brightness

Horizon 2020 grant agreement 676548

Source-Testing Facility
@Division of Nuclear Physics – LU

Sonnig

SOurce-based NeutroN Irradiation Group
Department of Nuclear Physics
Lund University

a user facility for neutron and gamma irradiation

Agenzia nazionale per le nuove tecnologie,
l'energia e lo sviluppo economico sostenibile

Developing a thermal neutron facility with uniform and extended irradiation area
HOTNES
HOmogeneous Thermal NEutron Source

Roberto Bedogni
(INFN-LNF)
Antonino Pietropaolo
(ENEA Frascati)

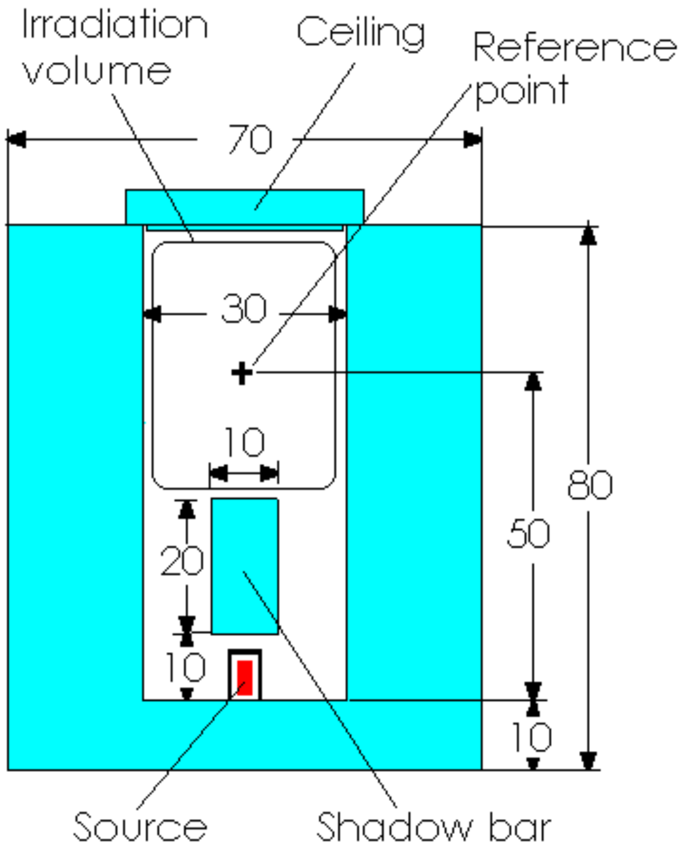
Lund University
14 December 2017

Talk breakdown

- Thermal neutron fields for metrology
- HOTNES concept
- Experimental features and reference metrology
- First HOTNES user program (2016)
- Conclusions and perspectives
- E-LIBANS project
- Frascati Neutron Generator (ENEA)

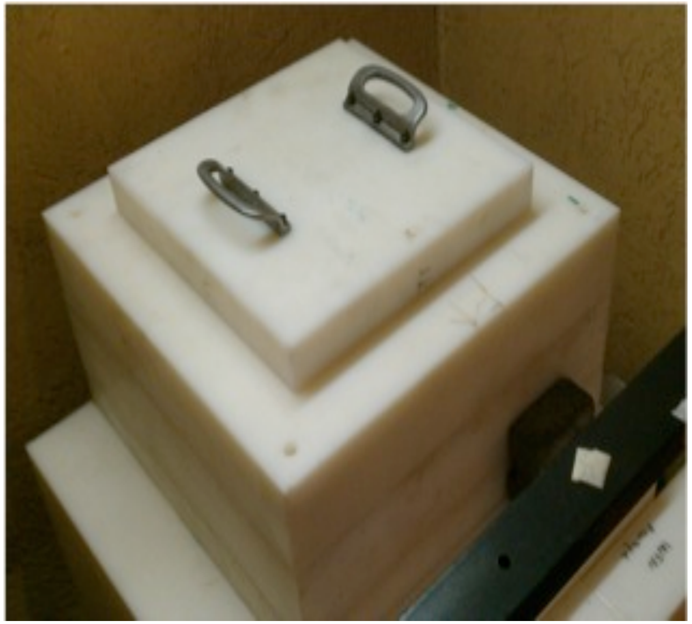
HOTNES concept

HOTNES new design exploits the **multiple scattering** in a large irradiation cavity, instead of the leakage field from a solid moderator block.

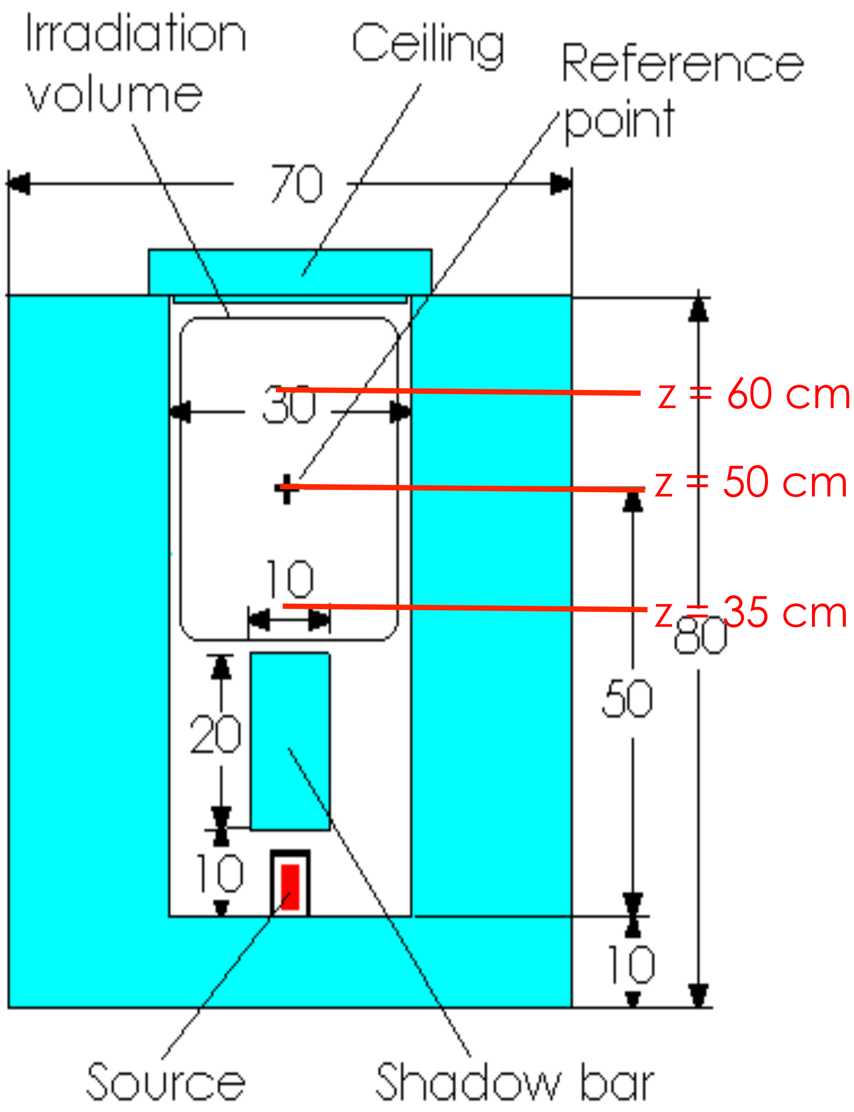


- Cylindrical symmetry
- Irradiation vol. 30 cm dia x 40 cm h
- Iso-fluence disks parallel to bottom
- Uniformity 1-2% on a disk
- Fluence rate can be changed by moving along the vertical axis (500 to 1000 $cm^{-2}s^{-1}$)
- Ceiling in/out governs direction distribution
- Few gammas (4-9 μSv/h)

