Background free γ-ray spectroscopy of the $^{7}\mathrm{Li}(p,\gamma)$ reaction at 441 keV

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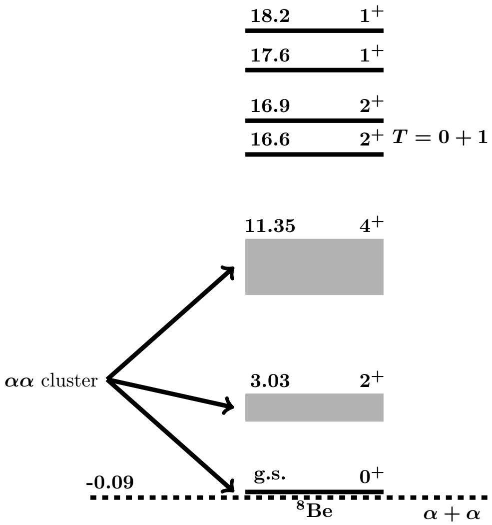
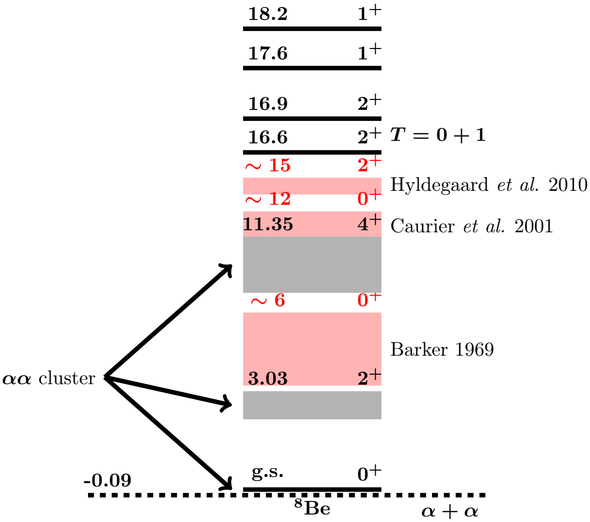
^{8}Be



^{8}Be intruders?



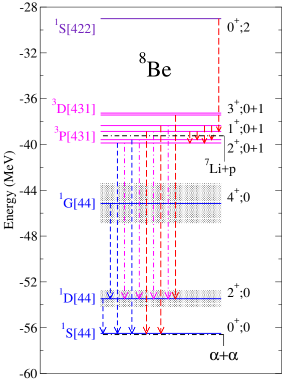
S. Hyldegaard. "Beta-decay studies of 8Be and 12C". PhD thesis. Aarhus University, 2010
E. Caurier et al. *Physical Review C* 64 (2001), p. 051301
F. C. Barker et al. *Australian Journal of Physics* 21 (1968), p. 239

ab initio

Quantum Monte Carlo calculations by Pastore et al.

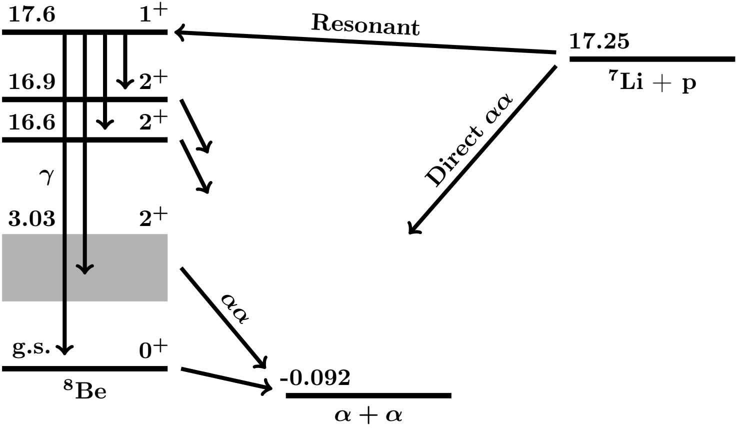
Includes most transistions.

