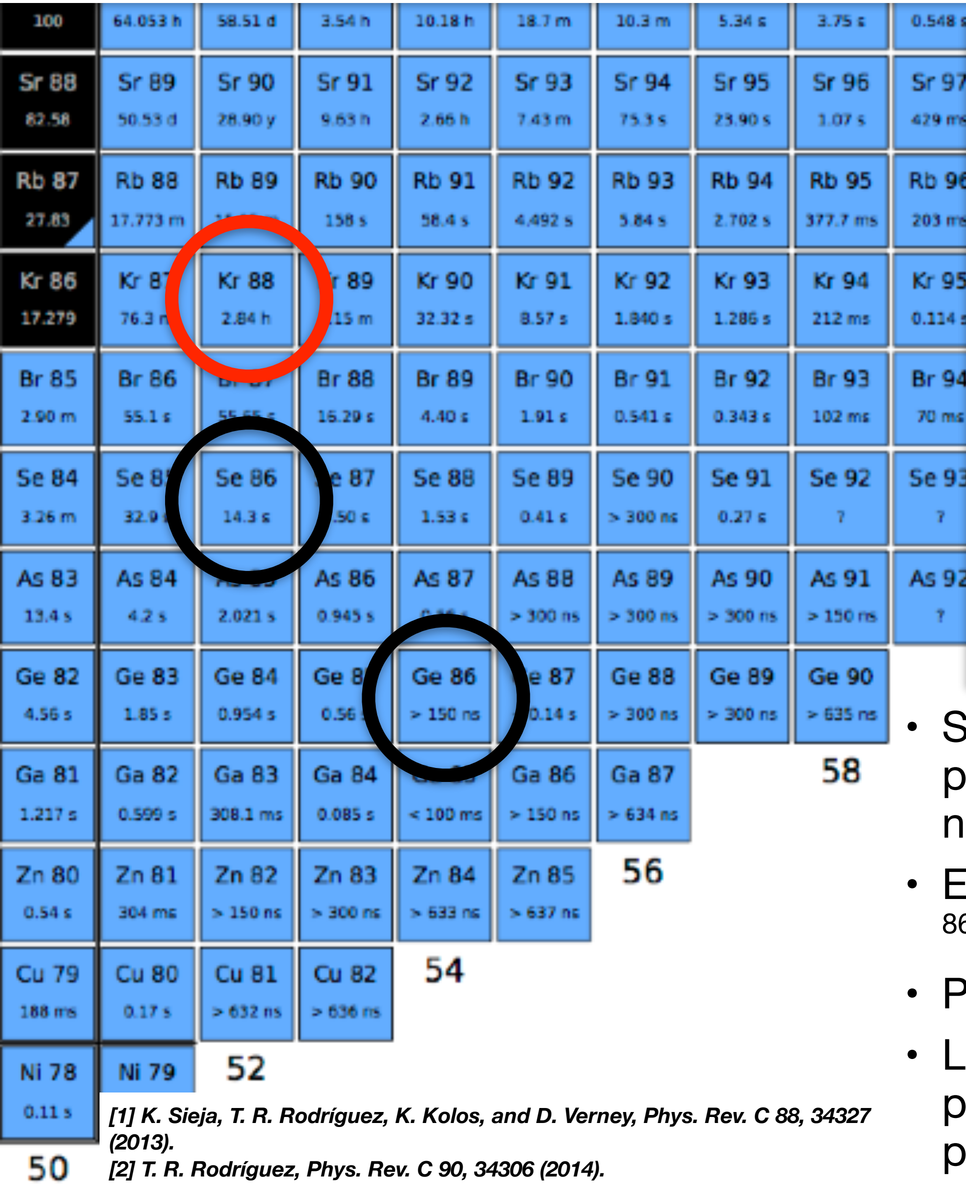
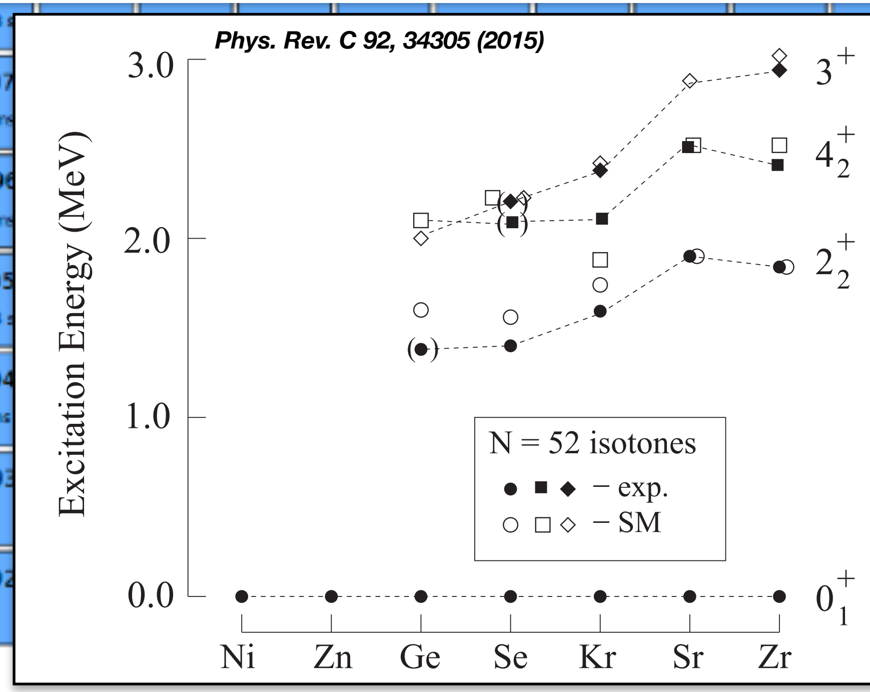
RDDS Lifetime Measurements after Coulomb-Nuclear Excitation of ^{88}Kr — Study of γ Collectivity in the N = 52 Isotones Above ^{78}Ni

Proposal to the ISOLDE and Neutron Time-of-Flight Committee — P-520

Kevin Moschner

Motivation: γ-collectivity above ^{78}Ni





- Shell model and beyond mean field studies predict non axiality and γ-collectivity in Se and Ge nuclei close to N = 50 [1,2]
- Experimentally supported by candidate 3^+ state in ^{86}Se [3]
- Possible counterparts also in ^{88}Kr and ^{92}Zr [4]
- Lowering of these states leading towards lower proton number and maximum triaxiality for ^{86}Ge predicted
- Recently confirmed by low lying 3^+ in ^{86}Ge [5]

[1] K. Sieja, T. R. Rodríguez, K. Kolos, and D. Verney, Phys. Rev. C 88, 34327 (2013).
[2] T. R. Rodríguez, Phys. Rev. C 90, 34306 (2014).
[3] T. Materna et al., Phys. Rev. C 92, 34305 (2015).
[5] Nuclear Data Sheets.
[4] M. Lettmann et al., accepted for Phys. Rev. C.

