Task 9.4.1

Resistive plate chamber development

LIP (PT)

Alberto Blanco
Andrey Morozov
Paulo Fonte
Luís Lopes
Luís Margato

TUM (DE)

Karl Zeitelhack

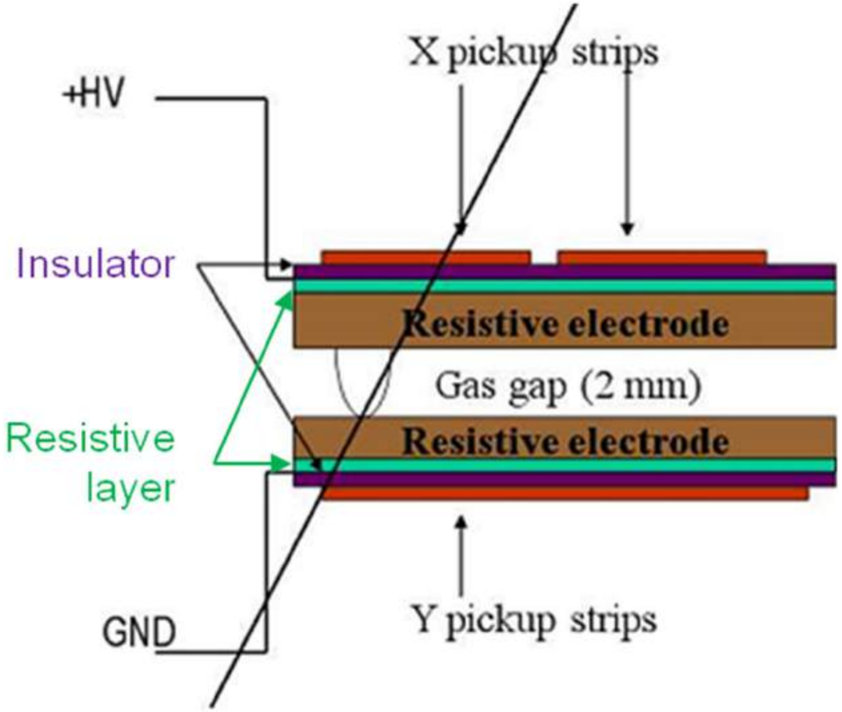
ESS (SE)

Irina Stefanescu

Summary

- RPCs Basics / Examples
- Thermal neutron detection with B4C coated RPCs
- First results with a 10B4C coated hybrid RPC
- Work Plan

RPC Basics



Fonte IEEE TNS 2002

Charging up of the resistive electrodes after avalanche (rate effects): time constant: $\tau = \rho\, \varepsilon_0\, \varepsilon_r$

ρ = Volume resistivity
ε_0 = Vacuum Permittivity
ε_r = Rel. permittivity

Generation of electron-ion pairs (Ionizing particles) in the gas-gap

Working modes

Depending on the applied voltage one may have different operation modes:

1. **Avalanche mode**

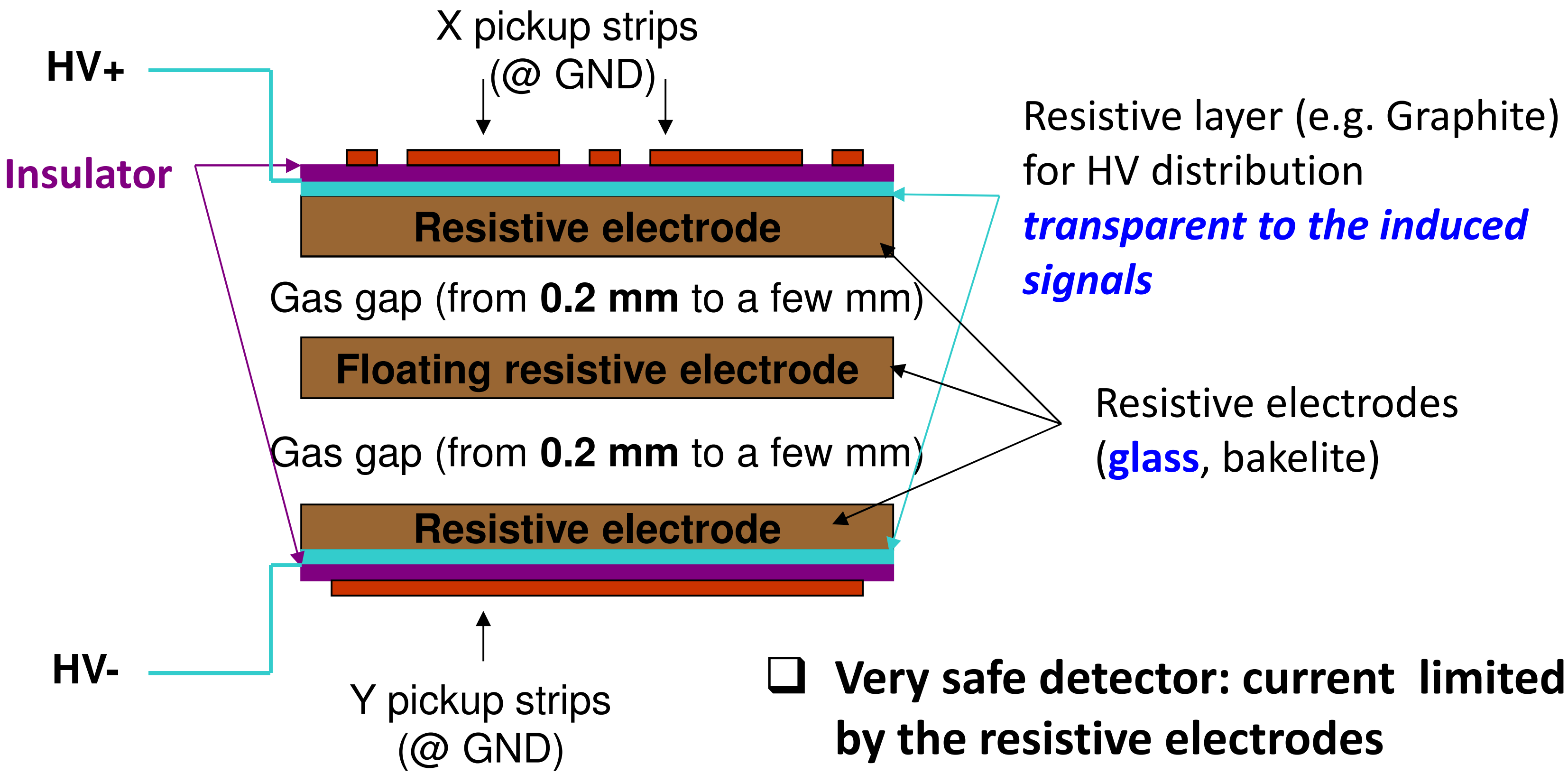
   Lower signal amplitude but more favourable for High rate operation

