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Nuclear data measurements at the new NFS facility at GANIL

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Abstract. The NFS (Neutrons For Science) facility is part of the SPRIAL 2 project at GANIL, Caen, France. The facility is currently under construction and first beam is expected early 2013. NFS will have a white neutron source covering the 1 MeV to 40 MeV energy range with a neutron flux higher than comparable facilities. A quasi mono-energetic neutron beam will also be available. In these energy ranges, especially above 14 MeV, there is a large demand for neutron-induced data for a wide range of applications involving dosimetry, medical therapy, single event upsets in electronics, and nuclear energy. Today, there are few or no cross section data for reactions such as (n,fission), (n,xn), (n,p), (n,d) and (n, α). We propose to install experimental equipment for measuring neutron-induced light charged particle production and fission relative to the H(n,p) cross section. Both the H(n,p) cross section and the fission cross section for ^{238}U are important reference cross sections used as standards for many other experiments. Nuclear data for certain key elements, such as closed shell nuclei, are also of relevance for development of nuclear reaction models. Our primary intent is to measure charged particle production (protons, deuterons and alphas) from ^{12}C , ^{16}O , ^{28}Si and ^{56}Fe and neutron-induced fission cross sections from ^{238}U and ^{232}Th .

1. Introduction

Neutron-induced reactions are of importance not only for basic physics research, but also for a number of applications e.g. in the fields of nuclear energy production, single event effects in microelectronics, medical diagnostics and treatment, materials research and production of radio-elements. Many applications rely on transport codes for calculations, and use evaluated nuclear data libraries which are based on experimental data and nuclear models. For reactions such as $(n, \text{fission})$, (n, γ) , (n, xn) and neutron-induced light charged particle production, and energies above 14 MeV, there is a lack of good quality nuclear data which affects the quality of the available nuclear data libraries. An example is shown in Fig. 1, illustrating the discrepancies in the $C(n, \alpha)$ cross section. The data situation is similar for other charged particle producing reactions for many nuclei such as O, Si, Fe.

Figure 1. $C(n, \alpha)$ from the literature. There are large discrepancies between evaluations and available data for several important reactions in the 1-40 MeV region.

With the building of the NFS (Neutrons for Science) facility, studies of neutron-induced reactions in the energy range 1-40 MeV will be possible with a neutron flux up to 2 orders of magnitude higher than those of other existing time-of-flight facilities in the 1-40 MeV range [1]. NFS will be part of the first stage in the building of SPRIAL-2 GANIL, Caen (France), a facility ultimately aimed at producing very intense radioactive ion beams (RIB) in the mass range from $A=60$ to $A=140$ [2]. Construction work has begun for SPRIAL-2, and NFS, belonging to phase one of the project, is expected to have first beam early 2013.

2. Description of NFS

The NFS facility will consist of two rooms, the converter cave for neutron conversion and the experimental hall. After conversion, a bending magnet will clear the neutron beam before it is collimated and enters the experimental hall. In the converter room, there

will be an irradiation box for activation technique measurements. The experimental hall will be 30 m long and allow time-of-flight measurements from 5 m up to 25 m away from the converter point.

Two neutron production modes will be possible. The first one is deuteron break-up reactions on a thick full-stopping converter made of either carbon or beryllium. These reactions generate neutrons with a continuous energy distribution (white neutron spectrum). At 0° , the spectrum extends up to maximum energy (40 MeV) with an averaged value of approximately 14 MeV [1].

The second production mode is the ${}^7\text{Li}(p,n){}^7\text{Be}$ reaction which produces a quasi-monoenergetic neutron spectrum with the peak energy slightly below the incoming proton energy. Since the Li target is thin (1-3 mm) a clearing magnet is needed downstream of the Li target.

In Ref. [3] a comparison is made between NFS and other major TOF facilities, namely n-TOF at CERN, WNR at Los Alamos and GELINA in Geel. It turns out that the neutron flux at NFS is very competitive between 1 and 35 MeV in terms of average flux [3].

At the converter point, the time spread is shorter than 1 ns, which, together with the length of the experimental area, gives an energy resolution at 40 MeV that is better than 1% [1].

3. Experimental proposals

Several letters of intent have been submitted to the scientific advisory committee of NFS. Two have been proposed by Uppsala University and are described in the sections below.

3.1. Light ion production with Medley

We propose to measure double-differential cross sections for neutron-induced light-ion production using the quasi-monoenergetic neutron spectrum from the ${}^7\text{Li}(p,n){}^7\text{Be}$ production mode. We would like to measure p, d and α production from some isotopes which are relevant from the applications point of view, namely C, O, Na, Si, Ca, Fe, Pb, Bi, and U. As mentioned before, data for these reactions are very scarce in the energy range of importance for applications and accessible by the NFS, i.e. 1-40 MeV.

Initial focus will be on C, O (medical applications), Si (together with O important in electronics applications), and Fe (construction material in many applications). To achieve this, we need to measure on three targets: Si, SiO_2 and Fe. The C data come for free since the (quasi-monoenergetic) neutron spectrum needs to be measured using a CH_2 target and a C target for carbon subtraction.

The detector to be used is the Medley setup, currently installed at The Svedberg laboratory in Uppsala. Medley consists of a vacuum chamber with eight detector telescopes and has been described in detail in Ref. [4].

Medley is designed for detection of charged particles and the eight three-element telescopes are mounted inside a cylindrical evacuated chamber with inner diameter of 800 mm. The telescopes are placed at 20° intervals, covering scattering angles from 20° to 160° simultaneously. Each telescope consists of two fully depleted ΔE silicon surface barrier detectors (SSBD) and a CsI(Tl) crystal. The thicknesses of the first ΔE detectors (ΔE_1) range between 50 and 60 μm and for the second (ΔE_2) between 400 and 500 μm . In addition, a group of ΔE_2 detectors with thicknesses around 1000 μm is available. The solid angle covered by each telescope, placed at distance of 15 cm from the target, is 13 msr.

For the target thickness we have to compromise between count rate and the necessary target-thickness corrections. We end up with target discs of 2.5 cm diameter with thicknesses of about 500 μm for SiO_2 , C and CH_2 , 300 μm for Si and 400 μm for Fe.

3.2. Fission cross section and fission fragment angular distribution

To measure cross sections and angular distributions for neutron-induced fission we plan to use an adapted version of the Medley set-up. The adaptation will consist of PPAC detectors on either side of the target and new thin (25 μm) silicon surface barrier detectors acting as ΔE_1 detectors in the Medley telescopes. The experiment will be performed using the white neutron beam at NFS, which means that we can measure at several incoming neutron energies simultaneously.

The PPACs have a timing resolution better than 0.5 ns and thus, at a distance of 6 m from the converter and combined with the expected width of the deuteron beam pulses, a neutron energy resolution of about 2 MeV at 30 MeV and about 1 MeV at 20 MeV will be achievable.

Initially, we plan to measure cross sections and angular distributions for neutron-induced fission of ^{238}U and ^{232}Th . The target masses will be obtained from counting alpha particles from alpha decay (during beam off) with the same detector arrangement. This, in combination with simultaneous measurement of elastic np scattering events (during beam on) with the smallest angle (20°) telescope of Medley (ΔE - ΔE -E arrangement) will allow for good determination of the cross section from the angular distributions since we avoid several normalisation problems. We will, therefore, be able to link together the np standard cross section and the fission cross sections with good accuracy.

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