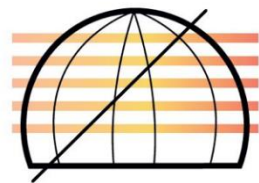


Development of a sealed MRPC with mylar spacers for high luminosity TOF systems

Botan Wang, Kai Sun, Xiaolong Chen, Yi Wang, Dong Han, and Baohong Guo

Tsinghua University, Beijing, China



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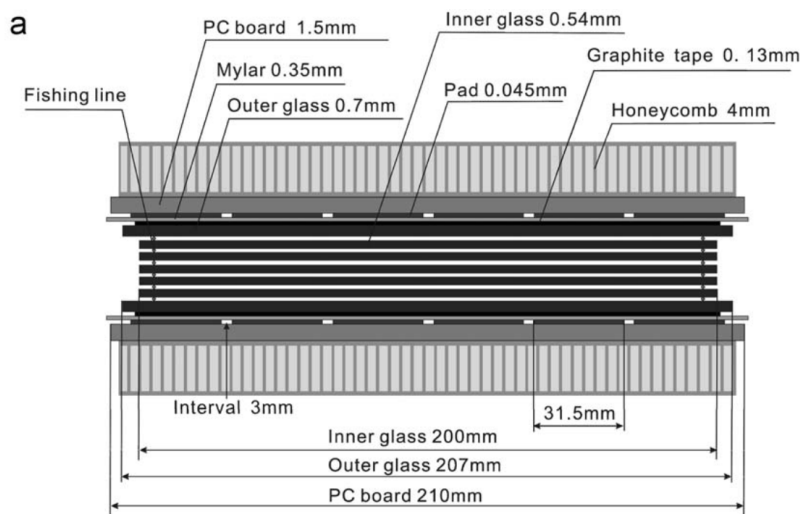
Outline

- Multigap Resistive Plate Chamber (MRPC) for high rate applications
- Gas related challenges and sealed MRPC
- Spacer effect of CBM-MRPC2 prototype
- Study on a mylar spacer MRPC prototype
- Summary

Multigap Resistive Plate Chamber

First proposed in 1996

MRPC has been broadly adopted to construct the Time of Flight (TOF) systems in HEP experiments.



- The multigap structure brings:
- Narrow gap thus high time precision
 - Necessary gap thickness for good efficiency

	STAR	ALICE	FOPI	BESIII	In construction CBM	Proposed SoLID
Active area per detector (cm)	22 x 8.4	120 x 13	90 x 4.6	0.5x(9.2+14.8)x32.8	33 x 27.6	--
Total active area (m ²)	50	141	5	1.33	120	10
Pad size (cm)	6.3 x 3.1	3.7 x 2.5	90 x 0.3	(9.1~14.1) x 2.4	27 x 1.0	(16~28) x 2.5
Gap × thickness(mm)	6 x 0.22	10 x 0.25	6 x 0.3	12 x 0.22	10 x 0.25	10 x 0.25
Gas mixtures (C ₂ H ₂ F ₄ /C ₄ H ₁₀ /SF ₆)	95/5/0	90/5/5	85/5/10	90/5/5	90/5/5	90/5/5
Operating field (kV/cm)	107	96	110	109	110	106
Efficiency	95-97%	99.9%	97 ± 3%	99%	97%	98%
Time resolution(ps)	60	40	73 ± 5	60	80	20 ps
Max rate (Hz/cm ²)	10	50	50	50	30k	10k

The MRPC applications are in the trend of the higher **counting rate** and **time precision**.

Expanding the MRPC rate capability

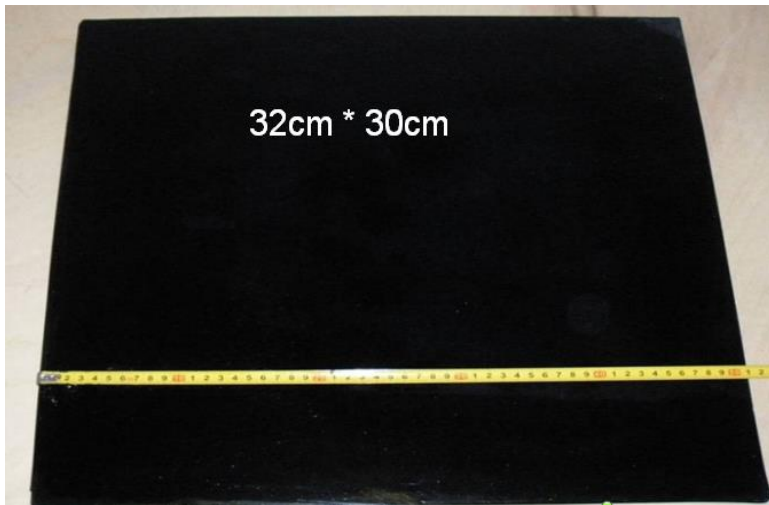
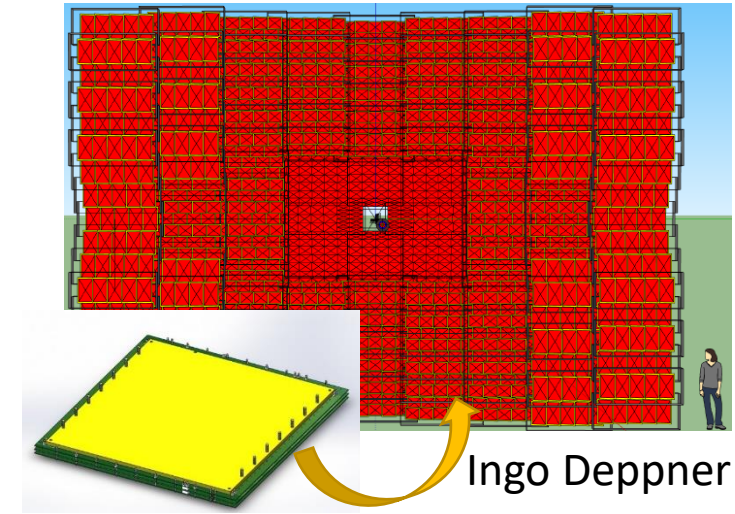
- One must control the voltage drop (efficiency loss) when incident flux goes up.

