^{6}He scattering within THO-CDCC framework

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Collaboration

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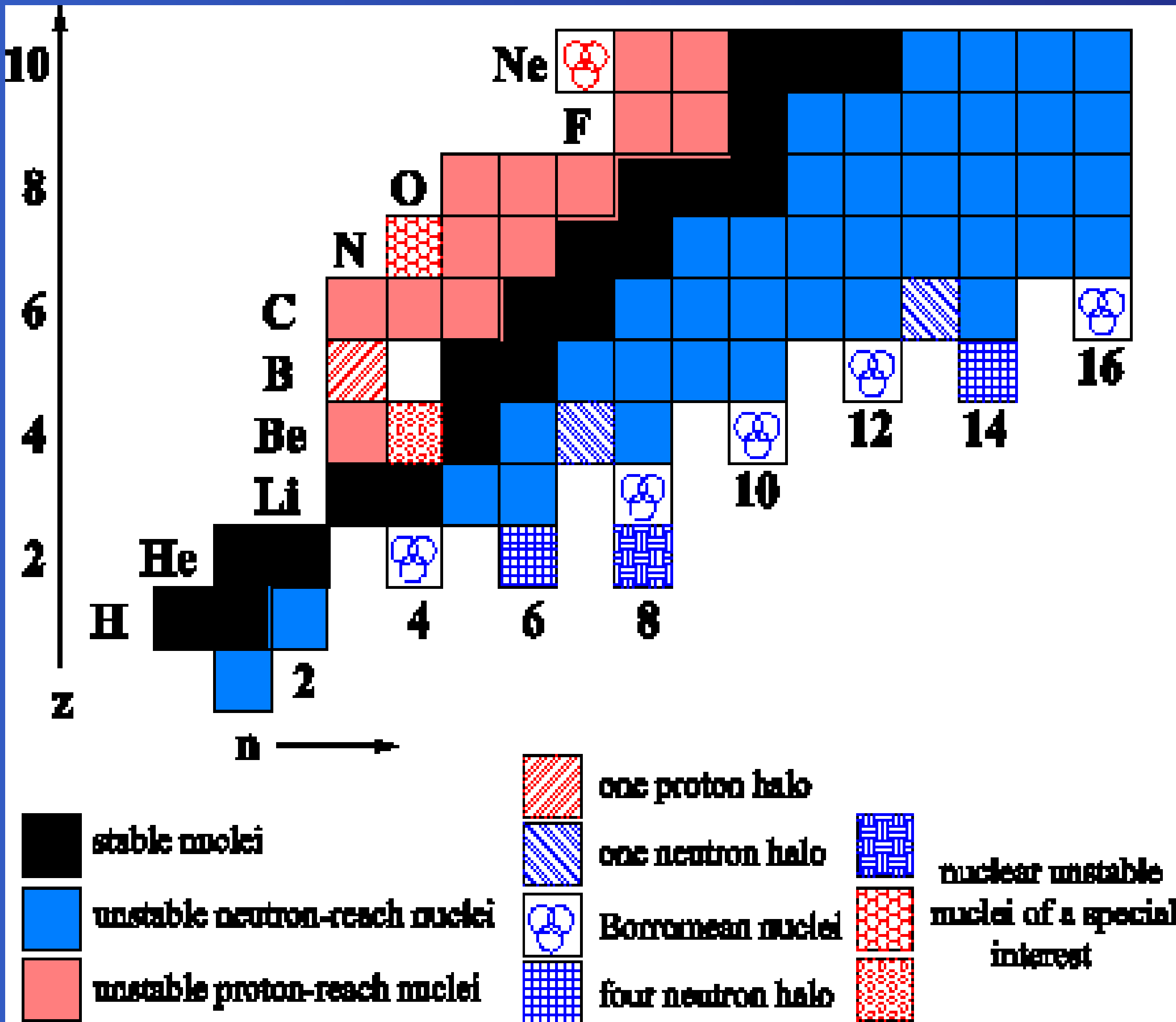
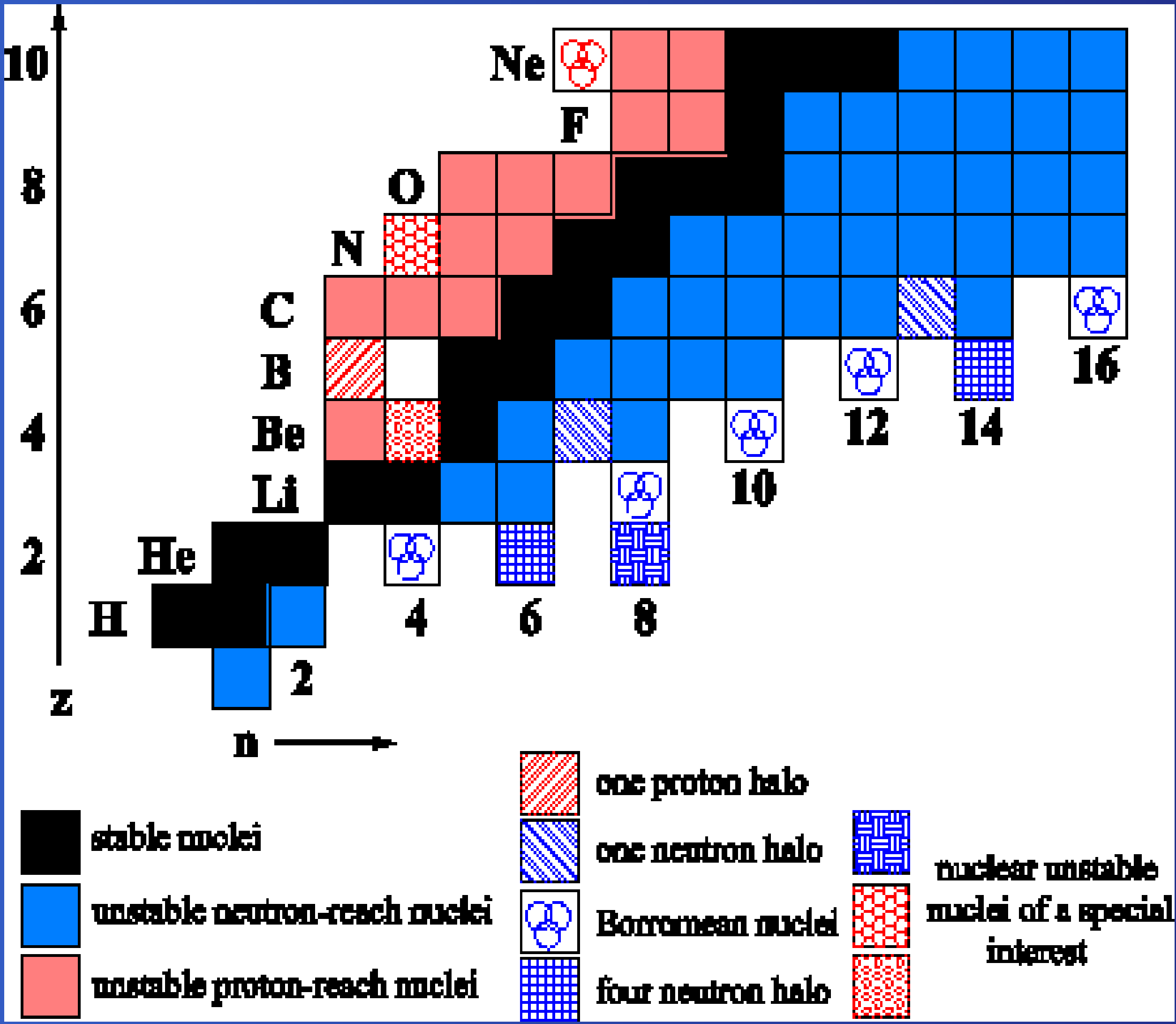
Outline

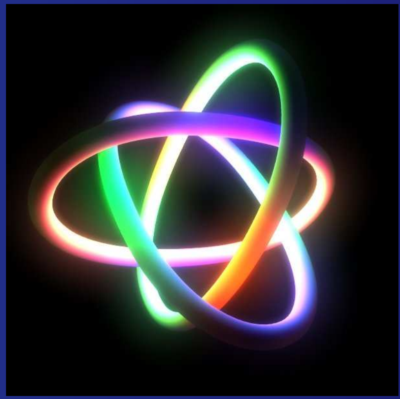
- Motivation
  - Borromean nuclei
- Transformed Harmonic Oscillator (THO) method
  - Application to a two-body system
  - Application to a three-body system: Hyperhespherical Harmonics method (HH)
- Scattering calculations for ^{6}He+target
  - Continuum Discretized Coupled Channels (CDCC)
- Summary and conclusions

