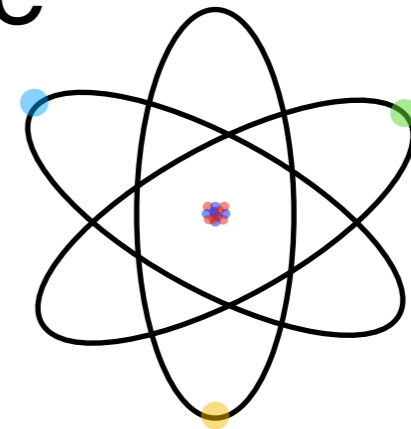


Exploring fundamental science  
at the intersection of  
atomic and nuclear physics



Jacinda Ginges



THE UNIVERSITY  
OF QUEENSLAND  
AUSTRALIA

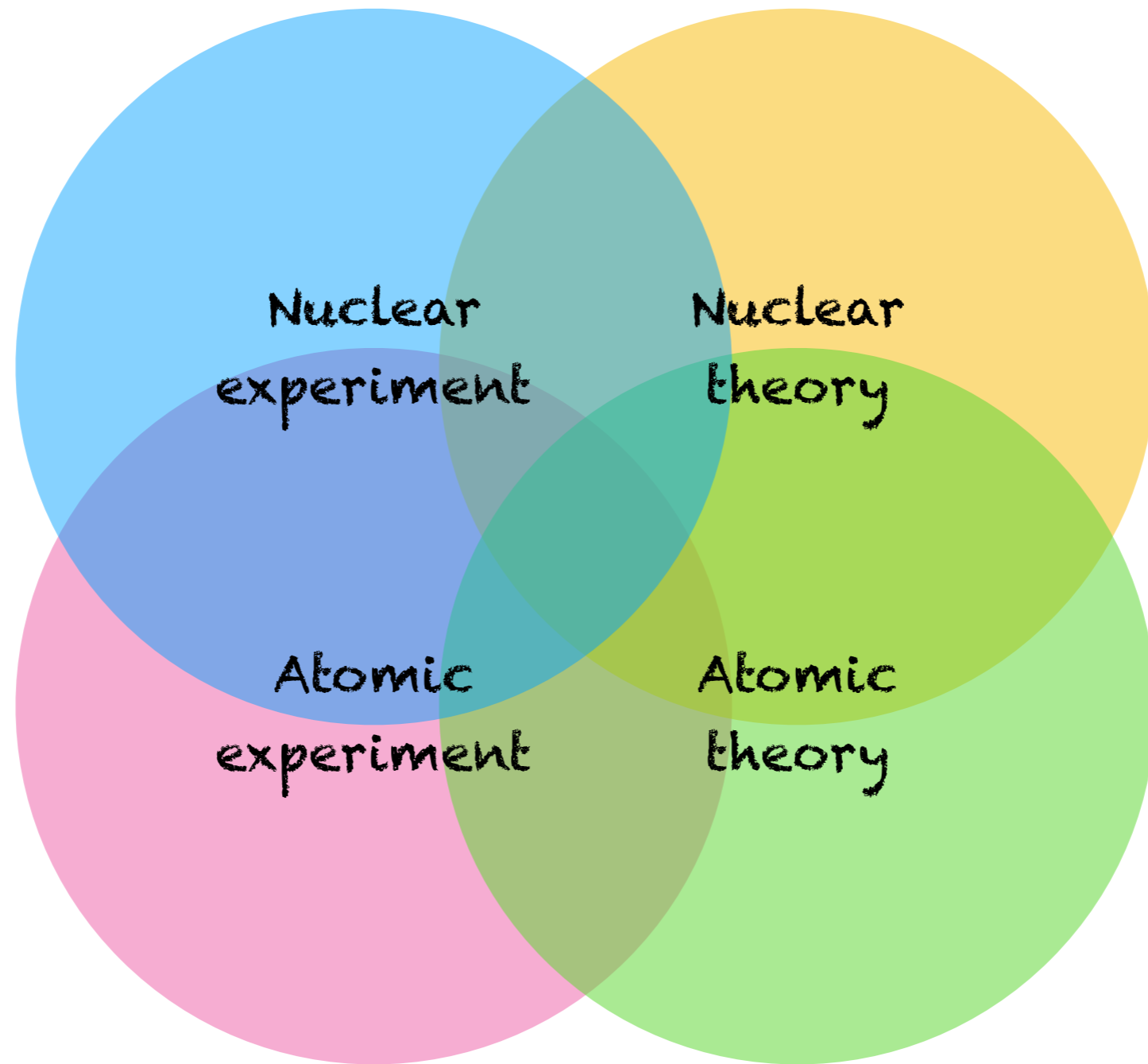


Australian Government  

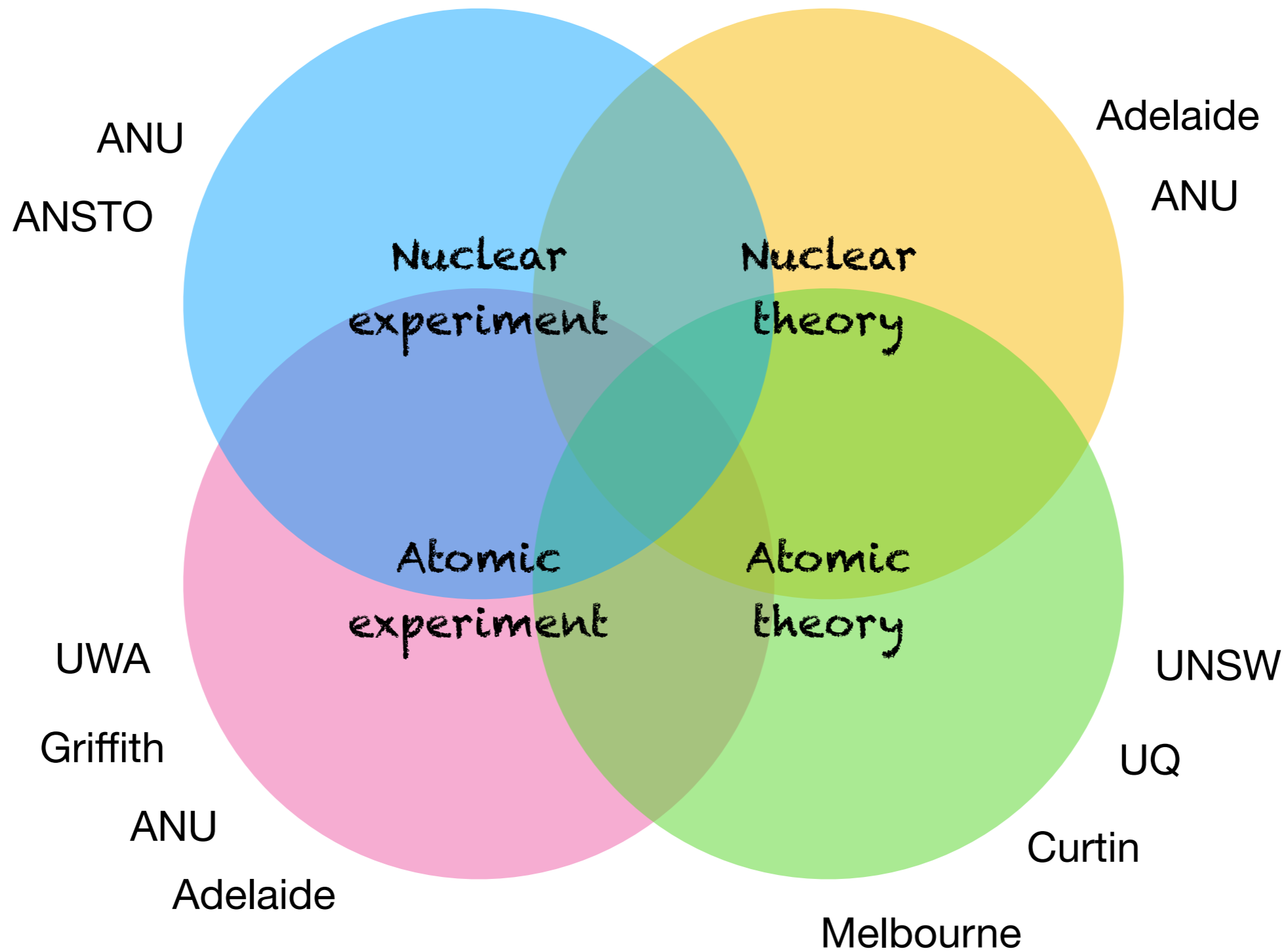
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Australian Research Council

