

A Novel Anti-Aging TBS MRPC

Ming Yao

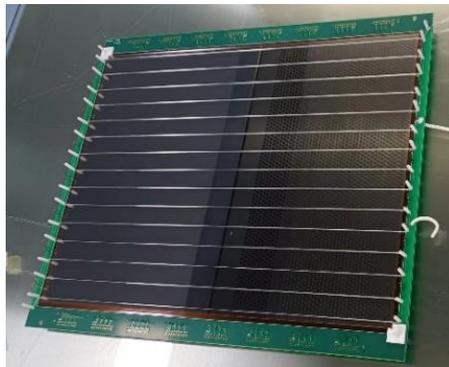
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Department of Modern Physics, USTC

- Introduction
- Detector aging effect
- TBS MRPC
 - Design and simulation
 - Performance test
- Summary

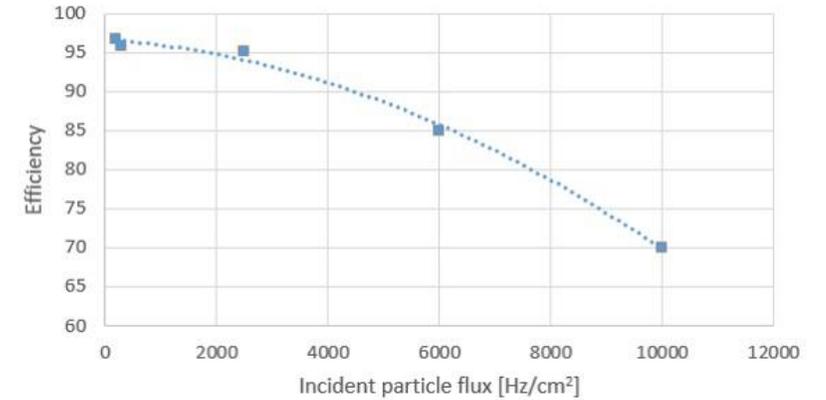
CBM-TOF

Parameters of MRPC3/4 for CBM-TOF

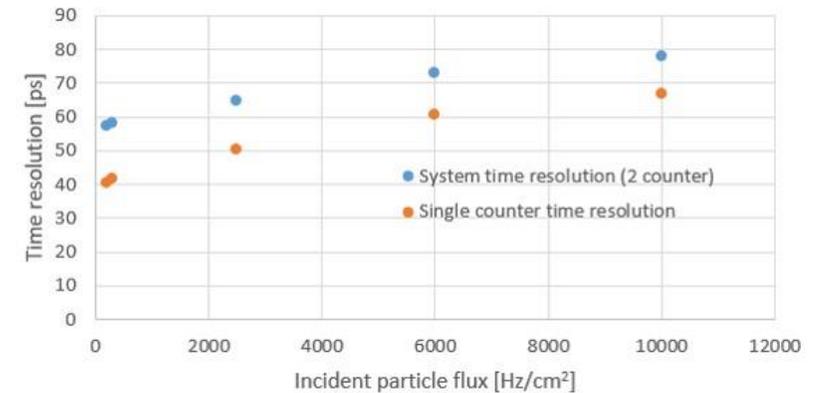
		MRPC 3	MRPC 4
		Double-stack	
Glass	Type	ultra-thin float	
	Size	353 x 276 x 0.23 mm	353 x 540 x 0.23 mm
Gaps	Size	0.230 mm	
	Number	5 x 2	
Readout strips		(0.7 cm + 0.3 cm) x 32 ,double-end strip readout	
Impedance		50 Ω differential signal to PADI	
Active area		320 mm x 270 mm	320 mm x 540 mm
Detector size		377 x 324 mm	377 x 588 mm



Efficiency as function of incident ch. particle flux



Time resolution as function of incident ch. particle flux

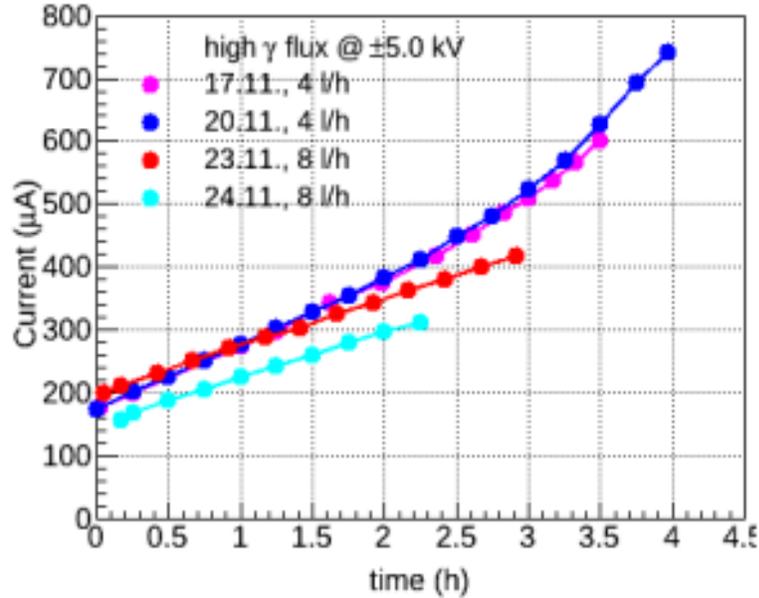


Facing **aging** challenges under the high radiation flux.

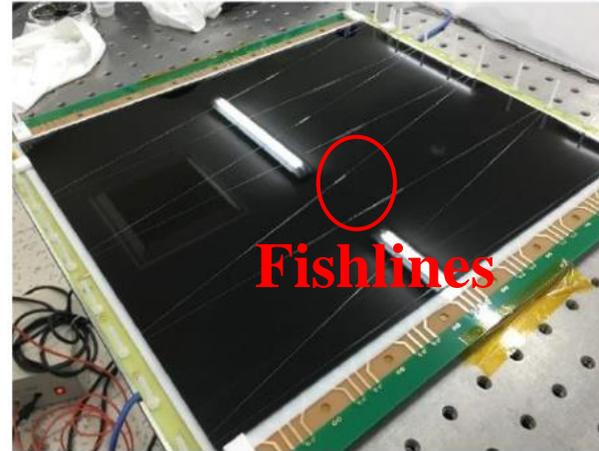
Detector aging effect

■ Aging effect observed under high beam intensity

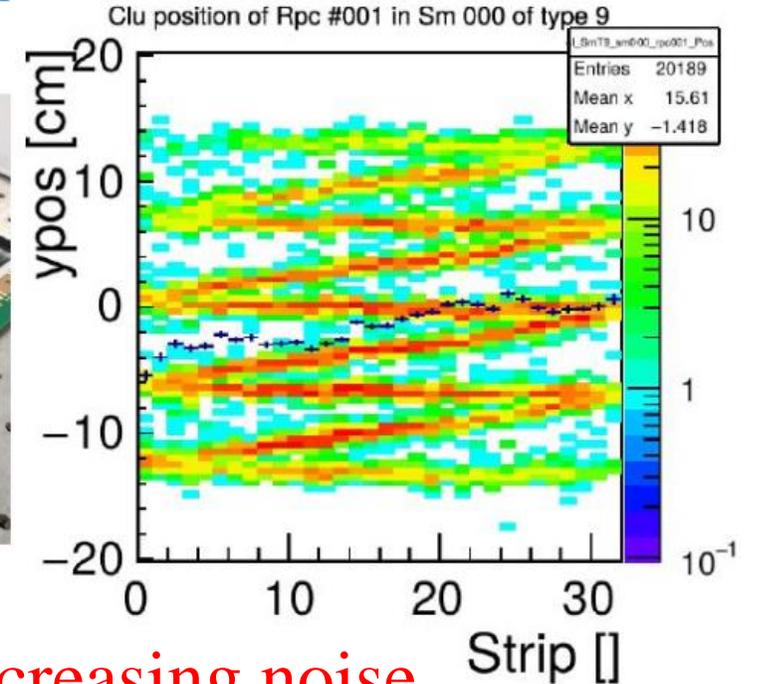
I. Deppner, 38th CBM collaboration Meeting



Increasing current



Fishlines



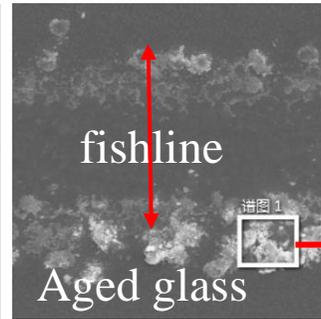
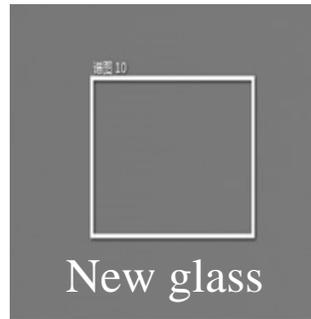
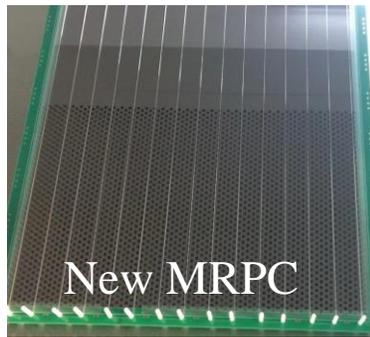
Increasing noise

