Collective isovector valence-shell excitations in the N=84 isotone ^{138}Xe

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Mixed-Symmetry States (isovector)

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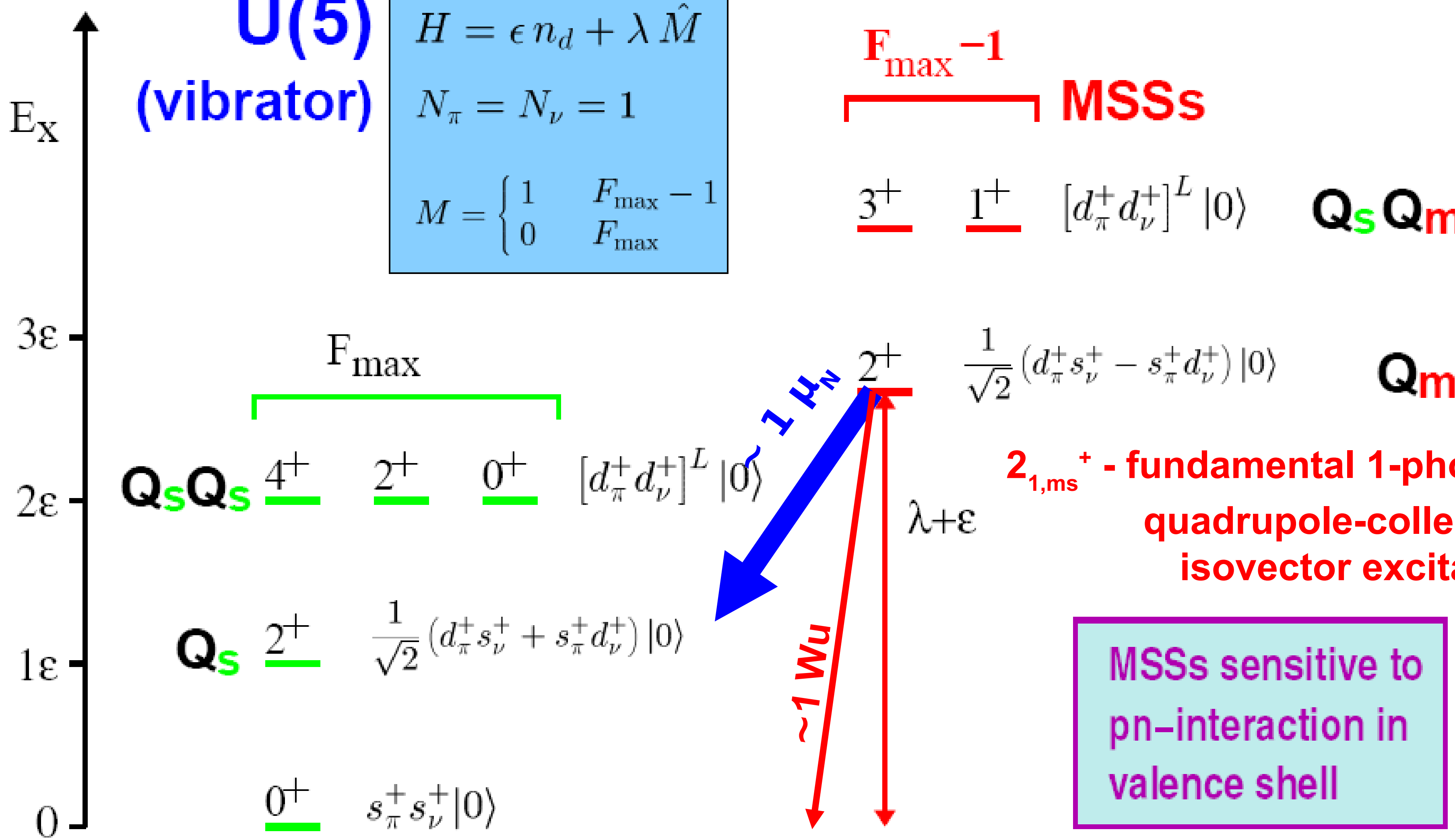
Simple Example: Harmonic Oscillator, N=2

U(5) (vibrator)

$$H = \epsilon n_d + \lambda \hat{M}$$

$$N_\pi = N_\nu = 1$$

$$M = \begin{cases} 1 & F_{max} - 1 \\ 0 & F_{max} \end{cases}$$



$2^+_{1,ms}$ - fundamental 1-phonon quadrupole-collective isovector excitation

MSSs sensitive to pn–interaction in valence shell

IBM-2 A. Arima, F. Iachello

Studies near N=82

- ^{142}Sm: ISOLDE (CoulEx)
  + HIL (angular correlations)

  Kern, PhD thesis TU Darmstadt
  Stetz, TU Darmstadt, in progress
- ^{140}Nd: ISOLDE (CoulEx)
  +Yale,Cologne (ang. corr./DSAM)

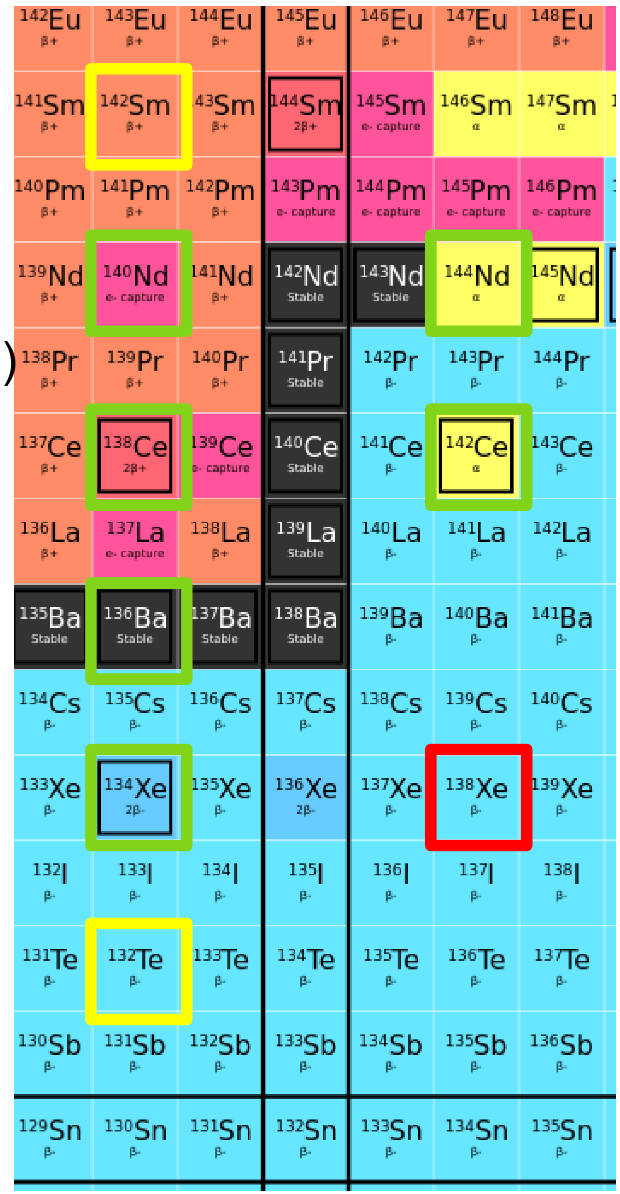
  Kern, PRC 102, 041304(R) (2020)
  Williams, PRC 80 / Gladnishki PRC 82
- ^{138}Ce: ANL (CoulEx+ang. corr.)

