Single-particle structure of ^{17}C

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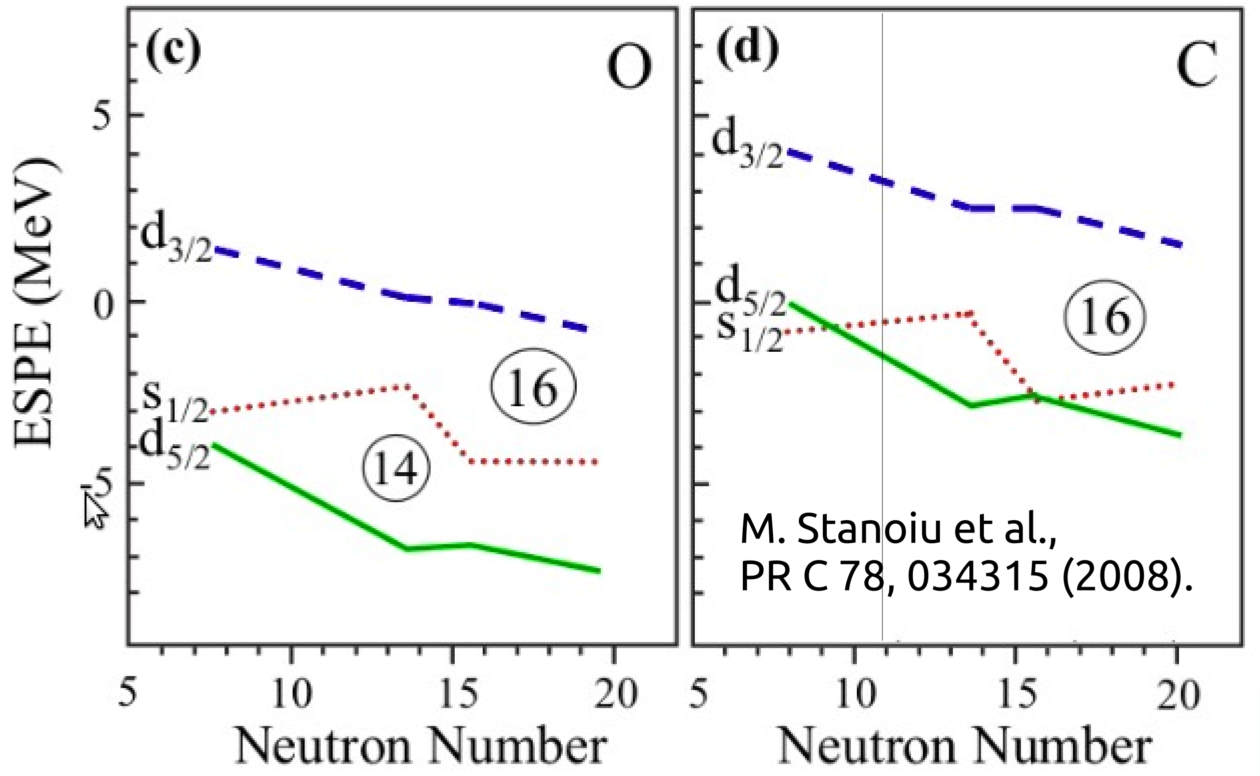
Shell evolution in n-rich C



- Evolution of N=14 and N= 16 shell gaps in the n-rich C isotopes.
- Locate the single particle energies of $d_{5/2}$, $s_{1/2}$ and $d_{3/2}$ orbitals using $^{16}C(d,p)^{17}C$.

Current knowledge on ^{17}C

- Energies of the bound states are well known.
- No spectroscopic factors (C^2S) measured apart from the ground state.
- Unbound states **$3/2^+$** have not been explicitly identified.

D. Smalley et al., PRC 92, 064314 (2015).
S. Kim et al., JPS Conf Proc 6, 030031 (2015).
H. Ueno et al., PRC 87, 034316 (2013).
Y. Kondo et al, PRC 79 014602 (2009).
Y. Satou et al., Phys.Lett. B 660, (2008).
D. Suzuki et al., Phys.Lett. B 666, (2008).
M. Stanoiu et al., PRC 78, 034315 (2008).
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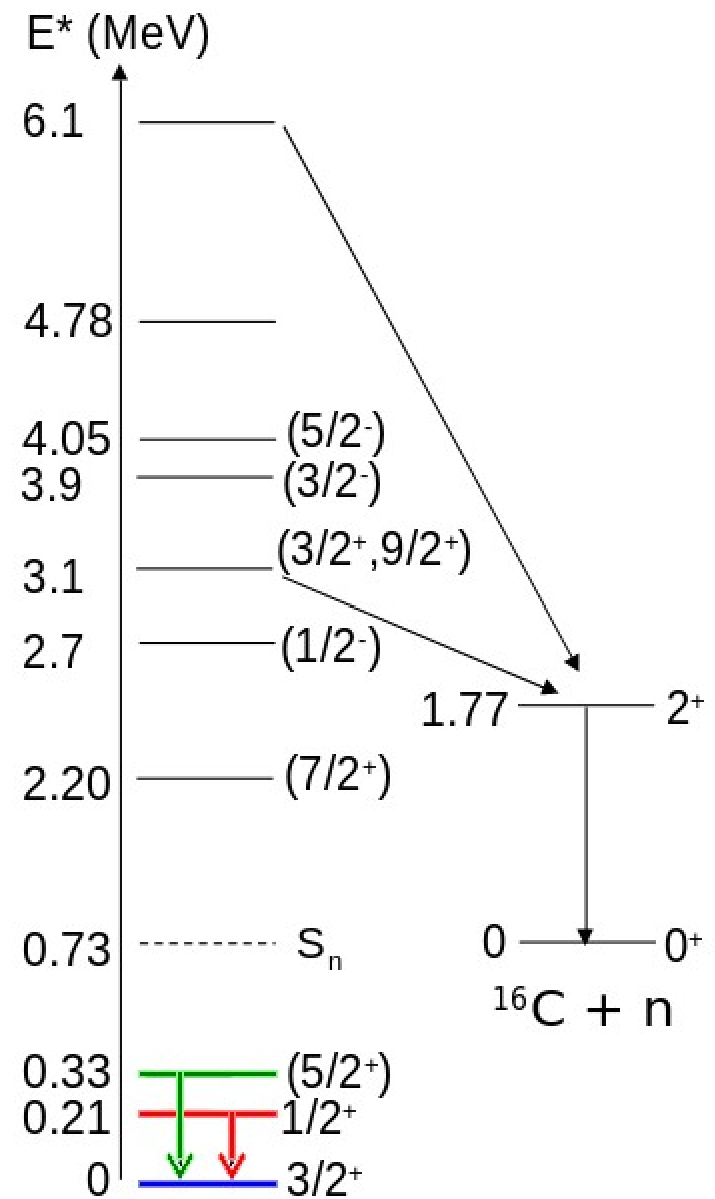
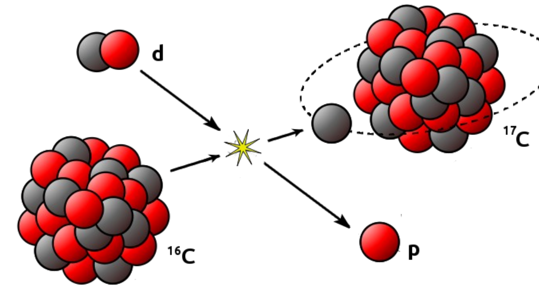
Z. Elekes et al., Nucl.Phys A 675, (2000).

