Photodisintegration of ^{9}Be through the ½+ state and pygmy dipole resonance

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Outline

1. Purpose
2. Experiment
3. Results

Purpose

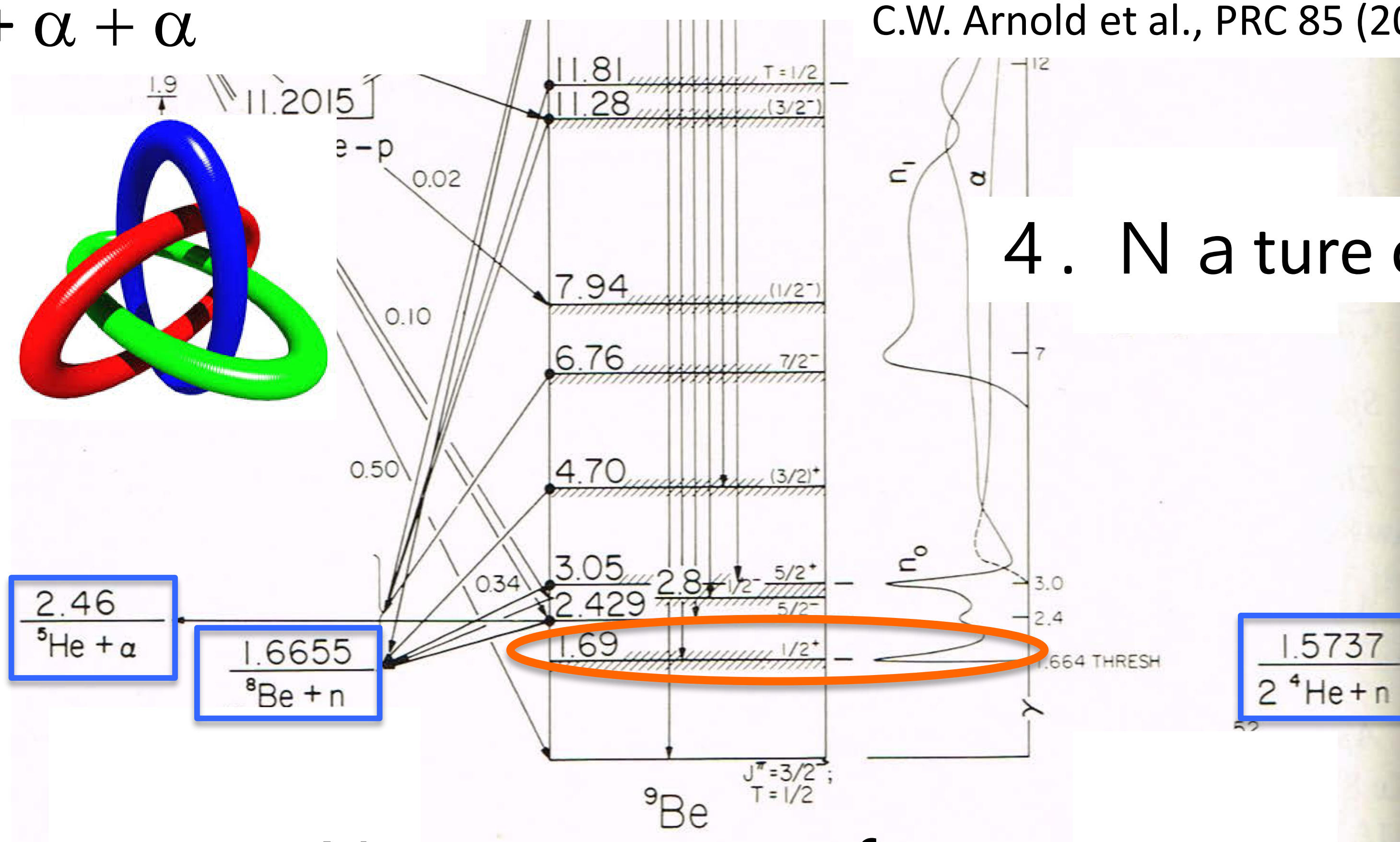
2. Nucleosynthesis of ^{9}Be

$\alpha\alpha \rightleftarrows$ ^{8}Be(n,γ)^{9}Be(α,n)^{12}C ---

H. Utsunomiya et al., PRC 63 (2001)
C.W. Arnold et al., PRC 85 (2012)

1. Borromean system

n + α + α



4. Nature of PDR

3. Nature of the ½$^{+}$ state

Resonance or Virtual state?