- Lead to electric field break down
- Decline of efficiency and time resolution

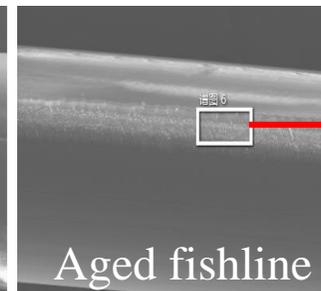
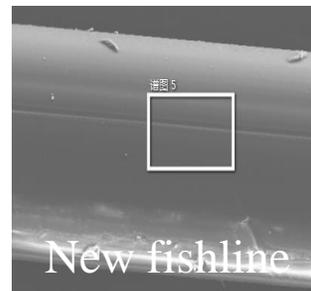
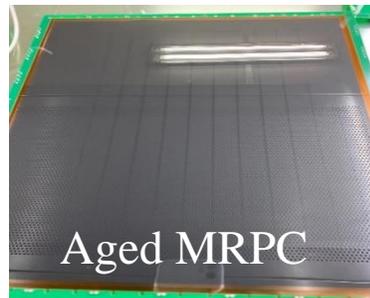
Detector aging effect

■ Inspection of aged MRPC from STAR-eTOF with SEM

SEM (Scanning Electron Microscope): 2D morphology scanning and elemental analysis



	wt%
C	1.77
O	27.14
F	21.28
Na	12.48
Si	26.92



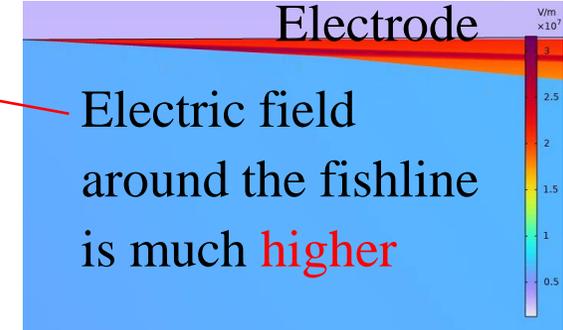
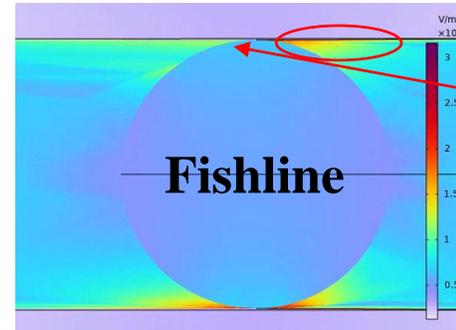
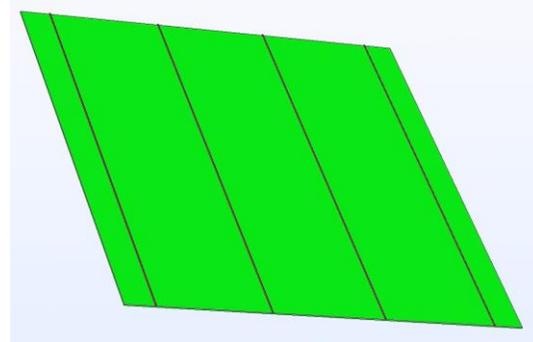
	wt%
C	42.93
O	9.03
F	31.99
Na	13.4
Si	2.36

✓ Aging may correlate with **fishline**.

Electric field simulation

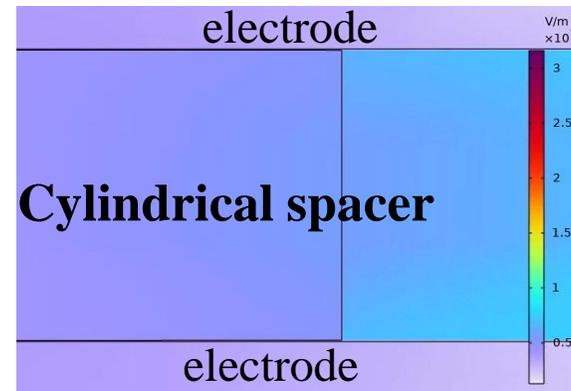
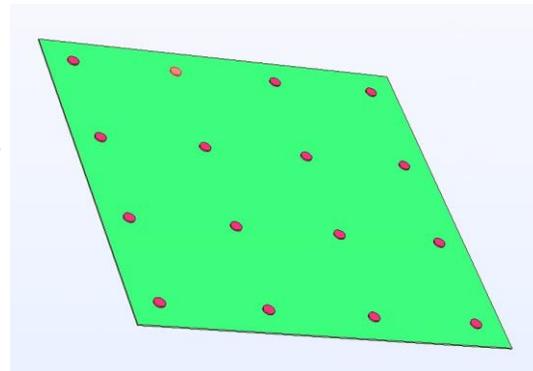
- Using the electromechanical coupling physics module in COMSOL

Fishline spacer



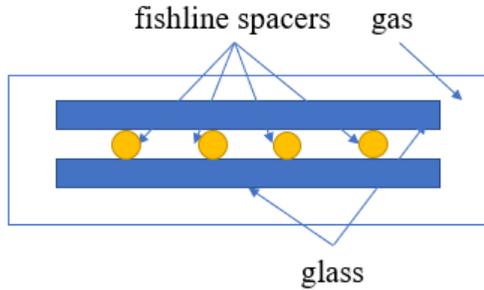
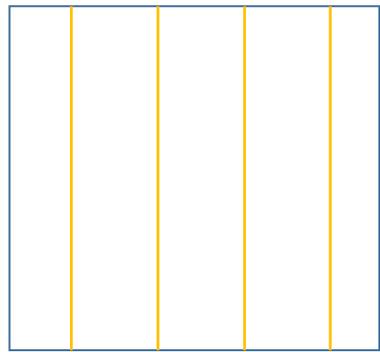
Electric field around the fishline is much **higher**

Cylindrical spacer



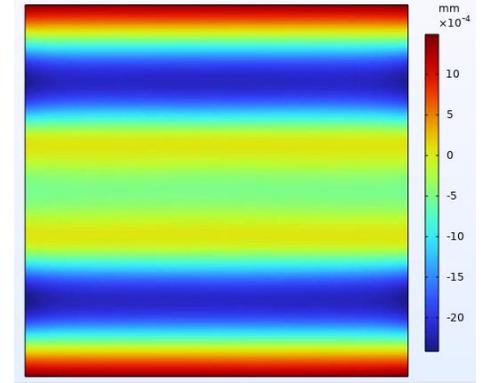
MRPC with cylindrical spacers may decrease aging effect!

TBS(Thermal Bonding Spacer) MRPC



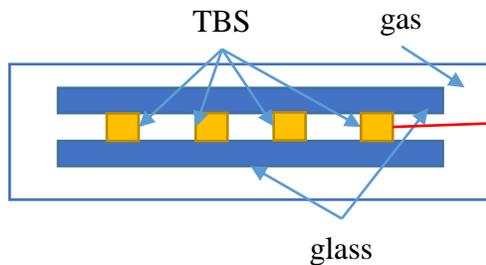
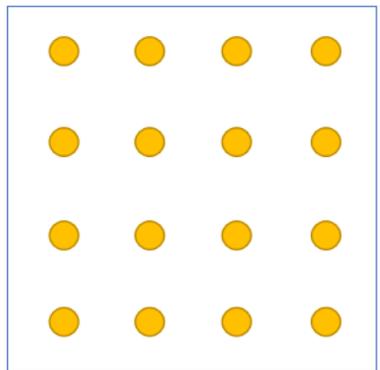
Structural design of a fishline MRPC for CBM-TOF

Fishline: 0.23 mm diameter, 19 mm interval

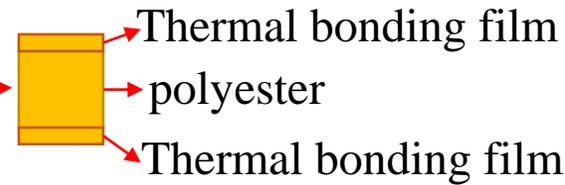


fishline structure
Max deformation ~ 2 μm

Replace fishline with TBS

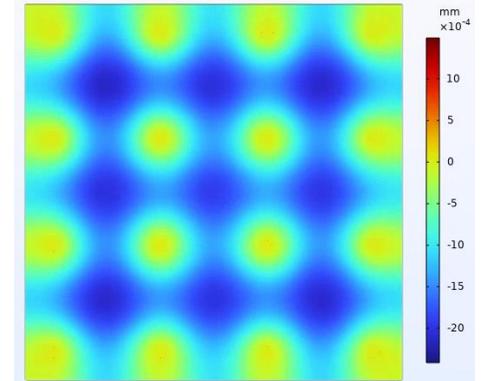


Z. Zhang et. al JINST. 9 (2014) C10028



Thermal Bonding Spacer(TBS)

