清華大學
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The novel sealed technology for high time precision MRPC in CEE project

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On behalf of eTOF subsystem of CEE

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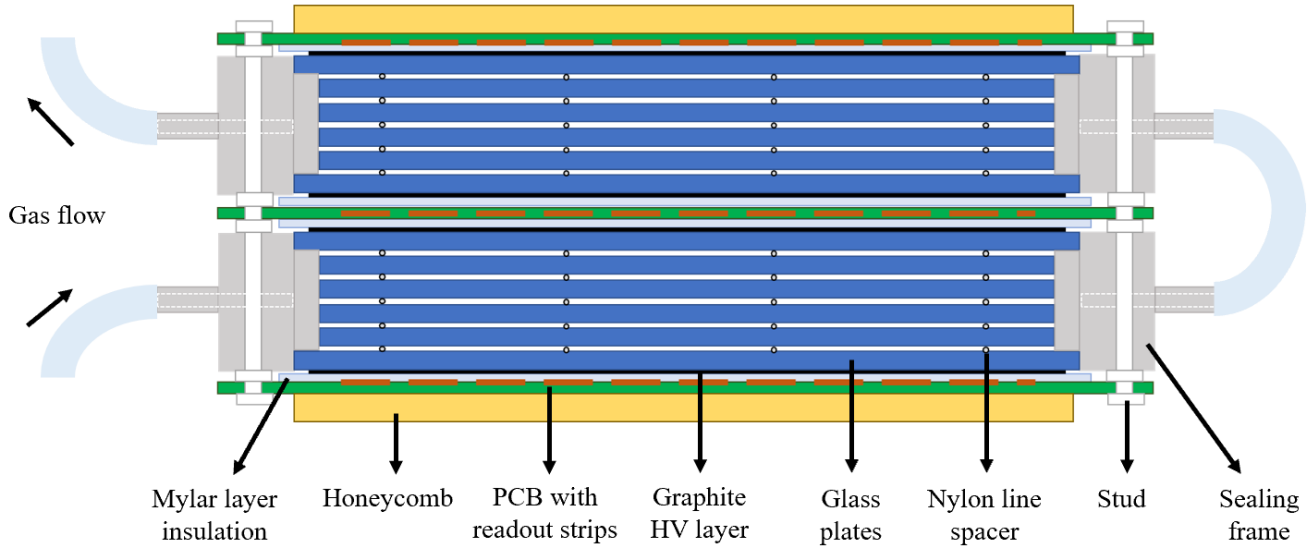
Outline

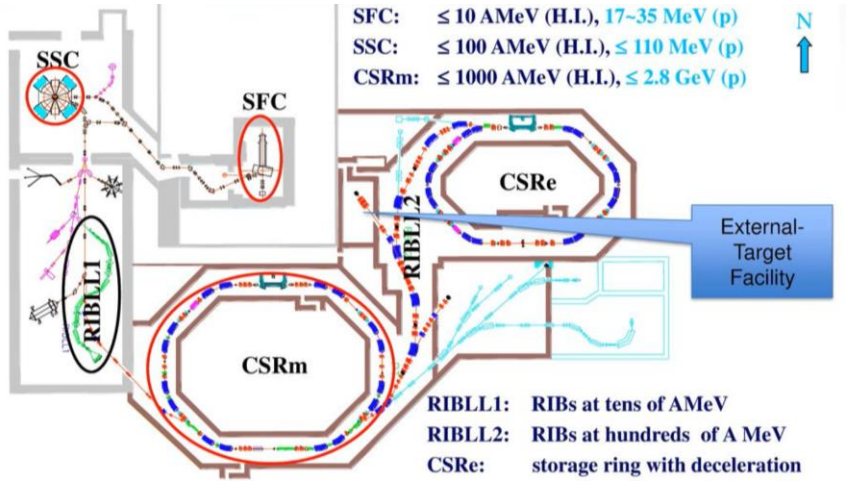
- The CEE project and eTOF sub-system
- The sealed MRPC
  - Motivation
  - Structural design
  - Prototype performance
- Status of CEE-eTOF
- Summary and outlook



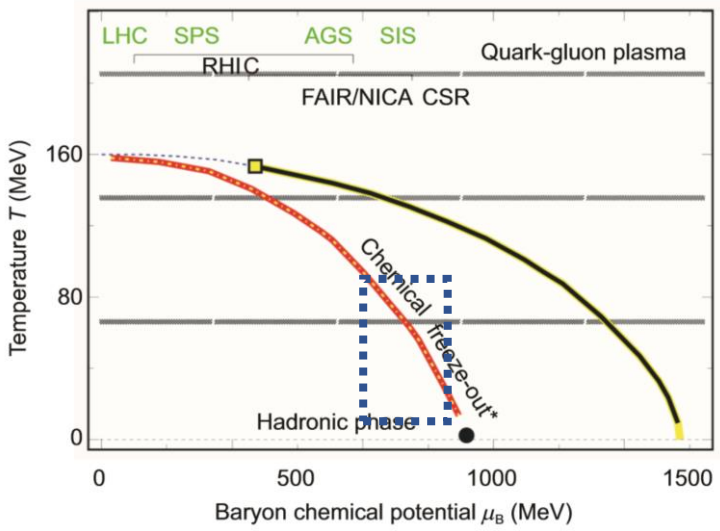
The CEE project

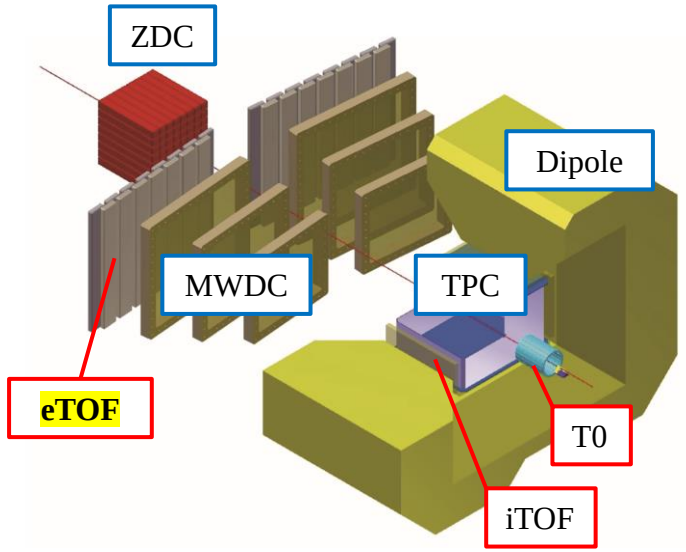
The CSR (Cooler Storage Ring) External-target Experiment (CEE)

- @ Heavy Ion Research Facility in Lanzhou, China. (HIRFL)
- **Physics destinations**: Low temperature & high density in QCD phase diagram, EOS for nucleus matter, hyper-nucleus.
- **Beam from CSR**: Heavy ion (up to U+U) collision, 0.5-1.2GeV/u, 10^4evts/s
- **Timing detectors** (MRPC): T_0, iTOF, eTOF



