INFN Istituto Nazionale di Fisica Nucleare

NESCOFI@BTF (2011-2013) closure & NEURAPID (2014-2016) start up meetings

INFN-LNF, 26 February 2014

Commissione Scientifica Nazionale V

10:00 – 10:15	NESCOFI final activity report (R. Bedogni)
10.15 – 10:30	Experimental tests of SP^2 and CYSP (D. Bortot)
10:30 – 10:45	Uncertainty in Monte Carlo simulation: the case of single moderator spectrometers (J.M. Gomez-Ros)
10:45 – 11.00	Patient neutron dosimetry with TNRD (M. Lorenzoli)
	Links beween EURADOS WGs and NESCOFI/NEURAPID
11:00 - 11:15	WG9. Radiation protection dosimetry in medicine (C. Domingo)
11:15 – 11:30	WG11. High energy radiation fields (A. Esposito)
11.30 – 12.30	D i s c u s s i o n
12:30 – 14:00	Lunch break (Buffet at Aula Conversi)
14.00 – 14.20	NEURAPID 2014: planned activity and milestones (R. Bedogni)
14.20 – 14:50	New conceptions of “thermal pile” (R. Bedogni, M.V. Introini)
14.50 – 15.15	Large Area Thermal neutron detectors (A. Pola)
15:15 – 16.00	D i s c u s s i o n

Short history

Years 2011 and 2012

Concluded with the final design of both spectrometers, the spherical SP^2 and the cylindrical CYSP, and choice and characterization of suitable thermal neutron sensors to be embedded in.

2013

Supposedly, building (September milestone) and testing (December milestone) at low & high Energy one active prototype per spectrometer.

Requested fund: 102 k€
Received fund: 51.5 k€

2013 Activity

CYSP

- ✓ *built (March)*
- ✓ *equipped with previously calibrated ATNDs (April)*
- ✓ *tested with ^{241}Am-Be at LNF (April)*
- ✓ *Test 144 keV, 565 keV, 2 MeV, 3.5 MeV, 5 MeV, 16.5 MeV and ^{252}Cf at NPL (November)*

See Davide and Jose Maria talks

SP^2

- ✓ *built (May)*
- ✓ *tested with ^{241}Am-Be at LNF (December)*
- ✓ *Test 14 MeV (Feb. 2014)*

See Davide talk

2013 Activity

TNRD development for medical applications

Contract with Seville University, see Michele talk.

III congreso conjunto SEFM-SEPR, Caceres

- *Nuevos instrumentos para espectrometria neutronica en tiempo real (invited)*
- *Use of a newly developed active thermal neutron detector for in-phantom measurements in a medical LINAC (poster)*

NEUDOS-12 (Aix), participation with Six papers directly or indirectly related to the collaboration (four oral)

- *Neutron energy spectra of the (p,n)Be reaction at 30 MeV (oral)*
- *Performance of a new active thermal neutron detector (poster)*
- *Design of two single exposure, multi-detector neutron spectrometers (oral)*
- *Use of compact thermal neutron sensors for neutron spectrometers (poster)*
- *Comparison of unfolding codes for neutron spectrometry with BS (oral)*
- *Neutron spect. and dosim. at the ithemba protontheraphy facility (oral)*

External funding

CRISP (LNF)	*detectors*
INFN-LNF (FISMEL)	*raw materials (polyethylene, etc.)*
Poli-Mi	*electronics*
Sevilla Univ.	*contract for providing in phantom dosimetry system based on TNRDs*

CSN V referee evaluation, Dec. 2013

"Hai davvero ragione nel ritenerti molto soddisfatto. E pure io, come revisore, lo sono" (P. Milazzo)

NEURAPID

NEUtron RAPId Diagnostics

(2014-2016)

LNF Unit

Roberto Bedogni Resp. LNF & Nazionale	*0.6 FTE*
J.M. Gomez-Ros Associato	*0.6 FTE*
B. Buonomo Tecnologo	*0.3 FTE*
A. Esposito Dir. Tecnologo	*0.2 FTE*
A. Gentile CTER	*0.4 FTE*

Milano Unit

Introini Maria Vittoria Associato	*0.5 FTE*
Lorenzoli Michele Associato dottorando	*0.3 FTE*
Pola Andrea Associato (resp. loc.)	*0.5 FTE*
Bortot Davide Associato dottorando	*0.5 FTE*

Objective

Developing instruments to measure neutron spectra in “emerging” fields, i.e. those fields where the neutron detection is made especially difficult:

(1) SPF (Single Pulse Fields): fs duration.
Produced when bombarding suitable gaseous or solid targets with ultra-intense (TW-PW) / ultrashort (fs) lasers.

