Neutron spectrometry from eV to GeV at neutron beam-lines: the NESCOFI@BTF project

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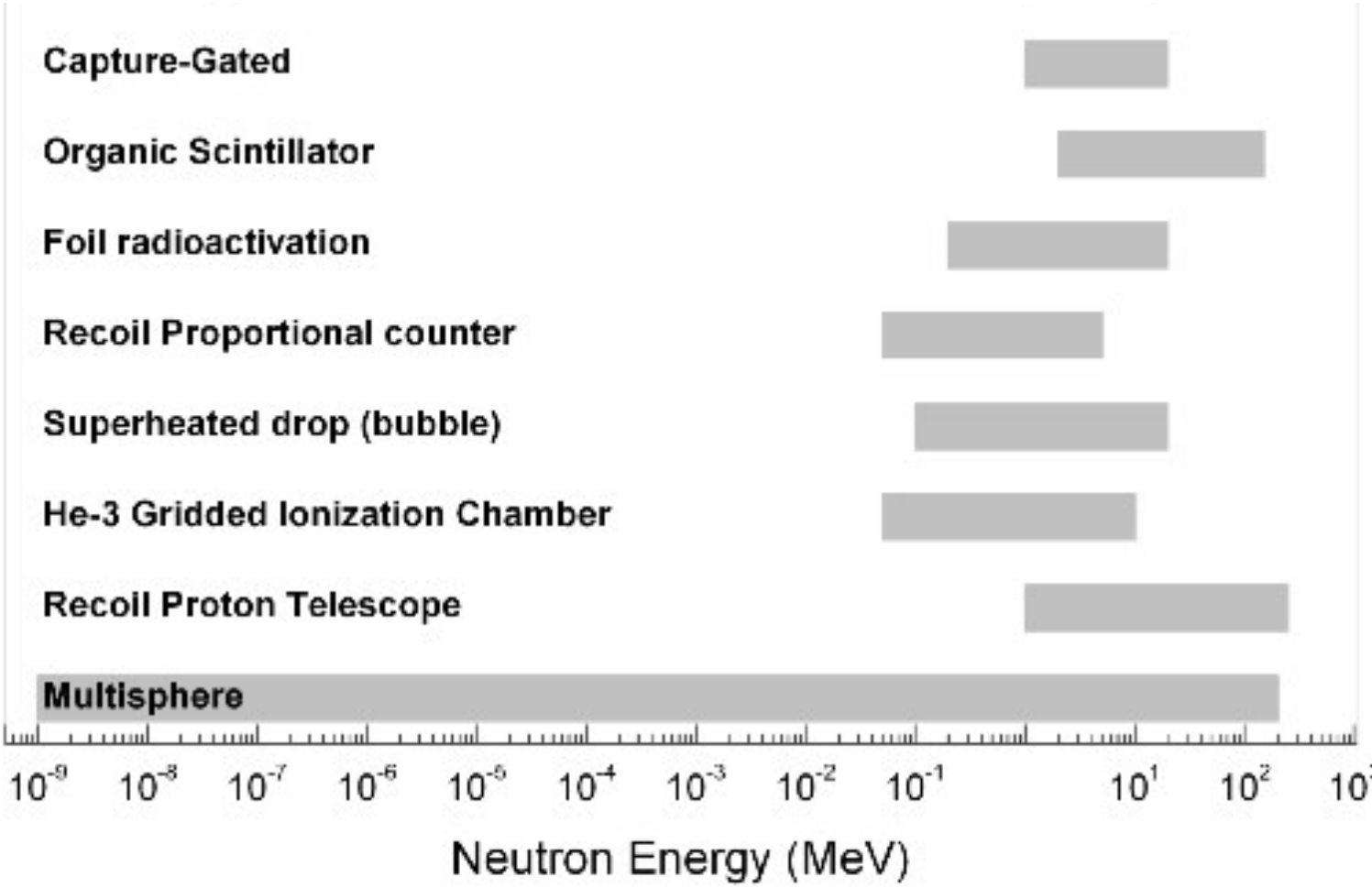
IRIDE photo-production workshop
10-11 June 2013


Capture-Gated
Organic Scintillator
Foil radioactivation
Recoil Proportional counter
Superheated drop (bubble)
He-3 Gridded Ionization Chamber
Recoil Proton Telescope
Multisphere
10-9 10-8 10-7 10-6 10-5 10-4 10-3 10-2 10-1 101 102 103
Neutron Energy (MeV)

Broad energy interval neutron spectrometry at beam-lines

No single-device instrument exists to perform a complete energy range spectrometry (eV - GeV).

