EXPERIMENT PROPOSAL

Proton inelastic cross sections of ^{24}Mg

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Scientific motivation

Magnesium has three stable isotopes: ^{24}Mg (78.99%), ^{25}Mg (10.00%) and ^{26}Mg (11.01%) [1], with ^{24}Mg being the most abundant. Magnesium represents a major ingredient of alloy steel which constitutes a common structural material in the design of nuclear reactors. Also, in the framework of the EUROTRANS project, CERCER (an alloy of a ceramic magnesia (MgO) matrix with incorporated mixed actinide dioxide fuel particles containing minor actinides – MAs) was chosen as one of the most feasible candidates for composite fuel systems used for transmutation of MAs in the European Facility for Industrial Transmutation (EFIT) [2].

In this context, a good knowledge of the neutron-induced reactions on ^{24}Mg becomes mandatory for the design of the generation IV reactors. Our group already measured the neutron inelastic cross sections on ^{24}Mg using the GELINA facility of EC-JRC, Geel and the GAINS spectrometer [3]. We were able to construct the excitation functions for several γ rays [4].

Through the present proposal we aim at the measurement of the proton-induced reactions on ^{24}Mg .

The main motivation is to compare the proton inelastic scattering cross sections with the neutron ones, already determined in Ref. [4]. The present proposal is a continuation of our previous work. We performed several previous experiments on ^{16}O, ^{28}Si [5,6] and ^{57}Fe within the CHANDA project [7], using charged particle beams. In the case of the present experiment we wish to compare the

$^{24}Mg(n, n'\gamma)^{24}Mg$ and $^{24}Mg(p, p'\gamma)^{24}Mg$ reaction cross sections in order to determine if and to which extent one can use charged particle cross sections to infer the neutron corresponding ones. By choosing an N=Z target, this investigation makes use of the isospin symmetry manifestation in the two mirror compound nuclei through which the two reactions proceed: ^{25}Mg and ^{25}Al, respectively. This symmetry induces very similar (low- excitation energy) level schemes for the two mirror nuclei from above. This could generate similar shapes and/or proportional inelastic cross sections in the proton and neutron cases (see also Figure 2). For neutron-induced reactions only the nuclear interaction plays a role while for the proton ones there is also the possibility of Coulomb excitations; considering the low Coulomb barrier (i.e. 1.99 MeV) for the proposed reaction, these are expected to play a limited role.

The second goal is to provide relatively precise and reliable experimental data on the proposed reaction, which is scarce. There is a single data set of angle integrated γ production cross sections for several ^{24}Mg transitions [8], but only at 5, 10, 15 and 20 MeV proton beam energies (see Figure 1 for the first ^{24}Mg transition). In the proposed experiment we intend to construct the excitations functions for all the observed ^{24}Mg γ rays in the entire 4-17 MeV incident proton energy range. Hence, we will start from just above the Coulomb barrier and we will use 1 MeV steps.

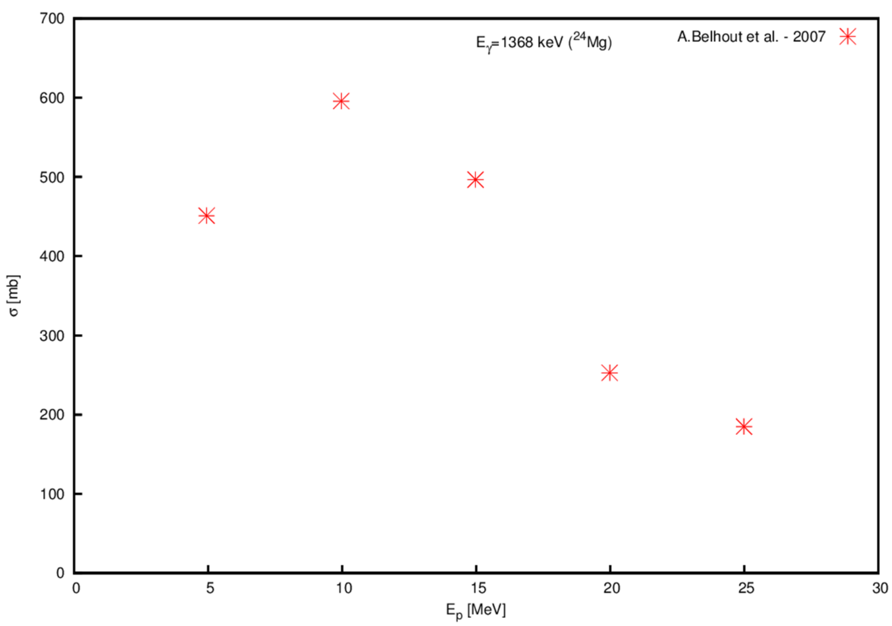

Fig 1: The angle integrated **γ** production cross section of the first transition in ^{24}Mg as given by Ref. [8]. The authors determined cross section points only at 5, 10, 15, 20 and 25 MeV incident proton energy (no uncertainties were reported).

