The (*d*,*p*) reaction on ^{11}Be: Bringing clarity to our understanding of the structure of ^{12}Be

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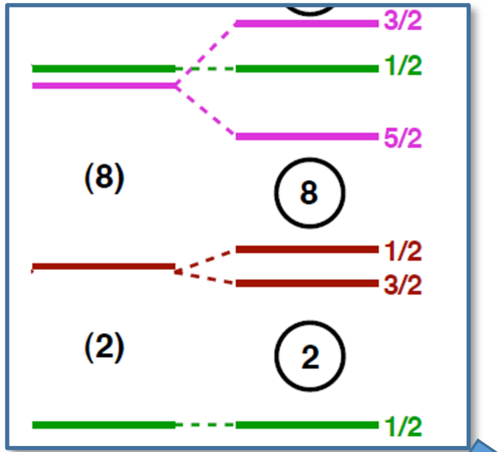
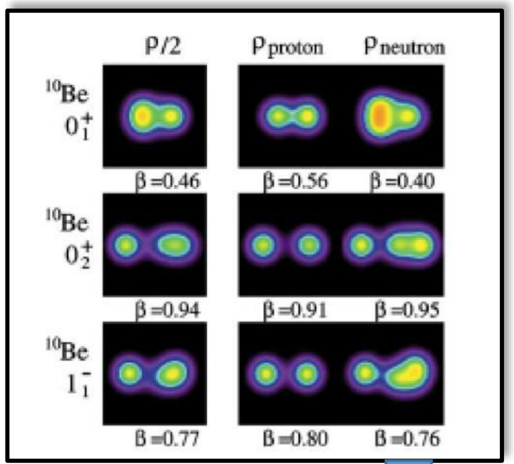
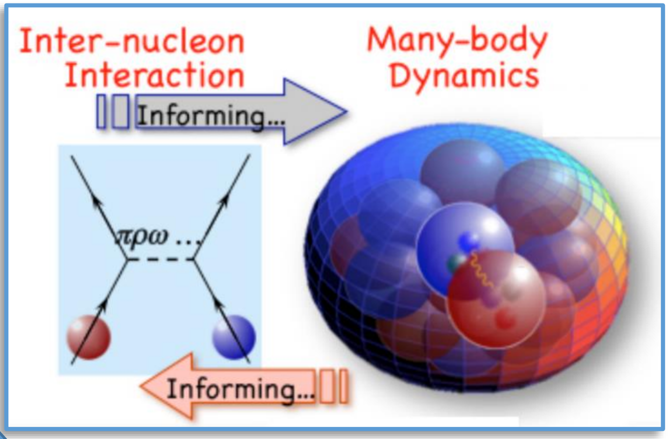
Examples: Be isotopes



