Modified r-matrix analysis of the ^{19}F(p,a)^{16}O HOES reaction

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Presidenza del Consiglio dei Ministri

Ministero dell'Istruzione dell'Università e della Ricerca

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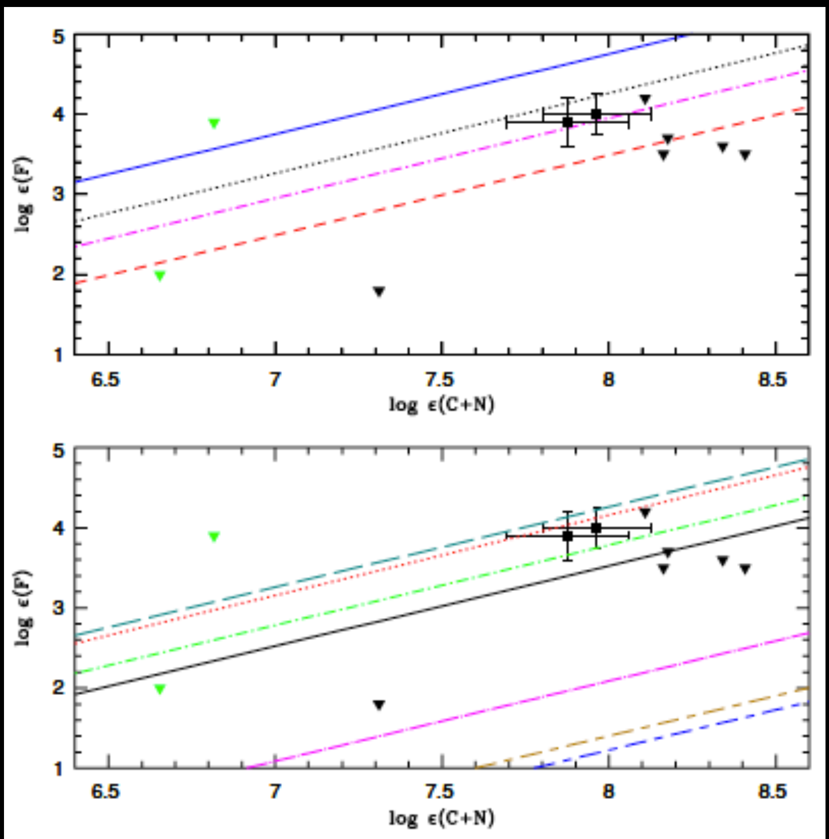
Fluorine in astrophysics

^{19}F is a key isotope in astrophysics as it can be used to probe AGB star mixing phenomena and nucleosynthesis. But its production is still uncertain!



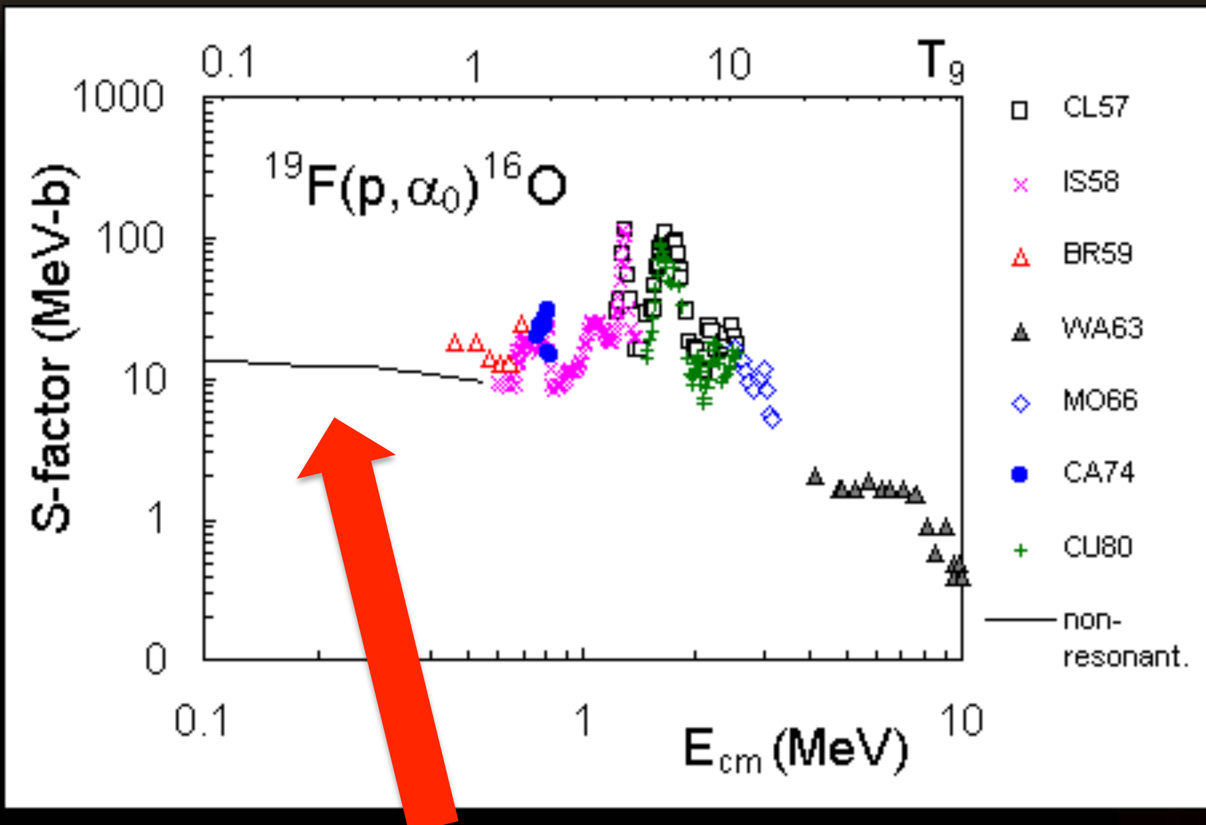
In AGB stars, the largest observed fluorine overabundances cannot be explained with standard AGB models.

