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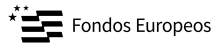
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2024

# 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



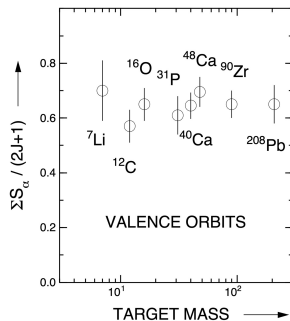
# A recap on spectroscopic factors

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

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

**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**!

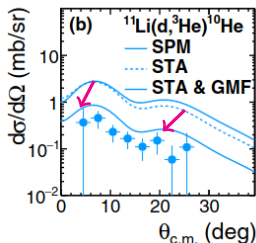


T. Aumann et al. Prog. Part. Nucl. Phys. 118 (2021)

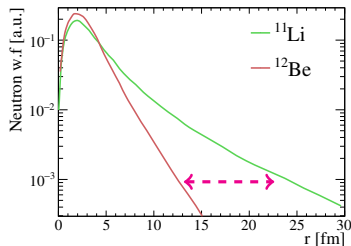
⇒ measure towards more exotic nuclei:  $|\Delta S| \uparrow$

# 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)

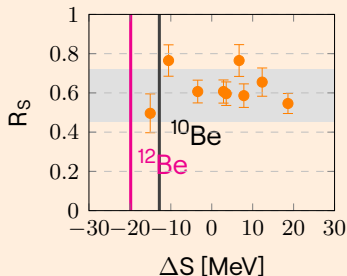
⇒ Need to correct  $C^2S$  by its value!

# Physics case of E748

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

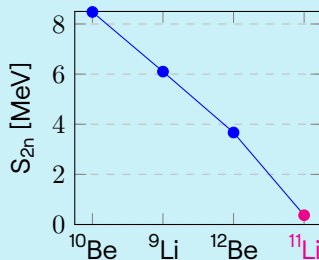
$R_S$  and  $\Delta S$  dependence:

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



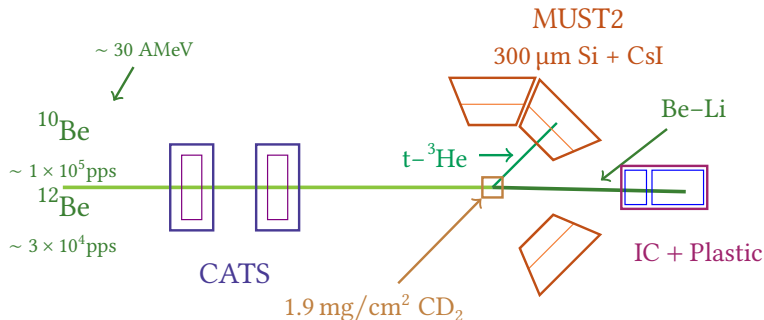
Explore effects of GMF:

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



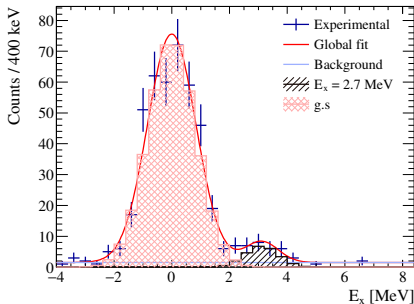
# Experimental technique

## Traditional solid target experiment @ LISE



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

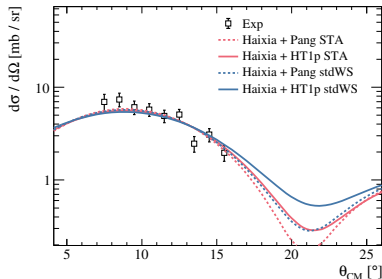
Excitation energy spectrum with all data:



Counts per  $\theta_{\text{CM}}$  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:

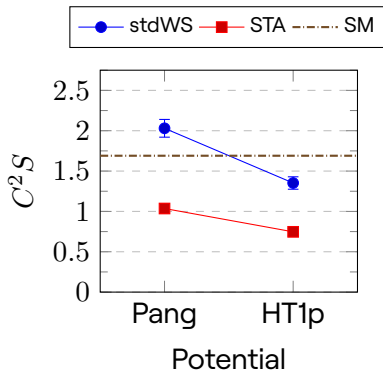
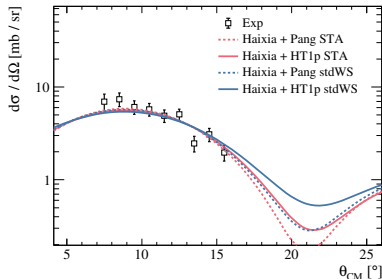
- In: Haixia *H. An et al. PRC 73 (2006)*
- Out: Pang and HT1p  
*D. Y. Pang et al., PRC 79, 91 (2009, 2015)*

