ISOLDE Solenoidal Spectrometer

MANCHESTER 1824

The University of Manchester

Single-particle state evolution along the N = 127 isotone chain using the *d*(212Rn,*p*)213Rn reaction (IS689)

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ISOLDE Physics Workshop and USERS meeting

15th December

MANCHESTER 1824

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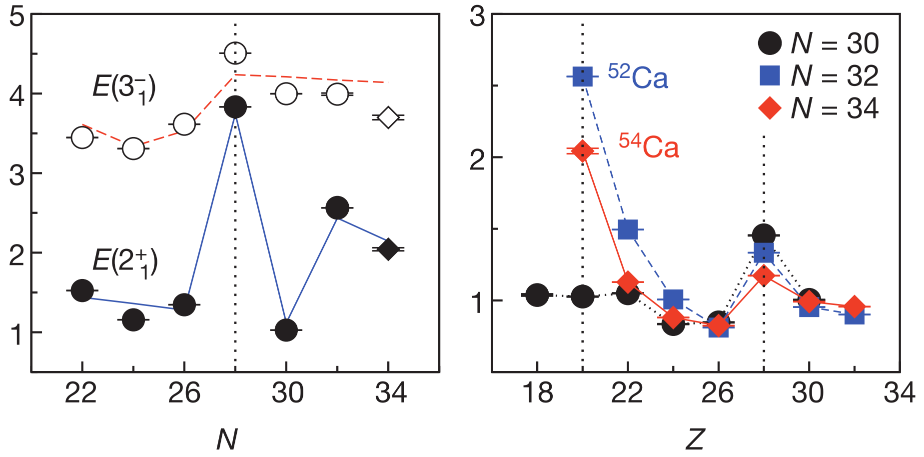
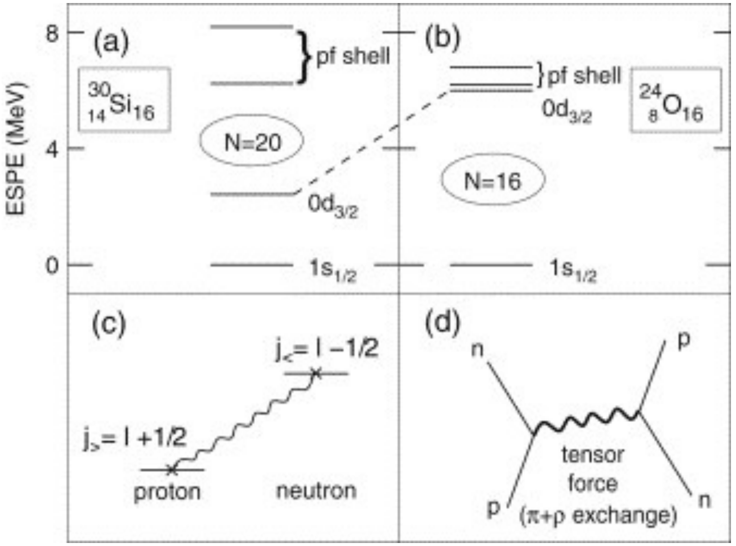
Single particle evolution – light nuclei

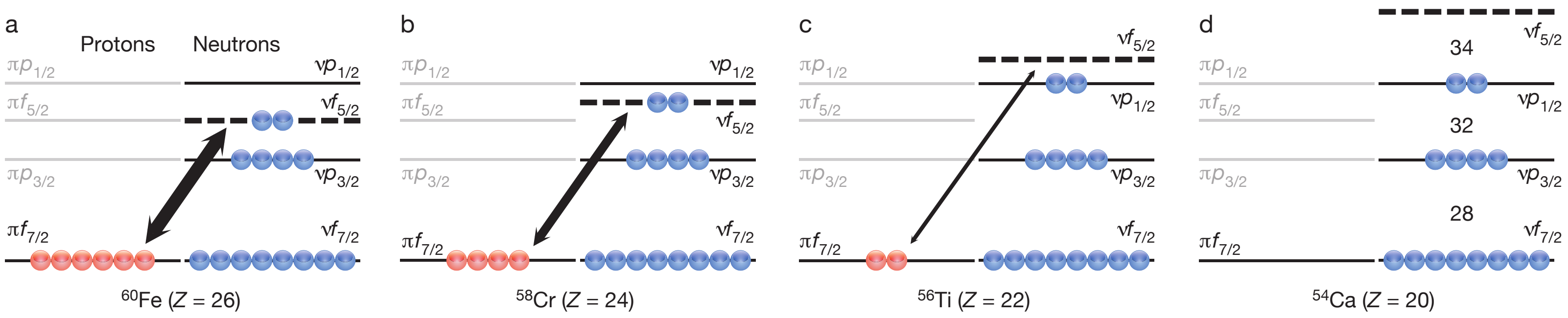
- Far from stability, shell closures have been shown to evolve for systems with imbalances of protons and neutrons

- Studies of light neutron-rich system have led to the discovery of new shell closures





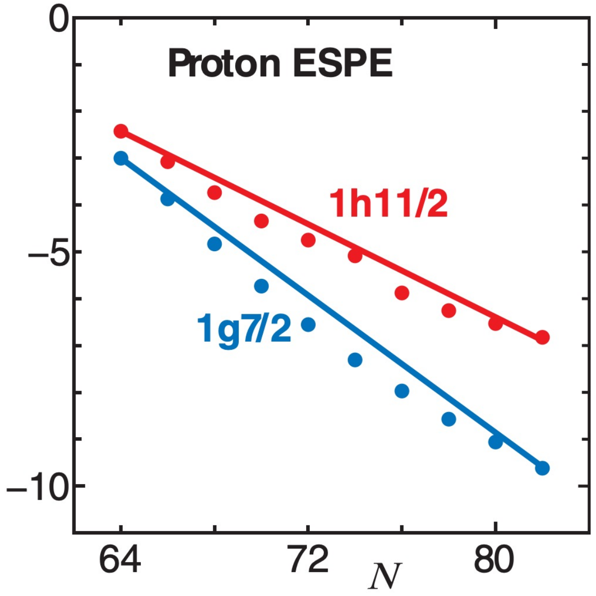
T.Otsuka and D. Abe Prog. In Particle and Nuclear Physics **59** 425 (2007)



