

# Performance Study of Mosaic High Rate MRPC

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# Outline



- ♪ Motivation
- ♪ Mosaic design 1 : glue glass
  - structure
  - simulation
  - cosmic ray test results
  - beam test results
- ♪ Mosaic design 2 : block by fishing line
  - beam test results – HV scan, position scan, rate scan etc.
- ♪ Summary

# Motivation

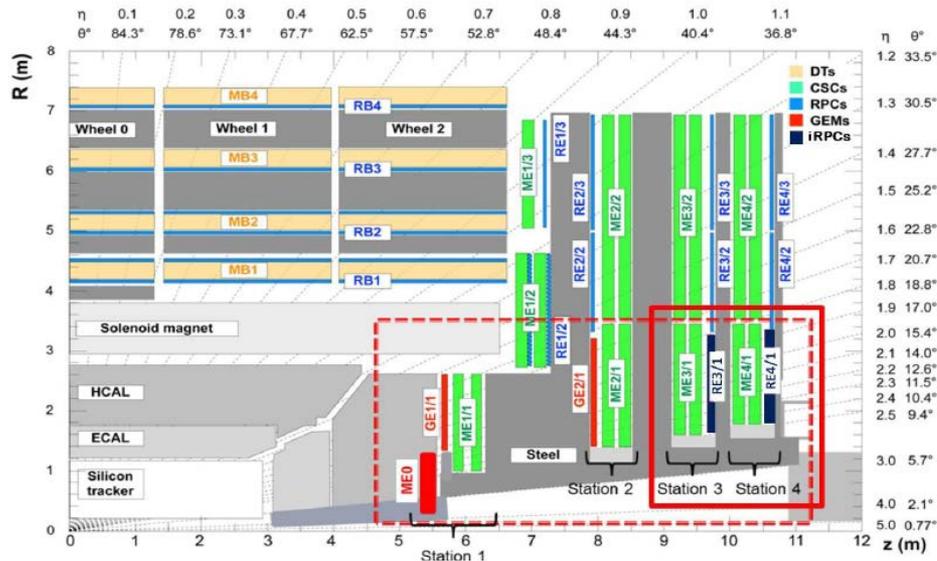


**In CMS muon system, the present design of the endcap RPCs, made of a double Bakelite gas gap and operating in avalanche mode, is not expected to be suitable for the particle rates amounting to several tens of kHz/cm<sup>2</sup> in the scenario of an LHC luminosity going up to 10<sup>34-35</sup> cm<sup>-2</sup>s<sup>-1</sup>**

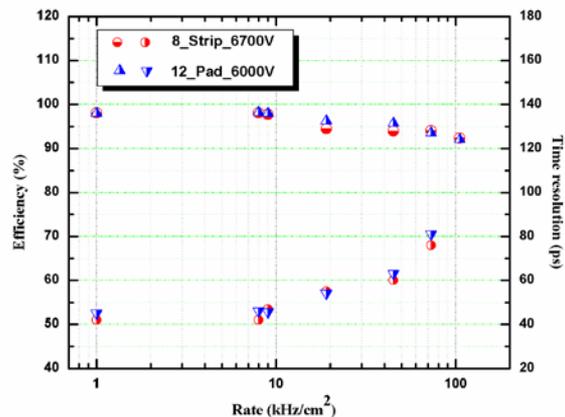
Requirement:  
 ■ Rate >2kHz/cm<sup>2</sup>

Tytgat M, Marinov A, Zaganidis N, et al. Construction and performance of large-area triple-GEM prototypes for future upgrades of the CMS forward muon system[C]//Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2011 IEEE. IEEE, 2011: 1019-1025.

# Motivation



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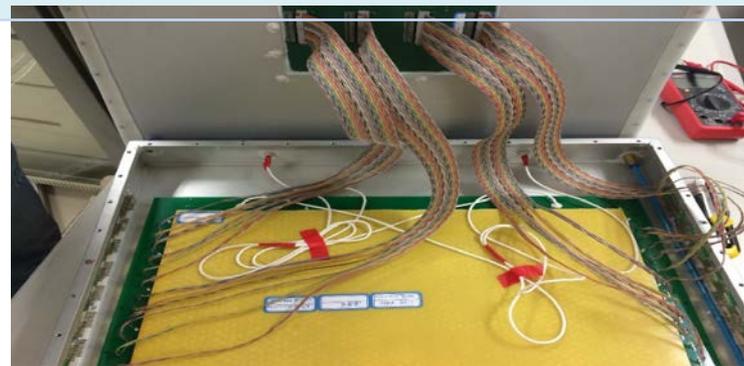
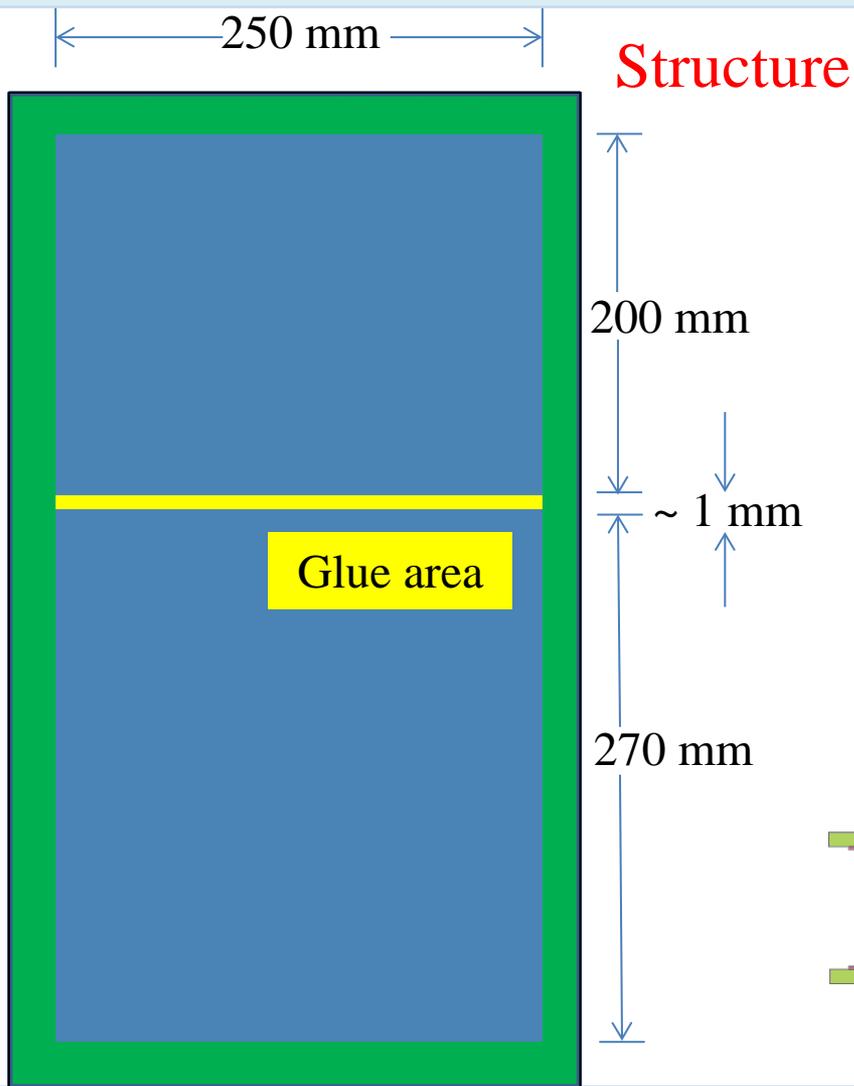


Test results at Nuclotron, Dubna

High rate MRPC based on low resistive glass is best candidate for the upgrade of endcap muon system.

