



INSTITUTO GALEGO
DE FÍSICA
DE ALTAS ENERXÍAS

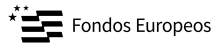
25  1999
2024

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

M. Lozano-González, A. Matta, B. Fernández-Domínguez,
F. Delaunay, J. Lois-Fuentes

USC-IGFAE and LPC-Caen

Status by October 2024



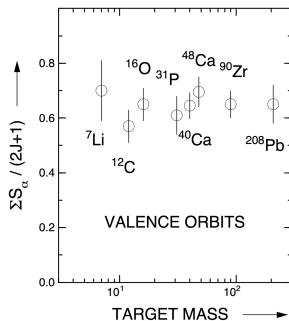
A recap on spectroscopic factors

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!**

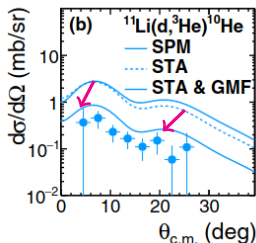


T. Aumann et al. Prog. Part. Nucl. Phys. 118 (2021)

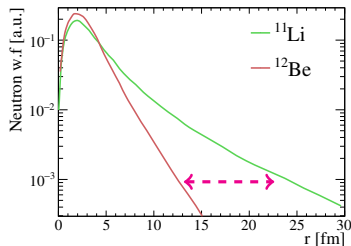
⇒ measure towards more exotic nuclei: $|\Delta S| \uparrow$

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)

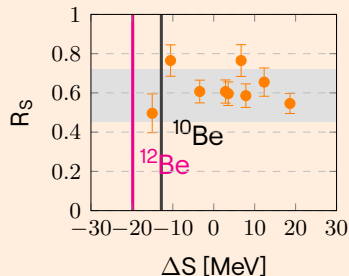
⇒ Need to correct C^2S by its value!

Physics case of E748

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

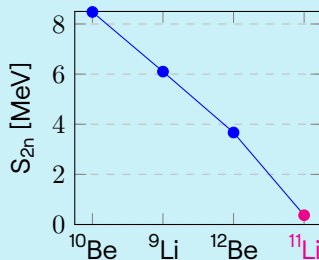
R_S and ΔS dependence:

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



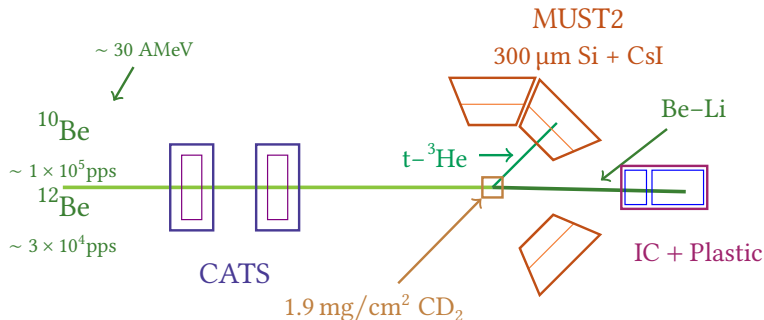
Explore effects of GMF:

