Task 9.4.1

Resistive Plate Chambers (RPCs) Development Status

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SINE 2020 Detector RTD Meeting, Wednesday 7th September 2016, Coimbra

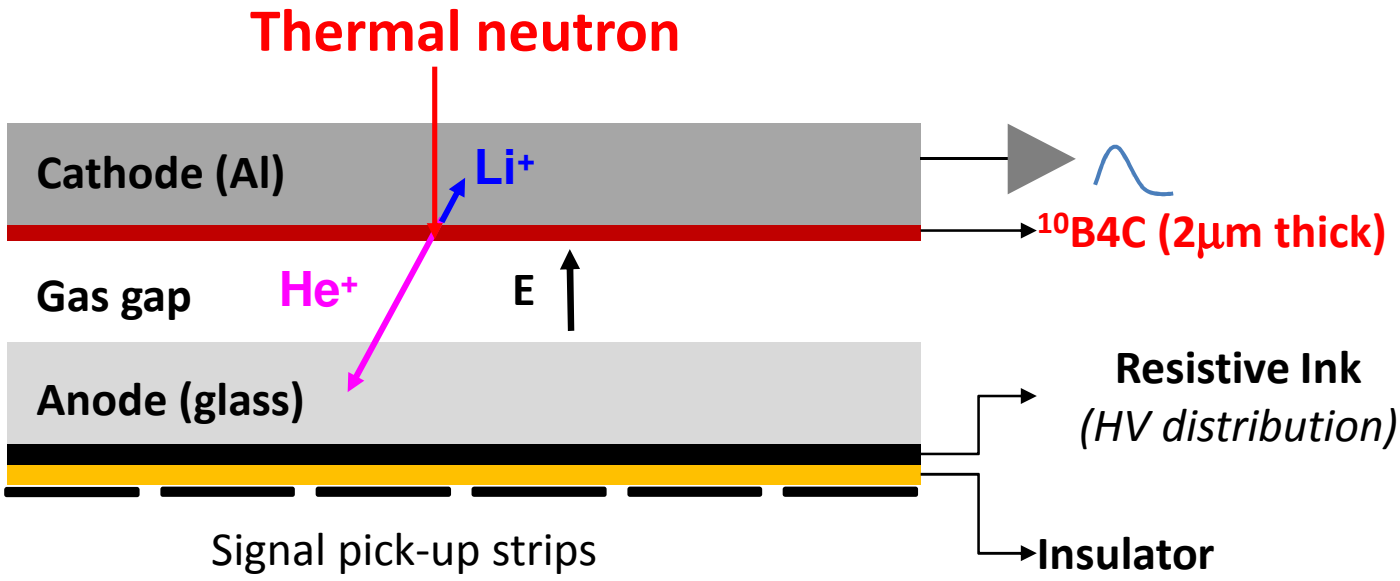
Task 9.4.1 Objectives

Evaluate the potential of ^{10}B coated RPCs for high resolution PSNDs

❑ Design Optimization, Prototyping and Evaluation

- ***MC SIMULATION:*** GEANT4 and ANTS2 package (open source) http://coimbra.lip.pt/ants/ants2.html
- ***PROTOTYPE***:
  - ➢ **Design and assembly $^{10}B_4C$ coated RPCs**
  - ➢ **Explore RPCs in Multilayer configurations Toward High Detection Efficiency, e.g. the Multi-gap RPC**
- ***FEASIBILITY STUDIES, e.g.***: Efficiency; Position resolution; Count rate and gamma sensitivity.
- ***FUNDAMENTAL STUDIES e.g.:*** RPCs operation with HIPs (e.g. 4He and 7Li); Seek for different signal signatures (PSD techniques) for gamma's and thermal neutrons; gas mixtures composition;
- ***2D POSITION SPATIAL RESOLUTION***

Thermal neutron detection with ^{10}B4C coated RPCs



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

- Plate of float glass (0.35 mm thick): 8 cm x 8 cm
- Plate of Al (1.0 mm thick, 8 cm x 8 cm area): coated with 2 µm of ^{10}B4C
- Gas-gap width: 0.35 mm; filled with C2H2F4 @ 1 atm
- Signal pick-up strips engraved on a PCB

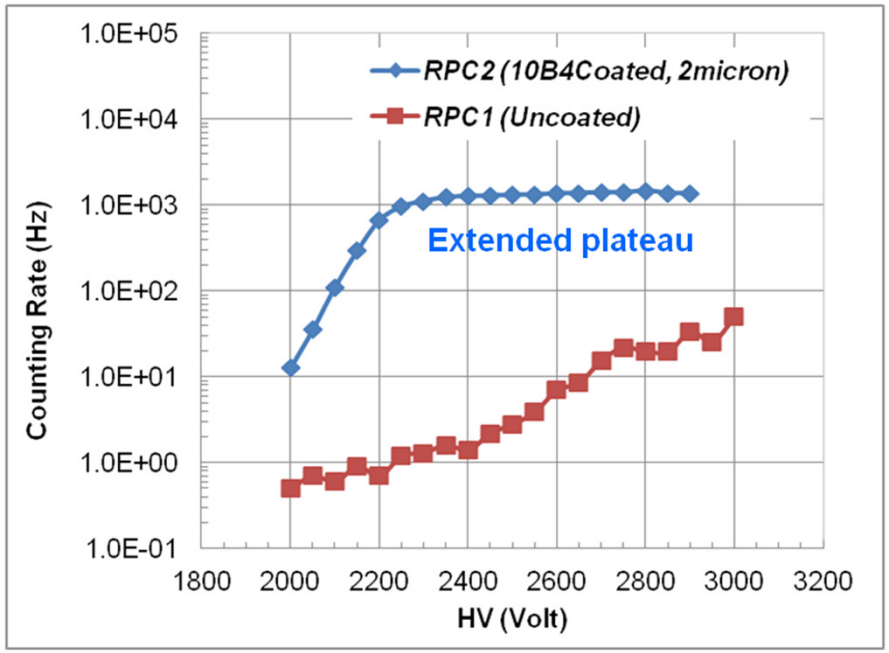
Very safe detector: current limited by the resistive electrodes

Previous Results

10B4C coatings manufactured @ ESS Detector Coatings Workshop in Linköping

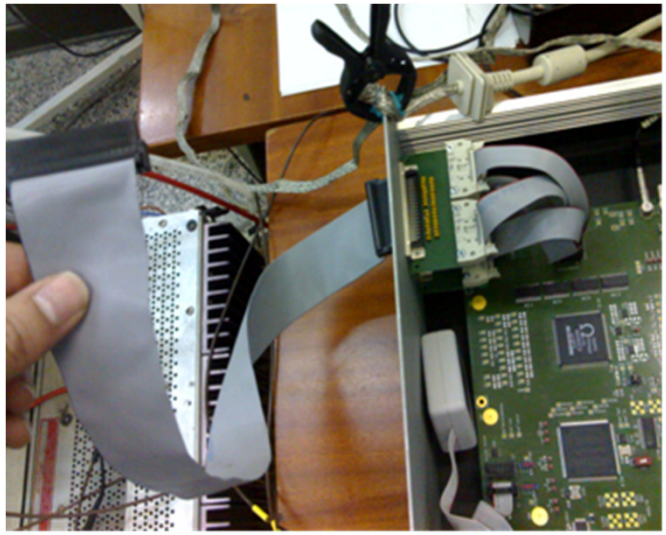
Feasibility tests of a ^{10}B4C coated Hybrid RPC in the monochromatic thermal neutron beam CT2 (λ=2.5Å) at ILL
(*In the framework of an Exploratory Project Funded by FCT*)

Plateau measurement



RPC1: *No coating*
RPC2: *Cathode coated with 10B4C layer* (2μm thick)

