Workshop on accelerator based neutron production
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Neutron spectrometry from thermal to GeV with single-moderator instruments: the *NESCOFI project*

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NESCOFI@BTF (2011-2013)

Funded by the INFN-CSN V

Goal

Providing devices for "real-time" spectrometry of neutron producing facilities over the whole energy interval of production (eV - GeV) with similar measurement performance as the Bonner spheres.

Condensing the characteristics of a BSS in TWO single moderator devices embedding multiple active thermal neutron detectors:

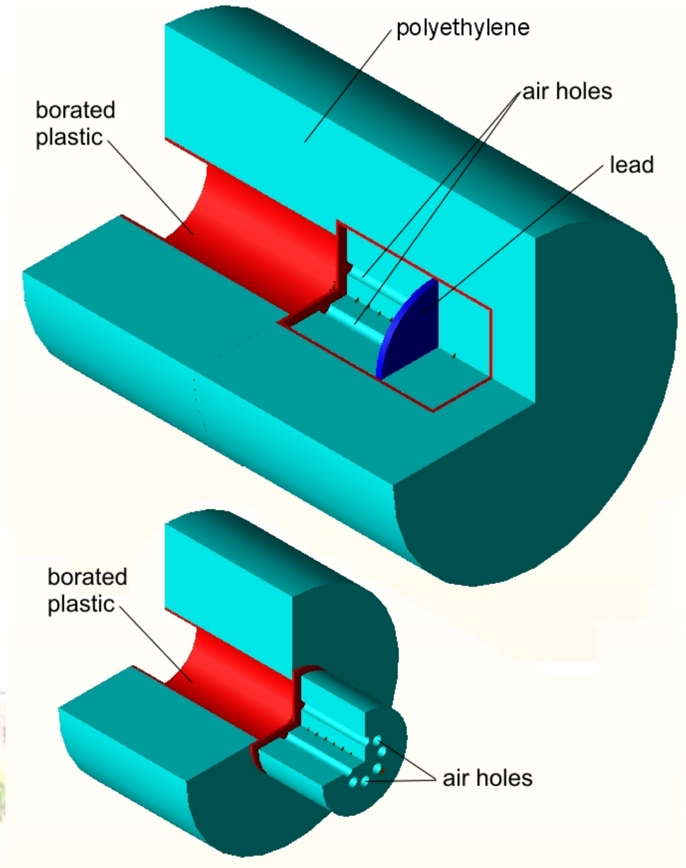
CYSP *Directional spectrometer*

SP^2 *Spectrometer with isotropic response*

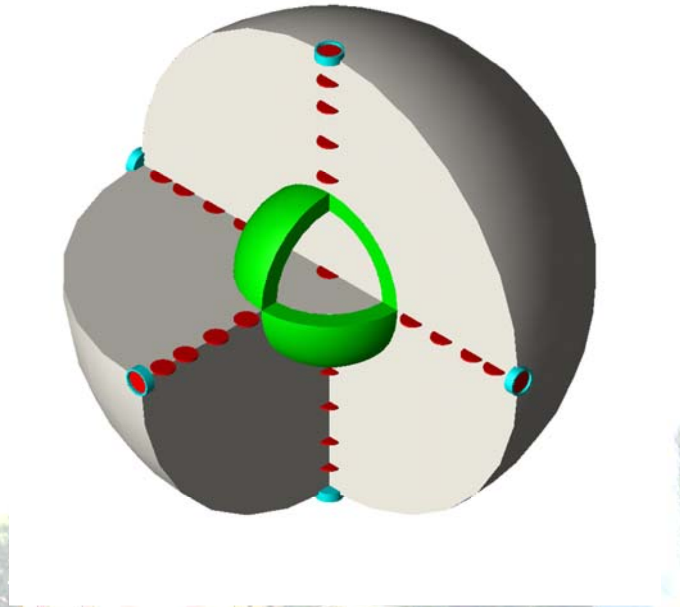
Fields of application

Research accelerators, industry, medical, homeland security, cosmic rays measurements

CYSP - CYlindrical SPectrometer



SP^2 - SPherical SPectrometer



Year "one" (2011)

- Theoretical design of SP^2 and CYSP, response matrix calculation (MCNPX 2.6)
- Manufacturing prototype operating with passive detectors (Dy activation foils) for response verification purposes.
- Experimental verification of the response matrix with quasi mono-energetic neutron fields (ERINDA program 2011)

Year "two" (2012)

Developling active TNDs and dedicated acquisition system with following constraints:

(1) Miniaturization (≈1 cm)
(2) Sensitivity such to allow responding from $\mu Sv/h$ to Sv/h
(3) Excellent photon rejection
(4) Low-cost (31 TNDs in a single spherical device)

Year "three" (2013)

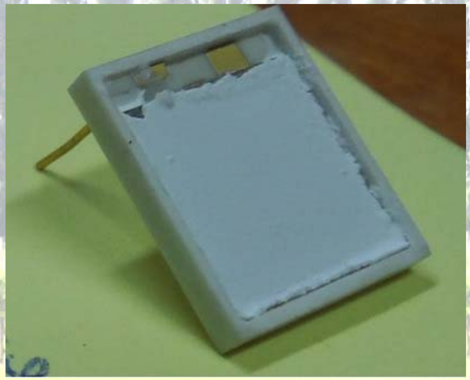
Manufacturing and testing the final spectrometers equipped with active TNDs.

Developing active TNDs - *the pulse detector*

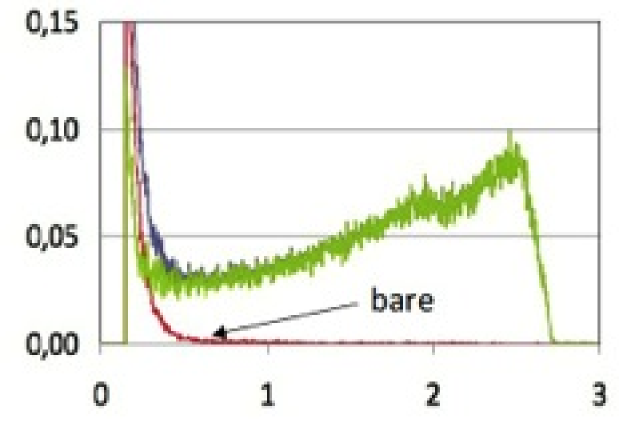
Thermal Neutron Pulse Detector TNPD, producing a pulse height distribution through a dedicated electronics.

