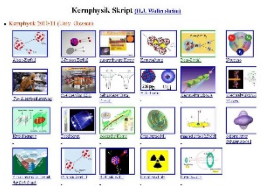
Outline: Doubly magic nucleus ^{208}Pb

Lecturer: Hans-Jürgen Wollersheim

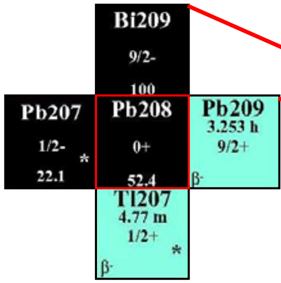
e-mail: h.j.wollersheim@gsi.de

web-page: https://web-docs.gsi.de/~wolle/ and click on



1. experimental single-particle energies
2. octupole vibrational states in the Pb region
3. Coulomb excitation ^{208}Pb on ^{208}Pb
4. superposition of vibrational and particle motion (^{209}Bi)
5. experiment above the Coulomb barrier

Doubly magic nucleus ^{208}Pb



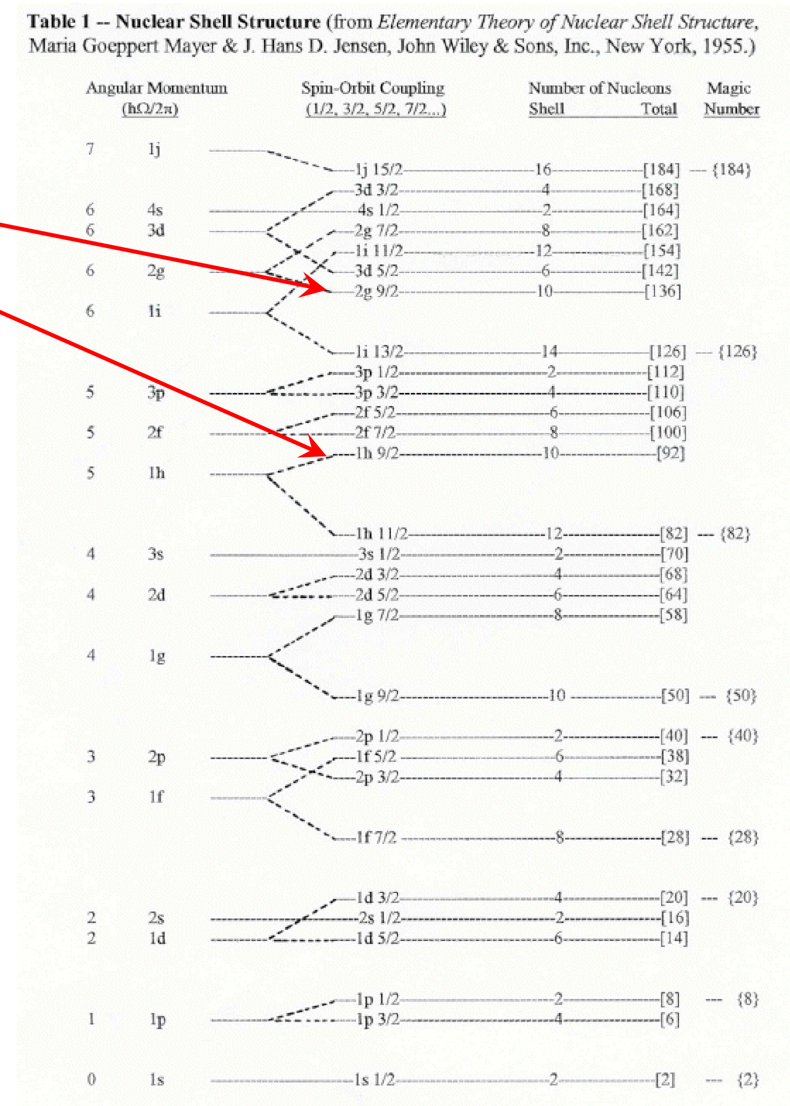


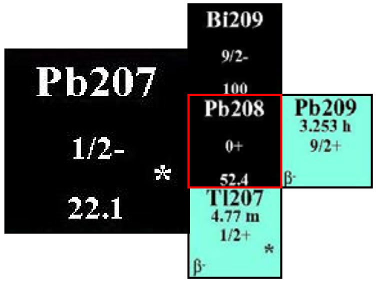
Table 1 -- Nuclear Shell Structure (from *Elementary Theory of Nuclear Shell Structure*, Maria Goeppert Mayer & J. Hans D. Jensen, John Wiley & Sons, Inc., New York, 1955.)

Angular Momentum (hΩ/2π)		Spin-Orbit Coupling (1/2, 3/2, 5/2, 7/2...)	Number of Nucleons Shell	Total	Magic Number
7	1j				
		1j 15/2	16	[184]	{184}
		3d 3/2	4	[168]	
6	4s	4s 1/2	2	[164]	
6	3d	2g 7/2	8	[162]	
		1i 11/2	12	[154]	
		3d 5/2	6	[142]	
6	2g	2g 9/2	10	[136]	
6	1i				
		1i 13/2	14	[126]	{126}
		3p 1/2	2	[112]	
5	3p	3p 3/2	4	[110]	
		2f 5/2	6	[106]	
5	2f	2f 7/2	8	[100]	
		1h 9/2	10	[92]	
5	1h				
		1h 11/2	12	[82]	{82}
4	3s	3s 1/2	2	[70]	
		2d 3/2	4	[68]	
4	2d	2d 5/2	6	[64]	
		1g 7/2	8	[58]	
4	1g				
		1g 9/2	10	[50]	{50}
		2p 1/2	2	[40]	{40}
3	2p	1f 5/2	6	[38]	
		2p 3/2	4	[32]	
3	1f				
		1f 7/2	8	[28]	{28}
		1d 3/2	4	[20]	{20}
2	2s	2s 1/2	2	[16]	
2	1d	1d 5/2	6	[14]	
		1p 1/2	2	[8]	{8}
1	1p	1p 3/2	4	[6]	
0	1s	1s 1/2	2	[2]	{2}