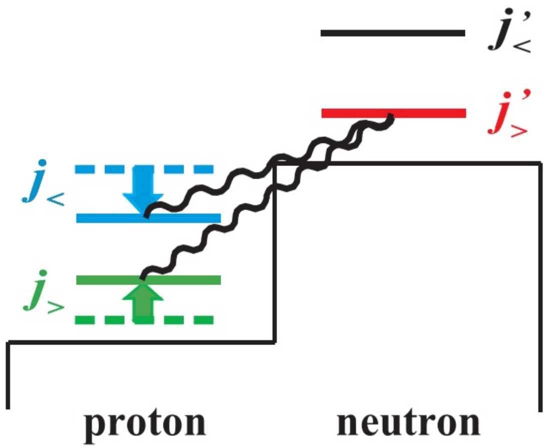
D. Steppenbeck *et al*, Nature **502** 207 (2013)

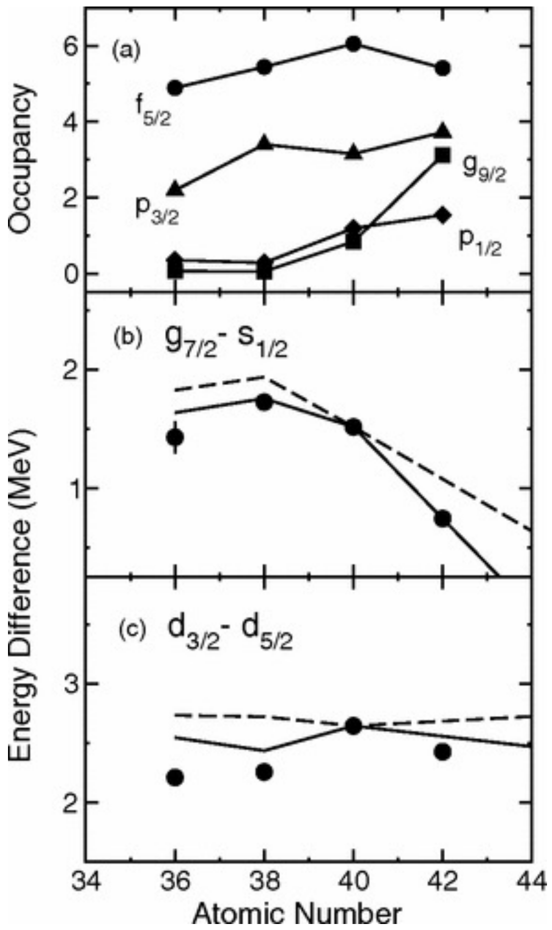
Single particle evolution – heavy nuclei

- In heavier stable nuclei trends have also been observed, particularly in high-j states as other high-j states fill with nucleons
- Studying chains of isotopes/isotones have pointed to the inclusion of a tensor interaction to explain systematics



Otsuka *et al*. Phys. Rev. Lett. **95,** 232502 (2005)