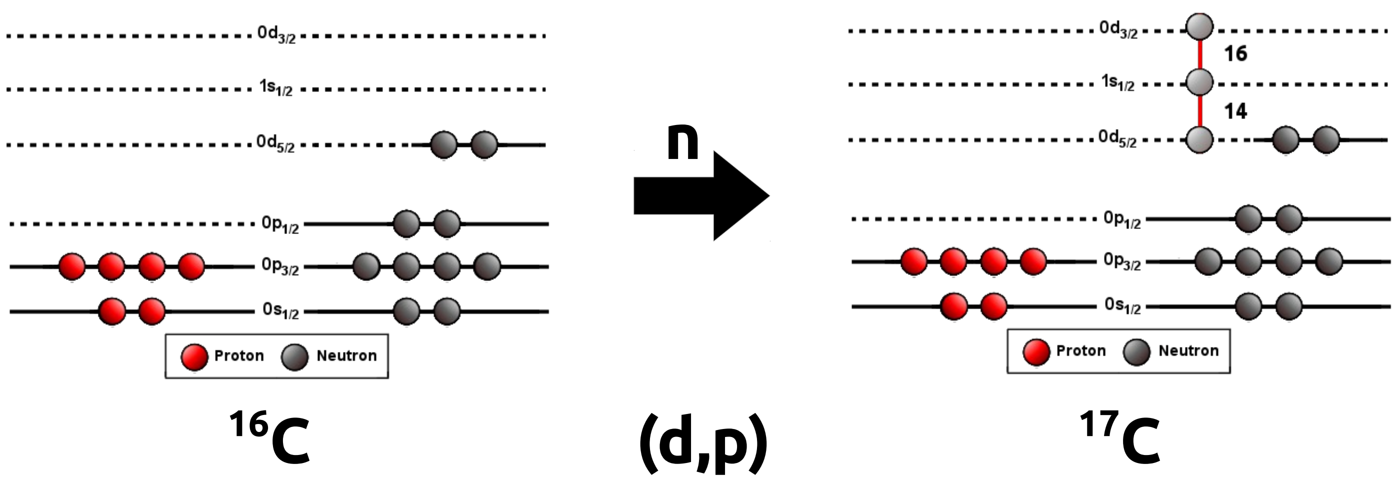


Goals of the experiment

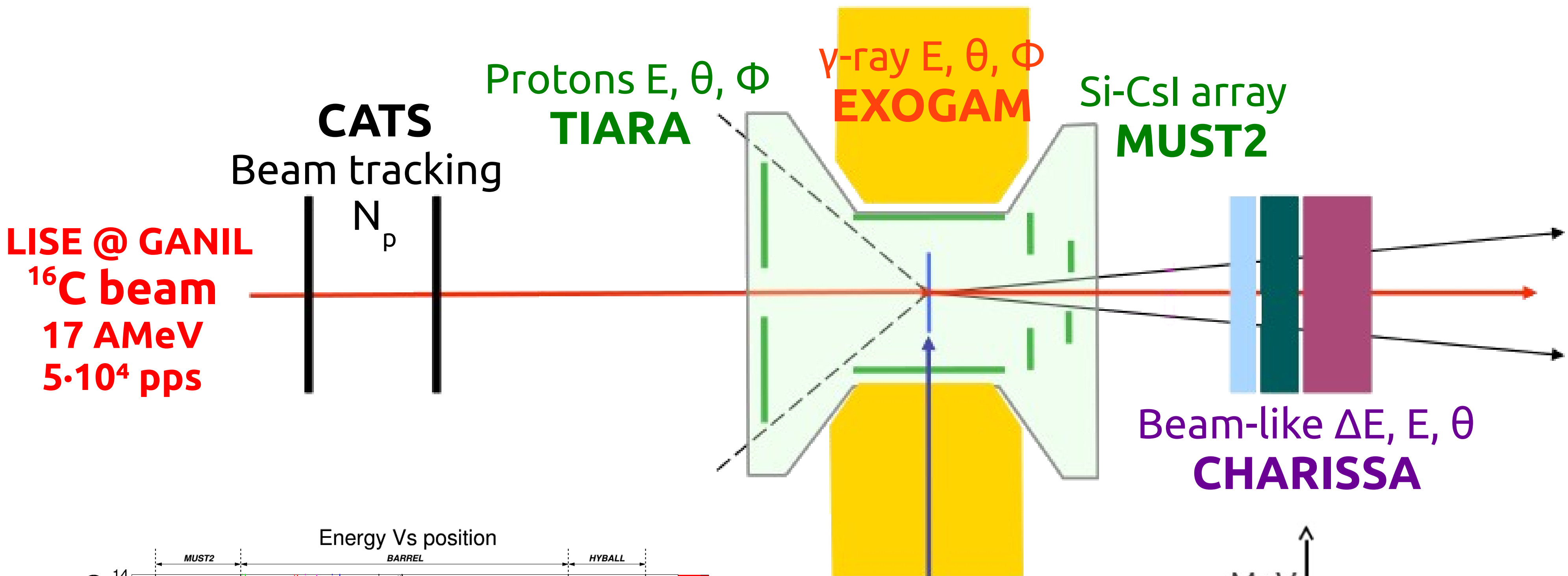


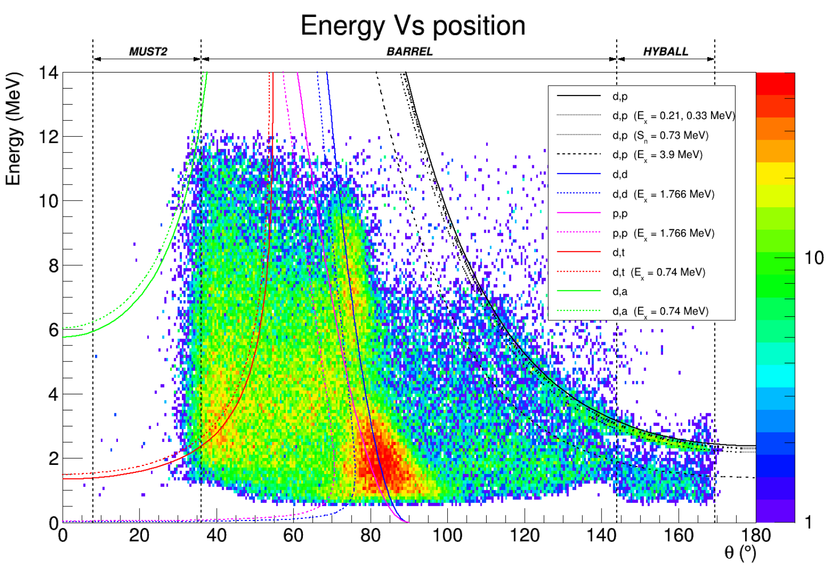
Why $^{16}C(d,p)^{17}C$?

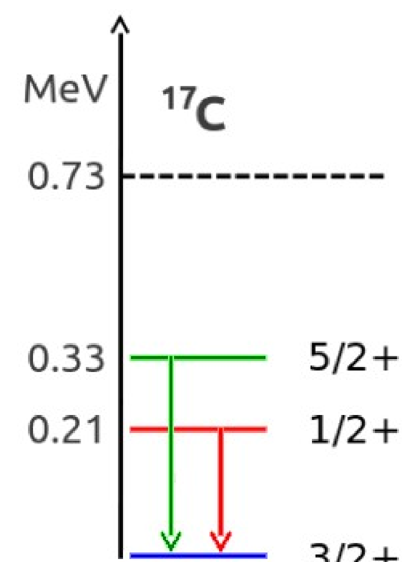
- Probe single-particle orbitals.
- Locate the single-particle $d_{5/2}$, $s_{1/2}$ and $d_{3/2}$ orbitals responsible for the N=14,16 magic numbers.
- Angular distributions provide l measurements.
- Deduce their spectroscopic factors for the first time.



