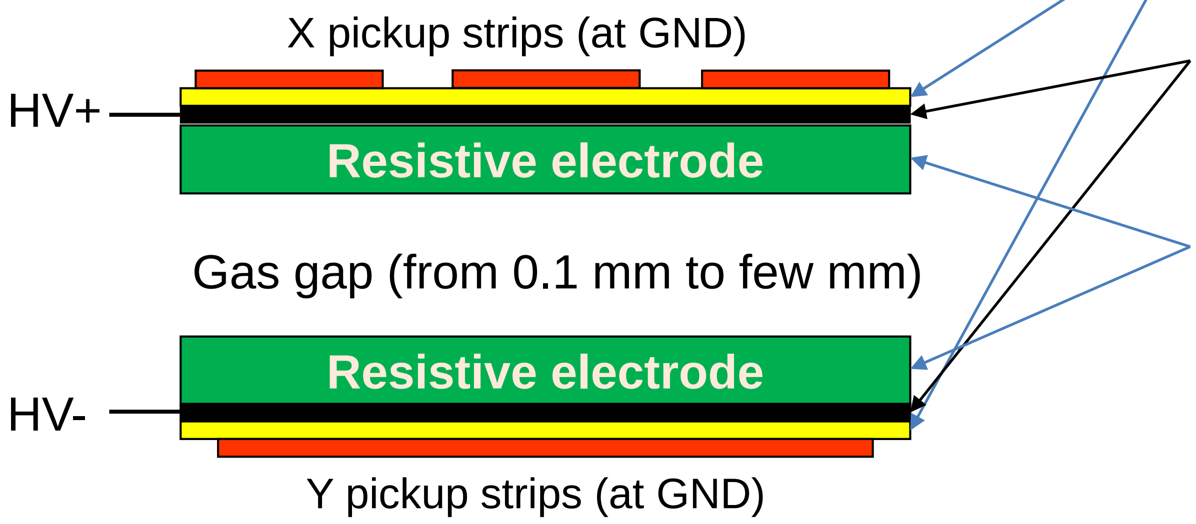
Resistive Plate Chambers (RPCs) at LIP-Coimbra

Luís Margato, Alberto Blanco, Andrey Morozov,

Luís Lopes, Paulo Fonte

RPCs basics

- Typical RPC Structure



High resistivity layer (e.g. PET)

HV distributed trough a medium resistivity layer (e.g. Graphite or resistive Ink) transparent to the induced signals

Resistive electrodes
(e.g. **glass**, bakelite,ceramics)

"Standard" gas mixture:

$C_2H_2F_4$ (tetrafluoretane or R134a)

1 to 10% SF_6 (sulphur hexafluoride)

0 to 5% C_4H_{10} (isobutane)

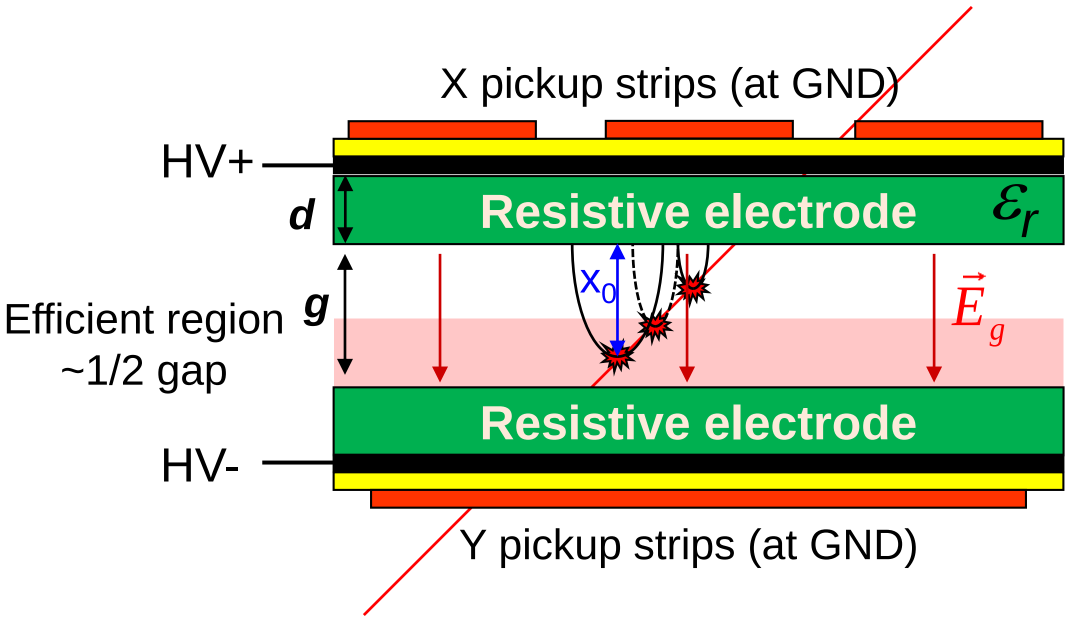
RPCs:

Gas detector developed in the early 1980's as a low-cost alternative to large scintillator planes