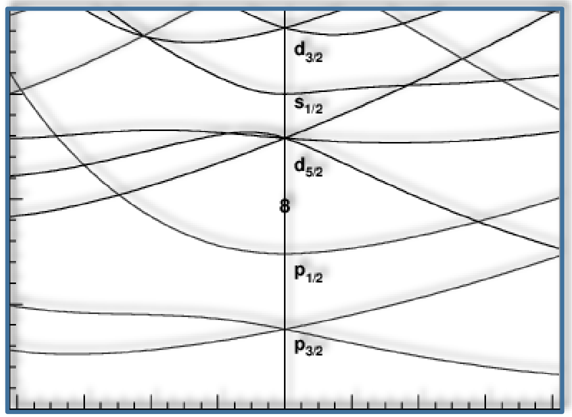
Shell model



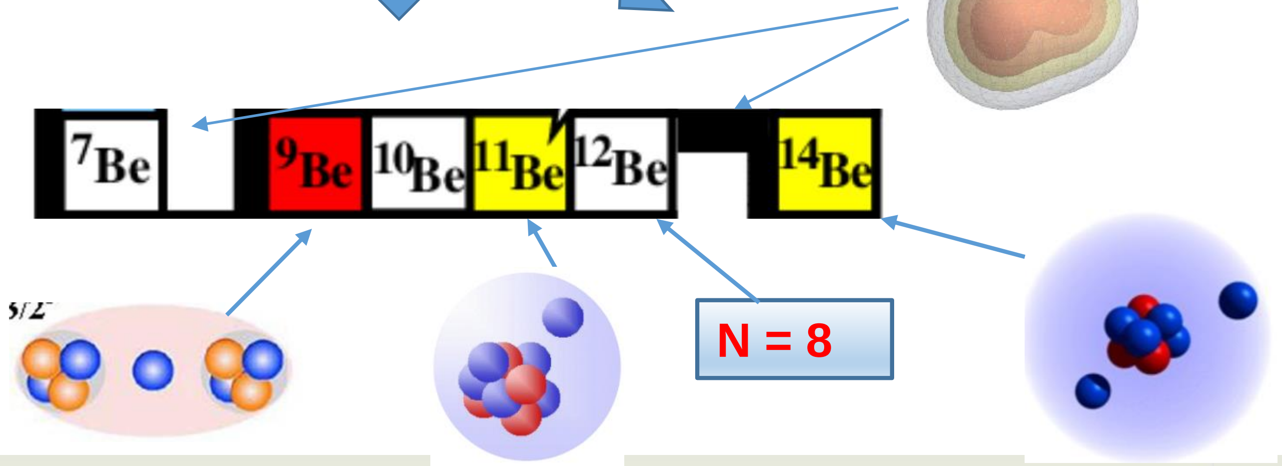
Cluster model



ab-initio



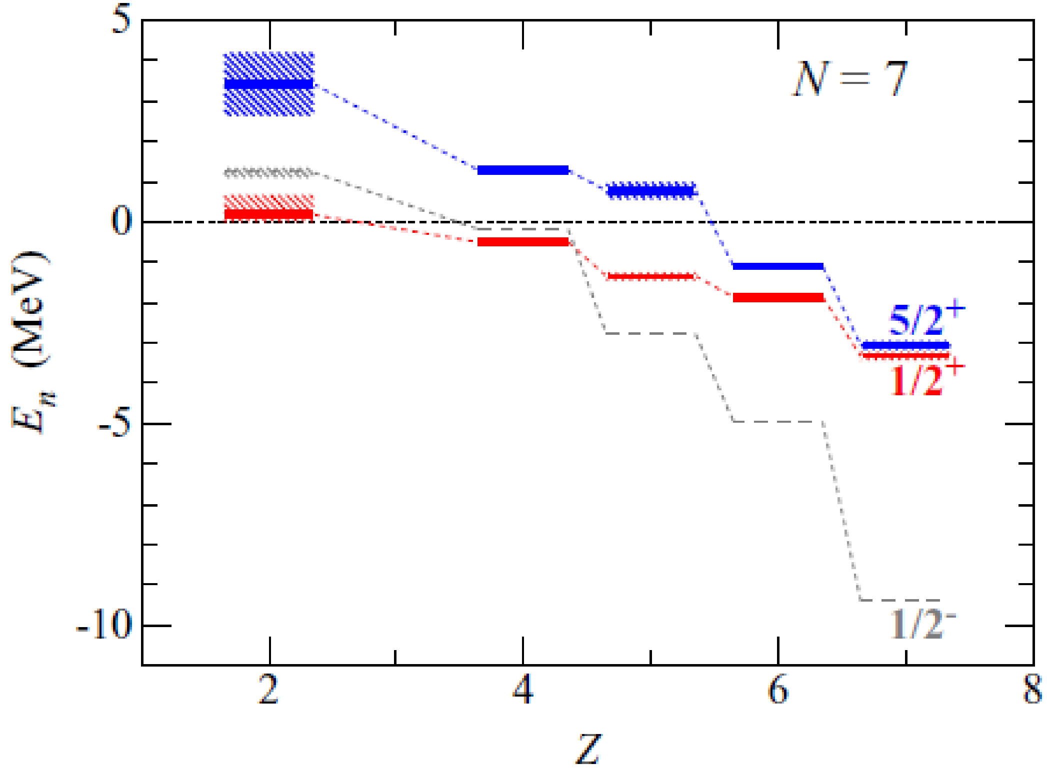
Nilsson model



One-neutron halo nucleus ^{11}Be

- Neutron loosely bound Sn=0.504 MeV
- Larger radius R= 2.91 fm
- ^{10}Be core + 1 valance n
- g.s. $1/2^+$

$$^{10}\text{Be} + n\,(2s_{1/2})\ \ (60\% \sim 80\%))$$



K. T. Schmitt *et al.* Phys. Rev.Lett. 108, 192701 (2012).

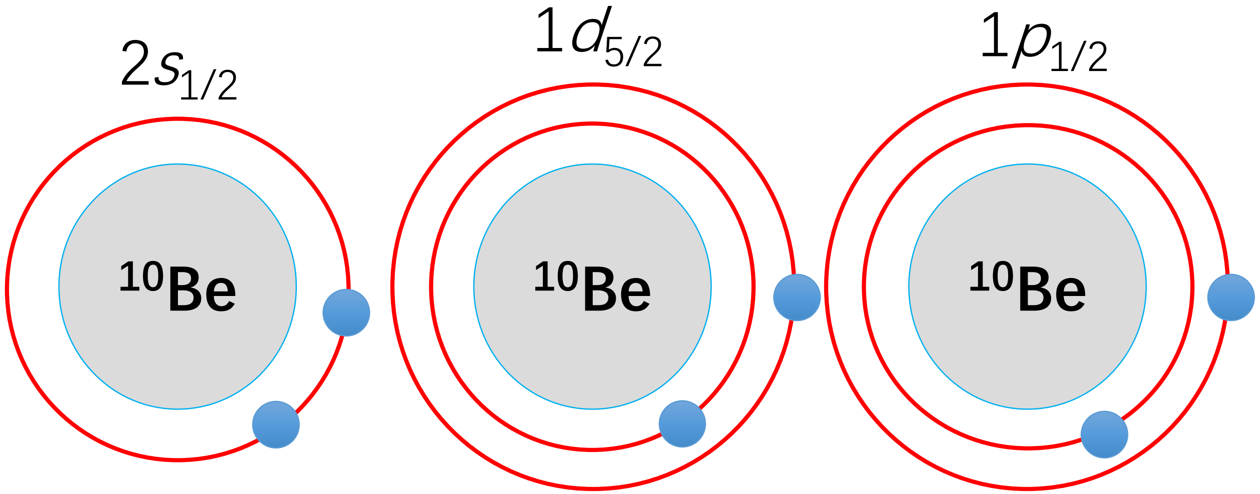
T. Aumann *et al.* Phys. Rev. Lett. 84, 35 (2000).

