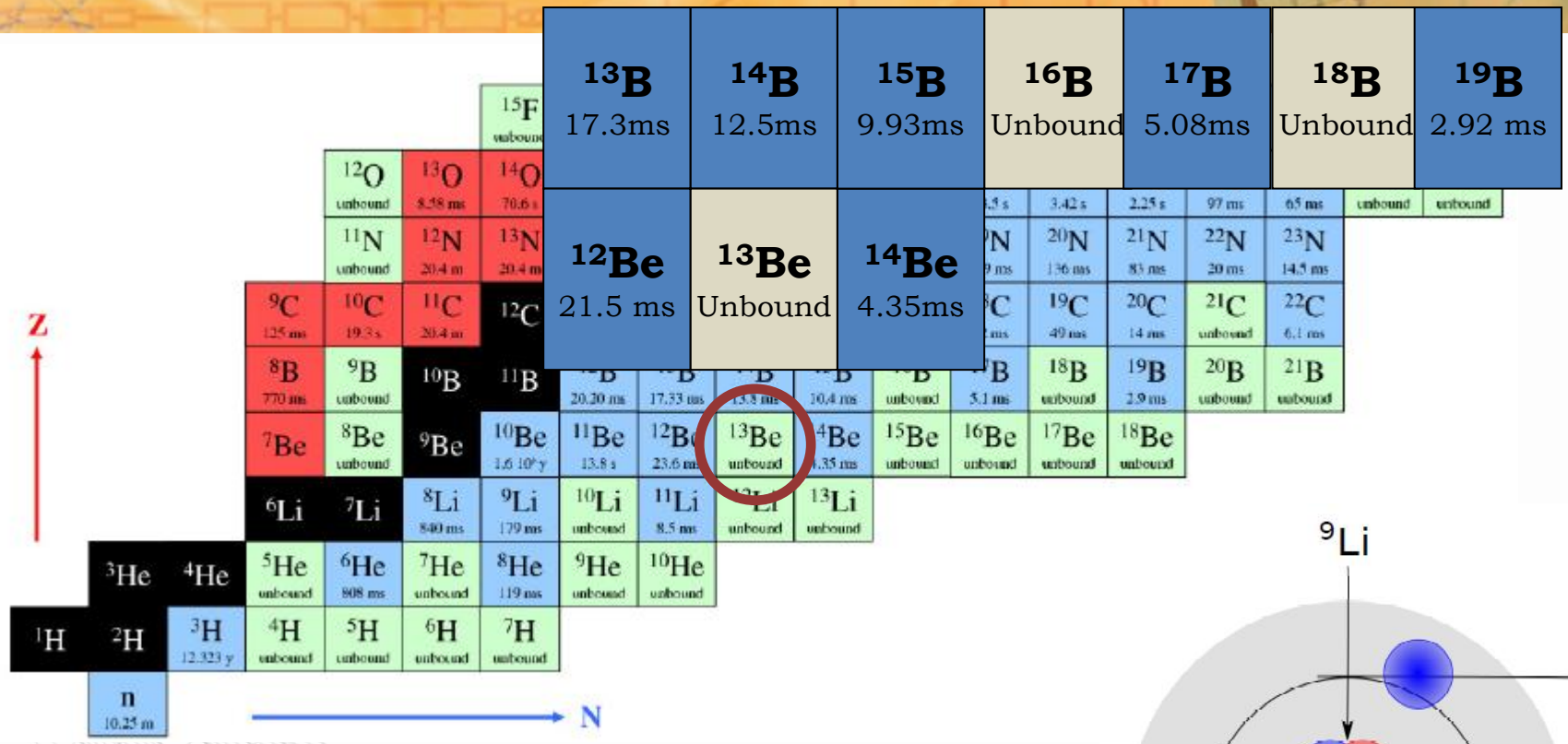
Detection of γ rays in the reaction ^{14}B(p,2p)^{13}Be and its importance to interpret the structure of ^{13}Be

E. Nácher, G. Ribeiro, O. Tengblad
Instituto de Estructura de la Materia – CSIC, Madrid

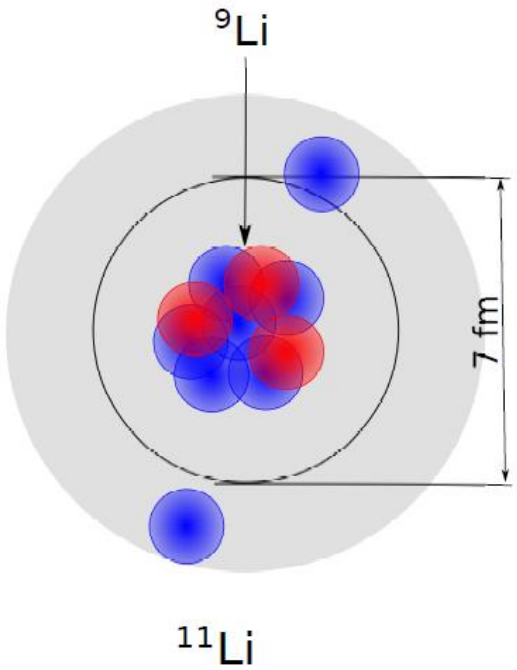
B. Jonson
Chalmers University, Göteborg

for the R3B collaboration

Intro: nuclei beyond the n drip-line



- Fix the ^{12}Be-n interaction to understand the 2-n halo nucleus ^{14}Be
- Study the shell evolution (N=8) close to the dripline

