The new HADES TOF Forward Detector

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on behalf of HADES collaboration

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Outlook

- HADES experiment
  - RPC-TOF: a TOF based on RPCs
  - New TOF for forward region => ForwarD RPC-TOF

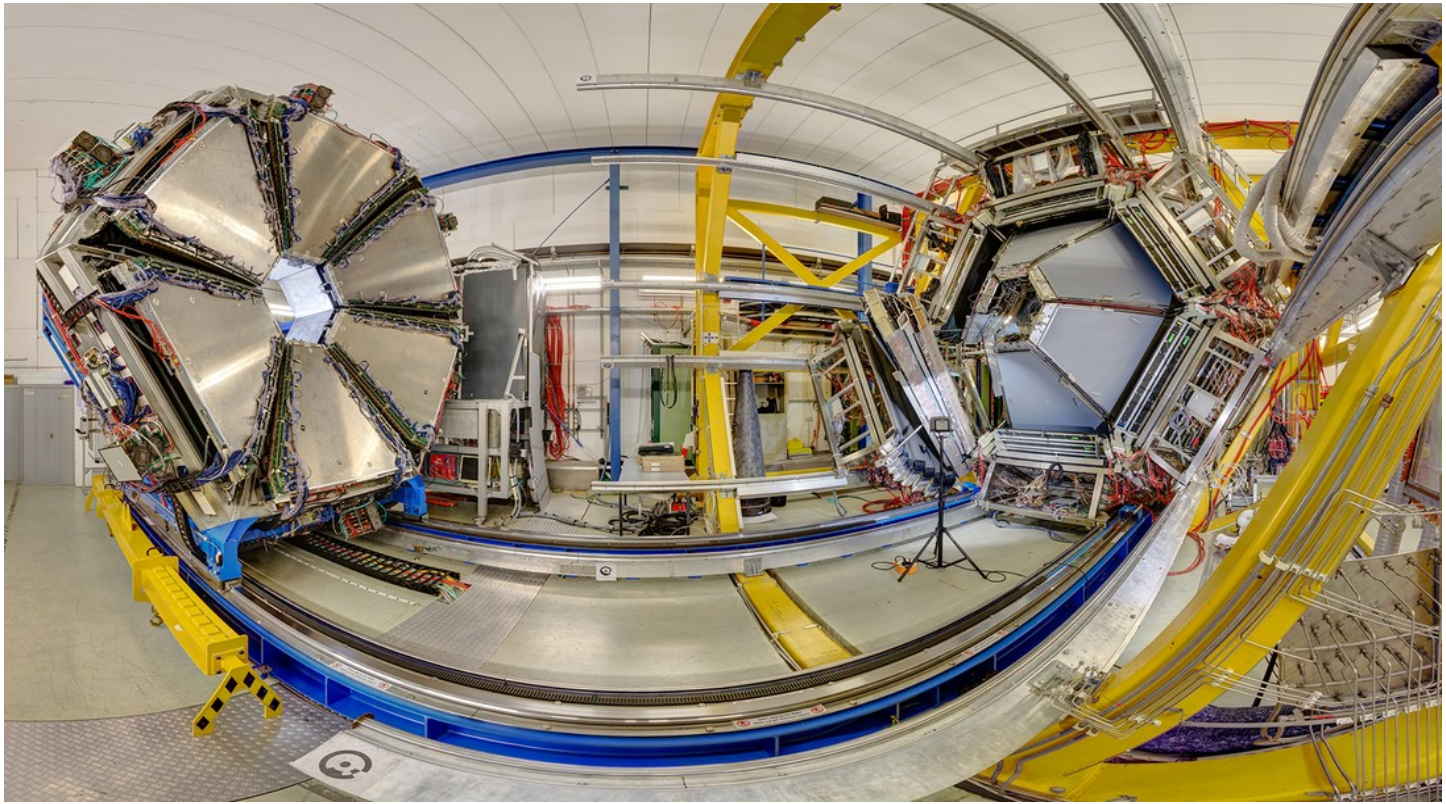
- Prototyping the FD RPC-TOF

- FD RPC-TOF installation and beam performance

HADES High Acceptance DiElectron Spectrometer @ GSI, Germany

Study of **“emissivity” and hadron properties in dense and cold nuclear matter**, detected via **e+ e- pairs** (dielectrons) and **strange hadrons**, produced in **proton, pion** and heavy **ion** induced reactions in a **1-3.5 GeV.**

Spectrometer with high invariant mass, resolution and high rate capability.
Installed at SIS18, GSI, Darmstadt. http://www-hades.gsi.de/



Project launched in late 1994
6 years R&D and construction

First production run in 2002

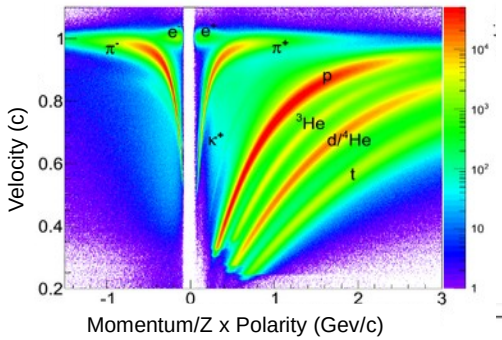
International collaboration of 27 institutions from 10 European countries.

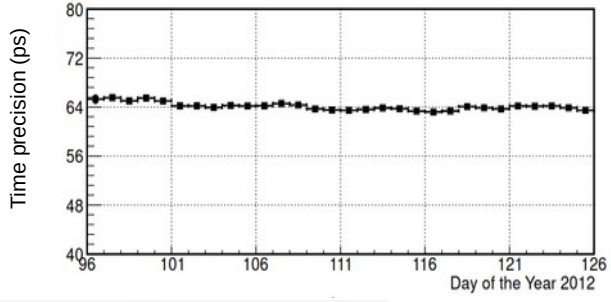
Cyprus, Czech Rep., France, Germany, Italy, Poland, Portugal, Russia, Slovakia, Spain.

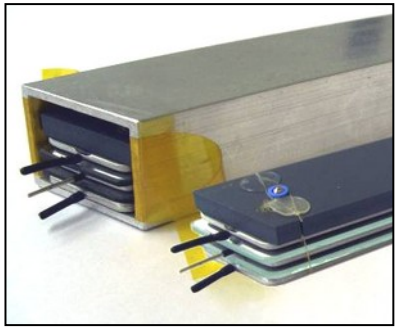
HADES High Acceptance DiElectron Spectrometer @ GSI, Germany. RPC-TOF

TOF detector based on RPCs
2400 electrically isolated cell

Efficiency > 90 %
Spatial resolution ~ 1 cm
Timing resolution ~60ps

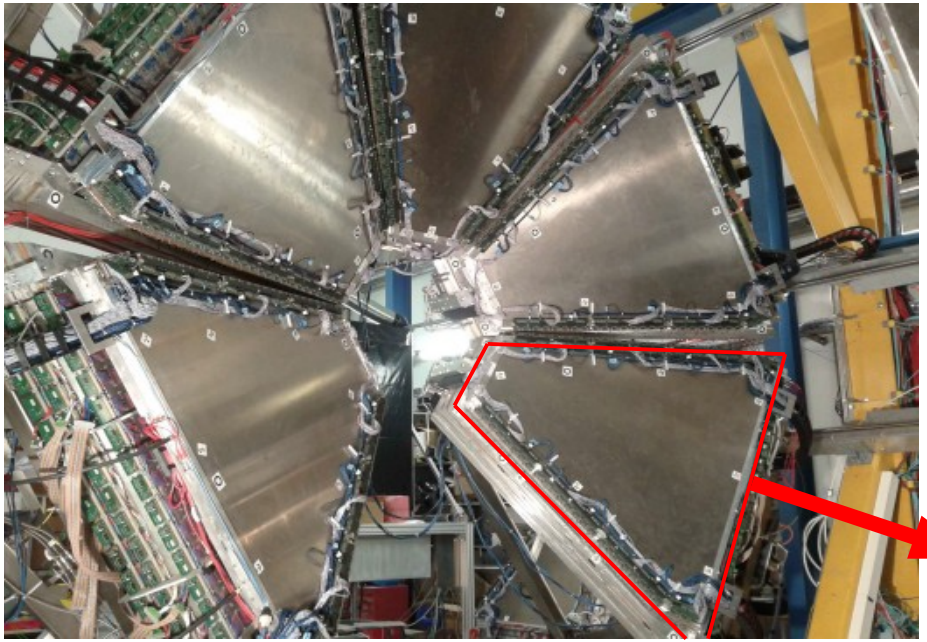


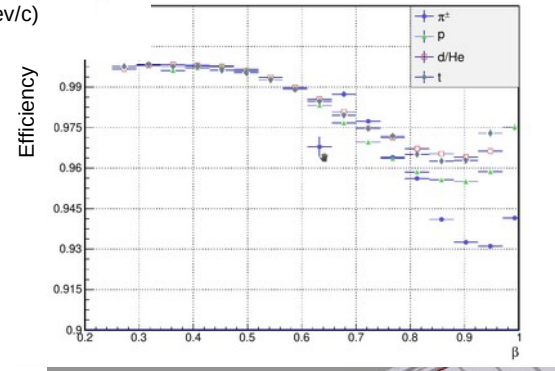


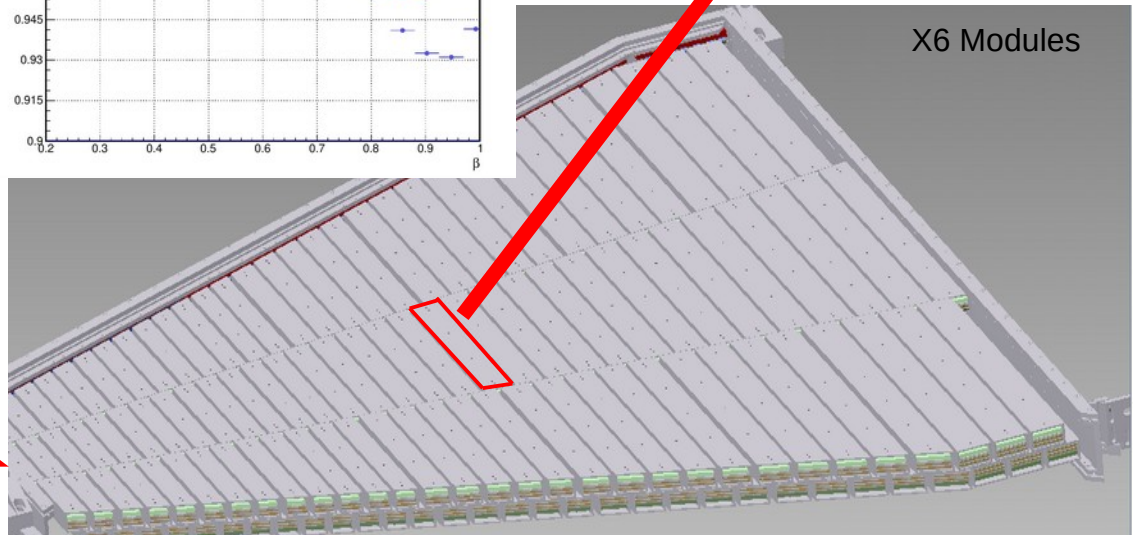


X1200
Electrically isolated cells

In a high multiplicity environment

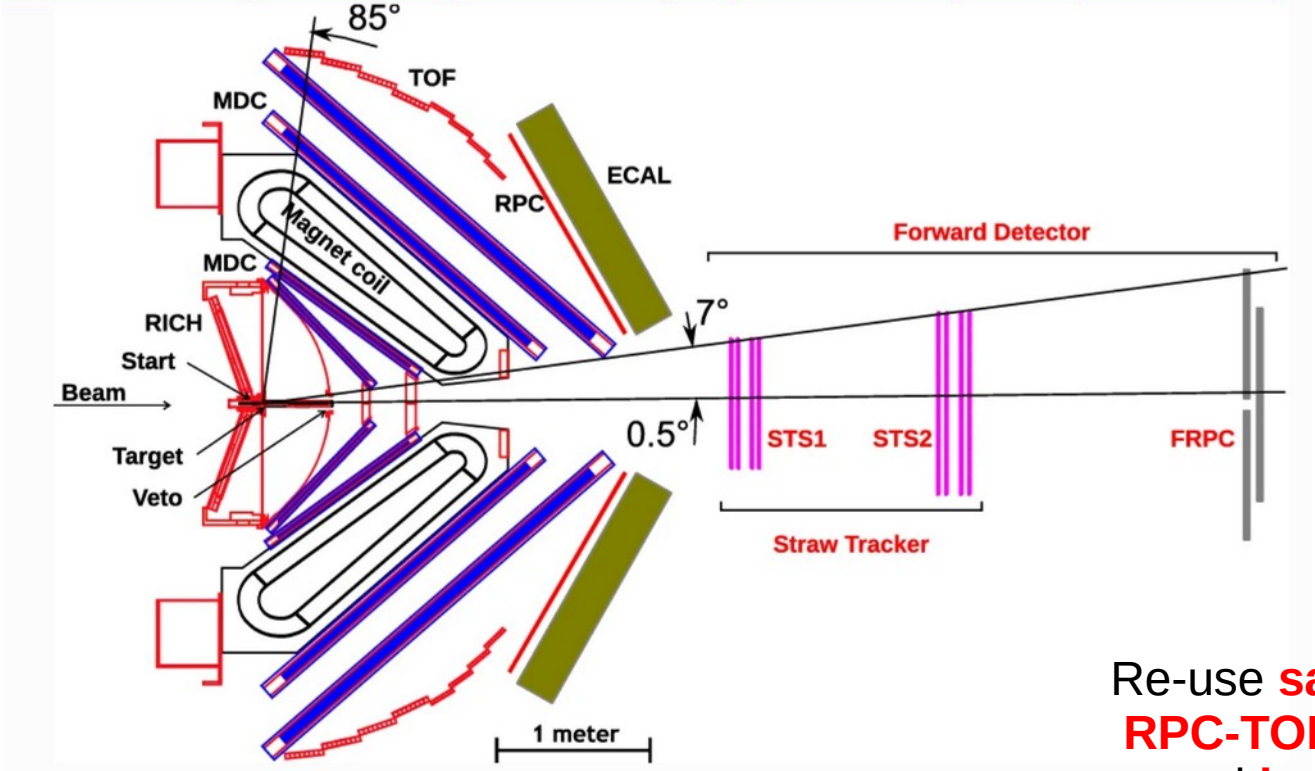






In order to **increase the forward region acceptance** and measure the **electromagnetic decays of the hyperon resonances** Σ(1385), Λ(1405) and Λ(1520) as well as the production of **double strange baryon systems** Ξ− and ΛΛ in p + p reactions at a beam kinetic energy of 4.5 GeV.

