WP7-Status and perspectives

+ HYDE project

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NEDENSAA NuPNET Collaboration Meeting 2013

http://www.lnl.infn.it/~nedensaa/

NEDENSAA Project

Neutron Detector Developments for Nuclear Structure, Astrophysics and Applications

- Home
- Project Description
- Management
- Working Packages
- Events
- News
- Document Server
- *NuPNET*

Presentation

Neutron detectors are used extensively at nuclear research facility across Europe, and will be essential instrumentation at FAIR, SPIRAL2, SPES, Jyväskylä, ISOLDE, etc. Their range of application covers nearly all the topics in basic and applied nuclear research. Paradoxically, the improvements over recent decades in neutron detection techniques have been very modest in comparison to other fields of nuclear instrumentation. The materials, detection techniques and electronics developed 40 years ago are still in many respects those employed today

The NEDENSAA NUPNET project is an effort to pool available resources and on going R&D by various groups throughout Europe with the aim of providing significant improvements in neutron detection. The project is divided in different work packages that cover the various technologies and methods relevant for the improvement of the detection of neutrons. These range from the chemistry for development of new scintillator materials, testing of the new materials as well as the comparison with existing ones, the study of innovative concepts for neutron detection, scintillator readout with SiPM, digital electronics as well as the study of the optimal geometry of the neutron detectors with other detector arrays (such as Ge arrays). In addition, efforts will be made explicitly towards networking and training so that the expertise and technological advances made within the project will be available to all and will reach beyond the lifetime of the project.

Participating institutions (in a.o.): CEA (France), CIEMAT (Spain), CNRS/IN2P3 (France), IFIC (Spain), INFN (Italy), Institute for Nuclear Research and Nuclear Energy (Bulgaria), The Scientific and Technological Research Council of Turkey, Technical University Dresden (Germany), University of Jyvaskyla (Finland), University of Uppsala (Sweden).

NEDENSAA Project

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- Home
- Project Description
  1. Background, rationale and review of the state of the art
  2. Objectives of the project and expected results
- Management
- Working Packages
- Events
- News
- Document Server
- *NuPNET*

Detailed project information

Background, rationale and review of the state of the art

Neutron detectors are commonly used in research centres all over the world for both basic science as well as for applications. However, the improvements over the last few decades in neutron detection techniques have been modest in comparison to other fields of nuclear instrumentation. The materials, detection techniques and the associated electronics developed 40 years ago are still the main stay of present day detection systems. Most of the neutron detectors used nowadays are:
- Gaseous detectors. These are mainly based on the 3He(n,p), 10B (n,alpha), 1H(n,p) and (n,fission) reactions. Owing to their gaseous nature, they have low intrinsic efficiencies, limited time resolution and require especial safety measures in their use (due to toxicity, flammability or other aspects). Furthermore, the recent price increase of 3He by a factor of about 10 supports the need to develop neutron detectors covering a range from thermal energies up to several hundreds of keV with reasonable efficiencies and cost.
- Liquid organic scintillators. They are based on the 1H(n,p) scattering and are still one of the preferred options for building large scale neutron spectrometers when neutron-gamma discrimination is required. They are however difficult to handle (due to their toxicity and flammability) and depending on the size, the lowest neutron energy that can be detected is ~100 keV.
- Solid organic scintillators. They are also based on the 1H(n,p) scattering and are one of the preferred options for building large neutron spectrometers when neutron-gamma discrimination is not required, i.e. for favorable neutron signal to γ-ray background ratios. The energy detection threshold is ~100 keV.
- Organic scintillators loaded with neutron converters. They rely on 1H(n,p) scattering which moderates

Joint Research Activity

Innovative Solutions for Nuclear Physics Detectors

From Basic R&D to Applications for the Society

European Commission

ERA-NET for Nuclear Physics Infrastructures

- Home
- Project Description
- Management
- Working Packages
  1. Development of new materials
  2. Characterisation of scintillator materials for neutron detection
  3. Innovative detector concepts
  4. Photosensors
  5. Processing Technologies
  6. Optimal design of neutron detectors and gamma-ray detectors
  7. Training and Networking
- Events
- News
- Document Server
- *NuPNET*

Working Packages

The activity of the Network is organized in seven Working Packages.

WP1: Development of new materials

Responsible: Louise Stuttgé, CNRS/IN2P3, stuttge@in2p3.fr

WP2: Characterisation of scintillator materials for neutron detection

Responsible: Heikki Penttilä, Department of Physics, University of Jyväskylä, heikki.t.penttila@jyu.fi

Joint Research Activity

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- *NuPNET*

Working Package 1

Development of new materials

Responsible: Louise Stuttgé, CNRS/IN2P3, stuttge@in2p3.fr

The activity of the WP 1 involves a network to which different units take part by contributing with their specific expertise.

- Strasbourg, IPCMS-IPHC:

Ionic liquids incorporating functionalized imidazolium cations offer a vast range of new materials for research and industry. They are characterized by exceptional properties such as extremely low volatility, high thermal stability, non-flammability, high chemical stability, both low and high ionic conductivity, and

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Search

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☐	WP2_Characterisation_of_scintillator_materials_for_n-detection	EMPTY	-	11:50 08-08-2012	755	
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Selection: 1 - 8

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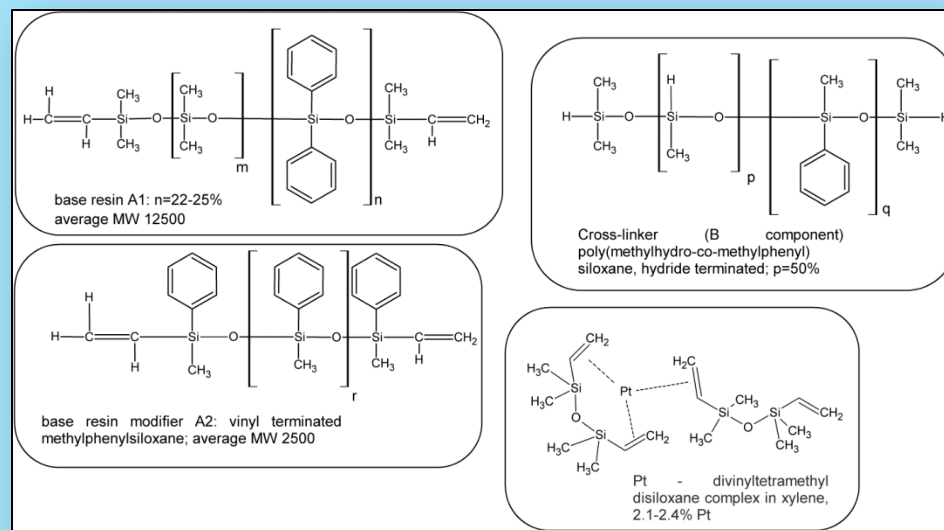
Polysiloxane Scintillators

Stable from -100 to +200 °C.

Cheap

(1 €/g vs. 14 €/g for commercial boron doped plastic scintillators)



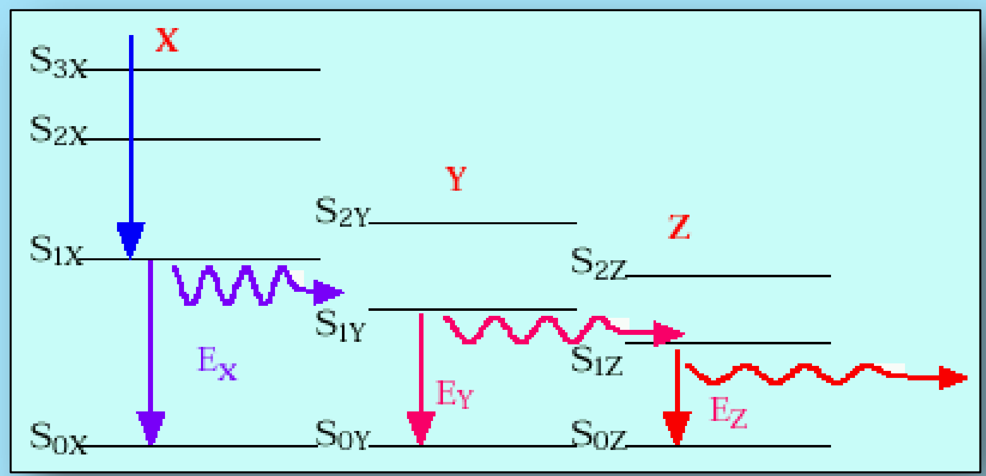
Easy to handle (PVT develops microcracks after touching)

