



Update of Ultrahigh Time Resolution MRPC for SoLID-ToF

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- Requirements for SoLID-ToF system
- High rate and ultrahigh time resolution MRPC
- Sealed MRPC: Reducing greenhouse gas emission & Higher gas exchange efficiency
- Pad spacer MRPC: Better in high rate environment
- Future MRPC for SoLID-ToF system

Requirements for SoLID-ToF system

- In SoLID experiment, the requirements for the TOF system are:
 - pi/k separation up to 7 GeV/c
 - Time resolution < 20 ps</p>
 - Rate capability > 10 kHz/cm²
- High rate and high time resolution MRPC is proposed
- The electronics: fast amplifier + waveform digitizer system







Multigap Resistive Plate Chamber



First proposed in 1996



The multigap structure brings:

- Narrow gap -> high time precision
- Necessary gap thickness -> good efficiency

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

	STAR	ALICE	FOPI	BESIII	CBM	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 ($C_2H_2F_4/C_4H_{10}/SF_6$)	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	50k	10k

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

High rate and ultrahigh time resolution MRPC Jefferson Lab

MRPC Simulation Result

Electronic noise and signal transmission are considered carefully

Substitution \mathbf{b} Gap thickness below 160 μm , more than 3 stacks, more than 4 gaps in one stack

→20 ps

➢ 4x8 gaps, 128 um gap thickness





	MRPC		
Gap thickness	128 um		
Number of gaps	$4 \times 8 = 32$		
Glass	Low resistive glass		
Glass thickness	400 um		
Readout strip	5 mm (2 mm gap)		



Electronic readout system





Diagram of the **AFE module**

- ➤ Gain: 26 dB~40 dB
- Band width: 1.4 GHz
- Time jitter: 4 ps



waveform sampling module

- SCA (DRS4): 1024 sampling capacitor
- ➢ Max sampling rate: 5.12 GHz
- Noise: 0.5 mV
- Time jitter: 3 ps







Time difference = $(T_{ch1} + T_{ch2})/2 - (T_{ch3} + T_{ch4})/2$

Cut: "Angle" of incident particle = $(T_{ch1} - T_{ch3})/2 - (T_{ch2} - T_{ch4})/2$



Cosmic ray test





Ultrahigh time resolution MRPC can reach a time resolution of $23.24/\sqrt{2} = 16.44 \text{ ps}$

Sealed MRPC: Reducing greenhouse gas useJefferson Lab





Sealed MRPC aims to reduce gas flow

- ➤10 gas gaps of 250µm thickness
- ➢ gas flow: less than **10sccm** for **1m²** sensitive area

decreased by a factor of 10 compared with traditional MRPCs



Sealed MRPC: Reducing greenhouse gas useJefferson Lab

The Global Warming Potential(GWP)

GWP is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of CO_2 .

Gas Type	GWP(100y)	Density (kg/m3)
CO ₂	1	2.00
SF ₆	23900	4.25
HFC-134a	1430	6.17



GWP Decrease of Sealed MRPC :

- ➤100 m² of MRPC Working for 1 year(non-stop)
- Traditional MRPC: 7740.2 kg HFC-134a and 624.3 kg of SF₆ In one year
- Sealed MRPC can reduce 90% emission of greenhouse gases
- ➢ Reduce the GWP down to $2.339 × 10^4$ tonnes of CO₂ each year

Sealed MRPC: Higher gas exchange efficiency efferson Lab

Decrease the wait time of gas purging: ➤ Reach the working HV in 2h since flowing the

gas

- Excellent current behavior under highrate irradiation:
- Stable current with constant rate condition.
- Fast decay of dark current since when X-ray is





Spacer related effect: evidences



- Practice at CBM observed high noise rate distributed Static simulation points out area with high Efield around fishline. with fishline pattern. Clu position of Rpc #001 in Sm 000 of glass plate [ເພິ sodk spacer -1(Continuous discharge may K. Wang -20 glass plate 20 strip i happen at spacer region
- 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



Development of first pad spacer prototype



- pad spacers of $3x3 \text{ mm}^2$ ($\Phi=4 \text{ mm}$ round pad for new one)
 - Smaller contact area: decrease by a factor of 2.
 - > High bulk resistivity: fishline $10^{14} \Omega$ cm, mylar $10^{17} \Omega$ cm

discontinuous placement

- spacers are pasted one-sided on the glass
- spacers distributed with uniform intervals of 5 cm

Prototype parameter

B	5 x 5 cm	 . Conservation	0	\backslash
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Active area per detector (cm)	33 x 27.6		
Stacks $ imes$ 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		

Pad spacer prototype: X-ray test results





Rate-current linearity

Working current increases linearly with an increasing count rate

10 h irradiation @7 kHz/cm²

 \succ the working current did not \succ The dark current also shows increase after the second irradiation round

Dark current decay

no increases after rounds of irradiations.

2023/5/8



> Ultrahigh time resolution MRPC can reach a time resolution of 23.24/ $\sqrt{2} = 16.44$ ps (4x8 gaps, 128 um gap thickness).

Sealed MRPC can reduce 90% emission of greenhouse gases and require higher gas exchange efficiency.

Pad spacer MRPC is more stable in dark current and working current, especially in a high-rate environment.



>Ultrahigh time resolution MRPC with a sealing frame is on the test.

Controlled experiments of cosmic ray and X-ray tests on fishline spacer and pad spacer MRPC are ongoing.

Build an ultrahigh time resolution sealed MRPC for SoLID