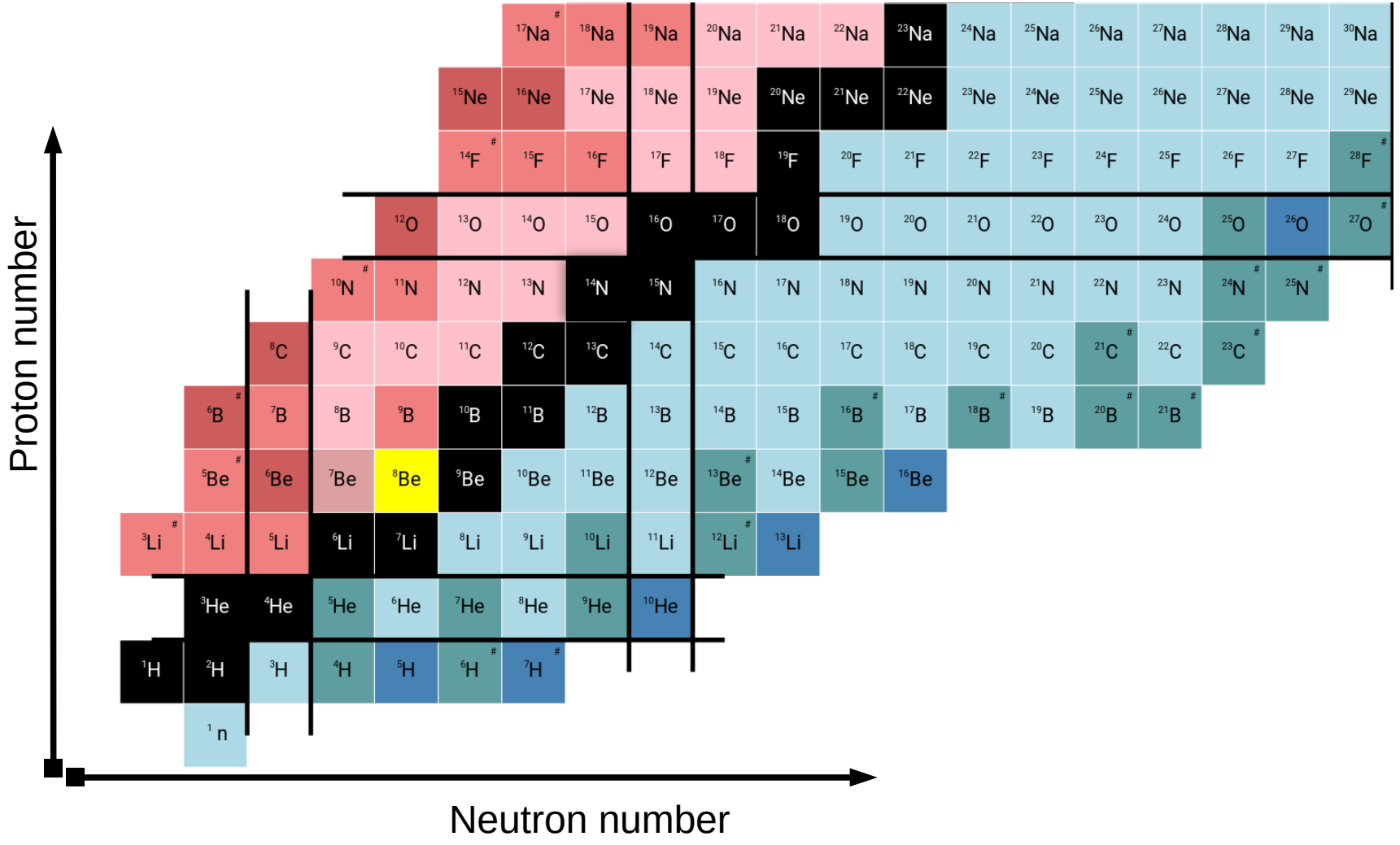
Study of neutron-neutron correlations in ^{12}Be

Armel KAMENYERO

Under the supervision of Olivier Sorlin and Miguel Marqués

JRJC, Centre Moulin-mer, 28th/November-2019

Nuclear energy levels



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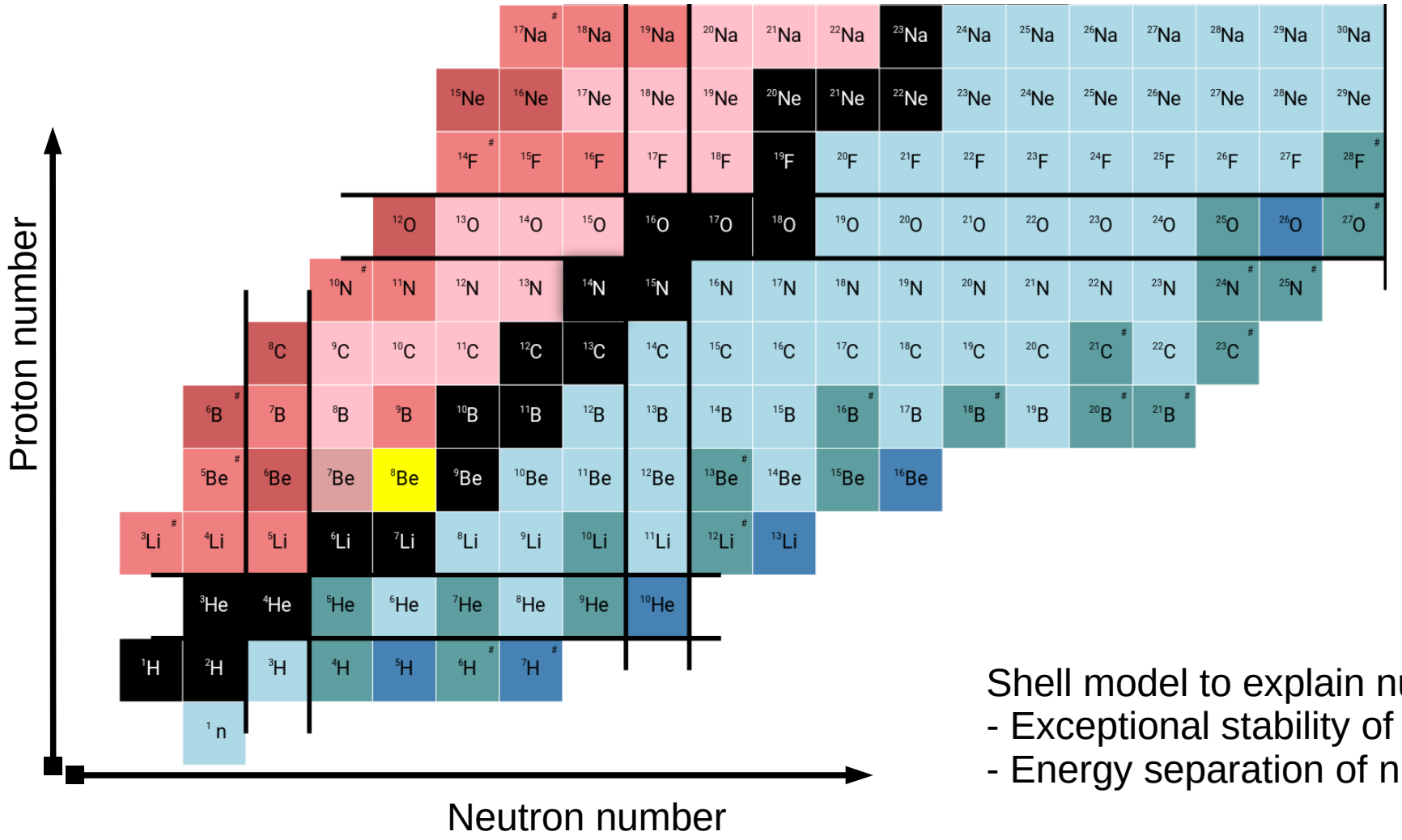
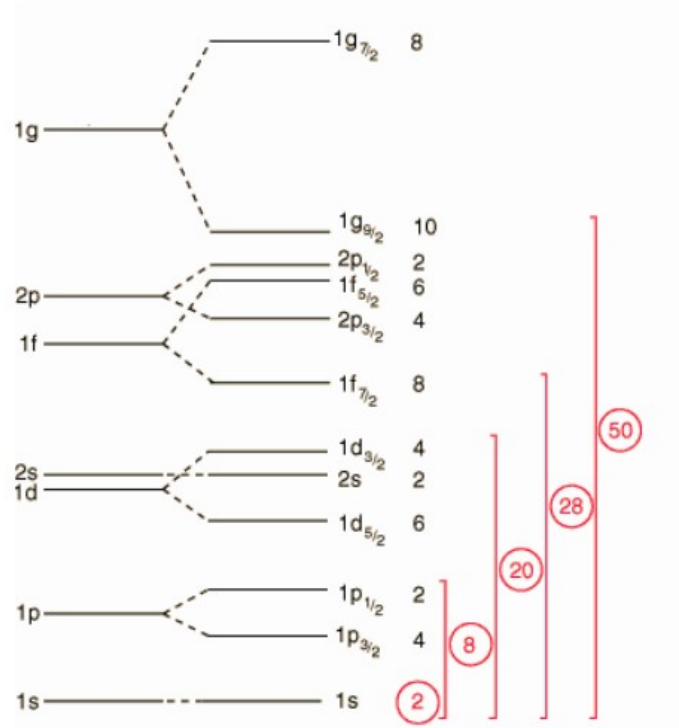




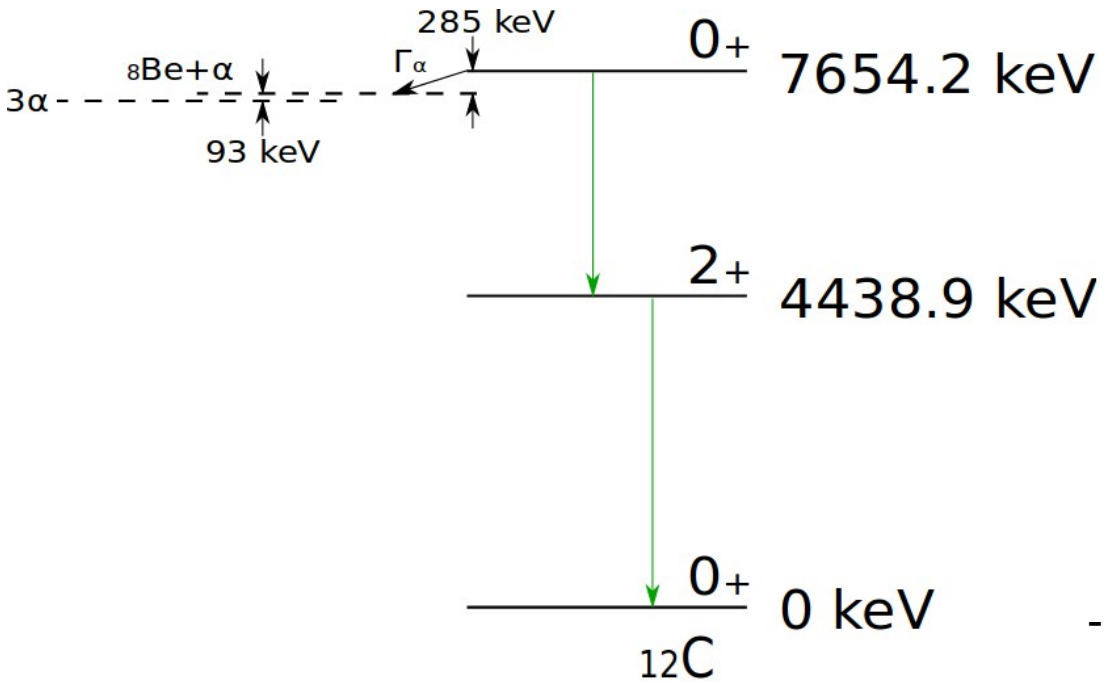
Shell model to explain nuclear structure :
- Exceptional stability of some nuclei (Magic Number)
- Energy separation of nuclei

↓

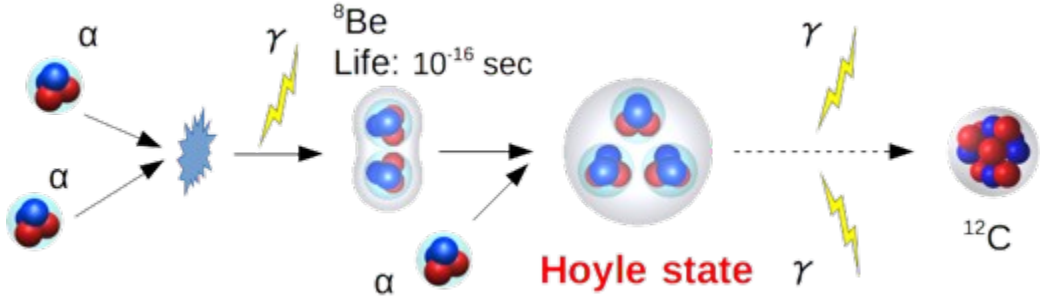
Single particle in a mean-field

Shell models vs new Phenomena in light nuclei

1. Clustering : Hoyle state



- Fred Hoyle : explaining the creation of ^{12}C form ^{4}He (α-particle)



- Ikeda conjecture : links clustering to α-emission threshold

Other examples : ^{8}Be, ^{16}O

Shell models vs new Phenomena in light nuclei

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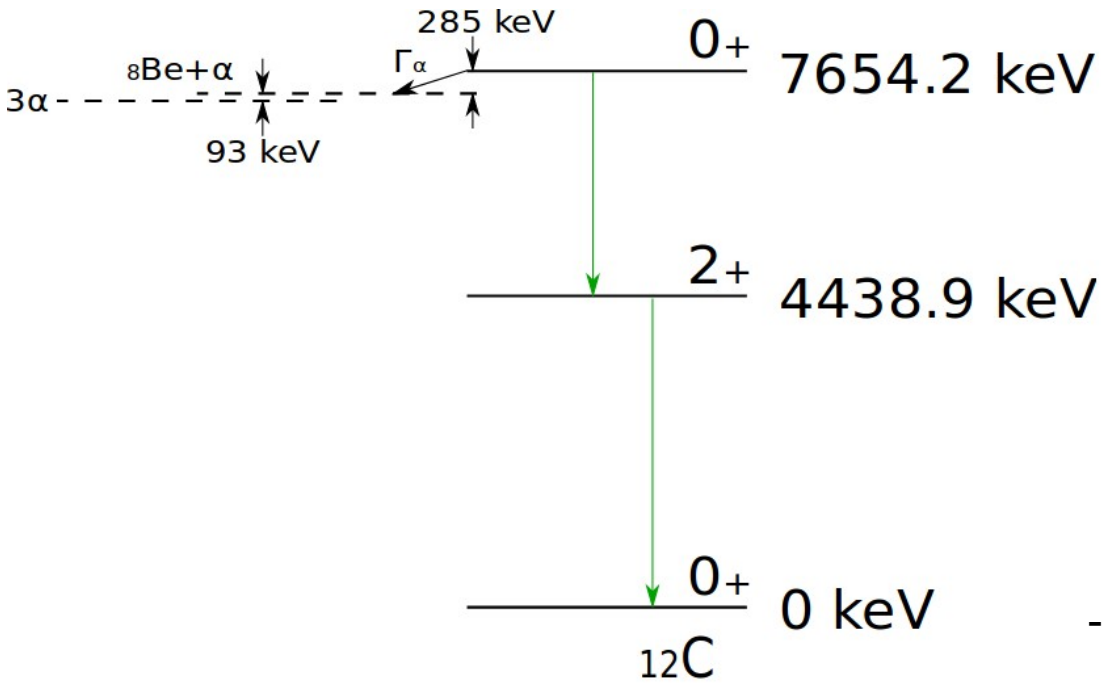

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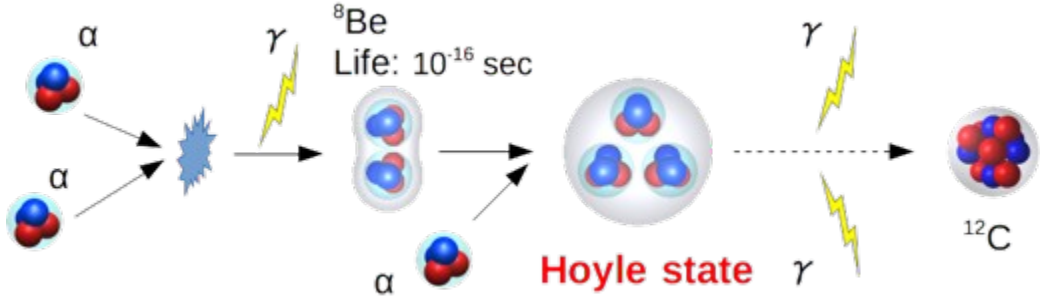


- Ikeda conjecture : links clustering to α-emission threshold

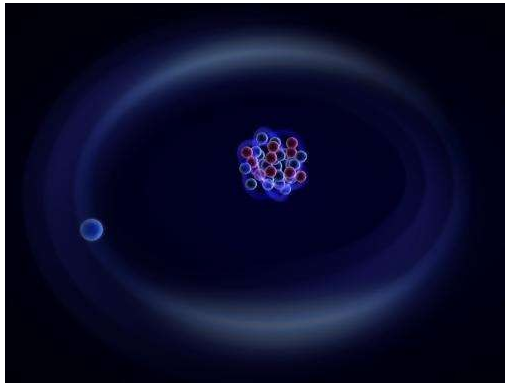
Other examples : ^{8}Be, ^{16}O

- Generalized Ikeda : neutron/proton clustering ?

Shell models vs new Phenomena in light nuclei

1. Clustering : Hoyle state

2. Neutron halo



- Spatial expansion of nuclei :
  Weakly bound neutrons form a cloud around a more compact core

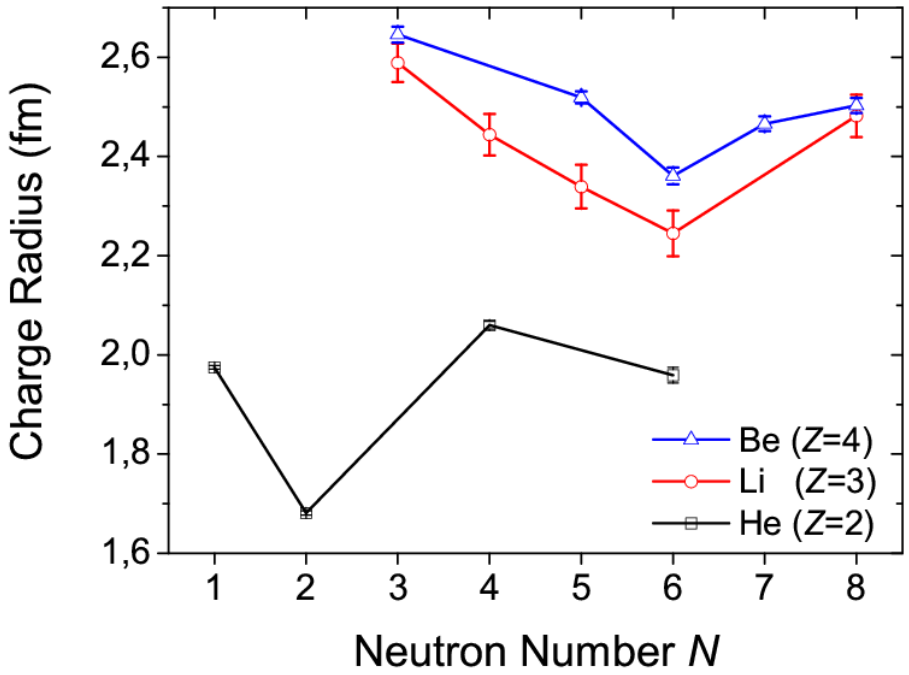
-examples : ^{11}Be, ^{11}Li , ^{14}Be

Shell models vs new Phenomena in light nuclei

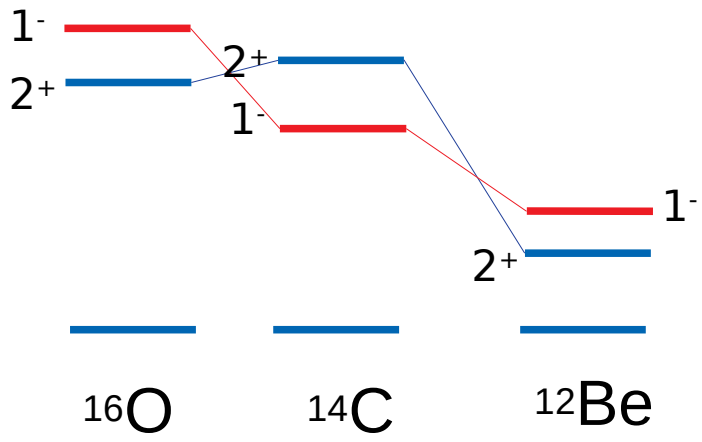
1. Clustering : Hoyle state

2. Neutron halo

3. Disappearence of Magic numbers N=8, 20



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



Shrinking of the gap between the ground state and first excited state in ^{12}Be

Shell models vs new Phenomena in light nuclei

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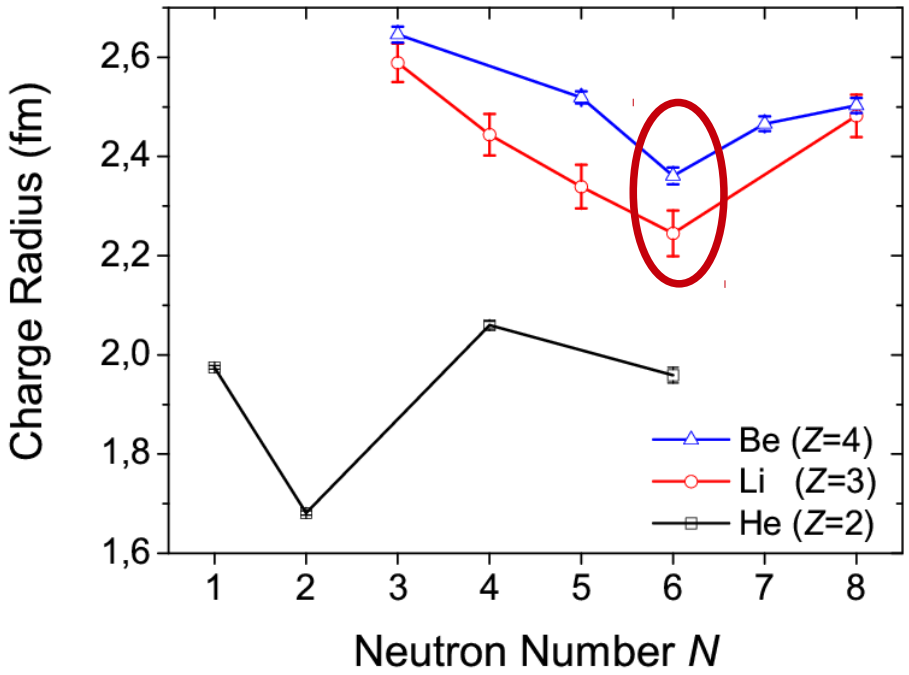