2. **Streamer mode**

   Higher signal amplitude allows a simpler design of the front-end electronics

RPC Basics

Multi-Gap RPC

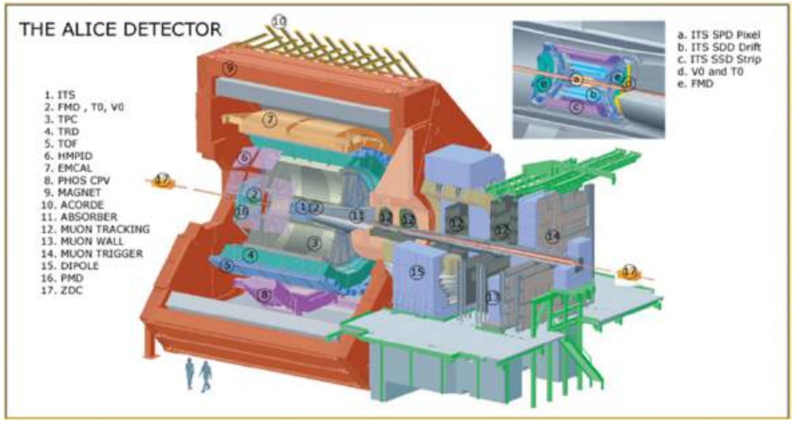


- ❑ **Very safe detector: current limited by the resistive electrodes**
- ❑ **Excellent time (~50 ps) and position resolution (< 100µm)**

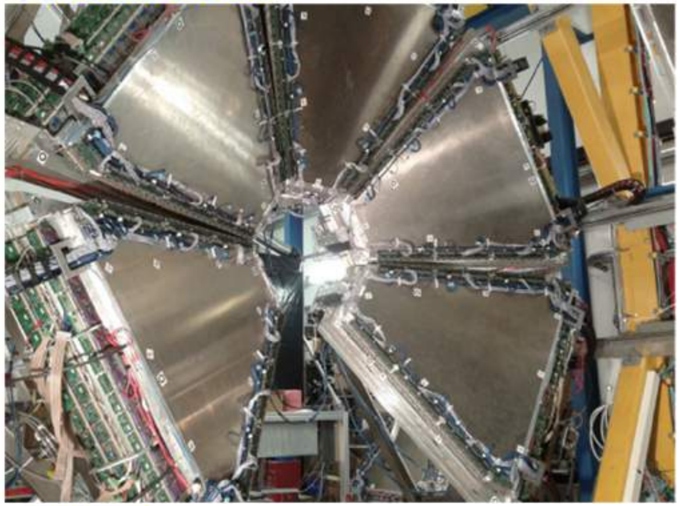
[Santonico & Cardarelli, 1981]
[E. Cerron Zeballos et al,1996]

Thermal neutron detection with RPCs

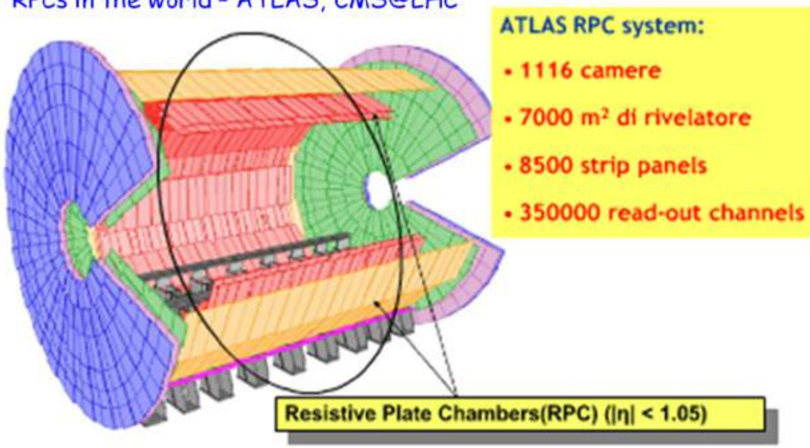
Examples of RPCs Applications



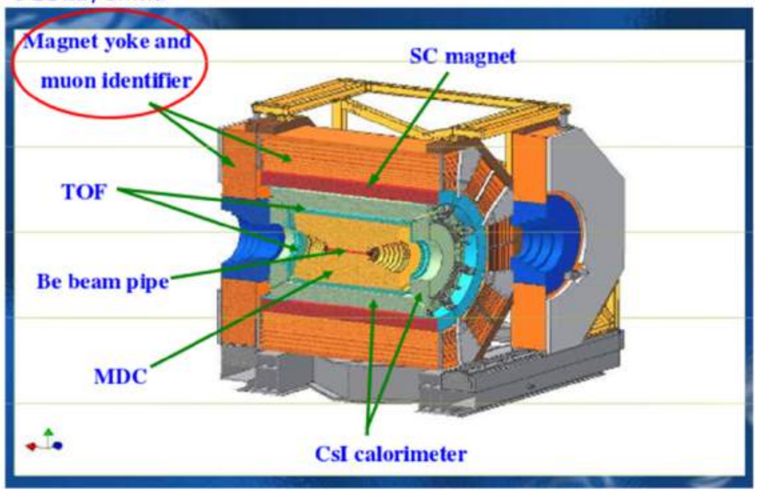
HADES@GSI



RPCs in the world - ATLAS, CMS@LHC



BESII, China



Thermal neutron detection with RPCs

Prior research

The idea to use RPCs to detect low energy neutrons has been suggested earlier (1993) by