C. R. Hoffman *et al.* Phys. Rev. C 89, 061305(R) (2014).

^{12}Be intruder states and single-particle configuration mixing

- **Breakdown** of conventional magic number: N=8
- **Isomeric state**: 0_2^+ 331(12) ns

E0 decay: e+e- pair **creation** **511keV** γ ~**83(2)**%

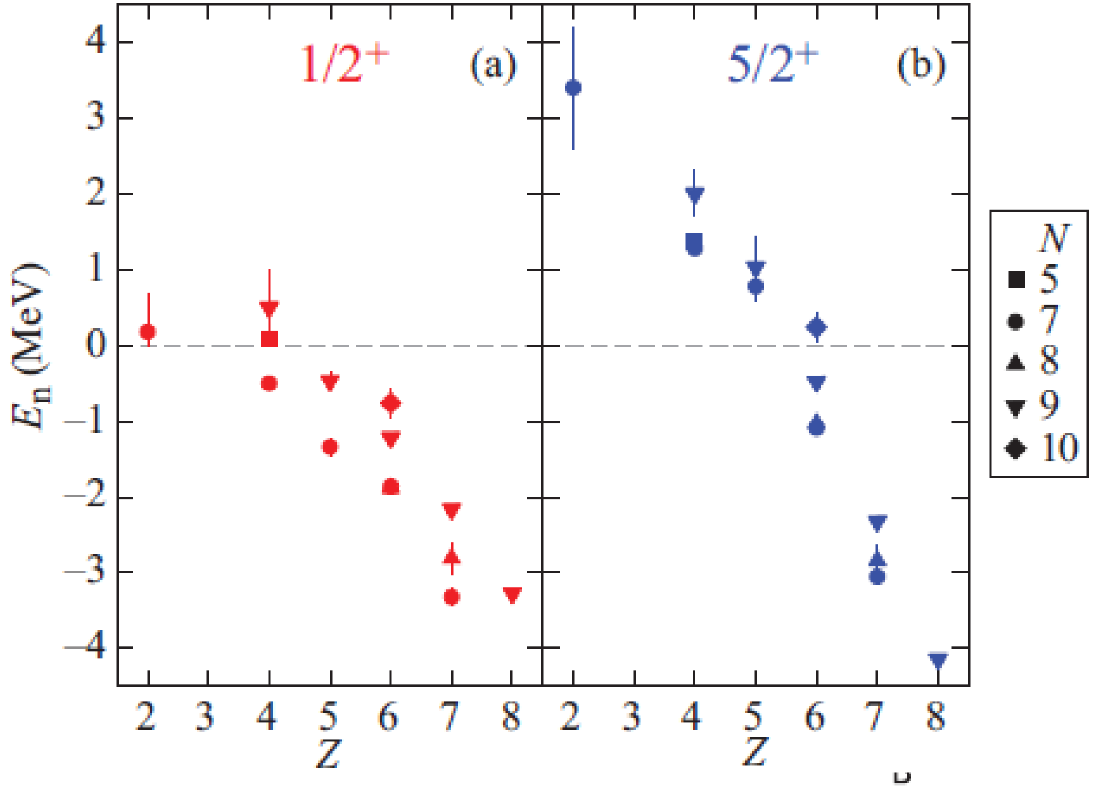


0+ **2+, 3+** **2-, 1-, 0-**

$2s_{1/2}$ single-particle energy

$1d_{5/2}$ single-particle energy

