Group Meeting 10.04

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Two-neutron halo is unveiled in ^{29}F

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Borromean nuclei

Borromean two-neutron halo consists of a bound state between a core nucleus and two neutrons, where any of the two-body subsystems are unbound.

FIG 1: Table of nuclides. [1]

[1]. NuDat 3.0, NNDC. https://www.nndc.bnl.gov/nudat3/

A new Borromean halo nuclei

N = 20, we discover the heaviest Borromean halo to date, and the first of its kind in the proton sd shell.

The measured total reaction cross section of the N = 20 nucleus 29F is much larger than that of 27F. This fact shows a two-neutron halo structure in 29F.

The information of 29F

- $S_{2n} = 1.4(6) MeV$
- The exited states of 27F and 29F are 915(12)keV, 1080(18)keV.
- Carbon is the last known element to exhibit a Borromean two-neutron halo, and we do not know about any neutron halos in fluorine.

Cross section of the 29F

- The Cross section of 29F is larger than others.
- 29F is far away from the linear relationship, increasing by about 12%.

This shows the presence of a two-neutron halo.

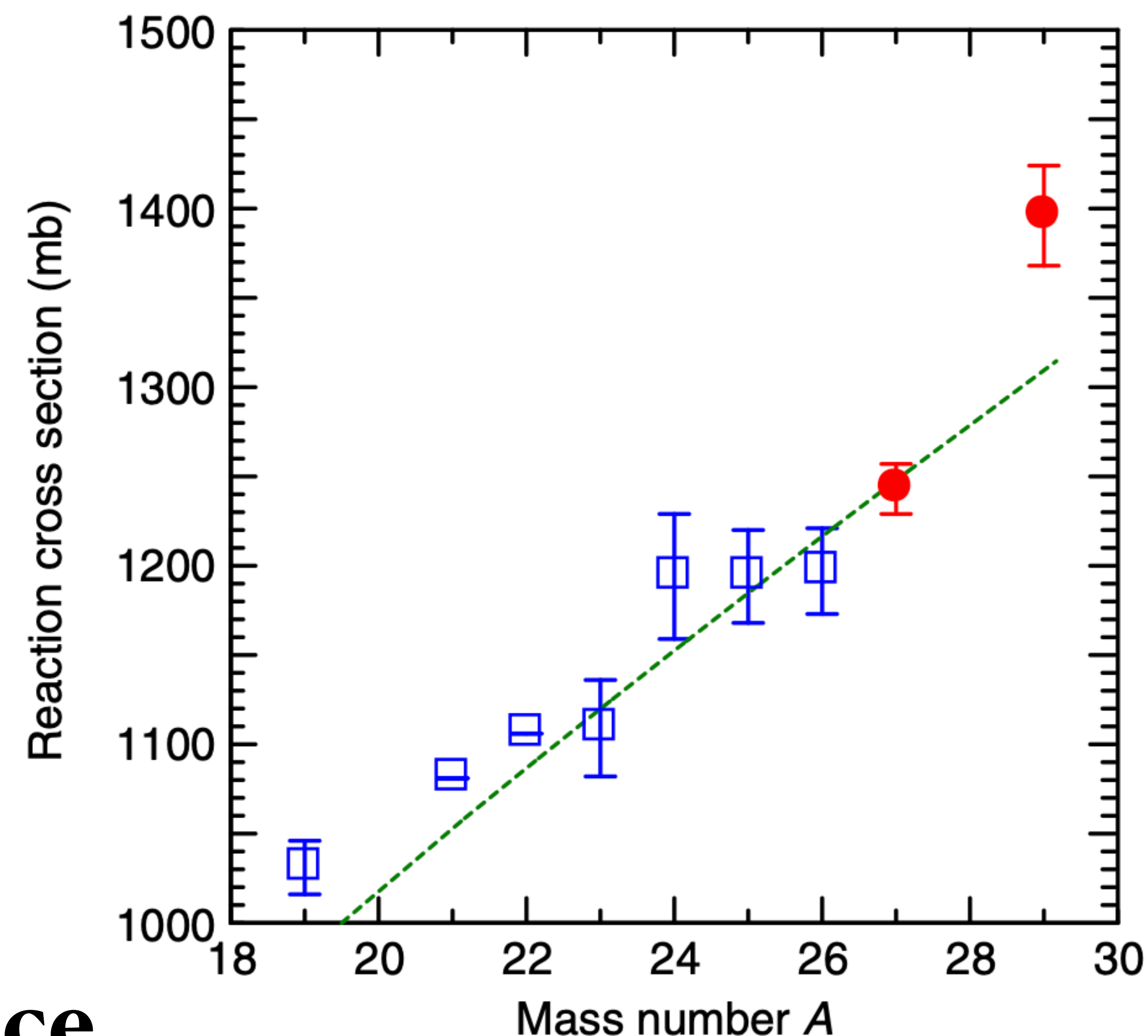


FIG 2: Cross section of Fluorine isotopes, A = 19 ~ 29

Cross section of the 29F

Meanwhile, we get the experimental radius of $3.15 \pm 0.04 fm$ and $3.50 \pm 0.07 fm$, increasing by 11%. And consider the 29F's proton radius as 27F's, we will get a large rms halo radius of 6.6fm for 29F.

The difference between 27F and 29F's radius is about 0.35fm, which is similar to other 2-halo nuclei.

Shell calculation

$$^{29}F \Rightarrow ^{27}F + n + n$$

There is a strong component of 2p3/2.

