Single-particle structure, effective proton charge, and emerging collectivity around ^{132}Sn

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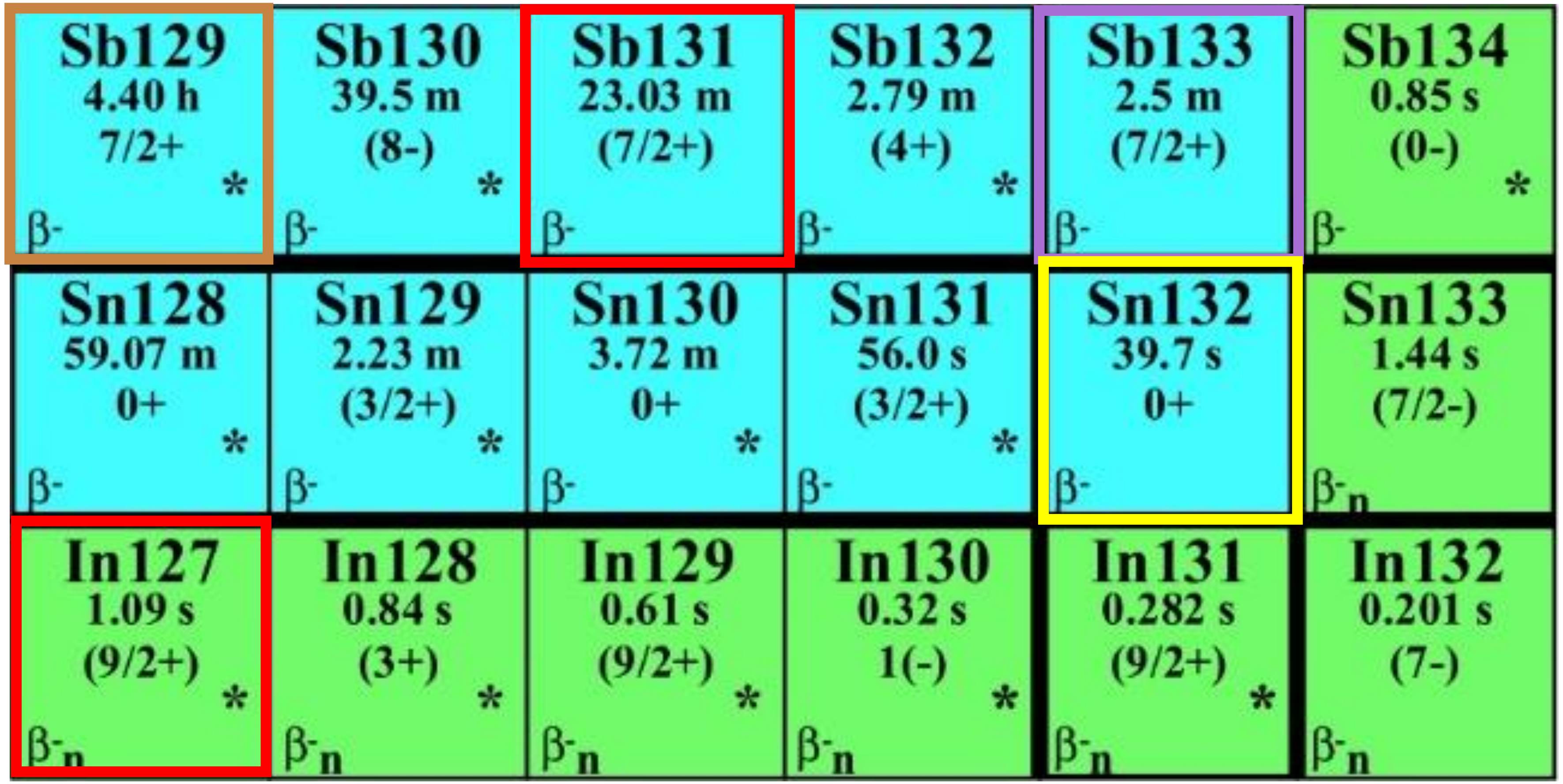
E2 Strength (Coulex) of Odd-Z Nuclei Near ^{132}Sn: Effective charges and *pn* Interactions

