Noise and Performance Study of Sealed MRPC Detectors with Different Spacers

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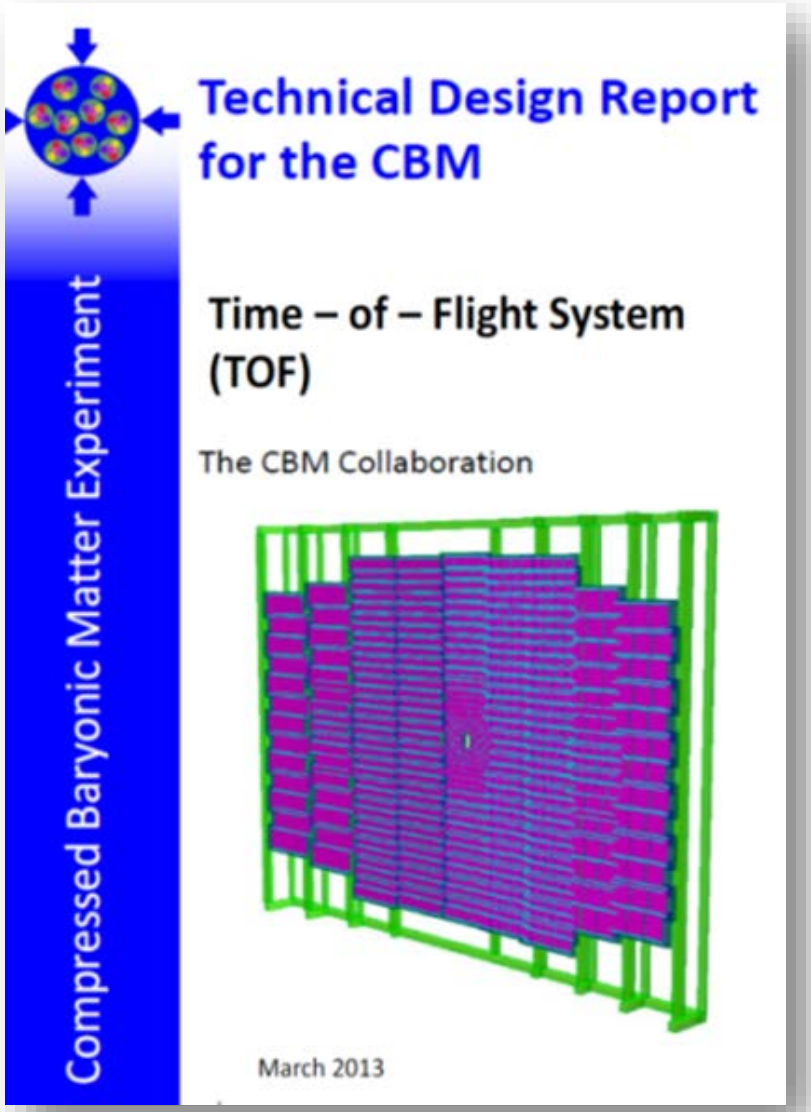
Outline

- MRPC2 at CBM-ToF Project
- Sealed MRPC2 and spacer-related effect
- Transient Flow Simulation(TFS) of sealed MRPC2
- Cosmic tests on pad spacer and fishline spacer MRPC2 – after X-ray exposure
  Scintillator Trigger results
  Self Trigger results – two MRPCs
  Self Trigger results – one MRPC
- Summary

CBM-ToF System



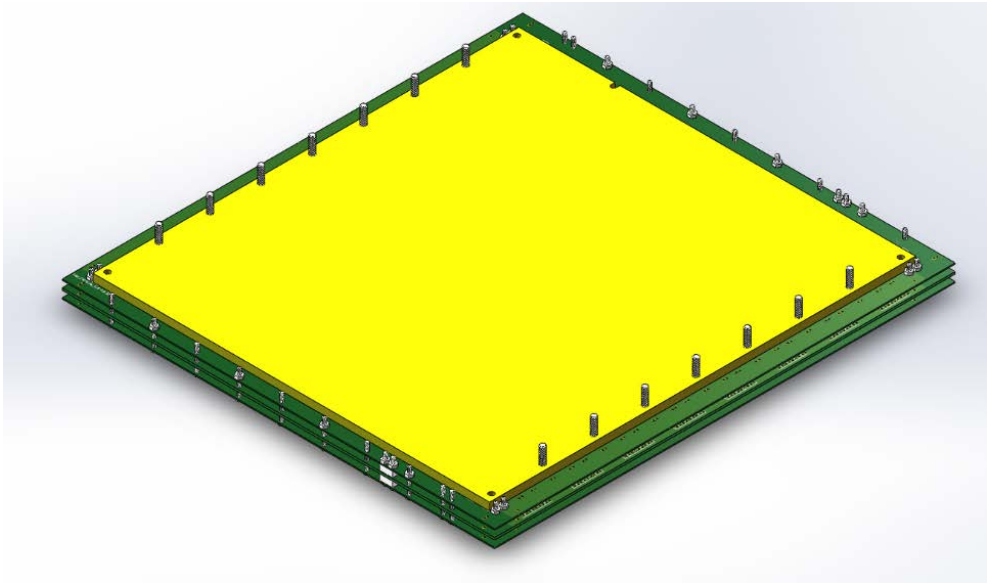
- Pad spacer MRPCs are built for CBM-ToF system with a high rate required

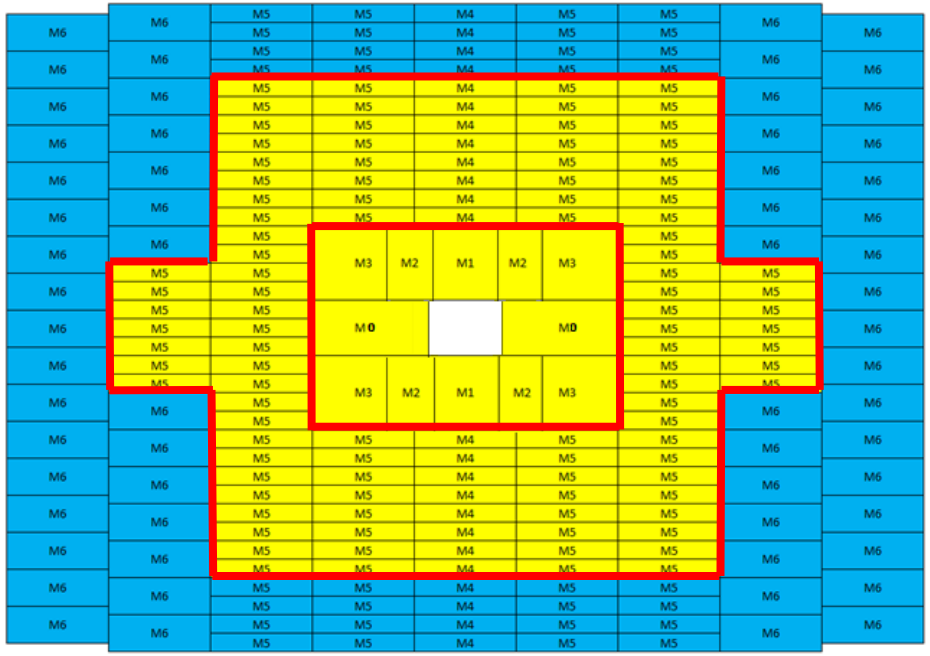
CBM-ToF Requirements

- Full system time resolution sT ~ 80 ps
- Efficiency > 95 %
- Rate capability ≤ 50 kHz/cm2
- Polar angular range 2.5° – 25°
- Occupancy < 5 %
- Low-power electronics
- (~100.000 channels)
- Free streaming data acquisition

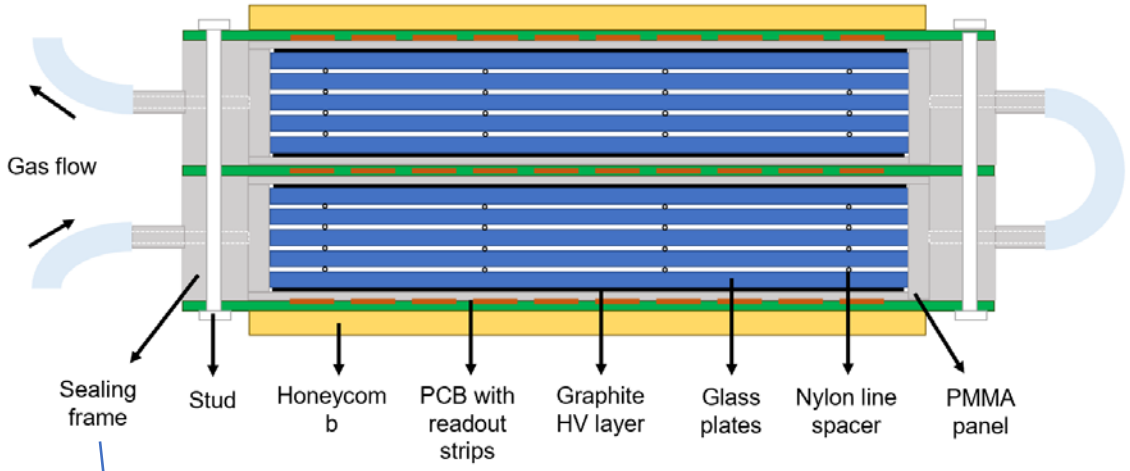
Progress of MRPC2 mass production

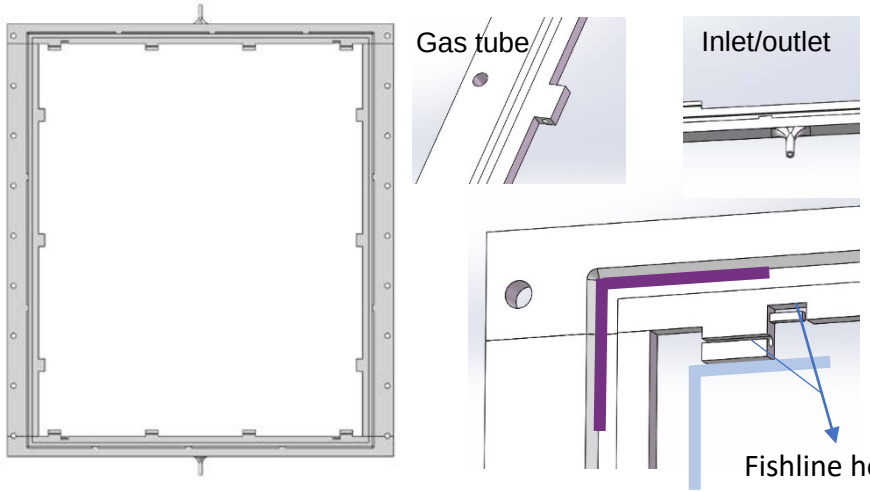
- Unsealed MRPC2 produced by THU forms model M5 in CBM-ToF wall.
- 580 unsealed MRPC2 in total is needed.
- The mass production is started on July 8, 2024.
- To date, 40 unsealed MRPC2 detectors have been manufactured.





Sealed MRPC2 – Today's topic

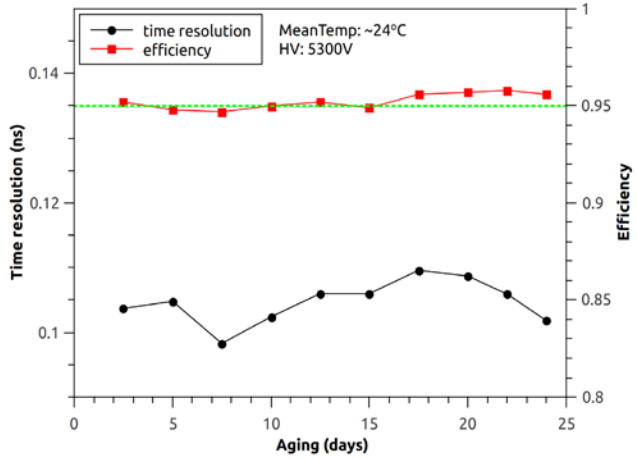




3D printed sealing frame with Good strength, insulation and radiation persistency

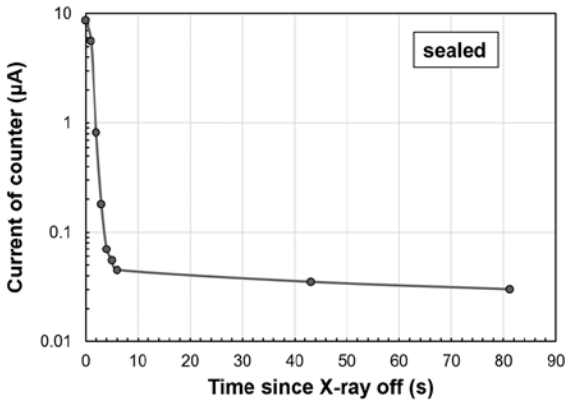
- Features :

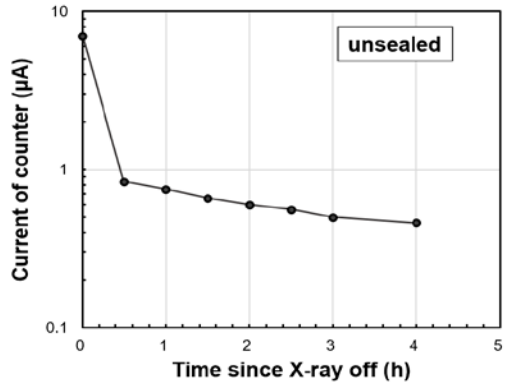
1. **Gas saving :** stable operation under < 10 sccm/m^2 gas flow in cosmic ray test