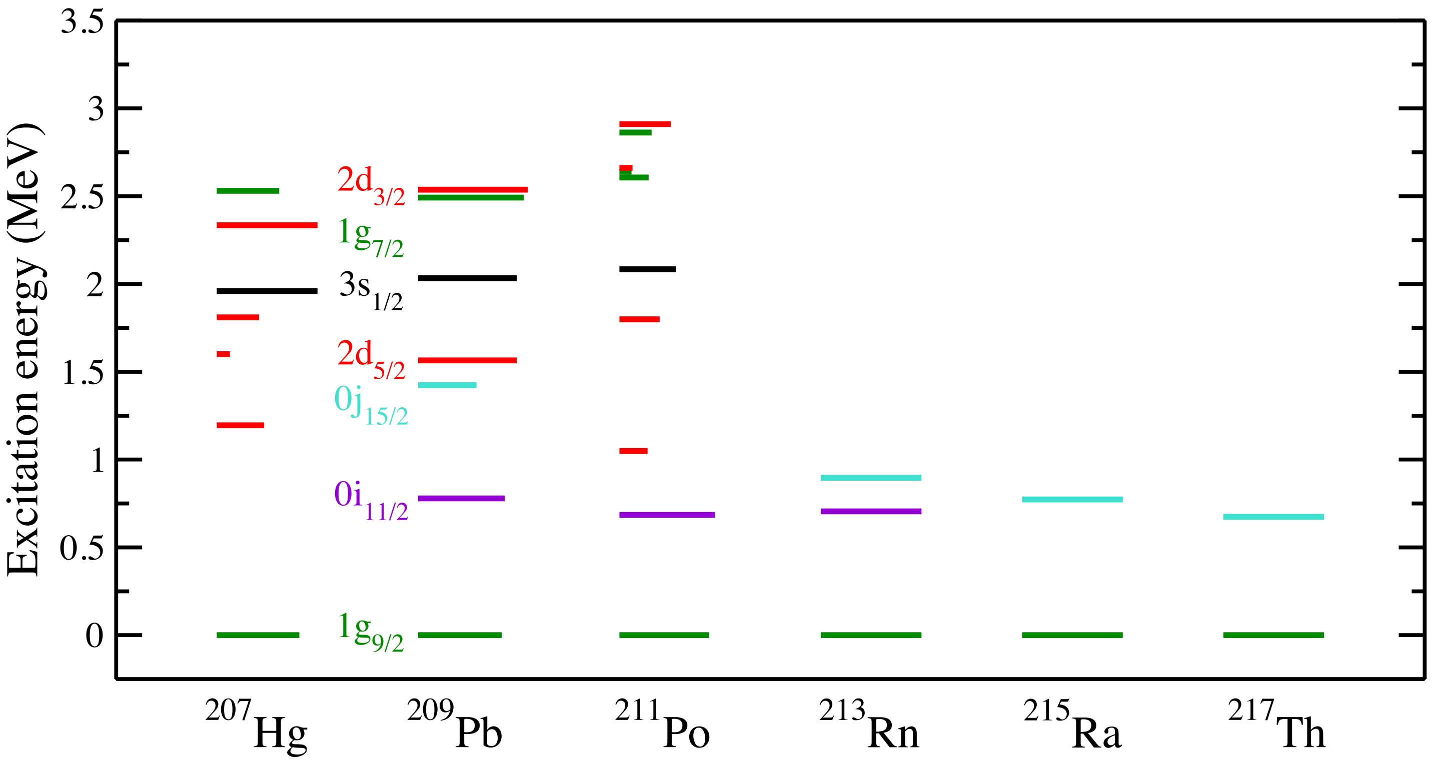




D.K. Sharp *et al*, Phys.Rev.C **87** 014312 (2013)

Single particle evolution along N=127

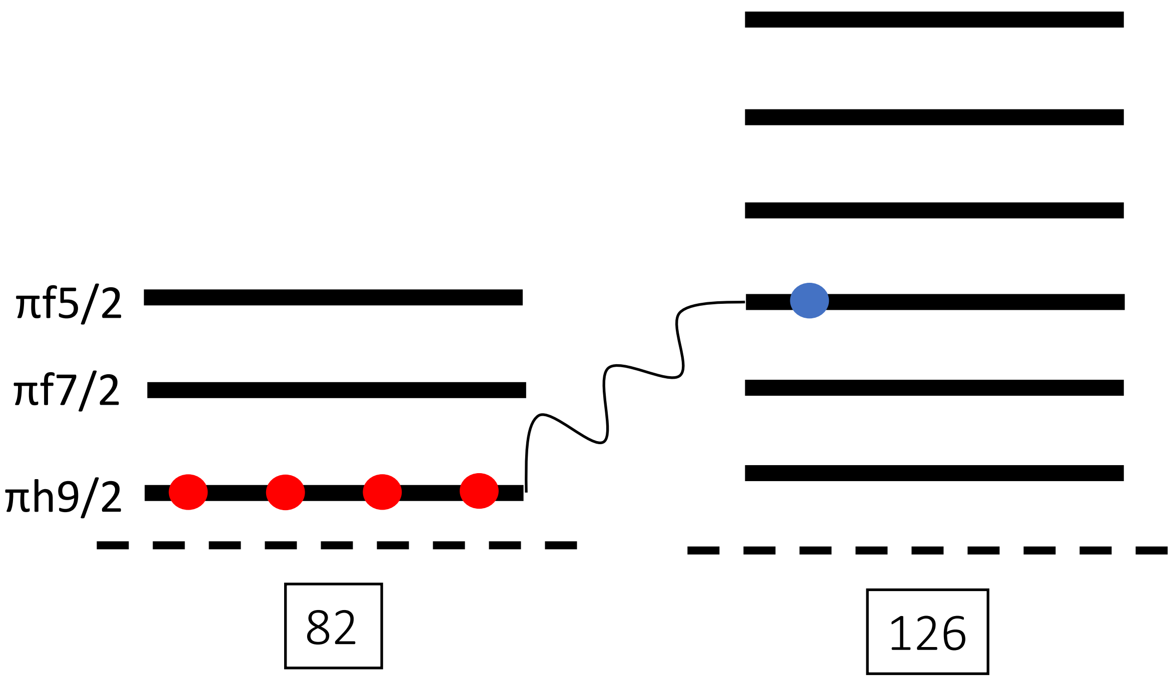
- Radioactive beams at HIE-ISOLDE allow chains further from stability to be studied
- Studies can be extended to N=126 isotones
- Currently data on states up to Z=84 (211Po) are known with data sensitive to single-particle behaviour
- Above this only energies are known with spin assignments based on systematics
- The location of nuclei with one neutron outside the N=126 closed shell makes them ideal testing grounds for modern shell-model calculations



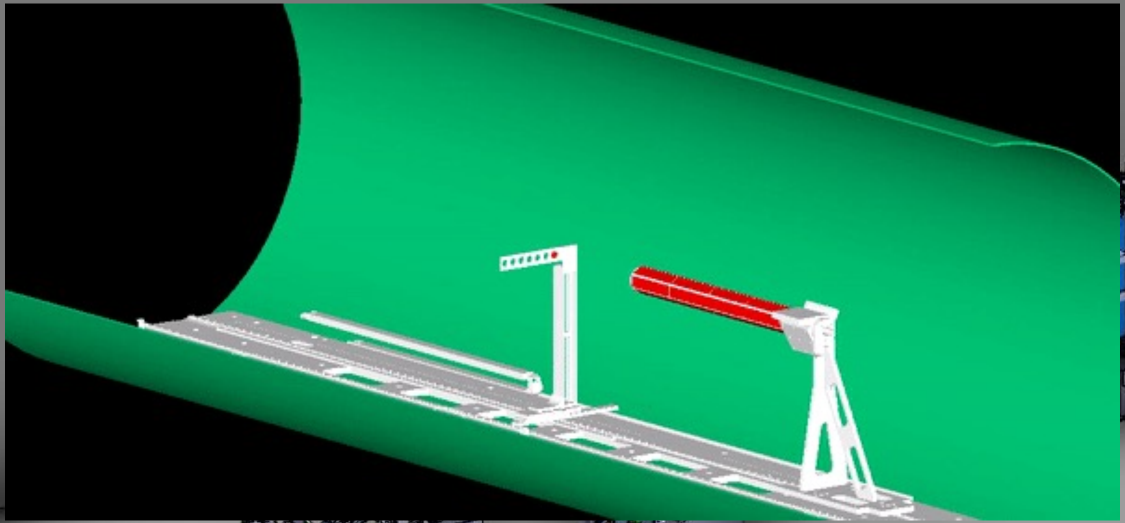
D. K. Sharp et al. INTC-P-594 (2020)

