Location of the $\nu1d_{3/2}$ strength in $^{17}C$

J. Lois-Fuentes, X. Pereira-López, B. Fernández-Domínguez, F. Delaunay and the e628 collaboration

USC/IGFAE & LPC-Caen
The N=16 shell gap

n-rich Oxygen : N=14, 16 gaps

- High $E_x$ of $2^+$ state in $^{22}\text{O}$ and $^{24}\text{O}$
  M. Stanoiu et al., PRC 69, 034312 (2004)
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- Small $\beta_2$ parameter in $^{22}\text{O}$ and $^{24}\text{O}$
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Locate the sp strength of the ν1d_{3/2} involved in the N=16 shell gap in ^{17}C
Previous spectroscopic experiments of $^{17}C$

No evidence of $^{3/2}_+^+$ single particle states!
Single-neutron transfer

Spectroscopic tool: Transfer reactions in inverse kinematics: $^{16}\text{C}(d,p)^{17}\text{C}^*$

Measurements $\Rightarrow$ Observables

$E_p, \theta \quad \rightarrow \quad E_x$

Natural width ($\Gamma$) $\rightarrow \quad C^2S$, some $l$ information

Selectively populates single-particle states in $^{17}\text{C}$
Experimental set-up

- CHARISSA
  - CsI (1 cm)
  - Si (65 μm)
  - Si (500 μm)

- MUST2
  - Si + CsI (300 μm + 3 cm)

- EXOGAM
  - Ge clovers

- Proton

- CD₂ target
  - 1.4 mg/cm²

- TIARA Barrel
  - Si resistive strips (400 μm)

- TIARA Hyball
  - Annular Si strip detector (400 μm)

- ¹⁶C beam
  - LISE spectrometer
  - 17.2 AMeV
  - ≈5×10⁴ pps

- CATS (MWPCs)
$^{17}$C (dp-channel: bound states)

$\chi_v^2 = 1.89$

$S_n = 0.735 \text{ MeV}$

$E_{x,\text{max}} = 6.7 \text{ MeV}$
$^{17}$C (dp-channel : bound states)

$\chi^2_v = 1.89$

$S_n = 0.735$ MeV

$E_{x,\text{max}} = 6.7$ MeV

$E_x$ limited by $E > 0.5$ MeV

Tiara Hyball threshold!
$^{17}$C (dp-channel : bound states)

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$E_x$ (keV)

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<tr>
<th>$E_x$ (keV)</th>
<th>$J^\pi$</th>
<th>$C^2 S$</th>
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<tbody>
<tr>
<td>0</td>
<td>3/2+</td>
<td>0.03 (5/3)</td>
</tr>
<tr>
<td>217</td>
<td>1/2+</td>
<td>0.80 (22)</td>
</tr>
<tr>
<td>335</td>
<td>5/2+</td>
<td>0.62 (13)</td>
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Weak sp strength for the 1d3/2!
**17C (dp-channel : unbound states)**

**Preliminary**

\[ \chi^2 = 1.89 \]

\[ S_n = 0.735 \text{ MeV} \]

\[ E_{x,\text{max}} = 6.7 \text{ MeV} \]

\[ F(E) = A_G \cdot e^{\frac{1}{2} \left( \frac{E - E_0}{\sigma} \right)^2} + A_{R1} \cdot V(E, E_{R1}, \sigma_{R1}, \Gamma_{R1}) + \]

\[ A_{R2} \cdot V(E, E_{R2}, \sigma_{R2}, \Gamma_{R2}) + A_{PS} \cdot S(E) \]

**Bound States**

**1st resonance**

**2nd resonance**

**Phase Space**

**Experimental Data**

**Bound states**

**1st resonance**

**2nd resonance**

**Total fit**

**Phase Space**
$^{17}\text{C} \text{ (dp-channel : unbound states)}$

$$F(E) = A_G \cdot e^{\frac{1}{2} \left( \frac{E-E_0}{\sigma} \right)^2} + A_{R1} \cdot V(E, E_{R1}, \sigma_{R1}, \Gamma_{R1}) + A_{R2} \cdot V(E, E_{R2}, \sigma_{R2}, \Gamma_{R2}) + A_{PS} \cdot S(E)$$