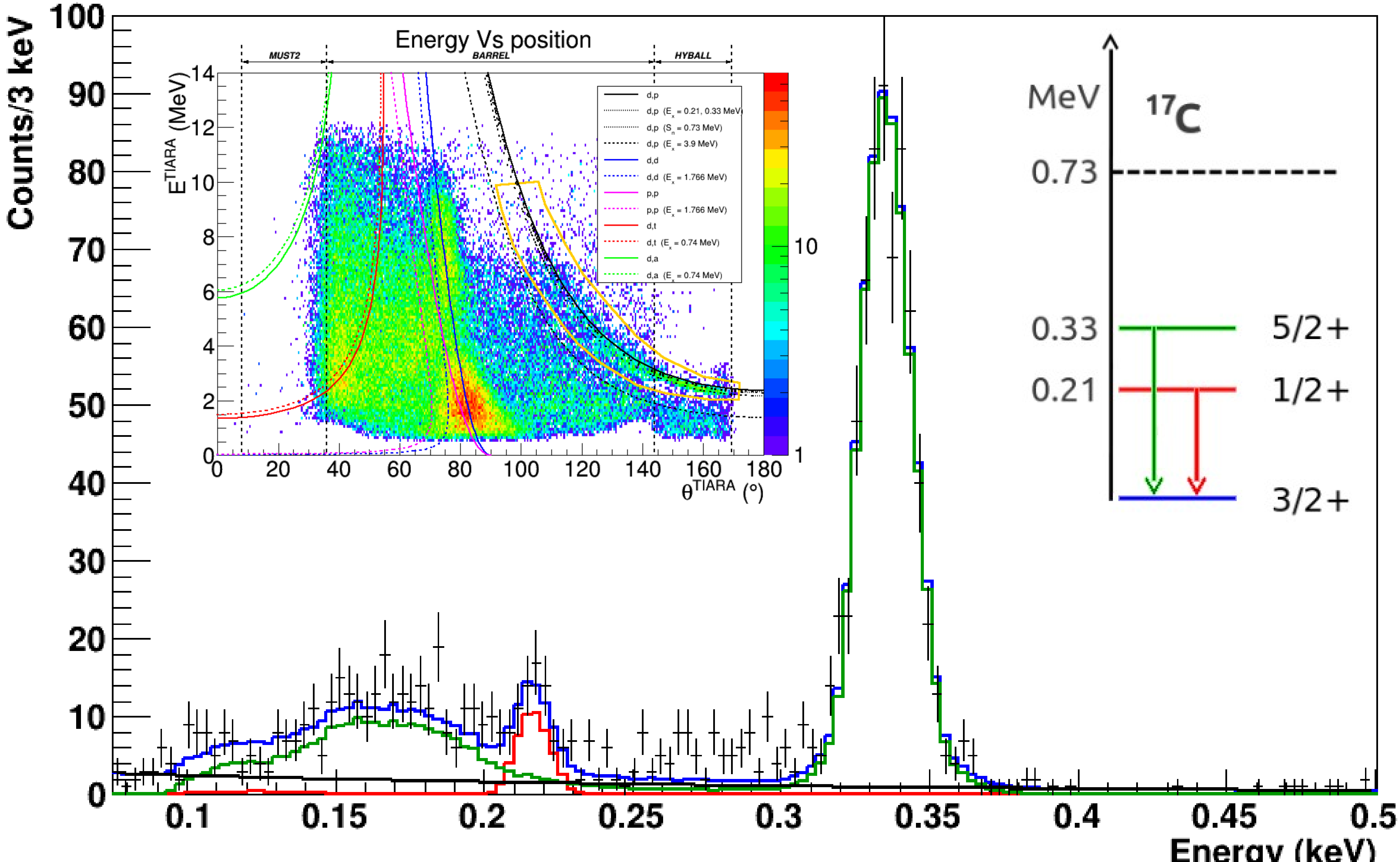
Experimental setup



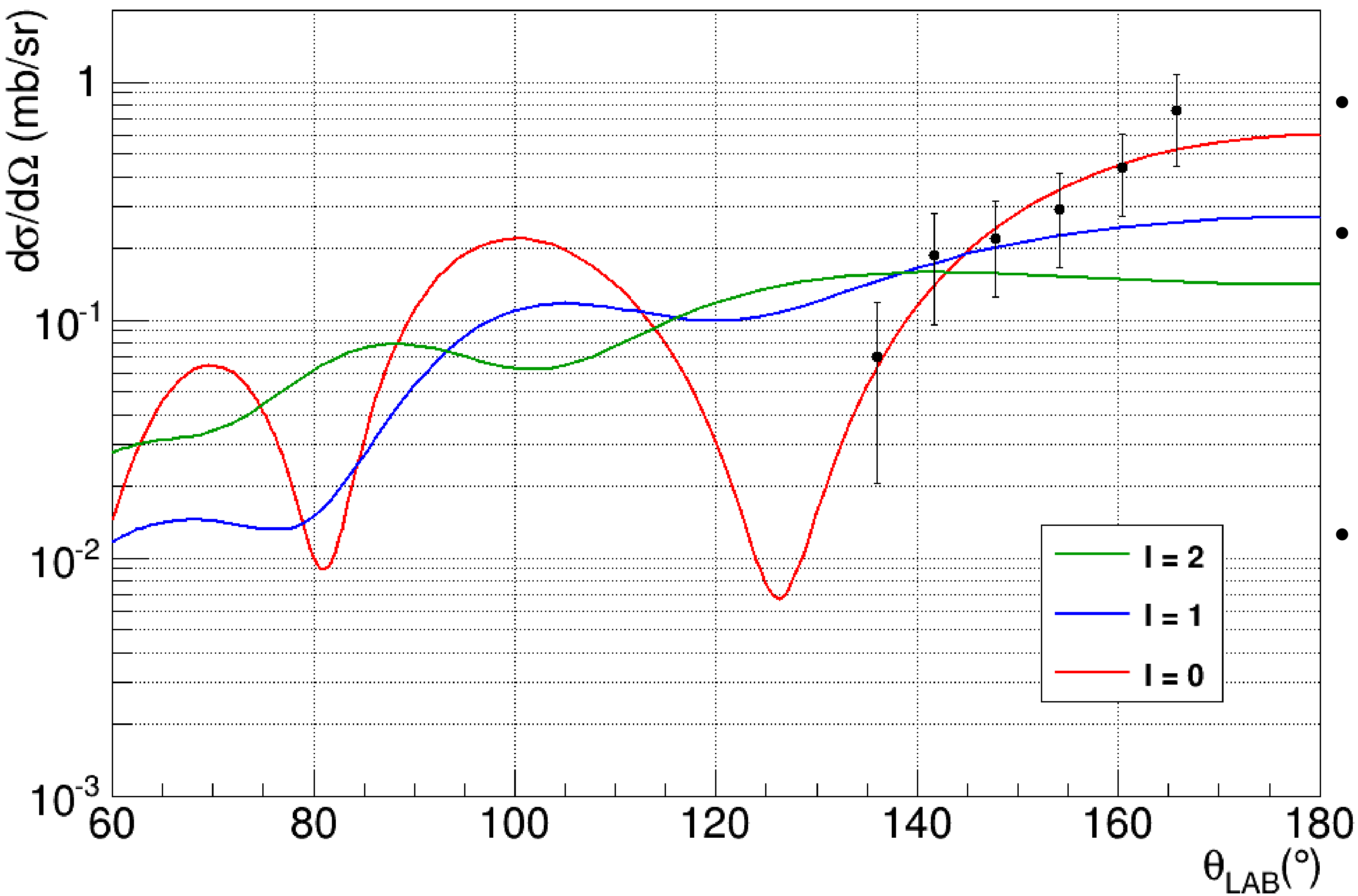




$^{16}C(d,p)^{17}C$: Bound states



$^{16}C(d,p)^{17}C^*$ $E^*=0.21$ MeV



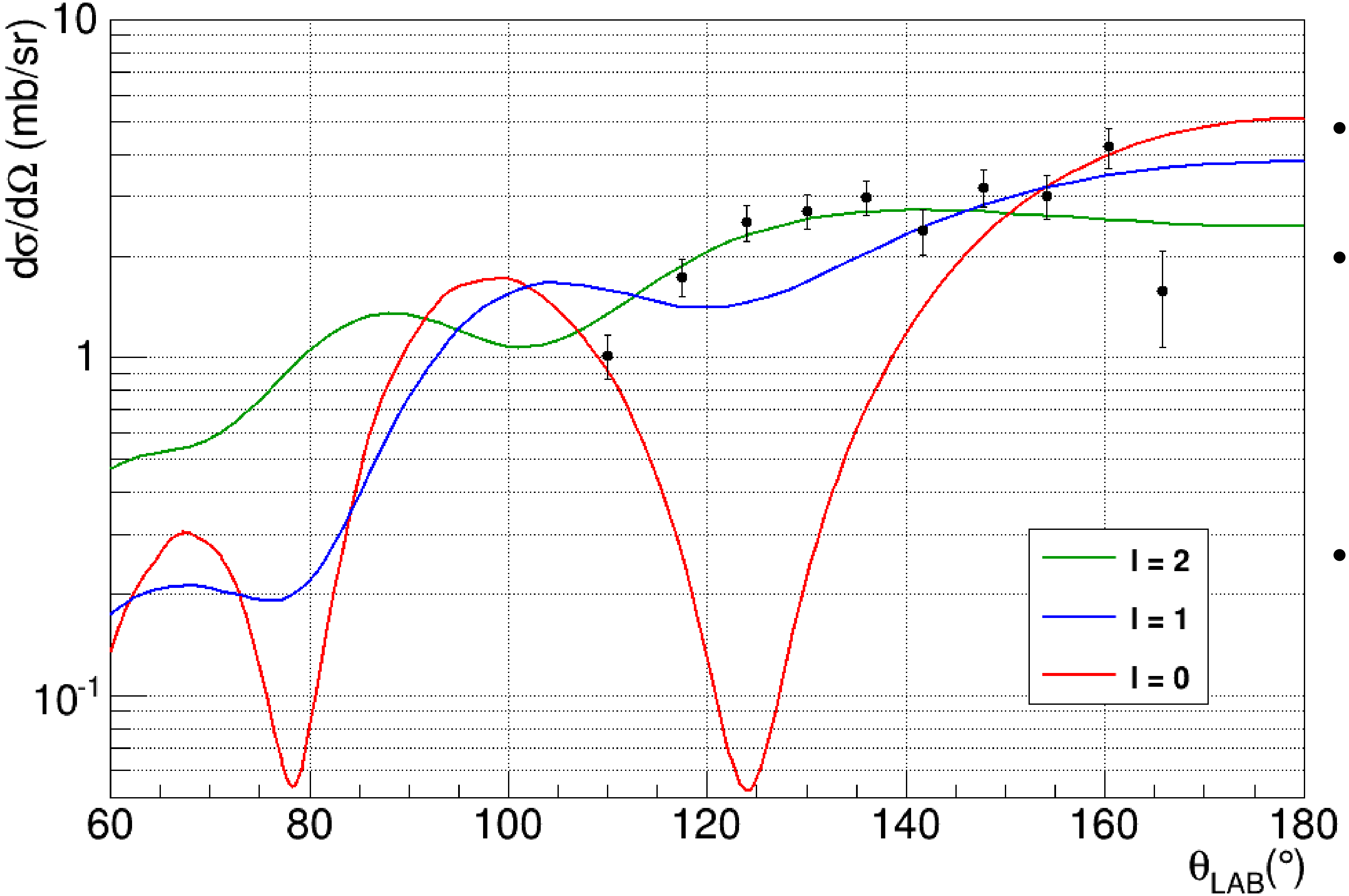
- ADWA
- Koning-Delaroche nucleon-nucleus optical potential
- Bound state WF :

  r_0 = 1.25 fm

  a_0 = 0.65 fm

C^2S = 0.89 (18)   (exp)

$^{16}C(d,p)^{17}C^*$ $E^*=0.33$ MeV



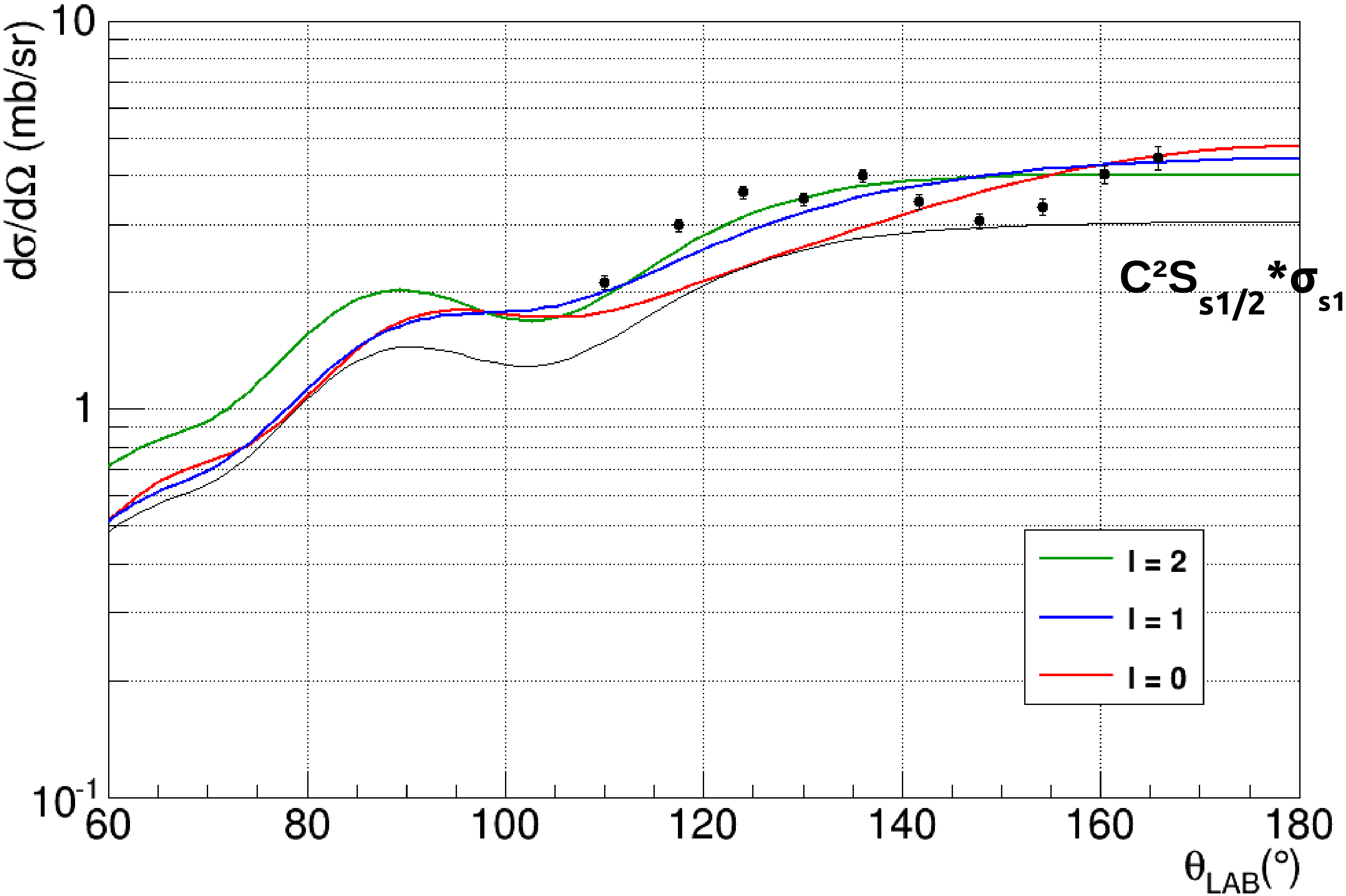
- ADWA
- Koning-Delaroche nucleon-nucleus optical potential
- Bound state WF :

  r_0 = 1.25 fm

  a_0 = 0.65 fm

C^2S = 0.62 (12)   (exp)

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



$C^2S_{s1/2} * \sigma_{s1/2} + C^2S_{d5/2} * \sigma_{d5/2}$

C^2S = 0.39 (23) (exp)

Summary

- Angular distributions for ^{17}C bound states confirm previous measurements.

E (MeV)	ℓ	J^{π}	C^2S_{exp}	C^2S_{USDB}	
0	2	$3/2^+$	0.39(23)	0.03	
0.210	0	$1/2^+$	0.89(18)	0.63	**Halo?**
0.330	2	$5/2^+$	0.62(12)	0.70	

- Results close to predictions by the USDB interaction except for ground state.
- Large fraction of the strength of the $s_{1/2}$ and $d_{5/2}$ orbitals has been located.
- Work is ongoing to analyse the unbound states.