Easy to synthesize: large volumes available by mixing the components

High radiation hardness

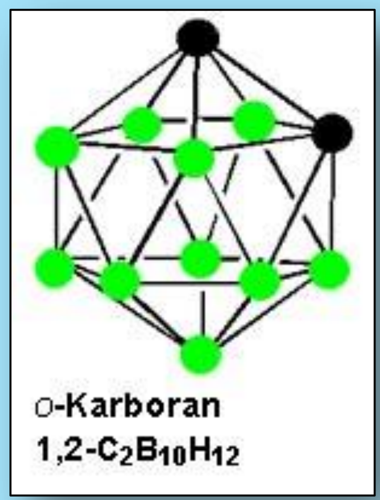
Polysiloxane Scintillators

SENSITIZATION (INFN Experiment ORIONE)



Luminescent dyes for the energy conversion into light

POL. **PPO** **Lumogen Violet**



O-carborane as thermal neutron sensitizer

$$n + {}^{10}B(20\%) \rightarrow {}^{7}Li(0.83\ MeV) + {}^{4}He(1.47\ MeV) + \gamma$$

Commercial Scintillators

Physical and Scintillation Constants:

Physical and Scintillation Constants	
Light Output, % Anthracene	65
Scintillation Efficiency, photons/1 MeV e^-	10,000
Wavelength of Max. Emission, nm	423
Rise Time, ns	0.9
Decay Time, ns	2.4
Pulse Width, FWHM, ns	2.7
No. of H Atoms per cm^3, x 10^{22}	5.17
No. of C Atoms per cm^3, x 10^{22}	4.69
No. of Electrons per cm^3, x 10^{23}	3.33
Density, g/cc:	1.023

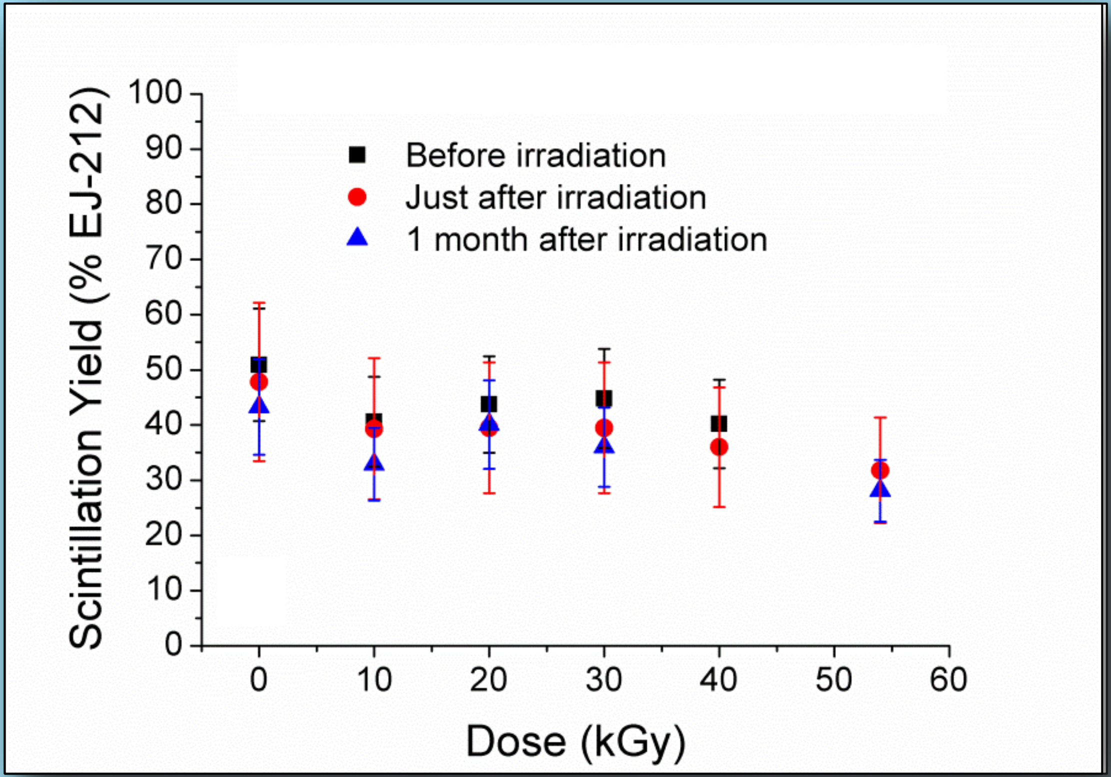
EJ-212

Physical and Scintillation Constants	**5% B**	**2.5%B**	**1%B**
Light Output, % Anthracene	48	56	60
Scintillation Efficiency, photons/1 MeV e^-	7,500	8,600	9,200
Wavelength of Max. Emission, nm	425	425	425
Decay Time, ns	2.2	2.2	2.2
No. of C Atoms per cm^3, x 10^{22}	4.44	4.55	4.62
No. of H Atoms per cm^3, x 10^{22}	5.18	5.17	5.16
No. of ^{10}B Atoms per cm^3, x10^{20}	5.68	2.83	1.14
No. of Electrons per cm^3, x 10^{23}	3.33	3.33	3.33
Density at 20°C, g/cc:	1.026	1.023	1.021

EJ-245
14 €/g

Polysiloxane Scintillators

RADIATION HARDNESS TESTS

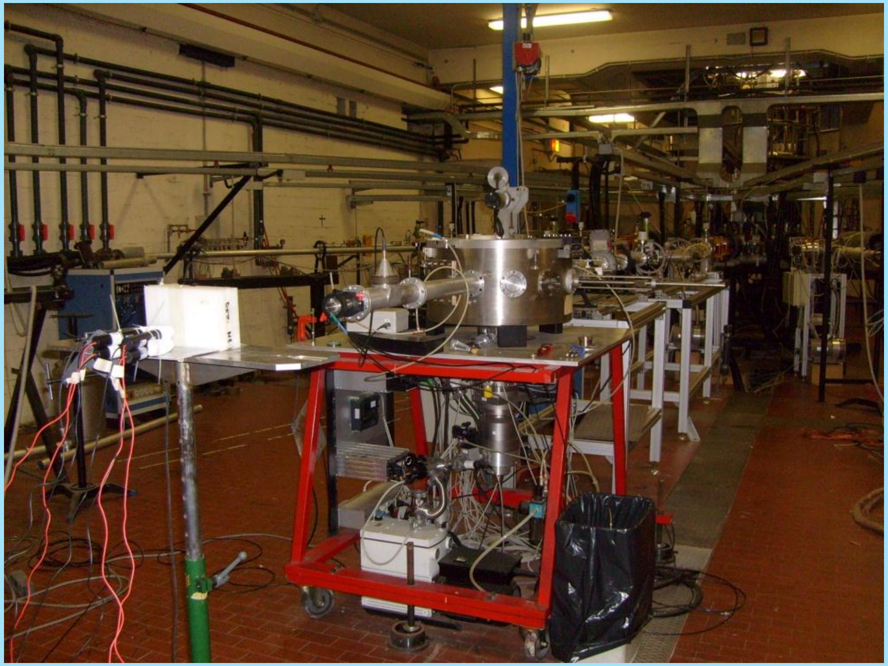


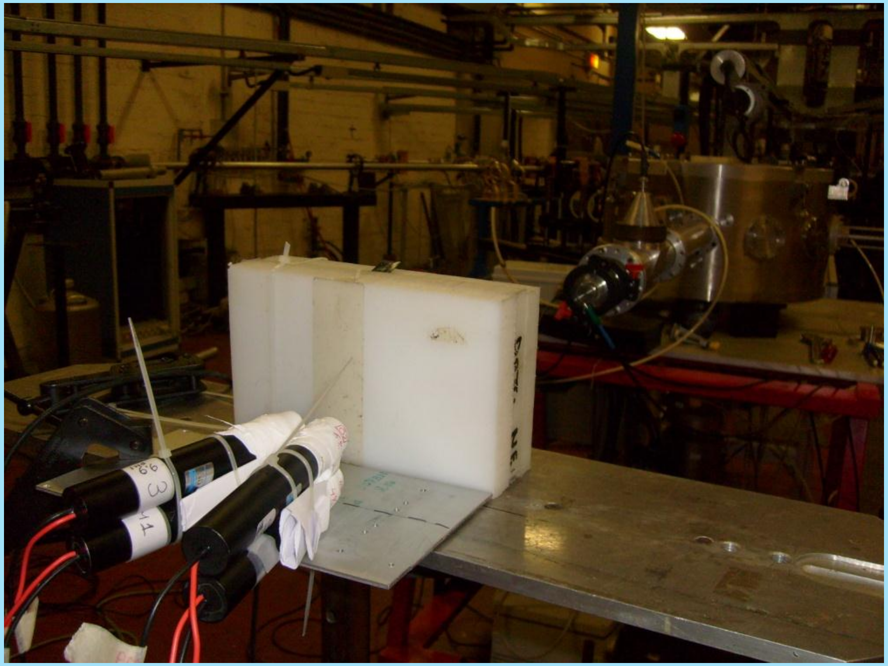
Polysiloxane Scintillators

SCINTILLATION YIELD

Sample	% EJ-212 α	% EJ-212 γ	% EJ-254 α	% EJ-254 γ
no B	65 ± 16	74 ± 15	-	-
B 4%	44 ± 13	49 ± 12	66 ± 22	69 ± 16
B 6%	40 ± 14	48 ± 11	64 ± 24	62 ± 15
B 8%	37 ± 13	41 ± 17	54 ± 17	57 ± 11