The base is a commercial sensor on which an optimized (n, charged particle) converter is deposited (deposition facility at INFN-LNF) (*patents under preparation*)

Typical thermal neutron response (count per unit fluence): 0.04 cm^2



NESCOFI board: Eight analog channels (Bias reg + Pre +amp)

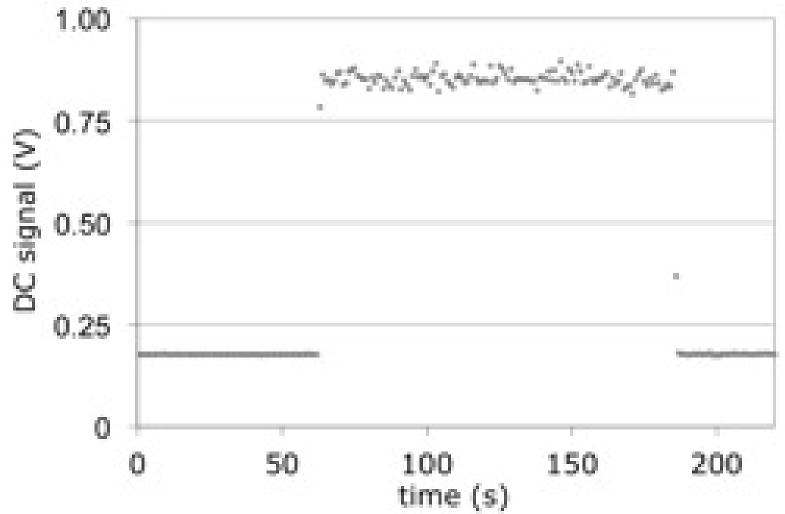


Developing active TNDs - *the rate detector*

Thermal Neutron Rate Detector TNRD gives a DC voltage level that is proportional to the thermal neutron fluence rate.

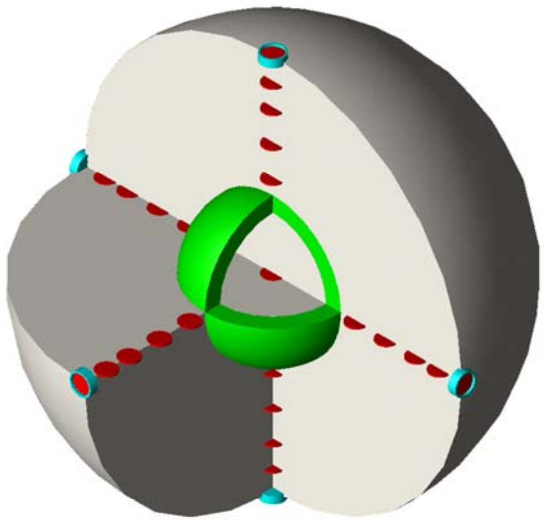
Dedicated ultra-low-current electronics was developed.

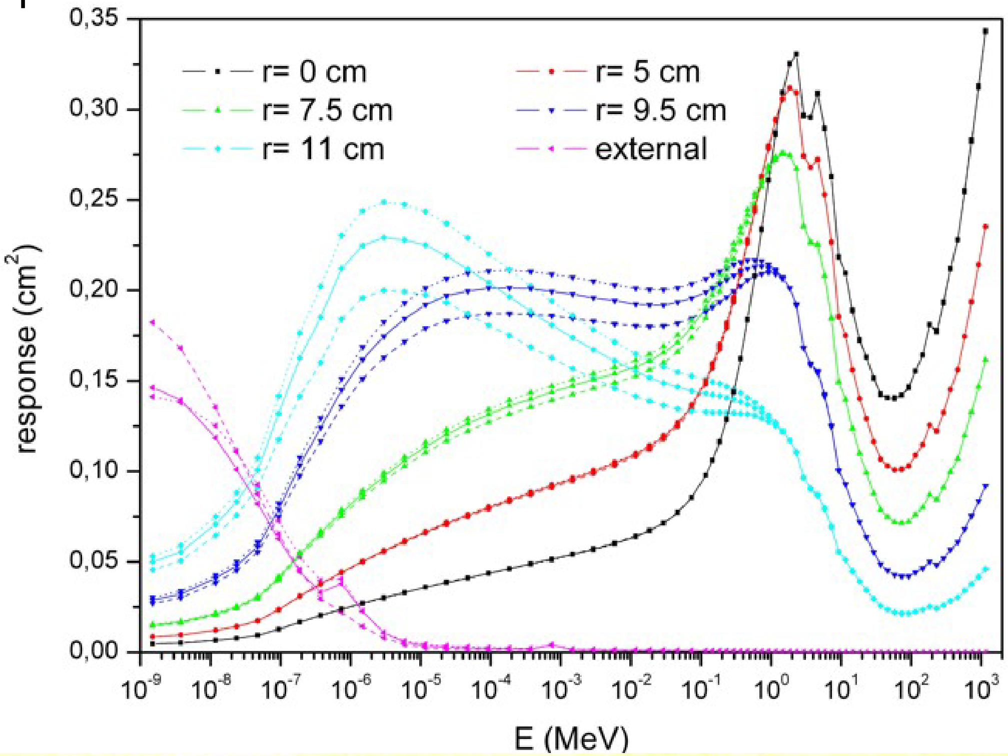
Linear over four orders of magnitude; lowest measurable thermal neutron flux ≈ tens $cm^{-2}\ s^{-1}$



The SPherical SPectrometer SP²

- Thirty-one thermal neutron detectors along three axes of a 25 cm sphere.
- Positions: radius 0.0 (centre), 5.5, 7.5, 9.5, 11 and external
- Response defined as average reading of detectors at the same radius
- An internal 1 cm thick lead shell (3.5 to 4.5 cm) to enhance high-Energy response
- Isotropic response for practical purposes