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



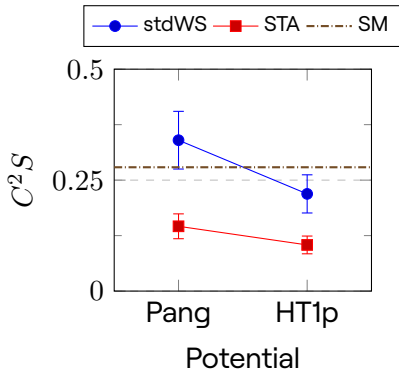
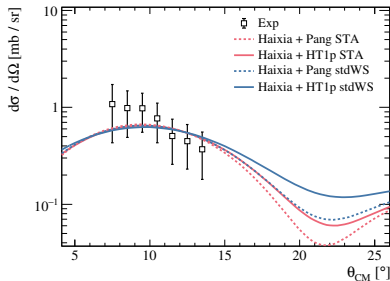
- stdWS yields twice the STA SF
- Sensitivity to  $r_0$  to be further investigated

*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.

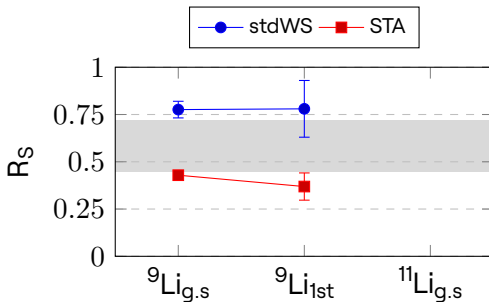


- **First** direct measurement!
- Same trends as for g.s.

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:

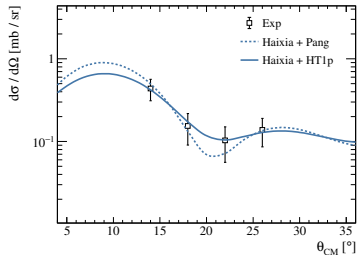
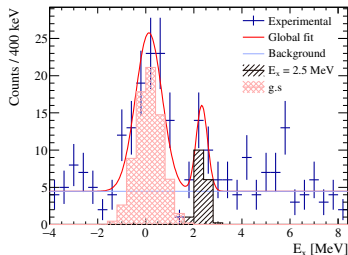


Compatible with  
accepted values for  $R_S$  in  
transfer

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.

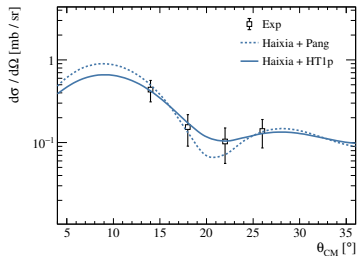
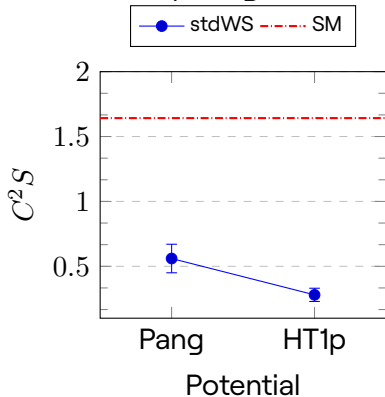


Much lower cross section!

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.

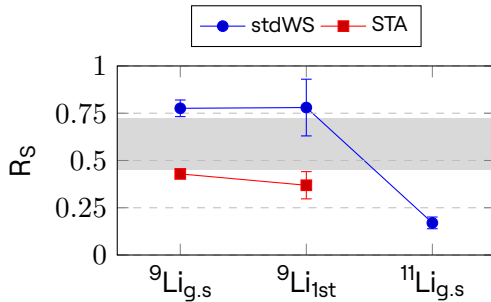


STA **not available** yet!

