Development of a compact neutron spectrometer based on multi-element activation analysis

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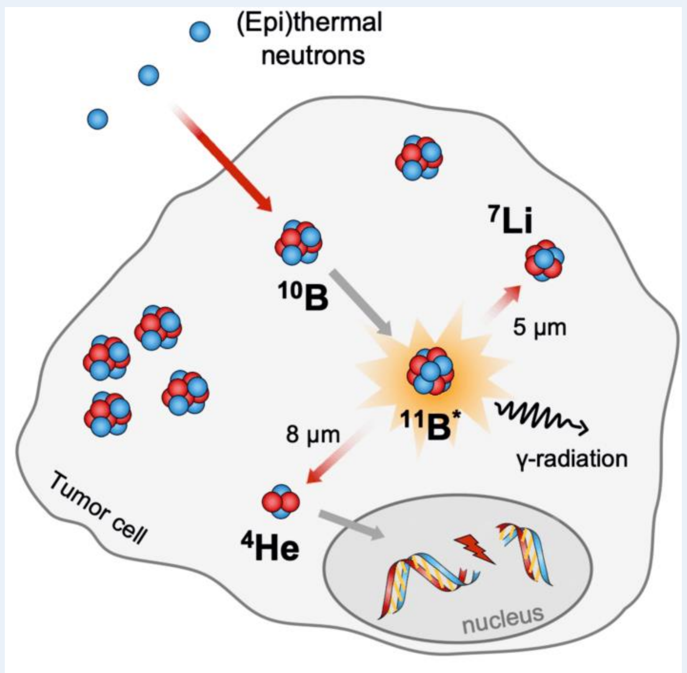
INTRODUCTION

In recent years, due to the introduction of accelerator-based facilities, the interest of the medical and scientific communities in the Boron Neutron Capture Theraphy (BNCT) dramatically increased. As far as beam diagnostics is concerned, the availability of spectrometry techniques adapted to BNCT is required for Quality Assurance and daily control measurements. This work aims to present a novel compact spectrometer with an isotropic response called Neutron Capture Therapy- Activation Compact Spectrometer (NCT-ACS), funded by INFN, highly sensitive in the energy interval ranging from thermal to 100 keV and suitable for in-phantom irradiation. The detector charachteristics and the experimental results collected at the Torino neutron facility are shown.

The Boron Neutron Capture Therapy (BNCT)

BNCT is a therapy for cancer treatment:

1. A ^{10}B compound is given to the patient. The ^{10}B concentration in the cancer cells is higher than that of healthy tissues.
2. The patient is exposed to an epithermal (0.4 eV – 100 keV) neutron beam.
3. The $^{10}B(n,\alpha)^{7}Li$ reaction fragments energy is deposited in few μm, destroying the hosting cell.

