Main Activities and Results 2024-2026

Report for year 2024

The activities of the research group focused on data analysis of the data set acquired during the second run of our LOI, that was scheduled between 13-19th of September in EAR1. Discussion were also started with our collaborators regarding the detector support for the next $LaBr_3$(Ce) campaign and detector characterization.

In order to measure absolute cross section, for the second run of the LOI, an enriched ^{24}Mg sample was used. The sample preparation was done at the target lab of IFIN-HH by physical vapor deposition (PVD) method. The sample mass had a mass of 422 mg and diameter of 2 cm. The sample thickness was decided based of the results of the test in May. A total of 5 $LaBr_3$(Ce) were placed at a distance of 17 cm from the sample and 125 angle with respect to the beam direction. Due to the fact that the diameter of the sample was smaller than the size of the neutron beam, a correction for the beam interception factor (BIF) had to be applied. As can be observed in Figure 1, this correction factor depends on the incident neutron energy, with a significant variation between 10^5 and 10^7, a region of interest for the inelastic channel in general.

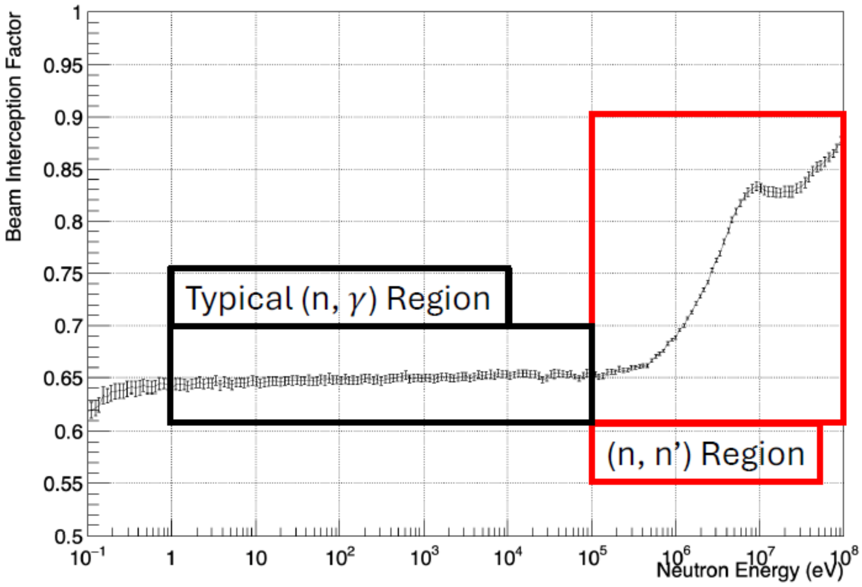

Figure 1: Beam interception factor as a function neutron energy expressed in eV, for a 2 cm diameter sample in EAR1 at n_TOF

The characteristics of the five $LaBr_3$(Ce) detectors were the following: three crystals of 1.5" x 1.5" and two of 1.5" x 2". The efficiency of the detectors was determined with the help of ^{152}Eu radioactive source and estimated at 1368 keV (the 1st excited state of ^{24}Mg) through an interpolation procedure. By combining the information on the evaluated flux, the sample mass and detection efficiency, preliminary results for the absolute cross section were calculated. The cross-section values obtained for 500 bins per decay are presented in Figure 2 together with the statistical uncertainty. A first comparison with previous results obtained at GELINA, show an overall good agreement with the n_TOF data. In order to further refine these results, a careful attention will be dedicated to the BIF correction and background subtraction procedure.

