Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics A 834 (2010) 491c–494c
NUCLEAR PHYSICS A
www.elsevier.com/locate/nuclphysa

Scientific program of the Radioactive Ion Beams Facility in Brasil (RIBRAS)

A.Lépine-Szily[a], R.Lichtenthäler[a], V.Guimarães[a], D.R.Mendes Junior[a], P.N.de Faria[a], A.Barioni[a], E.A.Benjamim[b], K.C.C.Pires[a], V.Morcelle[a], R.Pampa Condori[a], M.C. Morais[a], P.Descouvemont[c], A.M.Moro[d], M.Rodríguez Gallardo[e*], M.M.Assunção[f], J.A.Alcantara Nunez[b], J.M.B.Shorto[g], J.C.Zamora[a], E.Leistenschneider[a], C.E.F.Lima [a].

[a]Instituto de Fisica, Universidade de São Paulo, C.P.66318, 05389-970 São Paulo, Brazil

[b] Universidad de Santiago de Compostela, Spain

[c]Université Libre de Bruxelles, CP229 B1050 Brussels, Belgium

[d]Departamento de FAMN, Universidad de Sevilla, Apdo 1065, E-41080, Sevilla, Spain

[e]Instituto de Estructura de la Materia, CSIC, Serrano 123, E-28006 Madrid, Spain

[f]Depart.Ciências Exatas e da Terra, Universidade Federal de São Paulo, Diadema, Brazil

[g]Instituto de Fisica-Universidade Federal Fluminense, Niterói, Brazil

The RIBRAS facility (Radioactive Ion Beams in Brasil) is installed in connection with the 8MV Pelletron tandem of the University of São Paulo Physics Institute. It consists of two superconducting solenoids which focalize light radioactive secondary beams of low energy, produced by transfer reactions. Recent experimental results include the elastic scattering and transfer reactions of ^{6}He halo nucleus on ^{9}Be, ^{27}Al, ^{51}V and ^{120}Sn targets. The elastic scattering and transfer of ^{8}Li and ^{7}Be on several targets is also being studied. The transfer reaction ^{8}Li(p,α)^{5}He of astrophysical interest was also studied in the E_{cm}=0.2-2.5 MeV energy range.

1. Introduction

The Radioactive Ion Beams in Brasil (RIBRAS) facility is the first and unique device in the southern hemisphere to produce unstable secondary beams. It consists of two superconducting solenoids of 6.5 T maximum central field (5 Tm axial field integral)[1]. It can focalize the radioactive nuclei produced by transfer reactions on a production target, with a maximum angular aperture of $2 \leq \theta \leq 15$ degrees. The solenoids were designed to focalize heavier and more energetic secondary beams than those actually delivered by the Pelletron Accelerator (E = 3-5 MeV/nucleon). Our laboratory is installing a linear post-accelerator (LINAC) that should multiply by a factor 2 to 3 the actual maximum energy and should also deliver heavier beams. The main interest in measuring the elastic

*Present address:Departamento de FAMN, Universidad de Sevilla, Apdo 1065, E-41080, Sevilla, Spain

0375-9474/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.nuclphysa.2010.01.074

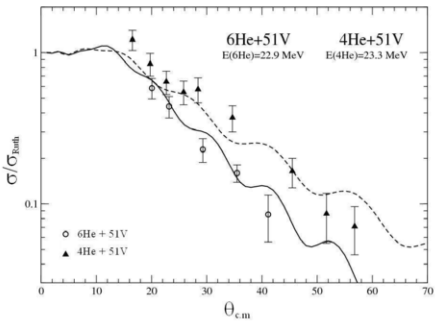

Figure 1. Elastic scattering angular distributions of ^{6}He and ^{4}He on ^{51}V