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



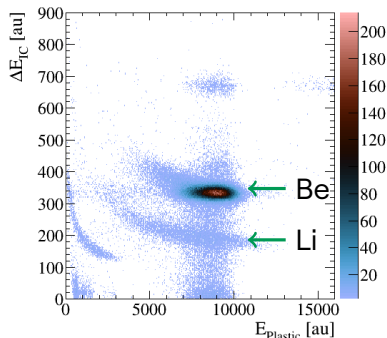
Experimental technique

Traditional solid target experiment @ LISE

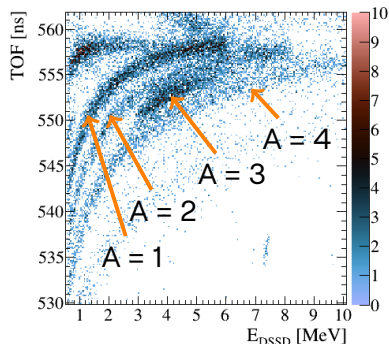


A glance at the analysis

1 Heavy ID at 0°



2 Light PID in DSSD

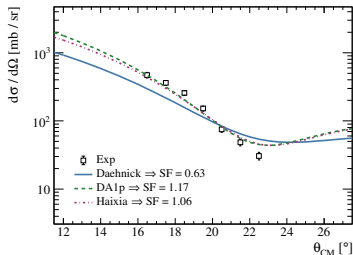
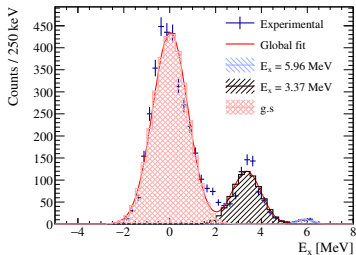


3 E_x from missing mass technique

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

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

Useful for normalization purposes.



Best fit is provided by newer **Haixia** OMP.

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

Experimental cross-section formula:

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

1 Target thickness not measured during experiment:

- Set it from normalization of elastic
- **Ongoing:** fix it from simulation

2 ZDD had a poor performance. Averaged ϵ :

- IC: 30 %
- Plastic: 50 %

From **npsimu**: $\epsilon_{\text{np}} = \epsilon_{\text{geo, MUST2}} \cdot \epsilon_{\text{reconstruction}} \cdot \epsilon_{\text{geo, ZDD}}$
Agglutinate missing factors: $\alpha = N_{\text{targets}} \cdot \epsilon_{\text{intrinsic, ZDD}} \cdot \epsilon_{\text{other?}}$

About DWBA calculations

1 OMPs for elastic

- $^{10,12}\text{Be} + d$: Haixia
- $^{9,11}\text{Be}, \text{Li} + t$ or ^3He : HT1p

2 Light overlap. Usually determines the xs strength.

- $\langle t | d + n \rangle$
- $\langle ^3\text{He} | d + p \rangle$

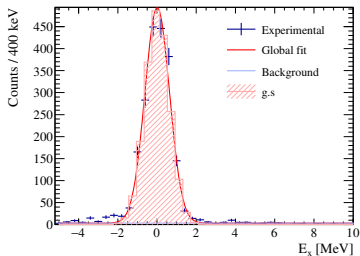
From GFMC calculations (*ab initio*)

3 Heavy overlap $\langle ^{10,12}\text{Be} | ^{9,11}\text{Be}, \text{Li} + n, p \rangle$. Two WS prescriptions:

- Standard $r_0 = 1.25 \text{ fm}$
- *N. Timofeyuk PRC 81 (2010)* Source Term Approach (STA): includes in a phenomenological way some correlations among nucleons. r_0 for each channel.

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

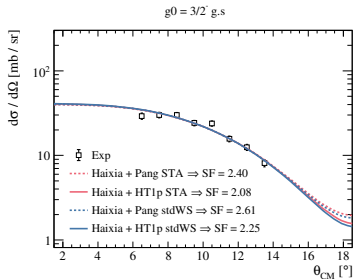
Relatively high statistics. Used for benchmarking analysis routines.



STA prediction:

$$C^2S = 1.50$$

Our result: $C^2S_{\text{exp}} = 2.08$

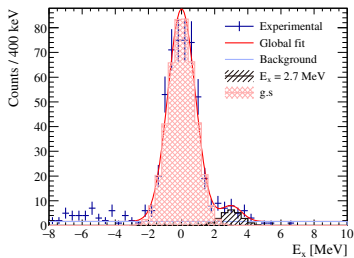


SFO-tls shell-model:

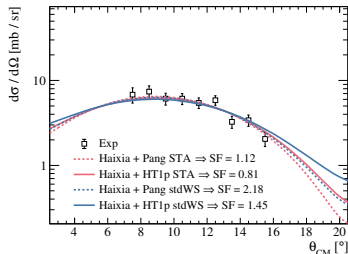
$$C^2S = 2.51$$

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

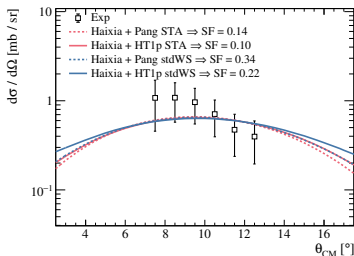
$3/2^-$ ground state and $1/2^-$ 1st excited state.