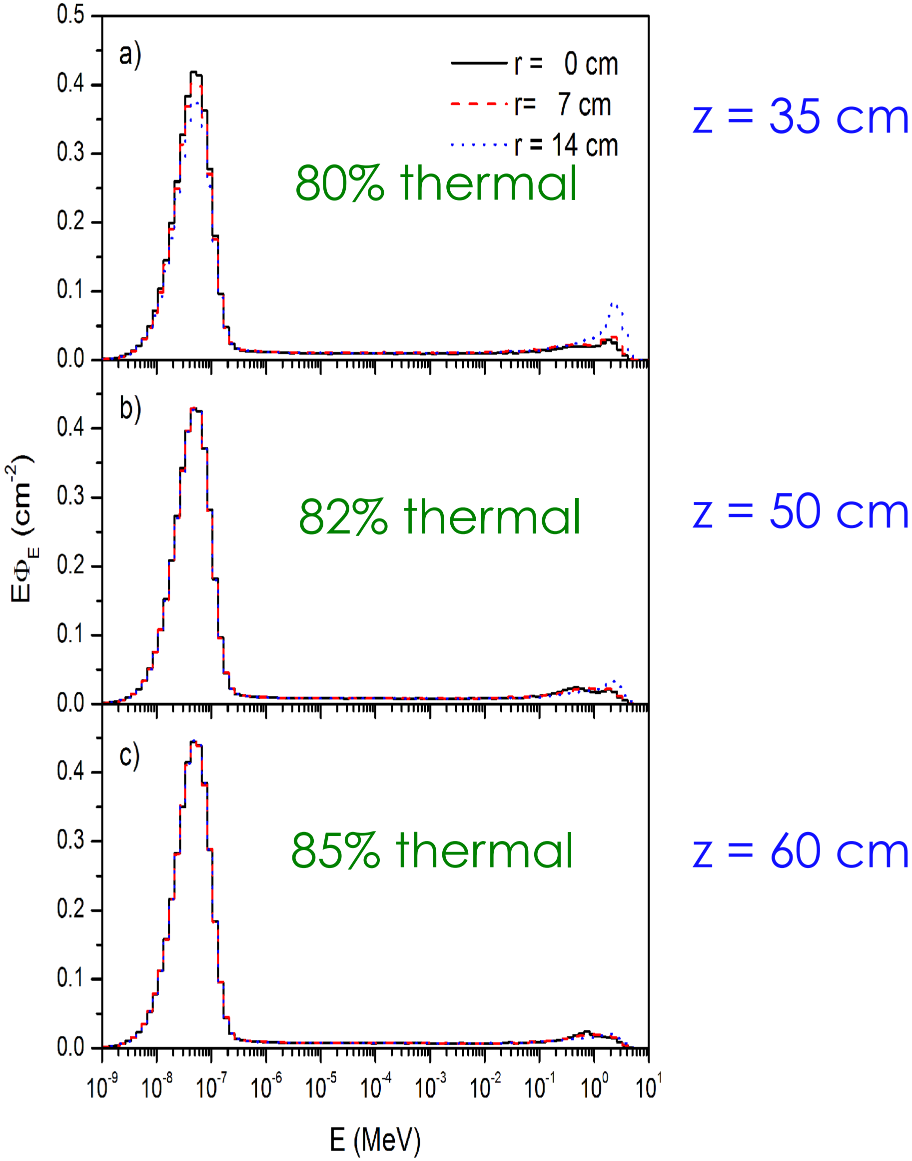
HOTNES built at ENEA Frascati



HOTNES spectra



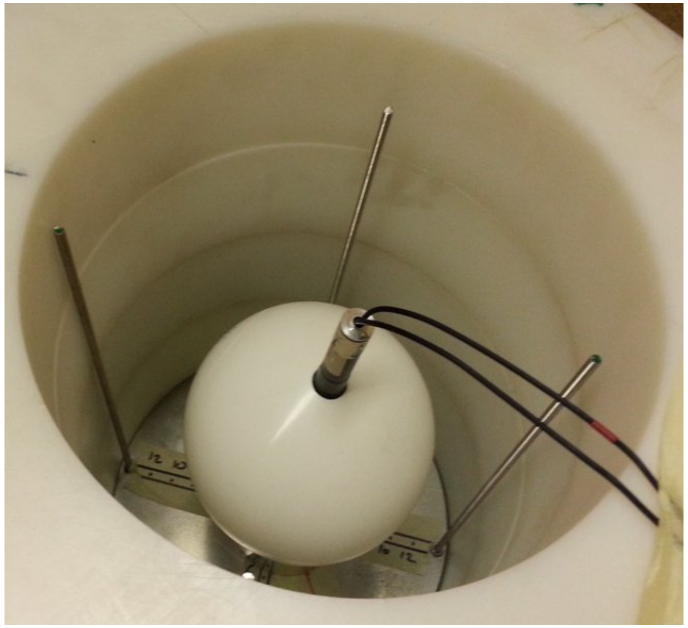
MCNPX

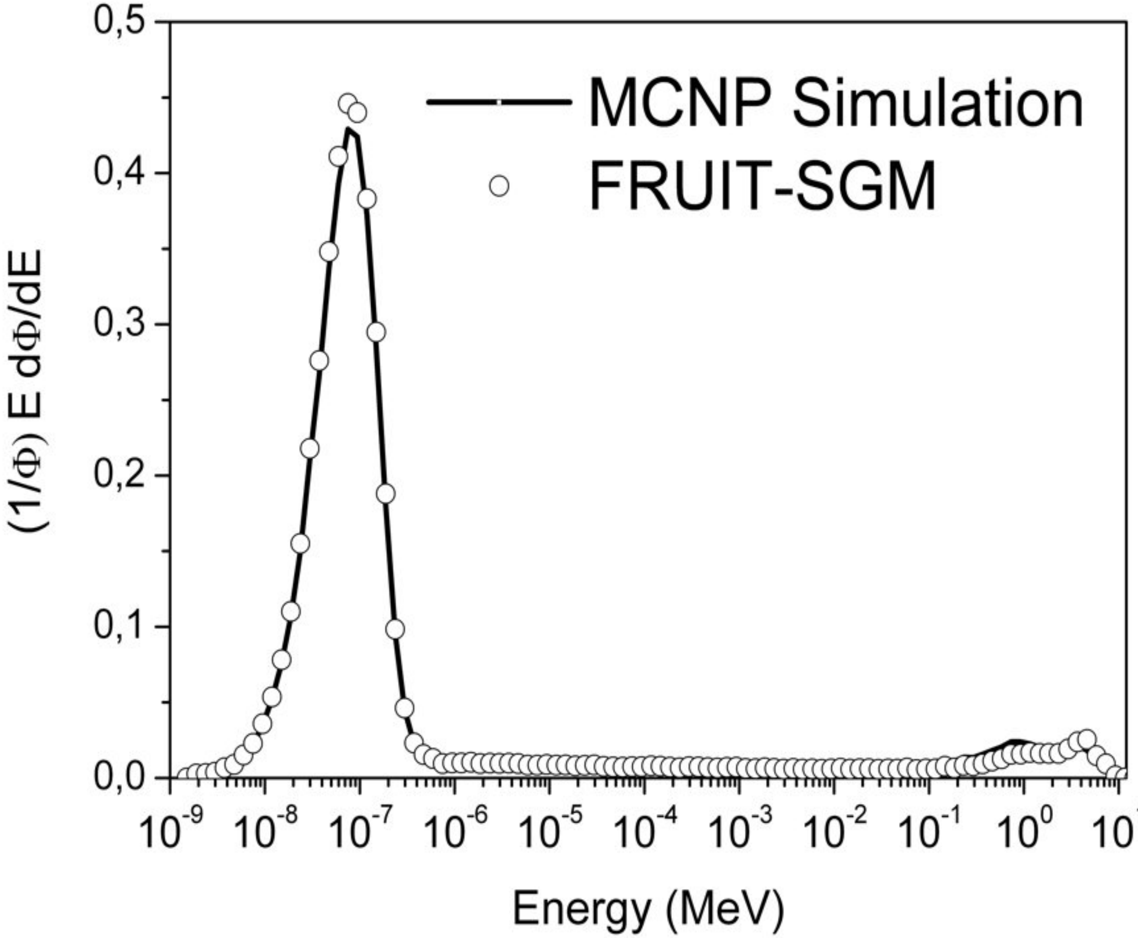


HOTNES spectra

Plane Z = 50 cm (cover in place)

