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COULOMB DISSOCIATION OF ^{8}B AT 254 MeV/u*

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As an alternative method to determine the cross section of ^{7}Be$\,(p,\gamma)^8$B, the Coulomb dissociation reaction $^8\mathrm{B} \to ^7\mathrm{Be} + p$ at $E_{\mathrm{inc}} = 254$ MeV/u was measured. Our preliminary results show the dominant role of the dipole excitation in the Coulomb break-up process. The extracted astrophysical S_{17} factor is consistent with the lower-value results both of the direct-capture studies, and the RIKEN Coulomb-dissociation experiment at ~ 50 MeV/u.

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1. Introduction

The astrophysical S-factor for the source reaction of high-energy solar neutrinos, $^7\mathrm{Be}\,(p,\gamma)^8\mathrm{B}$, plays a major role for understanding terrestrial measurements of the solar neutrino flux [1]. Five comprehensive experiments reported results for the $^7\mathrm{Be}\,(p,\gamma)$ reaction [2–6]. Since the absolute normalization of these results is based on the effective thickness of the radioactive ^{7}Be target measured through the $^7\mathrm{Li}\,(d,p)^8\mathrm{Li}$ reaction, derivation of accurate results is severely difficult. An additional uncertainty, as it was reported recently [7], may be caused by the target backing (mainly platinum was used), which can rescatter the recoil ^{8}Li or ^{7}Be nuclei from the target and therefore influence the measured cross section. Another complication is that the cross section at the Gamov peak, about 18 keV, is too small to be measured directly, so extrapolations to the relevant astrophysical energies are needed (*e.g.* [9]).

As an alternative method to study the $^7\mathrm{Be}\,(p,\gamma)^8\mathrm{B}$ reaction, the Coulomb dissociation $^8\mathrm{B}\rightarrow{}^7\mathrm{Be}+p$ was proposed [10]. The advantages of this inverse approach are straightforward: due to the phase-space factor and the use of a thicker target, and due to the high detection efficiency of high-energy charged particles, the Coulomb-dissociation yields are enhanced and therefore easier to be measured. However, different dependencies on the multipolarity of the virtual photon fluxes must be taken into account, and admixtures of M1 and E2 to the dominant E1 amplitude were investigated (*e.g.* [22, 25]). In RIKEN, two subsequent experiments on ^{8}B at about 50 MeV/u were performed. Iwasa *et al.* [11] (Kikuchi *et al.* [26]) measured the S_{17} factor in the interval 0.6-1.7 MeV (0.4-3 MeV) with the Coulomb dissociation method and found it consistent with the direct-capture datasets of Filippone *et al.* [2], Vaughn *et al.* [3] and Hammache *et al.* [6]. The angular distribution of the break-up products were found compatible with a pure E1 amplitude [12] but in view of the discrepancy noted in a study of the longitudinal momentum distribution [23, 24], it is clear, that further studies to elucidate the role of the E2 component are needed.

Here we report the Coulomb dissociation of ^{8}B at 254 MeV/u. The higher incident energy should reduce the E2 component and enhance the M1 resonance. Moreover, boost makes it possible to use the magnetic spectrometer KaoS [14] for the detection of the break-up products.

2. Experimental procedure

The experiment was performed at the heavy-ion facility at GSI [13]. A radioactive ^{8}B beam with an intensity of 10^4 ions/spill and a purity of 80% was produced through projectile fragmentation [13] from 350 MeV/u ^{12}C impinging on a beryllium target (8.02 g/cm^2). The secondary-beam particles were identified event-by-event by the TOF-ΔE method. The mean beam energy in the ^{208}Pb break-up target with a thickness of 199.7 ± 0.2 mg/cm^2 was 254.1 MeV/u.

The kinematically complete measurement of the break-up was performed using the large-acceptance ($p_{\rm max}/p_{\rm min} \approx 2$, $\Delta\theta = \pm 70$ mrad, $\Delta\phi = \pm 140$ mrad) spectrometer KaoS [14] as shown in Fig. 1. The break-up products were recognized by coincident hits in the left and right parts of the KaoS TOF wall consisting of 15 plastic scintillators each. For reconstructing the invariant mass, the momenta and the scattering angles of ^{7}Be and proton were measured. Two pairs of two one-sided silicon microstrip detectors were placed at the entrance of KaoS to track the reaction products. Readout of individual strips of each detector was performed by GASSIPLEX chips [15] and CRAMS modules [16]. The intrinsic angular resolution of the system of the four silicon microstrip detectors amounts to 2.8 mrad which takes into account crosstalks between neighbouring strips. In fact, due to angular straggling, the scattering angle resolution of the products was σ=4.8 mrad. The silicon microstrip detectors served also to discriminate the reaction products from background or parasitic reactions elsewhere than in the target, through both the energy-loss measurement and the vertex position reconstruction. The accuracy of the vertex determination in beam direction, σ_z=9mm, allowed an unambiguous identification of Coulomb break-up events in the ^{208}Pb target.