Ground state

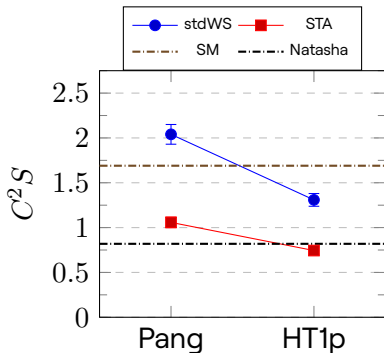


1st excited

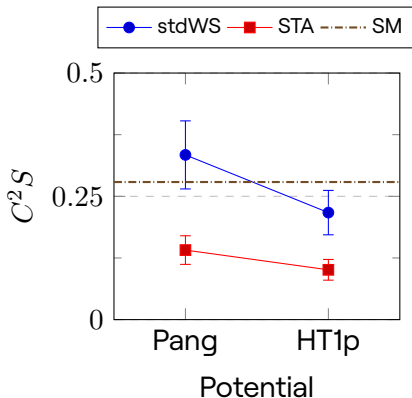


Results: $^{10}\text{Be}(d, ^3\text{He})^9\text{Li}$

Ground state



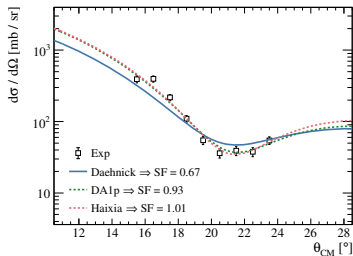
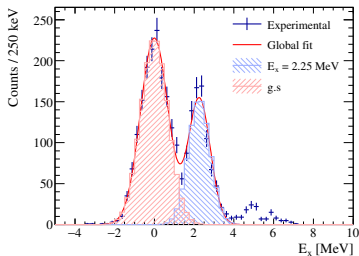
STA fit agrees with N. Timofeyuk prediction!



First direct measurement!

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

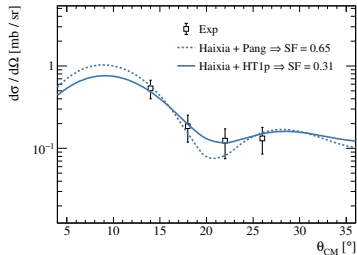
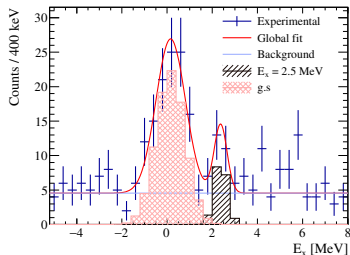
As before, this is used for setting the normalization of all channels.



N_{targets} is determined from the weighted average of this and the $^{10}\text{Be}(d,d)$ result

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

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

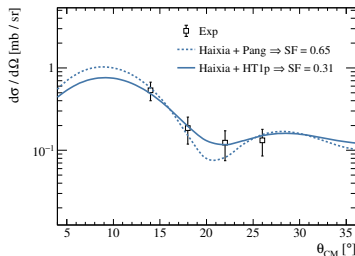
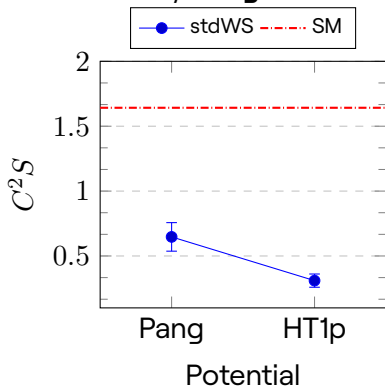


Much lower cross section!

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.

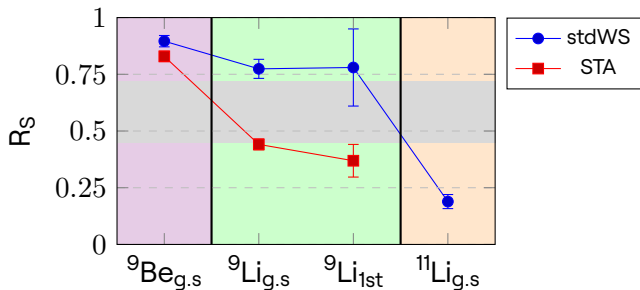


STA **not available** yet!