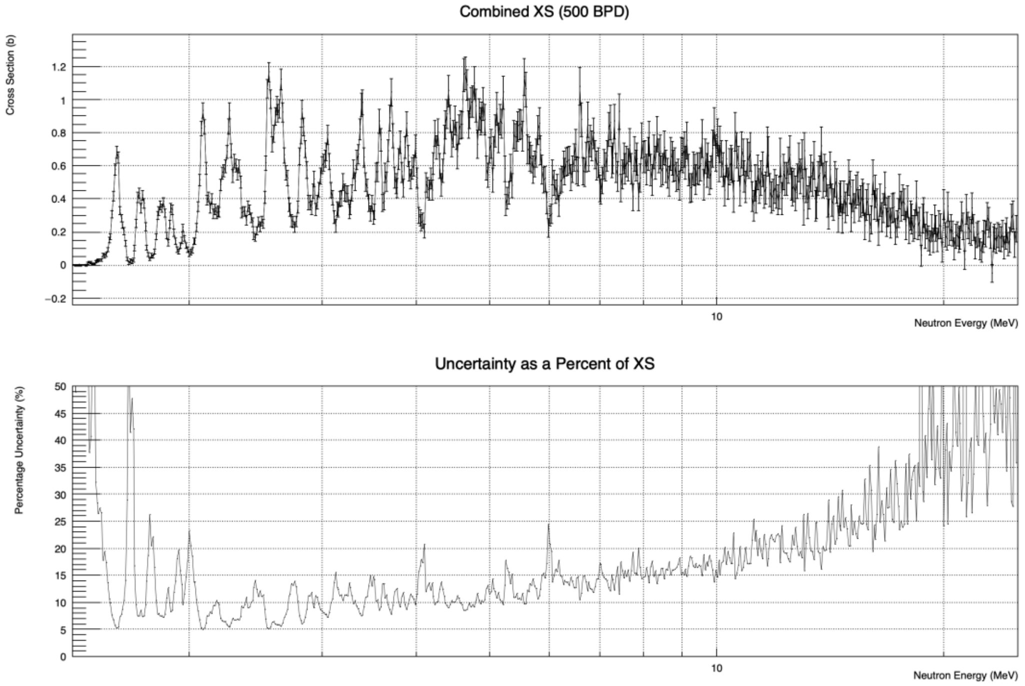

Figure 2: Preliminary results for the absolute cross section for the ^{24}Mg(n,n') reaction measured at n_TOF using an array of 5 LaBr$_3$(Ce) detectors.

Report for year 2025

The workplan for 2025 includes 3 main activities:

- i) finalization of the new high-resolution γ-spectroscopy detector array,
- ii) preparation of the ^{28}Si target for the ^{28}Si(n, n'γ)^{28}Si experiment
- iii) preparation of the ^{124}Sn target for the ^{124}Sn(n, γ) experiment

The two experiments mentioned above were proposed and accepted at the end of 2024. The motivation for these two physics cases was included in the previous reports and thus will only be shortly described here. For the ^{124}Sn(n, γ) experiment we want to provide neutron capture cross sections relevant for subtracting the (deep underground) neutron-induced background in neutrinoless double β decay searches. ^{124}Sn is one of the most feasible candidates for this decay mode owing to its favourable Q-value. In the ^{28}Si(n, n'γ) measurement we wish to determine the γ excitation function for the first transition from threshold up to 40-50 MeV. These data have a broad relevance: On the low energy region, they are of interest for new nuclear reactor concepts, like Gas-cooled fast reactors (GFRs). Above 20 MeV, they are important for both a better understanding of neutron damage in electronic circuits (in weather ballons, space crafts, etc.) and also for space exploration as inelastic scattering of cosmic neutrons can be used to determine the abundance of ^{28}Si in the surface of various cosmic objects.

Perhaps the most important achievement of our group in 2025 was construction and commissioning of a new γ-ray spectrometer, following several years of detector testing and optimization. An aluminium frame was designed and constructed. It can accommodate up to 10 $LaBr_3$ detectors, with various crystal shapes/sizes, at 110°, 125°, and 150° to the beam direction to minimize the γ-flash Compton scattering on the sample into the detectors (see Fig. 1).

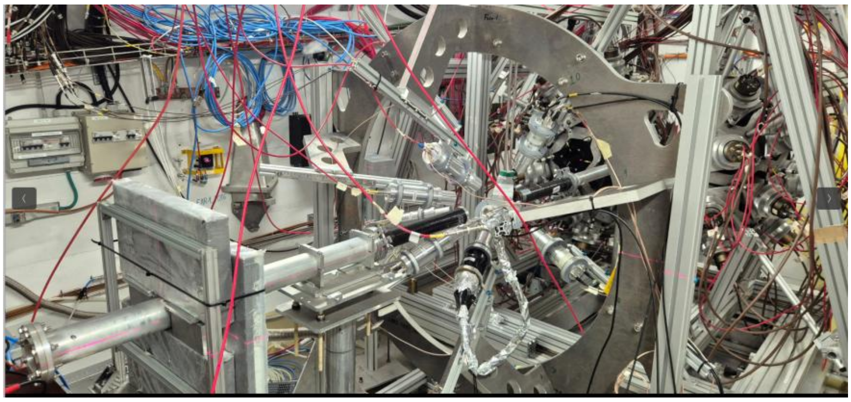

Figure 1: The new $LaBr_3$ spectrometer mounted in EAR1 at n_TOF

To minimize even further other sources of background, the amount of aluminium close to the neutron beam was reduced considerably in the final design. There is also the possibility of adding a second ring of 10 detectors in the forward semiphere around the sample (for other envisioned physics cases which may require a large efficiency). At the end of October our team, together with colleagues from University of Manchester, went to CERN for the commissioning of this new spectrometer in n_TOF's EAR1 bunker. A ^{235}U fission chamber was installed 1.5-m upstream the sample position for neutron beam monitoring. This will allow us to normalize our inelastic cross section to the well-known ^{235}U(n,f) standard cross section. Currently, the setup is used for the ongoing data taking of the ^{19}F(n,n'γ) campaign while the ^{28}Si is scheduled in the near future.

In preparation of the ^{28}Si data taking we performed a very careful optimization of the LaBr3 photomultiplier voltage in order to limit the gain shift (that depends on the counting rate) while improving the energy resolution of each detector for the main γ-ray transitions of interest (see Fig. 2).