Neutron Detection





FAST NEUTRONS

Pulsed proton beam on LiF target at CN 7 MeV accelerator

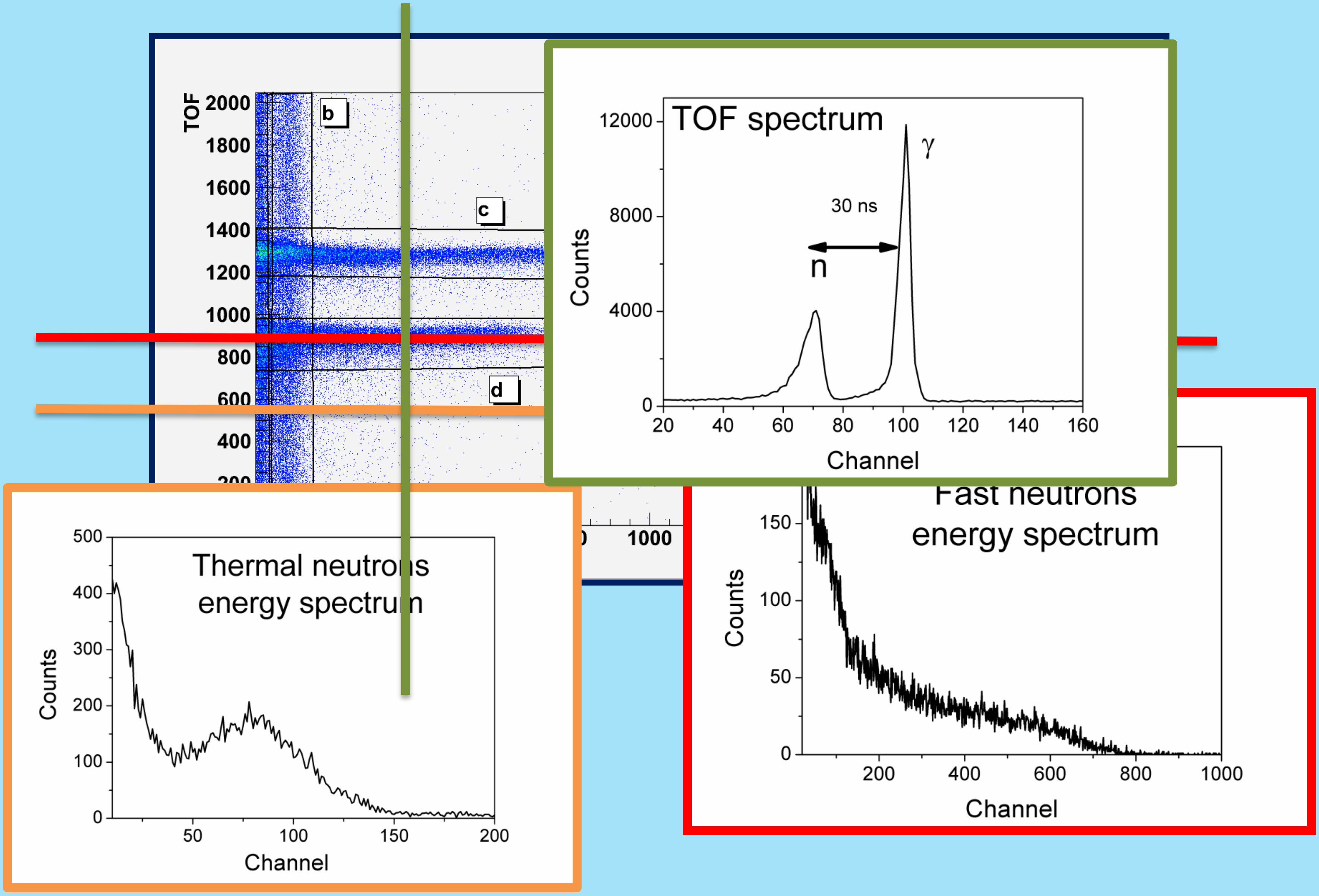
Laboratori Nazionali di Legnaro

2 ns pulse width, 3 MHz repetition rate.

Proton energy: 4.0 MeV. Main neutron peak: 2.3 MeV. ($^{7}Li(p,n)^{7}Be$)

Polyethylene bricks (6 cm) for **THERMAL NEUTRONS**.

TOF Measurements



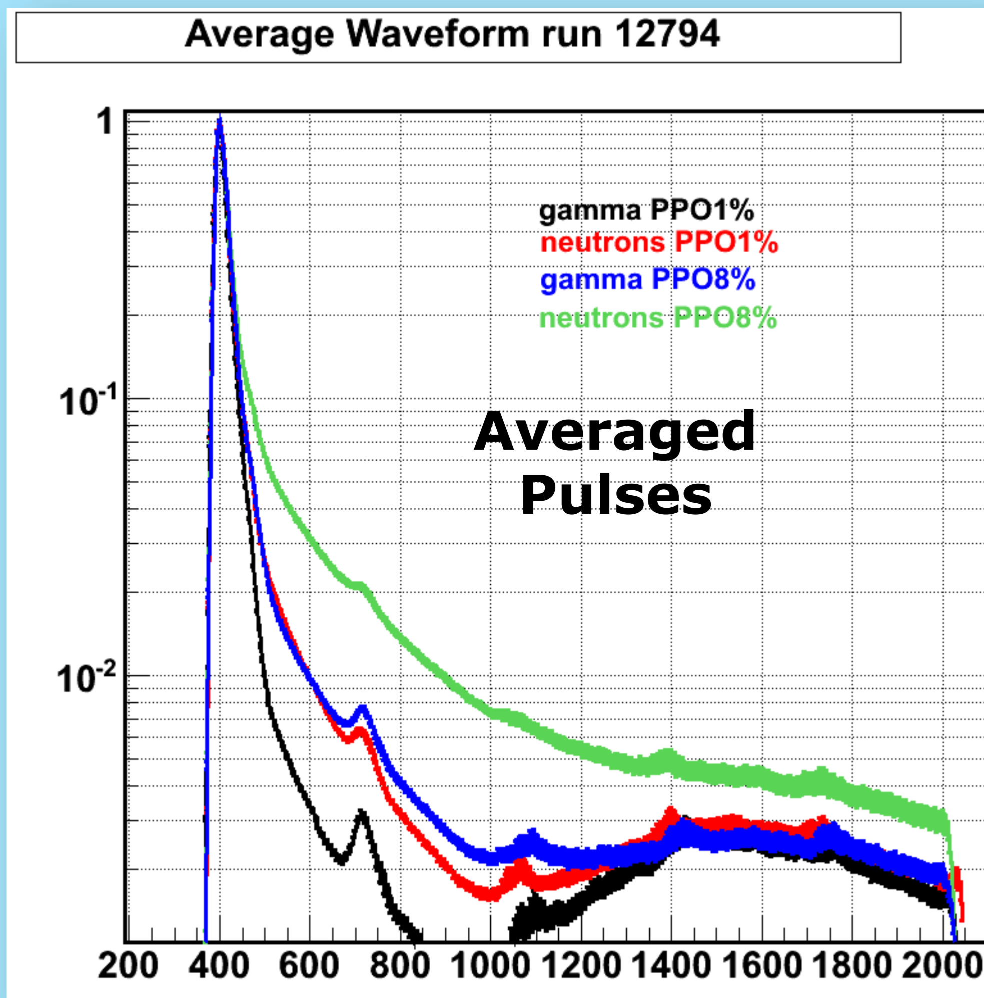
Thermal Neutrons

Relative to EJ-254

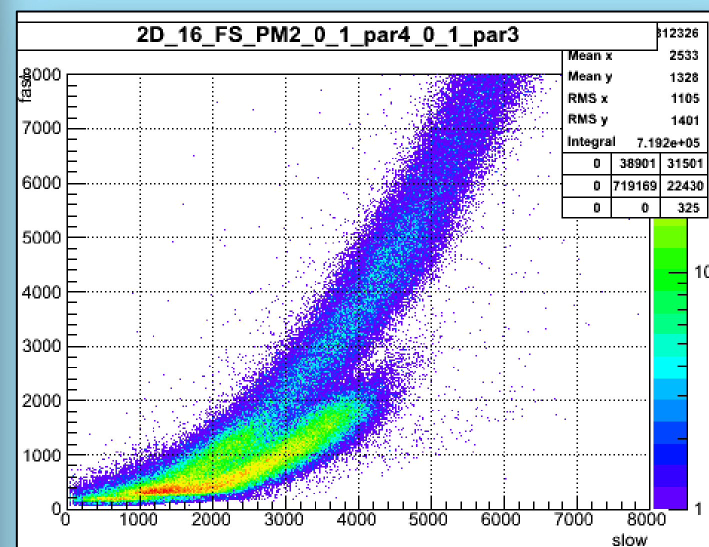
	B 4%	B 6%	B 8%
YIELD	72 ± 49 %	63 ± 42 %	59 ± 22 %
EFF.	0.7 ± 0.2	1.3 ± 0.5	1.4 ± 0.2