  Rainovski, PRL 96, 122501 (2006)
- ^{136}Ba: Stuttgart (NRF)

  Pietralla, PRC 58, 796 (1998)
- ^{134}Xe: ANL (CoulEx)

  Ahn, PLB 679, 19 (2009)
- ^{132}Te: ORNL (CoulEx, β-decay)
  + IFIN-HH (2n-transfer/DSAM)

  Danchev, PRC 84, 061306(R) (2011)
  Stetz/Mayr, TU Darmstadt, in progress

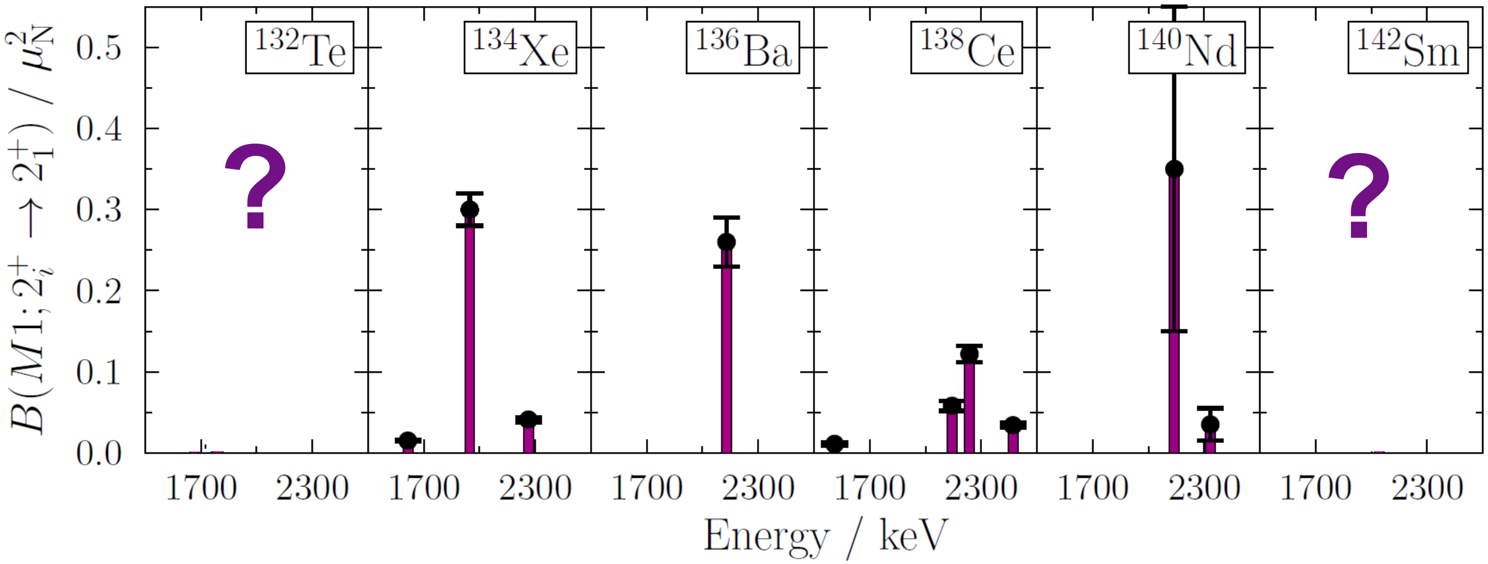


- ^{144}Nd: UKY (n,n'γ)

  Hicks, PRC 57, 2264 (1998)
- ^{142}Ce: UKY (n,n'γ)

  Vanhoy, PRC 52, 2387 (1995)
- ^{138}Xe: **This Proposal**

N=80: $2_{ms}^+ \rightarrow 2_1^+$ systematics to date



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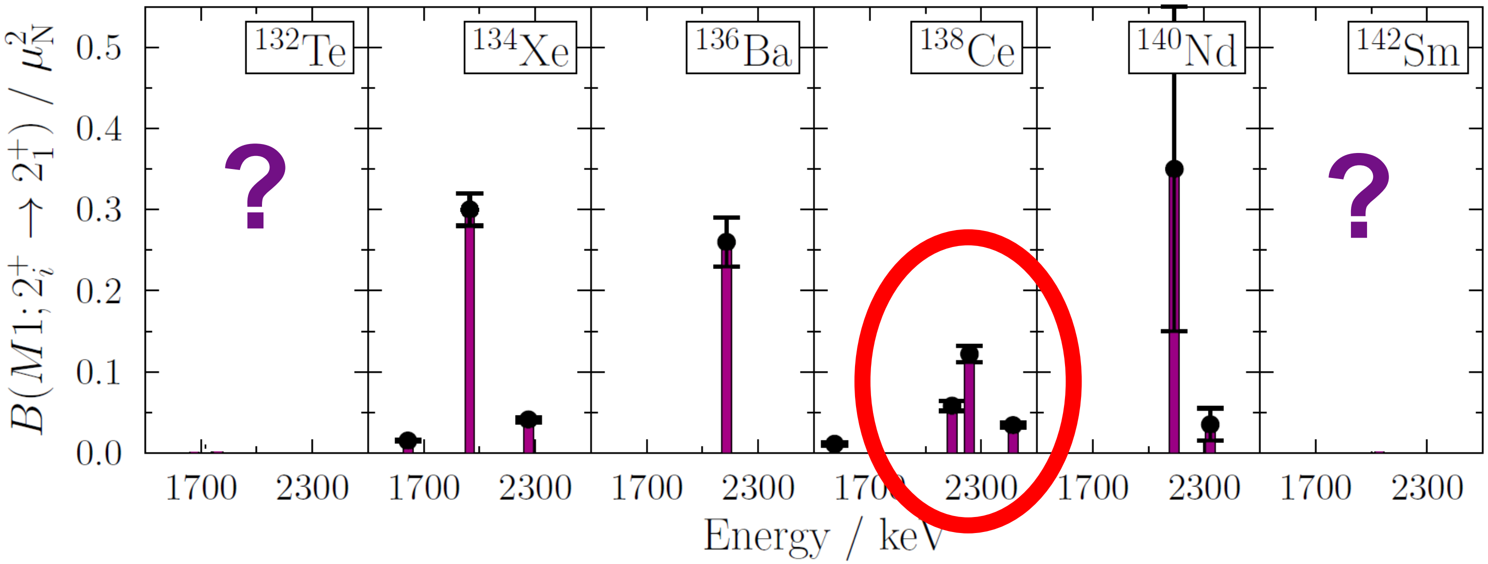

- Fragmentation at ^{138}Ce – has been discussed in terms of $\pi g_{7/2}$ sub-shell
- Complicated configurations lead to mixing with nearby symm. state(s)
- Restoration of "F-Spin" above ^{138}Ce

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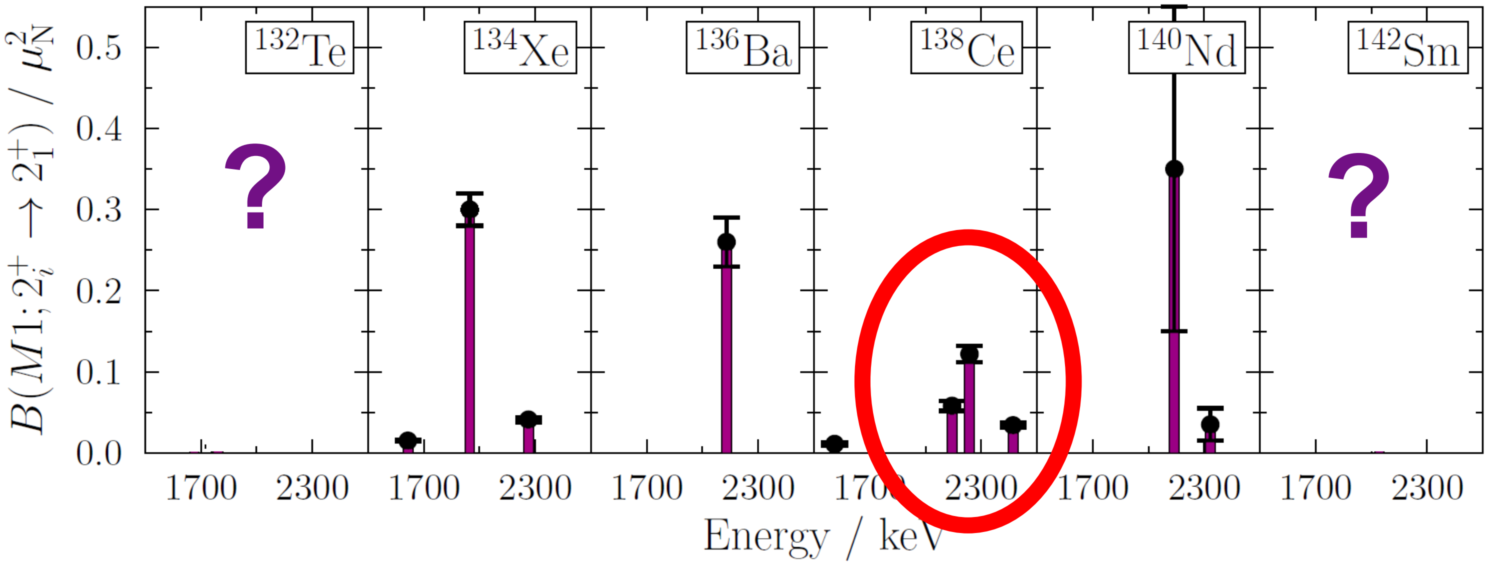

