Progress in sealed RPC towards outdoor operation

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On Behalf of the RPC R&D group

Fundação
para a Ciência
e a Tecnologia

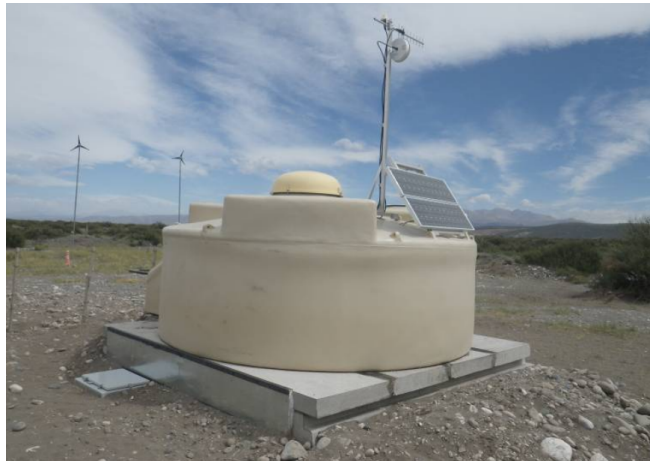
Outlook

- RPC and sealed RPC.
  - Medium size sealed MRPCs. SND@LHC case.
  - Large size sealed MRPCs.
- Characterization of RPCs at high altitude for SWGO.
- Next steps on our road-map.

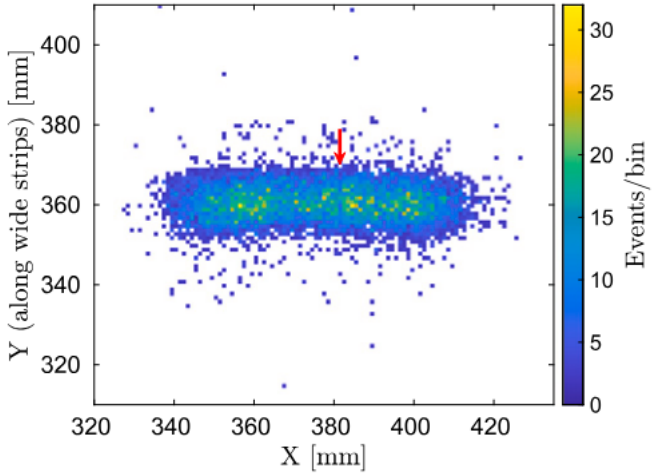
RPC technology.

The **RPC technology** is **mature** and widely adopted **worldwide**.

- Excellent (high and stable) **efficiency** **> 98 %**
- Very good **timing resolution** **~ 300 – 50 ps**
- **2D spatial resolution** (depends on the readout) **~ 0.6 – 0.05 mm**
- **Very low-cost for large-scale** deployments
- **Outdoor capable**

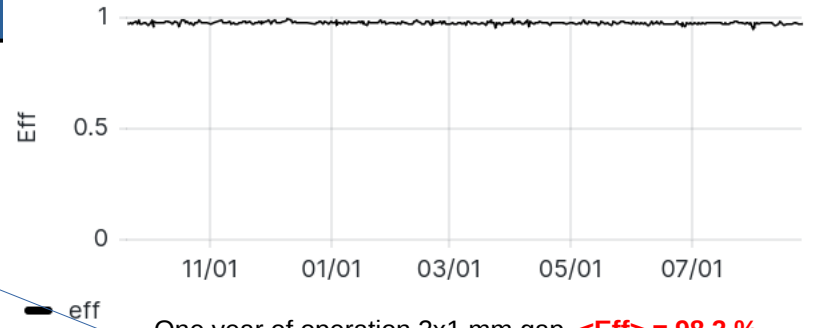


RPC deployed on the AUGER site under water Cherencov tank

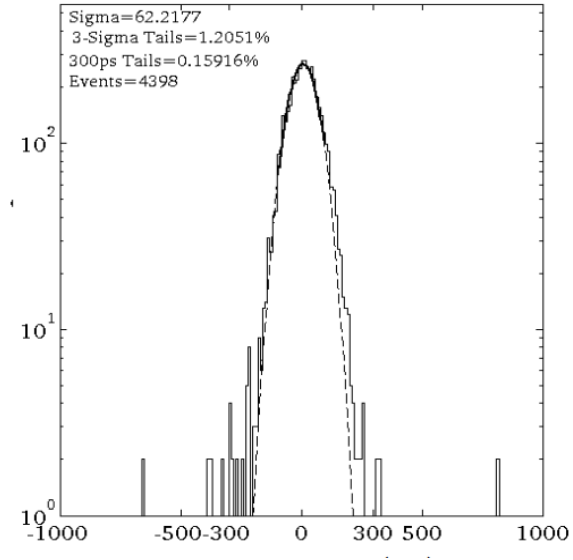


2D shadow of a scintillator. 0.3 mm spacer visible
12x0.3 mm gap, 1.2 m²
σ_t = 70 ps, σ_x < 0.6 mm

10.1016/j.nima.2025.170466



One year of operation 2x1 mm gap. **<Eff> = 98.2 %**
Cosmic ray experiment (indoor)



Time difference (ps)

Reference detector (34 ps) not substracted.
12x0.3 mm gap **σ_t = 51 ps**

10.1088/1748-0221/15/10/C10017

Sealed RPCs.

- **Sealed RPC.** RPCs that contain gas but are hermetically sealed after construction, similar to the Geiger-Müller detectors.

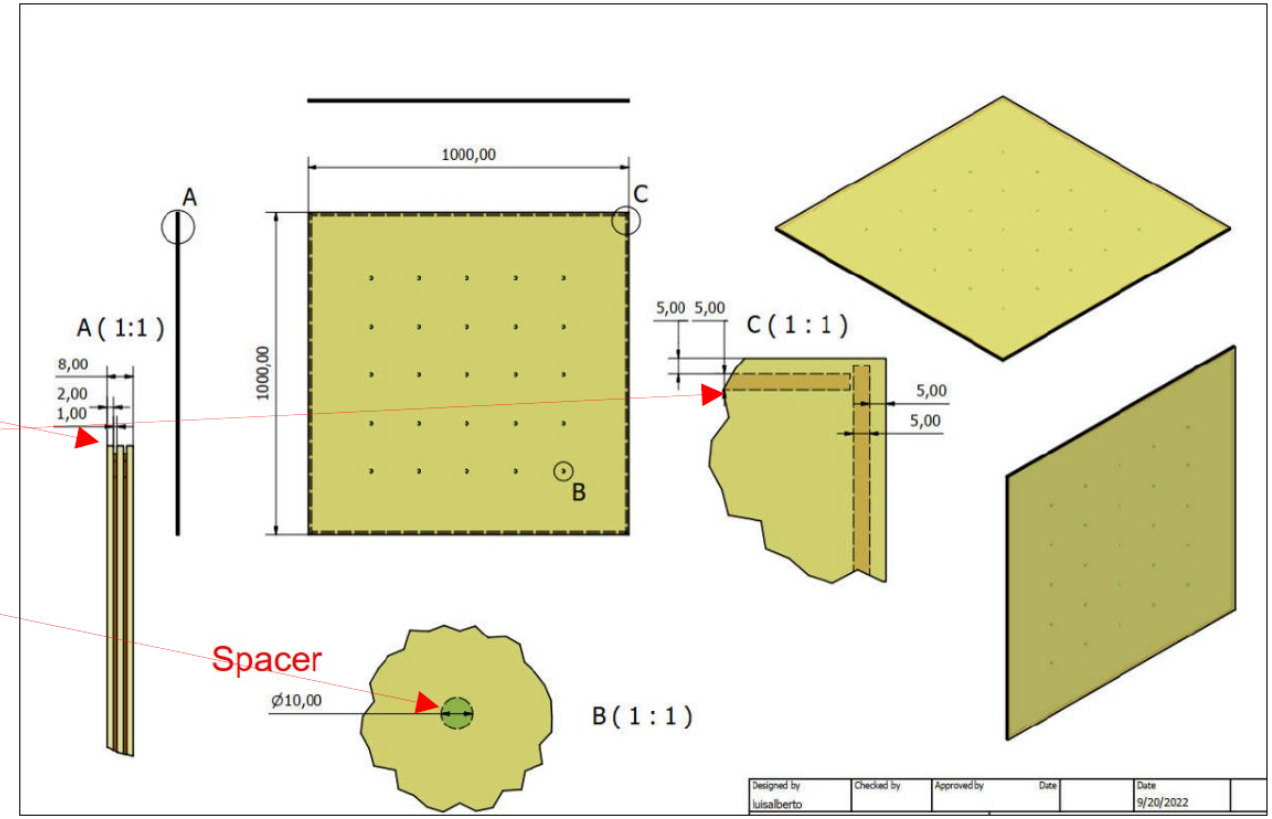
- **Improved portability and simplified maintenance** => muon tomography, installation of remote systems (Cosmic Ray experiments), hospitals?.
- Without gas system/consumption the **system is even much cheaper.**
- **Similar performance?** without gas supply.

Sealed RPCs . Concept.

Very **simple concept.** Similar construction compared to regular MRPCs but **gas can only be in contact with glass** (very stable and inert material).

Everything made with glass

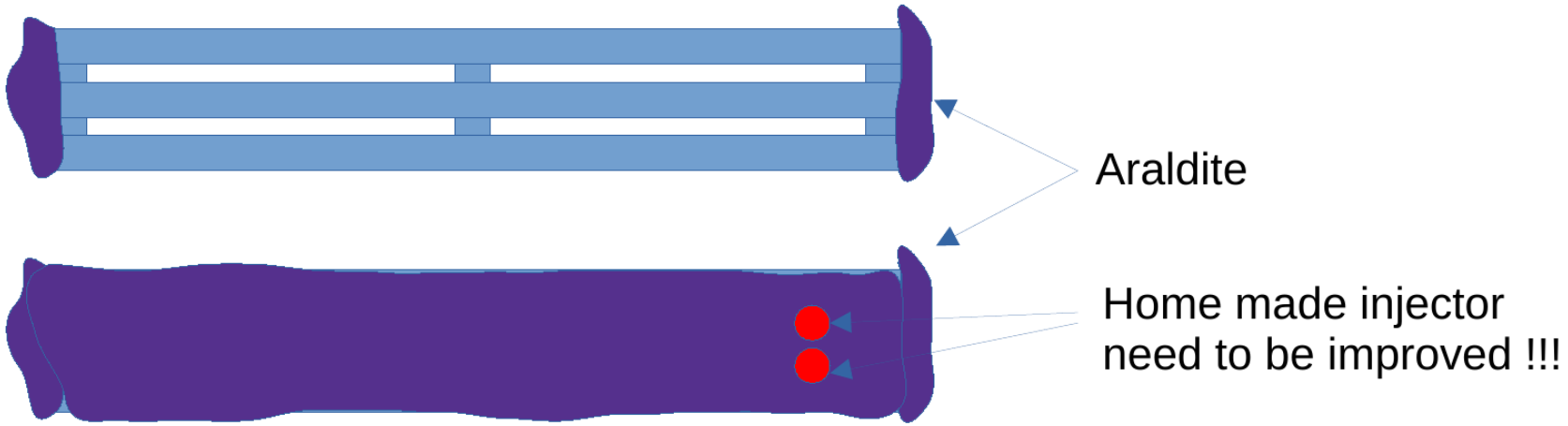
- MRPC electrodes.
- Peripheral spacers.
- Central spacers.



