EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

HPGe detector test at n_TOF: Feasibility study for neutron inelastic scattering measurements

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Abstract: Neutron inelastic scattering measurements can be employed for the advancement of both basic research and applications. They can be used to validate theoretical models, but are also essential for the development of new generation nuclear energy systems. Such reactions can be studied through high-resolution γ - spectroscopy. In order to start out on this field of research within the n_TOF collaboration, a prototype HPGe detector has been developed. This detector is equipped with a specially designed preamplifier that allows it to operate in n_TOF's specific experimental conditions. So far, several tests have been performed in the lab and the detector has been modelled through extensive GEANT4 simulations. The next step towards the realisation of this new type of physics research in n_TOF is the in-beam testing of the prototype HPGe. In this way, the pulse shape analysis code will also be validated and optimised. For these reasons, 7x10^{17} protons are requested.

Requested protons: 7×10^{17} protons on target
Experimental Area: EAR1

Neutron inelastic scattering is a powerful tool both for basic research and for nuclear technology applications. It can provide information on the nuclear reaction mechanisms but is also a non-selective tool for the investigation of the nuclear excited states. This information can then be used to test and validate theoretical models [1]. Additionally, high quality nuclear data are required for the development of new generation nuclear energy systems [2]. The performance of such systems, but also the effect of the irradiation on their structural materials, needs to be predicted through simulations and modelling. These calculations take into account energy absorption as well as particle transport and their success heavily depends on the accuracy of the nuclear data provided. One of the most important factors in the trasportation of neutrons that needs to be extensively studied is inelastic scattering, as it represents an essential energy-loss mechanism in the MeV region [2, 3].
The experimental study of an inelastic scattering reaction can be performed by detecting the γ - rays emitted during the de-excitation of the target nucleus after the scattering reaction. The advantages of this method, as opposed to directly detecting the scattered neutrons, are its good sensitivity and high resolution [1]. Numerous such high resolution measurements using γ - spectroscopy have been performed in the past and in various facilities, providing quality data with low uncertainties [2, 4–6].
^{7}Li(n,inl) was recently proposed as a reference for other γ-ray production cross-section measurements, in the energy range 0.8 - 8 MeV [7]. For this reason, it is well suited for the validation of our new detection systems for (n,inl) measurements. After the validation of our method and instrumentation, an especially interesting physics case that can be studied is inelastic scattering on ^{56}Fe. Iron is one of the primary structural materials of nuclear reactors [2]. Thus, its nuclear properties a significant impact on neutron transport calculations in steel reflectors of nuclear reactors. In this perspective, the neutron induced inelastic scattering cross section is one of the most important cross sections that need to be known with high accuracy for a large neutron energy domain.

The n_TOF facility can greatly aid in the production of high-quality neutron inelastic scattering data and on the further understanding of the reaction mechanisms involved. The energy distribution of its neutron beam, as seen in Fig. 1, takes its highest values in the energy range of 100 keV - 10 MeV (evaporation peak) which is exactly the energy region of interest for neutron inelastic scattering measurements.
Recently, a prototype HPGe detector was developed at n_TOF, one equiped with a specially designed preamplifier [8] that allows for a controlled grounding of the excessive charge caused by the so called "γ - flash". This detector has been tested using calibration sources, and modelled by means of the GEANT4 [9] simulation code [10]. With the present LoI, we aim to study the detector response under beam-on conditions, through the measurement of neutron inelastic scattering on ^{56}Fe and ^{7}Li. Specifically, as previoulsy mentioned, the ^{7}Li(n,n'γ) reaction is well measured reference reaction [7] and can be used

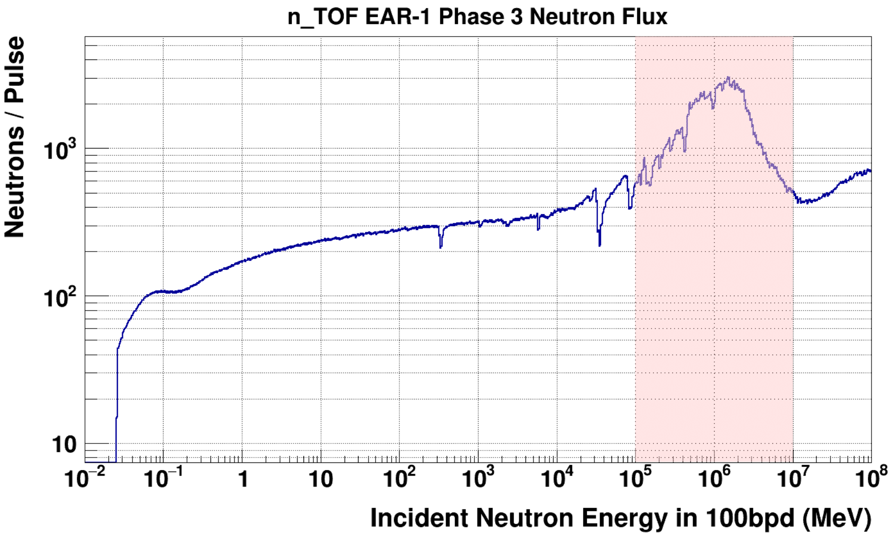


Figure 1: The neutron flux in neutrons per proton pulse in EAR1, as achieved in phase III of the n_TOF facility. The shaded area corresponds to the energy region of interest.