Single particle evolution along N=127

- Along this isotone chain it is expected that the nodeless πh9/2 orbital is filling
- Changes in single-particle centroids for the single neutron outside N=126 is then attributed to protons in the πh9/2 orbital
- Aim is to probe the strength of $s_{1/2}$, $d_{5/2}$, $g_{9/2}$, $i_{11/2}$ and $j_{15/2}$ orbitals
- Changes due to the tensor interaction should be pronounced in $i_{11/2}$ and $j_{15/2}$ orbitals



ISOLDE Solenoidal Spectrometer (ISS)



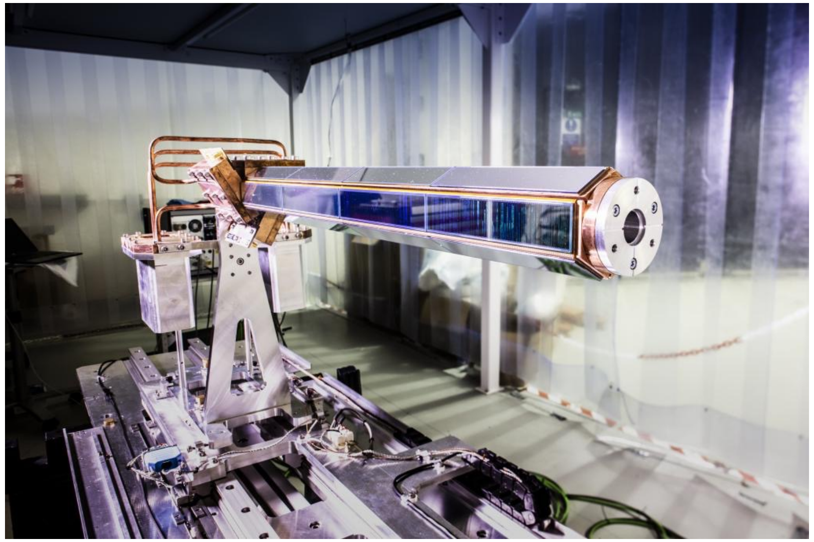
https://isolde-solenoidal-spectrometer.web.cern.ch/content/stfc-news-piece-iss-experiments

- 212Rn(*d*,*p*)213Rn reaction has been performed.
  - 7.63 MeV/u
  - ~10^6 pps
- Highest beam energy available was used to maximise cross-section of high-ℓ states
- Angular distributions are more forward peaked at higher beam energies
- Inverse kinematics protons at forward θ_{cm} are emitted at backward θ_{lab}

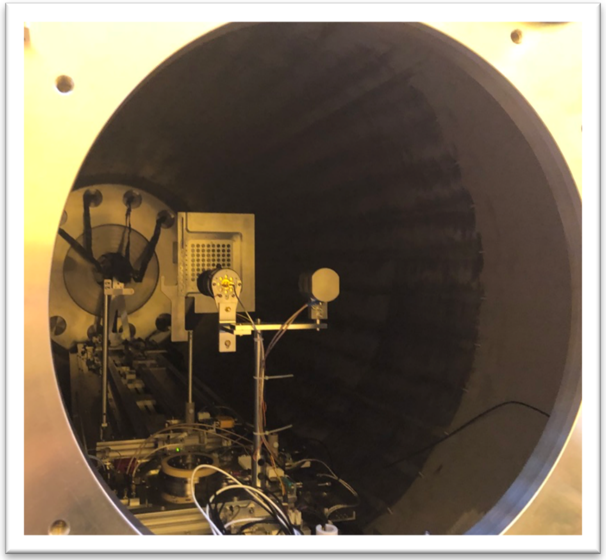
https://hie-isolde-project.web.cern.ch/hie-isolde-project/

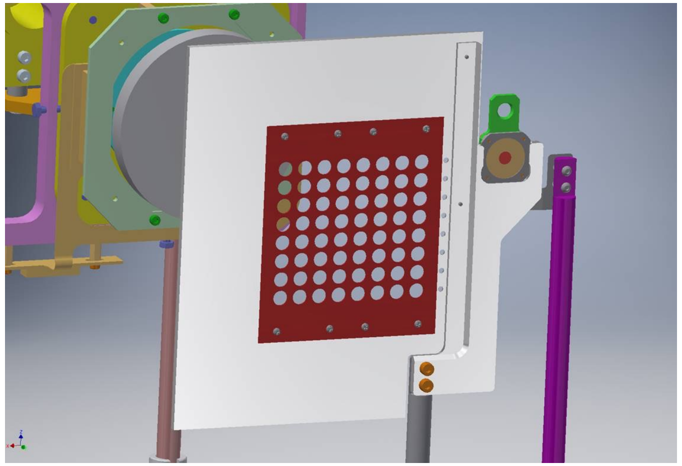
Experimental Details

- Beam: 212 Rn at 7.63 MeV/u
  - No evidence of any impurities
- CD2 targets: ~ 125 µg/cm^2
- Array: −50 cm from target
  - θ_{cm} = 10° to 40°
- Field: 2.0 T
- Si (*d*,*d*) monitor: +15cm from target, θ_{cm} = 15°