RPC technical drawings

Sealed RPCs . Concept.

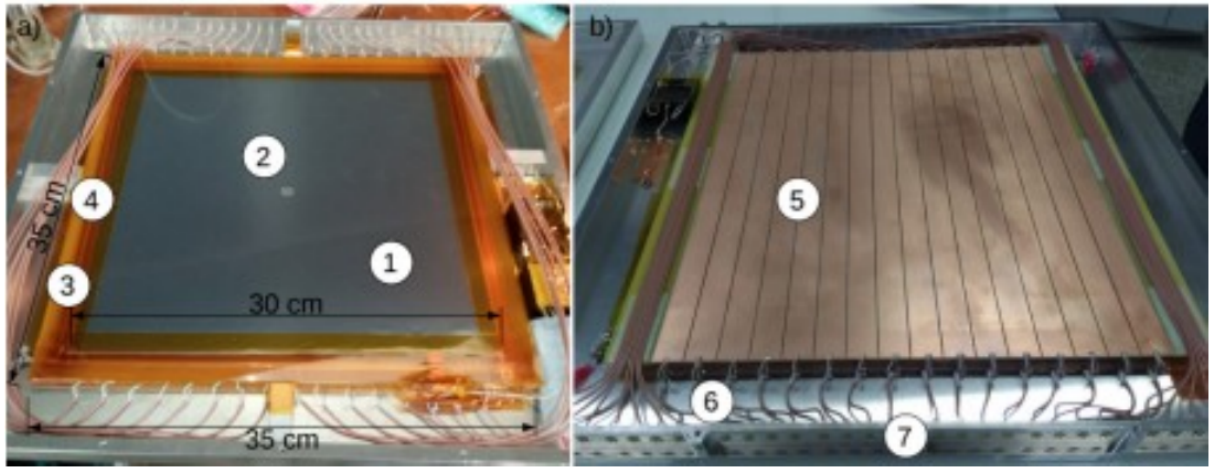
Very **simple concept.** Similar construction compared to regular MRPCs but **gas can only be in contact with glass** (very stable and inert material).



All the **glass pieces** are **stacked together and glued** (Araldite) **laterally.** One inlet and one outlet are left for each gas gap.

Medium size 0.1 m² sRPCs telescope.

- Four sRPC planes ~50x50x50 cm³
- MRPC active area 30x30 cm²
- Different gap widths for testing

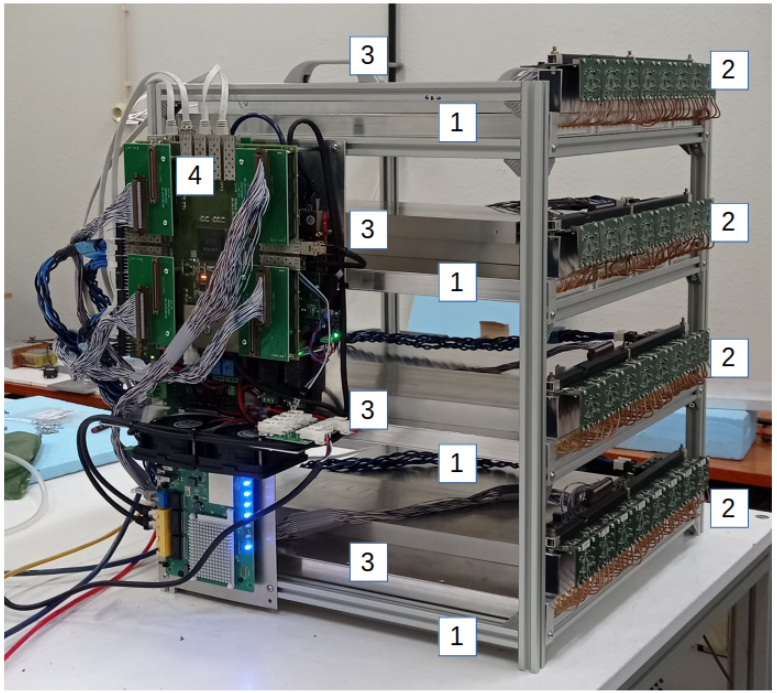


a) 1- HV layer, 2- Circular spacer in the center of the active area, 3- Strip spacer all around de the periphery and 4- Mylar and Kapton layers.
b) sRPC plane showing: 5- Readout strip plane, 6- Coaxial cables and 7- MMCX RF feedthrough connectors.

98 % C2H2F4 + 2 % SF6

10.1016/j.nima.2025.170396

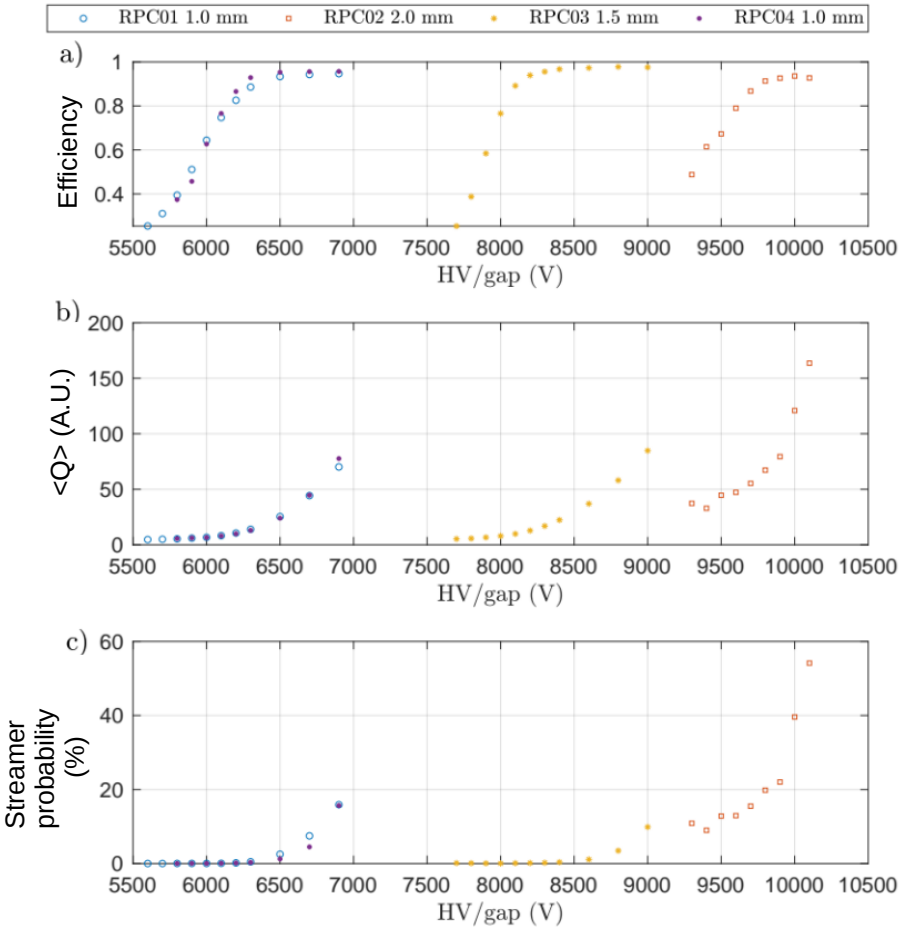
- ~ 60º opening angle, tracking capabilities ~ 1 cm²
- 300 ps timing precision
- Portable
- Autonomous operation

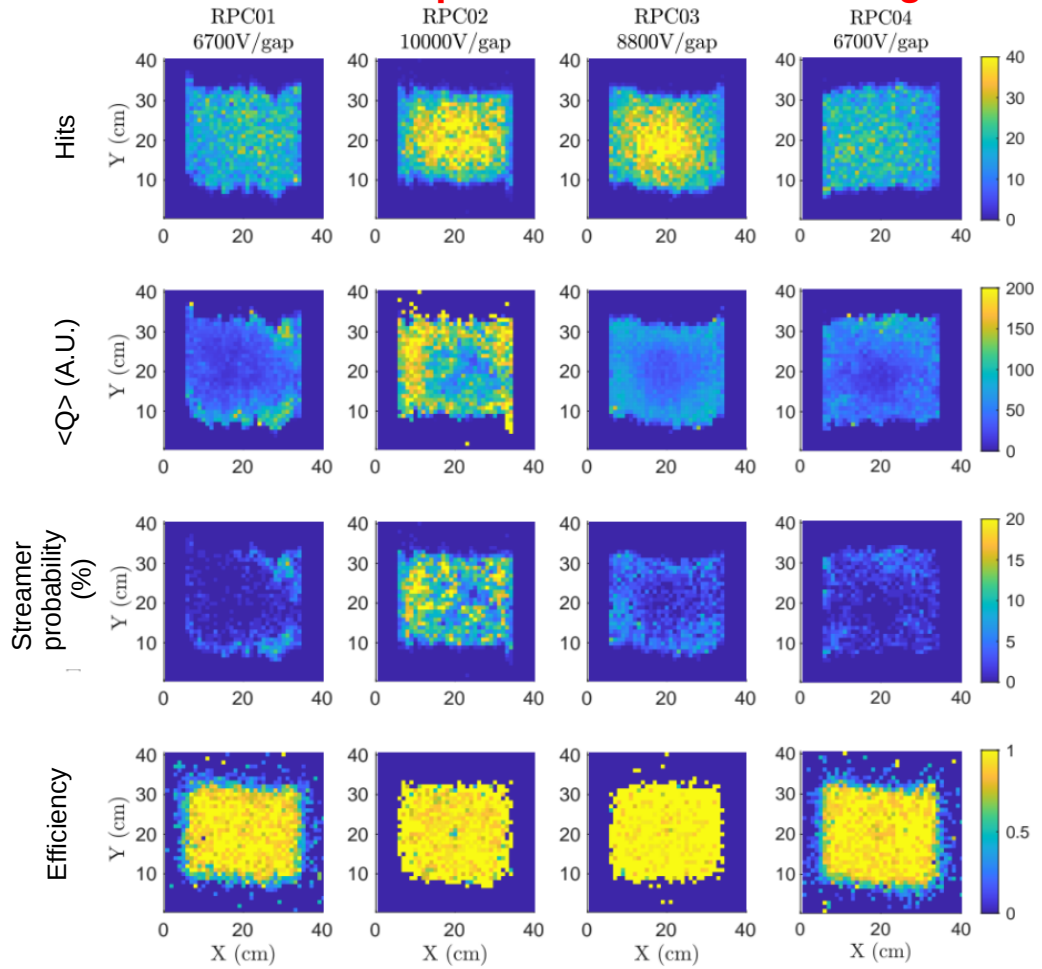


1- sRPC planes, 2 – FEE used to readout the signals from sRPC, 3 – High Voltage PS system, 4 – DAQ, computer and power supplies.