$1p_{1/2}$ single-particle energy



C. R. Hoffman *et al.* Phys. Rev. C 89, 061305(R) (2014)

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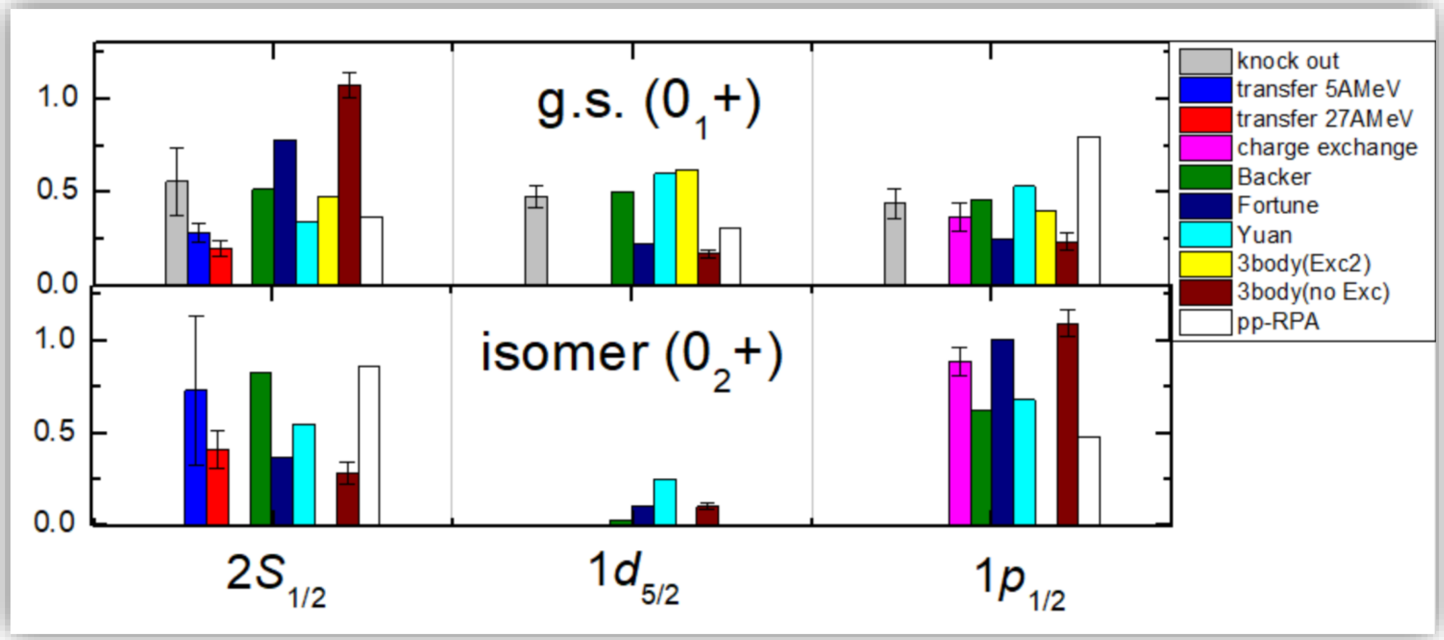
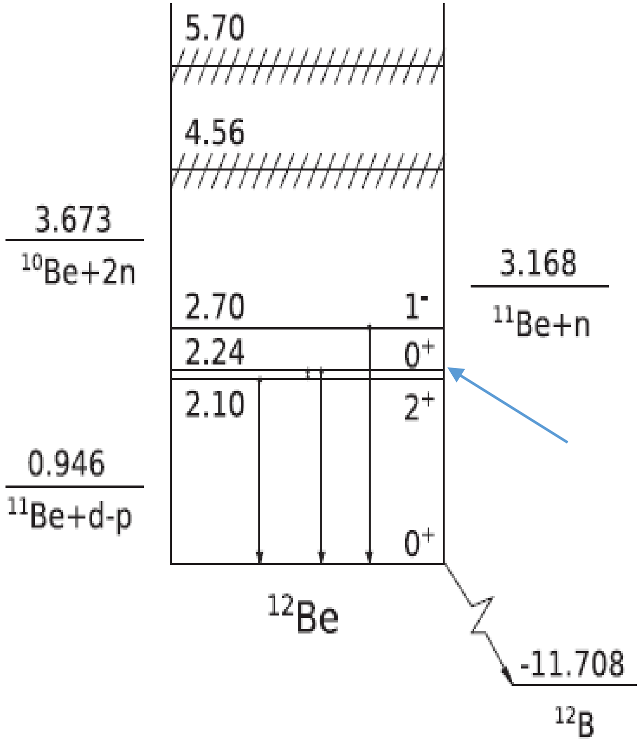
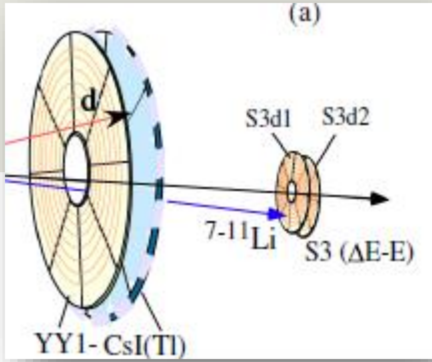
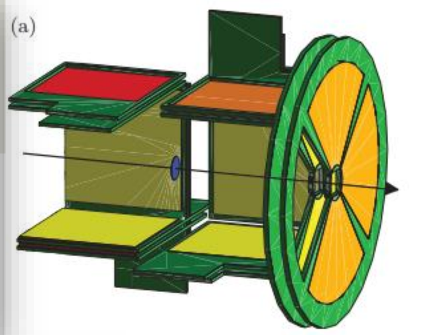




$$|0_i^+\rangle = a_i|1s^2_{1/2}\rangle + b_i|0d^2_{5/2}\rangle + c_i|0p^2_{1/2}\rangle \quad (i = 1, 2)$$

