Single-particle structure of ^{17}C studied with the $^{16}C(d,p)$ transfer reaction

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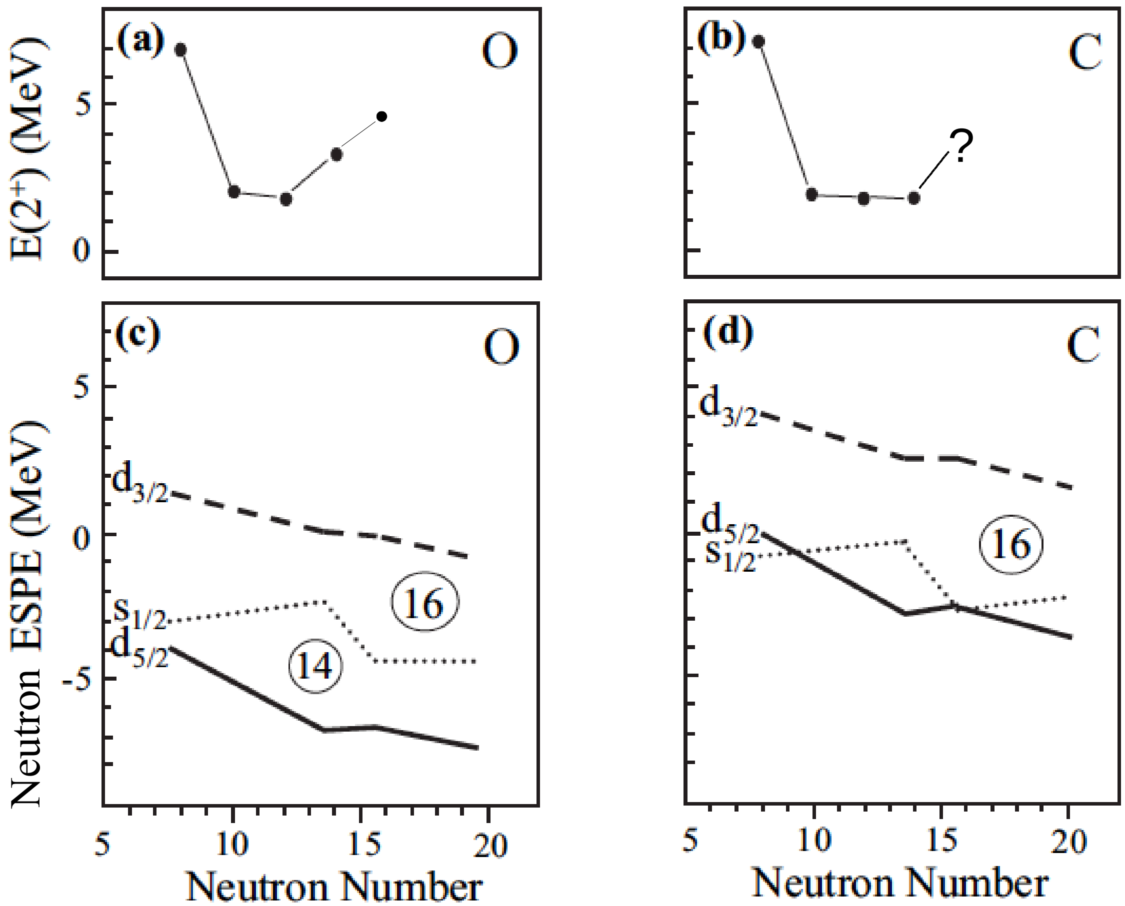
Motivation: Shell gaps in n-rich C isotopes



Stanoiu, PRC 78, 034315

ESPE: shell model (WBT)

^{24}O:

Hoffman, PLB 672, 17

Tshoo, PRL 109, 022501

New shell gaps at N=14 and N=16

ν2s1/2 and ν1d5/2 nearly degenerate

→ No gap at N=14

Gap at N=16?

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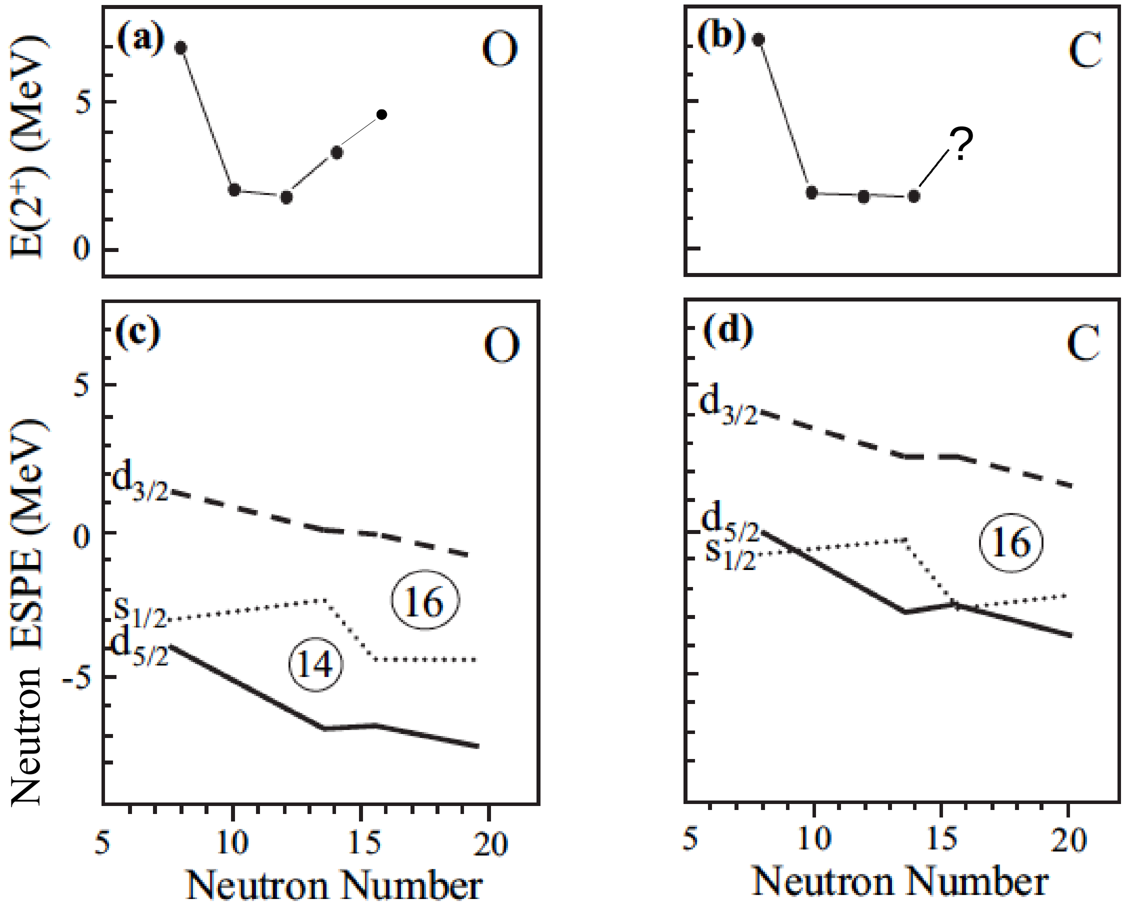

