

Find eco-gas mixtures for a coupled readout MRPC

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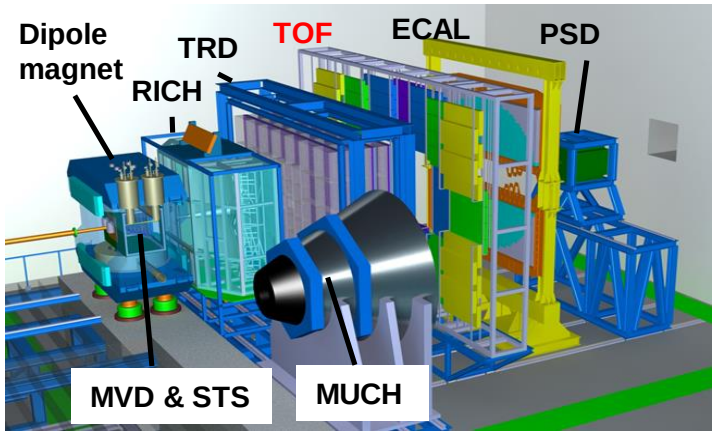
Outline

- Background
- Study on signal generation of coupled readout MRPC
- Cosmic test of coupled readout MRPC prototypes
- Test status of MRPC3a using eco-gas
- Conclusion

MRPC3a for CBM-TOF wall



Compressed Baryonic Matter experiment

Timing performance for PID:

$$m = p\sqrt{\frac{c^2t^2}{l^2} - 1} \qquad \Delta t < 80ps$$

High counting rate:

~ 30 kHz/cm^2

Structure of MRPC3a:

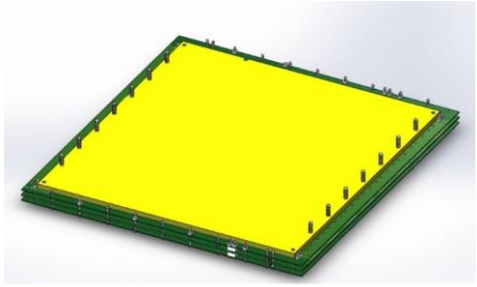
Glass: low resistive glass
0.7mm thick, 33cm*27.6cm

Strip: 27cm*0.7cm, 0.3cm interval, 32 strips

Gas gap: 8*0.25mm, two stacks

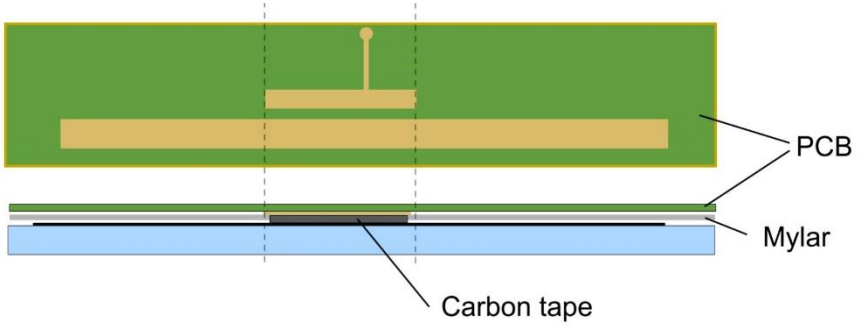
MRPC3a with low-resistive glass of ~10^{10}Ωcm :

Efficiency	>95%
Time Resolution	<60ps
Cluster Size	~1.6



Some drawbacks for MRPC3a

- Noise rate problem on the side strip near HV circuit



Method to apply HV. Only the side strip is shown. (32 strips in total)

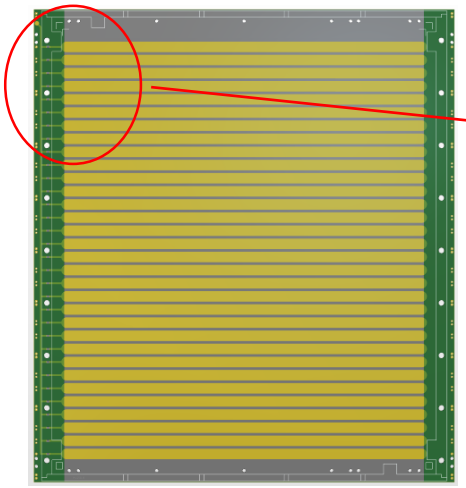
Side Strip	Others
2946	1.22

Noise rate (Hz/cm^2)