Medium size 0.1 m² sRPCs telescope.

Performance similar to what could be expected from such a detector operated in a continuous gas flow





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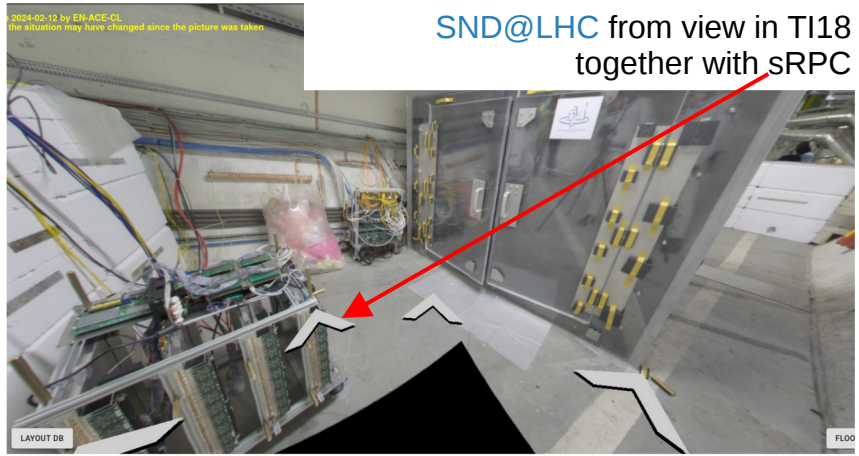
Medium size 0.1 m² sRPCs telescope @ SND@LHC experiment.

SND-LHC Scattering and Neutrino Detector at the LHC is a recently approved, compact and stand-alone experiment to perform **measurements with neutrinos produced at the LHC** in a until now unexplored pseudo-rapidity range of $7.2 < \eta < 8.4$ complementary to all the other experiments at the LHC, including FASER.

SND@LHC rear view in TI18

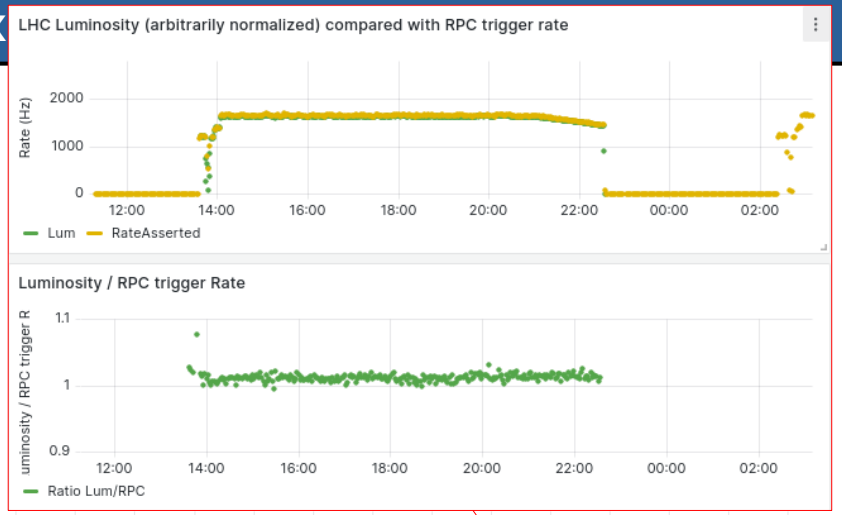
SND@LHC from view in TI18 together with sRPC

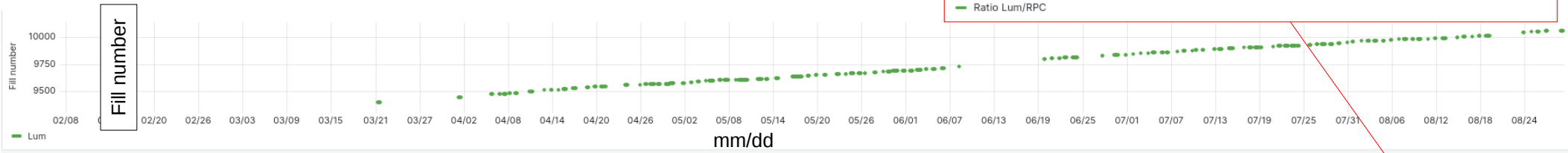


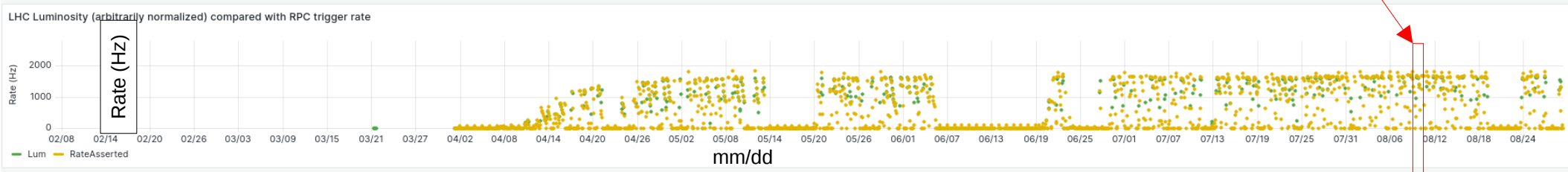
Medium size 0.1 m² sRPCs telescope @ SND@LHC ex

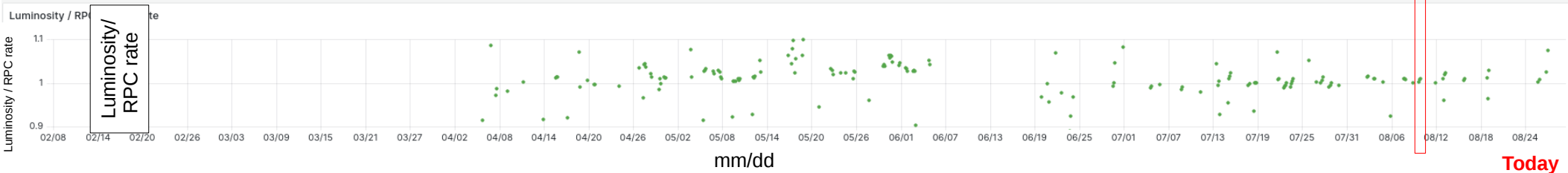
Installation performed on Feb 2024
Full operative 24/7 since then.

Luminosity (ATLAS) and raw trigger rate follow same trend. Ratio ~ 1.
No signal of degradation.
Raw data now correction applied.