Previous Results



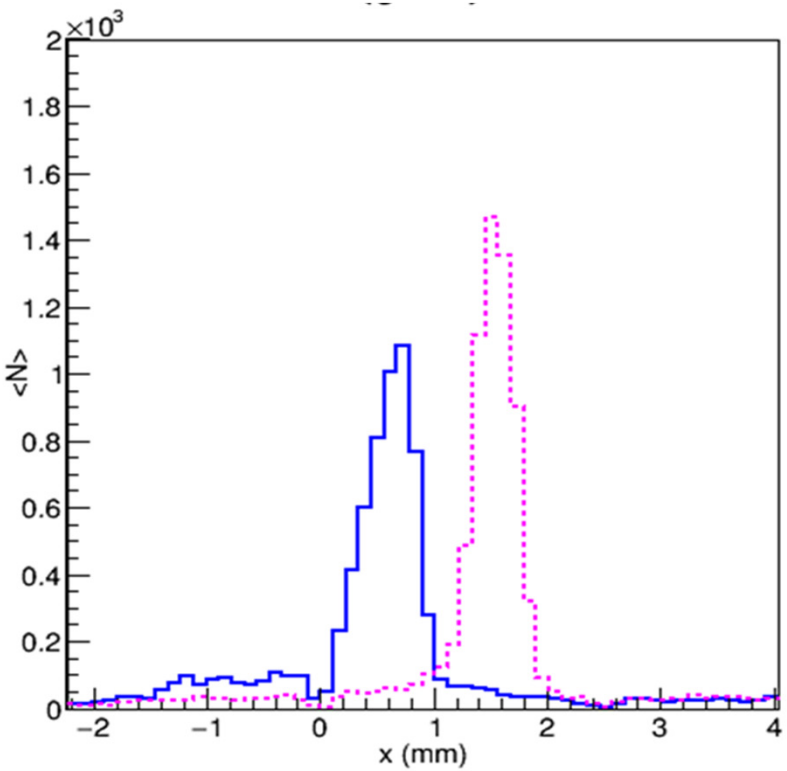
DAQ System: 64 channels Data Acquisition System based on MAROC3 ASIC from Omega

Control and data analysis Software (developed at LIP):

- **LULAS** (LIP Ultra-Light Acquisition Software) for the board control
- **ANTS2** for Data Analysis

http://coimbra.lip.pt/ants/ants2.html

Feasibility tests of a $^{10}B4C$ coated Hybrid RPC in the monochromatic thermal neutron beam CT2 (λ=2.5Å) at ILL
(*In the framework of an Exploratory Project Funded by FCT*)



Spatial Resolution (1D)
FWHM ~ 0.8 mm
(including the Slit width ~ 0.5 mm)

Good evidence for sub-millimeter resolution capability

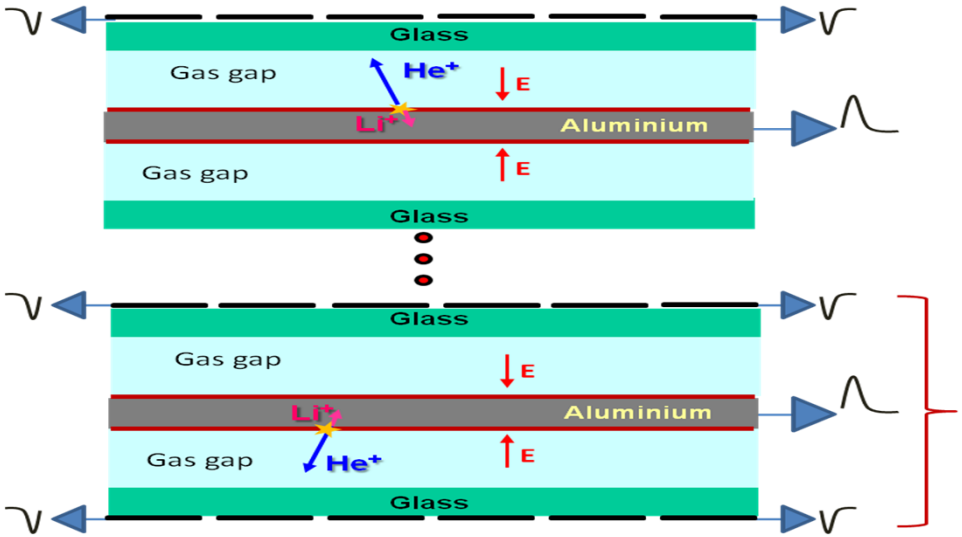
COG of 3 neighboring strips with the highest signal
Moving stage step: **0.6 mm**

Towards High D. Efficiency - Multilayer RPCs

High neutron detection efficiency with ^{10}B solid converters: **Multilayer configuration are needed** (or grazing angles)

RPCs configurations forseen for evaluation

- **Stack of double-gap RPCs** (Two anodes sharing the same cathode coated with $^{10}B4C$ on both sides)



Glass (Anode): thickness ~ 0.4 mm
Conductive layer / Strips: thickness~ 50 μm
Aluminium Plate (Cathode): thickness~ 0.4mm
10B4 layer: ~ 1- 2 μm
Gas-gap width: ~ 0.2 - 0.5 mm

- **Two anodes sharing the same cathode (Al) coated with $^{10}B4C$ on both sides**
- **B4C coatings into Al substrates → Established technique**
- **Challenge: 2D readout on the same plane**

Double gap RPC Thickness: 1.5 – 2 mm

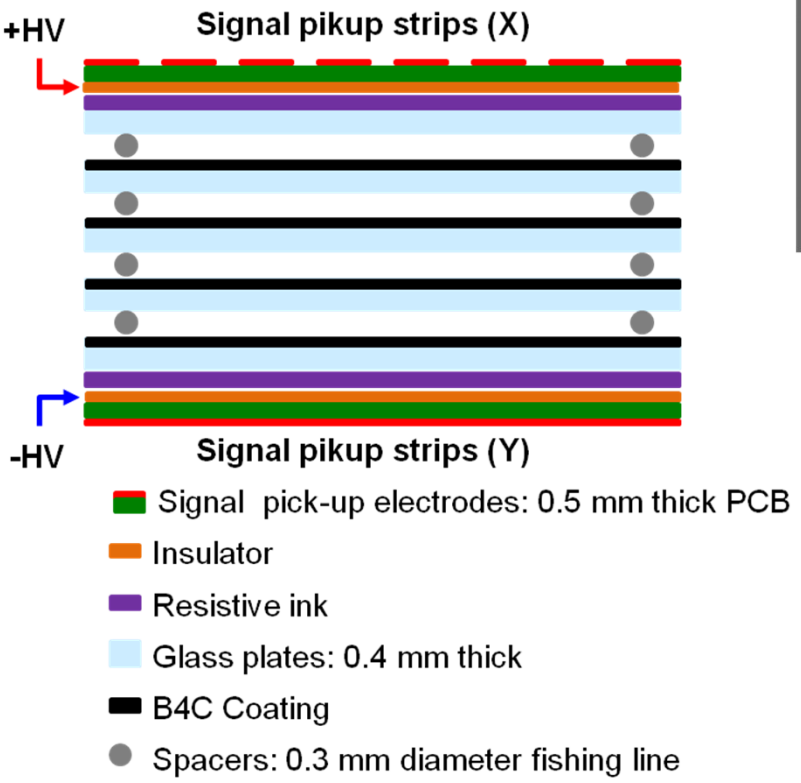
Stack of 10 Double gap RPCs
(20 layers of $^{10}B4C$)
15 – 20 mm

