LABORATÓRIO ABERTO DE FÍSICA NUCLEAR
PAC 2018

Proposal	N°
Title: Measurement of the 12C(p,p)12C resonance scattering to test the RIBRAS in-flight beam for resonance scattering purposes	
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Participant RIBRAS collaboration	
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Number of days for experiment: 6	
Period planned for the experiment (are the setup ready for beam time?): We need the great chamber after the second solenoid, with its internal plate in rotation to measure angular distribution also	

Technical information

Ion source			Accelerator			Experimental Area	
Beam	Cathode	$I_{mínima}$	V_{min}	V_{max}	Bunched beam?	Beam line	Target
12C	12C	600(FC3	7.0	7.8	no	45B	CH2

Other relevant/needed information:

Measurement of the 12C(p,p)12C resonance scattering to test the RIBRAS in-flight beam for resonance scattering purposes.

Experiment previously realized at 2-8/5/2018 with days of the Director

Requested beam time; 6 days

Spokesperson: Alinka Lépine-Szily

Participants: RIBRAS collaboration, including Rubens Lichtenthaler's group, Valdir Guimarães's group and external participants.

Summary: The resonance scattering method intends to study the spectroscopy of light radioactive nuclei, bound or even unbound. It is a powerful method, with clear theoretical interest and can be used in our Laboratory with the RIBRAS facility [1]. Using the "Thick Target Inverse Kinematics" (TTIK) method, described in detail in [2,3], one uses a radioactive beam and a thick proton target (CH2 foil, or CH4 gas target) and measures the emitted light particles, p, d, alpha at forward angles. As the heavy beam stops in the target, the energy spectrum of light particles yields the excitation function of the reaction. The method works very well with clean ISOL beams, however we have inflight production and our beams have some amount of contaminants and have a large angular dispersion after passing through a degrader. In order to test the method with our radioactive beams, we propose to measure the well known resonance of 12C+p at Ecm=1,606 MeV.

Introduction:

We already performed resonance scattering and resonance transfer reaction measurements using the 8Li radioactive beam, produced by the RIBRAS facility, hitting a thick polyethylene foil (~ 7mg/cm2). In the first measurement, published in 2012 [2] , we have measured the excitation function of the reaction 8Li(p,α)5He, populating high lying excited states of 9Be. More recently we have measured also the resonance elastic scattering 8Li(p,p)8Li and the resonance transfer reaction 8Li(p,d)7Li and the knowledge of 3 outgoing channels allowed a quite sure determination of the resonance parameters through the R-matrix fit to all data. This work was recently submitted to Phys. Rev.C [3]. In order to assure the correctness of our measurements we decided to measure the well- known resonances of 13N using the 12C+p resonance scattering. Fig. 1 presents a measurement of the 12C(p,p)12C cross section [4].