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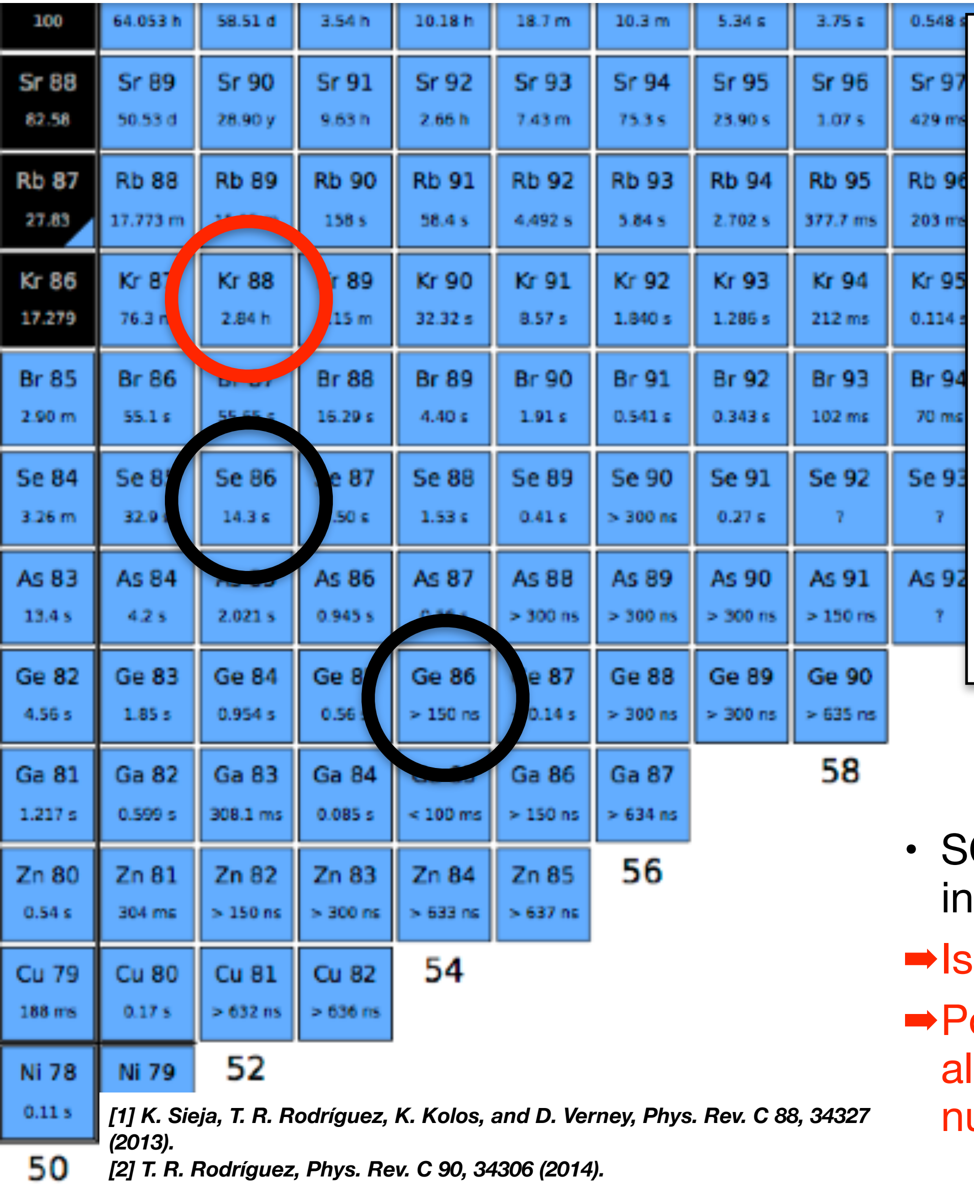

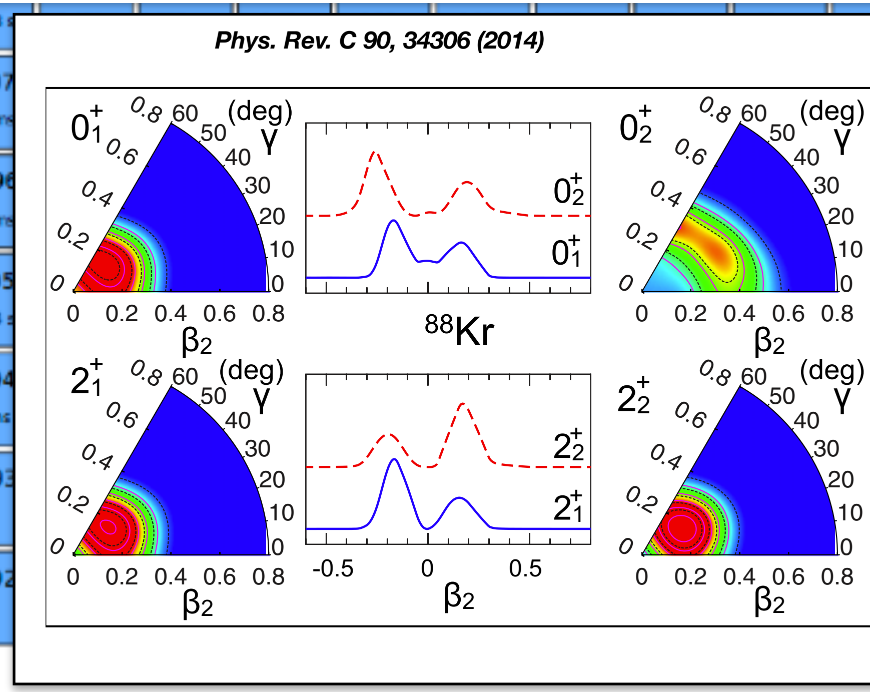

- SCCM calculations predict axial deformation also in ^{88}Kr

➡ Isolde provides high intensity beams

➡ Possibility to gain information on γ-collectivity, also essential for the more exotic Se and Ge nuclei

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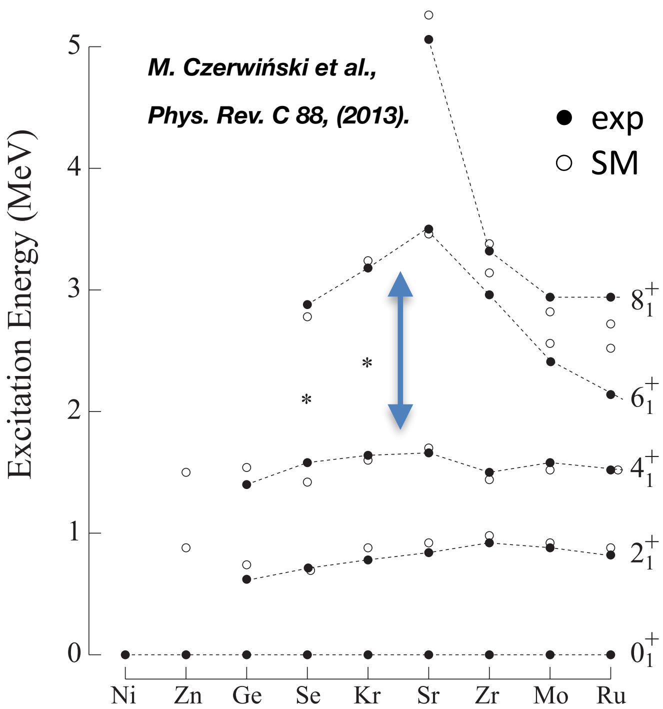
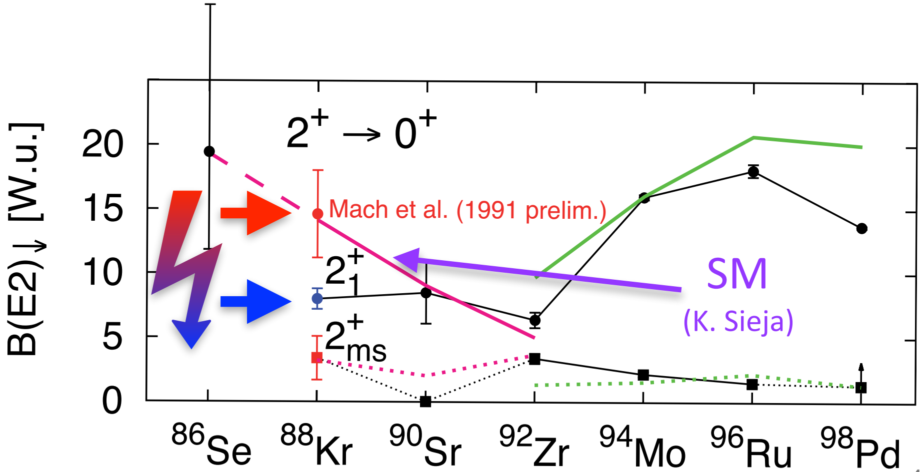
Motivation: Extensive Predictions by Shell Model