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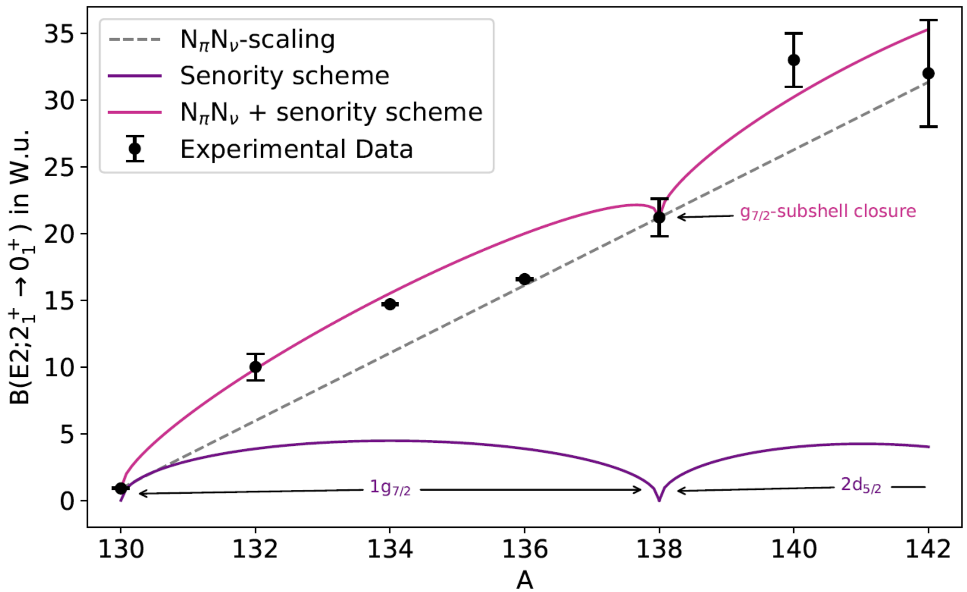

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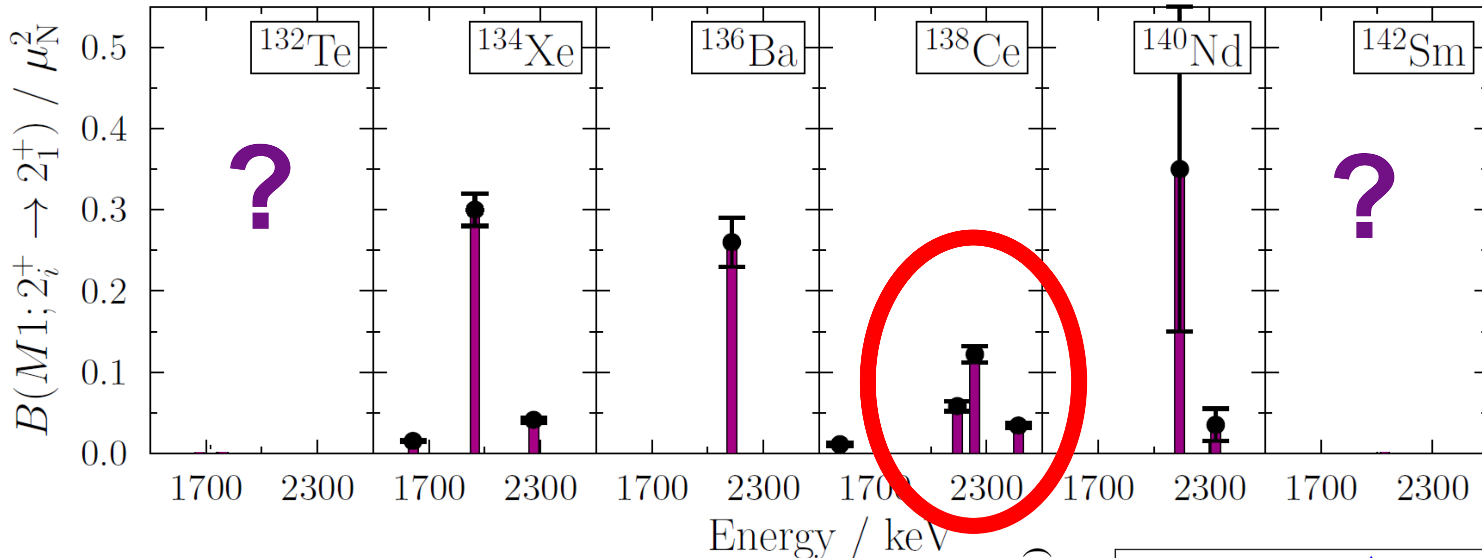

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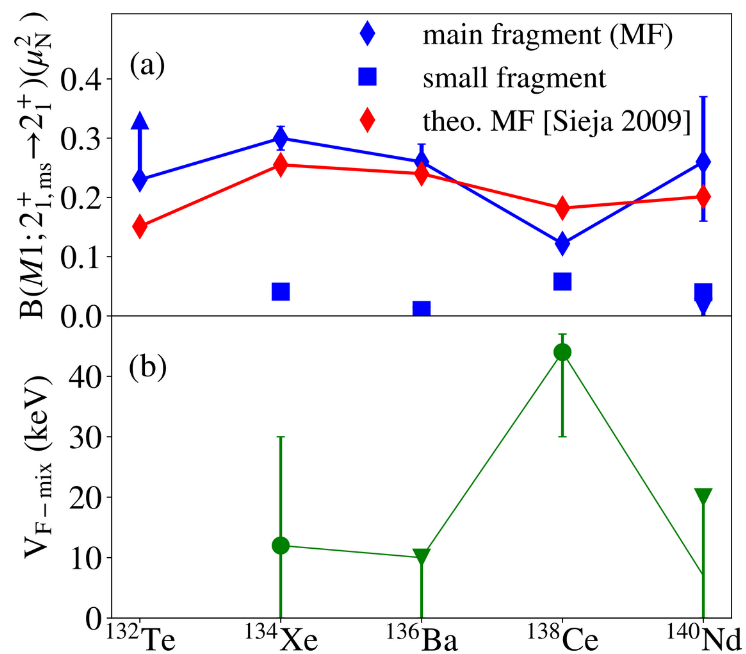
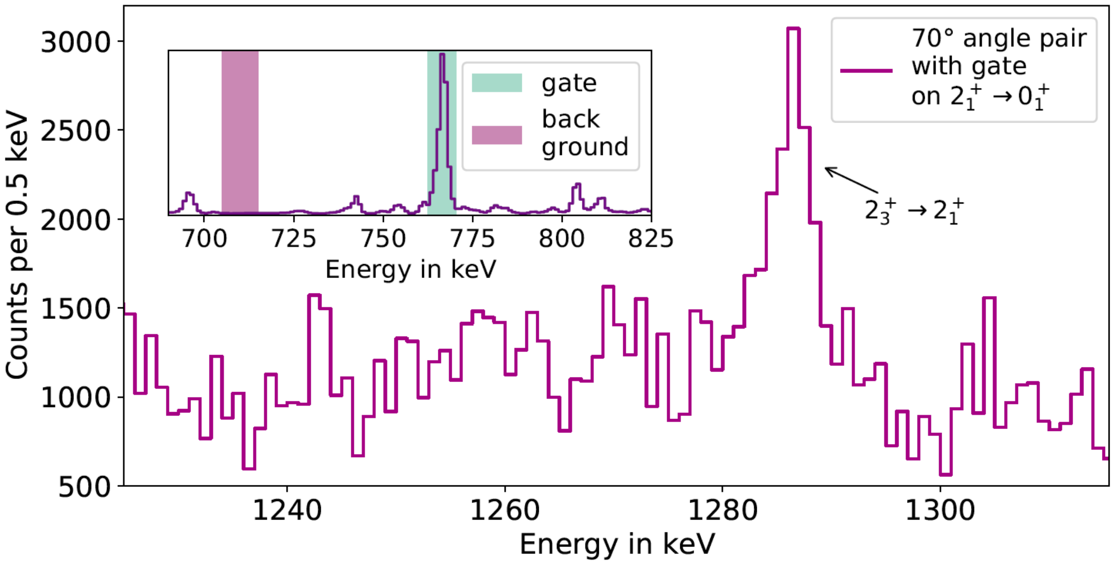
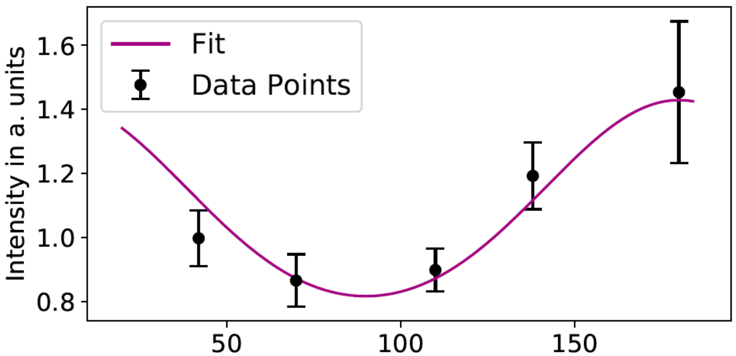


