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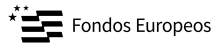
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2024

Quenching of spectroscopic factors in $^{10,12}\text{Be}(d, ^3\text{He})$ reactions

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USC-IGFAE, LPC-Caen and FRIB

Zakopane 2024 Conference



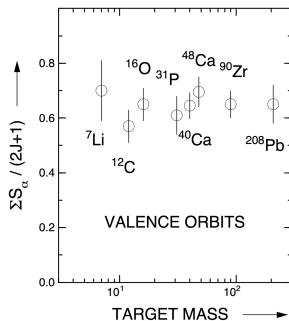
A recap on spectroscopic factors

Spectroscopic factors shed light on the occupancy of single-particle states:

$$\left. \frac{d\sigma}{d\Omega} \right|_{exp} = C^2 S \cdot \left. \frac{d\sigma}{d\Omega} \right|_{s.p}, \quad \sum C^2 S = (2j + 1) \text{ in IPSM}$$

Experimentally:
Reduction of $\sim 65\%$!

- **Short-range** correlations: tensor forces,...
- **Long-range:** vibrations, giant resonances,...



L. Lapikás, Nuclear Phys. A 553 (1993)

A long-standing puzzle

A trend with asymmetry energy $\Delta S \equiv S_n - S_p$ is found depending on the experimental **probe!**

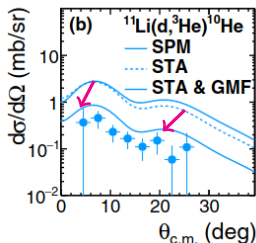


T. Aumann et al. Prog. Part. Nucl. Phys. 118 (2021)

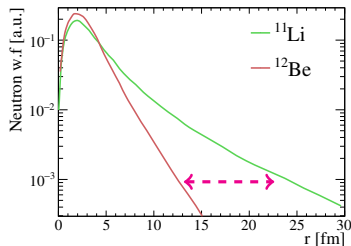
\Rightarrow measure towards more exotic nuclei: $|\Delta S| \uparrow$

Importance of GMF

Towards exotic nuclei (loosely bound or halo), a **geometrical mismatch factor** emerges from the very different w.f. in the overlap:



A.Matta et al., Phys. Rev. C 92 (2015)



N. K. Timofeyuk, private communication (in E748 proposal)

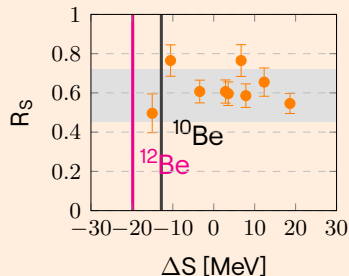
⇒ Need to correct C^2S by its value!

Physics case of E748

E748 @ GANIL back in 2017. Using $^{10,12}\text{Be}(d, ^3\text{He})$ reactions to:

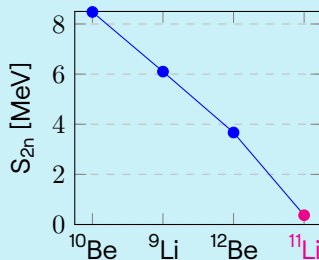
R_S and ΔS dependence:

- $\langle ^{10}\text{Be} | ^9\text{Li} \rangle$, $\Delta S = -12.8 \text{ MeV}$
- $\langle ^{12}\text{Be} | ^{11}\text{Li} \rangle$, $\Delta S = -19.8 \text{ MeV}$



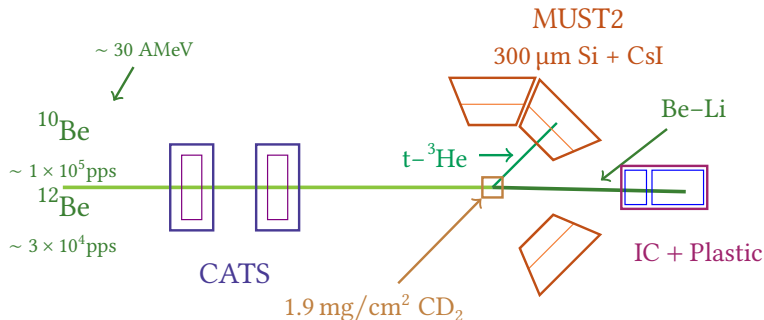
Explore effects of GMF:

- $\langle ^{10}\text{Be} | ^9\text{Li} \rangle$, GMF ~ 1
- $\langle ^{12}\text{Be} | ^{11}\text{Li} \rangle$, GMF $\sim 0.5?$



