Characterisation of a innovative RPC prototype with 1mm of gas gap thickness

XVI Workshop on Resistive Plate Chambers and Related Detectors

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Outline

Why 1mm gap thickness design?

Detector prototype layout and experimental setup description

Efficiency and muon cluster results

Time resolution measurement

Study with eco-friendly gas mixtures

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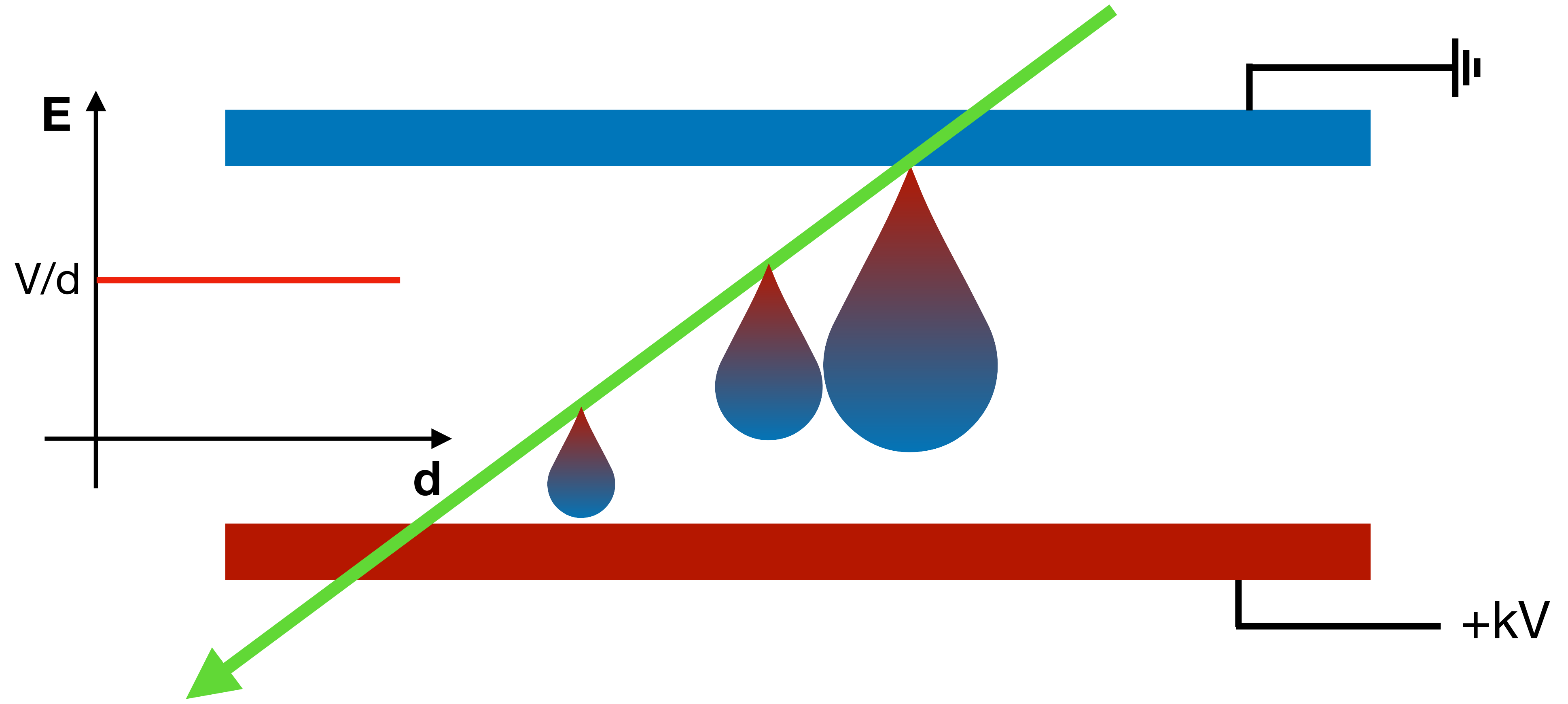
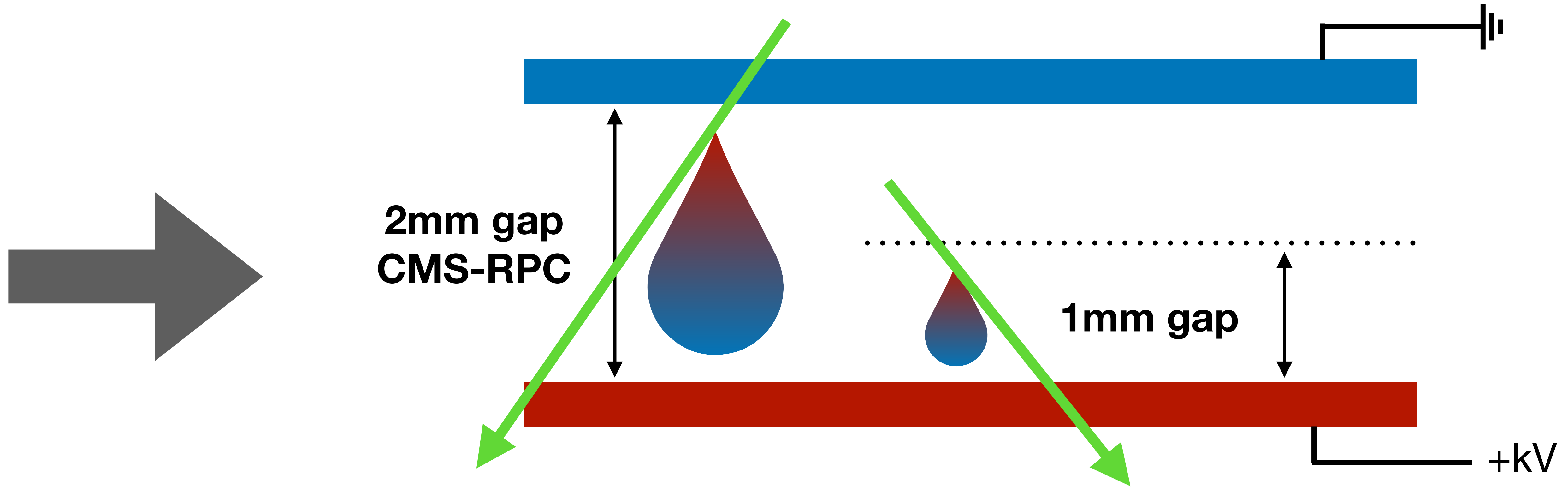
Why 1mm gas gap thickness?

Avalanche charge ⟷ Gas gap thickness





Reducing gap thickness

Smaller avalanche cloud

Lower WP

Smaller CLS ➤ better space resolution

Fast signal ➤ better time resolution and rate capability

FEB capable to operate at lower THR (≃ 50 fC)
Low noise operational conditions

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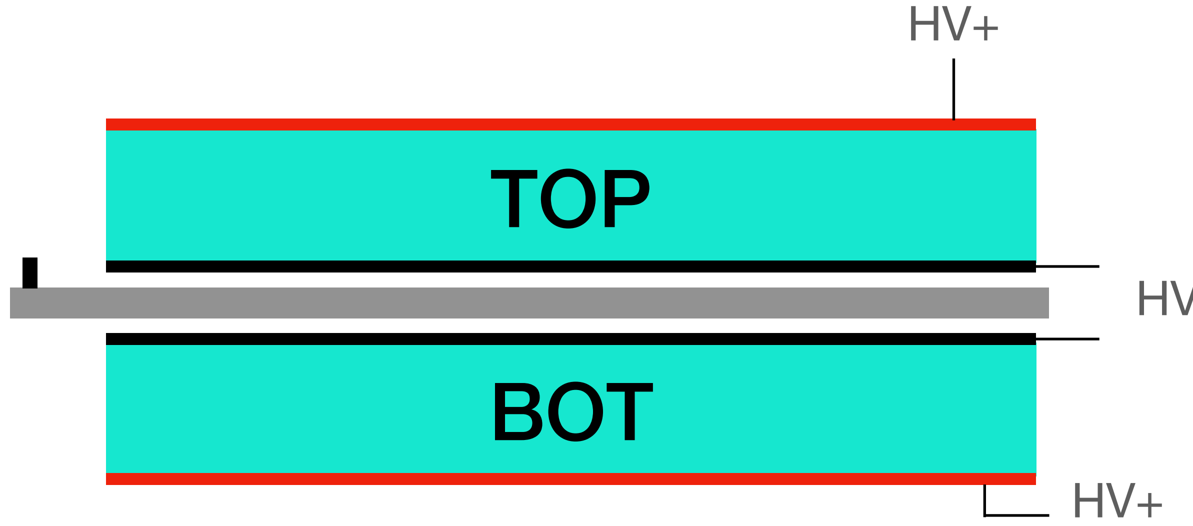
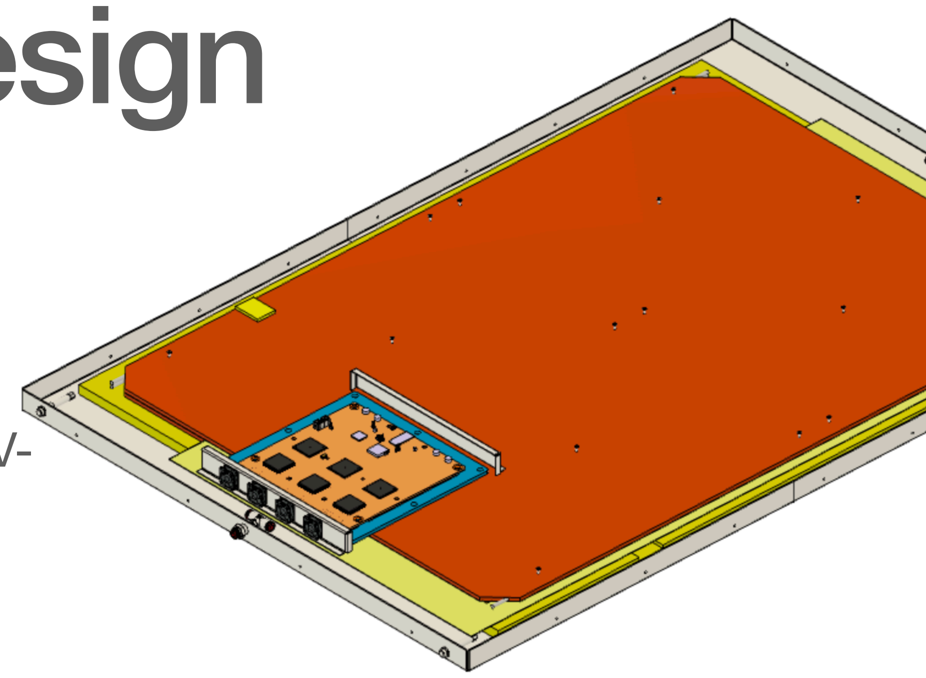
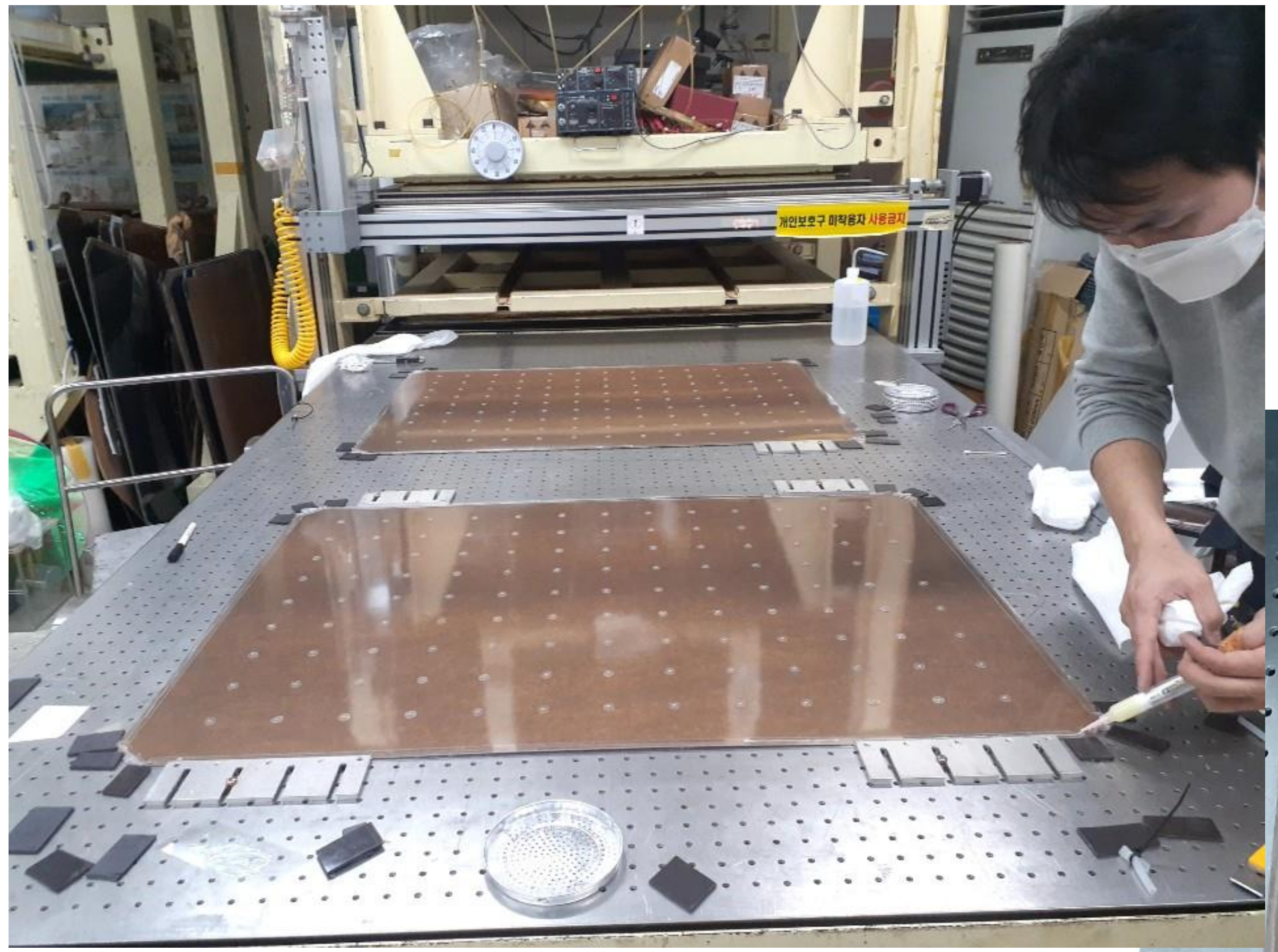
Detector prototype