E. Calligarich ; R. Cardarelli ;R. Santonico ; et al., doi:10.1117/12.138667

It has never been realised in a position-sensitive, high detection efficiency neutron detector

The multi-gap RPC configuration for neutron detectors has not yet been considered

What can be found in the literature

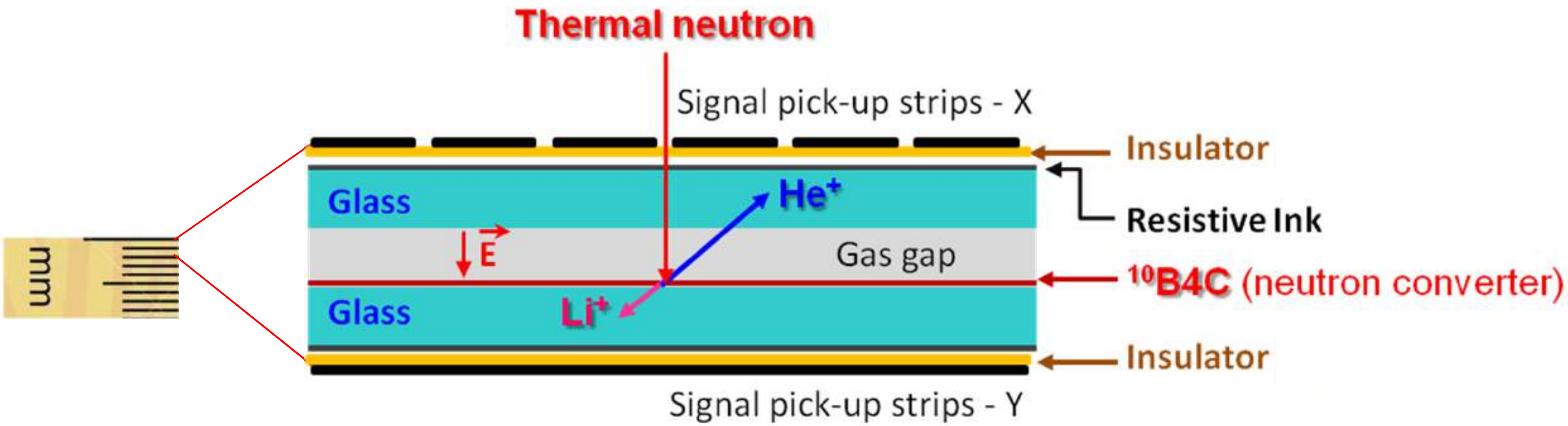
M. Abbrescia et al. → "Gd as a converter (Gd_2O_3 mixed with linseed oil) sprayed onto the bakelite electrodes of the RPC"
Nuclear Physics B (Proc. Suppl.) 125 (2003) 43-47

Arnaldi et al. → "B4C layer as neutron converter (single gap)"
Arnaldi, et al., NIMB 213 (2004) 284–288

K. S.Lee, et al., → "Have investigated a Lithium-Fuoride (LiF) coated RPC"
Journal of the Korean Physical Society, Vol. 48, No. 4, April 2006, 846-849.

Thermal neutron detection with RPCs

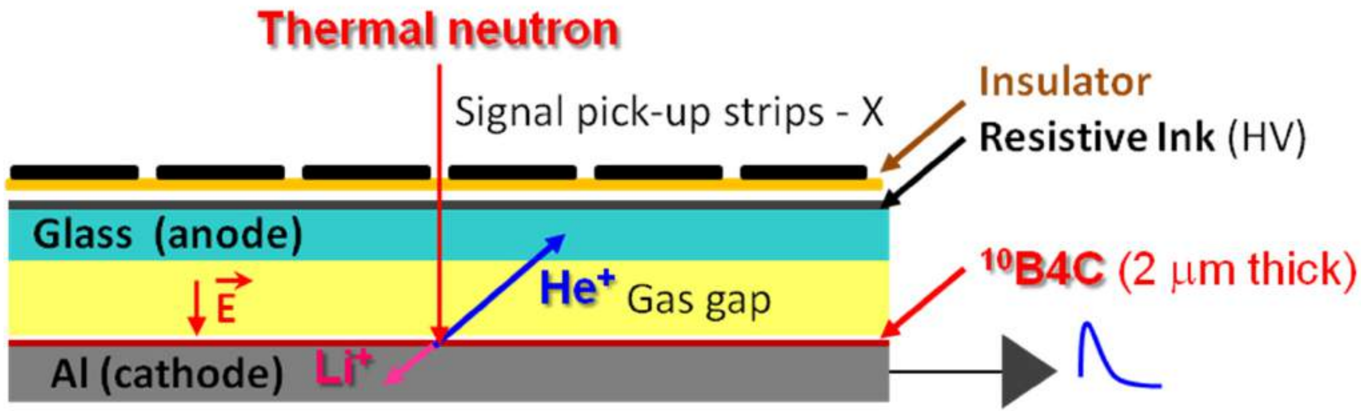
^{10}B Converter



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

First results with a 10B4C coated hybrid RPC

Hybrid RPC Configuration



Signal pick-up strips engraved on a PCB:

- **Strip width** = **2mm**
- **Pitch** = **2.5mm**

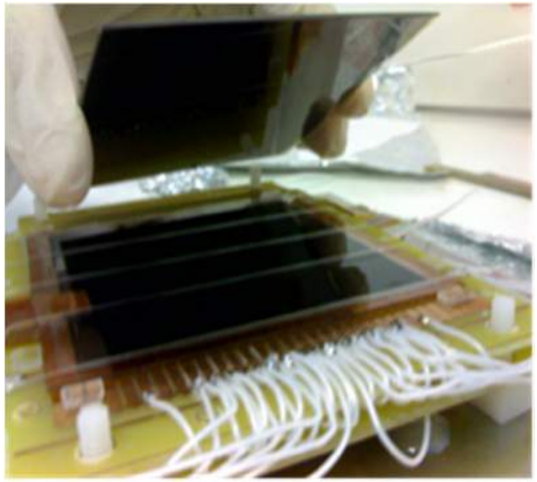
Plate of float glass (0.35 mm thick): 8cm x 8cm

