Study of the $^{17}O(n,\alpha)^{14}C$ reaction: extension of the Trojan Horse Method to neutron induced reactions

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AstroFisica Nucleare

ASTROPHYSICAL MOTIVATION

- **Inhomogeneus Big Bang Nucleosinthesys (IBBN) [1-4]**

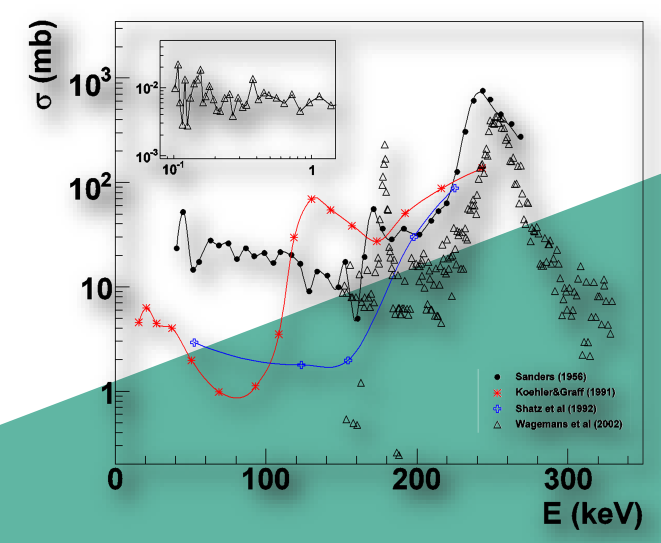
The reaction $^{17}O(n,\alpha)^{14}C$ represents one of the main channel for ^{14}C production, a key element for the ^{22}Ne production via $^{14}C(\alpha,\gamma)^{18}O(n,\gamma)^{19}O(\beta)^{19}F(n,\gamma)^{20}F(\beta)^{20}Ne(n,\gamma)^{21}Ne(n,\gamma)^{22}Ne$

- **Weak component s-process [5-6]**

$^{17}O(n,\alpha)^{14}C$ and $^{17}O(\alpha,n)^{20}Ne$ since they act as a neutron poison and a recycle channel during s-process nucleosinthesys in massive stars ($M>8M_\odot$)

Temperature → $0.8\cdot10^8<T<11\cdot10^8$ K
Energy range→ ~0-100 keV

STATUS OF THE ART



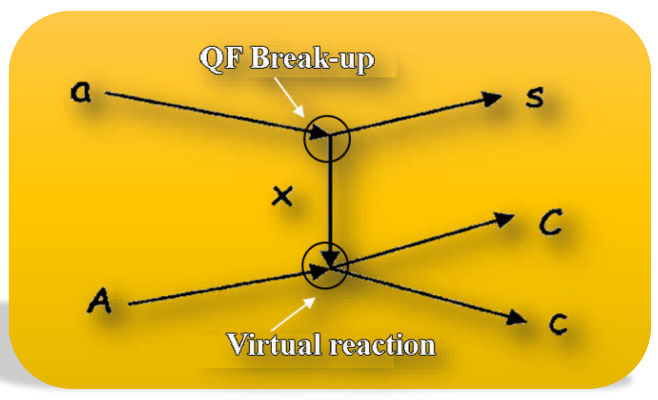
Direct measurements have shown the population of the two excited states at energies 8213 keV and 8282 keV and the influence of the sub-threshold level at 8038 keV. Moreover, the 8125 keV state of ^{18}O would be populated by f-wave neutrons, but due to the high orbital momentum barrier, the cross section is too low for direct measurement. [7-11]

$E_{c.m.}$ (keV)	$^{18}O^*$ (MeV)	J^π
-7	8.039	1^-
75	8.125	5^-
166	8.213	2^+
236	8.282	3^-

Subthreshold peak contribution
Suppressed by centrifugal barrier
Direct data (the reaction rate differ by a factor 2)

THE TROJAN HORSE METHOD

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 suitable three-body reaction a+A →c+C+s



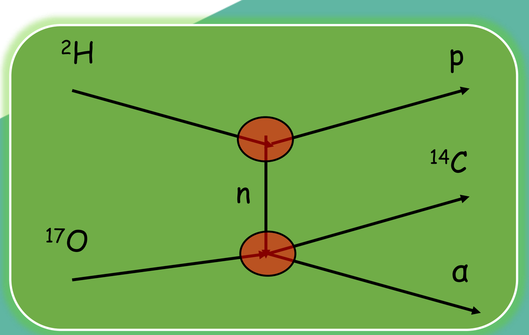
*The nucleus **a** (TH nucleus) is chosen with a strong **x ⊕ s** clusters structure and, in the Impulse Approximation description, only **x** interact with **A**, whereas **s** is considered to be spectator to the reaction. [12-16]*

