High rate MRPC for CBM-ToF system

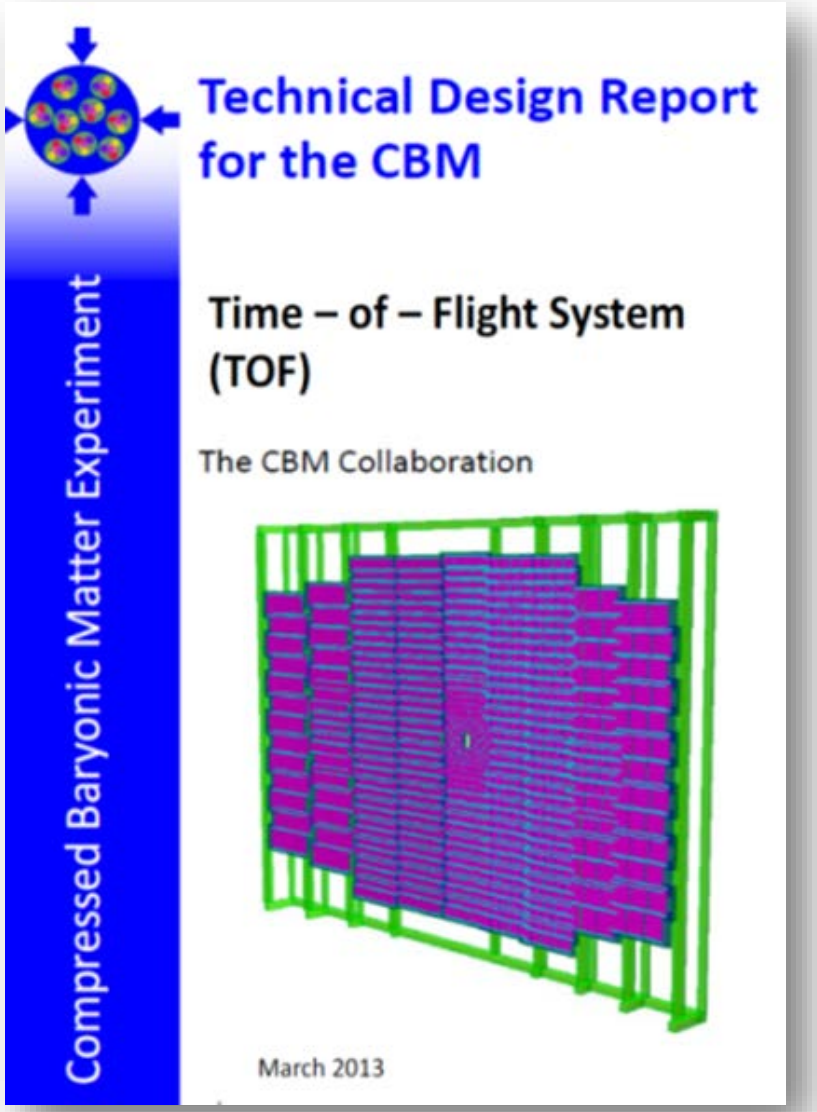
Kai Sun, Botan Wang, Yi Wang, Ingo Deppner

Tsinghua University, CBM Collaboration

Outline

- CBM-ToF requirements
- Sealed MRPC2 for CBM-ToF
- Low resistive glass MRPCs for high counting rate
- Development of pad spacer MRPCs
- Summary