Shell model with SFO-tls:
 $C^2S = 1.642$

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:



What happens with ^9Be ?

R_S compatible with literature

~ 20 % reduction
GMF playing a role
Need **STA**

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

Current issues

1 Found a quite low efficiency for the ZDD. This lowers the general efficiency since it is mandatory to gate on the heavy particle to identify on the ToF plot.

3- Combined efficiency of IC (= CHIO) and PL

Algorithm to count efficiency on physics data:

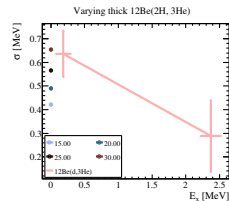
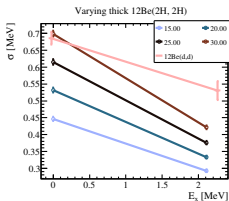
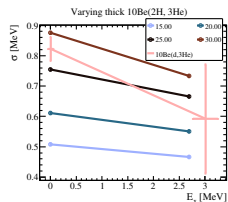
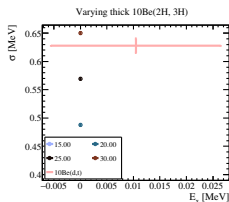
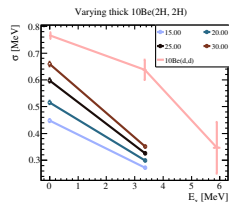
1. Select all the physical runs for 10Be or 12Be with PID already applied (this implies good CATS reconstruction as there is a cut in target position)
2. Count events with `Must2Multiplicity >= 1`
3. Relatively to that, count events with `0 <= IC_E <= 3000` (there is a constant overflow at 60000)
4. Relatively to those good IC events, count `QPlast > 0` (contrary to IC, here there is a constant underflow at -1000)

Here are the results for both beams

| Beam | IC / Must2 | PL / IC | Combined [%] |
|------|------------|----------|--------------|
| 10Be | 0.265027 | 0.532634 | 14.116 |
| 12Be | 0.198695 | 0.587892 | 11.681 |

Current issues

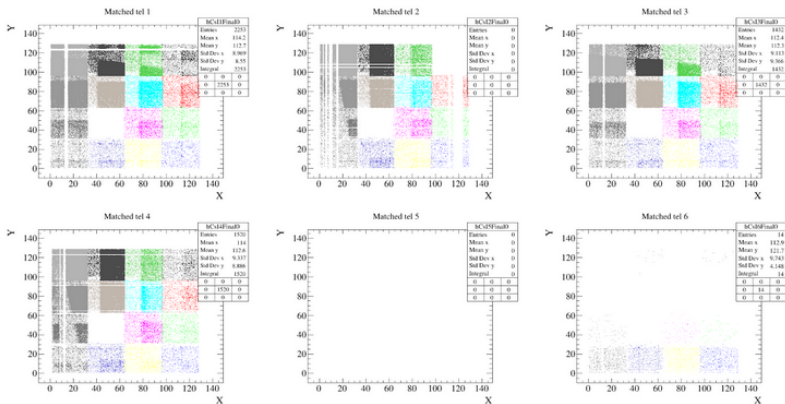
2 Experimental and simulated σ do not match \rightarrow Work in progress to infer target thickness from this feature.



Clearly all (but 10Be(d,d)...) agree when thickness $\sim 28 \mu\text{m}$

Current issues

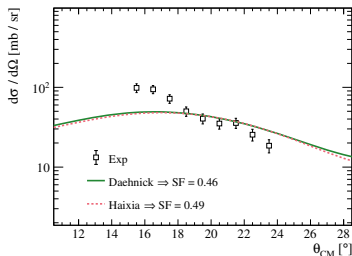
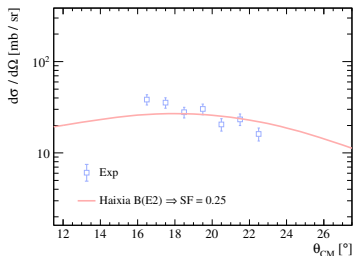
3 There is an issue with the Csl matching.



