Performance of a large-area Mosaic MRPC

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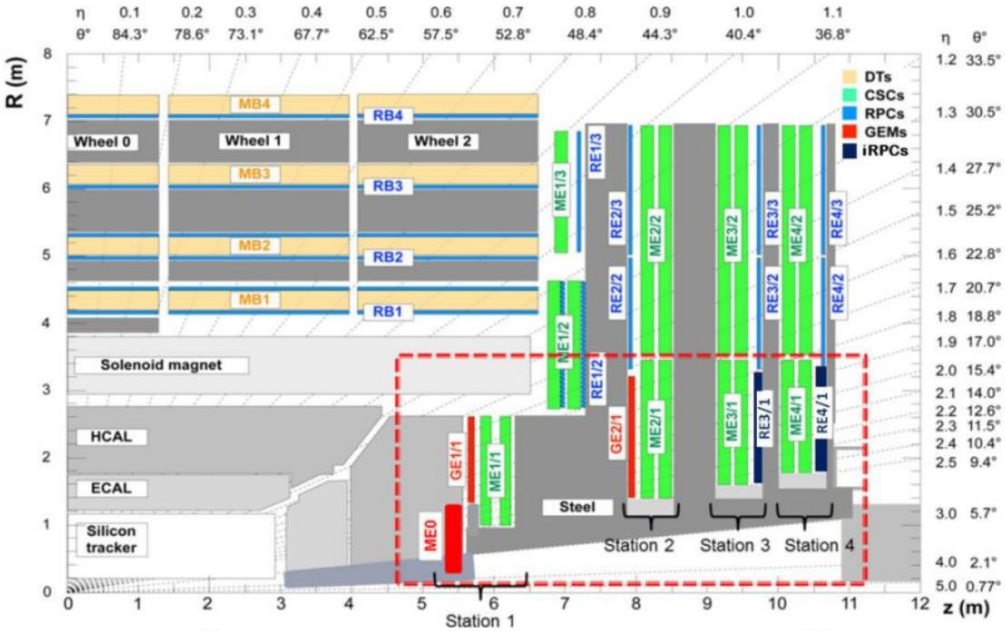
Outline

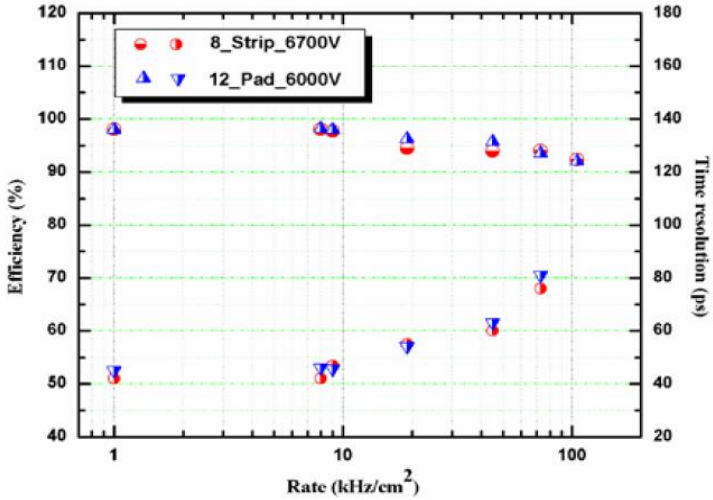
- Introduction of real-size mosaic MRPC
- 904 cosmic test
- HZDR beamtest
  - Beamtest preparation and setup
  - Preliminary result
- GIF++ beamtest
- Summary

Introduction of the mosaic MRPC



The planned HL operation during the LHC phase- Ⅱ :

- Larger instantaneous luminosity up to $5 \times 10^{34} cm^{-2} s^{-1}$
- Integrated luminosity up to 3000 fb-1
- Rate requirement :2 kHz/cm2

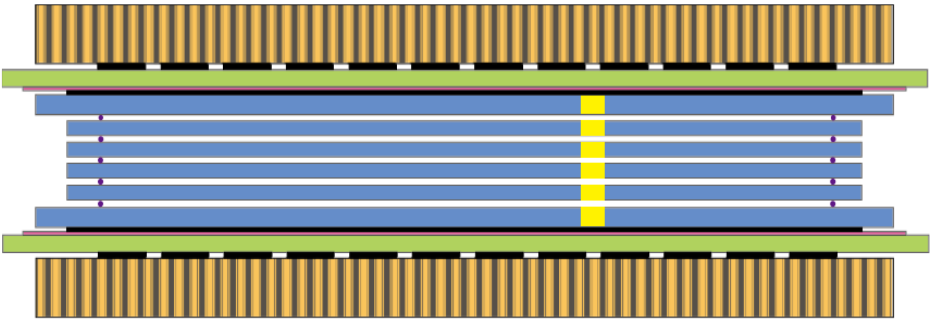


High rate MRPC based on low resistive glass is best candidate for the upgrade of endcap muon system.

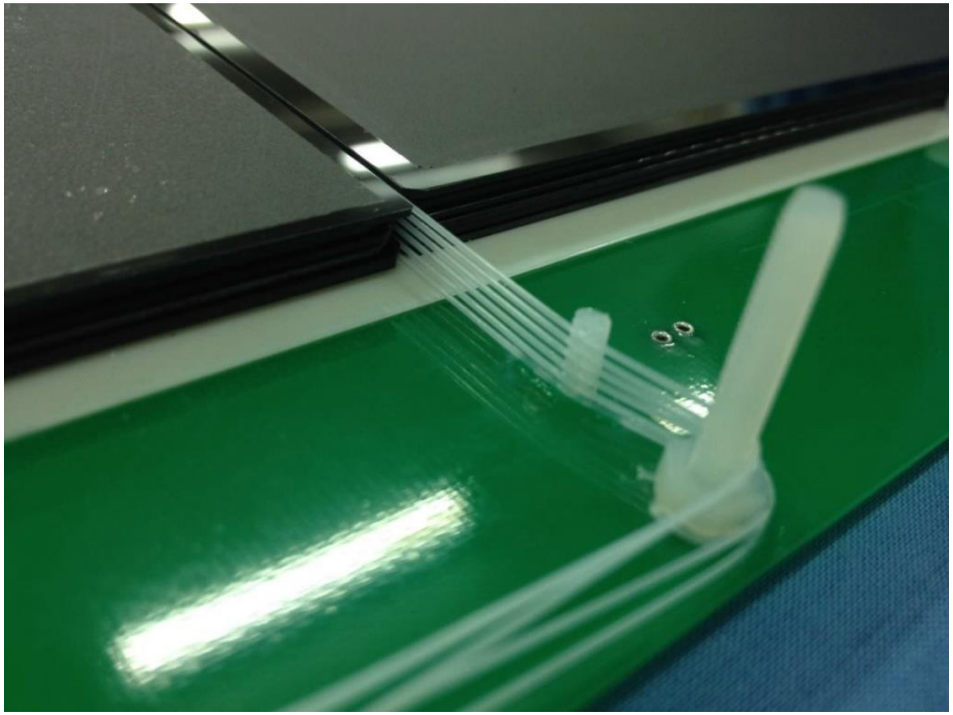
- **High rate capability >70kHz/cm2**
- **Time resolution<100ps, eliminate most of background**
- **Limitation: glass size** $33\ cm \times 28\ cm$
- **Solution: glass mosaic**

Introduction of the mosaic MRPC

Mosaic design 1 : glue glass

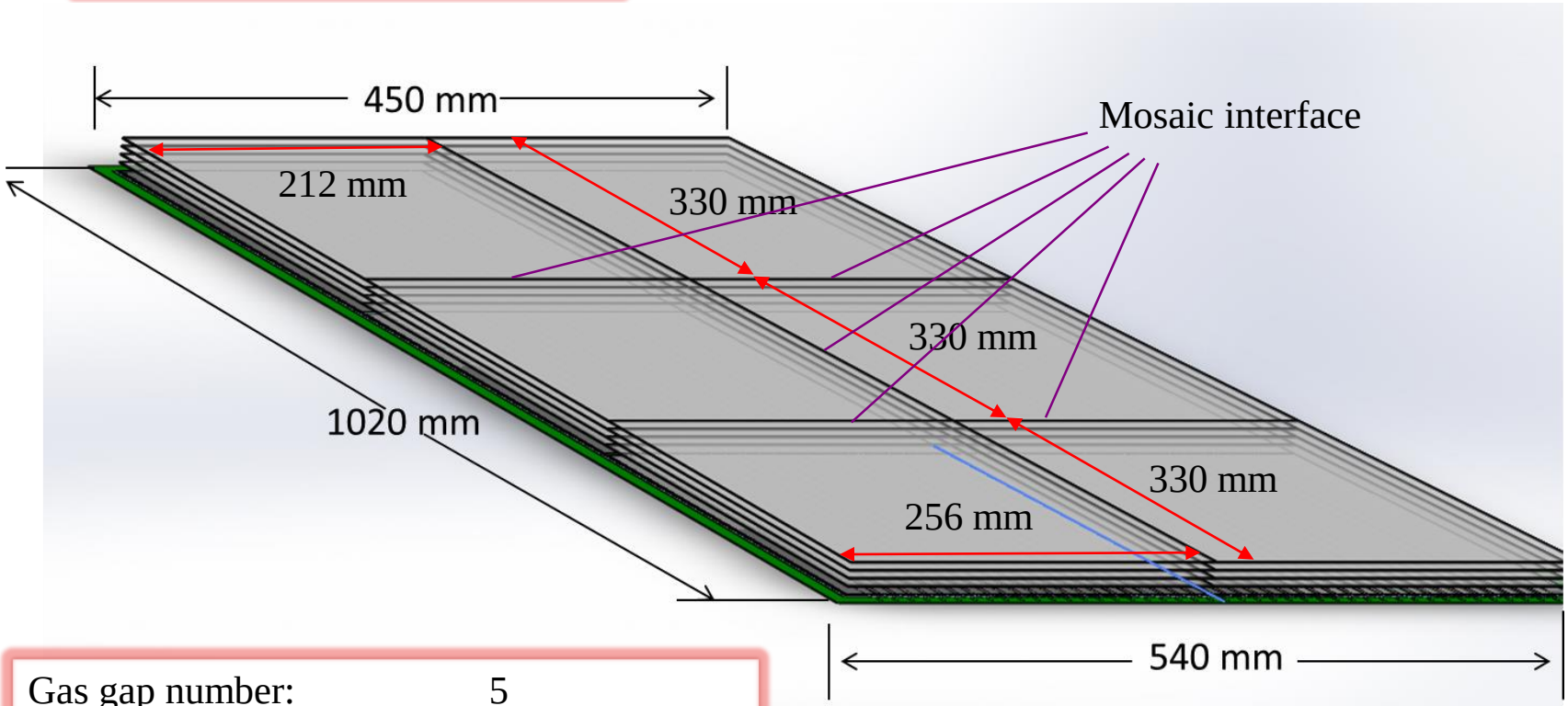


Mosaic design 2 : block by fishing line



Introduction of the mosaic MRPC

Real size mosaic MRPC.



