INSTITUTO GALEGO DE FÍSICA DE ALTAS ENERXÍAS

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Low-lying spectroscopy of $^{19,20}O$

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

USC-IGFAE and LPC-Caen

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AGENCIA ESTATAL DE INVESTIGACIÓN

EXCELENCIA MARÍA DE MAEZTU 2024-2029

XUNTA DE GALICIA

CENTROS

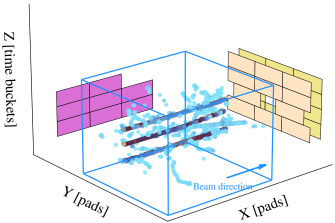
Cofinanciado por la Unión Europea

Fondos Europeos

Experimental setup

E796 was performed at LISE (GANIL) back in March 2022 under these experimental conditions:

- Beam: ^{20}O @ 35 AMeV
- Gas: $90\,\%$ D_2 and $10\,\%$ iC_4H_{10}
- Silicons: two front layers and one left. $500\,\mu$m-thick



(In)elastic
^{20}O(p, p)
^{20}O(d, d)

p and n removal
^{20}O(d, ^{3}He)
^{20}O(d, t)
^{20}O(p, d)

Physics case

Inelastic: ^{20}O(p,p') and (d,d') excitations

Probing their **isoscalar** or **isovector** character

1. Determine β_{nucl} from xs normalization
2. Use previous β_{em}
3. Bernstein formula for M_n/M_p ratio

	E_{exc} (MeV)	β(p,p') [Escu:74],[Jewe:99]	β(p,p')	β(em) [Ram:87] [Spea:89]	$\frac{M_n/M_p}{N/Z}$
^{18}O état 2^+	1,98	0,37 (3)	**0,37 (3)**	0,355 (8)	**1,05 (13)**
^{18}O état 3^-	5,09	0,35 (6)	**0,34 (4)**	0,562 (24)	0,63 (21)
^{20}O état 2^+	1,67	0,50 (4)	**0,55 (6)**	0,261 (9)	**2,35 (37)**
^{20}O état 3^-	5,61	-	**0,35 (5)**	-	-

Tableau 3.5 : Compilation des paramètres de déformation pour ^{18}O et ^{20}O. Les incertitudes sur le dernier chiffre significatif sont indiquées entre parenthèses. Les valeurs en gras sont les résultats de notre expérience.

E.Khan thesis (2000)

- $\sim 1 \Rightarrow$ isoscalar
- $\gg 1 \Rightarrow$ isovector

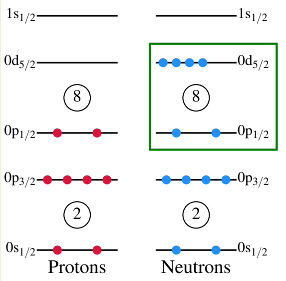
Physics case

Transfer: spectroscopy on $^{20}O(d,t),(p,d)^{19}O$

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

Two goals:

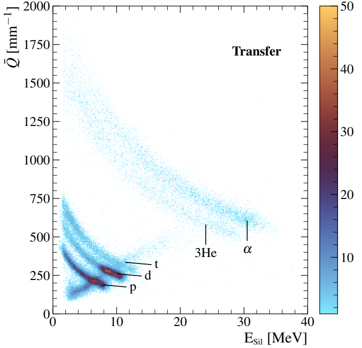
1. Study of the ^{20}O gs wave-function
2. Behaviour of $\mathcal{N} = 8$ gap

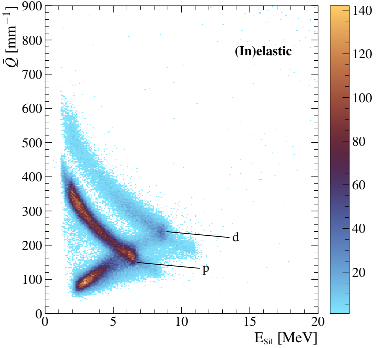


^{20}O shell-model prediction

A glance at the analysis

Independent analyis from Juan: same general idea but different execution and (I hope) some improvements.



