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Simulations of SP^2 and CYSP

1) SP^2: spettrometro sferico

2) CYSP: spettrometro cilindrico

3) Attività in corso and diffusione dei risultati

1) SP²: spettrometro spherico

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Designing an extended energy range single-sphere multi-detector neutron spectrometer

J.M. Gómez-Ros [a,b,*], R. Bedogni [b], M. Moraleda [a], A. Esposito [b], A. Pola [c], M.V. Introini [c], G. Mazzitelli [b], L. Quintieri [b], B. Buonomo [b]

[a] CIEMAT, Av. Complutense 40, 28040 Madrid, Spain
[b] IFNF-LNF, U.F. Fisica Sanitaria, via E. Fermi n. 40, 00044 Frascati, Italy
[c] Politecnico di Milano, Dipartimento di Energia, via Ponzio 34/3, 20133 Milano, Italy

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ABSTRACT

This communication describes the design specifications for a neutron spectrometer consisting of 31 thermal neutron detectors, namely Dysprosium activation foils, embedded in a 25 cm diameter polyethylene sphere which includes a 1 cm thick lead shell insert that degrades the energy of neutrons through (***n***,***xn***) reactions, thus allowing to extension of the energy range of the response up to hundreds of MeV neutrons. The new spectrometer, called SP² (SPherical SPectrometer), relies on the same detection mechanism as that of the Bonner Sphere Spectrometer, but with the advantage of determining the whole neutron spectrum in a single exposure. The Monte Carlo transport code MCNPX was used to design the spectrometer in terms of sphere diameter, number and position of the detectors, position and thickness of the lead shell, as well as to obtain the response matrix for the final configuration. This work focuses on evaluating the spectrometric capabilities of the SP² design by simulating the exposure of SP² in neutron fields representing different irradiation conditions (test spectra). The simulated SP² readings were then unfolded with the FRUIT unfolding code, in the absence of detailed pre-information, and the unfolded spectra were compared with the known test spectra. The results are satisfactory and allowed approving the production of a prototypal spectrometer.
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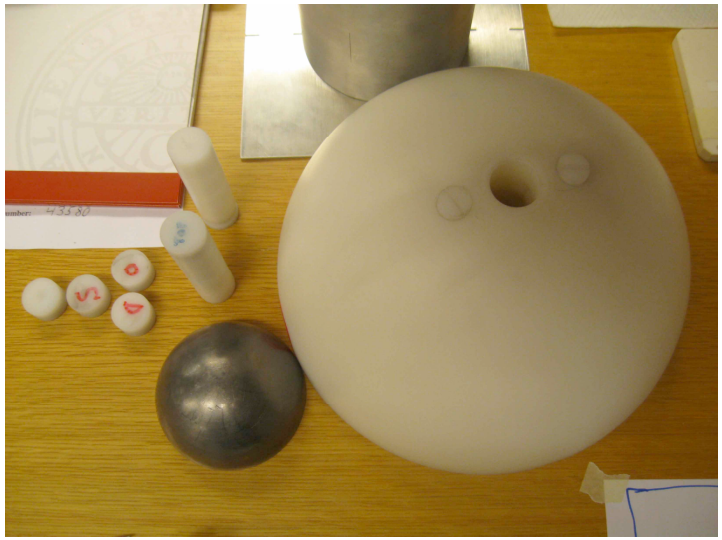
1) SP²: spettrometro spherico - disegno

Fig. 1. Schematic view of the spectrometer showing the arrangement of the activation foils detectors along three perpendicular axes, as well as the inner lead layer.