A possible lack of proper accounting for the contribution from C-bearing molecules might provide an interpretation in Population I stars (Abia et al. 2010).

In the case of metal poor AGB stars our understanding is far from satisfactory (Lucatello et al. 2011, Abia et al 2011).

We note that a significant fraction of the upper limits are located under the predicted lines (Lucatello et al. 2011)

The $^{19}F(p,\alpha_0)^{16}O$ reaction



The S(E) factor shows several resonances around 1 MeV.

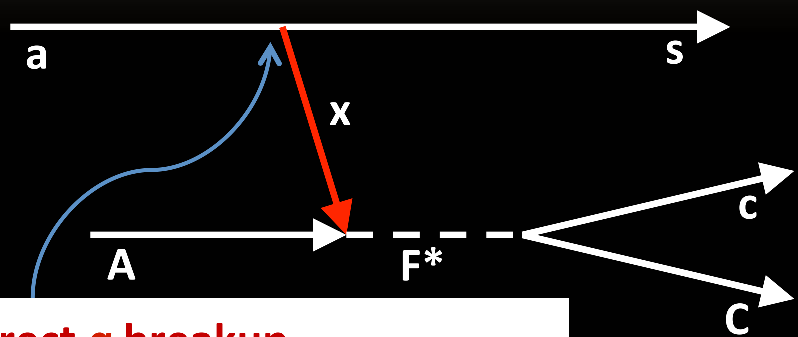
Breuer (1959) claimed the occurrence of two resonances at around 400 keV

Unpublished data (Lorentz-Wirzba 1978) suggests that no resonance occurs

α_0 is the dominant channel in the energy region of astrophysical interest

Below E_{cm} = 460 keV, where data do not exist, a non resonant contribution is calculated for *s*-capture. The S-factor was adjusted as to the lower experimental points between 460 and 600 keV

The THM for resonance reactions



Upper vertex: direct *a* breakup
$M_i(E)$ is the amplitude of the transfer

In the "Trojan Horse Method" (THM) the astrophysically relevant reaction, say A(x,c)C, is studied through the 2→3 direct process A(a,cC)s:

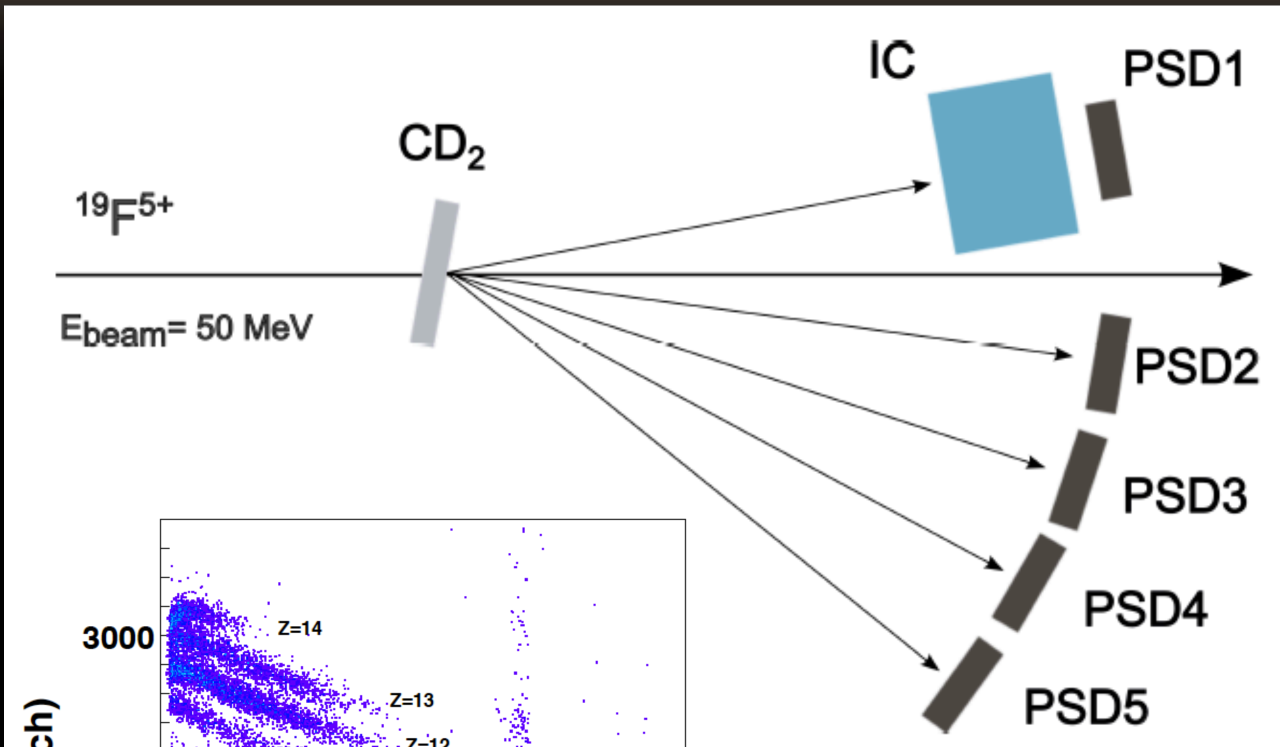
The process is a transfer to the continuum where x is participant, e.g. a proton or an alpha particle and s is the spectator