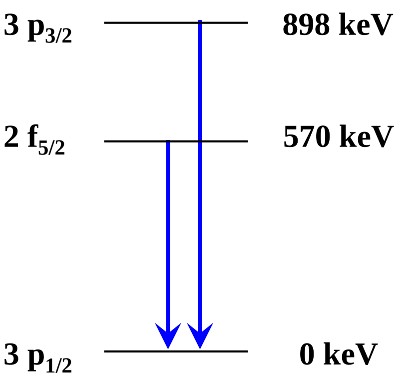
Maria Goeppert-Mayer

J. Hans D. Jensen

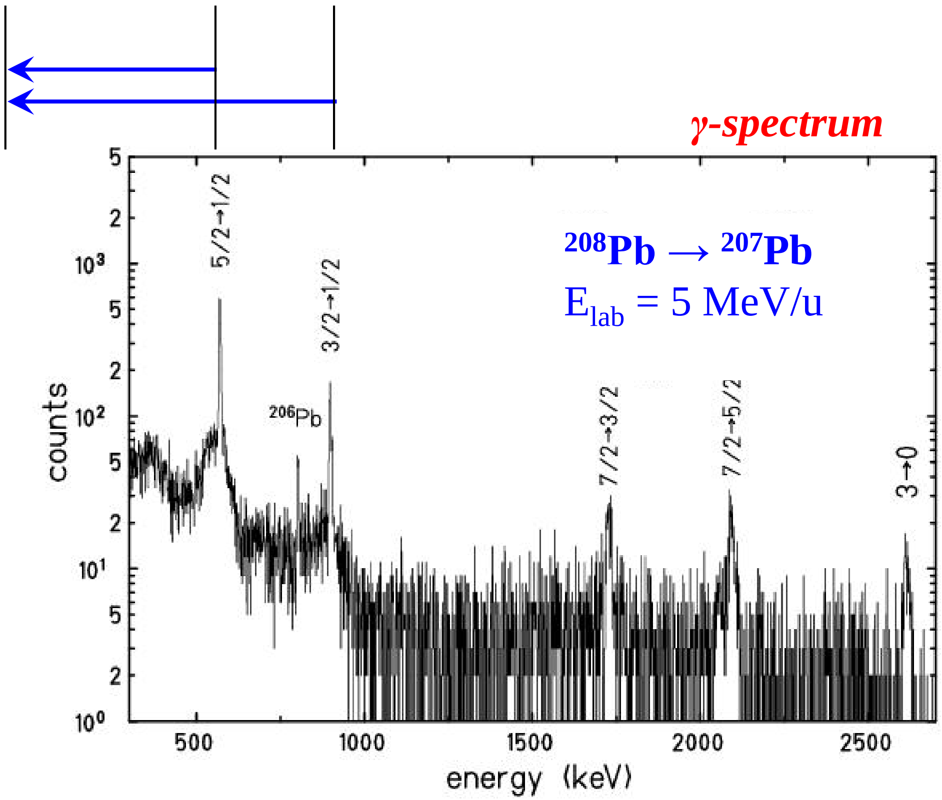
Experimental single-particle energies



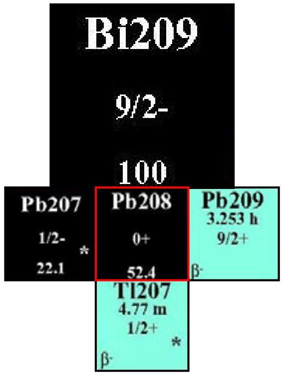
single-hole energies



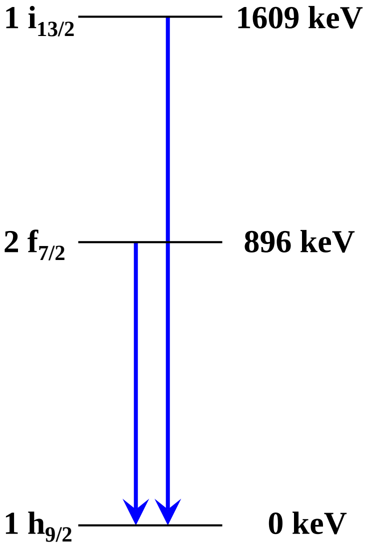
$^{207}_{82}Pb_{125}$



Experimental single-particle energies

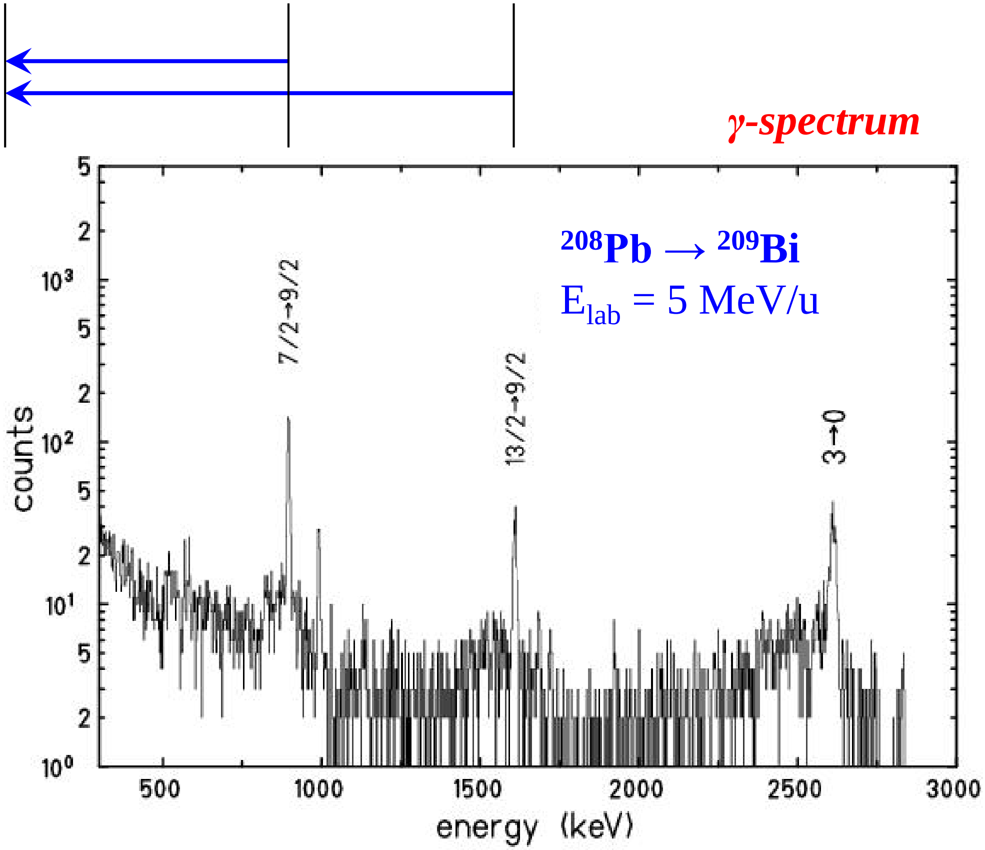


single-particle energies



$^{209}_{83}Bi_{126}$

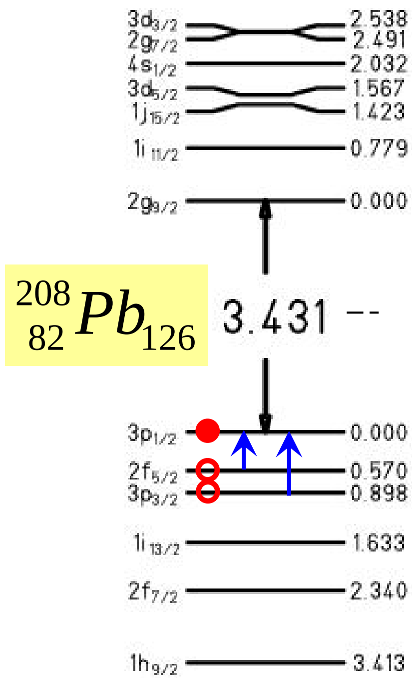
γ-spectrum



Experimental single-particle energies

particle states

^{209}**Bi** ^{209}**Pb**



^{207}**Tl** ^{207}**Pb**

hole states

neutrons

energy of shell closure:

$$BE(^{209}Pb) - BE(^{208}Pb) = E(2g_{9/2})$$

$$BE(^{207}Pb) - BE(^{208}Pb) = -E(3p_{1/2})$$

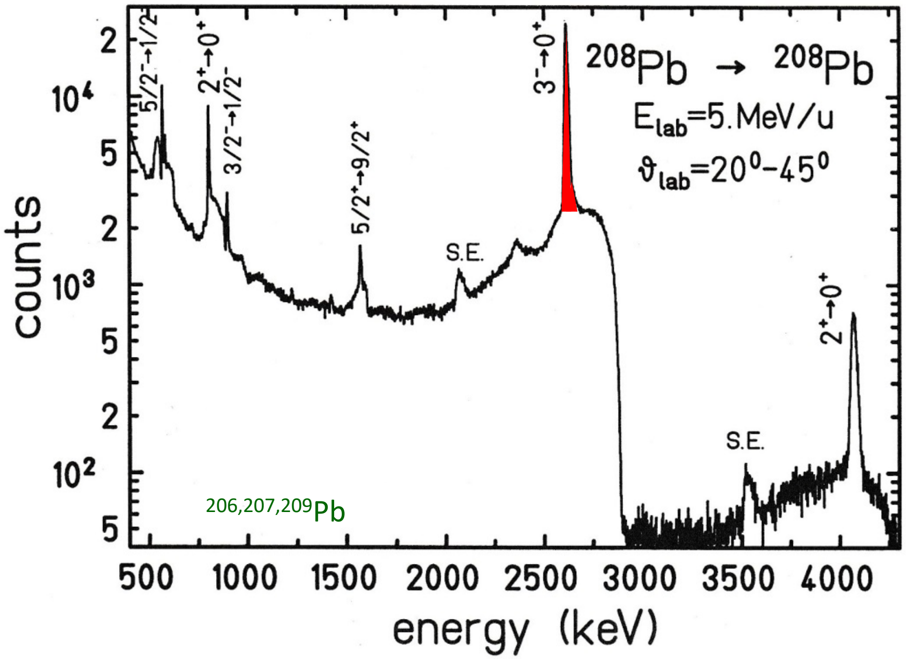
$$E(2g_{9/2}) - E(3p_{1/2}) = BE(^{209}Pb) + BE(^{207}Pb) - 2\cdot BE(^{208}Pb)$$
$$= -3.432$$

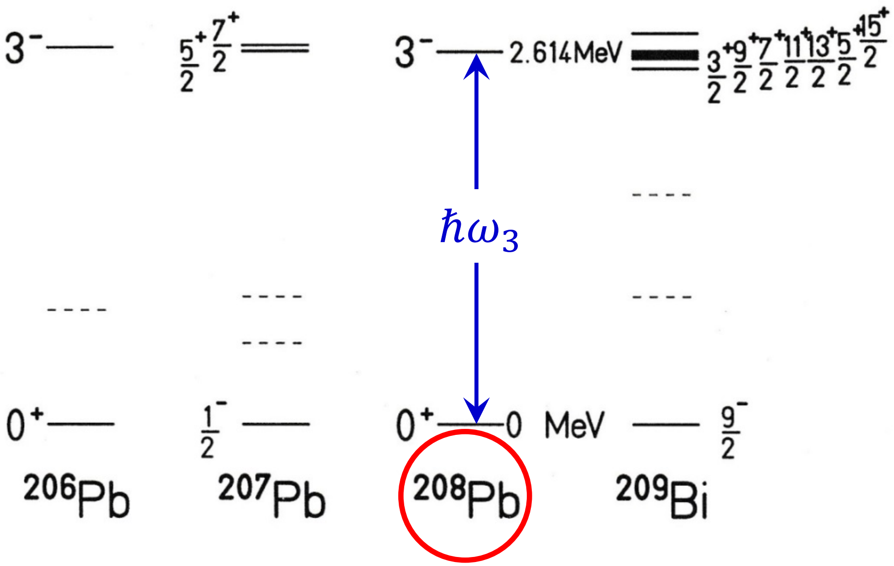
$$BE(^{209}Bi) - BE(^{208}Pb) = E(1h_{9/2})$$

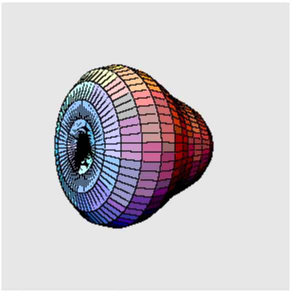
$$BE(^{207}Tl) - BE(^{208}Pb) = -E(3s_{1/2})$$

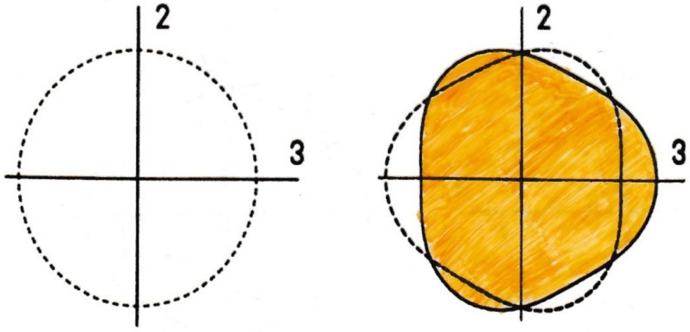
$$E(1h_{9/2}) - E(3s_{1/2}) = BE(^{209}Bi) + BE(^{207}Tl) - 2\cdot BE(^{208}Pb)$$
$$= -4.211\,MeV$$

