DOI: 10.15415/jnp.2015.31010

Fusion Nuclear Data activities at FNL, IPR

*P. M. PRAJAPATI[1], B. PANDEY[1], S. JAKHAR[1], C.V. S. RAO[1], T. K. BASU[2], B. K. NAYAK[3], S. V. SURYANARAYANA[3] AND A. SAXENA[3]

[1]Fusion Neutronics Laboratory, Institute for Plasma Research, Bhat, Gandhinagar – 382 428, India

[2]Raja Ramanna Fellow of DAE, Institute for Plasma Research, Bhat, Gandhinagar – 382 428, India

[3]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400 085, India

***Email: paresh_21soft@yahoo.co.in**

Received: June 07, 2015 | Revised: June 28, 2015 | Accepted: July 09, 2015

Published online: August 03, 2015

Abstract: This paper briefly describes the current fusion nuclear data activities at Fusion Neutronics Laboratory, Institute for Plasma Research. It consist of infrastructure development for the cross-section measurements of structural materials with an accelerator based 14 MeV neutron generator and theoretical study of the cross-section using advanced nuclear reaction modular codes EMPIRE and TALYS. It will also cover the proposed surrogate experiment to measure ^{55}Fe (n, p) ^{55}Mn using BARC-TIFR Pelletron facility at Mumbai.

Keywords: Neutron Generator, Scattering chamber, Cross-section and Surrogate method

1. INTRODUCTION:

The worldwide efforts in fusion energy technology aim at developing, in the long-term, power reactors that can contribute substantially to the supply of electricity. The construction and operation of the experimental fusion device ITER (International Thermonuclear Experimental Reactor) [9] is considered as essential next steps towards this long term goal. The development of fusion reactor require significant amount of new and improved nuclear data in extended energy regions as well as for a variety of new materials. There is a variety of materials present in the complex ITER device including materials of the TBM (Test-Blanket Module), the plasma facing components, the shield modules, the vacuum vessel, the super-conducting magnets and the

Journal of Nuclear Physics, Material Sciences, Radiation and Applications
Vol. 3, No. 1
August 2015
pp. 87–92

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biological shield. Since the near-term focus of the fusion Programme is on the TBM design, the elements Be, Pb, Li, Si, O, Fe, Cr, W, Ta, Cu, and Ti are currently considered as high-priority elements for which well-qualified evaluated data sets are required, including specific reaction data of its natural isotopes.

It is obvious from the above discussions that nuclear data play very important role on fusion reactor technology. Therefore at Fusion Neutronics Laboratory (FNL), it has been decided to initiate fusion nuclear data activity in order to generate new and improved data for fusion device. The current fusion nuclear data activity at FNL consists of following four things. (1) Infrastructure Development for the cross-section measurements – Scattering chamber design for an accelerator based 14 MeV neutron generator, (2) Double differential cross-section (DDX) study for the emission of alpha particles from ^{56}Fe (n, α)^{53}Cr with 14 MeV neutrons, (3) Theoretical study of ^{56}Fe(n, α)^{53}Cr reaction from threshold to 20 MeV and (4) Determination of ^{55}Fe(n, p)^{55}Mn cross-section using BARC-TIFR Pelletron facility by surrogate method. The present paper describes aforementioned four things in quite detail.

3. INFRASTRUCTURE DEVELOPMENT FOR THE CROSS-SECTION MEASUREMENTS – SCATTERING CHAMBER DESIGN FOR AN ACCELERATOR BASED 14 MeV NEUTRON GENERATOR

A general purpose scattering chamber has been designed [6] and it will be coupled with an accelerator based 14 MeV neutron generator [7] at FNL. This facility will be used to perform fundamental nuclear physics experiments for the development of Fusion Neutronics activity. The chamber is made of ASTM/ASME SA 312 Grade TP 304L. The configuration of the chamber is a vertical cylinder (Dimensions OD 356xL 200 mm) with six ports of different sizes varies from 35CF to 150CF. The wall thickness of the chamber has been kept as 3.56 mm. It has four ports 90º apart. The four ports are as follows: (1). Beam entry port (2). Beam exit port (3) Turbo Molecular Pump (TMP) port and (4). View port. Apart from these four main ports, the chamber has two additional ports at 45º along with the beam direction for BNC feed through and vacuum gauge. A special type of moving mechanical assembly has been fitted on the bottom flange of the chamber for holding target. It has been designed to house charged particle detector telescopes based on surface barrier detectors (SBD) for the on-line detection of charged particles. The schematic view of the general purpose scattering chamber has been shown in Fig.2.