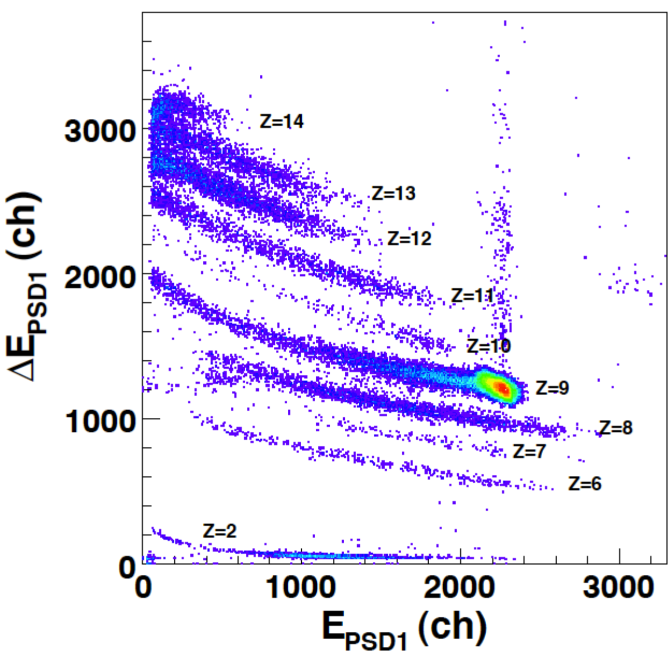
Standard R-Matrix approach cannot be applied to extract the resonance parameters of the A (x,c)C reaction because x is virtual → Modified R-Matrix is introduced instead

In the case of a resonant THM reaction the cross section takes the form

$$\frac{d^2\sigma}{dE_{Cc}\, d\Omega_s} \propto \frac{\Gamma_{(Cc)_i}(E)\, |M_i(E)|^2}{(E - E_{R_i})^2 + \Gamma_i^2(E)/4}$$