Octupole vibrational states in the Pb region

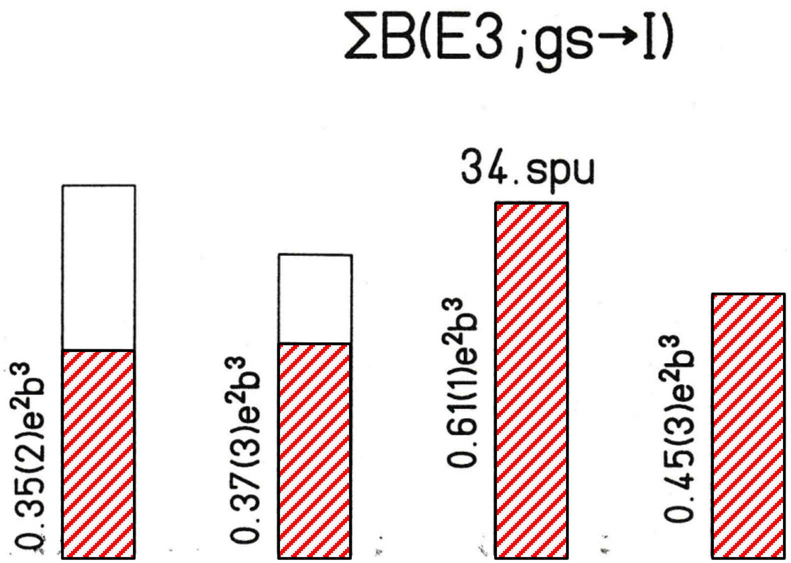


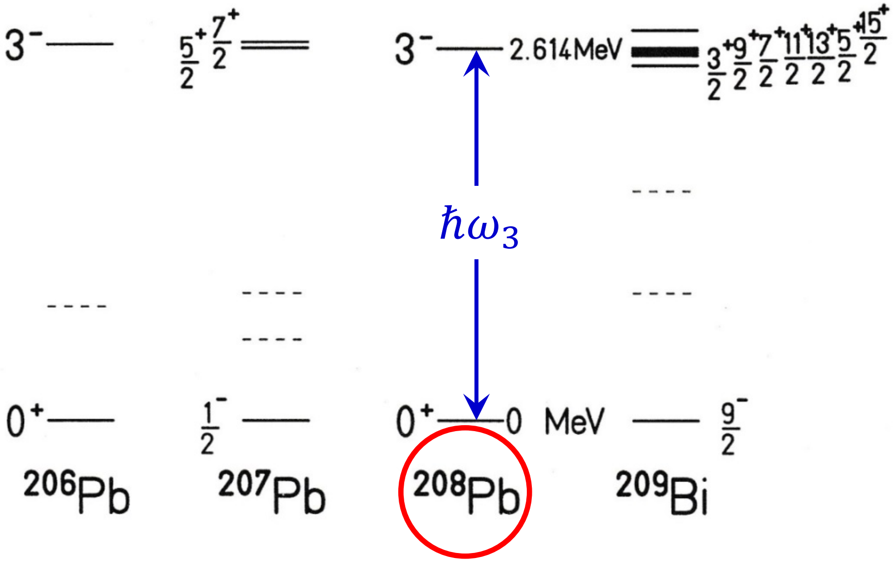


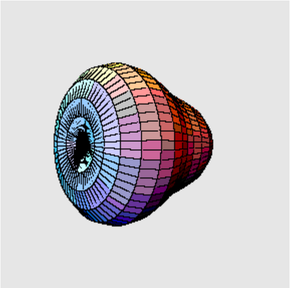


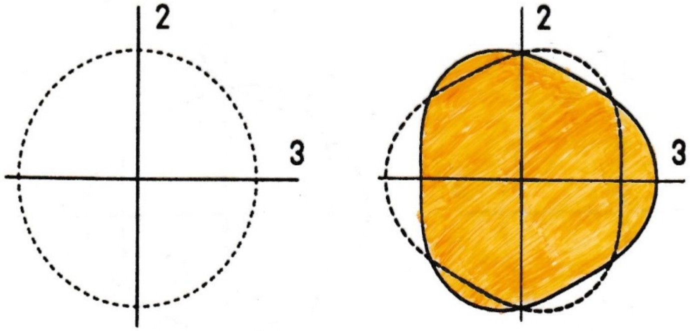


Octupole vibrational states in the Pb region

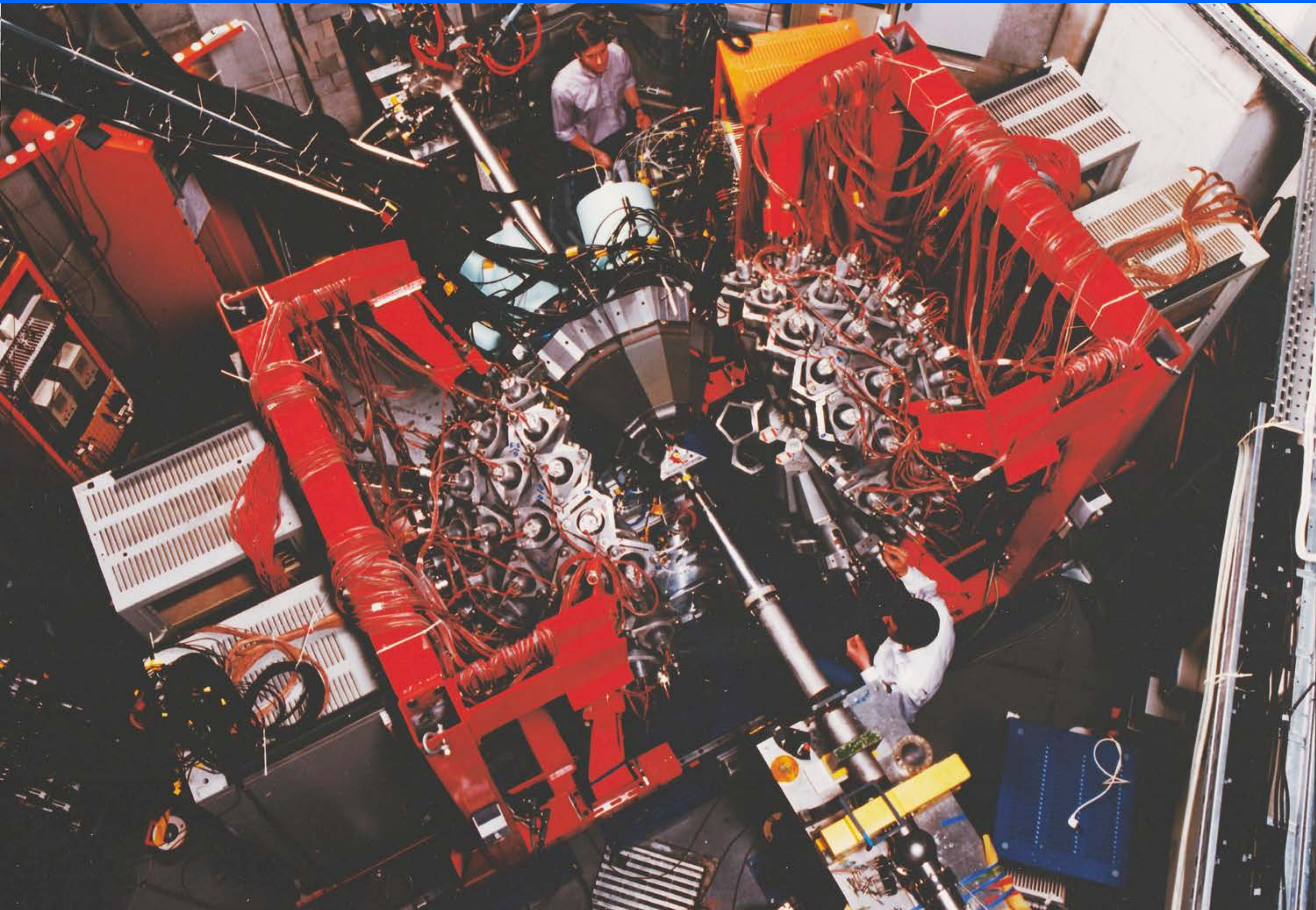








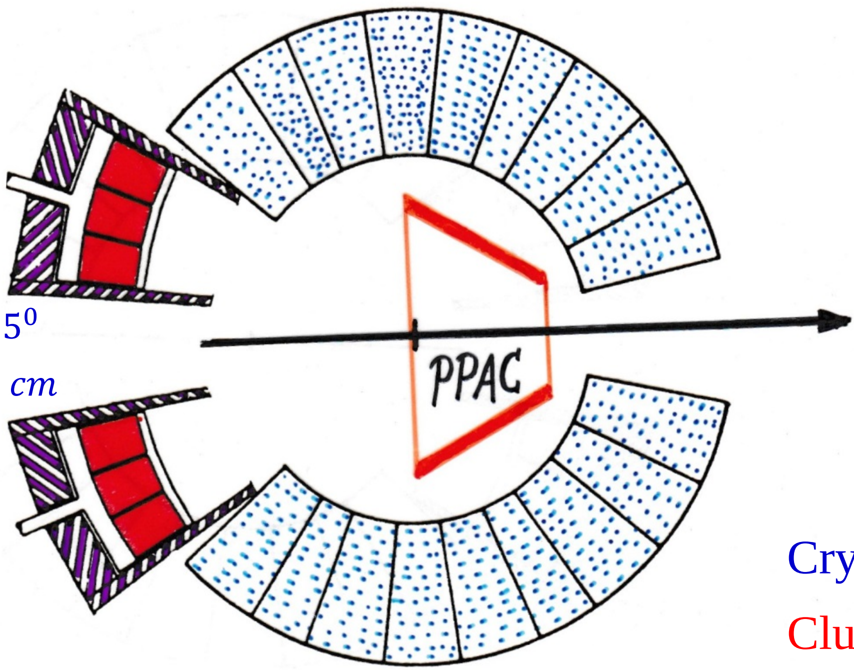
The Darmstadt-Heidelberg Crystal Ball extended by EUROBALL-3 Ge-detectors



The Darmstadt-Heidelberg Crystal Ball extended by EUROBALL-3 Ge-detectors

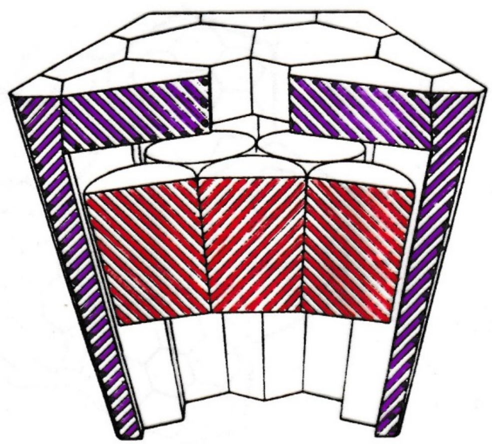
$\langle\theta_\gamma\rangle = 155^0$

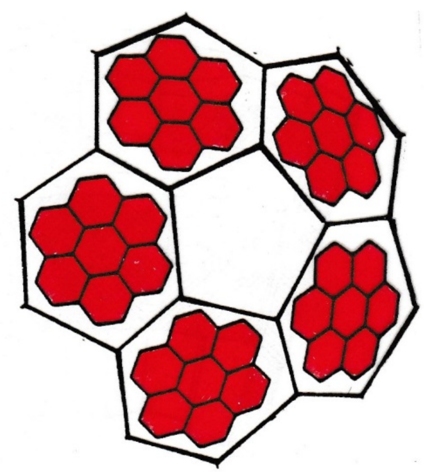
$R = 36\ cm$



Crystal Ball: $\Omega_{CB} = 83\%$ $P_{photopeak} \approx 53\%$

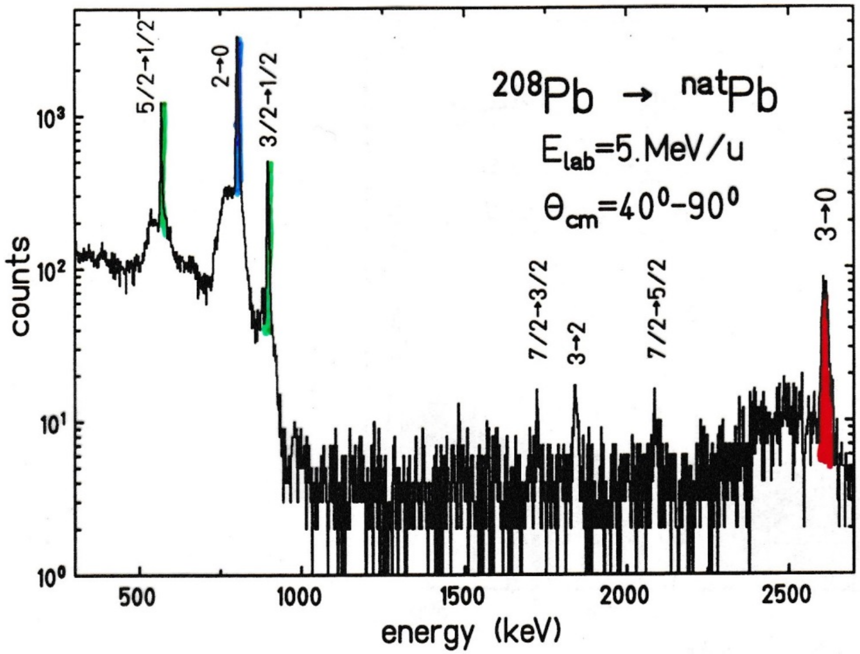
Cluster ring: $\Omega_{EB} = 7\%$ $P_{photopeak} \approx 2.2\%$





