MANCHESTER
1824

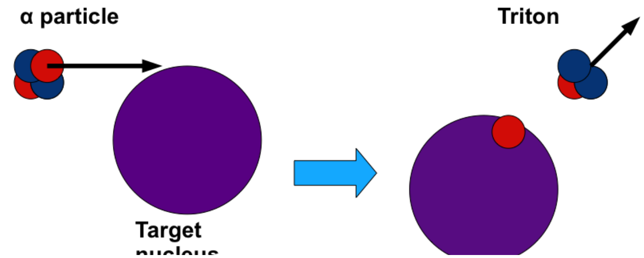
The University of Manchester

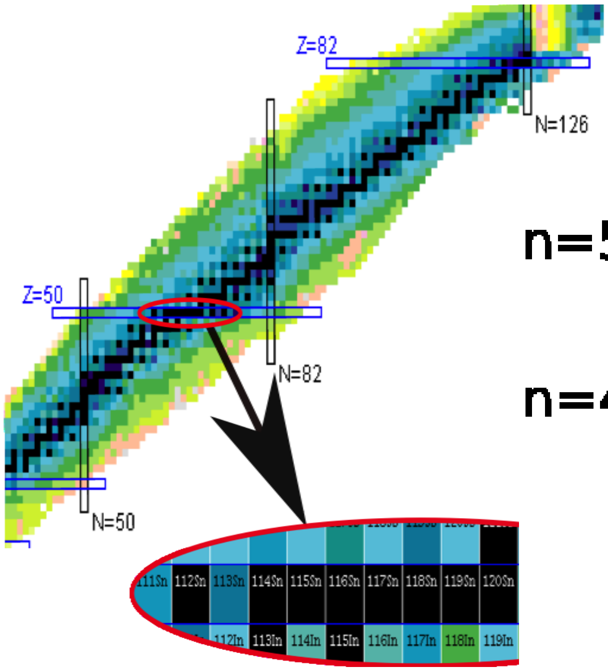
Investigating trends in proton single-particle states outside Z=50 isotopes

