Multiple Coulomb excitation of a neutron rich ^{88}Kr beam to study symmetric and mixed-symmetric states in inverse kinematics

Proposal to the ISOLDE and Neutron Time-of-Flight Committee — P-491

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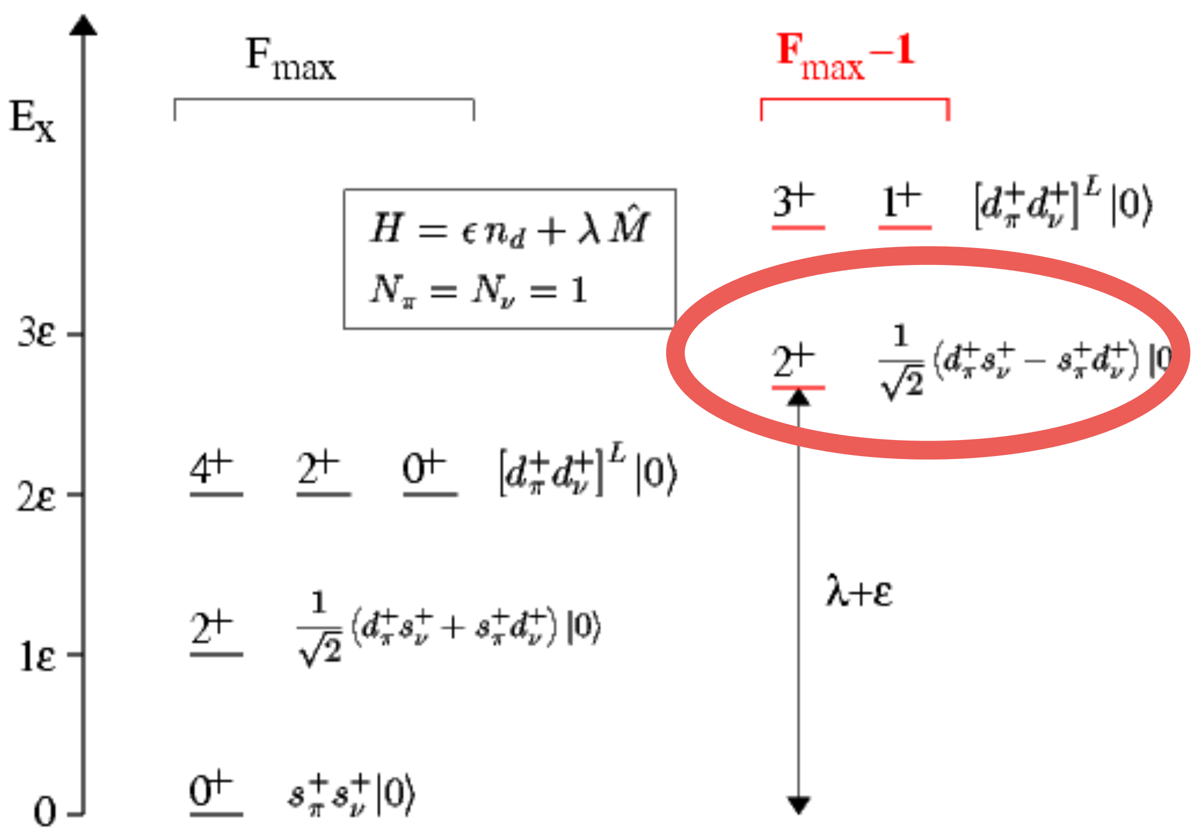
Universität zu Köln

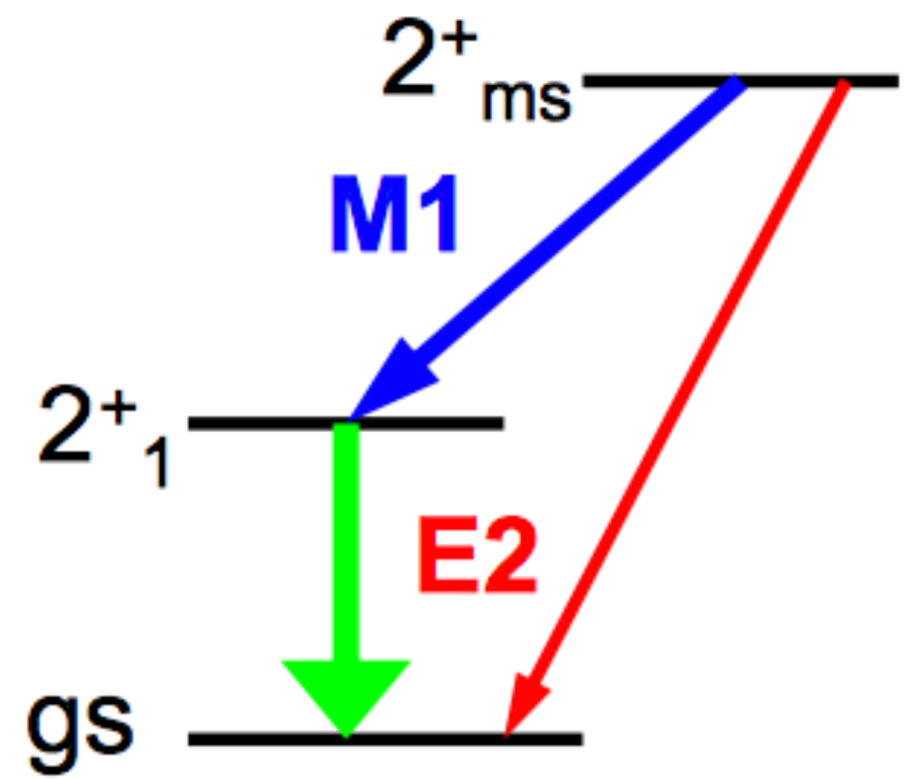
Motivation: Mixed-symmetry states (MSS) in the Interacting Boson Model 2 (IBM-2)

Pairing of valence particles to s- and d-bosons



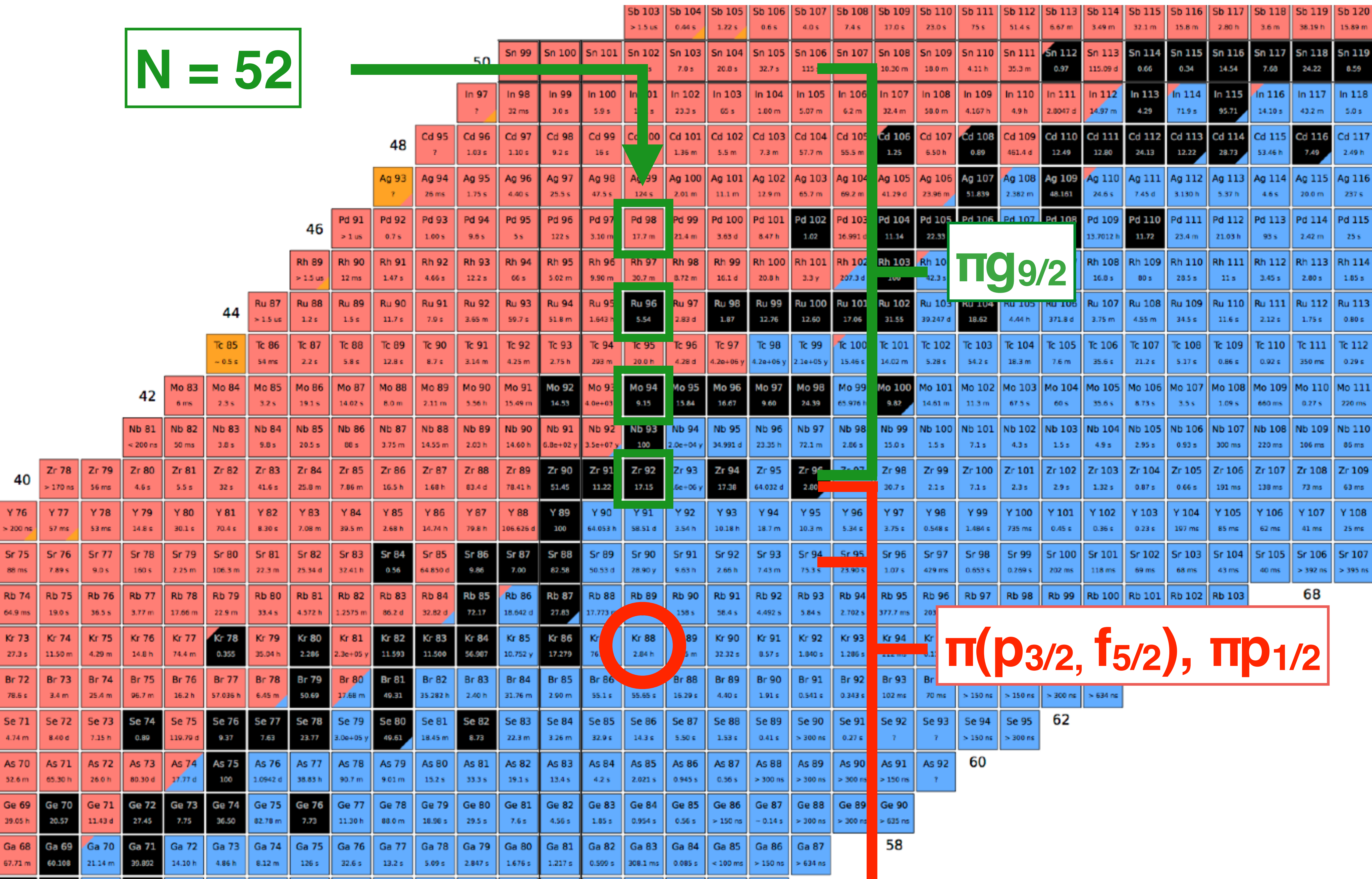
For details see review article by N. Pietralla et al.: Prog. Part. Nucl. Phys. 60 (2008)

