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, at the national level, the experimental work has relied upon ITN – Ion Beam Laboratory, based on a 2.5MV Van de Graaff accelerator. Internationally, the group has joined LUNA (Laboratory for Underground Nuclear Astrophysics) collaboration and also established collaboration with Prof. Claus Rolfs group of Bochum University. The reaction $^{14}N(p,\gamma)^{15}O$ has been studied to 70 keV and the reactions $^{6,7}Li(p,\alpha)^{3,4}He$ to 30 keV. A systematic study of electron screening effects was performed.

The acquisition of the 3MV tandem accelerator opened new perspectives of studying astrophysical relevant nuclear reactions, using the high sensitivity of the AMS line.

In the short term the work to develop a calibrated PIGE setup will be concluded and extended to a new accelerator line connected to the 3MV tandem accelerator, creating new perspectives in applied work in Environment, Materials and Health Sciences and Geology.

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, Research scholarship

Collaborators
R. MATEUS, Technical Assistant

(*) Also member of CFNUL.

Experimental Study of Nuclear Reactions for Astrophysics

J. Cruz[a,b], A. P. Jesus[a,b], Hélio Luis, Micaela Fonseca, J. P. Ribeiro[b,c]

Objectives

Nuclear reactions occur in stars at very low energies (Gamow peak), with extremely low cross sections decreasing exponentially with energy, showing effects as electron screening; experimentally, their study pushes to the limit existing techniques. During this year the work related to LUNA collaboration, namely the reaction $^{14}N(p,\gamma)^{15}O$, was concluded. Also the experimental study of the reactions $^{6,7}Li(p,\alpha)^{3,4}He$ was finished. The on-going work is related to the study of the electron screening effect (collaboration with Bochum) and to the preparation of the AMS line of the new tandem accelerator.

Results

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.

The recent analysis of our data, fig. 1 and 2 lead to a S(E = 0) factor of 3,6 ± 0,1 MeVb for $^{6}Li(p,\alpha)^{3}He$ and 60 ± 1 keVb for $^{7}Li(p,\alpha)^{4}He$.

Future Work

Continuing our goal to measure nuclear reactions relevant to nuclear astrophysics, the aim of future work is the optimization of the AMS technique to detect and quantify ^{6}Li and ^{53}Mn, in order to measure off-line d(alpha,gamma)^{6}Li and $^{51}V(3He,n)^{53}Mn$ reactions. So far the effort has been focused on assembling and making the AMS line operational after the transfer from Australia

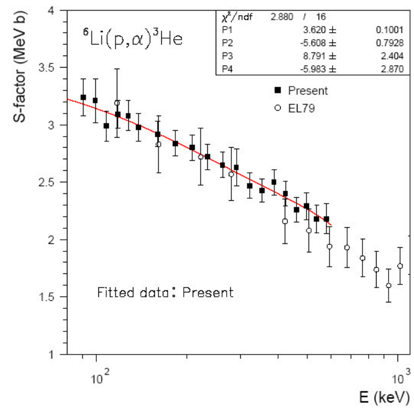

Fig. 1: Astrophysical S-factor for the $^{6}Li(p,\alpha)^{3}He$ reaction for bare nuclei electrões.

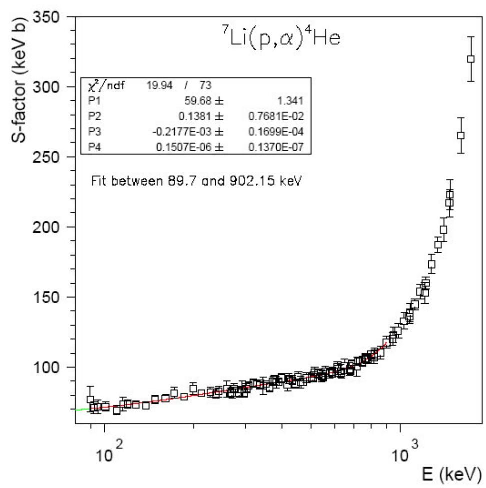

Fig. 2: Astrophysical S-factor for the $^{7}Li(p,\alpha)^{4}He$ reaction for bare nuclei electrons.

[a] Departamento de Física da Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa
[b] Centro de Física Nuclear da Universidade de Lisboa
[c] Departamento de Física da Faculdade de Ciências da Universidade de Lisboa

Calibration of a PIGE Set-up

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

The aim of this work is the extension to further light elements of previous work [1-4] in order to install an analytical set-up for light element analysis, based on the detection of the gamma radiation induced by low energy protons, PIGE.

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

A precise method based on a code [4] 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 functions for $^{27}Al(p,p'\gamma)^{27}Al$ and $^{25}Mg(p,p'\gamma)^{25}Mg$, were obtained to introduce as input. Thick target gamma yields for several samples containing Al and Mg were measured to be compared with calculated yields.

Application of this technique, for F, Li, B and Na analysis of biotite inclusions of granites was performed (fig.1) showing Li concentrations several orders of magnitude above the usual ones, what may be related with the degradation of some ornamental granites.

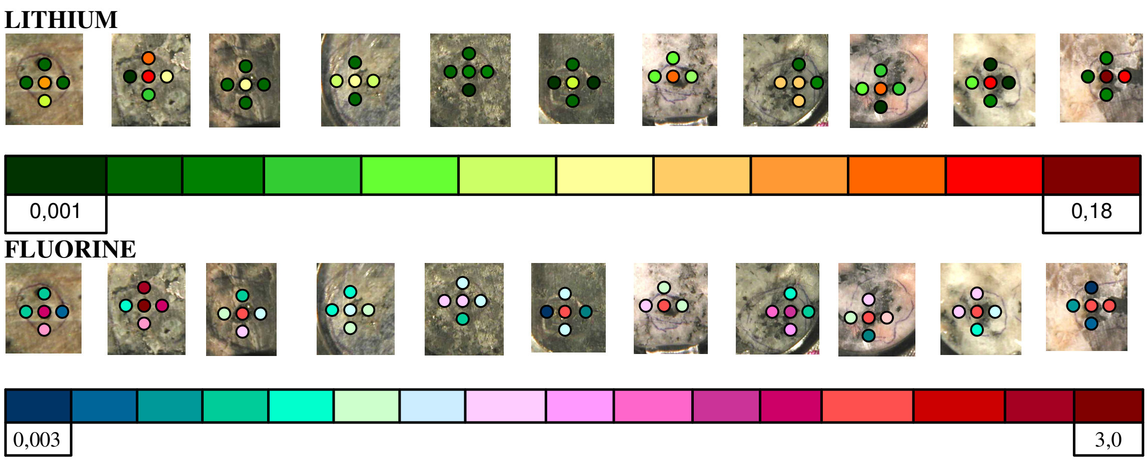

Fig. 1: Massic fractions in percent units of Li (above) and F (below) for several granite samples. The analysis was done on the shown points, being the central points biotite inclusions.

References

[1] R. Mateus, A.P. Jesus, B. Braizinha, J. Cruz, J.V. Pinto, J. P. Ribeiro, Nucl. Instr. Meth. B 190 (2002) 117-121

[2] R. Mateus, A.P. Jesus, J.P. Ribeiro, Nucl. Inst. and Meth. B 219-220 (2004) 519-523

[3] R. Mateus, A.P. Jesus, J. Cruz, J.P. Ribeiro, Nucl. Inst. and Meth. B 219-220 (2004) 307-311

[4] R. Mateus, A. P. Jesus, J. P. Ribeiro, Nucl. Inst. & Meth. B229, 302-308 (2005)

[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