Recently Published;
40% E2 enhancement

Beyond
particle-core

s.p. eff.
charges



Proton + neutron hole pairs

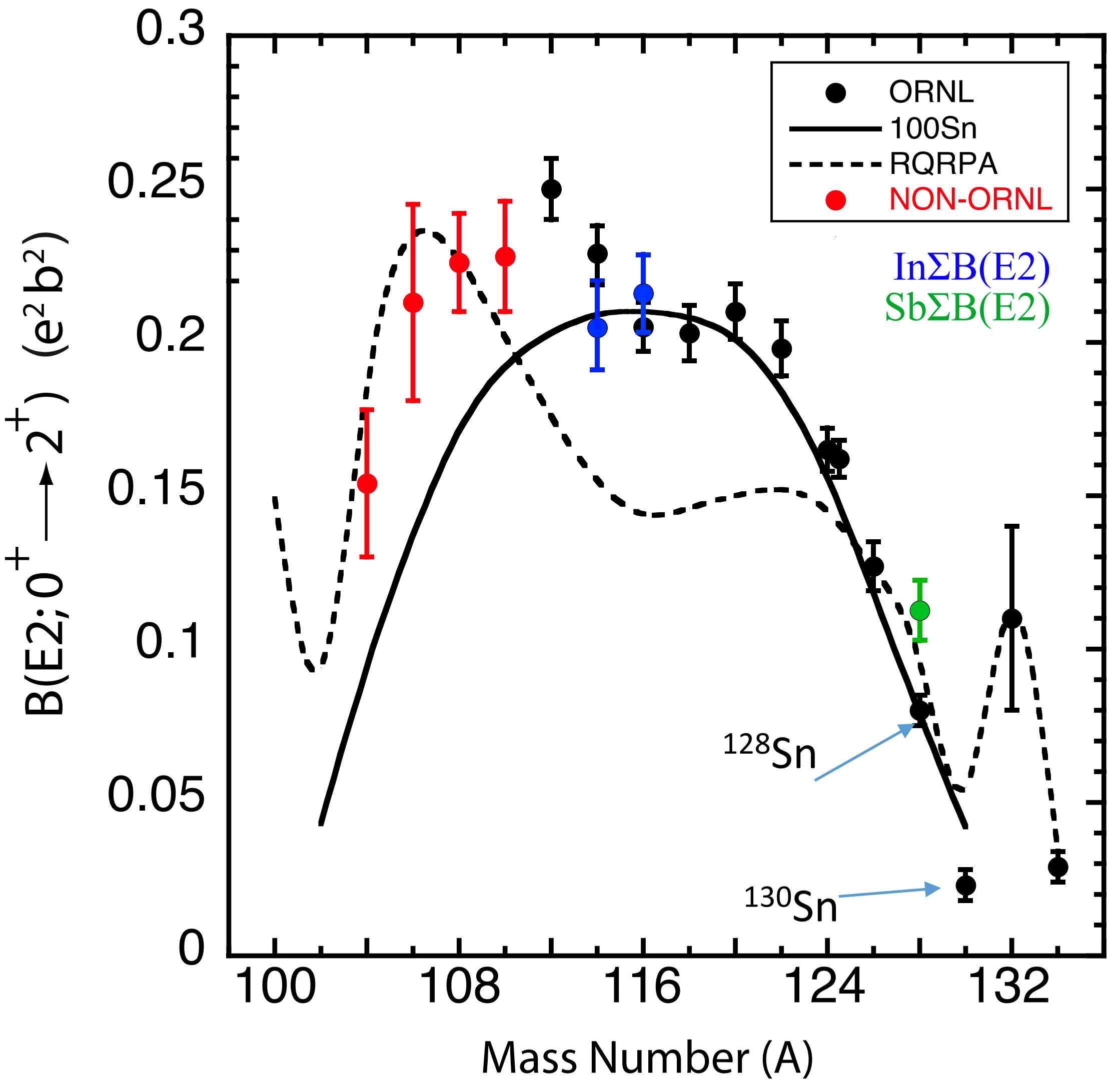
Proton hole + neutron hole pairs

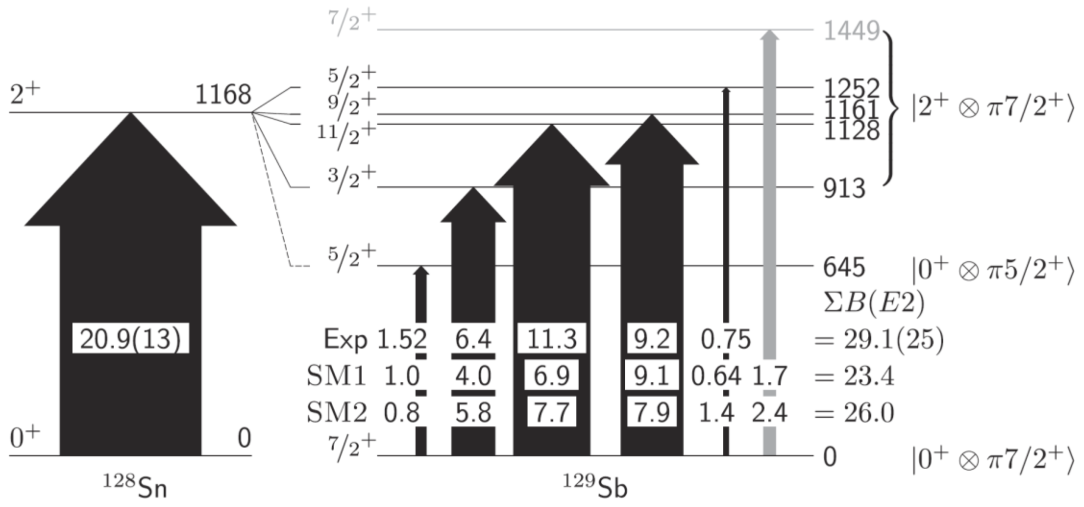
Beyond
particle-core

Sn B(E2) Systematics – moving to odd-proton neighbours

Total electric quadrupole strength of ^{129}Sb is enhanced compared to the Sn systematics

^{129}Sb PRL 124, 032502 (2020)





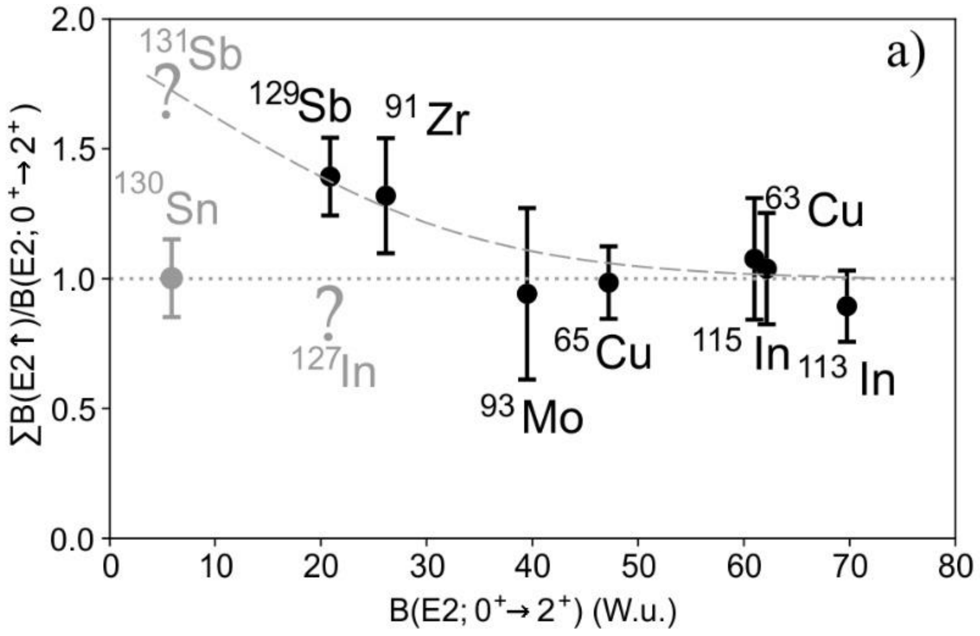
$$B(E2;0^+ \rightarrow 2^+)_{core} = \sum_i B(E2;I_{gs} \rightarrow I_i)_i$$