Most recent on N = 80: ^{142}Sm

- Original experiment at ISOLDE: Coulex of ^{142}Sm beam
  - yielded CoulEx cross sections
- Follow-up experiment at HIL: γ-spectroscopy after β-decays ^{142}Gd → ^{142}Eu → ^{142}Sm
- HIL Cyclotron + EAGLE HPGe Array



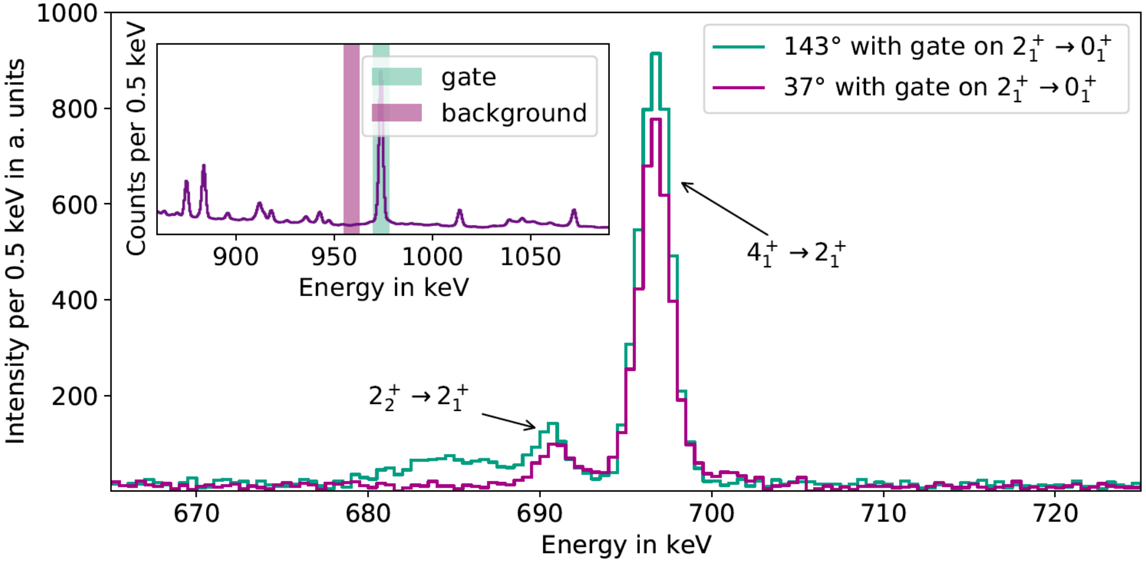


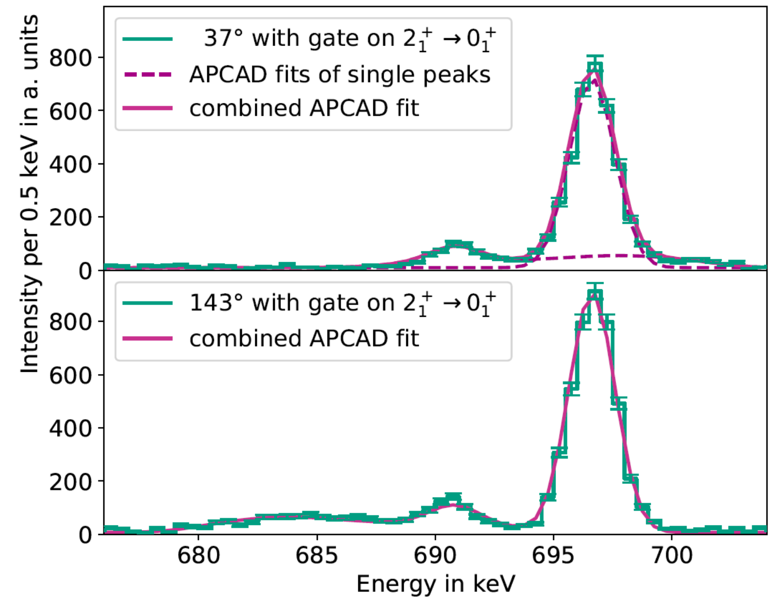
T. Stetz, PhD student, TU Darmstadt

Preliminary result multipole mixing ratio:
-0.09(8)
→ almost pure M1 transition

Most recent on N = 80: ^{132}Te

- CoulEx experiment ORNL (Danchev et al.): B(M1) > 0.23 μ_N^2
  - huge systematic uncertainties (g.s. branch intensity ~ 1.0(5) %)
- In reach for (^{18}O,^{16}O) 2-n transfer
- IFIN-HH tandem + ROSPHERE + SORCERER

