INVESTIGATION OF EXCITED 0^+ STATES POPULATED IN THE ^{162}Er TWO-NEUTRON TRANSFER REACTION

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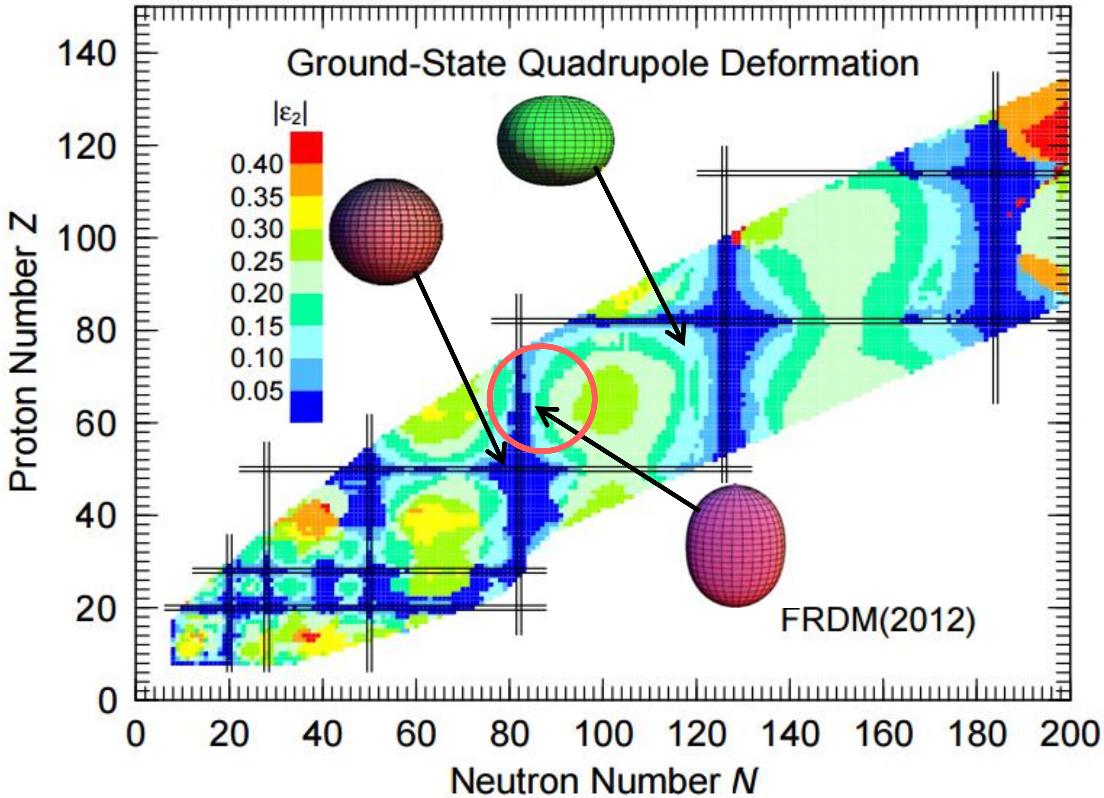
Motivation

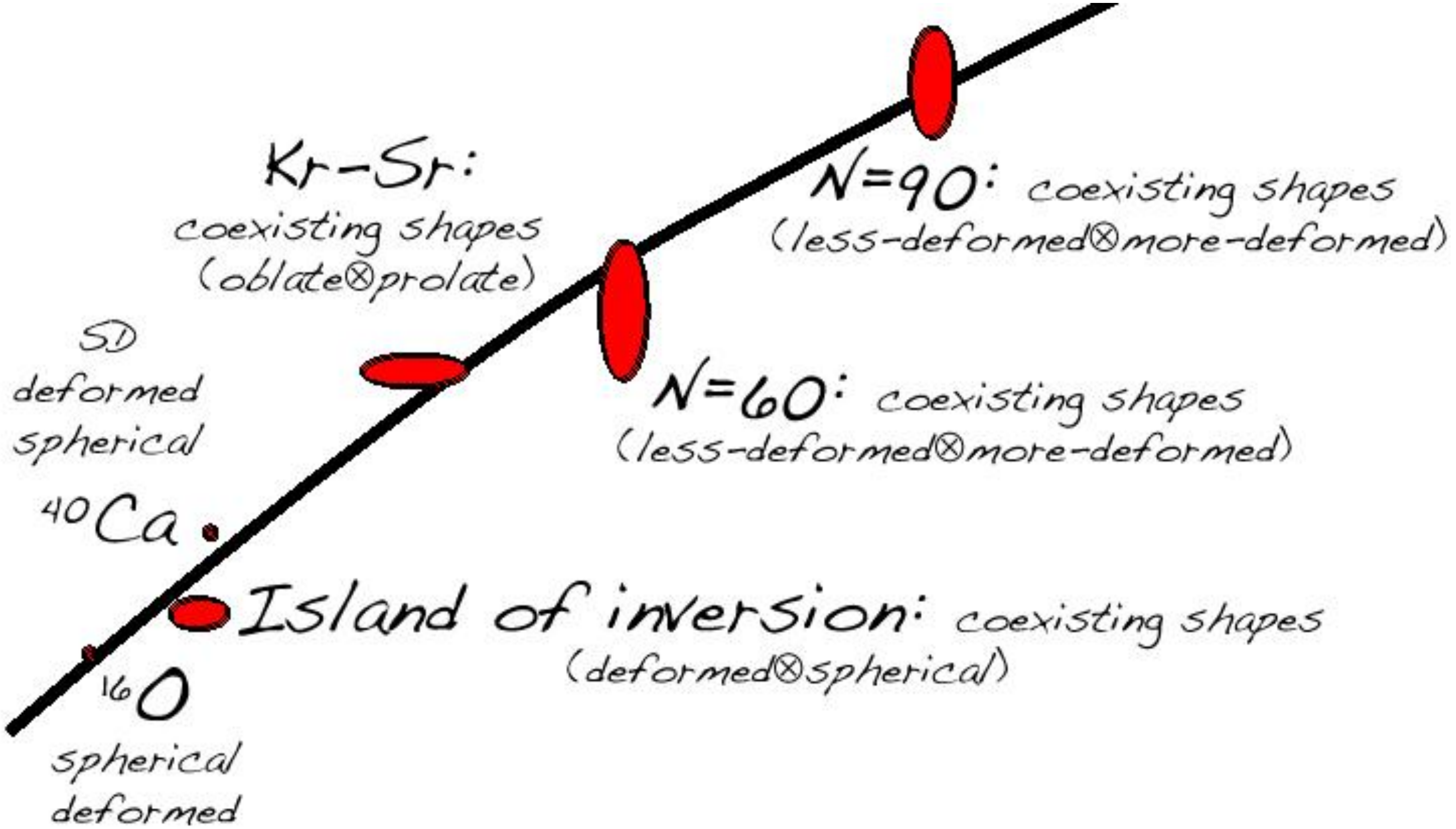
- Nuclear deformation occurs away from closed shells
- Shape coexistence may be expected in regions of rapid change in deformation



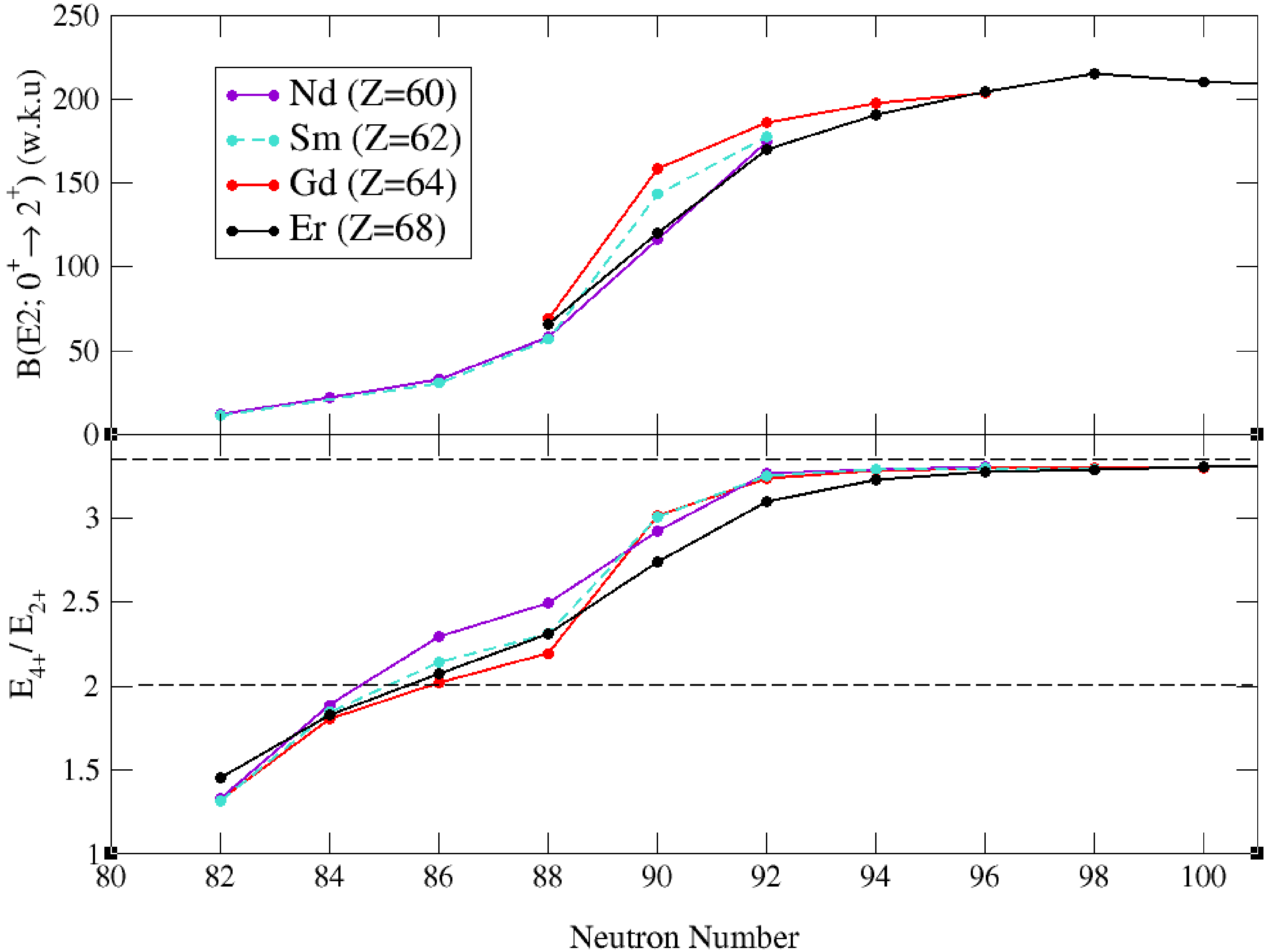
P. Moller. Nuclear ground-state masses and deformations: FRDM(2012)
Adapted from P. Fillip. Effects of Nulcear Deformation in Heavy Ion Collisions. Kent State University (2009)

Shape coexistence

- N~90 nuclei have excited states with a different level of deformation than their ground states