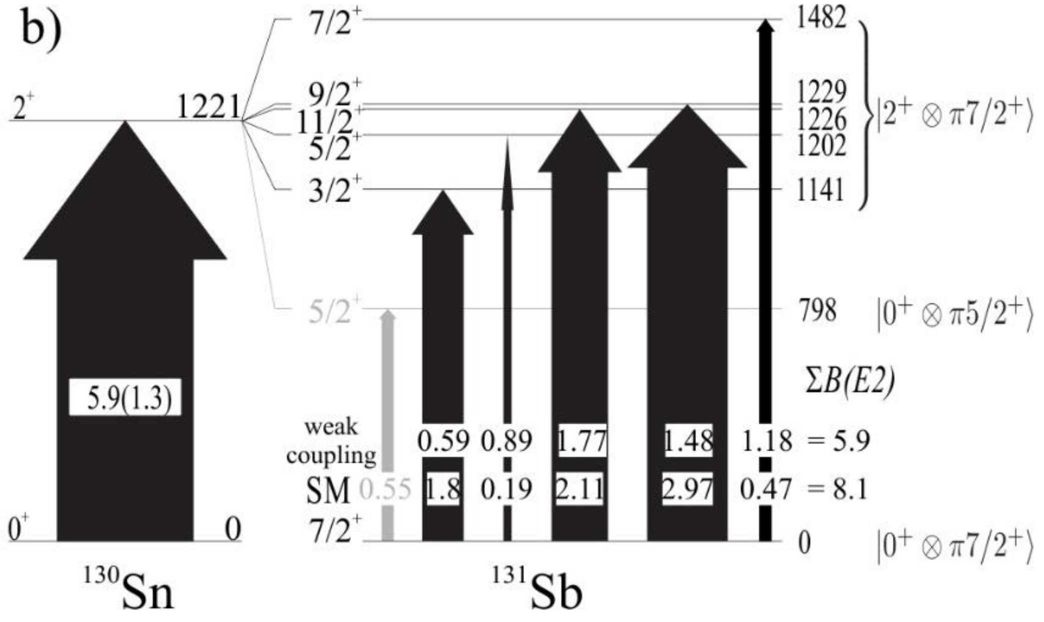
E2 sum as a tool & a measure of developing collectivity:

- Empirical comparison of E2 strengths
- *Detailed shell-model comparisons*

Core vs Particle-Core (fragmented) E2 Strength

- E2 Sum is invariant in particle-core model for all coupling strengths
- Breakdown of particle-core observed for B(E2) < 40 W.u. [Gray et al., PRL (2021)]
- Shell-model calculations predict different breakdowns for particles and holes; breakdown not understood, limited data

