Geant4 simulation of a Proton Recoil Telescope for the measurement of the ^{235}U(n,f) cross section up to 1 GeV at n_TOF

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Scientific motivation

The **^{235}U(n,f) cross section** is one of the most important cross-section standards used as **reference in many fields**. In particular, it is commonly used to measure the neutron flux in reactors, and in various neutron facilities worldwide, including n_TOF.

The ^{235}U(n,f) cross section is a standard at thermal neutron energy (25 meV) and between 0.15 MeV and 200 MeV.

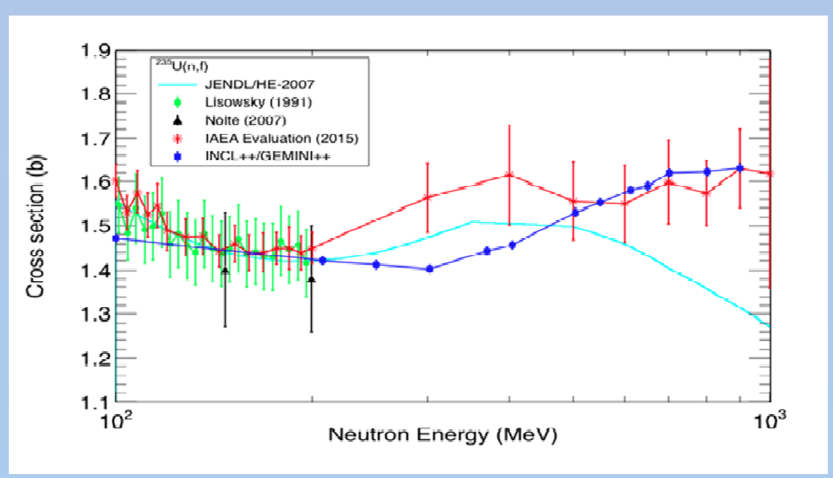


Figure 1: The ^{235}U(n, f) cross section above 200 MeV predicted by various libraries and theoretical calculations.

Despite the increasing importance of the high-energy region, at present **no data exist on the ^{235}U(n,f) reaction above 200 MeV**, and one has to rely on highly uncertain theoretical estimates.

A measurement of the ^{235}U(n,f) cross section above 200 MeV is **"urgently" needed**, according to a pressing **request from IAEA**.

n_TOF at CERN is the only neutron facility in the world where this measurement can be performed, thanks to a **very high flux** and a neutron spectrum that extends uo to **1 GeV**.

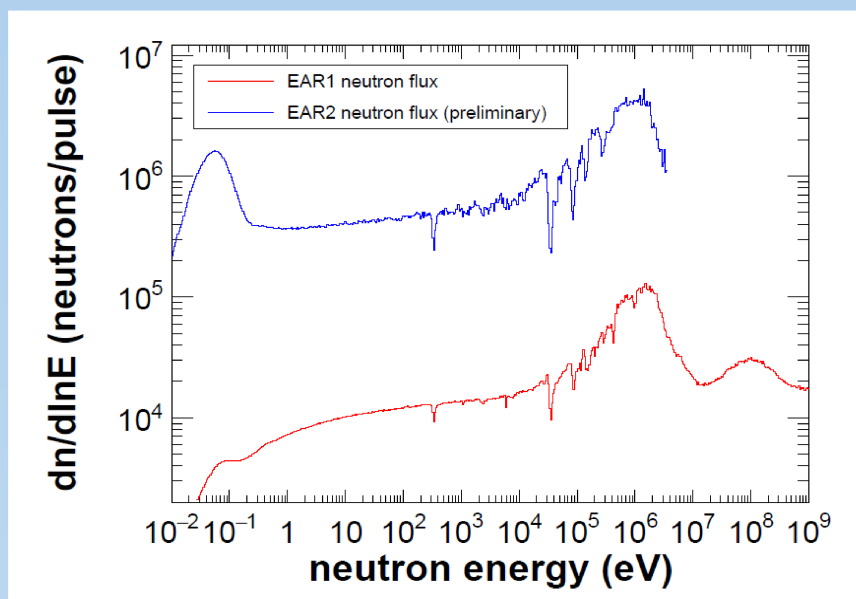
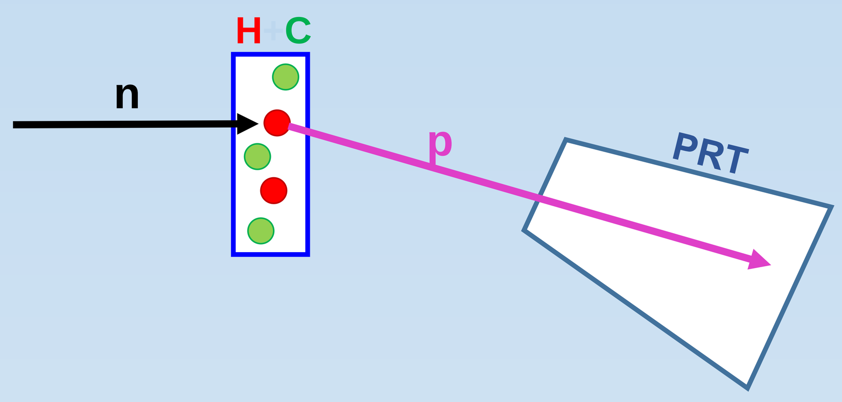


