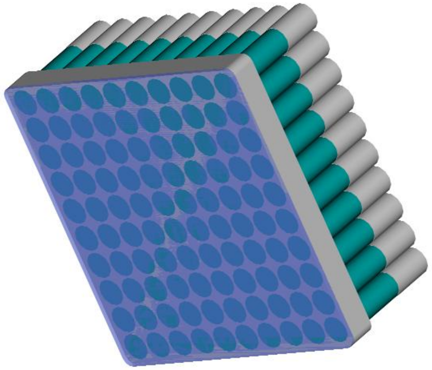
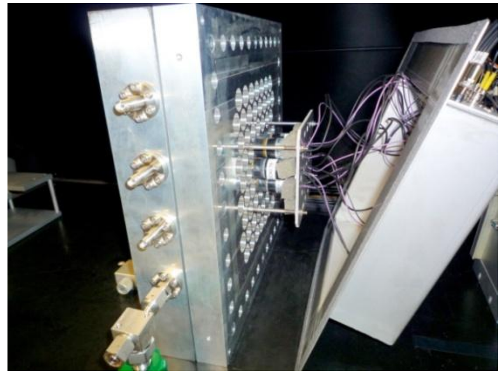
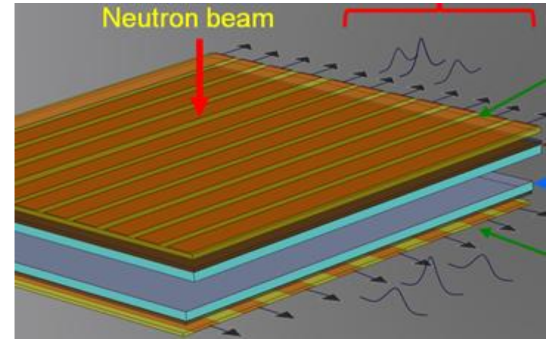






Detectores para Neutrões Térmicos

Active Scintillators for Neutron Detectors
RPCs for Neutron Detectors

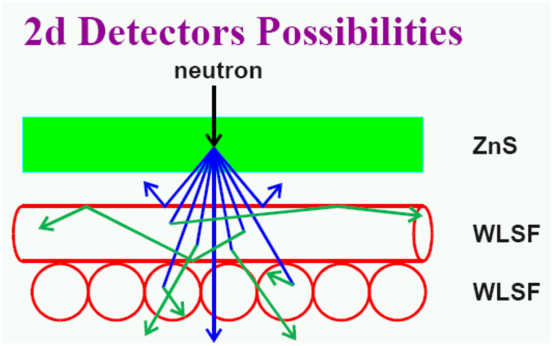
F. A. F. Fraga, M. M. F. R. Fraga, L. M. S. Margato , A. Morozov, L. Pereira,

LIP Coimbra, Universidade de Coimbra

Thermal Neutron Detectors

•nuclear reactions to convert neutrons

- n + 3He → 3H + 1H + 0.764 MeV   Gaseous detectors (CF4, prop.)
- n + 6Li → 4He + 3H + 4.79 MeV   Scintillators
- n + 10B → 7Li* + 4He→7Li + 4He + 0.48 MeV γ +2.3 MeV (93%)
  → 7Li + 4He +2.8 MeV (7%)
- n + 155Gd → Gd* → γ-ray spectrum → conversion electron spectrum
- n + 157Gd → Gd* → γ-ray spectrum → conversion electron spectrum
- n + 235U → fission fragments + ~160 MeV
- n + 239Pu → fission fragments + ~160 MeV

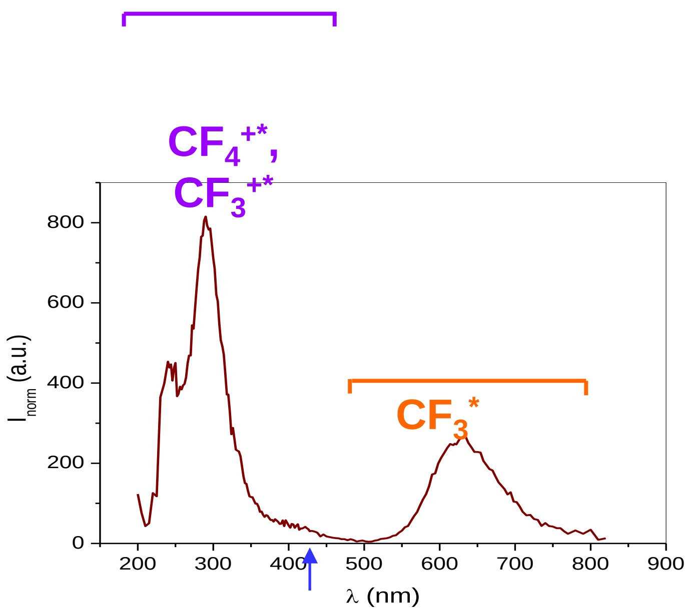


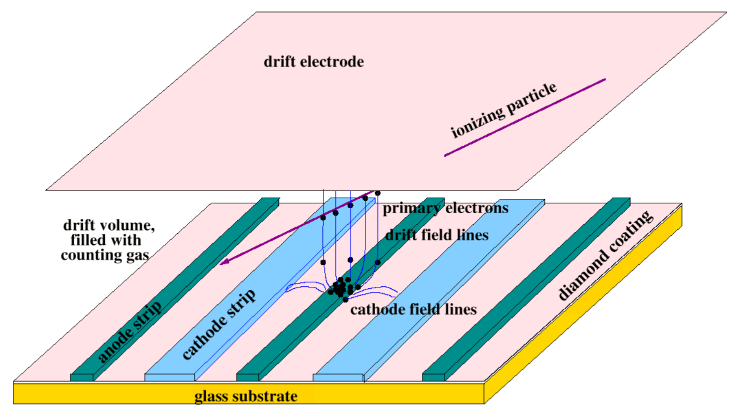
Gaseous detectors

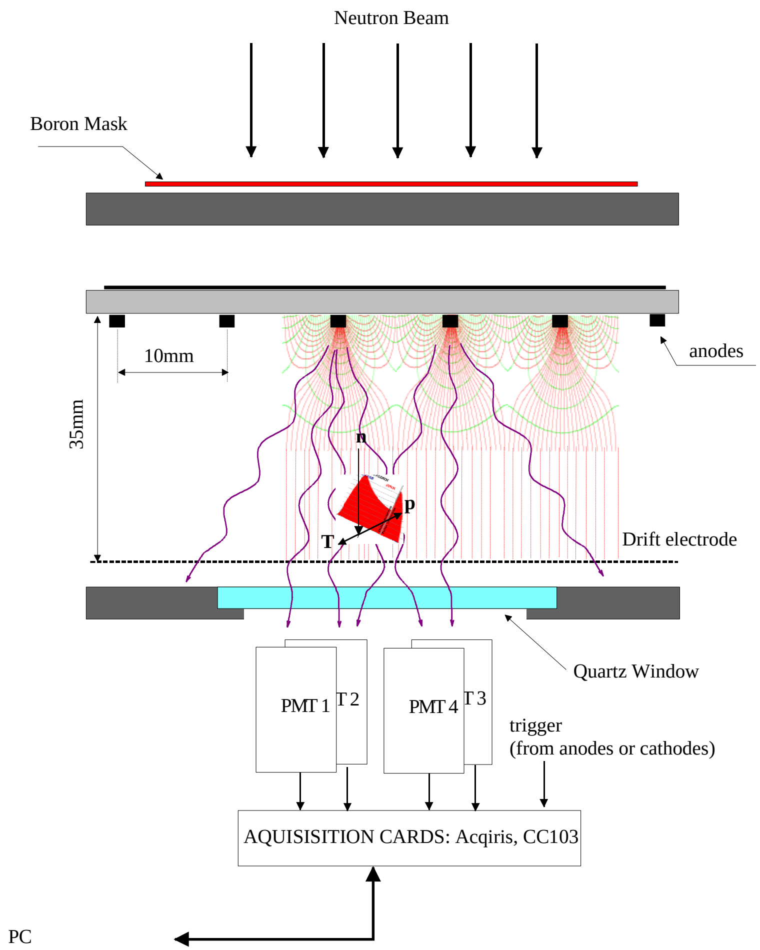
n + 3He → 3H + 1H + 0.764 MeV

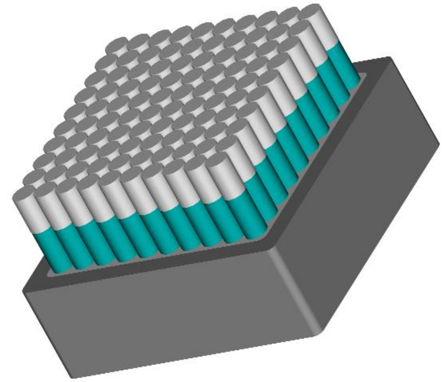
CF4 should be added to control the range -3 bar for 1mm FWHM

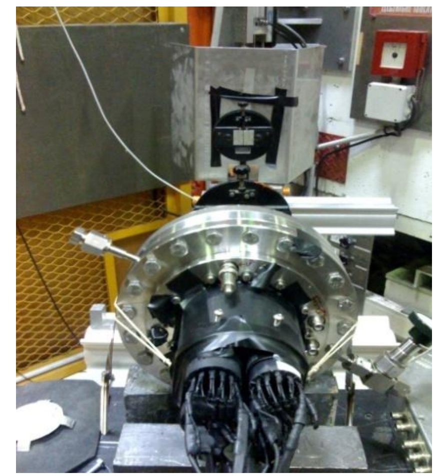
- CF4 is a good scintillator, but only a few primary photons
- Secondary scintillation ~.3 photon per secondary electron

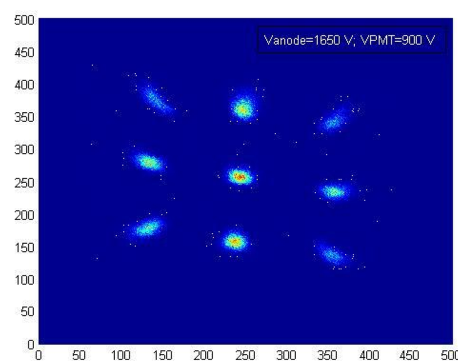


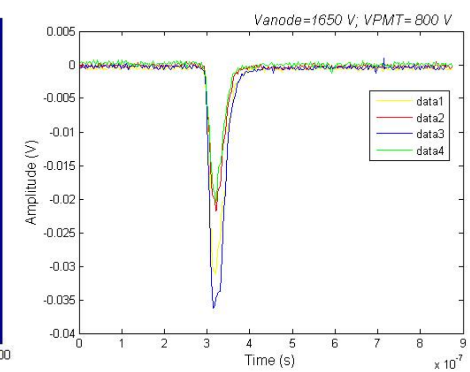



Neutron Beam
Boron Mask
anodes
10mm
35mm
n
p
T
Drift electrode
Quartz Window
PMT 1
T 2
PMT 4
T 3
trigger
(from anodes or cathodes)
AQUISISITION CARDS: Acqiris, CC103
PC






Vanode=1650 V; VPMT=900 V
0
50
100
150
200
250
300
350
400
450
500


Vanode=1650 V; VPMT= 800 V
Amplitude (V)
Time (s)
x 10^-7
data1
data2
data3
data4

For neutron reflectometers, there is a need for fast thermal neutron detectors with 20 cm x 20 cm sensitive area with improved 2D spatial resolution

The aim of this JRA is the development of new detector technologies based on Gaseous Scintillation Proportional Counters (GSPC).