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ESPE: shell model (WBT)

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New shell gaps at N=14 and N=16

Locate $\nu 2s_{1/2}$, $\nu 1d_{5/2}$ and $\nu 1d_{3/2}$ strength in ^{17}C with the ^{16}C(d,p) neutron transfer reaction

States of ^{17}C

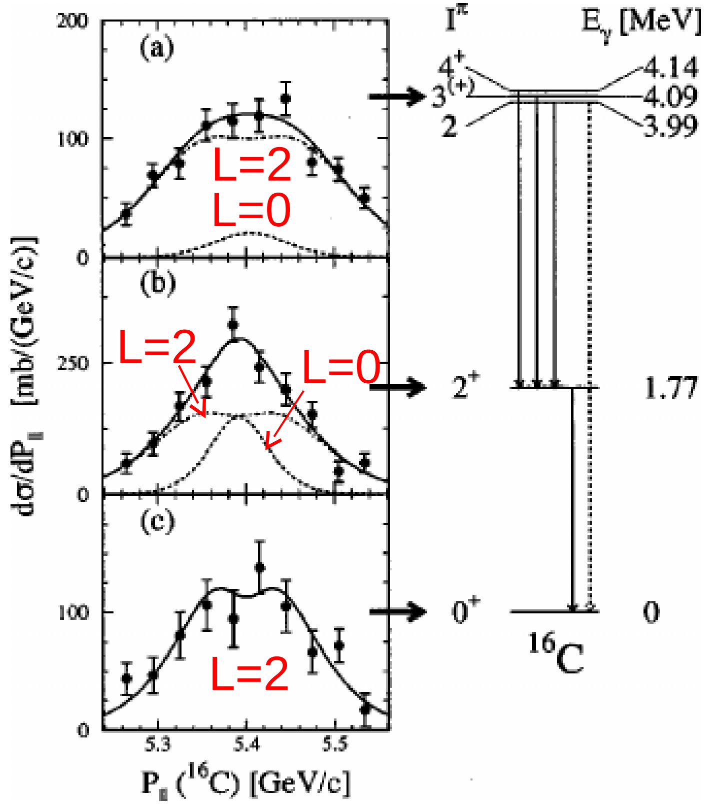
GS: One-neutron removal from ^{17}C

Sauvan, PLB 491, 1 ; PRC 69, 044603
Maddalena, PRC 63, 024613
Rodriguez-Tajes PRC 82, 024305

→ $J^\pi = 3/2^+$

→ $[2^+ \otimes \nu 1d_{5/2}]_{3/2^+}$ dominant component

→ $0^+ \otimes \nu 1d_{3/2}$ $C^2S_{exp} \approx 10 \times C^2S_{WBP}$ (0.03)



Bound excited states

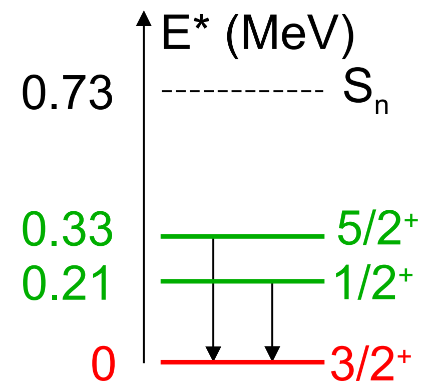
Known energies and spin-parities

Elekes, PLB 614, 174 ; Stanoiu, PRC 78, 034315 ;
Suzuki, PLB 666, 222 ; Kondo, PRC 79, 014602 ;
Ueno, PRC 87, 034316

→ No spectroscopic factors measured

→ $1/2^+$ state = halo candidate → $\ell = 0$ admixture?

Unbound states → No sp configurations probed



Goals of the experiment

- Use $^{16}C(d,p)$ to populate states of ^{17}C carrying single-neutron components

  → Locate the $\nu 1d_{5/2}$, $\nu 2s_{1/2}$ and $\nu 1d_{3/2}$ strengths

  → Investigate existence of N = 14 and 16 gaps in n-rich C isotopes

- Ground-state:

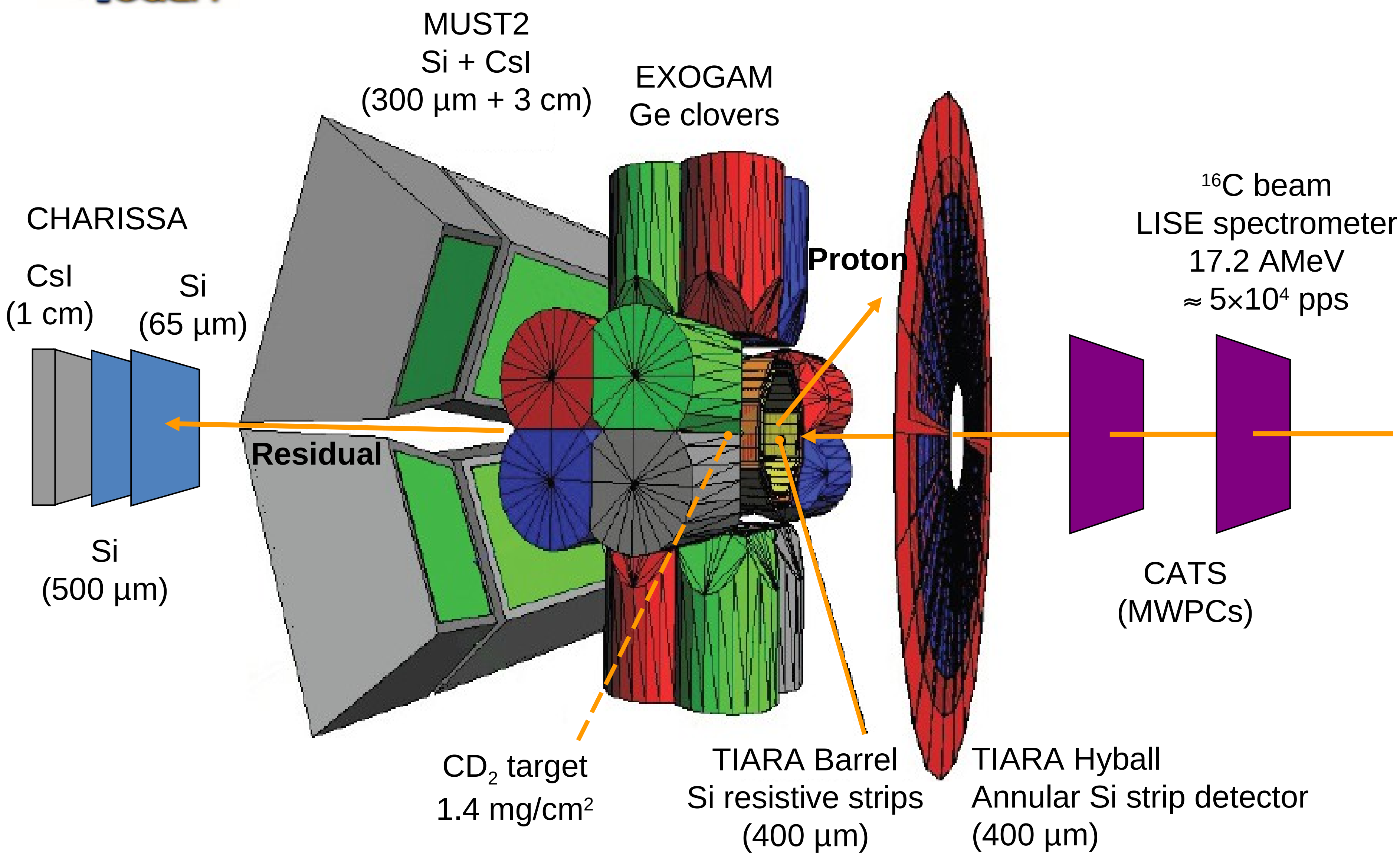
  → Independent measurement of the $0^+ \otimes \nu 1d_{3/2}$ spectroscopic factor