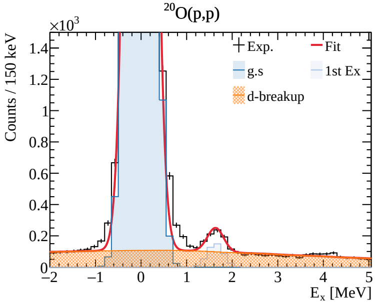


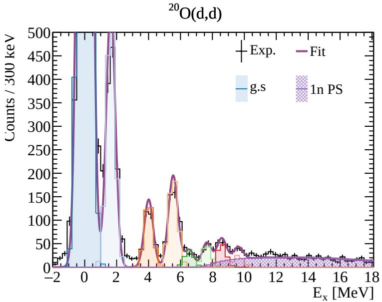
Good PID after vetoing punchthrough

E_x resolution in very good agreement with simulations!

Results: (in)elastic scattering

These are the excitation energy spectra for protons and deuterons.



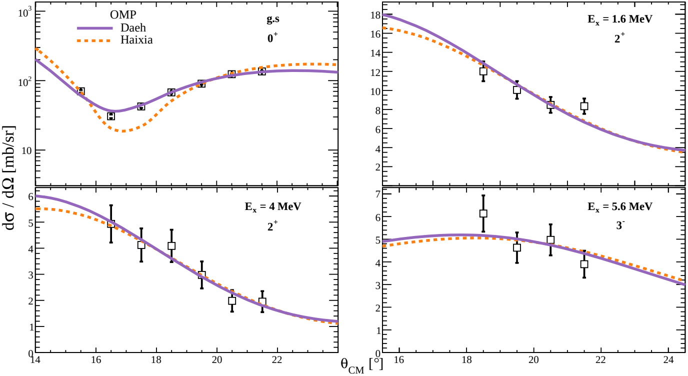


Only 1st excited state

Up to 7 $E_x > 0$ states observed!

Results: $^{20}O(d,d)$

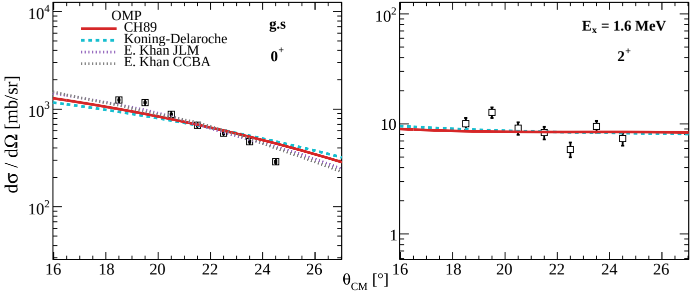
Angular distributions for the **ground state** and first excited states:



Remaining states: low stats. Coming soon.

Results: $^{20}O(p,p)$

For the proton scattering:



Issue: gs not reproduced by any OMP! 😰

1st excited seems fine $\Rightarrow$ compare β_2 with E. Khan

About normalizations

Just to recall the xs formula:

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

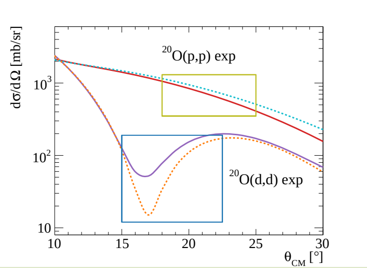
- $N_{\text{beam}} \leftarrow$ CFA counter
- $N_{\text{targets}} \leftarrow$ Gas mixture. Sensitive to p.