Double gap design

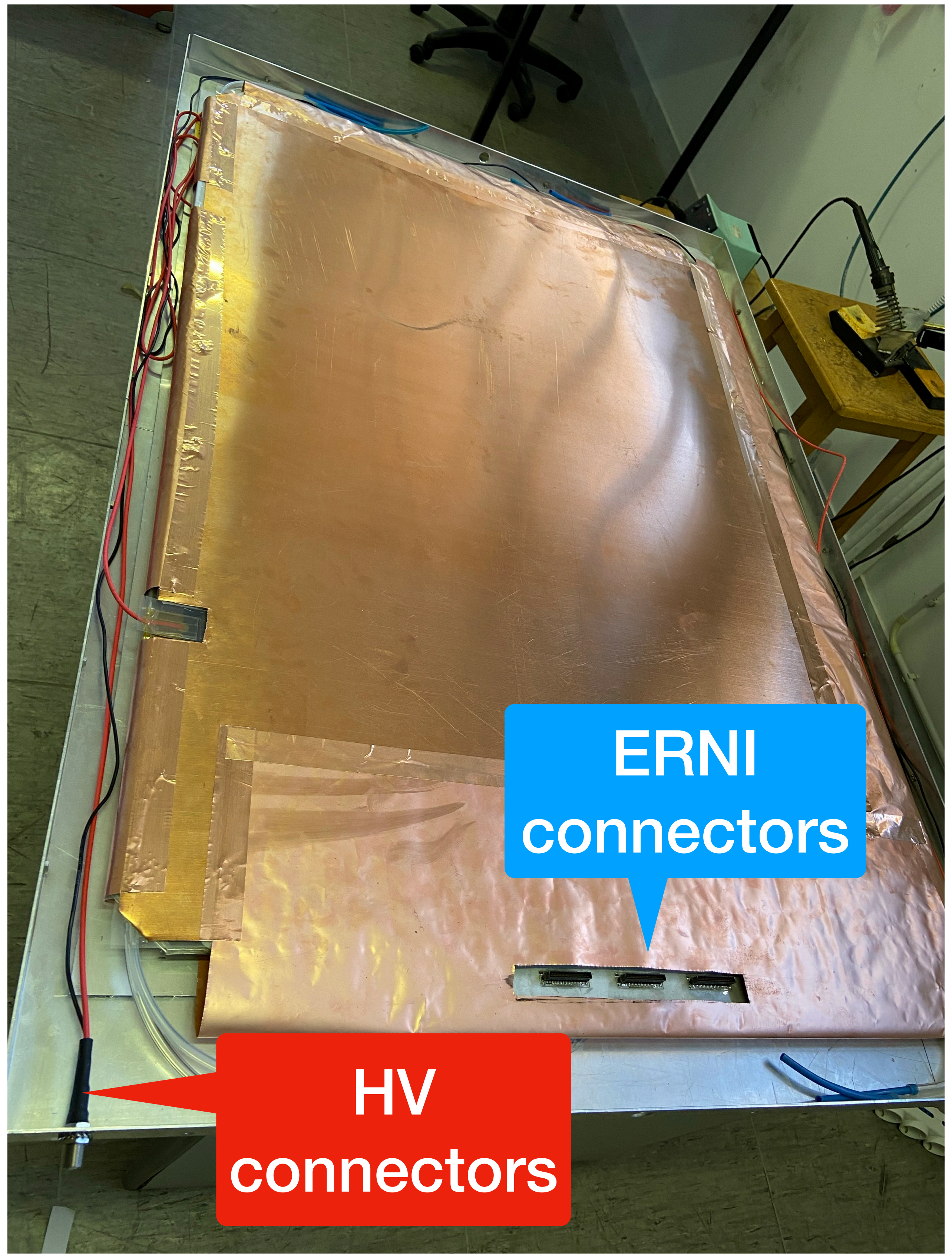




Gaps manufactured at KODEL



Gap area 70x100 cm^2
Gap thickness 1 mm
HPL 1.43 mm thick



1x0.5 m2
strip PCB
48 strips
1. cm pitch
4752 cm2
active area
XY read-out

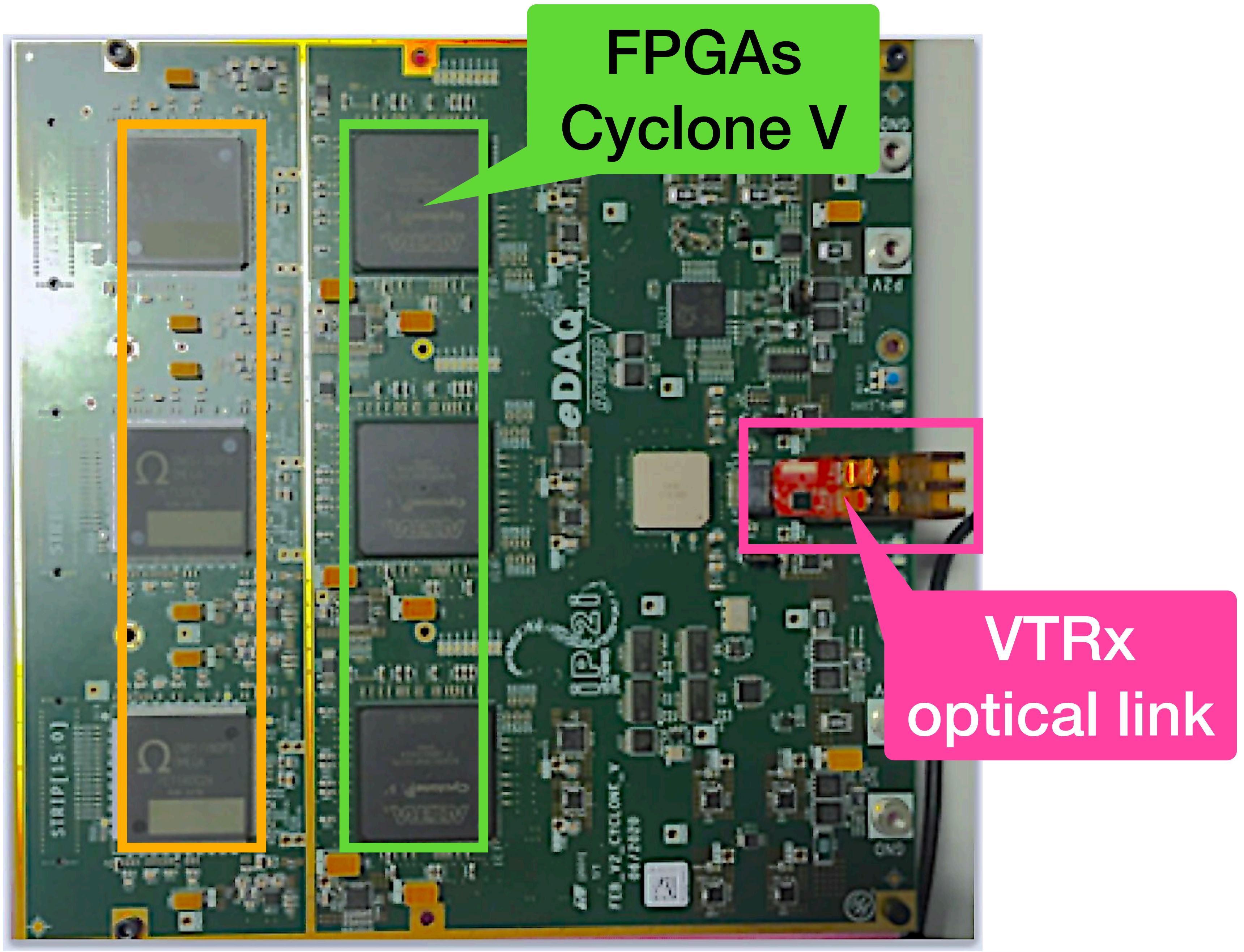
Assembly in BARI University

KOrea DEtector Laboratory, Korea University

Detector prototype

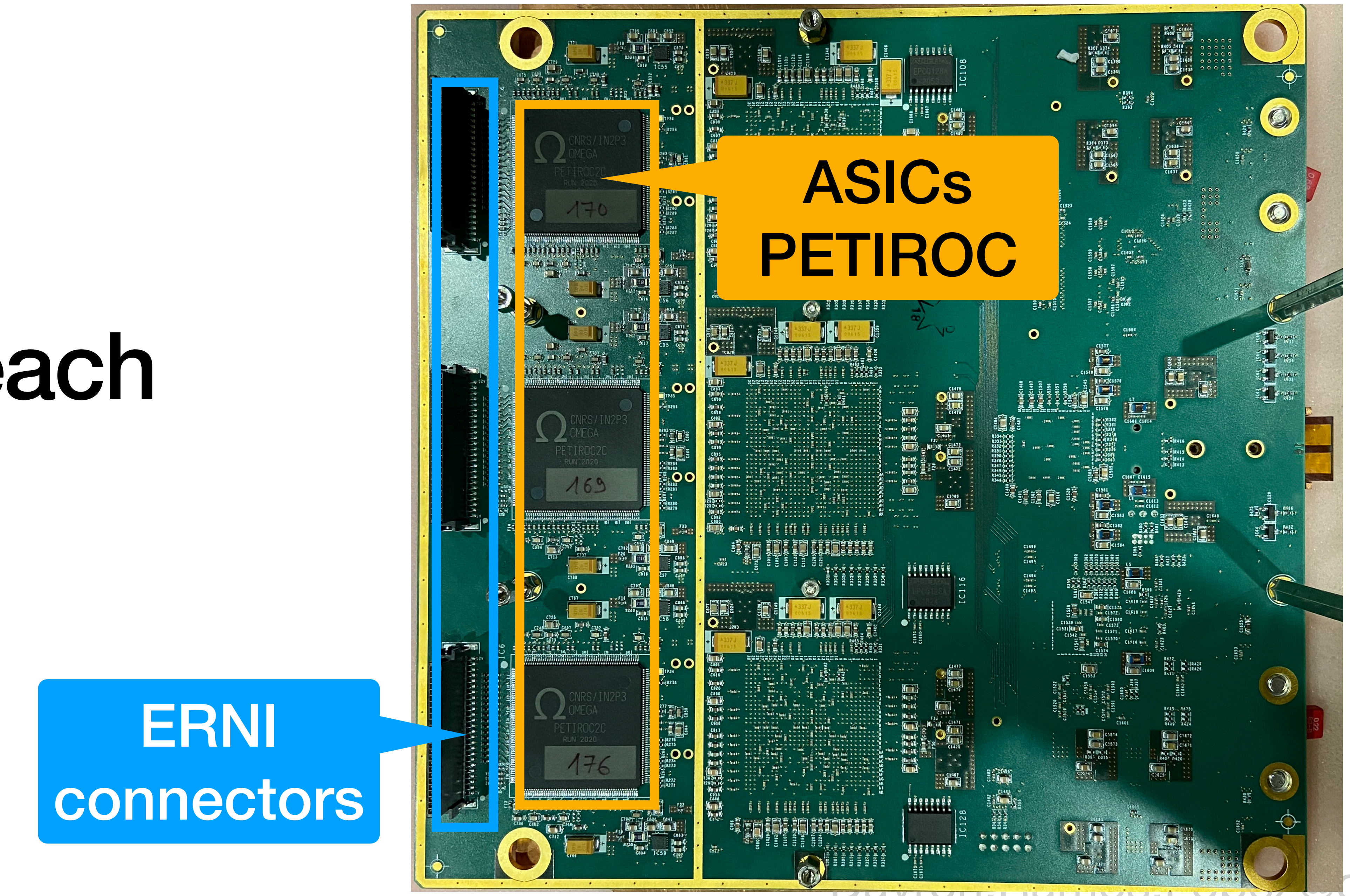
Front-end Electronics LYON v2.2

lower charge signal at the same time to keep efficiency high, the new front-end electronics are designed for the new iRPC

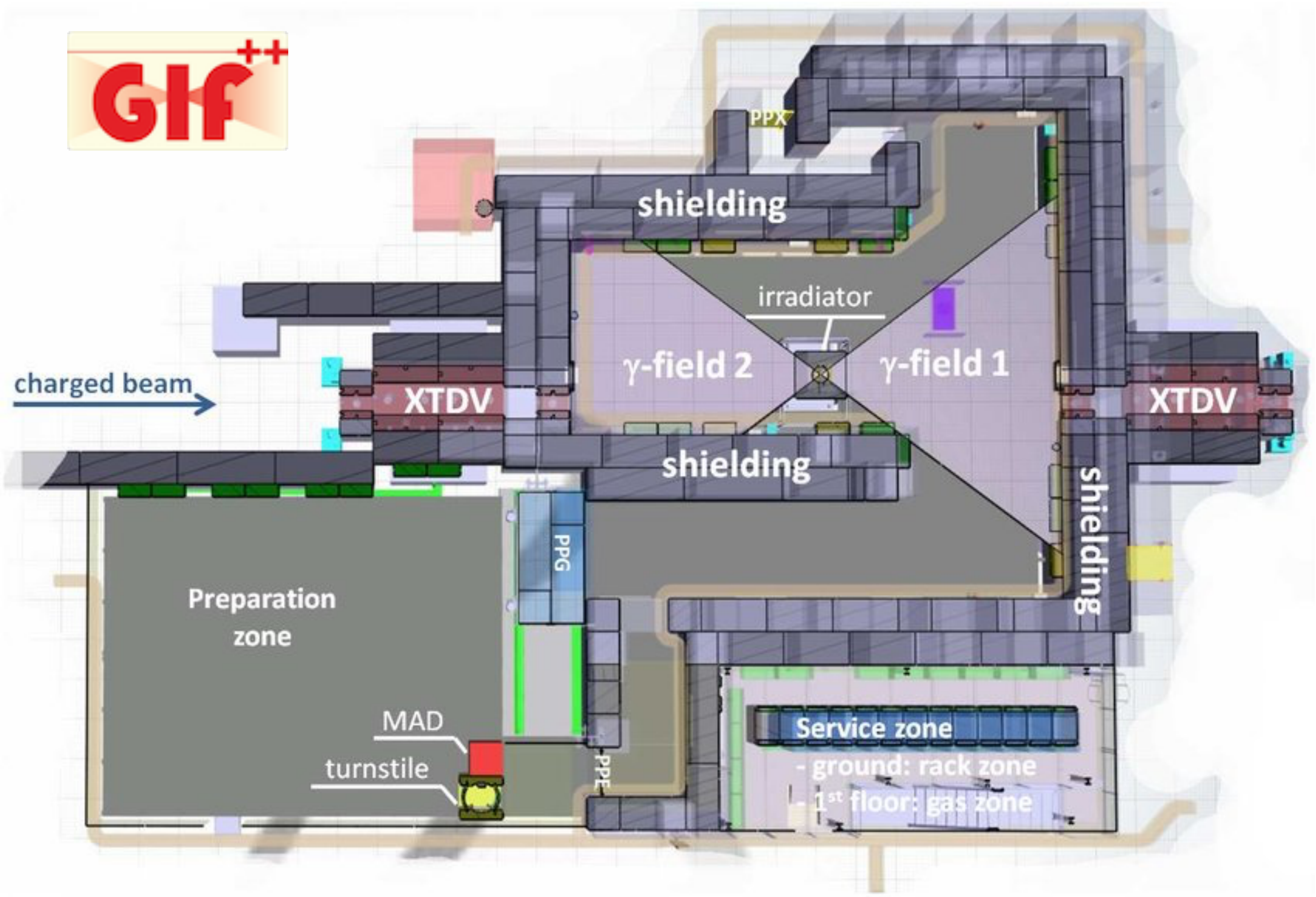


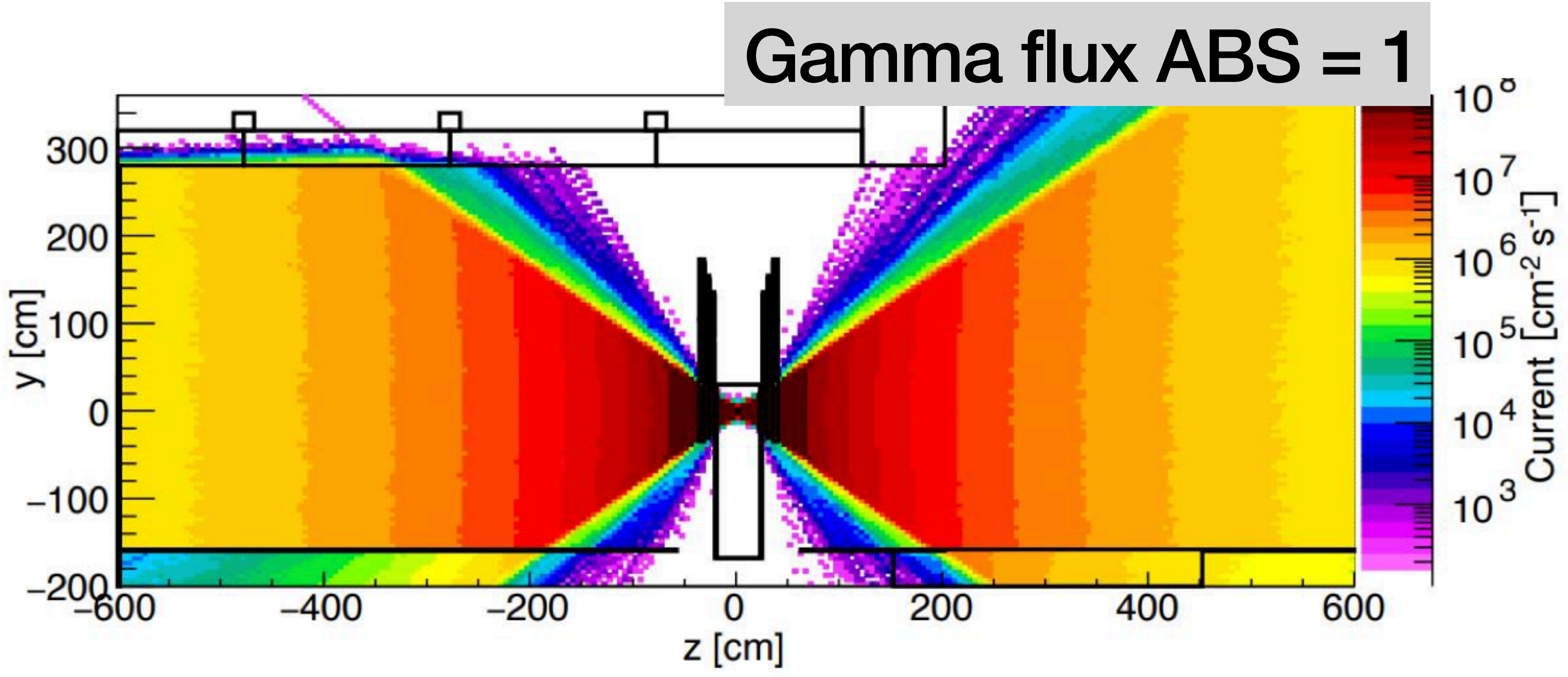
FEB is sensitive, has low-noise and high time resolution

The FEB composed of:
- 3 ERNI connectors with 32 channels each
- 6 ASICs PETIROC 2C (top & bottom)
- 3 FPGAs Cyclone V (non rad-hard)
- GBTx/GBT-SCA/VTRx.