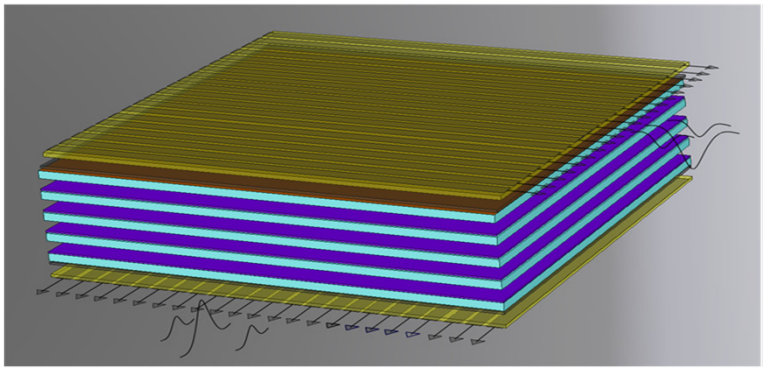
Towards High D. Efficiency - Multilayer RPCs

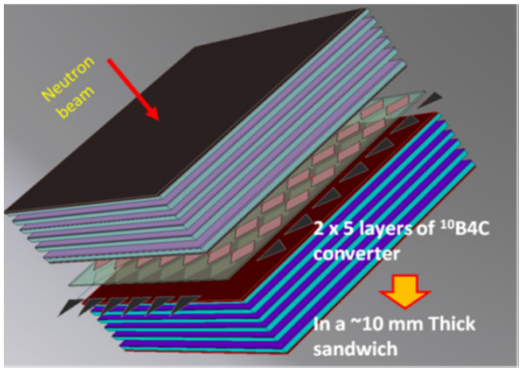
High neutron detection efficiency with ^{10}B solid converters: **Multilayer configuration are needed** (or grazing angles)

RPCs configurations forseen for evaluation

❑ Multi-gap RPC



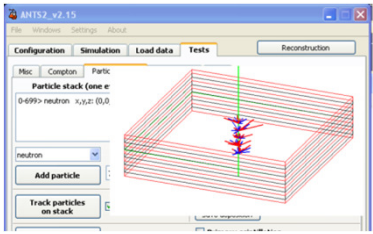




- **Leads to very modular and compact designs**
- **Small mass thickness** (minimization of neutron absorption and scattering in detector materials)
- **Challenges: $^{10}B4C$ coatings deposited onto resistive substrates (e.g. soda lime glass, ceramics) must show**
  - **— Good adhesion properties**
  - **— High surface resistivity (> 10^6 Ω/)**

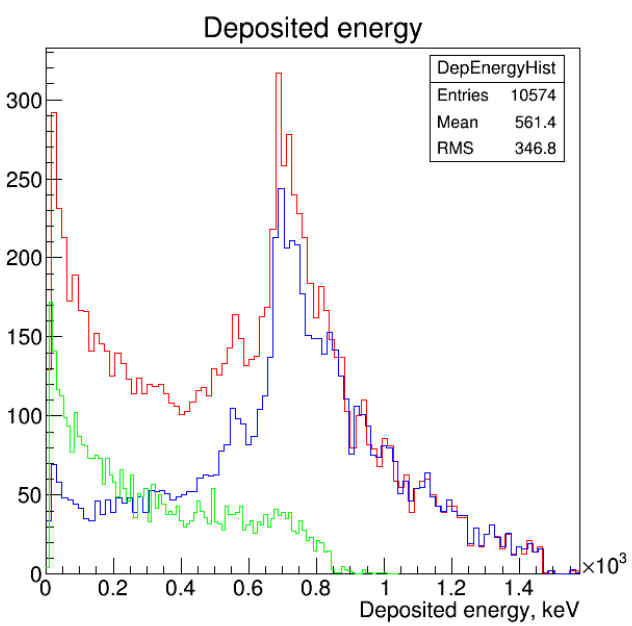
Towards High D. Efficiency - Multilayer RPCs

Both RPCs configurations needs optimization

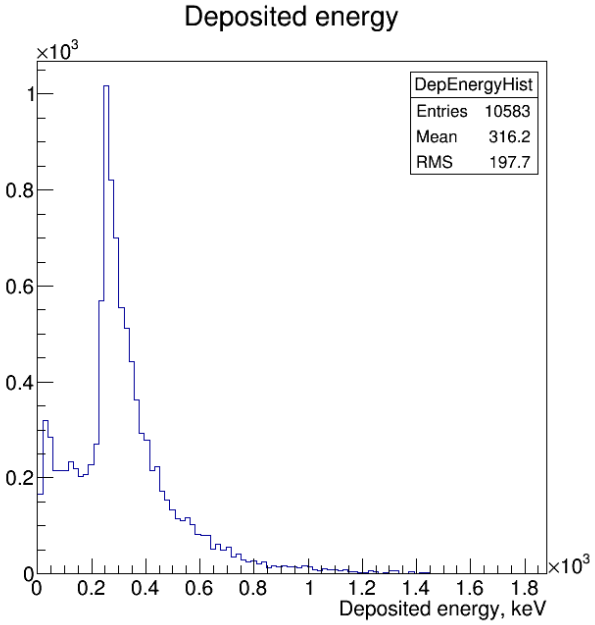


FROM ANTS2 Calculations it was found a significant dependence of the profiles of the Ranges and Energy deposits with the gas-gap width of the RPC

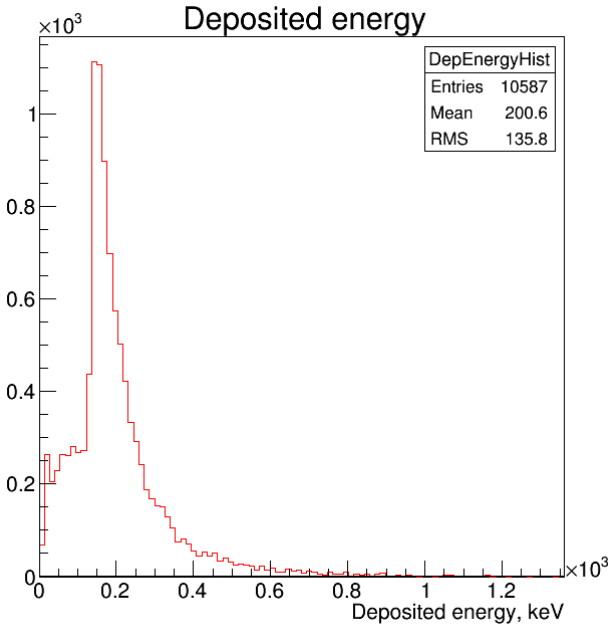
10B4C thickness = 2.0 μm; λ = 4.7 Å; C2H2F4 @ 1 atm



gas-gap: 1.0 mm



gas-gap: 0.35 mm

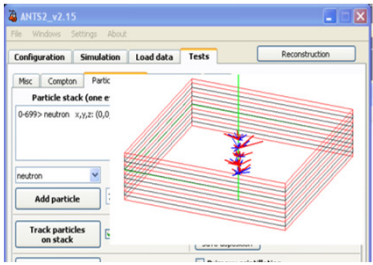


gas-gap: 0.20 mm

Deposited energy in the gas-gap (C2H2F4 @ 1 atm) for the 4He and 7Li fissions fragments