Plate of Al (1.0 mm thick): 8cm x 8cm

Gas-gap width: 0.35 mm; filled with $C_2H_2F_4$ @ 1atm

First results with a 10B4C coated hybrid RPC

Hybrid RPC

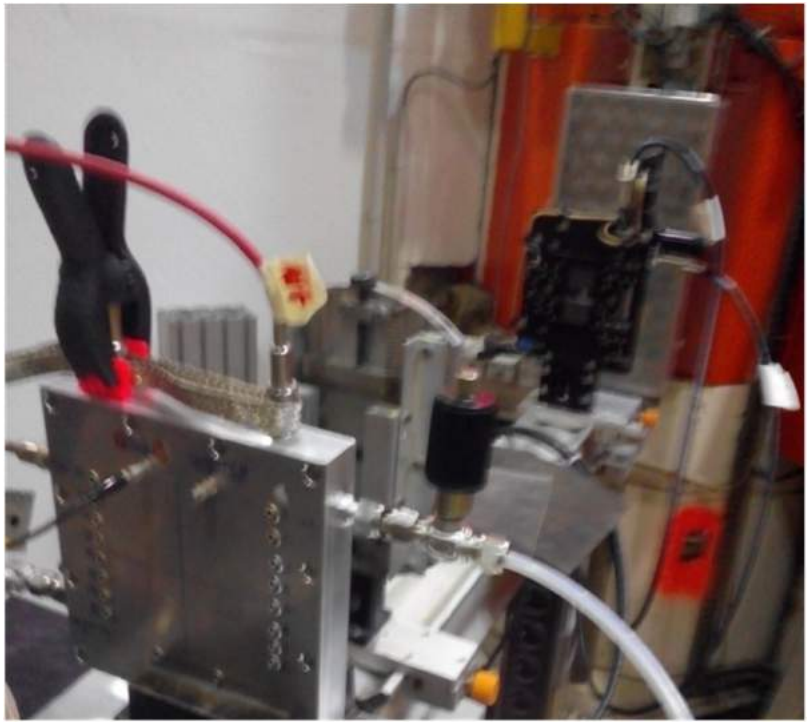


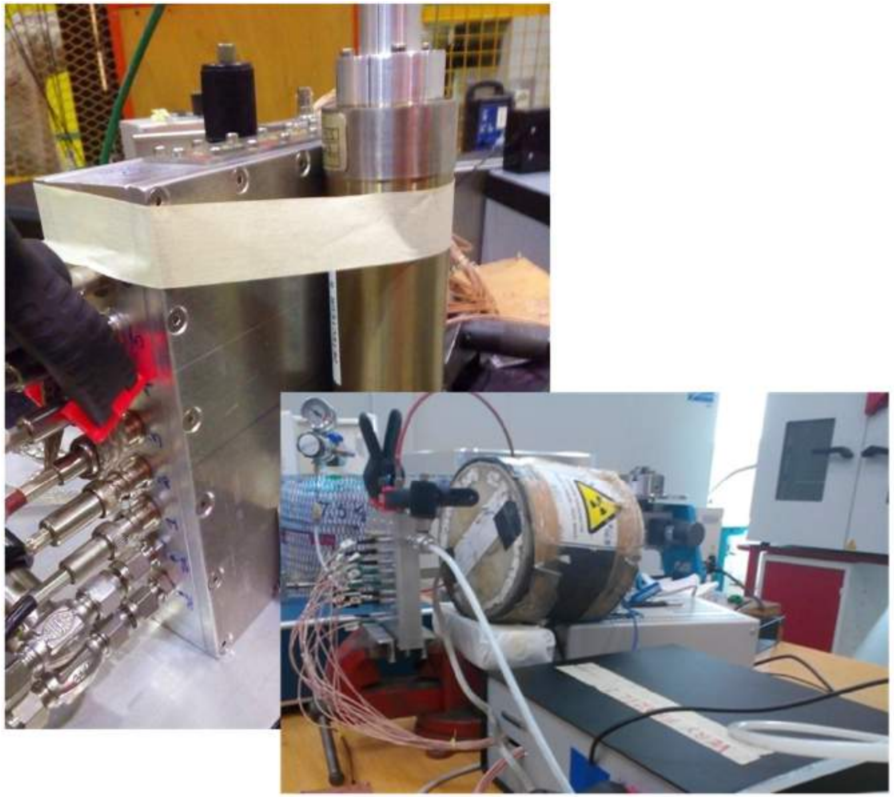
64 channels Data Acquisition System based on MAROC3 ASIC from Omega

Assembly of an 10B4C coated Hybrid RPC (Al cathode coated with 10B4C, 2 microns thick)

First results with a 10B4C coated hybrid RPC

Detector prototype in place at CT2 thermal neutron beam at ILL



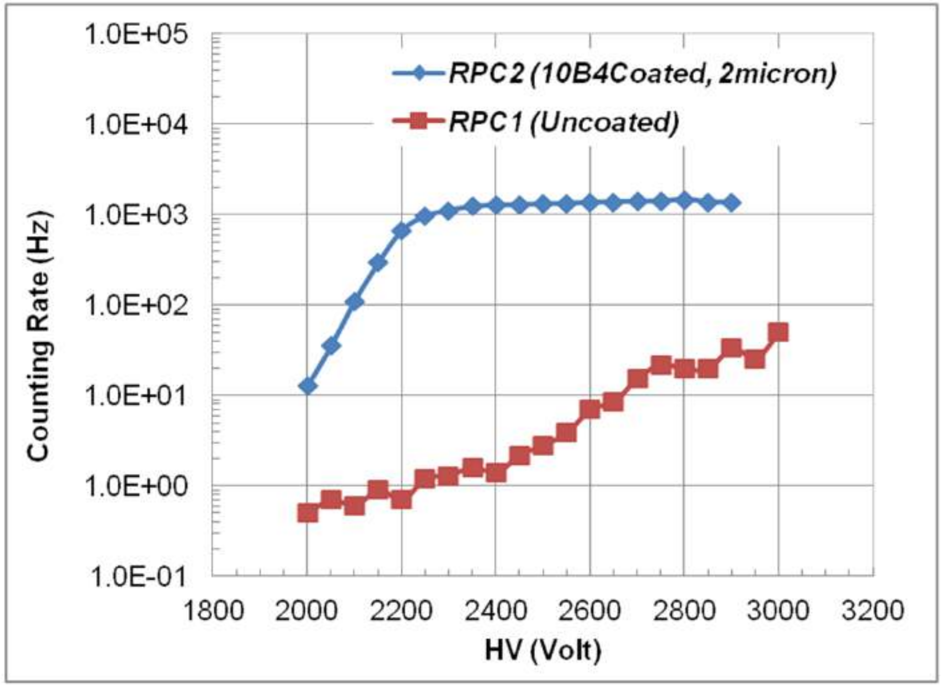


Debugging tests with a **Am/Be** neutron source, before moving the detection system into the Reactor Area.

