Investigation of the CNO-break-out reaction: ^{15}O$(2p,\gamma)^{17}$Ne by the Coulomb dissociation of ^{17}Ne

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Abstract. By the Coulomb dissociation of ^{17}Ne, the time-reversed reaction ^{15}O$(2p,\gamma)^{17}$Ne has been investigated. This reaction might play an important role in the *rp* process, as a bypass of the ^{15}O waiting point. The secondary ^{17}Ne ion beam of 500 AMeV has been dissociated on a Pb target, and the reaction products have been recorded with the LAND-R^{3}B experimental setup (GSI). This experiment allows to determine the Coulomb dissociation cross section σ_{Coul}, which can be converted into a photo-absorption cross section σ_{photo}, and a radiative-capture cross section σ_{cap} for the ^{15}O$(2p,\gamma)^{17}$Ne reaction. Additionally, informations about the structure of the ^{17}Ne nucleus, a possible two-proton halo, may be obtained. The analysis is still in progress.

1. Introduction

At high temperature and density conditions, the CNO cycle is linked with the *rp* process by the α capture reaction on the ^{15}O nucleus. By the *rp* process, which is a sequence of proton captures and β^+ decays, the initial CNO material can be processed towards heavier nuclei. ^{15}O

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is a waiting point nucleus, which hampers the reaction flow between the CNO cycle and the FeNi-mass region. The ^{15}O$(2p,\gamma)^{17}$Ne reaction can bridge this waiting point. The three-body radiative capture can proceed sequentially [1] or directly from the three-body continuum [2]. It has been suggested that the reaction rate can be enhanced by a few orders of magnitude by taking into account the three-body continuum [2]. In order to verify these calculations, the ^{15}O$(2p,\gamma)^{17}$Ne reaction has to be investigated and the radiative capture cross section has to be determined.

This experiment is also interesting for nuclear structure. The proton dripline nucleus ^{17}Ne is a promising candidate for a two-proton halo, because of a comparatively small $2p$ separation energy (S_{2p} = 970 keV) [3]. The mixture of the d^2 and s^2 configurations of the two protons outside the ^{15}O core in the ^{17}Ne ground state is still unknown. In the case of large s^2 weights of proton configurations the ^{17}Ne is a halo nucleus, while in the case of large d^2 weights the nucleus ^{17}Ne has no halo structure (Fig. 1).

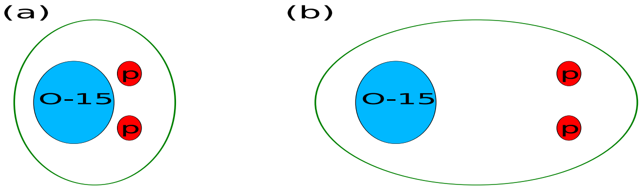

Figure 1. Schematic representation of the structure of ^{17}Ne, if: (a) - the d^2 component dominant; (b) - the s^2 component dominant.

2. Coulomb dissociation method

The Coulomb dissociation method is an indirect technique, which is useful in case of very small cross sections, unstable nuclei and three particles in an entrance channel. In this method, instead of the radiative-capture process, the time-reversed process is studied, and the Coulomb field of a heavy nucleus is used as a source of photons [4] (Fig. 2).

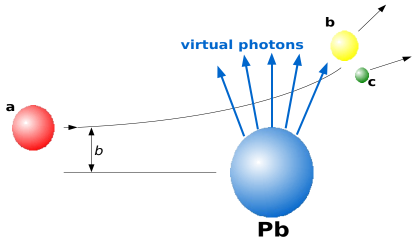

Figure 2. Coulomb dissociation in the field of a Pb target. (b - impact parameter)

Using virtual photon-theory, a Coulomb dissociation cross section σ_{Coul} can be converted into a photo-absorpion cross section σ_{photo}, which can then be converted into a radiative-capture cross section σ_{cap} with the help of the detailed-balance theorem.