R. Santonico, R. Cardarelli, NIMA 187(1981) 377

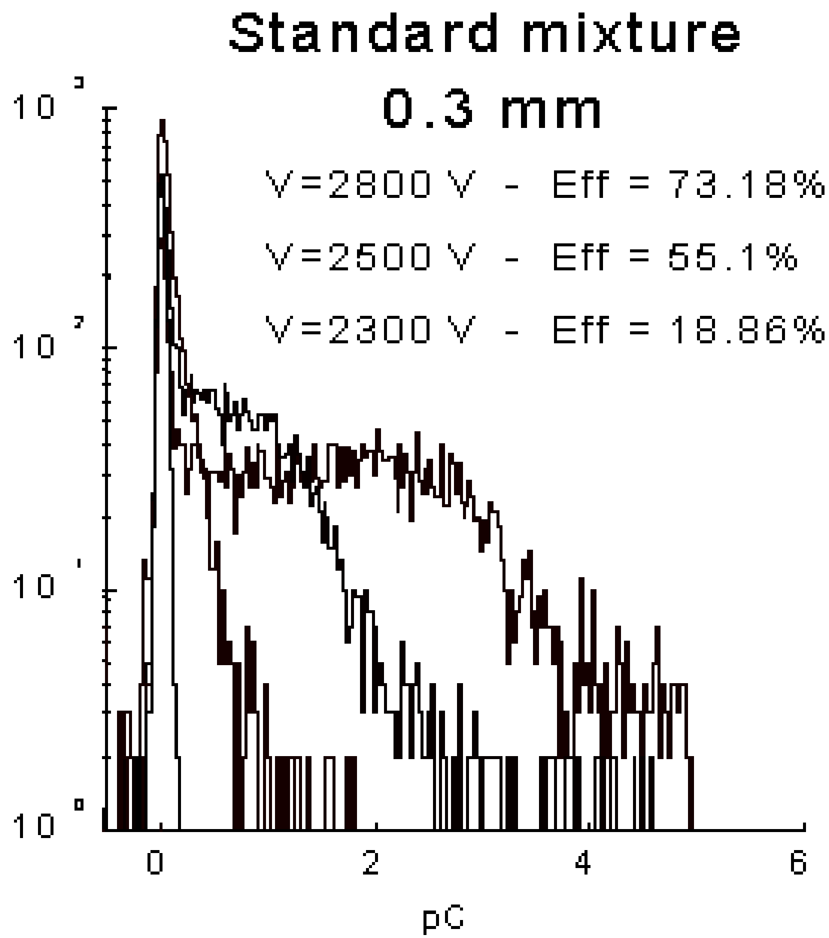
RPCs basics

- working principle



$$q_e = q_{e0} e^{\alpha x_0}$$

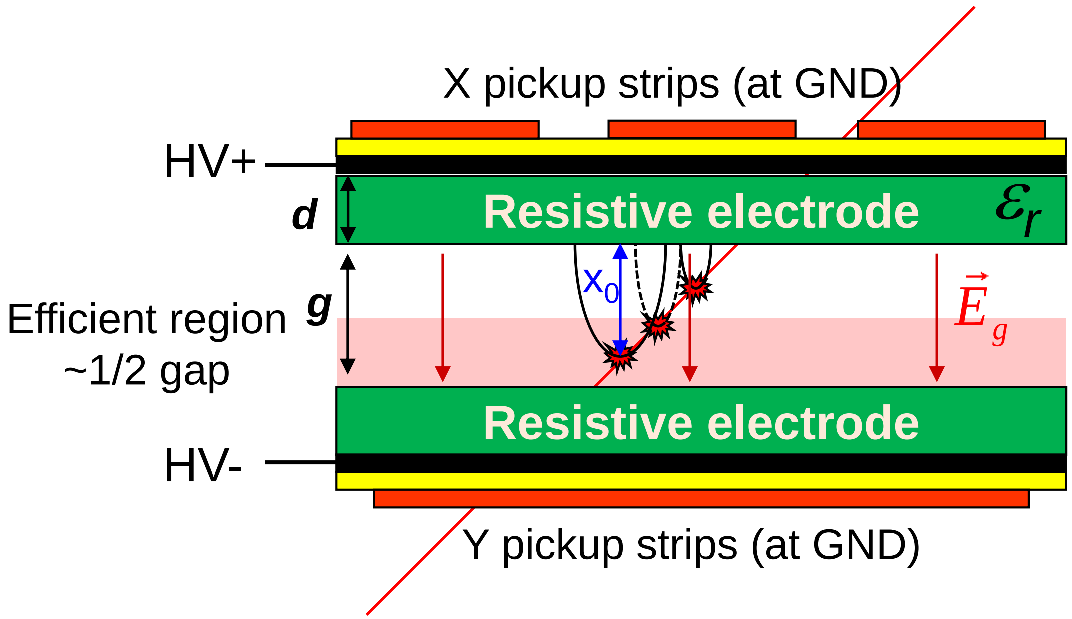
Generated charge/cluster depends exponentially on x_0 (α=ionizations/cm)



P. Fonte et al., Preprint LIP/00-04

RPCs basics

○ working principle



Operation modes:

1. **Avalanche mode**: lower signal amplitude but more favourable for High rate operation

2. **Streamer mode** : higher signal amplitude allows a simpler design of the front-end electronics

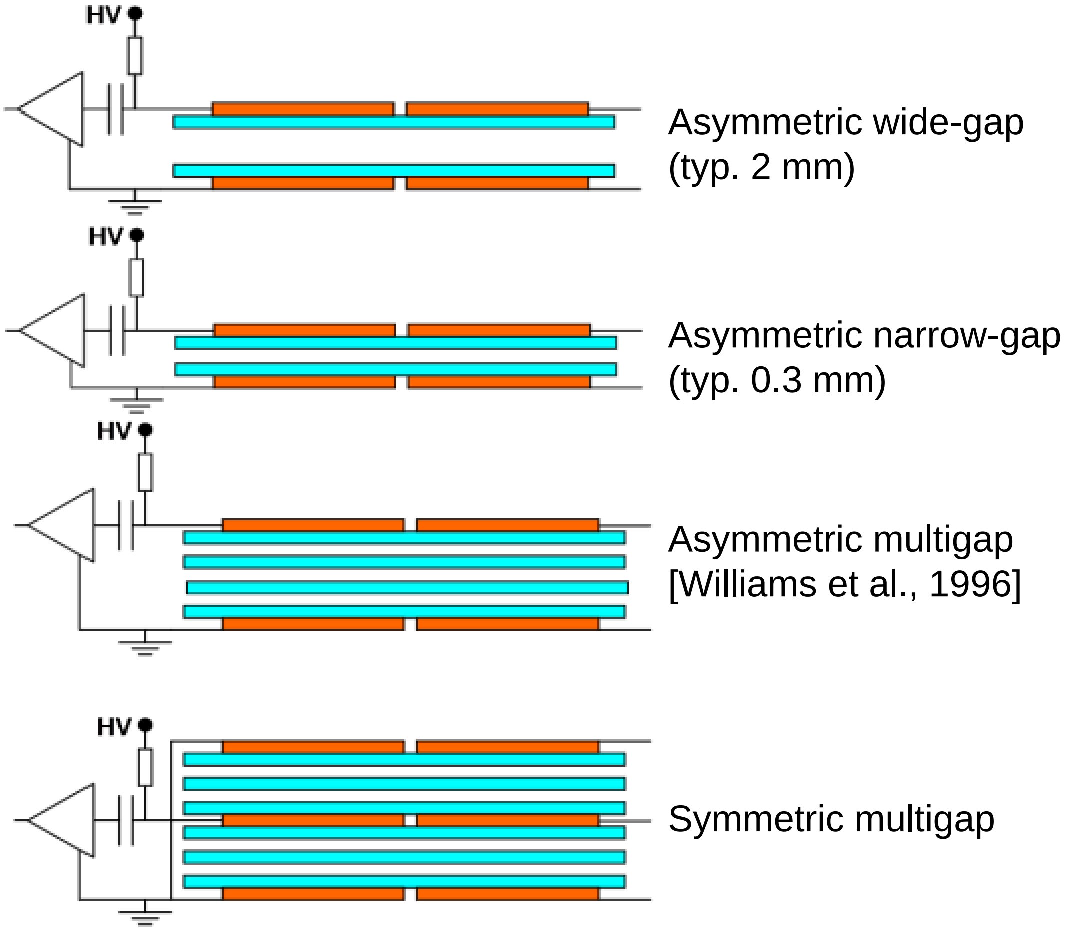
No sparks by construction ⇒ Very safe detector (the current is limited by the resistive electrodes)

Excellent efficiency (99%), time (1ns to 50 ps) and position resolution (~100µm)

RPCs - Detector Technology Appeals

- Modular detector design and good scalability;
- RPCs are well suited to operate in the multi-layer configuration;
- Good position resolution (~100 μm) and fast timing (< 1ns);
- Well-established technology: widely used for large area detectors (> 100 m^2) in high energy physics (HEP) and astroparticle physics
- Cheap technology (built with affordable materials); highly suitable for industrial production, etc.

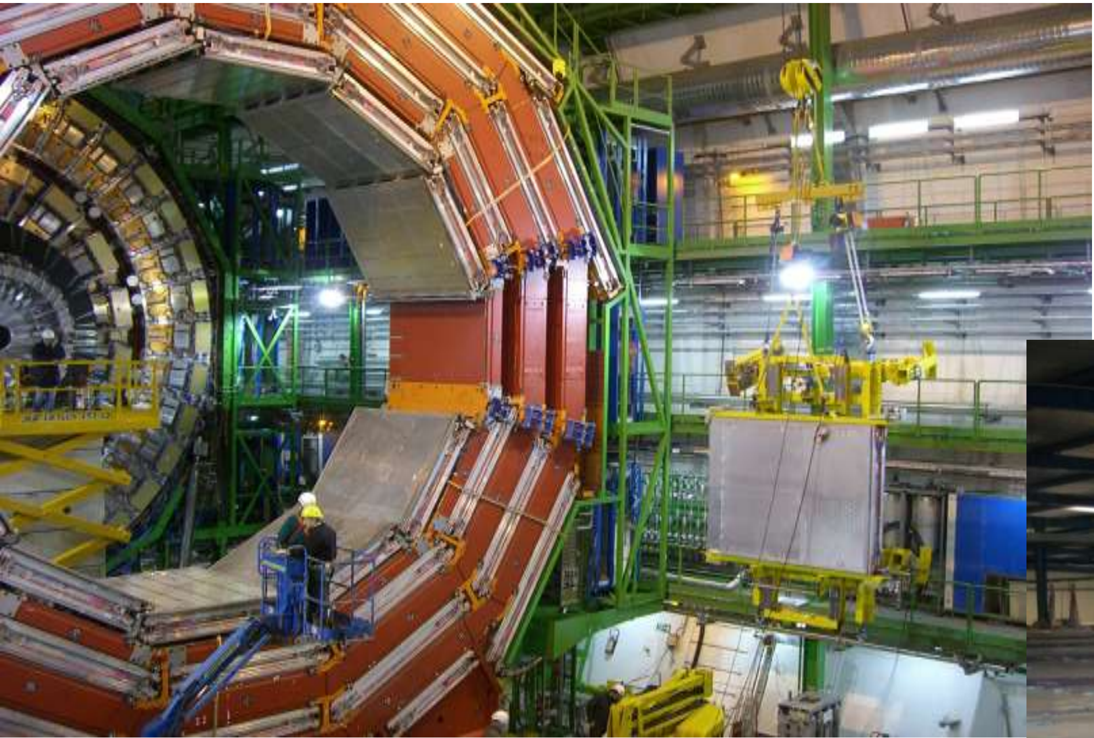
Many detector-electrode configurations are possible; Electrode shapes arbitrary; Both sides can be readout (opposite polarity).



