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Elastic scattering of a proton-halo nucleus: ^{8}B+^{58}Ni

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The elastic channel of the ^{8}B + ^{58}Ni system has been measured at energies around the Coulomb barrier. An optical potential fi to the experimental angular distributions is obtained. The total reaction cross section consistent with the obtained potential is reported and possible deviations from normal behaviour are discussed.

Keywords: Proton halo; elastic scattering.

Se midió el canal elástico del sistema ^{8}B + ^{58}Ni a energías alrededor de la barrera Coulombiana. Se obtuvo un ajuste con potencial óptico a las distribuciones angulares experimentales. Se reporta la sección efica total de reacción consistente con el potencial obtenido y se discuten posibles desviaciones de comportamiento normal.

Descriptores: Halo protónico; dispersión elástica.

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A recent work [1] on breakup of ^{8}B , done with a ^{58}Ni target at E_{lab}=25.75 MeV, has established the exotic, "proton halo" nature of this nuclide. Additional measurements at 25, 26.9 and 28.4 MeV gave consistent results [2]. One might wonder whether the sub-barrier reaction yields for this system would show similarities with, for instance, our observations of similar data for the neutron-halo projectile ^{6}He [3-5], where large enhancements are observed below the barrier with a ^{209}Bi target, as well as with those of Refs. 6 and 7, where targets closer to ^{58}Ni were used.

The present knowledge on proton halo effects is rather scarce. Rehm, $et\ al.$ [8] have studied the fusion of ^{17}F+^{208}Pb and found a slightly reduced fusion cross section below the barrier. Liang, $et\ al.$ [9] have measured breakup of ^{17}F on ^{208}Pb and found a very small cross section. It is not clear, however, that either of these experiments gives relevant information on the effect of the proton-halo state, which is an excited state in ^{17}F. The probabilty of Coulex to the halo state during the fusion reaction is very small [8], so the proton halo likely did not come into play. Also, the breakup experiment was performed at an energy well above the Coulomb barrier, and in an angular range where absorption via the imaginary part of the optical potential is very large, so peripheral breakup, which is sensitive to the halo state, was not being probed. So, it is far from clear that enhanced cross sections should be expected in the proton halo case and it is therefore important that raction yields near the barrier be studied for true proton-halo systems. Along these lines, some progress work on the elastic channel is reported here.

The ^{8}B beam was produced by the TwinSol radioactive nuclear beam facility at the University of Notre Dame [10]. The primary beam was $^{6}Li^{3+}$ at energies of 31 and 37 MeV, obtained from the Tandem FN accelerator, which produced in turn lab energies for ^{8}B (at the target center) of 20.7 and 27.2 MeV, respectively.

The scattered particles were detected with four Si position-sensitive detectors (PSD) and one E-ΔE telescope (see Fig.1), which were moved to cover both forward and backward angles. When used at small forward angles, where a good statistics is obtained, the PSD′s were software

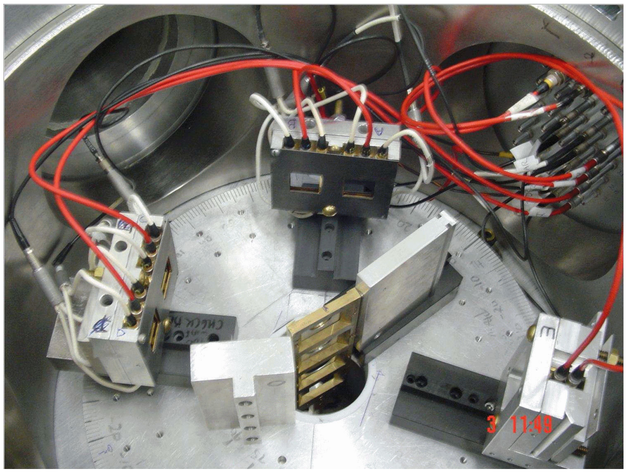

FIGURE 1. Experimental setup.

sectioned into two halves in order to get data for additional angles.

Typical one-dimensional spectra obtained with the PSD′s are presented in Fig. 2, while Fig. 3 shows a spectrum obtained with the telescope. The ^{8}B elastic peak is clearly separated in all spectra and we can see in the last figur that some ^{7}Be events, related to the breakup of ^{8}B, show up. These should produce only a negligible contribution to the corresponding elastic peaks in the one-dimensional spectra, which can be easily corrected for as part of the background.