# Synergies/collaborations

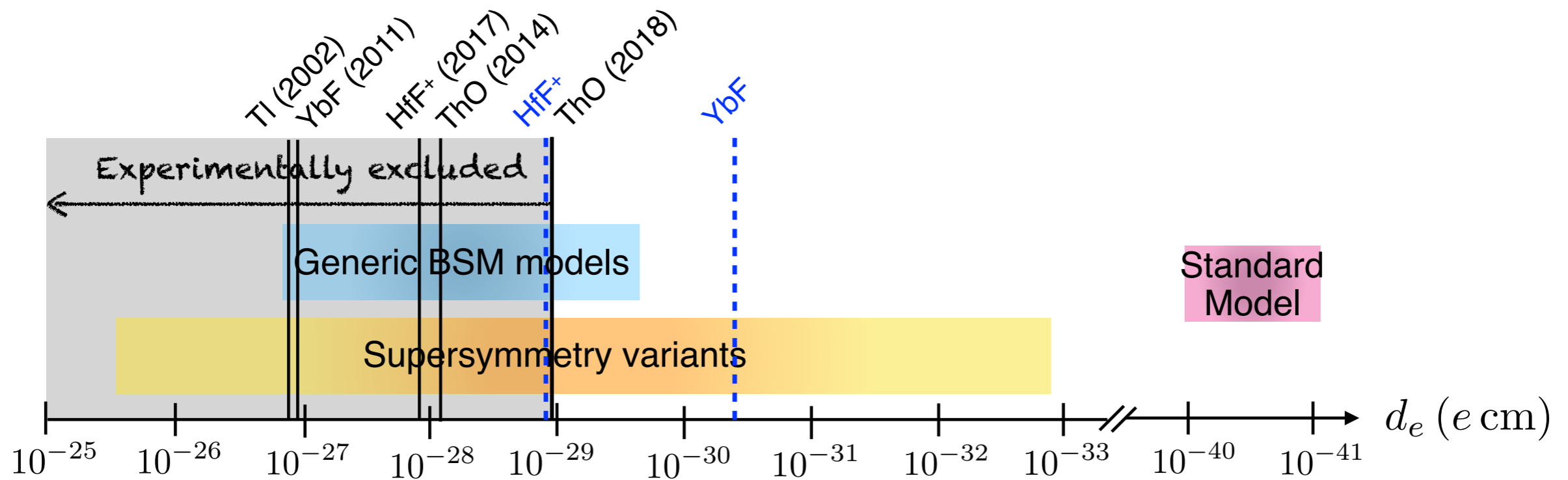


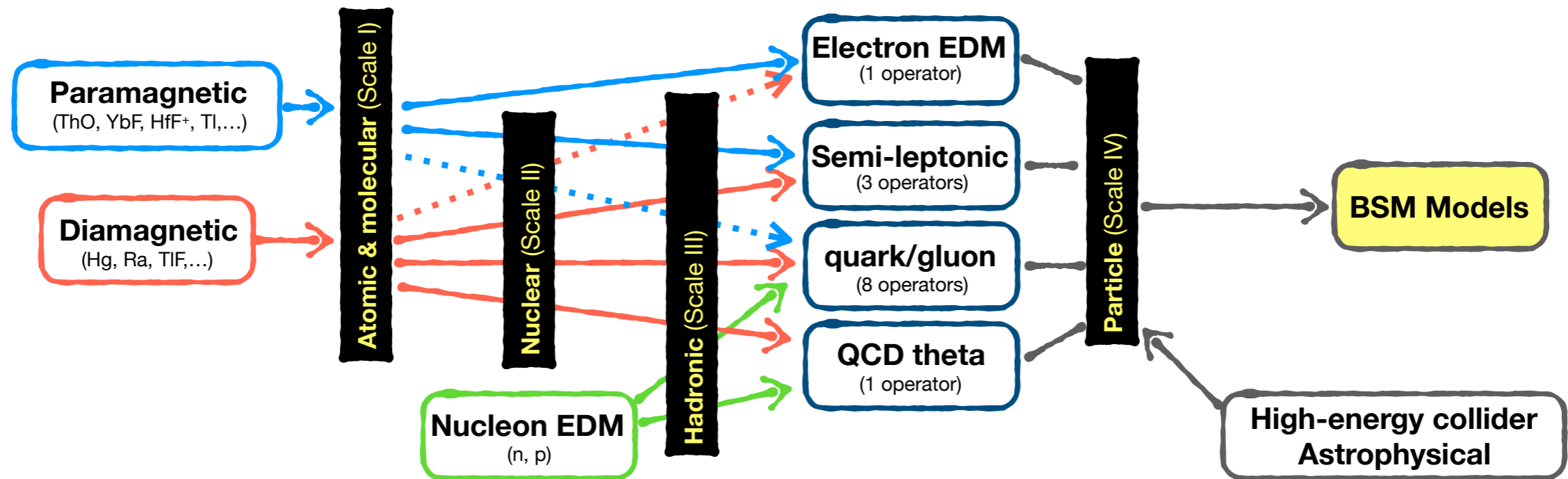
# Synergies/collaborations



# Electric dipole moments

- Search for CP-violation beyond standard model
- Could shed light on matter-antimatter asymmetry of Universe
- Next big particle physics discovery?