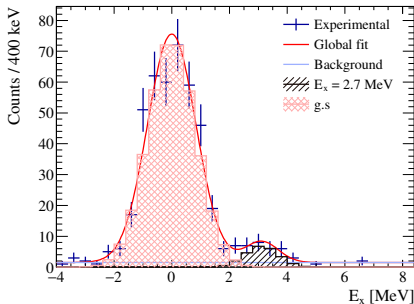
Experimental technique

Traditional solid target experiment @ LISE



Results: $^{10}\text{Be}(d, ^3\text{He})^9\text{Li}$

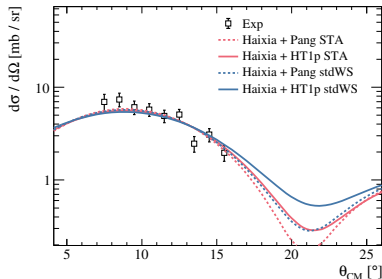
Excitation energy spectrum with all data:



Counts per θ_{CM} bin \Rightarrow **Angular distribution**
Theo. model: finite-range **DWBA** in *FRESCO* code

Results: $^{10}\text{Be}(d, ^3\text{He})^9\text{Li}$

Ground state: known $3/2^-$ ($\ell = 1$)



2 $\langle d| ^3\text{He} \rangle$: Accurate GFMC
I. Brida et al., PRC 84 (2011)

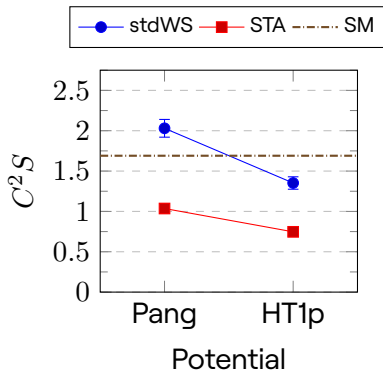
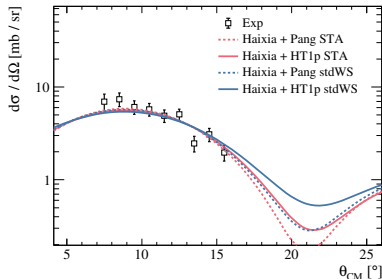
OMP:

- In: Haixia *H. An et al. PRC 73 (2006)*
- Out: Pang and HT1p
D. Y. Pang et al., PRC 79, 91 (2009, 2015)

1 $\langle ^{10}\text{Be} | ^9\text{Li} \rangle$

- A standard Wood-Saxon
- The novel source-term approach (STA) *N. Timofeyuk PRC 81 (2010)*

Results: $^{10}\text{Be}(d, ^3\text{He})^9\text{Li}$



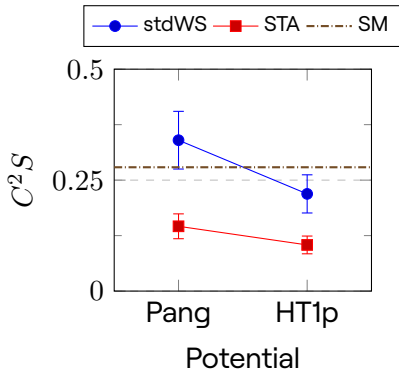
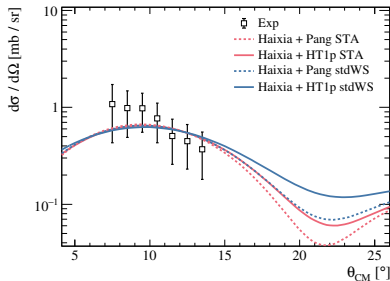
- stdWS yields twice the STA SF
- Sensitivity to r_0 to be further investigated

F. Flavigny et al., PRC 97 (2018)

Shell model calculation
with SFO-tIs interaction:
 $C^2S = 1.69$

Results: $^{10}\text{Be}(d, ^3\text{He})^9\text{Li}$

The **first** excited state $1/2^-$ ($\ell = 1$) is also accessible.

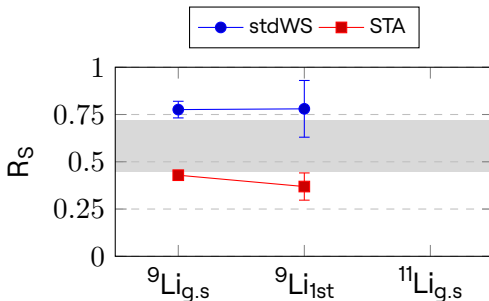


- **First** direct measurement!
- Same trends as for g.s.

