

DISCOVERY AND CHARACTERISATION OF LONG-LIVED STATES IN $^{116,118,120}\text{Ag}$ USING COLLINEAR LASER SPECTROSCOPY

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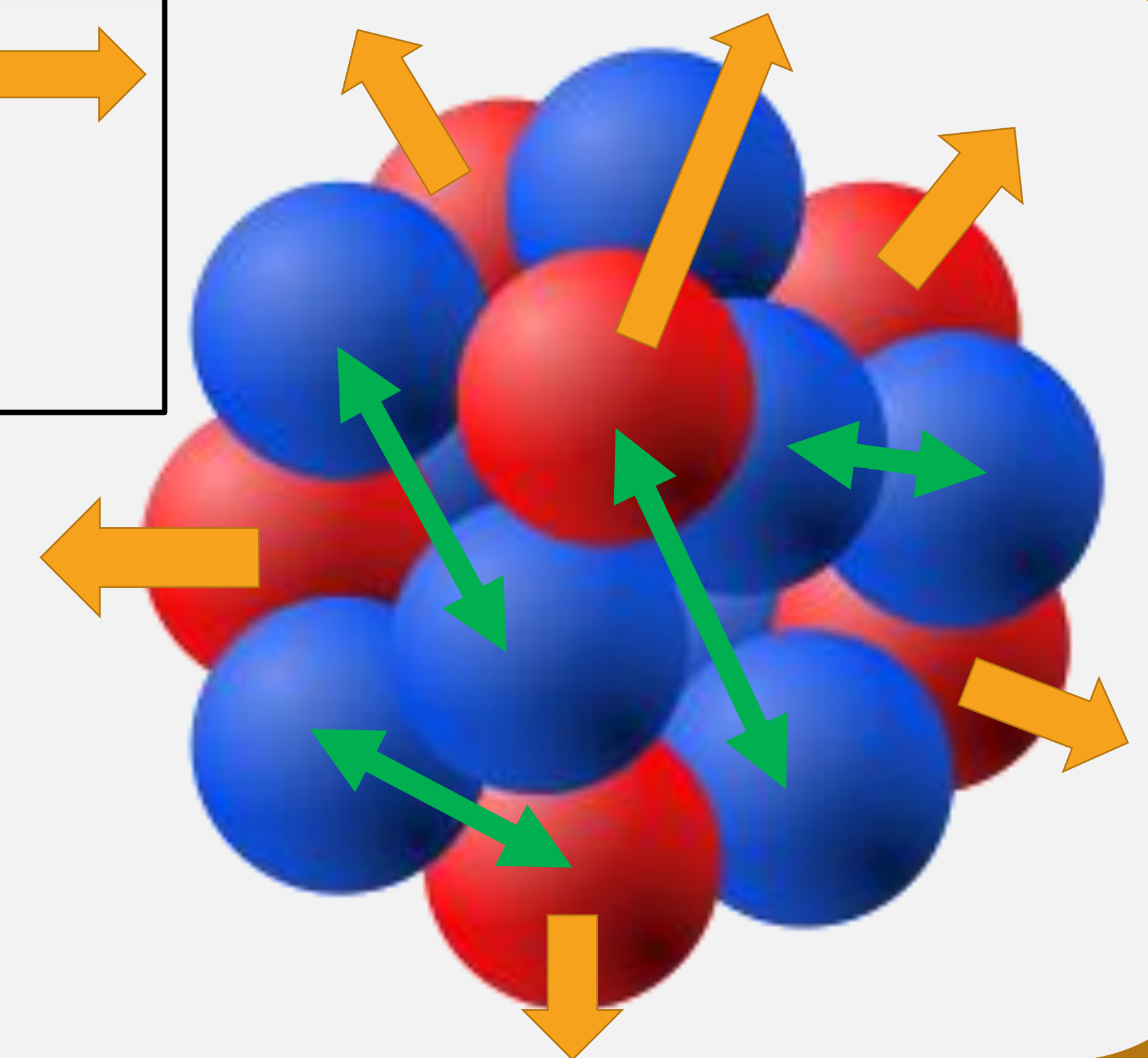
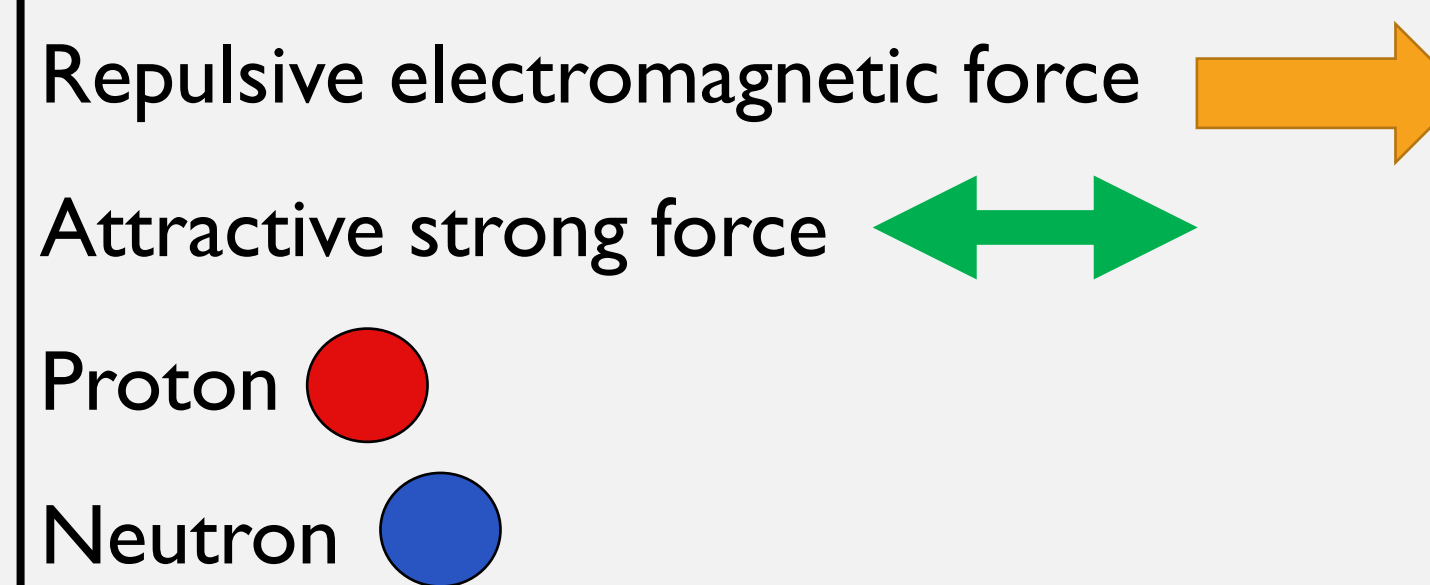
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Motivation