PSD Preliminary Tests

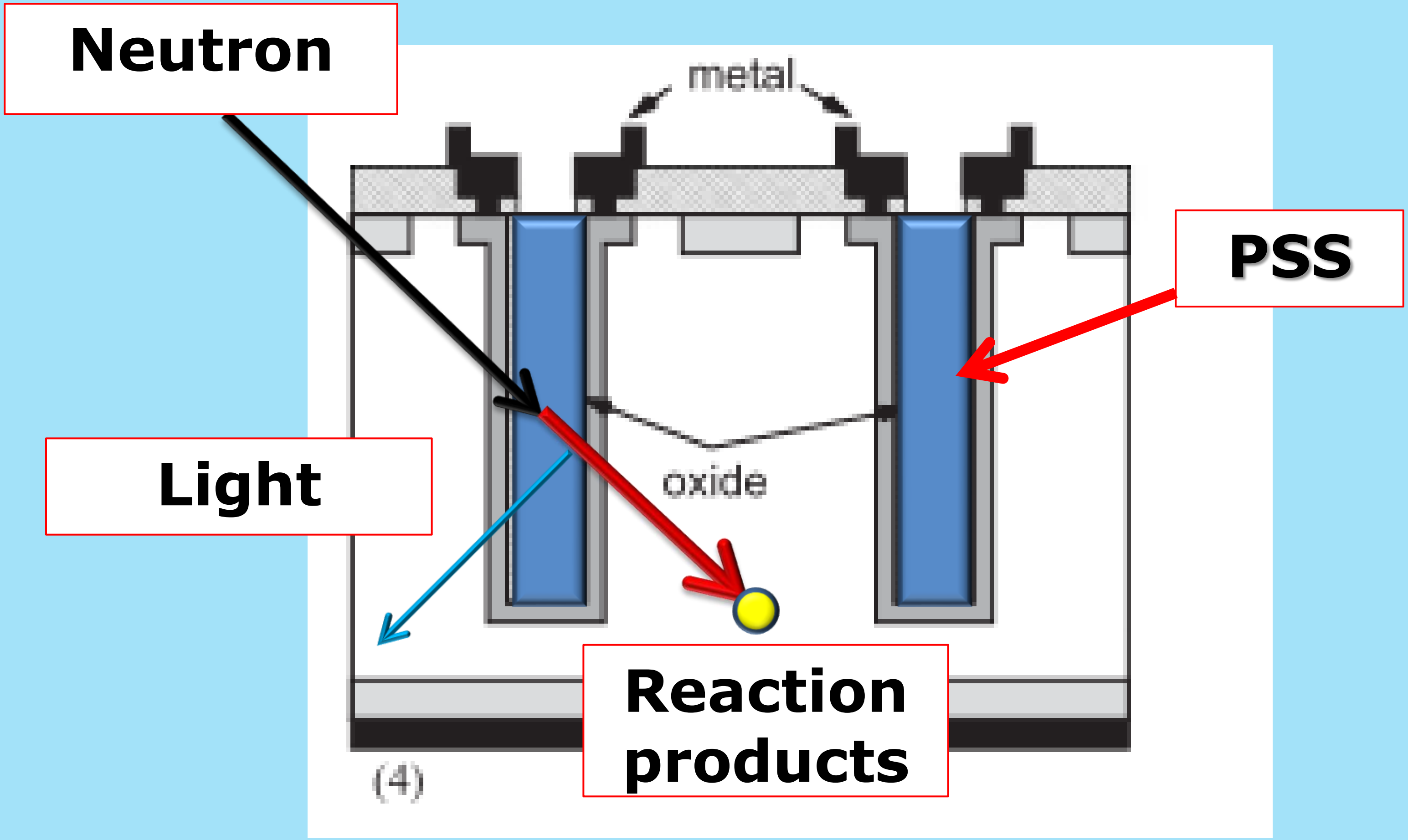
HIGH CONCENTRATION OF PRIMARY DYE
PPO 8%



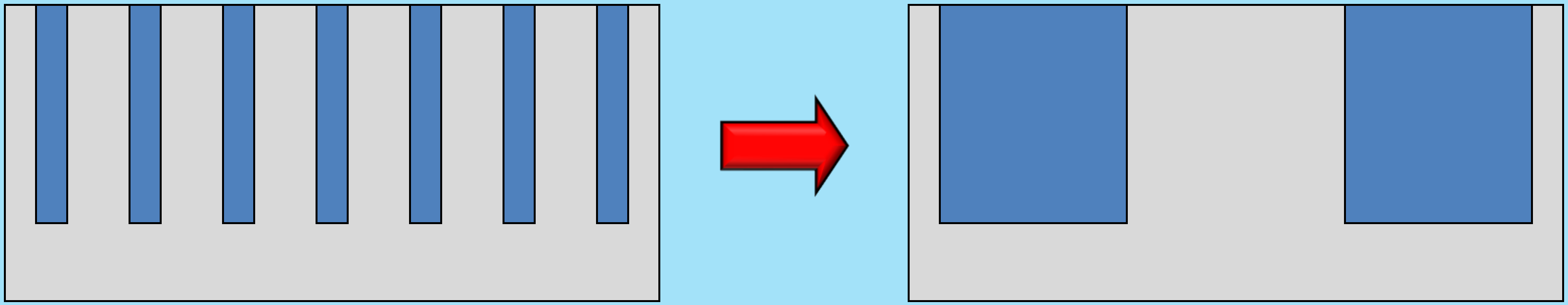
Fast vs. Slow



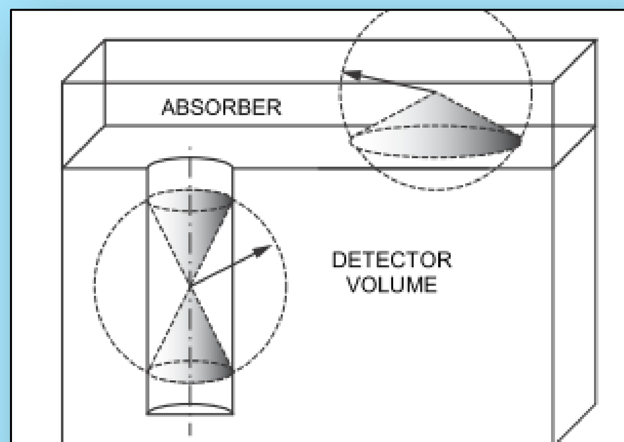
Aims of HYDE
(HYbrid DEtectors for neutrons)

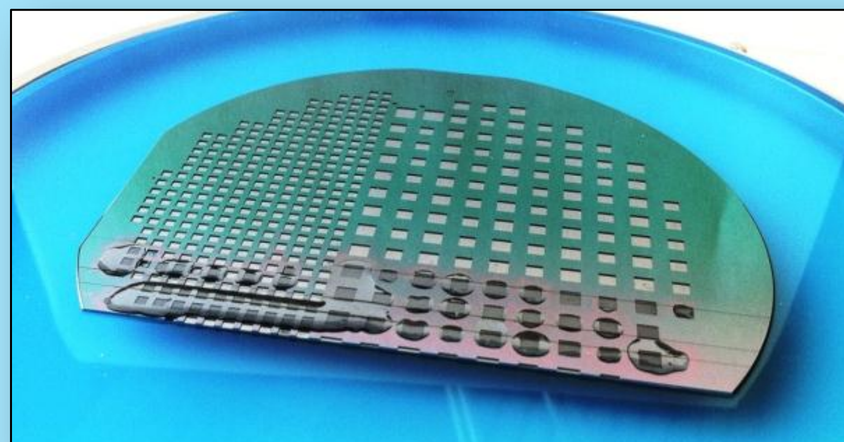


Aims of HYDE



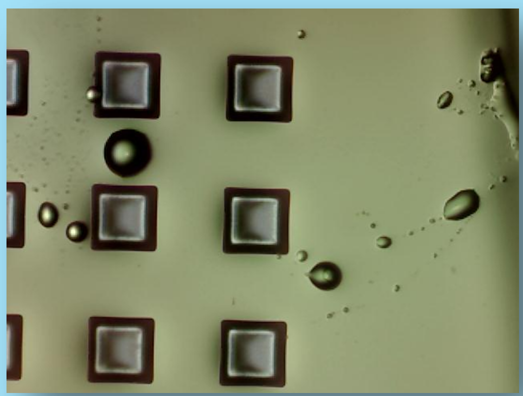
Higher aspect ratio
Higher interaction volume for neutrons