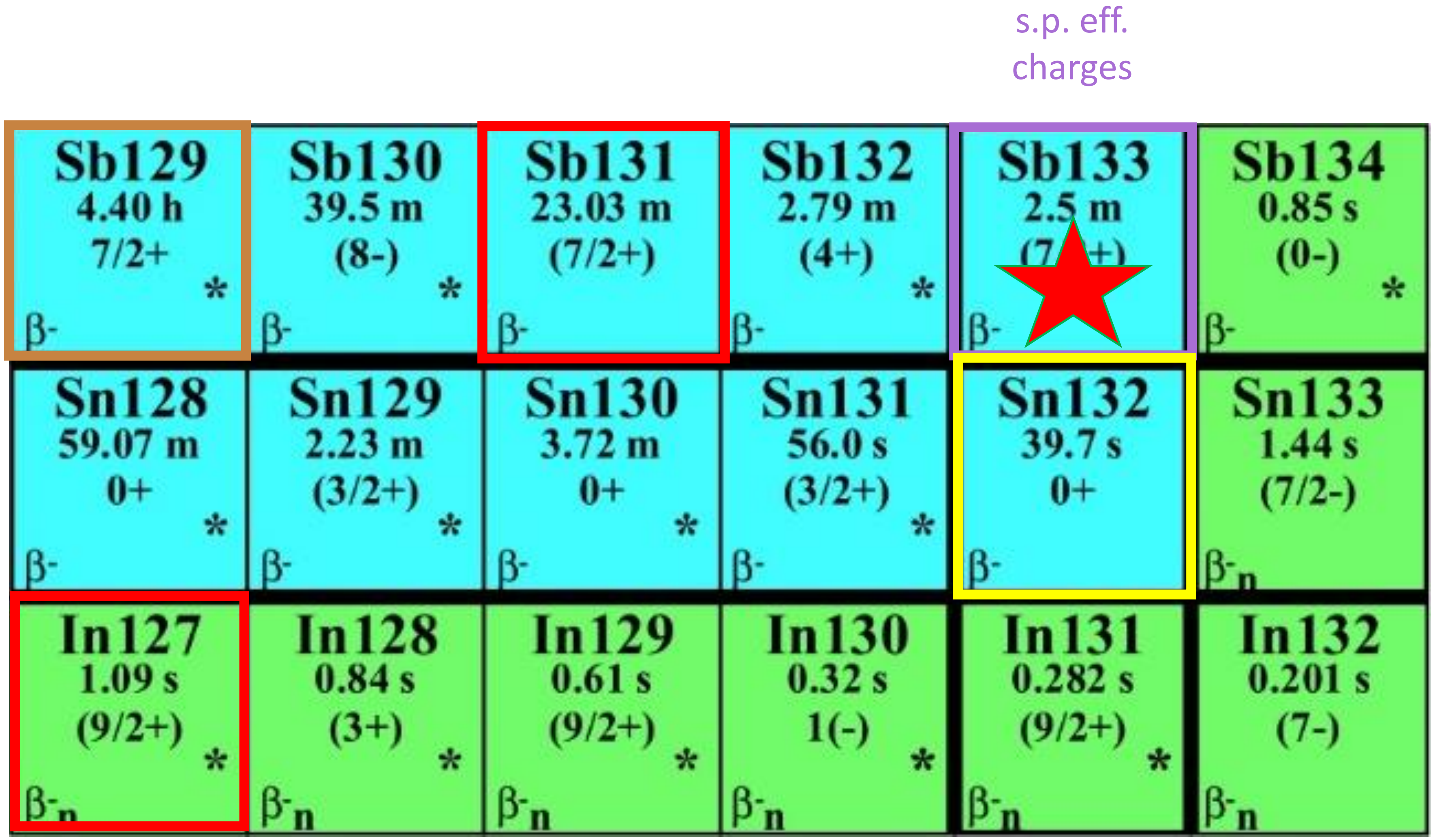


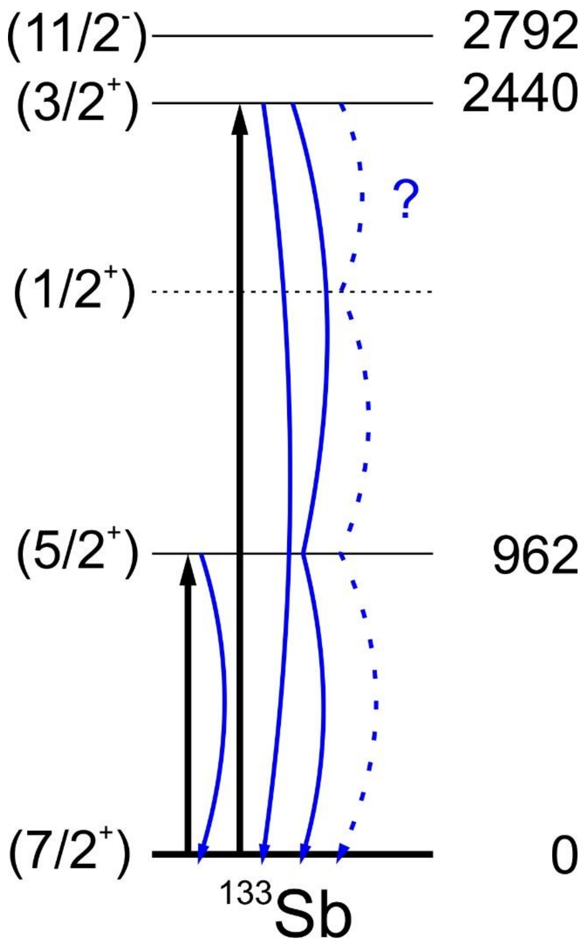


Breakdown pattern may not be monotonic

Shell model: NushellX. Full 50 < Z,N < 82 major shell. Interactions: sn100 (PRC 71, 044317) and GCN50:82 (PRC82, 064304)

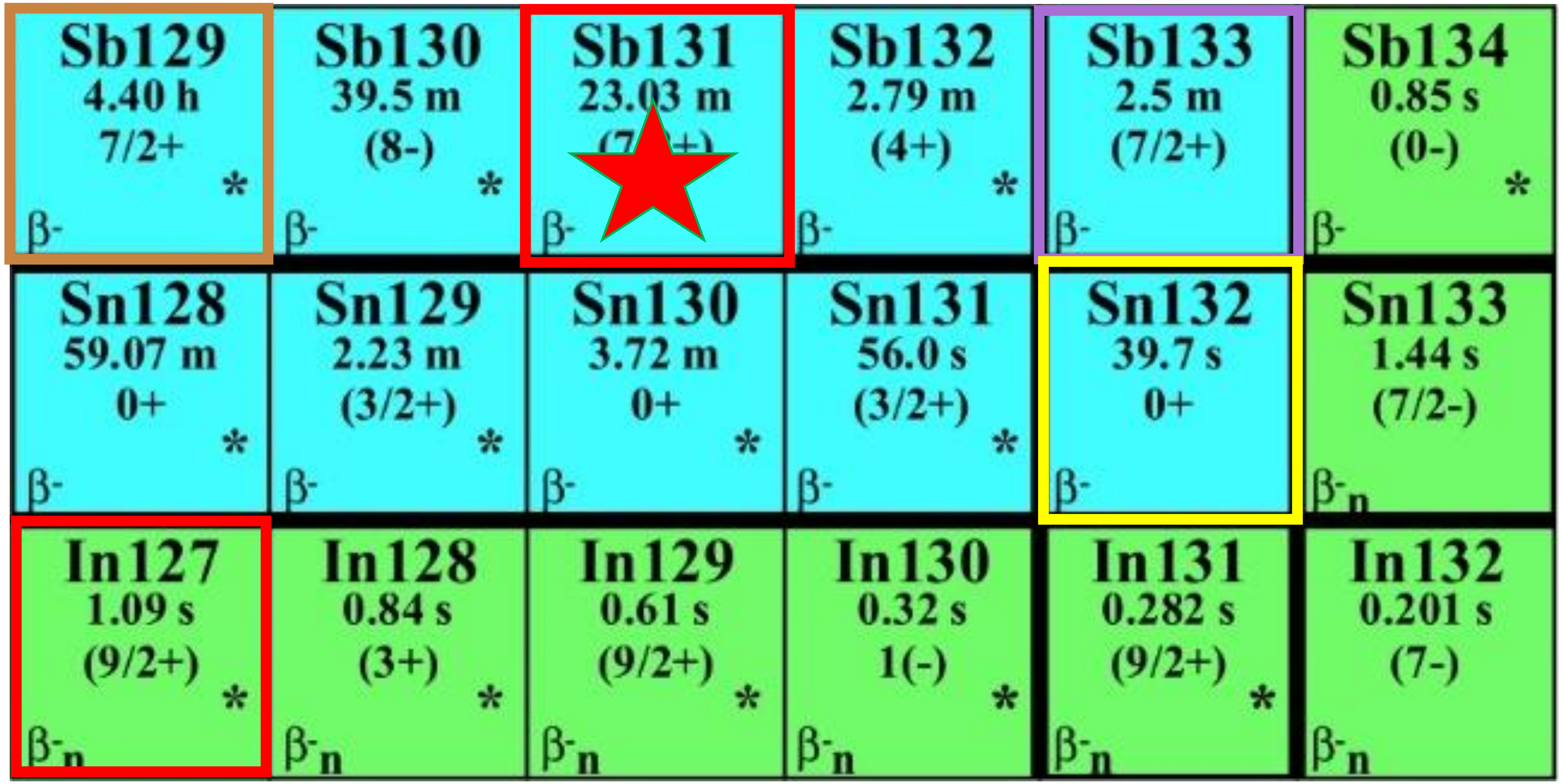
^{133}Sb: Effective charges next to ^{132}Sn