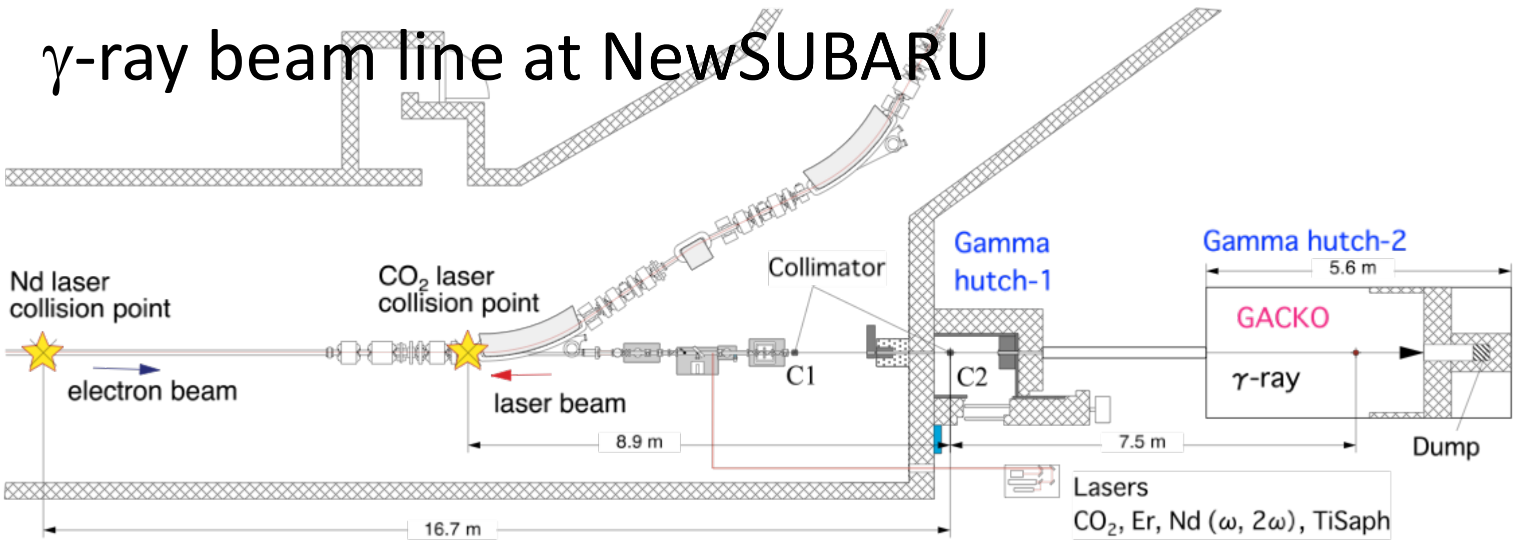
Poster I-7

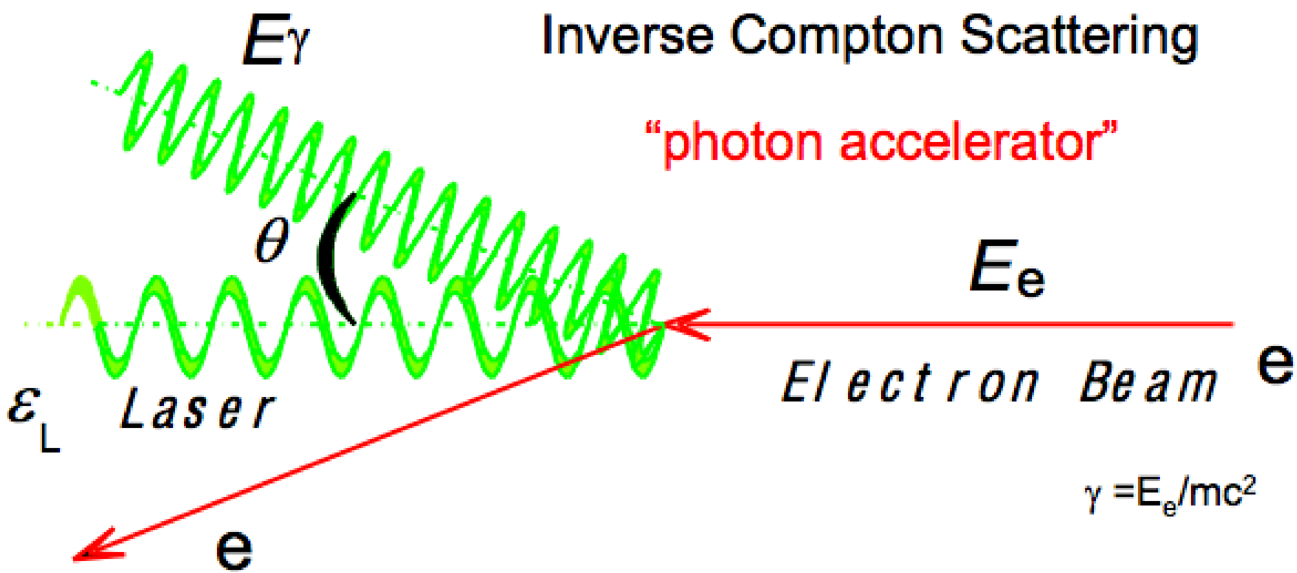
Seitarou Karayama

Details of the experiment


SPring8
8 GeV e- storage ring
SACLA
8 GeV e- linac
1 GeV e- Linac
NewSUBARU
MeV γ

γ-ray beam line at NewSUBARU





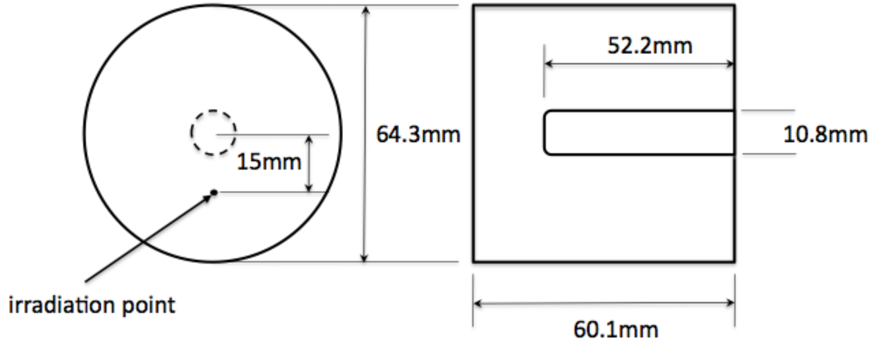
Nd:YVO_4 laser (INAZUMA) for high-energy γ-ray beams
Q-switch, λ=1064nm, 35W