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1) SP²: spettrometro spherico - matrice risposta

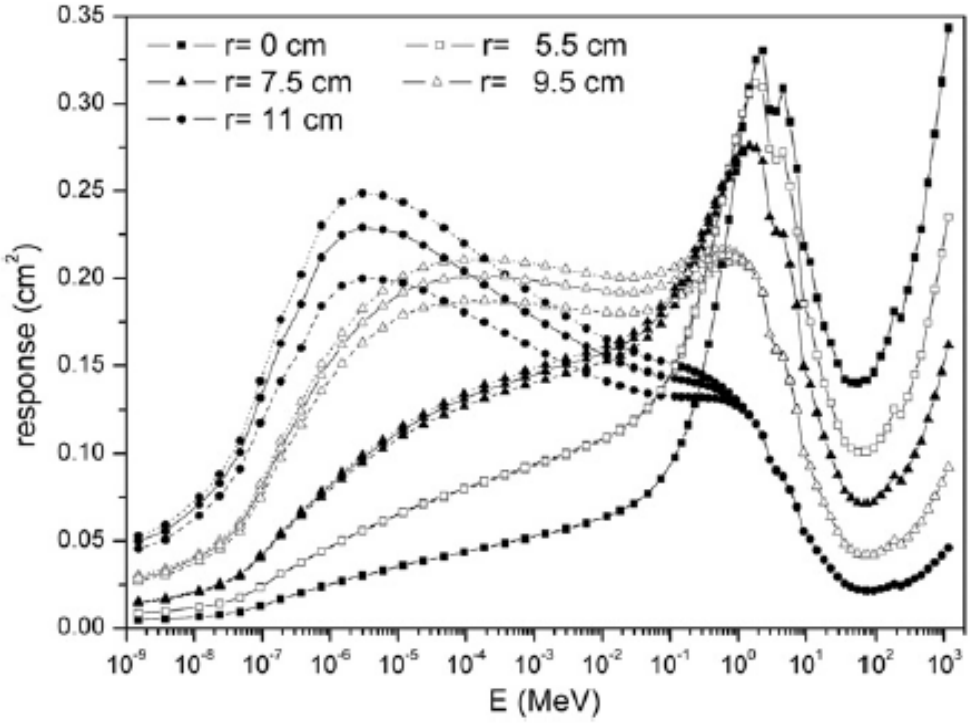
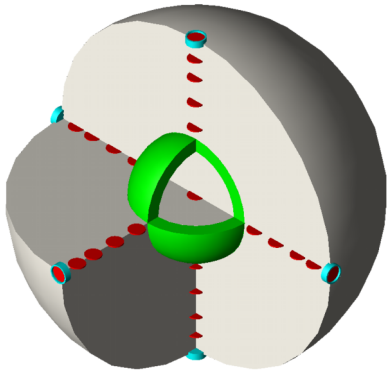


Fig. 2. Energy response functions to monoenergetic incident neutrons, averaged over the detectors located at the same distance from the centre, for three different irradiation geometries: along the (1 0 0) axis (dashed lines), isotropic (continuous lines), and along the (1 1 1) axis (dotted lines). The response functions have been calculated for radial distances 0, 5.5, 7.5, 9.5 and 11 cm.



The response functions have been calculated for radial distances:
0, 5.5, 7.5, 9.5, 11 cm, considering three different irradiation geometries:

- along the (1 0 0) axis
- isotropic
- along the (1 1 1) axis

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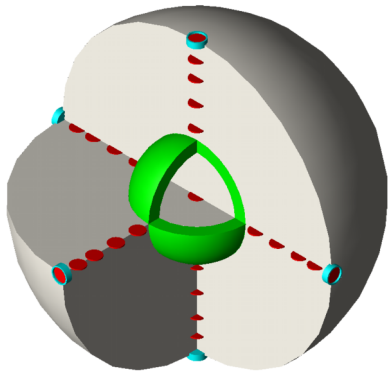
1) SP²: spettrometro spherico - neutroni termici



Energy response function to monoenergetic incident neutrons, averaged over the detectors located on the surface of the sphere, for three different irradiation geometries:

- along the (1 0 0) axis (dashed lines)
- isotropic (continuous lines)
- along the (1 1 1) axis (dotted lines)

a) withouht cadmium layer
b) with cadmium layer

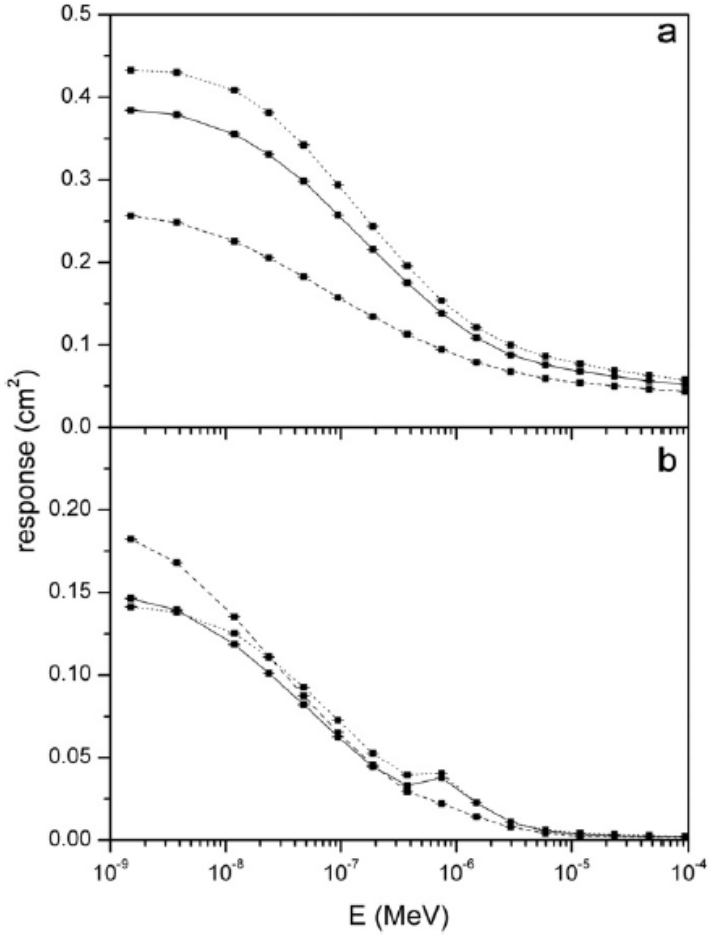


Fig. 3. Energy response function to monoenergetic incident neutrons, averaged over the detectors located on the surface of the sphere, for three different irradiation geometries: along the (1 0 0) axis (dashed lines), isotropic (continuous lines), and along the (1 1 1) axis (dotted lines): (a) without cadmium layer and (b) with cadmium.

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1) SP²: spettrometro spherico - alta energia

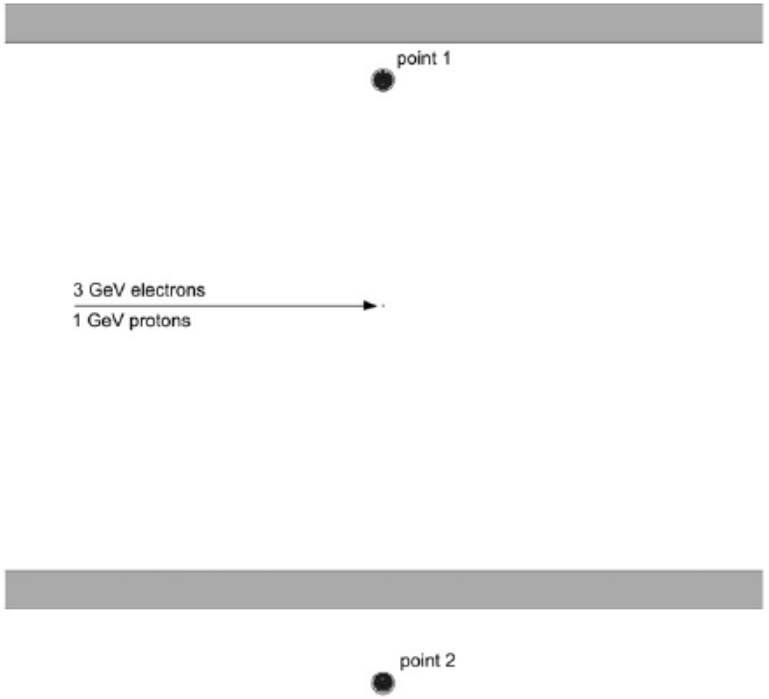

Fig. 5. Schematic view of the geometry used to simulate the exposure to high energy neutron field.