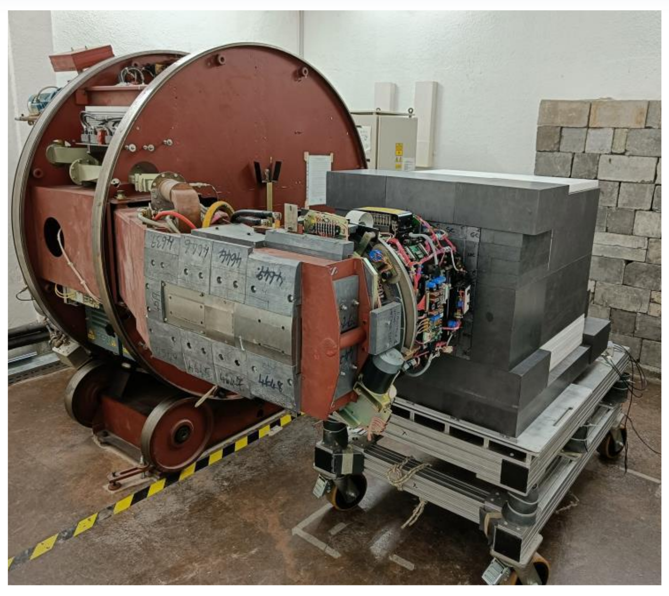


Cancer cell during a BNCT treatment

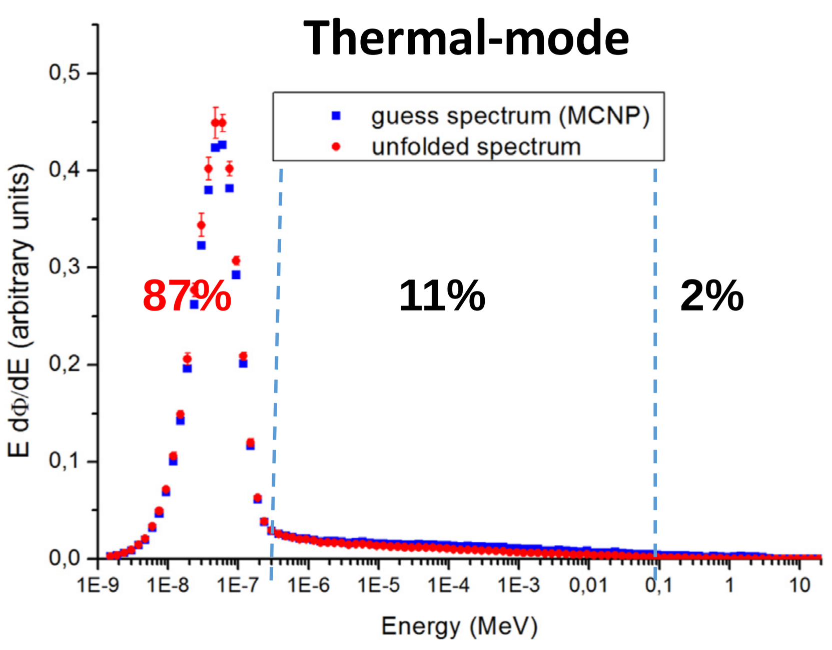
The e_LiBANS facility

At he University of Torino, a medical LINAC is coupled to a photo-converter to produce neutrons.

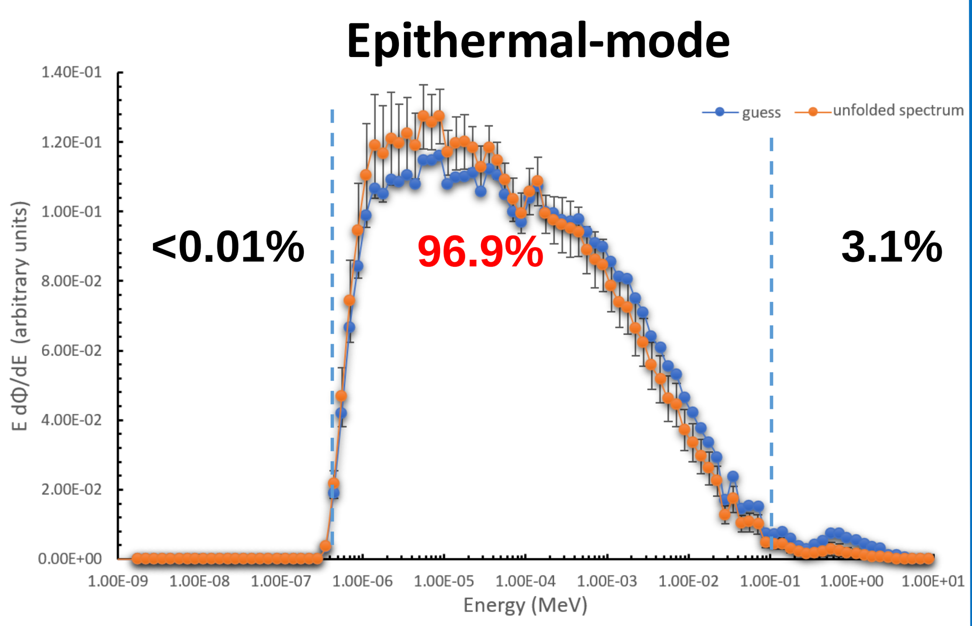
Two working modalities are possible:
- Thermal Mode
- Epithermal Mode



Picture of the e_LiBANS facility



$\Phi_{th} = (1.46 \pm 0.05)10^{6}\ cm^{-2}\ s^{-1}$
Irradiation cavity: 30 x 30 x 40 cm^3

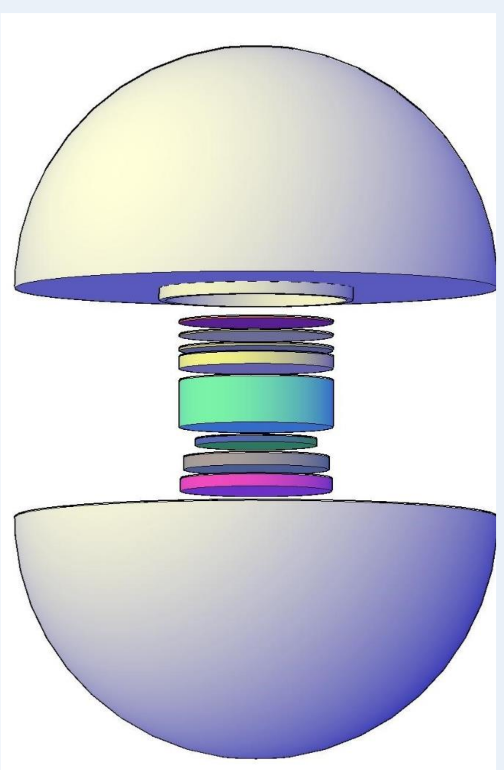


$\Phi_{epi} = (2.46 \pm 0.30)10^{5}\ cm^{-2}\ s^{-1}$
Irradiation cavity: 30 x 30 x 20 cm^3

