

RPC R&D group activities 2018-2019

News

- The **leadership** of the group was **transferred** from P. Fonte to A. Blanco. Early 2018.
- **RPC-PET group** was **re-integrated into the RPC R&D group**.
- **STRATOS project** approved. Construction of two CR Telescopes (for Hidronav company), a pre-prototype of macro scanner device for the scanning of truck containers in real industrial scale.
- **HiRezBrainPET project** approved. Aimed at the development of a PET scanner dedicated to the human brain with sub-millimeter resolution based on the RPC-PET technology.
- **RPC-Advance project** (Fundo CERN) **approved** in collaboration with Neutron detector group with the objective to address challenges on the RPC technology.

RPC R&D

Lines of work

RPC R&D group cooperates with several other LIP groups (Neutron Detectors, Auger, LATTES, HADES, SHiP) supporting their RPC-related activities

RPC-PET. Develop RPC technology for PET imaging.

Pre-clinical, human brain PET and full body human PET.

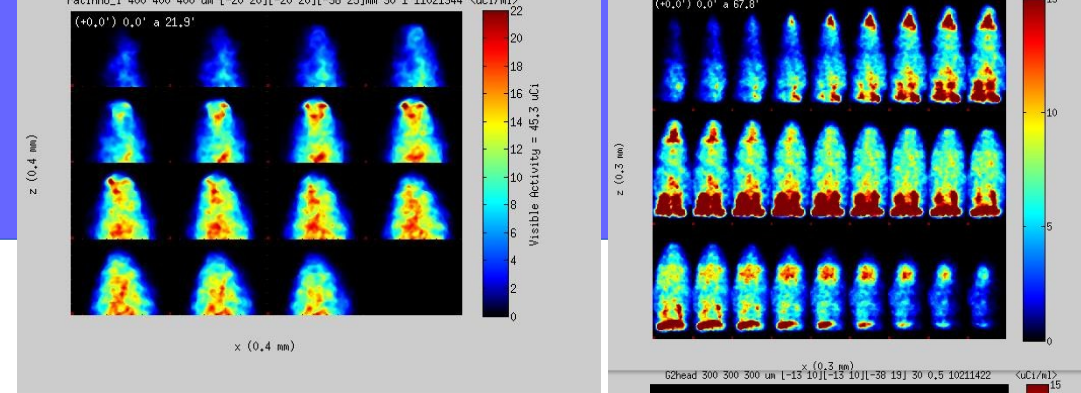
Timing and Position Sensitive RPCs. Develop timing RPCs for **high energy physics experiments** and in combination with position measurement to be applied in **muon tomography**. Both modalities, transmission (e.g. volcano and mine imaging) and scatter tomography (container scanning)

Developing RPC based technology **for SHiP and HADES collaboration. STRATOS** and **TRISTAN** cosmic ray telescopes, both dedicated to the precise measurement of cosmic ray flow, and **MUTOM** (together with the AUGER group) for muon tomography in mines.

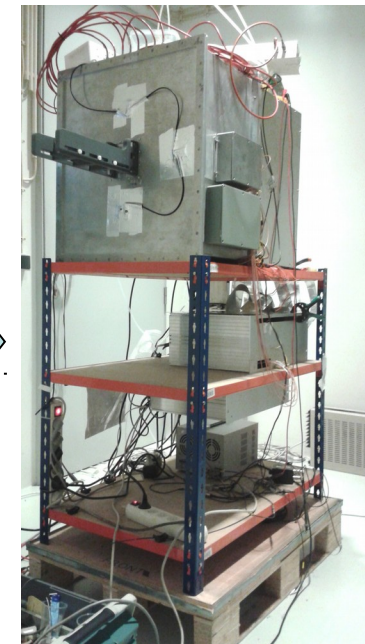
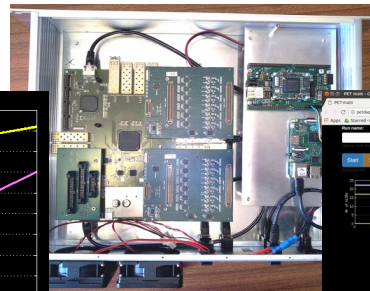
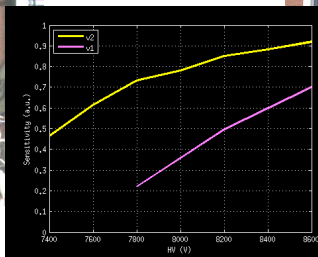
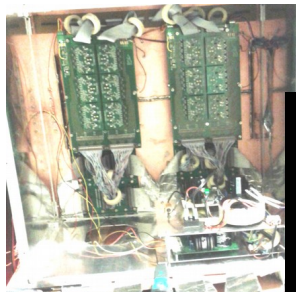
Autonomous RPCs. Outdoor, reliable, high performance, solar panel powered, auto-operated, low gas consumption and eventually sealed RPCs for **cosmic ray measurement**.

RPCs operated at high altitude (LATTES project) and operation of **RPCs in an ultra low gas flow regime** (eventually sealed).

RPC-PET. Pre-clinical PET



- Continuous support of **routine bio-research** activities ICNAS (hundred of mice scans). First biological results appeared => system is really working.
- Test and deploy of a **pre-commercial pre-clinical PET system**
 - New **FEE** 😊 (improve sensitivity), new **DAQ** 😊 (more channels), new **trigger system** 😊 (more versatile), new **environmental, HV and gas system** 😐, new friendly operator and data-user interface 😐



RPC-PET. HiRezBrinPET project

HiRezBrainPET: an RPC-PET brain scanner with sub-millimeter spatial resolution

Co-promotion project financed by COMPETE2020 involving:
ICNAS Produção (project leader) / Instituto Politécnico de Coimbra / LIP

Applications:

- Diagnosis and investigation of diseases of the central nervous system by allowing to resolve small brain structures such as the striatum, amygdala and thalamic subnuclei involved in neuropsychiatric diseases
- Characterization of cerebral vascular injuries
- Detection and staging of central nervous system tumors
- High-resolution PET imaging of other organs, such as the heart or liver, also with high clinical and scientific interest

Requirements:

- Spatial resolution **better than 1 mm**
- **Time resolution** better than **300 ps**
- **Solid angle** coverage better than **50 %**
- **Sensitivity** of at least **0.1 %**

Budget:

- "Total" investment: 529k€
- Hardware: 105k€
- Manpower: 72k€

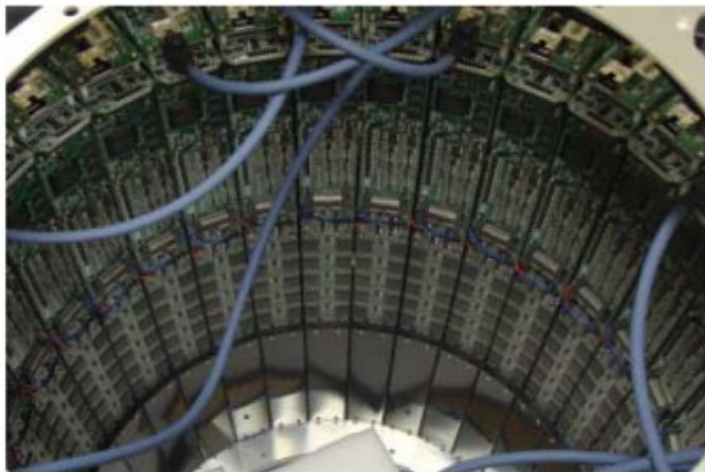
Timeframe: 28 months, starting 16 June 2019, ending 18 October 2021
1st iteration of full system expected by the end of 2020

Cofinanciado por:



UNIÃO EUROPEIA
Fundo Europeu
de Desenvolvimento Regional

RPC-PET. HiRezBrinPET competitors

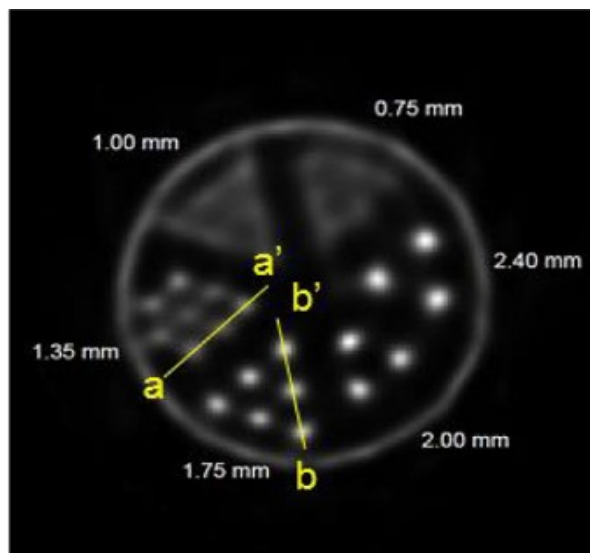


Performance evaluation of a high-resolution brain PET scanner using four-layer MPPC DOI detectors