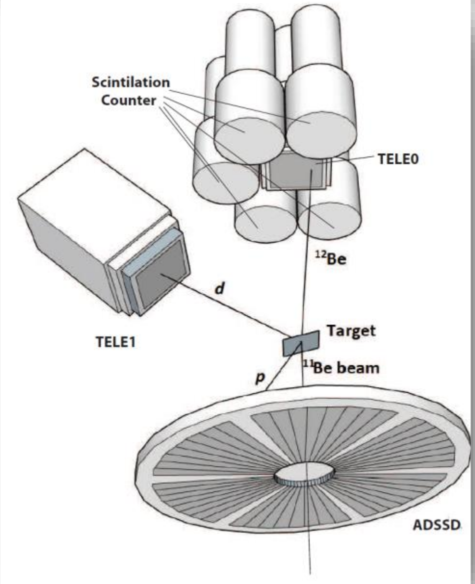
Previous $^{11}Be(d,p)$ reactions



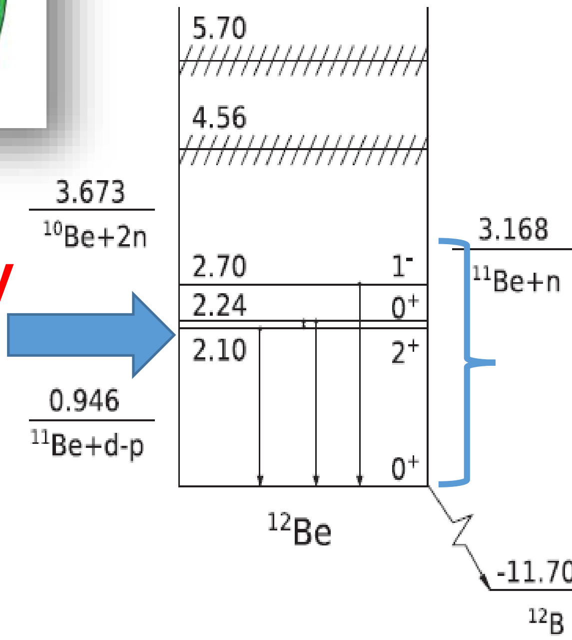


- **5 MeV/u TRIUMF**
- **2.8 MeV/u ISOLDE**
- **26.9 MeV/u RCNP isomer-tagging**

E0 decay: e+e- pair **creation** **511keV γ ~83(2)**%



140 keV apart



Moderate agree on the *S* of g.s., but a great deal of ambiguity in excited states

Directly resolve the isomer 0^+_2 state
Populate the low-lying resonances

ideal energy: 10MeV/u
100-keV FWHM resolution

→ ***ISS & HIE-ISOLDE***

R. Kanungo et al. PLB 682 (2010) 391 | J. G. Johansen *et al.* PRC 88 (2013) 044619 | J. Chen *et al.* PLB 781 (2018) 412 - 416