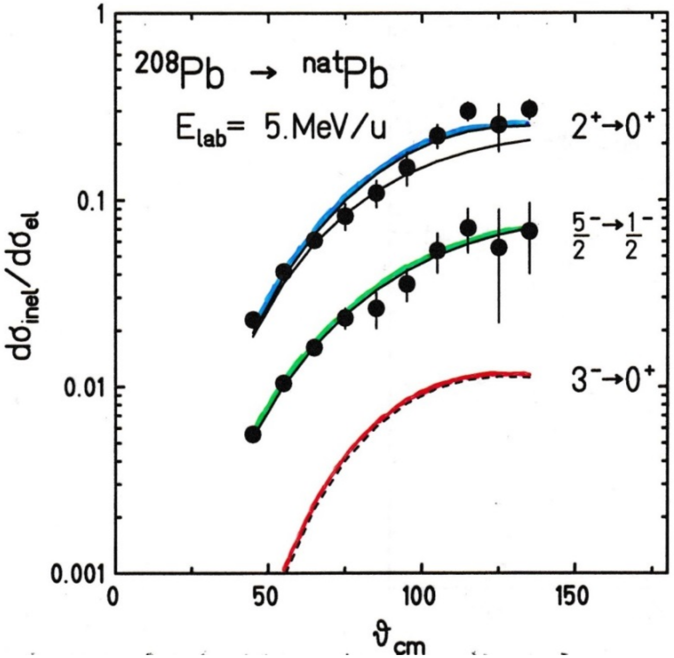
March 27 – September 6, 1996

Octupole vibrational states in the Pb region



^{206}Pb	24%
^{207}Pb	22%
^{208}Pb	52%

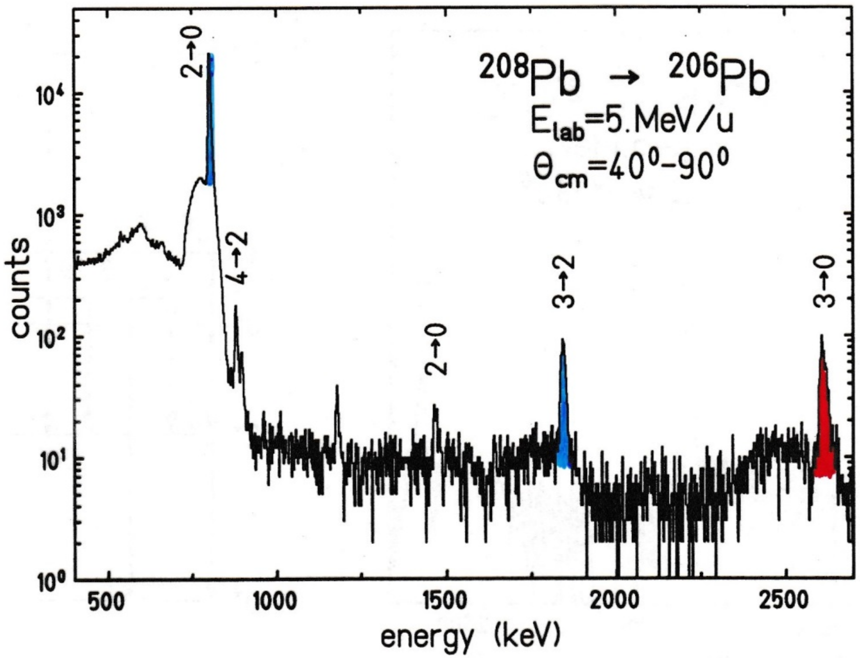
excitation probability for the 1-excited state

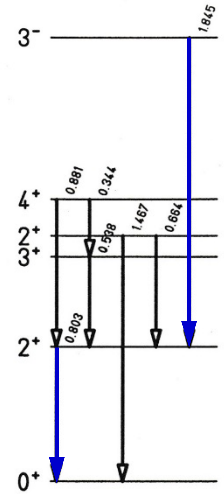


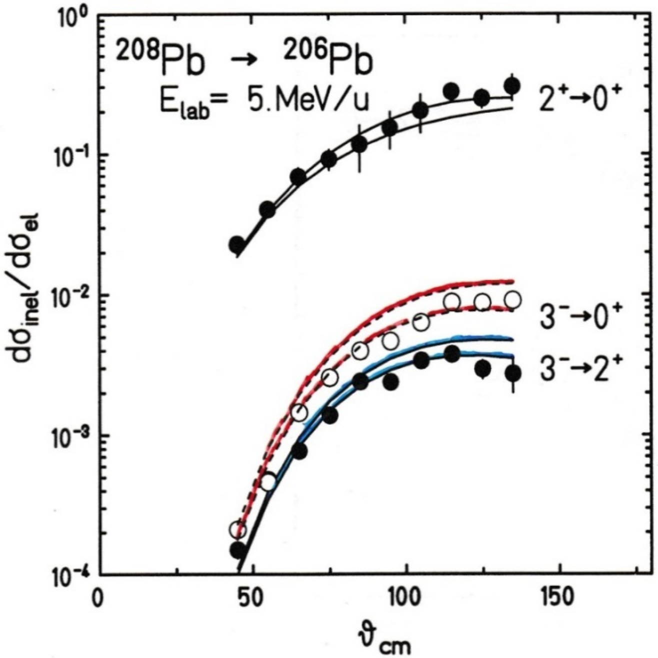
E2 excitation

E3 excitation

Coulomb excitation for ^{208}Pb on ^{206}Pb







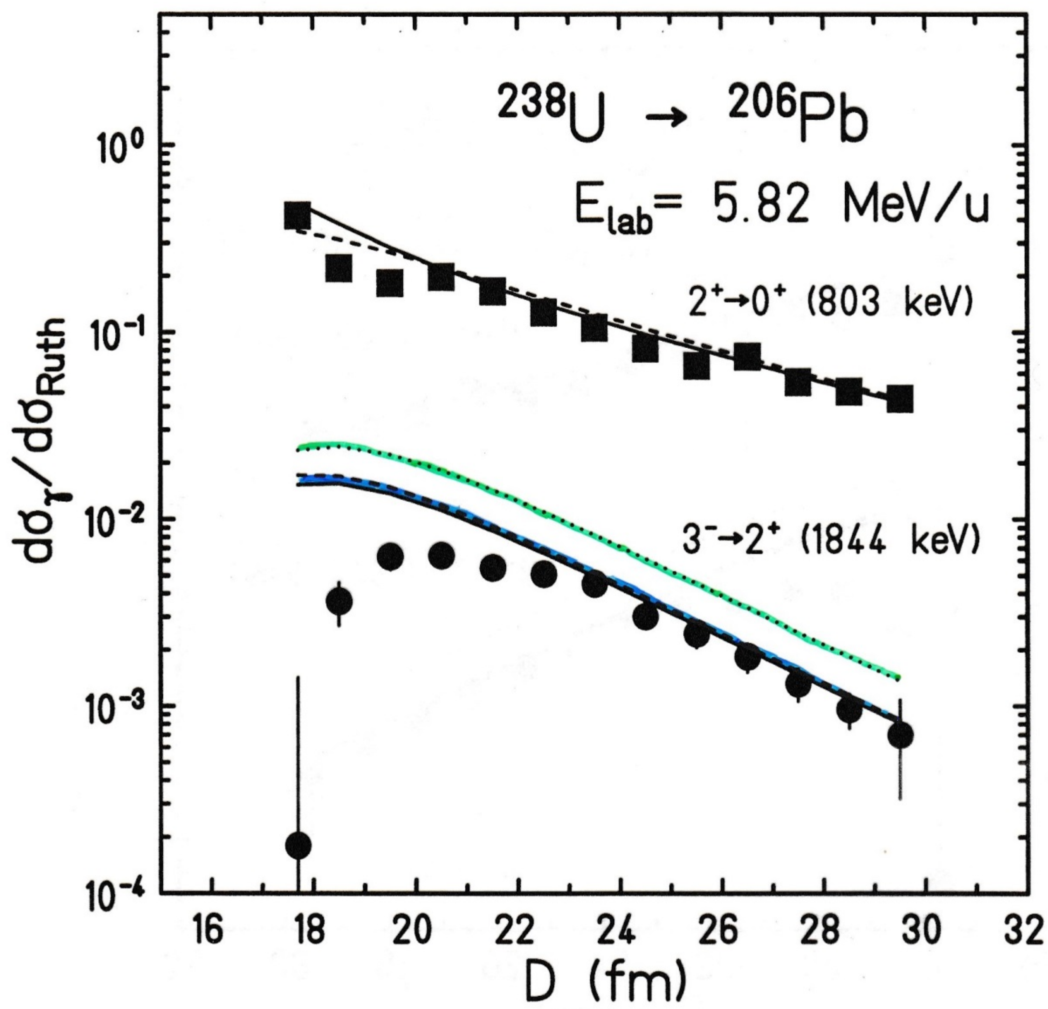
B(E3)

34 spu

20 spu

Nucl Data: 36 spu

Coulomb excitation for ^{238}U on ^{206}Pb



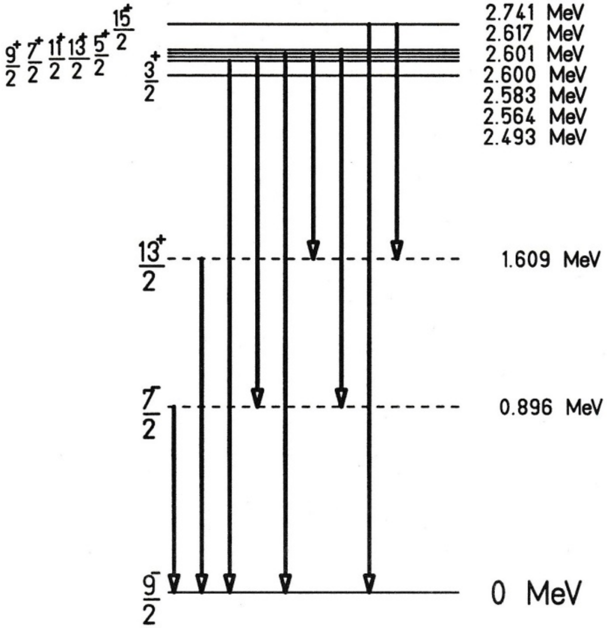
B(E3)