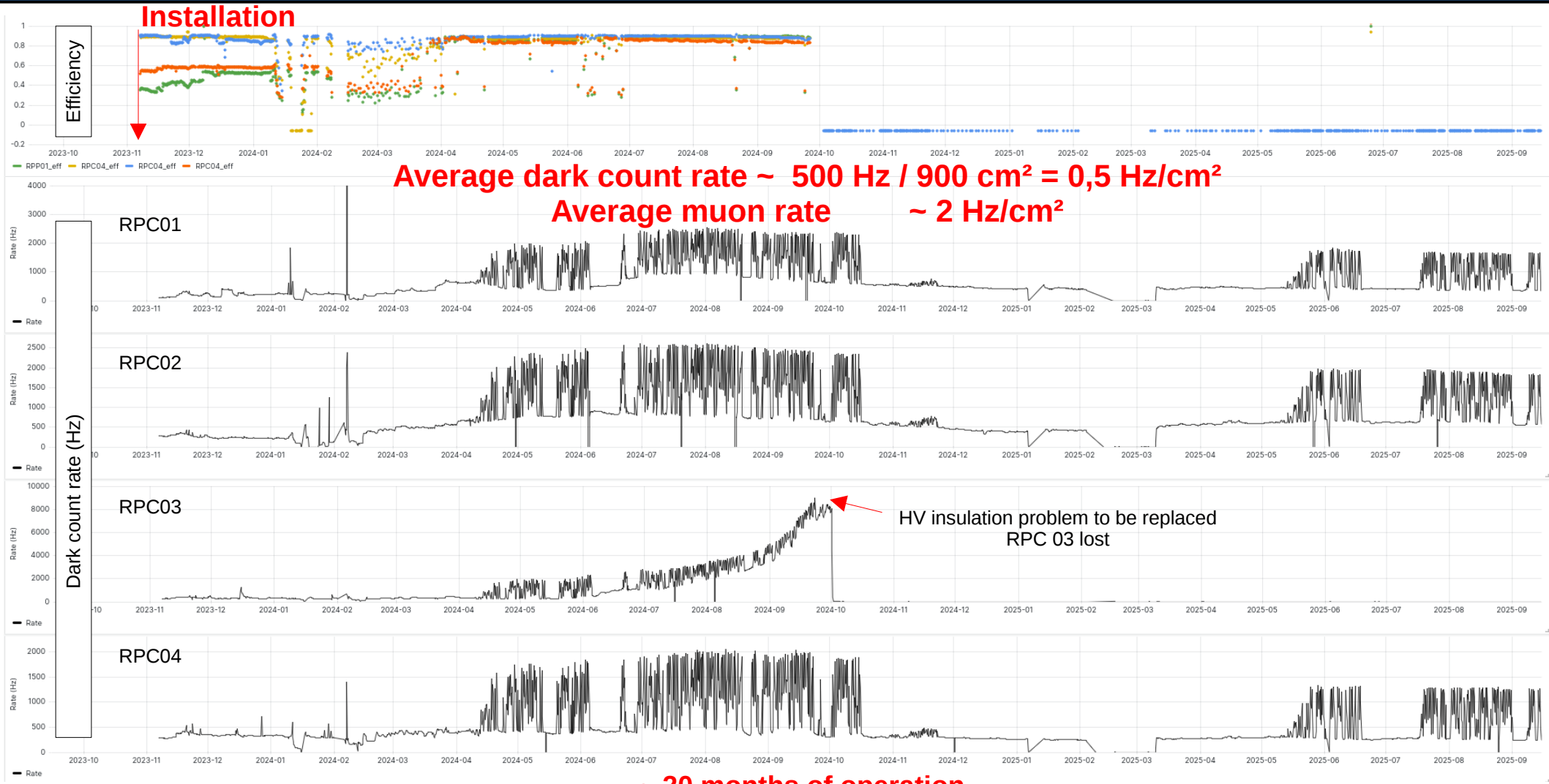








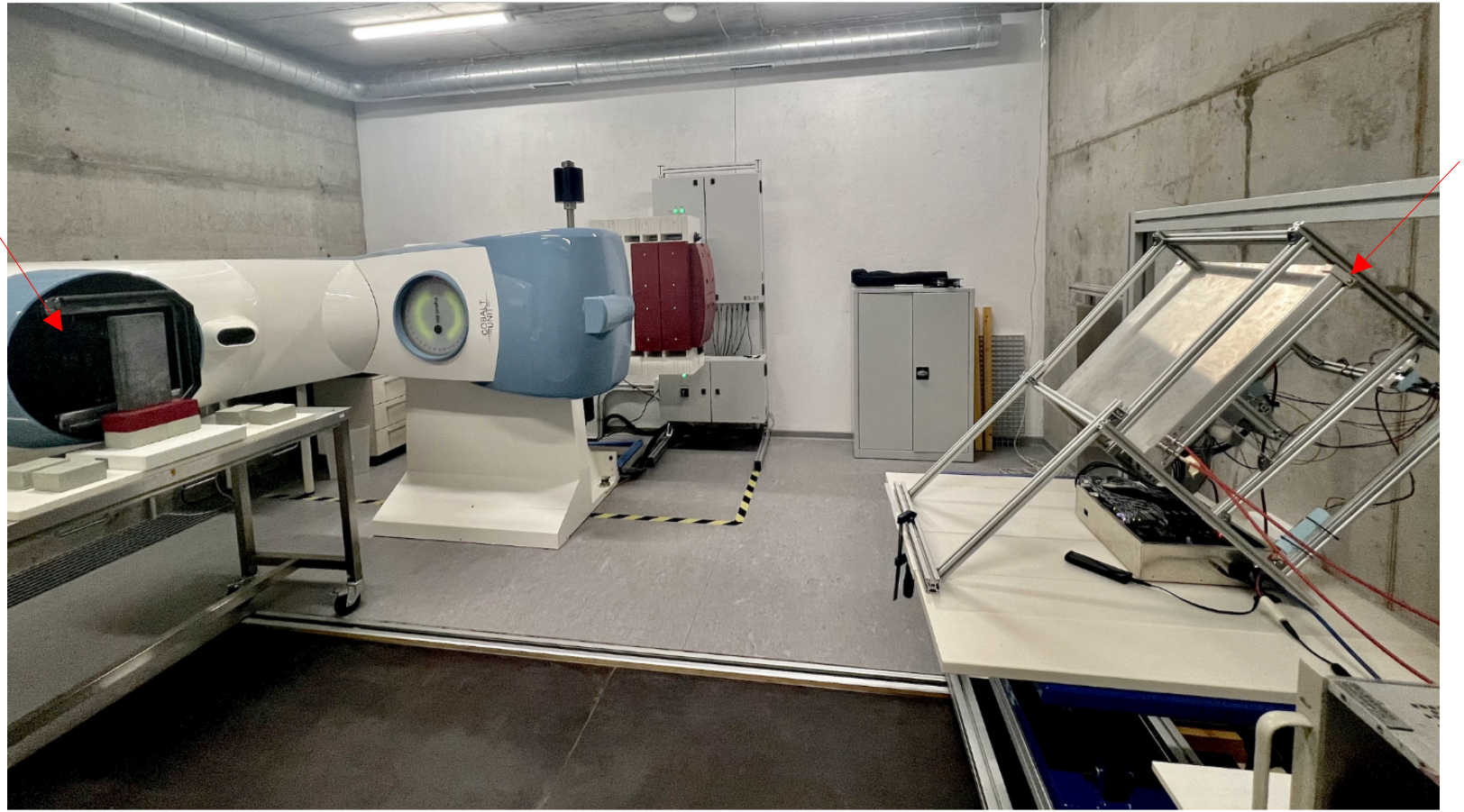
Medium size 0.1 m² sRPCs telescope @ SND@LHC experiment.



Medium size 0.1 m² sRPC at irradiation facility.

10.1016/j.nima.2025.170743

Irradiation facility @ Santiago de Compostela



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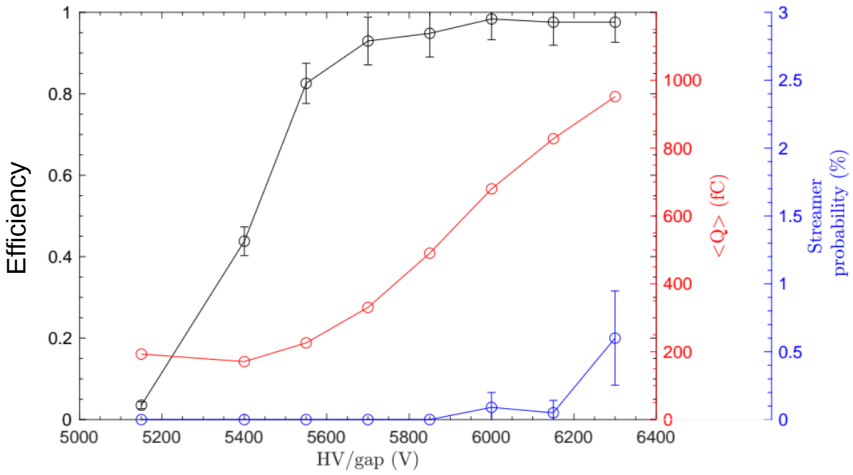
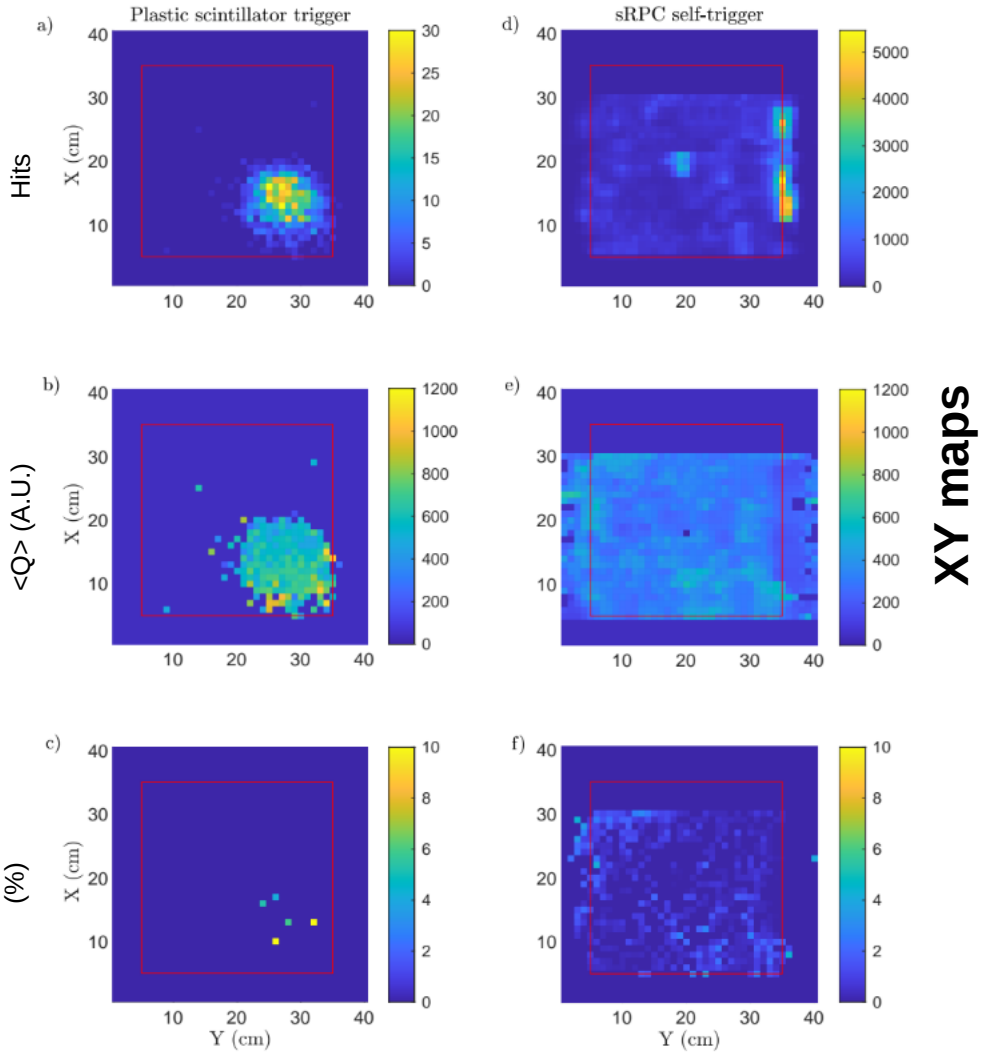
10.1016/j.nima.2025.170743



Performance similar to regular (gas flow) RPCs

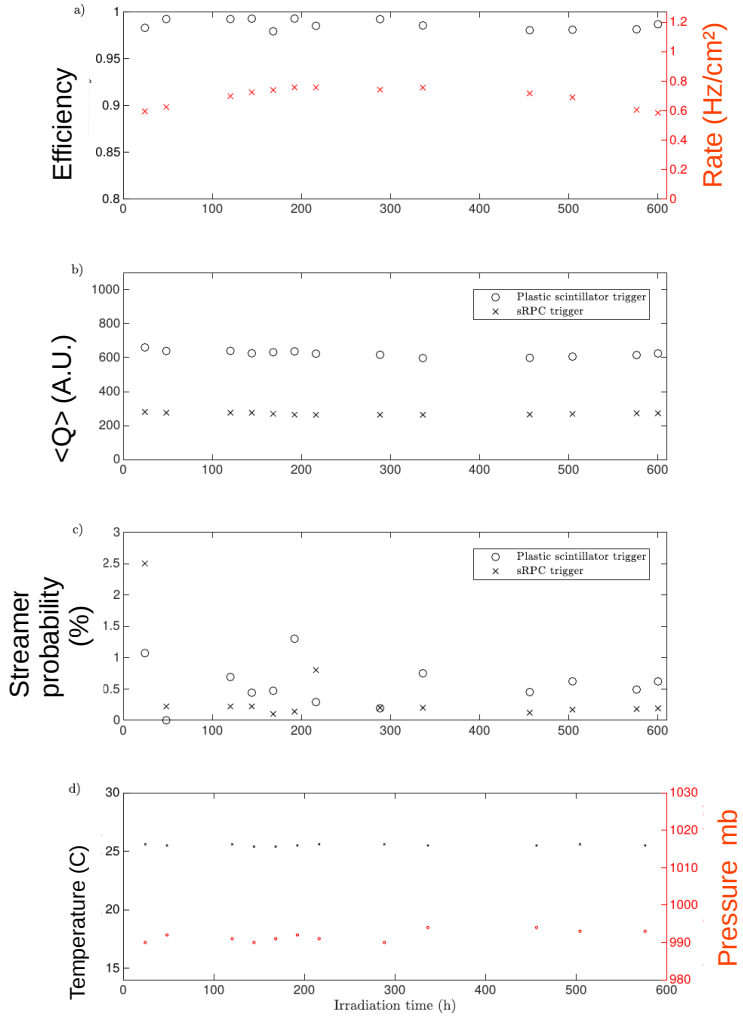
Cosmic trigger **Self trigger**



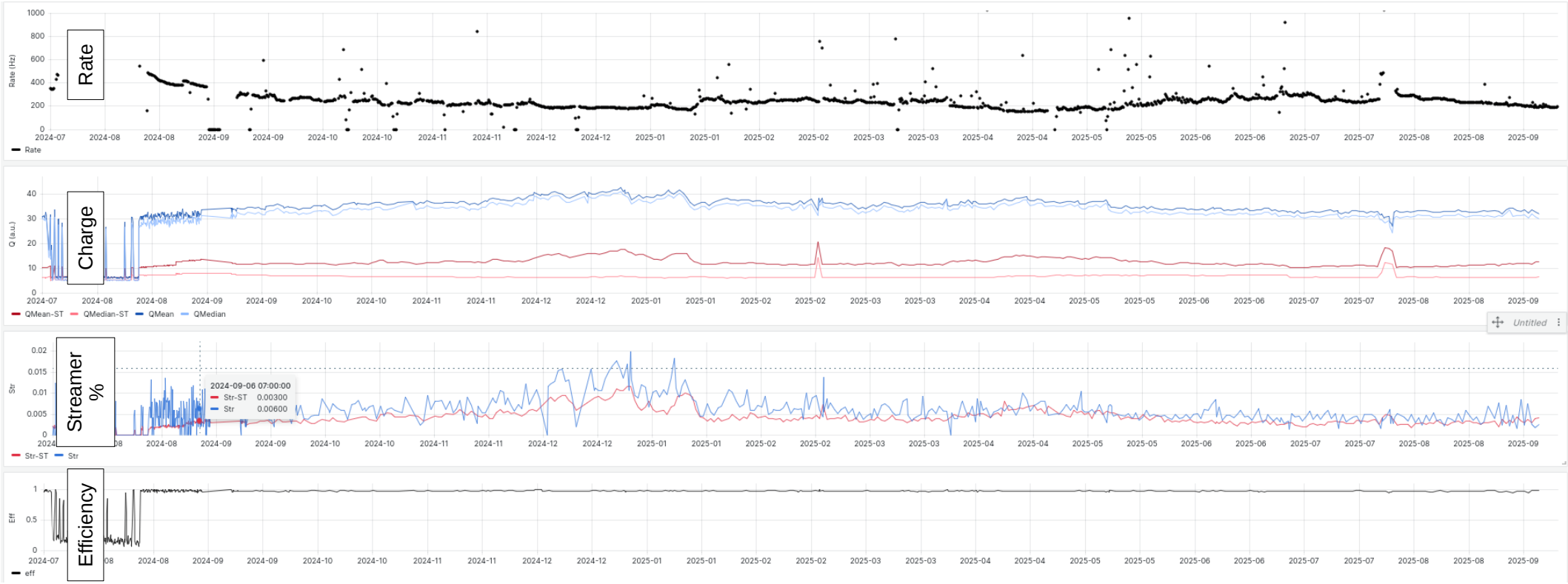
Medium size 0.1 m² sRPC irradiation facility.

Irradiation during 24 days @ 60 Hz/cm²

Corresponds to **~ 4 years of operation** in a Cosmic Ray experiment



Medium size 0.1 m² sRPC irradiation facility.



~ 12 months of operation indoor after irradiation

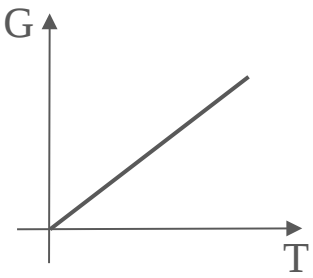
Medium size 0.1 m² sRPC irradiation facility.

Stable **efficiency ~98.2 %,** residual **correlation** of charge with **P and T well understood**

Non-sealed RPC

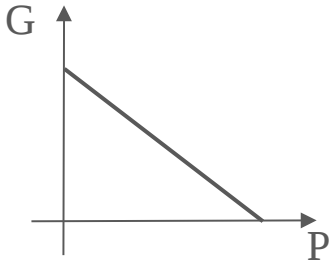
- **For Pressure and Volume constant:**

$$T\uparrow:\ n\downarrow N\downarrow \frac{E}{N}\uparrow G\uparrow$$



- **For Temperature and Volume constant:**

$$P\uparrow:\ n\uparrow N\uparrow \frac{E}{N}\downarrow G\downarrow$$

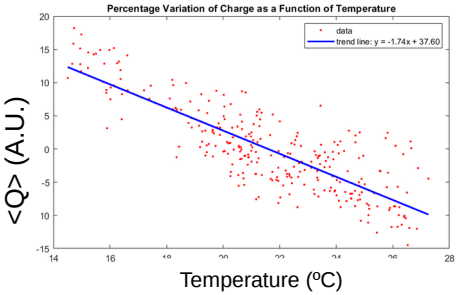


**** E = V/d ; G ~ E/N**

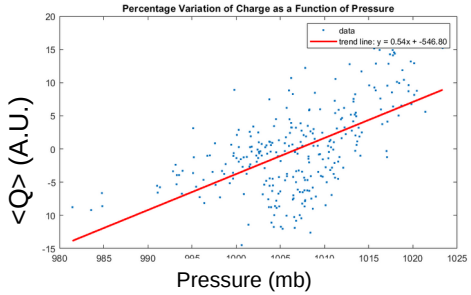
Sealed RPC

$$T\uparrow:\ P_{in}\uparrow V_{in}\uparrow d\uparrow E\downarrow G\downarrow$$

$$P_{out}\uparrow:\ P_{in}\uparrow V_{in}\uparrow d\downarrow E\uparrow G\uparrow$$



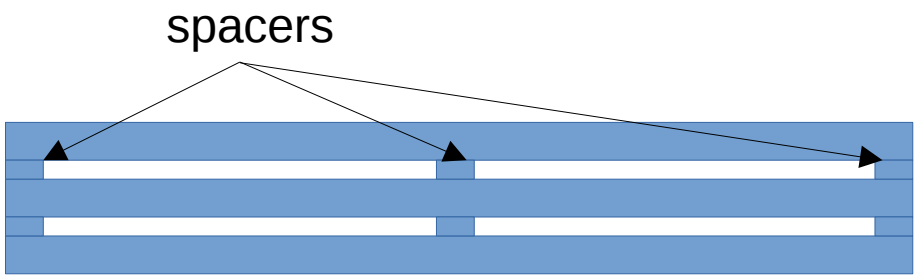
Correlation between Temperature and Charge (y = - 1.74x +37.60)



Correlation between Pressure and Charge (y = 0.54x - 546.80)

Medium size 0.1 m² sRPC irradiation facility.

Cross-section of
a sRPC chamber



3 glass electrodes
2 gas gaps

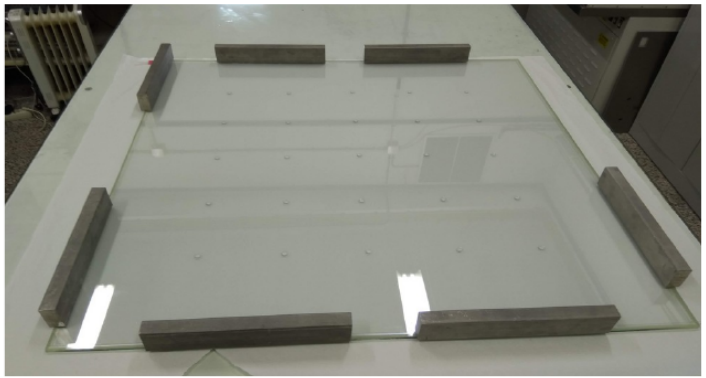
P_{atm} decreases
T increases
the chamber gaps are expanded

P_{atm} increases
T decreases
the chamber gaps are compressed

Modification of the chamber volume => gain, due to changes in P_{atm} and T

Large size 1 m² sRPC.

Assemble process

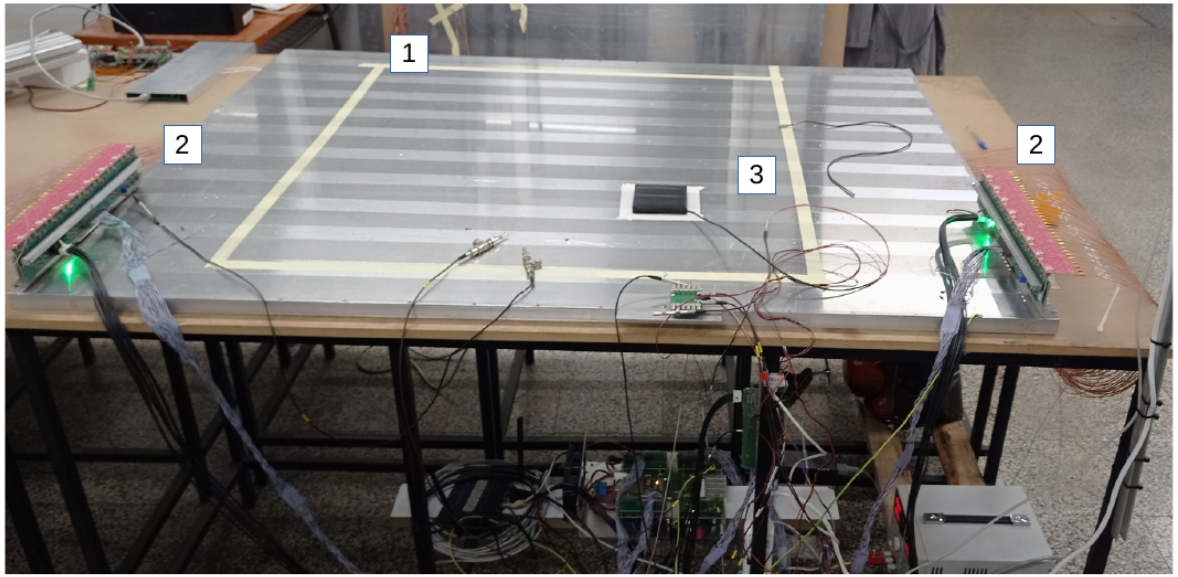


Multi-gap assembly: 5x5 spacer matrix + peripheral strip all around the gaps for sealing.

98 % C2H2F4 + 2 % SF6

Large area implementation => 1 m².
2 x 1 mm multi-gap.

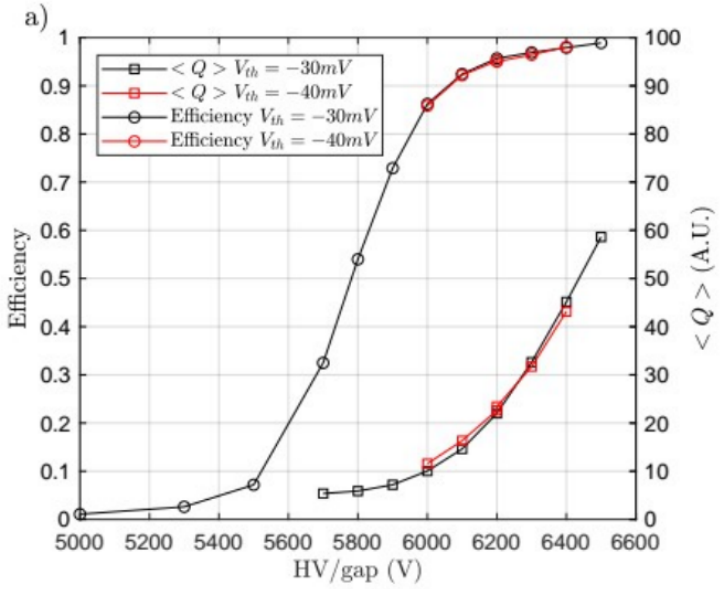
Readout by strips + fast FEE in both sides.

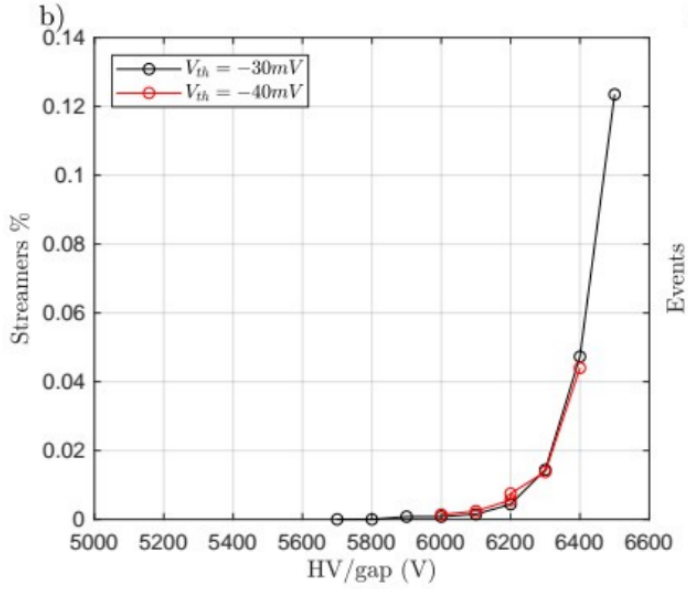


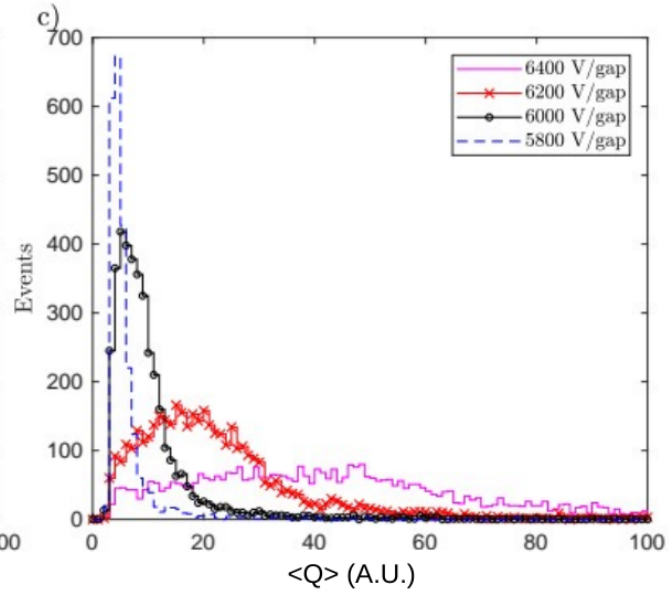
Experimental setup: 1- Active areas of sRPC, 2- FEE, 3- Small muon telescope based on Scintilator + SiPM readout.

Large size 1 m² sRPC.

Performance similar to what could be expected from such a detector operated in a continuous gas flow, efficiency higher than 95 % and streamer percentage below 1 %.

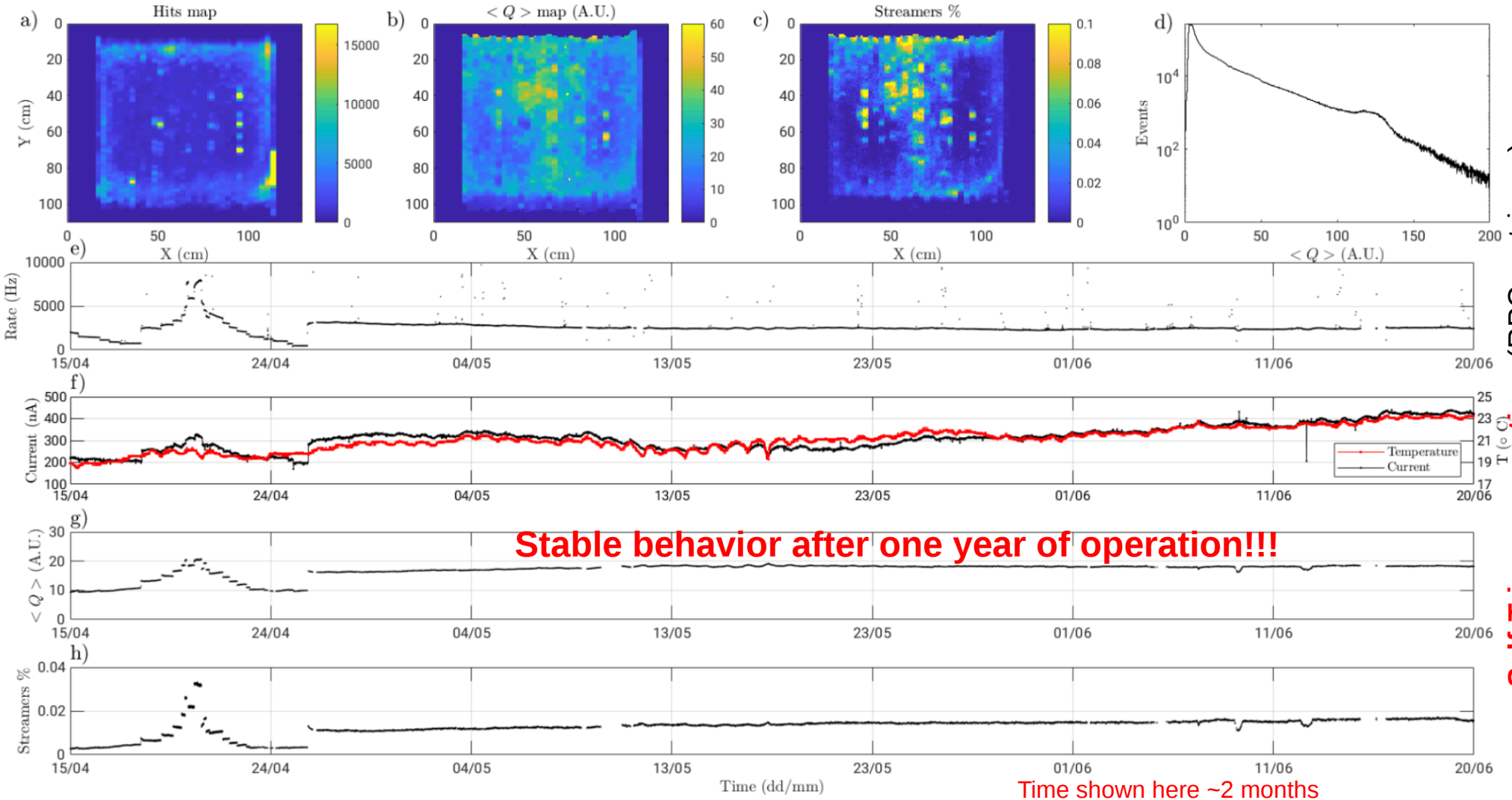






Eur. Phys. J. Plus 138, 1021 (2023)

Large size 1 m² sRPC.

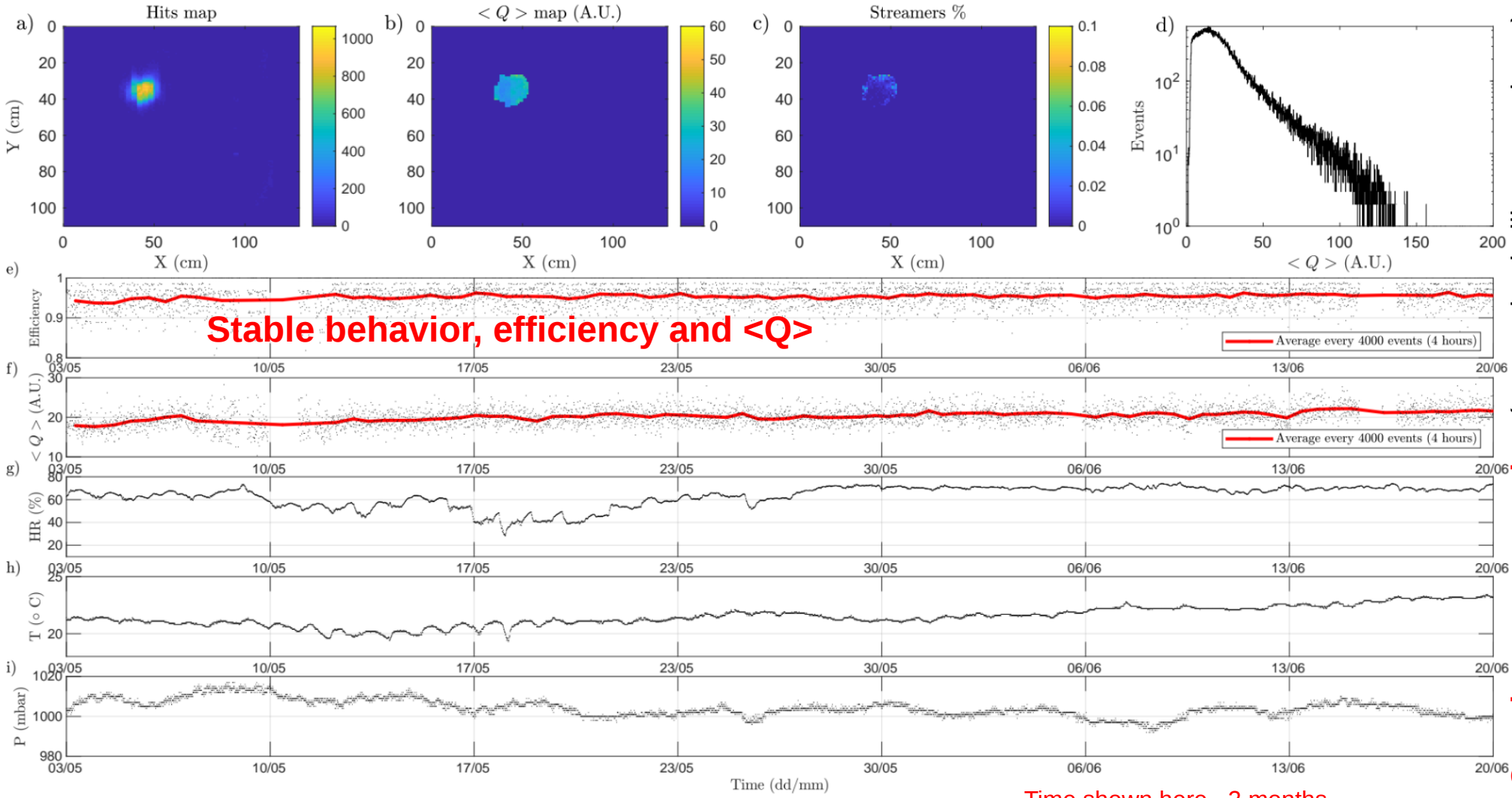


Stable behavior after one year of operation!!!

Time shown here ~2 months

Self-Trigger operation (RPC as trigger)

Large size 1 m² sRPC.



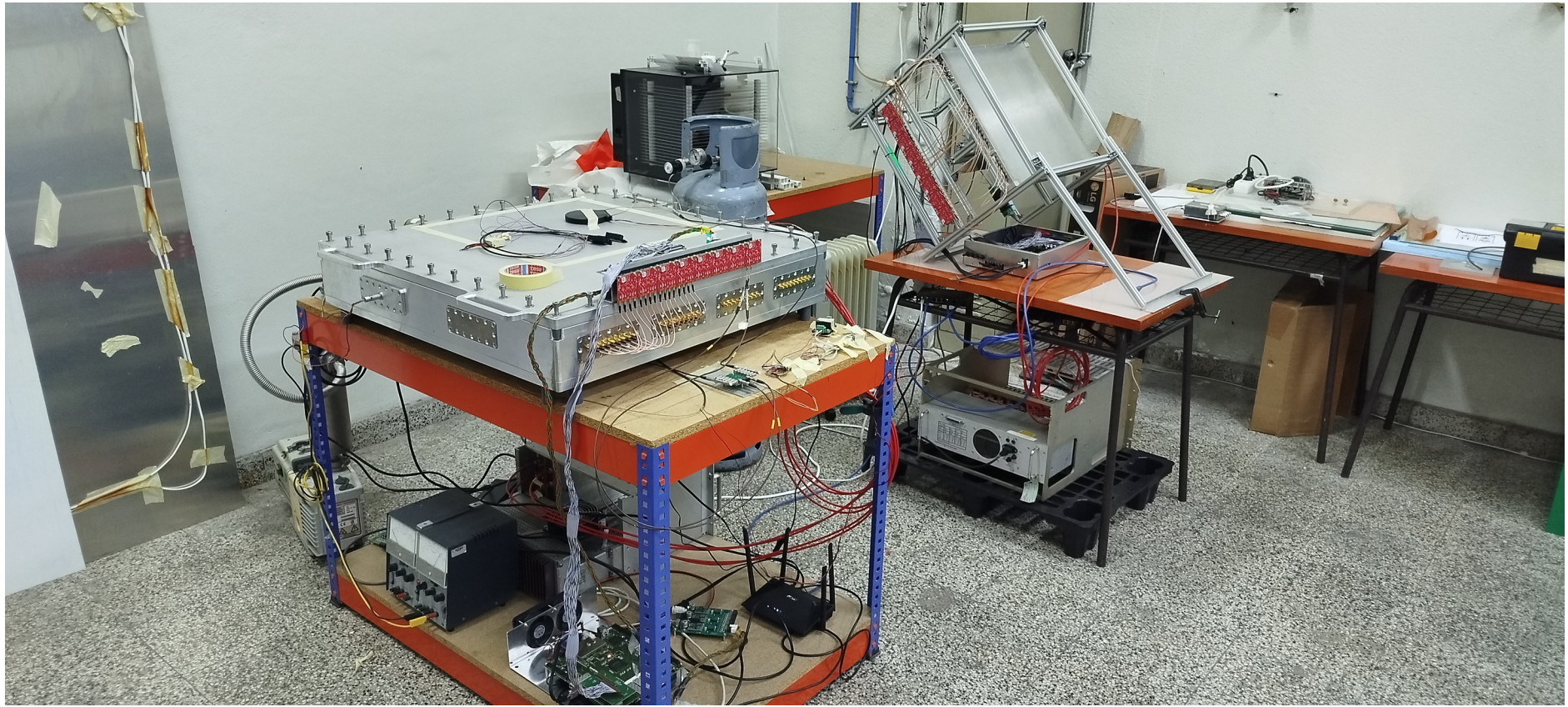
Stable behavior, efficiency and <Q>

Cosmic muons operation (external scintillator as trigger)

Time shown here ~2 months

Characterization of RPCs at high altitude for SWGO.

Setup ready for the characterization of **RPC operated at different operation pressures** (heights) in order to optimize the response of the detector.



Hipo-baric chamber with capacity to hold 4 RPC planes

Next steps

- Testing **RPC Vs pressure** to optimize the response at high altitude. (this year PhD student).
- Testing **large size 1 m² sRPC outdoor** (this year MsC student).
- Build first **timing sRPC** narrow gaps 0.3 mm. (ASAP).

- Technicalities: improve **gas in/outlets (injectors) and sealing.**

Conclusions

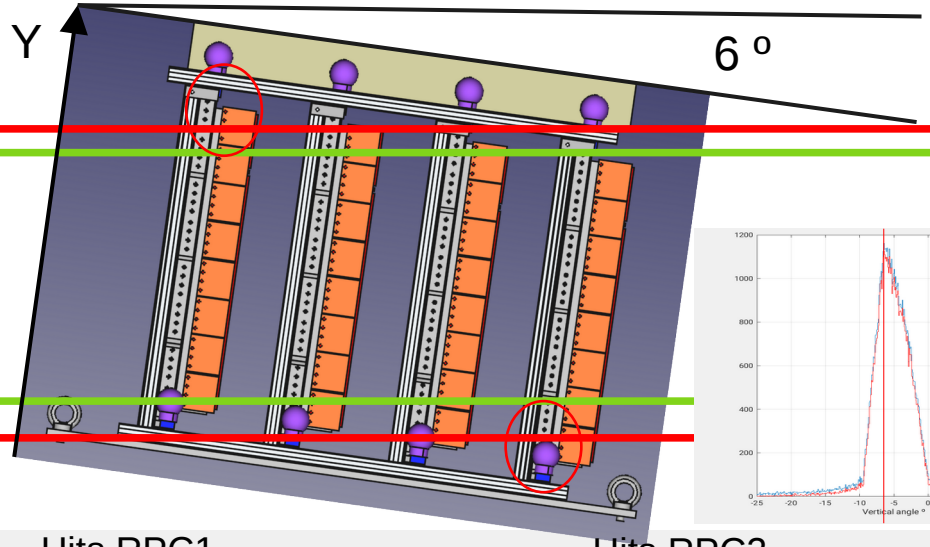
Sealed RPC have become a reality. We have demonstrated their feasibility to operate reliable for years under **indoor** conditions for **Cosmic Ray measurements.**

We need to **continue the development** by improving certain technical aspects and introducing timing.

It is also necessary to demonstrate that **sRPCs** can **operate outdoors.**

BACKUP

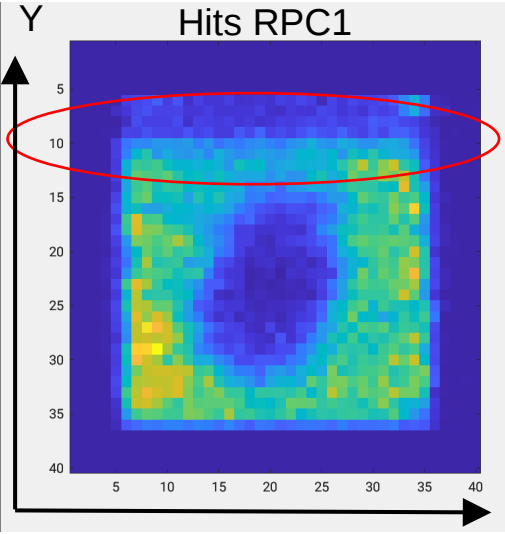
SND@LHC. Sealed RPC small telescope @ CERN. Efficiency geometry factors.



Deficit of events shown on Hit maps

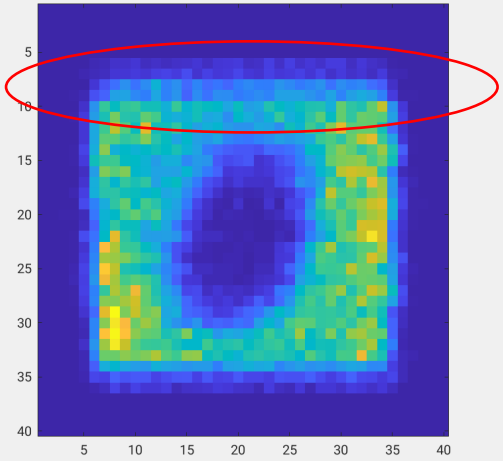
Not recorded muon (hit only two planes)

Recorded muon (hit three or more planes)

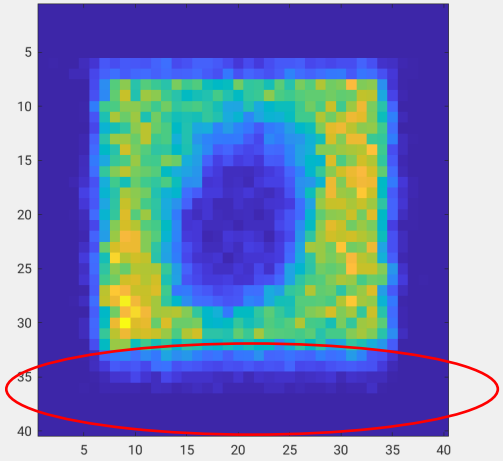


Hits RPC1

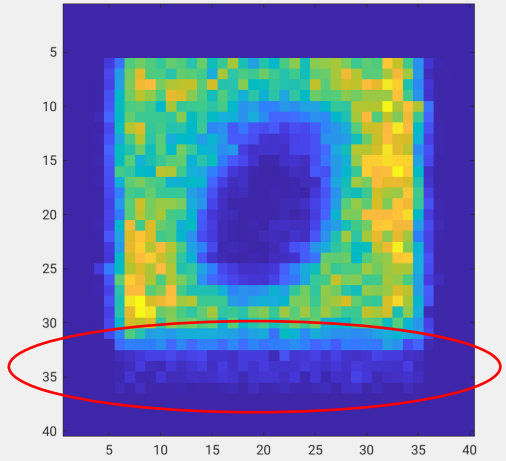
Hits RPC2



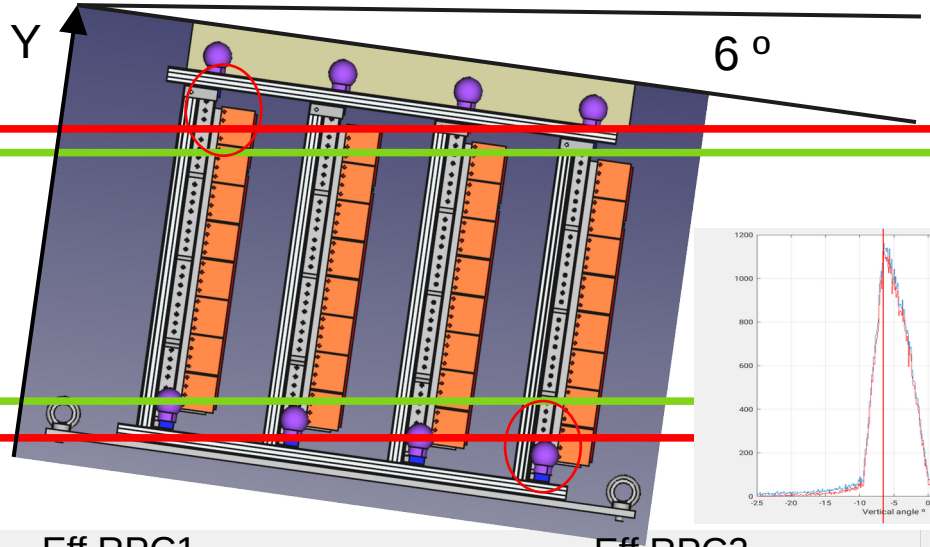
Hits RPC3



Hits RPC4



SND@LHC. Sealed RPC small telescope @ CERN. Efficiency geometry factors.



