The CEE-eTOF wall constructed with new sealed MRPC

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Outline

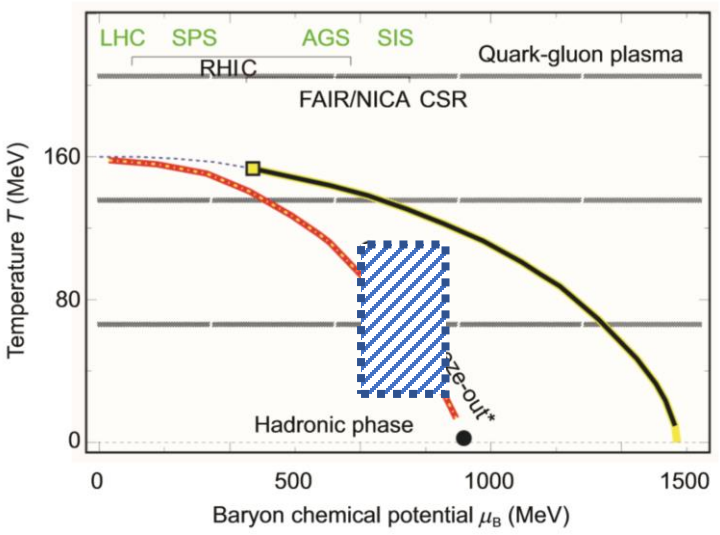
- Background and motivation
- General design of CEE-eTOF wall
- Structural design of sealed MRPC
- Cosmic test results
- Summary and outlook

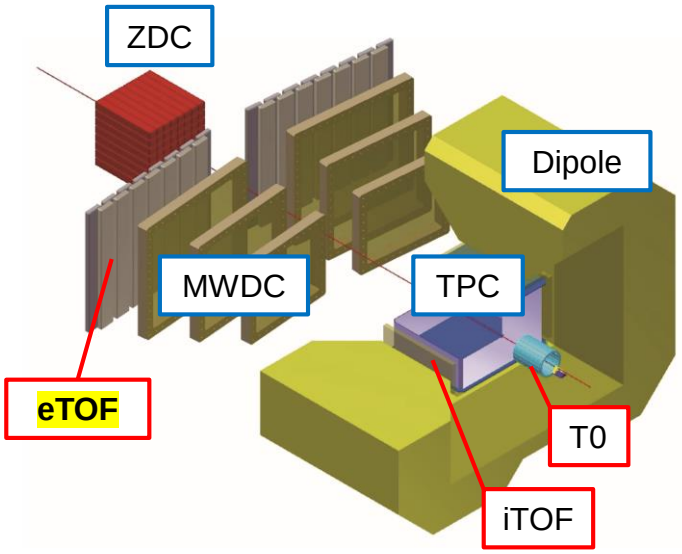
L. M. Lv, H. Yi, Z. G. Xiao, S. Zhang, G. Q. Xiao, and N. Xu, Conceptual design of the HIRFL-CSR external-target experiment, Sci. China-Phys. Mech. Astron.60, 012021 (2017), doi: 10.1007/s11433-016-0342-x

Background

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



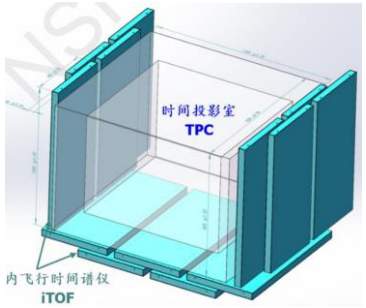


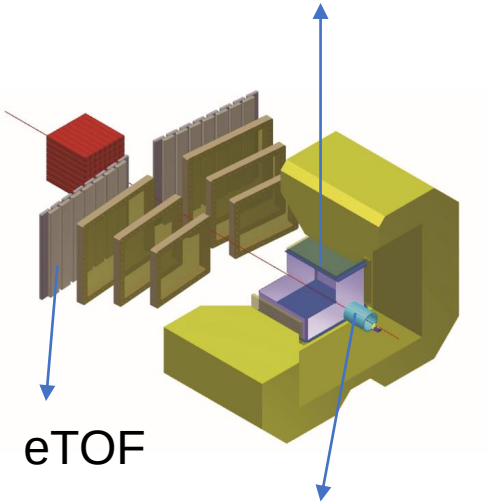
Background

Timing detectors using MRPC technology

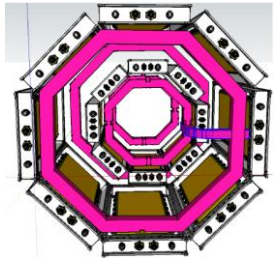
index	T0	iTOF	eTOF
Distance from collision	10~20cm (barrel inner diameter)	≥50cm	3m
Effective coverage	$1m^2$	$3m^2$	$8m^2$
channel	300	~1200	~1500
Timing requirement	50ps	50ps	80ps
Gas gaps	10~12	24~32	10

