NUCLEAR ASTROPHYSICS AT LABORATORI NAZIONALI DEL SUD

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Nuclear Astrophysics studies were initiated roughly 20 years ago at Laboratori Nazionali del Sud in Catania. In these two decades, the Trojan Horse Method (THM) was developed and applied to various astrophysical problems. It is based on the use of the quasi-free reaction mechanism in order to infer information on a two body nuclear reaction between charged particles of astrophysical interest, say \(a+x \rightarrow c+d\), from a reaction with three bodies in the final state, \(a+b \rightarrow c+d+s\). In the framework of Impulse Approximation the cross section of the three body process can be factorized in two parts: the virtual decay \(b \rightarrow x+s\) and the virtual reaction of \(x\) with \(a\) that brings to the \(c+d\) final state. The nucleus \(b\) is supposed to show a strong \(s+s\) cluster structure. Particle \(s\) remains a spectator in the process. Assuming one can identify the phase space region where the quasi-free mechanism is dominant then it is possible to derive the two body cross section of interest from the three body one. E.g., using a simple Plane Wave Impulse Approximation, these two cross sections are connected by a relation of the type

\[
\frac{d\sigma_{3b}}{d\Omega} \propto (KF)[\Phi(p_x)]^2 \frac{d\sigma_{2b}}{d\Omega}.
\]

In this equation, \((KF)\) is a purely kinematical factor, \(|\Phi(p_x)|^2\) represents the square modulus of the intercluster motion impulse distribution of \(x\) and \(s\) inside nucleus \(b\), \(\frac{d\sigma_{3b}}{d\Omega}\) and \(\frac{d\sigma_{2b}}{d\Omega}\) are the three- and two body reaction cross sections respectively. Details of the method can be found in ref. 1,2,3,4. An important extension of the THM is that it has been successfully applied to the measurement of cross sections of neutron induced reactions.

In the talk we presented the THM studies of the \(^{18}F+p \rightarrow ^{15}O+\alpha\) reaction, that is important for the Novae phenomenon, and of processes induced by neutrons, with particular attention to the \(^{17}O+n \rightarrow ^{14}C+\alpha\) reaction.

The first process, that is a destruction channel of \(^{18}F\) during Nova explosions, contributes to determine the abundance of this isotope in this astrophysical scenario. The \(^{18}F\) nucleus decays with positron emission, and this gives origin to a gamma emission (from \(e^+e^-\) annihilation) that will be the first signal that could be hopefully detected by gamma-ray telescopes in a Nova event. The study of the \(^{18}F+p \rightarrow ^{15}O+\alpha\) was performed at the CRIIB apparatus of the Center for Nuclear Study of The University of Tokyo based at the RIKEN campus in Wako. This was the first application of the THM to a reaction induced by a radioactive ion beam. Some preliminary results have been shown.

The second process mentioned above, the \(^{17}O+n \rightarrow ^{14}C+\alpha\) reaction, is important both in nuclear astrophysics, contributing to establish the \(^{16}O/^{17}O\) and \(^{18}O/^{17}O\) stoichiometric ratios found in asymptotic giant branch stars and in circumstellar Al2O3 meteorite grains (5), and in nuclear engineering, as the neutron-induce reaction on \(^{14}N\) and \(^{17}O\) are the dominant sources of the radioactive isotope \(^{14}C\) (\(T_{1/2} = 5730\) yr). The results of two experiments, performed at INFN–LNS and at the Nuclear Science Laboratory of Notre Dame University, have been reported in the talk (6).

REFERENCES