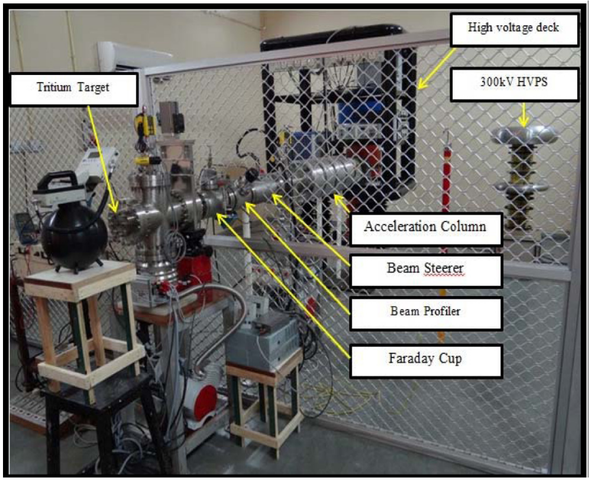

Figure 1: 14 MeV neutron generator at FNL.

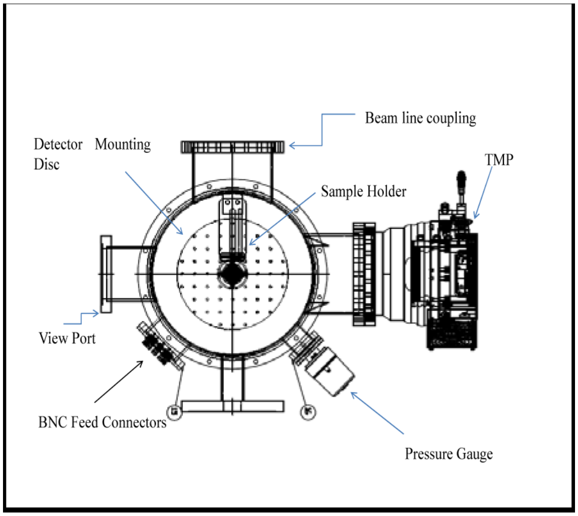

Figure 2: Schematic view of the scattering chamber.

3. DOUBLE DIFFERENTIAL CROSS-SECTION (DDX) STUDY FOR THE EMISSION OF ALPHA PARTICLES FROM ^{56}Fe (N, A)^{53}Cr WITH 14 MeV NEUTRONS

DDX data will play an important role in estimating the nuclear heating and damage of candidate materials of the fusion reactor irradiated with 14 MeV

Prajapati, PM
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Rao1, CVS
Basu, TK
Nayak, BK
Suryanarayana, SV
Saxena, A

neutrons from D(T, n) α reaction. A literature available in IAEA-EXFOR database indicates that there is no DDX measurement for ^{56}Fe (n, α) ^{53}Cr reaction at 14 MeV. In view of this, the double differential cross-section (DDX) for the emission of alpha particles from ^{56}Fe (n, α) ^{53}Cr has been calculated [5] using TALYS-1.4 [1] at 14 MeV neutron energy. It is shown in Fig.

4. THEORETICAL STUDY OF ^{56}Fe(N, α)^{53}Cr REACTION FROM THRESHOLD TO 20 MeV

The excitation function of ^{56}Fe (n, α) ^{53}Cr reaction from threshold to 20 MeV has been calculated [8] using the Hauser-Feshbach statistical model with pre-equilibrium effects by TALYS-1.4 code. The present calculations are compared with existing experimental data as well as with latest available evaluated nuclear libraries ENDF/B-VII, JEFF-3.2 and JENDL-4.0 and it is shown in Fig. 4. A good agreement between the calculated and experimental data validates the nuclear model approaches with increased predictive power to supplement and extend the nuclear database.