Theo. lines need **scaling** (α) to match experimental data

α in agreement with Juan's

$\Rightarrow$ Not likely ϵ issue

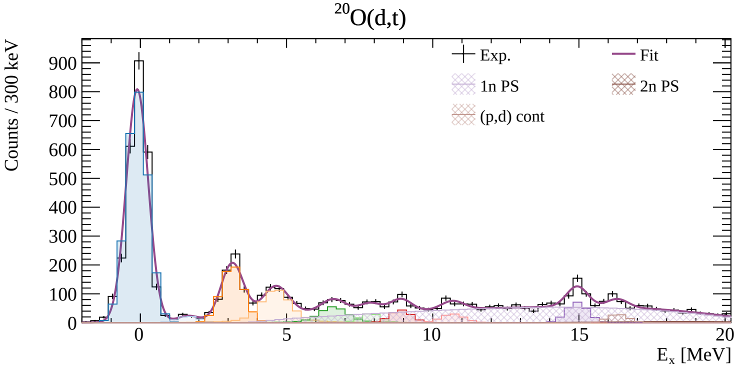
Which norm should we use?



Protons are more "reliable" 🤔

Results: $^{20}O(d,t)$

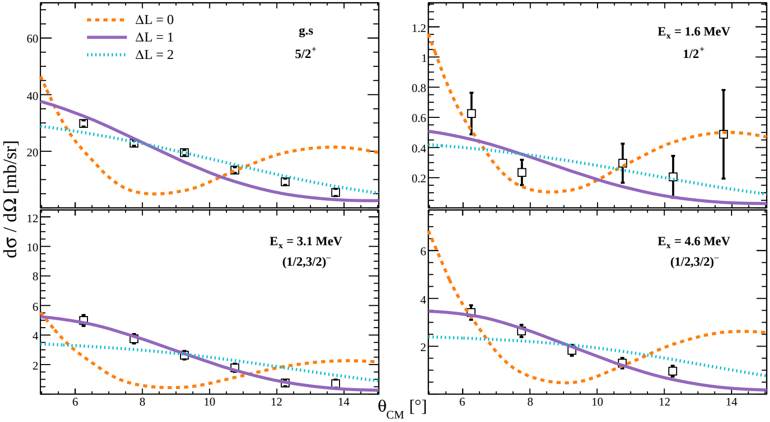
Excited states are populated up to ~ 15 MeV:



1n and 2n **phase spaces** are included in the fit. Small (p,d) contamination at ~ 16 MeV under control.

Results: $^{20}O(d,t)$

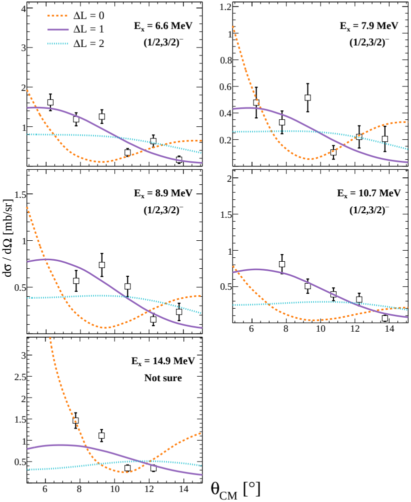
Fresco DWBA with OMPs: Daehnick (d), Pang (t)

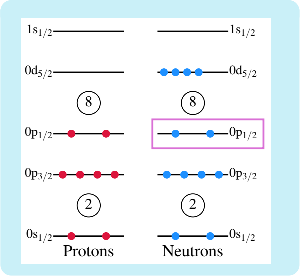


g.s fits well to $\Delta L = 2$.

Results: $^{20}O(d,t)$

Fresco DWBA with OMPs: Daehnick (d), Pang (t)

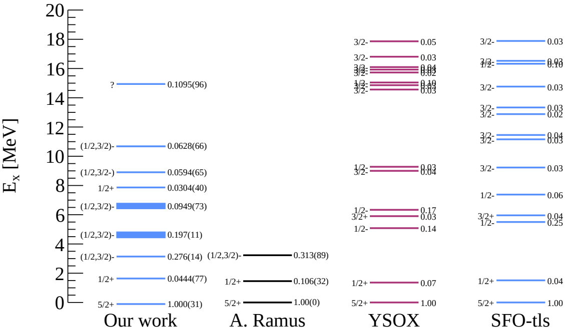




Almost all are
$\Delta L = 1!$

Results: $^{20}O(d,t)$

SF are compared with shell-model calculations with **YSOX** and **SFO-tls**.