2. **Higher gas exchange efficiency:**

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

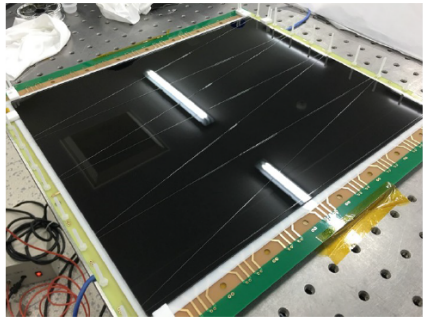


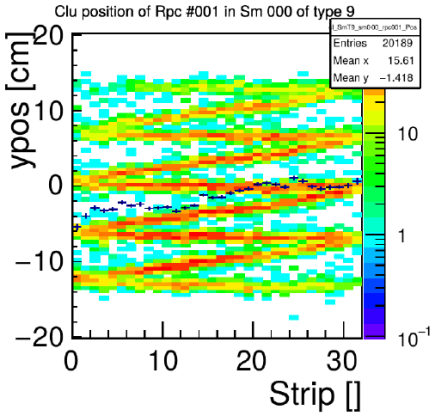


Spacer related effect of fishline spacer

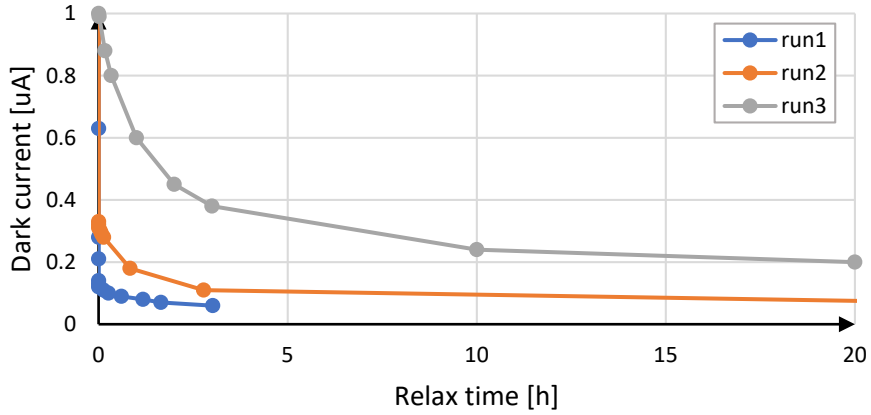
Continuous discharge happens at spacer region:

- High noise rate at fishline pattern @ Ingo Deppner.

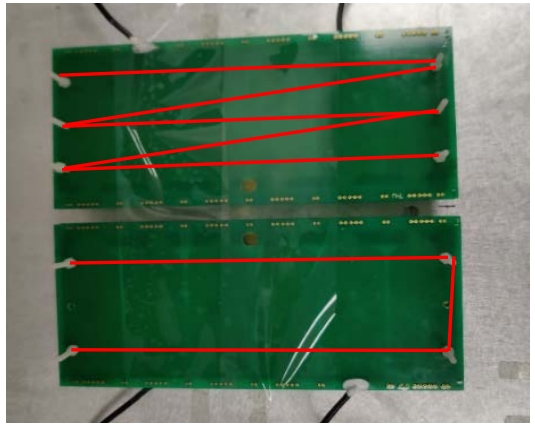


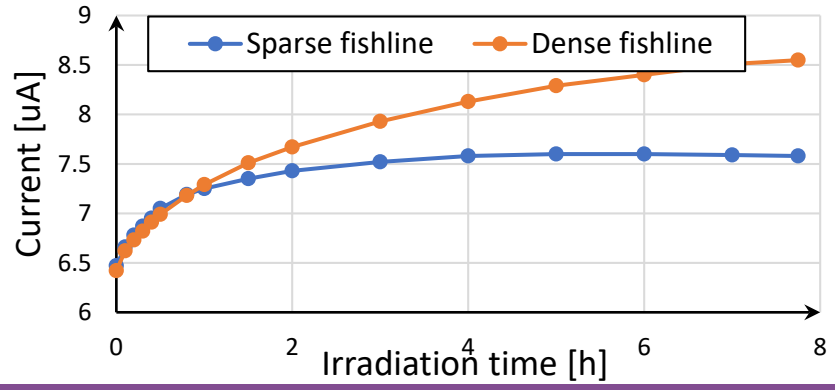


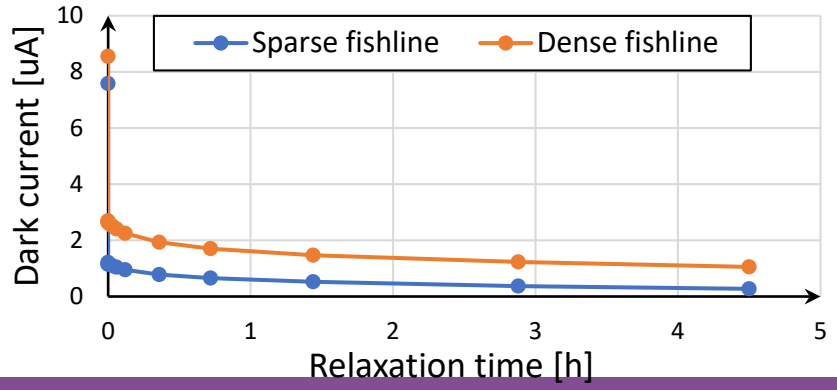
- Aging effect caused by repeated X-ray exposures.



- More fishline, more working &dark current under high rate(X-ray)







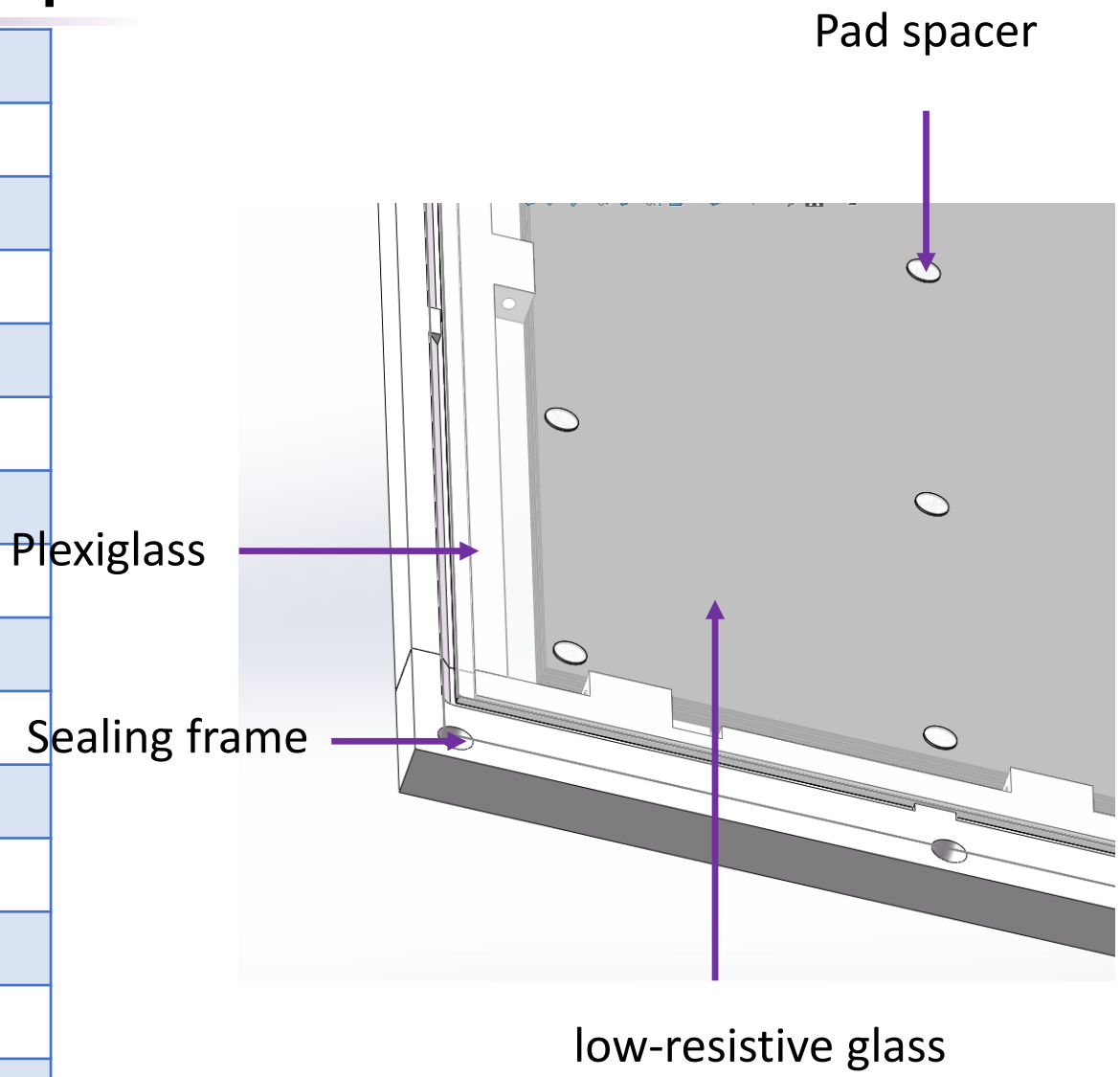
Pad spacer MRPCs

Benefits expected for Pad spacer MRPCs:

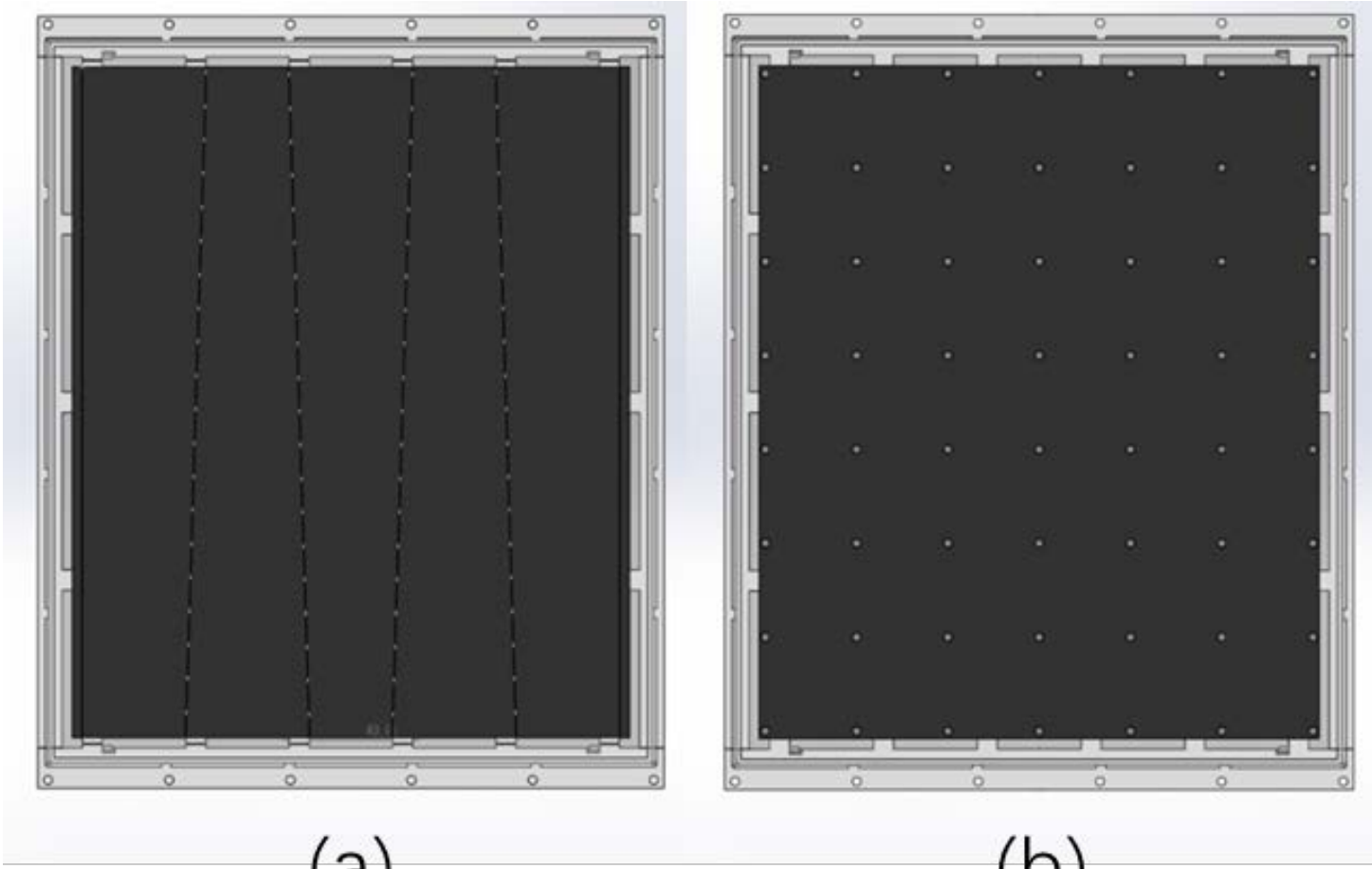
- Better gas exchange
- Minimize the dead zone of the detector
  – due to reduced contact area
- Less dark current at the spacer area
  – due to higher resistivity
- Less noise at the spacer area
- Less long-term effect under high luminosity condition

Pad spacer MRPC developed

Sealed MRPC2 parameters	
Active area per detector (mm)	330 x 276
Stacks × gaps	2 x 4
Gap thickness(mm)	0.25
Strip size (cm)	27 x 1.0
Operating field (kV/cm)	110
Round pad spacer parameters	
Dimensions (diameter)	Φ =3mm
Thickness(mm)	0.25
Number (horizontal × vertical)	8 x 7
Horizontal intervals(mm)	45
Vertical intervals (mm)	46.3
Total contact area (mm^2)	395.64
Fishline spacer parameters	
Dimensions (diameter)	Φ =0.25mm
Total contact area (mm^2)	> 495



