan)	Expensive, size limitations*

Construction: EMPHATIC RPC



Construction: EMPHATIC RPC



Acrylic Case Lid: White part is carbon cathode tape still with its protective plastic film

Carbon tape without plastic film. Glass plane has been laid on top, with fishing line woven on top

Acrylic case base:

Fishing Line: Queen Star (0.260mm)

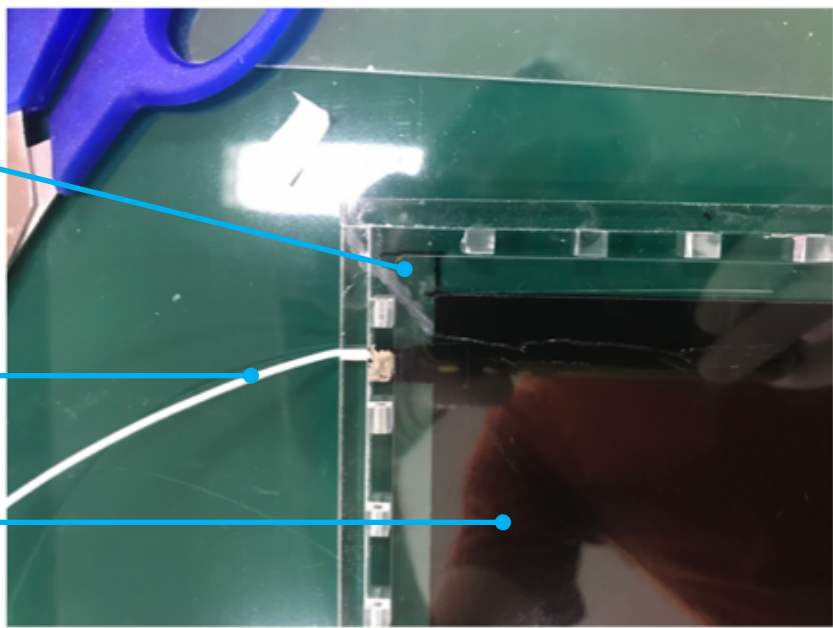
- Constructed in a normal lab space with copious use of compressed air.
- Future productions will use a simple clean room

Construction: EMPHATIC RPC

Glass laid atop carbon tape (black)

HV Lead – gas prevented from leaking via adhesive glue (Araldite)

Carbon tape (electrode) beneath glass, first glass plane with no fishing line

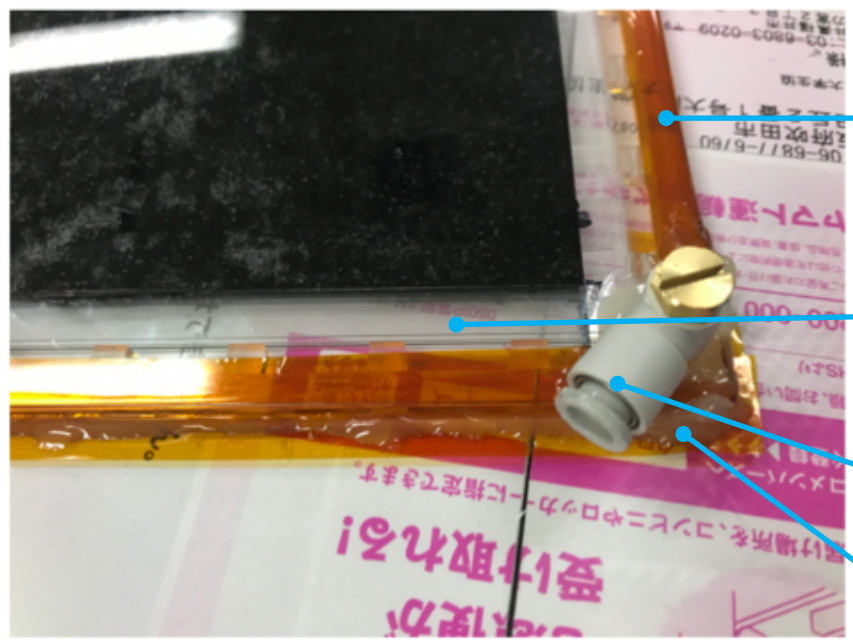


Lid sealed to case with Kapton tape in most places. 50mm wide tape now preferred (20mm in picture)