Isospin mixing “by hand”



S. Pastore et al. *Physical Review C* 90 (2014), p. 024321

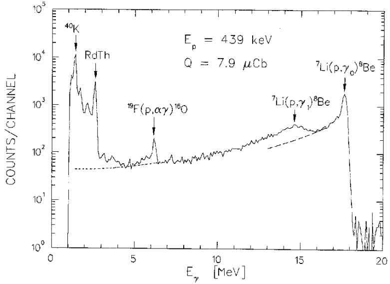
^{7}Li(p,γ)



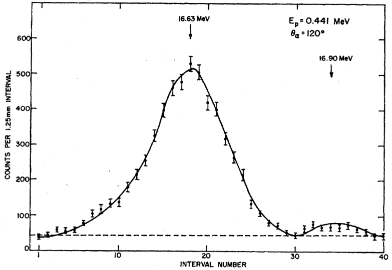
17.6
1+
Resonant
17.25
16.9
2+
16.6
2+
7Li + p
Direct αα
γ
3.03
2+
αα
g.s.
0+
-0.092
8Be
α + α

Previous measurement of $^{7}\mathrm{Li}(\mathrm{p},\gamma)^{8}\mathrm{Be}$

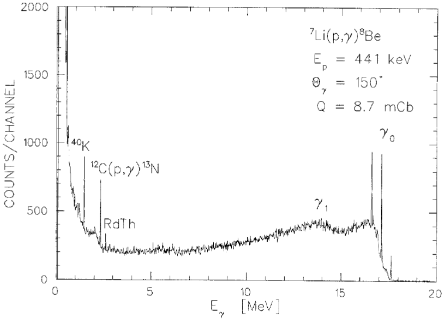
NaI



Magnetic spectronometer



Ge



D. Zahnow et al. *Zeitschrift für Physik A* 351 (1995), pp. 229–236
W. E. Sweeney et al. *Physical Review* 182 (1969), pp. 1007–1021

Problems:

- Non-trivial response function
- Poor resolution
- Limited range
- Background
- No interference

Solution:

- Indirect γ-ray spectoscopy

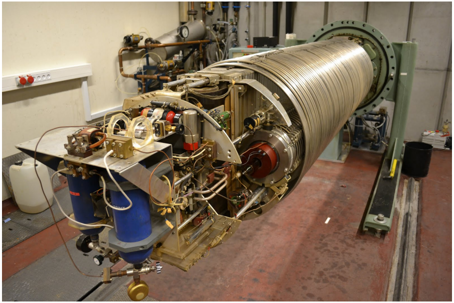
Experiment

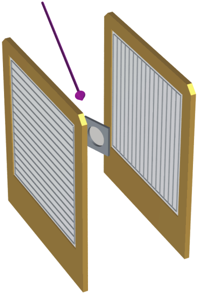
$^{3}H^{+}$ beam by 5MV Van de Graaff accelerator ~1nA