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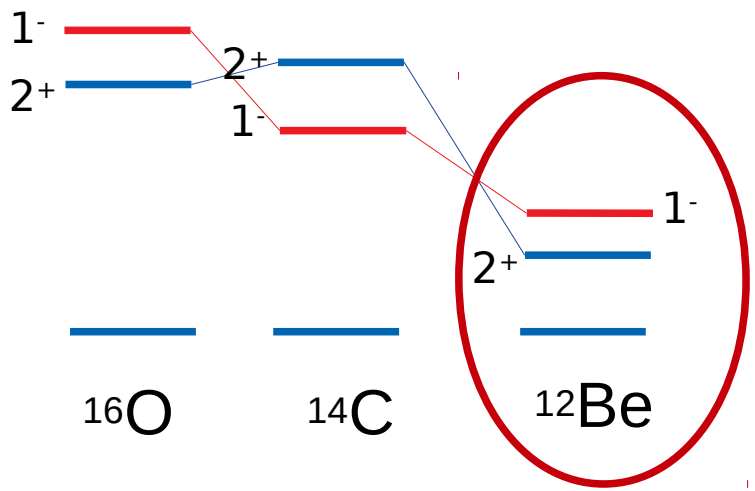
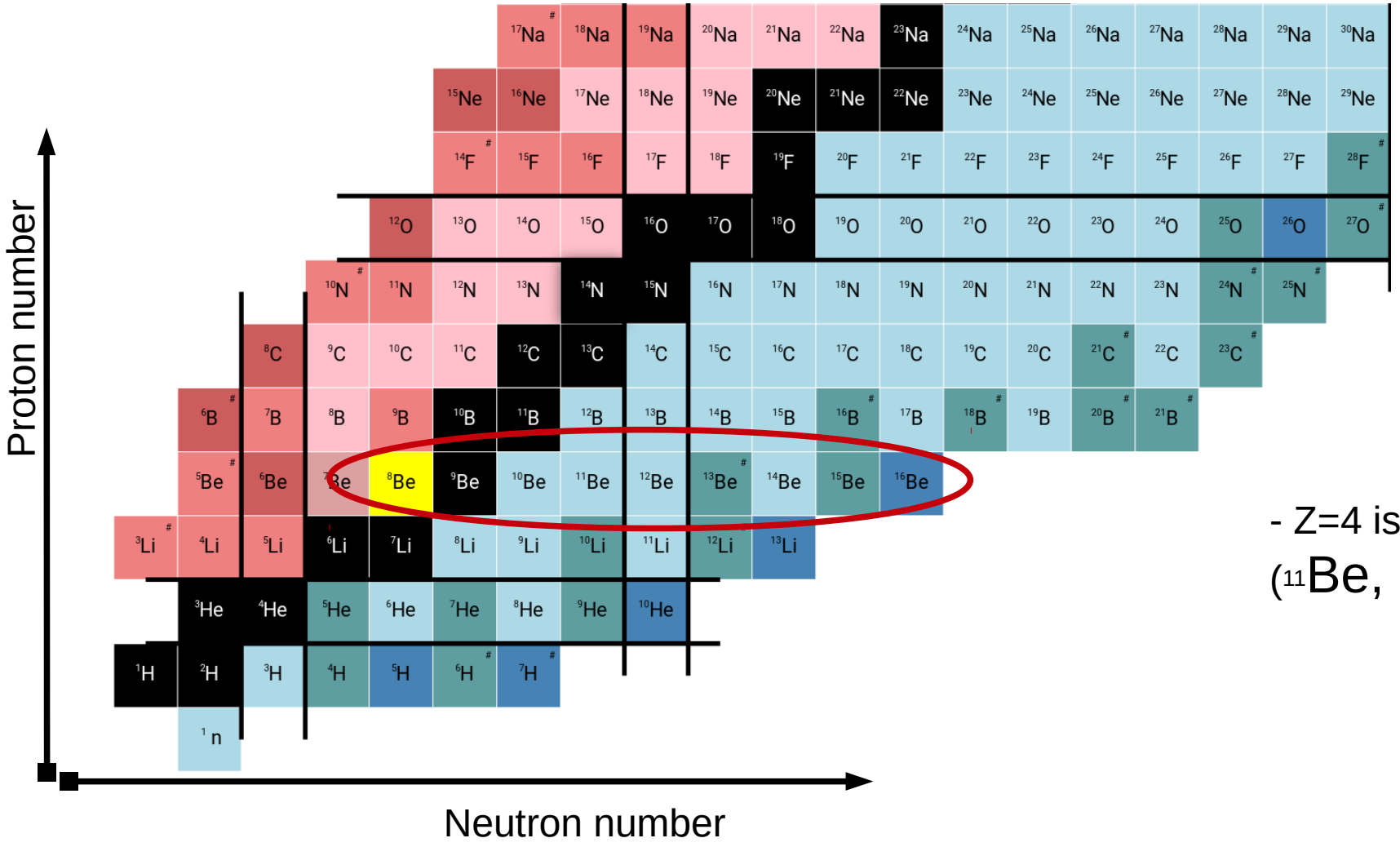


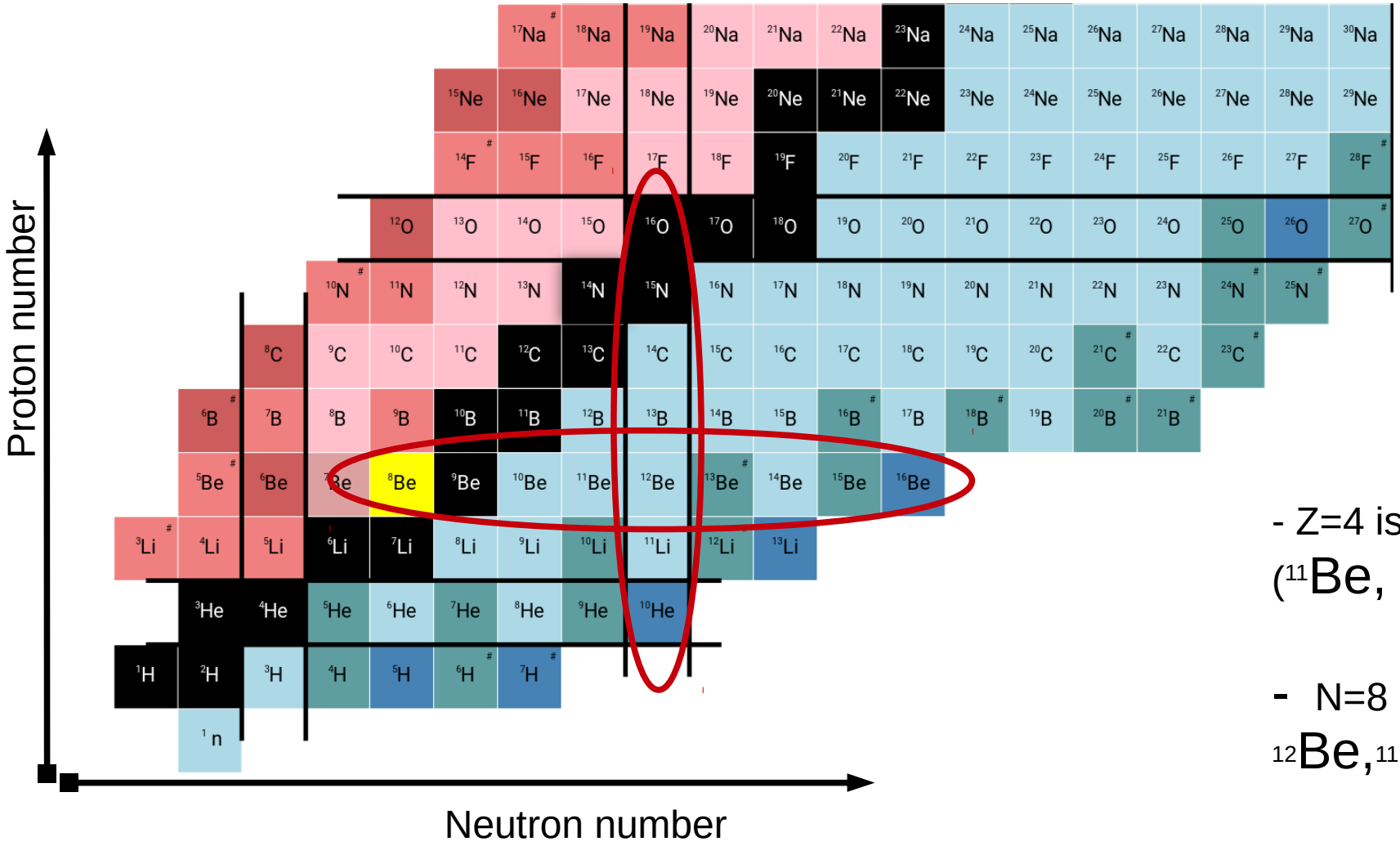
Breakdown of N=8 in ^{12}Be

Choosing ^{12}Be



- Z=4 isotopes : clustering (^{8}Be), halo (^{11}Be, ^{14}Be), and spherical (^{10}Be)

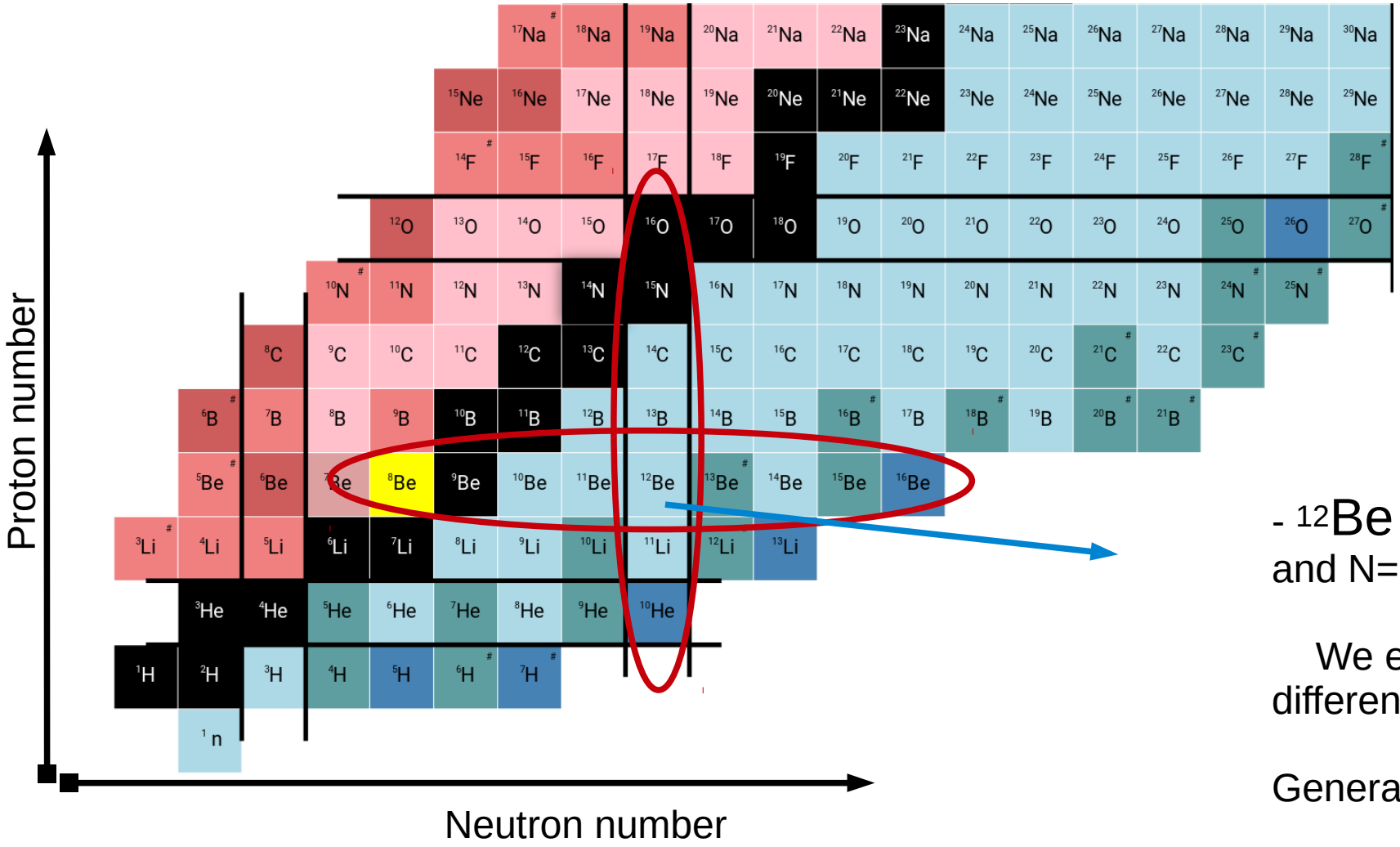
Choosing ^{12}Be



- Z=4 isotopes : clustering (^{8}Be), halo (^{11}Be, ^{14}Be), and spherical (^{10}Be)

- N=8 isotones : disappearence in ^{12}Be,^{11}Li

Choosing ^{12}Be

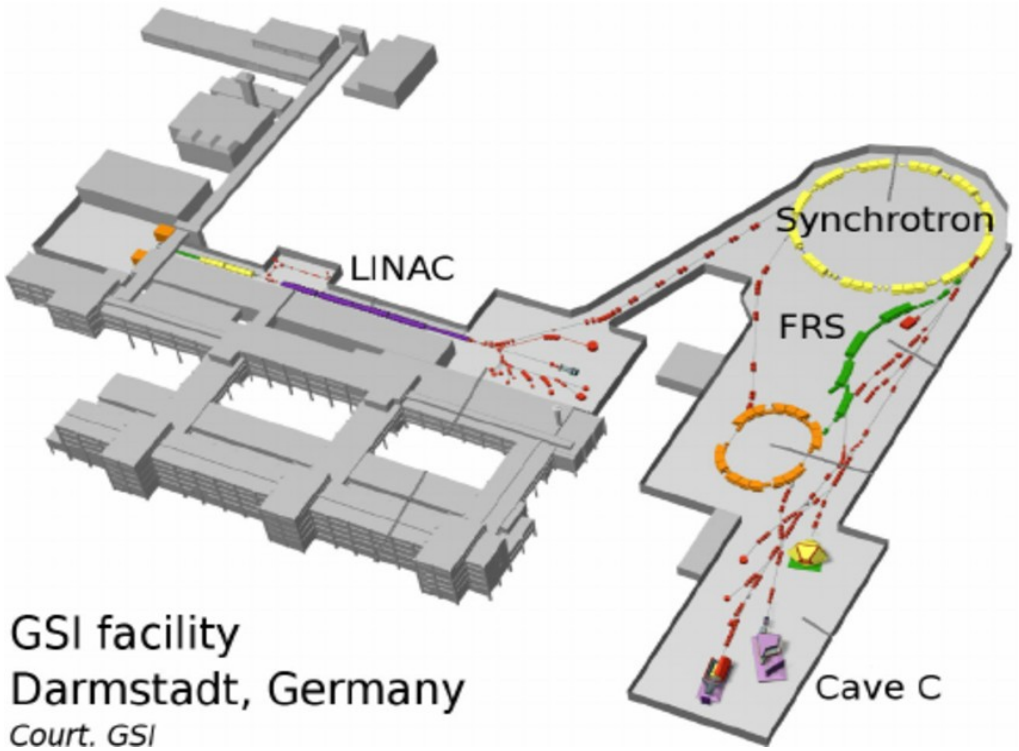


- ^{12}Be is at the crossroad of Z=4 isotopes and N=8 isotones :

We expect to find all these shapes at different energy levels,

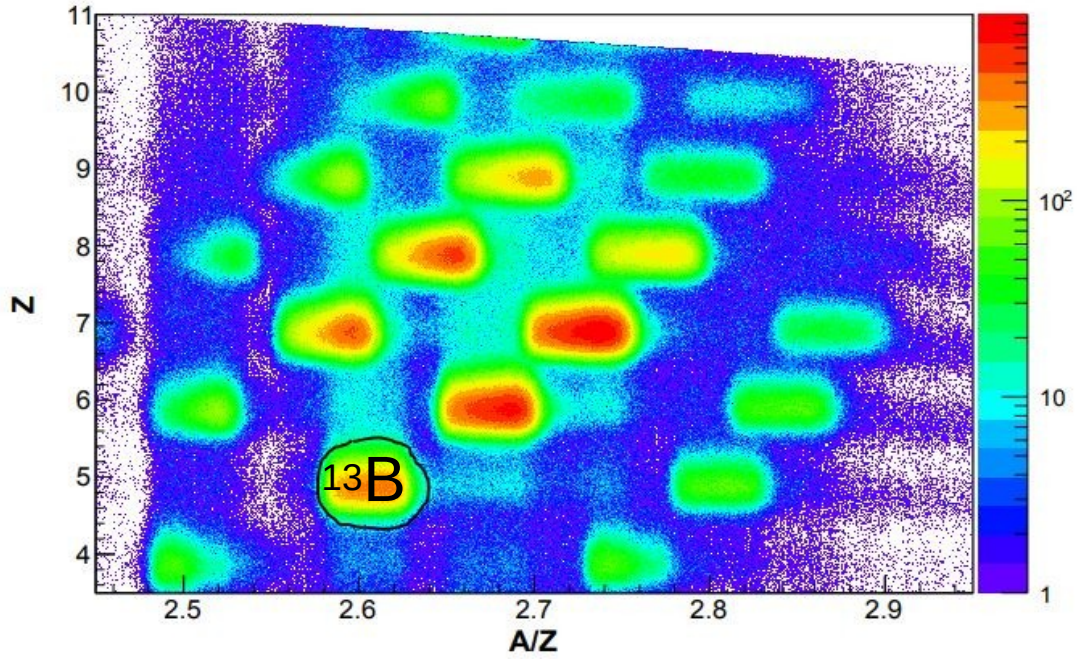
Generalized Ikeda : two-neutrons emitters

Experimental setup



S393 experiment(2010)

