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Title: The Prompt Fission Neutron Spectrum of 235U for Einc 0.7-5.0 MeV

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The Prompt Fission Neutron Spectrum of ^{235}U for E_{inc} 0.7-5.0 MeV

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The Chi-Nu experiment aims to accurately measure the prompt fission neutron spectrum (PFNS) for the major actinides. At the Los Alamos Neutron Science Center (LANSCE), fission can be induced using the white neutron source. Using a two arm time of flight (T.O.F) technique; Chi-Nu presents a preliminary result of the low energy component of the ^{235}U PFNS measured using an array of 22-Lithium glass scintillators.

1. Introduction

For applications of low energy nuclear physics, a thorough and precise knowledge of a fissioning system has obvious relevance. Prompt fission neutron spectra (PFNS) are of particular interest, and have recently been the subject of considerable theoretical and evaluation effort as seen in Refs. 1,2. As argued by Neudecker et al. in Ref. 2, there is currently a dearth of reliable and well documented data for many of the actinides of common interest. For fission induced by thermal neutrons, the PFNS of the fissile isotopes: ^{235}U and ^{239}Pu, have been studied by several groups. Fission induced by fast neutrons has received less experimental attention, and for fission of ^{239}Pu or ^{235}U, there are very few measurements, like Ref. 3 of the PFNS except for those made at the Los Alamos Neutron Science Center (LANSCE), see Refs. 4,5.

At LANSCE neutrons are generated via spallation off of a tungsten target at the end of an 800 MeV LINAC. At the Weapons Neutron Research Facility (WNR), the neutrons are used on various flight paths for a wide range of nuclear research. On the flight path 15° to the left of the target (15L), sits the Chi-Nu experiment. Chi-Nu is an experiment designed to be a high-precision, well-documented measurement of the fast-neutron induced prompt fission neutron spectra for the two major actinides: ^{239}Pu and ^{235}U. The focus of the results presented here is $^{235}\mathrm{U}(n, f)$. Chi-Nu is a joint effort by Los Alamos National Laboratory (LANL), and Lawerence Livermore National Laboratory (LLNL). Previous descriptions of the Chi-Nu experiment and its progress have been reported in various publications, see Refs. 6–10.

1.1. *Experimental Setup*

A Parallel-Plate Avalanche Counter (PPAC) housing ≈ 100 mg of ^{235}U was fabricated at LLNL and described in Ref. 11 to identify fission events and provide timing information. The PPAC is made of 10 plates that are perpendicular to the direction of the beam. Each plate actually consists of several layers, the first and last layer are platinum anodes, and in the middle of the stack that makes up each plate is the actinide sample. The PPAC is positioned in the center of the flight path cave, 21.5 m away from the WNR neutron production target and 106.7 cm above an 18 ft x 18 ft, thin aluminum floor. Incident neutron energies are determined on an event-by-event basis from the time of flight (T.O.F) for a neutron between the production target and the PPAC. Detection of a fission fragment in a PPAC cell also provides a start signal for the TOF measurement of the outgoing fission neutrons. Those neutrons are then detected in one of two arrays: an array of 22-Lithium Glass scintillation detectors (LiGl), 21 of which are doped with ^{6}Li, is used for measuring the low energy region of the PFNS (10 keV − 2.5 MeV), and an array of 54-liquid organic scintillators for the high energy region (500 keV − 15 MeV).

A significant source of background for measuring the prompt fission neutron spectrum in WNR is down-scattered neutrons, the shielding walls are placed a minimum of 3 m away from the arrays. In addition, beneath the thin aluminum floor there is a 2.1 m deep pit. To quantify the amount of room return and down-scattered neutrons seen by the Chi-Nu experiment, extensive modeling was done using the 'MCNPX-PoliMi' code which is a modified version of MCNPX the results of the modeling can be found in Ref. 12.

2. Data Analysis

2.1. ^{6}*Li Glass Array Data*

The data for ^{235}U were taken during the 2015 run cycle. A two-dimensional cut selecting fission neutrons is shown in Fig. 1, which is a histogram showing the outgoing T.O.F of fission neutrons and γ rays against the integral of the charge deposited in the LiGl detectors.

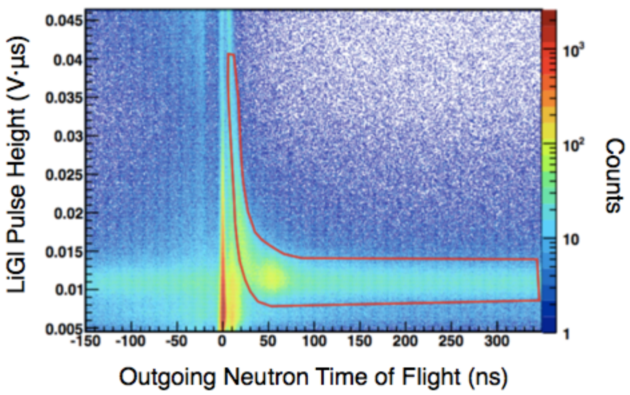

Fig. 1: A histogram showing TOF for the outgoing fission products versus the pulse height in the LiGl detector.The red polygon is a 2D cut attempting to select only the outgoing fission neutrons.

In this histogram, one can see the band in the x-direction at 0.01 Vμs, that is the Q-value band for the ^{6}Li$(n, \alpha)\,t$ reaction, with the resonance at 240 keV showing up as a more pronounced area on the band. One also notices that at $t = 0$ we see a vertical band corresponding to fission γ rays. The data that remain after the cut are binned not just by their outgoing neutron energy, but also by the energy of the neutron that was incident on the ^{235}U. Such a histogram can be seen in the upper panel Fig. 2. Using a robust algorithm for measuring the random coincidence background, described in Ref. 13, the Chi-Nu background is well described and shown in the lower panel of Fig. 2.