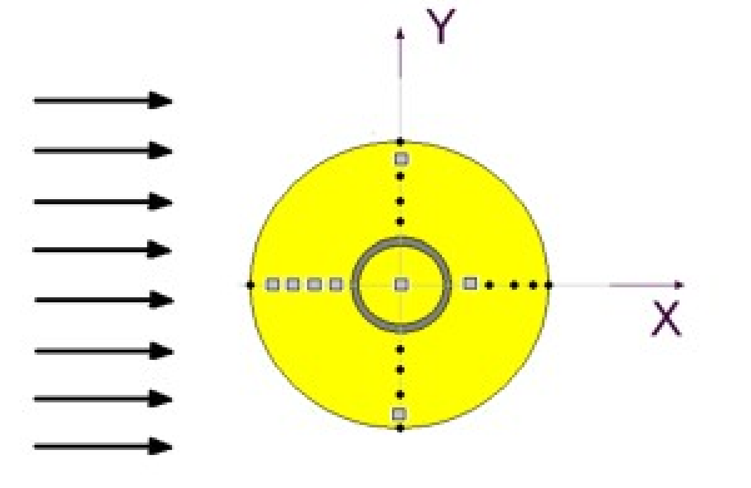


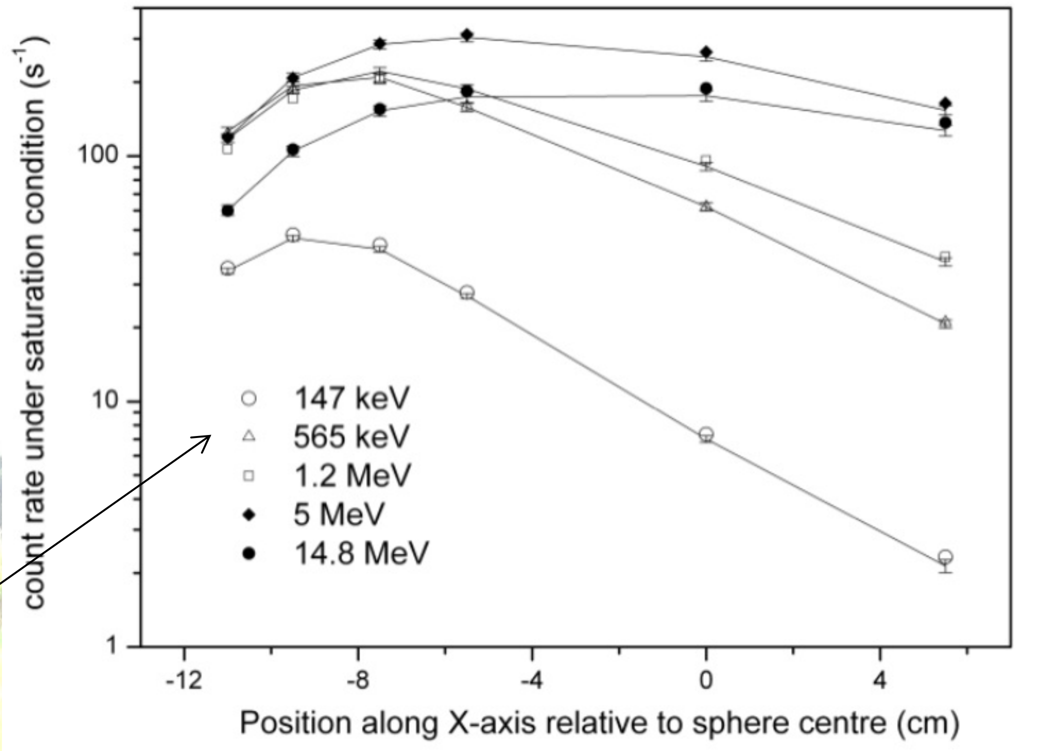


Nucl. Instrum. Meth. A 613, 127-133 (2010)
Nucl. Instrum. Meth. A 677, 4-9 (2012)

Response matrix verification with passive prototype (PTB, 144 keV to 14.8 MeV)

Tests at different mono-chromatic energies performed with Dy activation foils. Overall uncertainty estimated as ±3%