Experimental signatures for the one-phonon 2_{ms}^+ MSS

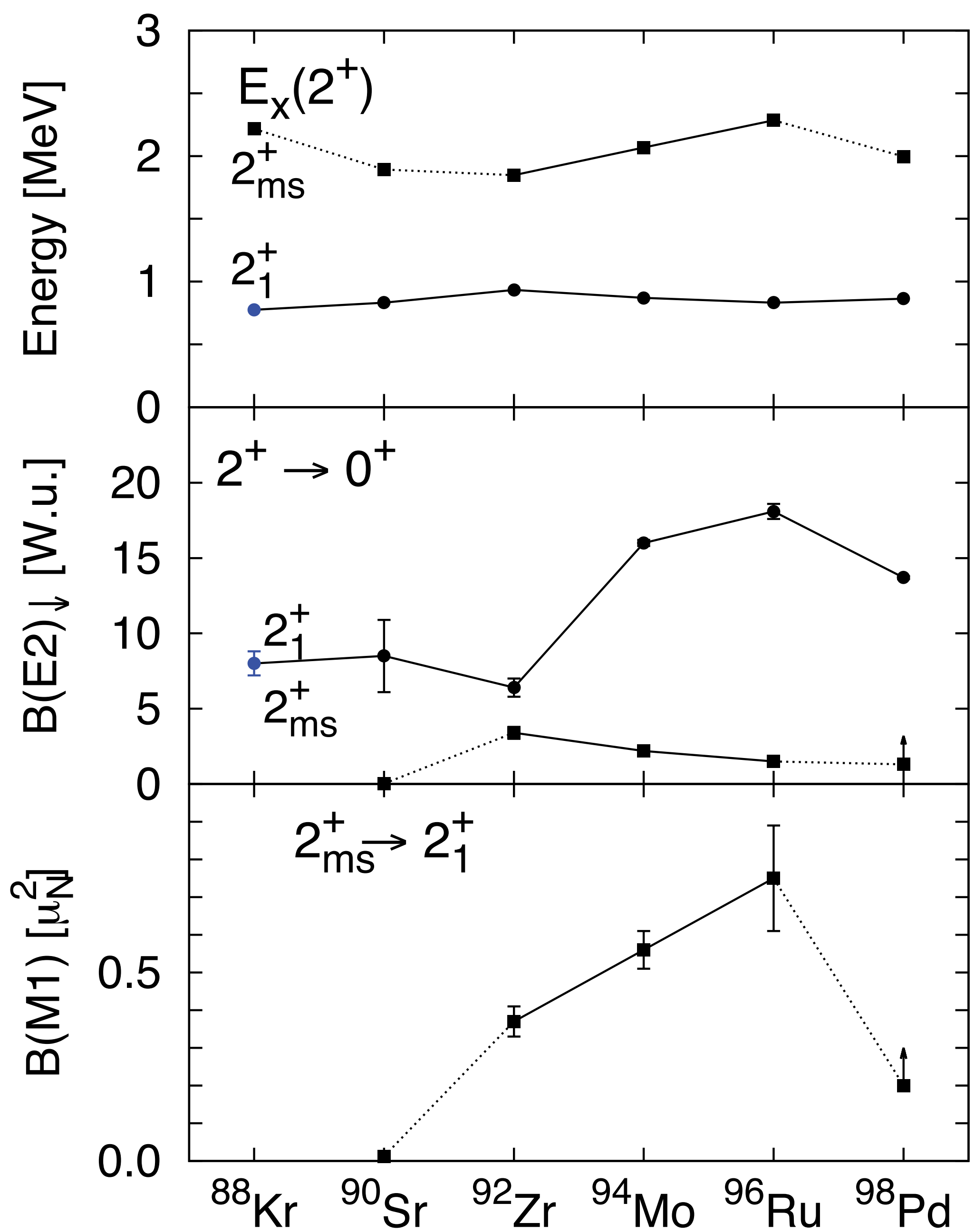


- Weakly collective E2 transition between 2_{ms}^+ state and ground state (~ 1-2 W.u.)
- Strong M1 transition between 2_{ms}^+ and fully symmetric 2_1^+ in the order of 1 μ_n^2

Motivation:
Study of mixed-symmetric one-phonon states in N = 52 isotones

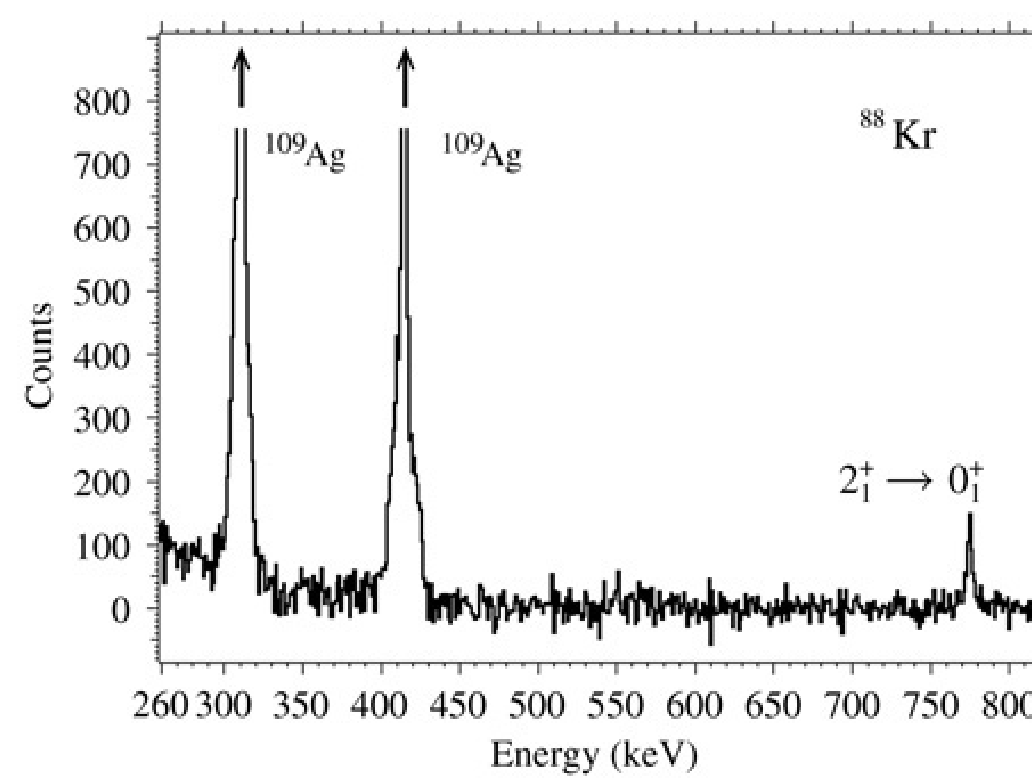


Motivation: Systematics in the N = 52 isotopes and studies of ^{88}Kr so far…



- ^{94}Mo: Textbook example for MSS
- Similar findings in neighbouring N = 52 isotopes enable tracking of MSS over different proton shells
- ^{88}Kr:
  - Previous Experiment at REX-ISOLDE [1]: B(E2; $2_1^+ \rightarrow 0_1^+$) = 8.0(8) W.u. No population of non-yrast states (too low E_{Beam})