Figure 2: Neutron flux in EAR1 and EAR2 at the n_TOF facility at CERN.

The Proton Recoil Telescope

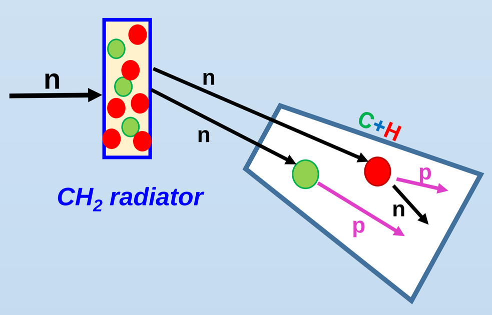
The **^{235}U(n,f) cross section** will be measured **relative to the elastic neutron–proton scattering** (n–p reaction), the best known and generally accepted primary reference at high energy.



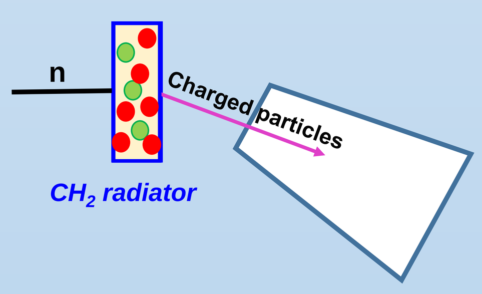
The setup consists of a target made of hydrogenous material (polyethilene) and a Proton Recoil Telescope, to detect and identify the recoiling protons from the n–p reaction.

The main issue in this measurement is the **background**. There are two possible sources of background, that affect the measurement.

1. Neutrons scattered from the target can undergo a n-p reaction in the detector;



1. neutron interaction with Carbon in the target produces protons and other light charged particles.



We studied with Geant4 simulations the best configuration for this measurement.

GEANT4 Simulations of the Proton Recoil Telescope

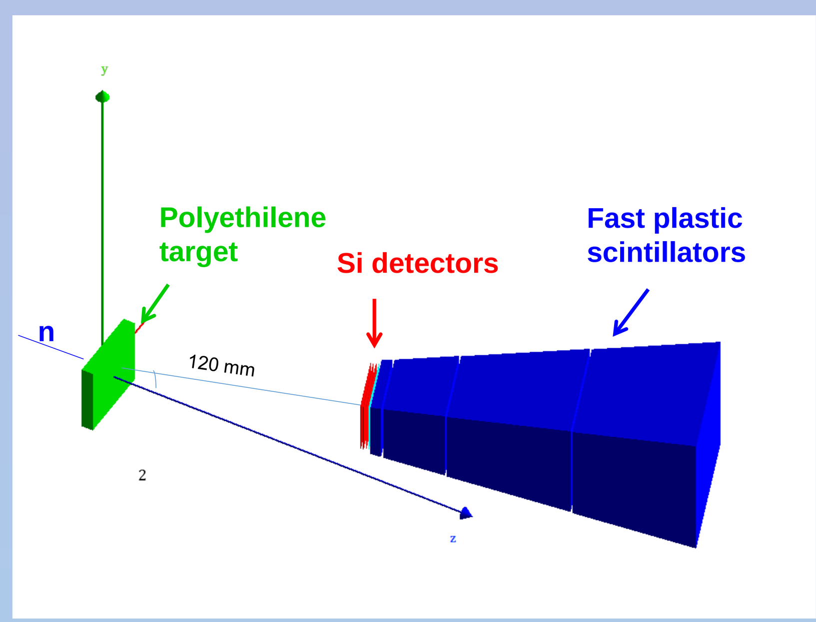


Figure 3: Schematic drawing of the PRT, as simulated in GEANT4. The telescope is mounted at an angle of 20 degrees relative to the neutron beam direction.