First results with a 10B4C coated hybrid RPC

Tests in a monochromatic thermal neutron beam at ILL

— Plateau Measurement



Two RPCs with a similar configuration:
RPC-1: No coating
RPC-2: Cathode coated with 2micron 10B4C

10B4C coatings were manufactured at ESS Detector Coatings Workshop in Linköping

Experiment performed in the thermal neutron beam CT2 (λ=2.5 Å)

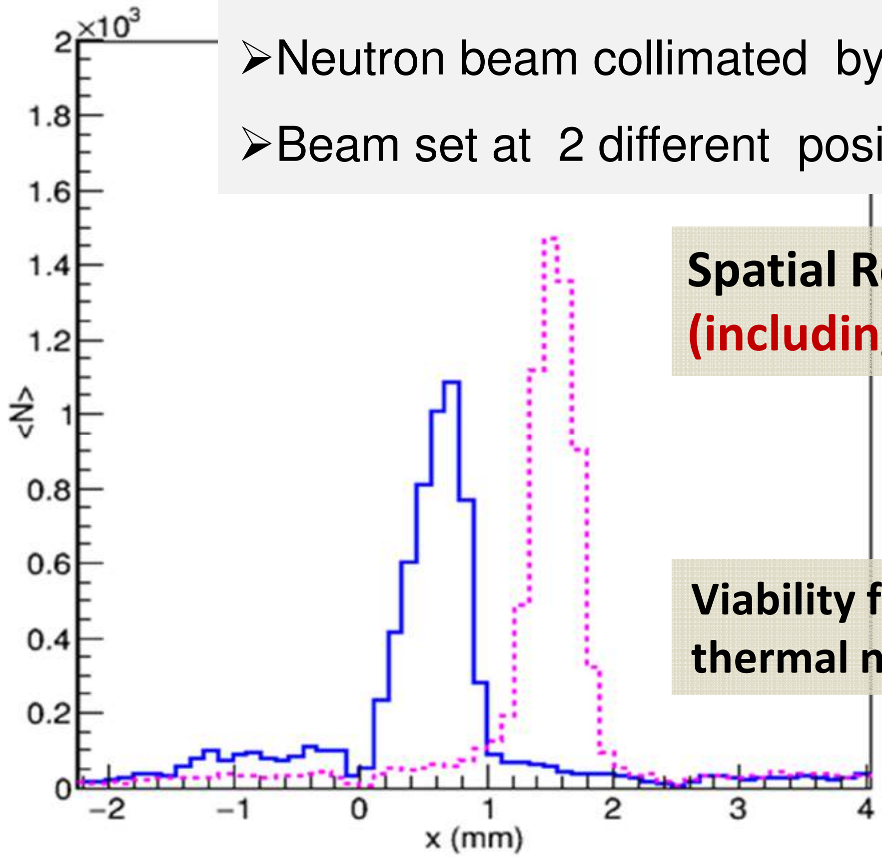
HV (Volt)	Efficiency
2400	~ 6 %

Obs.: Considering a efficiency for the 3He P. Counter ~ 80%

First results with a 10B4C coated hybrid RPC

Tests in a monochromatic thermal neutron beam at ILL

— Position resolution



- ➢Neutron beam collimated by a slit: **Slit width~0.5 mm**
- ➢Beam set at 2 different positions (moving stage step =1mm)

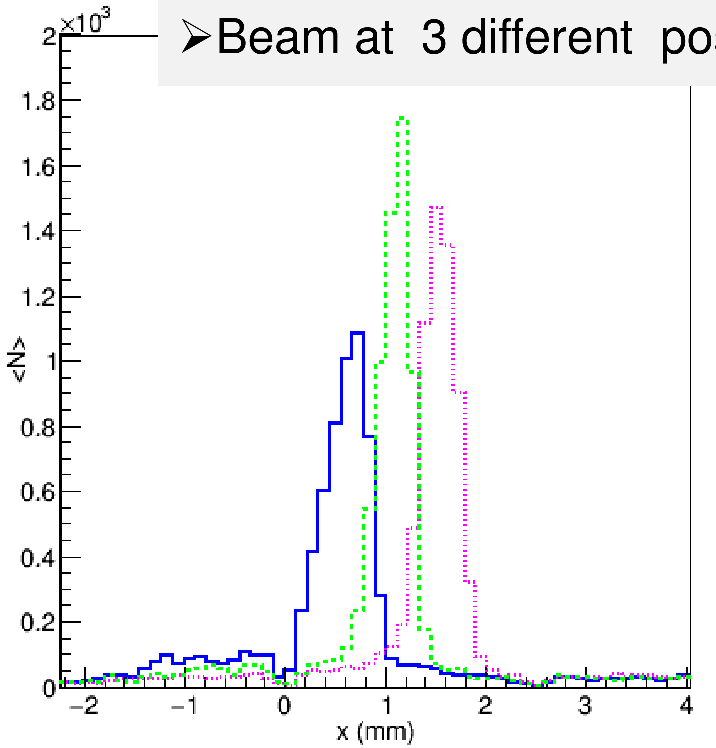
Spatial Resolution: FWHM ~ 0.8 mm
(including the Slit width ~ 0.5mm)

Viability for sub-millimeter resolution thermal neutron detectors

First results with a 10B4C coated hybrid RPC

Tests in a monochromatic thermal neutron beam at ILL
— Position resolution

- ➢Neutron beam collimated by a slit: **Slit width~0.5 mm**
- ➢Beam at 3 different positions (**moving stage step = 0.625 mm**)