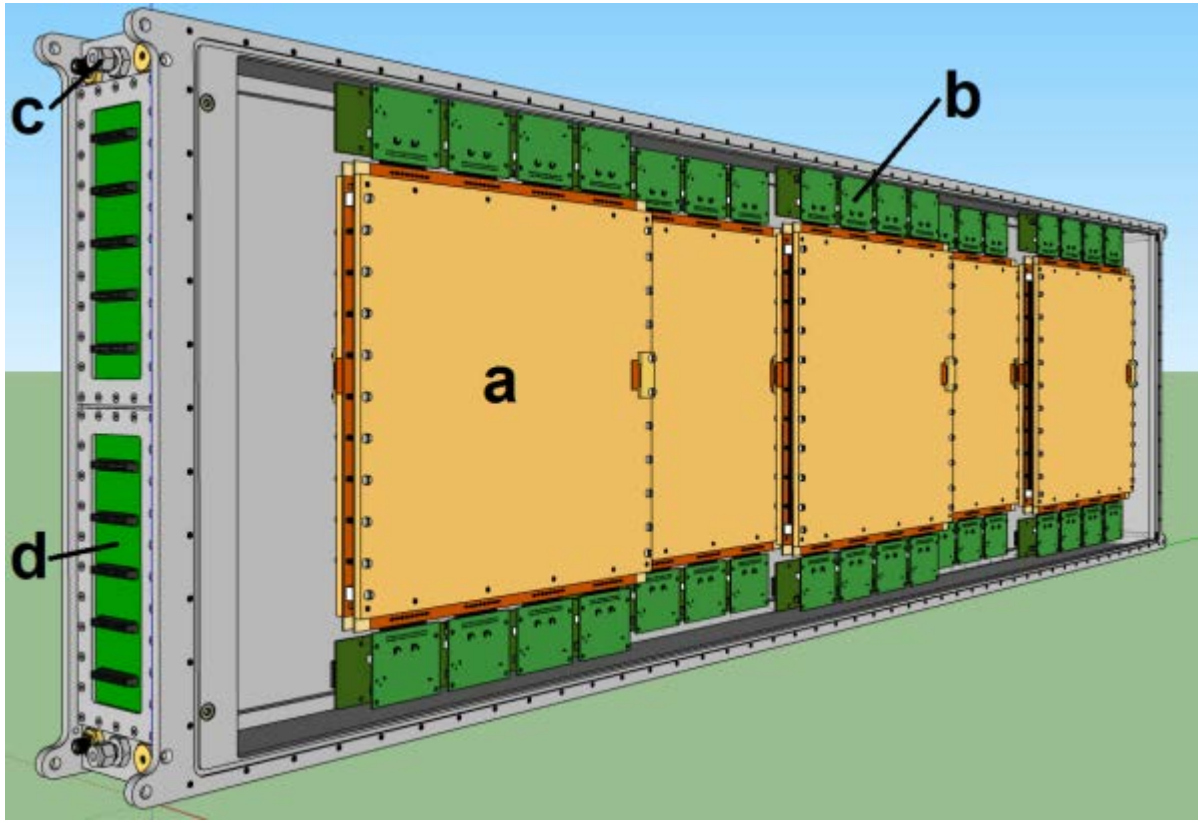
CBM-ToF requirements



CBM-ToF Requirements

- Full system time resolution sT ~ 80 ps
- Efficiency > 95 %
- Rate capability ≤ 30 kHz/cm2
- Polar angular range 2.5° – 25°
- Occupancy < 5 %
- Low-power electronics
- (~100.000 channels)
- Free streaming data acquisition

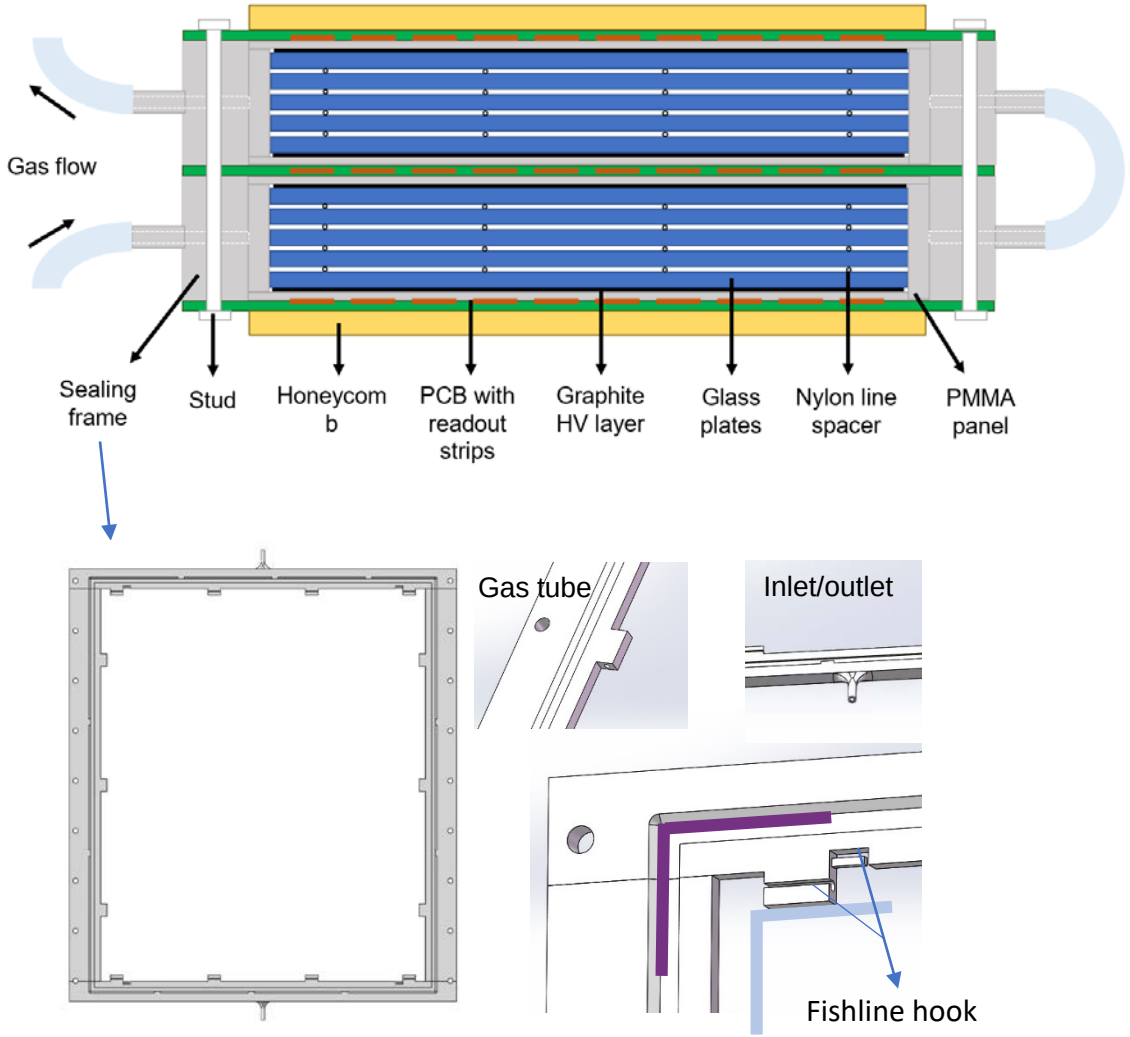
CBM outer ToF-wall module



	CBM
Active area per detector (cm)	33 x 27.6
Total active area (m^2)	120
Strip width(mm)	7(strip)+3(interval)
Stript length(mm)	270
Gap×thickness(mm)	8 x 0.25
Gas mixtures ($C_2H_2F_4$/ C_4H_{10}/SF_6)	90/5/5
Operating field (kV/cm)	110
Efficiency	97%
Time resolution(ps)	80
Max rate (Hz/cm^2)	**50k**
Glass type	**Low resistive glass**