Our goal is to demonstrate the feasibility of a detector with the following performances:

- Resol 0.5 mm in X and Y / Area 20 cm x 20 cm

- Counting rate > 10 kHz (local) / 1 MHz (global)

Solution proposed : MSGC Light readout with a matrix of PMTs

European Neutron-Muon Portal - Mozilla Firefox

File Edit View History Bookmarks Tools Help

European Neutron-Muon Portal

detectors.neutron-eu.net/Detectors

Google Advanced Search | Google Translate | Google Maps | Google Advanced Schol... | Audiogon high end aud... | HIFI - audio-markt.de - ... | securelogin | What's Best Forum | Snipe It Now! | Speakeasy - Speed Test | pssap_switch

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JRA Detectors

- Detectors Home
- Participants
- Tasks
- Meetings
- Publications
- Links
- Other NMI3 Research Activities
- NMI3 FP7

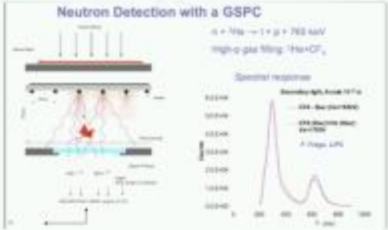
WP22 Detectors

Objectives

- Development of new detector technologies based on Gaseous Scintillation Proportional Counters (GSPC)
- Explore their potential to overcome the limitations in light output and rate capability of existing scintillation detectors
- Investigate their potential as high resolution detectors for Reflectometry or time resolved SANS.
- Built and study small scalable prototypes

The aim of this JRA is the **development of new detector technologies based on Gaseous Scintillation Proportional Counters (GSPC).** These devices have the potential of improving the performance of high position resolution detectors used in reflectometry and time resolved SANS. Present state of the art detectors, such as 3He-based Multi Wire Proportion Chambers already limit the performance of existing reflectometers due to their moderate count rate capability. They only provide limited spatial resolution of x ~1-2 mm and a time resolution in the microsecond range. More advanced devices based on solid 6Li doped glass scintillators with Anger camera readout, e.g. as recently developed at the SNS, can partially improve the performance achieving high position resolution (~1 mm) and providing good timing resolution due to the fast scintillation light pulse with a duration of about 200 ns. The low light output of 6Li glass however, diminishes the count rate capability due to the signal integration time required. A major drawback of 6Li based glass scintillation detectors is a non negligible sensitivity to a high gamma background environment.

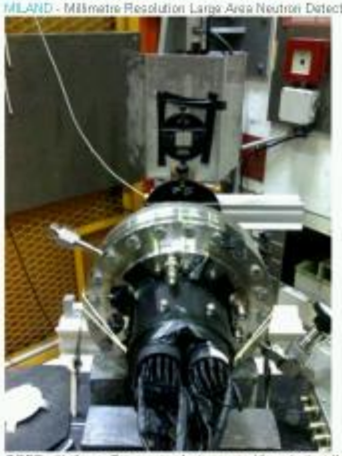
Micro pattern charge amplifying structures like MSGCs have been shown to be very efficient in the production of fast scintillation light in the visible region when operated in the proportional mode in gas mixtures of 3He-CF4. Photon yields per detected neutron can be ~100 times larger than that of 6Li-glass and light signal durations of less than 60 ns have been observed. In the proposed JRA particular emphasis is therefore placed on the development and study of new technologies based on these Gaseous Scintillation Proportional Counters with light readout. The application of this new technology in neutron detection could enable the design of neutron counting detectors with superior performance that exhibit a high count rate capability of up to 10 MHz, a high spatial resolution (~1 mm) and a low gamma sensitivity on a par with gaseous detectors.



Coordinator: Zeitelhack Karl

Forum: WP22 Detectors FORUM
(restricted access to JRA Partners)

Link to the JRA activities on detectors under FP6:
DETNI - Detectors for Neutron Instrumentation
MILAND - Millimetre Resolution Large Area Neutron Detector



GSPC with Anger Camera readout mounted for a test at ILL beam station CT1

start | Balance for fr... | Inbox - Outlo... | tartarugas coe... | fp7 | - Windows D... | Search Results | Fraga_jorned... | Anger_camer... | European Neu... | PT | 3:19 PM

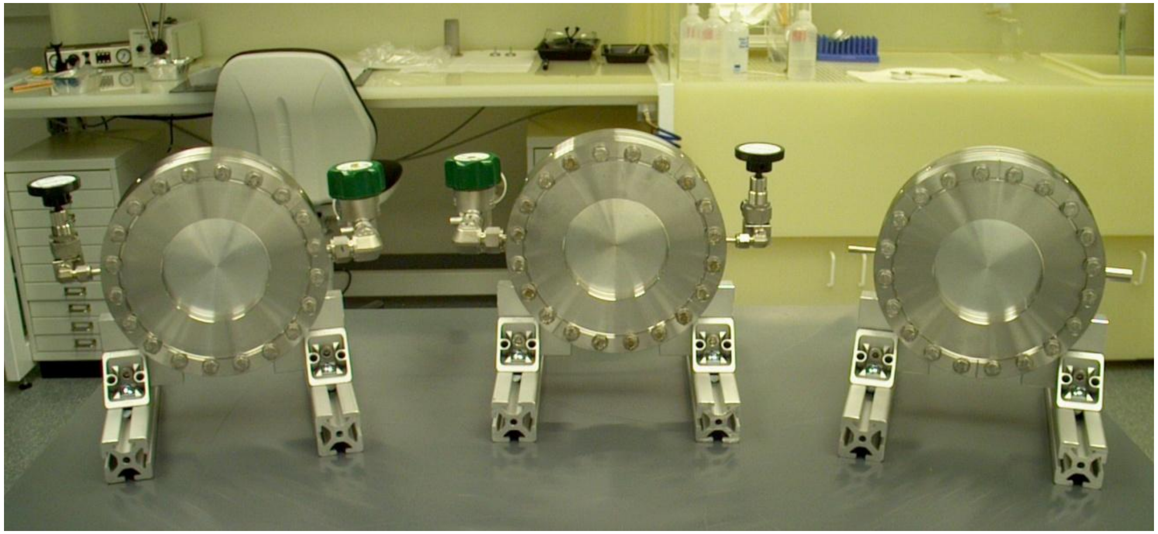
W22 - Detectors - Participants

Partners
ILL - Institut Laue-Langevin
LIP - Laboratório de Instrumentação e Física Experimental de Partículas. Portugal
STFC - Science and Technology Facilities Council
FZJ- Forschungszentrum Jülich
CNR - National Research Council, Italy
TUM - Technischen Universität München
Observers
ToU - University of Tokyo

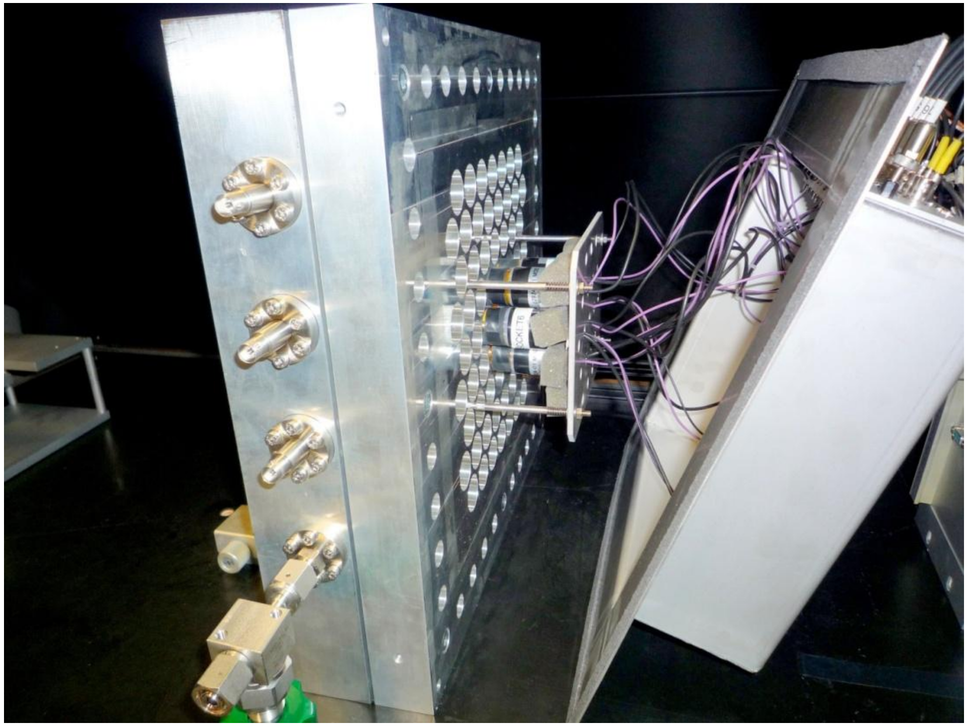
* LIP gas scintillation, simulation of the detector