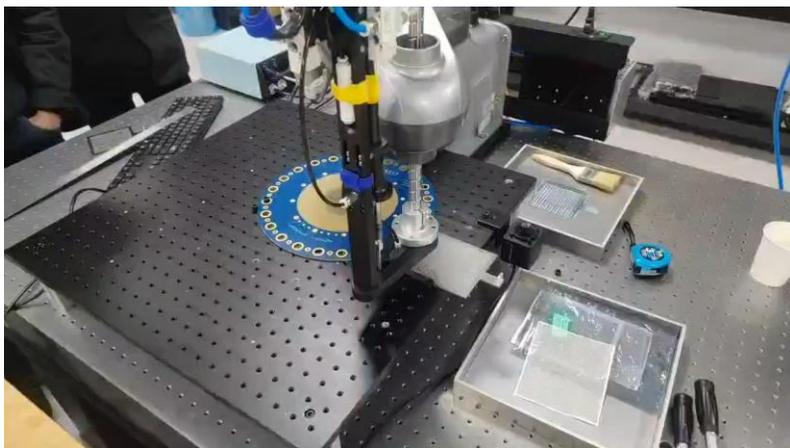
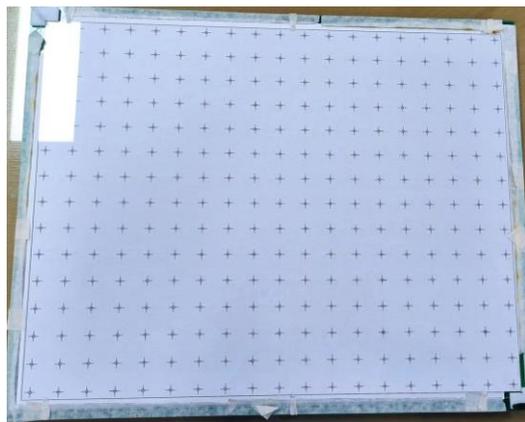
TBS: 2 mm diameter, 0.24 mm thickness, 19 mm interval



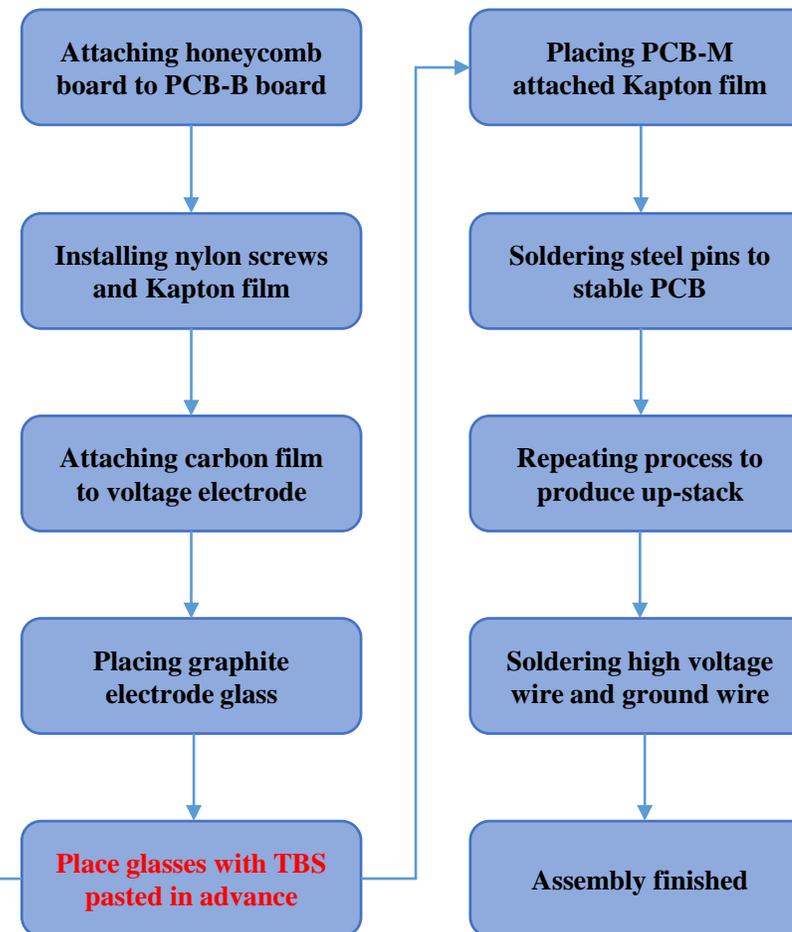
TBS structure
Max deformation ~ 2 μm

Production

Heat TBS and stick to glass when cooling



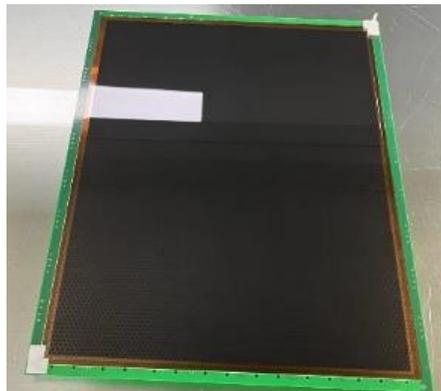
Machine to paste TBS



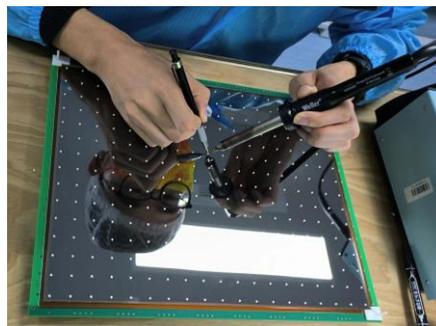
Production process

Production

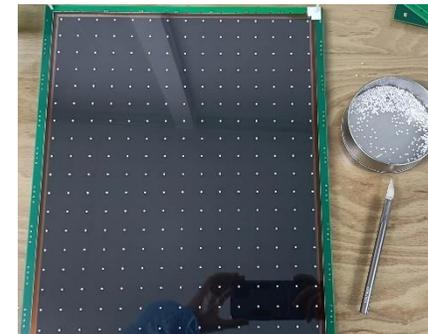
① Set Kapton and graphite electrode on PCB



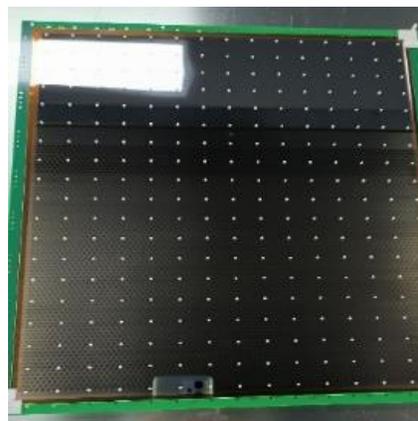
② Place glass with TBS pasted



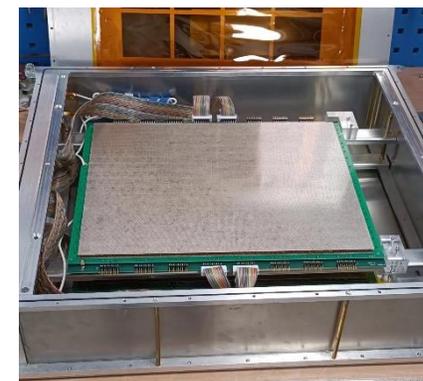
③ Bottom stack with 5 layers



④ Fix bottom stack with pins



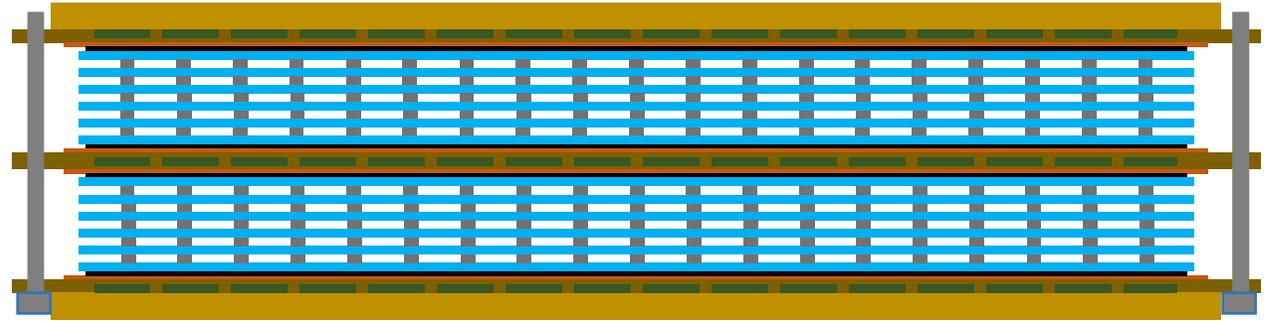
⑤ Top stack with 5 layers



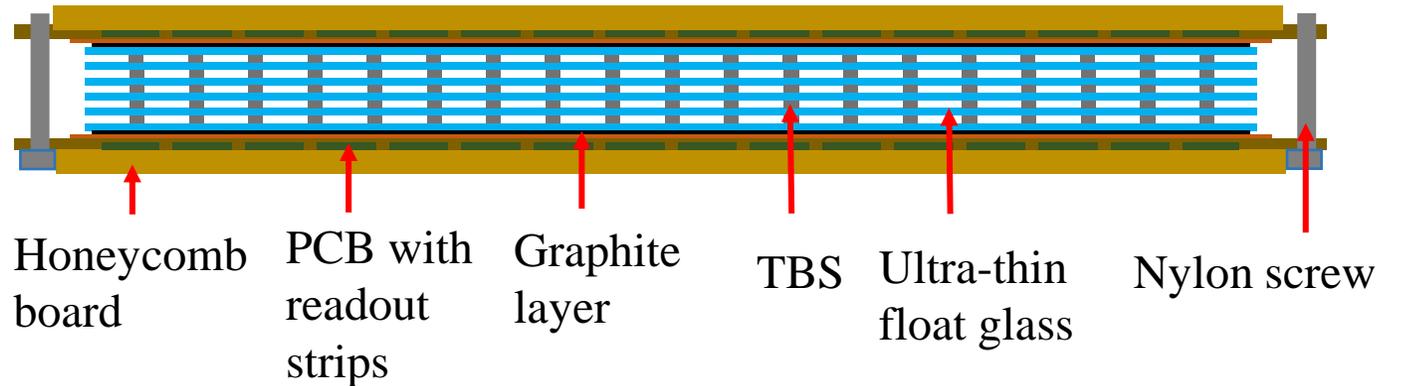
⑥ Placing detector inside box for testing