The experiment



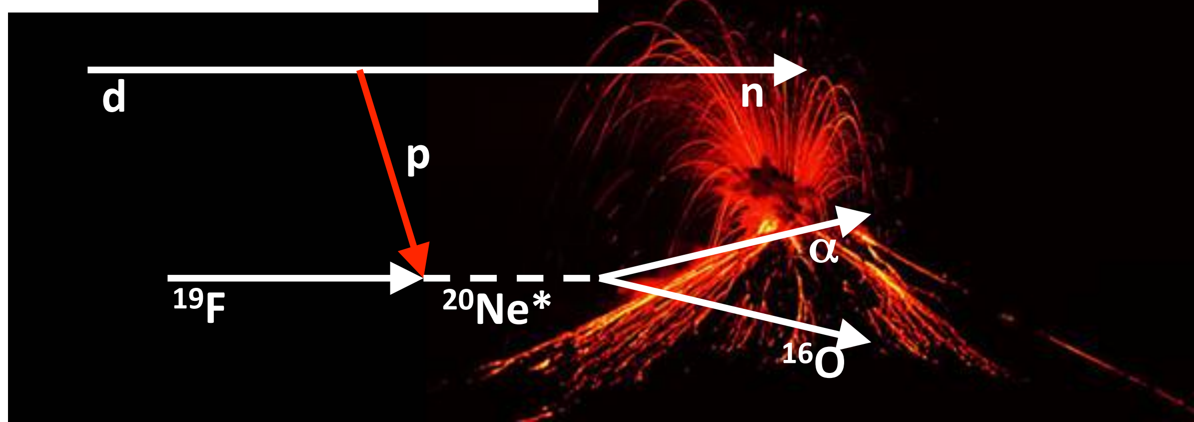


The experiment was performed at INFN-LNS Catania

Beam: ^{19}F@50 MeV

Only in the coincidence 1-5 the α_0 channel was populated significantly

→ α_1 channel in the 1-4



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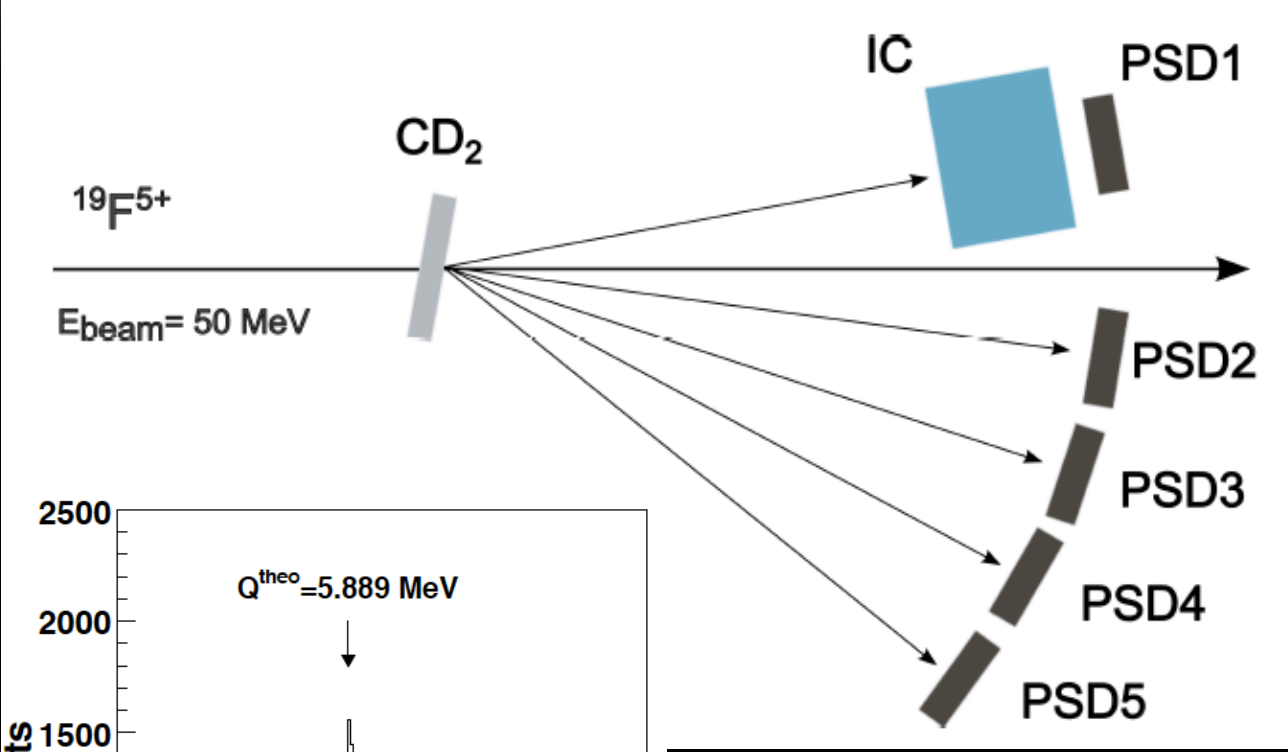

