EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of the prompt fission neutron spectrum in the neutron induced fission of actinide targets

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Abstract:

Prompt neutrons from the neutron induced fission plays an important role in improving our understanding of fission dynamics and also a vital role in the design of next generation reactors for sustainable nuclear energy. This letter of intent aims at studying the feasibility to measure the prompt neutron spectrum in neutron-induced fission of ^{235}U using the spallation neutrons at CERN n_TOF facility. The feasibility study will be made for incident neutron energy range from thermal to high energy for this target. The time-of-flight technique will be employed to determine the energy of fission neutrons using liquid scintillation detectors. The prompt neutrons will be measured in coincidence with fission fragments using CERN MicroMegas detector with more than 90% detection efficiency for fission. If it is successful to measure the emitted neutrons at n_TOF, this measurement can be extend to other actinides (for different isotopes from Th to Am) for precision measurement of the prompt neutrons spectra and also other important nuclear physics problems can be addressed through an exclusive measurement of fast neutrons at the n_TOF facility.

Requested protons: 7×10^{17} protons on target
Experimental Area: EAR2

The study of prompt fission neutron spectra (PFNS) and average neutron multiplicities in neutron induced fission of actinides is very important for many applications such as in the design of fast breeder reactors and development of accelerator-driven systems for the transmutation of nuclear wastes and also for the evaluation of nuclear data for actinide nuclei for Gen-IV, AHWR reactors and dosimeter. In addition, this is essential for the understanding of fission dynamics. The neutron multiplicity is also relevant for accurate predictions of nuclear reactor criticality. The measurements on PFNS from major actinides ^{235}U, ^{238}U, ^{239}Pu, ^{232}Th and minor actinides ^{237}Np, ^{241}Am, ^{240}Pu, ^{245}Cm are either limited to few incident energies or scarce in the relevant energy range [1, 2, 3]. Therefore. there is a need of accurate data of the PFNS and neutron multiplicities (nubar) from thermal to fast and high energy neutrons up to 100 MeV.

In a coordinated research project of IAEA, the prompt fission neutron spectra and neutron multiplicity have been measured using liquid scintillator detectors for ^{238}U at incident neutron energies of 2.0, 2.5 and 3.0 MeV [4] at BARC. The measured prompt fission neutron spectra were compared with the evaluated spectra taken from the ENDF/B-VII.1 library and the calculations carried out using the EMPIRE-3.2 (Malta) code with built-in Los Alamos and Kornilov PFNS models are shown in Fig. 1. The average neutron multiplicity deduced from the PFNS measurement increases with the excitation energy. Though the average neutron multiplicities have been measured for the above system up to 20 MeV, the prompt fission neutron spectra are not available for most of the cases. The measurement of the PFNS can be extended for actinide targets using advanced experimental setup for exclusive neutron measurement at the n_TOF facility over wide incident neutron energy range. Being the intense white neutron source as the beam, this letter of intent is for a feasibility study to measure the prompt neutrons from the neutron induced fission of ^{235}U that will address various issues related to the measurement of emitted neutrons such as pile up events, scattered neutron contribution and pre-equilibrium emission for high energy neutron beam. Our main motivation is to study both prompt fission neutron spectra and neutron multiplicity from neutron induced fission of actinide nuclei. In this letter of intent, we propose to measure the prompt fission neutron spectra as a function of incident neutron energy in the neutron induced fission of ^{235}U in EAR2. We would prefer to perform the experiment at EAR2 since it provides larger flight path for the neutron detectors (can be varied easily from 1 m to 2.5 m) and also the neutron flux is about 25 times higher than the flux at EAR1. The scattering from the walls will be less in EAR2. However the higher fission rate can contribute to pileup events which can be addressed in this feasibility study. Lower the target material helps in lowering the fission rate and so also the pile up. The statistics of event of interest will be less as the neutron detection efficiency is very small because the neutron is a neutral particle whose detection efficiency is both energy and threshold dependent. We require a reasonable statistics to have an opinion on various problems related to the measurement of emitted neutrons at n_TOF. We will measure the prompt fission neutrons using liquid scintillator based neutron detectors in coincidence with fission fragments using Micromegas detector. The liquid scintillators will be placed at about 1 m flight path from the target at various angles from 30° to 120°.