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



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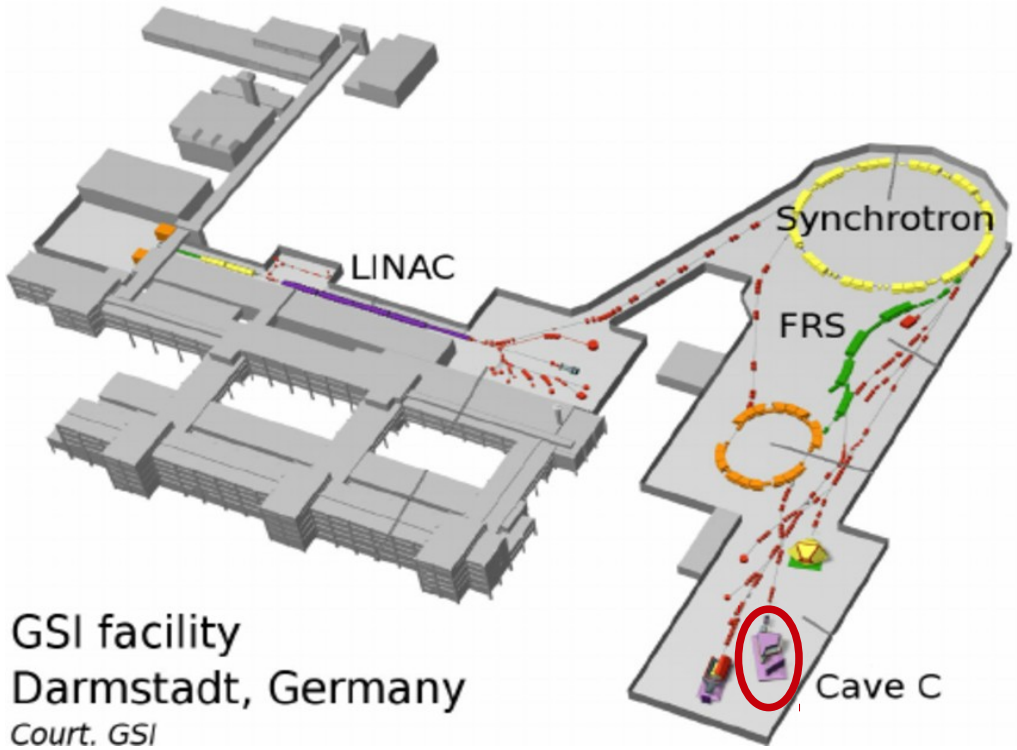

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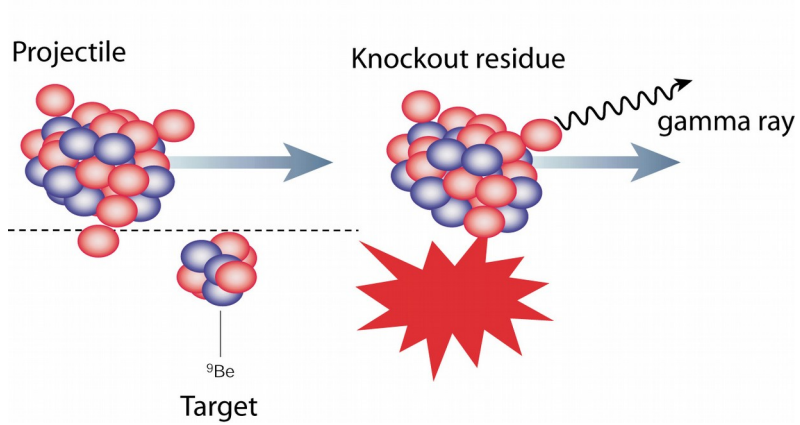
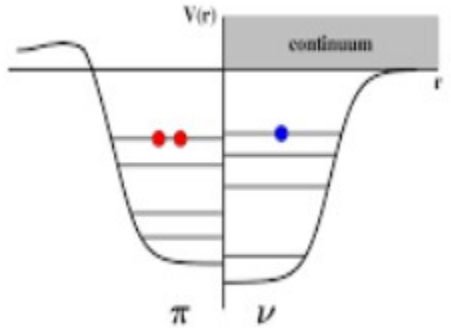
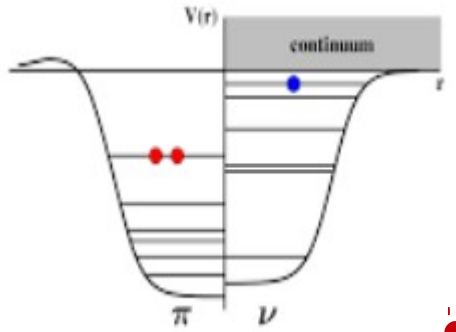


^{13}B $\xrightarrow{-p}$ ^{12}Be (+γ)
^{11}Be +n (+γ)
^{10}Be +2n (+γ)





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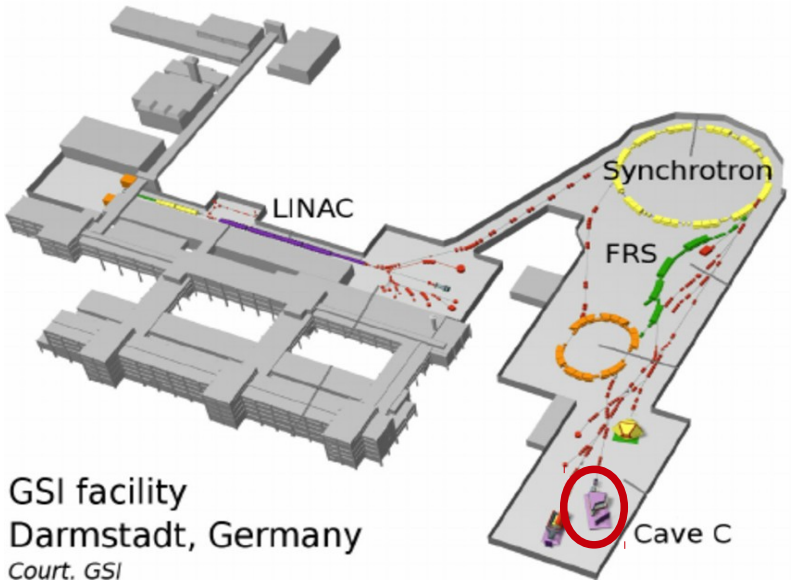
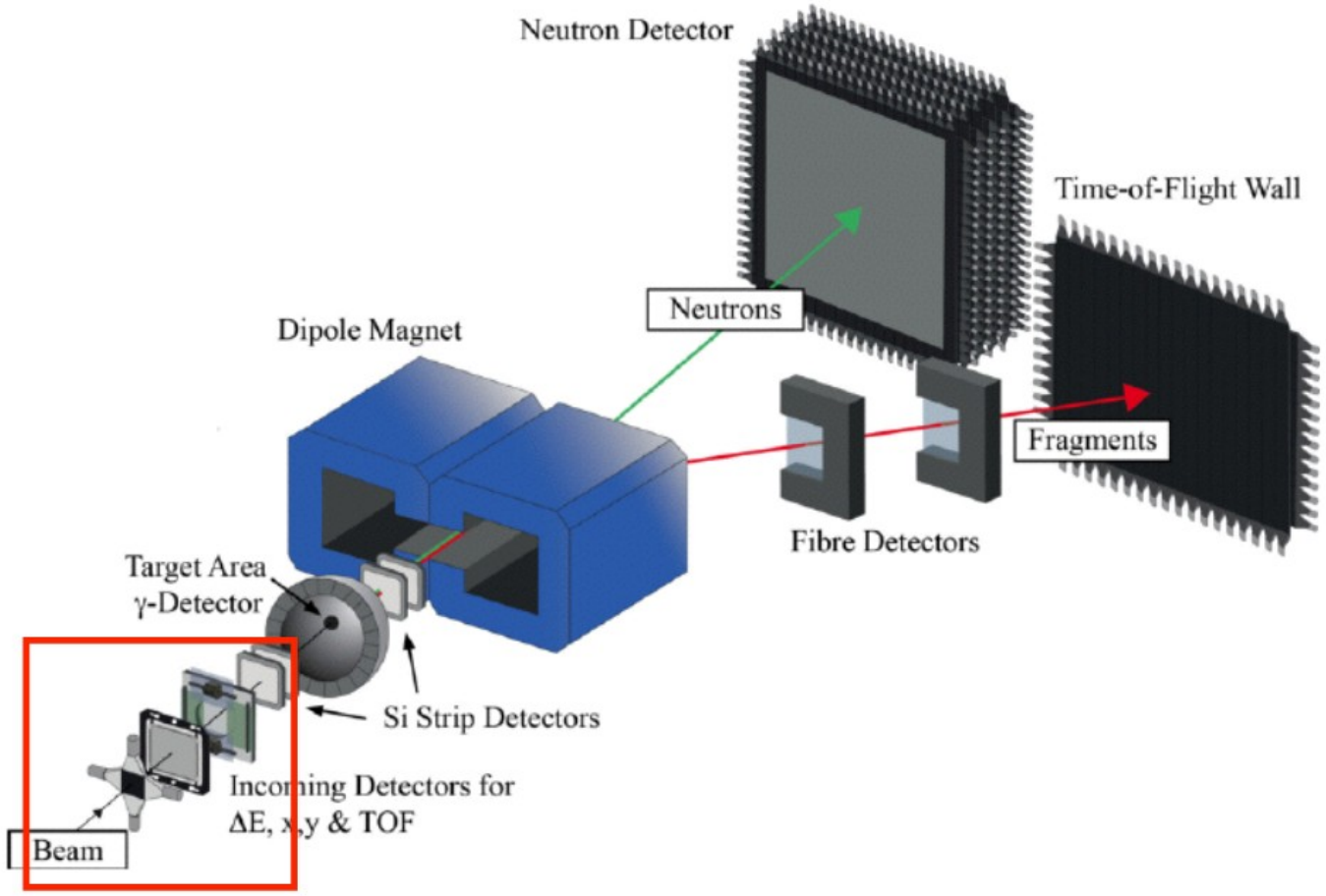


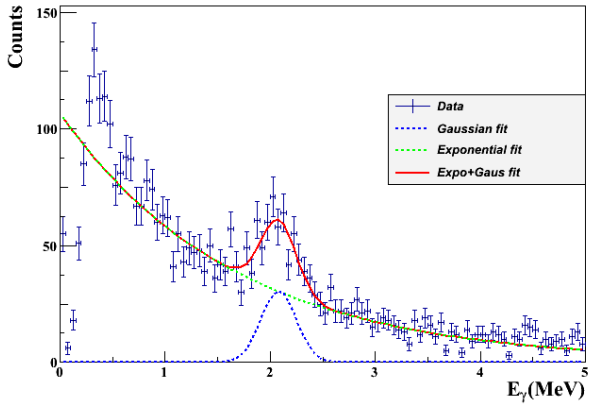
- The radioactive secondary beam is sent to the experimental area : cave C

- tracker detectors for position and tof measurement are placed before and after the target

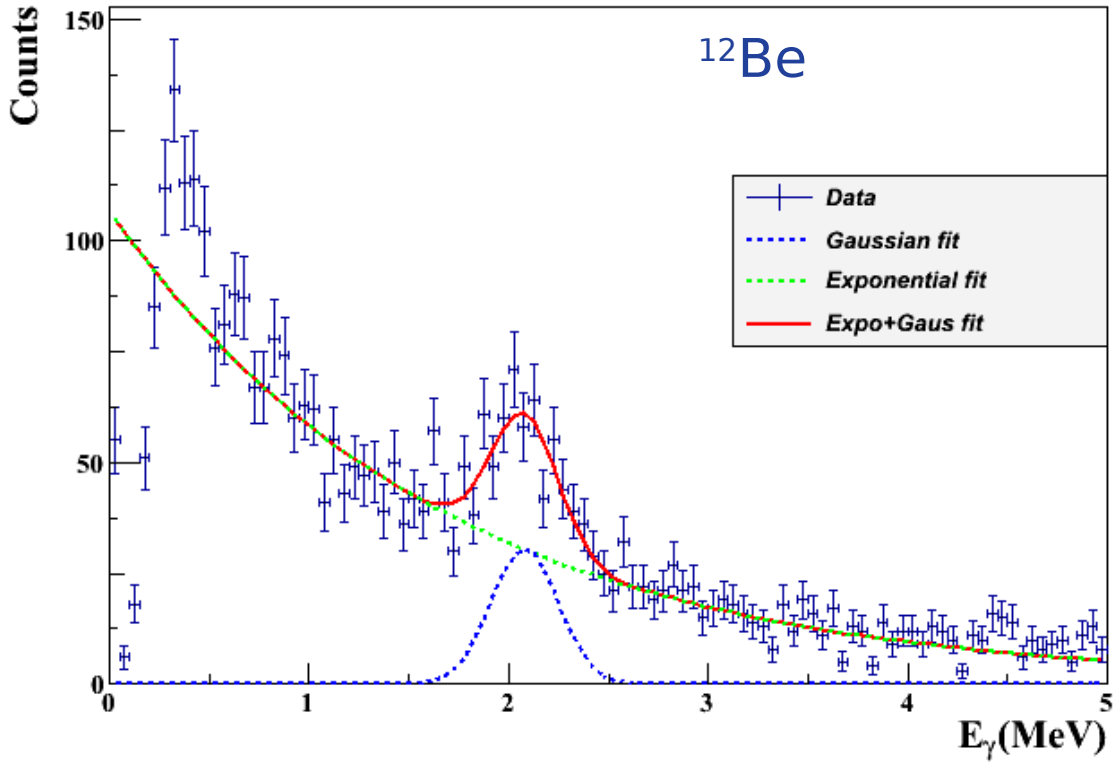


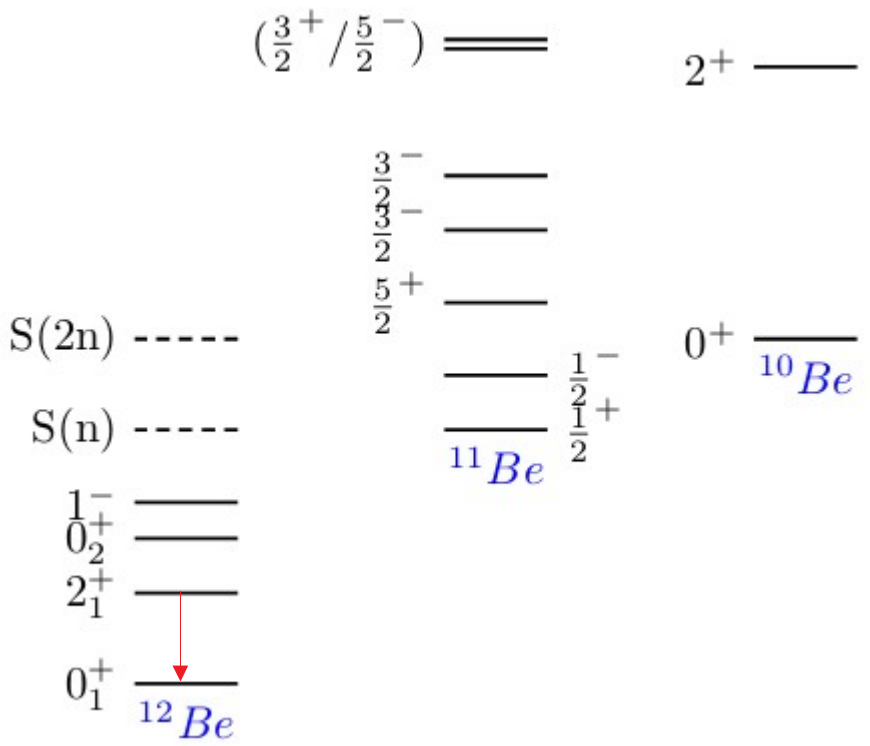
Experimental setup

$^{13}B \xrightarrow{-p} {}^{12}Be\ (+\gamma)$



Results : bound states





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$^{11}Be + n\ (+\gamma)$
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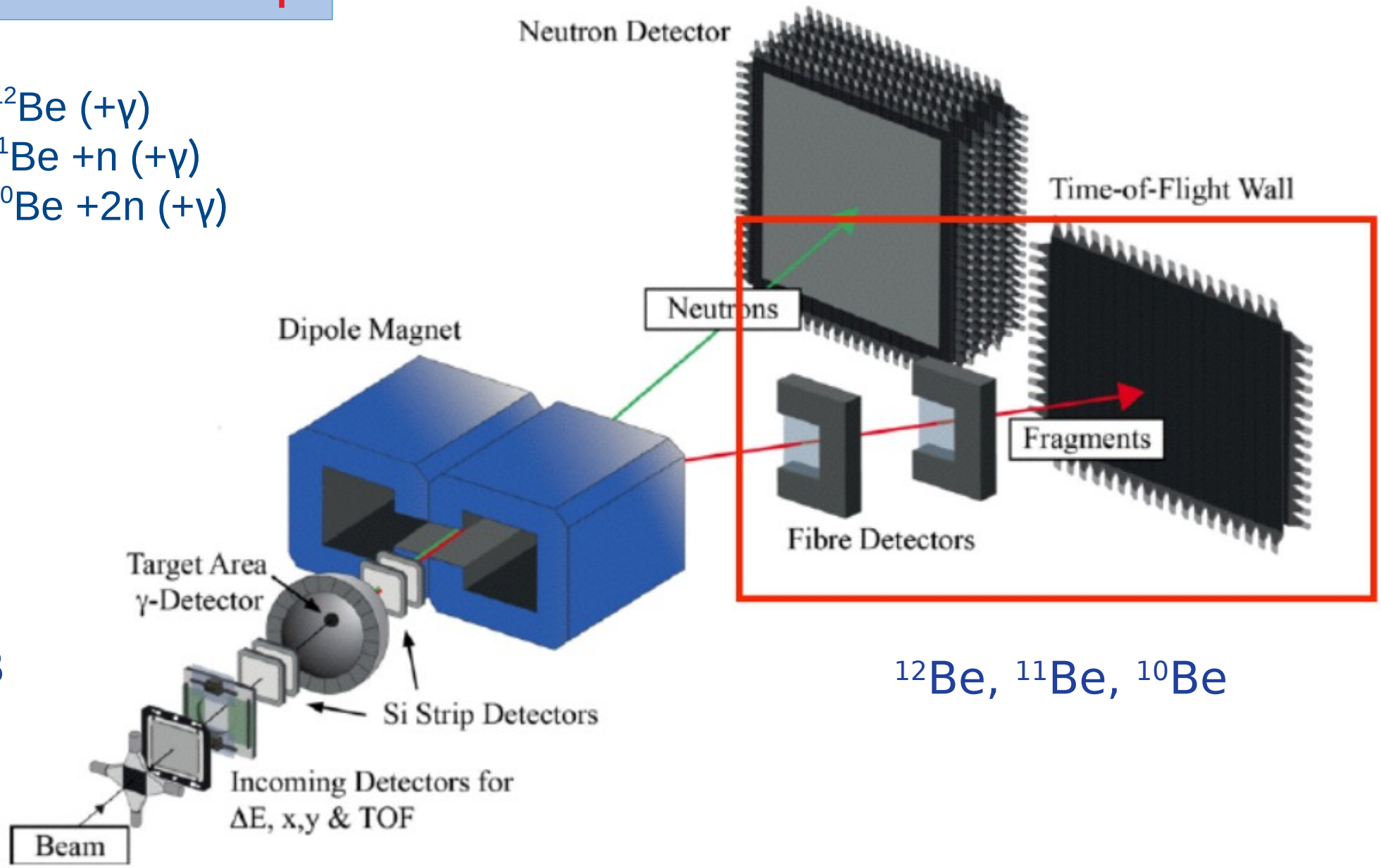
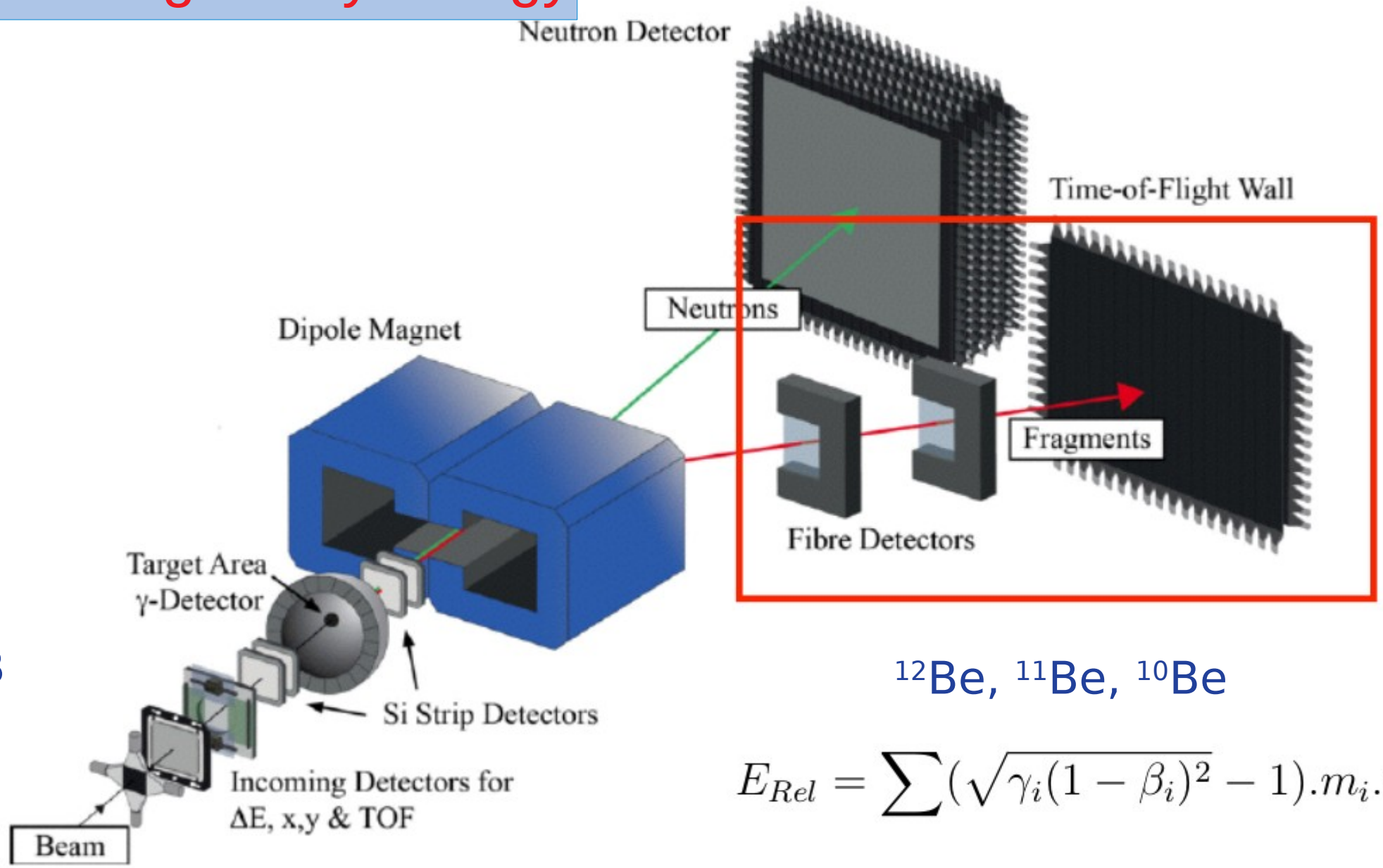