Excited states:

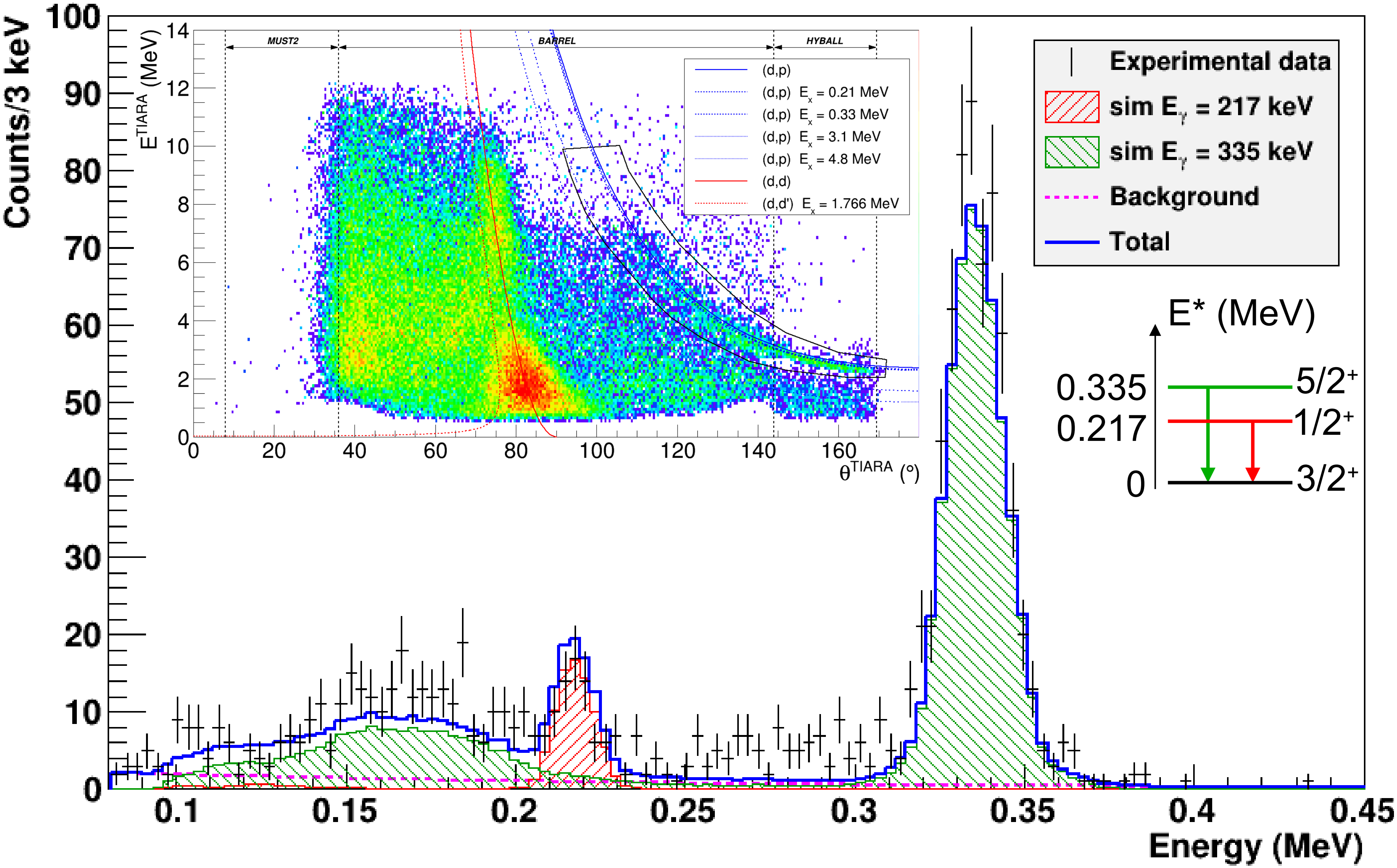
→ $0^+ \otimes \nu n\ell j$ spectroscopic factors

→ $\ell = 0$ admixture in the $1/2^+$ state

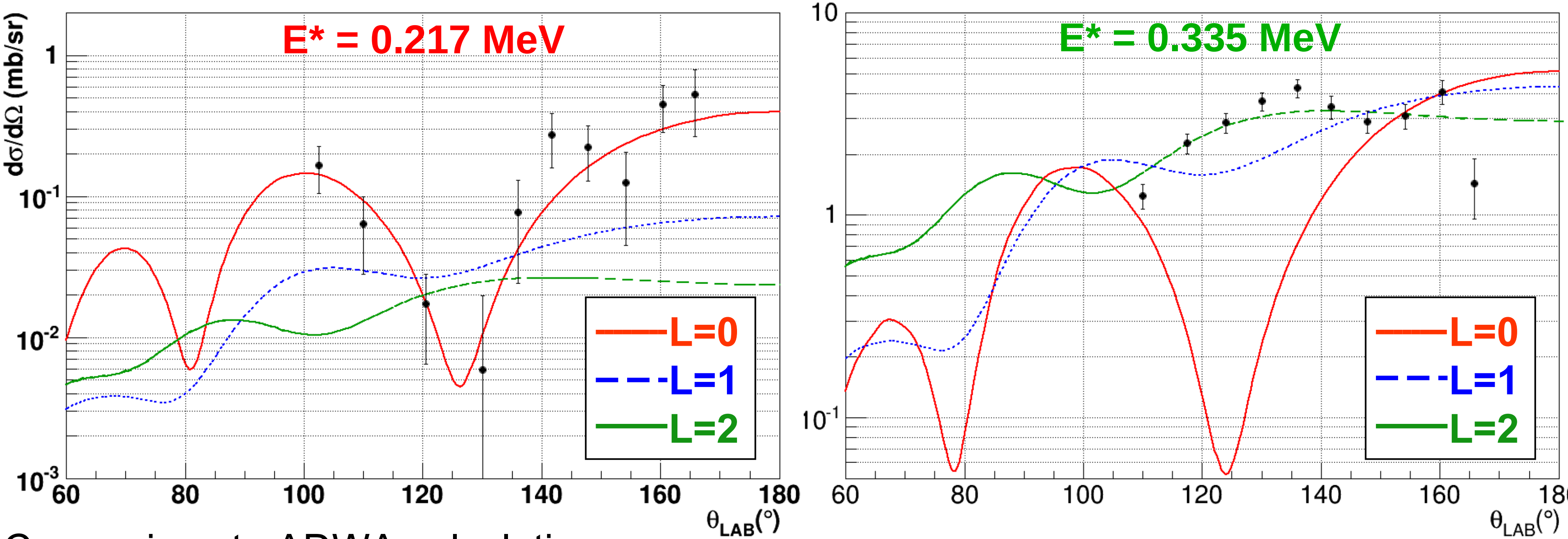
Experimental setup at GANIL



Proton - γ-ray coincidences



Bound states



Comparison to ADWA calculations

E^*_{exp} (MeV)	ℓ ; J^π	C^2S_{exp} (KD - CH89)	C^2S_{max} $^{16}C(-1n)$ *
0.217	0 ; $1/2^+$	0.59 - 0.75	0.70
0.335	2 ; $5/2^+$	0.62 - 0.63	0.80