Towards High D. Efficiency - Multilayer RPCs

Both RPCs configurations needs optimization



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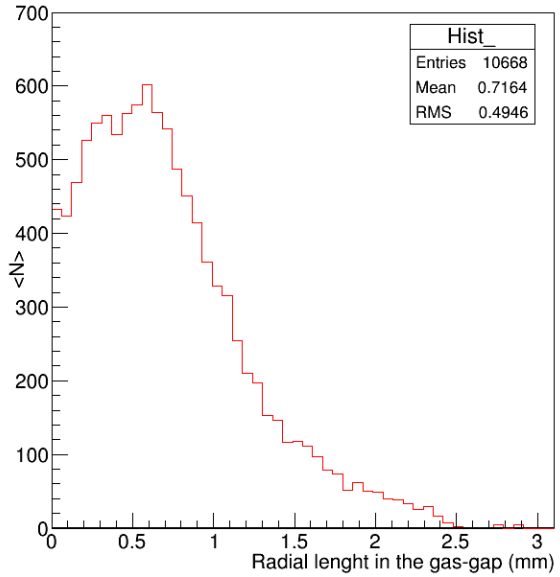
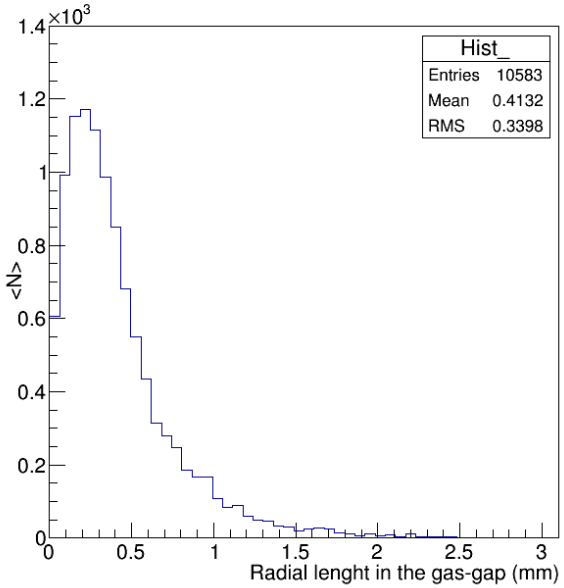
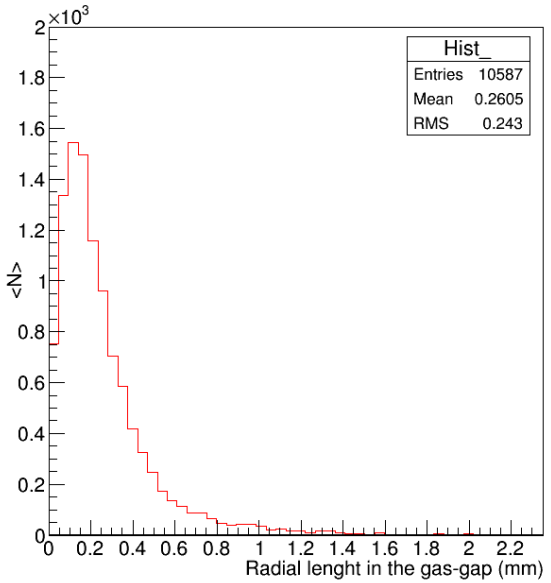


gas-gap: 1.0 mm



gas-gap: 0.35 mm



gas-gap: 0.20 mm

Distributions for the Range Projected in the direction parallel to the RPC plates

Towards High D. Efficiency - Multilayer RPCs

- ***Design and Building of two $^{10}B4C$ coated RPCs with different gas-gap widths***
  - ***RPC-1: 1mm***
  - ***RPC-2: 0.35mm***

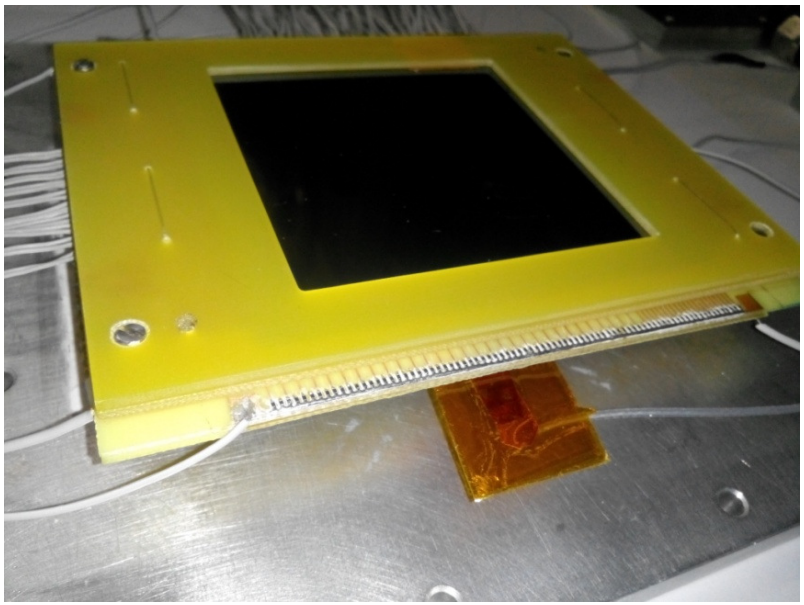
- ***Implementation of a 2D Position encoding based on two arrays of parallel signal pick-up strips, mutually orthogonal, facing the glass electrode***

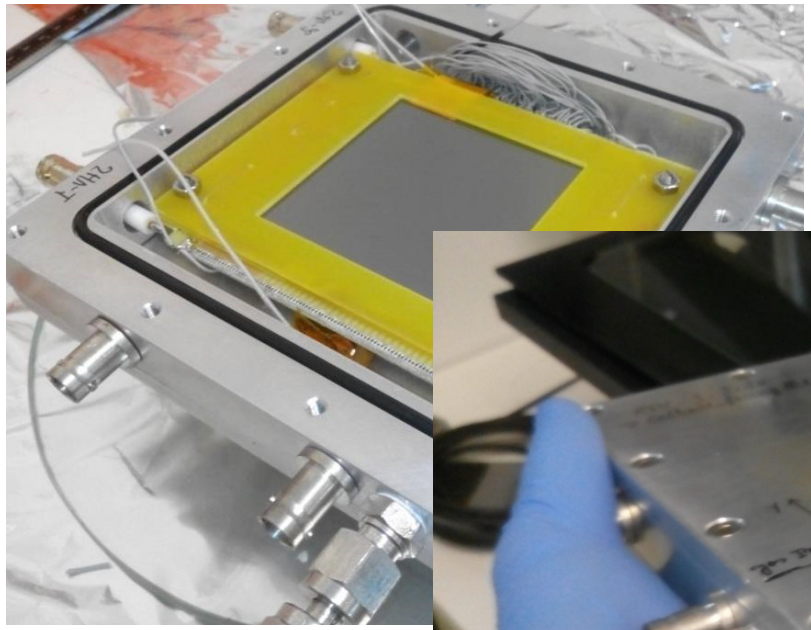
- ***Evaluation of the two RPCs in TREFF neutron beamline (λ=4.7Å) at TUM – FRM II***
  - ***Plateau and efficiency measurements***
  - ***RPC with inverted Polarity*** *(emulation of the $^{10}B4C$ layer on the anode)* ***to access the possibility of have two layers of $^{10}B4C$ per gas-gap*** *(check if there is a significant loss of efficiency)*
  - ***Test of the F.E.E /DAQ (TRB) from the RPC group at Coimbra in the acquisition of induced signals from thermal neutron events***

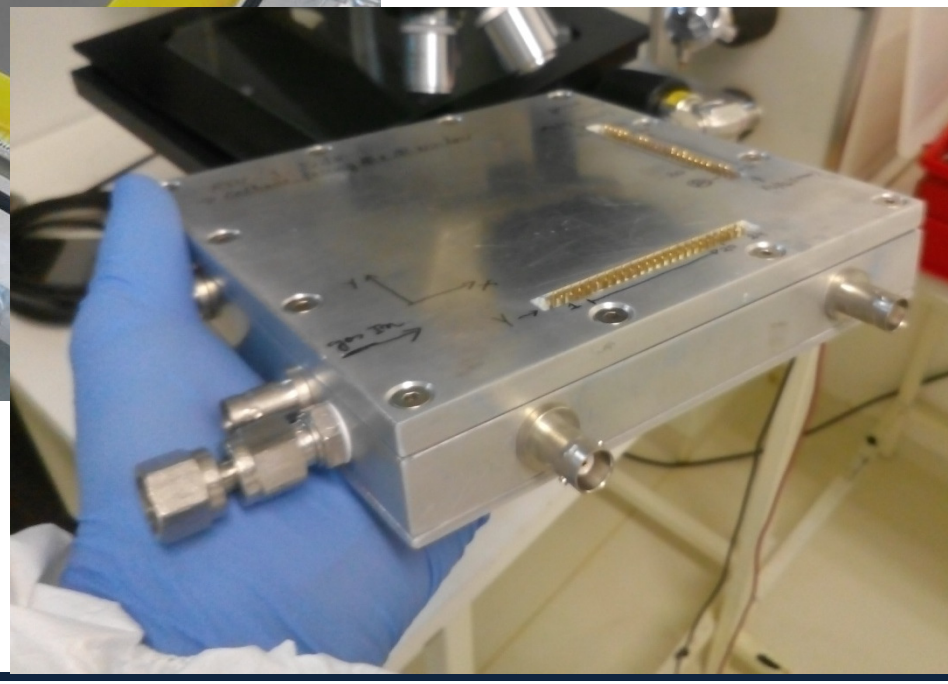
Towards High D. Efficiency - Multilayer RPCs