$$\sigma_R = \alpha\sigma_R(2p_{3/2}) + (1-\alpha)\sigma_R(1d_{3/2})$$

$$\alpha = 0.54 - 1$$

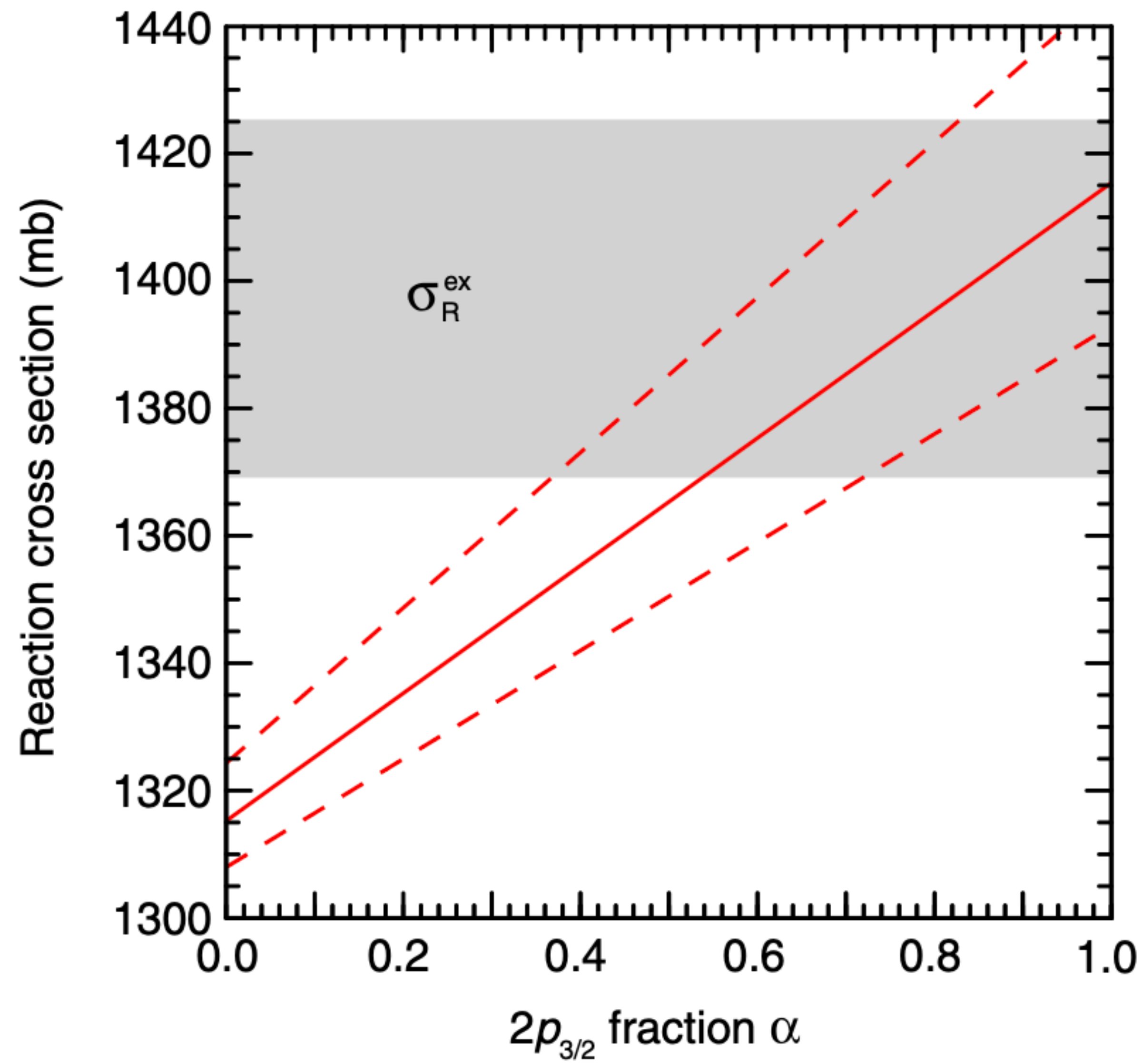


FIG 3: Mixing up 1d3/2 and 2p3/2

Shell calculation

- SDPF-MU hamiltonian
- EEdf1 interaction (including N3LO interaction and Fujita-Miyazawa three-body force)

Model	Isotope	1d3/2	1f7/2	2p3/2
SDPF-MU	27F	1.67	0.48	0.24
	29F	2.68	0.90	0.56
EEdf1	27F	0.84	2.19	1.26
	29F	0.80	1.08	0.67

FIG 4: The neutron occupying number of 27F and 29F, calculated by different shell models.

Other models and result

- Ab initio coupled-cluster

Δ-NNLO$_{GO}$

NNLO$_{SAT}$

In the deformed reference state, the neutrons are dominantly associated with the 1d3/2 orbital. These states were self-consistently selected by the Hartree-Fock method. But halo is more related to the neutron in 2p3/2.