Two 5x5cm 16x16 Double Sided Silicon Strip Detectors

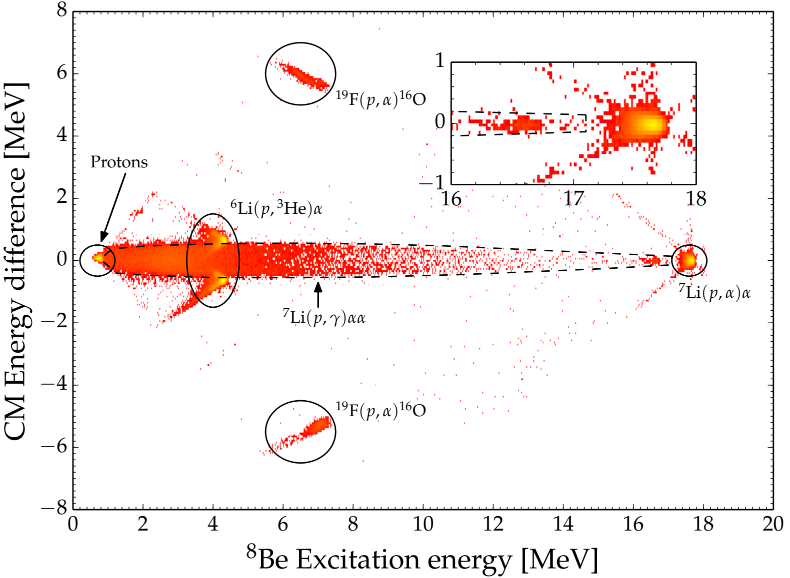
Detection: position, energy and time

Coincidences



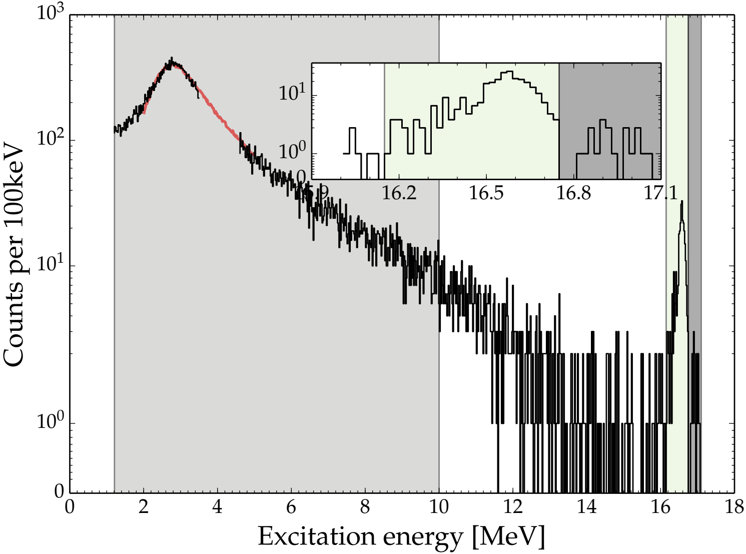


Coincidences



Spectrum

Determine widths by integration.

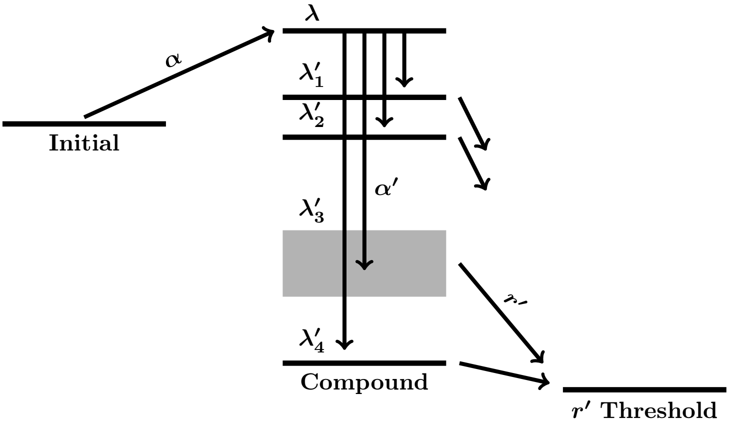


R-matrix

β-decay studies: "interfernce is important for ^{8}Be".

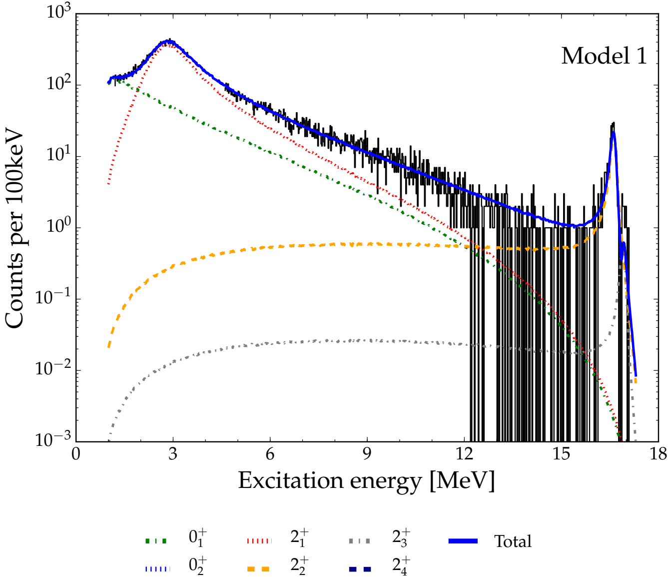
Sequential decay R-matrix expression.