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!**
- Largest GMF only recovers up to  $\sim 35\%$

- **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  $\sim 17\%$  reduction likely related to GMF

# Acknowledgments

## The E748 collaboration:

- Santiago:  
B. Fernández
- LPC-Caen:  
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- Surrey:  
N. Timofeyuk

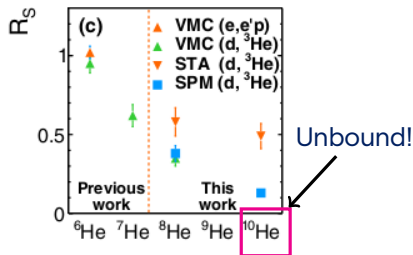
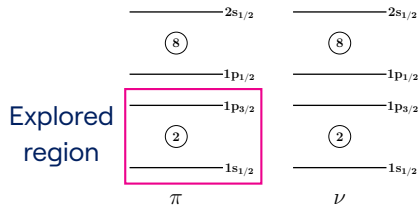




Backup

# Status with light isotopes

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



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

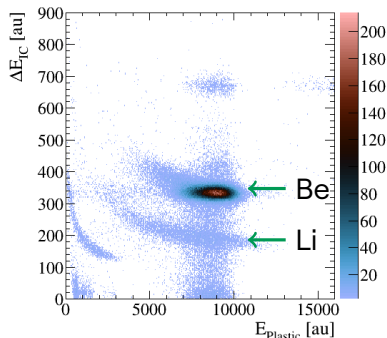
Several challenges in this region:

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

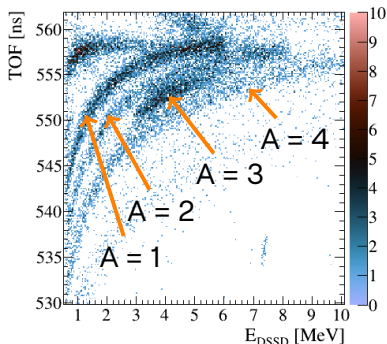
2 Many-body dynamics and/or core excitations

# A glance at the analysis

## 1 Heavy ID at 0°



## 2 Light PID in DSSD

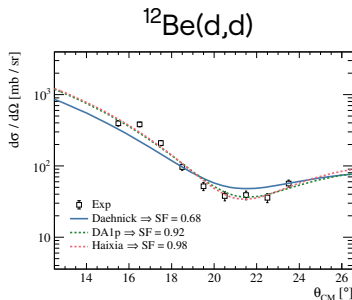
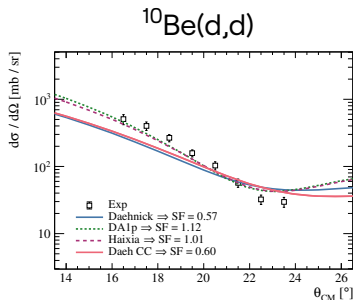


## 3 $E_x$ from missing mass technique

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

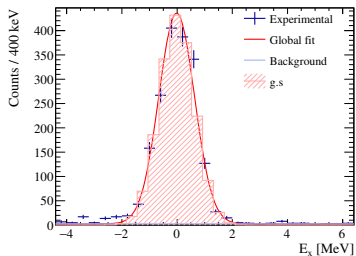
# Elastic cross sections

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

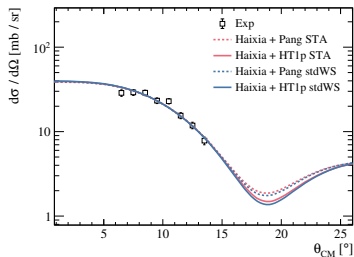


Best OMP: new ones DA1p and Haixia!

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

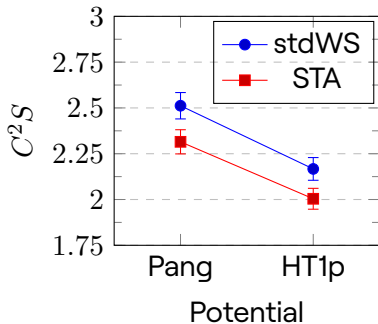


Same behaviour as for the other channels

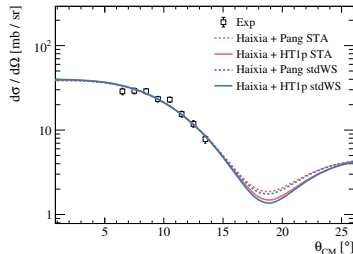


Match with  $\sim 65\%$  reduction  
if  $C^2 S_{\text{SM}} = 3.1$   
Not likely!

# 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