- High rate capability >70kHz/cm<sup>2</sup>
- Time resolution <100ps, eliminate most of background
- Limitation: glass size 33 cm × 28 cm
- **Solution: glass mosaic**

# Mosaic design 1 : glue



**PCB:**  $320 \times 540 \text{ mm}^2$

**Strip length:** 498 mm

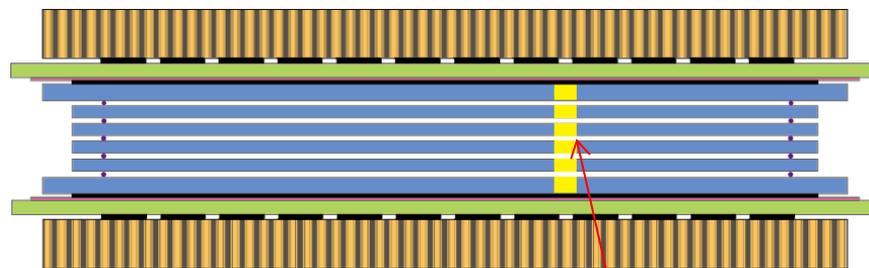
**Strip pitch:**  $(17 + 2) \text{ mm}$

**Strip number:** 12

**Glass:**  $(200 + 270) \times 250 \text{ mm}^2$ , 0.7 mm,  $10^{10} \Omega \cdot \text{cm}$

**Gas gap width:** 250  $\mu\text{m}$

**Gas gap number:** 5



Glue area

# Weighting field simulation

➤ Ansoft Maxwell 13.0

➤ Induced signal:  $I(t) = \frac{E_w}{V_w} \dot{X} q$  [S. Ramo, Proceedings of IRE 27 (1939)]

➤ Simulation of weighting field:

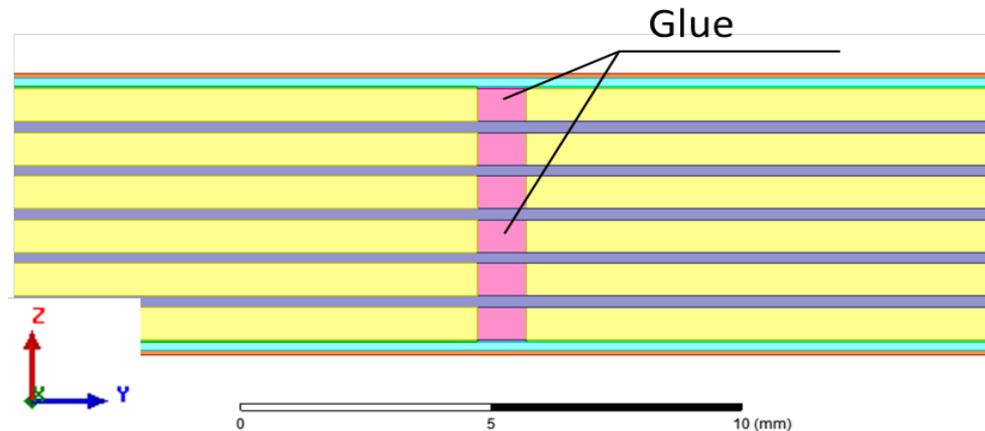
$$eff = 1 - e^{-\left(1 - \frac{\eta}{\alpha}\right) \frac{d}{\lambda}} \left[ 1 + \frac{V_w}{E_w} \frac{\alpha - \eta}{e_0} Q_t \right]^{1/\alpha\lambda}$$

[w. Riegler, C. Lippmann]

Model

➤ Our RPC model gets the same results as the previous study (Majumdar, 2008)

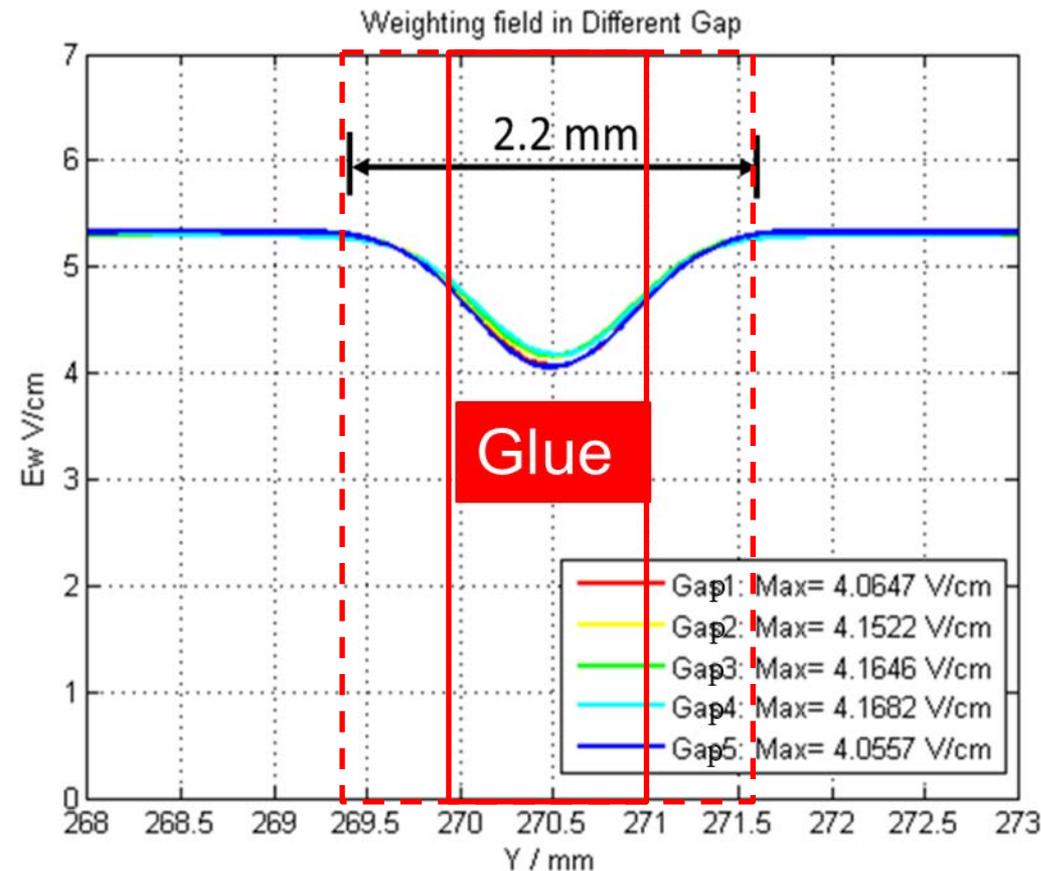
Size: 471 × 250 × 5.45 mm  
 Material: low resistive glass  
 Gluing width: 1 mm  
 5 gap: air



Component	Width (mm)
Read-out Strip	0.1
Insulated layer	0.18
Graphite	0.05
Gas Gap	0.7
Resistive plate	1
Gap	0.25