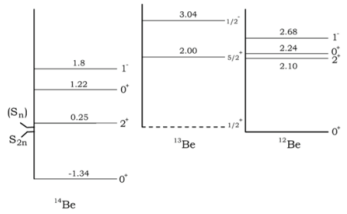


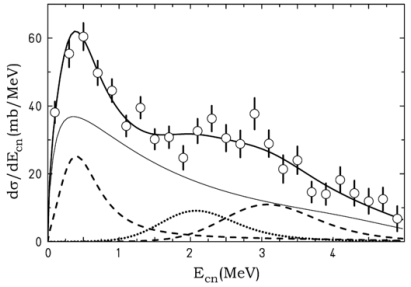
Previous studies

2007 GSI ^{14}Be(p,pn)^{13}Be

H. Simon et al. / Nuclear Physics A 791 (2007) 267–302

^{13}Be state	Neutron, knocked out from ^{14}Be	Structure of the ^{13}Be state	Appearance in the $n+^{12}$Be spectrum	Width (MeV)
		$0d_{3/2}\otimes 1^-$	0.36 MeV	
$1/2^-$	$0p_{1/2}$	$0p_{1/2}\otimes 0^+_1$	0.80 MeV	0.4
		$0p_{1/2}\otimes 0^+_1$	3.04 MeV	2.0
		$1s_{1/2}\otimes 1^-$	0.36 MeV	
$5/2^+$	$0d_{5/2}$	$0d_{5/2}\otimes 0^+_1$	2.00 MeV	0.3
		$1s_{1/2}\otimes 2^+$	low energy	narrow
$1/2^+$	$1s_{1/2}$	$1s_{1/2}\otimes 0^+_1$	low energy	broad
		$1s_{1/2}\otimes 0^+_2$	low energy	broad

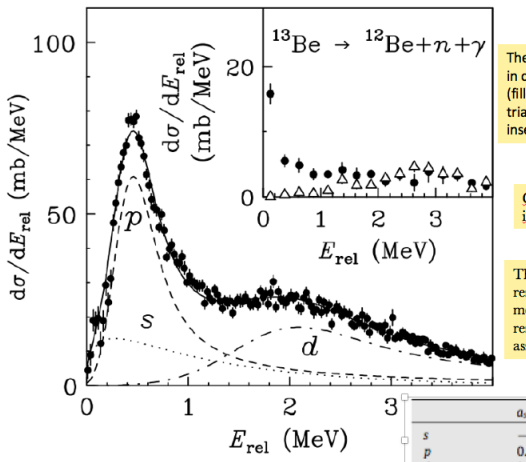




The ^{12}Be + n system reveals resonances with complicated structures.
Using the data obtained in other experiments, one may conclude that the s-wave interaction between the neutron and ^{12}Be fragment is much weaker than that in the ^{9}Li + n case. The Iπ = 1/2− assignment to the ^{13}Be state at 3.04(7) MeV was made from comparison with the neighbouring N = 9 isotones, and further confirmed by the measured ^{12}Be − n angular correlations.

2010 RIKEN ^{14}Be(p,pn)^{13}Be

Kondo et.al. Phys. Lett. B, 690, (2010), 245–249



The relative energy spectra obtained in coincidence with the 2.1-MeV (filled circles) and 2.7-MeV (open triangles) γ rays are shown in the inset.

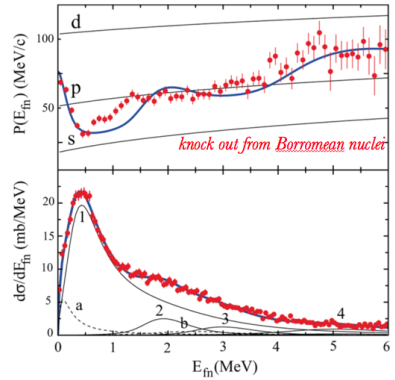
Concludes that the 0.5-MeV peak is the ground state of ^{13}Be.

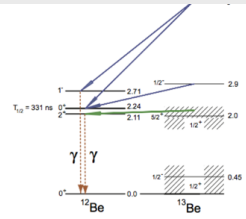
The *p*-wave nature of the 0.5-MeV resonance was shown by the transverse momentum distribution and the resonance width. This state was assigned to $J^\pi = 1/2^-$.

	a_s or E_r	Γ_r
s	−3.4(6) fm	–
p	0.51(1) MeV	0.45(3) MeV
d	2.39(5) MeV	2.4(2) MeV

2013 GSI ^{14}Be(p,pn)^{13}Be

Aksyutina, et.al. Phys. Rev. C, 87, 064316, (2013)
L.V. Chulkov, B. Jonson and M.V. Zhukov
Eur. Phys. J. A (2015) 51: 97





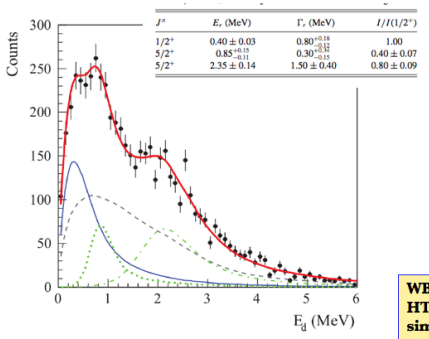
Momentum profile of the 12Be + n system after 1n knockout from ^{14}Be impinging on a H target at 304 MeV/u.