- more than 10 order of magnitudes in neutron energy.
- expected fluence per pulse in the order of 10^2-10^5 cm^{-2}/shot.

(2) Very Low Fluence Fields: cosmic-induced neutrons at ground level

- continuous spectrum meV-GeV neutrons
- a very low fluence rate, in the order of 10^{-2} cm^{-2} s^{-1} (spectrum integrated)

This constraint opens serious problems of detector efficiency, especially when a complete spectrum measurement is expected to be performed in minutes, see detection of GLE (Ground Level Enhancement), impacting aircrew radiation protection and prevention of failures in electronic equipment of aircrafts.

Ultra intense laser

Neutrons may be produced in ultra intense lasers

Bombarding solid targets

Los Alamos press release, 4th June 2013: from TRIDENT laser (120 J, 500 fs, 250 TW) on solid deuterated plastic evidenced neutrons up to150 MeV.

DOE-Los Alamos launched research program on laser-based neutron interrogation for illicit traffic detection.

Photo-production

Multi MeV electrons produced in laser-plasma interaction on high-Z targets. (Planned experiments at FLAME @ LNF).

Open problems

(1) Physics: determining energy and angle dependence of laser-based neutron fields (*directional spectrometer needed*)

(2) Radiation protection: correctly measure single pulse doses (*isotropic response needed*)

Cosmic-ray induced neutrons at flight-altitude and at ground level

Cosmic-ray-induced secondary neutrons account for about 50% of the effective dose received by aircrew in commercial flights. Airlines use computer codes (EPCARD, HZM) to estimate doses to pilots and cabin crew.

Instruments needed to:

-validate computer codes like EPCARD

-measure in real-time possible rapid increase of radiation (solar activity-induced) with potential impact on pilots and cabin crew exposure.

HZM: permanent mountain station (Zugspitze 2650 mt.) with BSS for neutron measurements (EPCARD validation and data production for ground based neutron monitor database (www.nmdb.eu)

BUT: spheres do not distinguish “top-down” from albedo and scattered neutrons !

A directional neutron spectrometer does not exist and is anxiously expected

HZM endorsed Neurapid and offered support for logistics and accommodation.

Strategy

Given the scientific cases, four problems have been identified

Problem 1: simultaneously measure spectra meV-GeV, directional or isotropic
CYSP and SP^2 provide real-time spectrum on the desired energy interval and field geometries.
BUT: current ATND sensitivity is adequate to measure > μSv/h

Problem 2: measure single pulses
Expected fluence per pulse 10^2-10^5 cm^{-2}. New types of ATND that do not saturate but, ideally, linearly activate and re-emit in seconds: activation foils coupled with plastic scintillators or large area silicon detectors.
In (14 sec, 202 barn) or Dy (78 sec, 2640 barn)

Problem 3: measure very-low fluence rates (LATND needed)
Detectors with large area and/or large efficiency (scintillator foils, large area diodes or combinations)

Problem 4: Establishing a thermal column for LATND testing
- Large and uniform homogeneity area
- *Reasonably high thermal flux with low fast component*
- *Low gamma contribution*

Instruments and tools to be developed

Large Area Thermal Neutron Detectors for PULSED and COSMIC mode

LATND-C
LATND-P

A CYSP able to work in PULSED or COSMIC mode

CSYP is made of three pieces: the collimator, the detector capsule and the capsule shielding. Keeping unaltered the collimator and the capsule shielding, different capsules may be produced for COSMIC or PULSE modes.

SPEEDY

Spherical instrument with H*(10) response in pulsed fields. A simplification of SP^2, Equipped with one or few LATND-P.

ETHERNES

Suitable to test both LATND-P and LATND-C

Project breakdown

2014 (1) Monte Carlo design of:
- CYSP-C and CYSP-P
- SPEEDY
- ETHERNES

(2) Acquiring a ^{241}Am-Be (2.7 Ci ^{241}Am) for ETHERNES

(3) ETHERNES commissioning (1 tonn HDPE donated by UAB)
- Metrology with activation foils and mapping with TNPD
- 2D profile diagnostic (GAFCHROMIC screens)
- Thermal flux Standard transfer from NPL

(4) Feasibility experiments for LATND-P and LATND-C definition

2015 (1) Production of final LATND-P and LATND-C

(2) Calibration and testing in Ethernes, n@BTF, FLAME (others to be identified)

(3) SPEEDY, CYSP-C and CYSP-P fabrication

2016 Testing SPEEDY, CYSP-C and CYSP-P in:

(1) mono-chormatic at NPL for Energy response verification

(2) pulsed facilities (FLAME, ELI)