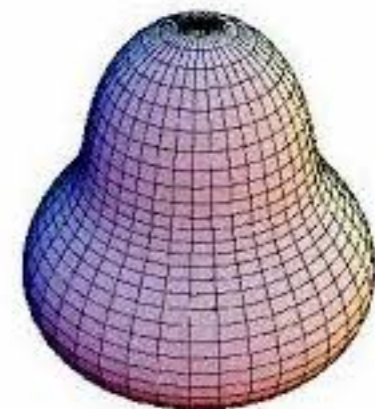




➤ Cross-disciplinary theory, spanning atomic and molecular → nuclear → hadronic → particle

➤ Parity- and time-reversal-violating nuclear moments, e.g., Schiff, magnetic quadrupole, electric octupole

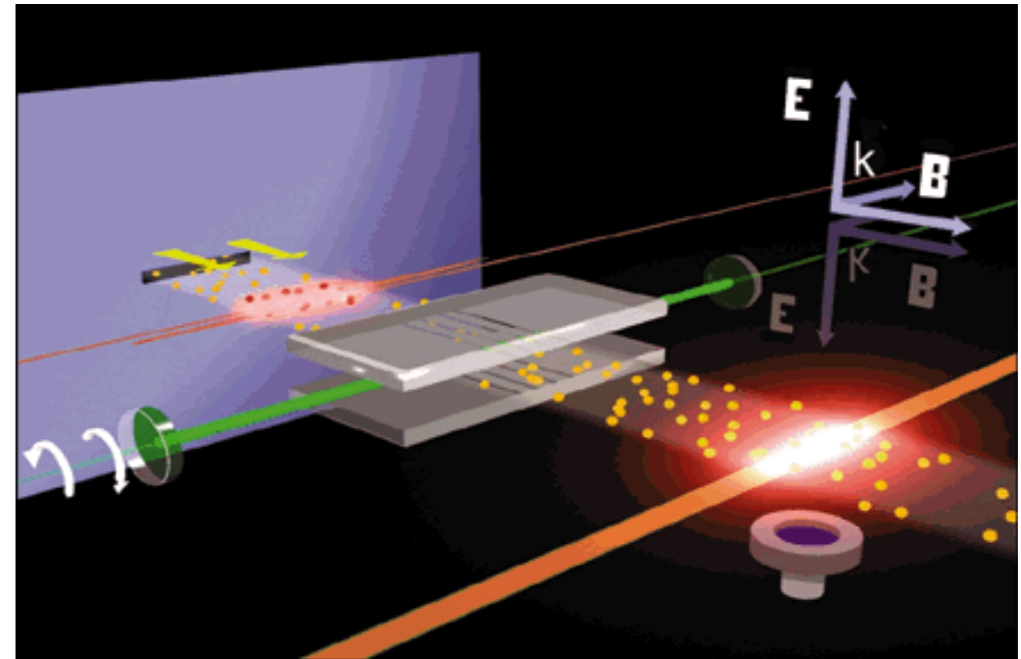
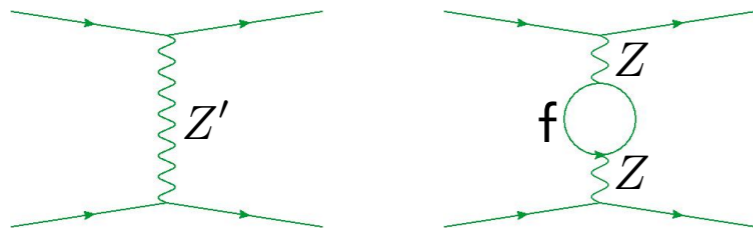
➤ Nuclear octupole deformation