Histograms for beam positioned at:

X0 (Blue)

X1=X0+0.625mm (Green)

X2=X0+1.25mm (Pink)

Position computed by COG using three neighboring strips

Task 9.4.1
Resistive plate chamber development

- **Explore the potential of 10B4C coated RPCs for PSNDs**
  - MC SIMULATIONS
  - PROTOTYPE DESIGN AND BUILDING OF 10B4C COATED RPCs
    - *PROTOTYPE´S CHARACTERIZATION*
  - STUDY OF 10B4C COATED RPCs OPERATION IN AVALANCHE MODE
  - 2D POSITION RECONSTRUCTION

Resistive plate chamber development

– *MC SIMULATIONS (GEANT4 and ANTS2 packages)*

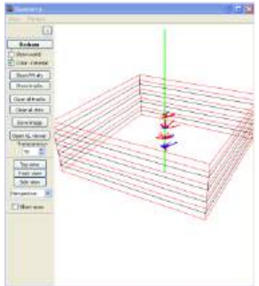
Optimization of position resolution and detection efficiency

- **Optimization parameters**
  - **Number of converter layers / Converter layers thickness**
  - **Gas-gap width**
    - ***Resolution information from:***
      - ⇒ Range of the charged particles inside the gas-gaps;
      - ⇒ Distribution of the energy deposition in the normal direction and along the surface

Second phase:

Include neutron absorption and scattering by materials in the beam path

Resistive plate chamber development

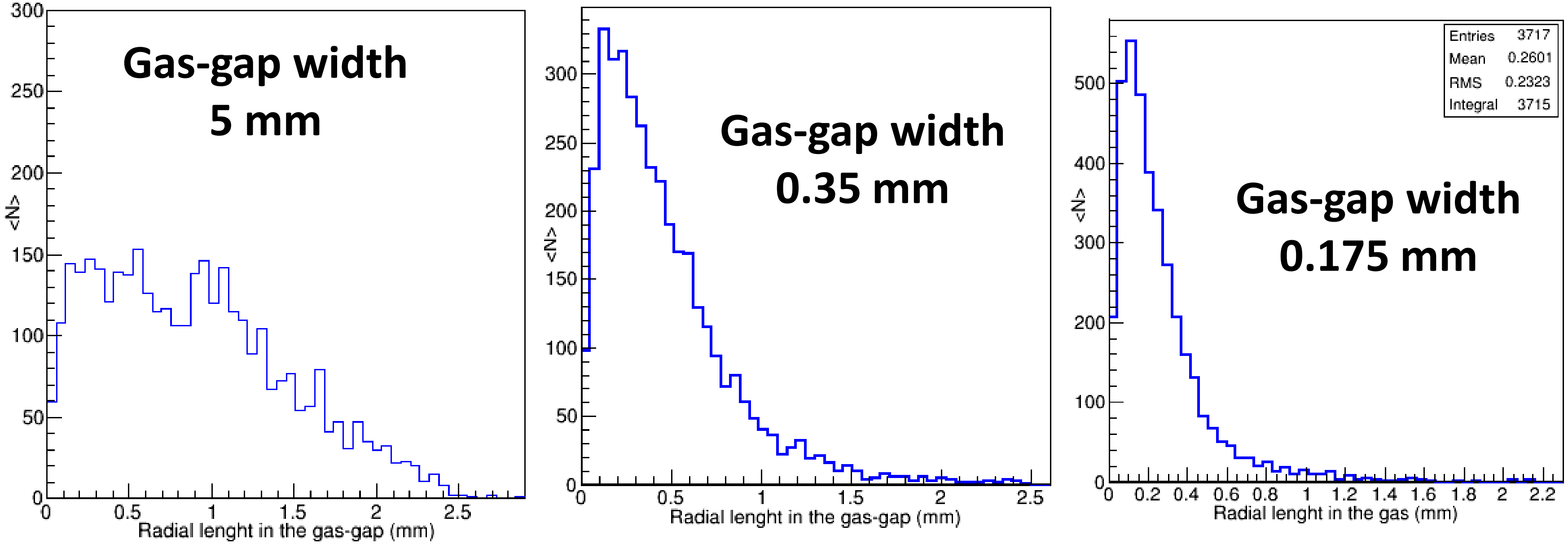


MC SIMULATIONS (GEANT4 and ANTS2 packages)

4He and 7Li particles Ranges in the gas-gap

10B4C thickness = 1.3 μm; λ = 1.8 Å

C2H2F4 @ 1 atm



Distributions for the length of the Ranges projected in the direction parallel to the plane of the electrodes

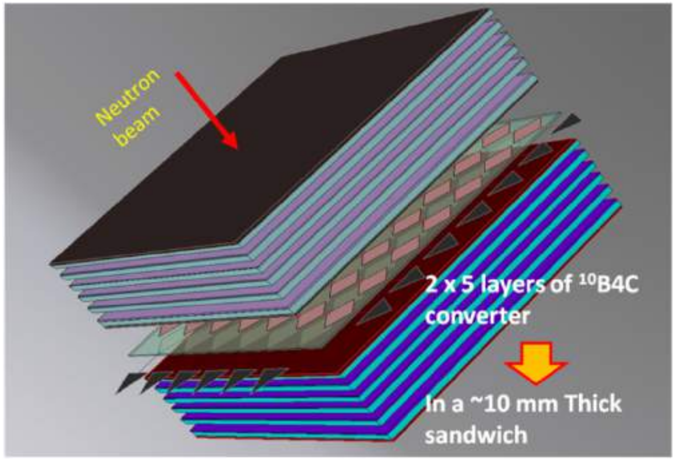
Task 9.4.1

Resistive plate chamber development

– **PROTOTYPE DESIGN AND BUILDING OF 10B4C COATED RPCs**

Different RPCs configurations are considered, e.g.:

- **Stack of:**
  - **Single-gap RPCs**
  - **Double-gap RPCs** (two anodes sharing the same cathode)
  - **Multi-gap RPCs: leads to very modular and compact designs; the 10B4C layers have to display a surface resistivity > 10^6 Ω/**



Feasible 10 layers of 10B4C in only a 10 mm stack height;