The experimental angular distributions for the two energies are shown in Fig. 4. An optical model calculation was

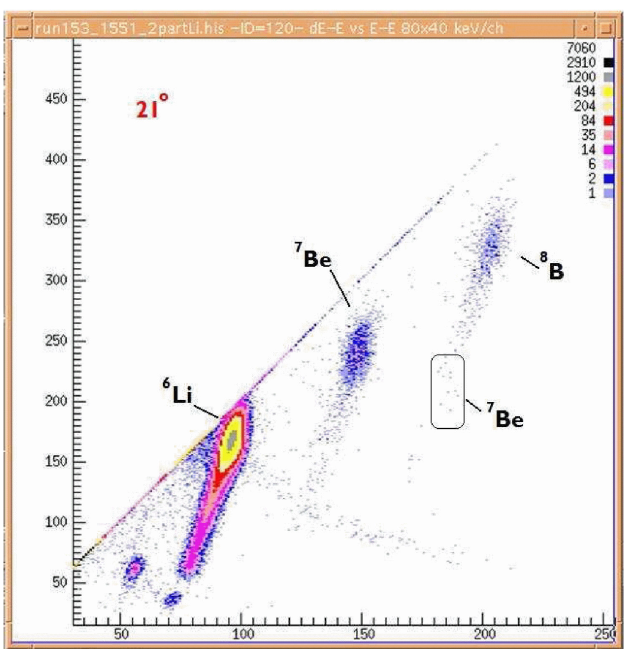

FIGURE 2. One-dimensional spectra obtained with PSD′s placed at 25, 47, 62 and 84 degrees, respectively. The elastic peak for ^{8}B as well as those corresponding to the most prominent contaminant beams are indicated.

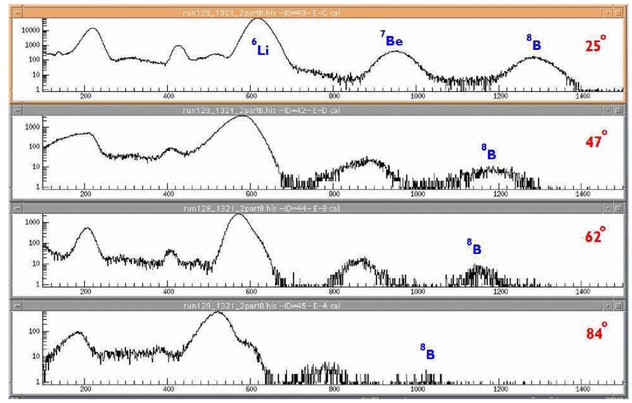

FIGURE 3. Two-dimensional spectrum obtained with the telescope placed at 21 degrees. The group labeled ^{7}Be below the elastic ^{8}B spot, is most probably related to breakup events.

firs done by using the Sao Paulo Potential (SPP) [11] without any fitting with an imaginary part obtained by multiplying the real one times a factor f=0.78. The corresponding result, which should represent the expectations for a normal system, were quite far from the data, predicting in particular a coincidence with Rutherford scattering up to much larger angles. The f factor was then varied until a reasonable fi to the data was obtained, requiring the quite large value f=3.6. In addition to a very big depth, the corresponding imaginary potential is characterized by a large radius. Keeping always the real SPP, a Woods Saxon (WS) form was then attempted for the imaginary part, getting an improved fi for the parameters W=160 MeV, a=0.6 fm, r=1.25. In common with the previous potential, once again a larger radius than expected is obtained, which makes one think about a possible halo effect.

The curves shown in Fig. 4 correspond to the WS imaginary part. The fact that the same potential

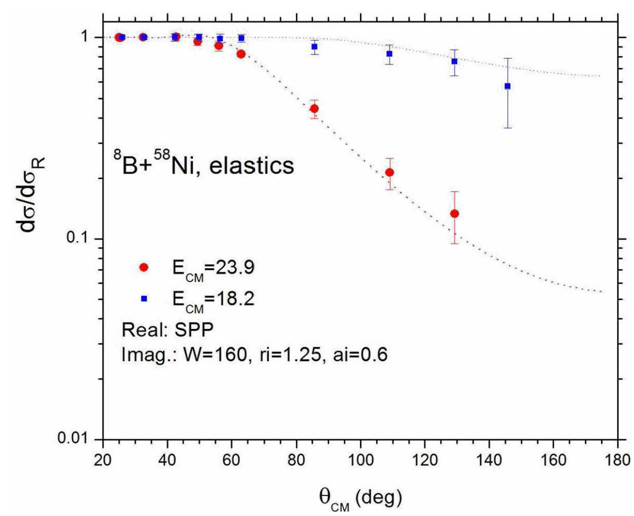

FIGURE 4. Elastic scattering angular distributions for the two indicated energies. The curves correspond to optical model fit discussed in the text.