CO_2 laser for low-energy γ-ray beams
CW, λ=10.5915 μm ± 3Å (grating fixed), 10W

γ-ray Profile Monitor Detectors

HPGe detector

Low-energy γ-ray beams

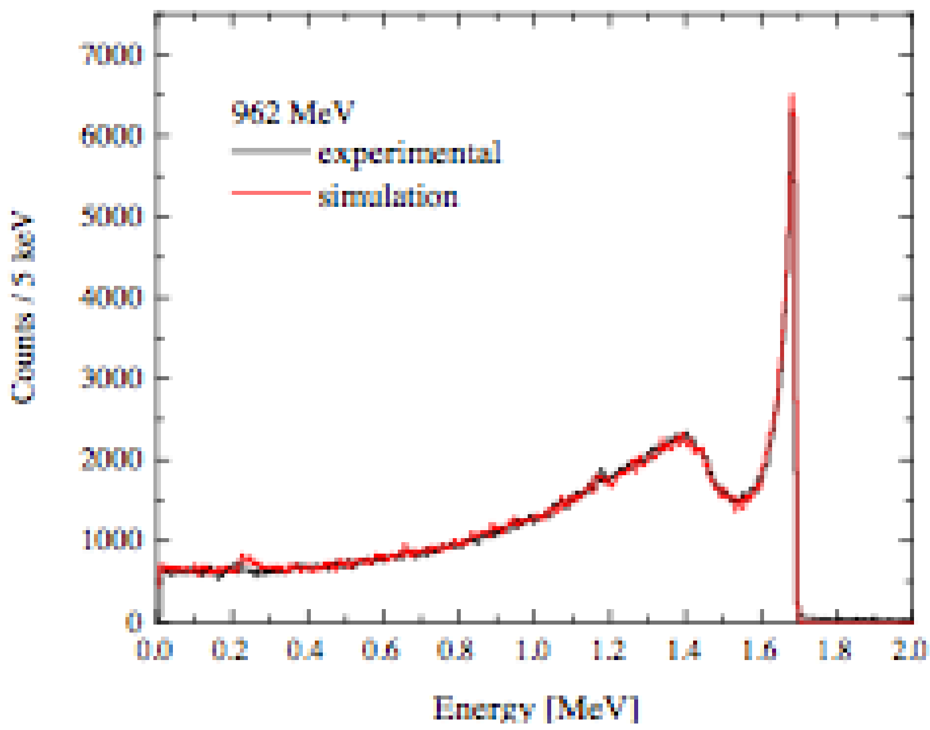


$LaBr_3(Ce)$ detector

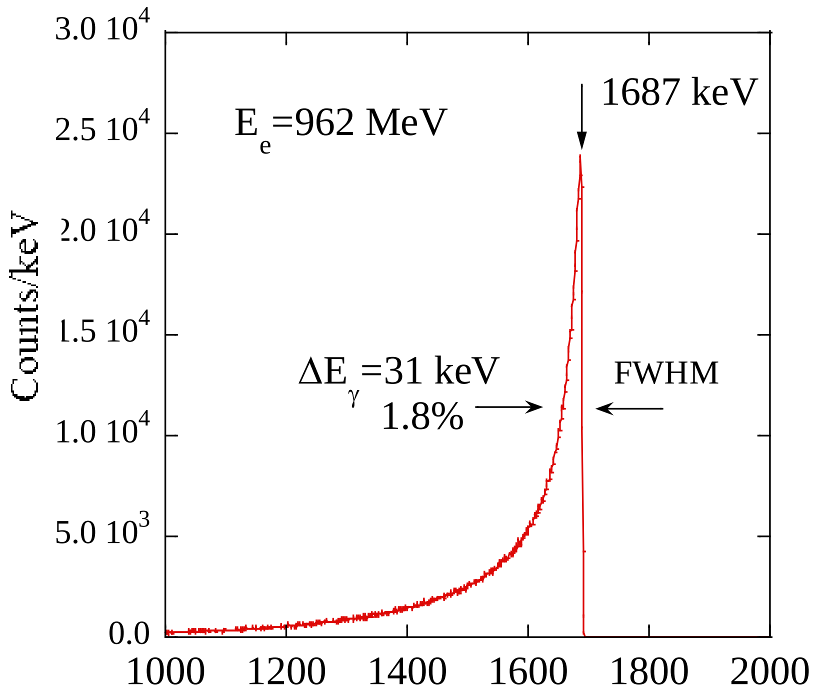
High-energy γ-ray beams

3.5” x 4.0”