# Atomic parity violation

## Nuclear weak charge

- test of standard model and search for new physics

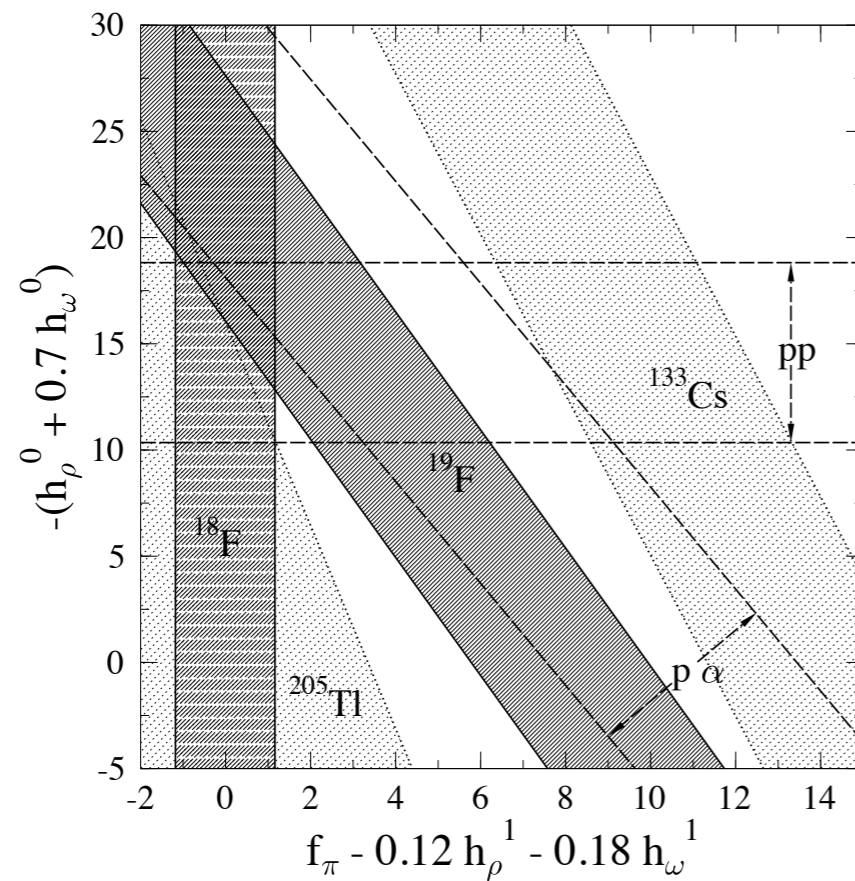
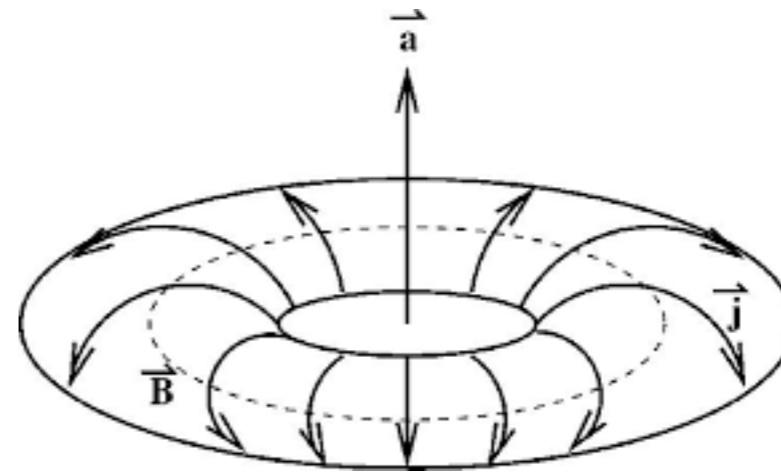


## Nuclear uncertainties that limit theory interpretation

- neutron skin  $R_n - R_p$
- nuclear magnetisation distribution
- nuclear charge distribution (?)

