ANC experiments for nuclear *astrophysics:* the $^{26}Si(p,\gamma)^{27}P$ case

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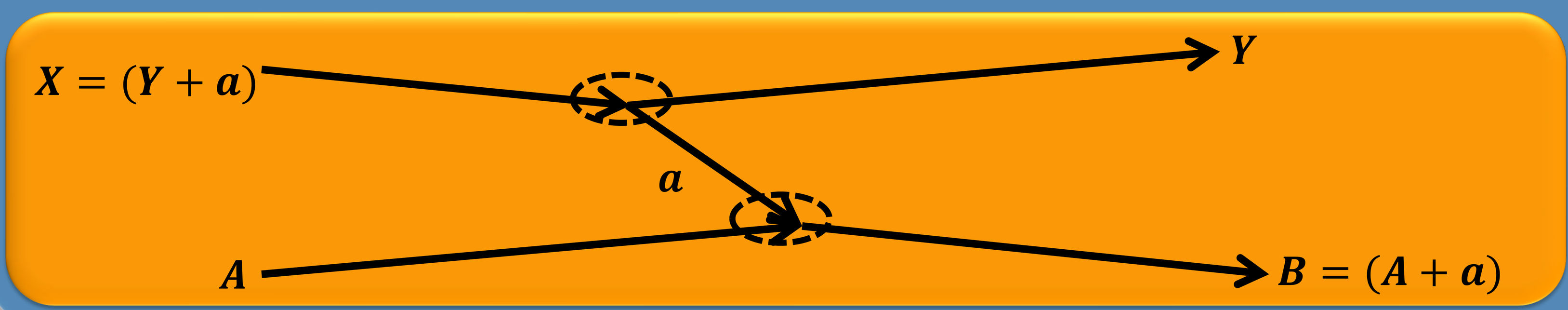
ASYMPTOTIC NORMALIZATION COEFFICIENT (ANC) METHOD

The Asymptotic Normalization Coefficient (ANC) method is widely used to gain information about DIRECT RADIATIVE CAPTURE $A+a\rightarrow Y+\gamma$ from a suitable transfer reaction $A+X\rightarrow Y+B$, being $X=(Y+A)$ and $B=(A+a)$, under the condition that the second one is PERIPHERAL [1,2,3]



Under such conditions, in DWBA the cross section can be approximated in terms of the so-called single-particle ANC (that depends on the shape of the potential wells involved for the B and X nuclei) b^2 and the proper ANC C^2

$$\frac{d\sigma}{d\Omega}=\sum_{j_B,j_X}\left(C^B_{Aa,l_B,j_B}\right)^2\left(C^X_{Ya,l_X,j_X}\right)^2\frac{\sigma^{DWBA}_{l_B,j_B,l_X,j_X}}{b^2_{Aa,l_B,j_B}b^2_{Ya,l_X,j_X}}$$

Here, C^2 must have a small dependence from the potential, while the ratio above is nearly independent from b^2

EXTENTION FOR MIRROR NUCLEI

Proton and neutron channel ANC of the g.s. for MIRROR PAIR NUCLEI are related [4,5]

$$\left(C_p\right)^2=R\left(C_n\right)^2,\text{ with } R=\left|\frac{F_l(ik_pR_N)}{k_pR_Nj_l(ik_nR_N)}\right|^2$$