- Nucleus dominantly governed by strong force which binds nucleons
 - BUT**, strong interaction not fully known yet
- Thus, use effective nuclear interaction which is tuned locally and highly constrained
- Strive to global understanding of the nucleus → derive nuclear force through QCD (ab-initio)
 - Benchmark these models with precision studies of fundamental nuclear properties
 - Choose isotopes with a rich nuclear structure, near magic proton number $Z = 50$

→ Silver isotopes have 47 protons and many neutron holes with respect to $N = 82$



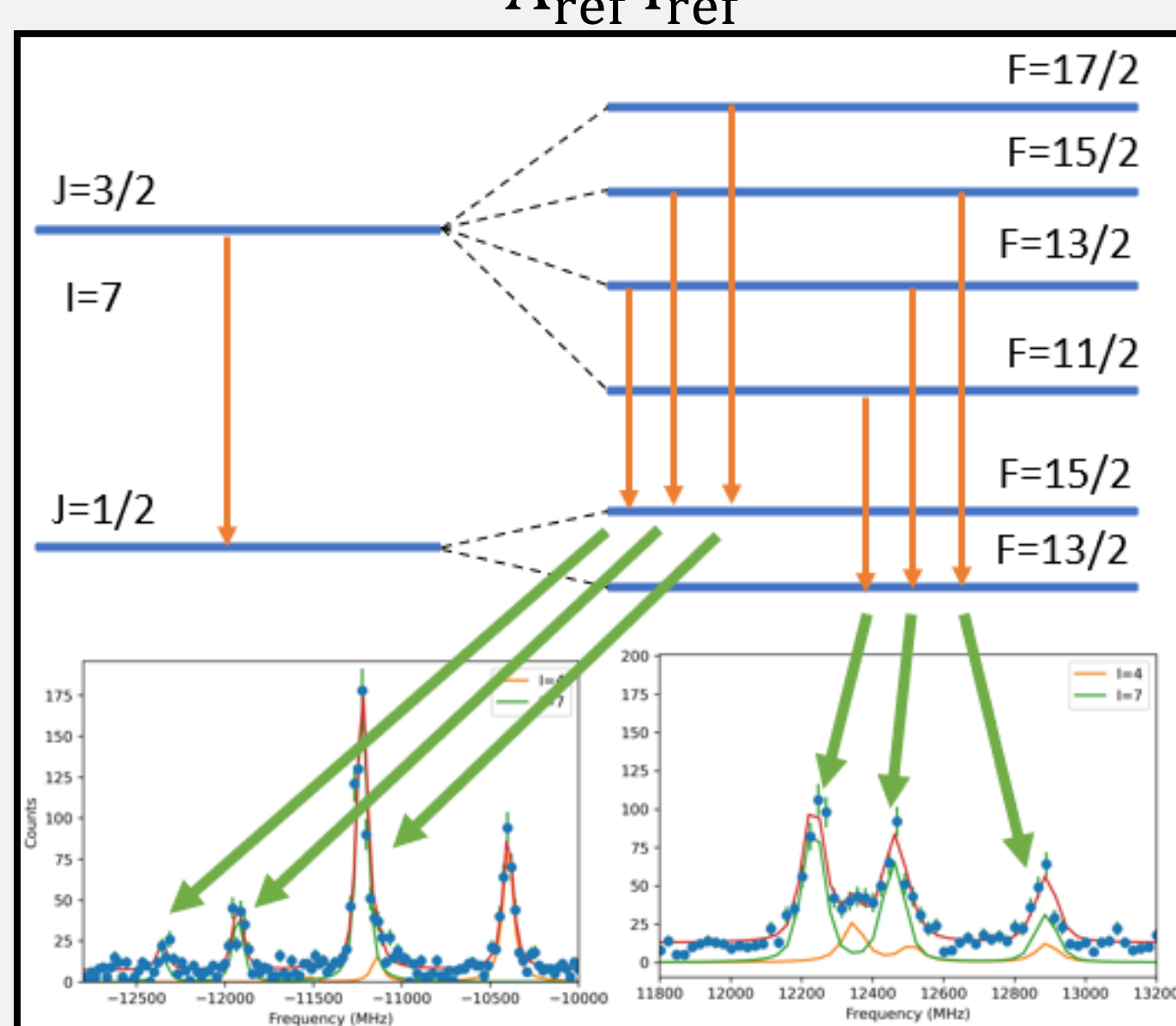
From: <https://en.wikipedia.org/wiki/Nucleon>

Atomic hyperfine structure as a probe of the nucleus:

$$\Delta E_F \approx \frac{1}{2} A C + B \frac{3C(C+1) - 4I(I+1)J(J+1)}{8I(2I-1)J(2J-1)}$$

