Low-lying spectroscopy of 20O

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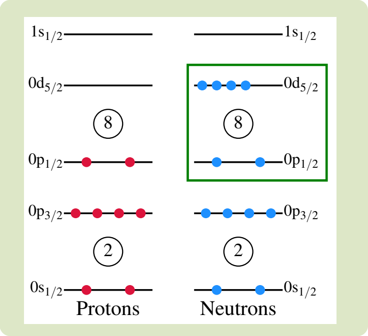
Physics case

Neutron-rich ^{20}O

- $N = 8$ shell gap
- Ground-state wave function



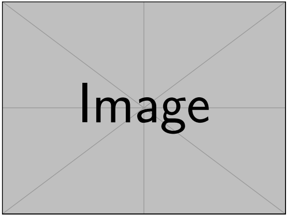
A recap on spectroscopic factors

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)

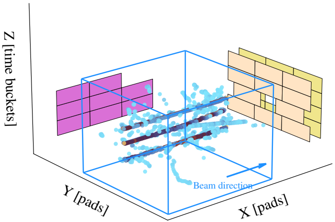
Experimental setup

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 µm-thick

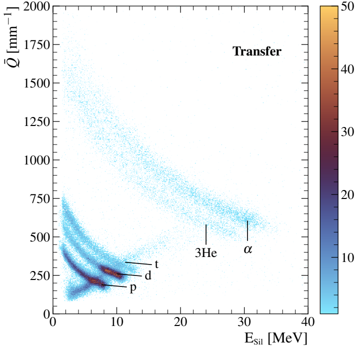
Neutron removal
$^{20}O(p, d)$
$^{20}O(d, t)$

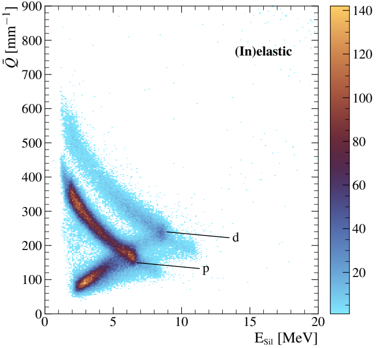
Proton removal
$^{20}O(d, {}^3He)$



A glance at the analysis

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



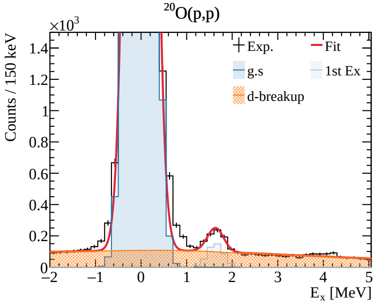


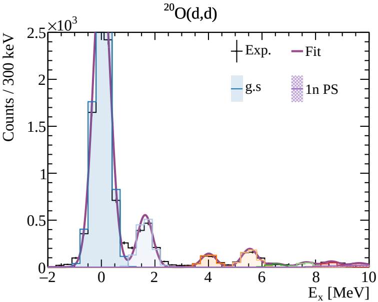
Good PID after vetoing punchthrough

E_x resolution in very good agreement with simulations!

Results: (in)elastic scattering

These are the excitation energy spectra for protons and deuterons.



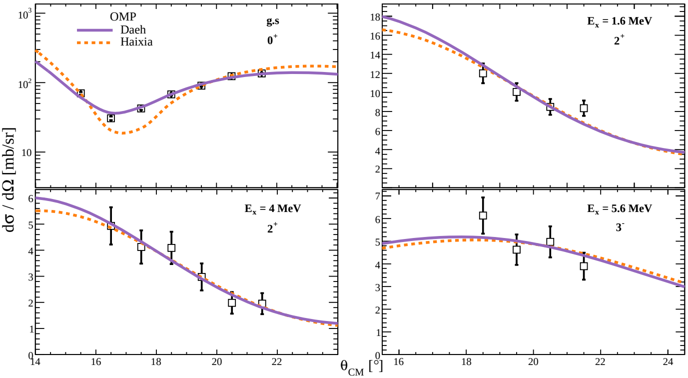


Only 1st excited state

Up to 7 $E_x > 0$ states observed!