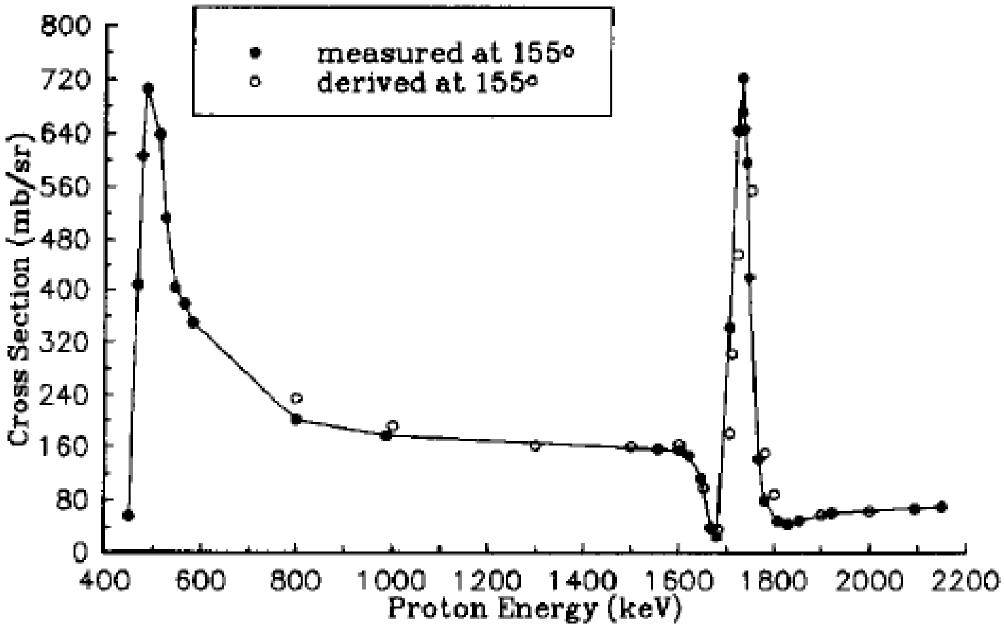
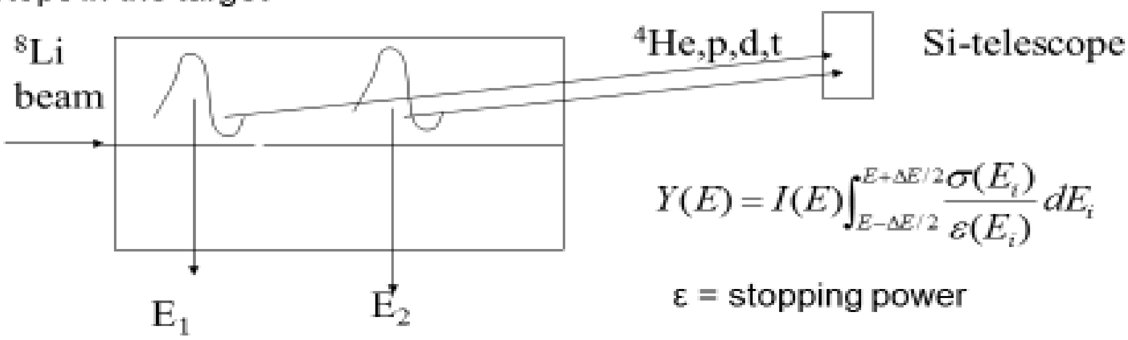


Fig. 1. Comparison of the elastic scattering cross sections of proton on carbon at 155°. The measured data are listed in

<u>TTIK method:</u>

TTIK – thick target inverse kinematics method:

thick secondary target CH_2 (7.7 mg/cm^2) ^{8}Li beam looses energy, stops in the target