Previous results of resonances in ^{12}Be

- ^{10}Be(t,p)^{12}Be reaction

H. T. Fortune, Phys.Rev. C 50, 1355 (1994)

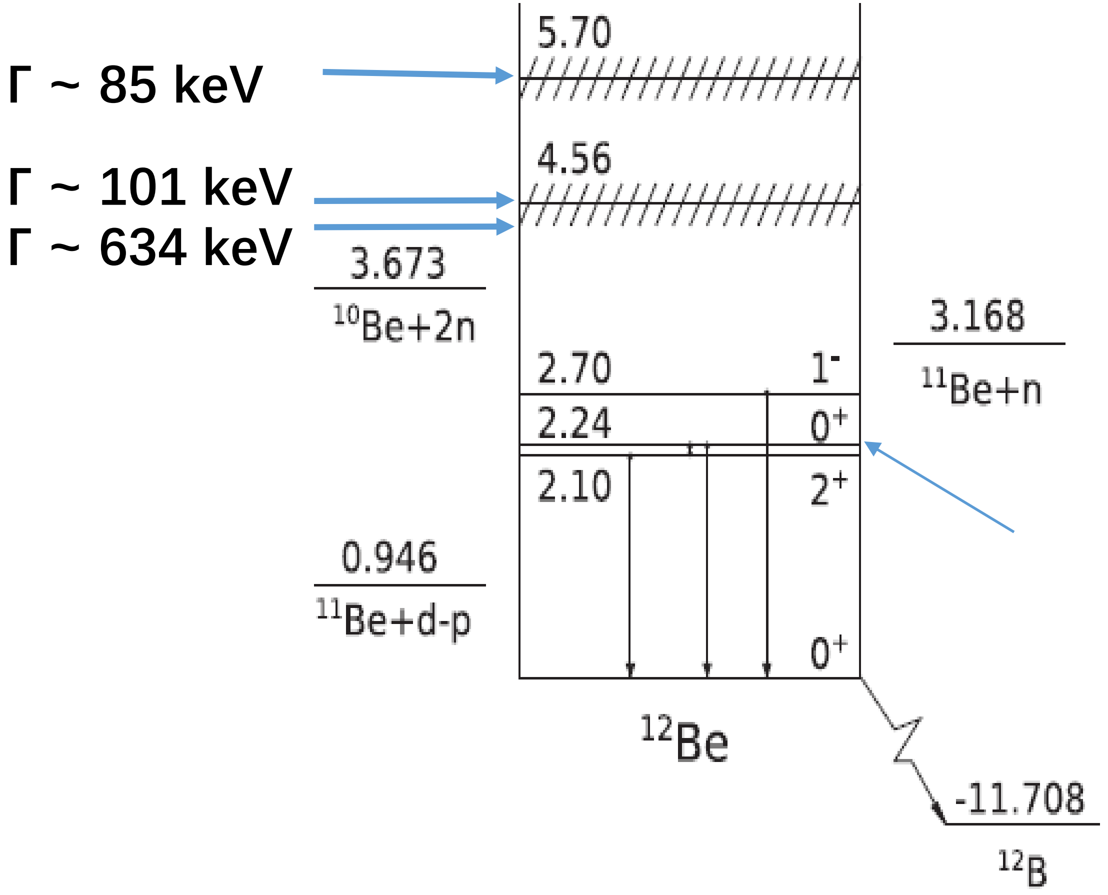
SOLARIS + ReA

B. P. Kay, Y. Ayyad et al.,

- ^{13}B proton knock out reaction

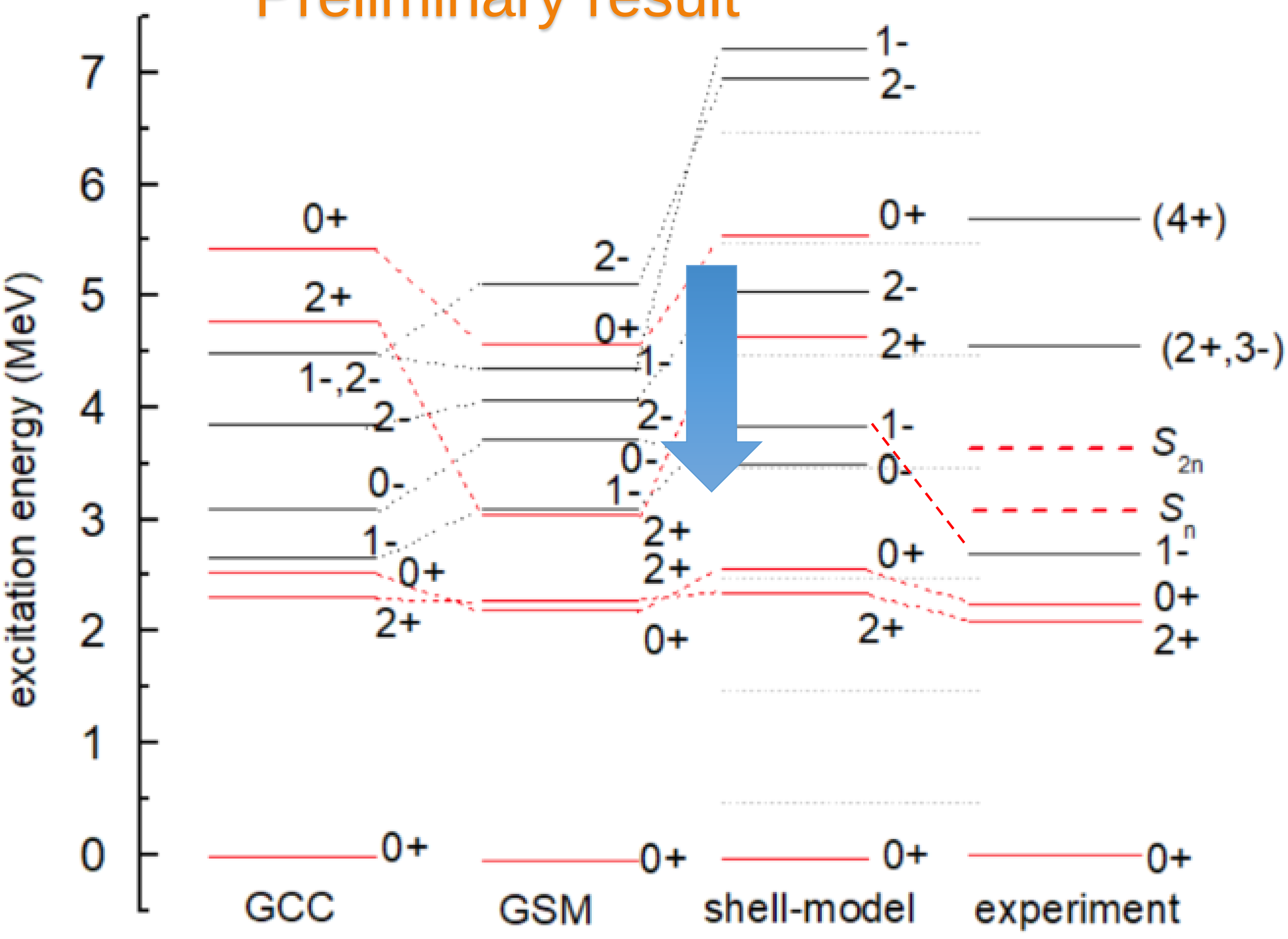
J. K. Smith, Phys.Rev. C 90, 024309 (2014)