Pad spacer and fishline spacer MRPC



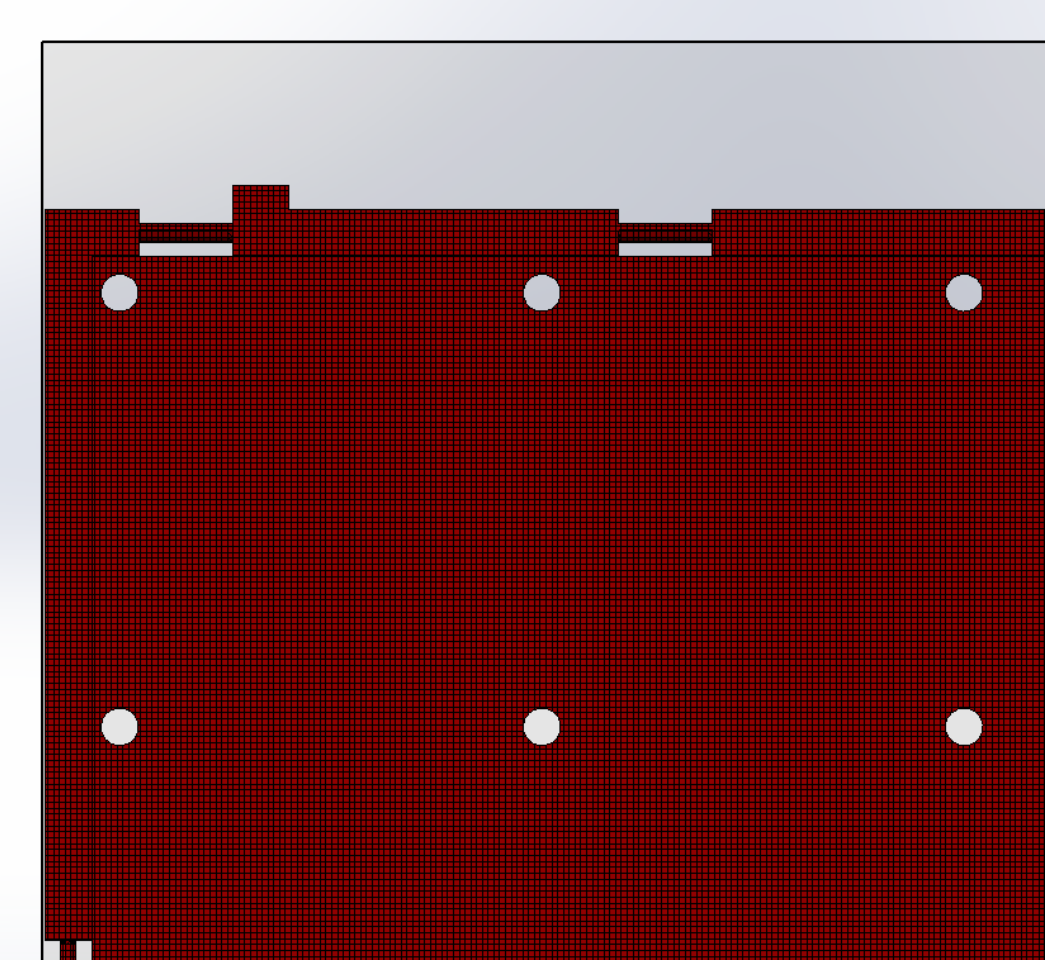
(a) Sealing stack of fishline spacer MRPC

(b) Sealing stack of pad spacer MRPC

Transient Flow Simulation of sealed MRPC2

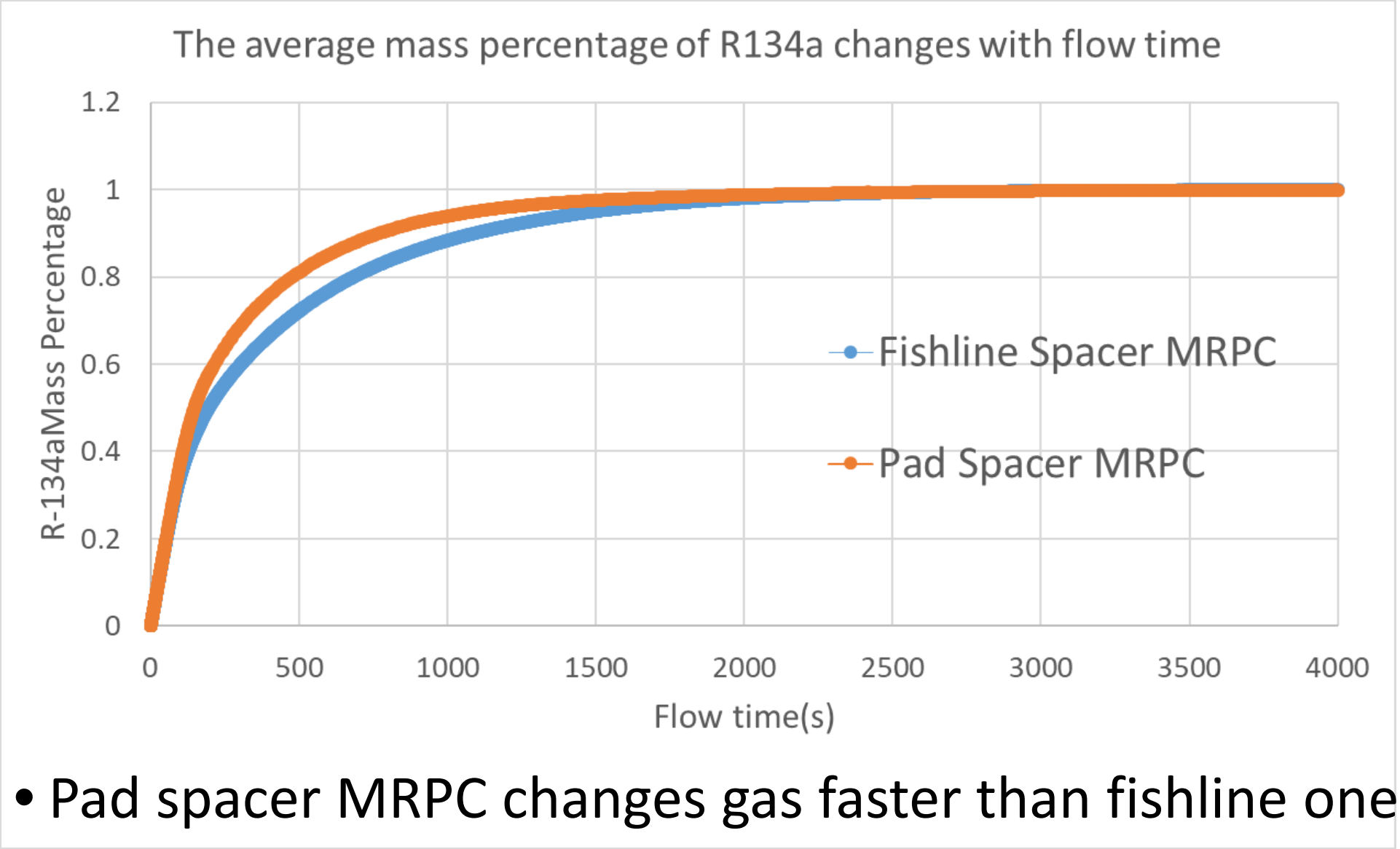
- Used SolidWorks for transient gas flow simulation
- Fishline may block the gas and decrease gas exchange efficiency

Simulation parameters	
Gas components	Air and Freon(R134a)
Initial Gas components	100% Air, 0% Freon.
Gas input: Volume flow	10sccm = $1.66*10^{-7} m^3/s$
Gas output	10825 Pa



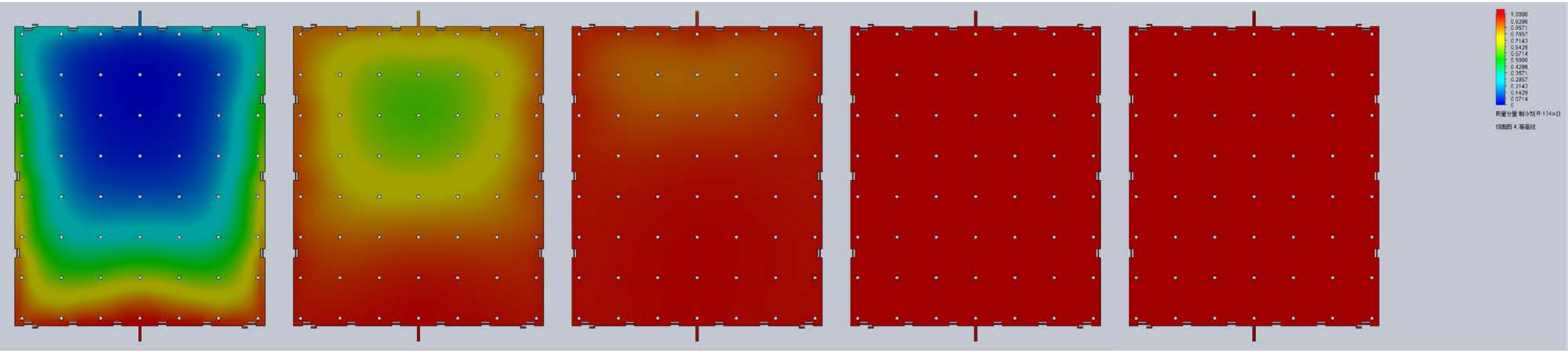
- Schematic diagram of fluid meshing

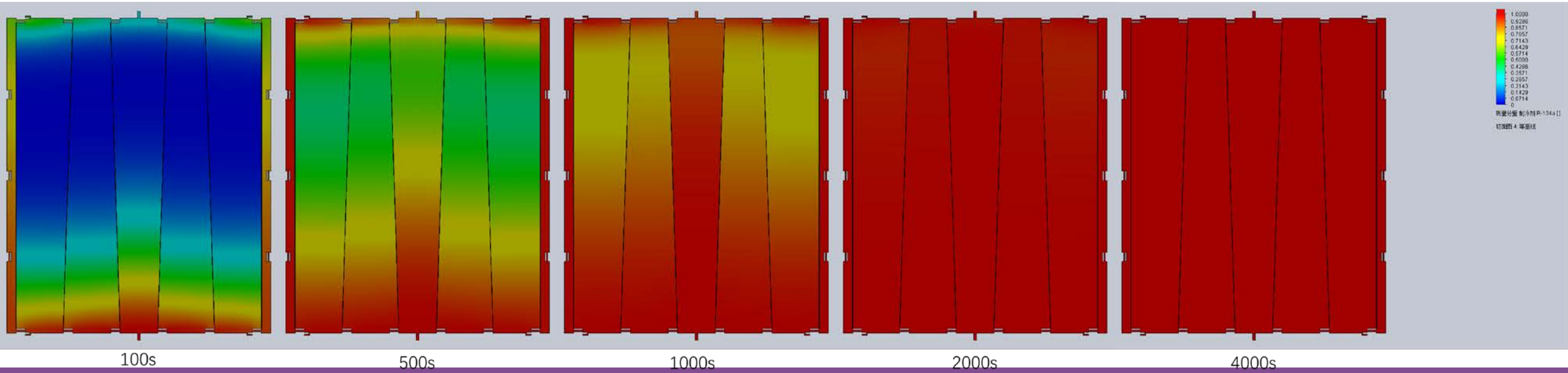
Transient Flow Simulation of sealed MRPC2



- Pad spacer MRPC changes gas faster than fishline ones

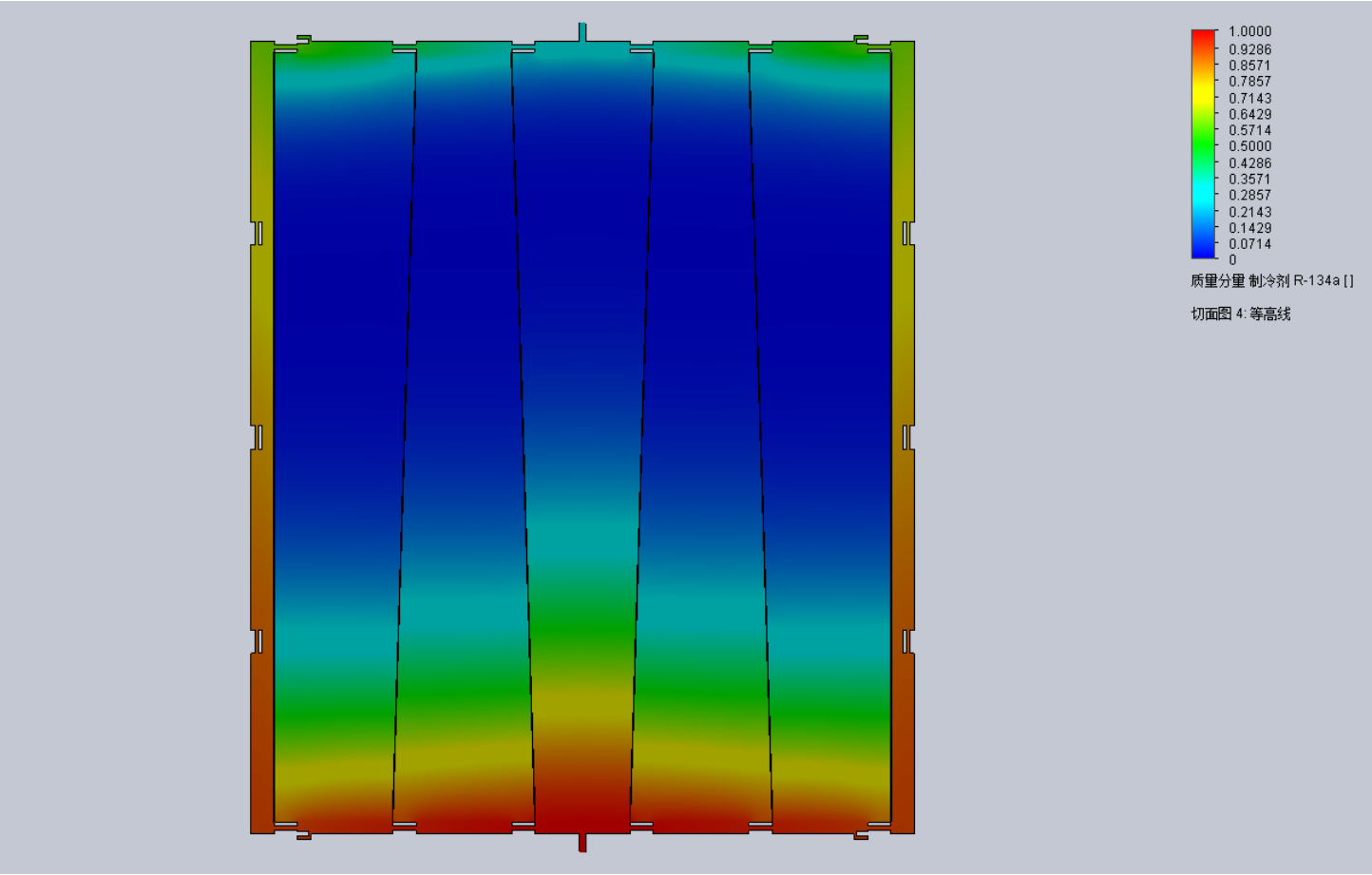
R134a mass percentage of stacks with time: 0s-4000s





