### Detailed R-matrix analysis of ${}^{7}\text{Li}(p, \gamma)$ at 441keV

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May 24<sup>th</sup> 2018, NMNP

# <sup>8</sup>Be

18.2	1+
17.6	1+
16.9	2+
16.6	$2^+ T = 0 + 1$



## <sup>8</sup>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

# $^{7}\mathrm{Li}(\boldsymbol{p},\gamma)$



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



#### Magnetic spectronometer





D. Zahnow et al. Zeitschrift für Physik A 351 (1995), pp. 220-236 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

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

Two 5x5cm 16x16 Double Sided Silicon Strip Detectors

Detection: position, energy and time

Coincidences





#### Coincidences



#### Spectrum

Determine widths by integration.



#### R-matrix

 $\beta$ -decay studies: "interfernce is important for <sup>8</sup>Be".

Sequential decay R-matrix expression.

(Expression in appendix)



#### Model 3

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



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### Conclusions

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

Evidence for 0<sup>+</sup> 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

#### Shadowed readout I



#### Shadowed readout II

Collaboration with Haakan Johanson (Chalmers)



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



#### Appendix I: R-matrix expression

Proceeding via narrow resonance

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

Density of states:

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

 $\gamma\text{-ray}$  "penetrability":

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

Observed widths:

$$\Gamma^{0}_{\lambda c'(\lambda')} = \int_{\lambda'} \delta \Gamma^{0}_{\lambda c'(E'_{2}r')} dE'_{2} \approx \frac{2P_{c'}\tilde{\gamma}^{2}_{\lambda c'(\lambda')}}{1 + \Sigma_{c}\tilde{\gamma}^{2}_{\lambda' c}\frac{dS_{c}}{dE}\big|_{\tilde{E}_{\lambda'}}}.$$