DOI:10.1140/epja/s10050-021-00388-w
DOI:10.5506/APhysPolB.51.239



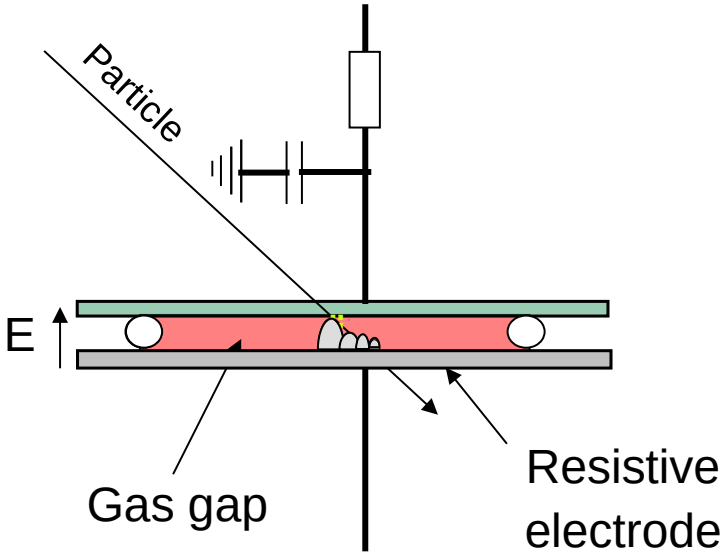
Forward Detector (FD)

- **Tracking system** based on 10 mm diameter straw tubes .
Station 1 540 tubes x4 layers
Station 2 1024 tubes x 4 layers

- **TOF** based on RPC
Efficiency > 90 %
Timing precision < 100 ps
Particle load, up to 1 kHz/cm²

Re-use **same technology** previously used on **RPC-TOF but** with **thinner glass** electrodes and **increase the working temperature**

The **idea** do **decrease the resistivity** of the electrode **by increasing** the working **temperature** is **not new** => NIMA 555(1):72-79, 2005 and eventually others



$$\phi_{max} \leq \frac{\Delta V}{\rho d \bar{q}}$$

Φ_{max} = maximum particulate flux
ΔV = allowable voltage drop at the resistive electrode, which do not compromise performance.
ρ = electrode resistivity
d = electrode thickness
q = average charge per avalanche

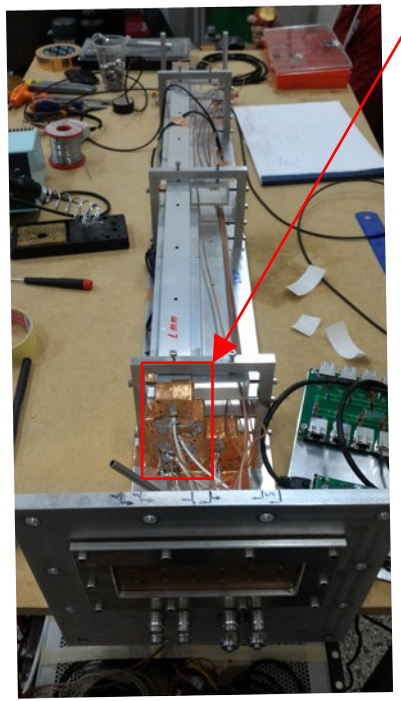
Φ_{max} can be increased by decreasing ρ
ρ can be decreased by increasing temperature

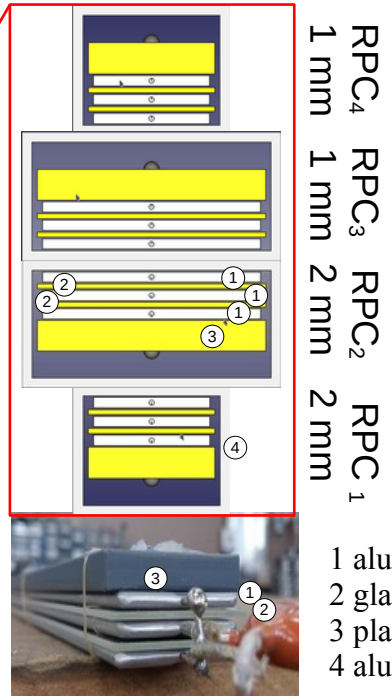
factor 10 every 25 ºC at least in glass

Prototype testing. Setup.

4x **individually shielded RPC cells** (**750 mm long**) with **4 x 0.28 µm gap** width. Two **widths (22 and 44 mm)** and two **glass (1 and 2 mm)** thickness and resistivities

1 mm glass ~4.10^{12} Ωcm
2 mm glass ~1.10^{13} Ωcm @ 25º

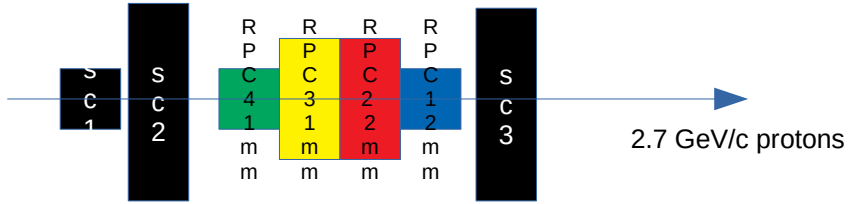




1 aluminum electrodes
2 glass electrodes
3 plastic support bar
4 aluminum tube.

RPC + heating system for count rate improvement

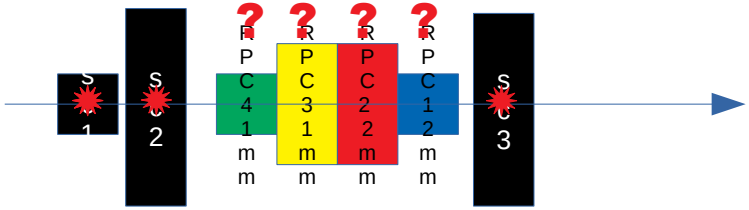
Beam line order (transverse view)



Chambers operated in open gas loop with a mixture of 97 % $C_2H_2F_4$ and 3 % SF_6
DAQ and FEE (from HADES) see following slides

Efficiency determination

Request hits in the scintillators and check the RPC

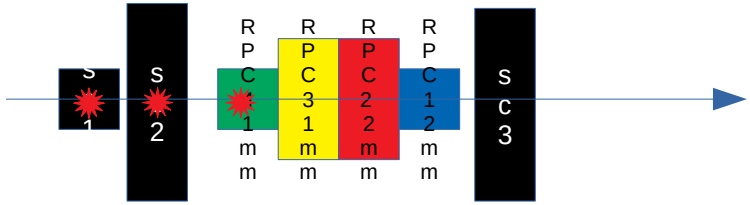


RPC should not be in the trigger since it introduce a bias.

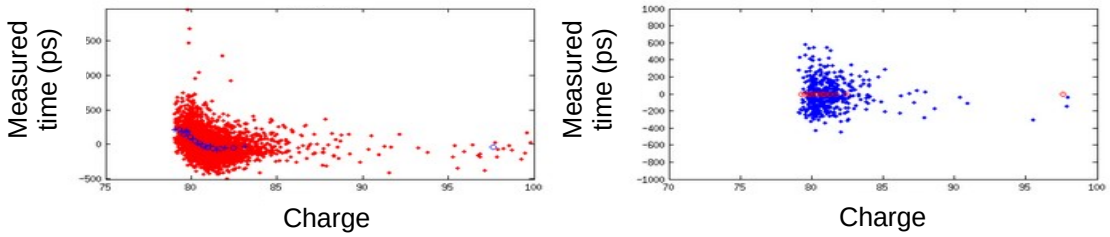
Timing precision determination

Compare RPC with scintillators 30 ps σ

$$\begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{pmatrix} \begin{pmatrix} \sigma(RPC)^2 \\ \sigma(SC1)^2 \\ \sigma(SC2)^2 \end{pmatrix} = \begin{pmatrix} \sigma(\Delta(RPCSC1))^2 \\ \sigma(\Delta(RPCSC2))^2 \\ \sigma(\Delta(SC1SC2))^2 \end{pmatrix}$$

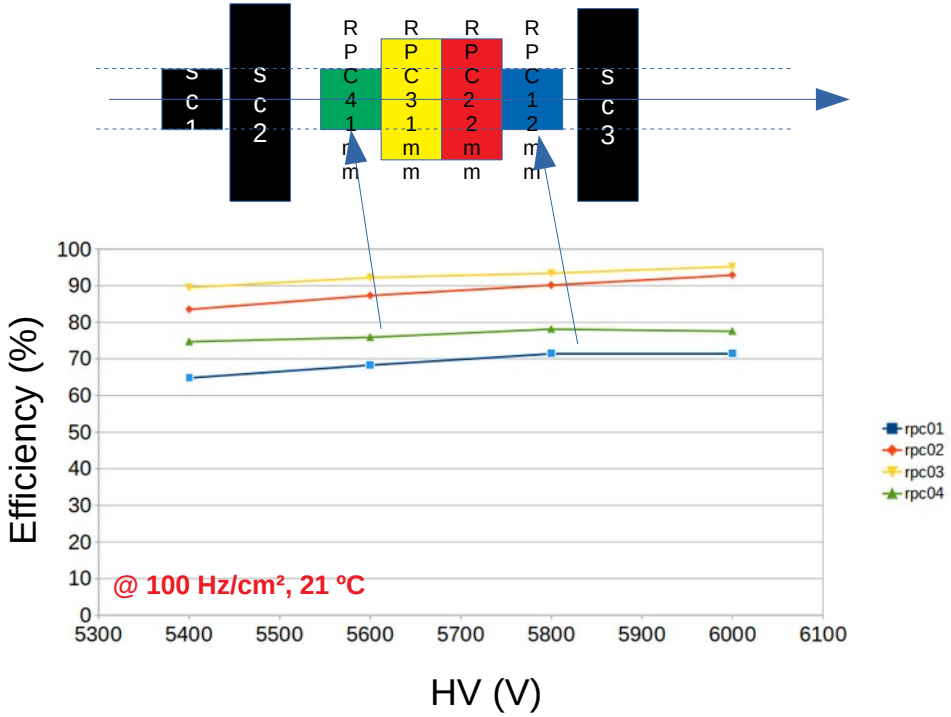


Time from RPC and scintillators are corrected by charge. Walk correction.

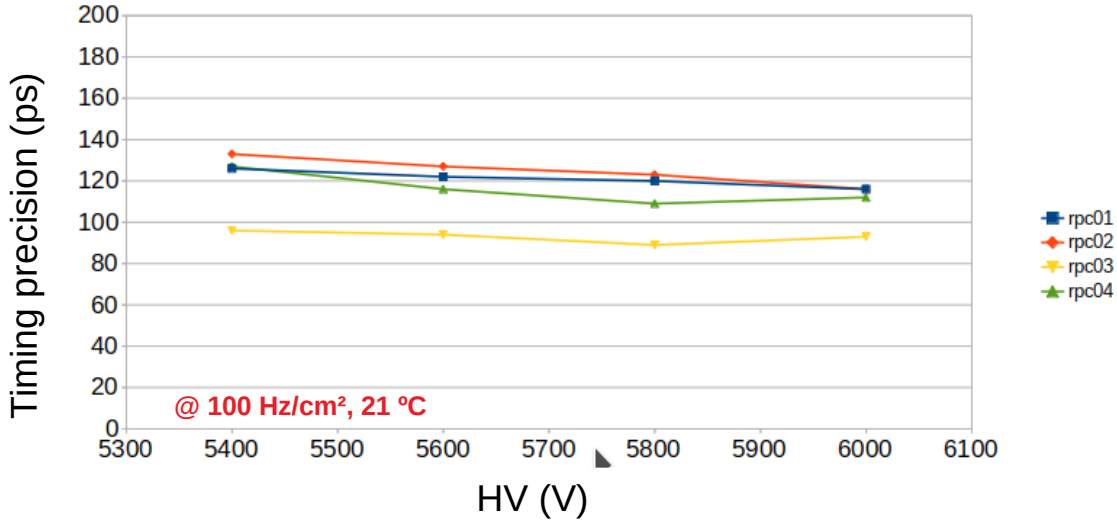


Prototype testing. Efficiency and timing precision vs HV.

- **Eff RPC 2,3 above 90 %**,
- 1,4 are not covered totally by scintillators => geometrical effect.