Transient Flow Simulation of sealed MRPC2

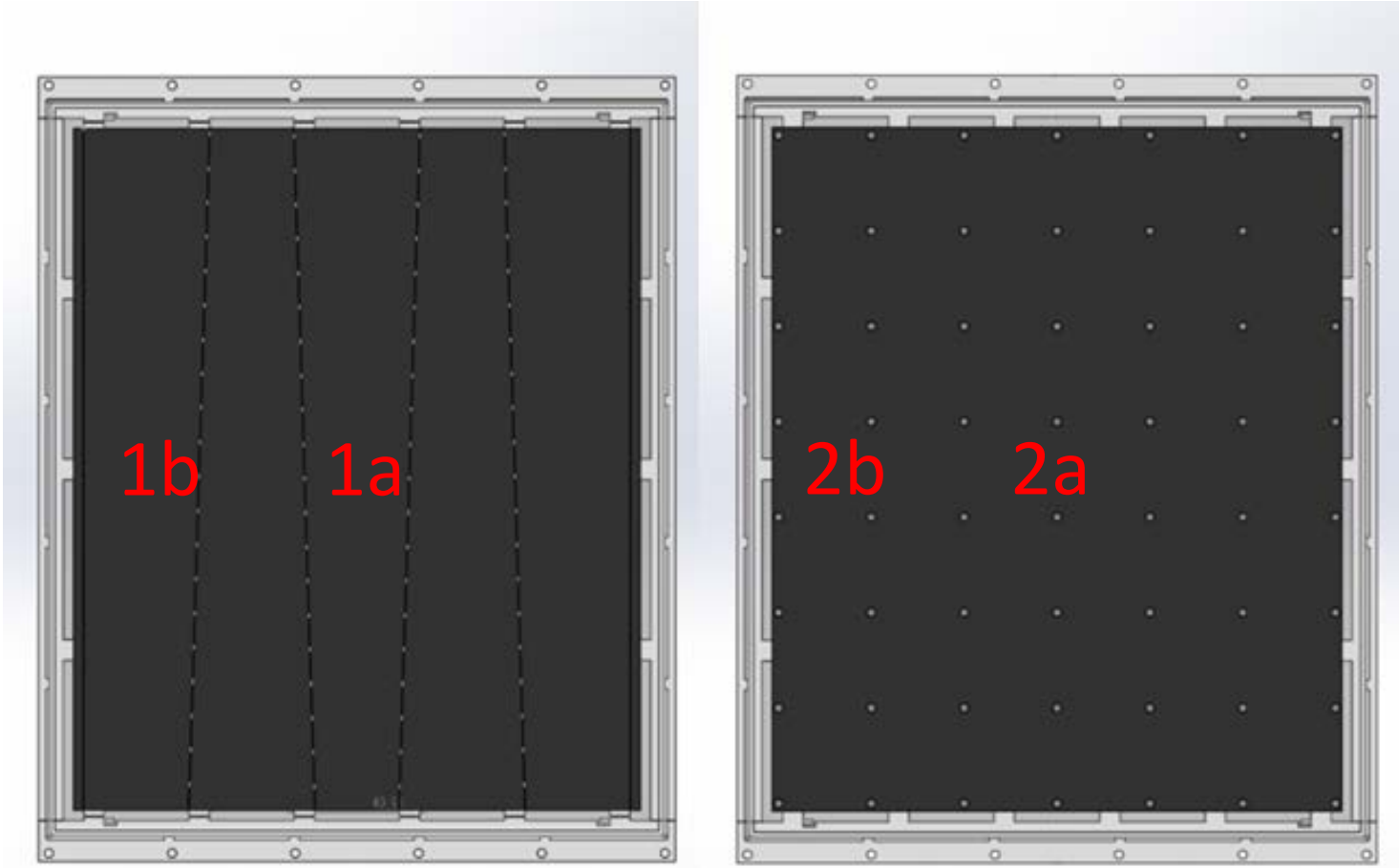
- Fishlines block gas exchange within gas gaps.
- Resulting different gas exchange rates in different area.



Mass percentage change in different places

- Fishline center: 1a
- Fishline edge: 1b

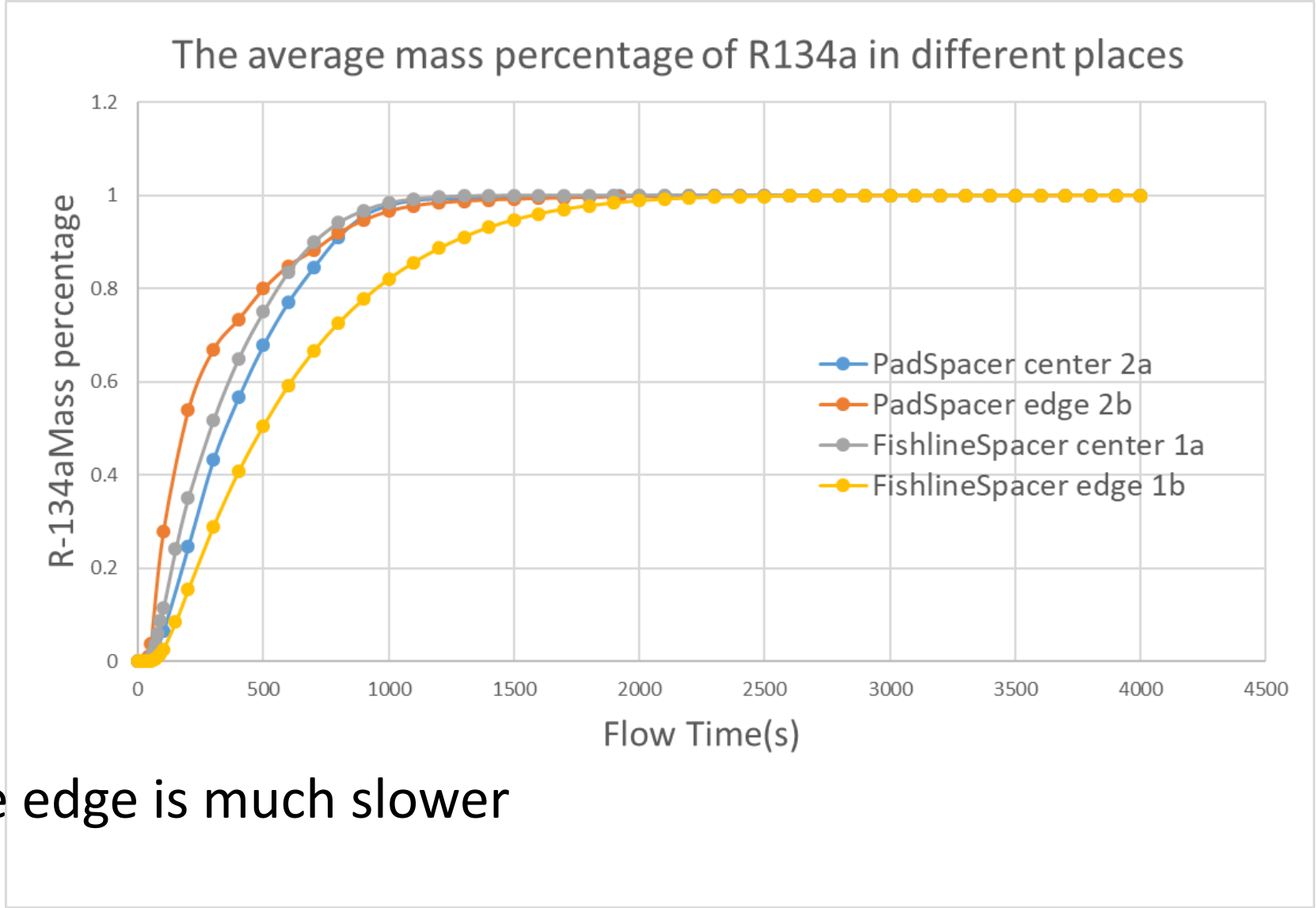
- Pad center: 2a
- Pad edge: 2b



Mass percentage change in different places

- Fishline center: 1a
- Fishline edge: 1b

- Pad center: 2a
- Pad center: 2b



- Gas change in Fishline edge is much slower

Results on transient flow simulation

- Gas exchange in pad spacer sealed MRPC is 1.5 times faster than in fishline ones.

- 23min (1400s) is enough for a 99% mass percentage of working gas at the edge position of one pad-spacer stack, at a gas flow of 10sccm = $1.66*10^{-7}m^3/s$.

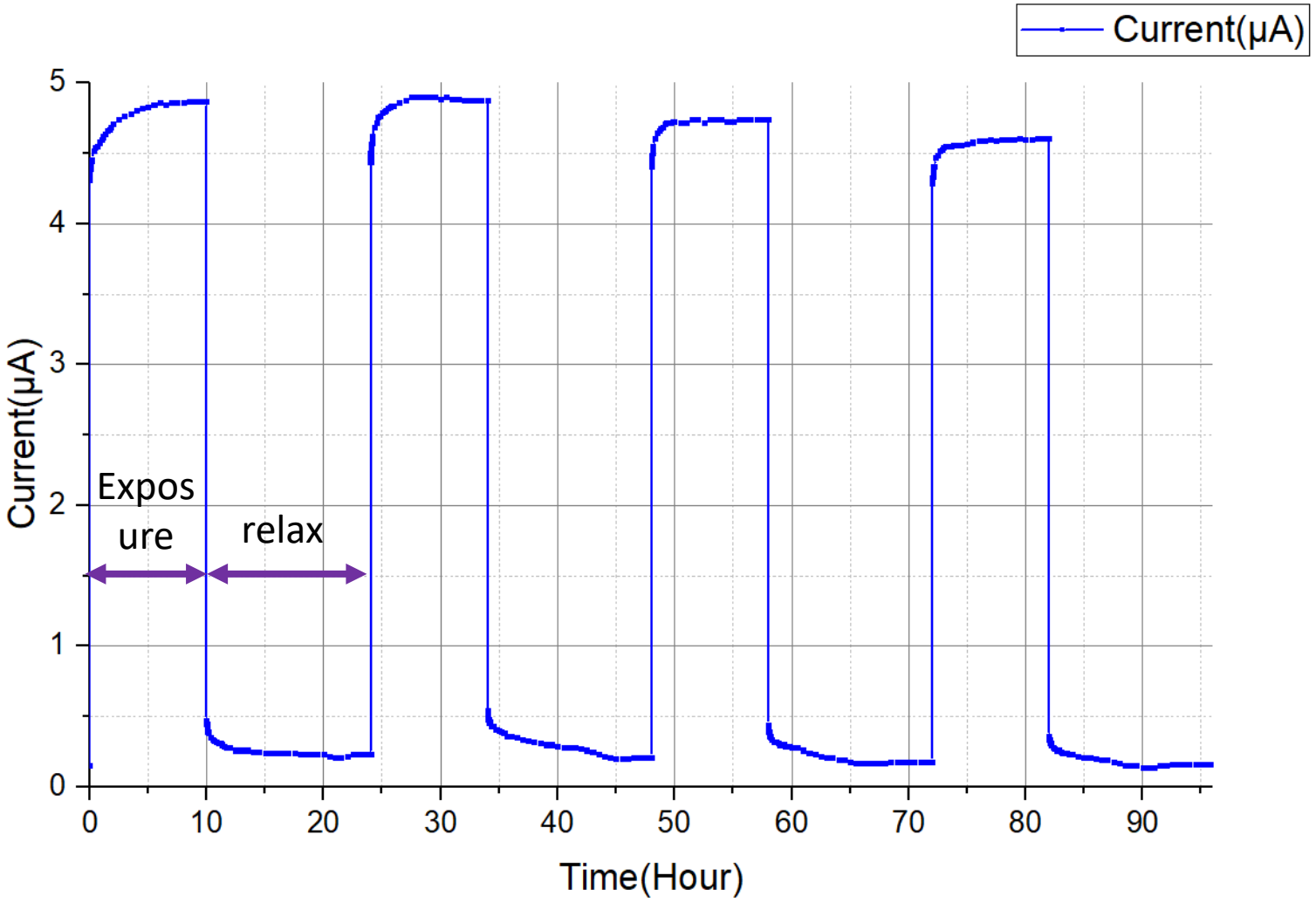
- For pad spacer sealed MRPC2, a 45min & 10sccm flow is enough for a 99% mass percentage of working gas at any place in the working area.