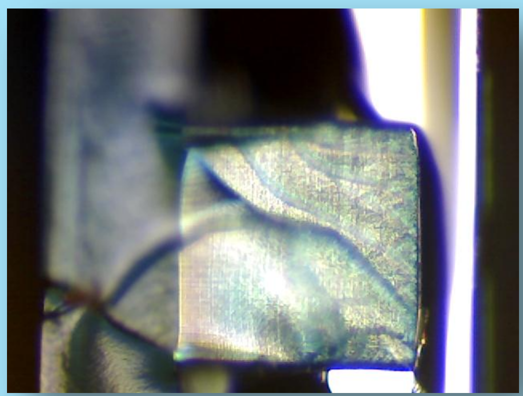


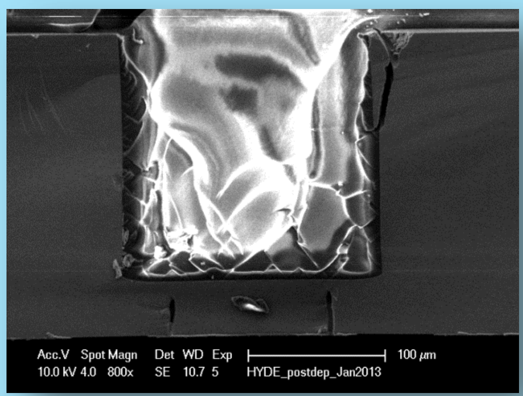


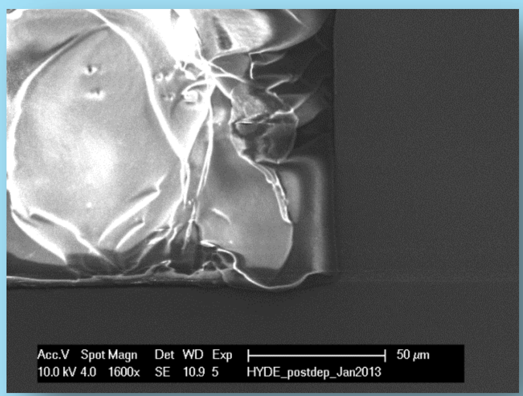
Filling tests

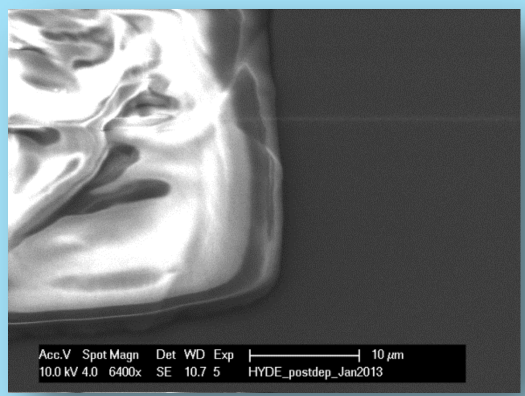
Very good matching and adhesion





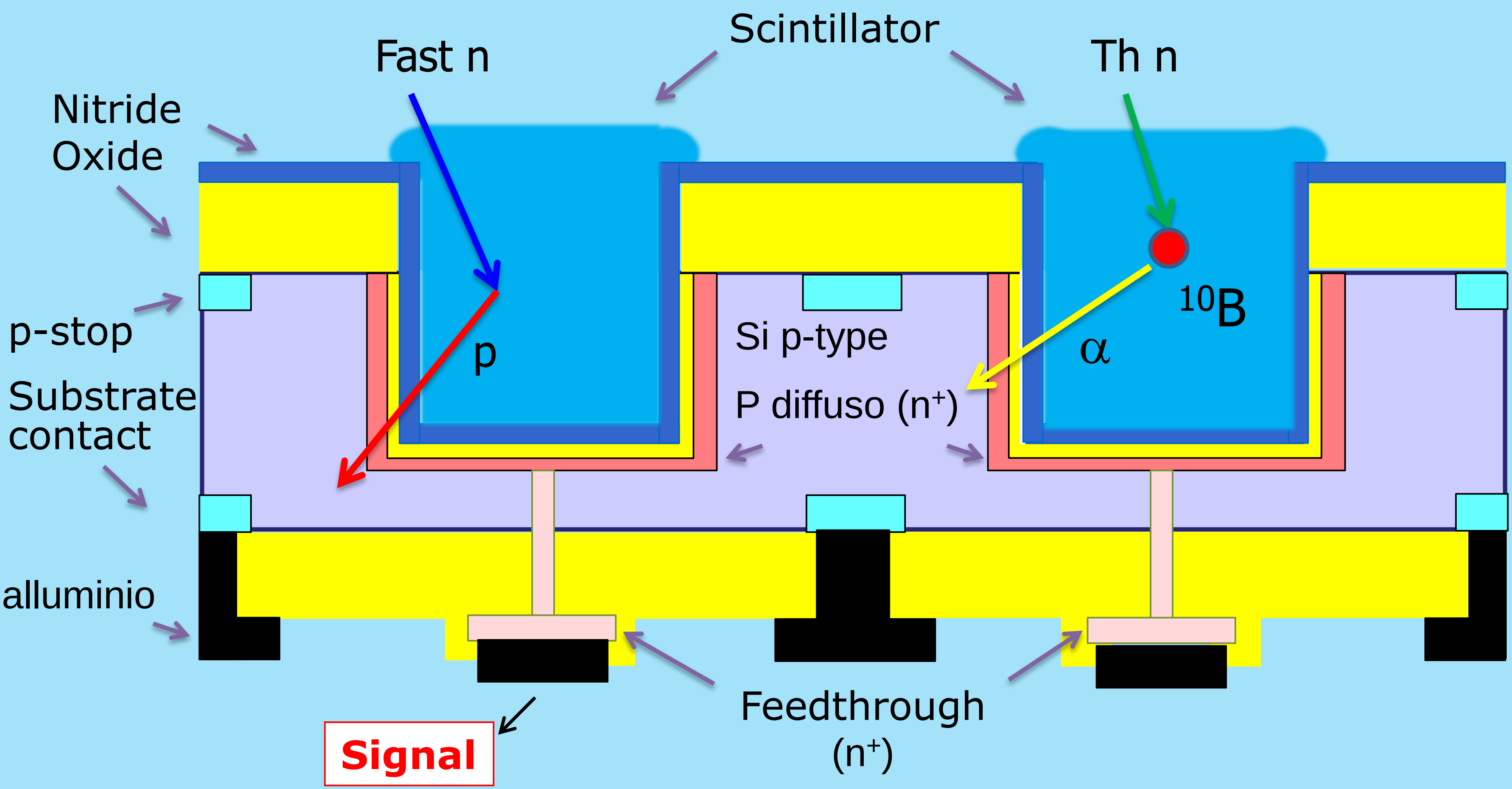






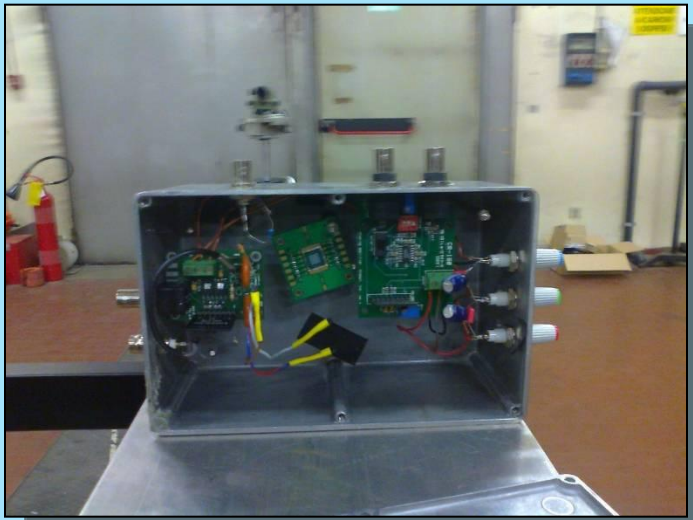
Preliminary Tests

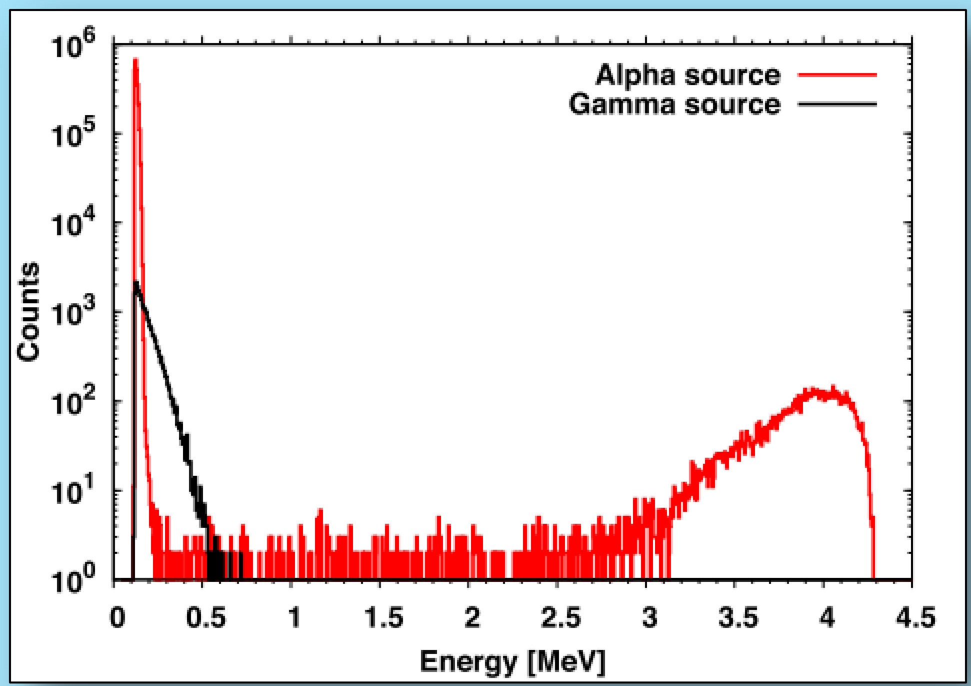
3D scheme