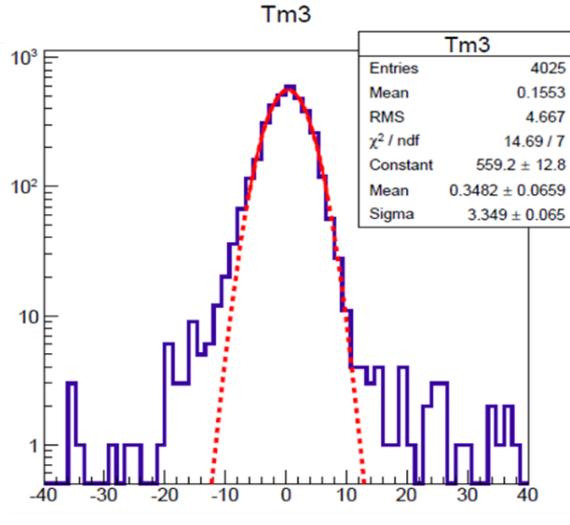
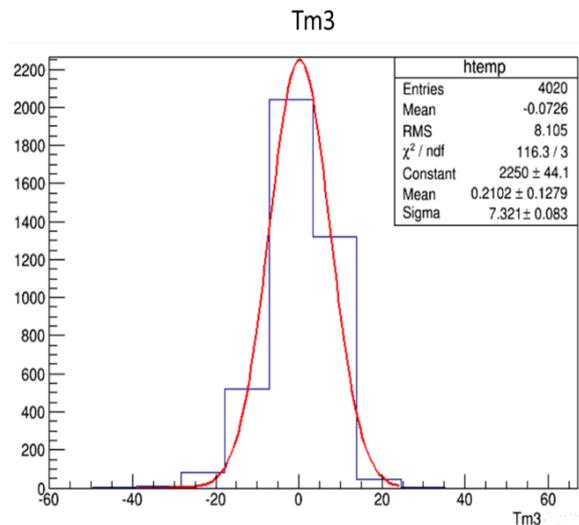
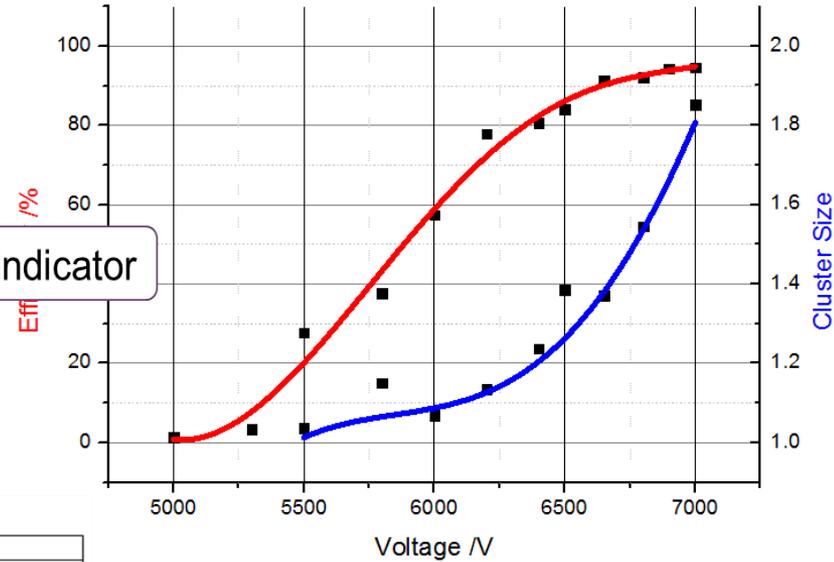
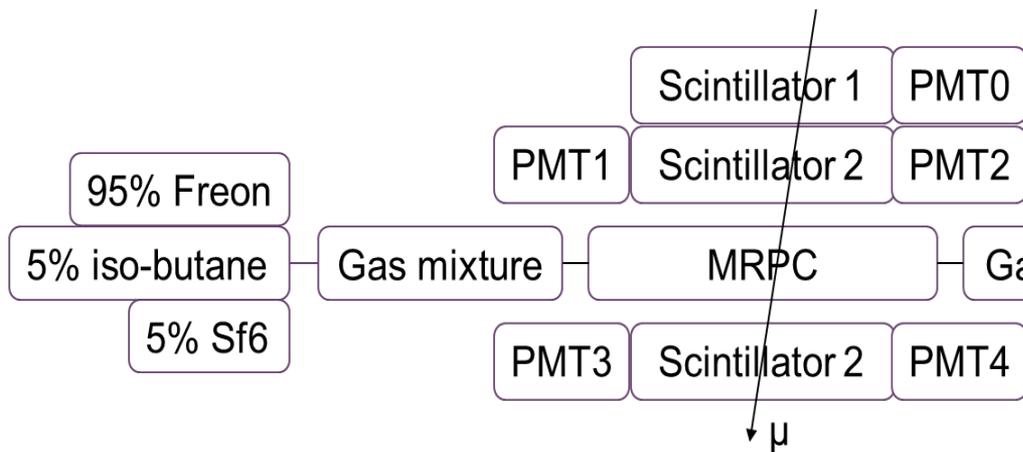
# Simulation results

Weighting field in different gap:



- Gluing region which is from 270 to 271 mm.
- On average, weighting field drops from 5.32 to 4.12 V/cm
- **Affected area is 2.2 mm,** 0.5% of the detector.
- @  $E = 11 \text{ kV/mm}$  ( $\pm 6.8 \text{ kV}$ ),  $\alpha=140/\text{mm}$   $\beta=10/\text{mm}$
- **lowest efficiency: ~93%,** 2% efficiency loss

# Cosmic ray test results



✓ Efficiency: 94%

✓ Time Resolution: 71 ps

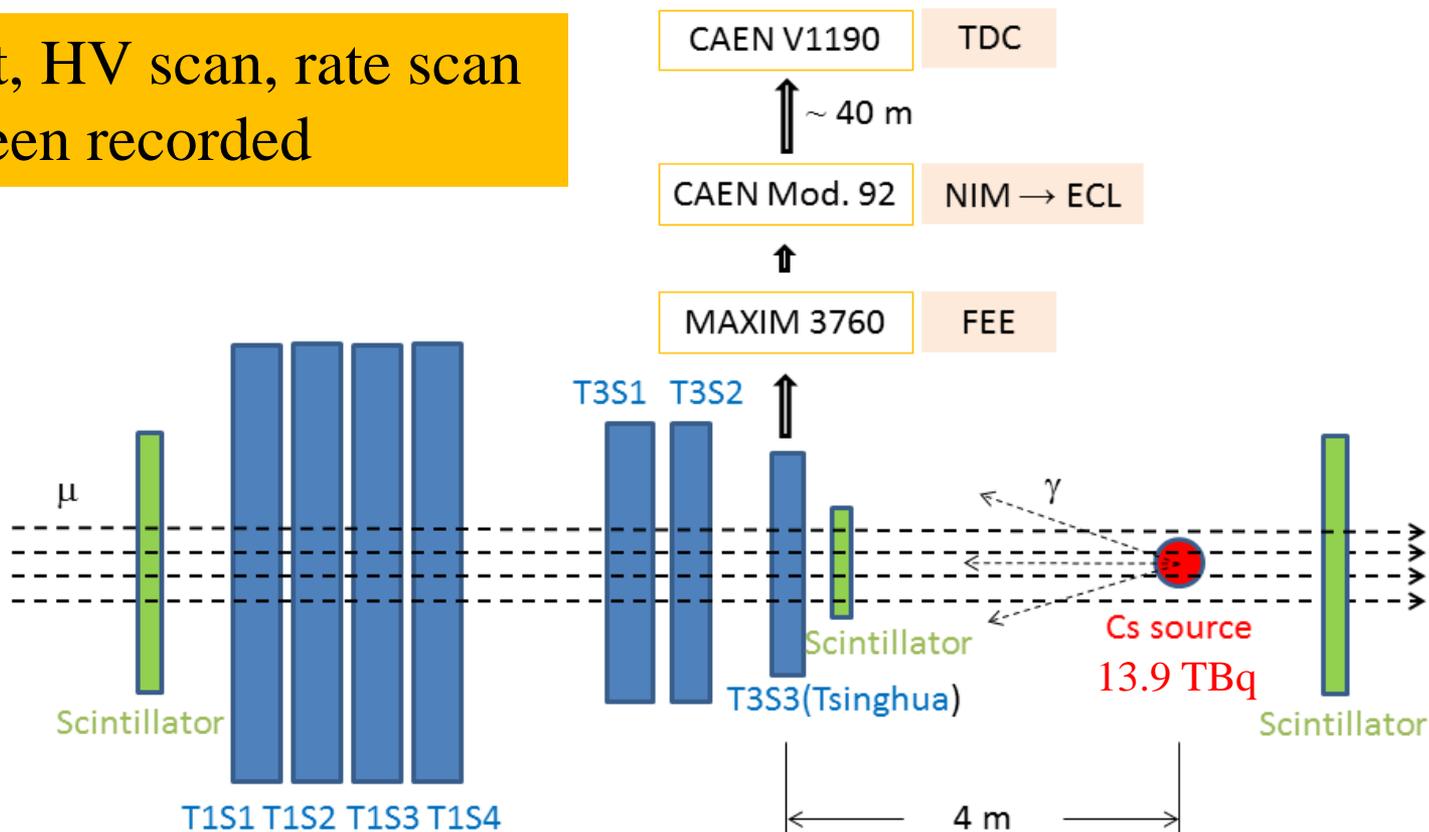
$$\delta = \sqrt{3.349^2 - 1.766^2} \times 25 = 71.1 \text{ ps}$$