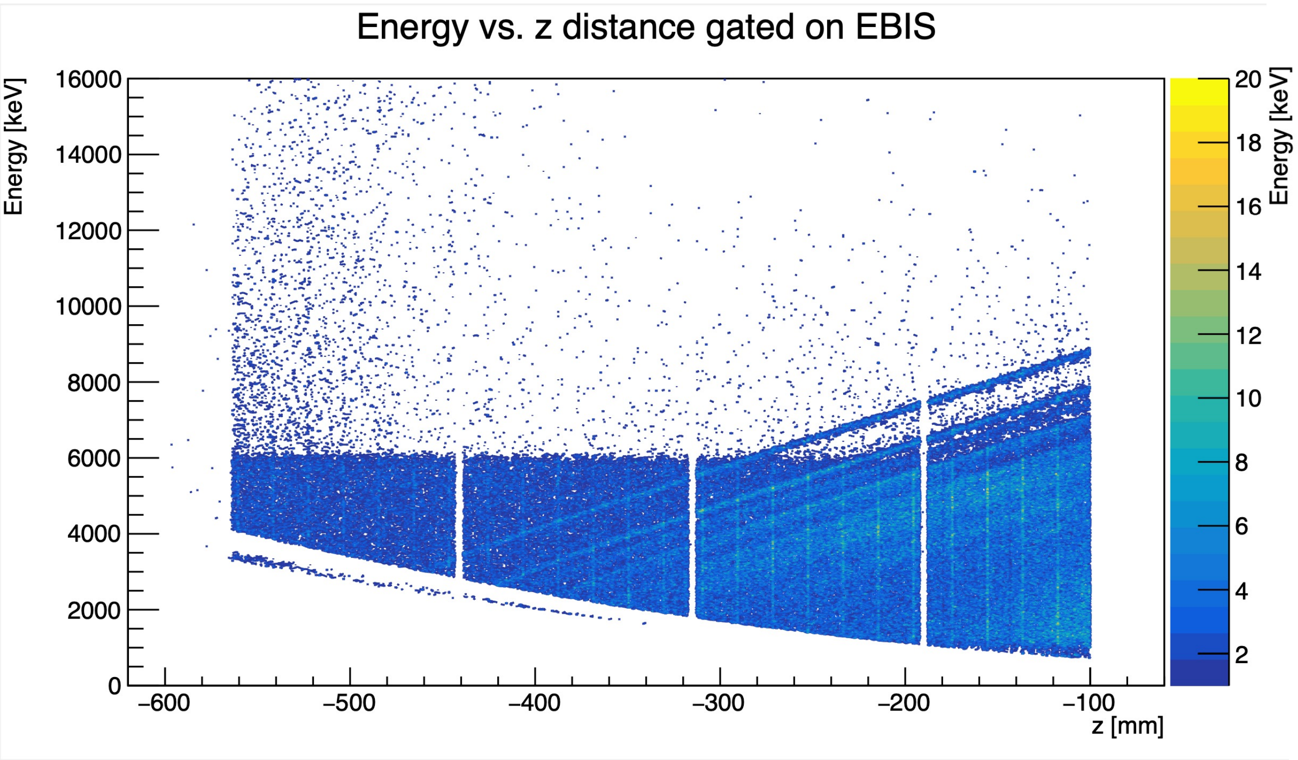


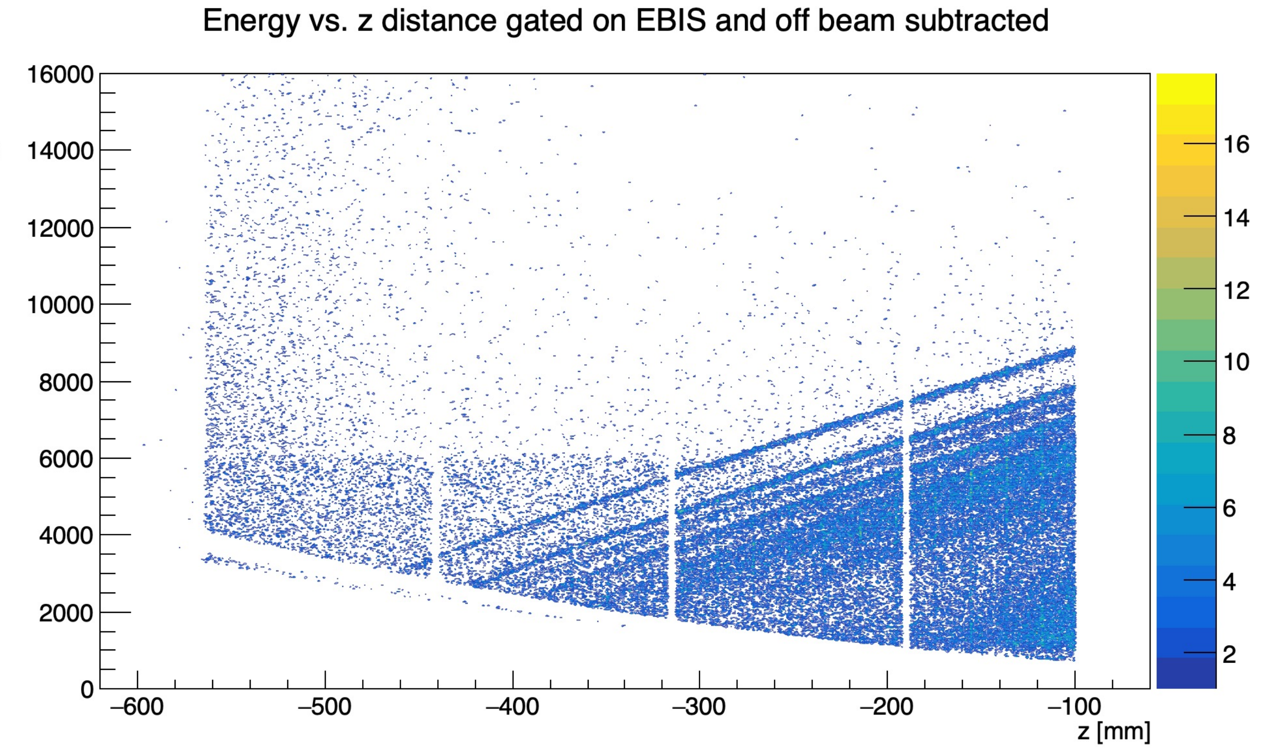
https://isolde-solenoidal-spectrometer.web.cern.ch/setup/si-detector-array