 $10^{3}$ 

#### Appendix III: Numbers

$\label{eq:constraint} \begin{array}{ c c c c c c c c c c c c c c c c c c c$	9(11) 3(3)
$\begin{array}{ccccc} & \gamma_{21,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.31(3) & 3.22(6) & 3.1 \\ \Gamma_{21,M1}^{0} \left(\mathrm{eV}\right) & 5.57(11) & 5.3(2) & 5.07(11) \\ \gamma_{21,E2} \left(10^{-22} \times \mathrm{eV}^{-3}\right) & -4.2(12) & -4(500) & 0.9(10) \\ \Gamma_{21,E2}^{0} \left(\mathrm{meV}\right) & 1.9(12) & <10 \mathrm{meV} & <1 \\ \gamma_{21,e2} \left(\mathrm{meV}\right) & -29.9^{+0.3}_{-0.3} & -29.3(5) & 28. \\ \Gamma_{21,e2}^{0} \left(\mathrm{MeV}\right) & 1701(27) & 1601(45) & 1544 \\ \hline E_{22} \left(\mathrm{keV}\right) & 16629(11) & 16588(5) & 165 \\ \gamma_{22,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 11.6(7) & 12.7(4) & 12. \\ \Gamma_{22,e2}^{0} \left(\mathrm{keV}\right) & [3.1] & [3.1] & [3] \\ \Gamma_{22,e2}^{0} \left(\mathrm{keV}\right) & [108] & [108] & [11 \\ \hline E_{23} \left(\mathrm{keV}\right) & [10922] & 16912(25) & 16991 \\ \gamma_{23,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{+1.7}_{-0.9} & 4.3(8) & 4.9 \\ \gamma_{23,04}^{0} \left(\mathrm{keV}\right) & [3.1] & (5.2^{+1.7}_{-0.9} & 4.3(8) & 4.9 \\ \hline \end{array}$	3(3)
$ \begin{array}{ccccc} \Gamma^0_{21,M1} \left( \mathrm{eV} \right) & 5.57(11) & 5.3(2) & 5.07(11) \\ \gamma_{21,E2} \left( 10^{-22} \times \mathrm{eV}^{-3} \right) & -4.2(12) & -4(500) & 0.99(12) \\ \Gamma^0_{21,E2} \left( \mathrm{meV} \right) & 1.9(12) & <10  \mathrm{meV} & <17(12) \\ \gamma_{21,\alpha_2} \left( \mathrm{MeV} \right) & -29.9^{+0.3}_{-1.5} & -29.3(5) & 28. \\ \Gamma^0_{21,\alpha_2} \left( \mathrm{MeV} \right) & 1701(27) & 1601(45) & 1544(12) \\ \overline{E}_{22} \left( \mathrm{keV} \right) & 16629(11) & 16588(5) & 165(12) \\ \gamma_{22,\alpha_3} \left( \mathrm{keV} \right) & 27.9(17) & 38(2) & 38(12) \\ \gamma_{23,\alpha_4} \left( \mathrm{\sqrt{keV}} \right) & [3.1] & [3.1] & [3.1] \\ \overline{E}_{2,\alpha_2} \left( \mathrm{keV} \right) & [108] & [108] & [11] \\ \overline{E}_{2,\alpha_3} \left( \mathrm{keV} \right) & [16922] & 16912(25) & 16991(25) & 16991(25) & 16991(25) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+1.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 4.3(8) & 4.9(12) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( \mathrm{eV}^{-1} \right) & 3.2^{+0.7}_{-0.9} & 3.3(8) \\ \gamma_{23,M1} \left( $	
$\begin{array}{ccccccc} \gamma_{2_3,E2} & (10^{-22} \times \mathrm{eV}^{-3}) & -4.2(12) & -4(500) & 0.9(\\ \Gamma_{2_1,E2}^0 & (\mathrm{meV}) & 1.9(12) & < 10  \mathrm{meV} & < 1 \\ \gamma_{2_1,\alpha_2} & (\sqrt{\mathrm{keV}}) & -29.9^{+0.3}_{-1.5} & -29.3(5) & 28. \\ \Gamma_{2_1,\alpha_2}^0 & (\sqrt{\mathrm{keV}}) & 1701(27) & 1601(45) & 154. \\ \hline E_{2_2} & (\mathrm{keV}) & 16629(11) & 16588(5) & 165 \\ \gamma_{2_3,M1} & (10^{-11} \times \mathrm{eV}^{-1}) & 11.6(7) & 12.7(4) & 12. \\ \Gamma_{2_3,M1}^0 & (\sqrt{\mathrm{keV}}) & [3.1] & [3.1] & [3] \\ \gamma_{2_3,\alpha_2}^0 & (\sqrt{\mathrm{keV}}) & [13] & [3.1] & [3] \\ \Gamma_{2_3,\alpha_2}^0 & (\mathrm{keV}) & [108] & [108] & [11 \\ \hline E_{2_3} & (\mathrm{keV}) & [16922] & 16912(25) & 1691 \\ \gamma_{2_3,M1} & (10^{-11} \times \mathrm{eV}^{-1}) & 3.2^{+1.7}_{-0.0} & 4.3(8) & 4. \\ \end{array}$	(11)
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	592)
$\begin{array}{cccc} & \gamma_{2_1,\alpha_2} & (\sqrt{\mathrm{keV}}) & -29.9^{+0.3}_{-1.5} & -29.3(5) & 28. \\ \Gamma^{2}_{2_1,\alpha_2} & (\mathrm{MeV}) & 1701(27) & 1601(45) & 154. \\ \hline E_2 & (\mathrm{keV}) & 16629(11) & 16588(5) & 165 \\ \gamma_{2_2,M1} & (10^{-11} \times \mathrm{eV}^{-1}) & 11.6(7) & 12.7(4) & 12. \\ \Gamma^{0}_{2_2,M1} & (\mathrm{meV}) & 27.9(17) & 38(2) & 38 \\ \gamma_{2_2,\alpha_2} & (\sqrt{\mathrm{keV}}) & [3.1] & [3.1] & [3] \\ \Gamma^{0}_{2_2,\alpha_2} & (\mathrm{keV}) & [108] & [108] & [108] \\ \hline E_{2_3} & (\mathrm{keV}) & [16922] & 16912(25) & 1699 \\ \gamma_{2_5,M1} & (10^{-11} \times \mathrm{eV}^{-1}) & 3.2^{+1.7}_{-1.7} & 4.3(8) & 4.5 \\ \end{array}$	meV
$\begin{array}{c ccccc} \Gamma^0_{2_1,\alpha_2} \ ({\rm MeV}) & 1701(27) & 1601(45) & 1544 \\ \hline E_{2_2} \ ({\rm keV}) & 16 \ 629(11) & 16 \ 588(5) & 16 \ 5\\ \gamma_{2_2,M1} \ (10^{-11} \times {\rm eV}^{-1}) & 11. \ 6(7) & 12.7(4) & 12. \\ \gamma_{2_2,M1} \ ({\rm meV}) & 27.9(17) & 38(2) & 38 \\ \gamma_{2_2,\alpha_2} \ ({\rm keV}) & [3.1] & [3.1] & [3] \\ \Gamma^0_{2_2,\alpha_2} \ ({\rm keV}) & [108] & [108] & [108] \\ \hline E_{2_3} \ ({\rm keV}) & [16922] & 16 \ 912(25) $	6(3)