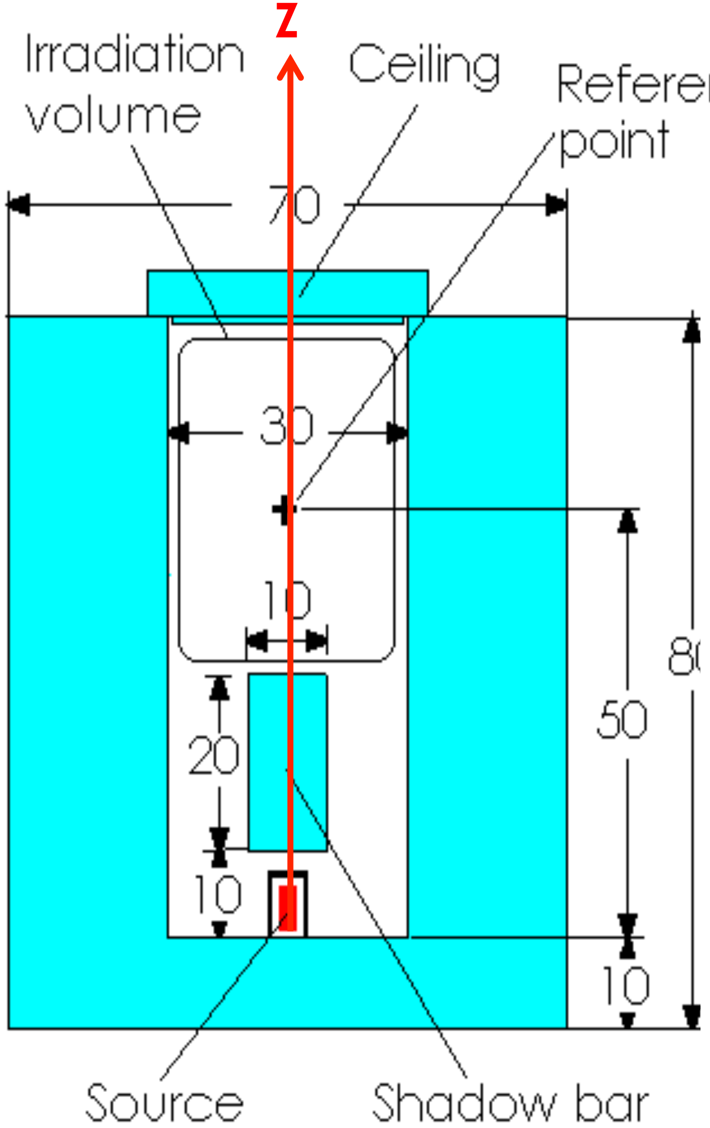
BSS with central detector $^{6}LiI(Eu)$



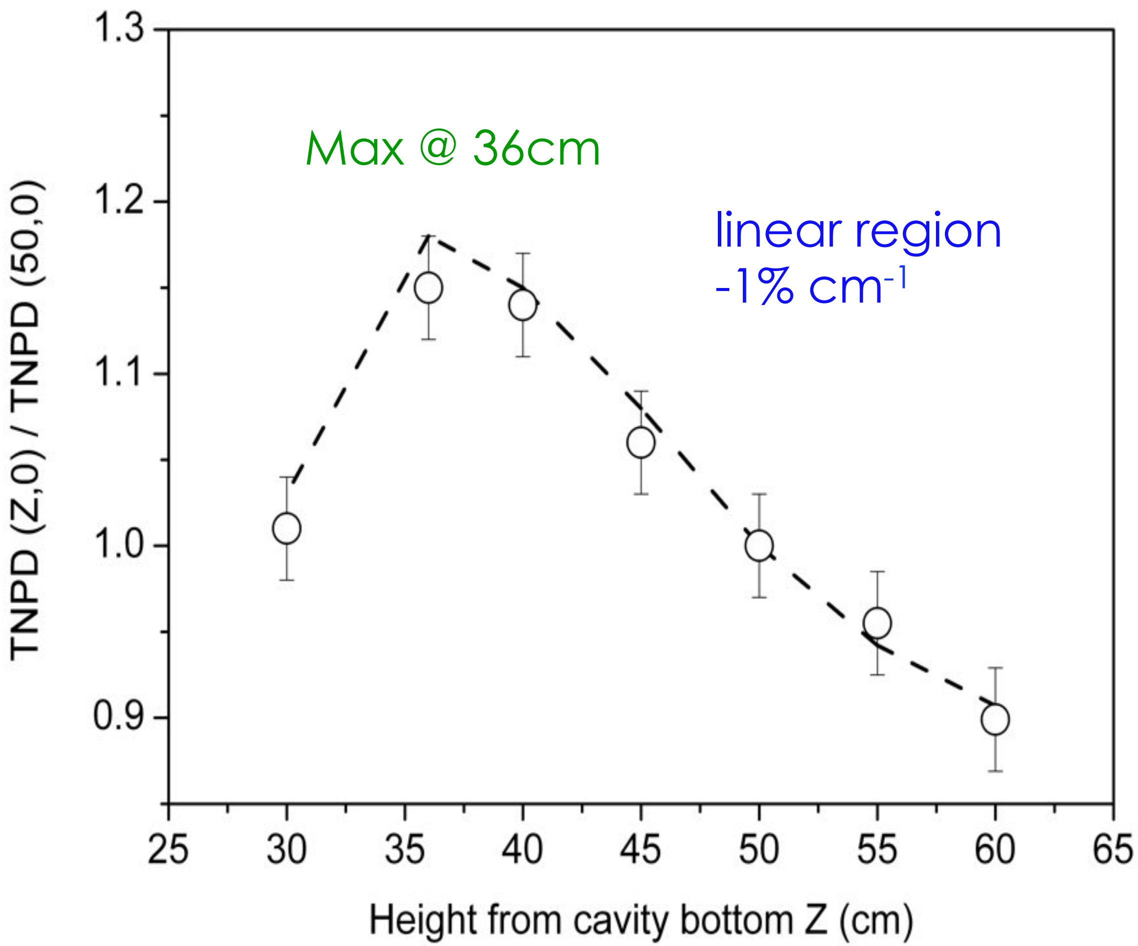


Gammas: from 9 μGy/h (30 cm) to 4 μGy/h (60 cm)