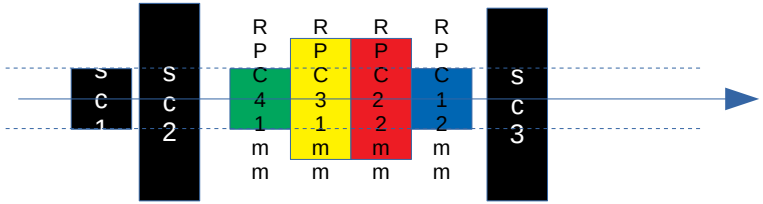


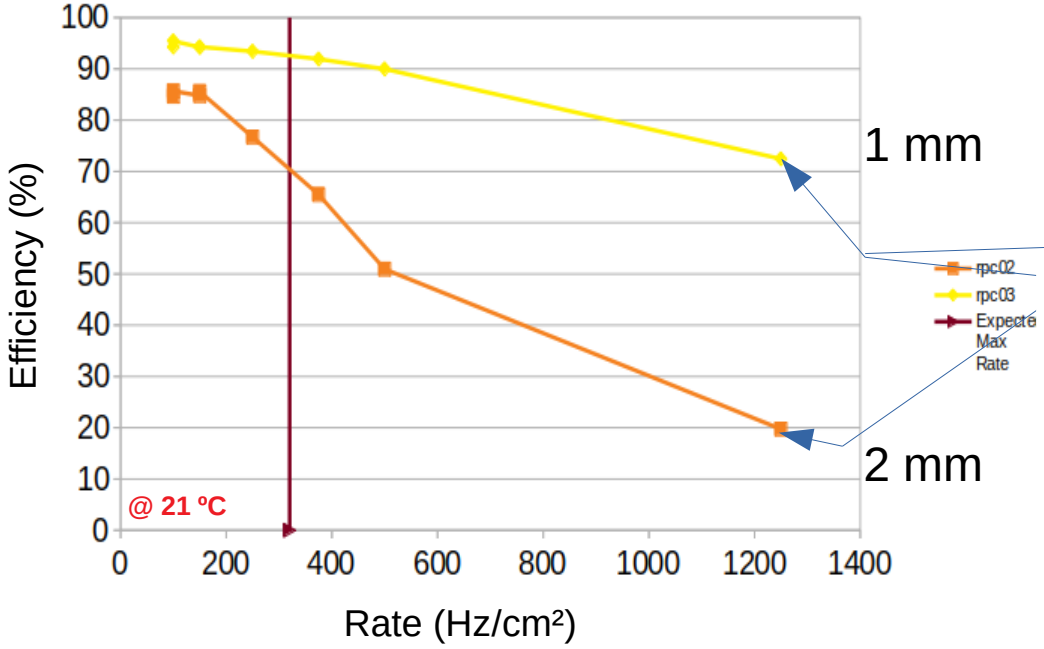
- **Timing precision at the level of 100 - 120 ps.**
- **2 mm glass already saturated @ 100 Hz/cm²**

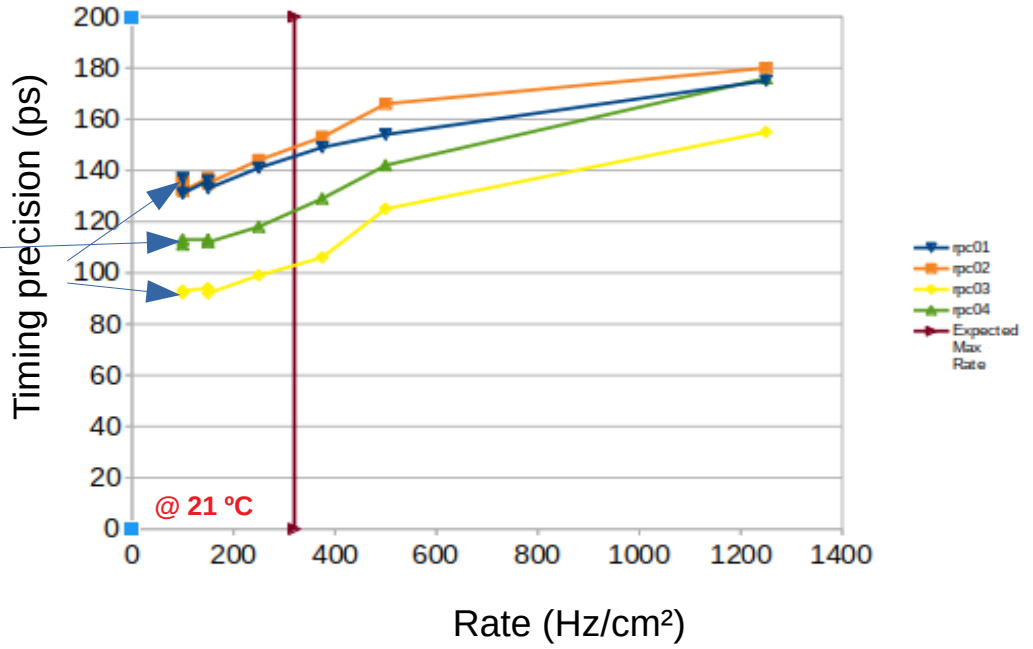


Prototype testing. Efficiency and timing precision vs rate.

- **Huge difference between 1 and 2 mm glass.** Thickness and resistivity explain this behavior, factor 4-6 In resistance.
- **1 mm glass, eff > 90% under < 400 Hz/cm²**
- **1 mm glass, time precision between 100-120 ps under < 400 Hz/cm²**

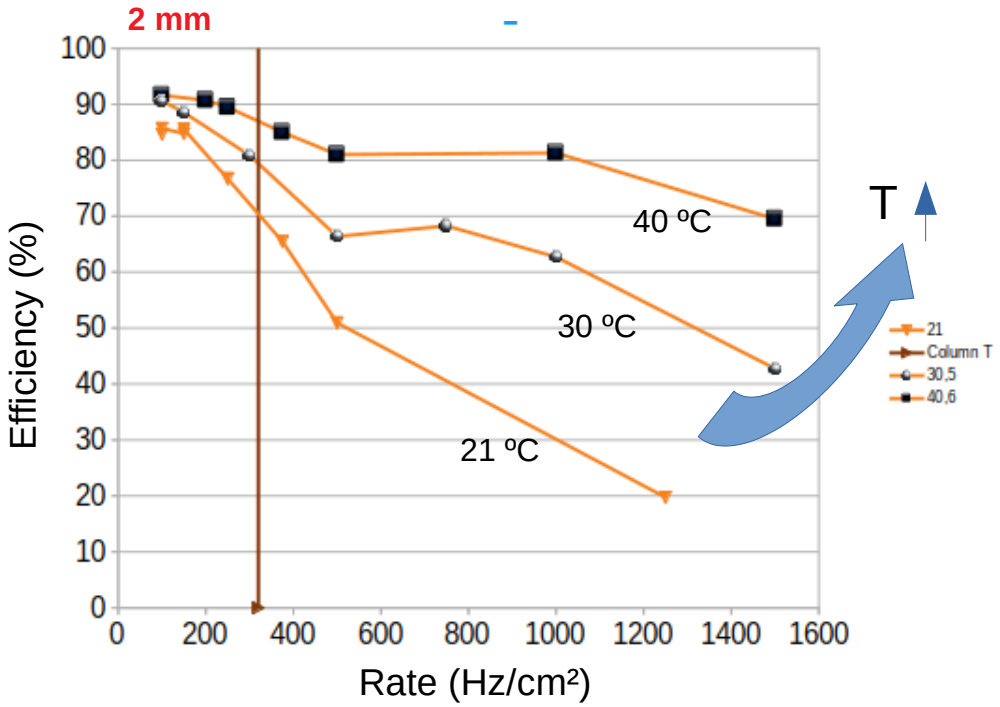


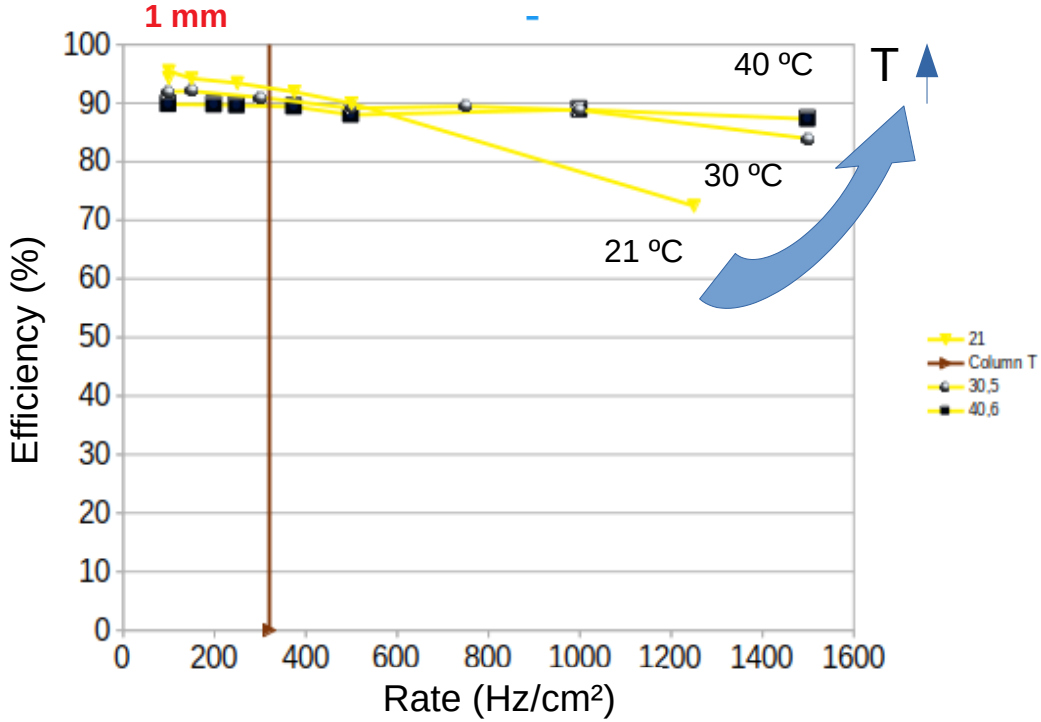




Prototype testing. Efficiency and timing precision vs rate vs temperature.

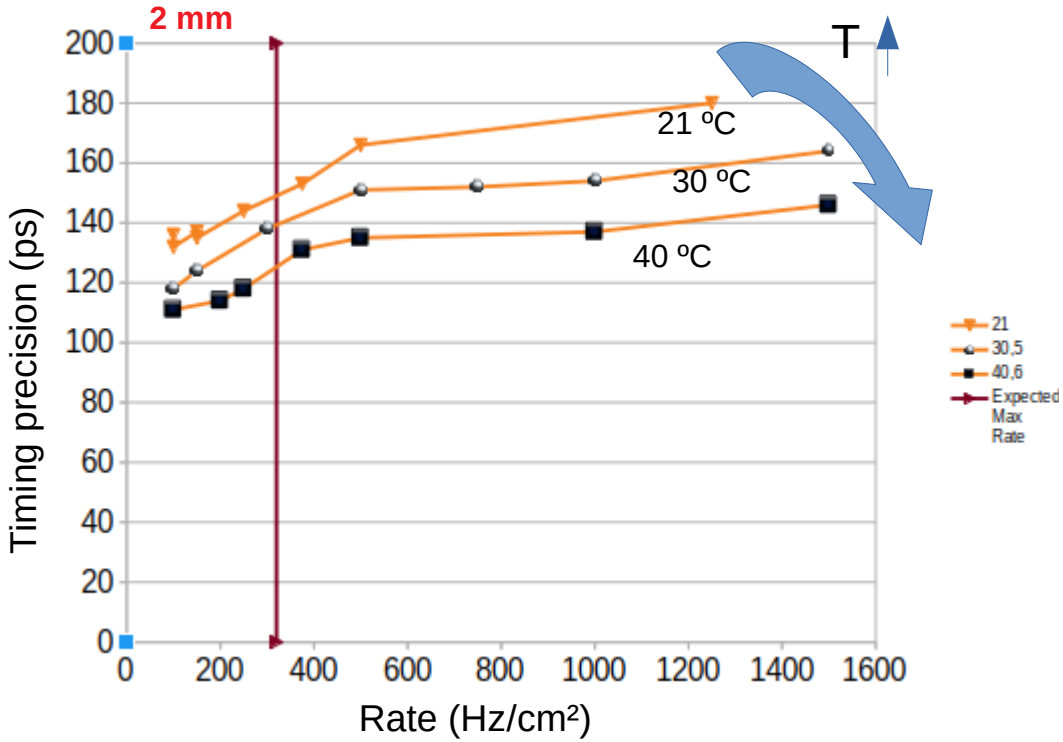
- Increase of **working temperature extent the count rate capability.**
- 1 mm glass, **efficiency above 90 % under 1000 Hz/cm² at 30, 40 ºC.**
- 2 mm glass**, huge recovery but not totally.**

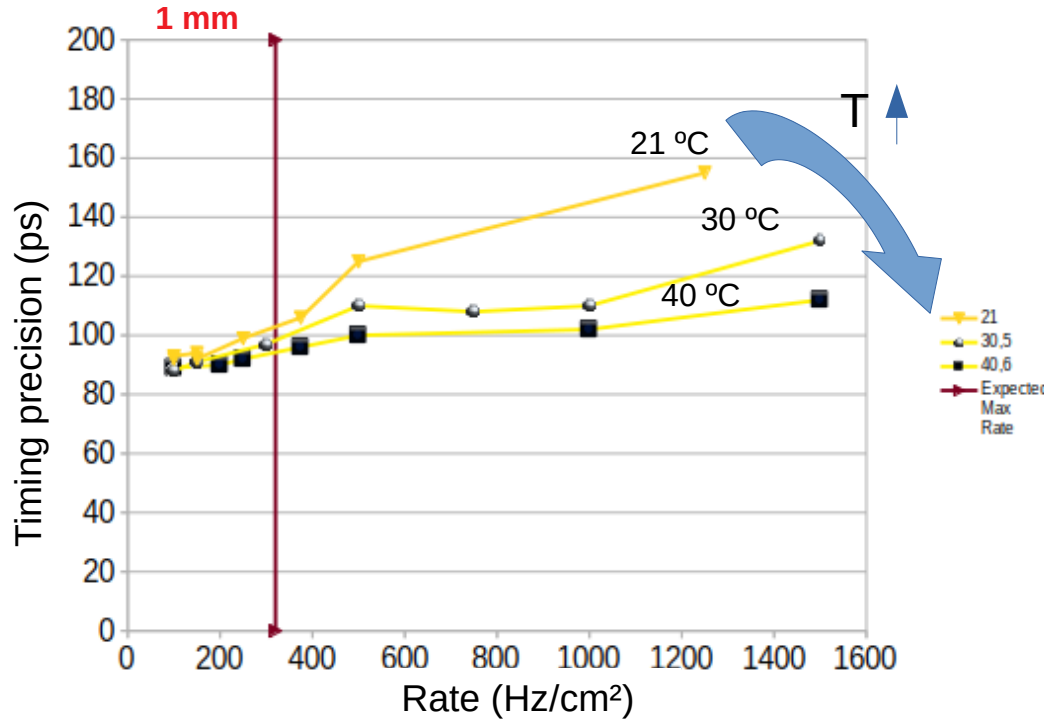




Prototype testing. Efficiency and timing precision vs rate vs temperature.