Stack of 6 glass panes (5 gaps)

6mm gas connector. New design uses 3mm tube outlet from the side of the box. Use this for WCTE

Corners glued to seal leaks



Construction: EMPHATIC RPC

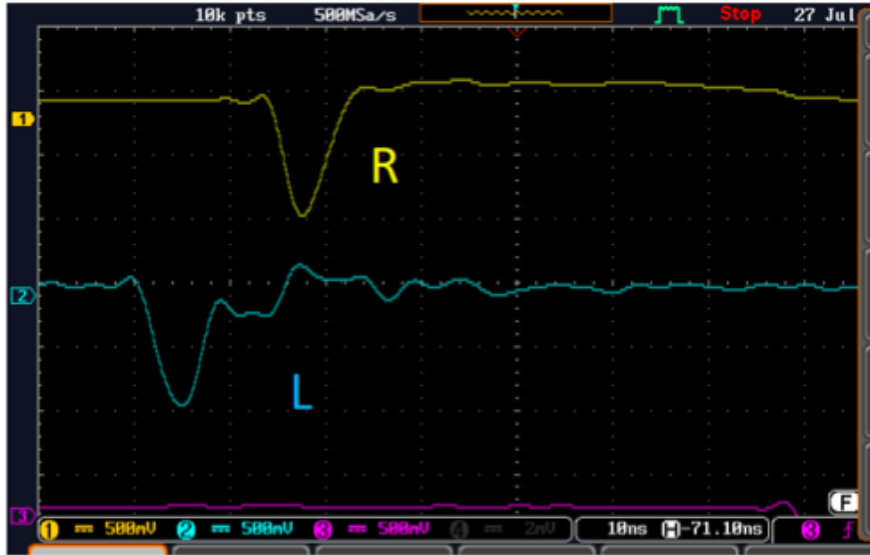


U.FI connection from readout strip to preamplifier

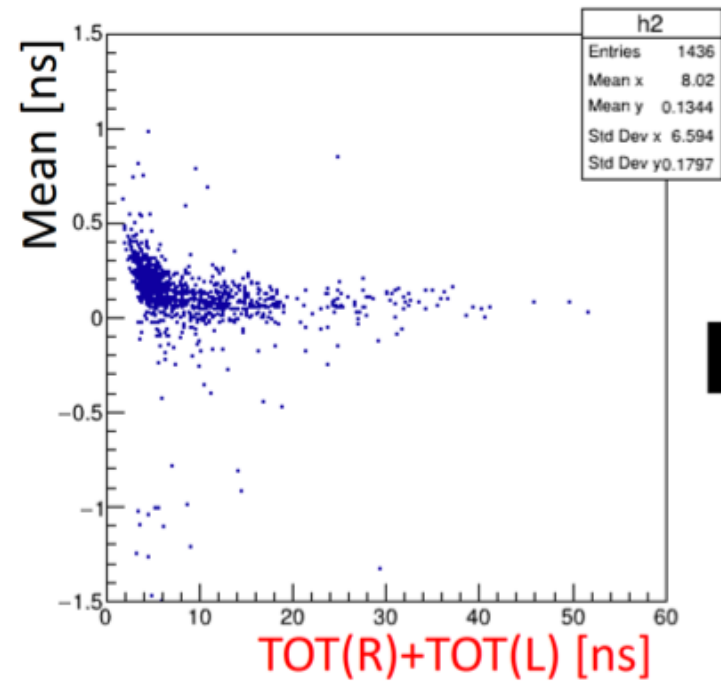
Rather complicated output of amplifier signal: U.FI \rightarrow SMA \rightarrow MCX to connect to fast discriminator