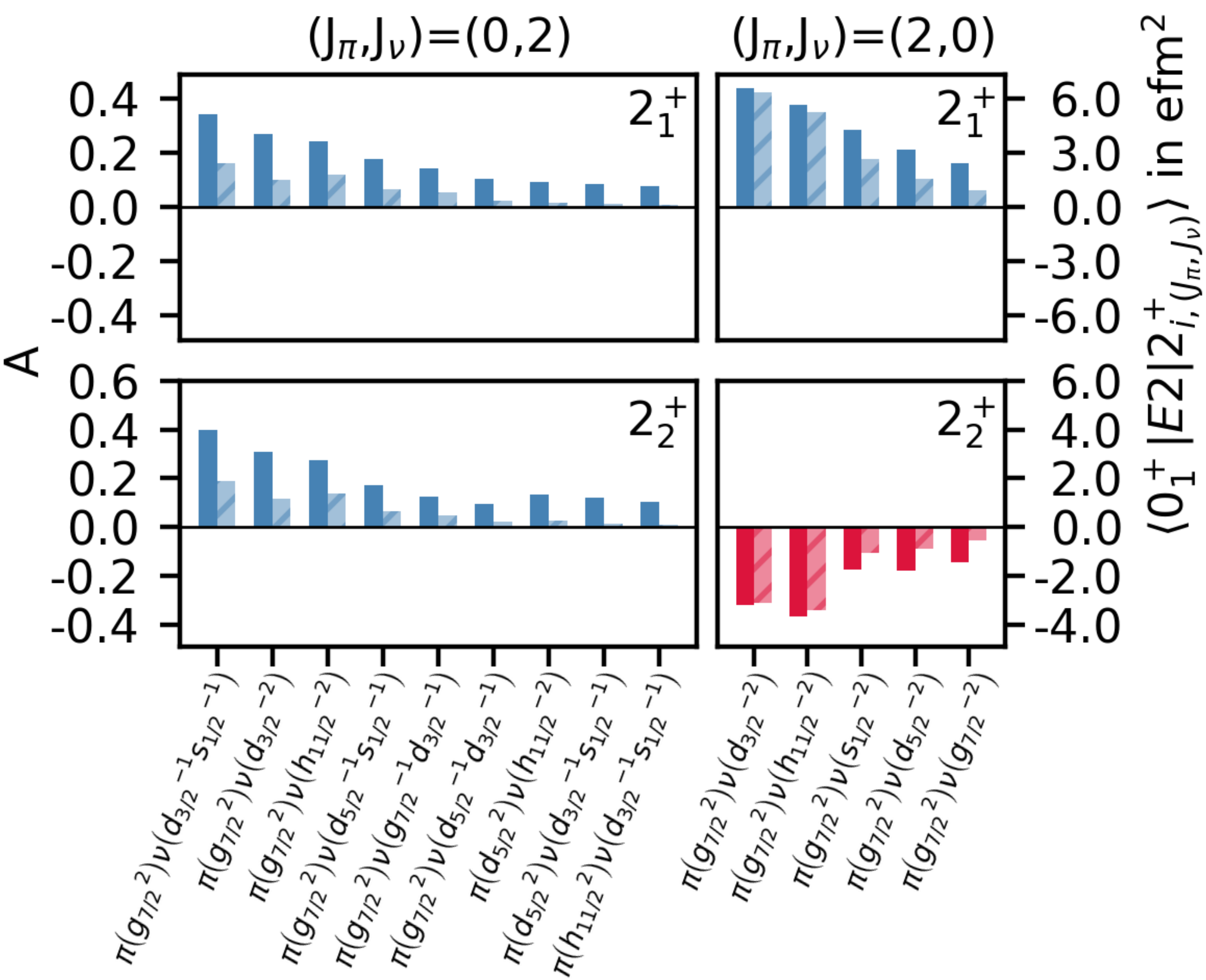




T. Stetz/H. Mayr, PhD students, TU Darmstadt
submitted to Phys. Rev. C

Result lifetime:
($2^+_{ms,1}$) = 0.92(7) ps

^{132}Te Wave Function Analysis



M1 vs E2 strengths at N = 80

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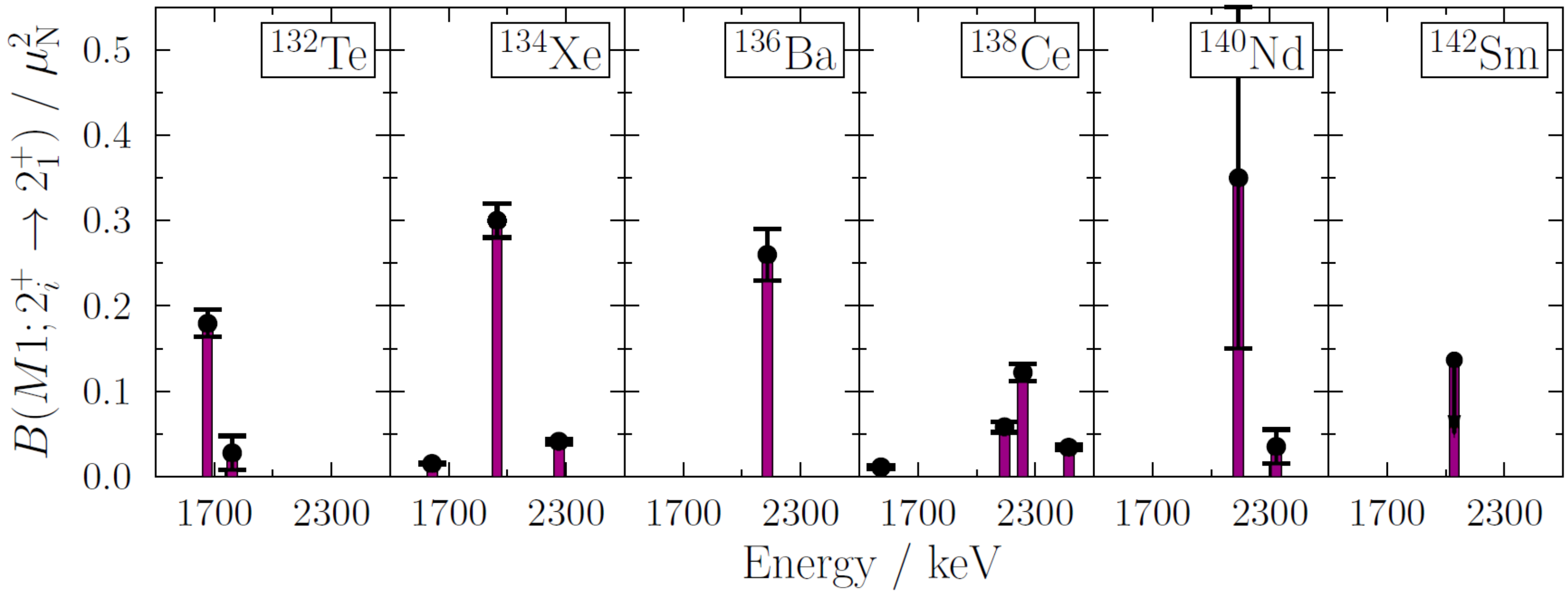
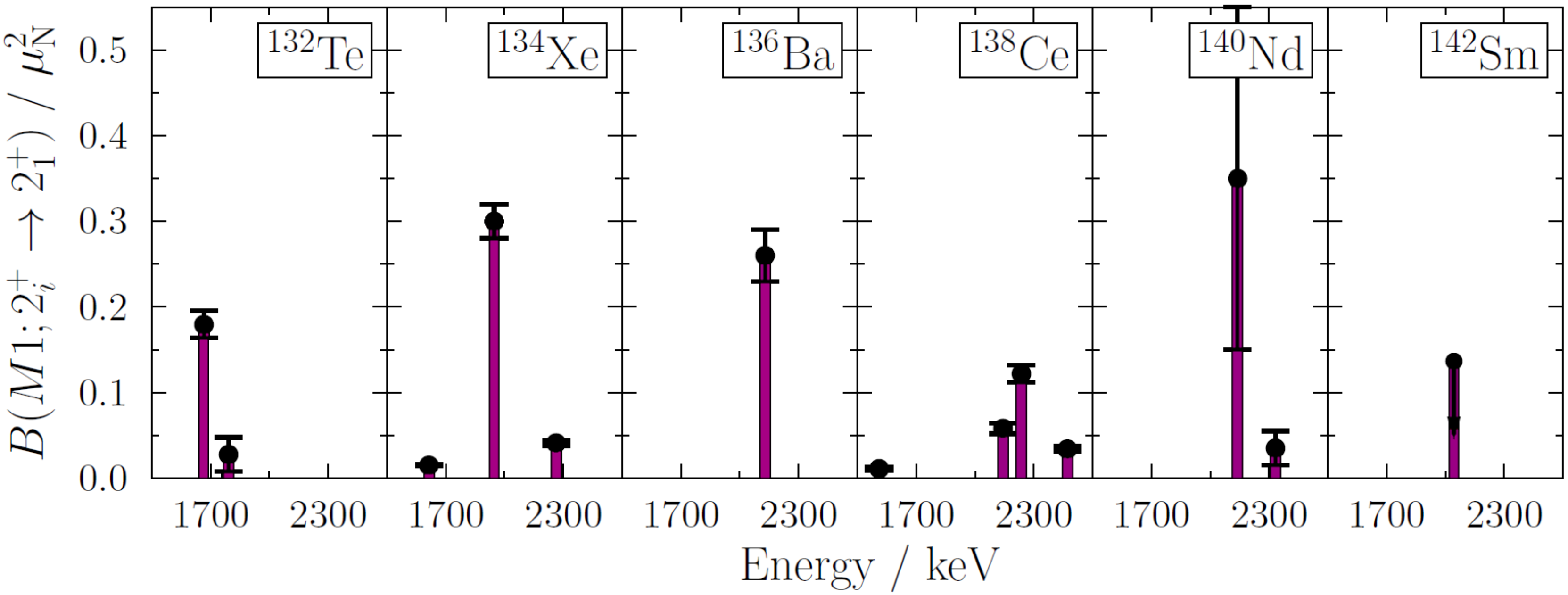
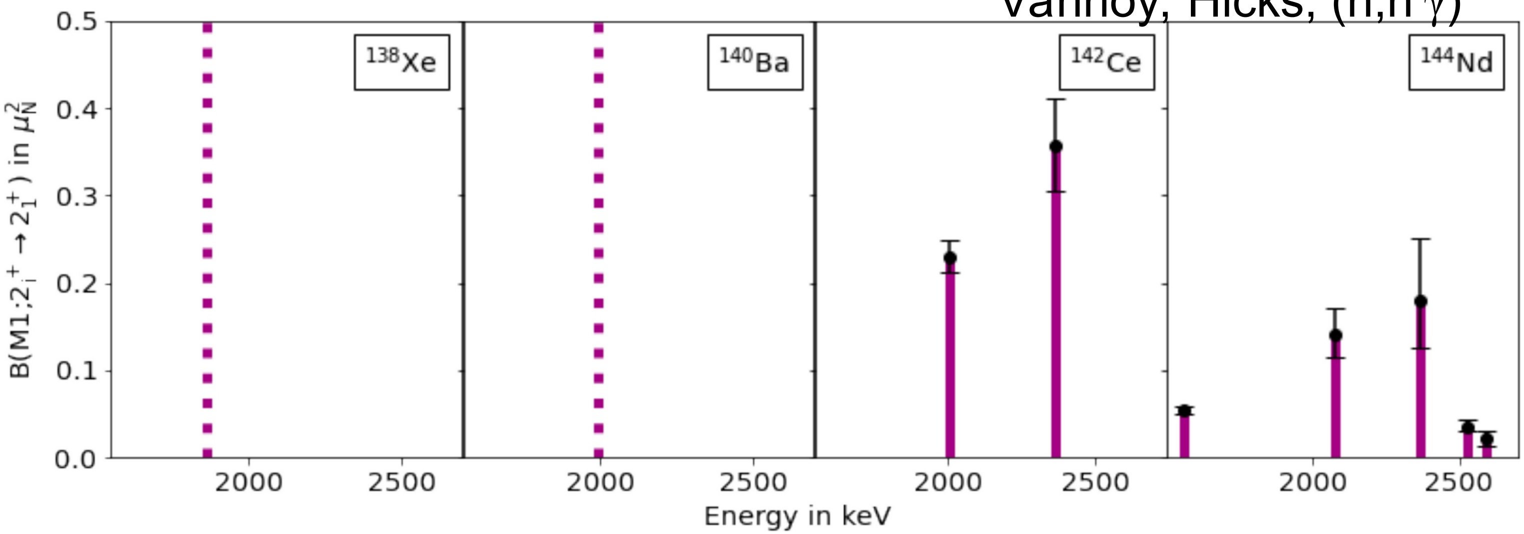