The LIP team

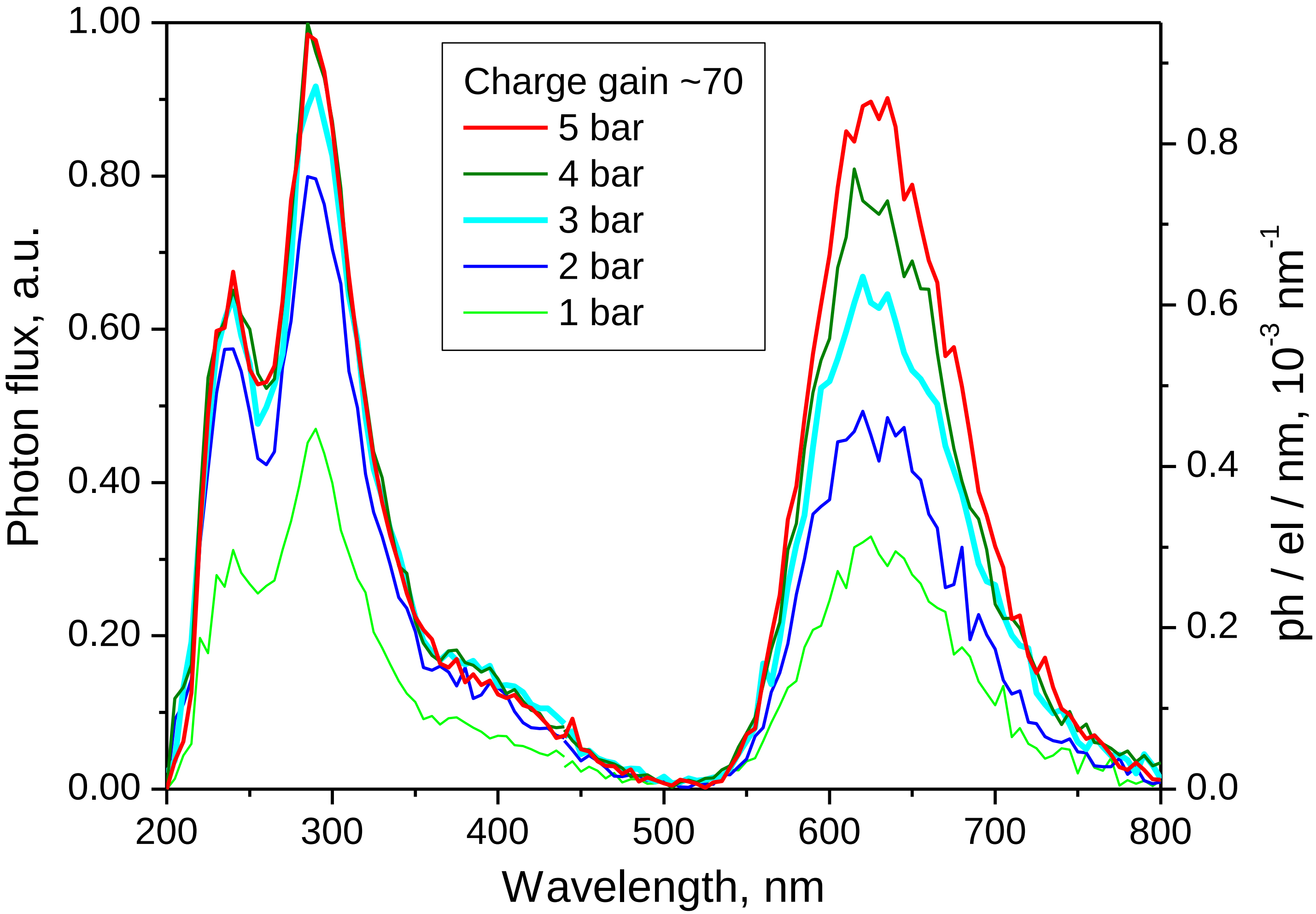
Francisco Fraga Researcher (LIP/FCTUC) 80
Andrey Morozov Researcher (LIP) 70
Luis Margato Post-Doc (LIP) 15
Luis Pereira PhD student (LIP) 100
Margarida Fraga Researcher (LIP/FCTUC) 70



Our first prototype and a view of the detector being built by the collaboration

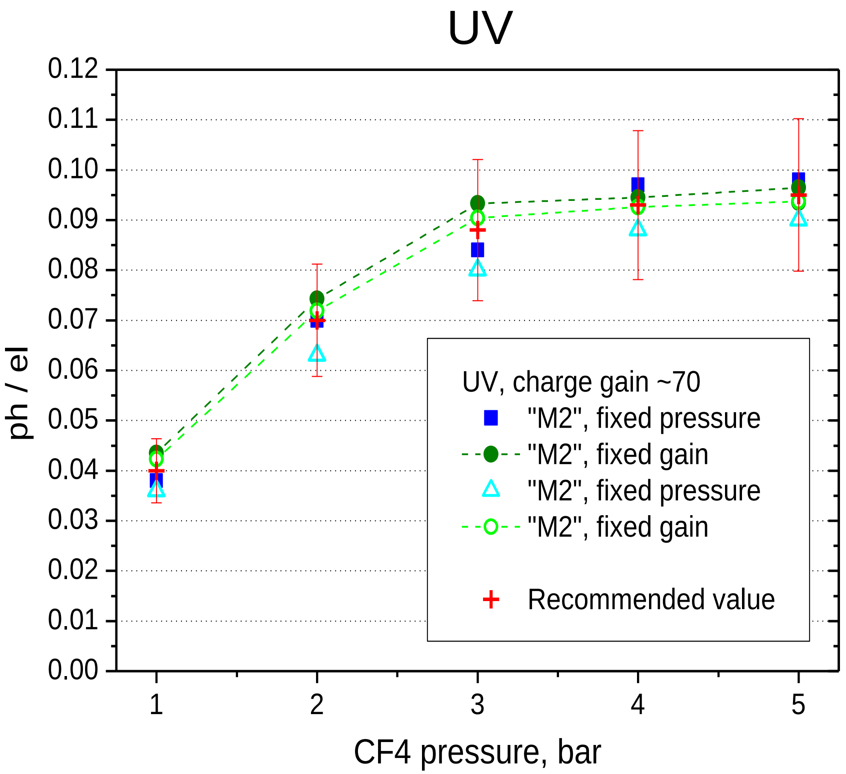


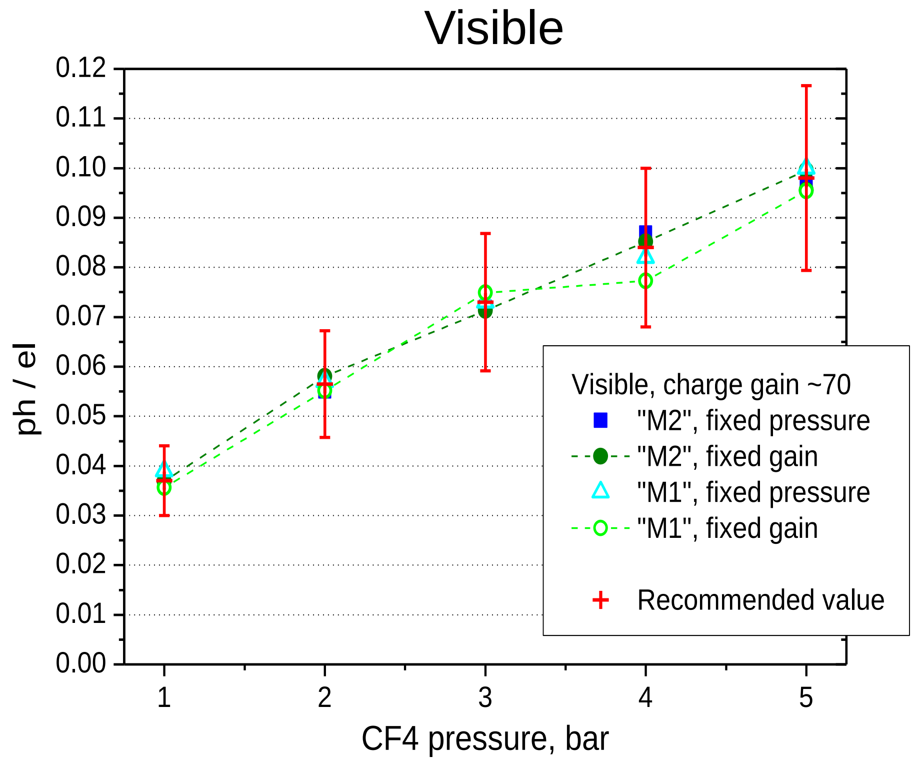
CF4 emission spectra



Emission spectra from different pressures are scaled using the ph/el ratios discussed below