RPCs are used in many physics experiments

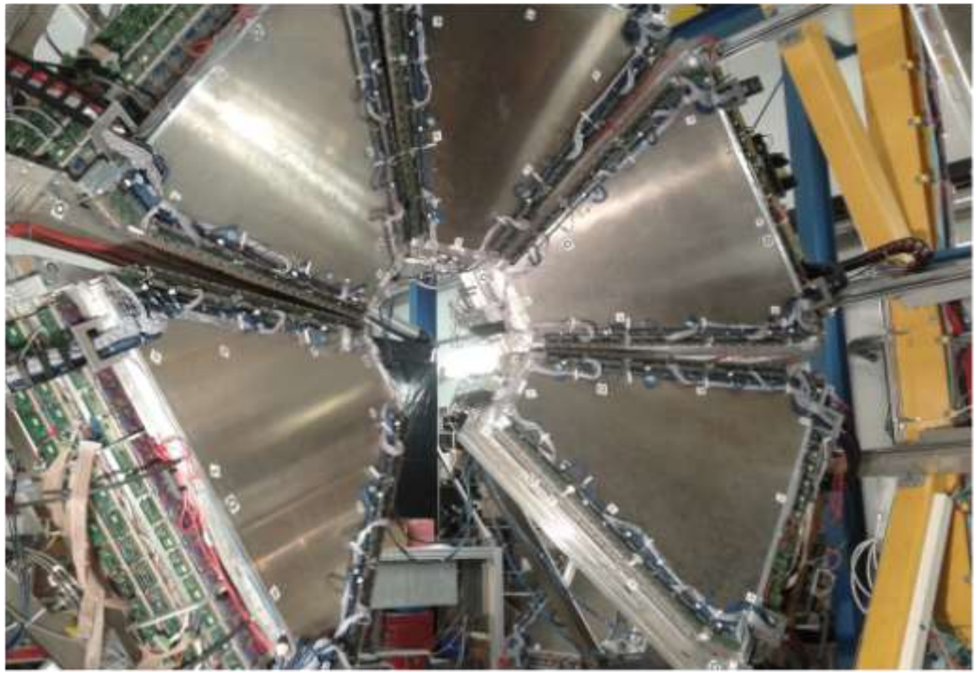
ATLAS@CERN
CMS@CERN
HARP@CERN (TOF)
ALICE@CERN (TOF)
HADES@GSI (TOF)
FOPI@GSI (TOF)
STAR@RHIC (TOF)
BELLE@KEK
OPERA@LNF
ARGO@Tibet
Etc.

CMS Trigger: (2953 m^2)

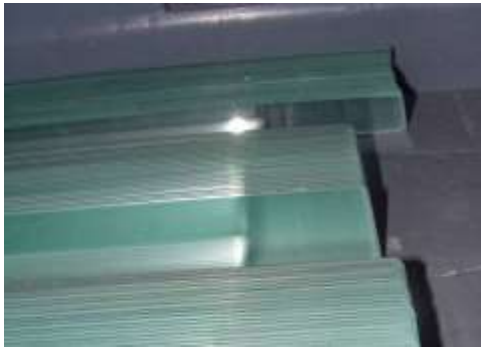


ARGO: (6700 m^2)

RPCs at LIP: RPC TOF Wall for the Hades Experiment@ GSI

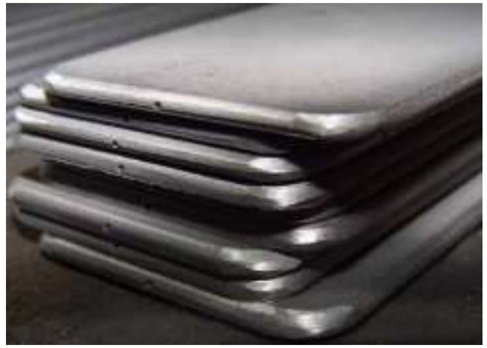


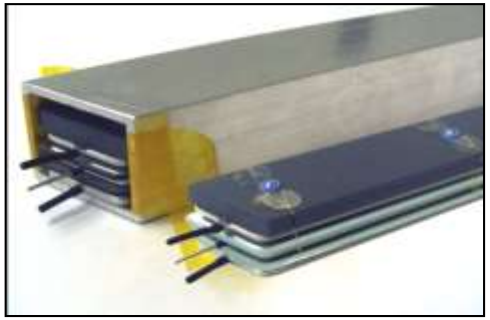
[NIMA 602 (2009) 687]
[2013 JINST 8 P01004]

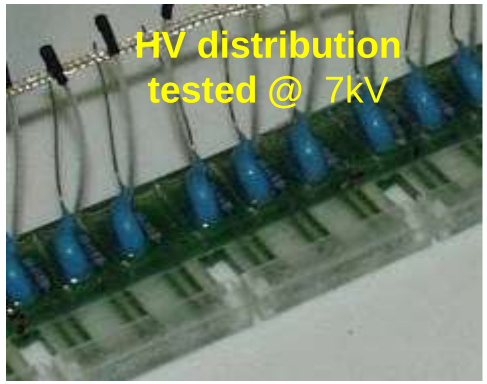


Glass electrodes
In a total length **>1,5 km**

Al electrodes:
Flatness checked over a total area **> 45 m²**







8m2 with 1116 variable-geometry timing RPCs
Readout by **2232** time and charge channels
Multi-hit capability