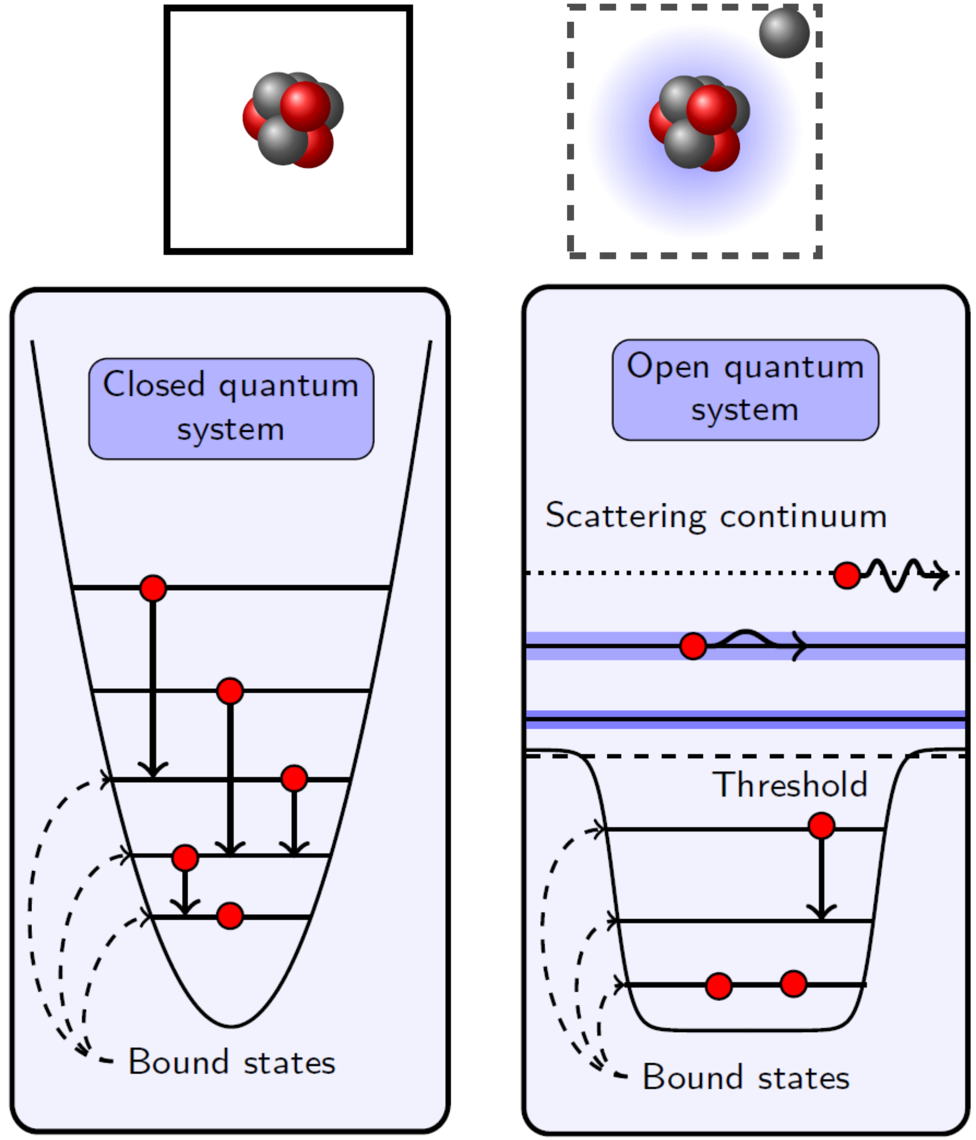
- ^{11}Be(d,p) reaction (preliminary)



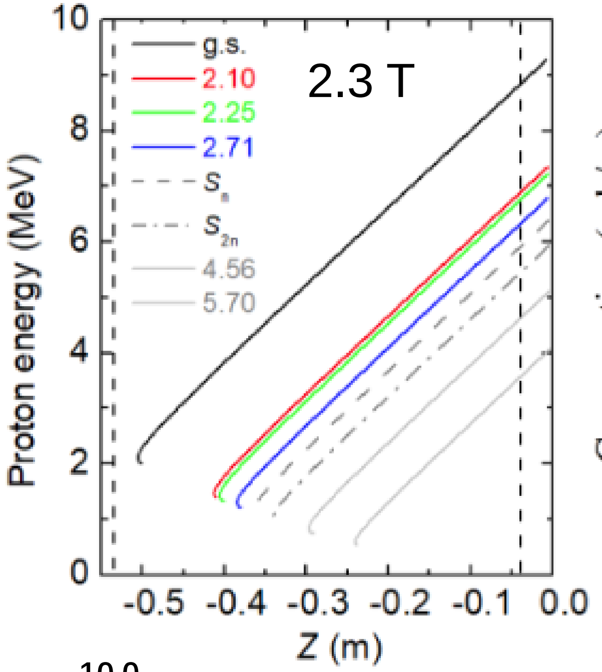
Resonances in ^{12}Be and the role of continuum