^{13}B

^{12}Be, ^{11}Be, ^{10}Be

Reconstructing decay energy

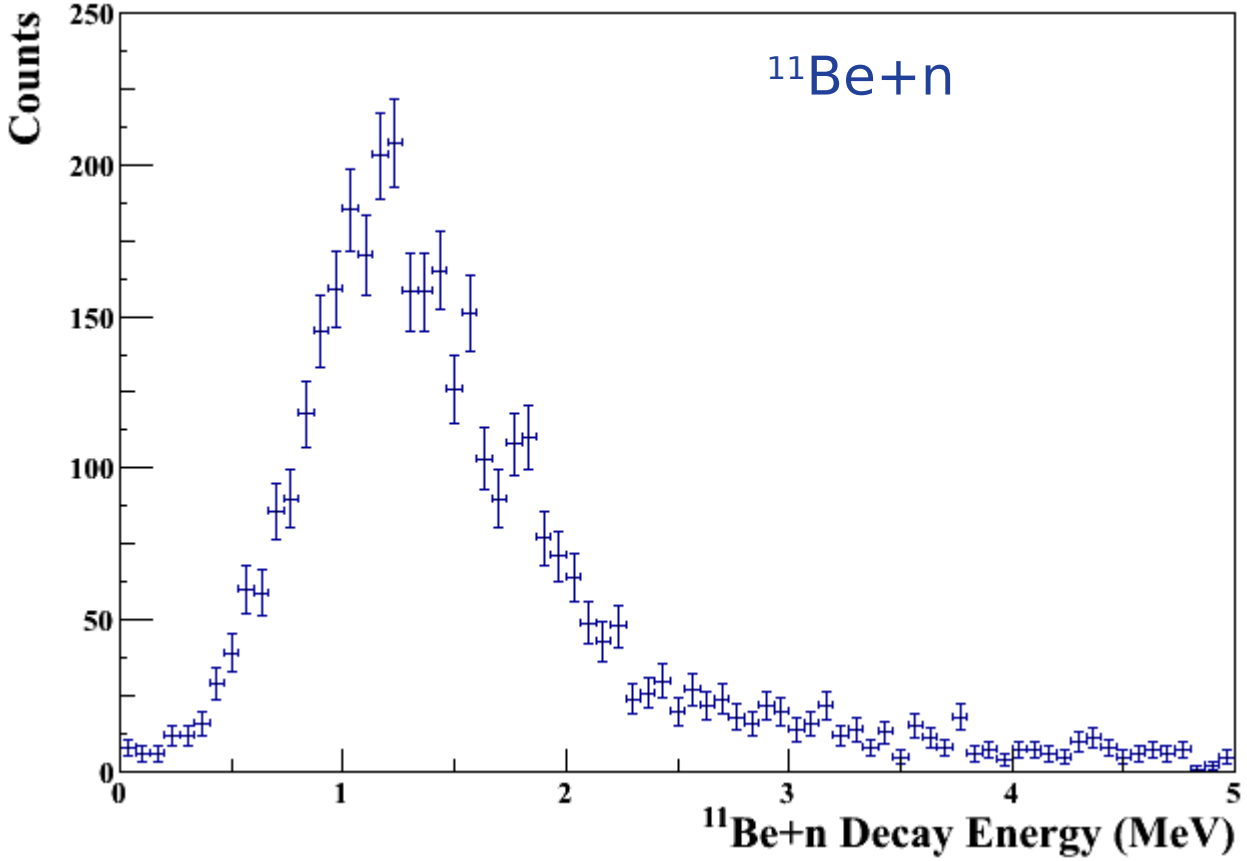


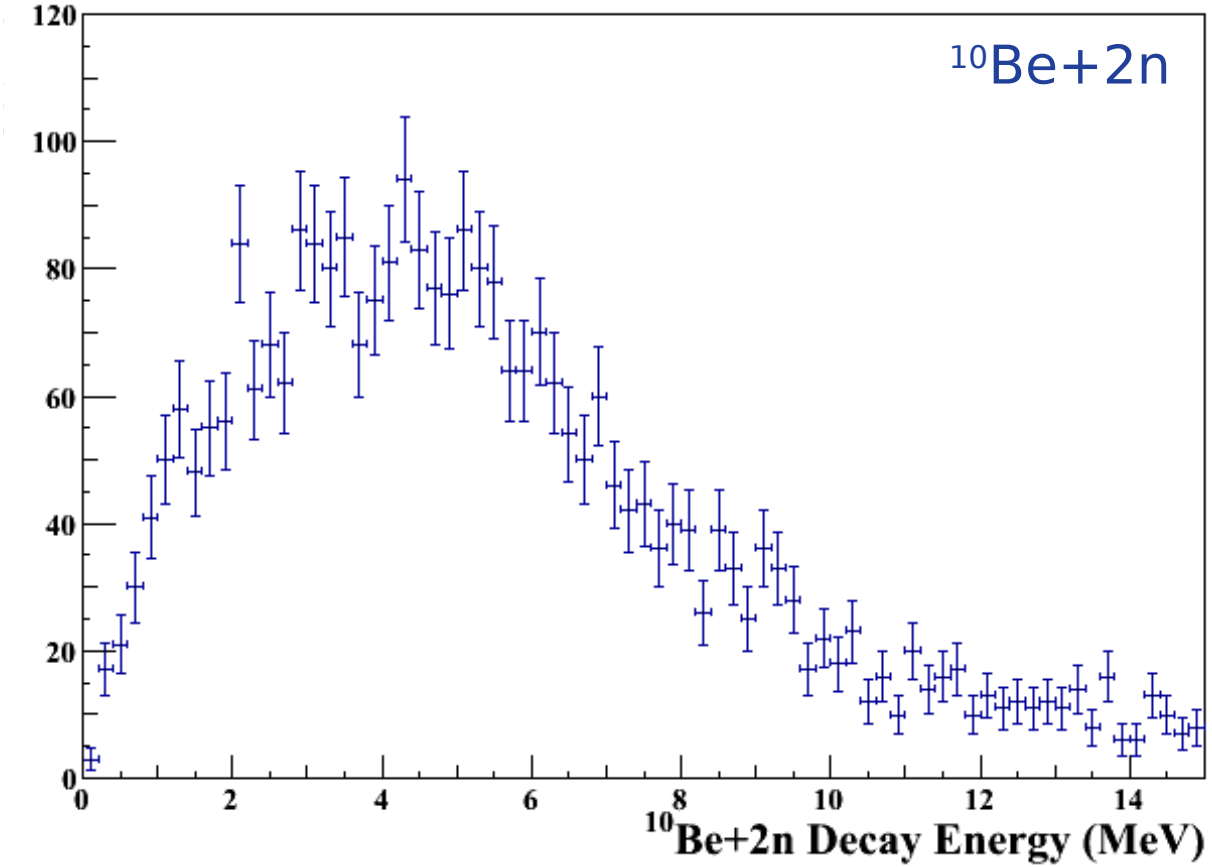
^{13}B

^{12}Be, ^{11}Be, ^{10}Be

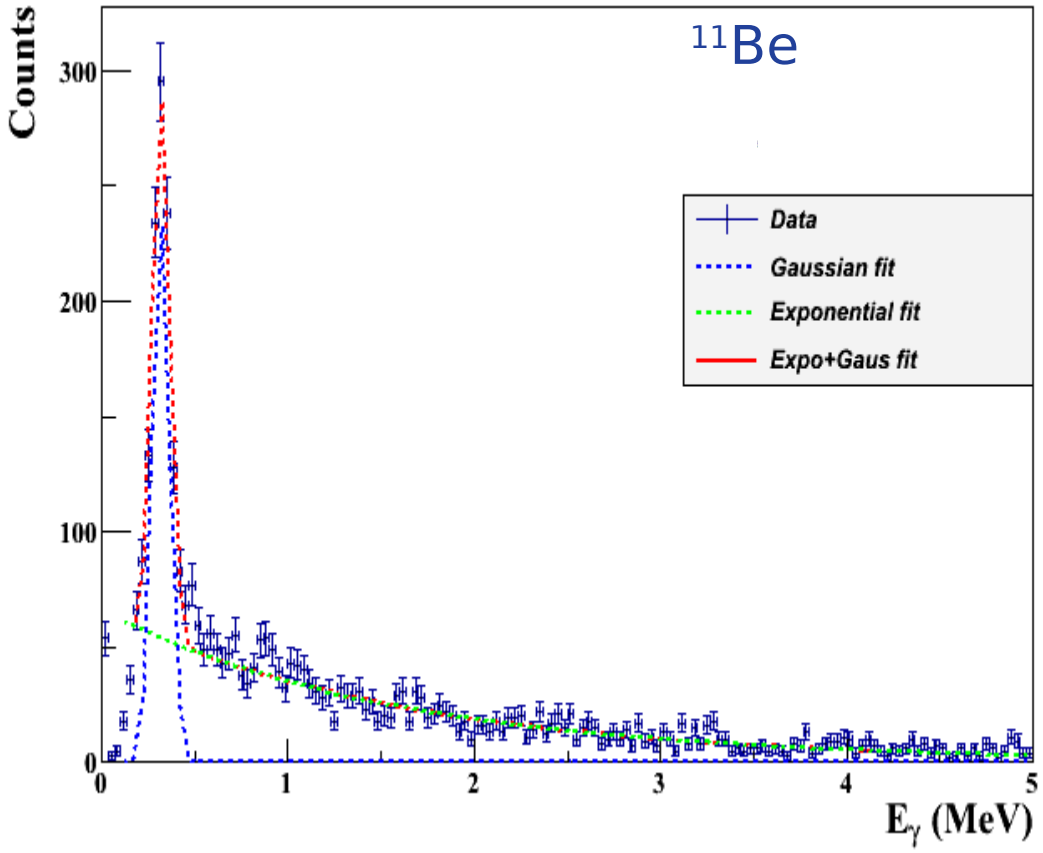
$$E_{Rel} = \sum (\sqrt{\gamma_i (1-\beta_i)^2} - 1).m_i.c^2$$

Decay energy for unbound states

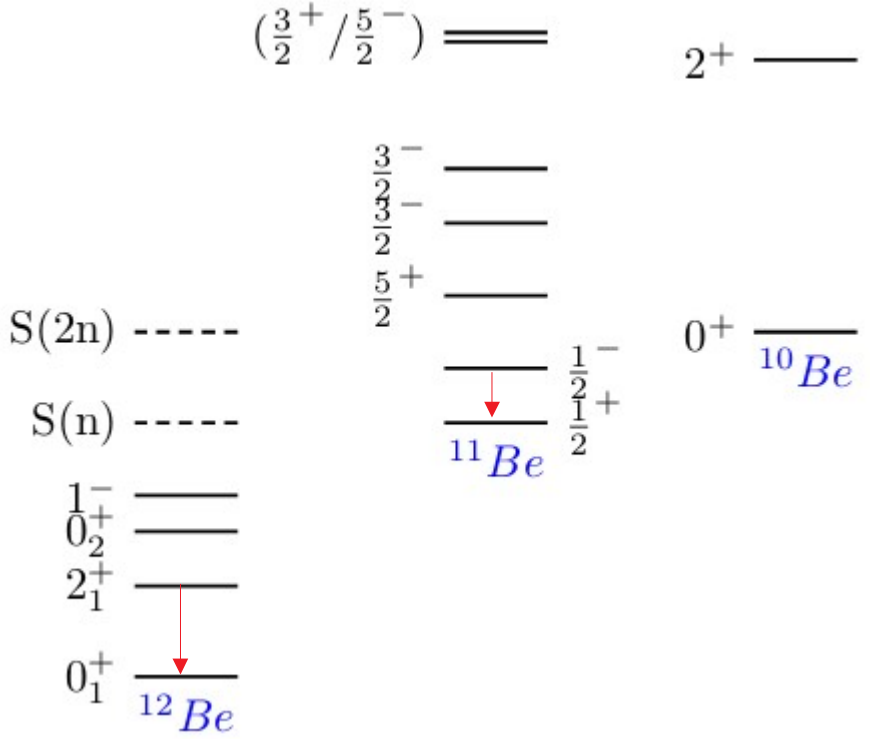




Results : Unbound $^{11}Be^{*}$+n states



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



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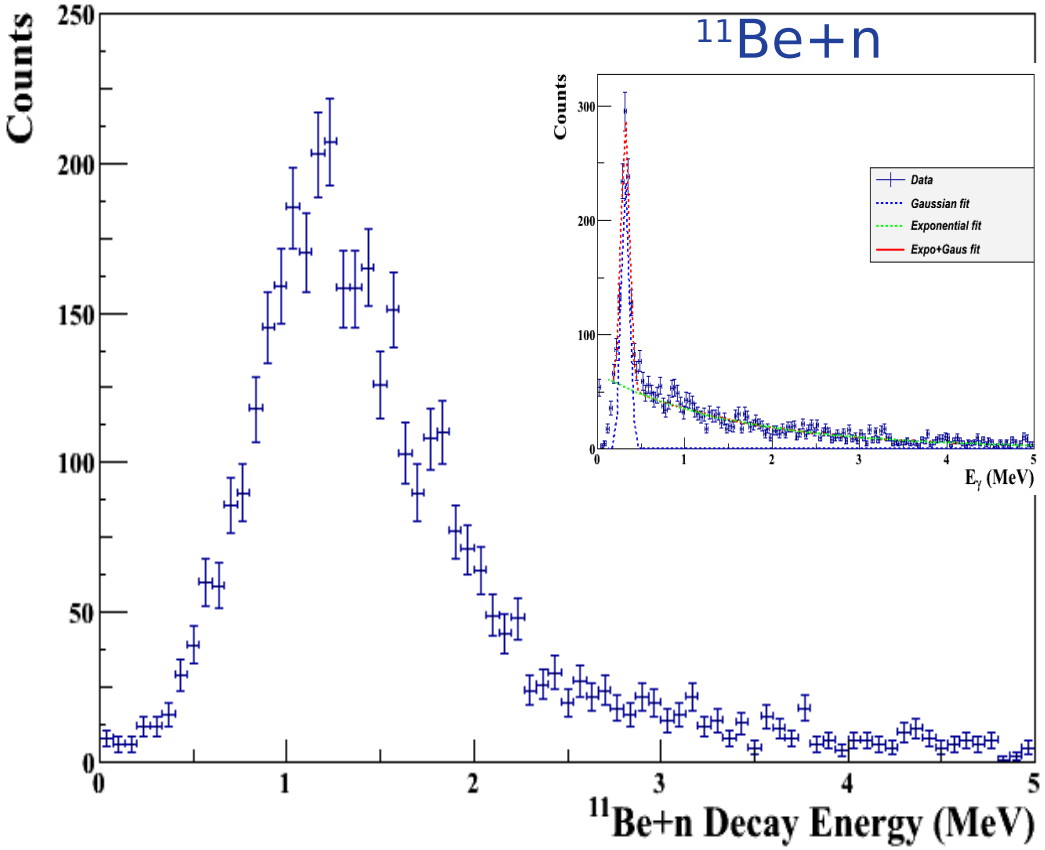

Fit : Momentum dependant Breit-Wigner function convolved by response function(resolution of the detector)

$$\sigma = \sigma_{max} \frac{\sum_l C^2 S(l) * \Gamma(l,E)}{(E - E_r)^2 + \sum_l C^2 S(l) * \Gamma(l,E)}$$

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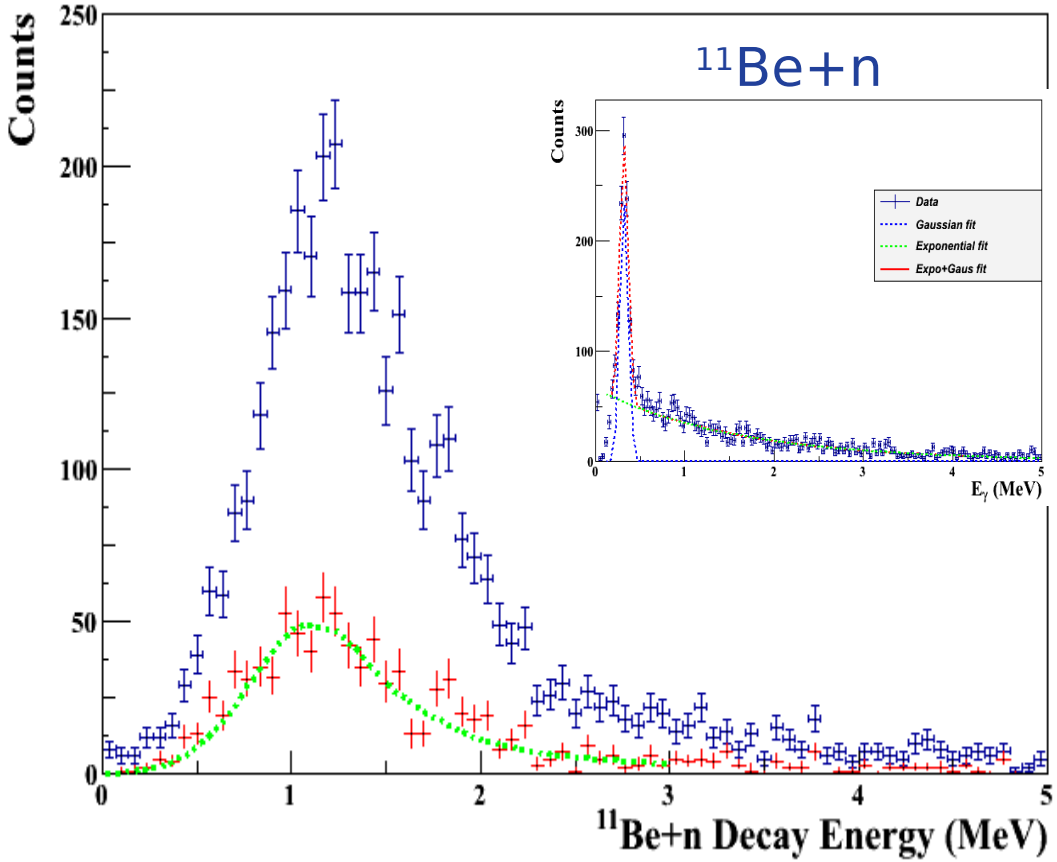
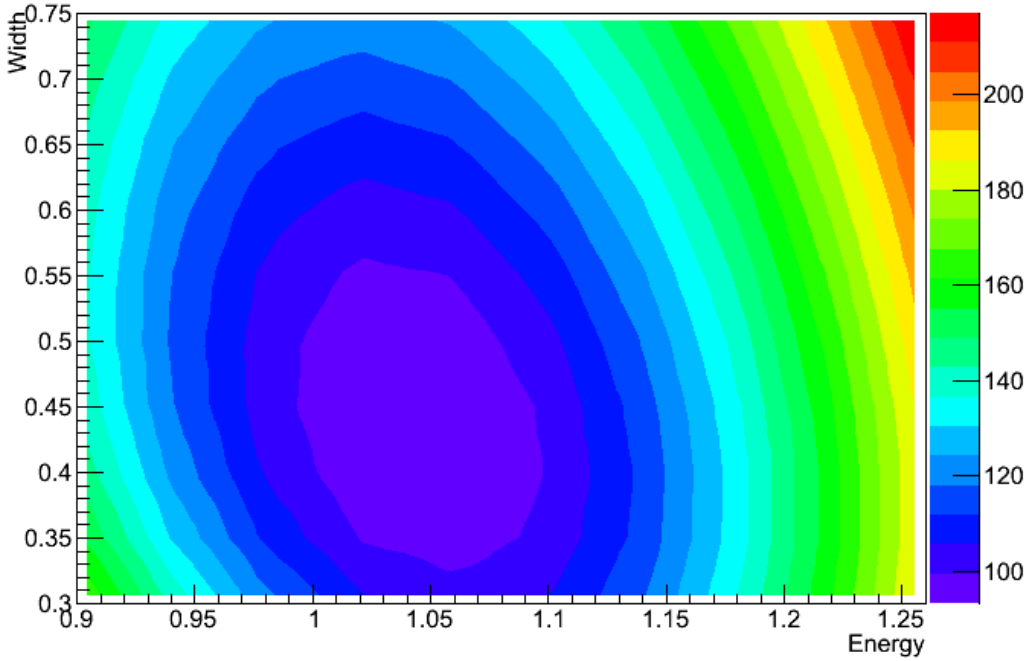


