Core deformation in weakly-bound exotic nuclei and the transfer to the continuum of 17C

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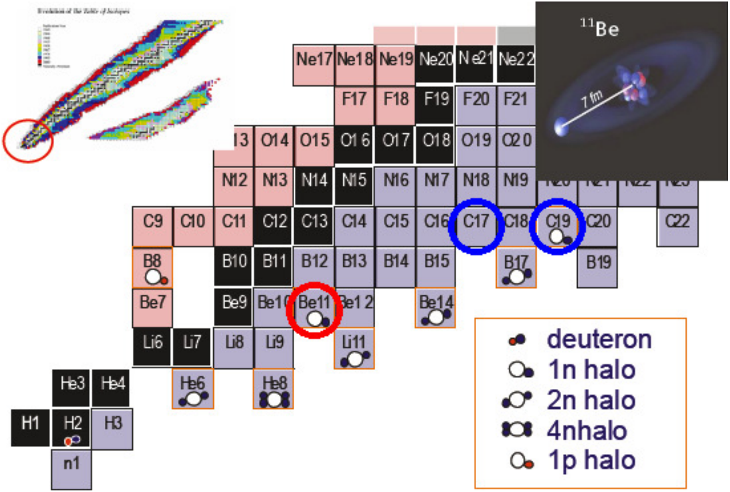
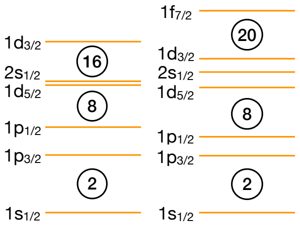
Bussang, 22nd September 2026

Light Exotic Nuclei

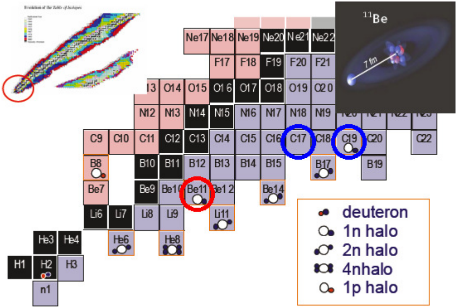


A playground for Shell evolution

- Different properties
  - Halo nature
  - Continuum
  - Deformation
  - Shell evolution

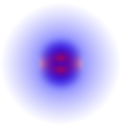


^{17}C Stable Nuclei



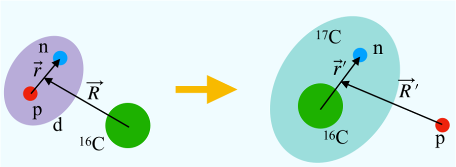
^{11}Be(gs)

^{17}C(1ex)



^{19}C(gs)

Experimental motivation ^{16}C(d,p)^{17}C @ 17.2 MeV/u

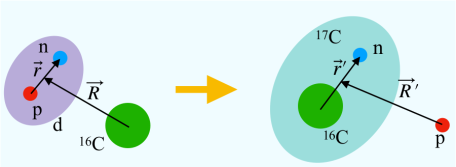


Experiment performed @ GANIL PLB811 (2020) 135939

- $\Rightarrow$ Possible halo excited state $1/2^+$
- $\Rightarrow$ Finding position of $d_{5/2}$, $s_{1/2}$, and $d_{3/2}$ single-particle orbits for possible $N = 16$ shell closure
  - ! But we have deformation

$$T^{(prior)} \approx \langle \Phi_{17C} \chi^{(-)}_{17C-p} | V_{n-16C} | \phi_{n-p} \Phi_{16C} \chi^{(+)}_{16C-d} \rangle$$

Ingreedients for the reaction



$$T^{(prior)} \approx \langle \Phi_{17C}\chi^{(-)}_{17C-p}|V_{n-16C}|\phi_{n-p}\Phi_{16C}\chi^{(+)}_{16C-d}\rangle \propto \langle \Phi_{17C}|\Phi_{16C}\rangle V_{n-16C}$$

$$\langle \Phi_{17C}|\Phi_{16C}\rangle \approx SA\phi_{n-16C}$$

$$SF = |SA|^2 = \int d\vec{r}|\langle \Phi_{17C}|\Phi_{16C}\rangle|^2$$

Challenges

- ✓ Continuum
- ✓ Deformation
- x Transfer to the continuum with models including deformation
- ? Pairing

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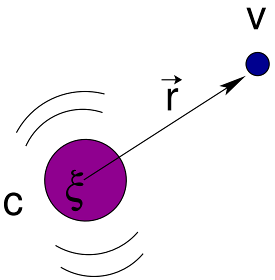
Structure models to account for deformation