$$V_{gap} = V_{ap} - \bar{V}_{drop}$$

$$\bar{V}_{drop} = \bar{I}R = \bar{q}\Phi\rho d$$

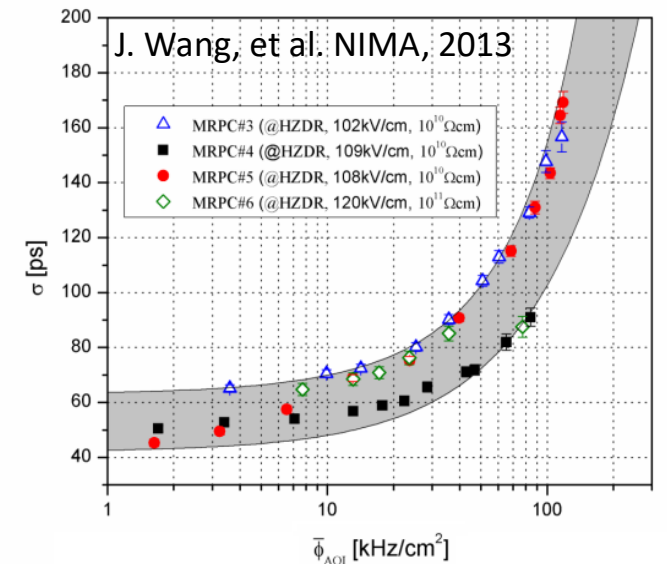
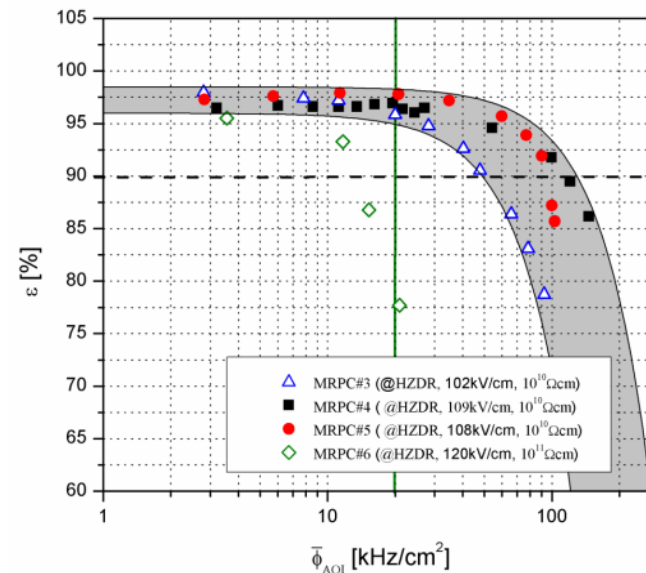
Decrease the resistivity of the electrodes

- MRPC2 with low-resistive glass will be applied in CBM-TOF wall, and has been operating at FAIR-Phase 0 programs like STAR-eTOF and mCBM



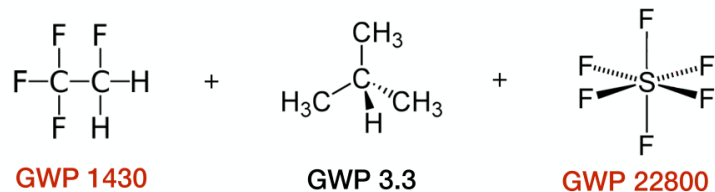
With the low-resistive glass developed in Tsinghua, resistivity has decreased by 2 orders of magnitude. (common float glass: $10^{12} \Omega\text{cm}$, low-resistive: $10^{10} \Omega\text{cm}$)

Rate capability verified through beam test: 93%, 80ps@70kHz/cm²

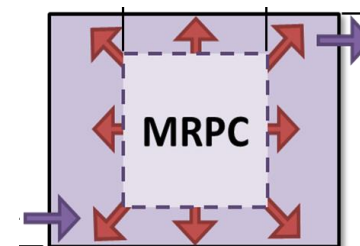


Gas-related challenges of MRPC

- Regulations against greenhouse gases causes uncertainty: availability, cost, eco-impact, ...

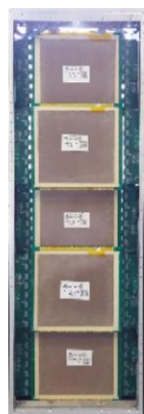
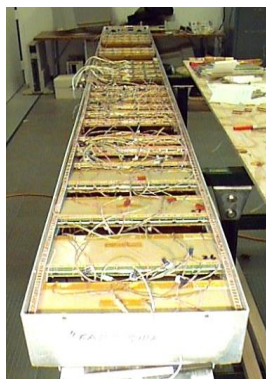


- Gas pollution effect in high rate conditions



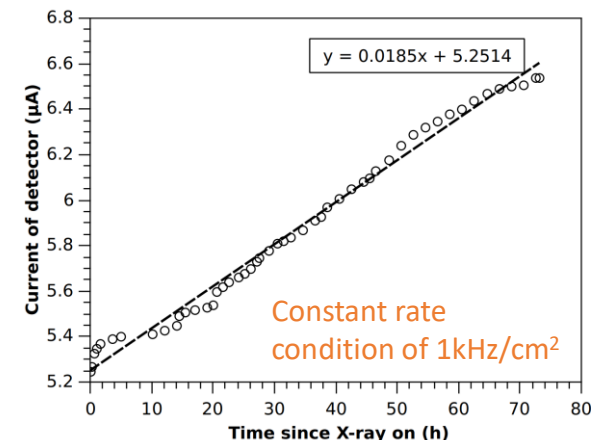
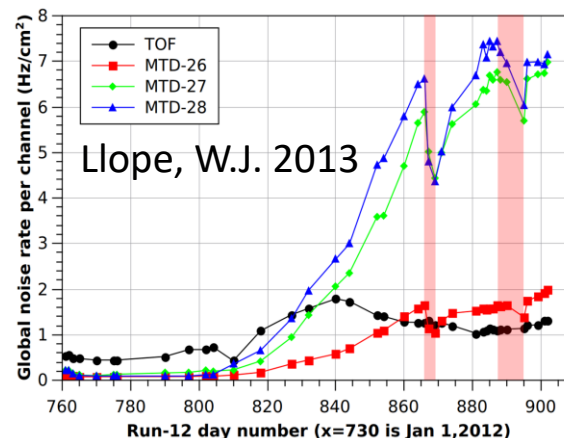
Narrow gap of MRPC and large gas volume --- ionization products exchanged slowly by **diffusion**

- Application with large area: gas flow, cost, leakage, ...



