DREB 2012

Direct Reactions with Exotic Beams

26-29 March 2012

Angular-momentum content of momentum profile in a neutron knockout from ^{14}Be.

L. V. Chulkov

LAND-ALADIN collaboration

This talk is devoted to a novel experimental method using momentum profile of ^{13}Be in a neutron knockout from ^{14}Be for studies the ^{13}Be structure.

Puzzling structures of neutron-rich berylliums require

Introduction

^{12}Be is well bound and is a good core for ^{13}Be

S_n = 3.7 MeV

S_{2n} = 3.2 MeV

½$^+$ state $^{13}Be = {}^{12}Be \otimes (1s_{1/2})$

Situation is complex: neutron-rich berylliums are essentially the few-body systems.

^{12}Be 0^+ ground state

F.C.Barker, J.Phys.G 2(1976)L45

T=2 states of A=12 nuclei.

Disappearance of N=8 magicity

1976

$$^{12}Be(g.s.) = \alpha\left[^{10}Be \otimes \left(1s_{1/2}\right)^2\right] + \beta\left[^{10}Be \otimes \left(0p_{1/2}\right)^2\right] + \gamma\left[^{10}Be \otimes \left(0d_{5/2}\right)^2\right]$$

^{13}Be ½$^+$ state

$$^{13}Be(1/2^+) = \zeta\left[^{10}Be \otimes \left(0p_{1/2}\right)^2 \otimes \left(1s_{1/2}\right)\right] + \eta\left[^{10}Be \otimes \left(0d_{5/2}\right)^2 \otimes \left(1s_{1/2}\right)\right]$$

	α^2	β^2	γ^2	S
H.Fortune +, Phys.Rev. C 74(2006)024301	0.53	0.32	0.15	≤0.47
C.Romero +, Phys.Rev. C 77(2008)054313	0.67-0.76	0.13-0.19	0.10-0.13	≤0.32
F.Barker, J.Phys. G 36(2009) 038001	0.35	0.31	0.34	≤0.69
A.Navin +, Phys.Rev.Lett., 85(2000)266	0.38*	0.32*	0.30	≤0.62

(*) numerical data are taken from F.Barker J.Phys. G 36(2009)038001.

Few-body system → s-wave resonance can exist.

$$S = (\beta\zeta + \gamma\eta)^2$$

s-wave resonances

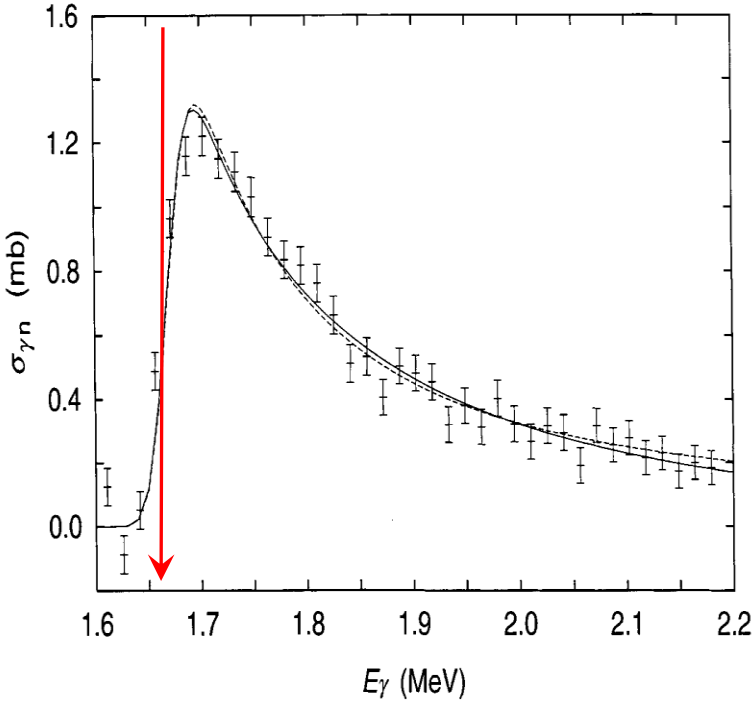
illustrated by the ½$^+$ state in ^{9}Be

The description of this unbound level is a long-standing problem. Despite the sizable amount of data, there still exist considerable uncertainties of the resonance parameters.

O.Burda et al., Phys.Rev. C 82, 015808 (2010)
F.Barker, Phys.Rev. C 68, 054602 (2003)
Aust. J. Phys. 53, 247 (2000).
V.Efros et al., Eur.Phys.J. A 4, 33 (1999)
E.Garrido et al., Phys.Rev.Lett. B 684, 132 (2010)

S-wave resonance or virtual state?

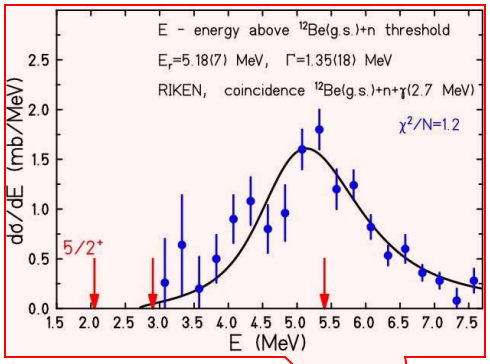
a = -27.6 fm; r_0= 8.8 fm → Efros +
E_s = -27 keV
E_r = 19 keV, Γ = 217 keV → Kuechler +
E_s= - 0.62 keV
E_r = 67.6 keV, Γ = 280 keV → Barker
E_s = - 23 keV
E_r = 83(6) keV, Γ = 274(10) keV → Burda +
E_s = -30 - *i* 77 keV

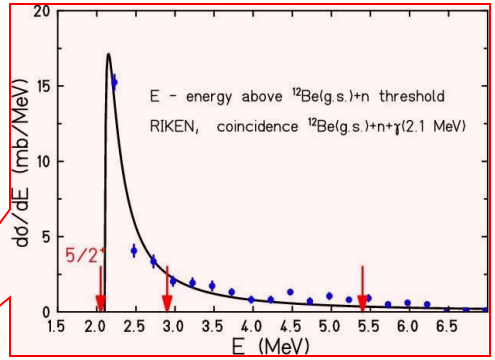


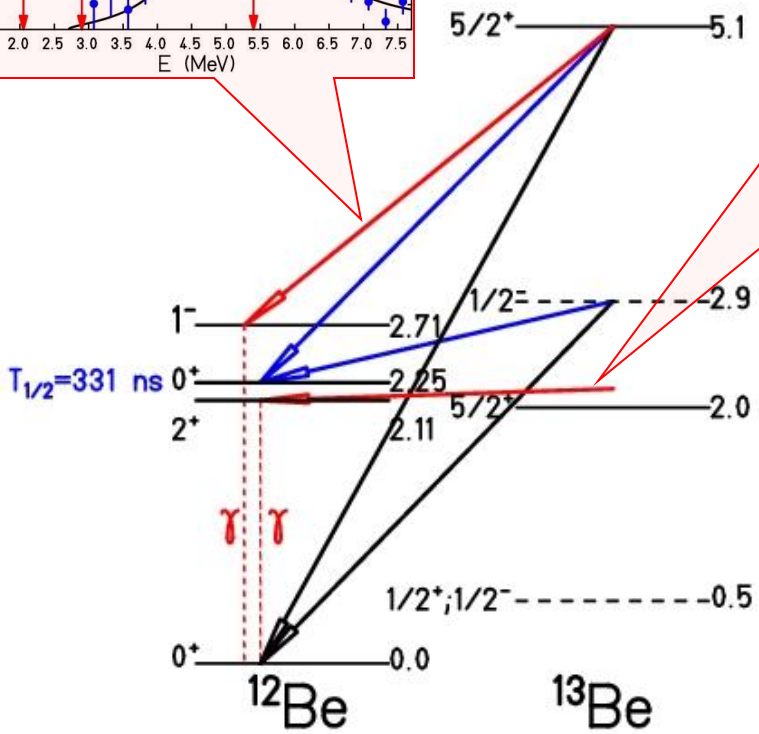
^{9}Be(γ, n)^{8}Be cross section as a function of E_γ
Kuechler et al., Z. Phys. A 326, 447 (1987).

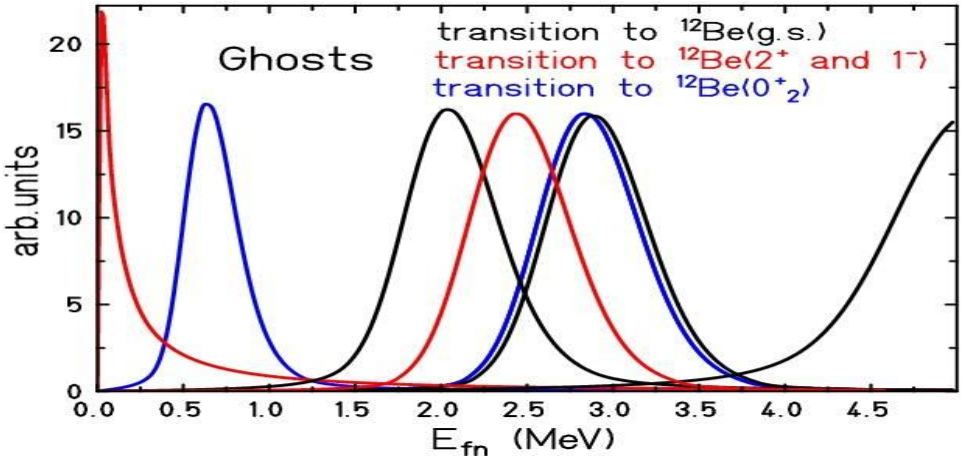
Situation is complex: ghosts in the ^{12}Be+n relative-energy spectrum

Y.Kondo et al., Phys.Lett. B 690, 245 (2010)
Coincidence with 2.7 Mev γ and 2.1 MeV γ



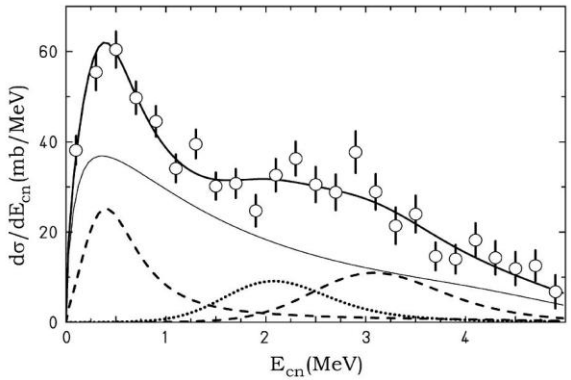






^{13}Be puzzle

Three recent experiments resulted to similar spectra but also to vastly different interpretations



Virtual state as a dominant

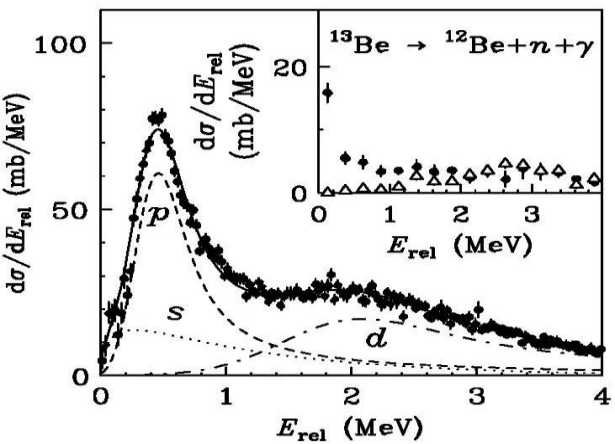
$a_s = -3.2(1.0)$ fm (antibound state)

Er = 0.41(8) MeV, Γ = 0.4(5) MeV

Er = 3.04 MeV, Γ = 0.4 MeV

Er = 2.0 MeV, Γ = 0.3 MeV

H.Simon et al., Nucl.Phys. A791, 267 (2007)



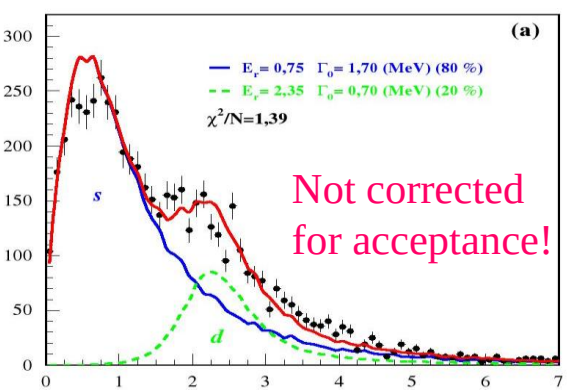
Narrow p-wave resonance

$a_s = -3.4(6)$ fm (antibound state)

Er = 0.51(1) MeV, Γ = 0.45(3) MeV

Er = 2.39(5) MeV, Γ = 2.4(2) MeV **$\Gamma = 2.5\ \Gamma_{sp}$!**

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



Broad s-wave resonance.

E_r=0.7(2) MeV, Γ=1.7(2) MeV

E_r=2.4(2) MeV, Γ=0.6(3) MeV

G.Randisi, PhD Thesis 2012,

see also J.L.Lecouey, Few-Body Systems 34, 21 (2004).

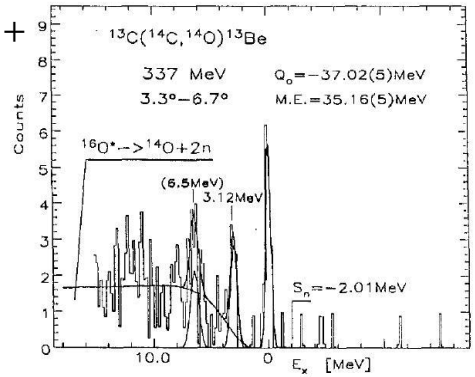
Reaction Dependence of Nuclear Decay Widths

Various reactions have been used to study the reaction dependence of a resonance decay width The resonance widths are self-consistent and indicate little if any reaction dependence.

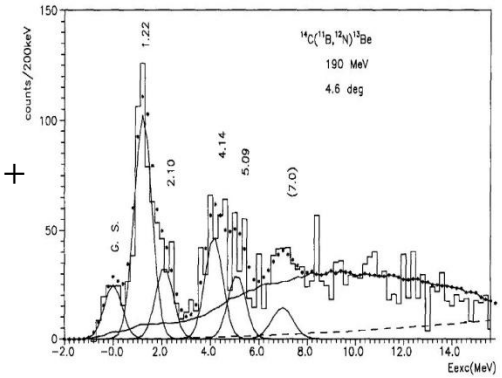
D.Overway et al., Nucl.Phys. A366, 299 (1981)

N.Arena et al., Il Nuovo Cimento, A106, 1007(1993)

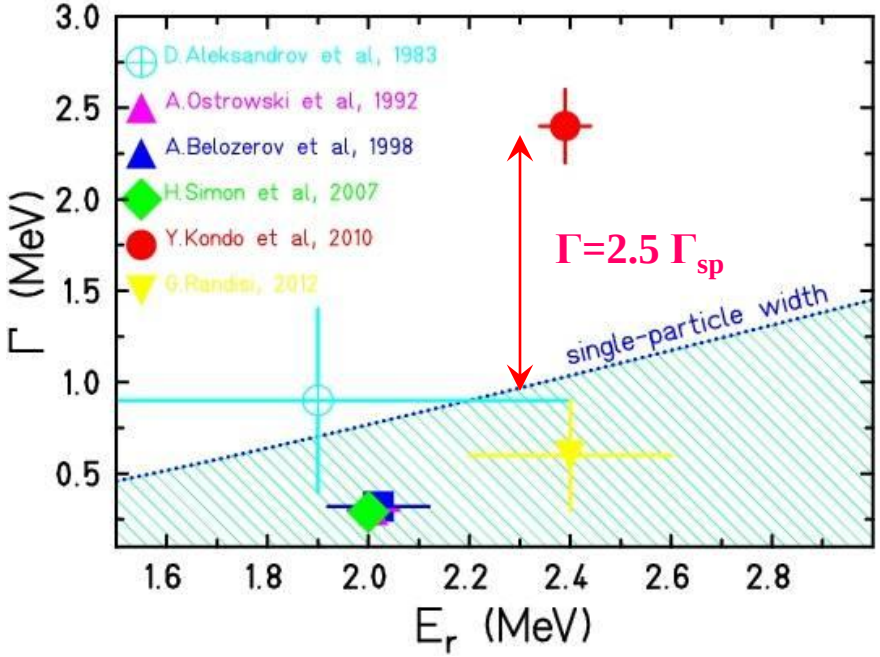
Ostrowski +



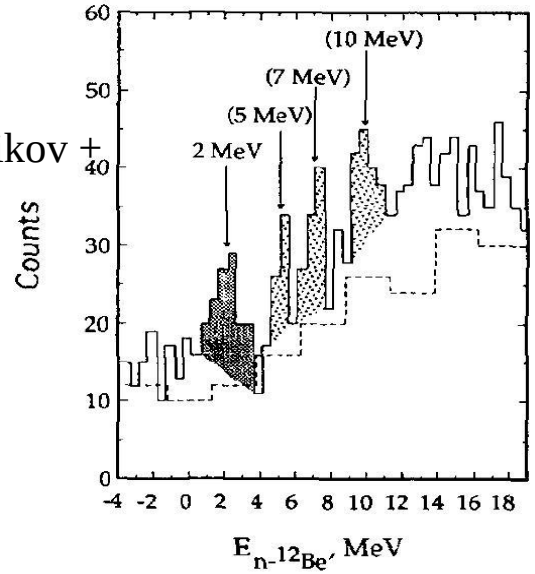
Belozerov +



5/2+ state in ^{13}Be



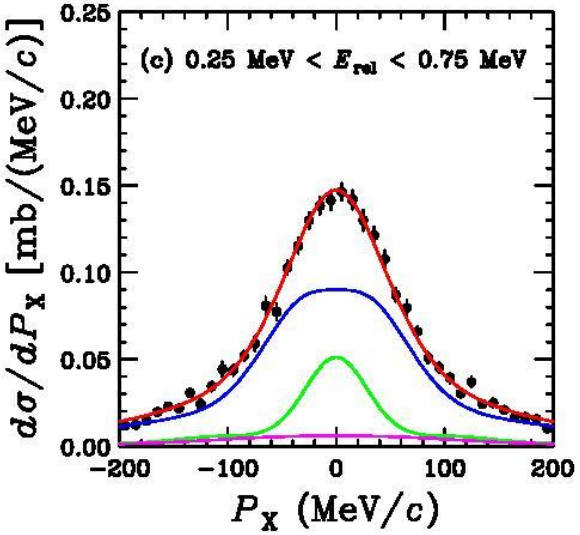
Korsheninnikov +

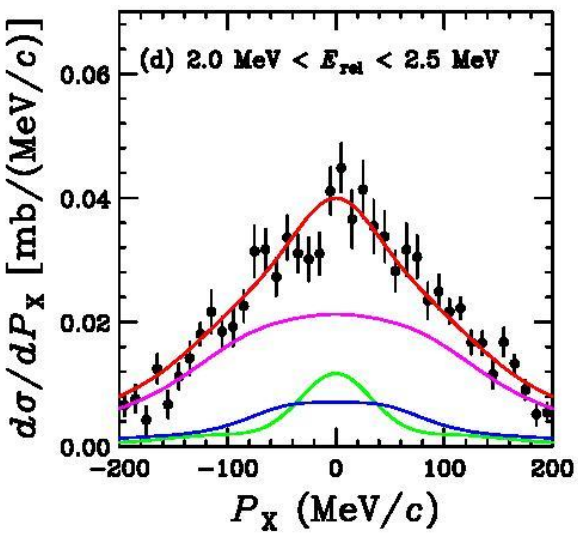


Reference for Γ_{sp}:

A.Bohr & B.R.Mottelson, Nuclear structure, 1998, v.1, p.441, Eq.3f-51

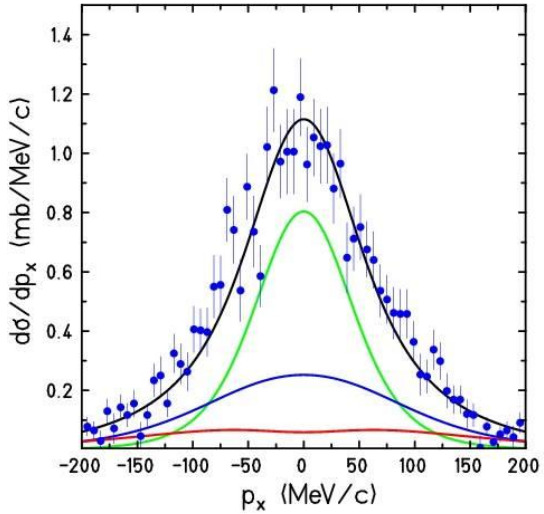
Shapes of momentum distributions cannot remove ambiguity





Yosuke Kondo
Doctoral Dissertation
2007
^{1}H(^{14}Be, ^{12}Be+n), E=69 MeV/u

s- p- d-



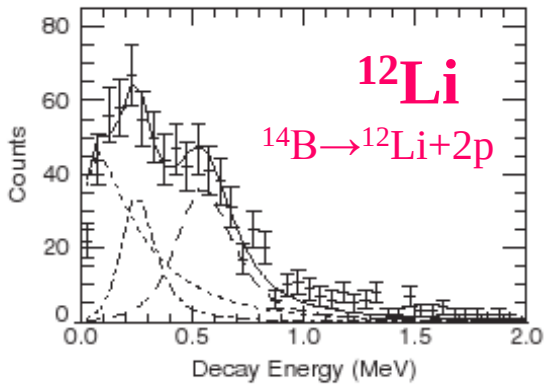
H.Simon at al., Nucl.Phys. A791, 267 (2007)
C(^{14}Be, ^{12}Be+n), E=287 MeV/u

Our aim is in finding
free from contradiction
interpretation of existing experimental data on
^{13}Be

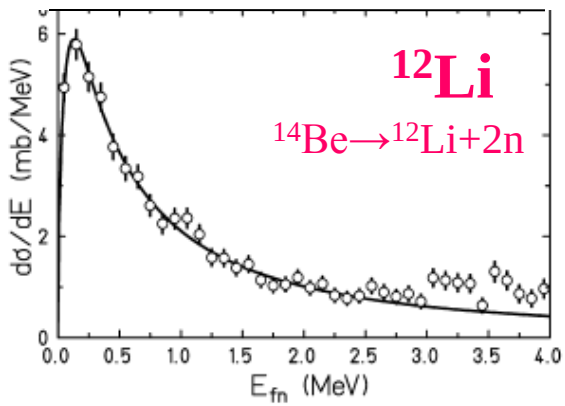
New observable – momentum profile-
width of ^{12}Be+n momentum distribution
as a function of ^{12}Be+n relative energy
in a neutron knockout from ^{14}Be.

Step aside….

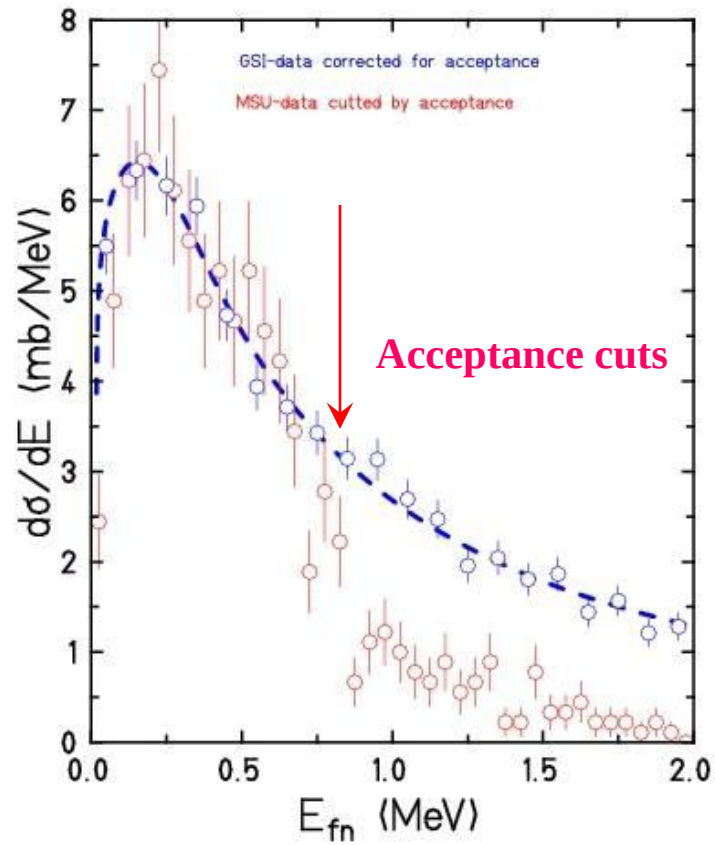
Our aim is in finding free from contradiction interpretation of existing experimental data



The ground state (dotted) and two *d* states (dot-dashed and dashed).



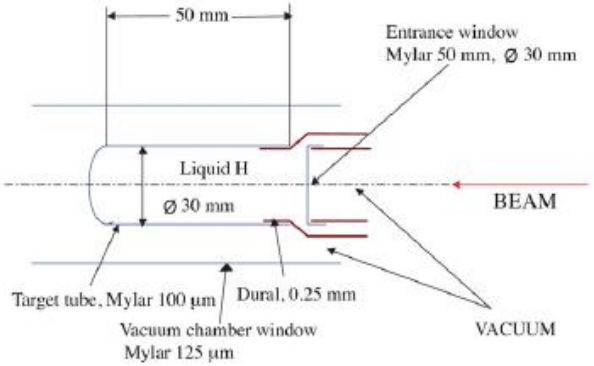
The spectrum is fitted with a single virtual *s*-state.

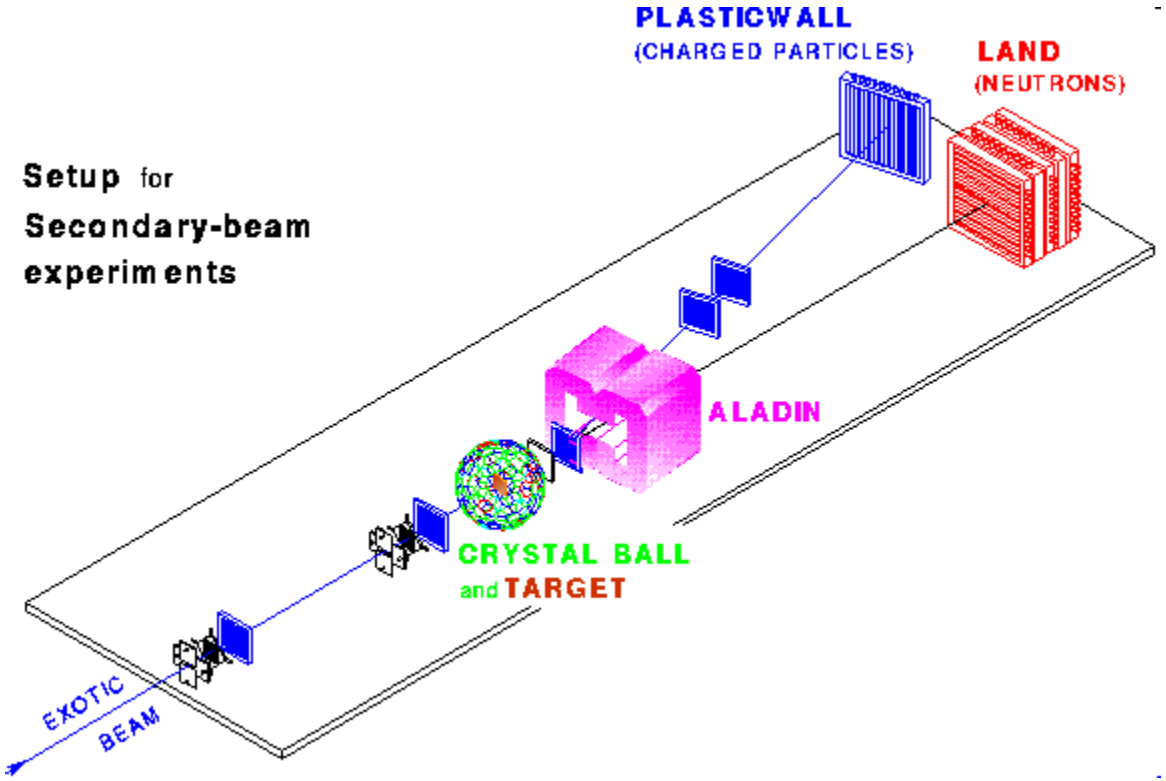


C.C.Hall +, Phys.Rev. C 81, 021302 (2010)
Yu.Aksyutina +, Phys.Lett. B 666, 430 (2008)

Experimental set up

^{8}He 240 MeV/u
^{11}Li 280 MeV/u
^{14}Be 304 MeV/u
Liquid hydrogen target

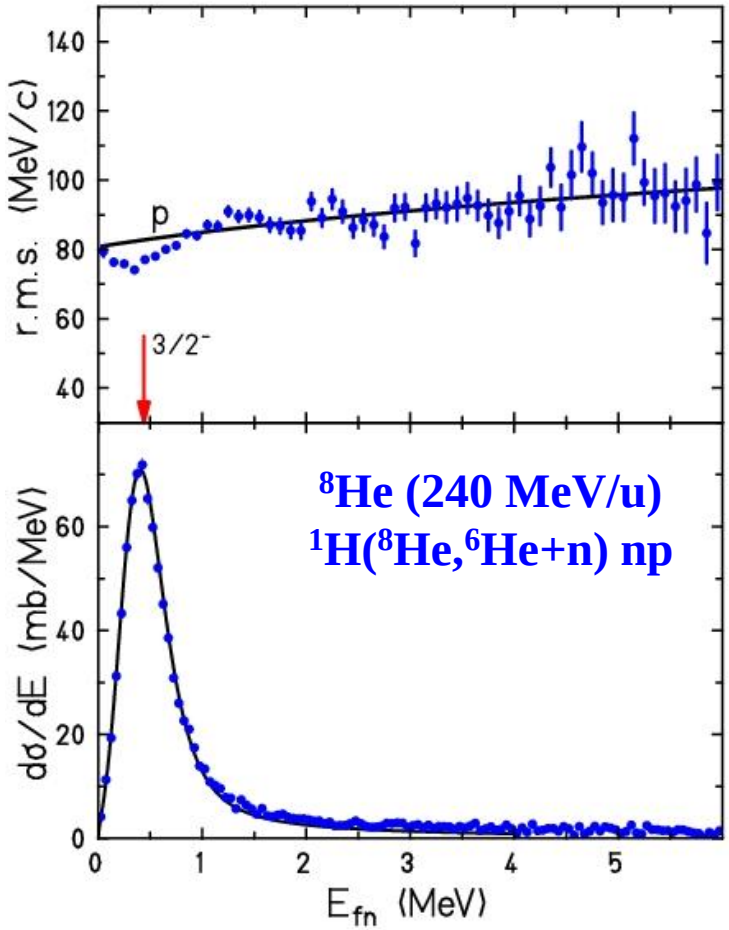


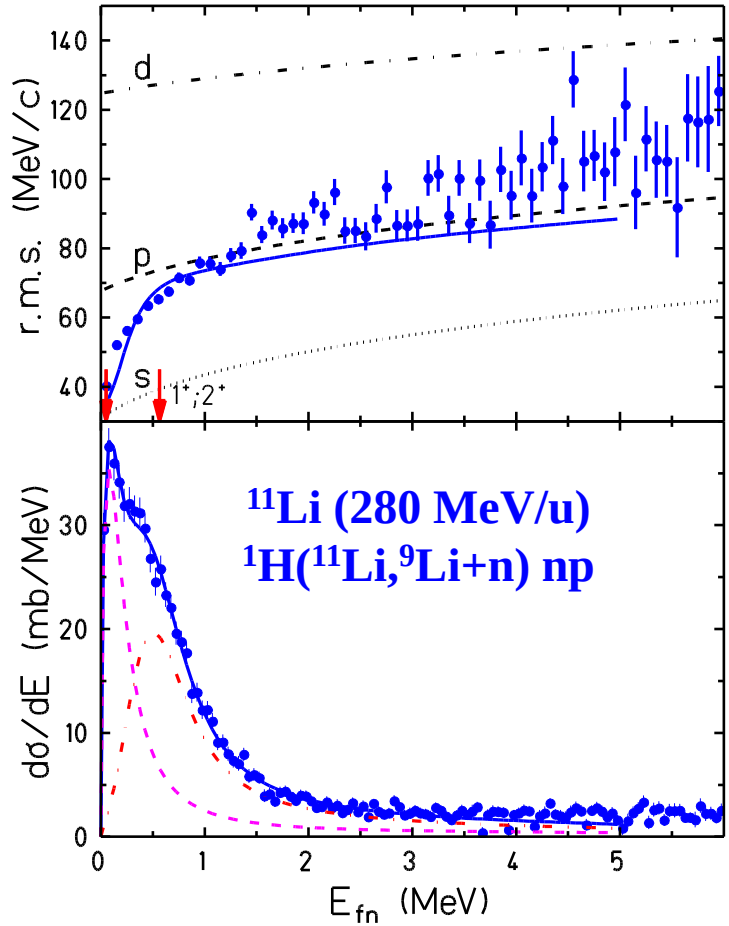


Momentum width as a function of *fragment-n* relative energy
Momentum Profile: ^{7}He & ^{10}Li

$$P(E_{fn}) = \sqrt{\left\langle (p_f^x + p_n^x)^2 \right\rangle - \left\langle (p_f^x + p_n^x) \right\rangle^2}$$

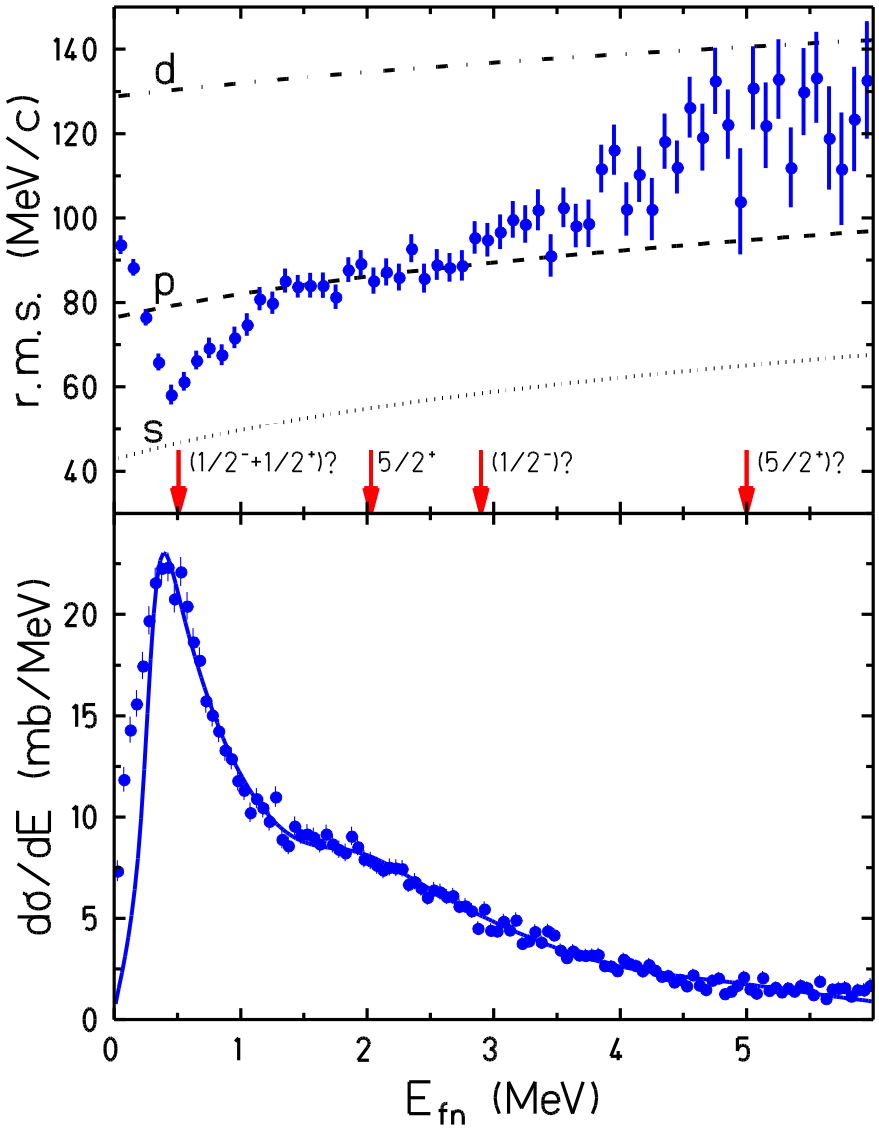
P.G. Hansen, PRL 77 (1996) 1016
M. Smedberg, Thesis Chalmers University of Technology





Momentum Profile: 13Be → 12Be(g.s.)+n

$$P(E_{fn}) = \sqrt{\left\langle (p_f^x + p_n^x)^2 \right\rangle - \left\langle (p_f^x + p_n^x) \right\rangle^2}$$



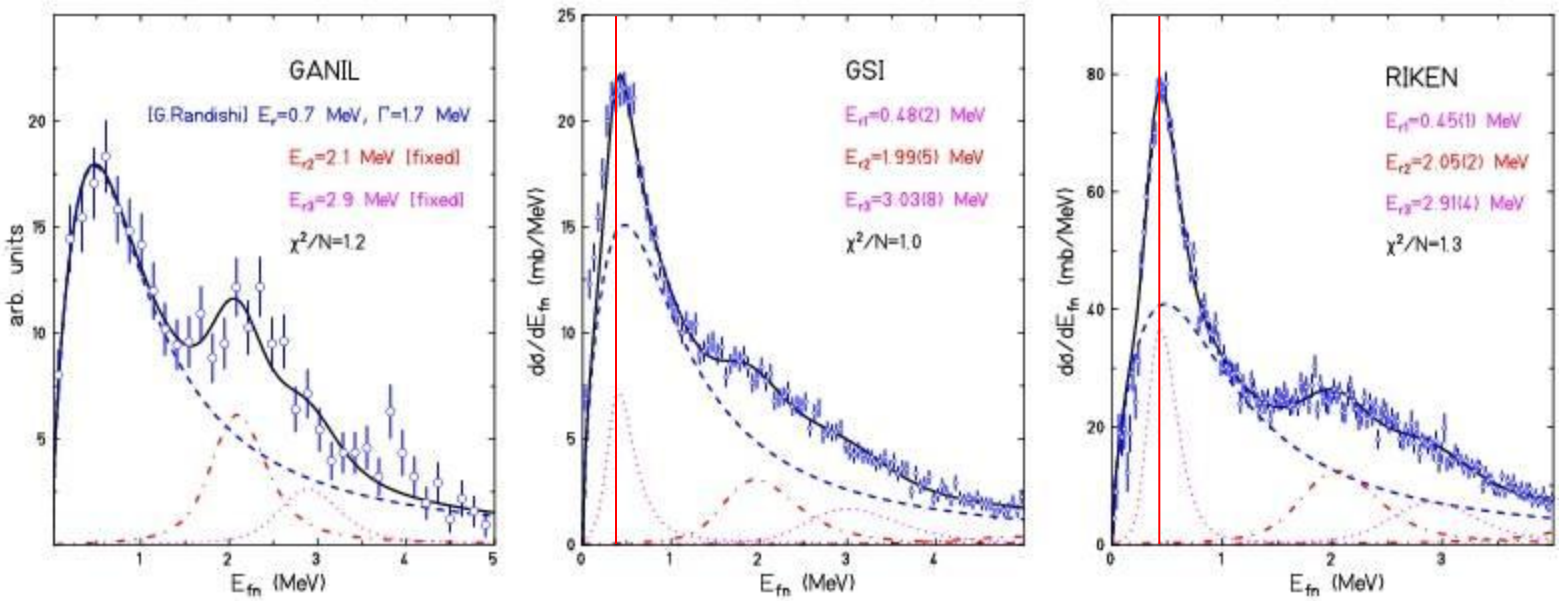
^{14}Be (304 MeV/u)
^{1}H(^{14}Be,^{12}Be+n) np

Breit-Wigner ℓ=0 resonance

$$\delta_0 = \tan^{-1}\left(\frac{\frac{1}{2}\Gamma_0}{E_r - E}\right)$$

$$\frac{d\sigma}{dE} \sim \frac{1}{k}(\sin\delta_0)^2 = 2\gamma^2\left(\frac{\Gamma_0}{(E_r - E)^2 + \frac{\Gamma_0^2}{4}}\right)$$

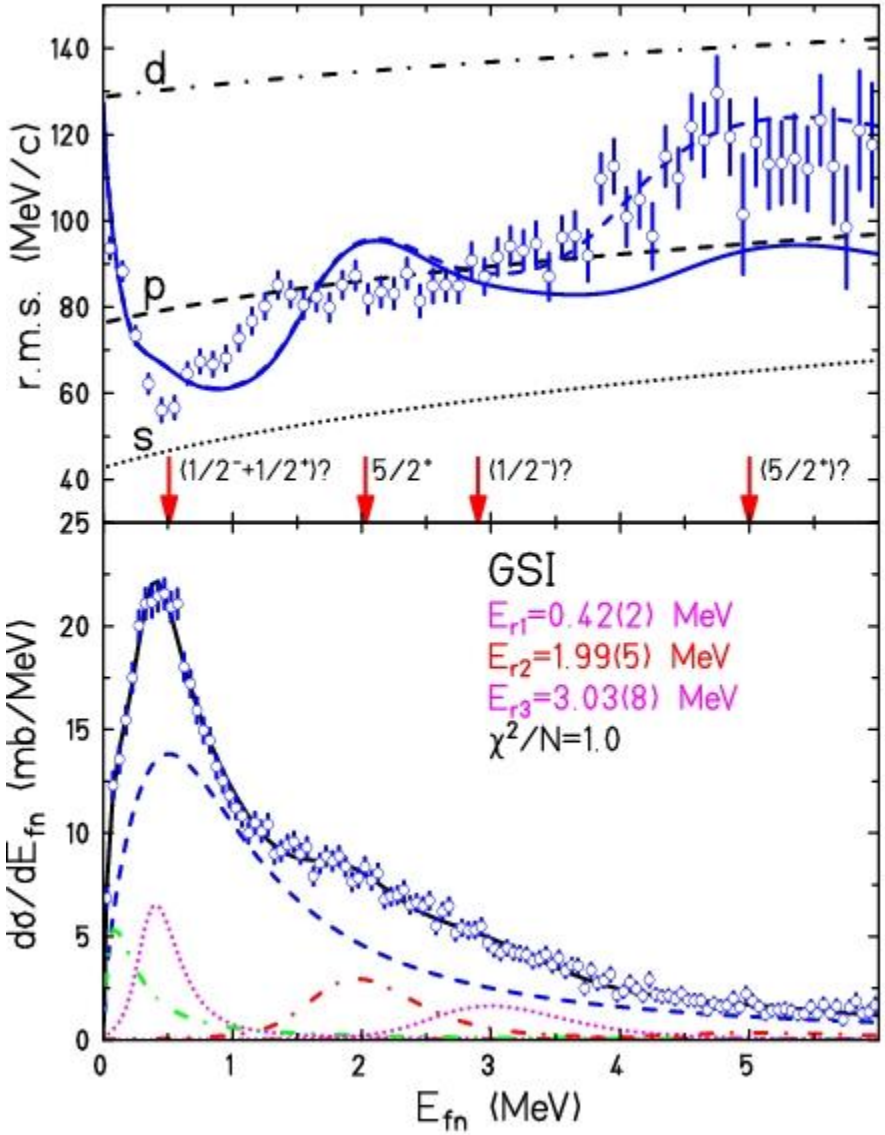
J.L.Lecouey, Few-Body Systems 34, 21 (2004), corrected for acceptance

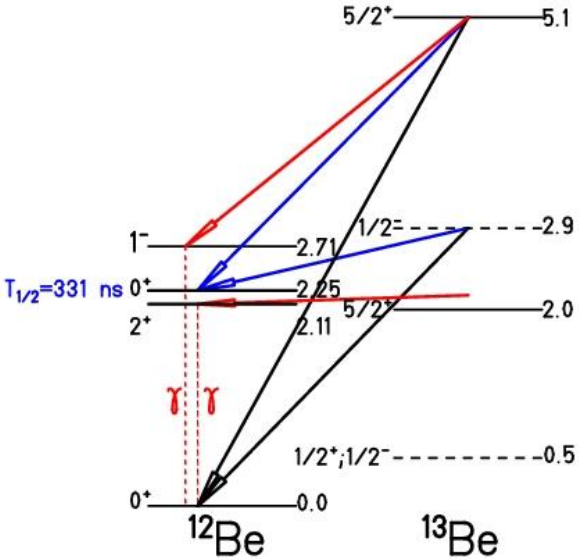


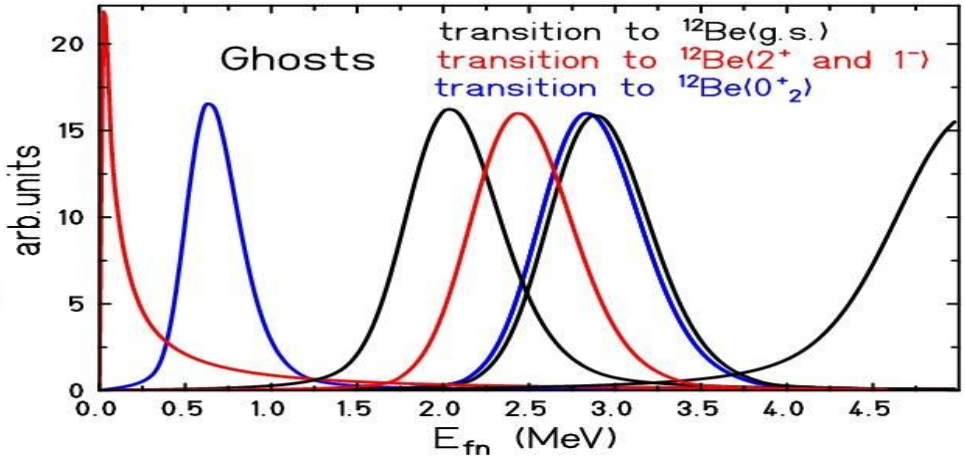
Interference with potential scattering (background phase shift)

$$\frac{d\sigma}{dE} \sim \frac{1}{k}(\sin(\delta_0 + \varphi_0))^2 = \frac{(\Gamma\mathrm{Cos}(\varphi_0) + 2(E_r - E)\mathrm{Sin}(\varphi_0))^2}{4k((E_r - E)^2 + \frac{\Gamma^2}{4})}$$

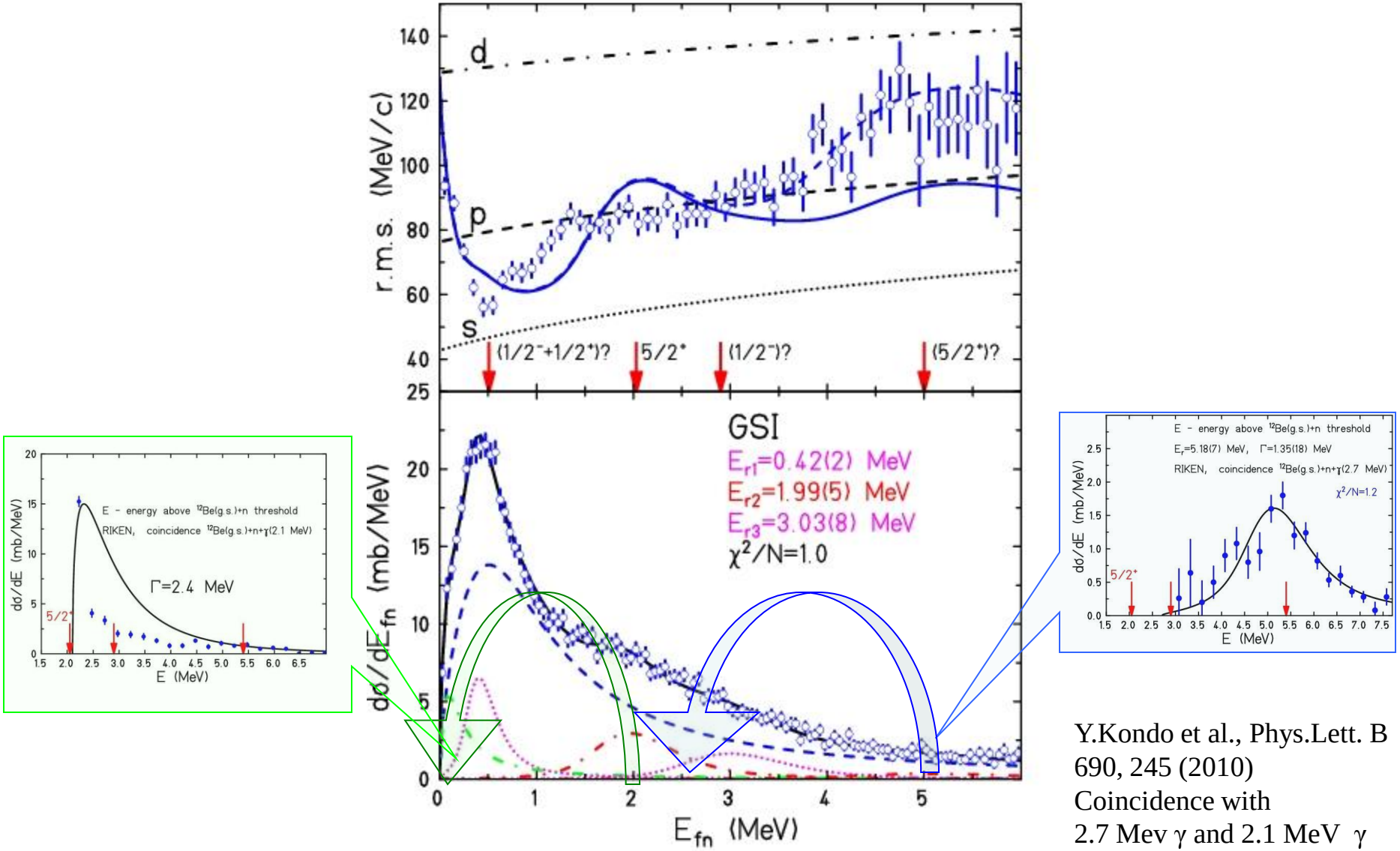
Momentum Profile: $^{13}Be \rightarrow {}^{12}Be(g.s.)+n$







Momentum Profile: $^{13}Be \rightarrow {}^{12}Be(g.s.)+n$



Y.Kondo et al., Phys.Lett. B 690, 245 (2010)
Coincidence with
2.7 Mev γ and 2.1 MeV γ

Thank you for your attention