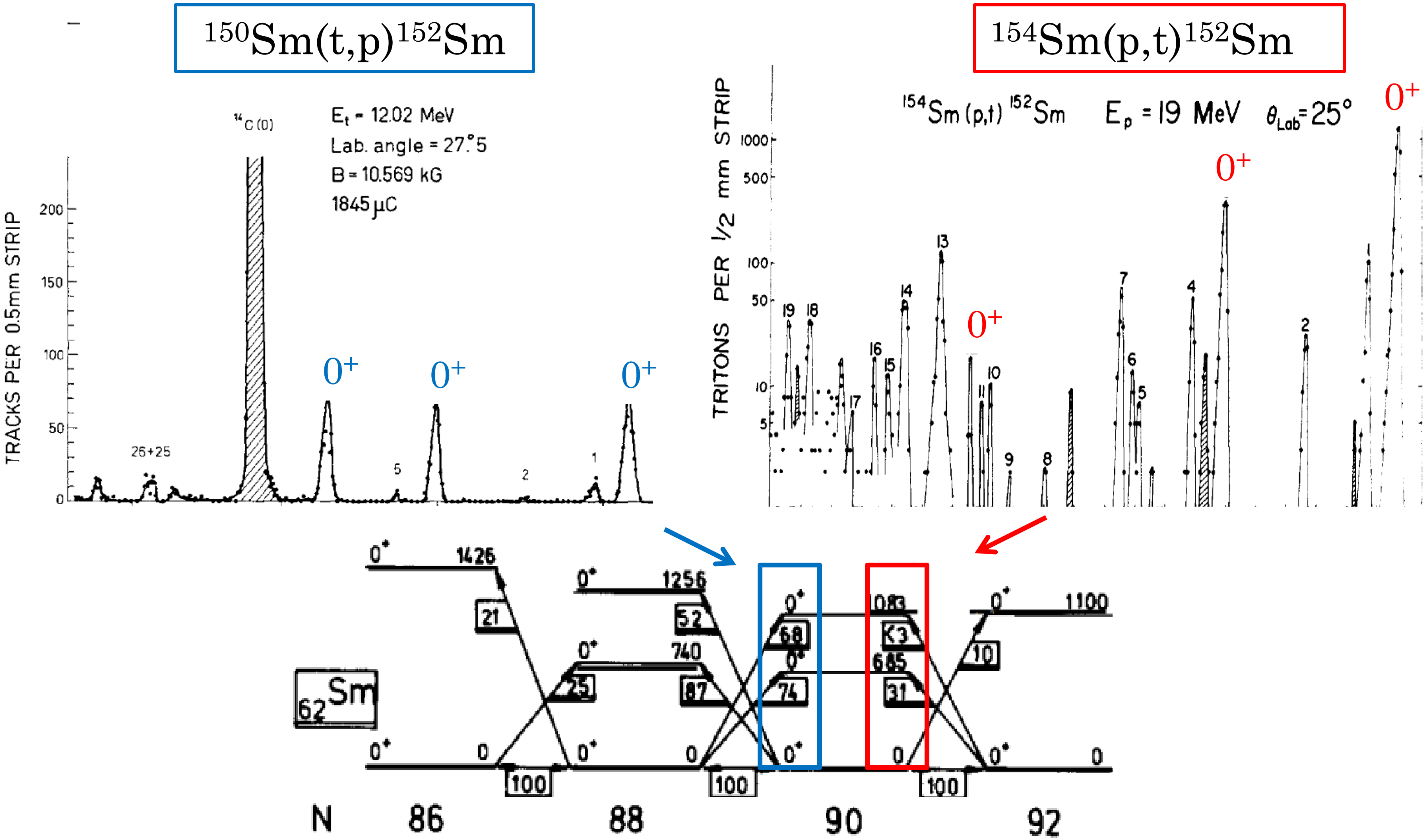
Motivation



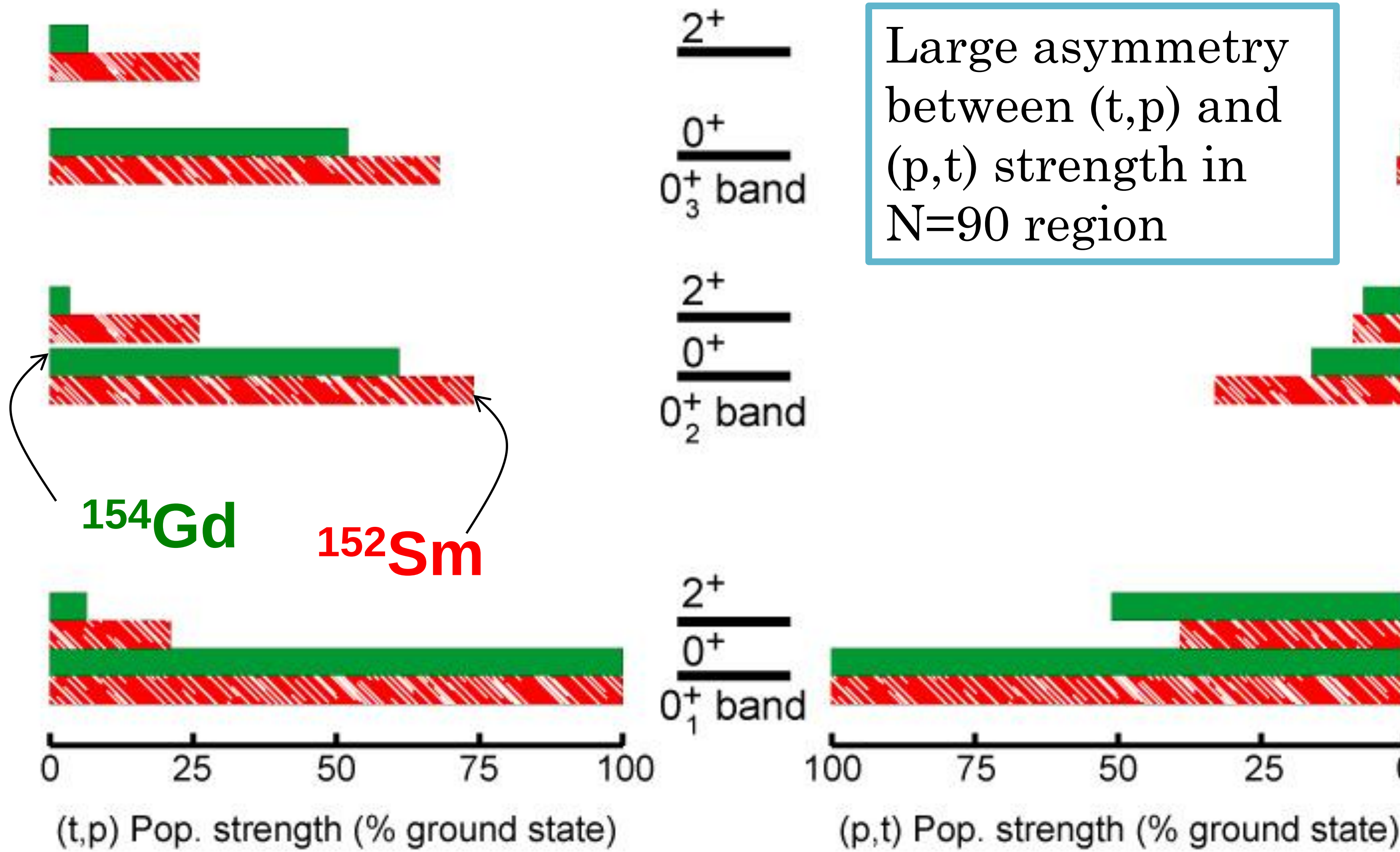
$R_{4/2} = 3.33$
→Rotor

$R_{4/2} = 2.0$
→Vibrator

Strength into N=90 nucleus ^{152}Sm



N=90 strength in ^{154}Gd, ^{152}Sm

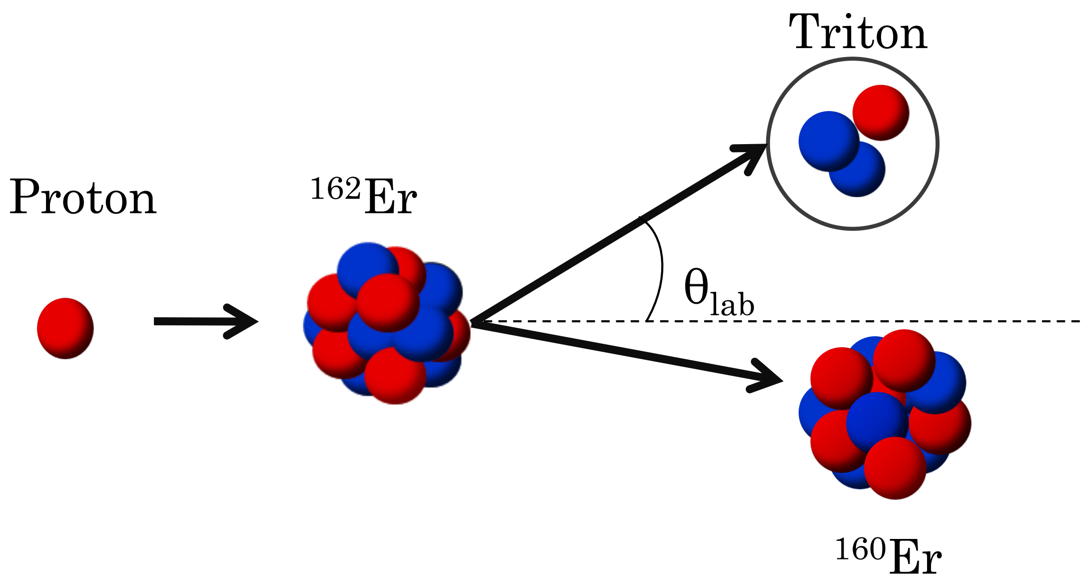


Large asymmetry between (t,p) and (p,t) strength in N=90 region

Why transfer reactions?

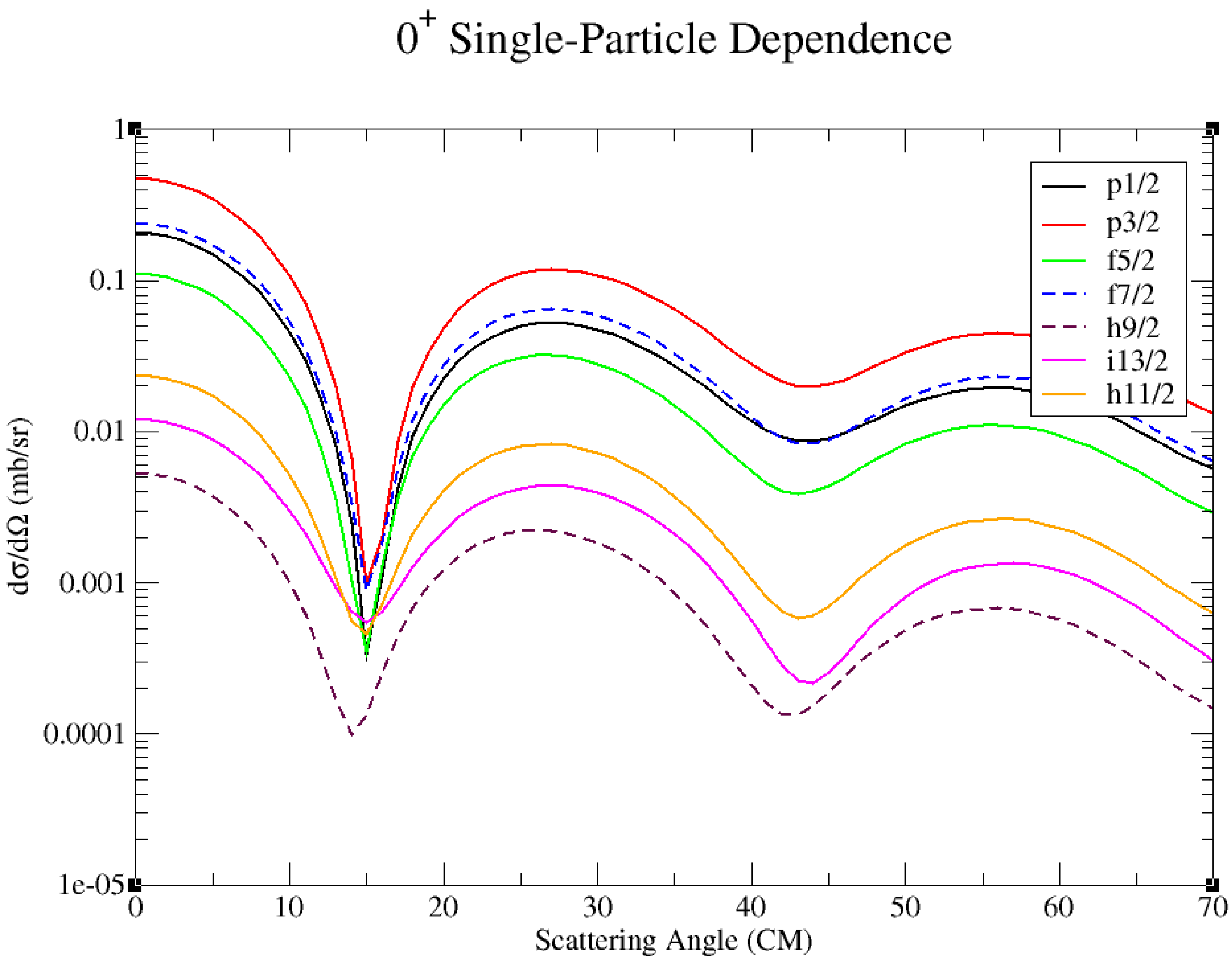
- Two-neutron transfers probe pairing correlations in the nucleus
- The reaction will not carry off much angular momentum, favouring L=0 transfers
- Strength of 0^+ states in residual nucleus related to pairing mechanism

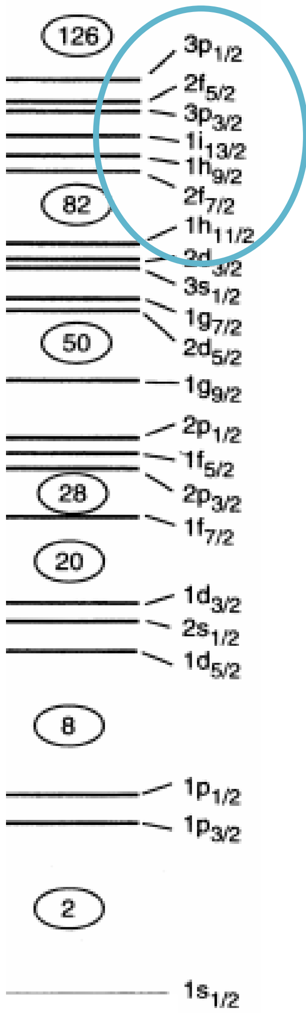
^{162}Er(p,t)^{160}Er reaction



- Angular distributions are compared to DWBA calculations using FRESCO to extract angular momentum
- Single-particle content is not known for two neutron transfer reactions – is this a problem?