S. M. Wang *et al*. Phys. Rev. C 99, 054302 (2019)

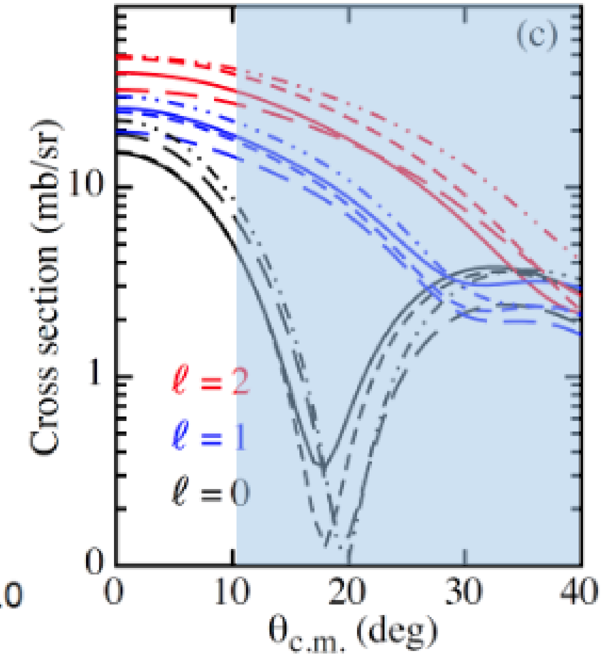


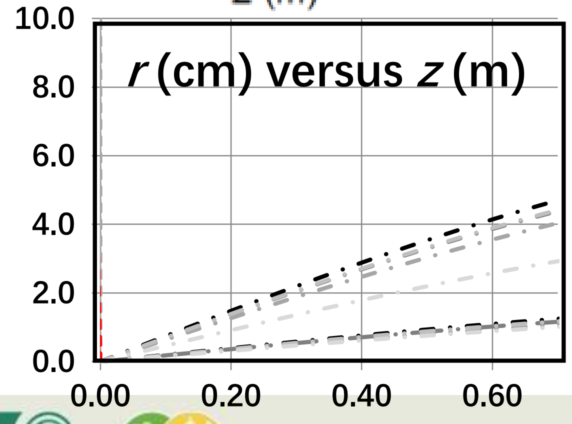


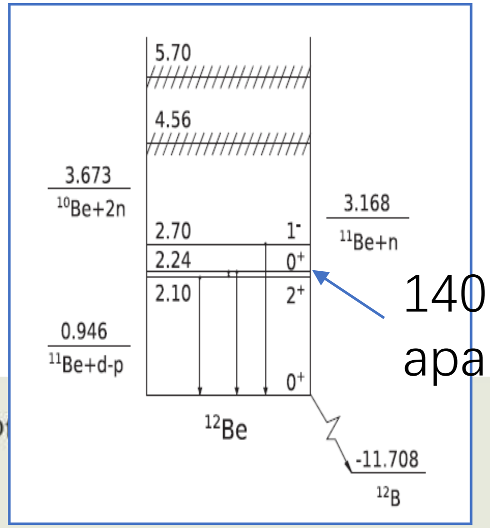
Kinematics, cross sections & resolution



Different OMPs







140 keV apart

- ELUM detector: normalize cross sections
- The present annular silicon recoil detectors
- Possible beam contaminations ^{22}Ne can be identified by the Recoil detectors
- Target CD_2 80 ug/cm^2 ⟶ 100 keV resolution

state	Energy (MeV)	Cross section (mb)	Counts in 15 shifts
0_1+	g. s.	2.5	200
2+	2.11	10.1	780
0_2+	2.24	1.0	80
1-	2.71	5.6	430

Summary

- We propose a study of the ^{11}Be(*d,p*)^{12}Be reaction at energies (10MeV/u) at which the results can be clearly interpreted in terms of well-tested reaction mechanisms.
- ^{11}Be(*d,p*)^{12}Be reaction will bring clarity of ambiguity in the excited states, and enrich our understanding of the interplay between the *p*-, *s*- and *d*-shell configurations in ^{12}Be and the weak-binding effect.
- 16 shifts of ^{11}Be beam at an estimated intensity of 1×10^5 pps using HIE-ISOLDE.
- Outgoing protons will be measured using the silicon array in the magnetic field of ISS to achieve a resolution of 100-keV, which allows for isolation of all the low-lying states in ^{12}Be

Collaborators

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Science & Technology Facilities Council Daresbury Laboratory — M. Labiche. I. Lazarus

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PEKING UNIVERSITY 1898 — J. L. Lou