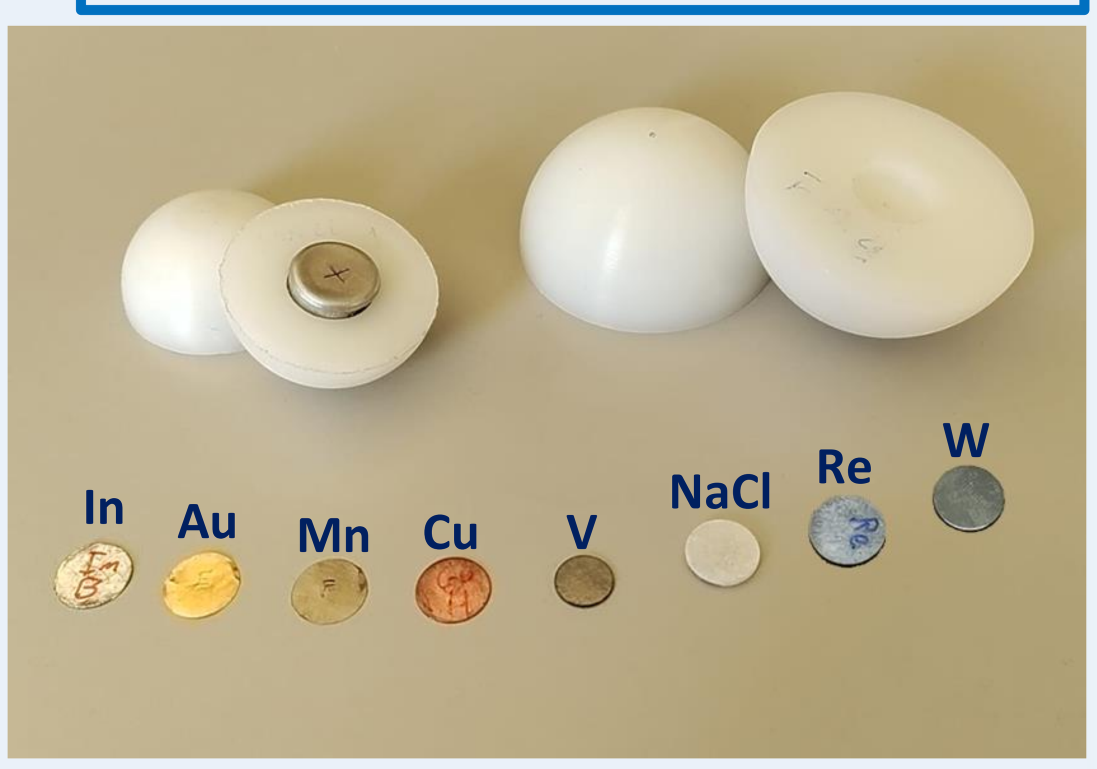
NCT-ACS geometry and composition

Main characteristics:

- Isotropic response
- Reduced size (r = 2cm and r = 2.8cm)
- Sensitivity from thermal up to 100 keV
- Single exposure working condition