Upper panel: The solid line calculated profile function obtained from the fit to the ^{12}Be + n relative-energy spectrum.
Lower panel: ^{12}Be+n relative-energy spectrum from
The fit gave χ2/N = 0.91.

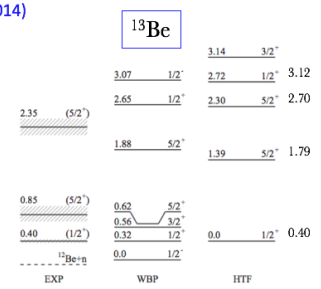
The curves show the decomposition
14 Be ⇒ 1) 13 Be(1/2+) + n (l = 0), 2) 13Be(5/2+) + n(l = 2)
⇒ 12Be(g.s.) a) 13Be(5/2+) + n (l = 2)
⇒ 12Be(2+) 3) 13Be(1/2−) + n (l = 1)
⇒ 12Be(g.s.) b) 13Be(1/2+)+n(l=0)
⇒12Be(1−) 4)13Be(5/2+ or3/2+)+ n(l = 2)

2014 GANIL ^{14}B(p,2p)^{13}Be

Randisi, et.al. Phys. Rev. C, 89, 034320, (2014)



J^π	E_r (MeV)	Γ_r (MeV)	$I/I(1/2^+)$
$1/2^+$	0.40 ± 0.03	$0.80^{+0.18}_{-0.12}$	1.00
$5/2^+$	$0.85^{+0.15}_{-0.11}$	$0.30^{+0.12}_{-0.15}$	0.40 ± 0.07
$5/2^+$	2.35 ± 0.14	1.50 ± 0.40	0.80 ± 0.09