It may be mentioned that an experiment on gamma ray energy spectra and multiplicity from neutron induced fission of ^{235}U has been recently carried out using STEFF

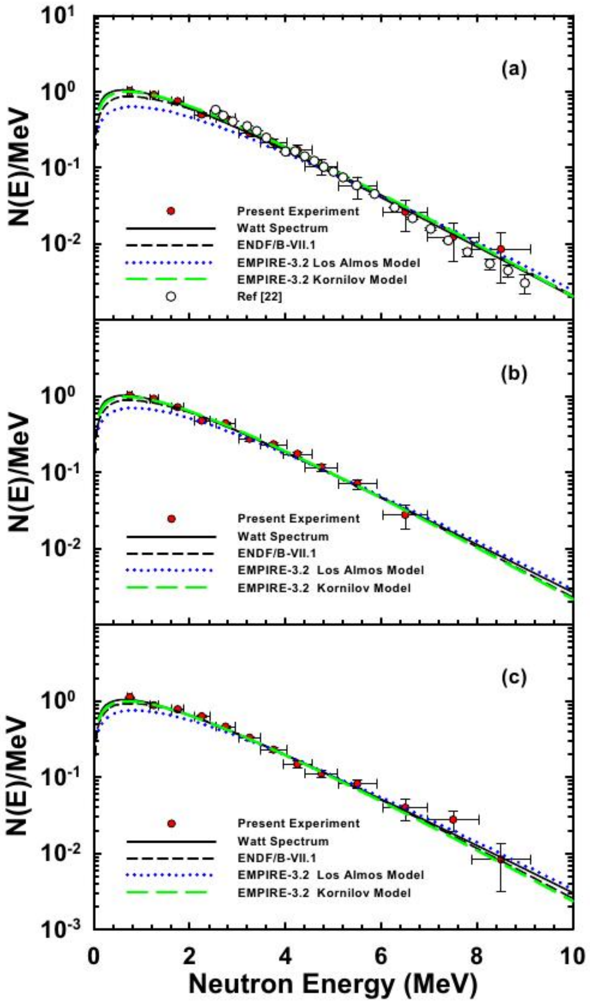

Figure 1: The prompt neutron spectra for ^{238}U measured at BARC [4] and comparison with Watt spectrum, ENDF (B-VII.1), EMPIRE-3.2 calculation using Los Alamos and Kornilov model at incident neutron energy of (a) 2.0 MeV, (b) 2.5 MeV, and (c) 3.0 MeV.

spectrometer in last experimental campaign at the EAR2 [5] where gamma rays are measured in coincidence with the fission fragments. The prompt gamma rays were measured using 12 NaI scintillation detectors as a function of mass and energy of the fragments for accurate knowledge of decay heat caused by gamma emission. In the present letter of intent, we will measure the prompt fission neutron spectrum using five liquid scintillators in coincidence with the detector of fission fragments. A schematic experimental setup is shown in Fig. 2. The liquid scintillator has very good timing (resolution$\sim$ns) in addition to its pulse shape discrimination property which enables unambiguous identification of neutrons amid gamma-ray background. Five detectors of 5 inch diameter and 5 inch long cylindrical liquid scintillator belonging to RIPEN array [6] will be used for the measurement of prompt neutrons. A MicroMegas detector (as in Fig. 2) will be used for measurement of fission fragments with nearly 100% detection efficiency. The

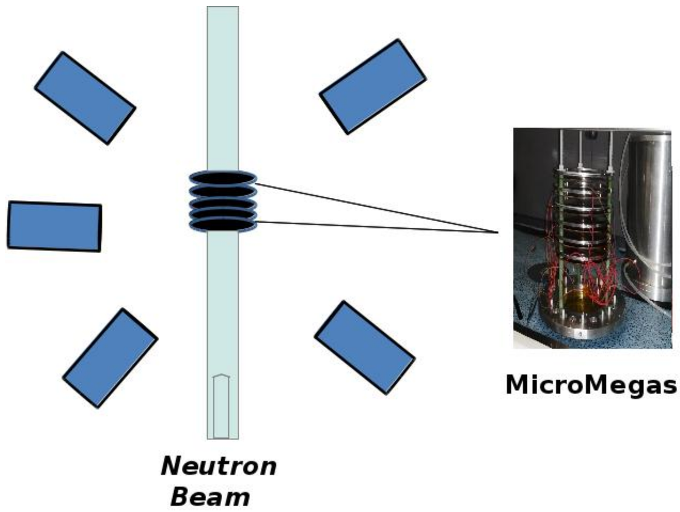

Figure 2: The schematic of the setup for the measurement of PFNS with five liquid scintillators and neutrons will be tagged by the fission fragments using MicroMegas detector loaded with ^{235}U target. The liquid scintillators will be brought from Legnaro.