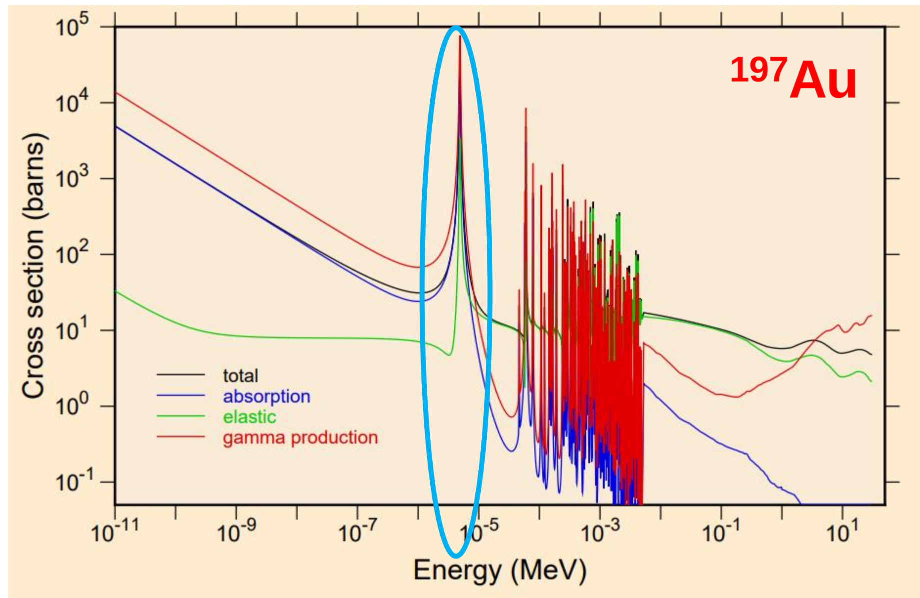


Simulated geometry scheme for NCT-ACS



Picture of the realized prototype geometry with the selected elements foils.

Neutron activation measurements



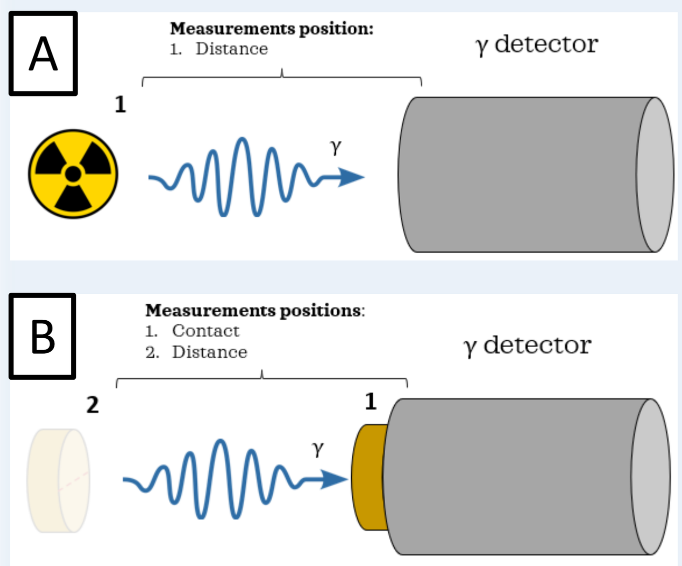
^{197}Au n cross section. Strong resonance at 4.5 eV

Two-step measure:

1. Foil irradiation to the neutron beam/field.
2. Gamma analysis of the activation

The foil activity quantifies the neutron fluence rate and provides spectrometric informations.

Gamma activation analysis



Calibration:

A. Calibration source at distance position (ε_s)
B. Activation foils at contact and at distance position. The ratio is a geometric factor F_g

$$\varepsilon_{contact} = \varepsilon_s \cdot F_g$$

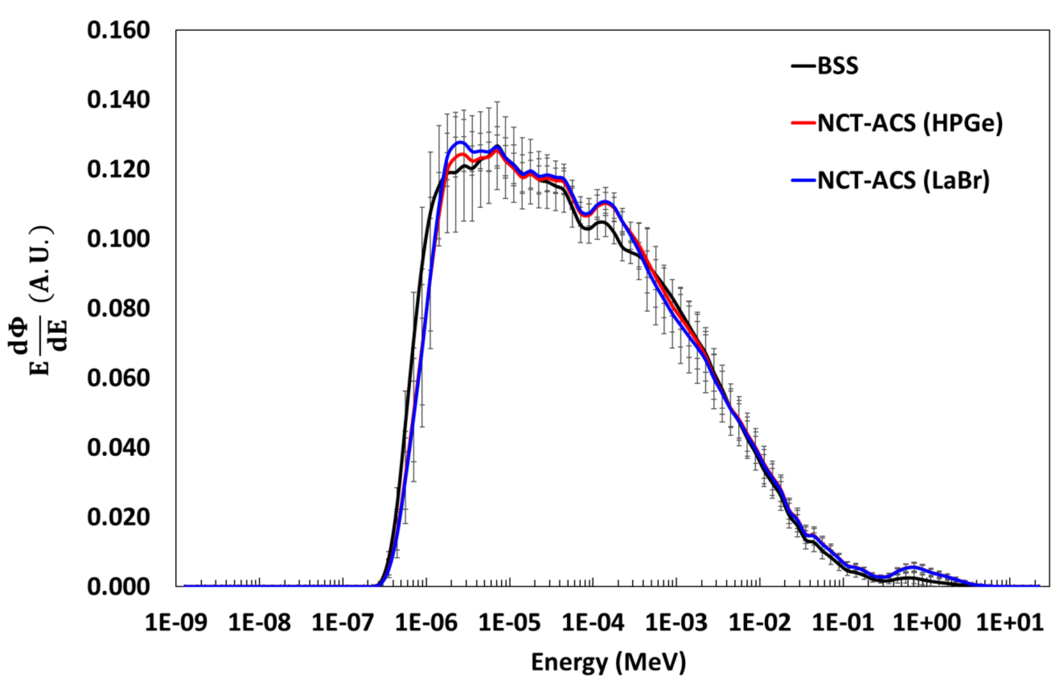
Faster measures. Higher statistics.