- Most experimental work in the region focused on establishing energetic level scheme
  - Good agreement for low lying yrast states including gap between 4_1^+ and 6_1^+
  - Less good understanding of non-yrast states and branchings into the yrast band
- Almost no information on transition strengths, which will help to constrain shell model description
- Ambiguity even for the 2_1^+ -> 0_1^+ transition:
  - COULEX at Isolde: B(E2)↓ = 8.0 (8) W.u.
    (D. Mücher et al., in AIP Conf. Proc. 1090, 587 (2009))
  - Fast timing: B(E2)↓ = 15 (3) W.u.
    (preliminary value given in: H. Mach et al., Nucl. Phys. A 523, 197 (1991))
  - Shell model also favours higher B(E2)
  - Trend continued in ^{86}Se: B(E2) = 19^{+11}_{-8} W.u.
- RDDS measurement will provide model independent lifetimes in a wide range for the mentioned states

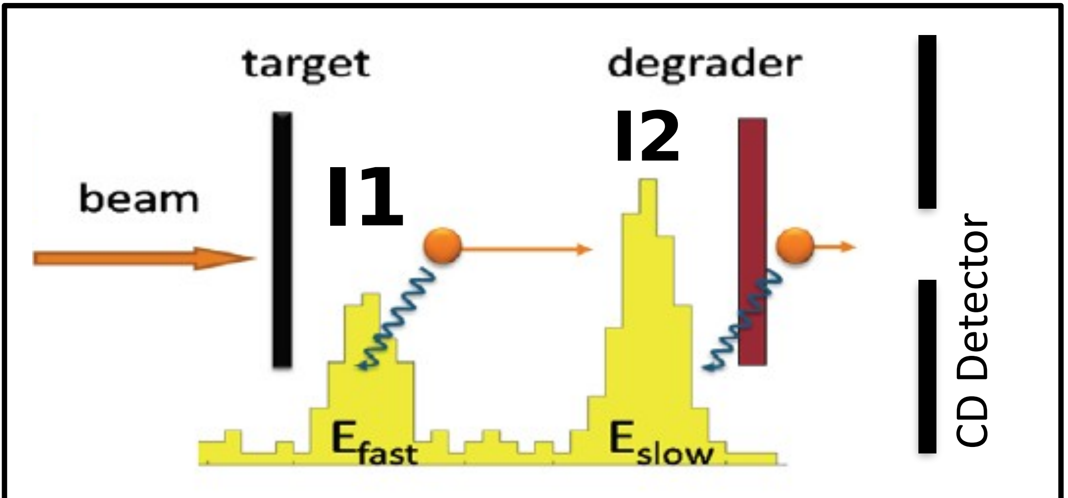
➡THIS PROPOSAL



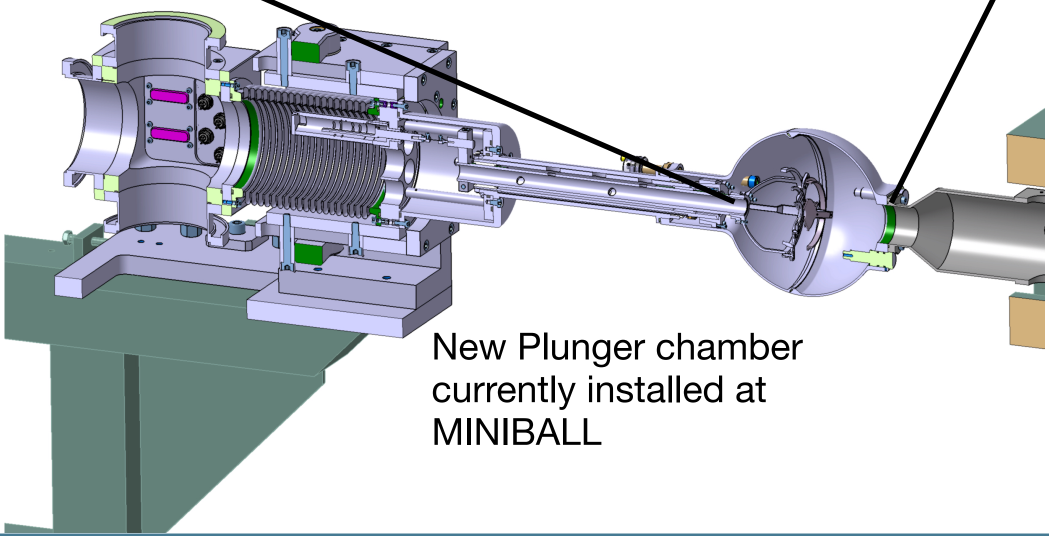


The Recoil Distance Doppler Shift (RDDS) Method and the Differential Plunger for MINIBALL

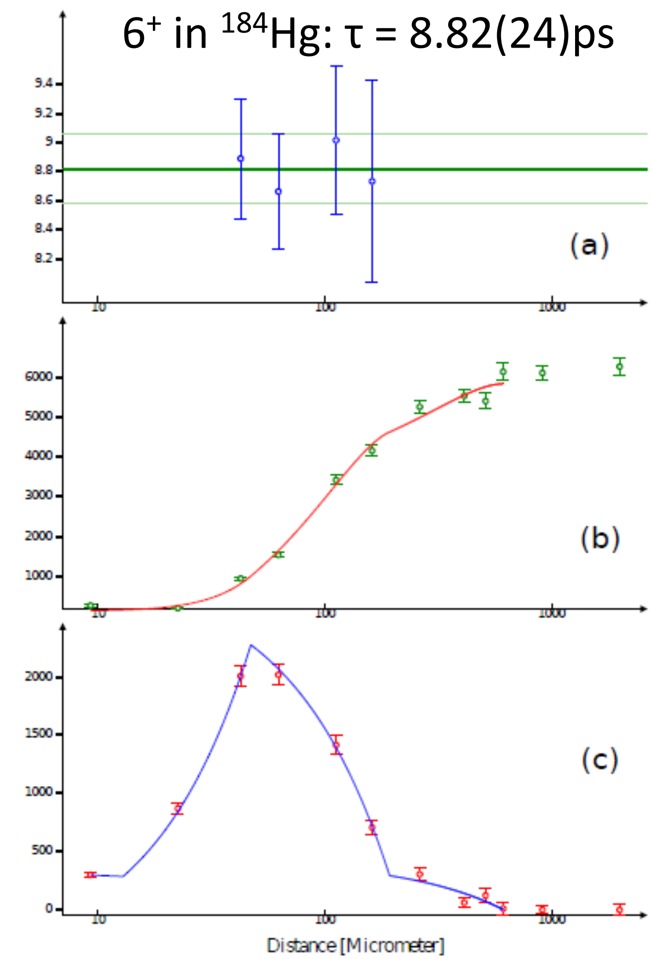
- Plot ratio $I_1/(I_1+I_2)$ vs. distance
- Every distance in sensitive range gives a lifetime value



