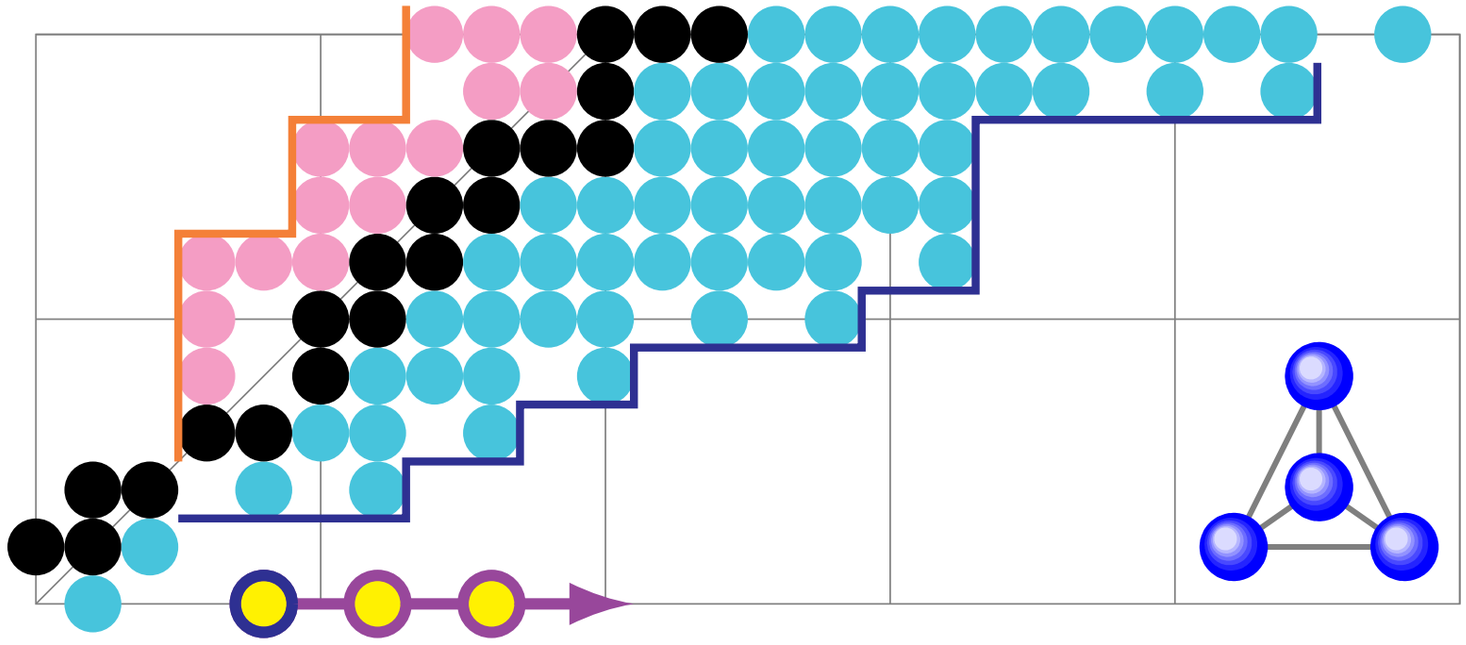
Neutral nuclei

- Do **neutral nuclei** exist?



- Candidates
  - Odd-even staggering → even N
  - Natural candidate → $N = 4$ (**tetraneutron**)
- Biggest issues
  - Production of very neutron-rich systems
  - Detection of a neutral object

