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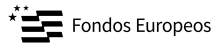
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2024

Quenching of spectroscopic factors in $^{10,12}\text{Be}$ transfer reactions

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USC-IGFAE and LPC-Caen

ASTRANUCAP and CPAN Days 2024



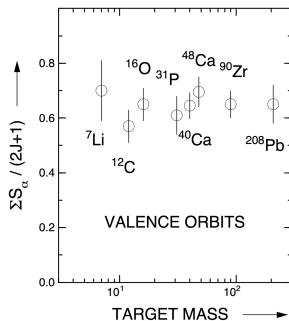
A recap on spectroscopic factors

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

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

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 $\Delta S \equiv \pm (S_p - S_n)$ is found depending on the experimental **probe!**

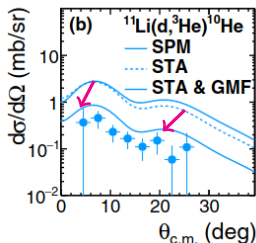


T. Aumann et al. Prog. Part. Nucl. Phys. 118 (2021)

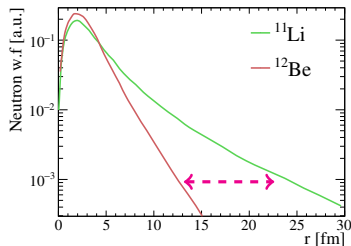
⇒ measure towards more exotic nuclei: $|\Delta S| \uparrow$

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)

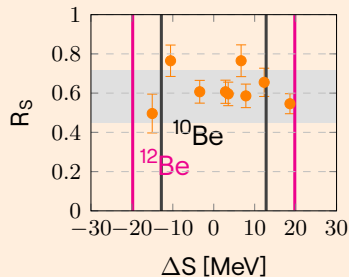
⇒ Need to correct C^2S by its value!

Physics case of E748

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

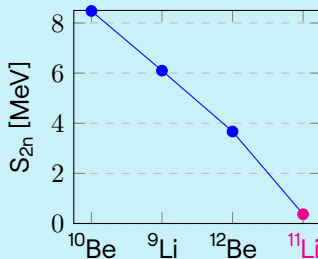
R_S and ΔS dependence:

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



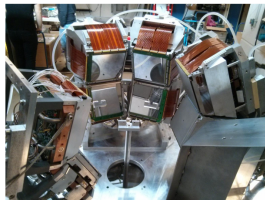
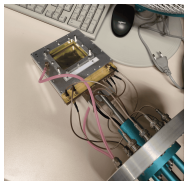
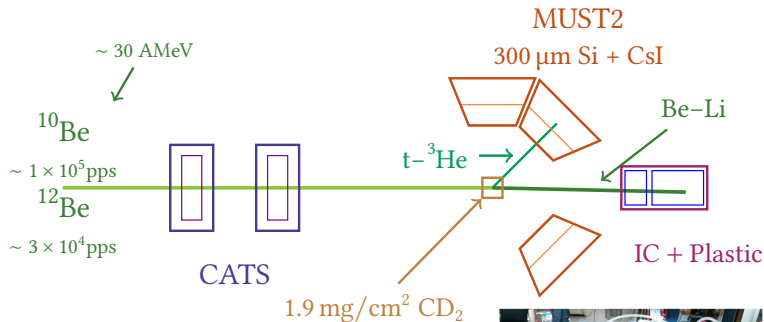
Explore effects of GMF:

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



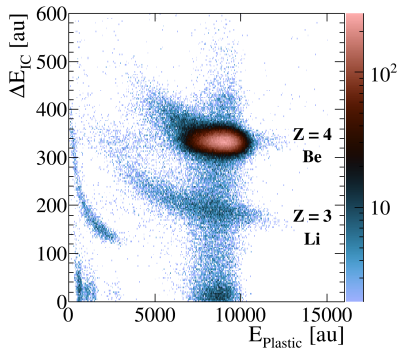
Experimental technique

Traditional solid target experiment @ LISE

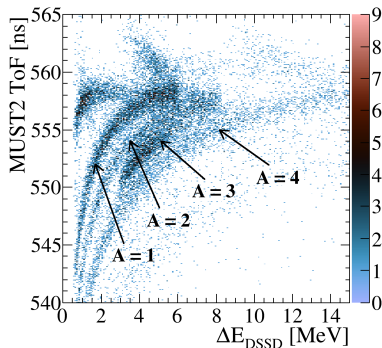


A glance at the analysis

1 Heavy ID at 0°



2 Light PID in DSSD

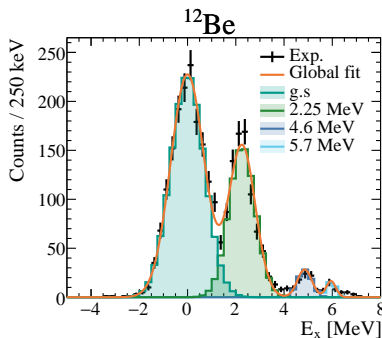
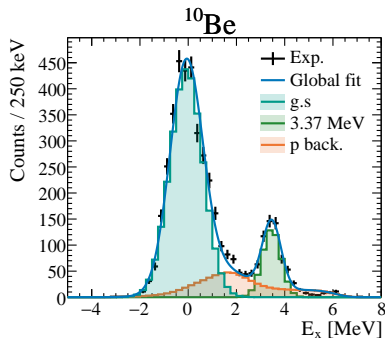


3 E_x from missing mass technique

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

Results: Elastic $^{10,12}\text{Be}(d,d)^{10,12}\text{Be}$

The **ground state** sets our normalization!



First 2^+ is seen in both cases but not yet exploited!

Results: Elastic $^{10,12}\text{Be}(d,d)^{10,12}\text{Be}$

Experimental cross-section formula:

$$\frac{d\sigma}{d\Omega} = \frac{N}{N_{\text{beam}} N_{\text{targets}} \epsilon \Delta\Omega} = \frac{N}{N_{\text{beam}} \alpha \epsilon_{\text{sim}} \Delta\Omega}$$

1 Target thickness not measured during experiment:

- Set it from normalization of elastic

2 ZDD had a poor performance.

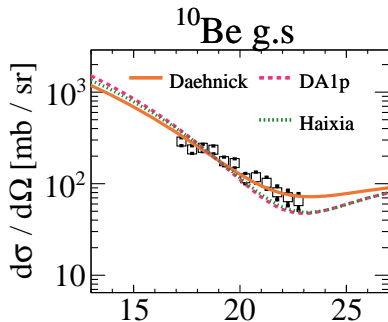
- Estimated $\sim 20\text{--}30\%$

Agglutination of unknown factors: $\alpha = N_{\text{targets}} \cdot \epsilon_{\text{intrinsic, ZDD}}$

α is determined from fits of theoretical cross-sections to data

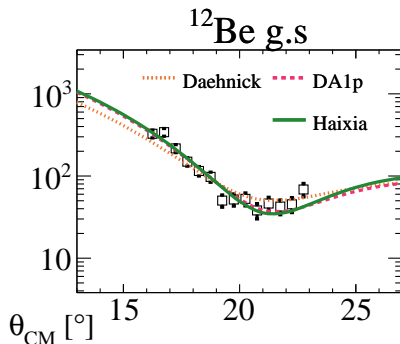
Results: Elastic $^{10,12}\text{Be}(d,d)^{10,12}\text{Be}$

The best OMP potentials can also be deduced from the fit quality.



$^{10}\text{Be} + d$: **Daehnick**

W. Daehnick et al. PRC 21 (1980)

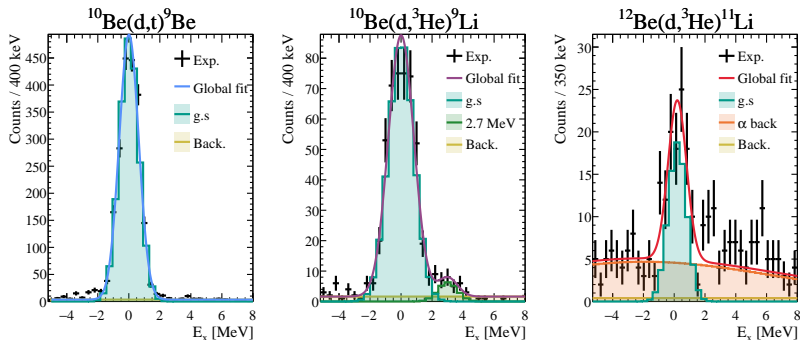


$^{12}\text{Be} + d$: **Haixia**

H. Ann, C. Cai. PRC 73 (2006)

Results: transfer

The **ground states** of the heavy recoils are populated.