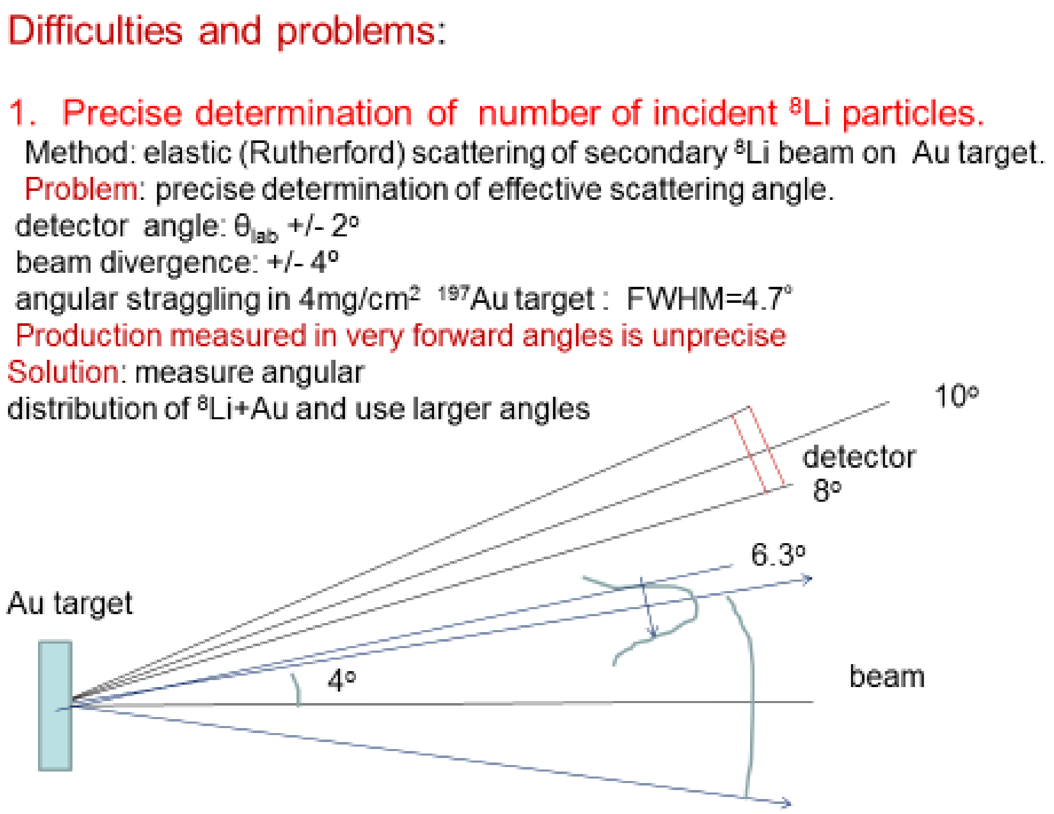


$$Y(E) = I(E)\int_{E-\Delta E/2}^{E+\Delta E/2} \frac{\sigma(E_i)}{\varepsilon(E_i)}\, dE_i$$

ε = stopping power

Simultaneous measurement of all incident energies: excitation function
Resonances populated in the target → peaks in energy spectrum of light ejectiles
Energy spectrum of ^{4}He, p, d → excitation function of reactions

Energy resolution: independent of beam dispersion, depends on energy loss of light ejectiles in target



A Monte Carlo simulation was developed (R. Lichtenthaler) to solve the problem of large angular beam dispersion. It which takes into account the collimator size, the secondary beam spot size (phi= 7mm), the secondary beam divergence, the angular straggling in the degrader and secondary target, and the angular distribution of the emitted particles. It yields the effective average detection angle, the total angular uncertainty and the effective solid angle.

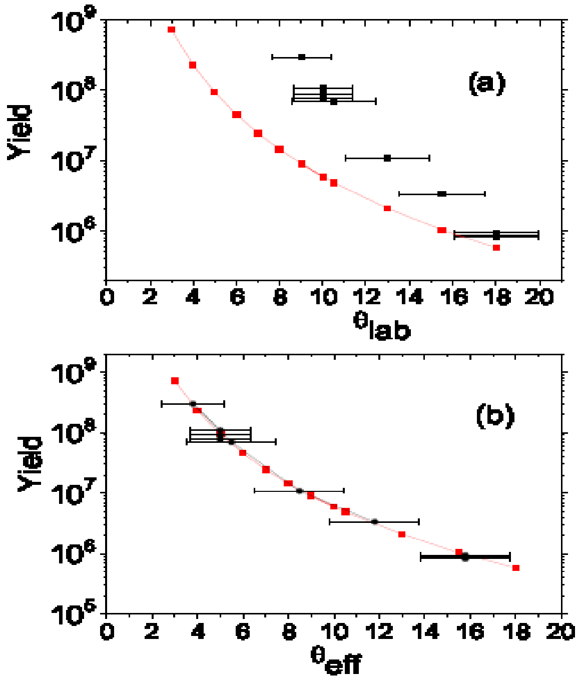


Fig.2 (a) The yield of the experimental 8$Li + 197Au angular distribution is presented by black squares. The red line is the Rutherford cross section. (b) Using the effective average scattering angle instead of the geometrical one, the angular distribution agrees with the Rutherford cross section.

The effective average detection angle is calculated as the weighted average angle, where the weight is given by the number of particles arriving/unit angle, or weighted by the Rutherford differential cross section, in our case.

In our first attempt (May 2018) to measure the resonance scattering of 12C+p, everything worked well, we obtained in the DeltaE-E telescope localized at 14 degrees the energy spectrum presented in Fig.3.