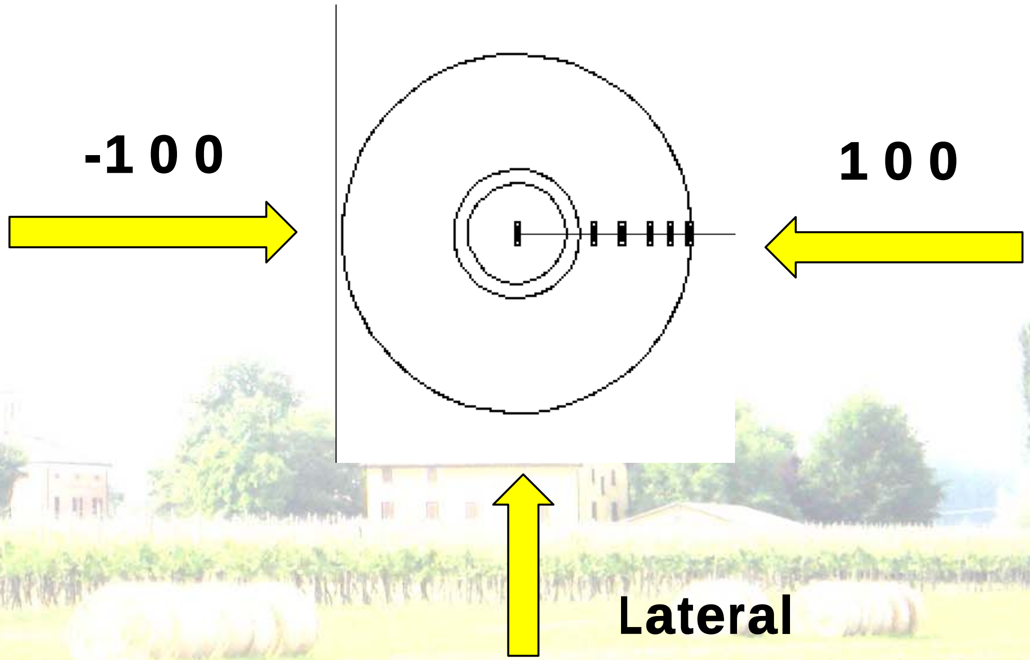


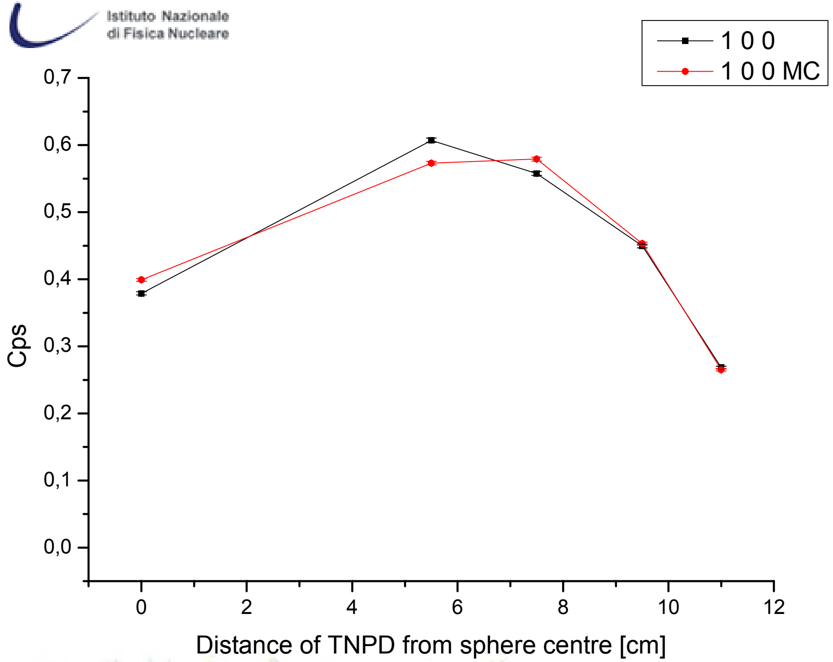


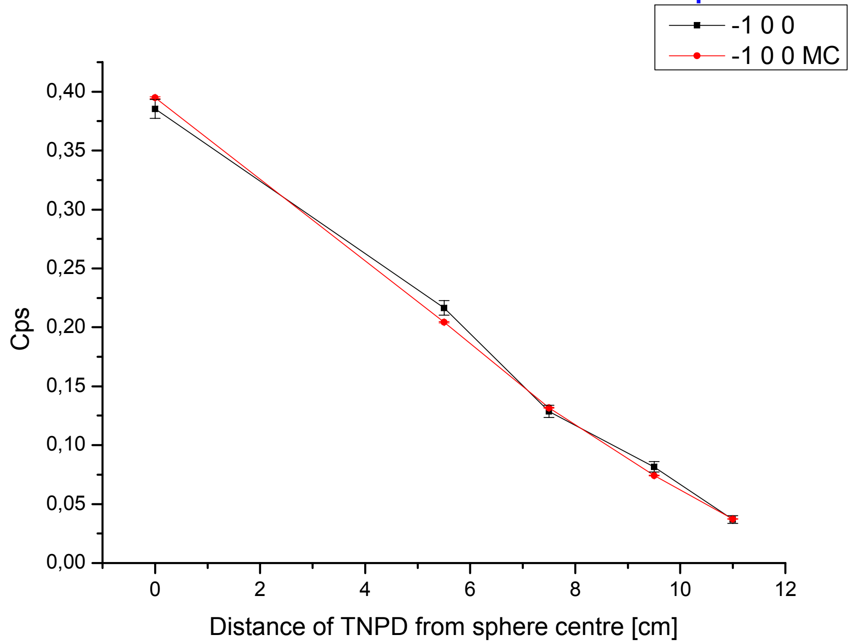
Response modulation allows spectrometry

SP^2 testing in reference ^{241}Am-Be field

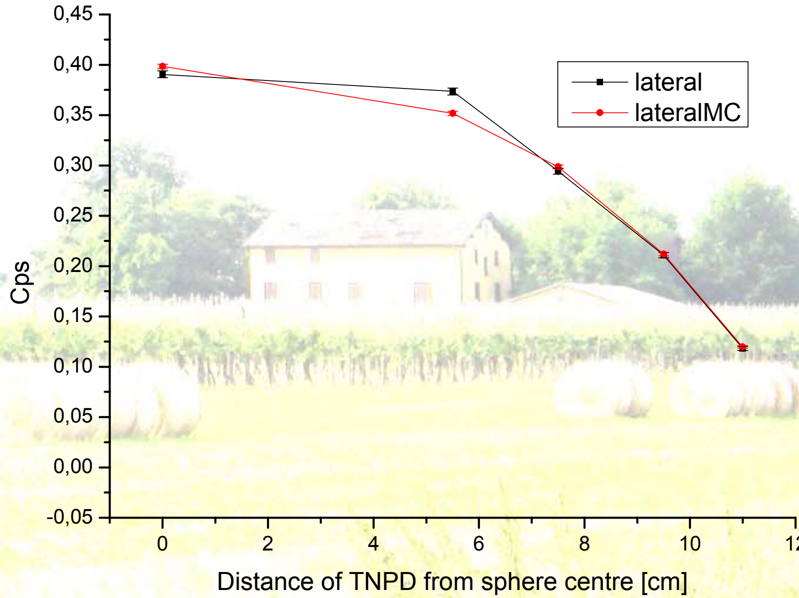
Focusing on a single "radius" of detectors, the detector readings were compared with those expected (from MC simulations), as the irradiation geometry changed.