Single-Particle Dependence



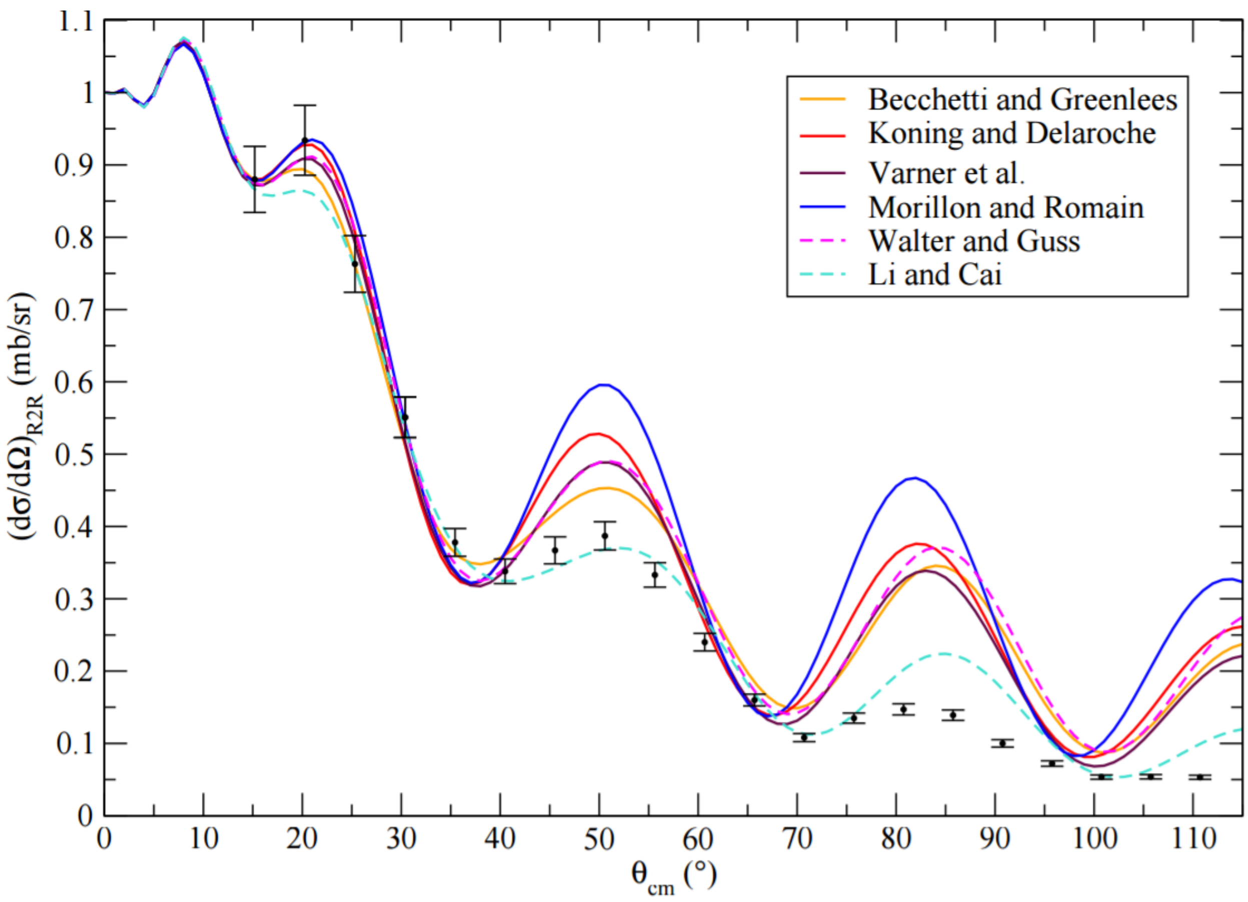


Experiment

- $^{162}Er(p,t)^{160}Er$ experiment conducted at the Maier-Leibnitz-Laboratorium, Garching, Germany

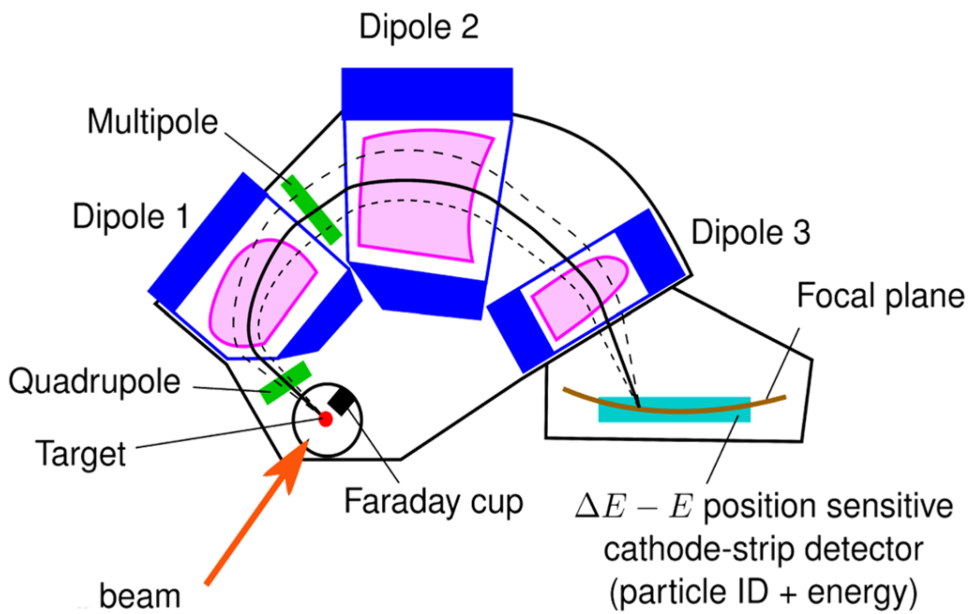
- 22-24 MeV proton beam supplied by 14MeV Tandem Van de Graaff

Target Thickness Determination

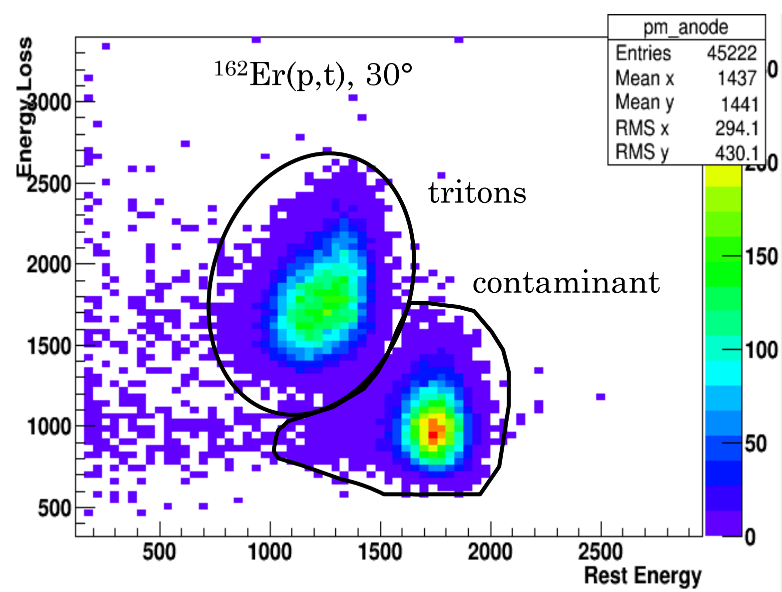


- ^{162}Er target thickness extracted with optical model fit to elastic scattering data

Q3D Magnetic Spectrograph

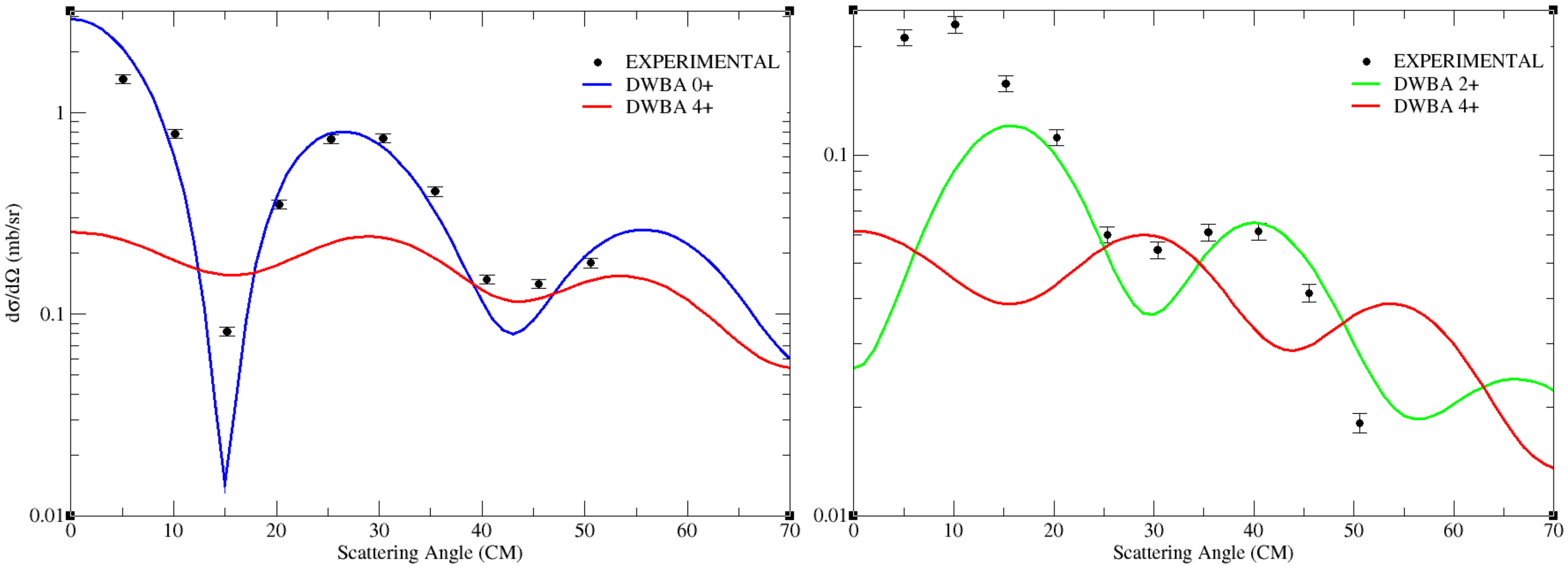


- Q3D magnetic spectrograph momentum analyzes reaction products using a focal plane detector



- Focal plane detector allows for particle identification

DWBA calculations - 0_1^+ and 2_1^+



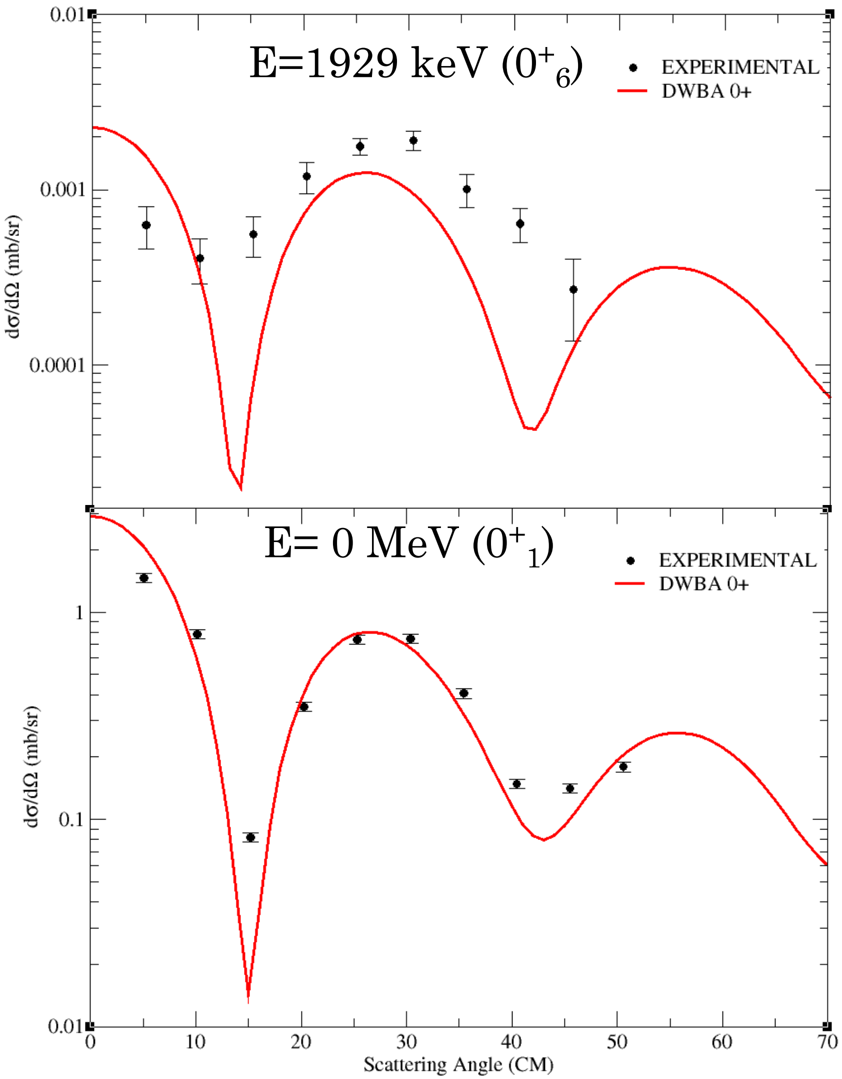
- We are able to extract the angular momentum transferred in the reaction using the shape of the angular distribution!