iTOF





eTOF



T0

General design of CEE-eTOF wall

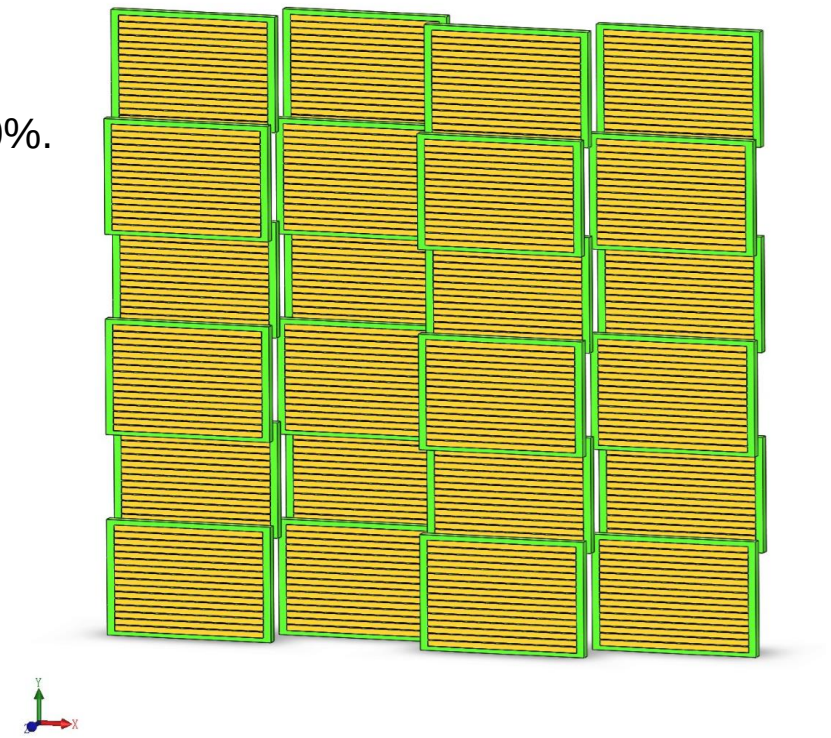
eTOF wall design

For each:

- 2m×2m coverage => acceptance much better than 50% (center of mass).
- Overlap: x – 3cm; y – 1.8cm(1 strip).
- 768 readout channels => occupancy < 10%.
- 3m from collision center
- 80 ps time resolution

Module design：

- 24 counters in 8 modules.
- 3 serial counters for gas supply

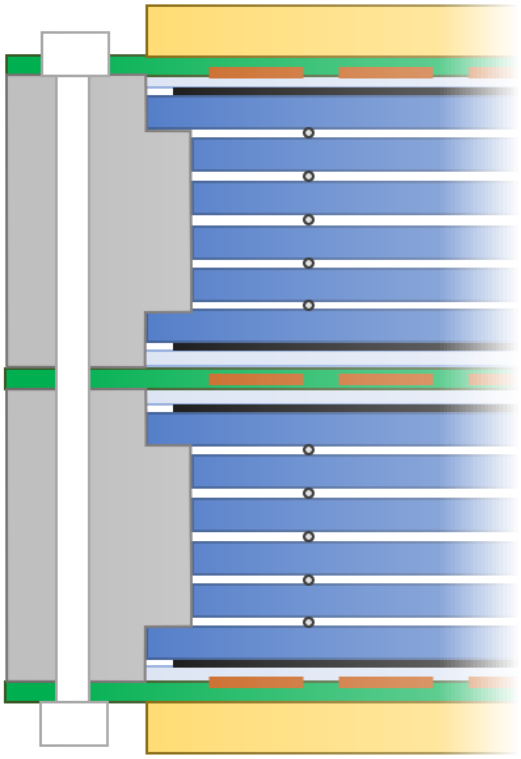


General design of CEE-eTOF wall

Future eTOF MRPC detector

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 strips
  - Pitch 22mm, 18mm width + 4mm gap.
  - Length 52cm
- **Estimated strip impedance 30Ω** *
- **Sealed design**



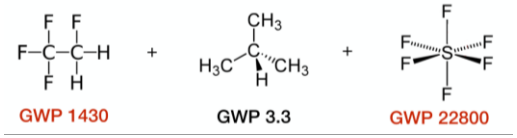
Conceptual layout

* 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

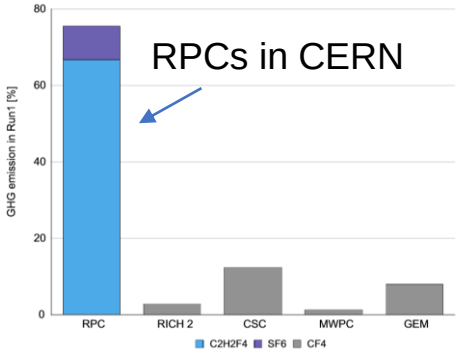
Sealed design —— Decreasing gas consuming for MRPC