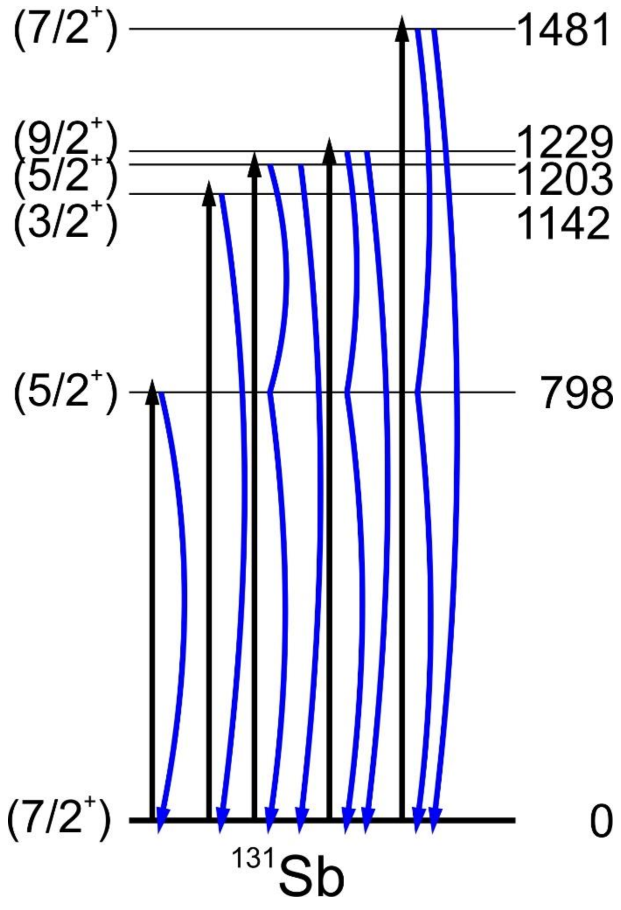




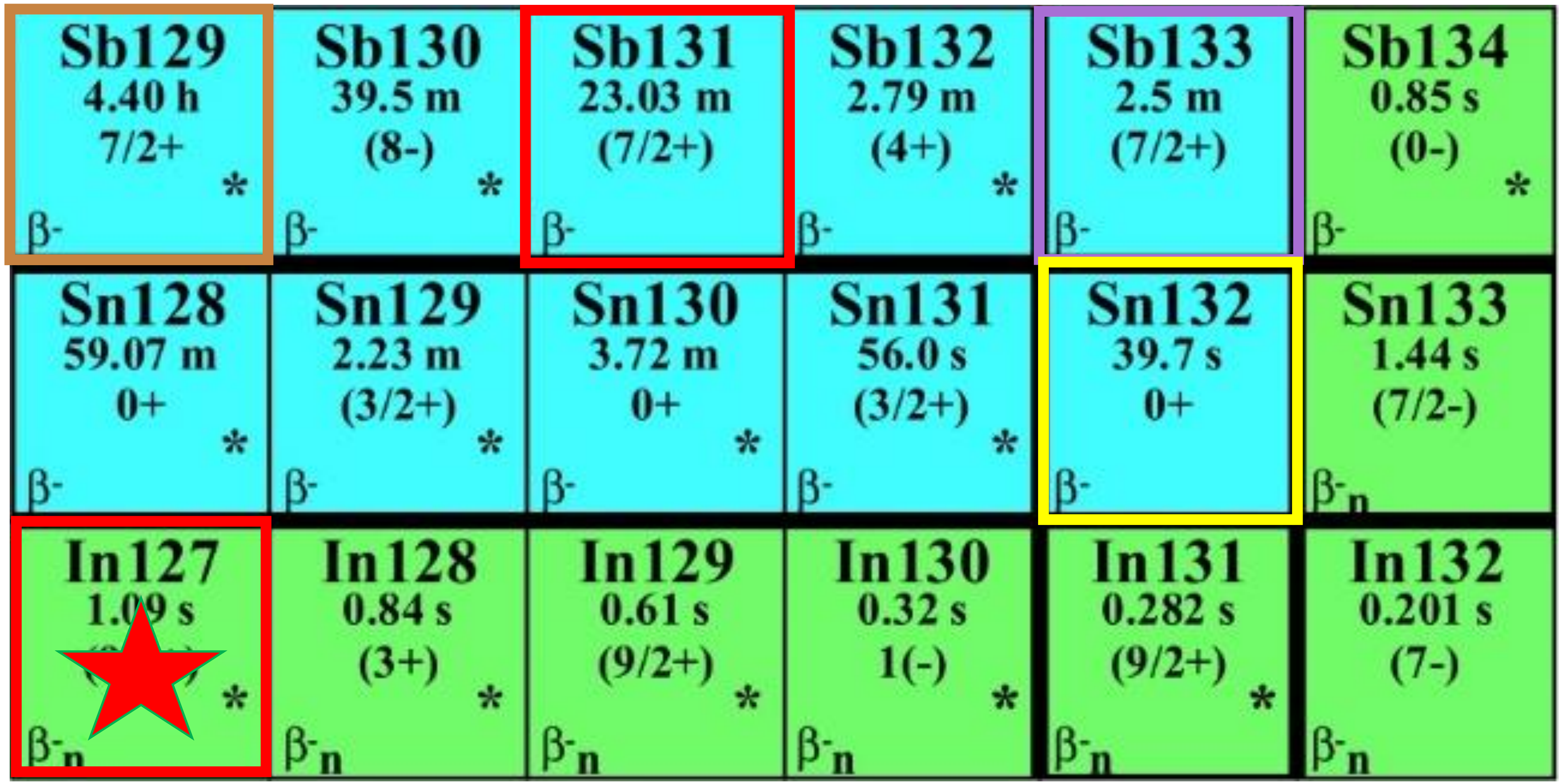
^{131}Sb: particle-core structure, *pn* interactions, developing collectivity

Beyond particle-core





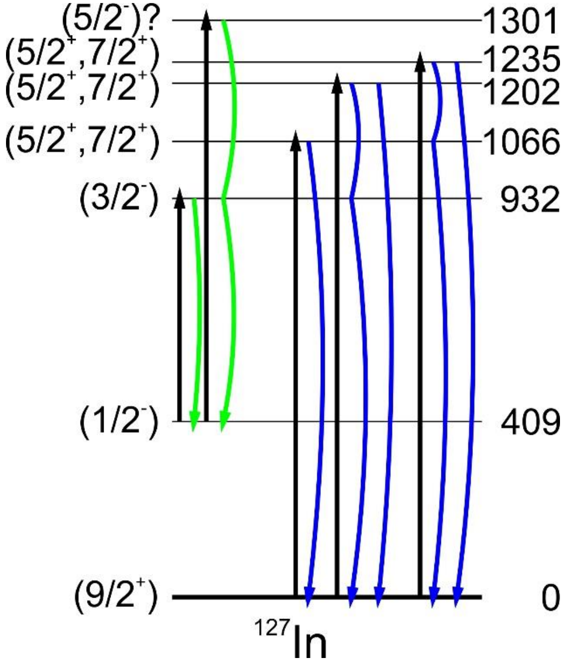
^{127}In: particle-core structure, $p^{-1}n$ interactions, developing collectivity



Beyond particle-core

9/2$^+$ g.s. beam

½$^-$ isomer beam



What we aim for and what the experiment will provide?