[1] Mücher et al., AIP Conference Proceedings, 587–588, 2009



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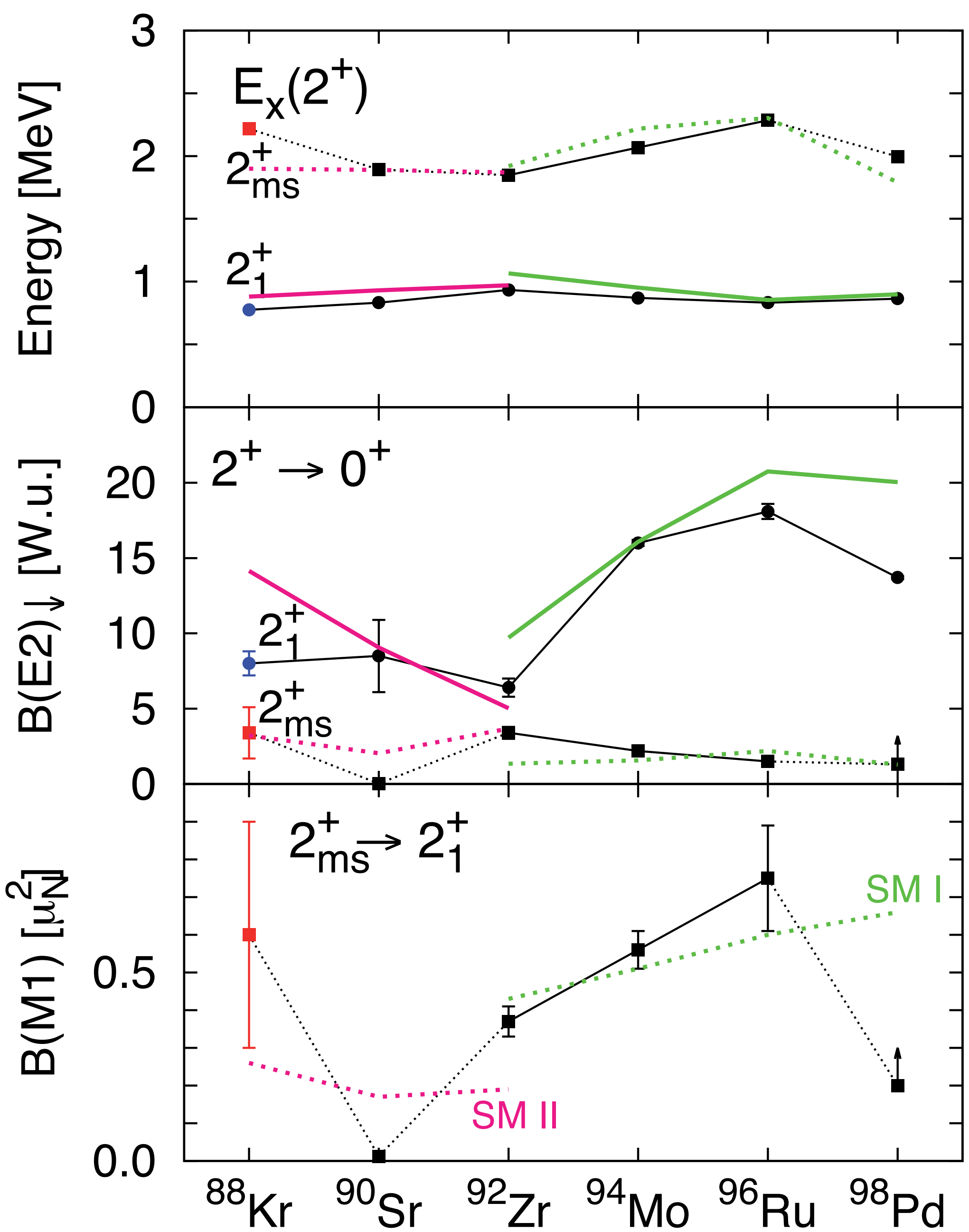

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  - Previous Experiment at REX-ISOLDE [1]:
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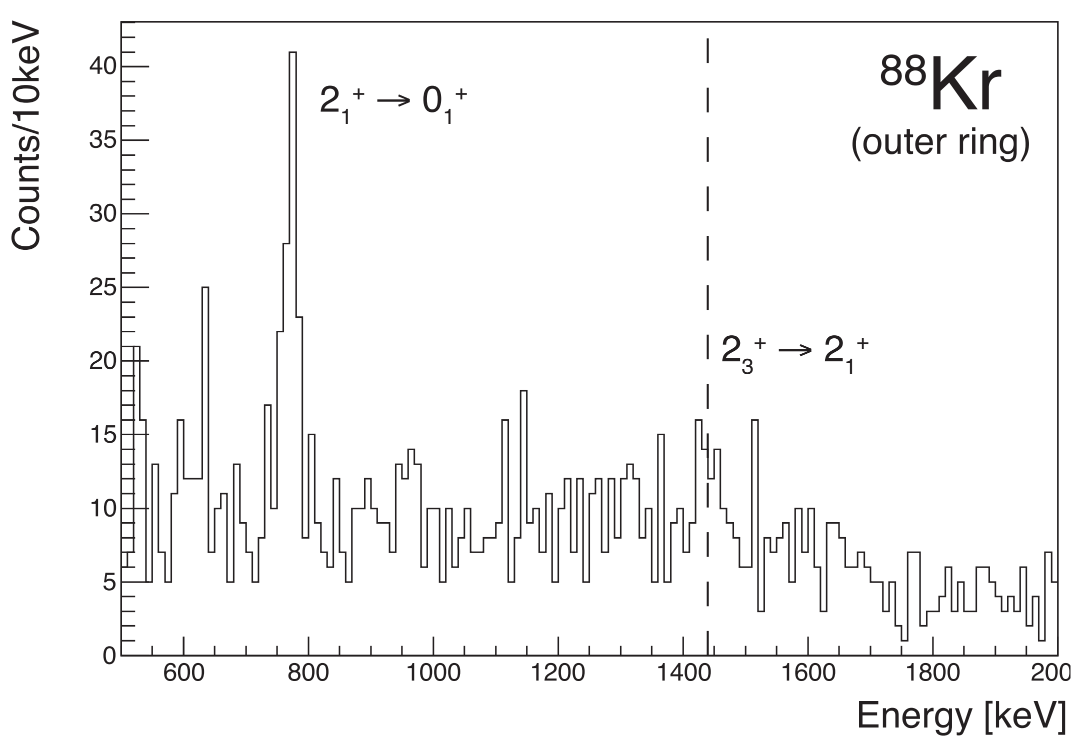
    No population of non-yrast states (too low E_{Beam})
  - Relativistic Coulex at GSI [2]:
    $B(E2; 2_3^+ \rightarrow 0_1^+) = 3.4(17)$ W.u.
    $B(M1; 2_3^+ \rightarrow 2_1^+) = 0.6(3)\ \mu^2_N$



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[2] Moschner et al., submitted to PRC

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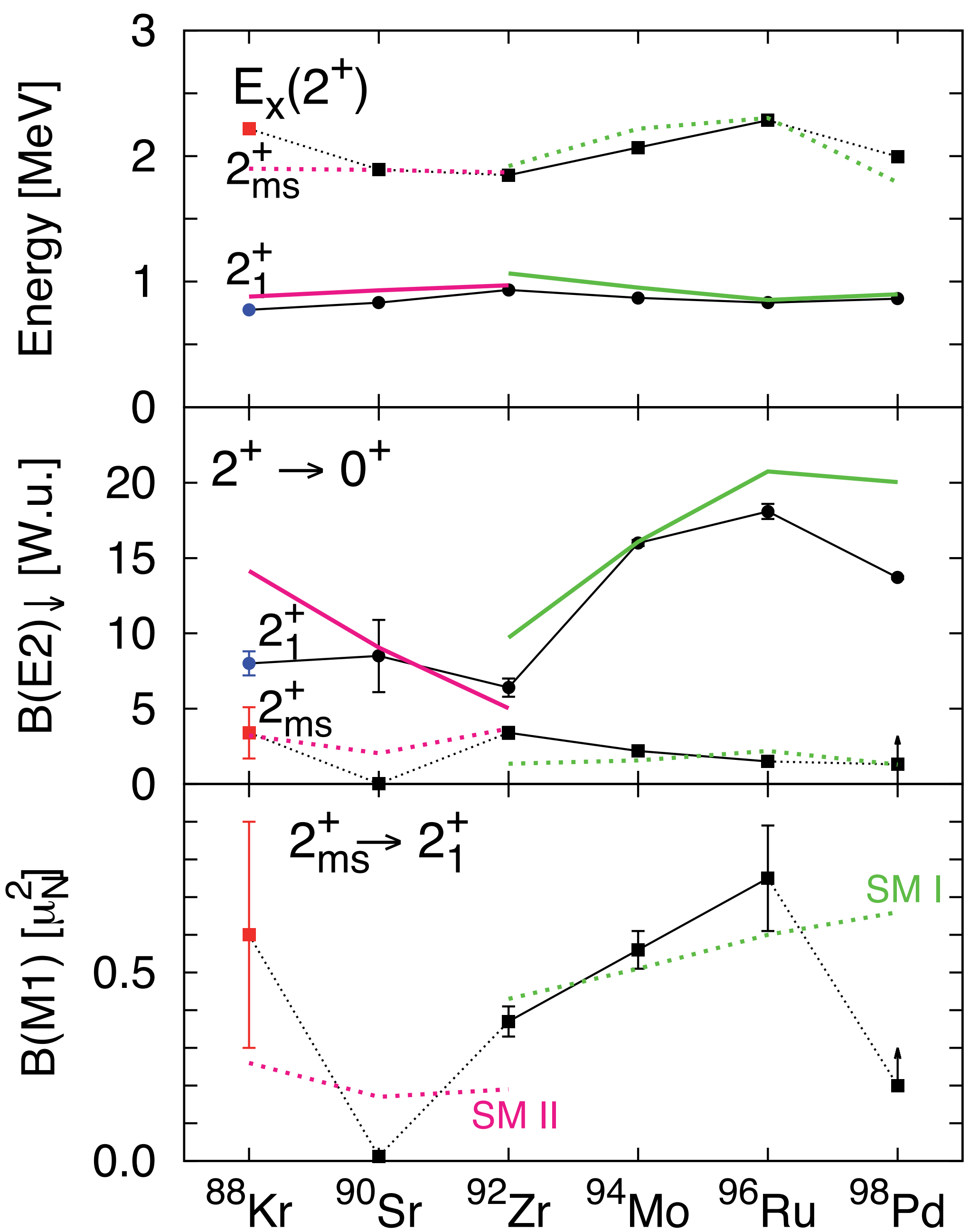

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    ?
- SM I: ^{88}Sr; Surface Delta Interaction; based on Ref [3]
- SM II: ^{78}Ni core, $\pi(1f_{5/2}, 2p_{1/2}, 2p_{3/2}, 1g_{9/2})$, $\nu(2d_{5/2}, 3s_{1/2}, 2d_{3/2}, 1g_{7/2}, 1h_{11/2})$; based on Ref. [4]

[1] Mücher et al., AIP Conference Proceedings, 587–588, 2009
[2] Moschner et al., submitted to PRC
[3] A.F. Lisetskiy et al., Nuclear Physics A 677 (2000)
[4] K. Sieja et al., Phys. Rev. C 79, 064310 (2009)