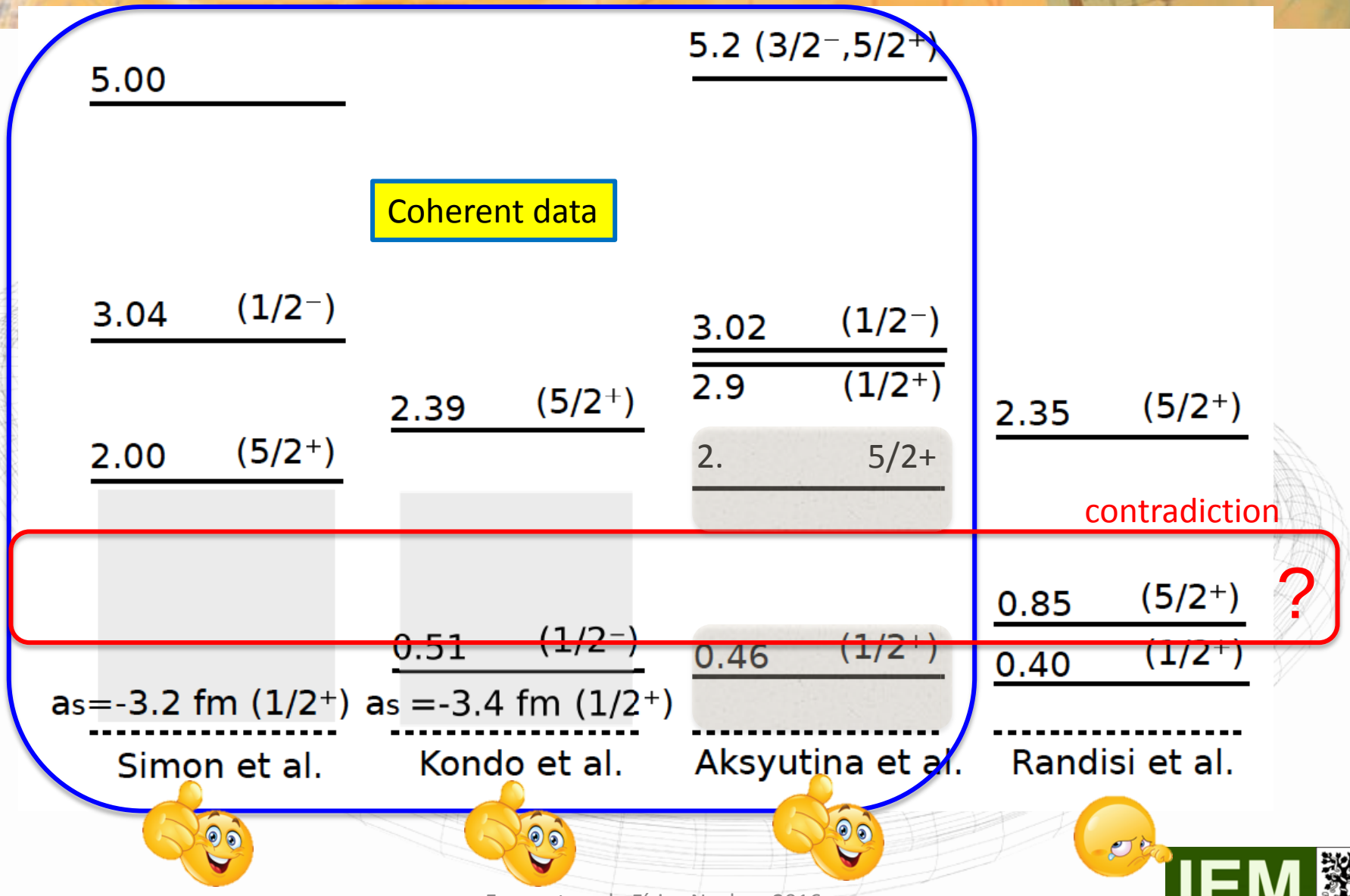


Reconstructed ^{12}Be + n decay energy for the C(^{14}B,^{12}Be + n) reaction compared to simulations incorporating an
s -wave virtual state
d -wave resonance
d -wave resonance
nonresonant continuum.

WBP - ω shell- model calculations
HTF estimated, for positive-parity states, within the simplified scheme of Fortune Phys. Rev. C **87**, 014305 (2013), where the lowest 1/2+ state is assumed to lie 0.4 MeV above threshold.

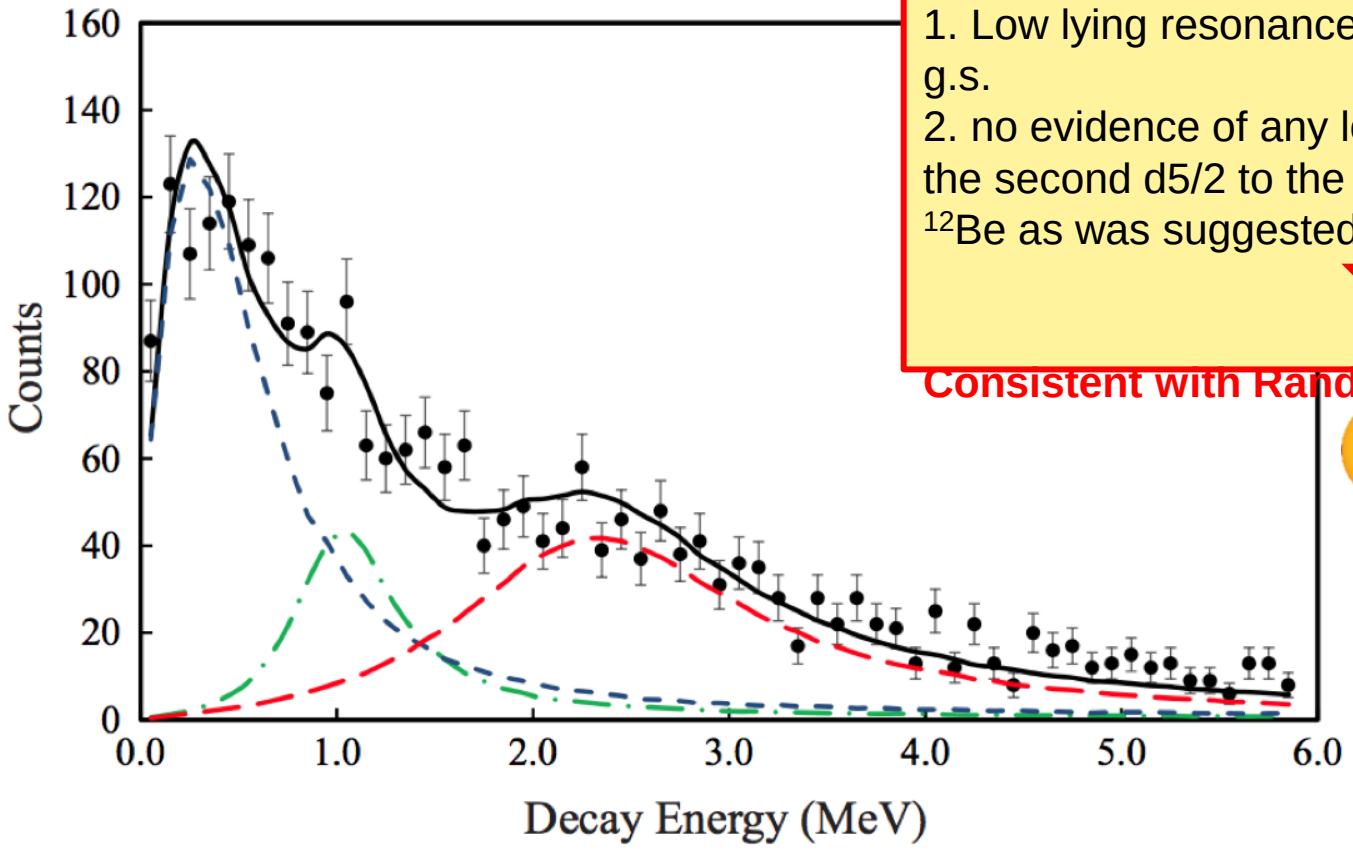
The Randisi results are shown (EXP), where the level 0.40 MeV above the ^{12}Be + n threshold is identified with the predicted 1/2+ state. Experimental energies are listed with respect to the ^{12}Be + n threshold.