^{133}Sb

- transition probabilities; purity of single-particle states; proton effective charge; single particle energies around ^{132}Sn

^{131}Sb

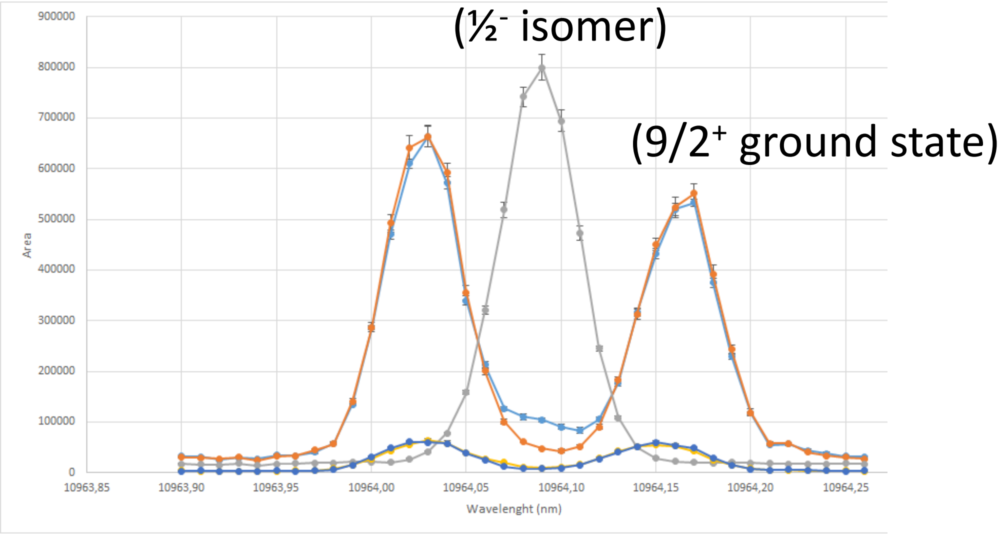
- probe the sum rule at ^{130}Sn - very sensitive test case; stringent test of shell model calculations; emergence of collectivity around shell closures; *distinguish between core modification and proton-neutron correlations*

^{127}In (1/2$^-$ isomer and 9/2$^+$ g.s. beams accelerated)

- measure B(E2) strengths
- excitation on ½$^-$ isomer should give B(E2)s and angular correlations
- spins and configuration assignment of the ‘known’ candidate multiplet states and search for other strongly Coulomb-excited states, which might be missing multiplet members
- identify other low-lying states (possibly with both positive and negative parities, when structures on top of the two isomeric states are excited) to be compared to shell-model calculations and E2 sum rule.

RIB production from ISOLDE and experimental details

- Use of a neutron-converter for reducing the surface-ionized spallation products (Cs, Ba etc.)
- Narrow-band RILIS for **isomer selection** in ^{127}In



isotopes	yield [p/μC]	surface contamination	rate @ Miniball [pps]
^{131}Sb	7.2 x 10^7	25%	3 x 10^6
^{133}Sb	4.7 x 10^7	50%	2 x 10^6
^{127}In	5.5 x 10^6	25%	2.5 x 10^5

Coulomb excitation measurement at Miniball (CD-only configuration)

- Beams – **^{133}Sb, ^{131}Sb; ^{127g}In, ^{127m}In**
- Energy – 4 MeV/u
- Targets – ^{196}Pt: 1 mg/cm^2 for ^{133}Sb and ^{131}Sb; **2 mg/cm^2 for ^{127}In**
- Standard Miniball Coulex configuration

beam energy and the **target** (composition and thickness) were **optimized** aiming at:

- **safe (single-step) Coulomb excitation** (within the angular coverage of the CD detector)
- **precise B(E2) values** - considering the influence of the *Q moment* on the B(E2)

Beam-time request

- **3 shifts** of beam on target with **^{131}Sb** beam;
- **3 shifts** of beam on target with **^{133}Sb** beam;
- **3 shifts** of beam on target with **^{127}In (9/2^{+})** using a narrow-band RILIS ionization;
- **3 shifts** of beam on target with **^{127}In (1/2^{-})** using a narrow-band RILIS ionization.
- **2 shifts** for changes between isotopes/isomers

A total of **14 shifts requested**.

(Technical Advisory Committee has OK'ed proposal: "The yields in the proposal are properly discussed and have been recently measured. " etc.)

What we aim for and what the experiment will provide?

^{133}Sb

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^{131}Sb

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- excitation on ½$^{-}$ isomer should give B(E2)s and angular correlations
- spins and configuration assignment of the ‘known’ candidate multiplet states and search for other strongly Coulomb-excited states, which might be missing multiplet members
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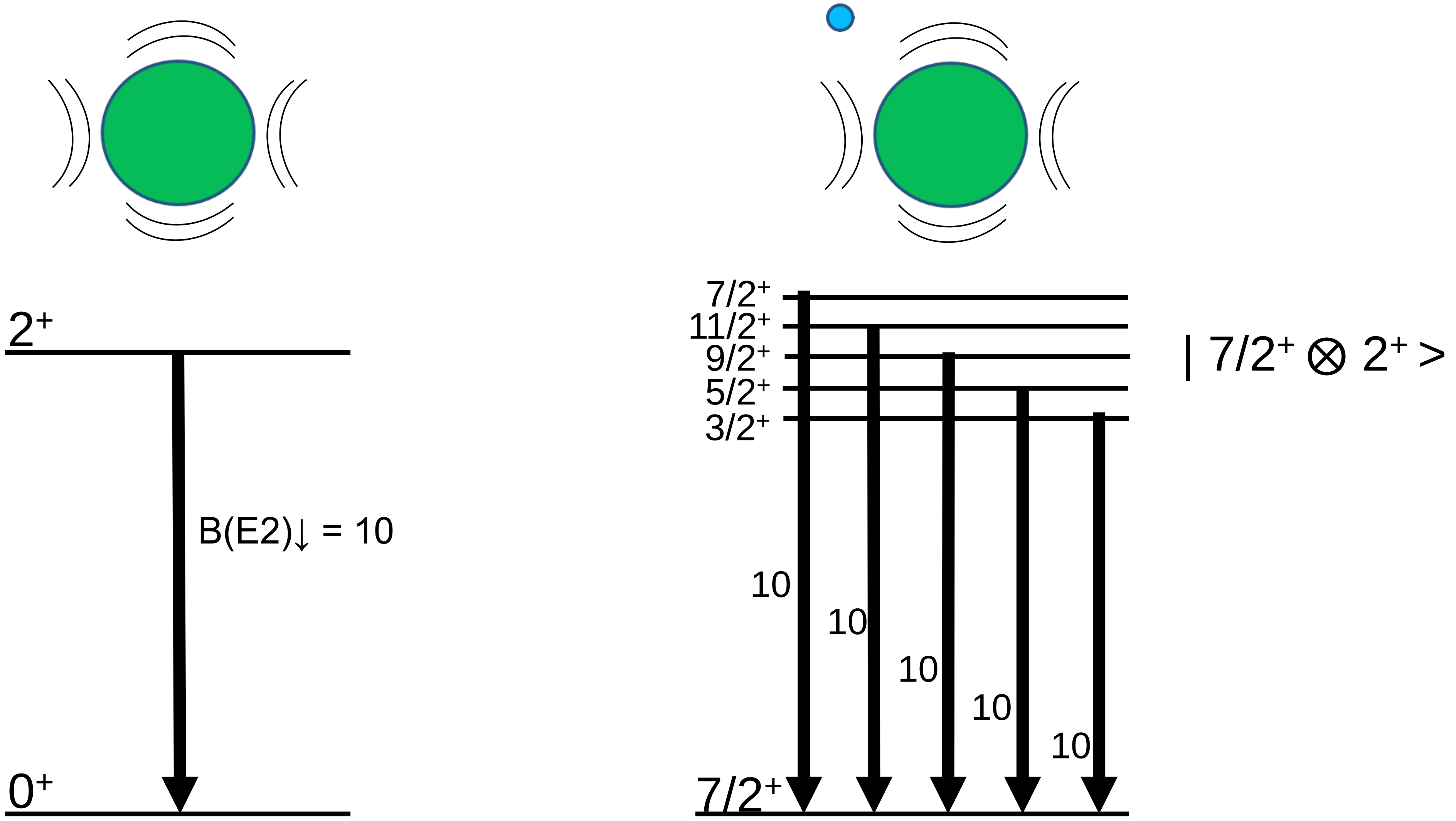
End