- CBM-ToF wall module 1a
- Parameters of MRPCs in module 1a

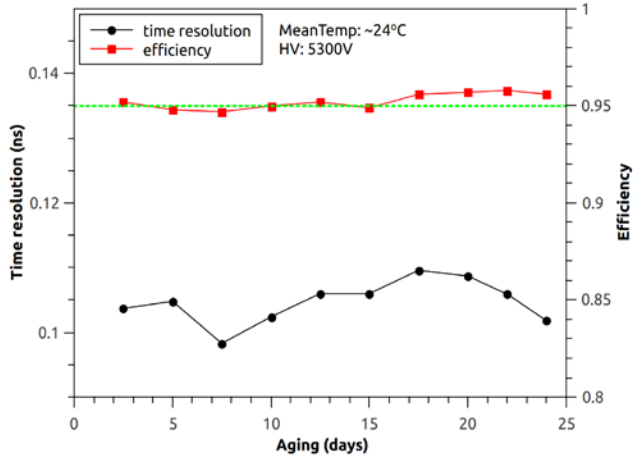
Sealed MRPC2 for CBM-ToF



3D printed sealing frame with Good strength, insulation and radiation persistency

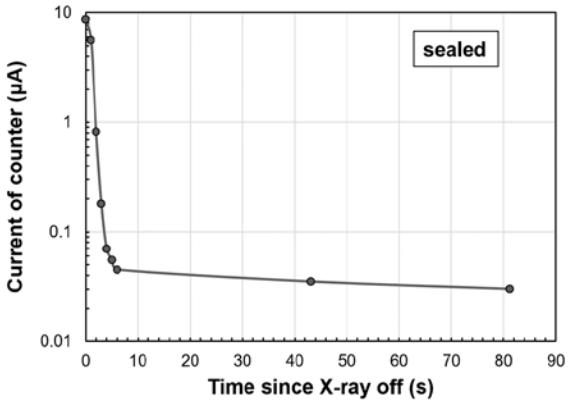
- Features :

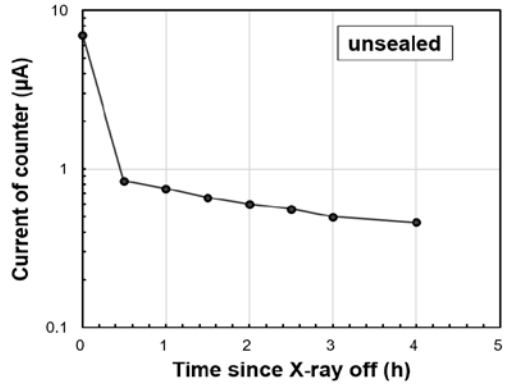
1. **Gas saving :** stable operation under < 10 sccm/m^2 gas flow in cosmic ray test



2. **Higher gas exchange efficiency:**

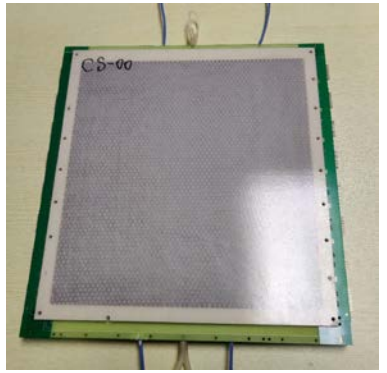
- Decrease the wait time for gas purging in X-ray test
- Excellent current behavior under high rate irradiation