Prototype of TBS MRPC

TBS MRPC for CBM-TOF:
Double stacks with 10 gas gaps,
Effective area: $35 \times 28 \text{ cm}^2$

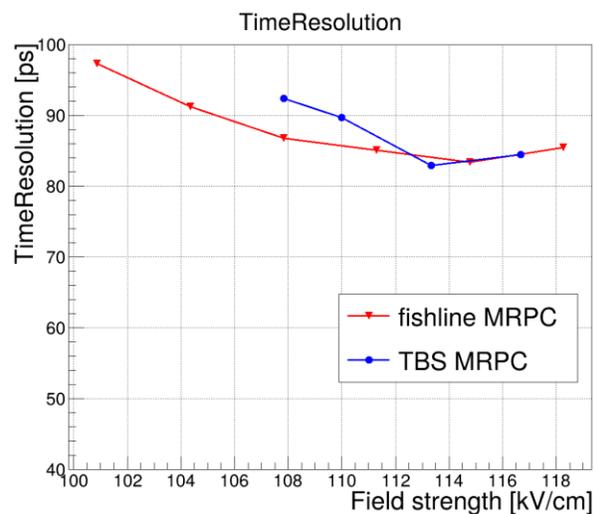
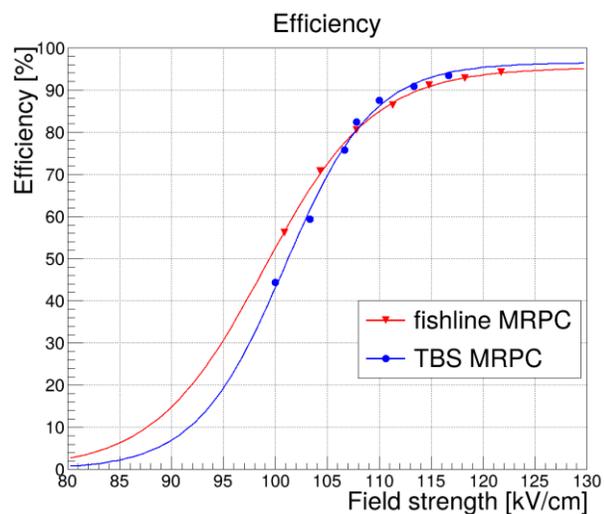
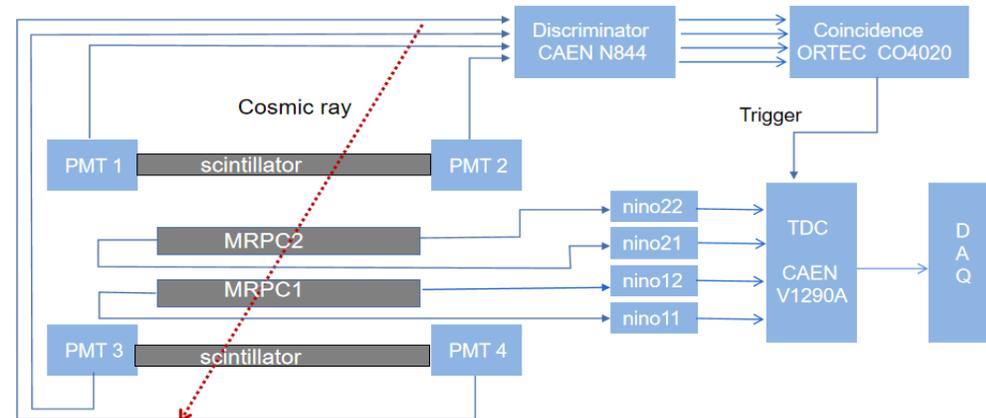
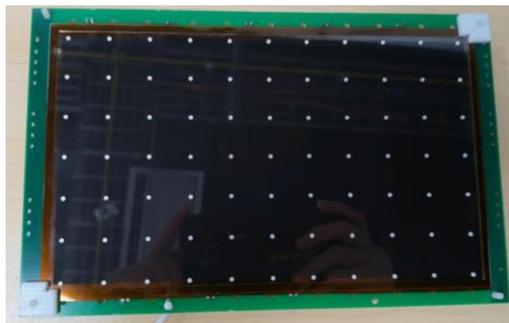
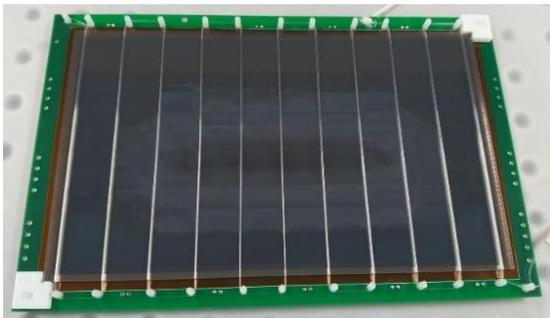


Prototype for test:
Single stack with 5 gas gaps,
Effective area: $20 \times 12 \text{ cm}^2$



Performance test

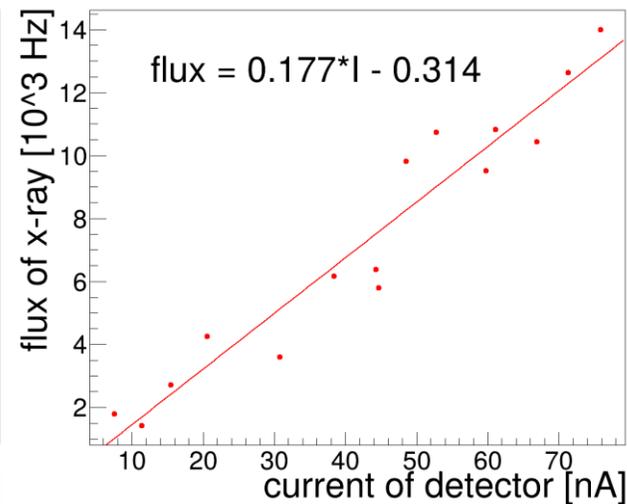
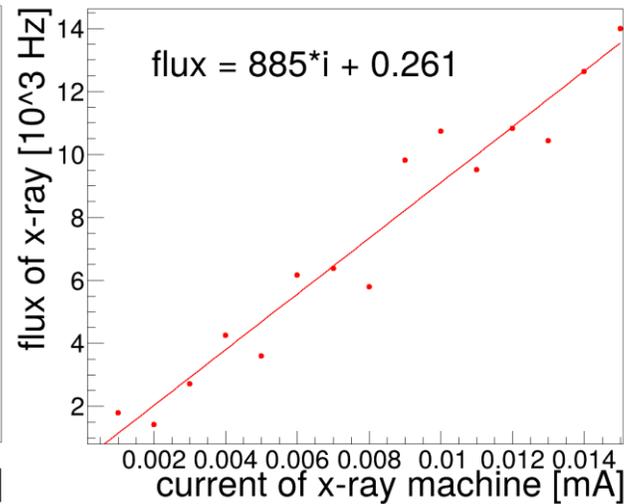
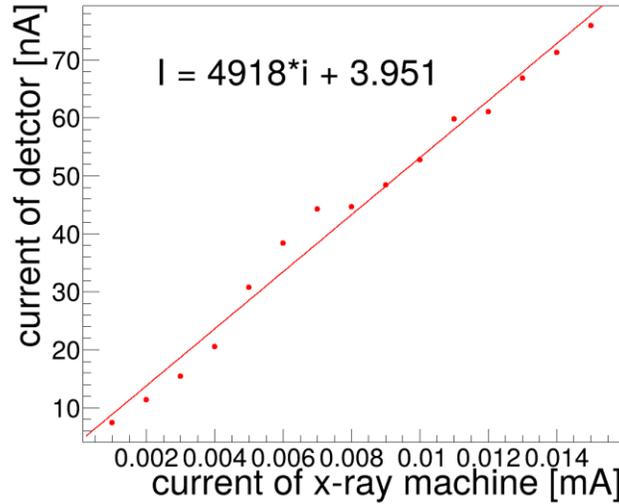
■ Performance under cosmic ray



Similar performance
tested with cosmic ray

Performance test

Flux calibration



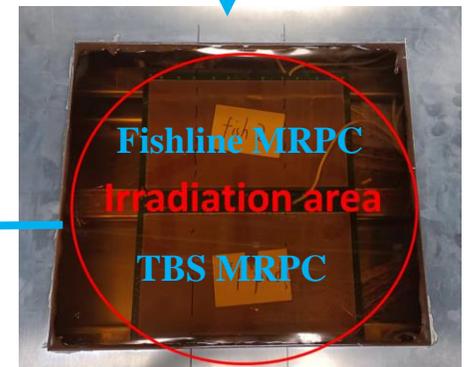
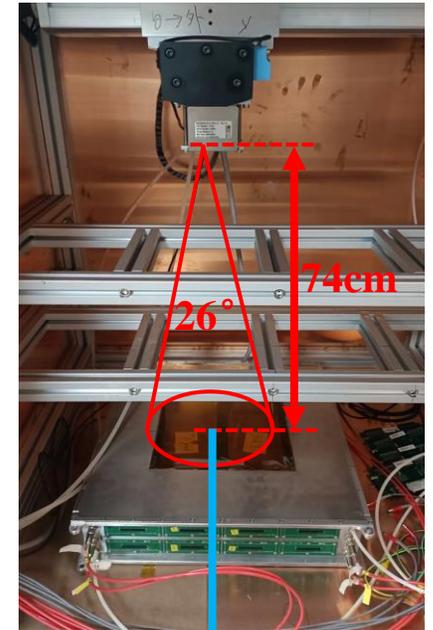
I : Current of detector
 i : Current of X-ray machine
 flux : flux of X-ray