Motivation: Borromean nuclei



Motivation: Borromean nuclei





Borromean

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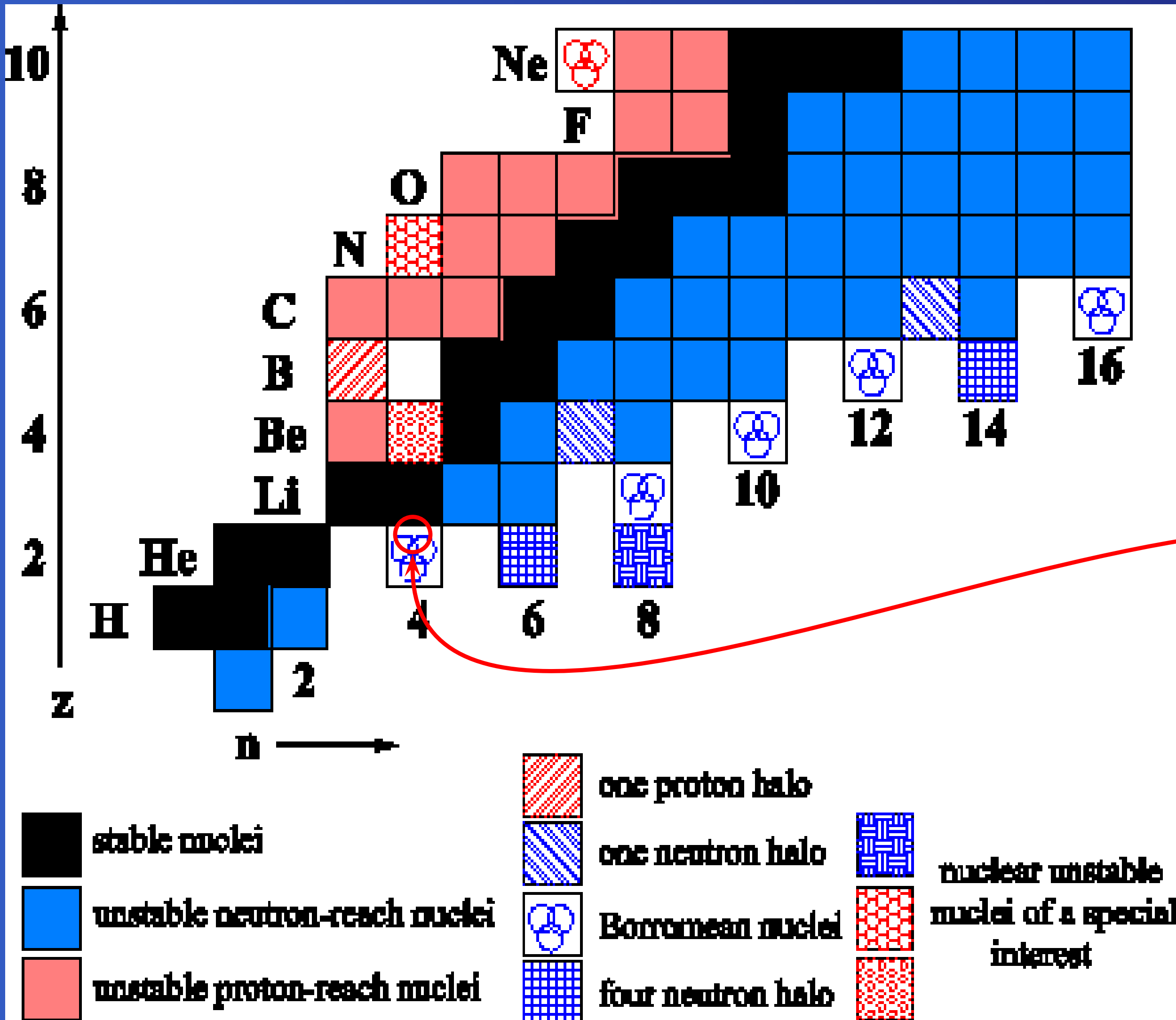
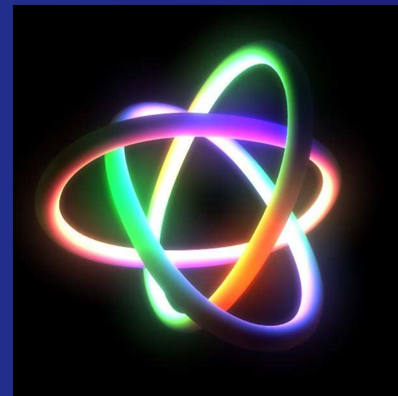
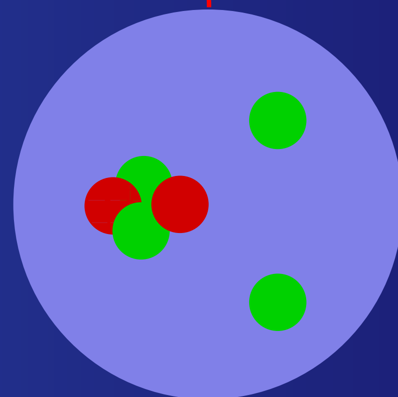




Borromean

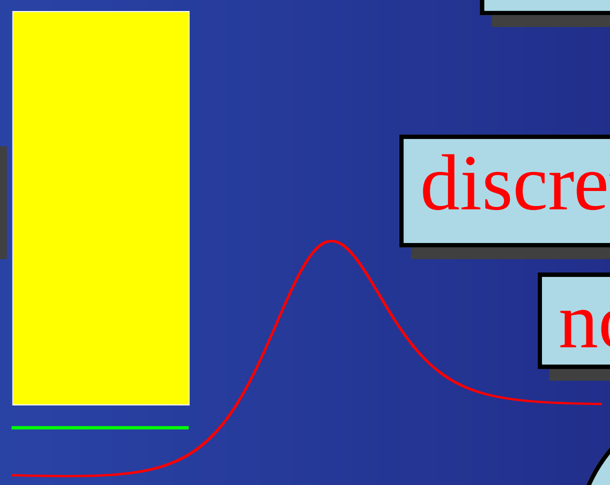


Motivation: General scheme

quantum system

↙ unbound states ⇓ continuum spectrum — non normalizable

↘ bound states ⇓ discrete spectrum — normalizable



▼ weakly bound system

discretization method

▼ ↪ strongly bound system

Motivation: General scheme

quantum system

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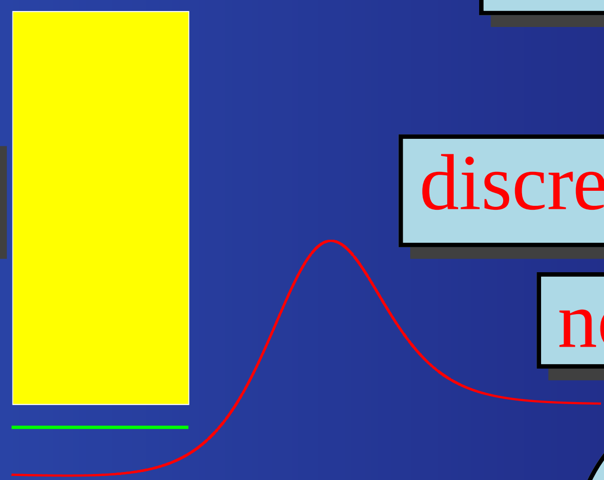


▼ weakly bound system

▼ ↪ strongly bound system

discretization method ◆ THO

THO method: 2-body system

- M.V. Stoitsov and I. Zh. Petkov, Ann. Phys., **184**, 121 (1988)

central potential

$$s(r)$$

$$\varphi_B(r) \quad \rightsquigarrow \quad \phi^{HO}_{0l_B}(s)$$

$$\Updownarrow$$

$$\int_0^r |\varphi_B(r')|^2 dr' = \int_0^s |\phi^{HO}_{0l_B}(s')|^2 ds'$$

$$\Downarrow$$

THO basis

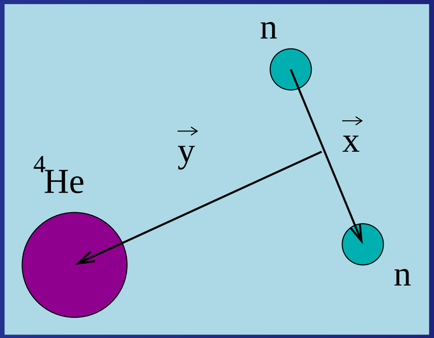
$$\psi^{THO}_{nl}(r) = \varphi_B(r)\, s(r)^{l-l_B} L_n^{l+1/2}\left(s(r)^2\right)$$

THO method: 3-body system

- HH method: The states of the system can be expanded in Hyperspherical Harmonics

$$\Psi_{\beta j \mu}(\rho, \Omega) = \rho^{-5/2} U_{\beta j}(\rho) \mathcal{Y}_{\beta j \mu}$$

$$\Omega \equiv \{\alpha, \widehat{x}, \widehat{y}\}$$
$$\beta \equiv \{K, l_x, l_y, l, S_x, j_{ab}\}$$



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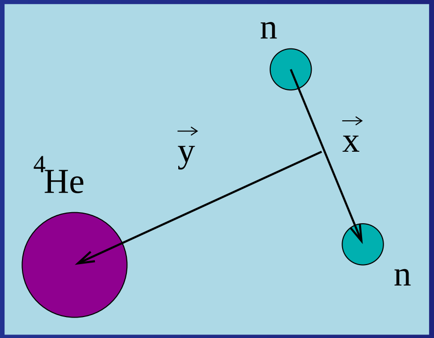
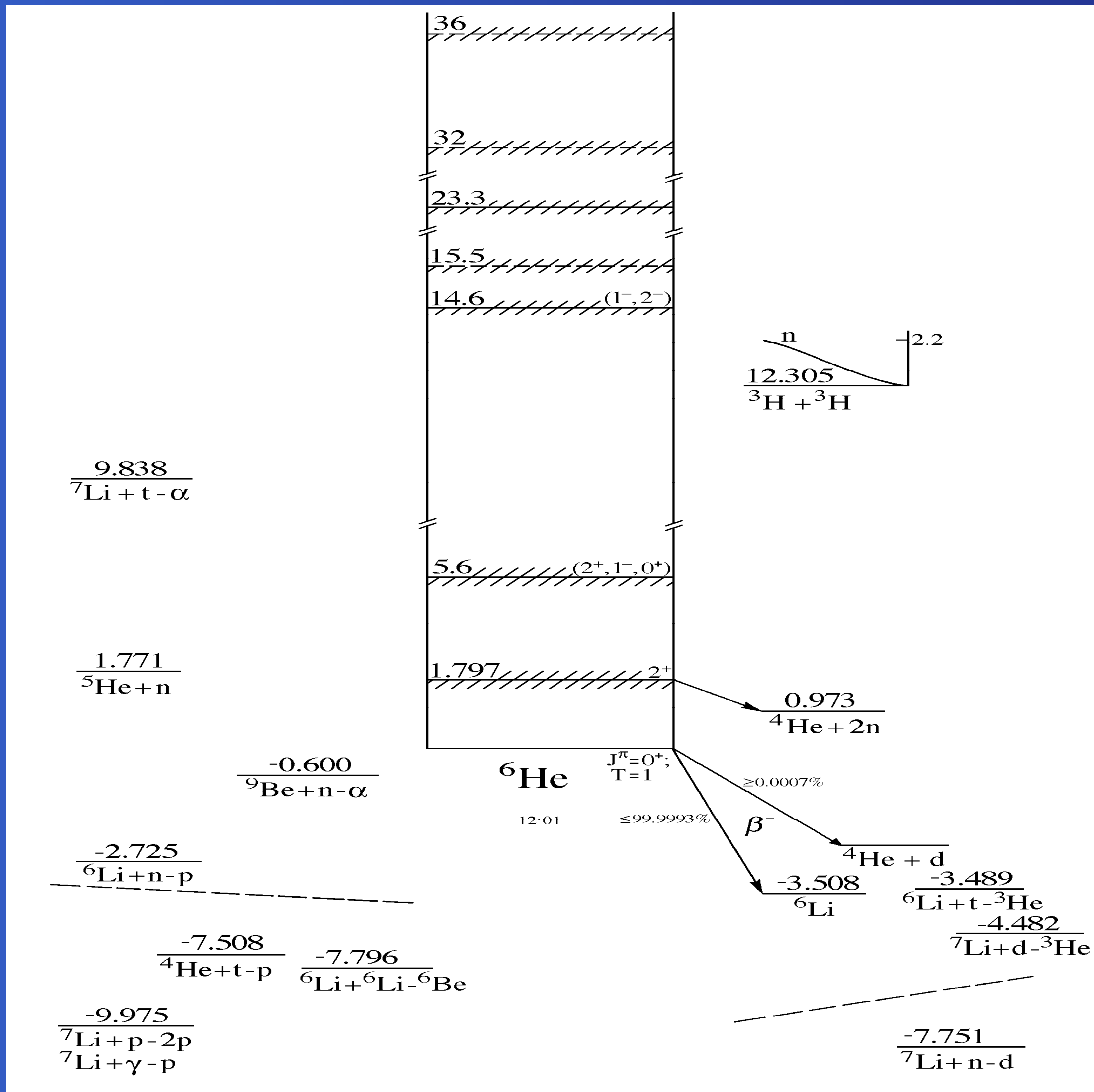