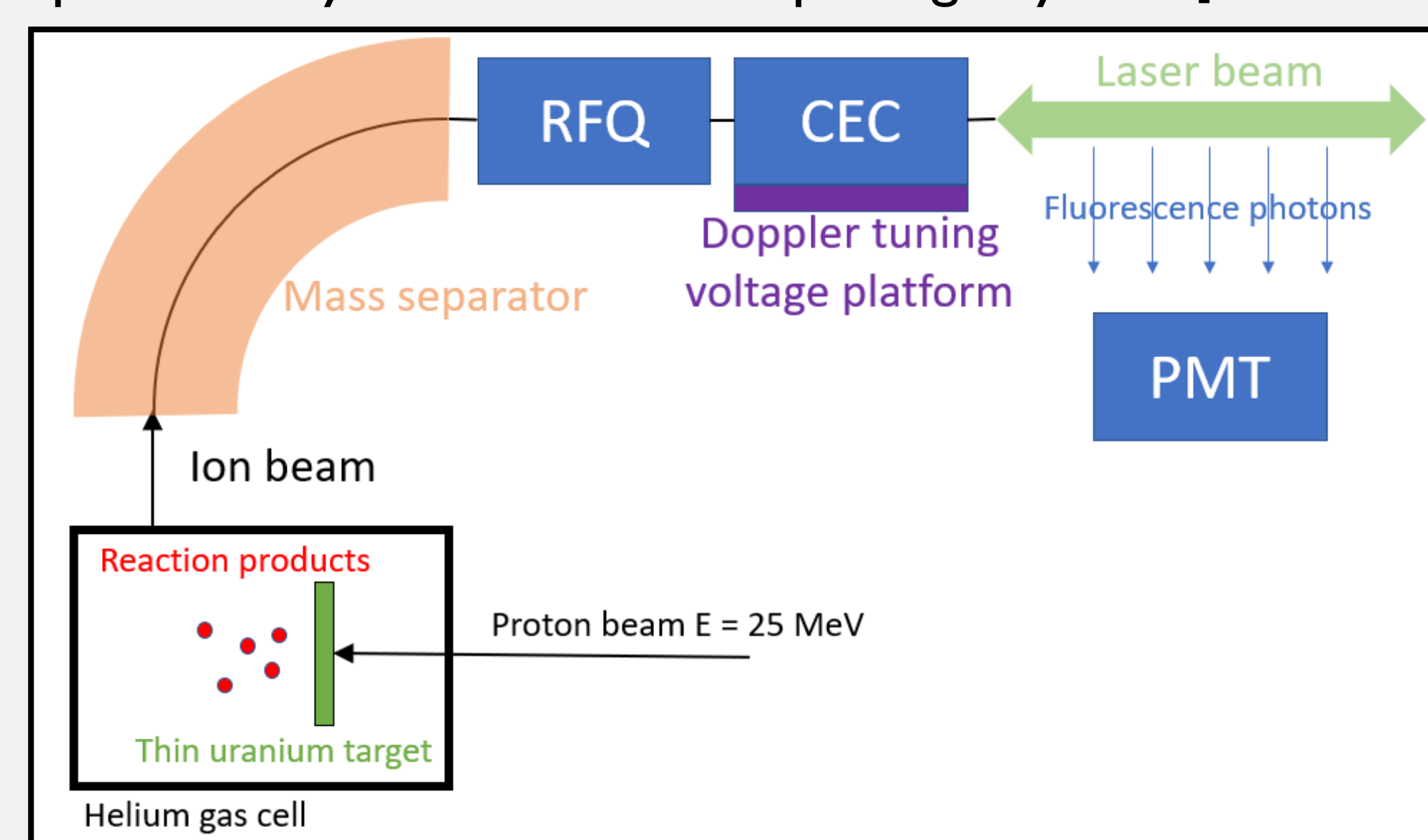
Magnetic dipole moment for a nucleus with spin I :

$$\mu \approx \frac{A}{A_{\text{ref}}} \frac{I}{I_{\text{ref}}} \mu_{\text{ref}}$$



Experimental approach: overlap a bunched radioactive beam with a CW laser beam – detect fluorescence decay