Gas gap number:	5
Gas gap width:	250 μm
Glass thickness:	0.7 mm
Glass bulk resistivity:	~ 10^{10} Ωcm
Mosaic interface:	glass directly mosaic together

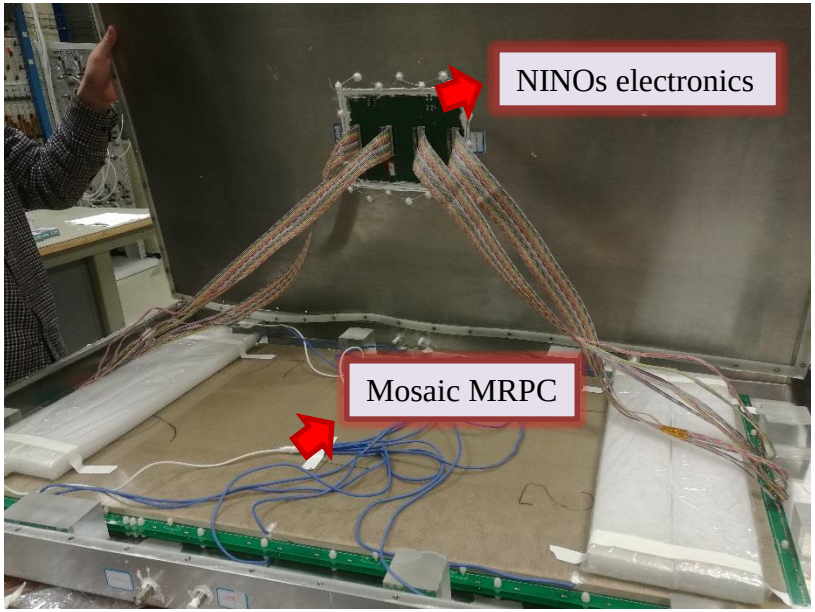
Strip number:	44
Strip shape:	trapezoidal (6 mm/8 mm)
Strip interval:	3 mm
Strip length:	1 m

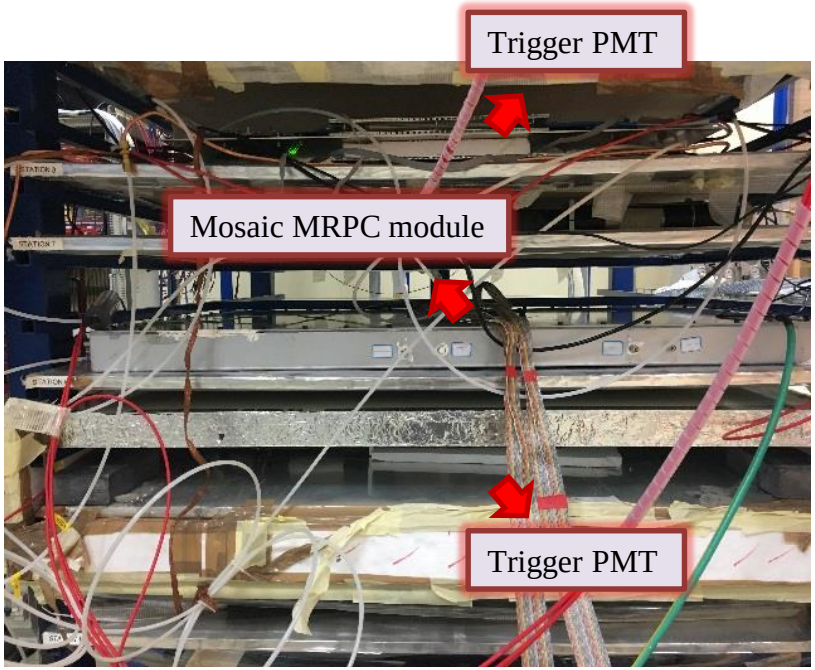
Cosmic test at CERN 904

Cosmic ray test at CERN in Feb, 2017:
Gas component: **90% $C_2H_2F_4$ + 5% i-C_4H_{10} + 5% SF_6.**

Mosaic MRPC in gas box.

Test module in cosmic setup.

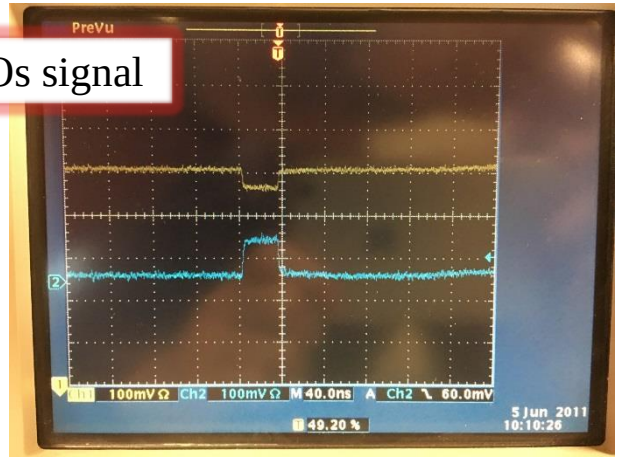


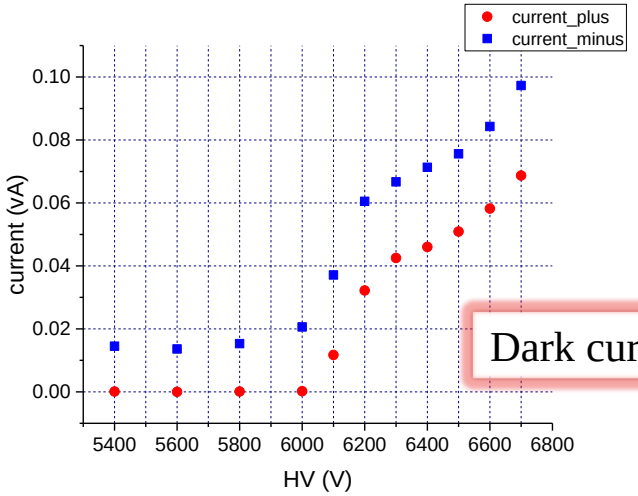


Cosmic test at CERN 904

Cosmic ray test at CERN in Feb, 2017:
Scan000086: 5000 trigger events.

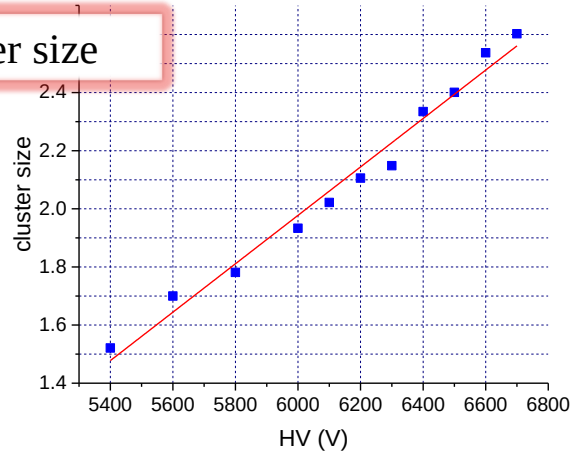
NINOs signal

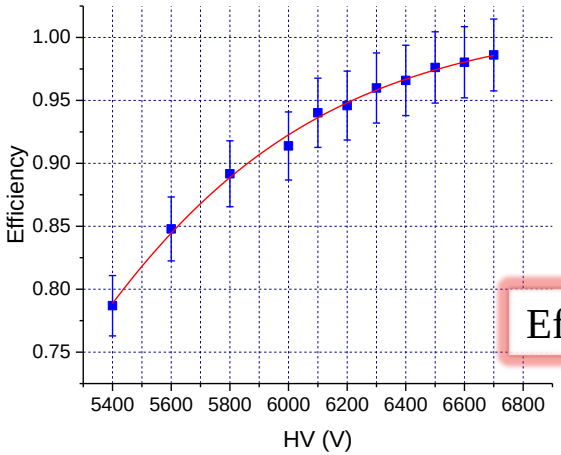




Dark current

Cluster size

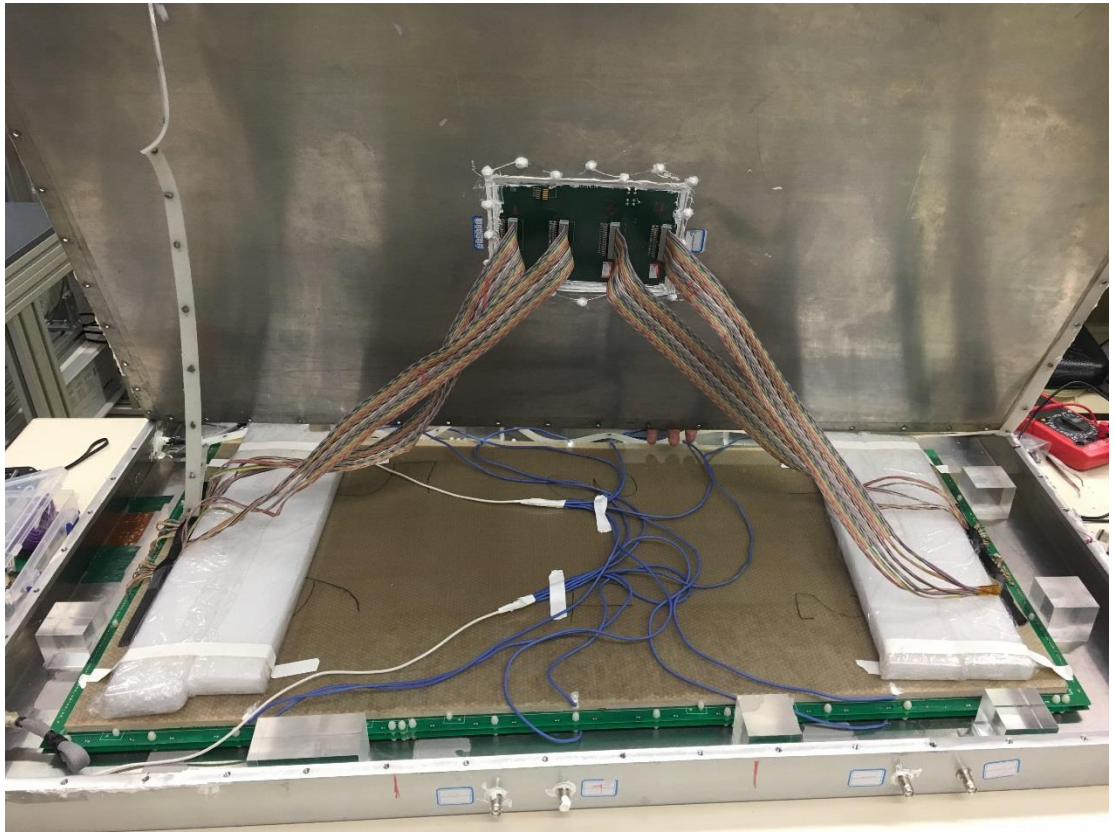




Efficiency

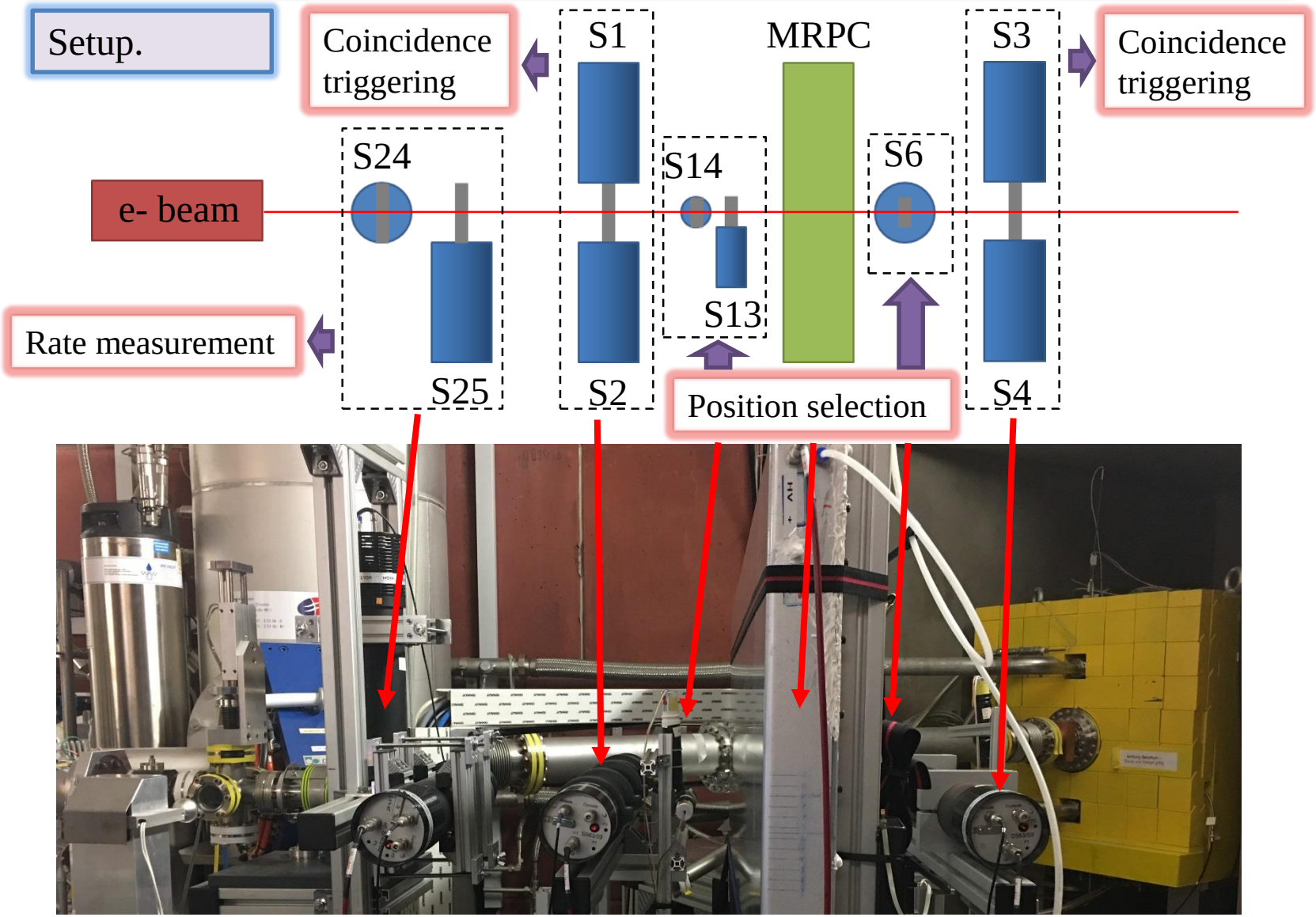
HZDR beamtest: Preparation

Maxime and xiaolong brought the **Mosaic MRPC to HZDR** by car on March 24th.