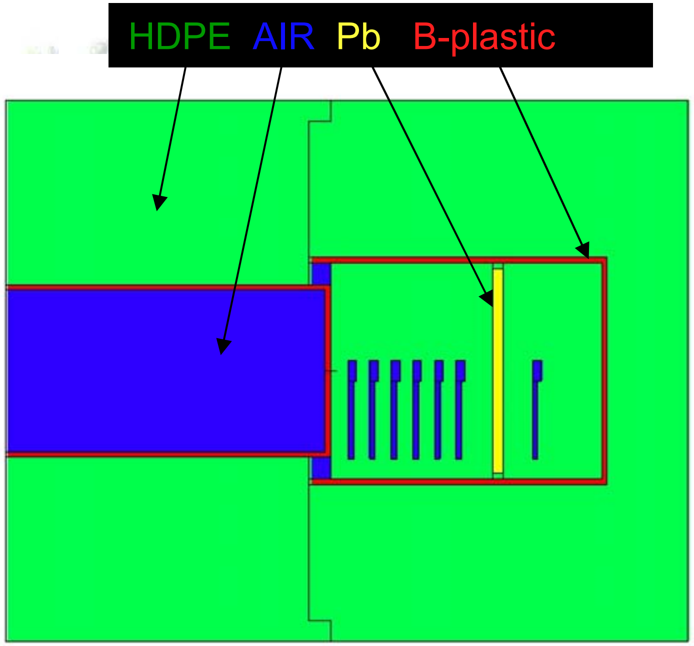


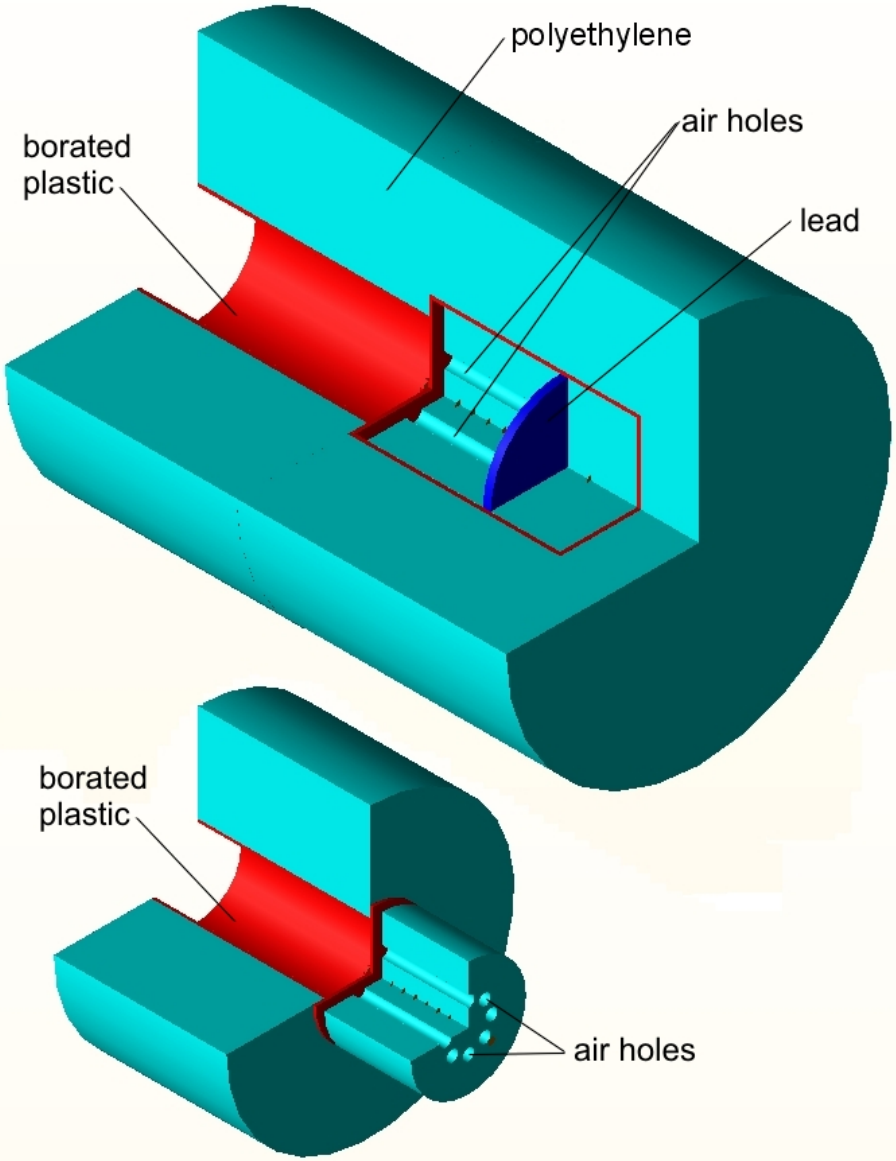
Response matrix overall uncertainty: ±2%



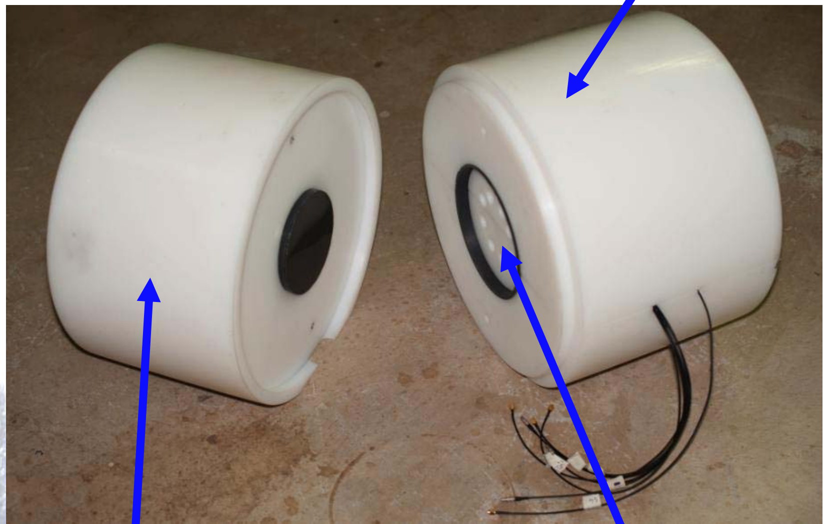
The **CY**lindrical **SP**ectrometer **CYSP**