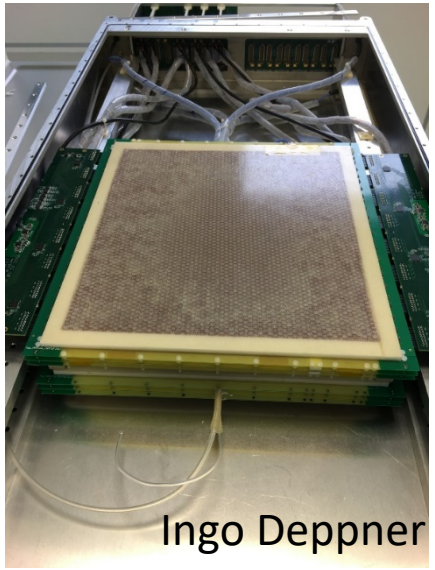


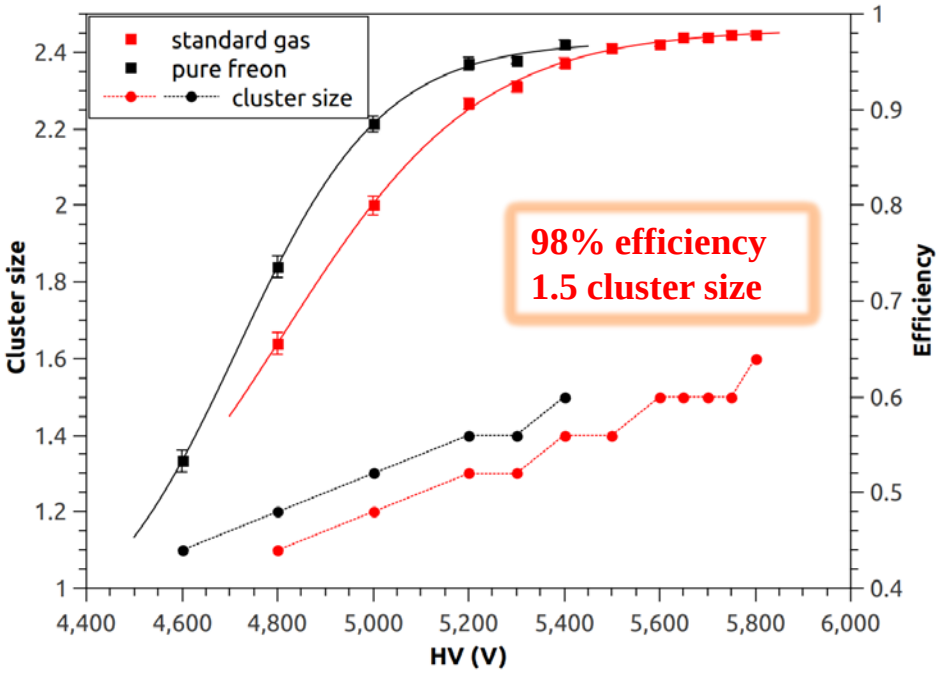


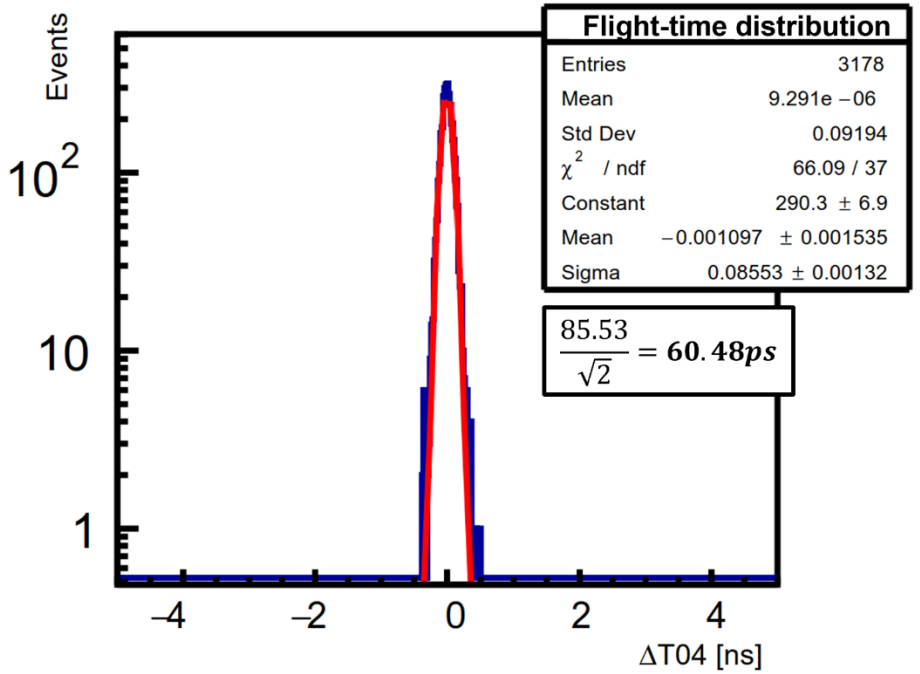
Sealed MRPC2 for CBM-ToF

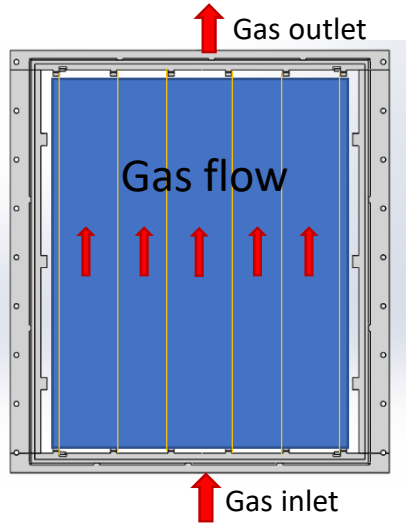
- Geometry unchanged, making substitution easier
- High efficiency and time precision maintained.











Low resistive glass for high counting rate

- Voltage drop in the gas gap when avalanche happens

$$\bar{V}_{drop} = V_{ap} - \bar{V}_{gap} = \bar{I}R = \bar{q}\phi\rho d$$

- The smaller the voltage drop, the higher efficiency and rate capability

- Low resistive glass reduces the voltage drop, obtaining a higher counting rate

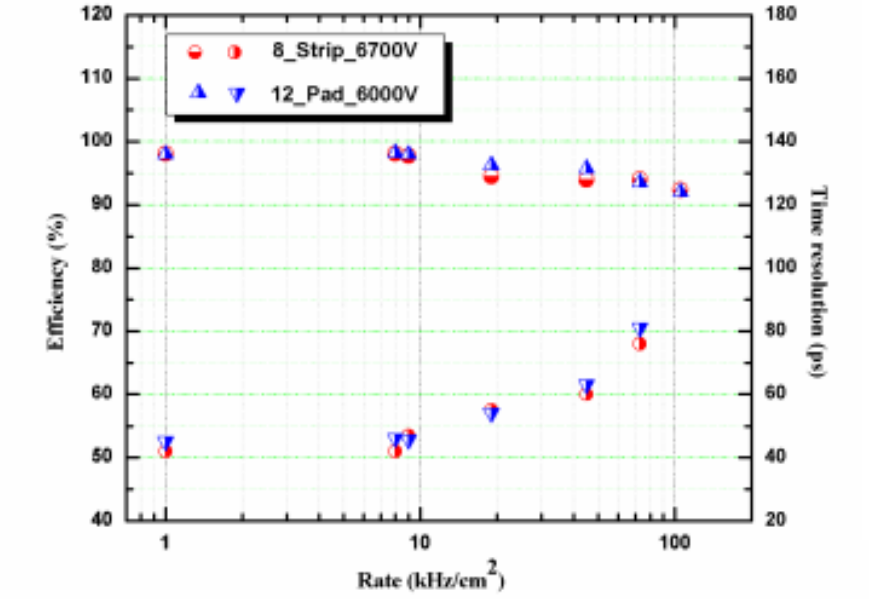
- Volume resistivity (Ω·cm): 10^{12} (Other glass)-> 10^{10} (Low resistive glass)