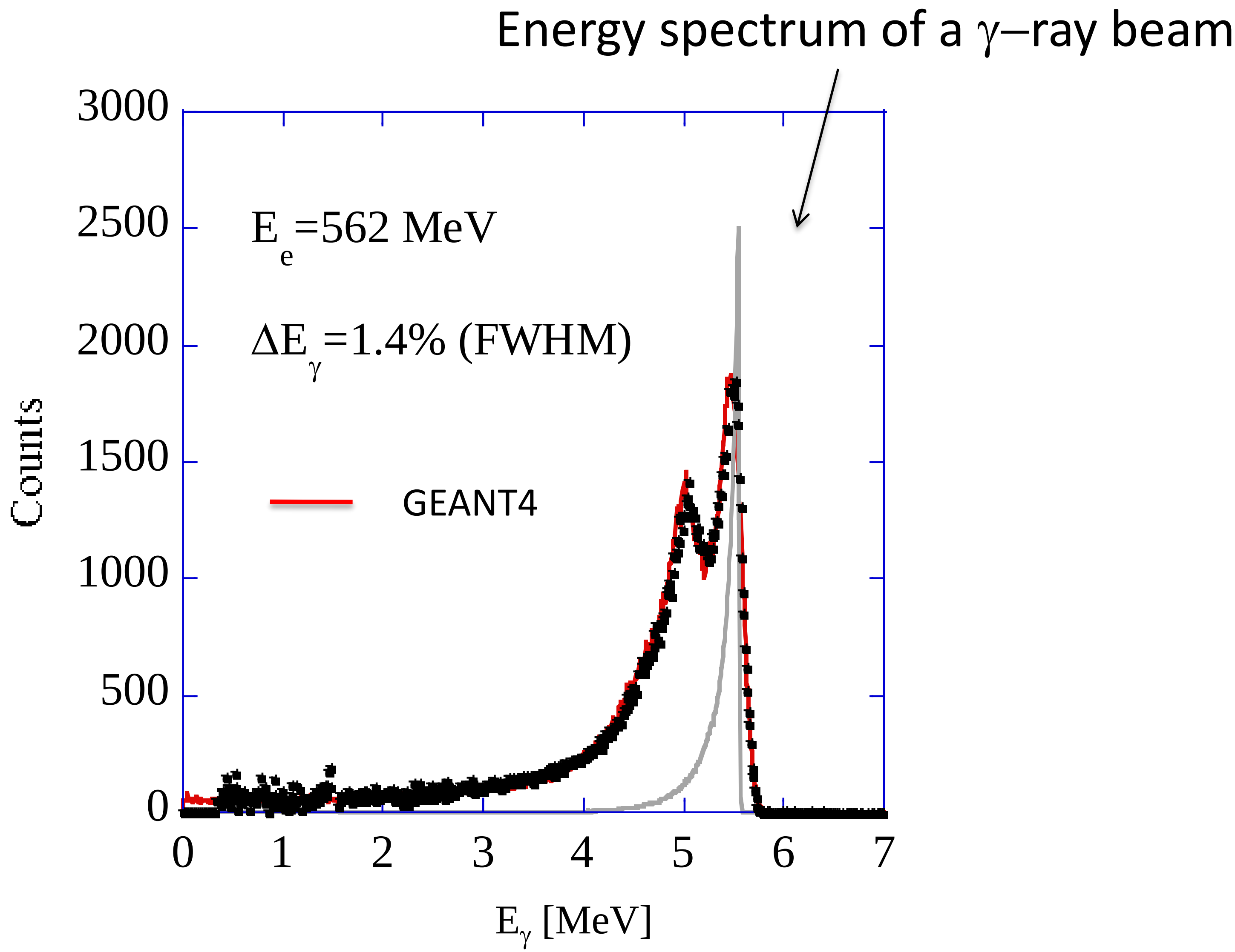
Response functions of a Ge detector



Energy spectrum of a γ–ray beam



Response function of a $LaBr_3$(Ce) detector



9Be Target

20mm (dia.) x 40mm (length)

γ-ray Flux Monitor

8.0” x 12.0” NaI(Tl), 100% efficiency

Number of incident γ-rays

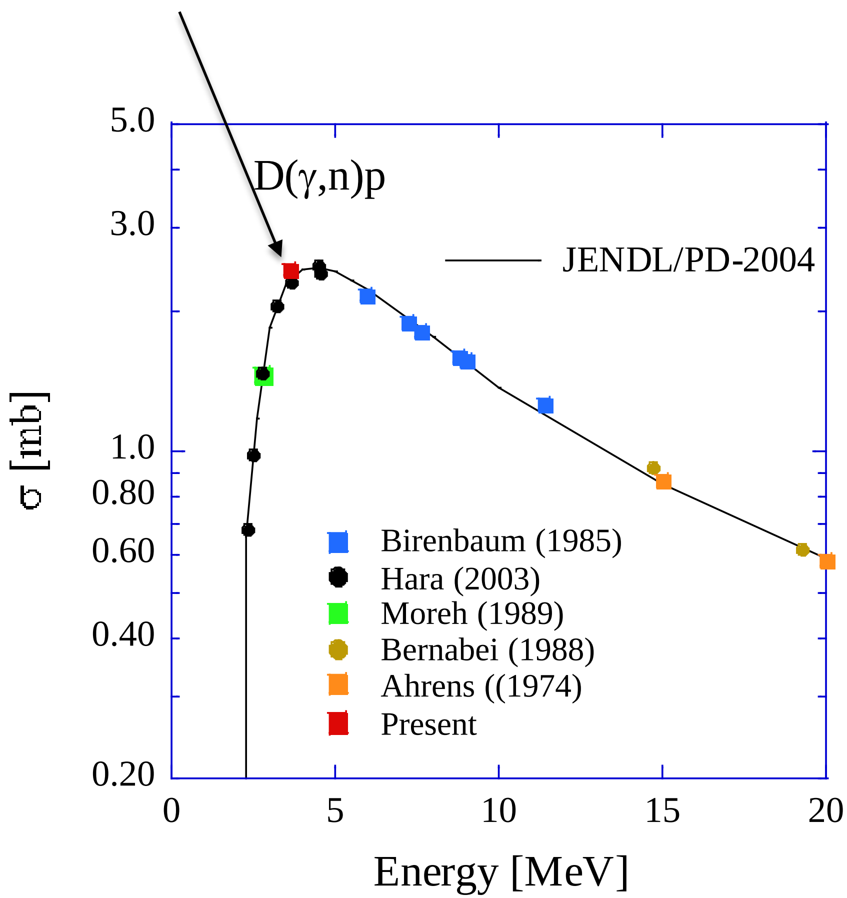
Poisson-fitting method for multi-photon spectra