(3) Zugspitze mountain or similar

External interest

INFN	BTF & SPARC-lab facilities 12.5 k€ (partial support for Am-Be source)
NPL	Usage of neutron facilities
HZM	Zugspitze, logistics and accommodation
UAB	HDPE for ETHERNES
CIEMAT	EULER cluster for calculation
SPD S.p.A UniPisa UniSevilla	Contract for use of ETHERNES

Funding

Struttura	A carico dell'I.N.F.N.							
	missioni	consumo	trasporti	manutenzione	inventario	licenze-SW	apparati	spservizi	TOTA
LNF	6.50	34.00	2.50		4.50		8.00		**55.50**
MI	4.00	11.00			6.00				**21.00**
Totali	**10.50**	**45.00**	**2.50**		**10.50**		**8.00**		***76.50***

Received 100% of requests

Thank to 21.5 k€ anticipated to LNF:

- ^{241}Am-Be source purchased
- ETHERNES design

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New conception of "thermal pile"

(R. Bedogni, D. Sacco, M.V. Introini)

ETHERNES
Monte Carlo design

Why a new conception?

Thermal neutron fields in the range of 10^2-10^3 of $cm^{-2}s^{-1}$ are easily achieved in small cavities (few cm) within moderating assemblies embedding radionuclide neutron sources. This is normally suited for irradiating small samples like activation foils and TLDs.

Testing LATND require:

1) uniform field over larger a size in an open space, to allocate cables and associated equipment (up to a phantom) in addition to the sensor.
2) Low gamma background
3) Low fast neutron contribution

- Thermal fields in open spaces have been achieved by allocating large sources (tens of Ci) inside big moderating blocks (more than 1 m^3 of graphite or polyethylene).
- The leakage field can be used for testing and calibration purposes.
- Apertures in the direction of the point of test increase the flux but worsen the spectrum quality.

Existing (or recently decommissioned) source-based facilities with open space field

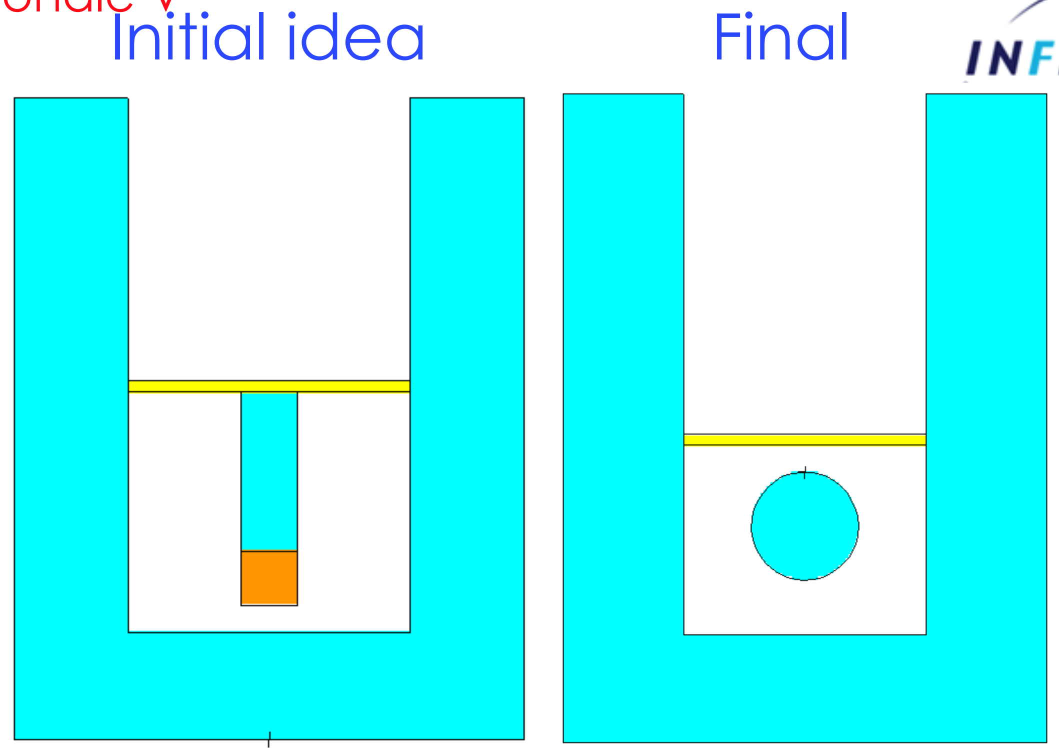
Facility	moderator	Flux (cm^{-2} s^{-1})	Am-Be (Ci)	Area	% th
SIGMA	8 m^3 graphite	1500	≈ 100	Few% in 30x30	88%
PTB	4 m^3 graphite	80	27	10% in 20x20	99%
ENEA Bo	1 m^3 HDPE	500	15	5% in 10x10	60%