Previous studies



Previous studies

Latest published data (MSU):
B. R. Marks, et.al Phys Rev C 92, 054320 (2015)



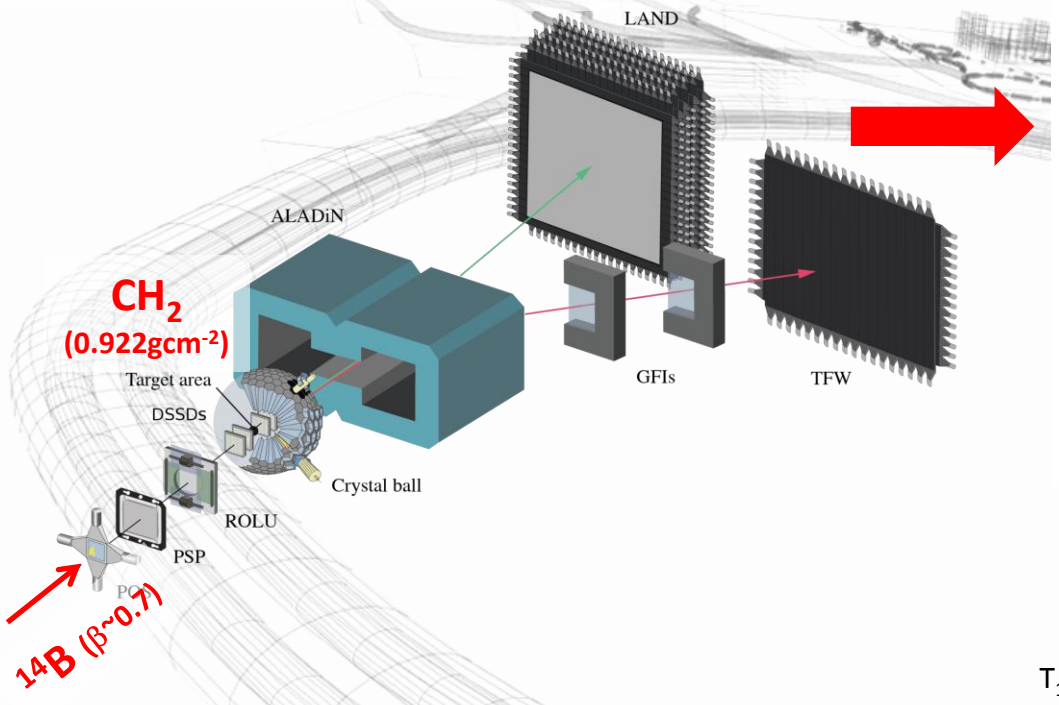
MSU conclusions:

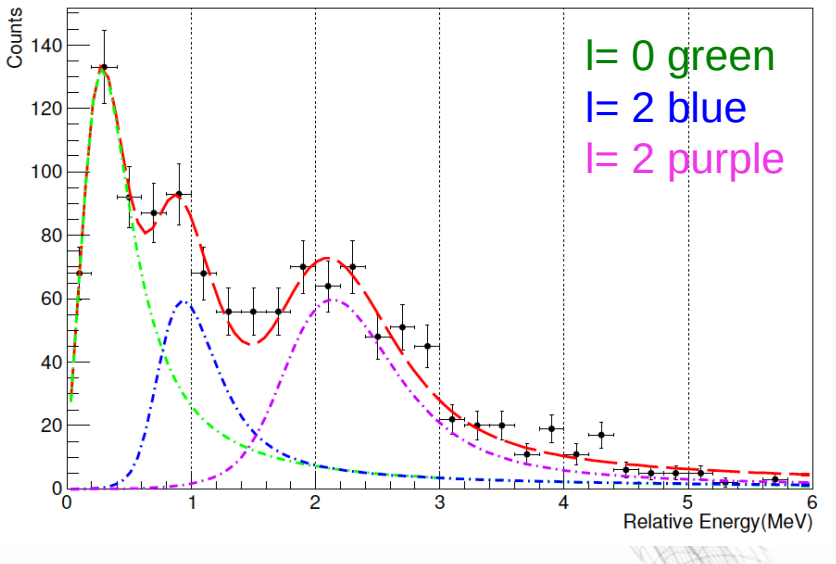
1. Low lying resonance at ~1 MeV above ^{12}Be g.s.
2. no evidence of any low- energy decay from the second d5/2 to the first excited 2+ state in ^{12}Be as was suggested by Aksyutina *et al.*.

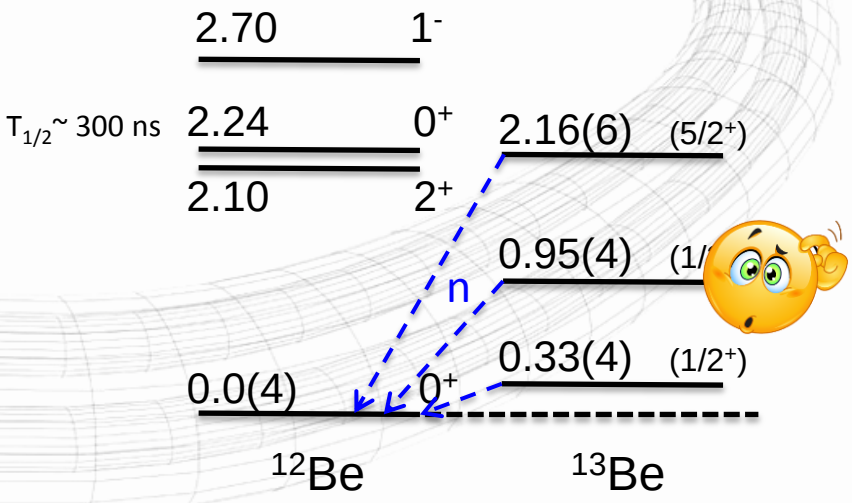
Consistent with Randisi *et al.* (GANIL)

The S393 experiment at GSI

$^{14}B(p,2p)^{13}Be \rightarrow ^{12}Be + n$

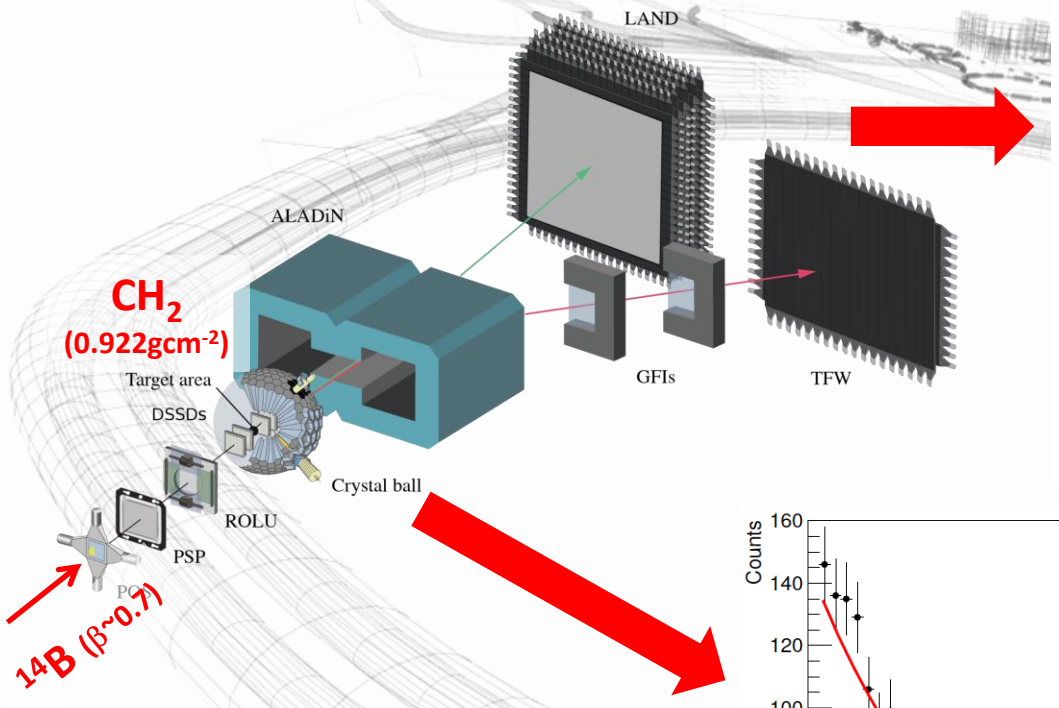


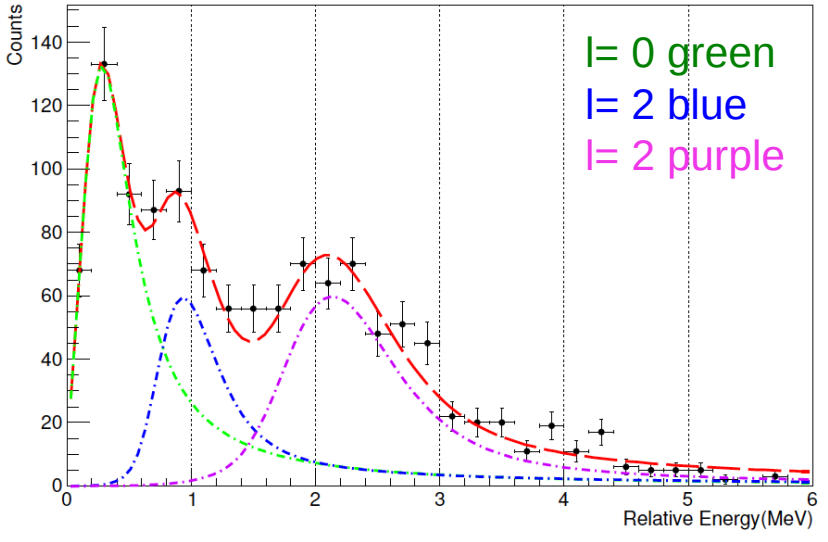


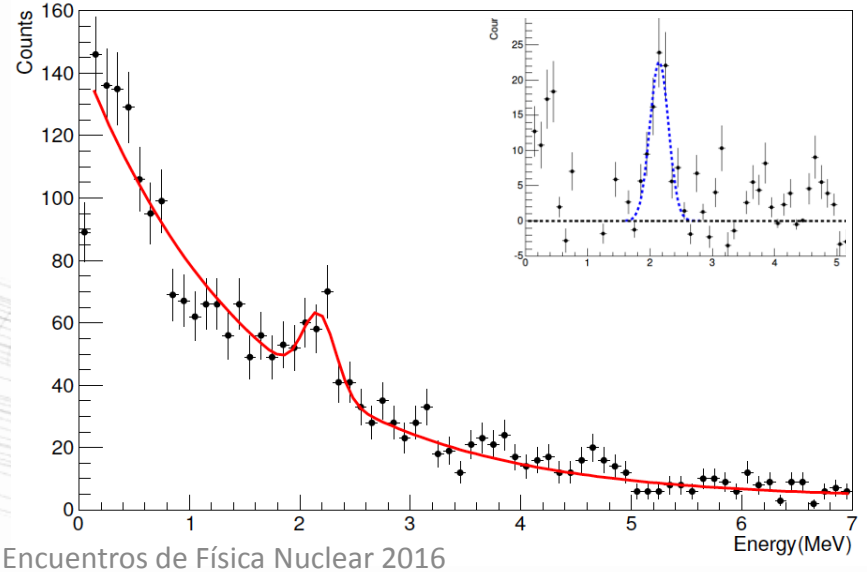


The S393 experiment at GSI

$^{14}B(p,2p)^{13}Be \rightarrow {}^{12}Be + n$







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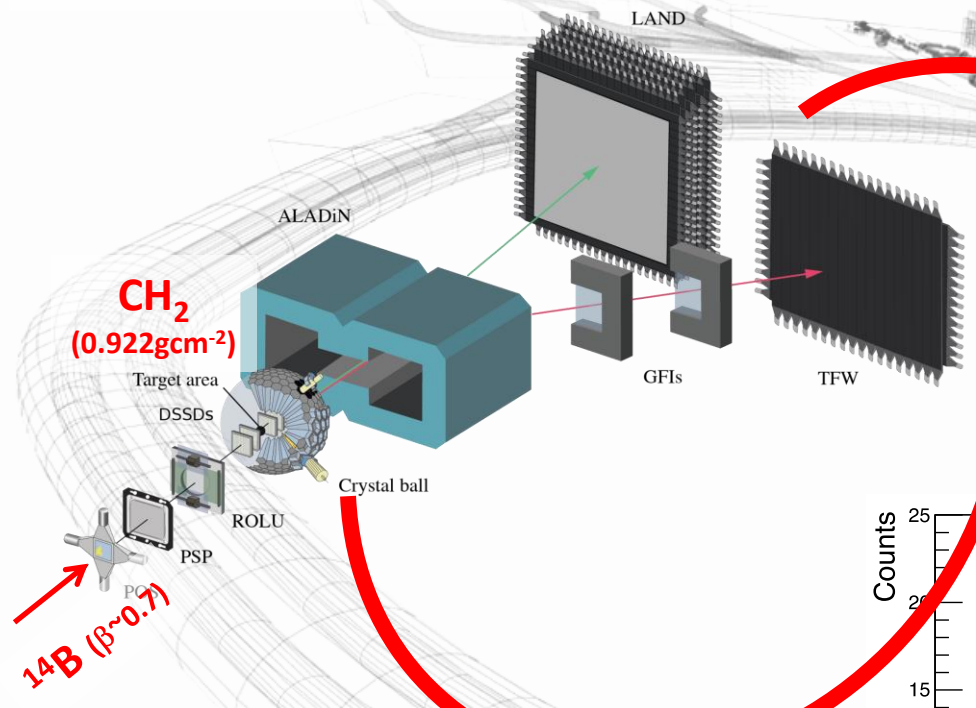

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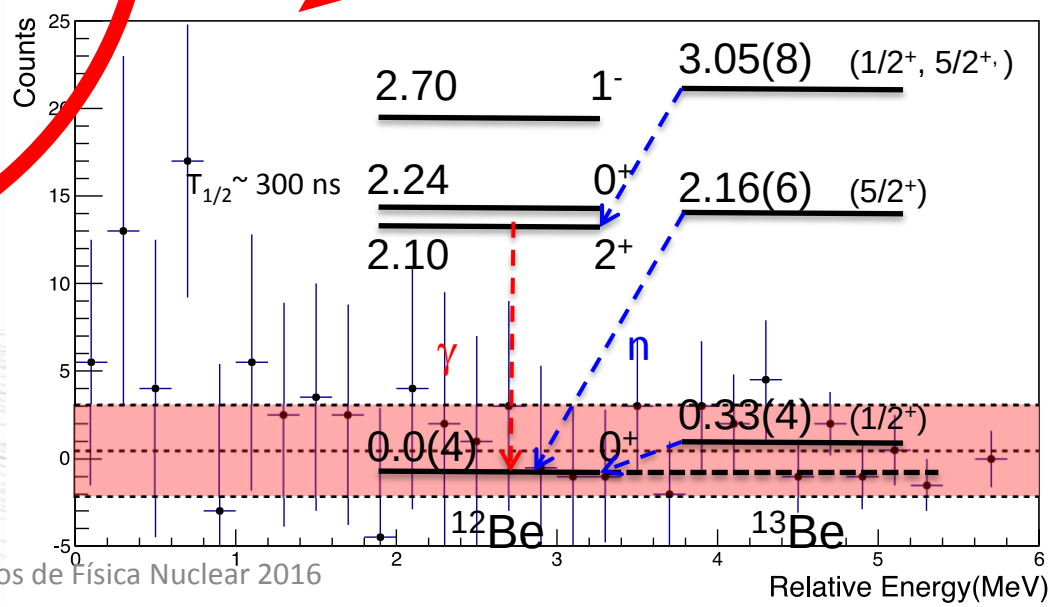


Conclusion

PHYSICAL REVIEW C 93, 054327 (2016)

Energies and widths in ^{13}Be

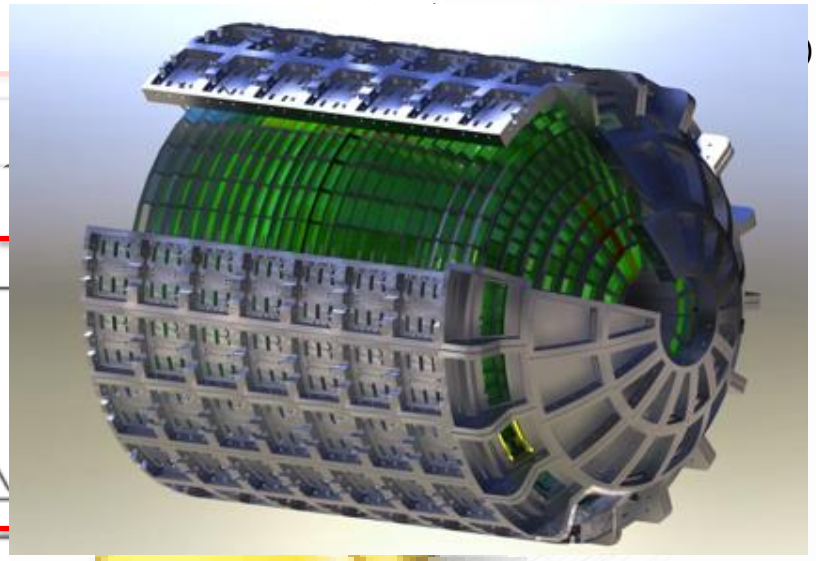
H. T. Fortune

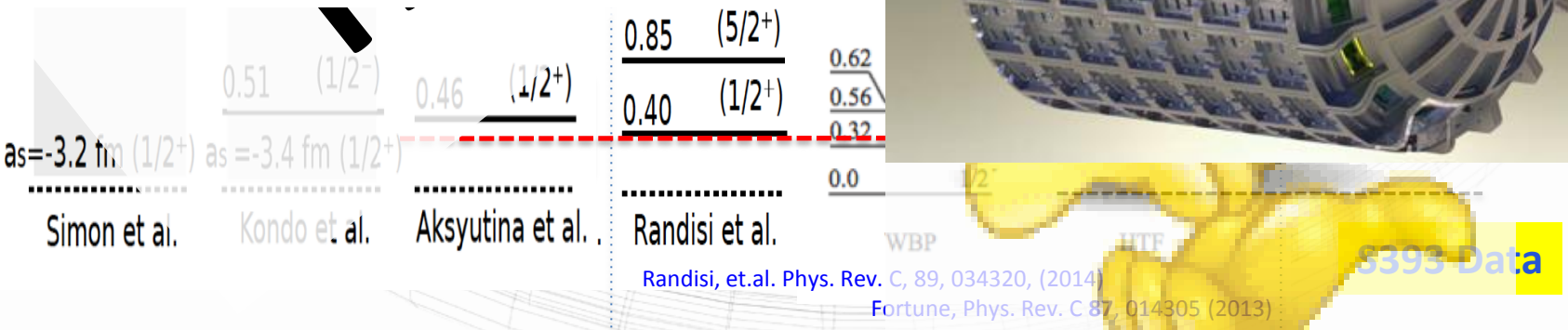
decays. The conclusion is that the differences in measured and expected widths are in serious conflict with the hypothesis of a $5/2^+$ resonance near (or just below) 1 MeV and a second one above 2 MeV. However, identifying the resonance just above 2 MeV with the *first* $5/2^+$ resonance gives good agreement between experimental and calculated widths. I also suggest that the resonance near 1 MeV, if it exists, might correspond to decay of a second $5/2^+$ resonance to the excited 0^+ state of ^{12}Be (and/or first $3/2^+$ or second $5/2^+$ decaying by *s* wave to the 2^+). I strongly urge an experiment designed to look specifically for such decays.

Our results are coherent with our own previous results and with the Riken data. They can even 'resolve' the problem with the GANIL & MSU data

Final interpretation of the level scheme needs new experiment and better statistics => CALIFA @ GSI in 2018 …

K YOU!!





Randisi, et.al. Phys. Rev. C, 89, 034320, (2014)

Fortune, Phys. Rev. C 87, 014305 (2013)