Gas box was again opened to switch the Jupiter HV connector to SHV connector.
Gas was flushed with a component: **90% $C_2H_2F_4$ + 5% i-C_4H_{10} + 5% SF_6**.

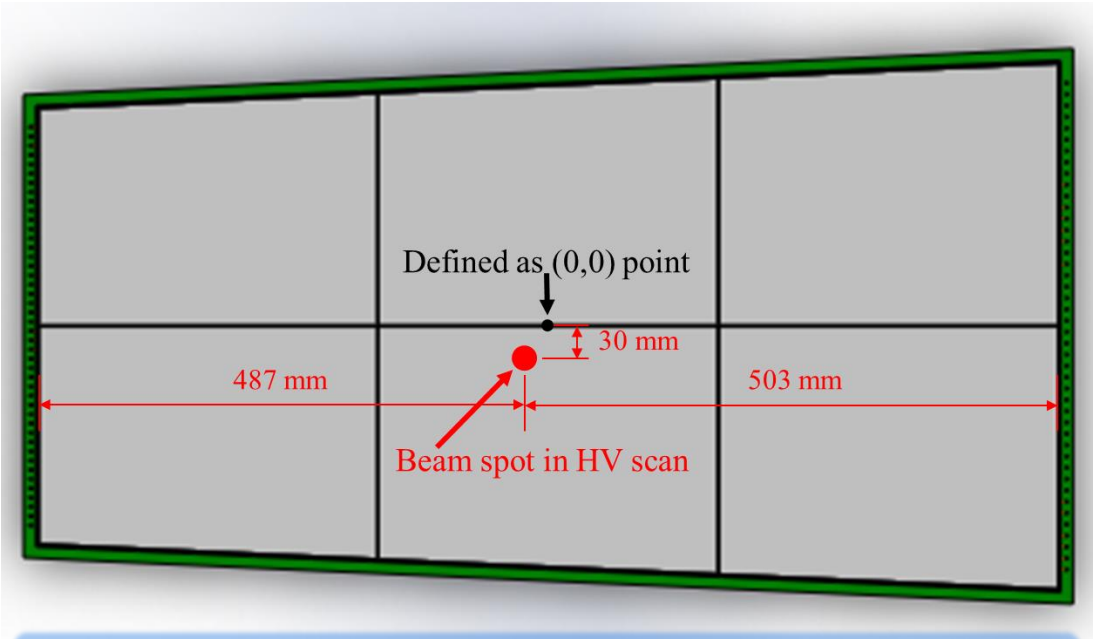
HZDR beamtest: Setup

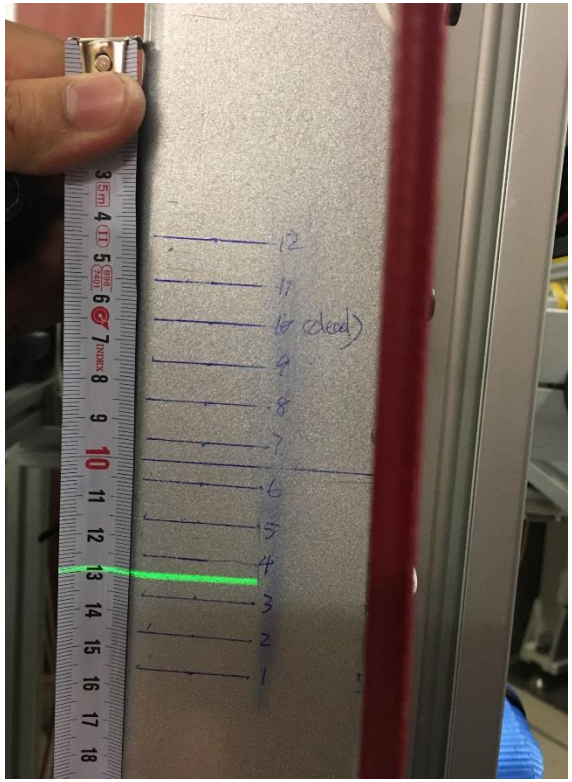


HZDR HV Scan: Setup

Run005 ~ Run021: HV: ±5400 V ~ ±6700 V; Rate: 11 kHz/cm^2.
Beam spot position: Horizontal – center; Vertical: between 3rd and 4th strip.

Define the horizontal center on the mosaic interface as zero point, beam spot at (-8, -30).

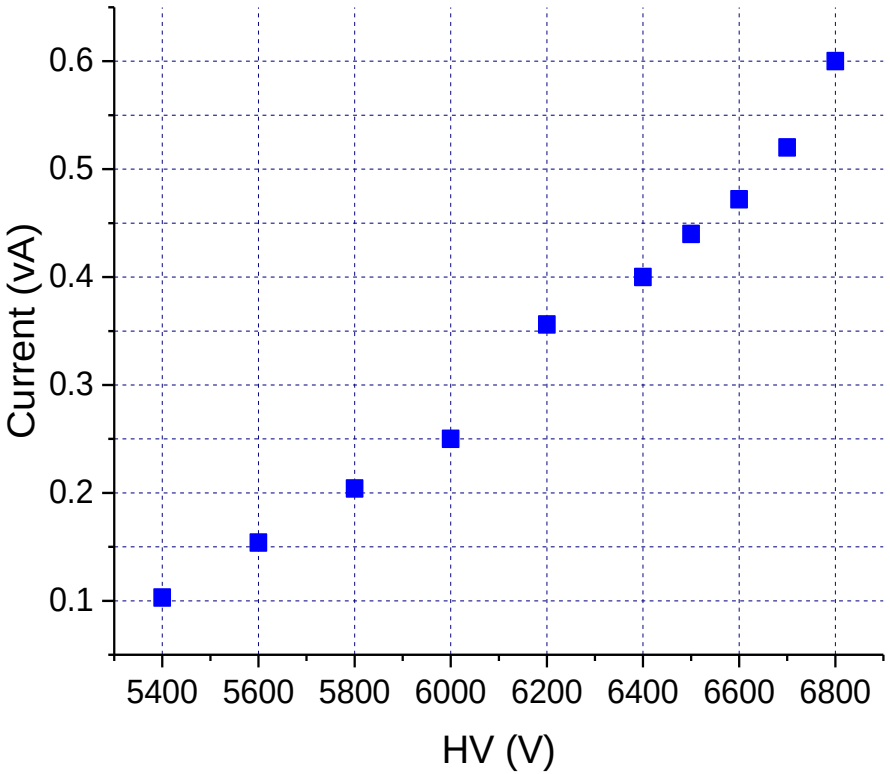


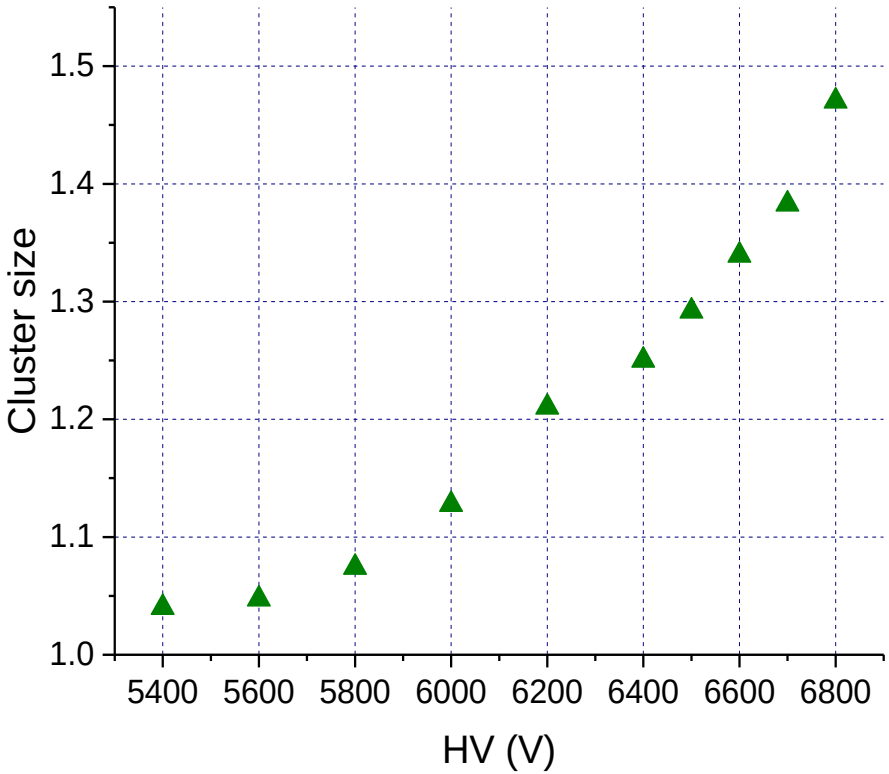


PMT Trigger (S1&S2&S3&S4) dimension: 20 × 20 mm^2.
Beam spot dimension: 100 mm in diameter.