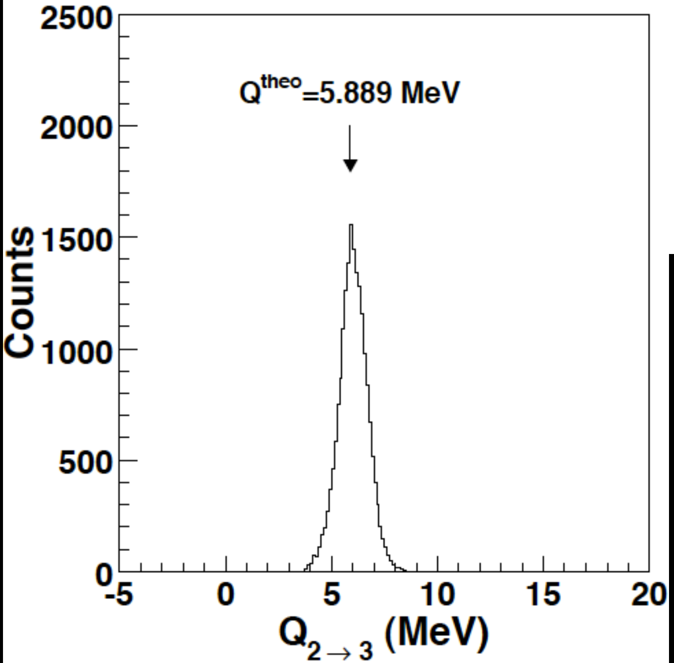

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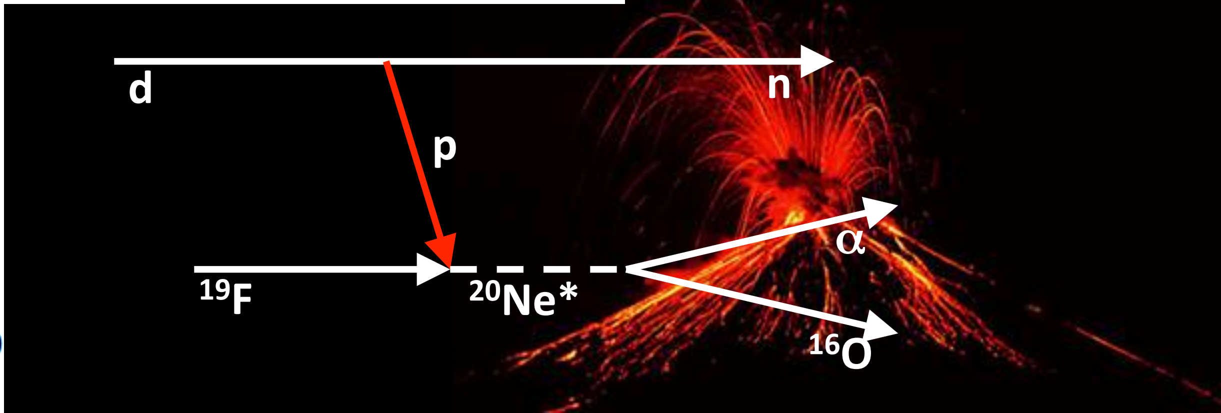
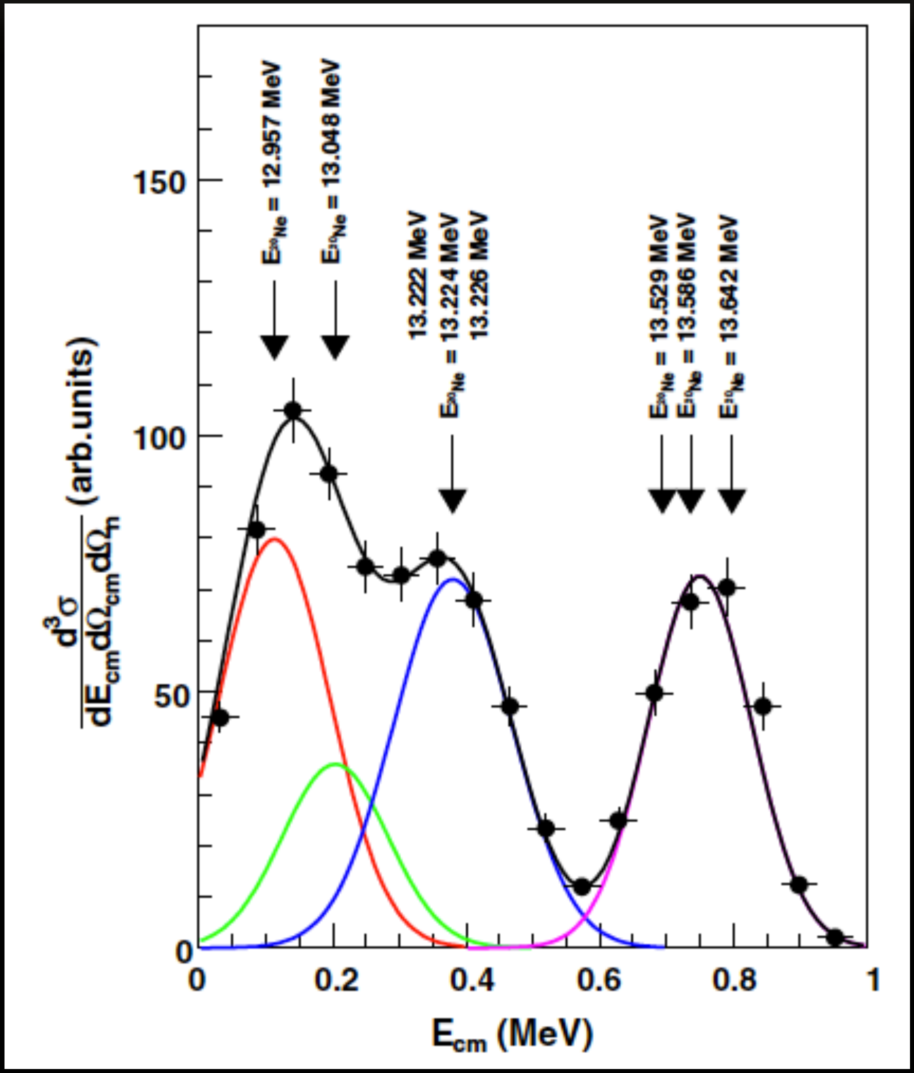


Observed ^{20}Ne states



Normalized coincidence yield obtained by dividing the selected coincidence yield by the product of the phase-space factor and of the *p* −*n* momentum distribution

Three resonance groups corresponding to 20Ne states at:

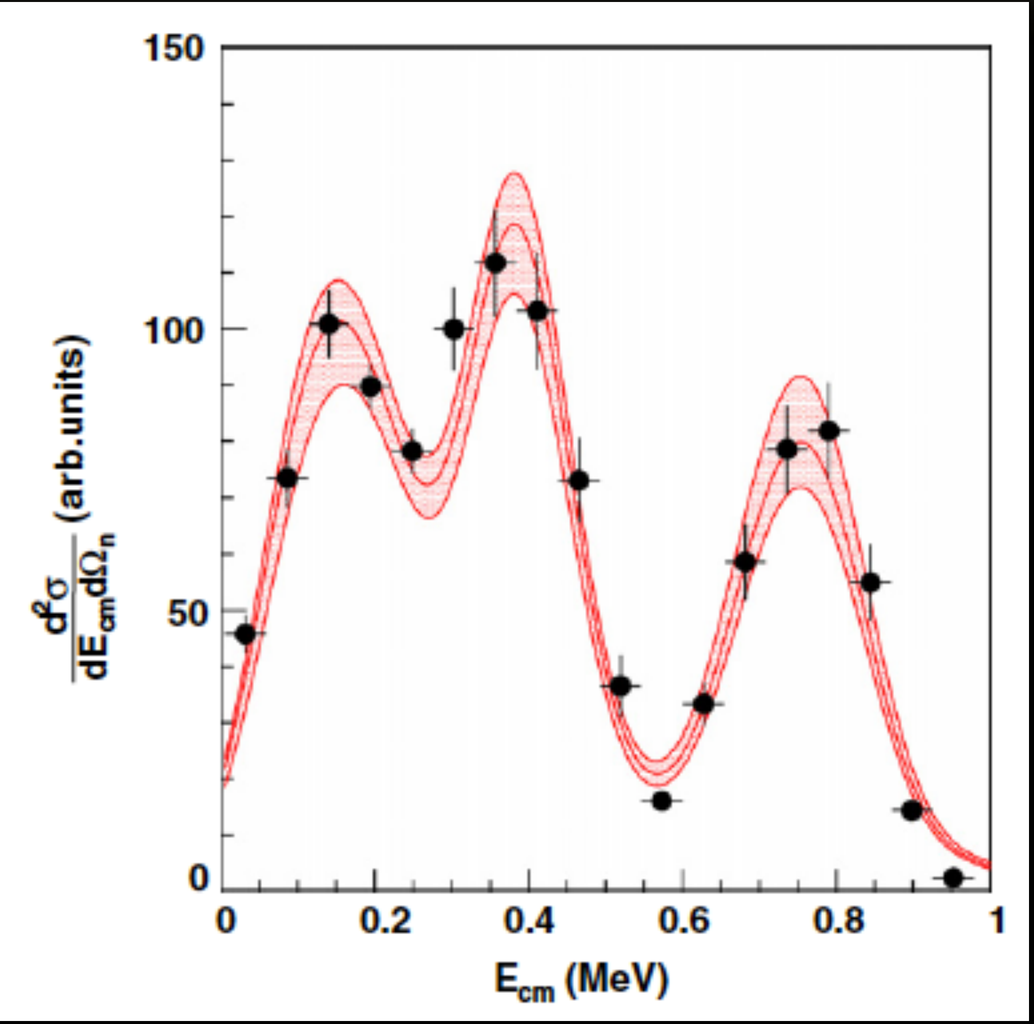
12.957 and 13.048 MeV;