(Expression in appendix)



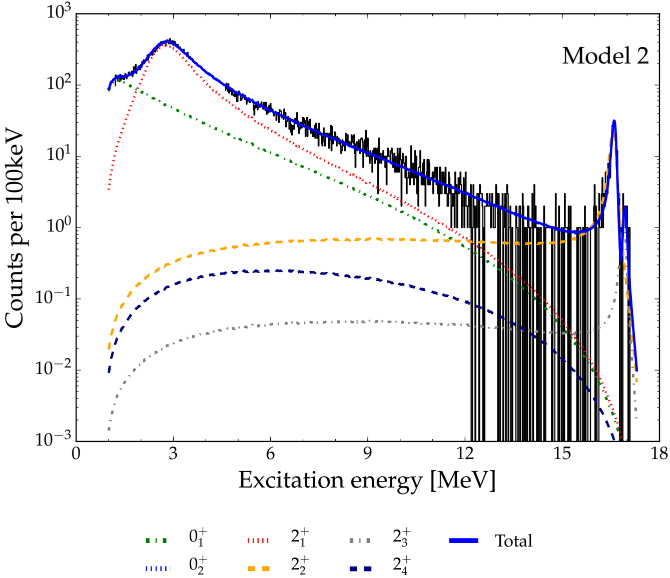
Model 1

0^+ GS, 2^+ 3, 16.6 and 16.9MeV



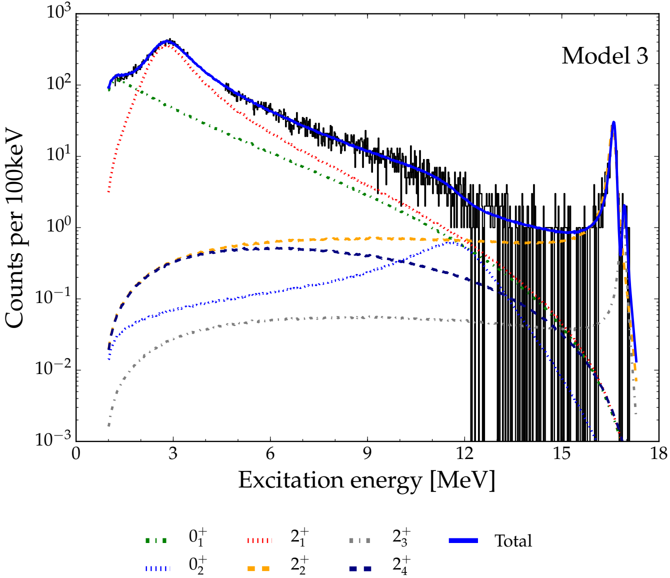
Model 2

Model 1 + 2^+ background pole



Model 3

Model 1 + 2^+ background pole + 0^+ intruder



Conclusions

Parameter	Present	Lit.	GFMC	R-Mat.
Γ_{0_1} (eV)	-	15.0(18)	12.0(3)	13.8(4)
Γ_{2_1} (eV)	6.0(3)	6.7(13)	3.8(2)	5.01(11)
Γ_{2_2} (meV)	35(3)	32(3)	29.7(3)	38(2)
Γ_{2_3} (meV)	2.1(6)	1.3(3)	2.20(5)	1.6(5)

Evidence for 0^+ at 12.0(3) MeV with $\Gamma_\alpha = 2.4(5)$ MeV and $\Gamma_{M1} = 12(3)$ eV.

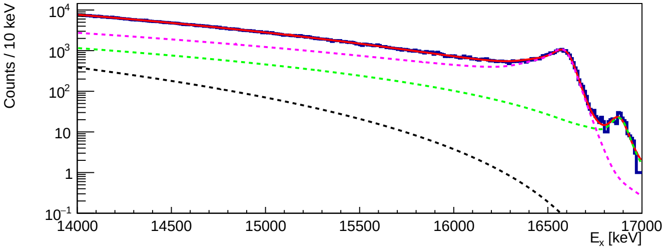
Insufficient comparison for "intermediary" region.