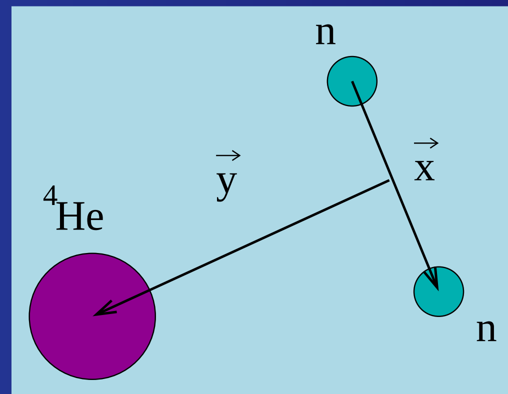
- THO method: $s(\rho)$ is calculated for each channel β included in the bound ground state

$$\int_0^\rho d\rho' |U_{B\beta}(\rho')|^2 = \int_0^s ds' |U_{0K}^{HO}(s')|^2$$

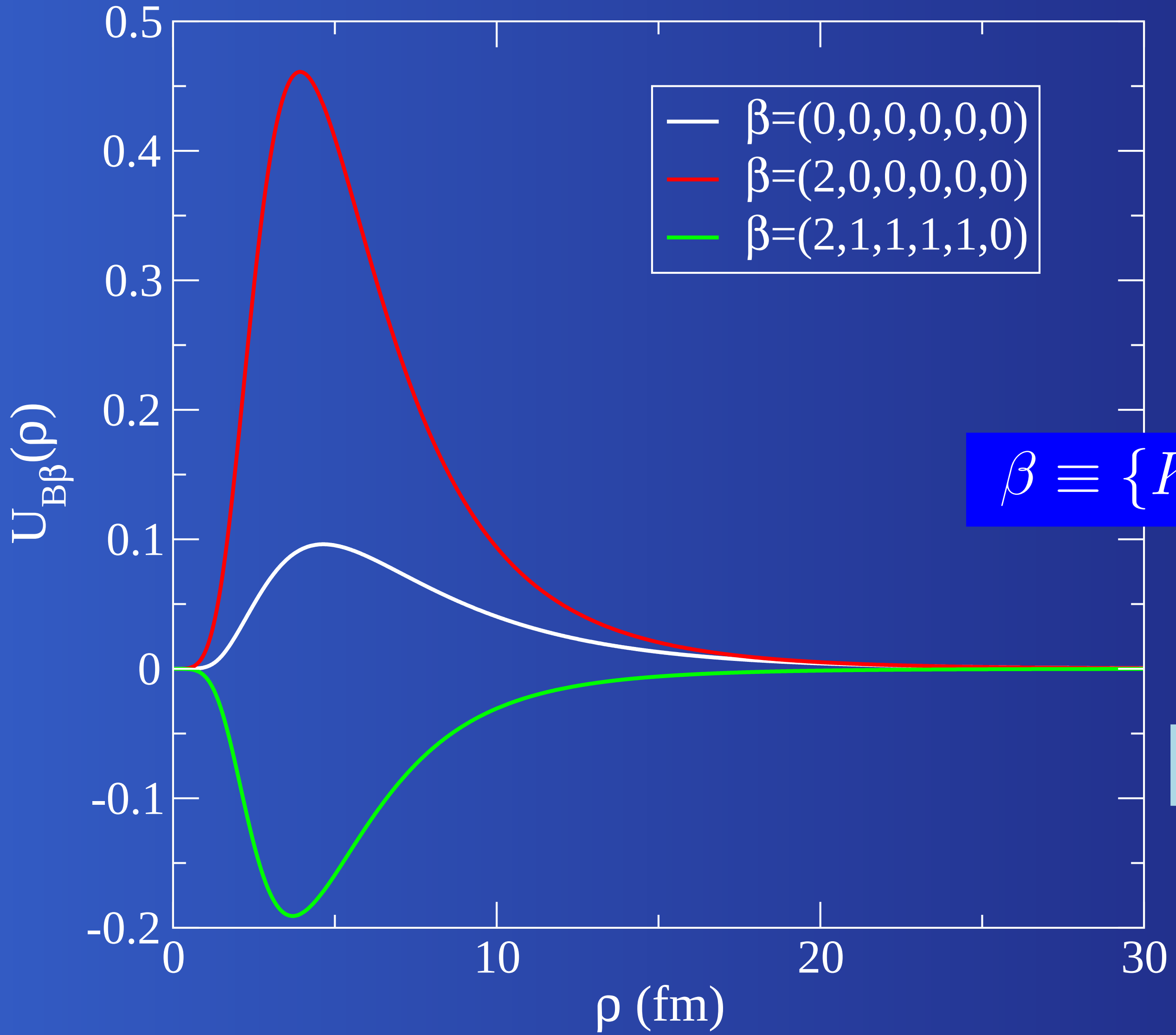
$$U_{i\beta}^{THO}(\rho) = U_{B\beta}(\rho) L_i^{K+2}\left(s_\beta(\rho)^2\right)$$