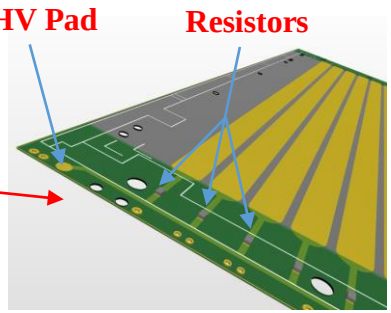
- Spraying colloidal graphite can be time-consuming and harmful for health.

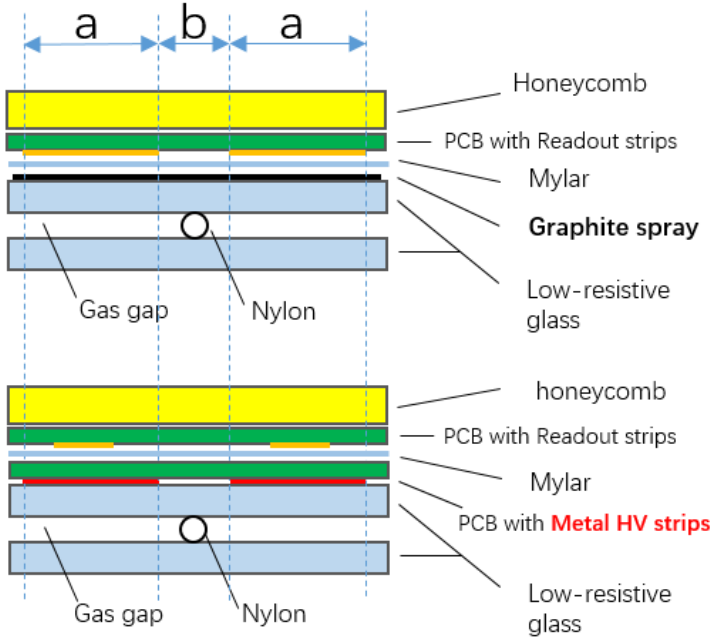
Structure & Feature of Coupled Readout MRPC

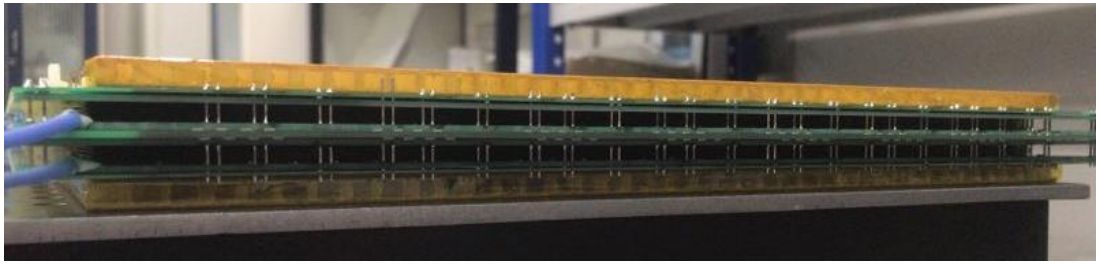
The improvements:
1. Easier and more eco-friendly to produce
2. Reduce noise of side strip
3. Easy for impedance matching in requirement of occupation.



HV Board



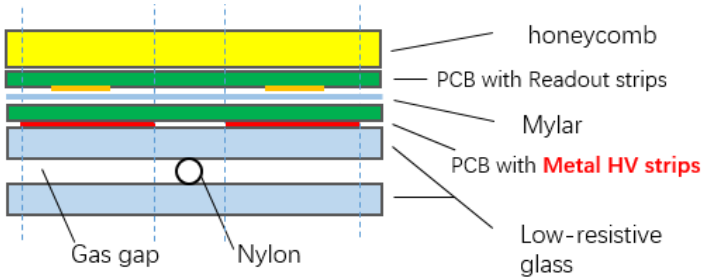




Why "Coupled Readout" ?