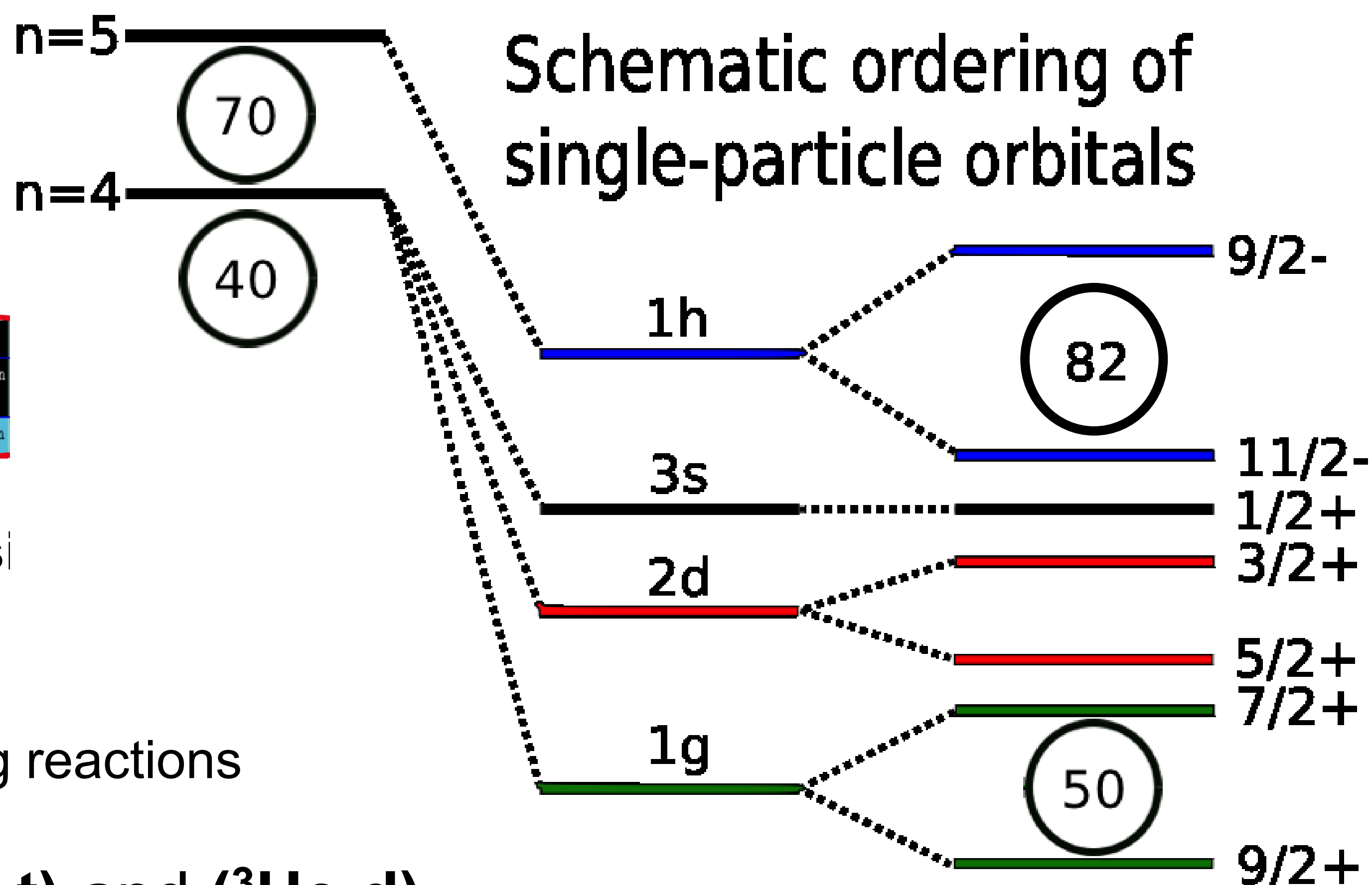
AJ Mitchell

NPPD Conference – Glasgow 2011

Single-particle states







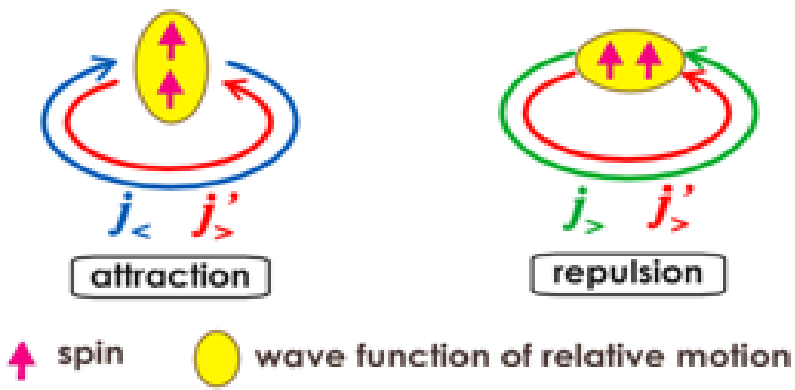
- Investigate **proton si**
states with increasing

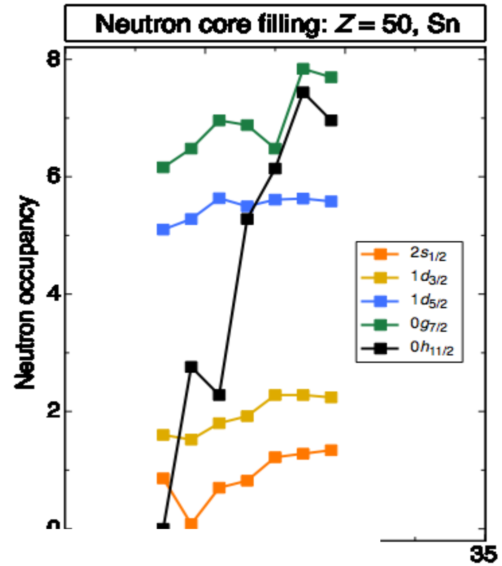
- Single-proton adding reactions on ***Z*=50** core:

=> **(α,t)** and **(^{3}He,d)**

Motivation –Tensor Interaction

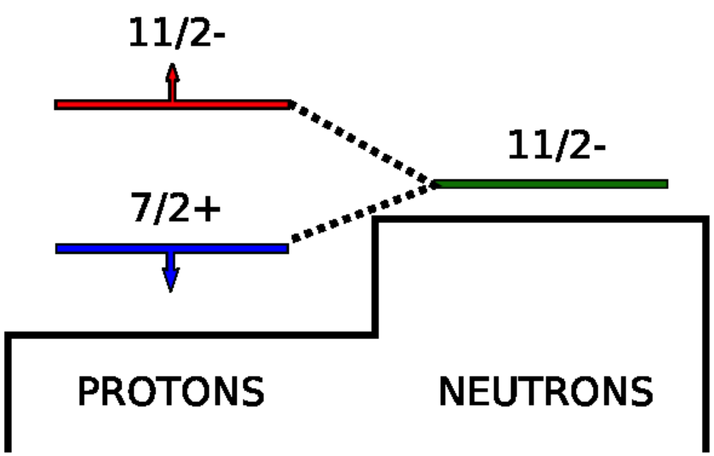
Tensor interaction: Driving force behind evolution of single-particle states?

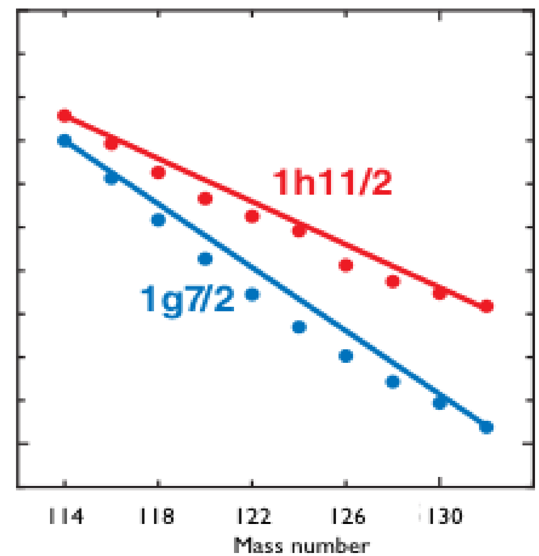




Neutrons predominantly fill ***νh***$_{11/2}$ orbital (previous (d,p) measurements).