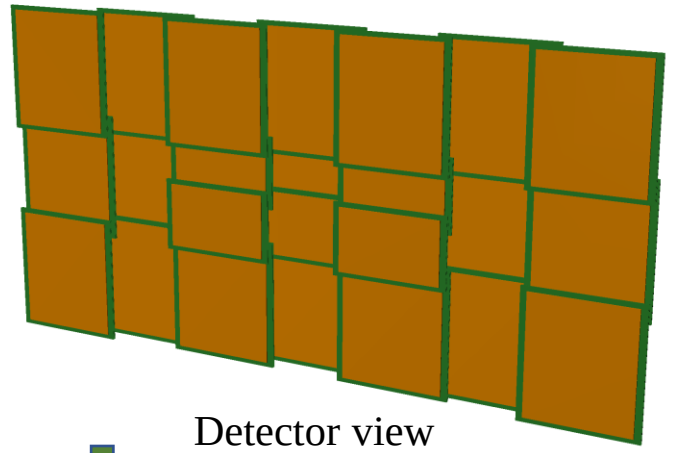
index	T0	iTOF	eTOF
Distance from collision	10~20cm (barrel inner diameter)	≥50cm	2.5m
Effective coverage	1m²	3m²	5.1m²
channel	300	~1200	~1500
Timing requirement	50ps	50ps	80ps
Gas gaps	10~12	24~32	10



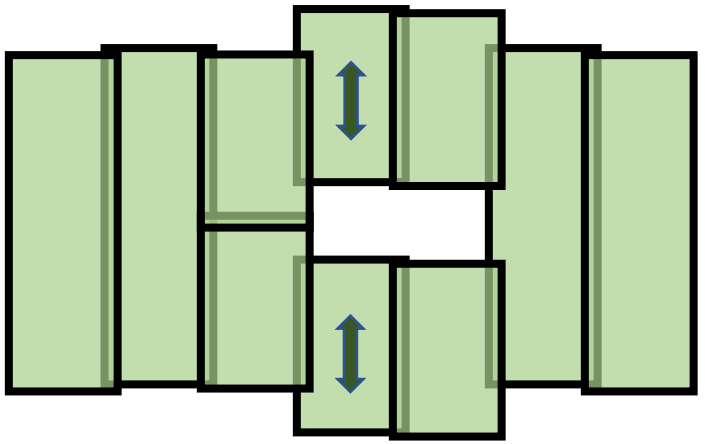


General design of eTOF wall

- Location: 2.5m from collision point, 2.15m from center of TPC.
- Coverage: 3.2m×1.6m, designed from CeeROOT simulation.
- Channel constraint: <1500
- Multigap resistive plate chamber (MRPC) technology.
- 2 types of size, with 32 and 16 readout strips.
- 2 kinds of modules, containing 2 or 3 counters.
- The inner modules move along Y direction, leaving space for various beam conditions.



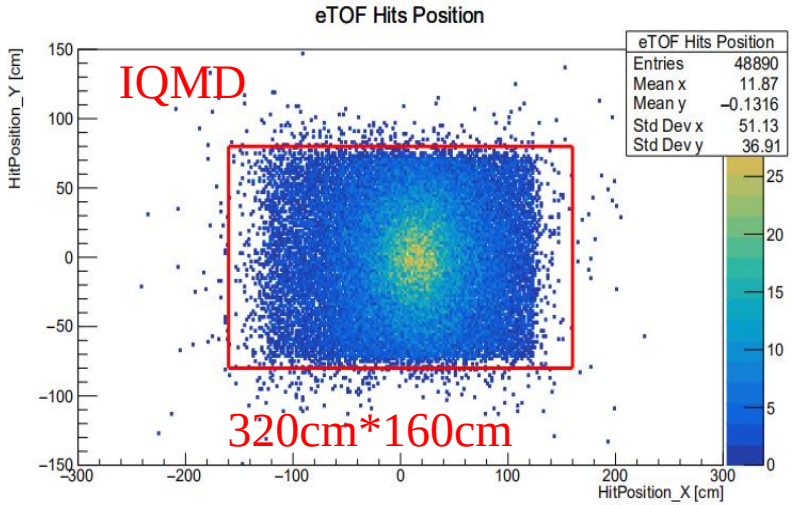
Detector view



Module view

Index	Value
Max rate	3 kHz/ch
Occupancy	< 15%
Flight-time width	~10 ns

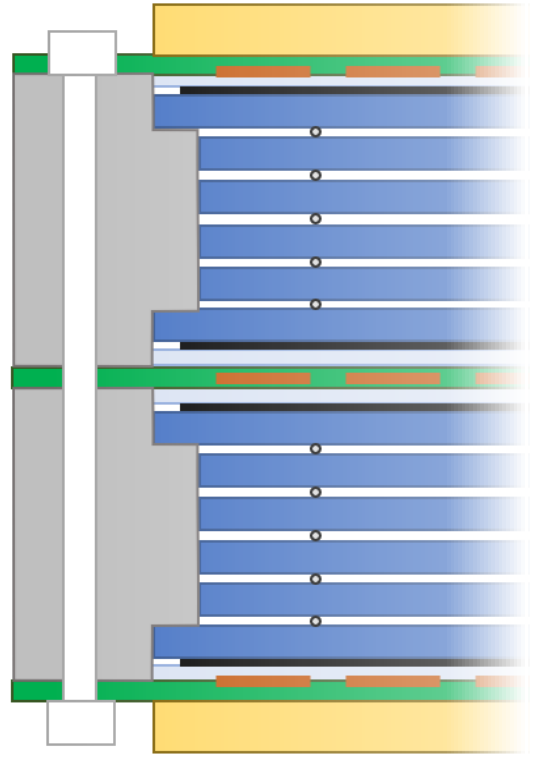
Parameters by simulation



eTOF MRPC design

Performance requirements：

- Efficiency: over 95%
  - Double stacks, 2×5 gas gap, 0.25mm for each gap
- Time resolution: better than 80 ps
  - Double-end readout
- Geometry:
  - 16, 32 strips
  - Pitch 17mm, 15mm width + 2mm gap.
  - Length 48cm
- **Estimated strip impedance 35Ω** *
- **Sealed design**



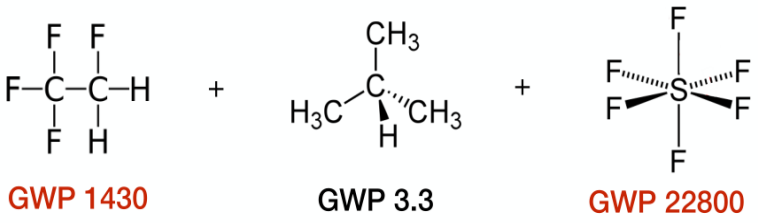
Conceptual layout

* Based on the empirical formula in:
Yu, Y., et al. "Study of transmission-line impedance of strip lines in an MRPC detector." *NIMA* 953 (2020): 163152.