Relative Cross Section

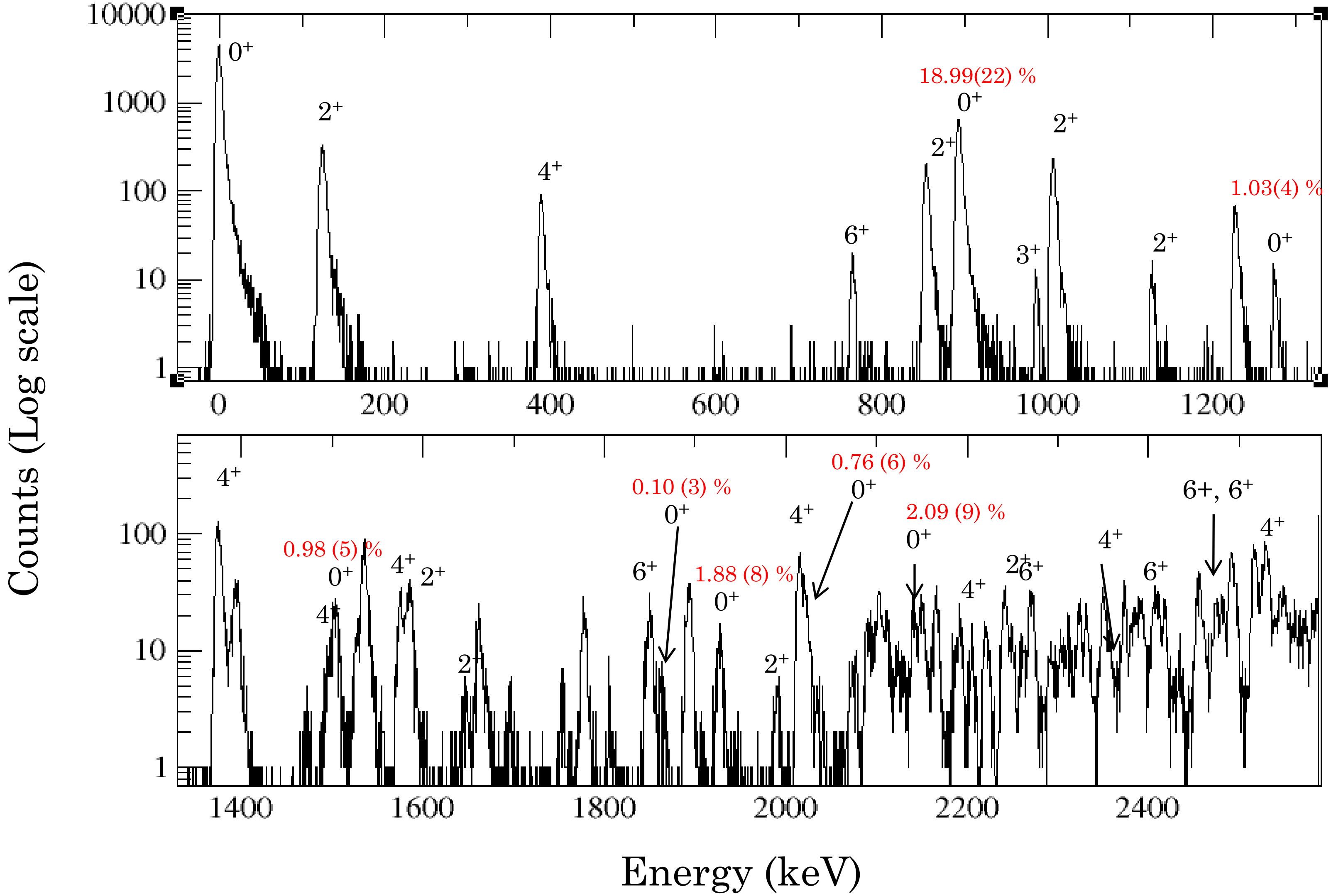
$$S = \frac{\left(\frac{d\sigma}{d\Omega}\right)^{lab}_{0^+_{ex}}}{\left(\frac{d\sigma}{d\Omega}\right)^{dwba}_{0^+_{ex}}} \Bigg/ \frac{\left(\frac{d\sigma}{d\Omega}\right)^{lab}_{0^+_{gs}}}{\left(\frac{d\sigma}{d\Omega}\right)^{dwba}_{0^+_{gs}}}$$

- Relative Cross Section gives a measure of the strength of the excited state relative to the GS

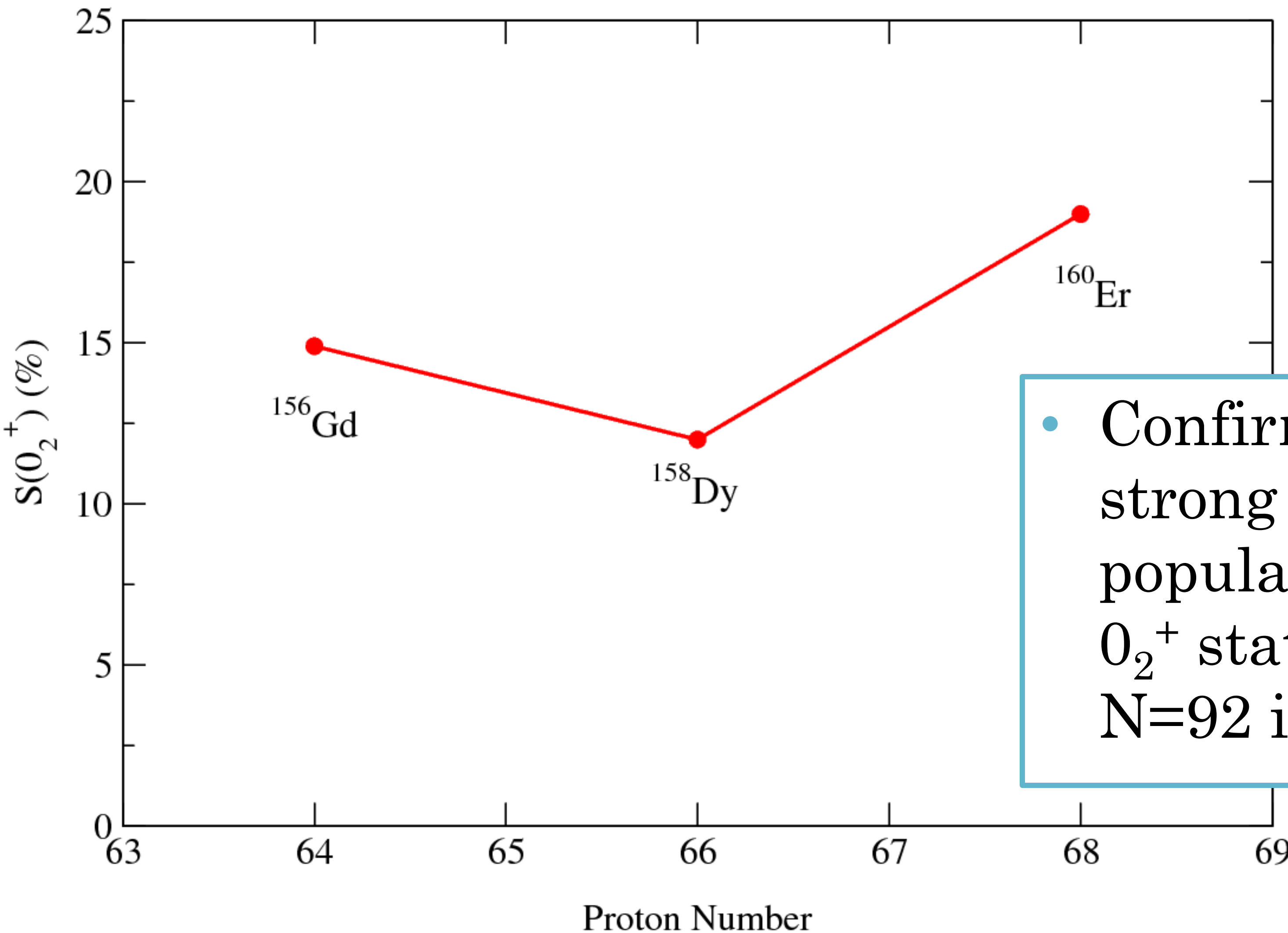
- Ratio of Exp/DWBA cross sections will provide a Q-value correction for kinematics



^{160}Er spectrum at 30°



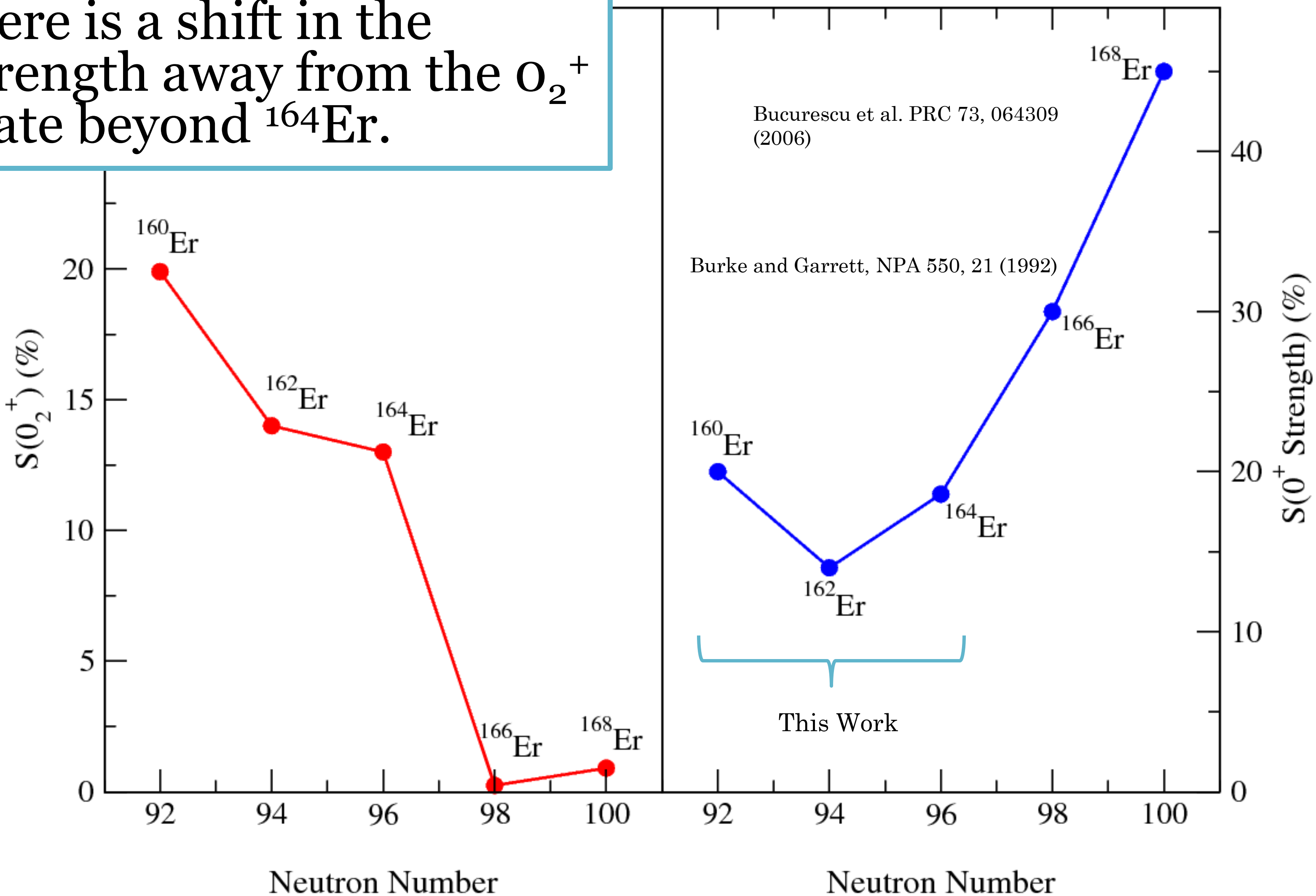
0_2^+ in N=92 isotones



- Confirmed strong population of 0_2^+ state across N=92 isotones

Isotopic trends in 0^+ states

There is a shift in the strength away from the 0_2^+ state beyond ^{164}Er.