13.222, 13.224, and 13.226 MeV;

13.529, 13.586, and 13.642 MeV.

The normalized yield was fitted simultaneously with four Gaussian curves to separate the resonance contributions

Fitting the THM cross section



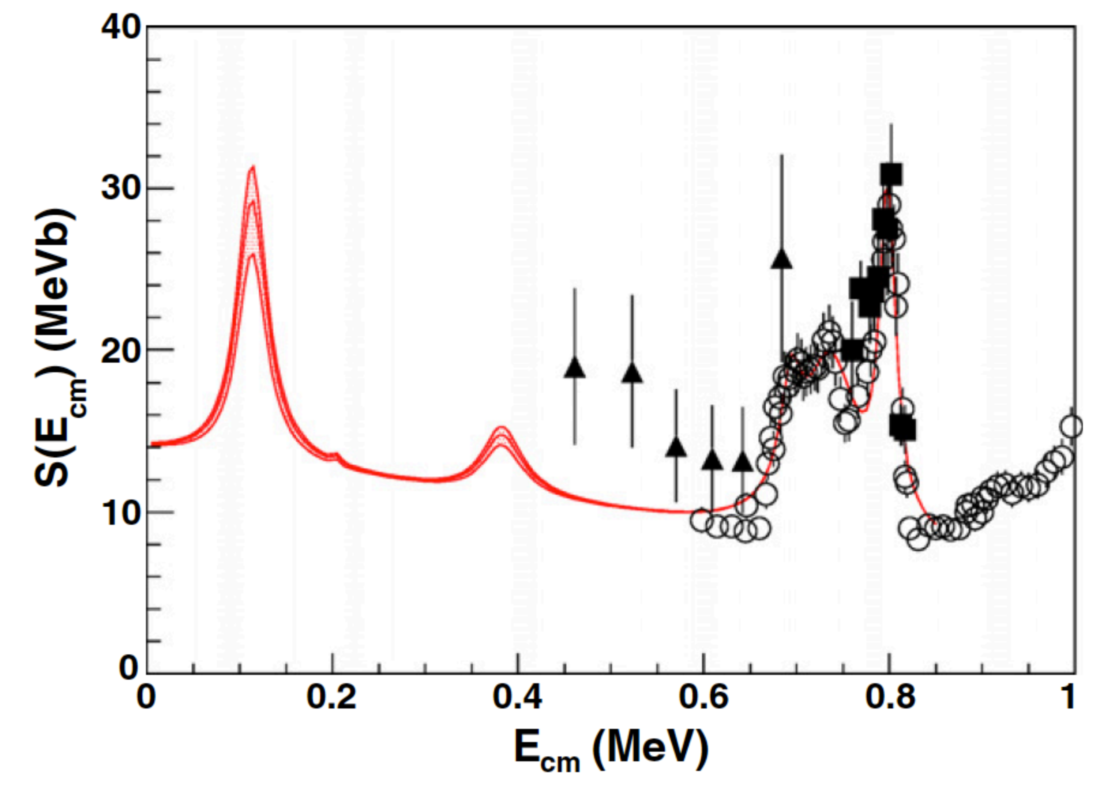
QF cross section of the $^2H(^{19}F,\alpha_0{}^{16}O)n$ reaction in arbitrary units.

horizontal error bars → $p-^{19}F$-relative-energy binning.

The vertical error bars → statistical and angular-distribution integration uncertainties.

Red band → the cross section calculated in the modified *R*-matrix approach, normalized to the peak at about 750 keV and convoluted with the experimental resolution.

The $^{19}F(p,a)^{16}O$ cross section



R-matrix parameterization of the $^{19}F(p,\alpha_0)^{16}O$ astrophysical factor.

