Competition of allowed and first-forbidden β^+/EC decays of ^{208}At

Matthew Brunet
University of Surrey

Region of Interest

85	207At	208At	209At	210At	211At	212At
84	206Po	207Po	208Po	209Po	210Po	211Po
83	205Bi	206Bi	207Bi	208Bi	209Bi	210Bi
82	204Pb	205Pb	206Pb	207Pb	208Pb	209Pb
81	203Tl	204Tl	205Tl	206Tl	207Tl	208Tl
	122	123	124	125	**126**	127

Features of ^{208}Po

- 84 protons (2 valence protons)
- 124 neutrons (2 valence neutron holes)
- Close to doubly-magic ^{208}Pb
- Lies in region of high octupole collectivity
- Prime candidate to explore shell and collective state interactions

Features of ^{208}At Decay

- **Exhibits competition between first-forbidden and allowed β^+/EC decays**
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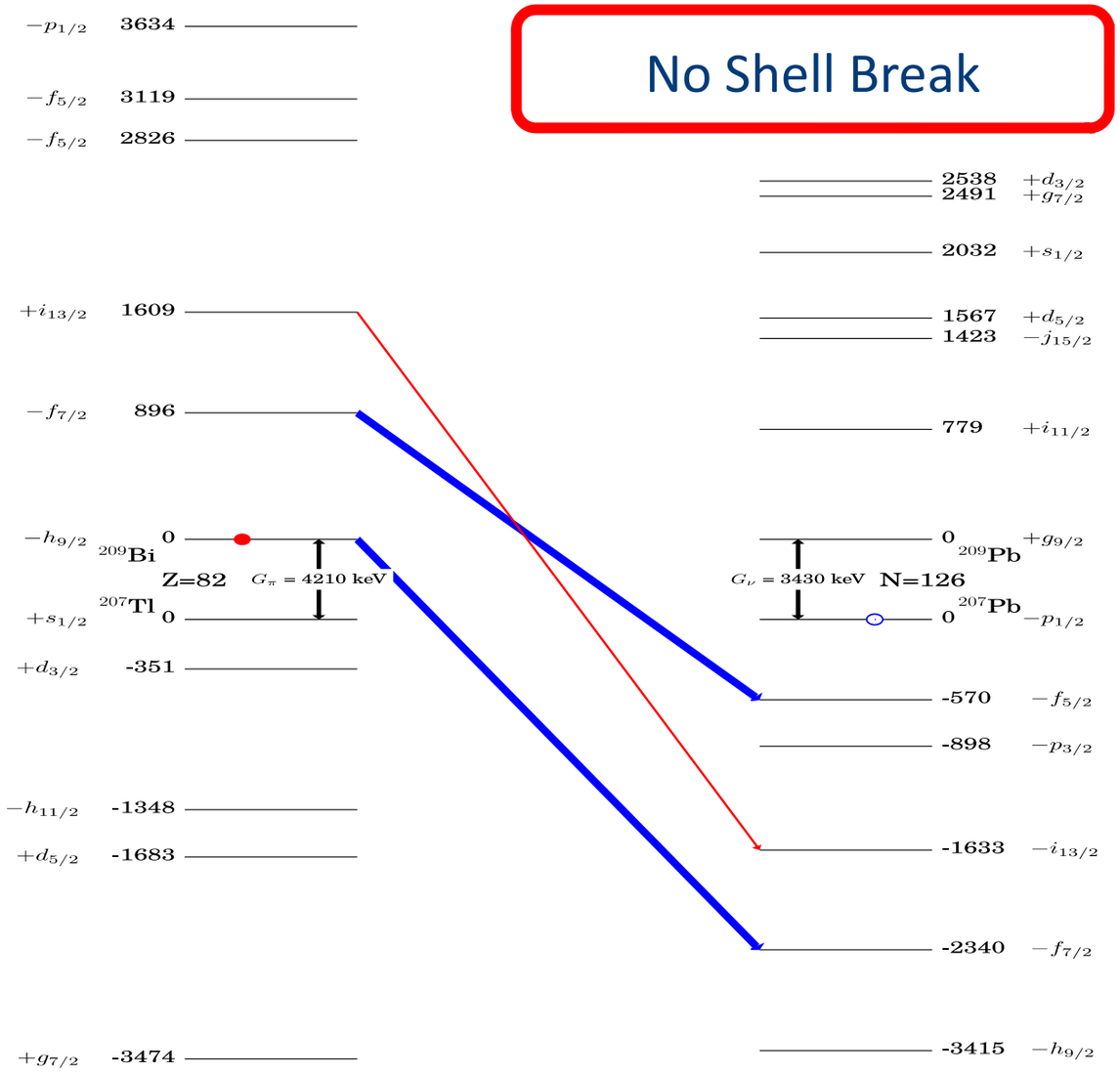
Possible β⁺/EC decay paths