- High GWP value

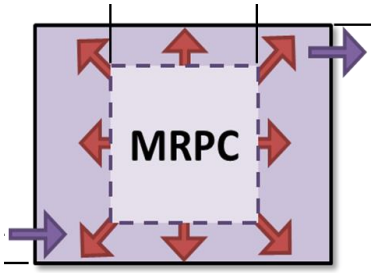


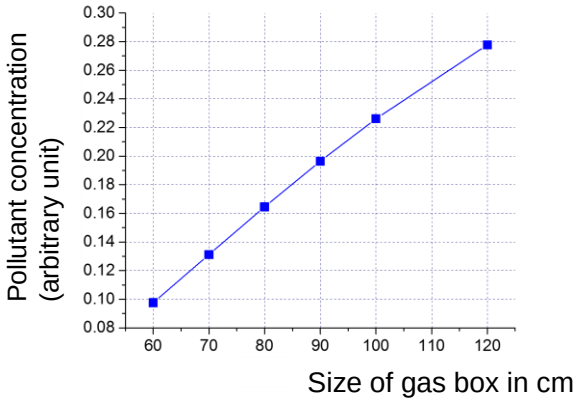
→ F-gas regulations

- 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.**
  - To keep the pure environment, gas flow can't decline much.
  - Shrink the gas box volume -> sealed design





（Simulation result from Pengfei）

Structural design of sealed MRPC

New thought for sealing

Using outermost glass plates and sealing frame

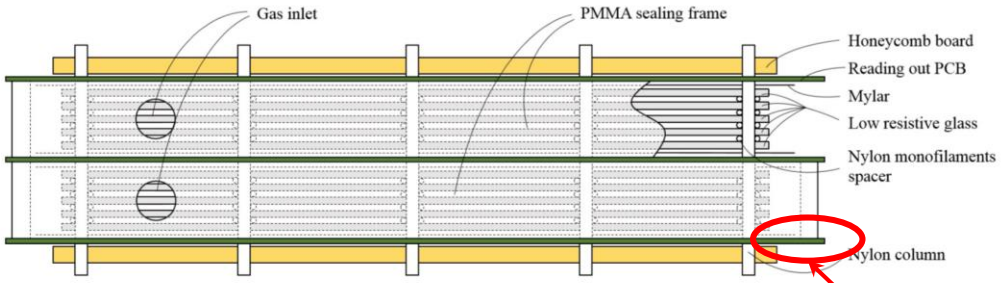
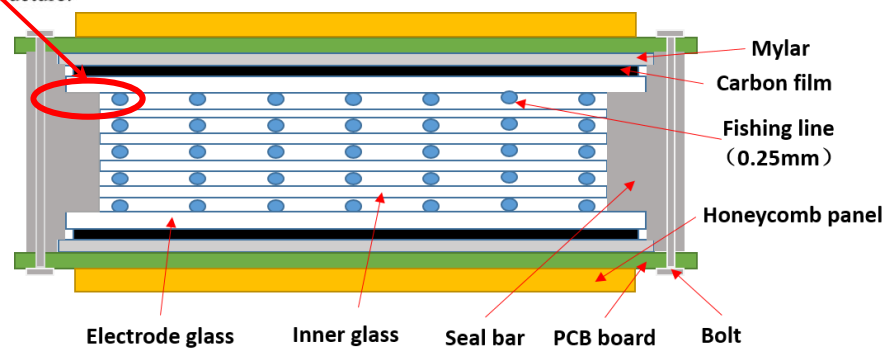


Figure 3. The sectional sketch of the double-stack MRPC prototype with the self-sealed structure.

Lyu, P., et al. "Development and performance of **self-sealed MRPC**." *JINST.* 12.03 (2017).

Different thoughts:
PCB or glass plate as sealing panel.



X.L Chen, et al. Design and Performance study of **Sealed MRPC** (SMRPC) with extremely low gas flow for muon tomography. Talk on IPRD19, Siena. https://indico.cern.ch/event/843258/contributions/3610599/