36 spu

20 spu

J. Baumann for EPOS

Superposition of vibrational and particle motion



$3^- |h_{9/2}\rangle$ septuplet

^{209}Bi

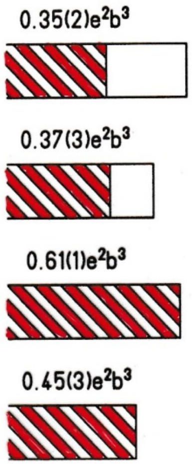
$|h_{9/2}\rangle$

weak coupling: $$B(E3; n_3 = 0, j \rightarrow (n_3 = 1, j)I) = \frac{2I+1}{7(2j+1)} B(E3; n_3 = 0 \rightarrow n_3 = 1)$$

	j^π I^π	$B(E3; n_3 = 0 \rightarrow n_3 = 1)$
$B(E3; 9/2^- \rightarrow 3/2^+)$	**0.017(3)**	**0.29(5)**
$B(E3; 9/2^- \rightarrow 9/2^+)$	**0.073(10)**	**0.51(7)**
$B(E3; 9/2^- \rightarrow 7/2^+)$	**0.052(8)**	**0.45(7)**
$B(E3; 9/2^- \rightarrow 11/2^+)$	**0.093(16)**	**0.54(9)**
$B(E3; 9/2^- \rightarrow 13/2^+)$	**0.080(18)**	**0.40(9)**
$B(E3; 9/2^- \rightarrow 5/2^+)$	**0.034(6)**	**0.40(7)**
$B(E3; 9/2^- \rightarrow 15/2^+)$	**0.104(17)**	**0.45(7)**
Σ:	**0.45(3)** e^2b^3	

