R-Matrix analysis for spin-parity assignments

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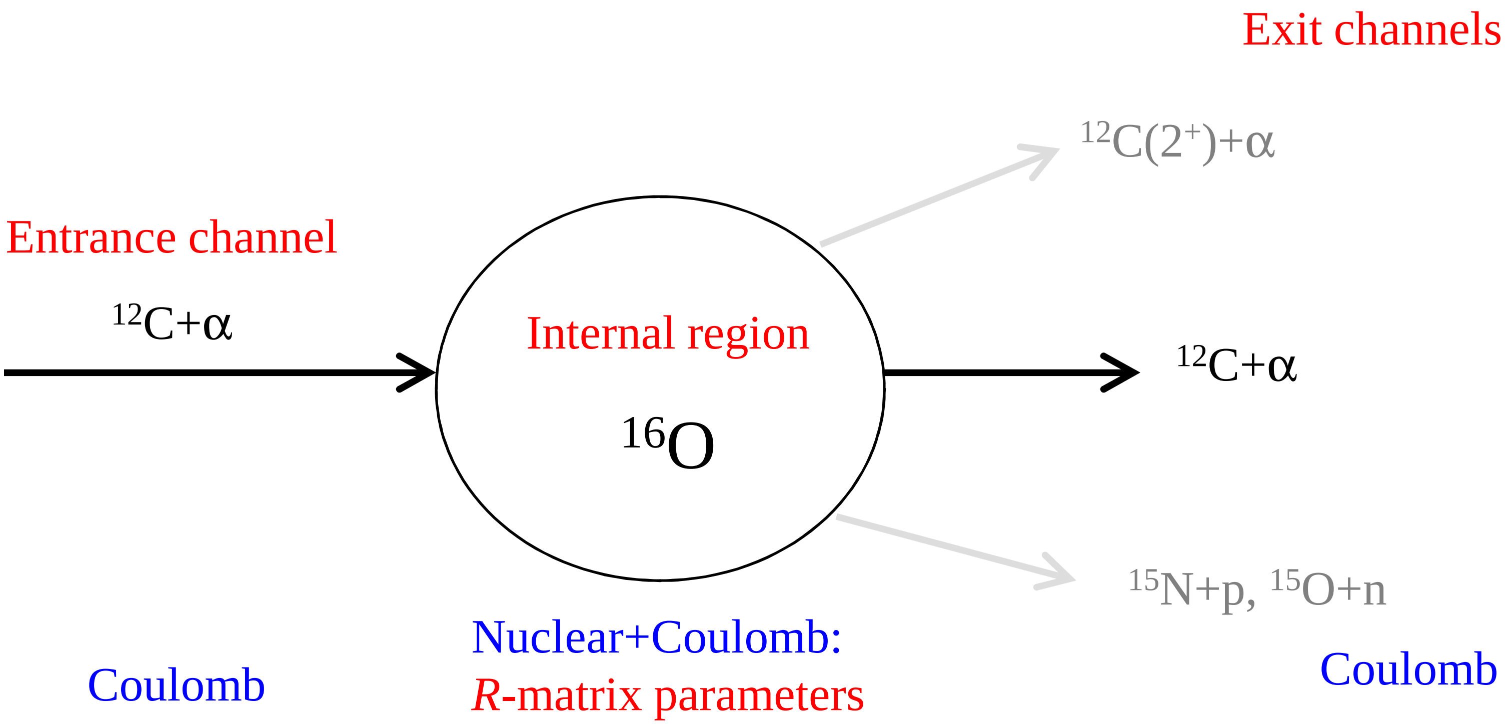
R-matrix theory

- Main idea: to divide the configuration space into 2 regions (radius a)
  - Internal: $r \leq a$: Nuclear + coulomb interactions
  - External: $r > a$: Coulomb only



Each low energy level must be considered individually, high energy levels with the same J^{π} treated as one for background.