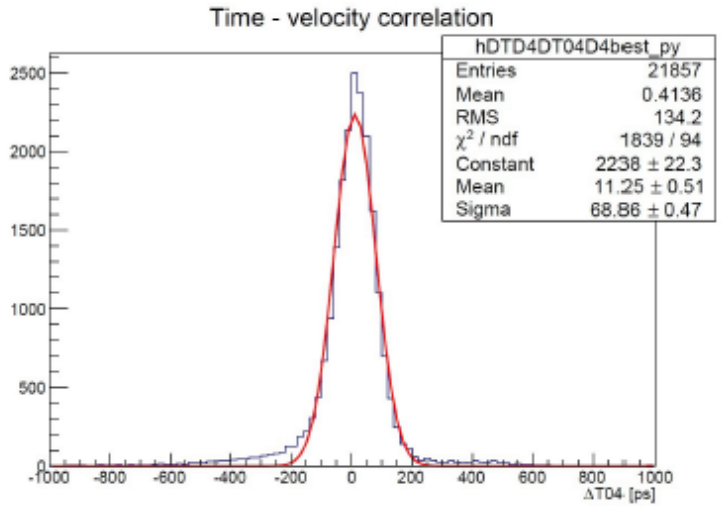
Low resistive glass

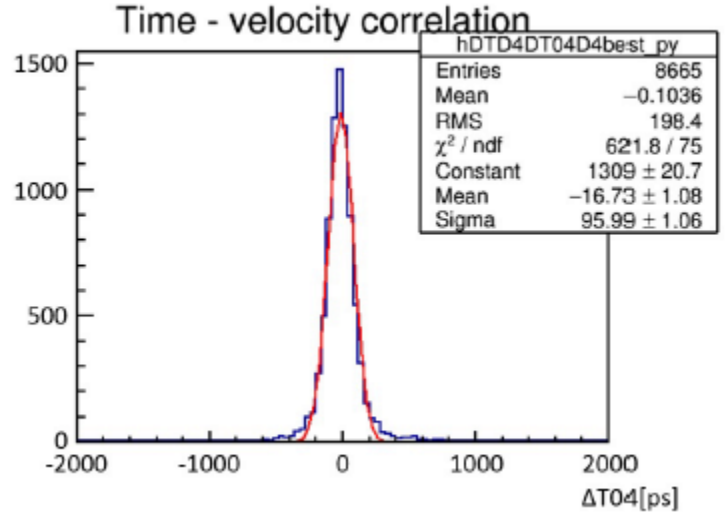
Dimension	**33 x27.6cm^2**
Bulk resistivity	**~$10^{10}\Omega$cm**
Standard thickness	**0.7, 1.1mm**
Thickness uniformity	**20μm**
Surface roughness	**<10nm**
Dielectric constant	**7.5 - 9.5**
DC measurement	**Ohmic behavior**
	stable up to 1C/cm^2

Parameters of low resistive glass MRPC in beam test

- Real-size high rate MRPC has been tested in CAEN, JINR, and GSI.







- JINR 2013 beam test scan

Rate: 70kHz/cm^2
Efficiency: 90%
Time resolution: 80ps

- GSI 2014 beam test

Rate: ＜1000Hz/cm^2
Efficiency: 97%
Time resolution: 48.7ps

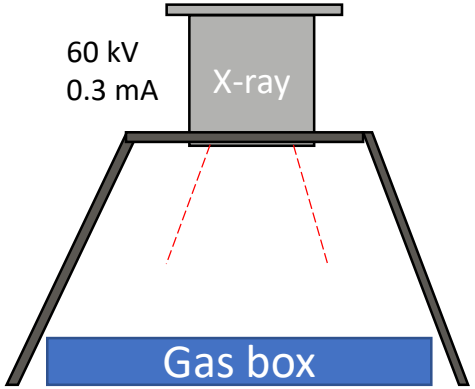
- CAEN 2015 beam test

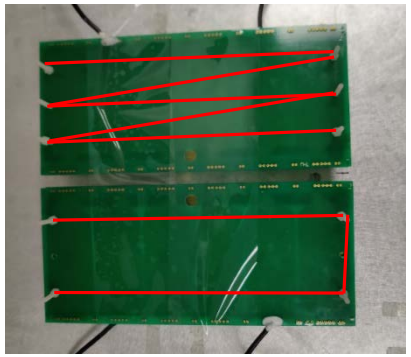
Rate: 1kHz/cm^2
Efficiency: 90%
Time resolution: 80ps

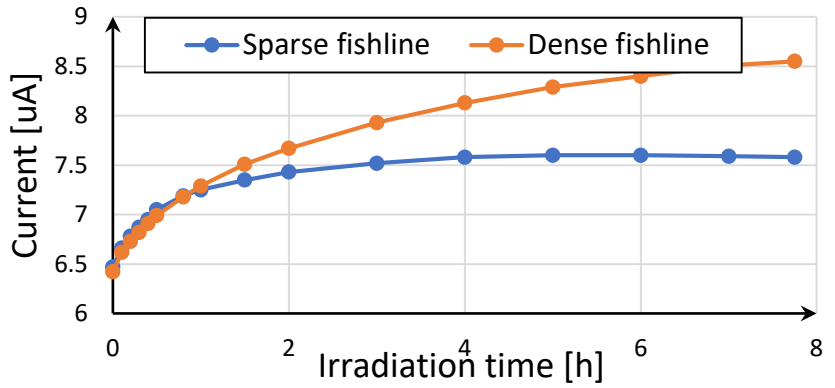
Spacer related effect: comparative study