Tetraneutron: experiments

⊙ DEMON experiment @ GANIL, **Caen**

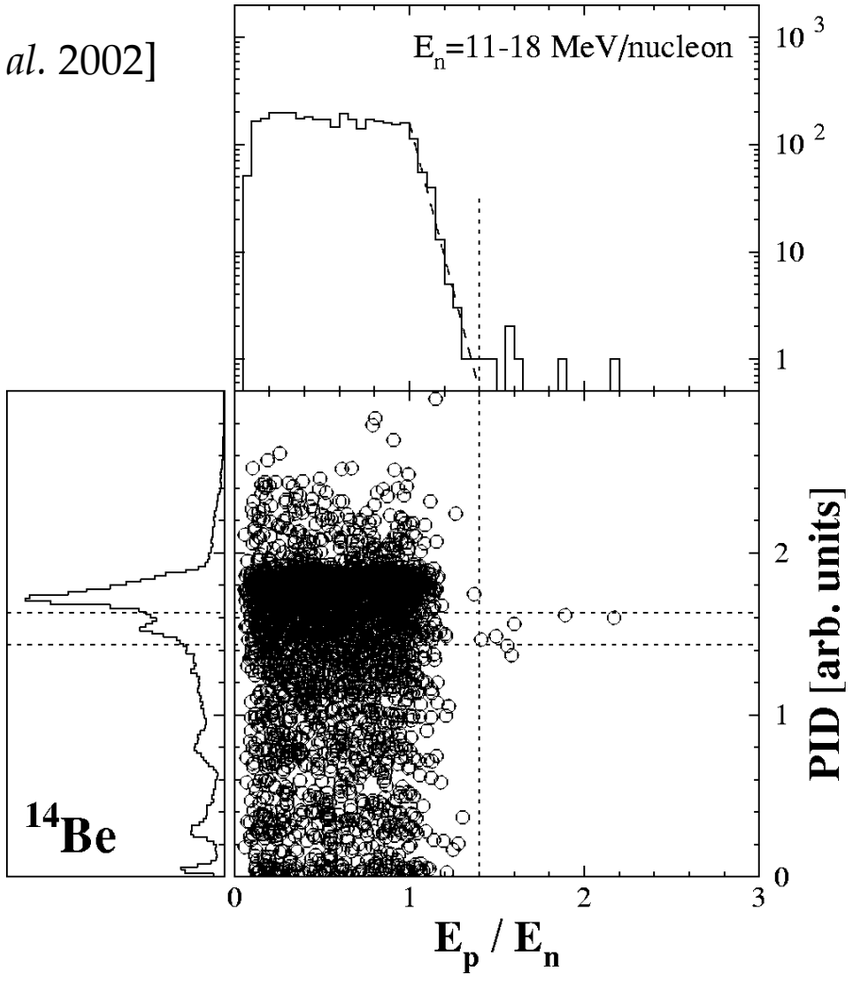
$$^{14}\mathrm{Be} \xrightarrow{(C)} {}^{10}\mathrm{Be} + {}^{4}\mathrm{n} \quad (\text{'01,'02})$$

$$^{8}\mathrm{He} \xrightarrow{(C)} {}^{4}\mathrm{He} + {}^{4}\mathrm{n} \quad (\text{'02})$$

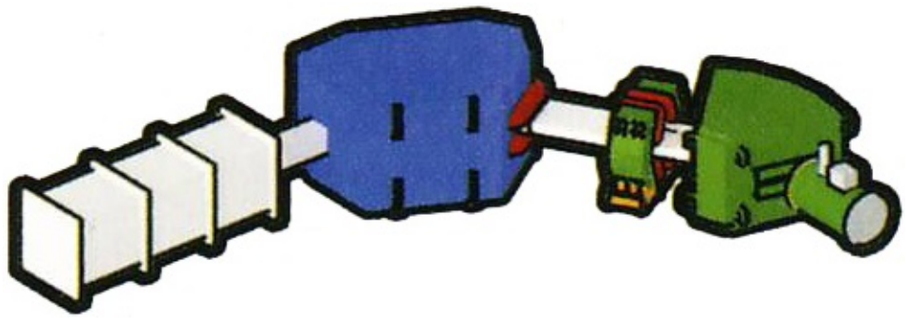
$$^{12/14}\mathrm{Be} \xrightarrow{(C)} \alpha\alpha + {}^{4/}{}^{6}\mathrm{n} \quad (\text{'02})$$

$$^{15}\mathrm{B} \xrightarrow{(C)} {}^{14}\mathrm{Be}^{*} \rightarrow {}^{4}\mathrm{n} \quad (\text{'05,'06})$$