Mitsuo Watanabe, Akinori Saito, Takashi Isobe, Kibo Ote, Ryoko Yamada, Takahiro Moriya and Tomohide Omura

Central Research Laboratory, Hamamatsu Photonics K.K., 5000, Hirakuchi, Hamakita-ku, Hamamatsu City 434-8601, Japan

Hamamatsu Photonics



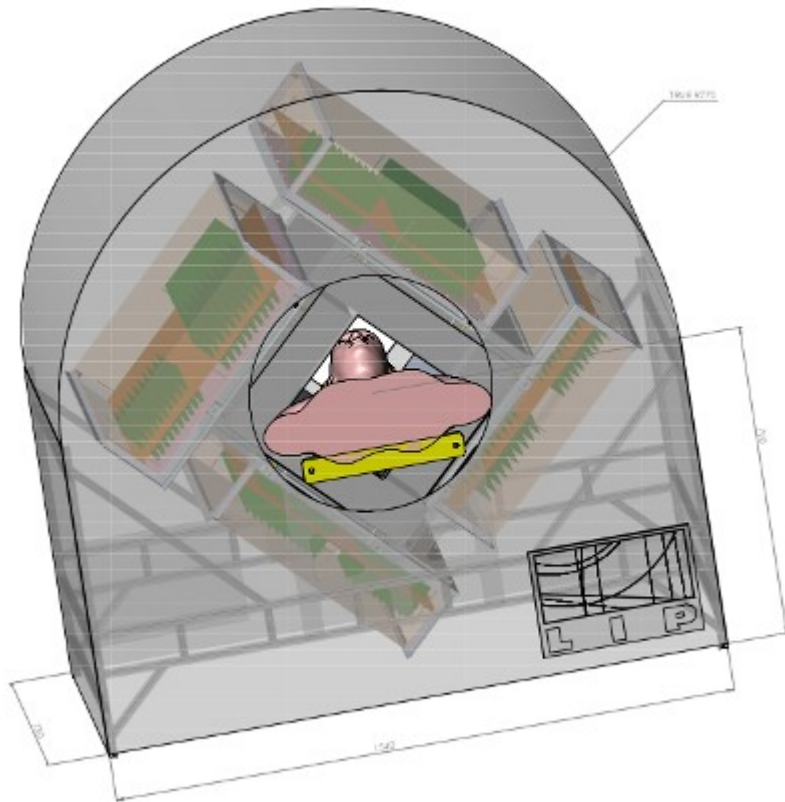
Resolution = 1.35 mm

665360 crystals!

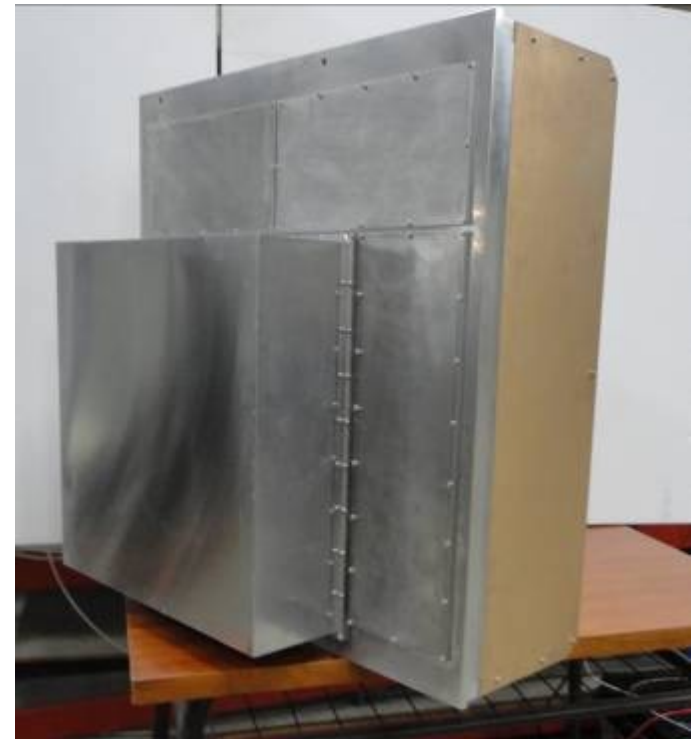
Cost: ? (use your imagination / common-sense)

We want to resolve the 1 mm sector by 105k€.
Something must give...