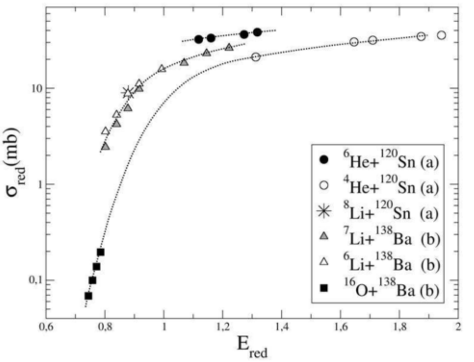

Figure 2. Reduced total reaction cross sections for ^{6}He, ^{6,7,8}Li, ^{4}He and ^{16}O, respectively, on ^{120}Sn and ^{138}Ba targets (a) ref.[5], (b) ref.[6]

scattering of the halo nucleus ^{6}He is to evaluate the role of the 2 neutron halo on the reaction cross section[2]. The production of a large amount of α-particles is also observed, they can come from the break-up of the ^{6}He in the presence of the target nucleus or from transfer reactions. It is of interest to decide between these different mechanisms. The ^{8}Li and ^{7}Be nuclei are unstable but do not present neutron halo, the comparison of their reaction cross section with those of the ^{6}He or with stable, weakly bound Li isotopes ^{6,7}Li can give important informations on the role of the halo in low energy reactions, close to the Coulomb barrier.

2. Elastic scattering of ^{6}He, ^{8}Li on several targets

The ^{6}He and ^{8}Li secondary beams were produced respectively by the one-proton and one-neutron transfer reactions, ^{9}Be(^{7}Li,^{6}He)^{10}B (Q= - 3.38 MeV) and ^{9}Be(^{7}Li,^{8}Li)^{8}Be (Q = 0.3677 MeV), using the ^{7}Li primary beam accelerated by the Pelletron tandem and a ^{9}Be target of 16 μm thickness. A central scattering chamber, located between the two solenoids, was used and the reaction products were detected using four ΔE-E Si telescopes, with detector thicknesses of 20 - 500 (or 1000) μm respectively. The angular uncertainty in our measurements was about 2.5 to 3 degrees, and the uncertainty in the incident energy of the secondary beam is around 400 keV. The secondary beam intensities were calculated by assuming pure Rutherford scattering of the secondary beam on a gold target. We have measured elastic scattering angular distributions of ^{6}He on secondary targets of ^{51}V of 1.9 mg/cm^2, ^{120}Sn (98.29%) of 3.8 mg/cm^2, Au of 3 mg/cm^2 and ^{9}Be of 1.9 mg/cm^2, and of ^{8}Li on targets of ^{51}V, Au of 3 mg/cm^2 and ^{12}C of 2.1mg/cm^2. The angular distributions were reproduced by optical model calculations that also allowed the determination of the total reaction cross sections. We present on Figure 1, two angular distributions, of the halo nucleus ^{6}He and of the tightly bound ^{4}He on ^{51}V at similar energies, 22.9 and 23.3 MeV, respectively. We can notice that the slopes are different, the angular distribution of the ^{6}He is steeper, indicating stronger absorption, which can be accounted by the presence of the halo and/or by the much weaker binding energy. Optical model calculations are superimposed on the data. We used the São Paulo potential[3], with diffusenesses 0.67fm and 0.59fm and with N_i (normalization of the imaginary potential) of

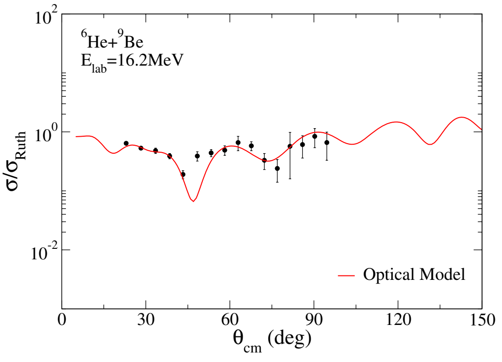

Figure 3. Elastic scattering angular distributions of ^{6}He on ^{9}Be at 16.2 MeV

