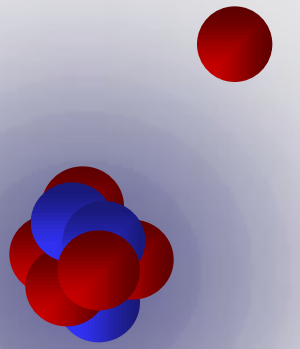
Possible Day One SAMURAI+NEBULA Experiments

Motivation/
Ground Rules

"Early Phase" -
Commissioning
Experiments



Day One Experiments

Conclusions

Motivation & Ground Rules …

EARLY PHASE / COMMISSIONING EXPERIMENTS

AIM: *validate operation of SAMURAI+NEBULA & analysis + simulation procedures*

REQUIREMENTS …

→ *Established systems/well known resonances (eg., ^{7}He, ^{10}Li …)*

→ *Single-neutron detection – core + n systems*

→ *No γ-ray detection (no core fragment bound E_x or not populated)*

→ *Short expts – high rate secondary beam(s) + reasonanble σ*

… multiple reaction channels from single beam

→ *Some physics in parallel – spectroscopy of n unbound systems*

⇒ *Light neutron-rich systems (A<15-20)*

Possibilities …

^{14}B → ^{7}He, ^{10}Li ("known") ^{9}He, ^{12}Li (N=7, 9 physics)

[^{17}C → ^{7}He, ^{16}B ("known") ^{15}Be (search, N=11)]

Approx. "Selection Rules" …

… removal of nucleon(s) from high-energy beam

(i) 1 & 2-proton knockout $\Rightarrow \Delta\ell_n = 0$ proj. valence neutron config.

eg. : $C(^{11}Be,^{9}Li+n)X$, $C(^{11}Be,^{8}He+n)X \rightarrow \nu s_{1/2}$ [^{11}Be $C^2S(\nu s_{1/2}) \approx 0.8$]

(ii) 1-neutron knockout from 2n halo $\Rightarrow$ halo valence neutron configs

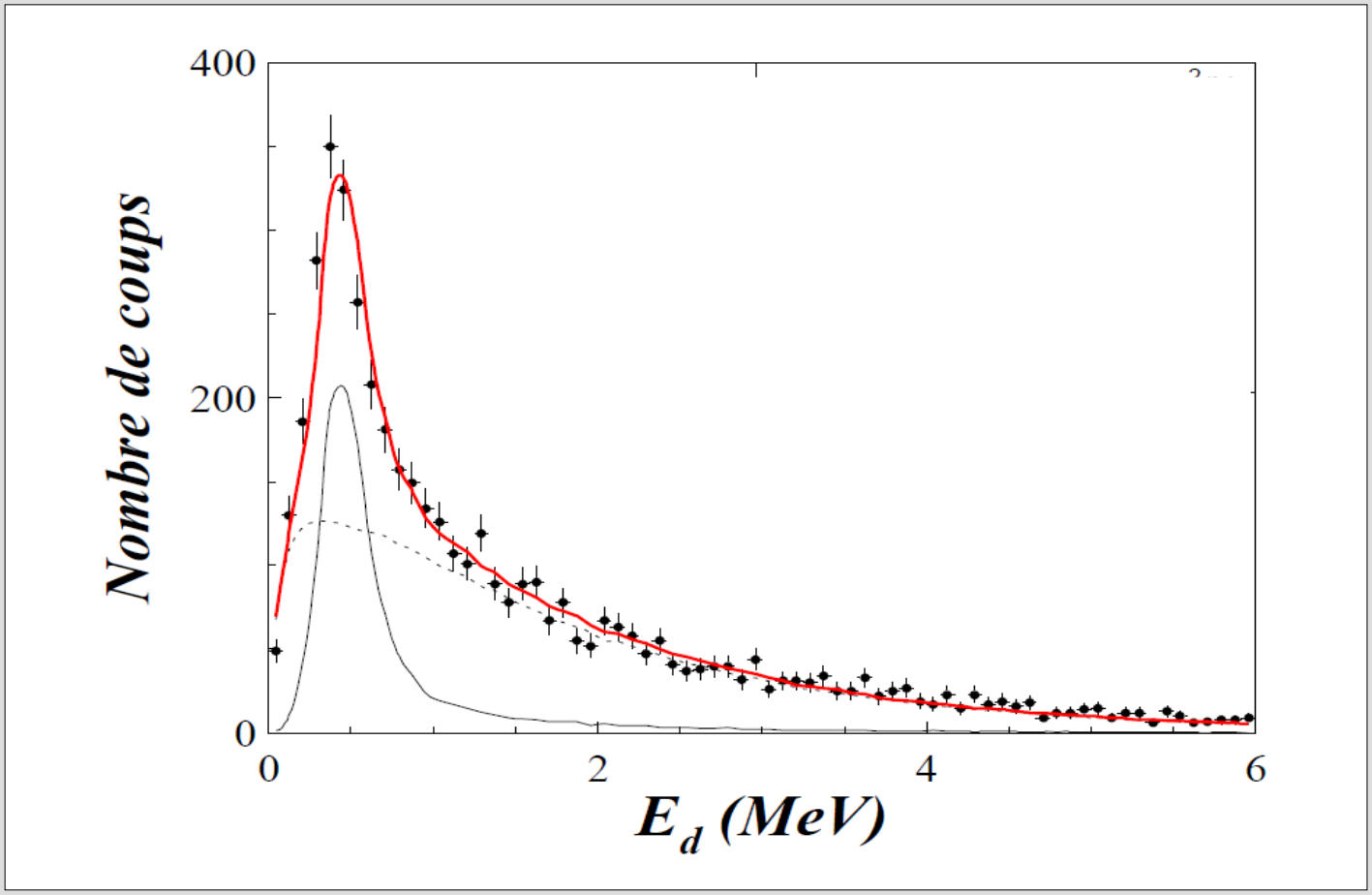
eg. : $C(^{11}Li,^{9}Li+n)X \rightarrow \nu s_{1/2} + \nu p_{1/2}$ [^{11}Li $(\nu s_{1/2})^2 + (\nu p_{1/2})^2 \approx 100\%$]

(iii) fragmentation (-xp,-yn) $\Rightarrow$ population via neutron-decay of N+1 system

eg. : $C(^{14}B,^{9}Li+n)X$, $C(^{14}B,^{8}He+n)X \rightarrow \nu s_{1/2} + \nu p_{1/2} + \ldots$

[$\rightarrow$ CAVEAT: decay of narrow resonances in N+1,2,… systems]

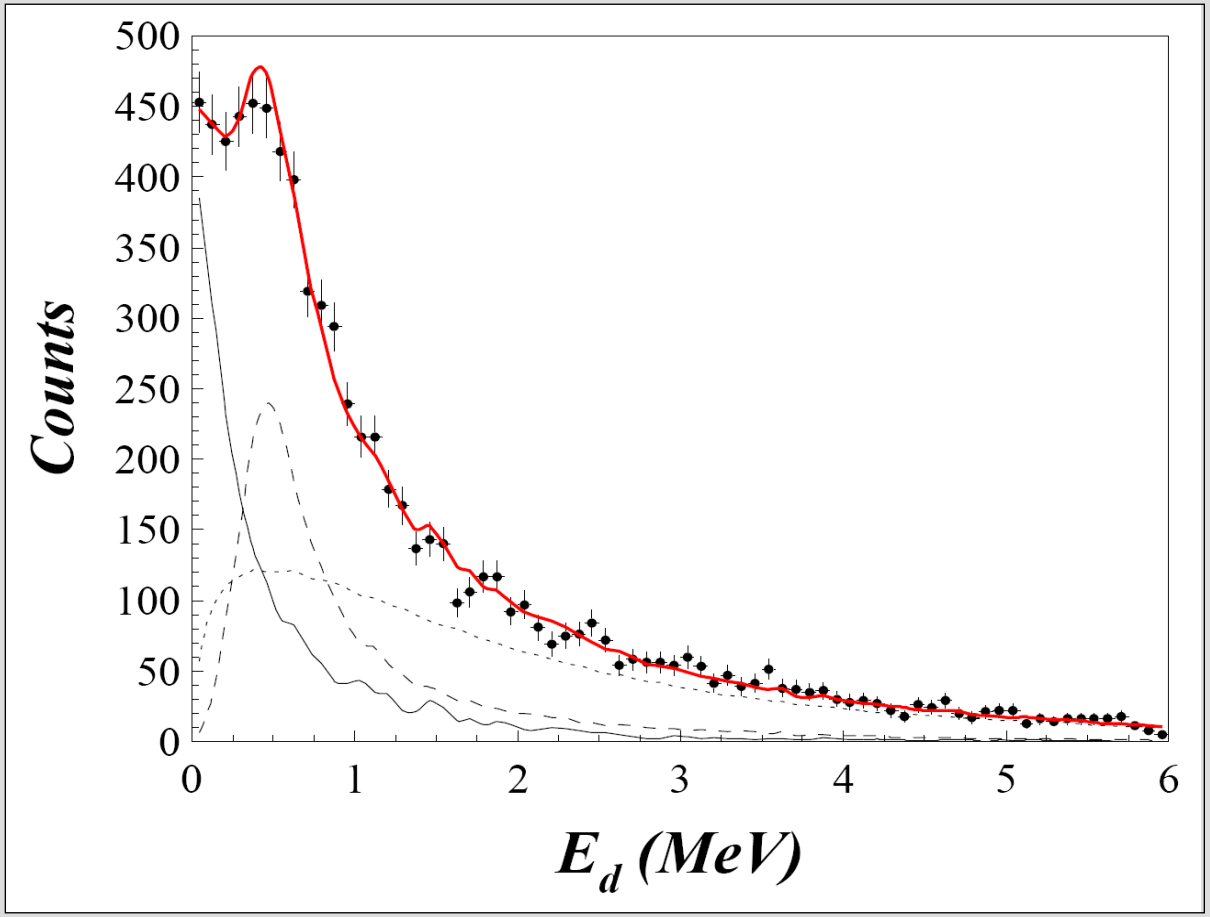
^{7}He: C(^{14}B,^{6}He+n)X … REFERENCE SYSTEM



$E_r = 0.44$ $\Gamma_0 = 0.16$ MeV

H Al Falou, LPCC T 07-02

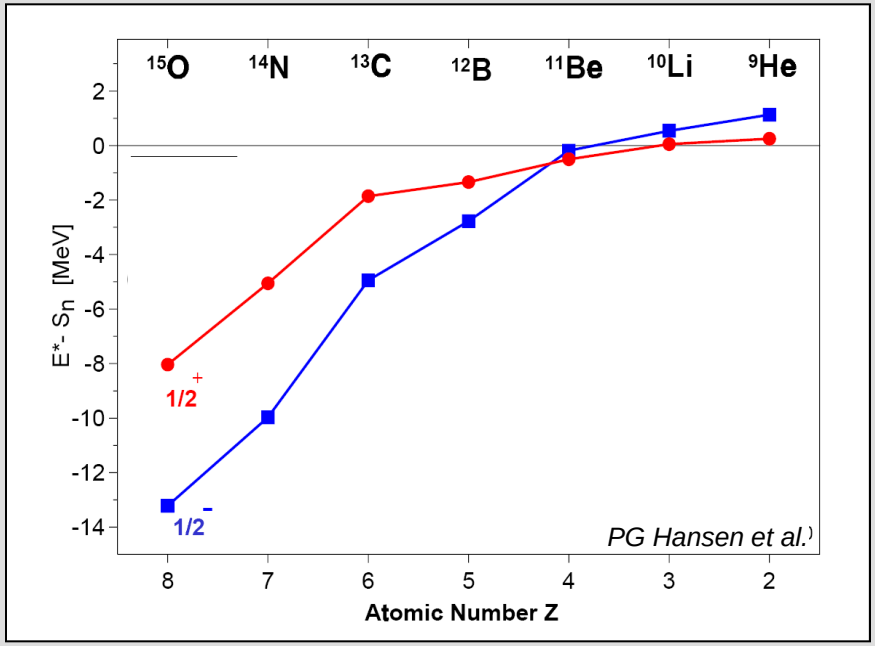
^{10}Li: C(^{14}B,^{9}Li+n) … RESOLVING POWER + LOW E_d RESPONSE



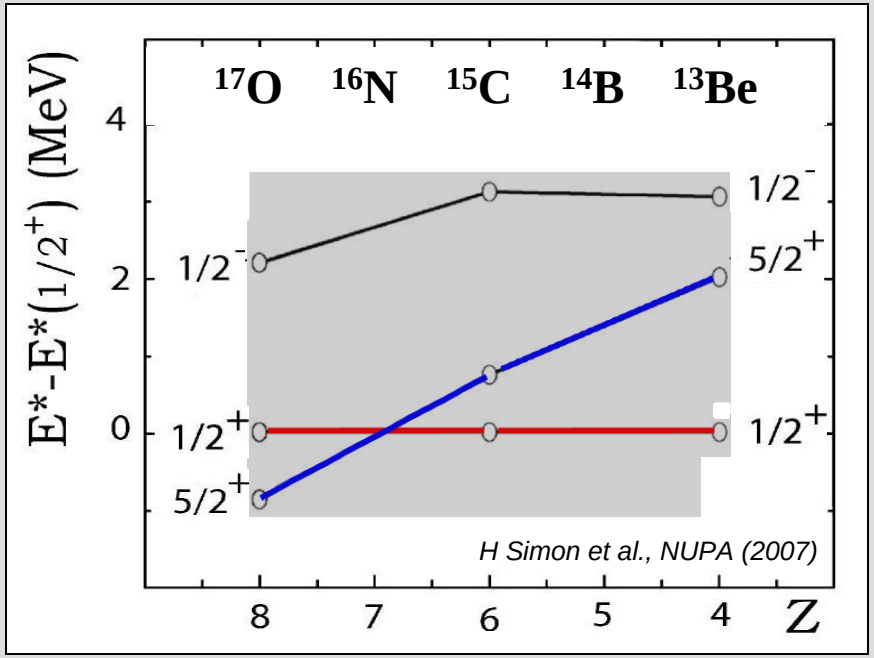
s-wave [a_s = -10 fm] + p-wave [E_r = 0.50, Γ_o = 0.50 MeV]

[see also GSI-LAND with ^{11}Li]

Physics: N=7 & 9 Structural Evolution with Isospin …

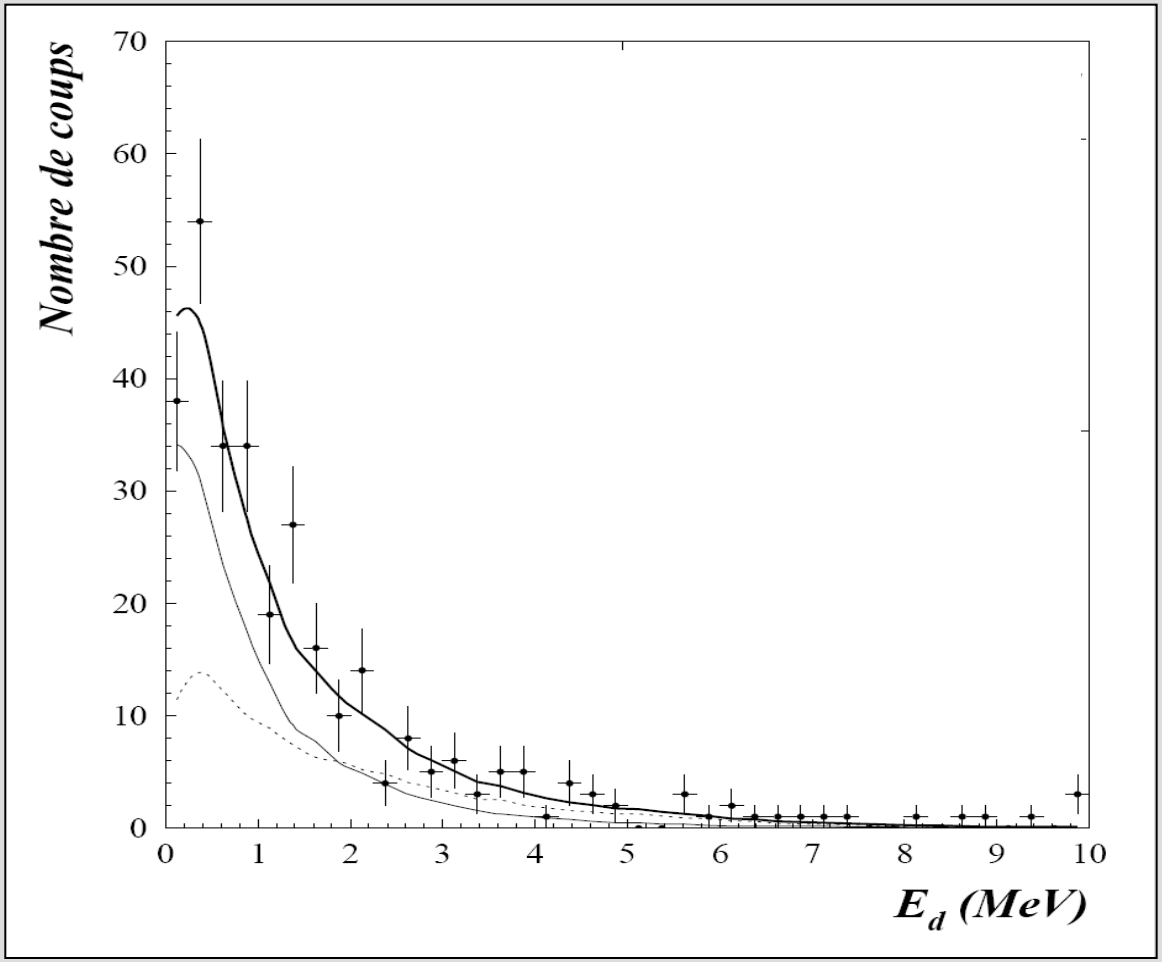


N=7 … ^{9}He ??



N=9 … ^{12}Li ??

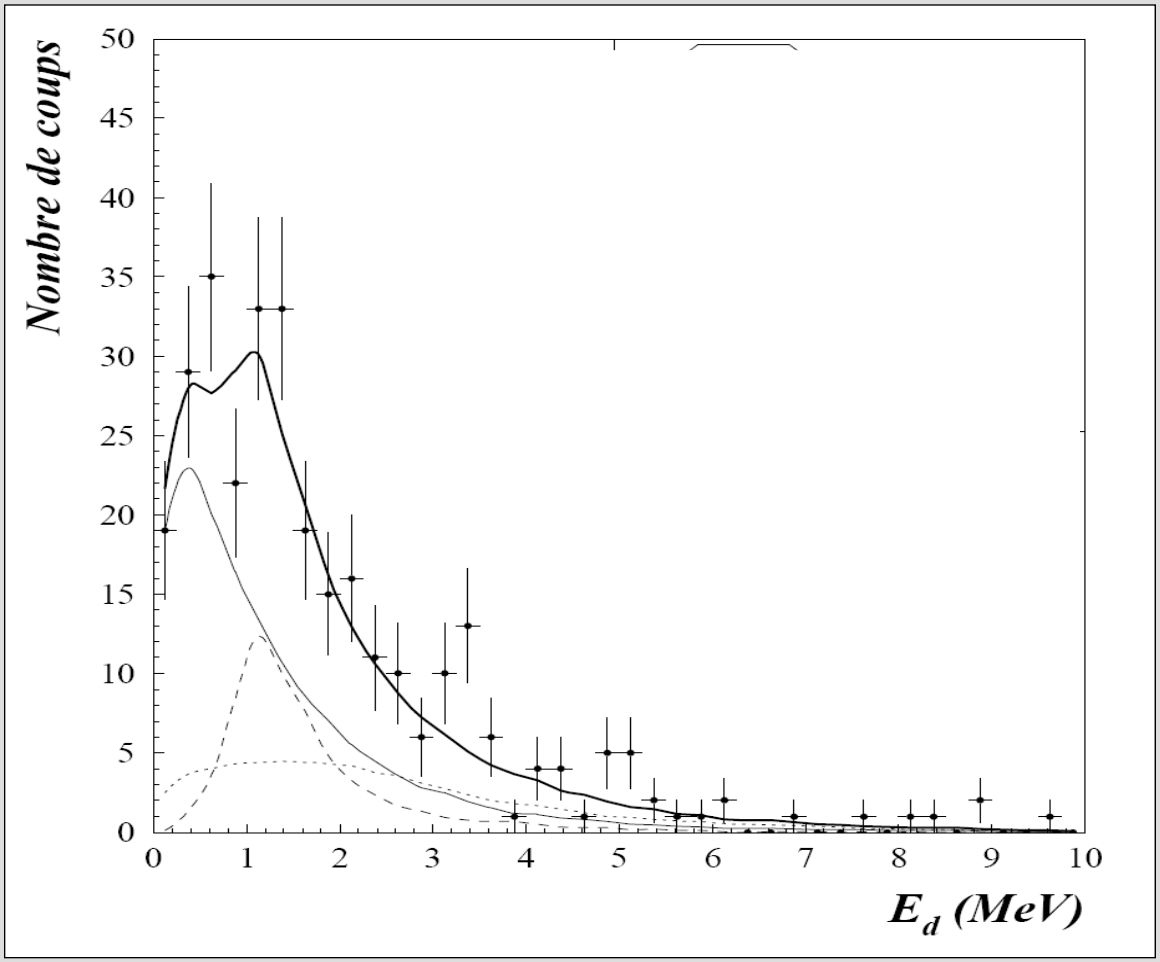
^{9}He: C(^{11}Be,^{8}He+n) … … N=7



s-wave [$a_s \approx -3$ fm]

Also … GSI-LAND : HT Johansson, et al. (2010)
MSU L Chen et al. (2000)

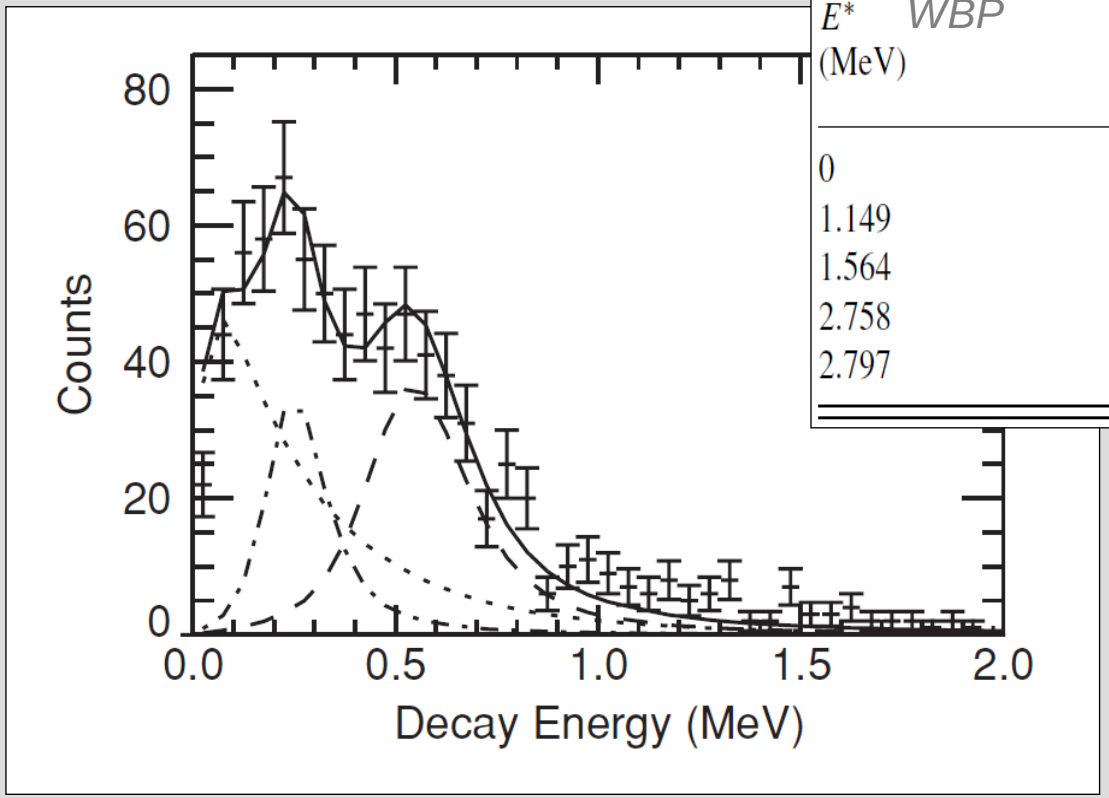
^{9}He: $C(^{14}B,^{8}He+n)$ … E_x* … N=7



s-wave [$a_s \approx -3$ fm] + p-wave [$E_r \approx 1.2$, $\Gamma_0 \approx 1.0$ MeV]

* Improve Statistics + Resolution

^{12}Li: Be(^{14}B,^{11}Li+n) … E_x – IMPROVE * + SEARCH for HIGHER E_x



E^* (MeV)	WBP I^π	SF $s_{1/2}$	SF $d_{5/2}$	
0	2^-	0.60	0.18	
1.149	4^-	–	0.85	?
1.564	1^-	0.83	0.01	
2.758	2^-	0.22	0.58	
2.797	1^-	0.01	0.81	?

$\pi p_{3/2} \otimes \nu s_{1/2} \Rightarrow 1^-, 2^-$

$\pi p_{3/2} \otimes \nu d_{5/2} \Rightarrow 1^- - 4^-$

s-wave [a_s = -14 fm] + d-wave [E_r =0.250, Γ_0 < 0.015 MeV + E_r = 0.55, Γ_0 < 0.08 MeV]

… s-wave fixed by p(^{14}Be,^{11}Li+n): Yu. Aksyutina et al. (GSI-LAND), Phys Lett. B (2008)

* Resolution + Statistics

MONa : CC Hall et al., Phys Rev. C (2010)

^{18}B & ^{21}C : two-neutron halo input structure @ N=13 & 15 …

POSSIBLE DAY ONE EXPERIMENTS

GOAL: *employ complementary reactions (-1n & -1p) to explore different states …*

… extend existing work + untilise power of BigRIPS N/Z>>1

→ ^{19}C + ^{19}B beam: C(^{19}C,^{17}B+n) ; C(^{19}B,^{17}B+n)

→ ^{22}N + ^{22}C beam: C(^{22}N,^{20}C+n) ; C(^{22}C,^{20}C+n)

REQUIREMENTS …

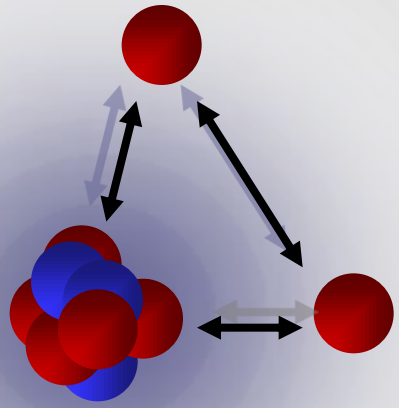
→ Single-neutron detection – core + n systems

→ γ-ray detection – core (E_x) … high ε_γ + moderate FWHM *

→ mixed beam (BigRIPS), -1p & -1n channels (SAMURAI)

* $^{17}B^*$ ($5/2^-$ @ 1.08 MeV) $^{20}C^*$ (2^+ @ 1.60 MeV)

Modelling Two-Neutron Halo Systems …

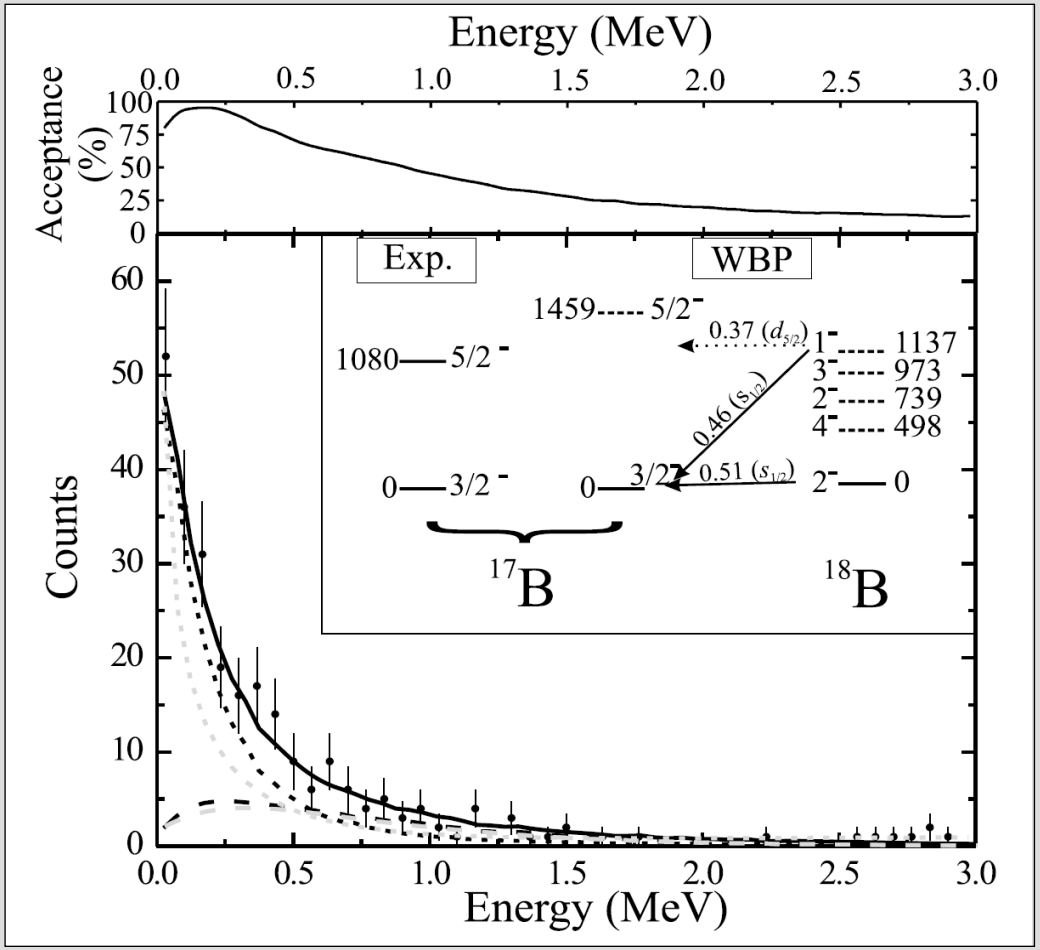


3-body systems ⇒ n-n and core-n interactions

^{19}B : ^{17}B-n interaction ~ ^{18}B ⇒ N=13 … $\nu s_{1/2} - \nu d_{5/2}$??

^{22}C : ^{20}C-n interaction ~ ^{21}C ⇒ N=15 … $\nu s_{1/2} - \nu d_{5/2}$??

^{18}B: Be(^{19}C,^{17}B+n) … s-wave Ground State … E_x ??



$\pi p_{3/2} \otimes \nu s_{1/2} \Rightarrow 1^-, 2^-$

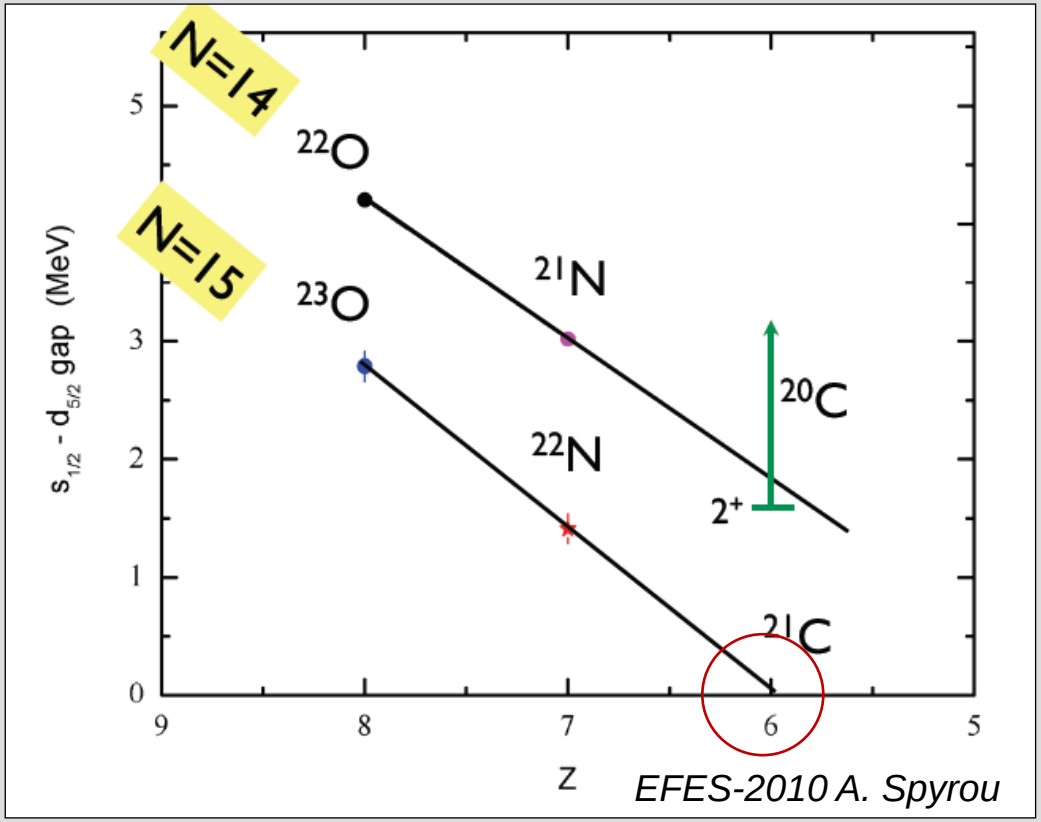
$\pi p_{3/2} \otimes \nu d_{5/2} \Rightarrow 1^- - 4^-$

s-wave [a_s < -50 fm]

* ^{17}B* (1.08 MeV) – NO γ-detection

A. Spyrou et al. PLB (2010)

^{21}C: N=15 $\nu s_{1/2} - \nu d_{5/2}$ … ??



^{22}C : σ_R @ 40 MeV/nucleon $\Rightarrow$ $(\nu s_{1/2})^2$ + … ??

K Tanaka et al., PRL (2010)

… also ^{22}C breakup – σ_{-2n} & $d\sigma/dp$ … *N Kobayashi, T Nakamura et al.*

Conclusions …

EARLY PHASE / COMMISSIONING EXPERIMENTS …

$^{14}B \rightarrow {}^{7}He, {}^{10}Li$ ("reference") $^{9}He, {}^{12}Li$ (N=7, 9 physics)

~1 day run … ^{18}O primary beam - moderate I_B, 150-250 MeV/nucleon OK

DAY ONE EXPERIMENTS – two-neutron halo input & structure @ N=13,15 …

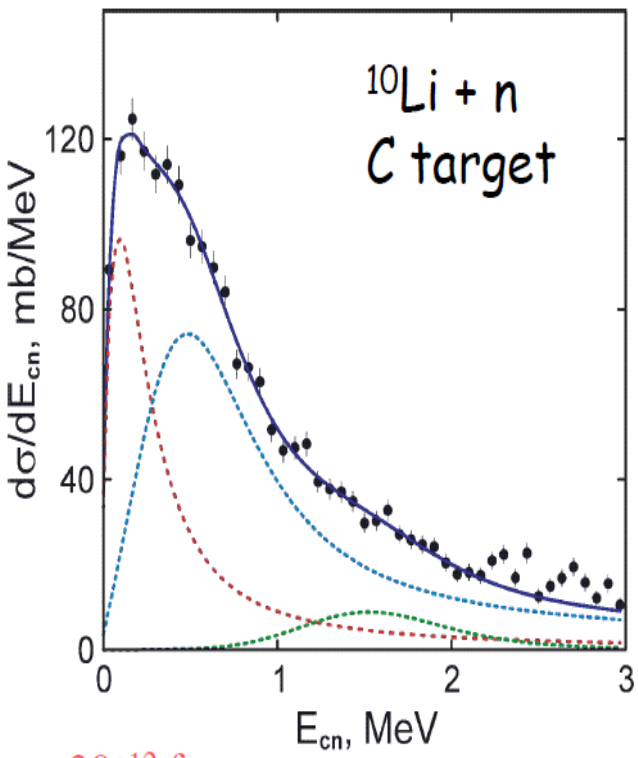
→ $^{19}C + {}^{19}B$ beam: $C(^{19}C,{}^{17}B+n)$; $C(^{19}B,{}^{17}B+n)$

→ $^{22}N + {}^{22}C$ beam: $C(^{22}N,{}^{20}C+n)$; $C(^{22}C,{}^{20}C+n)$

~3-5 day runs … ^{48}Ca primary beam – high I_B , γ-detection

NB: possibility to couple with EMD dB(E1)/dE measurements

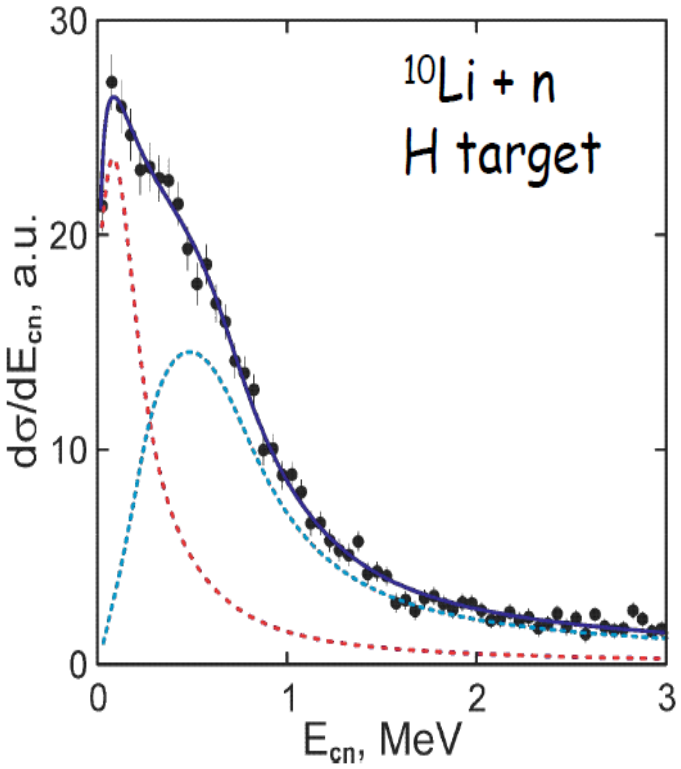
^{10}Li : p,C(^{11}Li,^{9}Li+n) …



$a = -30^{+12}_{-31}$ fm

$E_r = 0.510(44)$ MeV, $\Gamma = 0.54(16)$ MeV

$E_r = 1.486(88)$ MeV, $\Gamma < 2.2$ MeV

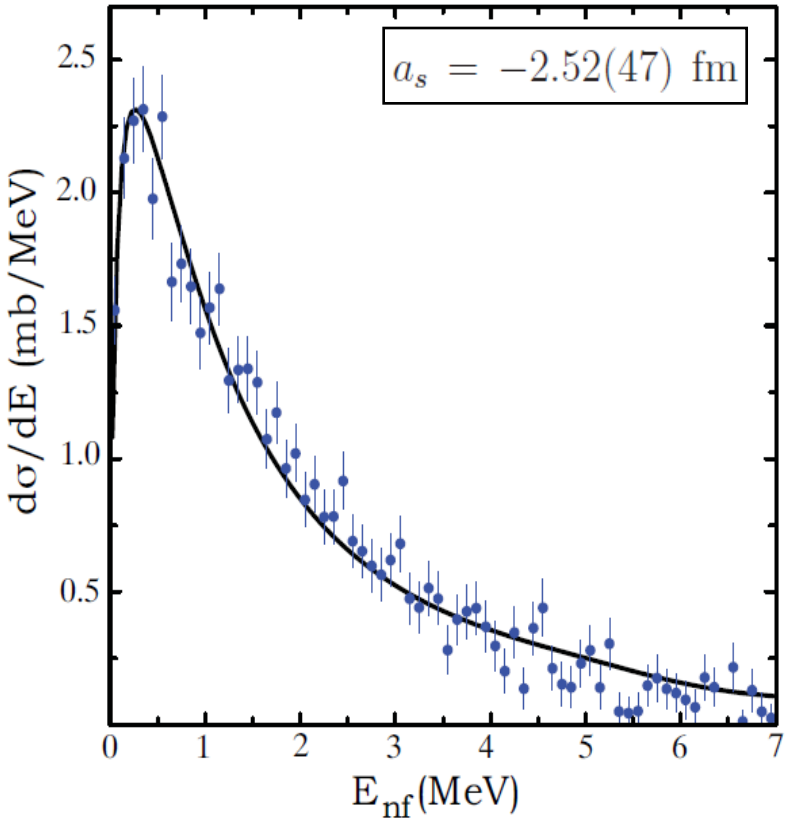


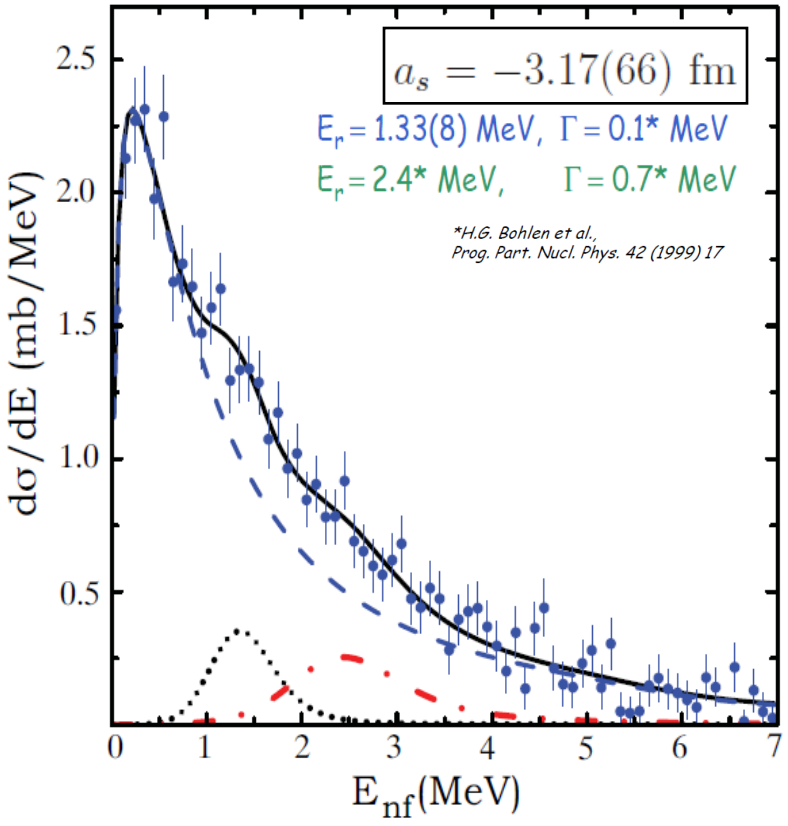
$a = -22(5)$ fm

$E_r = 0.566(14)$ MeV, $\Gamma = 0.548(30)$ MeV

H Simon et al. NUPA (2007) ; Yu. Aksyutina PLB (2008)

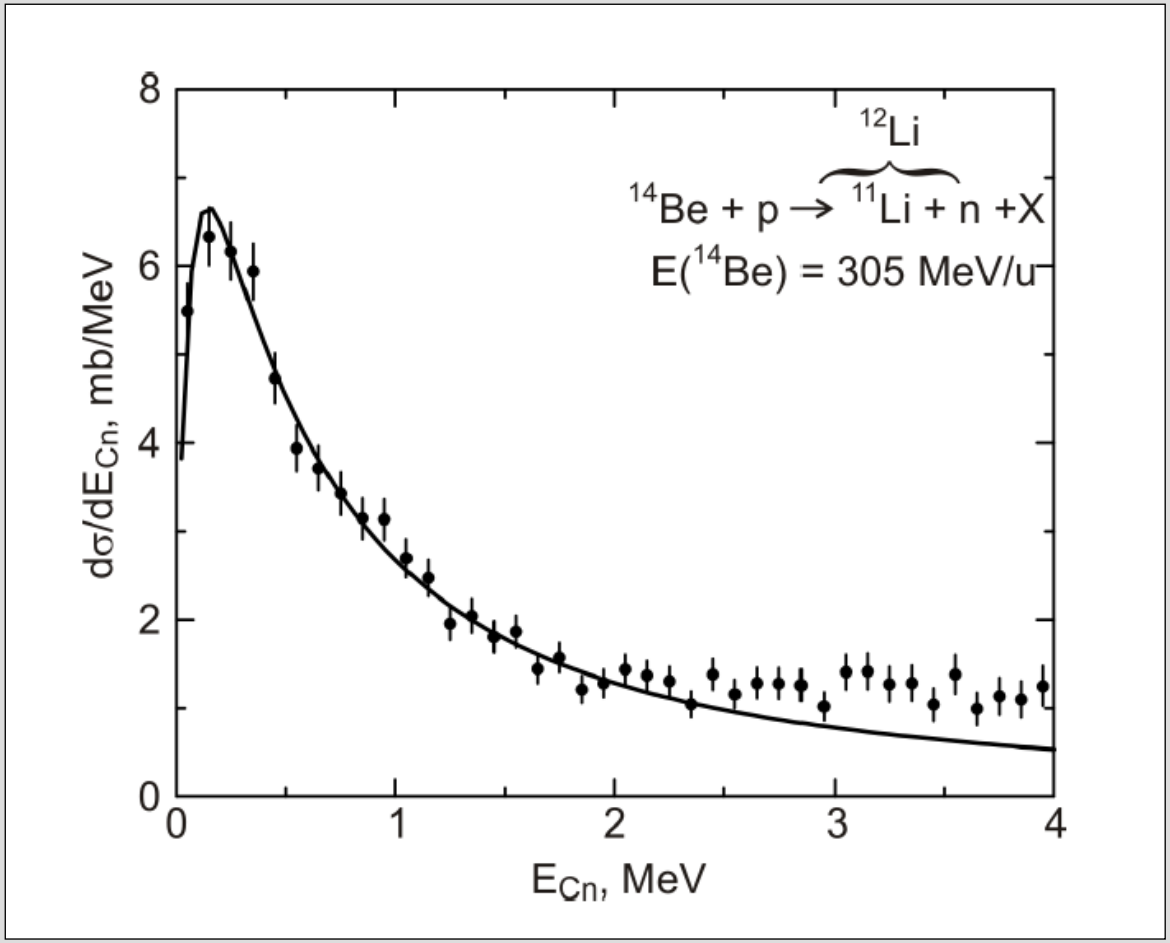
^{9}He: p(^{11}Li,^{8}He+n) … … N=7





GSI-LAND : HT Johansson, Yu. Aksyutina et al. (2010)

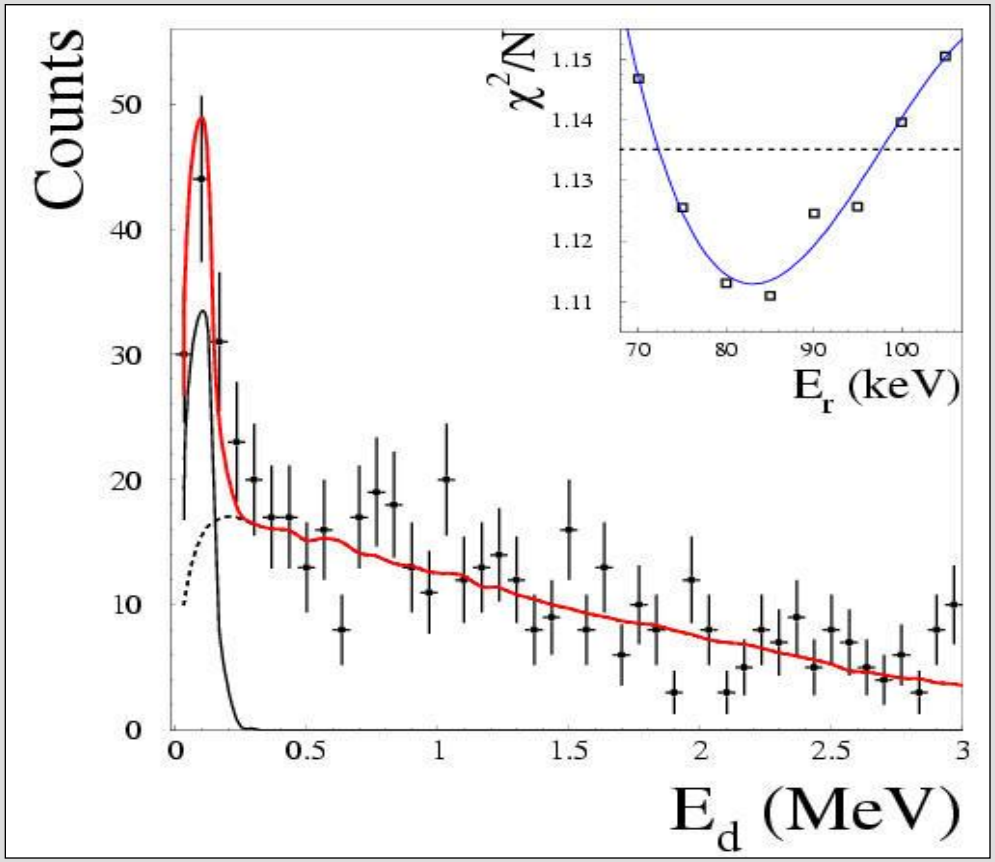
^{12}Li: p(^{14}Be,^{11}Li+n) … s-wave Ground State … N=9



s-wave [a_s = -14 fm]

GSI-LAND : Yu. Aksyutina et al., Phys Lett. B (2008)

^{16}B: C(^{17}C,^{15}B+n)X … REFERENCE RESONANCE



$E_r = 85 \pm 15$ keV

$\Gamma_{sp} << 100$ keV

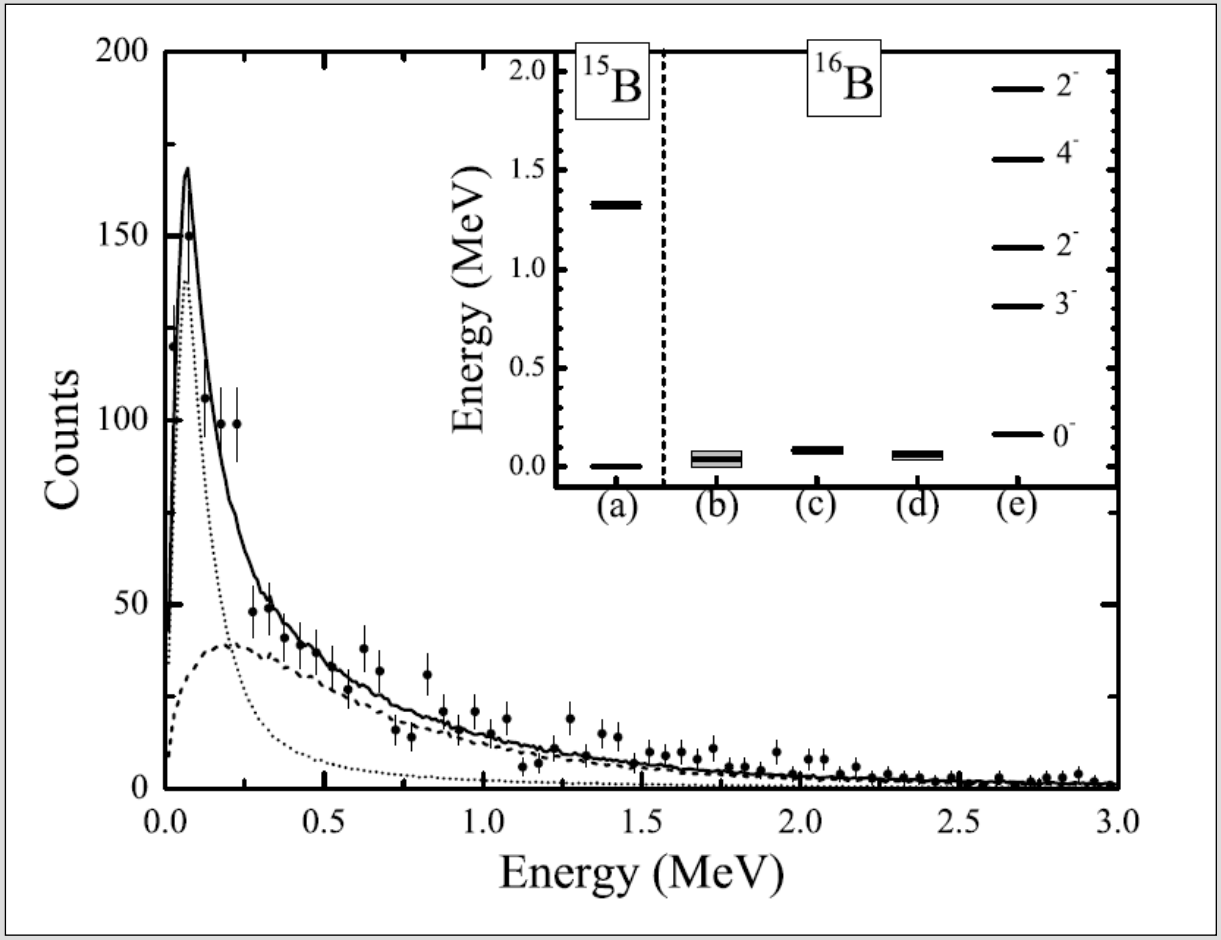
+

uncorrelated

^{15}B+n distribution

JL Lecouey et al, PLB (2009)

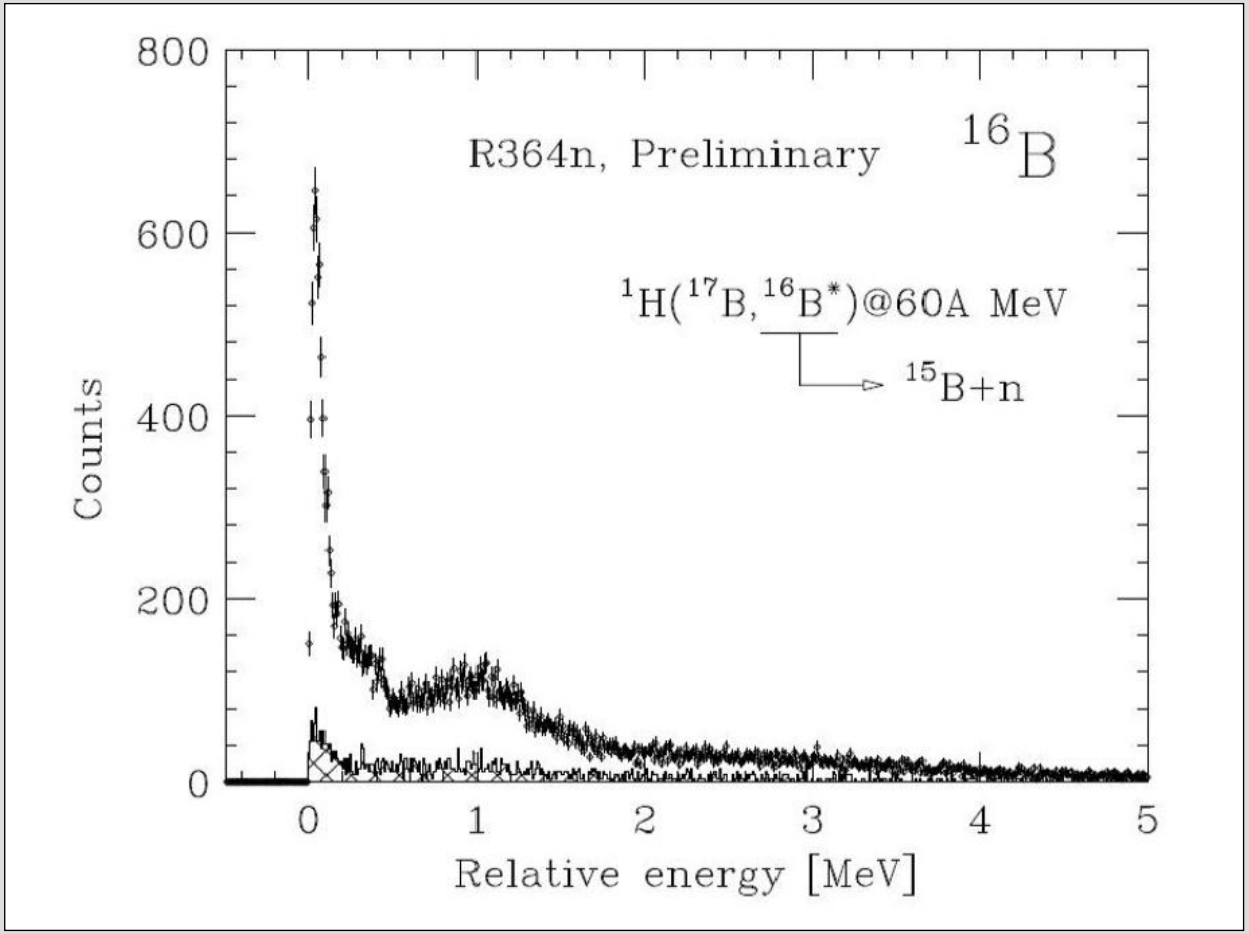
^{16}B: Be(^{17}C,^{15}B+n)X … REFERENCE RESONANCE



d-wave [E_r =0.060, Γ_0 << 0.1 MeV]

A. Spyrou et al. PLB (2010)

^{16}B: p(^{17}B,^{15}B+n)X … REFERENCE RESONANCE



Y. Sato et al, unpublished