STAR-TOF (left) and CBM-TOF (right) detectors in gas boxes forming a module

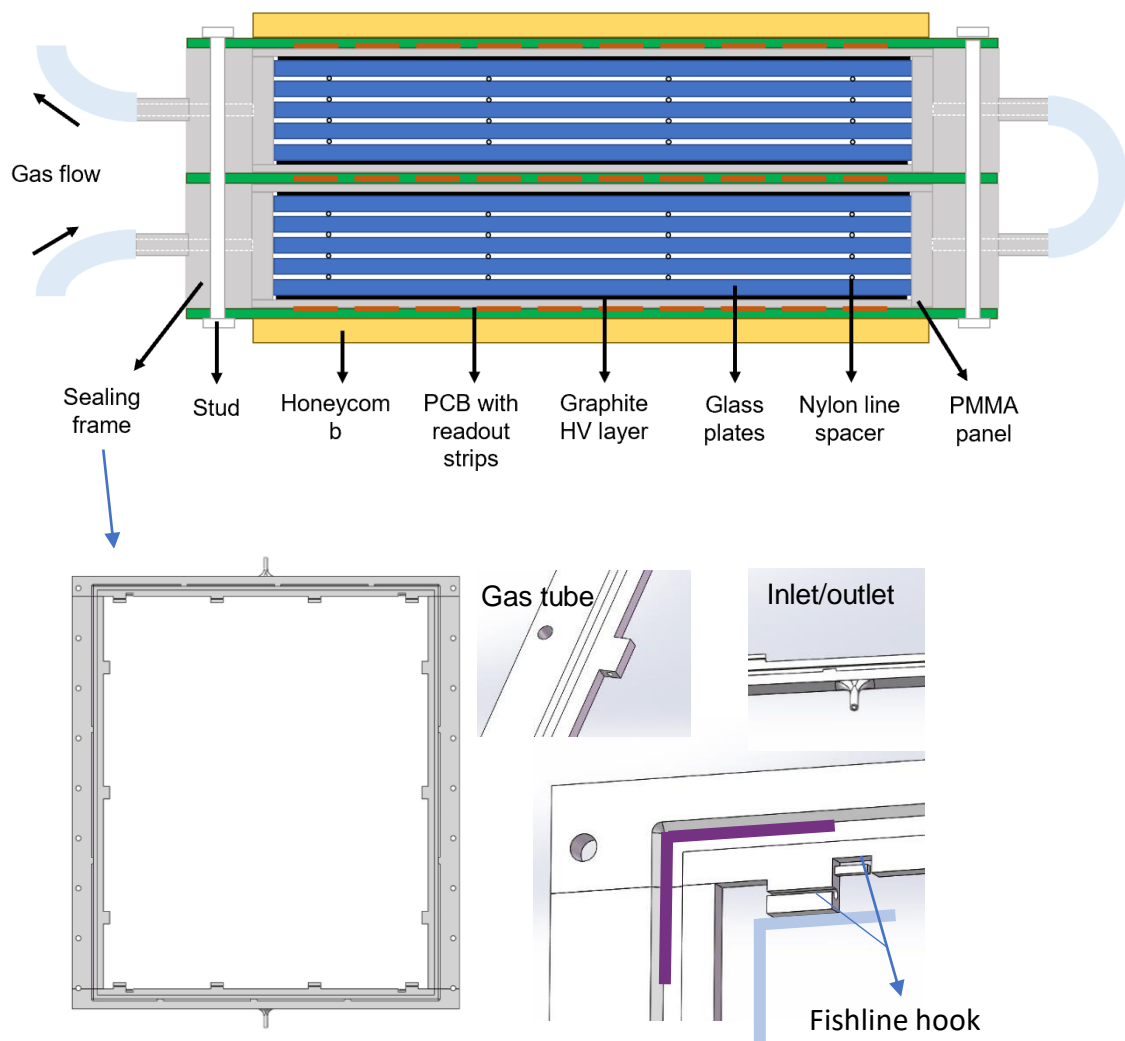
...observed in HEP experiments and lab tests.



Pollution caused noise and current rise

Motivation: A wise design of the gas volume shall promote the gas exchange and decrease the gas consume.

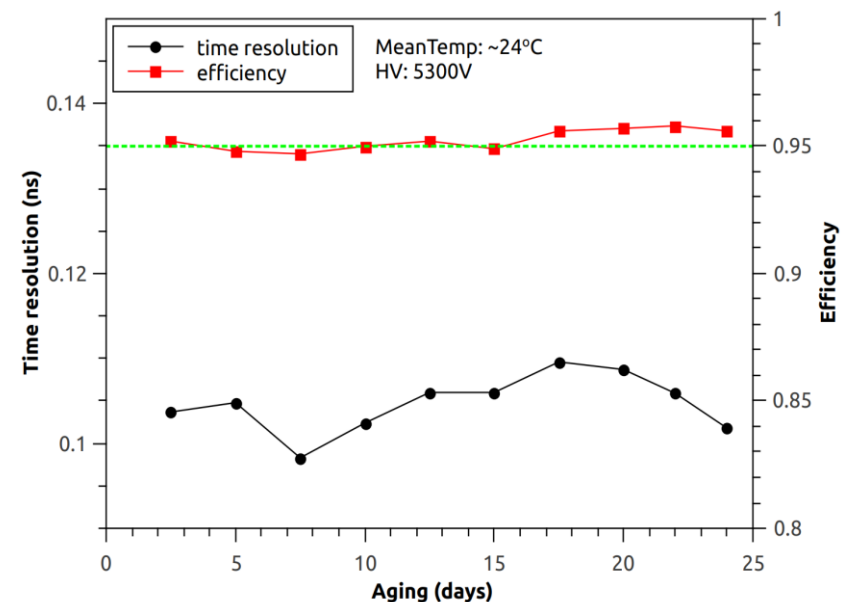
Sealed MRPC



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

□ With the lateral side mostly enclosed, the counter itself becomes a gas box. The sealed design brings the features of:

1. **Gas saving:** < 10 sccm/m² gas flow with common practice



In cosmic ray test of a counter (0.1 m²), 1 mL/min flow is examined with stable operation for the tested 24 days!