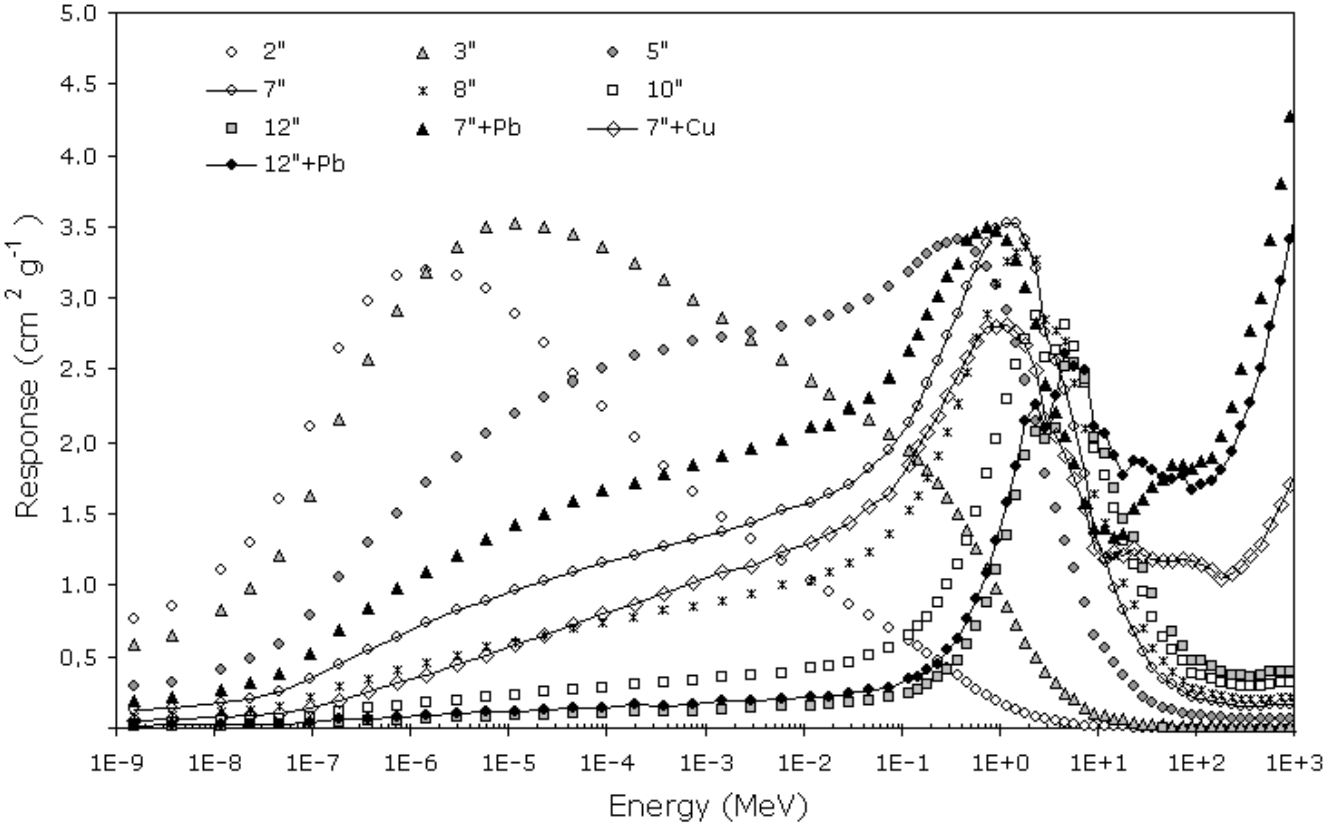
To date, the only spectrometric technique able to provide all energy component is the Extended Range Bonner Sphere spectrometer

Limitations:

- time consuming irradiation sessions
- poor energy resolution (partially compensated with a-priori information taken from MC simulations)

ERBSS

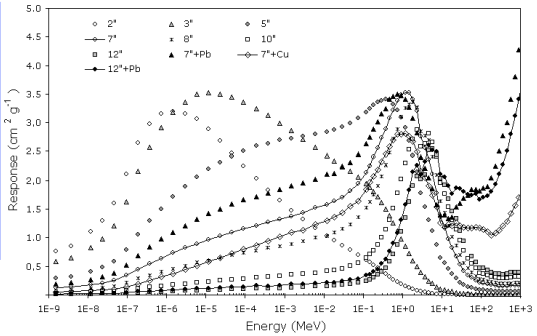
12"+Pb
internal part



n workshop
1 June 2013

BSS counts
(+ uncertainties)

Guess hypothesis
(physical models, parameterized spectrum, MC simulation)



Unfolding (FRUIT)

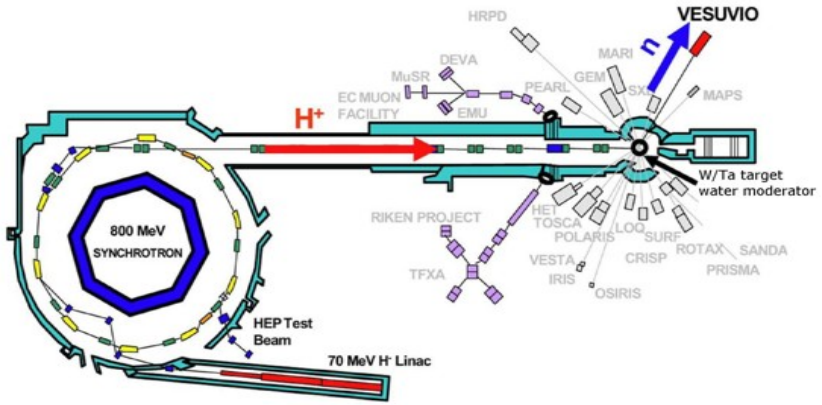
Altering guess hypothesis till "guess" counts counts are sufficiently in agreement with measured counts