Summary

- 7 new excited 0^+ states under 2.5 MeV identified with 0_2^+ population ~19 %
- Low-lying, highly populated first 0^+ state consistent with the shape coexistence picture
- ^{162,164,166,168}Er(p,t) part of an experimental campaign at MLL investigating collective pairing transitions

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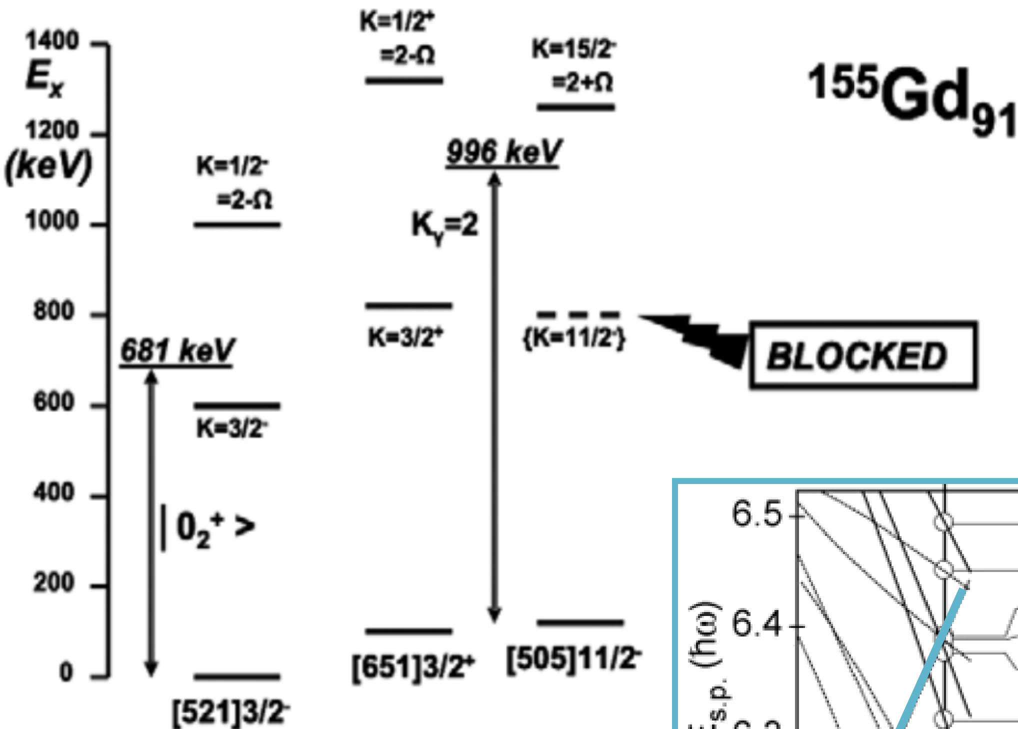
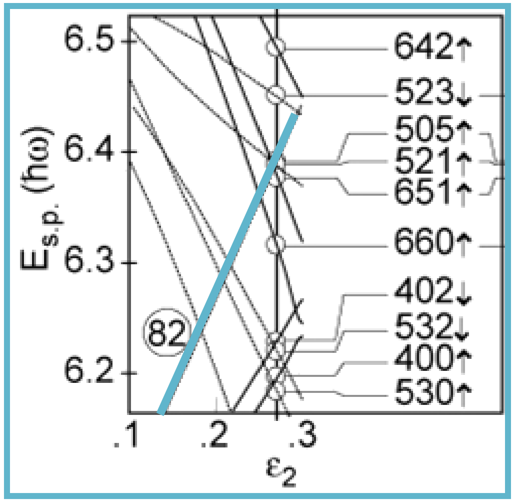
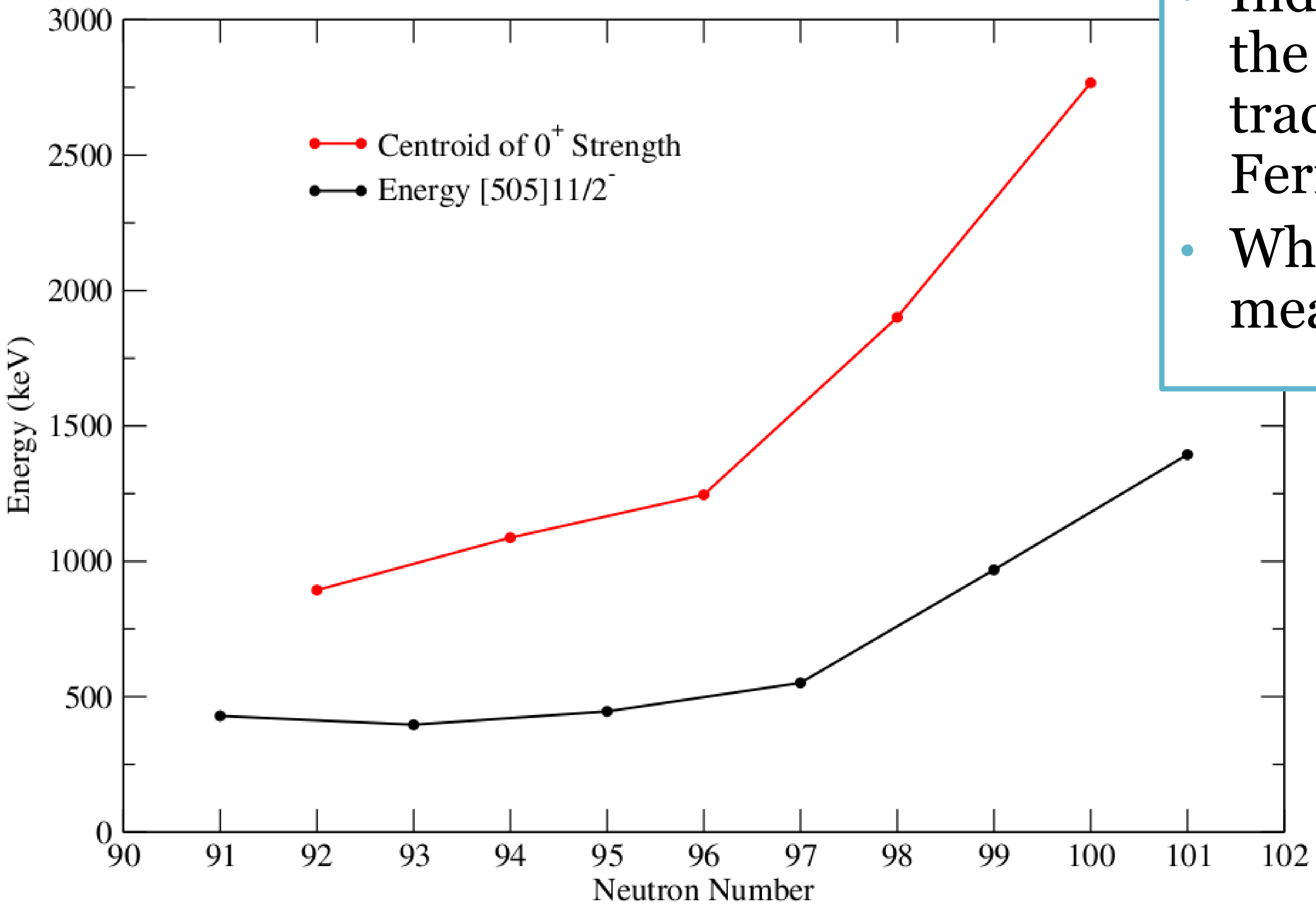
Interpretation: Pauli-blocked $\nu_{11/2}$





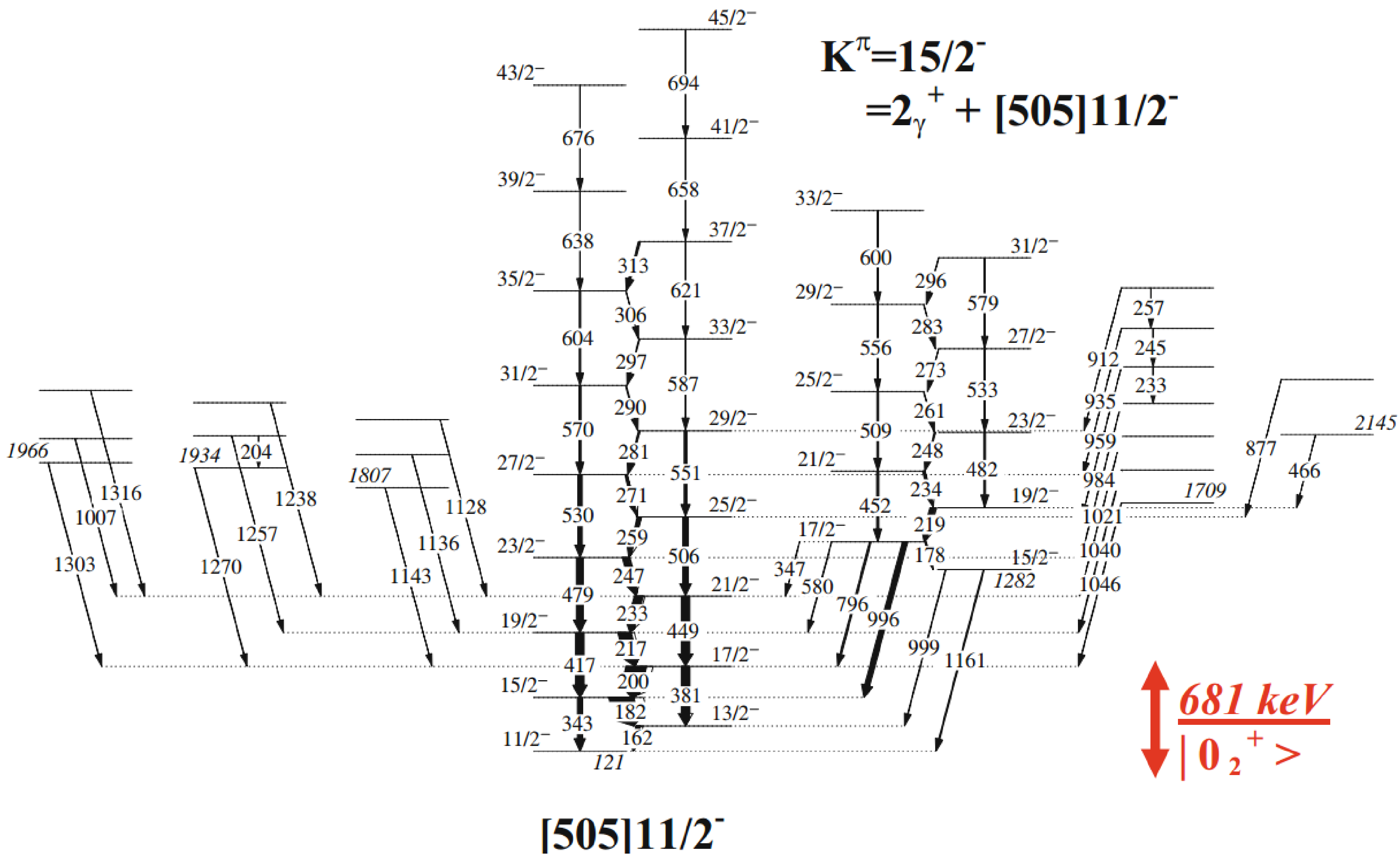
- 0_2^+ called "second vacuum state" due to the resemblance of level scheme to GS excitations
- The steeply up-sloping ν11/2[505] orbital is blocked in ^{155}Gd
- Thought to play a role with pairing in other isotopes in the N=90 region