Schematic represe
of the **monopole**
interaction produ
by the tensor force
between ***ν****j*$_<$ and
π *j*$_{<,>}$ orbitals.





Review Letters 95, 232502 (2005)

Expect increase in
πg$_{7/2}$ and ***πh***$_{11/2}$ or

Single-Particle Transfer

Transfer reactions:
• Single-step processes
• Change of single degree of freedom
• Highly selective in populating discrete low-lying states in the atomic nucleus

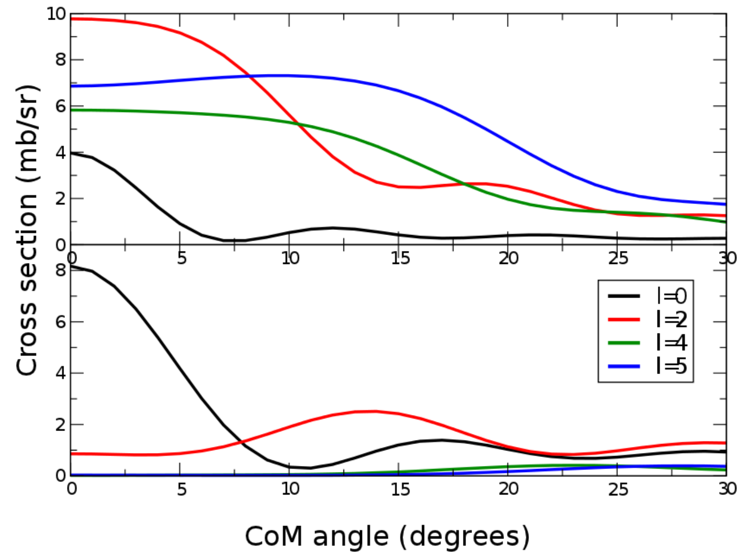
Can be modelled using the distorted-wave Born approximation (**DWBA**):

• Distorted wave describes relative motion of the nuclei
• Generated by realistic potential between nucleons in the entrance and exit channels – **Optical Potential**:

$$V(r) = -Vf(r) - iWf(r) + Vc + Vso\frac{1}{r}\frac{df(r)}{dr}(L.S)$$

where $$f(r) = \frac{1}{1+\exp\left(\frac{r-R}{a}\right)}$$

Theoretical distributions of (α,t) and (^{3}He,d) reactions on ^{124}Sn target



(α,t) 37.5 MeV

(^{3}He,d) 25.0 MeV

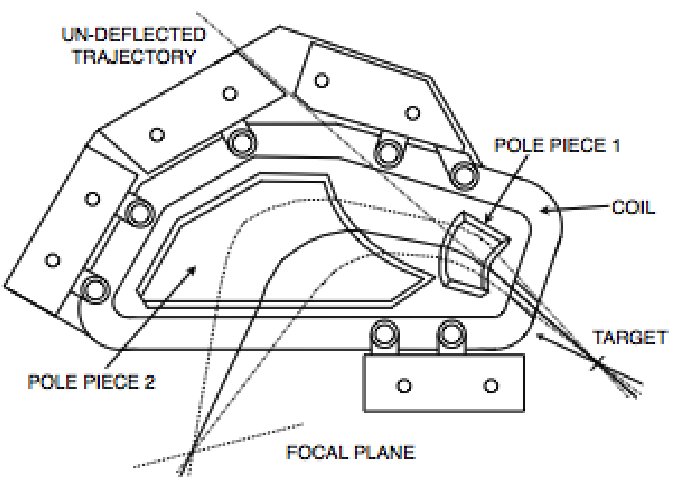
Transfer of angular momentum depends on reaction kinematics
⇒ **(α,t) high *j***
⇒ **(^{3}He,d) low *j***