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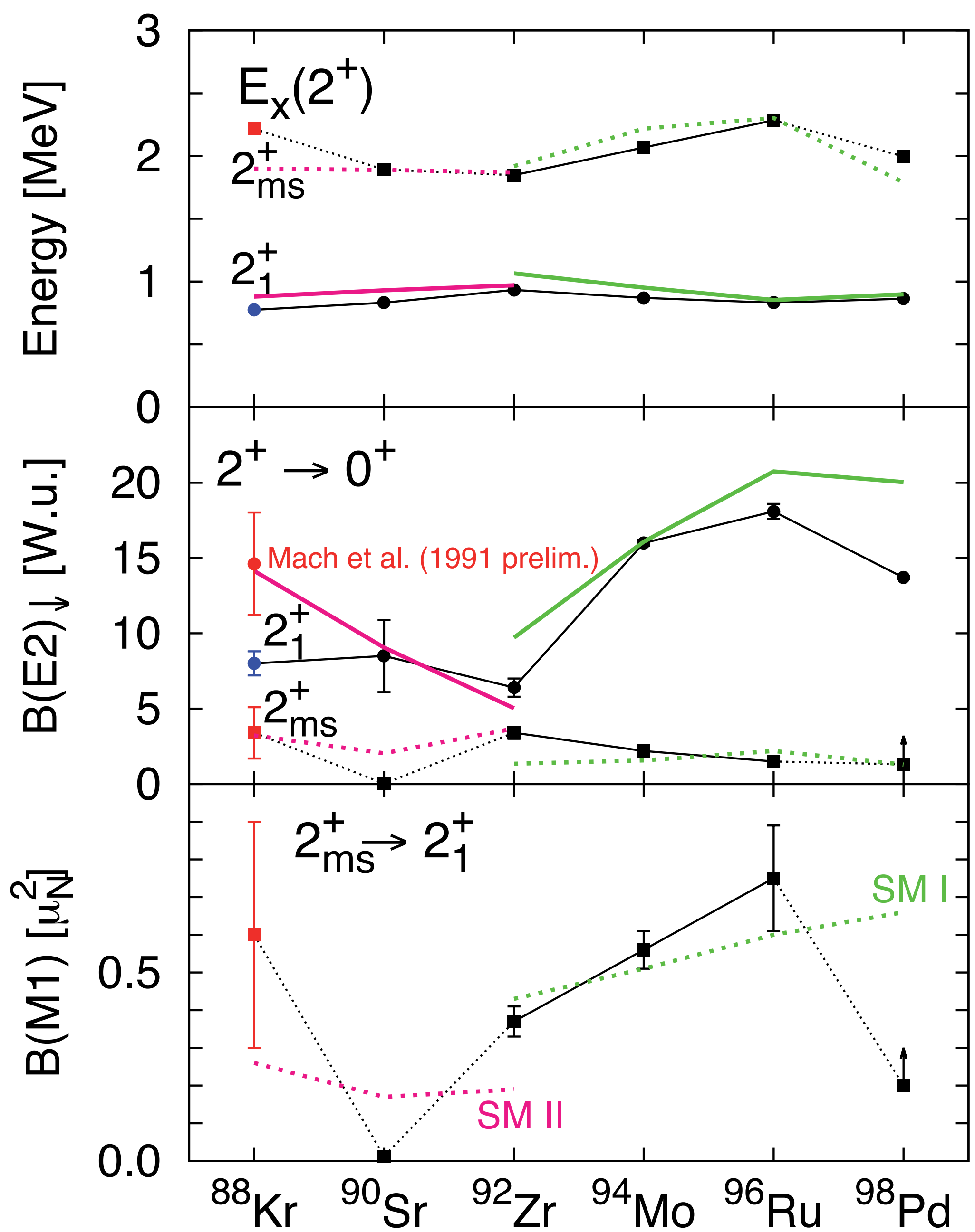

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More precise data on low spin states in ^{88}Kr desirable!

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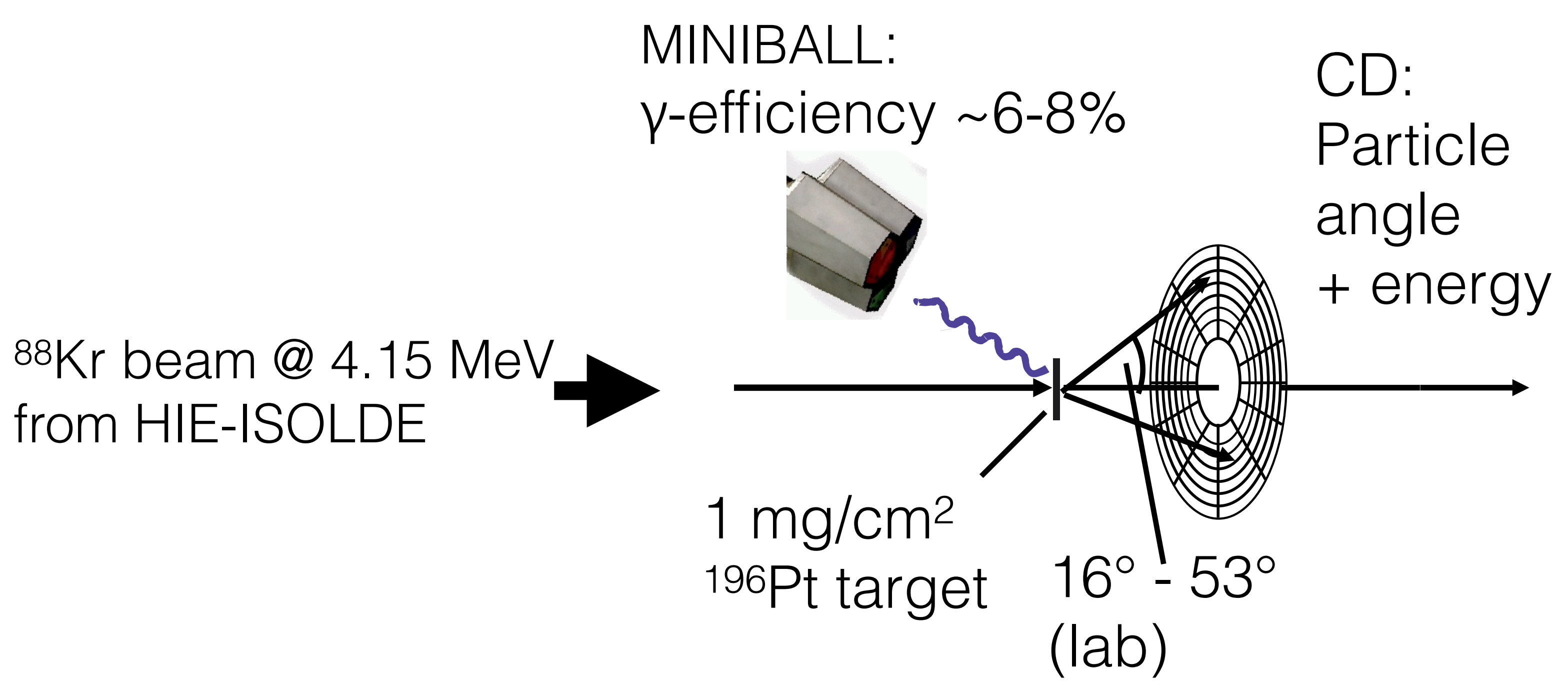
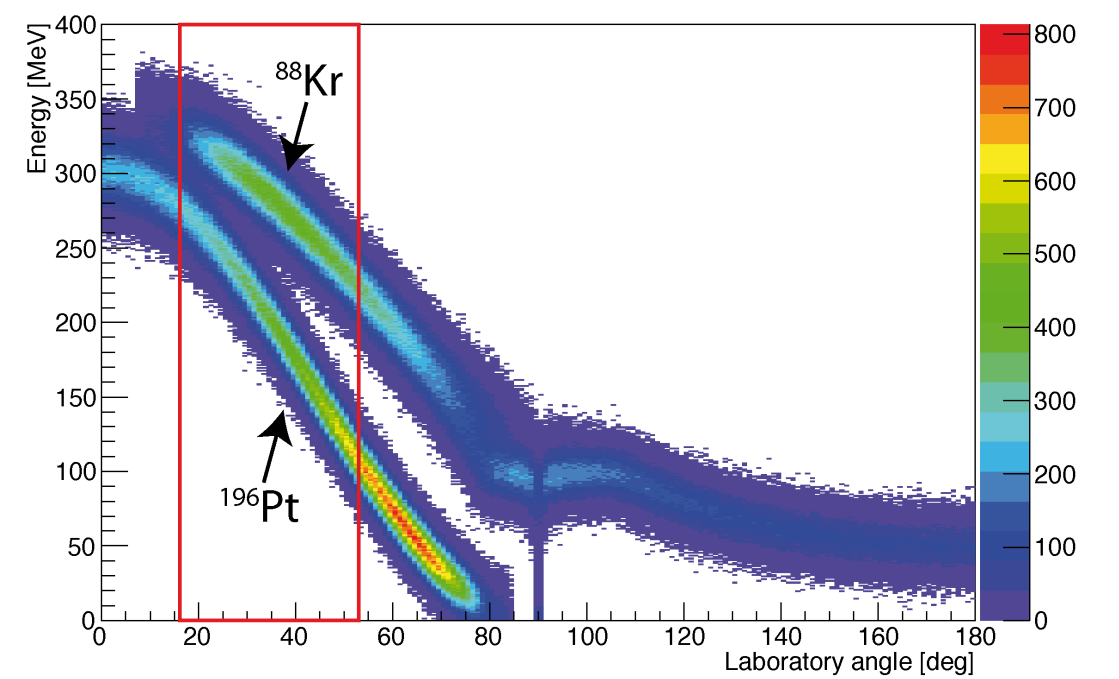
[4] K. Sieja et al., Phys. Rev. C 79, 064310 (2009)
[5] H. Mach et al., Nucl. Phys. A523, 197-227 (1991)