⇒ Weak Coupling: PAMD

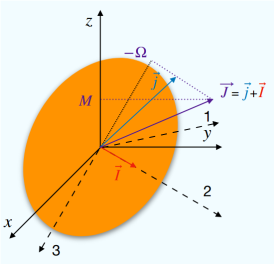


✓ No free parameters

x Not antisymmetrized

PRC89 (2014) 014333

⇒ Strong Coupling: Nilsson Model

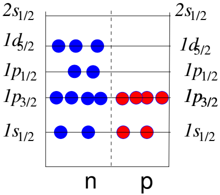


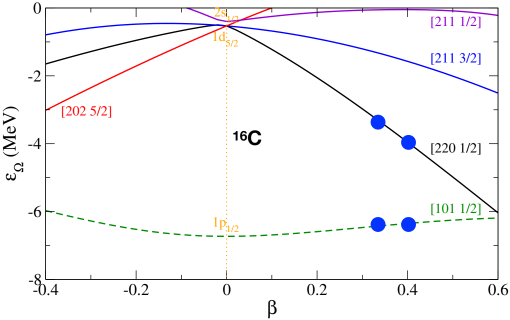
✓ easier to retrieve Pauli Blocking

✓ NAMD: no free parameters

P. Punta's PhD. thesis

Structure models to account for deformation

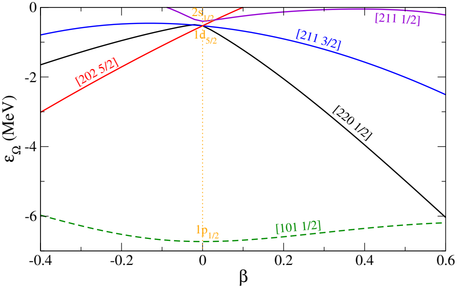




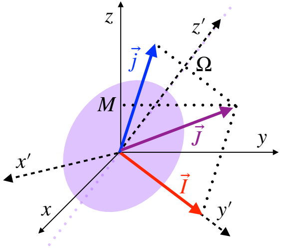
Particle-rotor model based in Nilsson Model

$$\mathcal{H}_N = T(\vec{r'}) + V_c(r) - \beta r \frac{dV_c(r)}{dr} Y_{20}(\hat{r}') + V_{\ell s}(r)(\vec{\ell}\cdot\vec{s})$$

$\Rightarrow$ Nilsson levels $[N n_{z'} \Lambda \Omega]$



$\Rightarrow$ We add $\mathcal{H} = \mathcal{H}_N + \frac{\hbar^2}{2\mathcal{J}}\vec{I}^2$



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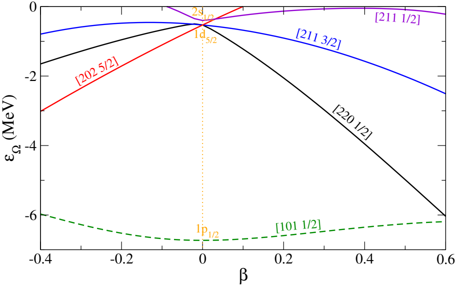
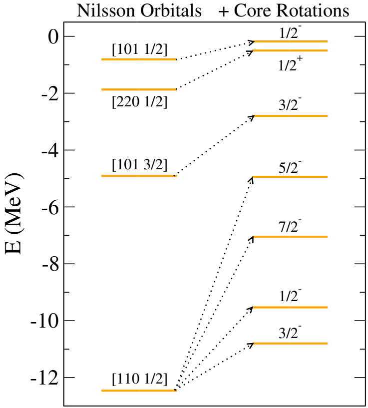
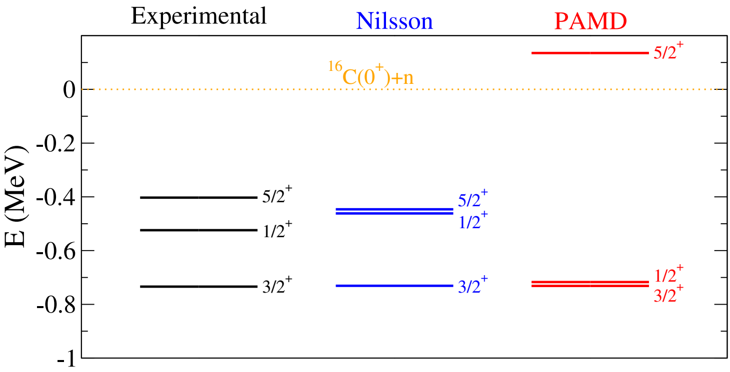
$$\mathcal{H} = T(\vec{r'}) + V_c(r) - \beta r \frac{dV_c(r)}{dr} Y_{20}(\hat{r}') + V_{\ell s}(r)(\vec{\ell}\cdot\vec{s}) + \frac{\hbar^2}{2\mathcal{J}}\vec{I}^2$$