- Need to achieve flux in the 10^2 -10^3 range with a single source smaller than 2.7 Ci - 100 GBq Americium (HASS exempted)
- Need for a large homogeneous area in open-space

Produce neutrons only by multiple scattering instead of transmission in a moderating block

Using Carles polyethylene to build a large cavity instead of a moderating block

•Separating the source and the irradiation plane only with a shadowing object
•Design neutron path so that only multiple-scattered neutrons may reach the POT

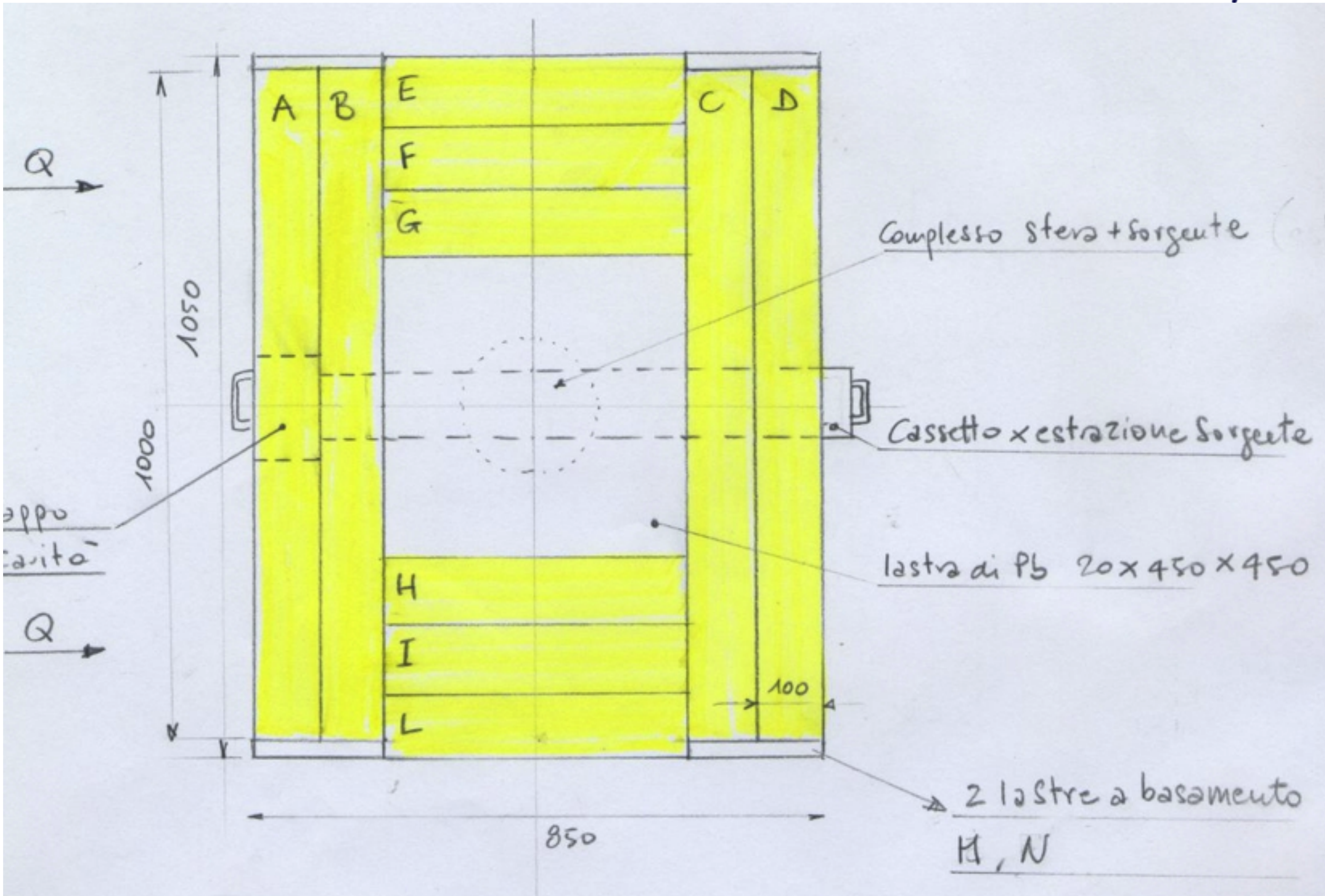


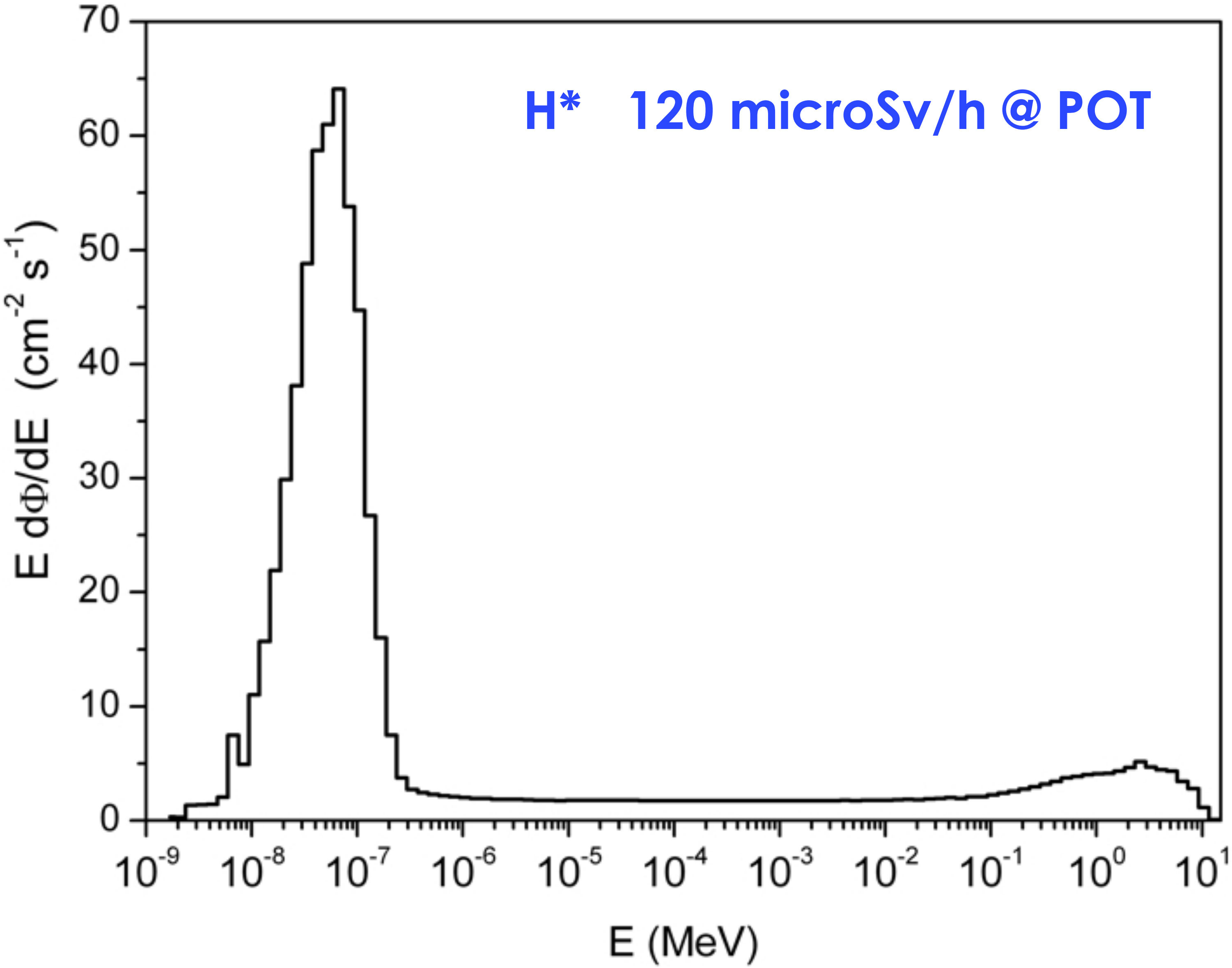
Unchanged details:

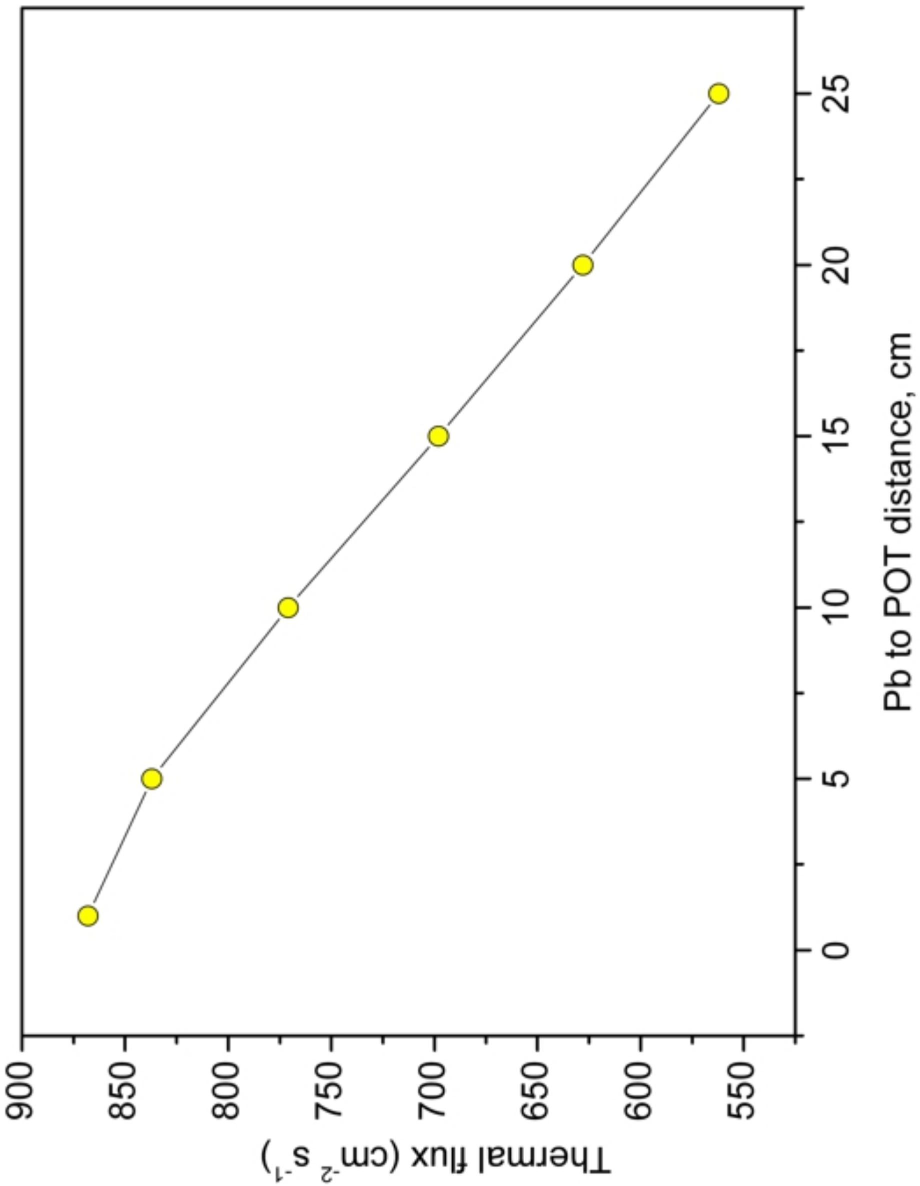
- Height 120 cm
- Square section
- 2 cm lead
- Base/walls 20 cm
- Source: 2.6 Ci

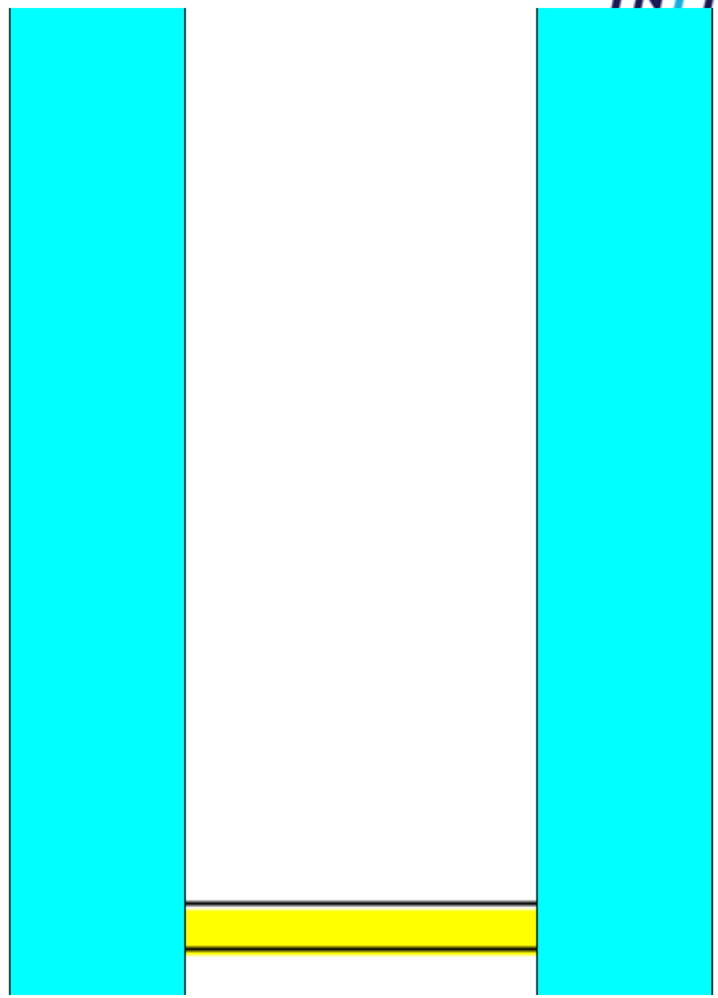
Base/walls, cm	**20**	**20**
Shadow object	10 Fe + 30 HDPE	20 cm diam. sphere
Useful cavity size, cm^3	50 x 50 x 53 h	45 x 45 x 63 h
Base to shadow distance, cm	5	10
Φ_{th} @ 5 cm from lead, $cm^{-2}s^{-1}$	400 or 75% of total Φ	837 or 74% of total Φ