Application to ^{6}He





Application to ^{6}He

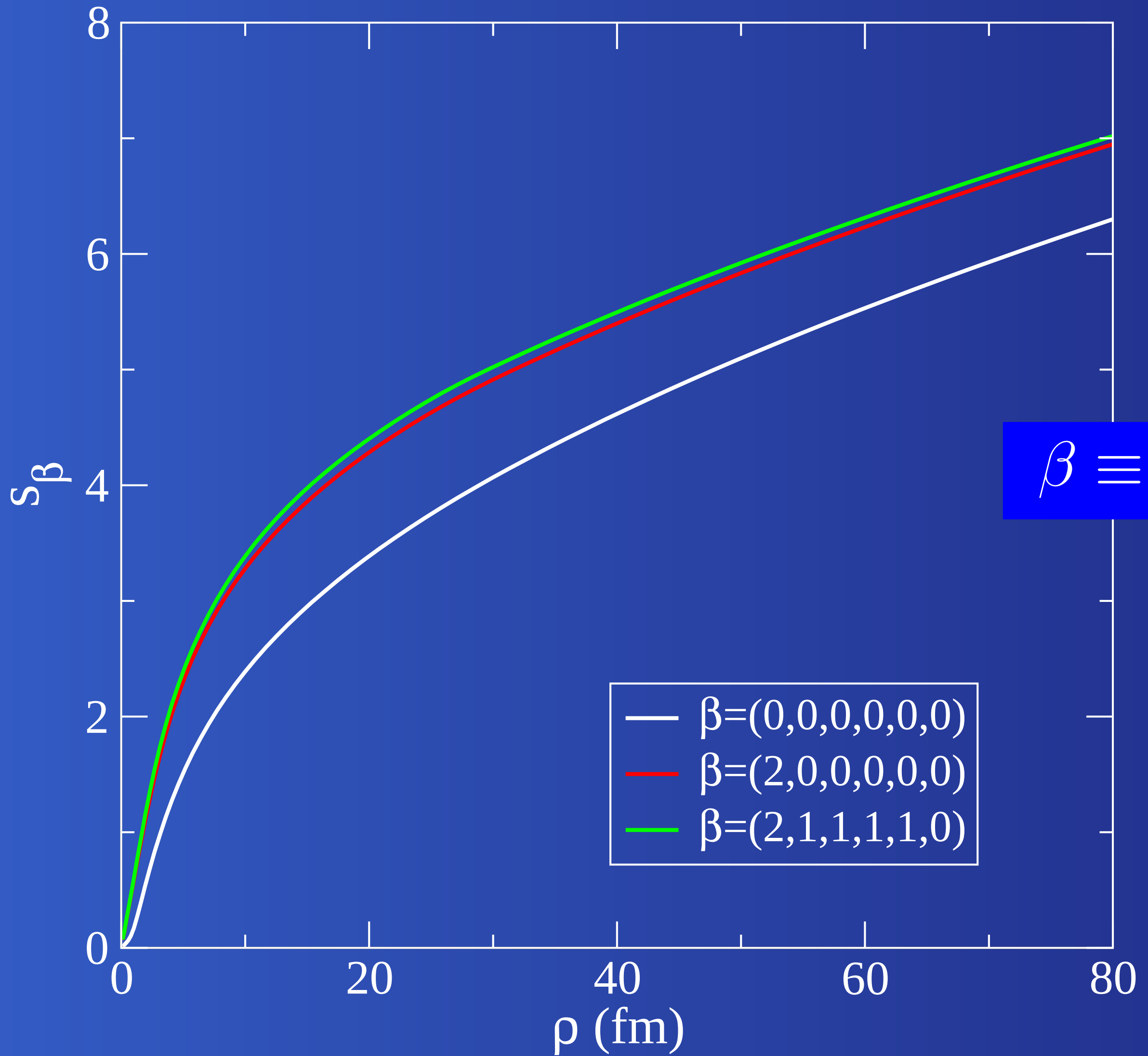


$$\beta \equiv \{K, l_x, l_y, l, S_x, j_{ab}\}$$

$$K_{max} = 8$$

Ground state

Application to ^{6}He



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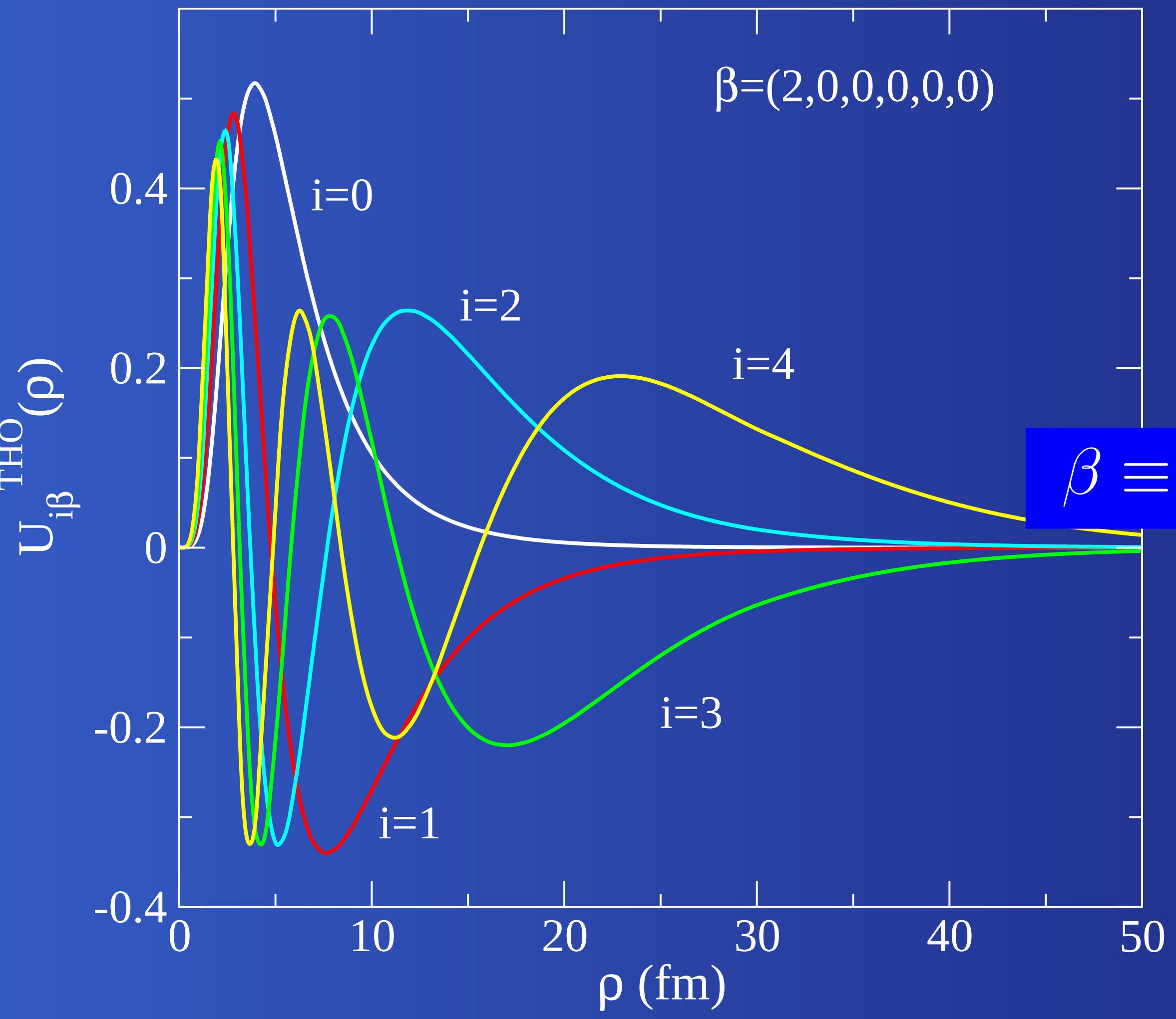
Application to ^{6}He



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Hamiltonian

$$\widehat{H}(\rho,\Omega) = \widehat{T}(\rho,\Omega) + \widehat{V}(\rho,\Omega)$$

$$V = V_{n\alpha} + V_{n\alpha} + V_{nn} + V_{nn\alpha}$$

- $n+\alpha$ $\boxed{V_{n\alpha} = V_c + V_{SO}}$

  V_c, V_{SO}: Woods-Saxon

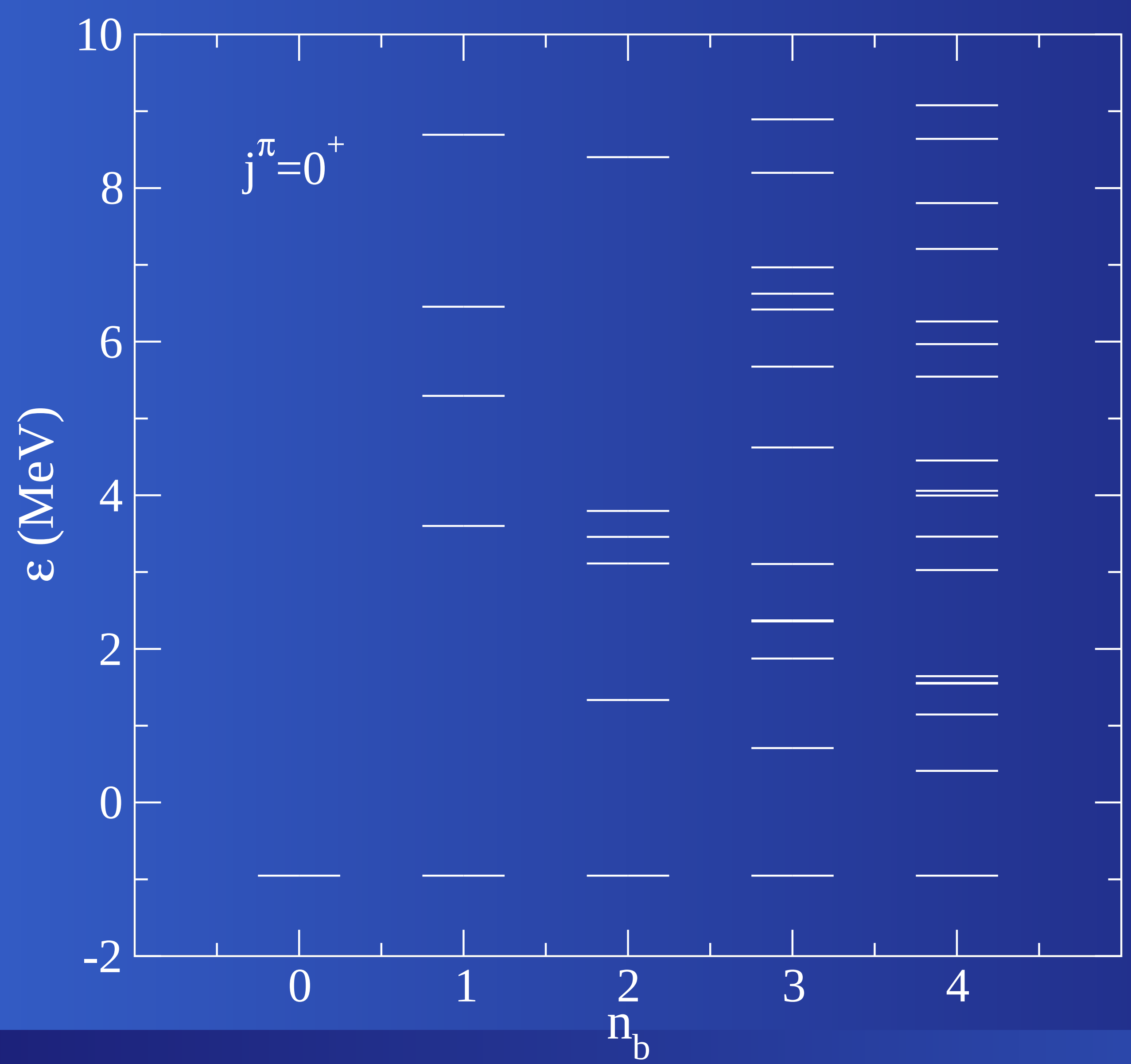
- GPT $n+n$ $\boxed{V_{nn} = V_c + V_{SO} + V_t}$