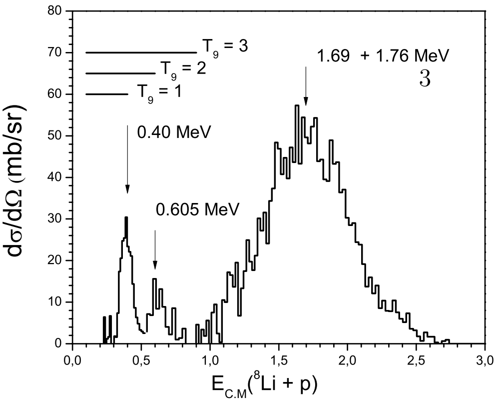

Figure 4. Excitation function of the ^{8}Li(p,α)^{5}He reaction.The arrows indicate the resonances at E*(^{9}Be)=17.298, 17.493, 18.58 and 18.65 MeV

1.4 and 0.45 respectively for the ^{6}He and ^{4}He, indicating the larger absorption for the ^{6}He projectile. In order to compare the reaction cross section of different systems, we used the procedure suggested by [4], where the cross sections are divided by $({A_p}^{1/3} + {A_T}^{1/3})^2$ and the center of mass energy by Z_pZ_T / $({A_p}^{1/3} + {A_T}^{1/3})$, where Z_p (Z_T) and A_p (A_T) are the charge and mass of the projectile (target), respectively. Figure 2 shows the results of the reduced total reaction cross sections, σ_R^{red}, for the halo ^{6}He, the weakly bound ^{6,7}Li, the unstable ^{8}Li and the tightly bound ^{4}He and ^{16}O projectiles, respectively, on the ^{120}Sn[5] and ^{138}Ba [6] targets. The reaction cross sections are the largest for the halo projectile, smaller and equivalent for ^{6,7,8}Li and even smaller for ^{4}He and ^{16}O, indicating the importance of the halo in the interaction. On Figure 3 we present the elastic scattering angular distribution of ^{6}He on ^{9}Be secondary target measured at 16.2 MeV. The optical model fit was performed with a Woods-Saxon potential.

3. Measurement of the ^{8}Li+p $\rightarrow$ ^{4}He+^{5}He reaction

The reaction above is the main path to destroy the ^{8}Li possibly formed in the primordial nucleosynthesis. It has a Q-value of +14.42 MeV. The ^{8}Li could help to bridge the A=8 gap, by the ^{4}He+^{8}Li$\rightarrow$ ^{11}B +n reaction. The comparison of these reaction rates at the astrophysical energies is an important issue. We have measured the excitation function of the ^{8}Li+p $\rightarrow$ ^{4}He+^{5}He reaction between E_{cm} = 0.2 - 2.5 MeV in inverse kinematics, by detecting the energetic α-particles at forward angles with four Si telescopes. We used a polyethilene target (CH_2) of 6.8 mg/cm^2 and a secondary beam of ^{8}Li at four different incident energies, 13.2, 14.5, 17.4 and 19.0 MeV. The contribution of the α-particles from the decay of the ^{5}He was calculated by a Monte-Carlo simulation and was subtracted from the energy spectra, it mainly contributes to the background. The reaction populates high lying resonances in the compound nucleus ^{9}Be. We present in Figure 4 the excitation function measured at $\theta_{cm} = 156^o$. R-matrix calculations are in progress.

REFERENCES

1. R. Lichtenthäler et al, Europ. Phys. Journ. A25 (2005) 733.
2. E. A. Benjamim et al, Phys. Lett. B649 (2007) 30.
3. L. C. Chamon et al, Phys. Rev. C66 (2002) 014610.
4. P. R. S. Gomes et al, Phys. Rev. C71 (2005) 017601.
5. P. N. de Faria PhD thesis 2008, unpublished.
6. J. M. B. Shorto et al, Phys. Lett. B678 (2009) 77.