Collaborators

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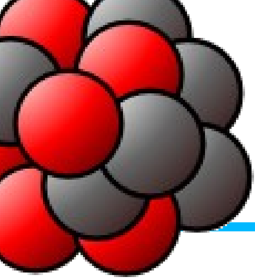
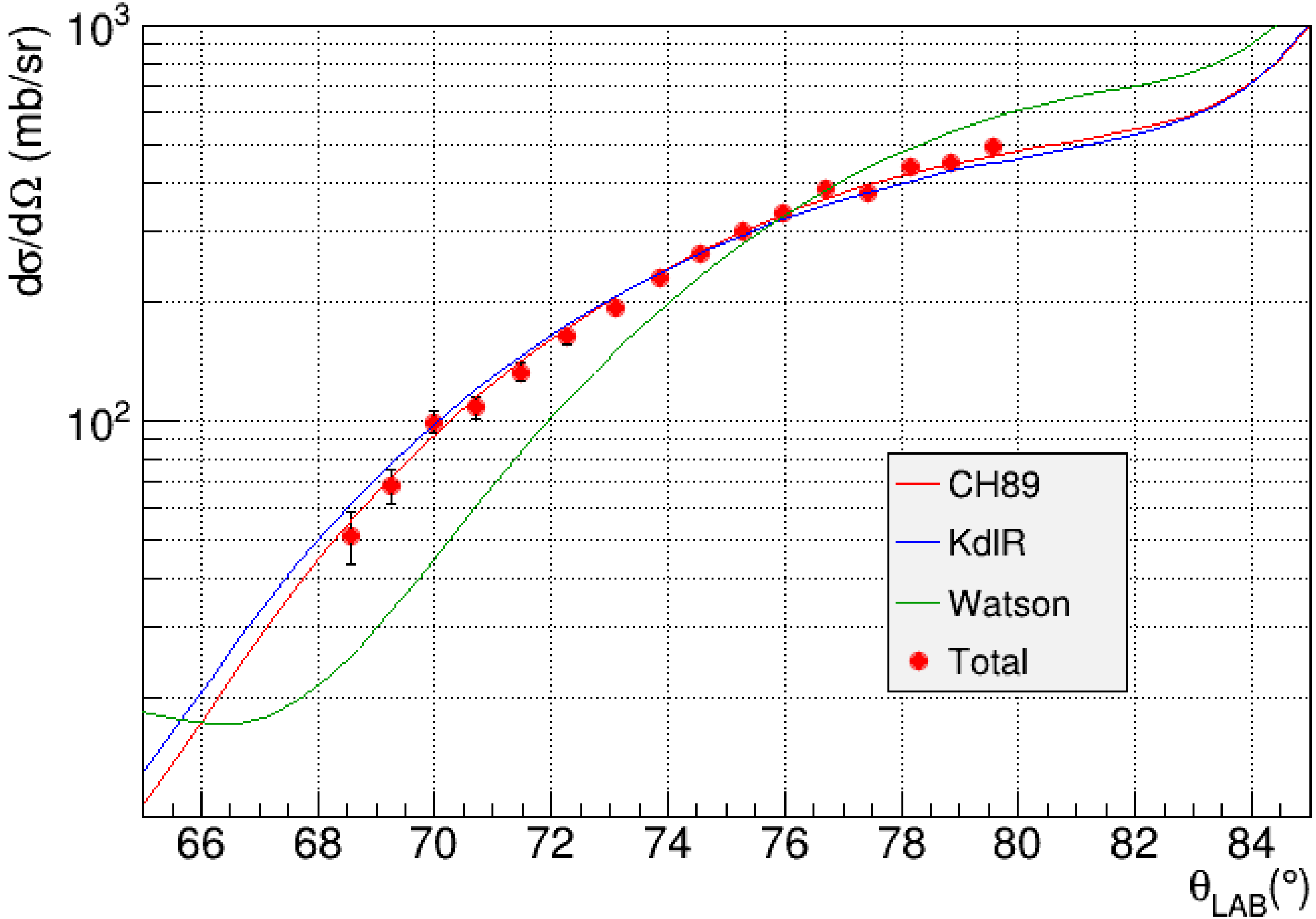


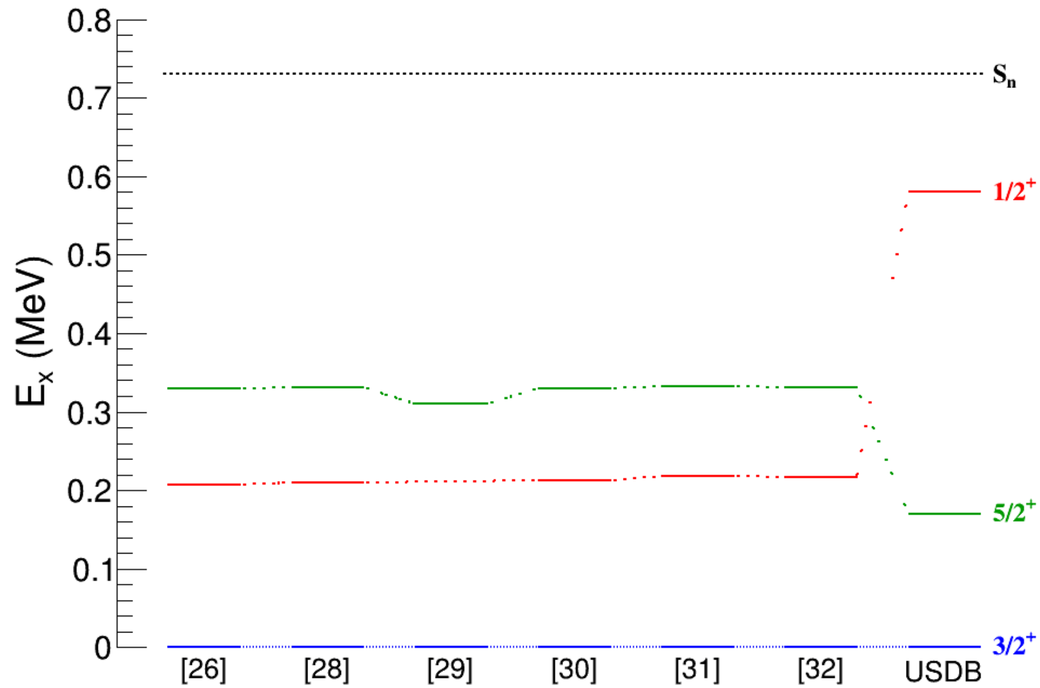


dσ/dΩ (mb/sr)
10^3
10^2
66
68
70
72
74
76
78
80
82
84
θ_LAB(°)
CH89
KdlR
Watson
Total

- Energies of the bound states are well known.

  [26] M. Stanoiu et al., PRC 78, 034315 (2008).
  [28] Z. Elekes et al., Nucl.Phys A 675, (2000).
  [29] H.G. Bohlen et al., Eur.Phys.J. A 31, (2007).
  [30] D. Suzuki et al., Phys.Lett. B 666, (2008).
  [31] D. Smalley et al., PRC 92, 064314 (2015).
  [32] H. Ueno et al., PRC 87, 034316 (2013).

- No direct assignments of spin and parity for 2nd state.



- No spectroscopic factors (C^2S) measured apart from the ground state:

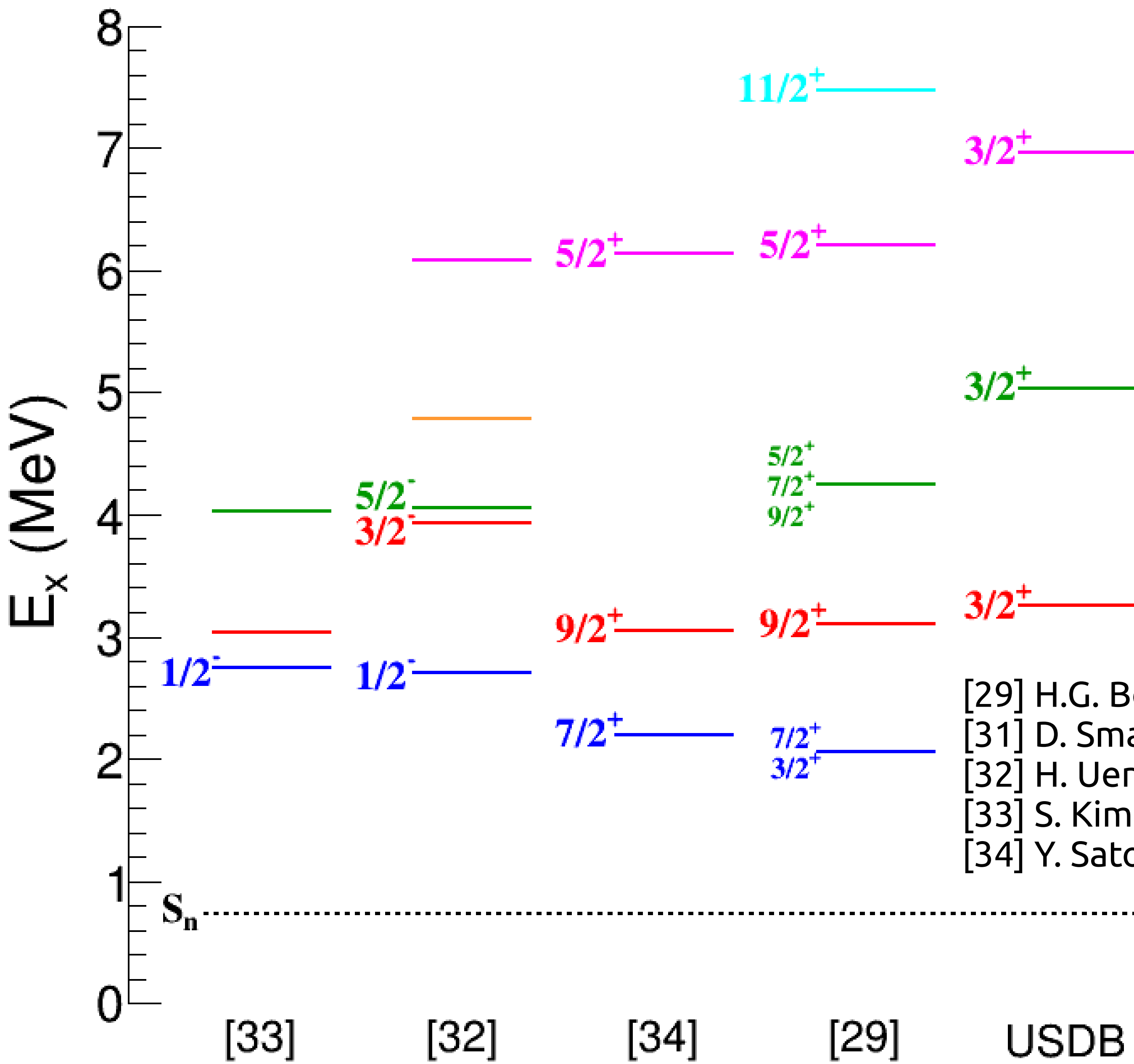
  Final configuration of ground state measured at MSU by 1n-knockout.

  $$0d_{5/2}\circ{}^{16}C(2^+)+1s_{1/2}\circ{}^{16}C(2^+)+0d_{3/2}\circ{}^{16}C(0^+)$$

  V. Maddalena et al., PRC 63, 024613, (2001).
  C. Rodríguez-Tajes, PhD Univ. Santiago de Compostela (2008).

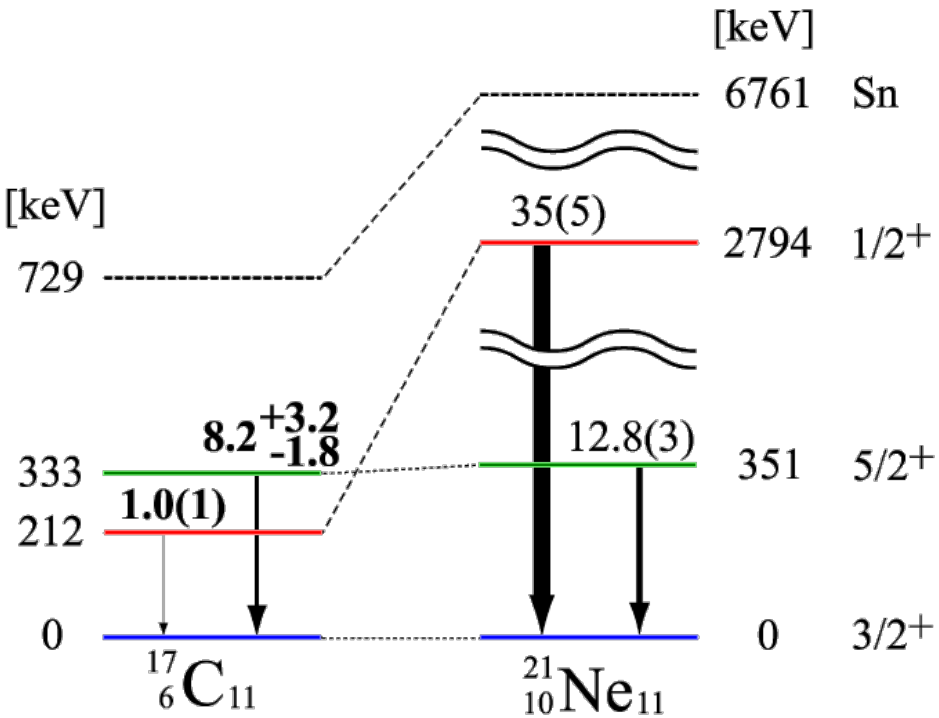
  in apparent contradiction with cross sections predicted by shell model calculations.

- S_n = 0.73 MeV → **1/2⁺** state candidate to present an halo structure.



[29] H.G. Bohlen et al., Eur.Phys.J. A 31, (2007).
[31] D. Smalley et al., PRC 92, 064314 (2015).
[32] H. Ueno et al., PRC 87, 034316 (2013).
[33] S. Kim et al., JPS Conf Proc 6, 030031 (2015).
[34] Y. Satou et al., Phys.Lett. B 660, (2008).