Ph / el ratios

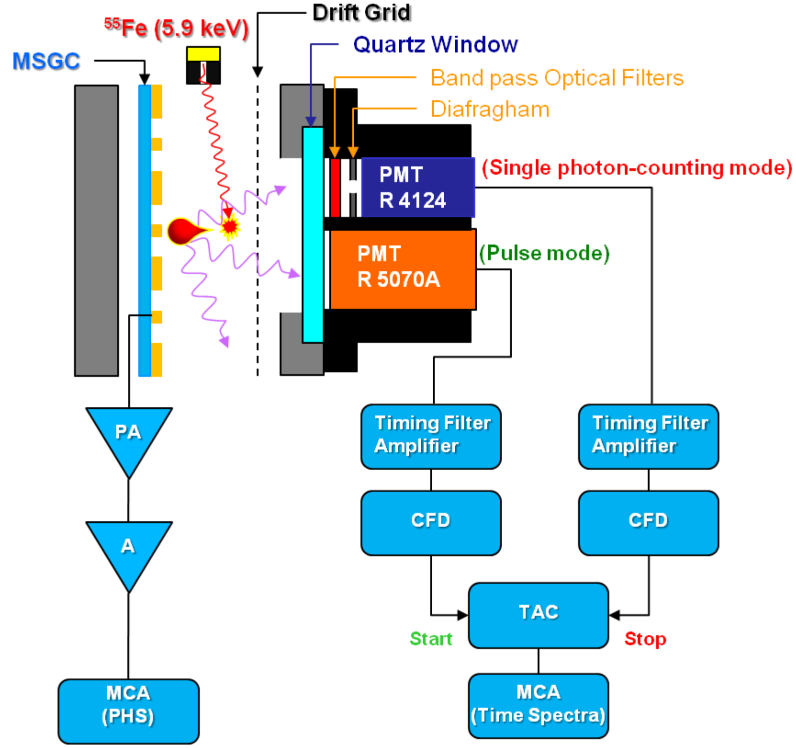




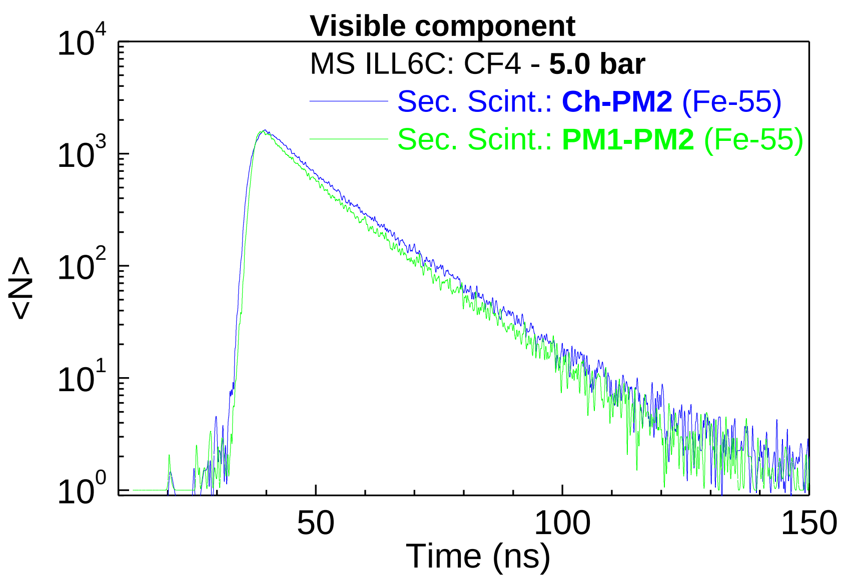
Ph/el ratios for the charge gain of ~70 from experimental series where either the gas pressure or the charge gain was the fixed parameter.

CF4 Secondary Scintillation

Time Spectra: Setup 2



Validation of the method



5 bar CF4: Setup 1 performance vs. Setup 2

Start trigger: PMT R5070A (pulse mode)

Stop trigger: PMT R4124 (single photon counting mode)

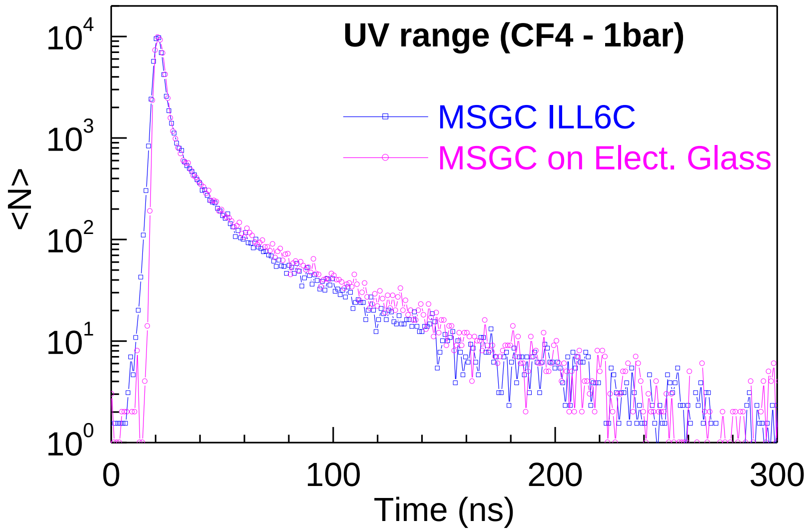
Luis Margato *(margato@coimbra.lip.pt)*

CF4 Secondary Scintillation

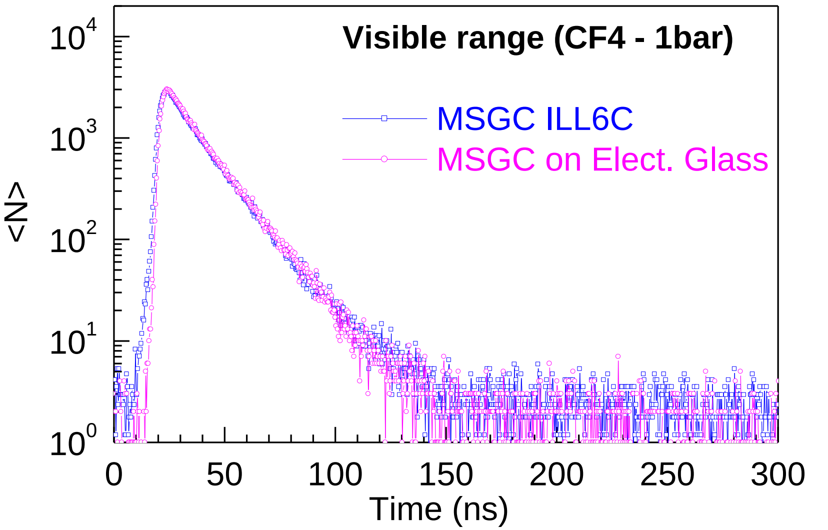
Time Spectra: CF_4 at 1 bar

ILL6C MSGC "DESAG D263 glass substrate" vs. Elect. glass MSGC "Shott S8900 glass substrate"

UV



Visible



An overlap between the time-spectra for both MSGCs is observed and this either for the emission in the UV and visible ranges.

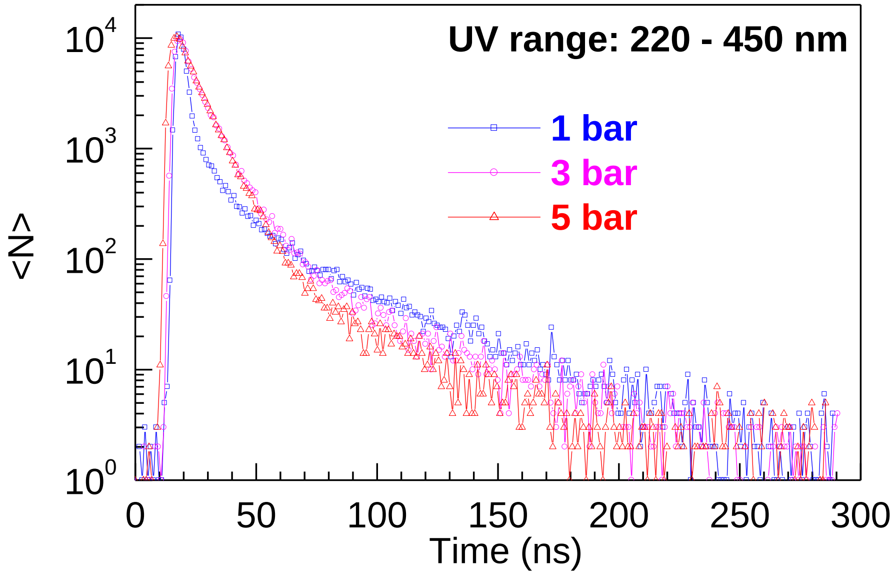
Time spectra recorded with the MSGC on S8900 glass shows a lower jitter in the start trigger

CF4 Secondary Scintillation

Time Spectra: 1, 3 and 5 bar CF_4

Elect. Glass MSGC

UV



UV reveals a multi-component scintillation decay time profile

Increasing the pressure the faster decay shows at 1 bar (τ_f~2 ns) tends to be slower (τ_f~10 ns) and remains approximately constant from 3 to 5 bar

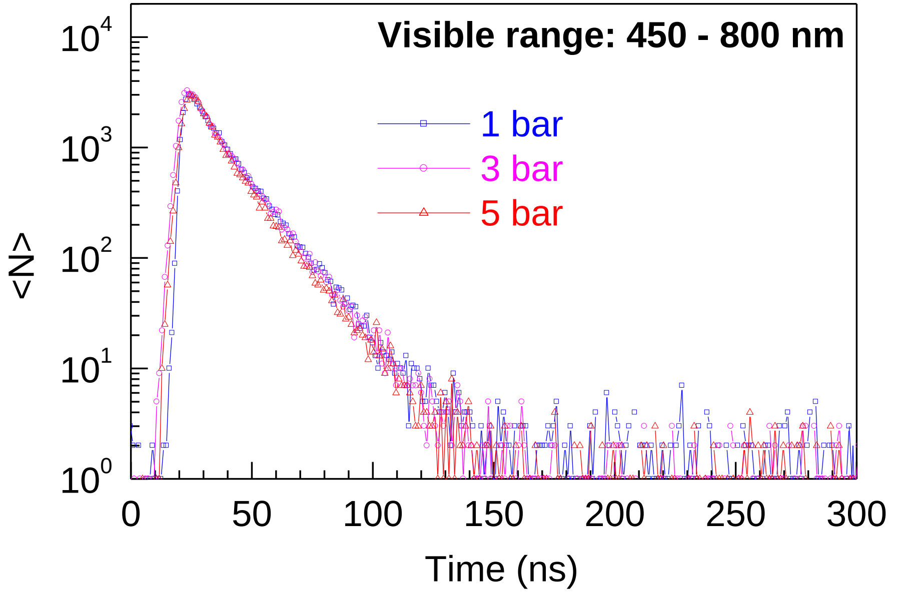
For a time above 80 ns the decay curve does not change significantly with pressure (τ_s~ 40 ns)

CF4 Secondary Scintillation

Time Spectra: 1, 3 and 5 bar CF_4

Elect. Glass MSGC

Visible



Visible emission:

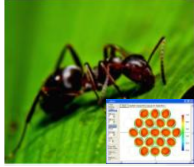
– Decay time profile appears to be insensitive to the CF_4 pressure (1 to 5 bar)

– Produces single time constant secondary scintillation showing a fast decay time

