$^{19}F(\alpha,p)^{22}Ne$ astrophysical factor for the AGB stars

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2017 PAC PROPOSAL

INTRODUCTION

The reaction $^{19}F(\alpha,p)^{22}Ne$ represents an important parameter in the ^{19}F nucleosynthesis for the AGB stars, explaining the ^{19}F mitigation/destruction from the AGB stars and its rate is highly uncertain at helium burning temperatures. The experimental data for the $^{19}F(\alpha,p)^{22}Ne$ reaction at energies close to the star environment has a recent input from C. Ugalde's experiment (2008) [1], for E_{lab}=792-1993 keV and an older one from J. Kuperus (1965) [3] for higher energies E_{lab}=1300-3000 keV. Interesting assumptions were done in this [1] case for the astrophysical factor S as a result of the resonance interference.

This reaction $^{19}F(\alpha,p)^{22}Ne$ had been recently checked [4] for depth profiling of ^{19}F in the energy range E_{lab}=2150-2520 keV.

The main uncertainties come from the extrapolation for the cross section at energies as low as for the Gamow window for the AGB stars. Different theoretical models predict different energy dependence for the cross section. Only a direct measurement towards the lower energies is the solution to this issue.

For explosive stellar scenarios ($T > 10^9$ K), the situation is even more difficult, as the spins and parities of resonances contributing to the cross section are uncertain. For this situation, direct measurements for energies above E_{lab}=2 MeV may help, and this will be our research proposal.

EXPERIMENTAL APPROACH

The $^{19}F(\alpha,p)^{22}Ne$ reaction takes mainly place by **α**-particle capture, forming a compound nucleus, ^{23}Na. The Q value of this reaction is Q=1.67 MeV, with a barrier energy of E_b=10.47MeV [2]. ^{23}Na nucleus decay by emitting protons (p) from the excited levels (10-13 MeV) on the ground state 0^+ (p_0) and on the first excited state 2^+ (p_1) of the ^{22}Ne nucleus. The ^{22}Ne de-excite from the first excited state to the ground state by emitting a **γ**-ray with energy E_γ=1.27 MeV [2].

A first approach for measuring the cross section for the $^{19}F(\alpha,p)^{22}Ne$ reaction is to count the number of protons (p_0 & p_1) using backward Si detectors. For this, 2 Si detectors are required, one for monitoring the beam (backward situated), and the other, at backward angles, covered with a thin foil of 2μm of mylar to stop the backward scattered α-beam (Fig.1).

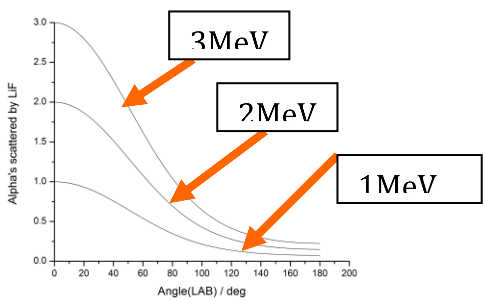

Fig.1 Angular distribution of the alpha-beam energy as scattered by LiF thin target

For the Si detectors to stop the protons coming from this reaction ($E_{\alpha LAB}$=1000-3000 keV), the depletion depth has to be around 400 μm (Fig. 2).

The beam energy has to be increased / decreased in energy-steps of 5-10 keV.

The target is thin, about 20μm/cm^2 of LiF/CaF_2 deposited on 0.5mm of W (and covered with a 10 μm/cm^2 Al). Only 10-30 keV of the α-beam energy ($E_{\alpha LAB}$=1000-3000 keV) is lost into the thin LiF target. Within these values, the cross-section of the reaction $^{19}F(\alpha,p)^{22}Ne$ may be accepted as constant. Target preparation will be done in our target lab by evaporating LiF or CaF_2 on a tungsten substrate. The stoichiometry, the purity and the thickness of the target will be measured using the IBA methods (such as RBS) on the 1st beam line of the 3MV accelerator.

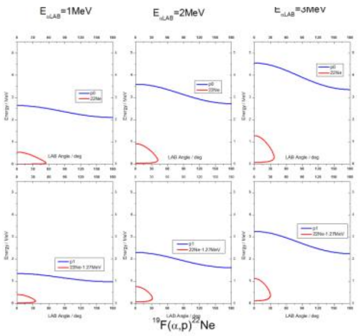

Figure 2. Output products from the $^{19}F(\alpha,p)^{22}Ne$ reaction: Proton and ^{22}Ne energy dependence with the angle.

A second approach for the reaction $^{19}F(\alpha,p)^{22}Ne$ is represented by implanted ^{19}F in different pure metal-foils (Fe, Cu, Ta). Implantation is done on the 2nd beam line of the 3MV accelerator. A check for the stability of the ^{19}F inside the metal-foil will be done, using IBA methods such as RBS or measuring a resonance for the $^{19}F(p,\alpha\gamma)^{16}O$ reaction, on the 1st beam-line of the 3MV accelerator. In case we obtain a positive situation for the stability of the implanted ^{19}F, we'll run the experiment for higher intensities of the α-beam on a water-cooled target.