$\text{flux} \propto I$

X-ray machine at 30 kV, 1.0 mA : **736 Hz/cm²**

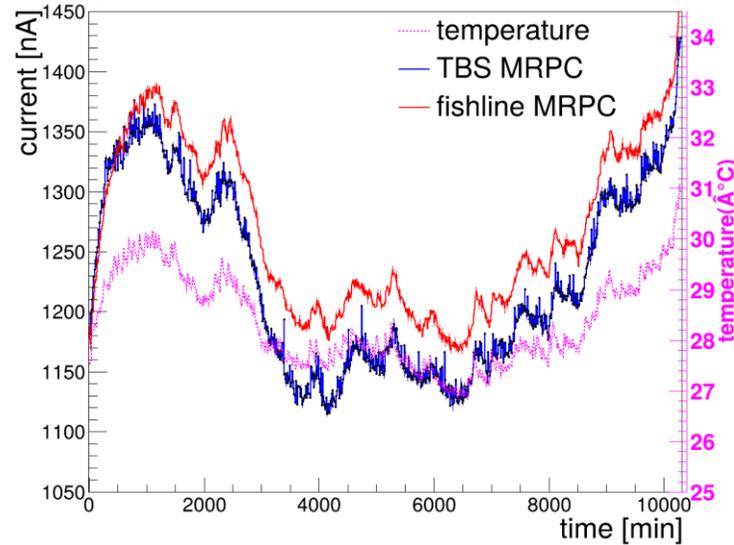
Two prototypes placed side by side for similar intensity of X-ray irradiation

X-ray test system

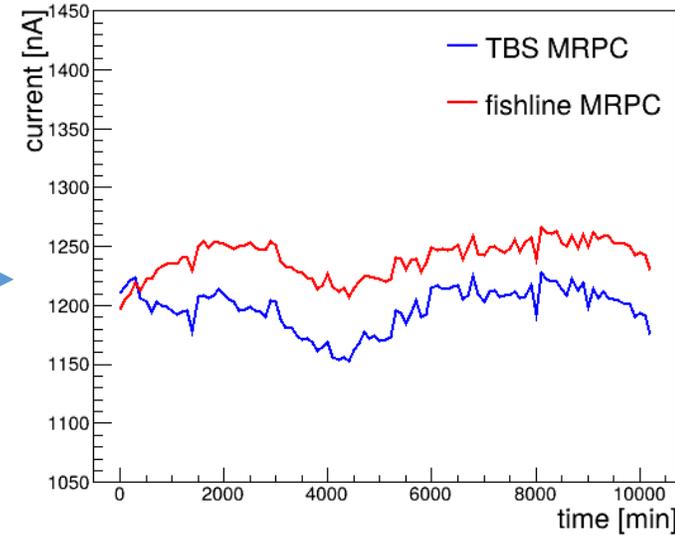


Dark current test

■ Comparison of dark currents of two prototypes during X-ray irradiation

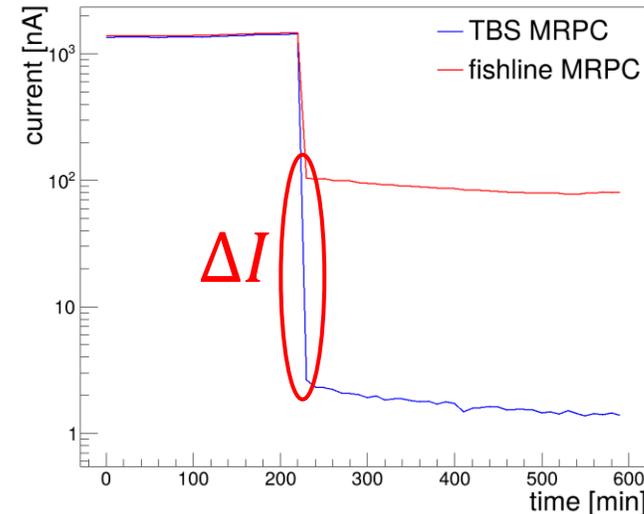


Temperature correction



● $\Delta I = I_{fishline} - I_{TBS} \approx 100 \text{ nA}$

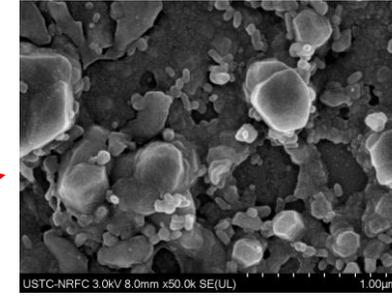
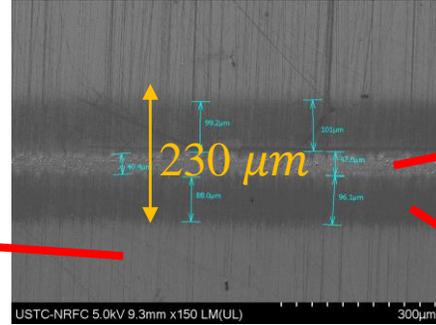
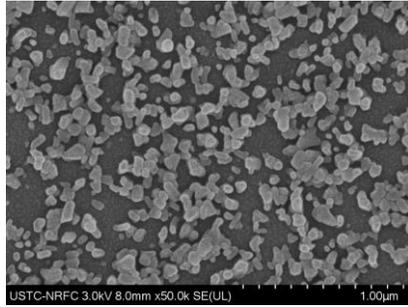
- ✓ TBS MRPC → neglectable accumulated charge
- ✓ Fishline MRPC → significant accumulated charge



Current decrease after turning off X-ray

SEM scanning after irradiation

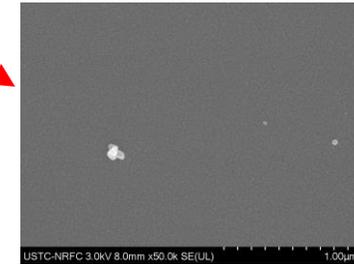
	wt%
O	45.37
Na	9.79
Si	25.87
F	6.62
C	2.32



	wt%
O	38.15
Na	10.38
Si	22.46
F	14.14
C	3.53

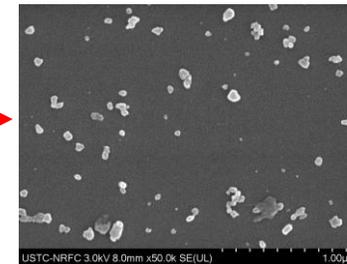
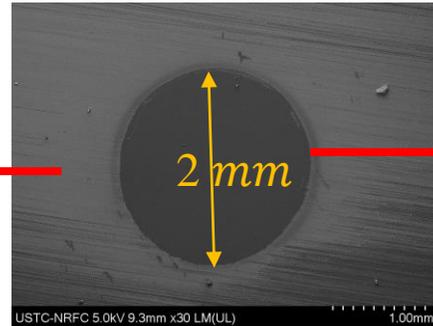
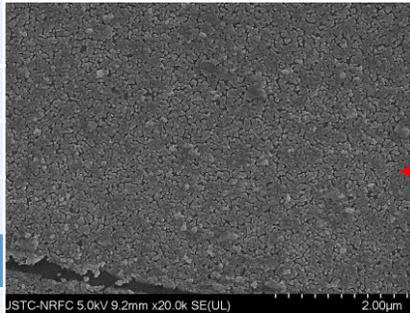
Glass of fishline MRPC

✓ Less F found in the TBS MRPC.