Normalized to gs SF

More $p_{1/2}$ strength than predicted at $E_x < 10$ MeV

About ESPEs

Effective single-particle energies (ESPEs) are needed to locate the $1p_{1/2}$ and $1d_{5/2}$ orbits: **Baranger's formula**

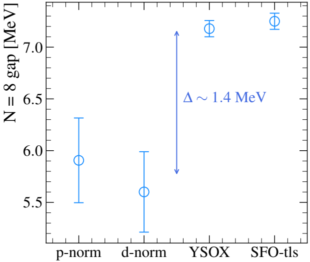
$$\mathsf{ESPE}_{nlj} = \frac{\sum_{i+}(2j+1)\mathsf{SF}_{i+}(E_{i+}-E_0) + \sum_{i-}\mathsf{SF}_{i-}(E_0-E_{i-})}{\sum_{i+}(2j+1)\mathsf{SF}_{i+} + \sum_{i-}\mathsf{SF}_{i-}}$$

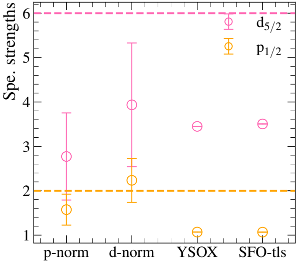
Removal $(-)$ from our (d,t) or (p,d) channels.

Adding $(+)$ from $^{20}O(d,p)^{21}O$ by B. Fernández-Domínguez *et al.* PRC 84 (2011)

Results: $^{20}O(d,t)$

Assuming all $\Delta L = 1$ states below $E_x = 10$ MeV are $p_{1/2}$...





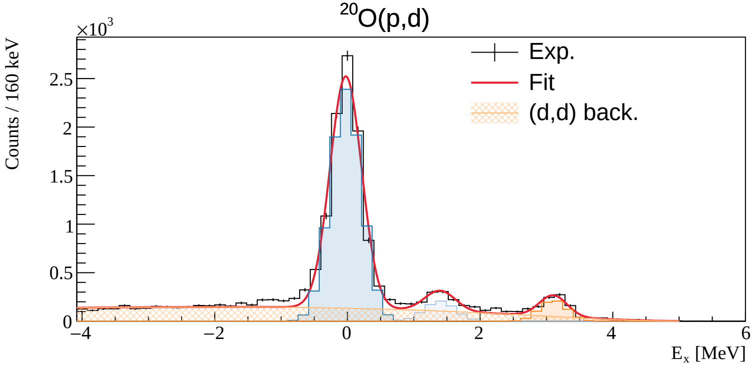
Smaller experimental gap than predicted!

Higher $1p_{1/2}$ occupation according to exp.

Note: *p-norm* refers to absolute SFs with (p,p) normalization, whereas *d-norm* to (d,d) data

Results: $^{20}O(p,d)$

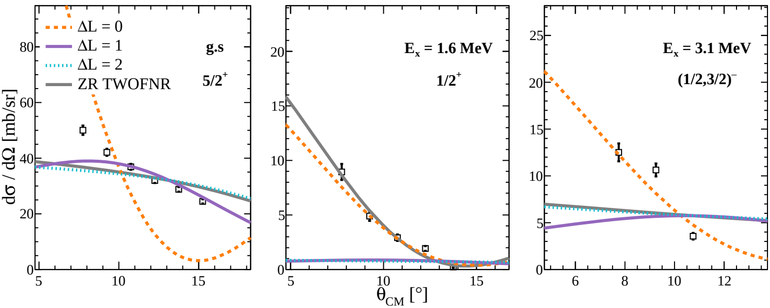
Fewer states are populated in this channel:



Strong (d,d) background since we only identify the outgoing deuteron!

Results: ^{20}O(p,d)

OMPs: CH89 (p), ADWA (d). Not so encouraging results:



Either Fresco or ZR Twofnr fail to reproduce **gs** 😕

Yet 1st excited state seems well-reproduced! 🤨

Future work

Detailed study of **inelastic** channels

Solve normalization issue or find it an explanation

Ask theoriticians if interactions can be tuned for our data

Continue to investigate (p,d)