Sealed MRPC

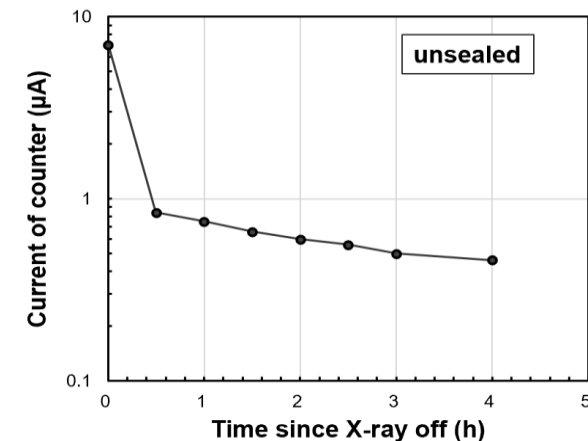
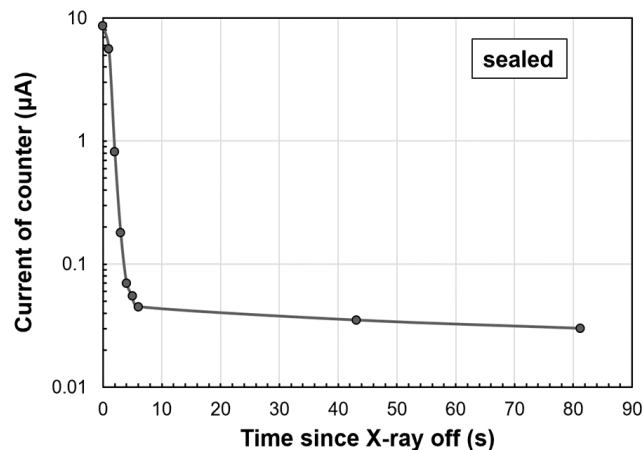
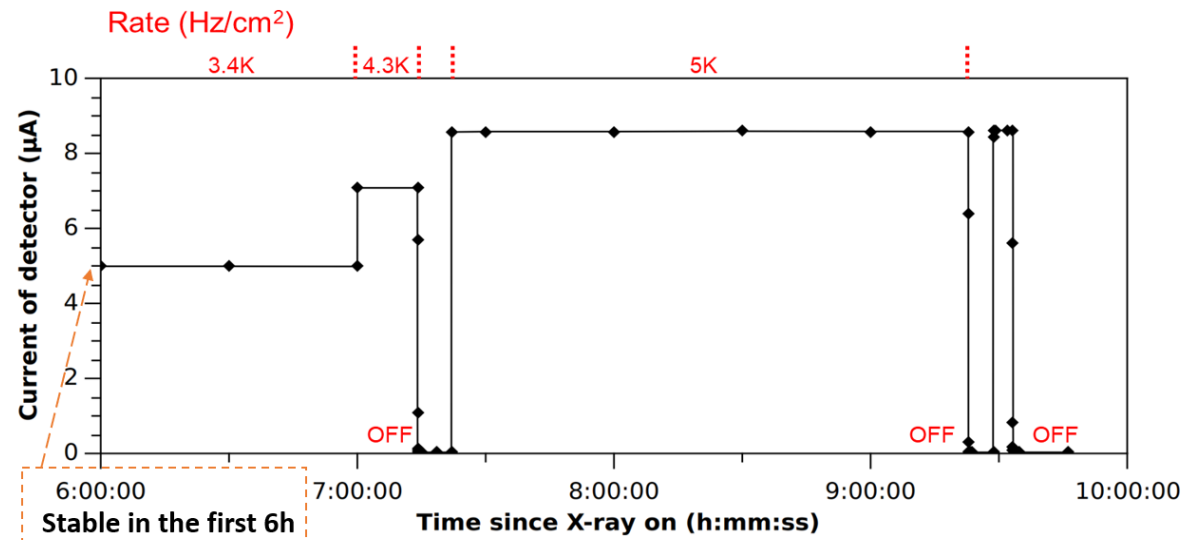
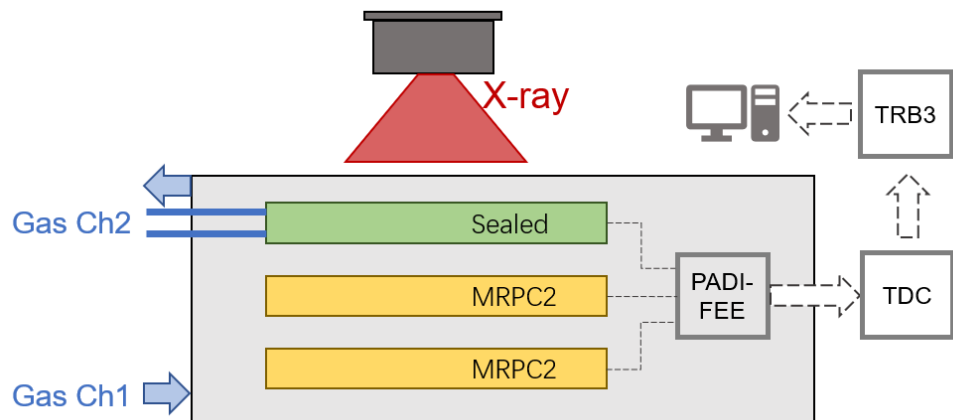
2. Promoted gas exchange

Decrease the wait time of gas purging:

- Reach the working HV in 2h since flowing the gas

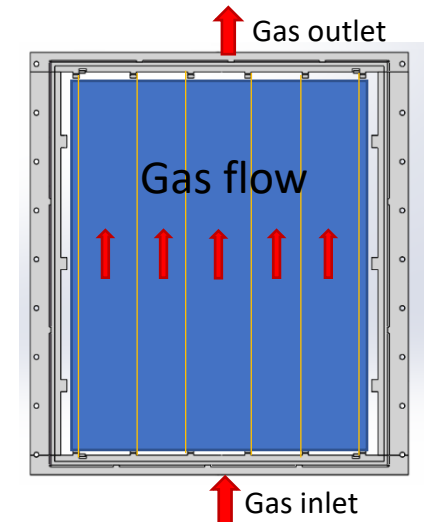
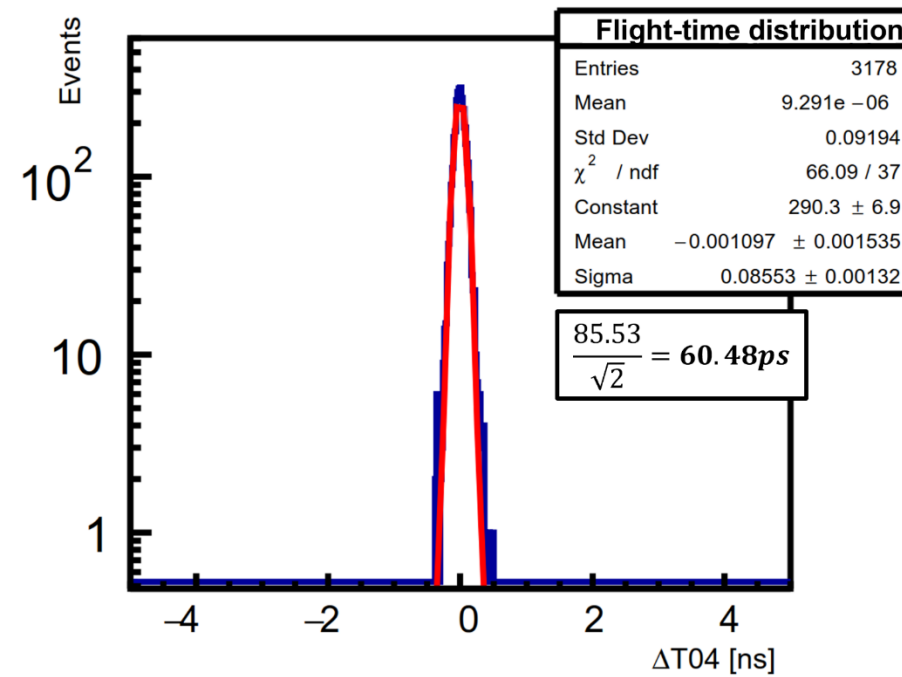
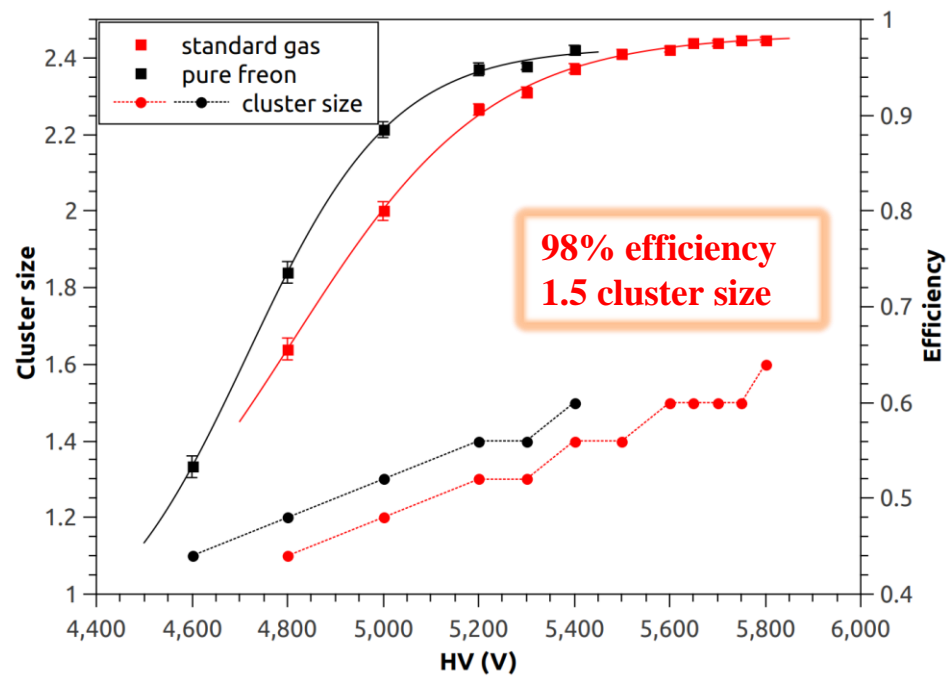
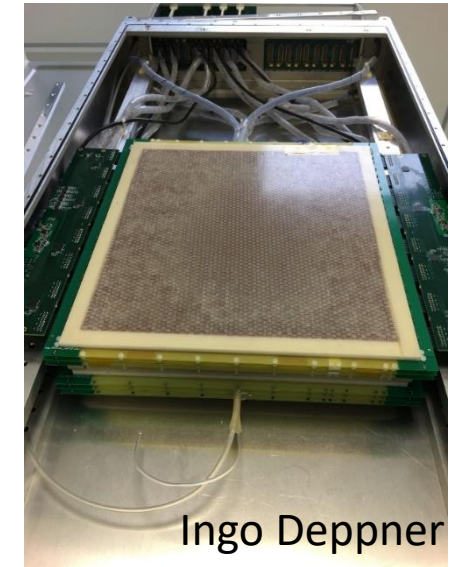
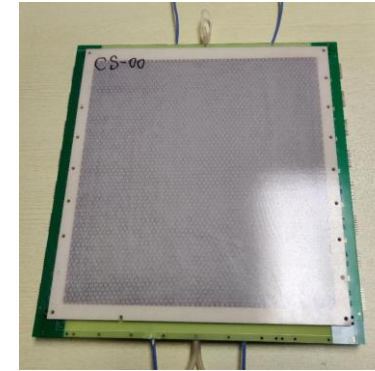
Excellent current behavior under high rate irradiation:

- Stable current with constant rate condition.
- Fast decay of dark current since when X-ray is off



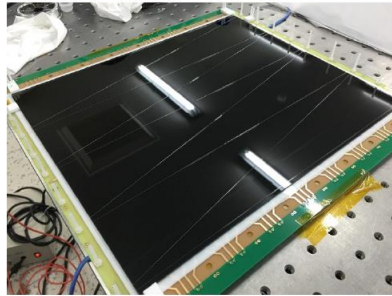
Sealed MRPC2 for CBM-TOF

- High efficiency and time precision maintained.
- Geometry unchanged, making substitution easier
- Fishline arrangement modified from triangular to parallel

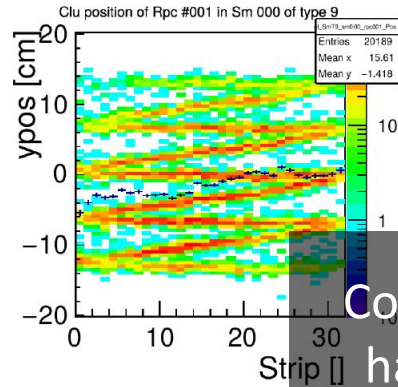


Spacer related effect: evidences

- Practice at CBM observed high noise rate distributed with fishline pattern.