Two ^{10}B4C coated RPCs Designed and Assembled at LIP

- *Cathode : 1mm thick Al plate (80 mm x 80 mm) coated with ^{10}B4C (2 μm thick)*
- *Anode: 0.35mm thick soda lime glass plate (80 mm x 80 mm)*



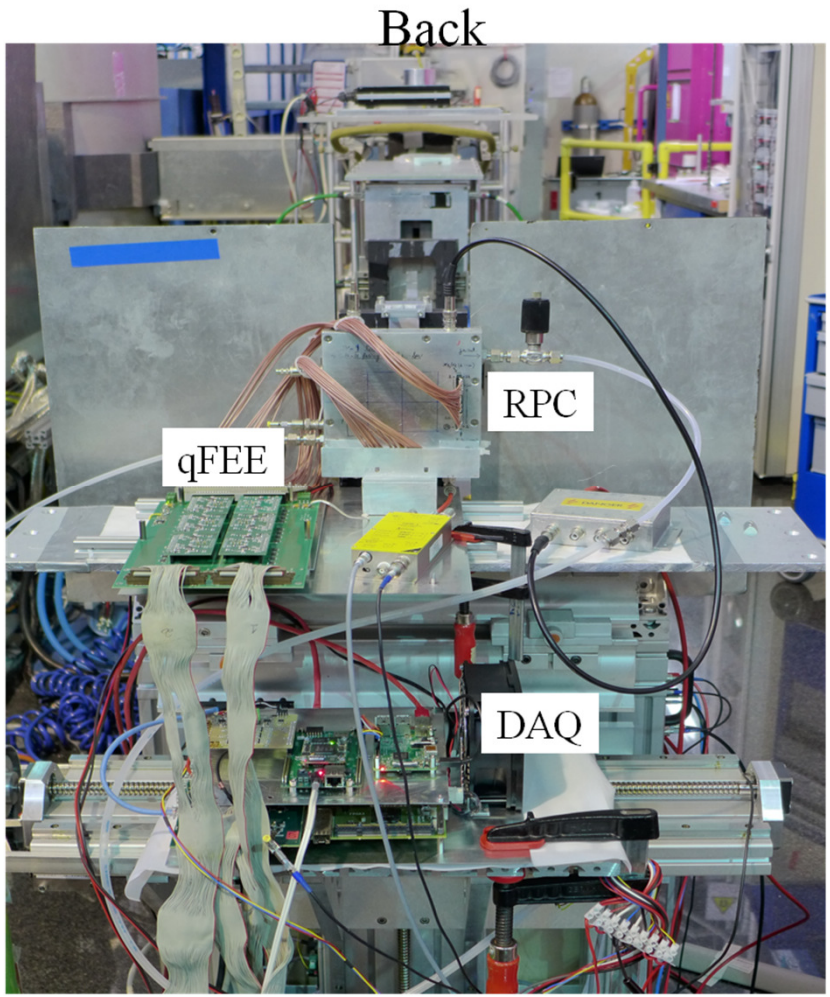




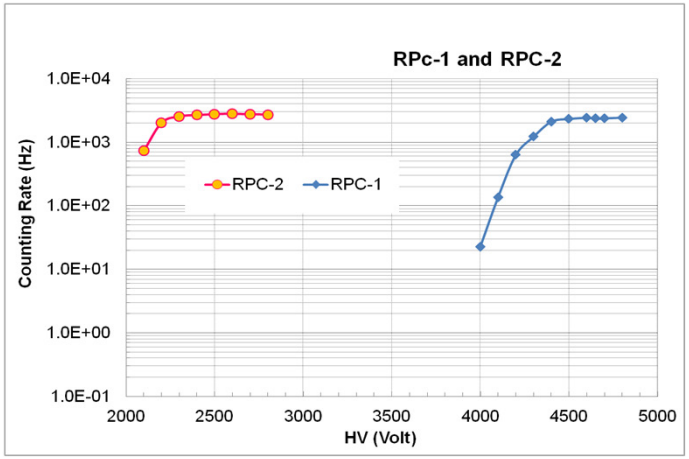
^{10}B4C coatings provided by the ESS Detector Coatings Workshop

1st Tests at TREF neutron beamline in TUM-FRM II

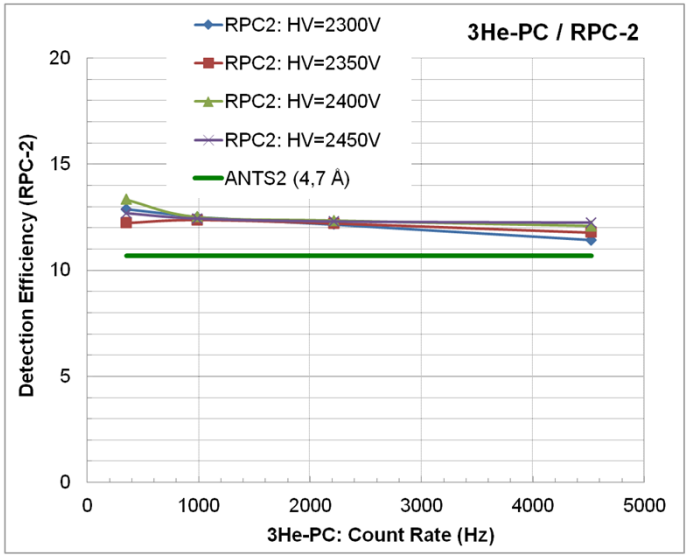
Tests at TREF/FRMII neutron beam line λ 4.7 Å



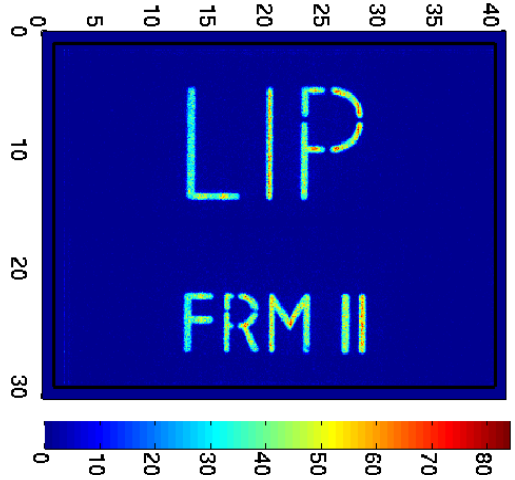
Plateau for RPC-1 and RPC-2

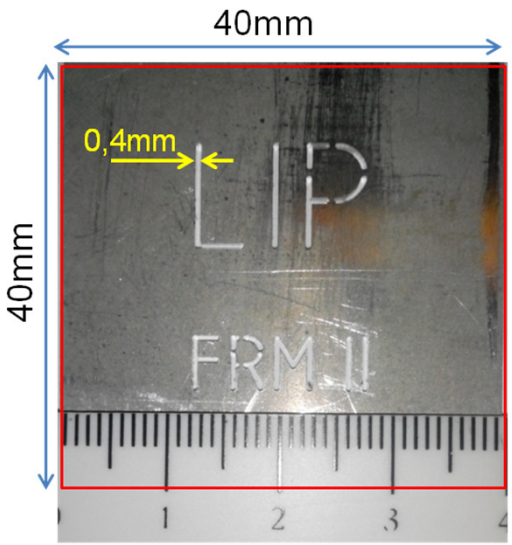


Detection Efficiency



RPC-2 : 2D Spatial Resolution





Cd Mask (1mm thick)