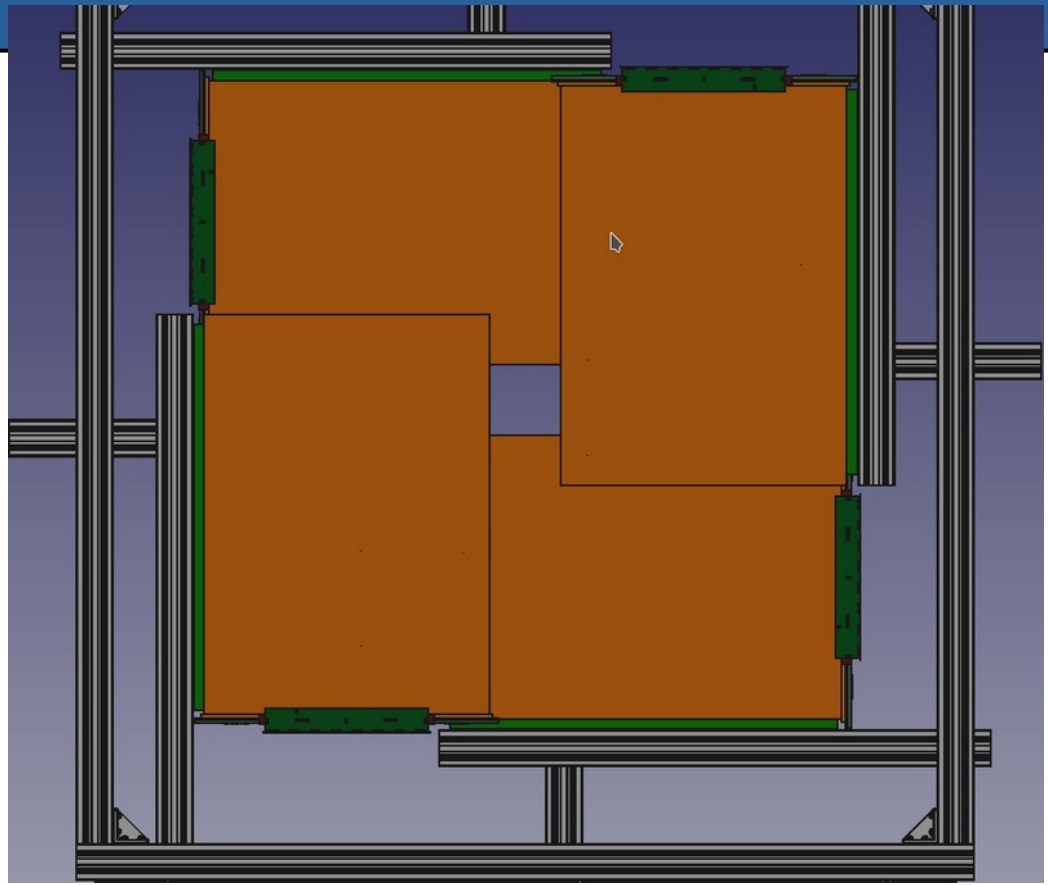
- Increase of **working temperature extent the count rate capability.**
- 1 mm glass, **timing precision ~ 100 ps under 1000 Hz/cm².**





Forward RPC. Layout.

- **Four sectors with 32 individually shielded RPCs**, of two different widths 22 and 44 mm. Distributed in **two layers** to create a surface with no holes in efficiency.



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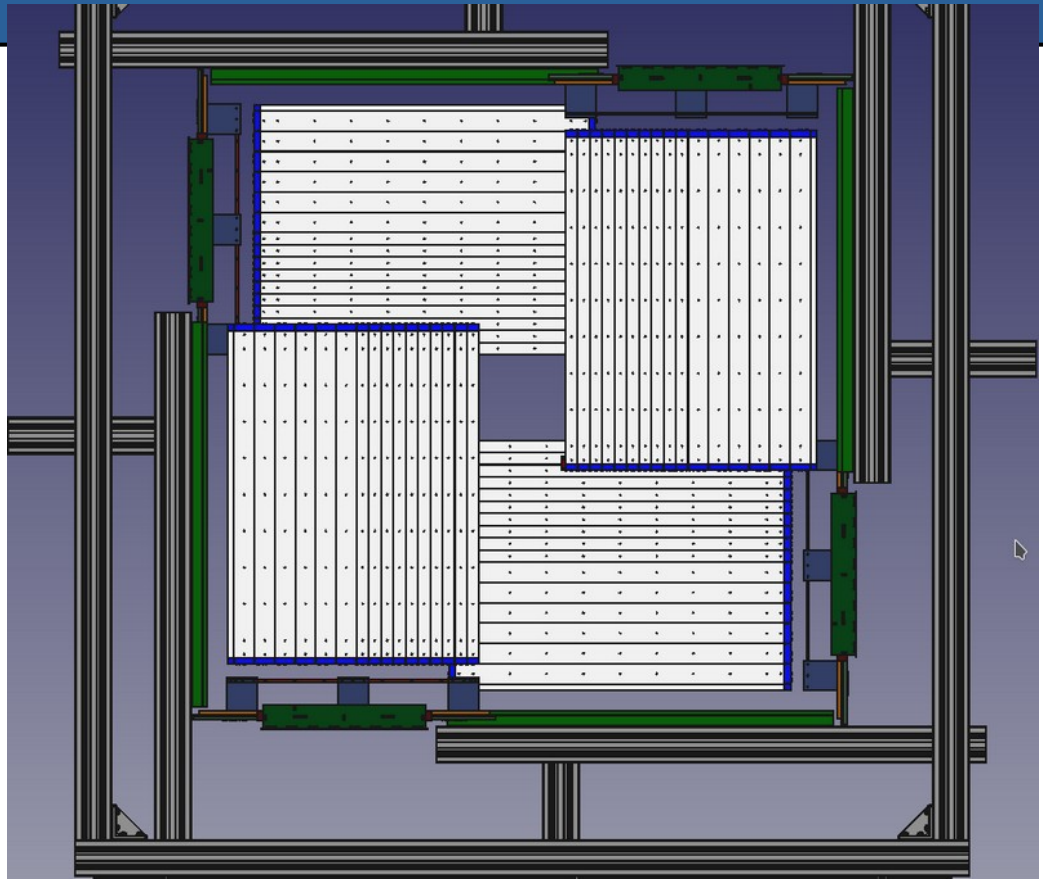
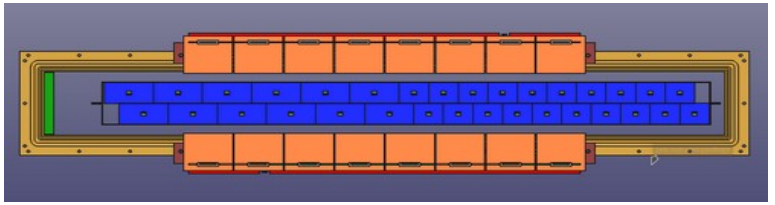
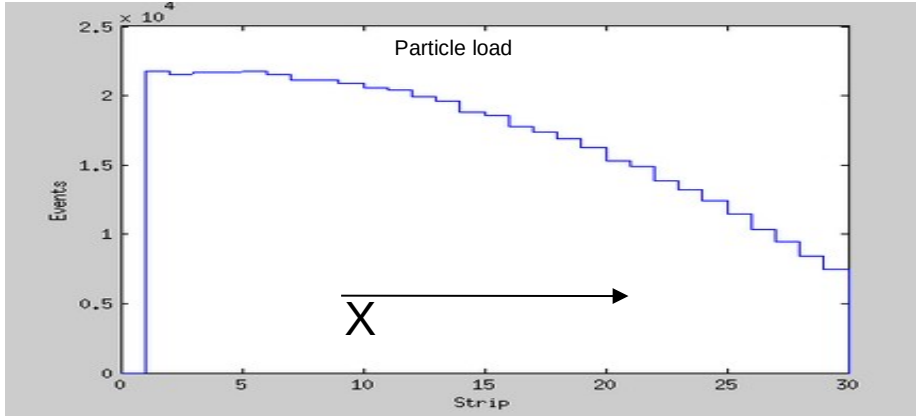


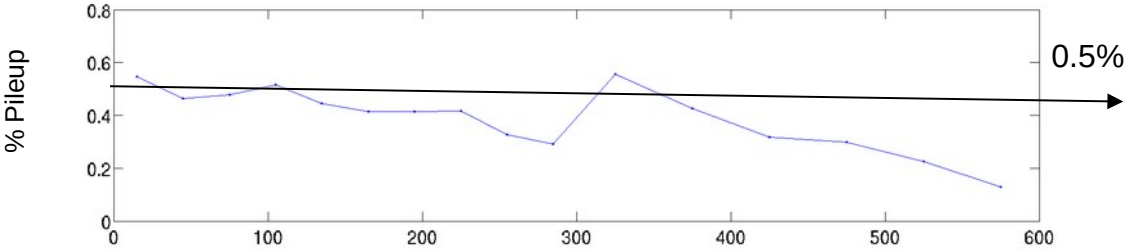
Internal structure. Two layers with 16 cells each, readout in both sides

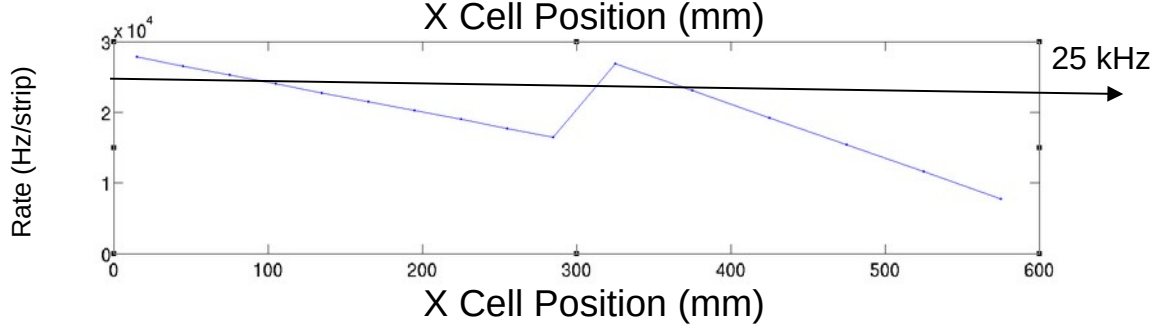


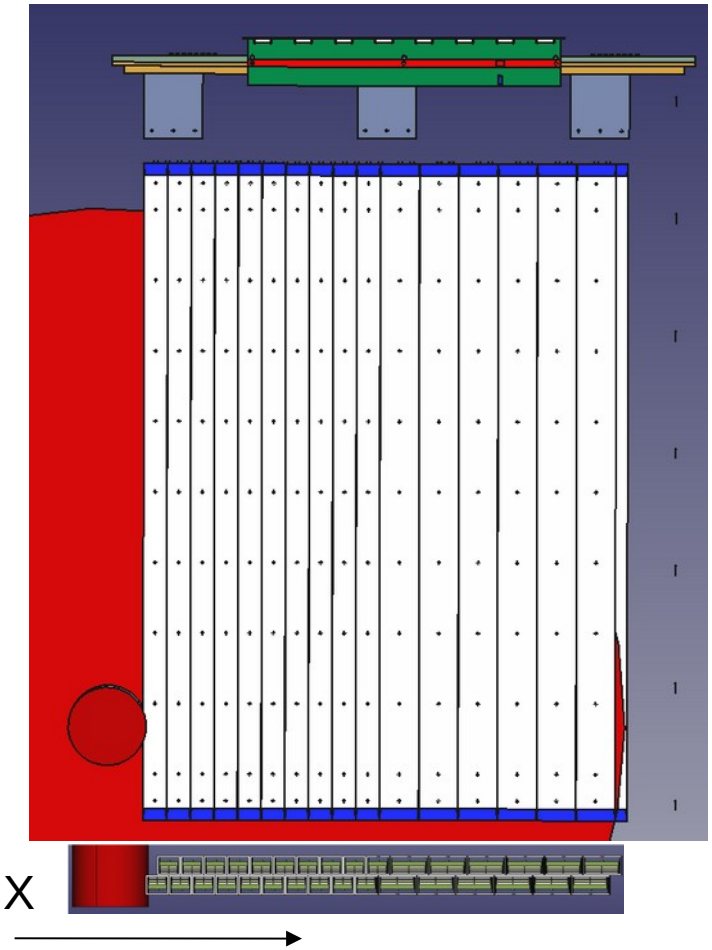
Forward RPC. Layout.

- **Two different widths** 22 and 42 mm to accommodate the particle load.





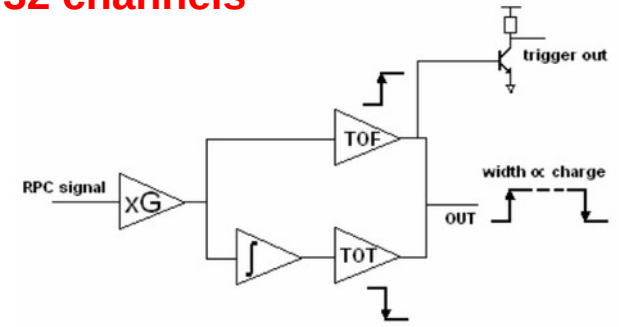




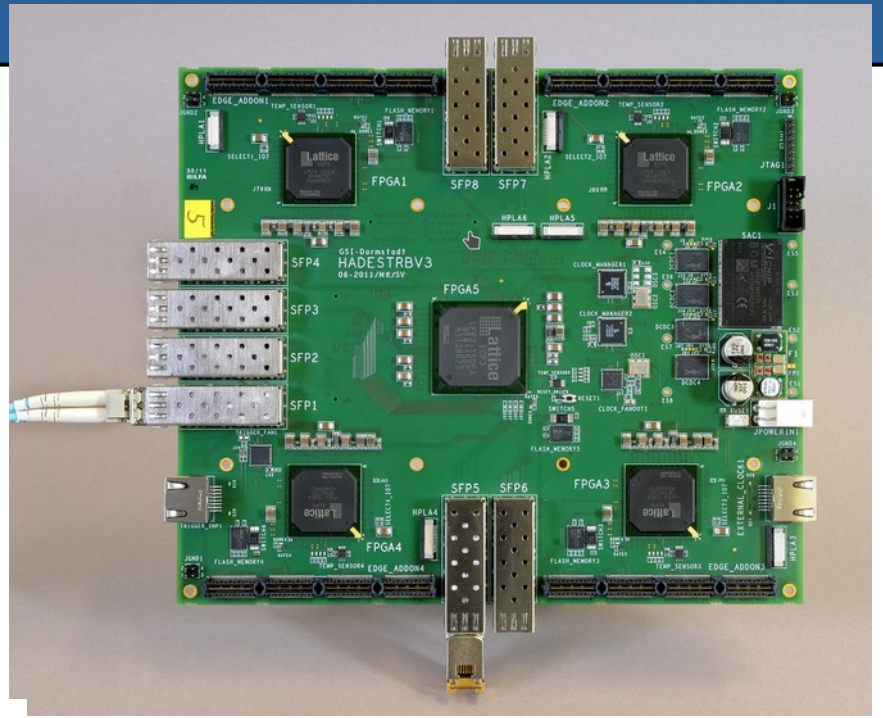
Forward RPC. DAQ and FEE.