χ^2-Graph



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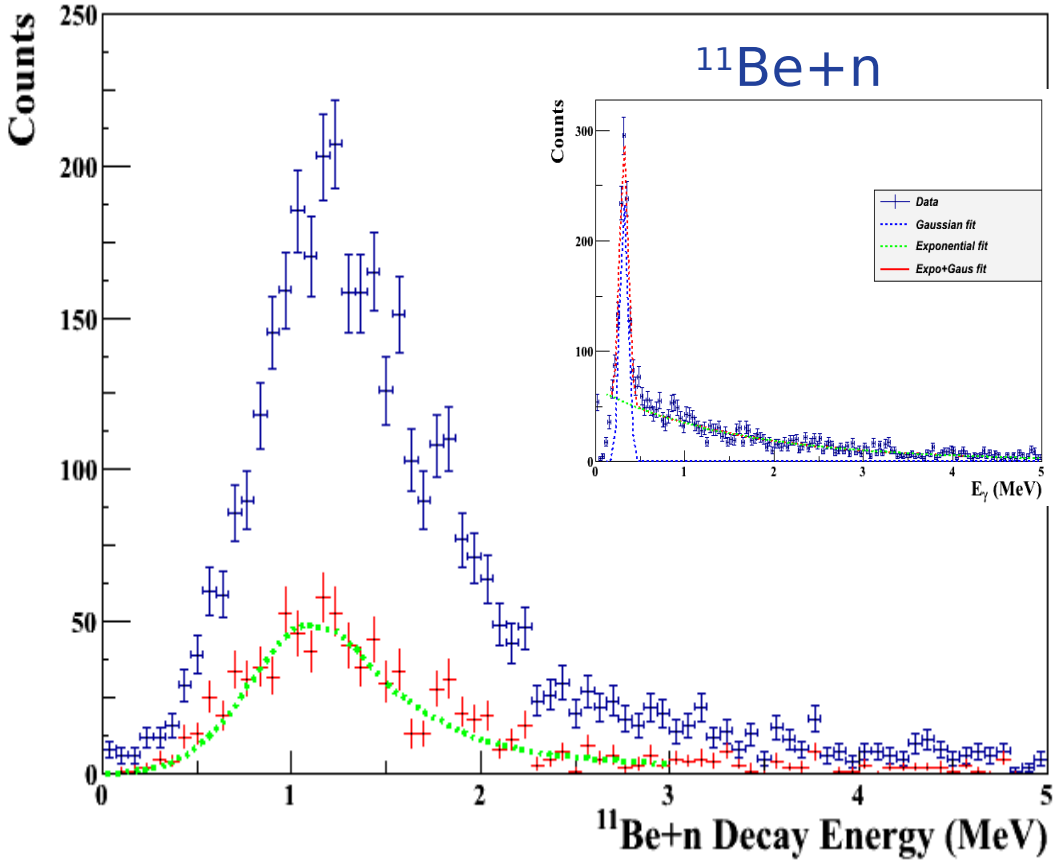

Tourte aux blettes

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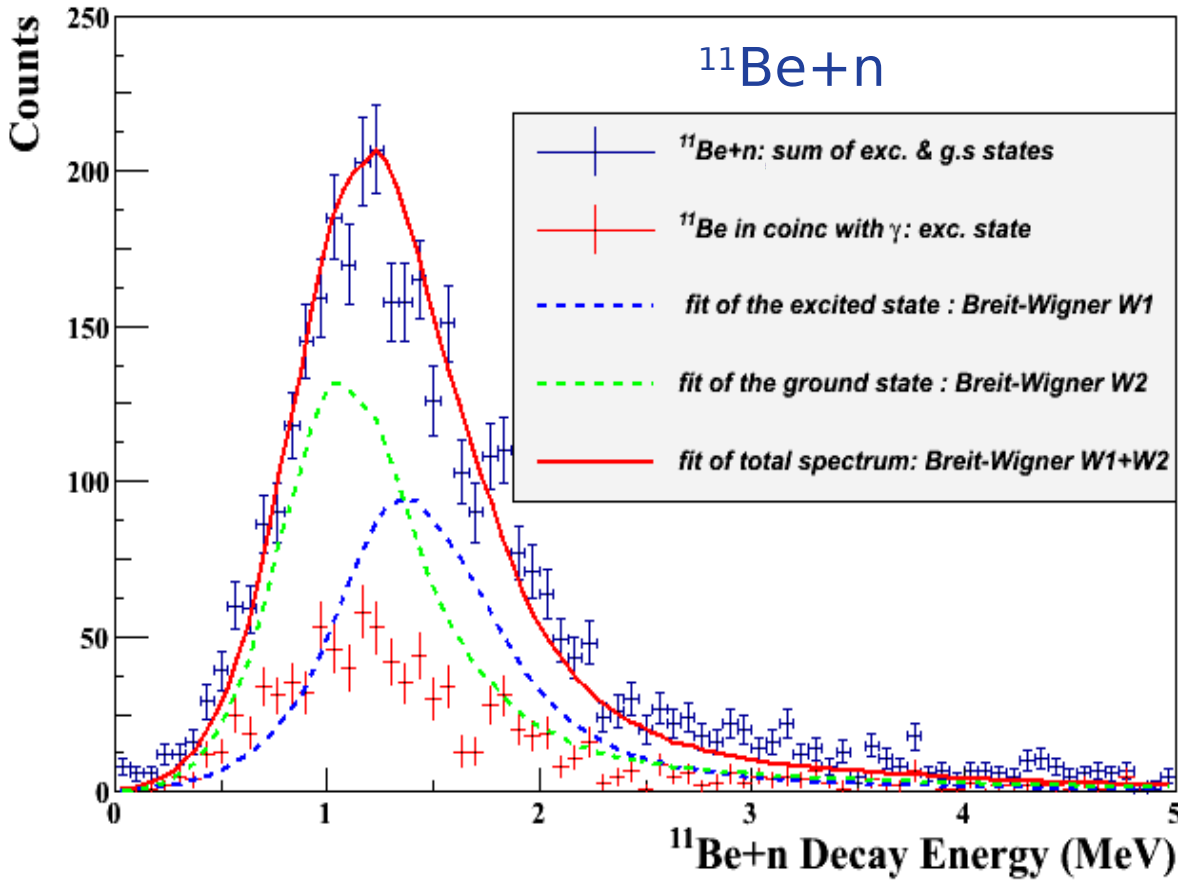
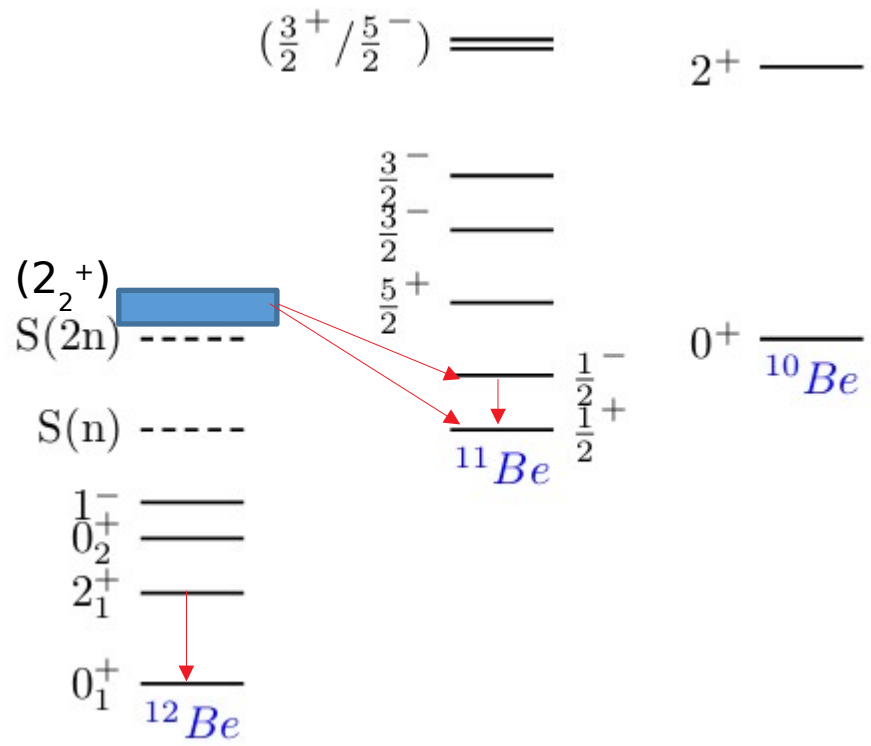


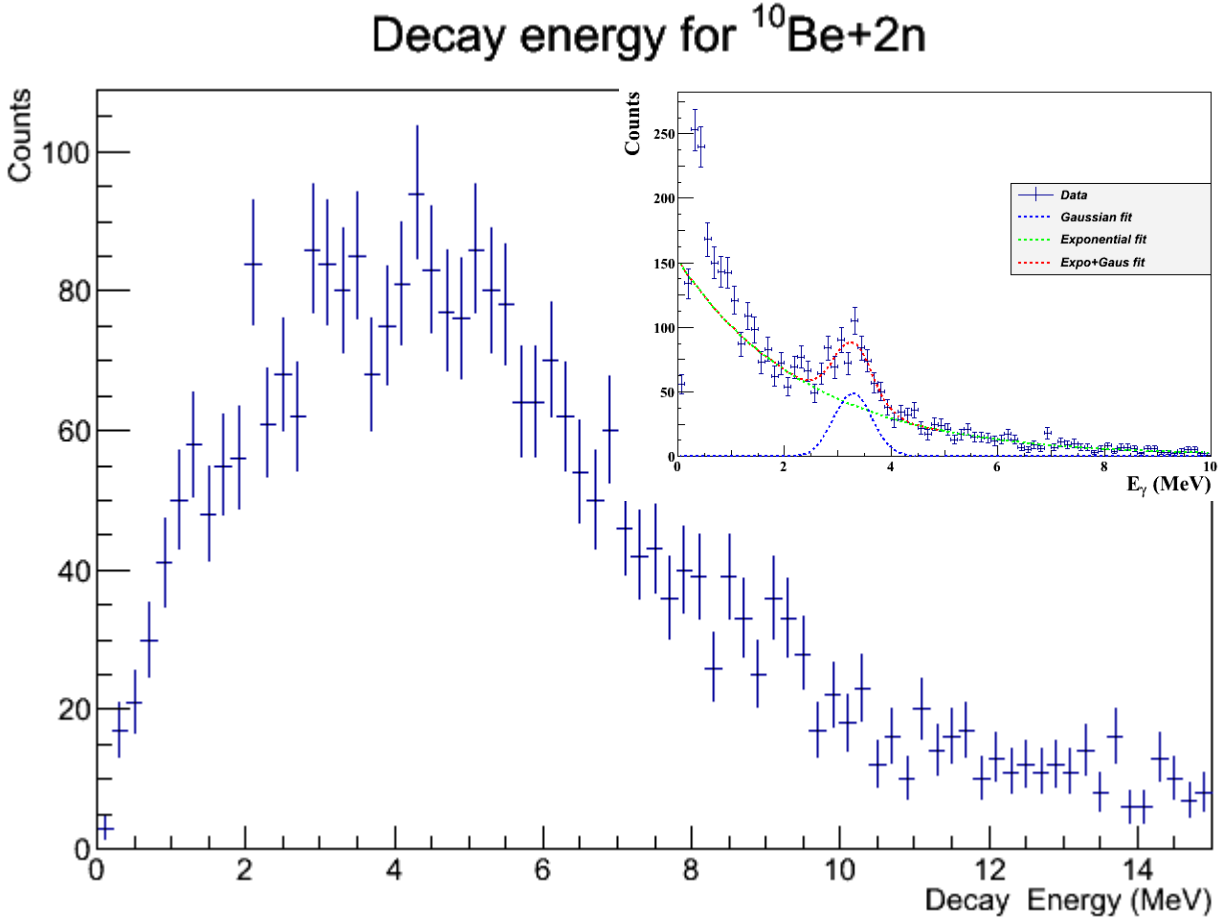


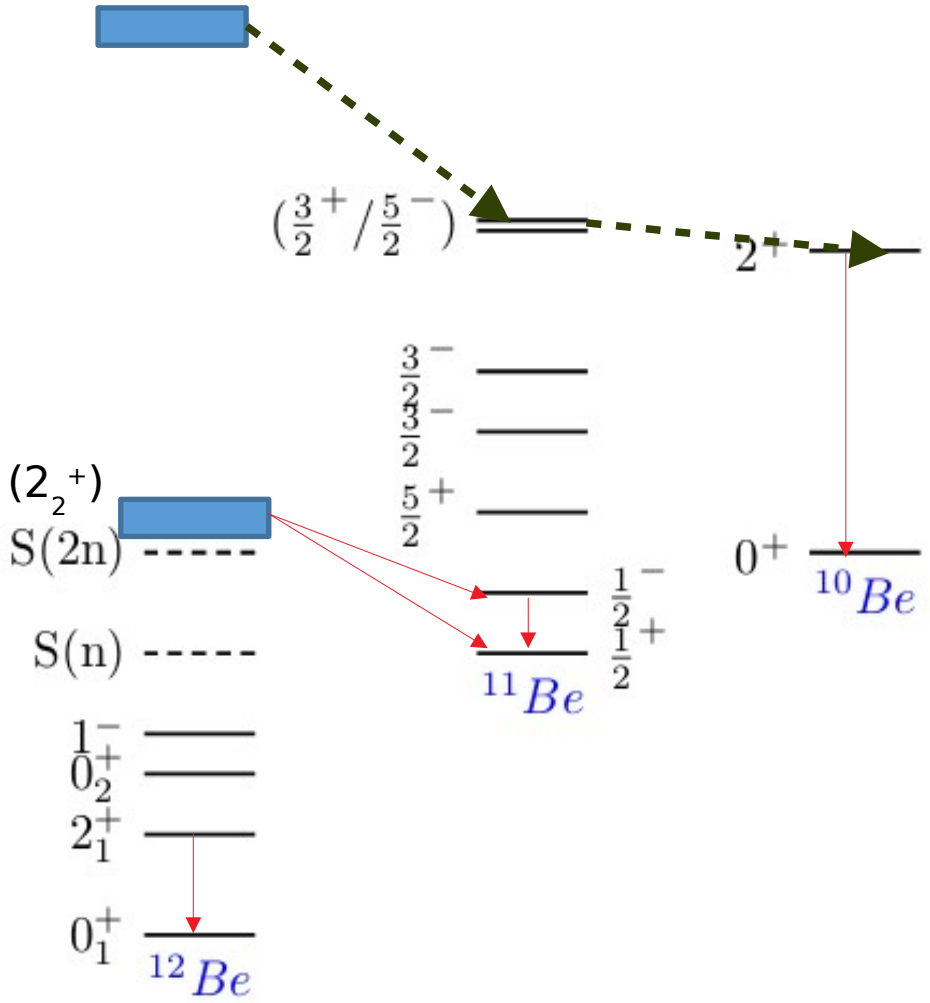
The first unbound state observed decays by emitting 1n mainly on the excited state of ^{11}Be

$$E_r = 1.360 \pm 0.040 \text{ MeV}$$

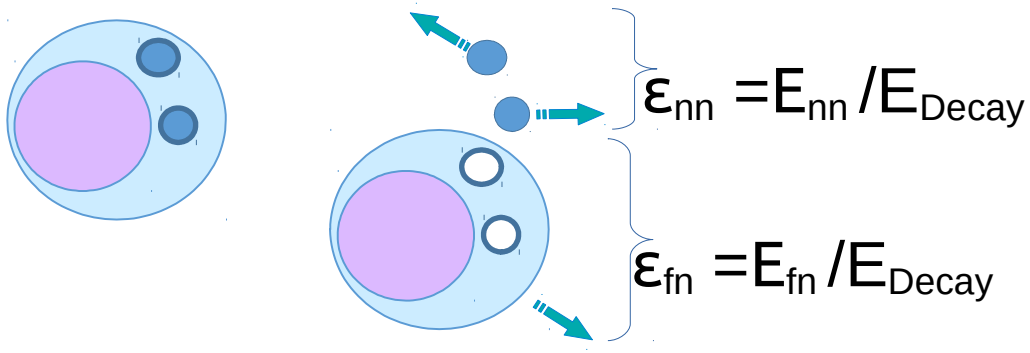
$$\Gamma_r = 0.460^{+0.090}_{-0.140} \text{ MeV}$$

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



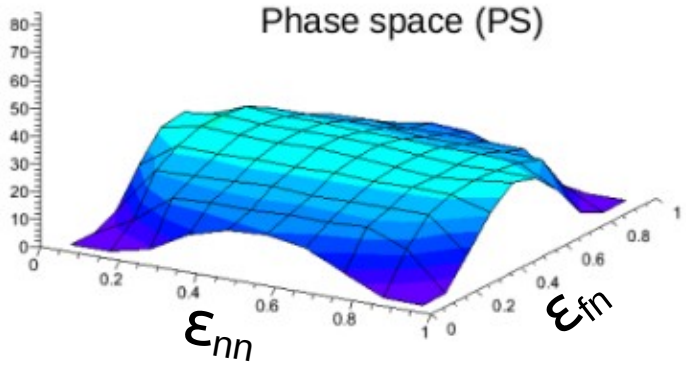


Correlations and Dalitz plots



$\varepsilon_{nn} = E_{nn} / E_{Decay}$

$\varepsilon_{fn} = E_{fn} / E_{Decay}$



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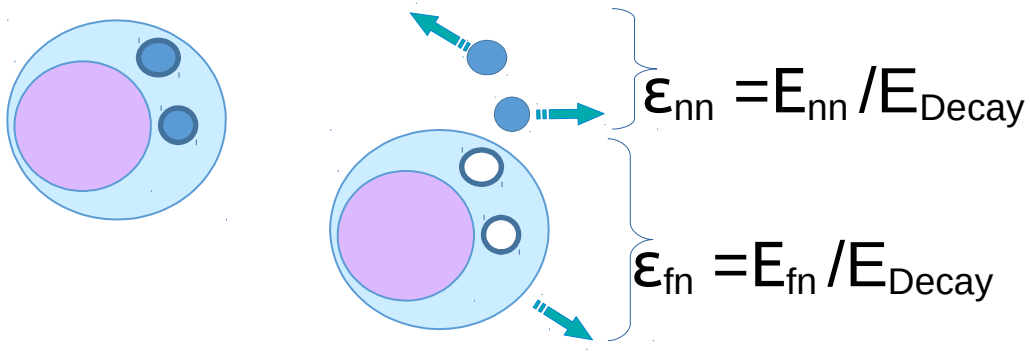