Small mass thickness
(minimization of neutron absorption and scattering in detector materials)

Task 9.4.1

Resistive plate chamber development

- **PROTOTYPE DESIGN AND BUILDING OF 10B4C COATED RPCs**
  - ***PRODUCTION OF 10B4C COATINGS WITH REQUIRED FEATURES***
    - ***Adequate surface resistivity for the Multi-gap RPC***
  - ***PROTOTYPES CHARACTERIZATION (with thermal neutrons and γ's sources) e.g.:***
    - **Efficiency**
    - **Position resolution**
    - **gamma sensitivity**

Tests of prototype´s in a thermal neutron beam should be foreseen / planned

Task 9.4.1
Resistive plate chamber development

– *STUDY OF B4C COATED RPC OPERATION IN AVALANCHE MODE*

Operation of the RPC with HIPs e.g. with **4He** particles; Namely the effect of a high ionization density in the gas-gap;

Look for differences in signal shapes for gamma's and thermal neutrons: towards Pulse Shape Discrimination (PSD)

Gas mixtures optimization for the operation of 10B4C coated RPCs in the **Avalanche Regime** and with **lower HV**

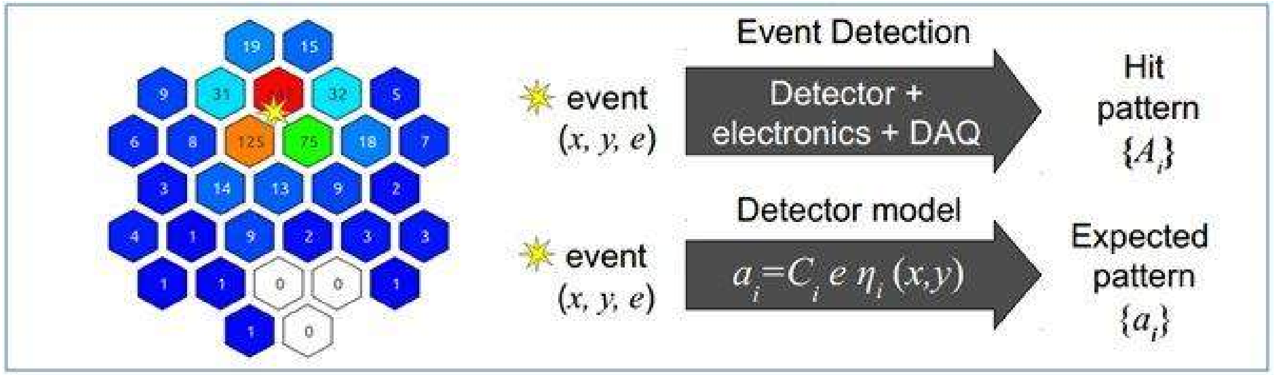
Task 9.4.1

Resistive plate chamber development

– *2D POSITION RECONSTRUCTION*

- **Readout electrodes design:**
  - Arrays of parallel strips (optimization of the geometry)
  - *For 2D codification in the same plane of readout*

- **Statistical reconstructions algorithms:**



Analogy: PMTs ⇒ Pads electrodes

We would like to apply the experience which LIP has acquired during work on position sensitive detectors with optical readout.

Thank you for your attention

Backup Slides

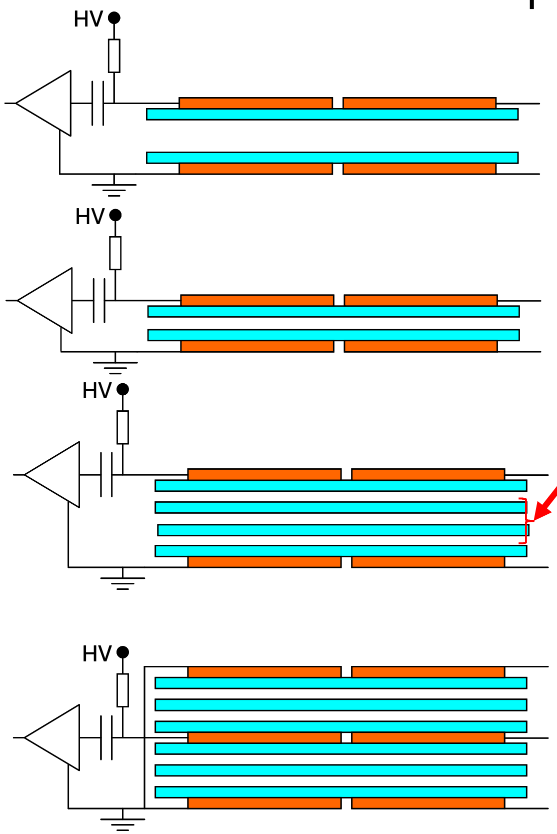
Backup Slide

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.

Backup Slide

Some of the possible electrodes configurations



Asymmetric wide-gap (typ. 2 mm)

Asymmetric narrow-gap (typ. 0.3 mm)

FLOATING

Asymmetric multigap [Williams et al., 1996]