	wt%
O	44.83
Na	7.18
Si	23.47
F	0.82
C	1.36

	wt%
O	45.87
Na	6.75
Si	24.27
F	1.16
C	0.89



	wt%
O	47.38
Na	3.96
Si	25.35
F	0.29
C	5.71

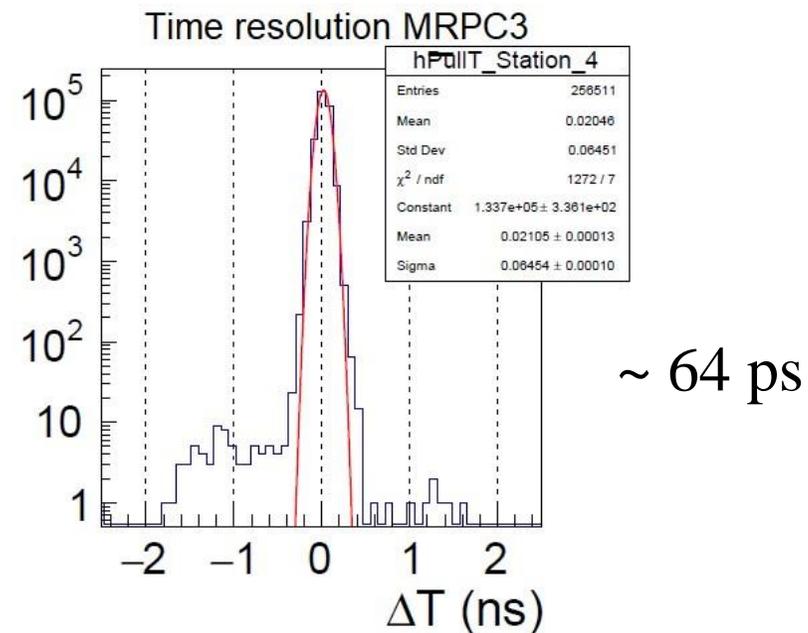
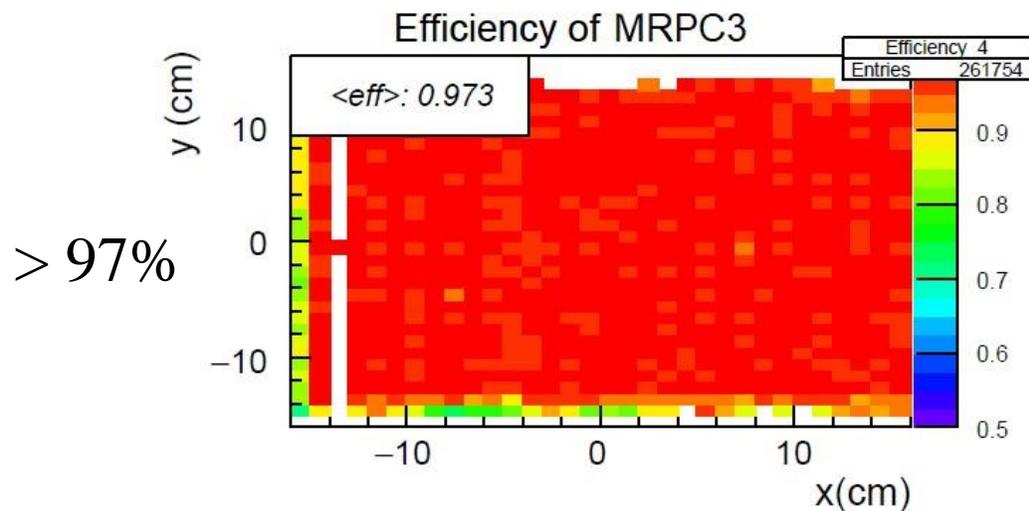
Glass of pad MRPC

Noise and beam test

■ Noise

	Dark current(nA/cm ²)	Noise(Hz/cm ²)
Normal fishline MRPC	0.0045	0.31
Aged fishline MRPC	0.14	31.77
Normal TBS MRPC	0.0092	0.49
Aged TBS MRPC	0.0064	0.40

■ TBS MRPC beam test





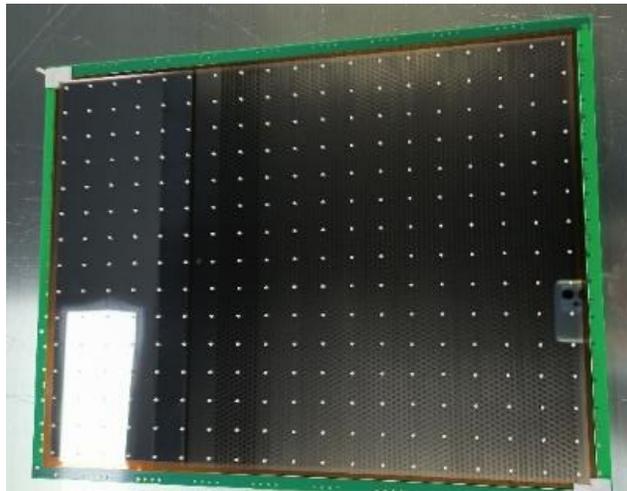
Summary

- Preliminary exploration on aging effects through SEM scanning.
- Novel TBS MRPC for solving aging effect has been developed.
- Comparative tests indicate that TBS MRPC has an excellent anti-aging performance.
 - Less accumulated charge
 - Less deposition of F
 - Lower noise

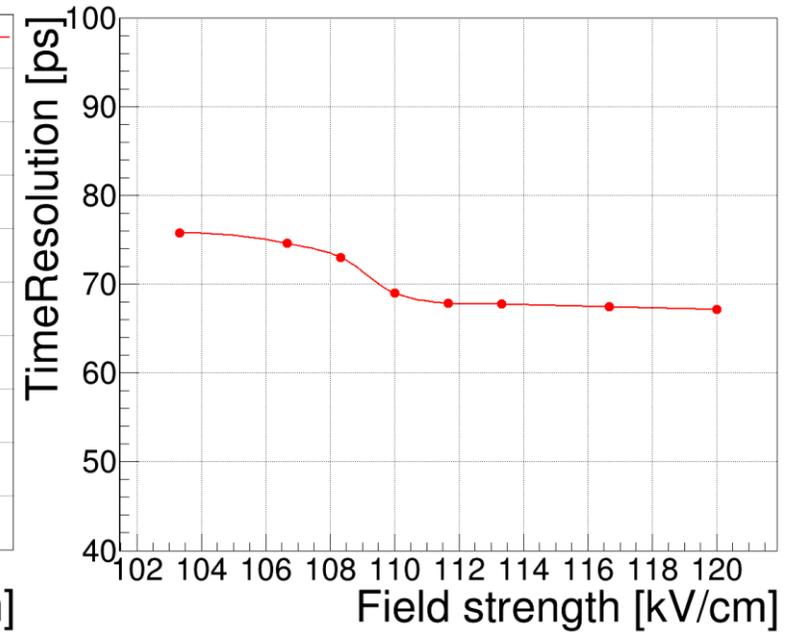
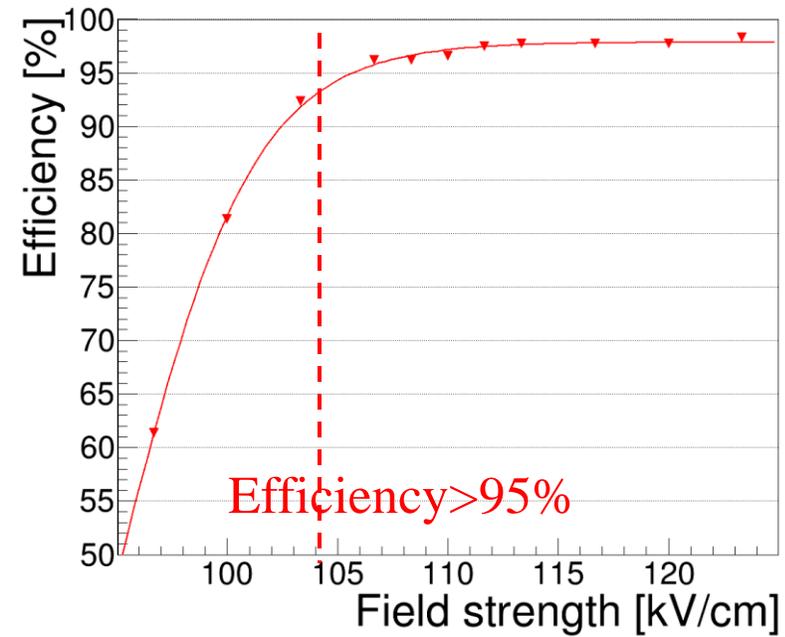
Thank you!



Back up



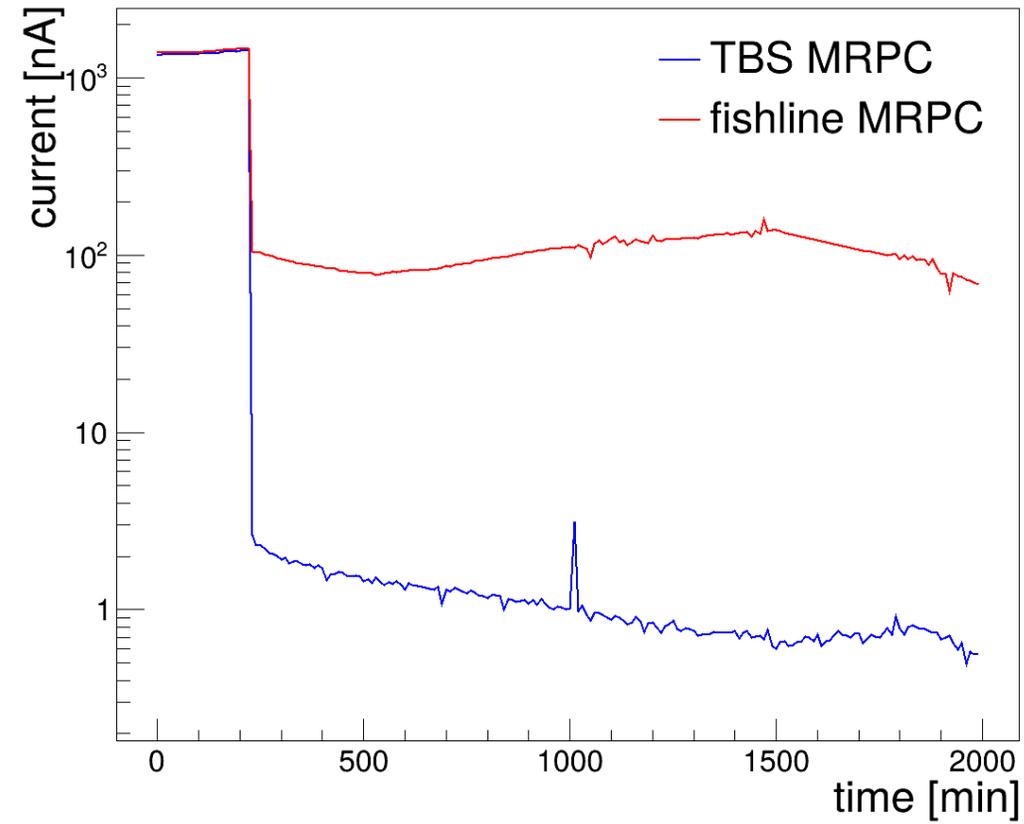
TBS MRPC3 for CBM-TOF



Polarity	Grounded Cathode
Flange Type	(6) 8-32 thread
High Voltage Range	4-60 kV ¹
Anode Current	1-3mA ¹
Continuous Rating	50-100 W ¹
Focal Spot	50 μ m, 100 μ m
Filament Current, max.	1.7 A
Filament Voltage, (nominal)	2.5 V
Flow Rate - Water	0.79 gallon/min (3 liters/min)
Inlet Water Temperature, max.	21°C
Stabilization Time	< 5 minutes
Weight	3.5 lbs (1.59 kg)
Inherent Filtration	0.005 inch Be
Target Materials	Cu, W Others available on request
Target Angle	20°
Radiation Coverage	26°
Radiation Leakage	<2 μ Sv/hr @ 50 mm (60 kV, 1 mA)