RPC-PET. HiRezBrinPET. Mechanics

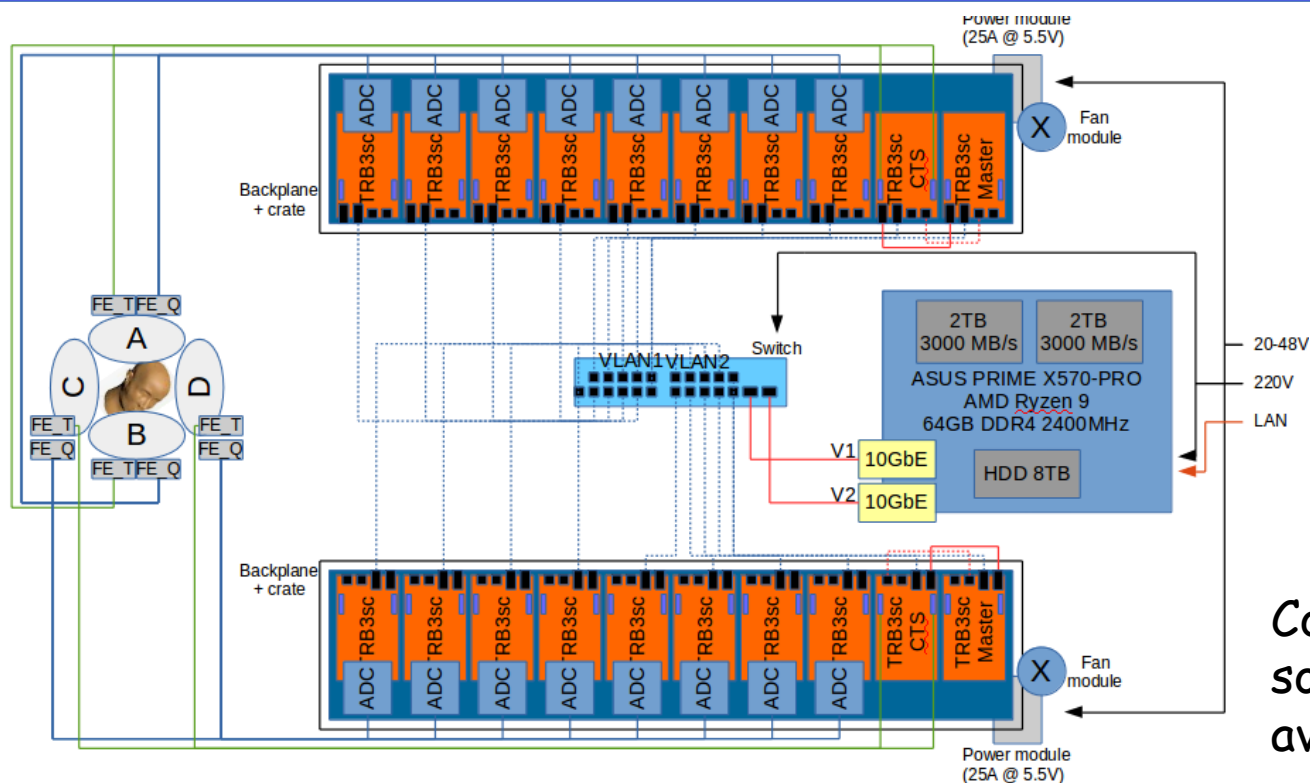


Mechanical project v1



Head 0 produced

RPC-PET. HiRezBrinPET. DAQ



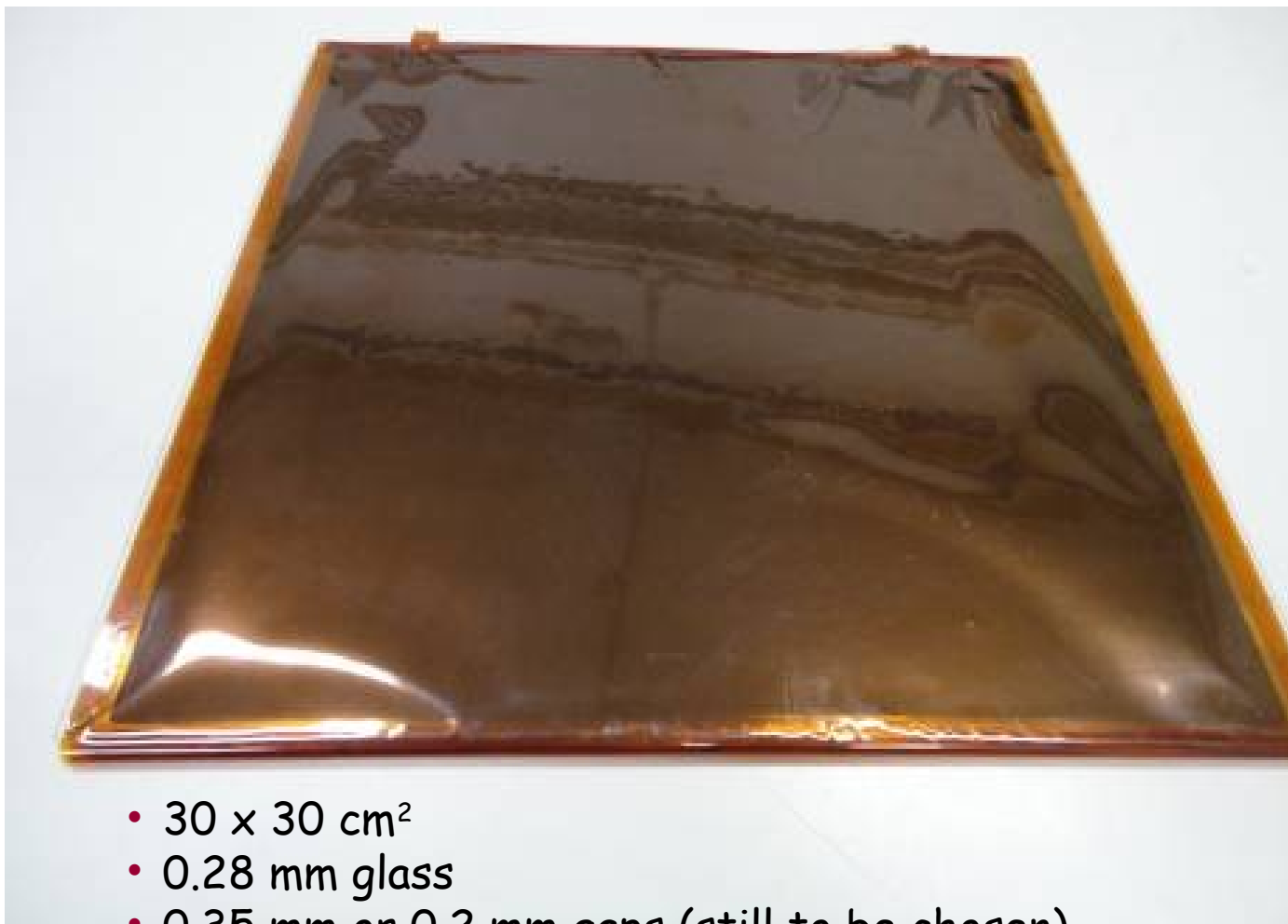
- based on TRB3sc+ADCaddon
 - cost 31k€
- ordered from GSI

Cost for an inferior commercial solution was 127k€ (more than the available total budget)

- 768 streaming ADC channels
- 10 ps TDCs (many)
- complex triggering possible
- ~10 Gb/s data rate

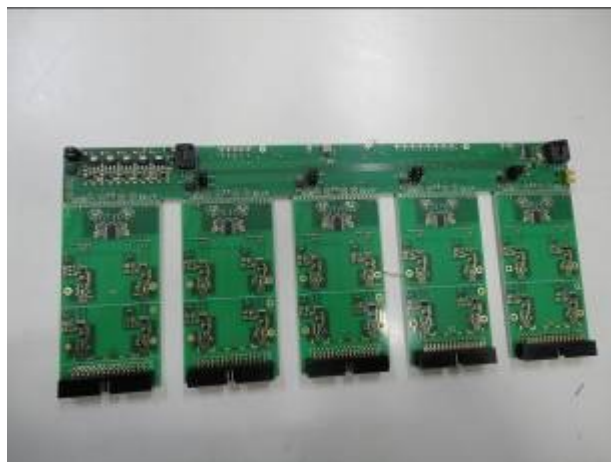


RPC-PET. HiRezBrinPET. Detectors



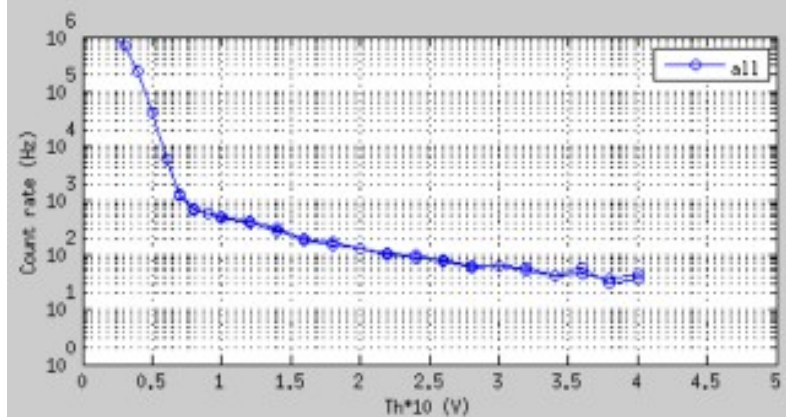
- $30 \times 30 \text{ cm}^2$
- 0.28 mm glass
- 0.35 mm or 0.2 mm gaps (still to be chosen)
- 5 gaps
- $\sim 5 \times 10^8 \text{ } \Omega/\square$ resistive HV layers
- **Still under development**

RPC-PET. HiRezBrinPET. FEE



Timing FEE

- 10 ch ORed
- $>40\text{dB}$ gain @ 700 MHz
- Stable down to e-noise equiv. to $\sim 500\text{ }\mu\text{V}$ or $10\text{ }\mu\text{A}$
- Polarity-selectable

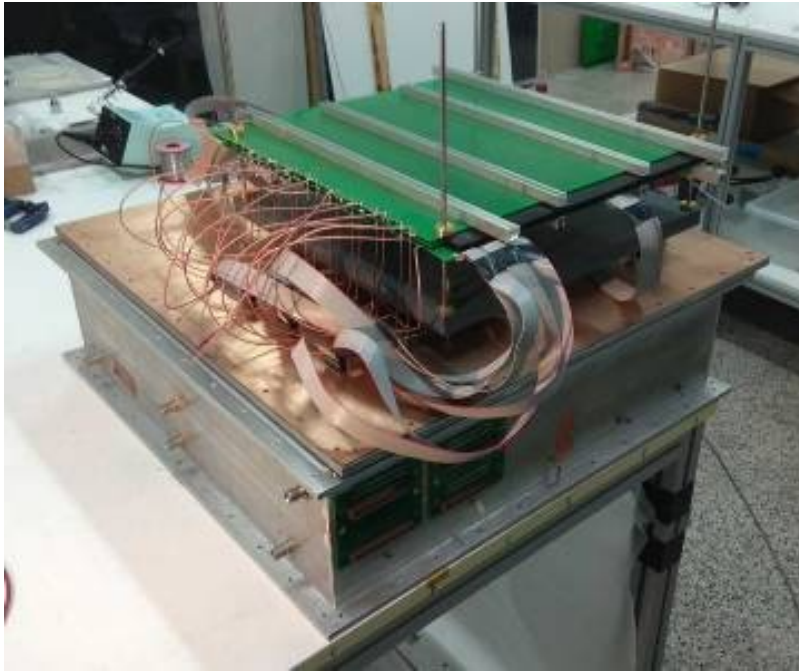


Charge FEE

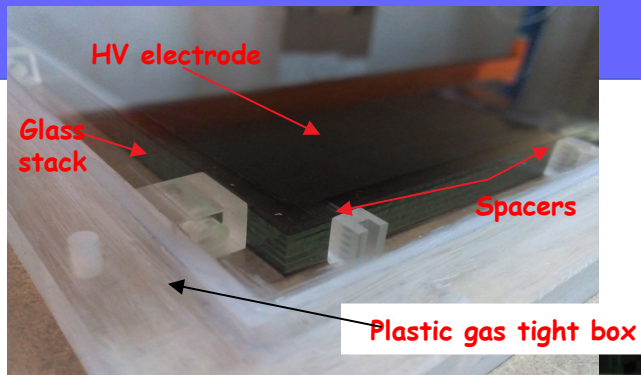
- 250mV/pC
- Noise 2 fC + 1 fC/nF
- 200 μs integration
- 24 ch
- 50 k Ω isolation between pre-amp and amp
- Bipolar