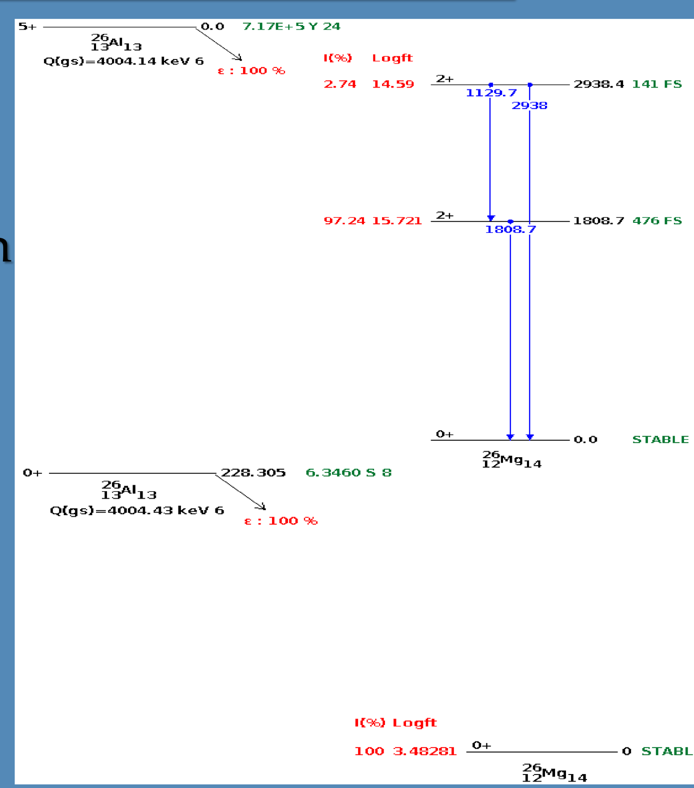
- F_l: regular Coulomb wave function
- j_l: Bessel function
- R_N: radius of the nuclear interior
- $k_{p(n)}=\left(\frac{2\mu\epsilon}{\hbar^2}\right)^{1/2}$

Also, for EXCITED STATES [6]:

$$\frac{\Gamma_p}{|C_n|^2}=R_\Gamma\approx R_0^{res}=\frac{\kappa_p}{\mu}\left|\frac{F_l(\kappa_pR_N)}{\kappa_pR_Nj_l(i\kappa_nR_N)}\right|^2$$

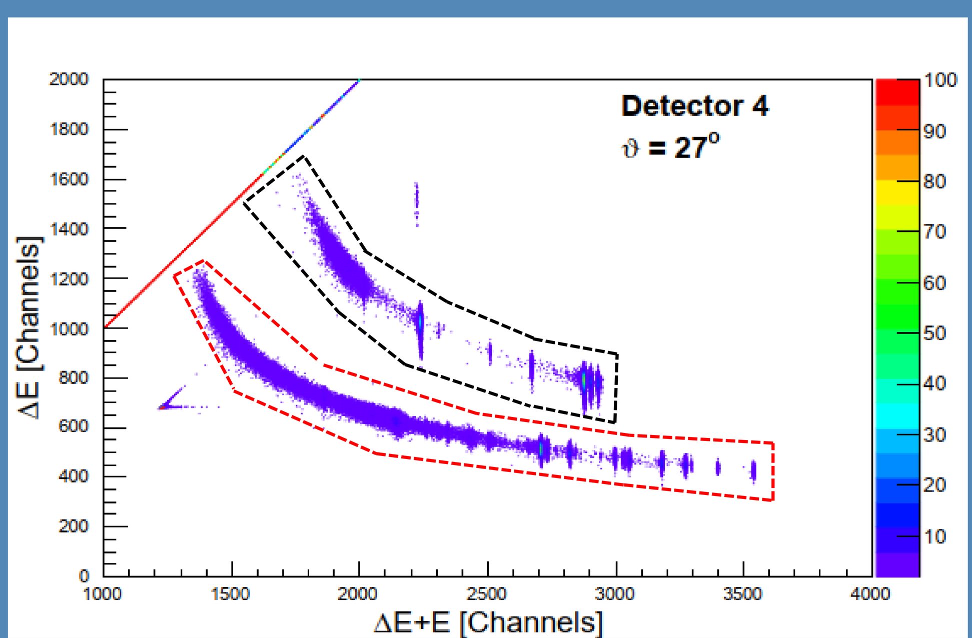
ASTROPHYSICAL SCENARIO

^{26}Al can be produced in **Core-Collapse Supernovae**, **Wolf-Rajet Objects** and **AGB Stars** [7], **Novae** [8] and **X-ray bursts** [9]
Its production can occur via the reaction chain $^{24}Mg(p,\gamma)^{25}Al(\beta^+)^{25}Mg(p,\gamma)^{26}Al$.
Production hampered by the **isomer** $^{26}Al^m$ ($T_{1/2}=6.35$ sec).
The $^{25}Al(p,\gamma)^{26}Si(\beta^+)^{26}Al^m$, bypasses ^{26}Al production, and directly feed its isomer syntesis. ^{26}Si can be depleted by the $^{26}Si(p,\gamma)^{27}P$ reaction, interfering with both the ground state and isomeric state creation.