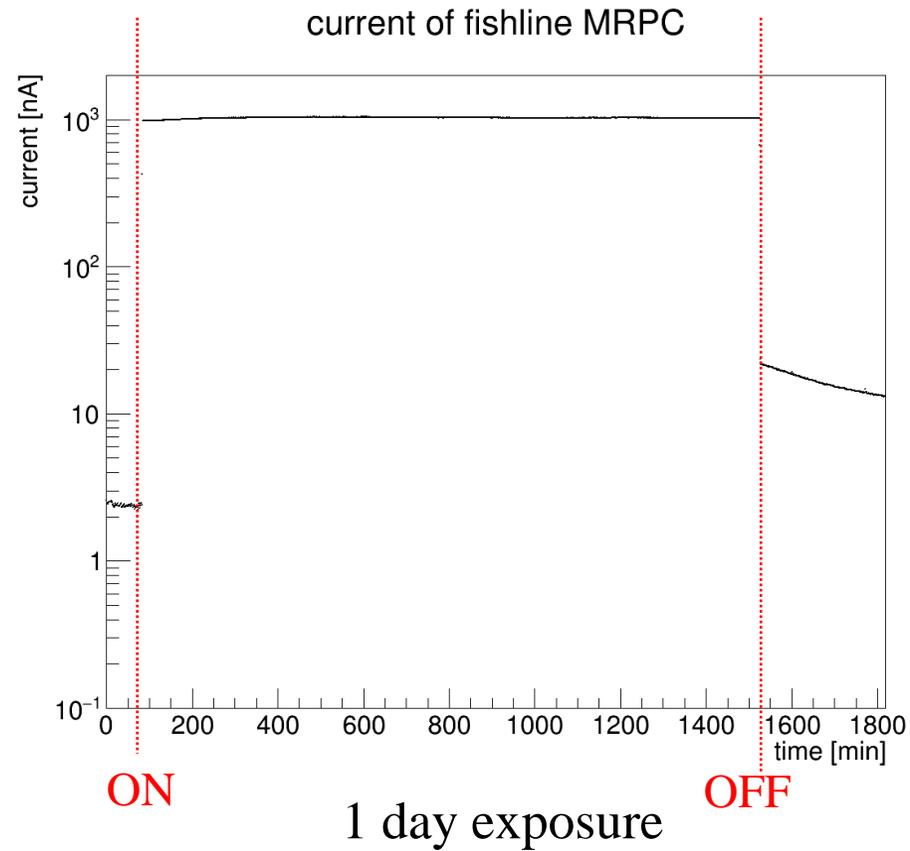
Parameters of X-ray machine

Decrease of current

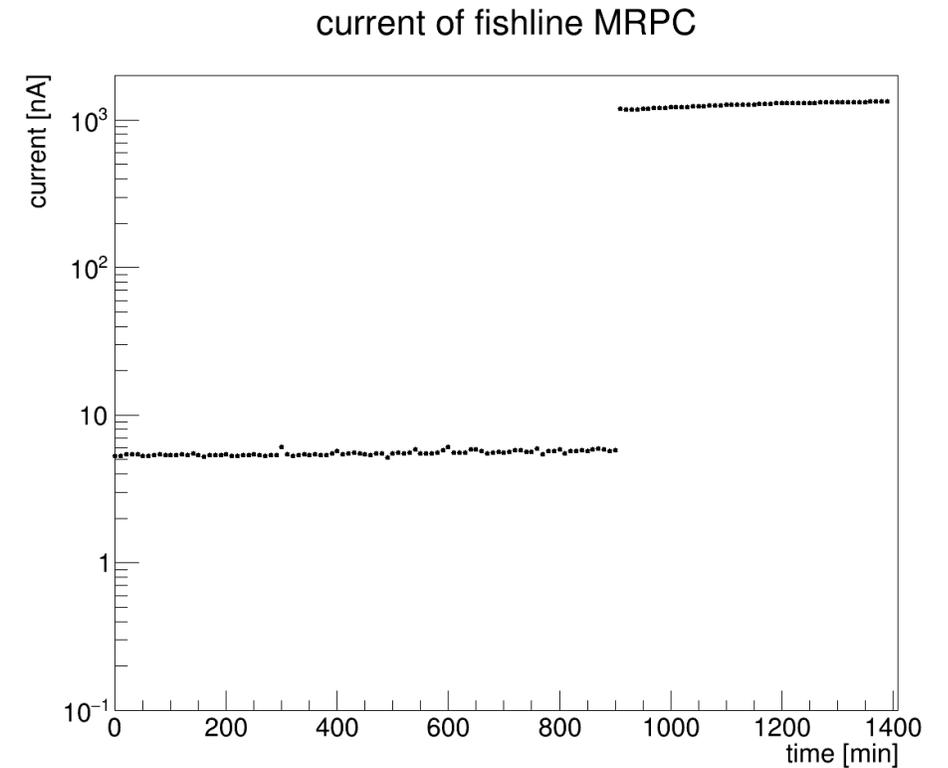


Decrease of current

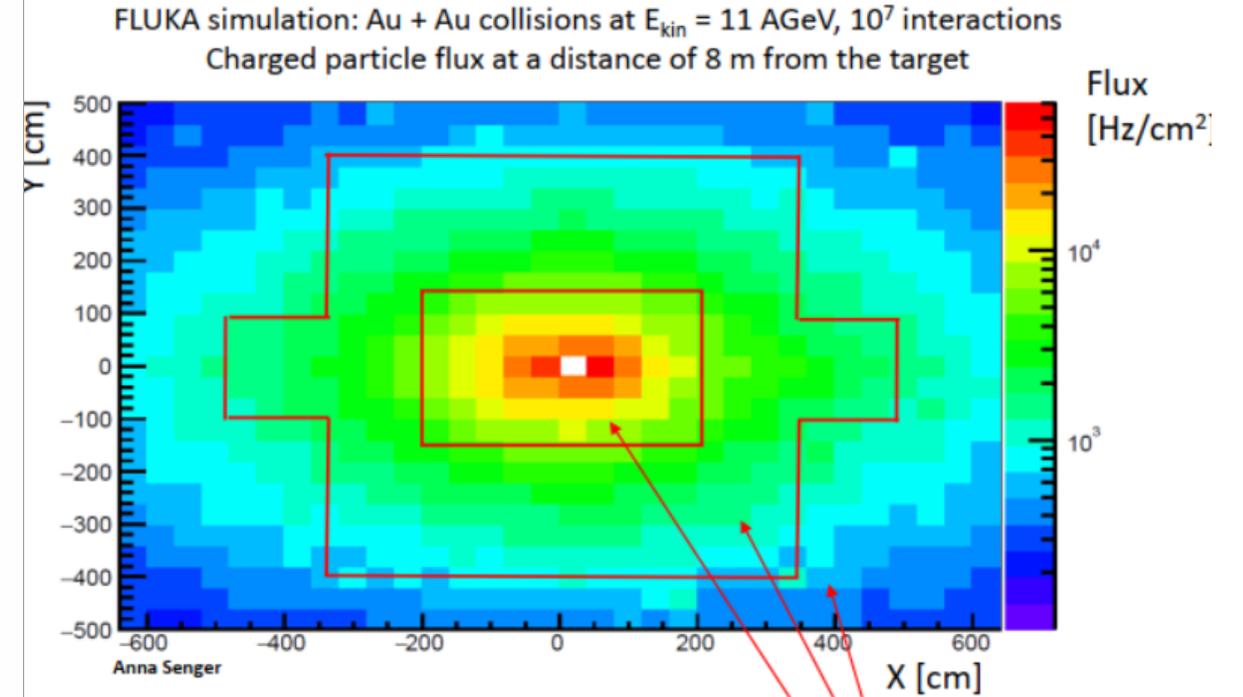
Current of fishline MRPC



1 month

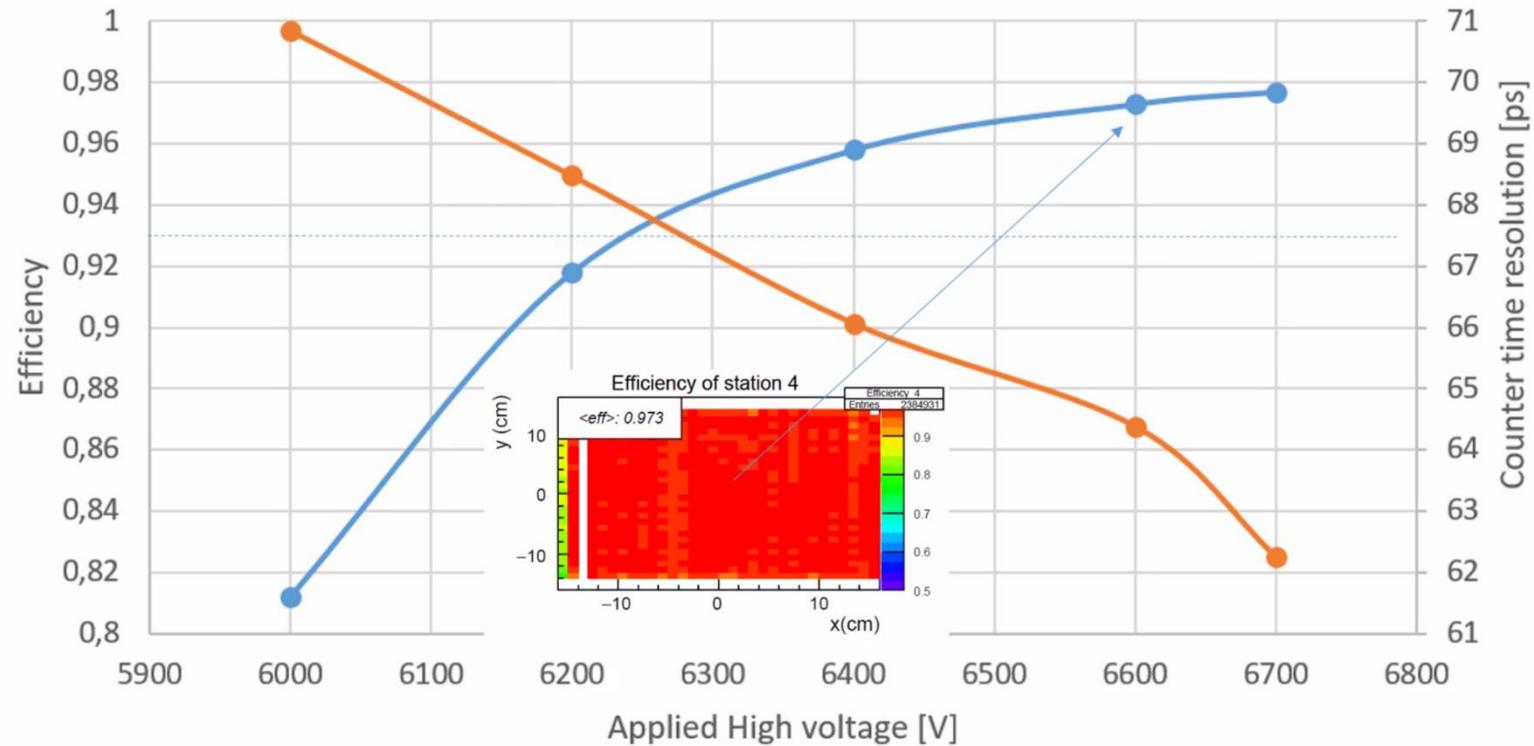


Counter	MRPC3	MRPC4
Name	910	700
Area [cm ²]	862	1696
Current [μA]	7.5	17
Current density [μA/cm ²]	0.0087	0.010
Rate [Hz/cm ²]	750	
Current [μA]	13	29
Current density [μA/cm ²]	0.015	0.017
Rate [kHz/cm ²]	1.3	
Current [μA]	20	48