Ready for production

RPC-PET. HiRezBrinPET. Engineering test box

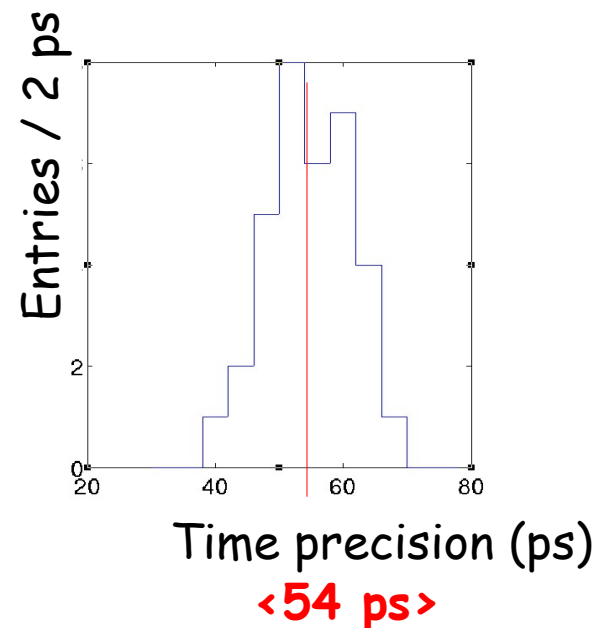
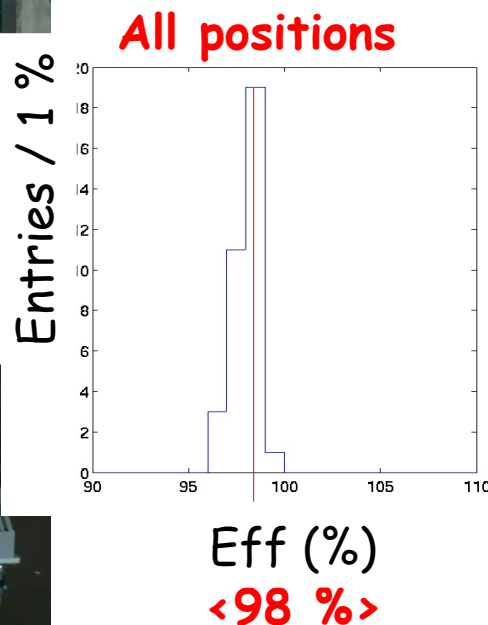
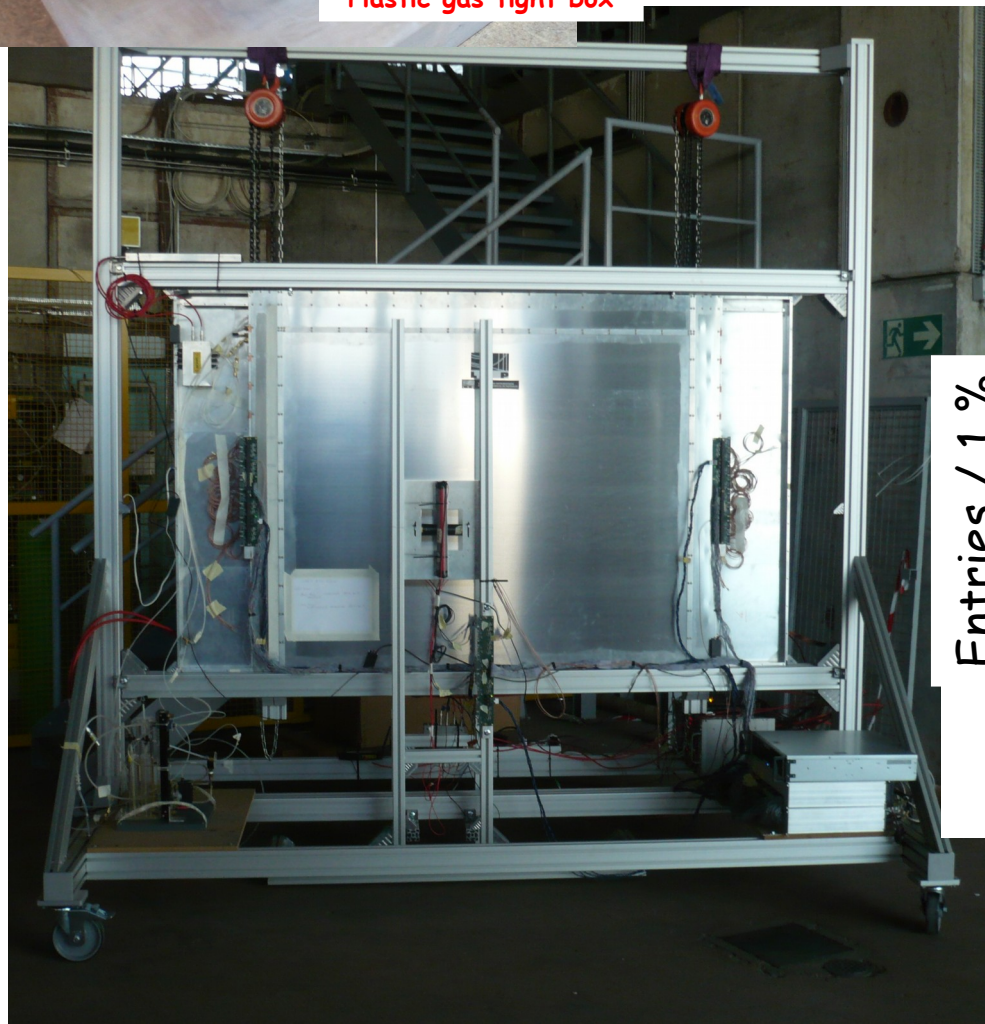


Timing RPCs. SHiP



Requirements of the **ShiP timing detector** are **fulfilled** by the proposed technology based on MRPC.

Timing accuracy ~ 54 ps together with an efficiency of **98 %** without noticeable dependence with position over ~ 2 m² active area.



Timing RPCs. SHiP

Detector completely rewired during beam time

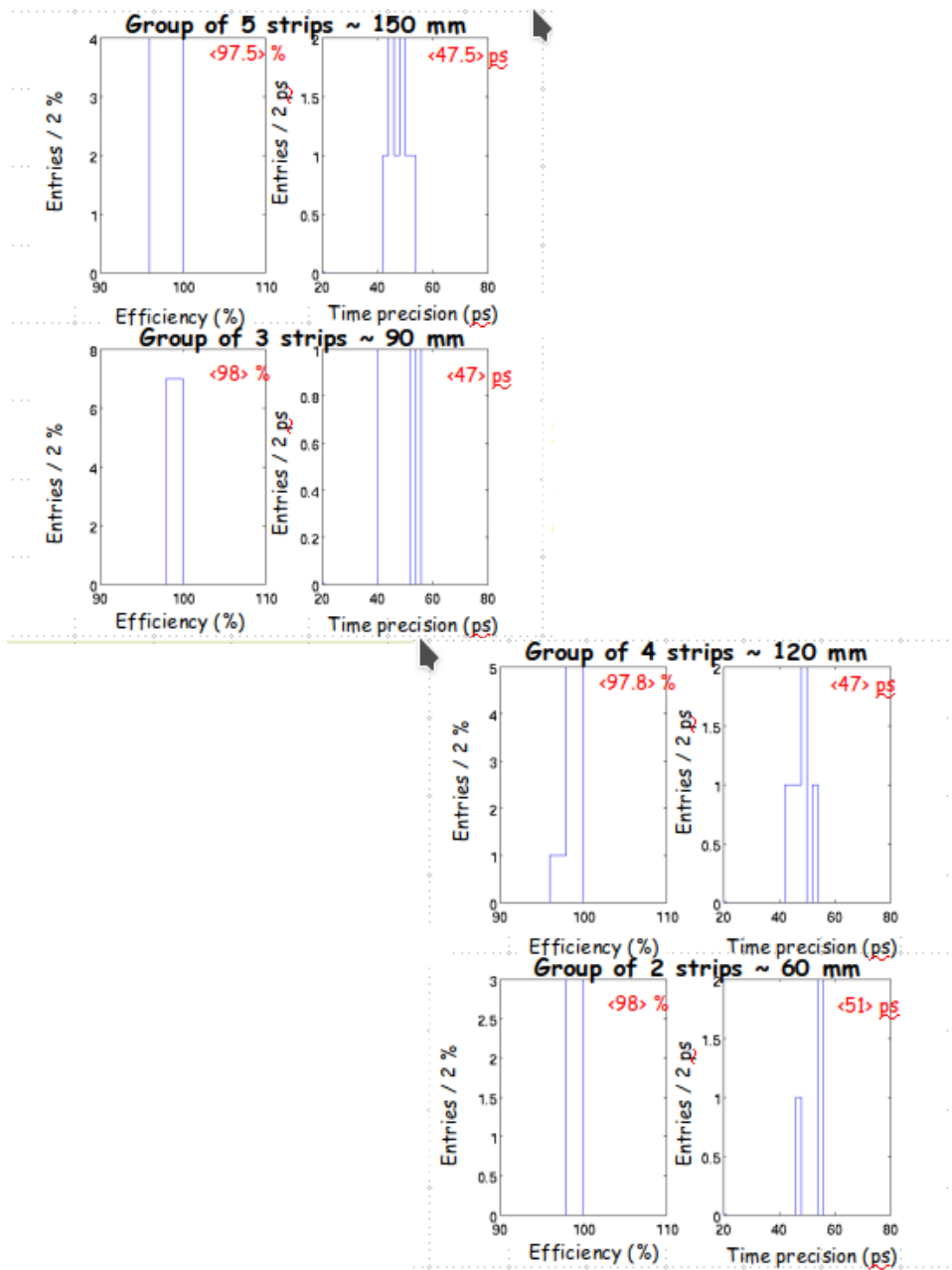
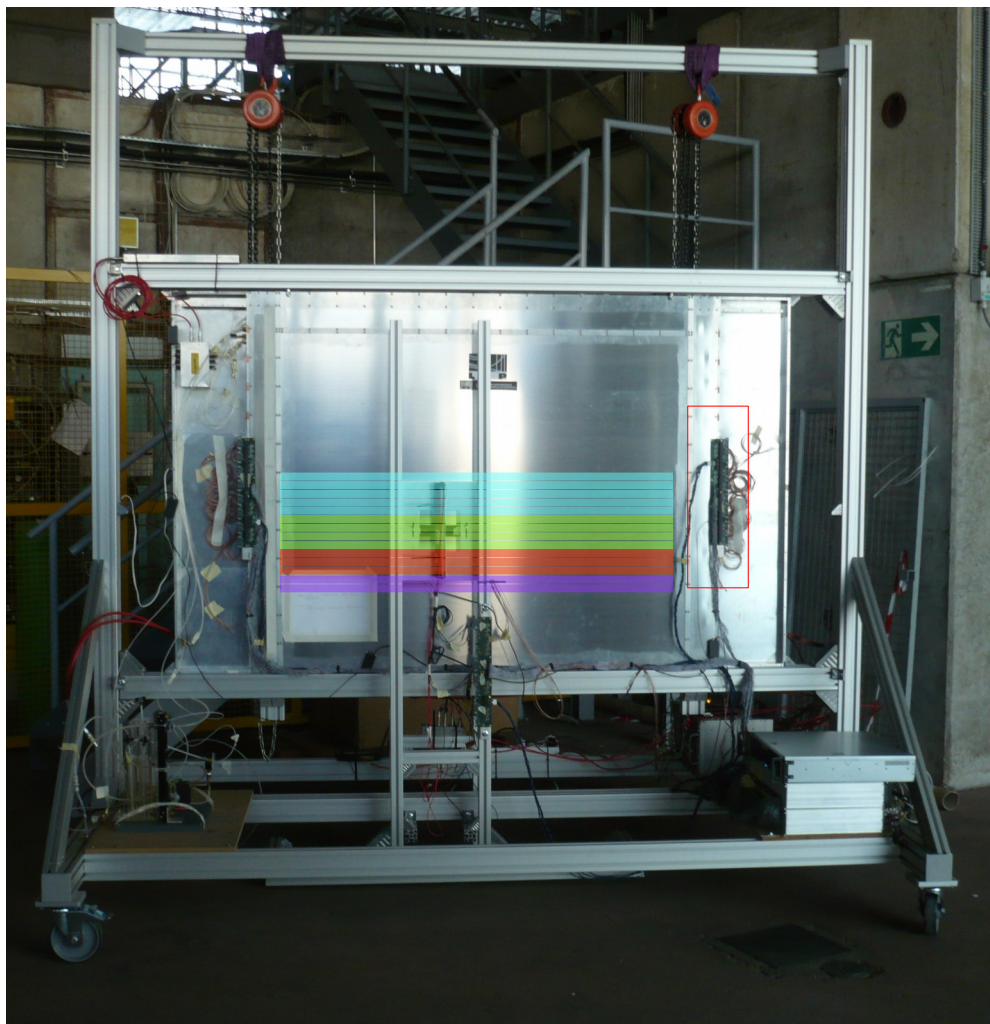


