Study of ^{12,13}C+^{9}Be reaction dynamics at energy above the Coulomb barrier.

J. P. Fernández-García[1,2], M. A. G. Alvarez[1], A. Arazi[3], L. C. Chamon[4], J. Chaves[4], B. Fernández[2], F. J. Ferrer[1,2], L. Garrido-Gómez[1], L. R. Gasques[4], W. Hatano[4], L. Martinis[4] V. Scarduelli[4]

[1] *Departamento FAMN, University of Seville, Spain.*

[2] *Centro Nacional de Aceleradores, Seville, Spain*

[3] *Laboratorio TANDAR, Comisión Nacional de Energía Atómica, San Martín, Argentina*

[4] *Instituto de Física, University of São Paulo, Brazil.*

Spokesperson: J.P. Fernández-García (jpfernandez@us.es) and M. A. G. Alvarez (malvarez@us.es)

Contact person: L. Gasques (lgasques@if.usp.br)

Abstract

We propose to measure the reactions ^{12,13}C+^{9}Be at incident energy of 22.5 MeV ($E_{c.m.}$ = 9.6 MeV), which is above the Coulomb barrier, $V_C \sim 5$ MeV. Different reaction channels, one-neutron transfer, inelastic excitation of projectile and target and breakup will be obtained. One of the main goals is to measure the alpha particles constituents of the projectile and/or target, in coincidence. Complementary to this proposal, the same reactions will be measured at low incident energies (below the Coulomb barrier) at the Centro Nacional de Aceleradores (CNA) in Seville (Spain).

Introduction

During the last decades, the study of collisions induced by halo nuclei has revealed that their diffuse structure associated with a very low breakup threshold have an effect in their reaction dynamics (see e.g. [1] and references therein). Due to its low binding energy, the dissociation of the projectile into two or more fragments is an important mechanism occurring in collisions induced by these radioactive nuclei, and coupling effects to the continuum can deeply affect the other reaction channels around the barrier.

Stable weakly bound nuclei have similar characteristics to halo nuclei, such as a low breakup threshold associated with a marked cluster structure of their ground state. Therefore, the study of reactions induced by stable weakly bound nuclei (where good quality data are easier to obtain due to the higher beam intensities and measurements carried out applying detectors with large active area) help to provide an understanding of the reaction dynamics of halo nuclei.

Motivation

The ^{13}C nucleus is a stable isotope of carbon, it has an excited state $1/2^+$ at 3.09 MeV and $3/2^-$ at 3.68 MeV and the neutron binding energy is 4.95 MeV, while ^{12}C has an excited state 2^+ at 4.44 MeV and the excited state 0^+ at 7.65 MeV (the Hoyle state). On the other hand, ^{9}Be has a neutron binding energy of 1.66 MeV and an excited state $1/2^+$ at 1.68MeV. It is important to note that both ^{9}Be and ^{12}C are stable nuclei with a Borromean structure, since ^{8}Be(α+α) is not bound.

According to the Q-values, at the incident energy of 22.5 MeV ($E_{c.m.}$ = 9.6 MeV with a Coulomb barrier at 5.0 MeV) different channels to produce alpha particles are possible for the ^{12}C+^{9}Be reaction.

- ^{9}Be + 3α (Q=-7.27 MeV)
- ^{12}C + n + 2α (Q=-1.57 MeV)
- ^{13}C + 2α (Q=+3.37 MeV)
- ^{16}O + n + α (Q=+5.59 MeV)
- ^{17}O + α (Q=+9.73 MeV)

For the reaction ^{13}C+^{9}Be,

- ^{10}Be + 3α (Q=-5.41 MeV)
- ^{13}C + n + 2α (Q=-1.57 MeV)
- ^{17}O + n + α (Q=+4.78 MeV)
- ^{14}C + 2α (Q=+6.60 MeV)
- ^{18}O + α (Q=+12.83 MeV)

We can observe either the weakly bound neutron of ^{9}Be or the extra neutron of ^{13}C favours the production of alpha particles coming from different reactions: transfer of one-neutron to the target, breakup of the target, transfer of one-neutron to the projectile and alpha transfer to the projectile. Therefore, high accuracy alpha coincidence measurements will help us to understand the ^{12,13}C+^{9}Be reactions and the effect of the extra neutron of ^{13}C on the dynamics of the reaction.

In Ref. [2], a study of the one-neutron transfer in the reaction ^{12}C+^{9}Be at the $E_{c.m.}$ =4.9, 6.0, 7.3, 8.6 MeV was presented. We propose to measure at energy above to those of Ref. [2] ($E_{c.m.}$ = 9.6 MeV), applying detectors with large active areas, at the Laboratorio Abierto de Fisica Nuclear (LAFN) in São Paulo (Brazil). Complementary to this measurement, the same reactions will be obtained at energies below of Ref. [2] ($E_{c.m.}$ = 0.5 to 5 MeV) at the Centro Nacional de Aceleradores (CNA) in Seville (Spain).

Experimental setup

The measurements will be performed using the scattering chamber located at the beam line 30B. A self-supporting ^{9}Be will be used in the experiment. The ^{12,13}C elastically and inelastically scattered (due to excitation of the projectile and target), the ^{9}Be recoil and the different alpha and reaction products will be measured in coincidence by the detection system STAR2, consisting of two 50x50 mm^2 silicon telescopes (ΔE-E), each composed by a 20 μm thick SSSSD detector (vertical strips) as a ΔE followed by 300 μm thick SSSSD (horizontal strips) as a $E_{\rm res}$ detector.

Thanks to this detection system a wide angular range will be covered. The ratio of the solid angles will be determined by the Rutherford scattering of $^{12,13}C$ on a ^{197}Au target.

Beam time request

Considering the low statistic of alpha coincidence measurements, $^{12,13}C^{4+}$ ion beams, a terminal voltage of 4.5 MV (i.e. incident $^{12,13}C$ energy of 22.5 MeV) and an average intensity at the 30B beam line of 100nA, we ask three days (72h) for the reaction $^{13}C+^{9}Be$ and one day for $^{12}C+^{9}Be$ (in order to compare with the reaction induced by ^{13}C). For calibrations and solid angle normalization we ask for one more day. Thus, we ask 5 days in total.

References

[1] L. Canto et al, Physics Reports 596, 1 (2015).

[2] P.H. Barker et al. Nuclear Physics A155 (1970) 401-416.