$$E_{obs} \approx E_0 \cdot (1 + \frac{v}{c} \cos\theta)$$

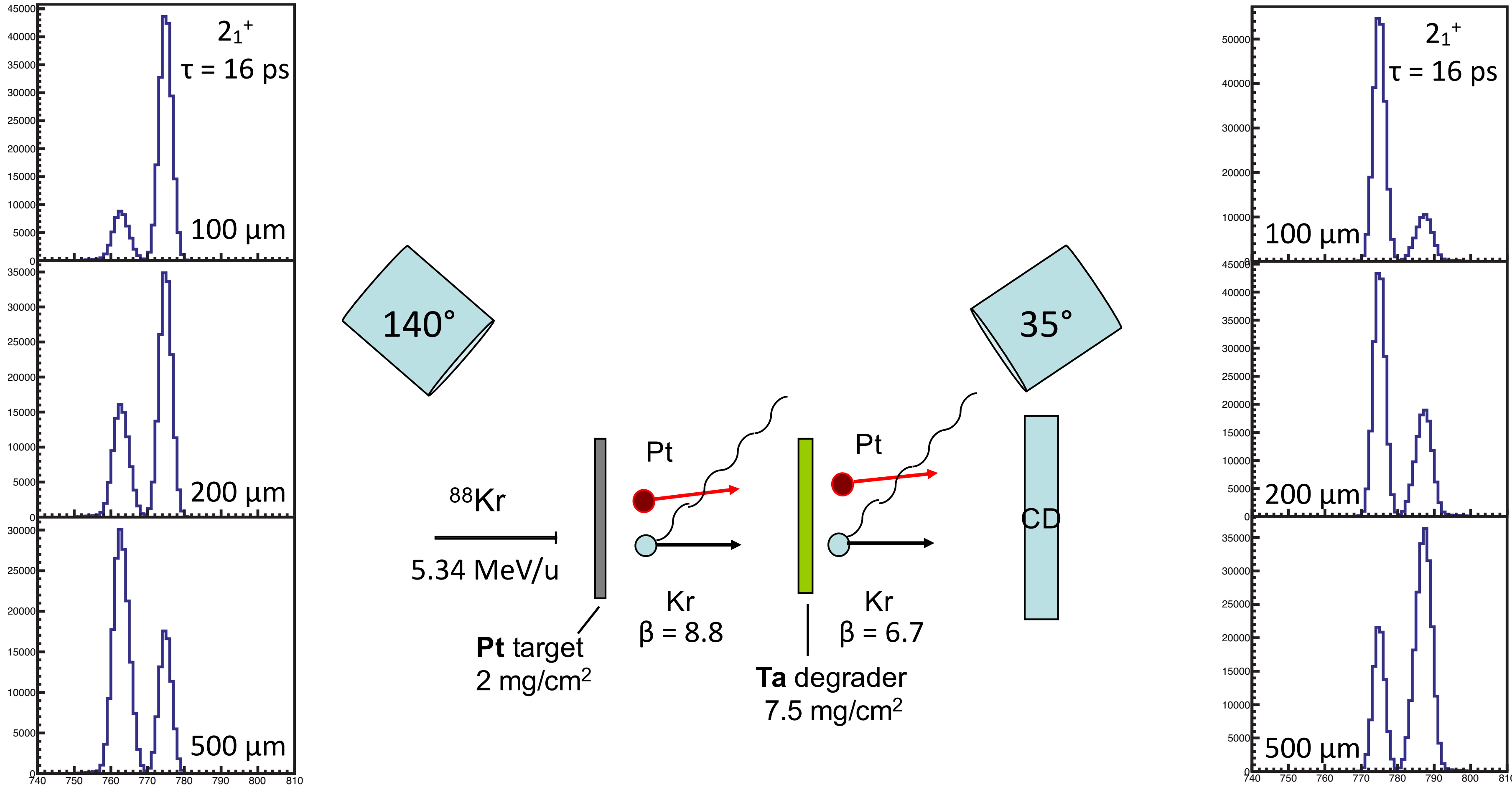


New Plunger chamber currently installed at MINIBALL



Proposed experiment - RDDS measurement of ^{88}Kr

- Coulomb-Nuclear Excitation (CNE) of ^{88}Kr beam at beam energy of 5.34 MeV/u on ^{196}Pt target
- MINIBALL for detection of emitted γ rays. Efficiency about 2-3% in each angular ring
- Use 2 mg/cm^2 ^{196}Pt target and 7.5 mg/cm^2 ^{181}Ta degrader for desired velocities and sensitivity for lifetimes in the range from 1 ps to 250 ps