Group several strips in one single channel
2 (60 mm), 3 (90 mm),
4 (120 mm) , 5 (150 mm)
strips together

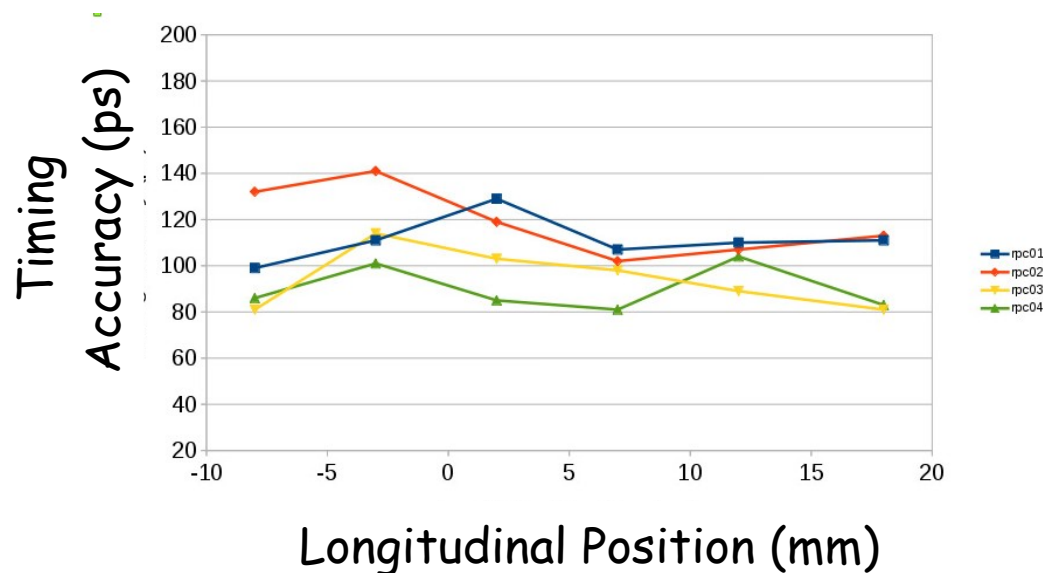
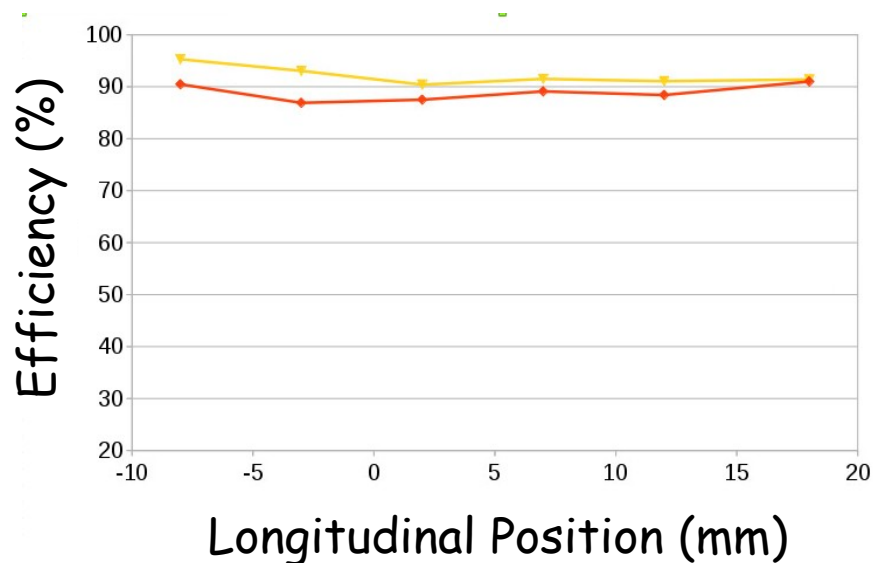
Motivation => simplify the detector, if possible, to make it cheaper but keeping performance unaltered.

Timing RPCs. SHiP

Detector completely rewired during beam time



Timing RPCs. RPC-TOF Forward Detector



RPC + heating system for count rate improvement



Reference scintillators

Requirements of the HADES-FD timing detector are **fulfilled**.

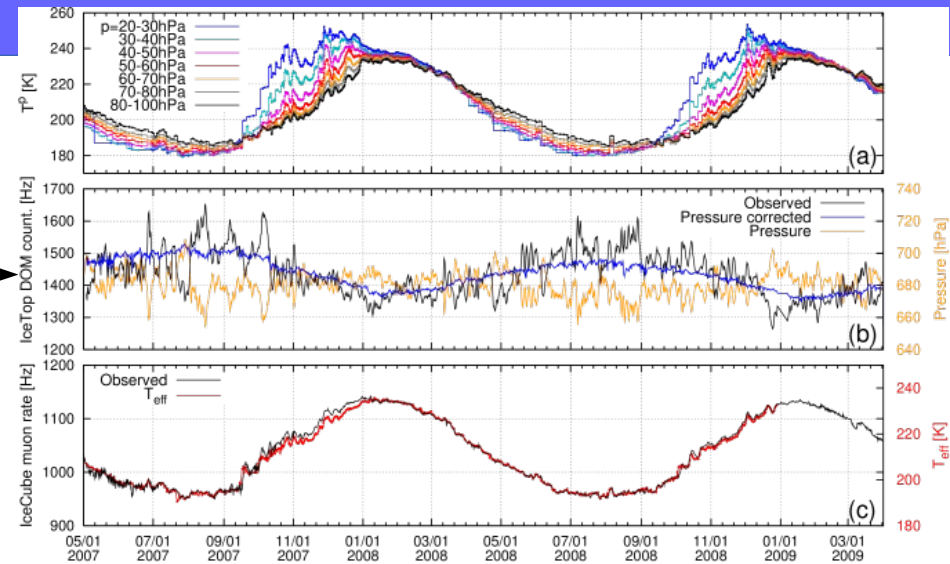
Rate capability with **~90% eff** and **~100 ps up to 400-500 Hz/cm²**