First state at 2.7 MeV of ^9Li is seen too! 😊

Results: transfer

Fresco is employed to perform the **DWBA** calculations.

OMP

- In: set from elastic
- Out: HT1p

D. Y. Pang et al., PRC 91 (2015)

Light overlap

$$\langle t, {}^3\text{He} | d \otimes n, p \rangle$$

Accurate GFMC

I. Brida et al., PRC 84 (2011)

1 Heavy overlap

$$\langle {}^{10,12}\text{Be} | {}^{9,11}\text{Be}, \text{Li} \otimes n, p \rangle$$

A standard WS

$$r_0 = 1.25 \text{ fm}, a = 0.65 \text{ fm}$$

2 Heavy overlap

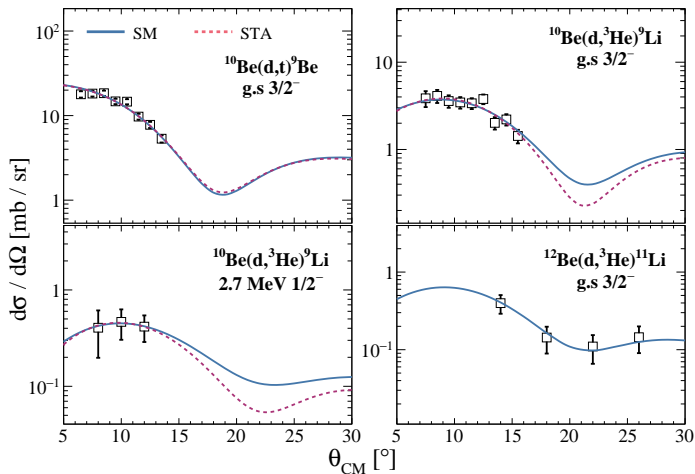
$$\langle {}^{10,12}\text{Be} | {}^{9,11}\text{Be}, \text{Li} \otimes n, p \rangle$$

WS from novel *Source Term Approach* (STA)

N. Timofeyuk PRC 81 (2010)

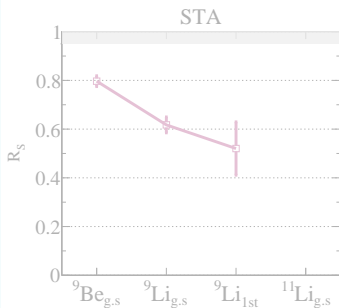
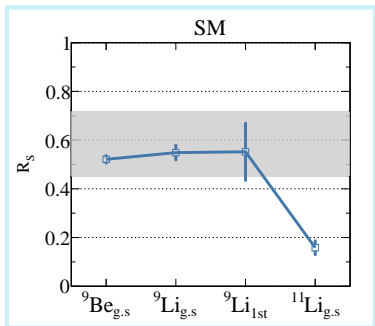
Results: transfer

Angular distributions for all the states



Results: quenching factor

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



SFO-tls interaction

T. Suzuki, T. Otsuka PRC

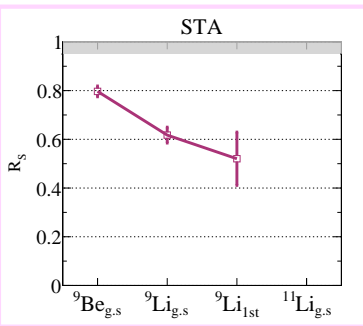
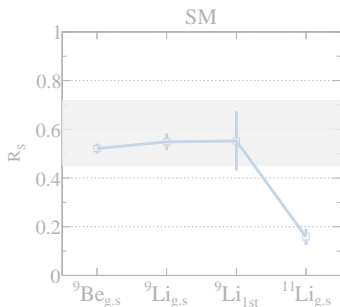
78 (2008)

Compatible with
current
systematics 👍

^{11}Li requires GMF
correction
(pending)

Results: quenching factor

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



$R_S = 1$
is expected now

Falls short in
modelling SRCs

Needs to be
extended to ^{11}Li

Conclusions

Angular distributions for ^9Be , ^9Li and ^{11}Li have been extracted and compared with DWBA

R_S for SM agrees with literature, while STA still underestimates NN correlations

