EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the
ISOLDE and Neutron Time-of-Flight Experiments Committee
for experiments with HIE-ISOLDE

Elastic resonance scattering study with a ^{20}Mg beam : p(^{20}Mg,p)^{21}Al

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Abstract

We intend to continue our investigations of light exotic nuclear systems by using the technique of elastic resonance scattering. The case of the unbound ^{21}Al reached by bombarding ^{20}Mg on a proton target will extend the exploration of N=8 nuclei up to Z=13, which extends the comparison of these systems with Oxygen isotopes up to ^{21}O. Production of energetic, neutron-deficient Mg isotopes require both the laser ion source, a SiC target, and a beam energy as high as possible in the 5-10 MeV/A region, and could therefore be a unique case for HIE-ISOLDE.

1. Introduction

The structure of light exotic nuclei is one of the major topics of current Nuclear Physics. Experimentally both drip lines can be reached at least up to Neon [1]. The neutron-deficient nuclei are in general not as well known as their neutron-rich mirrors because the Coulomb interaction leads to unbound states at lower energy on the proton-rich side. The region hosts a number of open quantum systems where even the ground states are unbound, i.e., ^{8}Be, ^{9}B, as well as systems beyond the drip lines, ^{10,11}N [2,3,4], ^{12}O[5,6], ^{16}F[7], ^{16}Ne[7], and ^{19}Na[8], but in general the proton separation values are low. Apart from posing an experimental challenge, the open particle emission channels also provide extra information from which structure information may be extracted.

An experimental method well suited for the study of this region is elastic resonant scattering on a thick target. At radioactive beam facilities this method is used in inverse kinematics with the heavy radioactive beam incident on a light target of e.g. proton (either isobutene or Hydrogen gas or solid) or Helium, and hence this method scans the resonances in the energy range from the incident energy of the beam down to zero energy in the centre of mass. Due to the thick target the method is possible with modest beam intensities down to of the order 10^2-10^3 ions per second.

In general, elastic resonant scattering provides information on the energy (or mass) and width of the ground state and lowest excited states of the system. The position of the first exited state in the beam nucleus determines when inelastic scattering becomes possible (typically of the order of 2-3 MeV for the systems discussed here), and e.g. the position of the proton separation energy in the beam nucleus determined when protons from inelastic scattering can contribute to the proton spectrum. The excitation spectrum can be decomposed with potential models or R-matrix analysis.

2. Physics case

The odd-even staggering of nuclear binding energies allows to populate unbound odd-Z systems in with beams of even-Z isotopes e.g. $^{9-10}$C, $^{13-15}$O, $^{17-18}$Ne, ^{20}Mg, $^{22-24}$Si, $^{27-29}$S, $^{31-33}$Ar and $^{35-38}$Ca on a proton target. At ISOLDE we are presently planning to study p(^{9}C,p)^{10}N[9], while p(^{10}C,p)^{11}N [2,3], and p(^{18}Ne,p)^{19}Na[8] have been studied at GANIL and MSU. The next case, ^{20}Mg, is the main focus of the present letter of intent, while Si seems difficult at ISOLDE due to the chemical properties of this element. On the other hand S and in particular Ar could become feasible with only modest increases in yields at ISOLDE in the future. The very interesting case of Oxygen would need dedicated beam development.

Resonant elastic scattering of ^{20}Mg on a proton target yields information on the unbound system ^{21}Al, the mirror nucleus of ^{21}O. Presently an upper limit for the lifetime is the only available information on ^{21}Al [10]. For the case of the mirror nucleus ^{21}O, in-beam γ-ray spectroscopy using fragmentation reactions at GANIL has provided a detailed level scheme up to an excitation energy of 5 MeV [11]. With the HIE-ISOLDE energy upgrades to 5 MeV/A and later 10 MeV/A it will become possible to explore the excitation region up to about 5 MeV and 10 MeV in ^{21}Al, respectively.

Along the chain of Oxygen isotopes information on excited states is available for neutron numbers N=5 to 16 (^{12}O to ^{24}O). The mirror systems with N=8 may be explored from Z=5 (^{13}B) to 14 (^{22}Si) including the two unbound systems ^{19}Na and ^{21}Al, where the latter will be provided by the work suggested in the present letter of intent.

3. Experimental setup

The experimental setup for the ^{20}Mg elastic resonant scattering at HIE-ISOLDE will consist of a proton target (poly-ethylene foil of 70-200 µm or a solid cryogenic Hydrogen target), in which the ^{20}Mg beam will be fully stopped, and a thin Double-Sided Silicon Strip-Detector (DSSSD) backed by a thick Si-pad detector, all centred at zero degrees. The setup is shown in Fig. 1 and will be very similar to the setup used in earlier elastic resonant elastic scattering experiments [12].

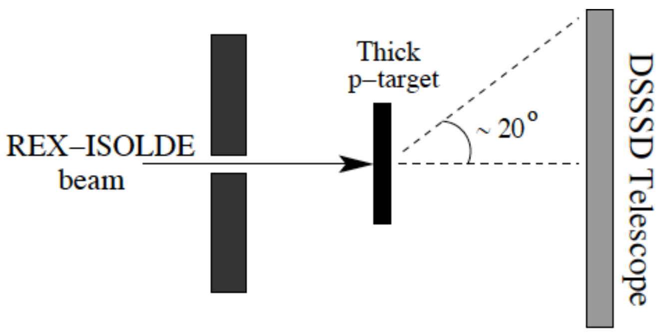

Figure 1: Setup for elastic resonance scattering of ^{20}Mg on protons.

The active target ACTAR is an alternative to the setup discussed above [13]. Here a separation between elastic and inelastic scattering is possible by identifying the interaction vertex, which

determines the energy at which the reaction occurs. However, this method restricts the maximum beams intensity on target and therefore the choice of setup will be dictated by more specific beam intensity estimates.
The space requirements are the same as specified in the letter of intent for transfer reactions at the driplines [14].

4. Beam requirements

Production of the neutron deficient Magnesium isotopes ^{21}Mg and ^{22,23}Mg has recently been demonstrated at ISOLDE with yields of 10^4 ions/μC and 10^5-10^7 ions/μC, respectively. Assuming a reduction in yield by a factor 100 per mass implies a ^{20}Mg yield of 10^2-10^3 ions/μC. This makes the experiment difficult with present REX-ISOLDE, but feasible with the HIE-ISOLDE upgrade. We estimate the lowest possible yield of ^{20}Mg for a successful experiment to be roughly10^2/μC. There is presently a strong Na contamination from the SiC target, however, with the improved HRS foreseen for HIE-ISOLDE this background may be strongly reduced.

5. Safety aspects

We do not anticipate any safety risks with the suggested experiment. The development of a cryogenic Hydrogen target is under consideration. Its design and safety aspects will be done in accordance with the CERN safety rules.

6. References

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