Modify for WCTE design

Operation: EMPHATIC RPC



Data from e⁺ beam (converted) at Spring-8

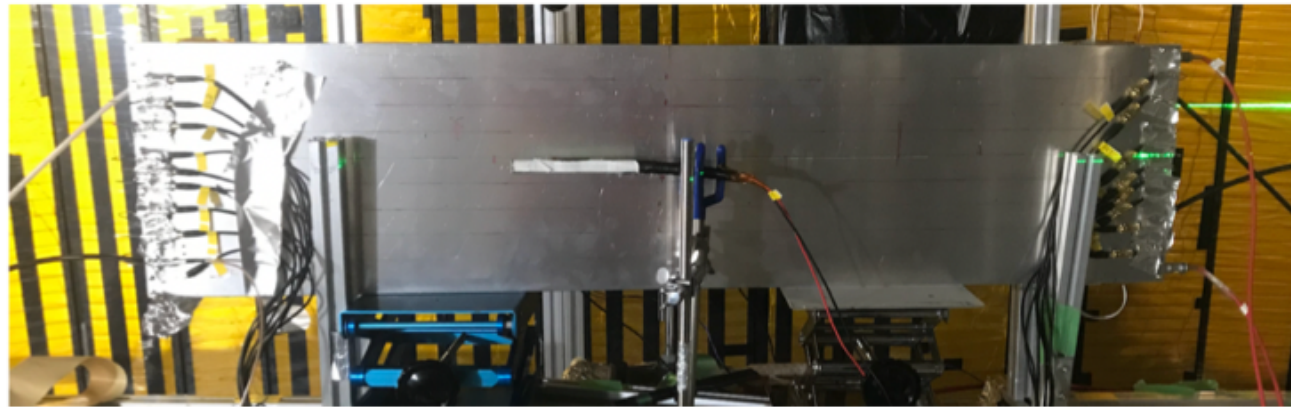


- Nominally operate at ~ 40 cc / min with R134a:SF6:Butane - 90%:5%:5%
- Readout both sides of the RPC
 - Typical noise ~ 20 - 30 mV, discriminate ~ 100 mV
 - Amplifier output < 2 V
- Time over threshold used for slewing corrections
 - Some localization based on timing difference at edges
- ~ 60 ps at < 20 Hz /cm² for EMPHATIC RPC

Operation Comments:

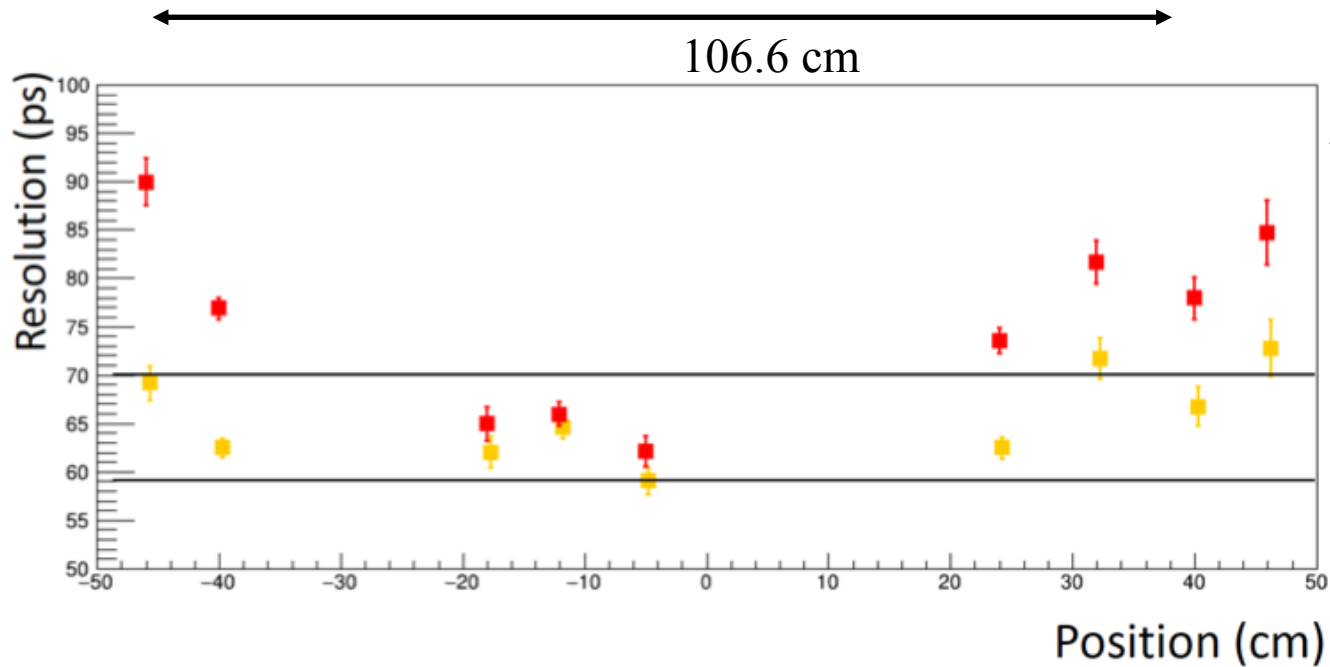
- For our tests thus far, circulated (positive pressure) gas is released into the atmosphere after flowing through RPC
 - With a reclamation system, any and all gas could be reused in principle
 - Currently not done for lack of such a system, but will add to R&D items if necessary
- With current acrylic gas volume leak rate is found to be negligible, essentially zero, when sealed (3M polyimide tape + adhesive glue) and operated at 40 cc/min
 - With reclamation: very little greenhouse gas emission expected
 - Without : ~38 cc/min (95~98% R134a+SF6)