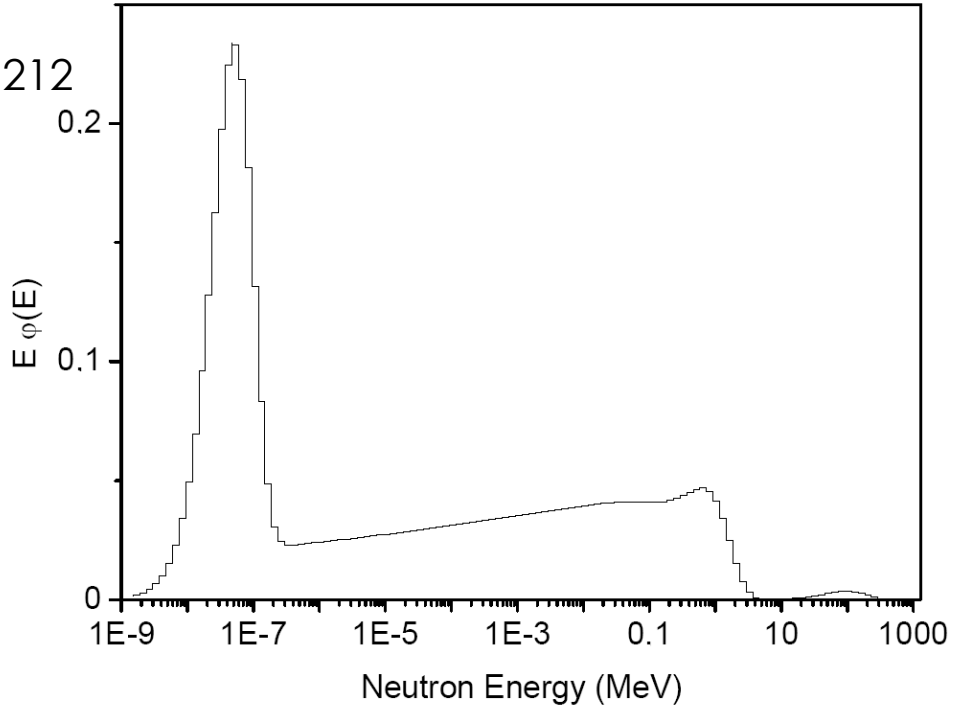
→ **Spectrum**

IRIDE photo-production workshop
10-11 June 2013

ERBSS spectrometry at Vesuvio (ISIS)

NIM A 612 (2009)143–148
Radiation Measurements 45 (2010) 1205-1212





Integral quantities related to the neutron spectrum of the VESUVIO beam-line.

Total fluence normalized to one incident proton	$(1.07 \pm 0.06) \times 10^{-8}\,\mathrm{cm}^{-2}$
Fluence fraction ($E < 0.4\,\mathrm{eV}$)	46.9%
Fluence fraction ($0.4\,\mathrm{eV} < E < 100\,\mathrm{keV}$)	40.9%
Fluence fraction ($100\,\mathrm{keV} < E < 10\,\mathrm{MeV}$)	11.5%
Fluence fraction ($E > 10\,\mathrm{MeV}$)	0.7%

oduction workshop
10-11 June 2013

NESCOFI@BTF (2011-2013)

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:

SP² *Spectrometer with isotropic response*

CYSP *Directional spectrometer*

Fields of application

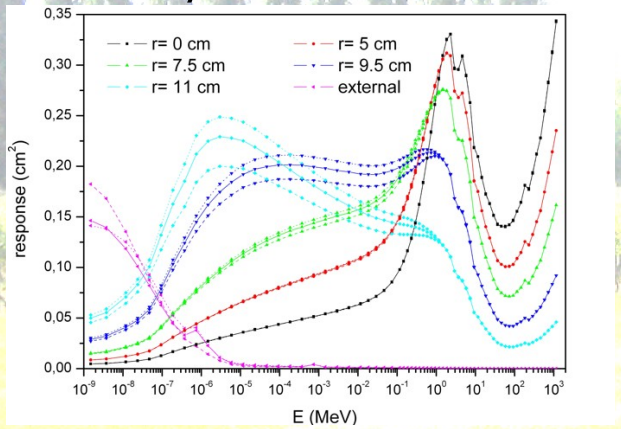
Research accelerators, industry, medical, aerospace, homeland security, cosmic rays measurements

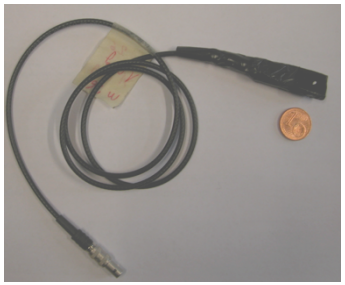
Year "one" (2011)

(1) Theoretical design of SP^2 and CYSP, response matrix calculation (MCNPX 2.6)

(2) Manufacturing an SP^2 prototype operating with passive detectors (Dysprosium activation foils, only for response verification purposes

