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Fusion of ^{8}He with ^{206}Pb around Coulomb barrier energies

V. V. Parkar[1,a], G. Marquinez[1], I. Martel[1], A. M. Sánchez-Benítez[1], L. Acosta[1], R. Berjillos[1], J. Dueñas[1], J. L. Flores[1], J.P. Bolívar[1], A. Padilla[1], M.A.G. Alvarez[2], D. Beaumel[3], M.J.G. Borge[4], A. Chbihi[5], C. Cruz[4], M. Cubero[4], J. P. Fernandez Garcia[2], B. Fernández Martínez[2], J. Gomez Camacho[2], N. Keeley[6], J. A. Labrador[2], M. Marquis[7], M. Mazzocco[8], A. Pakou[9], N. Patronis[9], V. Pesudo[4], D. Pierroutsakou[10], R. Raabe[11], K. Rusek[12], R. Silvestri[10], Ł. Standylo[6], I. Strojek[12], N. Soic[13], O. Tengblad[4], R. Wolski[14], and A. H. Ziad[2]

[1] Departamento de Física Aplicada, Universidad de Huelva, E-21071 Huelva, Spain
[2] Centro Nacional de Aceleradores, Universidad de Sevilla, 41092 Sevilla, Spain
[3] Institut de Physique Nucléaire, IN2P3-CNRS, 91406 Orsay, France
[4] Instituto de Estructura de la Materia, CSIC, Madrid, Spain
[5] GANIL, CEA/DSM-CNRS/IN2P3, Bd Henri Becquerel, BP 55027, F-14076 Caen Cedex 5, France
[6] Department of Nuclear Reactions, The Andrzej Soltan Institute for Nuclear Studies, ul. Hoża 69, PL-00-681 Warsaw, Poland
[7] LPC, CNRS/IN2P3, Ensicaen, Université de Caen Basse Normandie, F-14050 Caen cedex, France
[8] Dipartimento di Fisica, INFN, I-35131 Padova, Italy
[9] Department of Physics and HINP, The University of Ioannina, GR-45110 Ioannina, Greece
[10] INFN - Sezione di Napoli, via Cinthia, I-80126 Napoli, Italy
[11] Instituut voor Kern-en Stralingsfysica, K.U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium
[12] Heavy Ion Laboratory, University of Warsaw, Pasteura 5A, 02-093 Warsaw, Poland
[13] Rudjer Boskovic Institute, Bijenicka 54, HR-10000 Zagreb, Croatia
[14] Institute of Nuclear Physics PL-31342, Krakow, Poland

Abstract. The experimental study of the fusion of light neutron-rich nucleus ^{8}He with ^{206}Pb is reported in this work. A fusion stack of ^{206}Pb targets has been used for this study. The most prominent evaporation residue (^{210}Po), which has half-life of 138 days and decays by alpha emission, is populated in the reaction. Radiochemical analysis technique is used to extract the yield of this evaporation residue.

1 Introduction

From the first experiments where evidences for a halo structure in ^{11}Li were reported [1], similar effects were also found in other exotic nuclei far away from the valley of stability. The availability of these exotic nuclei has triggered new interest in the field of nuclear structure and reaction dynamics [2,3]. There have been also many improvements in the theoretical side which provide a deeper understanding of experimental findings by using different approaches. The coupled channels approach is nowadays extensively being used to understand simultaneously different reaction channels by means of codes like FRESCO [4]. The strength and coupling between the different reaction channels can be properly described by the use of coupled channels calculations [5], including coupling to the continuum. Even for four body correlations [6], the theoretical framework was reasonably well established along last few decades from the study of nuclear reactions with stable heavy ions. At coulomb barrier energies, the data can also be described using semi-classical models [7], complementary to the sophisticated coupled channels calculations, providing an elegant insight on the relevant mechanisms participating in the dynamics of the collision process.