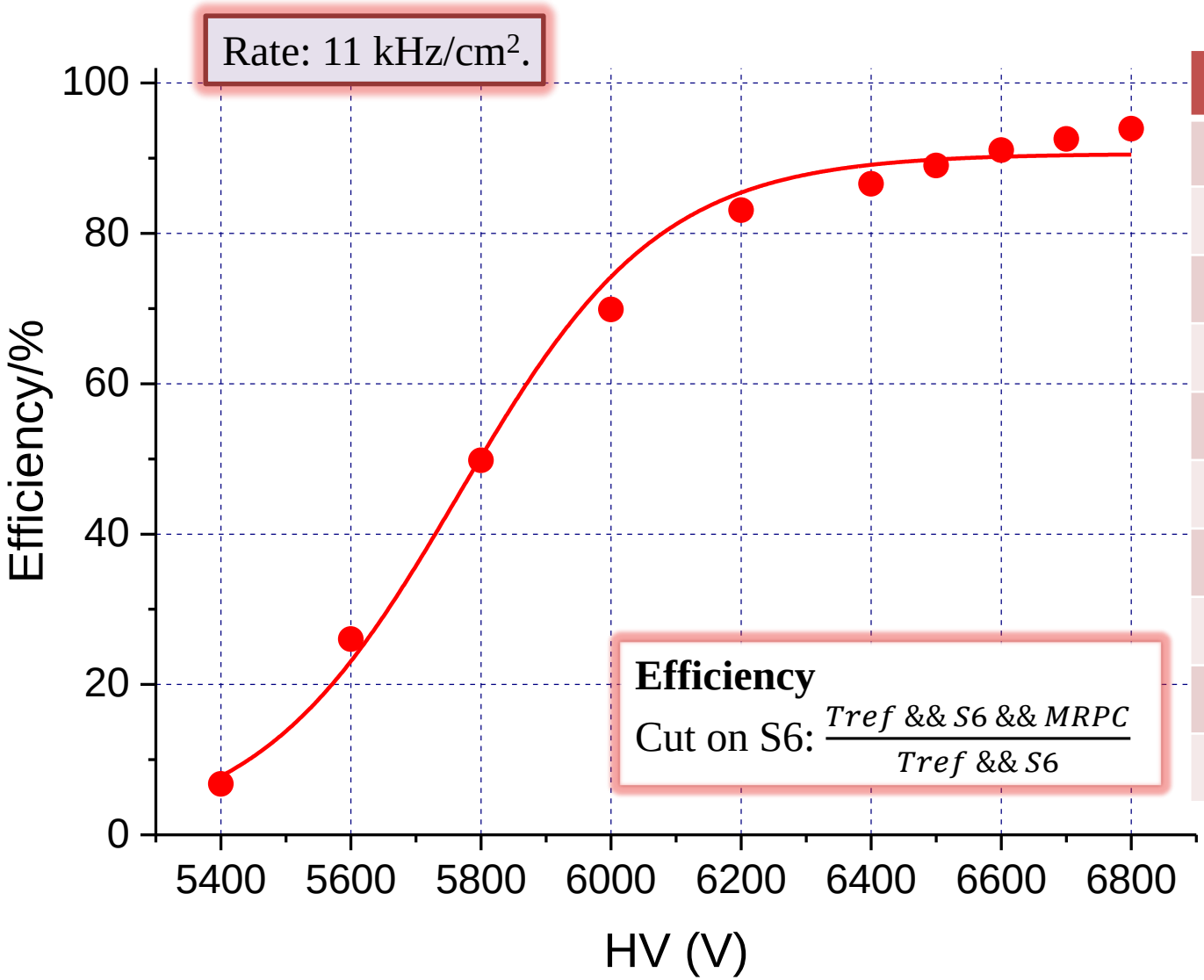
HZDR HV Scan: Current and Cluster Size

Rate: 11 kHz/cm^2



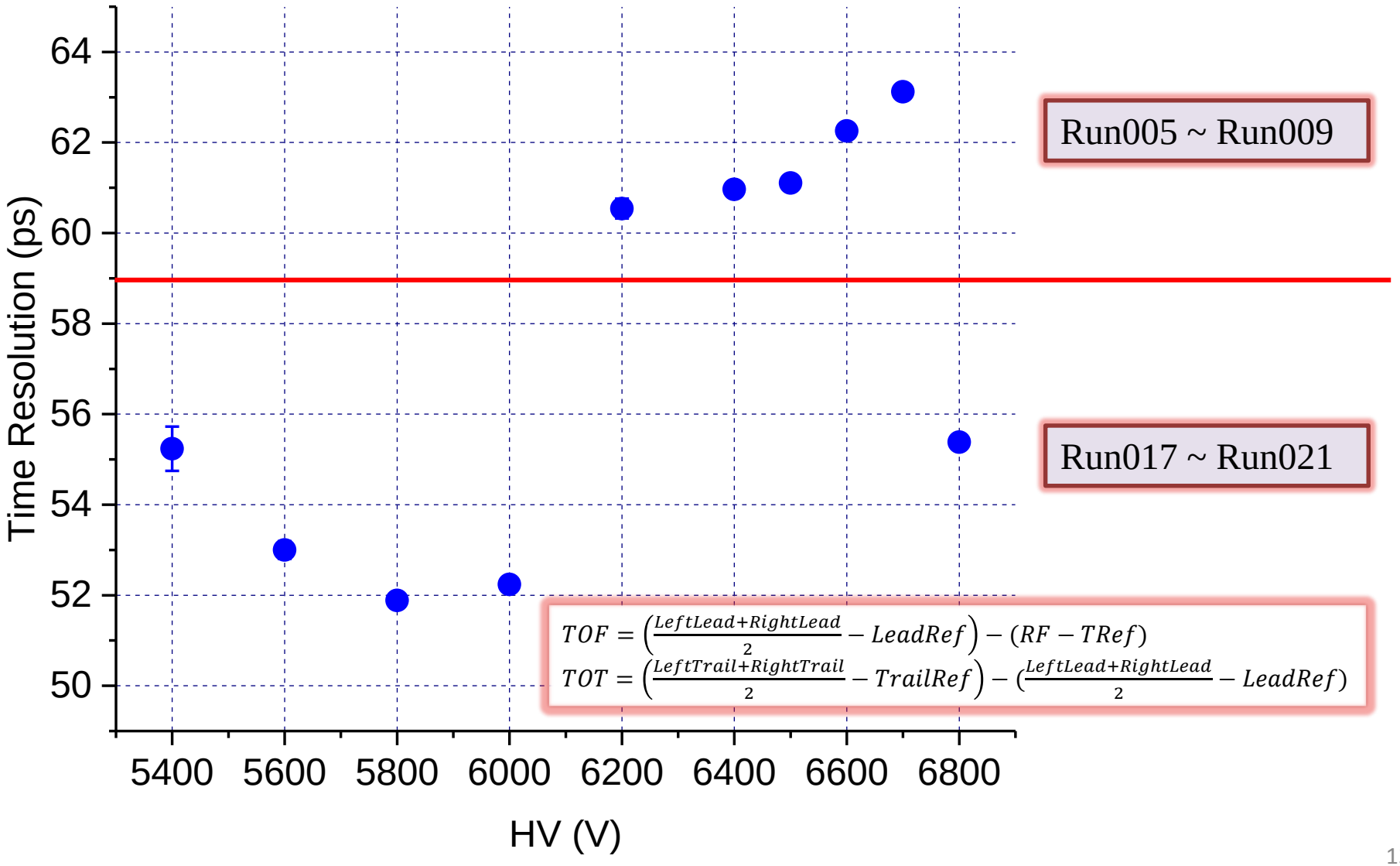


HZDR HV Scan: Efficiency



HV/V	Efficiency
±5400	6.7%
±5600	26.0%
±5800	49.8%
±6000	69.9%
±6200	83.1%
±6400	86.6%
±6500	89.0%
±6600	91.1%
±6700	92.6%
±6800	93.9%

HZDR HV Scan: Time Resolution



$$TOF = \left(\frac{LeftLead+RightLead}{2} - LeadRef\right) - (RF - TRef)$$

$$TOT = \left(\frac{LeftTrail+RightTrail}{2} - TrailRef\right) - \left(\frac{LeftLead+RightLead}{2} - LeadRef\right)$$

HZDR Rate Scan

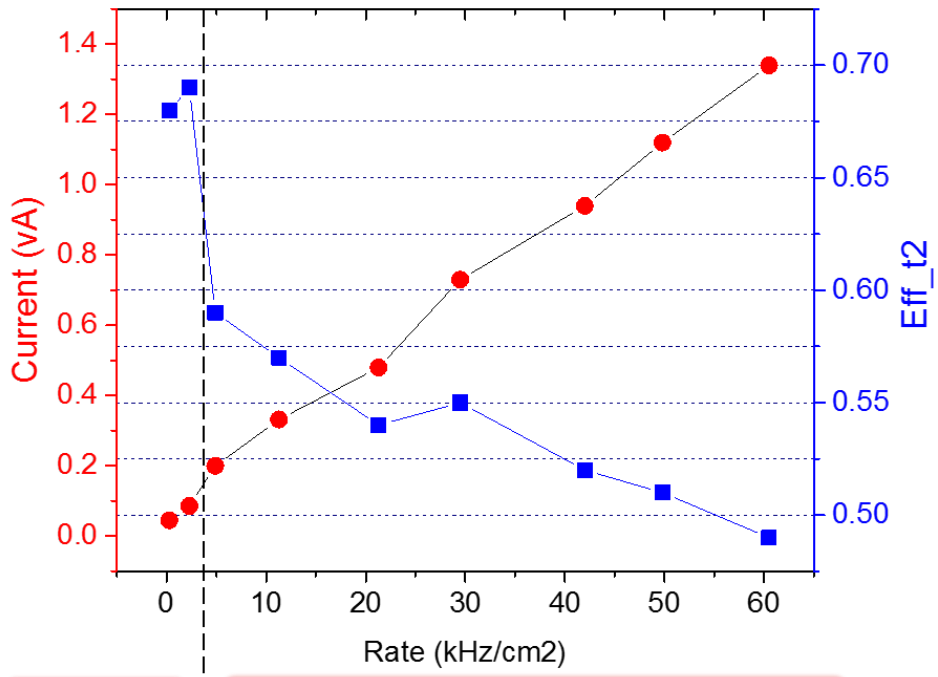
Rate scan plan: at ±7000V

Rate/ kHz/cm²	Eff_t2
0.35	96%
2.3	96%
5	×
10	×
20	×
30	×
40	×
50	×
60	×

Actual rate scan: at ±6000V

Rate/ kHz/cm²	Eff_t2
0.35	68%
2.3	69%
4.9	59%
11.3	57%
21.3	54%
29.5	55%
42	52%
49.8	51%
60.5	49%

Current and efficiency in the rate scan:



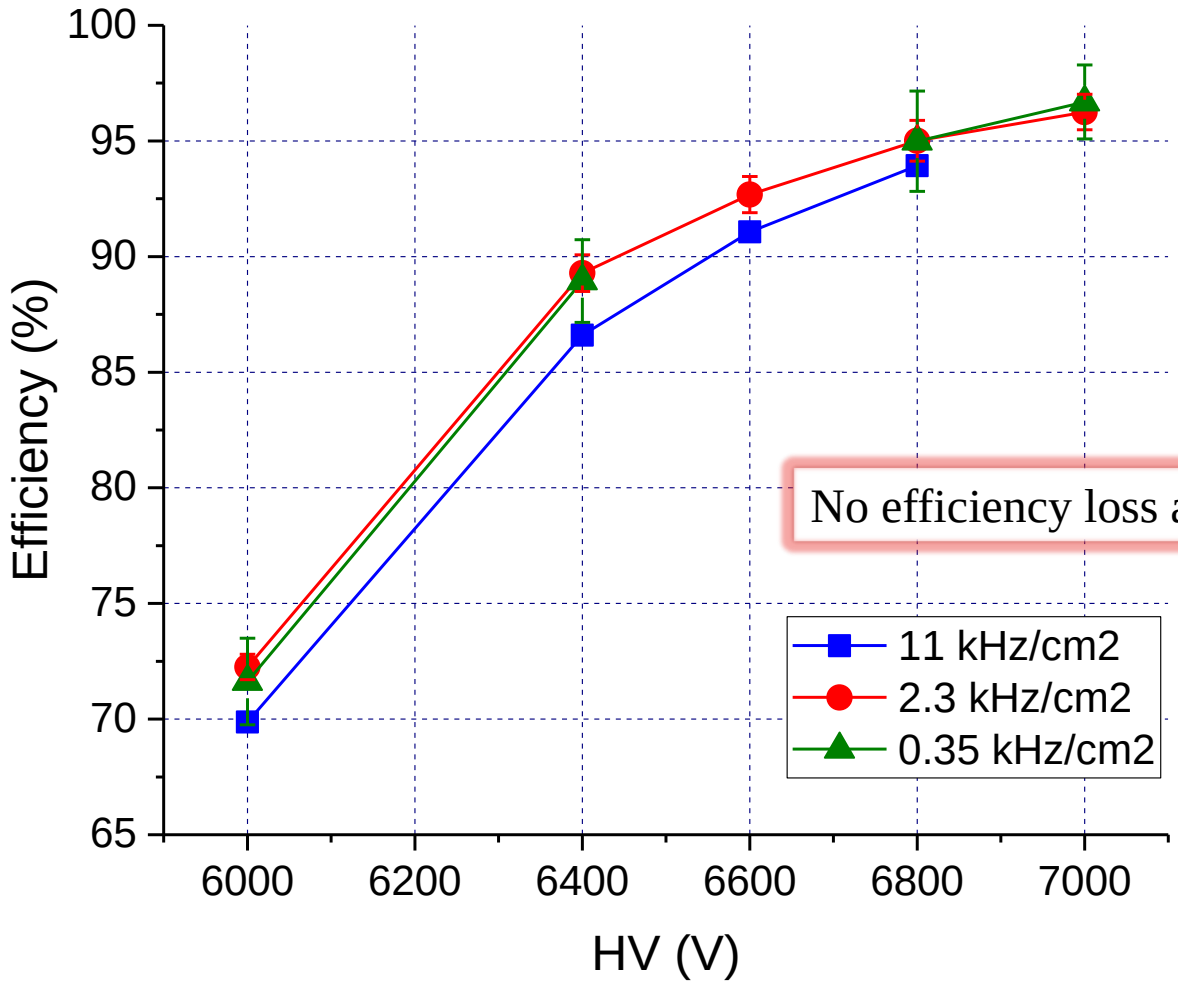
Before

After the MRPC was damaged.

When increasing from 2 kHz/cm² to 5 kHz/cm², rate went directly to 120 kHz/cm². Current went up to 8 μA. After 10 s, rate dropped back to 5 kHz/cm², but **MRPC can't work** anymore.

HZDR Rate Scan: Efficiency

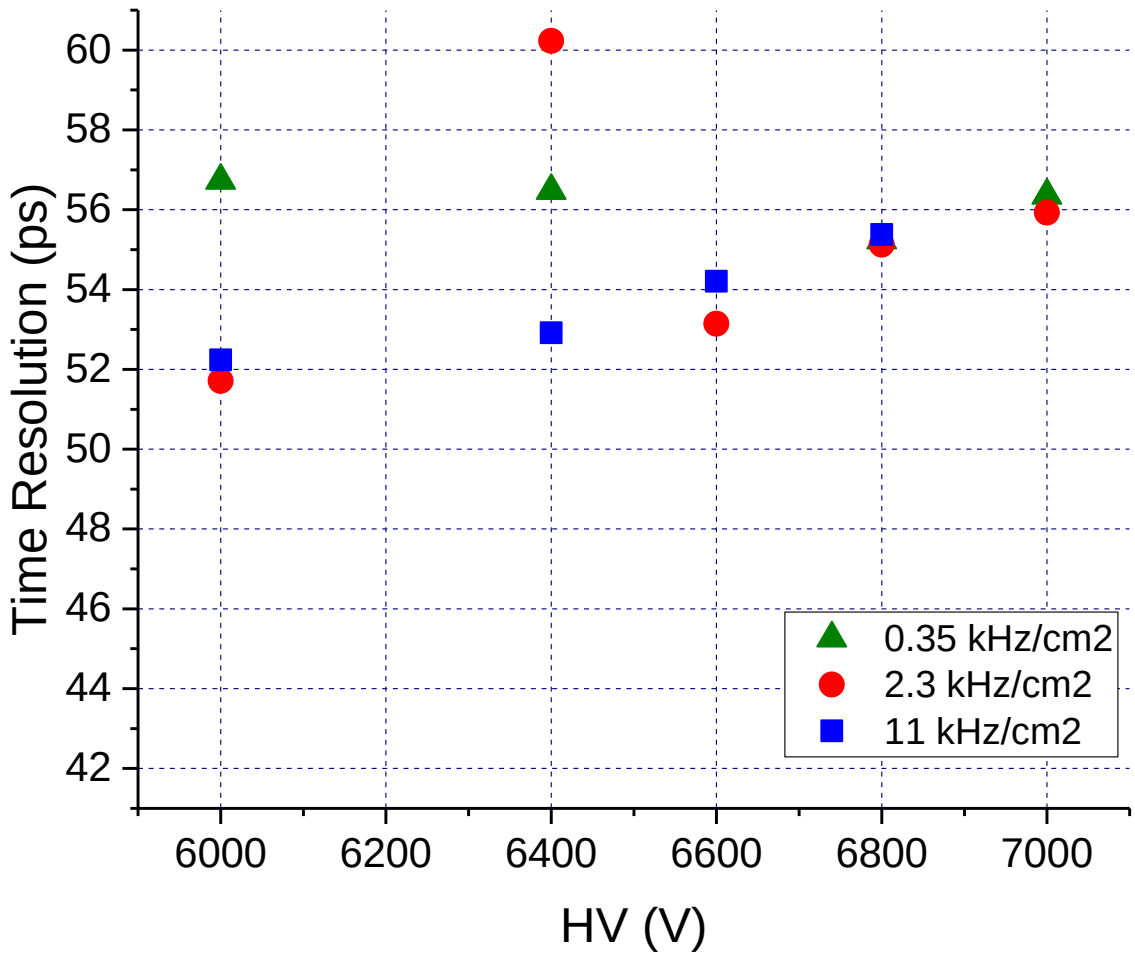
HV scan at different rate of 0.35 kHz/cm^2, 2.3 kHz/cm^2 and 11 kHz/cm^2 before the MRPC was damaged.