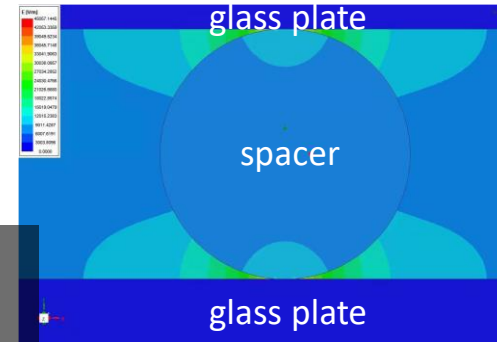


Ingo Deppner



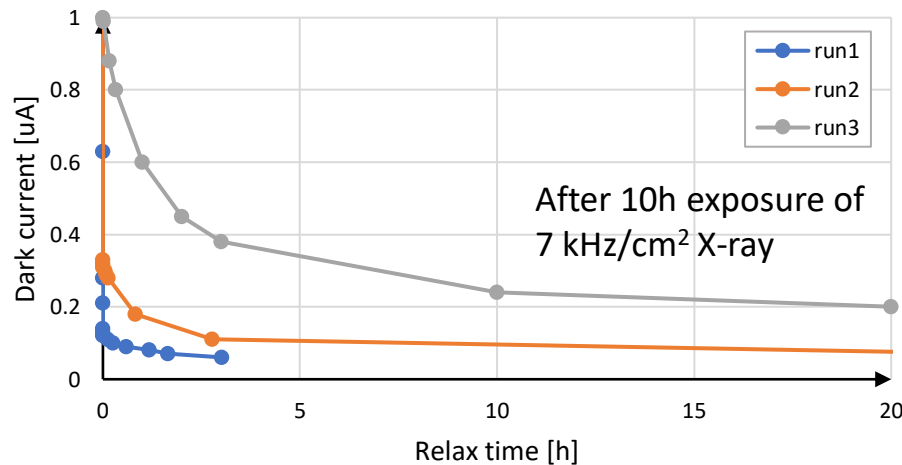
Continuous discharge may happen at spacer region

- Static simulation points out area with high E-field around fishline.

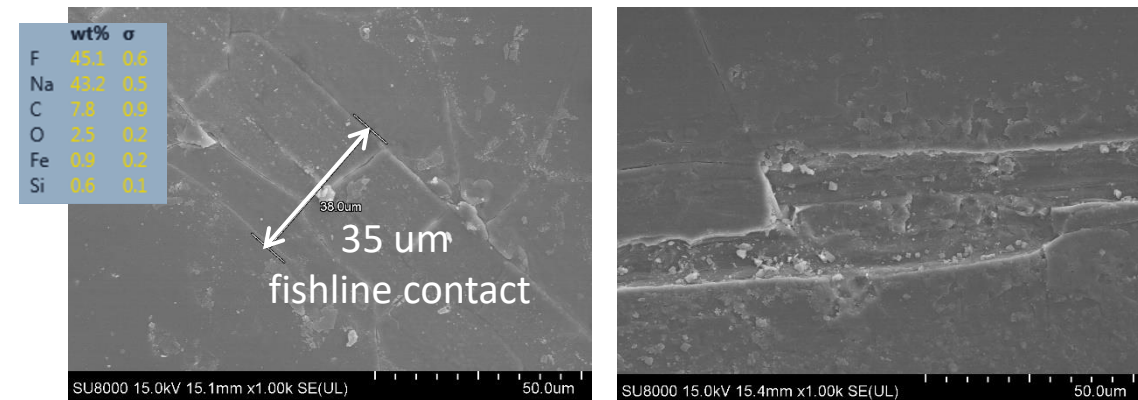


K. Wang

- The high rate sealed MRPC show an aging effect caused by repeated X-ray exposures.



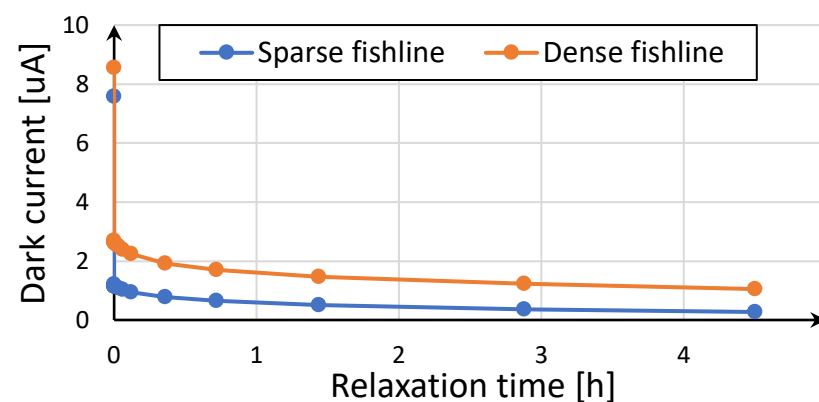
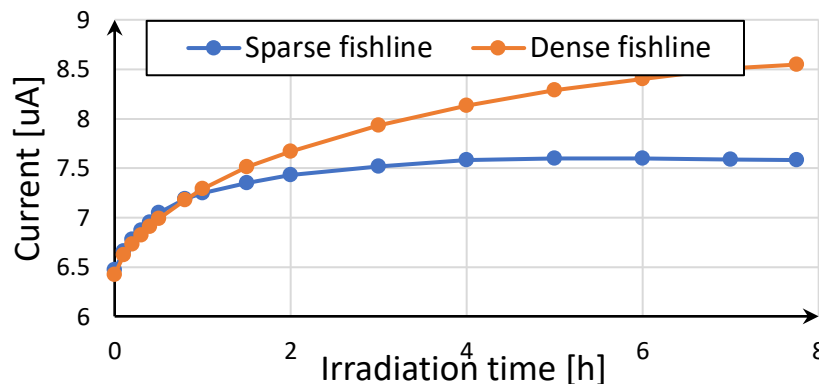
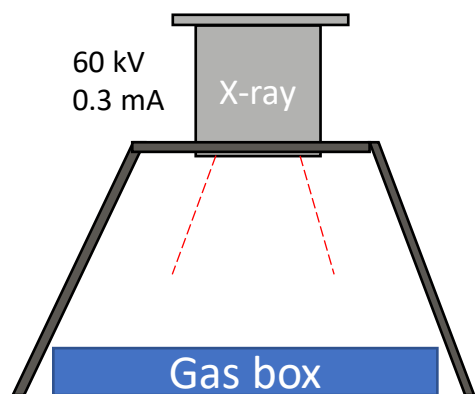
- SEM investigations find cracks on the glass surface at around fishline.