Allowed Decays J=0,1 =no

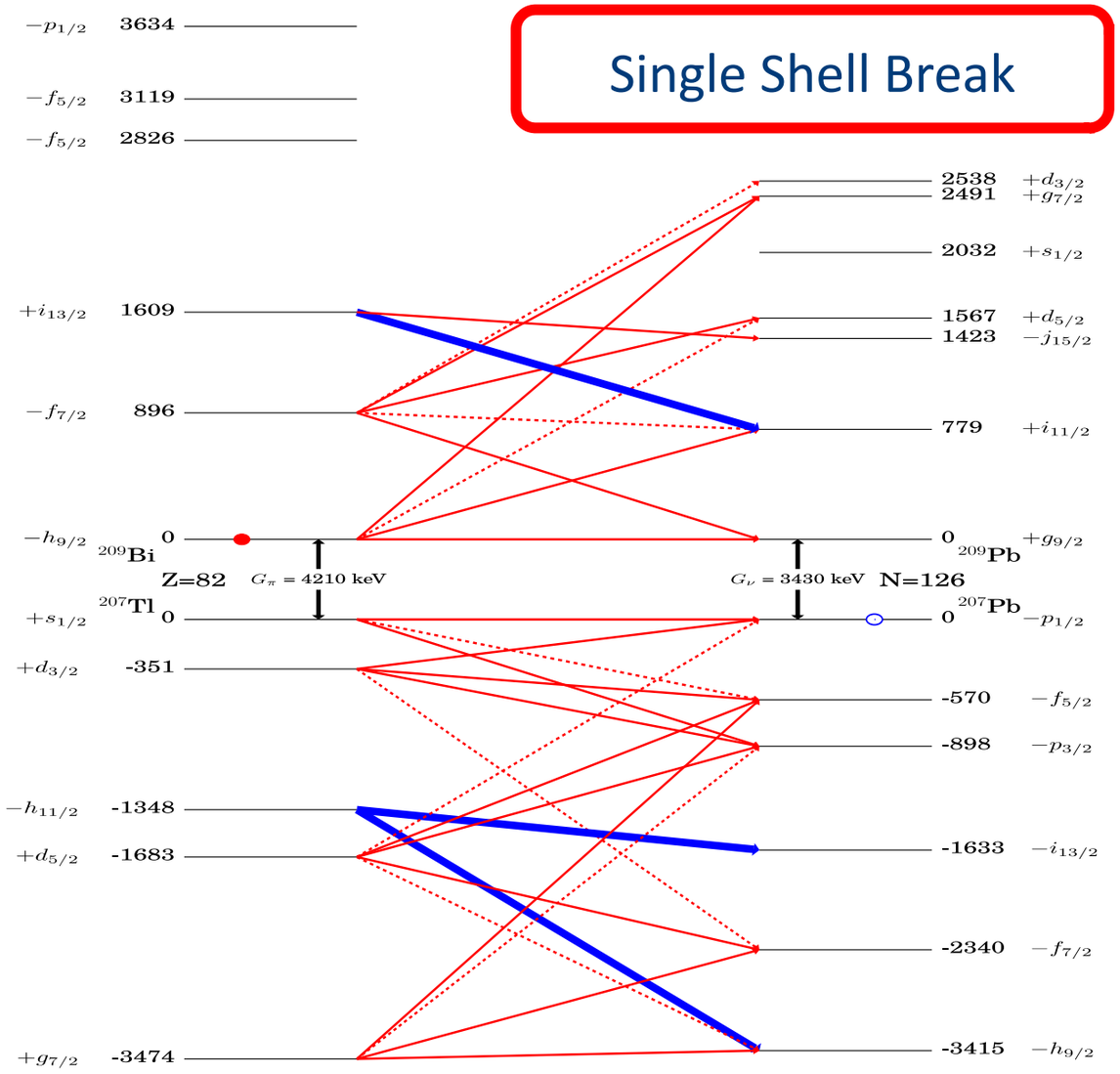
- Limited allowed decay paths
- Allowed decays supressed by occupied neutron shells and/or unoccupied proton shells