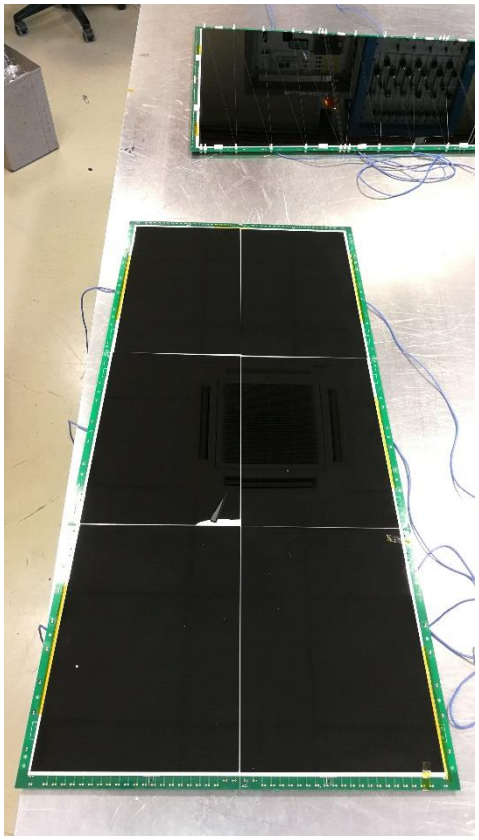
No efficiency loss at 2.3 kHz/cm^2.

HZDR Rate Scan: Time Resolution

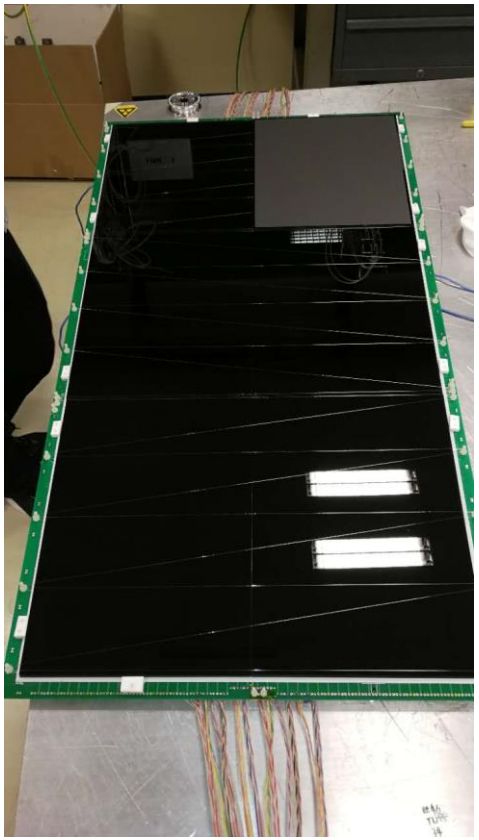
HV scan at different rate of 0.35 kHz/cm^2, 2.3 kHz/cm^2 and 11 kHz/cm^2 before the MRPC was damaged.



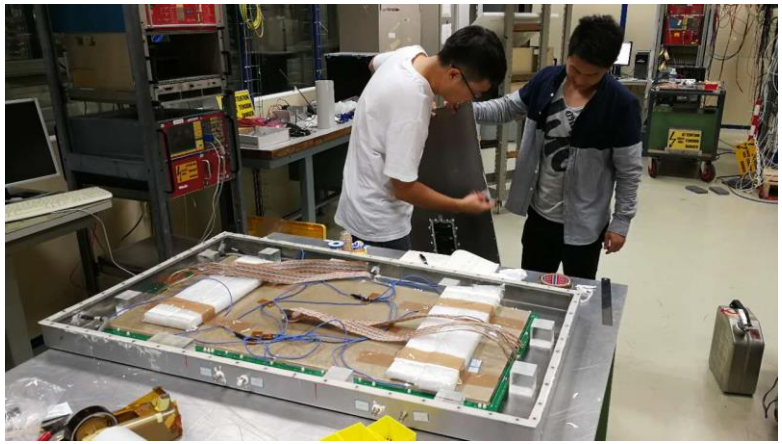
GIF++ beamtest: Preparation



Before repair

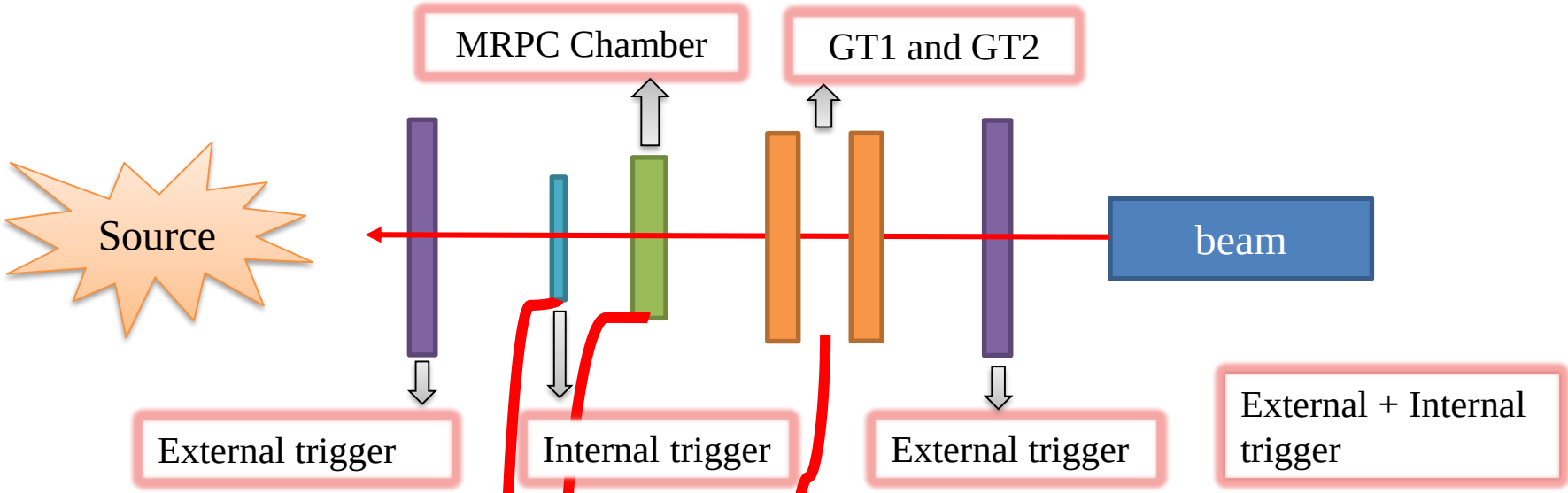


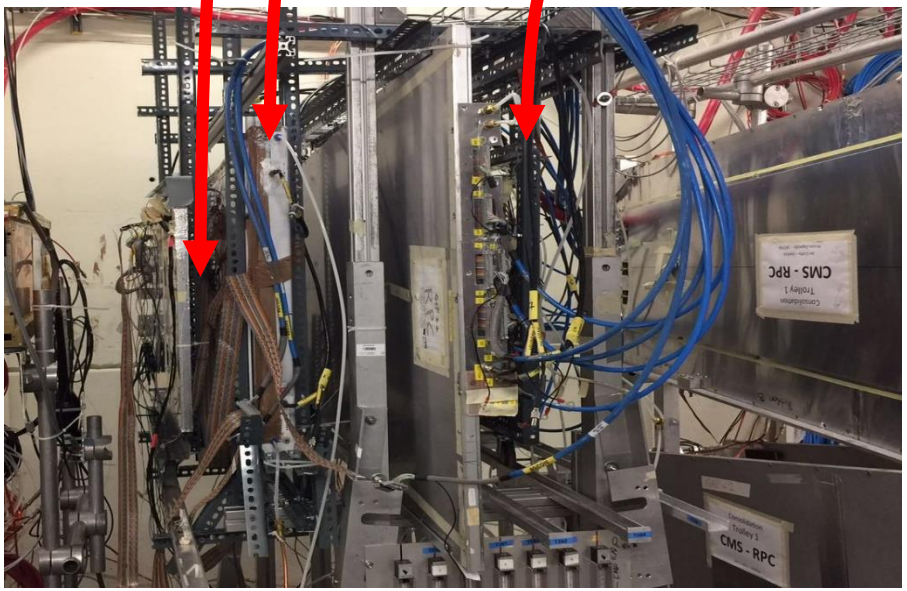
After repair



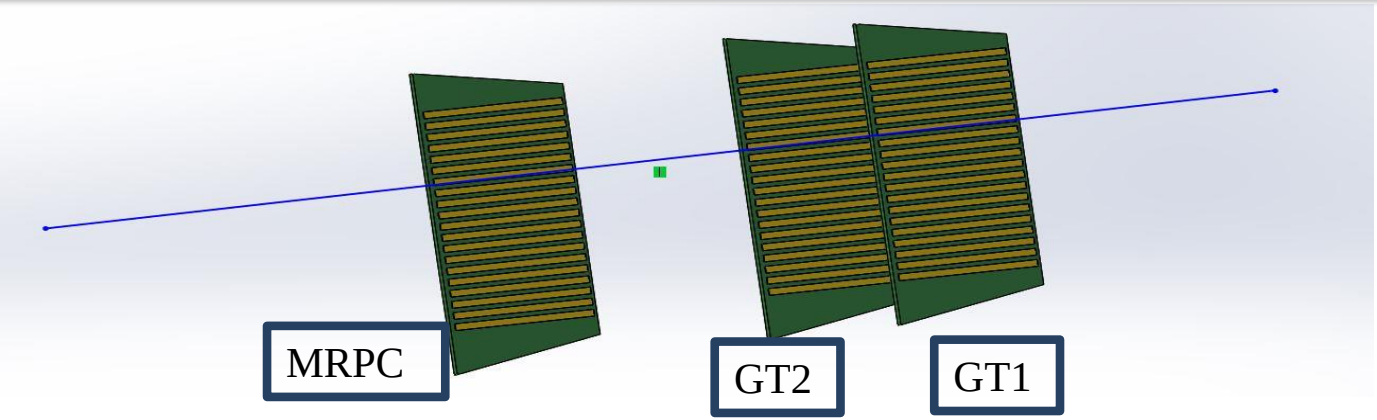
- Chamber has been repaired at CERN in Sep, 2017
- It was flushed with CMS gas: **95.2% $C_2H_2F_4$ + 4.5% i-C_4H_{10} + 0.3% SF_6.**
- Dark current was **0.02 μA** at ±5000 V