Flux variation over 30 cm x 30 cm: ±2.5%

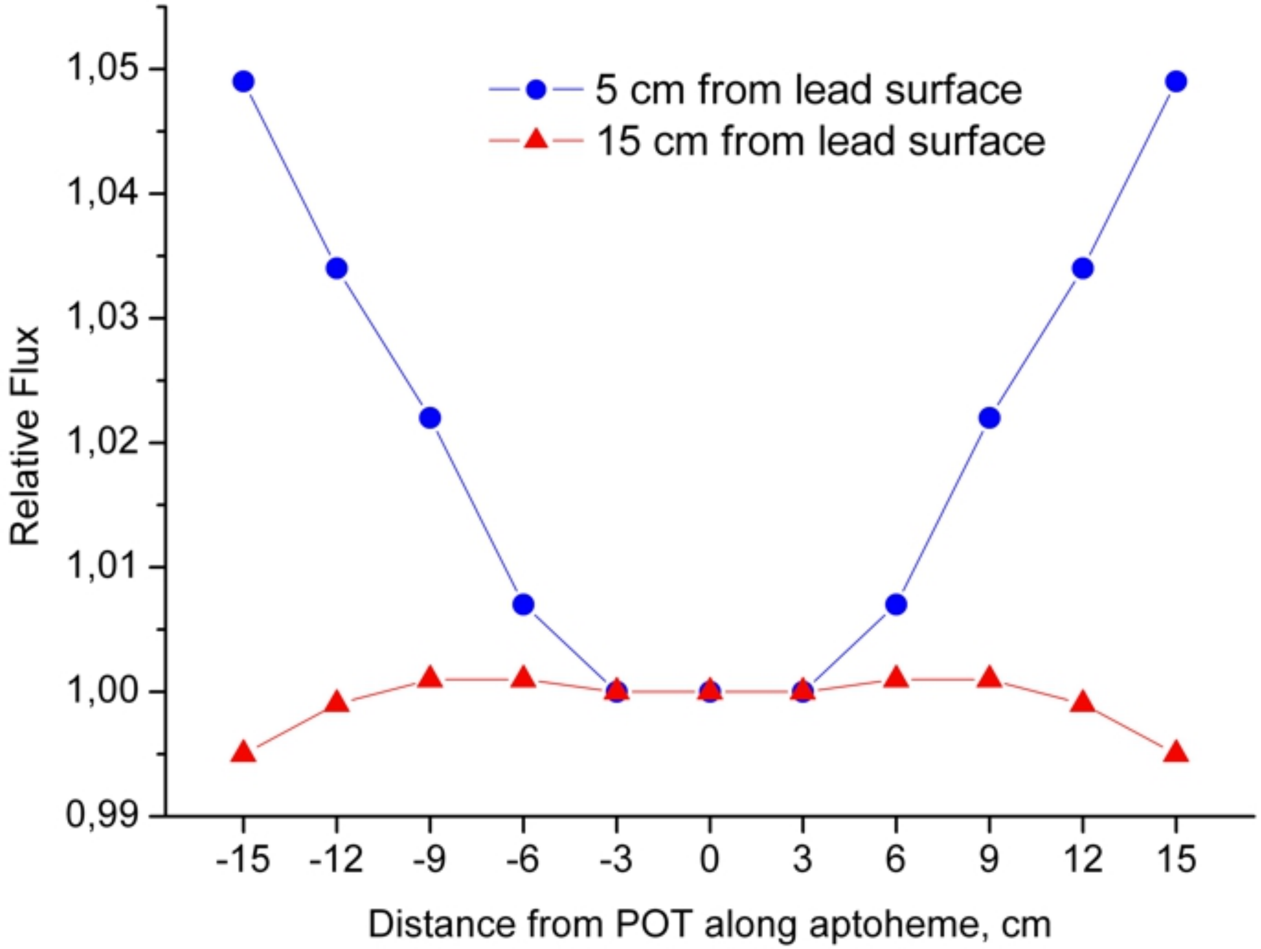

A
B
C
D
E
F
G
H
I
L
Q
Q
1050
1000
850
100
Complesso sfera + sorgente
Cassetto x estrazione sorgente
lastra di Pb 20 x 450 x 450
2 lastre a basamento
M, N