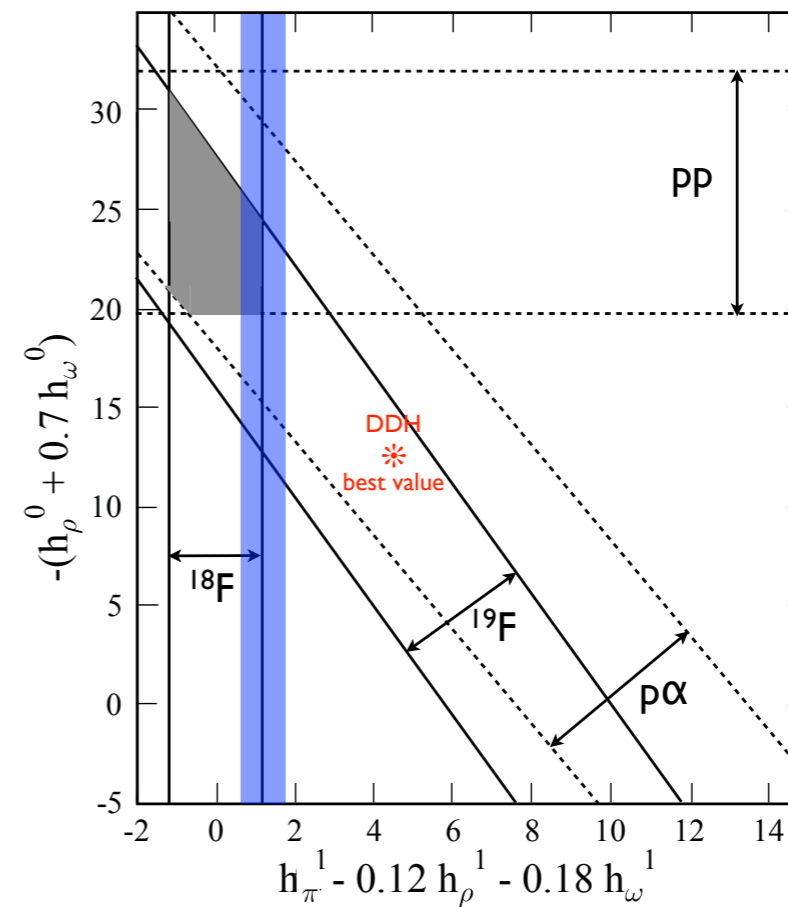
# Nuclear anapole moment

- probe of hadronic parity violation
- cesium result in tension with other experiments



Haxton and Wieman (2001)

VS

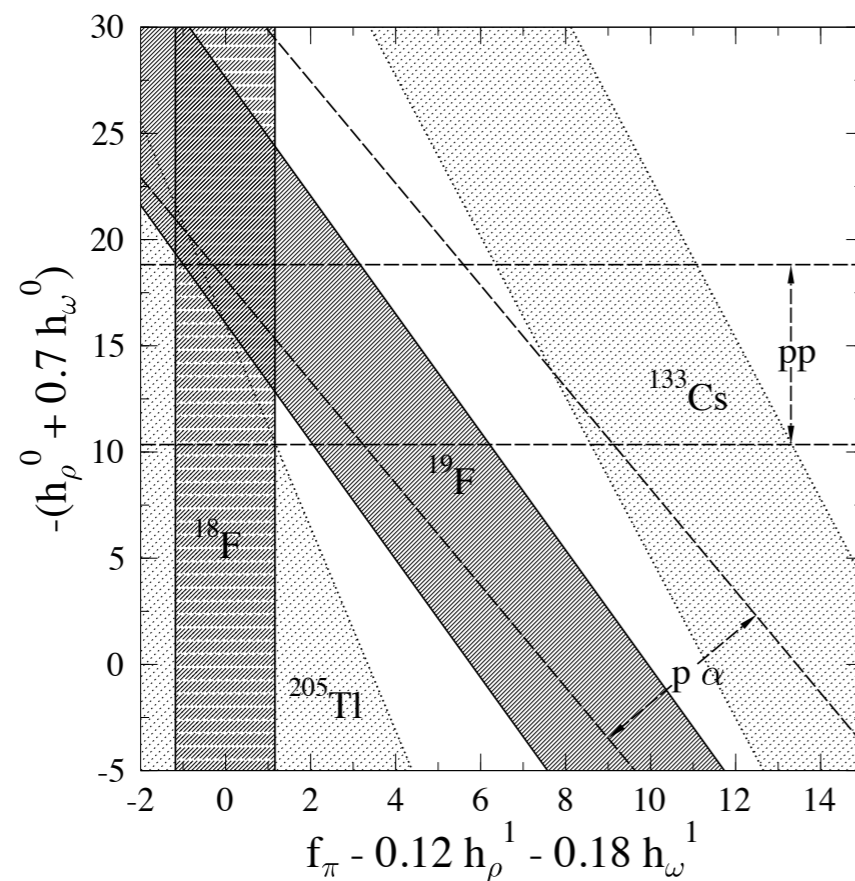
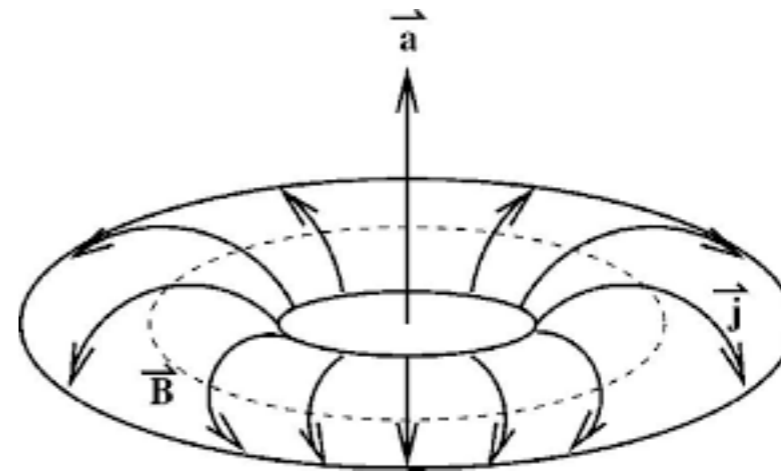