M1 strengths N = 80 vs N = 84



Vanhoy, Hicks, (n,n'γ)



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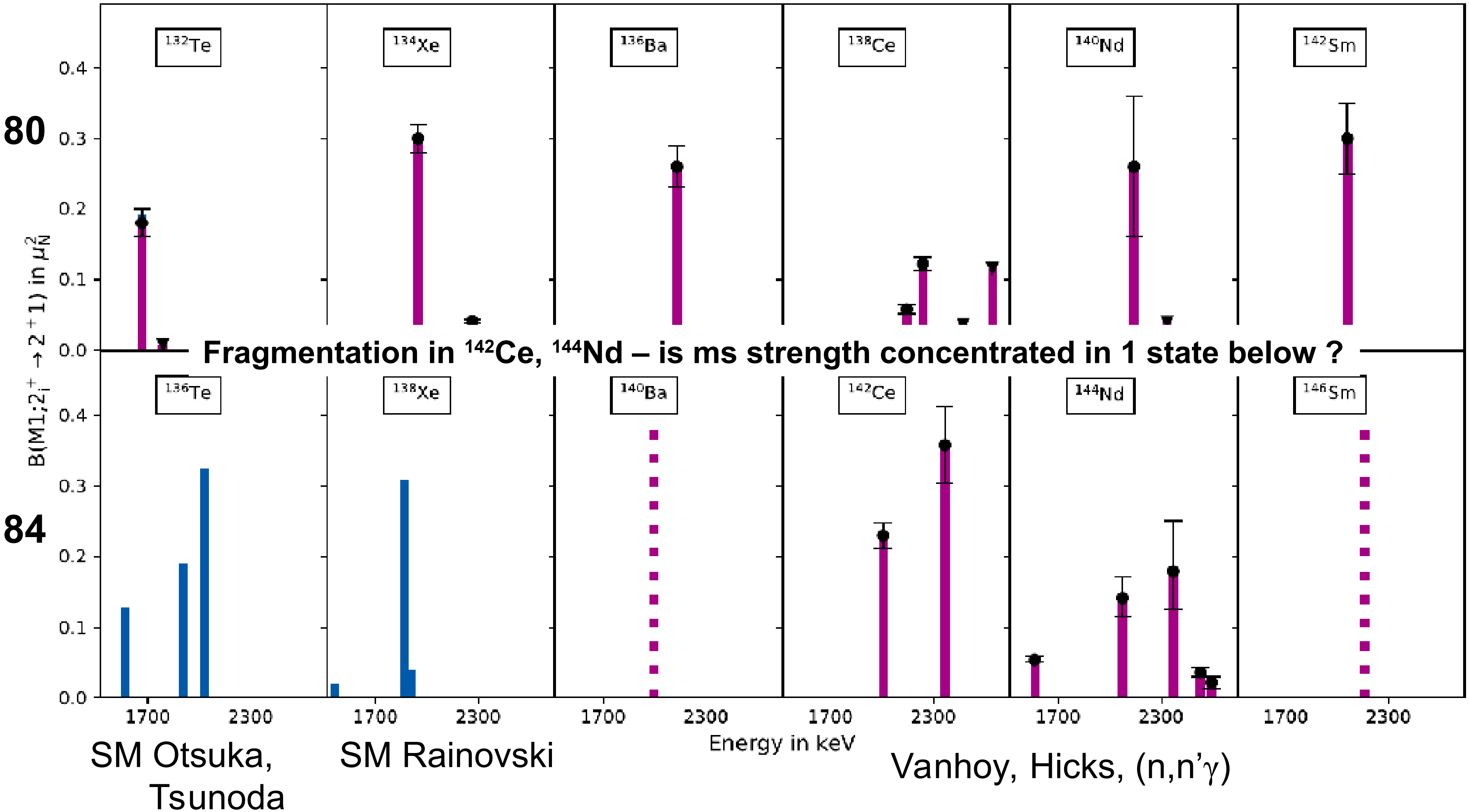
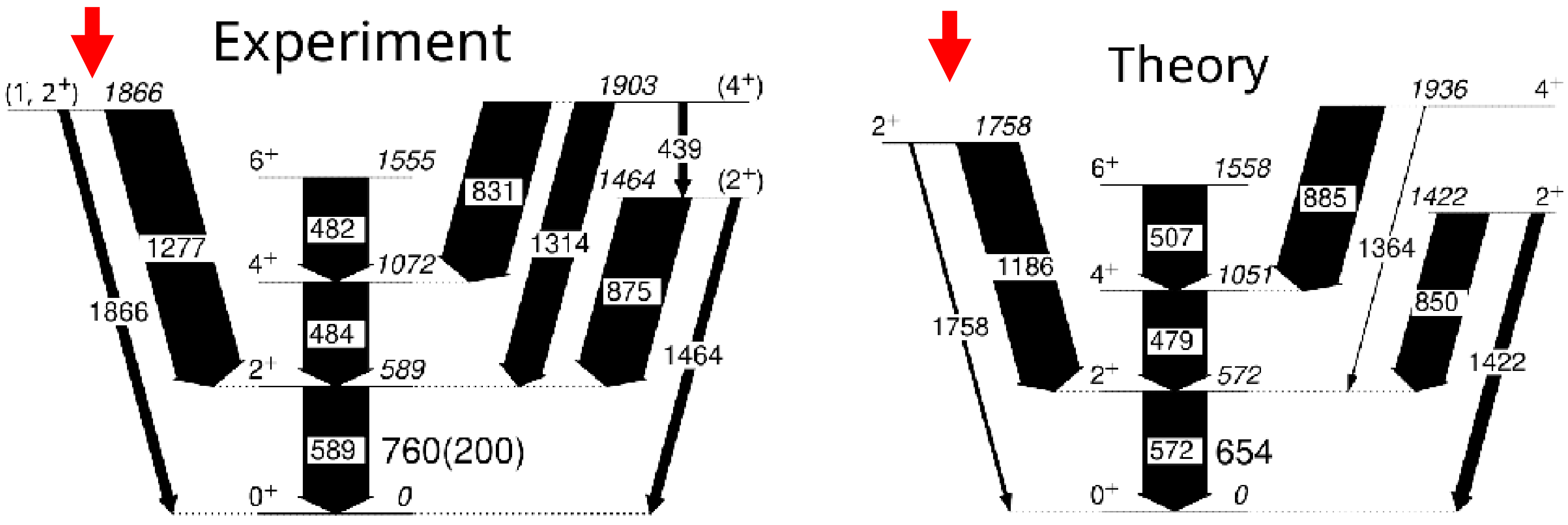


Why ^{138}Xe ?