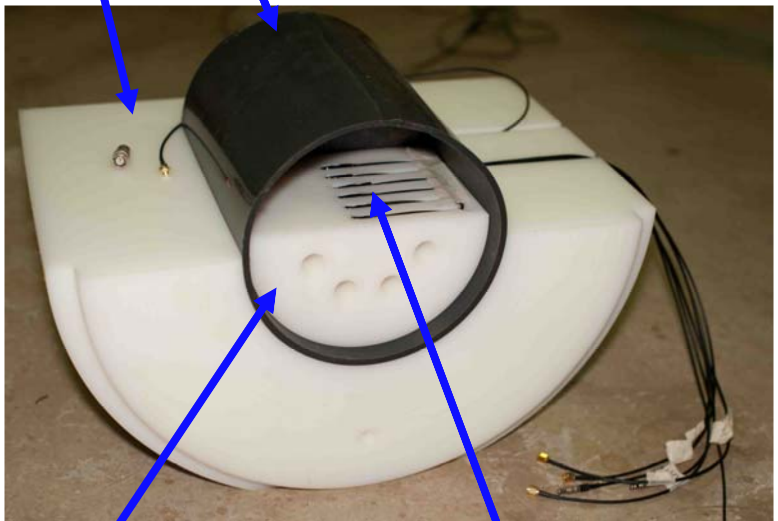
- Seven TNDs along the axis
- Spectral resolution and lateral rejection
- HPDE Collimator 50 cm diam x 30 cm h
  Hole diameter 16 cm, B-plastic lined
- Capsule for detectors: 20 cm diam,
  includes one cm lead disk (high-E)
- Air holes to increase deep response





CYSP equipped with active detectors (type TNPD)