# Beam test results

Beam test @ GIF++, Aug, 2015

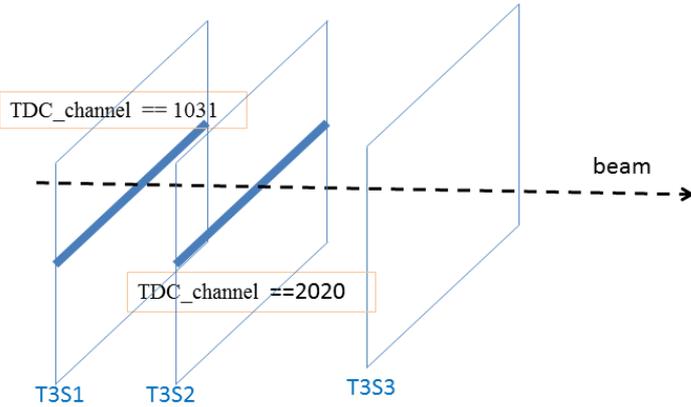
Current, HV scan, rate scan  
have been recorded

## Setup



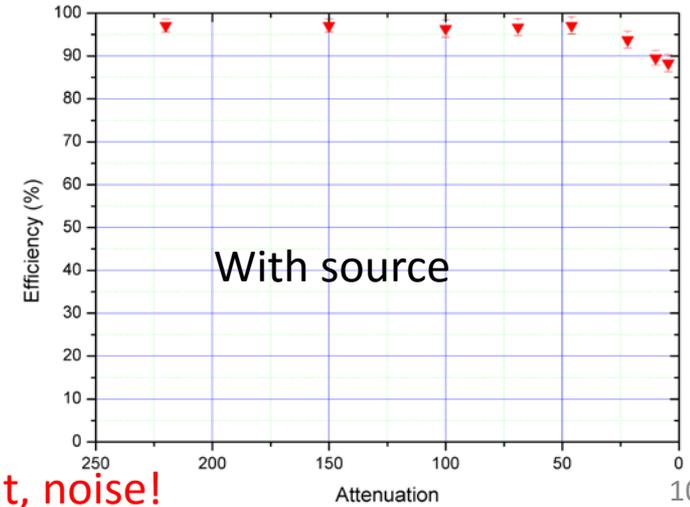
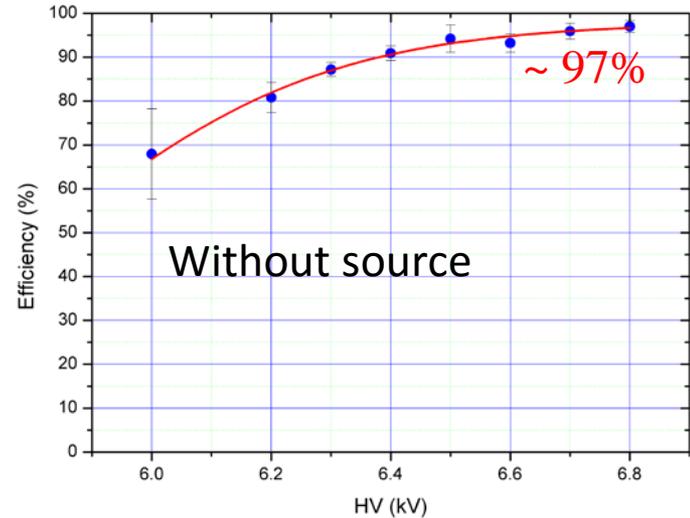
Gas supply: 94.5% Freon, 5.2% iso-butane, 0.3% SF6, 1L/h

# Beam test results



HV scan

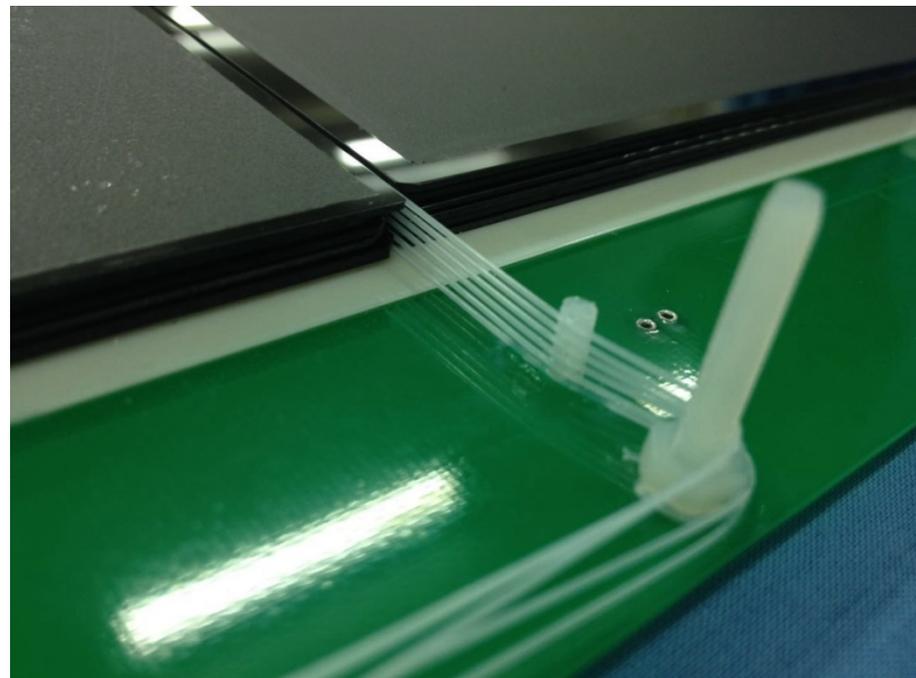
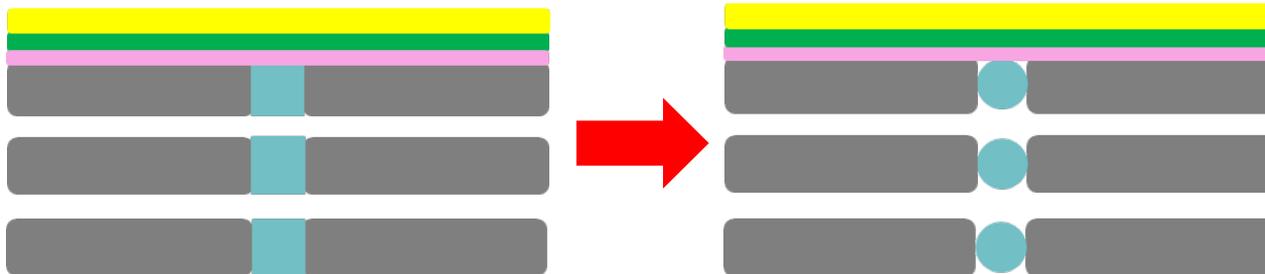
$$\text{Efficiency} = \frac{\text{Ch1031} \ \&\& \ \text{Ch2020} \ \&\& \ \text{T3S3}}{\text{Ch1031} \ \&\& \ \text{Ch2020}}$$