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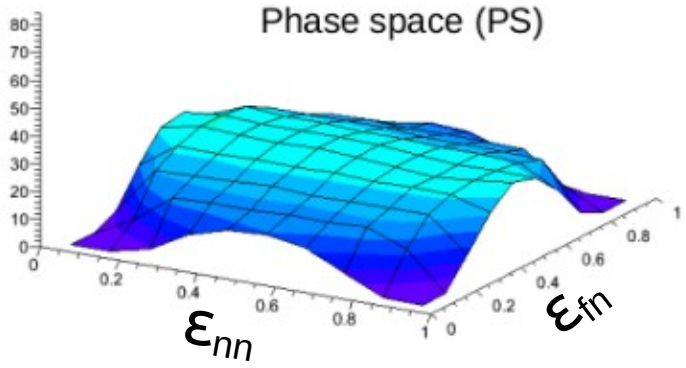
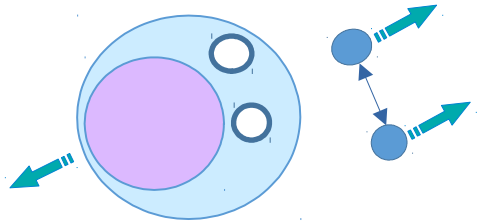
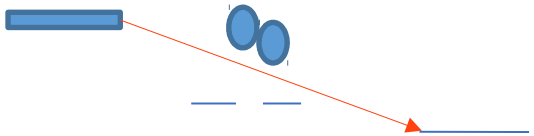
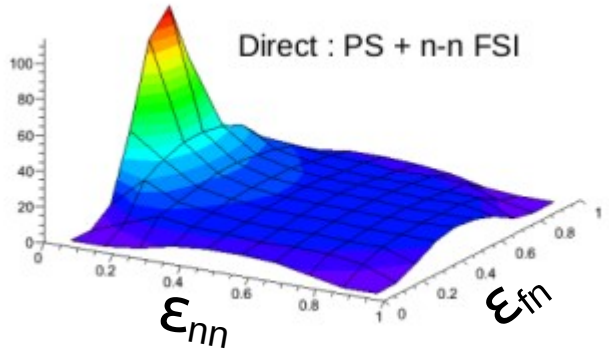


Final State interaction



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





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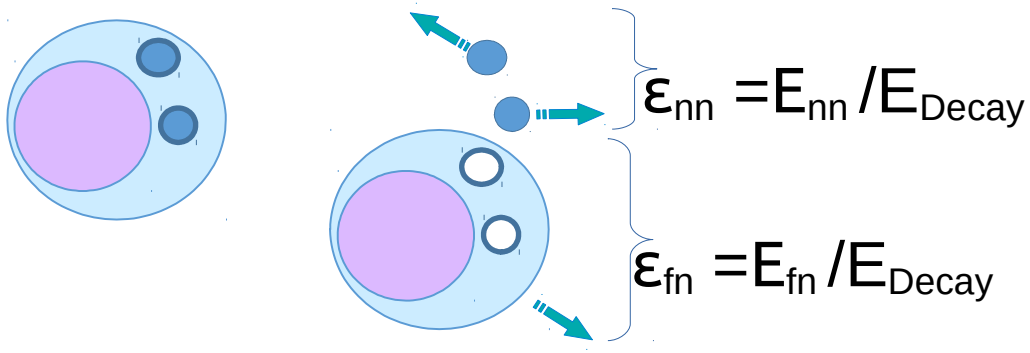

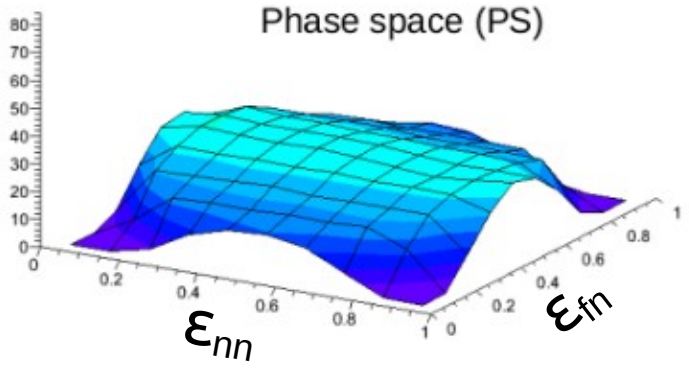

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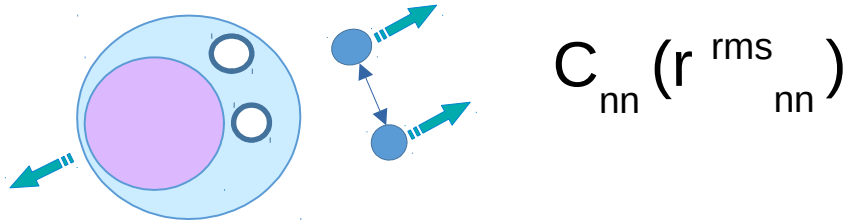
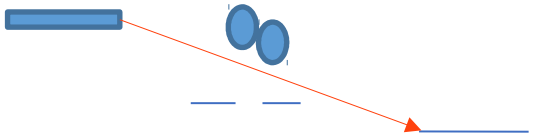
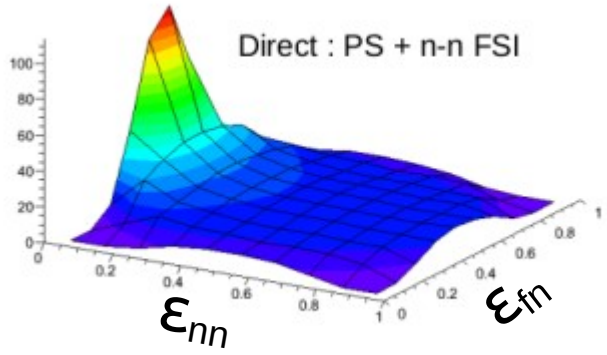
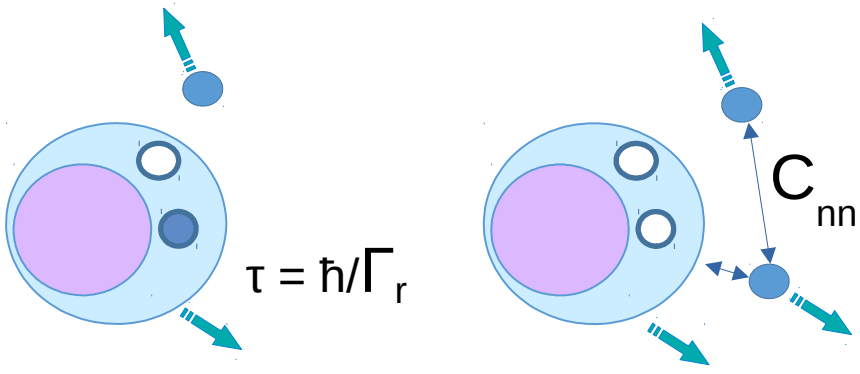
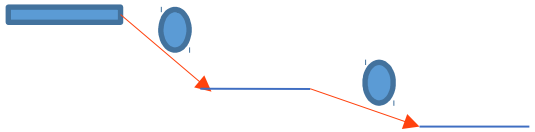
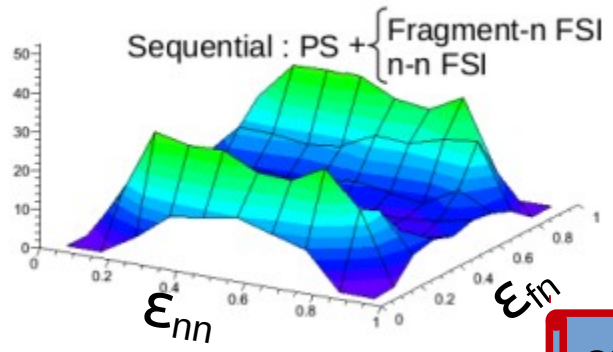




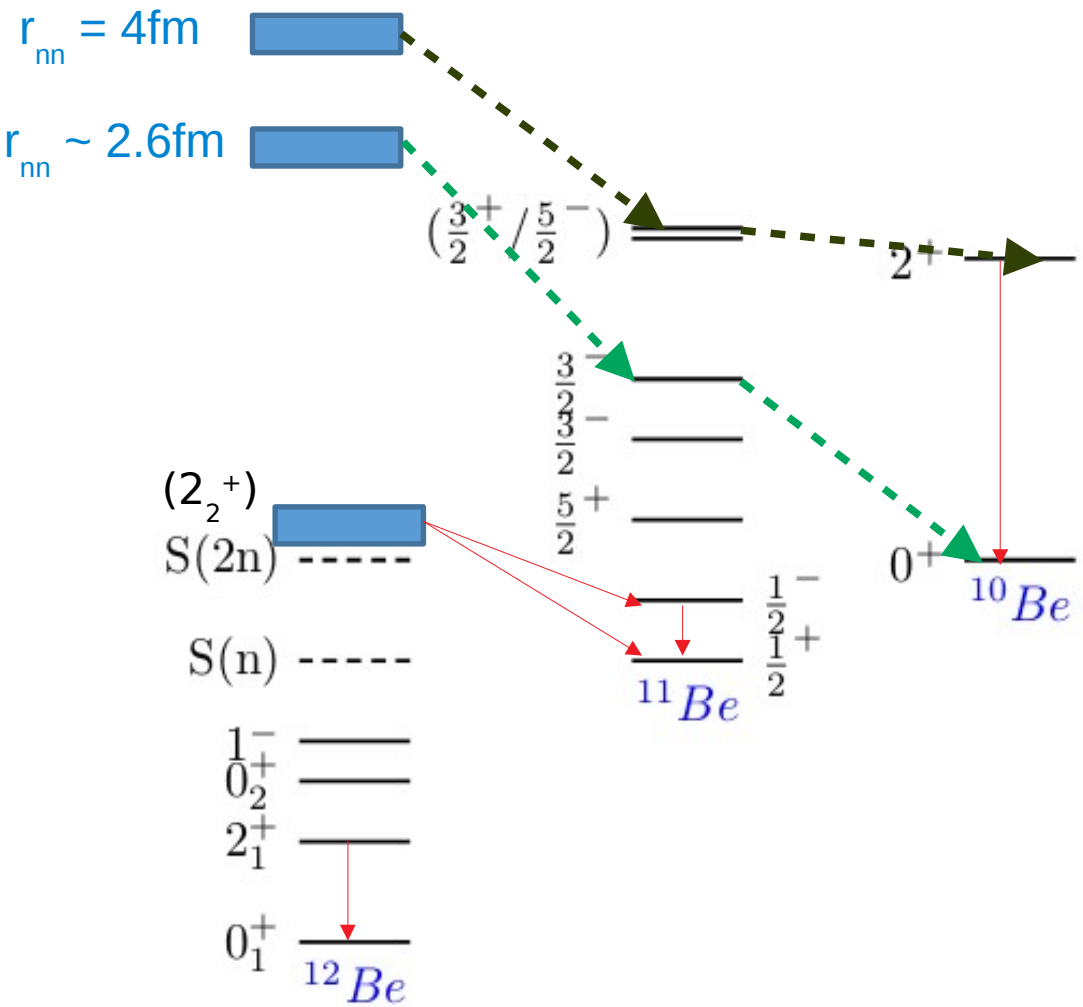


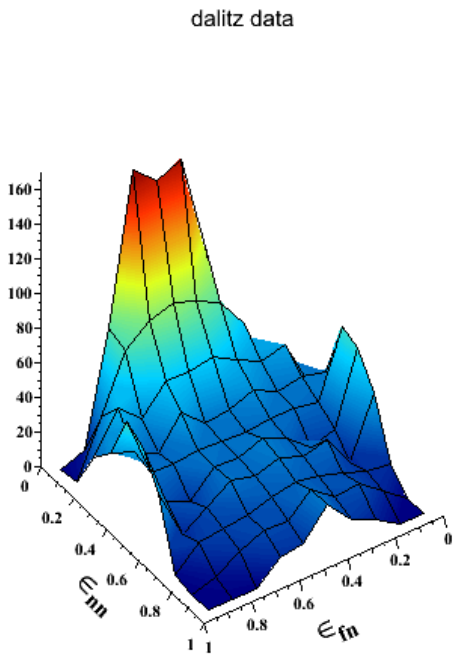


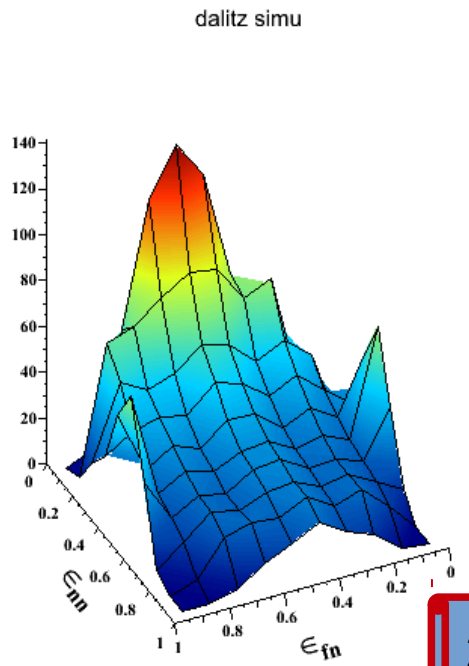




Correlations and Dalitz plots





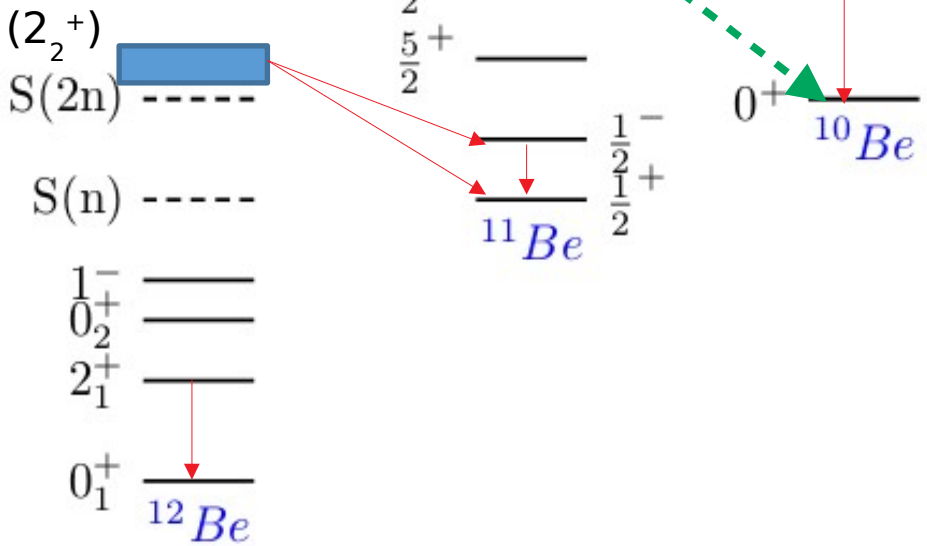


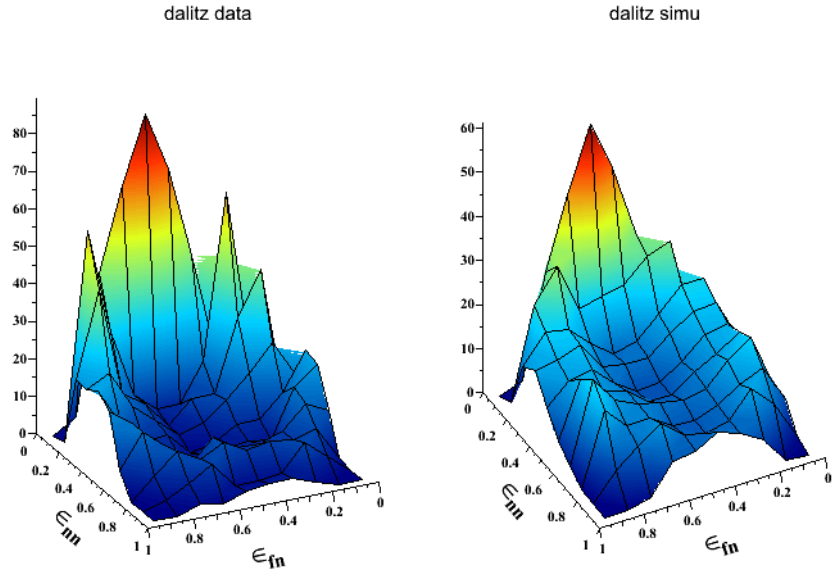
Correlations and Dalitz plots

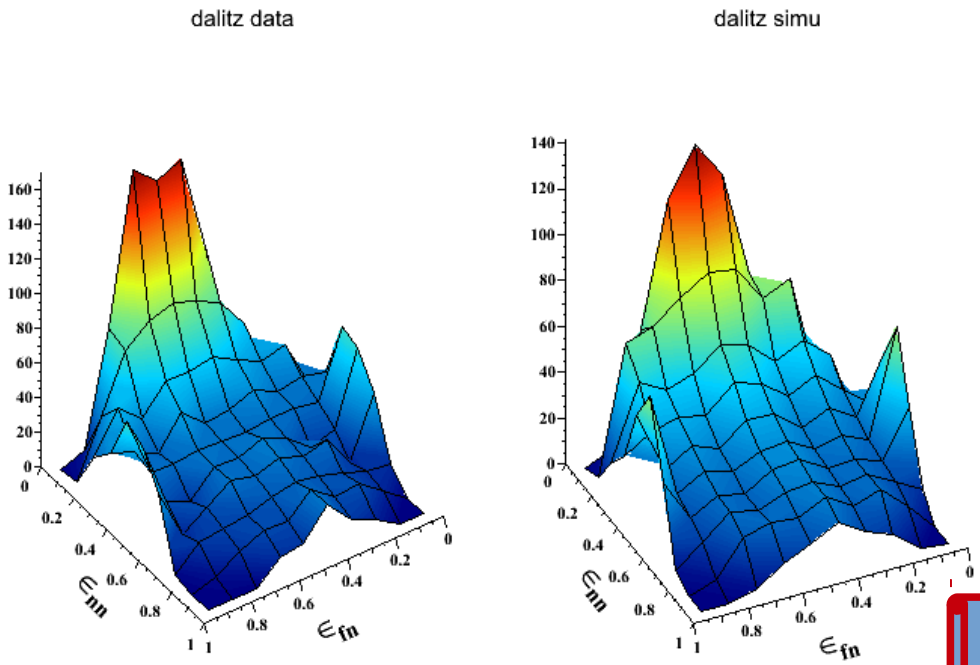
r_{nn} < 2.6fm Dineutron ?

r_{nn} = 4fm

r_{nn} ~ 2.6fm







Conclusion

The aim was to study n-n correlation in the region of netron-rich nuclei

- ^{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 :

- Bound, 1n and 2n unbound states were observed. Their decay modes were studied using Dalitz plots ;

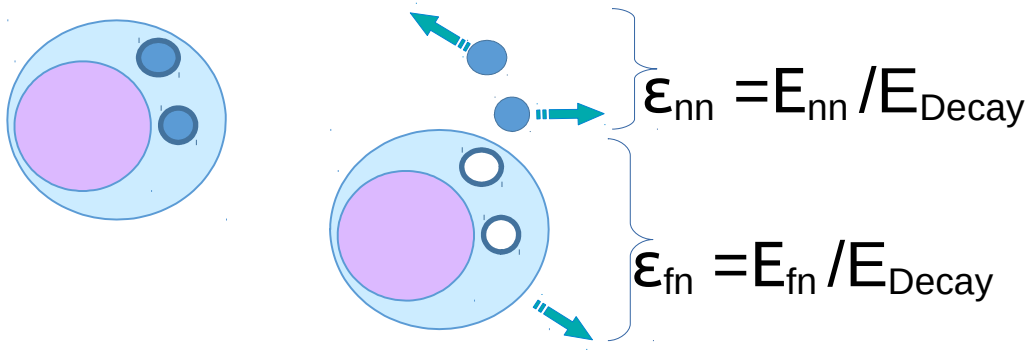
- States with different configutions : Two high excited states are very compact : « dineutrons » ?