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



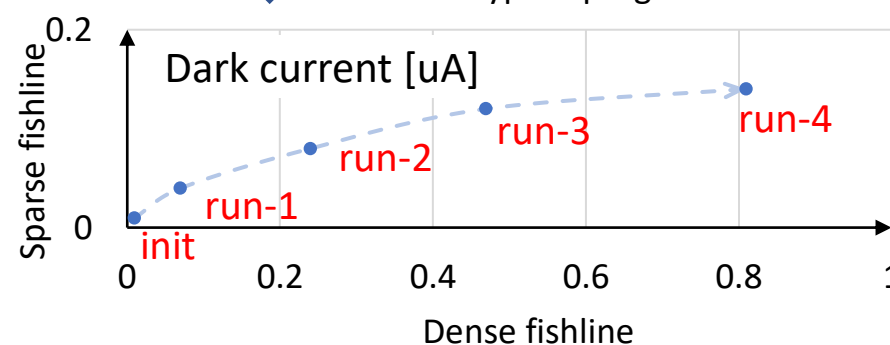
Gas + Spacer effect:

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 mylar spacer prototype

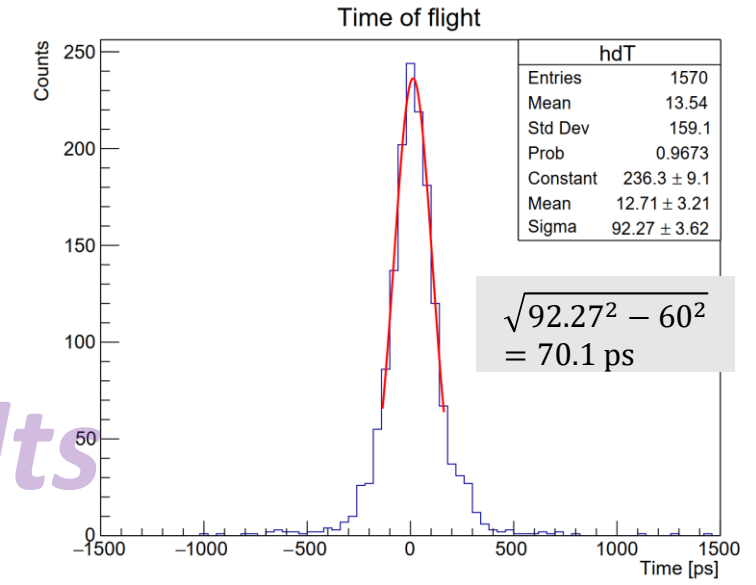
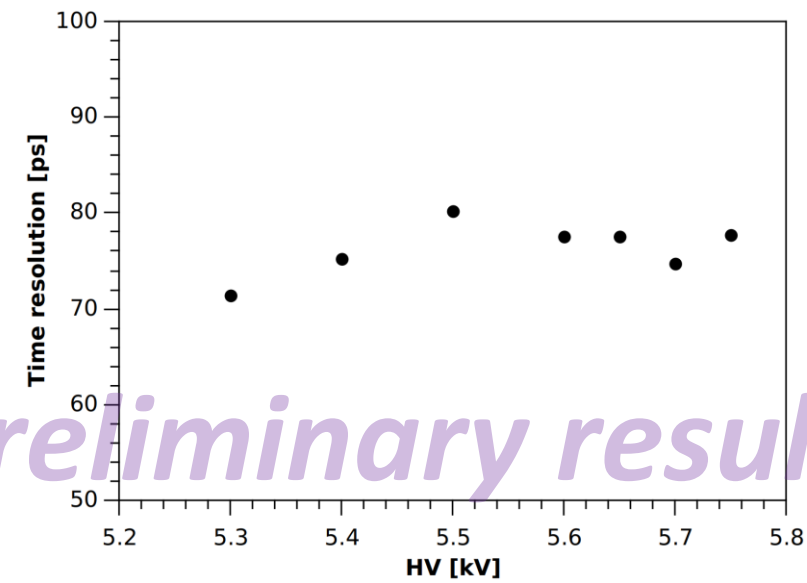
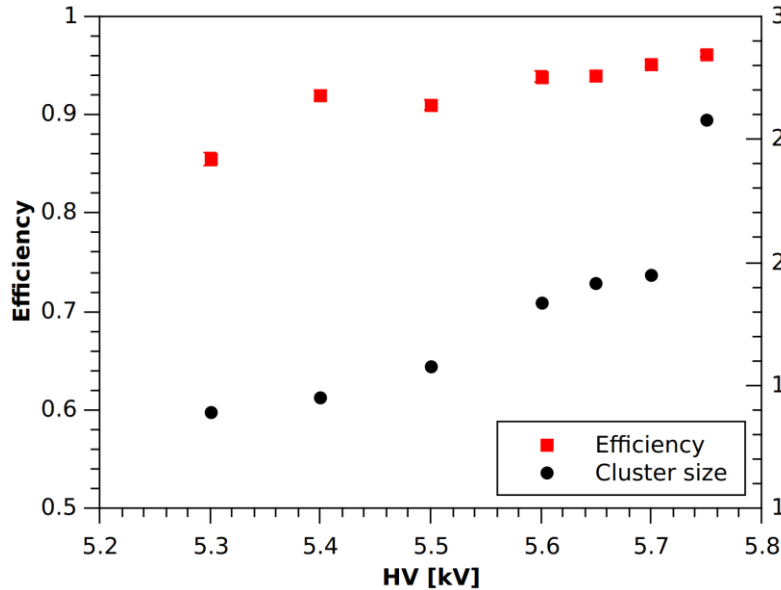
- Mylar spacers
 - Smaller contact area: decrease by a factor of 2. 3.78 vs. 7.2 cm² per gas gap
 - High bulk resistivity: fishline – 10¹⁴ Ωcm, mylar – 10¹⁷ Ωcm
 - Cubic shape, discontinuous placement
- spacers are pasted one-sided on the glass
- spacers distributed with uniform interval of 5 cm
- Sealed 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