rate scan

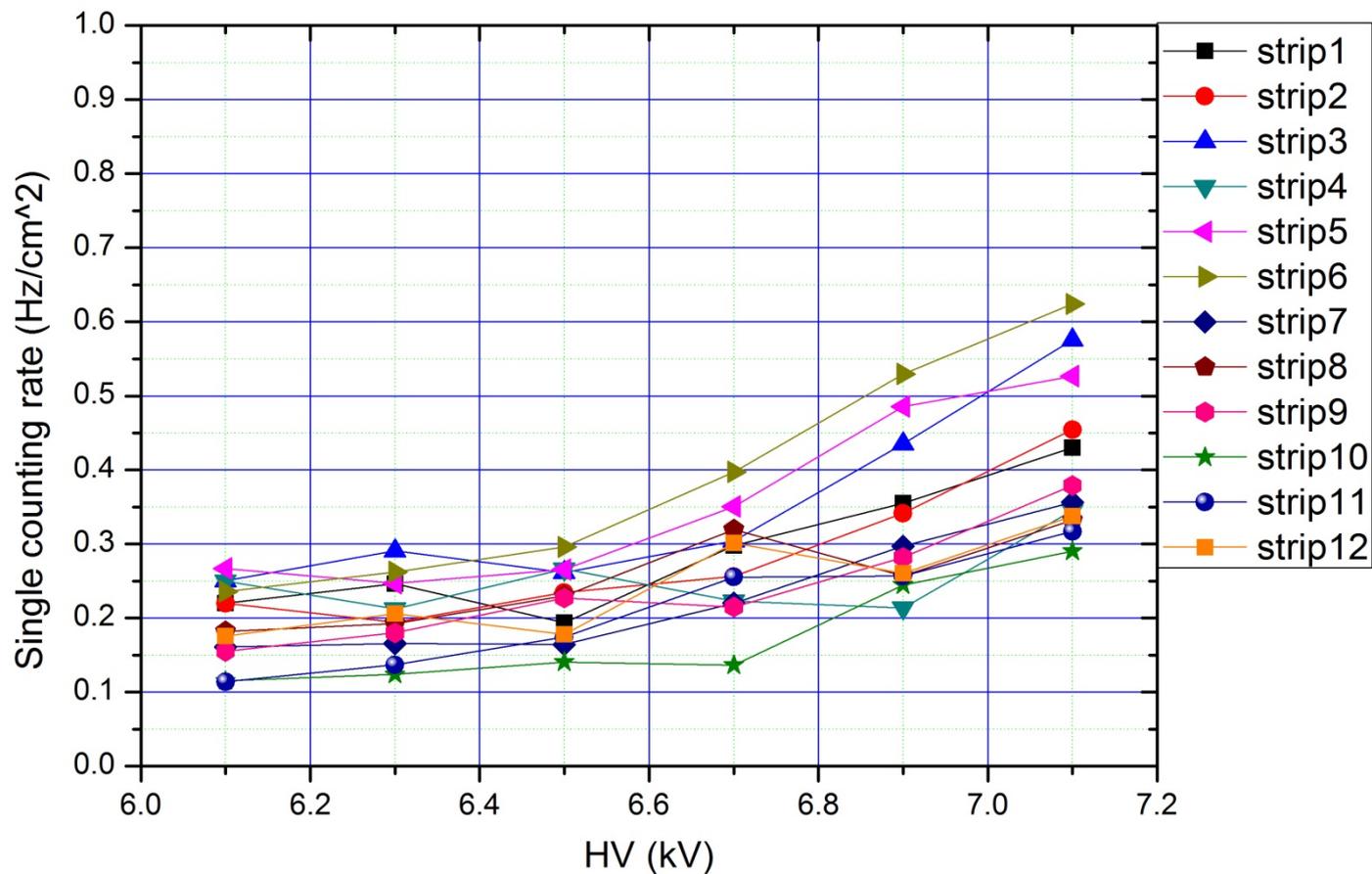
Problem: big current, noise!

# Mosaic design 2



# Mosaic design 2

The noise of this new design can be lower than  $1\text{Hz}/\text{cm}^2$ .

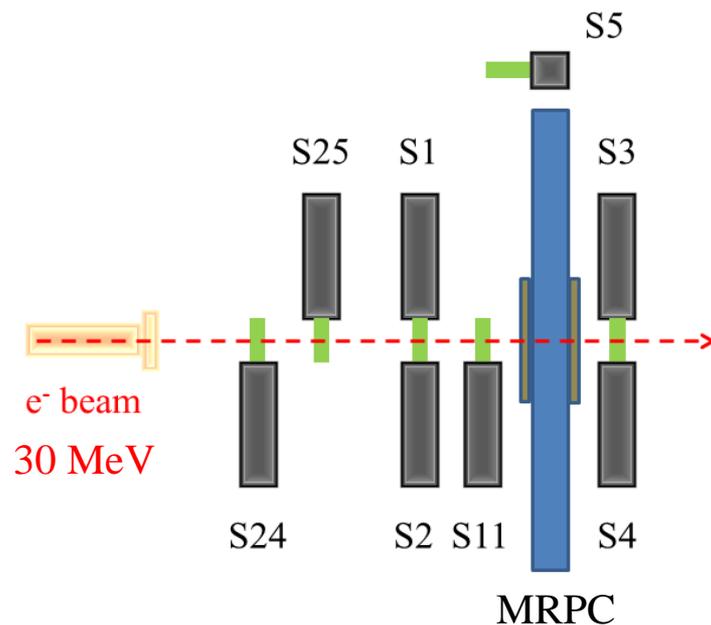


# Beam test results

Beam test @ ELBE, HZDR, Sep, 2015



S24, S25 :  $4 \times 4 \text{ cm}^2$   
 S11 :  $5 \times 5 \text{ mm}^2$   
 S1, S2, S3, S4 :  $2 \times 2 \text{ cm}^2$



