The ^{18}F(p,α)^{15}O reaction studied via TECSA

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Classical Novae gamma-ray emission is dominated, during the first hours of the explosion, by positron annihilation resulting from the beta decay of radioactive nuclei. The main contribution to this process arises from the decay of the ^{18}F [1]. Therefore the emission is directly related to ^{18}F production and destruction during the outburst. Among the physical inputs, which are necessary to evaluate the ^{18}F nucleosynthesis, a crucial role is played by the proton captures. The abundance of ^{18}F depends largely on few reaction rated highest, among which the ^{18}F(p,α)^{15}O is one.

Measuring cross sections at astrophysical energies (in the case of novae nucleosynthesis few hundreds of keV) in the case of charged particle induced reactions is very difficult and this becomes an almost impossible task in the case of radioactive ion beams induced reactions. In order to by-pass these problems indirect methods are usually applied. One of the most powerful in the case of charged particle induced reactions is the Trojan Horse Method (THM) [2 - 4].

In particular, the THM selects the quasi-free (QF) contribution of an appropriate three-body reaction performed at energies well above the Coulomb barrier to extract a charged particle two-body cross section. The idea of the THM is to extract the cross section of an astrophysically relevant two-body reaction *A(x,c)C* at low energies from a suitably chosen three-body quasi-free reaction *A(a,cC)S*. This is done with the help of direct theory assuming that the nucleus *a* has a strong *x+S* cluster structure. In many applications this assumption is trivially fulfilled e.g. *a* = deuteron, *x* = proton, *S*=neutron. This three-body reaction can be described by a Pseudo-Feynmam diagram, where only the first term of the Feynman series is retained.

The upper vertex describes the virtual break-up of the target nucleus *a* into the clusters *x* and *S*; *S* is then considered to be spectator to the *A(x,c)C* reaction which takes place in the lower pole. In the

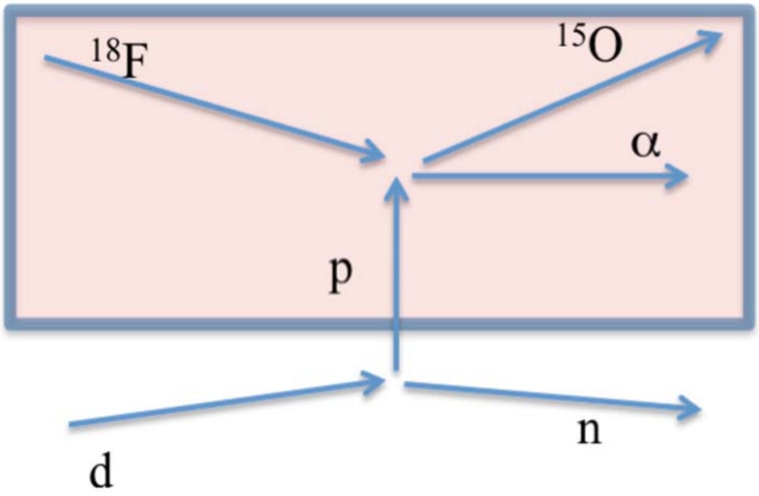

FIG. 1. Schematic sketch of the ^{18}F(p,α)^{15}O studied by means of the THM.

present case we plan to study the ^{18}F(p,α)^{15}O through the ^{18}F(d,α^{15}O)n (see Fig. 1 for the present case); thus the deuteron will act like a Trojan Horse nucleus, the proton *p* as participant and the neutron as spectator.

Once the three body reaction cross section is determined (by means of ^{15}O and α detection in coincidence) it is possible to extract the binary reaction cross section of interest (in our case the ^{18}F(p,α)^{15}O) at the energies of astrophysical interest.

In the simplest approach, the plane wave impulse approximation, the three body cross section can be factorized as:

$$d^3\sigma/dE_a\, d\Omega_a\, d\Omega_{15O} \propto (KF)\, |\Phi(p_s)|^2\, d\sigma^N/d\Omega$$

where KF is a kinematical factor containing the final state phase space factor, $|\Phi(p_s)|^2$ is the momentum distribution of the spectator *neutron* inside *deuteron*, and $d\sigma^N/d\Omega$ is the differential nuclear cross section for the two body reaction ^{18}F(p,α)^{15}O [5,6].