Basis: Shockley-Ramo Theorem $Q = -q\varphi_0(\boldsymbol{x})$

$i = q\boldsymbol{v} \cdot \boldsymbol{E}_0(\boldsymbol{x})$



Two contributions to readout signal:

1. Directly induced by moving charges, which can be described by S-R Theorem.
2. Induced by capacity coupling between HV and readout strips.

$$\frac{dq}{dt} = N_0 e^{\alpha_E v t} q_e v E'_w + \frac{C_t}{C_{HV}} \frac{dQ}{dt}$$

For charge in HV strip:

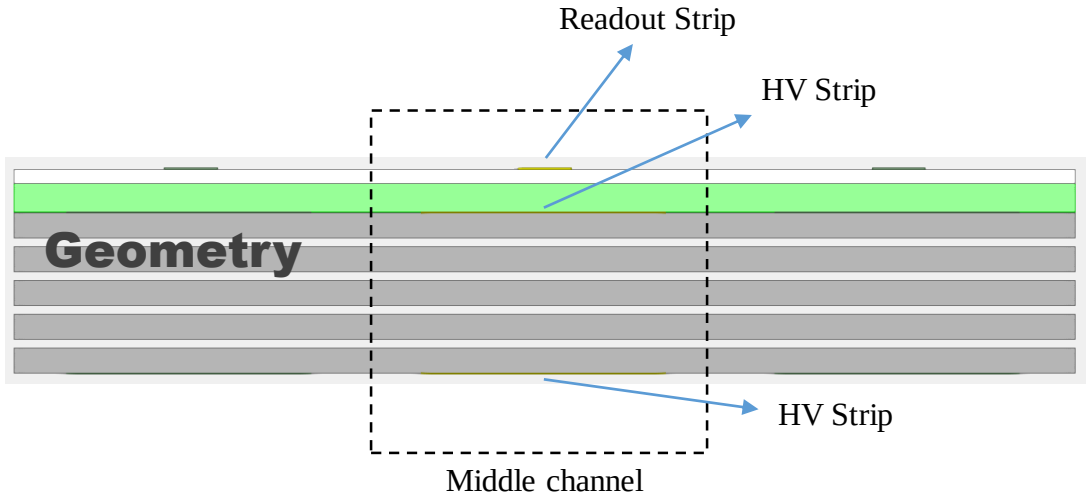
- Induced by moving charges in gaps, fit S-R Theorem.
- Flow from HV strip to the power source.

$$\frac{dQ}{dt} = N_0 e^{\alpha_E v t} q_e v E_w - \frac{Q}{C_{HV} R_{HV}}$$

E_w、 E'_w、 C_{HV}、 C_t、 R_{HV} are important for further calculations.