Gas supply: 90% Freon, 5% iso-butane, 5% SF6, 50ml/min

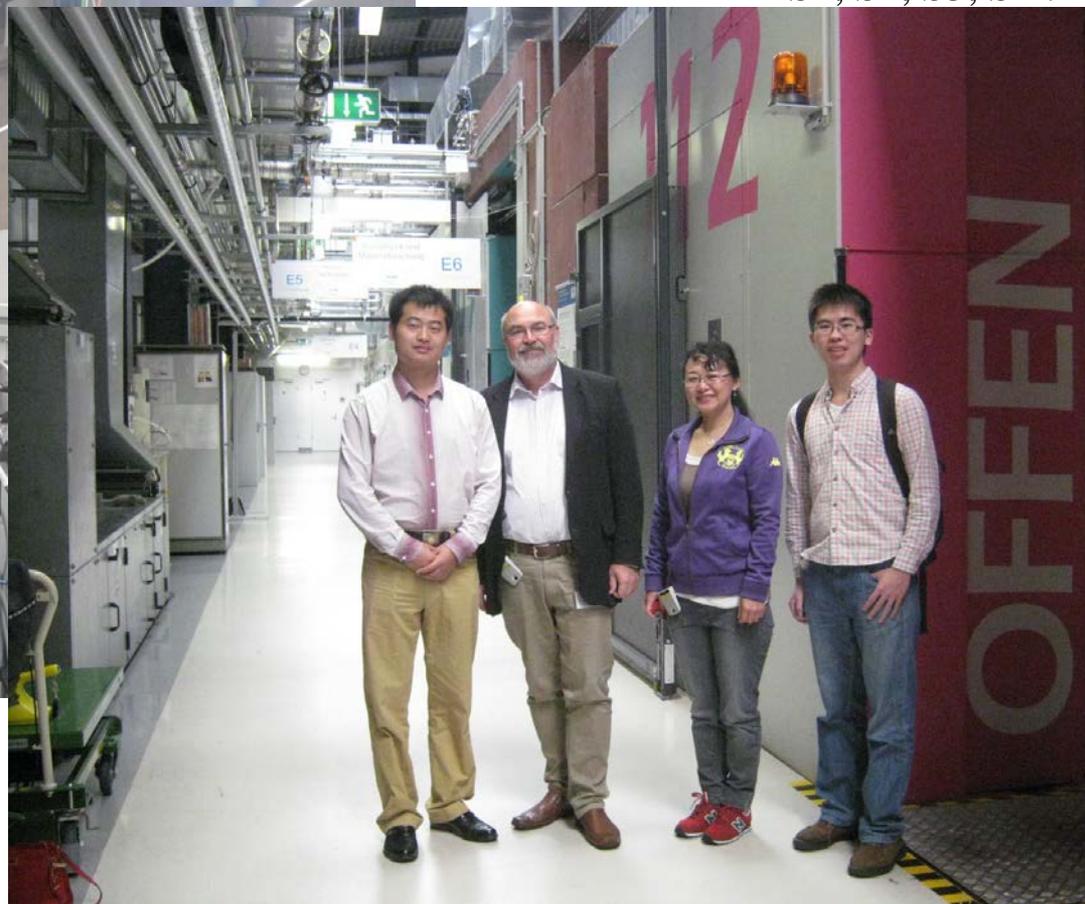
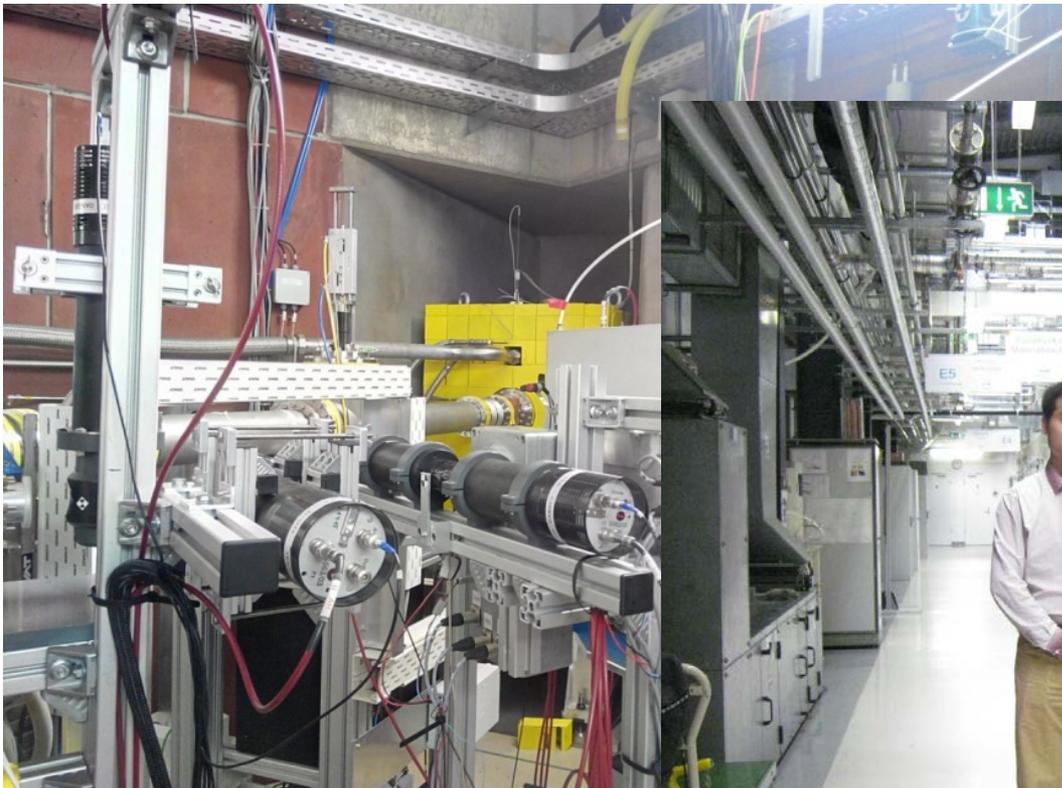
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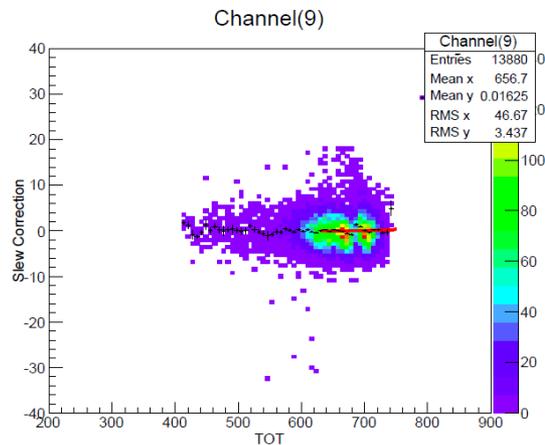
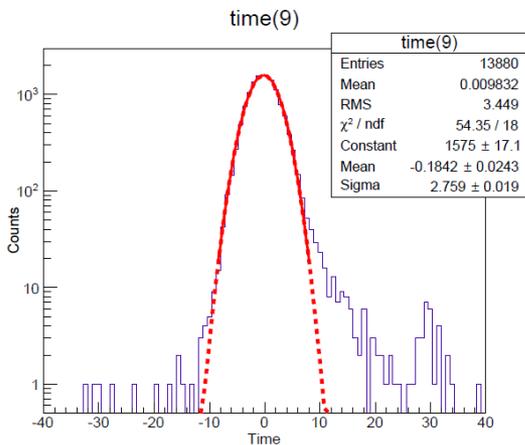
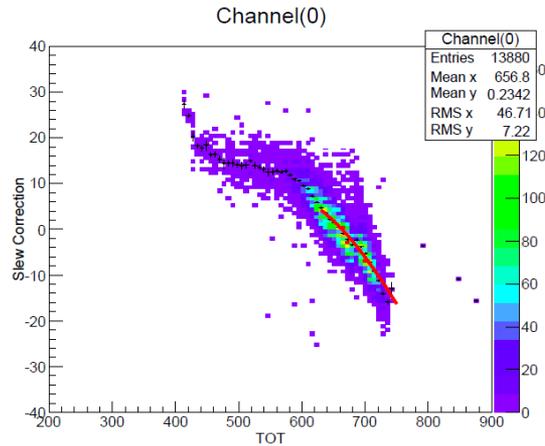
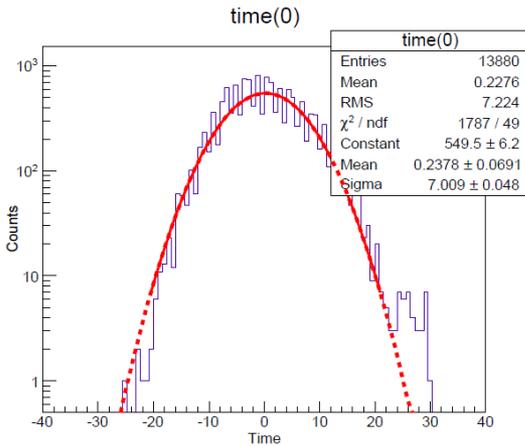
S11 :  $5 \times 5 \text{ mm}^2$