Gamma Irradiation Facility (GIF++)





Located at the H4 beam line in EHN1, Prevessin North Area
High gamma radiation Cs-137 source up to 12 TBq
Muon beam 10-450 GeV/c
Gamma flux modulated independently using a system of six attenuation filters

Guida, R. GIF++: The new CERN Irradiation Facility to test large-area detectors for HL-LHC in 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)(2015), 1–4

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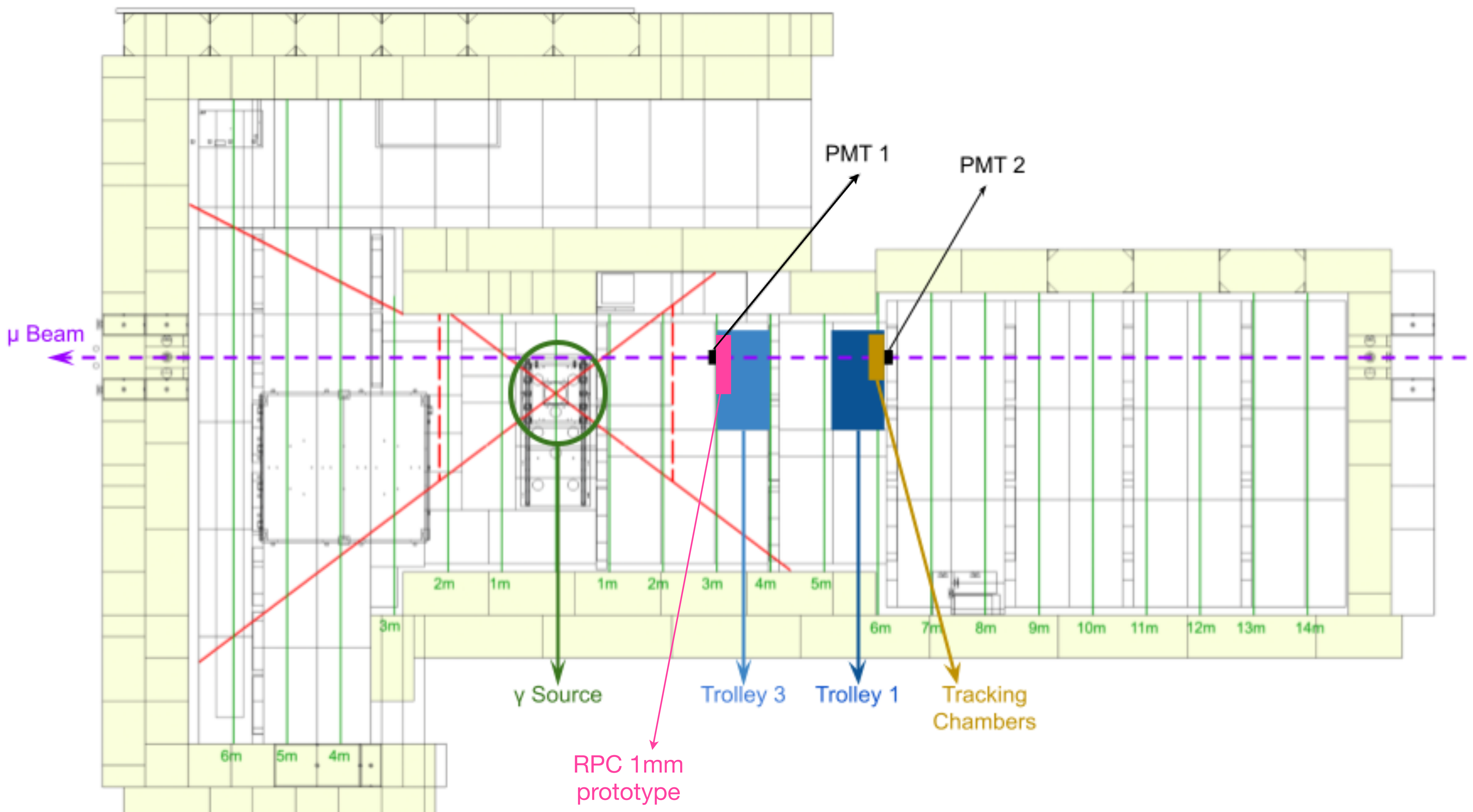
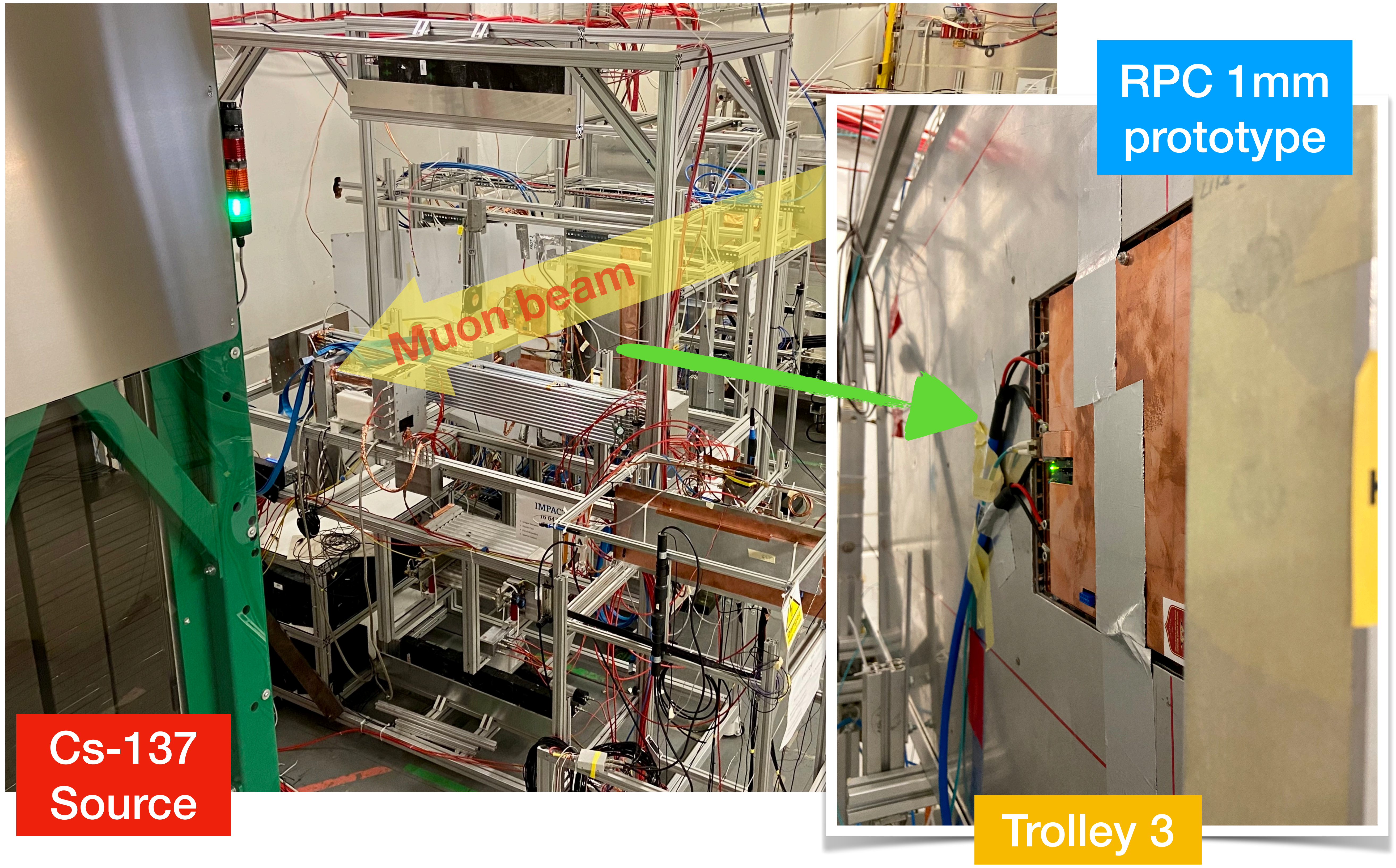
RPC set-up at GIF++





RPC 1mm prototype at 3. m from the source in Trolley 3
2 PMTs as muon trigger

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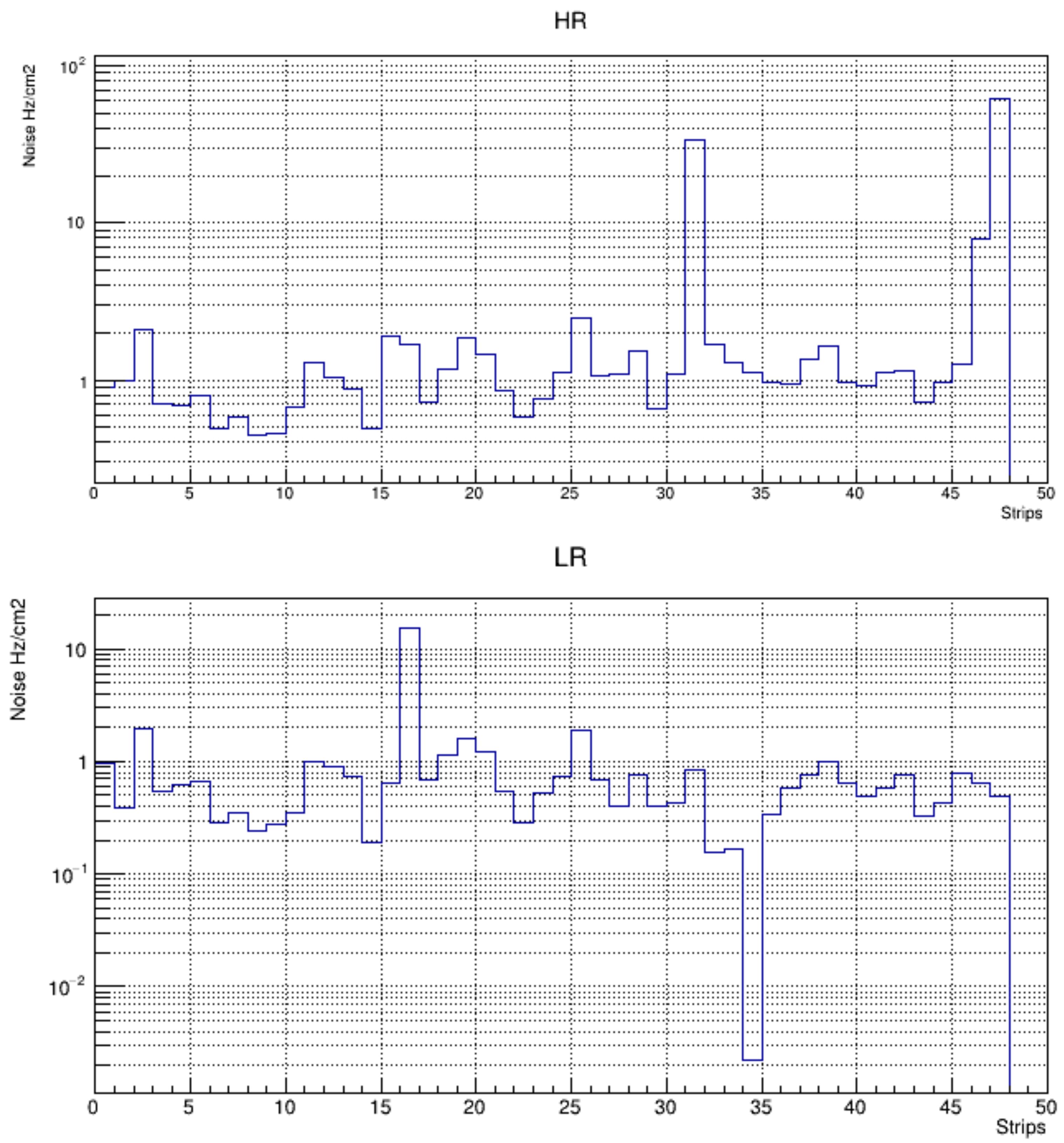
Detector commissioning

