Single-Pass Recycling of Radioactive Ion Beams

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(p,γ) reactions play a crucial role in astrophysical reaction networks, e.g. in the rp process. Typically model calculations are used to characterize those reaction networks, however, due to the large uncertainties still included in those calculations detailed experimental data are indispensable. A prototype reaction is ^{35}Ar(p,γ)^{36}K, which has been proposed for REX-ISOLDE by Wiescher, Thielemann and Kratz [1]. In this proposal the resonance strength for this reaction was estimated to be 6.5 meV, resulting in a reaction rate at REX-ISOLDE (based on a beam intensity of $3.3 \cdot 10^7$ ^{35}Ar nuclei per second) of 0.5 events per hour in case of a polyethylene target, equivalent to a reaction probability in the order of 10^{-11}. Including the detection efficiency an extremely low detection rate of 1.8 events per day was estimated, despite of the decent reaction cross section of 3.4 mb. It is the extremely small width of the (p,γ) resonance that causes the small reaction yields. Due to the energy loss dominated by the electronic stopping in the polyethylene target the resonance width of 6.8 meV corresponds to an effective target thickness of only 0.34 ng/cm^2, which is equivalent to 1/1000 of a monolayer. This situation could only be improved by permanently hitting the exact resonance maximum while passing through the target, which means effectively switching-off the energy loss. An experimental approach to enhance the yield for such very narrow Breit-Wigner resonances could be realized by compensation of the energy loss in the target via single-pass re-acceleration. The basic idea is to use a stack of thin polyethylene target foils that induce only a small energy loss. They will be arranged as an electrostatic accelerator column via a resistor chain. Acceleration between the individual foils will compensate for the energy loss and keep the beam energy on resonance.

Presently 6 μg/cm^2 thick foils can be produced, but the goal is to reach 2 μg/cm^2, which is equivalent to a thickness of 200 Angstrom.

Fig. 1: Setup for the development of ultra-thin polyethylene foils at the Technological Laboratory.

In the Technological Laboratory methods are being developed to reach this regime of foil thickness via film casting, Fig. 1 shows the setup used. This method will be first tested using the setup designed for 10 foils as shown in Fig. 2, where an overall high voltage of about 20 kV will be applied. When passing through the target foil the projectile will reach an average charge state of typically 10^+, which is advantageous since it helps to reduce the acceleration voltage needed to compensate for the energy loss. After debunching the primary beam energy spread will be about 10^{-3}, which is smaller than the energy loss in the target. The total target thickness should lead to an energy spread of the beam not exceeding the original beam energy spread. In order to preserve the resonance condition while passing through the foil-stack target, we will exploit the resonant (p,p') cross section, which is orders of magnitude larger than the (p,γ) channel. This decay channel can be used to stabilize the acceleration voltage onto the resonance energy.

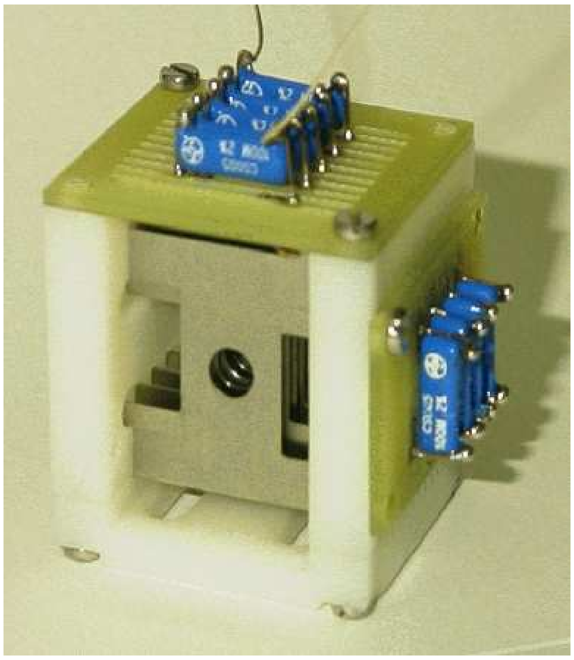

Fig. 2: Test setup for an multi-foil target of up to 10 foils with the resistor chain forming the acceleration column to compensate for the energy loss.

The final goal is to develop targets which will allow to increase the (p,γ) yield by a factor of 10-100.

We plan to perform first tests with the system shown in Fig. 2 at the Garching Tandem, in a next step a realistic test beamtime with an astrophysical (p,γ) reaction in inverse kinematics at the ISOL radioactive beam facility at Louvain-la-Neuve has already been approved.

References

[1] M. Wiescher, *et al.*, CERN/ISC 94-21 (1994)