S1, S2, S3, S4 :  $2 \times 2 \text{ cm}^2$



# Time resolution

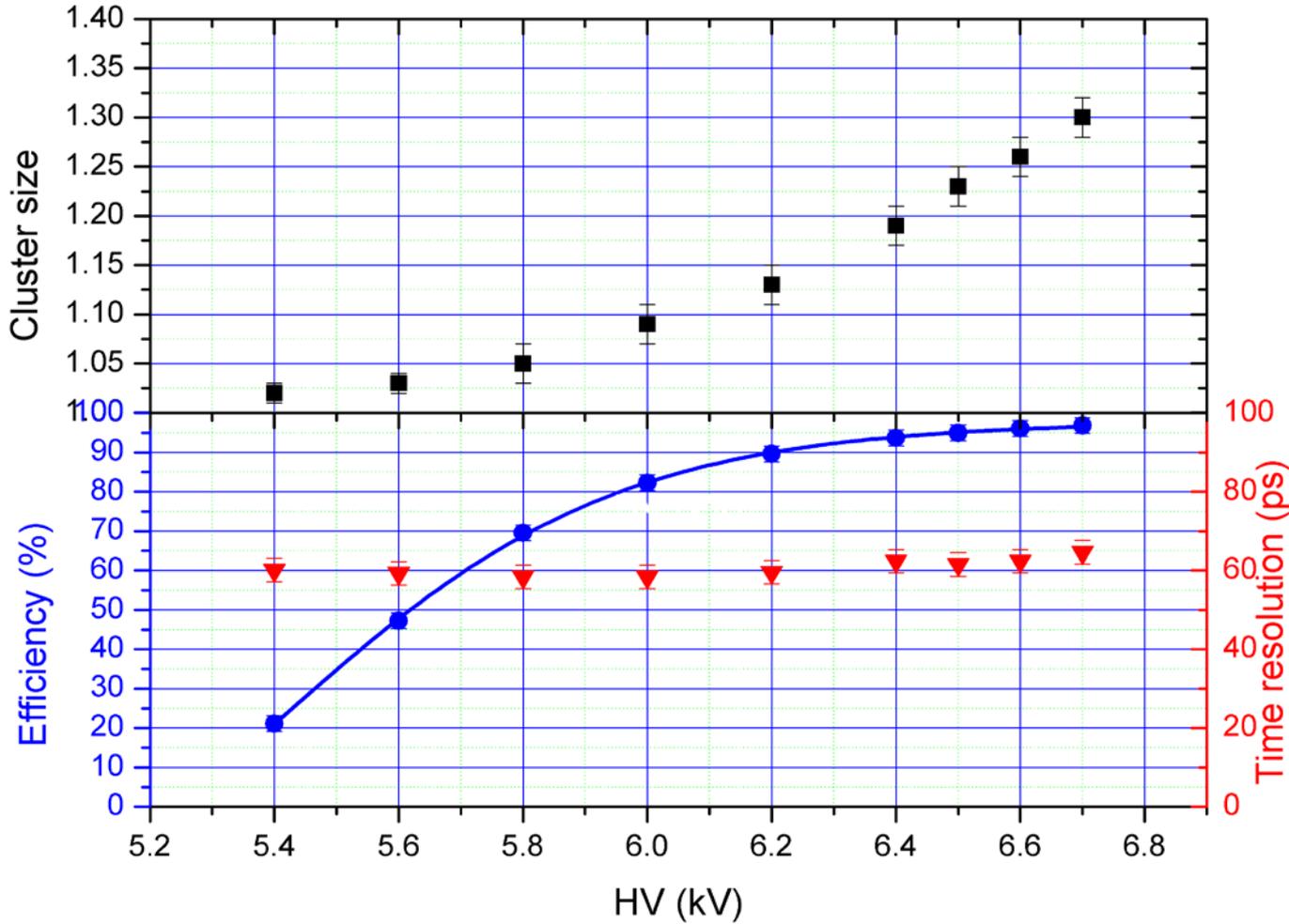
## Time resolution @ HV = ± 6 kV



- ✓ Walk correction
- ✓ Deviation of time can be corrected from 7.00 to 2.76.
- ✓ Resolution of the start time (RF) is **35 ps.**
- ✓ Every channel is 25 ps.

$$\sigma(T_{MRPC}) = \sqrt{(2.76 \times 25)^2 - 35^2} = 59.5 \text{ ps}$$

# HV scan

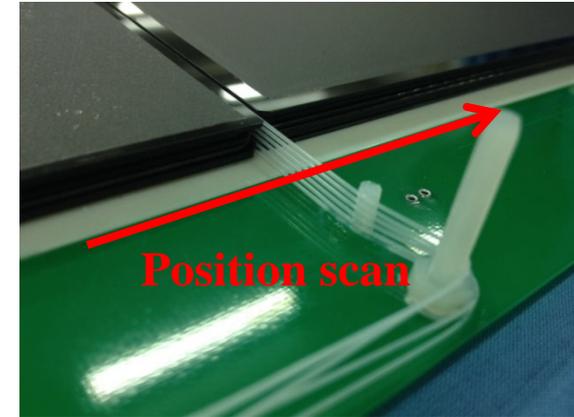
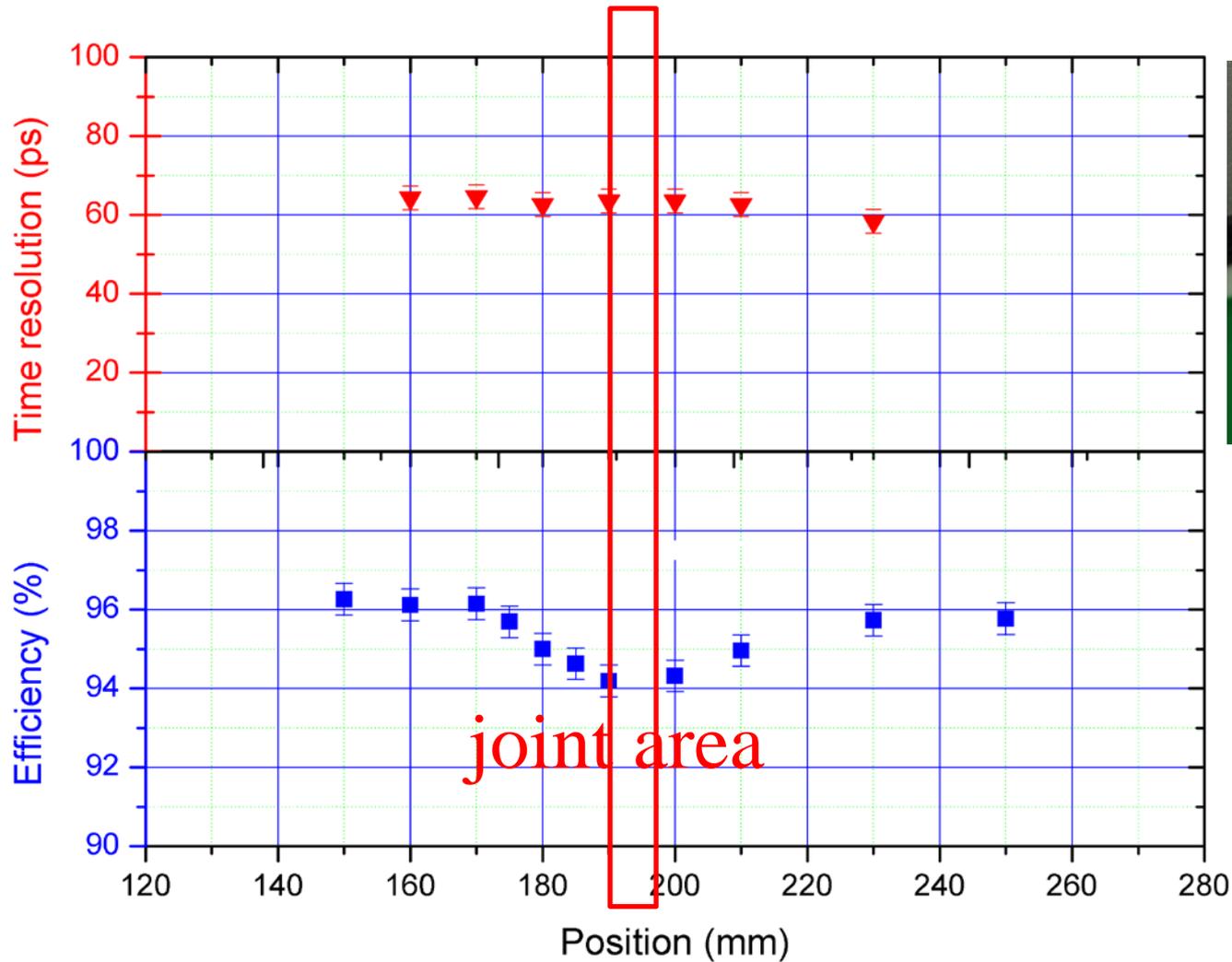