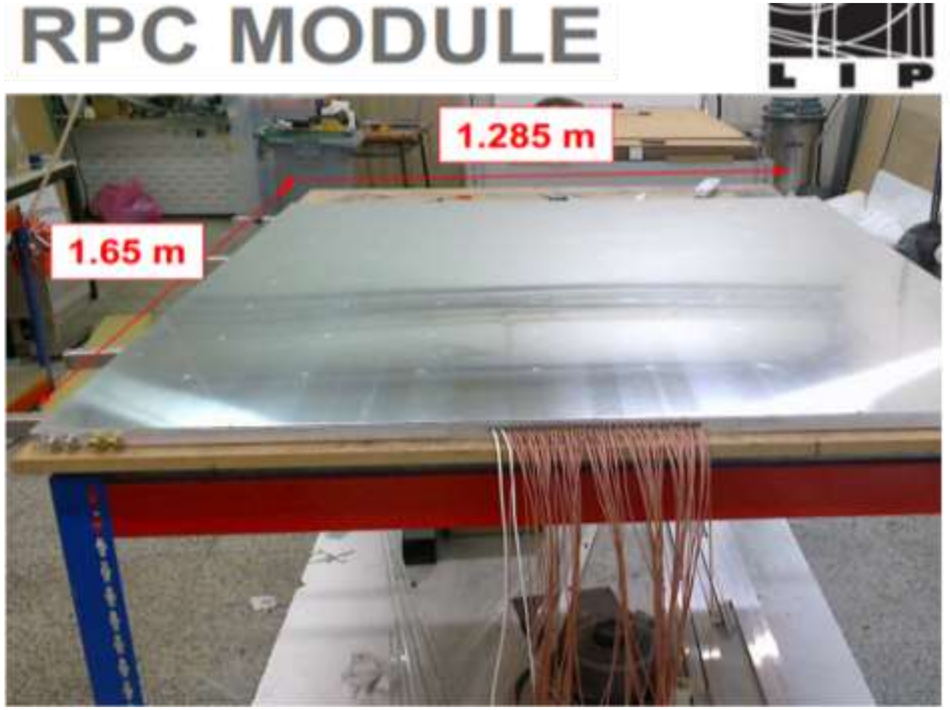
< **76 ps** time resolution

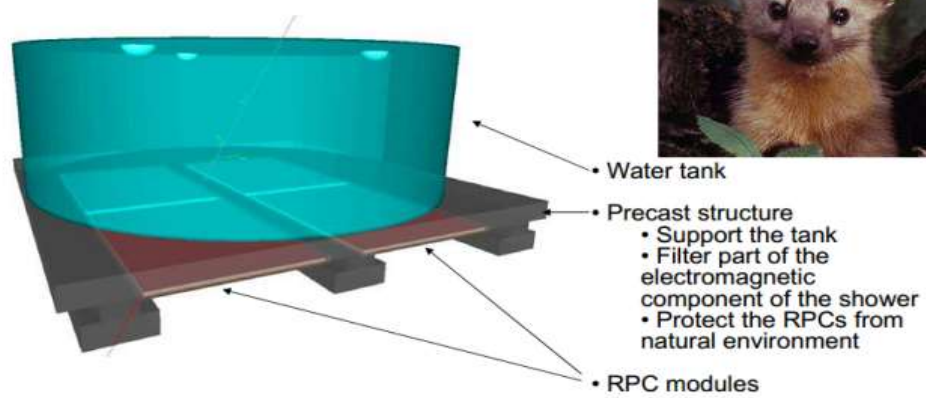
>97% efficiency for MIPS

Hybrid RPCs: Al and glass electrodes

4-gap,symetric, timing RPCs: 0.3 mm width gas-gap

RPCs at LIP: Outdoor RPCs for extreme environmental conditions





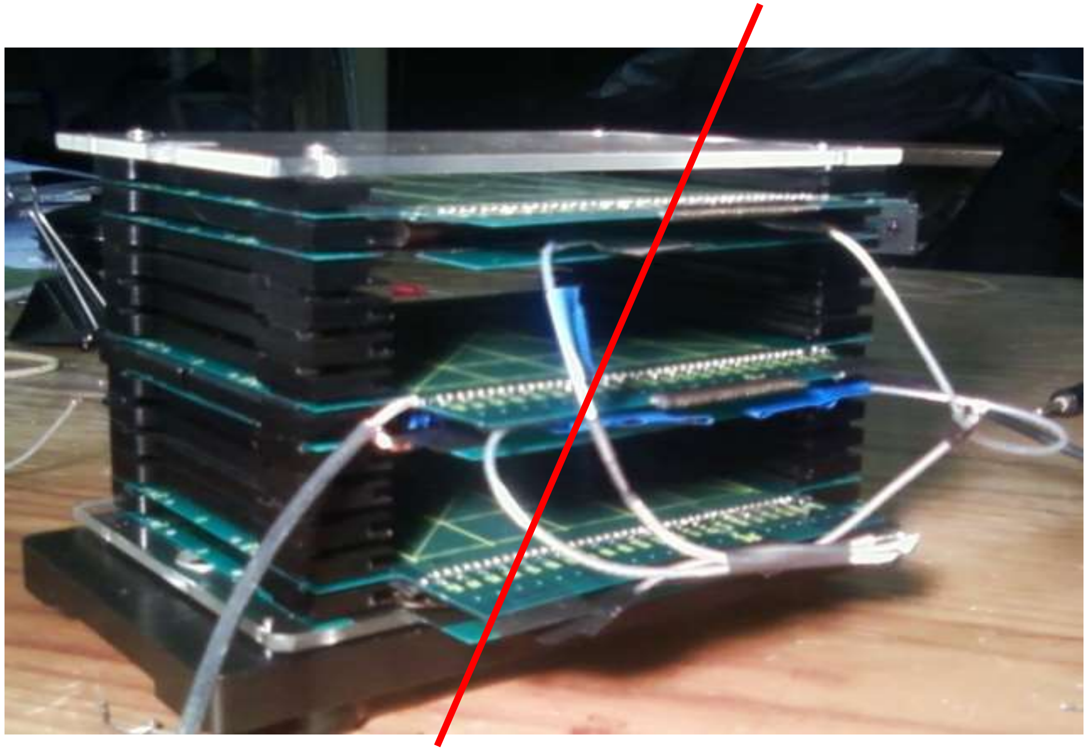
[http://166.111.32.59/indico/contributionDisplay.py?contribId=66&sessionId=11&confId=1]

RPCs in the AUGER experiment

RPCs for outdoors operation, Large area, low gas flow consumption

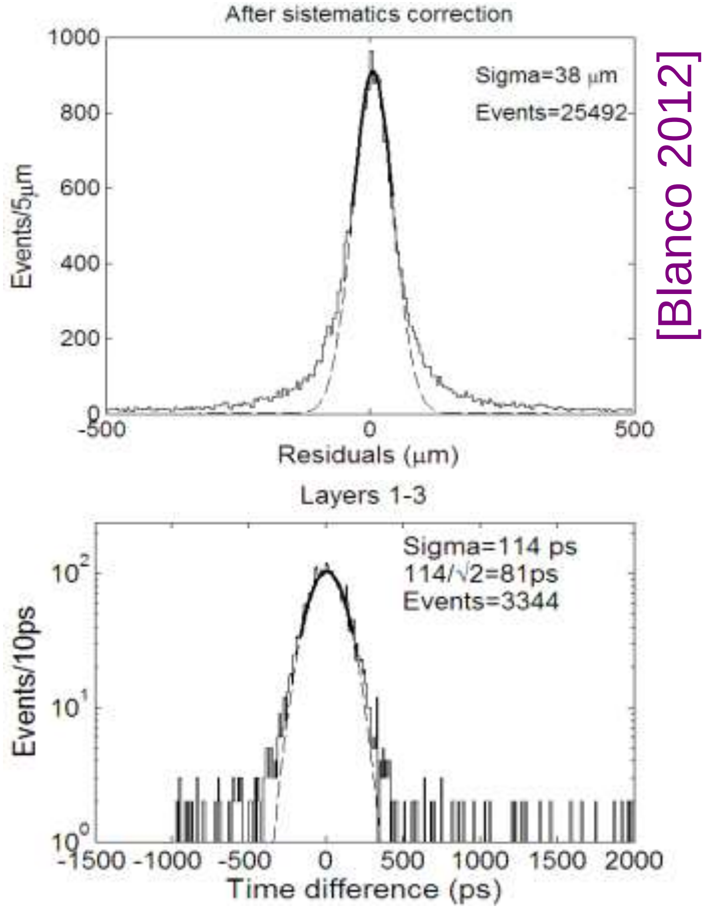
RPCs at LIP: TOFTracker

We expanded the technology in several directions: position as well



Simultaneous position resolution of 38 μm
and time resolution of 80 ps with cosmic rays