Current density [μA/cm ²]	0.023	0.028
Rate [kHz/cm ²]	2.0	
Current [μA]	40	100
Current density [μA/cm ²]	0.046	0.059
Rate [kHz/cm ²]		
Current [μA]	50	50
Current density [μA/cm ²]		
Rate [kHz/cm ²]		



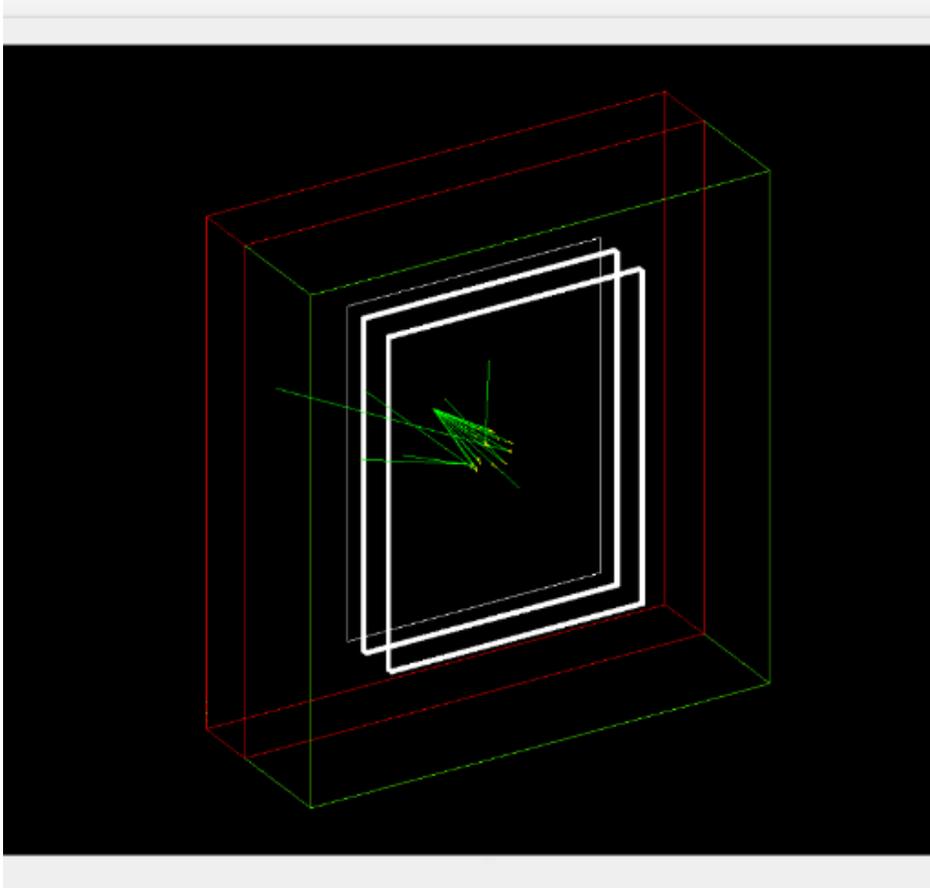
Results of MRPC3 unsealed, pad

Efficiency and time resolution vs. applied high voltage

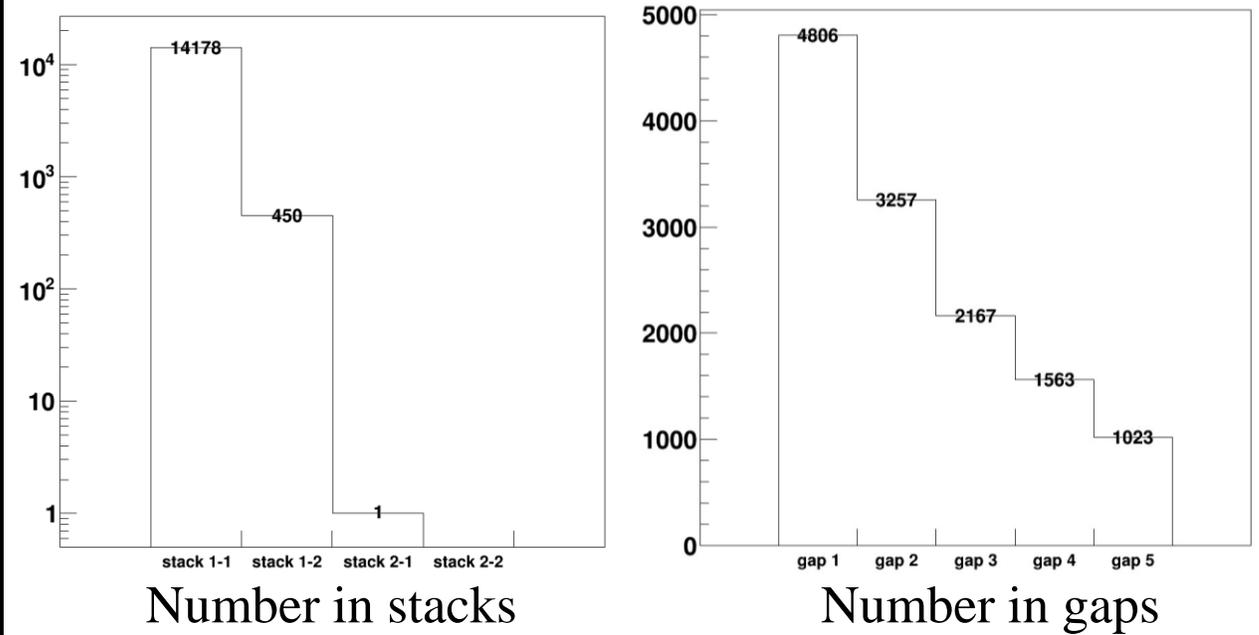


Geant4

To simulate the penetration of X-ray in detector



Total events: 100,000



Most X-ray absorbed in the first stack.