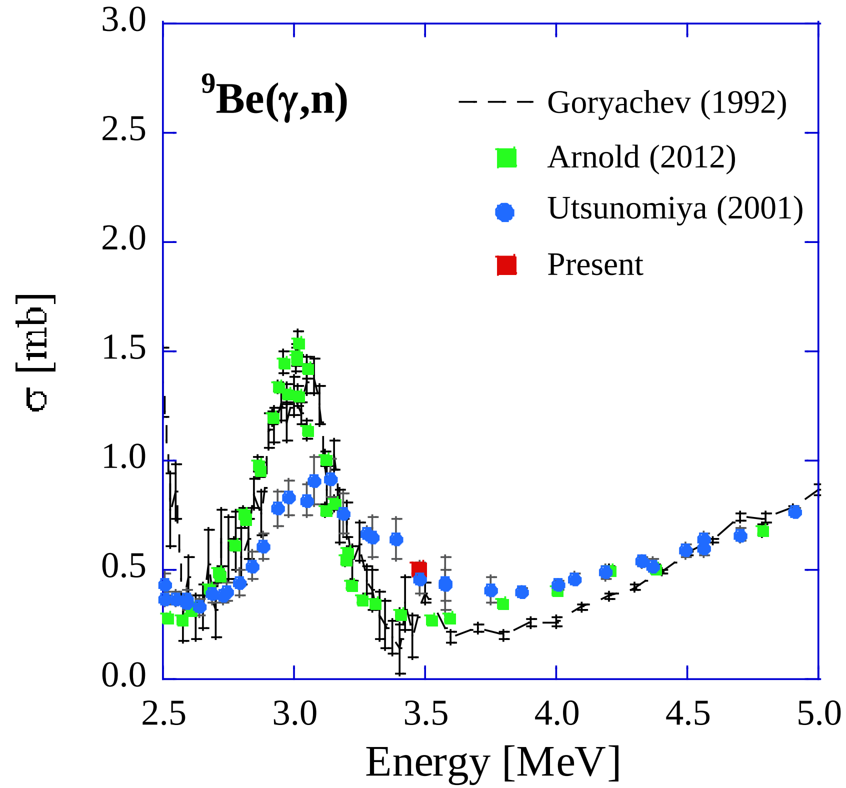
T. Kondo et al., NIM A 659, 462 (2011)

D(γ,n)p cross sections

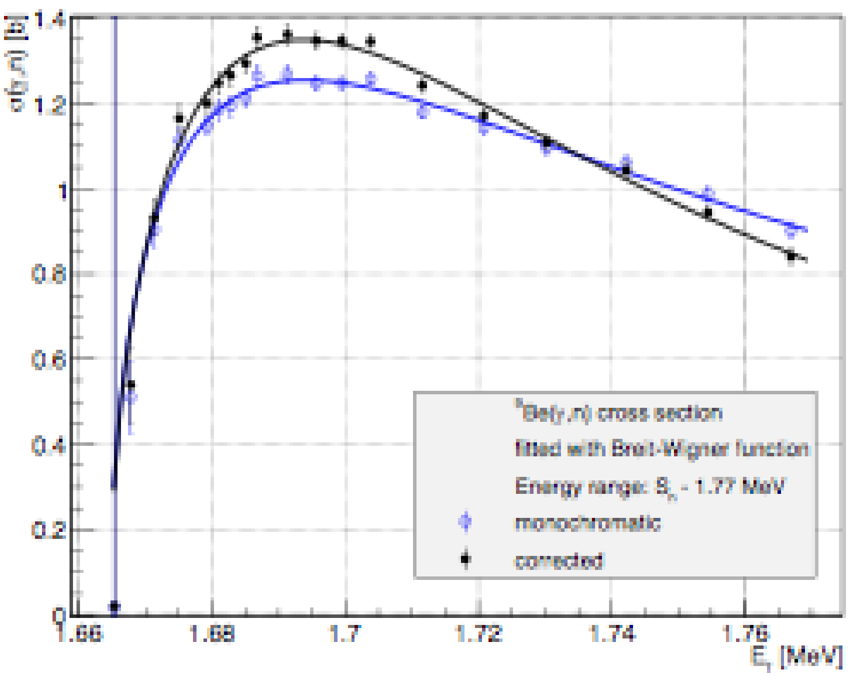
^{9}Be(γ,n) cross sections

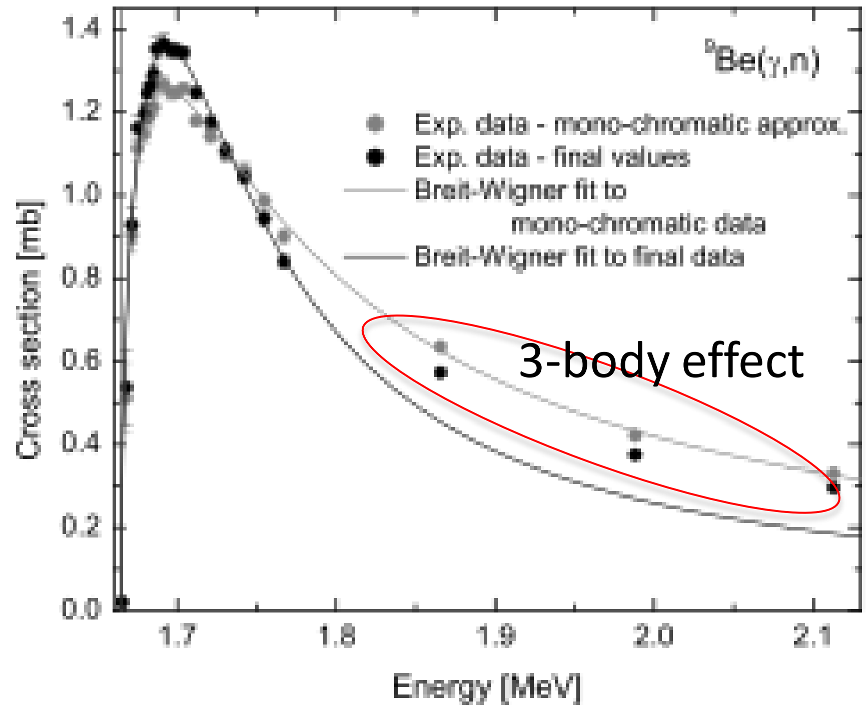
Present cross section
2.44 mb at 3.64 MeV