Sub-barrier fusion of neutron rich nuclei depends strongly on the reaction channels still present at energies below the barrier. In neutron-rich nuclei the fusion cross section could be increased due to a reduction in the effective Coulomb barrier [8]. However the characteristic low binding energy should favour the break-up channel and reduce the fusion probability [9]. Several experiments were performed to study the effect of neutron halo on the fusion process, and extraordinary experimental efforts have been carried out in the past for measuring sub-barrier fusion of ^{6}He [9–11]. The case of ^{8}He is different, as we are dealing with a skin nucleus, a system with a thick layer of neutron matter surrounding the inner nuclear core. Whether the halo or the skin will produce strong effects on fusion cross sections is still a matter of investigation. Very recently, a first measurement to understand the fusion mechanism was performed at GANIL using ^{197}Au targets [12].

The motivation of the present work is the understanding of the interplay between the various reaction channels

[a] e-mail: vivek.parkar@dfa.uhu.es

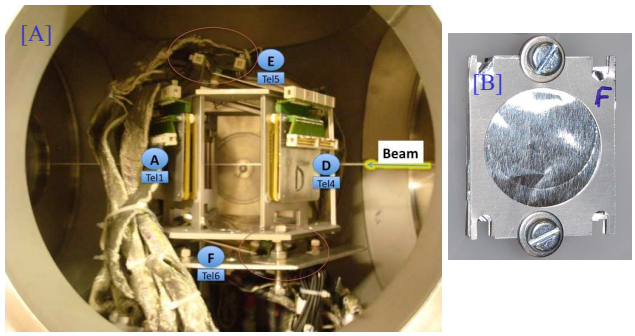

Fig. 1. [A] Picture of experimental setup used for the detection of the charged particles produced in the ^{8}He+^{208}Pb collisions (see text for details) [B] Picture of the fusion stack which was placed downstream of the scattering chamber in a separate chamber.

in the fusion process. A new experiment was performed using the SPIRAL RIB facility at GANIL (Caen, France) in October 2010, where two targets along the beam line were used. In this experiment, the ^{8}He beam was first scattered on a ^{208}Pb target, where direct reaction processes were investigated by using the Huelva University charged particle array (GLORIA). A few meters downstream the beam line, a fusion stack of four ^{206}Pb targets (separated by mylar in front and aluminium in back) was placed to measure sub-barrier fusion cross sections. Here the evaporation residues (ER) produced after the fusion of ^{8}He with ^{206}Pb were implanted on ^{206}Pb and successive Al assembly, where the yield of ^{210}Po (an active alpha emmiter having a half life of 138 days) was accumulated during several hours of irradiation. The details of experimental setup, radiochemical procedure and the results are given in the following sections.

2 Experimental Details

In the experimental setup, a new simple but highly efficient charged particle detector array developed at the University of Huelva (Spain) named GLORIA (GLObal ReactIon Array) was used to measure the elastic scattering and direct reaction channels. In addition, a stack of ^{206}Pb foils was used to extract the fusion residues using the activation technique. The schematics of the experimental setup, the scattering chamber and the GLORIA array, is shown in Fig. 1[A]. The fusion stack was placed downstream of the scattering chamber for irradiation, as it is shown in Fig. 1[B]. The GLORIA silicon ball is a compact and high granularity detection system, covering a wide angular range from θ_{lab} = 10° to 170°. The system is made of 12 DSSSD (16 x 16 strips each) particle telescopes. For each telescope: ΔE-40 μm, E-500 μm. The detector system is fully equipped by its own analog chain, logic and DAQ system on a VME platform. The typical two dimensional spectrum of ΔE vs. Etot for ^{8}He+^{208}Pb reaction measured at E_{lab} = 22 MeV and θ_{lab} = 26.7° is shown in Fig. 2. In the case of the fusion stack used for irradiation, it consists of stack of four ^{206}Pb targets separated by mylar (~ 2.5 μm) in the front (to stop the backscattered ERs) and aluminium (~ 14.7 μm)