First Forbidden Decays J=0,1 =yes

- Limited FF decay paths
- FF decays also suppressed by orbital structure

Allowed — First Forbidden — First Forbidden Unique

Possible β⁺/EC decay paths



Allowed Decays J=0,1 =no

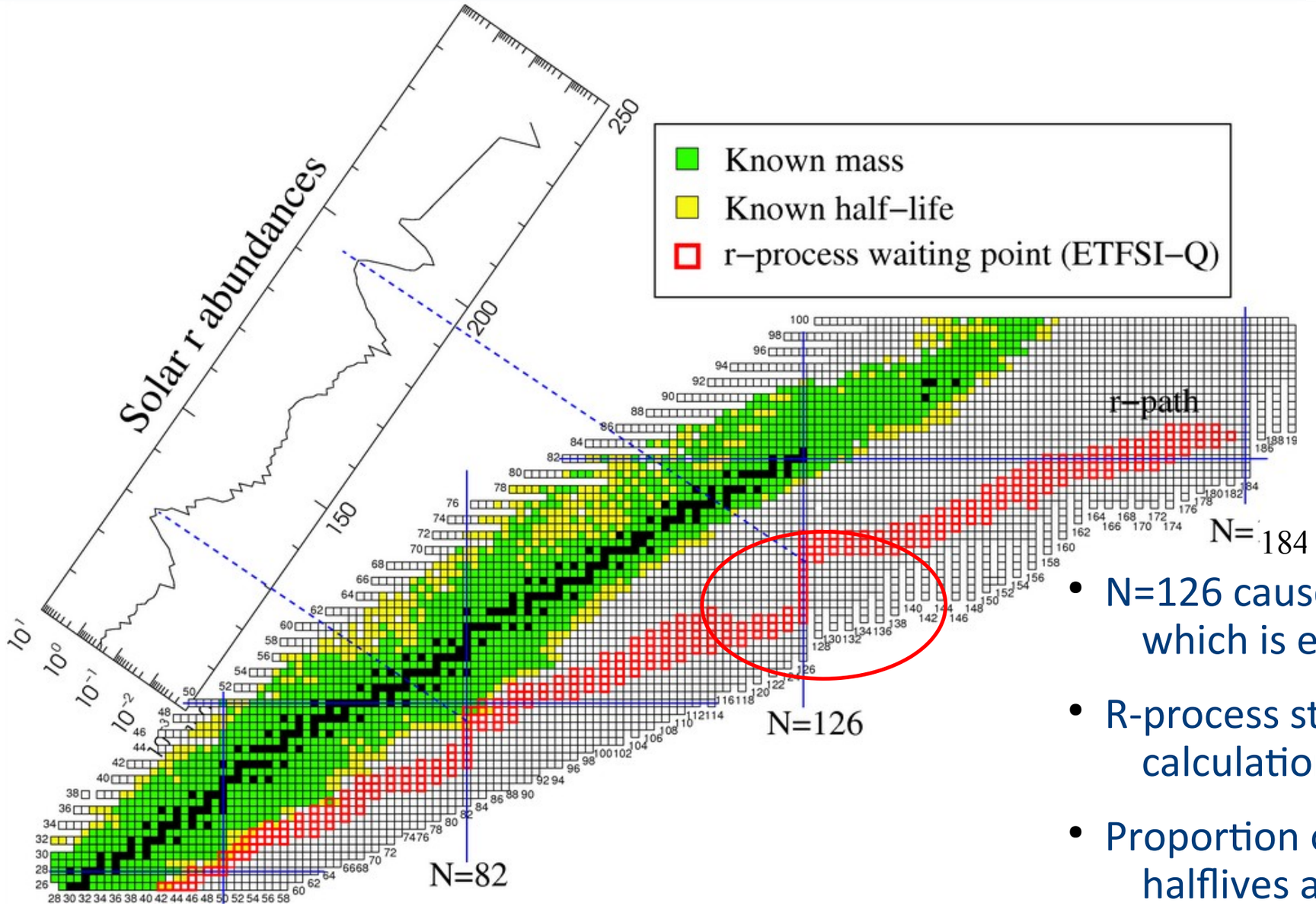
- Again limited allowed decay paths
- Possible allowed decays still supressed by occupied neutron shells and/or unoccupied proton shells