Similarity to $\nu_{11/2}$ orbital

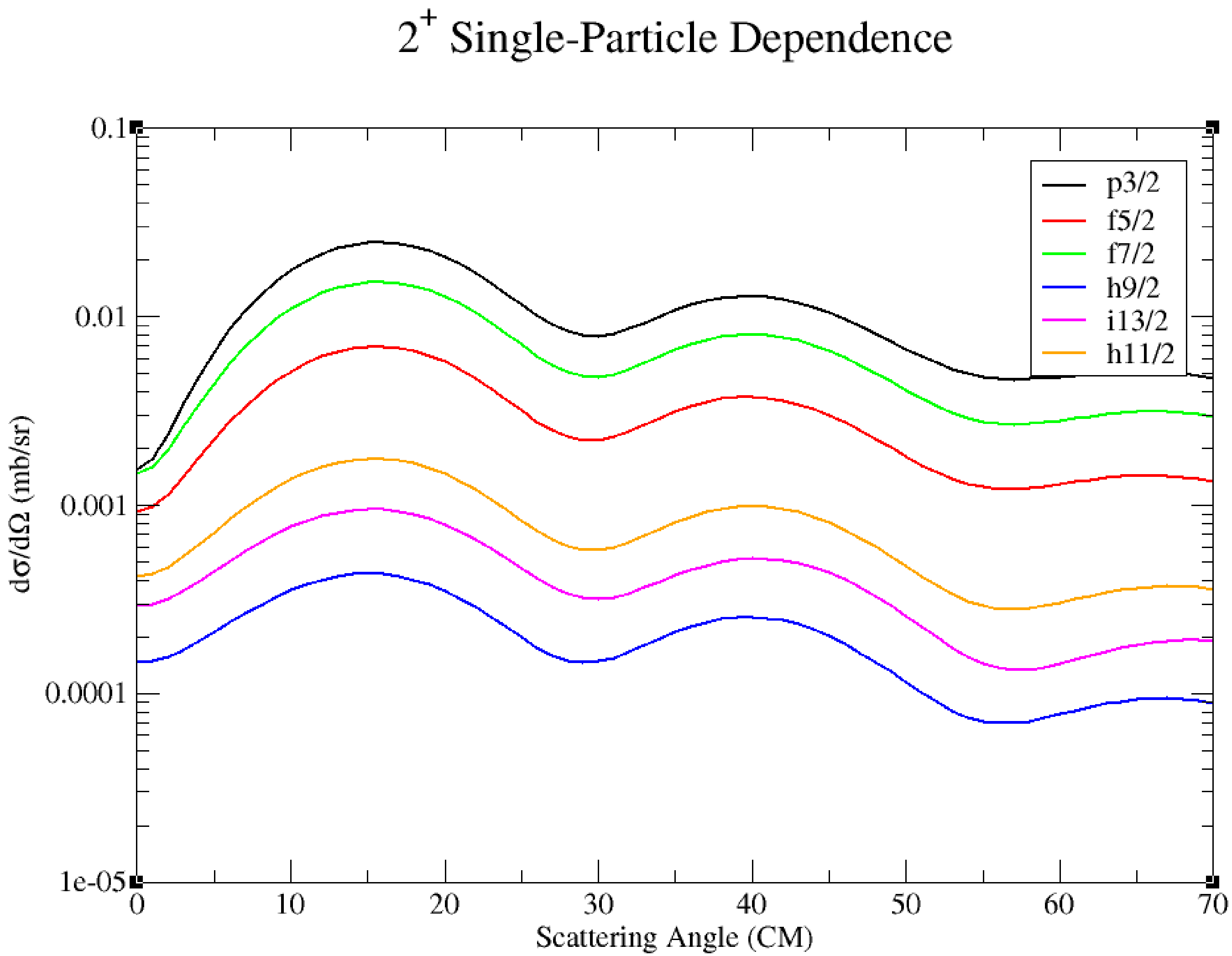


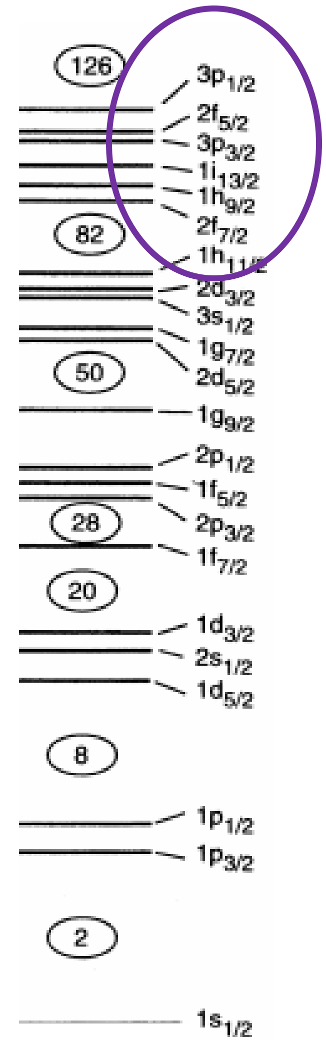
- Indication that the 0^+ strength tracks with the Fermi surface
- What does this mean?

^{155}Gd band structure

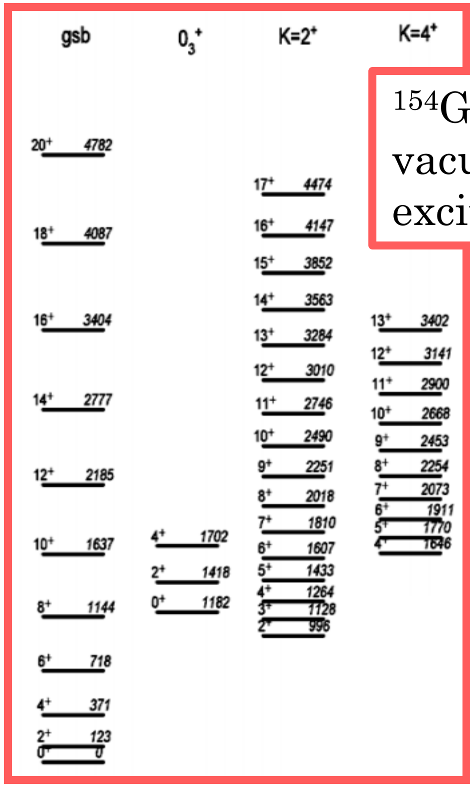


Single-Particle Dependence

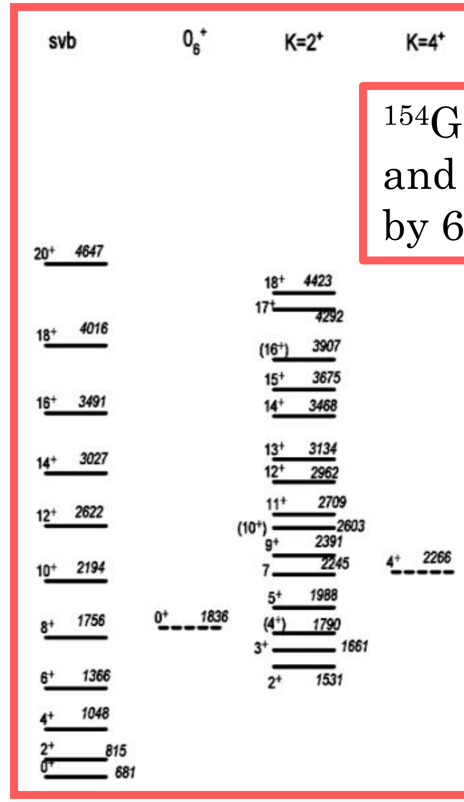




^{154}Gd level scheme



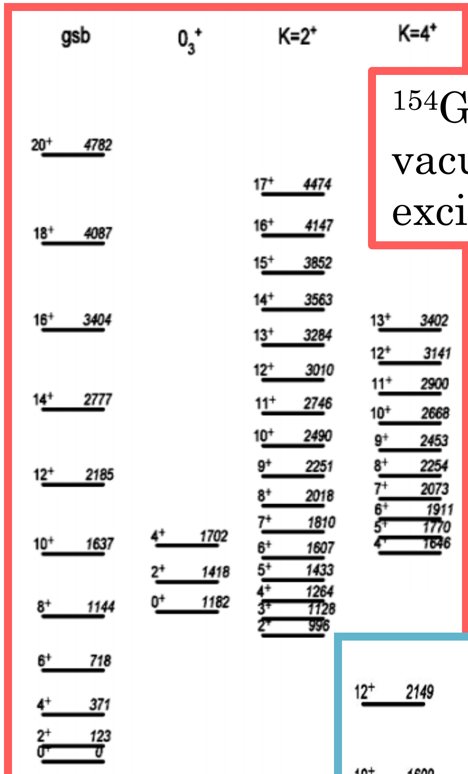
^{154}Gd ground state vacuum and excitations



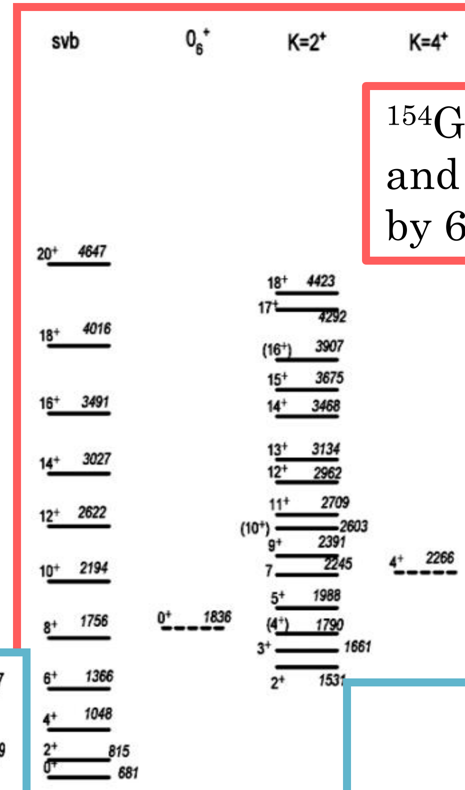
^{154}Gd second vacuum and excitations lowered by 681 keV

- Second vacuum state has same level hierarchy as ground state excitations

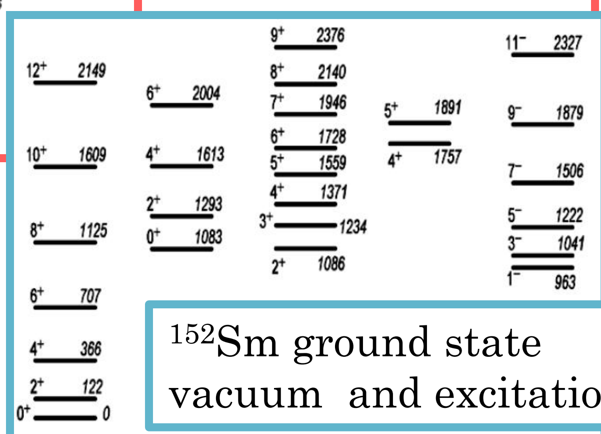
Comparison to ^{152}Sm level scheme



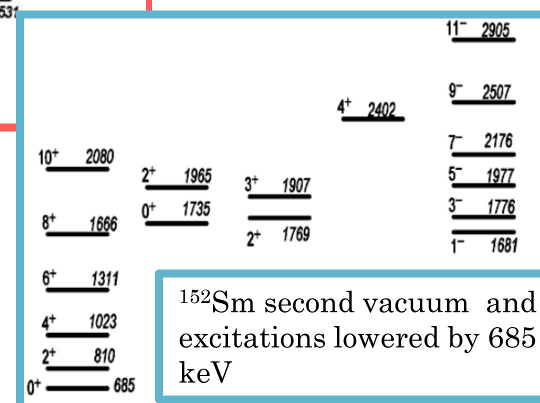
^{154}Gd ground state vacuum and excitations