(3) Experimental verification of the response matrix with quasi mono-energetic neutron fields (ERINDA program 2011)





Year "two" (2012)

Setting up 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)

Two types of TNDs (different levels of cost/sensitivity):

TNPD pulse detector (~0.04 cm^2), producing a PHD

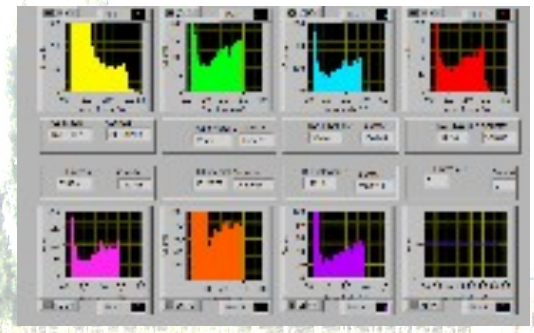
TNRD rate detector, giving a DC voltage level that is proportional to the thermal neutron fluence rate.
Lowest measurable thermal neutron flux ≈ tens cm^{-2} s^{-1}

Year "three" (2013)

Manufacturing and testing the final spectrometers equipped with active TNDs.

State of art

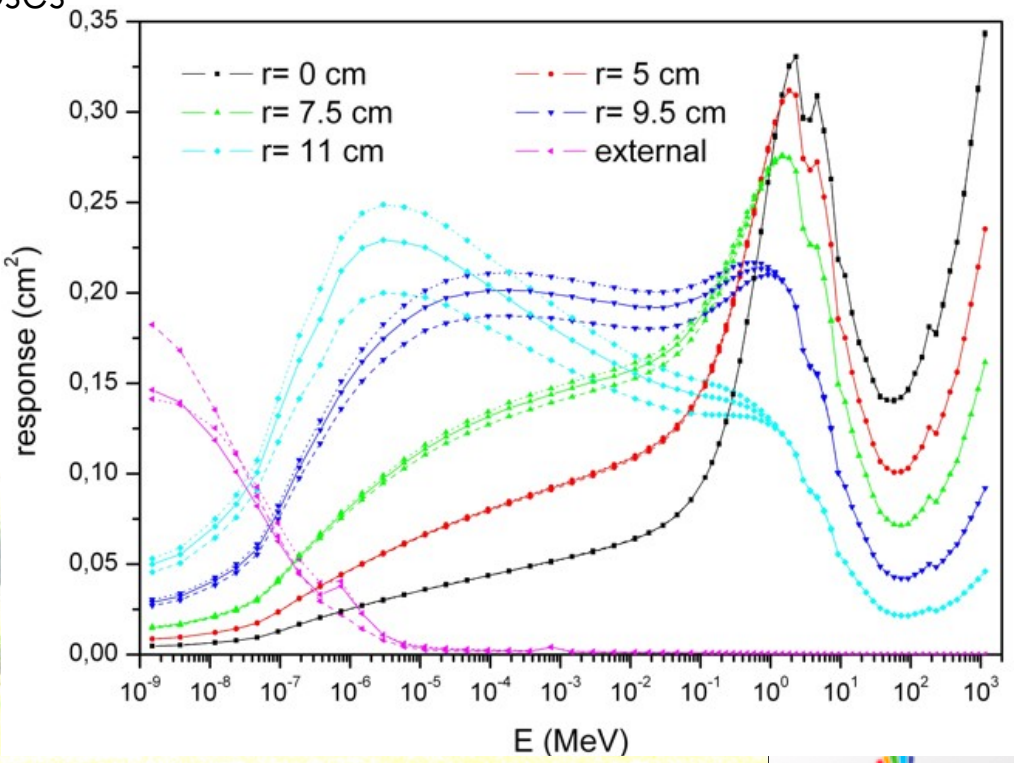
(1) CYSP was fabricated and tested at the INFN-LNF with an Am-Be source. A more exhaustive testing campaign with quasi mono-energetic neutron fields is planned.



(2) The active SP^2 is under fabrication.

The **SP**herical **SP**ectrometer **SP²**

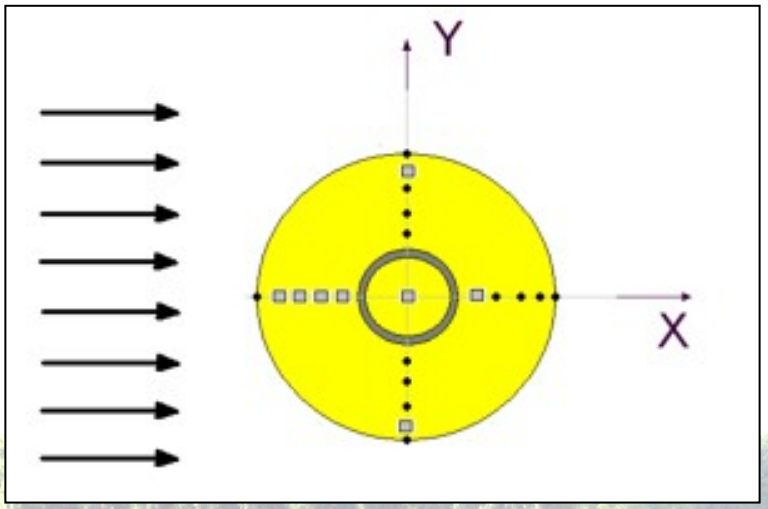
- Thirty-one thermal neutron detectors along three axes of a 25 cm sphere.
- Positions: radius 0.0 (centre), 5.5, 7.5, 9.5, 11 and 12.5 cm (external)
- Response defined as average reading of detectors at the same radius
- An internal 1 cm thick lead shell (3.5 to 4.5 cm) to enhance high-Energy response
- Isotropic response for practical purposes