(Blue: lattice QCD)

Haxton and Holstein (2013)

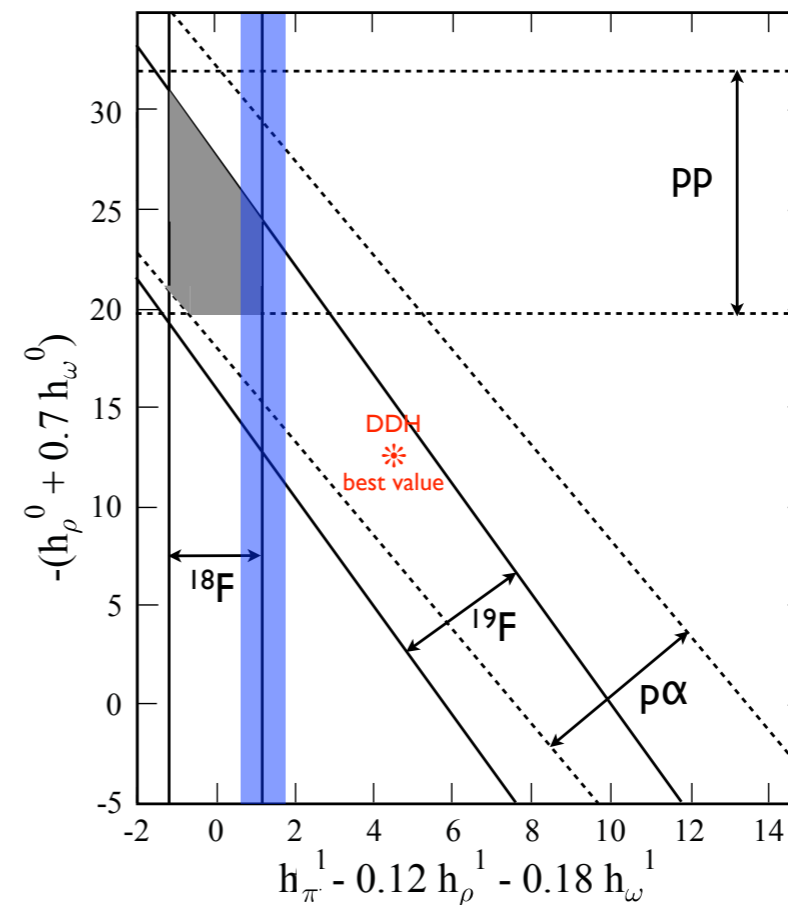
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- results from Cs and Tl anapole moments not considered reliable due to complex nuclear polarizability corrections



# Superheavy elements

**PERIODIC TABLE**  
**Atomic Properties of the Elements**

FREQUENTLY USED FUNDAMENTAL PHYSICAL CONSTANTS<sup>§</sup>  
1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of <sup>133</sup>Cs

speed of light in vacuum	$c$	299 792 458	$\text{m s}^{-1}$	(exact)
Planck constant	$h$	6.626 070 × 10 <sup>-34</sup>	$\text{J s}$	
elementary charge	$e$	1.602 177 × 10 <sup>-19</sup>	$\text{C}$	
electron mass	$m_e$	9.109 384 × 10 <sup>-31</sup>	$\text{kg}$	
	$m_e c^2$	0.510 999	$\text{MeV}$	
proton mass	$m_p$	1.672 622 × 10 <sup>-27</sup>	$\text{kg}$	
fine-structure constant	$\alpha$	1/137.035 999		
Rydberg constant	$R_\infty$	10 973 731.569	$\text{m}^{-1}$	
	$R_\infty c$	3.289 841 960 × 10 <sup>15</sup>	$\text{Hz}$	
	$R_\infty hc$	13.605 693	$\text{eV}$	
electron volt	$\text{eV}$	1.602 177 × 10 <sup>-19</sup>	$\text{J}$	
Boltzmann constant	$k$	1.380 65 × 10 <sup>-23</sup>	$\text{J K}^{-1}$	
molar gas constant	$R$	8.314 5	$\text{J mol}^{-1} \text{K}^{-1}$	

<sup>§</sup> For the most accurate values of these and other constants, visit [pml.nist.gov/constants](http://pml.nist.gov/constants).

