

Active Scintillators for Neutron Detectors

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LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

Thermal Neutron Detectors

- nuclear reactions to convert neutrons

- $n + 3\text{He} \rightarrow 3\text{H} + 1\text{H} + 0.764 \text{ MeV}$ Gaseous detectors (CF₄, prop.)
- $n + 6\text{Li} \rightarrow 4\text{He} + 3\text{H} + 4.79 \text{ MeV}$ Scintillators
- $n + 10\text{B} \rightarrow 7\text{Li}^* + 4\text{He} \rightarrow 7\text{Li} + 4\text{He} + 0.48 \text{ MeV} \gamma + 2.3 \text{ MeV}$ (93%)
 $\rightarrow 7\text{Li} + 4\text{He} + 2.8 \text{ MeV}$ (7%)
- $n + 155\text{Gd} \rightarrow \text{Gd}^* \rightarrow \gamma\text{-ray spectrum} \rightarrow \text{conversion electron spectrum}$
- $n + 157\text{Gd} \rightarrow \text{Gd}^* \rightarrow \gamma\text{-ray spectrum} \rightarrow \text{conversion electron spectrum}$
- $n + 235\text{U} \rightarrow \text{fission fragments} + \sim 160 \text{ MeV}$
- $n + 239\text{Pu} \rightarrow \text{fission fragments} + \sim 160 \text{ MeV}$

FP6 NMI3 JRA2 RII3-CT-2003-505925 ended 2008

MILAND – development of thermal neutron detectors

- Would increase knowledge about neutron detectors, but should have a deliverable working detector prototype with a *firm and clear* specification

- 32 x 32 cm² detector
- 1 mm resolution (FWHM) res/length = 3×10^{-4}
- 1 MHz global count rate
- 100 kHz / mm² local (peak) count rate
- Gamma background rejection 10^{-8}
- 50% efficient at 1.8 Å
- parallax free
- Cost is critical

- Partners and Observers
- [P1 CCLRC](#) N. Rhodes (UK) T3, T6, T7
- [P2 GKSS](#) R. Kampmann (Germany) T1, T4, T5, T6, T7
- [P3 BNC](#) L. Rosta (Hungary) T1, T5, T6, T7
- [P4 ILL](#) B. Guerard (France) T1, T2, T3, T4, T5, T6, T7 coordinator
- [P5 LLB](#) C. Fermon (France) T2, T4, T6, T7
- [P6 FRM-II](#) K. Zeitelhack (Germany) T1, T2, T4, T6, T7
- [P7 LIP](#) F. Fraga (Portugal) T2, T3, T6, T7

Observers

- [EFO1 BNL](#) G. Smith (USA)
- [EFO2 SNS](#) R. Cooper (USA)
- [EFO3 TU](#) H. Takahashi (Japan)
- [EFO4 RAL](#) J. Mir (UK)
- [EFO5 BNL](#) R. Krueger TU Delft (NL)

Integrated Infrastructure Initiative for
Neutron Scattering and Muon
Spectroscopy