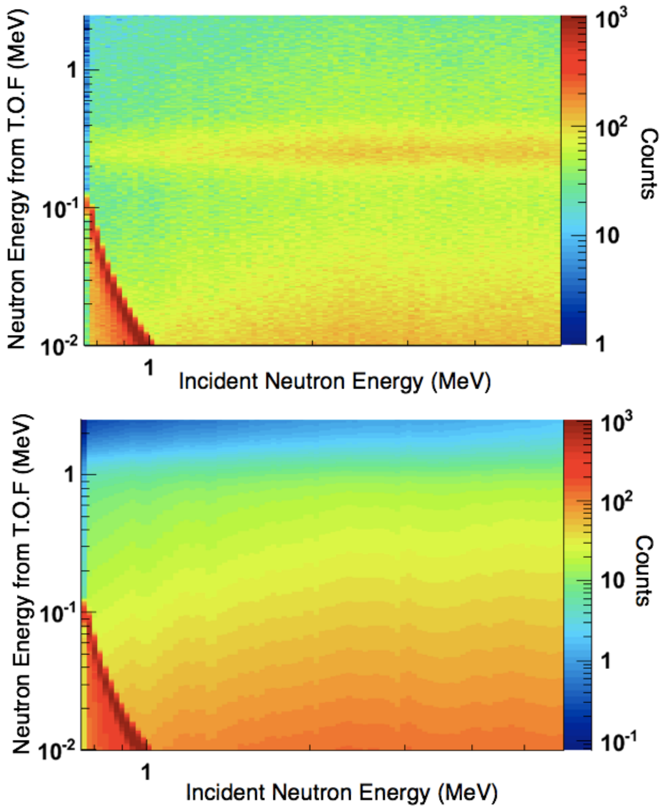

Fig. 2: Top Panel: A χ-matrix histogram for Chi-Nu data as was taken. The x-axis is incoming neutron energy, and the y-axis is the outgoing neutron energy. Bottom Panel: A χ-matrix histogram for the measured random background created using the algorithm in Ref. 13

2.1.1. *Low-Energy Results*

Using both panels of Fig. 2, one can project the data and the measured background into any arbitrary incident and outgoing bins a user desires. Combining the one dimensional projections of the foreground and the background for an incident neutron energy of (0.7 - 5.0 MeV), we see the result show in Fig. 3.

The PFNS presented in Fig. 4 is made by combining the data seen in Fig. 3 and the corresponding output from a detailed MCNP model.

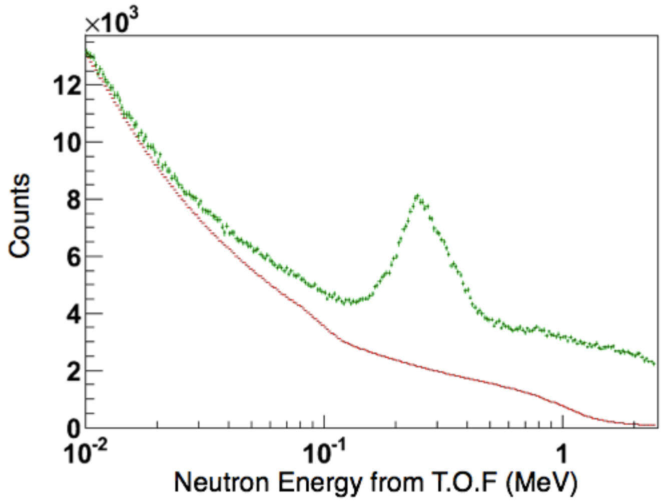

Fig. 3: One dimensional slice of χ-matrix histograms for the incident neutron energy range of (0.7 - 5.0 MeV). Measured total signal is shown by the black line, while measured random background is shown in red.

2.2. *Liquid scintillator Array Data*

Data were also taken on the PFNS of neutron-induced fission of ^{235}U with the liquid organic scintillator array, for outgoing neutron energies above 0.5 MeV. The analysis of these data is ongoing. These detectors use pulse-shape discrimination to separate neutron detection from γ-ray detection. Like the LiGl array, the response of the array is being modeled extensively with a high-accuracy MCNP model, and the same background determination methods are being used. The results of both the low energy and high-energy arrays for the ^{235}U(n, f) are expected to be presented in the near future.

3. Acknowledgements

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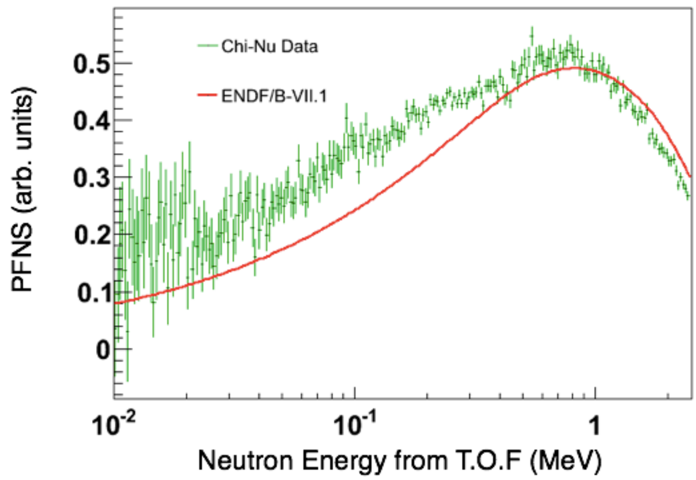

Fig. 4: Low energy portion of the PFNS for ^{235}U, the red curve is the PFNS from ENDF/B-VII.1. Both the data and ENDF are normalized over the plotted range.

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