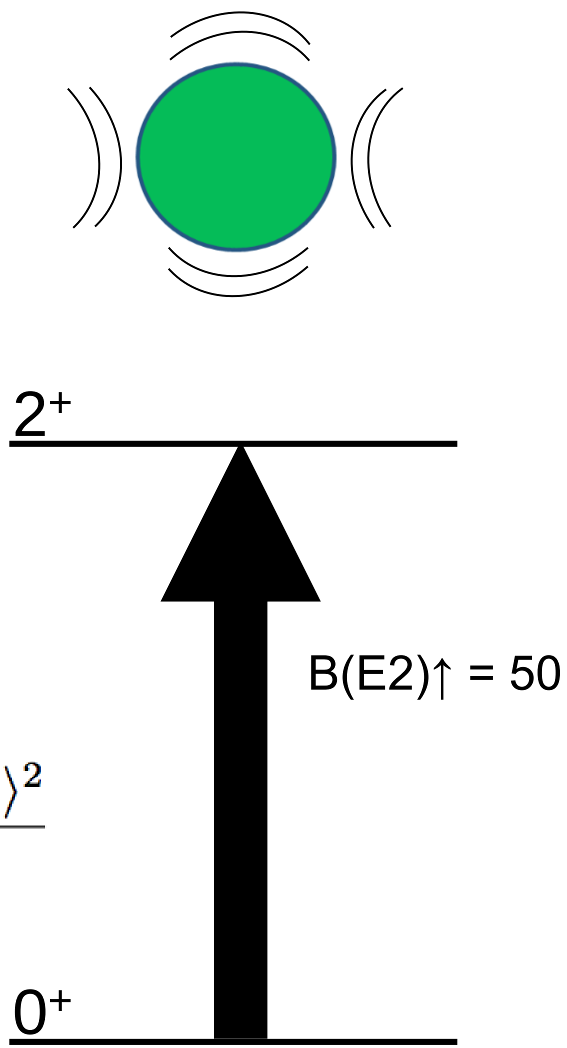
Particle-Core Coupling

The weak-coupling limit yields equivalent B(E2)↓ values; strong coupling would repartition strength