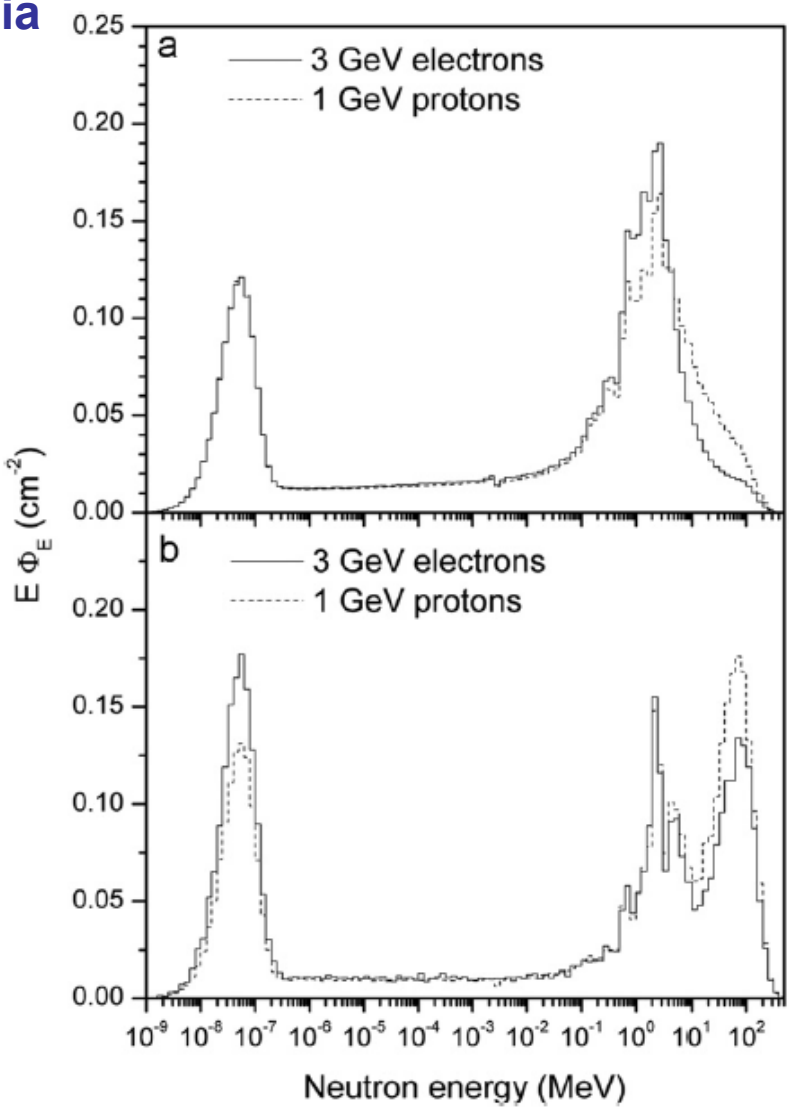

Fig. 6. Simulated high energy neutron spectra calculated according to the geometry depicted in Fig. 5.

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1) SP²: spettrometro spherico - alta energia

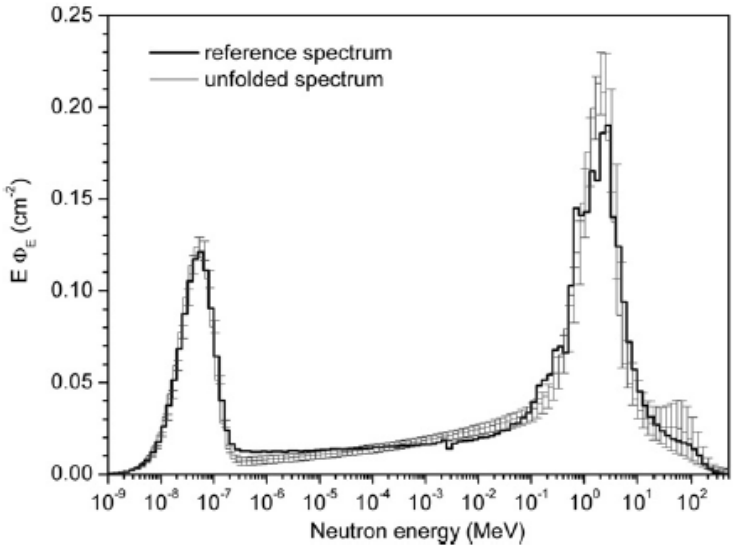

Fig. 7. Simulated exposure to a high energy neutron field (unshielded high energy electron source).