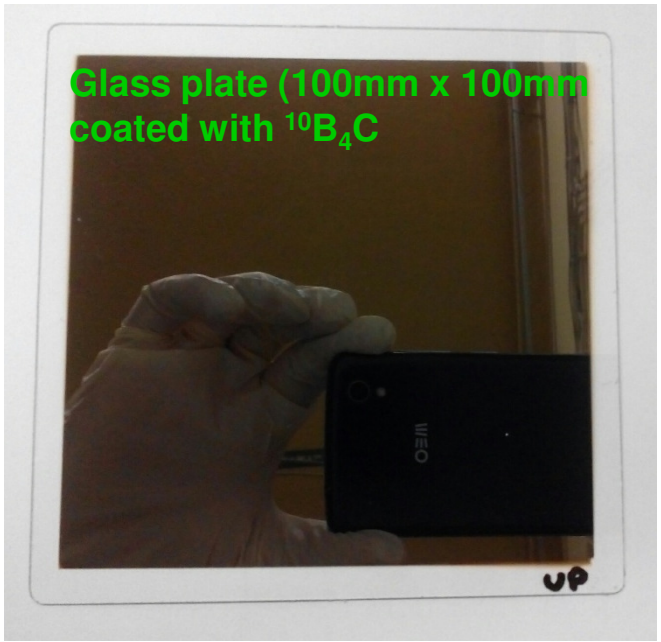
Towards High D. Efficiency - Multilayer RPCs

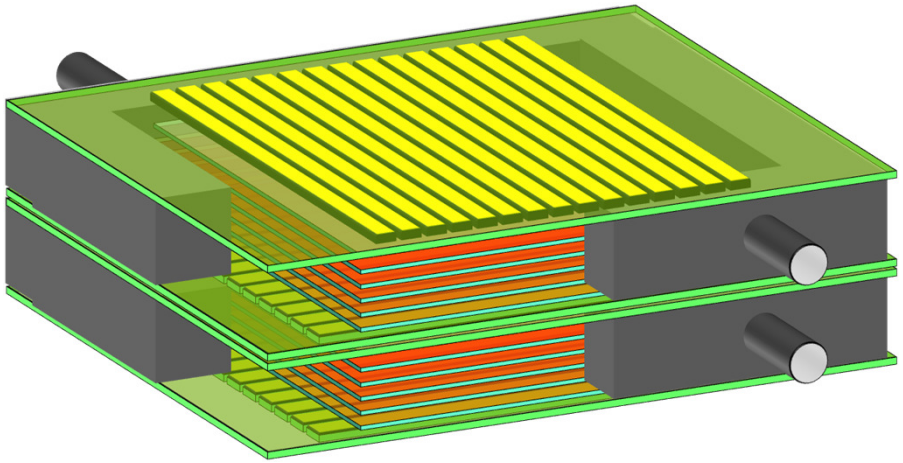
Work in progress

- **Charaterization of the *gamma sensitivity* of the two RPCs tested in TUM-FRMII with ^{22}Na and ^{60}Co gamma sources at LIP**
- **Acquisition and analysis of the waveforms of the Fast and Slow component of the induced signals**
  - Look if there is any significant difference in the time structure of different kind of events (different nature of the primary ionization, e.g. BKG, gammas and Alfa particles) that will make possible Pulse Shape Discrimination (PSD)
- **Design and Building a stack of double-gap RPCs**
  - **Al-plates (100 mm x 100 mm) coated with 10B4C (1150 nm) on both sides already provided by the ESS Detector Coatings Workshop**
  - **Considering the results from the test at FRM II we will go for narrow gas-gap widths**

Future

- **Building and evaluation of a Multigap-RPC) with thermal neutrons**
  - **A batch of soda lime glass plates (100mm x 100mm, 0.4mm thick) coated with ^{10}B4C (1150 nm)** exhibiting **a surface resistivity > 1E6 Ω / was already provided by the ESS Detector Coatings Workshop** – *Until the present the coatings adhesion on glass remains stable*



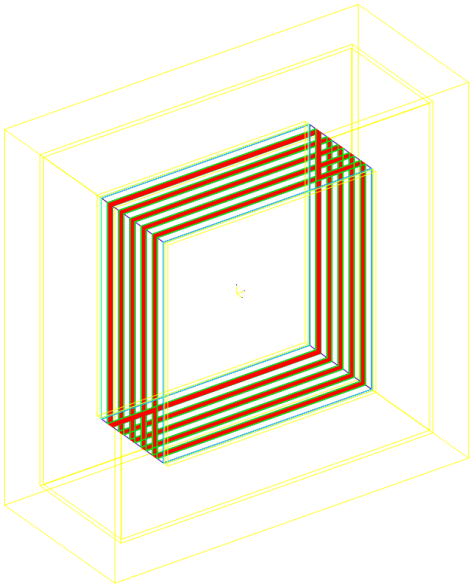


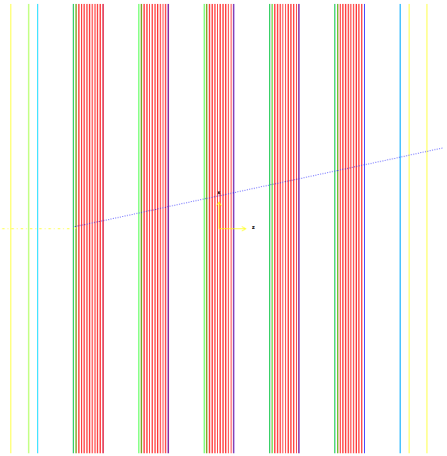
Future

- ***MC SIMULATIONS (GEANT and ANTS2 packages) should proceed***

Neutron transport considering absorption and scattering by materials in the beam path is being implemented in GEANT

The geometry is implemented and code is being tested to work with very thin volumes