- Mid-shell ($\pi g_{7/2}$) between ^{132}Sn and ^{142}Ce
  - This is where the 2_{ms}^+ state should be “stabilized” (= good F-spin)
  - If so: expect concentration in one state

- First shell model calculation with NuShellX (jj56pnb)
  - ^{132}Sn core, N3LO+Coulomb
  - $e_\nu = 0.5$, $e_\pi = 1.5$, $g_{l\nu} = -0.065$, $g_{l\pi} = 1.107$, $g_{s\nu} = -2.083$, $g_{s\pi} = 3.234$
  - **$B(M1;2_3^+ \rightarrow 2_1^+) = 0.31\ \mu_N^2$**



Planned experiment

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- Coulomb excitation of ^{138}Xe
  - Analog to previous work at ISOLDE
  - Optimum conditions at HIE-ISOLDE
- Determine CoulEx yields – 2_{ms}^+ will stand out
  - Relative to target excitation
  - ^{206}Pb: B(E2; $2_1^+ \rightarrow 0_1^+$) = 0.0204(7) @ 803 keV
  - If we see a ms-state, dominating M1 for the $2^+ \rightarrow 2_1^+$ transition will be implied (unreasonably strong E2 ruled out)
- Nevertheless, multipole-mixing ratio desirable to fix M1/E2:
  - determine from angular correlations here, or follow up with another experiment like in other cases before (Sm, Nd)
- 15 shifts requested
- Beams are developed and available (cold plasma source, EBIS → clean)
  - Been done with REX-ISOLDE, lower energies, lower-Z target → 2_1^+ only

Th. Kröll, EPJ Sp. T. **150**, 127 (2007)

- Use standard setup of MINIBALL plus DSSD

REX-ISOLDE Spectrum

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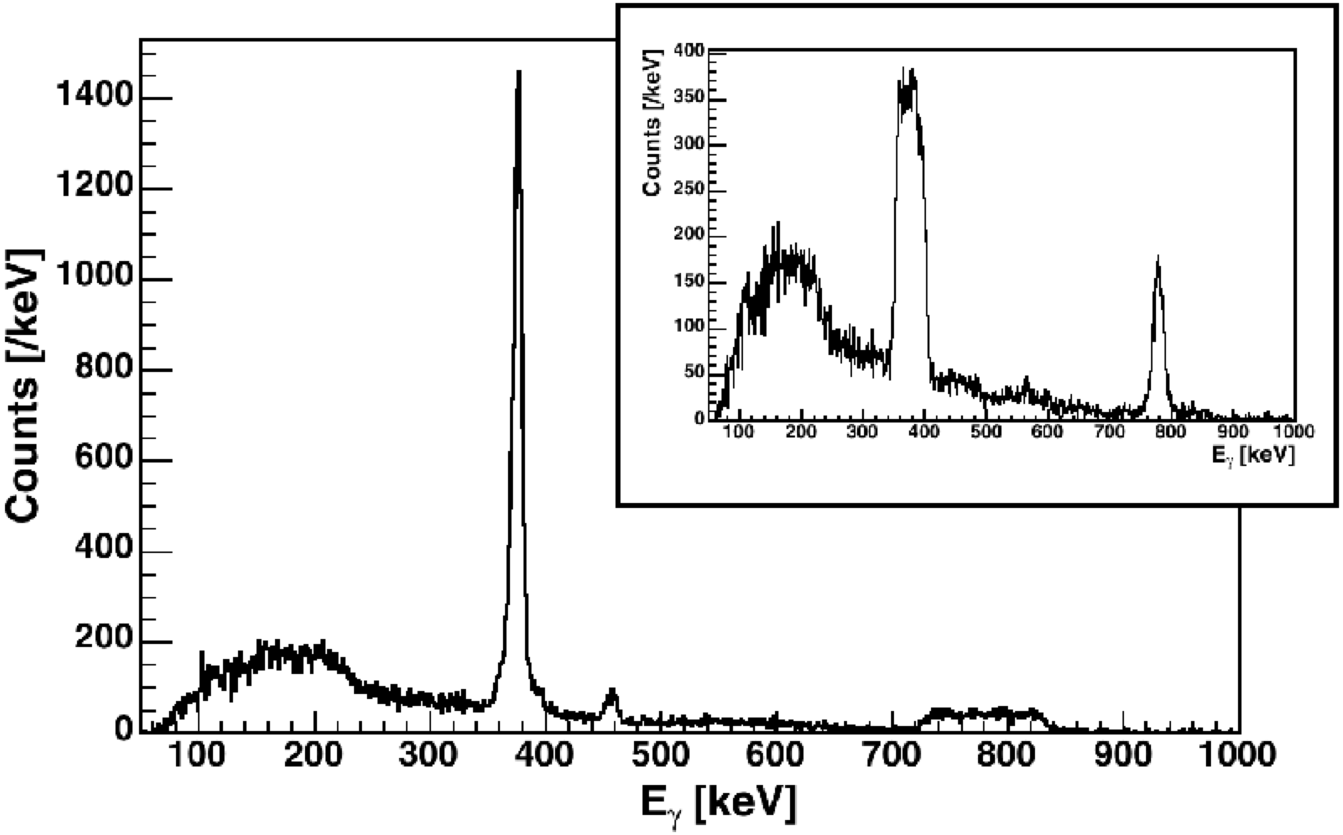
^{140}Xe @ 2.84 MeV/u on ^{96}Mo

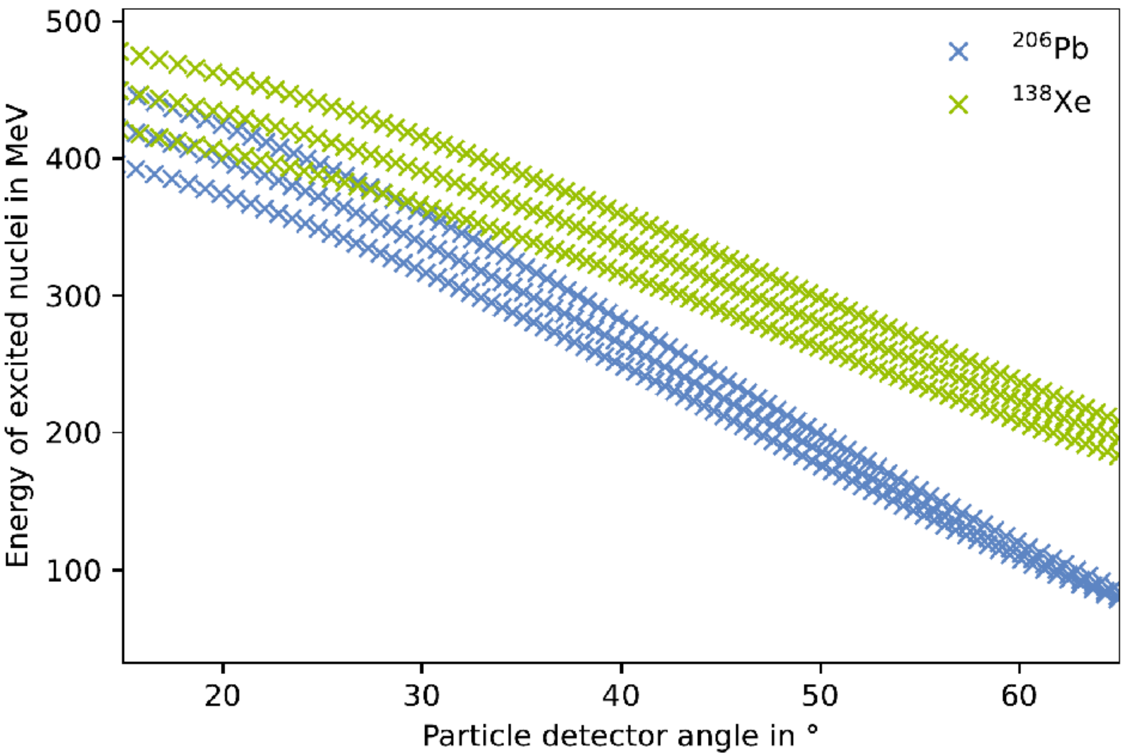


^{138}Xe: $B(E2; 2_1^+ \rightarrow 0_1^+) = 0.38(10)\ e^2b^2$
(26%)

Th. Kröll, EPJ Sp. T. **150**, 127 (2007)

Planned experiment

- HIE-ISOLDE: beams of 3.6 MeV/u
- Impinging on 2 mg/cm^2 ^{206}Pb target
  - well-known 2_1^+ target excitation for relative measurement
- DSSD ~ 25 mm behind target, 20 – 60 degrees angular coverage



Planned experiment

- Determine e.-m. Matrix elements through GOSIA fit

- Yields in 2^+ states:
  - Unknown Matrix elements calculated with NuShellX (jj56pnb)
  - Cross sections obtained with CLX
  - $1.5\cdot10^8$ pps after primary target
  - 2% transmission efficiency