M. Stanoiu et al., PR C 78, 034315 (2008).



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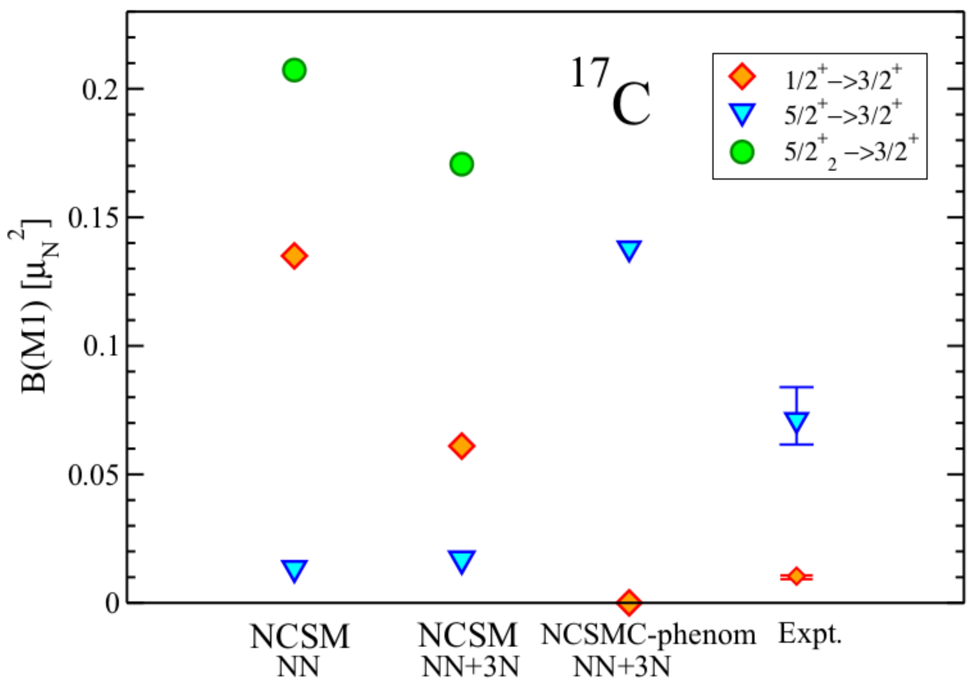
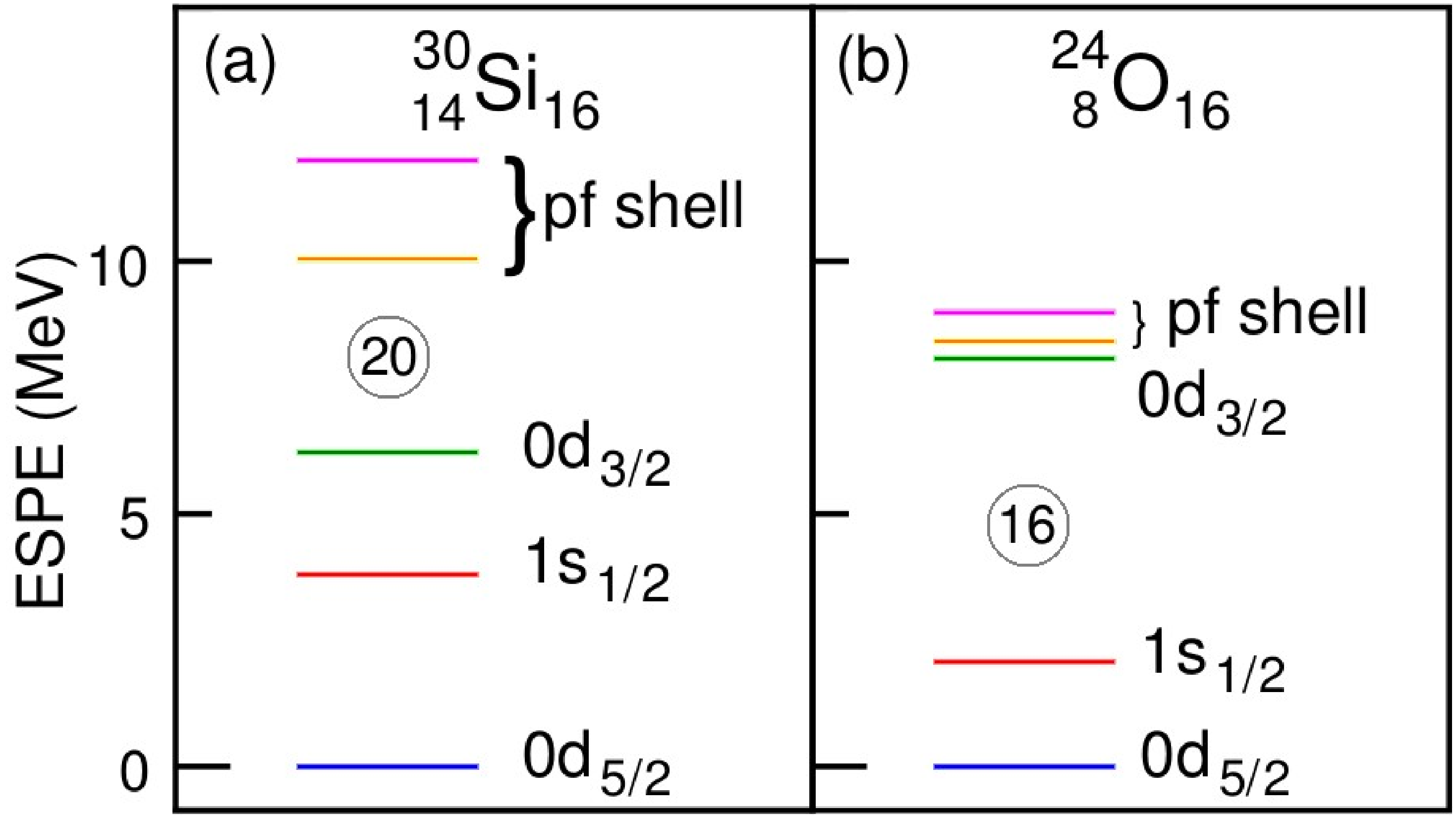


- Hindrance of M1 transition for **1/2⁺** state reveals particular structure. ➡ Halo?
- Similar energies and B(M1) in **3/2⁺** and **5/2⁺** states in ^{17}C and ^{21}Ne suggest similar deformation.

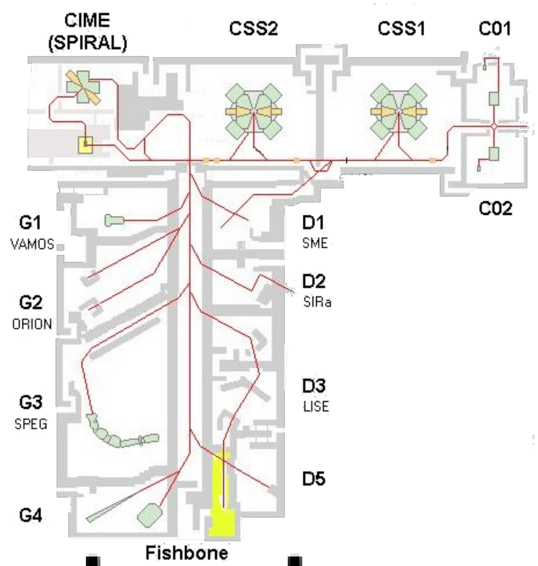
- NCSM calculations show the importance of chiral 3N forces and the continuum for the binding of ^{17}C.
- Inclusion of the continuum enhances the S-wave of the **1/2⁺** state.

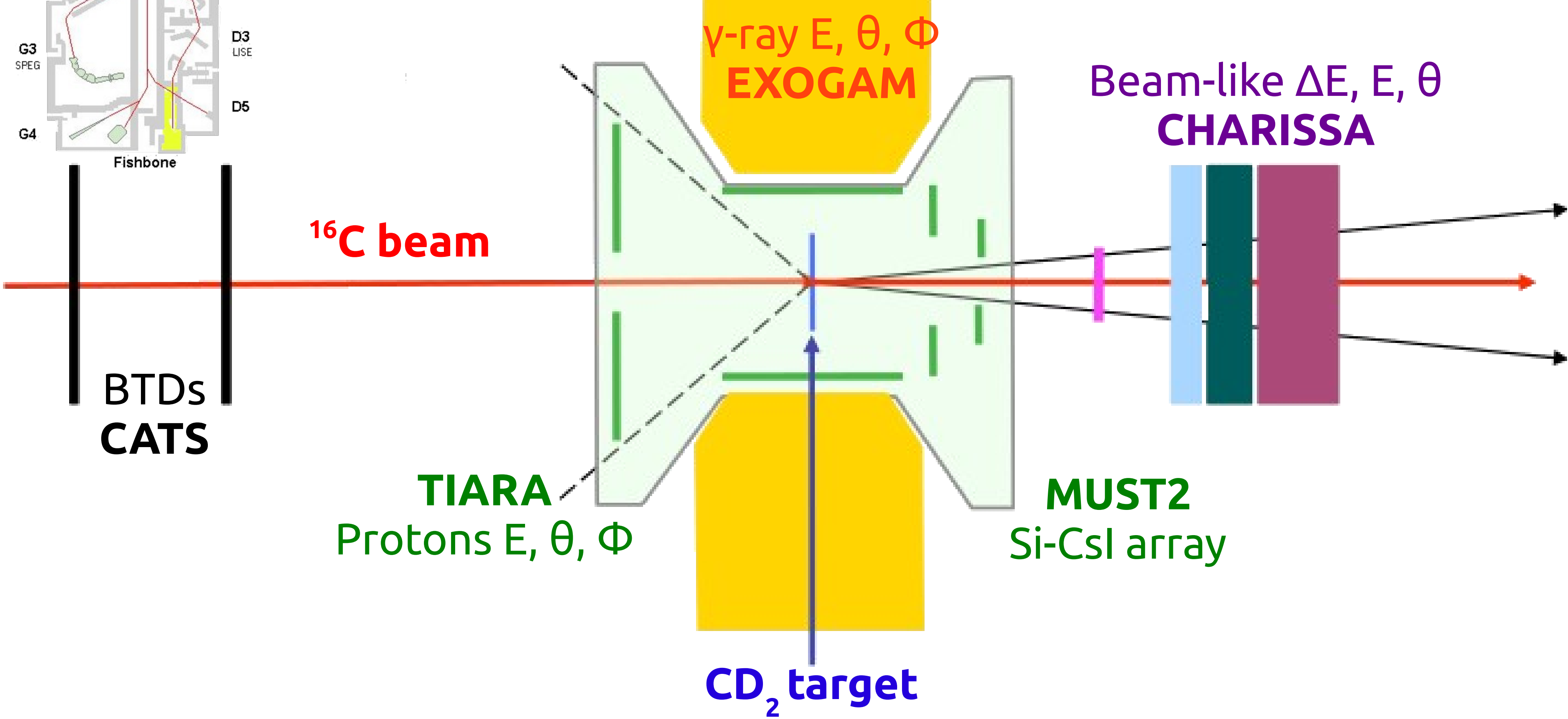
Magic numbers

The shell structure of stable nuclei and the associated magic numbers are one of the key ingredients in the description of the nuclear structure. These magic numbers evolve from the valley of stability to the drip lines. Experimental evidence shows the existence of new shell gaps at N=14,16 in exotic nuclei, leading to the vanishing of the N=20.