Several telescope configurations have been simulated. The chosen setup for the simulations consists of **four Silicon detectors**, and **four fast plastic scintillators** to identify particles **:**

Si Det.	Si Det.	Si Det.	Si Det.	Pl. Scint.	Pl. Scint.	Pl. Scint.	Pl. Scint.
300 μm	300 μm	300 μm	200 μm	0.5 cm	3 cm	6 cm	6 cm

For a well defined solid angle, a **trapezoidal shape** has to be used for the scintillators

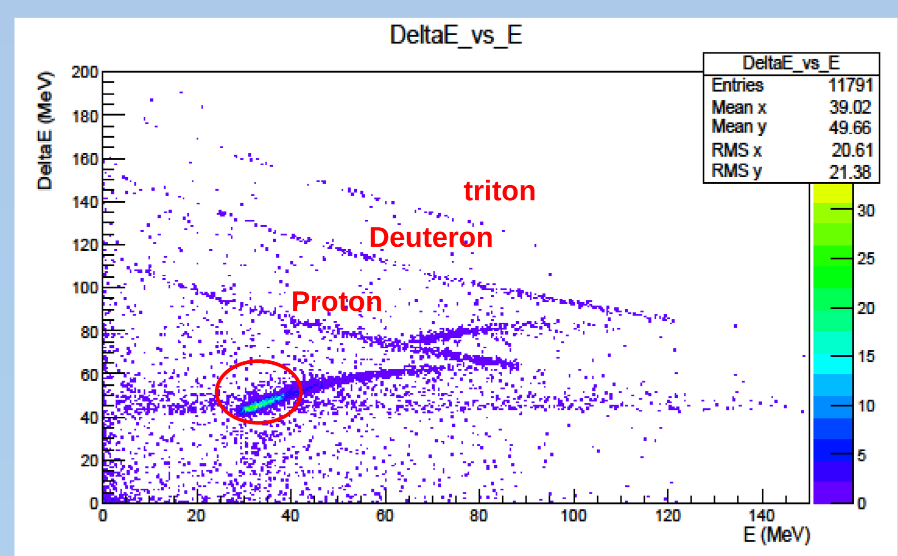


Figure 4: E-ΔE spectrum for ineutron of **E=250** MeV impinging on the Poliethylene radiator.

The chosen configuration is able to stop *protons* only up to 150 MeV. Nevertheless, higher energy protons from the n-p reaction can still be identified and separated from the background caused by neutron reactions with carbon in the polyethylene target.

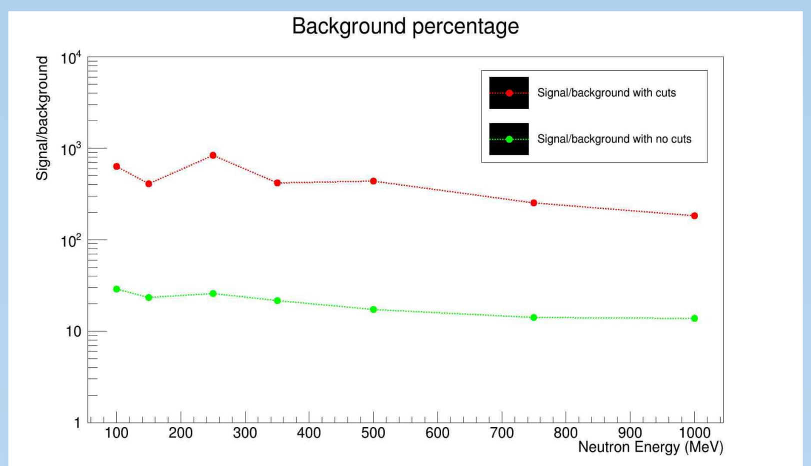


Figure 5: Signal/background ratio as a function of neutron energy with and without cuts on the E-ΔE plots, for neutrons interactions in the scintillators.