FEE, time (σ_t~35ps) and charge measurement in one single channel.

Mother and daughter board architecture with 32 channels



[IEEE TNS 57, 2848 (2010)]



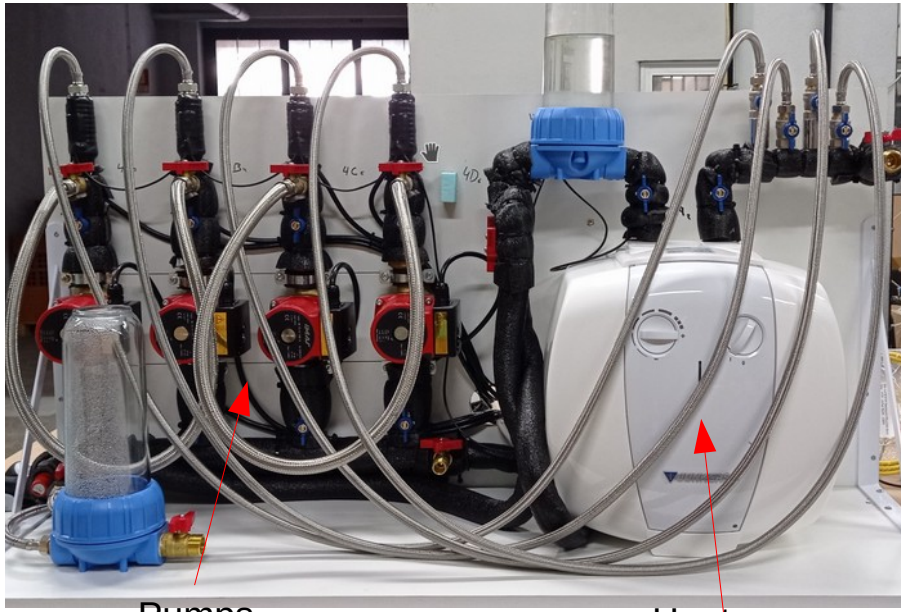
One central FPGA with trigger management capabilities plus 4 sockets with capability to operate.

4 X 32 Multi-hit TDC
Time precision < 20 ps

And much more ….

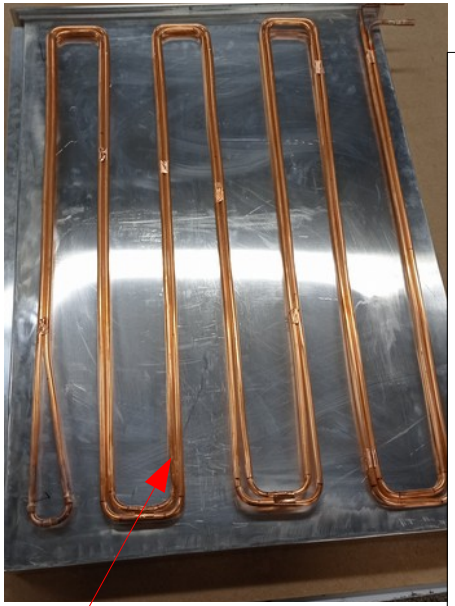
A Neiser et al 2013 JINST 8 C12043
doi: 10.1088/1748-0221/8/12/C12043

Forward RPC. Heating system.



Pumps

Heater



Radiator before installation

- Principle => **hot water circuit.**
It can provide and remove heat.

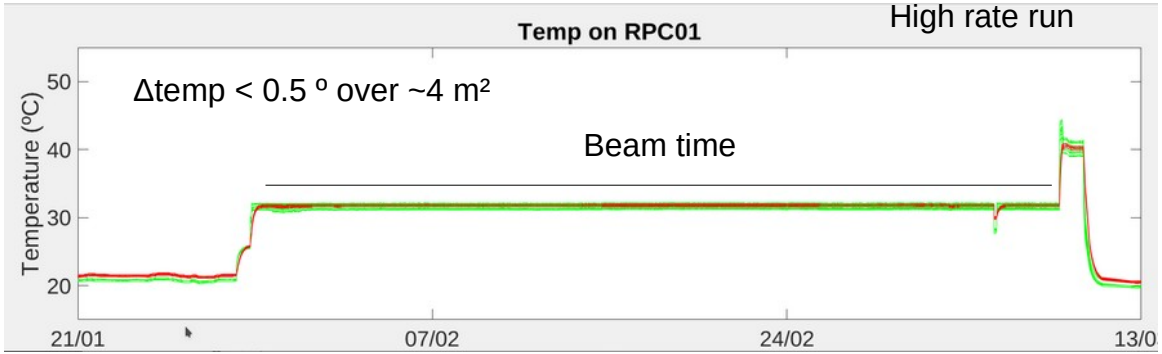
- Controlled (proportional-integral-derivative controller)
shared heating element 1500W.

- **x4 pumps** (one per sector).
Water distributed in parallel.

- RPC sector **radiator** (front and back)
Made of 10 mm **copper pipe** + copper tape as extra radiator.

- 64 I^2C **temperature sensors**.

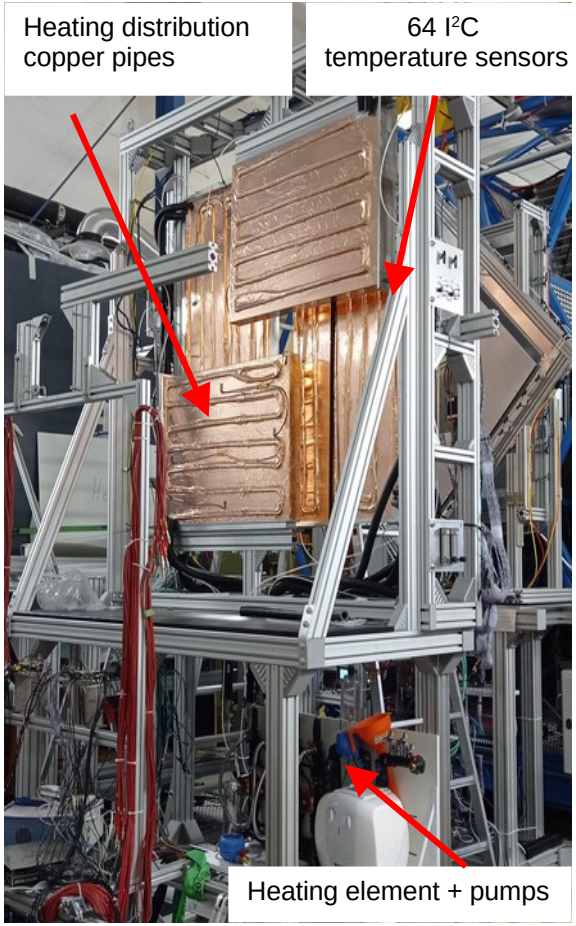
- **XPS** and **foam** thermal **insulation.**

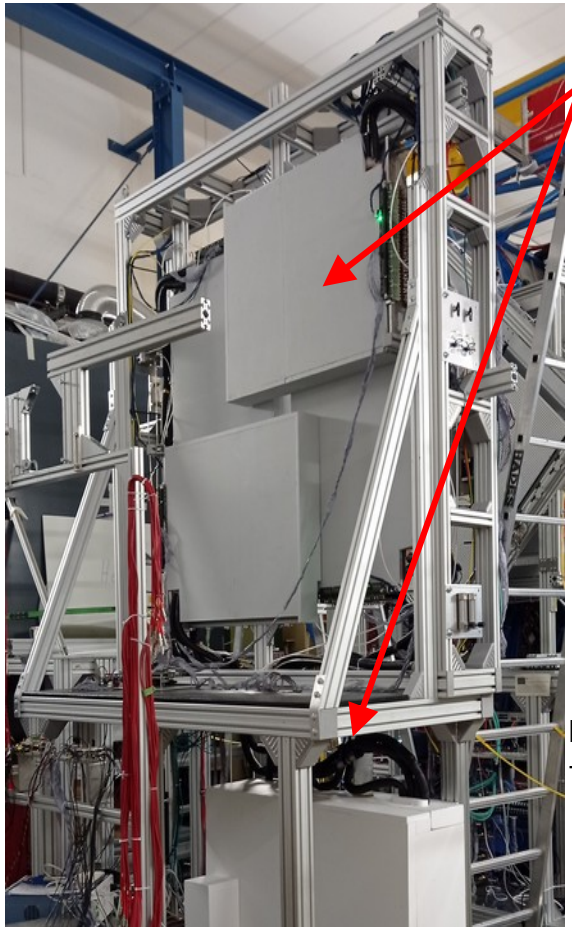


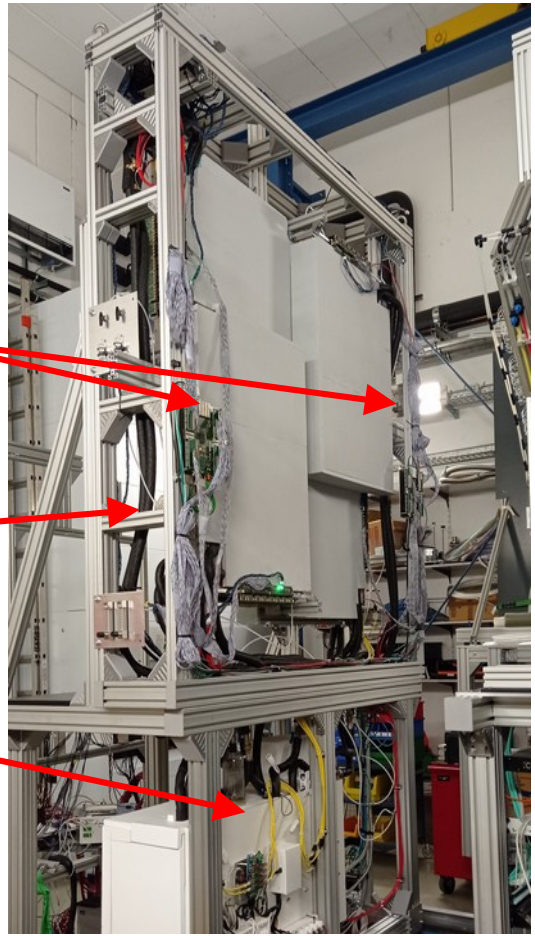
Forward RPC. Installation @ GSI.