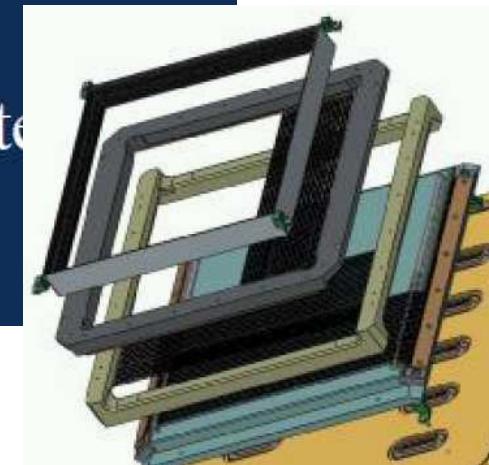


MILAND
European project
32 x 32 cm²
sensible area,

**1 mm position
resolution,**

low parallax,

1 MHz count rate



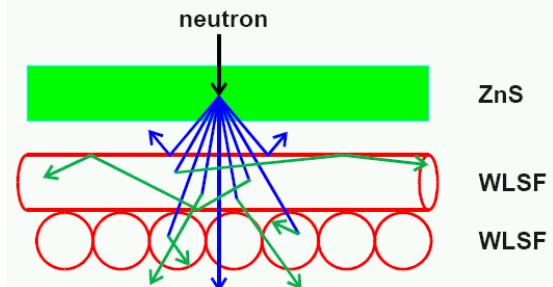
Scintillators for Neutron Detectors

Table 1
Traditional and new thermal-neutron scintillators

Host	Dopant (conc mol%)	Density ρ (g/cm ³)	ρZ_{eff}^4 ($\times 10^{-6}$) ^a	Abs. Length at 1.8Å (mm)	Light yield photons per		α/β Ratio	λ_{em} (nm)	τ (ns)
					Neutron	MeV gamma			
⁶ Li-glass	Ce	2.5		0.52	~6000	~4000	0.3	395	75
⁶ LiI	Eu	4.1	31	0.54	50,000	12,000	0.87	470	1400
⁶ LiF/ZnS	Ag	2.6	1.2	0.8	160,000	75,000	0.44	450	> 1000
LiBaF ₃	Ce,K	5.3	35		3500	5000	0.14	190–330	1/34/2100
LiBaF ₃	Ce,Rb	5.3	35		3600	4500	0.17	190–330	1/34/2400
⁶ Li ₆ ^{dep} Gd(¹¹ BO ₃) ₃	Ce	3.5	25	0.35	40,000	25,000	0.32	385,415	200/800
⁶ Li ₆ ^{dep} Gd(¹¹ BO ₃) ₃ + Y ₂ SiO ₅	Ce	}3.9		}1	40,000	30,000		420	200/800
	Ce				—	30,000		420	70
Cs ₂ ⁶ LiYCl ₆	Ce (0.1)	3.3		3.2	70,000	22,000	0.66	380	~1000
					—	700		255–470	3
Cs ₂ ⁶ LiYBr ₆	Ce (1)	4.1		3.7	88,000	23,000	0.76	389,423	89/2500

^a As an indication of gamma-ray detection efficiency by photoelectric effect ρZ_{eff}^4 values are presented

2d Detectors Possibilities

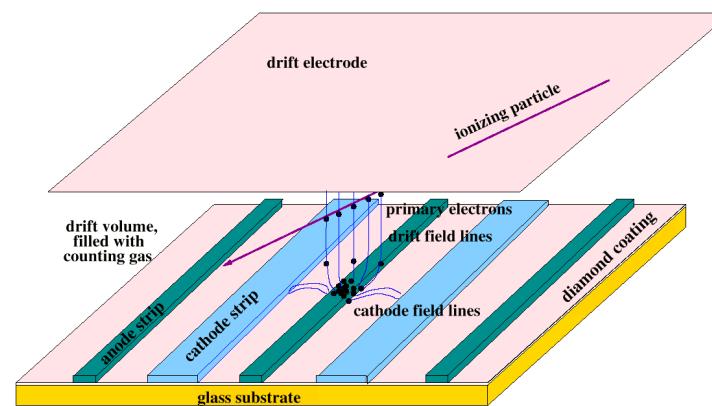
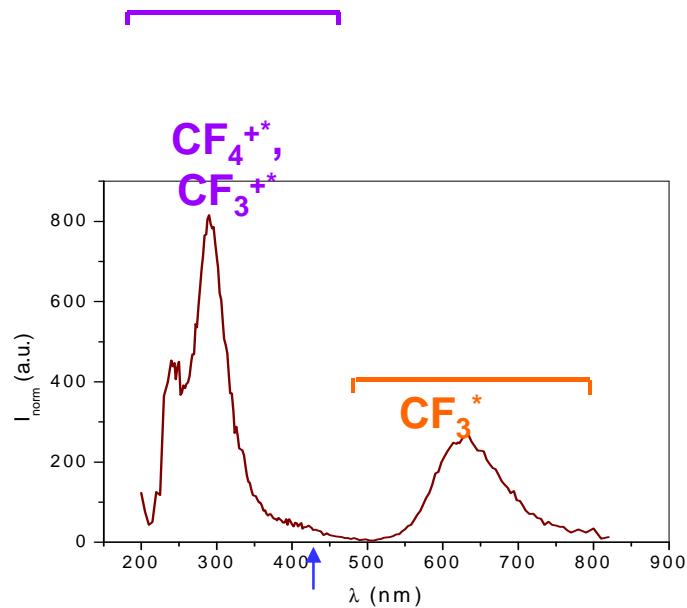