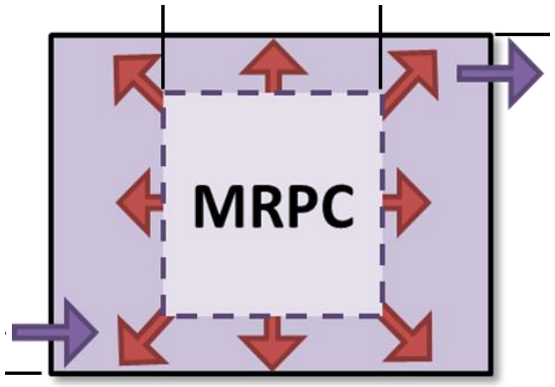
Motivation

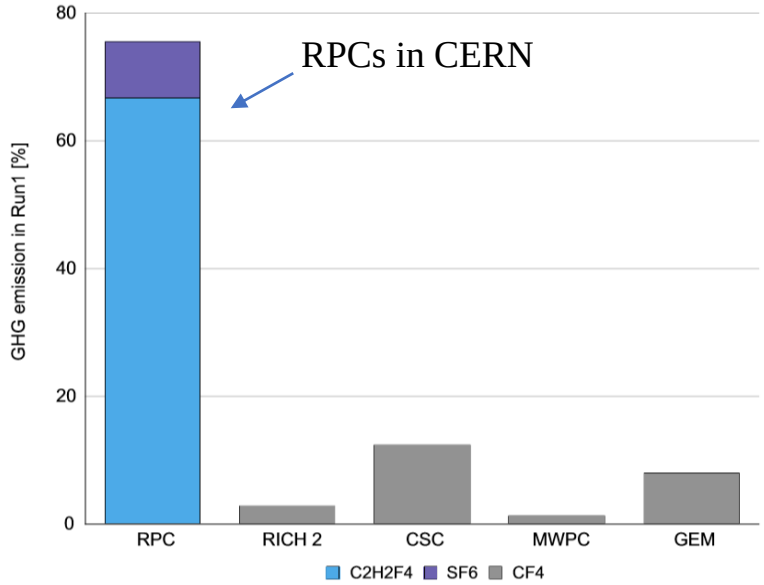
Sealed design —— Decreasing gas consuming for MRPC

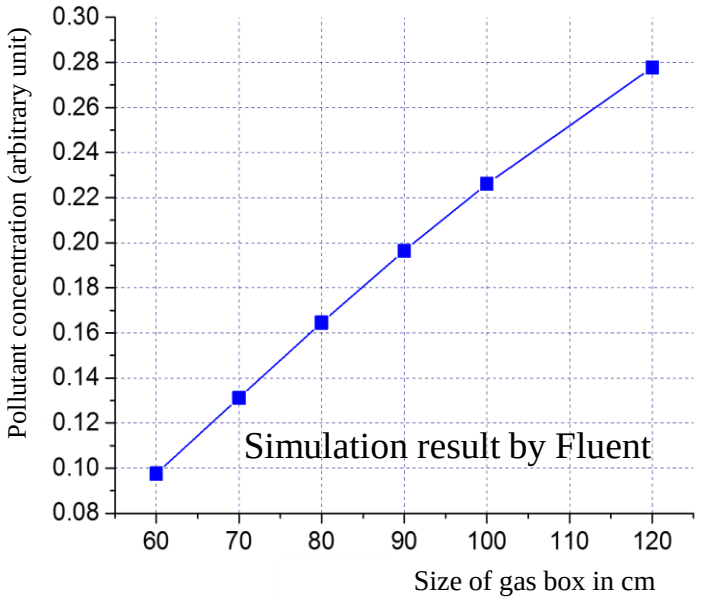
- High GWP value of working gas lead to “F-gas regulation”.
- Gas leak
  - RPC takes up most of the GHG emission.
  - e.g. CMS Phase-II RPC, gas leakage 900L/h in 2019
- High flow
  - gas exchange for MRPC is mainly by **diffusion.**
  - With a unique flow, pollutant concentration is higher with a larger box
  - High gas flow is needed to keep the clean environment in a larger box.
  - Shrink the gas box volume -> sealed design



Freon/iC_4H_{10}/SF_6 90/5/5 GWP=2427







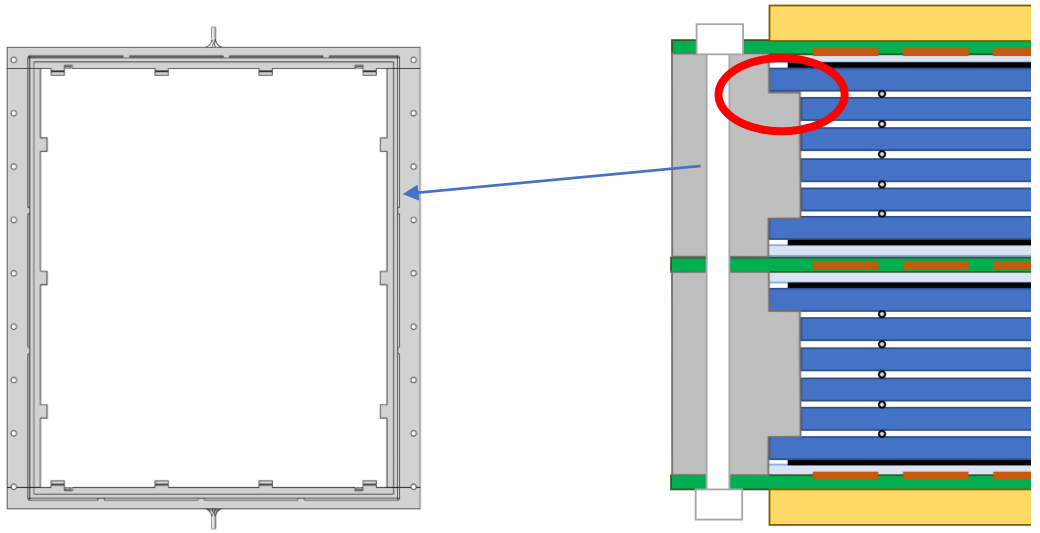
Structure design: sealing frame

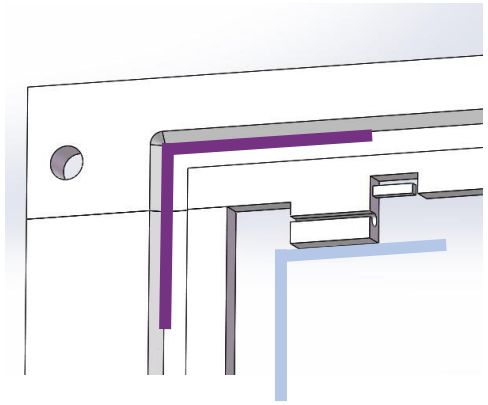
Sealing frame by 3D printing

- Gas inlet/outlet
- Spacers
- Glass position holder
- Screwing hole

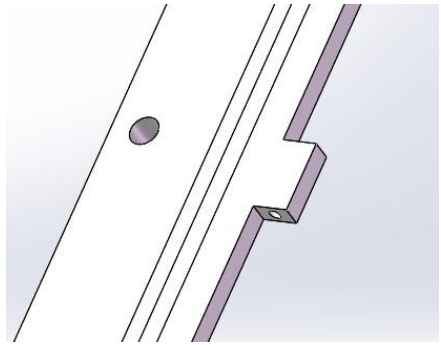
Material: photosensitive resin

- ➢ HV tolerance up to +/-10kV in test
- ➢ No aging damage observed under X-ray (45kV 0.3mA)