(forthcoming tomorrow by Sabina Ronchin)



Preliminary Tests

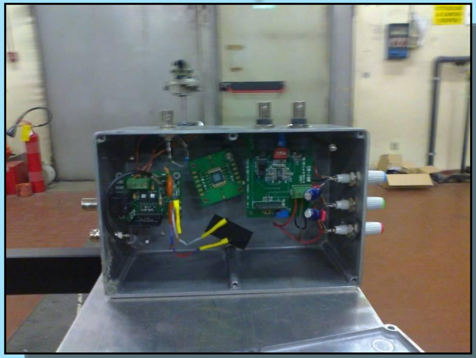
Response to alpha and gamma of the bare 3D system

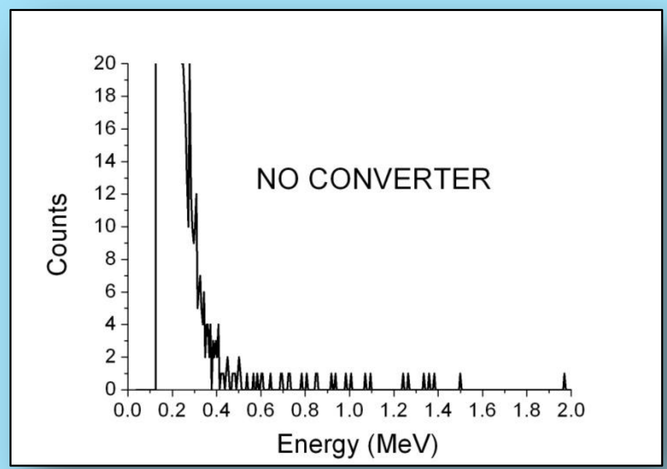


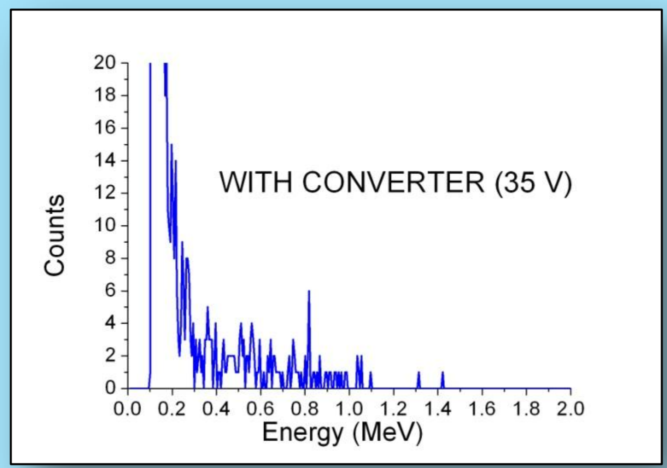


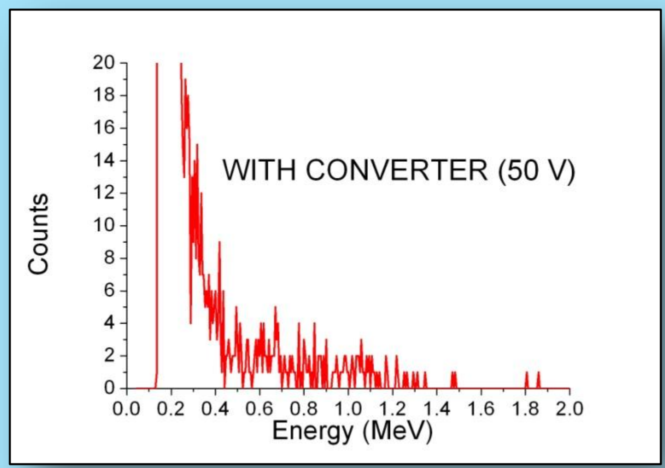
Preliminary Tests

3D system covered with polysiloxane as converter of fast neutron into protons
400 μm