for the benchmarking and validation of our developments on the detection systems, as well as on the analysis software. Concerning the ^{56}Fe(n,n'γ) reaction, extensive experimental information is available from previous studies [2, 5, 6] but, considering the importance of this reaction, higher accuracies are definitely needed. Accordingly, the proposed measurement of the ^{56}Fe(n,n'γ) reaction, besides the validation purposes that it serves, can also be considered as a feasibility study of a future scientific proposal aiming to the improvement of the accuracy of the experimental information and of our understanding on the reaction mechanisms.
Considering both the need for angle integration of the cross-section data and for avoiding excessive background energy deposition due to the γ - flash, the detector will be placed at an angle of 125^0 with respect to the neutron beam [3, 11]. To improve the statistics as much as possible, the detector will be initially placed at a distance of 10 cm from the sample. However, the sample - detector distance represents one of the free parameters of the present measurement, as a compromise between optimal background conditions and reasonable statistics has to be found. The dimensions of both targets were chosen according to the dimensions of the neutron beam and again as a compromise between satisfactory statistical uncertainty and minimal background neutron scattering towards the direction of the detector. The experimental set-up is graphically shown in Fig. 2.

During the proposed beam-on measurements, the γ - rays emitted from the de-excitation of the target nucleus' first excited state will be recorded for both reactions under study. The results of the test will allow for the inspection of the background conditions and for the optimisation of the analysis code. Considering 1x10^{17} protons for the optimisation of our electronics (DAQ, gate conditions, etc) and 3x10^{17} protons for each physics case, the expected number of counts was calculated. For both cases, experimental γ - production cross-section data from the EXFOR database [12–14] were used. The results are shown in Fig. 3, and the statistics are deemed satisfactory.

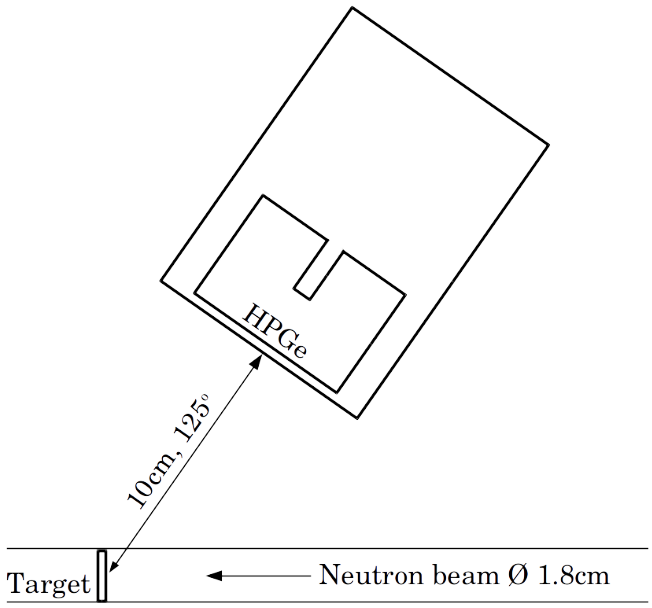
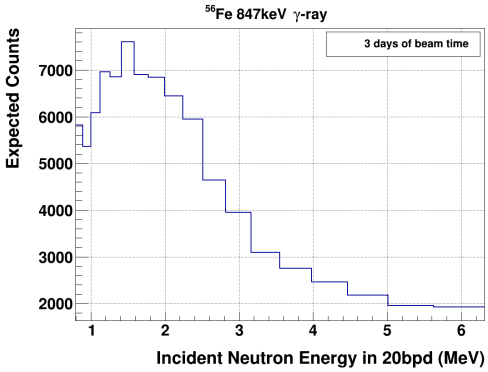
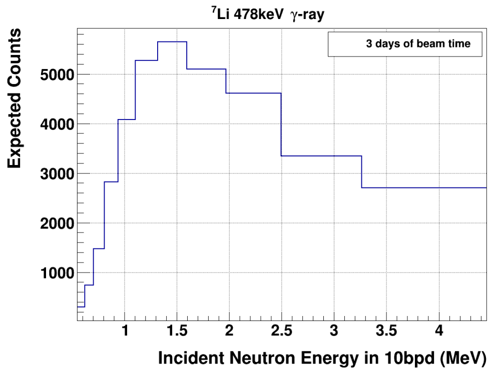


Figure 2: Experimental set-up of the proposed test measurement. The detector is placed at an angle of 125^o with respect to the neutron beam.



(a) Iron case



(b) Lithium case

Figure 3: Counts expected to be recorded for 3 days of beam. The targets are natural Fe and LiF respectively and they both are of 1.8 cm in diameter. The iron sample has a thickness of 0.5mm while for the lithium one we considered a thickness of 0.2 cm.

In conclusion, through the proposed action, the beam background conditions will be evaluated and the developed detection system and data analysis code will be tested and fine-tuned. Furthermore, the effectiveness of the grounding circuit for the minimastion of the effect of the γ - flash will be verified. Finally, the possibility of improving the existing experimental information for the important ^{56}Fe(n,n'γ) reaction through a future experimental campaign at the n_TOF facility will be considered.

Summary of requested protons: 7x10^{17}

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