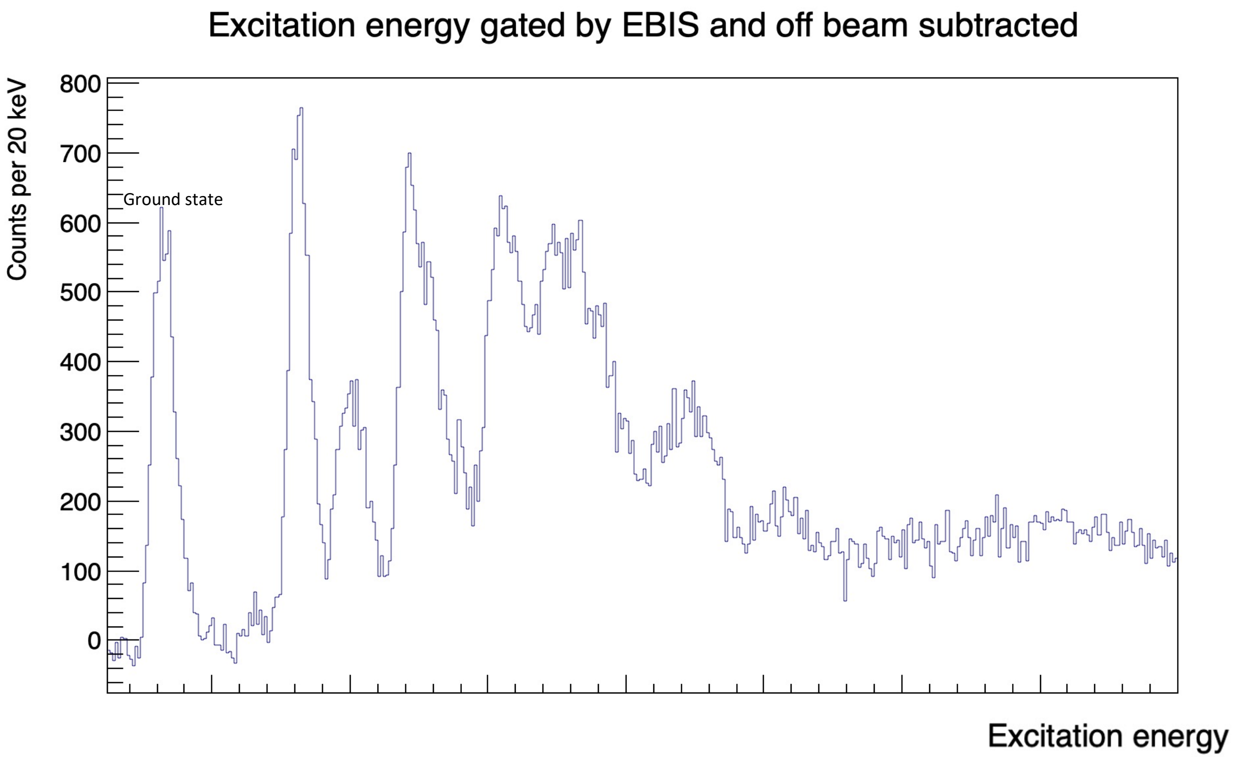
Analysis Method

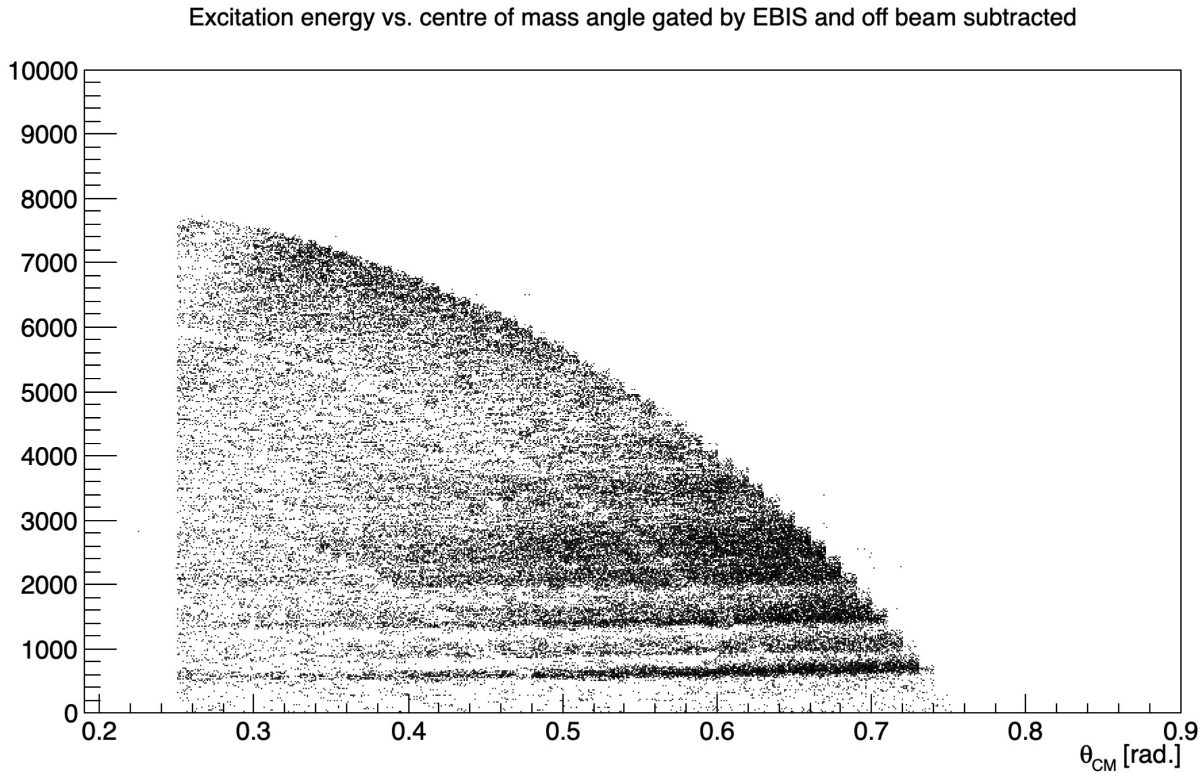




$$E_{\mathrm{cm}} = E_{\mathrm{lab}} + \frac{m}{2} V_{\mathrm{cm}}^2 - \frac{m V_{\mathrm{cm}} z}{T_{\mathrm{cyc}}}$$

Preliminary Results – excitation spectrum

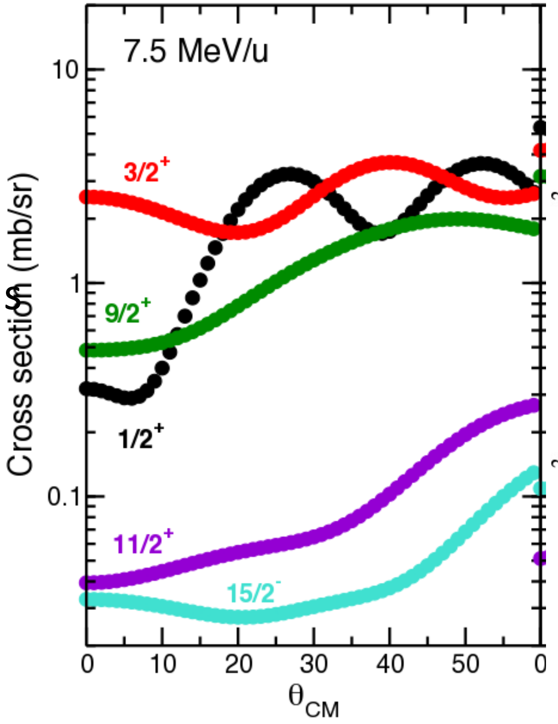


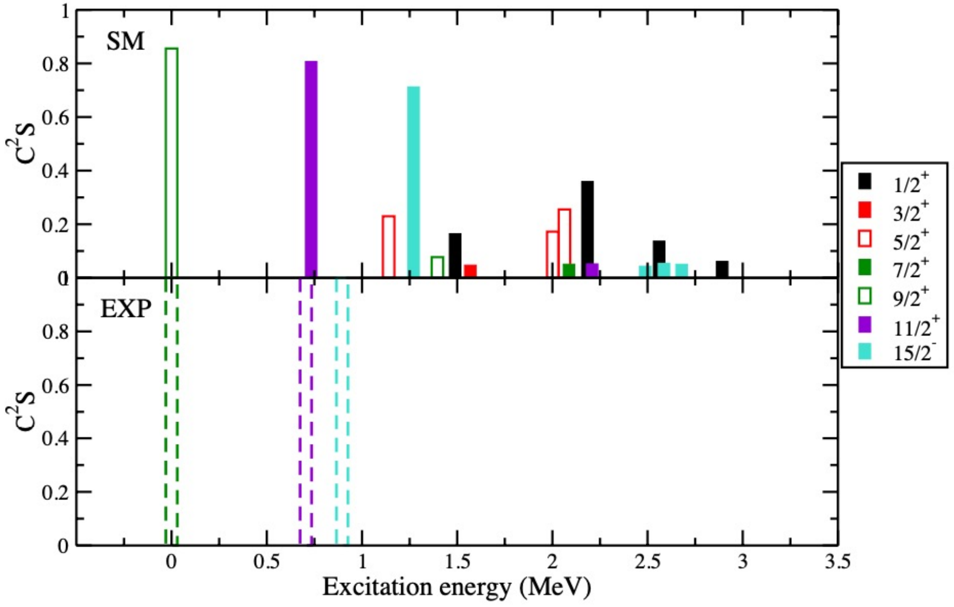


DWBA calculations

$$\left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{EXP}} = C^2 S_{j\ell} \left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{DWBA}}$$

- Absolute cross sections will be compared to DWBA calculations from PTOLEMY
- Allows ℓ assignments of states and spectroscopic factors to be extracted
- Single-particle centroids can be calculated and compared with theoretical calculations
- Different optical models will be used to compare absolute spectroscopic factors