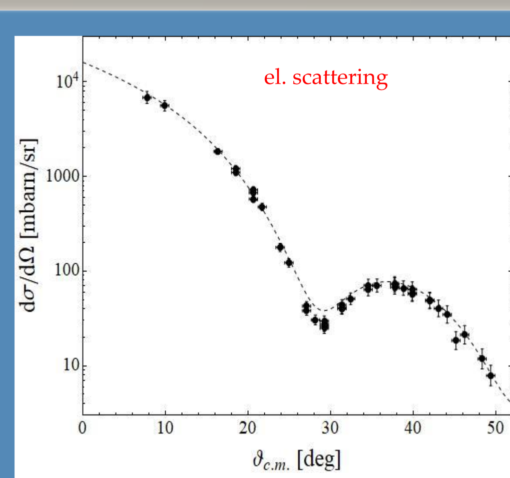
EXPERIMENTAL SET-UP AND OMP EXTRACTION

The ANC method has been applied on the $^{26}Mg(d,p)^{27}Mg$, that than has been used to retrieve information on the $^{26}Si(p,\gamma)^{27}P$. Protons and deuterons coming from the reaction have been detected and identified by means of the ΔE–E technique [10]. Such particles are then used to extract the Optical Models Parameters (OMP) for the entrance $\left(^{26}Mg+d\right)$ and exit $\left(^{26}Mg+n\right)$ channel respectively

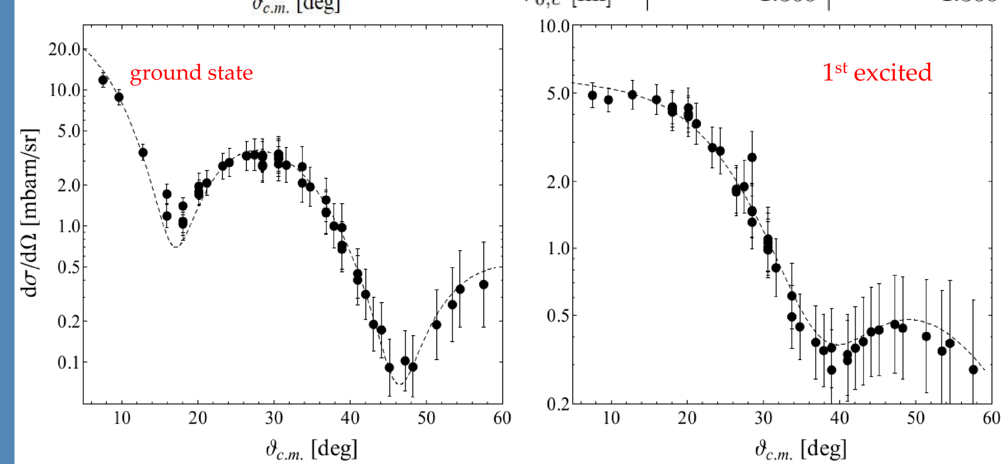


In Distorted Wave Born Approximation (DWBA, using FRESCO)formalism [10] :

$$U=V_c(r_c)-V_0f(x_0)-\left[Wf(x_w)-4W_D\frac{d}{dr}f(x_D)\right]+\frac{\hbar^2}{m_\pi c}V_{LS}(L\sigma)\frac{1}{r}\frac{d}{dr}f(x_{LS})$$



Set	D	P1
V_0 [MeV]	88.500	48.140
r_{0r} [fm]	1.085	1.058
a_r [fm]	0.850	0.650
W_D [MeV]	13.250	7.850
r_{0D} [fm]	1.300	1.205
a_D [fm]	0.650	0.650
v_{LS} [MeV]	//	6.200
$r_{0,LS}$ [fm]	//	1.010
$a_{0,LS}$ [fm]	//	0.750
$r_{0,c}$ [fm]	1.300	1.300