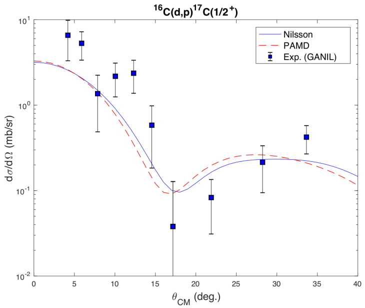


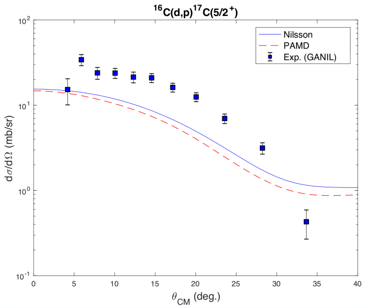
Level scheme



P. Punta *et al* PRC108, 024613 (2023)

Reaction ^{16}C$(d,p)^{17}$C

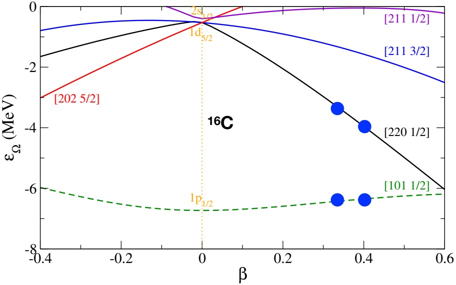


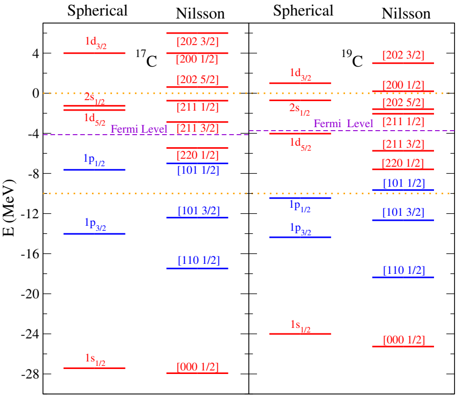


$\Rightarrow$ $1/2^+$ r.m.s. radius 6.44 fm in Nilsson (5.24 fm in PAMD)

$\Rightarrow$ no $d_{3/2}$ $\Rightarrow$ should be in the continuum, $N = 16$ closure?