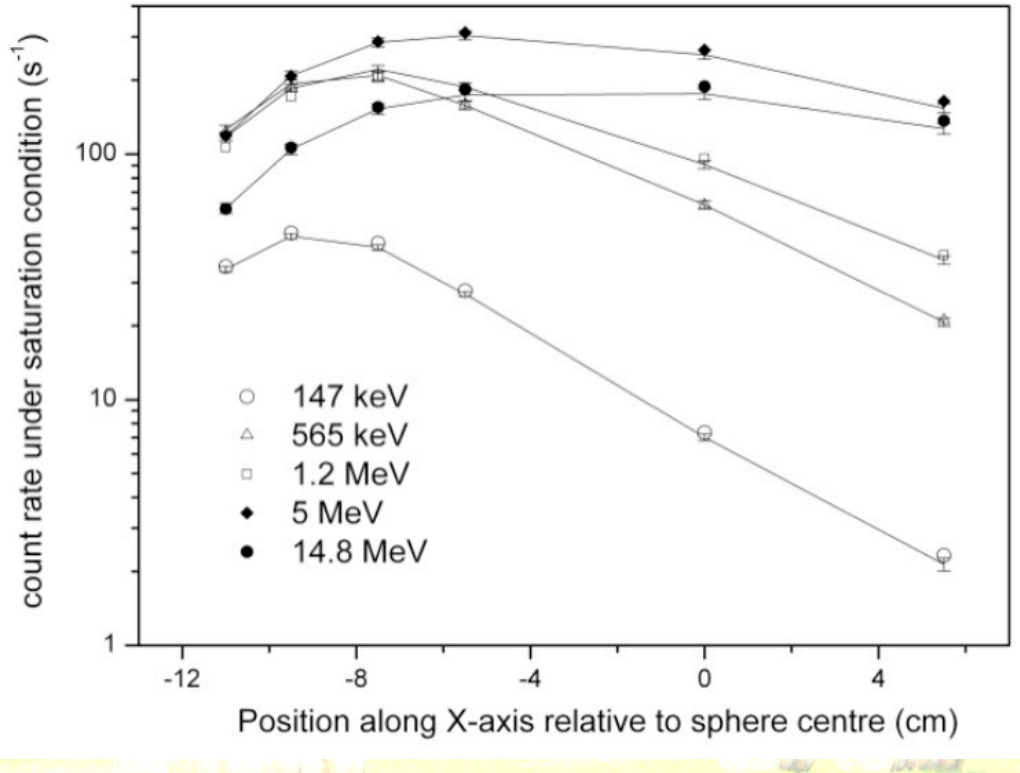


Nucl. Instrum. Meth. A 613, 127-133 (2010)
Nucl. Instrum. Meth. A 677, 4-9 (2012)

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

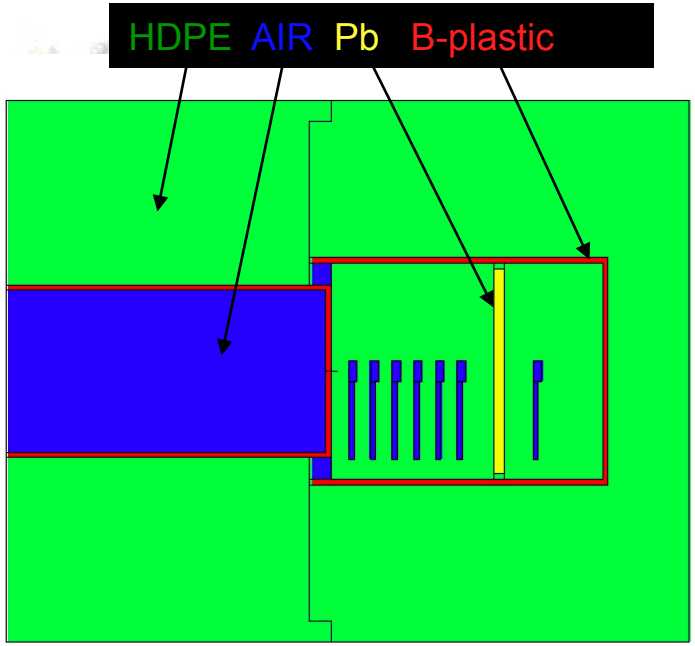
Tests at different mono-chromatic energies performed with Dy activation foils. Overall uncertainty estimated as ±3%