Proposed experiment - Additional sensitivity via DSAM

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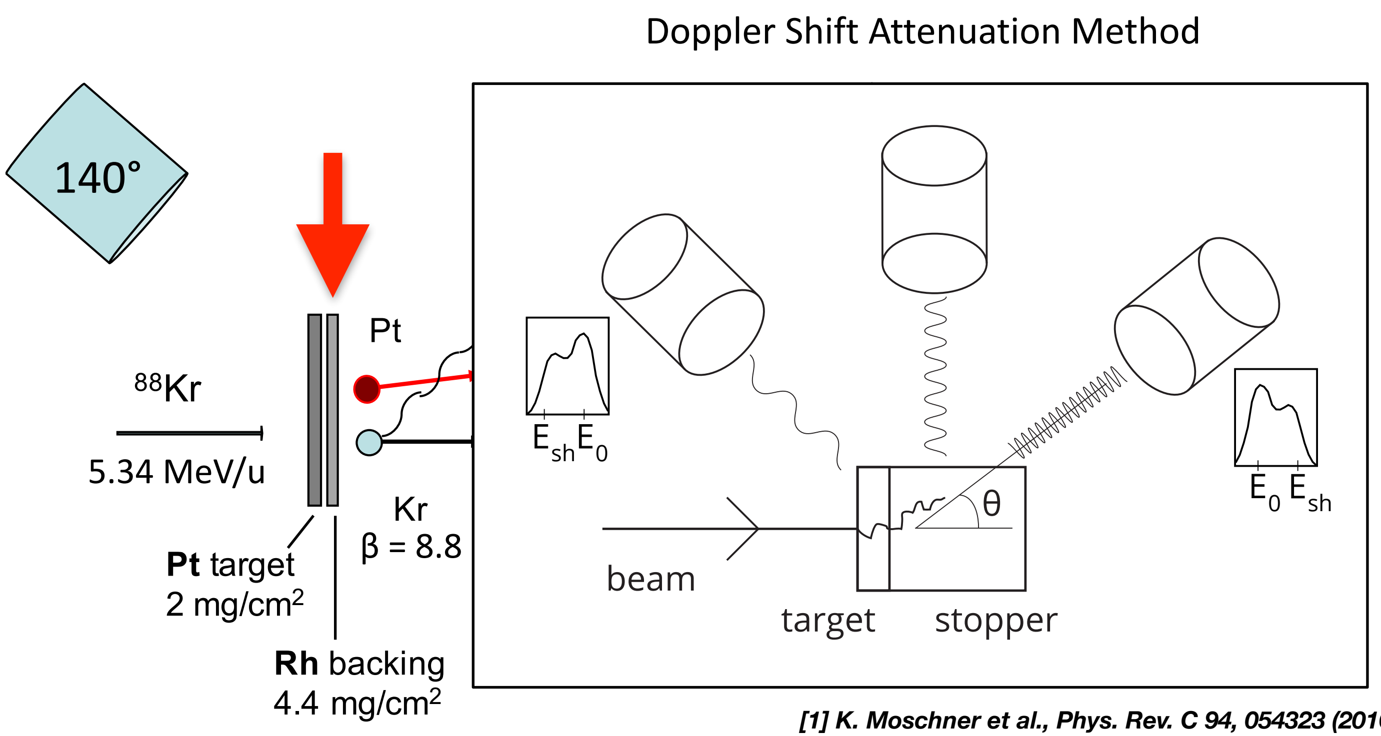
- Additionally use 4.4 mg/cm^2 Rh backing for sensitivity below ~1 ps via DSAM
  - ➡Does not affect sensitivity for longer lifetimes
  - ➡Possibility to directly measure $\tau(2_3^+)$ = 28(14) fs (from relative B(E2)↑/norm. to 2_1^+-> 0_1^+ [1])



[1] K. Moschner et al., Phys. Rev. C 94, 054323 (2016).

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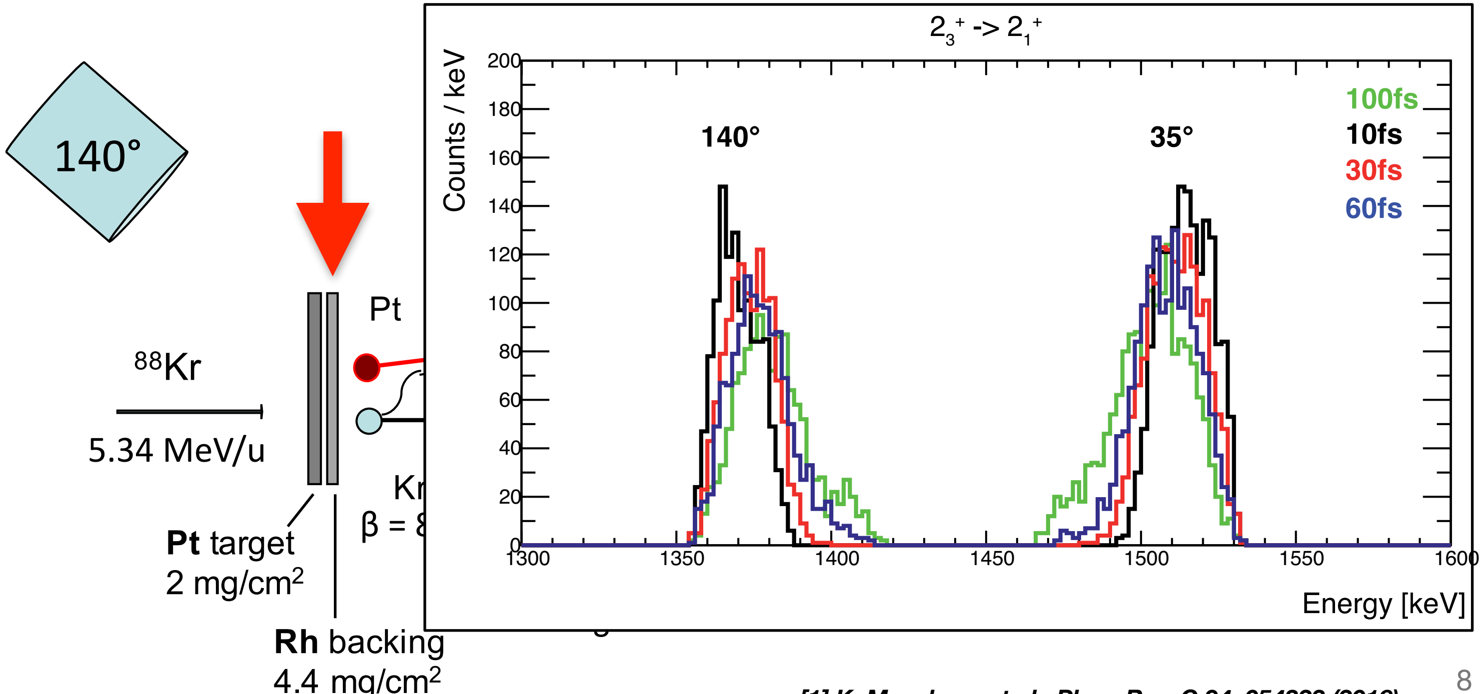

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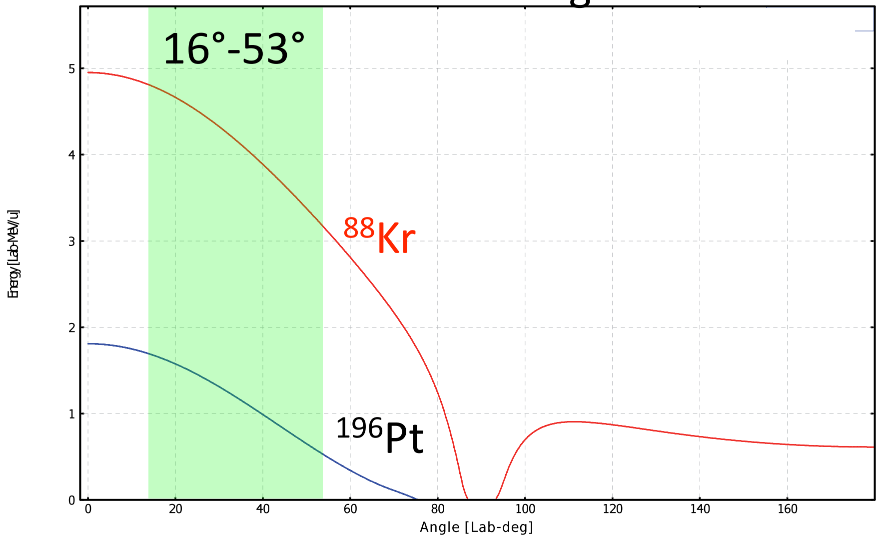
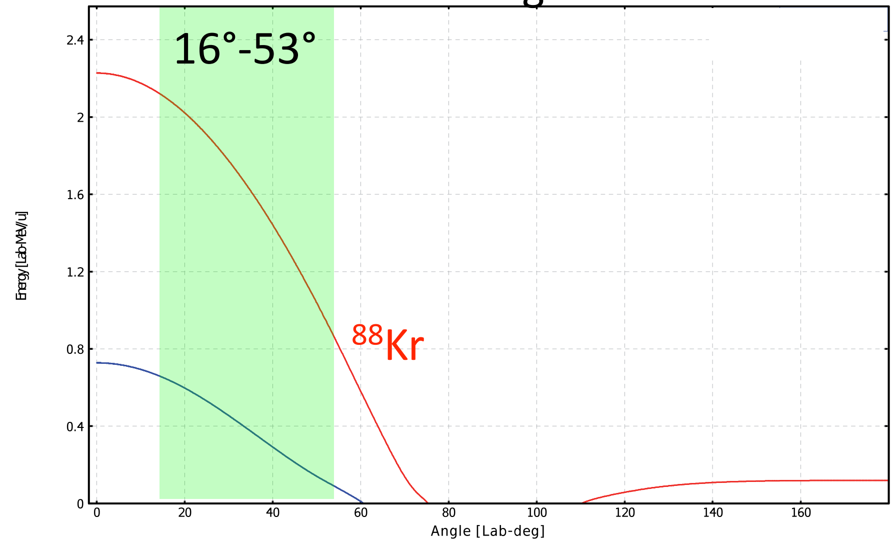
Reaction Kinematics / Detection of Scattered Projectiles