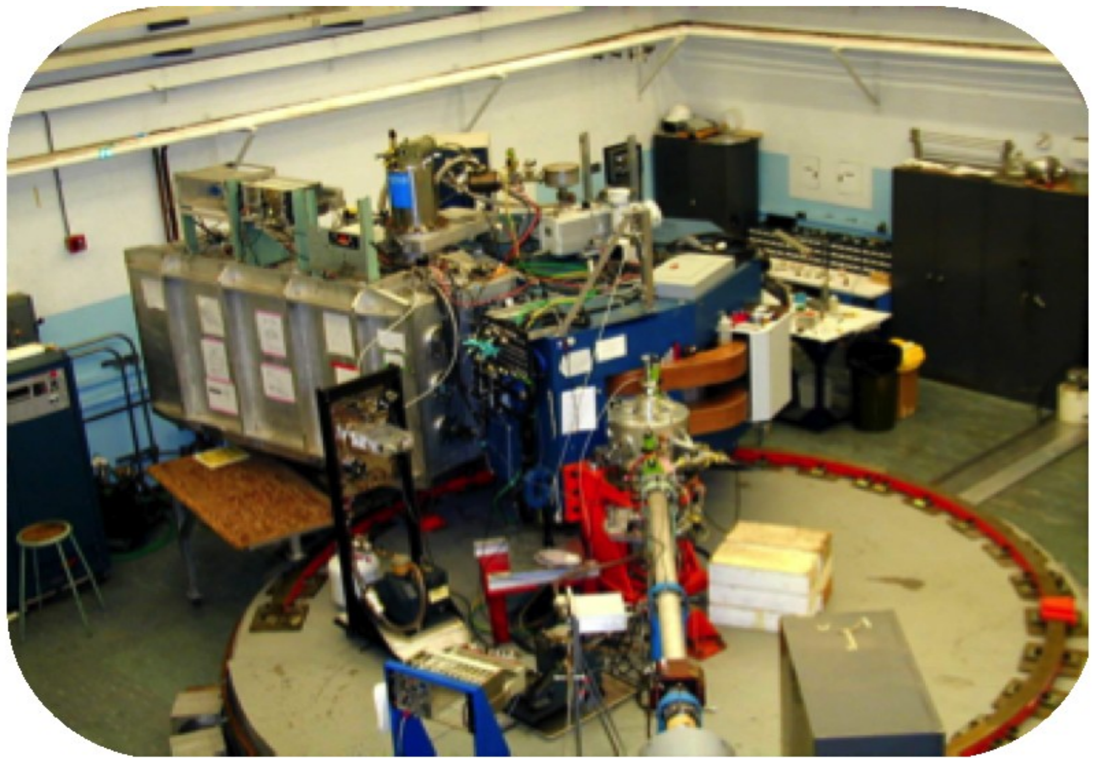
Reactions performed at **peaks** of distributions – more reliable

Experimental set up –
A. W. Wright Nuclear Structure Laboratory

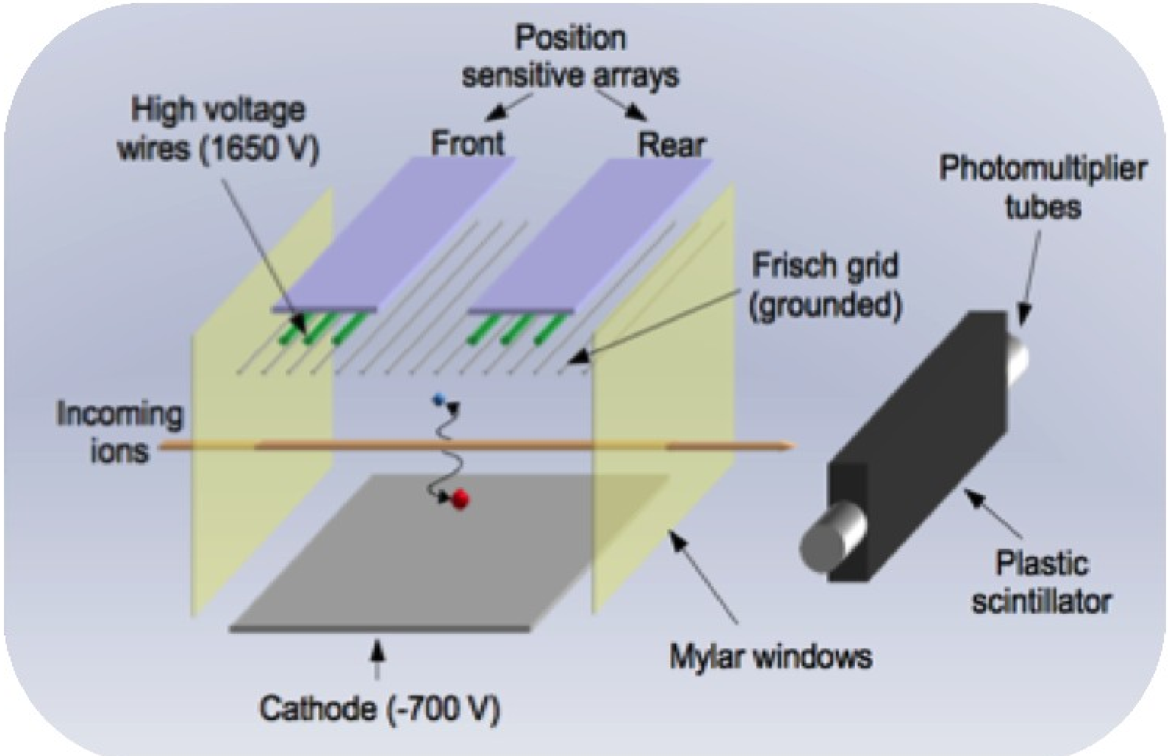
ESTU tandem Van de Graaff accelerator:

- **15.0 MeV α** particles for **elastic scattering**
- **37.5 MeV α** particles for **(α,t) reactions**
- **25.0 MeV ^{3}He** nuclei for **(^{3}He,d) reactions**





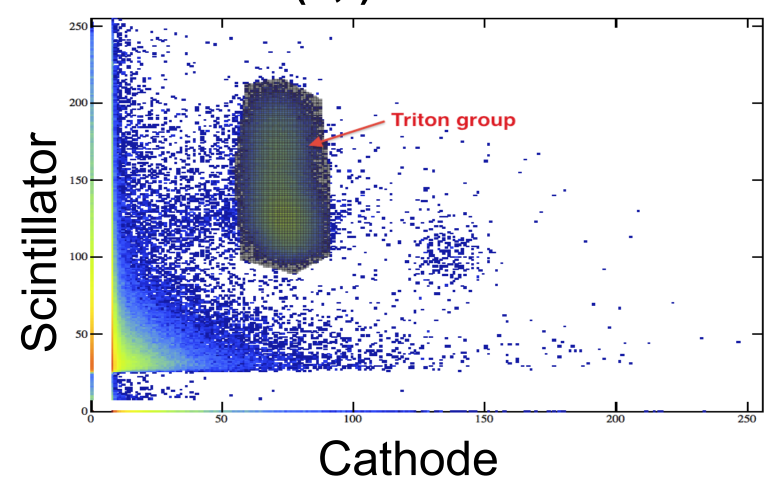
Data acquisition



Simplified schematic of particle detection system

- **High voltage wires** – position in focal plane
- **Cathode** – energy loss of particles, ΔE
- **Scintillator** – final energy of particles, E

$^{124}Sn(\alpha,t)^{125}Sb$ at 18°

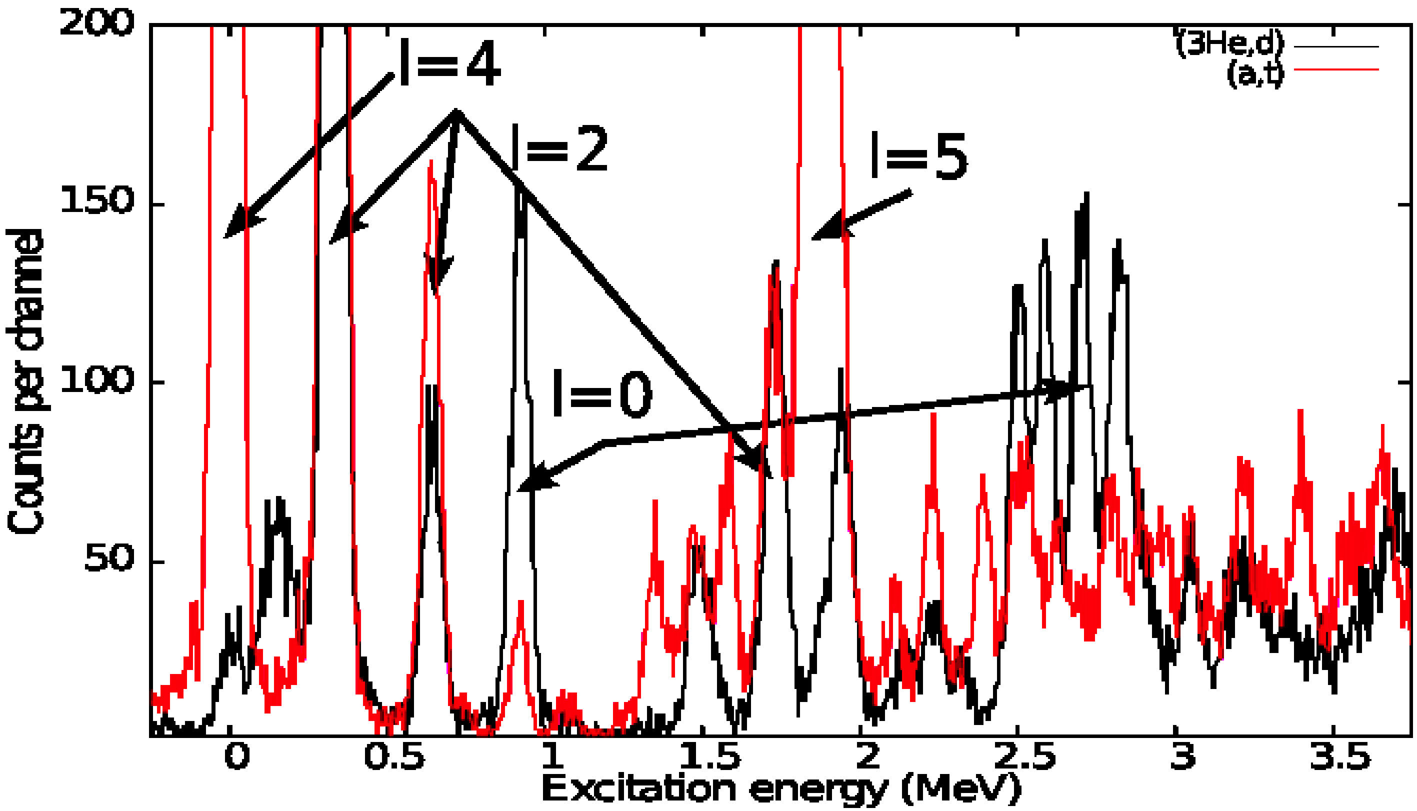


These measurements are used in particle identification.