Large strength fractions exhausted

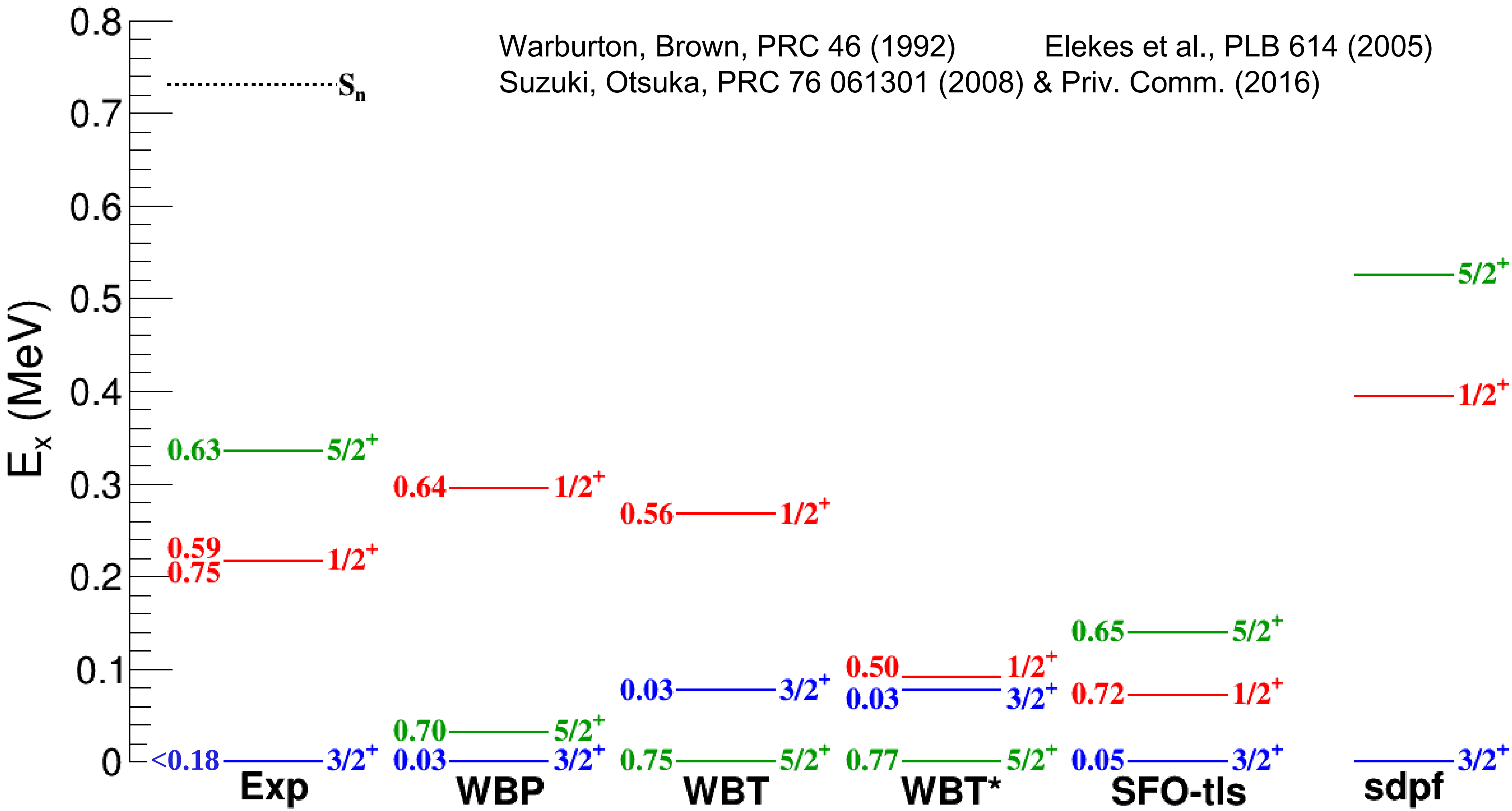
→ ℓ = 0 dominant → Probably halo

* Maddalena, PRC 63, 024613

Cross-section to $^{17}C_{g.s.}$: $\sigma_{gs} = \sigma_{incl.} - \sigma_{5/2+} - \sigma_{1/2+}$ → **C^2S_{exp} < 0.18 (Preliminary)**