Increase the operation temperature will improve the rate capability

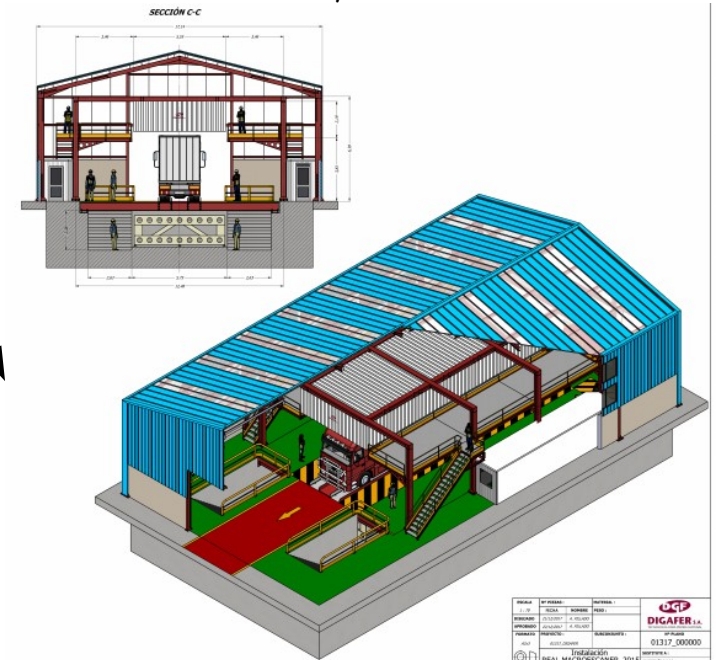
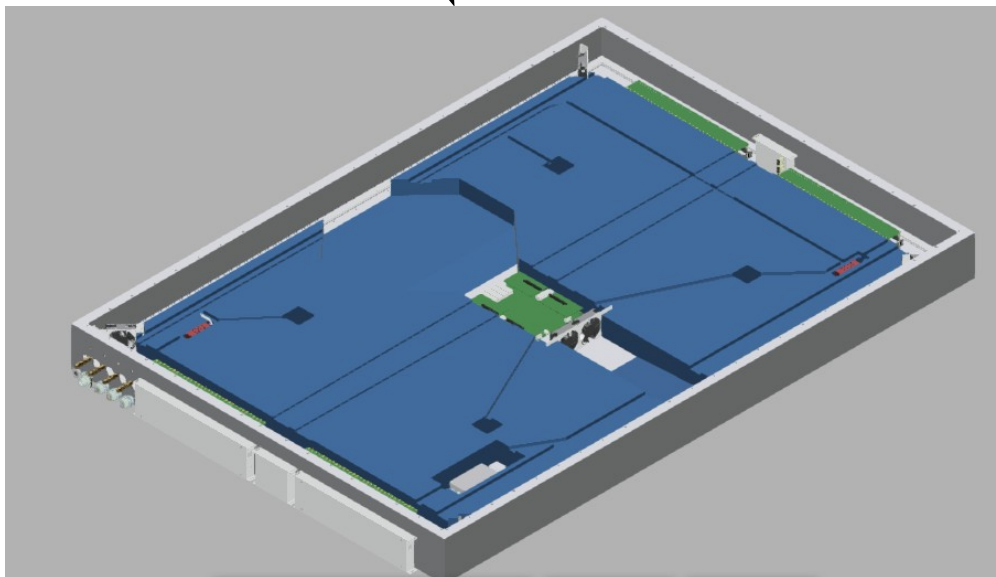
Timing and Position Sensitive RPCs. STRATOS

2x four plane RPC telescope meant for the **precise measurement of cosmic ray flow**, in order to **address the temperature of the stratosphere**, but a pre-prototype of macro scanner detector.

Severely delayed, but **significant progress has been made in developing industrial methods** for the production



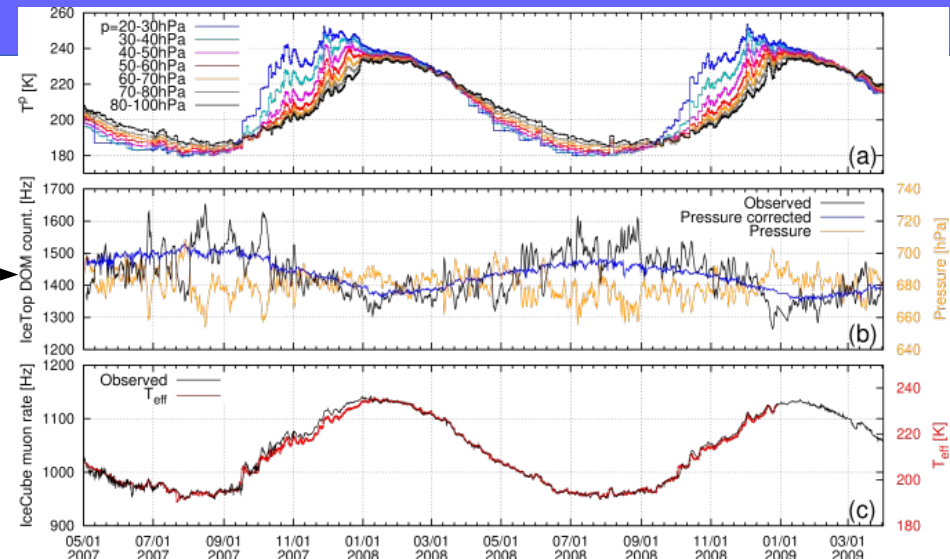
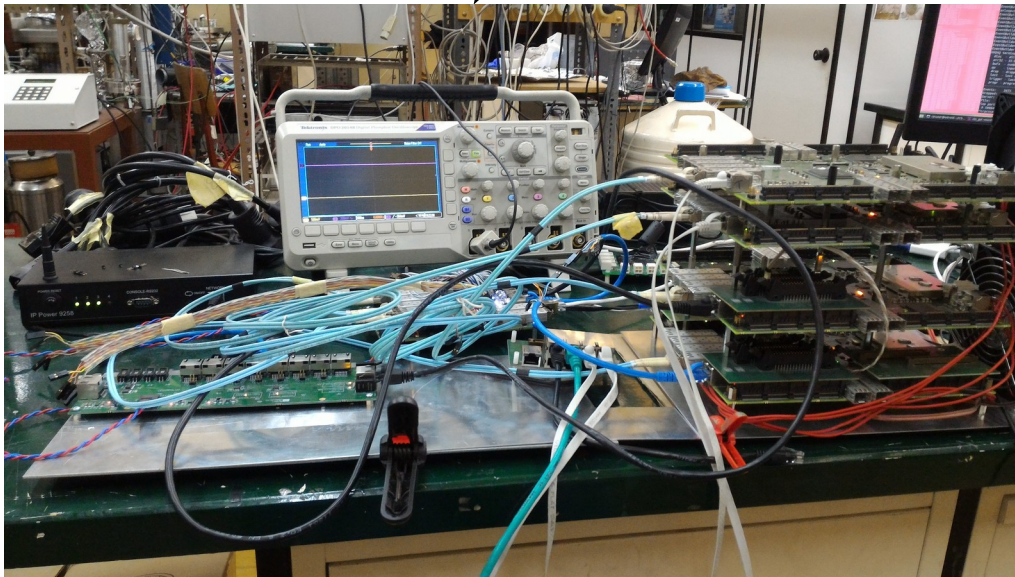
Correlation between cosmic ray flow and stratosphere temperature measured by ice cube.



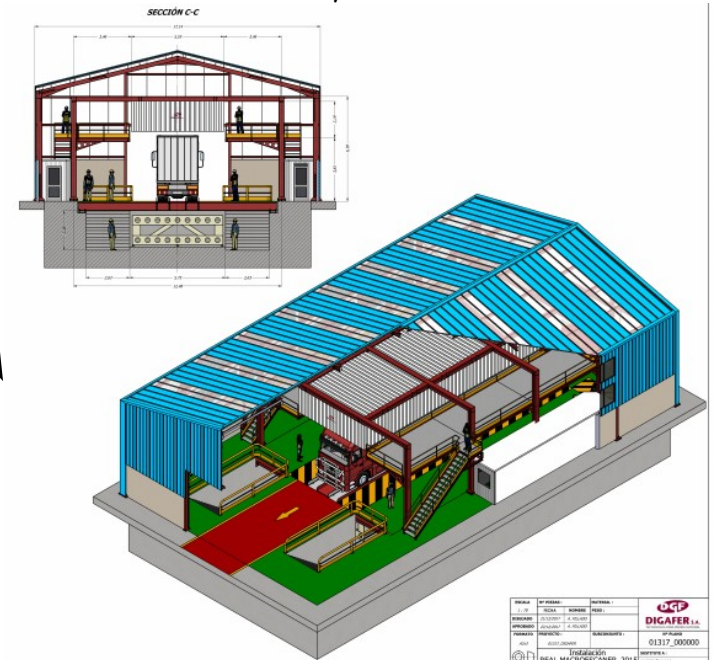
Timing and Position Sensitive RPCs. STRATOS

2x four plane RPC telescope meant for the **precise measurement of cosmic ray flow**, in order to **address the temperature of the stratosphere**, but a pre-prototype of macro scanner detector.