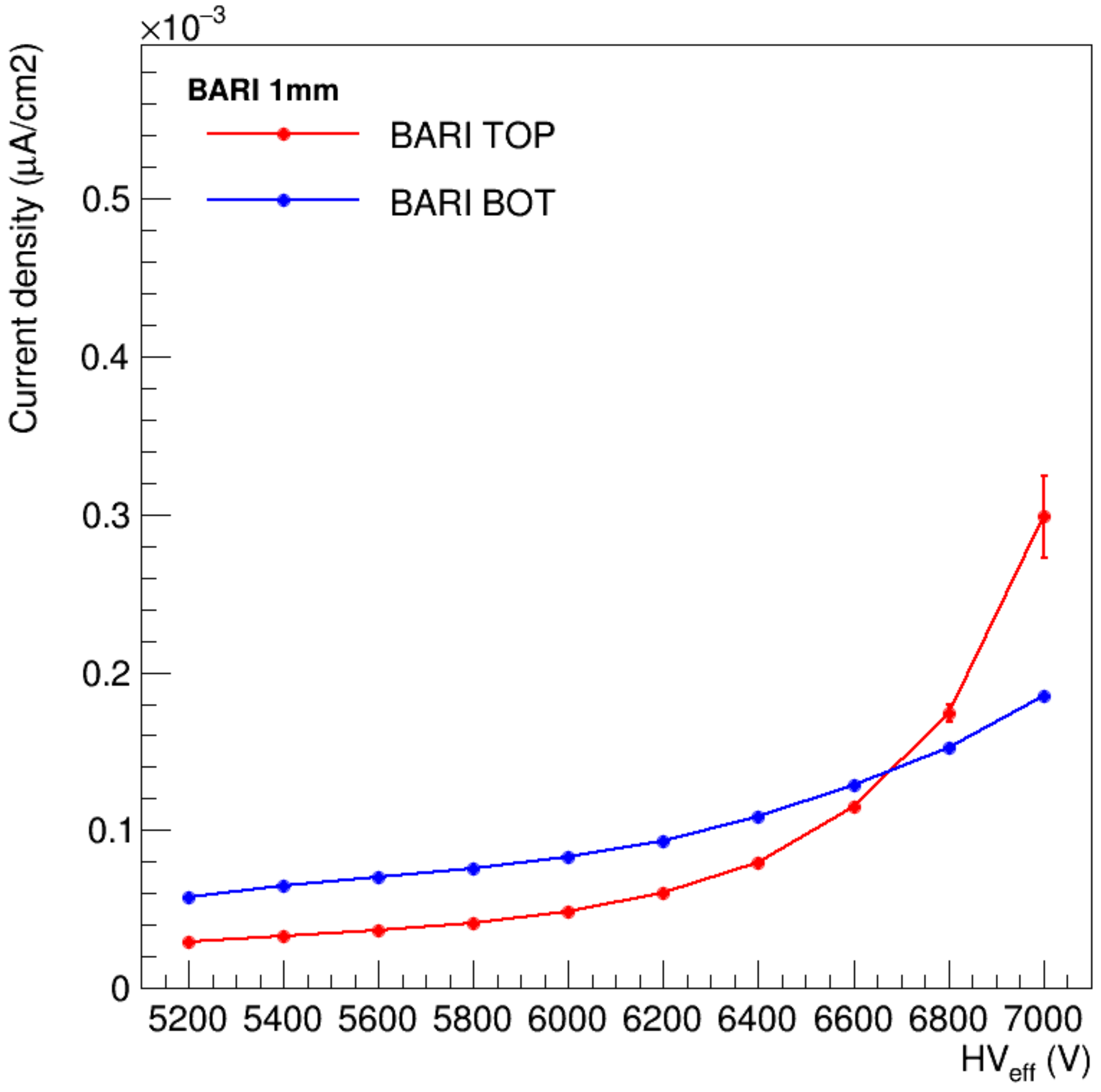
Current and noise scan



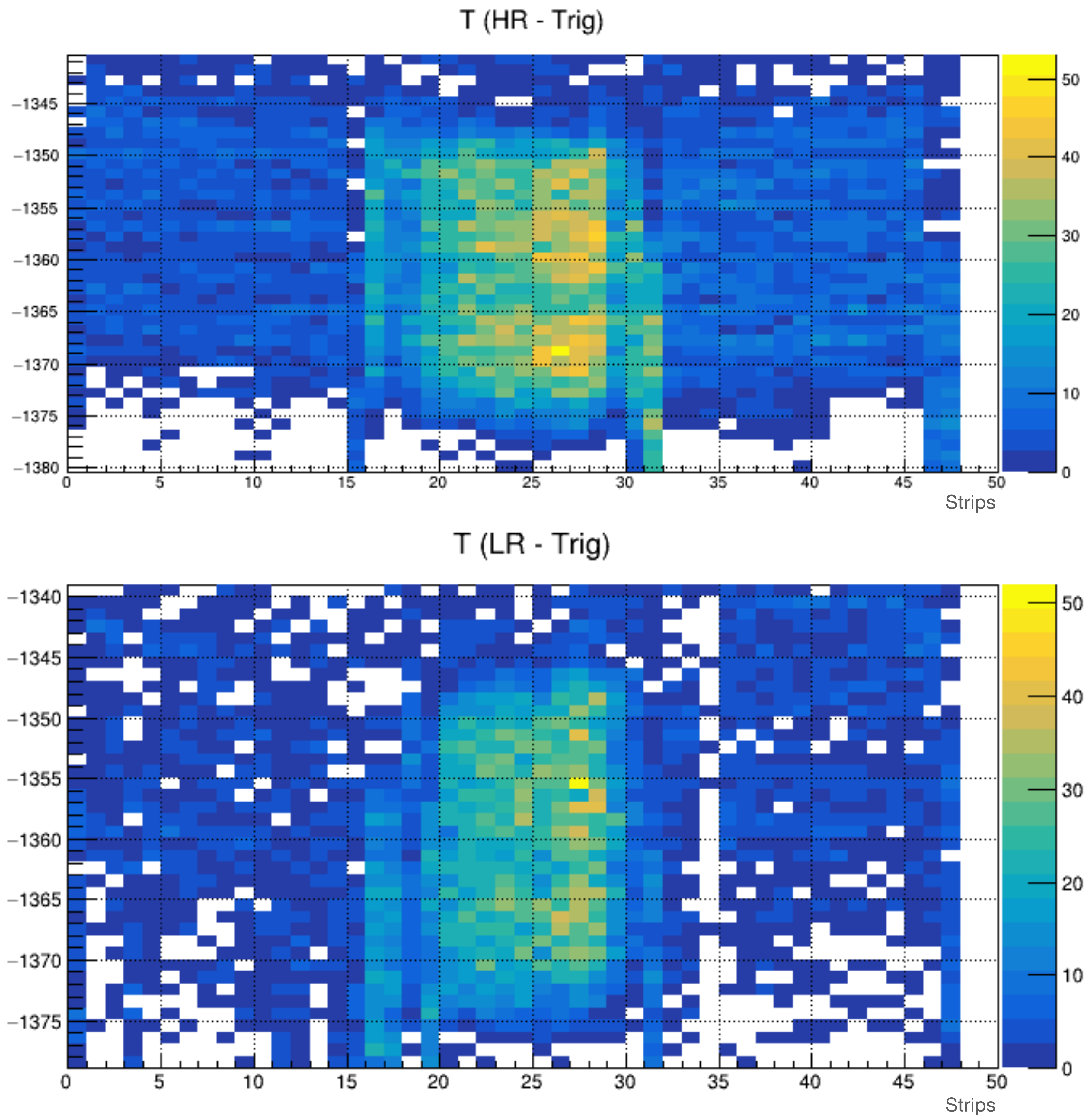
Source and beam OFF

Current density below 3e-04 μA/cm2

Mean noise ≃ 1 Hz/cm2



Detector-beam alignment



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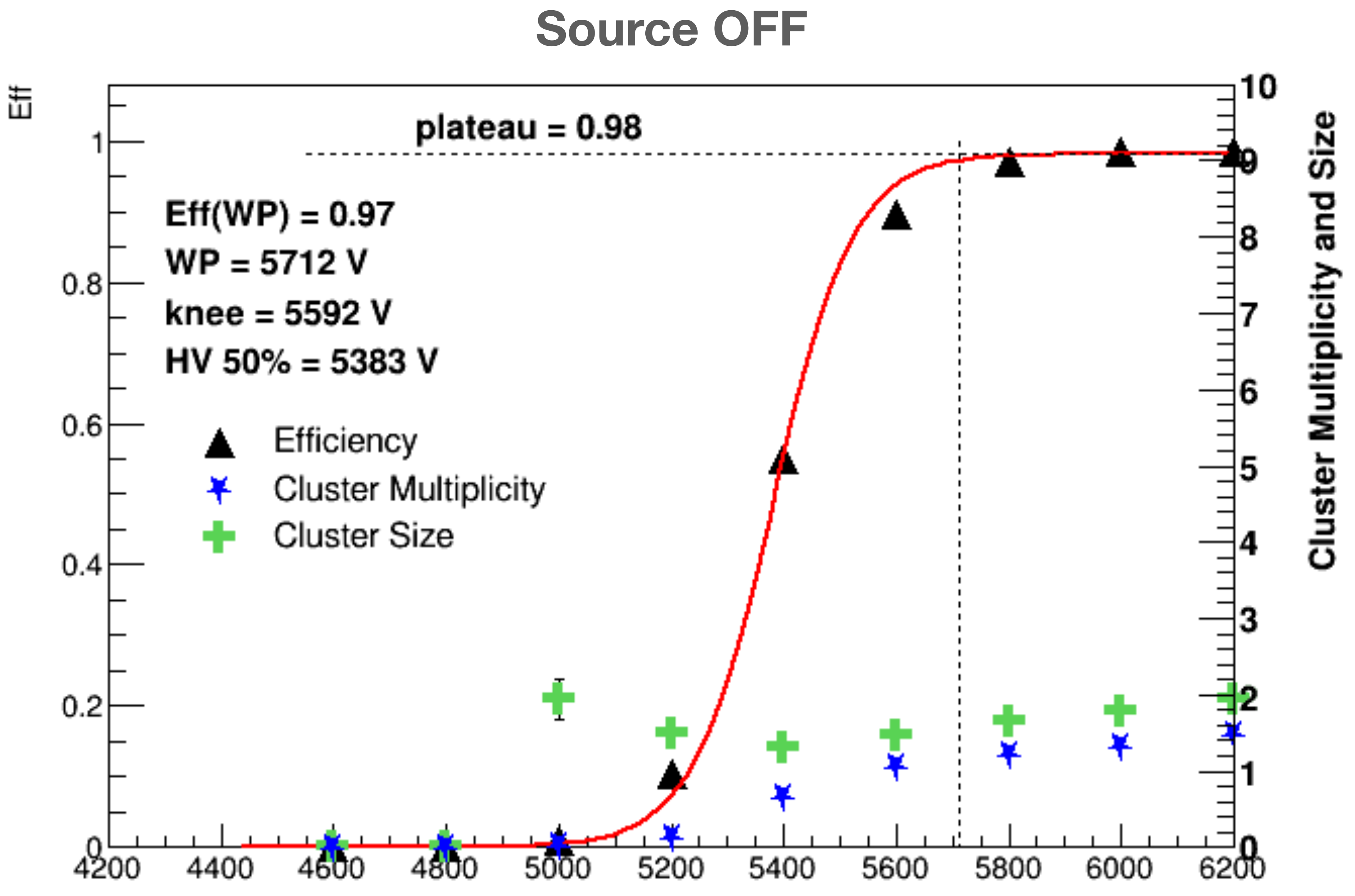
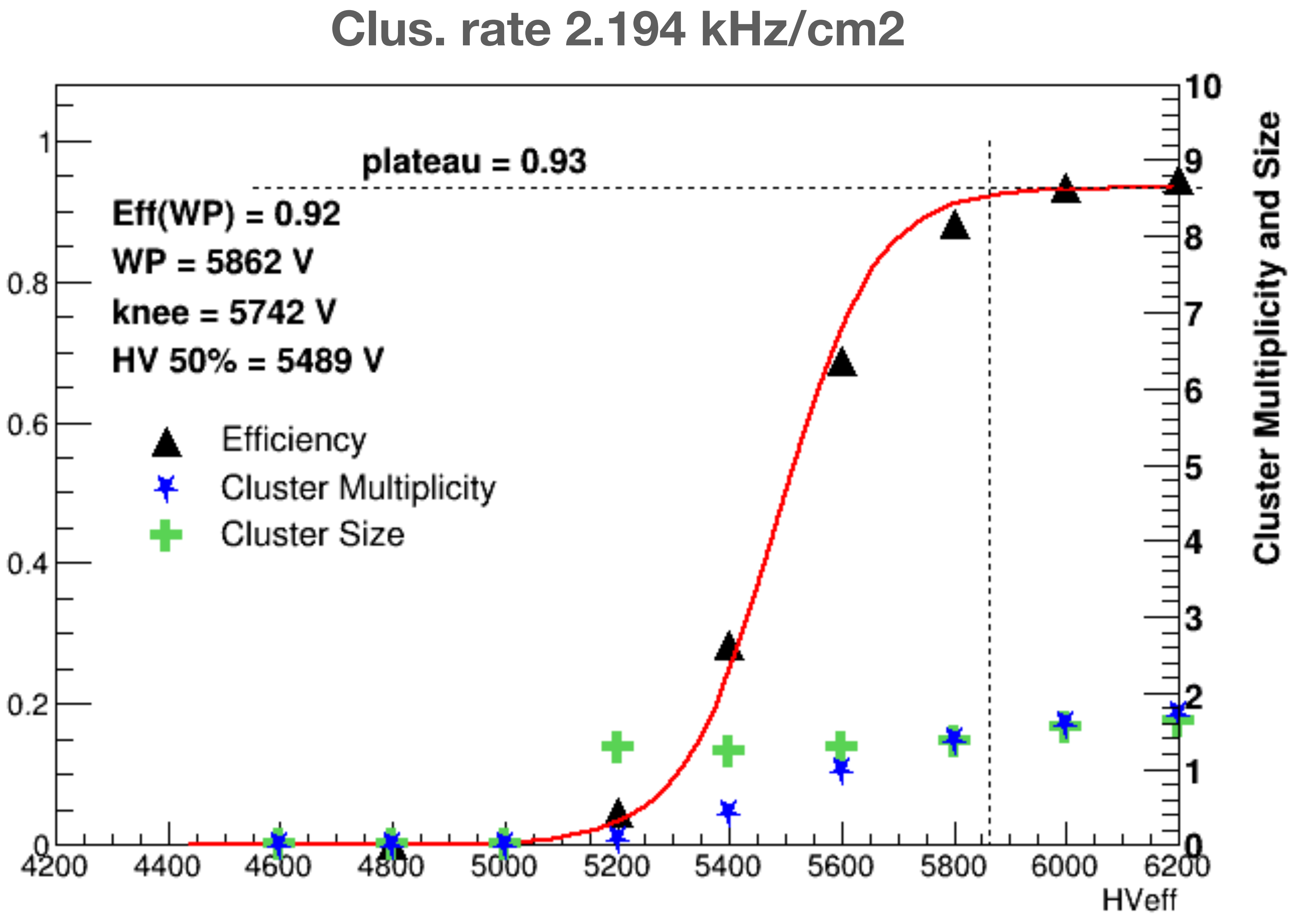
Results double gap mode

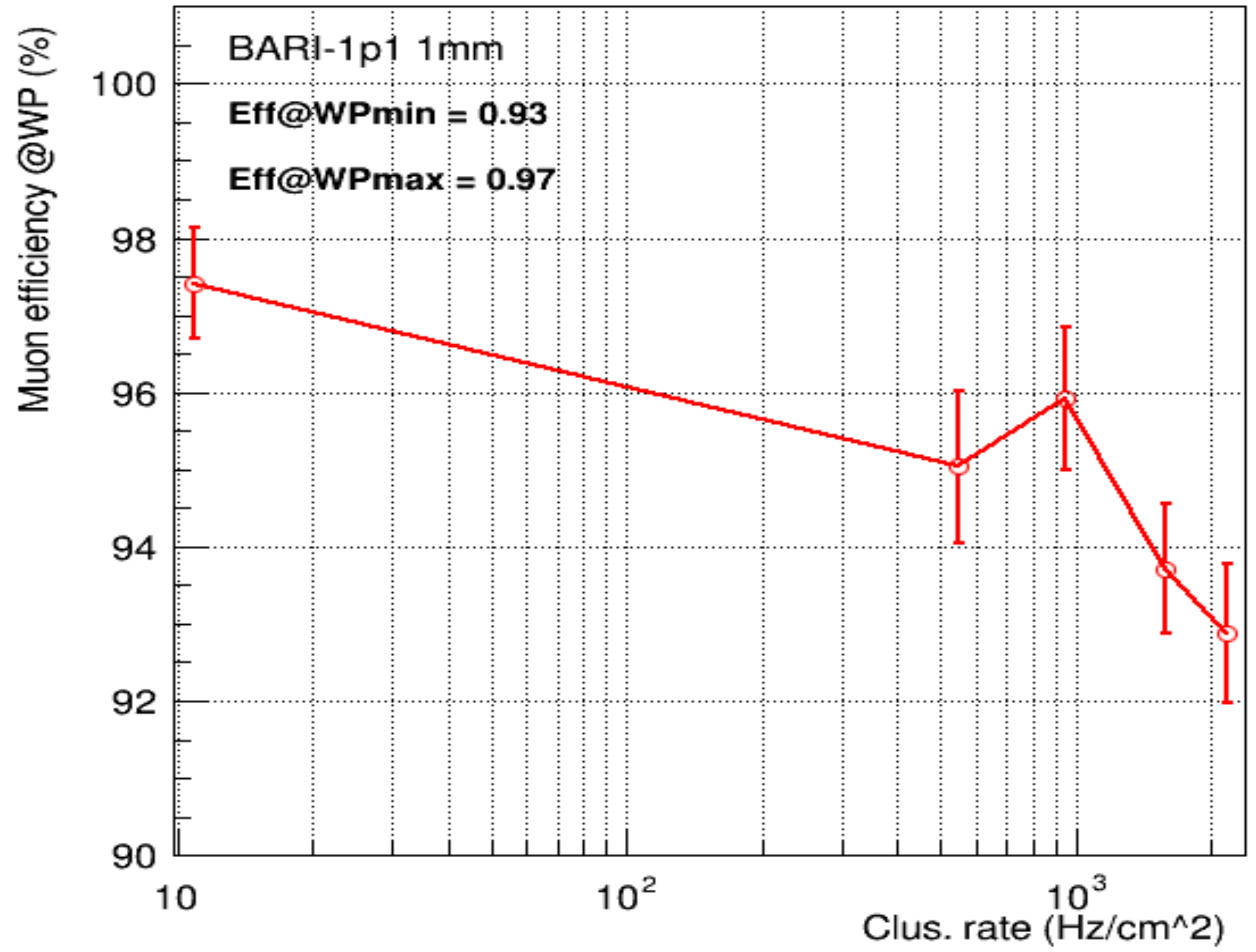
Muon efficiency, muon clus. size and clus. multiplicity measurements