H*   120 microSv/h @ POT
E dΦ/dE (cm-2 s-1)
E (MeV)
0
10
20
30
40
50
60
70
10-9
10-8
10-7
10-6
10-5
10-4
10-3
10-2
10-1
100
101





Thermal flux gradient < 2% cm^{-1}



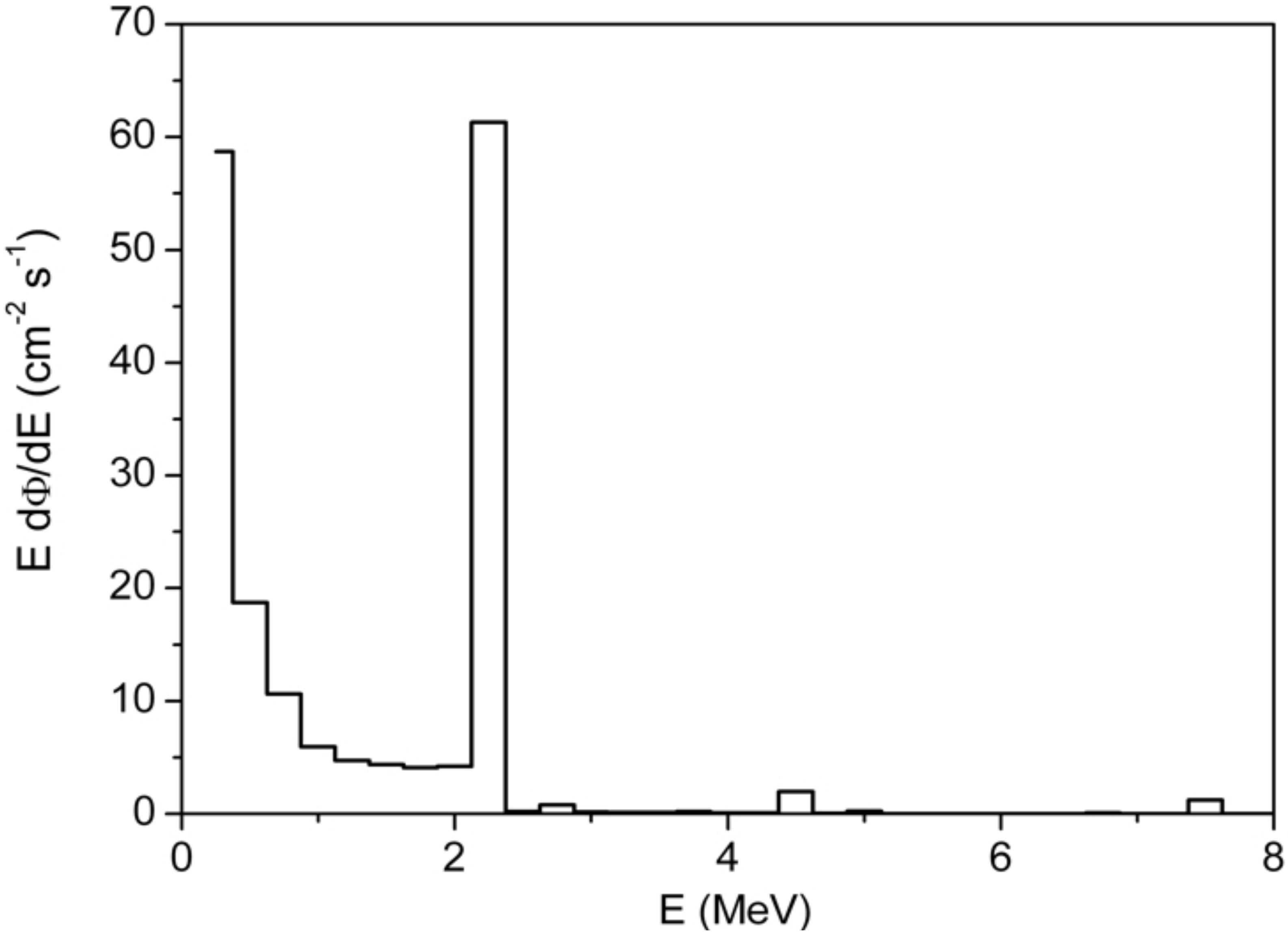
At 5 cm: thermal flux variation over 30 cm x 30 cm: ±2.5%
At 15 cm: < 0.25%

Effetto tappo (10 cm HDPE):

+80% in thermal fluence (1500 $cm^{-2}s^{-1}$)

Thermal fraction from 74% to 83%

GAMMA 3 microSv/h @ POT



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PoliMi thermal neutron facility

CINESO
cylindrical Neutron Source

NEURAPID Start up meeting INFN-LNF, 26-02-2014