Proposal for a compact ECR+RFQ based neutron Time-of-Flight facility at BARC for fast neutron induced fission, (n,Xn) reactions and applications

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Introduction

Compact accelerator-driven neutron sources (CANS) based on low-energy neutron-producing reactions, are being built across the world due to their increasing importance in basic and applied research [1]. These facilities typically consist of a high current ECR ion source (IS) coupled to an RFQ along with the required beam transport elements, buncher and chopper systems to accelerate p, D and/or light ions up to an energy of 1-2 MeV/u. Experiments proposed/performed with these facilities include study of fast neutron induced fission of actinides and their prompt fission neutron/gamma energy spectra, and various aspects of nuclear astrophysics and nuclear spectroscopy [2]. In addition, the neutron time of flight (TOF) will provide opportunities for neutron induced reaction measurements including fission and (n,Xn) reactions important for nuclear technology and applications such as fast neutron radiography, radioisotopes production etc.[1,3].

Schematic of the facility

Development of a prototype heavy-ion accelerator is envisaged at Hall-9, NPD, BARC. As phase-I of the program, a high current ECR-IS will be installed along with the development of an RFQ. While low energy nuclear reactions have already been initiated with the ECR-IS facility at NPD, BARC [4], we propose to implement a fast neutron production facility, including TOF, using the D+^{7}Li reaction as an additional development. The schematic of such a facility is shown in Fig. 1. It is expected that the total footprint of the main facility, shielding and associated supporting facilities would be less than 1000 sq-meters [5] which is well within the available space in Hall-9. The ECR-IS can deliver wide range of ion species (ranging from proton to bismuth) beams of mA current and can operate at 30 kV extraction voltage on the 300 kV platform.

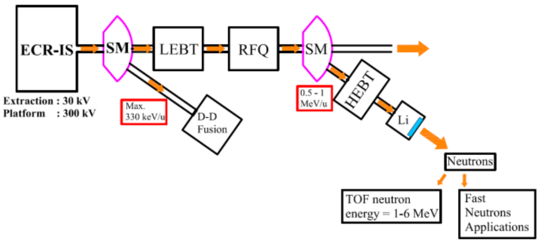

Fig.1 Schematic of the proposed facility for fast-neutron induced - basic and applied research at NPD, BARC.

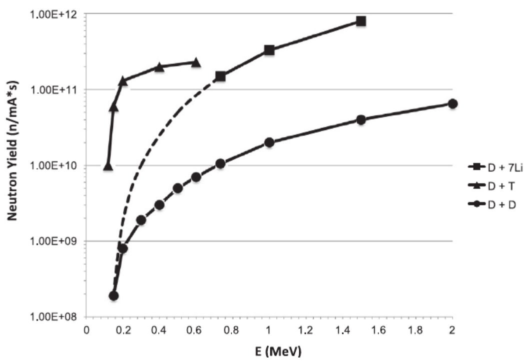

Fig.2 Neutron yield versus the incident deuteron bombarding energy [6].

With the addition of an RFQ (0.5-1 MeV/u), it can provide deuterium beams in the range of 1-2 MeV at high currents. Fig. 2 shows the neutron yield per mA per second as a function of incident energy for three common neutron producing reactions. It is evident that in the energy region mentioned above, the most promising appears to be the D+^{7}Li reaction.

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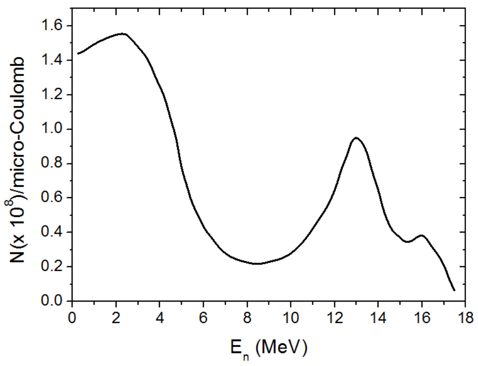

Fig. 3 Typical 0º neutron spectrum from the D+^{7}Li reaction.

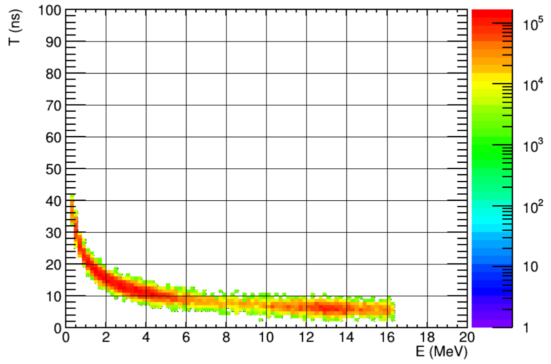

Fig. 4 Energy vs TOF of neutrons at 30 cm from the target.

Simulations of neutron spectra

Monte Carlo simulations were carried out for obtaining the energy versus TOF distribution of neutrons produced from the D+^{7}Li reaction using the 0º neutron spectrum (see Figs. 3 & 4) for the reaction at a deuteron energy of 2 MeV. As can be seen, the D+^{7}Li reaction is a positive Q-value reaction producing neutrons all the way up to ~ 17 MeV. The simulations were carried out using GEANT4, where the particle generator produces neutrons sampled from the spectrum shown in Fig. 3. A time resolution ~ 1 ns was introduced while generating the corresponding TOF spectrum. Fig. 4 shows the energy, E, versus TOF, T, for neutrons at a distance of 30 cm from the Li target. Table 1 shows the average energy and flux of the neutrons at a given distance from the Li target for various TOF windows.

Distance (cm)	TOF (ns)	Average neutron energy (MeV)	Average flux (N/cm^2/mA*s)
30	8-10	5.91	3.35 x 10^6
30	10-12	3.81	3.41 x 10^6
30	12-14	2.89	2.70 x 10^6
30	14-16	2.16	1.92 x 10^6
30	16-18	1.64	1.34 x 10^6
20	12-14	1.31	2.79 x 10^6
20	14-16	0.96	1.81 x 10^6

Table.1. Neutron mean energy and the estimated flux.

It can be seen that a neutron flux ~10^6 /cm^2/s can be produced at 30 cm from the ^{7}Li target for the entire energy range of interest using deuterium beam at an average current of ~1 mA. The total power that needs to be dissipated ~ 1-2 kW, which is well within the limit of about 16 kW for water cooled solid Li targets [2]. We would also like to emphasize that besides ^{7}Li, ^{9}Be and ^{13}C are also suitable candidates as targets depending on the requirement of the fast neutron spectrum for a given application. It should be noted that, this flux and energy is well suited for fast neutron induced fission studies of actinides where accurate data regarding various fission observables are required in the context of Gen-IV reactor systems.

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