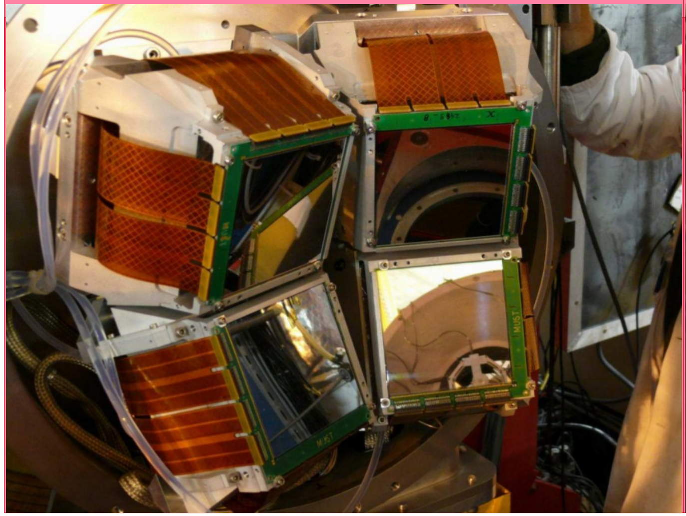
A ^{16}C beam of ~10^5 pps and 17.2 AMeV from LISE3 at GANIL was used on CD_2 target of 1.4mg/cm^2. The experimental setup includes:





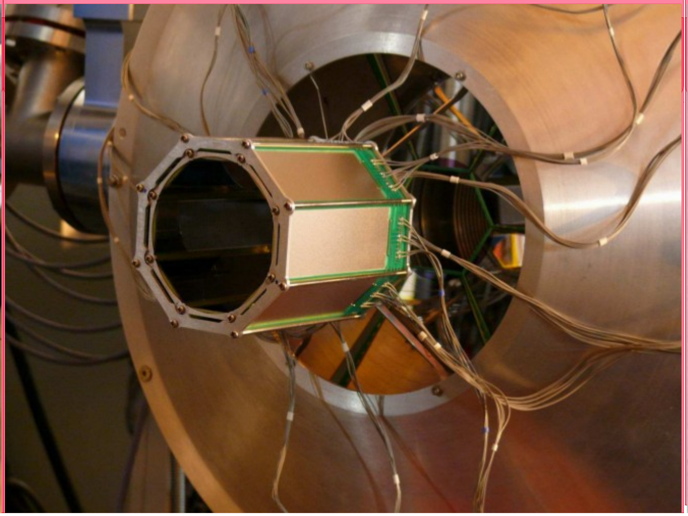
MUST2

- Si-CsI telescope.
- 8° - 36°.
- 128x128 strips.
- 4x4 CsI array.



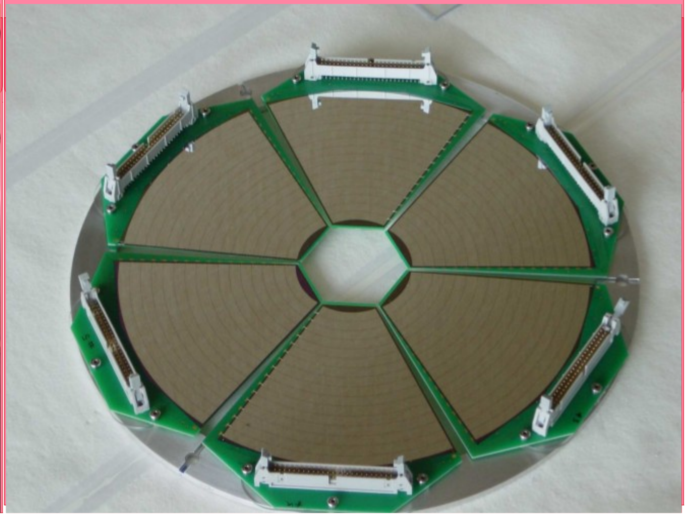
Barrel

- DSSSD.
- 36°-144°.
- 2 layers: 400 & 700 μm
- 8 detectors.
- 8*4 resistive strips.
  - ΔE/E ~ 2.7%

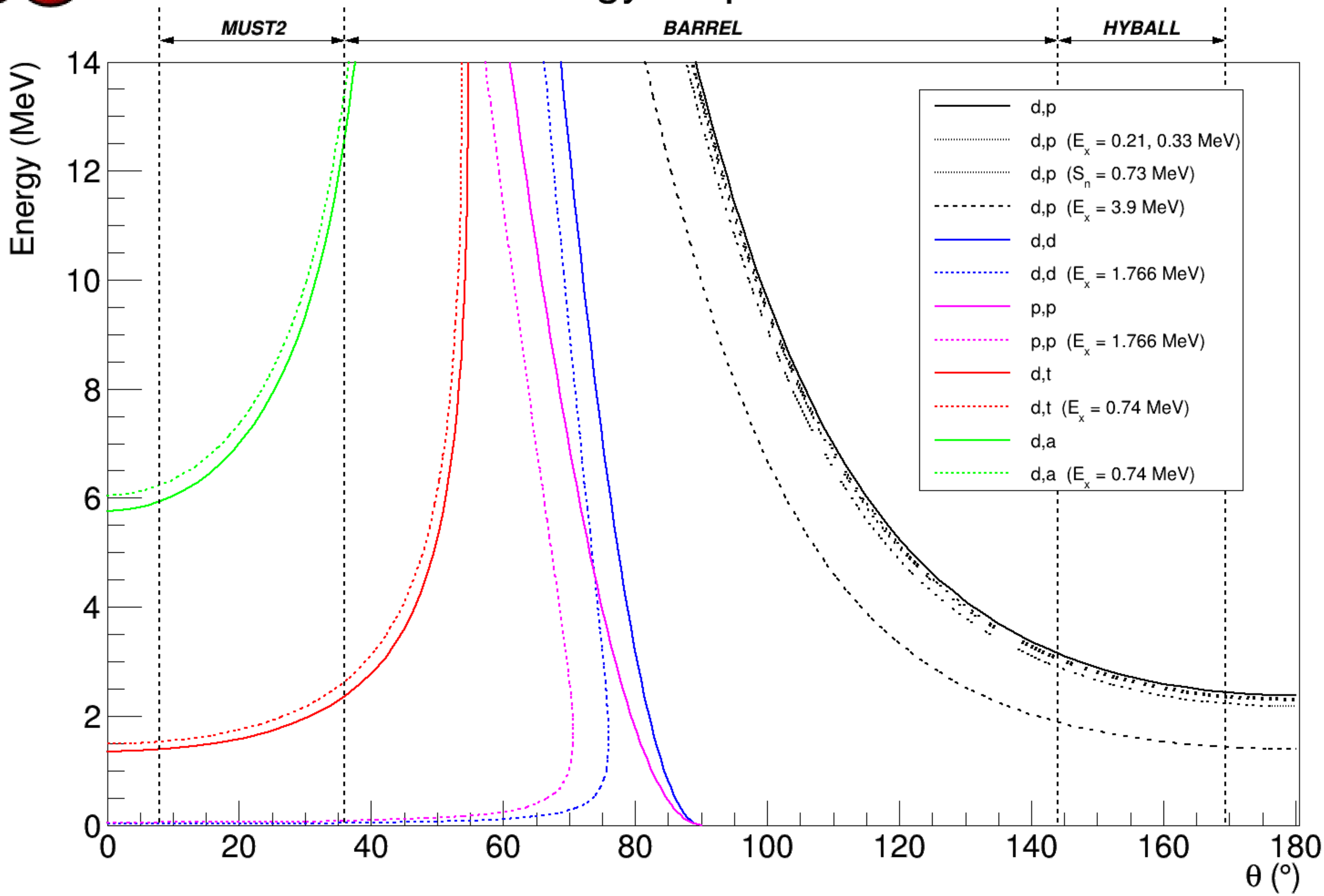


Hyball

- DSSSD.
- 144°-169.4°.
- 6 wedges.
- 6*16 rings.
  - ΔE/E ~ 0.75%
- 6*8 sectors.
  - ΔE/E ~ 1.3%



Energy Vs position



Energy Vs position