- Radio Frequency Quadrupole trap cools and bunches the beam:
 - Energy spread of less than **1 eV** - Bunching time of **100 ms** - Released bunch length **10 μs**
- Neutralize the ion bunch in Charge Exchange Cell
- Resonantly excite the atoms through Doppler tuning of the laser frequency by varying the ion velocity – detect the fluorescence photons as a function of the observed laser frequency
- Hyperfine spectra analysed with SATLAS package Python [Gins et al., 2018]

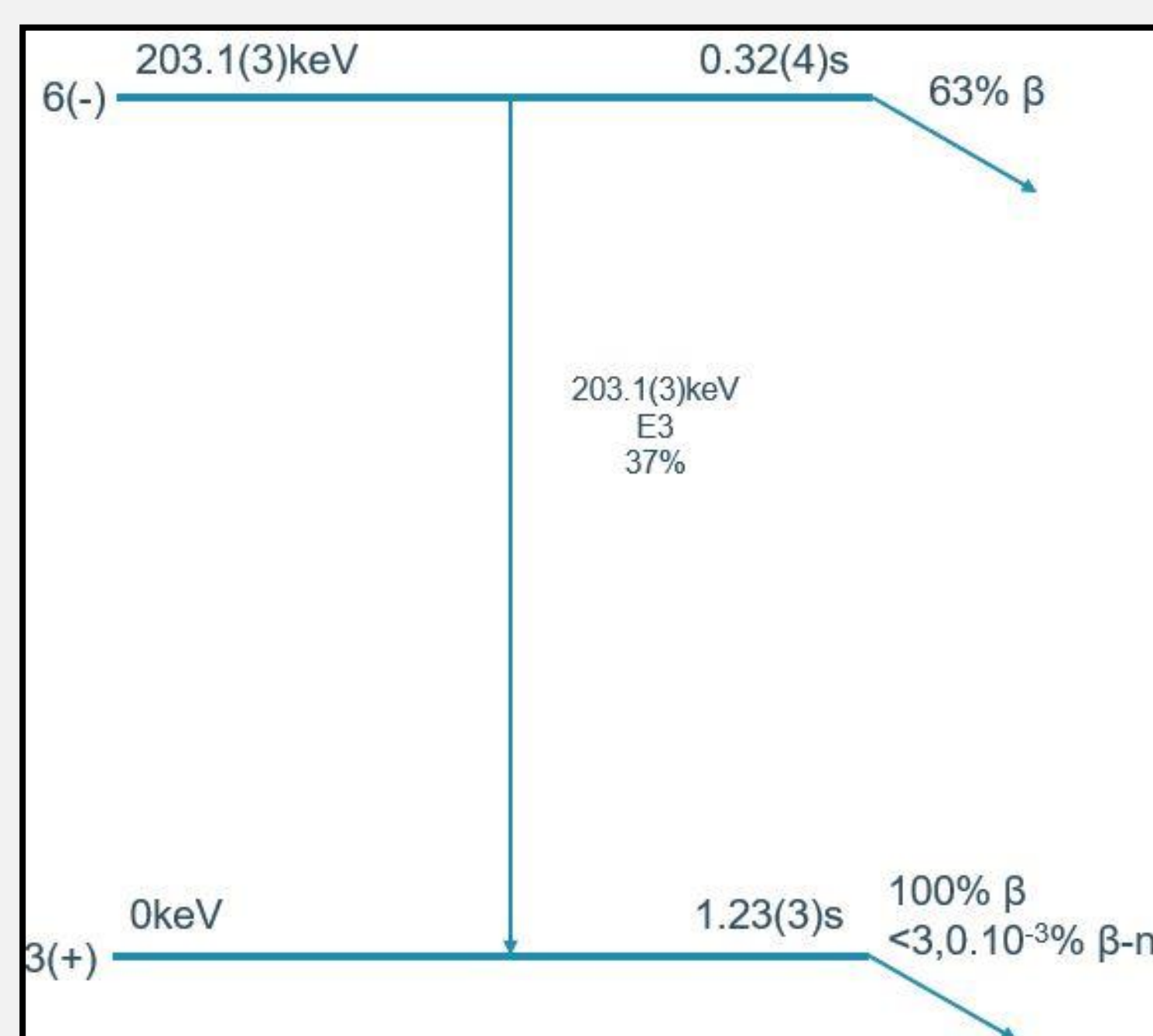


Analysis of hyperfine structure of ^{120}Ag

Literature on ^{120}Ag [Fogelberg et al., 1971]

and [Wang et al., 2003]

