EXL/R3B Theory/Simulations:

Milano activity, Points for discussion

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Outline

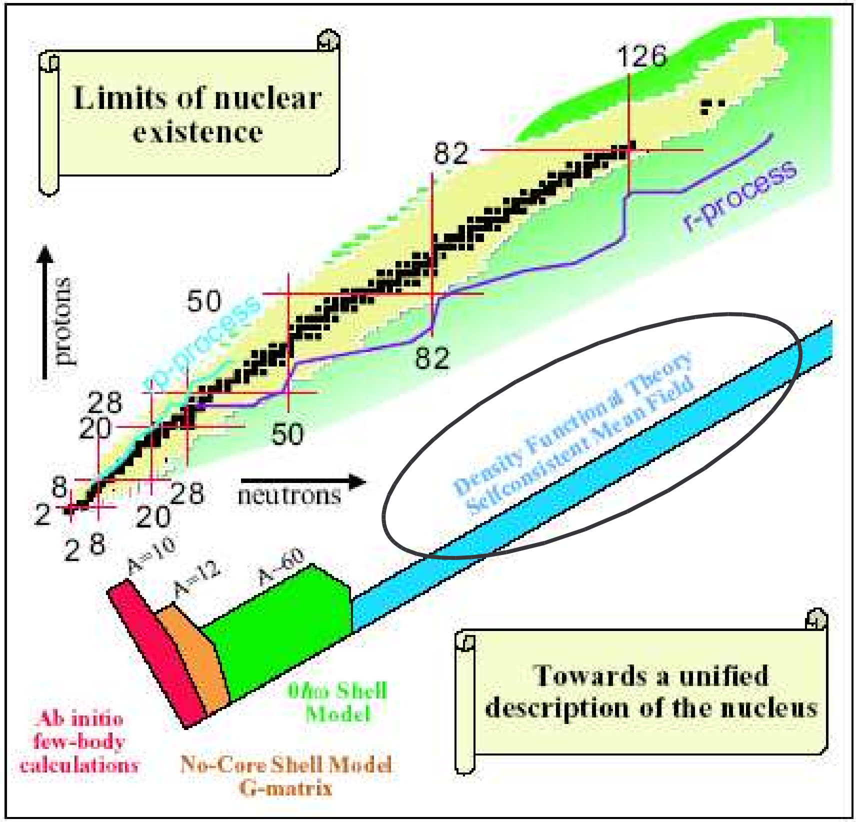
- The physics case : what is our contribution ?

- Ground state/excited states : calculations of elastic/inelastic cross sections ("theory" activity)

- What next ?

Self-consistent mean field calculations (and extensions) are probably, so far, the only possible framework in order to understand the structure of medium-heavy nuclei.

The study of vibrational excitations is instrumental in order to constrain the effective nucleon-nucleon interaction.