^{154}Gd second vacuum and excitations lowered by 681 keV

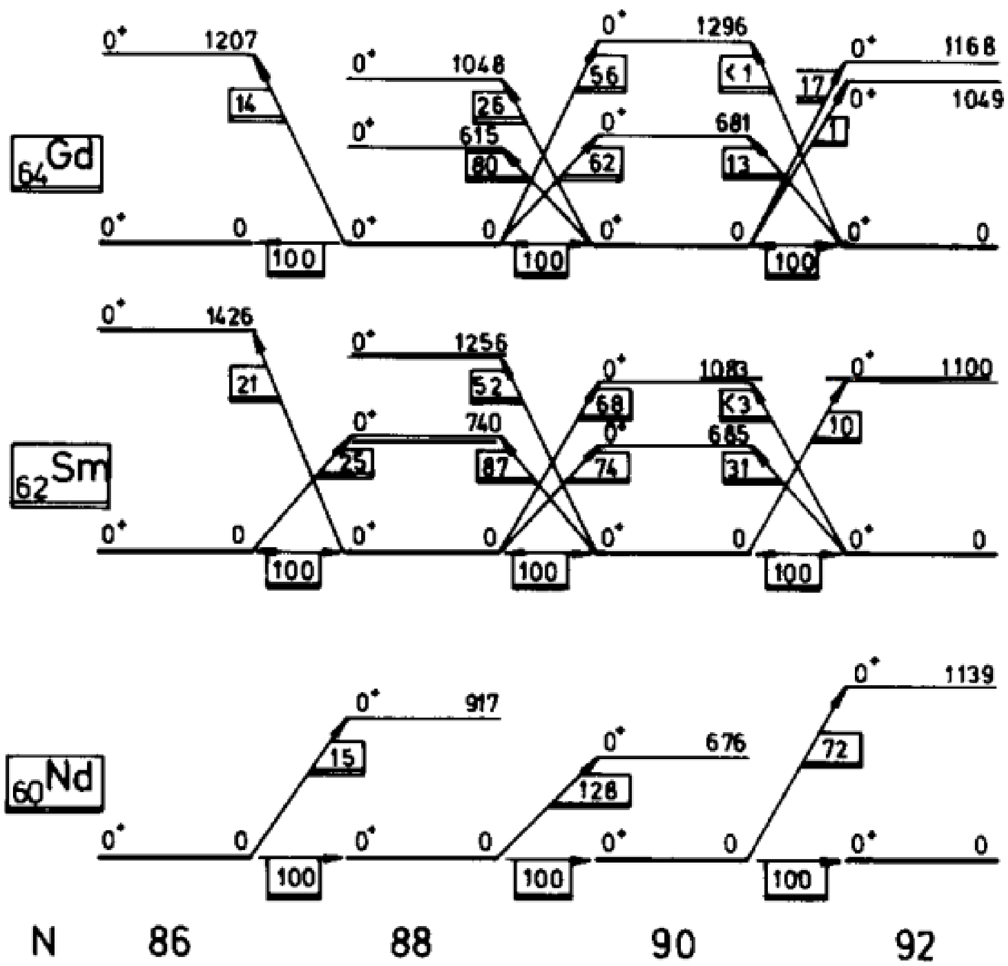


^{152}Sm ground state vacuum and excitations



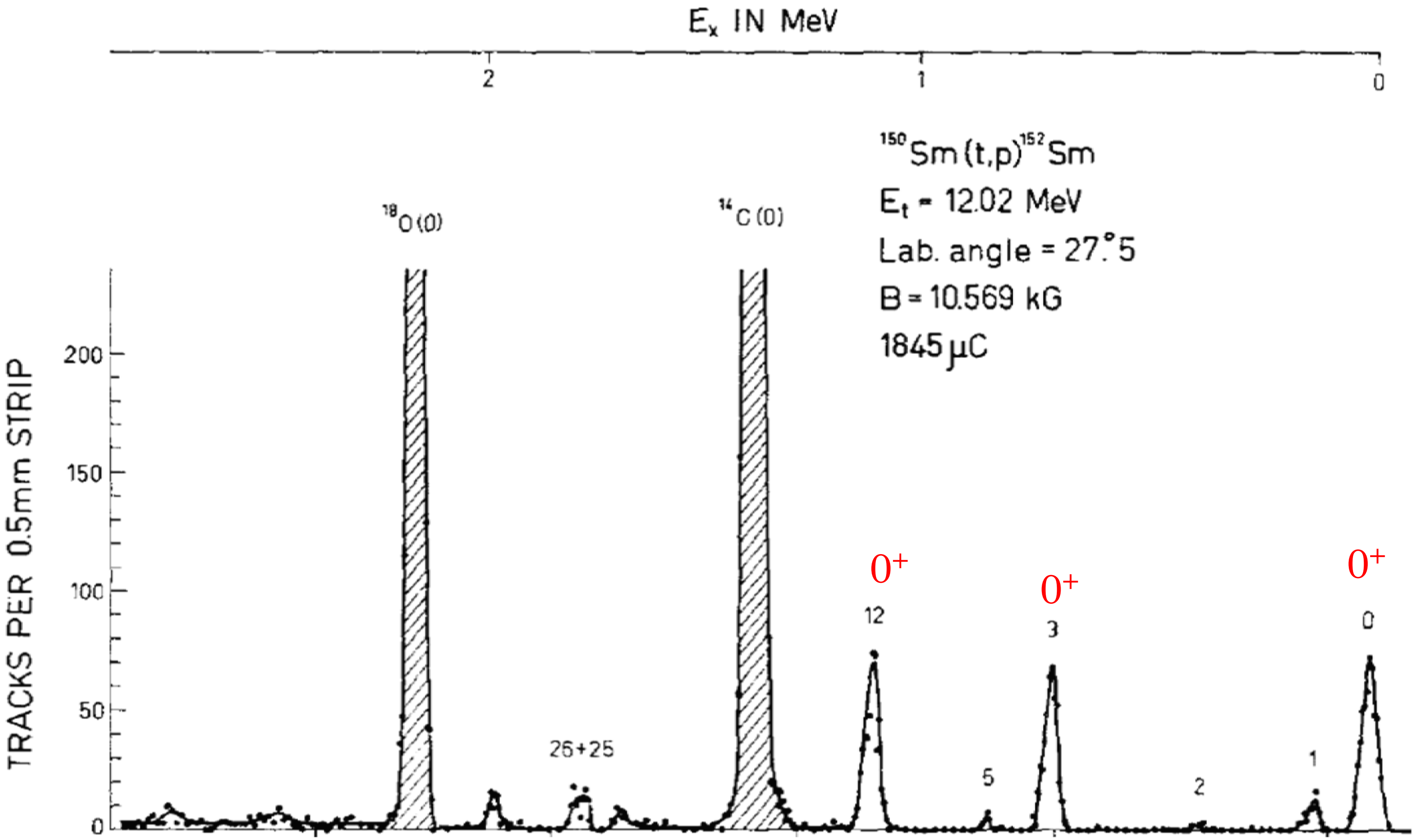
^{152}Sm second vacuum and excitations lowered by 685 keV

Transfer strength in N=90 region



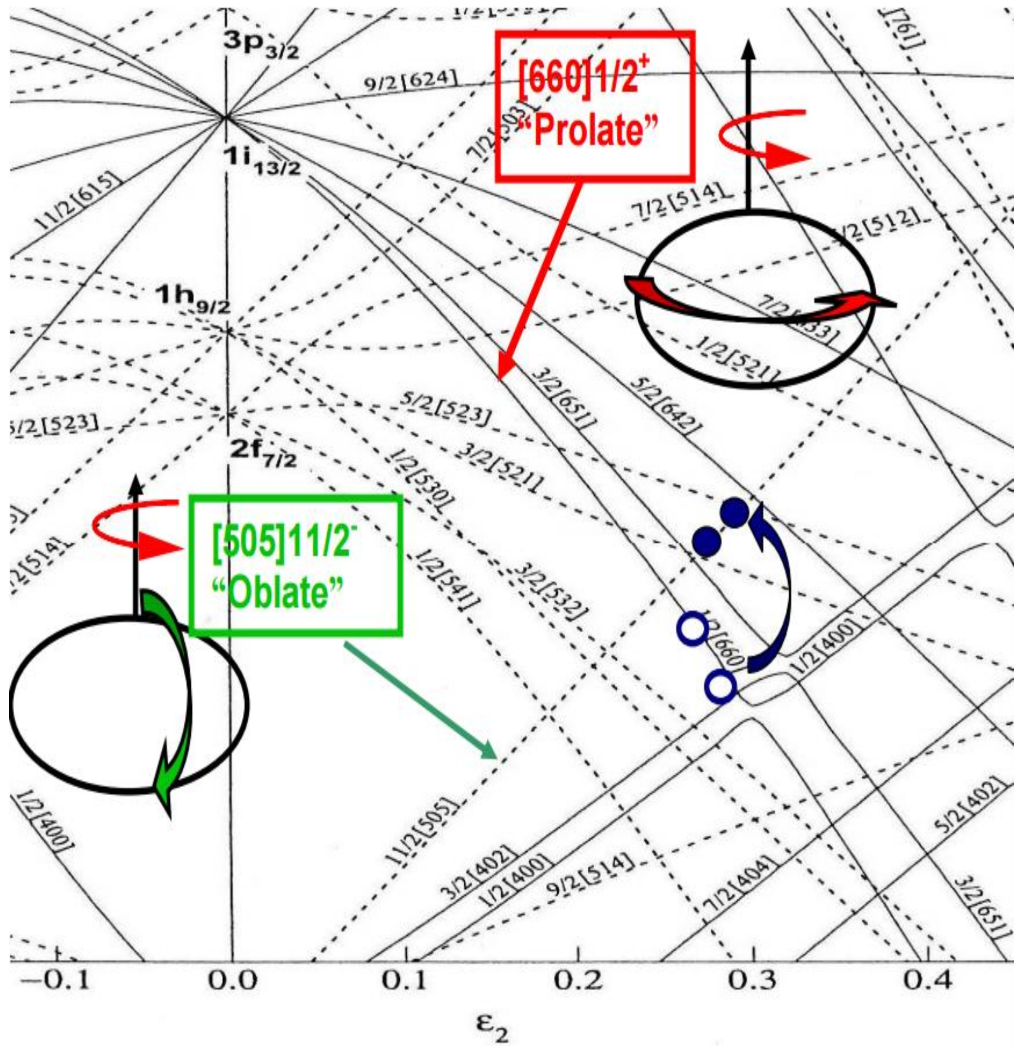
- Large GS→GS transition strengths until ^{152}Sm, ^{154}Gd
- For N<90 population to 0_2^+ and 0_3^+ strong
- For N>90 population only to 0_2^+ strong