$\rightarrow$ well adapted to nuclear astrophysics

R-matrix differential cross section

$$(2s+1)\frac{k_\alpha^2}{\pi}d\sigma_{\alpha s,\alpha' s'}d\Omega_{\alpha'}$$

$$= (2s+1)|C_{\alpha'}(\theta_{\alpha'})|^2\delta_{\alpha' s',\alpha s}$$ Coulomb scattering

$$+\frac{1}{\pi}\sum_L B_L(\alpha' s',\alpha s)P_L(\cos\theta_{\alpha'}) - \delta_{\alpha' s',\alpha s}(4\pi)^{-\frac{1}{2}}$$ Resonant scattering

$$\times\sum_{Jl}(2J+1)2\Re\left[i\left(T^J_{\alpha' s' l',\alpha s l}\right)^* C_{\alpha'}(\theta_{\alpha'})P_l(\cos\theta_{\alpha'})\right]$$ Interference term

$$B_L(\alpha' s',\alpha s) = \frac{1}{4}(-1)^{s-s'}\sum_{J_1 J_2 l_1 l_2 l_1' l_2'}\bar{Z}(l_1 J_1 l_2 J_2, sL) \times \bar{Z}(l_1' J_1 l_2' J_2, s' L)\left(T^{J_1}_{\alpha' s' l_1',\alpha s l_1}\right)\left(T^{J_2}_{\alpha' s' l_2',\alpha s l_2}\right)^*$$

$$T^J_{\alpha' s' l',\alpha s l} = e^{2i\omega_{\alpha l}}\delta_{\alpha' s' l',\alpha s l} - U^J_{\alpha' s' l',\alpha s l}$$

Collision matrix $U = \frac{I(a)}{O(a)}\frac{1-L^* R}{1-LR} = \exp(2i\delta)$ R matrix

with

$$R = \sum_\lambda \frac{\tilde{\gamma}^2}{E_\lambda - E} \quad \text{and} \quad L = ka\frac{O'(a)}{O(a)} = S + iP$$

P=penetration factor
S=shift factor

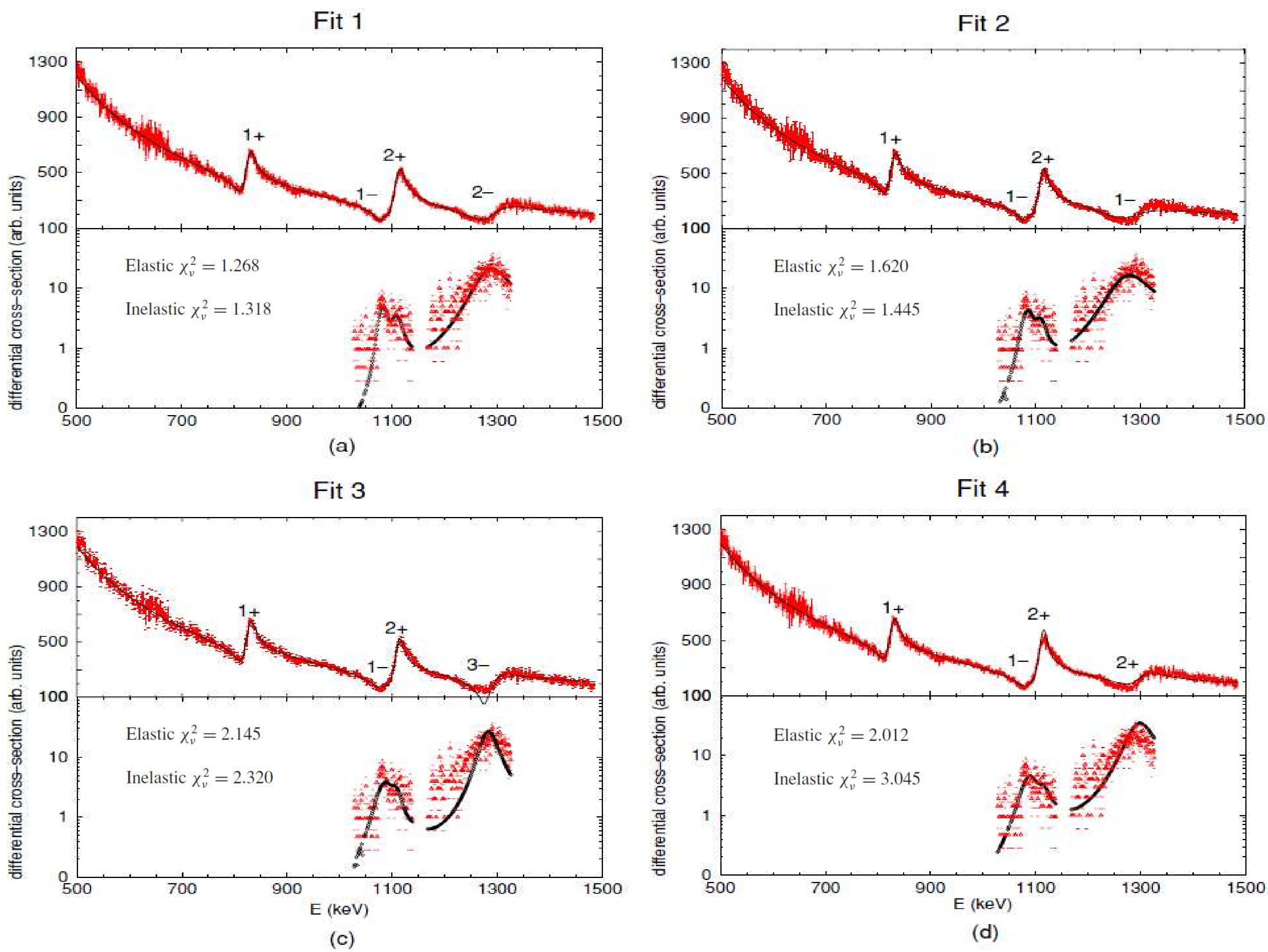
<u>R-matrix parameters</u> E_λ given by $(H - E_\lambda)u_\lambda = 0$