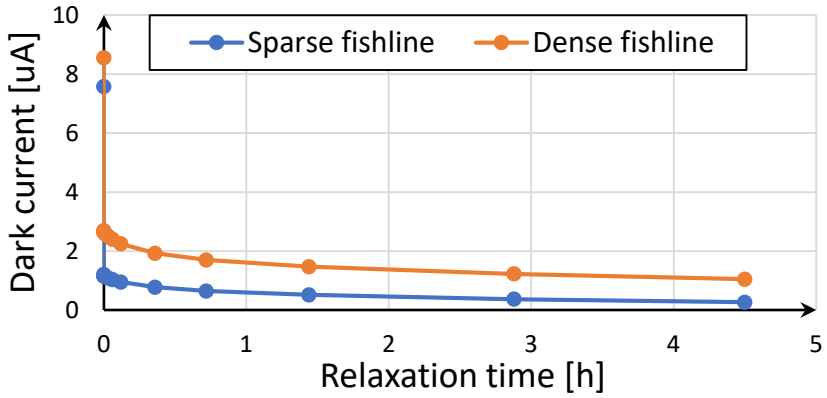
- Two unsealed prototypes assembled
- Identical geometry and different fishline density
- Positions careful adjusted for identical flux condition
- Dark current correlated positively to **fishline contact region size.**

Glass dimension [mm]	180 x 60 x 0.7
Sensitive area [mm]	170 x 50
Gas gap thickness [mm]	0.25
N. of gaps	5
Working field [kV/cm]	110







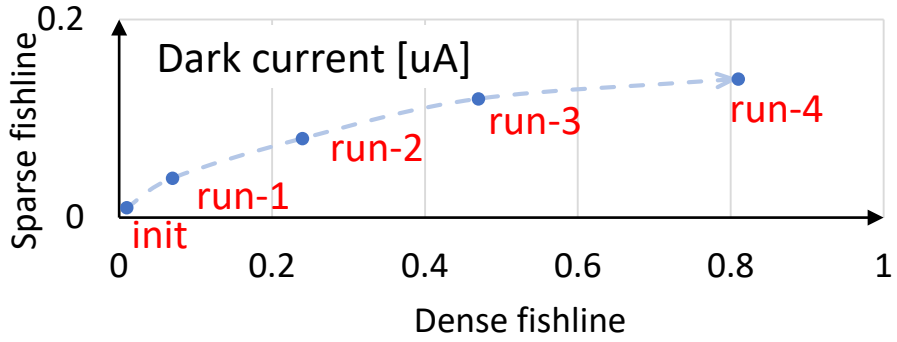


Gas + Spacer effect:

Sparse fishline prototype shows early saturation and less dark rate.

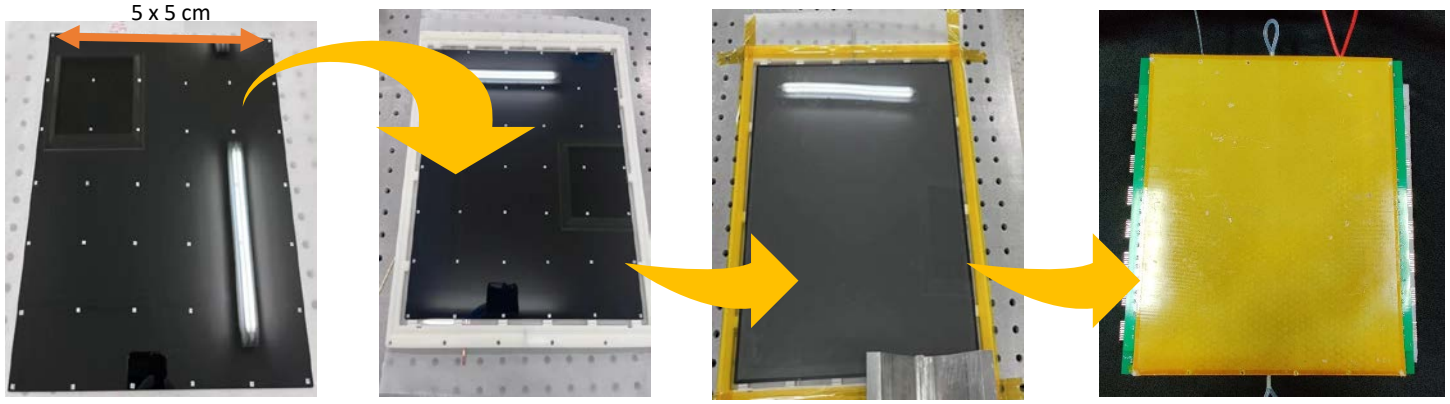
Spacer effect:

Dark current evolution after relaxing for 24h - a typical purge time.



Development of pad spacer prototype

- pad spacers of 3x3 mm^2 (Φ=4 mm round pad for new one)
  - Smaller contact area: decrease by a factor of 2 3.78 vs. 7.2 cm^2 per gas gap
  - High bulk resistivity: fishline – 10^{14} Ωcm, mylar – 10^{17} Ωcm
  - discontinuous placement
- spacers are pasted one-sided on the glass
- spacers distributed with uniform intervals of 5 cm