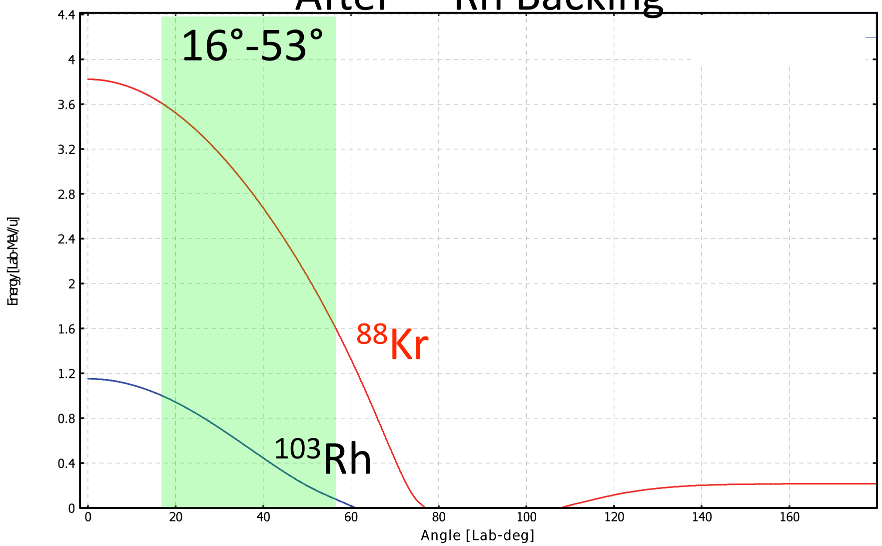
After ^{196}Pt Target



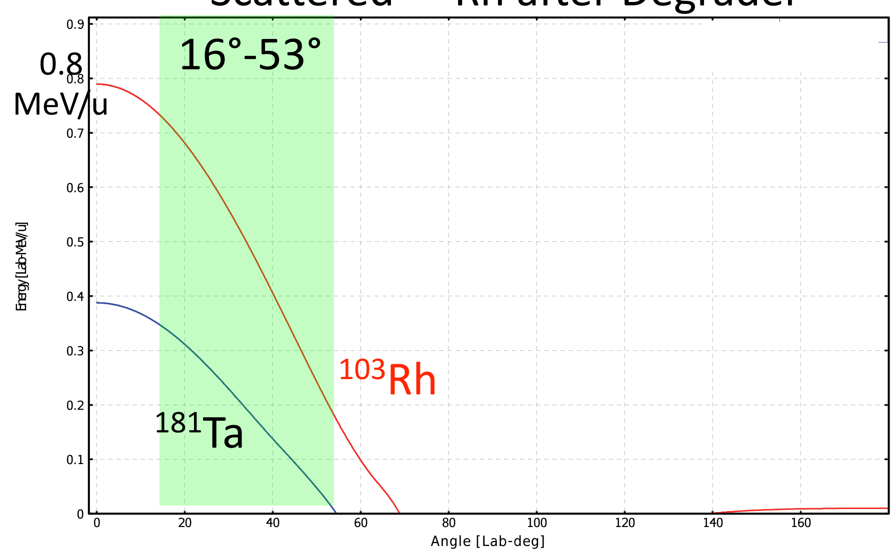
After Degrader



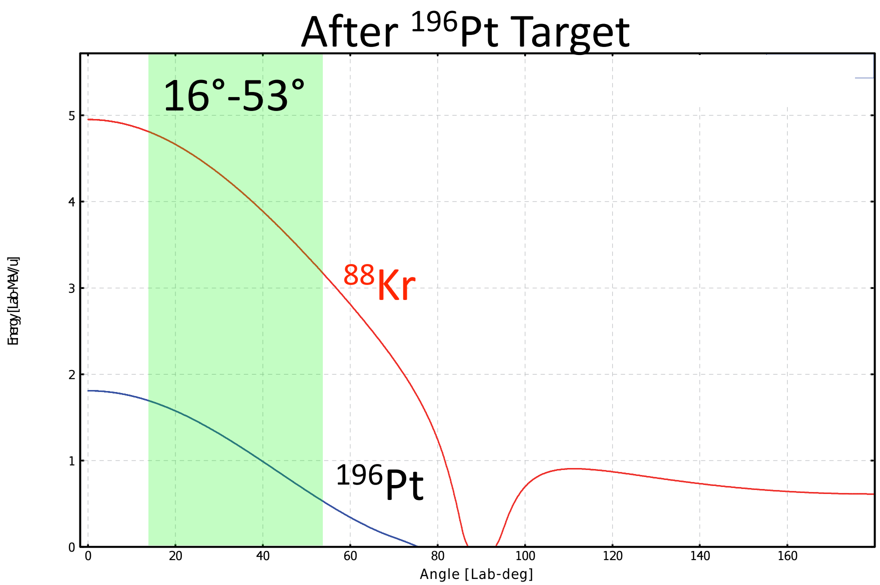
After ^{103}Rh Backing

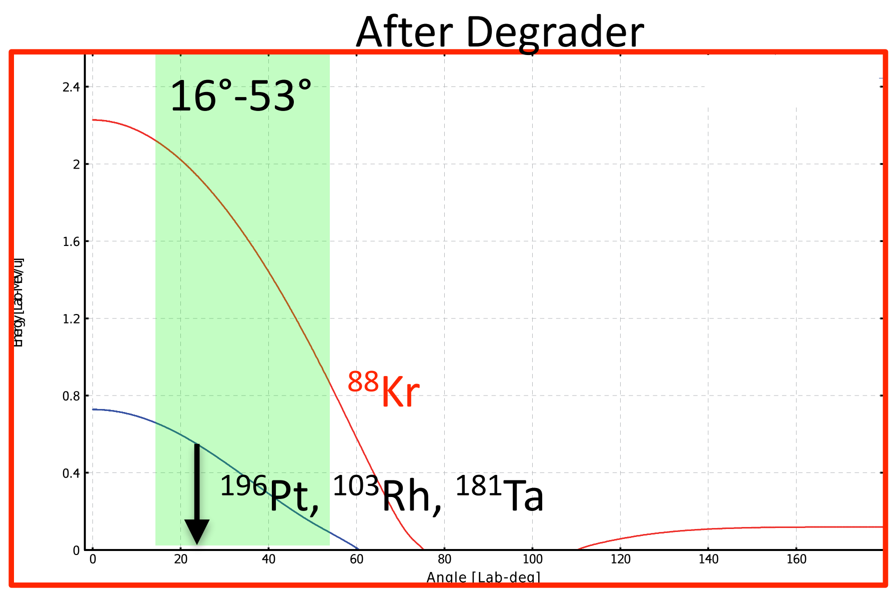


Scattered ^{103}Rh after Degrader



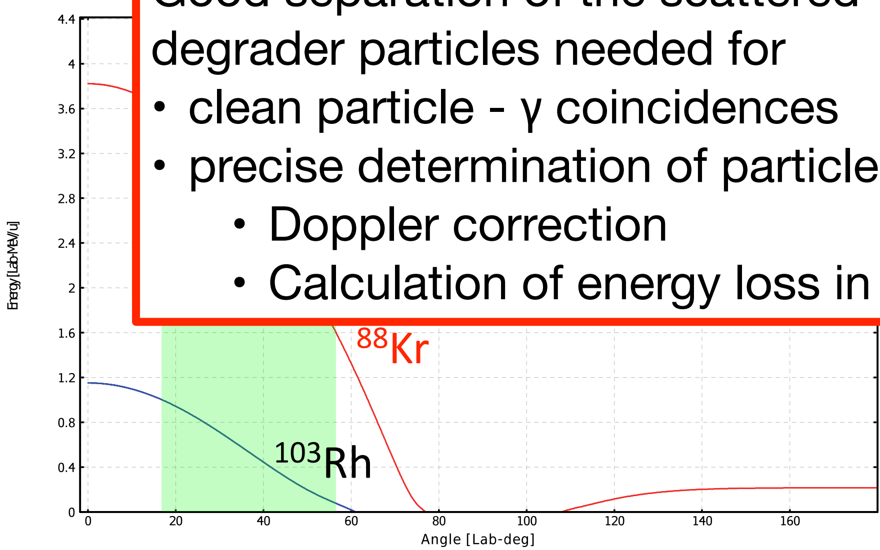
Reaction Kinematics / Detection of Scattered Projectiles

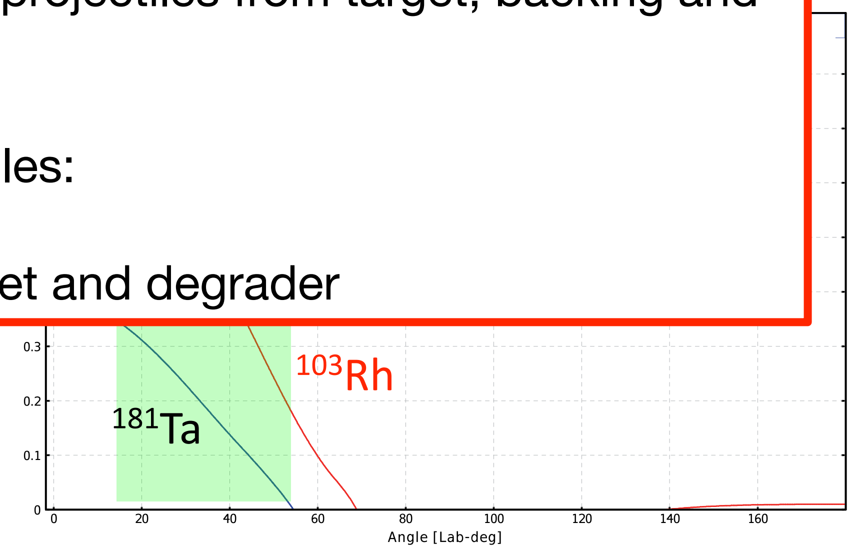