Comparison to Shell-Model

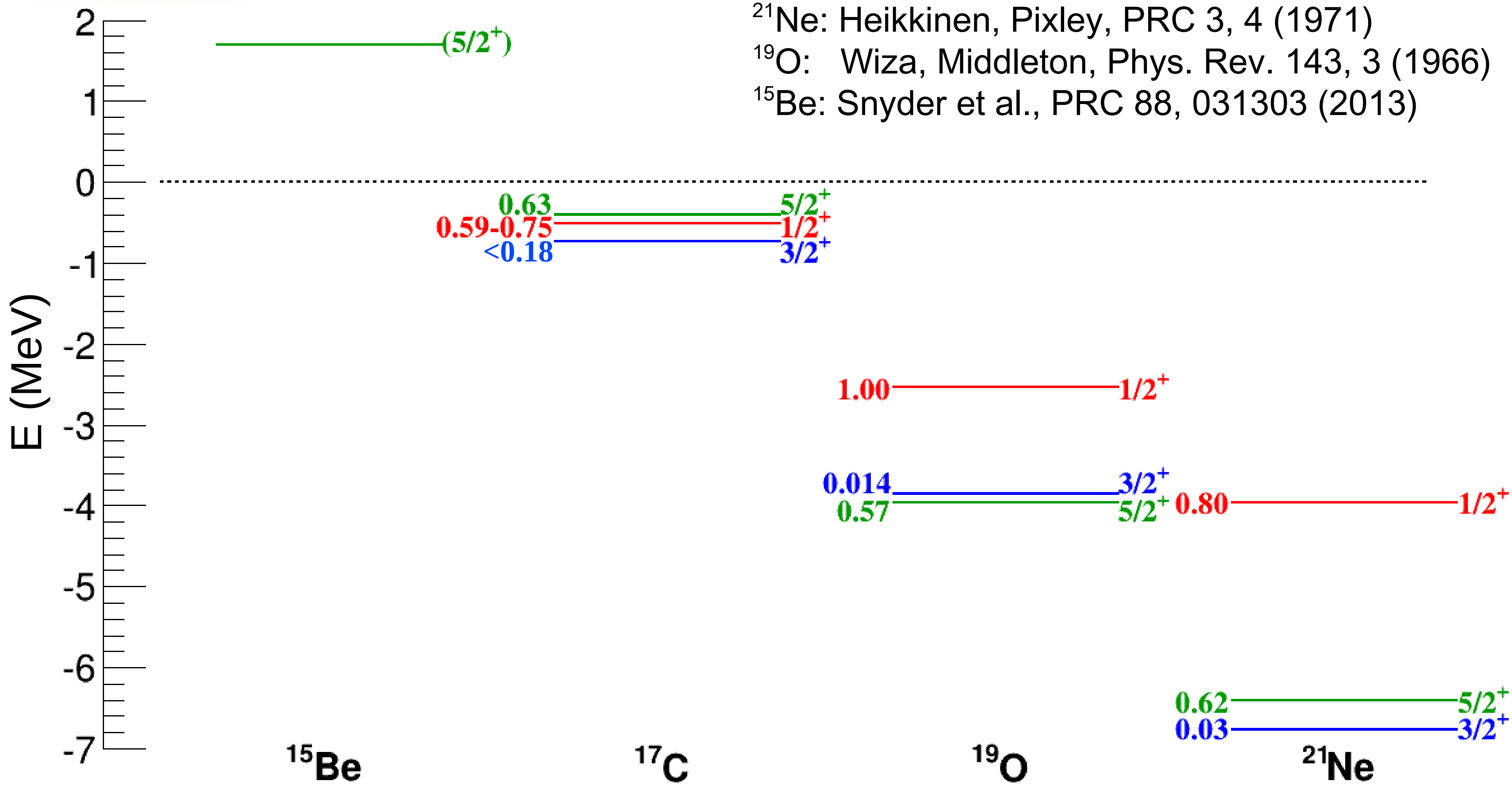
Warburton, Brown, PRC 46 (1992) Elekes et al., PLB 614 (2005)
Suzuki, Otsuka, PRC 76 061301 (2008) & Priv. Comm. (2016)



→ Overall good agreement

N = 11 isotones

^{21}Ne: Heikkinen, Pixley, PRC 3, 4 (1971)
^{19}O: Wiza, Middleton, Phys. Rev. 143, 3 (1966)
^{15}Be: Snyder et al., PRC 88, 031303 (2013)



- $E_{3/2+} \approx E_{5/2+}$
- Given J$^{\pi}$: Similar C^2S_{exp}
- $E_{1/2+} - E_{5/2+}$ decreases towards the dripline
- ^{17}C: 5/2$^+$ and 1/2$^+$ degenerate → no gap at N=14

Summary and outlook

$^{16}C(d,p)^{17}C$ at 17.2 AMeV at GANIL-LISE with TIARA+EXOGAM+CHARISSA

Bound states:

→ ℓ in agreement with previous J^{π} assignements

→ Large fractions of $\nu 2s_{1/2}$ and $\nu 1d_{5/2}$ located

→ $1/2^+$ state at 0.217 MeV: large ℓ = 0 C^2S_{exp} → Probably halo state

→ $3/2^+$ ground state: $C^2S_{exp} < 0.18$

→ C^2S_{exp} in good agreement with shell-model

→ Similar C^2S_{exp} in other neutron-rich N=11 isotones

→ $\nu 2s_{1/2}$ and $\nu 1d_{5/2}$ degenerate → Non-existence of N=14 gap in ^{17}C

Improved $\nu 2s_{1/2} - \nu 1d_{5/2}$ energy difference: combine $^{16}C(d,p)$ and $^{16}C(d,t)$

Further analysis of the ground state and unbound states in progress ($\nu 1d_{3/2}$)

Thank you for your attention!