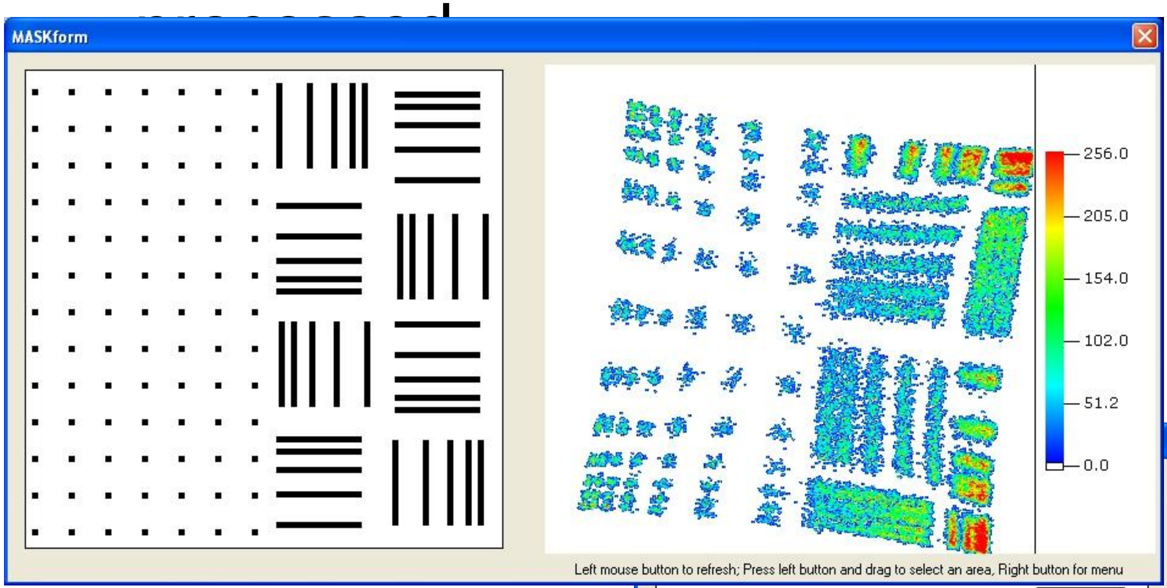
Typical effective lifetime of τ ~ 15 ns

Luís Margato *(margato@coimbra.lip.pt)*

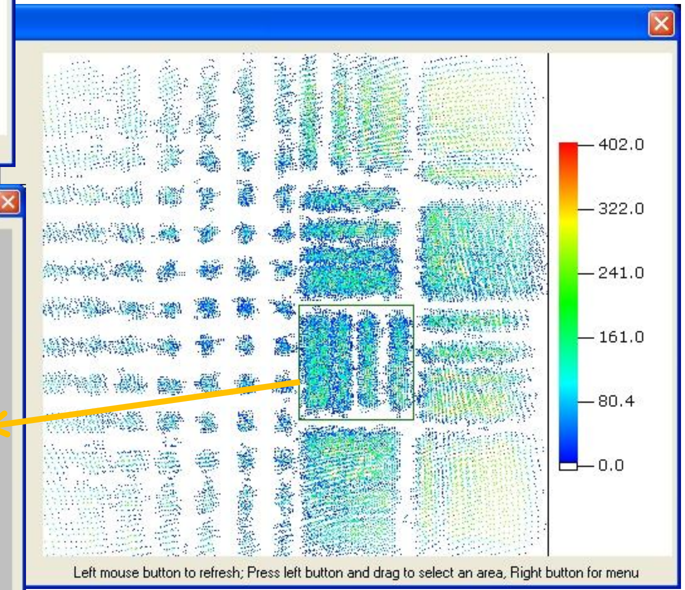
New features in ANTS: Distortion corrections

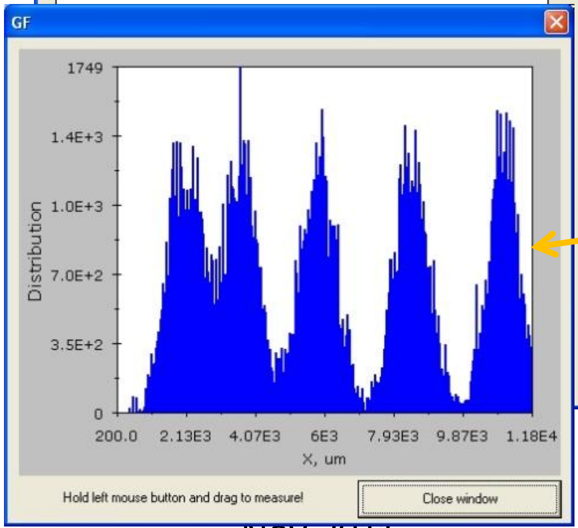


✓Experimental data (text array or .bmp file) can be processed



Shift + rotation to match the experimental geometry, then <u>corrections for the distortions due to the localization algorithm</u>

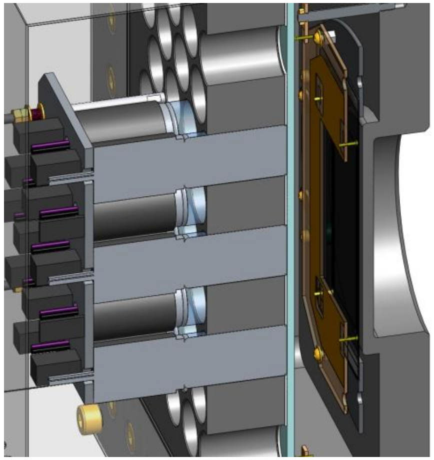


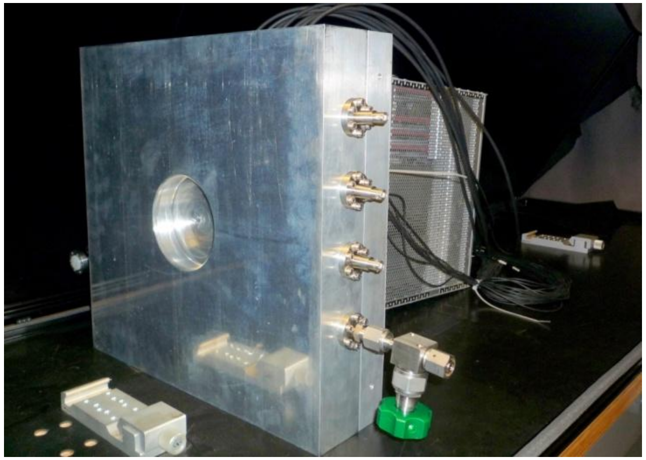


New features for neutron mask simulation mode:

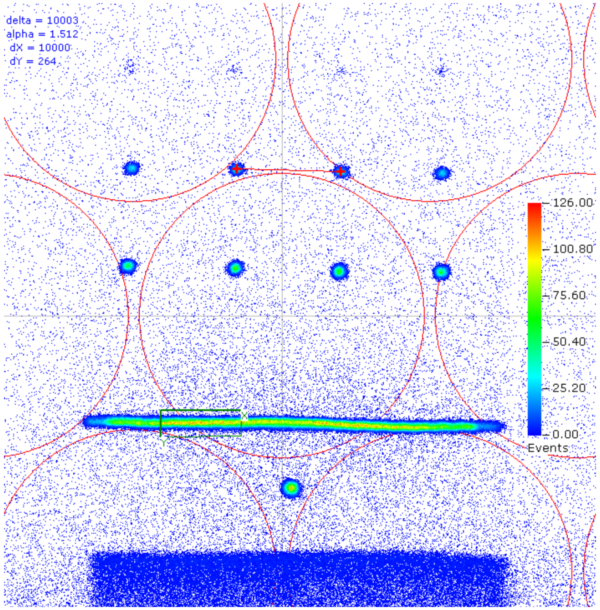
- um/pixel for the mask file;
- 100 → 20 um tracking array step;
- Possible to save data as an array or .bmp file with an arbitrary step

A. Morozov et al, LIP Coimbra

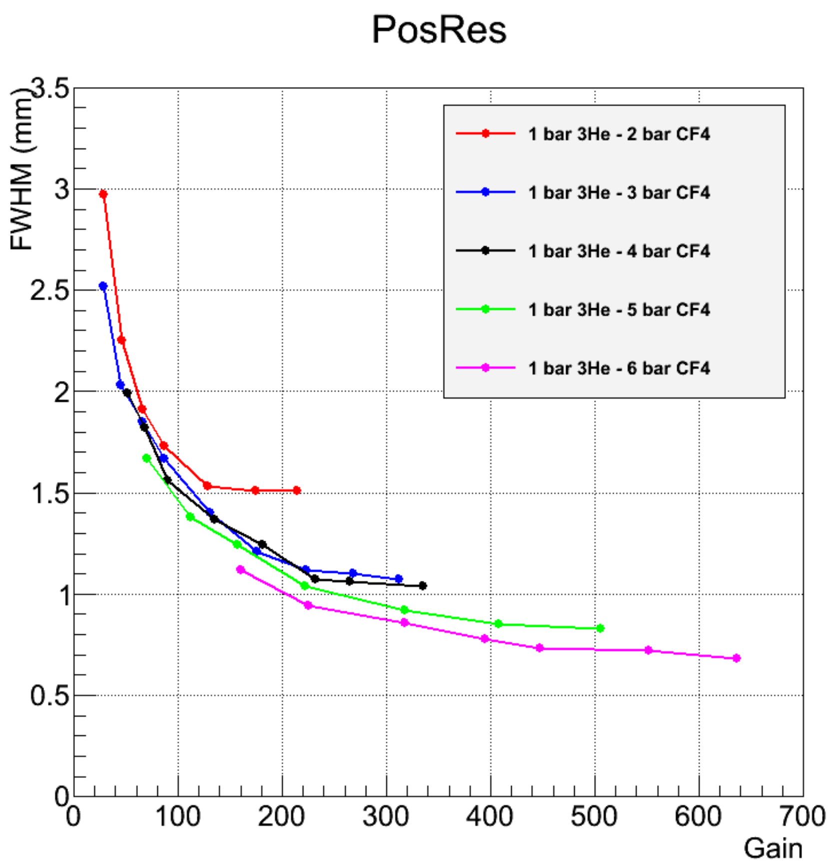




Schematic view and cross section of the GSPC prototype developed at ILL



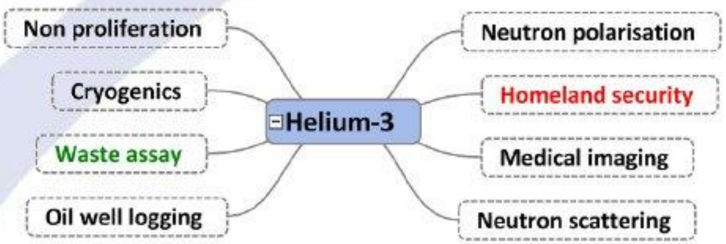
2D-position spectrum of 2.5A neutrons with a multi-hole / slit mask mounted in front of the GSPC recorded with the 32-channel readout system. Data analyzed with ANTS, using adaptive algorithms.