- Particle rotor

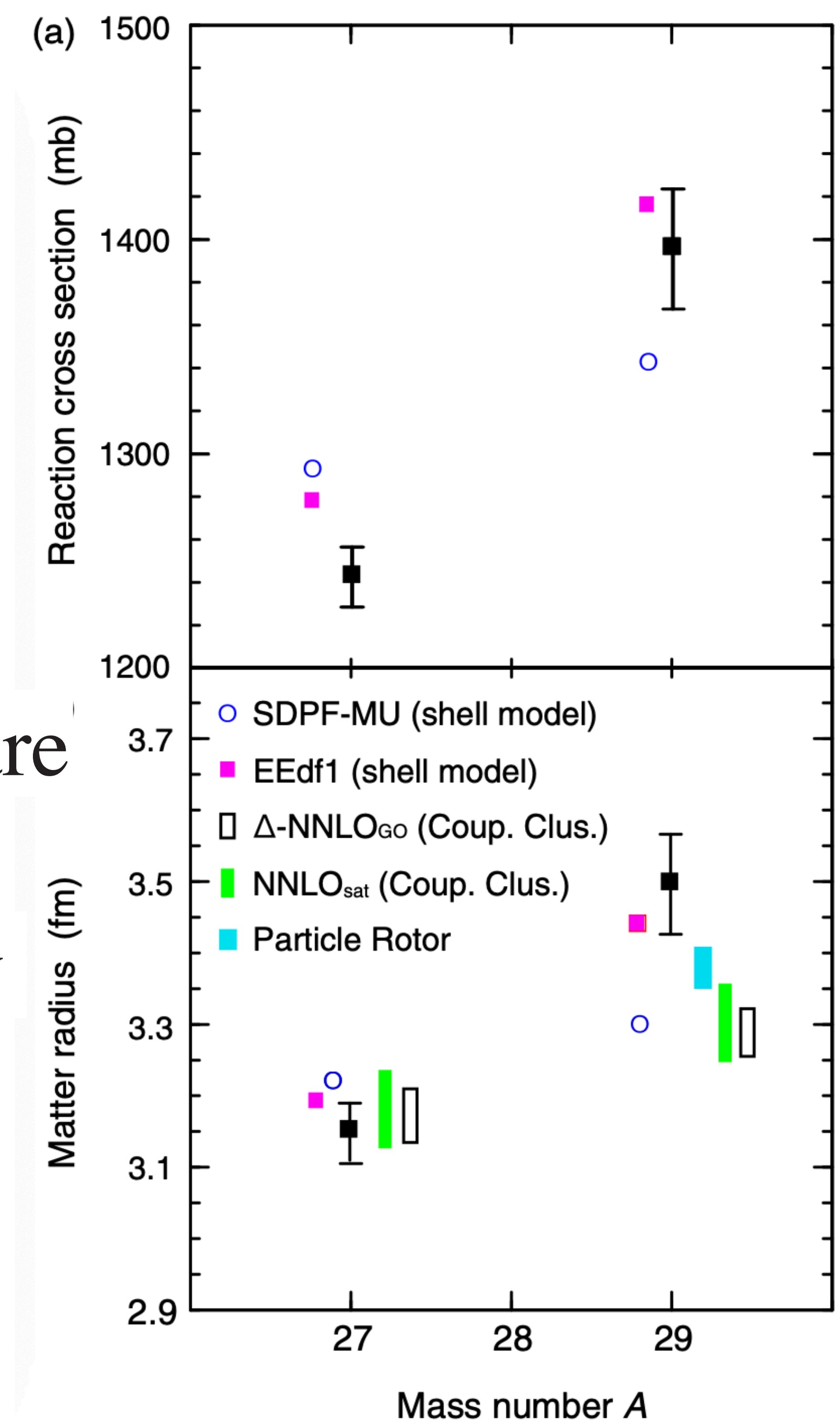
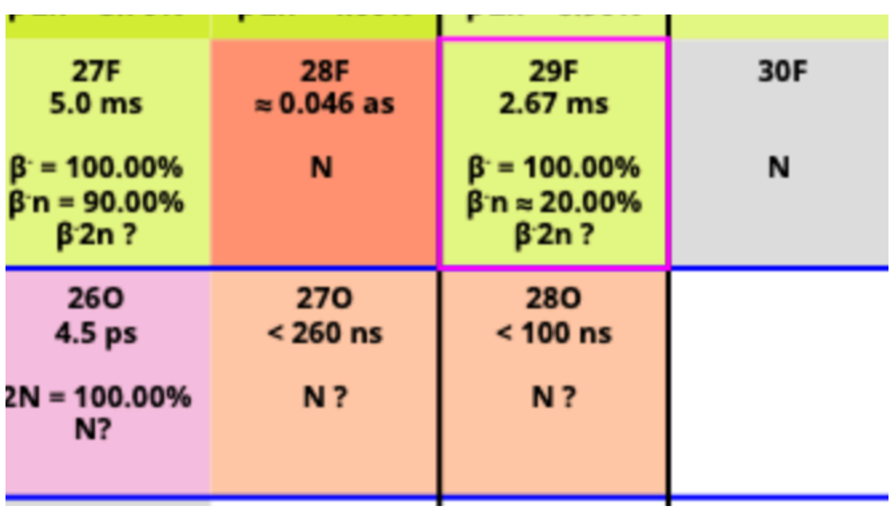
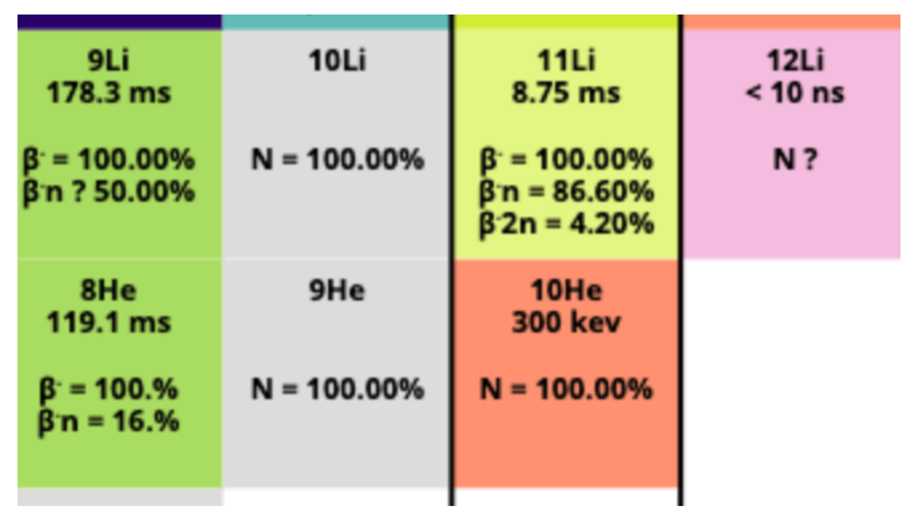


FIG 5: Cross section predicted by different models

Conclusion

This work shows that a small neutron separation energy (~1 MeV) and tensor force effects lead to a p-wave halo in 29F, one proton above conventional doubly closed shell Z = 8 and N = 20, just like 11Li.





To get further, we want to know whether or not similar nuclei exist on N=50, 82, 126.