Proposed experiment + setup: Coulomb excitation using MINIBALL

- Higher beam energies of HIE-ISOLDE allow for:
  - Confirmation of the mixed-symmetric character of 2_3^+ state and strong reduction of error bars
  - Confirmation of $B(E2; 2_1^+ \rightarrow 0_1^+)$ used as normalisation for other transitions
  - \+ Determination of collectivity of other symmetric low-spin states using multiple COULEX

- ^{88}Kr beam on ^{196}Pt target (beam should be clean; some contamination from ^{84}Kr)
- Use MINIBALL with standard CD detector
- Kinematics allows for proper separation of projectile and target
- No interfering γ-rays with ^{196}Pt target (however, ^{208}Pb is an option as well)





Calculated γ yields per 8h shift

- Based on:
  - ^{88}Kr production cross section of 1.0 x 10^9 per 1μC protons on PbBi
  - 1% transmission efficiency —> estimate 1.0 x 10^7 ions/s on secondary target
  - Transition matrix elements from experiment -> shell model -> mapped IBM-2

Target	E_{beam} [MeV/u]	Transition	E_γ [keV]	N_γ [Counts]
^{196}Pt	3.00	$2_1^+ \to 0_1^+$	775.28	17360
		$2_2^+ \to 0_1^+$	1577.41	0
	lab. ang.	$2_2^+ \to 2_1^+$	802.14	2
	16° - 53°	$4_1^+ \to 2_1^+$	868.4	10
		$\mathbf{2_3^+ \to 0_1^+}$	**2216.3**	**1**
		$\mathbf{2_3^+ \to 2_1^+}$	**1440.5**	**10**
^{196}Pt	4.15	$2_1^+ \to 0_1^+$	775.28	58159
		$2_2^+ \to 0_1^+$	1577.41	8
	lab. ang.	$2_2^+ \to 2_1^+$	802.14	48
	16° - 53°	$4_1^+ \to 2_1^+$	868.4	193
		$\mathbf{2_3^+ \to 0_1^+}$	**2216.3**	**73**
		$\mathbf{2_3^+ \to 2_1^+}$	**1440.5**	**592**

Clean one-step population of **2_1^+** state: **5 x 10^4 counts in 3 shifts**

Measure relative to 2_1^+: **For 2_3^+ —> 2_1^+: 1 x 10^4 counts in 18 shifts**

850 counts for 2_2^+ —> 2_1^+

3500 counts for 4_1^+ —> 2_1^+

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Target	E_{beam} [MeV/u]	Transition	E_γ [keV]	N_γ [Counts]	N_γ [Counts] CD partially shielded
^{196}Pt	3.00	$2_1^+ \to 0_1^+$	775.28	17360	16195
		$2_2^+ \to 0_1^+$	1577.41	0	0
	lab. ang.	$2_2^+ \to 2_1^+$	802.14	2	2
	16° - 53°	$4_1^+ \to 2_1^+$	868.4	10	10
		$\mathbf{2_3^+ \to 0_1^+}$	**2216.3**	**1**	**1**
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^{196}Pt	4.15	$2_1^+ \to 0_1^+$	775.28	58159	50791
		$2_2^+ \to 0_1^+$	1577.41	8	8
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		$\mathbf{2_3^+ \to 2_1^+}$	**1440.5**	**592**	**590**
^{196}Pt	4.0	$2_1^+ \to 0_1^+$	775.28	55314	46656
		$2_2^+ \to 0_1^+$	1577.41	8	8
	lab. ang.	$2_2^+ \to 2_1^+$	802.14	45	44
	19° - 57°	$4_1^+ \to 2_1^+$	868.4	187	183
		$\mathbf{2_3^+ \to 0_1^+}$	**2216.3**	**60**	**57**
		$\mathbf{2_3^+ \to 2_1^+}$	**1440.5**	**481**	**464**

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850 counts for 2_2^+ —> 2_1^+

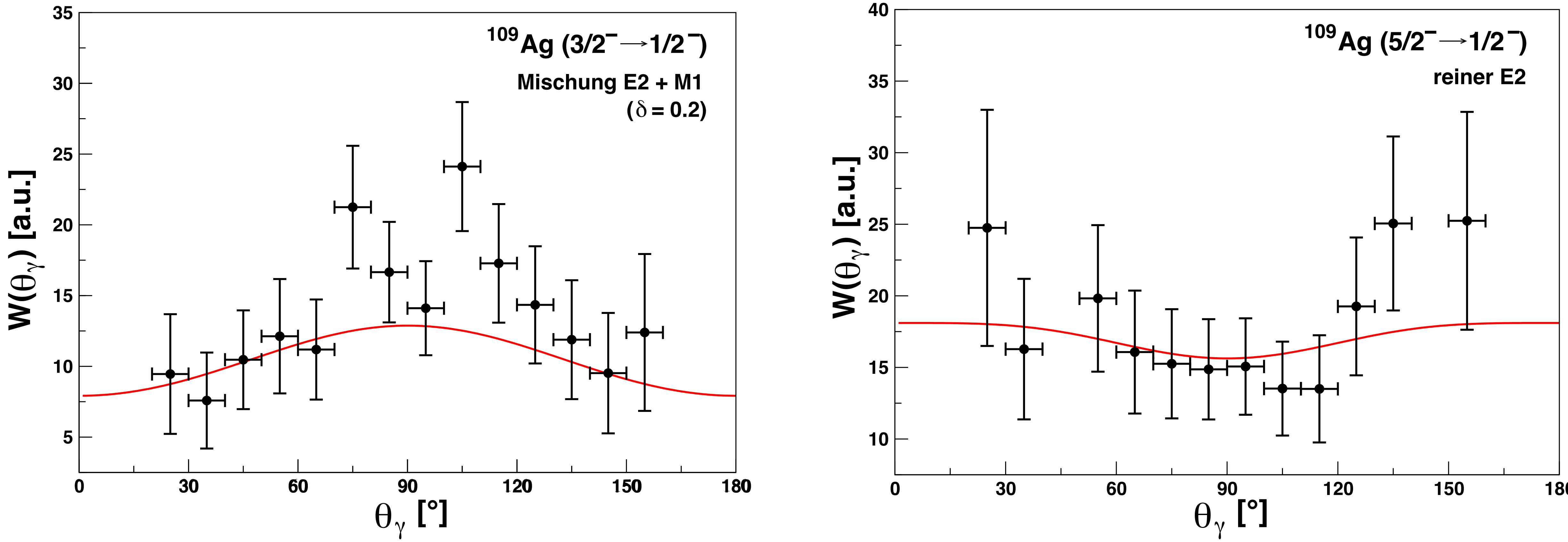
3500 counts for 4_1^+ —> 2_1^+

→ Similar yields also in case beam energy of just 4 MeV/u is available

→ High count rate on CD can be avoided by shielding inner rings of the CD detector

Multipolarity of the $2_3^+ \longrightarrow 2_1^+$ transition:

Attempt to measure γ-ray angular distributions with MINIBALL in
M. Seidlitz, Diploma thesis, Univ. of Cologne (2008):