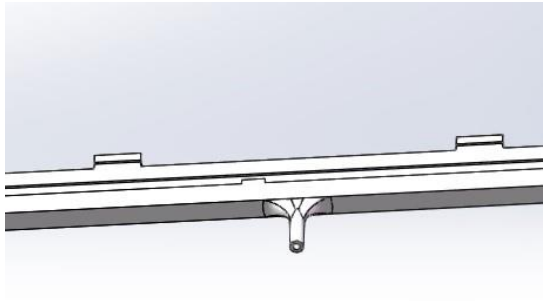




Outer (electrode) glass
Inner glasses



Gas tube

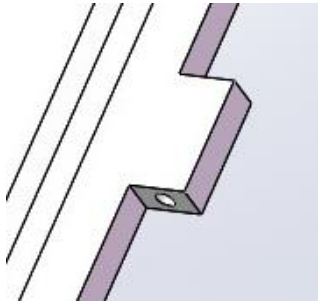


Inlet/outlet

Structure design: flow field

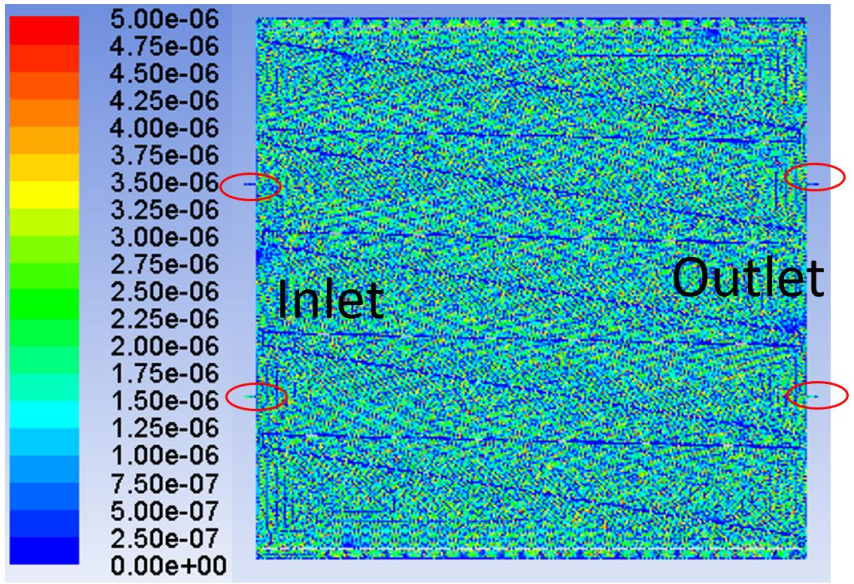
Gas flow uniformity

- Optimize the inlet/outlet placement
- 3D Flow field simulation by *ANSYS Fluent*, 3mL/min gas flow.
- Low velocity zone indicates pollutant concentration.

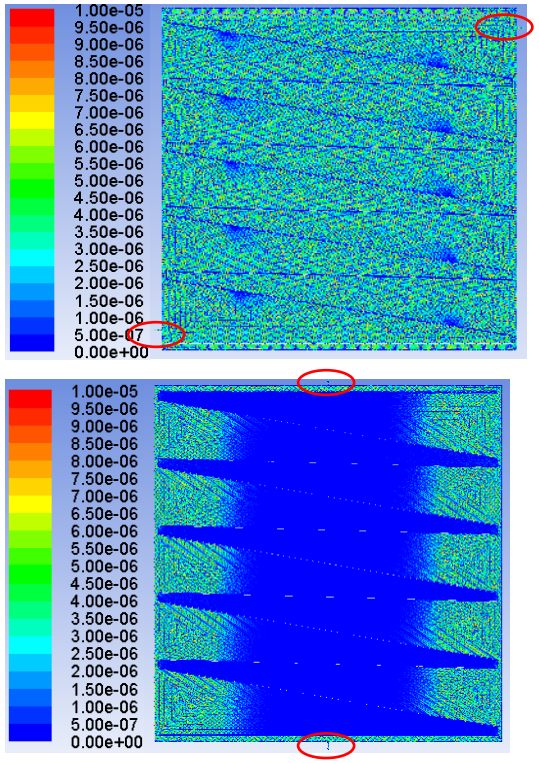


Gas tube connect the triangle gap areas

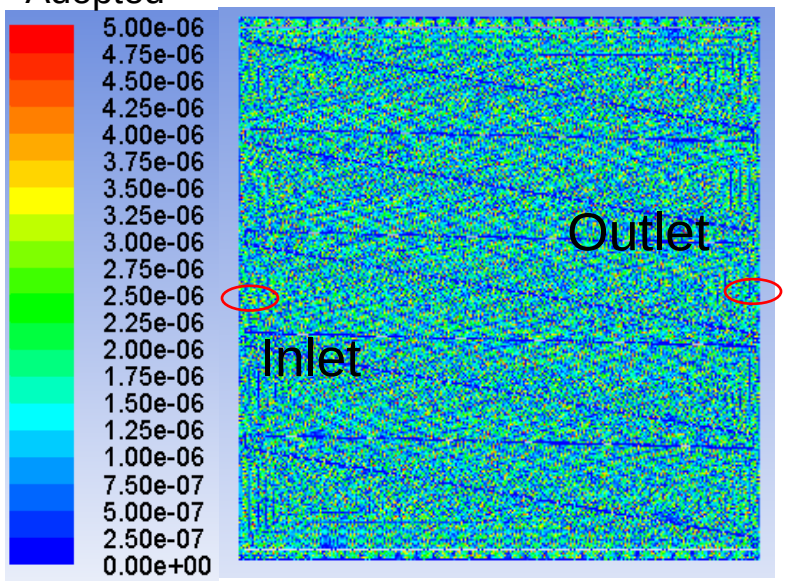
2 pairs:



Tubes at different position



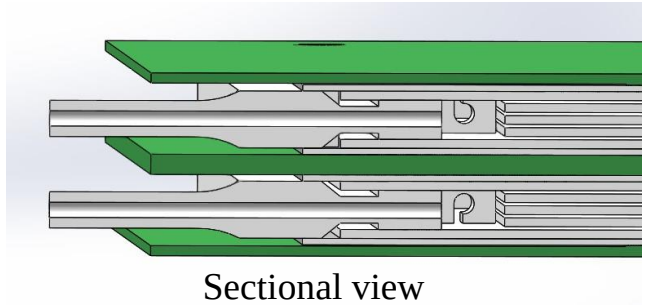
Adopted



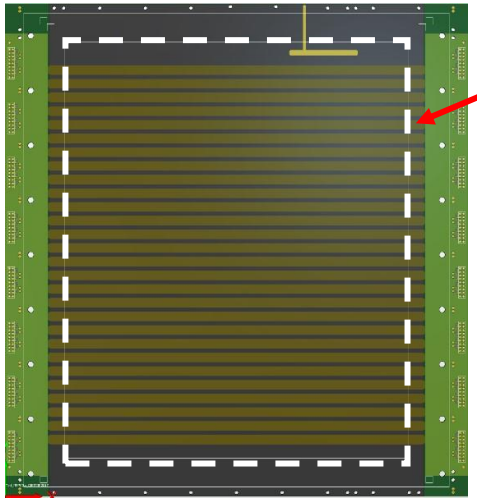
Sealed MRPC prototype

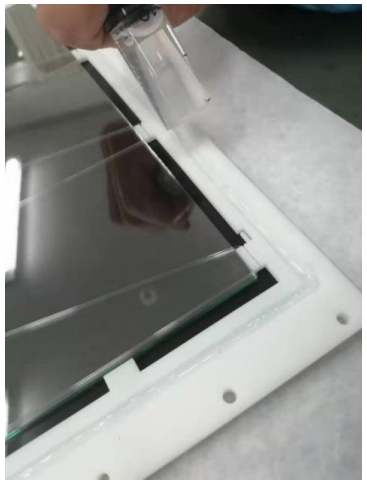
To fit with our cosmic test system, the prototype geometry is similar as MRPC2

- 2 stack * 4 gas gap * 0.25mm
- Float glass plates of 0.7mm width
- 30 channels, differential signal
- 2-end readout
- Strip length 27cm, 7mm width+3mm gap
- Sealed design, total gas volume ~170ml