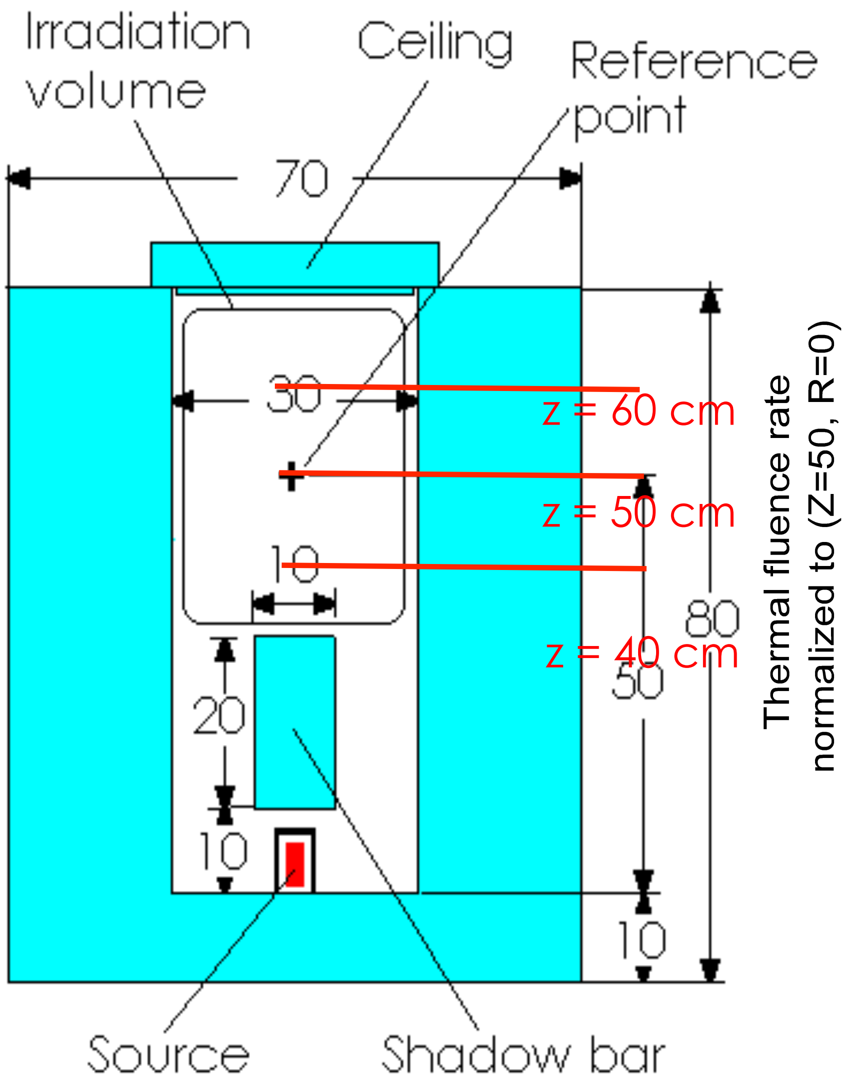
Vertical gradient



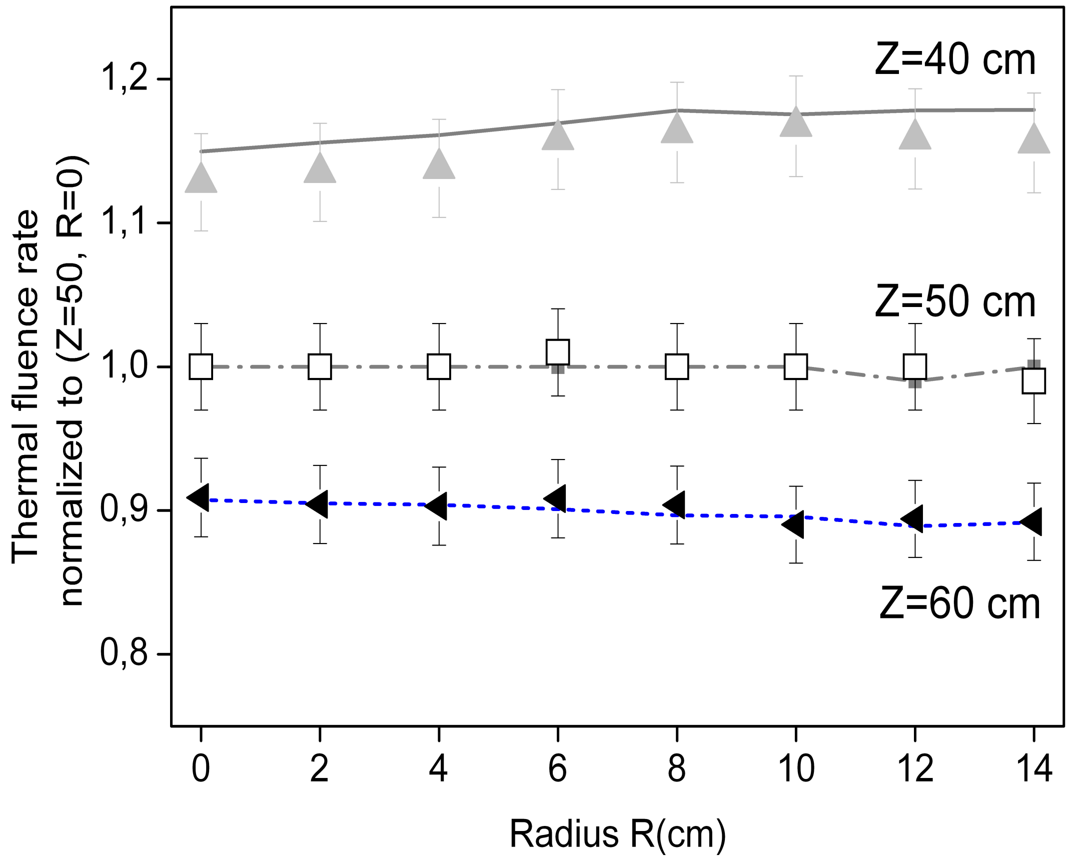
MCNPX vs. experiment



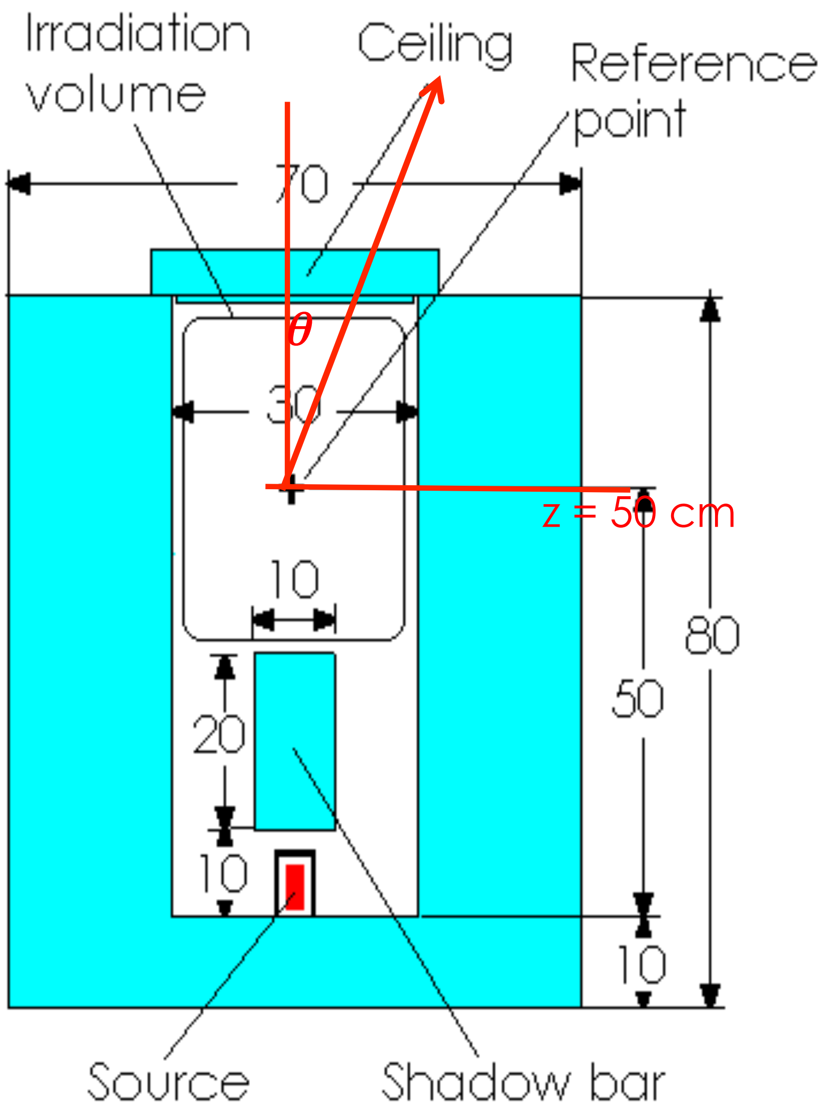
Radial distribution and uniformity

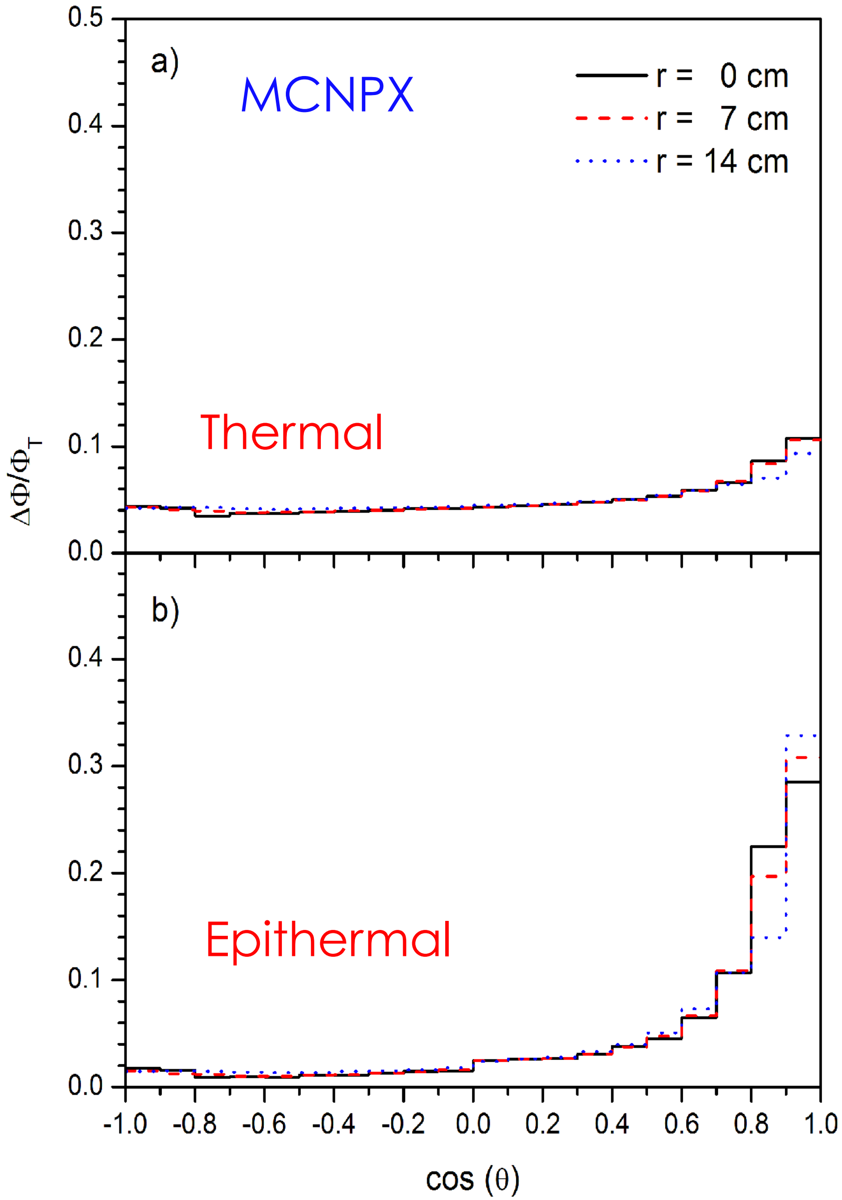


MCNPX vs. experiment



Direction distribution





Fluence rate measurements

Comparing thermal neutron fluence measurements in the large homogeneity area HOTNES facility

R. Bedogni, M. Angelone, A. Pietropaolo, M. Pillon, N.J. Roberts, M. Romano, P. Salvador-Castiñeira, O. Sans-Planell. D.J. Thomas, M. Treccani

Presented as a poster to NEUDOS13 (Krakow, May 2017)

Au foils with different diameter and thickness, irradiated with/without Cd, then counted at NPL and INFN-ENEA

NPL low-background beta counters (< 0.01 cps background)
INFN HPGe P-type 60% ORTEC Poptop Germanium

Common analysis considered:

- Incomplete thermal attenuation in Cd
- Epithermal attenuation in Cd
- Thermal attenuation in Au

Fluence rate measurements

Foil	Sub-Cd cut-off fluence rate in Westcott convention $\Phi_W(th)$ ($cm^{-2}s^{-1}$)	
	NPL	INFN-ENEA
50 μm x 1 cm^2	760 ± 7	748 ± 10
50 μm x 4 cm^2	746 ± 8	737 ± 11
10 μm x 1.77 cm^2		758 ± 14

Publications

- ARI 127 (2017) 68-72
- NIM A 843 (2017) 18-21

- Andrea Sperduti Master Thesis (Tor Vergata University, Roma), now ph.D. student in Uppsala Univ "*Characterization of Homogeneous Thermal Neutron Source HOTNES*"

HOTNES users program 2016

Involved Institutions

- INFN Frascati, Italy
- INFN Torino Italy
- Universitat Autonoma de Barcelona UAB, Spain
- CIEMAT, Madrid, Spain
- Universidad de Sevilla, Spain
- Politecnico di Milano, Milano, Italy
- Universitat Rovira i Virgili Tarragona, Spain
- Science and Technology Facilities Council ISIS facility, UK

Results of the first user program on the Homogenous Thermal Neutron Source (JINST, in press)

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HOTNES users program 2016

Tested devices

- Cadmium Zinc Telluride (CZT)
- Lithium glass scintillation detectors
- Single crystal diamond detectors
- Gas Electron Multipliers (GEM)
- Thermal Neutron Rate Detector (TNRD)
- High purity Cesium Iodide (CsI)

Conclusions

- New design of thermal pile with extended and homogeneous field in a large cavity
- Simple design and well-established metrology
- Few source neutrons needed to yield unit thermal flux
- Simple method to vary the flux
- Different field geometries with/without cover
- Few gammas
- Low cost (when a source is available)
- Neutron community "triggered"
- 1st user programme (2016)

Intense thermal neutron field from a medical-type LINAC: the E_LiBANS project

E_LiBANS: Electron Linac Based Actively monitored Neutrons Source

Proj. leader: Marco Costa (Torino University and INFN)
Roberto Bedogni (INFN)
Valeria Monti (Torino University and INFN)
and the e-LIBANS team

The collaboration

Torino University and INFN Torino
M. Costa, N. Amapane, E. Durisi, M. Ferrero, V. Monti, M. Ruspa, L. Visca, A. Zanini

Trieste University and INFN Trieste
G.Giannini, D. Treleani, M. Vascotto, K. Alikaniotis

INFN-Frascati
R.Bedogni, J.M. Gomez-Ros, M. Treccani, O. Sans-Planell

Politecnico Milano
A.Pola, D. Bortot, L. Garlati, A. Porta

San Luigi Hospital and San Giovanni Bosco Hospital
S. Anglesio, U. Nastasi

Elekta srl
Cristiano Cavicchi, Dario Carità, Augusto Saletta

Background

Building intense thermal (2017) and epithermal (2018) sources based on a medical LINAC.