Superposition of vibrational and particle motion

$B(E3; n_3=0 \rightarrow n_3=1)$

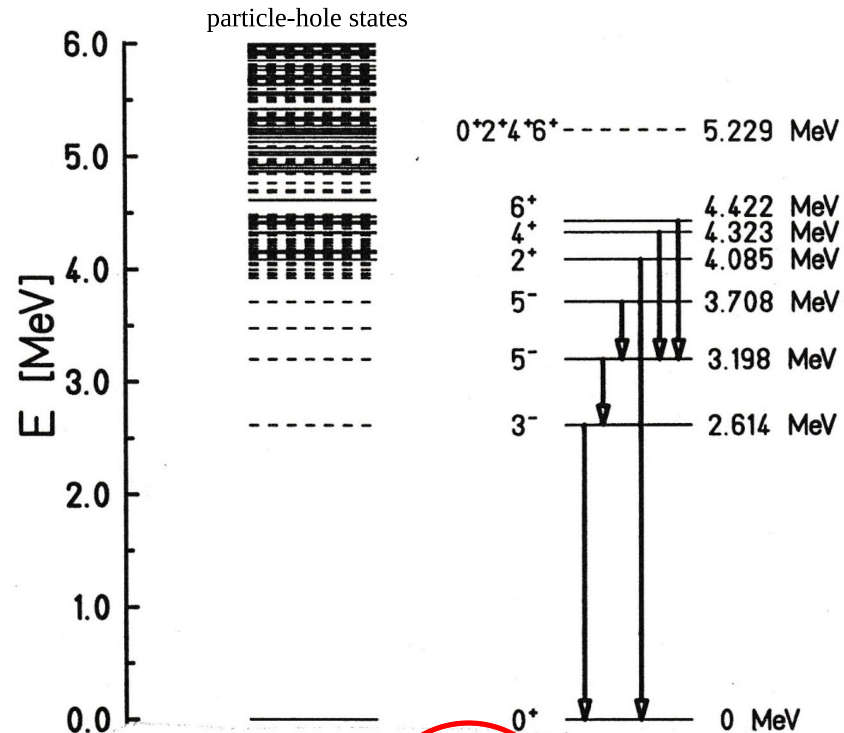


^{206}Pb $\nu(p_{1/2}, -2)$

^{207}Pb $\nu(p_{1/2}, -1)$

^{208}Pb

^{209}Bi $\pi(h_{9/2}, +1)$

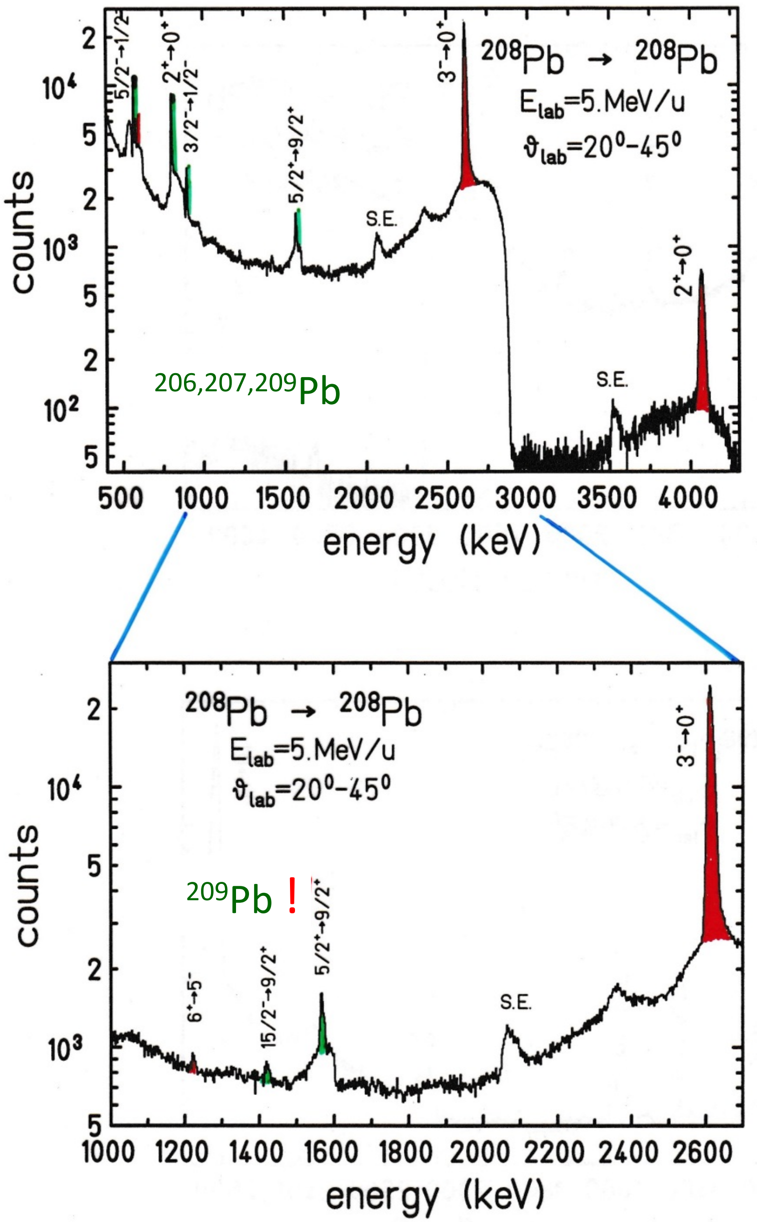


2 - phonon

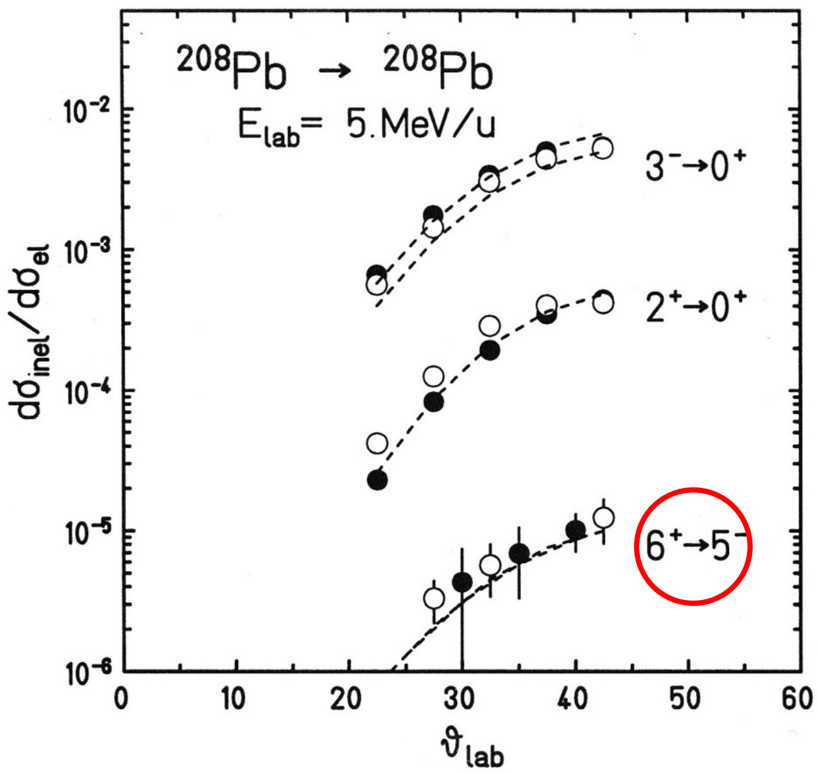
1 - phonon
octupole vibration

^{208}**Pb**

Coulomb excitation for ^{208}Pb on ^{208}Pb

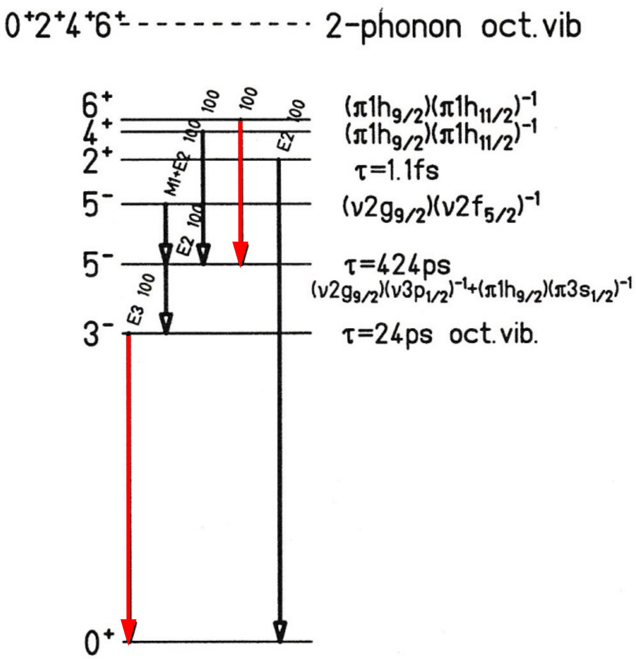


Coulomb excitation for ^{208}Pb on ^{208}Pb at 5.0 MeV/u



$$\frac{B(E3;6^+ \to 3^-)}{B(E3;3^- \to 0^+)} = 0.35(11)$$

$2.0_{vibrational}$



Octupole vibrational states in ^{206}Pb, ^{207}Pb, ^{208}Pb and ^{209}Bi

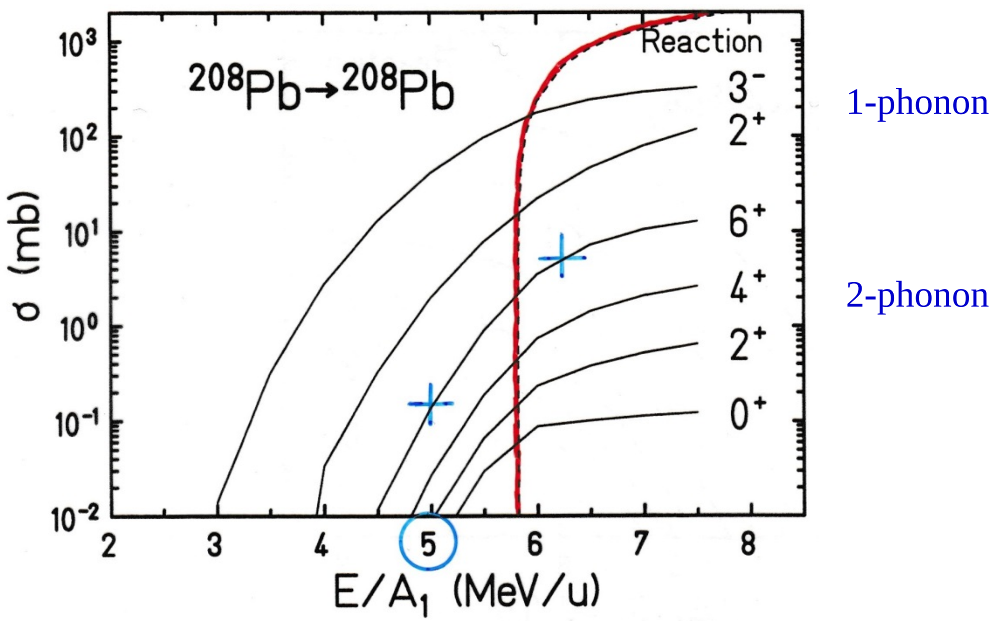
- vibrational excitation $\hbar\omega_3$ is very similar
- B(E3) values are well described in weak coupling model
- collective strength depends on particle configuration
- 2-phonon octupole vibrational states not observed at 5 MeV/u (insufficient Compton suppression of EUROBALL detectors)
- 6^+ particle-hole state contains 18% of the collective vibrational strength
- transfer reactions (^{209}Pb) observed at 5 MeV/u

H.J. Wollersheim, E. Lubkiewicz, A. Gadea, J. Gerl, M. Kaspar, I. Kojouharov, Th. Kröll, R. Kulessa, I. Peter, M. Rejmund, J.A. Ros, H. Schaffner, Ch. Schlegel, K. Vetter
GSI-Darmstadt, Jagellonian University Cracow, I.F.I.C.-Valencia

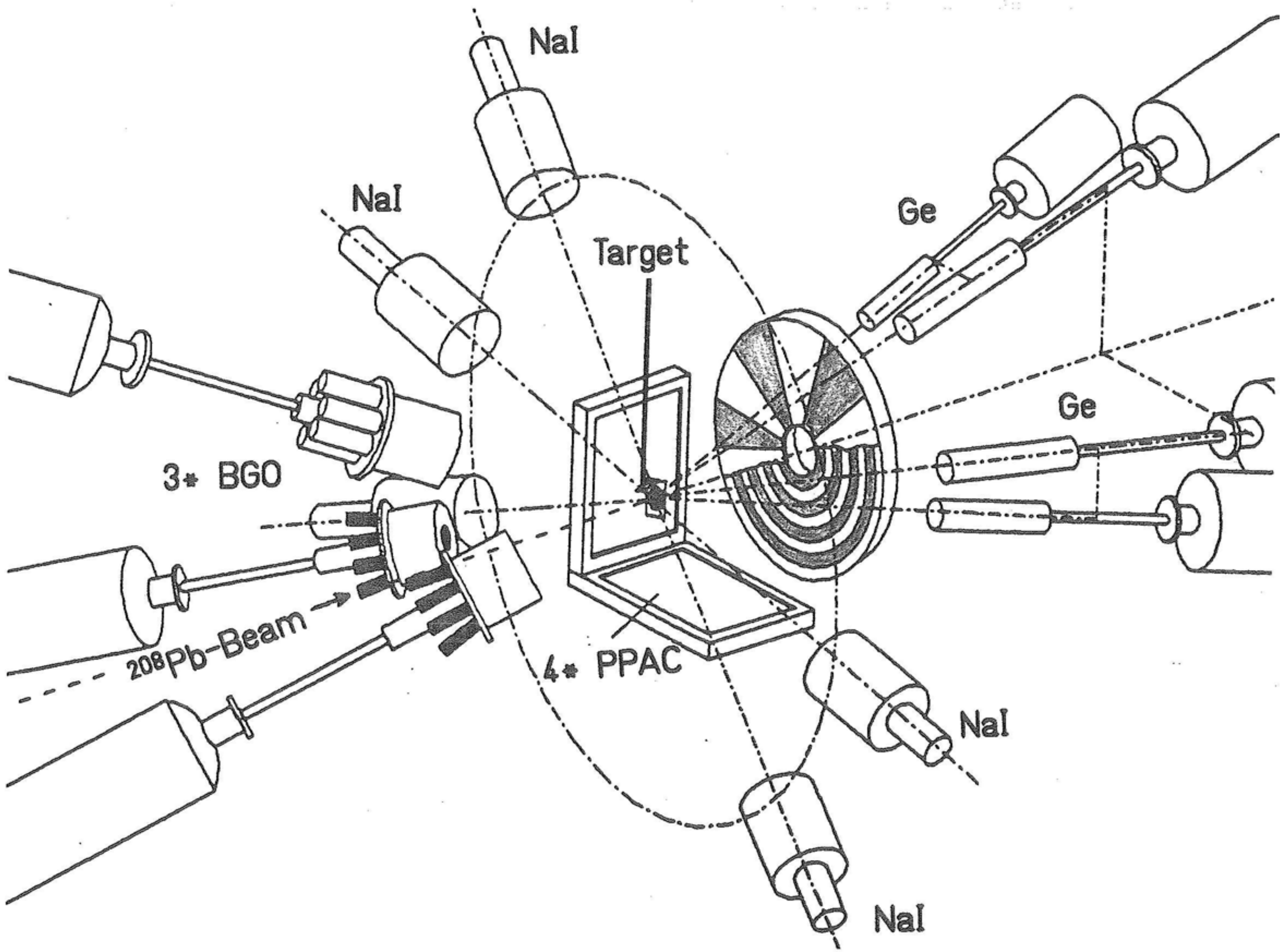
Octupole vibrational states in the Pb region

^{208}**Pb** + ^{208}**Pb**; E/A$_1$ = 5 MeV/u

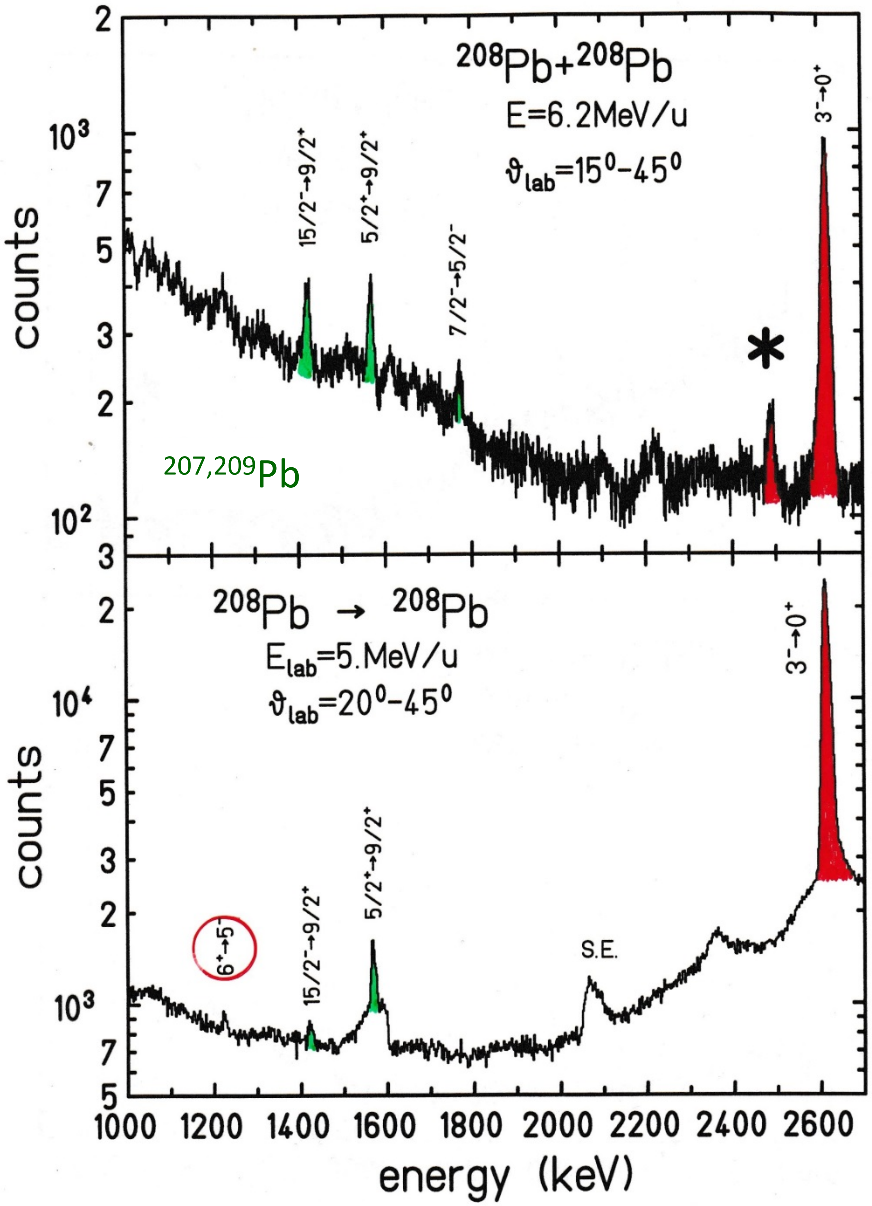
$$\sigma_{6^+} = 0.138\, mb$$
$$\sigma_{4^+} = 0.027\, mb$$
$$\sigma_{2^+} = 0.009\, mb$$
$$\sigma_{0^+} = 0.004\, mb$$