Software gates exclude unwanted data from final spectra to be analysed.

Energy spectra

^{125}Sb energy spectra from (α,t) and (^{3}He,d) reactions



- (^{3}He,d) scaled for comparison with (α,t) spectrum
- High-*j* dominant in (α,t), low-*j* dominant in (^{3}He,d)
- *l*=2 appear in both
- Typical resolution
  - (α,t) ~ 60 – 75 keV
  - (^{3}He,d) ~ 50 – 75 keV

Analysis

- **Target thicknesses** determined using elastic scattering of α particles.
- Subsequent calculations use product of target thickness and aperture size to minimise error.

Target	Thickness (μg cm^{-2})	Enrichment (%)
^{112}Sn	107.0(5)	80.04(5)
^{114}Sn	223.3(7)	61.23(5)
^{116}Sn	211.6(6)	95.60(5)
^{118}Sn	137.5(5)	97.79(5)
^{120}Sn	168.5(6)	98.05(5)
^{122}Sn	100.9(4)	92.19(5)
^{124}Sn	86.8(4)	96.17(5)

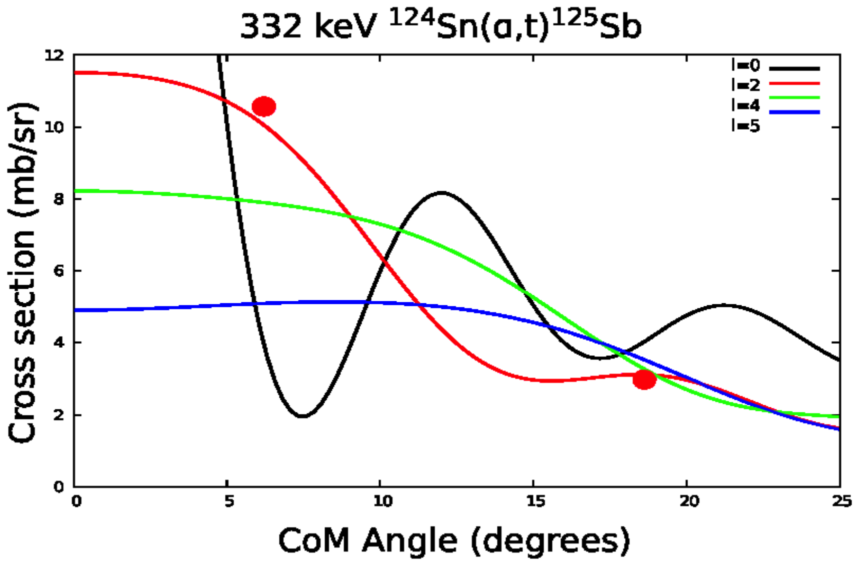
Differential cross section for the population of each state is obtained from the yield of the corresponding peak at the focal-plane:

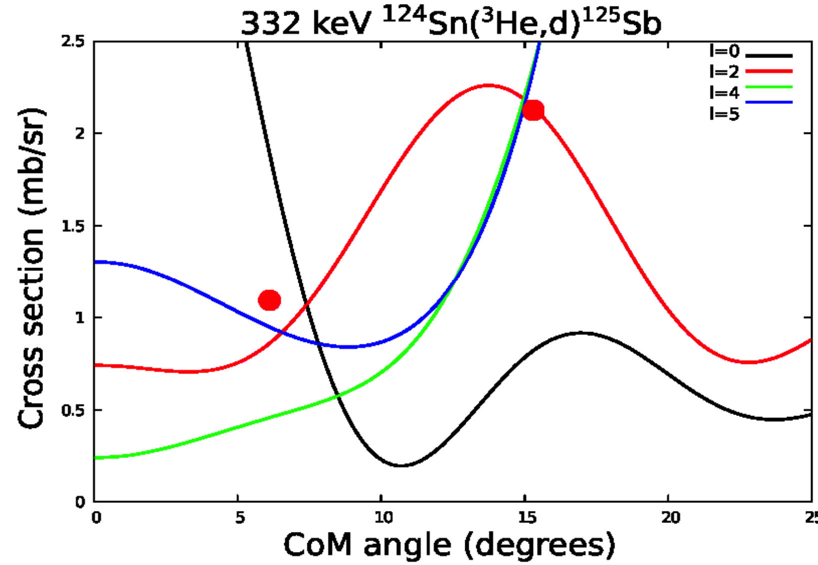
$$\frac{d\sigma}{d\Omega} = \frac{Y}{N_b N_t \Delta\Omega \epsilon}$$