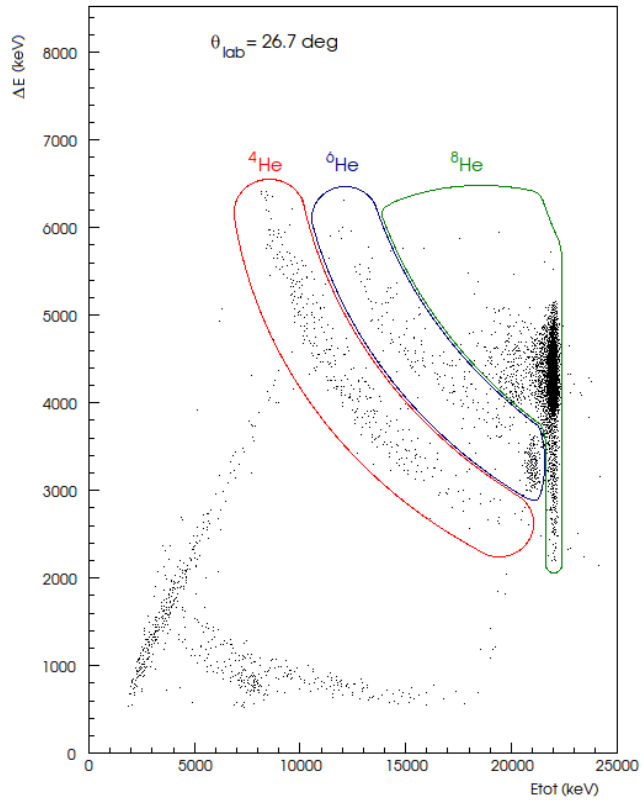

Fig. 2. A typical two dimensional spectrum of ΔE vs. Etot for ^{8}He+^{208}Pb reaction measured at E_{lab} = 22 MeV and θ_{lab} = 26.7°. Different isotopes of 'He' can be easily identified in this telescope.

in the back (to degrade the beam energy). The whole stack is irradiated for 22 MeV. The incident beam energy on the successive target foils was determined based on the energy loss for the mylar, Pb and Al foils using SRIM [13]. After irradiation, the activated ^{206}Pb foils went through a radiochemical treatment in which the ^{210}Po was isolated and deposited on a silver coin. The coins were introduced in the alpha station system at University of Huelva, where the yield of ^{210}Po was obtained.

2.1 Preparation of samples and radioactivity measurement

The fusion stack irradiated during the experiment has been subjected to chemical processing at the Radiochemical laboratory at the University of Huelva. The picture of the measurement cell is shown in Fig. 3. Each target was dissolved and a known amount of ^{209}Po was added as a tracer in order to fix an efficiency of the chemical process. The element of interest was extracted and put into dedicated alpha activity measurement cells. As the half-life of alpha decay from ^{210}Po is 138 days, the activity is measured for 30 days to accumulate sufficient statistics. We also took a background run to confirm that no other peaks were present in the region around 5300 keV (emitted alphas from ^{210}Po). A typical spectrum for one of the samples after one month of

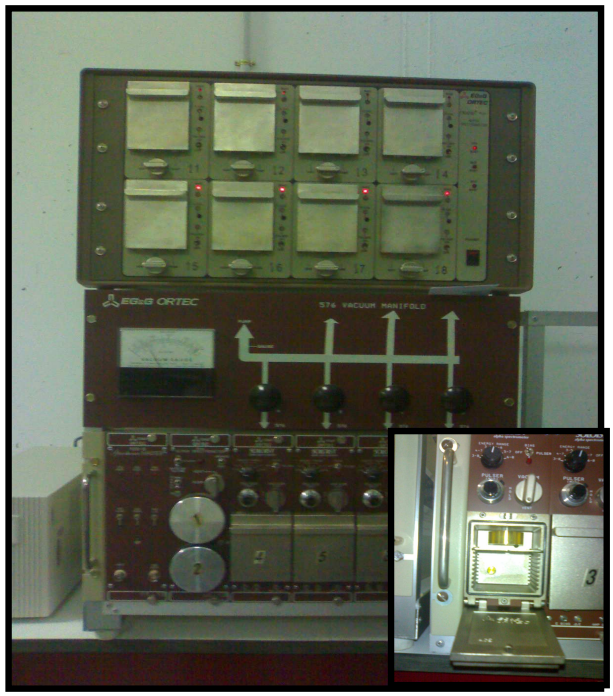

Fig. 3. Picture of measurement system at the Radiochemistry laboratory at the University of Huelva. In the inset, the detector and the sample holder can be seen.

statistics is shown in Fig. 4[A]. The distinct peak of alpha particles from ^{210}Po at 5300 keV can be seen along with the room background (^{228}Th peak) and the radiotracer ^{209}Po peaks. The peak of interest (^{210}Po) has been fitted (shown in Fig. 4[B]) and the area under that peak was extracted.