WP 9 Instrumentation: Detectors

Thank you for your attention

Backup Slides

Multigap RPC

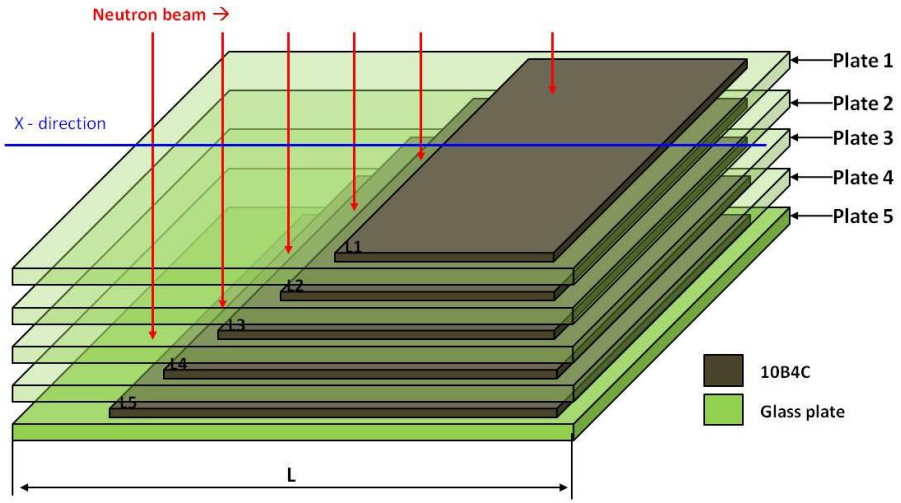


Figure-A

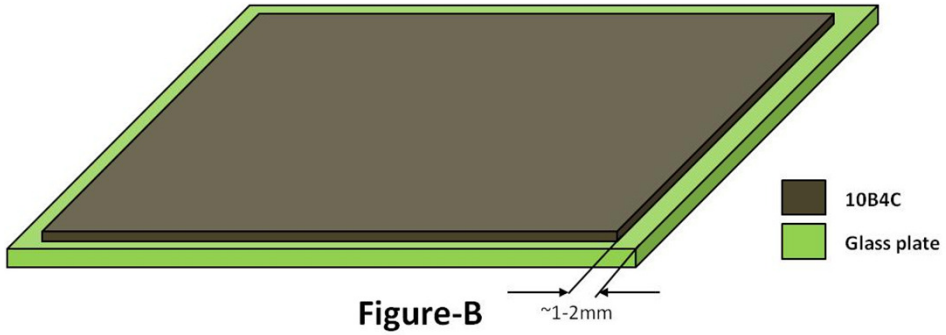
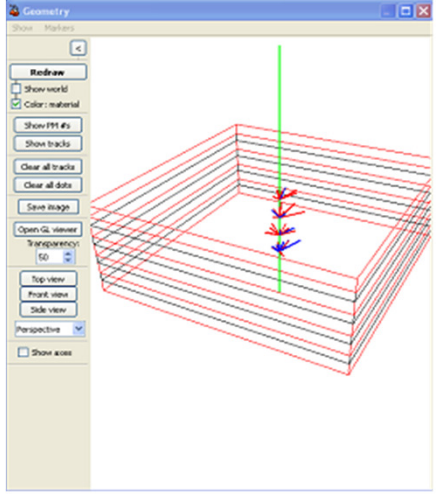


Figure-B

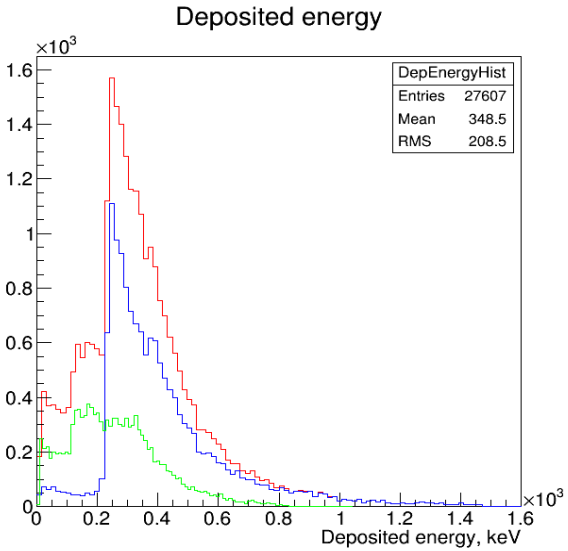
ANTS2 Simulations

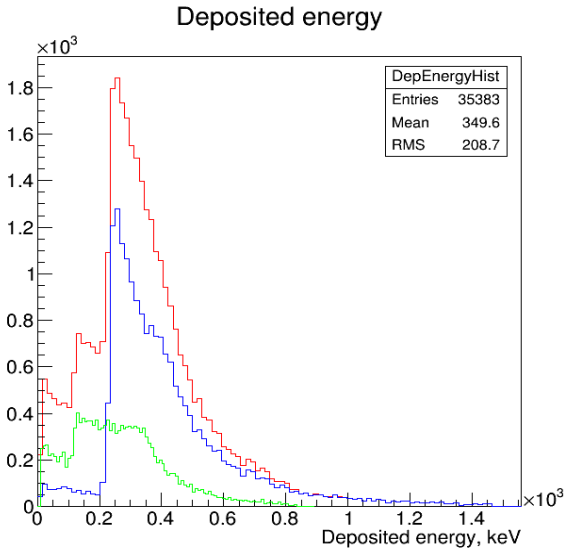


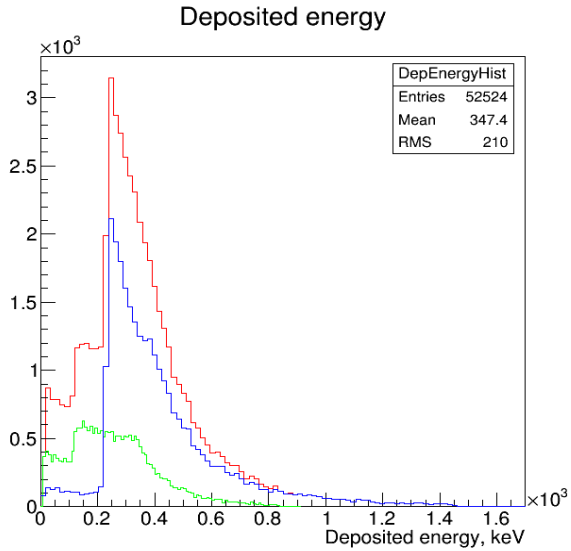
Multigap RPC (10 gap's)

Deposited energy in the gas-gap (C2H2F4 @ 1 atm) for the 4He and 7Li fissions fragments :

- **Gas-gap width: 0.35 mm**
- Glass Thickness: 0.35 mm
- 10B4C coating thickness: 1150 nm
- **Number of layers: x 10**







λ= 1.8 Å / Det. Efficiency~27,6 %
Red: sum (^{4}He+^{7}Li)
Blue: ^{4}He
Green: ^{7}Li

λ= 2.5 Å / Det. Efficiency~35,4%
Red: sum (^{4}He+^{7}Li)
Blue: ^{4}He
Green: ^{7}Li

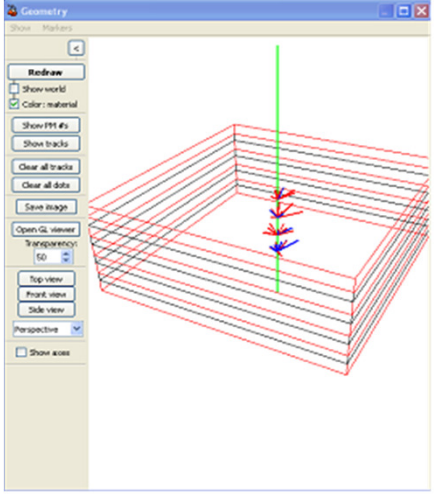
λ= 4.7 Å / Det. Efficiency~52,5%
Red: sum (^{4}He+^{7}Li)
Blue: ^{4}He
Green: ^{7}Li

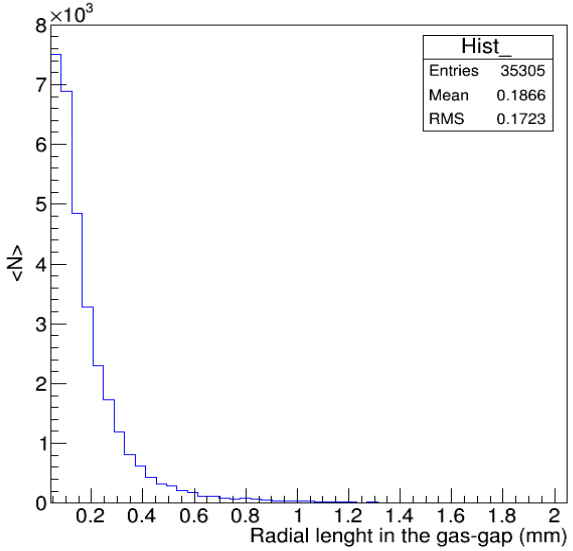
ANTS2 Simulations

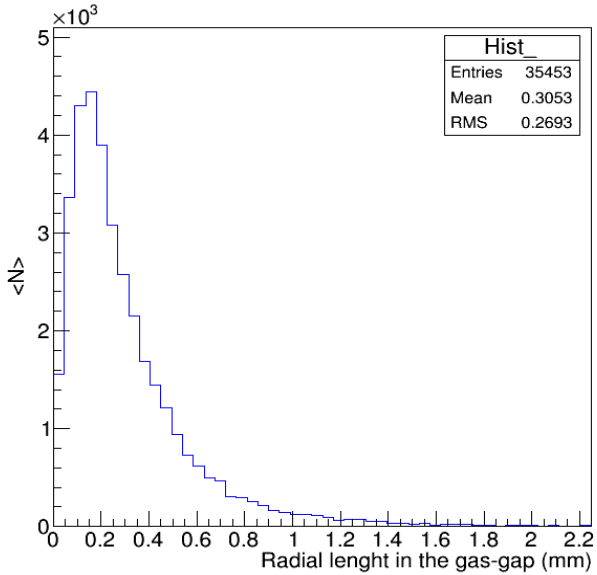
Multigap RPC (x10 gap's)