Y: Yield at the focal plane
N_b: number of beam ions
N_t: target thickness
ΔΩ: entrance aperture of spectrometer
ε: efficiency

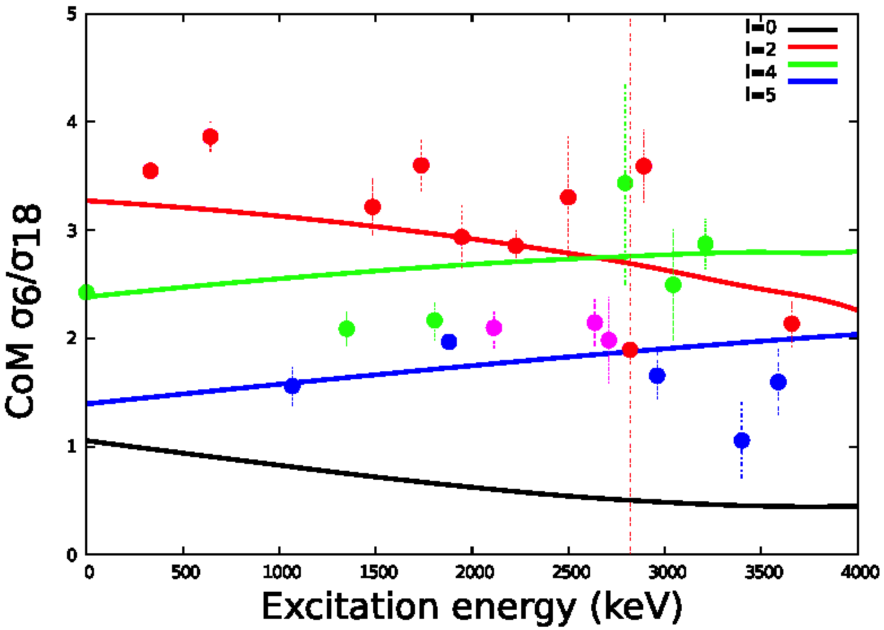
Each populated state corresponds to a particular **spin-parity** – need to find out which…

Spin-parity assignments



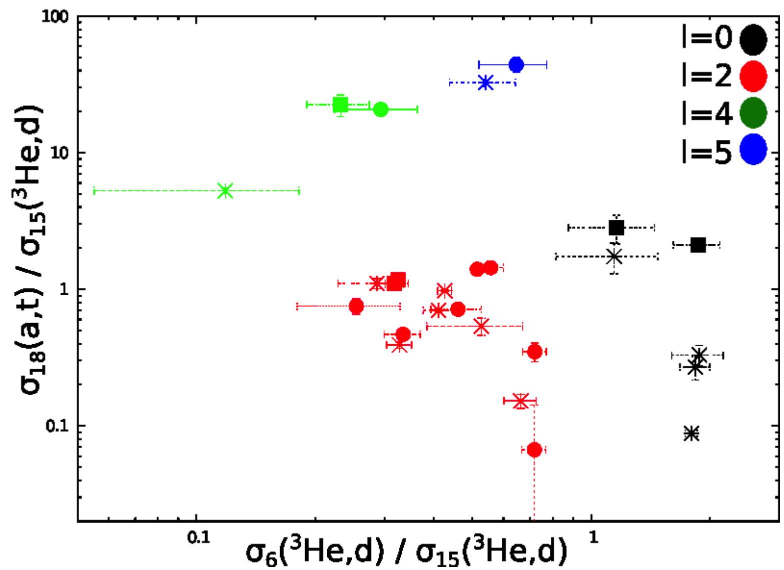


Ratio (α,t) cross sections Vs excitation energy



Reaction ratios for ^{121}Sb, ^{123}Sb and ^{125}Sb

Circle = ^{125}Sb, Square = ^{123}Sb, Star = ^{121}Sb



Spectroscopic factors – work ongoing

Independent particle model – single-proton orbitals.

Reality – residual interactions create fragmentation of single-particle strength.

Spectroscopic factor – measure of single-particle nature of a state:

$$S_{ij} = \sigma_{exp} / \sigma_{DWBA}$$

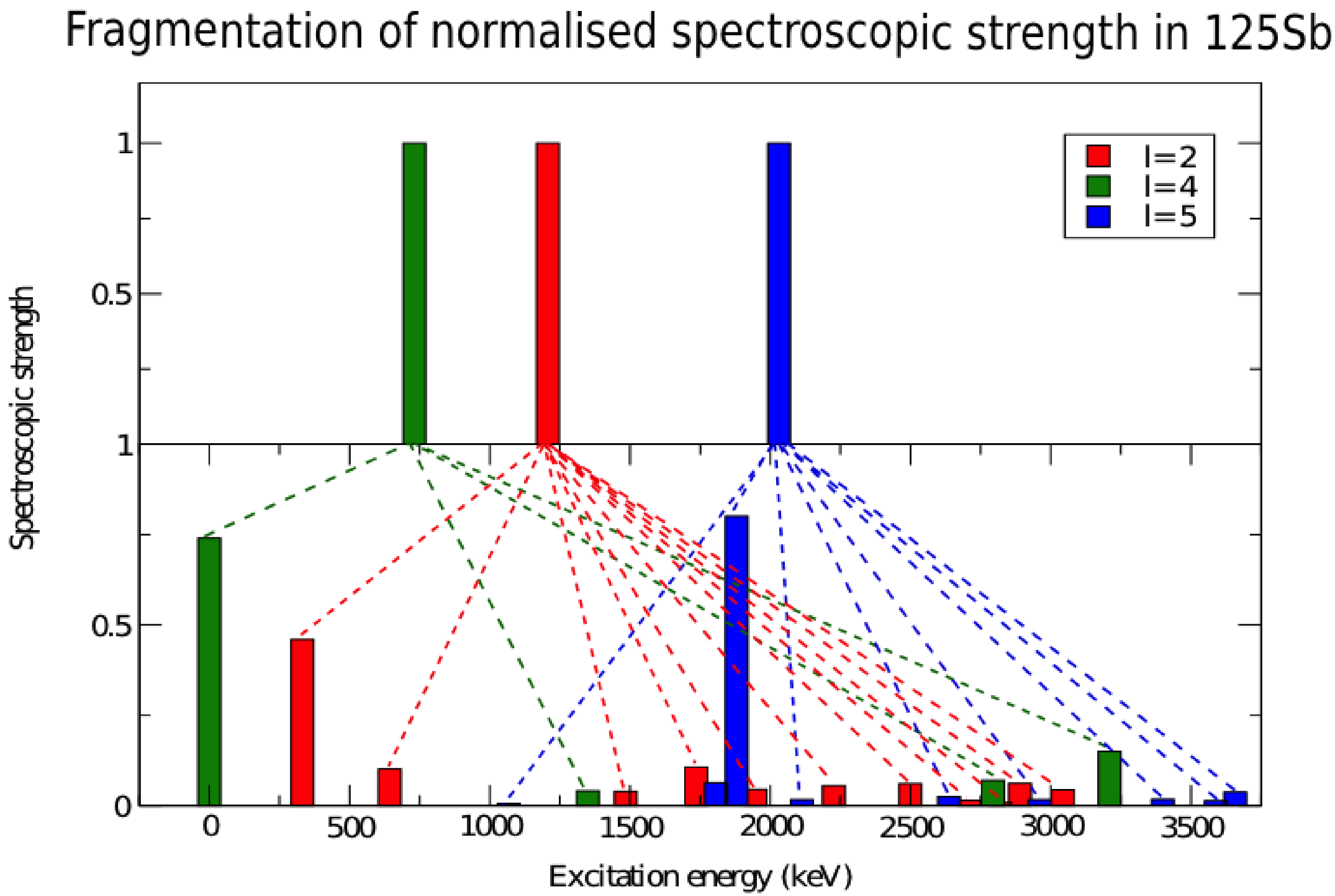
S_{MAX} = 1 for single-proton adding on closed shell.

Require common normalisation across all orbitals and targets to obtain **relative spectroscopic factors**.

Summed spectroscopic factors from (α,t) measurements

SP orbital	^{121}Sb	^{123}Sb	^{125}Sb
l =2	2.79(5)	2.86(3)	2.93(5)
l =4	1.47(1)	1.54(1)	1.60(2)
l =5	1.44(5)	1.20(1)	1.54(2)

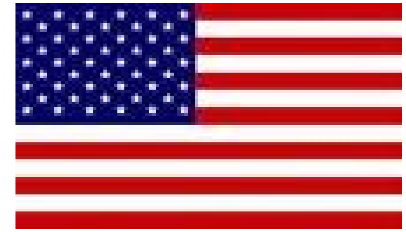
Fragmentation and energy centroids



Future work

- Extend analysis to include lower mass isotopes.
- Determine relative spectroscopic factors via a common normalisation across all targets and states.
- Reproduce energy centroids for all spin-parity orbitals.
- Investigate evolution of effective single-proton energies with increasing neutron excess.

Thank you for listening



Acknowledgements

A.J. Mitchell[1], S.J. Freeman[1], J.P. Schiffer[2], J.A. Clark[2],

C.M. Deibel[2,3], C. R. Hoffman[2], A.M Howard[1], B.P. Kay[2],

S. McAllister[1], P.D. Parker[4], D.K. Sharp[1] and J. S. Thomas[1].

[1]Schuster Laboratory, The University of Manchester, UK
[2]Physics Division, Argonne National Laboratory, USA
[3]Joint Institute for Nuclear Astrophysics, Michigan State University, East Lansing, MI 48824, USA
[4]Wright Nuclear Structure Laboratory, Yale University, USA

Focal plane spectra