$$\tilde{\gamma}_\lambda = \left(\frac{\hbar^2}{2\mu a}\right)^{1/2} u_\lambda(a)$$ =reduced width

The best fit to the experimental cross section

Resonance energies resonance widths spin-parites

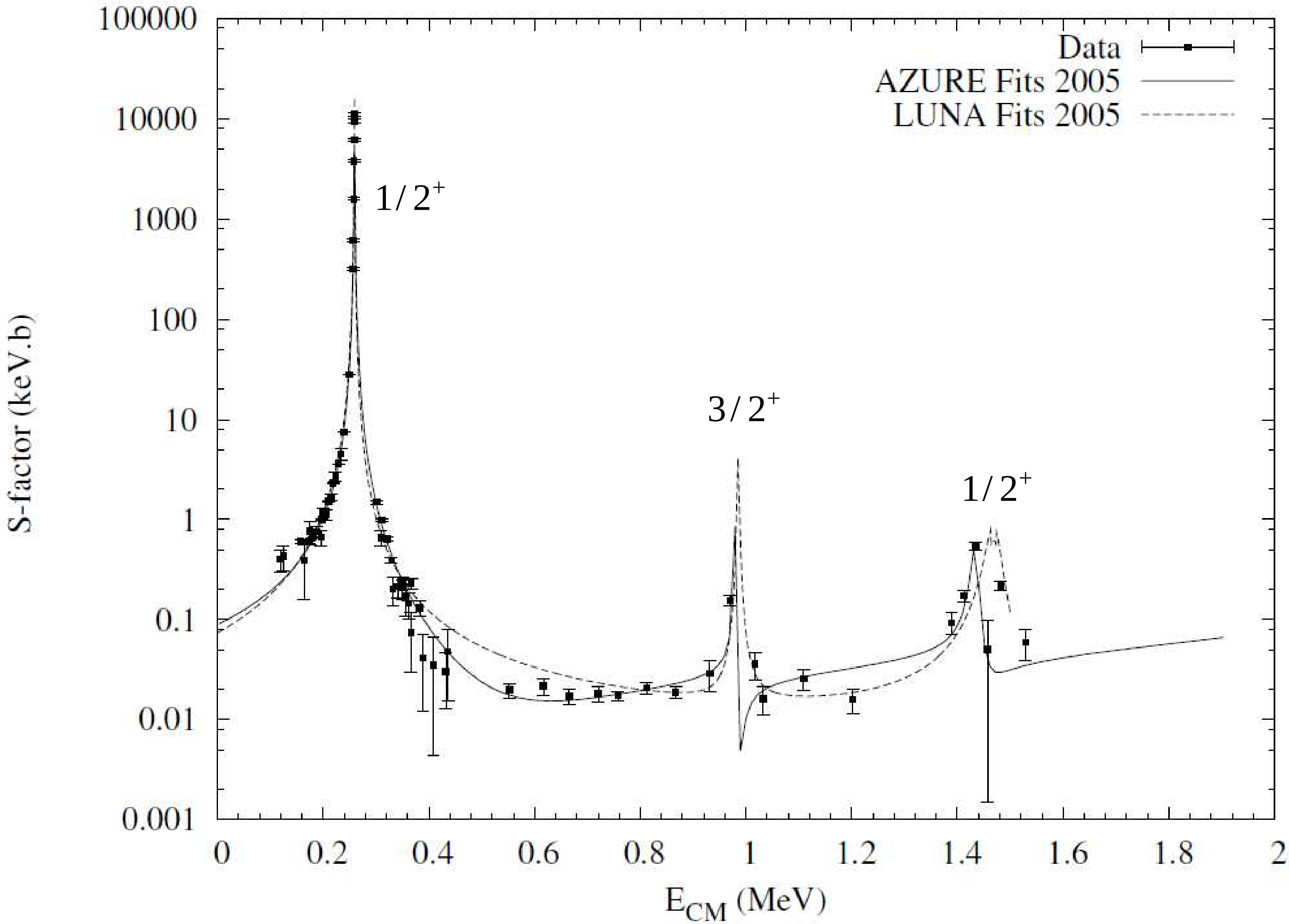
Applications: scatterings $^{21}Na(p,p)^{21}Na$