GIF++ beamtest: Setup

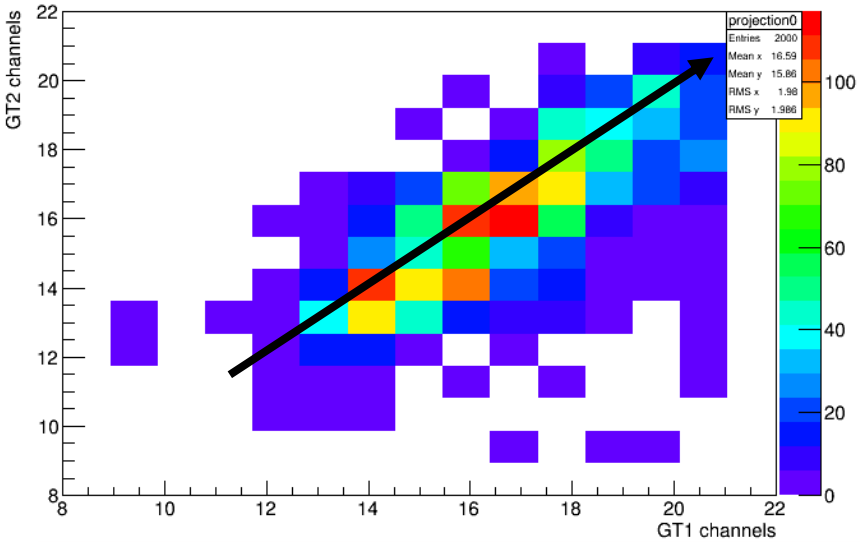




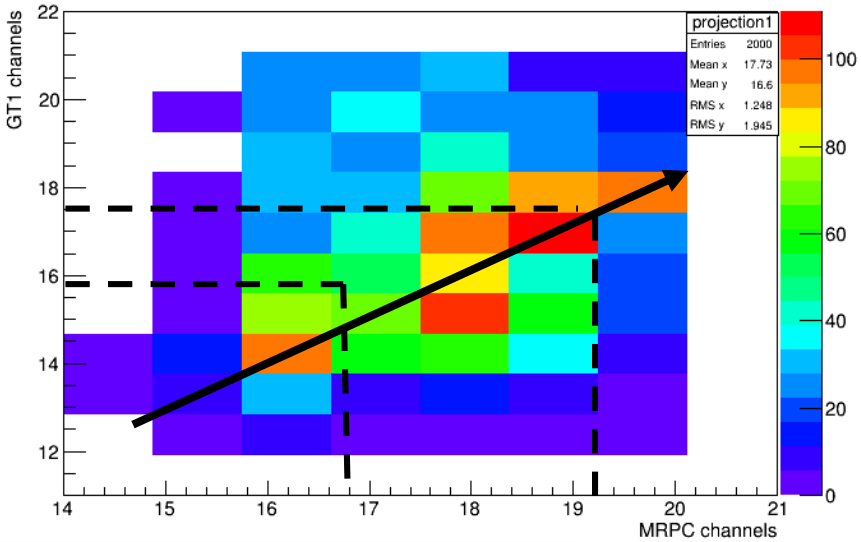
GIF++ beamtest:Tracking Method



Projection of GT1 and GT2

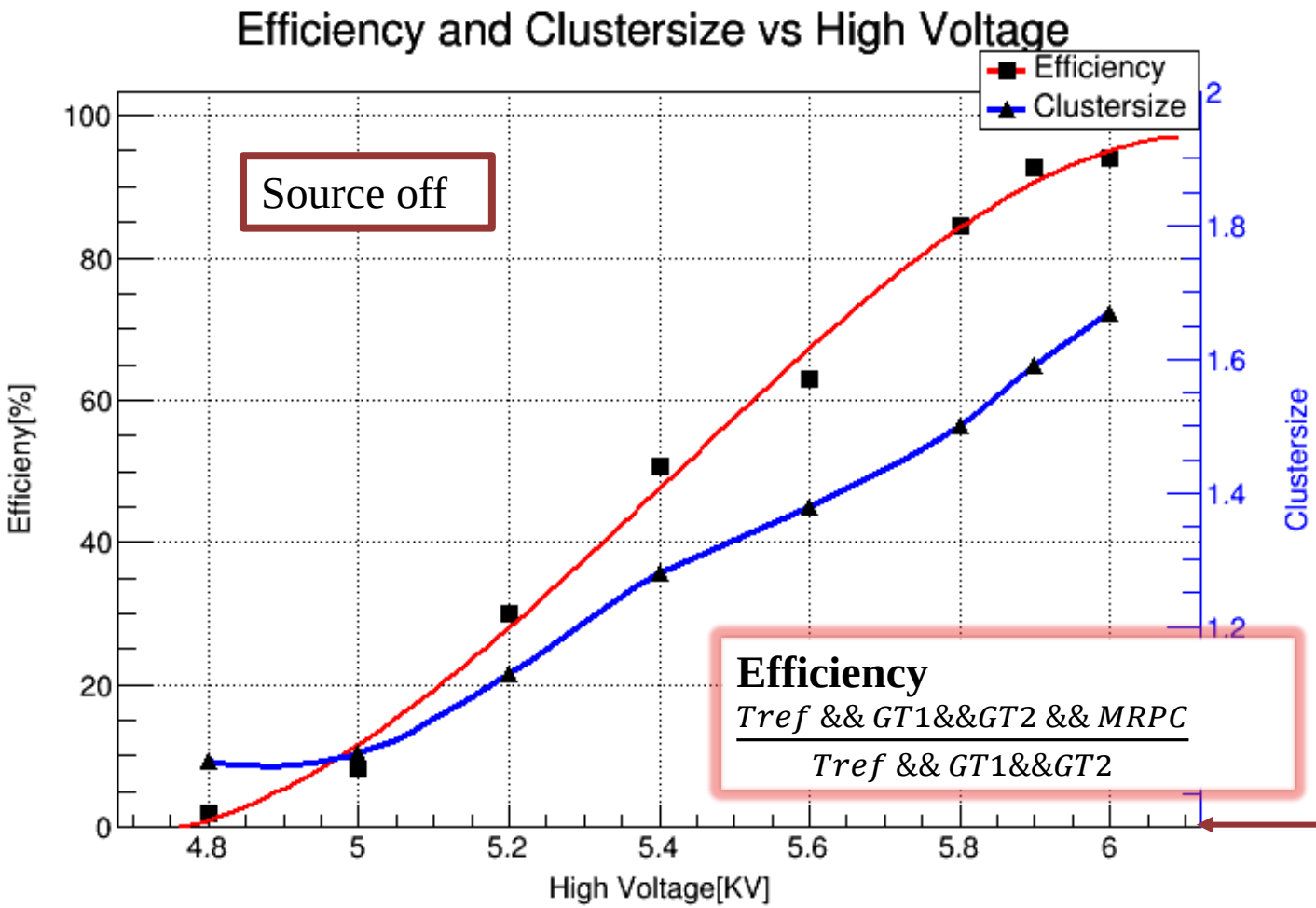


Projection of GT1 and MRPC



- Get the strip projection of GT chambers and MRPC chamber

GIF++ beamtest:HV Scan



Source off

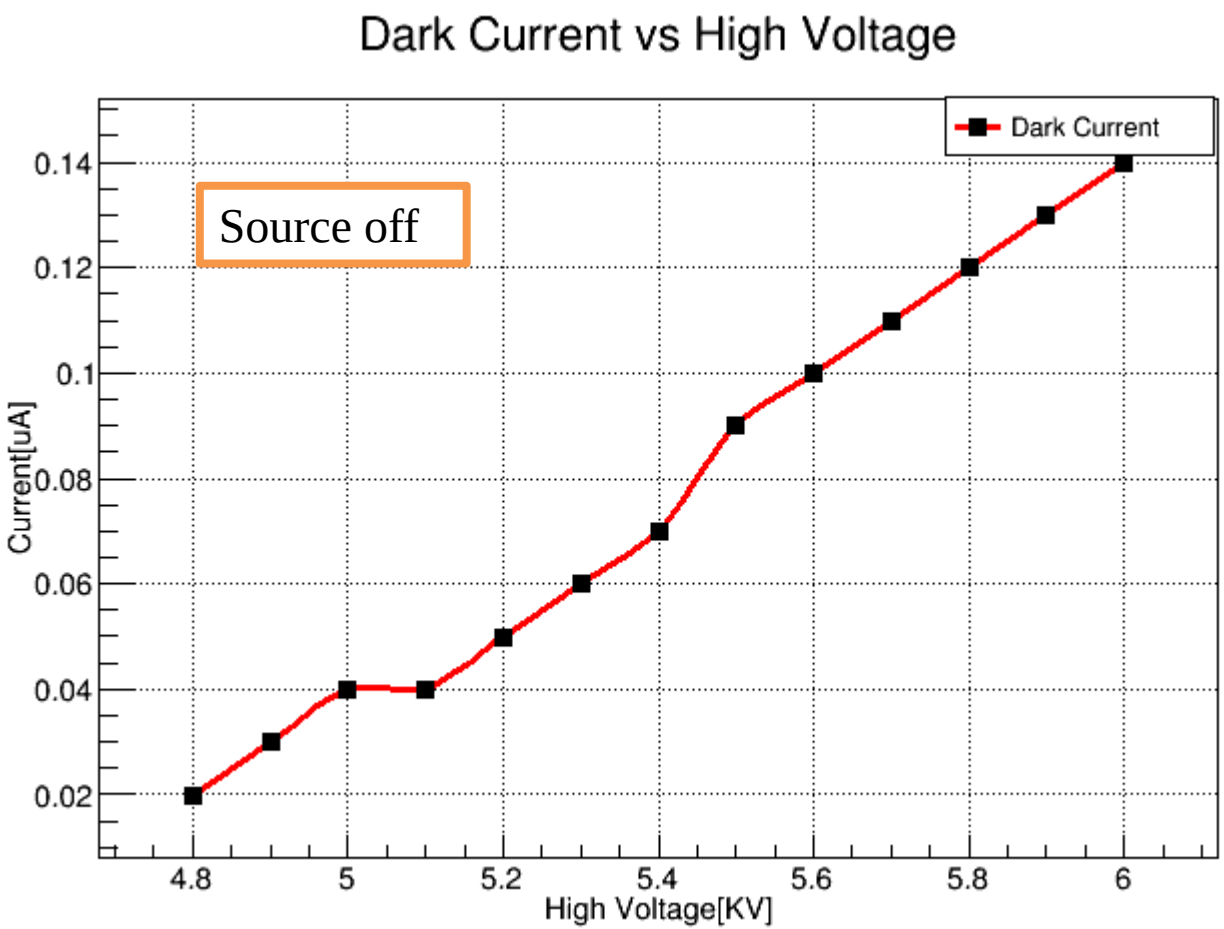
Efficiency

$$\frac{Tref\ \&\&\ GT1\&\&GT2\ \&\&\ MRPC}{Tref\ \&\&\ GT1\&\&GT2}$$

±6800V

There is a big working point shift at different gas mixture!

GIF++ beamtest:HV Scan



GIF++ beamtest:Rate Scan

Rate[kHz/cm^2]	Efficieny[%]
0	94.12
0.29	94.81
0.58	93.41
1.007	95
2.64	94.68
4.64	93.93
10.83	93.75

- There is no efficiency loss along with high rate. Efficiency always reaches about 94% at ± 6000V.

Summary

- Cosmic ray test at CERN
  - Efficiency above 95% is reached at ±6800V.
- 30 MeV electron beam at HZDR at rate of 10kHz/cm^2
  - Efficiency reaches 95% at ±6800V
  - Time resolution around 55ps.
  - Efficiency loss at mosaic interface is about 2%.
- The real size mosaic MRPC can keep good performance with CMS dry gas.
  - Efficiency can reaches about 94% at ± 6000V at rate of 10kHz/cm^2.
  - Working voltage shift.

Thank You!

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- Department of Engineering Physics,
- Tsinghua University, Beijing, China

- Feb 23th, 2018

Backup

Structure and performance of small mosaic MRPC

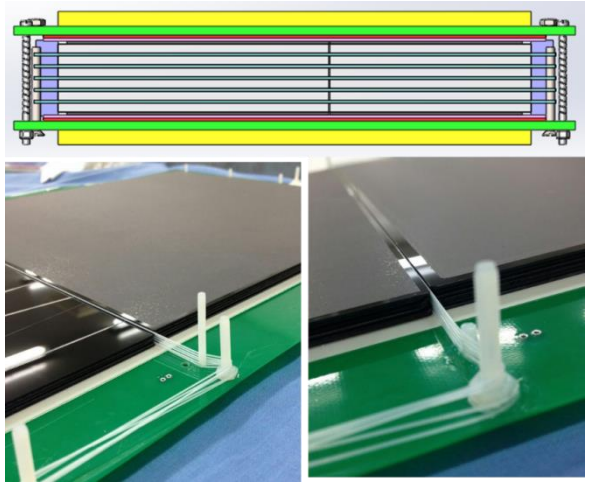


Fig.1 structure of mosaic MRPC

Table 1 Component of mosaic MRPC

MRPC Component	Size (mm)
Honey Comb	255×472×6
PCB	320×540×0.7
Mylar	260×480×0.18
Mosaic Glass	250×470×0.7 & 250×200×0.7
Spacer	0.5
Gap	0.25×5