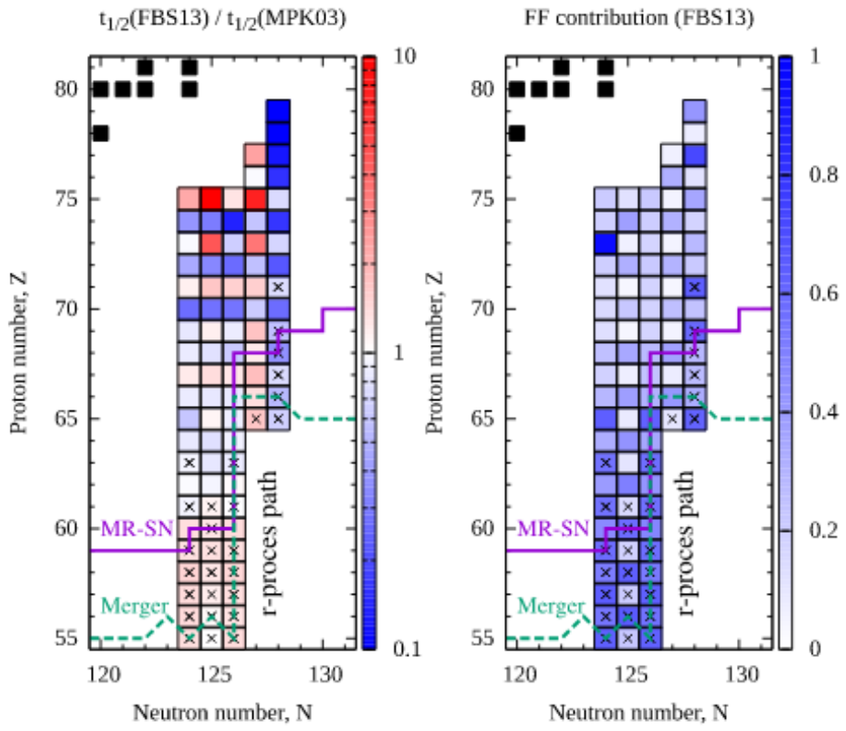
First Forbidden Decays J=0,1 =yes

- Abundance of FF decay paths
- Large number of FF decays are unsuppressed by orbital structure
- Require shell breaking, populated states will have high energy ~3MeV

Allowed — First Forbidden — First Forbidden Unique

r-process Nucleosynthesis





- N=126 causes solar abundance peak at A195 which is experimentally unreachable.
- R-process studies are reliant on theoretical calculations.
- Proportion of FF decays significantly impacts halflives and decay simulations.

Images taken from: N. Nisihimura et. al., Phys. Lett. B. **276**, 273-277, (2016)