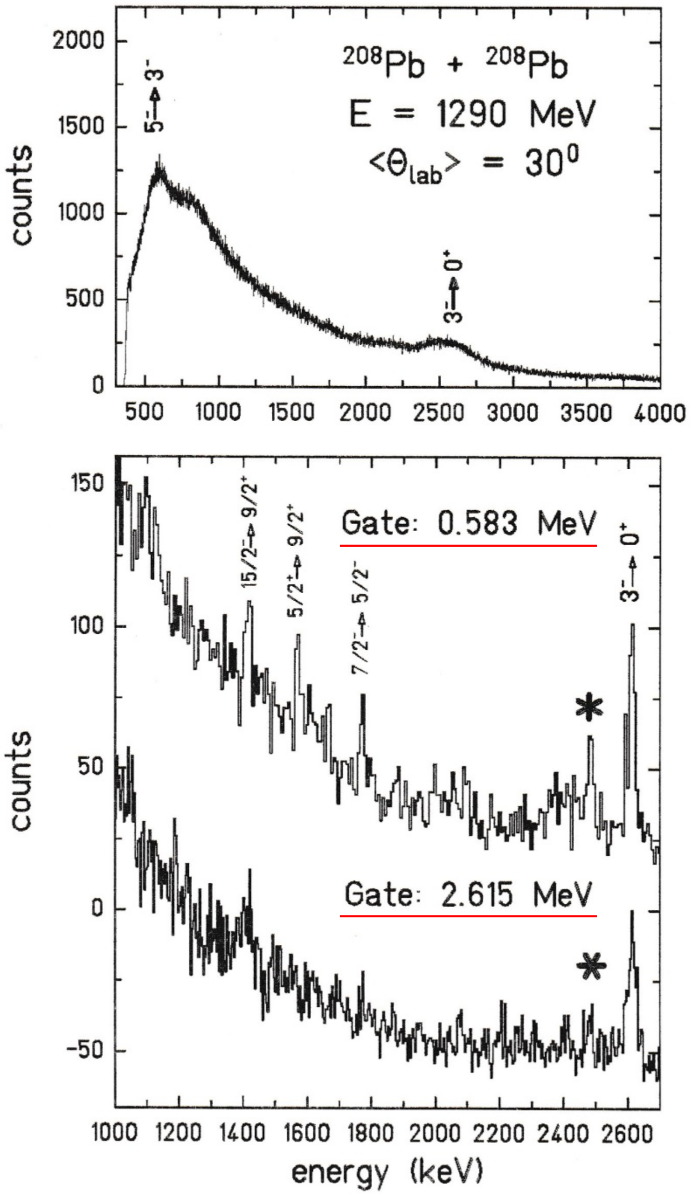
Experimental set-up for ^{208}Pb on ^{208}Pb at 6.2 MeV/u

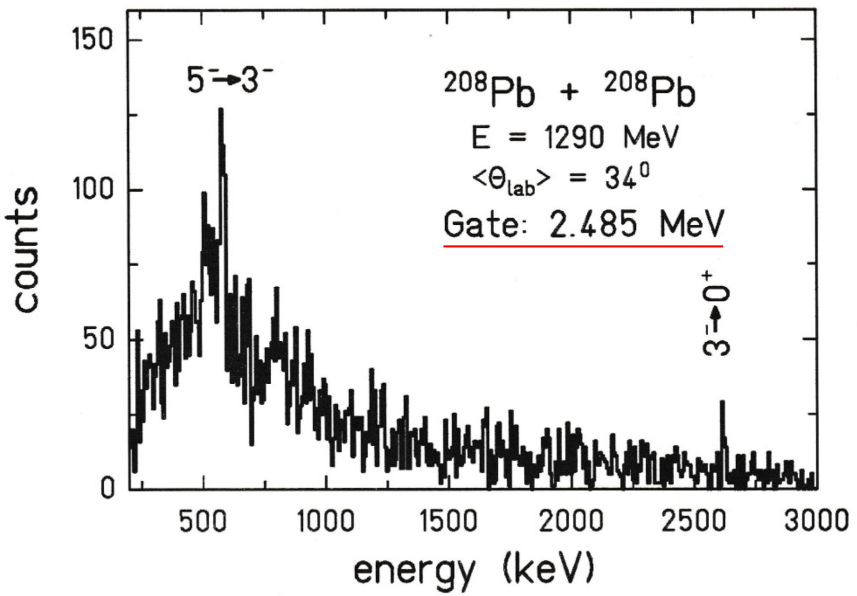


Coulomb excitation for ^{208}Pb on ^{208}Pb at 6.2 MeV/u

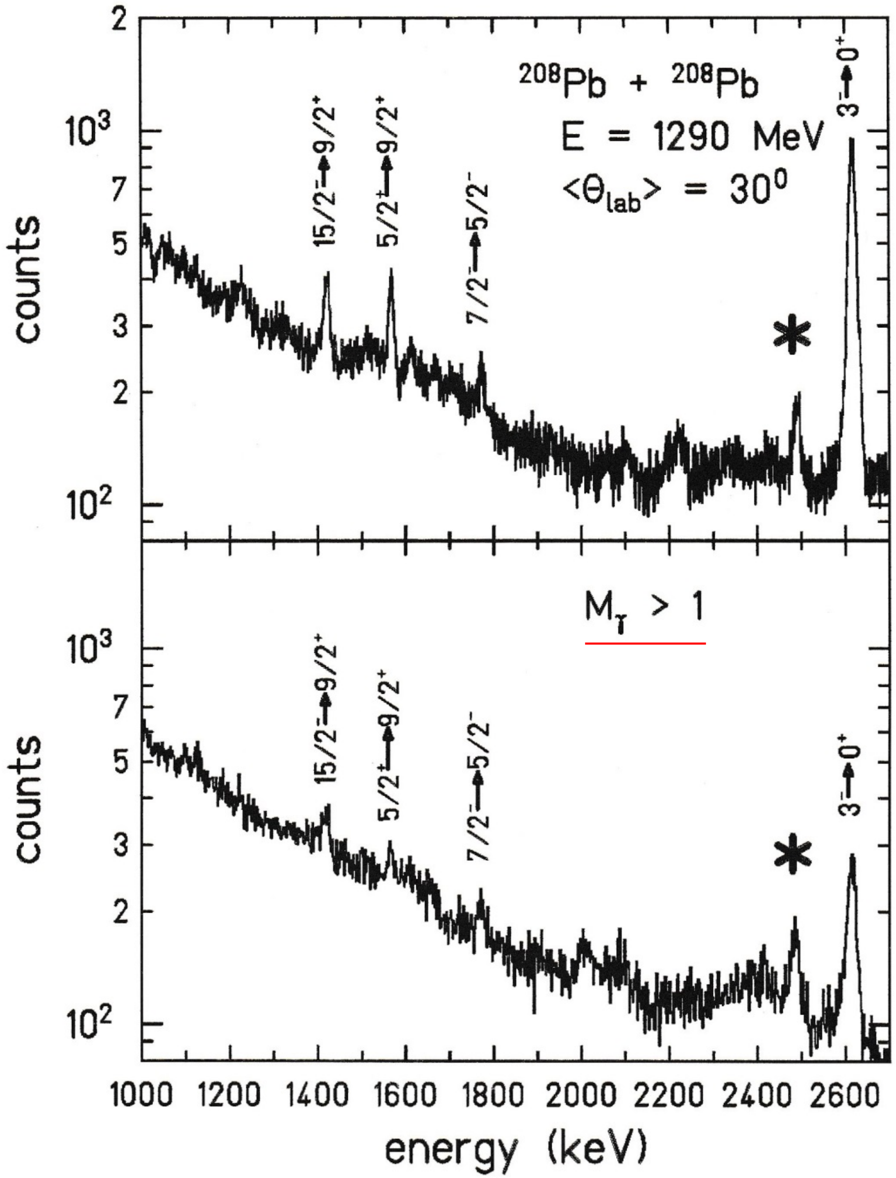


Coulomb excitation for ^{208}Pb on ^{208}Pb at 6.2 MeV/u

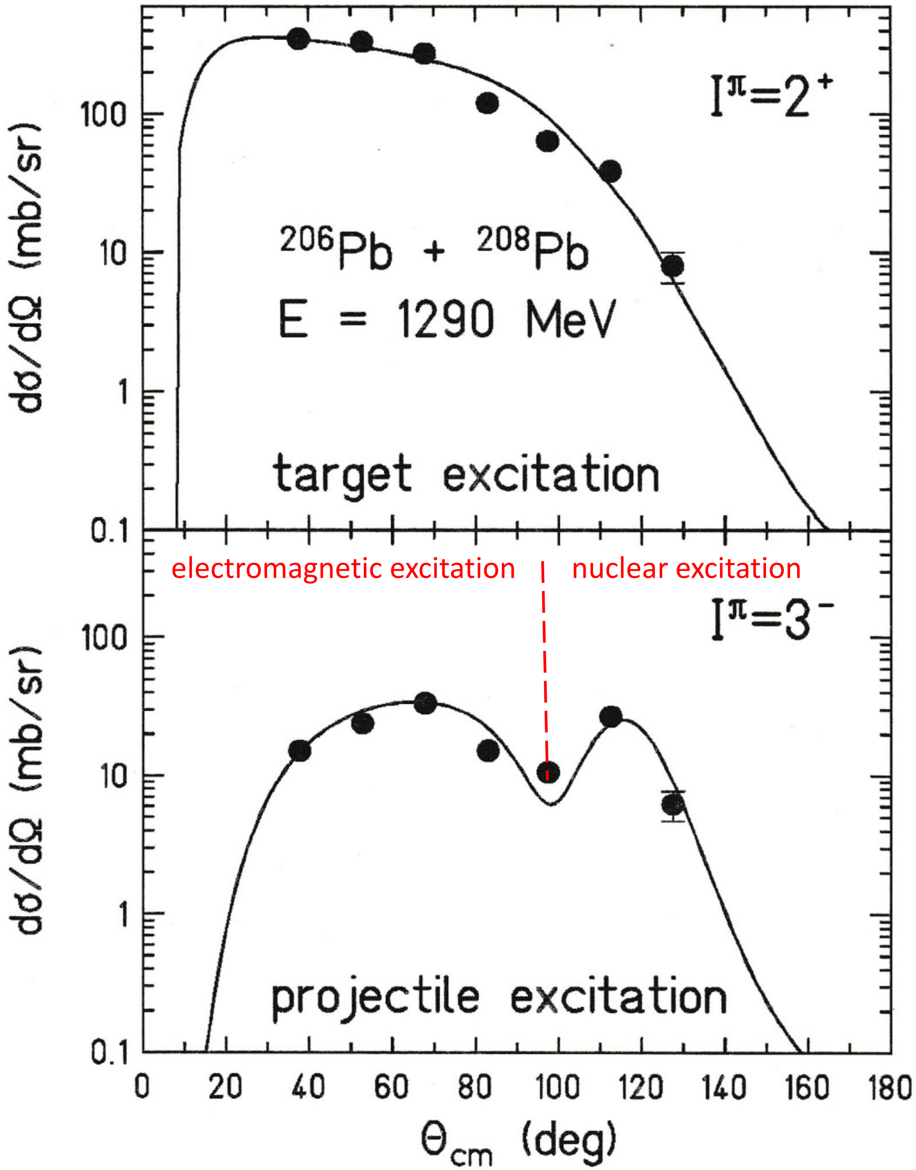




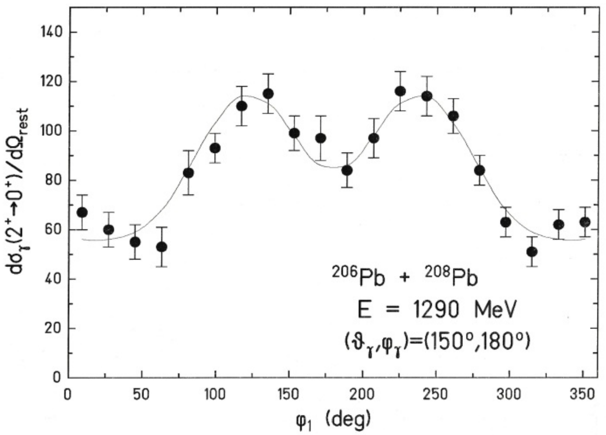
Coulomb excitation for ^{208}Pb on ^{208}Pb at 6.2 MeV/u