Shell model:
 $C^2S = 0.279$

Results: $^{10}\text{Be}(\text{d}, ^3\text{He})^9\text{Li}$

The reduction factor $R_S = C^2 S_{\text{exp}} / C^2 S_{\text{SM}}$ is computed:

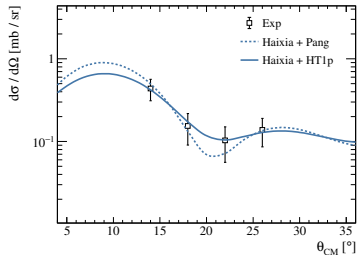
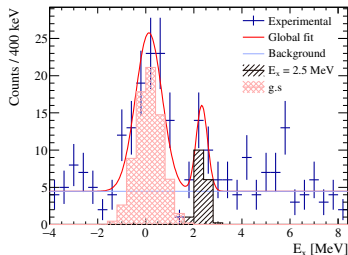


Compatible with
accepted values for R_S in
transfer

Systematic 50 %
difference STA–stdWS

Results: $^{12}\text{Be}(d, ^3\text{He})^{11}\text{Li}$

So far only the **ground state** $3/2^-$ ($\ell = 1$) is analyzed.

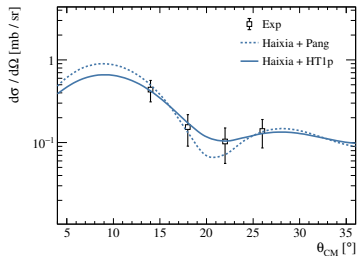
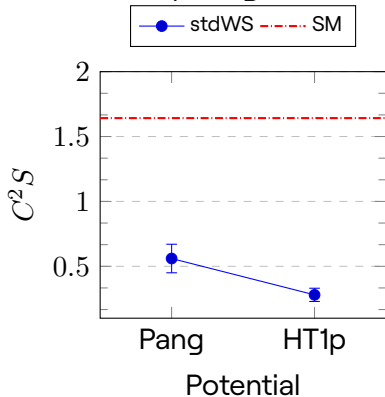


Much lower cross section!

Expected sizeable
contribution of GMF

Results: $^{12}\text{Be}(d, ^3\text{He})^{11}\text{Li}$

So far only the **ground state** $3/2^-$ ($\ell = 1$) is analyzed.

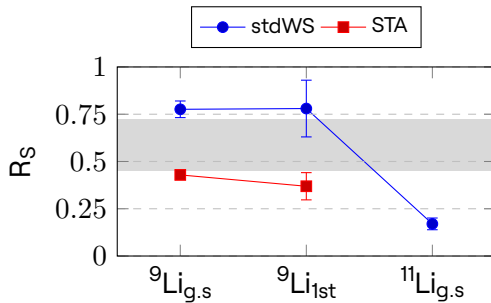


STA **not available** yet!

Shell model:
 $C^2S = 1.642$

Results: $^{12}\text{Be}(d, ^3\text{He})^{11}\text{Li}$

The reduction factor $R_S = C^2 S_{\text{exp}} / C^2 S_{\text{SM}}$ is computed:



- 17(3) % **reduction!**
- Need to correct for **GMF** (ongoing)

- **STA** still in development
- **stdWS** requires physical constraints to r_0

Conclusions

Angular distributions for $^{10,12}\text{Be}(d, ^3\text{He})$ have been extracted and compared with DWBA

Found strong sensitivity to nuclear overlap: stdWS or newer STA

R_S for $\langle ^{10}\text{Be} | ^9\text{Li} \rangle$ in agreement with systematics

R_S for $\langle ^{12}\text{Be} | ^{11}\text{Li} \rangle$ displays a strong reduction linked to GMF

Acknowledgments

The E748 collaboration:

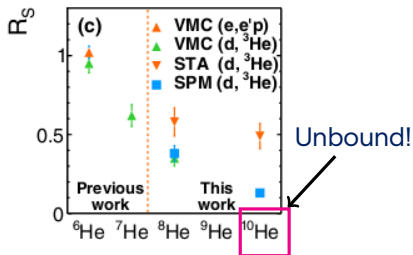
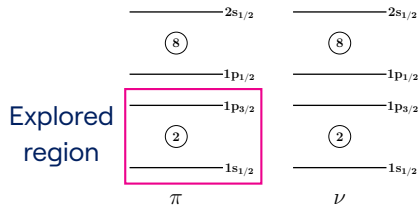
- Santiago:
B. Fernández
- LPC-Caen:
A. Matta
F. Delaunay
N. L. Achouri
F. Flavigny
J. Gibelin
M. Marques
N. Orr
- IJCLab:
D. Beaumel
M. Assié
Y. Blumenfeld
S. Franchoo
A. Georgiadou
V. Girard-Alcindor
F. Hammache
N. de Séreville
A. Meyer
I. Stefan
- GANIL:
B. Jacquot
O. Kamalou
A. Lemasson
M. Rejmund
T. Roger
O. Sorlin
J.C. Thomas
M. Vandebrouck
B. Bastin
F. de Oliveira
C. Stodel
- RIKEN:
S. Koyama
D. Suzuki
- Surrey:
N. Timofeyuk