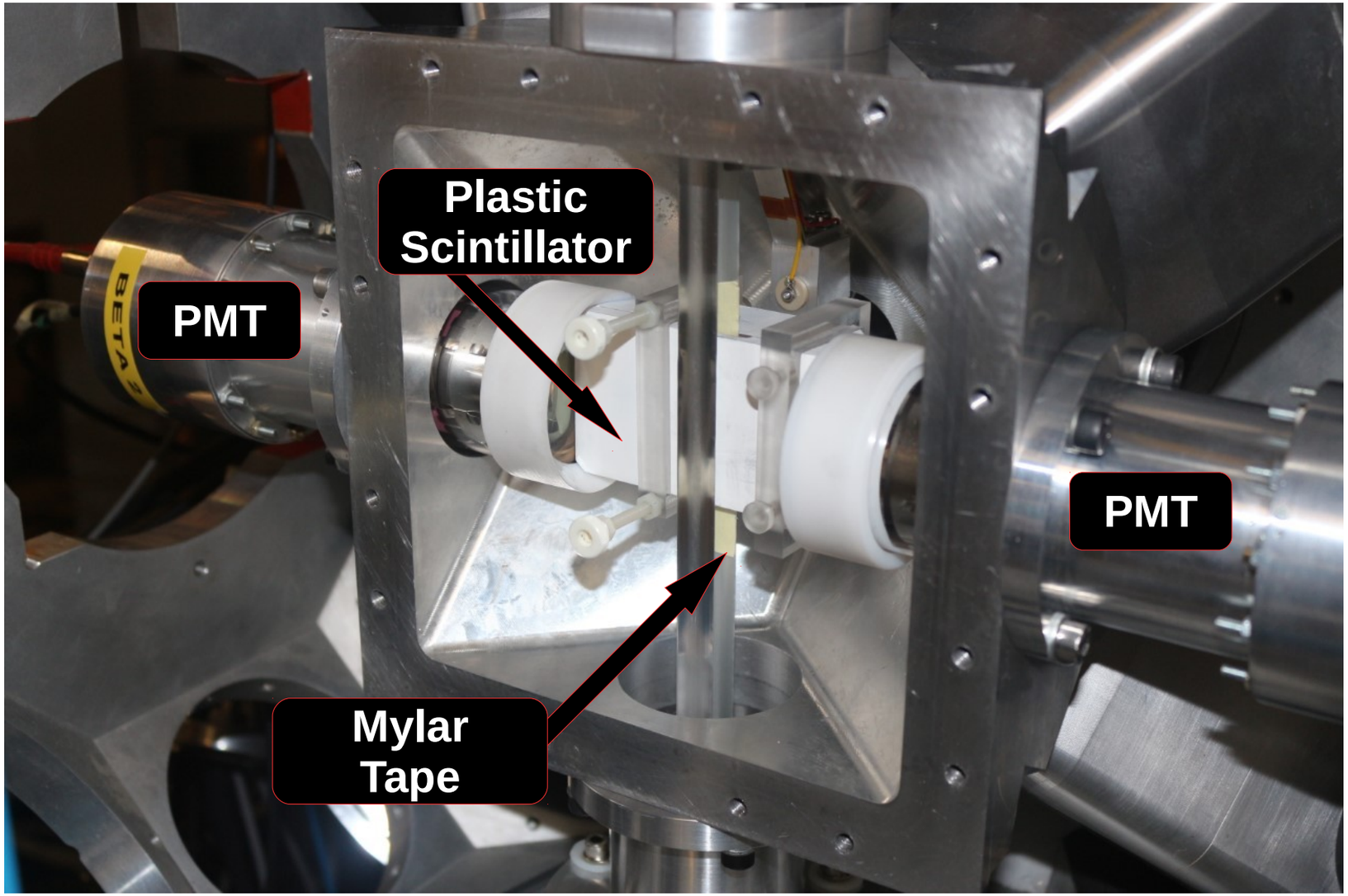
Experimental Setup

ISOLDE Beam

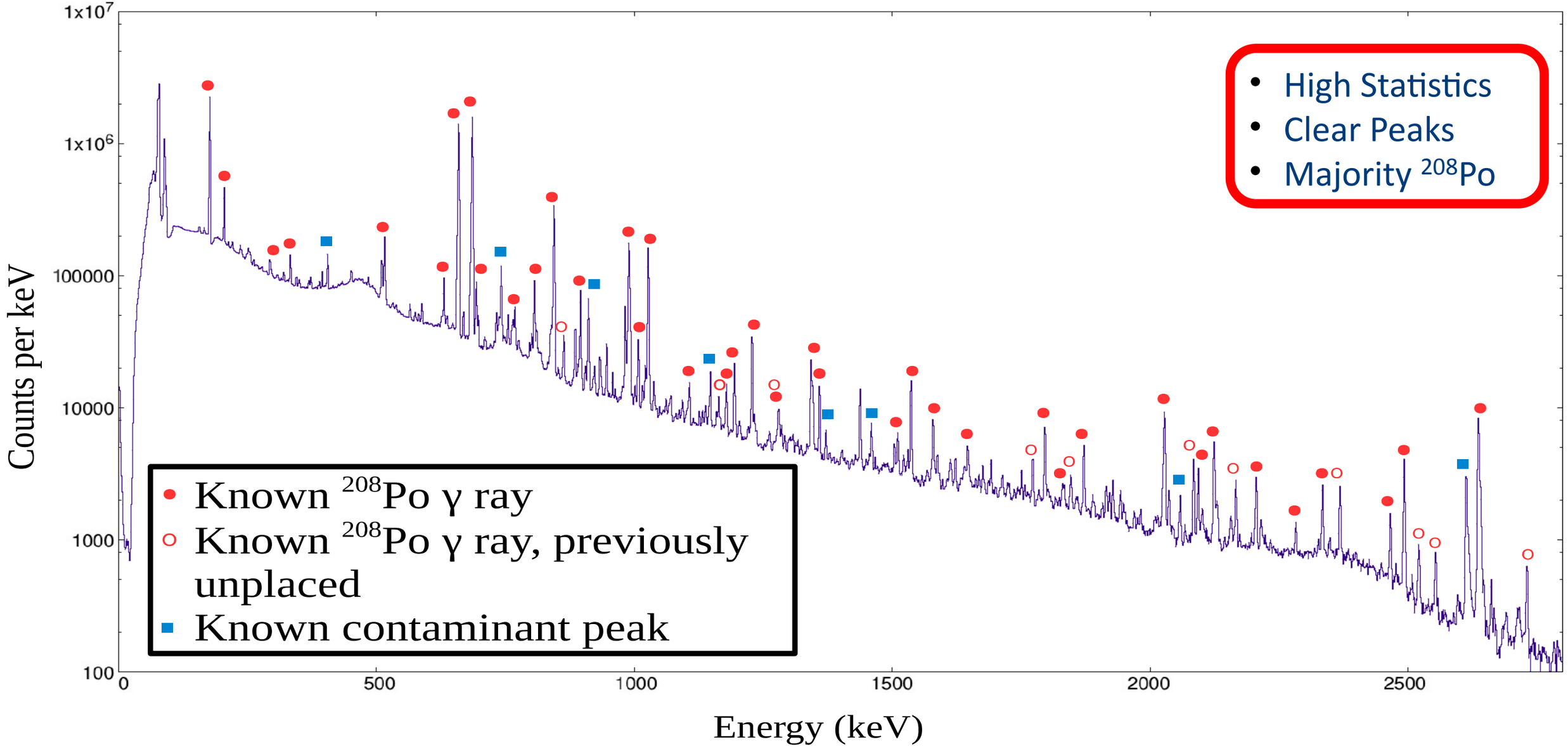
- High energy proton beam on a molten lead target.
- Mass separator for A=208.

Decay Station Setup

- Five high energy resolution HPGe clover detectors.
- Plastic scintillator β detector for decay coincidences.