  V_c, V_t, V_{SO}: Gaussian

- $n+n+\alpha$: power $\boxed{V_{pow} = \frac{a}{[1+(r/b)^c]}}$

- Pauli forbidden states: repulsive V_c for s-waves

Energy spectrum



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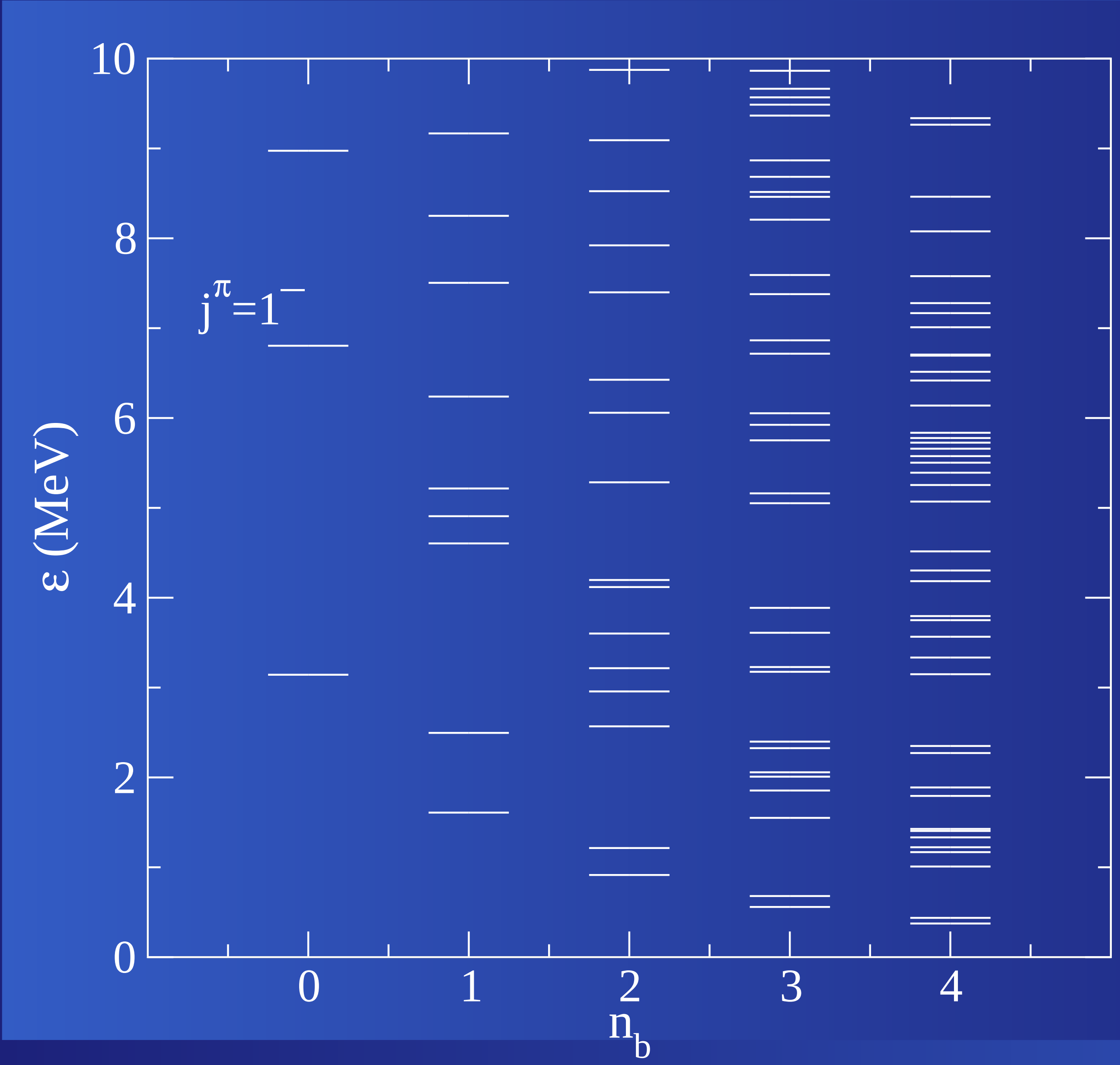
Energy spectrum



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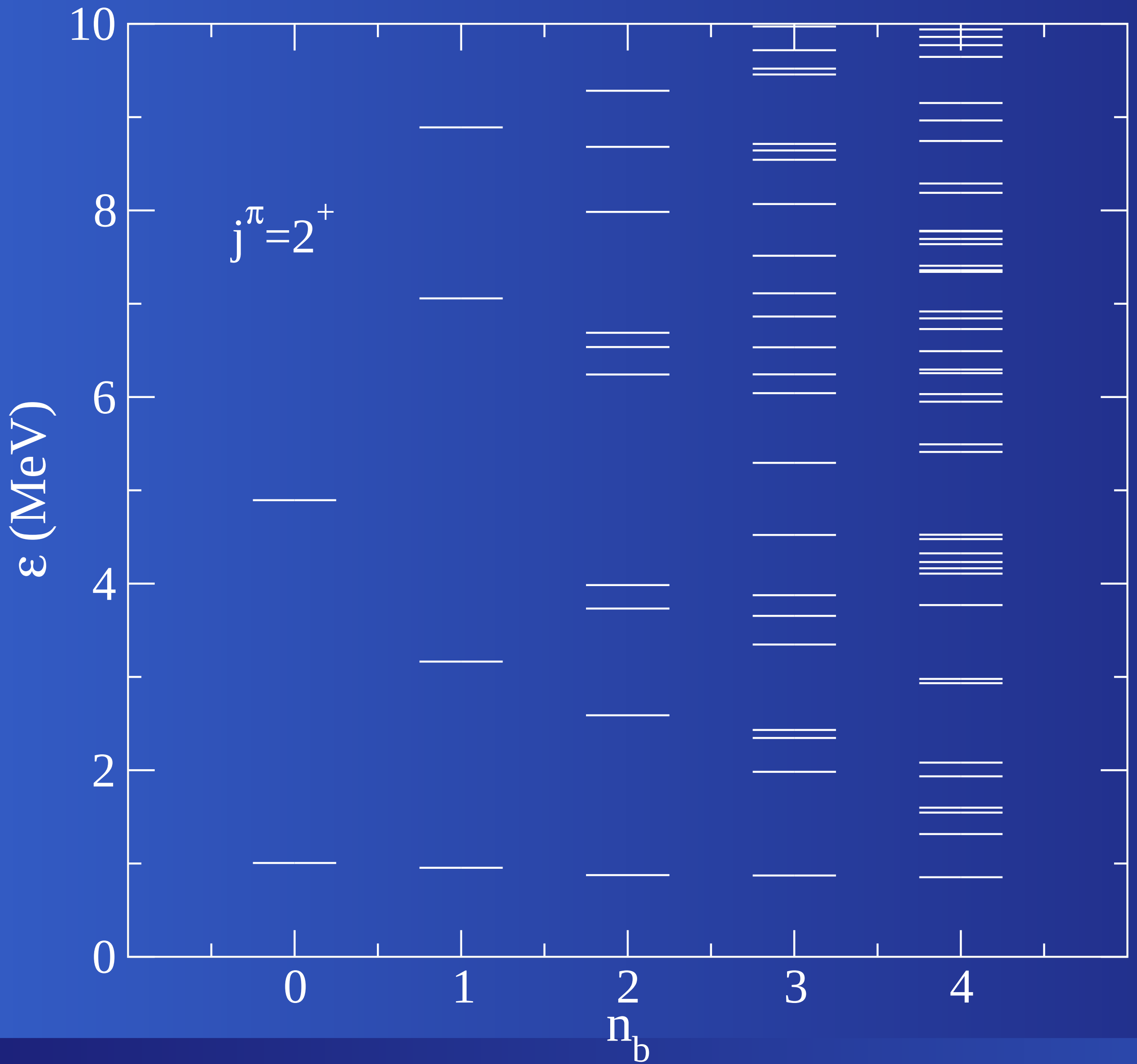
Energy spectrum

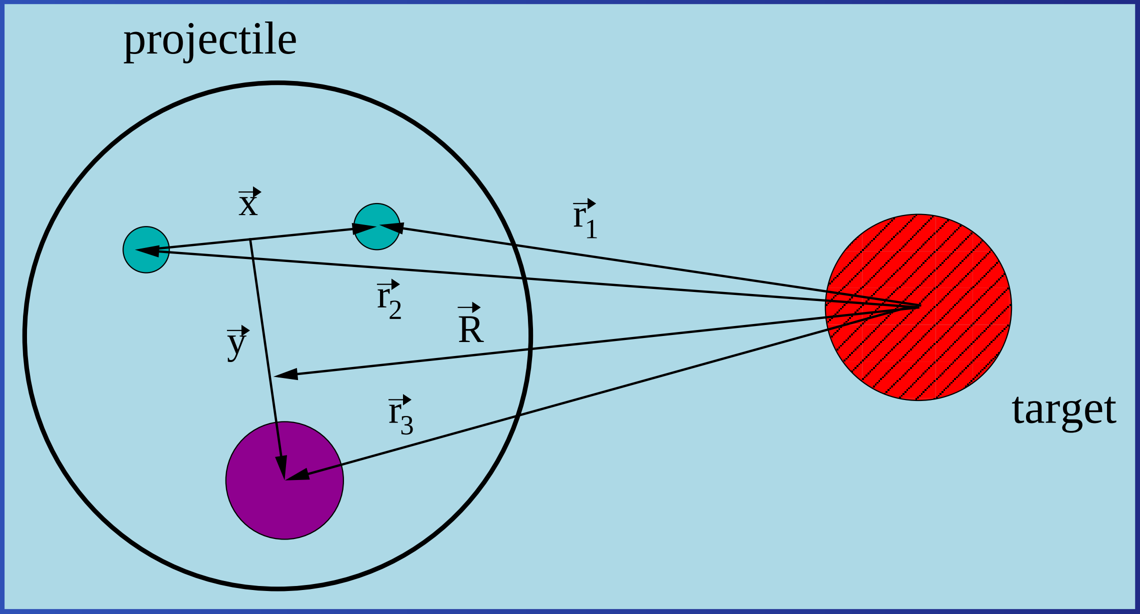


$K_{max} = 8$

Scattering: ^{6}He+target

- CDCC formalism
- THO method
- Coupling potentials for 4-body problem

$$V^{J}_{Lnj,L'n'j'}(R) = \langle LnjJM | \sum_{k=1}^{3} \widehat{V}_{kt}(\vec{r}_k) | L'n'j'JM \rangle$$