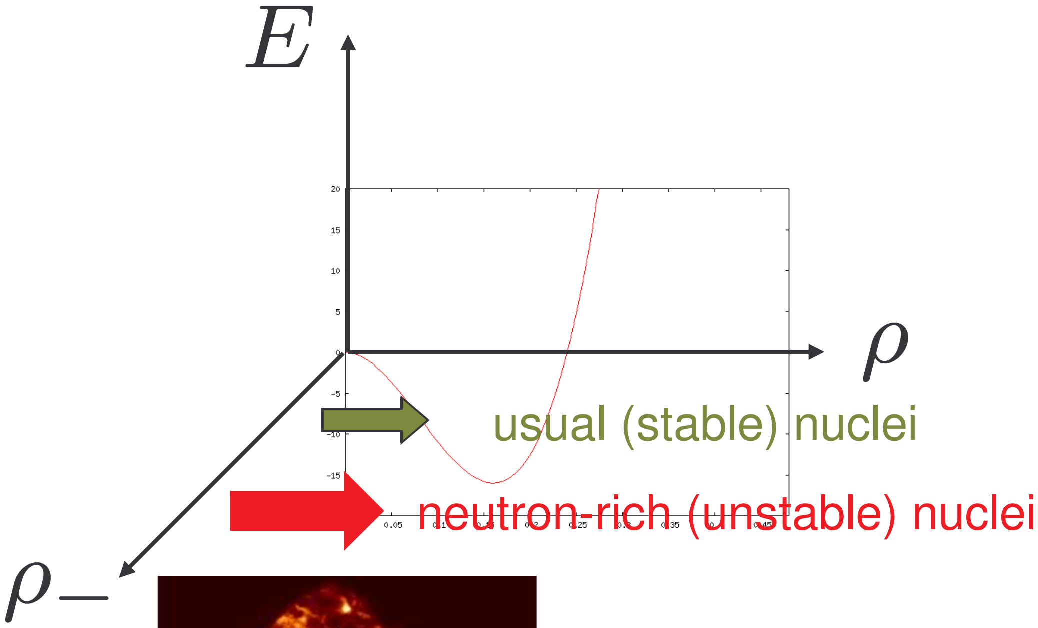
For example, the knowledge of the Gamow-Teller (GT) states is connected with the spin-isospin part of the interaction.

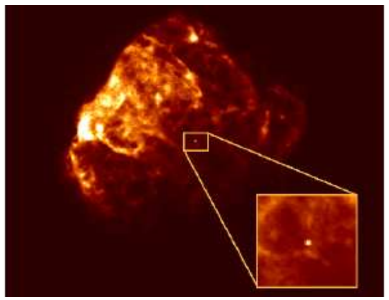
Impact on nuclear astrophysics (r-process path is governed by GT β-decay, neutrino properties are also inferred by ββ, etc.)

What is the most critical part of the nuclear energy functional ?

In the nuclear systems there are neutrons and protons.

$$E[\rho_n, \rho_p] = E[\rho, \rho_-] \qquad \rho = \rho_n + \rho_p, \;\; \rho_- = \rho_n - \rho_p$$





neutron stars

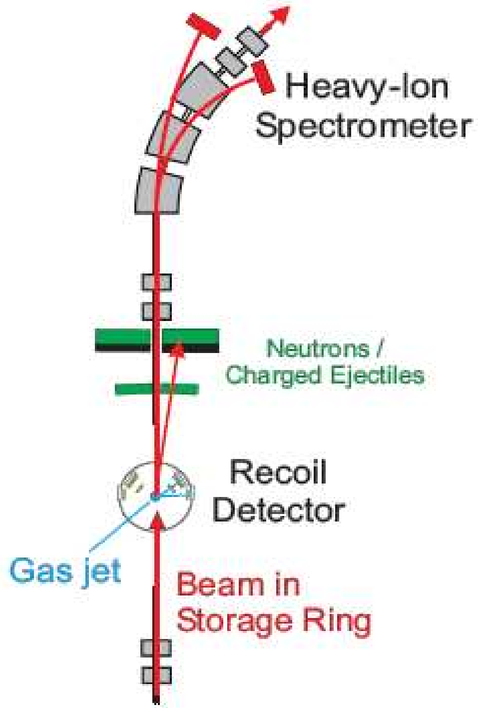
The largest uncertainities concern the ISOVECTOR, or SYMMETRY part of the energy functional.

$$\mathcal{E}(\varrho, \varrho_-) = \mathcal{E}_0(\varrho) + \varrho S(\varrho)\left(\frac{\varrho_-}{\varrho}\right)^2$$

Theory input: two levels !

• One level is the discussion of the physics case (see before).