Maxwell 2D Simulation

E_w	~ 700 V/m
E'_w	~ 1.6 V/m
C_{HV}	189.3 pF/m
C_t	60.418 pF/m



Simulation result

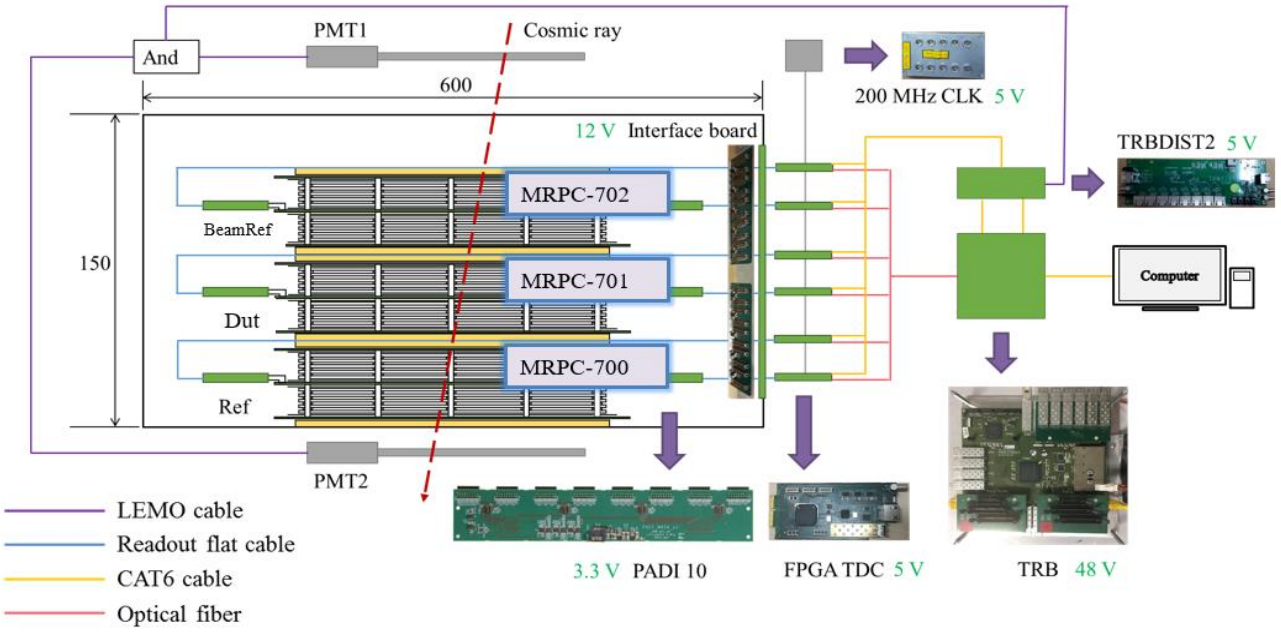
$$\frac{dq}{dt} = N_0 e^{\alpha_E v t} q_e v E'_w + \frac{C_t}{C_{HV}} \frac{dQ}{dt}$$

$$\frac{dQ}{dt} = N_0 e^{\alpha_E v t} q_e v E_w - \frac{Q}{C_{HV} R_{HV}}$$

$$\frac{C_t}{C_{HV}} \sim 1/3$$

$$\frac{C_{HV}}{C_t} \frac{E'_w}{E_w} \sim 1/100$$

Cosmic Test System



Settings:

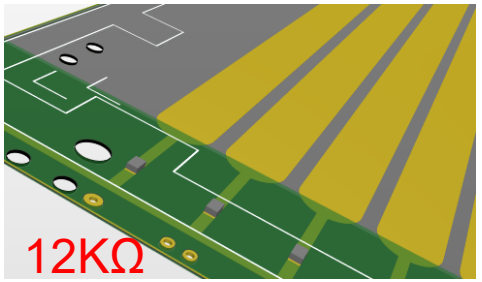
700, 702: MRPC3a, 5600V

701: Coupled MRPC, with and without resistors

Gas: Freon/iC4H10/SF6 90/5/5, 70ml/min

Threshold: 300mV

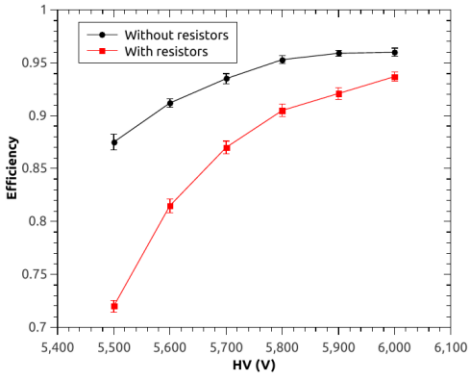
Triggering area: 20cm*5cm



HV board

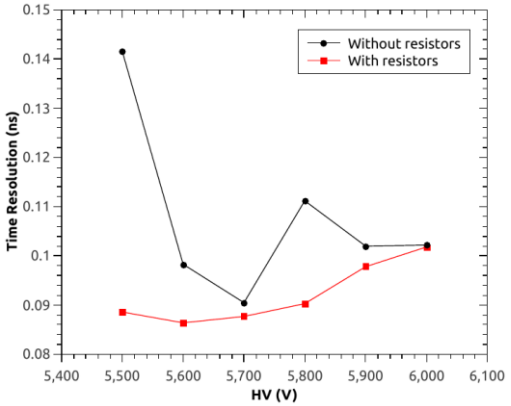
Test Results: HV Scan

Efficiency:



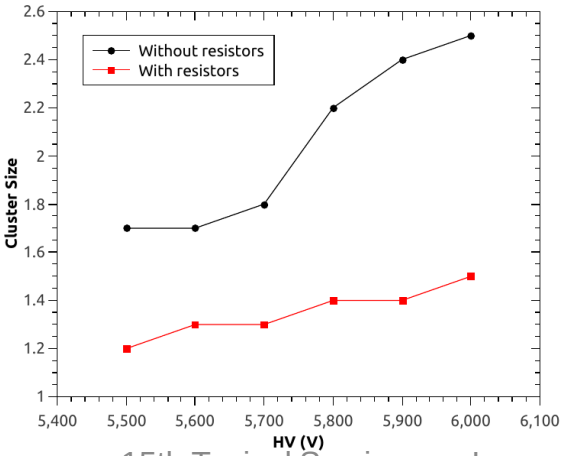
Adding resistors decreases efficiency from 96% to 93%
Working point around 6000V

Time resolution:



Gets better with resistors.
Less than 100ps.(System σ)

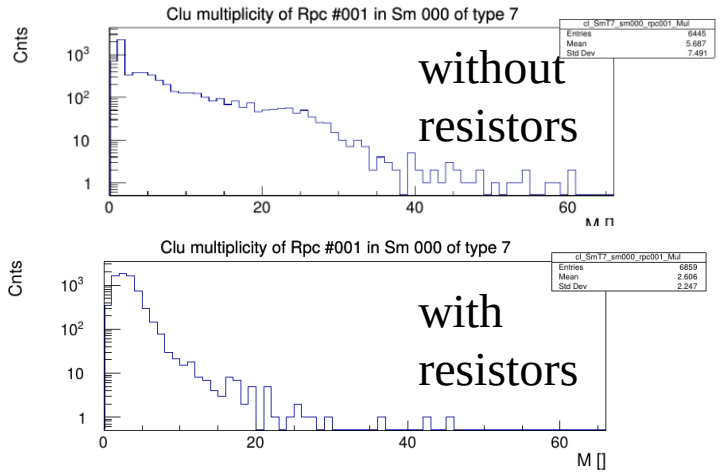
Cluster size:



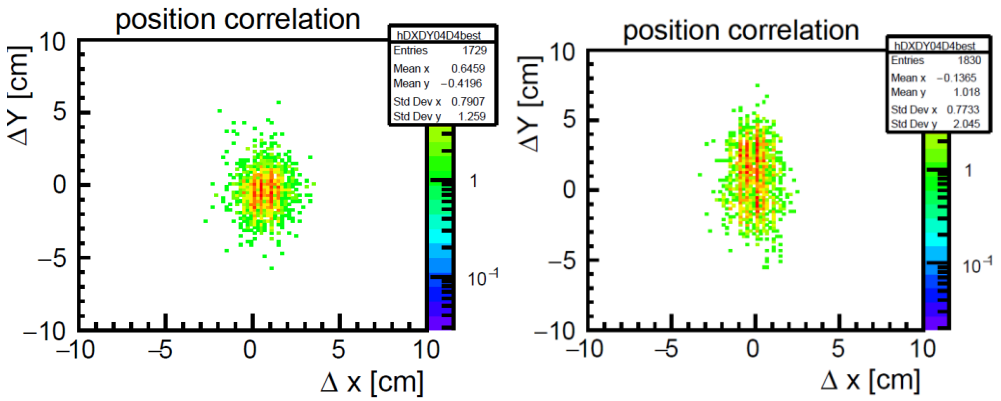
Decreases apparently with resistors.
Less than MRPC3a's level (~1.6)

Test Results at Working Point

Multiplicity:



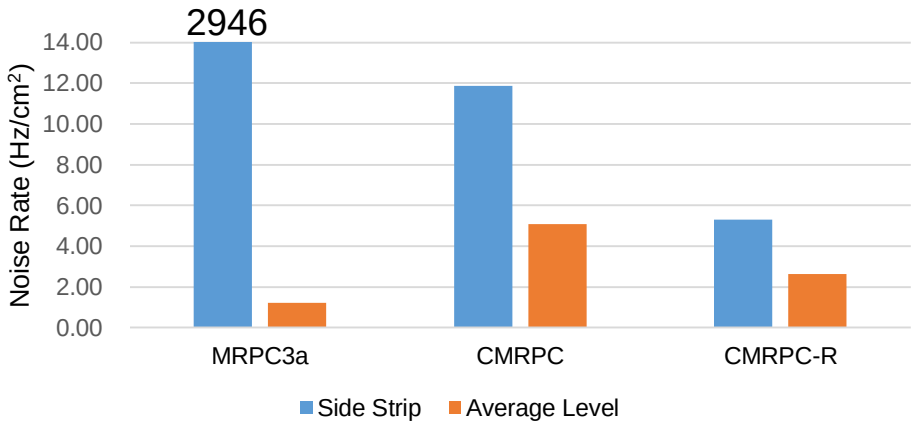
Y position reconstruction:



without resistors

with resistors

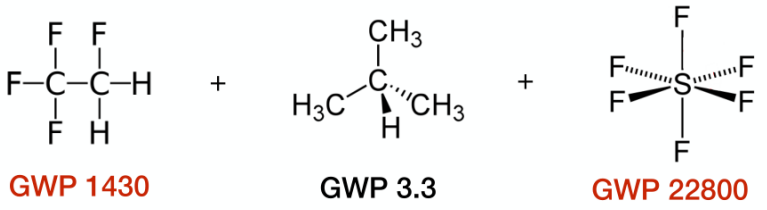
Noise on side strip:



Coupled MRPC can solve the noise rate problem on the side strip.

Motivation on eco working gas

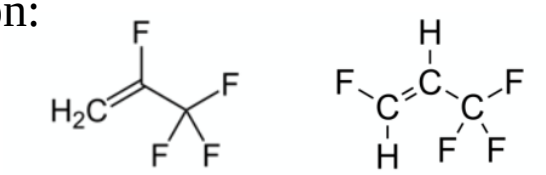
Global Warming Potential measures how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide.



European Union **"F-gas regulation"**:
-**Limiting the total amount** of F-gases that can be sold in the EU
-**Banning the use of F-gases** in many new types of equipment.
-**Preventing emissions** of F-gases from existing equipment.

Much uncertainty about the **price and availability** in the future

Eco-gas replacements:
-for Freon:



GWP 4 6

* One more carbon with a double bond, ideal substitute as refrigerant. Unknown about the performance of ionization.
-Eco-gas mixtures
He, CO_2, i-C_4H_{10} …