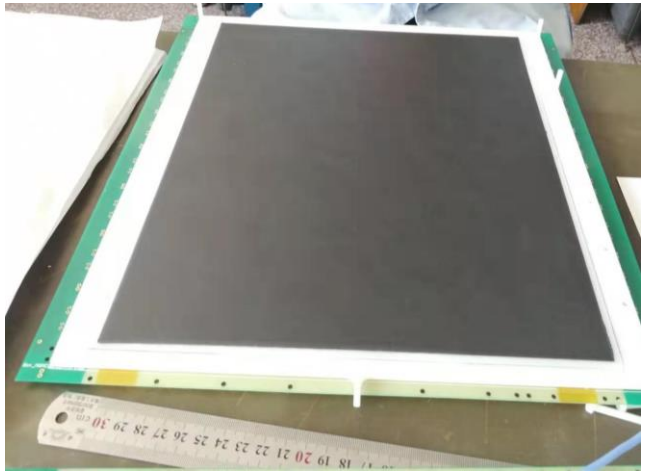


Sectional view

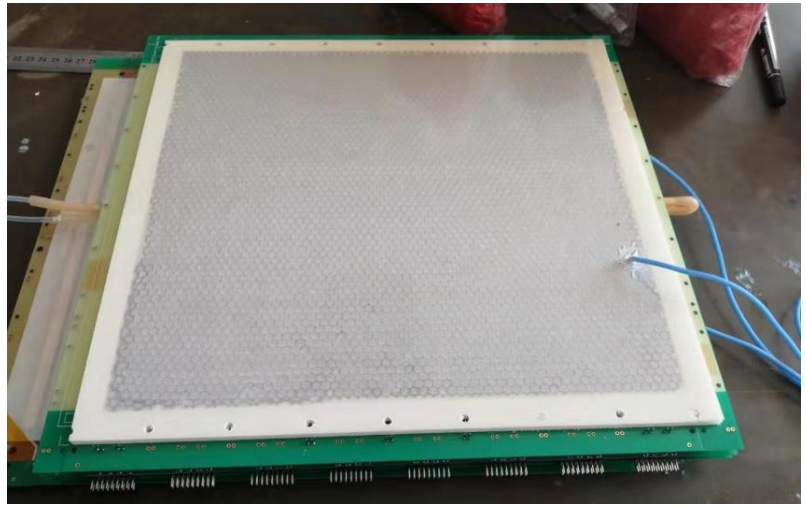




Gluing



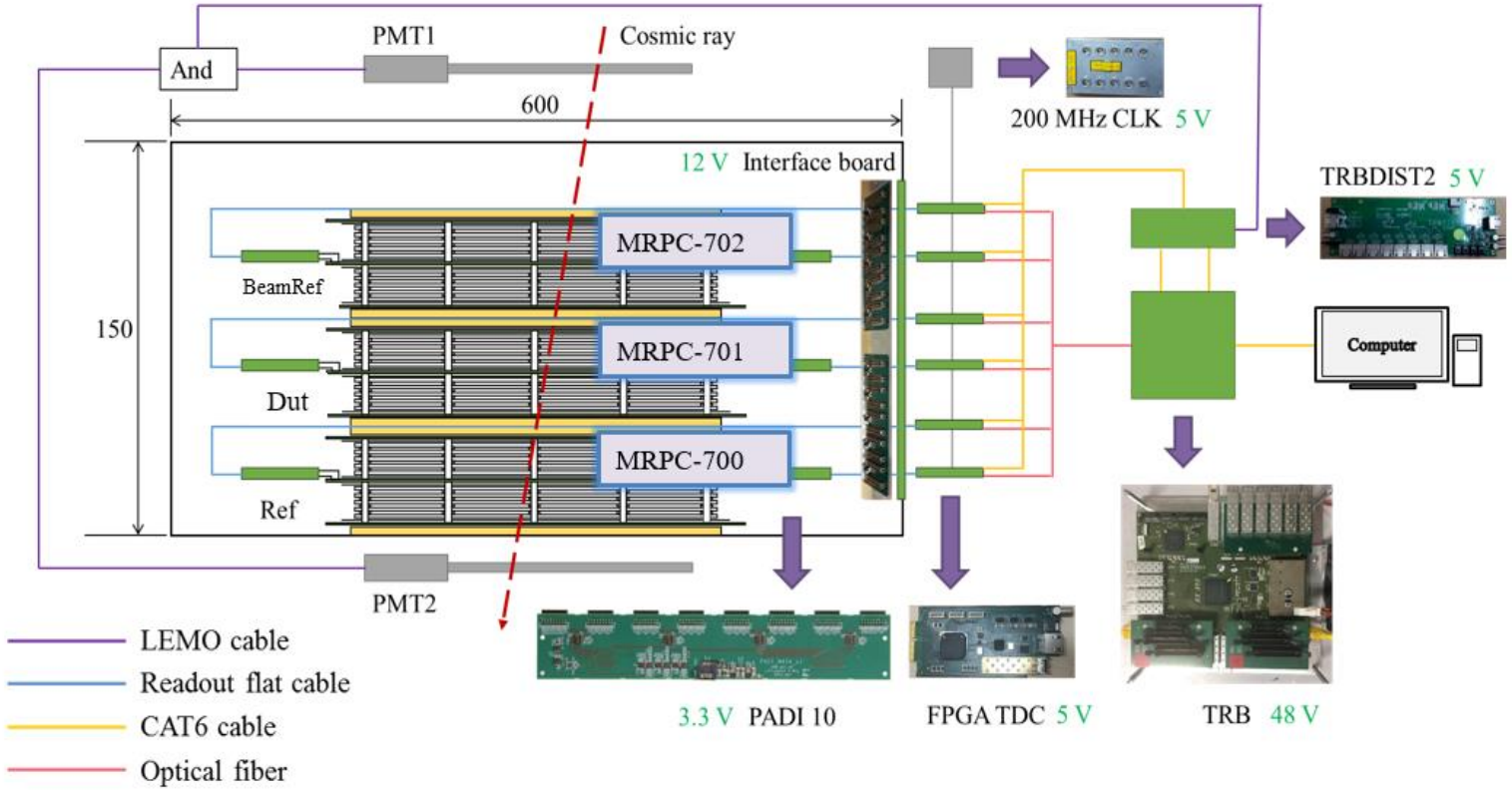
Sealed chamber (stack)



Prototype picture

Prototype and cosmic test system

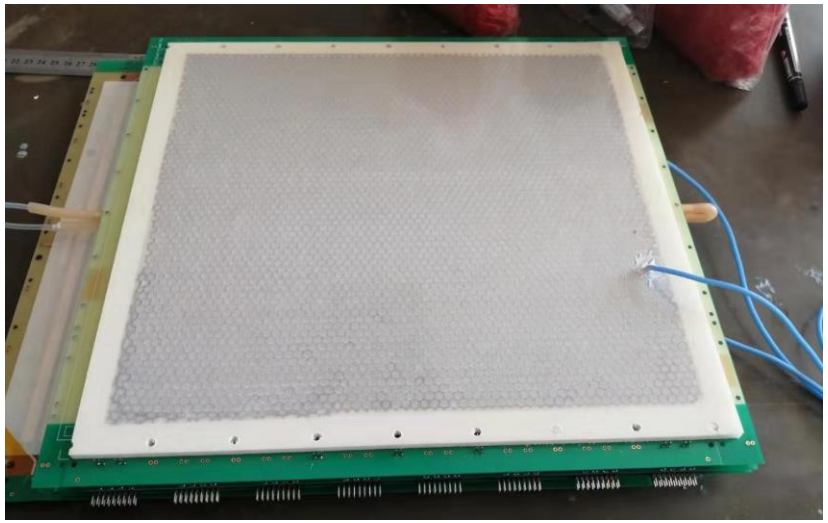
- CBM-MRPC2 mass production test system is used. Two MRPC2 as ref counters.
- Sealed prototype with MRPC2 geo：2×4×0.25mm gas gap, 0.7+0.3cm readout strip pitch.