- Two relatively long-lived states
 - $3(+)$ and $6(-)$ spins
 - E3 transition between these states



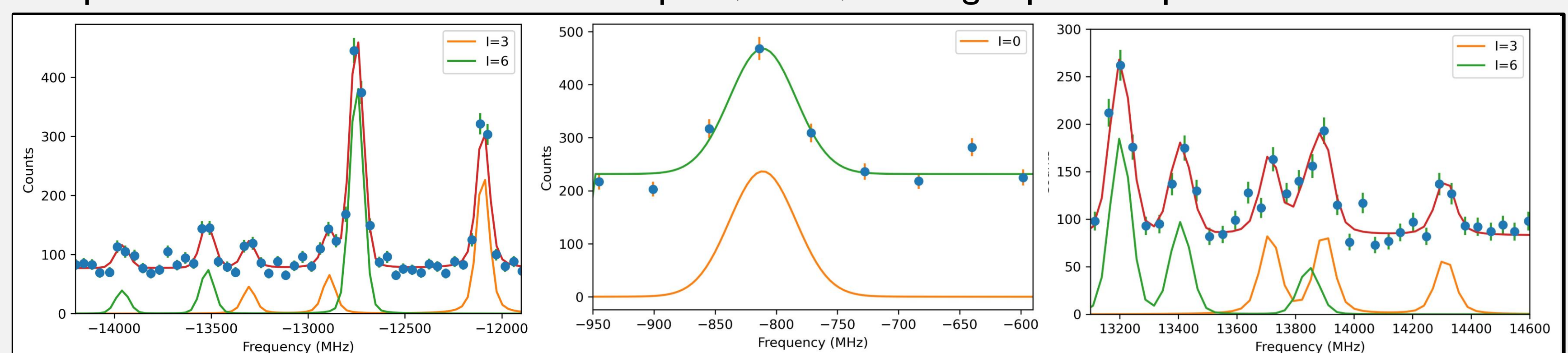
Fogelberg, B., Bäcklin, A., and Nagarajan, T. (1971). Energy levels in 114 , 116 , 118 , 120 , ^{122}Cd as observed in the beta decay of Ag isotopes. *Physics Letters B*, 36(4):334–336.

Wang, Y. et al. (2003). Beta decay of neutron rich Ag-118 and Ag-120 isotopes. *Phys. Rev. C*, 67:064303.

Gins, V., de Groote, R., Bissell, M., Granados Buitrago, C., Ferrer, R., Lynch, K., Neyens, G., and Sels, S. (2018). Analysis of counting data: Development of the satlas python package. *Computer Physics Communications*, 222:286–294.