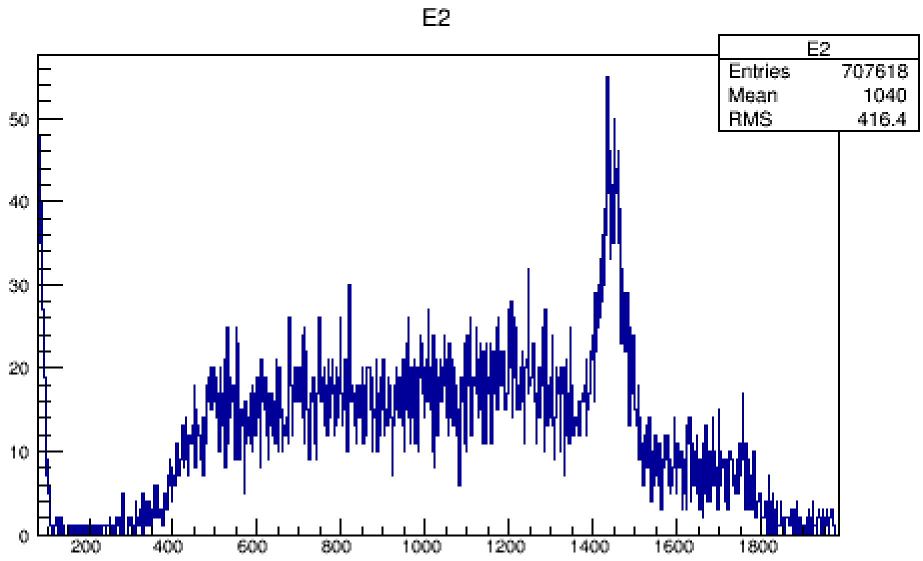


Figure 3. The proton energy spectrum measured at RIBRAS, using a primary beam of 12C of 42.5 MeV, production target of 9Be (12 μm), Al degrader of 4.6 mg/cm2 in central chamber 2 of RIBRAS, CH2 target in final chamber 3 with thickness of 7.0 mg/cm2. E-DeltaE telescope at 14 degrees.

The 12C beam of 29.5 MeV stops in the detector DeltaE after traversing the Au target in chamber 3, so we have to use both DeltaE and E as trigger for the acquisition. Our problem was that the telescope with trigger on DeltaE was at a forward angle, the plate in chamber 3 had no rotation and the 12C beam has much larger angular straggling than 8Li. In this case the Monte Carlo program was unable to calculate the effective scattering angle to be able to normalize the data and transform the yield into cross section.

Solution:

The automated rotation of the plate is being reinstalled by the technicians (Wellington, Otavio). As soon as we have enough liquid He to cool down the 2nd solenoid, and the plate can rotate without problem, we are in condition to repeat the measurement.

References:

1. Lépine-Szily, A. , Lichtenthäler, R. and Guimarães, Eur. Phys. J. A 50 (2014) 128-163
2. Mendes, D. R. , Lépine-Szily, A., Descouvemont, P. , Lichtenthäler, R. Guimarães, V. , de Faria, P. N. , Barioni, A. , Pires, K. C. C. , Morcelle, V. , Pampa Condori, R. , Morais, M. C.,Leistenschneider, E. , Lima, C. E.

F. , Zamora, J. C. , Alcantara, J. A. , Zagatto, V. , Assunção, M. and Shorto, J. M. B., Phys. Rev. C 86 (2012) 064321.

3. E. Leistenschneider, A. Lépine-Szily, M. A. G. Alvarez, D. R. Mendes Jr, R. Lichtenthäler, V. A. P. Aguiar, M. Assunção , R. Pampa Condori, U. U. da Silva, P. N. de Faria, N. Deshmukh, J. G. Duarte, L. R. Gasques, V. Guimarães , E. L. A. Macchione, M. C. Morais, V. Morcelle, K. C. C. Pires, V. B. Scarduelli, G. Scotton, J. M. B. Shorto,V. A. B. Zagatto Submitted to Phys. Rev. C

4. Jingai Liu, Tianbao Xie, H.J. Fischbeck NIM B79 (1993) 468.