Detector 1: HPGe
- Low background
- High E resolution
- Low efficiency
- Not portable

Detector 2: LaBr(Ce)
- Intrinsic background
- Medium E resolution
- High efficiency
- Portable

Very well calibrated and under control system. HPGe taken as standard, LaBr(Ce) for in-situ measures.

Results



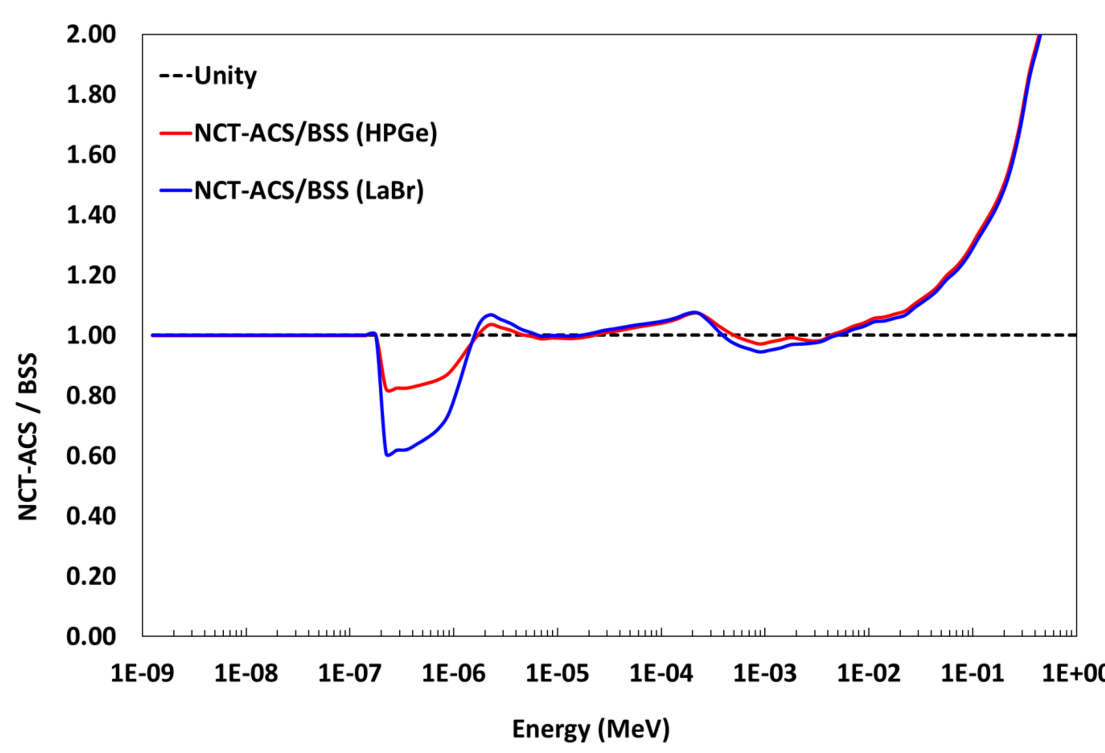
Unfolded spectra using the FRUIT algorithm.

Black: Standard technique (BSS)
Red: NCT-ACS + HPGe measure
Blue: NCT-ACS + LaBr measure

Excellent compatibility with the standard technique (BSS).

Dispersion around the BSS data:

- **6% for the HPGe** configuration.
- **12% for the LaBr** configuration.



CONCLUSIONS

A novel neutron spectrometer called NCT-ACS, based on the activation of a multi element geometry, have been developed at the university of Torino. The device is compact (4-6cm), sensitive to a large neutron energy range, isotropic and can be used in a single neutron irradiation. The prototype has been tested at the electron Linac facility in Torino and the activation data have been analysed using two gamma detectors. The results showed an excellent compatibility with the spectrum measured using a standard technique (BSS) within a dispersion of few %. This achievement stands as a significant milestone in meeting the stringent criteria for the beam quality assurance in BNCT.