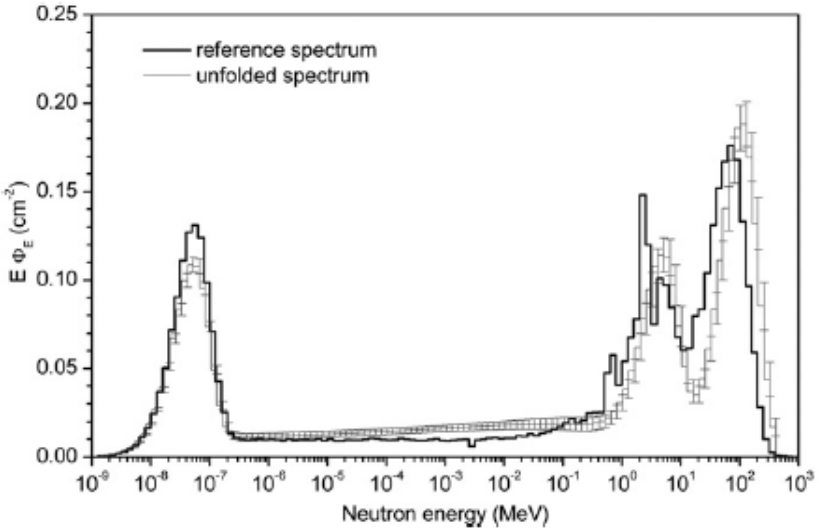

Fig. 8. Simulated exposure to a high energy neutron field (shielded high energy proton source).

Table 2
Comparison between the integral quantities, Φ and $h^*(10)$, and fluence fractions derived from the reference high energy spectra and those obtained by unfolding.

Neutron Spectrum		Total Fluence (cm^{-2})	$h^*(10)$ ($pSv\ cm^2$)	Fluence Fractions (%)			
				$E < 0.4$ eV	0.4 eV $< E <$ 10 keV	10 keV $< E <$ 20 MeV	$E > 20$ MeV
High-E electrons unshielded point	Reference	1	216	12.6	26.2	57.2	4.0
	Unfolded	0.98 ± 0.02	218 ± 11	14.0	24.2	56.9	4.9
High-E protons shielded point	Reference	1	247	12.8	21.8	35.1	30.3
	Unfolded	1.07 ± 0.05	238 ± 15	11.6	22.9	29.5	36.0

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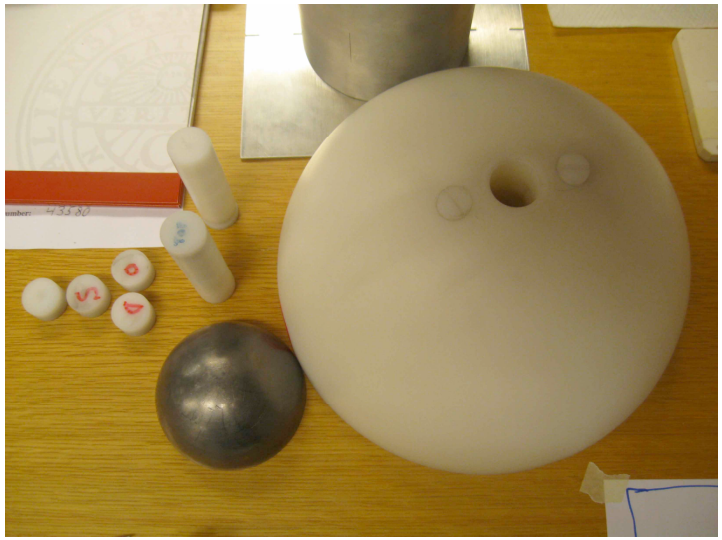
1) SP^2: spettrometro spherico - conclusioni

1) Final design was established and published in Nucl. Instrum. Meth. A.