REAR

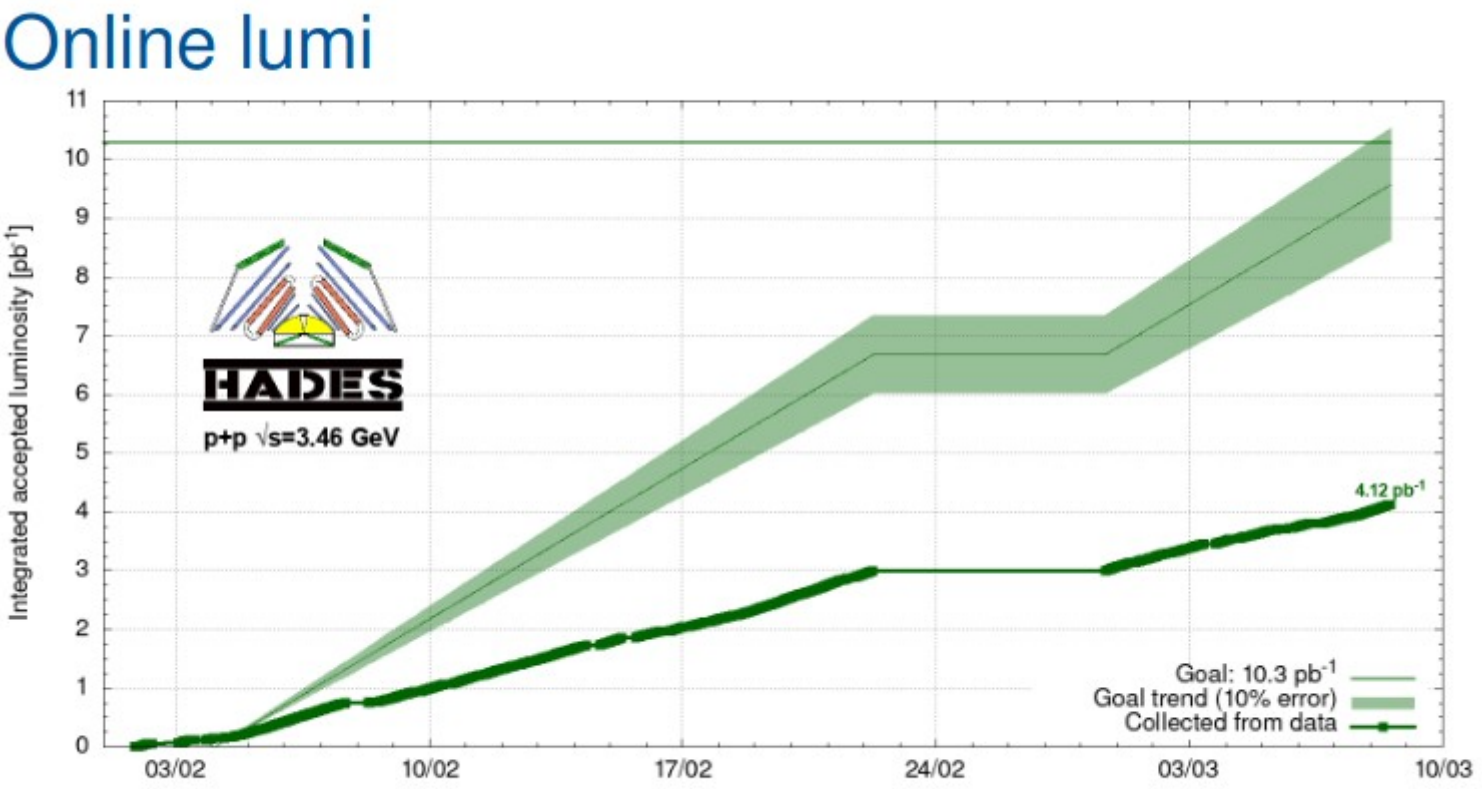
FRONT





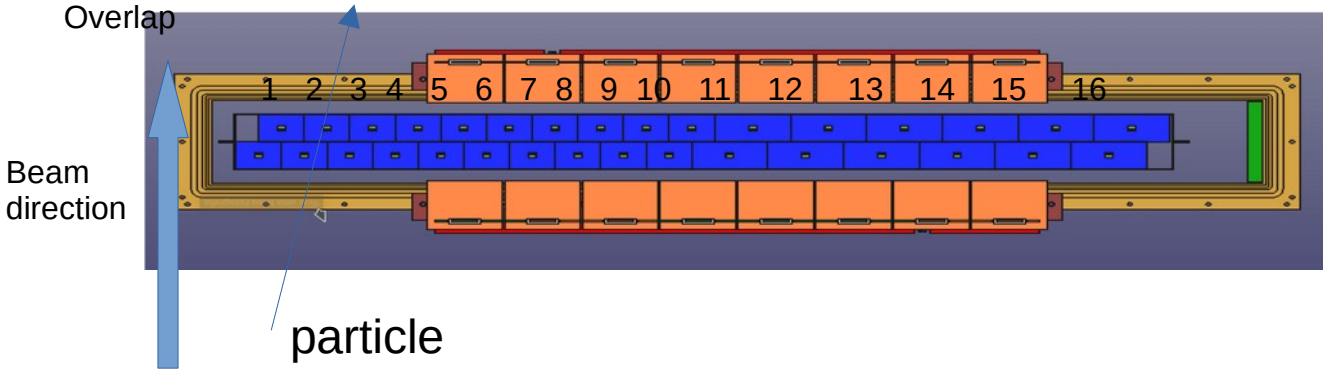


February 22 beam time.



Six weeks of **beam time**, (Feb 22) p+p 4.5 GeV, 0.8 10^8 p/second
Operation @ **31.5 ºC**
Maximum particle load ~0.6 kHz/cm²

Monitoring of each cell. Performance (σ_t) through overlap.



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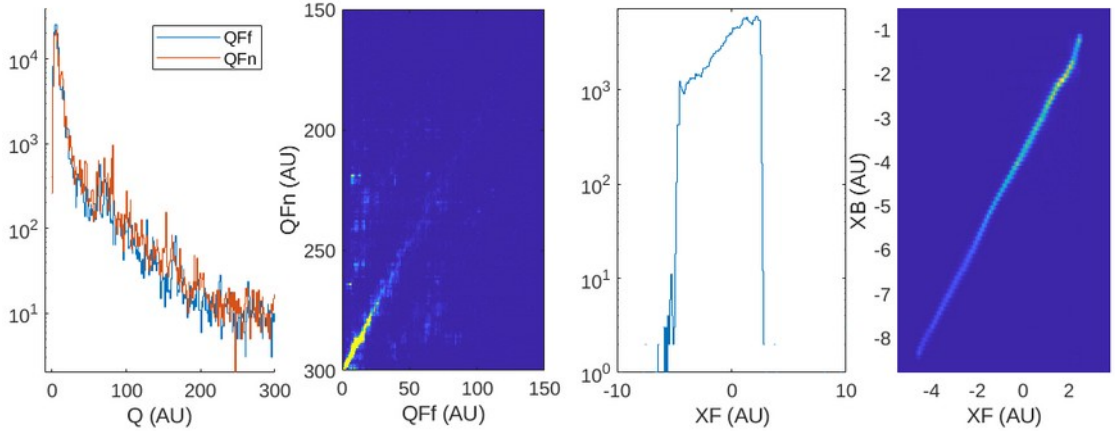
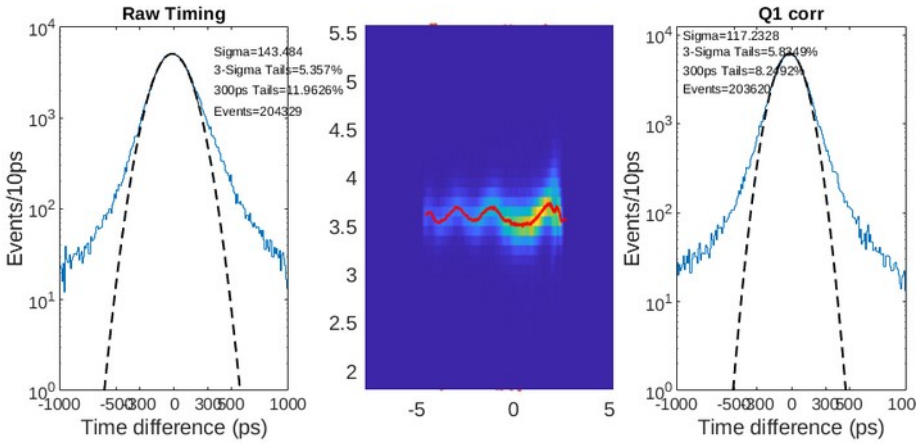
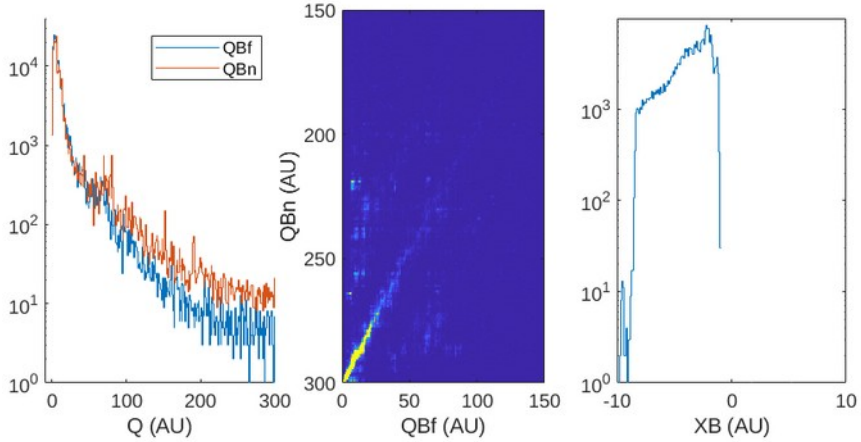
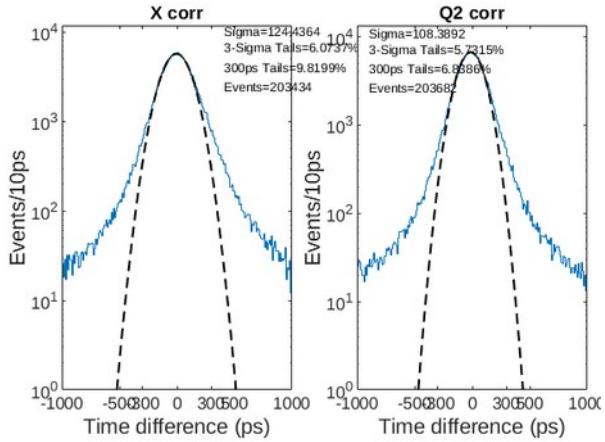


140 ps



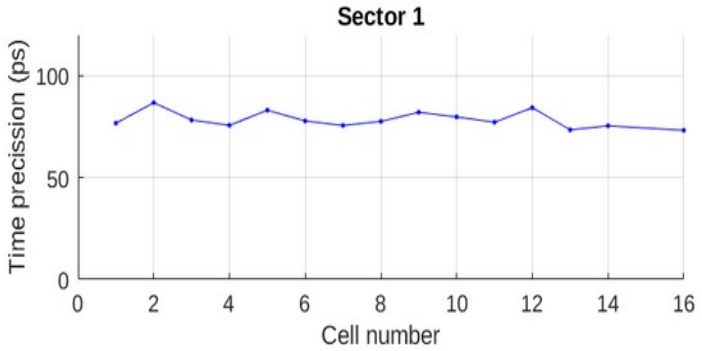


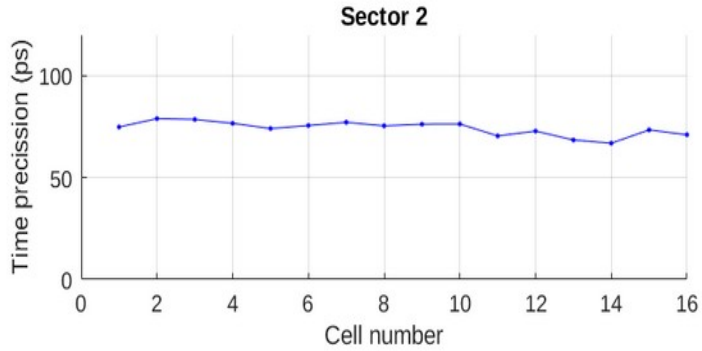
124 ps **108 ps**

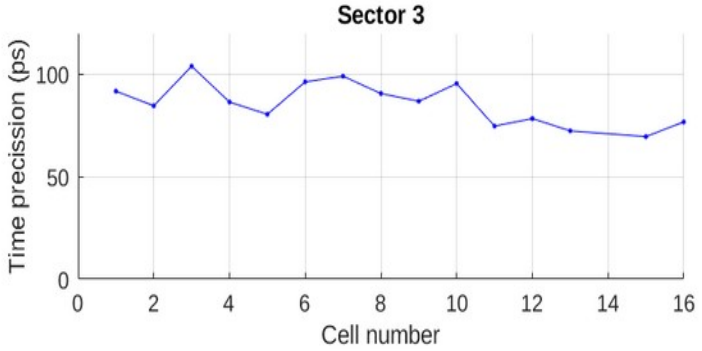


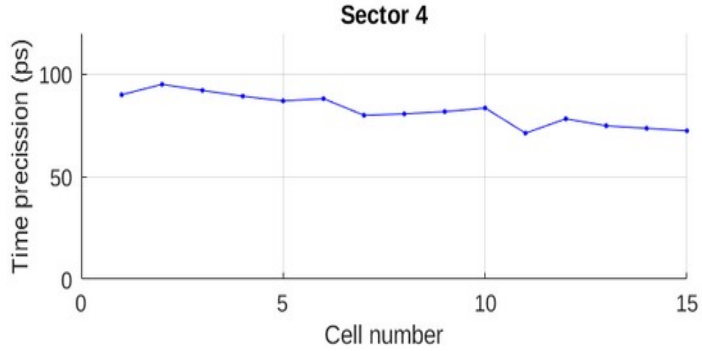
Timing precision: raw, position and walk corrected

Monitoring of each cell. Performance (σ_t) through overlap.