$^{150}Sm(t,p)^{152}Sm$

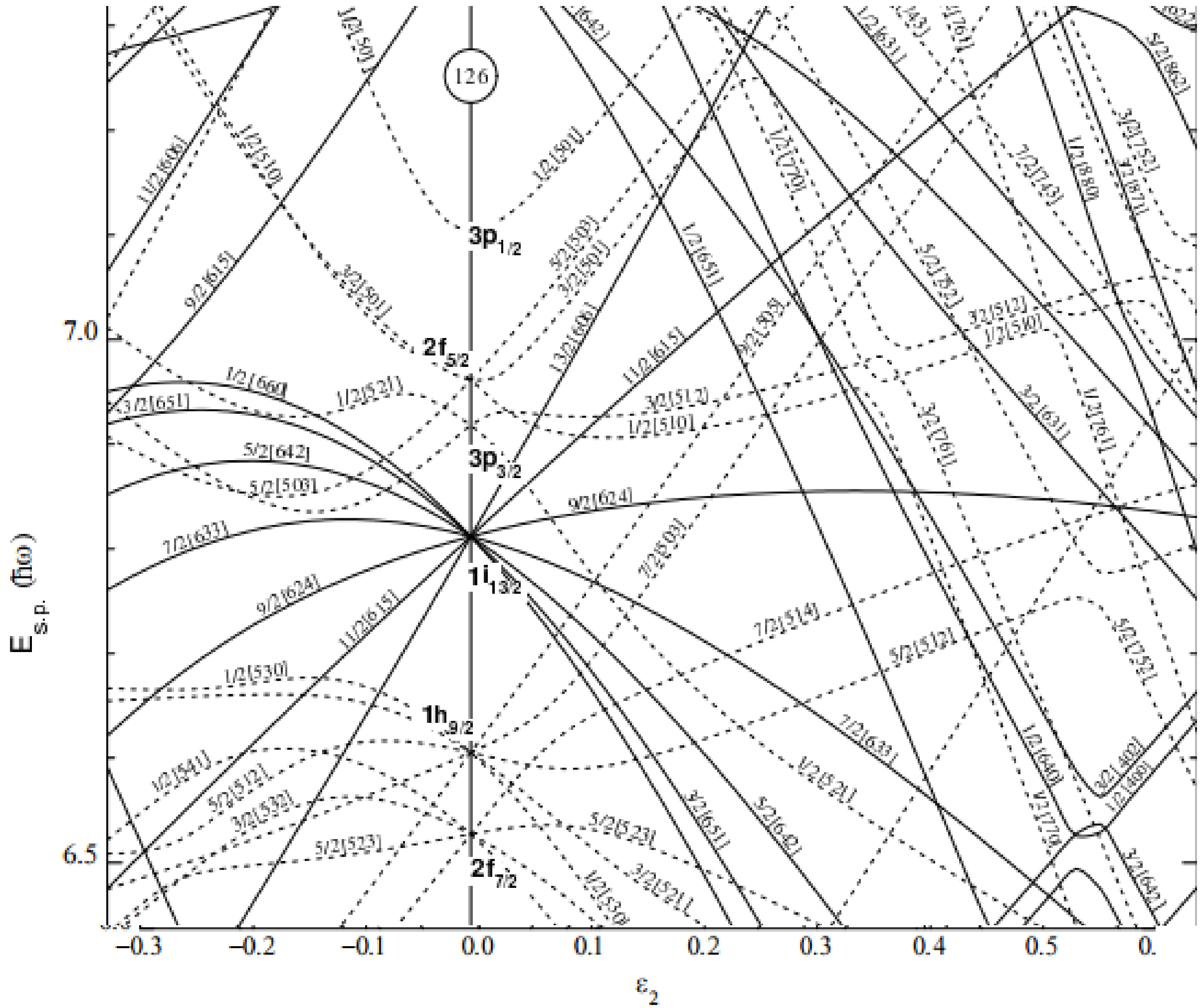


Configuration of 0_2^+ states in N = 90 nuclei

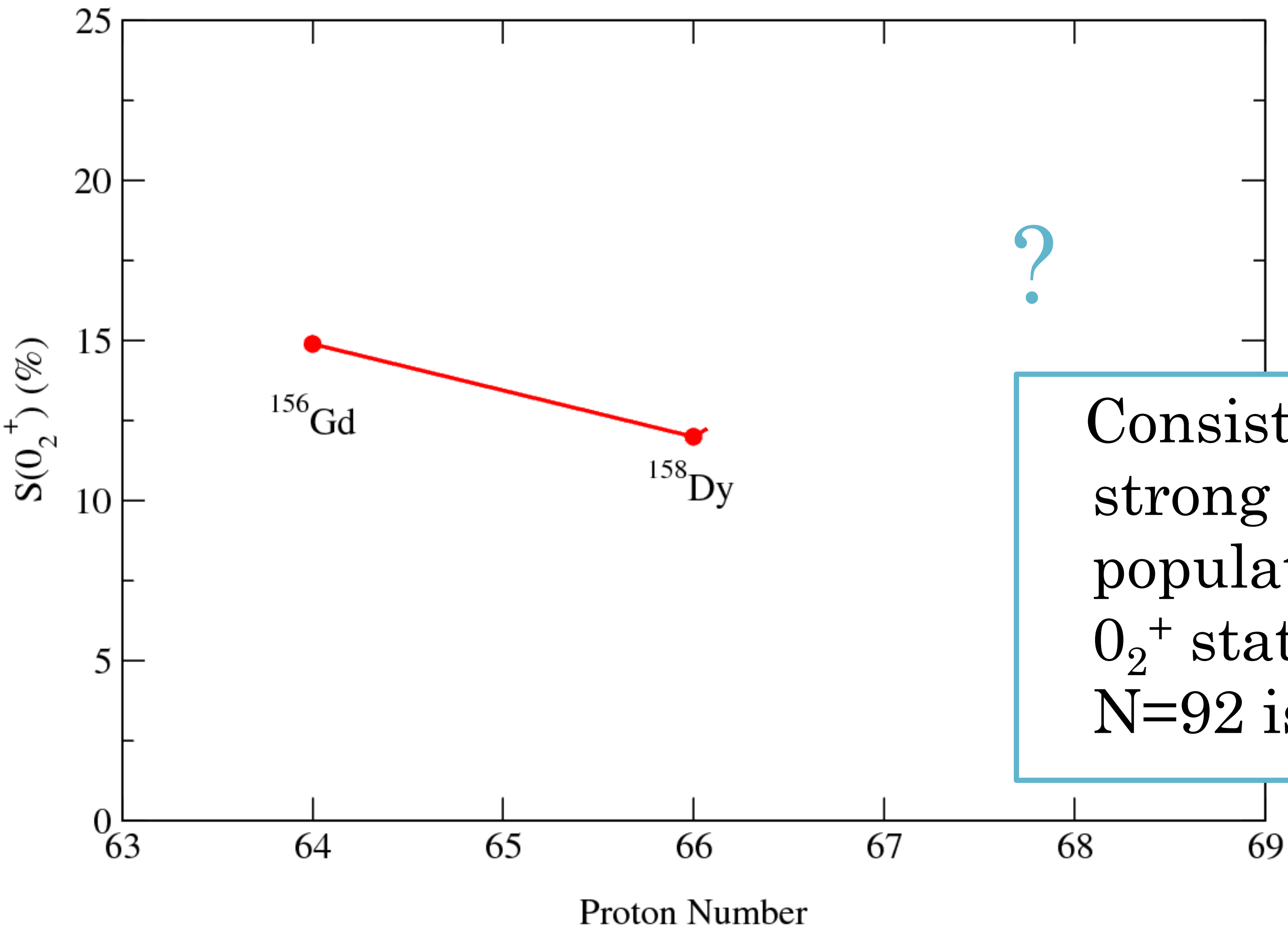
- 2v are transferred from down-sloping prolate to up-sloping $[505]11/2^-$ oblate orbital
- This configuration-dependent pairing decouples the high density of down-sloping prolate orbitals from the low density of up-sloping oblate orbitals
- Formation of “vacuum” state



Nilsson Diagram

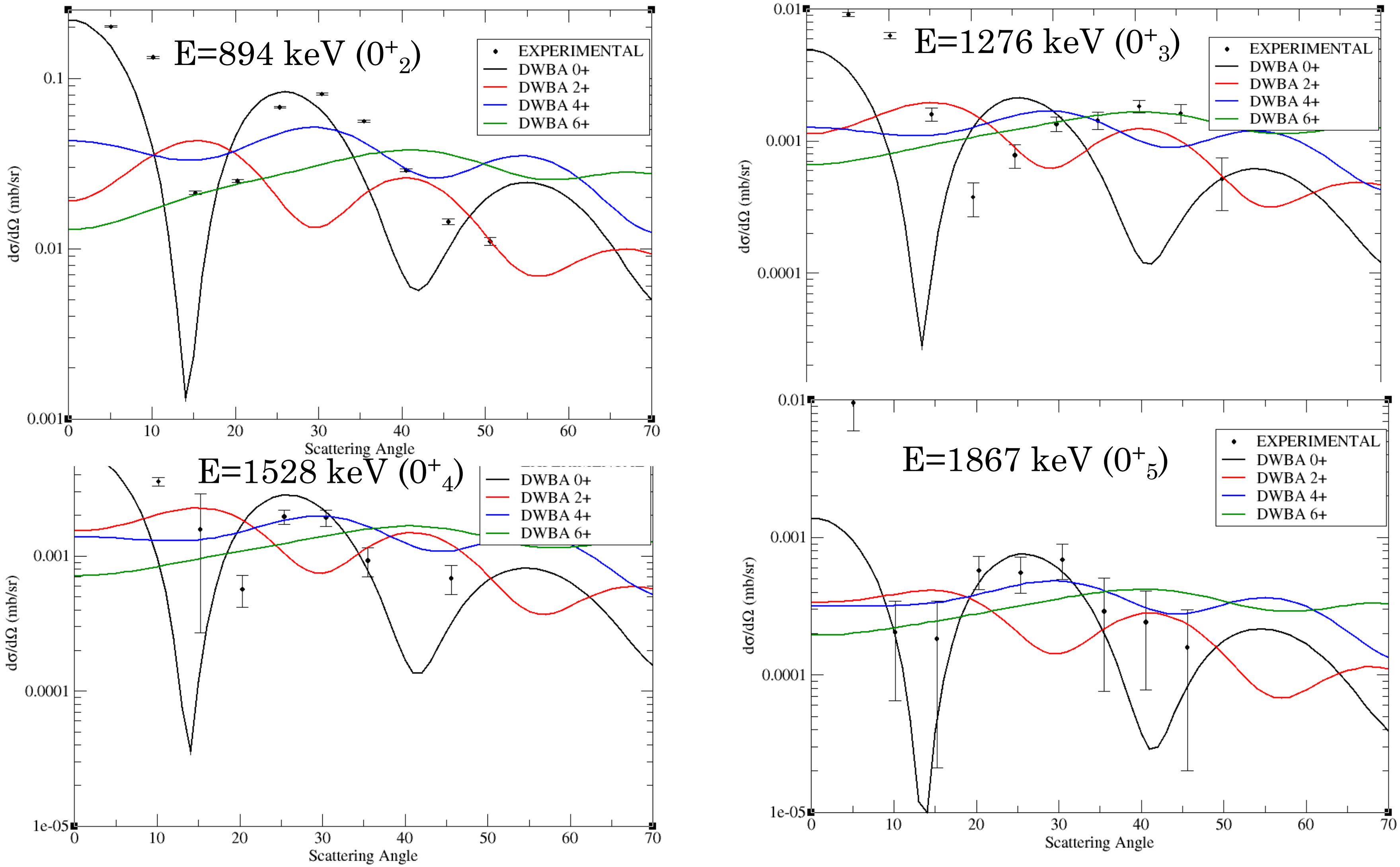


0_2^+ in N=92 isotones

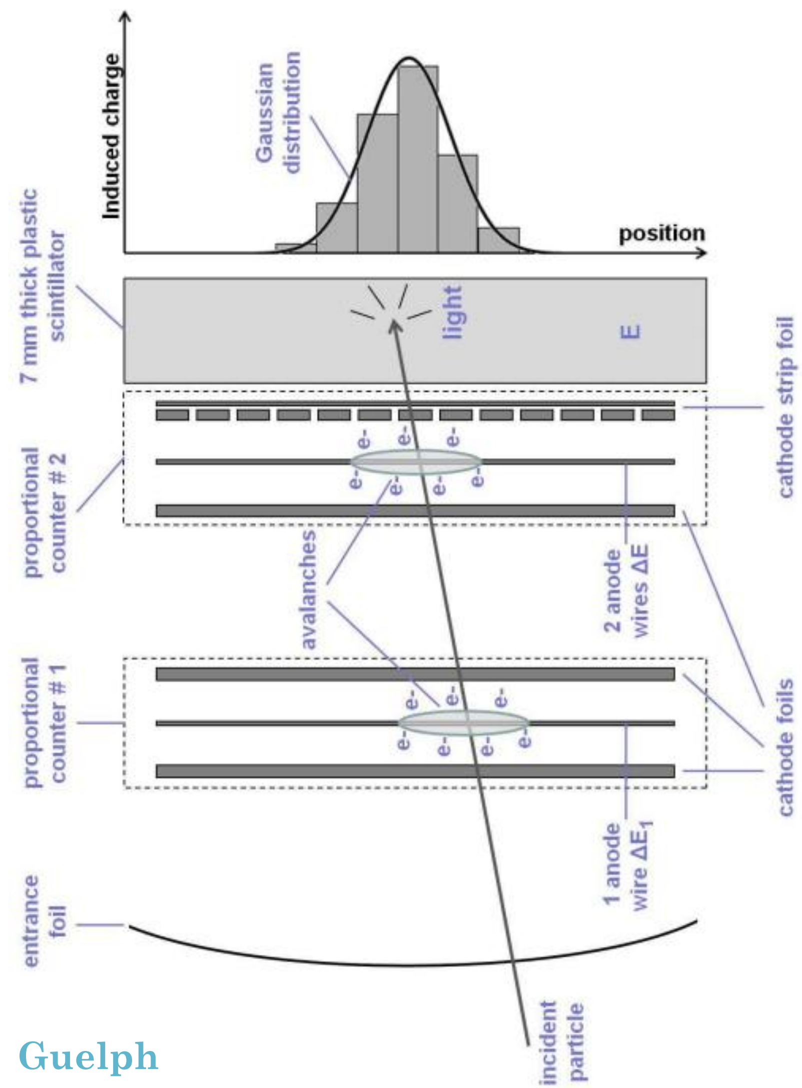


Consistent strong population of 0_2^+ state across N=92 isotones ?

Excited 0^+ States

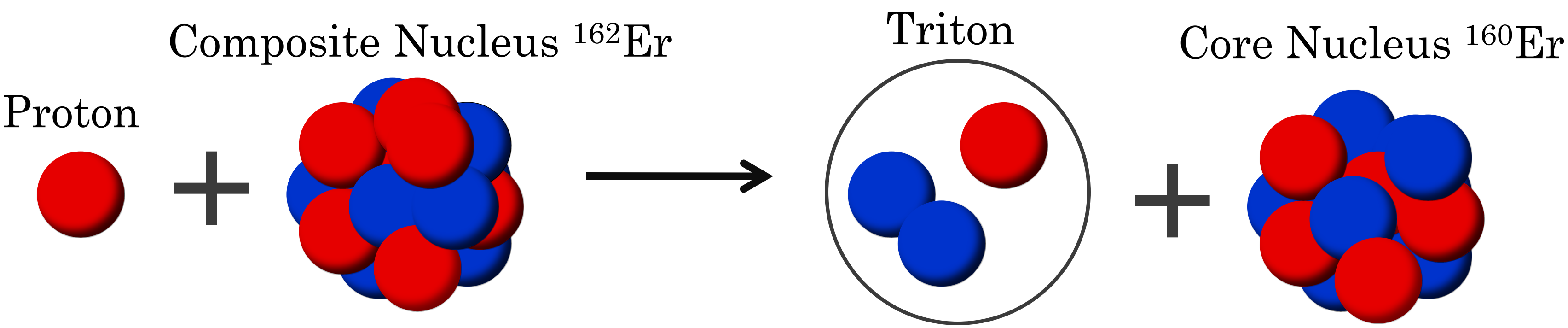


Focal Plane Detector



S. Chagnon-Lessard

^{162}Er(p,t)^{160}Er transfer reaction

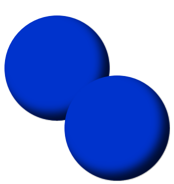


$$S = \vec{s}_1 + \vec{s}_2$$

$$L = \vec{l}_1 + \vec{l}_2$$

$$|L - S| < J < |L + S|$$

$$S = 0$$



J=L even-parity states in most tnt

0^+ Single-Particle Dependence