C. Ruiz, PHYSICAL REVIEW C 71, 025802 (2005)

Applications: captures

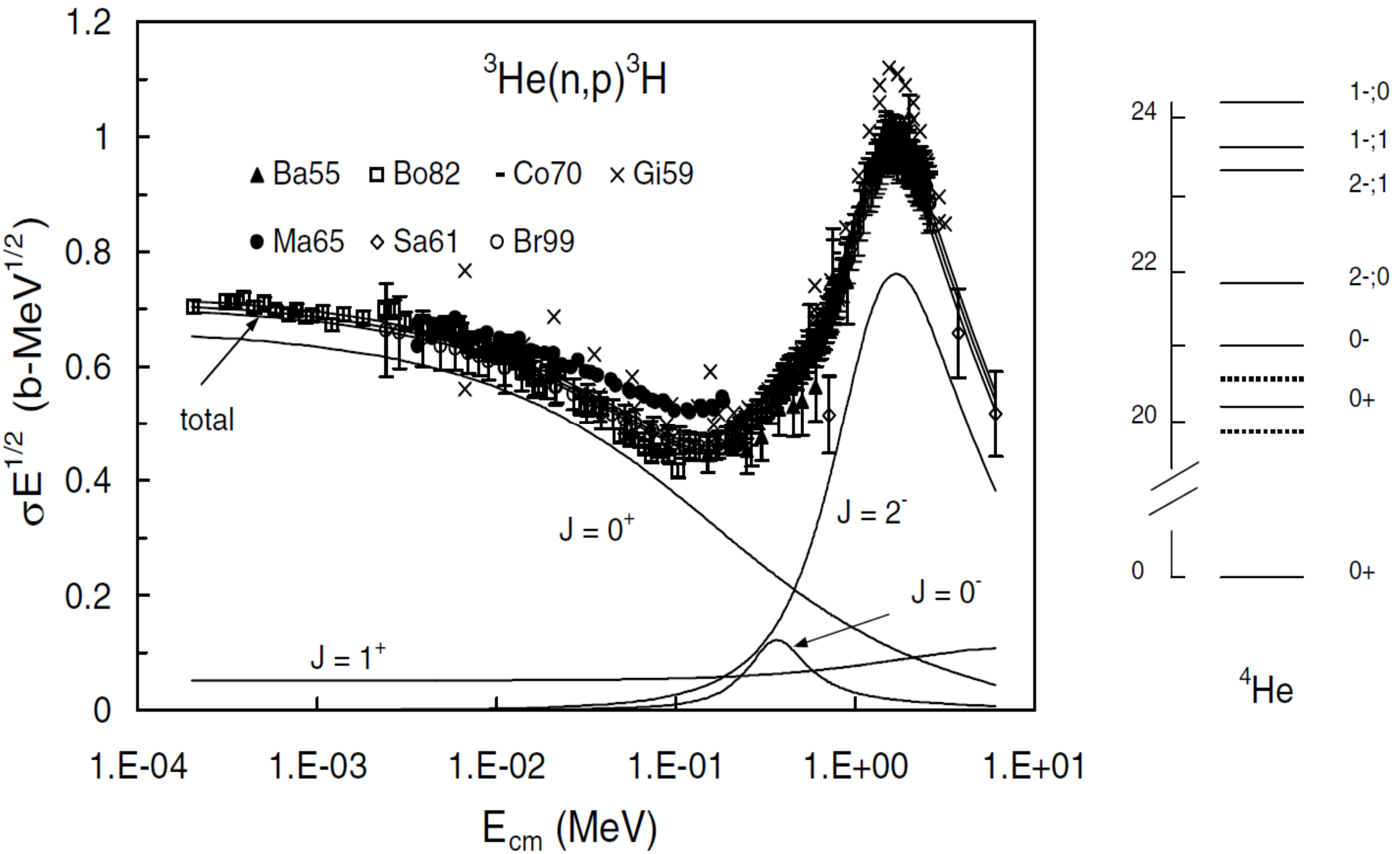
$^{14}N(p,\gamma)^{15}O$