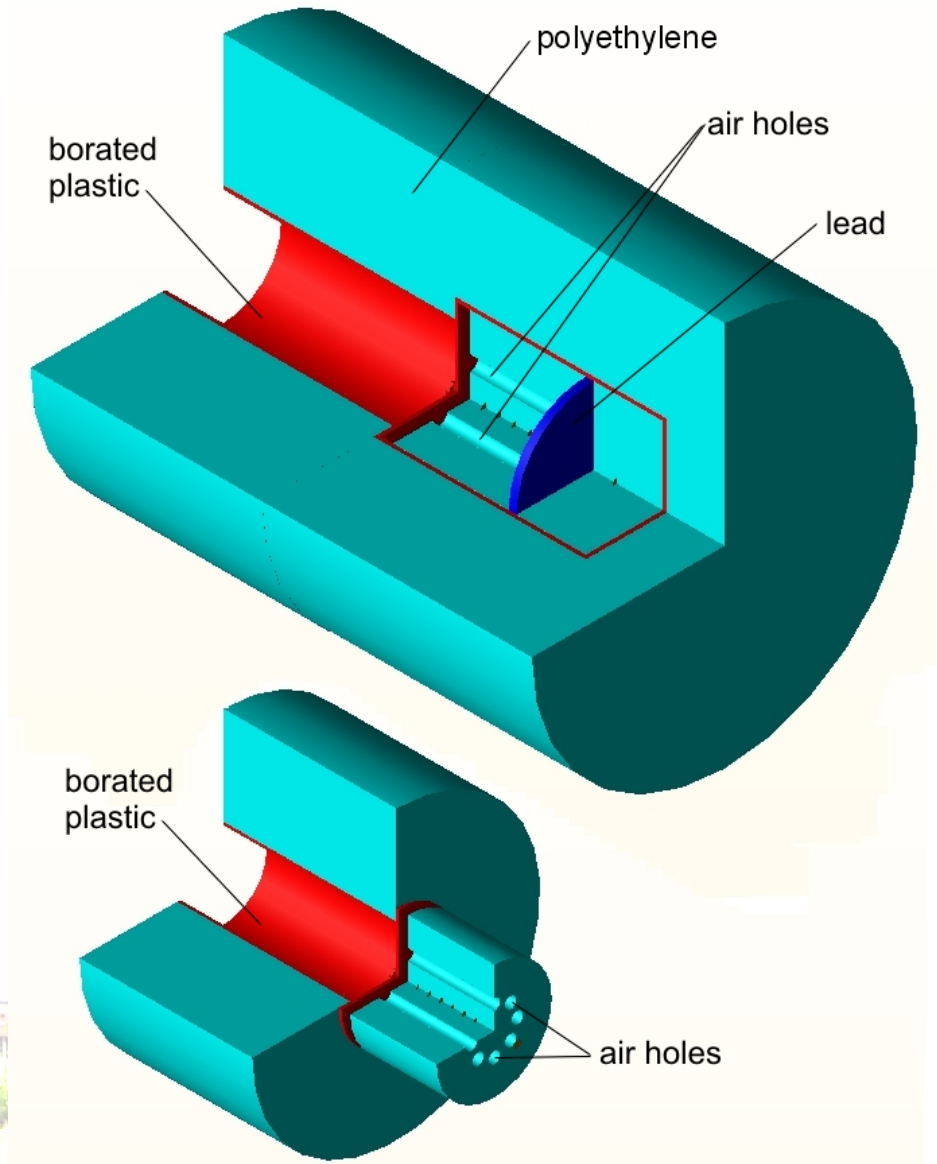




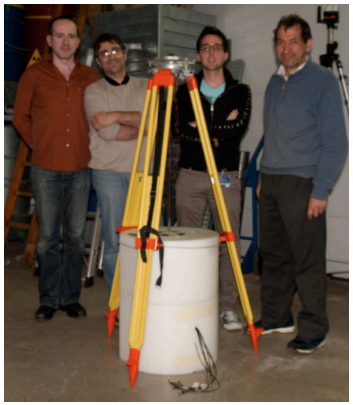
The **CY**lindrical **SP**ectrometer **CYSP**