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

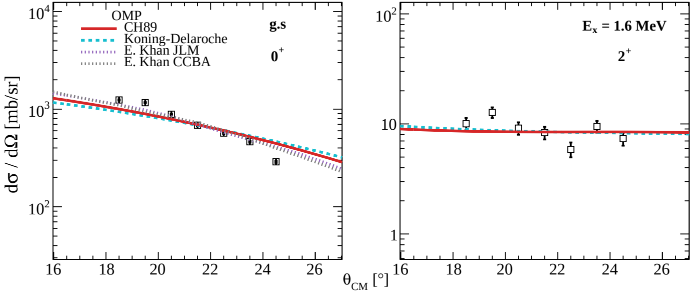
Angular distributions for the **ground-state** and first excited states:



Remaining states: low stats. Coming soon.

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

For the proton scattering:



Issue: gs not reproduced by any OMP! 😰

1st excited as well?

About normalizations

Just to recall the xs formula:

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

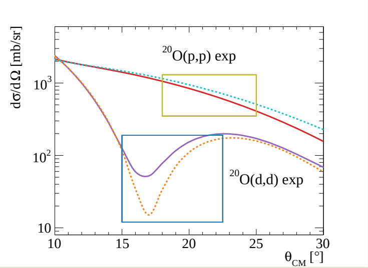
- $N_{\text{beam}} \leftarrow$ CFA counter
- $N_{\text{targets}} \leftarrow$ Gas mixture. Sensitive to p.

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

α in agreement with Juan's

$\Rightarrow$ Not likely ϵ issue

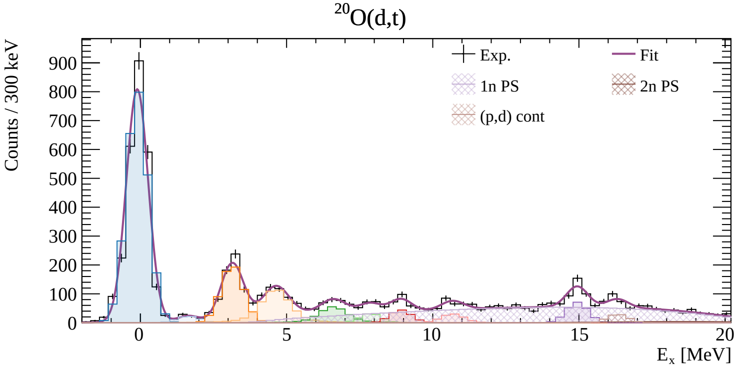
Which norm should we use?



Protons are more "reliable" 🤔

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

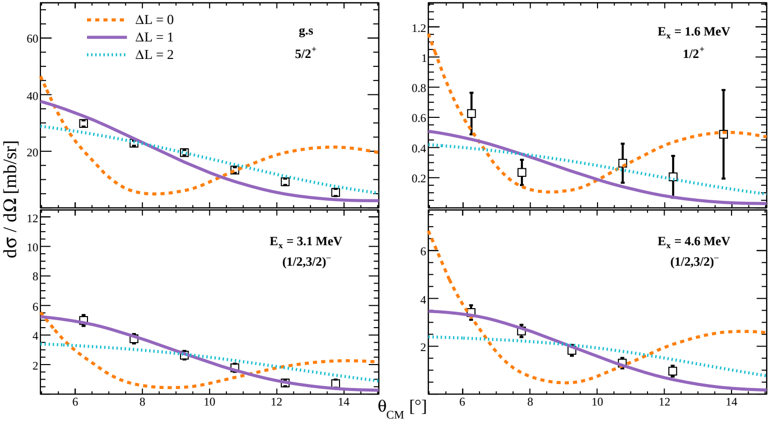
Excited states are populated up to ~ 15 MeV:



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

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

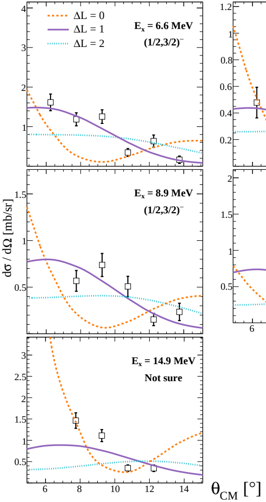
OMPs: Daehnick (d), Pang (t)



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

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

OMPs: Daehnick (d), Pang (t)

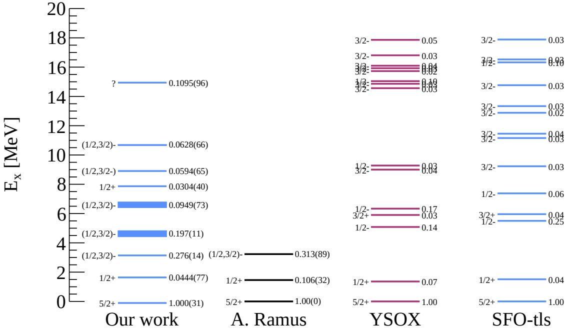


Few stats for some. Rebinning is foreseen.

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**

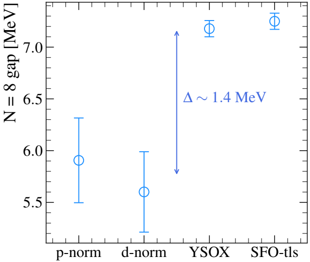
$$\mathsf{ESPE}_{nlj} = \frac{\sum_{i+}(2j+1)\mathsf{SF}_{i+}(E_{i+}-E_0) + \sum_{i-}\mathsf{SF}_{i-}(E_0-E_{i-})}{\sum_{i+}(2j+1)\mathsf{SF}_{i+} + \sum_{i-}\mathsf{SF}_{i-}}$$

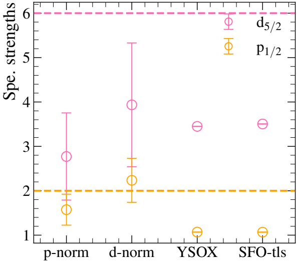
Removal $(-)$ from our (d,t) or (p,d) channels.

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 $p_{1/2}$...





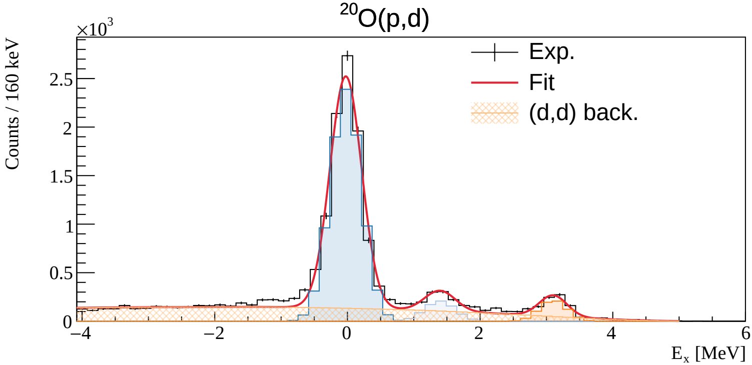
Smaller experimental gap than predicted!

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

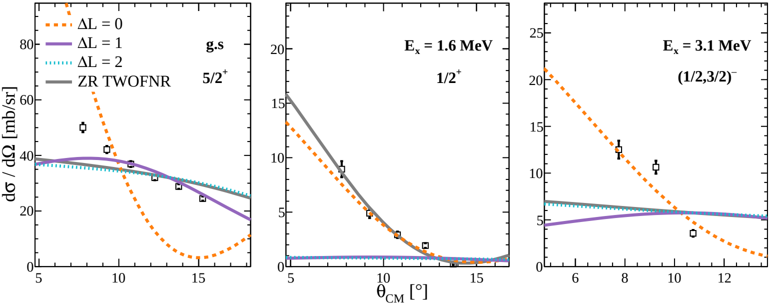
Fewer states are populated in this channel:



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! 🤨