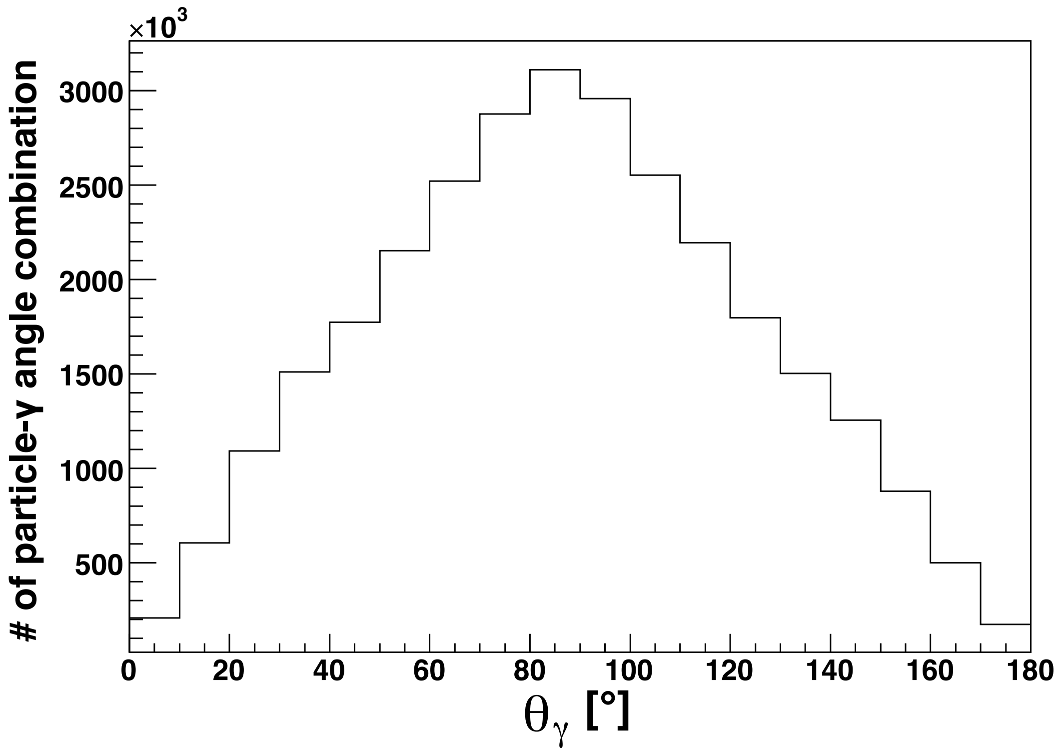


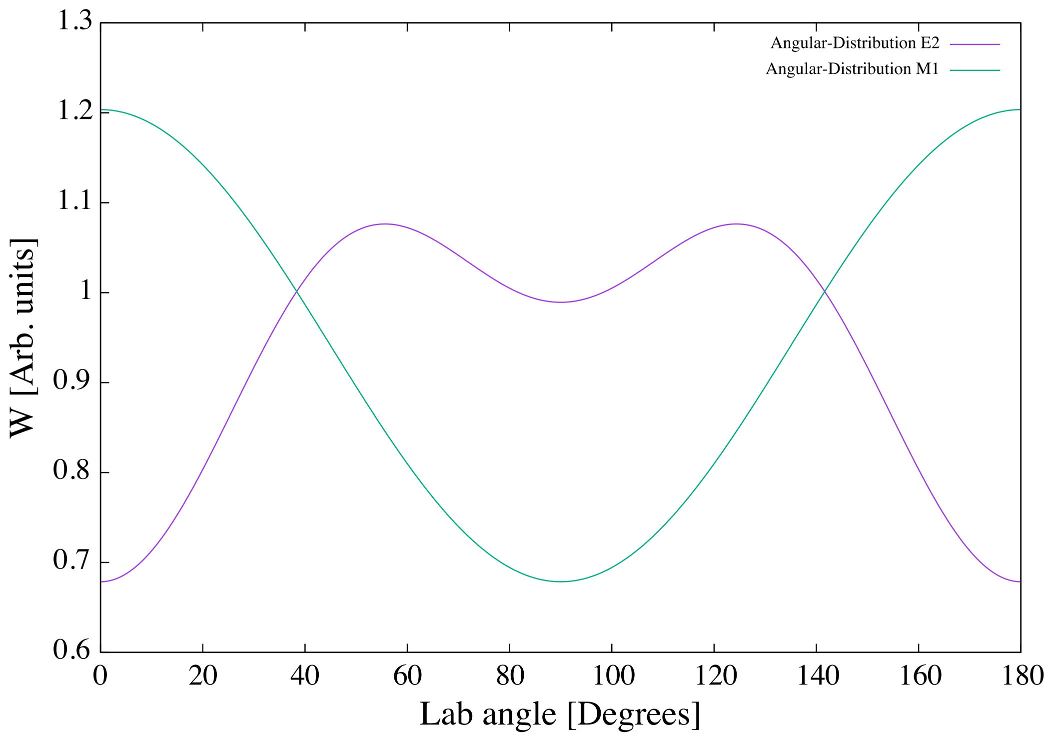
50% uncertainty in δ at roughly 1/10 of our expected statistics for 2_3^+ -> 2_1^+

-> we expect ~5% for every datapoint with an angular binning of 15°

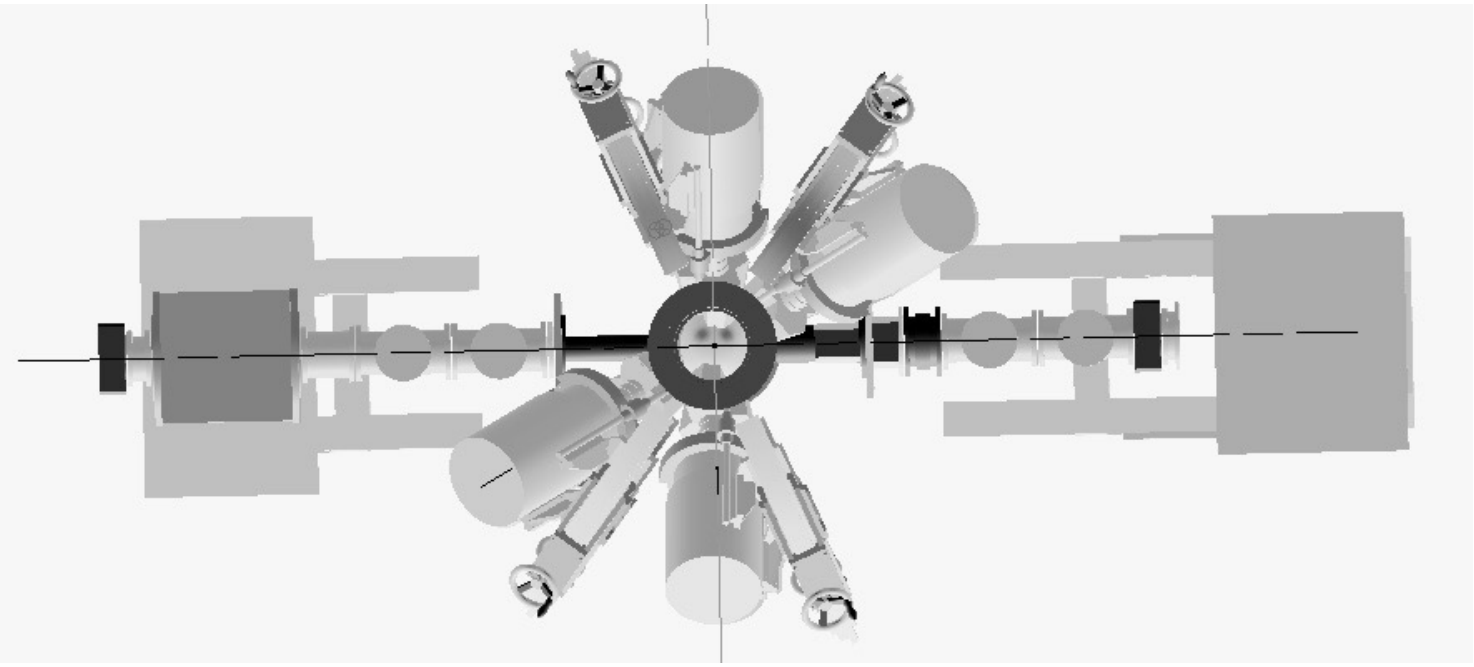
Multipolarity of the $2_3^+ \longrightarrow 2_1^+$ transition:

Distribution of particle-γ angles for typical MINIBALL setup is clearly peaked at 90°
(Simulation from: M. Seidlitz, Diploma thesis, Univ. of Cologne (2008))





Rearrangement of MINIBALL would distribute particle-γ angles more evenly



Beam time request

- 18 shifts of ^{88}Kr beam at 4.15 MeV/u for confirmation of 2_{MS}^+ state and multi-step excitation of higher lying states.

- 3 shifts of ^{88}Kr beam at 3.0 MeV/u for re-measurement of $B(E2; 0_1^+ \rightarrow 2_1^+)$

➡ Total request: **21 shifts**

Thank you!