Legend: ■ Solids, ■ Liquids, ■ Gases, ■ Artificially Prepared

NIST National Institute of Standards and Technology  
U.S. Department of Commerce 18  
VIII A

from Ch. Duellmann (GSI) slides

For the most precise values and uncertainties visit [ciaaw.org](http://ciaaw.org) and [pml.nist.gov/data](http://pml.nist.gov/data).  
NIST SP 966 (July 2018)

- synthesis of new elements @ GSI Darmstadt and RIKEN
  - Hinde and Dasgupta — nuclear fusion reactions DP
- superheavy atomic physics and chemistry — experiment and theory

Hyperfine structure, anomalies, nuclear moments

nuclear magnetic moments

# Hyperfine structure, anomalies, nuclear moments

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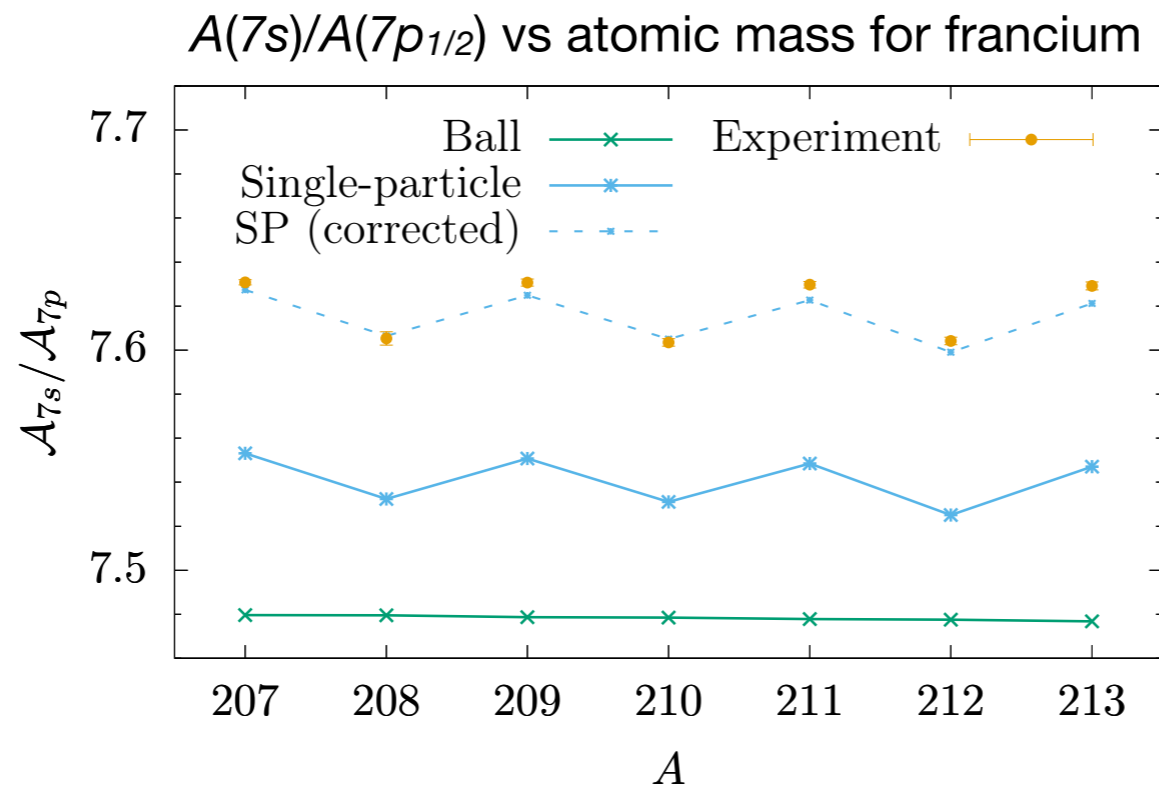
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Roberts and  
Ginges (2000)

## Hyperfine anomaly

Hyperfine constant  $\mathcal{A} = \mathcal{A}_0(1 + \epsilon) + \delta\mathcal{A}_{\text{QED}}$

magnetic hyperfine anomaly



Ratio of hyperfine constants of different isotopes of the same element

$$\mathcal{A}^{(1)} / \mathcal{A}^{(2)} = g_I^{(1)} / g_I^{(2)} (1 + {}^1\Delta^2)$$

Typically for nuclei of different spin,  ${}^1\Delta^2 \approx \epsilon^{(1)} - \epsilon^{(2)}$

[Collaborating with M. Kowalska (CERN-ISOLDE) and J. Dobacewski (York)]



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