Cosmic ray test for MRPC2

- Before cosmic test, MRPCs overcome long-time X-ray irradiation

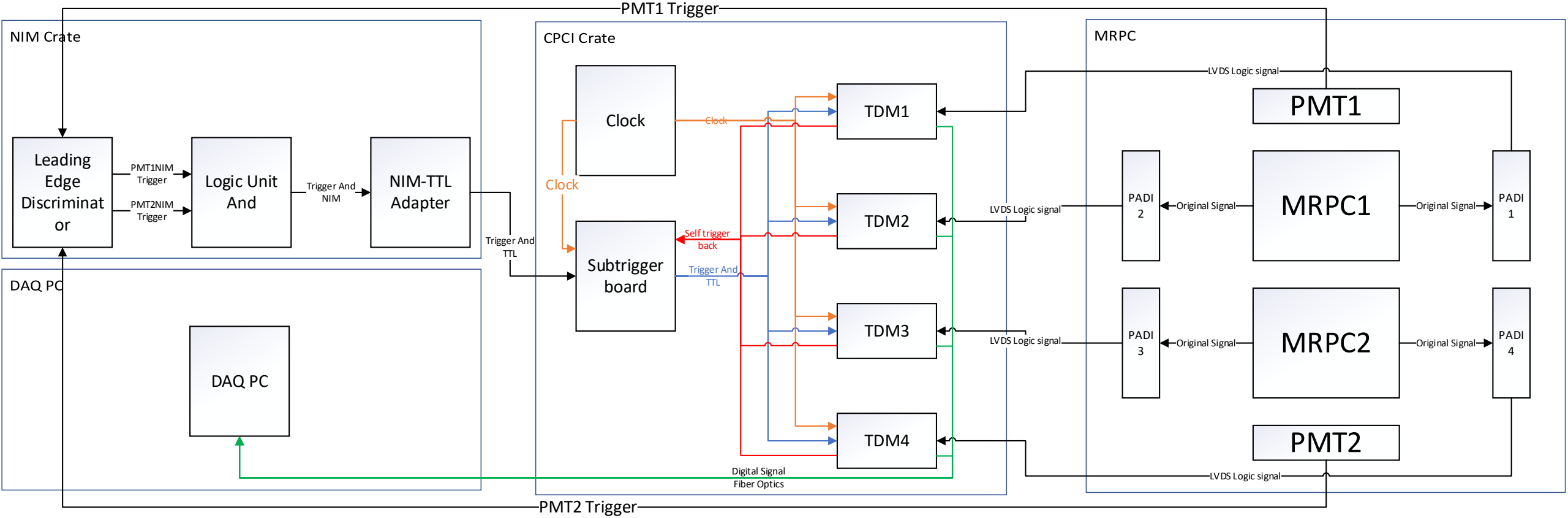
Aging test:

- X-ray tube: 45kV / 0.1mA
- 4 rounds
- 10 hours of X-ray exposure
- 14 hours of relax
- Irradiation 3KHz/cm^2



Setup of cosmic ray test platform

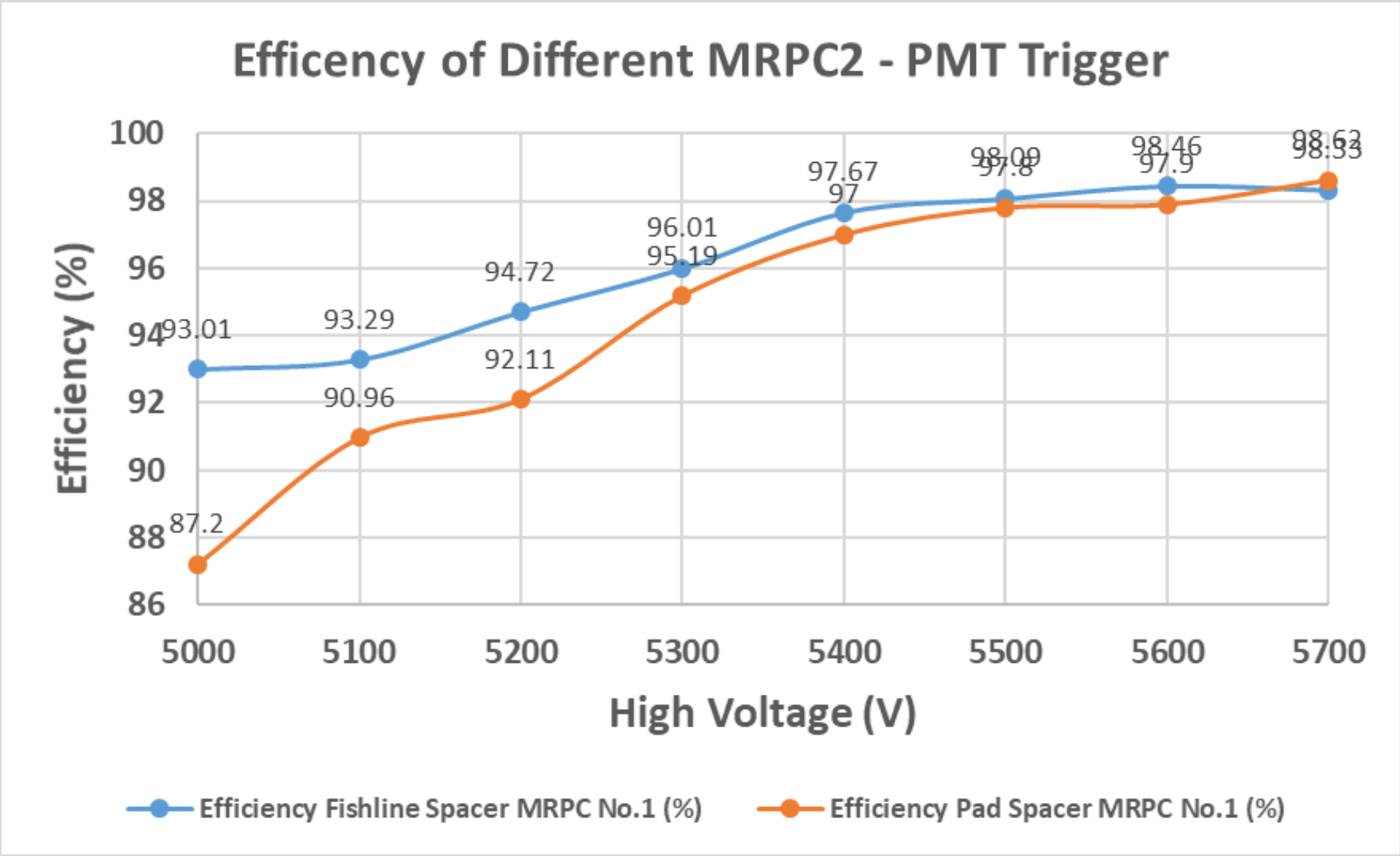
- PADI-FEE
- time-to-digital module (TDM), based on FPGA -from USTC



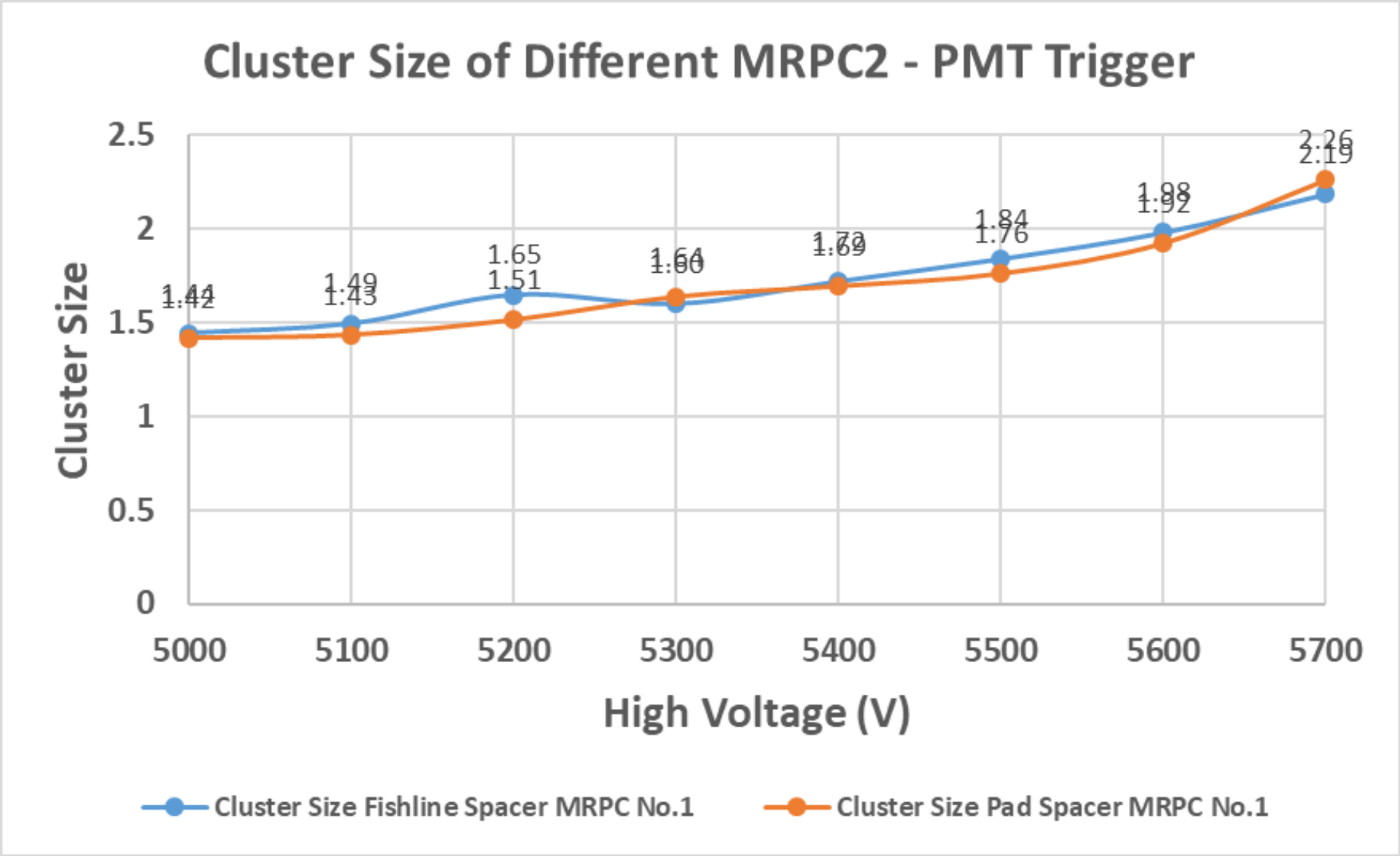
Three trigger method of cosmic test

- Scintillator Trigger
  Use coincidence triggering with two scintillators
  For efficiency, resolution, and cluster size
- Self Trigger – two MRPCs
  Triggered when all four ends of the two MRPCs have signals
  For counting rate, resolution, and quicker event collect
- Self Trigger – one MRPC
  Triggered when both ends of a specific MRPC have signals
  For noise rate and noise behavior