E. Simpson, Thesis(2005)

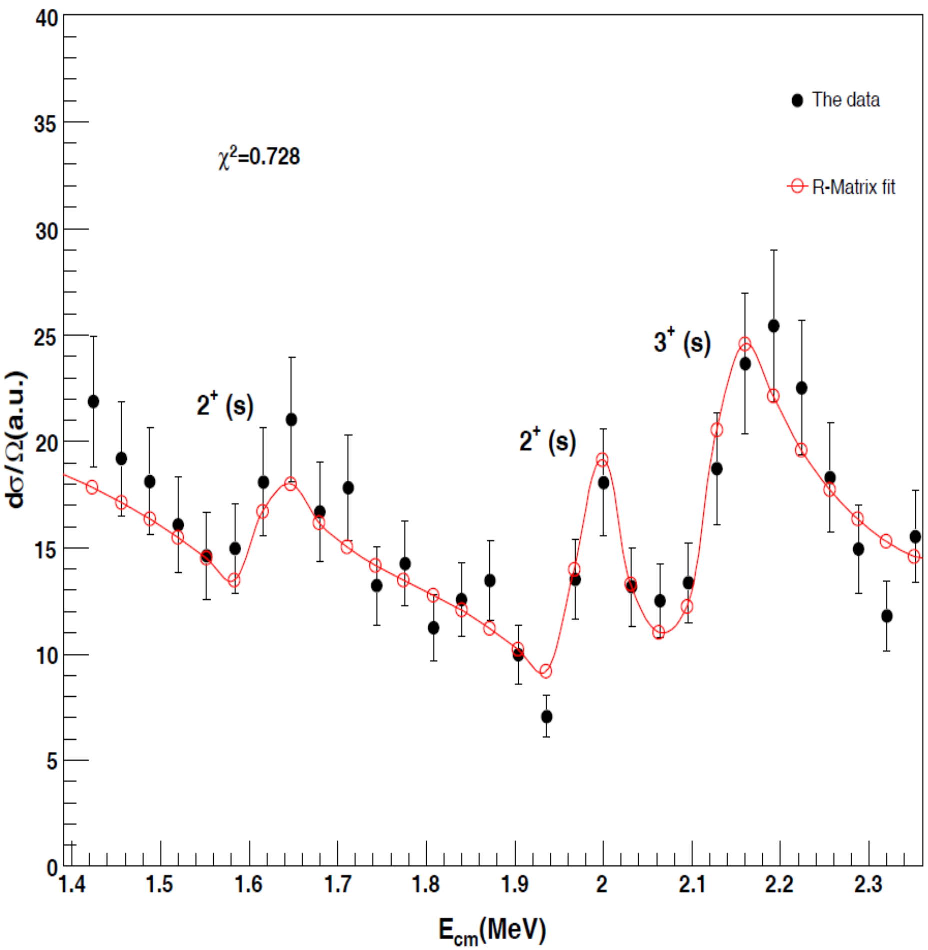
Applications: reactions

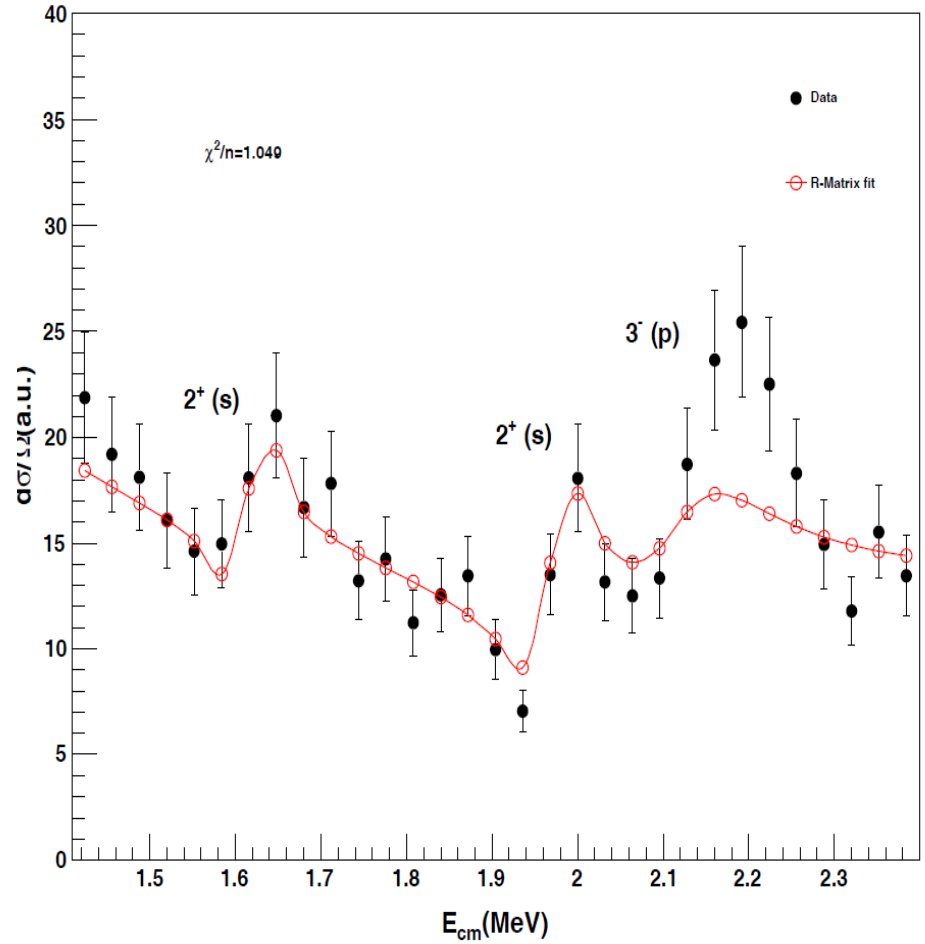
$^3He(n,p)^3H$



A. Adahchour and P. Descouvemont2, J. Phys. G: Nucl. Part. Phys. 29 (2003) 395–403

Applications: our experiment $p(^{25}Al,p)\,^{25}Al$





Jun Chen, Thesis(2009)