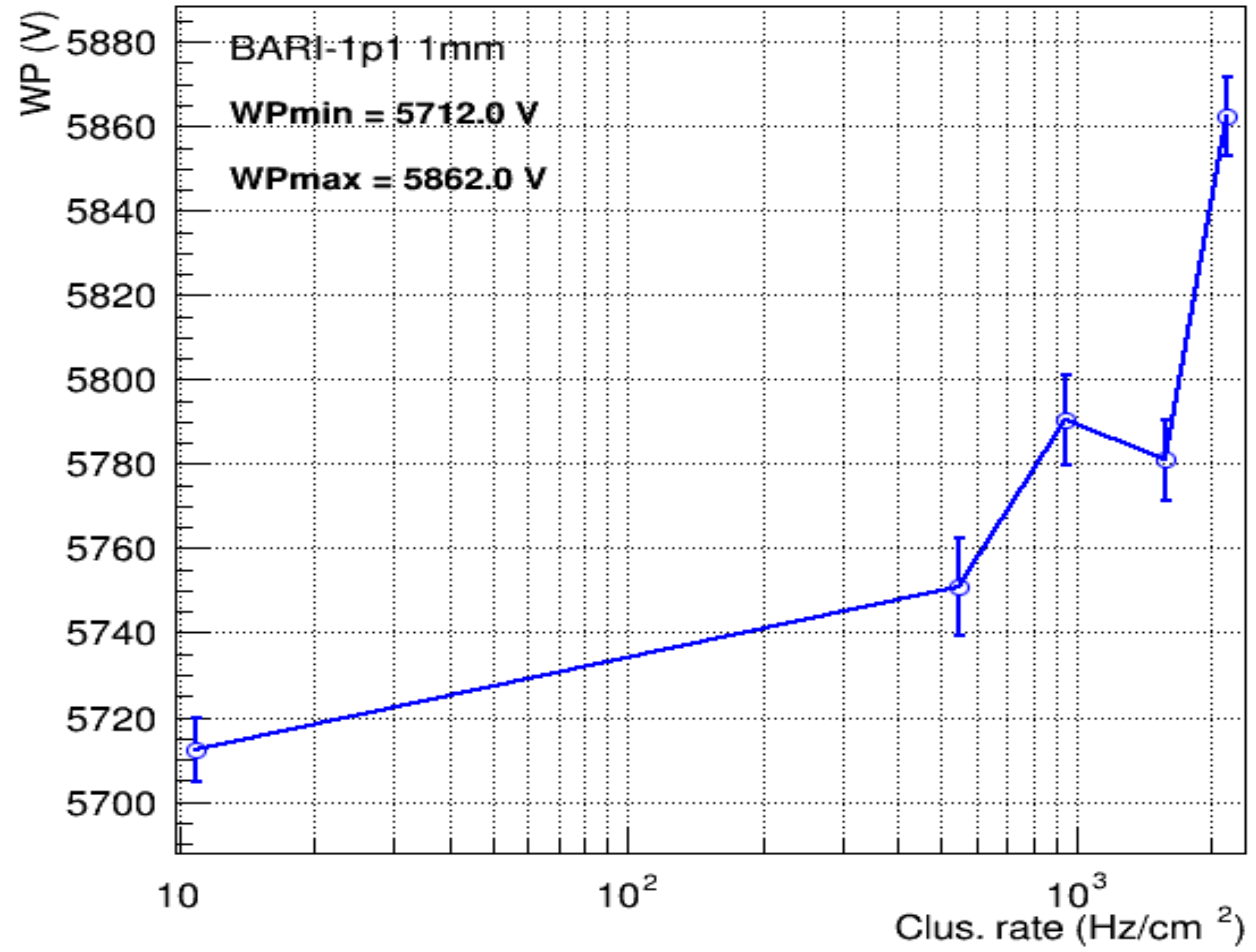
$$E = \frac{E_{max}}{1 + e^{-\lambda*(HVeff - HV50)}}$$

$$WP = -\frac{log(1/(0.95-1))}{\lambda} + HV50 + 120$$









THR 7DAC (≈ 35 fC)
CLS ≈ 1.5
WP shift 150 V up to 2 kHz/cm2 gamma clus. rate

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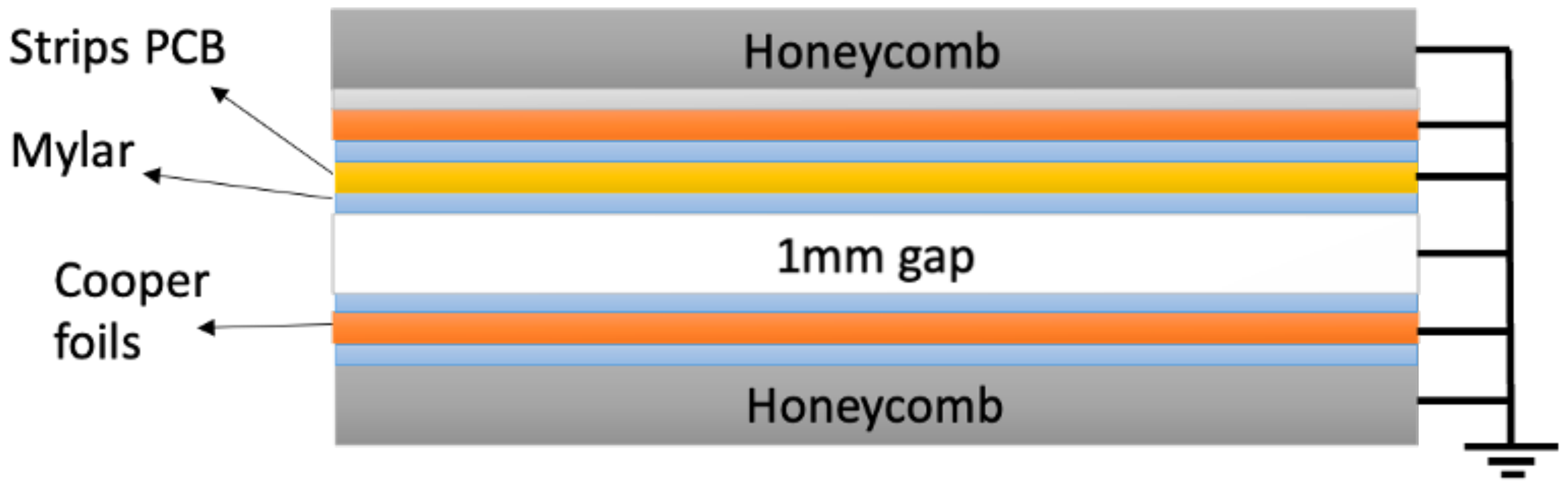
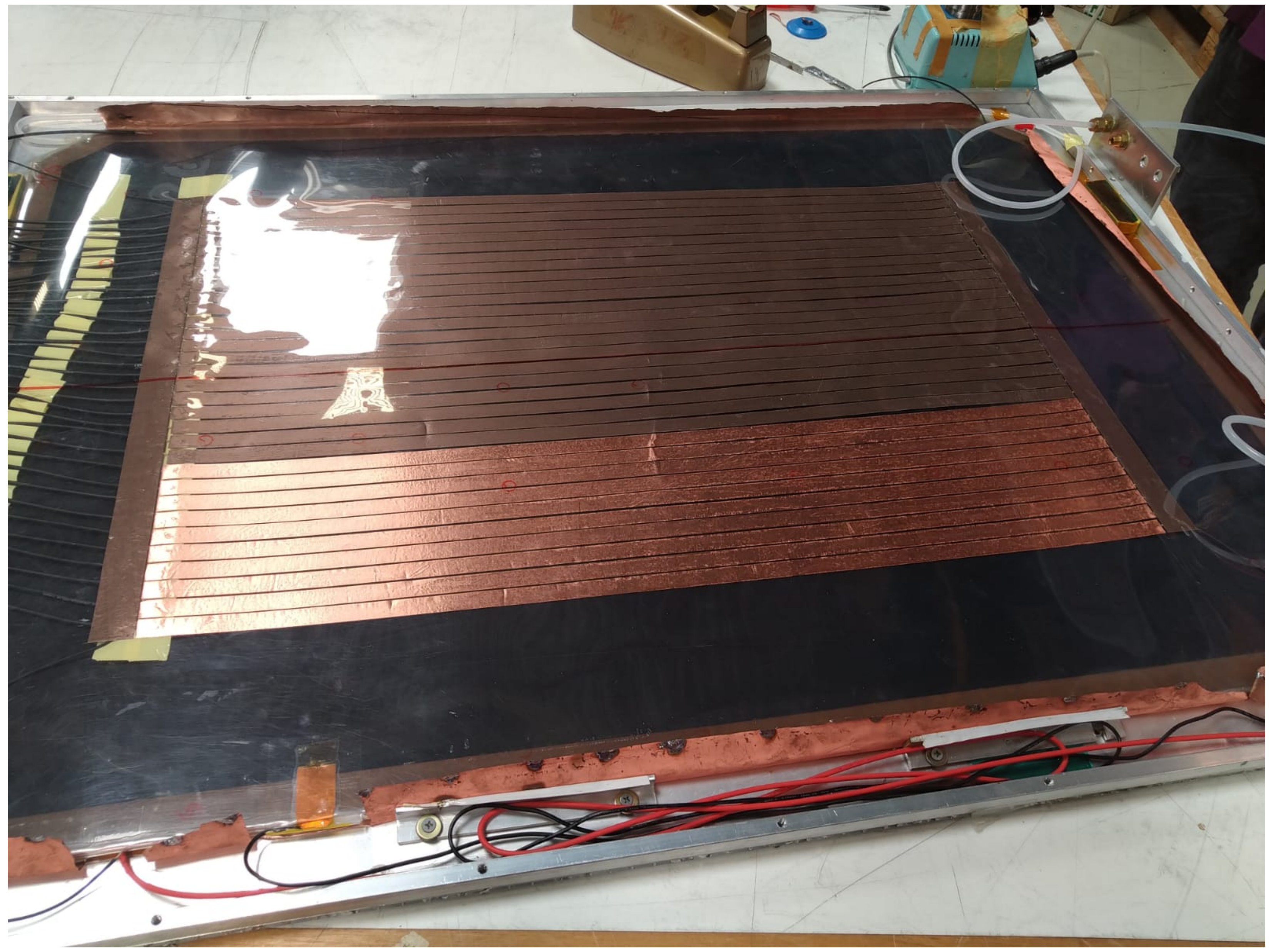
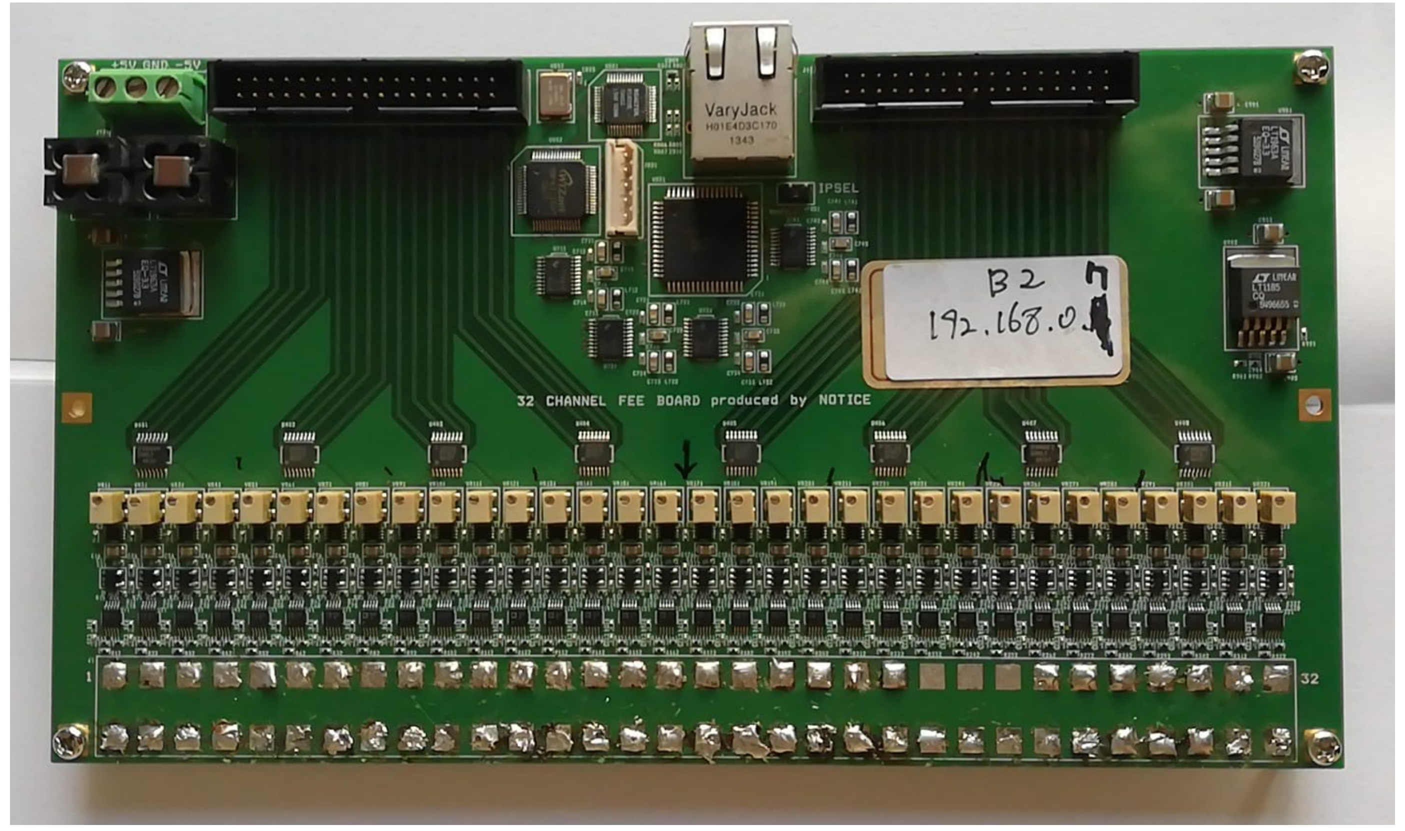
Time resolution measurements

Single gap prototype

Gas gap 1mm thickness
Gap area 70x100 cm^2
32 strips, 1 Kodel FEB
THR: 750 uV (~90 fC)
Strip pitch: 1.27 cm







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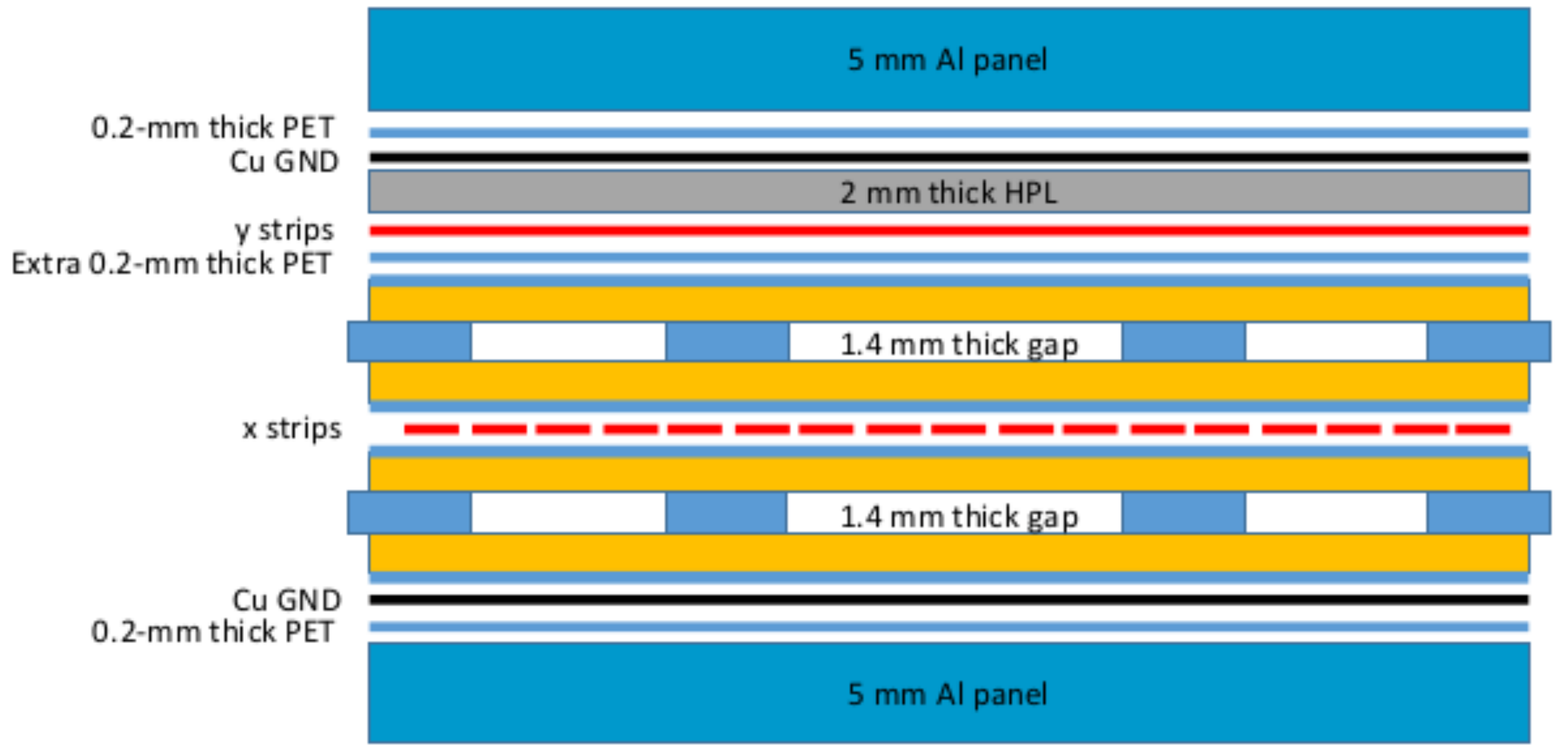
Time resolution measurements