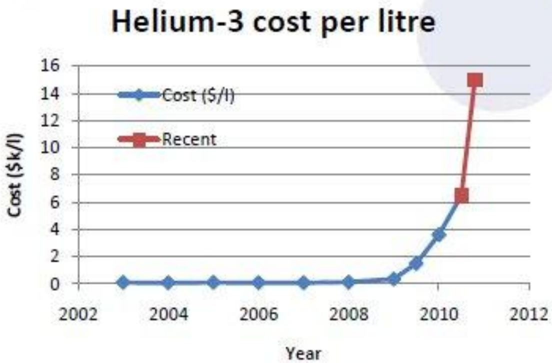


Final results : Position resolution (FWHM) as a function of gas gain and CF_4 pressure.

Global ^{3}He shortage

- Annual production <30kl, demand >60kl (R. Cooper, Oak Ridge at ILL seminar Sep 2009)
- Cost has risen over ~2 years from $75/l to ~$6500/l
- But cost is irrelevant as effectively unavailable





R.L. Kouzas, US Department of Energy PNNL report 18388

- US stock pile now "strategic asset"
- Production based on tritium decay, 12 year half-life so no short term solution

Table 1. Projected demand of helium-3 for neutron detectors at neutron scattering facilities in the period 2009–2015.

Facility	Maintenance [litre/year]	small detectors [litre]	large detectors [litre]
ORNL (SNS)	100	1,300	17,100
ORNL (HFIR)	100	1,210	1,060
Los Alamos	100	1,994	12,362
NIST	100	560	
BNL	50	180	
FRM II	100	650	4,500
HZ Berlin	100	520	7,850
ILL	100	1,000	3,000
JCNS	40	15	7,200
LLB	50	600	600
PSI	50		2,000
STFC	100	400	11,300
J-PARC	100	40	16,100
JRR-3	31	71	
BNC/KFKI	50	118	500
Sum	**1,171**	**8,658**	**83,572**

93401 l
x
2000$/l

> 180 x 10^6 $
(180 Million Dollars)

But cost is irrelevant if He-3 are not available

KARL ZEITELHACK, Search for alternative techniques to helium-3 based detectors for neutron scattering applications, Neutron News, Vol. 23 Number 4 (2012) 10-13.

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons

Common nuclear Reactions for Neutron Detectors

- $n + {}^{3}He \rightarrow {}^{3}H + {}^{1}H + 0.764$ MeV ($\sigma_c = 5330$ barns for 1.8 Å)
- $n + {}^{6}Li \rightarrow {}^{4}He + {}^{3}H + 4.79$ MeV ($\sigma_c = 937$ barns for 1.8 Å)
- $n + {}^{10}B \rightarrow {}^{7}Li^{*} + {}^{4}He \rightarrow {}^{7}Li + {}^{4}He + 2.31$ MeV+ gamma (0.48 MeV) (93%)
  $\rightarrow {}^{7}Li + {}^{4}He + 2.79$ MeV (7%)
  ($\sigma_c = 3840$ barns for 1.8 Å)
- $n + {}^{14}N \rightarrow {}^{14}C + {}^{1}H + 0.626$ MeV
- $n + {}^{157}Gd \rightarrow Gd^{*} \rightarrow$ gamma-ray spectrum + conversion electron spectrum (~70 keV)
- $n + {}^{235}U \rightarrow xn$ + fission fragments + ~160 MeV ($\langle x \rangle \sim 2.5$)