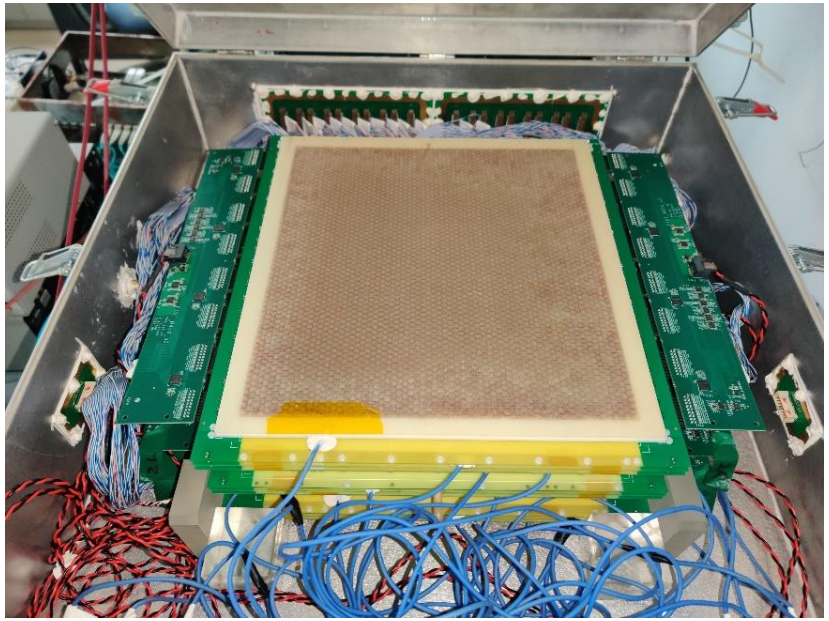


Trigger and readout board v3 (TRB3):
<20ps RMS between 2 channels
8*(64+1) channels
Web interface
Hit rate up to 66MHz

PreAmplifier-DIscriminator ASIC chip (PADI)
50Ω impedance
Bandwidth ~400MHz, Gain 30mV/fC
Threshold set to 300mV during test.

2* scintillators
Triggering area: 5cm*20cm
Parallel to strip length

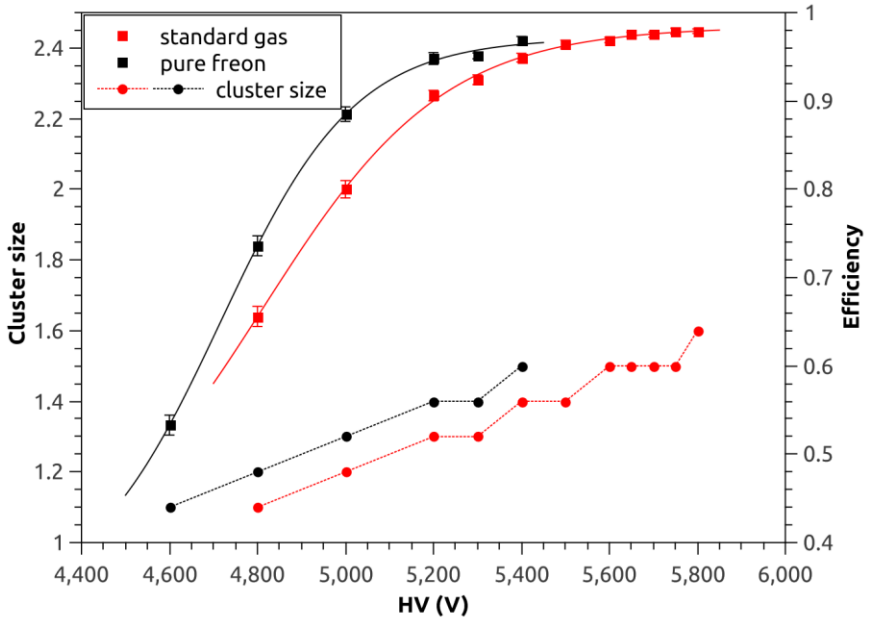




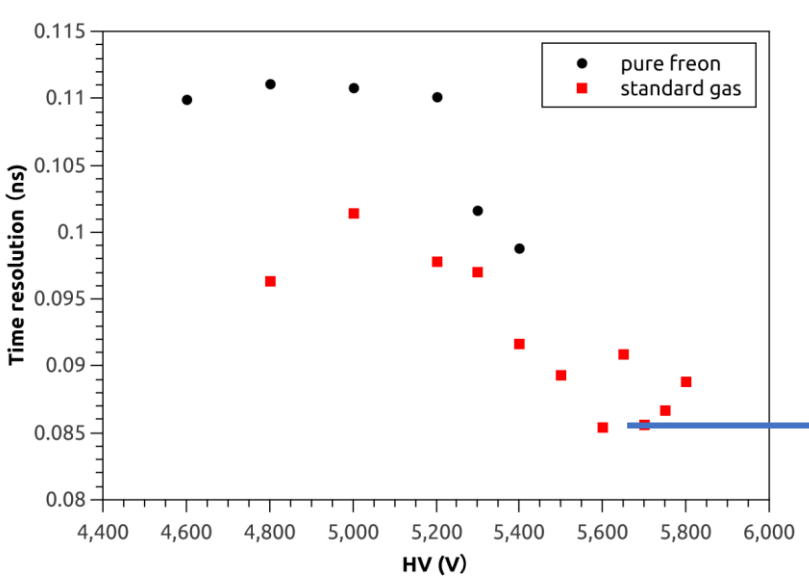
Performances

- Two types of gases were examined:
  - Standard gas flow: Freon/iC4H10/SF6 90/5/5
  - Pure Freon gas.
- 1 ml/min individual supply for sealed MRPC, 50 ml/min for others in gas box.
- Temperature 25℃, humidity 20%.

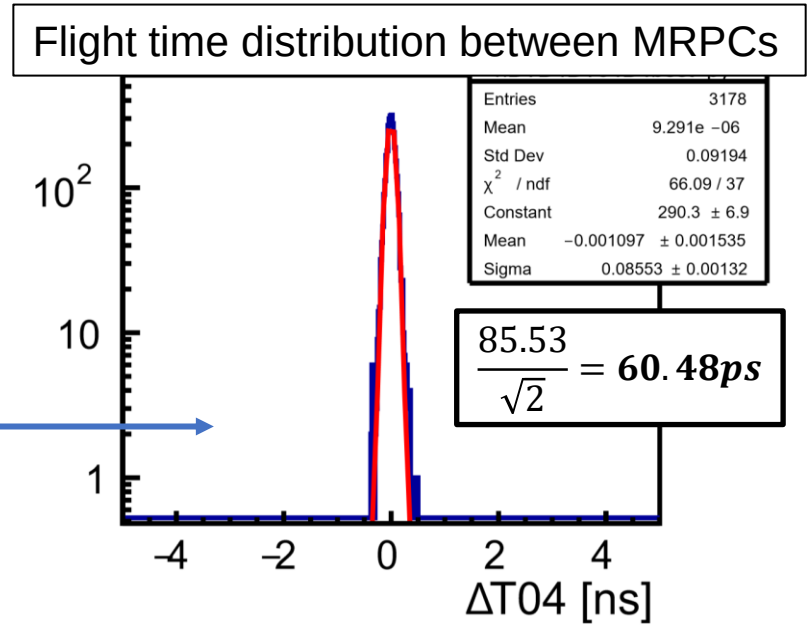
Excellent air-tightness
Low gas consume
Fast purge
Fast HV application