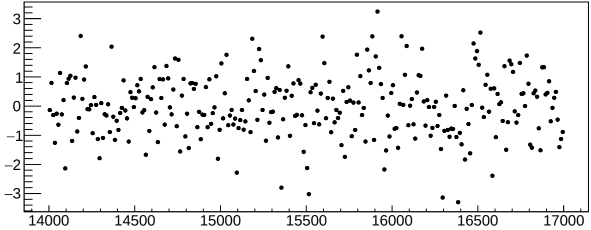
Needs theoretical spectrum.

GFMC discrepancy depends on 1^+ isospin mixing.

arXiv: 1802.10404

Appendix 0: $^{8}\mathrm{B}(\beta\alpha)$





Courtesy of Andreas Gad

Appendix I: R-matrix expression

Proceeding via narrow resonance

$$\frac{d\sigma_{\alpha\alpha'}(E_2'r')}{dE_2'} = \frac{\pi}{k_a^2} \sum_{s\ell s'\ell'} g_J \frac{\Gamma^0_{\lambda c}\,\delta\Gamma^0_{\lambda' c'}(E_2'r')}{(E^0_\lambda - E)^2 + (\sum_{c_p}\Gamma^0_{c_p}/2)^2},$$

Density of states:

$$\delta\Gamma^0_{\lambda c'(E_2'r')} = \frac{2P_{c'}2P_{r'}}{2\pi}\Big|\sum_{\nu\mu}\tilde{\gamma}_{\lambda c'(\nu)}\tilde{\gamma}_{\mu r'}\tilde{A}_{\nu\mu}\Big|^2$$

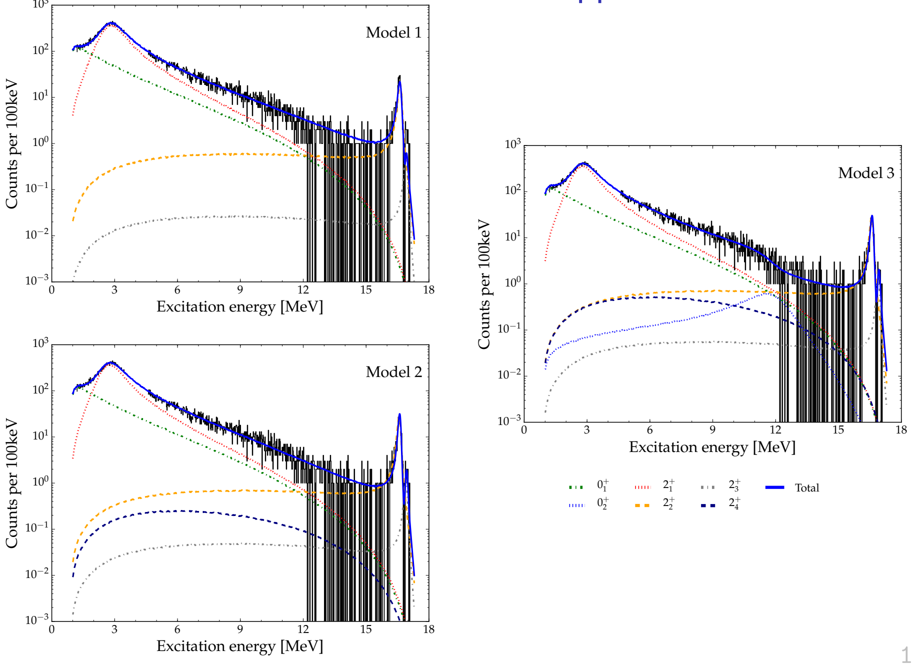
γ-ray "penetrability":

$$P_{c'} = E^{2L+1}$$

Observed widths:

$$\Gamma^0_{\lambda c'(\lambda')} = \int_{\lambda'} \delta\Gamma^0_{\lambda c'(E_2'r')}\; dE_2' \approx \frac{2P_{c'}\tilde{\gamma}^2_{\lambda c'(\lambda')}}{1 + \Sigma_c \tilde{\gamma}^2_{\lambda' c} \frac{dS_c}{dE}\Big|_{\tilde{E}_{\lambda'}}}.$$