The experiment was performed at the Cyclotron Institute of the Texas A&M University where the K500 cyclotron provided an ^{18}O beam as a primary beam at 9 A MeV. The K150 cyclotron was used in the beginning of the run for the same purpose, but problems to the injection line prevented to use this machine for the entire run. The MARS spectrometer was then used to get a ^{18}F beam via the p(^{18}O,^{18}F)n reaction, after energy degrading of the primary beam by means of 1.25 mils Al degrader. The obtained secondary beam was tuned through MARS with a final energy of 56.7 MeV and then the beam-spot was tuned at the TECSA target position on a position sensitive detector. A beam-spot of 3 x 5 mm x mm was obtained after the tuning was completed. The energy spread of the beam was around 2%. The isotopic purity of the beam was checked during the tuning and it was found that the beam was 94% pure and the intensity of the beam was about 3-4 x 10^5 ions/sec. All these beam characteristics are clear from Fig. 2

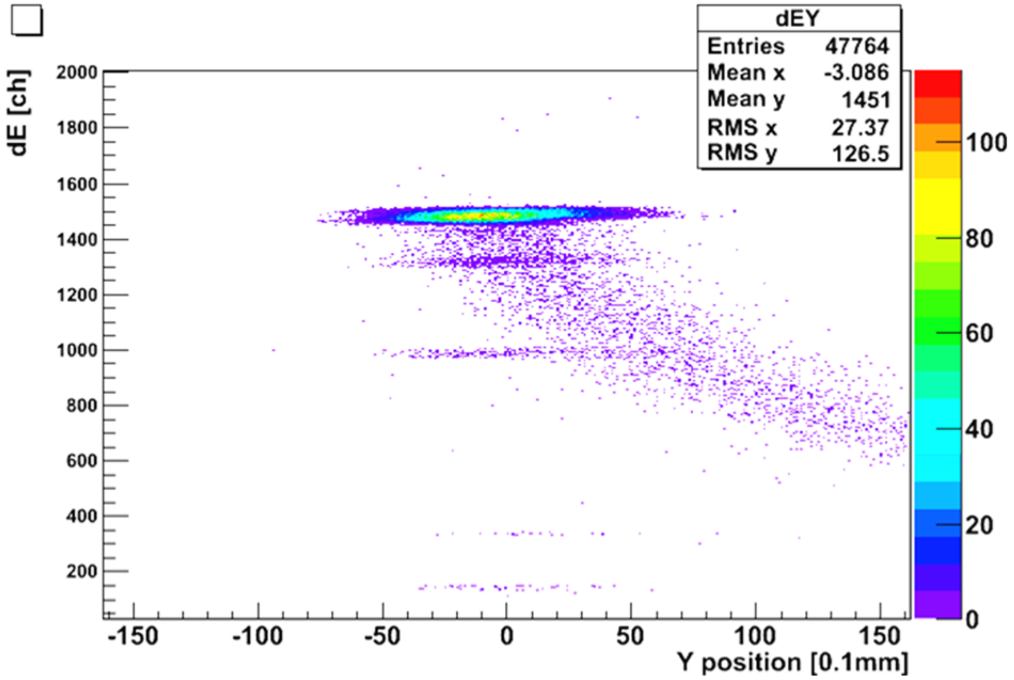

FIG. 2. Energy vs. y position plot for the target detector. A clear and more intense spot, related to ^{18}F is evident. Other isotopes represent only few percent of the total yield.

where the energy is reported as a function of y position in the target detector.

The beam impinged on an isotopically enriched deuterated polyethylene target (98% purity) around 800 μg/cm^2 thick. The experimental set-up consisted of two detector arrays working in coincidence. The TECSA array (Texas Edinburgh Catania Silicon Array) [7], made up of 8 YY-1-300 Micron detectors (each one with 16 strips), was set at 190 mm from target covering angles in the range $\theta=15^o-40^o$. Closer to the beam axis a second detector array, the CROSS, is positioned, consisting of two position sensitive detectors (16 strips each), placed at 340 mm and covering angles from 3 to 12 degrees. The TECSA array was devoted to the detection of the alpha particles while the CROSS was used to detect the ^{15}O in coincidence. The experimental set-up is sketched in Fig. 3. The displacement of the experimental setup was chosen in order to cover the whole Quasi-Free angular range, known "a priori" from a Monte Carlo simulation. A scintillator was used to improve the definition of the timing of the experiment.