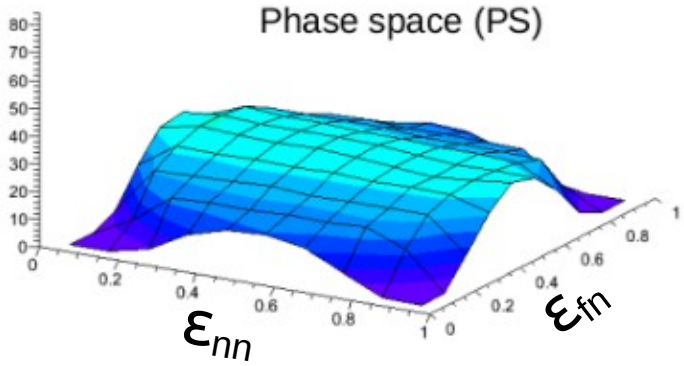
Thank you for your attention

Merci

Back up

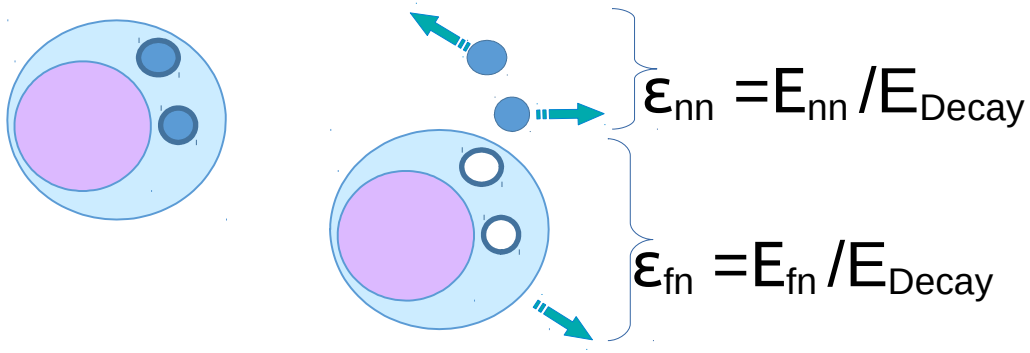
Correlations and Dalitz plots



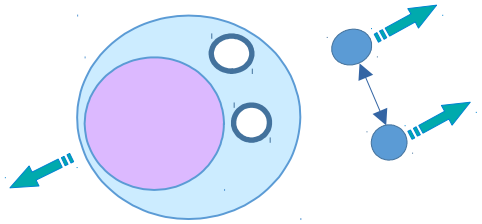


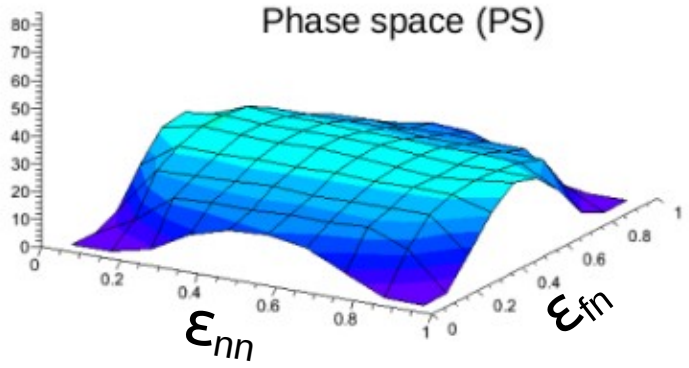
Correlation femtoscopy, R.Lednicky, NuclPhys A (2006)

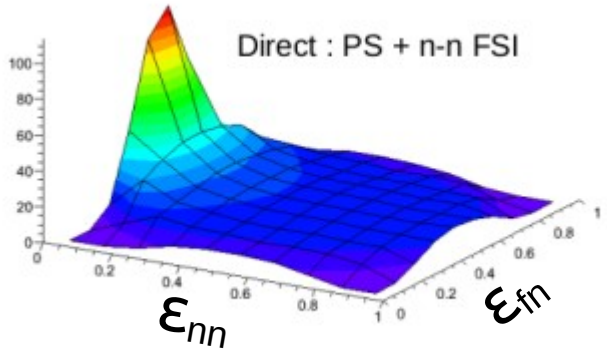
Correlations and Dalitz plots



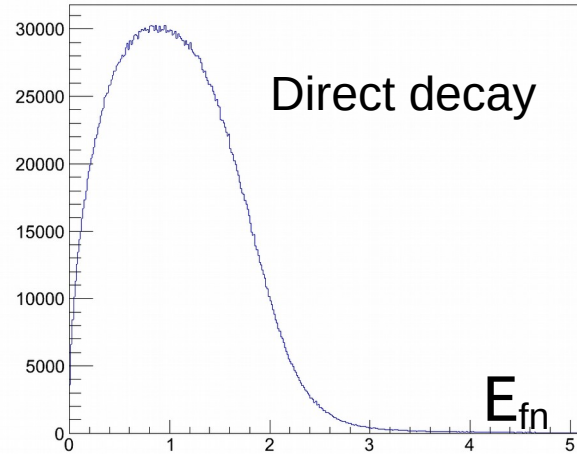
Final State interaction



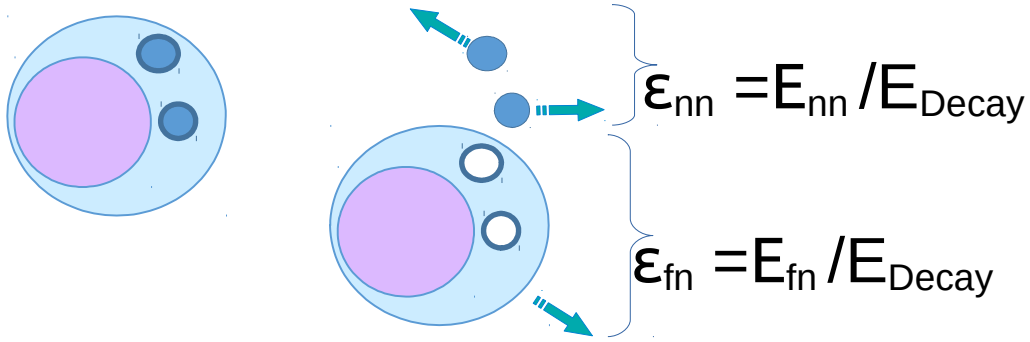


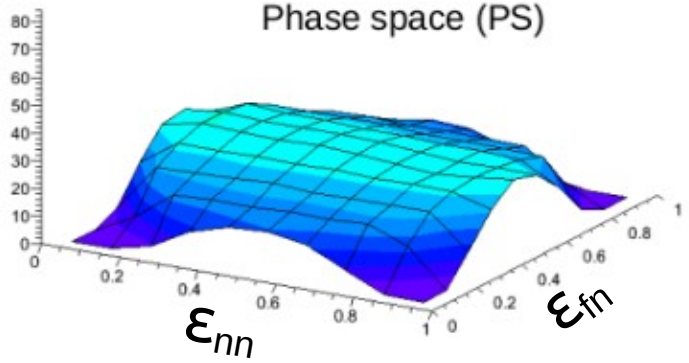


Correlation femtoscopy, R.Lednicky, NuclPhys A (2006)



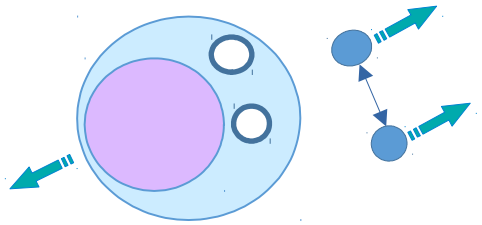
Correlations and Dalitz plots



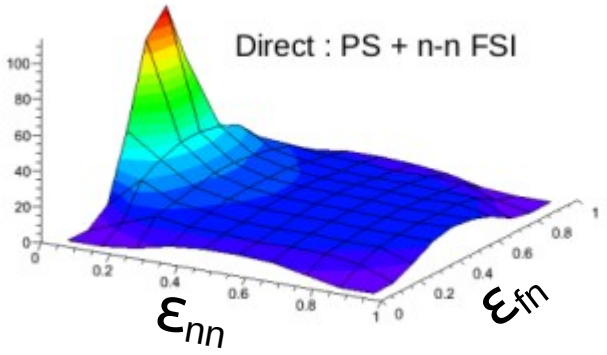


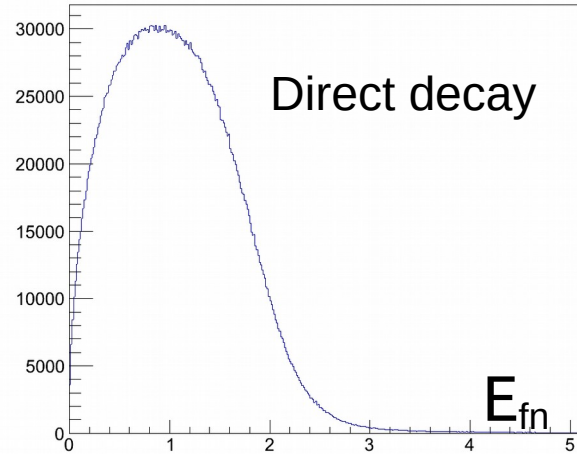
Correlation femtoscopy, R.Lednicky, NuclPhys A (2006)

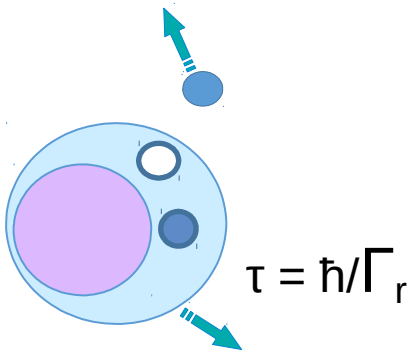
Final State interaction



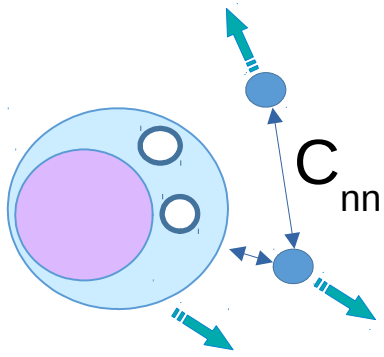
$C_{nn}(r^{rms}_{nn})$



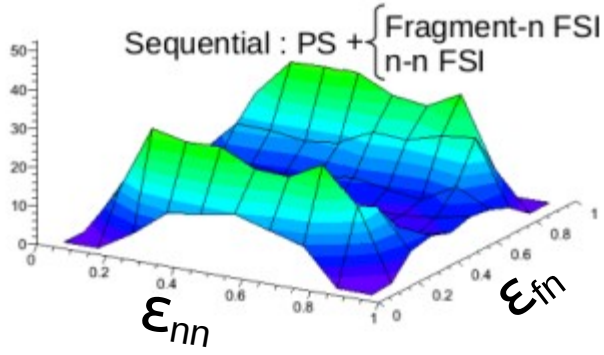


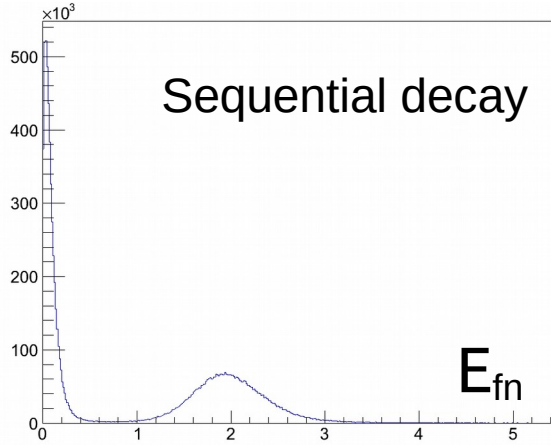


$\tau = \hbar/\Gamma_r$

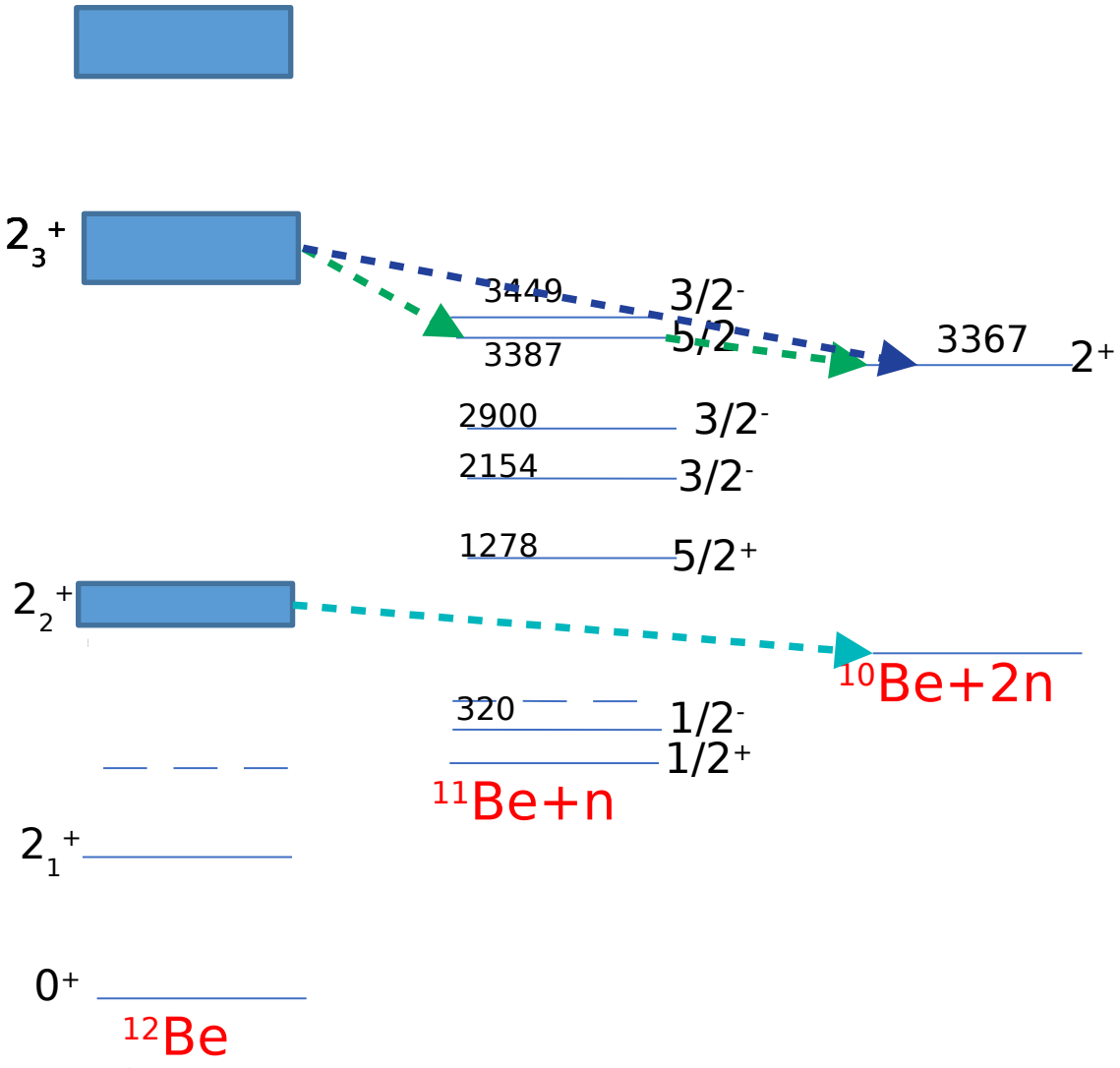


$C_{nn}(r^{rms}_{nn}, \tau)$



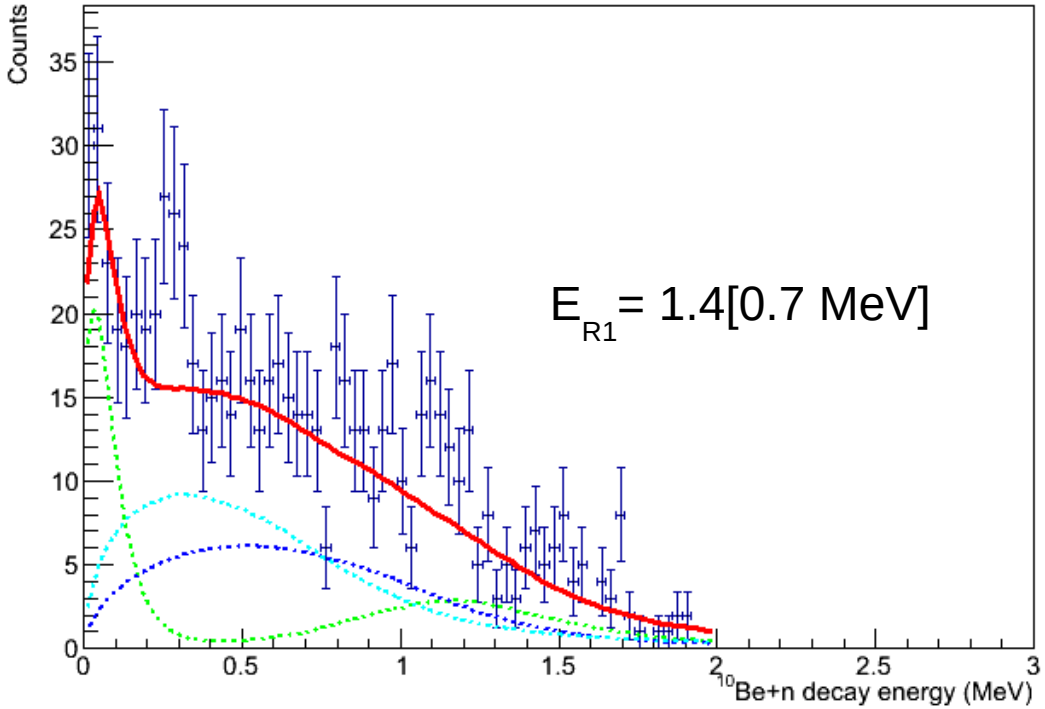


0-2MeV

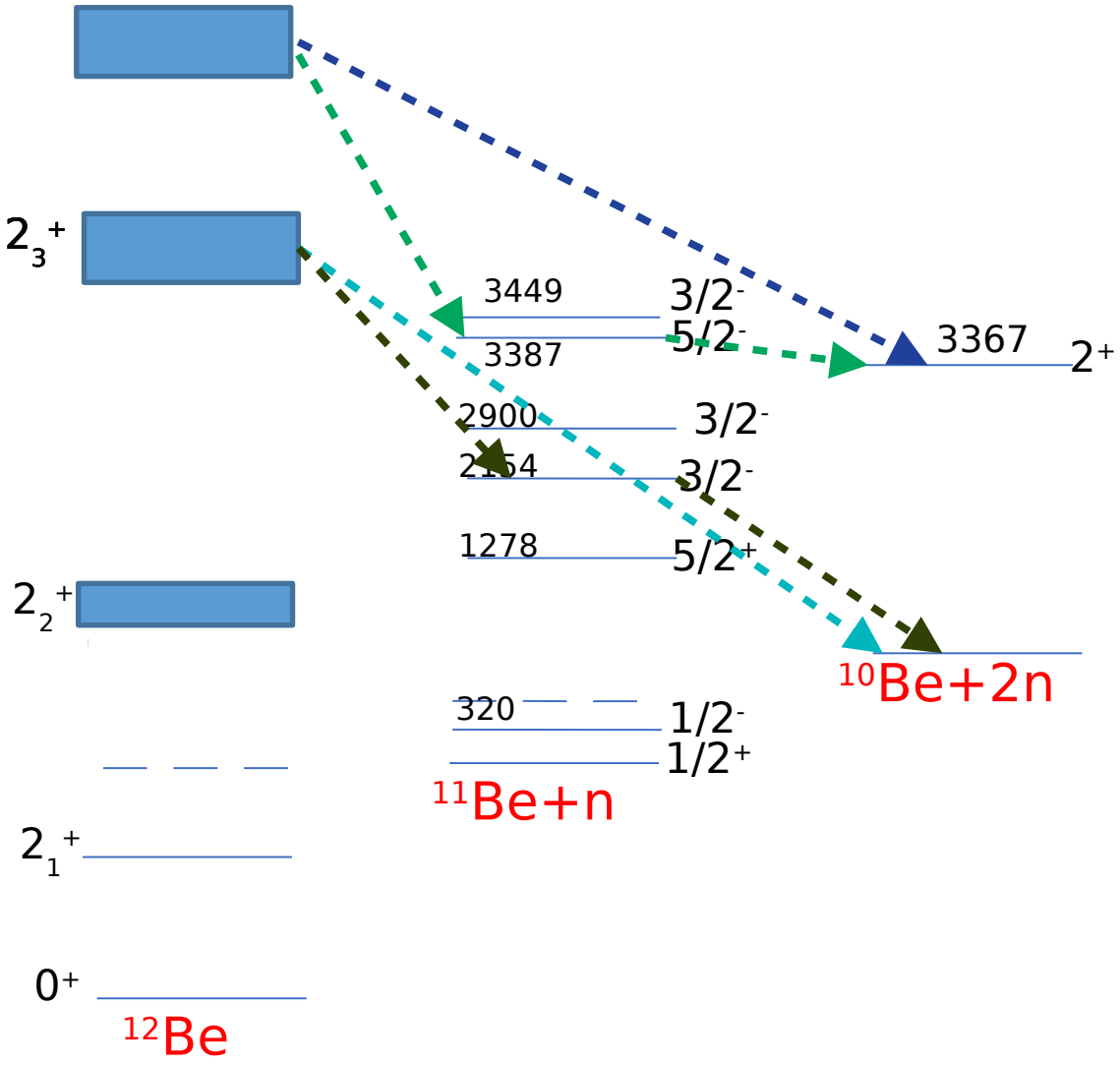


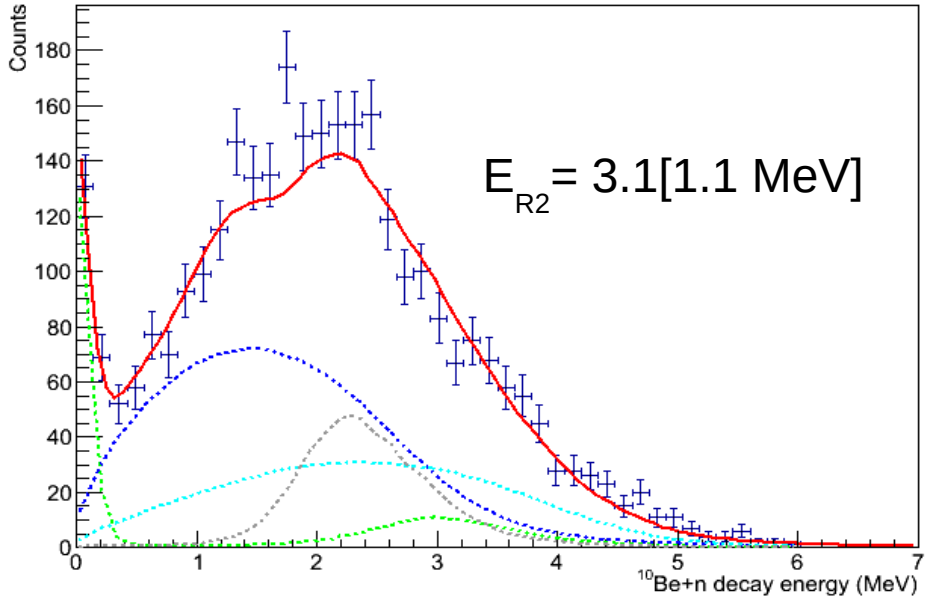
Pour fitter E2n et E1n, j'essaie deux états au dessus du premier état excité du ^{10}Be (2^+) : Un premier plus bas ~ 1MeV et un autre plus haut > 2MeV

Ainsi, je choisi de faire des tranches de 0-2 MeV, 2-6 Mev et 6-8 MeV : le premier état sera compris dans la première tranche et le second dans la tranche plus haute.