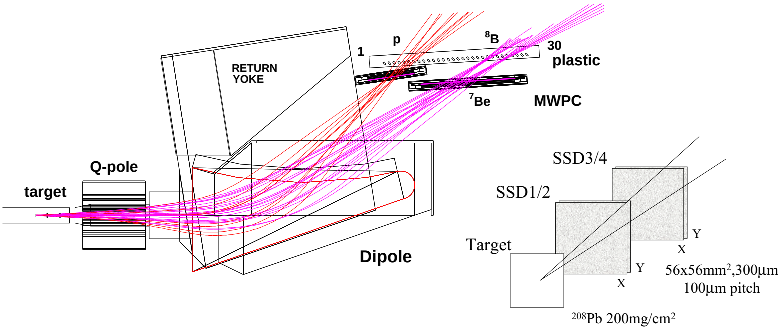

Fig. 1. Experimental setup. On the right we sketch the target and two pairs of silicon microstrip detectors separated by distances of about 15 cm, respectively.

Momenta of the reaction products were analysed by KaoS. The spectrometer was filled with helium gas (1 atm.) to reduce angular and energy straggling. The momentum calibration was done by a sweep run of a primary ^{12}C beam over the full range of both MWPC. The same was performed with a secondary ^{8}B-beam of 261.8 MeV/u for the heavy-ion momentum range. The position-to-momentum calibration coefficients were obtained from Monte-Carlo simulations with the program package GEANT [21]. Resolution of the momentum determination amounts to $\sigma_p/p = 0.5\%$.

Transmission losses of the break-up particles, due to nuclear reactions in the layers of matter downstream from the target, were calculated to be 2% from interpolated total reaction cross sections [17].

3. Preliminary results

The experimental yield as a function of the relative energy of proton and ^{7}Be is presented in Fig. 2. The plotted error-band shows the systematical uncertainties, which are dominant over the statistical errors. Since our ^{8}B-beam had relatively low intensity, we had to use a 200 mg/cm^2 thick target which results in a rather poor relative-energy resolution amounting to $\sigma_{E_{\mathrm{rel}}}$=100 keV (180 keV) at E_{rel}=0.6MeV (1.7 MeV). This is clearly visible at the M1 resonance.

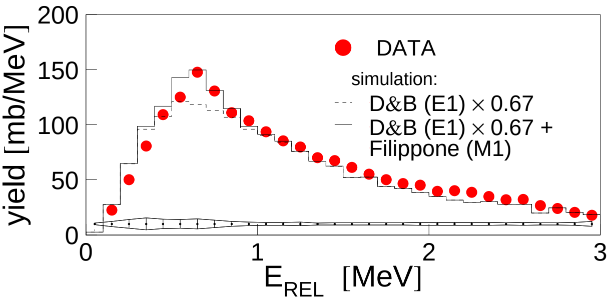

Fig. 2. Preliminary ^{7}Be–p coincidence yield ($\frac{d\sigma}{dE} \times \varepsilon$) as a function of the relative energy in comparison with a Monte-Carlo simulation of the theoretical E1 component of Descouvement *et al.* [18], and the experimental M1 contribution from the data of Filippone *et al.* [2].

As a comparison to the experimental data, a GEANT Monte Carlo simulation was done which took into account the detection efficiency of our setup. The simulation assumed a nonresonant astrophysical factor calculated by Descouvement and Baye [18] (normalized to the datasets of Filippone [2] and Vaughn [3]), which was then converted to the Coulomb-dissociation cross section by the semiclassical theory of Bertulani and Baur [20] (dashed histogram). If we add in a similar way the experimental M1-resonance contribution [2] (full histogram) we obtain a fairly good agreement with the data, thus confirming dominant role of E1+M1 contributions to the Coulomb-dissociation cross section at our bombarding energy. Also the angular distributions of the excited ^{8}B seem to leave no room for E2, but further studies are necessary to confirm this result. Fig. 3 shows the S_{17} factor obtained by comparison of the measured and the simulated yield, binned according to the resolution. Our result is consistent with the lower-value S_{17} measurements [2, 3, 6]. A theoretical model fitted to our data [19] shows a possible extrapolation to zero energy.

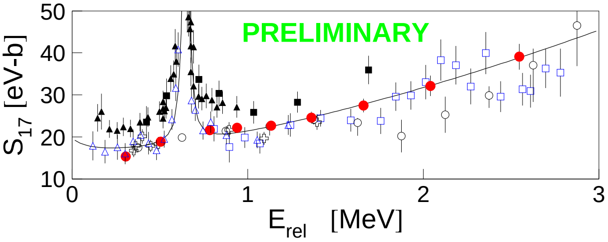

Fig. 3. The extracted S_{17} factor for the full range of the measured Coulomb yield (filled circles), preliminary. The solid curve shows the theoretical model of Bertulani *et al.* [19] for the E1 amplitude plus the M1 resonance from the dataset of Filippone, fitted to our data. Direct-capture results are drawn: Filippone *et al.* [2] (open triangles), Vaughn *et al.* [3] (open boxes), Kavanagh *et al.* [4] (filled triangles), Parker *et al.* [5] (filled boxes) and Hammache *et al.* [6] (open crosses), all normalized to the ^{7}Li$(d,p)^8$Li $E_{\rm CM}$=0.61 MeV resonance of 147mb [8]. Open circles denote results of Kikuchi *et al.* [26] from the RIKEN Coulomb-dissociation experiment.

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