EMPHATIC RPC: Resolution with Finger Scintillator Trigger



Strip Numbers

8
7
6
5
4
3
2
1

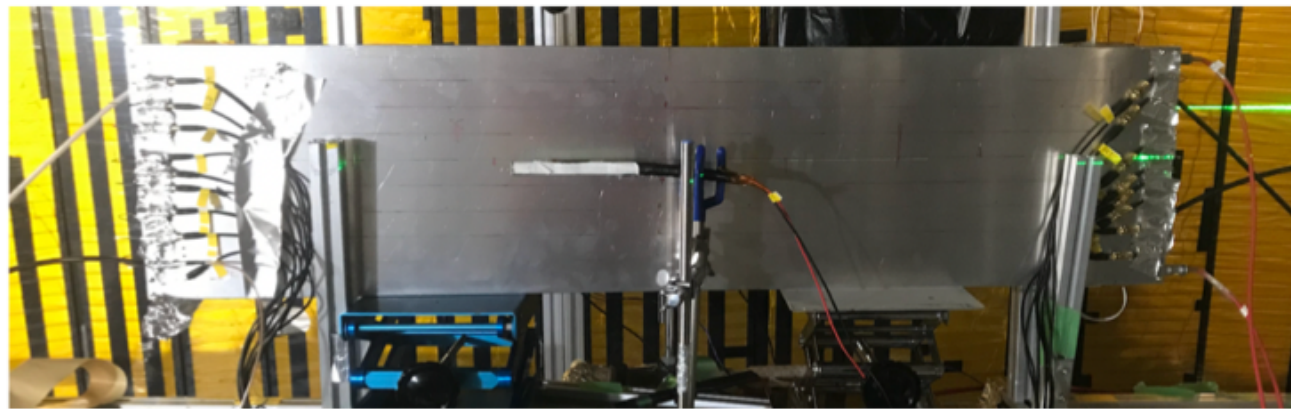


N. Tomida

Strip 5

Without slewing correction
TOT-integral slewing correction

EMPHATIC RPC: Resolution with Finger Scintillator Trigger

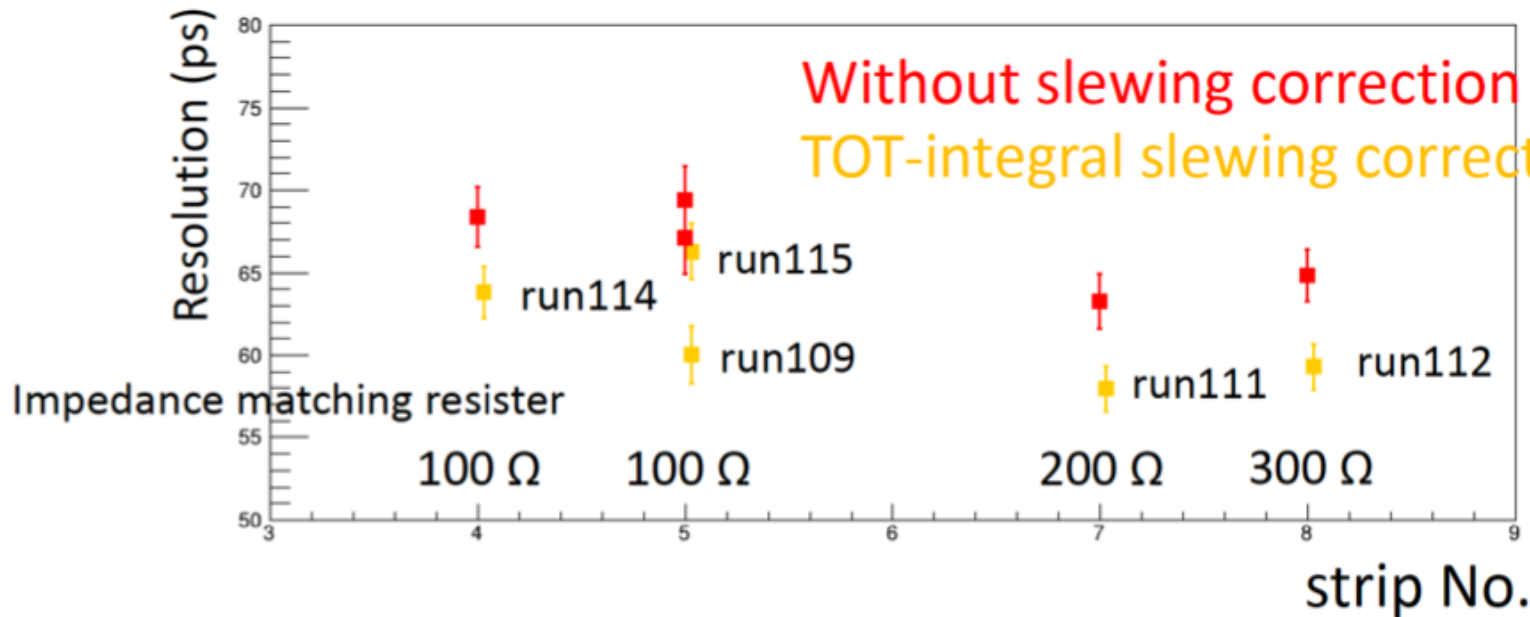


25.2 cm*

Strip Numbers

8
7
6
5
4
3
2
1

106.6 cm



N. Tomida

X = -5 cm

■ Similar resolution across strips

Status

- Submitted application for funding through Japanese Kakenhi system in Fall 2021 (Lead PI: Masaki Ishitsuka)
 - Expect funding decision before April, 2022
 - Would cover TOF, Water System, mPMTs
- Prototype tracker RPC for E50-Drell-Yan experiment in development now, similar to what is envisaged for WCTE
 - 1020mm x 530 mm gas volume
 - 5mm pitch strips
 - 2-layer PCB, ground plane and strips on opposite sides
 - → Refine WCTE design based on test early next year

Howemork, R&D

- Current PCB company has size limitation of 550mm x 1060 mm,
 - 600+ mm square may require new company or multiple smaller RPCs
- Carbon tape used for EMPHATIC RPC expensive, production size limitations → WCTE and E50 Tracker RPCs will be made using a different tape
 - Much cheaper and lager
 - First test with a full-sized RPC upcoming
- Beam test scheduled for January 2022 at Spring-8 (Japan)
 - Basic performance of Tracker RPC for E50 Drell Yan
 - Test impact of reduced SF6 and reduced Butane gas
 - Test temperature dependence

Summary

- WCTE RPC is being designed in consideration of recent R&D efforts at EMPHATIC and E50 experiments
- No major hurdles from a construction perspective
 - Funding is still pending, but will be known in spring next year
 - Need design for gas reclamation?
- Beam test in January 2022 will address some lingering questions, like reduced SF6 impact, and confirm basic performance of an RPC similar to what we would like for WCTE