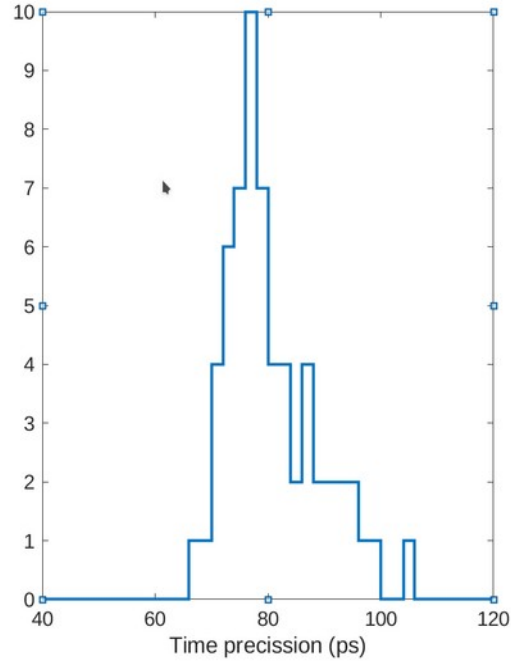








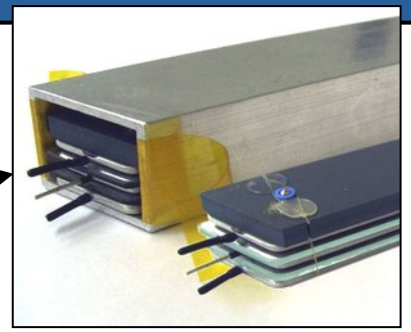
$\langle\sigma_t\rangle$ = 80 ps

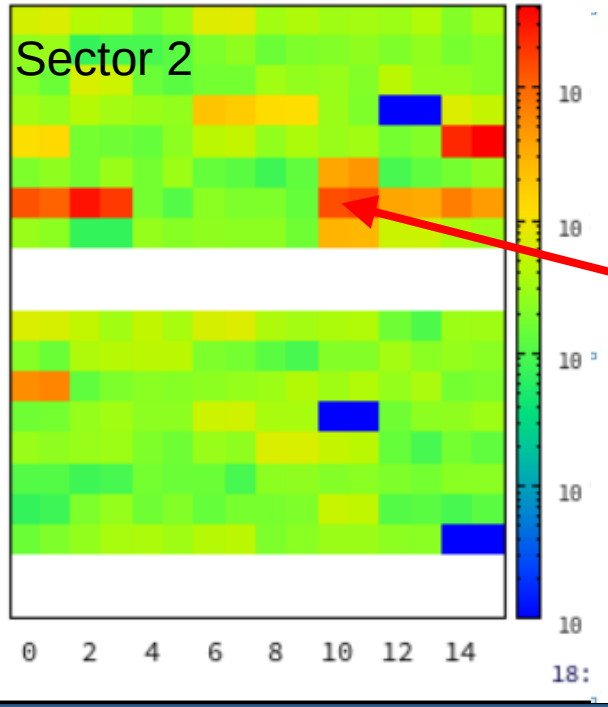


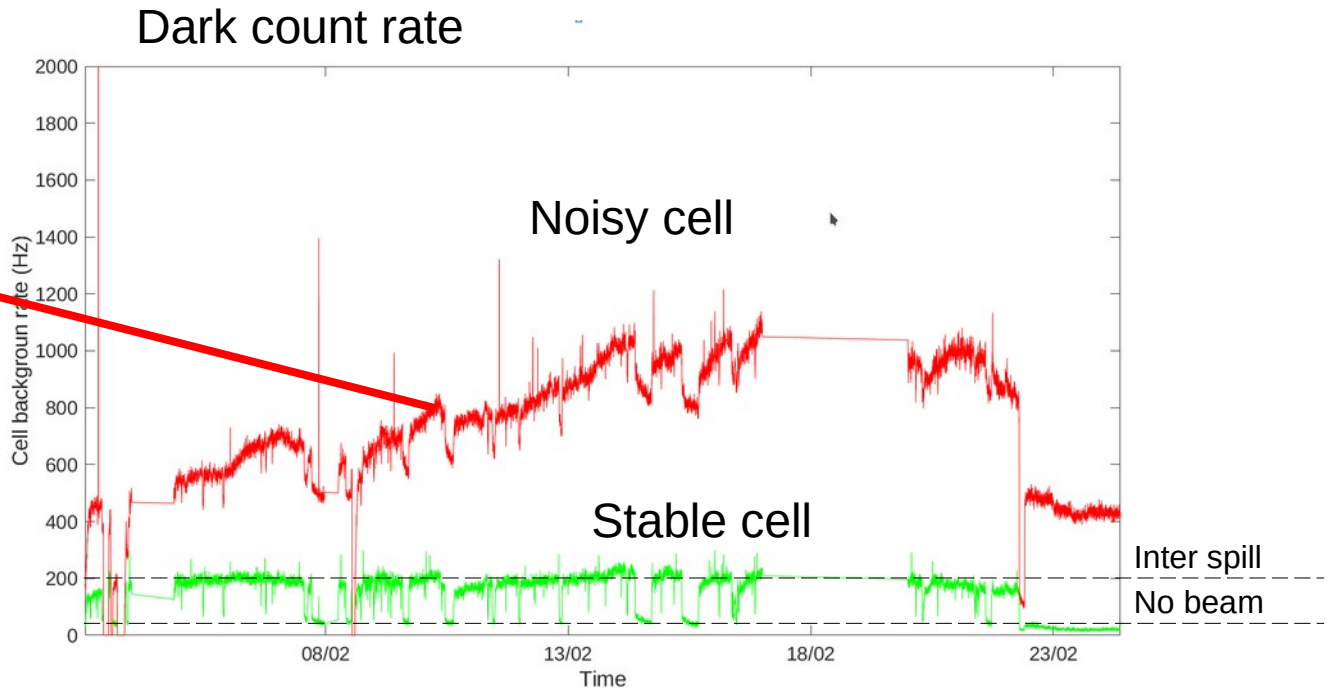
Monitoring of each cell. Dark count rate.

Dark **count rate (vs temperature) seems to be not a problem**

We have some **noise channels** mainly in **sector 2**
They were **quiet in the beginning.**
This behavior started before heating or irradiate the detector
We suspect that it is due to a **gas distribution problem.** Cell is quite close







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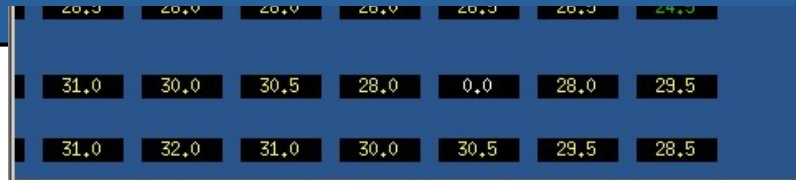

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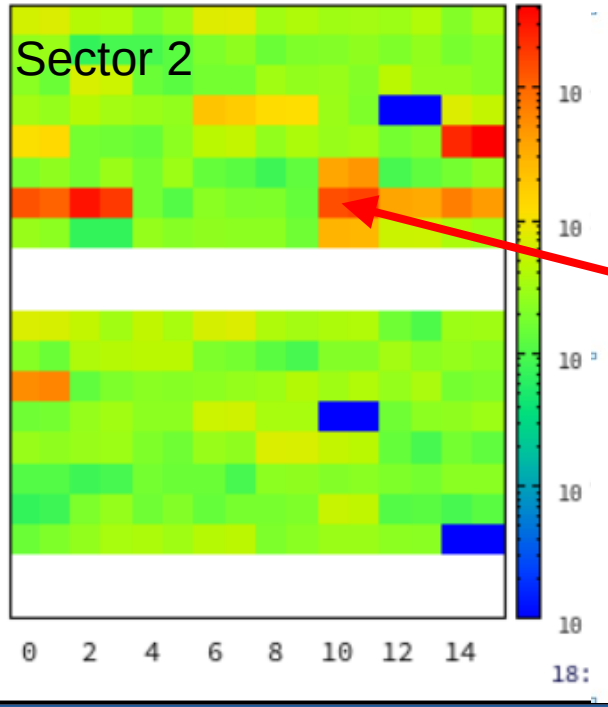
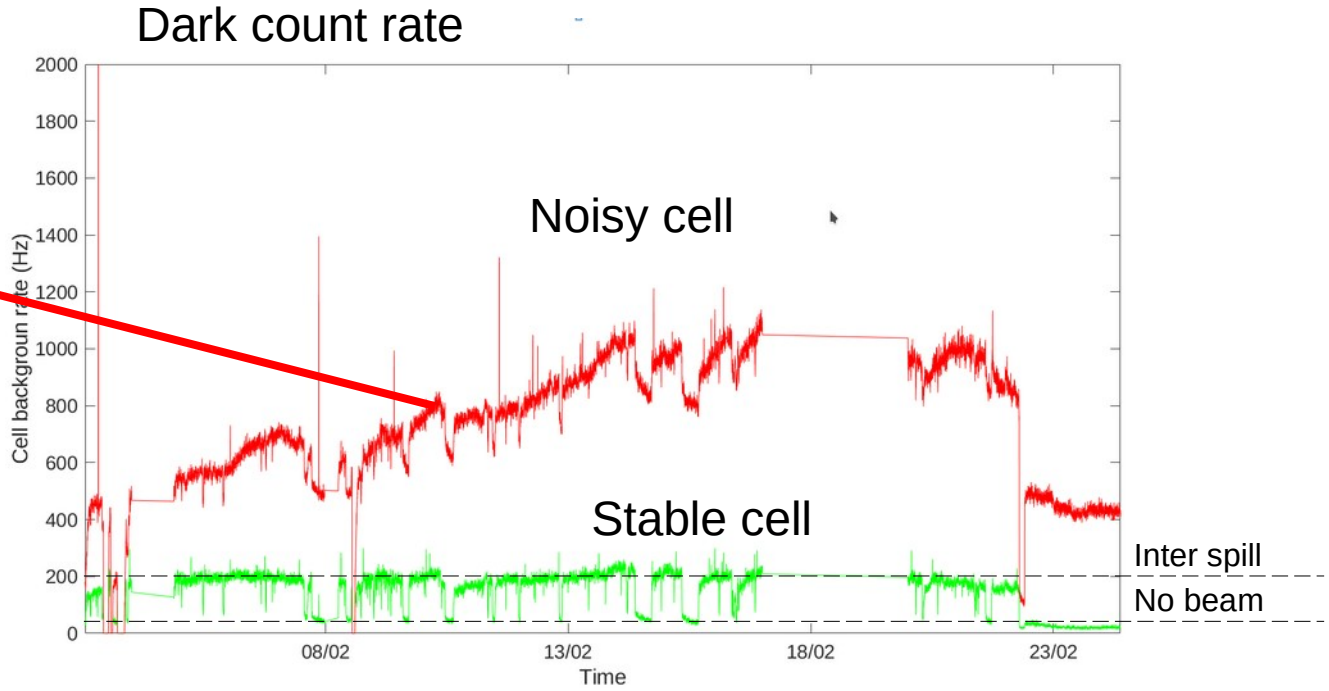
HADES already works at
~30ºC due to FEE heating





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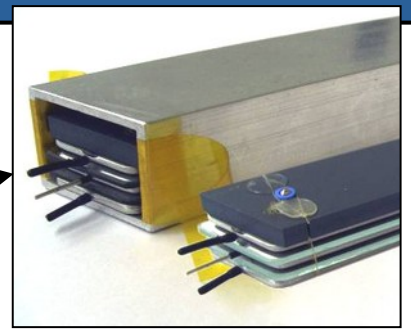
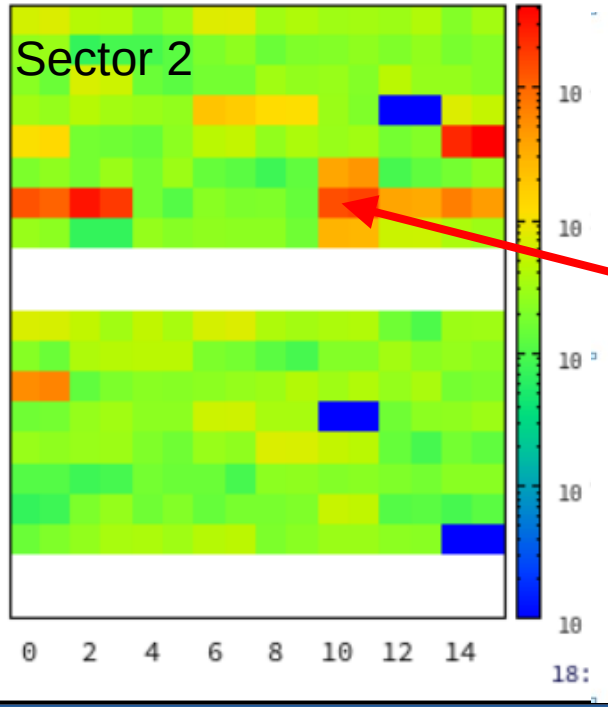
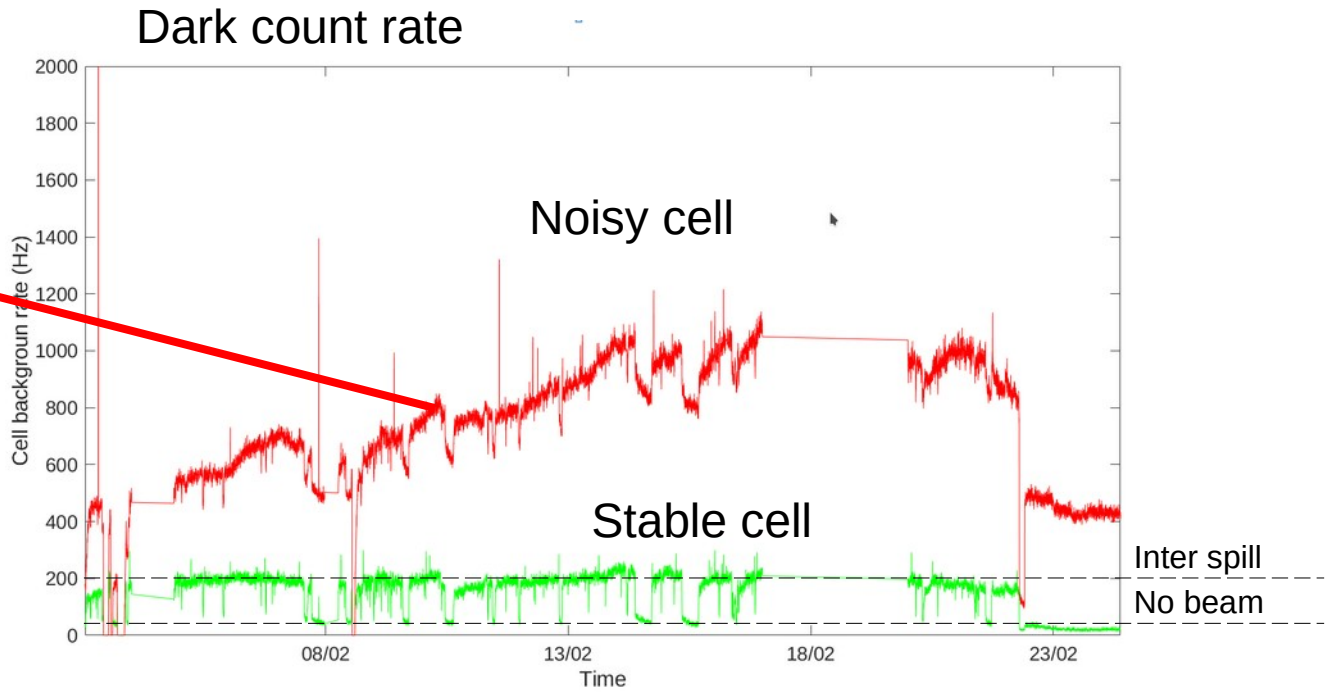






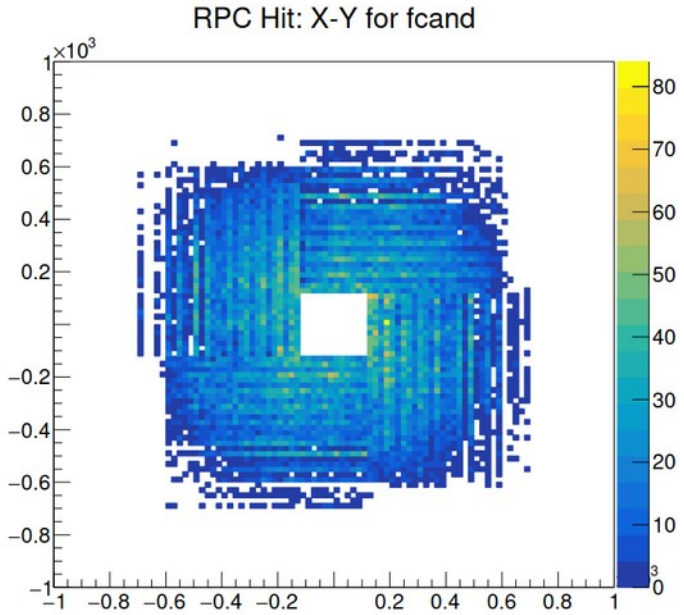
Next steps.

- Understand if we have a **gas distribution problem?**.

- Check the **efficiency** of the detector using the tracking system.

- Fully **calibrate** the system.