Appendix II: Models



Appendix III: Numbers

Parameter	Model 1	Model 2	Model 3
E_{0_1} (keV)	[0]	[0]	[0]
$\gamma_{0_1 M1}$ ($10^{-11} \times$ eV^{-1})	4.35(5)	4.36(6)	[4.36]
$\Gamma^0_{0_1 M1}$ (eV)	13.7(3)	13.8(4)	[13.8]
$\gamma_{0_1\alpha_0}$ ($\sqrt{\text{keV}}$)	[22.1]	[22.1]	[22.1]
$\Gamma^0_{0_1\alpha_0}$ (eV)	[5.57]	[5.57]	[5.57]
E_{0_2} (MeV)	-	-	12.0(3)
$\gamma_{0_2 M1}$ ($10^{-11} \times$ eV^{-1})	-	-	0.58(8)
$\Gamma^0_{0_2 M1}$ (eV)	-	-	12(3)
$\gamma_{0_2\alpha_0}$ ($\sqrt{\text{keV}}$)	-	-	$-15.2(15)$
$\Gamma^0_{0_2\alpha_0}$ (MeV)	-	-	2.4(5)

Parameter	Model 1	Model 2	Model 3
$E_{2_1,}$ (keV)	3008^{+55}_{-9}	2960(22)	2969(11)
$\gamma_{2_1,M1}$ ($10^{-11} \times$ eV^{-1})	3.31(3)	3.22(6)	3.13(3)
$\Gamma^0_{2_1,M1}$ (eV)	5.57(11)	5.3(2)	5.01(11)
$\gamma_{2_1,E2}$ ($10^{-22} \times$ eV^{-3})	$-4.2(12)$	$-4(500)$	0.9(592)
$\Gamma^0_{2_1,E2}$ (meV)	1.9(12)	$<$ 10 meV	$<$ 1 meV
γ_{2_1,α_2} ($\sqrt{\text{keV}}$)	$-29.9^{+0.3}_{-1.5}$	$-29.3(5)$	28.6(3)
$\Gamma^0_{2_1,\alpha_2}$ (MeV)	1701(27)	1601(45)	1546(25)
E_{2_2} (keV)	16 629(11)	16 588(5)	16 590(5)
$\gamma_{2_2,M1}$ ($10^{-11} \times$ eV^{-1})	11.6(7)	12.7(4)	12.9(4)
$\Gamma^0_{2_2,M1}$ (meV)	27.9(17)	38(2)	38(2)
γ_{2_2,α_2} ($\sqrt{\text{keV}}$)	[3.1]	[3.1]	[3.1]
$\Gamma^0_{2_2,\alpha_2}$ (keV)	[108]	[108]	[108]
E_{2_3} (keV)	[16922]	16 912(25)	16 910(23)
$\gamma_{2_3,M1}$ ($10^{-11} \times$ eV^{-1})	$3.2^{+1.7}_{-0.9}$	4.3(8)	4.5(7)
$\Gamma^0_{2_3,M1}$ (meV)	0.8(8)	1.4(5)	1.6(5)
γ_{2_3,α_2} ($\sqrt{\text{keV}}$)	[2.2]	[2.2]	[2.2]
$\Gamma^0_{2_3,\alpha_2}$ (keV)	[74]	[74]	[74]
E_{2_4} (MeV)	-	24(3)	[24]
$\gamma_{2_4,M1}$ ($10^{-11} \times$ eV^{-1})	-	$-1.1(2)$	$-1.8(2)$
$\Gamma^0_{2_4,M1}$ (meV)	-	57(20)	160(40)
γ_{2_4,α_2} ($\sqrt{\text{keV}}$)	-	38(7)	35.9(18)
$\Gamma^0_{2_4,\alpha_2}$ (MeV)	-	20(8)	18.0(18)
χ^2/ndf	878/735	838/731	808/730
P (%)	0.02	0.36	2.3

Appendix IV: Resonance scan

Yield of 2α between 2 and 3MeV.