lateral protection

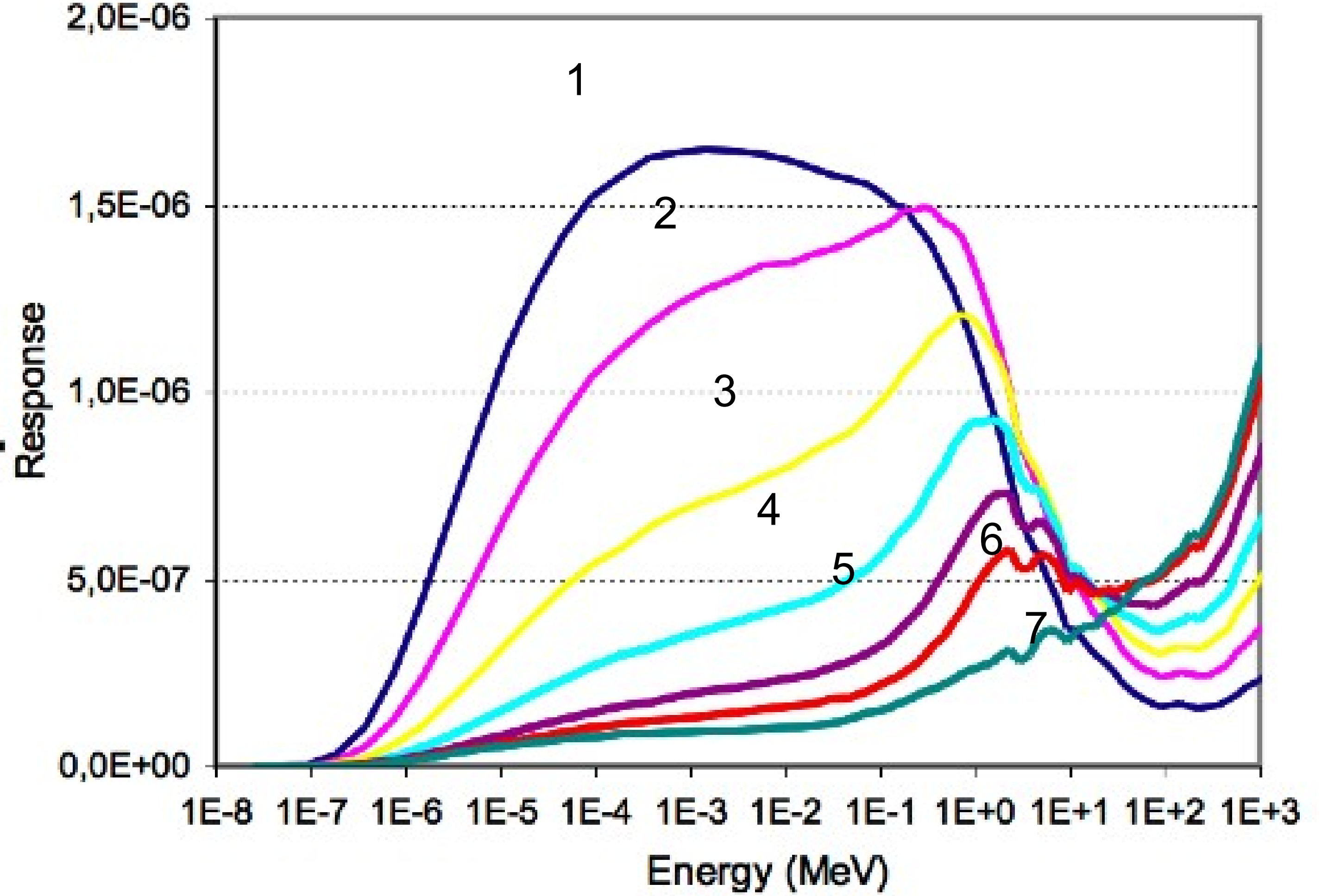
B-plastic

collimator

capsule for detectors

detectors

CYSP response matrix

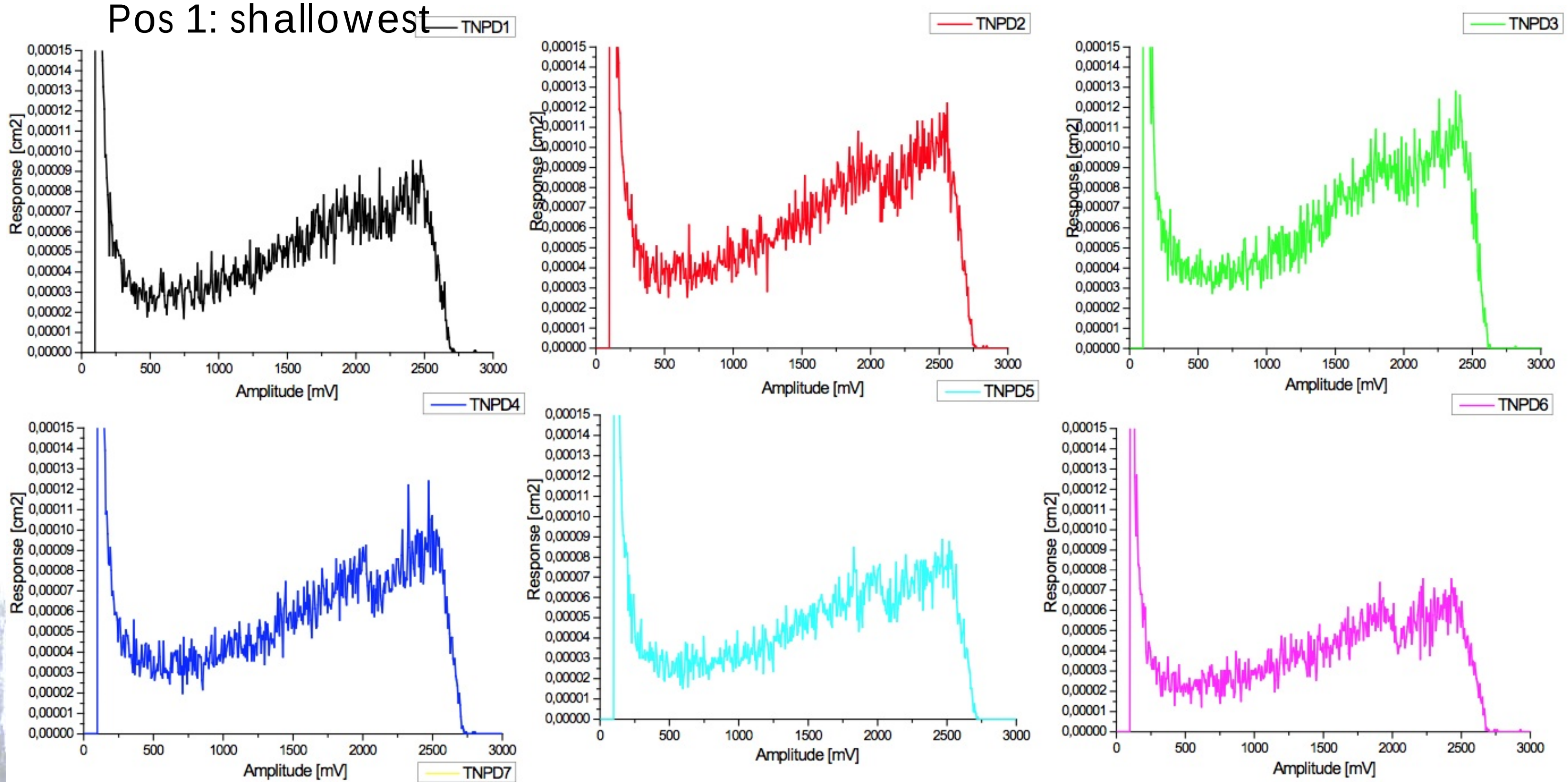


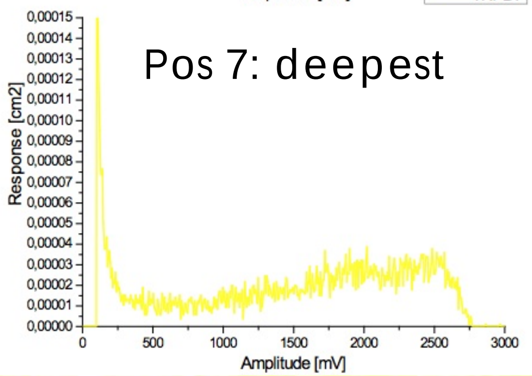
Testing the CYSP

(NPL, mono-chromatic fields 0.144 – 16.5 MeV)

Neutron Energy [MeV]	Angle of Fluence Measurement	Shadow Cone
0,144	0°	YES
0,565	0°	YES
2,0	0°	YES
3,5	70°	NO
5,0	0°	YES
16,5	0°	YES

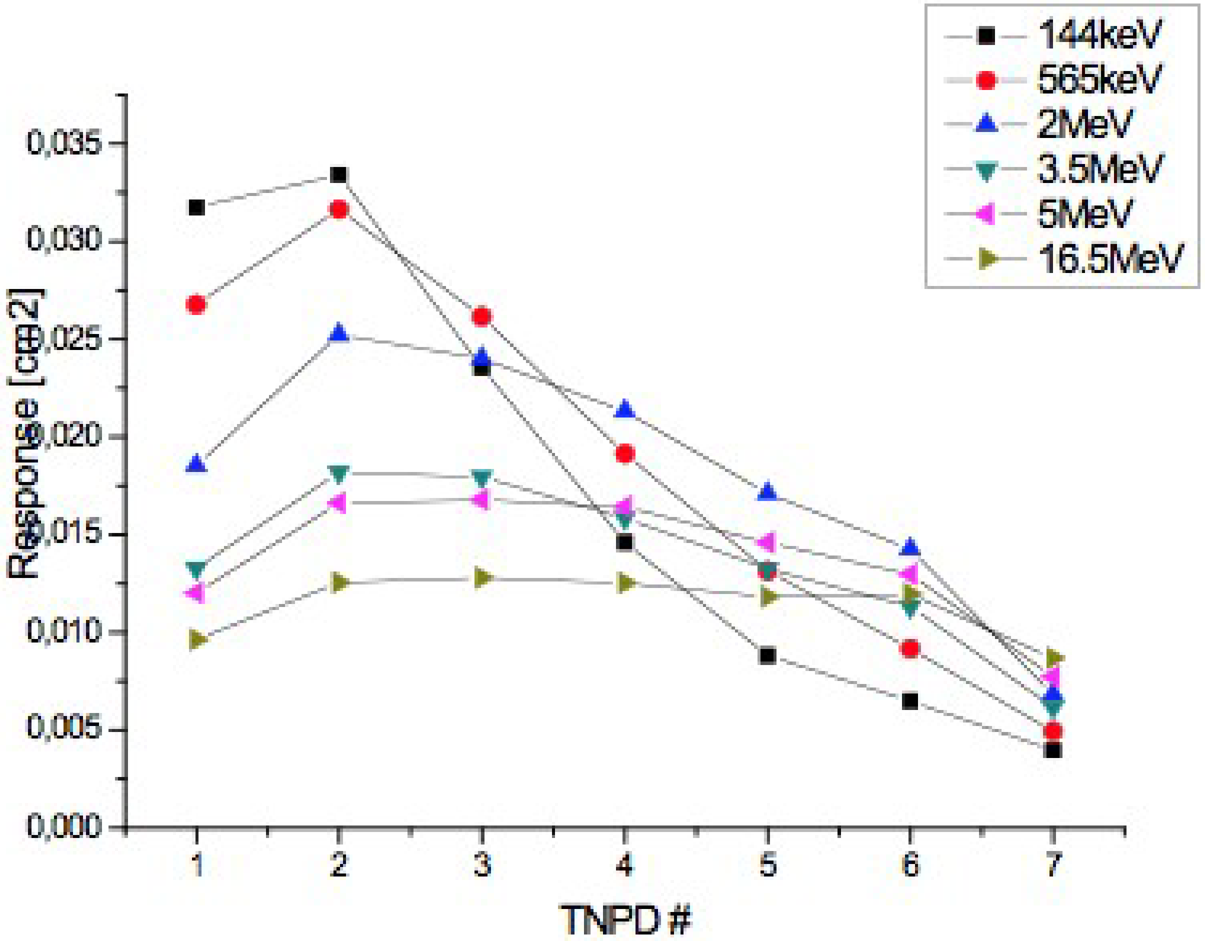
Neutron Source	Fluence rate [$cm^{-2}\,s^{-1}$]	Shadow Cone
Cf-252	54,41	YES