Role of Pauli-Blocking and Pairing





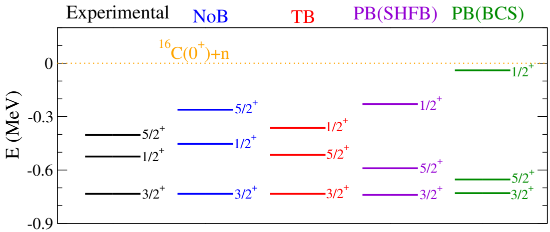
⇒ No Blocking

⇒ Total Blocking

⇒ Partial Blocking

- BCS
- sHFB

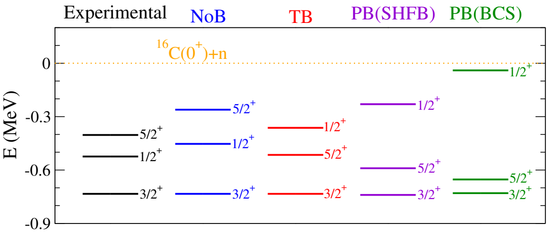
Role of Pauli-Blocking and Pairing

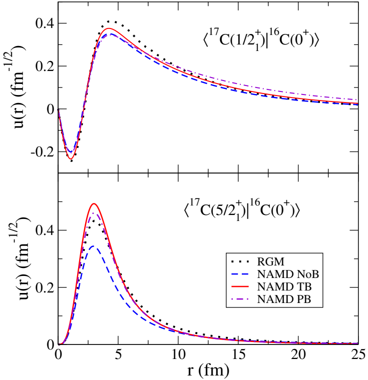


SF $(\langle^{17}\mathrm{C}(5/2^+)|^{16}\mathrm{C}(0^+)\otimes 1d_{5/2}\rangle)$

NoB	TB	PB	RGM	GANIL
0.33	0.66	0.59	0.56	0.62±0.13

Role of Pauli-Blocking and Pairing

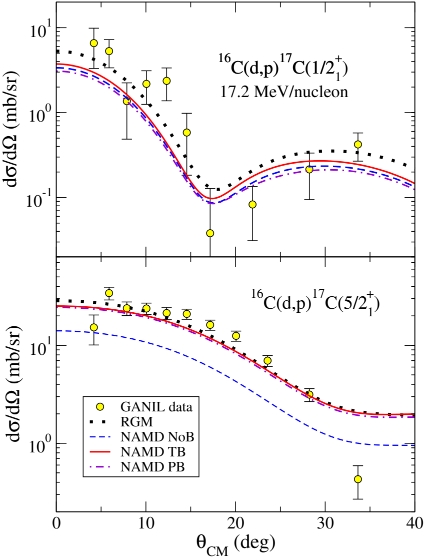




SF ($\langle ^{17}\mathrm{C}(5/2^+)\vert ^{16}\mathrm{C}(0^+) \otimes 1d_{5/2}\rangle$)				
NoB	TB	PB	RGM	GANIL
0.33	0.66	0.59	0.56	0.62±0.13

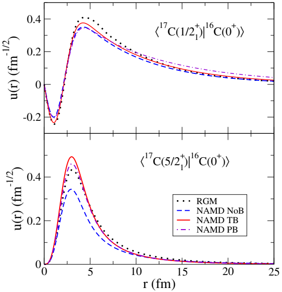
P. Punta *et al* PRC111, 064614 (2025)

⇒ RGM from P. Descouvemont [PRC 108, 044605 (2023)]



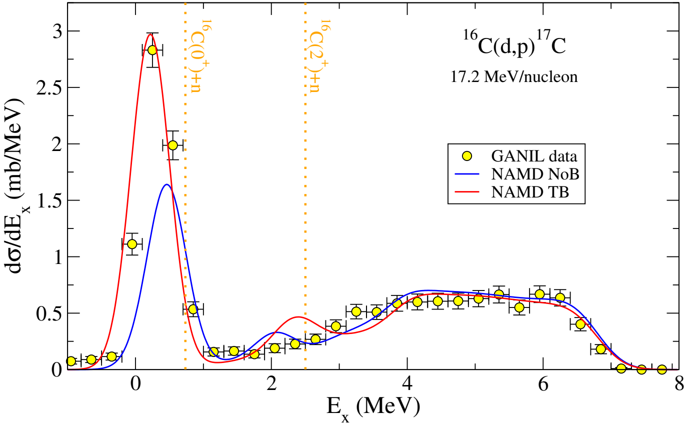
✓ Good agreement of both PB and TB

⇒ We decided to continue only with TB for exploring the continuum



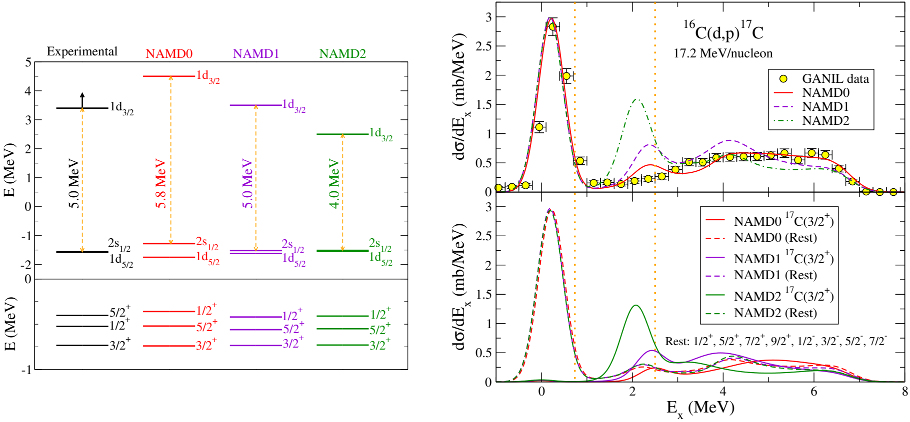
Then you get a reward

$^{16}C(d,p)^{17}C$: Bound and unbound states



GANIL data: Lois-Fuentes *et al.* PLB**867** 139600 (2025)

^{16}C$(d,p)^{17}$C: $N = 16$ shell gap



A shell gap greater than 5 MeV is required to be consistent with the data

P. Punta *et al* PLB879, 140653 (2026)

Conclusions

Conclusions

- ⇒ NAMD model successfully reproduced transfer reaction to ^{17}C experimental data
- ⇒ It required to combine deformation and right treatment of the continuum and Pauli Blocking
- ⇒ TB model obtained similar results as sHFB
- ⇒ Shell gap greater than 5 MeV at $N = 16$ shell closure

Outlook

- ⇒ Applying the model to heavier exotic nuclei ^{31}Ne, ^{37}Mg ⇒ Pairing?