In the Plane Wave Impulse Approximation (PWIA) the cross section of the three body reaction can be factrorized as [17-19]:

$$\frac{d^3\sigma}{d\Omega_c d\Omega_C dE_c} \propto KF \cdot |\Phi(p_s)|^2 \cdot \frac{d\sigma_{Ax}}{d\Omega}$$

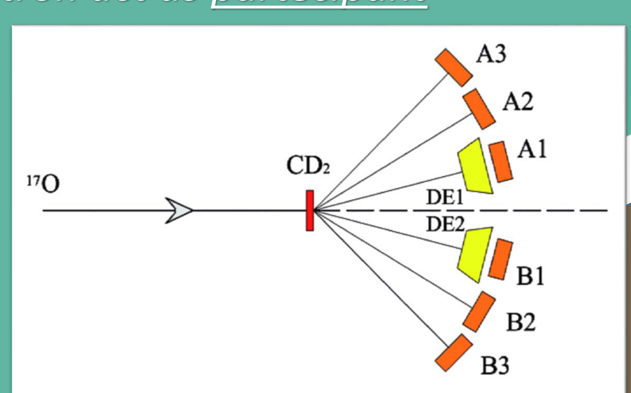
Three body measured cross section — *Calculated kinematical factor* — *Fourier trasform for the x-s intercluster motion* — *Astrophysically relevant two body cross section*

THE EXPERIMENT



- *The reaction $^{17}O(n,\alpha)^{14}C$ was studied via the $^2H(^{17}O,\alpha^{14}C)p$, V_{coul}=2.3 MeV;*
- *The deuteron is the TH nucleus. B=2.2 MeV, $|p_s|$=0 MeV/c ;*
- *The neutron act as participant*

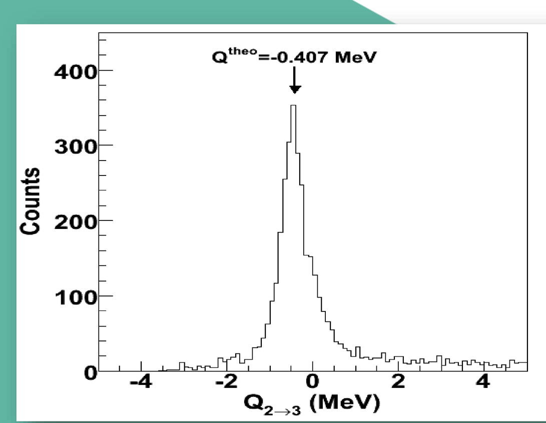
- ✓*Experiment performed at ISNAP at the University of Notre Dame (USA);*
- ✓*$E_{beam}(^{17}O)$= 43.5 MeV;*
- ✓*Target thickness CD_2 ~150 μg/cm^2;*
- ✓*IC filled with ~50 mbar isobutane gas;*
- ✓*Angular position to cover the QF angular region*
- ✓*Symmetric set-up in order to increase the statistic.*

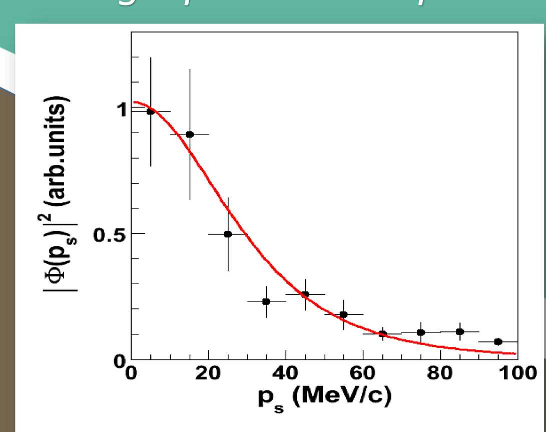


THE ANALYSIS

- **Reaction Channel Selection**

Experimental Q-value spectrum in agreement with the theoretical prediction of -0.407 MeV (arrow) for the $^2H(^{17}O,\alpha^{14}C)p$ reaction. No additional process takes place as a single peak show up in the spectrum.