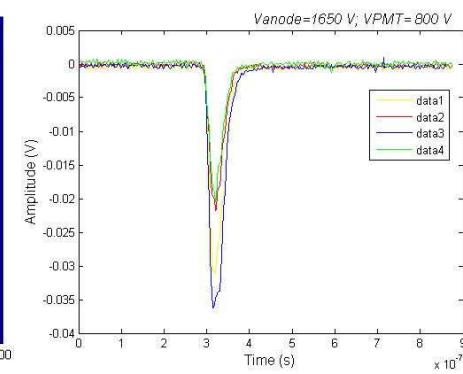
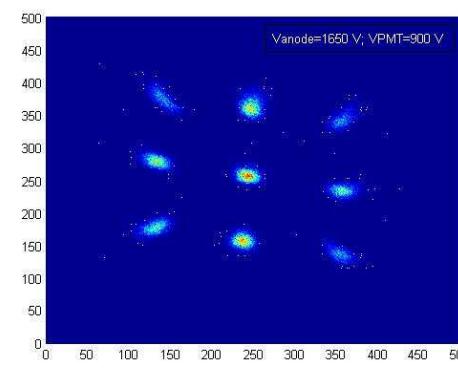
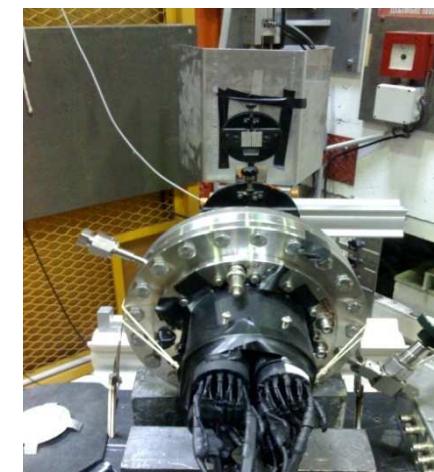
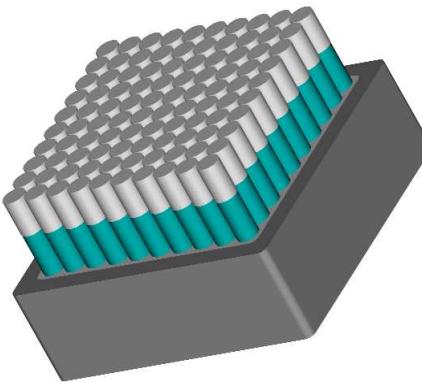
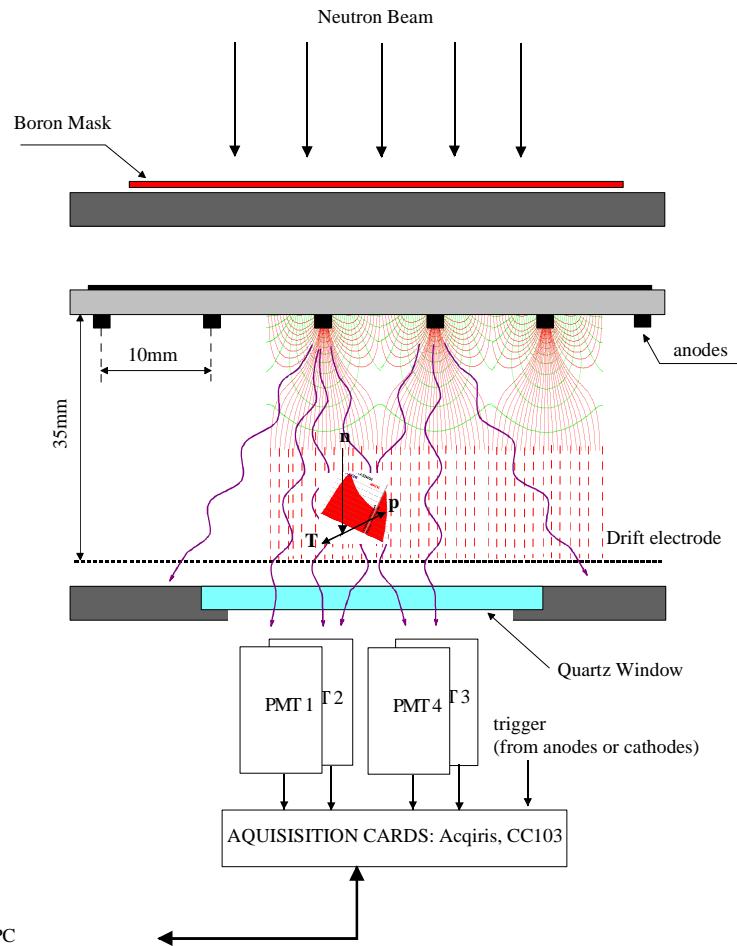
Gaseous detectors