$ \begin{array}{ccccc} E_{2_2} \left( \mathrm{keV} \right) & 16629(11) & 16588(5) & 165\\ \gamma_{2_2,\mathrm{M}} \left( 10^{-11} \times \mathrm{eV}^{-1} \right) & 11.6(7) & 12.7(4) & 12.\\ \Gamma_{2_2,\mathrm{M}}^0 \left( \mathrm{keV} \right) & 27.9(17) & 38(2) & 38\\ \gamma_{2_3,\alpha_2} \left( \mathrm{keV} \right) & [3.1] & [3.1] & [3]\\ \Gamma_{2_2,\alpha_2} \left( \mathrm{keV} \right) & [108] & [108] & [1\\ E_{2_2} \left( \mathrm{keV} \right) & [108] & 108] & [1\\ \end{array} $	6(25)
$\begin{array}{cccc} \gamma_{2_2,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 11.6(7) & 12.7(4) & 12. \\ \Gamma_{2_2,M1}^0 \left(\mathrm{meV}\right) & 27.9(17) & 38(2) & 33 \\ \gamma_{2_2,\alpha_2} \left(\sqrt{\mathrm{keV}}\right) & [3.1] & [3.1] & [3] \\ \Gamma_{2_2,\alpha_2} \left(\mathrm{keV}\right) & [108] & [108] & [11] \\ \overline{E_{2_1}} \left(\mathrm{keV}\right) & [16922] & 16912(25) & 1691 \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{+1.7}_{-0.0} & 4.3(8) & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 4.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 3.2^{-1.7}_{-0.0} & 3.2^{-1.7}_{-0.0} & 3.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 3.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 3.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.2^{-1.7}_{-0.0} & 3.3(8) \\ \gamma_{2_1,M1} \left(10^{-11} \times \mathrm{eV}^{-1}\right) & 3.3(8) \\ \gamma_{2_$	90(5)
$ \begin{array}{cccc} \Gamma^0_{2_2,M1} & (\text{meV}) & 27.9(17) & 38(2) & 38\\ \gamma_{2_2,\alpha_2} & (\sqrt{\text{keV}}) & [3.1] & [3.1] & [3]\\ \Gamma^0_{2_2,\alpha_2} & (\text{keV}) & [108] & [108] & [1]\\ E_{2_3} & (\text{keV}) & [16922] & 16912(25) & 1691\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.0}_{-1.0} & 4.3(8) & 4.4\\ \end{array} $	9(4)
$\begin{array}{c cccc} \gamma_{2_2,\alpha_2} & (\sqrt{\text{keV}}) & [3.1] & [3.1] & [3] \\ \Gamma_{2_2,\alpha_2}^0 & (\text{keV}) & [108] & [108] & [1\\ E_{2_3} & (\text{keV}) & [16922] & 16912(25) & 1691\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.3(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.3(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.3(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.3(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.5}_{-1.5} & 4.5(8) & 4.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) & 3.5\\ \gamma_{2_3,M1} & (10^{-11} \times \text{eV}^{-1}) &$	(2)
$ \begin{array}{c c} \Gamma_{2_2,\alpha_2}^0 (\text{keV}) & [108] & [108] & [1\\ \hline E_{2_3} (\text{keV}) & [16922] & 16912(25) & 1691\\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.7}_{-1.7} & 4.3(8) & 4.2(8) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.7}_{-1.7} & 4.3(8) & 4.2(8) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.7}_{-1.7} & 4.3(8) & 4.2(8) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.7}_{-1.7} & 4.3(8) & 4.2(8) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.7}_{-1.7} & 4.3(8) & 4.2(8) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) & \gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1}) \\ \gamma_{2_3,M1} (1$	.1]
$\begin{array}{cccc} E_{23} \ (\text{keV}) & [16922] & 16912(25) & 1691\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+1.7}_{-0.9} & 4.3(8) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 4.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.4(5) & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1}) & 3.2^{+0.9}_{-0.9} & 1.9\\ \gamma_{23,M1} \ (10^{-11} \times \text{eV}^{-1})$	08]
$\gamma_{2_3,M1} (10^{-11} \times \text{eV}^{-1})  3.2^{+1.7}_{-0.9}  4.3(8)  4.5$	.0(23)
$= 0  (\dots, 1/1)  0  0  0  1  1/(1)  1/($	5(7)
$1_{2_3,M1}$ (mev) $0.8(8)$ $1.4(5)$ $1.6$	5(5)
$\gamma_{2_3,\alpha_2}$ ( $\sqrt{\text{keV}}$ ) [2.2] [2.2]	.2]
$\Gamma^{0}_{2_{3},\alpha_{2}}$ (keV) [74] [74]	'4]
E <sub>24</sub> (MeV) - 24(3) [2	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)
$\gamma_{2_4,\alpha_2}$ ( $\sqrt{\text{keV}}$ ) - 38(7) 35.9	9(18)
$\Gamma^0_{2_4,\alpha_2}$ (MeV) - 20(8) 18.0	)(18)
$\chi^2/\text{ndf}$ 878/735 838/731 808	
P (%) 0.02 0.36 2	/730