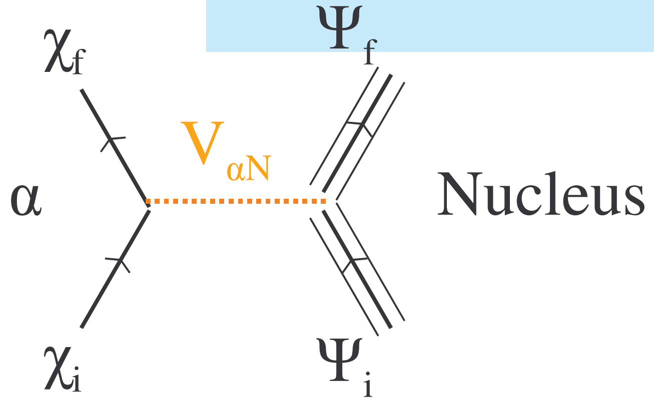
• Another level: provide specific input for simulations, that is CROSS SECTIONS. In this case a preliminary list of reactions had been discussed (e.g., $^{132}Sn(p,p')$ etc.).



Groups involved: Madrid,Milano,Surrey…

Milano: eikonal model for elastic/inelastic, DWBA

DWBA and inelastic excitation



$$\frac{d\sigma^{DWBA}}{d\Omega} = (\frac{\mu}{2\pi\hbar^2})^2 \frac{k_f}{k_i}|T_{fi}|^2$$

$$T_{fi} = \langle\chi_f^{(-)}\Psi_f|V|\chi_i^{(+)}\Psi_i\rangle = \begin{cases} \langle\Psi_f|\mathcal{O}_{sc}|\Psi_i\rangle, & \mathcal{O}_{sc} \sim \int \chi_f^{(-)*} V \chi_i^{(+)} \\ \langle\chi_f^{(-)}|U_{tr}|\chi_i^{(+)}\rangle, & U_{tr} \sim \int \Psi_f^* V \Psi_i. \end{cases}$$

Theorists: calculate transition strength S(E) within HF-RPA using a simple scattering operator $F \sim r^L Y_{LM}$:

$$S(E) = \sum_n |\langle\Psi_0|F|\Psi_n\rangle|^2 \delta(E - E_n)$$

Experimentalists: calculate cross sections within Distorted Wave Born Approximation (DWBA):

$$\frac{d\sigma(E)}{d\Omega} = (\frac{\mu}{2\pi\hbar^2})^2 \frac{k_f}{k_i}|\langle\chi_f^{(-)}|U_{tr}|\chi_i^{(+)}\rangle|^2$$

$$U_{tr} \sim \frac{\partial U}{\partial r}$$ or using folding model.