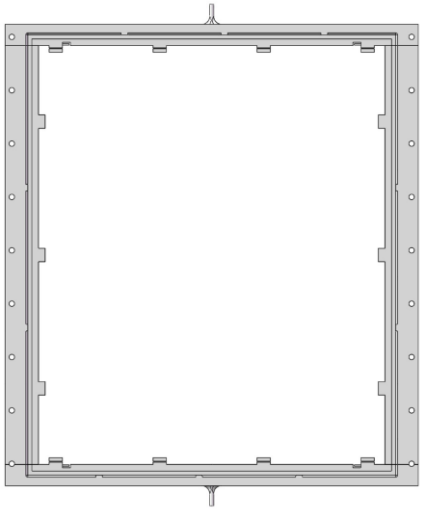
Structural design of sealed MRPC

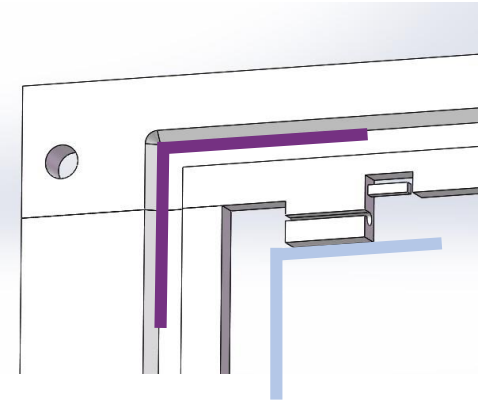
Sealing frame by 3D printing

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

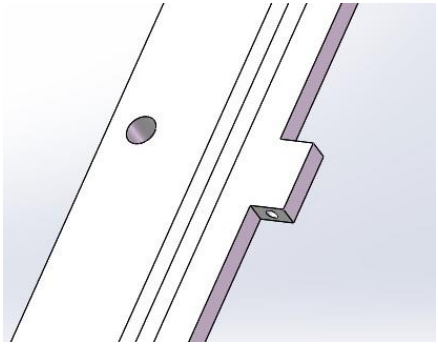
Material: photosensitive resin

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

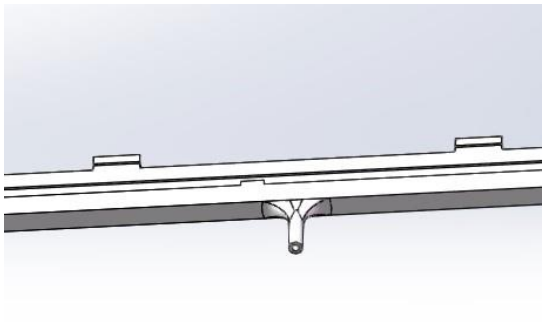




Outer (electrode) glass
Inner glasses



Gas tube



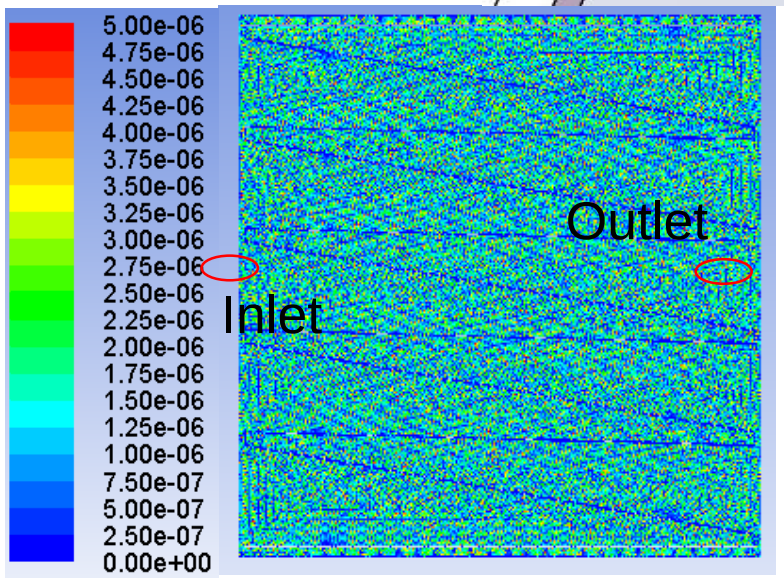
Inlet/outlet

Structural design of sealed MRPC

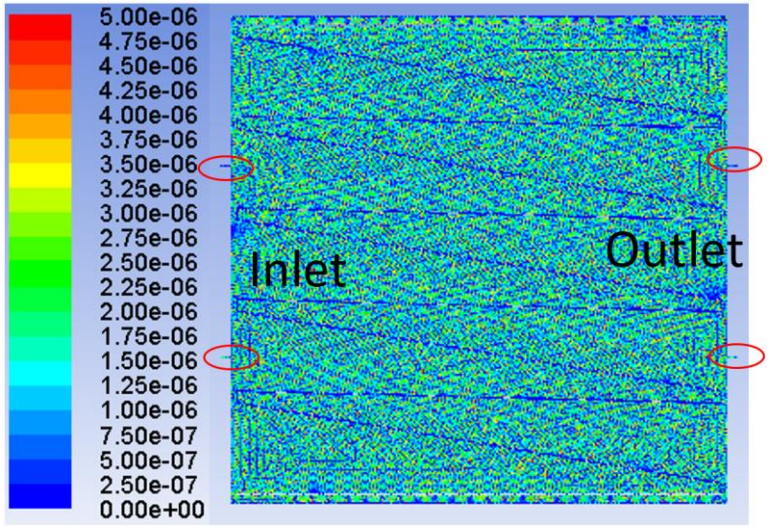
Gas flow uniformity

- Inlet/outlet placement
- 3D Flow field simulation by *ANSYS Fluent*
- Low velocity zone indicates pollutant concentration.

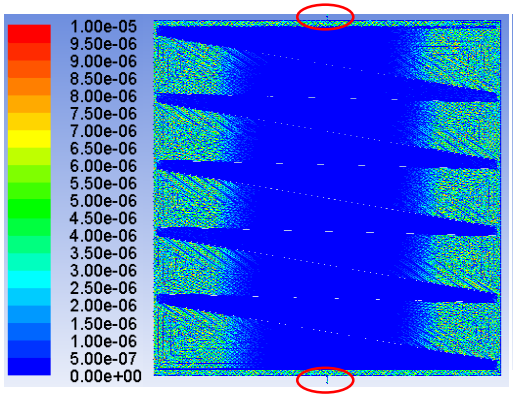
Adopted

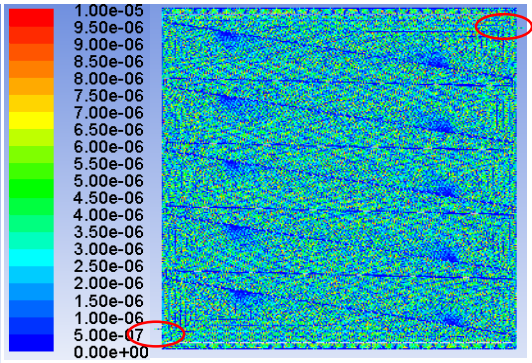


2 pairs:



Gas flow: 3ml/min





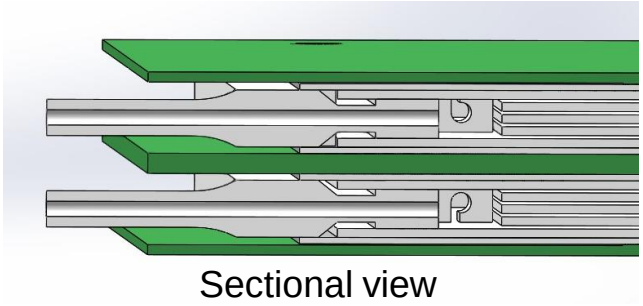
Tubes at different position

Structural design of sealed MRPC

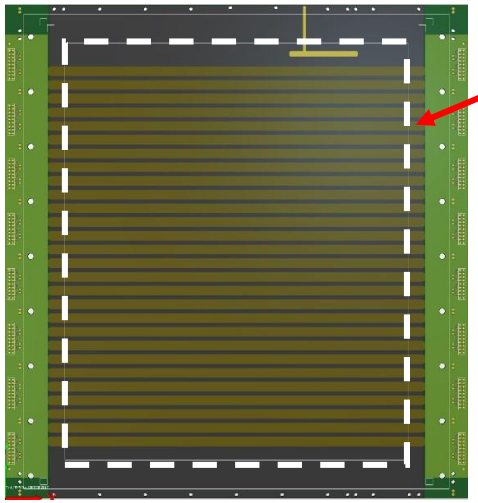
Sealed MRPC prototype

Type similar as MRPC3a

- 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

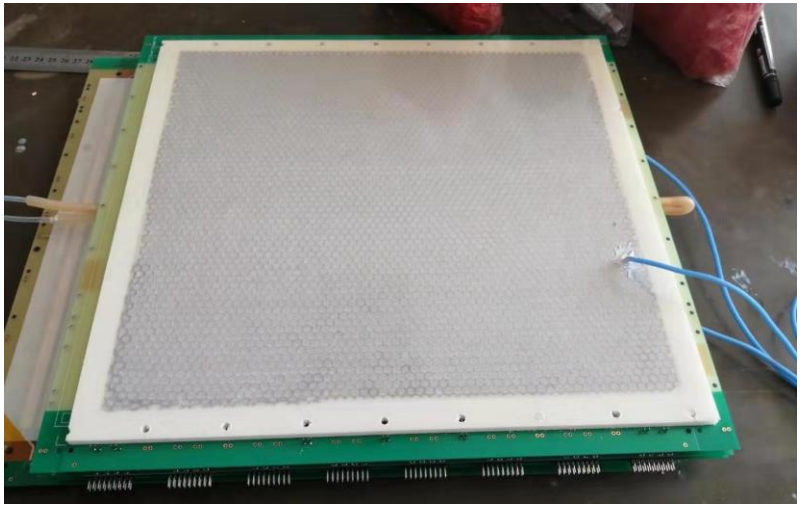


Sectional view



Frame edge

Mid PCB, 2 less strips for more sealing space.

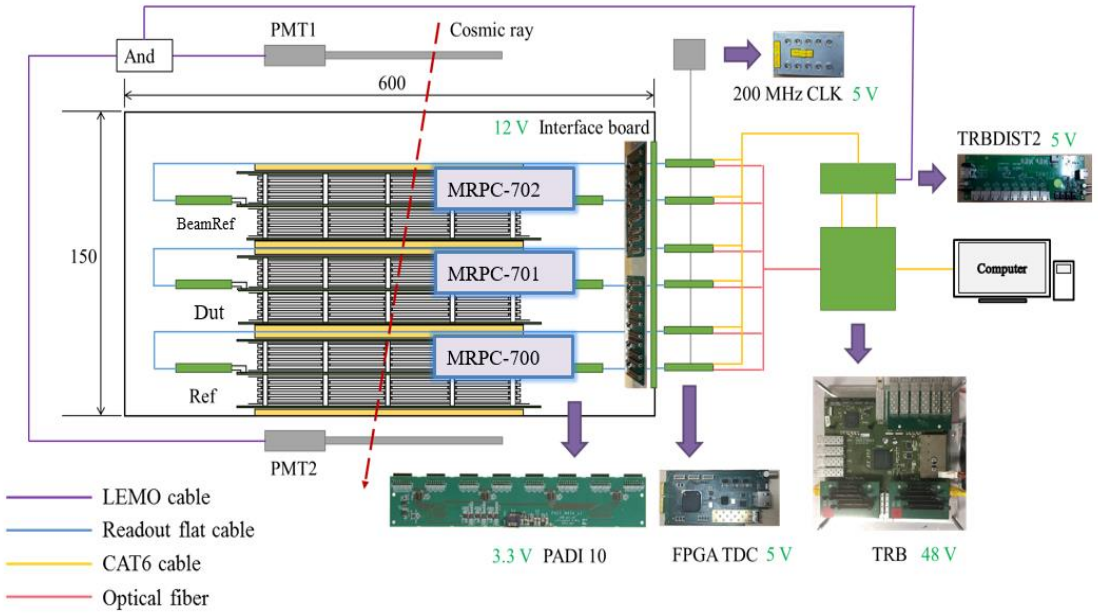


Real detector picture

Cosmic test system

Originally developed for CBM-TOF MRPC3a mass production
Performances of 3 counters can be obtained in single run