				. )
Parameter	Model 1	Model 2	Model 3	Г 
E <sub>01</sub> (keV)	[0]	[0]	[0]	E
$\gamma_{0_1M1} (10^{-11} \times \text{eV}^{-1})$	4.35(5)	4.36(6)	[4.36]	7
$\Gamma_{0,M1}^{0}$ (eV)	13.7(3)	13.8(4)	[13.8]	Г
$\gamma_{0_1\alpha_0}$ ( $\sqrt{\text{keV}}$ )	[22.1]	[22.1]	[22.1]	7
$\Gamma^0_{0_1\alpha_0}$ (eV)	[5.57]	[5.57]	[5.57]	
E02 (MeV)	-	-	12.0(3)	E
$\gamma_{0_2M1} (10^{-11} \times \text{eV}^{-1})$	-	-	0.58(8)	7
$\Gamma^{0}_{0_{2}M1}$ (eV)	-	-	12(3)	Г
$\gamma_{0_2\alpha_0}$ ( $\sqrt{\text{keV}}$ )	-	-	-15.2(15)	1
$\Gamma^0_{0_2 \alpha_0}$ (MeV)	-	-	2.4(5)	Г 

#### Appendix IV: Resonance scan

Yield of  $2\alpha$  between 2 and 3MeV.