Good separation of the scattered ^{88}Kr projectiles from target, backing and degrader particles needed for

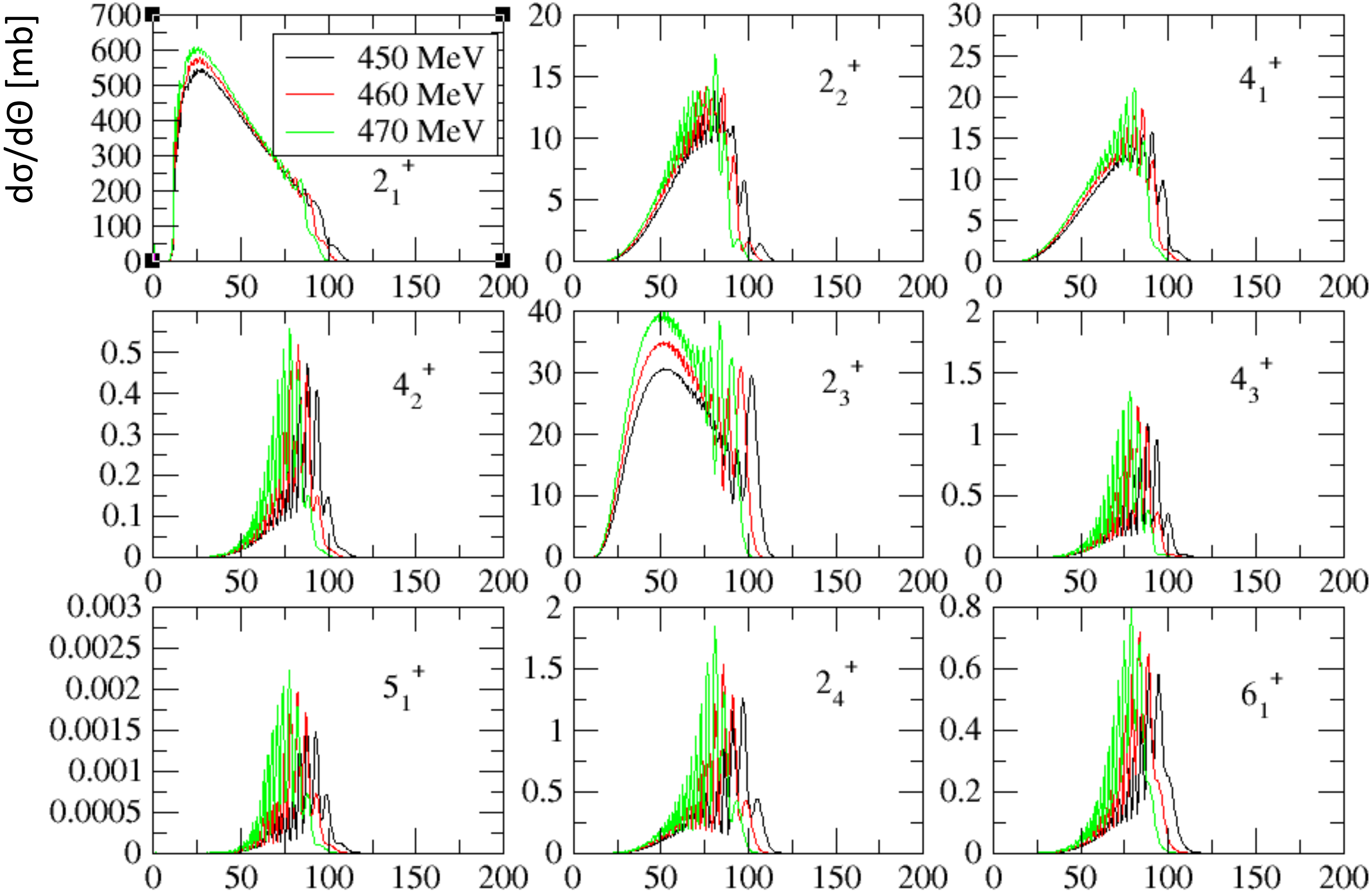
- clean particle - γ coincidences
- precise determination of particle angles:
  - Doppler correction
  - Calculation of energy loss in target and degrader





CNE: Cross section calculated with FRESCO

Acceptance of CD: 23°-74° CMS



Scatt. Ang. CMS [deg.]