- Dut：Detector under test
- Ref: provide time reference
- Beamref: for hit selection



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

Cosmic test system

Cosmic test system

- 2*MRPC3a for CBM as references
- TRB3 chip as DAQ
- Strip->PADI10 FEE->TDC->TRB-> Computer

➢ Environment：~25℃，23%

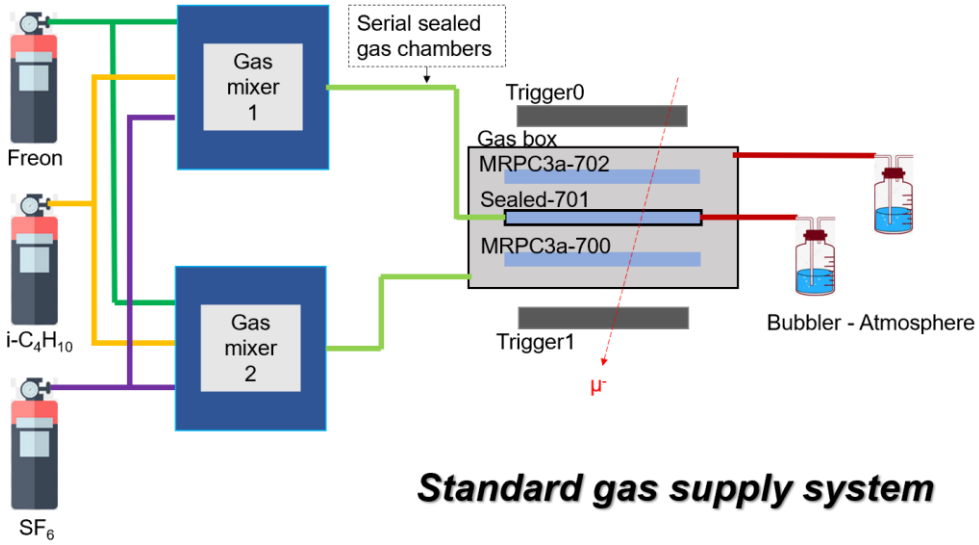
➢ HV: CAEN SY4527

In test runs：

➢Quick gas exchange at 20ml/min flow

➢Apply the working HV within 1hr.

➢For comparison, gas box needs 2 days before applying HV



Standard gas supply system

Cosmic test results

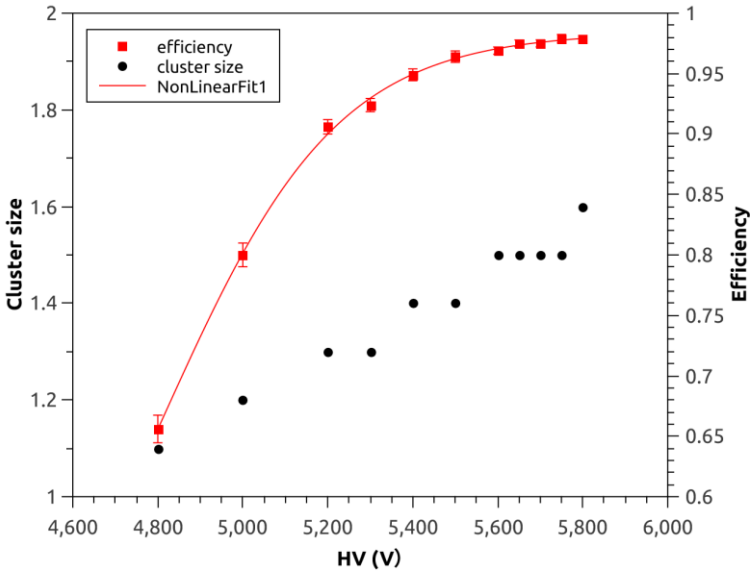
Standard gas flow 4 ml/min (minimum setting for mixer)