Eco-gas Test Status

Settings：3 MRPC3a counters

Gas：70ml/min

a. Pure HFO

b. HFO/iC_4H_{10} 95/5

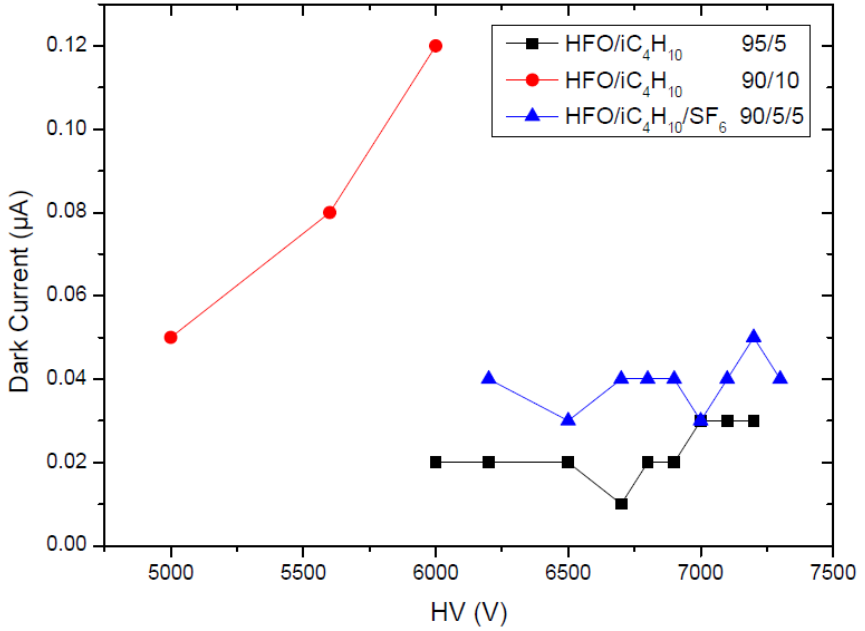
c. HFO/iC_4H_{10} 90/10

d. HFO/iC_4H_{10}/SF_6 90/5/5

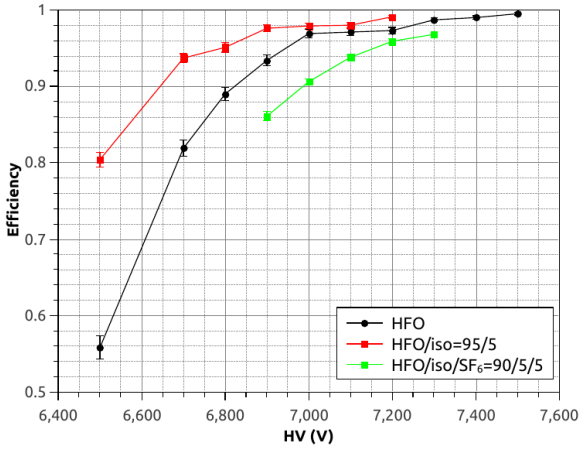
Threshold: 300mV

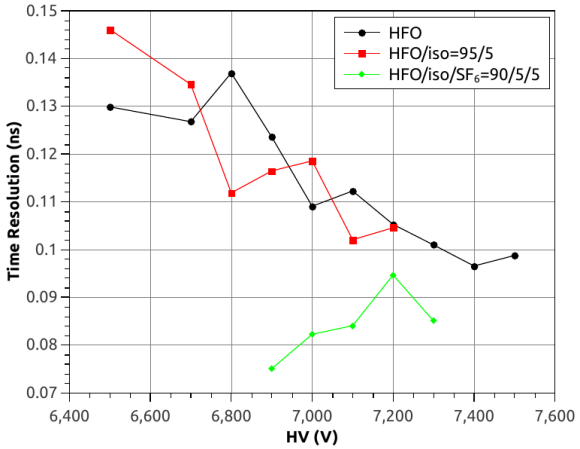
Dark current should be no more than 0.1μA to protect counters.

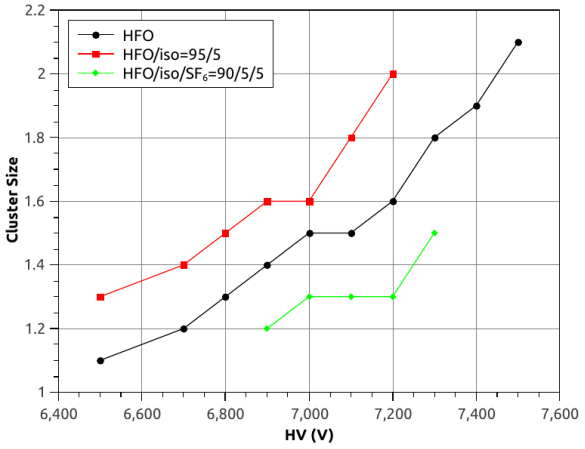
For gas c, fail to apply high enough HV for test. Other gas mixtures can execute the HV scan.



Preliminary Test Results







At working point：

E_g:
~140 kV/cm

~110kV/cm

	HV (V)	Eff	Noise (Hz/cm^2)
HFO	7000	0.959	3.02
HFO/iso 95/5	6900	0.974	1.63
HFO/iso/SF_6 90/5/5	7200	0.962	2.8
Std Gas	5500	>0.975	1.22

Conclusion

- The principle of signal generation for Coupled readout MRPC has been studied. Coupled signal gives main contribution.
- Prototypes produced for cosmic test, and adding the resistors between HV strips and cable can help decrease the cluster size, multiplicity and noise level.
- However, more investigations on HV resistivity and producing process should be considered. More prototypes will be produced soon.
- Eco-gas test is still ongoing for more gas mixtures.

Thank you !