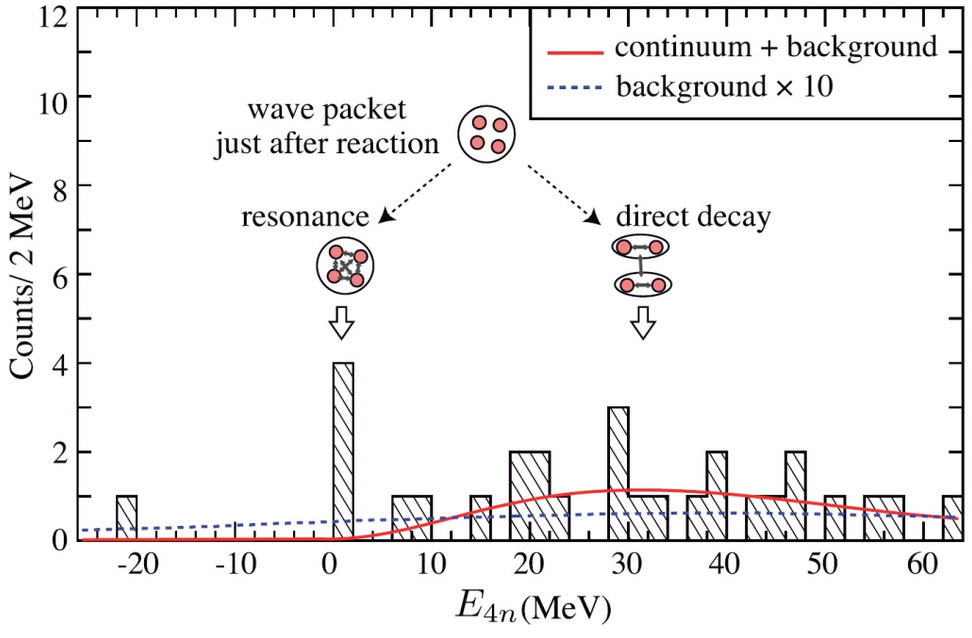
[Marques *et al.* 2002]



⊙ SHARAQ experiment @ RIKEN, **Tokyo**



$^{4}\mathrm{He}\,(^{8}\mathrm{He}, \alpha\alpha)\,{}^{4}\mathrm{n}$ ('12)



$\rightarrow$ $\mathrm{E}(^{4}\mathrm{n}) = 0.8 \pm 1.3$ MeV !

$\rightarrow$ $\Gamma(^{4}\mathrm{n}) < 2.6$ MeV

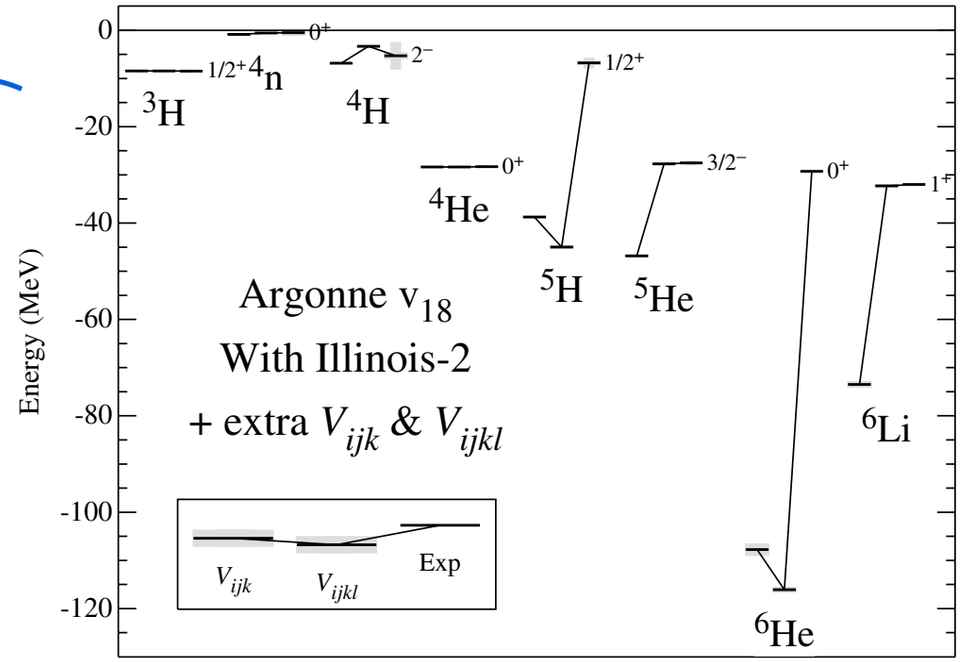
[Kisamori *et al.* 2016]