FRESCO calculations by B.S. Nara Singh

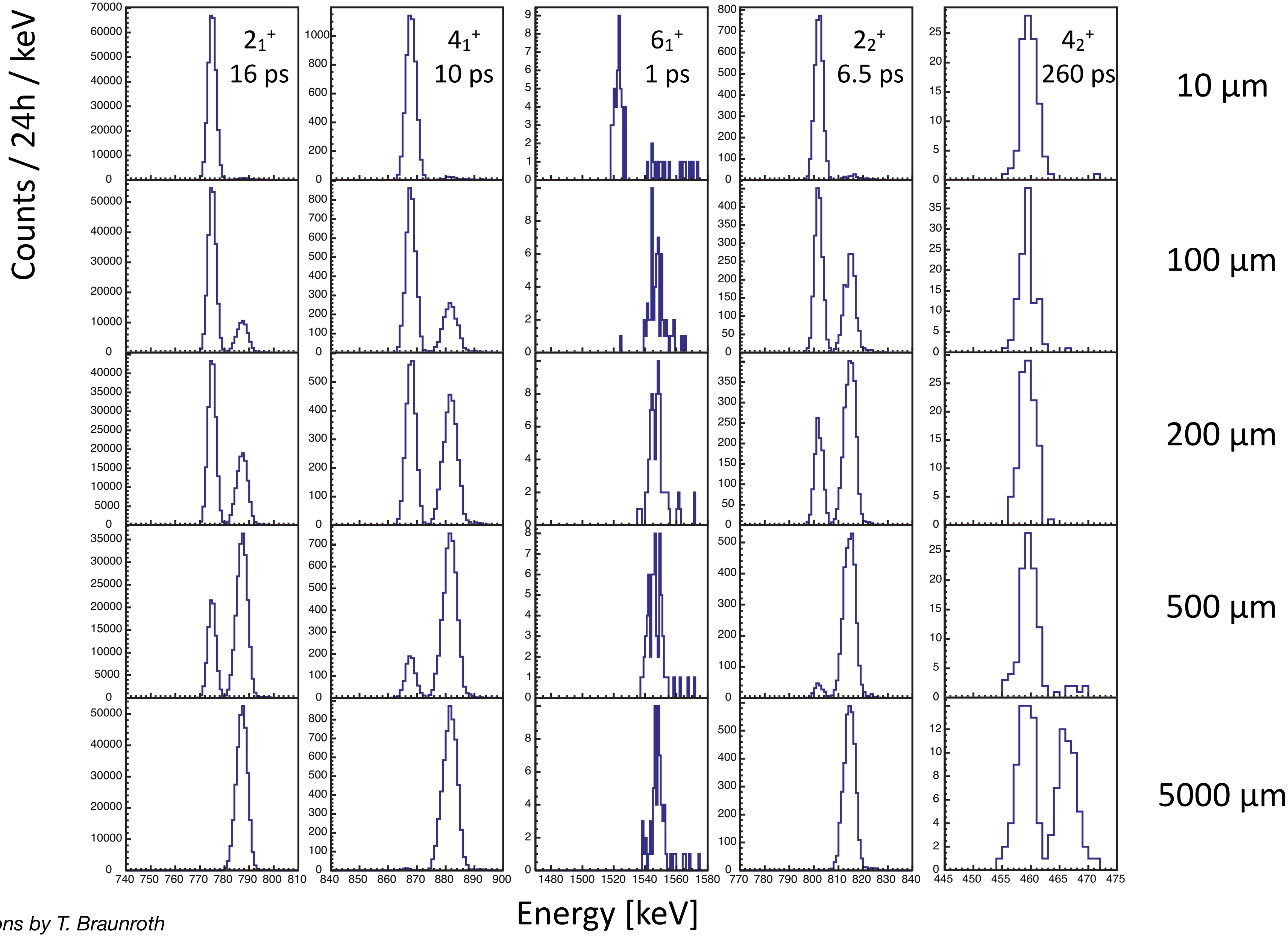
Proposed experiment - Yield calculations

- Assuming 1.0x10^9 ions of ^{88}Kr produced per second in PbBi target and transmission of 1% we estimated secondary beam intensity of 1.0x10^7 on the MINIBALL target.
- Transitions matrix elements from large-scale shell-model calculations in $\pi(1f_{5/2}, 2p_{1/2}, 2p_{3/2}, 1g_{9/2})$, $\nu(2d_{5/2}, 3s_{1/2}, 2d_{3/2}, 1g_{7/2}, 1h_{11/2})$ space and lower experimental value for 2_1^+ -> 0_1^+
- Using CNE at 470 MeV (5.35MeV/u) drastically increases cross rates and enables study of higher lying states
- Staying for 48h on one RDDS distance enables γ-γ coincidence analysis
- Expected yield leads to statistical uncertainties of lifetimes below 20% for all considered states

Expected γ-ray yields in 48h - one RDDS distance

Initial state	$\tau[ps]$	Transition	E_γ [keV]	N_γ [Counts per angular ring]
2_1^+	16.0(17)	$2_1^+ \to 0_1^+$	775.28	517316
4_1^+	10*	$4_1^+ \to 2_1^+$	868.4	9873
6_1^+	1*	$6_1^+ \to 4_1^+$	1523.4	100
2_2^+	6.5*	$2_2^+ \to 0_1^+$	1577.41	1144
		$2_2^+ \to 2_1^+$	802.14	6546
2_3^+	0.028(14)	$2_3^+ \to 0_1^+$	2216.3	2976
		$2_3^+ \to 2_1^+$	1440.5	24370
4_2^+	260*	$4_2^+ \to 2_1^+$	1328.9	9
		$4_2^+ \to 4_1^+$	460.0	136

Expected sensitivity after 24h / distance (35°)



Simulations by T. Braunroth

Summary

- We propose to use Coulomb-Nuclear Excitation to populate excited states in ^{88}Kr
- RDDS measurement using the newly build PLUNGER for MINIBALL will enable model independent measurement of nuclear lifetimes:
  - 2_1^+,2_2^+ and 4_1^+ with statistical uncertainty of 1-2%
  - 4_2^+ and 6_1^+ still with statistical uncertainty of < 20%
- Combined DSAM measurement enables determination of lifetimes in the 10 -100 fs regime
  - Direct measurement of 2_3^+
- Additional possibility to access quadrupole moments by nuclear deorientation effect

- Beam time request:
  - 18 shifts for the measurement RDDS measurement with 3 target-degrader distances
  - 3 additional shifts for setup and
  - ➡ 21 shifts requested in total

Thank you for your attention