Above 0.6 MeV, the reduced partial widths were obtained through an *R*-matrix fit of direct data

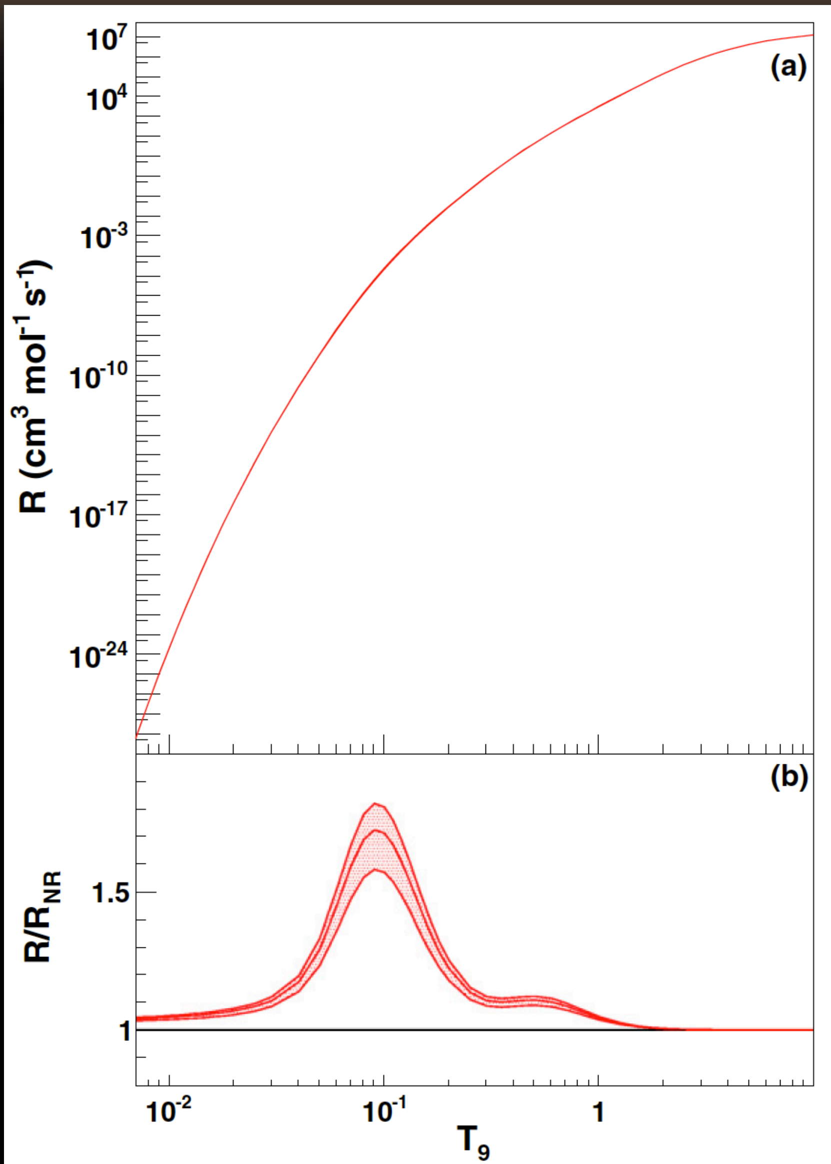
Below 0.6 MeV, the resonance parameters were obtained from the modified *R*-matrix fit

The non-resonant contribution is taken from NACRE (1999).

Because of spin-parity, only the resonance at 12.957 MeV provide a significant contribution

Gamow window: 27-94 keV → this level lies right at edge of the Gamow window for extramixing in AGB stars

$^{19}F(p,a)^{16}O$ reaction reaction rate

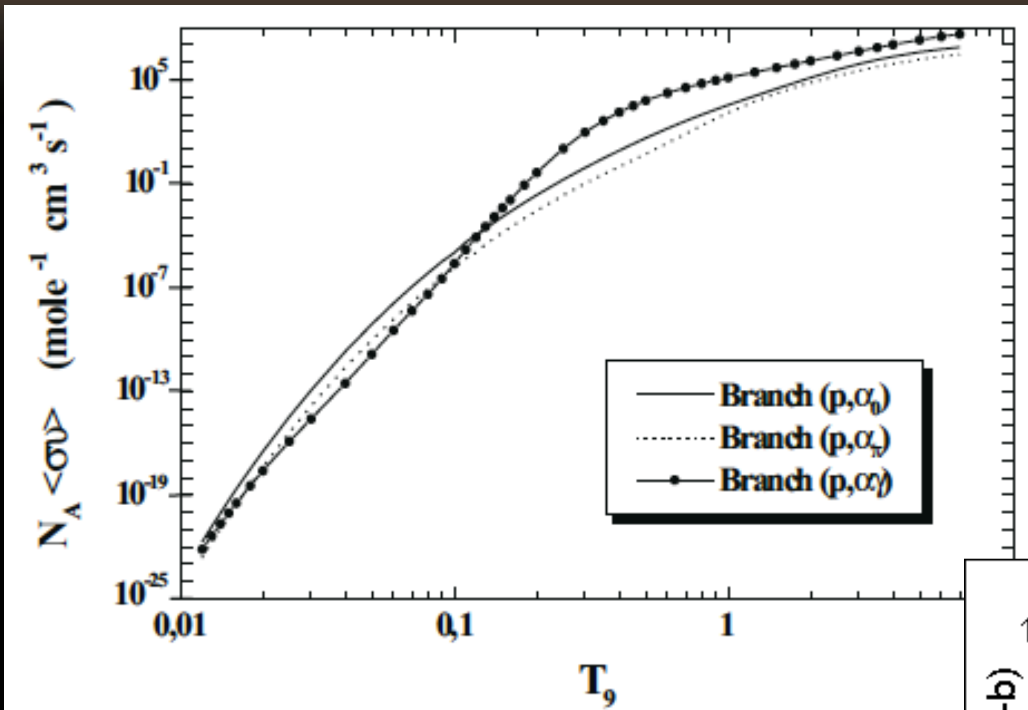


(a) Reaction rate for the $^{19}F(p,\alpha_0)^{16}O$. Upper and lower limits are also given, though they are barely visible because of the large rate range.