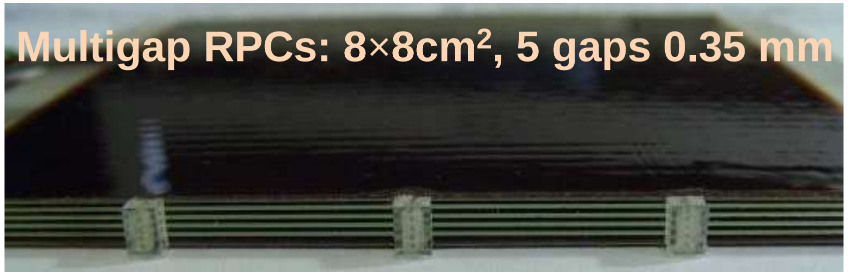
Residuals to the straight-line fit

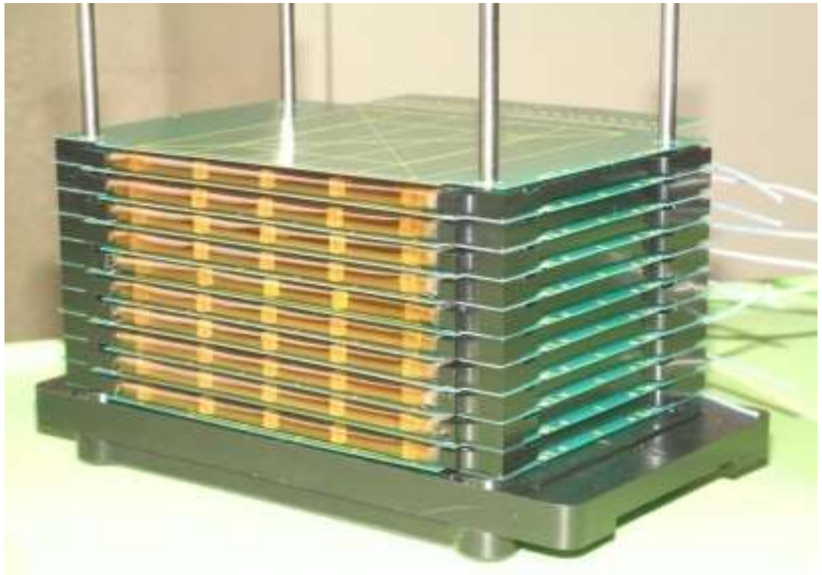


RPCs at LIP: RPC-PET for small animals

http://166.111.32.59/indico/contributionDisplay.py?contribId=40&sessionId=33&confId=1

A full scanner prototype for mice already installed in the Hospitals of the University of Coimbra

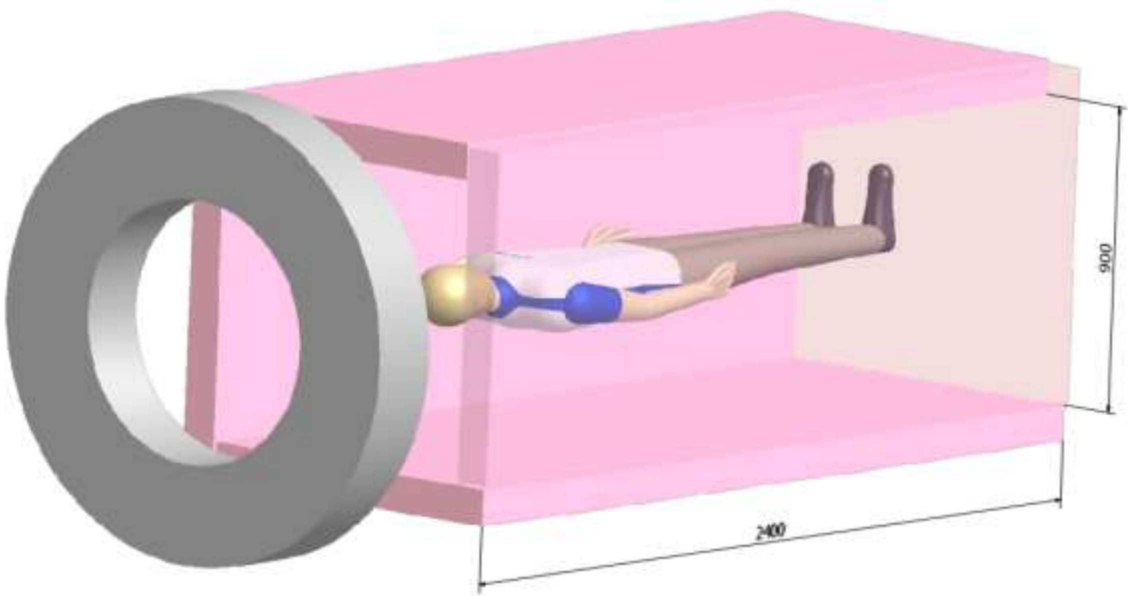


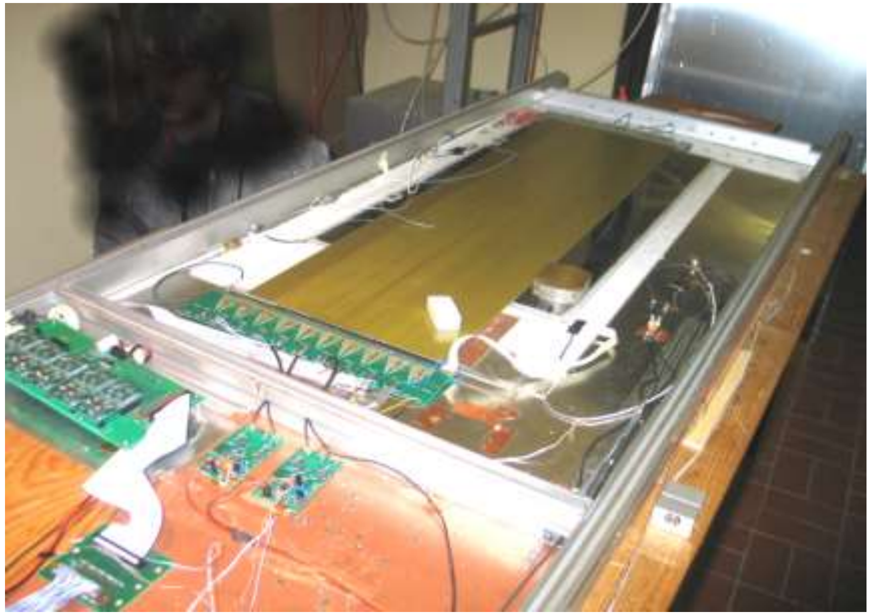


Full head: x,y,z capability
Profile across image (0.4 mm FWHM)