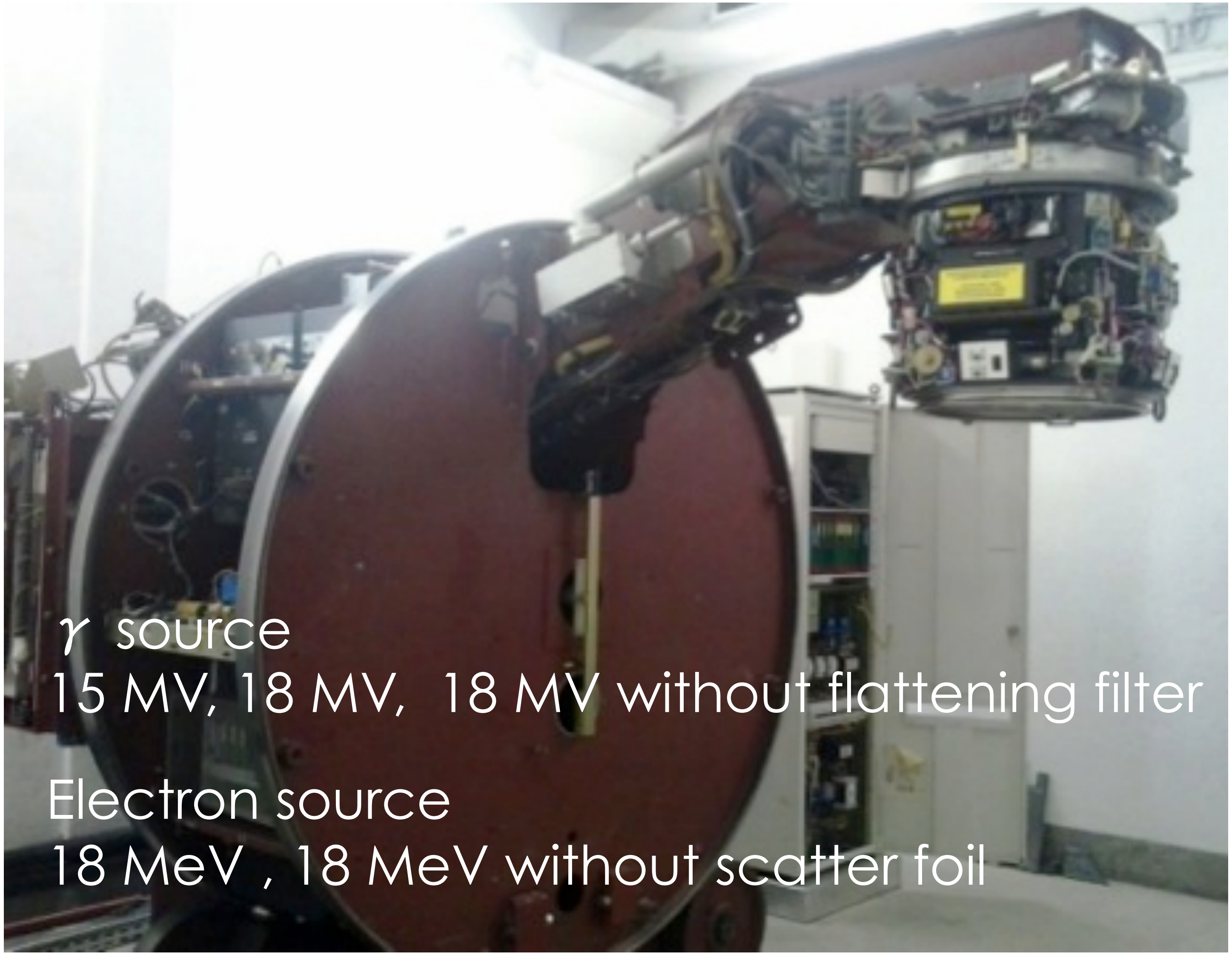
- Tunable source (Linac current and Energy)
- Well-established metrology
- “Large” and tunable cavity (up to 30x30x30 cm)
- Known and limited gamma field (17 mGy/h at max N yield)
- Thermal fluence rate up to 2E+6 $cm^{-2}s^{-1}$

Applications: BNCT preclinical, Material studies, Neutron diagnostics development, Instruments calibration

Electron LINAC ELEKTA SL18/PRECISE installed and commissioned at Torino University in July 2016.

Contributing Institutions

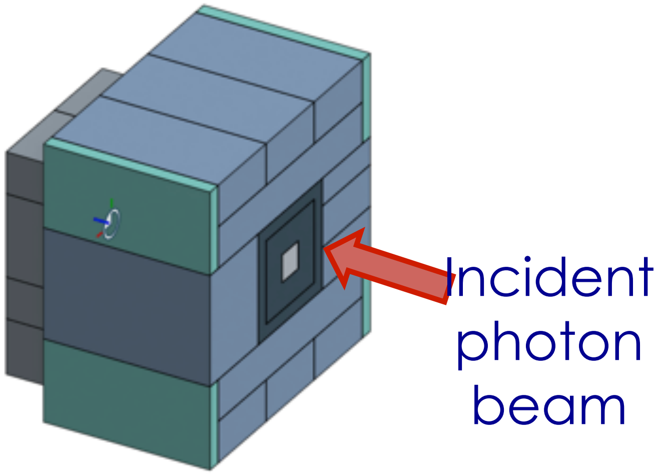
The machine



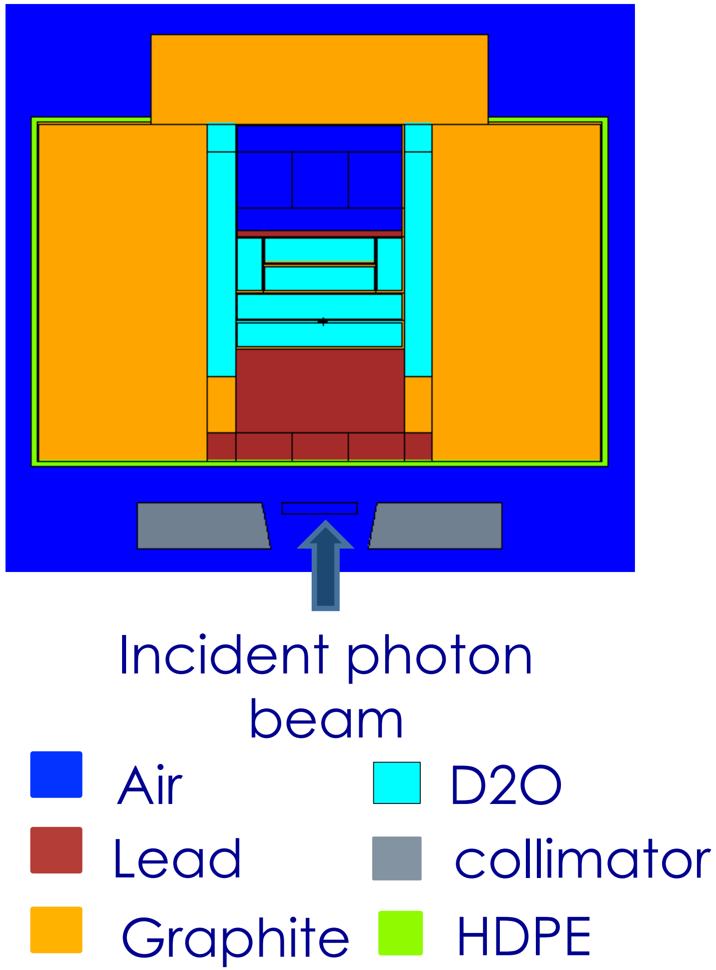
γ source
15 MV, 18 MV, 18 MV without flattening filter

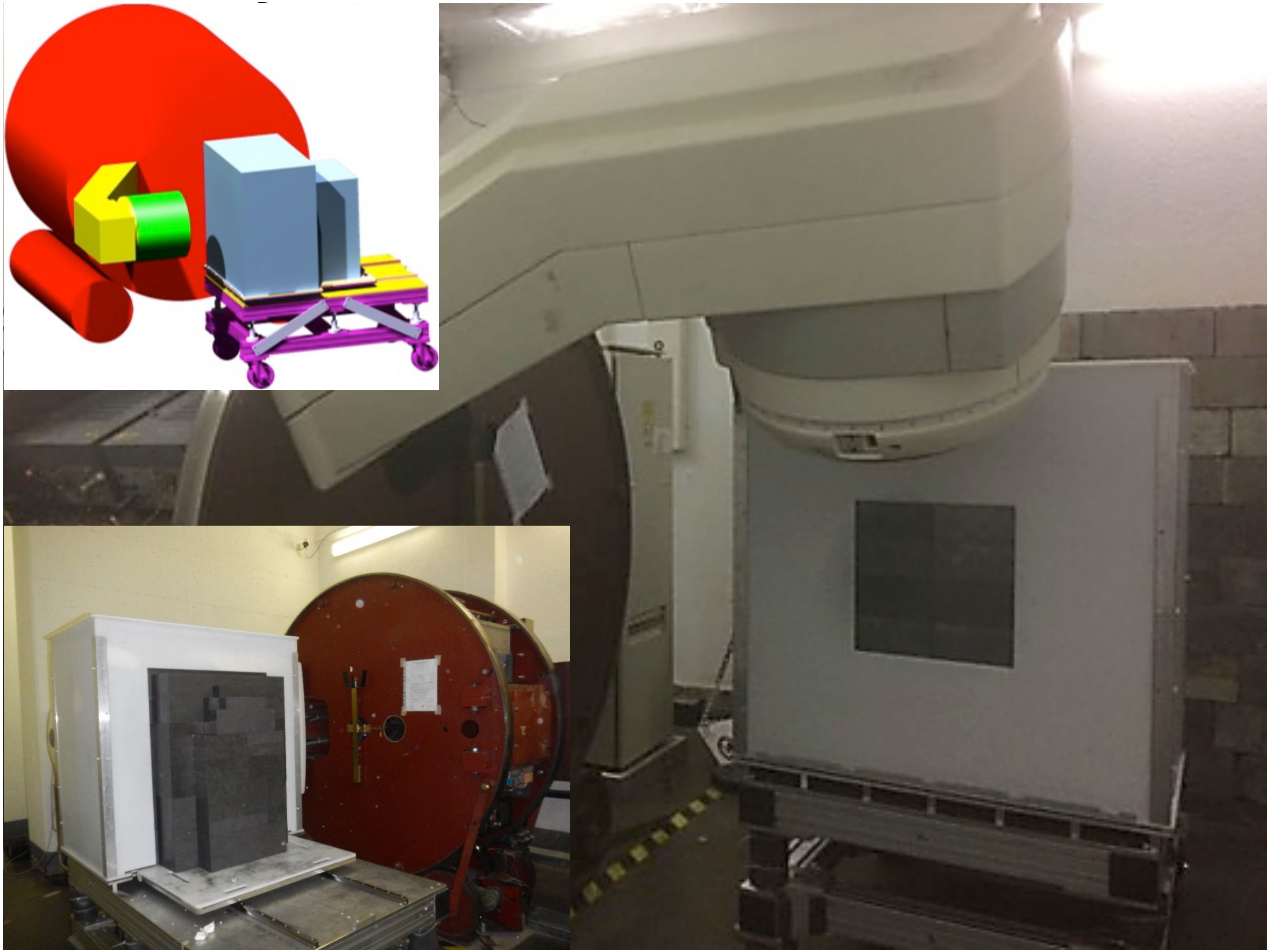
Electron source
18 MeV , 18 MeV without scatter foil