3. Experiment and preliminary results

The primary ^{20}Ne beam from an ion source was preaccelerated in the universal linear accelerator (UNILAC) and injected into the heavy-ion synchrotron (SIS) at GSI in Darmstadt, Germany. The accelerated primary beam was directed to a beryllium production target and the secondary ^{17}Ne beam was produced via nuclear fragmentation. The reaction products were separated by means of the fragment separator (FRS) [5], where dipole magnets filter out all species except those with a specific A/Z ratio ($B\rho = \frac{p}{Q} \propto \frac{A}{Z}\beta\gamma$). The secondary beam of ^{17}Ne, with an energy

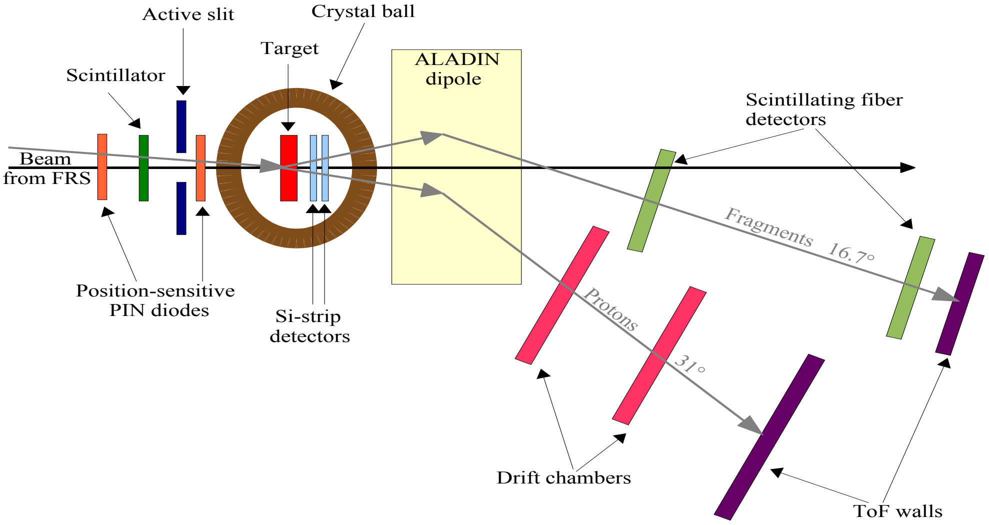

Figure 3. Experimental setup.

$E = 500$ AMeV, was identified in the experimental area (Fig 3), by means of energy-loss and position measurements with position-sensitive pin diodes and time-of-flight measurements.

Dissociation of ^{17}Ne nuclei was induced by a secondary Pb target (200 mg/cm^2). The reaction products have been identified using two Si-strip detectors placed before the large-gap dipole magnet (ALADIN). After the magnet, two scintillating-fibre detectors and a two-layer Time-of-Flight (ToF) wall have been used to detect the fragments. The protons have been recorded by two drift chambers and a large two-layer ToF wall [6]. By means of time-of-flight and energy-loss measurements, all reaction products have been identified (Fig. 4).