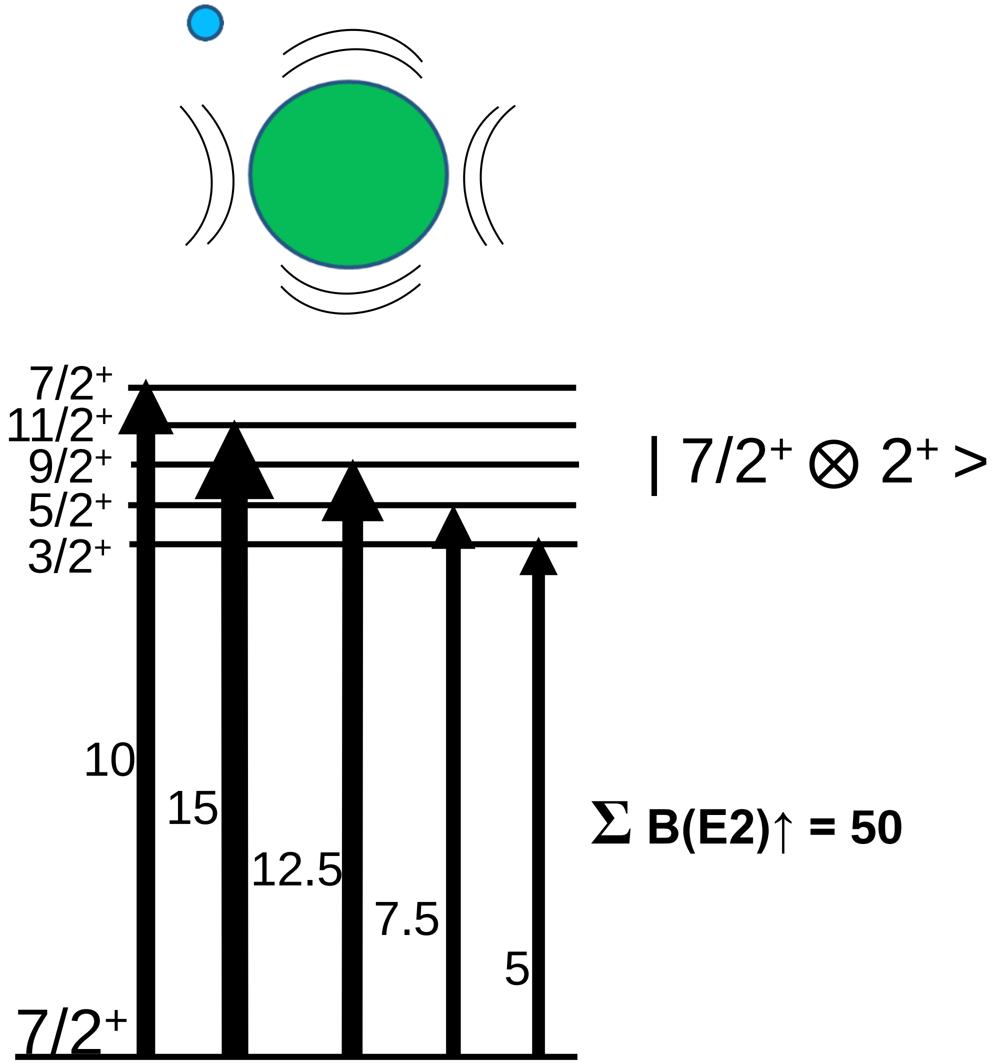


Particle-Core Coupling

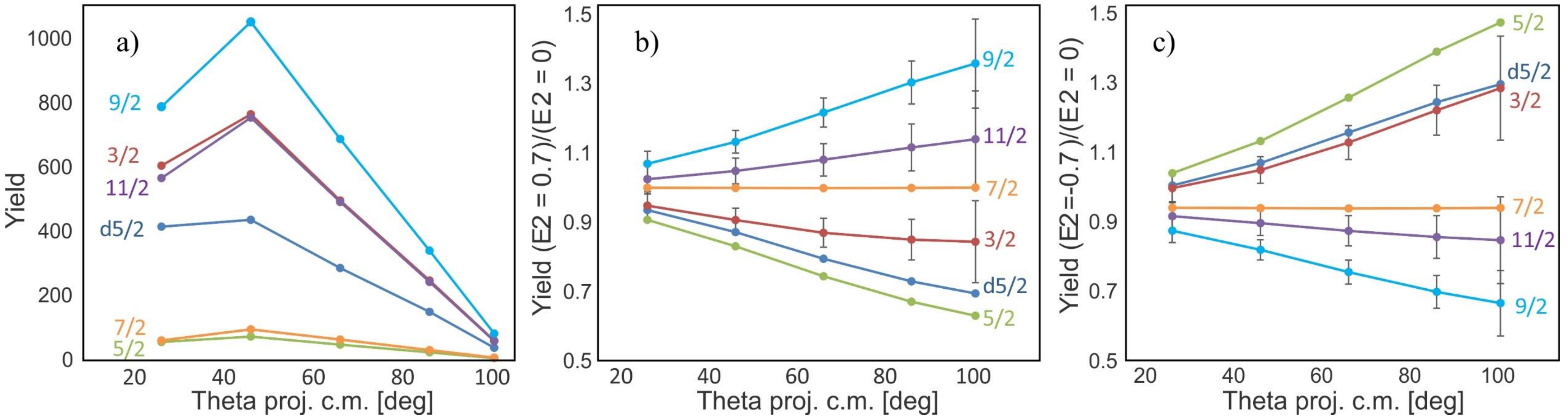
All particle-core coupling schemes (e.g., weak and strong) preserve the total strength up, $\langle Q^2 \rangle_{core} = \Sigma\, B(E2)\uparrow$



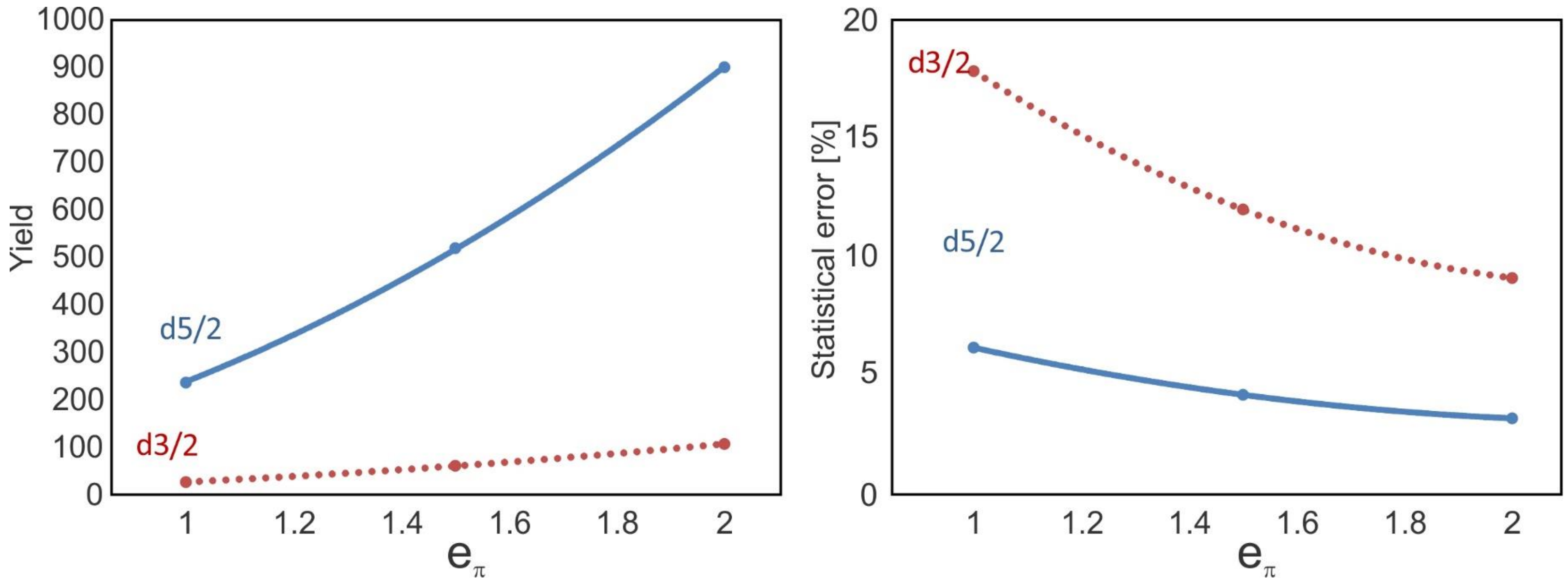
$$B(E2; I_i^+ \rightarrow I_f^+) = \frac{\langle I_f || E2 || I_i \rangle^2}{2I_i + 1}$$



High-accuracy B(E2)’s from Coulex – the pitfalls



Proton effective charges from ^{133}Sb



Expected γ-yields at Miniball

isotope	I_i	I_f	E_x [MeV]	B(E2) [W.u.]	p-g yields	B(E2) stat. err. [W.u.]	stat. err. [%]
^{131}Sb	7/2	$5/2_{d5/2}$	0.798	0.55	1325	0.015	2.7
		3/2	1.141	1.8	2174	0.039	2.1
		5/2	1.202	0.19	205	0.014	7.0
		11/2	1.226	2.11	2114	0.046	2.2
		9/2	1.229	2.97	2951	0.055	1.8
		7/2	1.482	0.47	257	0.029	6.2
^{133}Sb	7/2	$5/2_{d5/2}$	0.962	0.31	520	0.014	4.4
		$3/2_{d3/2}$	2.439	2.79	62	0.35	13
^{127}In	9/2	11/2	1.066	7.1	921	0.20	3.3
		13/2	1.235	7.2	458	0.34	4.7
		5/2	~1.1	3.8	658	0.15	3.9
		7/2	~1.6	0.34	14	0.09	27
		9/2	~1.6	0.2	8	0.07	35
^{127}In	1/2	3/2	0.524	2.5	2948	0.04	4.0
		5/2	~1	1.5	1905	0.03	2.8