Small cluster size

Efficiency > 96%

Time resolution ~60ps

# Position scan

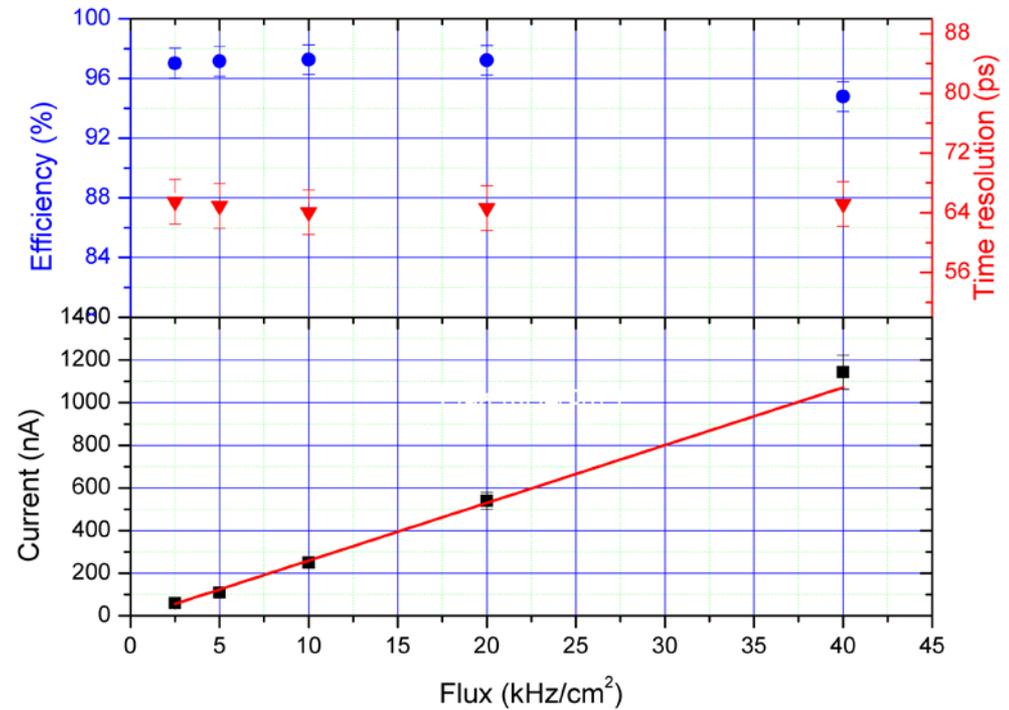
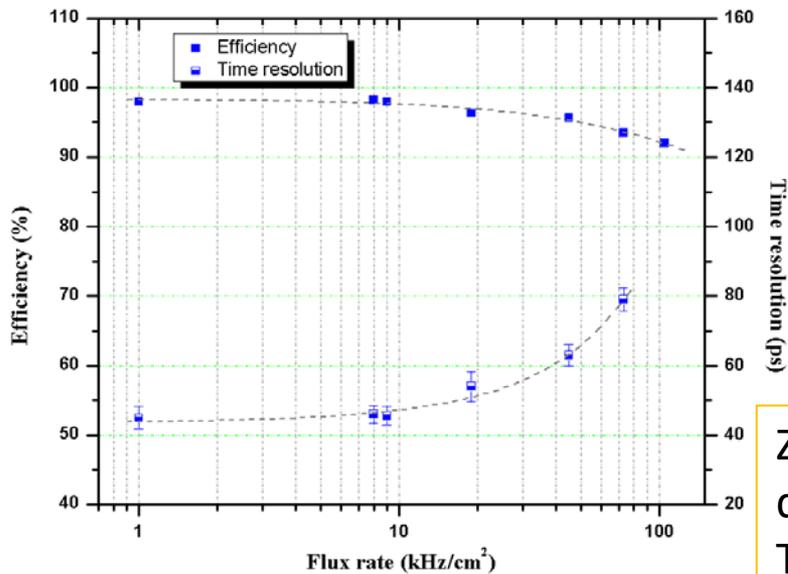


Efficiency loss  
in the gap area:  
~ 2%

# Rate scan

Efficiency  $\sim 95\%$  at  $40 \text{ kHz/cm}^2$

The linear relationship between current and flux rate



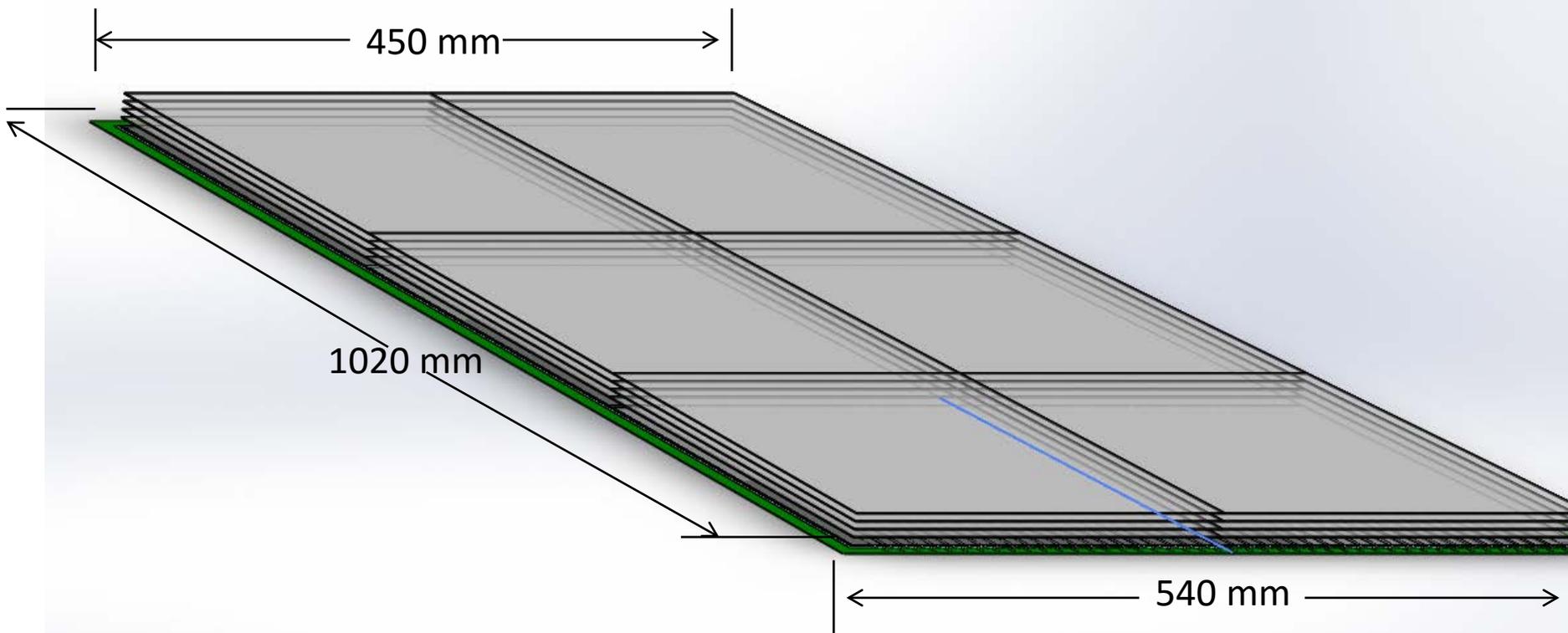
70k Hz/cm<sup>2</sup>, achievable

Zhu W P, Wang Y, Feng S Q, et al. A real-size MRPC developed for CBM-TOF[J]. Science China Technological Sciences, 2013, 56(11): 2821-2826.

# Summary

- Two kinds of large area mosaic MRPC were developed. Simulation proves that the influence of 1mm glue is only 0.5% of the detector and the lowest efficiency point in the detector can still reach 93%.
- Cosmic and Beam test of gluing MRPC shows that it has efficiency higher than 94% and 97%, time resolution around 73 ps. But the noise is too big.
- Mosaic MRPC uses fishing line to separate two glasses and achieve efficiency higher than 96%, time resolution around 60 ps in beam test.
- Fishing line block is a good way to develop large area high rate MRPC with small pieces of low resistive glasses.

# Next to do



Big trapezoidal high rate MRPC will be developed, and test at GIF++.

# Thank you for your attention