Full Spectrum: Statistics

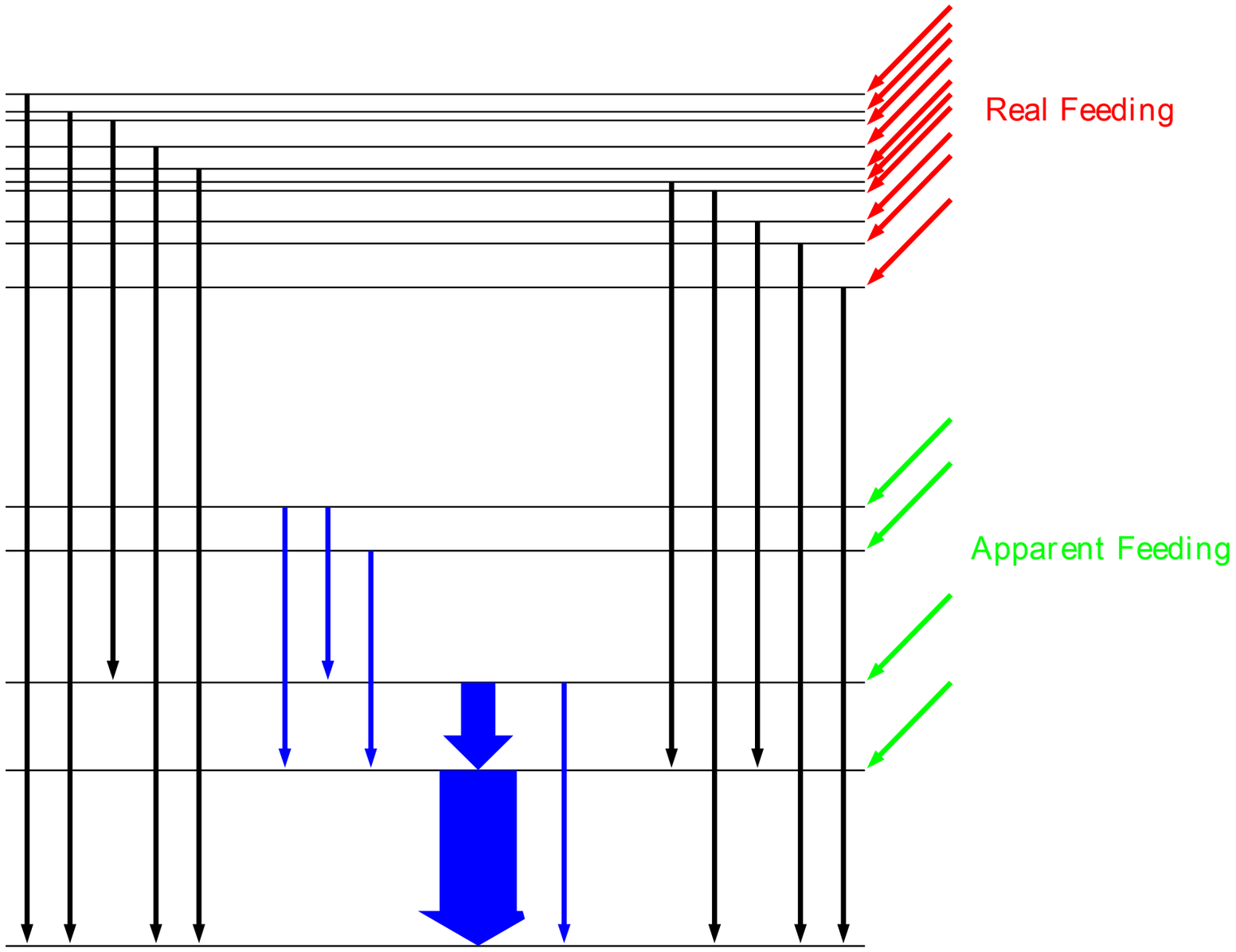


- High Statistics
- Clear Peaks
- Majority ^{208}Po

Full Level Scheme

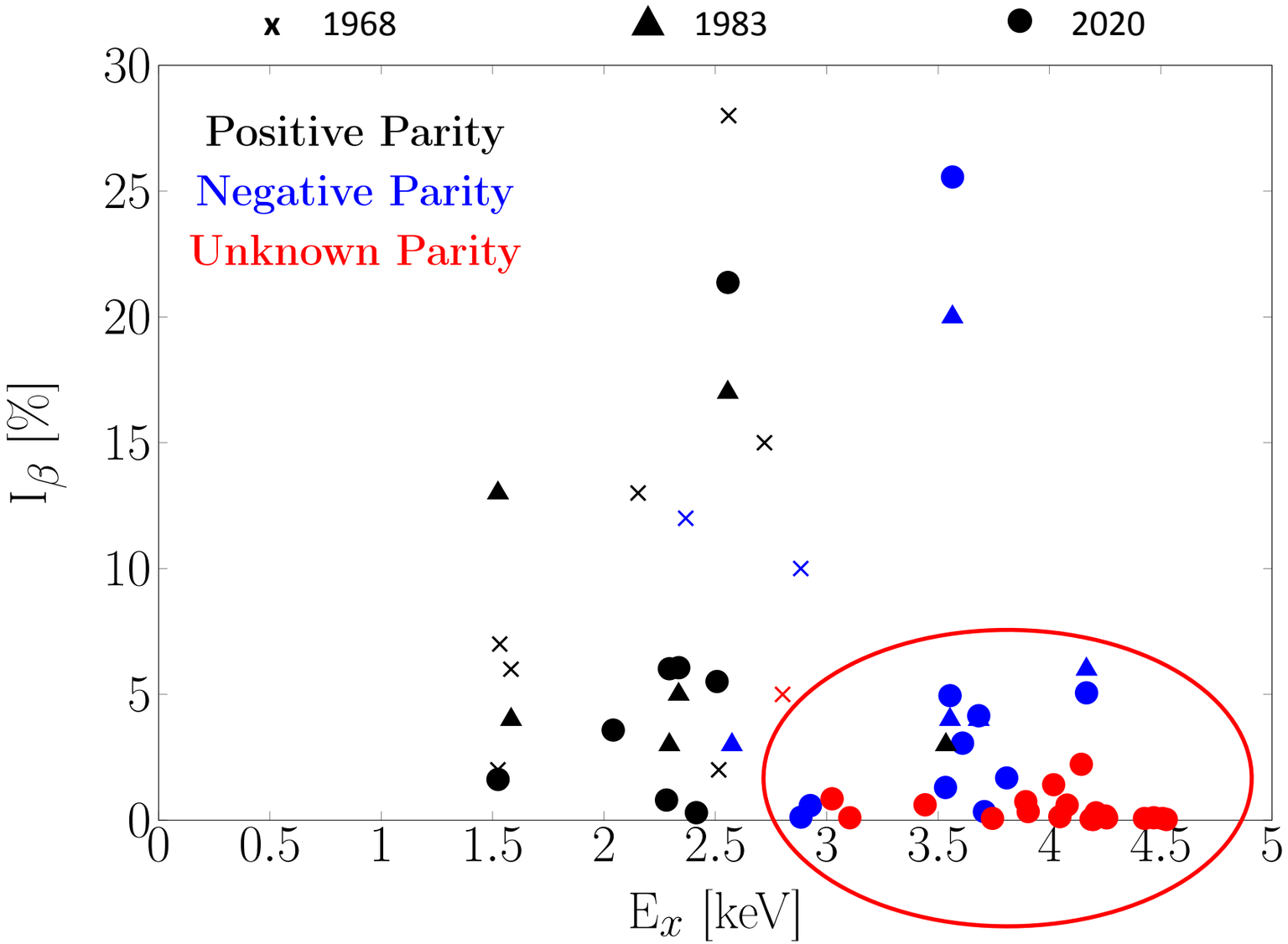
90 New/Reassigned Transitions
26 New States

Pandemonium Effect



- High energy states tend to decay via high energy transitions
- High energy and/or low intensity transitions require higher detection efficiency to observe
- Feeding to lower energy states will dominate in older decay studies with lower detection efficiency

