Study of the ^{3}H(p,n)^{3}He neutron producing reaction at N.C.S.R. “Demokritos” – Application on the ^{232}Th(n,f) reaction

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Introduction

In the present work, the **$^{3}H(p,n)^{3}He$** reaction was used for the **first time** at "Demokritos" for the production of quasi-monoenergetic neutron beams. For detecting and monitoring the neutrons the following reference reactions **^{238}U(n,f)**, **^{235}U(n,f)** and **^{237}Np(n,f)** were used. Furthermore, a systematic study of the parasitic neutrons, produced via reactions on the target constituents, was performed.

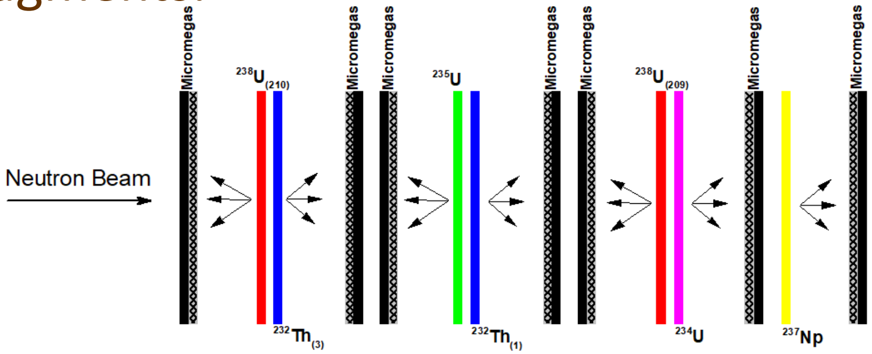
At the same time, the neutron beams produced via the $^{3}H(p,n)^{3}He$ reaction, were used to determine the cross section of the **^{232}Th(n,f)** reaction in the energy range from **2 to 5.5 MeV**, where discrepancies in the experimental and evaluated data have been observed, up to **30%** and **11%** respectively. The neutron fluence impinging on each target was estimated via Monte Carlo simulations, implementing the **MCNP6** code.

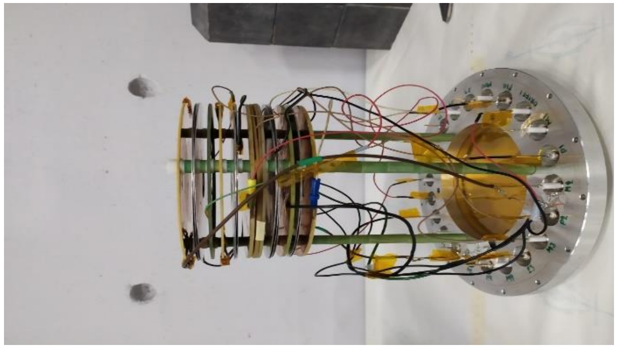
Finally, statistical model calculations, using the **EMPIRE** code were performed on the data measured in this work as well as on data reported in the literature.

Experimental Setup

The experiments were carried out at the 5.5 MV Tandem Van de Graaff accelerator of N.C.S.R. “Demokritos”.

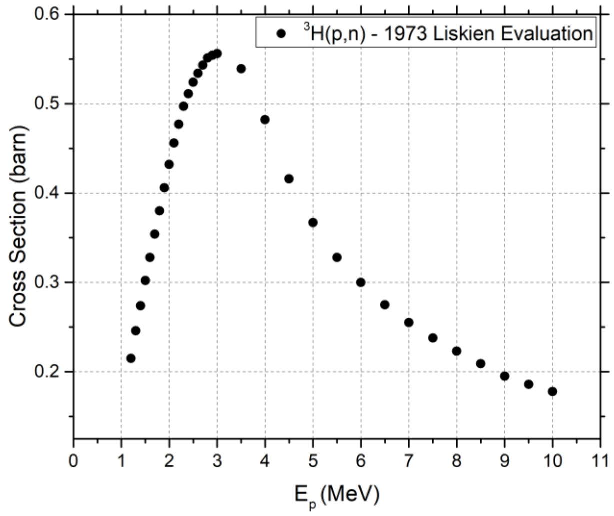
Seven actinide targets were used, all placed in a closed **aluminum chamber** filled with **Ar:CO_2 (90:10) gas** at atmospheric pressure and room temperature. **Aluminum masks** of 4 and 5 cm diameter were placed in front of all targets along with the **Micromegas** detectors for the detection of the fission fragments.