Tetraneutron: theory

- Ab initio calculations: **contradictory results**

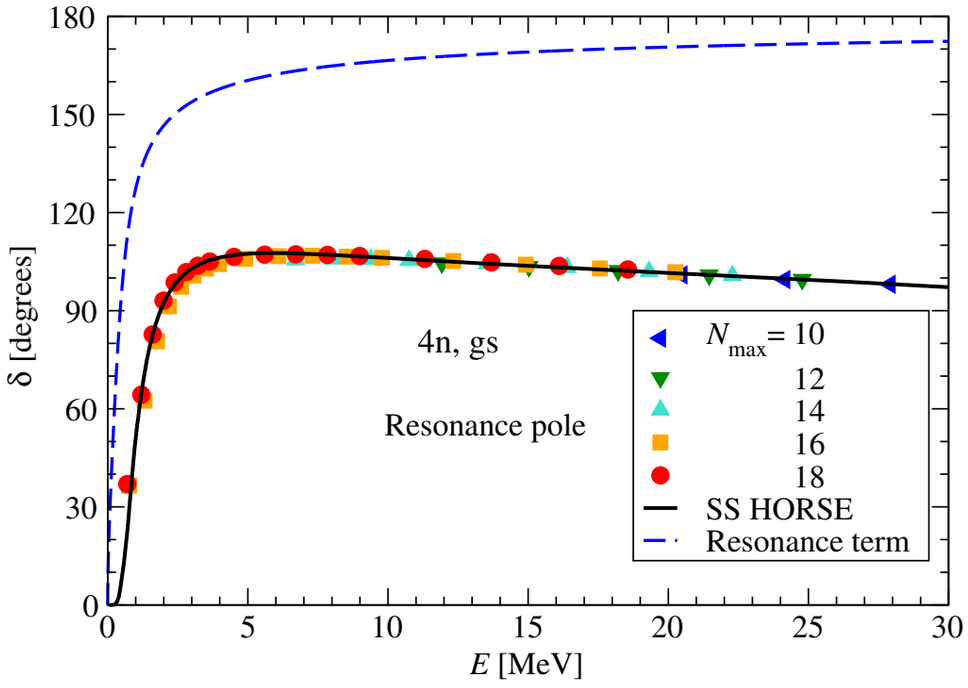
Bound 4n incompatible with other light nuclei

Realistic 3N forces leads to very broad resonance

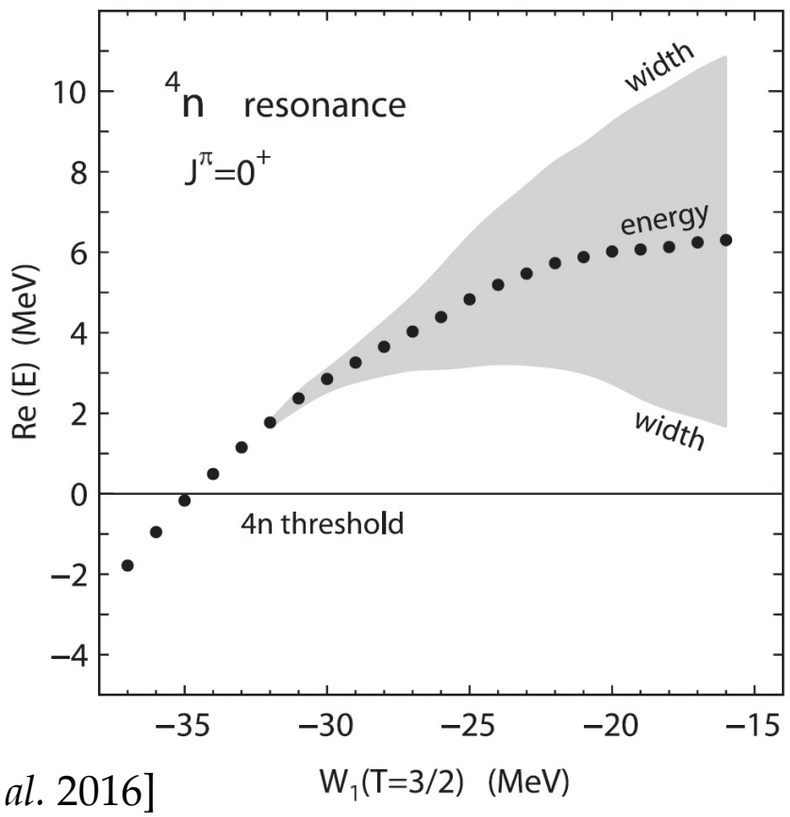


[Pieper 2003]

Narrow resonance found at 0.8 MeV



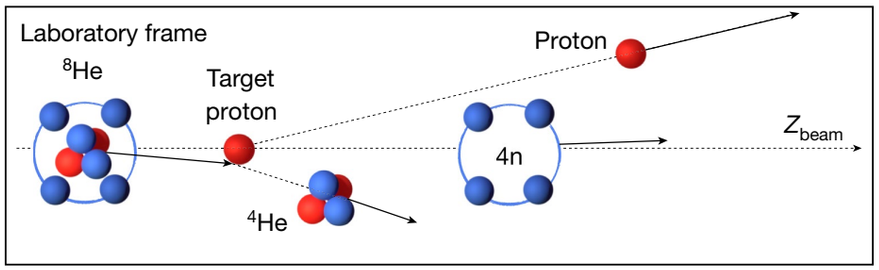
[Shirokov *et al.* 2016]