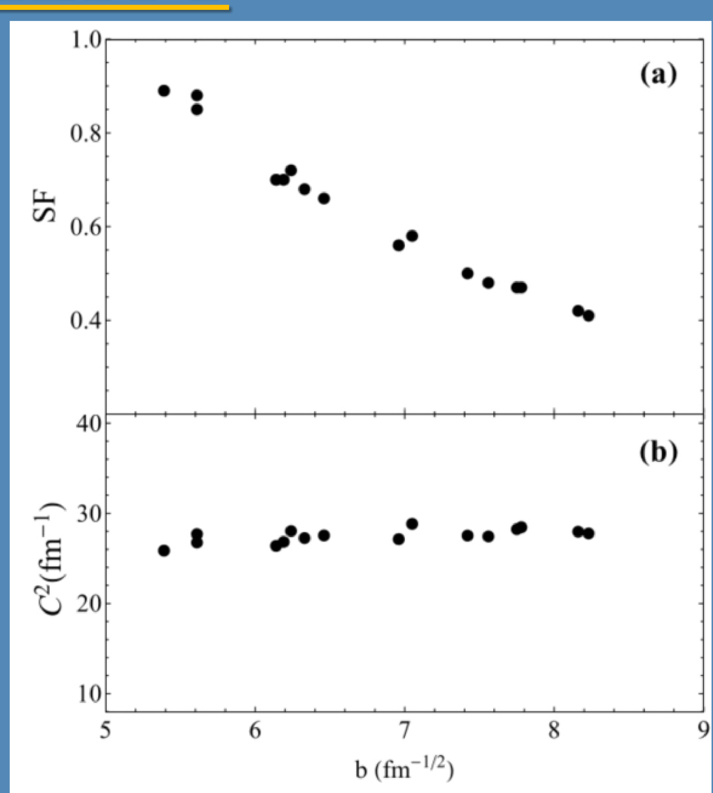


PERIPHERALITY

To check the peripherality one can change r_0 and a parameters to see the behaviour of ANC and S-factor with respect to the SPANC [10]:

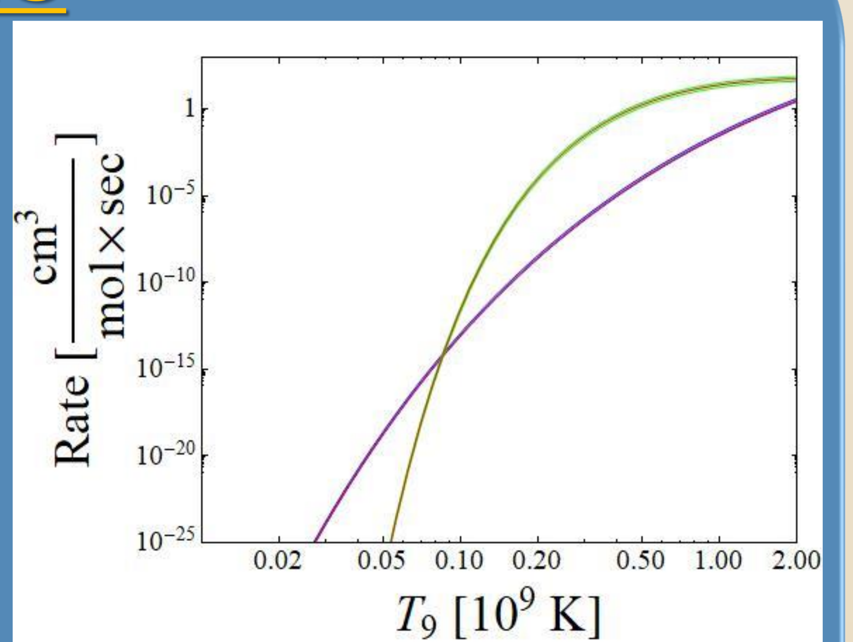
For $1.1\le r_0\le 1.4$ fm and $0.5\le a\le 0.7$ fm the experimental spectroscopic factor shows a variation of ≈ 55%, while the ANC shows a variation of 13%.

THE REACTION CAN THEREFORE BE CONSIDERED PERIPHERAL!



RESULTS

Using the parametrization above the ANC for the two states has been calculated in $C^2_{gr}=28.26\pm4.24\ \mathrm{fm}^{-1}$ and $C^2_{1st}=1.51\pm0.27\ fm^{-1}$,(in agreement with [11]). Finally, using the mirror nuclei procedure, the results have been used to extract the ANC for the radiative capture in the ground state ($C^2_{gr}=1420\pm255\ \mathrm{fm}^{-1}$), and $\Gamma_p=(6.76\pm1.35)\times10^{-9}$ MeV for the first excited stare. Such value have been used to calculate the reaction rate (blue for the non-resonant and green for the resonant contributions), using the ratio Γ_γ/Γ_p reported in [12].



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