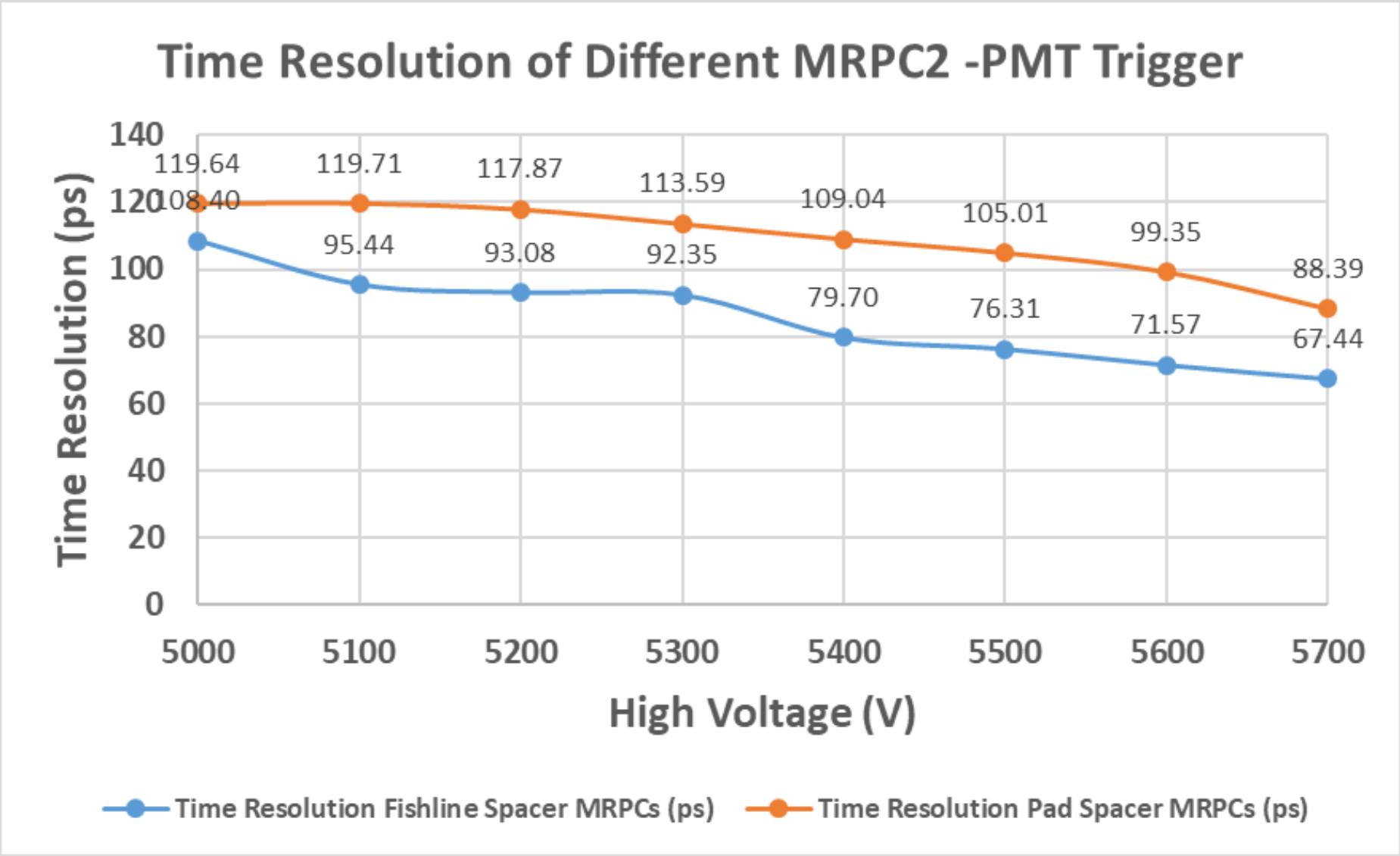
Scintillator Trigger results – HV scan



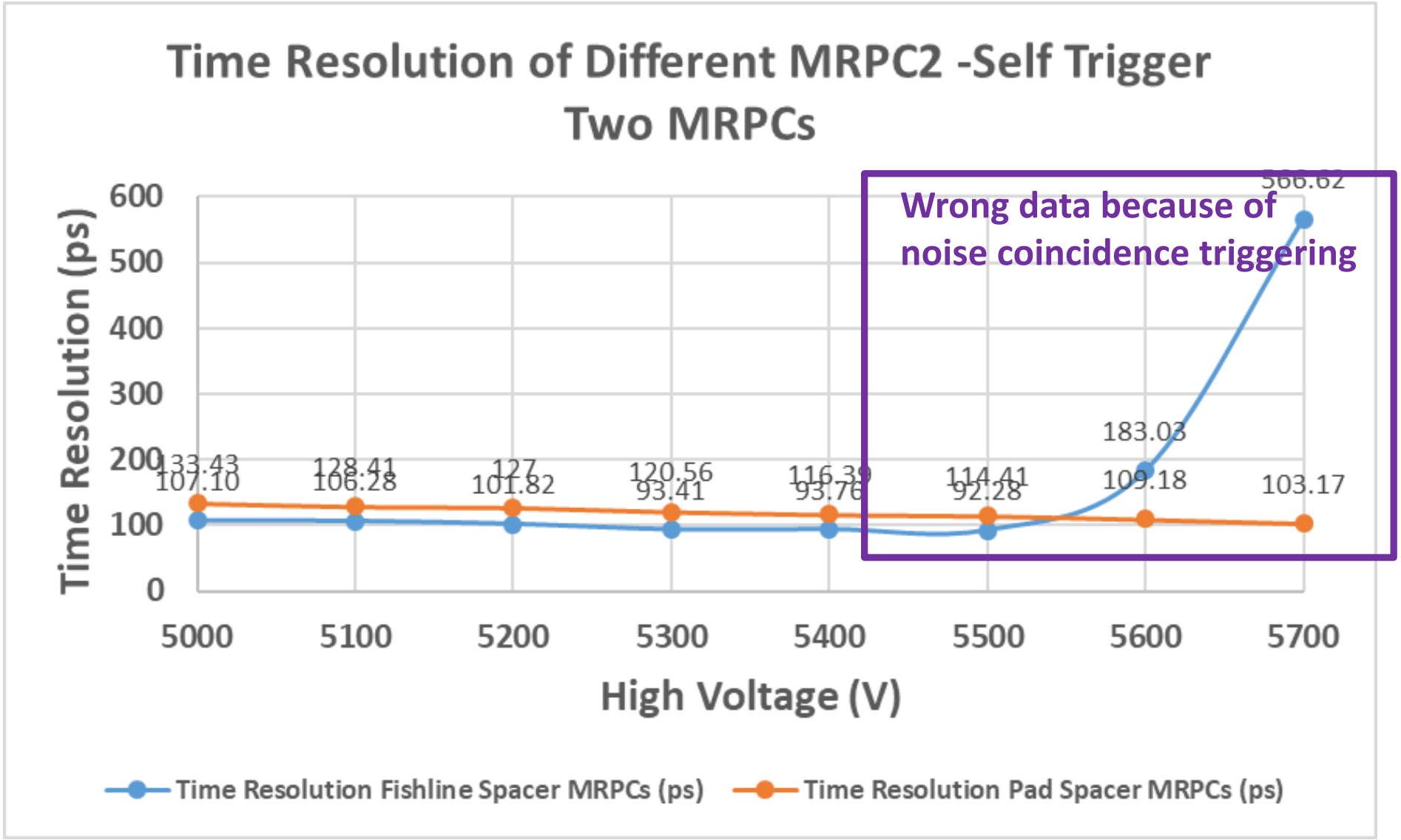
Scintillator Trigger results – HV scan



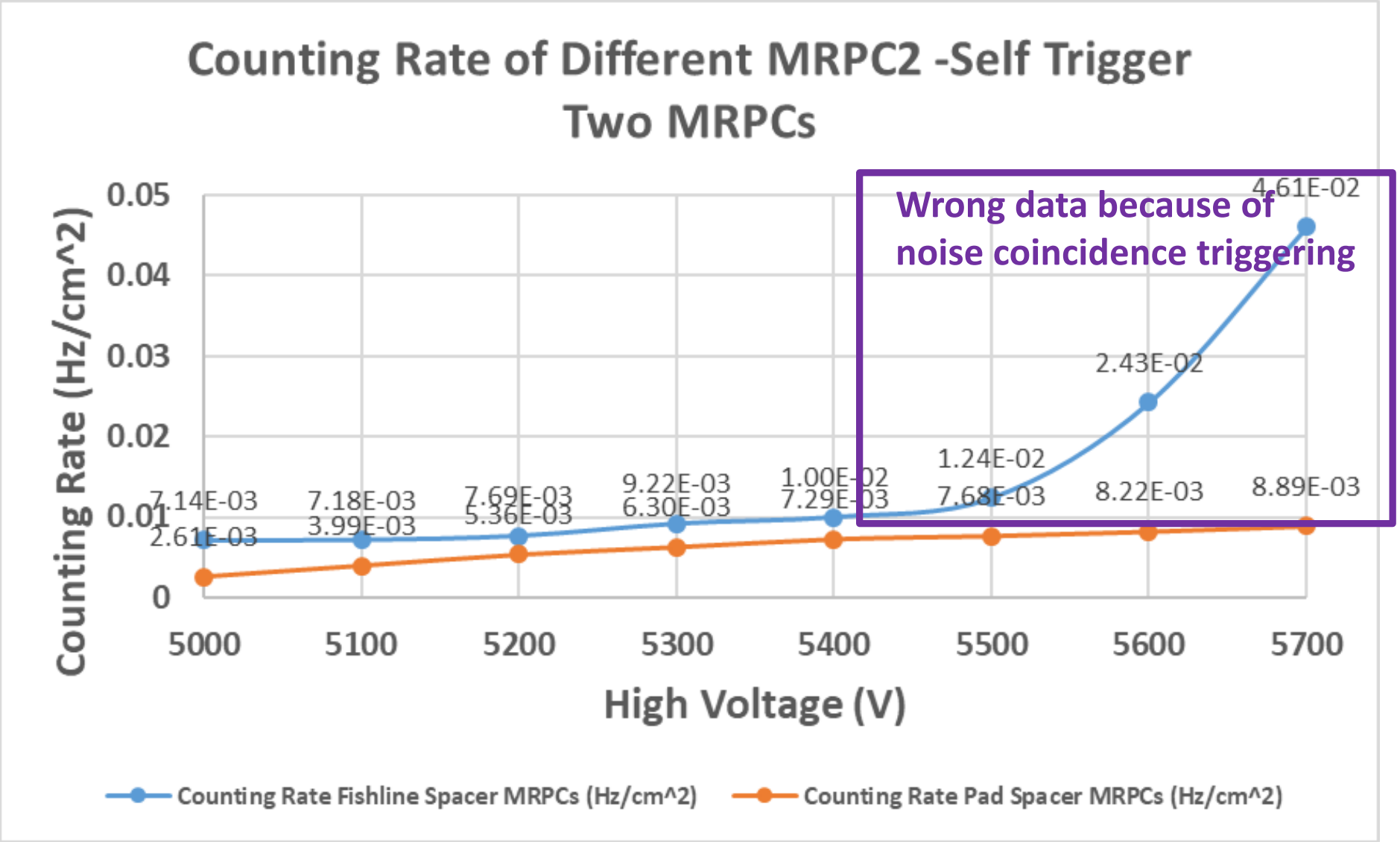
Scintillator Trigger results – HV scan



Self Trigger results of two MRPCs – HV scan

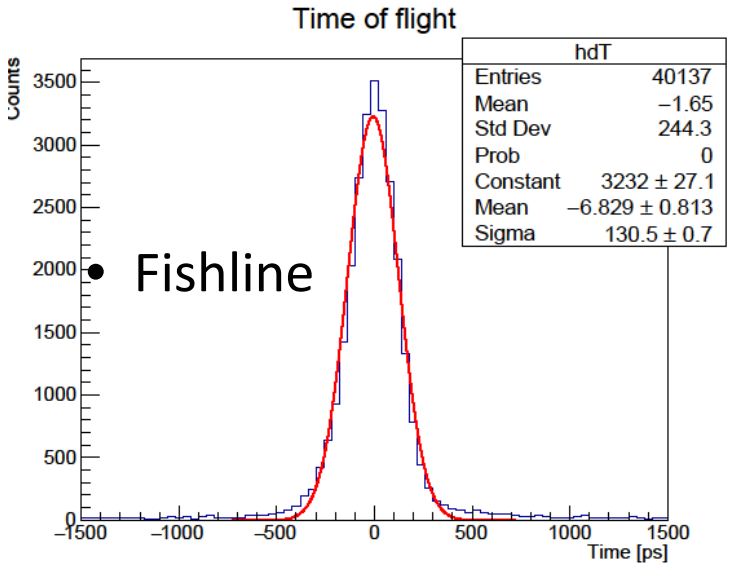


Self Trigger results of two MRPCs – HV scan

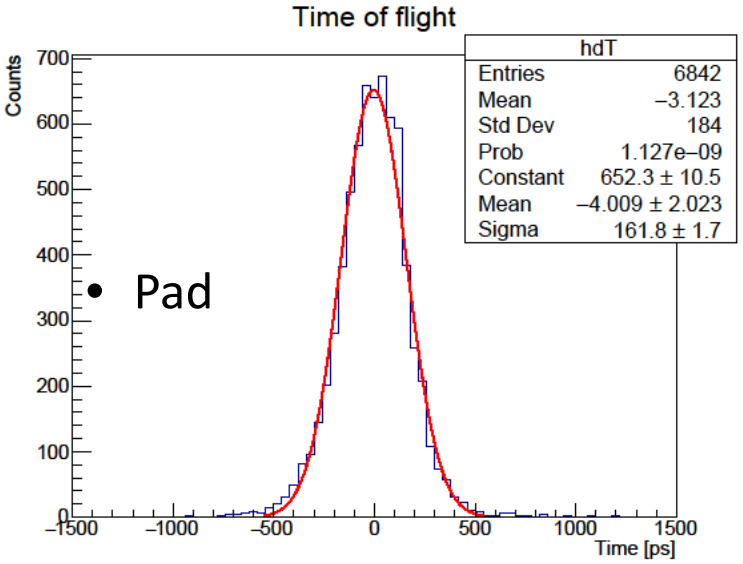


Self Trigger results of two MRPCs – HV scan

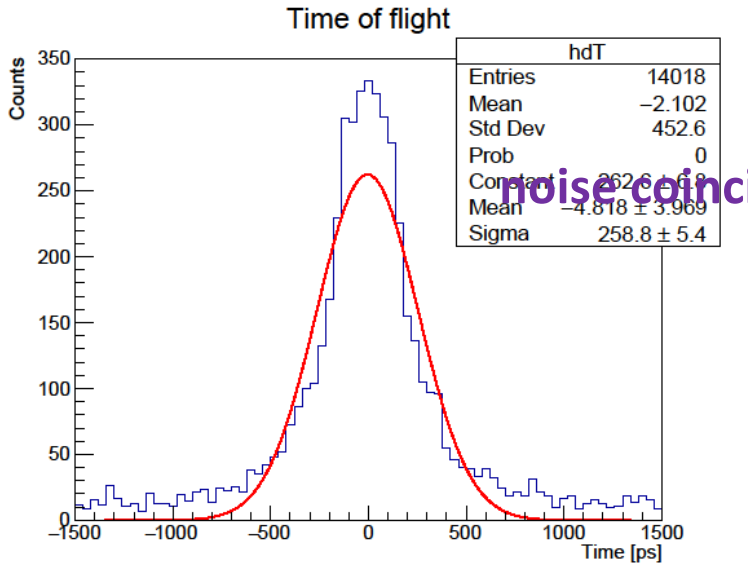
- Fishline



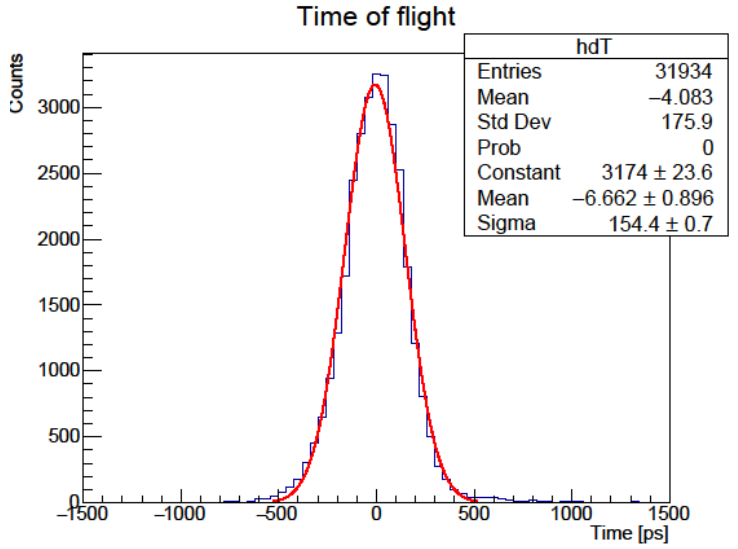
- 5500V



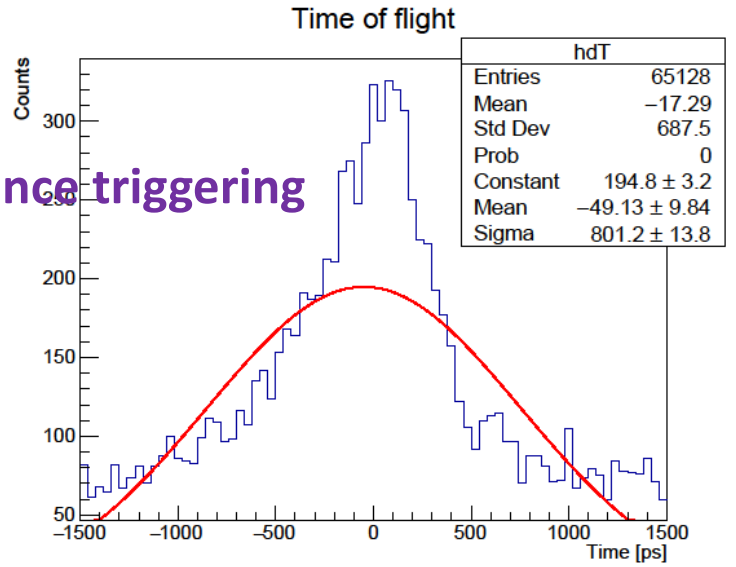
- Pad



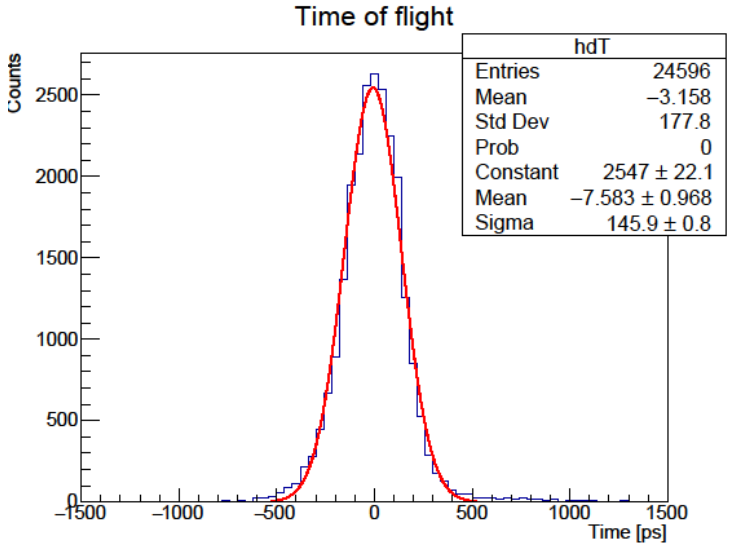
- 5600V



