CERN-INTC-2010-074 / INTC-I-129
08/10/2010

EUROPEAN OGANIZATION FOR NUCLEAR RESEARCH

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

Probing the optical potential and reaction mechanisms at near barrier energies for $^{8}B+^{28}Si$

N. Patronis[1], A. Pakou[1], R. Raabe[2] , N. Alamanos[3] , N. Keeley[4], G. Souliotis[5], S. Stiliaris[6], K. Rusek[7], K. Zerva[1]

[1] Department of Physics and HINP, The University of Ioannina, Greece
[2] Instituut voor Kern- en Stralingsfysica, K.U.Leuven, Belgium
[3] CEA-Saclay DSM/IRFU/DIR, F-91191 Gif-sur-Yvette, France
[4] The Andrzej Soltan Institute for Nuclear Studies, Warsaw, Poland
[5] Department of Chemistry and HINP, University of Athens, Greece
[6] Department of Physics and HINP, University of Athens, Greece
[7] Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland and the Andrzej Soltan Institute for Nuclear Studies, Warsaw, Poland

Spokesperson: A. Pakou (apakou@cc.uoi.gr)

Contactperson: J. Pakarinen (Janne.Pakarinen@cern.ch)

Abstract

We propose the study of $^{8}B+^{28}Si$ at near barrier energies for probing the optical potential via elastic scattering and backscattering barrier distribution measurements. The breakup and transfer channels will be also detected simultaneously with the elastic scattering and will be used together with extensive CDCC and full CRC calculations for probing the reaction dynamics.

Introduction

As is well known for heavy ion reactions, approaching the vicinity of the Coulomb barrier, couplings between various channels increase in importance. Describing elastic scattering, either these couplings have to be taken into account through coupled channel theories, or the energy dependence of the various optical model parameters has to be considered explicitly (potential threshold anomaly)[1] . In an intermediate approach the analysis of the energy dependence of the potential is made by considering the optical potential as a sum of a bare and polarization energy dependent potential which takes into account deviation from the average interactions between the collision partners due to strong couplings. In either case studies at near or sub- barrier energies are very important as they probe the potential in a sensitive energy region interesting from the point of view of astrophysical problems, while they simultaneously give insight on reaction mechanisms. Both issues are inter-related and have to be unfolded as to obtain solid conclusions.

Nowadays this research field becomes more and more appealing since with the development of radioactive beams the study of exotic nuclei is available. One particular feature of exotic nuclei has to do with the last nucleon or group of nucleons forming a halo which is weakly bound to the core nucleus. This feature at near barrier energies should give a very different aspect to coupling effects and therefore to the energy dependence of the potential or to the polarization potential. As it is already known from weakly bound but stable nuclei the influence of breakup and/or transfer effects is vital. In that respect, we had undertaken the last years a comprehensive study on the ^{6,7}Li+^{28}Si system [2] as a predecessor system to studies with radioactive nuclei. After the successful completion of these studies, relevant not only to the optical potential but also to reaction mechanisms at near barrier energies, it is the time to extend these studies with radioactive weakly bound projectiles. To this instance a very appealing projectile is ^{8}B.

^{8}B is a proton rich, drip line nucleus, attracting a strong interest due to its role in the production of high energy neutrinos in the sun [3] and its unusual structure with a possible proton halo [4]. The binding energy of the last proton to the ^{7}Be core is just 0.137 MeV while another interesting feature which makes ^{8}B an even more interesting nucleus is that its core ^{7}Be is also a weakly bound nucleus with respect to the ^{3}He+^{4}He breakup threshold with binding energy 1.583MeV. The existence or not of a halo is still in an exploratory stage since there are contradictory results concerning predictions in theory and/or experiment with no proton halo and experimental evidence on proton halo [5-6]. Moreover a possible decoupling of the proton from the ^{7}Be core is under investigation [6].

While ^{8}B is a very important and unique nucleus it is produced via in-Flight techniques at RIKEN and Notre Dame and recently at Legnaro. The beam is produced as a cocktail of ^{8}B, ^{7}Be and ^{6}Li nuclei at very low intensities suitable mainly for measurements with detectors at zero degrees. In that respect a preliminary experiment at Legnaro at the end of November 2010, is scheduled aiming to beam development and to a total reaction cross section measurements for $^{8}B+^{28}Si$ at near barrier energies with an active target technique. In order to visualize a comprehensive study for this system which will include elastic scattering angular distribution measurements, excitation functions with elastic backscattering for the determination of barrier distributions and the measurement of various reaction channels as breakup and one proton transfer, a pure beam of considerable intensity of the order of 10^3 up to 10^6pps is necessary. ISOLDE and REX-ISOLDE in that respect can play a decisive role by developing such a beam.

The Physics case

The goal of the proposed study in this Letter of Intent concerns the study of $^{8}B+^{28}Si$ for probing the halo structure of ^{8}B, the optical potential at near barrier energies and the involved reaction mechanisms.

Weakly bound nuclei are expected to show a different behavior in respect with both the potential and reaction mechanisms than the corresponding well bound ones due to their trend to break and/or to transfer some of their nucleons. For example for ^{6}Li, which is a weakly bound but stable nucleus, the imaginary part of the optical potential was found to be increasing when approaching the barrier from above, in contrast to the well bound nuclei [7-10]. This was related to a rather flat or slightly curved with negative slope trend for its real part, in accordance with dispersive relations.

Due to low beam intensity of radioactive ion beams the type of threshold anomaly as well as the reaction dynamics is not fully understood in the case of weakly bound unstable nuclei. Therefore the first task within the proposed work will be the determination of elastic scattering angular distributions at various near barrier energies for $^{8}B+^{28}Si$ for probing the energy dependence of the potential. An appropriate experimental setup will allow a simultaneous measurement of breakup and other direct reaction channels.

The intrinsic lack of sensitivity for obtaining the energy dependence of potential parameters, at energies close to the Coulomb barrier, leads occasionally to vague conclusions. It was proven recently [11] that this can be avoided by performing complementary measurements of elastic backscattering barrier distributions. Such measurements are time consuming, but the benefit of it is great and worth to be attempted. Backscattering measurements will help also to obtain information on the coupling mechanisms-breakup and inelastic scattering [12].

The experimental set up

For the elastic scattering measurements four telescopes can be used with an area of 5x5 cm^2 at the appropriate distance so that to span an angular range of 15 to 150^0 . These telescopes will be composed by a first stage gas detector backed by DSSSD detectors (Double Sided Silicon Strip Detector). The last DSSSD stages will be used to determine the scattering angle. Reaction events will be separated from elastic scattering events with the ΔE-E technique or/and by TOF requirements when necessary. The applied ΔE-E technique will also allow the identification of the various reaction channel events for a better understanding of the reaction mechanisms. A coincidence requirement between the different modules will also allow breakup exclusive measurements detecting in coincidence the two boron fragments that is the proton and the ^{7}Be nucleus. The measurement will be repeated in a few near barrier energies between 2.0 to 4.3 A MeV.

Beam request

Requested beam intensities are listed according to the type of measurement

- Total reaction cross section with the solid active target method: 500 to 1000pps
- Elastic scattering, 10^3 to 10^4 pps
- Backward scattering: 10^4 to 10^5 pps
- Identification of other reaction channels: 10^5 to 10^6 pps

As indicated above, measurements of total reaction cross section could be performed with weak boron beams. These measurements could be considered as the starting point of a general research project aiming to more complete measurements when higher ^{8}B beam intensities become available.

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