Nuclear Reactions

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This group has been involved in the experimental study of nuclear reactions relevant to nuclear astrophysics and also to ion beam analytical techniques.

The on-going work is related to the development of the AMS line to study reactions relevant to nuclear astro-physics.

In the short term the work to develop a calibrated PIGE set-up will be extended to a new accelerator line connected to the Tandem 3MV accelerator, creating new perspectives in applied work for Environment, Materials and Health Sciences and Geology.

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Experimental Study of Nuclear Reactions for Astrophysics

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Objectives

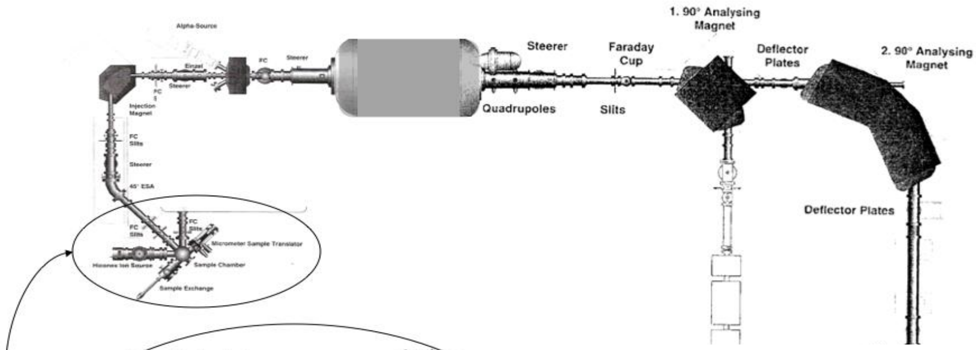
Nuclear reactions relevant for primordial and stellar nucleo-synthesis usually take place at energies much lower than the Coulomb barrier between the target nuclei and positive projectiles. Its cross sections dominated by the probability of tunnelling through the Coulomb barrier, decrease exponentially, as the energy drops down, achieving values that, for the purpose of an experimental measurement, represent a real challenge. AMS – accelerator mass spectrometry is a technique that has been developed to quantify rare isotopes, achieving for some of them very high sensitivities.
The aim of the present work is the experimental study of reactions relevant for nuclear astrophysics, namely $d(\alpha,\gamma)^{6}Li$ and $^{51}V(^{3}He,n)^{53}Mn$ reactions, through the optimization of the AMS technique to detect and quantify ^{6}Li and ^{53}Mn, products of the referred reactions.

Results

The AMS line (Fig.1) is part of the Tandem accelerator and lines purchased to an Australian laboratory.
The going-on work is related to the assembling, tuning and testing of the AMS line. Due to the high number of parameters involved this task has been very demanding in man-power. The line and the ion source are already assembled; tuning and testing are being done with some carbon spectra already obtained before the accelerating stage (Fig. 2).
In connection to the reactions to be studied targets have been prepared; Ti and Hf have been implanted with deuterium, but the amount obtained was not enough; vanadium foils were bombarded with ^{3}He and the complex gamma-spectra obtained are being analysed.

Future Work

After finishing the tuning and testing of the AMS line, backing materials (for targets) will be tested in order to assess their purity. A nuclear reaction line will be assembled at the Tandem accelerator in order to produce the referred nuclear reactions, whose produtcts will be measured by AMS.



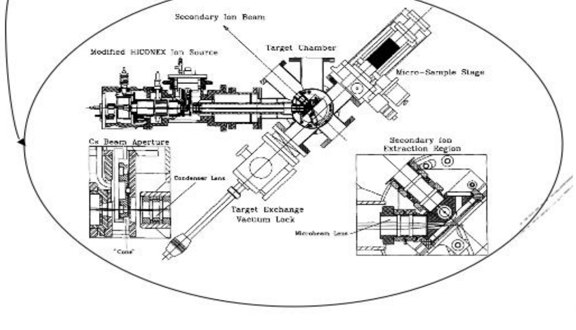


Fig. 1 The AMS line with detail of the ion source.

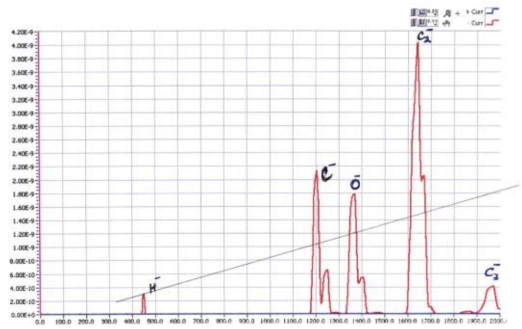


Fig. 2 Carbon spectrum obtained before the accelerating stage.

Calibration of a PIGE Set-up for Al and Mg

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Objectives

The aim of this work is the extension to Al and Mg 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.

Results

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. Results for Al have been published [5].

Table 1

Ratios Y_{exp}/Y_{cal} between experimental and calculated γ-ray yields obtained for three different thick samples containing aluminum: Al_2TiO_5, Al_2O_3 and pure Al. Results are given for both 844 keV and 1014 keV γ-emissions of the $^{27}Al(p,p'\gamma_{1,2})^{27}Al$ nuclear reaction. The incident proton beam was fixed at 2.0 MeV, 2.2 MeV and 2.4 MeV.

	Y_{exp}/Y_{cal} - 844 keV emission			Y_{exp}/Y_{cal} - 1014 keV emission		
Thick sample	2.0 MeV beam	2.2 MeV beam	2.4 MeV beam	2.0 MeV beam	2.2 MeV beam	2.4 MeV beam
Al_2TiO_5	1.00	1.00	0.95	1.00	0.99	1.00
Al_2O_3	0.98	0.97	0.93	0.98	0.96	1.00
Al	0.99	0.99	-	1.00	1.00	-

Future work

At energies lower than 2.5 MeV, this work will be concluded by including the case of Be. A nuclear reaction line will be assembled at the Tandem accelerator in order to extend the present work to higher energies and be able to quantify C, N and O.

References

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