- 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



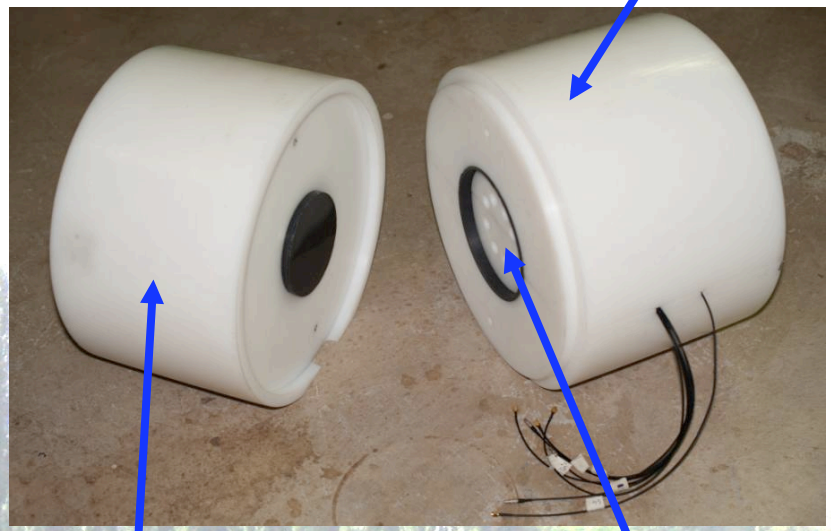


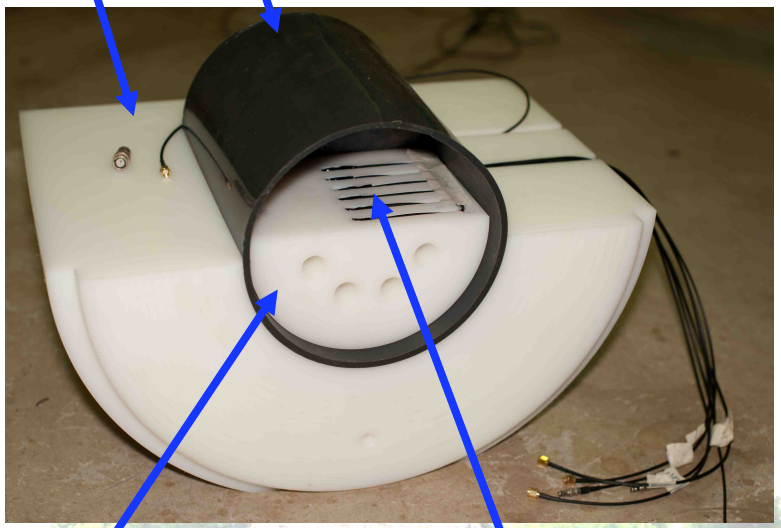
CYSP equipped with active detectors (type TNPD)