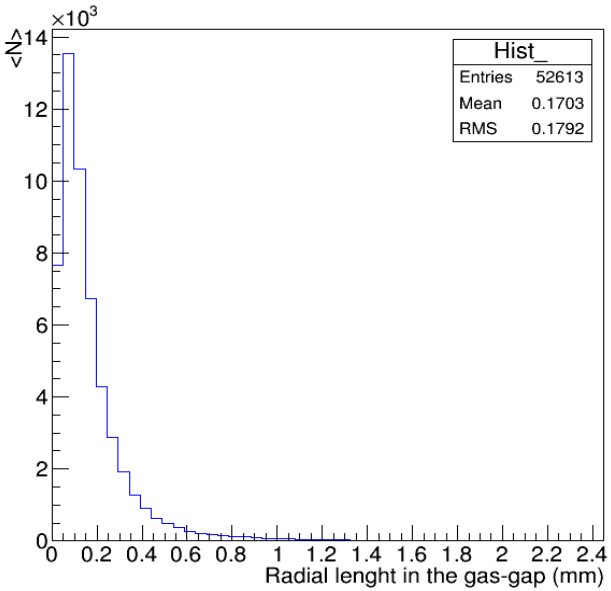
Ranges for the 4He and 7Li particles in the gas-gap (C2H2F4 @ 1 atm)

- **Distributions for the length of the Ranges projected in the direction parallel to the plane of the electrodes**
  - Glass Thickness: 0.35 mm
  - 10B4C coating thickness: 1150 nm
  - Number of layers: x 5







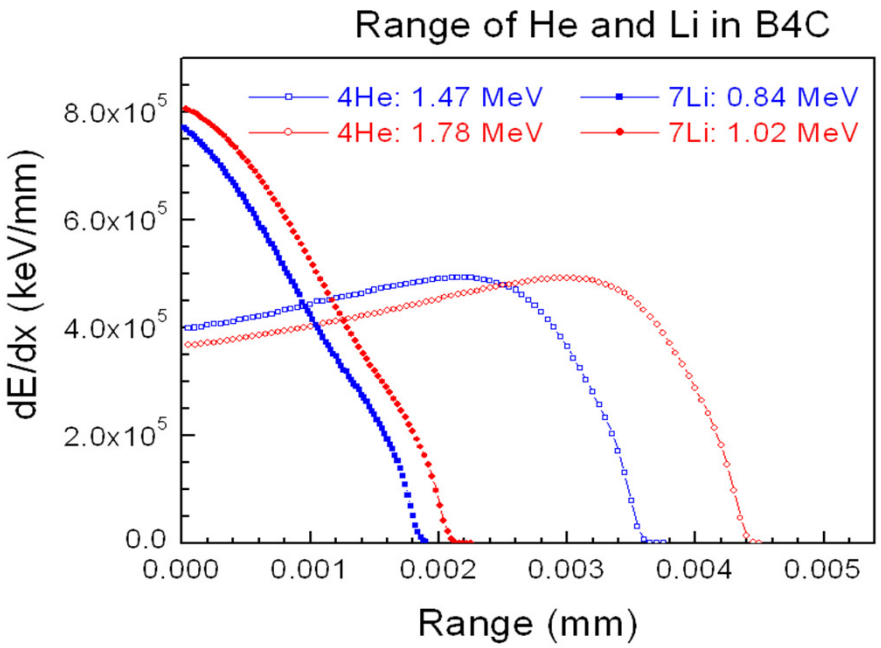


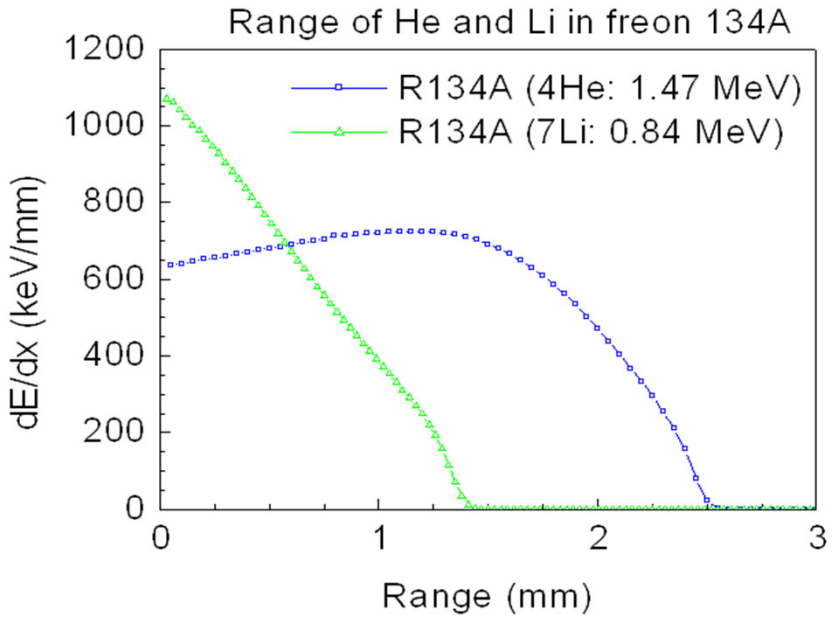
λ= 2.5 Å / Det. **Efficiency~35,3 %**
Gas-gap width: 0. 1mm

λ= 2.5 Å / Det. **Efficiency~35,5 %**
Gas-gap width: 0.2mm

λ= 4,7 Å / Det. Efficiency~ 52,6%
Gas-gap width: 0.1 mm

Backup Slide





$n + {}^{10}B \rightarrow ({}^{11}B)^*$

- $\rightarrow {}^{7}Li^* (0{,}84\ MeV) + {}^{4}He (1{,}47\ MeV)$ Q = 2,31 MeV (94 %)
- $\rightarrow {}^{7}Li (1{,}02\ MeV) + {}^{4}He (1{,}78\ MeV)$ Q = 2,79 MeV (6 %)

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Typical gas mixture:

- Freon R134a (tetrafluoroethane): high electron affinity (electron capture $\Rightarrow$ avalanche confinement);
- SF6 (sulphur hexafluoride): 1 to 10% (to suppress streamer discharges);
- C4H10 (Iso-Butane): 0 to 5% (to prevent photon induced streamers.

Task 9.4.1
Resistive plate chamber development

Timeline

	Year 1	Year 2	Year 3	Year 4
MC SIMULATIONS				
PROTOTYPE DESIGN ; 10B4C COATINGS MANUFACTURE				
BUILDING OF FIRST 10B4C COATED RPCs; *EXPLORTORY TESTS*				
STUDY 10B4C COATED RPCs OPERATION IN AVALANCHE MODE				
2D POSITION RECONSTRUCTION				
PROTOTYPE´S CHARACTERIZATION (Detailed Tests with a neutron beam and gamma sources); Report conclusions				