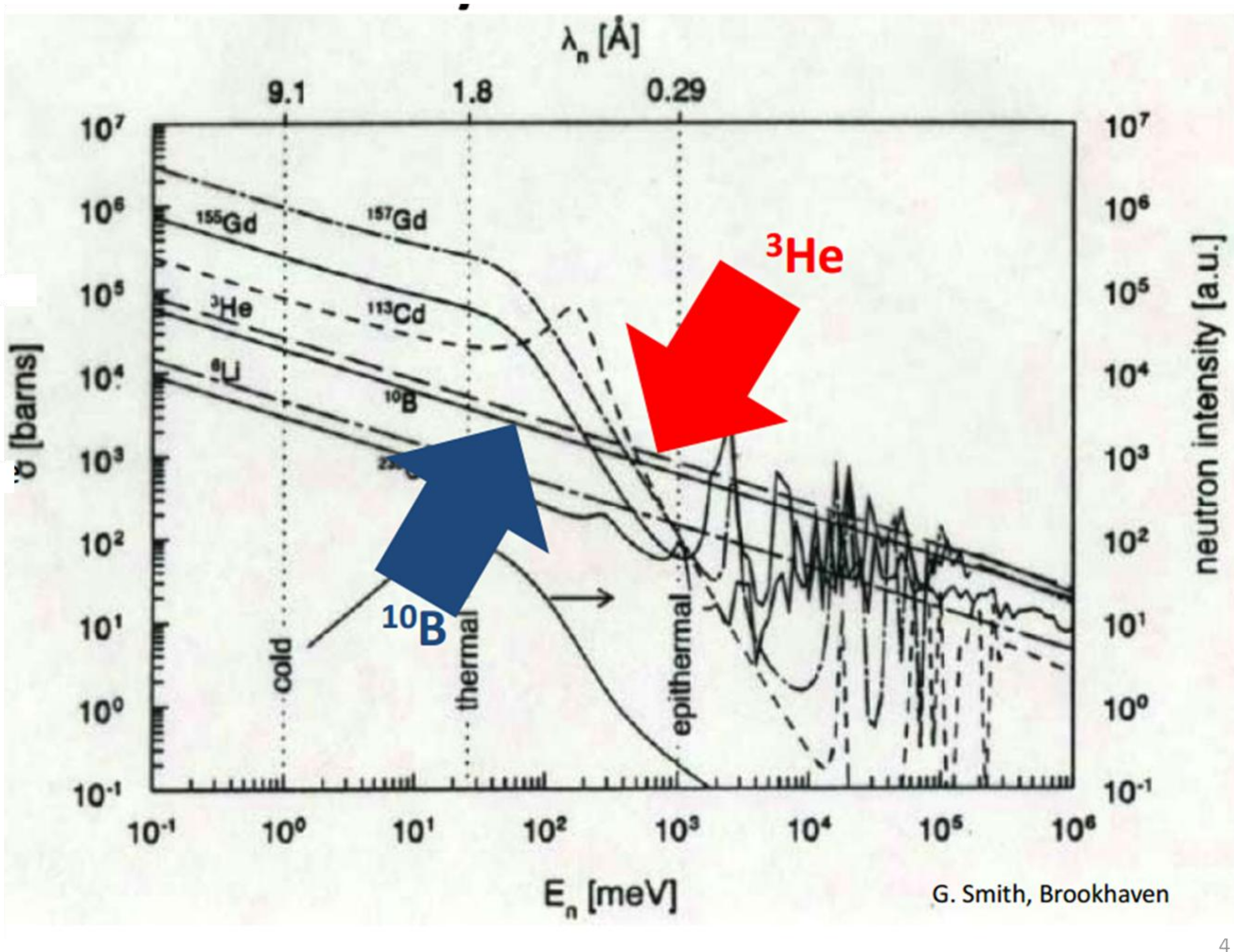
Natural fraction

${}^{10}B$: 19.8%

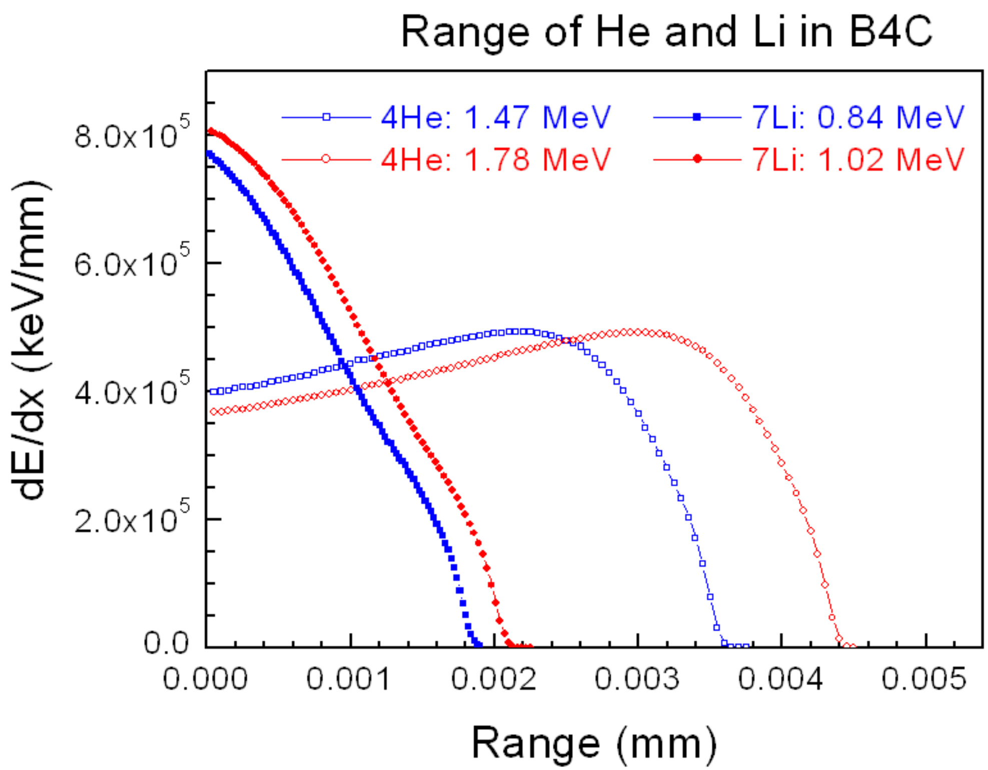
${}^{6}Li$: 7.6%

${}^{157}Gd$: 15,7%

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons



Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutron detectors

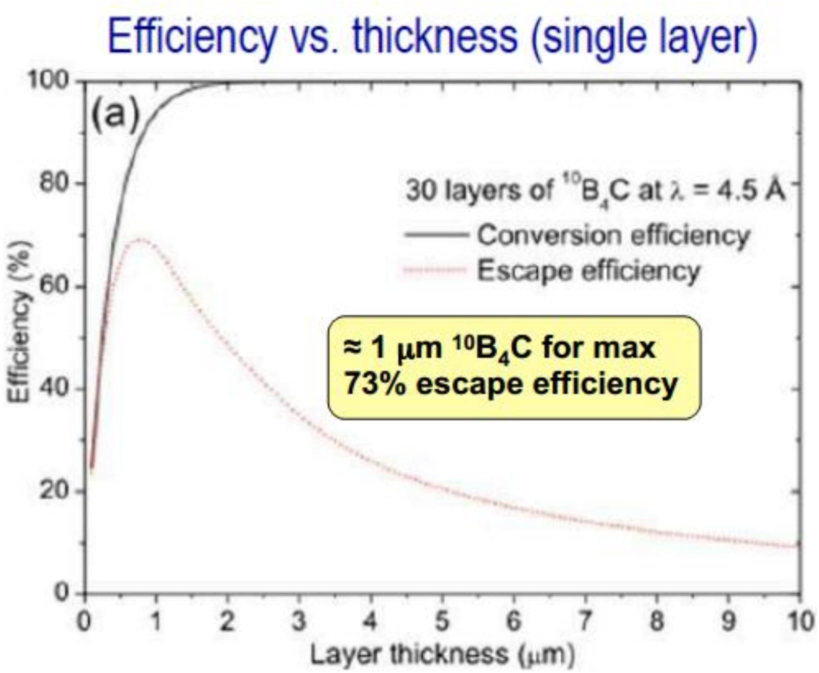


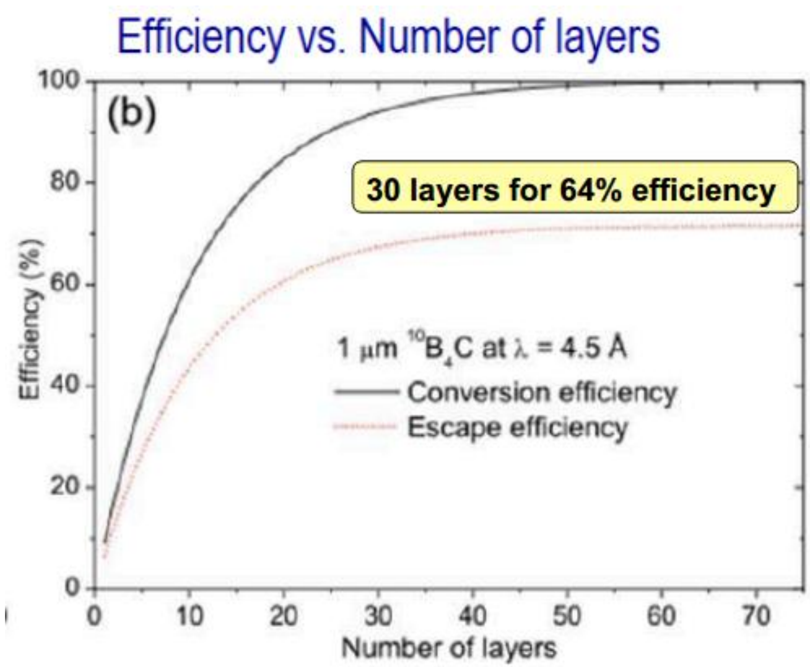
$n + {}^{10}B \rightarrow ({}^{11}B)^{*}$

→ ${}^{7}Li^{*}$ (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 %)

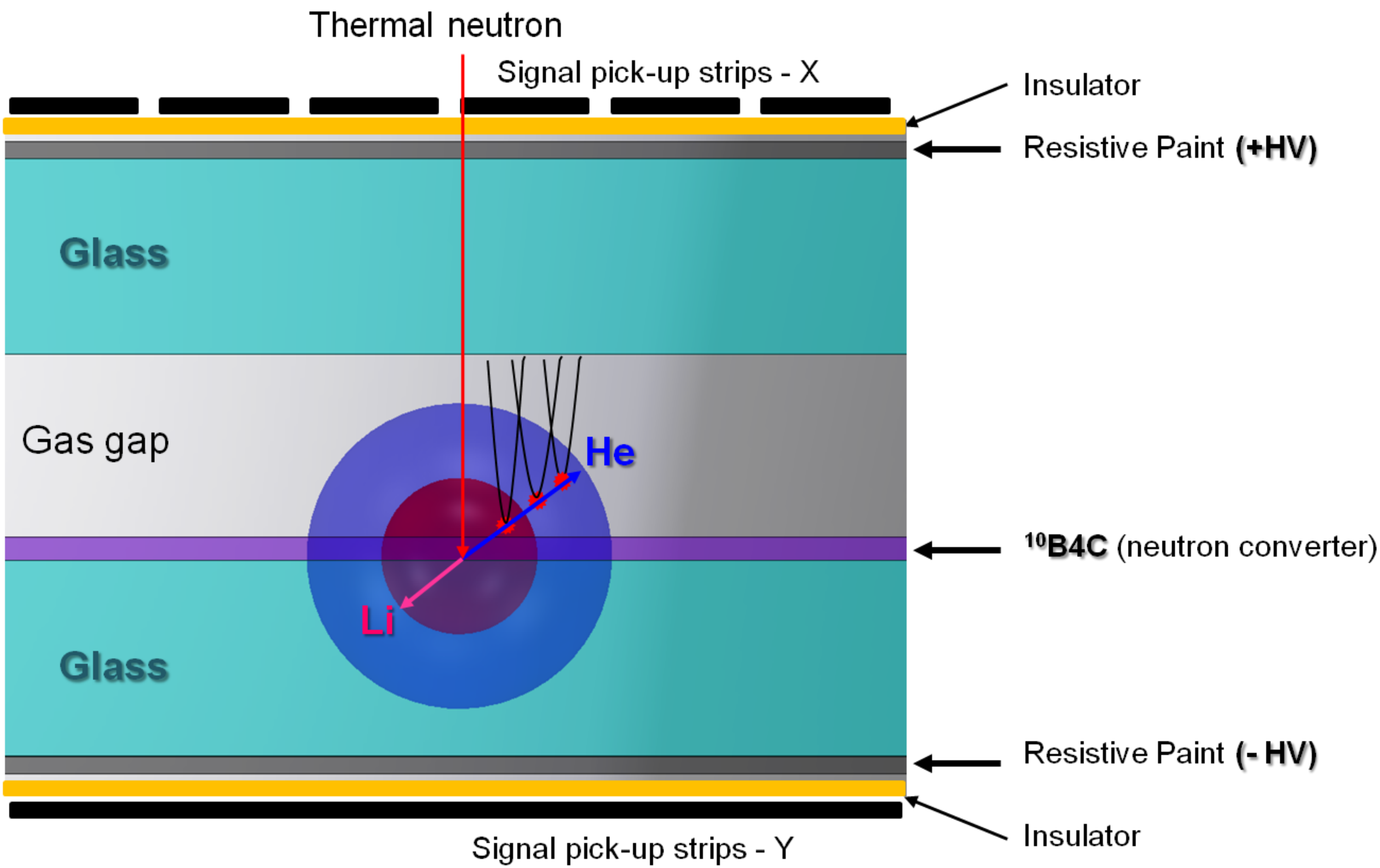
Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons



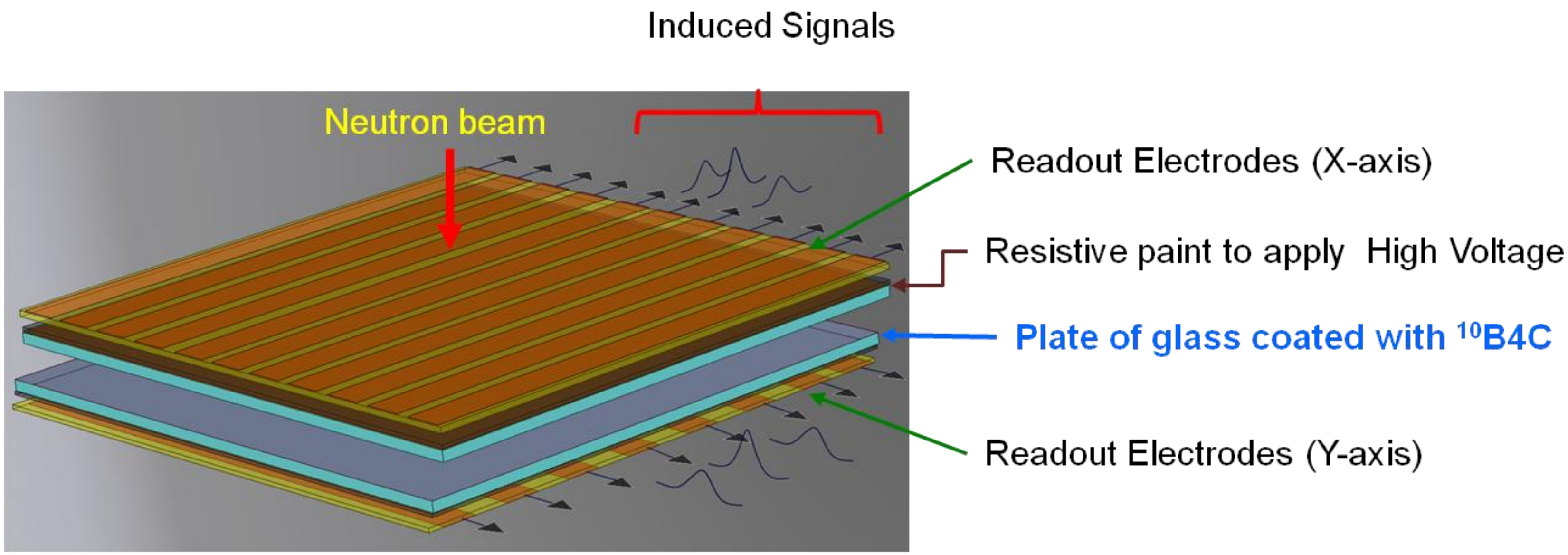


Ref: C. Höglund, J. Birch, *et al.* "B4C thin films for neutron detection", JVST, submitted (2011)