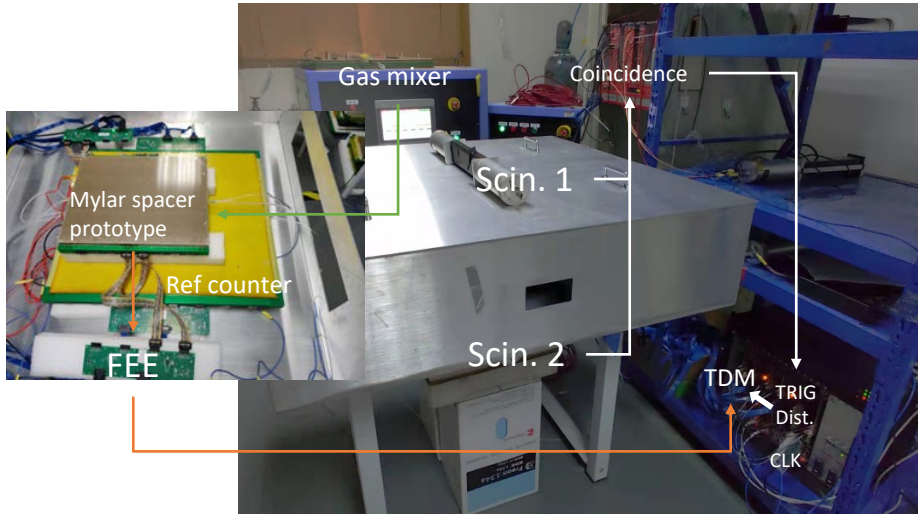


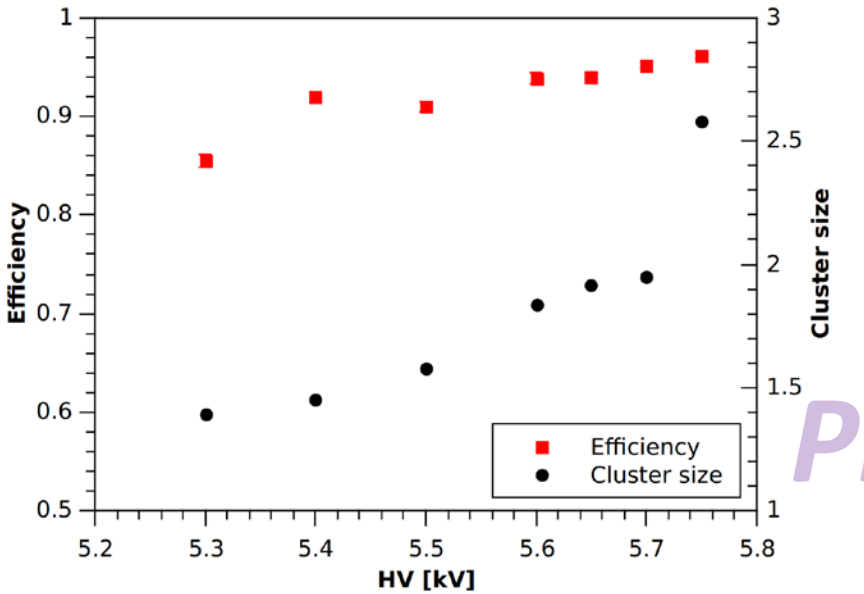
Prototype prepared with CBM-TOF MRPC2 geometry.

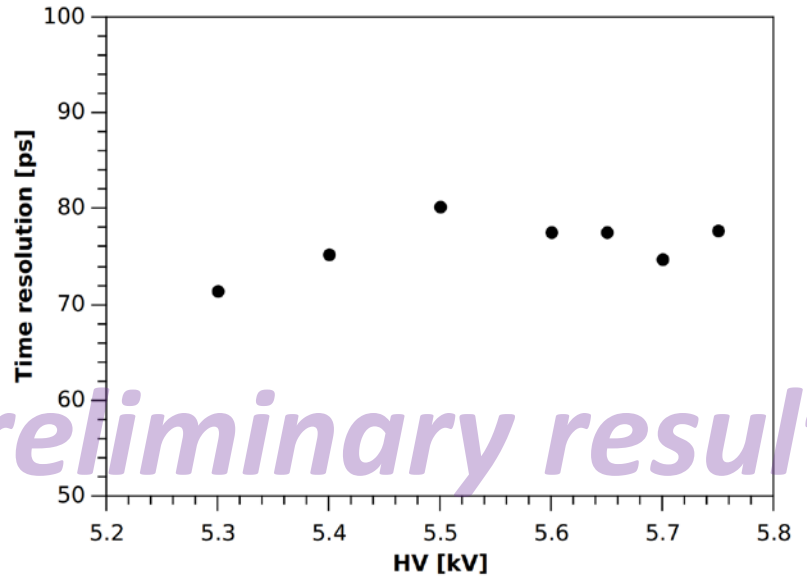
Active area per detector (cm)	33 x 27.6
Stacks × gaps	2 x 4
Gap thickness(mm)	0.25
Strip size (cm)	27 x 1.0
Gap thickness(mm)	0.25
Operating field (kV/cm)	110

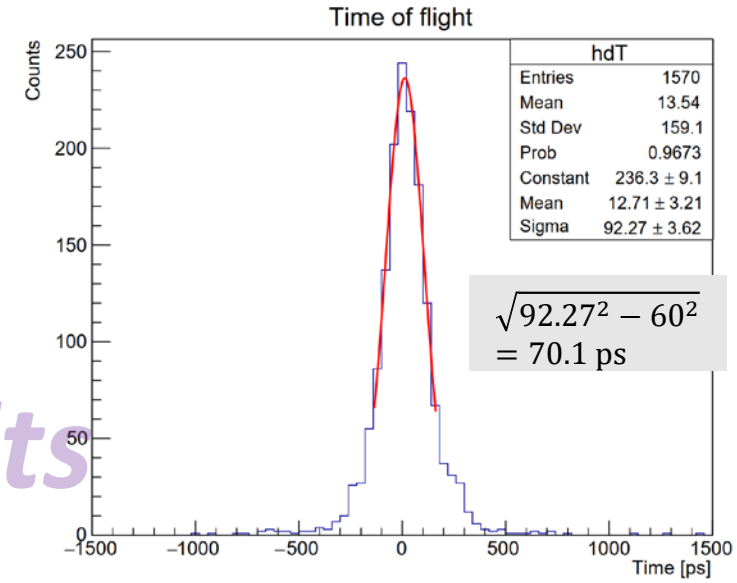
Cosmic test results

- 5 ps timing precision for readout electronics
- NINO-based FEE: 150 mV threshold
- FPGA-TDM J. Lu et al. 2020
- HV scan carried out
- Plateau field 108-114 kV/cm
- Dark current: <50 nA
- 95% efficiency and 71 ps resolution verified.