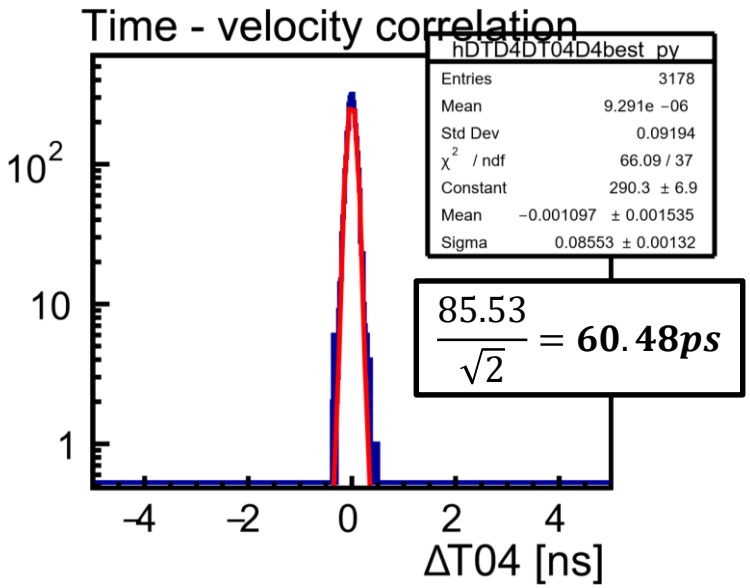
Freon/iC_4H_{10}/SF_6 90/5/5; Temp: 25℃, dark current ~20nA

At working point 5600V(112kV/cm): Eff 97.5%, time resolution 85.5ps (time difference)

Reference MRPC3a, flow 50ml/min for gas box:

Working HV 5300V (106kV/cm), eff 97.9%, time resolution 83ps





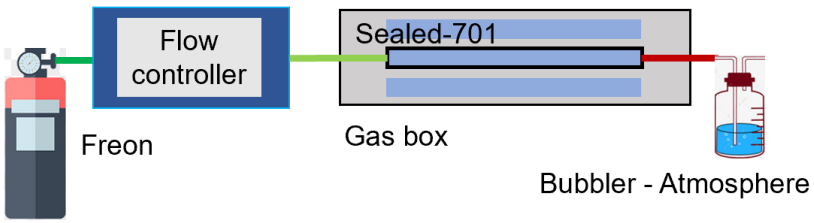
Cosmic test results

Pure Freon flow 1ml/min

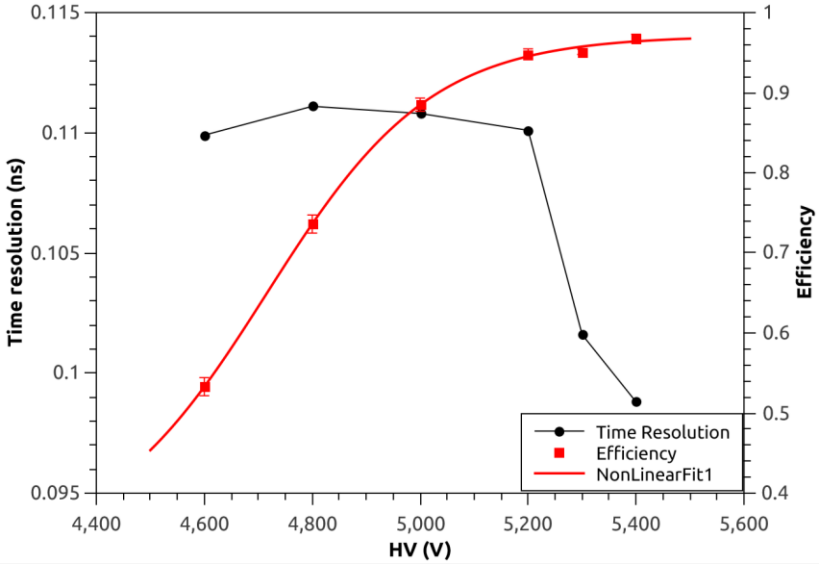
Temp: 25℃, dark current ~20nA

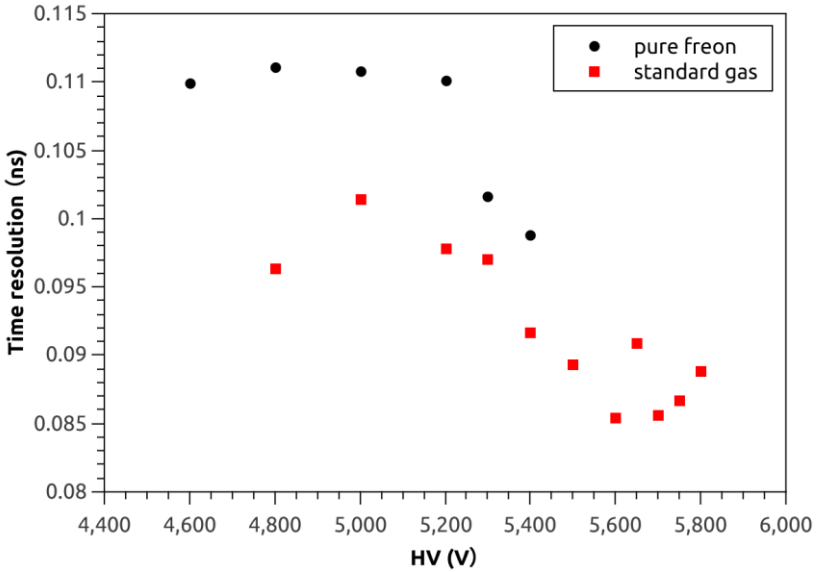
At working point 5300V (106kV/cm):