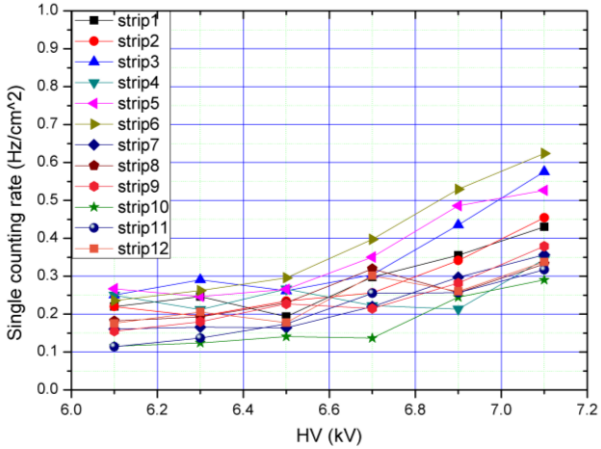


Fig.2 Noise rate

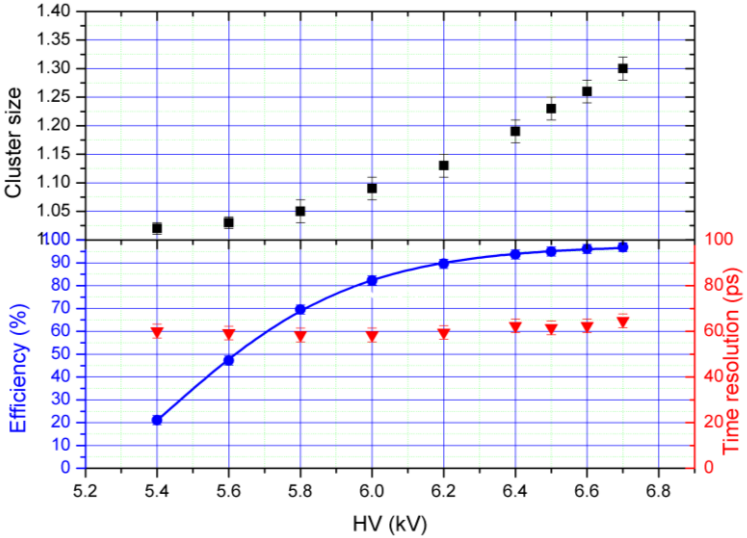


Fig.3 Efficiency, time resolution and cluster size

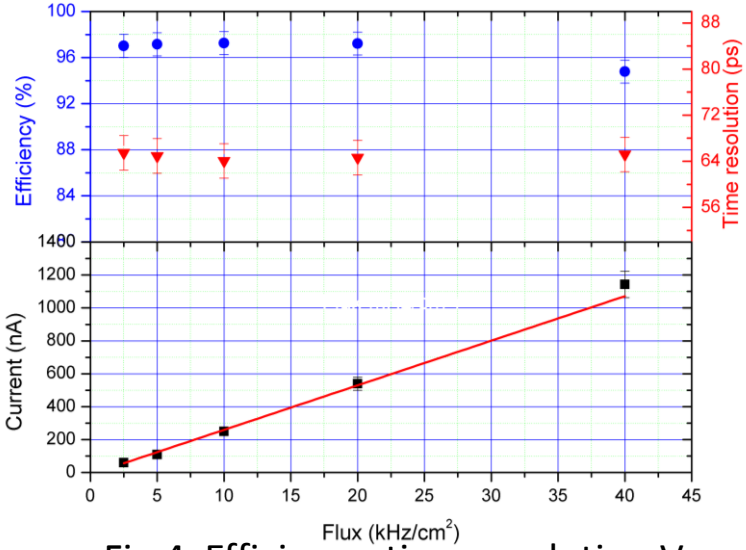
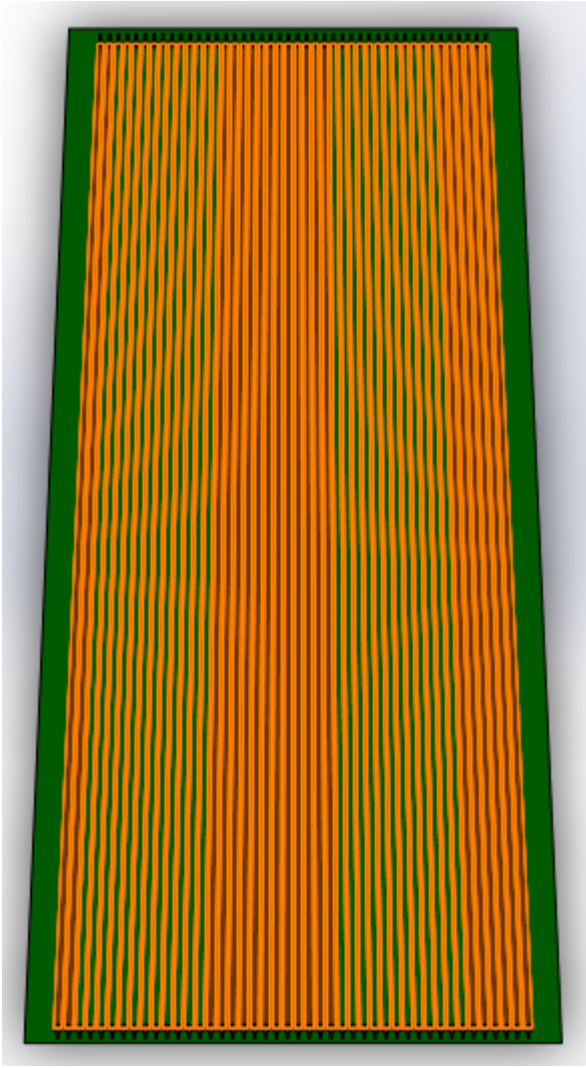


Fig.4 Efficiency, time resolution Vs. rate

Introduction of the mosaic MRPC

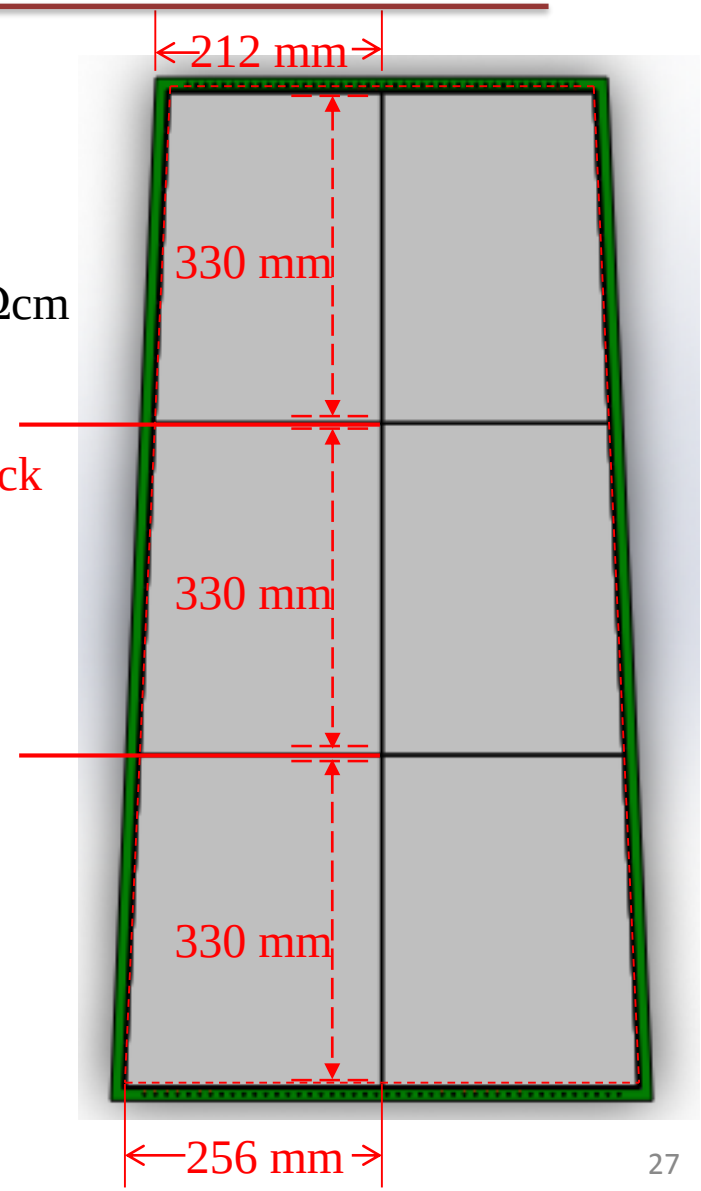


Gap number: 5

Gap width: 250 μm

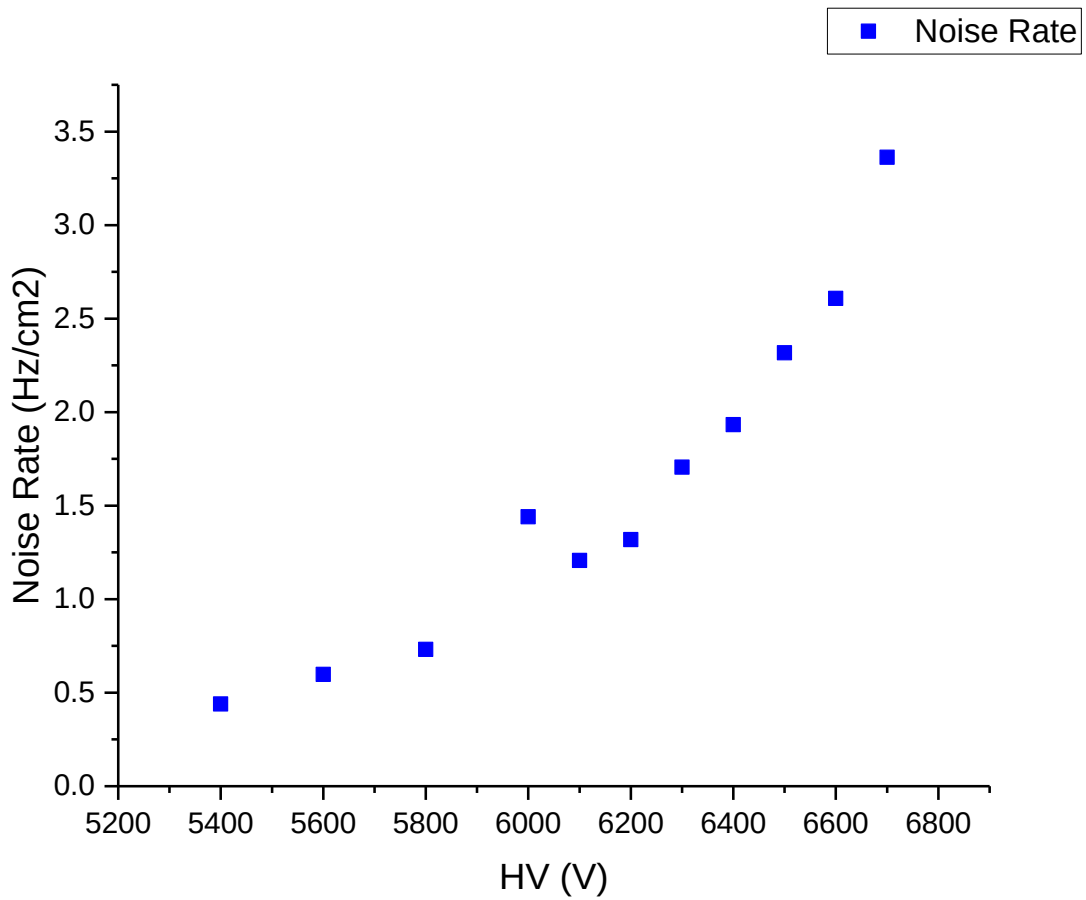
Glass thickness: 0.7 mm

Bulk resistivity: ~ 10^{10} Ωcm



Strip number: 44
Strip shape: trapezoidal
(Narrow side 6 mm,
Wide side 8mm)
Internal width between strips:
3mm
Strip length: 1 m

Cosmic Test: Noise Rate



Geometry of HZDR beamtest setup

The geometry of the setup is as follows:

element	material	thickness mm	width mm	height mm	diameter mm
window	Be	0.2			40
drift	air	140			
S24	BC408	2			40
drift	air	133			
S25	BC408	2			40
drift	air	225			
S1S2	BC418	5	20	20	
drift	air	115			
S14	BC408	2.5	5	15	
drift	air	105			
S13	BC408	2.5	15	5	
drift	air	25.00			
box	aluminum	3			
MRPC	glass	215			
drift	working gas	435			
box	aluminum	3			
drift	air	650			
S6	BC408	5	35	35	
drift	air	155			
S3S4	BC418	5	20	20	