According to GEANT4 simulations, with a selection in the E-ΔE plot the background related to neutrons scattered in the scintillators can be reduced to a few percent only

Neutron-induced reactions with Carbon in the polyethilene target is a problem to be reckoned with. Even with the E-ΔE selection, the background at high energy accounts for 60% of the events.

However, this background component can be measured with a Carbon target, and subtracted.

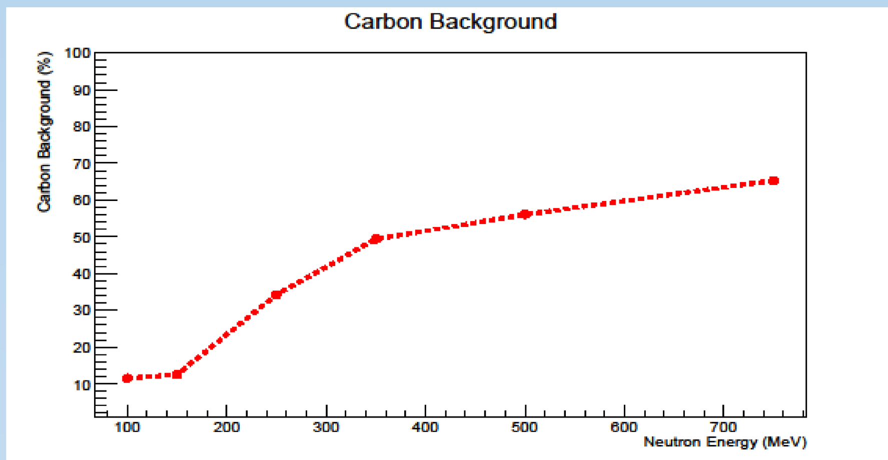
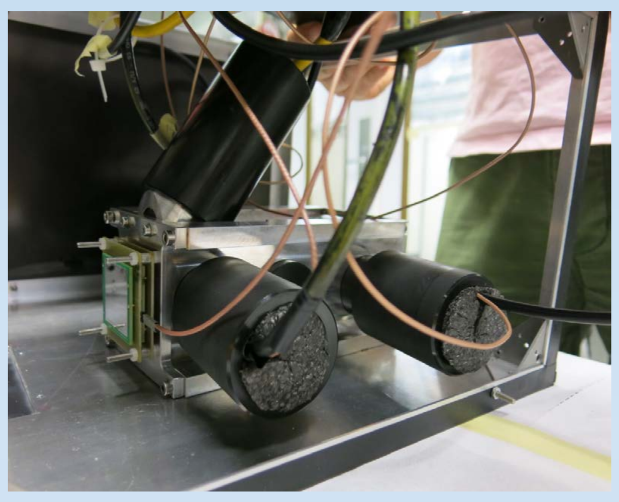
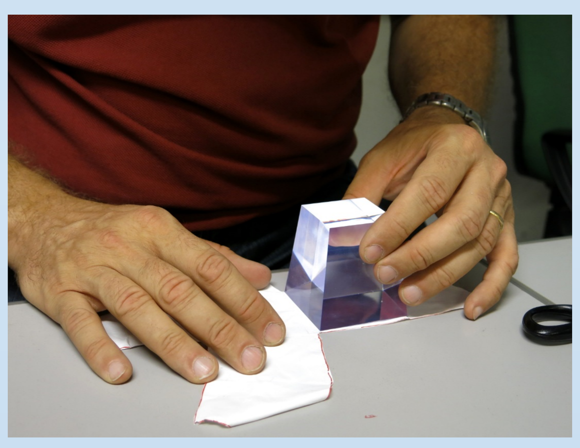


Figure 6: Background percentage of neutrons interaction with the carbon in the polyethylene radiator.

The test run at n_TOF



A prototype of the Proton Recoil Telescope has been built by the INFN team and mounted in EAR1 at n_TOF.



Data have been taken for a week. The analysis is in progress, but the preliminary results are encouraging.

CONCLUSIONS

The measurement is challenging (especially close to 1 GeV) but feasible. Simulations indicate that at high energies a large background due to interactions of neutrons with the carbon in the polyethilene target is present. However, this can be measured and subtracted.
A prototype has been built and tested at n_TOF. A first measurement should take place in 2017.