The photo-converter (MCNP6)



- **Pb** → N production/gamma shield
- **D_2O and Graphite** → moderation and reflection
- **Tuneable cavity**
- **Total weight c.a.1600 kg**

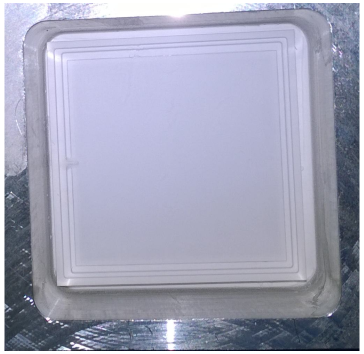


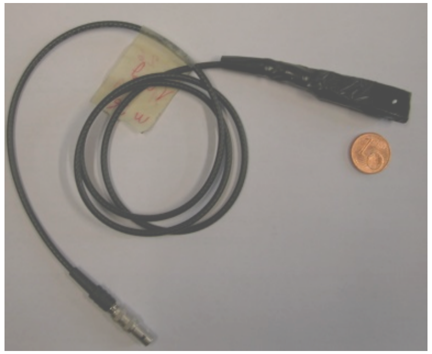


Detector development: the TNRD

Developed by chemical deposition of ^6LiF on commercial Si p-i-n diodes.

- In-house process
- Very reproducible (few %)
- Satisfactory n/g
- Low-cost

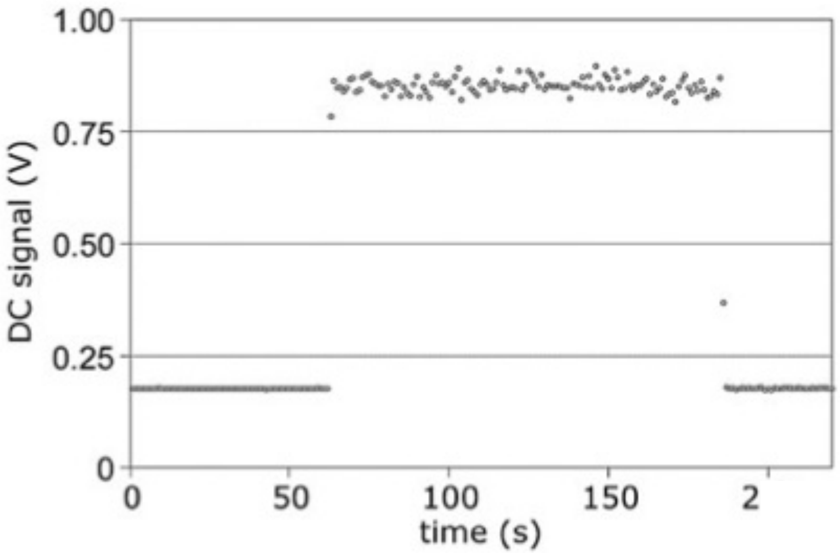




Readout

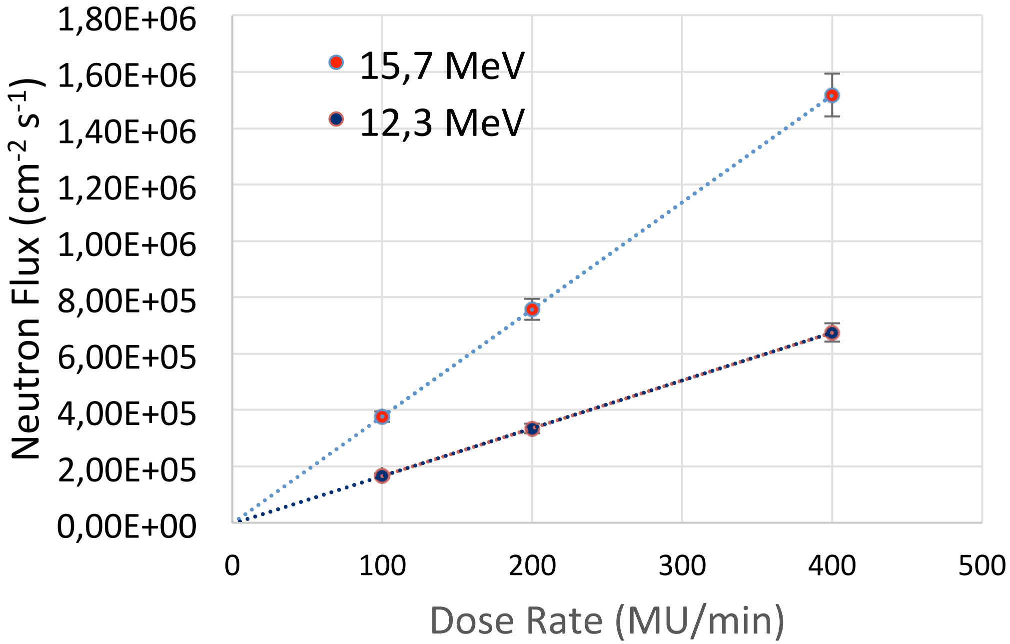
- Custom, low-cost, multi-detector, analog board
- Current readout
- Impressive linearity ($10^2 - 10^6$ $cm^{-2}s^{-1}$)
- Slow digitizers
- LabView-based acquisition software