½+ state data





Breit-Wigner fit

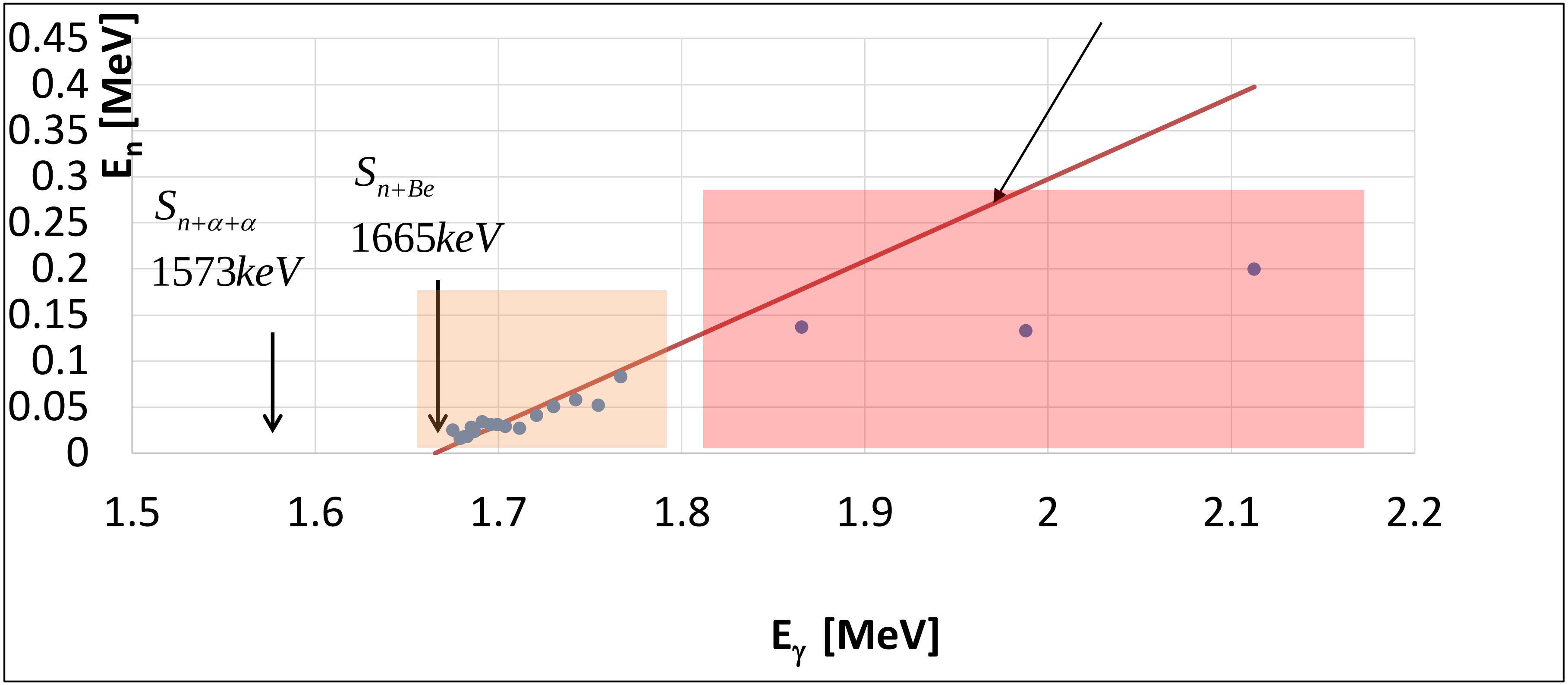
$$\sigma(E : I \to J) = \pi \frac{2J+1}{2(2I+1)} \left(\frac{\hbar c}{E}\right)^2 \frac{\Gamma_\gamma \Gamma_n}{(E-E_R)^2 + (\Gamma/2)^2}$$