**Experimental Data**
- Bound states
- $1^{st}$ resonance
- $2^{nd}$ resonance
- Total fit
- Phase Space

$\chi^2 = 1.89$

$S_n = 0.735 \text{ MeV}$

$E_{x,\text{max}} = 6.7 \text{ MeV}$

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\[ C^2 S = \frac{\Gamma_{exp}}{\Gamma_{sp}} \]

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\[ E_x (\text{MeV}) \]

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$^{17}$C (dp-channel : unbound states)

![Graph showing experimental data and fitted curves]

- $\chi^2 = 1.89$
- $S_n = 0.735 \text{ MeV}$
- $E_{x,\text{max}} = 6.7 \text{ MeV}$

**Fitting Formula**

$$F(E) = A_G \cdot e^{\frac{1}{2} \left( \frac{E-E_0}{\sigma} \right)^2} + A_{R1} \cdot V(E, E_{R1}, \sigma_{R1}, \Gamma_{R1}) +$$

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**Experimental Data:**

- **Bound States**
- **1st resonance**
- **2nd resonance**
- **Total fit**
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**Assignments:**

- $l=1$: $\Gamma_{sp} \gg \Gamma_{exp}$
- $l=3$: $\Gamma_{sp} \to 0$
- $l=2$: $\frac{d\sigma}{d\Omega} \to \text{coherent } C^2S$

**Assigned to be $l=2$**
The energy and strength of the unbound states found is similar to the 2nd and 3rd resonances predicted by the SM. No evidence of the 1st resonance.
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Effective single-particle energy of the $\nu 1d_{3/2}$

$^16C$

$$\Delta_{N=16} = \epsilon_{\nu 1d_{3/2}} - \epsilon_{\nu 2s_{1/2}}$$

$2s_{1/2} = 2.16(45)$

$1d_{3/2} = 3.45(86)$

$$\epsilon = \frac{\sum_{f=0}^{n-}(E_0 - E_f^-)C^2S_f^- + (2J_f + 1)\sum_{f=0}^{n+}(E_f^+ - E_0)C^2S_f^+}{\sum_{f=0}^{n-}C^2S_f^- + (2J_f + 1)\sum_{f=0}^{n+}C^2S_f^+}$$

$$\epsilon_{\nu 1d_{3/2}} = 3.84 (30) \text{ MeV}$$

---

b -> V. Maddalena et al. PRC 72, 011302(R) (2014)
c-> M. Baranger et al. NPA 149, 225 (1970)
The N=16 Shell gap survives in n-rich Carbon isotopes
The $N=16$ Shell gap survives in n-rich Carbon isotopes.

The $\nu 1d_{3/2}$ is less bounded than the predictions.

\[
\Delta_{N=16}(^{16}\text{C}) = \epsilon_{1d_{3/2}} - \epsilon_{2s_{1/2}} = 5.41(34) \text{ MeV bigger than } \sim \Delta_{N=16}(^{18}\text{O}) = 4.24 \text{ MeV}
\]
Conclusions

• 1. Two resonances have been found at $E_x = 4.05(20)$ and $6.10(17)$ MeV and associated widths were deduced to be $\Gamma = 1.32(33)$ and $1.52(44)$ MeV respectively.
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6. We observe that the $\nu 1d_{3/2}$ is less bound that what is expected in the n-rich C isotopes.
Future work

• 1. Apply the Gamow Shell model to take into account the radial extension of the wave function in the unbound states.

• 2. Estimate the contribution of the $2^+$ in $^{16}C$.

• 3. Combine the location of the $\nu 1d_{3/2}$ with previous results of the energy of the $\nu 1d_{5/2}$ to study the spin-orbit splitting.
E628 Collaboration


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NO PART OF THE TALK
In this first analysis we’re assuming that all the $C^2S$ is going to the GS $^{16}C(0^+)$.

We’re still working on gating with the $\gamma$ to determine how much of the unbounds decays to the excited $2^+$ state.

In this stage our results of the $C^2S$ are just upper limits!