2) The moderator is a polyethylene sphere 25 cm in diameter, with 31 detectors along three perpendicular axis. A inner lead shell is used to extend the energy range above 20 MeV.

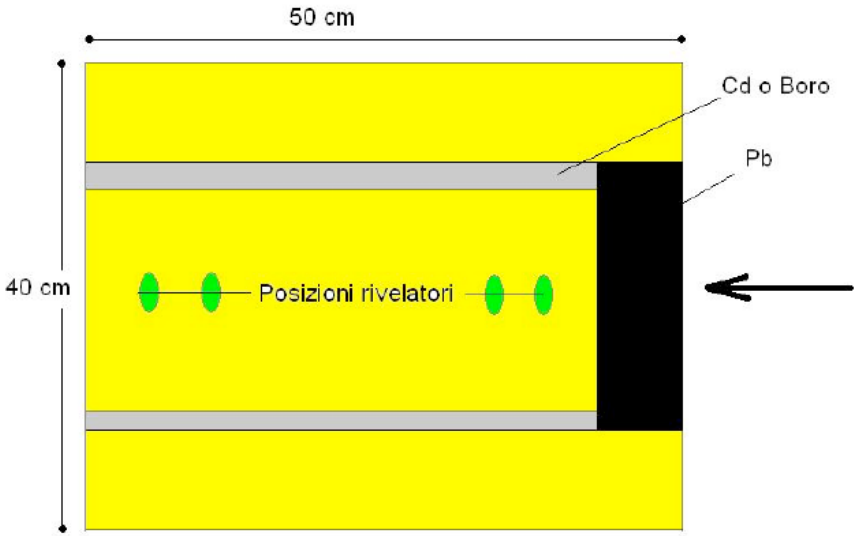
3) Two prototypes have been fabricated and tested. One only with polyethylene moderator and energy response up to 20 MeV; one with lead shell and extended response up to 100 – 200 MeV. A nearly isotropic response has been obtained by averaging the signal from the six detectors at the same radial distance.



2) CYSP: spettrometro cilindrico - disegno

primo disegno

CYSP migliorato



3) Attività in corso

1) Frabication of the CYSP according the specification of the new design.
2) Validation of prototypes (INFN Am-Be source, n@BNG, FNG, NPL, PTB).
3) Implementation of new active detectores (see A. Pola and D. Bortot).
4) Validation experiments at TSL and further tests.
5) Publication of last results.

3) Diffusione dei risultati

Articoli pubblicati (2011 – 2012):

1) J.M. Gómez-Ros, R. Bedogni, I. Palermo, A. Esposito, A. Delgado, M. Angelone, M. Pillon. *Design and validation of a photon insensitive multidetector neutron spectrometer based on Dysprosium activation foils*. Radiat. Meas. 46 (2011) 1712-1715.

2) R. Bedogni, L. Quintieri, B. Buonomo, A. Esposito, G. Mazzitelli, J. M. Gómez-Ros. *Experimental and numerical characterization of the neutron field produced in the n@BTF Frascati photo-neutron facility*. Nucl. Inst. Meth. A 659 (2011) 373-377.

3) J.M. Gómez-Ros, R. Bedogni, M. Moraleda, A. Esposito, A. Pola, M.V. Introini, G. Mazzitelli, L. Quintieri, B. Buonomo. *An extended energy range multidetector neutron spectrometer*. Nucl. Inst. Meth. A 677 (2012) 4-9.

4) R. Bedogni, J.M. Gómez-Ros, A. Esposito, A. Gentile, M. Chiti, L. Palacios-Pérez, M. Angelone, L. Tana. *Workplace testing of the new Single Sphere neutron Spectrometer based on Dysprosium activation foils (Dy-SSS)*. Nucl. Inst. Meth. A (2012) accepted.

2012 – 2013: