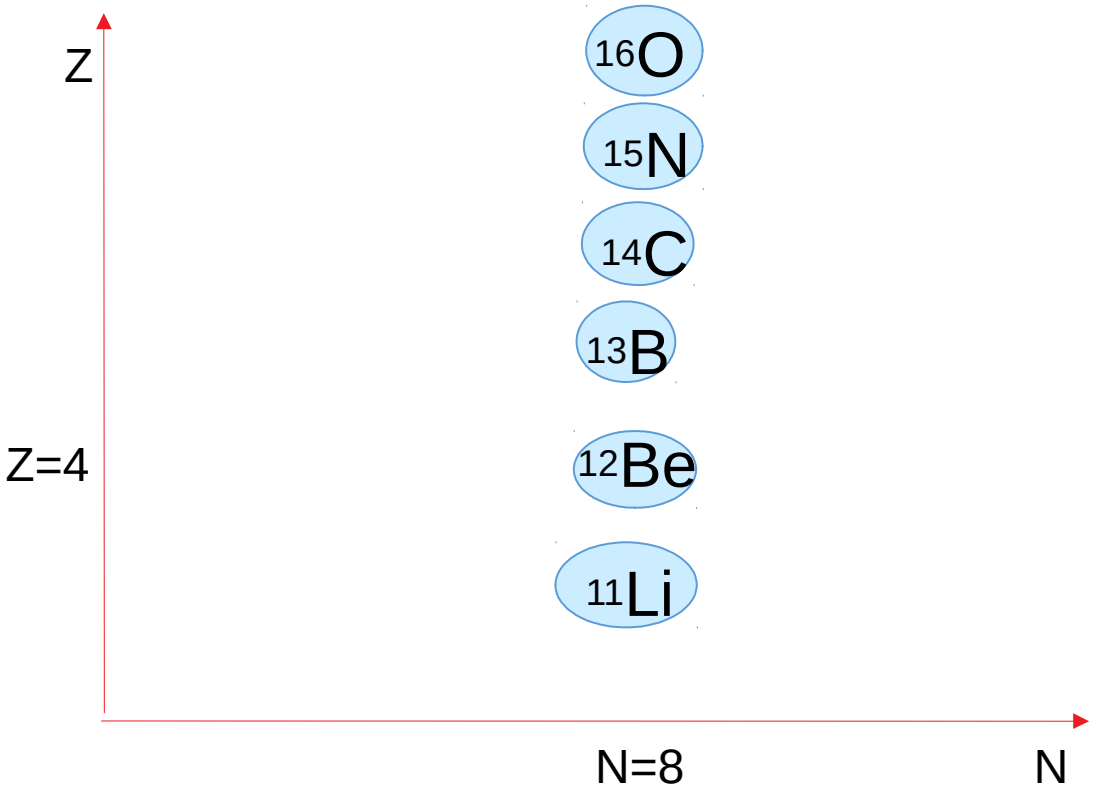
Spherical, cluster and halo states in ^{12}Be

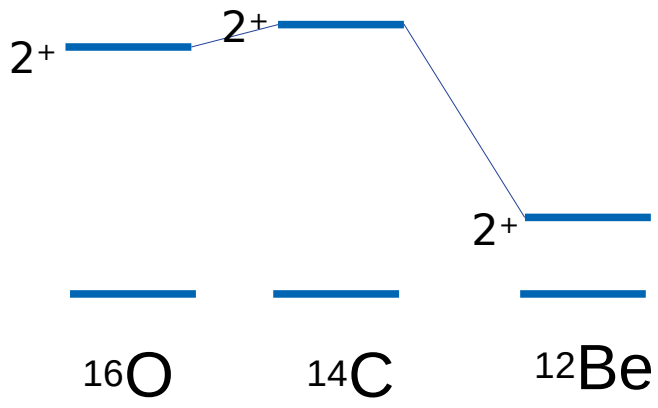
Armel KAMENYERO

Under the supervision of Olivier Sorlin and Miguel Marqués

GANIL community meeting, Strasbourg, 10-May-2019

Motivations





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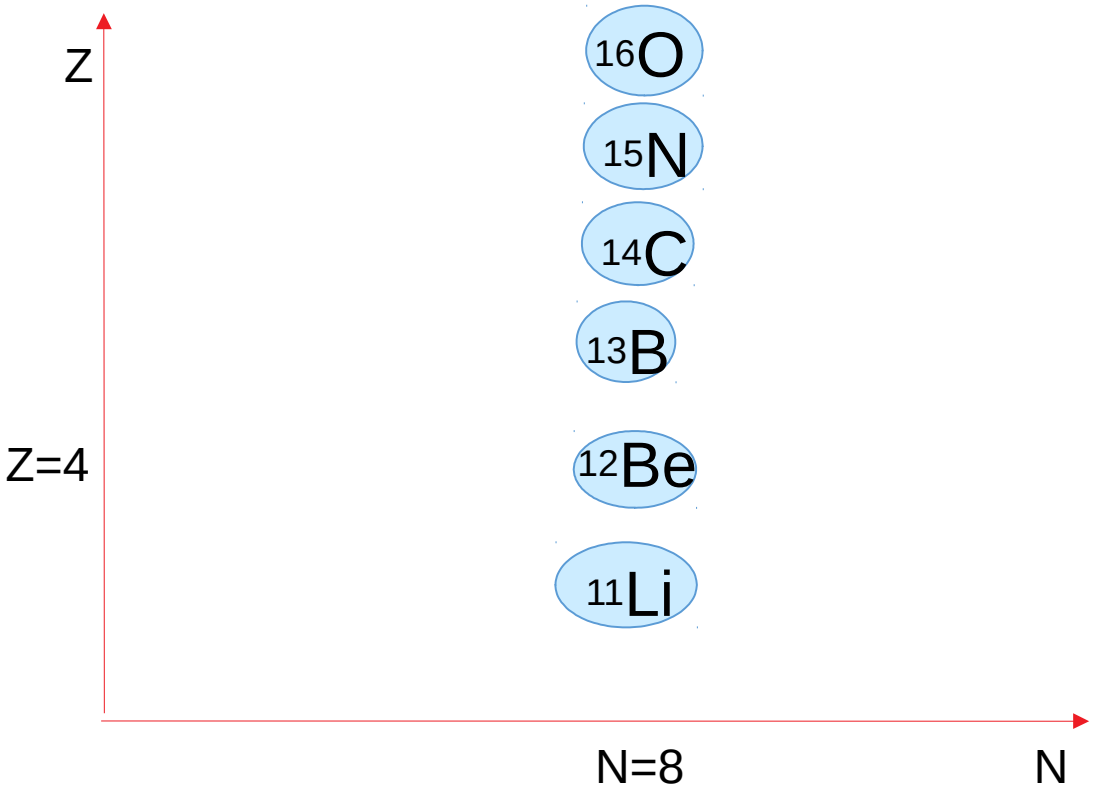

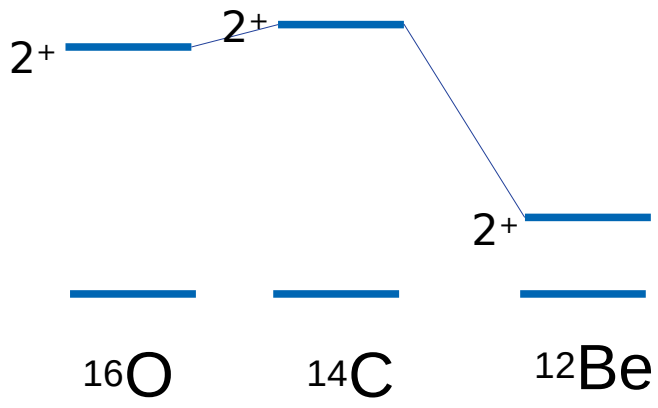

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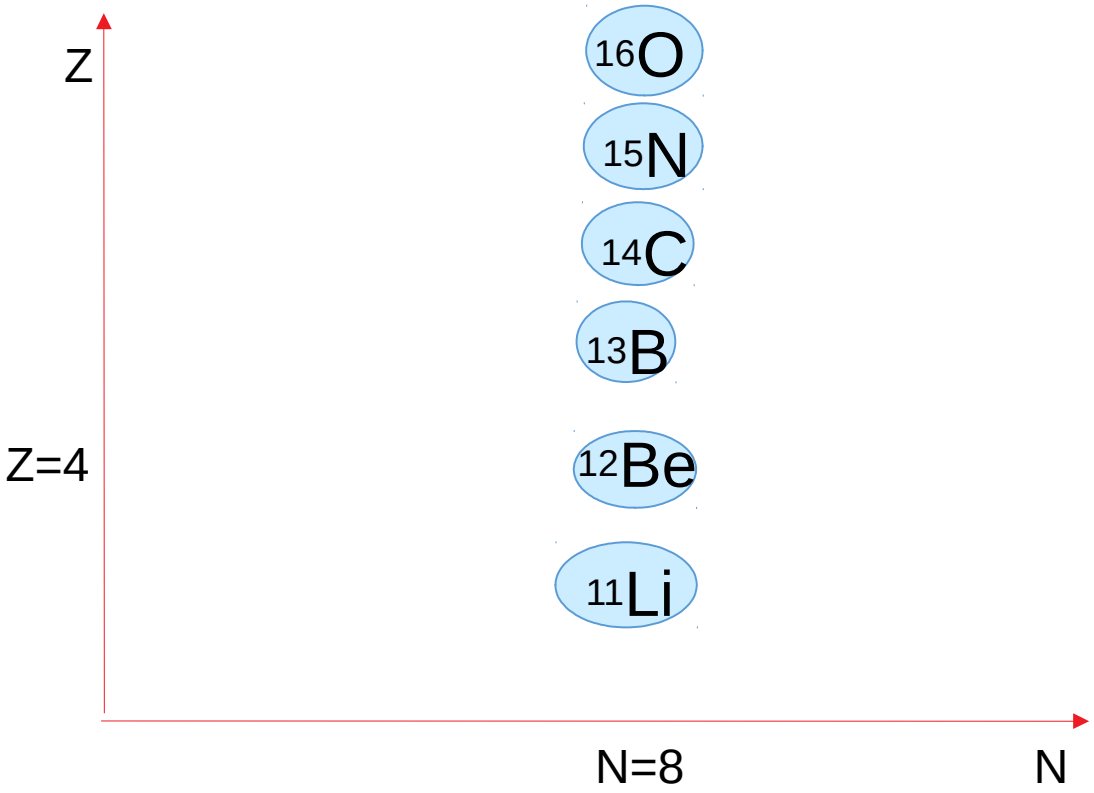
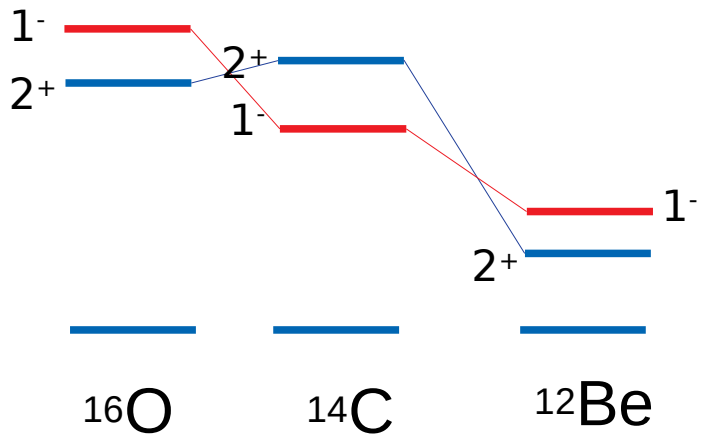


H.Iwasaki et al., EPJ A (2002)



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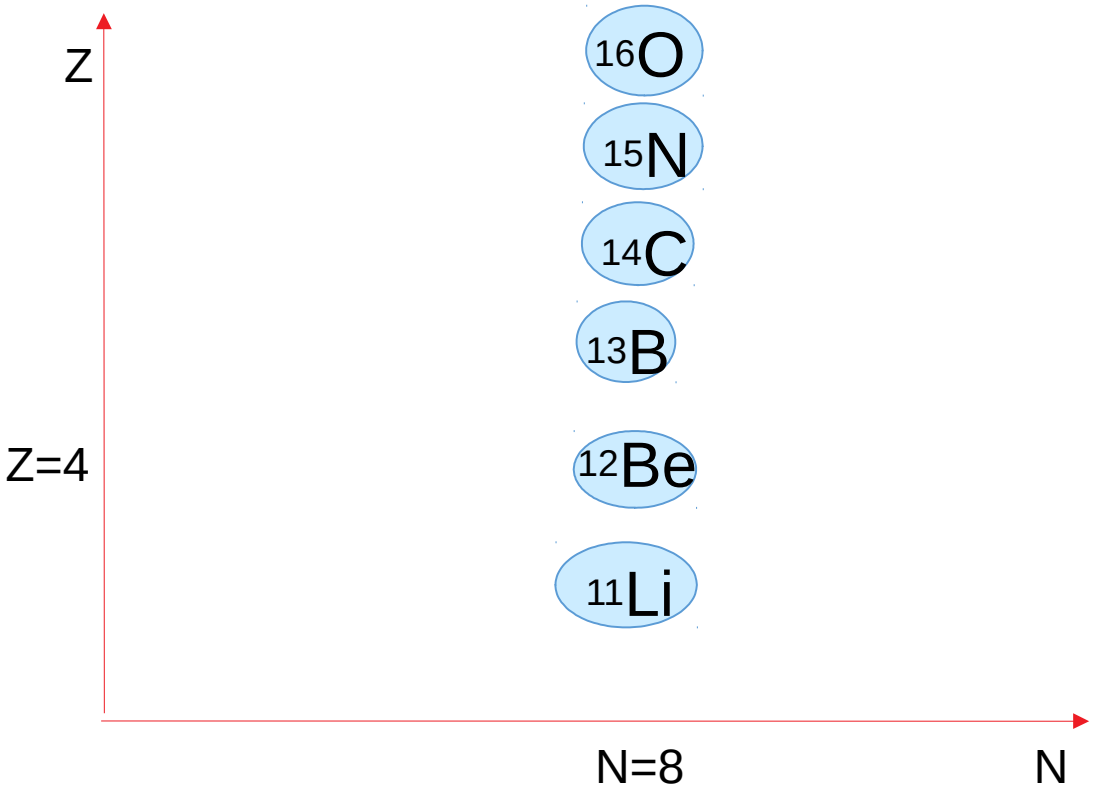

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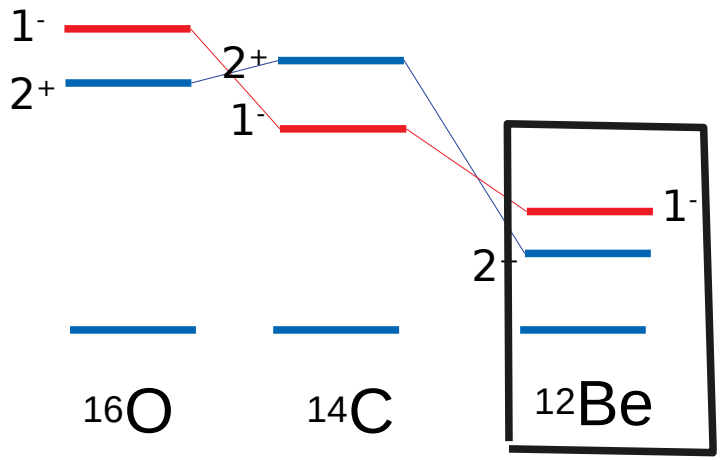
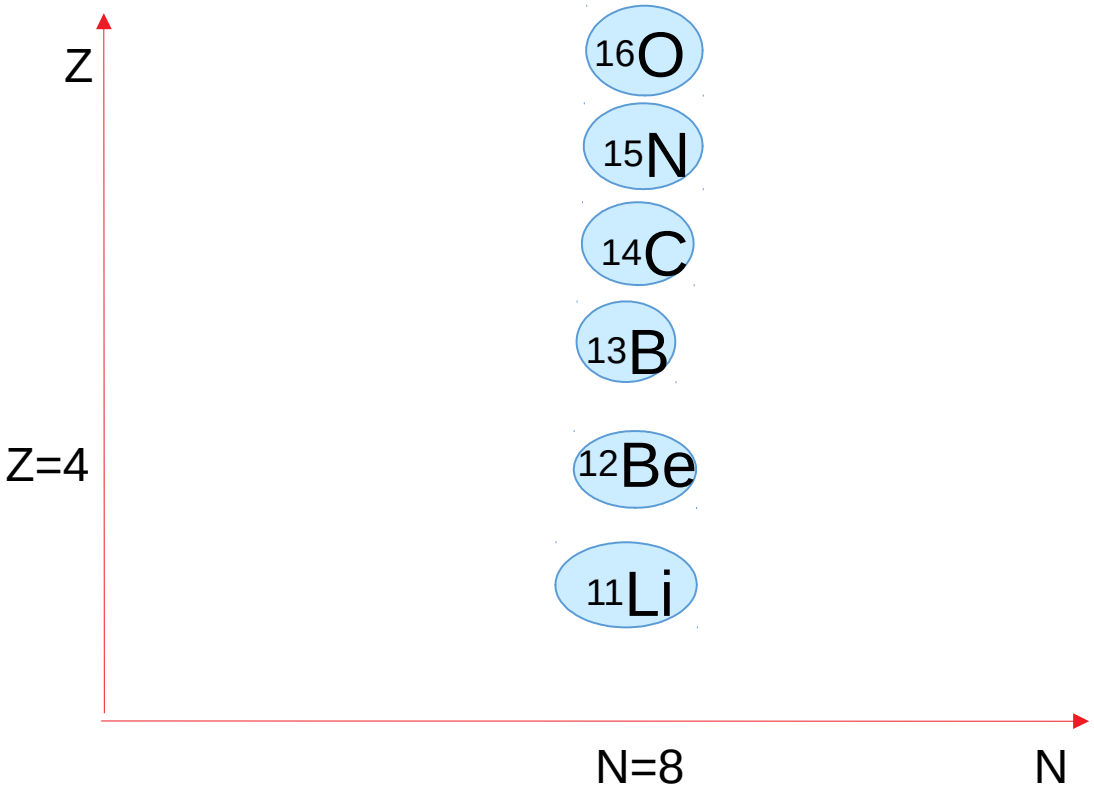


N=8 vanishes

Motivations



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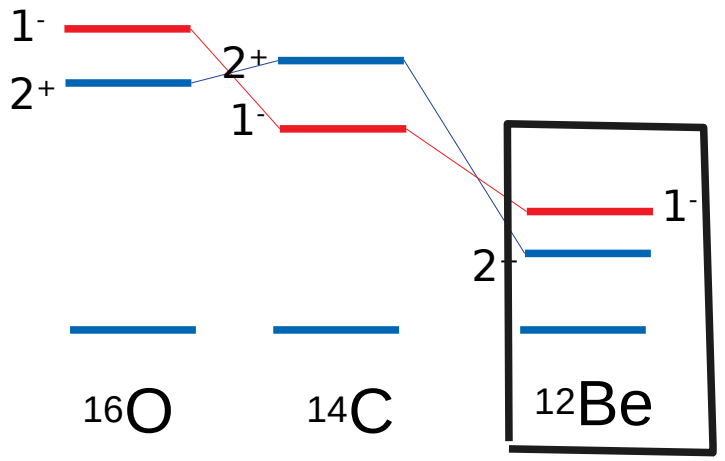

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p-sd Shell mixing

A.Navin et al., PRL (July 2000)

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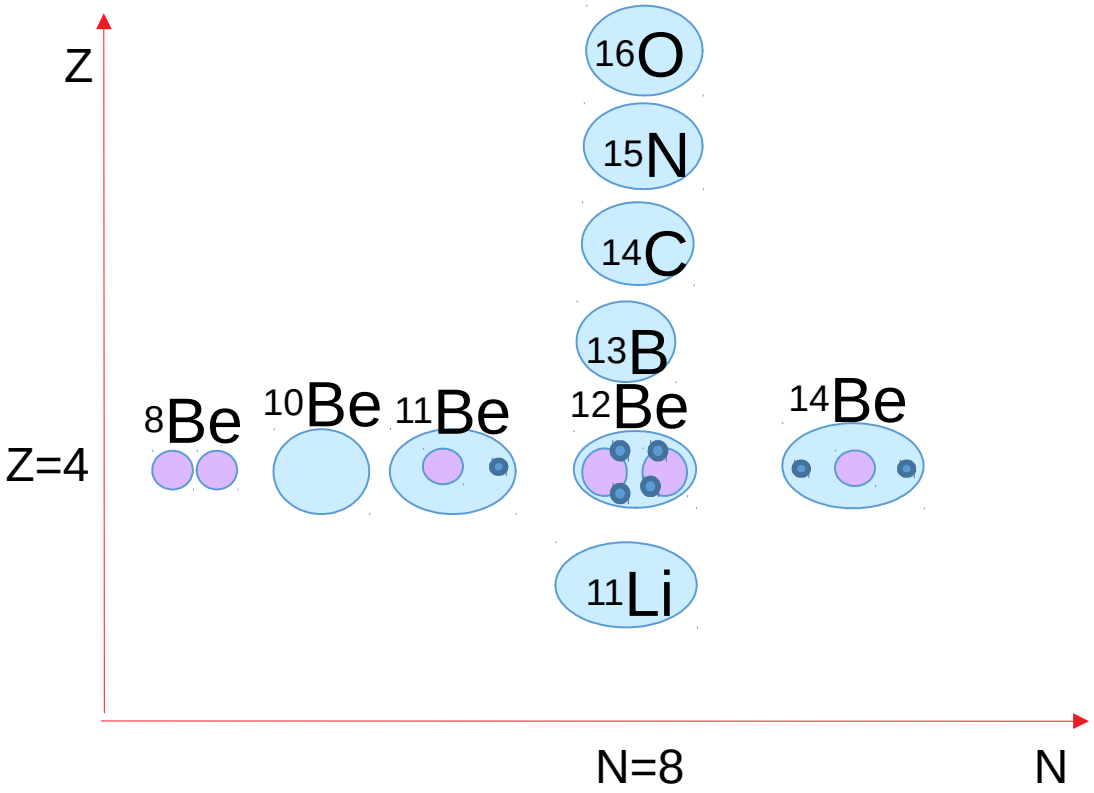

M. Freer et al., PRL (February 1999)

Y. Kanada En'yo et al., PRC (2003)

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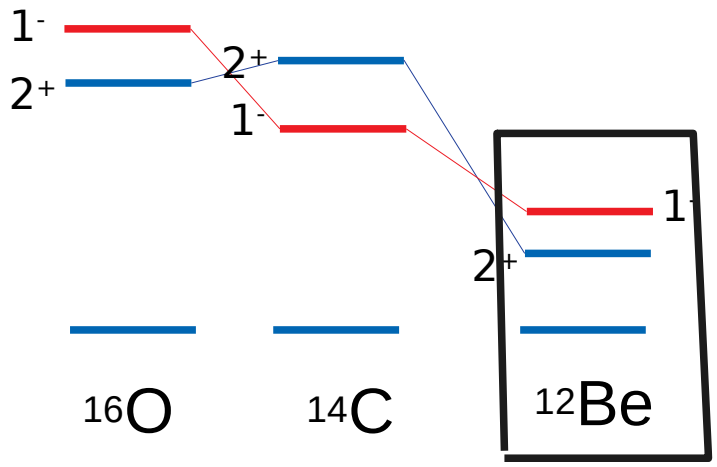

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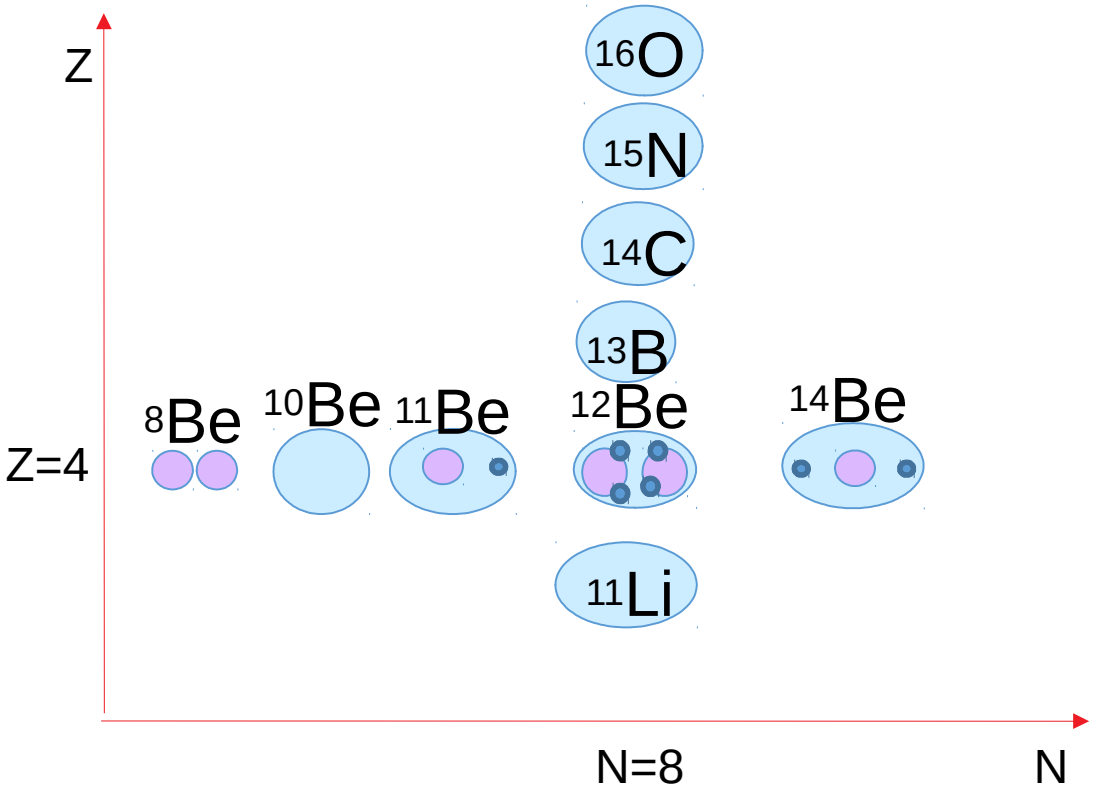

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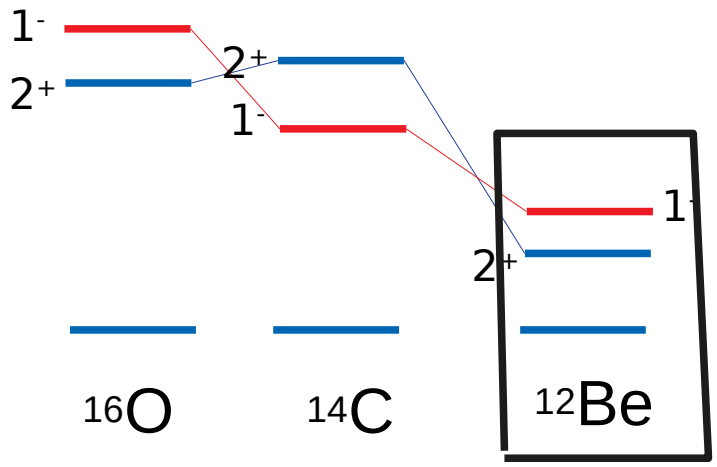

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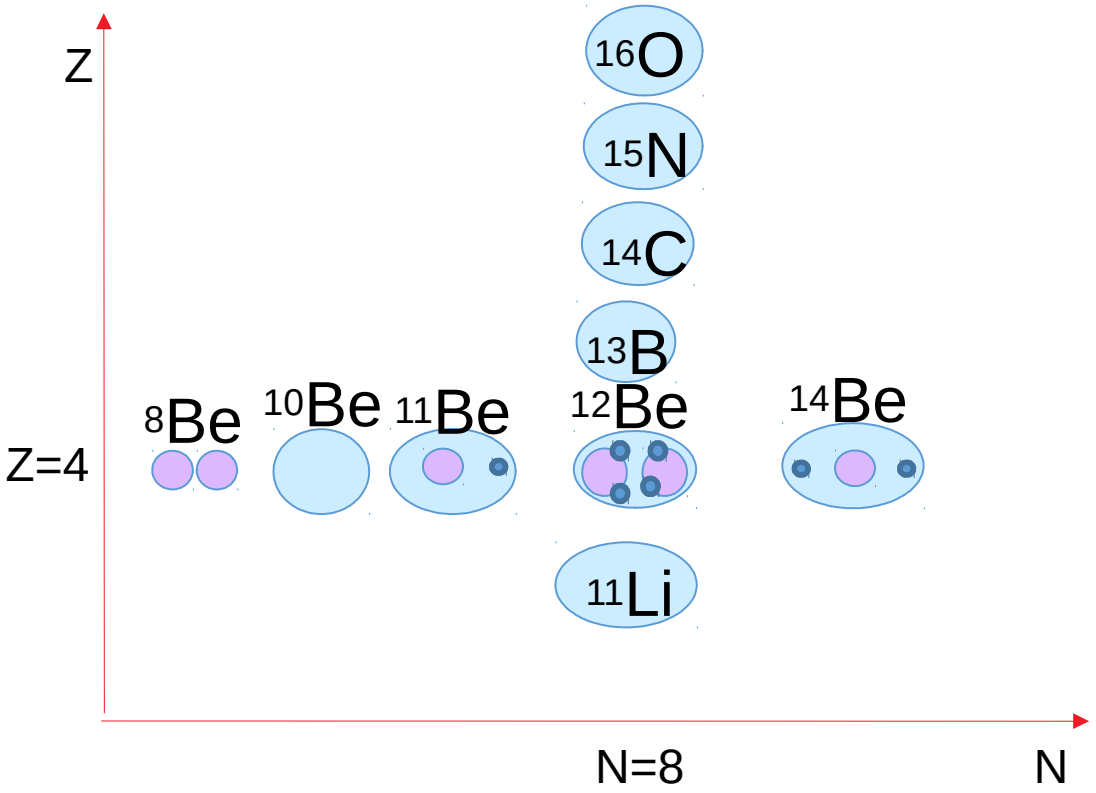
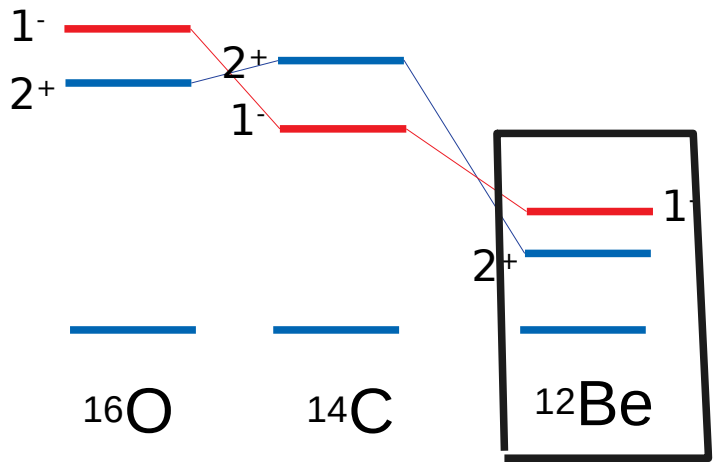
- ^{12}Be is at the crossroad of different configurations : possibility of finding these configurations at different energy levels in ^{12}Be

Previous study of ^{12}Be





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Cluster Structures of the Ground and Excited States of ^{12}Be Studied with Antisymmetrized Molecular Dynamics

Y. Kanada-En'yo
Institute of Particle and Nuclear Studies,
High Energy Accelerator Research Organization,
Ibaraki 305-0801, Japan

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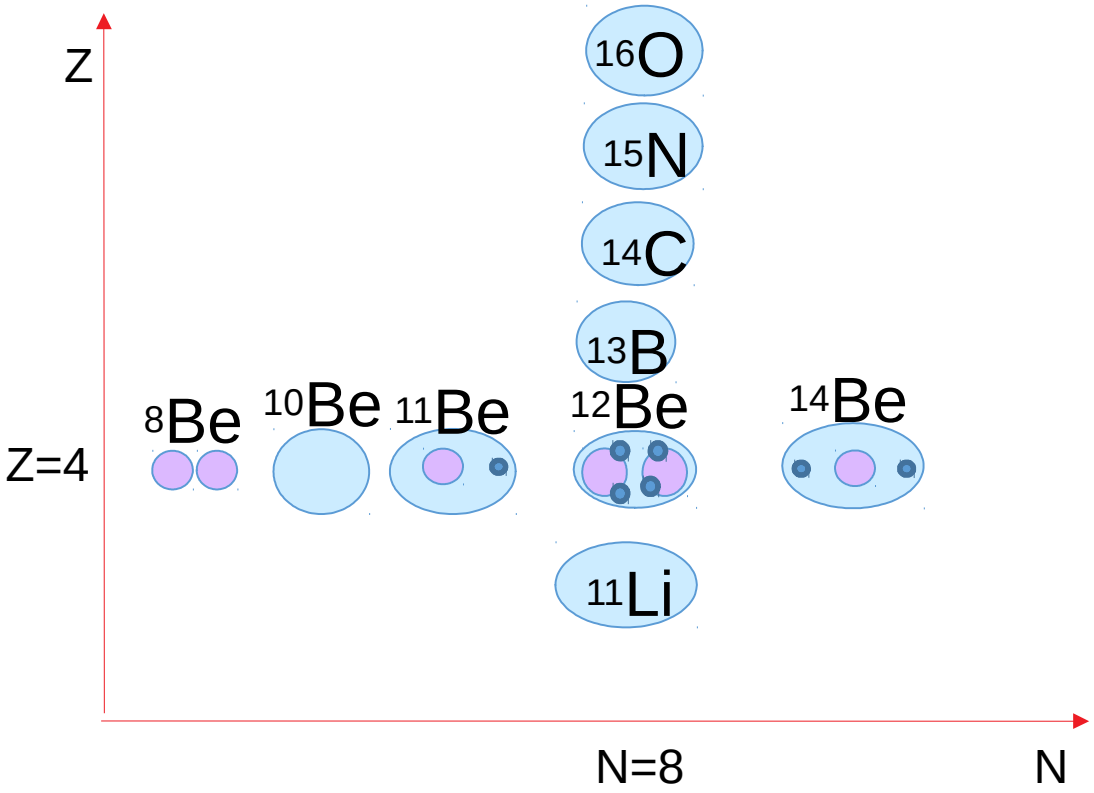

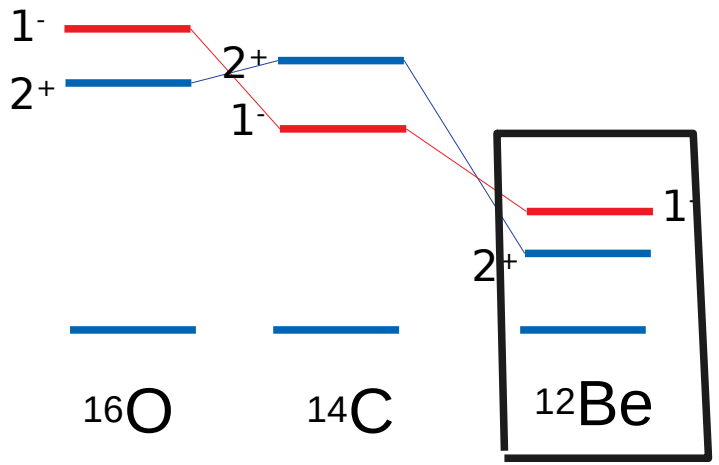

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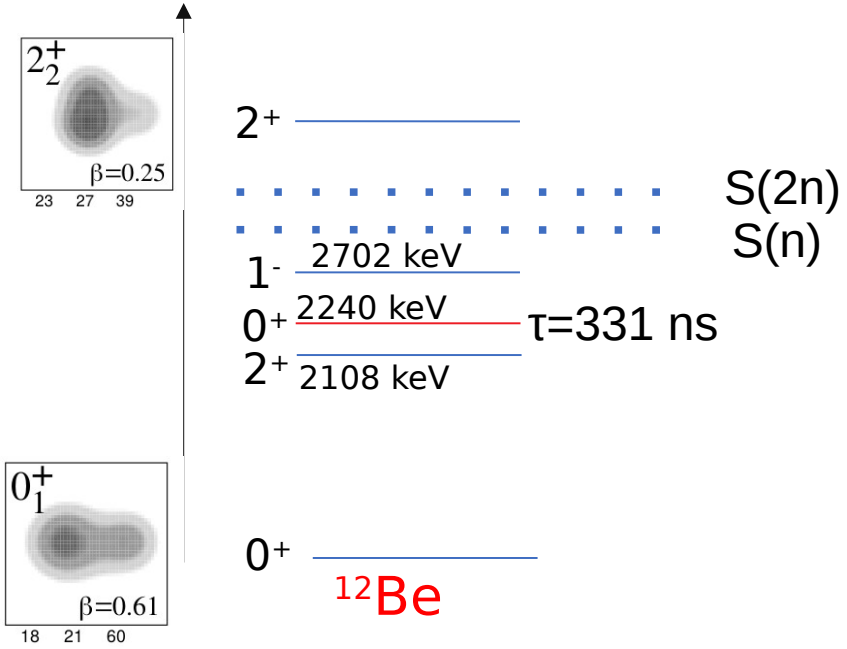
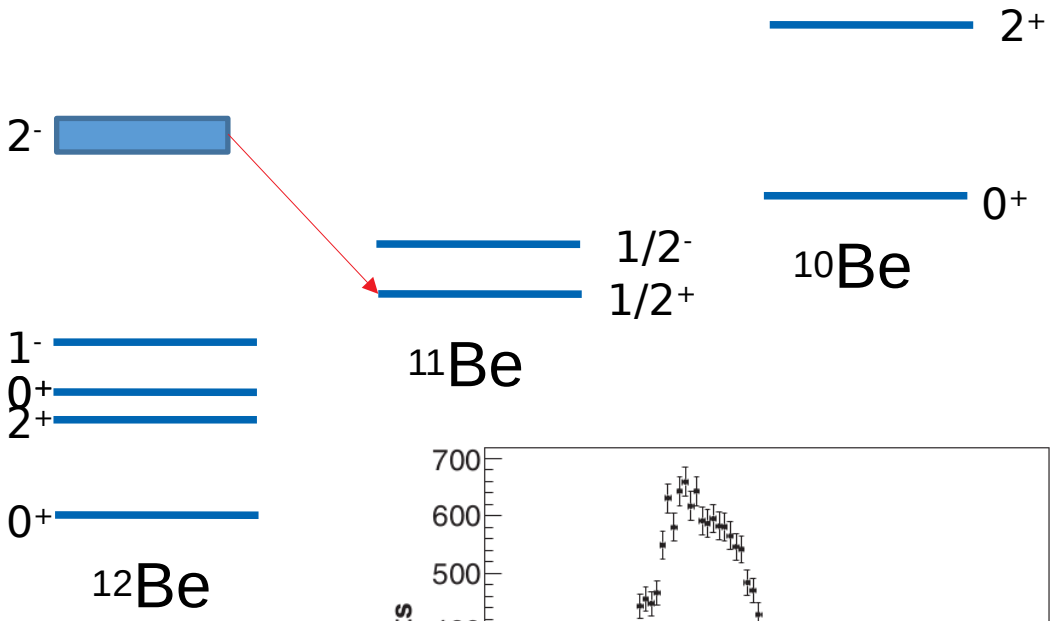
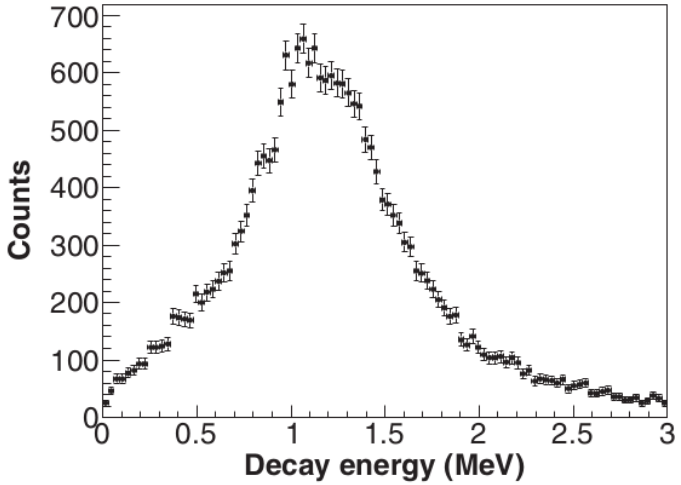


Study of excited states of ^{12}Be through ^{13}B(-p)

Previous study :
J.Smith et al., Phys Rev, *Low-lying unbound states in ^{12}Be*
Perfomed at MSU NSCL



E=1243 keV
Γ= 640 keV



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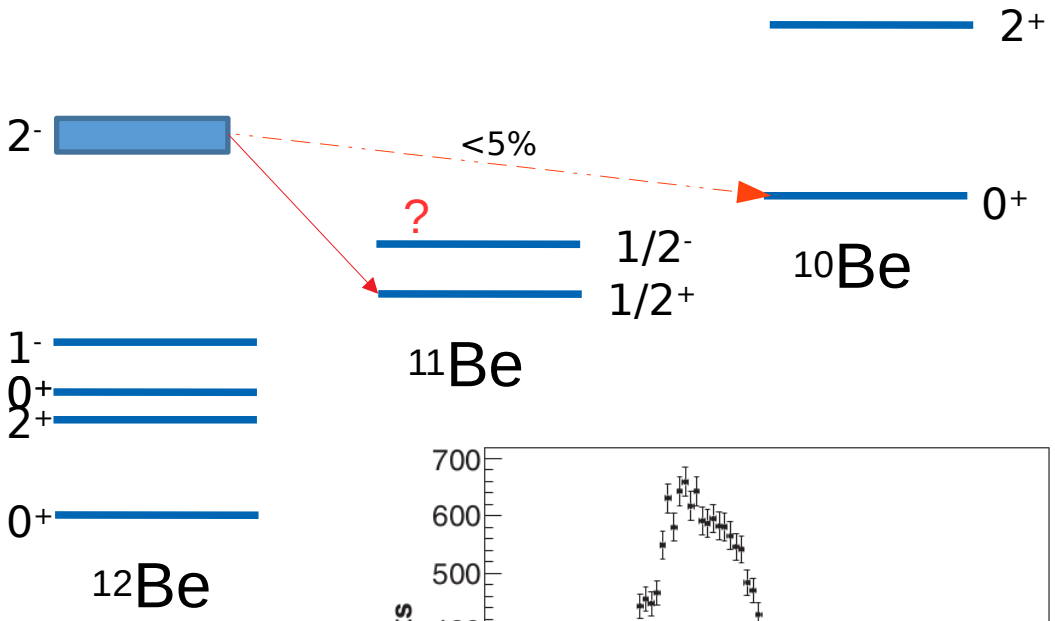

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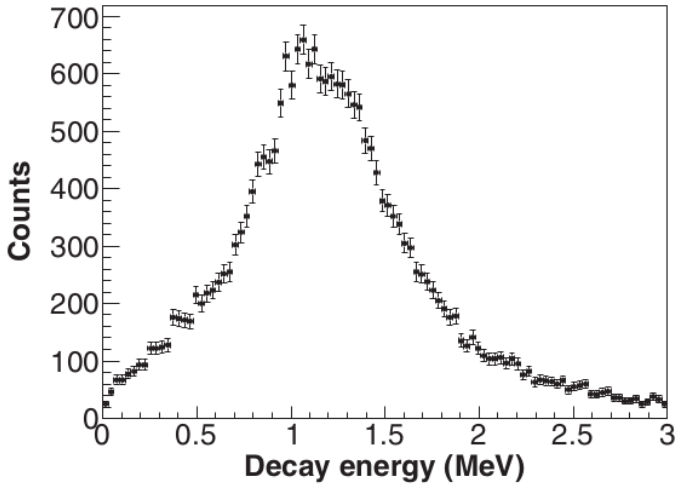

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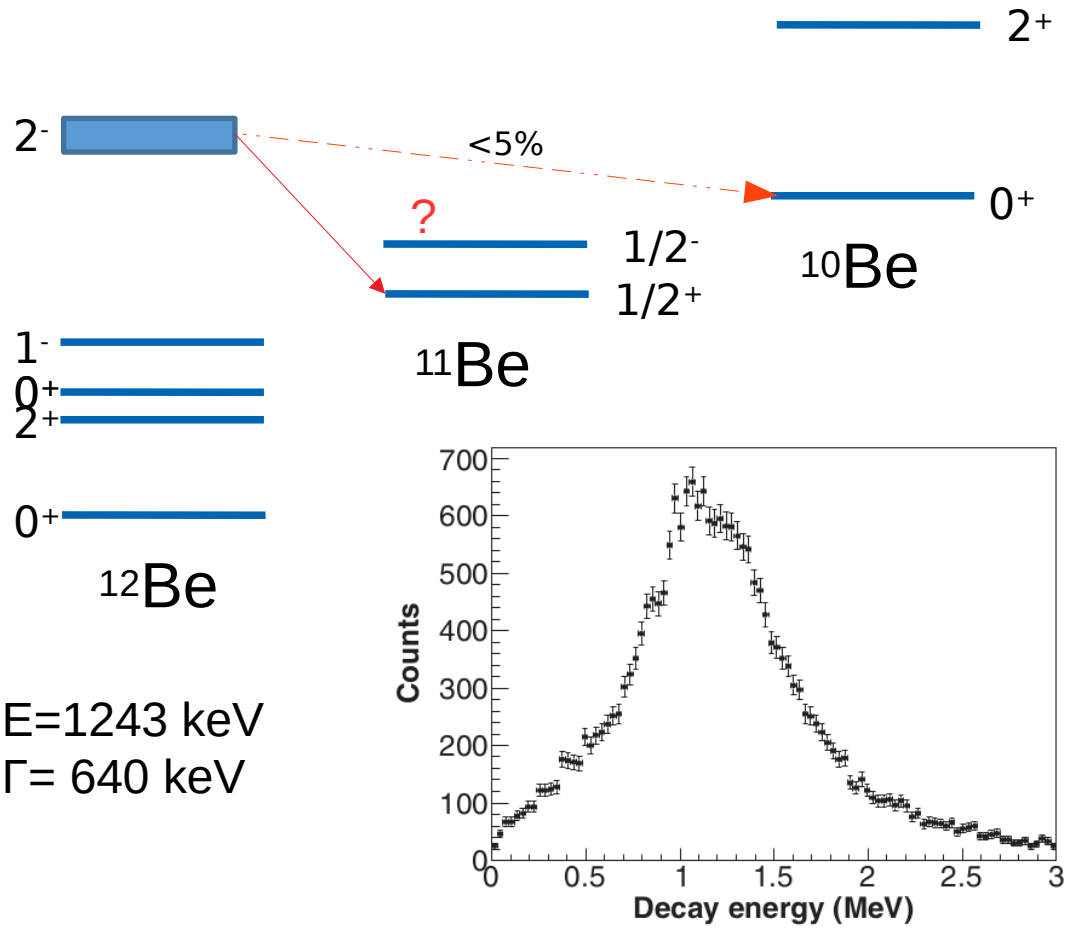

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Nature of the $E_n = 1.24$ MeV state in ^{12}Be

H.T. Fortune[a]

Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania, 19104, USA

Study of excited states of ^{12}Be through ^{13}B(-p)

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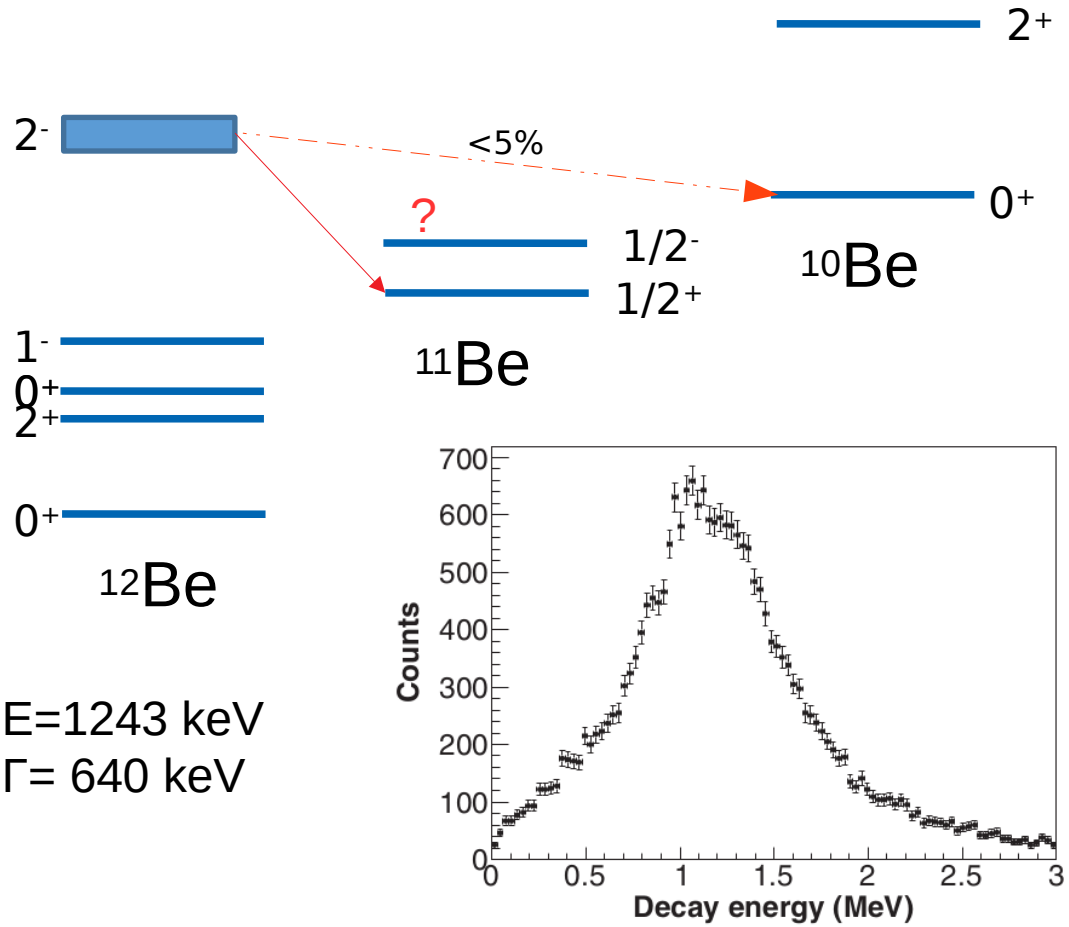

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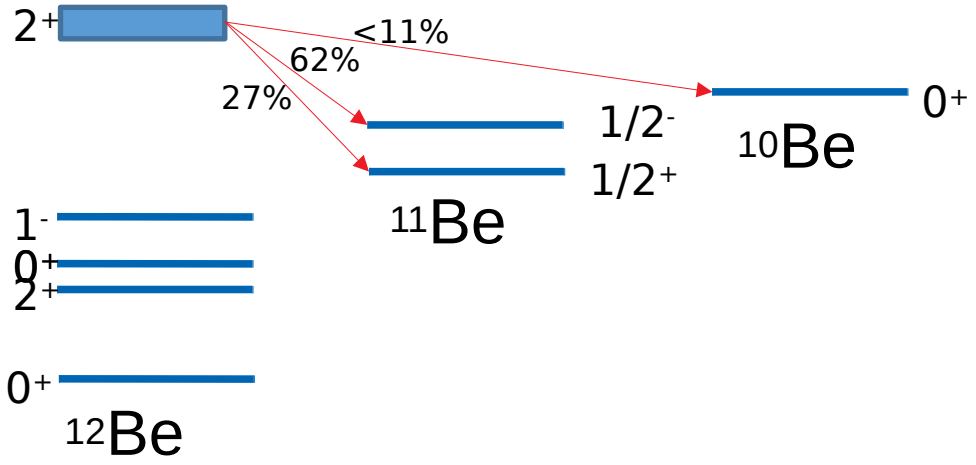

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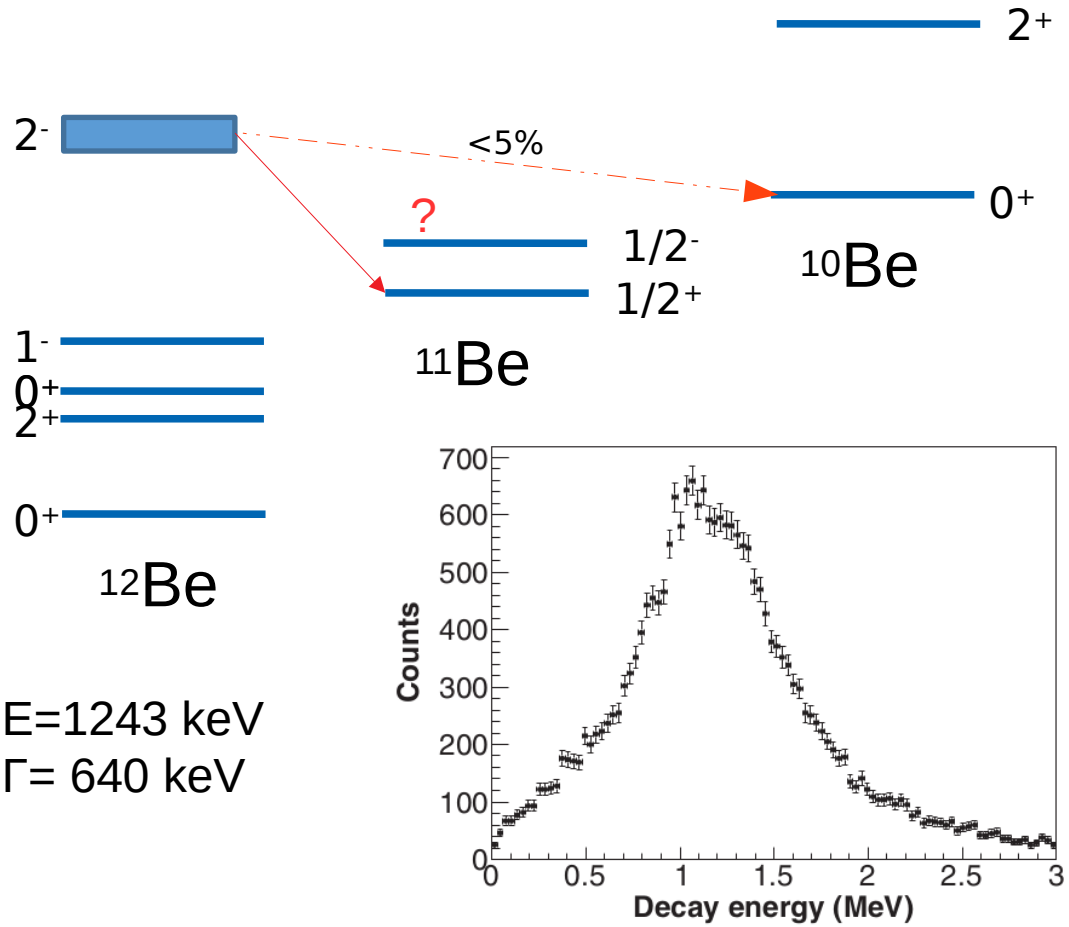

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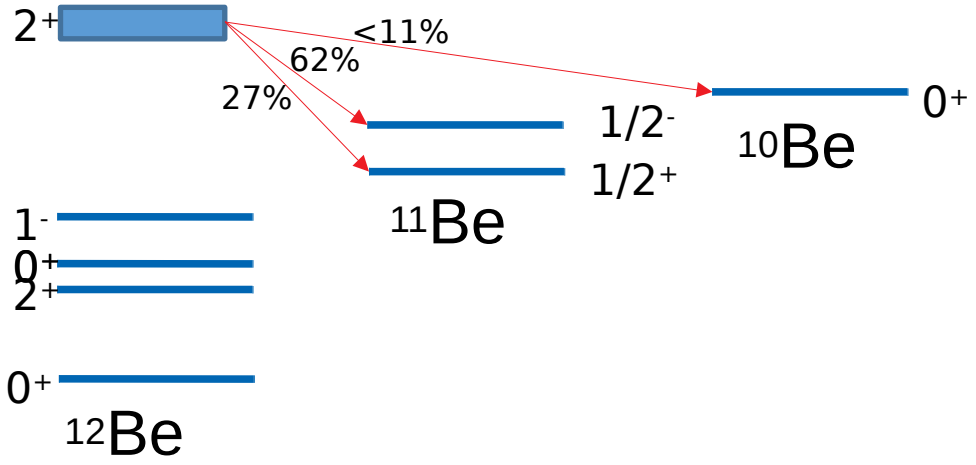
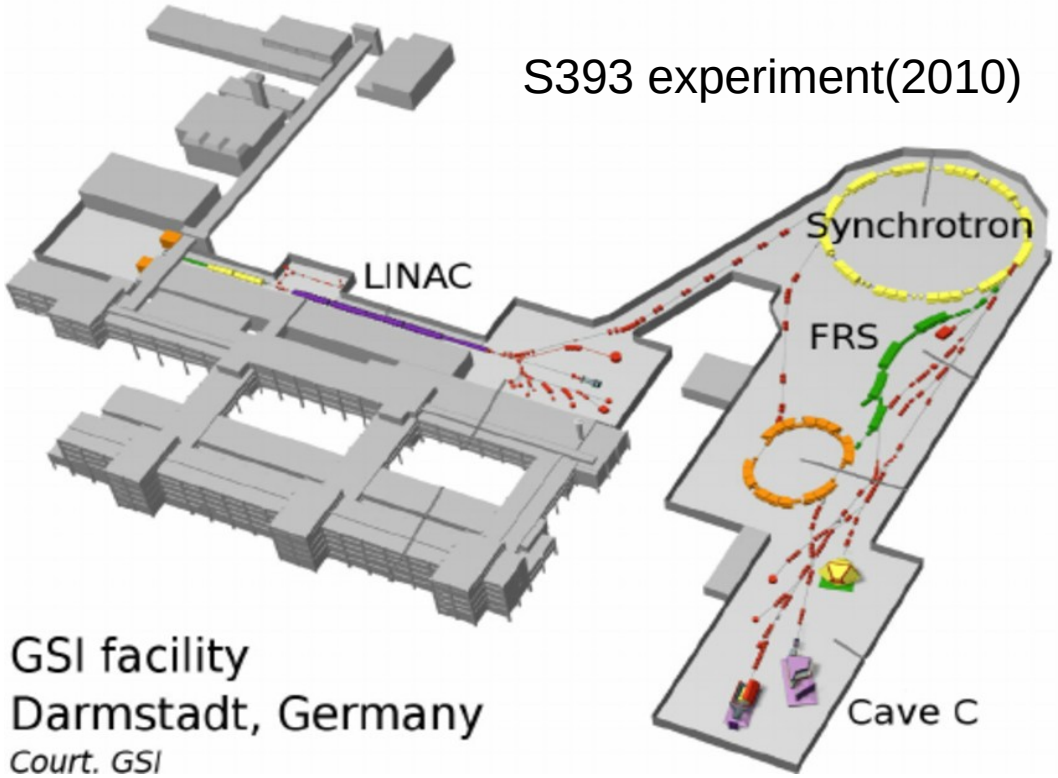


Disagreement between Smith and Fortune
(state parity and decay mode)

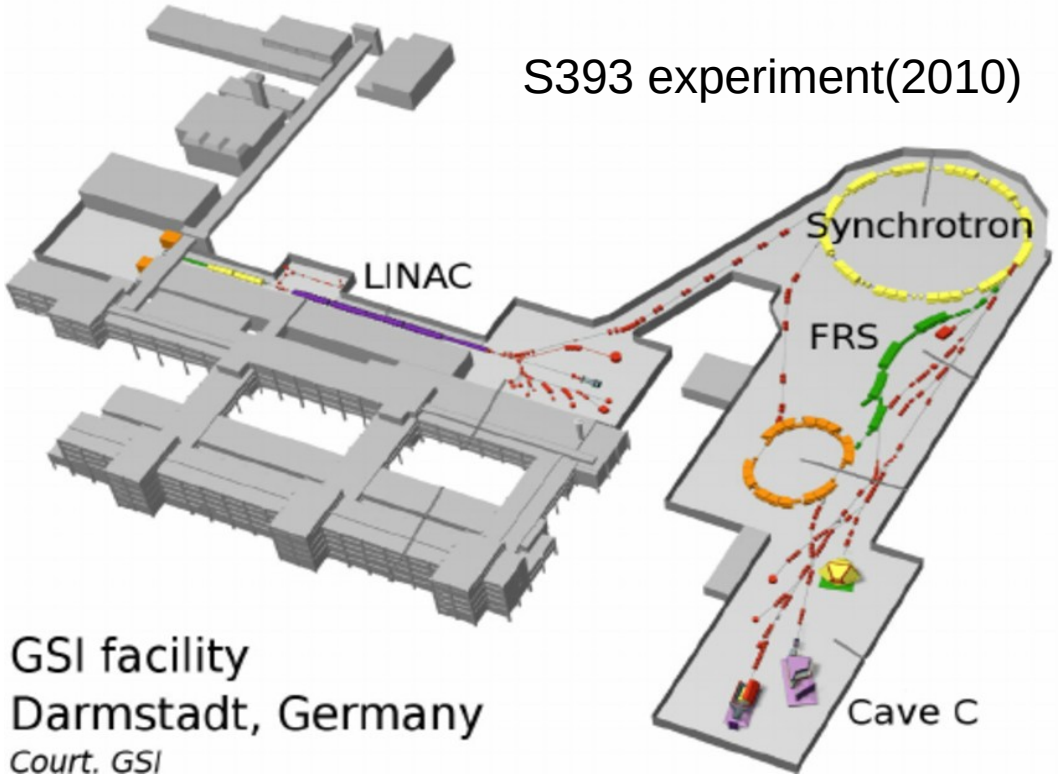
Experimental setup

S393 experiment(2010)



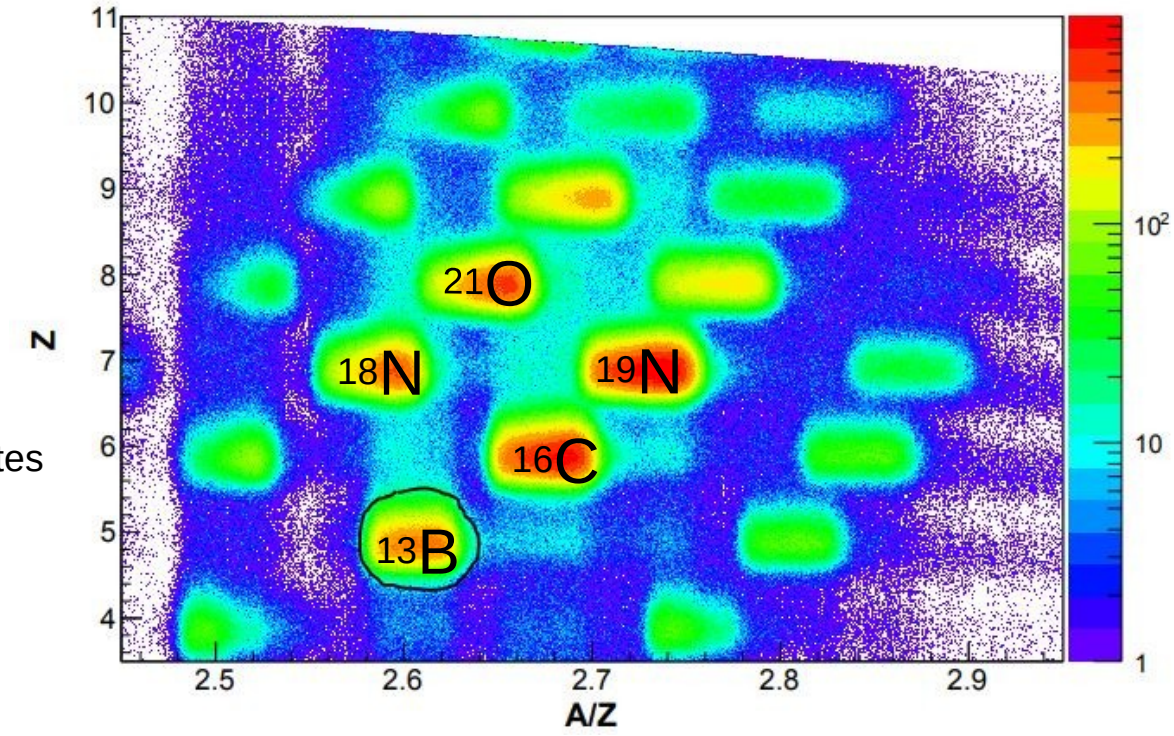
GSI facility
Darmstadt, Germany
Court. GSI

Experimental setup



- ✓ Primary beam : ^{40}Ar 490MeV/n
- ✓ Nuclei of interest : Bρ , FRS degrader
- ✓ Secondary beam → target (CH2~1g/cm2)

Study ^{13}B(p,2p)^{12}Be reaction

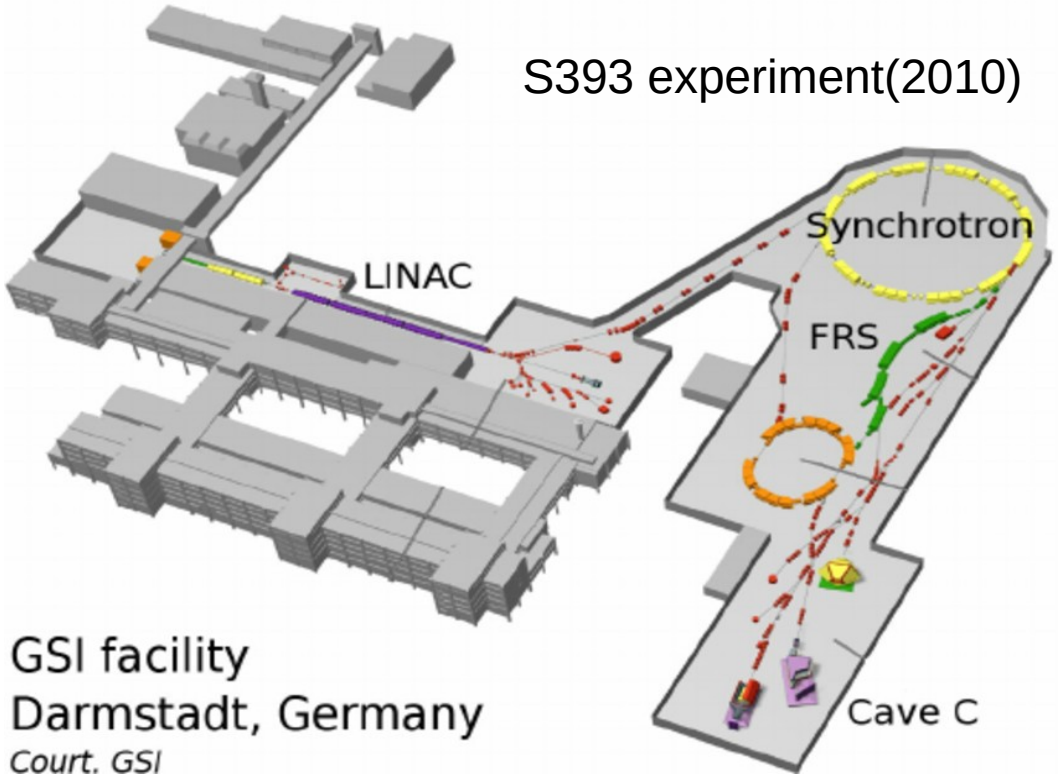


Some publications on the same set of data:

- Effective proton-neutron interaction near the drip line from unbound states in ^{25,26}F, *M. Vandebrouck et al.*, PRC(2017)

- Strong Neutron pairing in core+4n nuclei, *A.Revel et al.*, PRL (2018) (^{18}C & ^{20}O)

Experimental setup



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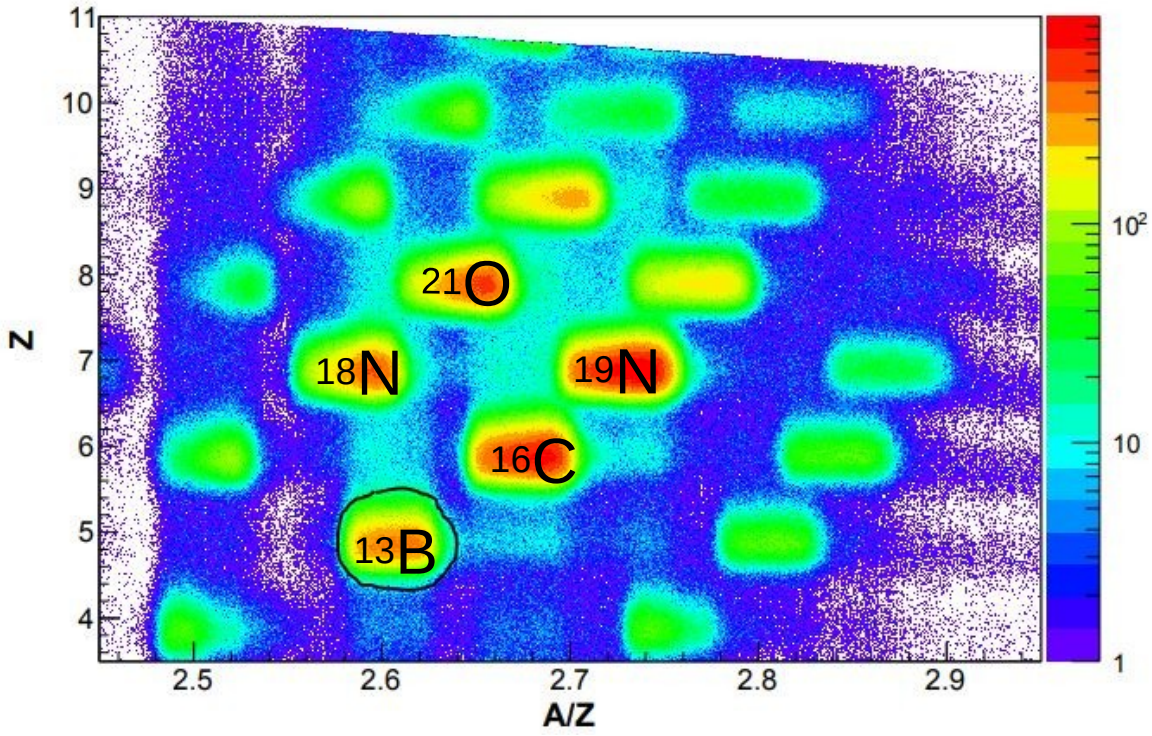
Study ^{13}B(p,2p)^{12}Be reaction

^{13}B $\xrightarrow{-p}$ ^{12}Be (+γ)
^{11}Be +n (+γ)
^{10}Be +n (+γ)



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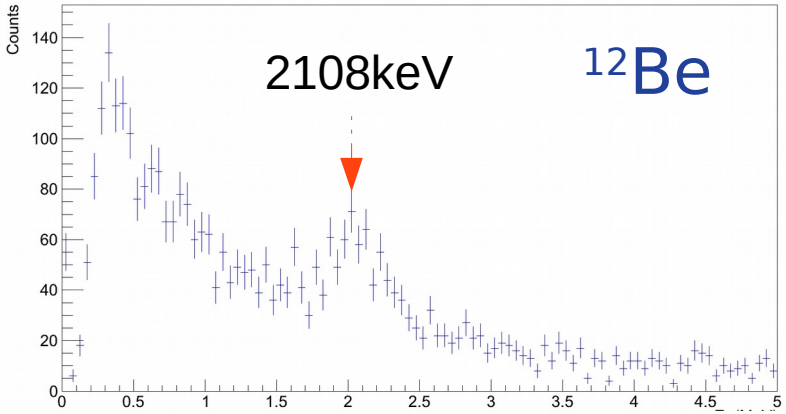
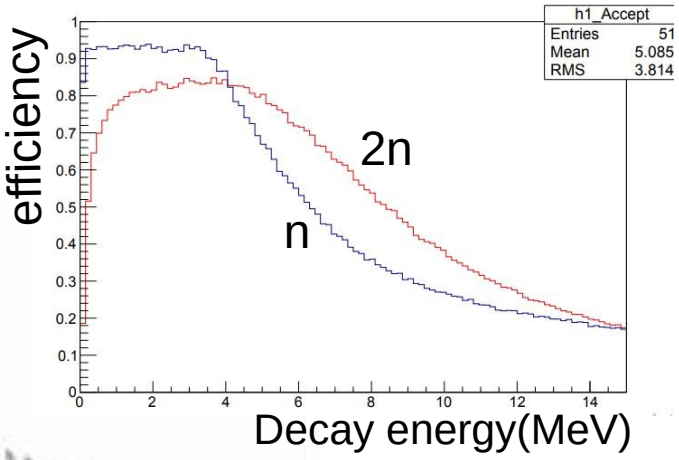
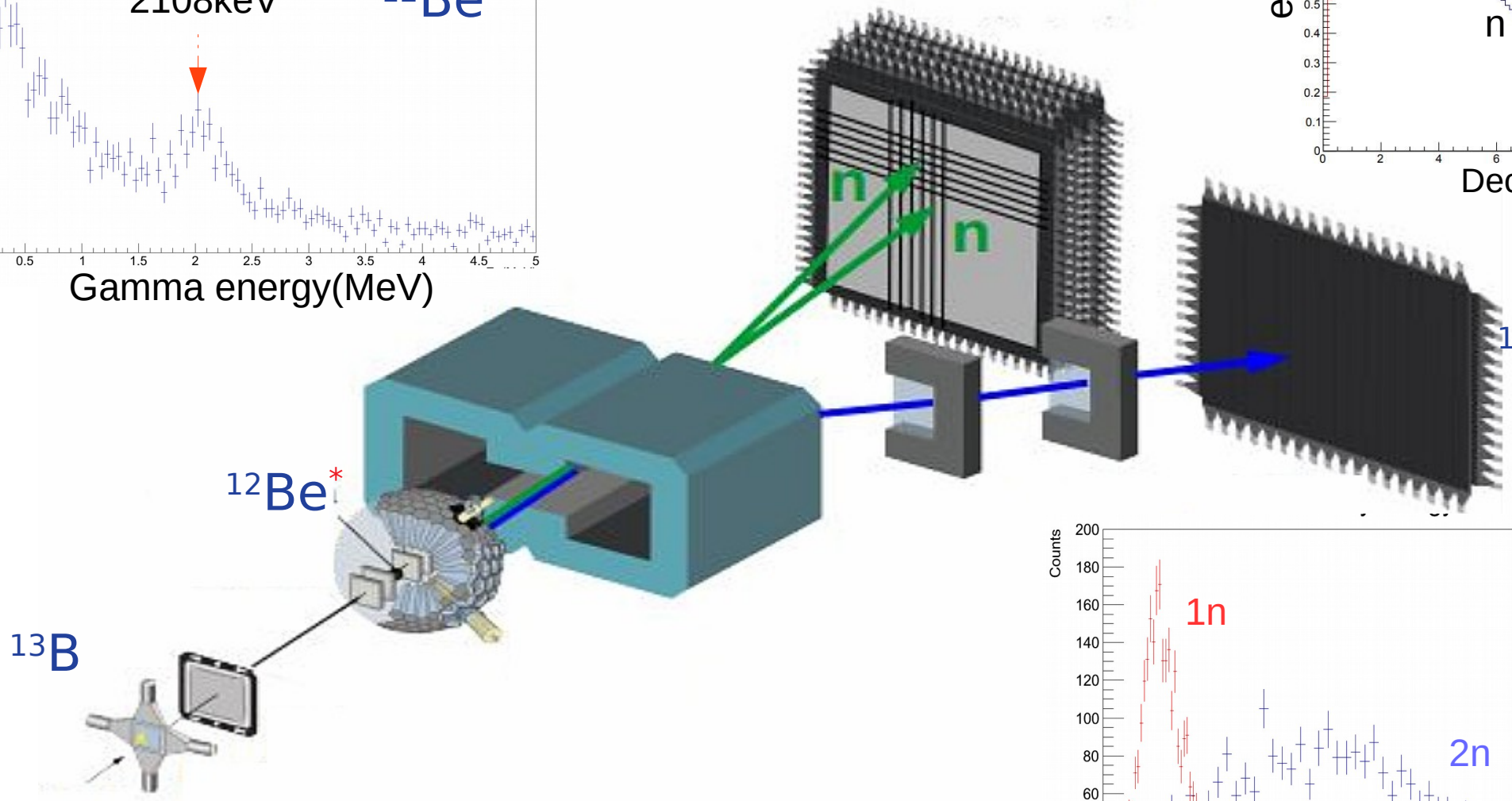
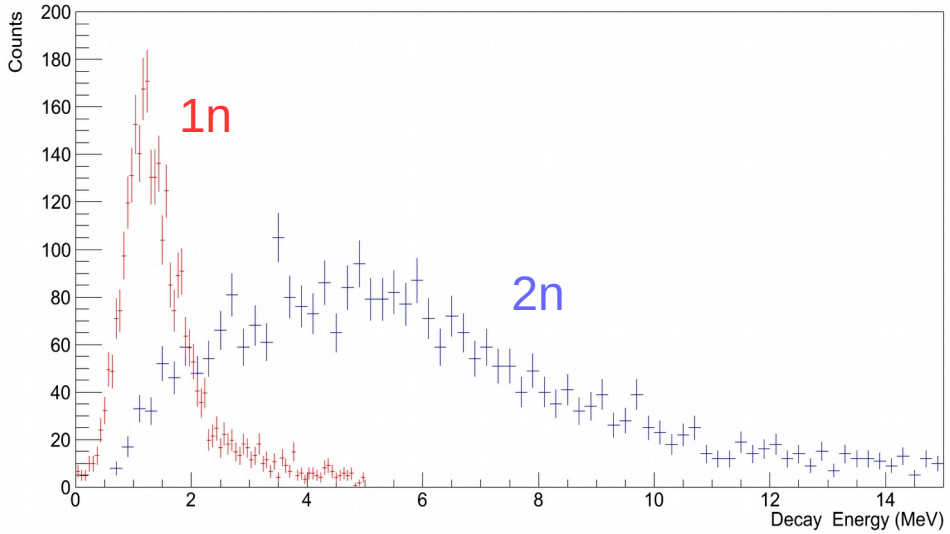


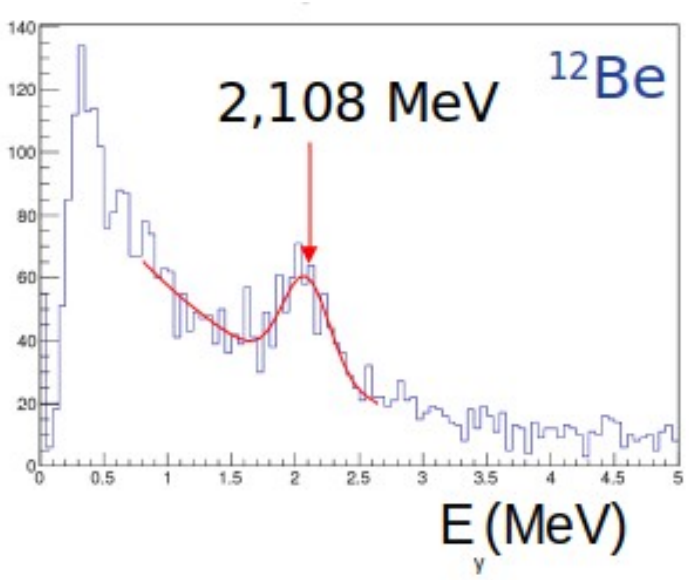


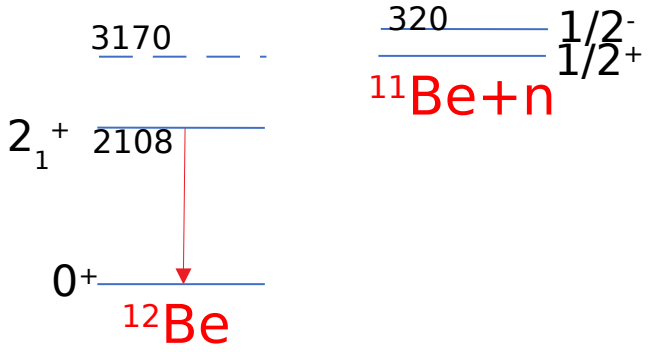




Better set up as compared to that of NSCL : gamma detection, better neutron efficiency → 2n detection

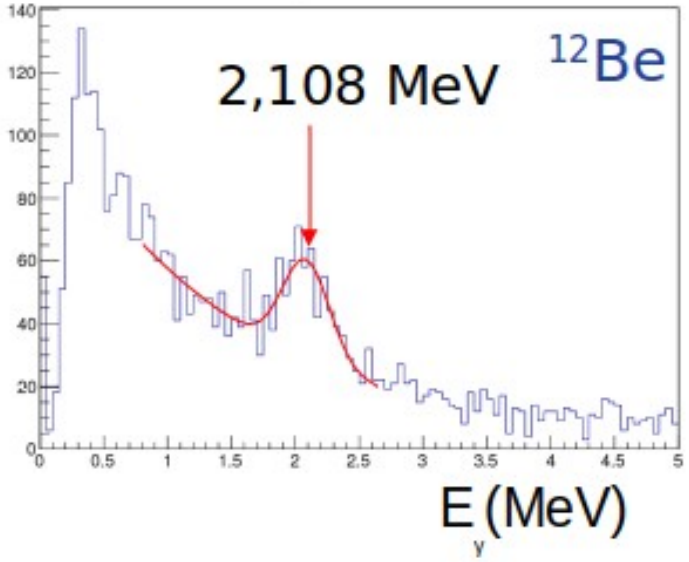
Results : bound and $^{11}Be^{*}$+n states

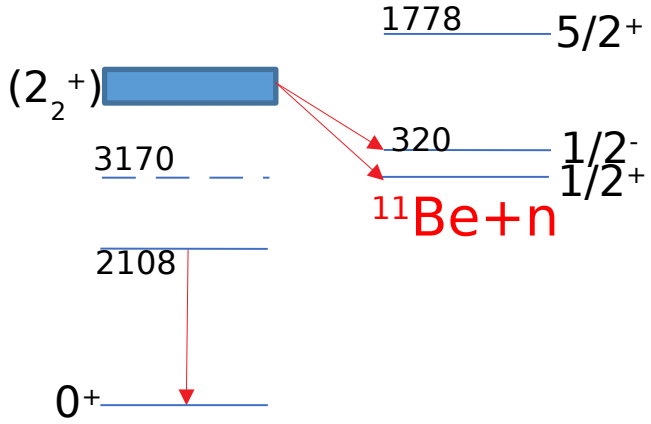


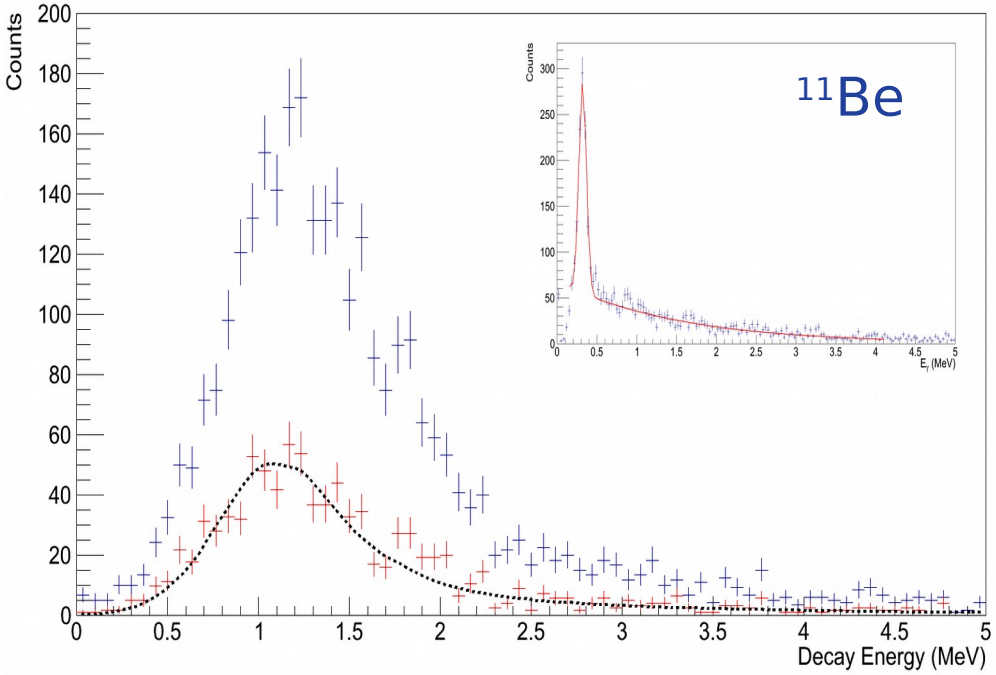


Results : bound and $^{11}Be^{*}$+n states

-detection of gamma at 320 keV in ^{11}Be







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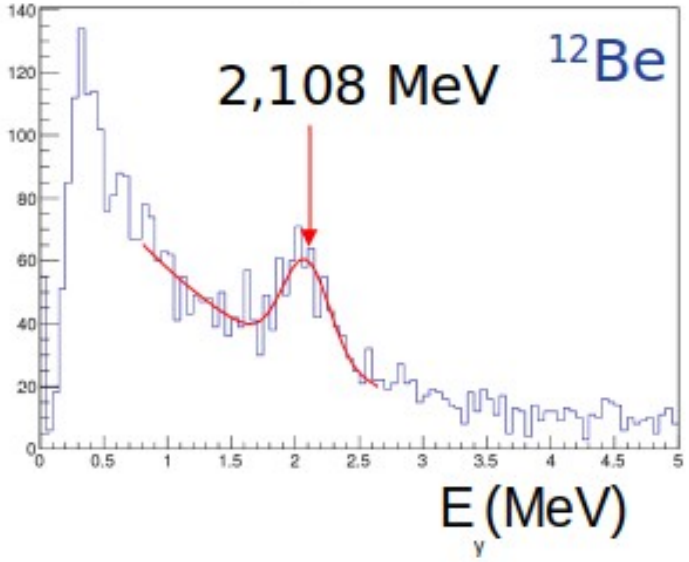
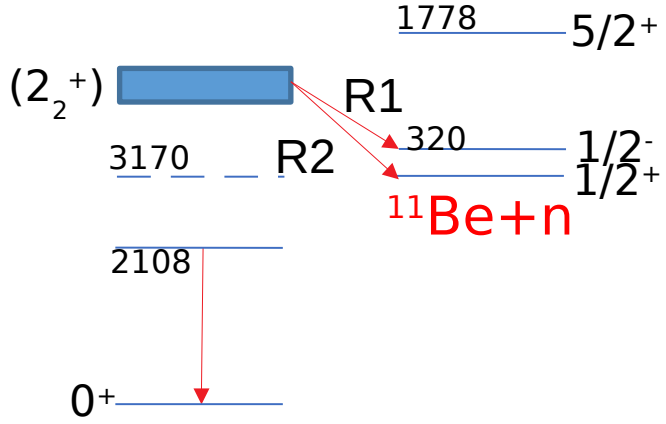
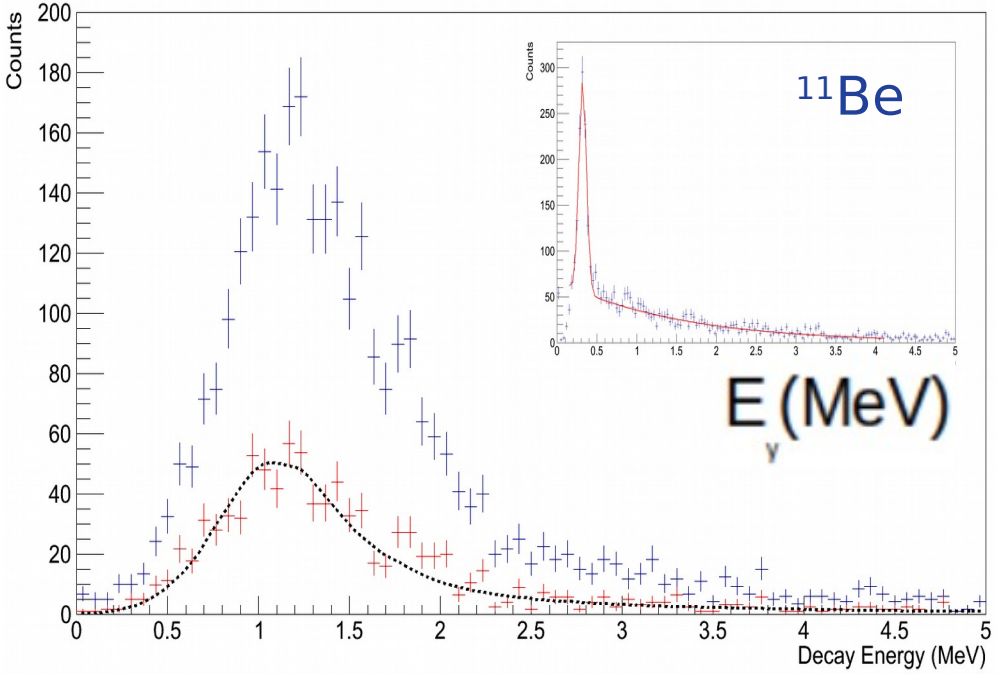
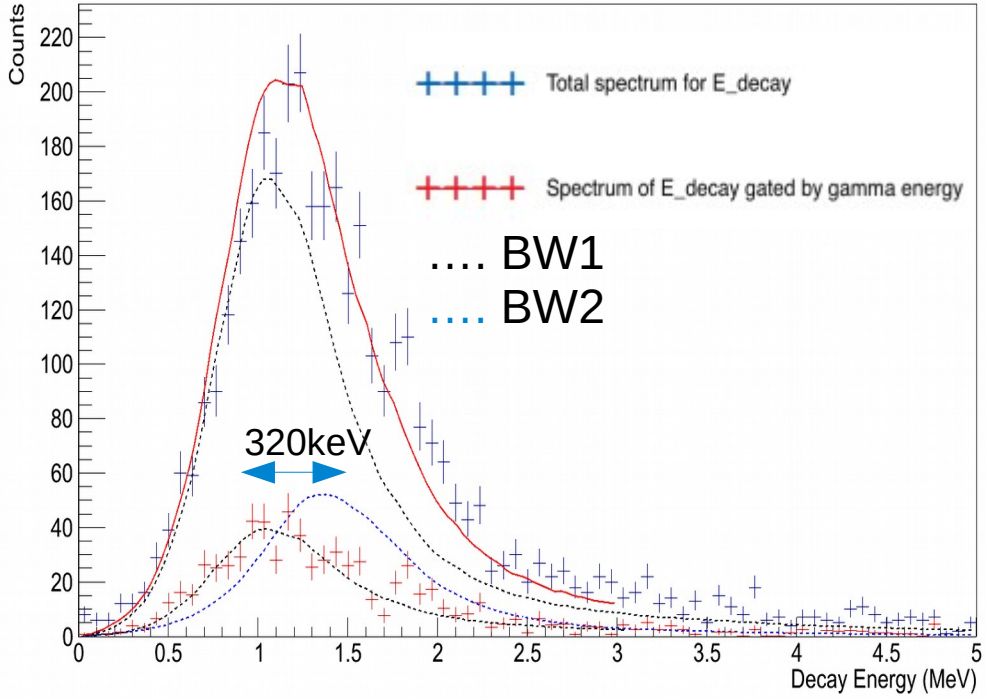




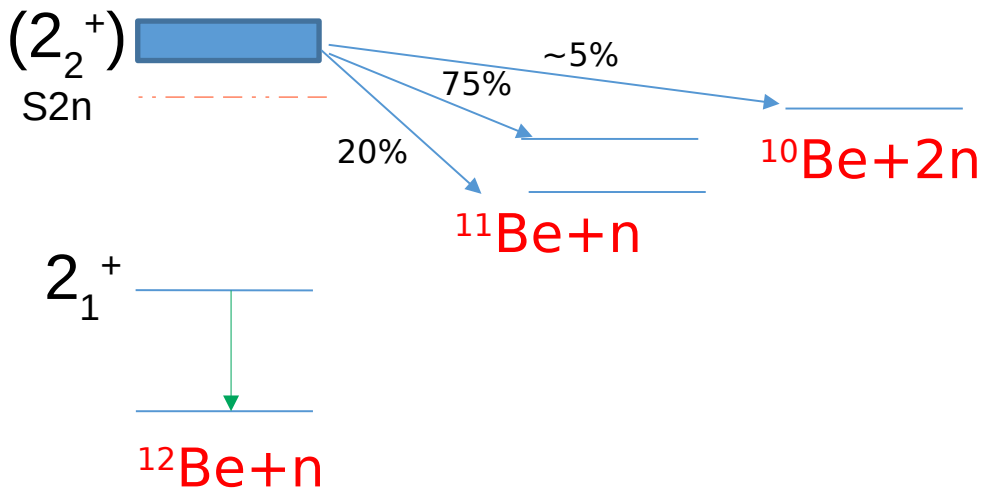
Fit : BW convolved by response function



E ~ 1300 keV
Γ ~ 400 keV



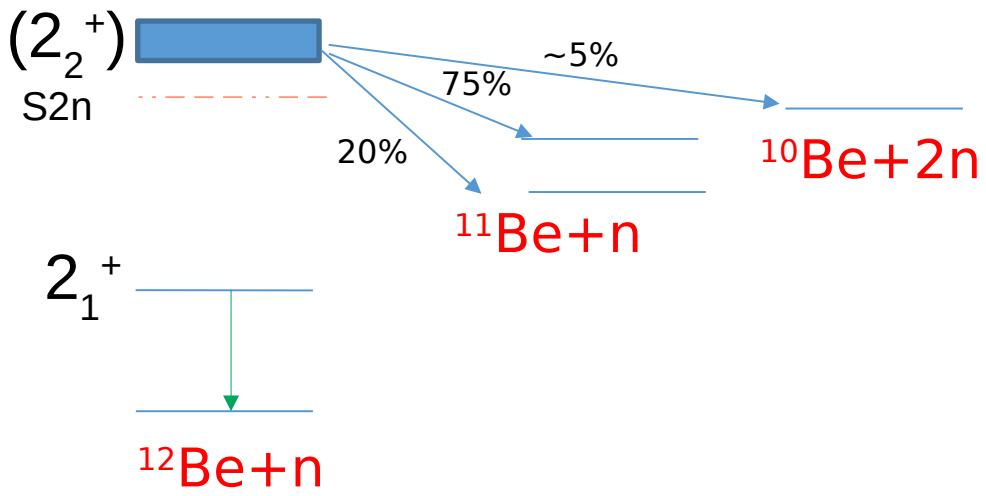
Results : $^{11}Be^{*}$+2n states



Good agreement with H.T Fortune :

- Halo state of ^{11}Be weakly populated
- Excited state is mostly populated

Results : $^{11}Be^{*}$+2n states

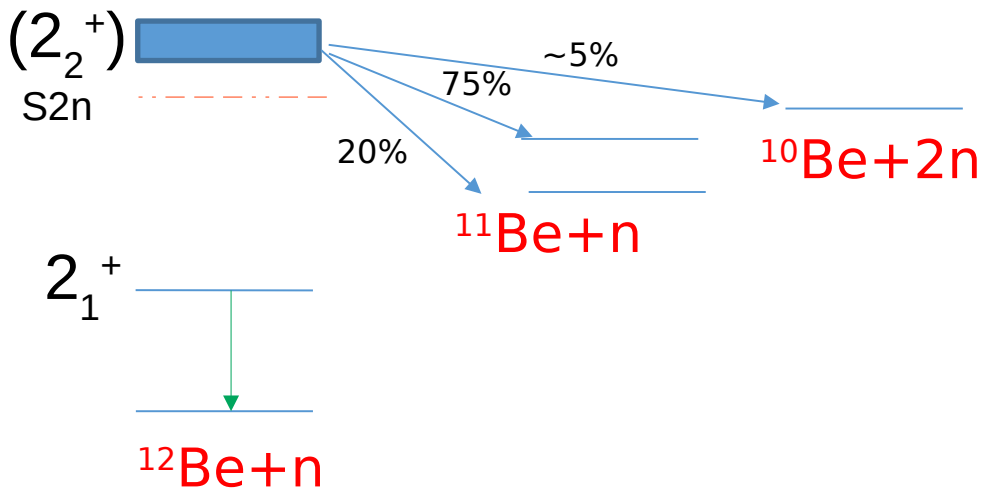


Good agreement with H.T Fortune :

- Halo state of ^{11}Be weakly populated
- Excited state is mostly populated

- The bound 2^{+}_{1} (deformed) decays by gamma
- The unbound one (2^{+}_{2}) decays by 1n emission

Results : $^{11}Be^{*}$+2n states



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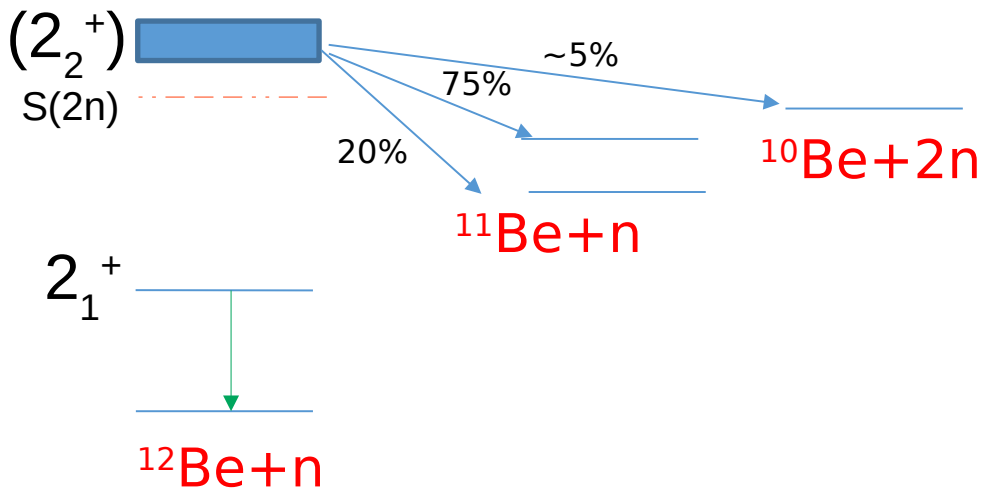
Which % of 2n emission ? Direct decay

Results : $^{11}Be^{*}$+n states



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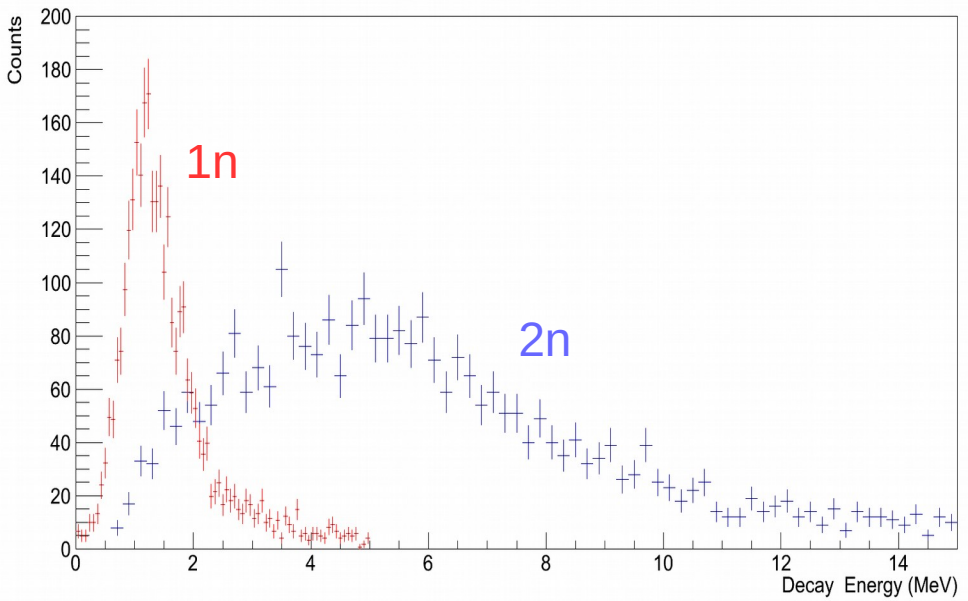
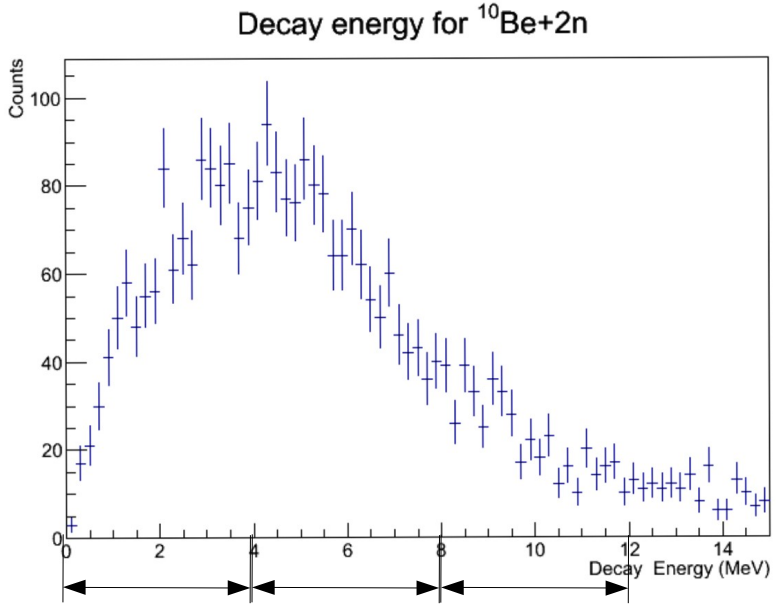
Study of 3 body decay

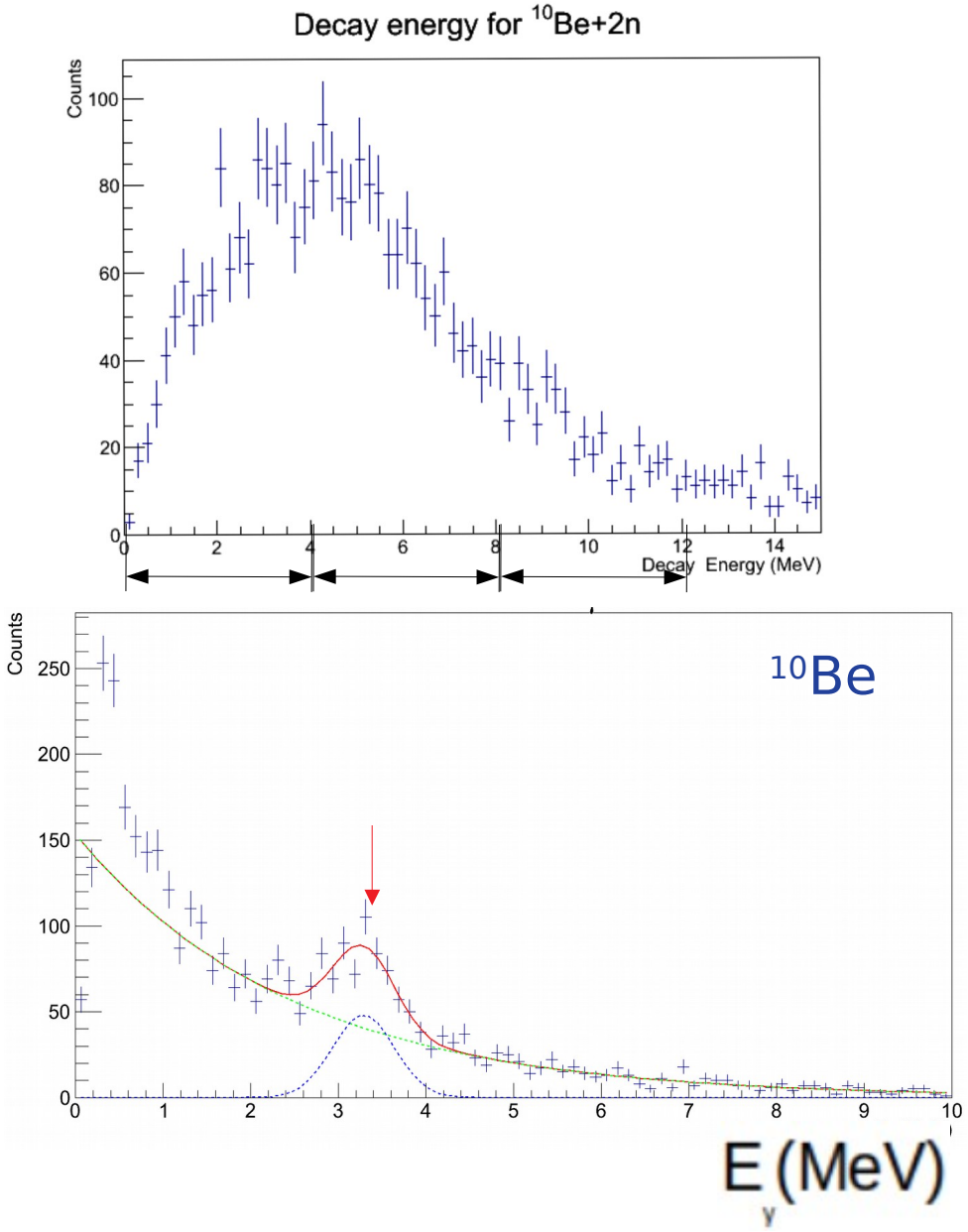
Decay spectrum

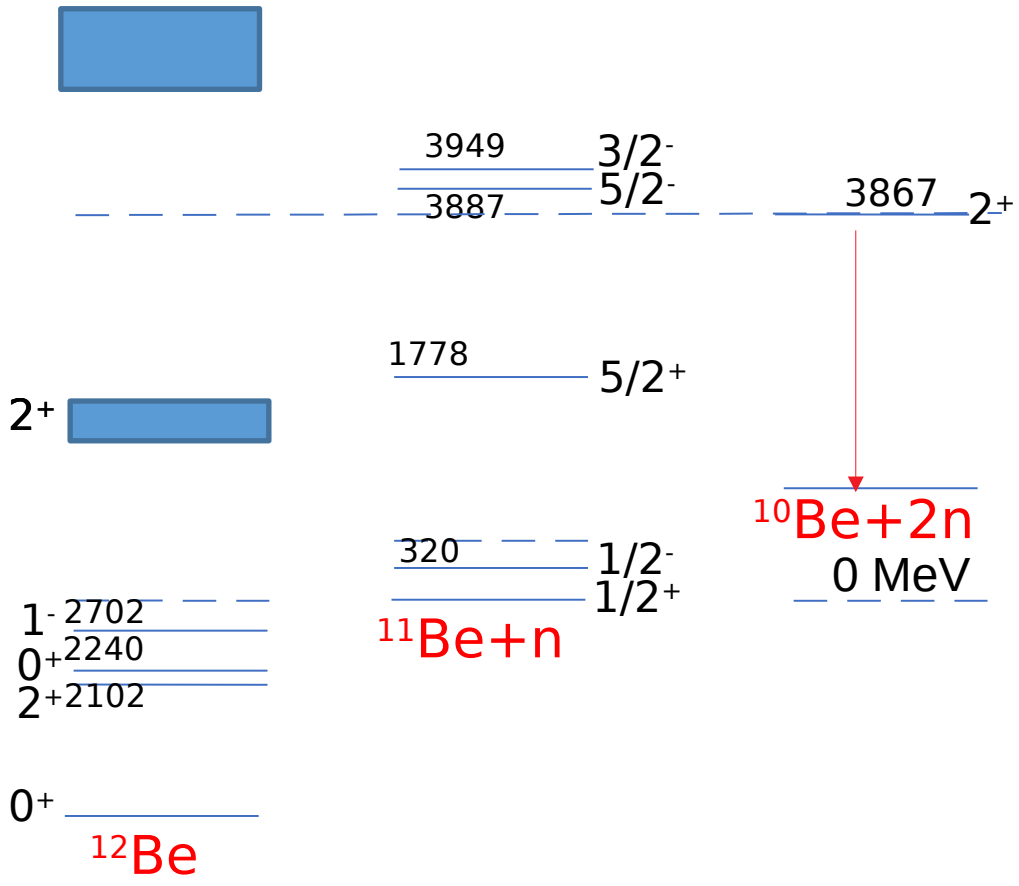


Results : $^{10}Be^{*}$+n states

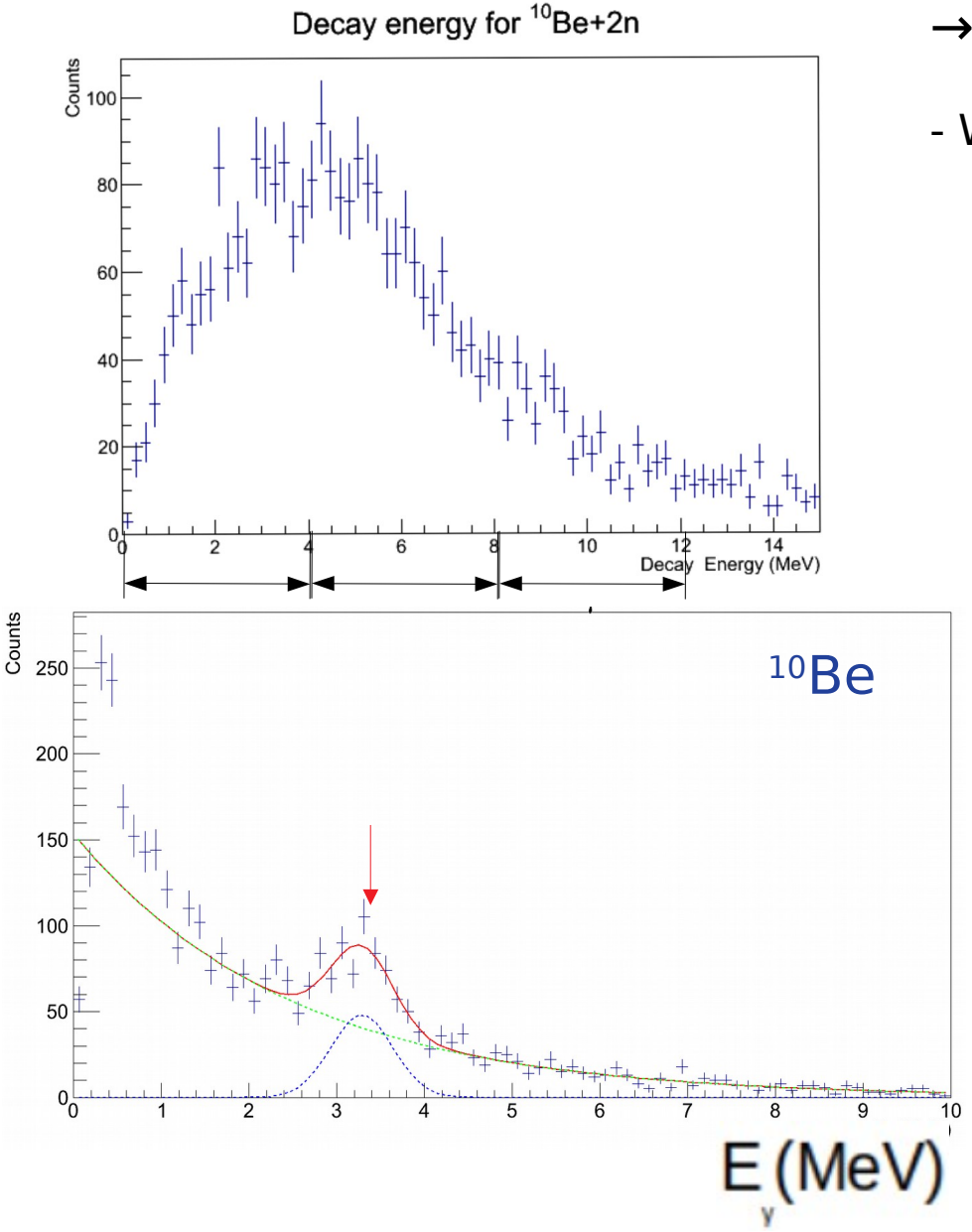


Results : $^{10}Be^{*}$+n states





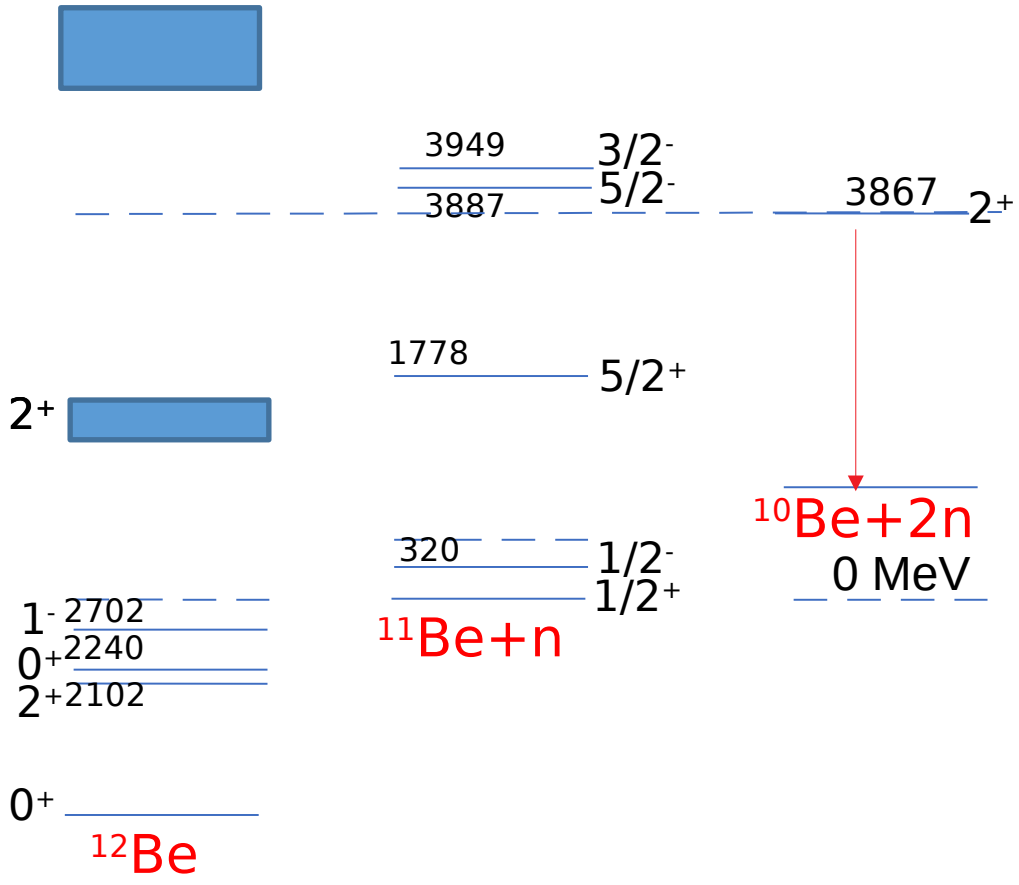
Results : $^{10}Be^{*}$+n states



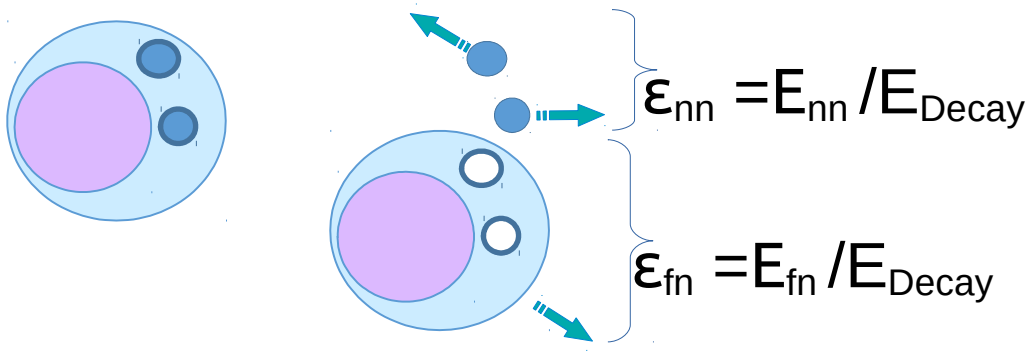
- We detect a gamma at 3.4MeV in ^{10}Be

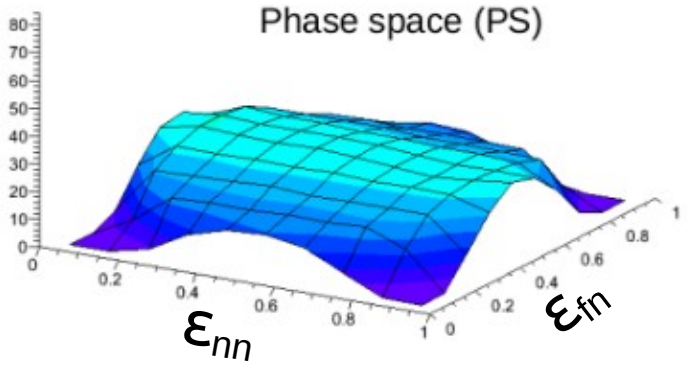
→ Possible decay through 2^+ → Shift of 3.4MeV in 2n Energy decay

- We split the 2n spectrum in 3 ranges of energy: 0-4, 4-8 and 8-12 MeV



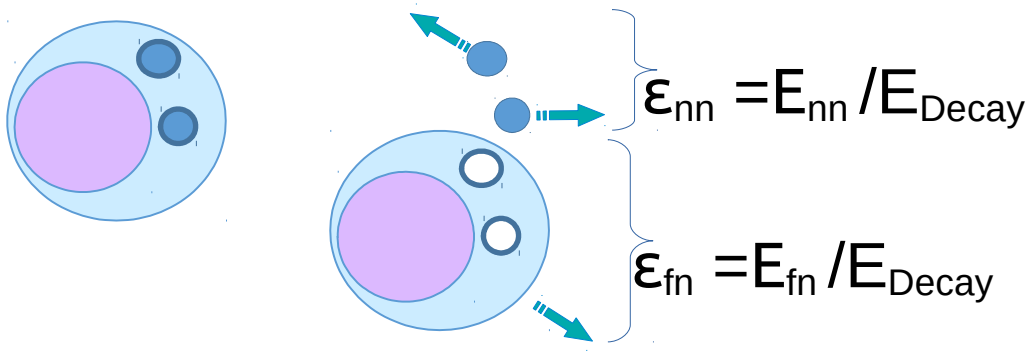
Correlations and Dalitz plots



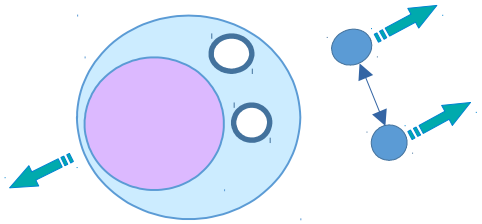


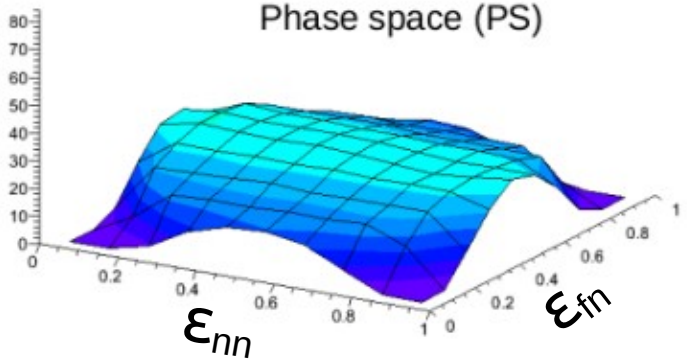
Correlation femtoscopy, R.Lednicky, NuclPhys A (2006)

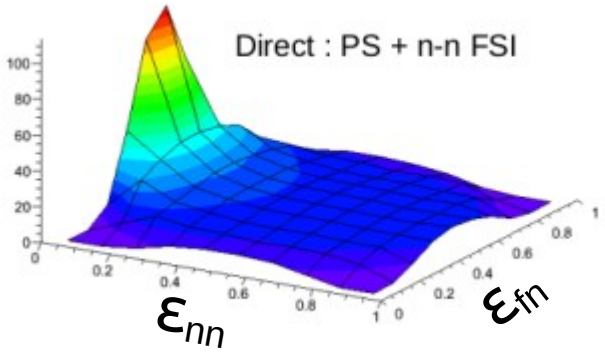
Correlations and Dalitz plots



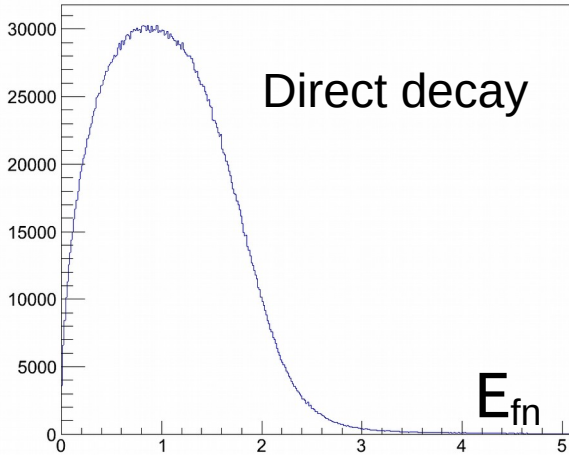
Final State interaction







Correlation femtoscopy, R.Lednicky, NuclPhys A (2006)



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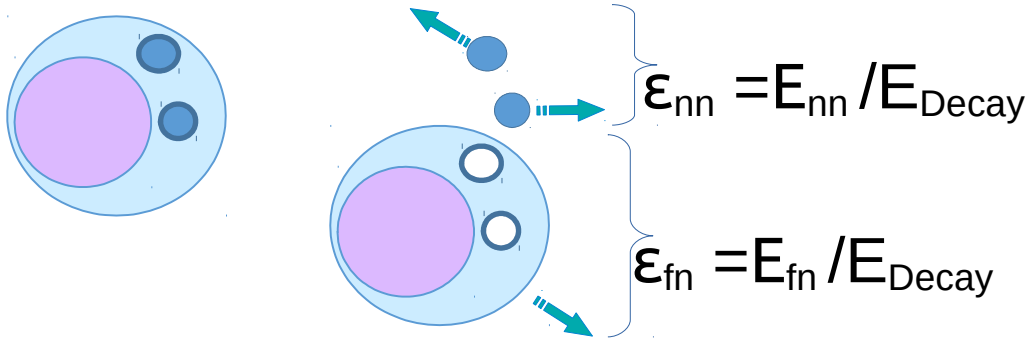

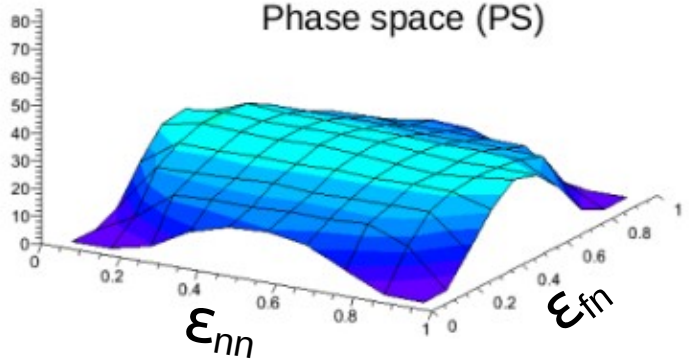

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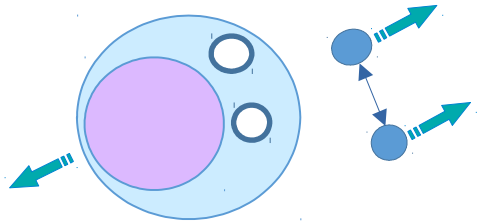
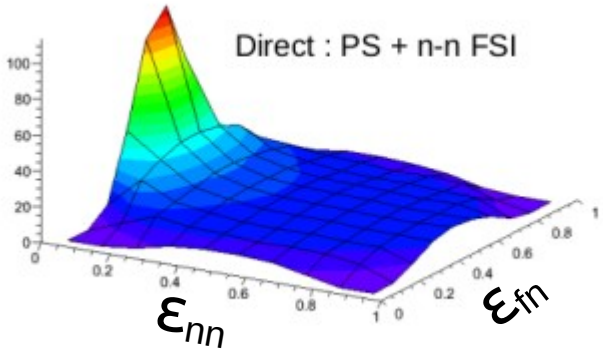
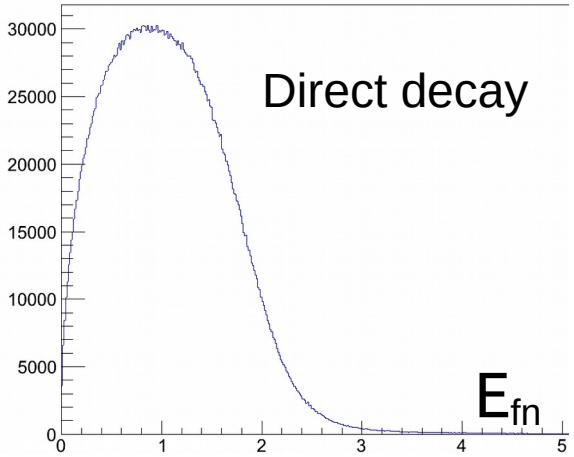
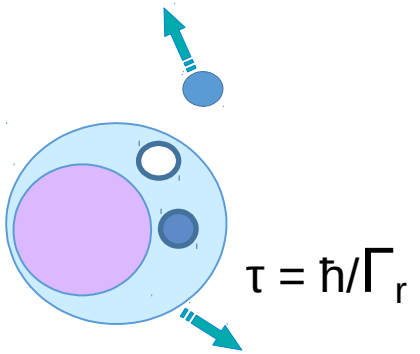


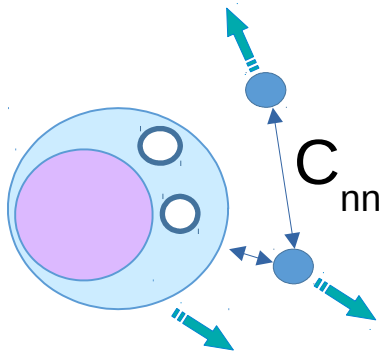
$C_{nn}(r^{rms}_{nn})$



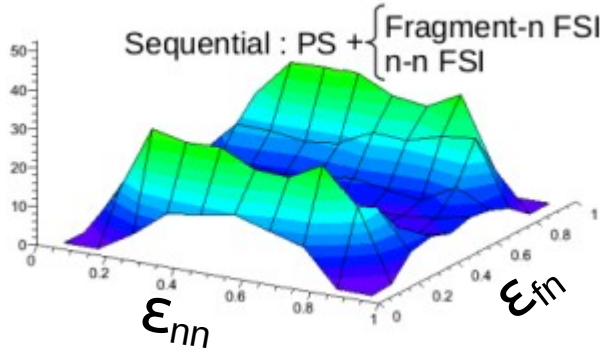


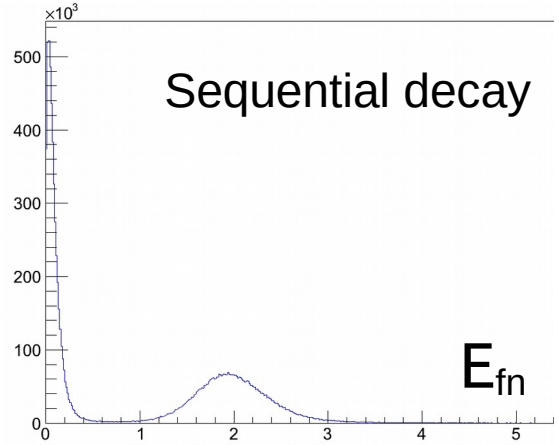


$\tau = \hbar/\Gamma_r$

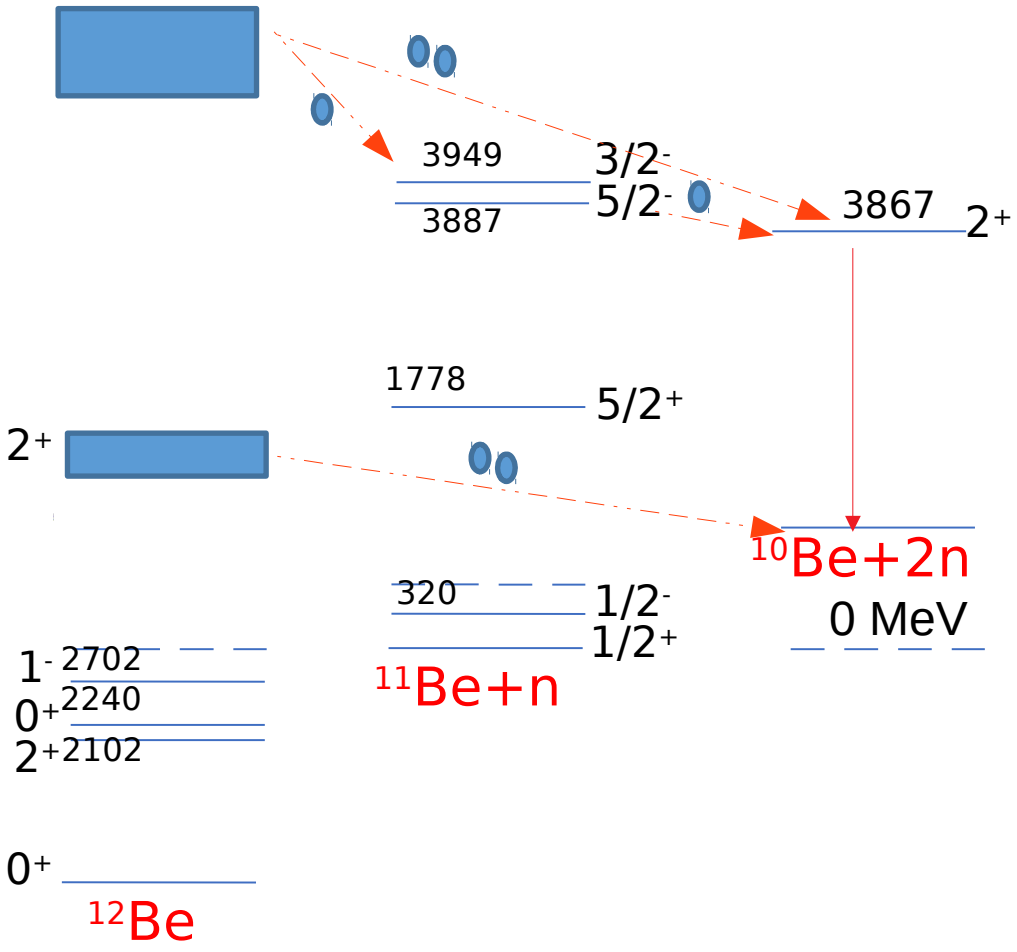


$C_{nn}(r^{rms}_{nn}, \tau)$





Results :Dalitz plots for $^{10}Be^{*}$+2n states



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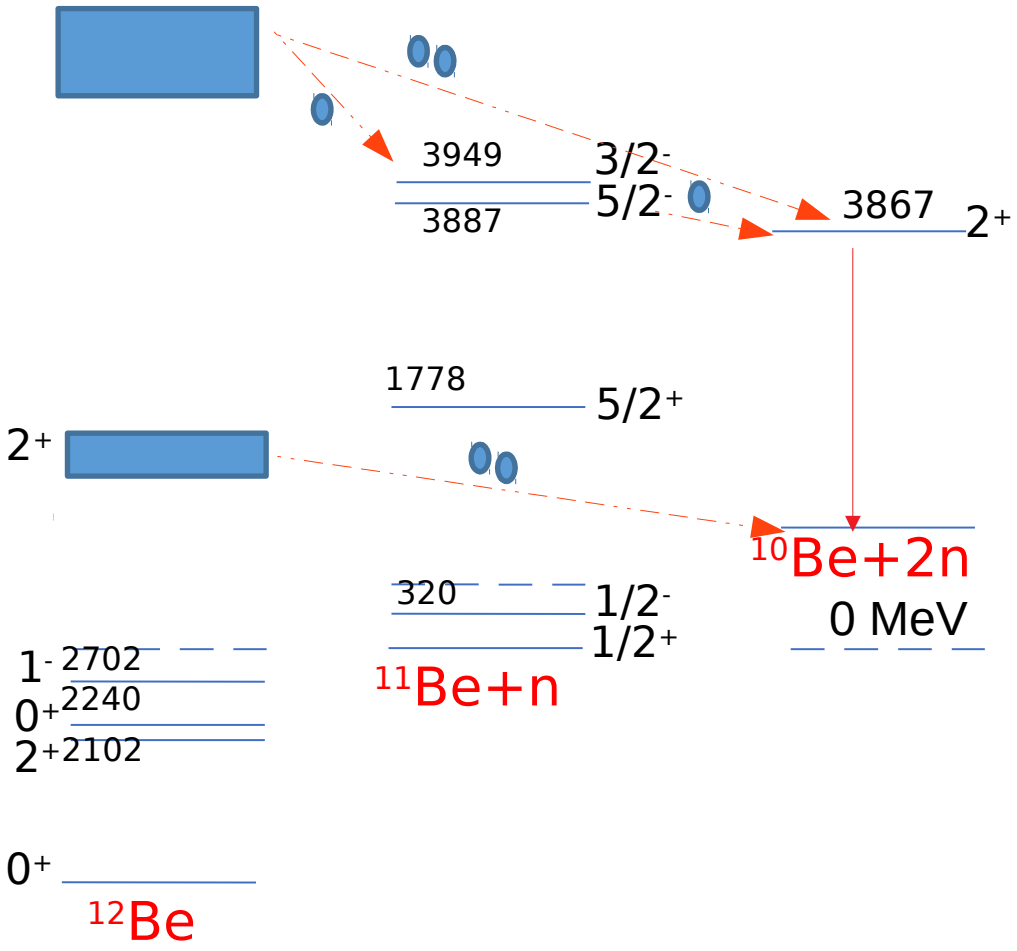

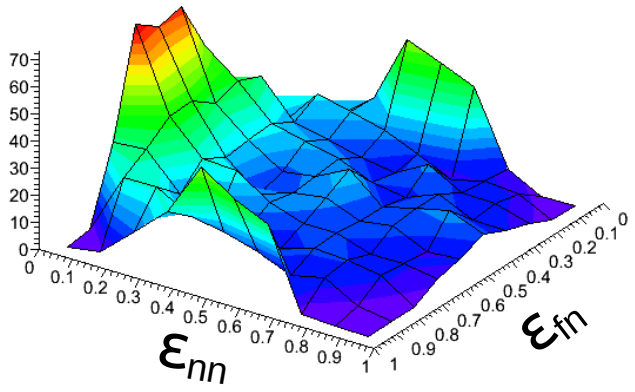

EXP

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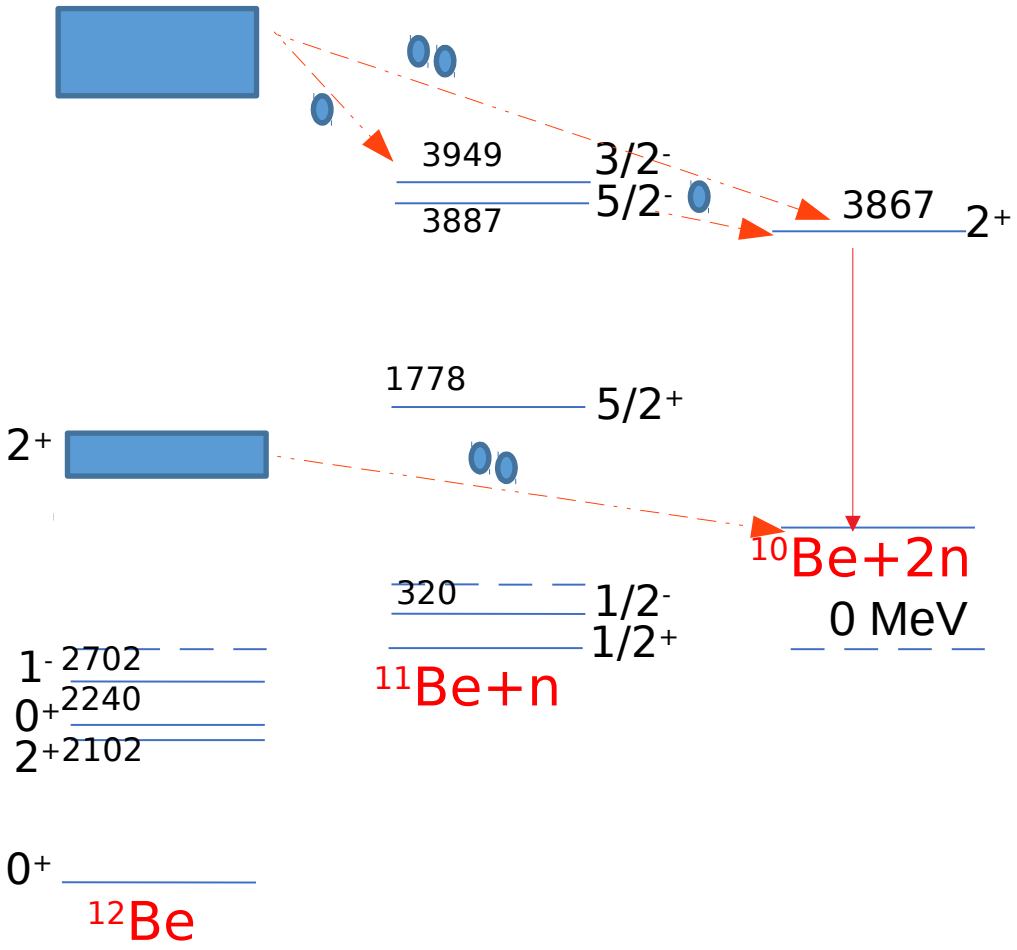
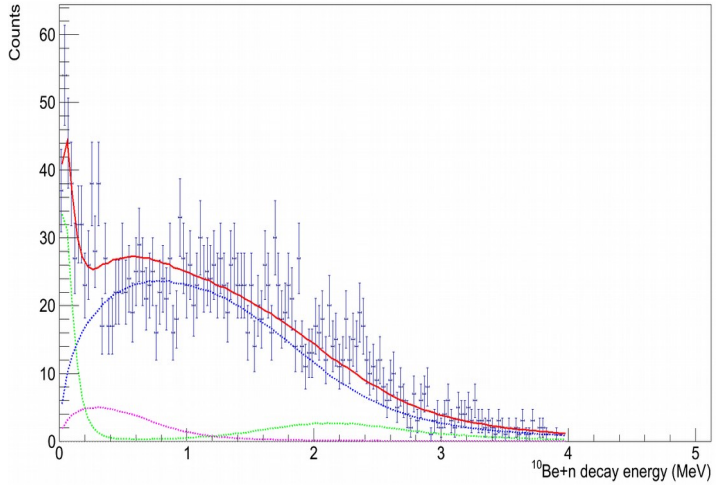
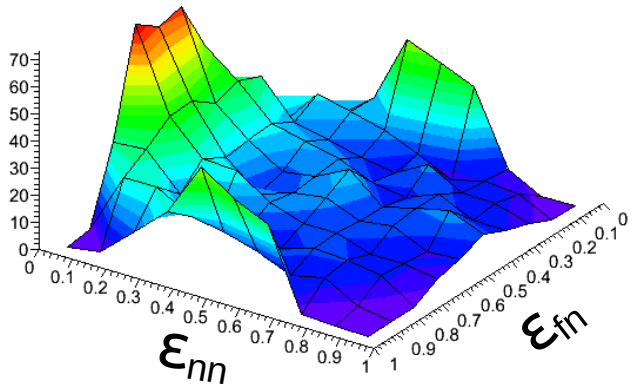


SEQ: 15%
DIR: 85%

E_{fn} for $0 < E_{2n} < 4$ MeV





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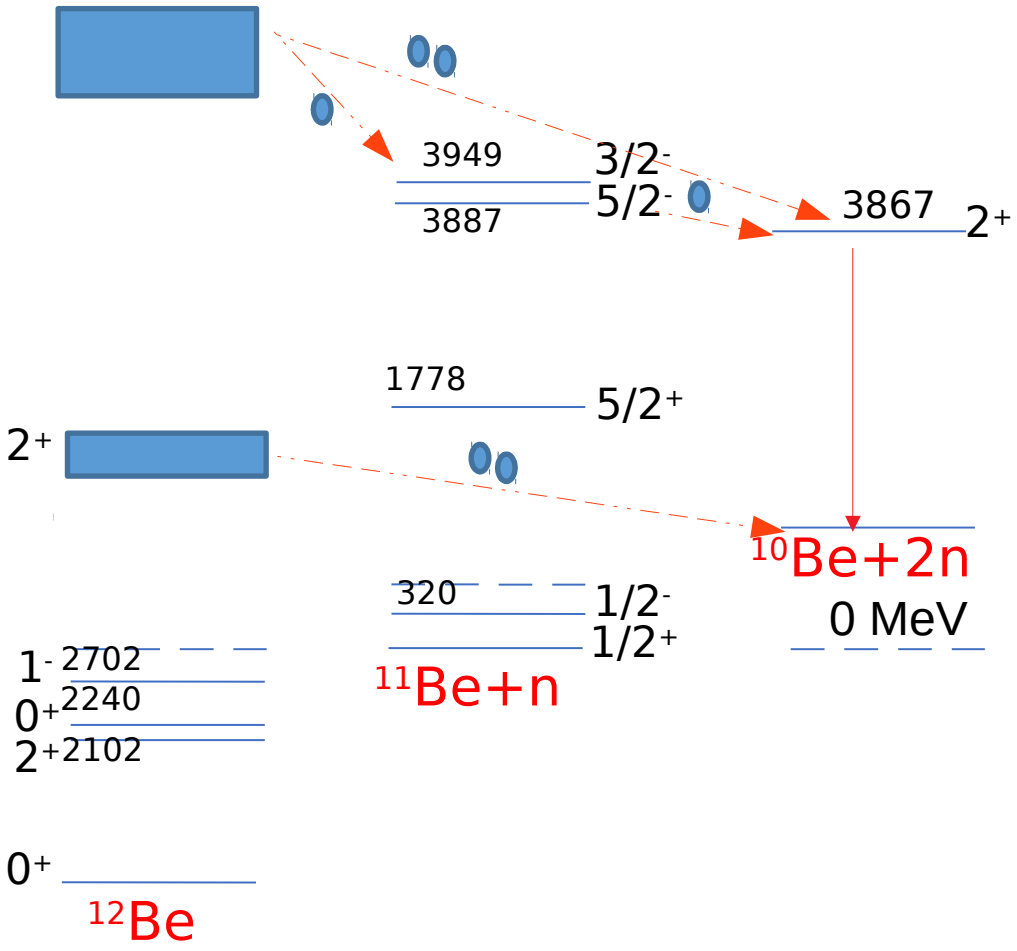

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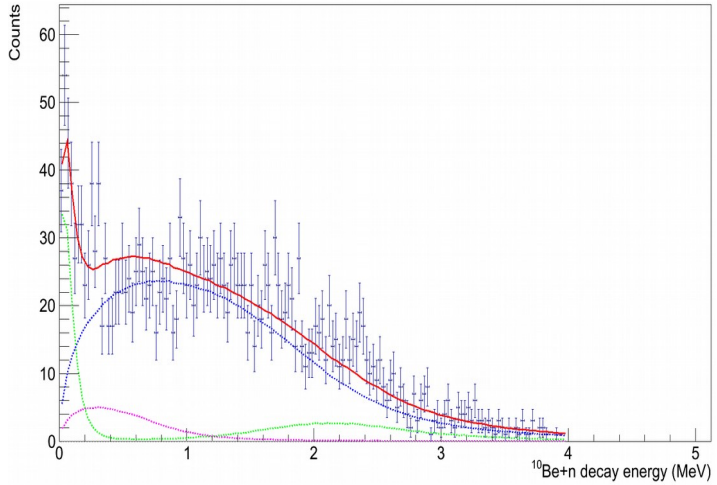
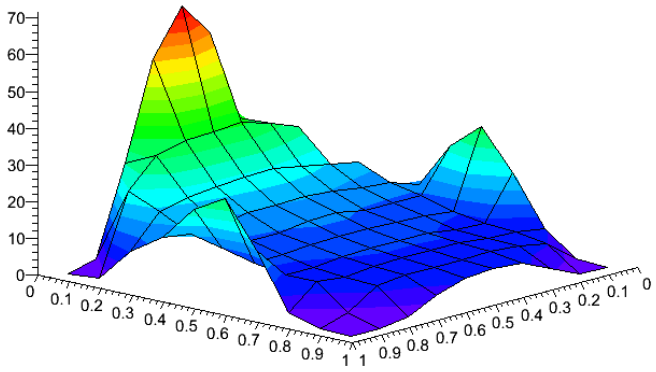
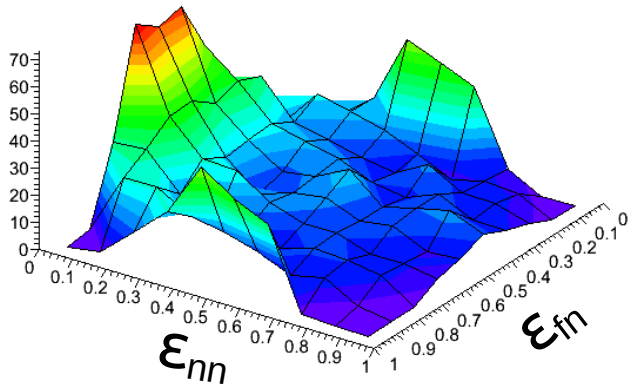




SIMUL



EXP

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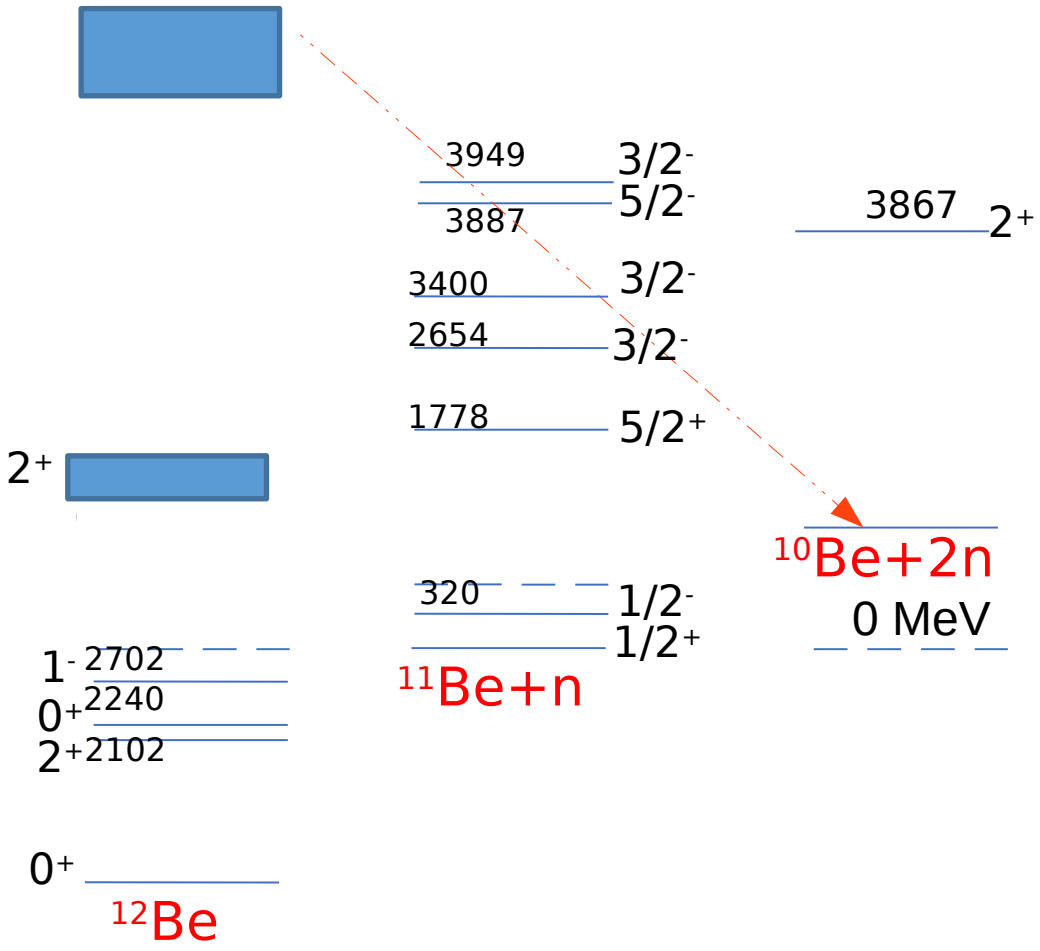

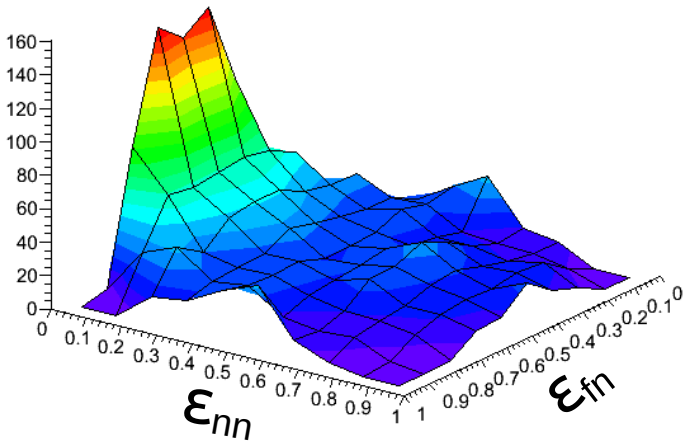

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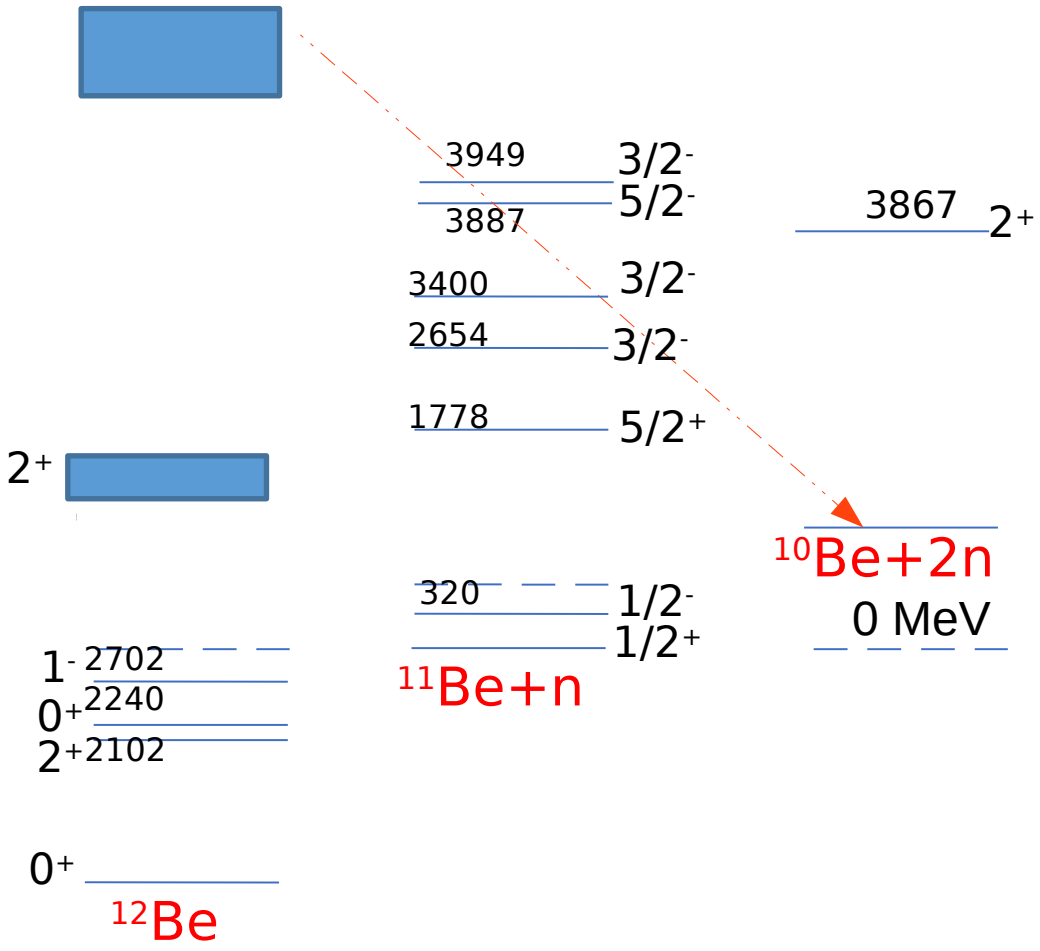
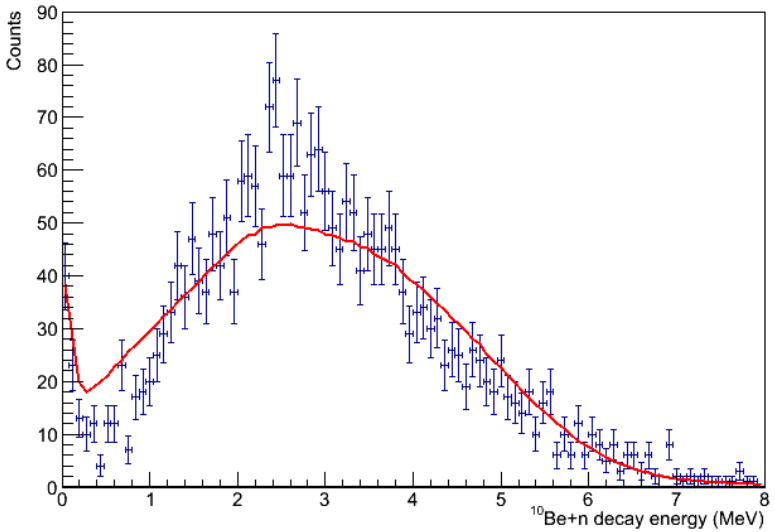
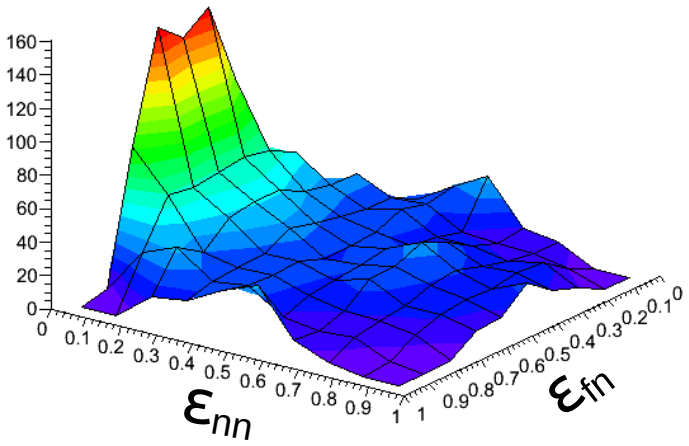


E_{fn} for $4 < E_{2n} < 8$ MeV





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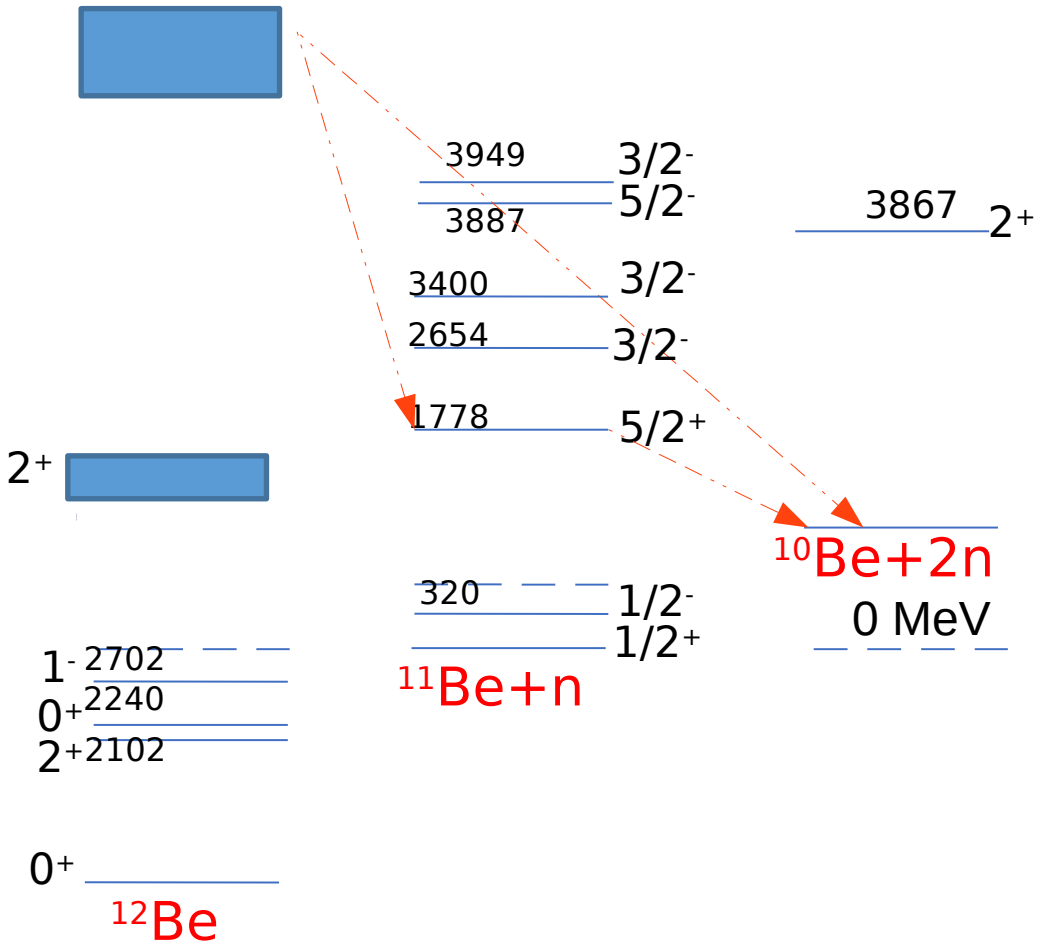

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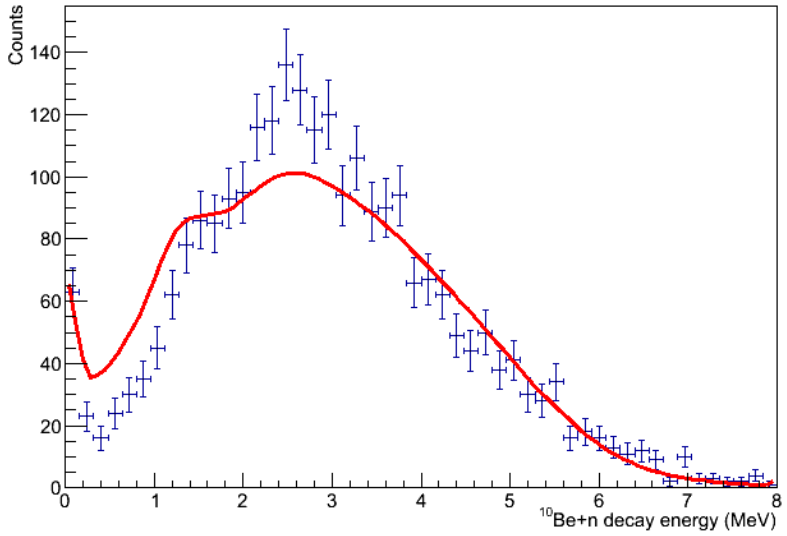

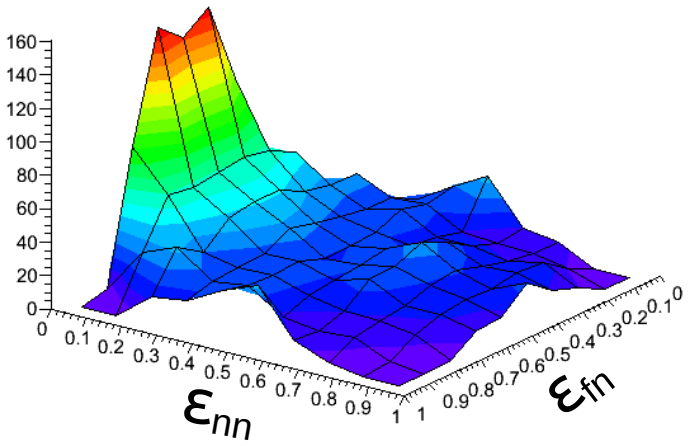

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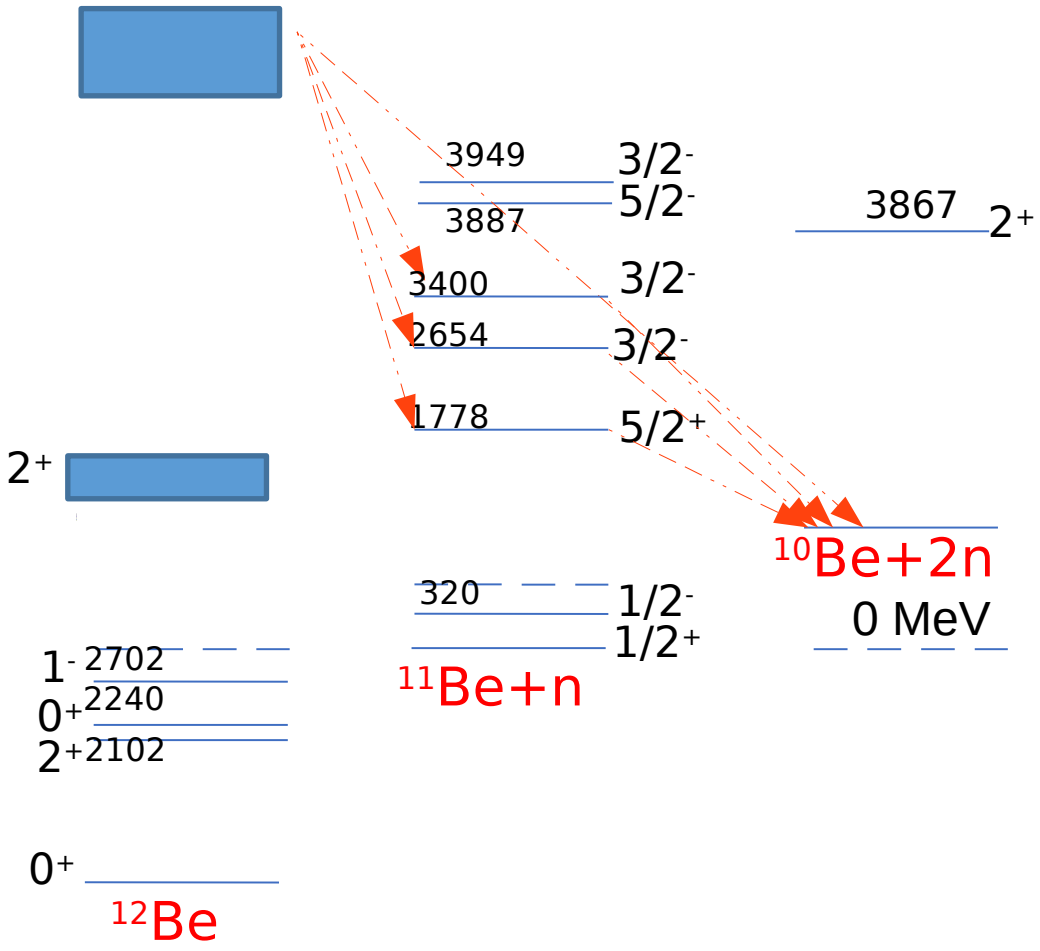

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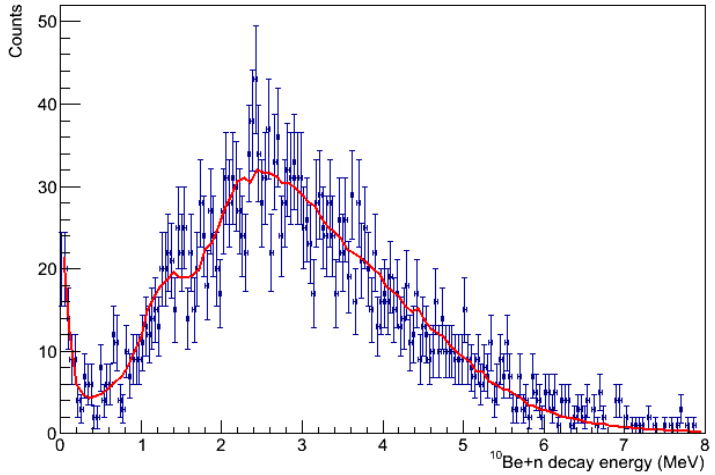

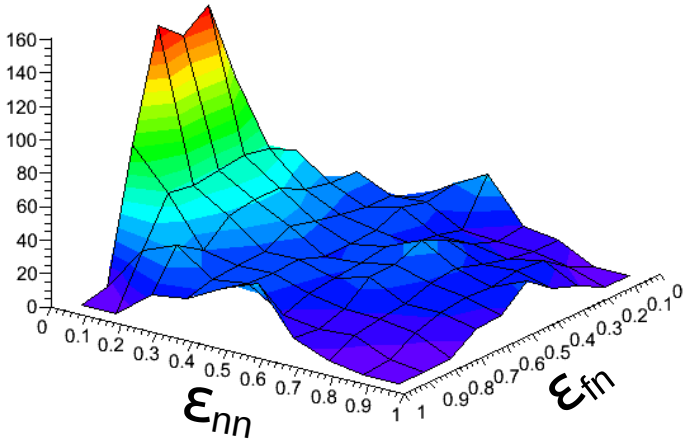

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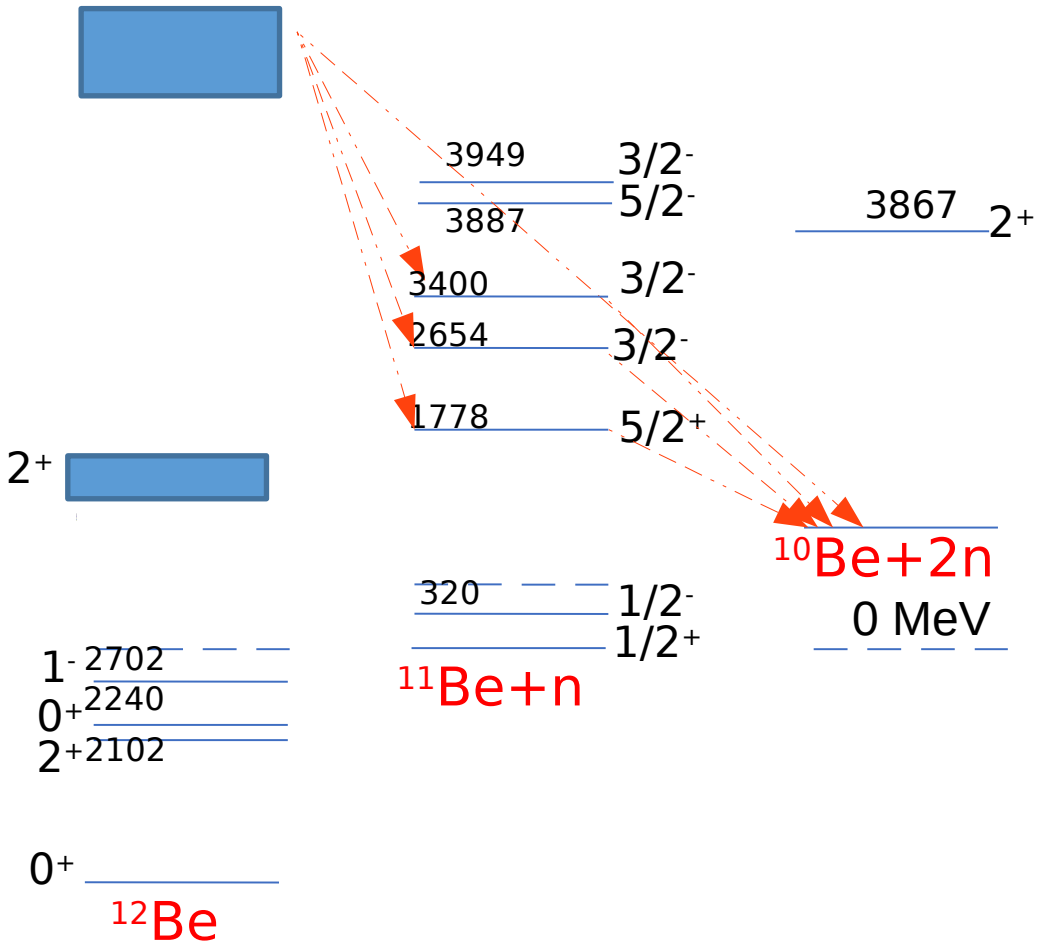

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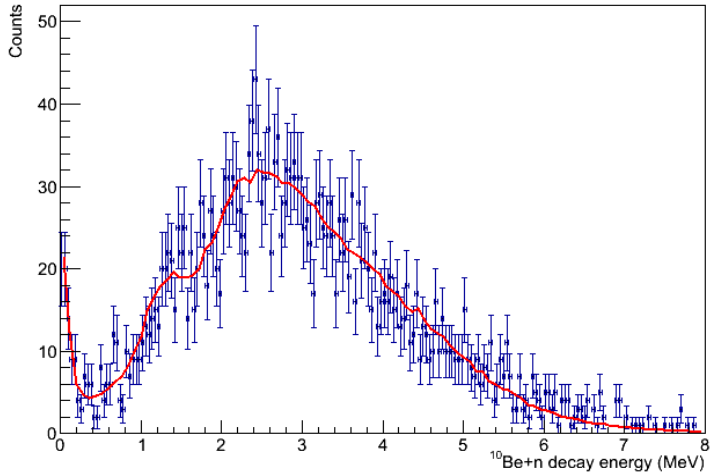
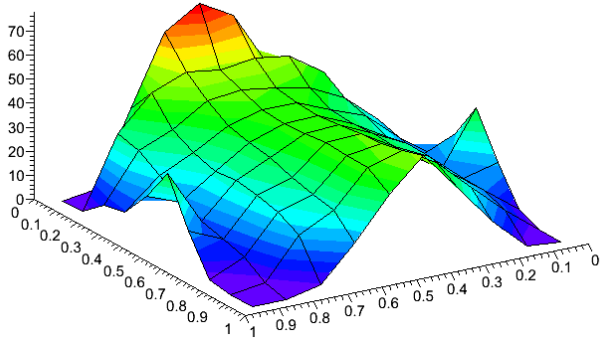
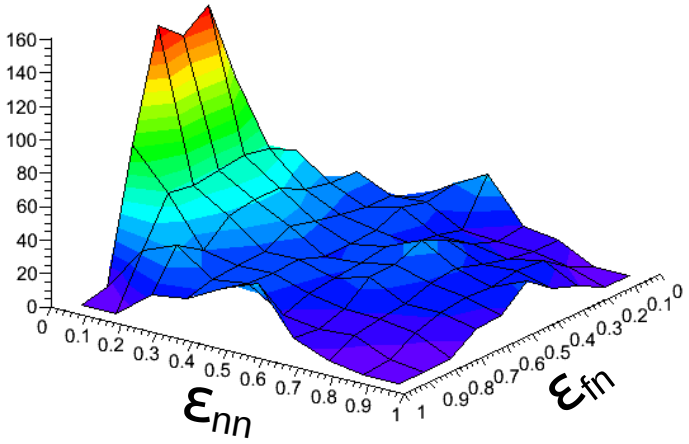




SIMUL



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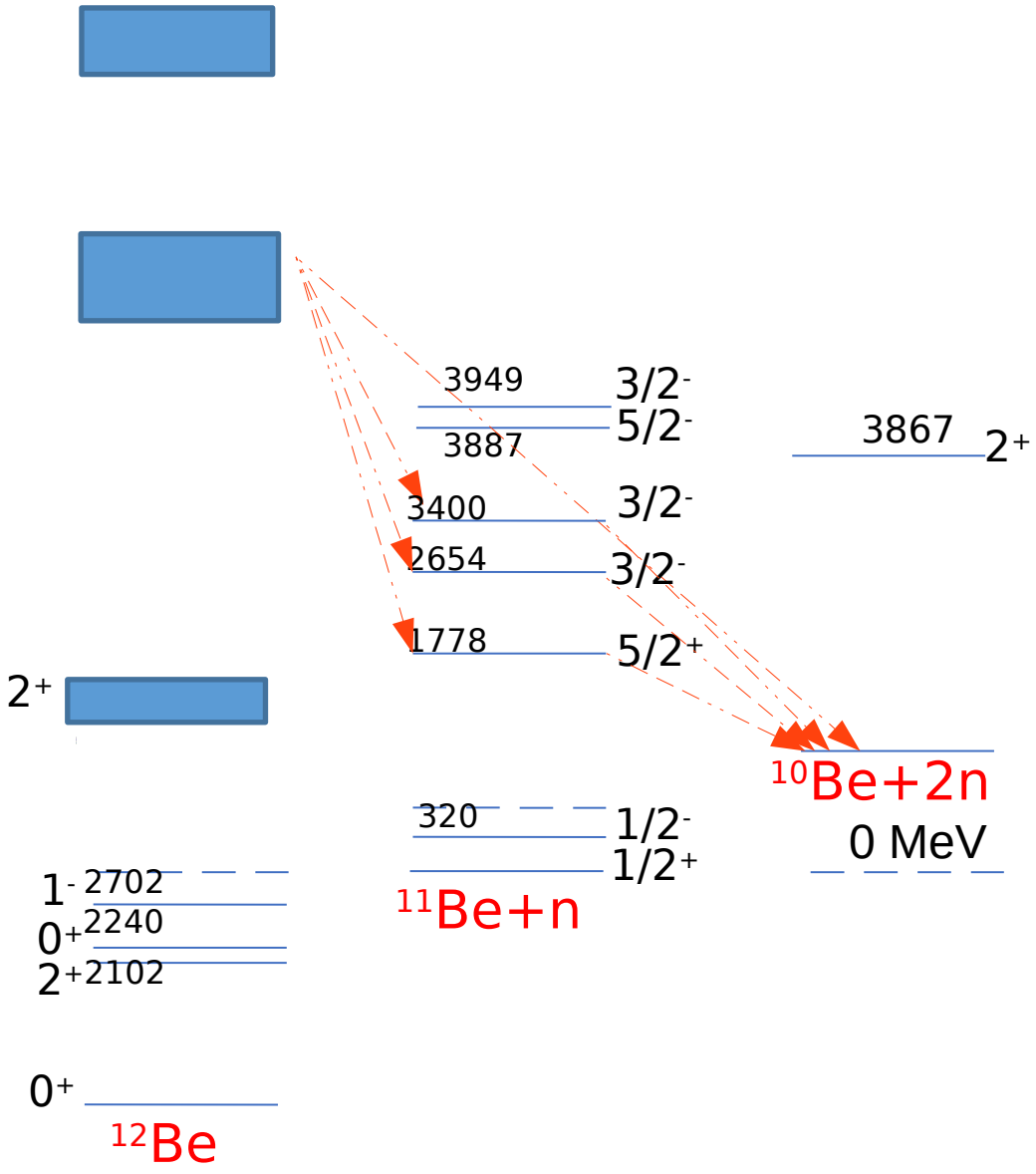
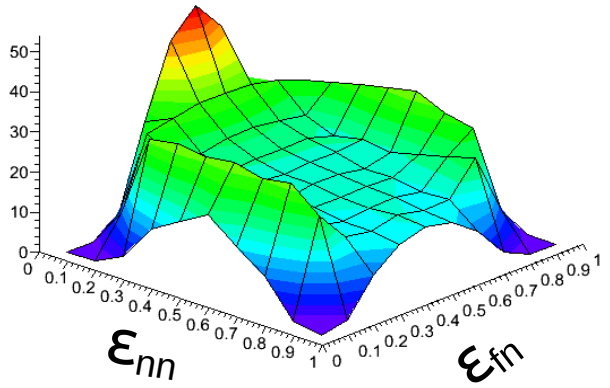
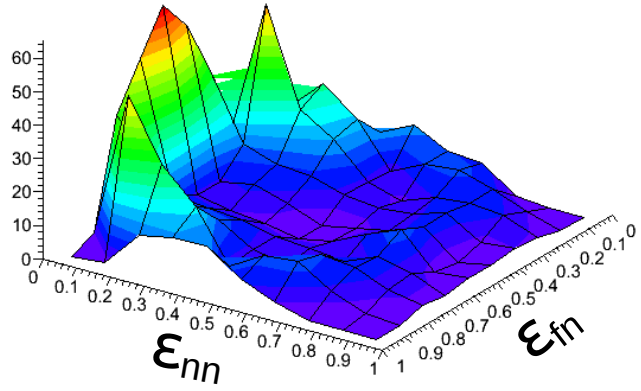
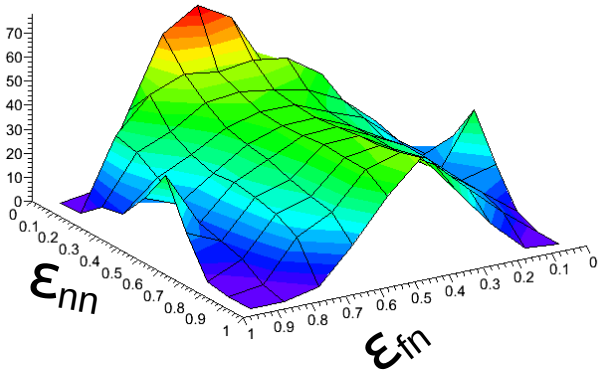
Results :Dalitz plots for $^{10}Be^{*}$+2n states

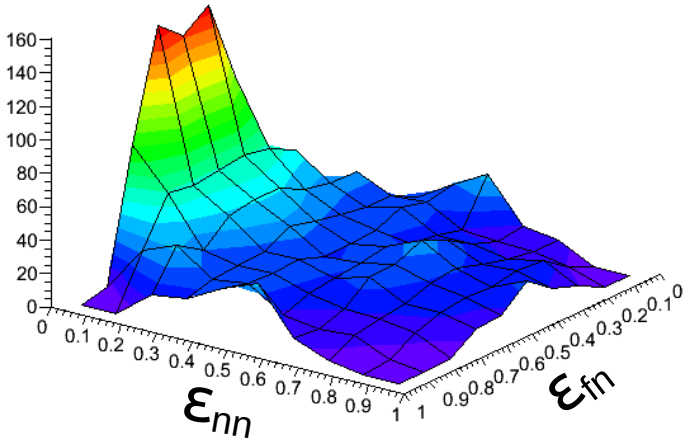






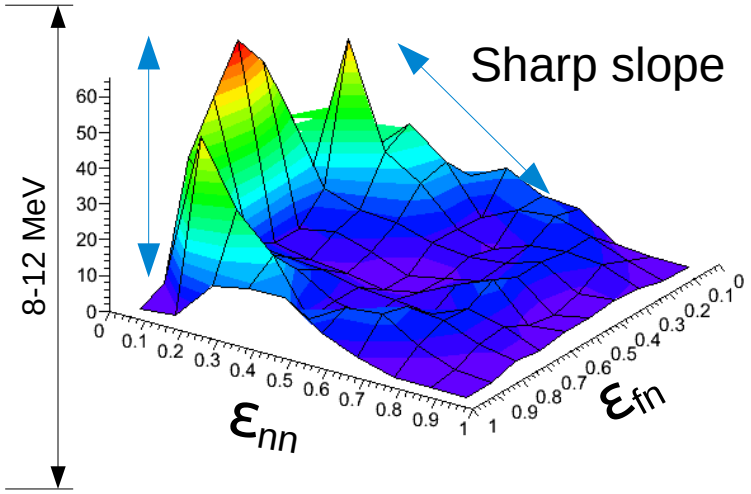


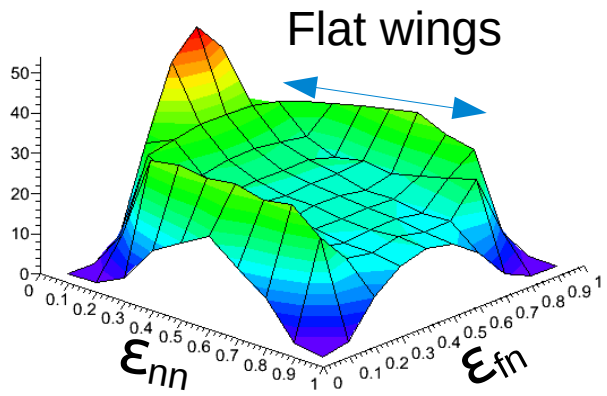
SIMUL



EXP

New Phenomenon



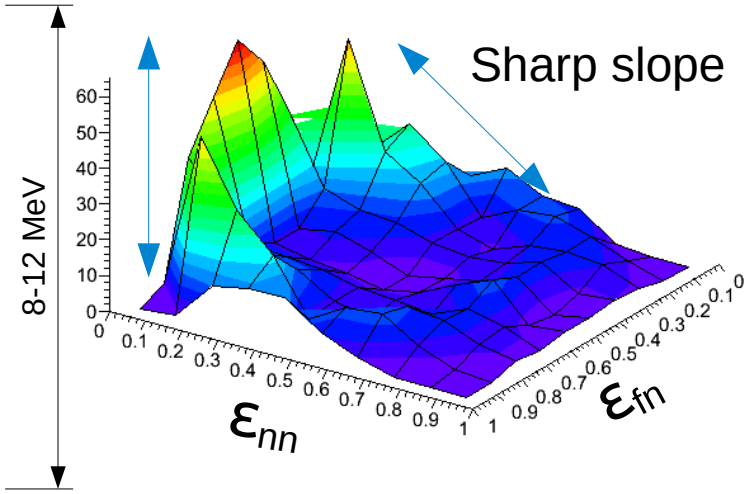


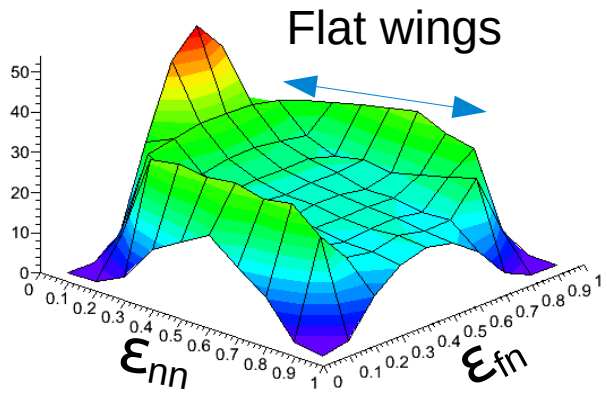
Contradictory inputs

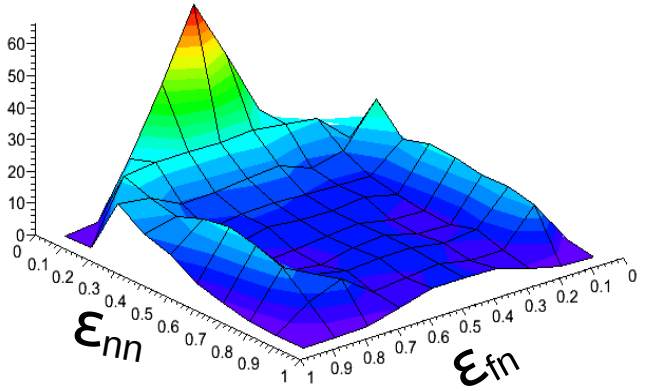
- short living resonance
- narrow resonance

$\tau = \hbar/\Gamma_r$

New Phenomenon





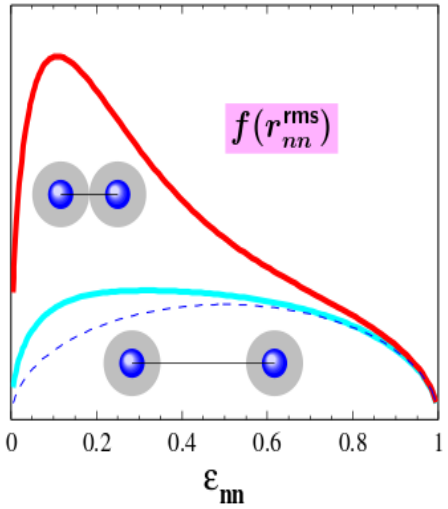


Contradictory inputs

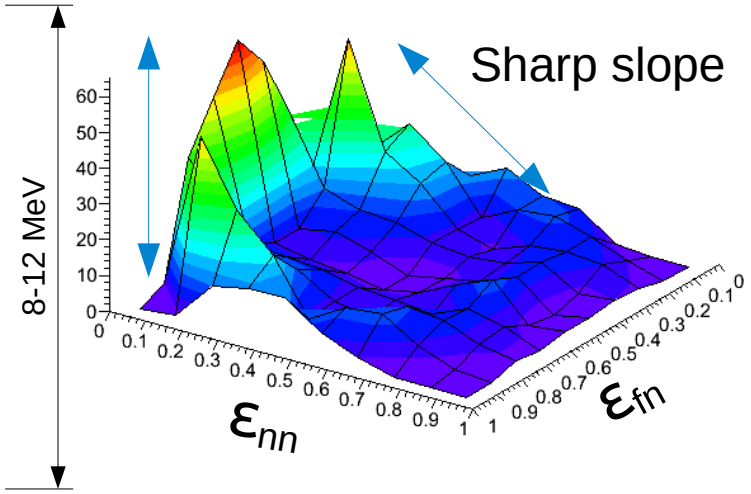
- short living resonance
- narrow resonance

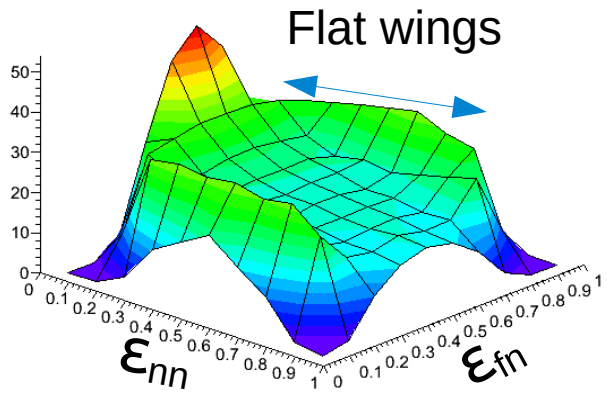
Possible explanations

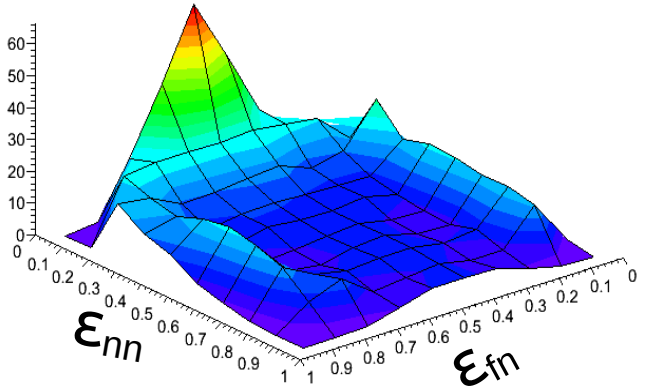
- Very compact structure : $r_{nn} < 2.6$fm



New Phenomenon





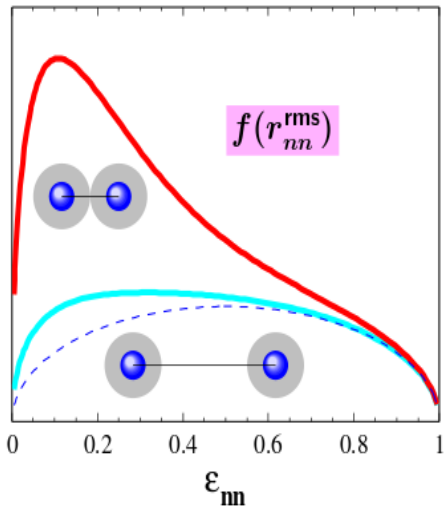


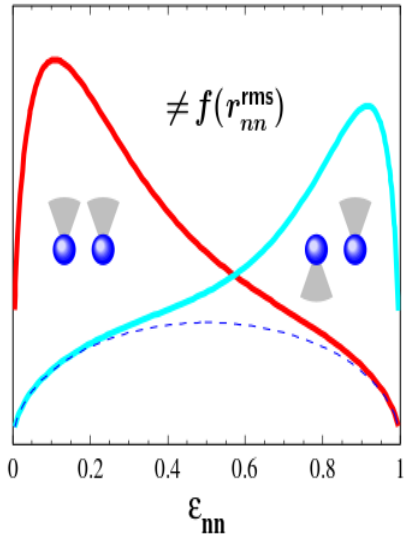
Contradictory inputs

- short living resonance
- narrow resonance

Possible explanations

- Very compact structure : $r_{nn} < 2.6$fm
- Strong momentum correlation : $W(r_{nn}) \rightarrow W(r_{nn}, q_{nn})$



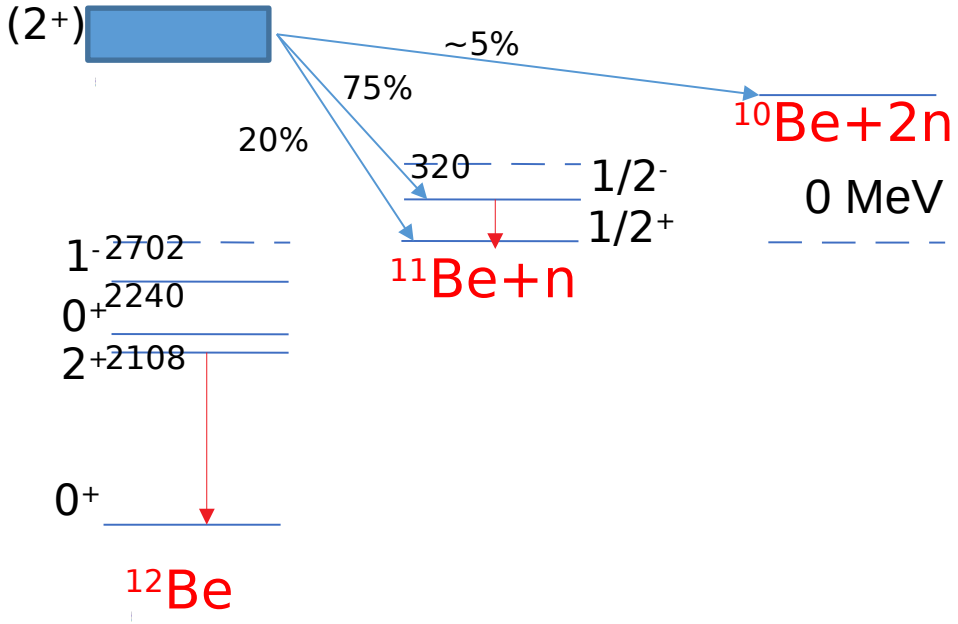


Summary

- ^{13}B was produced by a primary beam of ^{40}Ar (490MeV/n)at GSI

- Using proton knock-out reaction bound and unbound states of ^{12}Be were populated

- A combined detection of Gamma, neutrons and core-fragments allowed us to study these states in detail



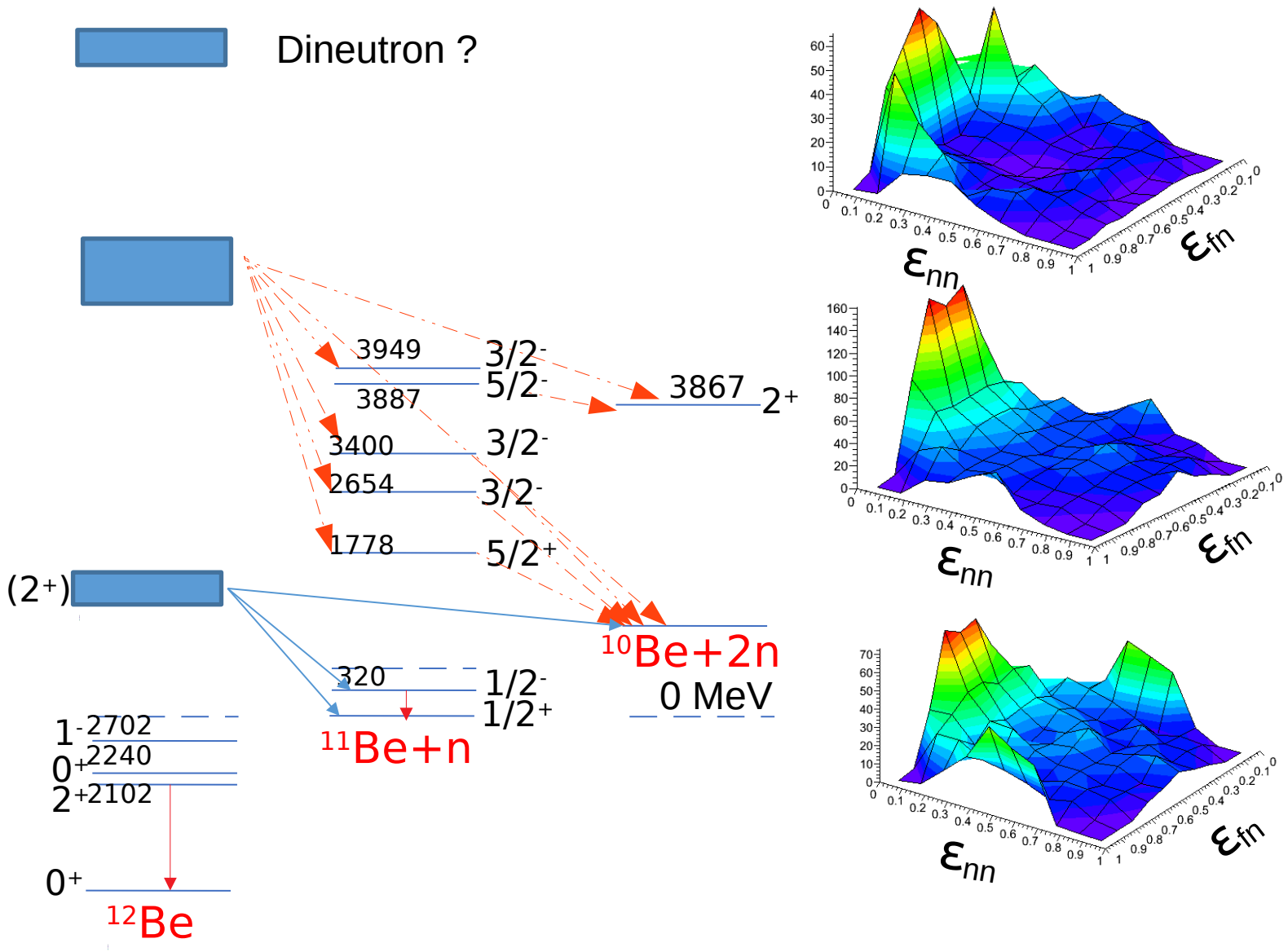
- a bound 2^+ state was observed by gamma detection at 2108 keV

- The second 2^+ state was strongly populated and its decay modes were studied:

The fact that this state decays mainly on the excited state of ^{11}Be (less deformed) and populated from spherical ^{13}B gives a hint on its sphericity

Summary

Higher excited states were studied using Dalitz plots



0-4MeV:
Fit with 15% Sequential decay + 85% Direct decay

New phenomenon

Very compact structure :
$r_{nn} < 2.6$fm
or
Strong momentum correlation :
$W(r_{nn}) \rightarrow W(r_{nn}, q_{nn})$