Backup

Status with light isotopes

Several experiments allowed for the extraction of C^2S with Li-induced (d, ^3He) reactions:



A. Matta et al., Phys. Rev. C 92 (2015)

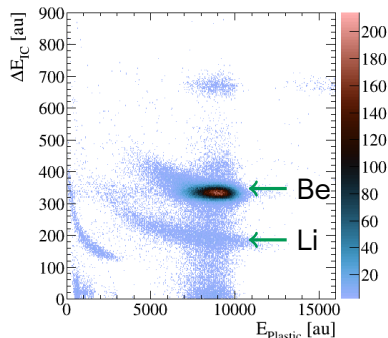
Several challenges in this region:

1 Dealing with **unbound** nuclei (^{10}He)

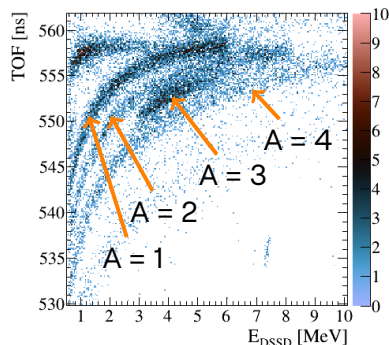
2 Many-body dynamics and/or core excitations

A glance at the analysis

1 Heavy ID at 0°



2 Light PID in DSSD

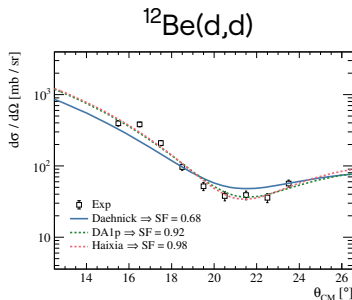
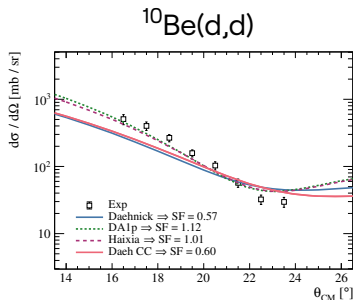


3 E_x from missing mass technique

$$E_{beam} + (E, \theta)_{Lab} \rightarrow E_x$$

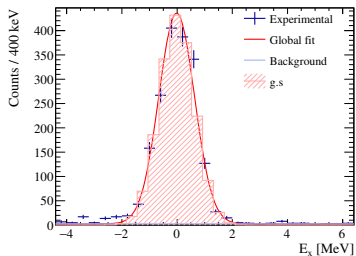
Elastic cross sections

Normalization of all cross-sections was obtained from fits to the elastic data using the Haixia potential.

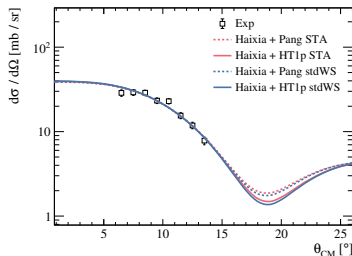


Best OMP: new ones DA1p and Haixia!

Crosscheck: $^{10}\text{Be}(d,t)^9\text{Be}$

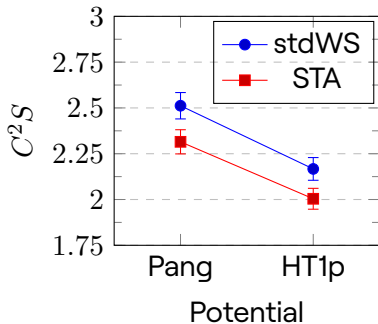


Same behaviour as for the other channels

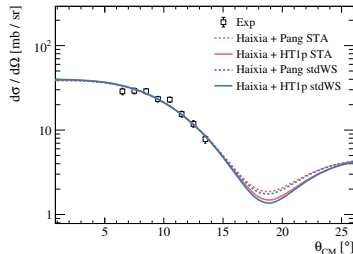


Match with $\sim 65\%$ reduction
if $C^2 S_{\text{SM}} = 3.1$
Not likely!

Crosscheck: $^{10}\text{Be}(d,t)^9\text{Be}$



Same behaviour as for the other channels



Match with $\sim 65\%$ reduction
if $C^2S_{\text{SM}} = 3.1$
Not likely!

Kinematical lines