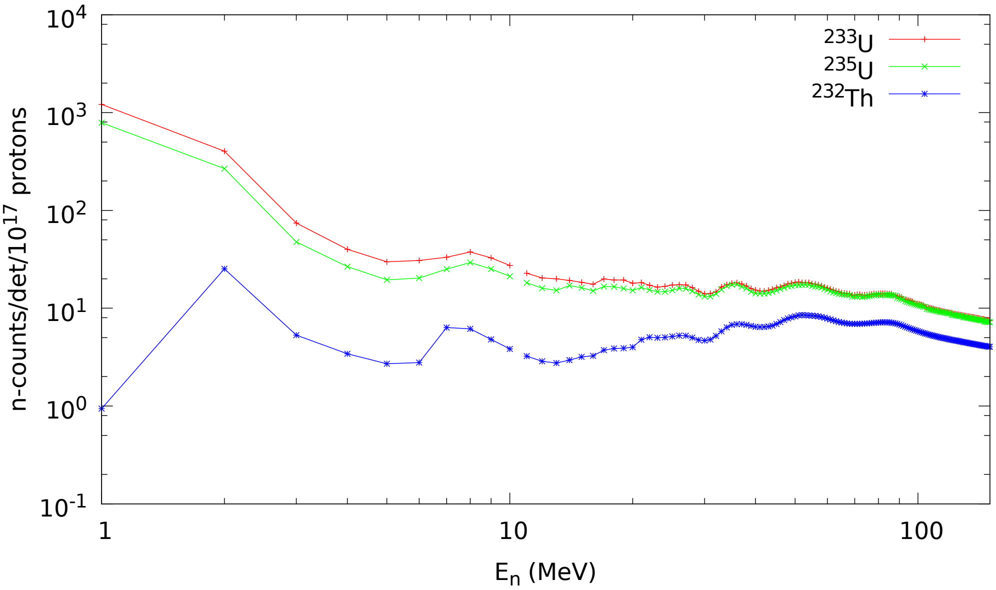

Figure 3: Calculated neutron and fission coincidence event rate per energy bin for ^{233}U,^{235}U and ^{232}Th using the fission probability, 50mg target material, neutron flux of EAR2 and an average efficiency of 50% for each neutron detector with appropriate efficiency for fission detector.

equivalent thickness of target material of 50 mg can be used in the final measurement. An estimation of count rate for the various targets has been carried out considering the fission cross section, neutron multiplicity and detector efficiency. The flux in EAR2 is taken from the recent report by C. Weiss [7] by considering 1 MeV energy binning of flux. The calculated count rate per 10^{17} protons for each neutron detector is shown in Fig. 3 for ^{233}U,^{235}U and ^{232}Th. Since ^{232}Th(n,f) has a threshold and the fission cross section below 1.0 MeV is very small, we calculated fission and coincidence prompt fission neutron count rates from 1MeV to 100 MeV. The fission cross section data has been taken from ENDF-B-VII.1 and ROSFOND-2010 evaluation consistent with EXFOR data base. For prompt fission neutron calculation, we used average prompt neutron multiplicity data [8] and made linear extrapolation from 20 MeV to 80 MeV of neutron energy region.

In the present feasibility study, we will use the existing micromegas detector loaded with two ^{235}U targets on Al backing. The ^{235}U samples are of thicknesses 118 and 281 μg/cm^2 deposited on an Al backing of 30 μm. The diameter of the micromegas can be 6 cm or 9.5 cm. The small collimator (corresponding neutron beam spot size of 6 cm) will be used in this measurement. The signals from each detector will be processed using n_TOF digital signal processing acquisition system. As shown in Fig. 3, the prompt fission neutron counts per 10^{17} protons for ^{235}U vary with incident energy for all detectors assuming thresholds and energy dependent efficiency for the liquid scintillators. In order to address various problems related to the measurement of emitted neutron with a meaningful statistics a beam time of 7 days is required. The efficiency measurement of the neutron detectors will be carried out using ^{252}Cf source and the measurement requires the beam hall access for a day. The outcome of this feasibility experiment will decide the possibility for the measurement of emitted neutrons in neutron induced reaction at n_TOF facility.

Summary of requested protons: 7×10^{17} protons on target

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