The $^3H(p,n)^3He$ Reaction

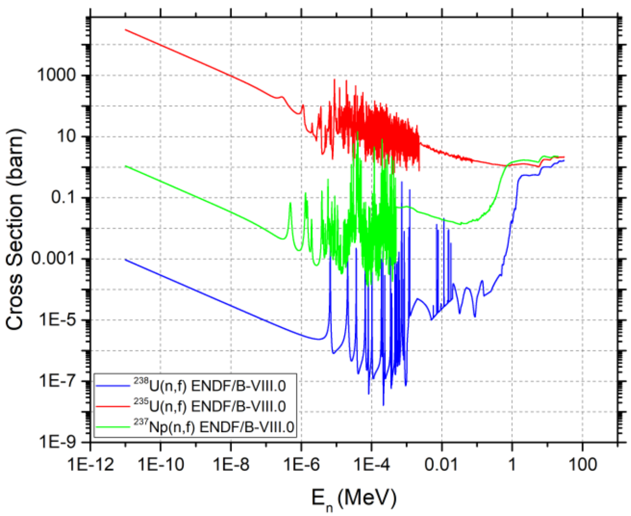
Eight different proton beams were used, in the energy range where the cross section of the $^3H(p,n)^3He$ reaction has the highest values, that corresponds to eight different neutron beams in the energy range between **2 and 5.5 MeV**.



Three reference reactions were used, in order to monitor and help characterize the neutron beams:

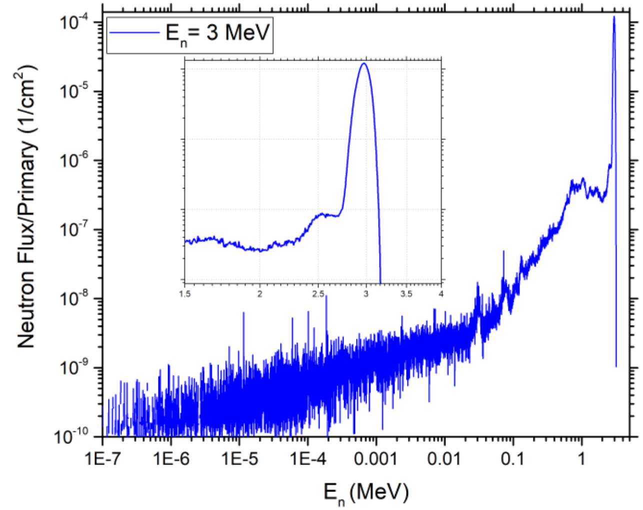
E_p (MeV)	E_n (MeV)
3.4	2.0
3.8	2.5
4.3	3.0
4.8	3.5
5.2	4.0
5.5	4.3
5.8	4.7
6.5	5.3

- The ^{235}U **(n,f)** reaction, highly sensitive in thermal neutrons.
- And the ^{238}U**(n,f)** and ^{237}Np **(n,f)** reactions, with high cross section values in the fast neutron region.



Neutron Flux Characterization

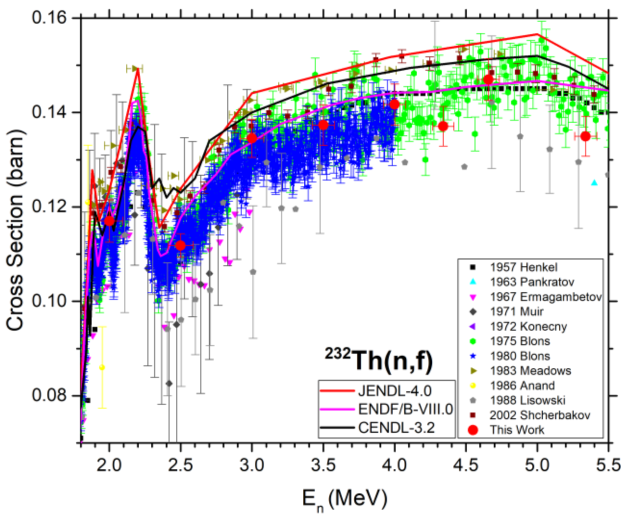
Monte Carlo simulations using the code **MCNP6** were performed for the determination of the neutron fluence incident on each target. Except from the main neutron beam, parasitic neutrons produced via scattering on the experimental setup are also included in the simulations.



The neutron flux estimated by the simulations for the first ^{238}U target for **E_n = 3 MeV**.

Also, parasitic neutrons were generated from **(p,n)** reactions on the **Ti-T** target's materials: **Ti**, **Mo** and **Cu**. After a systematic study on each irradiation, taking into account an approximate mass for each of the nuclei, the fluence of the proton beam and the cross section of each (p,n) reaction, it was noticed that under "Demokritos" experimental setup, the **$^3H(p,n)^3He$** reaction can produce strictly monoenergetic neutron beams in the energy range **0.5 to 2.5 MeV.**

The ^{232}Th(n,f) Measurement



The cross section of **^{232}Th(n,f)** reaction was deduced, via **relative measurement**, in the energy range between **2 and 5.5 MeV**, using as reference the **^{238}U(n,f)** reaction , which has a similar shape cross section as the ^{232}Th(n,f) reaction and are expected to yield a similar response to parasitic neutrons. The values appear to be in good agreement with the latest ENDF/B-VIII.0 evaluation and several previous experimental data sets.

Hauser-Feshbach statistical model calculations were performed, using the code **EMPIRE.** A three-humped fission barriers approximation was used in order to reproduce the resonances that appear in the lower energy region of the fission cross section of ^{232}Th (in the energy range 1.5 – 2.5 MeV), known as **thorium anomaly**. The **work is still on progress**, although the preliminary results seems to be in good agreement with the experimental data.