Tracking system

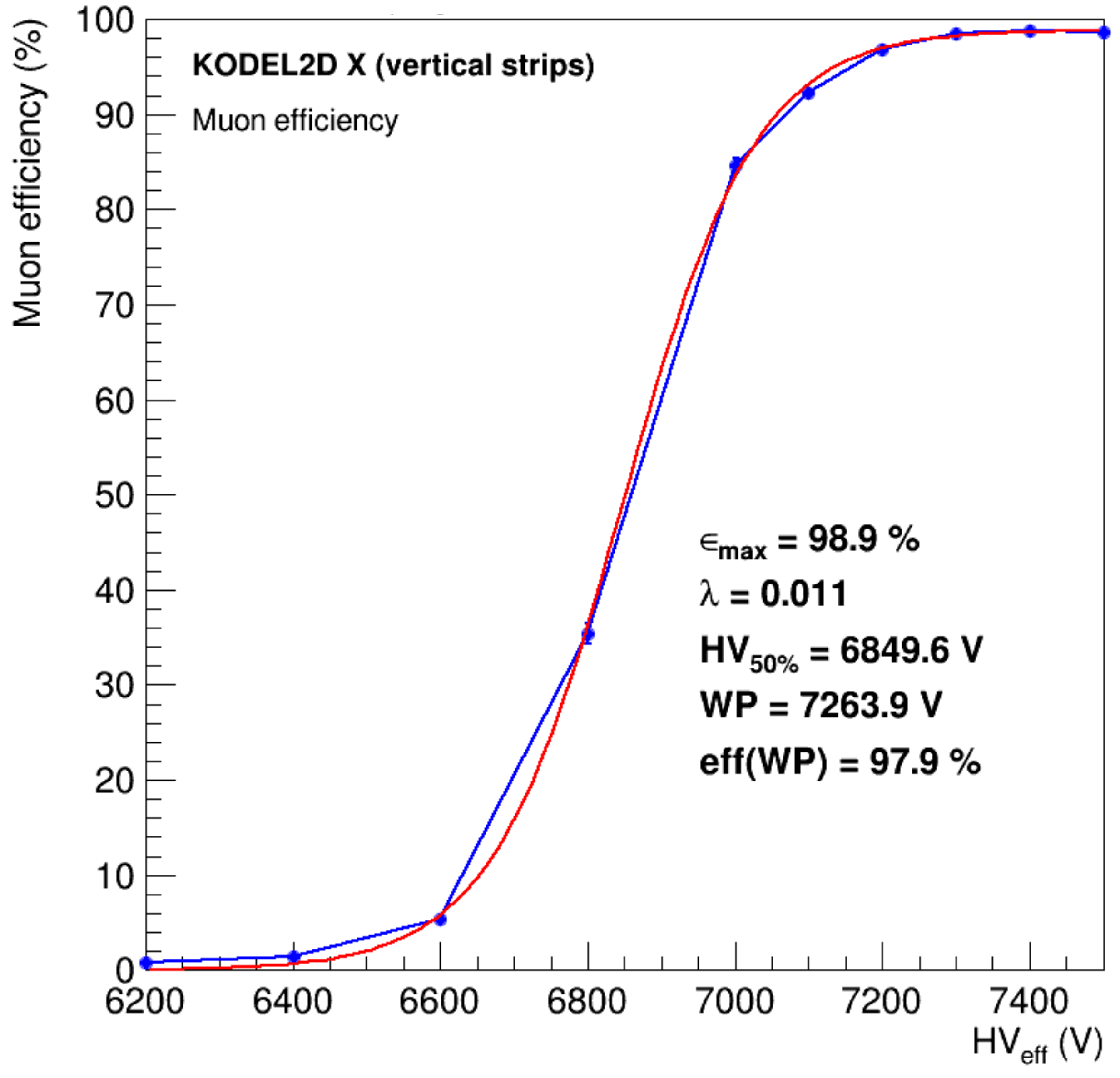


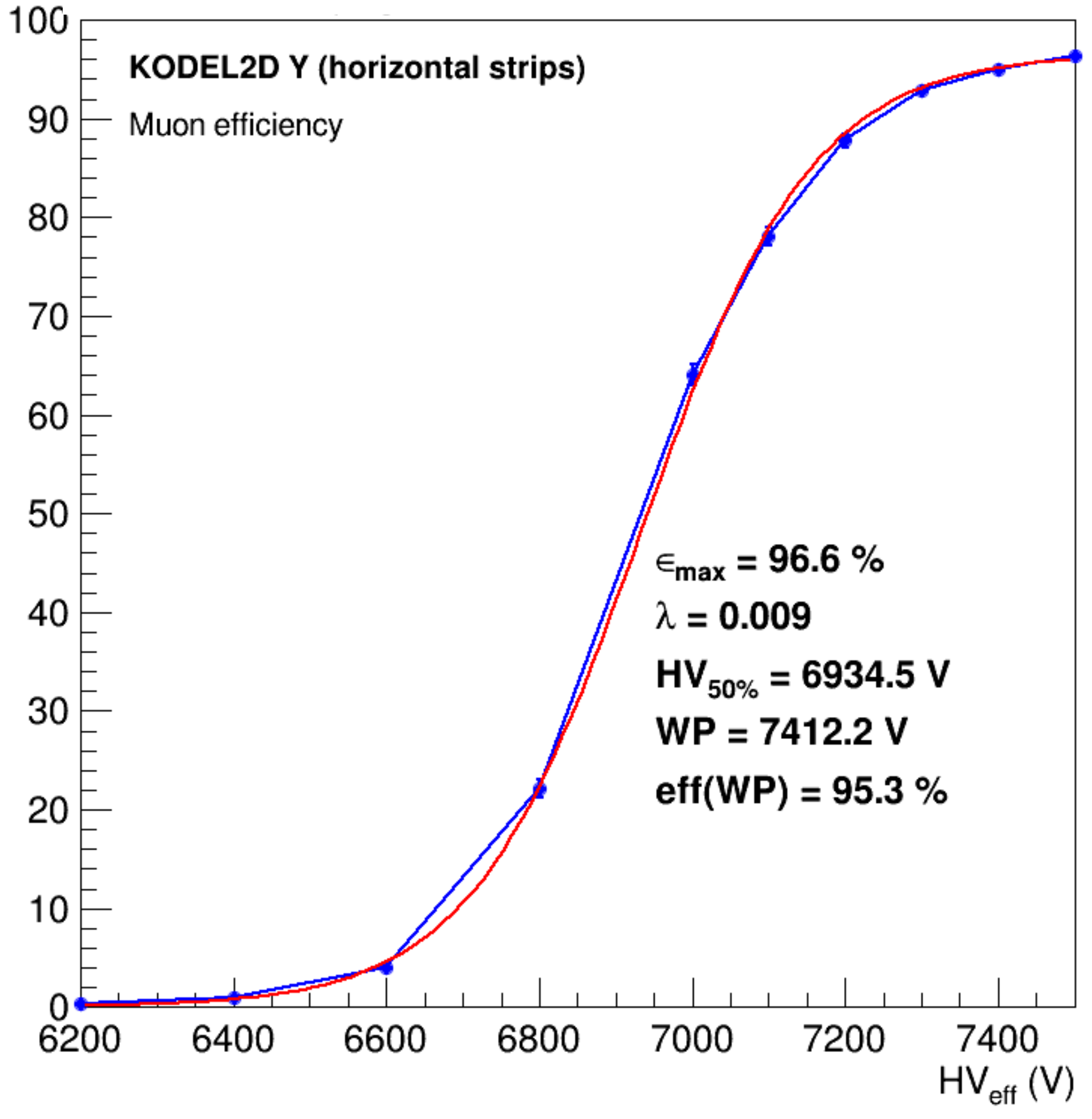
2D readout detector

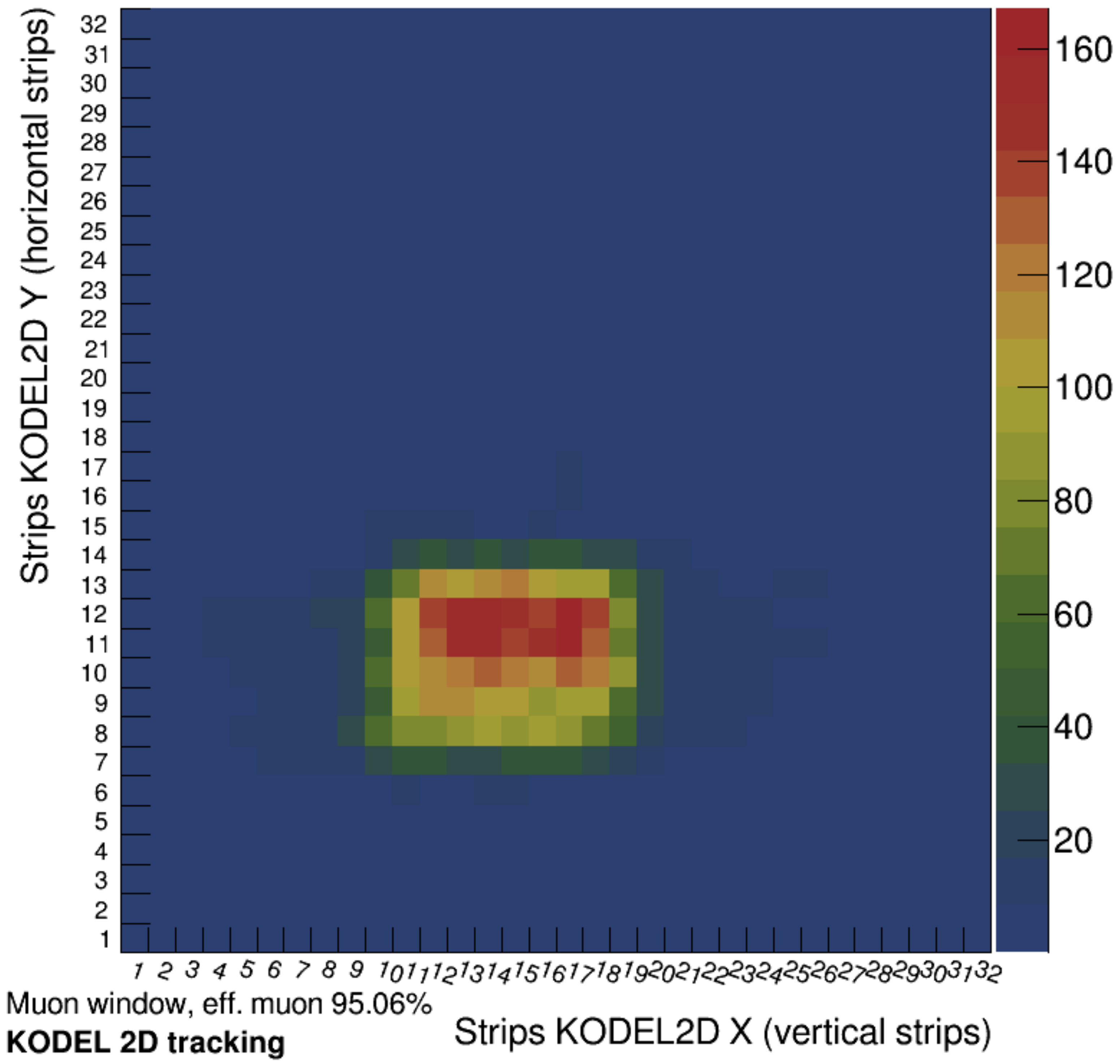
Each dimension has 32 strips, pitch x 1.0 and y 2.0 cm, double gap 1.4 mm thickness

Fixed at WP 7.4 kV with muon eff. of 98 and 95 % (Source OFF)