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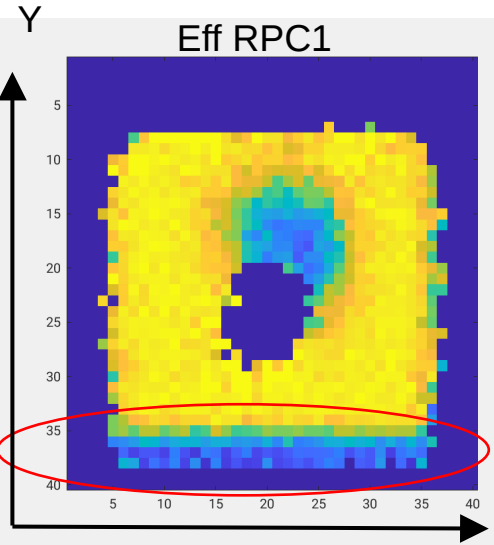
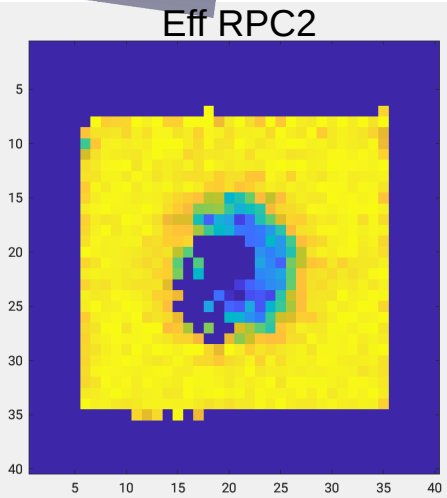
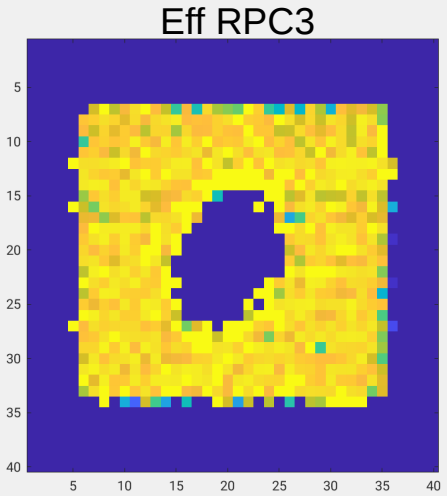
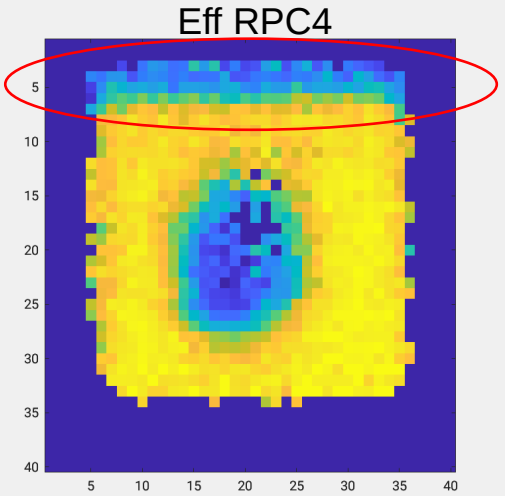


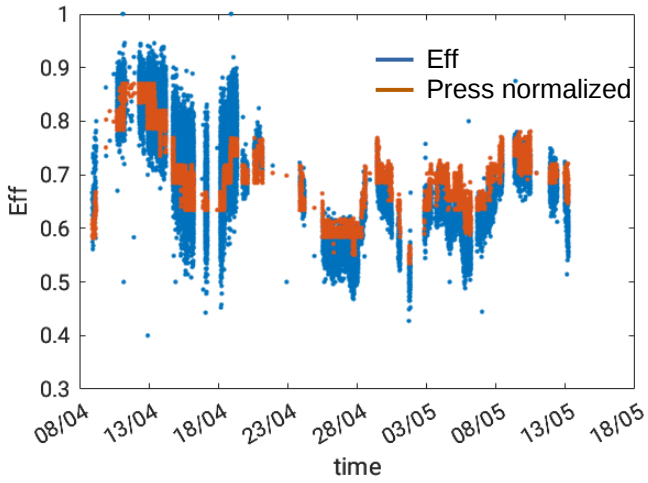


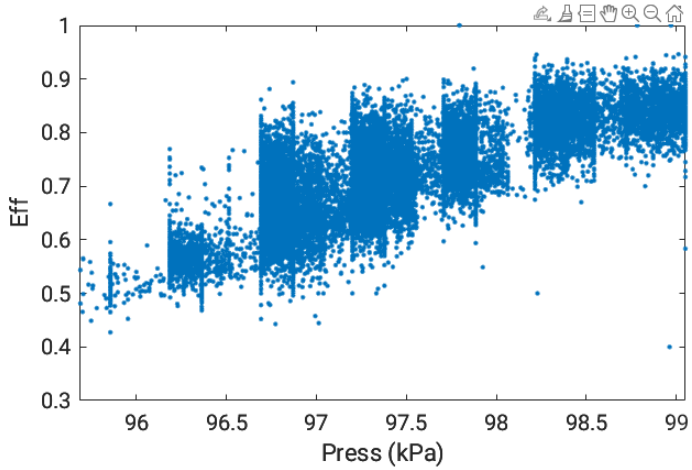


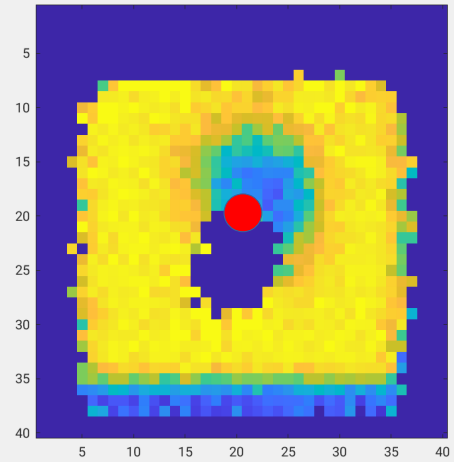


SND@LHC. Sealed RPC small telescope @ CERN. Efficiency other factors.

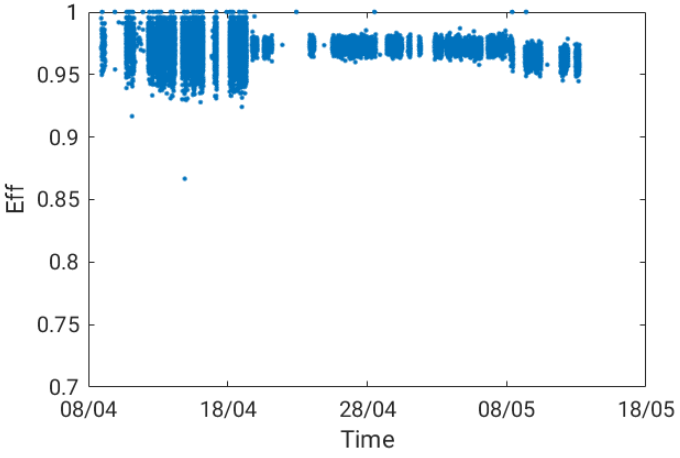
Center

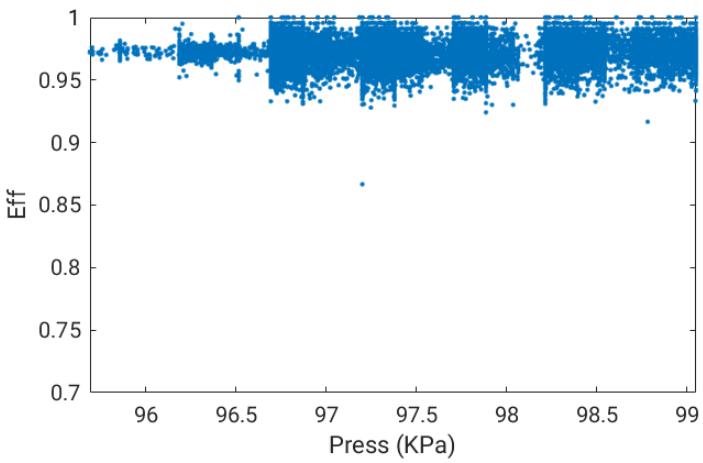


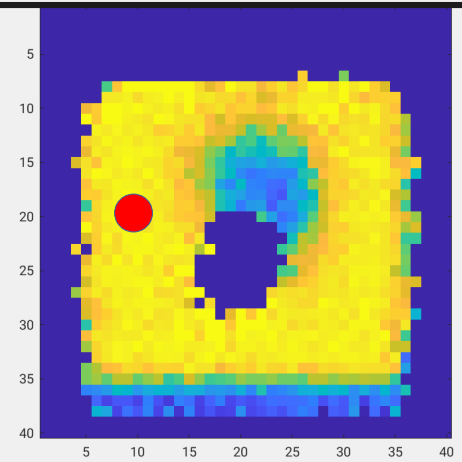




Peripheral



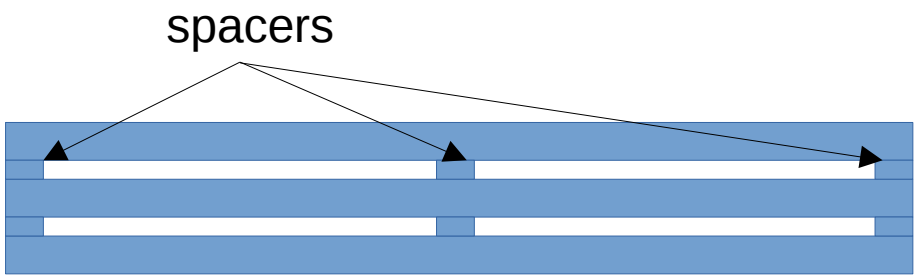




Huge variation of **efficiency** on the center of the chamber **correlated with Atmospheric Pressure**

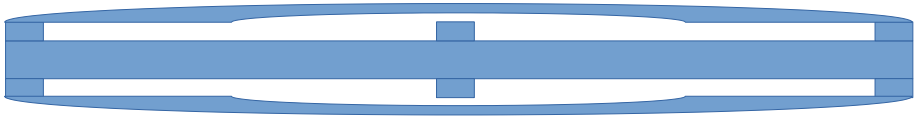
SND@LHC. Sealed RPC small telescope @ CERN. Efficiency other factors.

Cross-section of
a sRPC chamber



3 glass electrodes
2 gas gaps

P ↓ the chamber could change the gap width in the center
if the central spacer is not glued anymore
Sealed RPCs are not atmospheric detectors



Center spacer is not glued and eventually fragile

Huge variation of **efficiency** on the center of the chamber **correlated with Atmospheric Pressure**