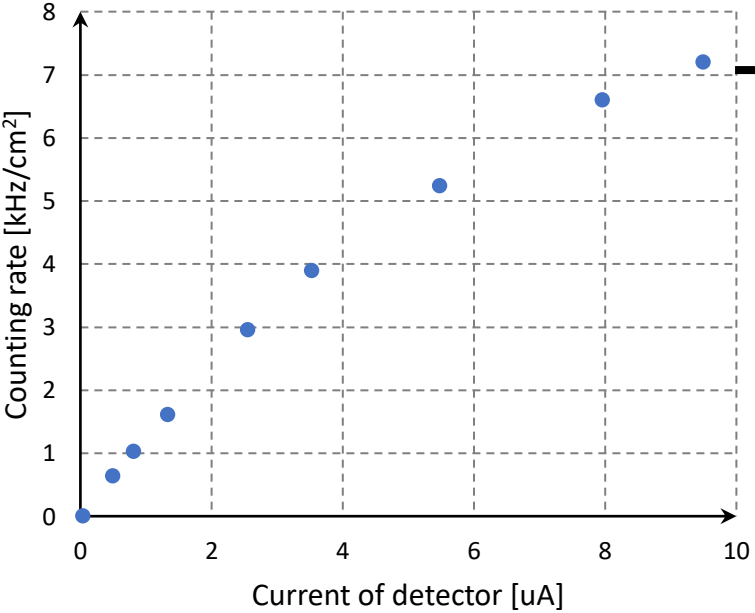
Cosmic test results

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

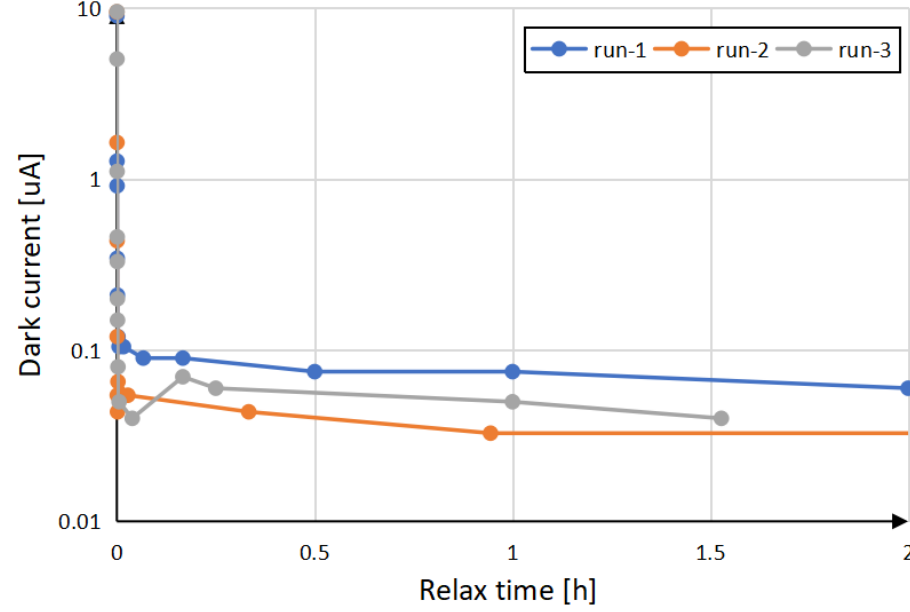
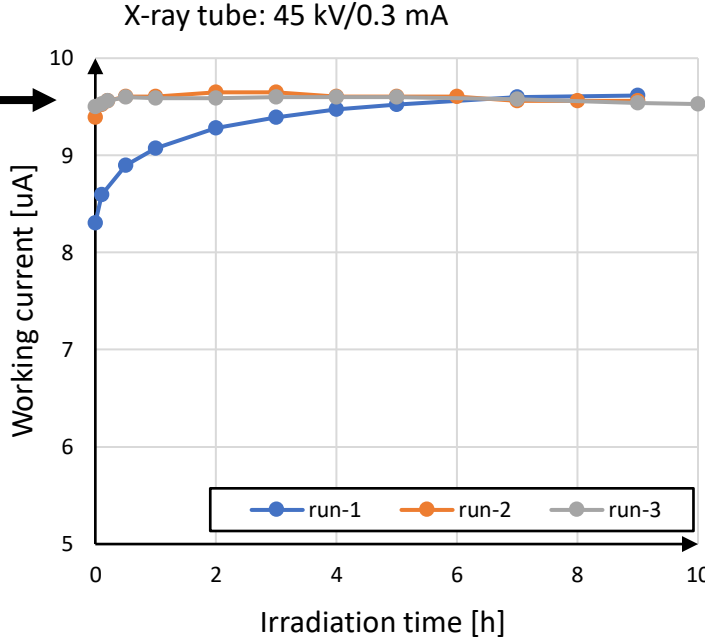


Preliminary results

X-ray test results



Rate-current linearity



Dark current decay after 10h @7 kHz/cm² condition

Preliminary results

Summary

- **Gas related effects become a significant problem for high rate MRPCs**

- Sealed MRPC helps mitigate the gas pollution: stable working current

- **Spacer effect observed at fishline region**

- Cubic mylar spacer MRPC prototype show promising first results

Status and outlook:

- Further evaluations needed: 20 sealed MRPC2 are being produced for further tests at mCBM, 15 with fishline spacer and 5 with mylar spacer
- Study on spacer size, assembling methods, noise behavior ongoing

Thank you !

wbt19@mails.tsinghua.edu.cn