^{11}Li needs correction for a major geometrical mismatch value

STA requires further developments to reach ^{11}Li

Acknowledgments

The E748 collaboration:

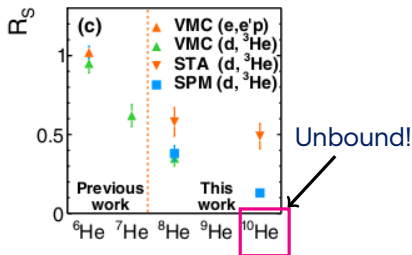
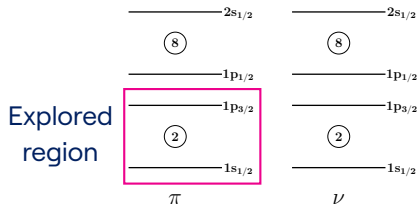
- Santiago:
B. Fernández
- LPC-Caen:
A. Matta
F. Delaunay
N. L. Achouri
F. Flavigny
J. Gibelin
M. Marques
N. Orr
- IJCLab:
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O. Sorlin
J.C. Thomas
M. Vandebrouck
B. Bastin
F. de Oliveira
C. Stodel
- RIKEN:
S. Koyama
D. Suzuki
- Surrey:
N. Timofeyuk



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)

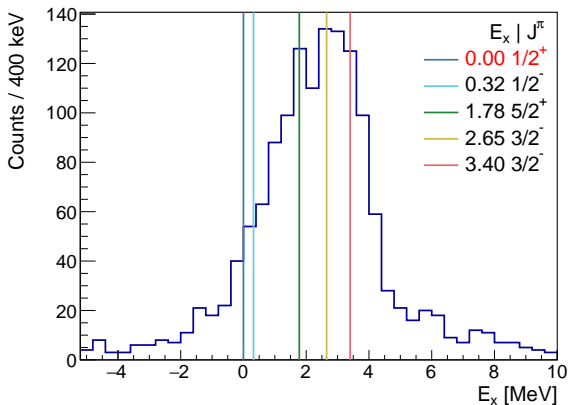
Several challenges in this region:

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

2 Many-body dynamics and/or core excitations

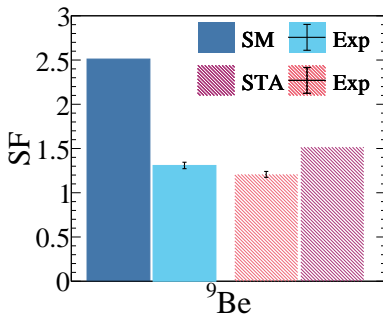
What happens with ^{11}Be ?

It shows a strong inhibition of the ground state.



Impossible to disentangle excited states 😞

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

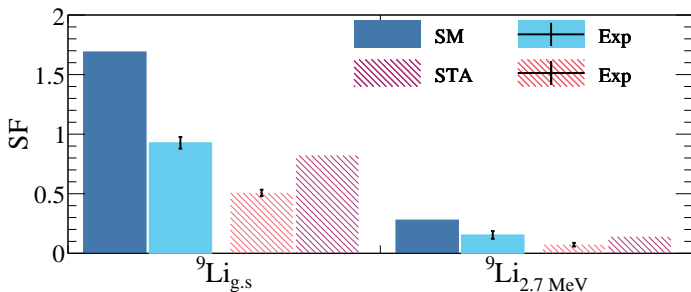


SM calculation using **SFO-tls** interaction

T. Suzuki, T. Otsuka PRC 78 (2008)

STA yields 40 % of SM value.
Better accord with exp values

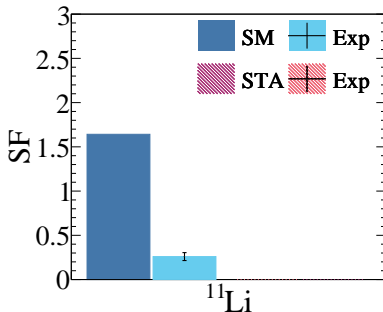
Results: $^{10}\text{Be}(d, ^3\text{He})^9\text{Li}$



Same significant differences
SM-STA

Worse agreement within STA
data
~ 40 % discrepancies

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



Gigantic quenching,
signature of **GMF** playing a
role

No STA predictions yet 😞

Kinematical lines