Interaction potentials

$$V_N(r) = U(r) + iW(r)$$

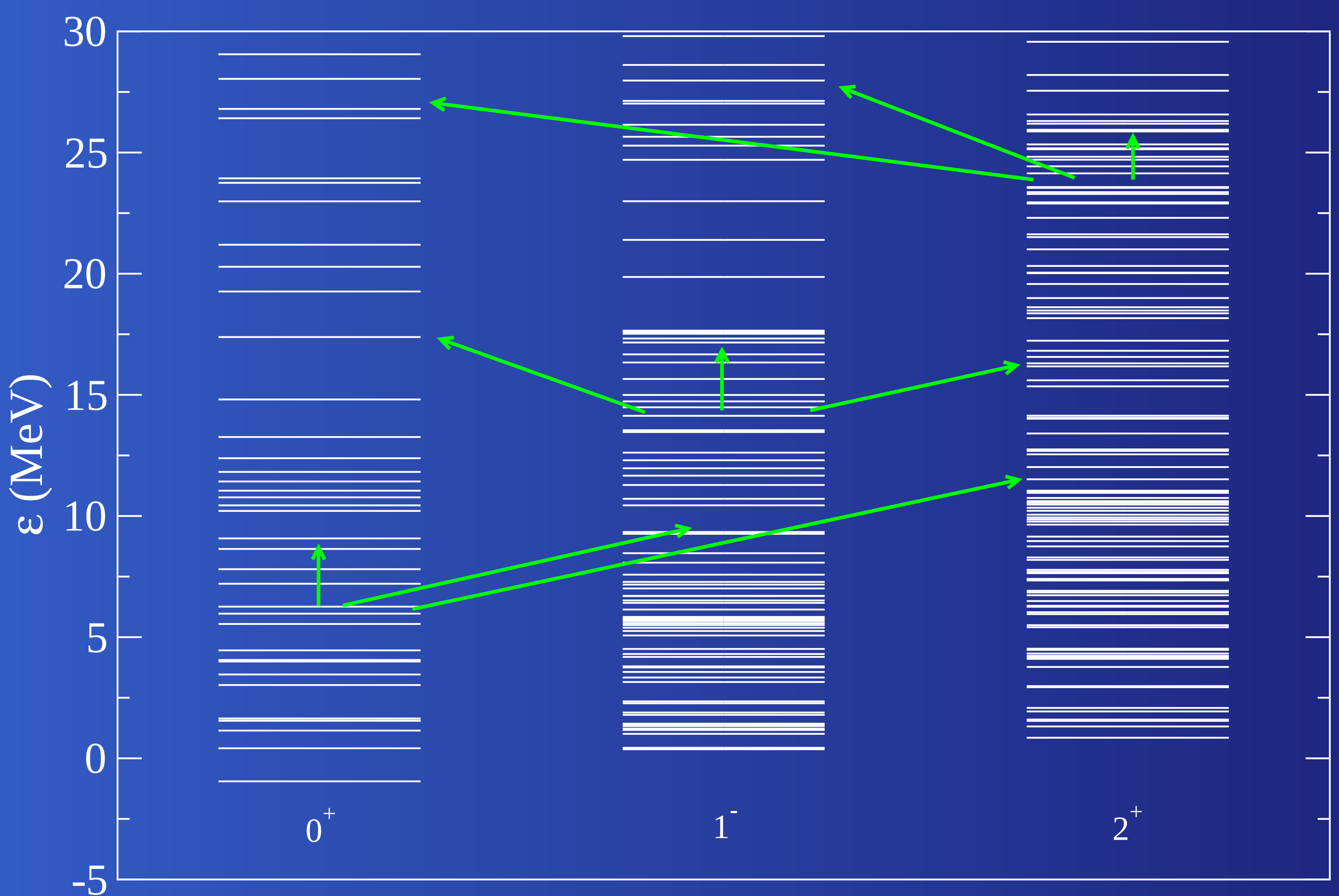
where

$$W(r) = n_i U(r)$$

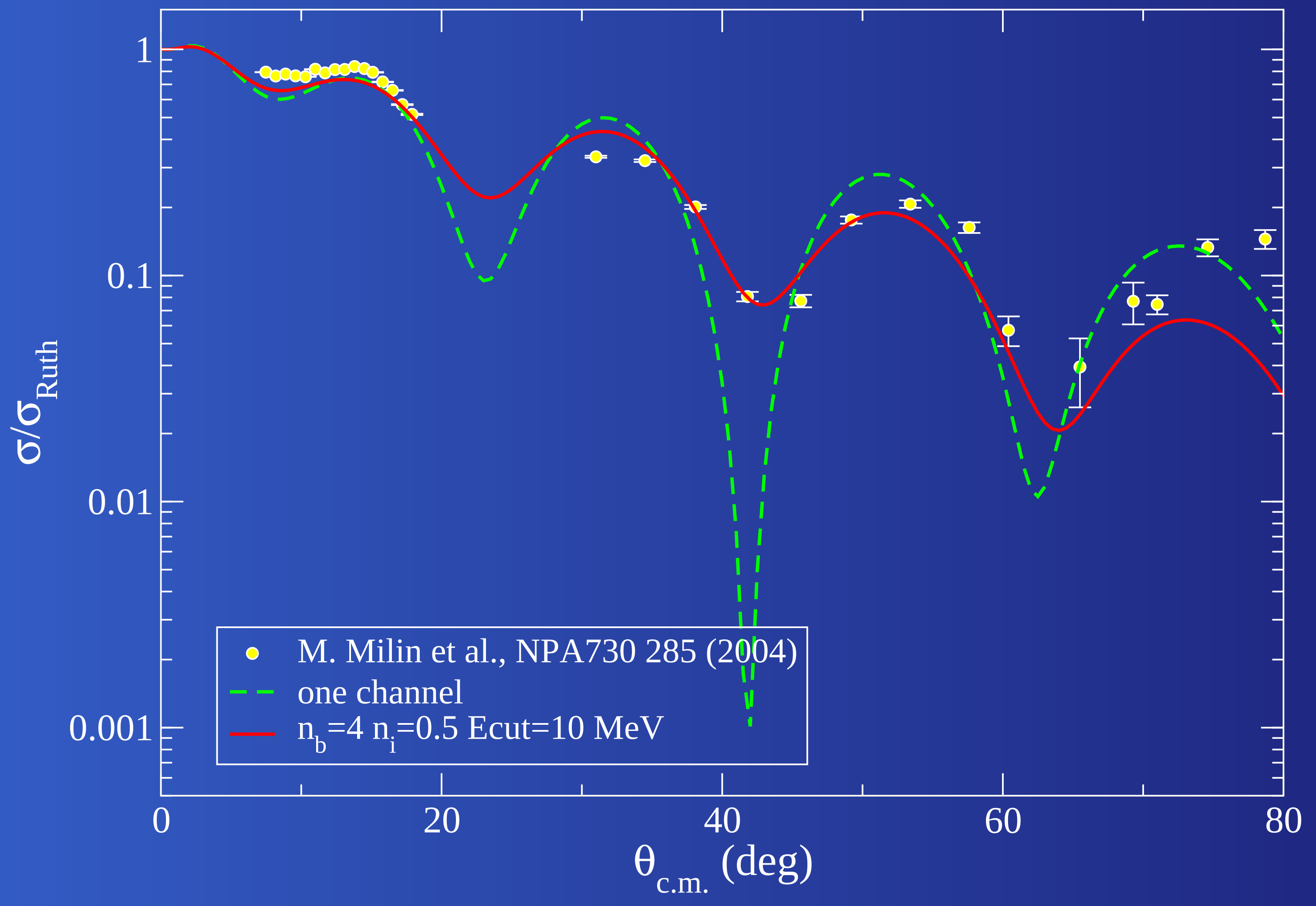
with n_i a parameter chosen in order to reproduce σ_e

$$V_C(r) = \begin{cases} \frac{zZe^2}{2r_0}\left(3 - \frac{r^2}{r_0^2}\right) & r < r_0 \\ \frac{zZe^2}{r} & r > r_0 \end{cases}$$

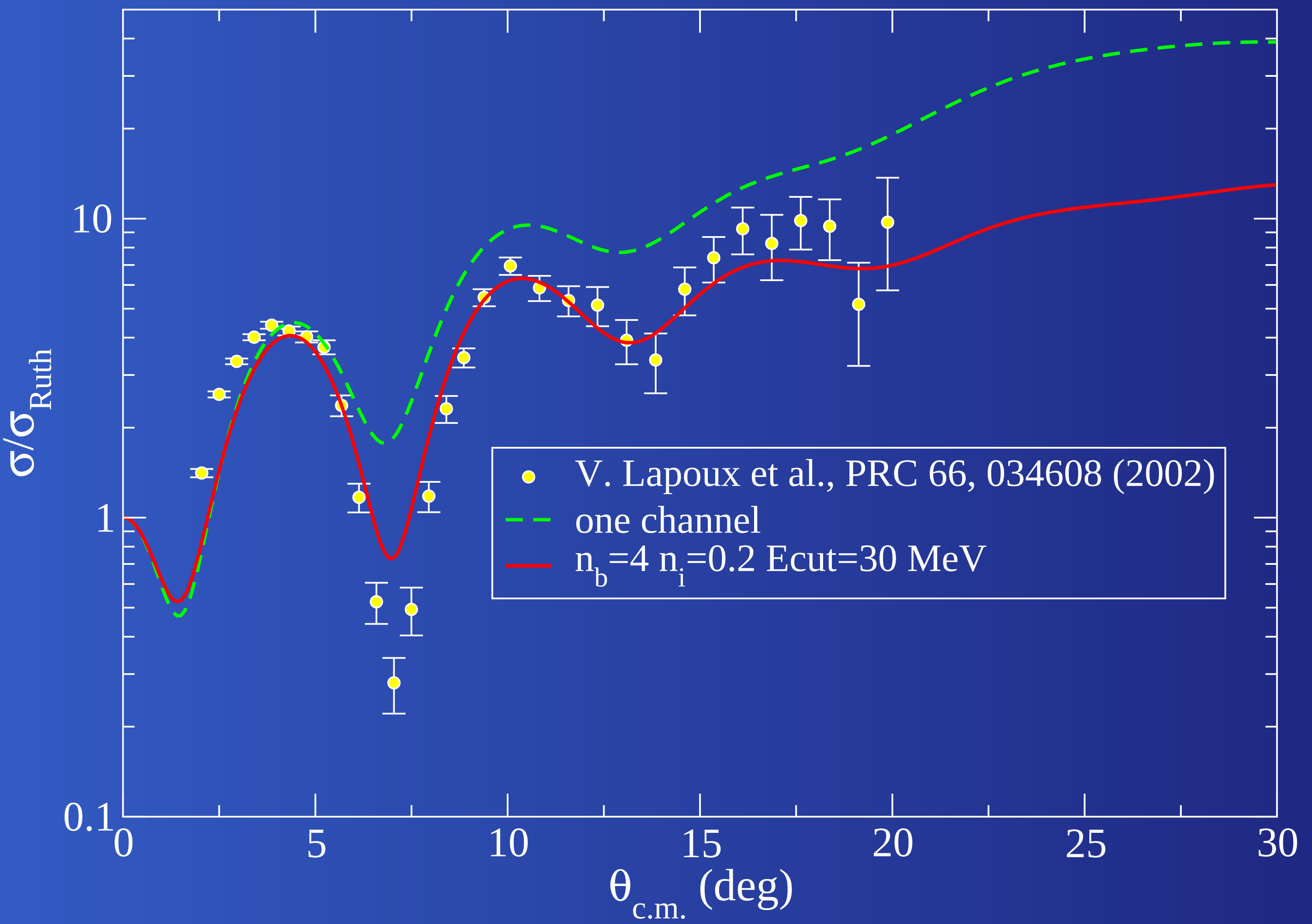
Energy spectrum $n_b = 4 \; K_{max} = 8$