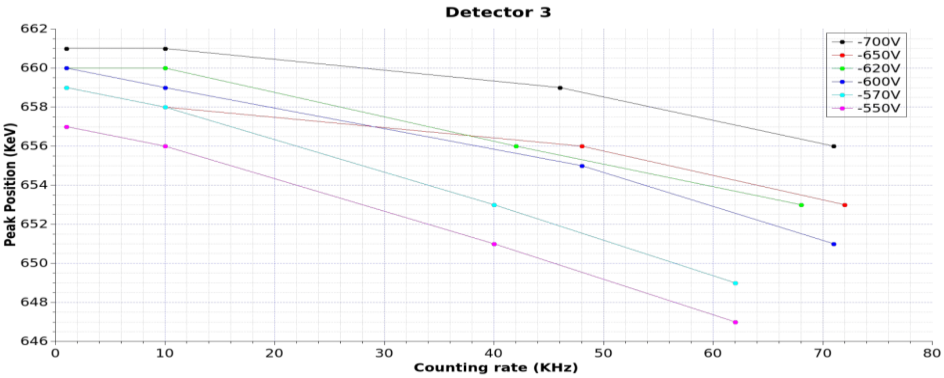

Figure 2: The gain shift of the 661-keV line (^{137}Cs calibration source) as a function of counting rate for one of our LaBr₃ detectors for several HV applied.

Isotopically enriched metallic powder of ^{124}Sn and ^{28}Si was purchased from international suppliers (Trace Sciences International, Canada and ISOFLEX, USA). The preparation of the ^{124}Sn and ^{28}Si samples was done at the target making laboratory of IFIN-HH (see Fig. 3). The powder was pressed at 40 T yielding the desired diameter (2.0 cm for ^{124}Sn, 3.2 cm for ^{28}Si) and thickness (1-2 mm) with a total mass of ~1 g (^{124}Sn) and ~2 g (^{28}Si). This, combined with the assumed inelastic cross section and the full efficiency of the spectrometer, should give us the planned statistics inside the approved beam time without having to measure at a too high counting rate/small sample-detector distance.

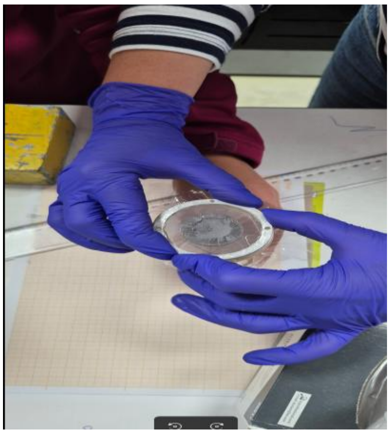

Figure 3: Preparation of the ^{28}Si sample in the target laboratory of IFIN-HH.

The LaBr₃ efficiencies were measured with calibration sources and Monte Carlo simulations of the neutron flux, the sample and the detection setup were performed for the approved number of protons by the INTC ($20 \cdot 10^{18}$ protons) for the ^{28}Si(n,n'γ) campaign. The results are shown in Fig. 4 for 5 LaBr₃ detectors.

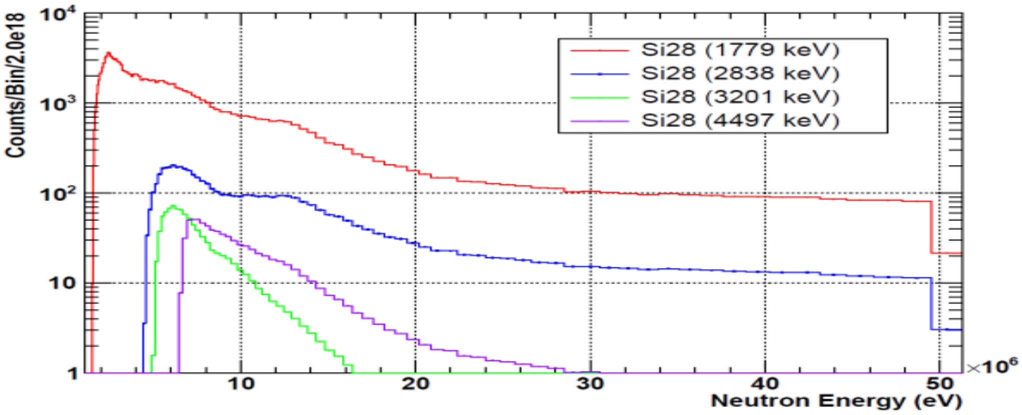

Figure 4: Simulated number of counts for the most important γ transitions in ^{28}Si, considering $2 \cdot 10^{18}$ protons in EAR1, 5 LaBr$_3$ detectors placed at distance of 17 cm from the ^{28}Si sample (1-mm thickness).

Several ^{124}Sn and ^{28}Si samples were prepared for backup, together with ^{12}C, ^{nat}Sn and a 3-g ^{124}Sn sample necessary for background subtraction and multiple scattering corrections in the neutron capture experiment.