Efficiency and crosstalk in two gases. Working point around 5400V(108kV/cm)



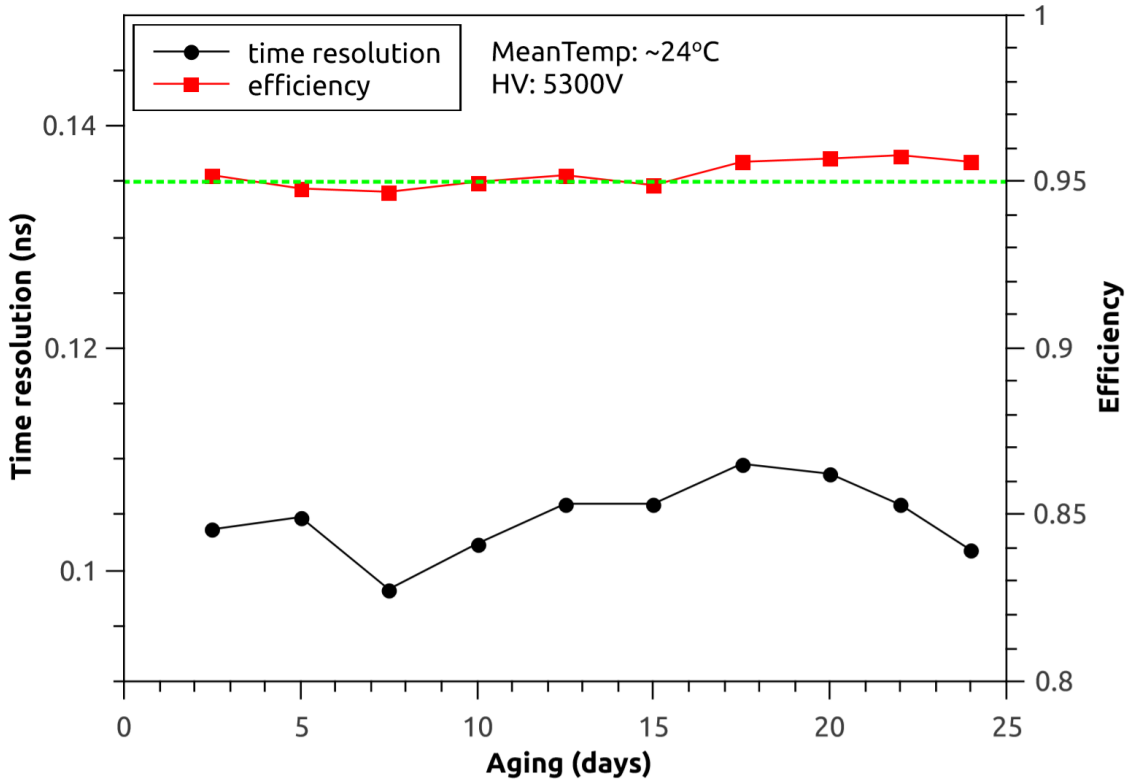
Time resolution of the whole system in two gases.

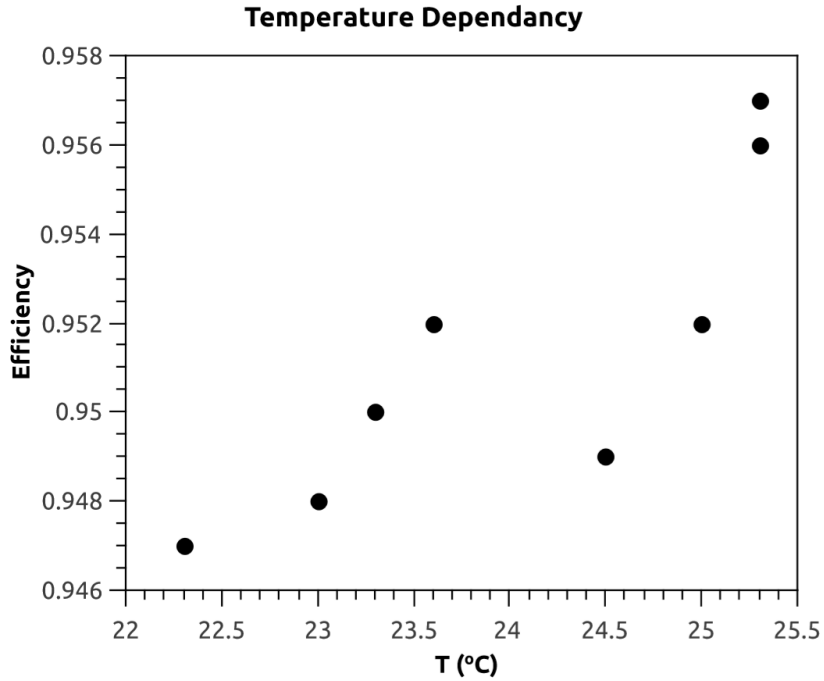


Long-term stability

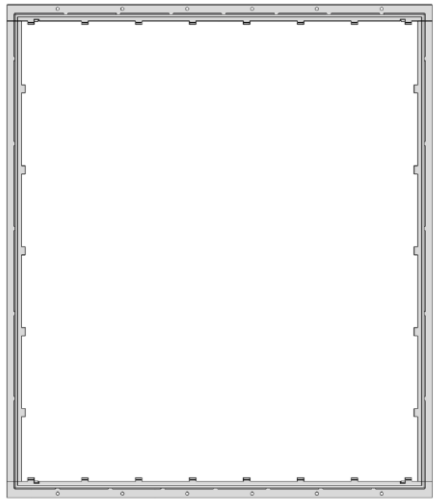
- 1 ml/min pure Freon flow, 5.3 kV
- Temp. dependency, humidity ~19-25%
- Event number >10k for each run

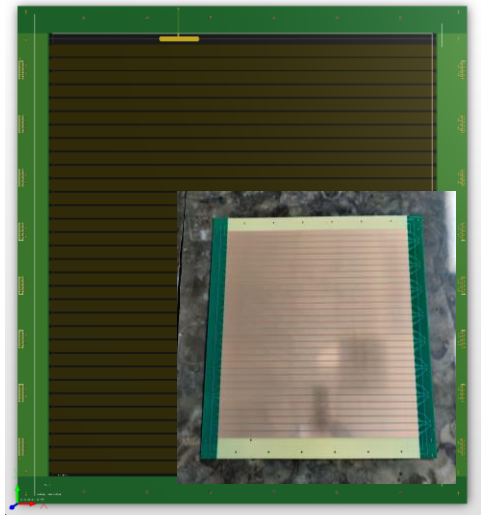
Stable operation over 3 weeks.
Good performance in conservative HV and temp.