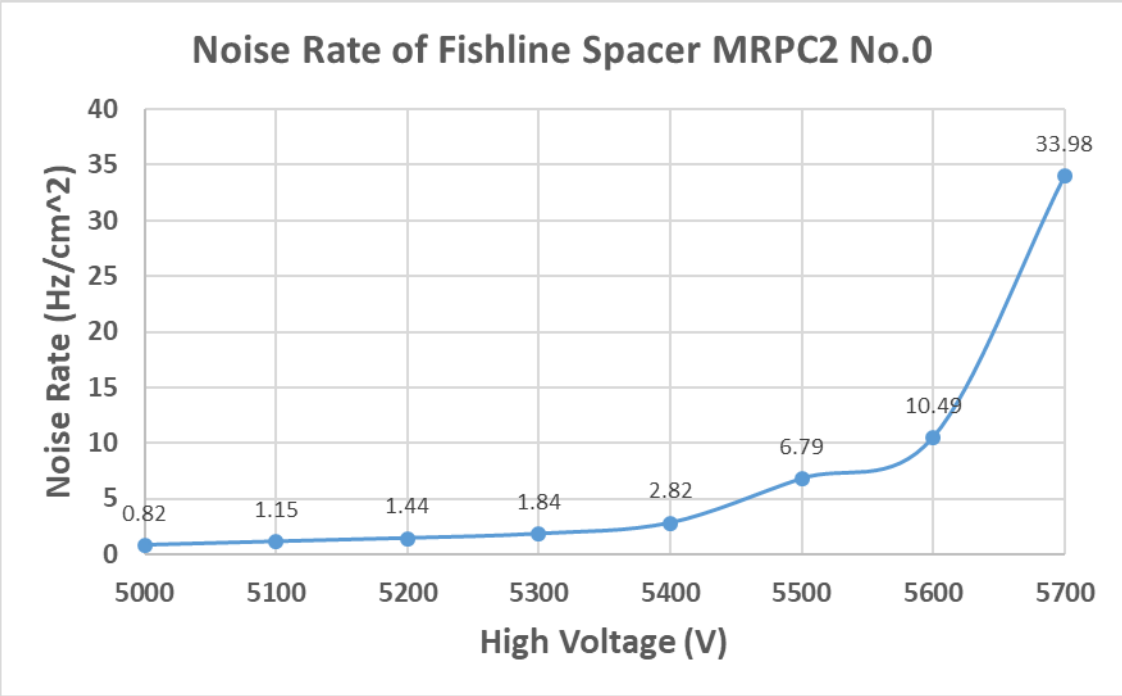
noise coincidence triggering

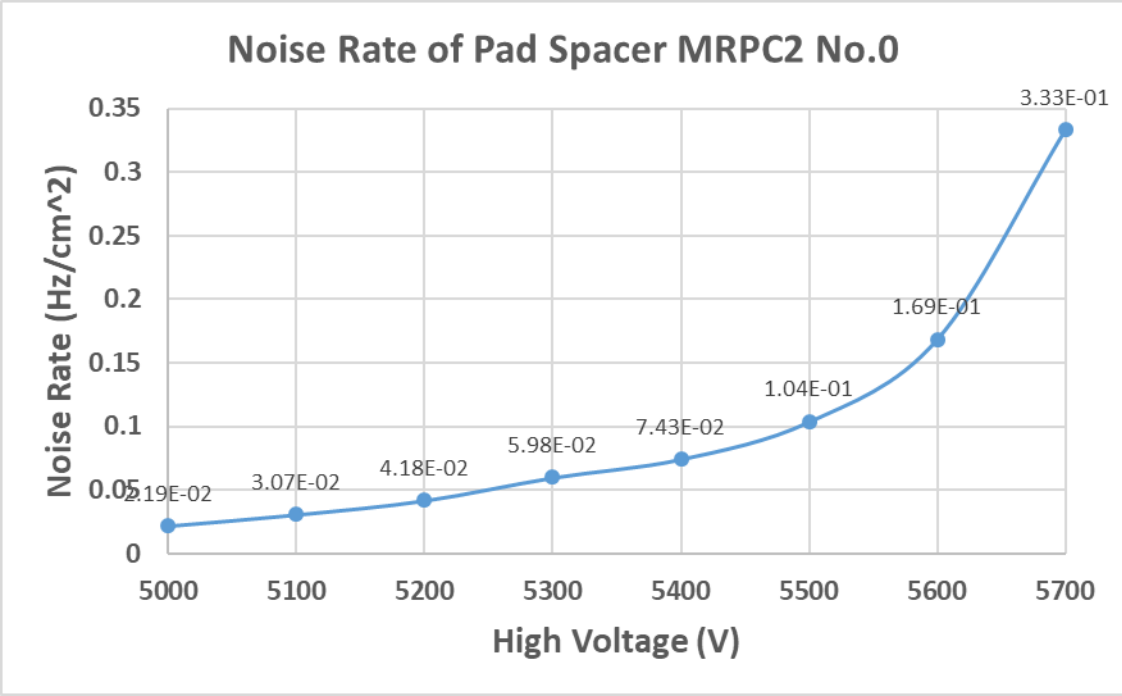


- 5700V



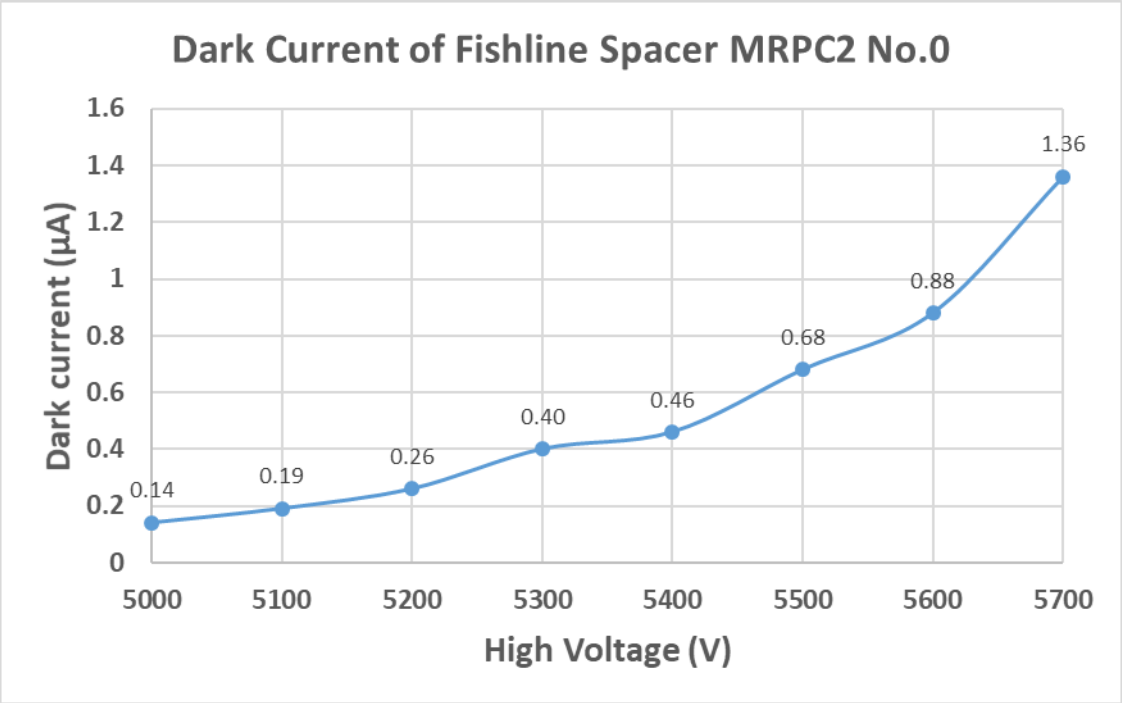
Self Trigger results of one MRPCs – HV scan

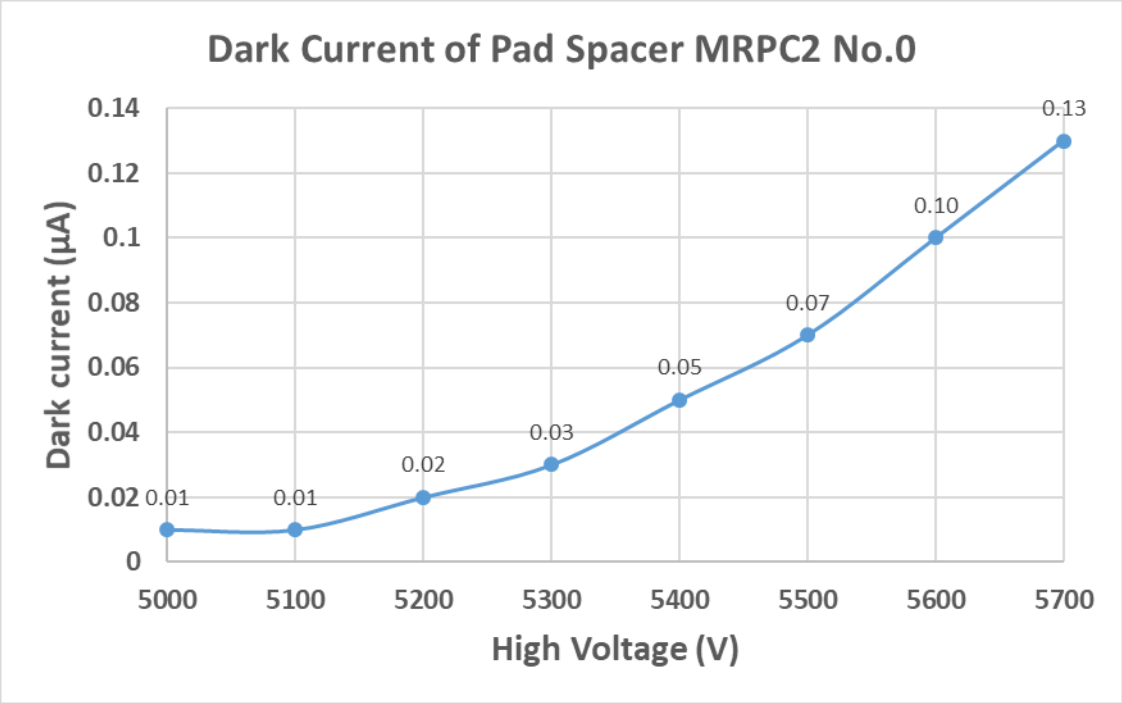




- Noise rate of pad spacer MRPC is about 0.01 amount of fishline spacer MRPC.
  5700V Fishline: 33.98 Hz/cm^2
  5700V Pad: 0.333 Hz/cm^2

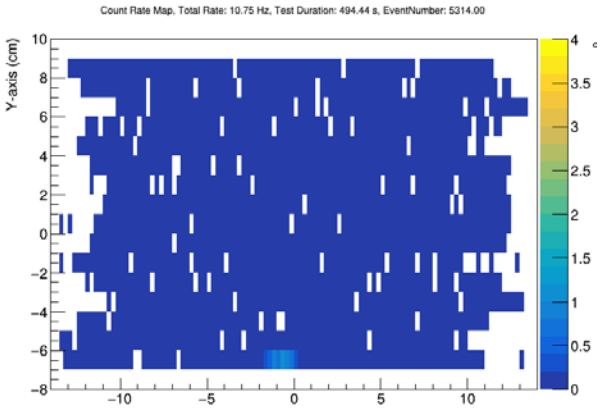
Self Trigger results of one MRPCs – HV scan



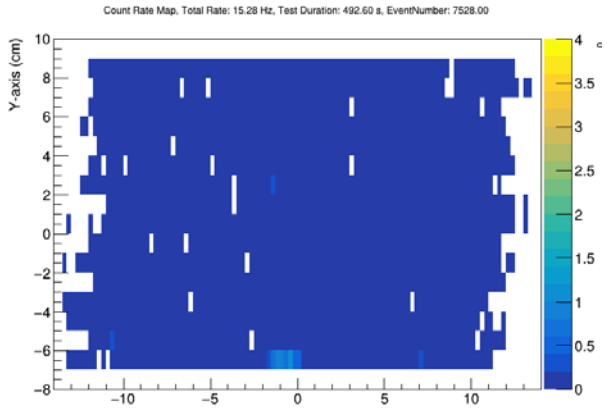


- The dark current of pad spacer MRPC is 0.1 amount of fishline spacer MRPC.
  5700V Fishline: 1.36 μA
  5700V Pad: 0.13 μA
- Dark current is not proportional to noise rate?