Severely delayed, but **significant progress has been made in DAQ**



Correlation between cosmic ray flow and stratosphere temperature measured by ice cube.



Timing and Position Sensitive + autonomous RPCs. TRISTAN

Three layers MARTA RPC +
HADES like readout
telescope

Meant for the **precise**
measurement of cosmic ray
flow, in 2x latitudinal survey
and permanently in Antarctic

DAQ System – main features

- **System Fully Autonomous**
 - Data acquisition starts automatically
 - Hardware power-cycle in case of failure
 - Log analysis, search out of range values
- **Alarms** sent via email in case of issue
- **Daily Reports** sent via email
- **Rates & Coincidences** sent every 30 minutes

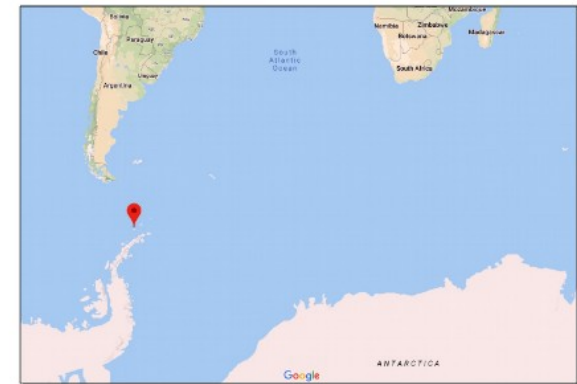


TRISTAN Detector

3 RPC planes to study Secondary Cosmic Rays

Designed to be part of the **ORCA Observatory**¹
in the Livingston Island²

Before installation in the Antarctic base, the
detector made a **Latitude Survey** from Vigo
(Spain) to Punta Arenas (Chile)



co et al., ORCA (Antarctic Cosmic Ray Observatory): 2018 latitudinal survey, ICRC 2019

Antarctic Station "Juan Carlos I" in the Livingston Island - Antarctica

P. Saraiva (LIP)

The TRISTAN Detector - RPC2020

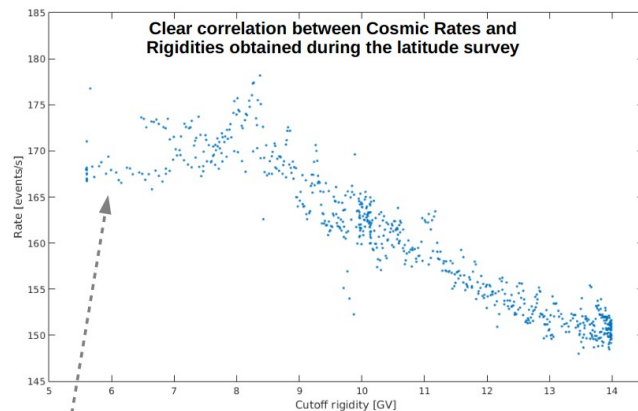
February 10-14, 2020

Fully autonomous system
with almost 100% duty cycle

Timing and Position Sensitive + autonomous RPCs. TRISTAN

Three layers MARTA RPC +
HADES like readout
telescope

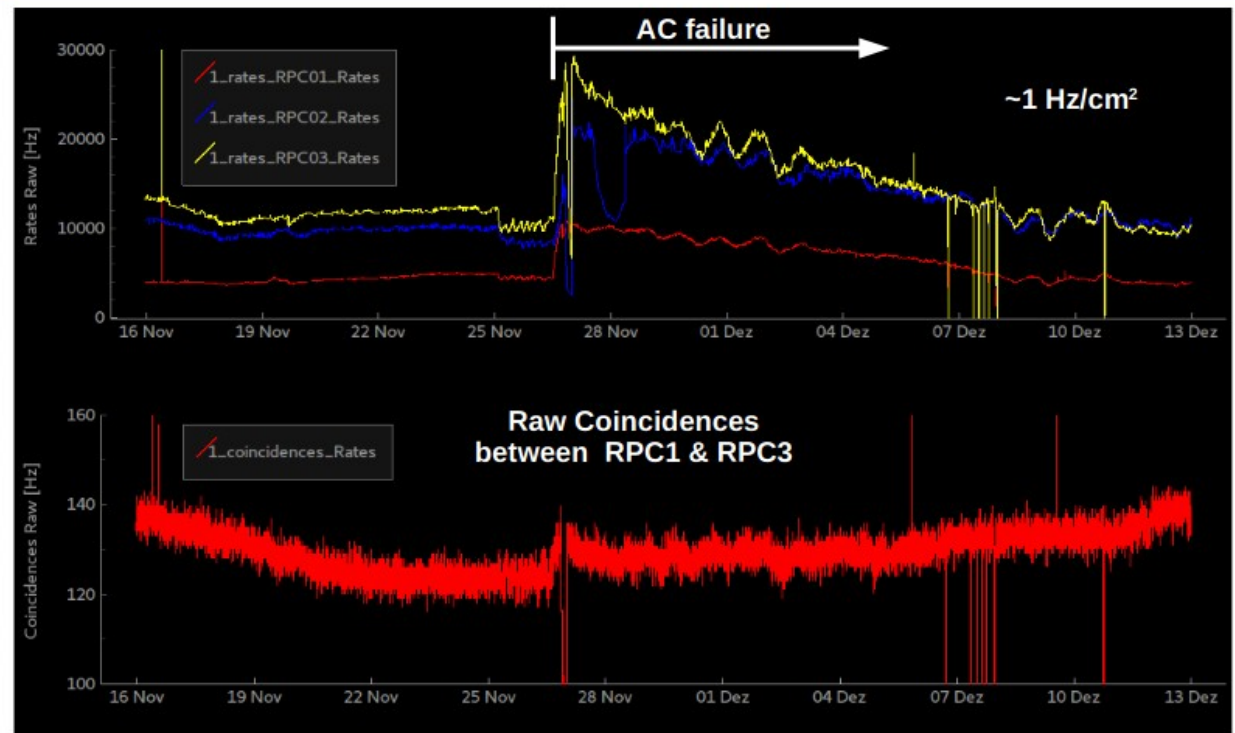
Meant for the **precise**
measurement of cosmic ray
flow, in 2x latitudinal survey
and permanently in Antarctic



-> points outside the correlation region being investigated

Clear correlation with rigidity

Background Rates & Raw Coincidences



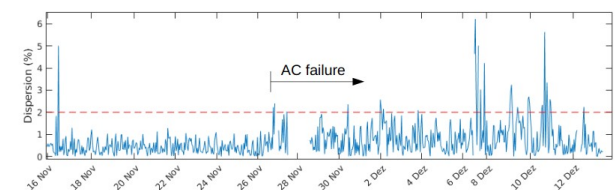
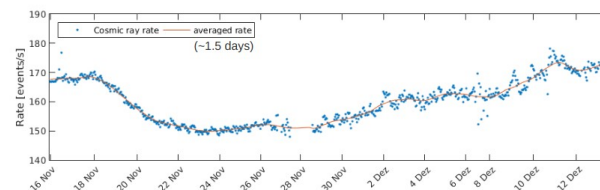
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J.P. Saraiva (LIP)