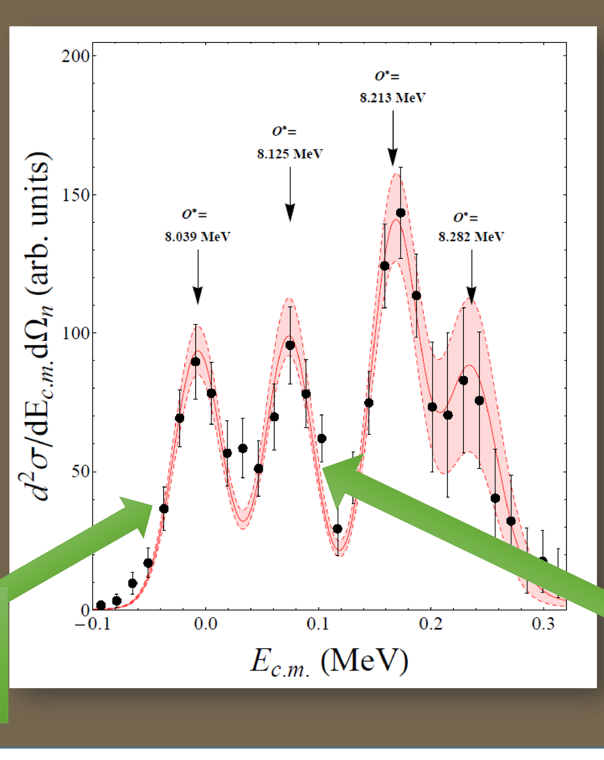
- **Selection of the QF Mechanism**

Experimental distribution (black points) for the proton-momentum values compared with the theoretical Hulthèn function (red line). The agreement is a necessary condition for the presence of the QF-mechanism.

RESULTS AND CONCLUSIONS

- R-matrix fit

Quasi-Free cross section of the $^2H(^{17}O,\alpha^{14}C)p$ reaction in arbitrary units. The black points are the experimental data with their error bars. The black solid line represents the the best fit to the data calculated in the modified R-matrix approach, normalized to the peaks at about 166 and 236 keV [20].



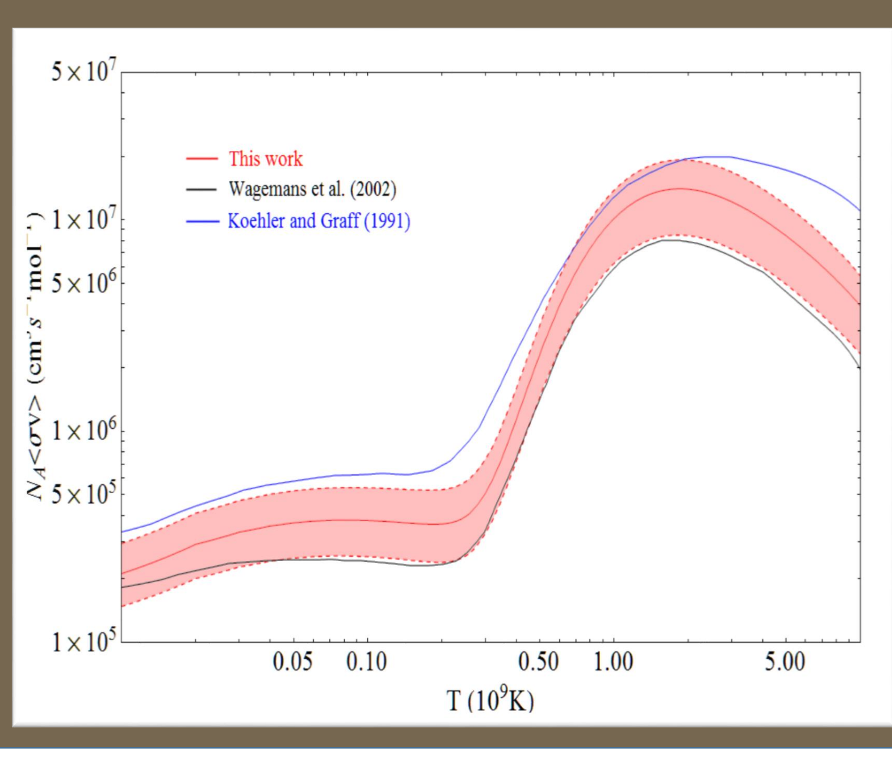
-7 keV in c.m. → SUBTHRESHOLD

The THM Γ values of the ^{18}O resonant states in the energy range explored by the present experiment in comparison with the direct ones [11].

$E_{c.m.}$ (keV)	Γ_{tot}^{THM} (eV)	$\Gamma_{tot}^{dir.}$ (eV)
-7	2362±307	2400
75	36±5	-
166	2257±293	2258
236	14735±3832	14739

75 keV in c.m. → SUPPRESSED BY CENTRIFUGAL BARRIER

- Reaction rate



The reaction rate (red band) calculated by the standard formula and compared to the other data of Koehler and Graff [9] (blue line) and Wagemans et al. [11] (black line).

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