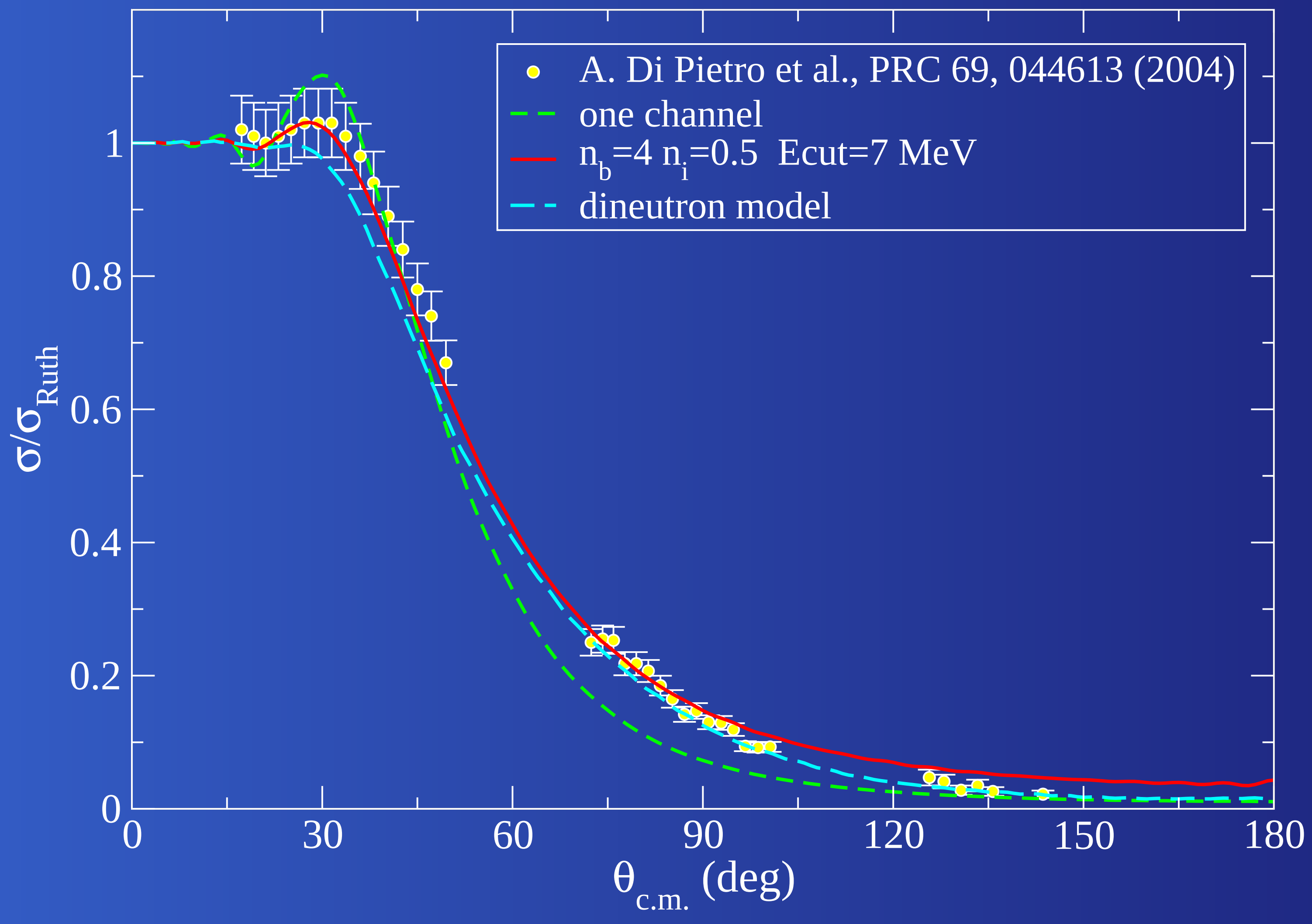
^{6}He+^{12}C@18MeV



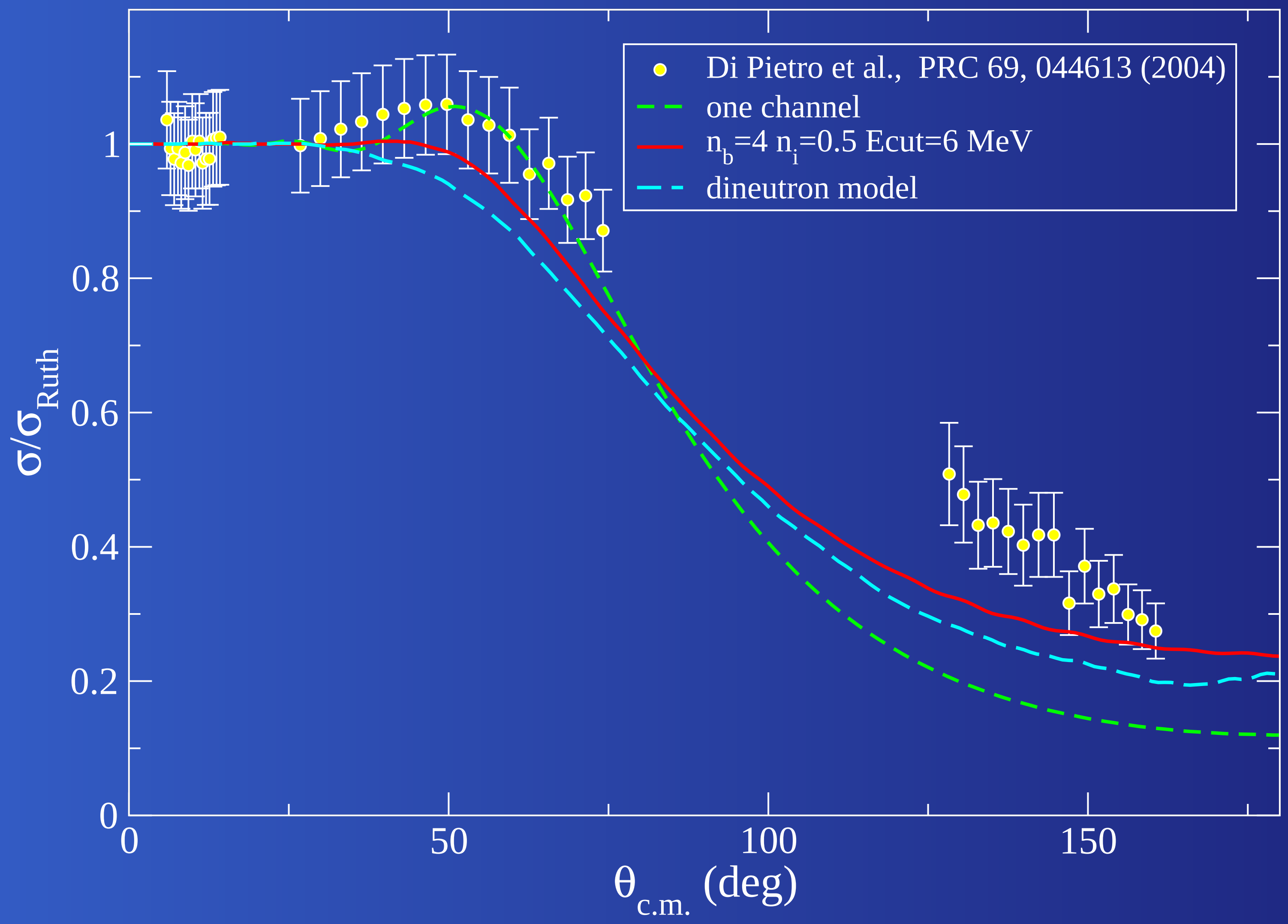
$^{6}He+^{12}C$@229.8MeV



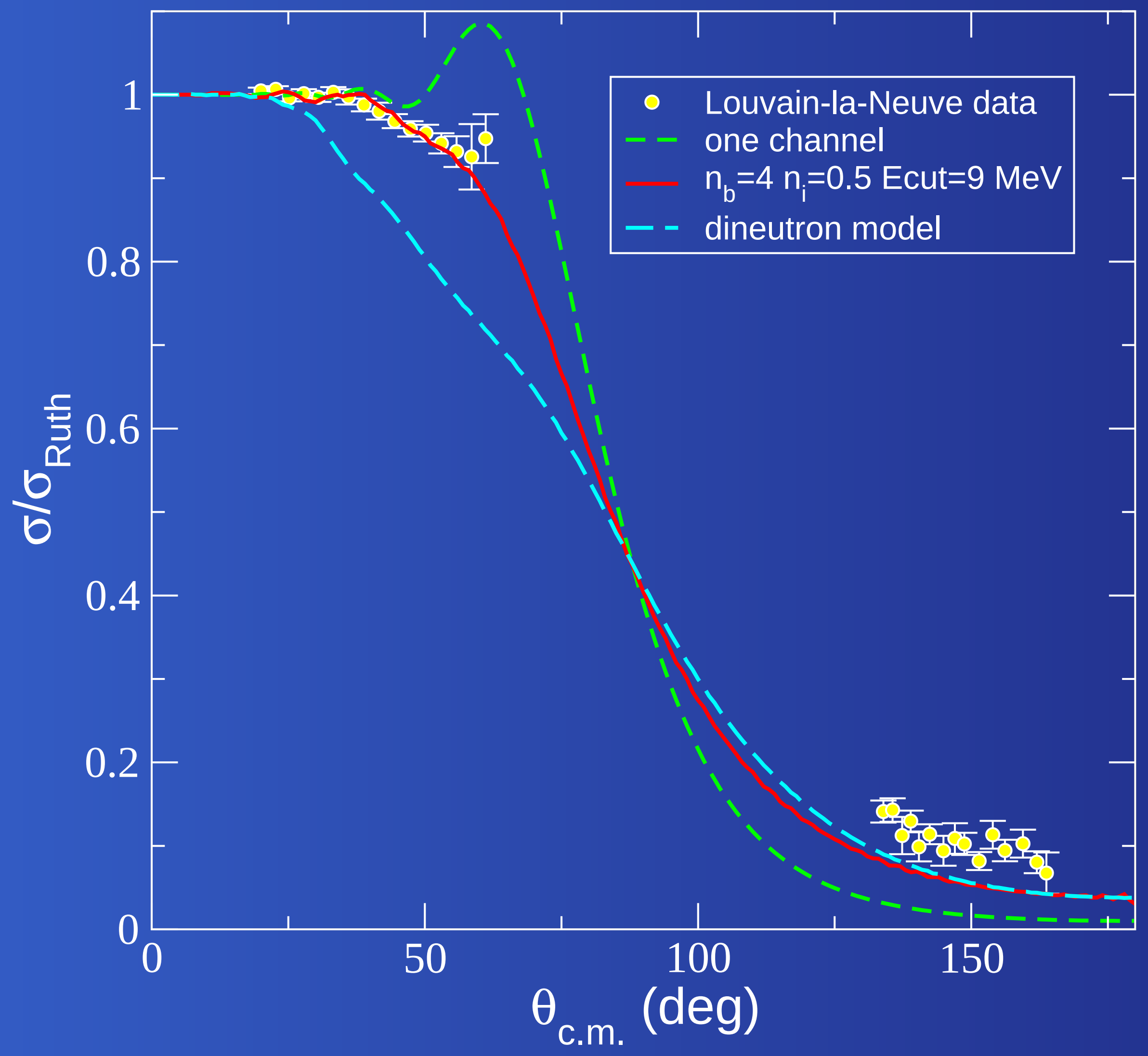
$^{6}He+^{64}Zn@13.6MeV$



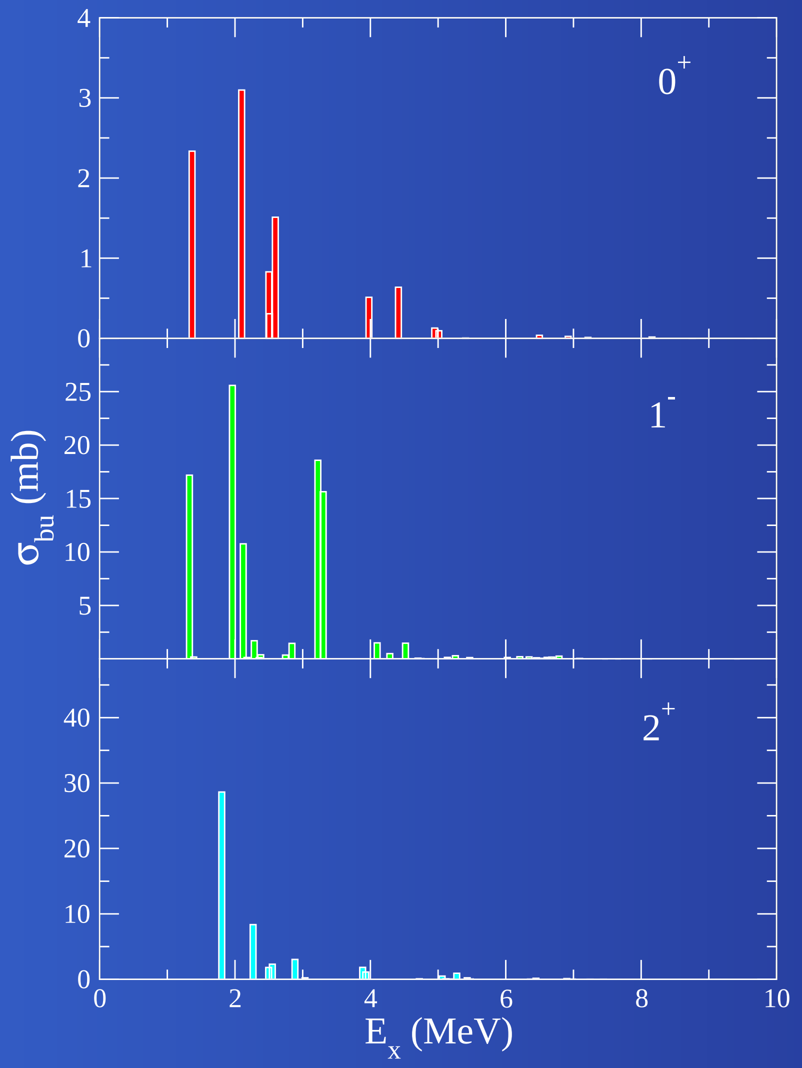
^{6}He+^{64}Zn@10MeV



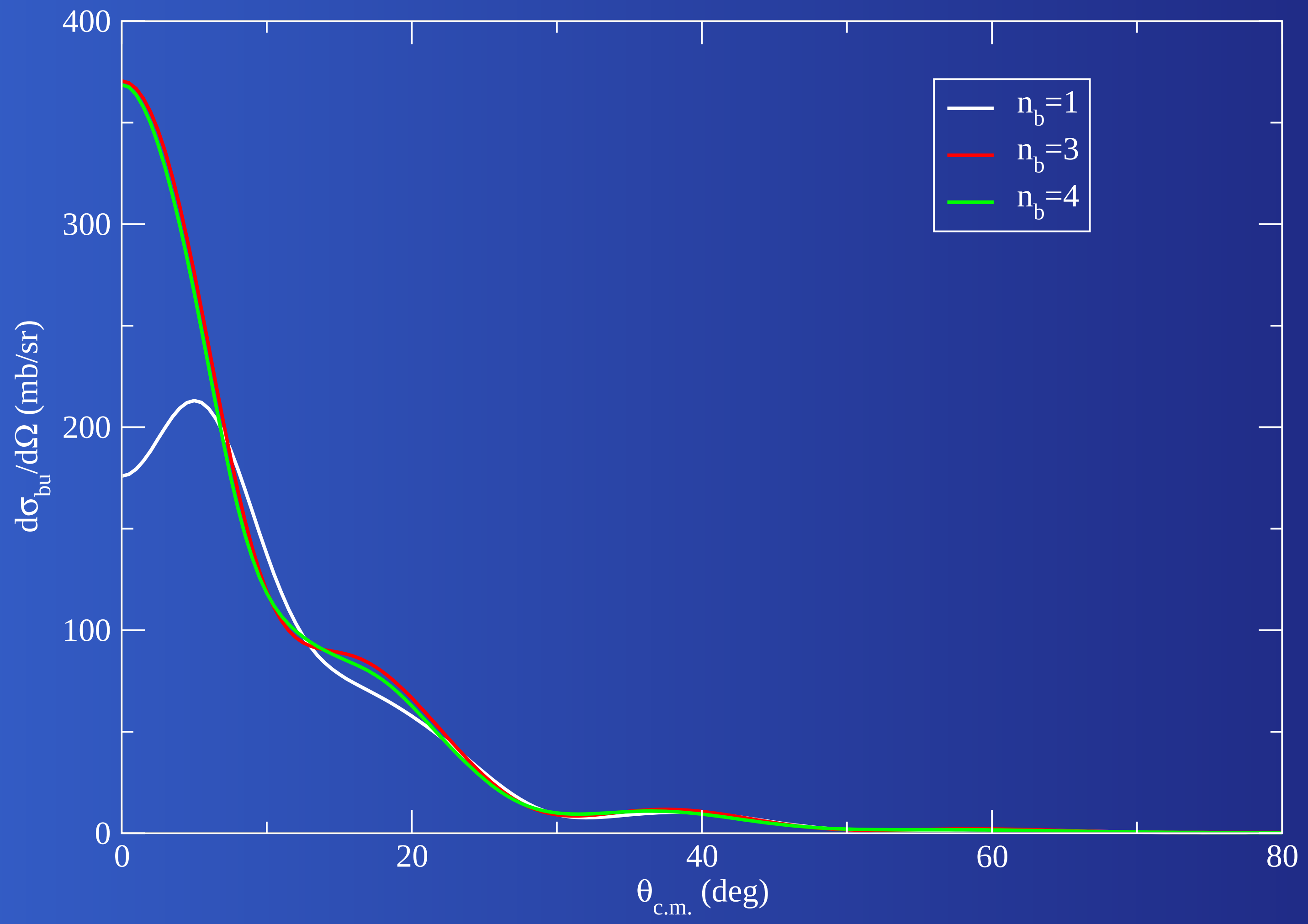
^{6}He+^{208}Pb@22MeV



^{6}He+^{208}Pb@22MeV: Breakup



$^{6}He+^{12}C$@18MeV: Breakup



Summary and conclusions

- We have presented a discretization method (THO) for a three-body system that provides a basis from the knowledge of its ground state.
- The formalism has been applied to the Borromean nucleus ^{6}He.
- We have performed CDCC calculations for the reaction of ^{6}He with different targets and at differents energies.

Summary and conclusions

In general we can say:

- A proper inclusion of the three-body continuum is essential to describe the scattering of ^{6}He.
- The CDCC calculations with THO as discretization method is an efficient procedure for the treatment of three-body projectiles.
- The dineutron model is inappropriate to describe ^{6}He scattering.

Open questions

- Proper treatment of absorption.
- Understanding better the complicated convergence of the four-body CDCC calculations.
- Calculation of α and neutrons breakup observables.
- Application to other Borromean nuclei like ^{11}Li, ^{14}Be.