Additional backup slides

Energy dependence of cross section

Target	E_{beam} [MeV/u]	Transition	E_γ [keV]	N_γ [Counts]	N_γ [Counts] CD partially shielded
^{196}Pt	3.00	$2_1^+ \rightarrow 0_1^+$	775.28	17360	16195
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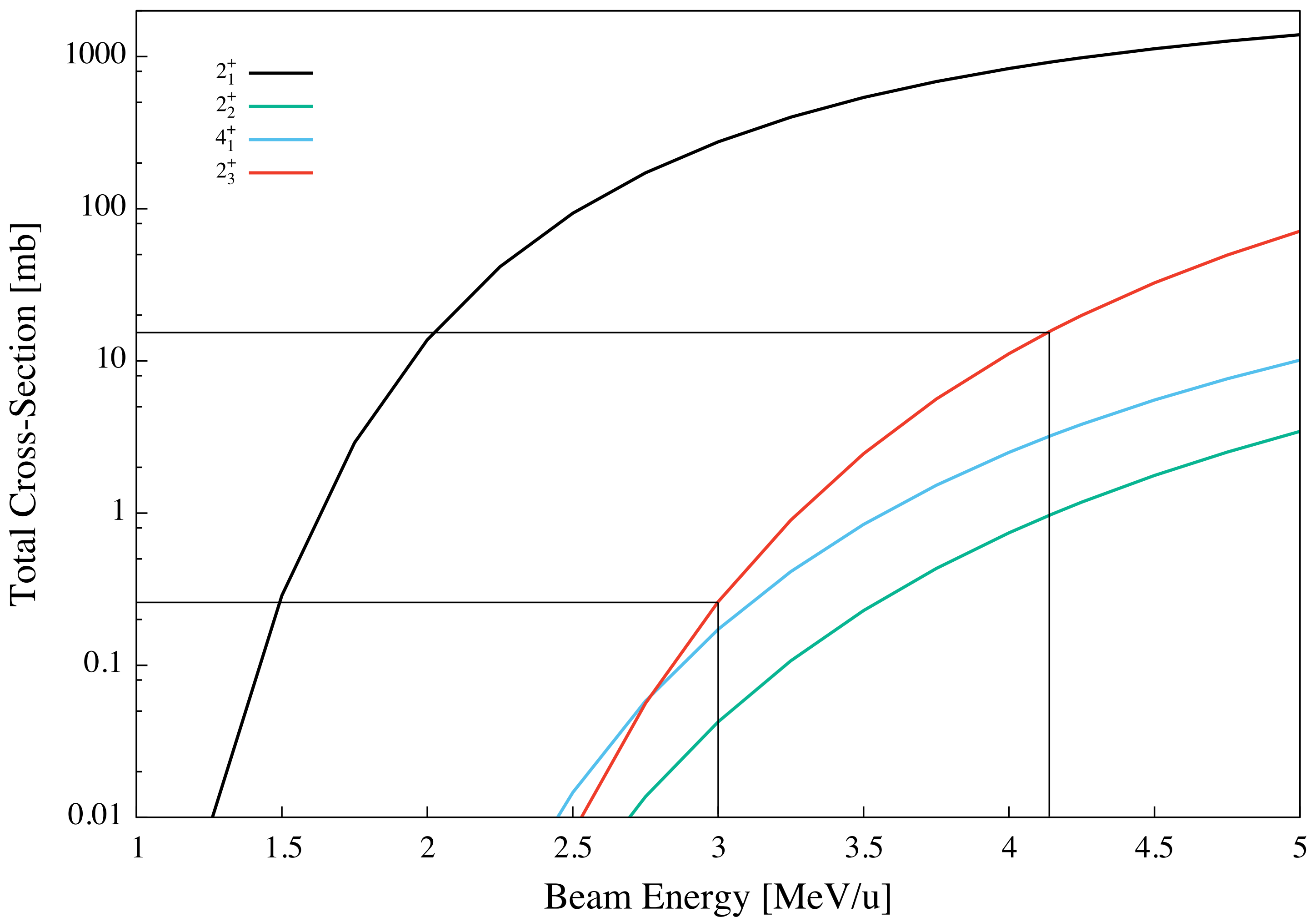
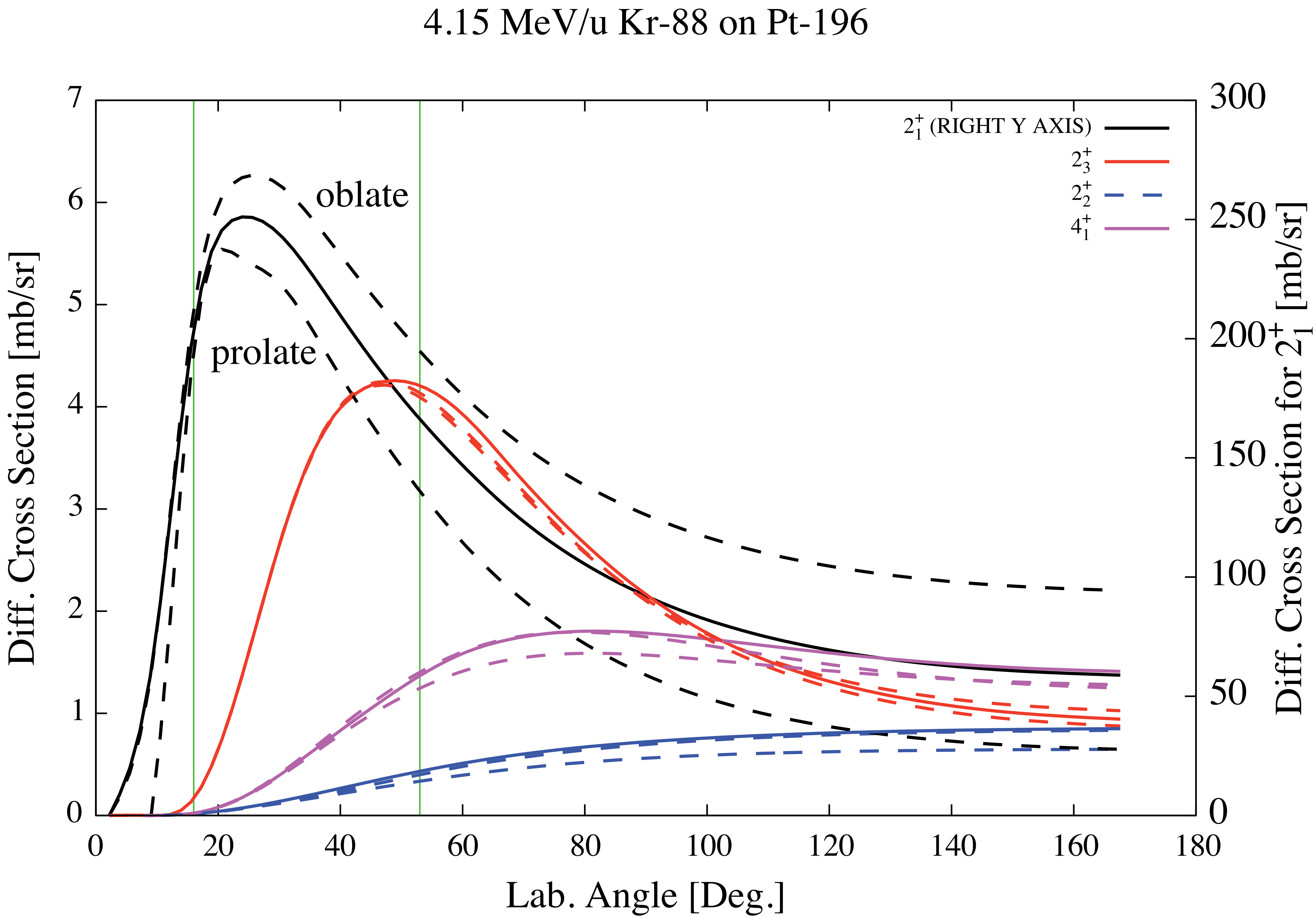


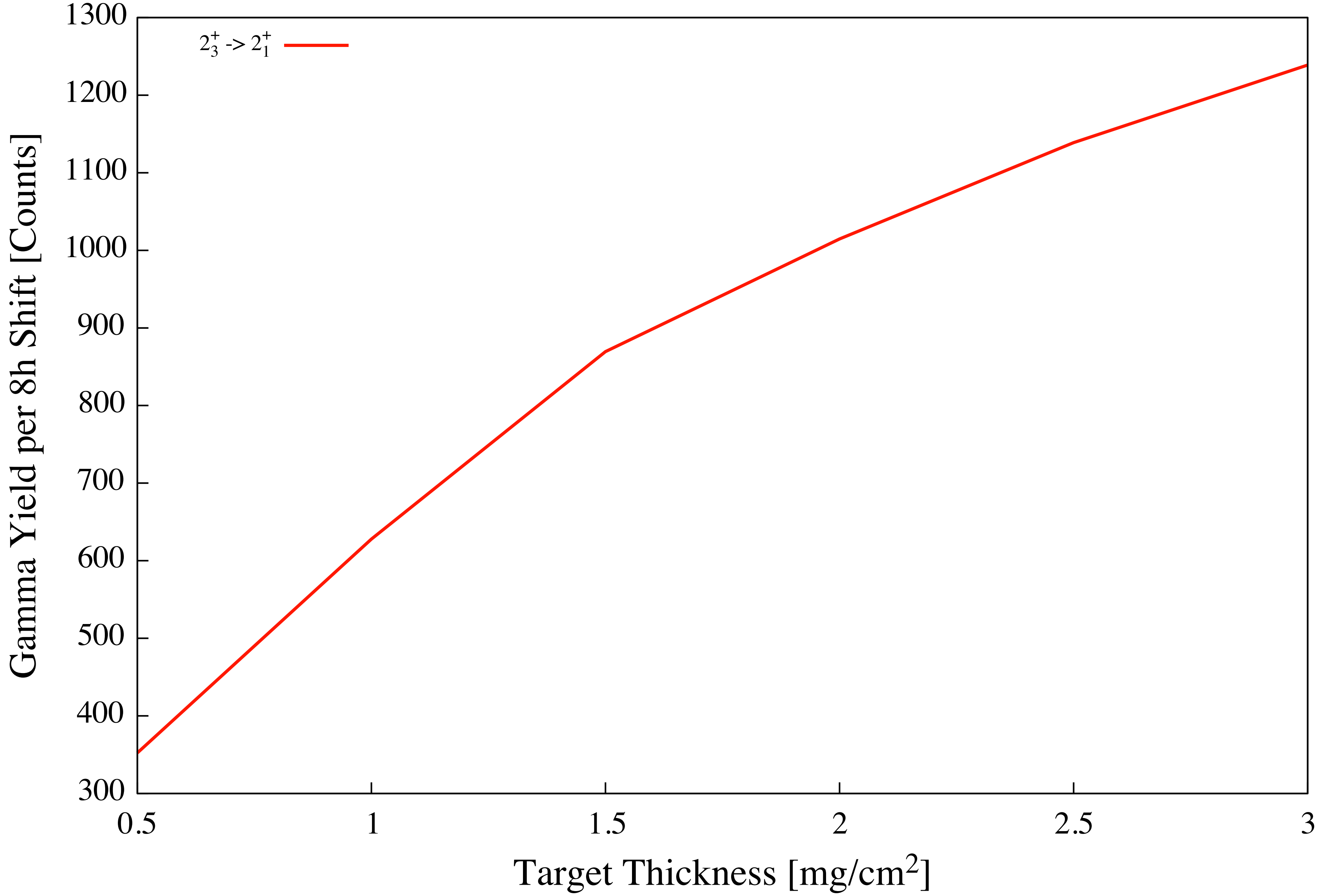
^{208}Pb Target is an even better option