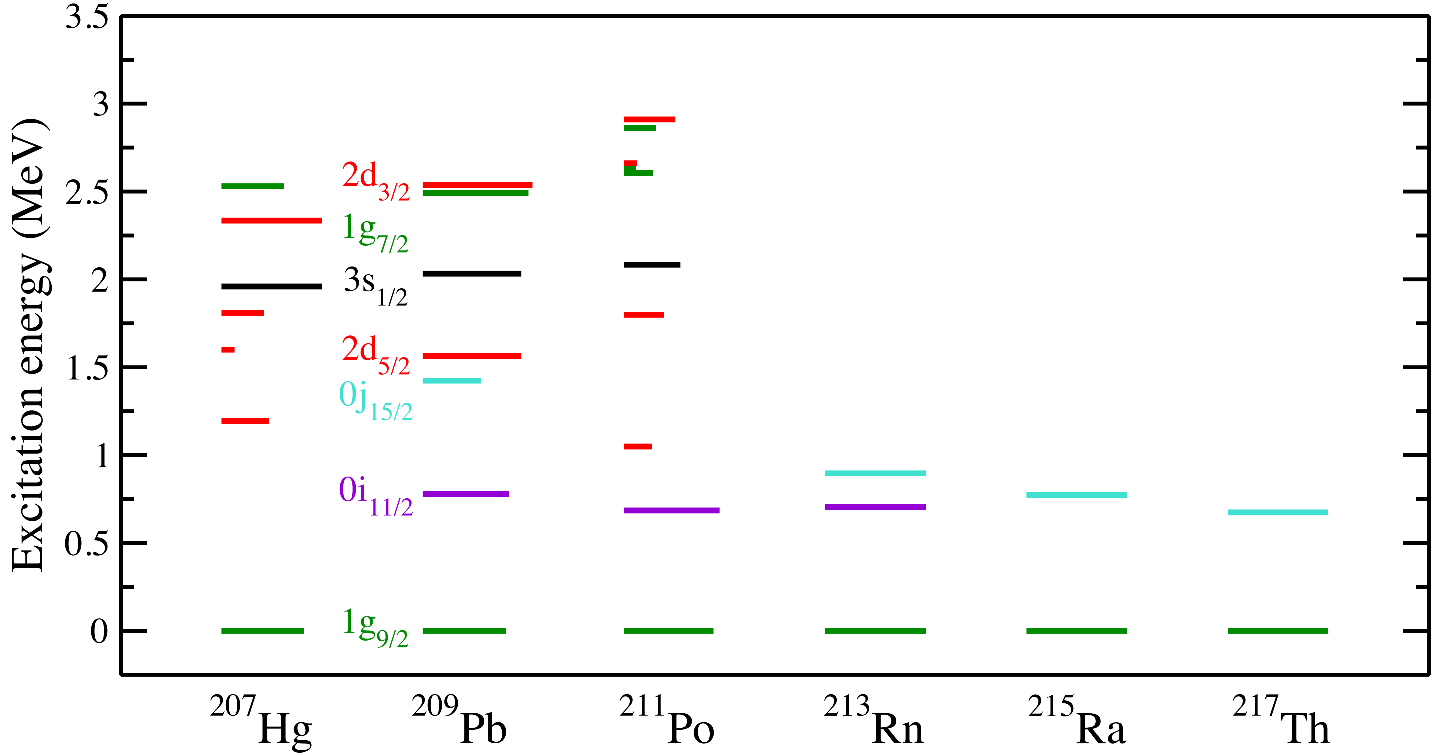




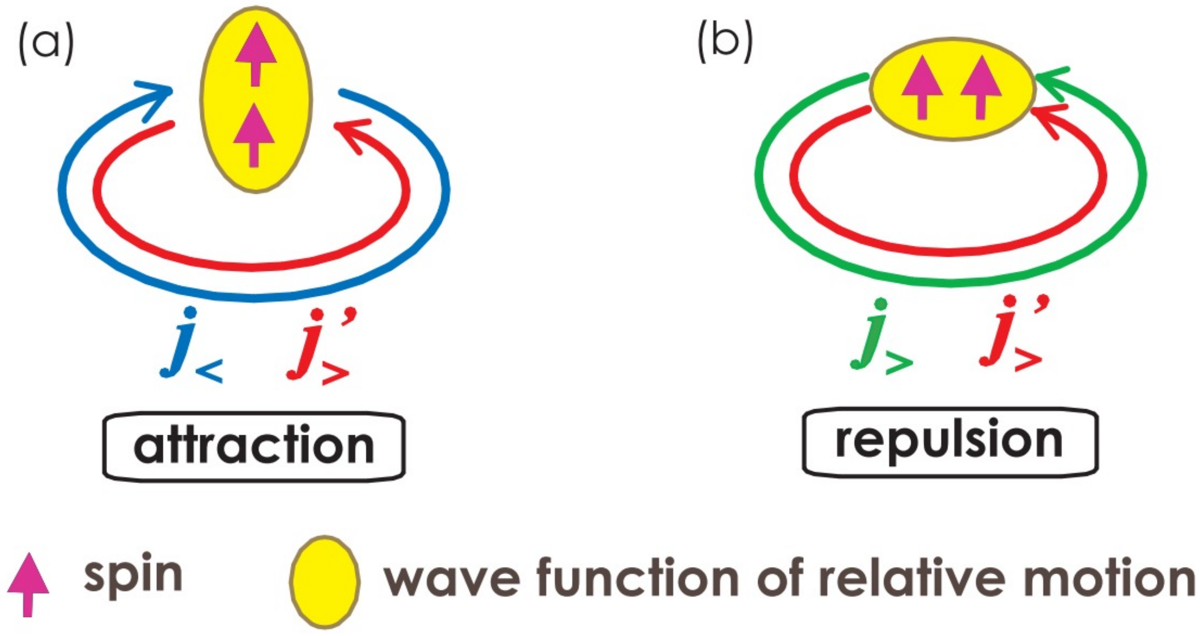
D. K. Sharp et al. INTC-P-594 (2020)

Conclusions and Future Work

- *d*(212Rn,*p*)213Rn
  - ℓ assignments
  - Extract SF
- 214Ra(d, p)215Ra



Tensor interaction



$$\Delta \epsilon_p(j) = \frac{1}{2}\{V^{T=0}_{j,j'} + V^{T=1}_{j,j'}\}n_n(j')$$

Otsuka *et al*. Phys. Rev. Lett. **95,** 232502 (2005)