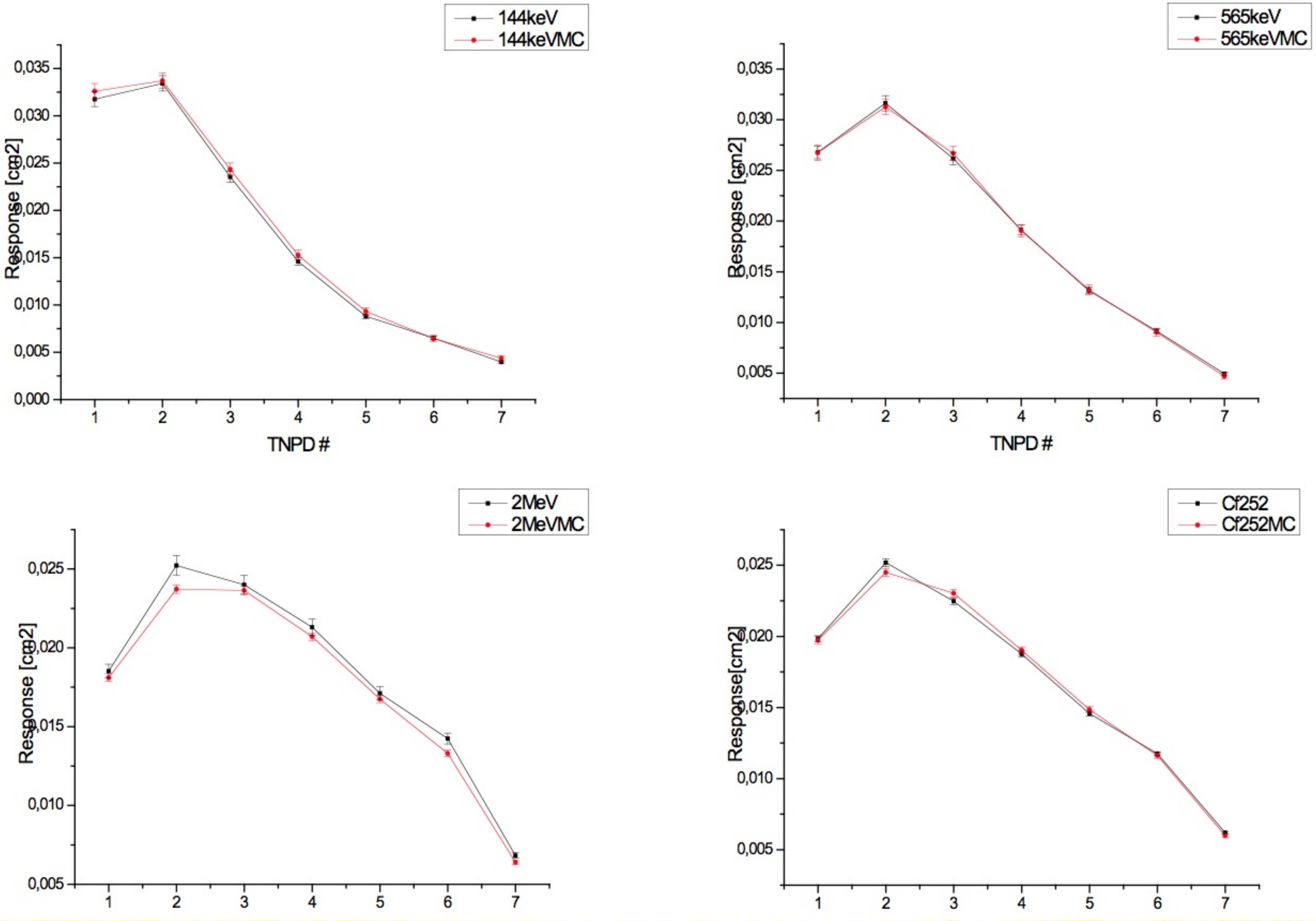


TNPD spectra at different positions within the CYSP (E=2 MeV)

Response profiles as a function of the energy



Comparison with simulated response: overall uncertainty better than 2%.



Conclusions

1. Two single-moderator neutron spectrometers, called SP^2 and CYSP, were designed in the framework of the INFN project NESCOFI@BTF.

2. Dedicated active thermal neutron detectors were developed to meet the specific needs of the project

3. The response matrix of the devices was verified in reference monochromatic or continuous neutron spectra, showing accuracy better than 2%.

4. The instruments may be replicated and distributed to third party Institutions under collaboration agreement.