- Analyze a **high intensity run** at the end of beam time with rates up to **5kHz/cm²** and operation at **40 ºC**.



Hits in FRpc correlated with tracks (matching < 200 mm)

Conclusion.

The **possibility to improve the count rate capability of a glass timing RPC by increasing the working temperature** has been demonstrated.

Implemented in the **HADES FD-TOF.**

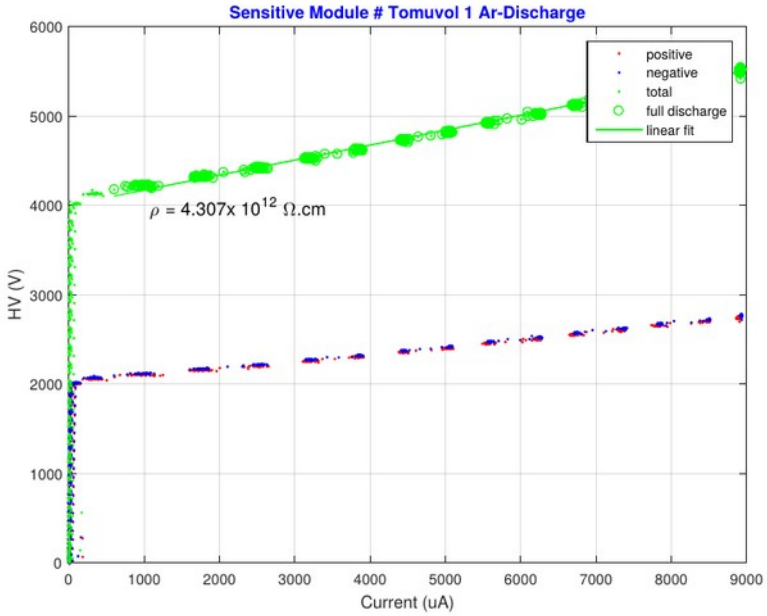
The HADES Forward RPC can stand up to **0.6 kHz/cm² @ 31º without any performance degradation.**

Six weeks of operation has been completed.

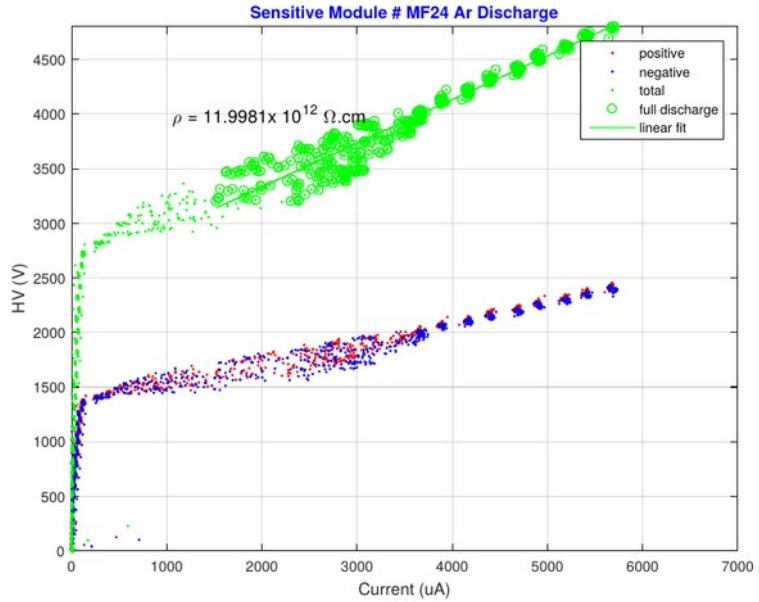
Timing resolution of 80 ps.

~ factor 6 in resistance => x6 in rate capability

1 mm glass

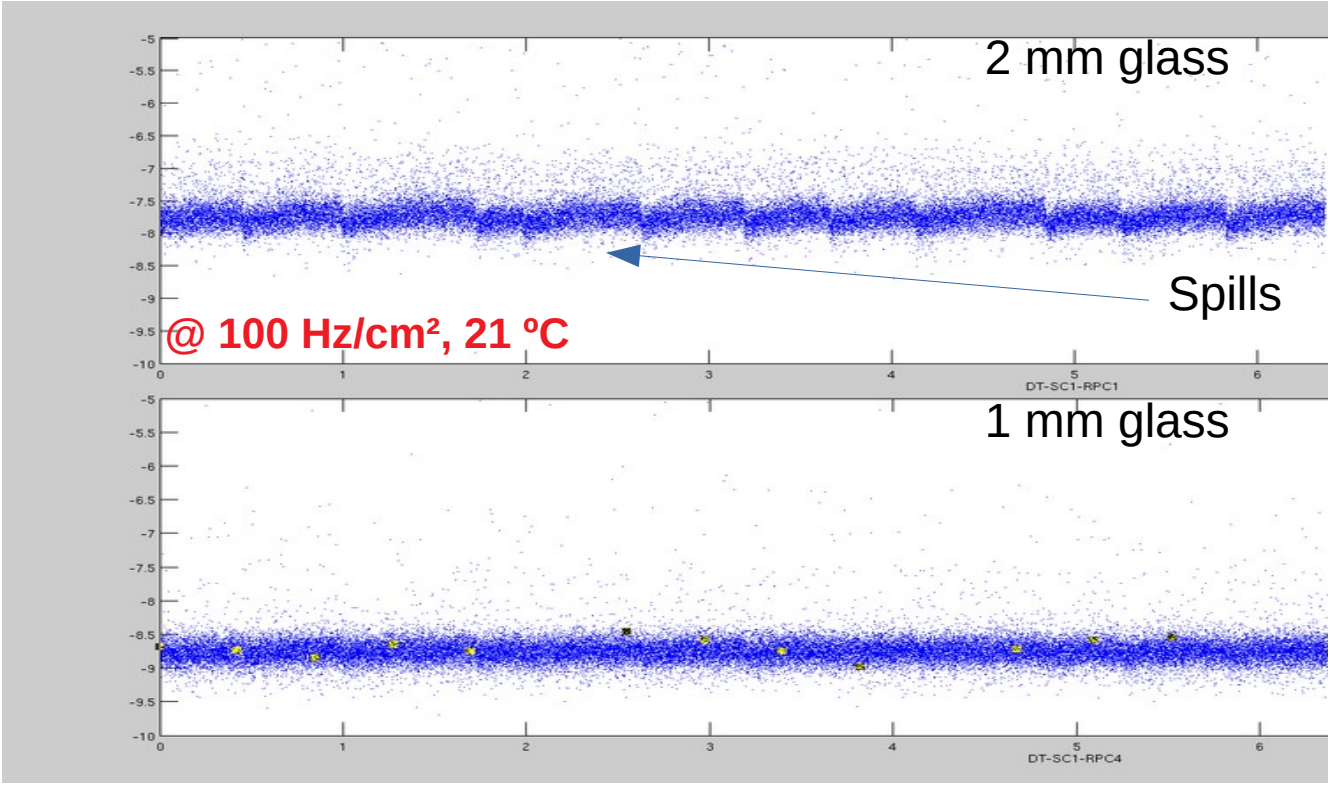


2 mm glass



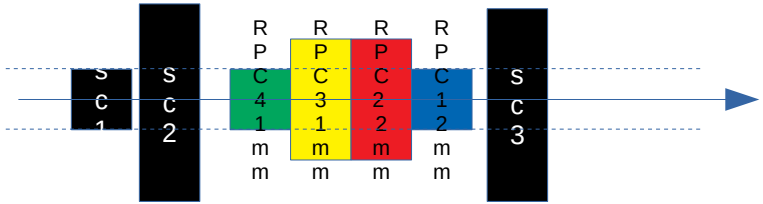
Prototype testing. Efficiency and timing precision vs HV.

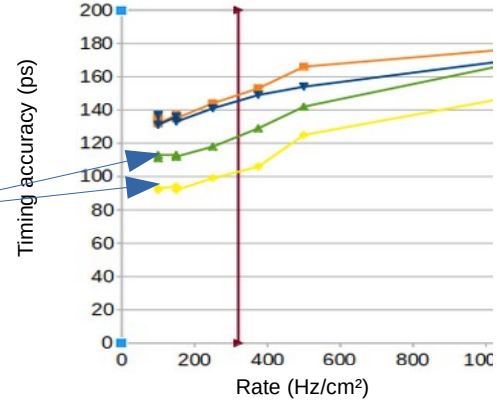
- **RPC2 (2 mm glass) already affected** by particle rate **100 Hz/cm².**

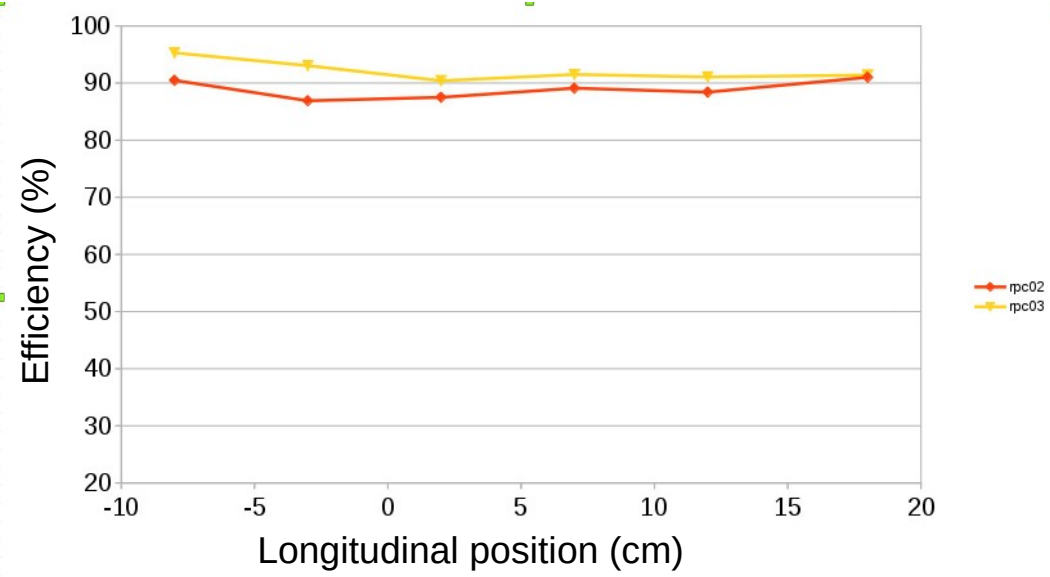


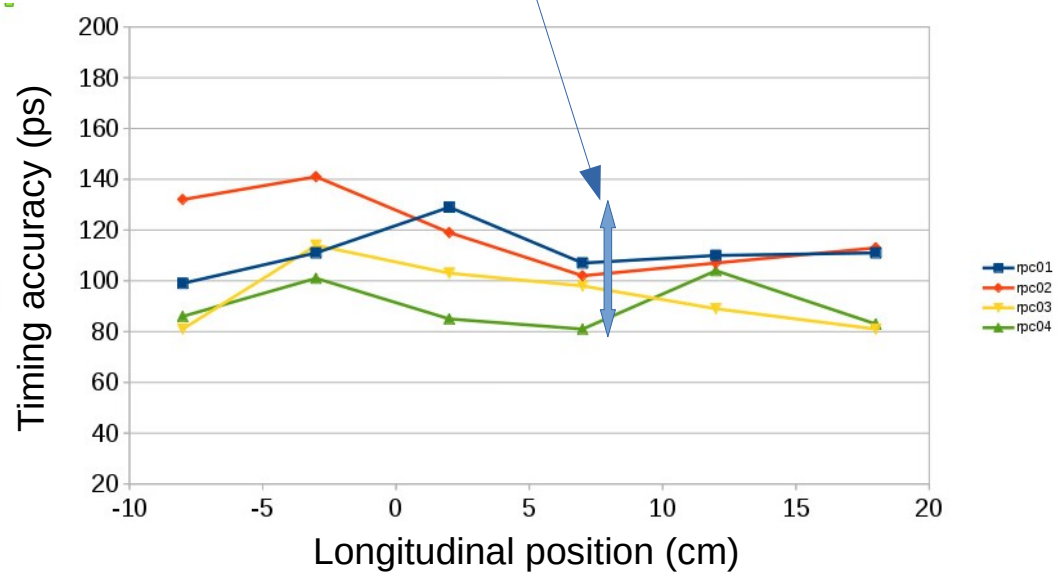
Prototype testing. Efficiency and timing accuracy Vs position

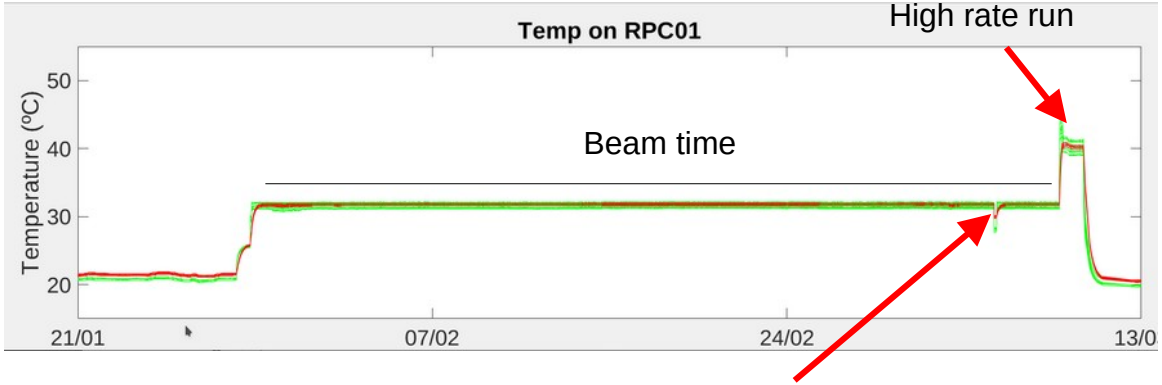
- **Efficiency relatively stable as a function of longitudinal position.**
- **Timing accuracy with some fluctuations** depending on the position
=> could explain why RPC 3 and 4 are not always grouped











- Δtemp < 0.5 º over ~4 m²
- Just one crash of the system to be improved.
- Tip: never use mechanics relays !!!!!

210 W @ ΔT = 14º 450 W @ ΔT = 22º