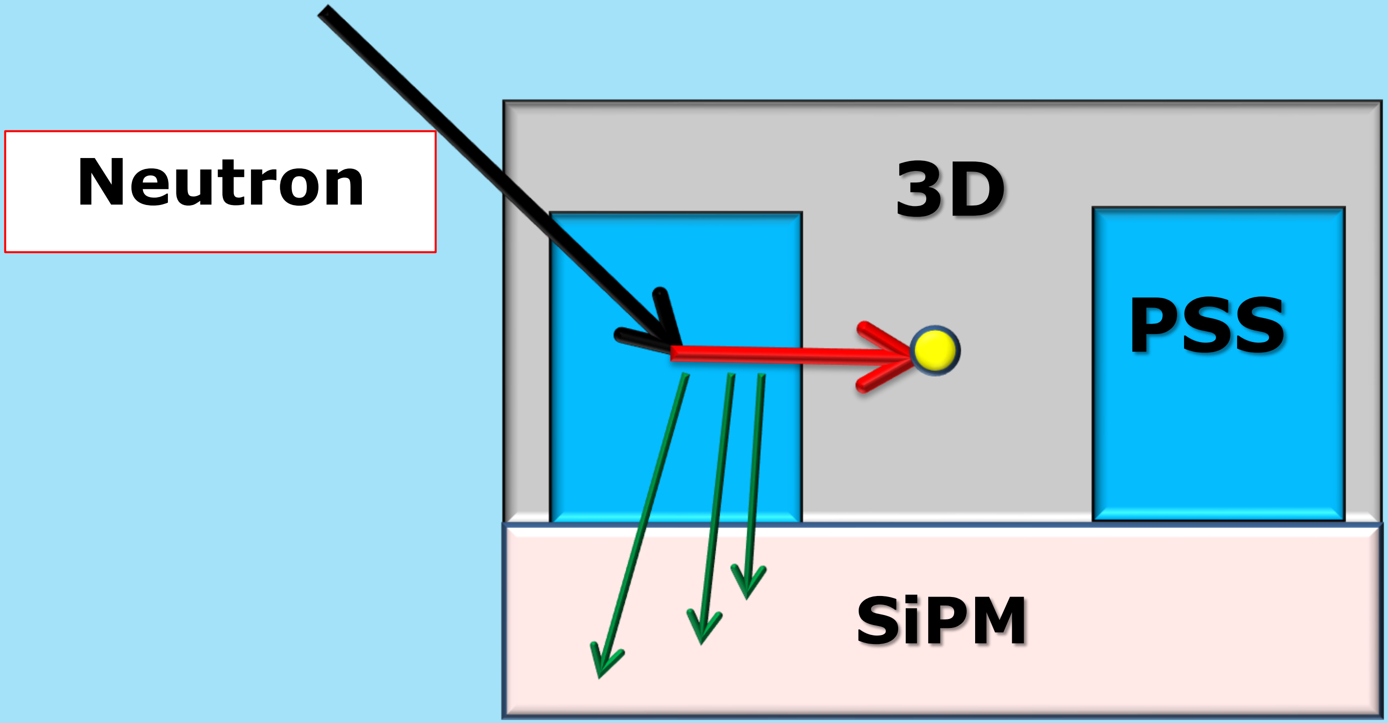






Planned Work

3D detector for reaction products
APD/SiPM photodetector for scintillation light

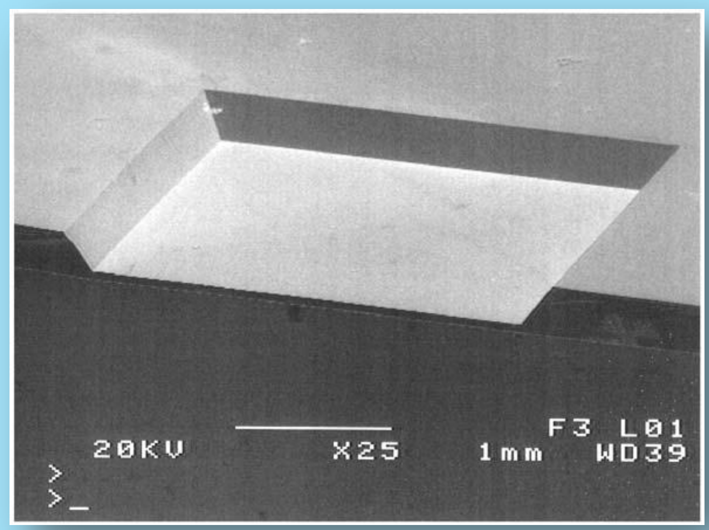


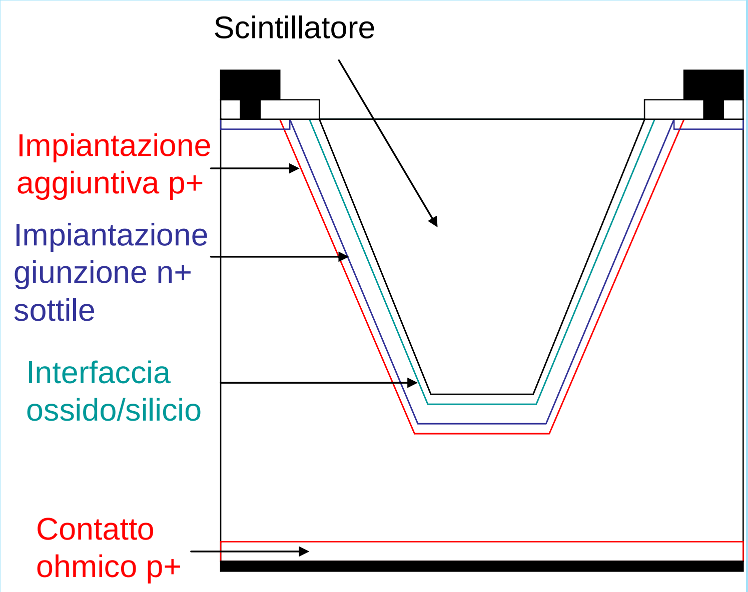
Advanced Approach:
3D – APD

- **Integration of avalance photodiodes (APD) in 3D structures.**

→ **Ion implantation doping**

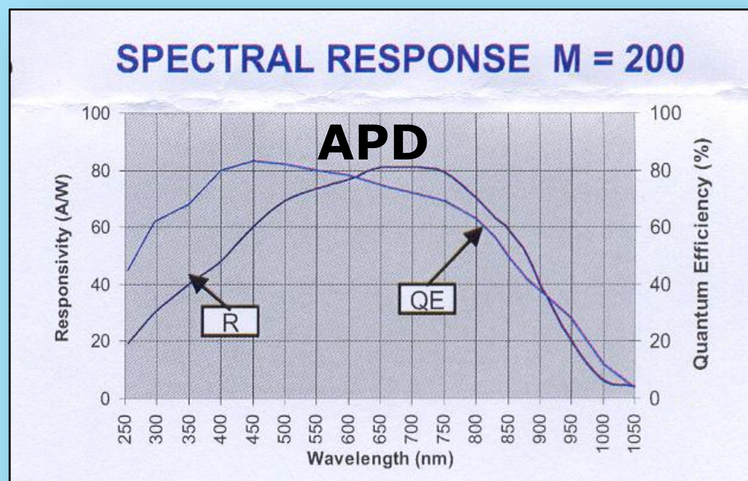
→ **TMAH wet etching giving 54° inclined walls and ion implantation for fixing the breakdown tension.**

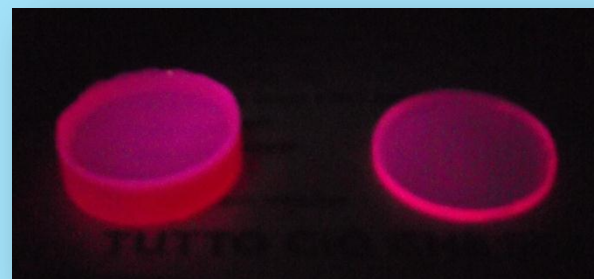




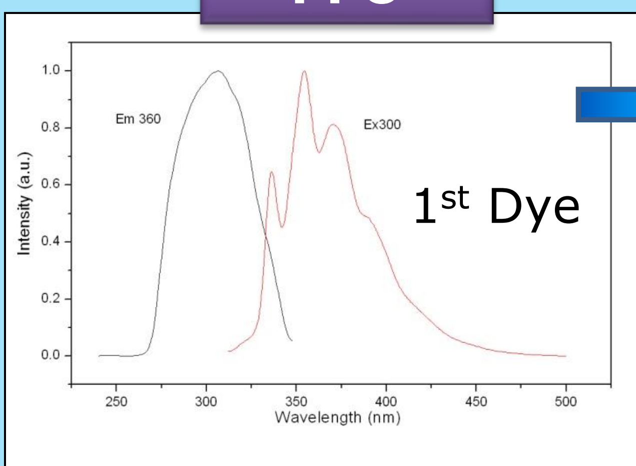
Red Emitting Scintillators

Red emitting scintillators for standard APD detectors.