The TRISTAN Detector - RPC2020

February 10-14, 2020

Stability better than 1 % in 1 h time

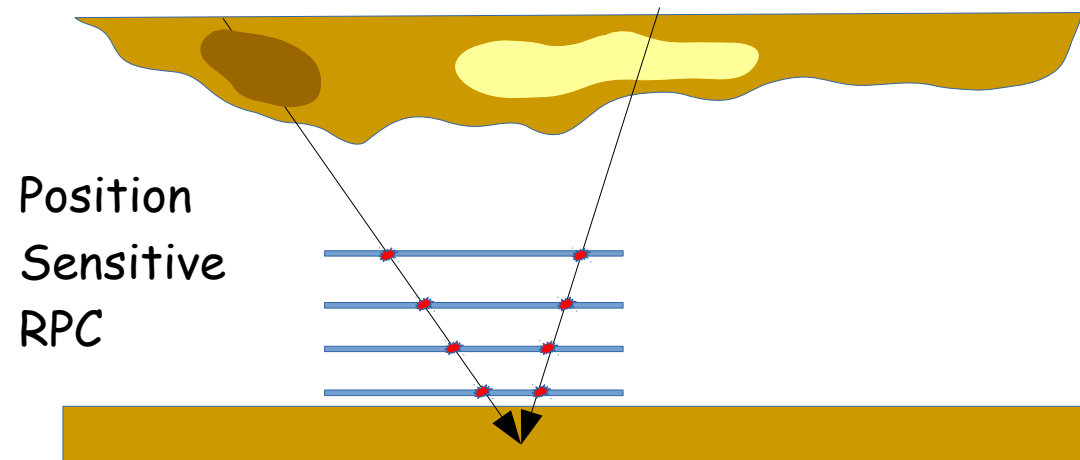


More than 99% of measurements are below a 2% dispersion

-> can be even better with controlled temperature

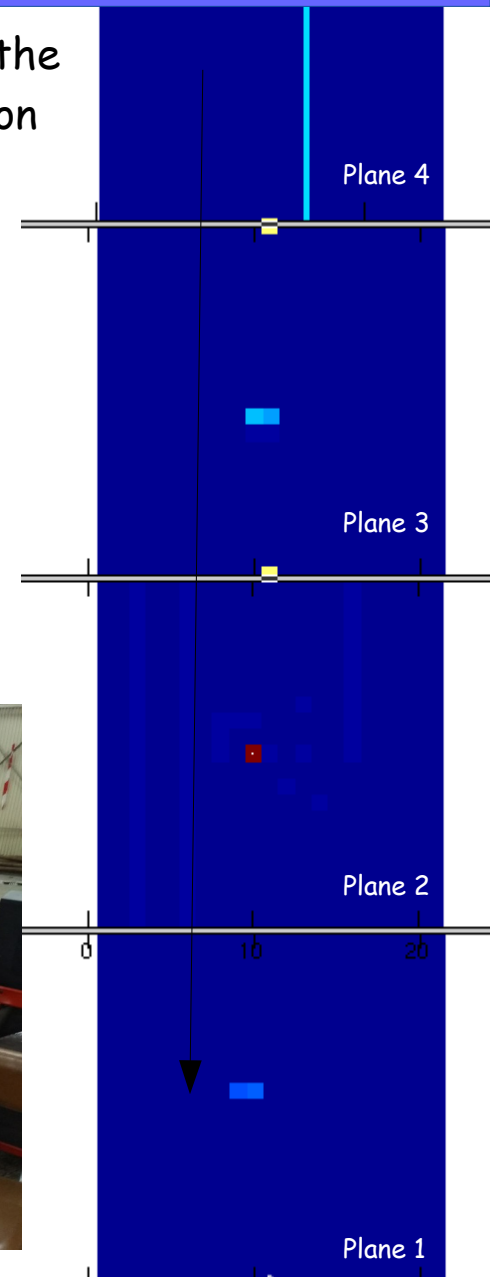
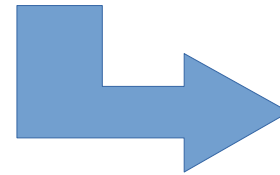
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Timing and Position Sensitive timing + autonomous RPCs. MUTOM

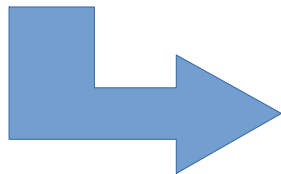


Transmission tomography at the Lousal mine.

Real event displayer with the detection of a single muon

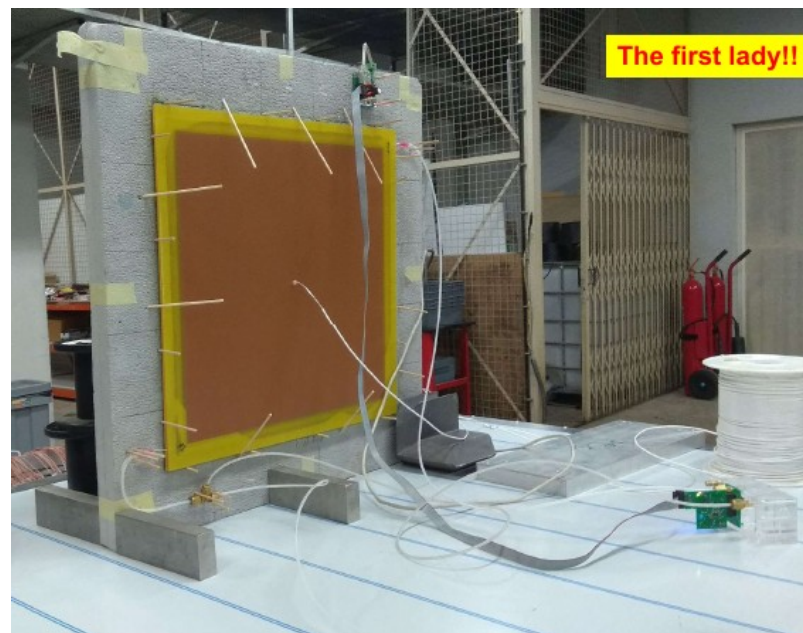


Four layers RPC telescope based on MARTA-like modules and DAQ **fully equipped**. Under construction at the Coimbra DL.

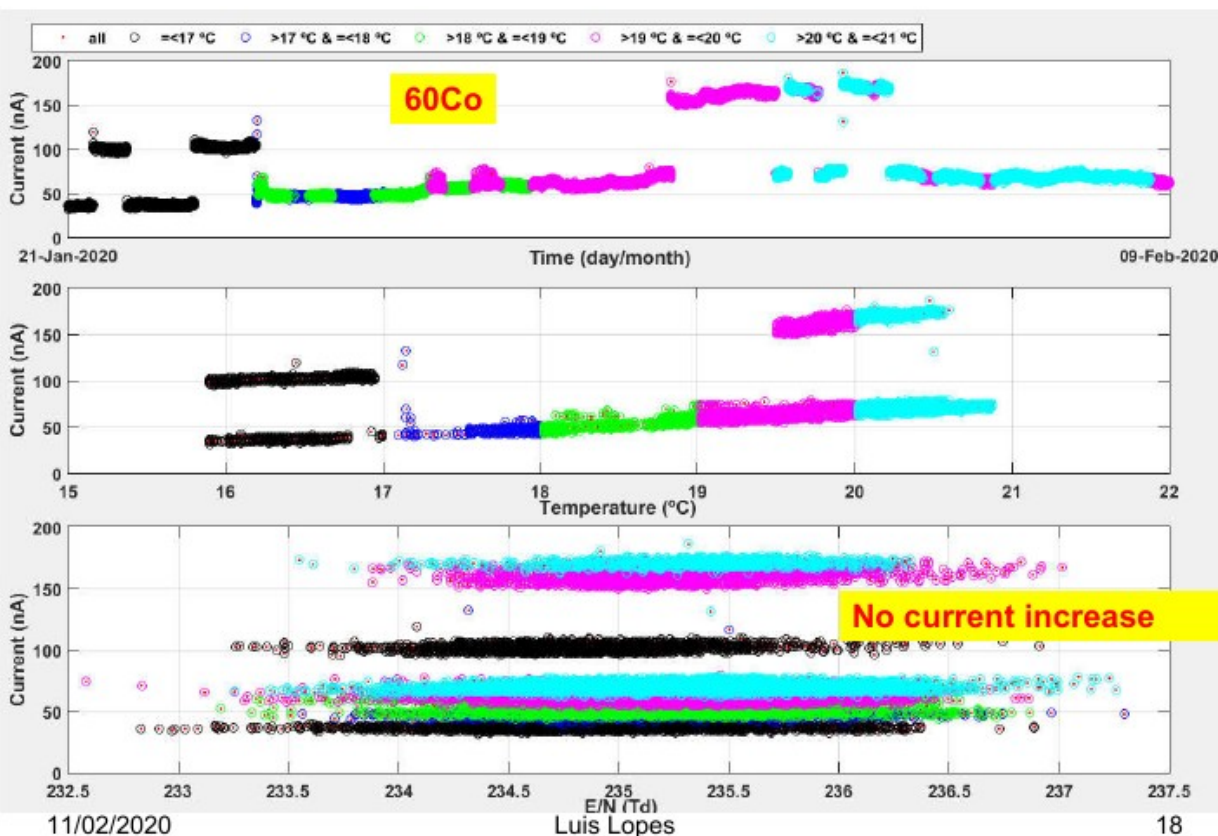


Autonomous RPCs. Sealed RPCs

Third prototype of **RPC sealed chamber** seems to **have a promissory behavior** After two months the chamber continue with stable operation



It will bring a **breakthrough** in HEP and particularly in Astroparticle experiments, **opening up new possibilities**, for example, by making possible **installation of stations equipped with RPC detectors in unattended remote locations in future experiments**



Near future

- Continue with the R&D and construction of the **HRezBrainPET**.
- Continue with **SHIP R&D** and finalize the **HADES-FD** construction.
- Start and finalize the construction of **STRATOS**.
- Continue with the successful operation of **TRISTAN** and initiate the **MUTOM** field operation.
 - Continue with the development of sealed RPCs and the high altitude operation RPCs (**LATTES/SWGO**).
- Initiate the RPC-ADVANCE project focused on:
 - Large area ultra low gas consumption RPCs.
 - Medium area RPCs offering simultaneous accurate measurement of timing and two-dimensional position,
 - Medium area high rate tRPC.
 - High rate position and neutron sensitive RPCs
- We want to attract **students** to the group.