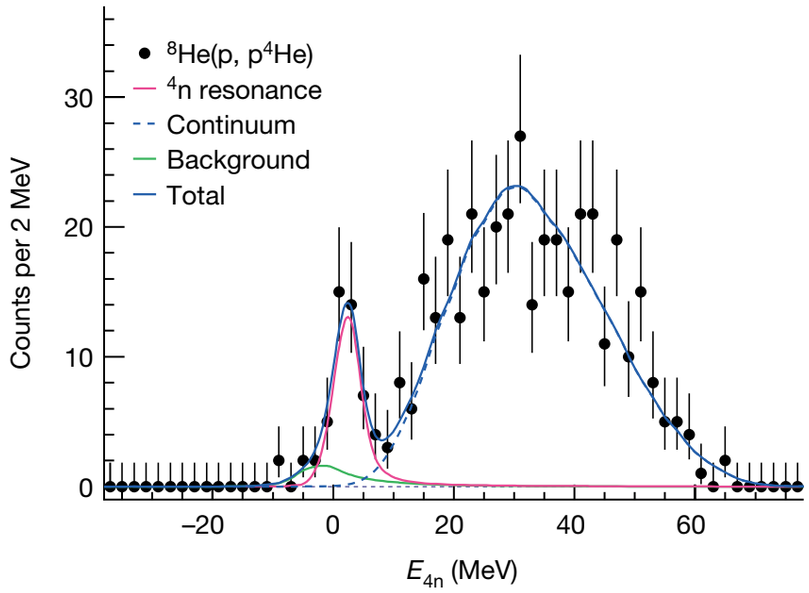
[Hiyama *et al.* 2016]

Tetraneutron: latest developments

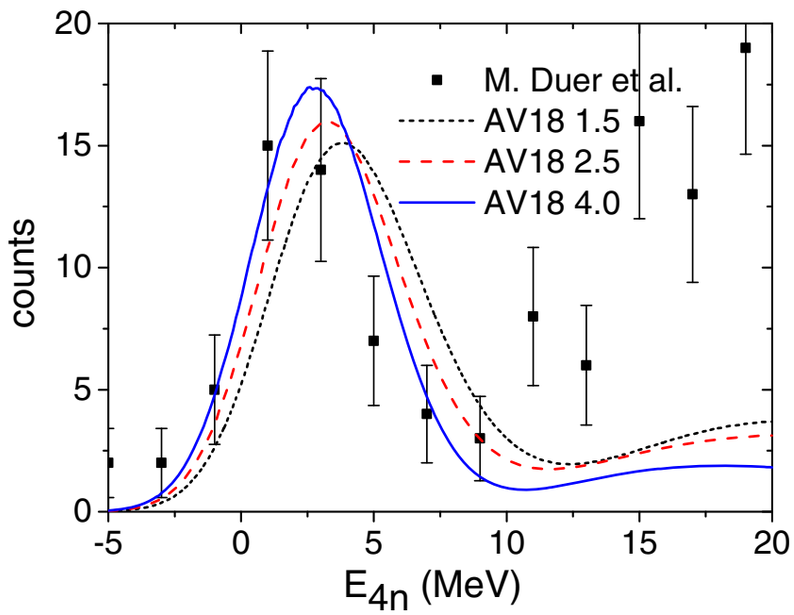
- New RIKEN experiment claims finding of a narrow 4N resonance



[Duer *et al.* 2022]



- New calculations explain it in terms of final-state (dineutron-dineutron) correlations



[Lazauskas *et al.* 2023]

Literature

- Experiment
  - F. M. Marques *et al.*, Phys. Rev. C **65** 044006 (2002)
  - K. Kisamori *et al.*, Phys. Rev. Lett. **116** 052501 (2016)
  - M. Duer *et al.*, Nature **606** 678 (2022)
- Theory
  - S. Pieper, Phys. Rev. Lett. **90** 252501 (2003)
  - E. Hiyama *et al.*, Phys. Rev. C **93** 044004 (2016)
  - A. M. Shirokov *et al.*, Phys. Rev. Lett. **117** 182502 (2017)
  - S. Gandolfi *et al.*, Phys. Rev. Lett. **118** 232501 (2017)
  - A. Deltuva and R. Lazauskas, Phys. Rev. Lett. **123** 069201 (2019)
  - R. Lazauskas, Phys. Rev. Lett. **130** 102501 (2023)