RPCs at LIP: Human RPC-PET

Pursued applications in medical physics: full-body field-of-view PET with TOF



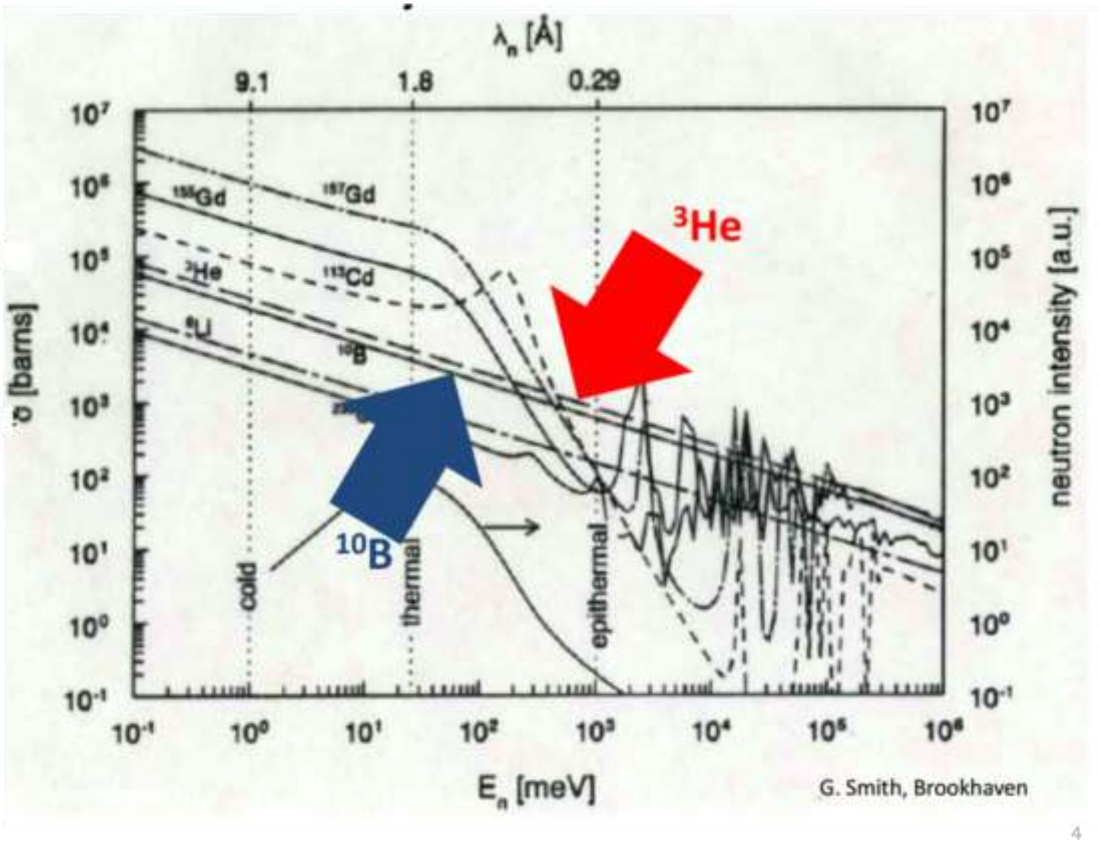


Fully enclose the patient with multilayered RPC detectors

Hardware test beds

RPCs R&D @ LIP for Neutron Detectors

Making RPCs sensitive to Thermal Neutrons



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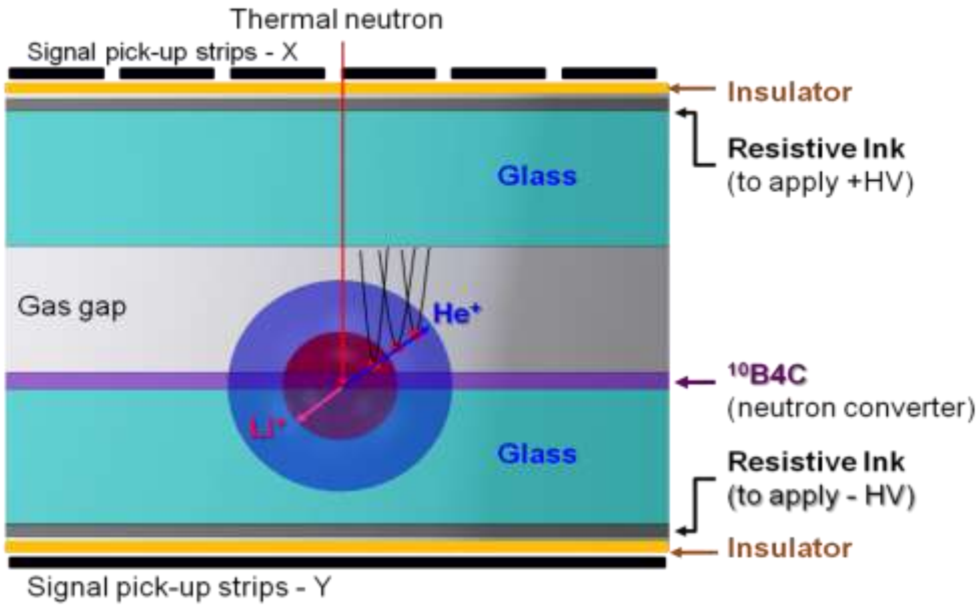
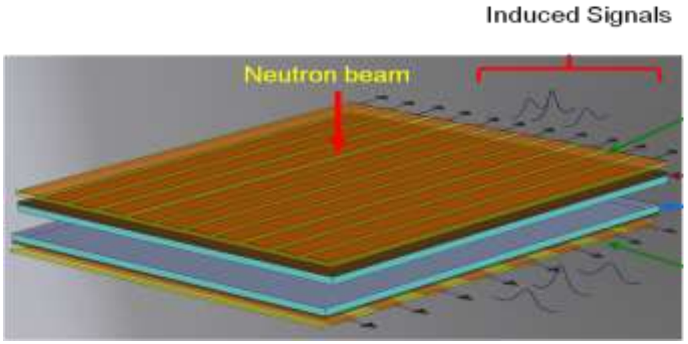




Neutron converter: ^{10}B

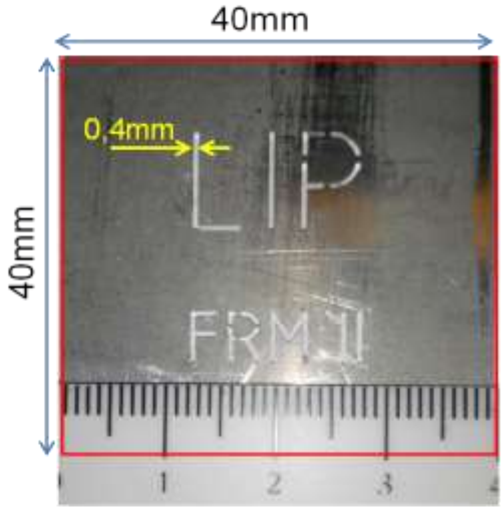
$$n + {}^{10}B \rightarrow \begin{cases} {}^{7}\mathrm{Li}(0.84\ \mathrm{MeV}) + {}^{4}\mathrm{He}(1.47\ \mathrm{MeV}) + \gamma(0.47\ \mathrm{MeV}), & 94\% \\ {}^{7}\mathrm{Li}(1.01\ \mathrm{MeV}) + {}^{4}\mathrm{He}(1.78\ \mathrm{MeV}), & 6\%. \end{cases}$$

10B4C coatings:
ESS Detector Coatings Workshop

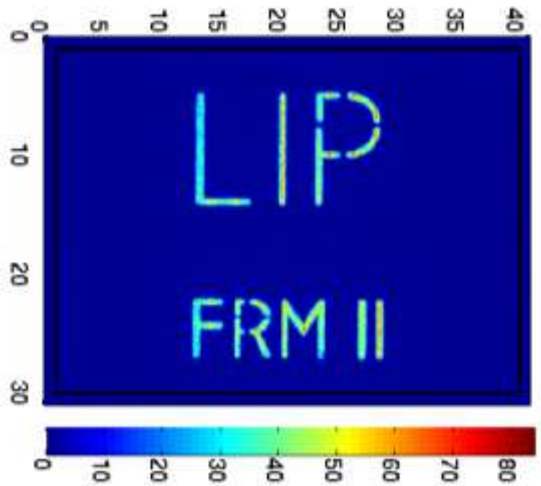
Linköping University

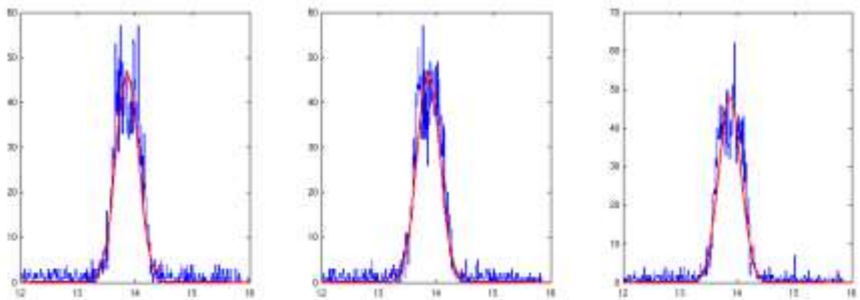
RPC Tested at TREFF neutron beam-line in TUM-FRM II

2D Spatial Resolution



Cd Mask (1mm thick)