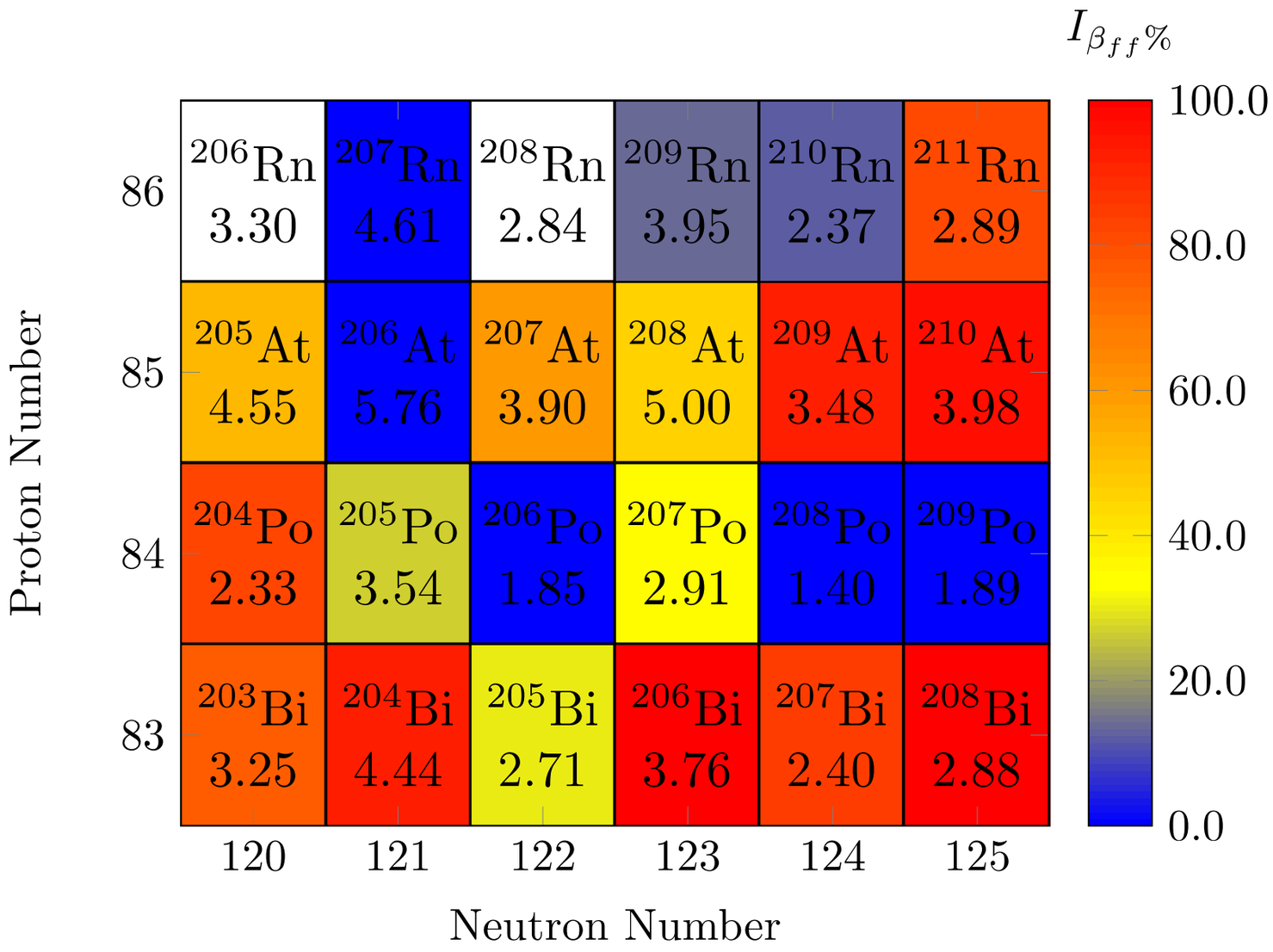
Pandemonium Effect



- High number of previously-unobserved, β-populated states.
- Increased proportion of first-forbidden decays.
- Unknown parity states could further increase FF proportion.

	1968	1983	2020
Allowed	73	57	42
First-Forbidden	22	42	48
Unknown	5	1	10

Competition of FF-Allowed Decay Systematics



A=208 region

- High FF proportion in this region.
- Outliers are the result of low Q_{EC} values (^{206,208,209}Po,^{210}Rn) or lack of data/observed negative parity states (^{206}At, $^{206\text{-}210}$Rn).
- Low Q_{EC} and no positive parity states result in high FF proportion (^{206,207,208}Bi).
- High $I_{\beta ff}$% comparable to the N=126 waiting point.

Summary of Results

^{208}Po Structure

- ^{208}Po level scheme has been significantly expanded.
- Large number of previously observed transitions placed into the level scheme.

Pandemonium Effect

- Large number of previously-unobserved high energy states and transitions.
- High Q_{EC} value, and underlying structure suggests additional unobserved β-populated states.

r-process Nucleosynthesis

- First-forbidden decays prevalent for ^{208}At, and the surrounding mass region.
- Results reaffirm N<126, Z>82 as lucrative testing ground for r-process simulations.
- Further decay studies of this region are required to improve understanding.

Thank you for listening

Competition between allowed and first-forbidden β decays of ^{208}At and expansion of the ^{208}Po level scheme

M. Brunet,[1] Zs. Podolyák,[1] T. A. Berry,[1] B. A. Brown,[2] R. J. Carroll,[1] R. Lica,[3,4] Ch. Sotty,[4,5] A. N. Andreyev,[6,7] M. J. G. Borge,[3] J. G. Cubiss,[3,6] L. M. Fraile,[8] H. O. U. Fynbo,[9] E. Gamba,[10] P. Greenless,[11] L. J. Harkness-Brennan,[12] M. Huyse,[5] D. S. Judson,[12] J. Konki,[11] J. Kurcewicz,[3] I. Lazarus,[13] M. Madurga,[3] N. Marginean,[4] R. Marginean,[4] I. Marroquin,[14] C. Mihai,[4] E. Nácher,[15] A. Negret,[4] S. Pascu,[4] R. D. Page,[12] A. Perea,[14] J. Phrompao,[16] M. Piersa,[17] V. Pucknell,[13] P. Rahkila,[11] E. Rapisarda,[3] P. H. Regan,[1,18] F. Rotaru,[4] M. Rudigier,[1] C. M. Shand,[1] R. Shearman,[1,18] E. C. Simpson,[19] T. Stora,[3] O. Tengblad,[14] P. Van Duppen,[5] V. Vedia,[8] S. Vinals,[14] R. Wadsworth,[6] N. Warr,[19] and H. De Witte[5]

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