NEUTRON INDUCED REACTION DATA AT EXTREME ENERGIES -STATUS AND DEMANDS

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The neutron-induced reaction data program in the Indian scenario is proceeding well based on ^{7}Li(p,n) neutron sources, D-T neutron generators etc. The energy ranges above 14 MeV is accessed through surrogate technique. However, there is a larger missing of neutron-induced reaction data in resonance regions, 4 - 13 MeV and energy range higher than 30 MeV, which has great demand in the interdisciplinary areas. It requires dedicated facilities to attempt and resolve the problem. However, as a primer to this, the exciting facilities can be utilized up to an extent.

1. Introduction

There is a great attempt over Indian nuclear physics group for quantifying the nuclear reaction data, generating covariances and compiling to EXFOR. The current nuclear data physics program is based on protons, neutrons, alpha projectiles and heavy ions at low and intermediate energy region.

Neutron-induced reactions in the resonance region have significant importance in reactor physics, Medical physics, nuclear astrophysics etc. In the Indian scenario, the neutron reaction data program is based on ^{7}Li(p,n) channel, which produces tunable quasi-monoenergetic neutrons up to 3 MeV[1]. There are many successful attempts to predict neutron spectrum using tabulated ^{7}Li(p,n) channels, gives more confidence in tailing correction approach [2].

D-T neutron generation is one of the other prominent channels for neutron energies around 14 MeV. The research-based on 14 MeV neutrons are concentrated in PURNIMA laboratory, BARC and Pune University neutron generator laboratory. Also, there are many attempts to measure the spectrum averaged cross sections by photoneutrons, produced via ^{9}Be(γ,n) reactions from Pune University microtron facility and other established medical accelerators.

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Further neutron-induced data program at higher energy side (above 15 MeV) is governed by the surrogate method[3]. The feasibility of the surrogate method for neutron-induced reactions is successfully demonstrated, in recent years. However, the accepted fact that the preequlibrium and direct component of the nuclear reaction excitation function will be missed through this method. Present theoretical (statistical ad semi-statistical) codes are quite successful to predict neutron induced reaction cross sections at energy ranges, where the present data program is progressing.

However there is a large missing of neutron induced cross section data in the low energy ranges of 1 eV to 100 keV, and 5 MeV to 13 MeV and above 30 MeV etc. This is due to the unavailability of quasi-monoenergetic neutron sources in these energy ranges. The data in low energy range is mostly quantified as spectrum averaged, and above 30 MeV it is not attempted.

The proton and heavy ion radiotherapy facilities are using beam energies typically to 300MeV/nucleon. This will make a shower of secondary particles significantly, up to an energy of 100 MeV. The neutrons produced via these channels produce an additional, unwanted dose to the patient, cause to the secondary malignancy. To quantify this the interaction behaviour of these neutrons has to be well measured and evaluated.

2. Probing into Low Energy Region

Low energy neutron-induced data including inelastic cross sections, elastic cross sections and capture cross sections are important for the neutron transport in reactor physics as well as the dosimetric calculations. This demands a repository of high-quality nuclear data includes uncertainties and covariances. However, there are no monoenergetic neutron sources with a lesser energy spread is available in this energy range. The reaction residues may stable, short-lived with halflife less than a second, or long-lived. These highlights limit the feasibility of activation analysis methods. Such condition demands the requirement of ToF tagged neutron setup for the measurement of the cross section in this energy range. It also doesn't matter that the residue will be radioactive or not.

The neutron time of flight tagged online measurement facilities are already established in many of the laboratories in the world, such as the neutron chopper setup in Brookhaven National Laboratories, GELINA Neutron time-of-flight facility of European Commission, CERN n_ToF etc[4][5]. Such a facility has to be introduced in India to address the nuclear data requirements in the country. The feasibility of such a measurement has been verified using 10Ci Am-Be source at the University of Calicut, through neutron energy tagged via 4.4 MeV γ-rays.

Such facilities can be immediately established in the low energy accelerator facilities available at FRENA in SINP and LEHIPA in BARC, that can produce pulsed beams. Thick target ^{7}Li(p,n) channel can provide neutrons in the energy range of few eV and up to 1 MeV. Further FRENA facility can provide neutron up to 15 MeV with utilizing the feature of α beams.[7]

3. Neutron Induced Data in Intermediate Energies

The 4 MeV to 13 MeV neutron energy band is also suffering because of the unavailability of mono-energetic neutron sources in the energy range. However, the 4 to 13 MeV band is important as the reactor physics, radiotherapy, isotope production as well as the basic nuclear physics interest. These energy ranges can be probed through the inverse kinematic channels like ^{1}H(^{7}Li,n), ^{1}H(^{11}B,n),^{1}H(^{13}C,n) etc., which can be tunned from 4 MeV to 15 MeV as a monoenergetic neutron source[6]. These channels can also support the neutron data physics requirements, with utilizing present accelerator facilities in India. However, the beam current limitations and target issues are the major problems and none of these inverse kinematic neutron sources has tested in India. ^{3}H(p,n) channel is one of the globally established channels to produce monoenergetic neutrons, tunable in the range of few keV to 10 MeV. The feasibility of implementing ^{3}H(p,n) reaction, with TIFR pelletron, VECC - K130 cyclotron etc. has to be verified, with considering health physics requirements. However, with keeping the present current limitations, the online methods can overcome this upto an extant and will make the experiments possible. Further, in-depth research has to be initiated for production of monoenergetic neutron sources, tunable neutron sources in the energy ranges of keV to several MeV to support the nuclear data physics program and nuclear physics interest.

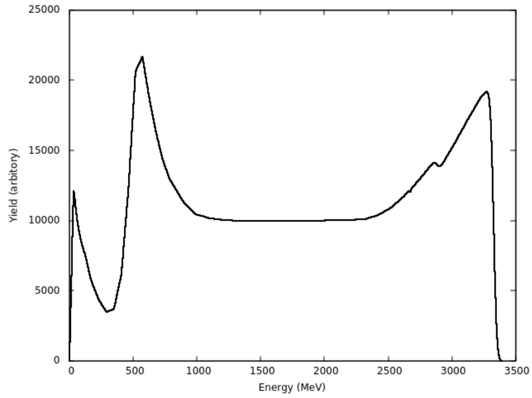

FIG. 1: Neutron spectrum from 5 mm thick Li target through ^{7}Li(p,n), at 3 MeV