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





European Neutron-Muon Portal - Mozilla Firefox

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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 scale 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 ~ 1.2 mm and a time resolution in the microsecond range. More advanced devices based on cold EU-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 EU glass however, diminishes the count rate capability due to the signal integration time required. A major drawback of EU based glass scintillation detectors is a non negligible sensitivity to a high gamma background environment.

Micro pattern charge amplifying structures like MEBCs 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 EU-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.

Neutron Detection with a GSPC

$n + ^{3}\text{He} \rightarrow ^{1}\text{H} + ^{2}\text{H}$ and
Inorganic scintillating glass CF4

Signal response

Time response

Angular resolution 100% of 100%
- 3He Gas (CF4)
- 3He Gas (CF4)
- Proport. Glass

Coordinator: Zeljkočić Kralj
Forum: [WP22 Detectors FORUM](#)
(restricted access to JRA, Facets)

Link to the JRA activities on detectors under FFE:
DETR - Detectors for Neutron Instrumentation
MELAND - Millimetre Resolution Large Area Neutron Detector

GSPC with Anger Camera readout mounted for a test at ILL beam station C71

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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

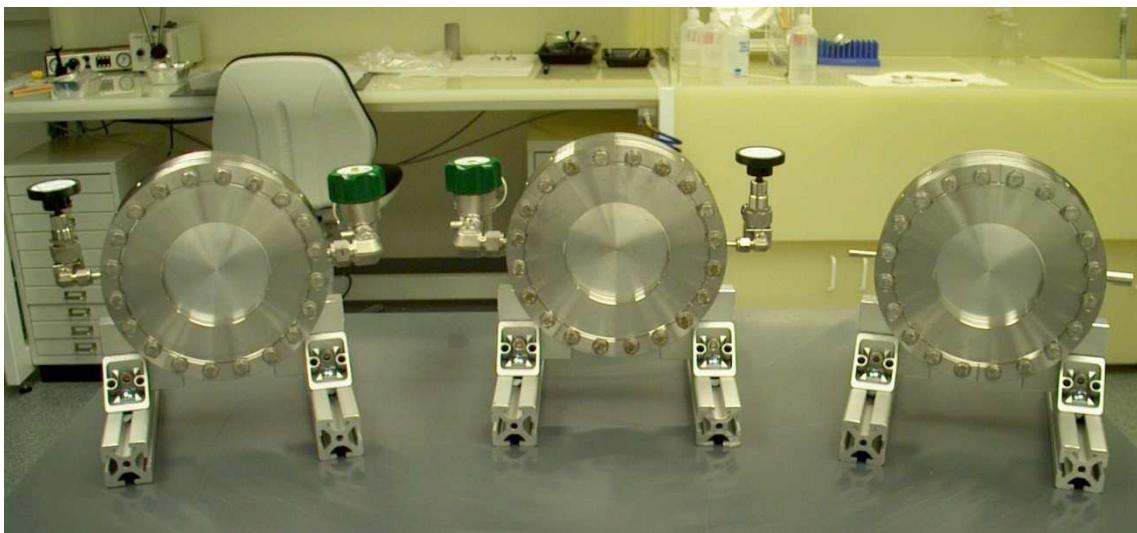
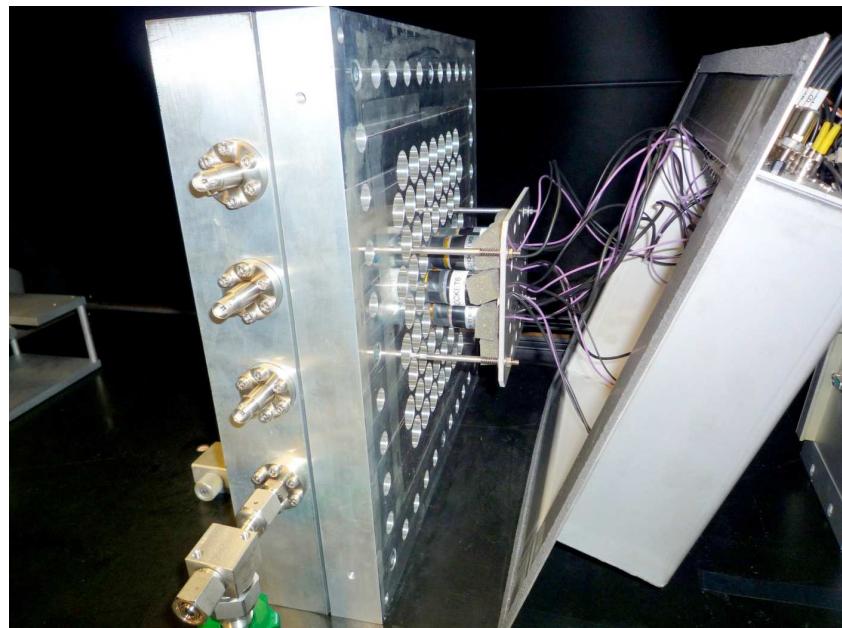
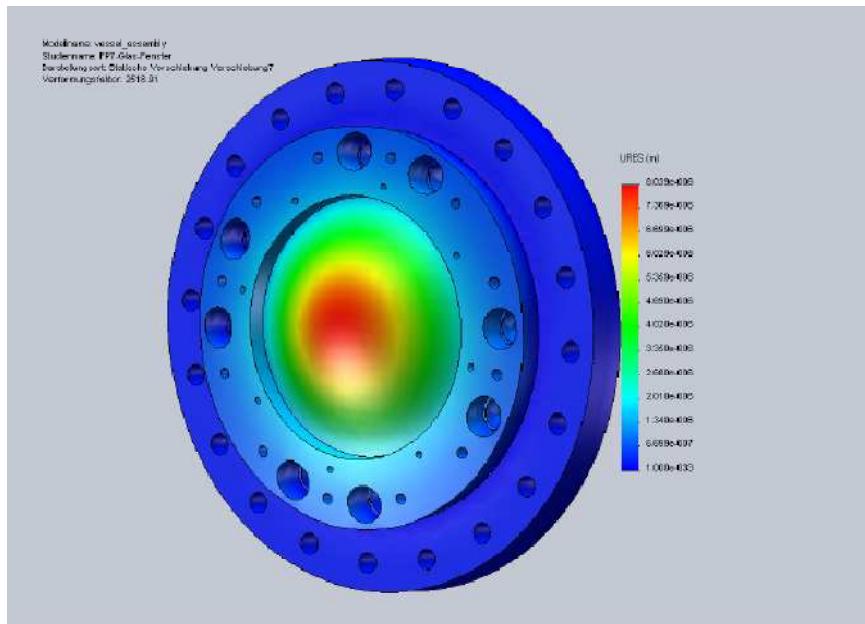
[CNR](#) - National Research Council, Italy

[TUM](#) - Technischen Universität München

Observers

ToU - University of Tokyo

* LIP gas scintillation, simulation of the detector



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- nuclear reactions to convert neutrons

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR



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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