3 Results and Discussion

In order to determine the cross-section of interest (production of ^{210}Po), the total flux of the projectiles during the irradiation is necessary. It will be obtained by normalizing the elastic scattered particles detected in the forward angle ($\theta < 30°$), where Rutherford scattering is expected. The analysis of the elastic scattering channel is in progress to get the final (production of ^{210}Po) cross-sections.

4 Summary

The production of ^{210}Po populated in the fusion of ^{8}He with ^{206}Pb has been measured for energies around the Coulomb barrier. The method of activation in a stack of foils has been utilized for this study. The elastically scattering projectiles from ^{208}Pb target at forward angles will be utilised for absolute normalization to determine the production cross-sections. The full elastic scattering distribution data acquired in the same experiment will also be reported shortly.

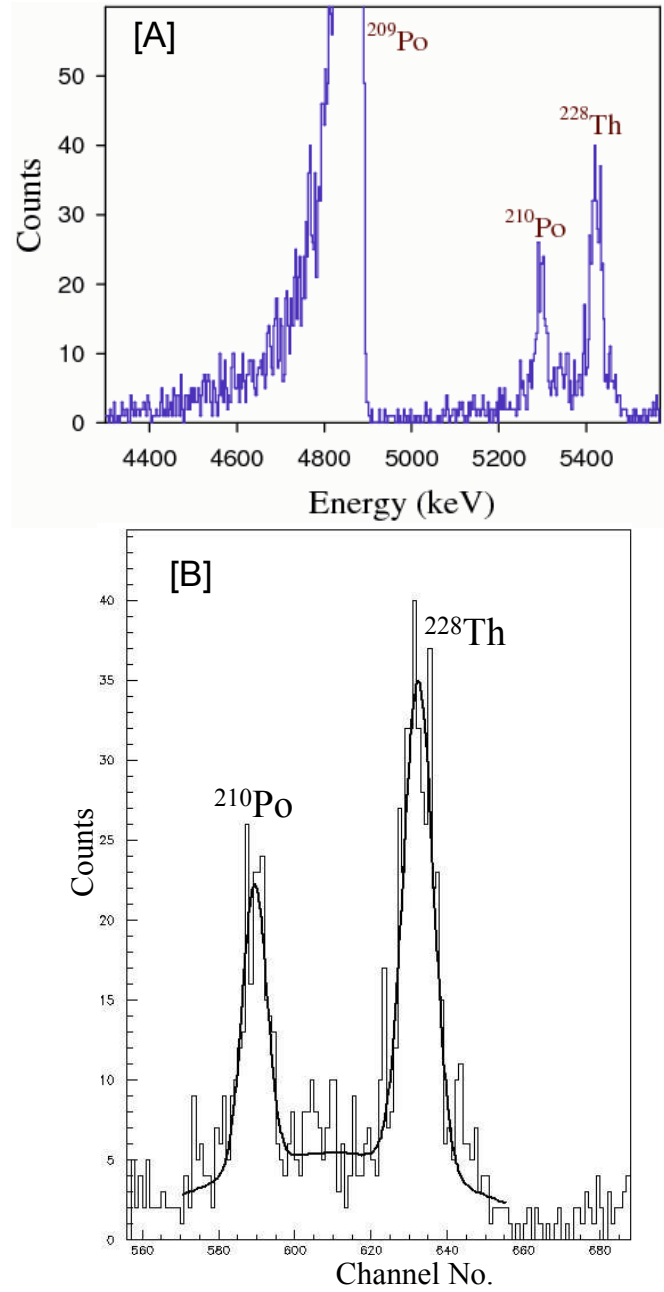

Fig. 4. [A] Typical energy spectrum from the sample after radiochemical and self deposition process on the silver disk. The peak corresponding to the alpha decay of ^{210}Po at 5300 keV is clearly seen to be separated from other radioactive contaminants. The bigger peak corresponding to the alpha decay energy of the radiotracer ^{209}Po at 4880 keV can also be seen. [B] Fitting procedure used to extract the yield of ^{210}Po.

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