5. DETERMINATION OF ^{55}Fe(N, p)^{55}Mn CROSS-SECTION USING BARC-TIFR PELLETRON FACILITY BY SURROGATE METHOD

^{55}Fe ($t_{1/2}$ = 2.73 years) is one of the radio-nuclide which is produced in large quantities inside the fusion reactor via the ^{56}Fe (n, 2n) ^{55}Fe, ^{54}Fe (n,γ) ^{55}Fe, ^{58}Ni (n,α) ^{55}Fe [8]. Neutron induced cross-section for long-lived activation products produced in fusion reactor are very important since they could pose a serious radiation damage & waste disposal problem. These cross-sections are very important for reactor system studies, diagnosing fusion experiment and for fluence monitors for radiation damage experiments. The measurement of neutron induced cross-section of these nuclides is extremely difficult as they do not exist in nature. Surrogate method, which is an indirect way of determining cross-sections for nuclear reactions that proceed through a compound nucleus, is a promising method for neutron induced cross-section measurement on such nuclides [4]. Here our attempt is to initiate the measurement of (n, p) (n,α) reaction cross-section for the radioactive nuclides which are important in Fusion Reactor Technology. Such studies would be the first of its kind on fusion materials. Currently, we have proposed the reaction ^{6}Li+ ^{52}Cr $\rightarrow$ d + (^{56}Fe)* as a surrogate of the n + ^{55}Fe $\rightarrow$ (^{56}Fe)* $\rightarrow$ p+ ^{55}Mn. In this context, we have performed the detailed theoretical study of the desired reaction ^{55}Fe (n, p) using nuclear reaction modular codes EMPIRE and TALYS [2]. All the conditions which must have to satisfy before using the surrogate method have been checked. The energy of ^{6}Li beam is selected in such a way to get

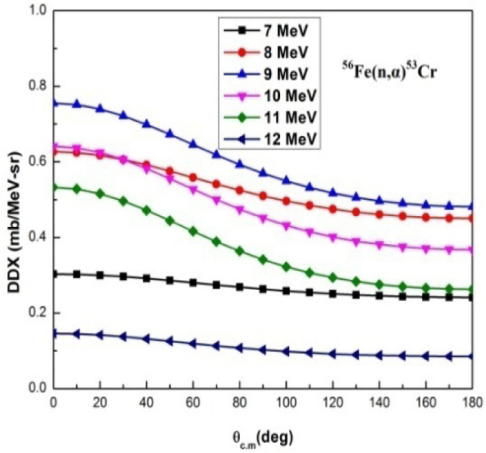

Figure 3: DDX of ^{56}Fe (n, α)^{53}Cr reaction at 14 MeV.

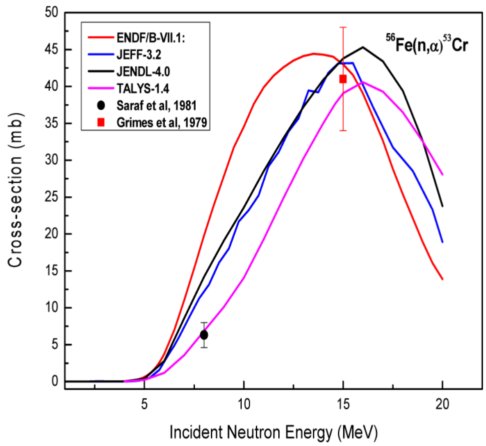

Figure 4: Excitation functions of ^{56}Fe (n, α) ^{53}Cr.

equivalent neutron energy in the region of 9-14 MeV, which is the main energy interest in fusion reactor application [3]. On the basis of the present study an experiment has been proposed at BARC-TIFR Pelletron facility Mumbai to measure the cross-section of ^{55}Fe(n, p)^{55}Mn reaction with surrogate reaction ^{6}Li(^{52}Cr,d)^{56}Fe.

The self-supporting target of nat-Cr and enriched ^{52,53}Cr are being prepared using various sputtering technologies and electroplating as normal rolling does

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not work due to its very brittle nature. For 1-3 micron Cr target deposition, we are using sub micron grade polished NaCl crystal as substrate.

ACKNOWLEDGMENTS

We are grateful to Profs. Roberto CapoteNoy (NDS, IAEA), S. Ganesan (BARC, Mumbai), H. M. Agarwal (GBPU, Pantnagar), H. Naik (BARC, Mumbai) and S. Mukherjee (MSU, Baroda) for their valuable suggestions.

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