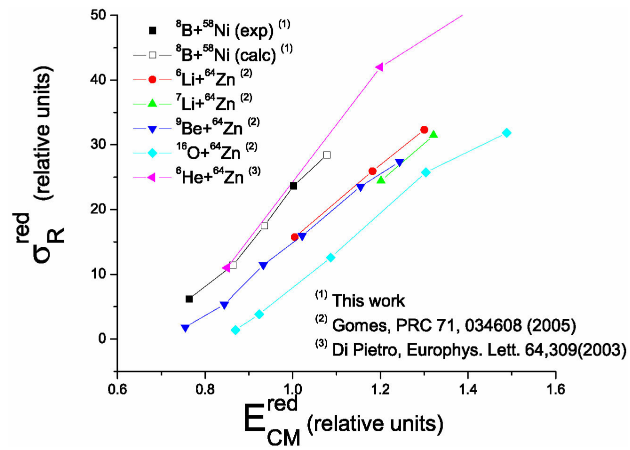

FIGURE 5. Total reaction cross sections calculated from the Sao Paulo optical potential with a Woods Saxon imaginary part, as discussed in the text.

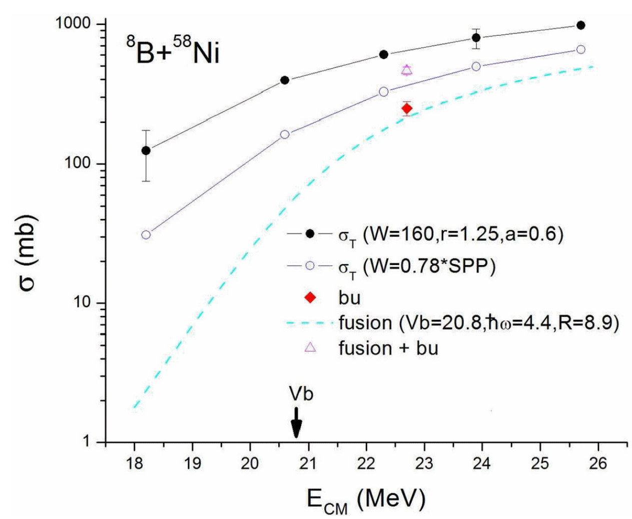

FIGURE 6. Reduced cross sections and comparison to other data.

gives a reasonable description of the data for two quite different energies indicates that,to some extent, estimations based on the same energy-independent potential should give also reasonable predictions for neighboring energies. Under this assumption, we estimated the total reaction cross sections not only for the two experimental energies but also for three additional ones, chosen to better illustrate the predicted data trend in the energy range of interest. The results are shown in Fig. 5, along with the fusion excitation function predicted by the one-dimensional barrier penetration model (BPM). The corresponding barrier parameters were obtained from the real SPP and they are actually in good agreement with those obtained from well known empirical formulas [12,13]. In addition, an integrated breakup cross section was also estimated from the results in Ref. 1 and this is shown by the diamond. The sum of this with the corresponding fusion cross section predicted by the BPM is shown by the triangle. According to this estimation, some yield is still missing to exhaust the total reaction cross sections. Either the actual fusion cross section might present an enhancement or some other reaction mechanisms become important. In order to corroborate this result, it will be important to have actual measurements for the fusion cross section in this region.

In order to compare with existing results for other systems, a reduction of the data was made by dividing the cross sections by the factor $(A_p{}^{1/3} + A_t{}^{1/3})^2$ and the energy by the factor $Z_pZ_t/(A_p{}^{1/3} + A_t{}^{1/3})$. The results are presented in Fig. 6. The most striking result in this figur is the fact that the ^{8}B data show a similar enhancement as that present for the neutron halo nucleus ^{6}He. In semiclassical terms, Coulomb polarization favors neutrons in the halo residing in the region between the core and the target, which then enhances the reaction probabilities, as has been observed. In contrast, for the proton halo case one would expect that polarization of the projectile via the Coulomb force, would result in the valence proton spending more time at large distances from the target where it is shielded by the core from the full Coulex effect. This would also tend to keep transfer and fusion yields near those of the core, so there is no apparent reason to expect enhanced cross sections. The present results thus pose a challenge for theorists to explain.

Summarizing, elastic scattering angular distributions for the ^{8}B+^{58}Ni system are reported at two energies around the Coulomb barrier. The optical potential that fit the data has an imaginary part characterized by a large radius, consistent with the idea of an extended proton halo wave function. The extracted total reaction cross sections are not exhausted by the sum of breakup plus predicted fusion, indicating either a possible fusion enhancement or the presence of other unknown reaction processes. Comparison with data for neighbouring systems shows a reaction enhancement similar to the one present in the case of the neutron halo projectile ^{6}He.

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