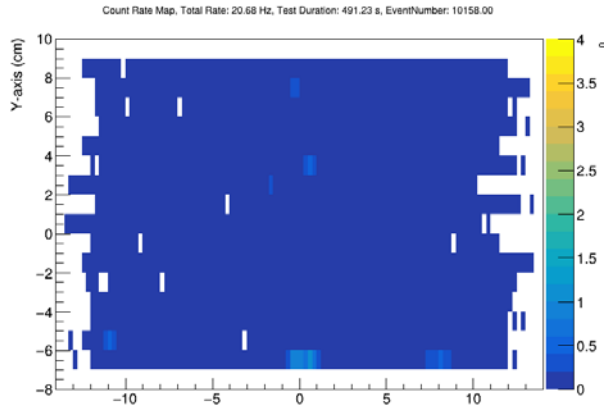
Self Trigger results of one MRPCs – HV scan



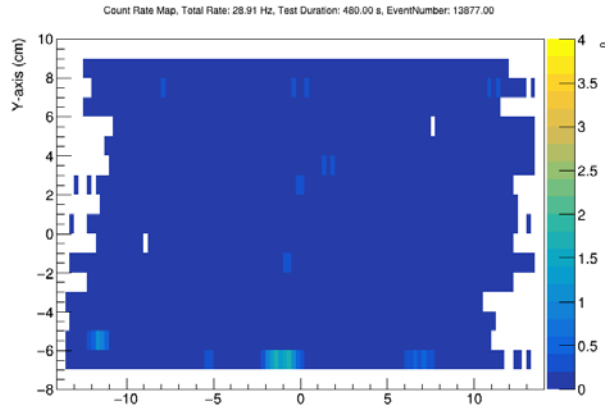
5000V



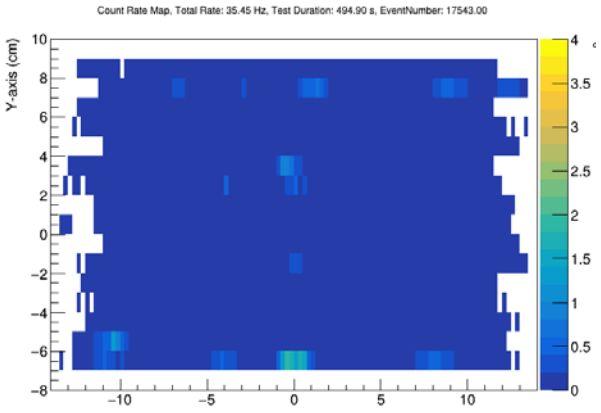
5100V



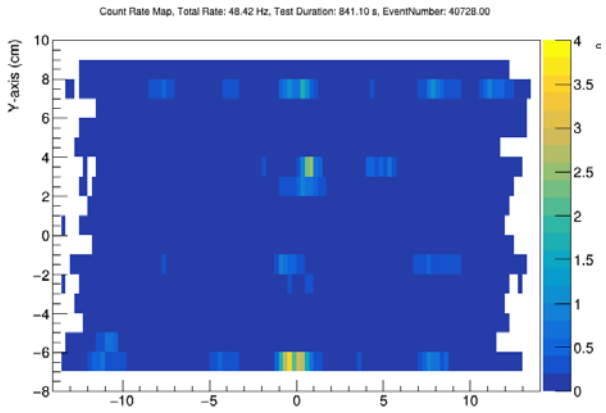
5200V



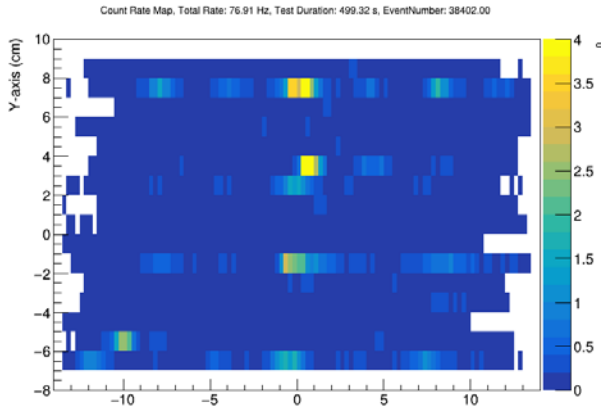
5300V



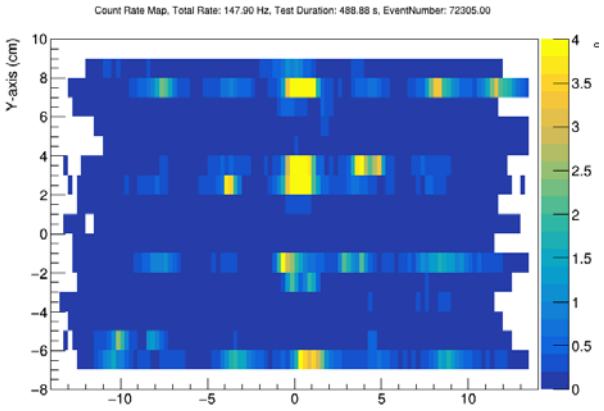
5400V



5500V



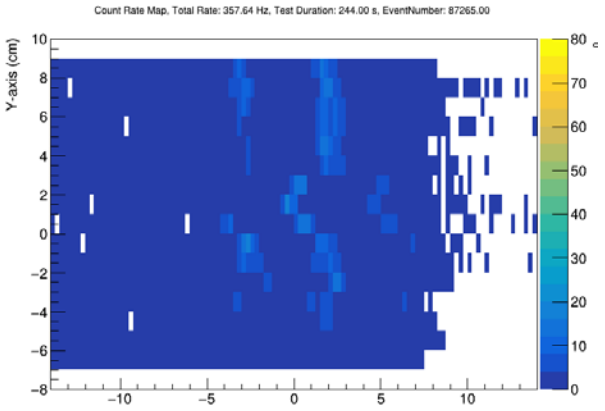
5600V



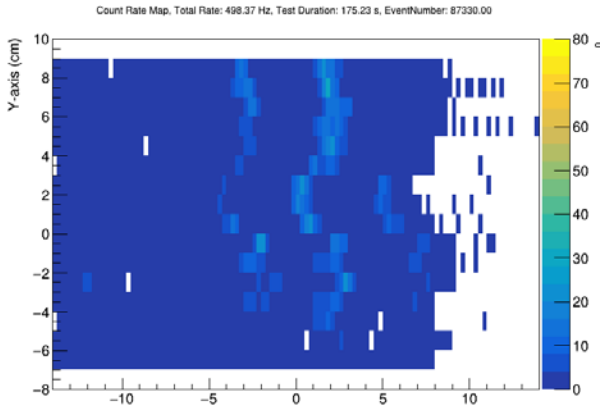
5700V

- Grows of noise rate map of pad spacer MPRCs under increasing HV.

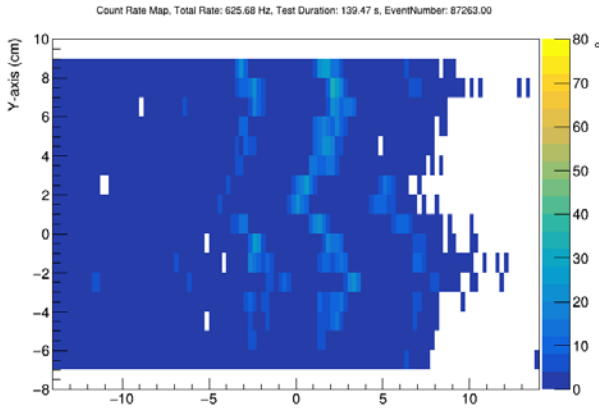
Self Trigger results of one MRPCs – HV scan



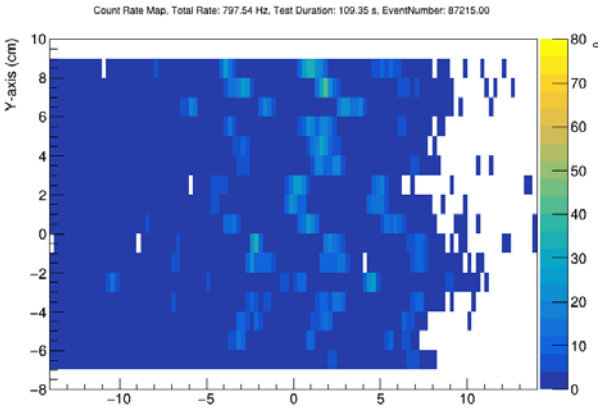
5000V



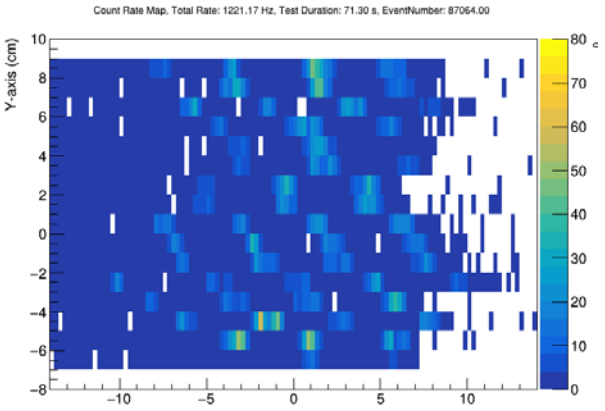
5100V



5200V



5300V



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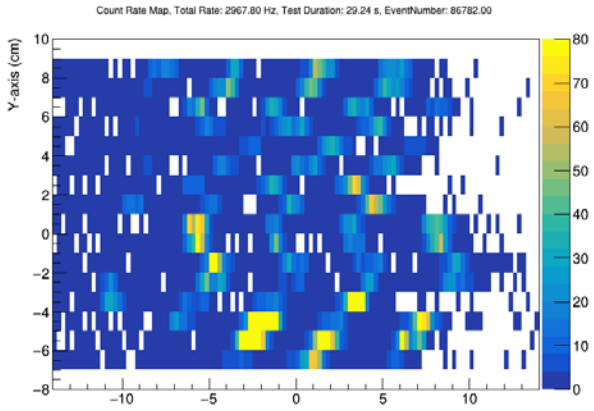
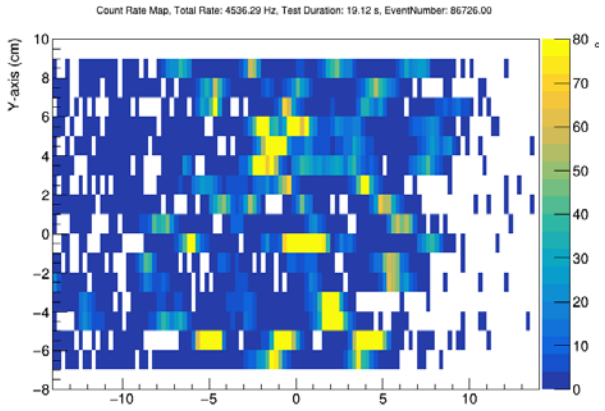
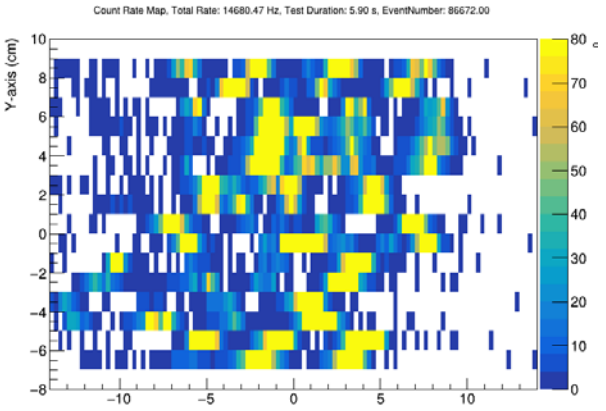


5500V



5600V



5700V

- Grows of noise rate map of fishline spacer MPRCs under increasing HV.

Summary

Benefits found for Pad spacer MRPCs:

- Better gas exchange: 1.5 times better than fishline ones
- Didn’t see obvious efficiency increase
- No obvious long-term effect under high luminosity condition, compared with fishline ones
- After long-term effect, pad spacer sealed MRPC2 shows:
  Less dark current at the spacer area – 10 times smaller
  Less noise at the spacer area – 100 times smaller

What to do next

- CFD electronic field simulation and further test on spacer effect, understanding the principle behind this.

- Find out why current is not proportional to rates when it comes to mostly dark current and dark rate.

- Get clearer about the increasing dark rate of fishline spacer MRPCs under the X-ray exposure.

Thank you!

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