Coulomb and nuclear excitation for ^{208}Pb on ^{206}Pb at 6.2 MeV/u



particle-γ angular correlation

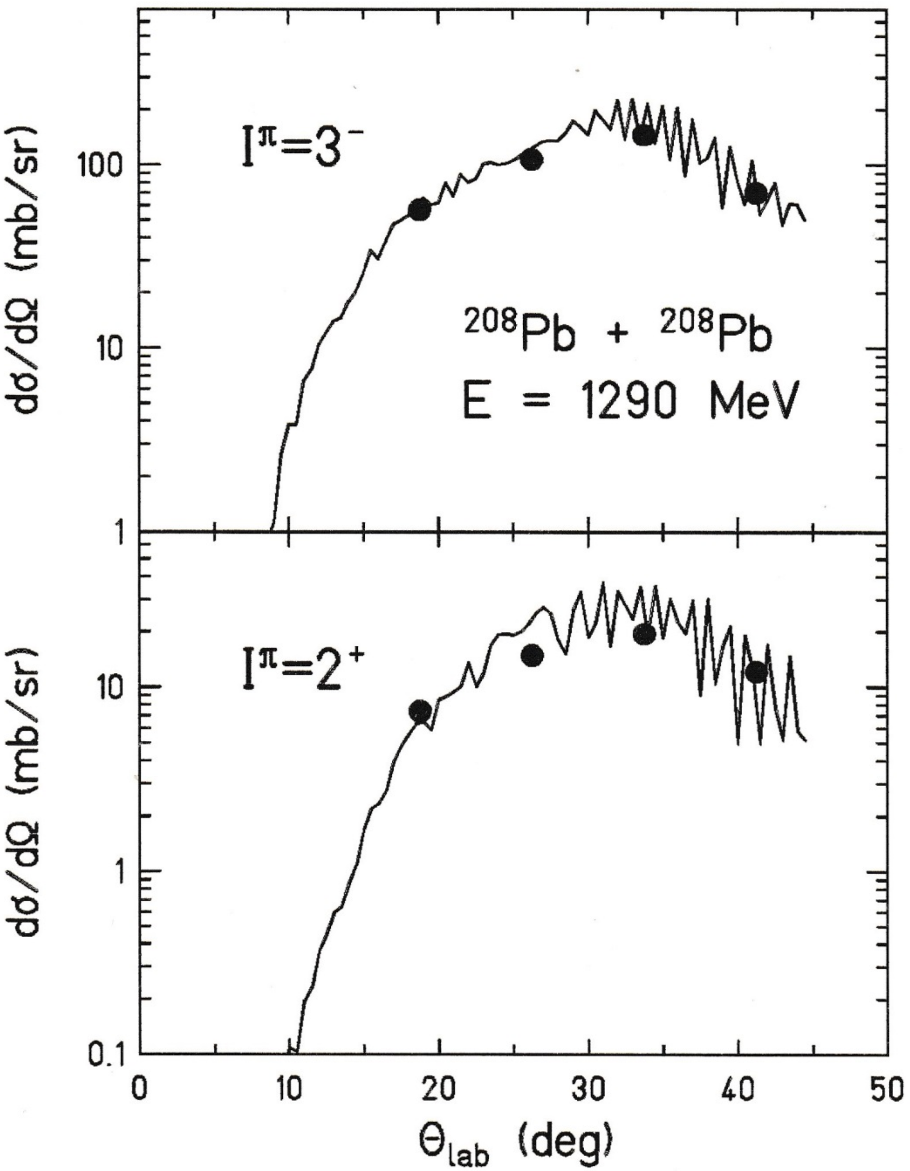


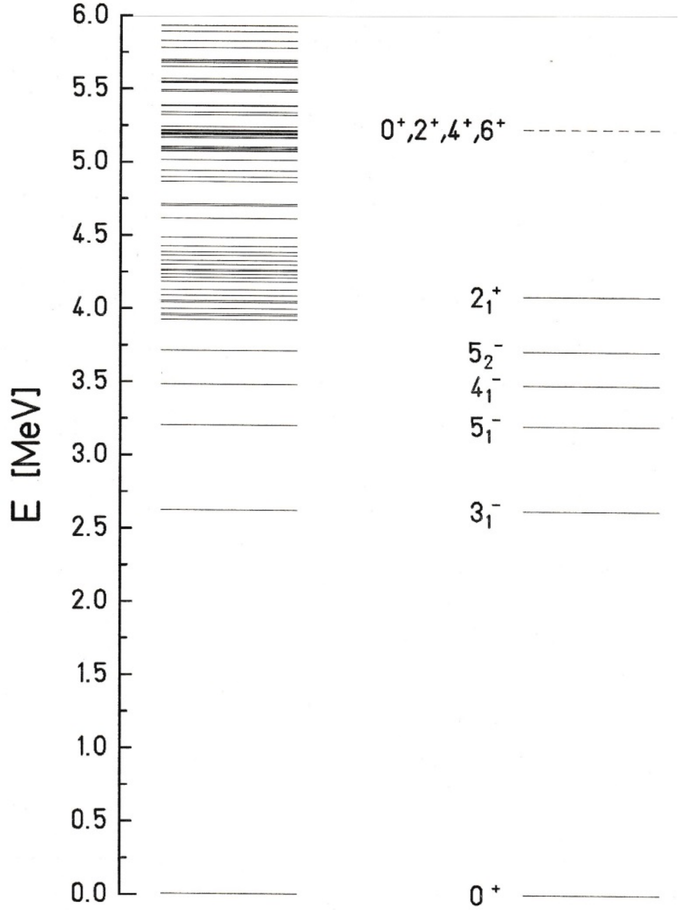
❖ $g(2^+) = 0$ → unperturbed p-γ angular correlation

$$\frac{\sigma_{nucl}}{\sigma_{total}} = 63\%$$

analysis with Ptolemy code

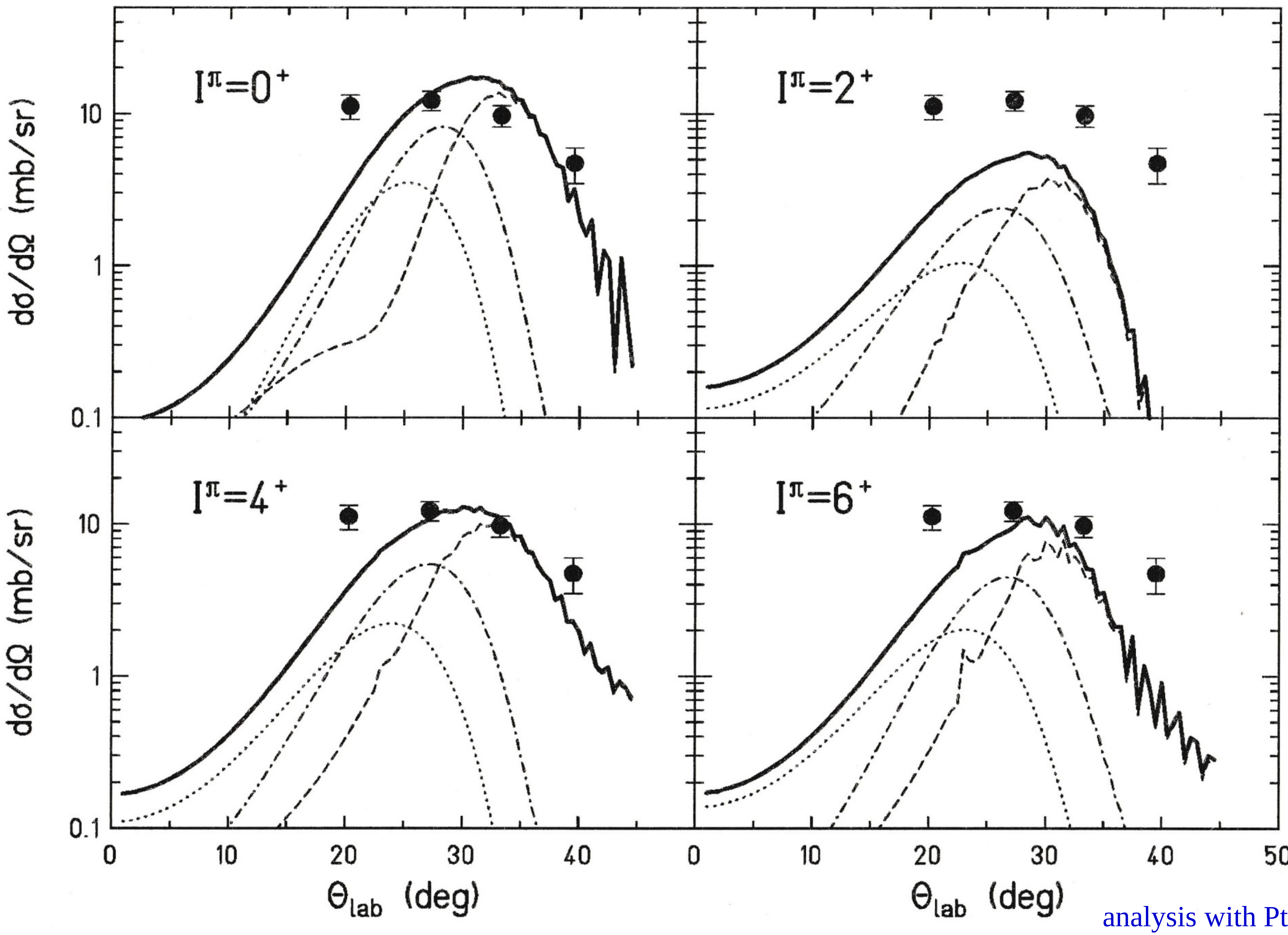
Coulomb and nuclear excitation for ^{208}Pb on ^{208}Pb at 6.2 MeV/u





analysis with Ptolemy code

Coulomb and nuclear excitation for ^{208}Pb on ^{208}Pb at 6.2 MeV/u



analysis with Ptolemy code

Energy splitting of the 2-phonon states