N = 11 isotones

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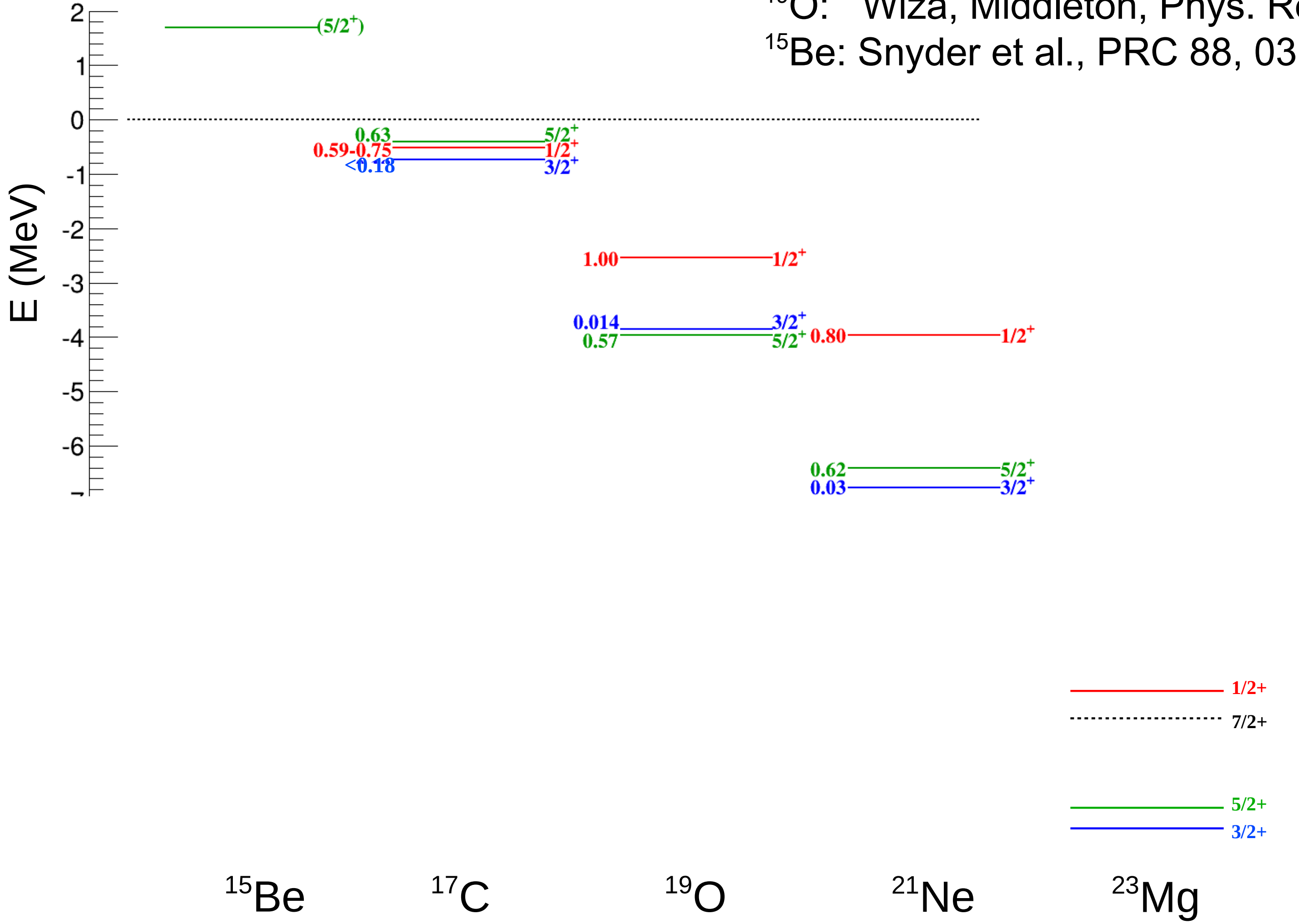
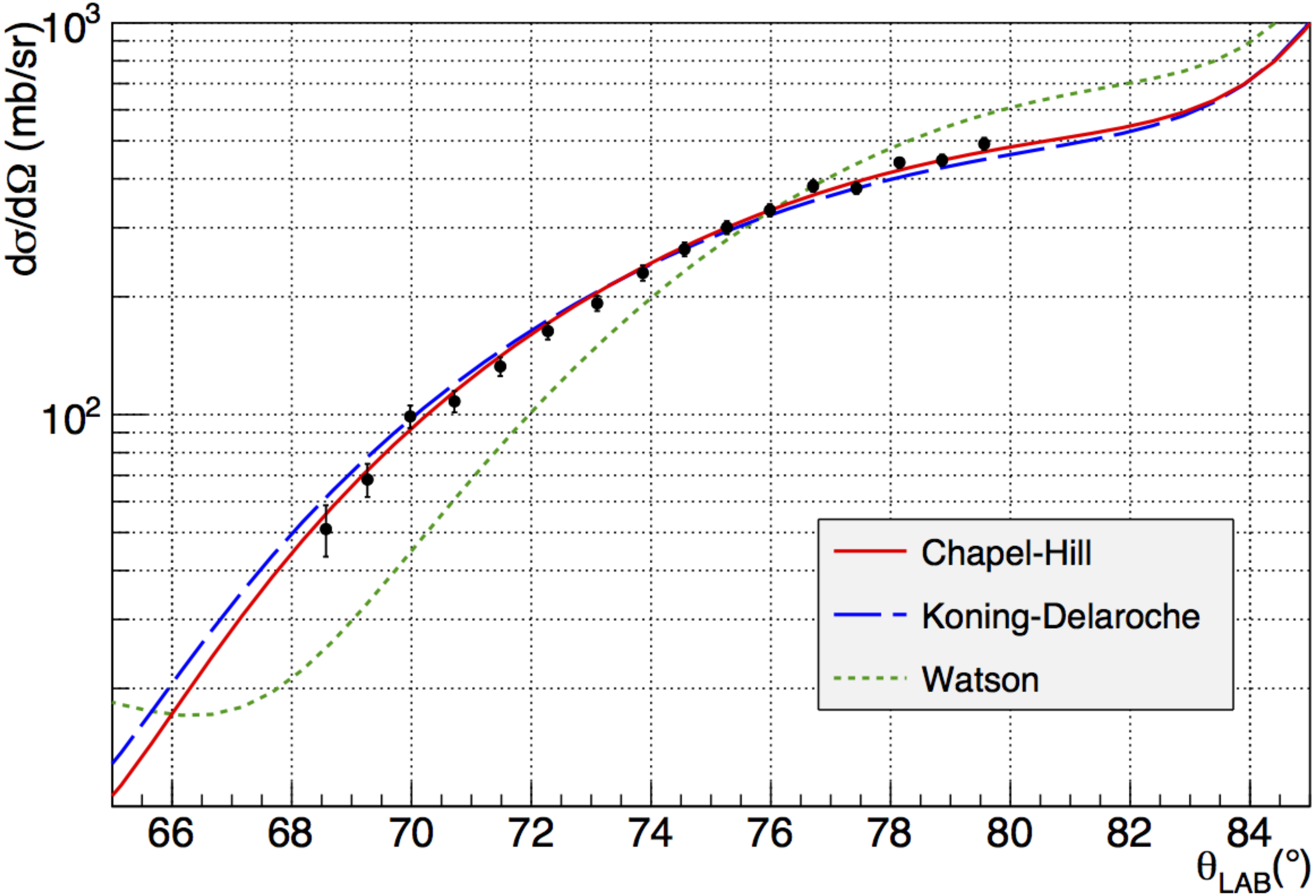
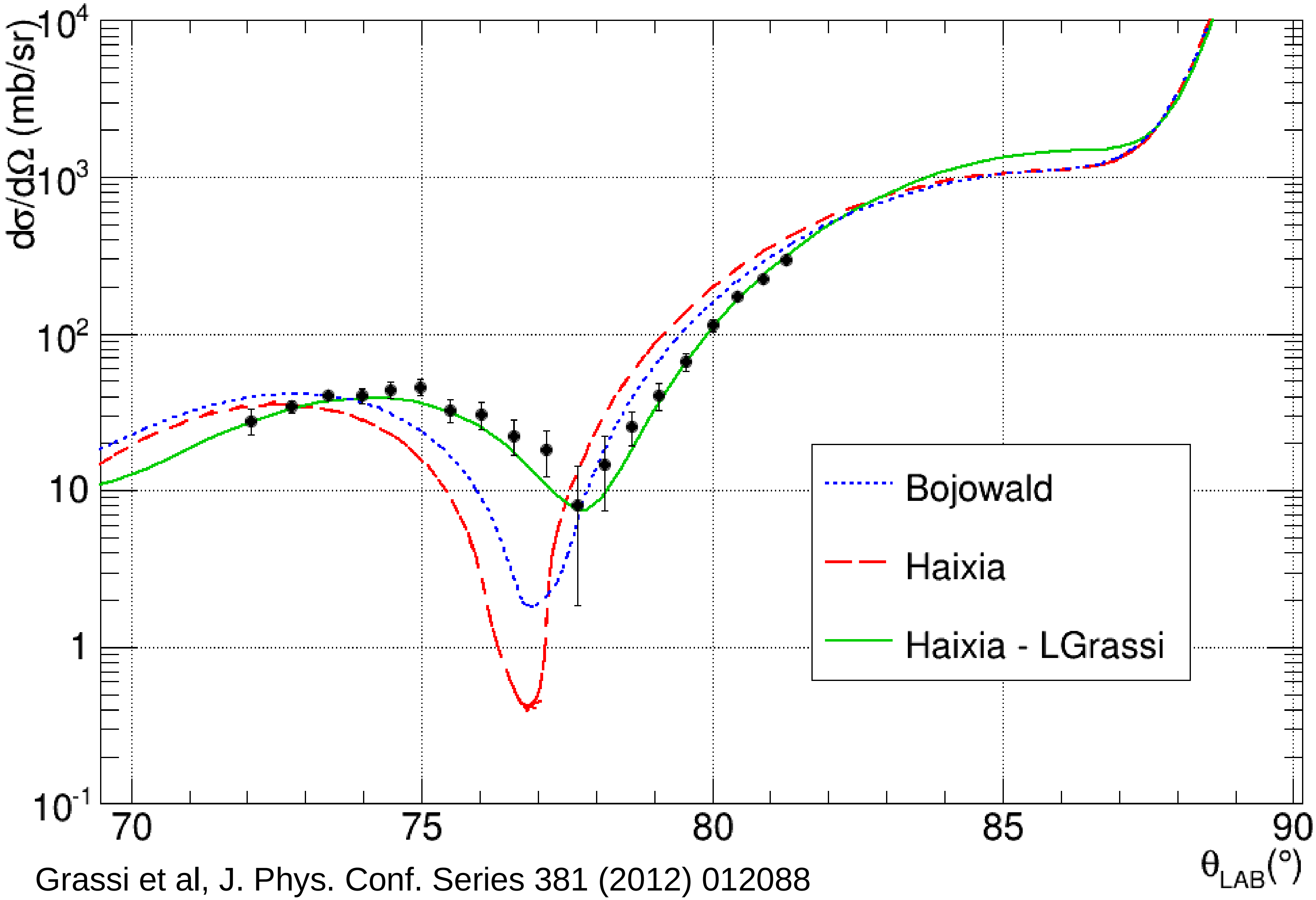