$B(E1) = 0.110[e^2\ fm^2]$ E_R=1.728 MeV

Average neuron energy

Two-body kinematics

$$E_n = \frac{8}{9}(E_\gamma - 1.6653)$$

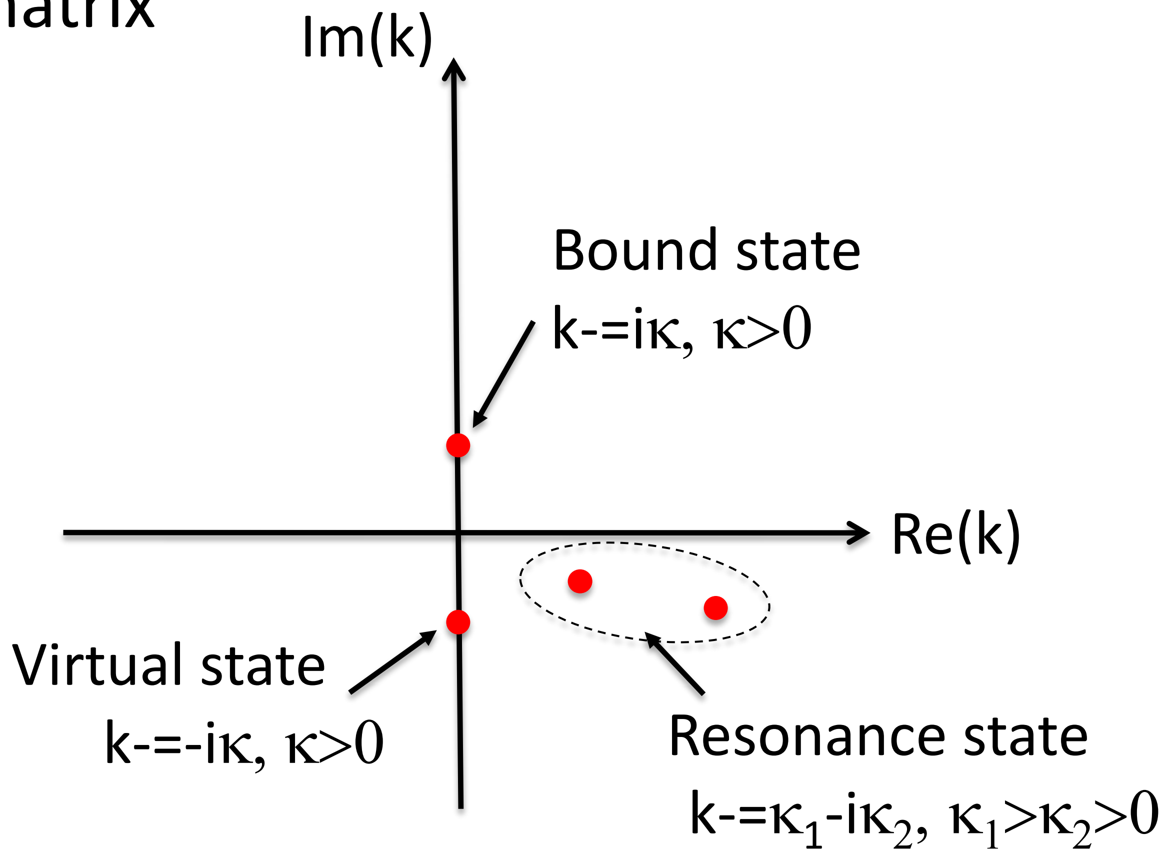


Comparisons

½+ state	Present	Arnold (2012)	Utsunomiya (2001) Sumiyoshi (2002)
Peak cross section	1.35mb	1.7mb	1.3mb
Resonance energy	1.728 MeV	1.713 MeV	1.748 MeV 1.735 MeV
B(E1)	0.110 e^2 fm^2	0.136 e^2 fm^2	0.107 e^2 fm^2 0.104 e^2 fm^2