Experimental details

The purpose of the experiment is to measure **γ** production cross sections in ^{24}Mg following the inelastic scattering of protons. For this we will employ a similar setup with the one used in the $^{16}O(p, p'\gamma)^{16}O$ experiment [6]. Two HPGe detectors with 100% relative efficiency will be placed at 110° and 150° relatively to the beam direction. The chosen angles will allow the extraction of angle integrated cross section values. For data normalization a Faraday cup, placed at the back of the reaction chamber, will be used.

Figure 2 displays an estimate of the cross sections for the most relevant reactions of interest, calculated using the TALYS 1.8 code [9]. The proton inelastic cross section dominates in the entire energy domain followed by (p,α) and (p,n) contributions. A possible difficulty is related to the competing channel $^{24}Mg(p, n)^{24}Al$. ^{24}Al decays into ^{24}Mg ($T_{1/2}$ = 2.53 s) and therefore the online peaks corresponding to ^{24}Mg may be polluted through this process. However, considering that the (p,n) channel is very small we do not expect any significant parasite contribution to the ^{24}Mg **γ** production cross sections coming via the β^+ decay of ^{24}Al. The (p,α) channel produces ^{21}Na which, via β^+ decay, goes with a 94,93%

intensity to the ground state of ^{21}Ne (stable). The background generated by stopping the proton beam inside the Faraday cup will be handled by properly shielding the HPGe detectors using lead blocks. Hence, we expect a relatively clean spectra with no relevant contributions polluting the **γ** peaks of interest.

The target nucleus is relatively light and its low lying excited levels have very short half-lives (in the *fs* range). Therefore, another concern could be given by Doppler broadenings of the ^{24}Mg **γ** peaks (especially at higher proton energies) which might complicate the **γ** peaks integration procedure. Given our previous experience [6] we believe it can be properly handled by careful **γ** peak integration.

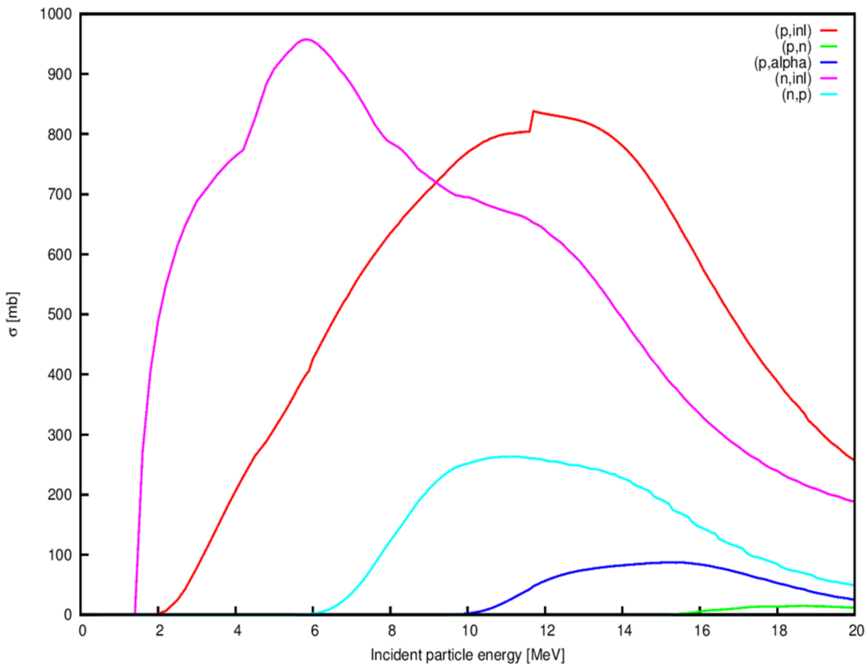

Fig. 2: Default TALYS 1.8 [9] calculations for neutron and proton induced reaction cross sections on ^{24}Mg.

Beam time estimation

We intend to measure the production cross section of the ^{24}Mg **γ** rays at 1368.6, 2734.0, 4237.9, 3866.1, 4641.1 and 5063.3 keV and for proton energies in the E_p= 4-17 MeV range, in steps of 1 MeV (i.e. 14 points). According to TALYS 1.8 [9], the average proton inelastic **γ** production cross section of the first ^{24}Mg transition (1368 keV) is around 350 mb. Considering an absolute HPGe detector efficiency of ε=0.003, a target with an areal density of ρ_x=0.05 mg/cm^2, a beam intensity of 0.5-3 pnA and an acceptable amount of gathered statistics of 100.000 counts in the 1368 keV peak, the necessary beam time will be around 3-4 hours per proton energy.

Taking into account that an average measuring time of one shift is around 6-7 hours for each point (including the time required for changing the beam energy and the tuning of the beam), this adds up to 4-5 days of beam time. One or two additional shifts will be necessary for calibrations. We note that a dedicated efficiency calibration procedure will be necessary in order to extrapolate the detectors energy calibration at high gamma energies. In conclusion, we ask for 5 days of beam time.

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