Symmetric multigap

and several other combinations…

Multi Gap RPC

E. Cerron Zeballos et al., NIMA 374(1996)132-135

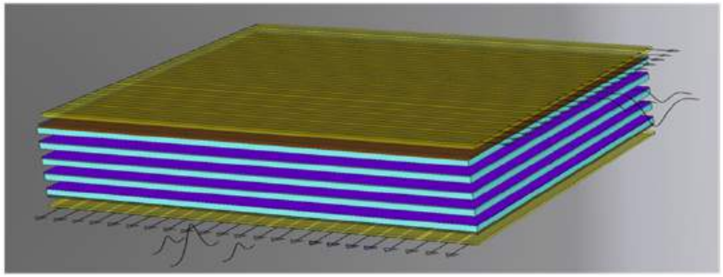
Improved time resolution

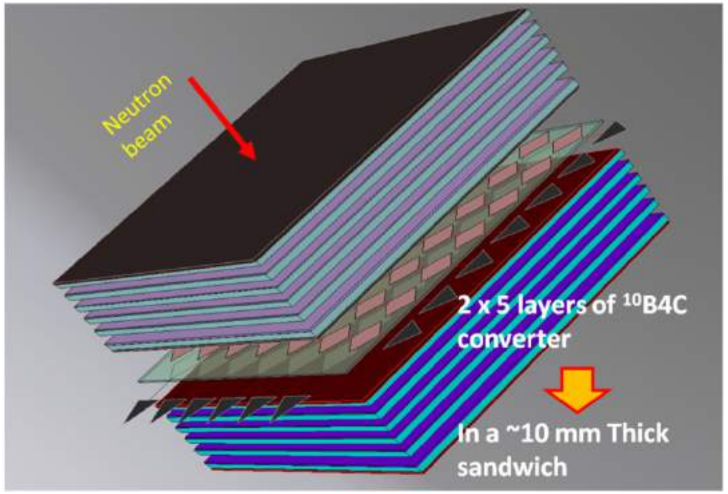
High rate capabilitry

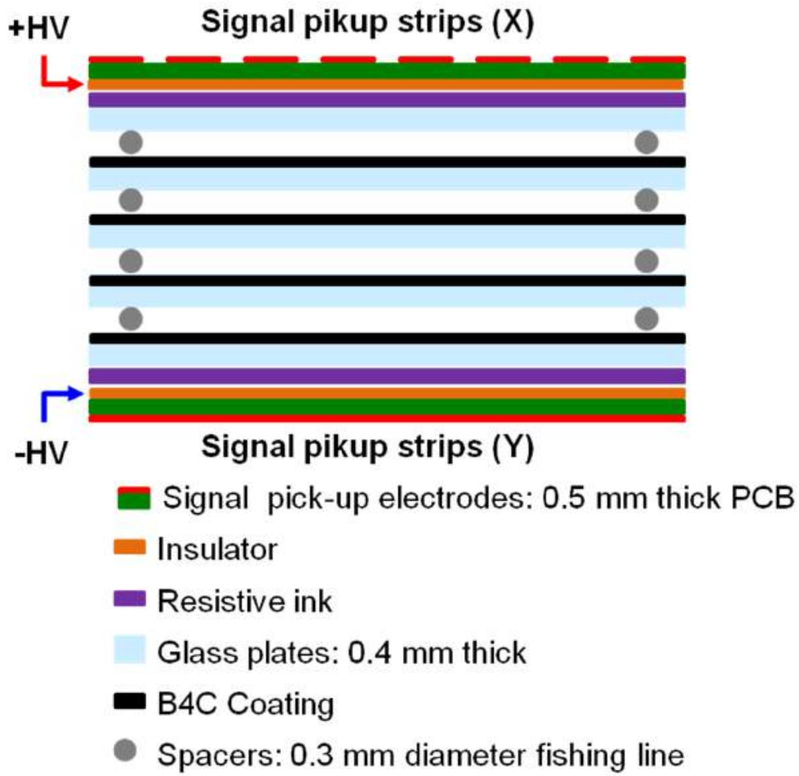
Fonte IEEE TNS 2002

Backup Slide

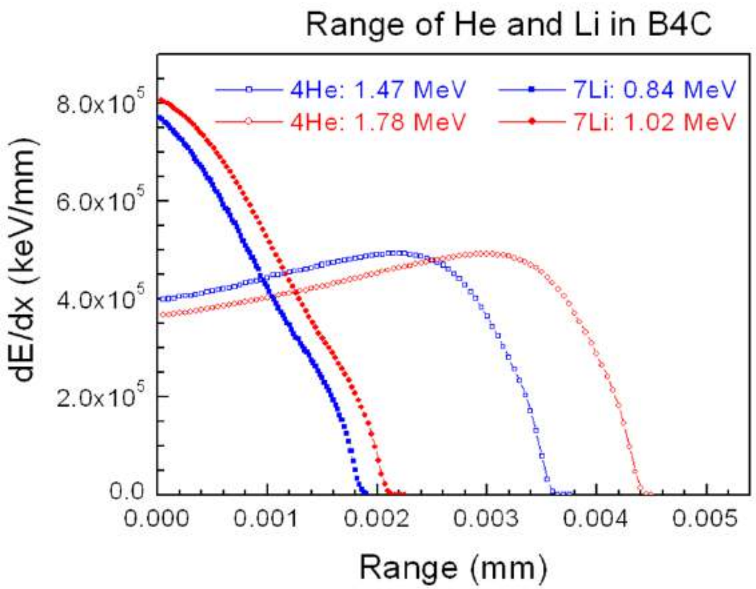
$^{10}B_4C$ coated multigap RPCs for position sensitive neutron detectors: possible detector configurations

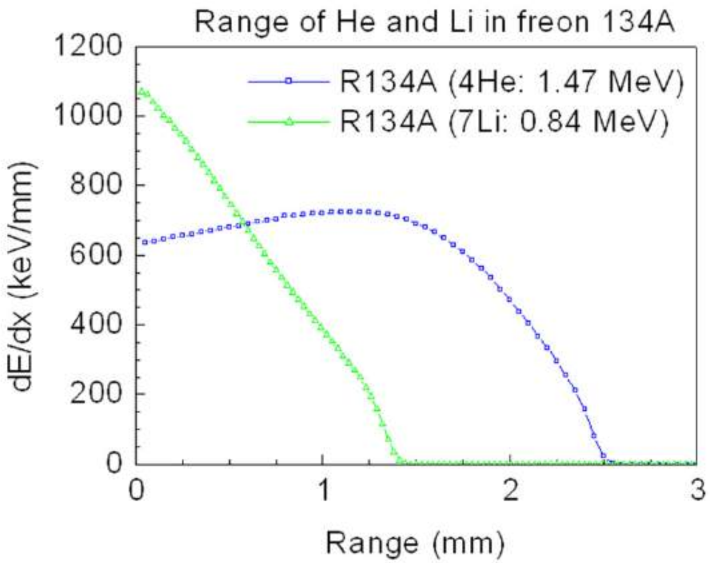






Backup Slide





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

→ ${}^{7}Li^*$ (0,84 MeV) + ${}^{4}He$ (1,47 MeV)   Q = 2,31 MeV (94 %)

→ ${}^{7}Li$ (1,02 MeV) + ${}^{4}He$ (1,78 MeV)   Q = 2,79 MeV (6 %)

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				