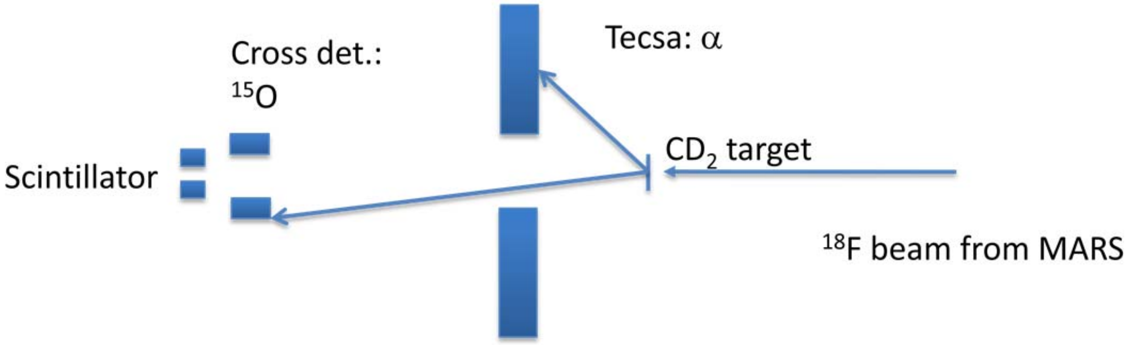

FIG. 3. Sketch of the experimental set-up described in the text.

The detectors were calibrated in energy by means of standard alpha sources and ^{18}F scattering off the CD_2 target. The CROSS detector was also calibrated in position by means of a mask which was used during the calibration runs. The measurement of the energy and position of the two ejectiles will give the possibility to calculate all the kinematic variables regarding the third, undetected, particle as well as other variables of interest for the following data analysis (e.g. Q-value, relative energy α-^{15}O, spectator momentum).

After calibration (and taking into account the energy loss of beam and ejectiles in the target) the kinematic locus of α-^{15}O energy is studied and plotted in Fig. 4. At this time, only coincidences between detector number 4 of the TECSA array and the bottom detector of the CROSS have been partially examined. The data analysis is still going on and will study, as the next step, the presence of the quasi-free mechanism.

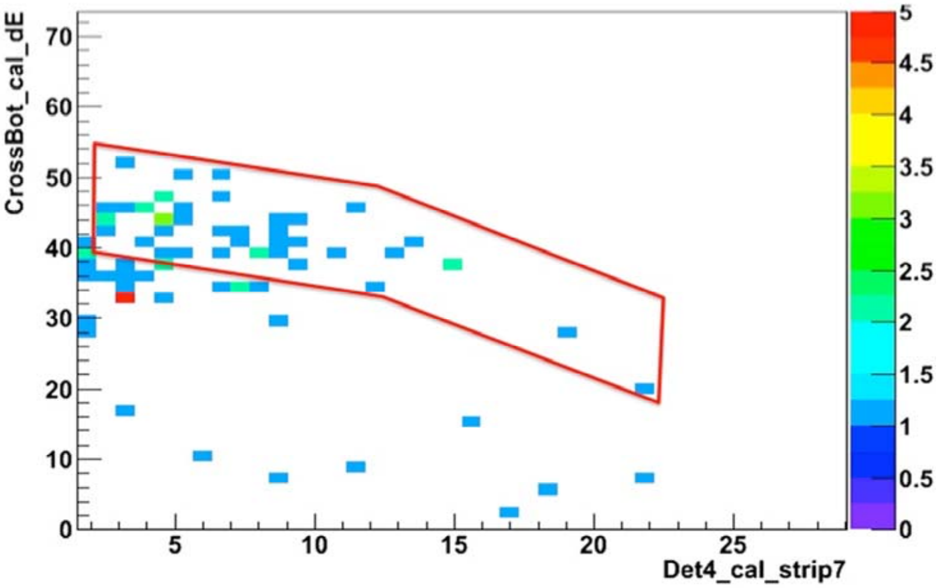

FIG. 4. Typical kinematic locus for the α-^{15}O coincidence for one strip of detector #4 of TECSA and the bottom detector of the CROSS. The red curve marks the region where the three body reaction of interest is expected.

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