FHHM (x) ~551 mm

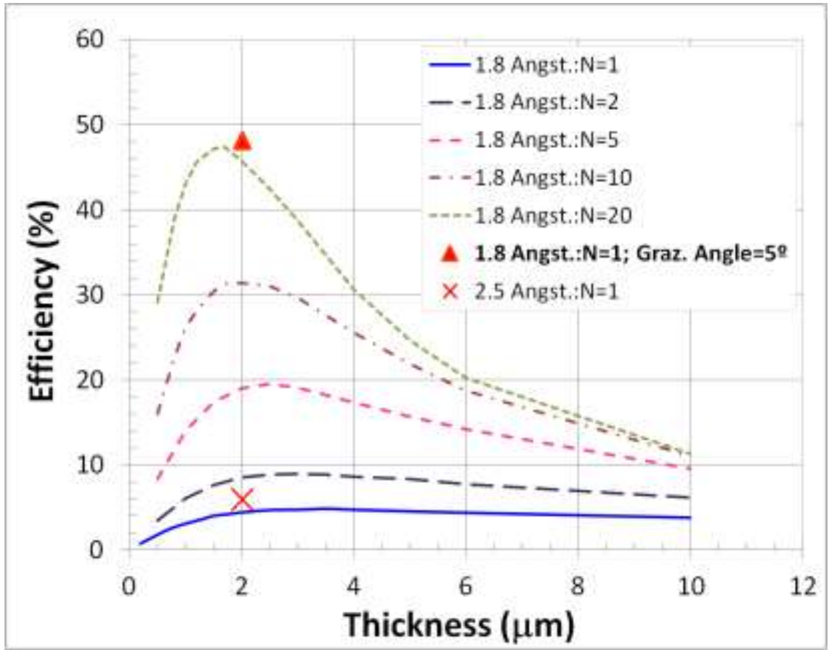
FHHM (y) ~468 mm

Main challenges

Detection efficiency of a single layer of $^{10}B_4C$ is only ~5%.

Multilayer configurations

- **Stack of single-gap or double-gap RPCs**
- **$^{10}B_4C$ coated multi-gap RPCs**
- **Upcoming Ideas …**



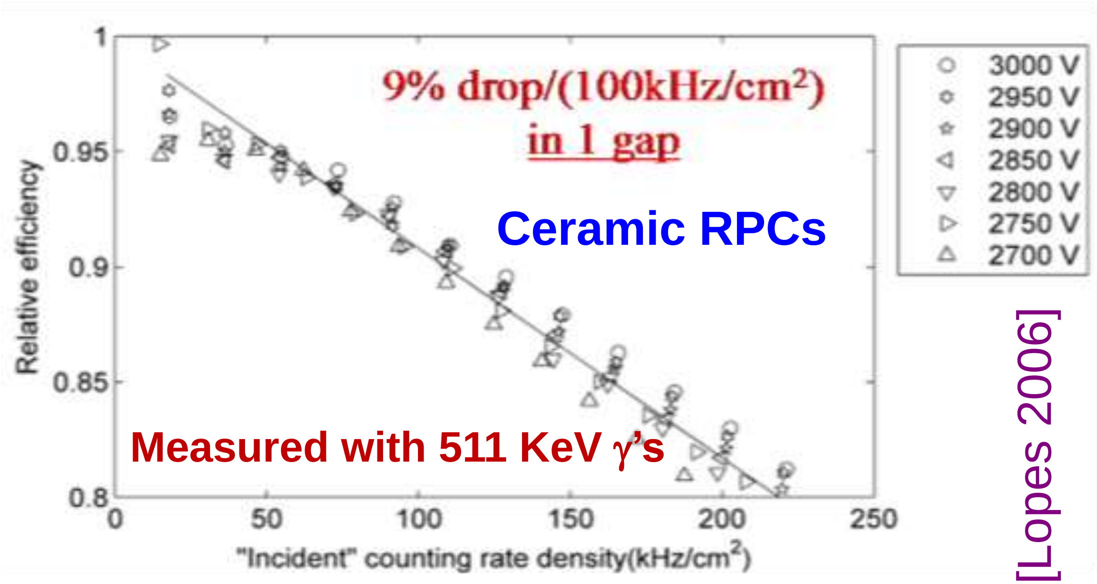
- **$^{10}B_4C$ coatings deposited onto resistive substrates (e.g. soda lime glass, ceramics) must show**
  - **— Good adhesion properties**
  - **— High surface resistivity (> 10^6 Ω/□) for the multi-gap RPCs**
- **Materials in the beam path not prone to suffer activation and showing low neutron elastic scattering cross section**

Main challenges

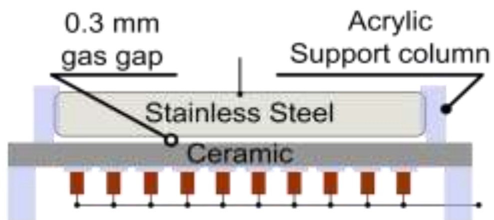
Counting Rate

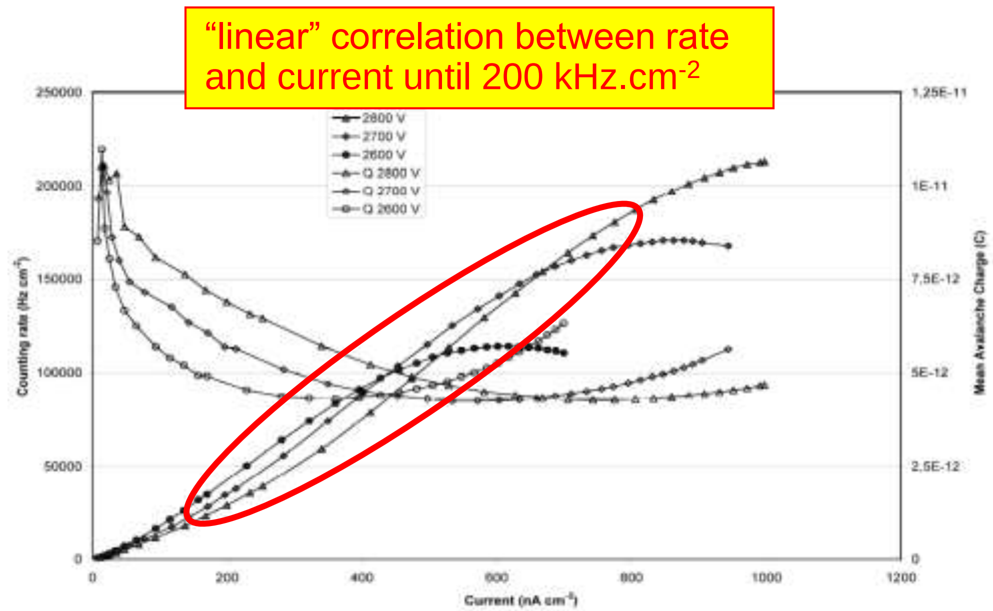
Are really RPCs slow detectors?

- Thinner resistive electrodes
- Front end electronics with higher sensitivity
- Increase the temperature (glass resistivity decreases)
- **Low resistivity materials** (e.g. Ceramics, doped glass, PEEK loaded with Carbon (ρ = 1-3 10^9 Ω.cm) .



