

# Measurement of absolute cross-sections for alpha induced reactions on $^{162,164}\text{Er}$

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## Abstract

We propose to measure the absolute cross sections of the  $^{162}\text{Er}(\alpha,\gamma)^{166}\text{Yb}$ ,  $^{164}\text{Er}(\alpha,n\gamma)^{167}\text{Yb}$  reactions at effective center-of-mass energies between 11.3 to 14.0 MeV, close to the Gamow window. The  $\alpha$  beam will be delivered by the IFIN-HH 9 MV Tandem accelerator, while the beam-induced activity will be measured in close-to-detection geometry setup using two large volume HPGe detectors.

## Scientific motivation

The p-process of stellar nucleosynthesis is aimed at explaining the production of the stable proton-rich nuclei heavier than iron that are observed up to now in the solar system exclusively. The generally accepted main process involves sequential  $(\gamma,n)$  reactions starting from s and r-nuclei and driving the nuclei towards the proton rich region [1–4]. Along this isotopic path, the binding energy of neutrons becomes gradually larger, the reaction flow slows down and, at some point in a chain of isotopes,  $(\gamma,p)$  and/or  $(\gamma,\alpha)$  reactions will become faster than the neutron emission, and the flow will branch and feed another isotopic chain. The synthesis process requires a large reaction network involving more than ten thousand reactions. This is the reason why, with very few exceptions, the astrophysical reaction rates have been calculated by means of the statistical Hauser-Feshbach model. Realistic input of the statistical model depends on accurate parameters for the particle potentials, level densities and  $\gamma$ -widths. Among those, the transmission coefficients for charged particles computed with the optical model will be the most important ones, especially when dealing with projectile energies close to the Coulomb barrier, as is the case for the p-process.

As shown by Rapp et al. [2], variations in the  $(\gamma,\alpha)$  reaction rates impact the abundances predictions in the mass range above  $N=82$ , and consequently this calls for more systematic studies in the mass region  $140 < A < 200$ . Improved data are necessary since a reduction of the associated uncertainty will help to identify more clearly other uncertainties yielding from insufficient model description of the p-process scenario. Moreover, in this problematic mass region in explaining the production of  $p$  nuclei, very few  $\alpha$ -induced reaction data are known. In the case of the  $p$  nuclei, above the  $A \sim 100$  mass region there are practically no experimental  $(\alpha,\gamma)$  data below the Coulomb barrier except the  $^{144}\text{Sm}(\alpha,\gamma)^{148}\text{Gd}$  [5]. In this case the experimental measured  $^{144}\text{Sm}(\alpha,\gamma)$   $S$  factors indicate deviations of up to one order of magnitude than the standard predictions

at astrophysical energies. Only recently  $\alpha$ -induced reaction on  $^{168}\text{Tm}$  [6] and  $^{141}\text{Pr}$  [7] were reported. These nuclei are closed to the problematic region but are not  $p$  nuclei. For the proposed cases here there are no experimental data for  $^{162}\text{Er}(\alpha,\gamma)^{166}\text{Yb}$  or  $^{164}\text{Er}(\alpha,n\gamma)^{167}\text{Yb}$  reactions.

### **Proposed experiment**

For both isotopes,  $^{162}\text{Er}$ , and  $^{164}\text{Er}$ , we propose to measure the absolute cross sections of the reactions induced by alphas at 4 different energies ranging from 11.5 to 14.3 MeV using the activation method. For these nuclei the Gamow window is between 8.7 and 12.5 MeV. The half-life of the reaction products are  $^{166}\text{Yb}(T_{1/2}=56.7(1) \text{ h})$  and respectively  $^{167}\text{Yb}(T_{1/2}=17.5(2)\text{m})$ . For each erbium isotope we will use target stacks having three layers consisting of erbium, aluminum and titanium. Each stack will be irradiated using the scattering chamber mounted on beam line #5. The decay spectra will be measured off-line with a specially designed low-background passive setup consisting of a pair of large volume HPGe detectors surrounded by Pb walls clothed with Cu and Al plates on the inside. The HPGe detectors of about 50% will be mounted in close-to-detection geometry in order to maximize the detection efficiency. The absolute cross sections for each reaction populating a certain decaying nucleus will be extracted from the peak areas of the corresponding characteristic  $\gamma$ -rays.

### **Beam time request**

We want to measure  $\alpha$ -induced cross sections on two erbium isotopes at four energies each. For each energy and isotope we ask for one day of irradiation for measuring the induced characteristic activation. Therefore we ask a total of 8 days of beam time, which may be not necessarily consecutive.

The alpha beam should have an intensity of at least 50 nA, kept constant as much as possible, thus allowing a precise extraction of the absolute cross sections.

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