  => $3\cdot10^6$ pps @Miniball

ε_γ : 5 %

I_{beam} : $3*10^6$ pps @Miniball

Goal:
Rel. unc. ΔA/A ~ 5 %

Excited state	Energy (keV)	σ (mb)	Branching ratio to 2_1^+	Yield/day	Total yield in $4\frac{2}{3}$ days	Statistical uncertainty
2_1^+	588	$2.9\cdot10^3$	—	$2.2\cdot10^5$	$1.0\cdot10^6$	0.1%
2_2^+	1463	8.0	93%	563	2630	2.0%
2_3^+	1866	1.3	87%	85	400	5.0%

Request

14 shifts data taking + 1 shift beam setup/tuning

Total: 15 shifts

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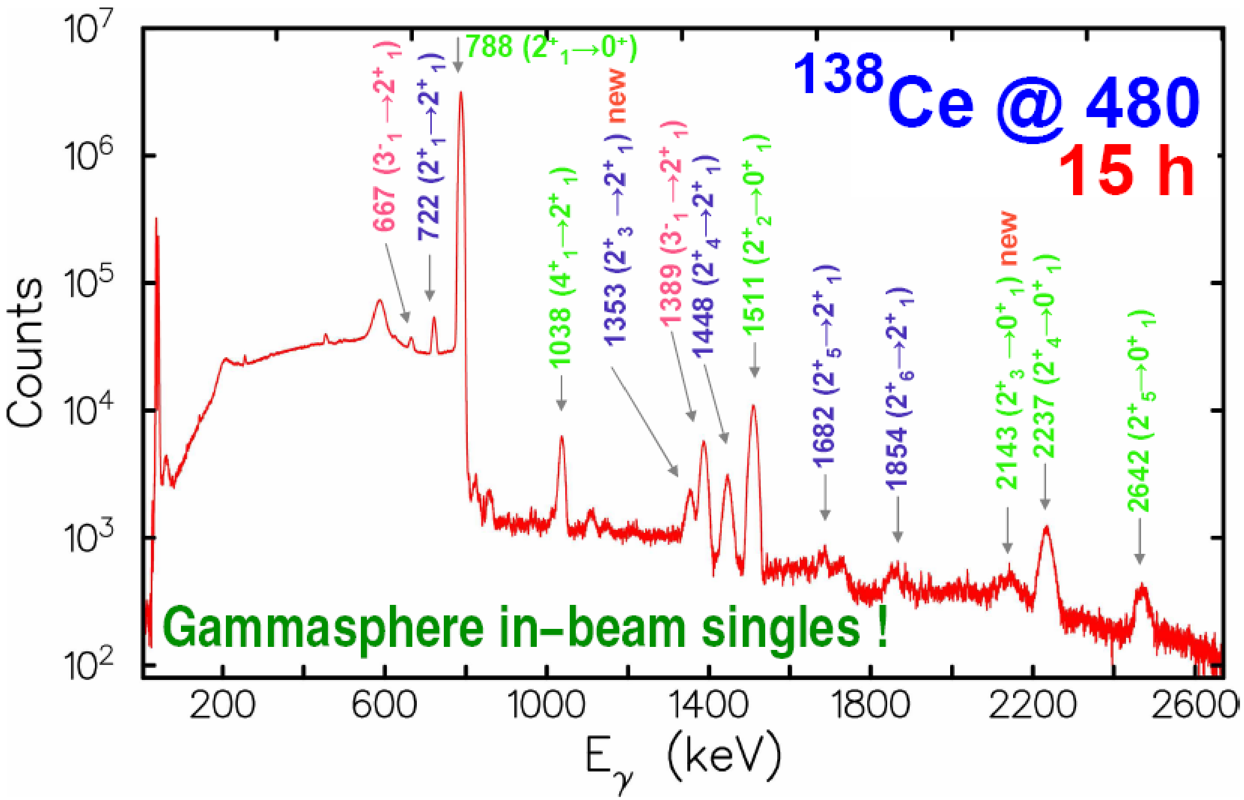
^{206}Pb 2_1^+	803	~200			~10^5	~0.3%

Example of Data: ^{138}Ce CoulEx on ^{12}C @ 480 MeV (ANL)



G.Rainovski, N. Pietralla et al., Phys. Rev. Lett. ***96*** *122501 (2006).*

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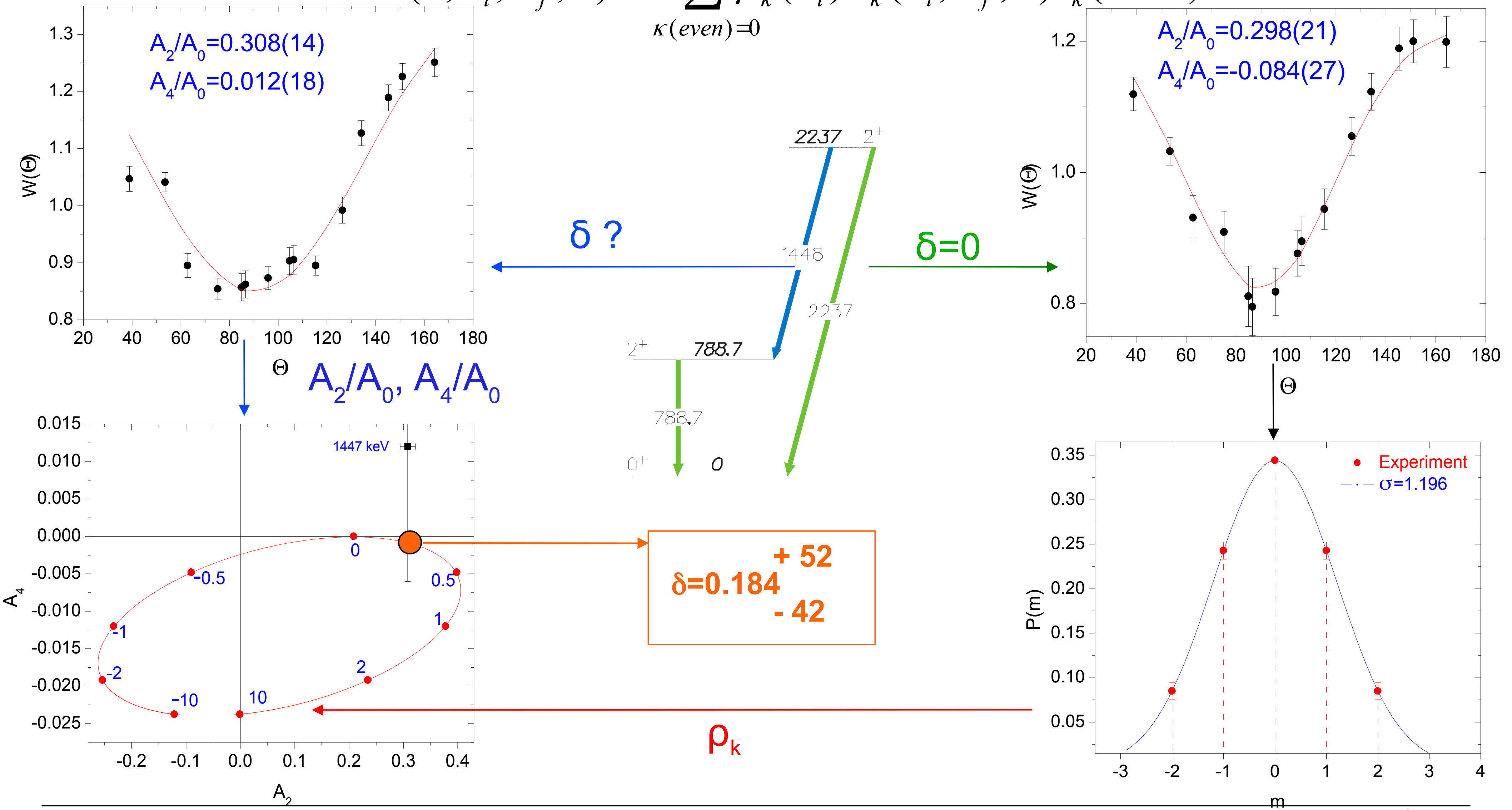
$$W(\theta,J_i,J_f,\delta) = \sum_{\kappa(even)=0}^{2} \rho_k(J_i)A_k(J_i,J_f,\delta)P_k(\cos\theta)$$



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