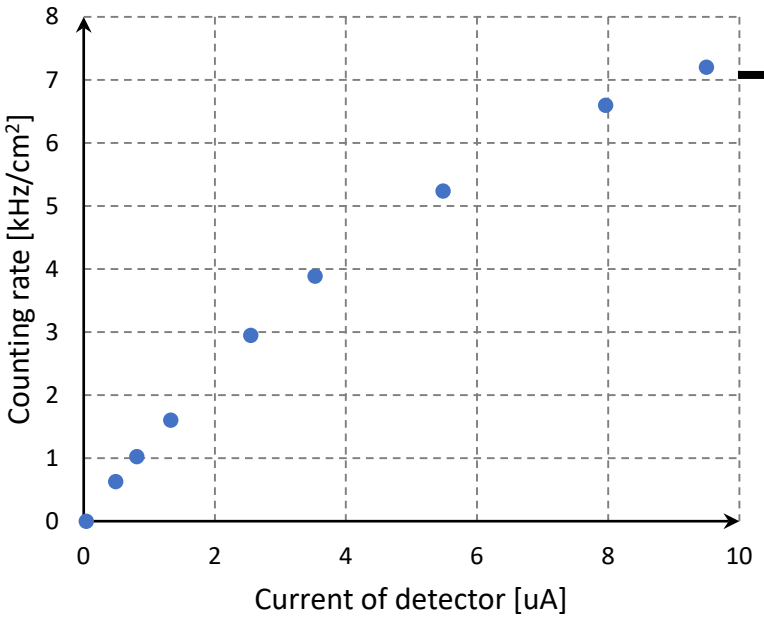




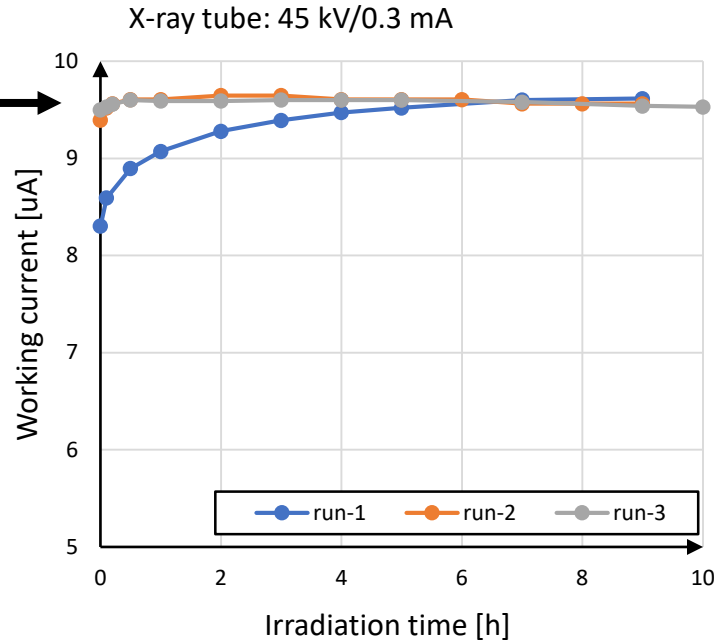


Preliminary results

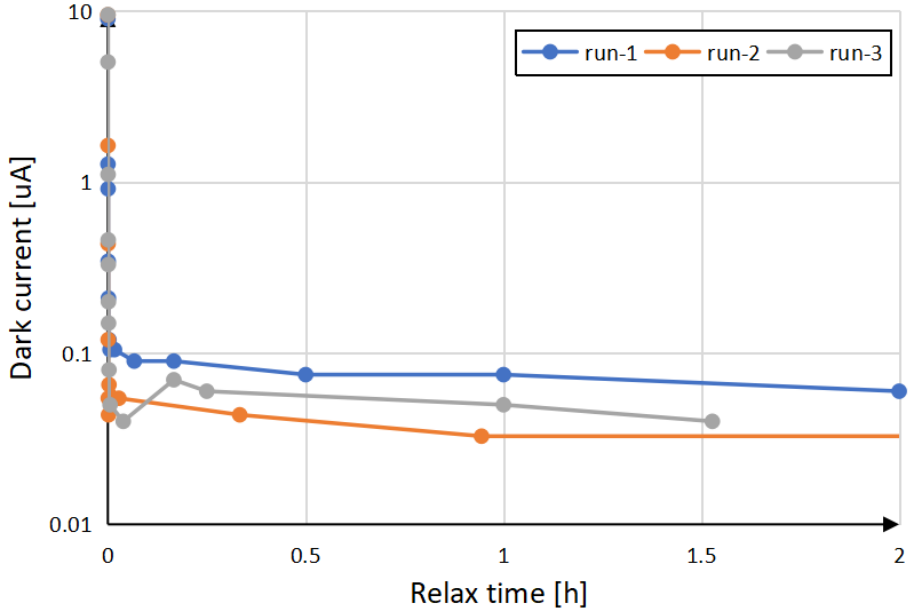
X-ray test results



Rate-current linearity



10 h irradiation @7 kHz/cm^2



Dark current decay

Preliminary results

Summary

- **Sealed MRPCs are developed for CBM-ToF, reducing gas-related effects at a high rate**
- **Low resistive glass for a high counting rate is developed and tested. High-rate MRPC for CBM can work stably at a rate of 70kHz/cm^2**
- **Spacer effect observed at fishline region, pad spacer MRPC prototype shows good first results**

- **What's next:**

A beam test of the pre-production series of the CBM-ToF is planned to be held. The parameter of pad spacer MRPC will be examined at that time.

Thank you!

sun-k21@mails.tsinghua.edu.cn
yiwang@mail.tsinghua.edu.cn