B-plastic

lateral protection



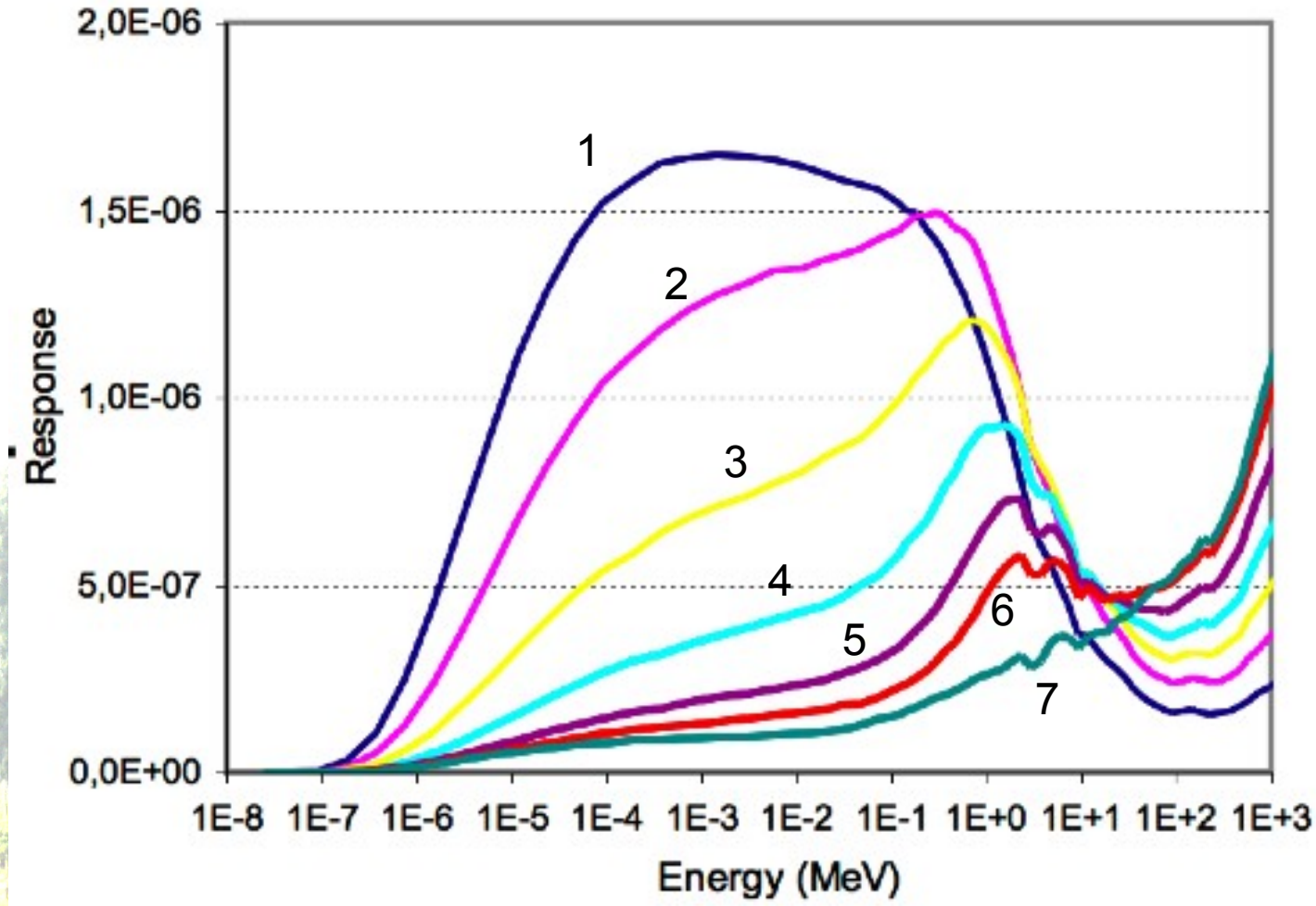


collimator

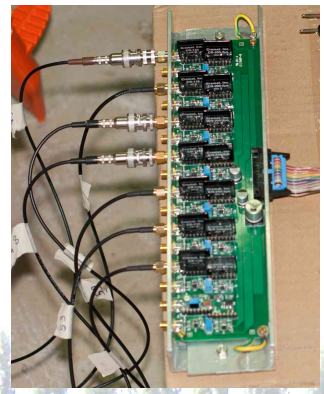
capsule for detectors

detectors

CYSP response matrix



Signal processing

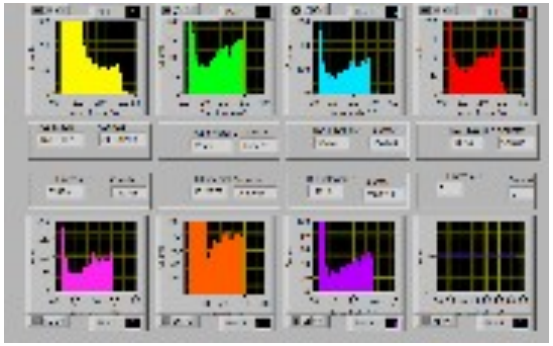


Analog module
designed within the project
Eight channels
(Bias regulator + Preamp +amp)

+

8 channel digitizer

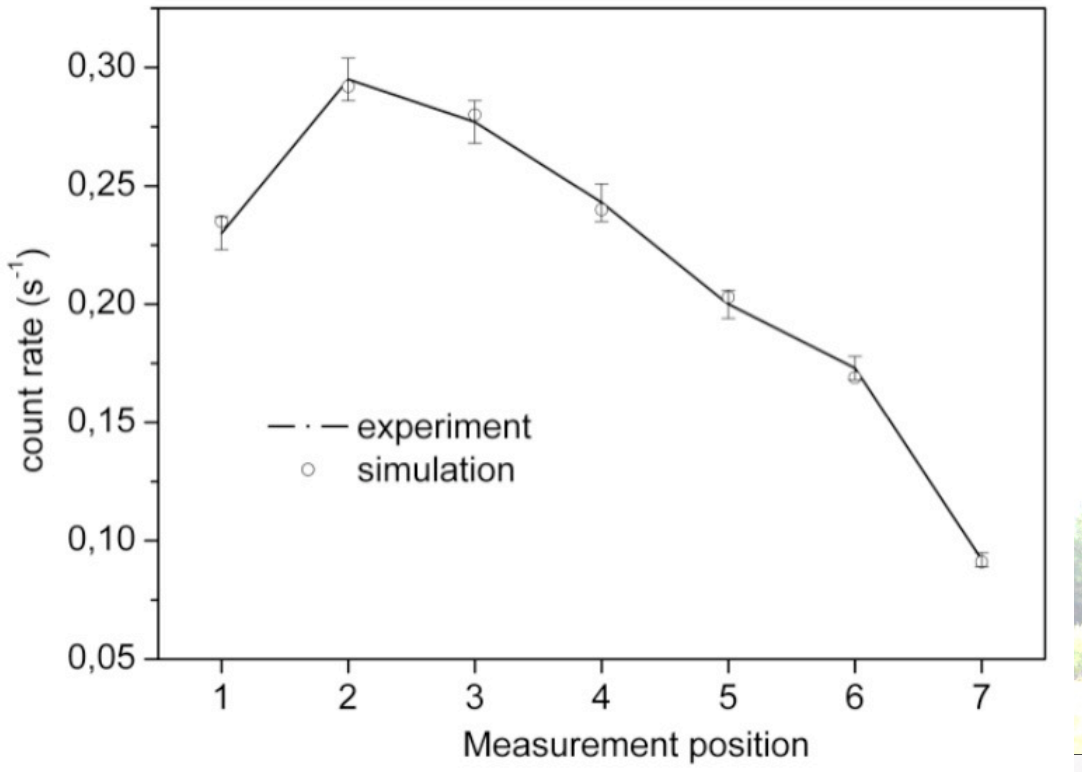
=



Simultaneous
acquisition of up to
eight detectors
(Labview based)

Testing the CYSP

- Am-Be calibrated source (2E+6 s^{-1}) in **intentionally high scattering** workplace
- Simultaneous acquisition from the seven detectors
- Count profile: simulated compared with experimental (st.dev. of ratios 2%)



Conclusions

1. Broad-energy interval neutron spectrometry at beam-lines can be performed "on-line" with similar performance as those of the ERBSS
2. Two prototypal single-moderator neutron spectrometers, called SP^2 and CYSP, were designed in the framework of the INFN project NESCOFI@BTF.
3. Testing phase done by the end of 2013.