Eikonal approximation

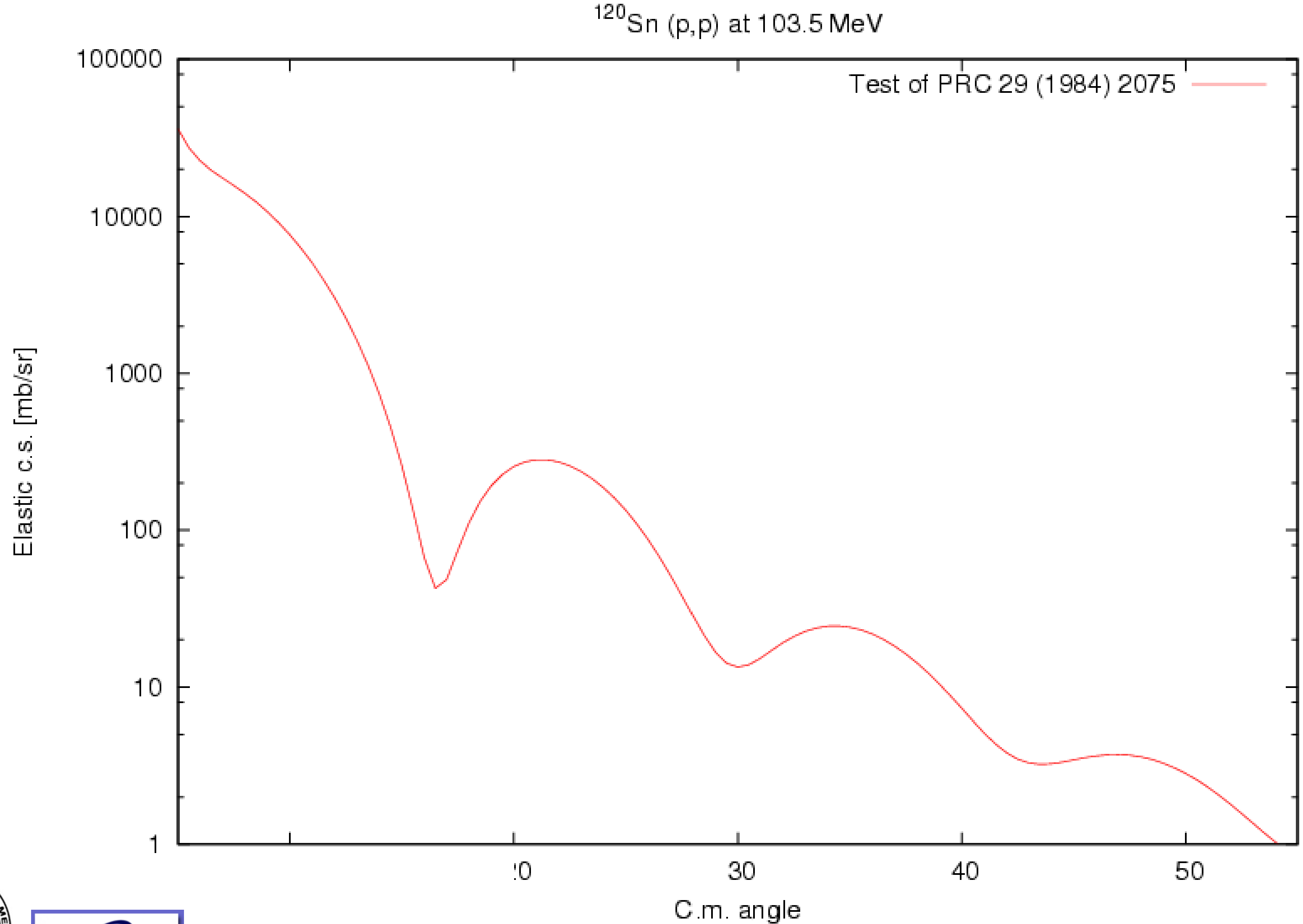
$$f_{LM}(\vartheta) = -\frac{m}{2\pi\hbar^2}\int d^3 r_p \Psi_f^*(\mathbf{r}_p) V_{\text{int}}(\mathbf{r}_p) \Psi_i(\mathbf{r}_p)$$

Appr. here: $e^{i\boldsymbol{kr}} e^{\chi(\boldsymbol{b})} < LM \,|V_{\text{int}}|\, 0 >$

$$V_n(\mathbf{R}) = -\sigma_{nn}\frac{\hbar v}{2}(\alpha_{nn} + i)\int d^3 r \rho_t(\mathbf{r})\rho_p(\mathbf{r}+\mathbf{R})$$

It can be used in connection with Glauber approximation or not.

Elastic



120Sn (p,p) at 103.5 MeV
Test of PRC 29 (1984) 2075
Elastic c.s. [mb/sr]
100000
10000
1000
100
10
1
:0
30
40
50
C.m. angle

Plan:

• compare results from different groups (Glauber model is also used at GSI for test experiment, elastic cross sections can be also produced at Madrid, cf. Jose Udias)

• insert the cross sections in event generators for simulations

• Missing cross sections, missing physics ?

Surrey University – Jim Al Khalili's group

(p,2p) knockout studies in inverse kinematics.

One and two-neutron knockout studies within eikonal and CDCC.

Optical potential studies for proton scattering from exotic nuclei in inverse kinematics.

G. Hillhouse *et al.*

(p,2p) on ^{208}Pb at 392 MeV