Check this link for further info

Current issues

4 What happens with the B(E2) deformations of $^{10-12}\text{Be}$?



Coulomb deformation:

$$p_2 = \sqrt{B(E2)}$$

Nuclear deformation:

$$p_2 = \beta_2 \cdot R_0 \text{ with } R_0 = 1.3 \text{ fm} \cdot A^{1/3}$$

Acknowledgments

The E748 collaboration:

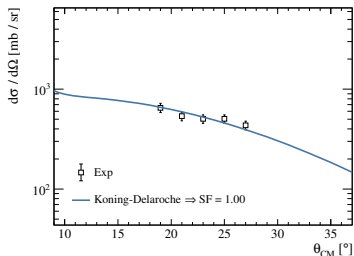
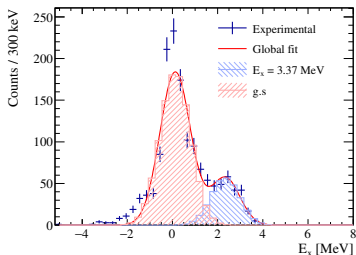
- Santiago:
B. Fernández
- LPC-Caen:
A. Matta
F. Delaunay
N. L. Achouri
F. Flavigny
J. Gibelin
M. Marques
N. Orr
- IJCLab:
D. Beaumel
M. Assié
Y. Blumenfeld
S. Franchoo
A. Georgiadou
V. Girard-Alcindor
F. Hammache
N. de Séreville
A. Meyer
I. Stefan
- GANIL:
B. Jacquot
O. Kamalou
A. Lemasson
M. Rejmund
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

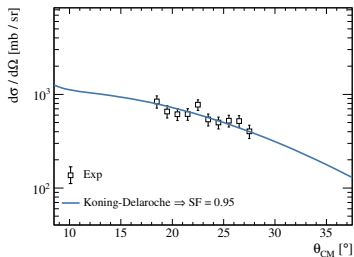
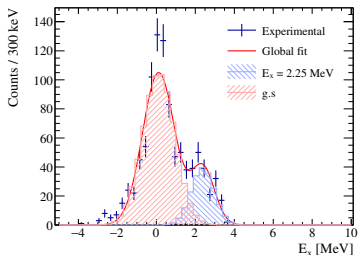
Additional: $^{10}\text{Be}(p,p)$

This ground state is employed to obtain the number of protons in the target



Additional: $^{12}\text{Be}(p,p)$

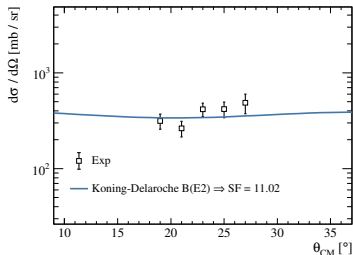
Same as before but for ^{12}Be



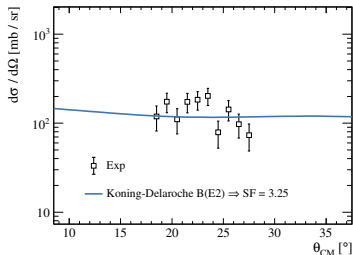
Additional: inelastic B(E2) with protons

The deformations included in the potential are exactly the same as for (d,d) channel.

$^{10}\text{Be}(p,p)$



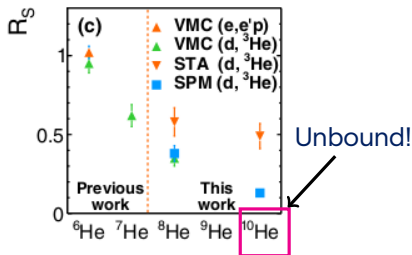
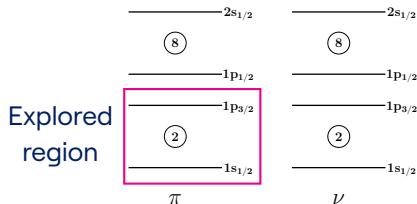
$^{12}\text{Be}(p, p)$



For $^{10}\text{Be}(p,p)$ efficiency is critical: events impinge onto the boundary of the telescope

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

Kinematical lines