A correct measurement for the α-beam intensity is required on all beam-lines from the 3MV accelerator. On the 1st beam line, a current integrator, provided by the accelerator provider, is attached to the experimental chamber, but not to the 2nd beam-line. We have to insert our own way of measuring the beam-charge and check for the correctness of our measurements (electron suppressor and ORTEC 439).

In both approaches (evaporated and implanted targets), two Si detectors will be used, and one Ge detector to measure the γ-rays with energy E_γ=1.27MeV. We expect to measure proton (p_0,p_1) spectra such as the one from Figure 3.

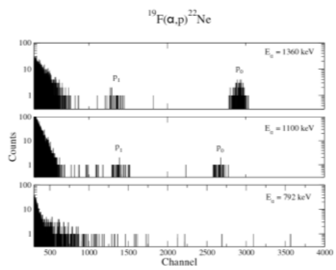

Fig.3 Spectra from Ugalde C.

The cross section in the energy range 1500keV – 3000keV is in the milibarn range [4].

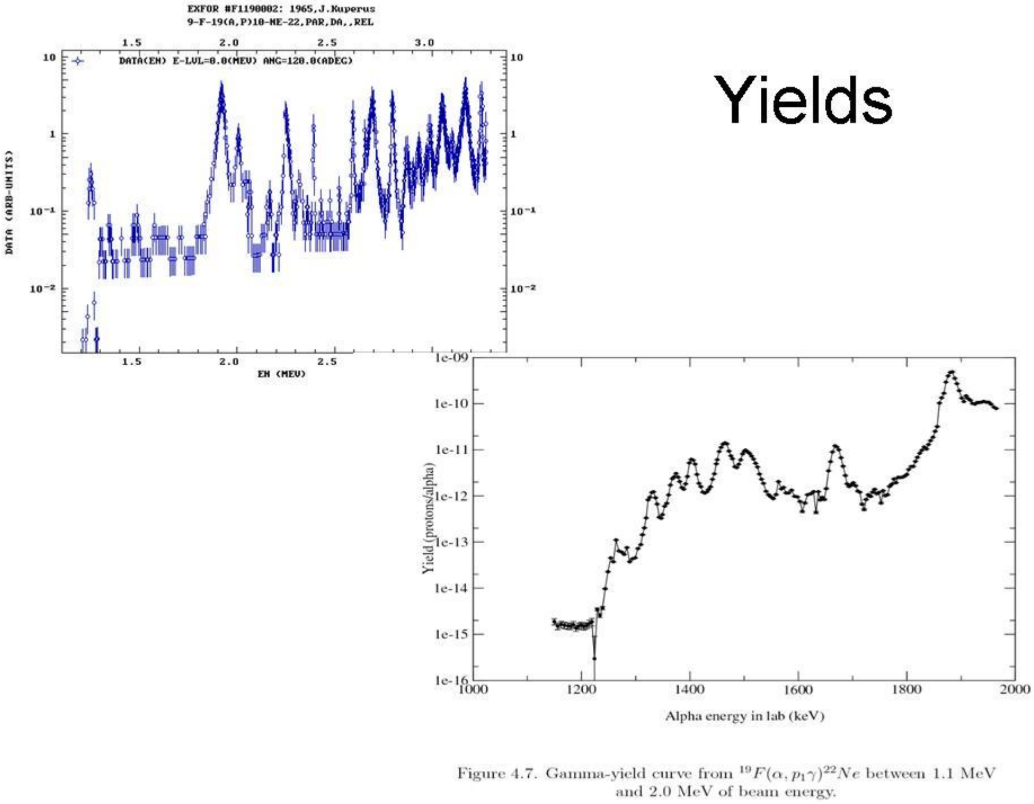

Figure 4. Kuperus' and Ugalde's yield

Recently a new measurement was done using the Trojan Horse method [6] for beam energies lower than 1 MeV.

For carrying a trustful experiment, several other activities are proposed, for which accelerator experimental time is required.

1- Beam energy calibration using several resonance or threshold reactions [5]
2- Si detector calibration in energy for protons and alphas
3- Ge efficiency calibration on beam-line
4- Target stoichiometry measurement
5- Collimator adjustment
6- Target implantation with ^{19}F (tilting 70°-80° as much as possible the substrate to the direction of the beam)
7- Check for the implanted target stability in Ta, Cu and Fe substrate
8- Check for the implanted target profile using 874keV resonance of the $^{19}F(p,\alpha\gamma)^{16}O$ reaction
9- Monitoring the implanted target thickness
10- Electron suppressor correctness in beam-current measurement
11- Beam-current integrator accuracy for measurement on different scales (ORTEC 439, or accelerator build-in)
12- Water-cooling system for the target for higher beam intensity
13- Carbon buildup mitigation on the target by using a LN_2 cold-trap

My proposal for March 2017 PAC call is:

- Characterization for the reaction cross section $^{19}F(\alpha,p)^{22}Ne$
- In the energy range for the beam $E_{\alpha(LAB)}$~1.5-2.4 MeV
- At the accelerator: 3MV
- Using beam lines: 1 and 2
- With beam intensity for α and proton: from 10nA to the highest (μA)
- Necessary accelerator time: at least, 4 weeks
- Detection system: 2 Si detectors, 1 Ge detector
- New constructions for the target chamber: YES
  1. water cooling for the target
  2. collimators
  3. whatever is necessary

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