Tracking chamber
Reference scans

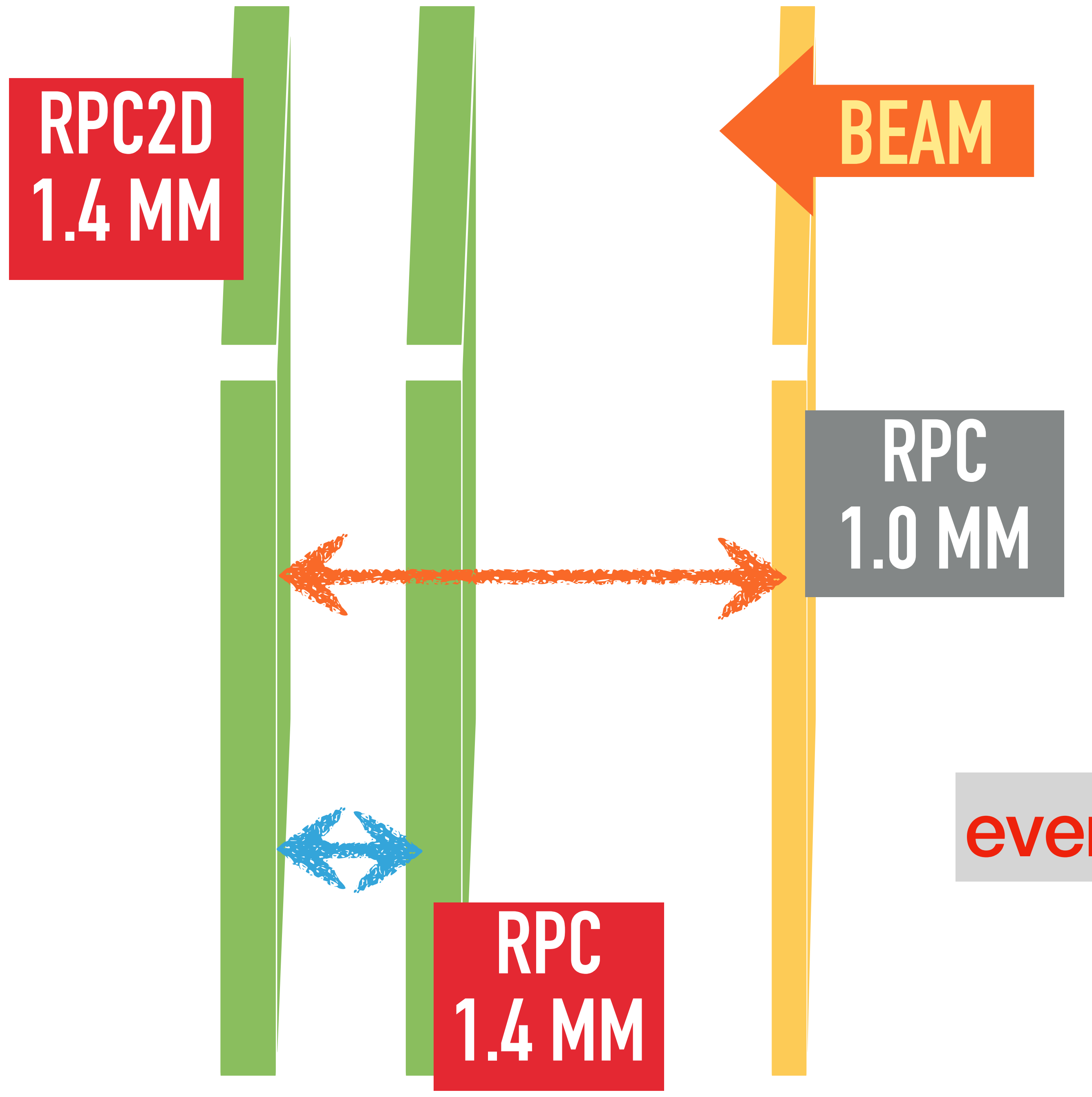




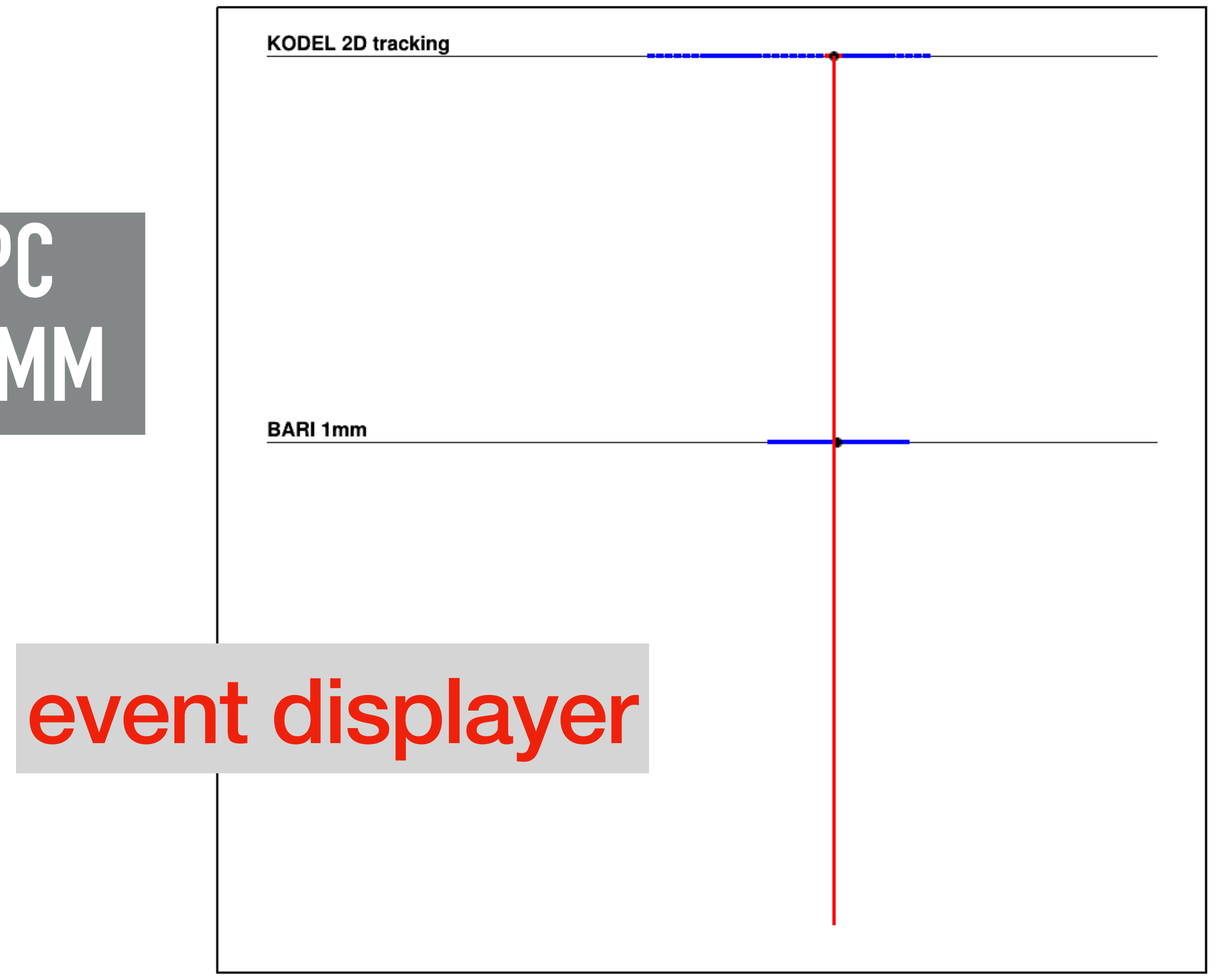


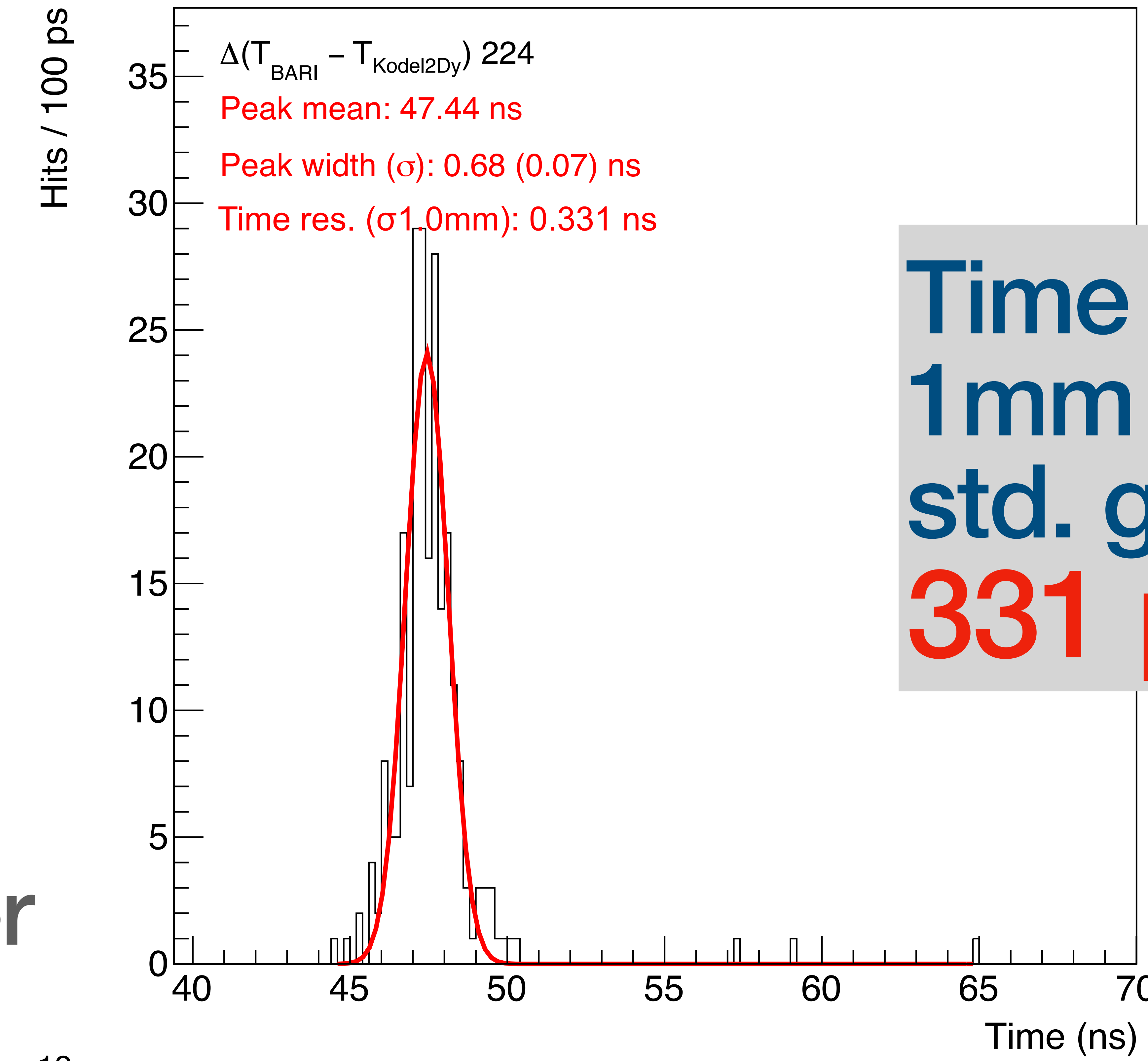
Time resolution measurements

Experimental schema and results



$$\sigma_{1.4mm} = \frac{\sigma_{RPC2D_{1.4}-RPC_{1.4}}}{\sqrt{2}} \Rightarrow \sigma_{1.0mm} = \sqrt{\sigma^2_{RPC2D_{1.4}-RPC_{1.0}} - \sigma^2_{1.4mm}}$$





Time resolution 1mm gap and std. gas mixture 331 ps

Same FEB for all chamber

Analysis cuts

1D tracking using RPC2D chamber

Single strip triggering

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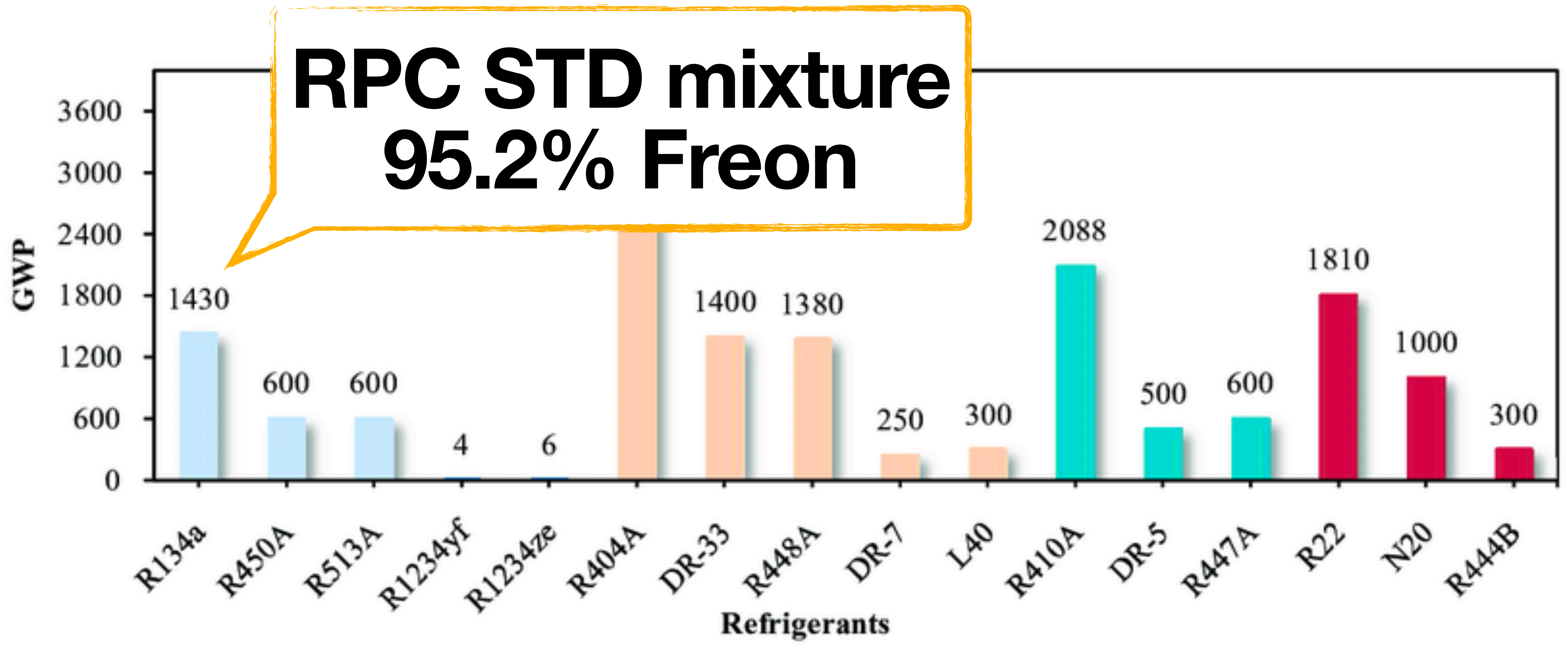
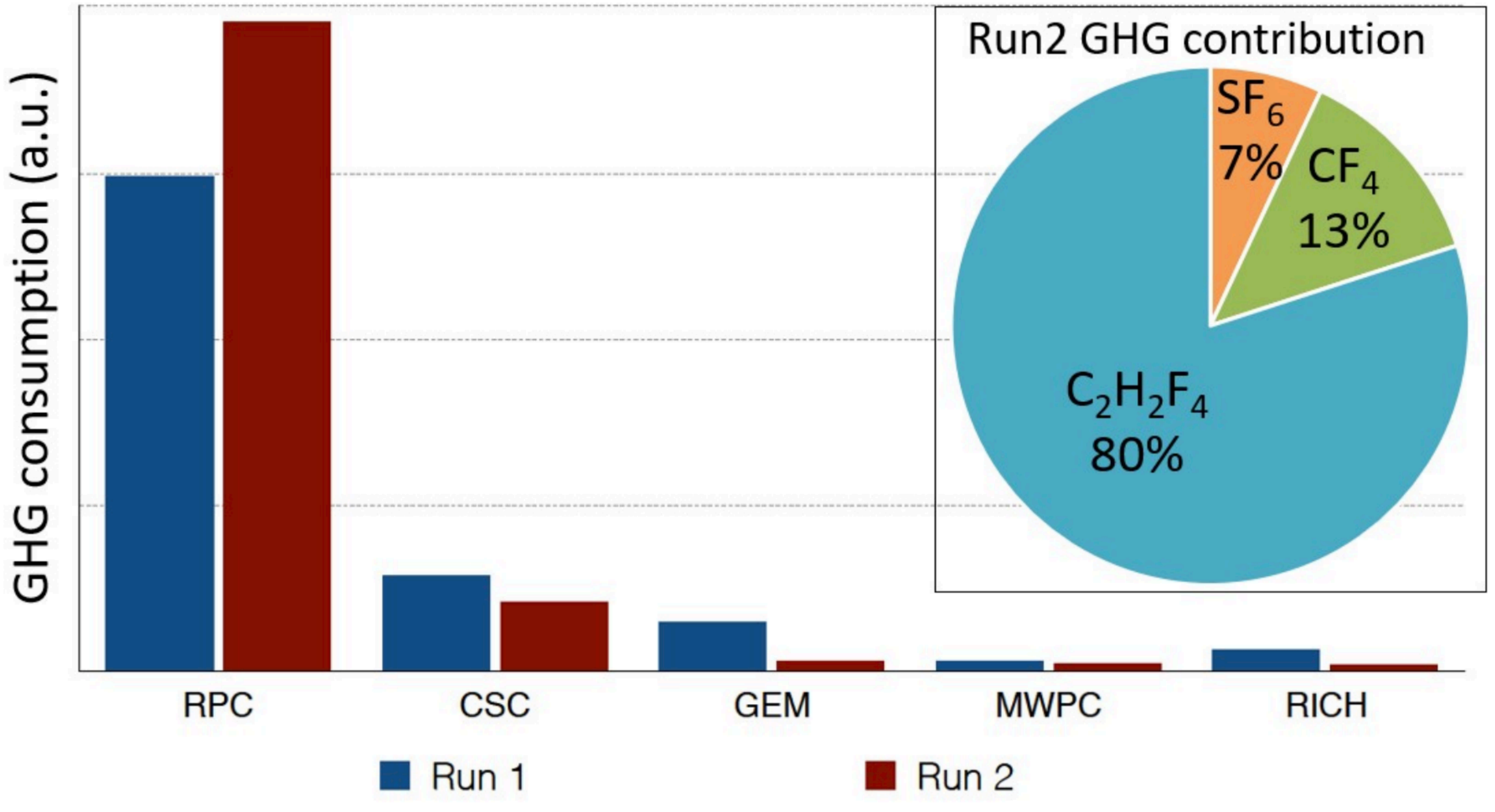
Eco-friendly gas mixture study



Fluorinated greenhouse gases (GHGs) with high Global Warming Potential (GWP) have been limited in EU [EU regulation 517/2014]