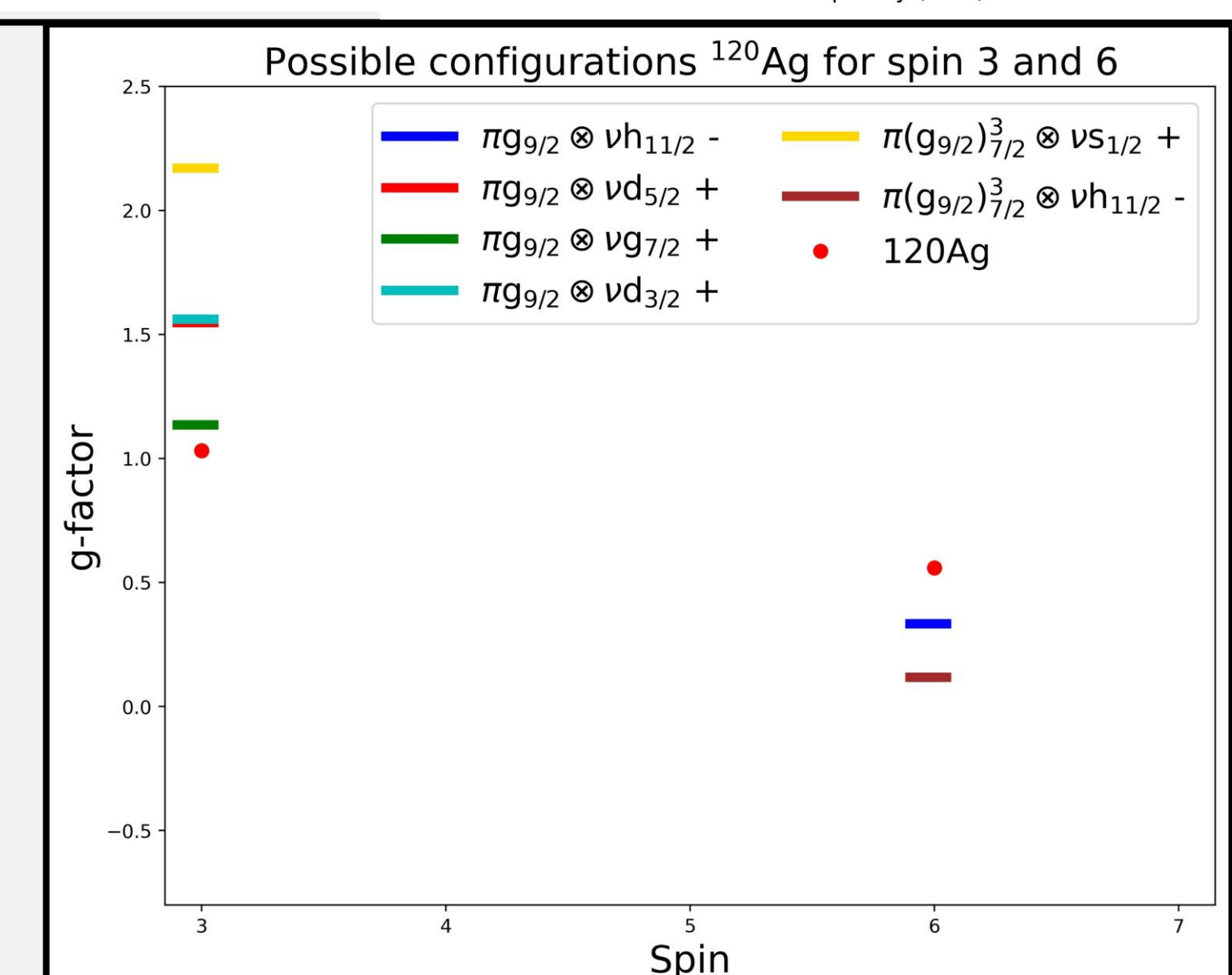
Spin assignments

- Three long-lived states!
- Spin 0 or 1 for central structure and spin 3, 6 or 4, 7 for high-spin multiplet based on E3 transition



G-factors and configurations

- 3 proton holes below $Z = 50$, in the $g_{7/2}$ orbit for the high-spin states
- The g-factors are sensitive to the orbital of the unpaired neutrons: $g_{7/2}$ for the $I^\pi = 3(+)$ state, $h_{11/2}$ for the $I^\pi = 6(-)$ state.
- The low-spin state has a mixed wave function



Conclusion

- Spin assignments**
 - Cleared up some uncertainties and conflicting results in literature
 - Discovered **one new isomeric state** in both ^{118}Ag and ^{120}Ag
- Configurations**
 - Obtained g-factors that can be used to benchmark different models
 - The validity of the *extreme single particle shell model* was benchmarked in this region and shown to be not sufficient for these isotopes

Future outlook

- Laser spectroscopy studies at CERN**
 - Firmly establish spins for states in ^{118}Ag and ^{120}Ag
 - Higher statistics at CERN
- β-decay spectroscopy on isomeric beams at CERN**
- Mass measurements to determine the excitation energies of new isomeric states**