Detector development: the TNRD



TNRD operation
Radiat. Prot. Dosim. (2014) 161 241-244

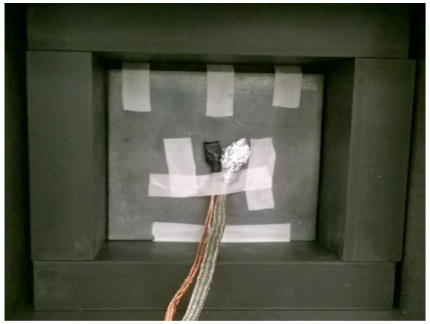
TNRD linearity in E_LIBANS cavity

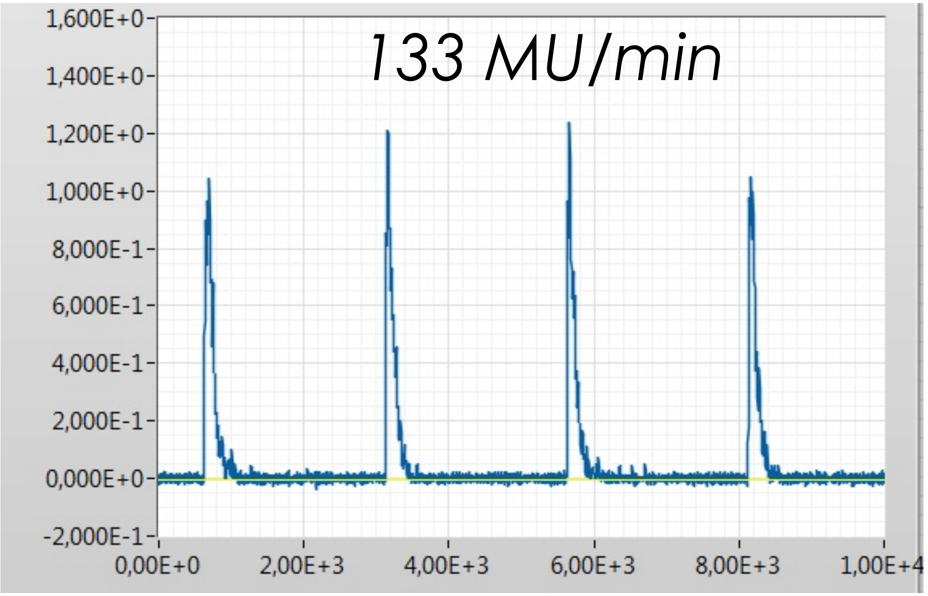


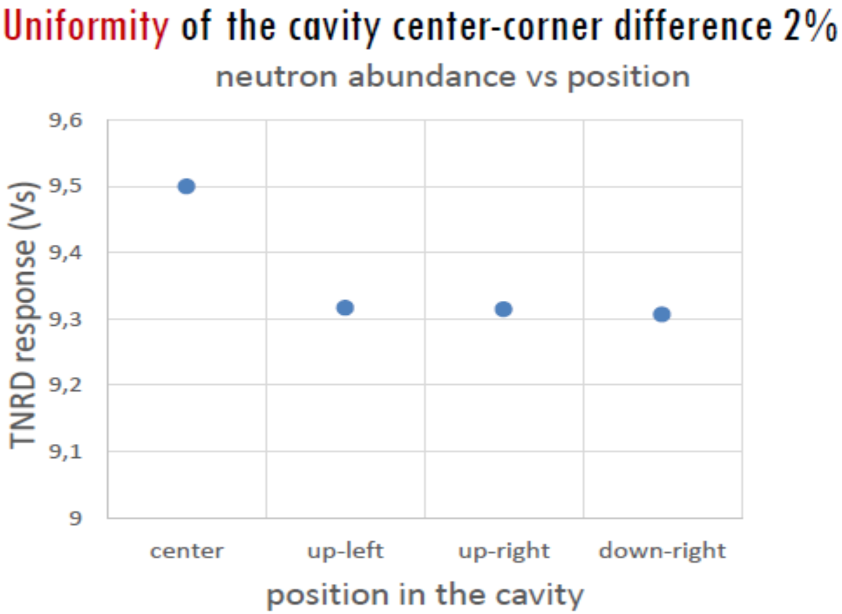
TNRD in E_LIBANS

TNRD useful for:

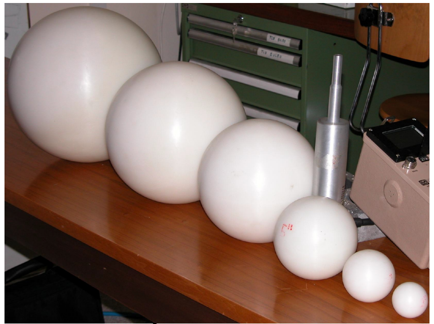
- Absolute fluence rate measurements
- Spatial mapping
- Studying time structure
- BSS spectrometry

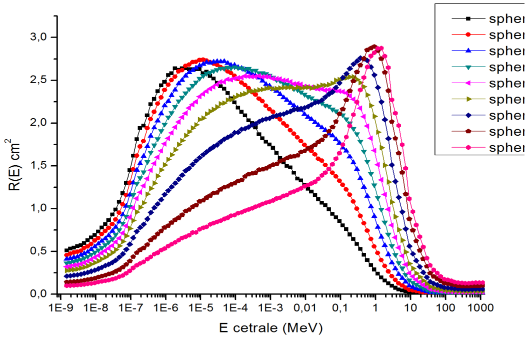


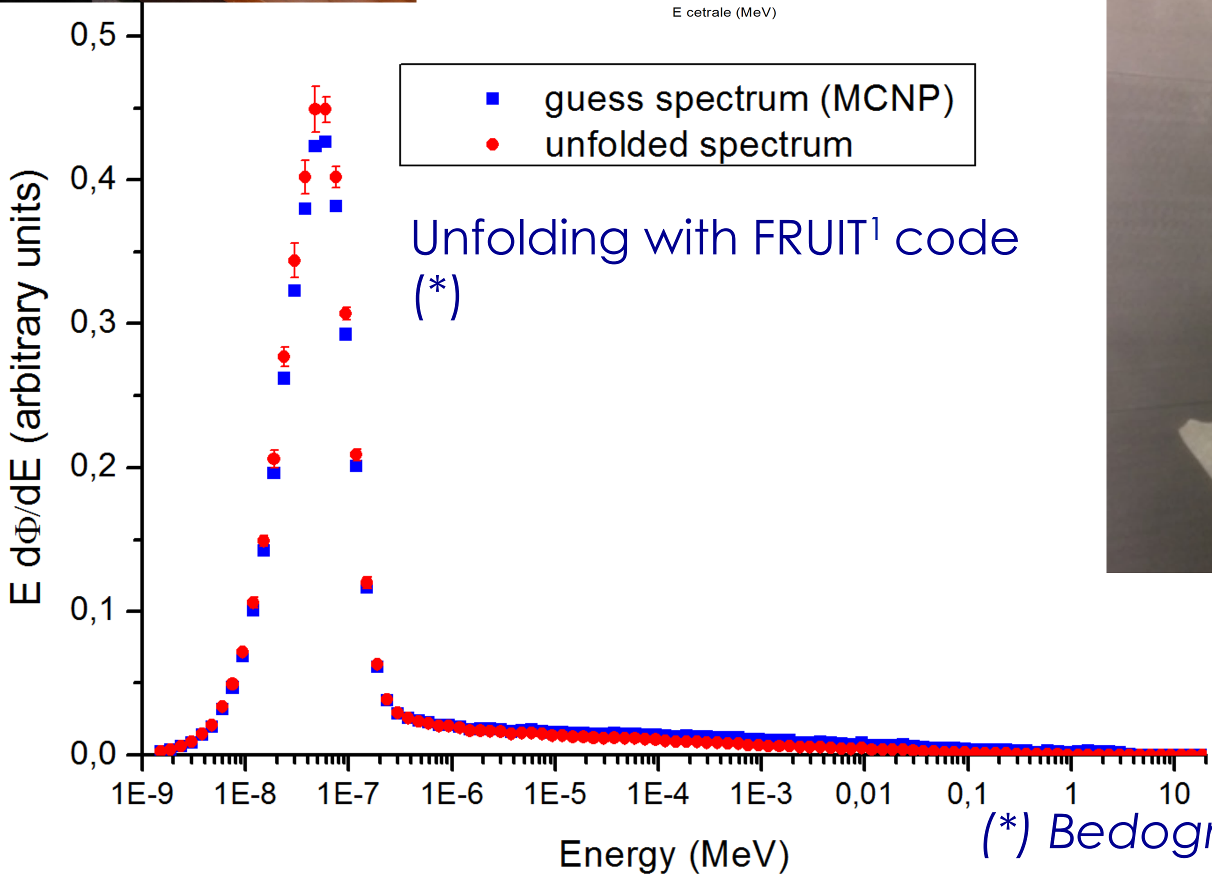




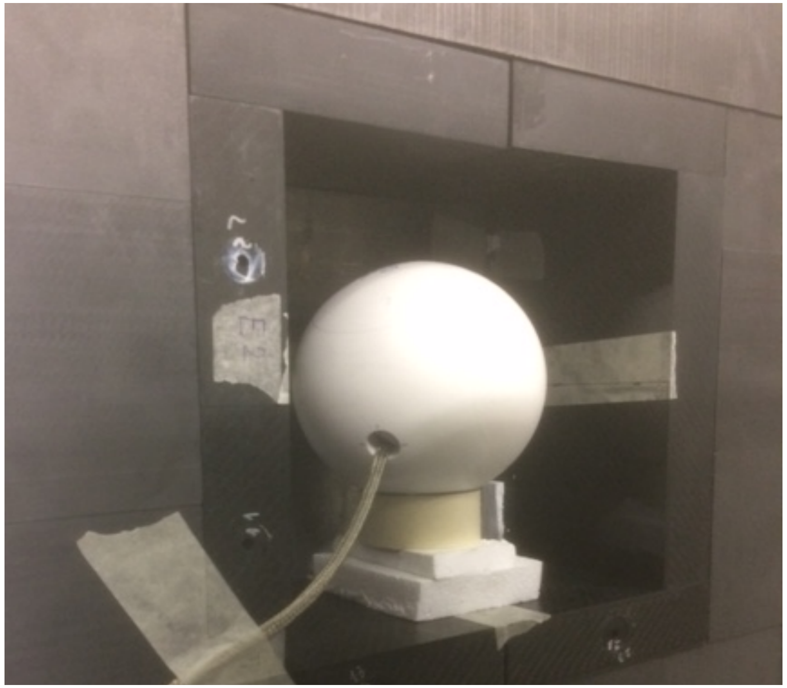
TNRD-BSS for spectrometry







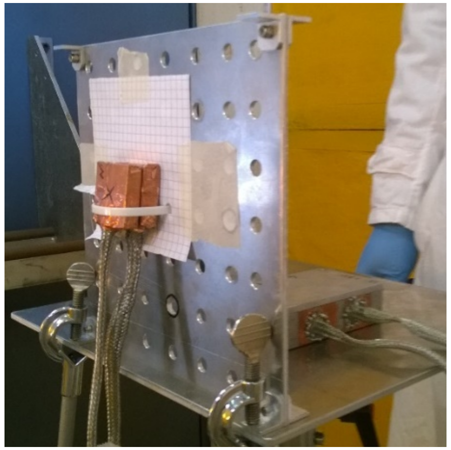
Unfolding with FRUIT[1] code (*)