S-matrix for n-^{8}Be scattering

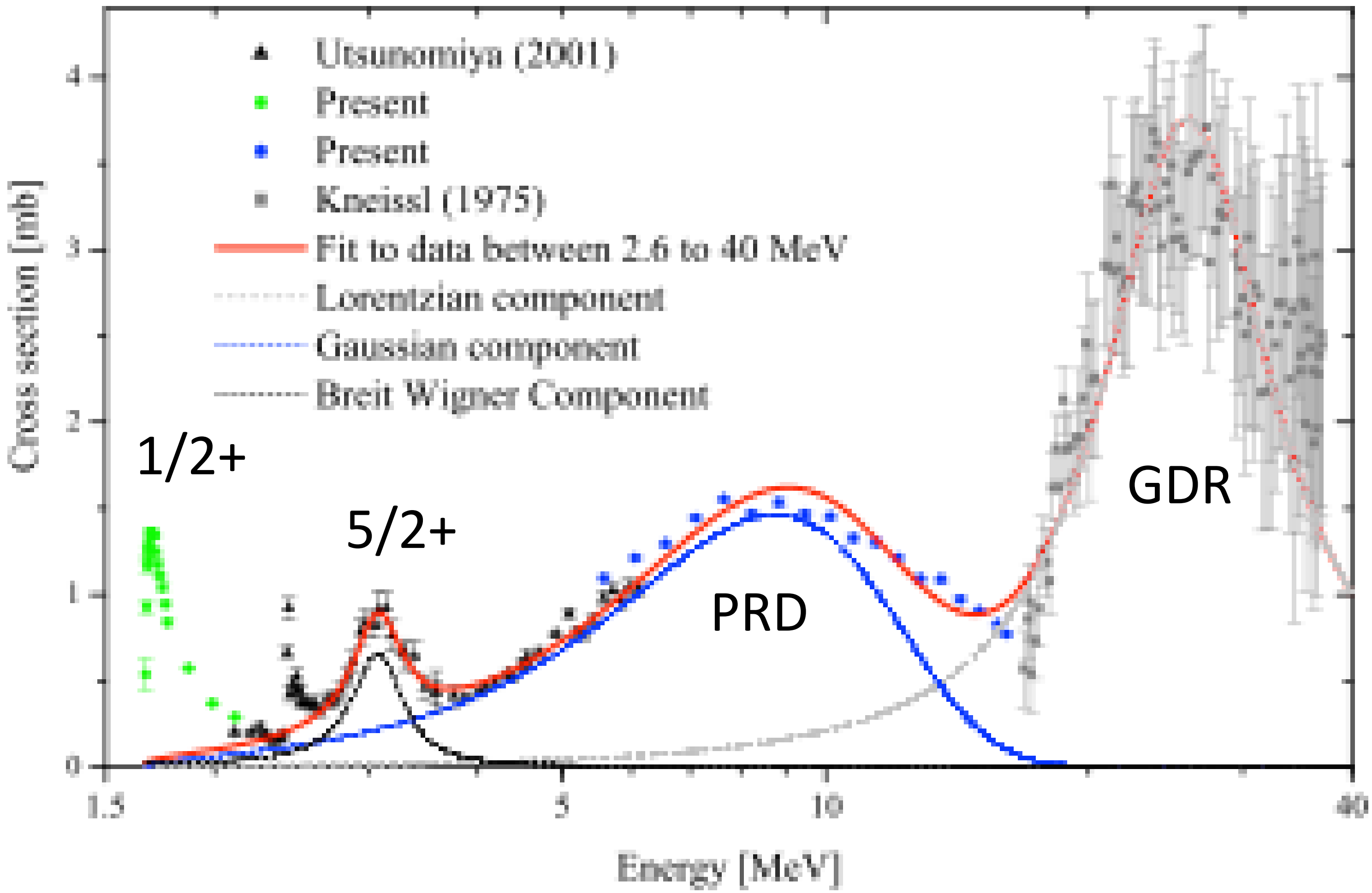
Poles of S-matrix



PDR Data

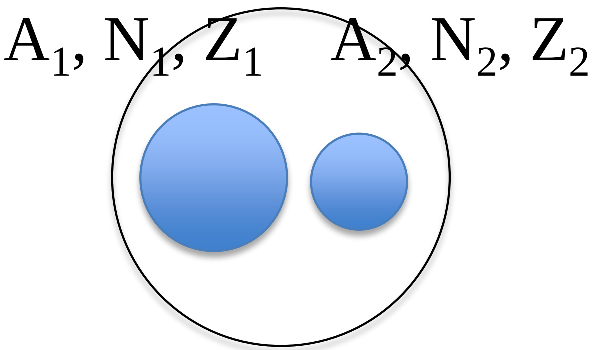
$$\int \sigma_{PDR}(E)dE = 11.3\,MeV \cdot mb$$

GDR: Lorentzian function
PDR: Gaussian function
$5/2^{+}$ state: Breit-Wigner

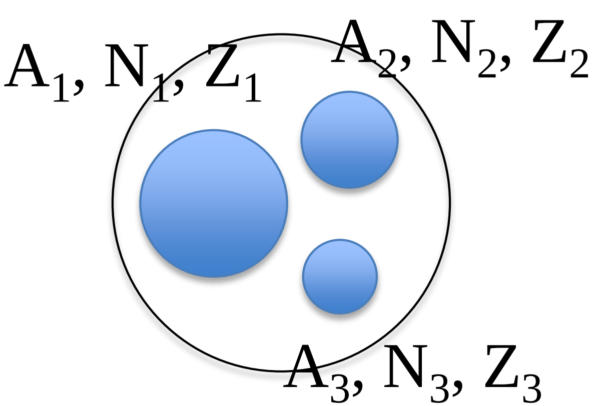


Cluster dipole sum rule

Y. Alhassid, M. Gai, G.F. Bertsch, Phys. Rev. Lett. 49, 1482 (1982)
H. Sagawa, M. Homma, Phys. Lett. B 251, 17 (1990)
R. De Diego, E. Garrido, A.S. Jensen, D.V. Fedorov, Phys. Rev. C 77, 024001 (2008)



A, N, Z



TRK

$$\int \sigma_{E1}(E)dE = 60\left(\frac{NZ}{A} - \sum_{i=1} \frac{N_i Z_i}{A_i}\right) MeV \bullet mb$$

TRK 133.3 MeV mb

$^{9}Be = {}^{8}Be + n \quad \rightarrow \quad 60 \times \frac{2}{9} = 13.3\, MeV \cdot mb$

$^{9}Be = \alpha + \alpha + n \quad \rightarrow 60 \times \frac{2}{9} = 13.3\, MeV \cdot mb$

Comparisons

Experimental result ^{9}Be

$$\int \sigma_{PDR}(E)\,dE = 11.3\,MeV \cdot mb \qquad Fit$$

TRK 133.3 MeV mb

Cluster dipole sum rule

^{8}Be+n 13.3 MeV mb

$\alpha + \alpha + n$ 13.3 MeV mb

Summary

1. The ½+ state cross section was newly measured at the NewSUBARU facility. The peak cross section ~ 1.35 mb is smaller than that (1.7 mb) of Arnold et al. (2012) and is rather consistent with the previous 2001 data.
2. $\sigma(E_\gamma) \sim 0$ $\quad S_{n+\alpha+\alpha} < E_\gamma < S_{n+8Be}$
3. The average neutron energy data show 2-body ($n+{}^8Be$) breakup in the peak region of the cross section and suggest the emergence of 3-body ($n+\alpha+\alpha$) breakup in the high-energy tail.
4. The new ½+ cross section may help to investigate the nuclear structure of the ½+ state, resonance or virtual state.
5. The PDR cross section is consistent with the cluster dipole sum rule, which however does not distinguish whether a neutron oscillates in ${}^8Be+n$ or $\alpha + \alpha + n$ configurations. To identify the configuration, a new experiment of $\alpha + \alpha + n$ coincidences is necessary.