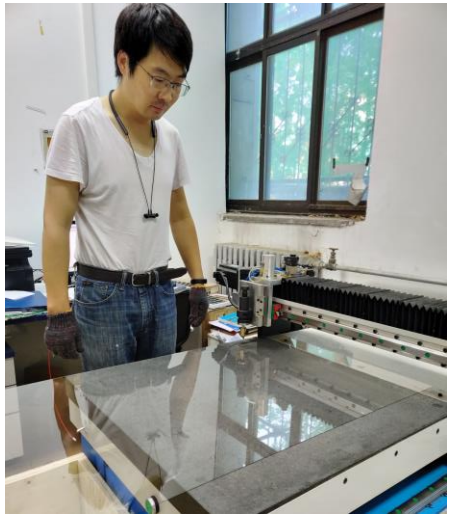




Status: CEE real-size prototype



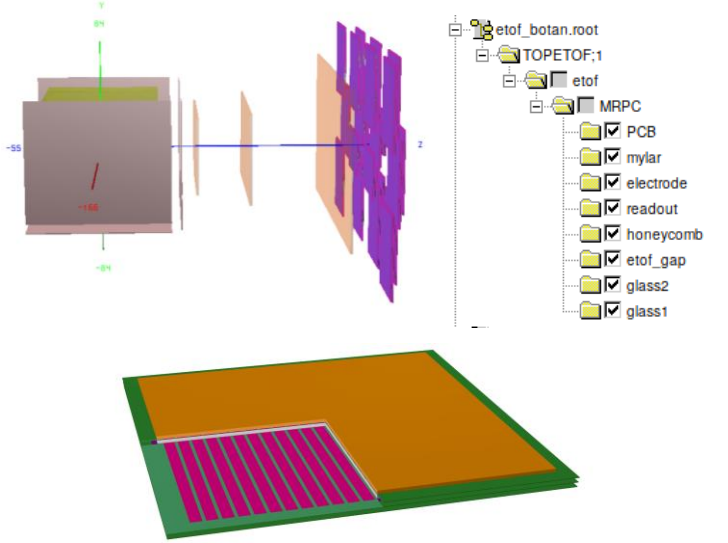




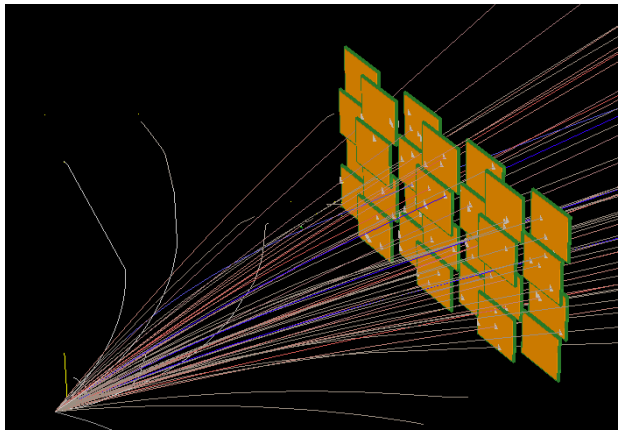
Component preparation

One module containing 3 counters will be ready for test in this year!

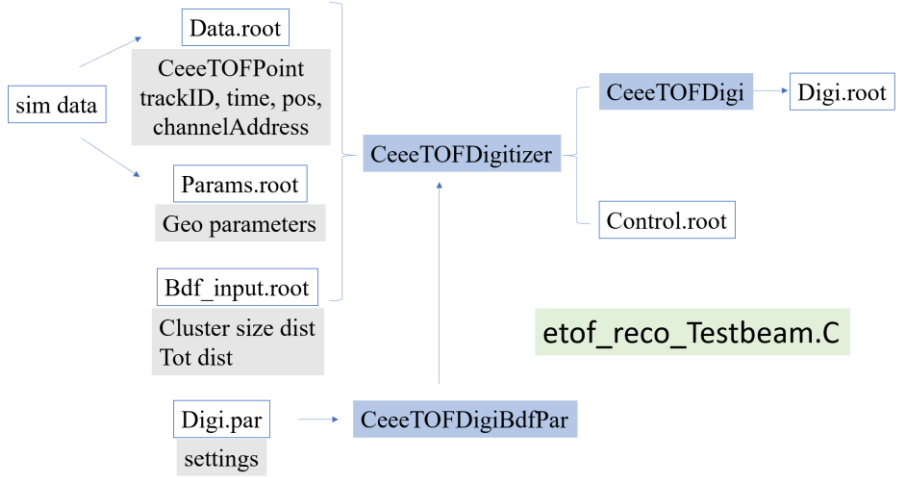
Status: eTOF simulation



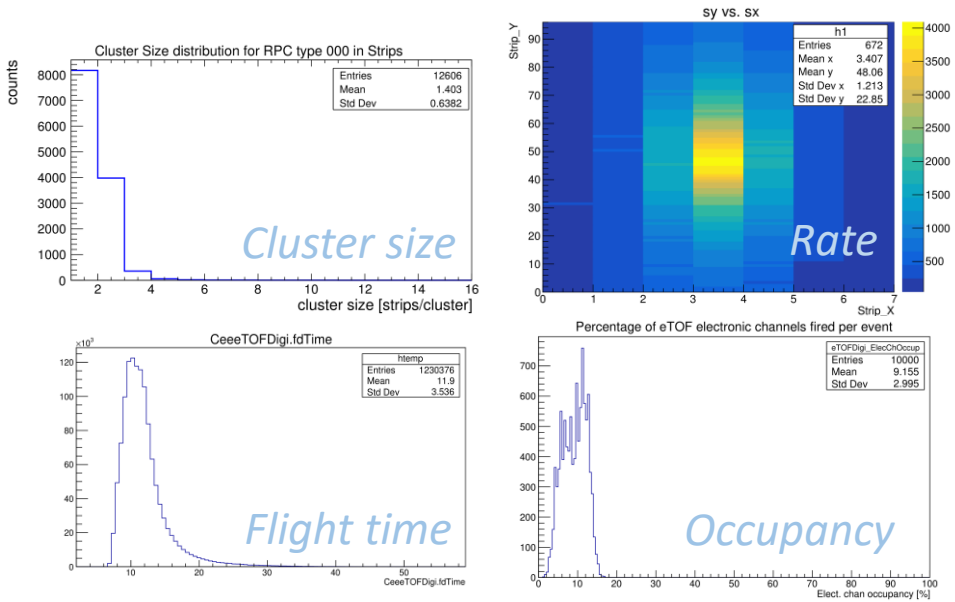
eTOF geo, medium



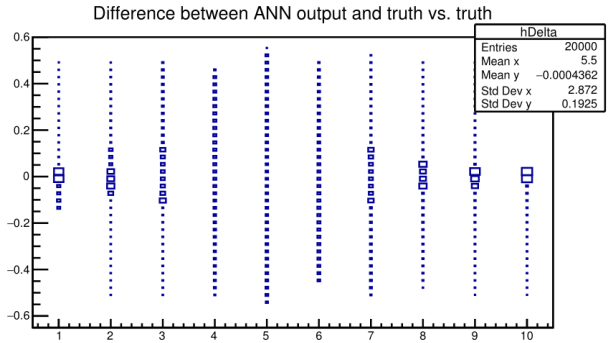
CeeROOT，Sn + Sn @ 600MeV/u

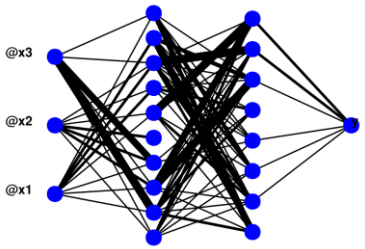


eTOF digitizer based on beam data



eTOF features





Prediction of impact parameters by MLP method

Summary and outlook

- The CEE project
  - Aim at promising findings of QCD phase, EOS, hyper-nucleus, etc.
  - Full operation by 2024.
- The eTOF system
  - The first to be applied with the sealed MRPC.
  - Simulation and detector production are ongoing.
- The sealed MRPC
  - Advantages: low gas consume, easy installation, fast HV readiness.
  - Prototype: efficiency >96%, time resolution 60 ps, long-term stability.
  - More tests and optimization.

Thank you !

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