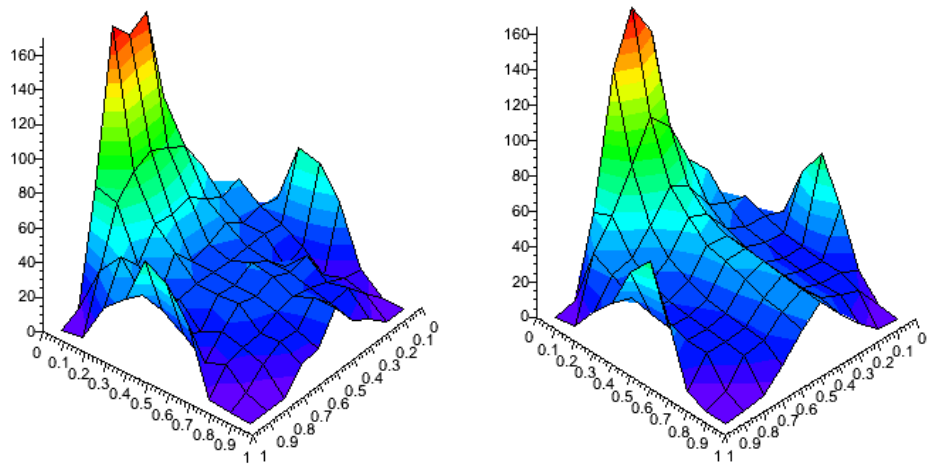
2-6MeV



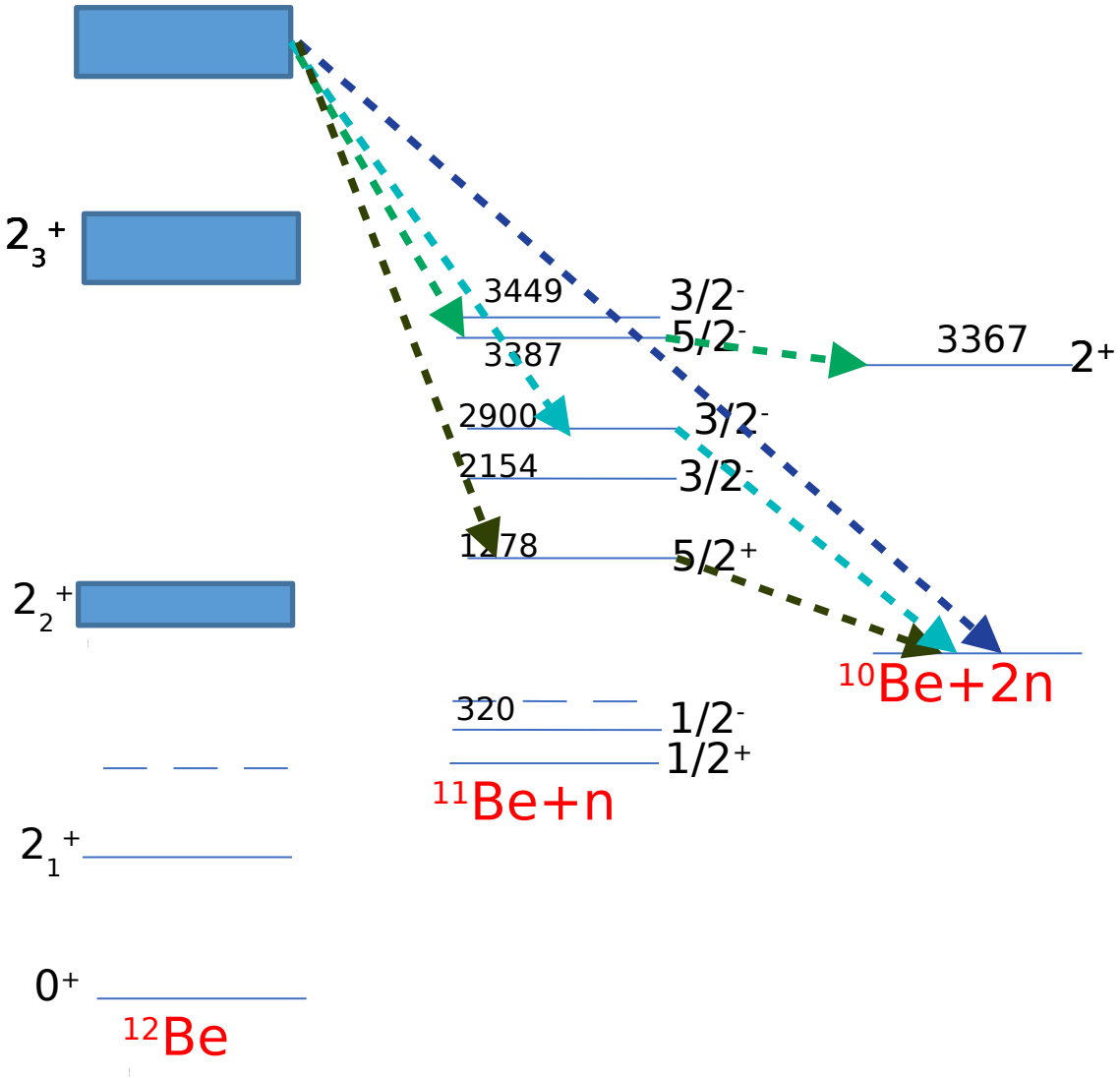


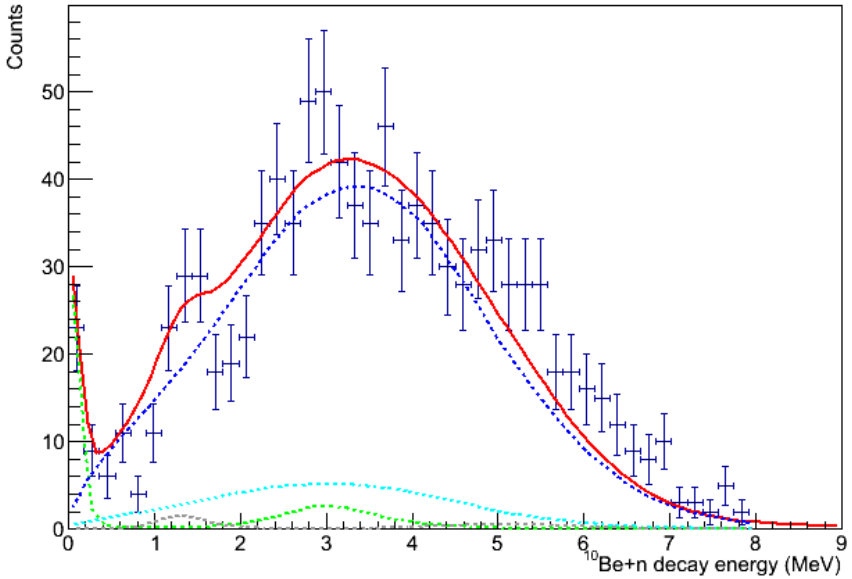
dalitz data

dalitz Simu

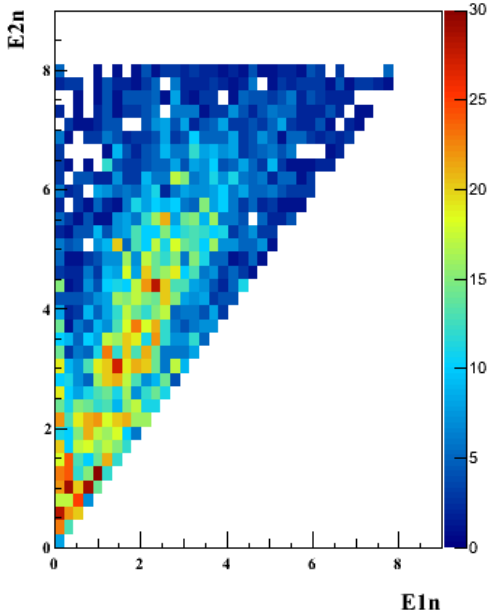


6-8MeV

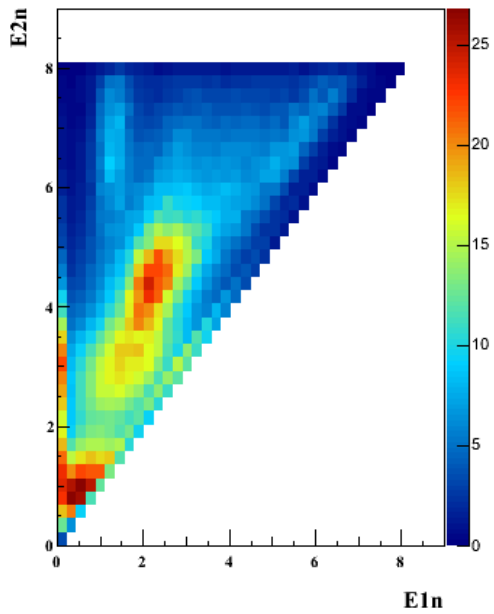

2₃⁺
2₂⁺
2₁⁺
0⁺
¹²Be
3449
3387
2900
2154
1278
320
3/2⁻
5/2⁻
3/2⁻
3/2⁻
5/2⁺
1/2⁻
1/2⁺
¹¹Be+n
3367
2⁺
¹⁰Be+2n


Counts
0
10
20
30
40
50
0
1
2
3
4
5
6
7
8
9
¹⁰Be+n decay energy (MeV)

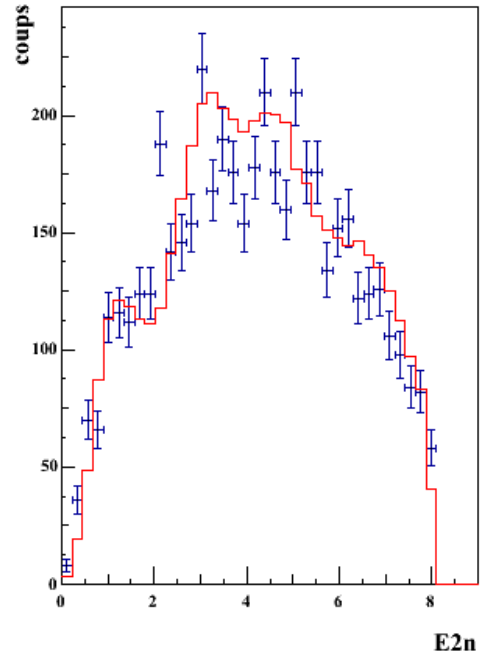
2n vs 1n data



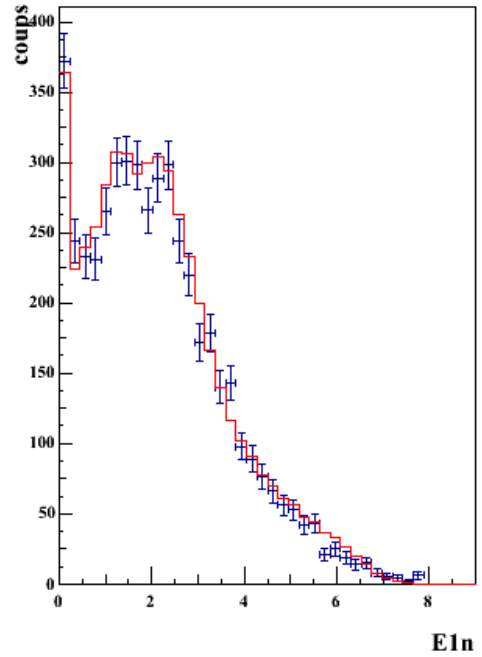
2n vs 1n Simu



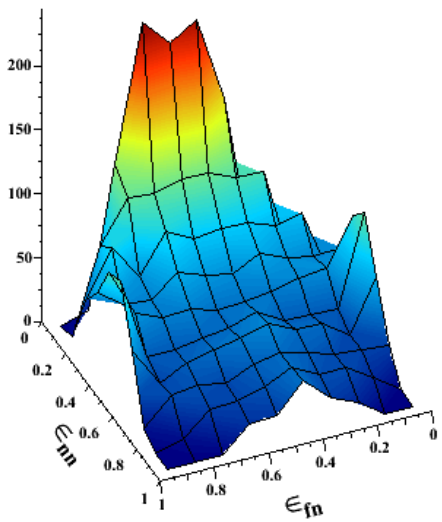
E2n : simu vs simu



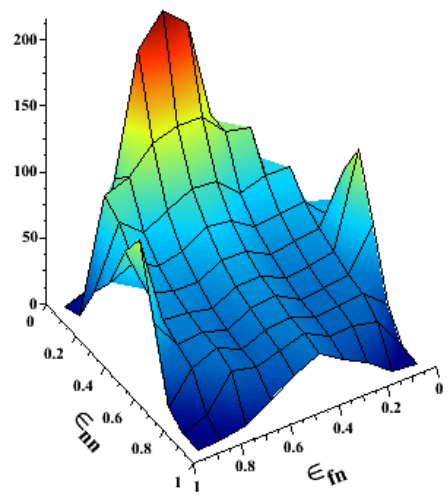
E1n : data vs simu



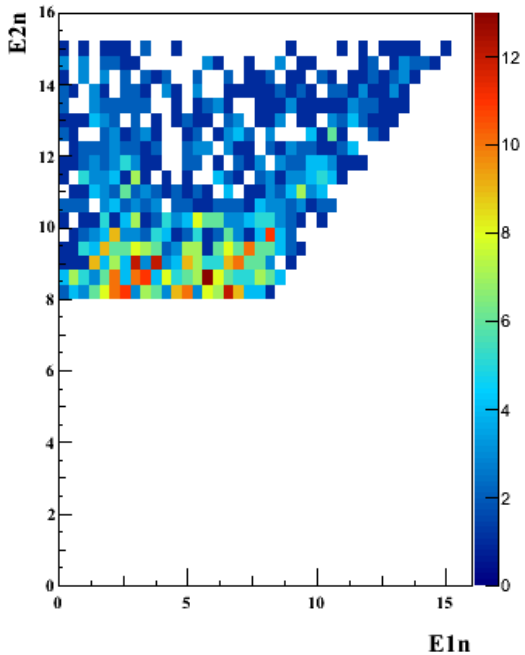
dalitz data



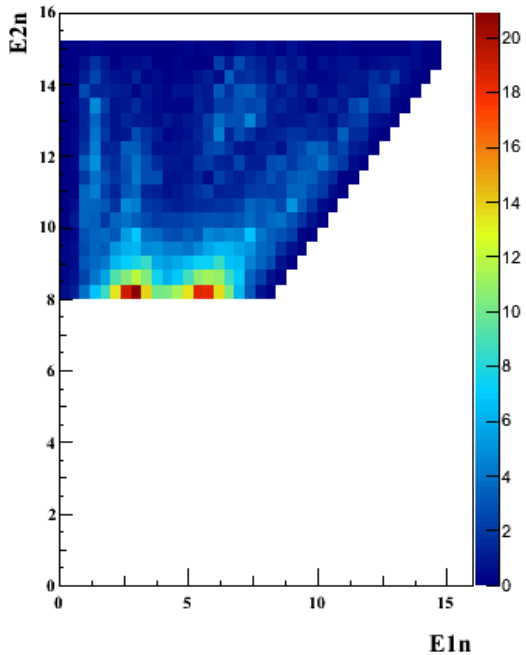
dalitz simu



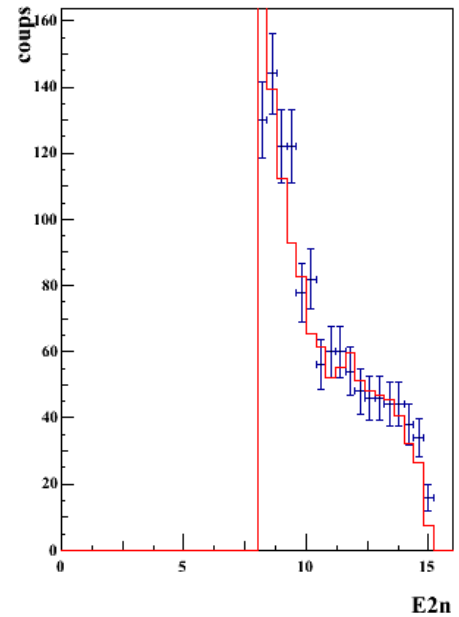
2n vs 1n data



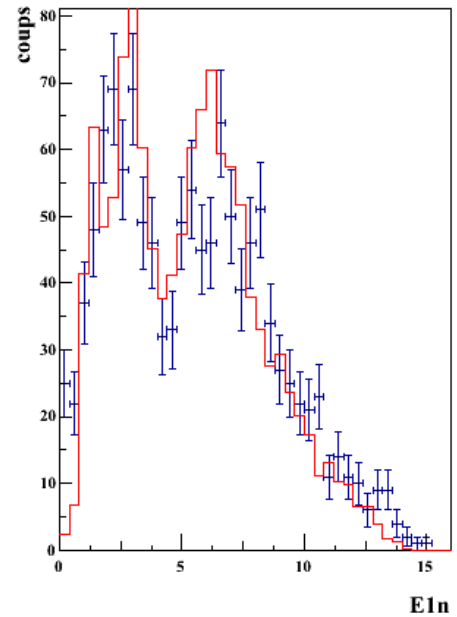
2n vs 1n Simu



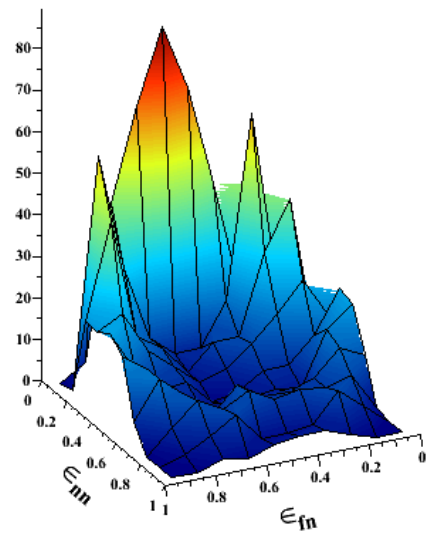
E2n : simu vs simu



E1n : data vs simu



dalitz data



dalitz simu