CERN is committed to reducing its direct greenhouse gas emissions



Extensive RPC applications (CMS, ATLAS) ➤ higher contribution to GHG consumption

eco-friendly mixtures

	R134a	i-C6H10	SF6	HFO	CO2
STD	95.2	4.5	0.3	-	-
ECO3	-	5	1	25	69
ECO2	-	4	1	35	60

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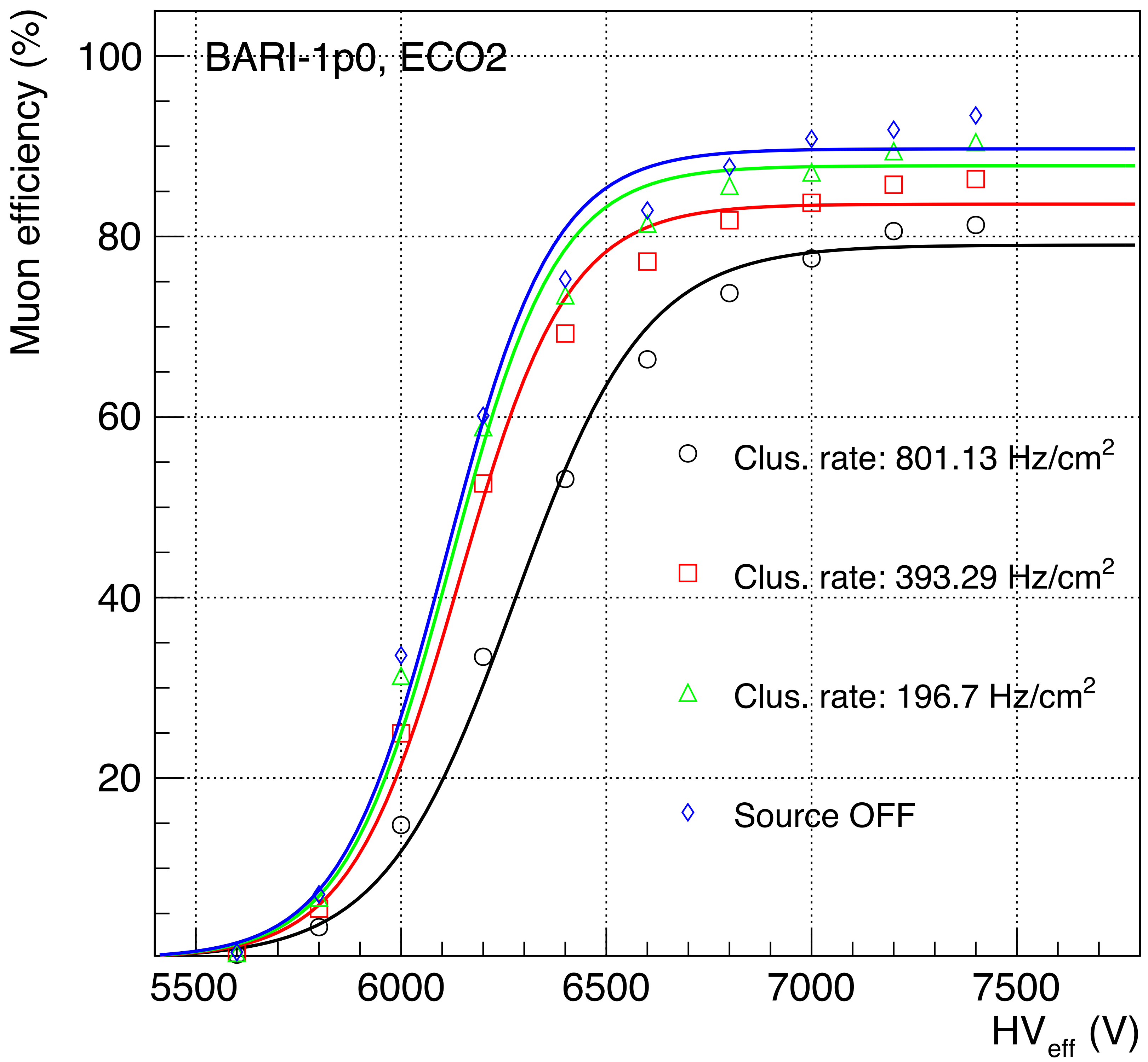
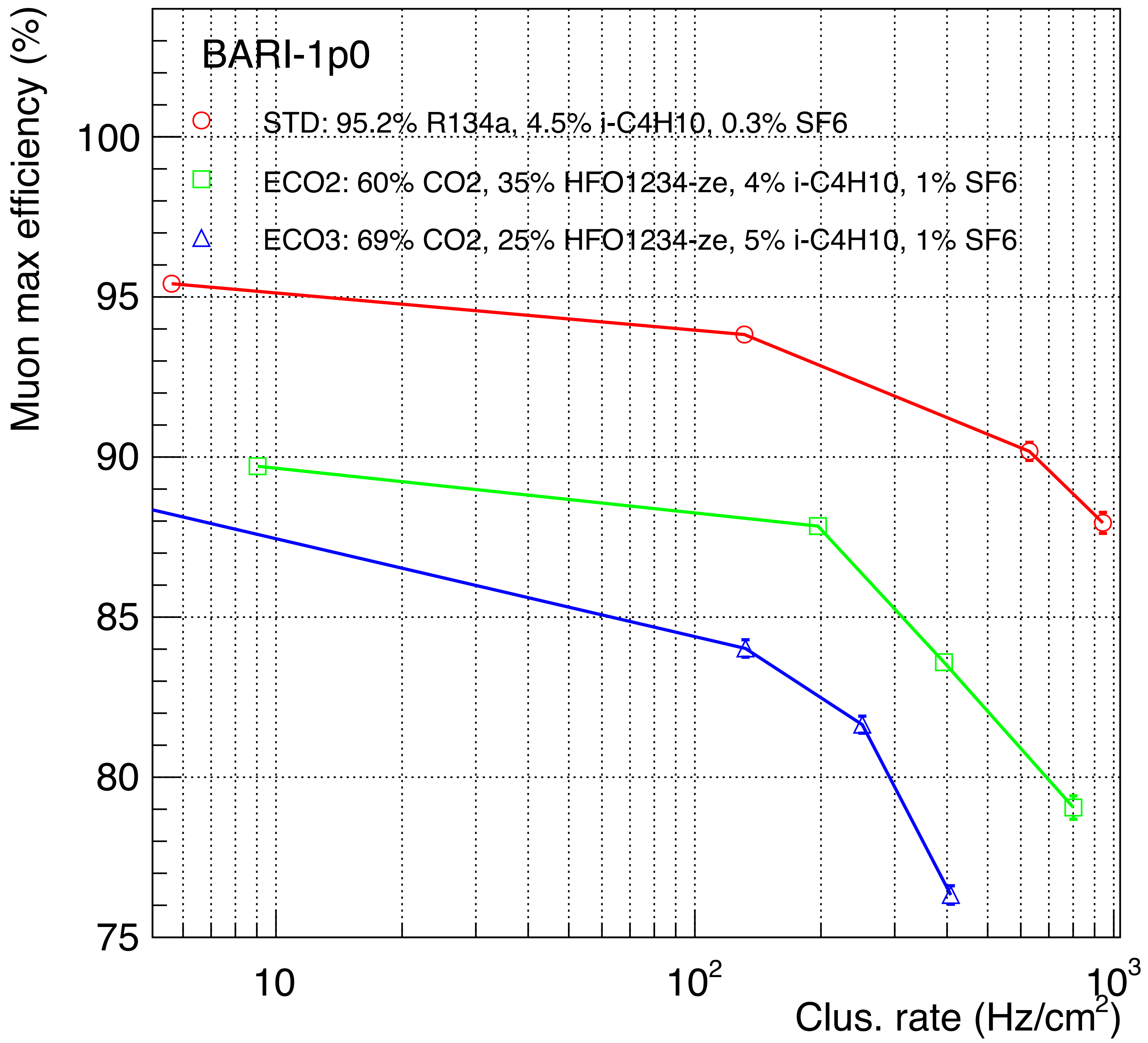
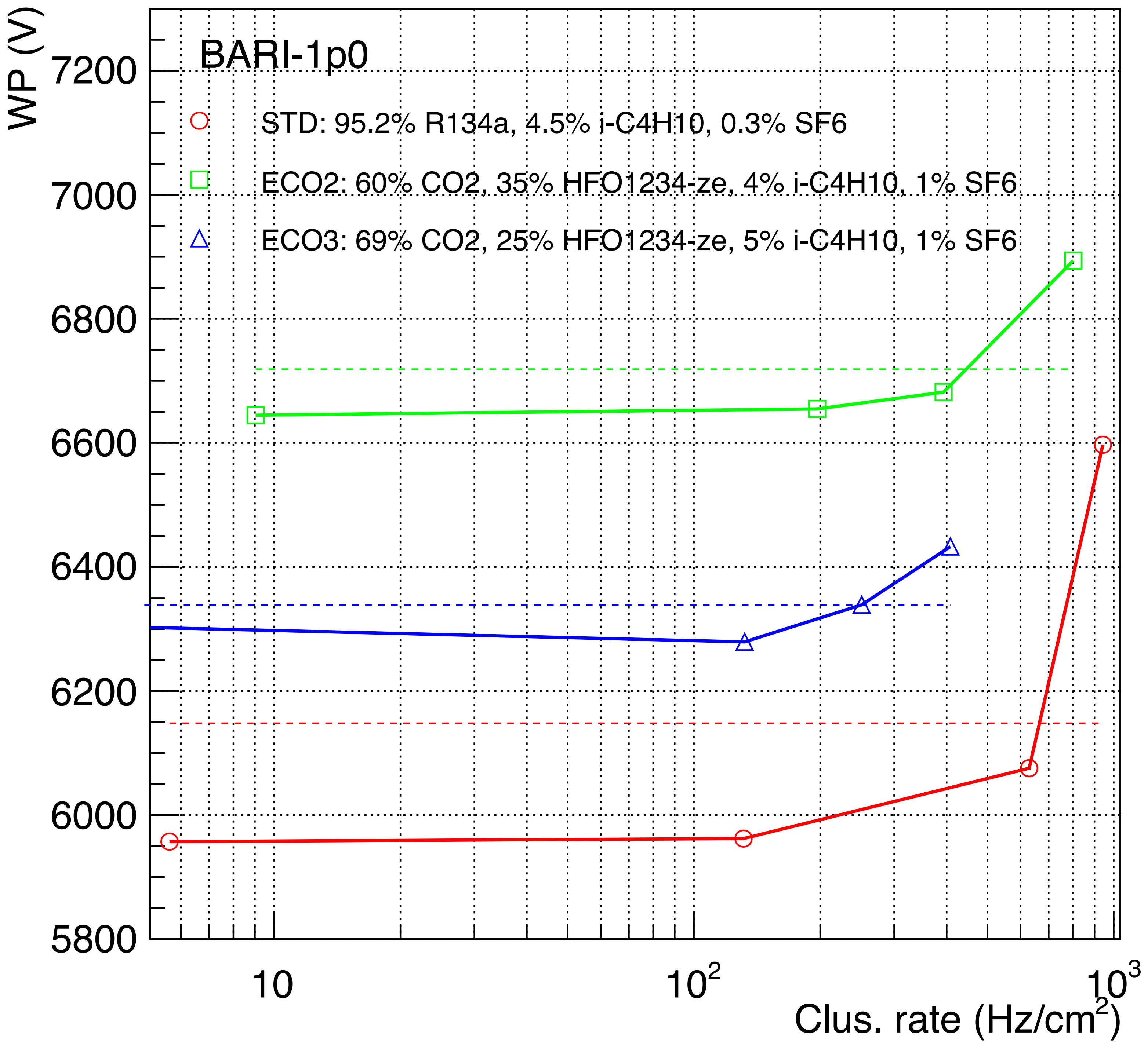
Eco-friendly gas mixture study

Results single gap





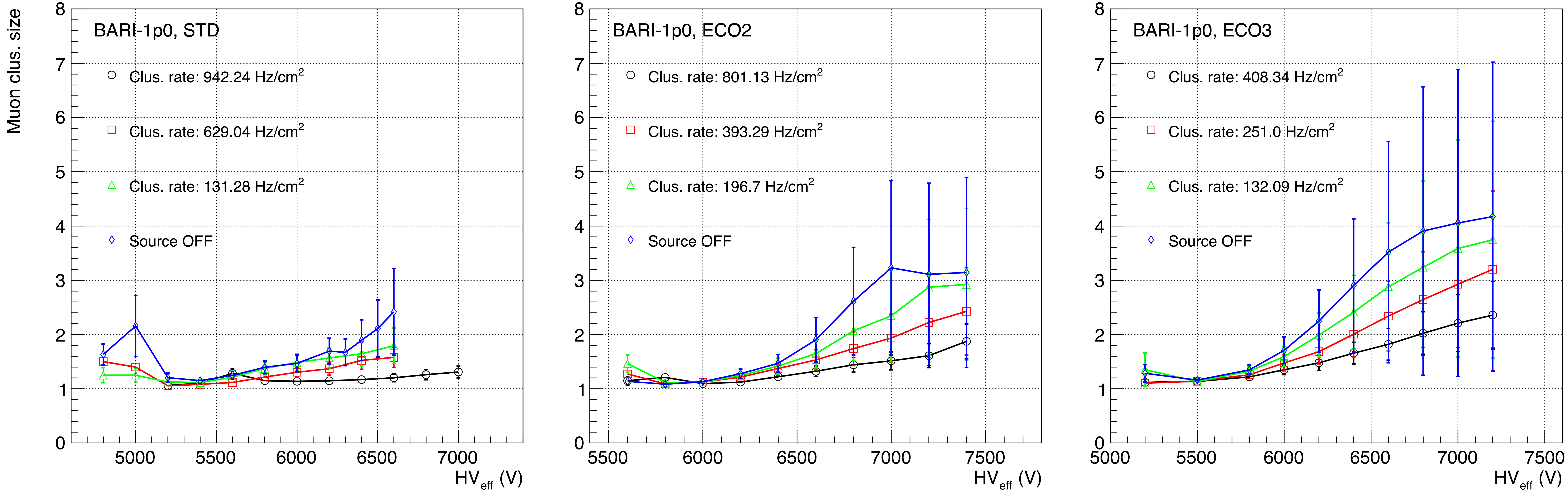


Asymmetric sigmoidal ➤ no charge saturation with HFO-based mixtures

Max eff. ≈95% with STD
ECO2 mix more promising with eff 90-79% till 800 Hz/cm2
WP shift 6.65-6.9 kV for ECO2 and 6.3-6.45 kV for ECO3

Eco-friendly gas mixture study

Results single gap muon clus. size analysis



smaller CLS with ECO2 mix ($CLS_{ECO3}/CLS_{ECO2} \approx 1.3$)

➤ better space resolution

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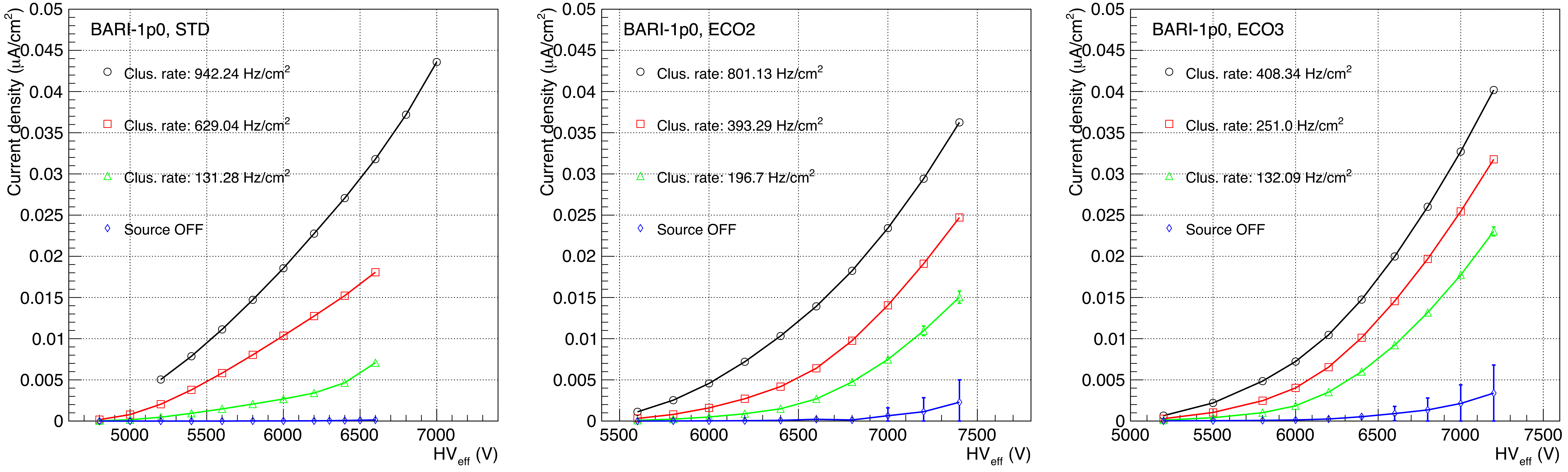
Eco-friendly gas mixture study

Results single gap current plots



Similar currents with STD and ECO2

ECO2 and ECO3 at equivalent rate $I_{ECO3}/I_{ECO2} \approx 1.6$

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Conclusions and next steps

- Fully performant RPC using 1mm gas gap
- Muon efficiency of 92% at WP with high background radiation on 2.2 kHz/cm2 (ex: required for HL phase of CMS)
- Fast conventional RPC with a time resolution of 331 ps
- ECO2 mixture more suitable but still with low efficiency

Next:

- Aging irradiation campaign and new performance analysis
- Space resolution measurements
- New eco-mixture tests

Thanks!

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