Thank you!!

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Plan Estatal PID2023-146401NB-I00

Discretization of the continuum

⇒ We expand the solutions of the Hamiltonian in a certain basis ⇒ Transformed Harmonic Oscillator (THO)

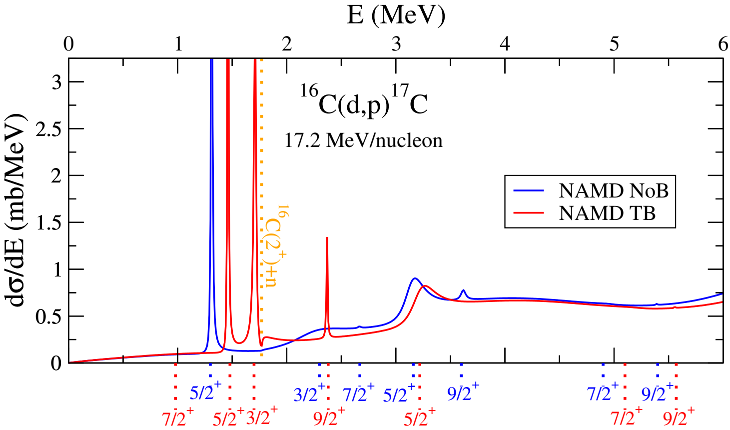
⇒ Eigenstates of ^{17}C are obtained by diagonalizing the Hamiltonian in that basis of a certain size N

- One obtains as many negative energy eigenstates as bound states are in the system (n_b)
- The rest of eigenstates $(N - n_b)$ have positive energy and are a discrete representation of the continuum of the system

⇒ Transfer cross section is later calculated as if they were bound states ⇒ set of discrete values.

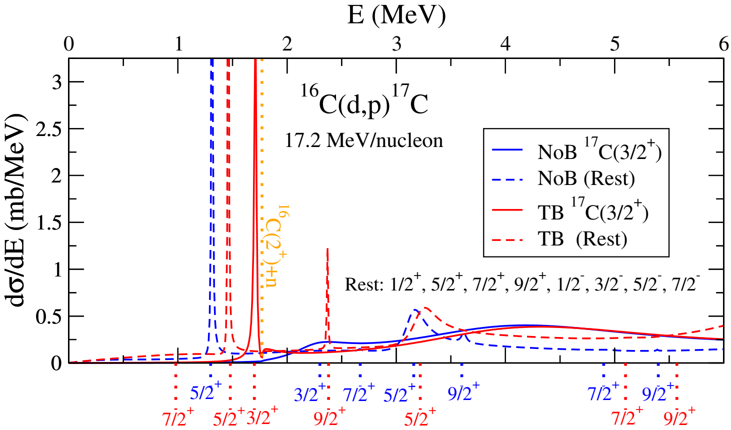
⇒ Energy distribution of the transfer cross section is recovered as we know $\langle THO|\vec{k}\rangle$

^{16}C$(d,p)^{17}$C: Transfer to the continuum



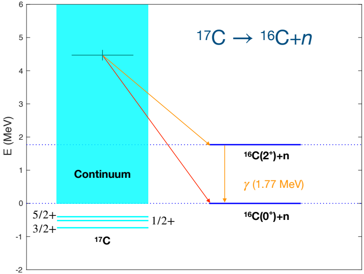
- Energy with respect to ^{16}C$(0+) + n$ threshold
- Several narrow resonances at low energies

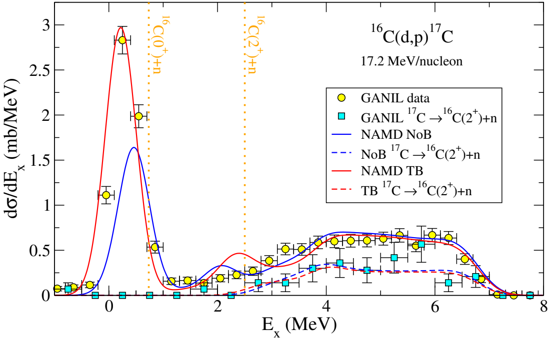
$^{16}C(d,p)^{17}C$: Transfer to the continuum



- Energy with respect to $^{16}C(0+) + n$ threshold
- Several narrow resonances at low energies
- Major contribution associated with the population of $3/2^+$ states

^{16}C$(d,p)^{17}$C: Bound and unbound states





GANIL data: Lois-Fuentes *et al.* PLB**867** 139600 (2025)