Eff: 96%, time resolution 102ps

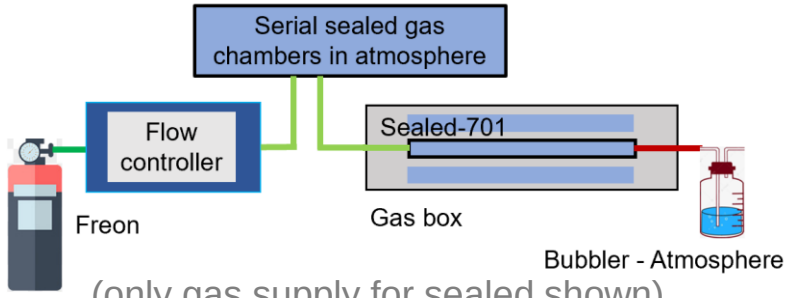


(only gas supply for sealed shown)





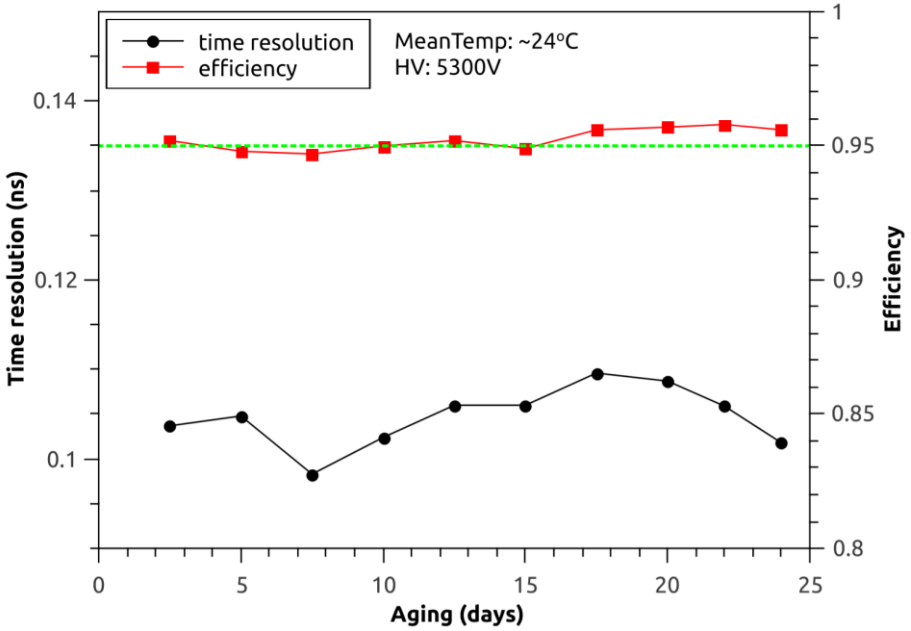
Cosmic test results

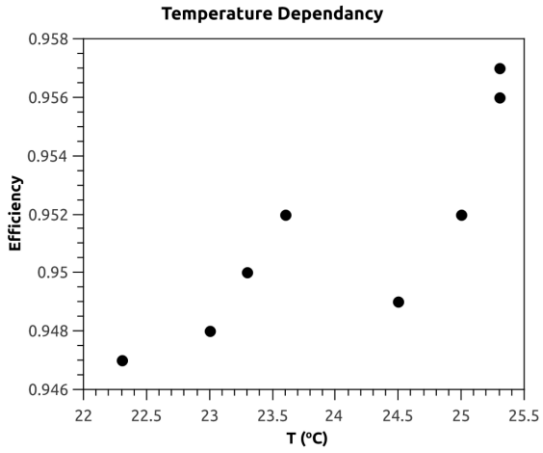


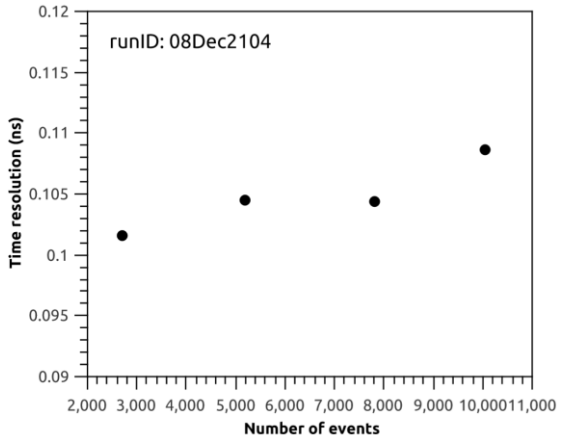
(only gas supply for sealed shown)

Pure Freon flow 1ml/min, serial chambers, stability test

- No leak point/performance decline/gas chock
- Temp. dependency, humidity insensitive ~19-25%
- Event number >10k for each run
- Timing — events dependency may caused by temperature fluctuation.







Summary and outlook

- The CEE-eTOF wall will be constructed with sealed MRPC.
- By gluing the electrode glasses with sealing frame, gas volume reaches as low as 170ml, in which case gas exchange becomes better.
- To optimize flow field uniformity, placements of space holder, in/outlets, etc. must be considered and verified by simulation.
- Sealed MRPC prototype has low gas consume and works stably under cosmic ray, at a flow 1ml/min for over 20 days. time resolution can reach ~60ps in standard gas.

Next step:

- Eco-gas test
- Real-size prototypes for CEE
- High-rate aging test

Thank you!