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutron detectors



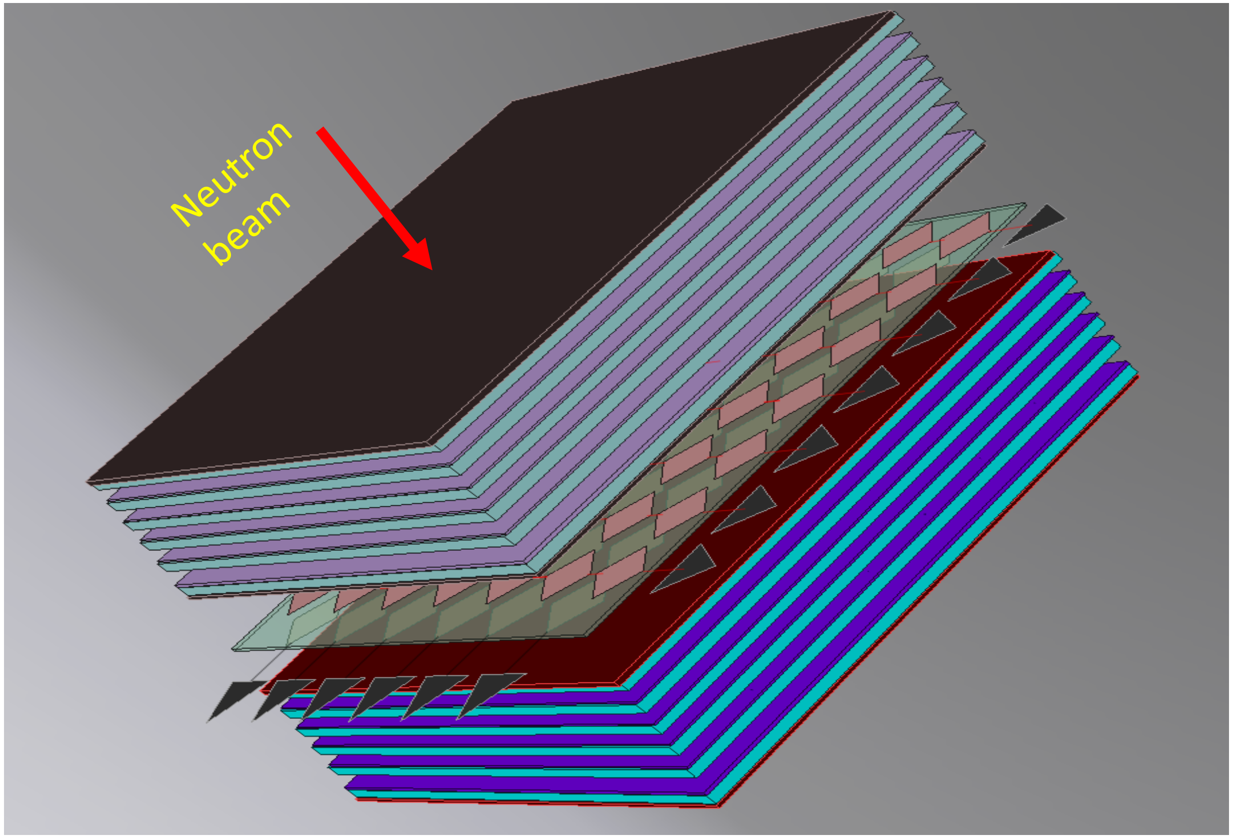
Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons



$$n + {}^{10}B \rightarrow ({}^{11}B)^* \rightarrow \begin{cases} {}^{7}Li^{*}\ (0{,}84\ MeV) + {}^{4}He\ (1{,}47\ MeV) & Q = 2{,}31\ MeV\ (94\ \%) \\ {}^{7}Li\ (1{,}02\ MeV) + {}^{4}He\ (1{,}78\ MeV) & Q = 2{,}79\ MeV\ (6\ \%) \end{cases}$$

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons

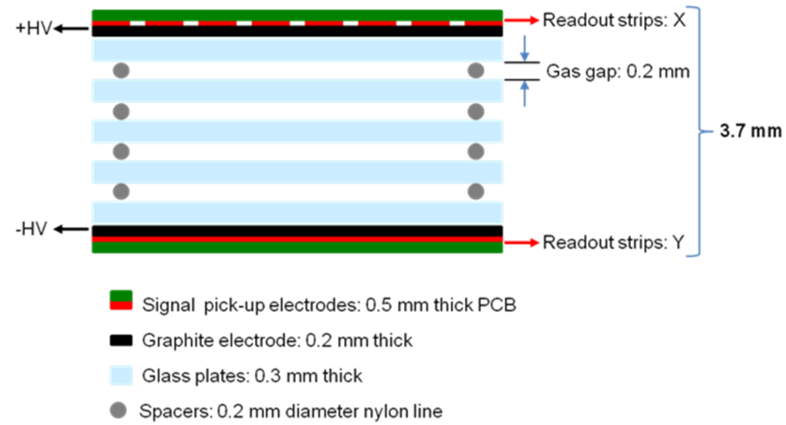
Multi-gap Configuration Detector Concept



2 x 5 layers of $^{10}B_4C$ converter

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons

Project of the RPC detectors prototypes



Geometry

- Area: 8 cm x 8 cm;
- Gap thickness: ~ 0.30 mm;
- Number of gap´s: 1 to 5;

Boron Layers

- B4C Layers deposited on glass by DC-Sputtering;
- Layers thickness: ~ 1 μm;

Gases

- Freon R134a: $F_3C - CH_2F$ (Tetrafluoroethane);
- Iso-Butane
- SF6;

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons

Deposit of B4C layers by DC-Sputtering in the Engineering Surfaces Group at the Mechanical Engineering Research Center - University of Coimbra

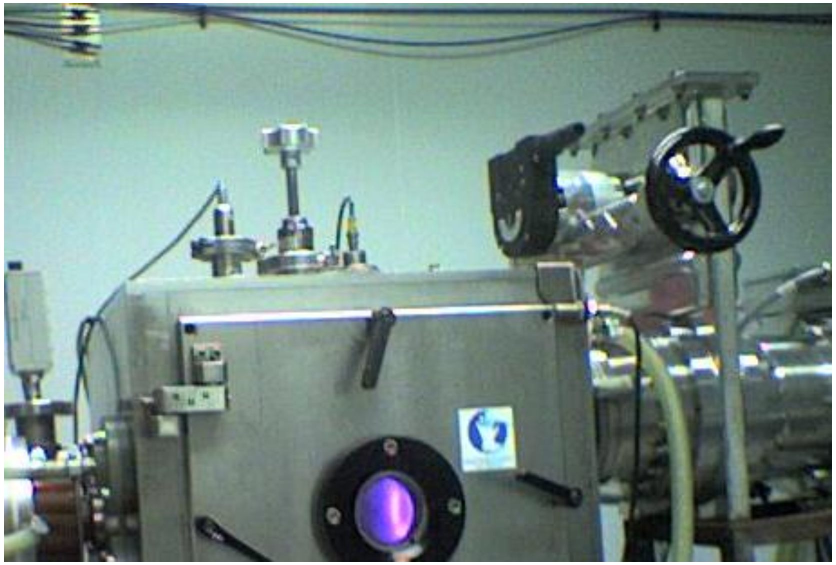
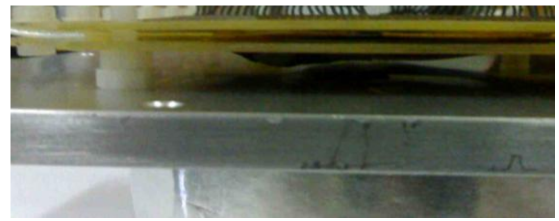
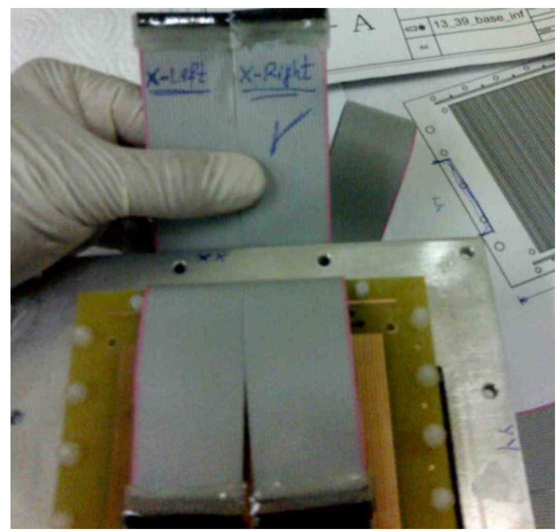


Plate of soda lime glass (0.4 mm thick) coated with a 0.5 μm layer of B4C

Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutrons

RPC detector prototype





FCT Fundação para a Ciência e a Tecnologia

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Concursos de Projectos de I&D
Calls for R&D Projects

Título do projeto (em português)
Project title (in portuguese)

RCPs revestidas com boro para detectores de neutrões

Título do projeto (em inglês)
Project title (in english)

Boron coated RPCs for thermal neutron detectos

Título do projeto (em português) Project title (in portuguese)
Investigacao e desenvolvimento de Multi-Gap RPCs com revestimentos de B4C para detectores de neutroes termicos sensiveis a posicao

Título do projeto (em inglês)
Project title (in english) Research and development of B4C coated Multi-Gap RPCs for position sensitive thermal neutron detectors

H2020-INFRADEV-1-2014-1
DEVELOPING NEW WORLD-CLASS RESEARCH INFRASTRUCTURES

Expressions of Interest submitted to NMI3 for a possible Joint Research development in

High resolution, High rate Neutron detectors

- **Task 1: ^{10}Boron gas detector development**

  Partners: ICMA, HZG, BNC, ILL, TUM, ESS, LLB, CNR Milano, LIP

  (…)

  One detector technology that has not been explored extensively for neutron scattering applications is resistive plate chamber technology. RCPs lend themselves very well to a layered configuration and are used in HEP as time projection chambers. LIP, who has been developing RCPs for 15 years, will explore the potential of these devices, interspersed with layers of 10B4C, for neutron scattering applications. Advantages include sub-millimetre position resolution, nanosecond time resolution and large area coverage with many square meters currently in operation in other applications.
- (…)

- **Task 2: Scintillation detector development**
- **Task 3: 3He detector development**
- **Task 4: Imaging detector development**