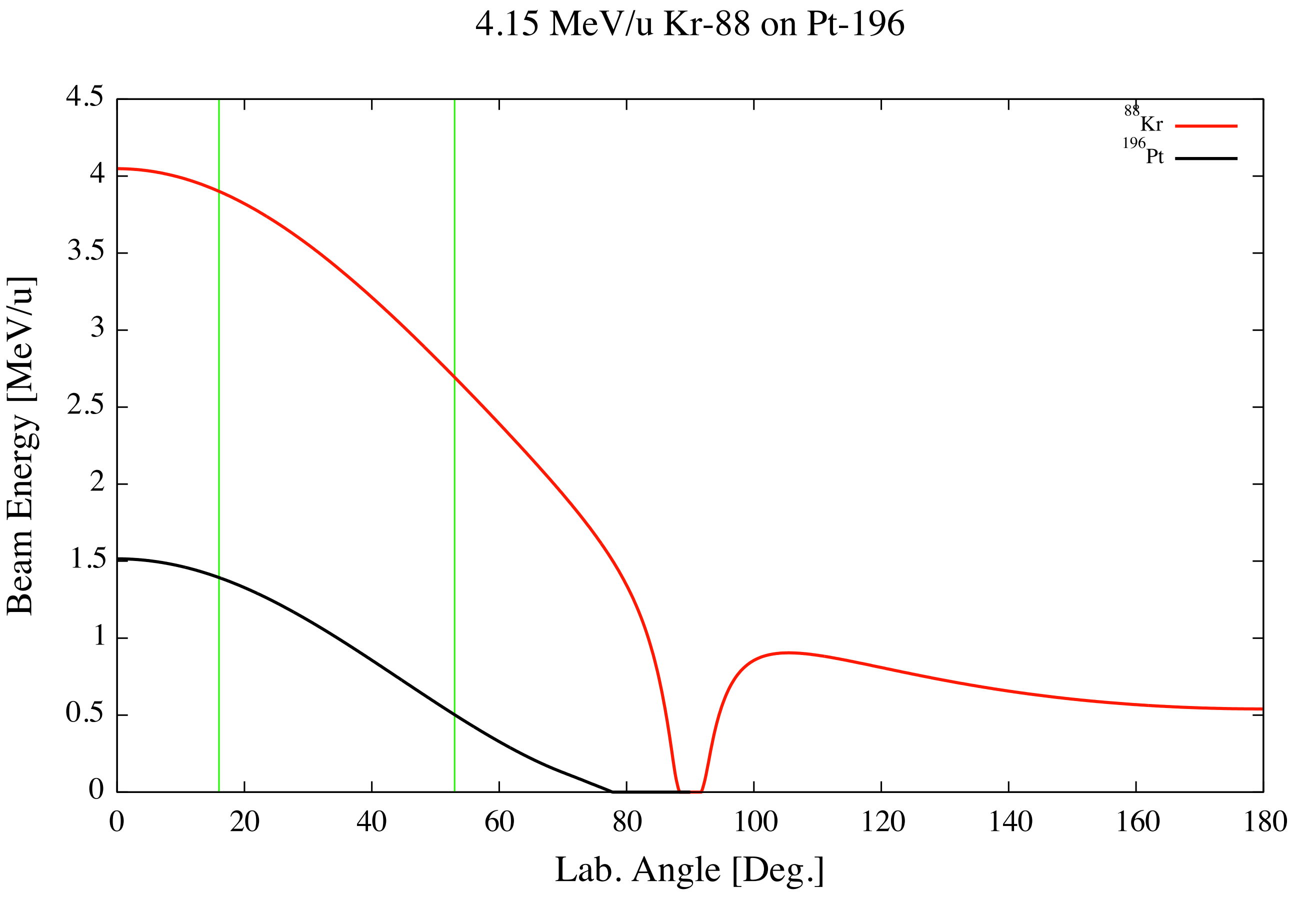
Target	E_{beam} [MeV/u]	Transition	E_γ [keV]	N_γ [Counts]
^{196}Pt	4.15	$2_1^+ \rightarrow 0_1^+$	775.28	58159
		$2_2^+ \rightarrow 0_1^+$	1577.41	8
	lab. ang.	$2_2^+ \rightarrow 2_1^+$	802.14	48
	16° - 53°	$4_1^+ \rightarrow 2_1^+$	868.4	193
		$\mathbf{2_3^+ \rightarrow 0_1^+}$	**2216.3**	**73**
		$\mathbf{2_3^+ \rightarrow 2_1^+}$	**1440.5**	**592**
^{208}Pt	4.35	$2_1^+ \rightarrow 0_1^+$	775.28	65634
		$2_2^+ \rightarrow 0_1^+$	1577.41	10
	lab. ang.	$2_2^+ \rightarrow 2_1^+$	802.14	61
	16° - 53°	$4_1^+ \rightarrow 2_1^+$	868.4	245
		$\mathbf{2_3^+ \rightarrow 0_1^+}$	**2216.3**	**97**
		$\mathbf{2_3^+ \rightarrow 2_1^+}$	**1440.5**	**787**

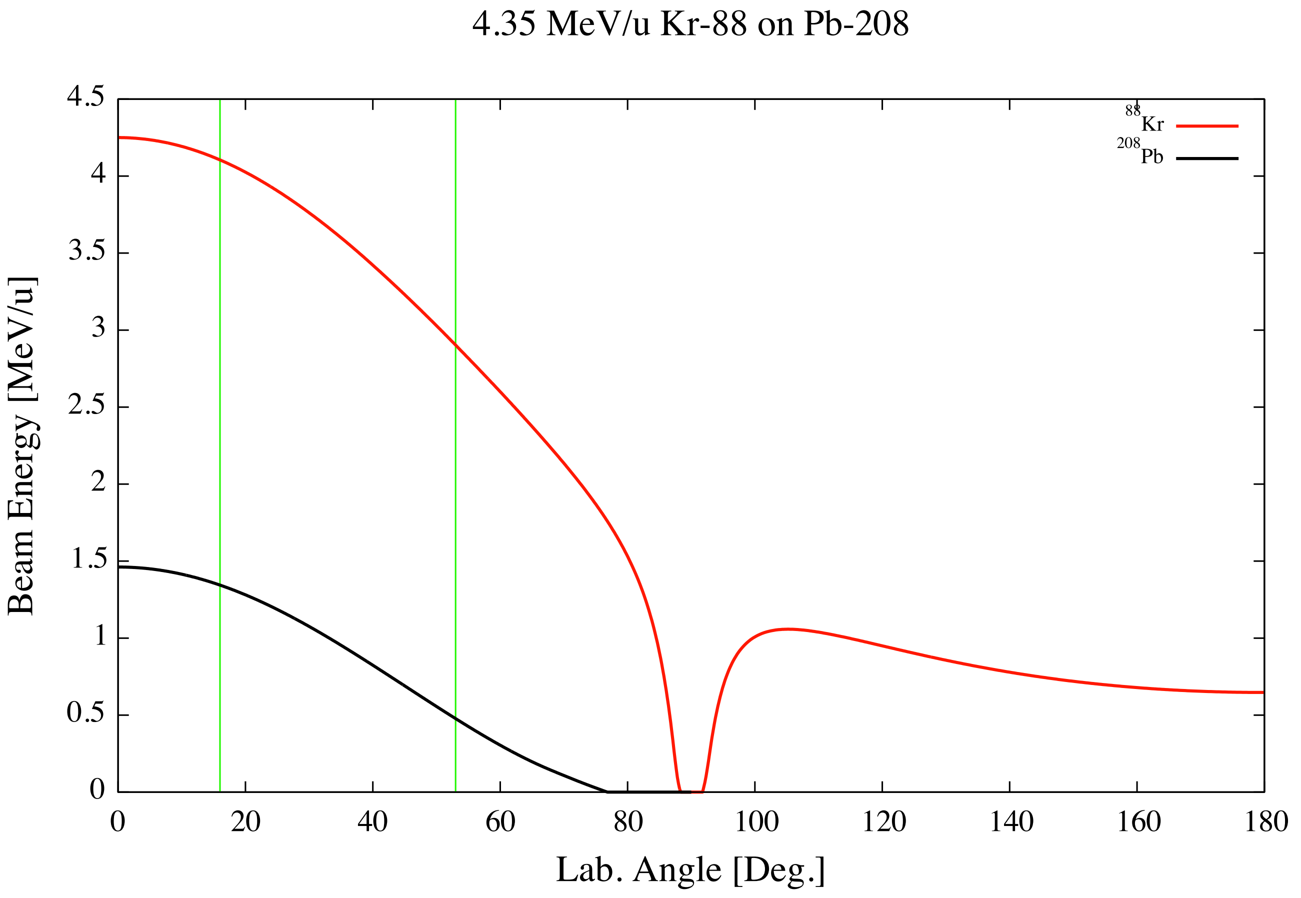
Dependence of CS on 2_1^+ quadrupole moment



Yield vs target thickness




4.15 MeV/u Kr-88 on Pt-196
88Kr
196Pt
Beam Energy [MeV/u]
Lab. Angle [Deg.]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
20
40
60
80
100
120
140
160
180


4.35 MeV/u Kr-88 on Pb-208
88Kr
208Pb
Beam Energy [MeV/u]
Lab. Angle [Deg.]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
20
40
60
80
100
120
140
160
180