HZDR beamtest: Setup

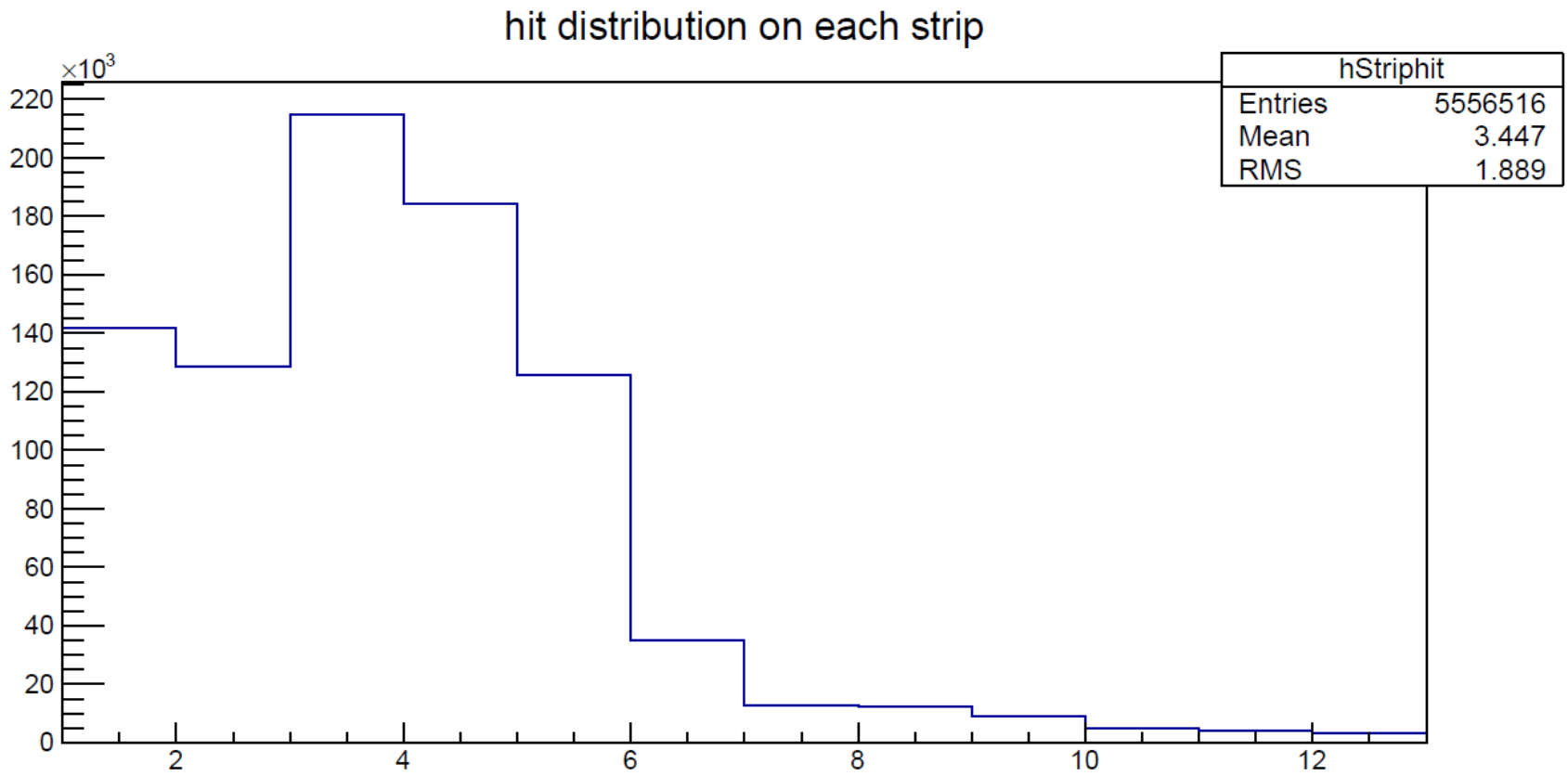
Timing of trigger.

Coincidence of scintillators: S1&S2&S3&S4.

R_F: Accelerator clock.

TDC trigger: S1&S2&S3&S4 & R_F.

Run005: Efficiency

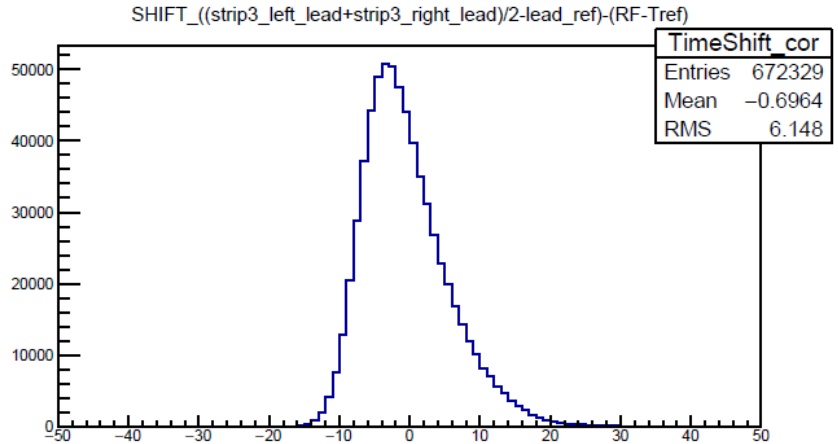


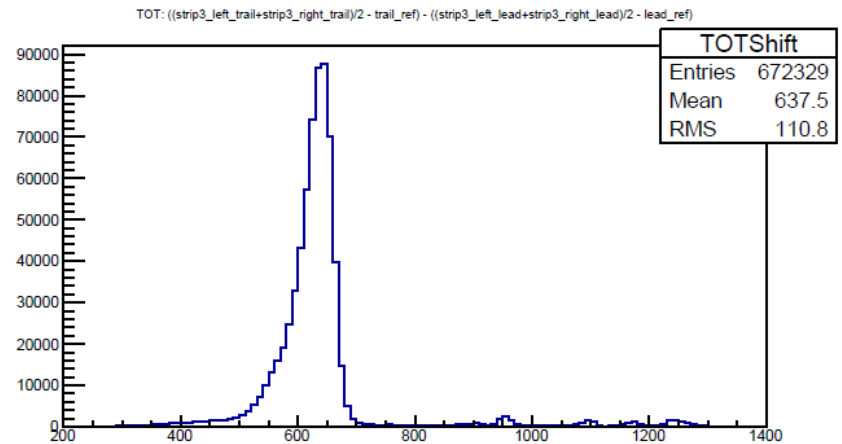
Efficiency

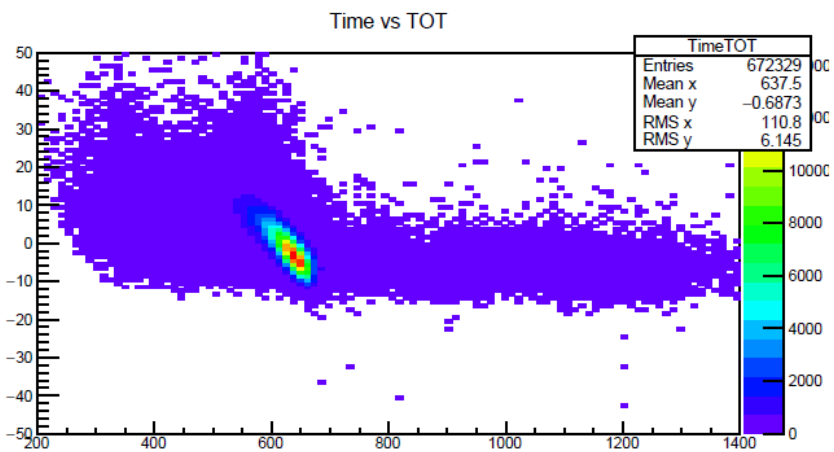
No cut: $\frac{Tref\ \&\&\ MRPC}{Tref}$ 93.62%

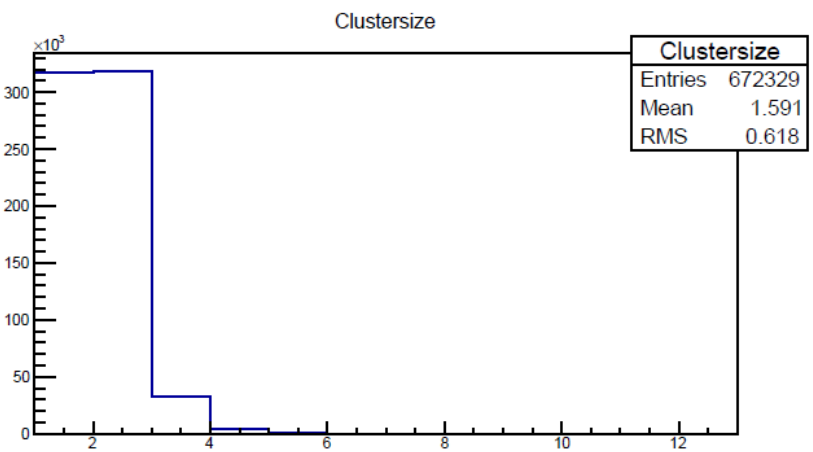
Cut on S6: $\frac{Tref\ \&\&\ S6\ \&\&\ MRPC}{Tref\ \&\&\ S6}$ 93.93%

Run005: Time Resolution





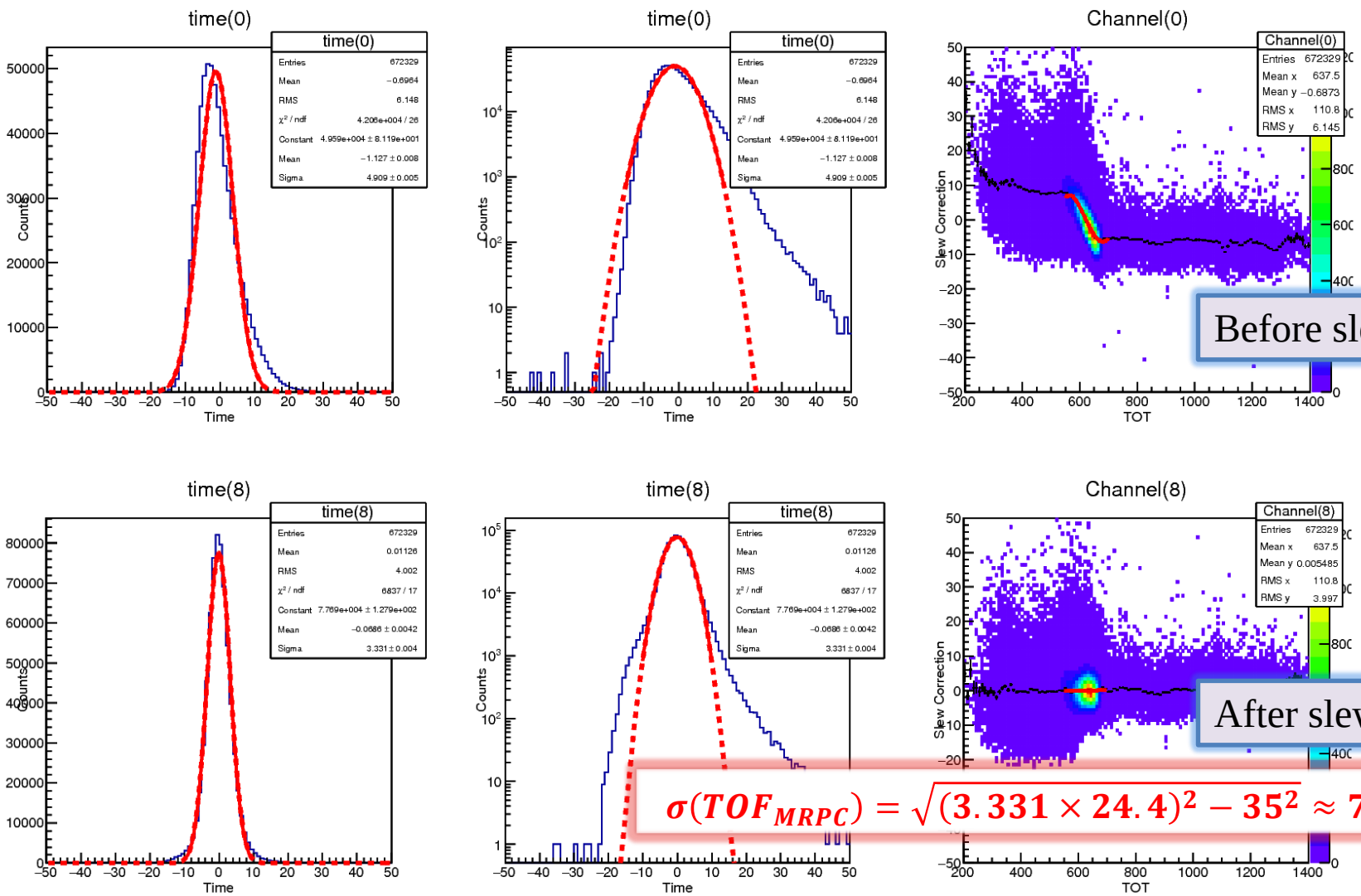




$$TOF = \left(\frac{LeftLead+RightLead}{2} - LeadRef\right) - (RF - TRef)$$

$$TOT = \left(\frac{LeftTrail+RightTrail}{2} - TrailRef\right) - \left(\frac{LeftLead+RightLead}{2} - LeadRef\right)$$

Run005: Time Resolution



$$\sigma(TOF_{MRPC}) = \sqrt{(3.331 \times 24.4)^2 - 35^2} \approx 73.4\ ps$$

HZDR Rate Scan: Efficiency

HV: ±6000 V