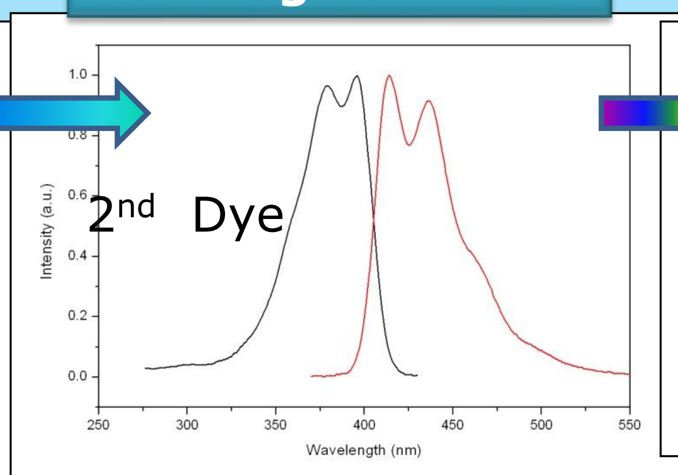




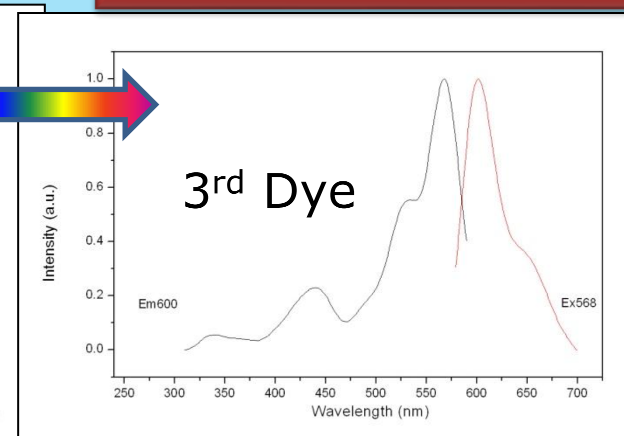
PPO



Lumogen Violet

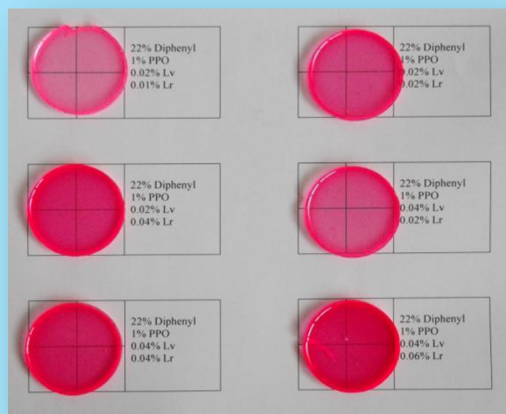


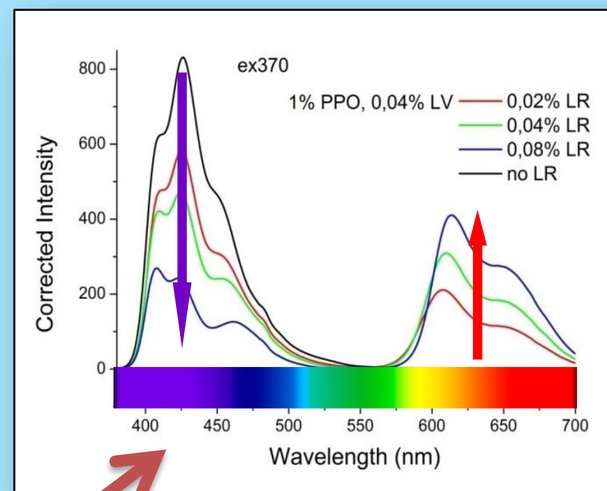
Lumogen Red

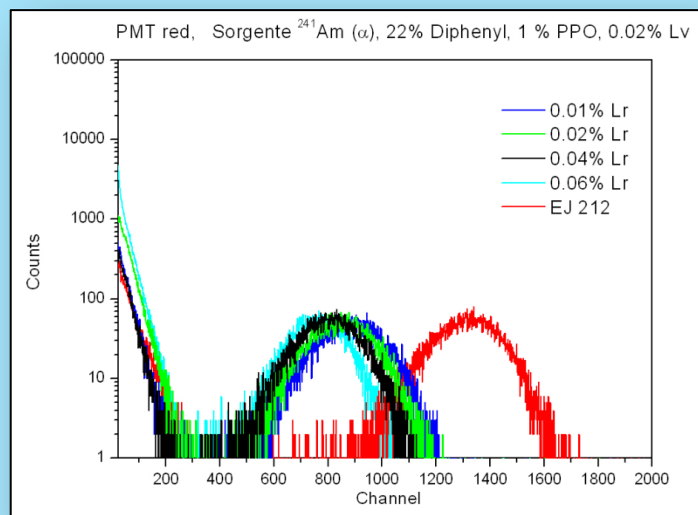


Red Emitting Scintillators

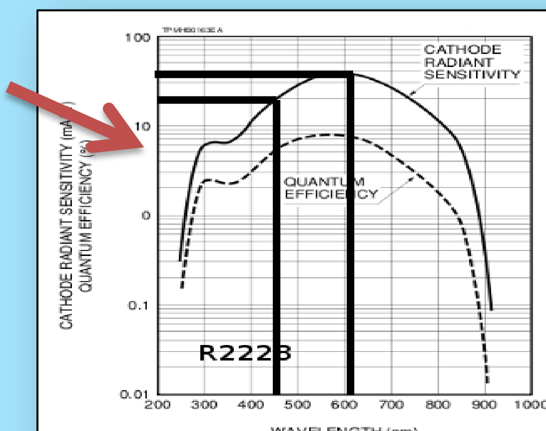
Tests with red enhanced PMT





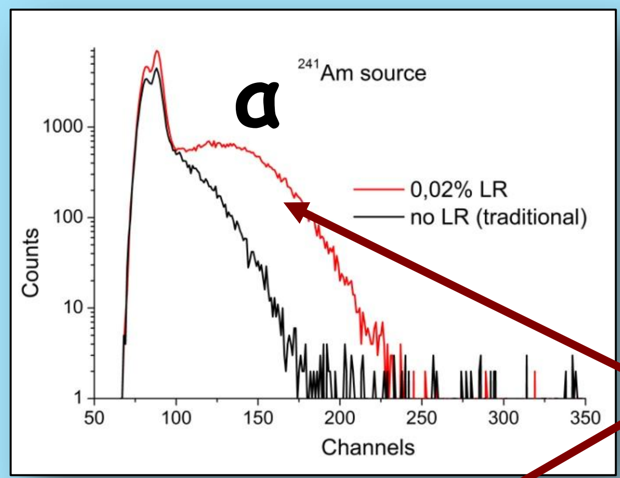


LV contribution to the scintillation yield

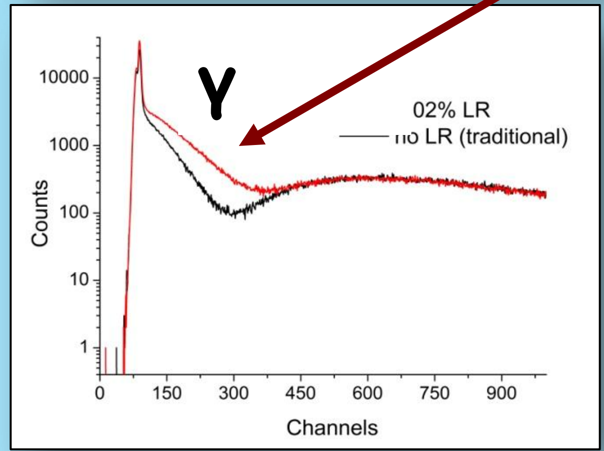


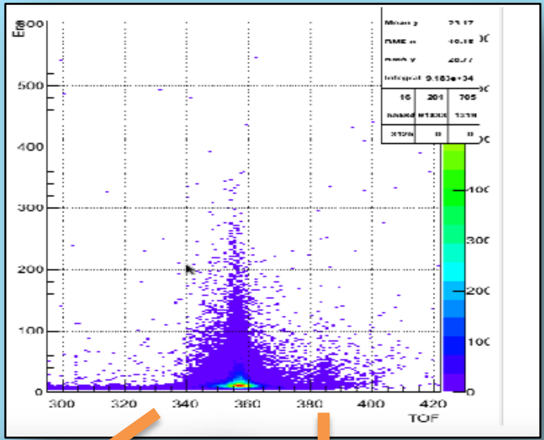
Red Emitting Scintillators

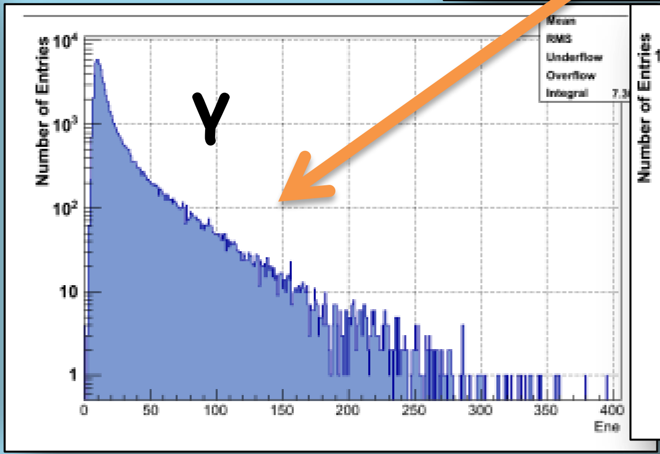
Tests with APD
SD 630-70-72-500 Advanced Photonics
1 mm thin scintillator

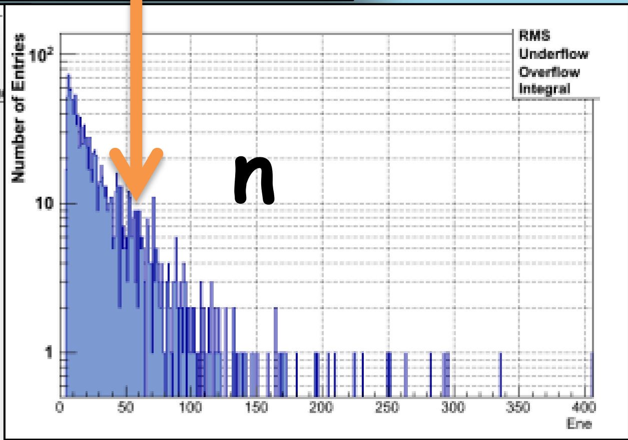


≈ 40% higher light yield









Summary

- Polysiloxane based scintillators are a suitable system for neutron detection.
- Polysiloxane systems can be easily coupled to 3D silicon detectors.
- Hybrid PSS+3D detectors are promising for the detection and mapping of neutrons.
- Red emitting scintillators can enhance the sensitivity of silicon based detection systems.

Staff

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Nicola Zorzi

Thank You for your attention