$^{16}C(p,p)$ elastic scattering

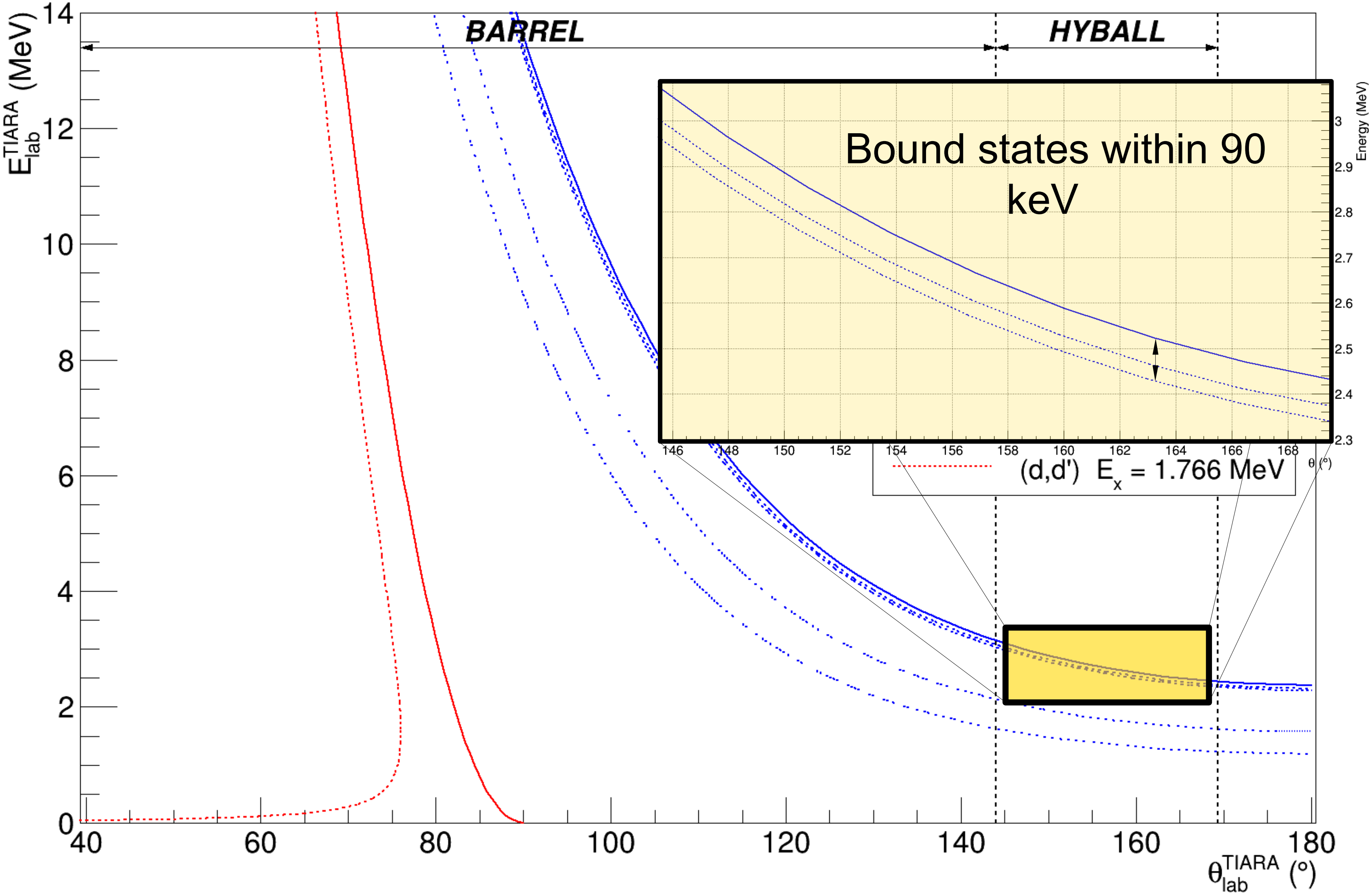


$^{16}C(d,d)$ elastic scattering

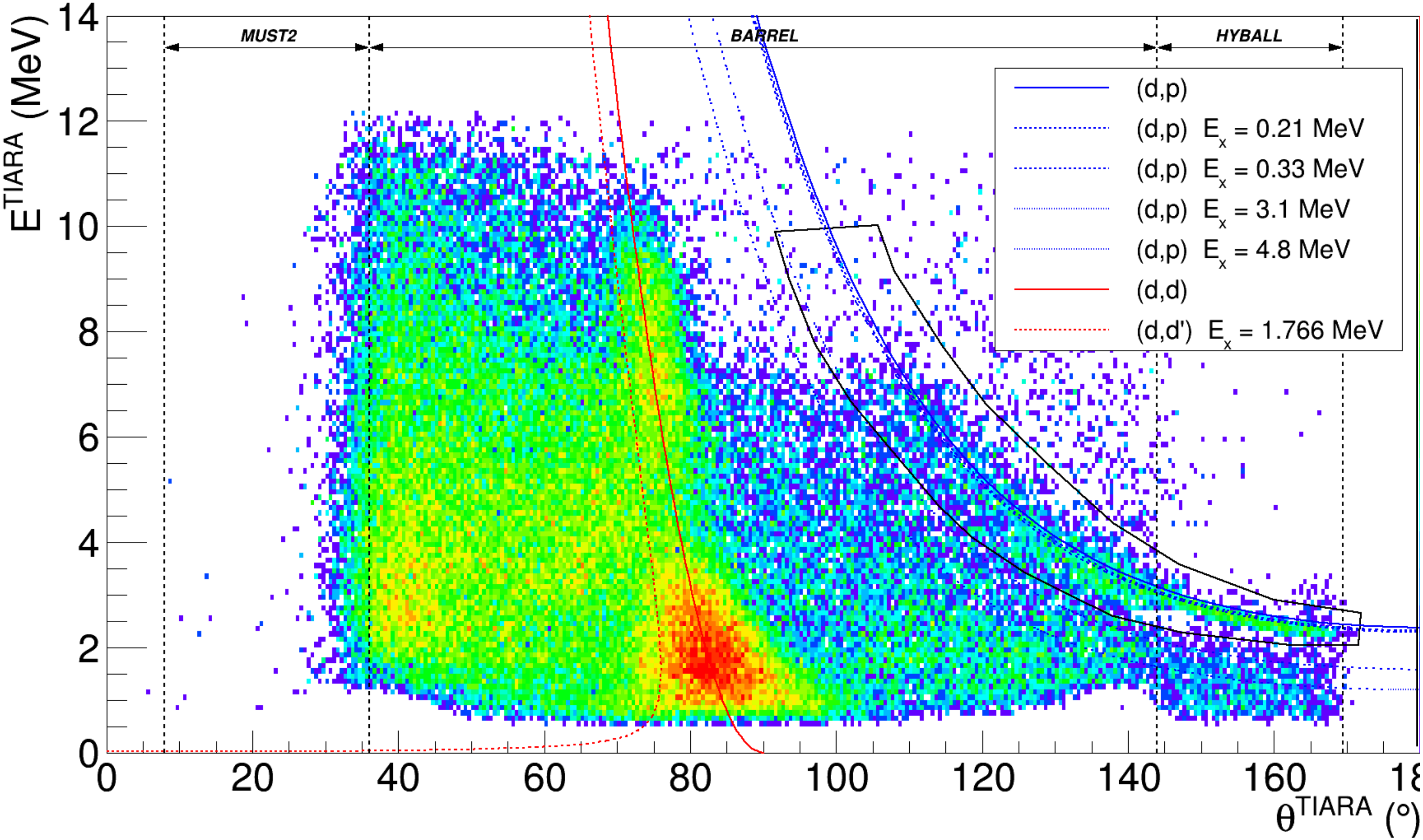


Grassi et al, J. Phys. Conf. Series 381 (2012) 012088

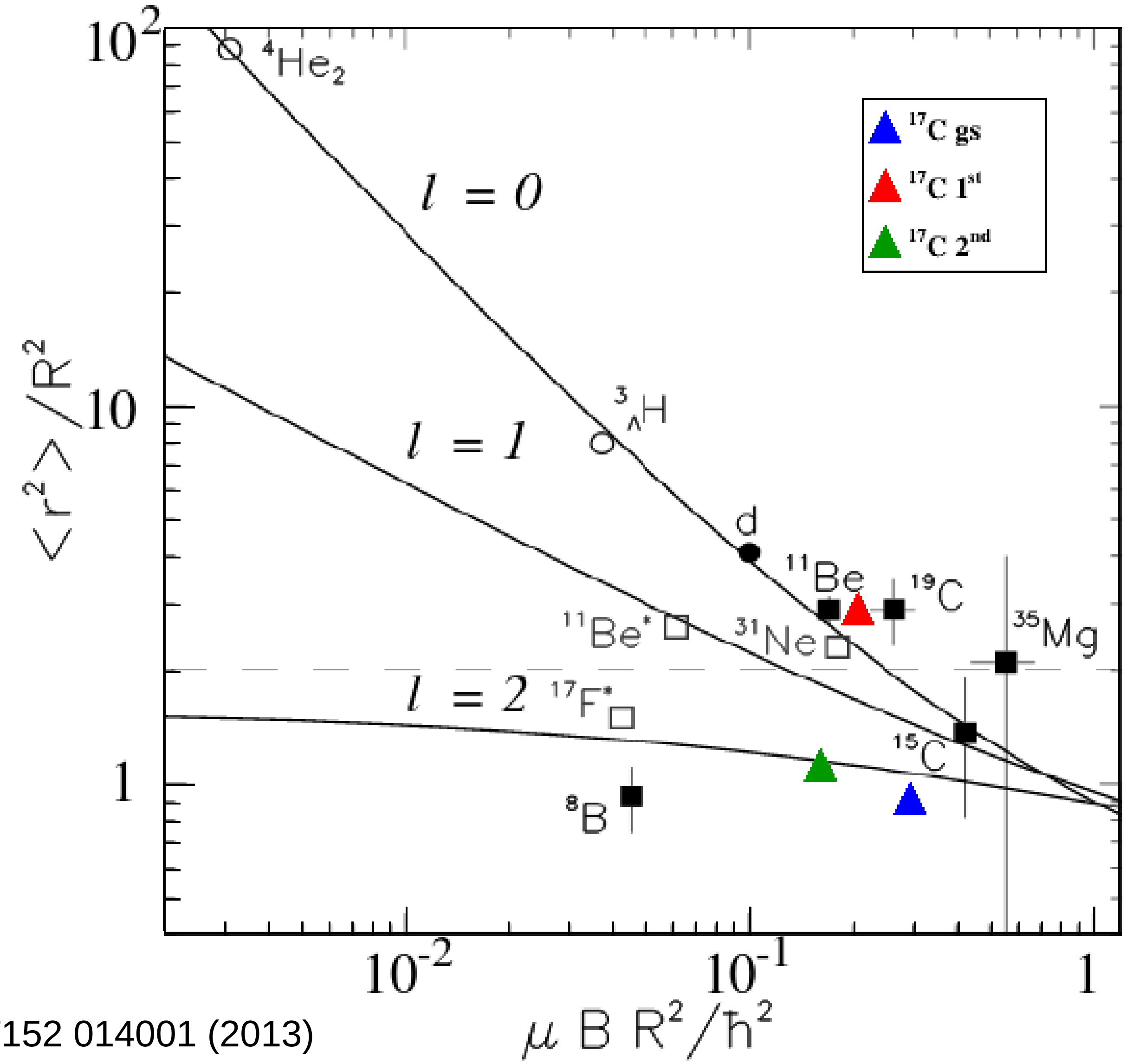
Kinematical lines



TIARA: Energy vs angle



Two-body haloes



$$R^2 = \frac{5}{3}\left(\langle r^2 \rangle_{^{16}C} + 4\,fm^2\right)$$

$\sqrt{\langle r^2 \rangle}_{16C} = 2.7$ fm

Ozawa, NPA 691

K. Riisager,
Phys. Scr. T152 014001 (2013)

$\nu 2s_{1/2} - \nu 1d_{5/2}$ energy difference

Single-particle centroid energy

PRELIMINARY

Combine:

- particle addition: $^{16}C(d,p)$ (present work)
- and removal : $^{16}C(-1n)$ (Maddalena, PRC 63, 024613)

$$\epsilon = \frac{\Sigma_f \left(-S_{n16} - E_{x15}\right) C^2 S^- + \left(2J_f + 1\right)\left(-S_{n17} + E_{x17}\right) C^2 S^+}{\Sigma_f \; C^2 S^- + \left(2J_f + 1\right) C^2 S^+}$$

Baranger, NPA 149, 225
Signoracci, Brown, PRL 99, 099201

(% sum rule)

$$\rightarrow \epsilon_{\nu 1d_{5/2}} \approx -1.5 \text{ MeV} \qquad (84)$$

$$\epsilon_{\nu 2s_{1/2}} \approx -1.7 \text{ MeV} \qquad (90\text{-}100)$$

$$\epsilon_{\nu 1d_{5/2}} - \epsilon_{\nu 2s_{1/2}} \approx 0.2 \text{ MeV}$$