[Lopes 2006]



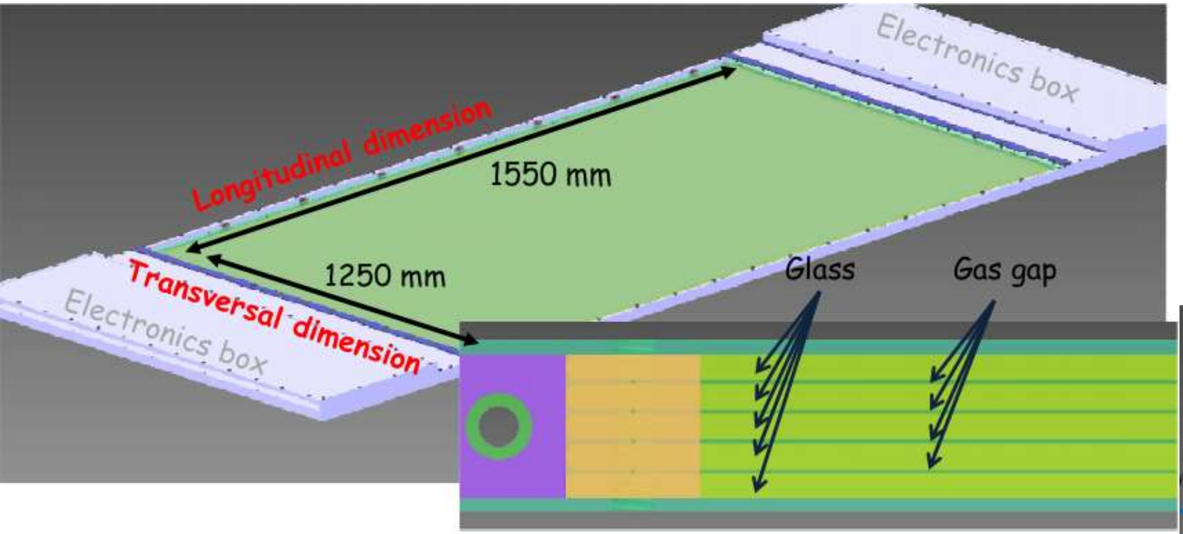


Specific needs relying on suppliers

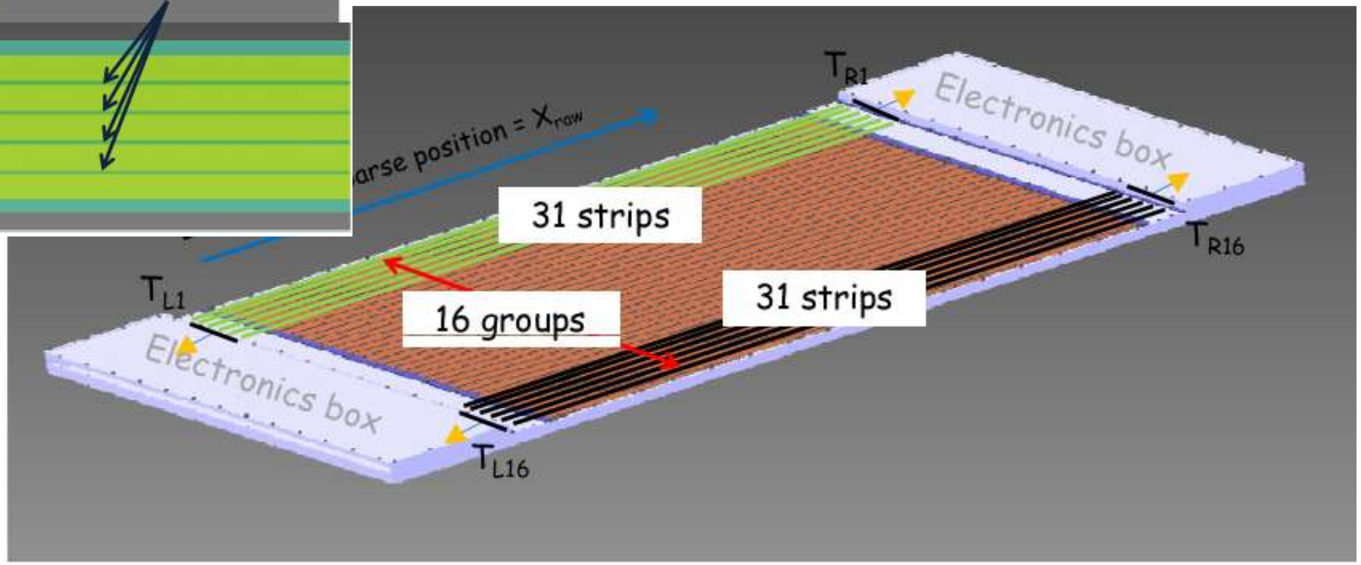
- Good quality Boron-10 coatings
- Resistive electrodes (e.g. thin float glass in large areas > 1 m2)
- Aluminum laminate with very good flatness and smooth surface
- Readout electronics and DAQ system
- HV power supplies
- Printed circuit boards manufacturing

How a detector might look: e.g. could derive from TOF Tracker design resized to an area of 30 cm x 30 cm

TOF- tracker Design

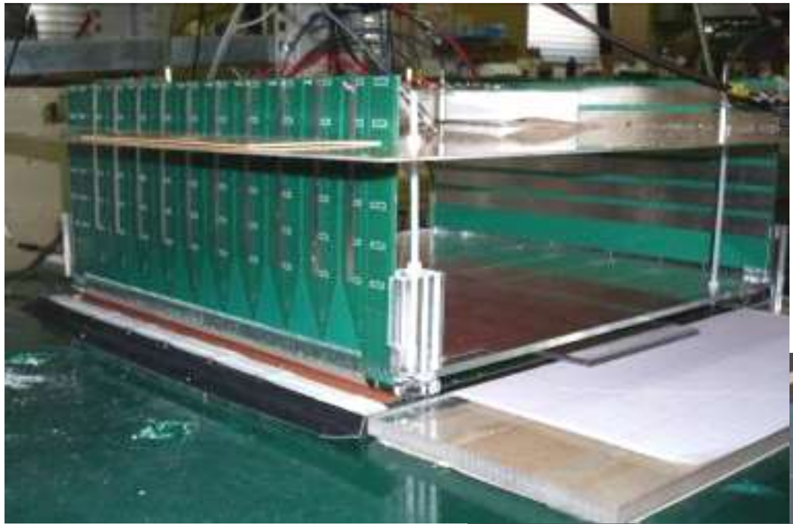


Large area (~2 m2) RPC detectors capable of measuring time and 2D position at the same time Readout by 53 channels/layer (time+charge)

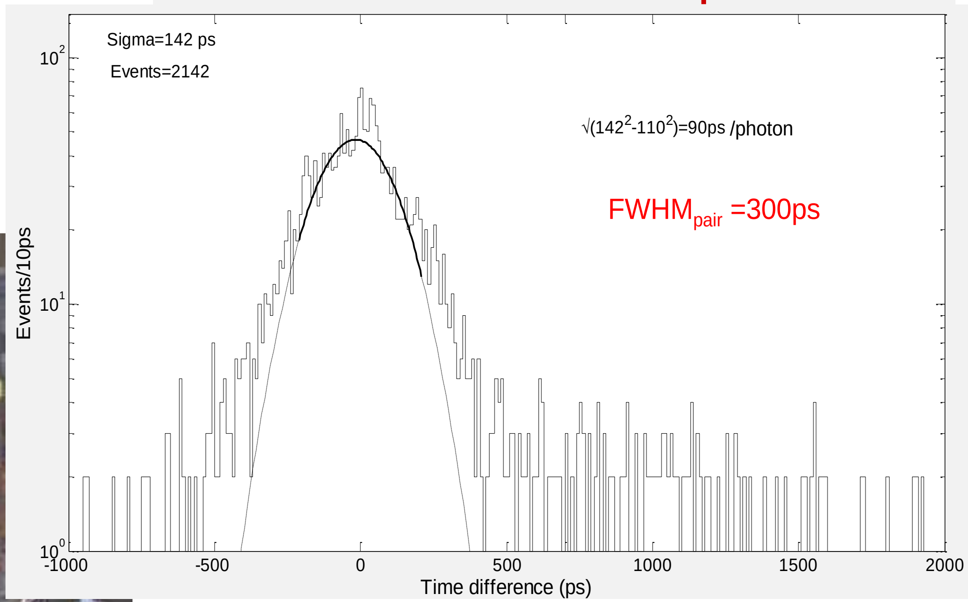


How a detector might look: e.g. could derive from TOF Tracker design resized to an area of 30 cm x 30 cm

Prototype detecting head (30×30cm² × 8 gaps)



Time resolution – 300 ps FWHM



Thank you for your attention