Nuclear Reactions

Adelaide Pedro de Jesus

This group has been involved in the study of proton-induced nuclear reactions with the objectives to obtain cross sections of nuclear reactions relevant to nuclear astrophysics and to extend analytical capabilities to light elements.

So far, the experimental work has relied upon ITN – Ion Beam Laboratory based on a 2.5 MV Van de Graaff accelerator. This facility has allowed the development of an accurate method to measure in an absolute way cross sections of relevant nuclear reactions. Also for the applied point of view an effort has been done to complement the already installed PIXE facility by developing a set-up of PIGE analysis for light elements.

In order to proceed with experimental work related to astrophysically relevant nuclear reactions, the group has joined LUNA (Laboratory for Underground Nuclear Astrophysics) collaboration and also established collaboration with Prof. Claus Rolfs group of Bochum University. Work under LUNA collaboration was centred on the study of the reaction ^{14}N (p,γ) ^{15}O and in Bochum the work was related to the study of electron shielding effects on nuclear reaction cross sections and also to the study of the reaction $^{7}Li(p,\alpha)^{4}He$, at very low energies. Target preparation and stoicheiometry analysis by ERD, RBS, PIGE and NRA, has been done at ITN. Also the experimental study of ^{7}Li (p,α) ^{4}He at energies above 100 keV is proceeding in ITN.

In the short term the work to develop a calibrated PIGE set-up will be concluded, opening new perspectives in applied work for Environment, Materials and Health Sciences and Geology. The acquisition of a new accelerator will bring new perspectives of studying ITN astrophysical relevant nuclear reactions, opening also a broad field of implementation of analytical techniques.

Research Team

Researchers (*)

A.P. JESUS, Full Professor, FCT/UNL,
Group Leader
J.P. RIBEIRO, Associate Professor, FCUL

Students

J. CRUZ, Ph.D. student, FCT/UNL
M. FONSECA, Ph.D. student, FCT/UNL
M. MORENO, Ph.D. Student, FCT/UNL
H. LUÍS, Graduate student

Collaborators

R. MATEUS, Technical Assistant

(*) Also member of CFNUL.

Experimental Study of Nuclear Reactions for Astrophysics

J. Cruz[1,2], A.P. Jesus[1,2], Hélio Luís, Micaela Fonseca, J.P. Ribeiro[2,3]

Objectives

A precise knowledge of nuclear reactions cross sections (or S-factor) of light elements is crucial for the understanding of the evolution of the very early universe.

Since these reactions occur in stars at very low energies (Gamow peak), with extremely low cross sections decreasing exponentially with energy, efforts to measure it at theses energies requires pure targets, low background environments and very stable accelerator machines. The going-on work program is related to:

1. Measurement at ITN of cross sections and angular distributions of the reaction $^{7}Li\ (p,\alpha)\ ^{4}He$.
2. Experimental work on reaction cross-sections at relevant energies (around the solar Gamow peak) under LUNA (Laboratory for Underground Nuclear Astrophysics) collaboration, namely the reaction $^{14}N\ (p,\gamma)\ ^{15}O$.

Results

1. Lithium is one of the most interesting and puzzling elements in the field of nucleosynthesis. Its most abundant isotope, ^{7}Li, has the rather unique status of requiring three entirely different nucleosynthetic processes, which are not completely understood.

   The reaction $^{7}Li(p,\alpha)^{4}He$ is the major reactions of Li destruction, having thus a crucial contribution to Li abundances. Even though there are several different cross sections measurements for this reaction, they lead to different astrophysical S-factors at relevant energies.

   At ITN, the experimental set-up for nuclear reactions measurements has been modified and optimized to study this reaction; also at very low energies measurements were done in Bochum. Fig. 1 pertains to results of the astrophysical factor obtained in Bochum, showing at low energies the electron shielding effect.

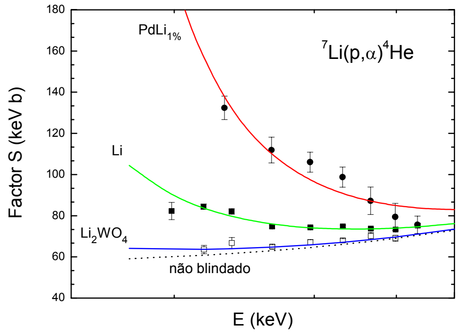

Fig. 1 - Astrophysical factor and screening effect of the $^{7}Li\ (p,\alpha)\ ^{4}He$ reaction measured with different Li targets.

2. At Gran Sasso work on the $^{14}N\ (p,\gamma)\ ^{15}O$ reaction, was completed. Measurements related to a gas target setup have allowed to attain lower energies than before (with the solid target) leading to a more accurate value of the S astrophysical factor for total capture.

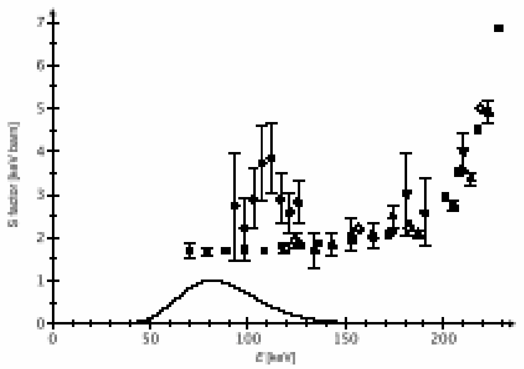

Fig. 2 - Astrophysical S-factor for the $^{14}N\ (p,\alpha)\ ^{15}O$ reaction from the present work (filled squares) and from previous studies. Error bars (1σ statistical uncertainty) are only shown where they are larger than the symbols used. The Gamow peak for $T^{6} = 80$ is also shown.

[1] Departamento de Física da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
[2] Centro de Física Nuclear da Universidade de Lisboa
[3] Departamento de Física da Faculdade de Ciências da Universidade de Lisboa

Calibration of a PIGE Set-up

Bruno Vicente[1,2], R. Mateus[2], Micaela Fonseca[1,2], A. P. Jesus[1,2], Hélio Luis[1,2], J. P. Ribeiro[2,3]

The aim of this work was the extension to further light elements of previous work to install an analytical set-up for light element analysis, based on the detection of the gamma radiation induced by low energy protons, PIGE, in order to complement the already installed PIXE analytical facility.

This technique will open new perspectives of applied work in environment and health problems.

A precise method, based on a code developed in-house that integrates the nuclear reaction excitation function along the depth of the sample, was implemented for thick and intermediate samples. For that purpose some reaction excitation functions were measured in the same analytical conditions. The energy steps needed to define accurately the excitation function were used as energy intervals for the integration procedure.
After the work done for F, Li, B and Na, the excitation function for ^{27}Al (p,p´γ) ^{27}Al, were obtained to introduce as input. Thick target gamma yields for several samples containing Al will be calculated and compared with yields obtained experimentally.

[1] Departamento de Física da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
[2] Centro de Física Nuclear da Universidade de Lisboa
[3] Departamento de Física da Faculdade de Ciências da Universidade de Lisboa