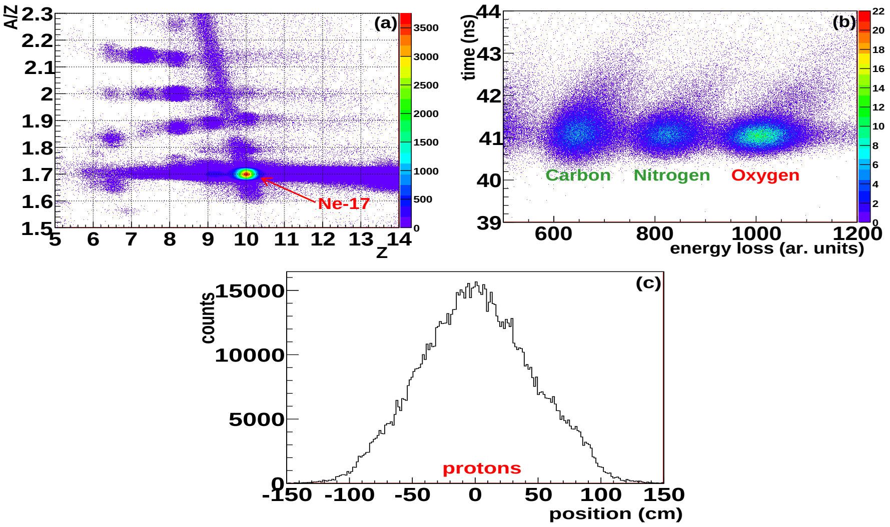

Figure 4. (a) - The identification of incoming beam nuclei; (b) - the identification of outgoing fragments; (c) - detected protons in a large two-layer ToF wall.

To obtain masses and momenta of the reaction products a tracking procedure was utilized. The mass specra of oxygen are given in Fig. 5.

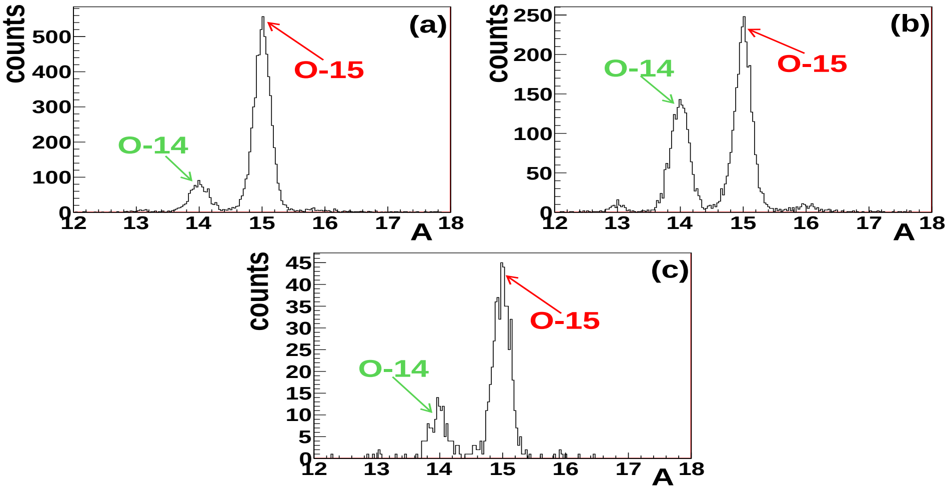

Figure 5. The oxygen mass spectra after tracking. (a) - for data with the Pb target; (b) - for data with the C target (to subtract the nuclear contribution); (c) - for data without any target (to subtract the background).

The measured Coulomb dissociation cross section is given by the formula:

$$\sigma_{Coul} = p_{Pb}\left(\frac{M_{Pb}}{d_{Pb}N_{Av}}\right) - p_C\left(\alpha\frac{M_C}{d_C N_{Av}}\right) - p_{empty}\left(\frac{M_{Pb}}{d_{Pb}N_{Av}} - \alpha\frac{M_C}{d_C N_{Av}}\right), \tag{1}$$

where p is the interaction probability for a target, M - the molar mass of target material [g/mol], d - the target thickness [g/cm^2], N_{Av} - Avogadro's number [mol^{-1}] and α is a scaling factor between Pb and C targets.

Using this formula the preliminary exclusive Coulomb dissociation cross section has been determined. The value is $\sigma_{Coul} = 253 \pm 36$ mb (only statistical uncertainty).

4. Summary

The secondary ^{17}Ne beam has been produced by fragmentation reactions of ^{20}Ne, and the ^{15}O$(2p,\gamma)^{17}$Ne reaction has been studied. The incoming beam and outgoing reaction products have been identified, and the preliminary exclusive Coulomb dissociation cross section has been obtained $\sigma_{Coul} = 253 \pm 36$ mb (only statistical uncertainty). The next steps of the analysis will be the calculations of the photoabsorption and the radiative capture cross sections, which are not only relevant for the *rp* process but also are of interest with regard to the two-proton halo structure of ^{17}Ne. The analysis is still in progress.

5. Acknowledgments

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