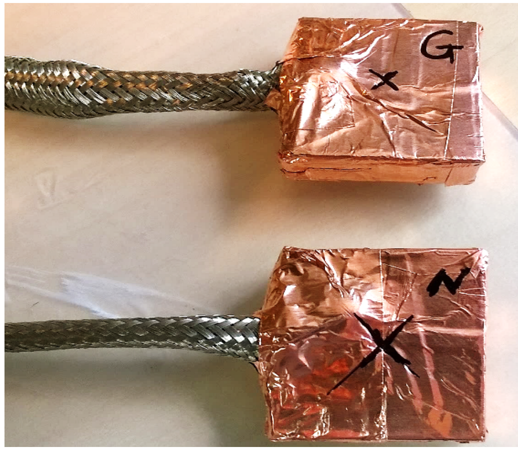


(*) *Bedogni et al NIM A 580 (2007) 1301*

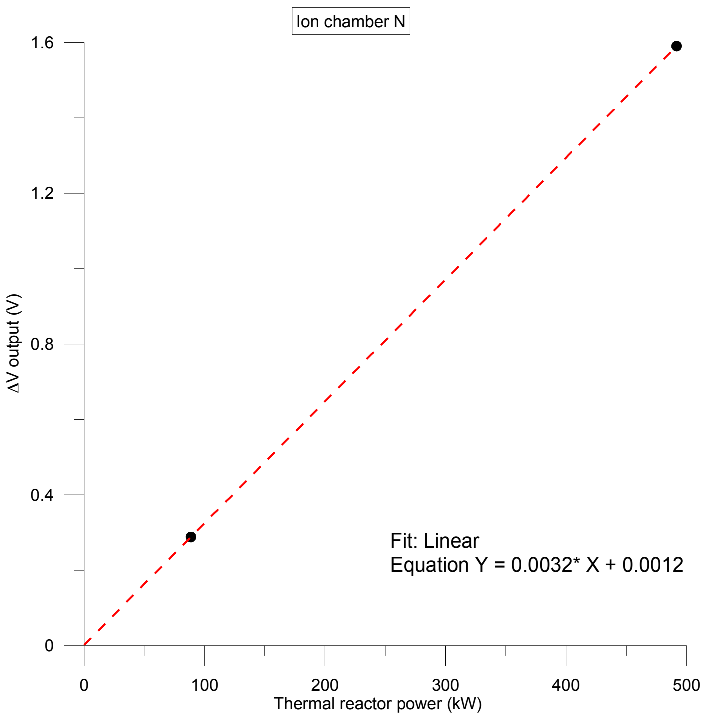
Resistant detectors: twin ion chambers

- Sensitive Vol ≈ cm^3
- In-house neutron sensitization (6LiF deposition) on the Neutron one. No deposit on the G one
- 200 V bias



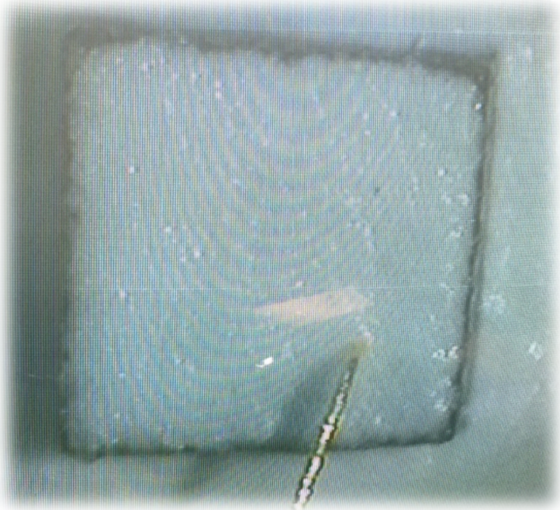


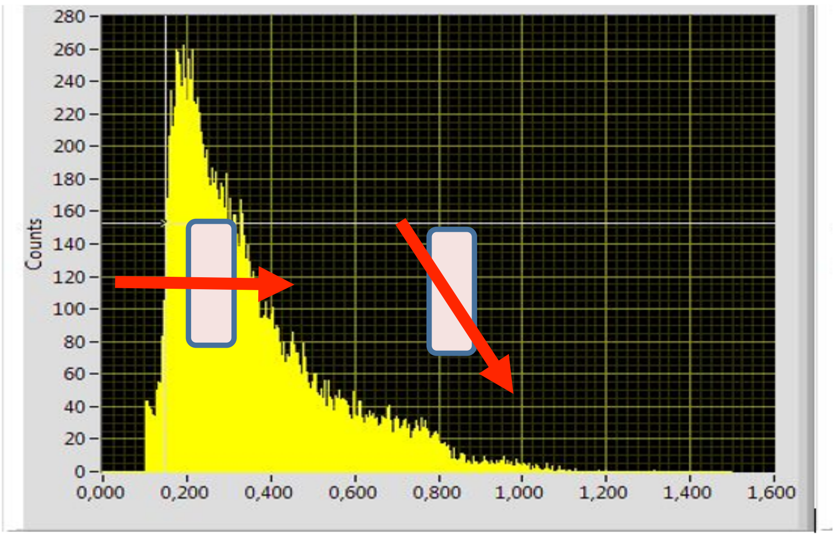
Calibration at TRIGA reactor (ENEA)

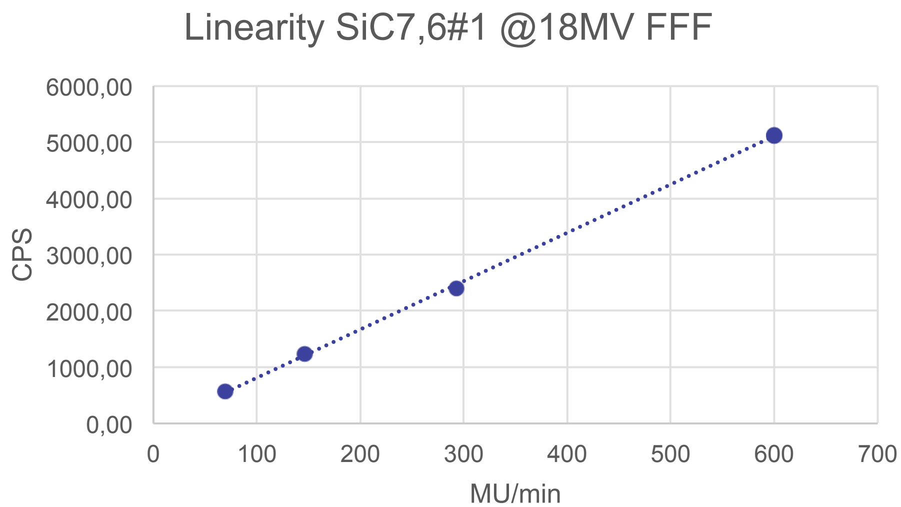


Resistant detectors: Silicon carbides

- 1 to 8 mm^2
- Minimal sensitive layer (1-3 μm)
- In-house 6LiF deposition
- Current or pulse mode



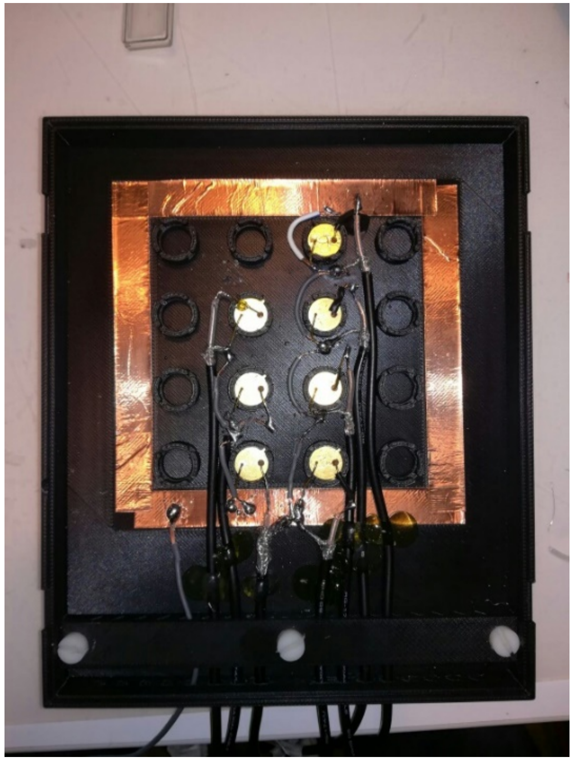




Silicon carbides 2D array

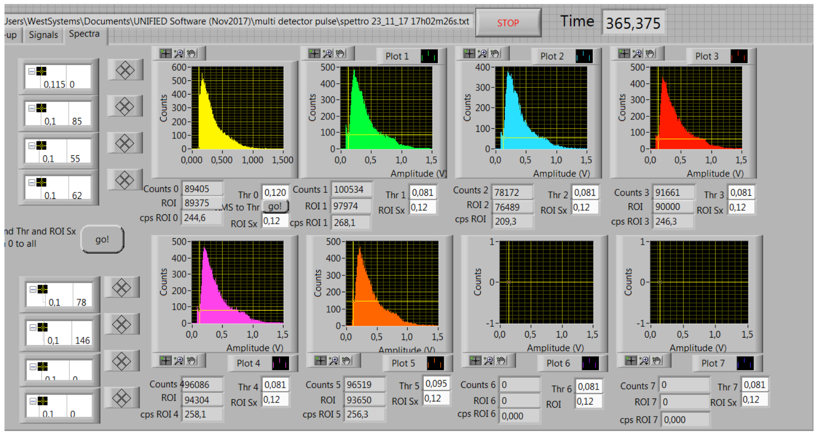
- 16 7mm^2 SiC with ^{6}LiF layer in a matrix 15x15 cm2 (INFN-LNF design)
- Parallel acquisition
- Current mode and pulse mode

Irradiation of the matrix in Elibans thermal cavity



Matrix structure with 7 SiC

Multichannel acquisition software



Conclusions

- Thermal and (in next future) epithermal neutron source available for detector testing, material and biology studies
- Thermal neutron beam up to $2.2*10^6$ cm^{-2} s^{-1} with
  - low gamma and fast N contamination
  - good spatial uniformity (5%)
  - Highly thermalized spectrum (83%)
- Well-established metrology
- New detectors development
- Thermal source available as user facility

THANK YOU