(b) Ratio of the reaction rate in panel (a) to the rate of the $^{19}F(p,\alpha_0)^{16}O$ reaction evaluated following the prescriptions in NACRE (1999). The red band arises from statistical and normalization errors.

→ A reaction rate enhancement up to a factor of 1.8 is obtained close to temperatures of interest for astrophysics (for instance, T_9~0.04 in AGB stars)

Perspectives

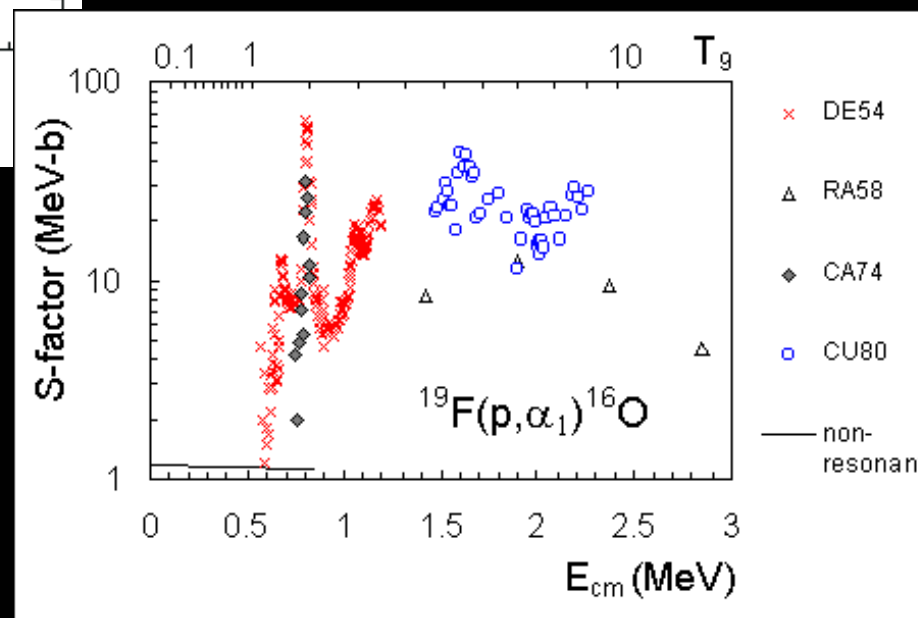


The contribution of the α_0 channel only has been addressed since this is currently regarded as the dominant one at temperatures relevant for AGB stars

← Spyrou et al. (2000)

α_1 channel is even more uncertain!

An experimental campaign is scheduled to extract the cross section for the α_1 channel and to improve the spectroscopy of the resonances discussed here.



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THE FLUORINE DESTRUCTION IN STARS: FIRST EXPERIMENTAL STUDY OF THE $^{19}F(p, \alpha_0)^{16}O$ REACTION AT ASTROPHYSICAL ENERGIES

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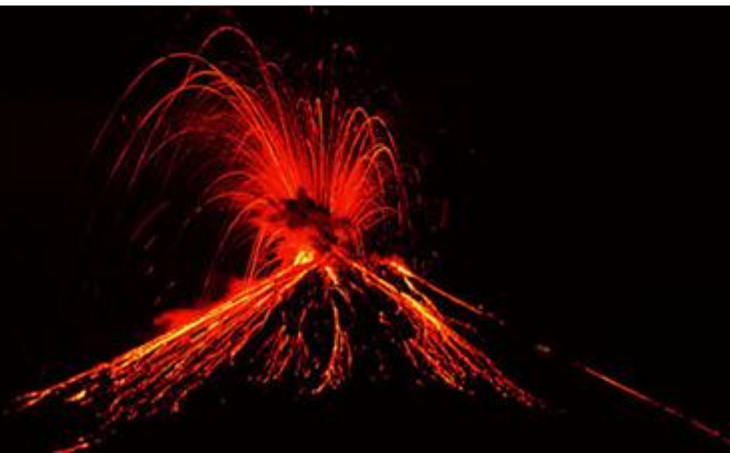

Press Office

Rome, 23 September 2011

Statement by the Minister for University and Research Mariastella Gelmini

"The discovery by CERN in Geneva and by the National Institute for Nuclear Physics is a scientific event of the utmost importance."

I extend my congratulations and my sincerest congratulations to the authors of a historical experiment. I am deeply grateful to all the Italian researchers who contributed to this event that will change the face of modern physics.

Exceeding the speed of light is a momentous victory for scientific research around the world.

The construction of the tunnel between CERN and Gran Sasso Laboratories, through which the experiment took place, Italy has contributed a sum now estimated at around 45 million euros.

In addition, today Italy supports CERN with absolute conviction, with a contribution of more than 80 million euros per year and the events we are experiencing are confirming that it is a right and far-sighted choice".

http://www.istruzione.it/web/ministero/cs230911