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THE STATE UNIVERSITY OF NEW JERSEY

Single-neutron excitations near 132Sn

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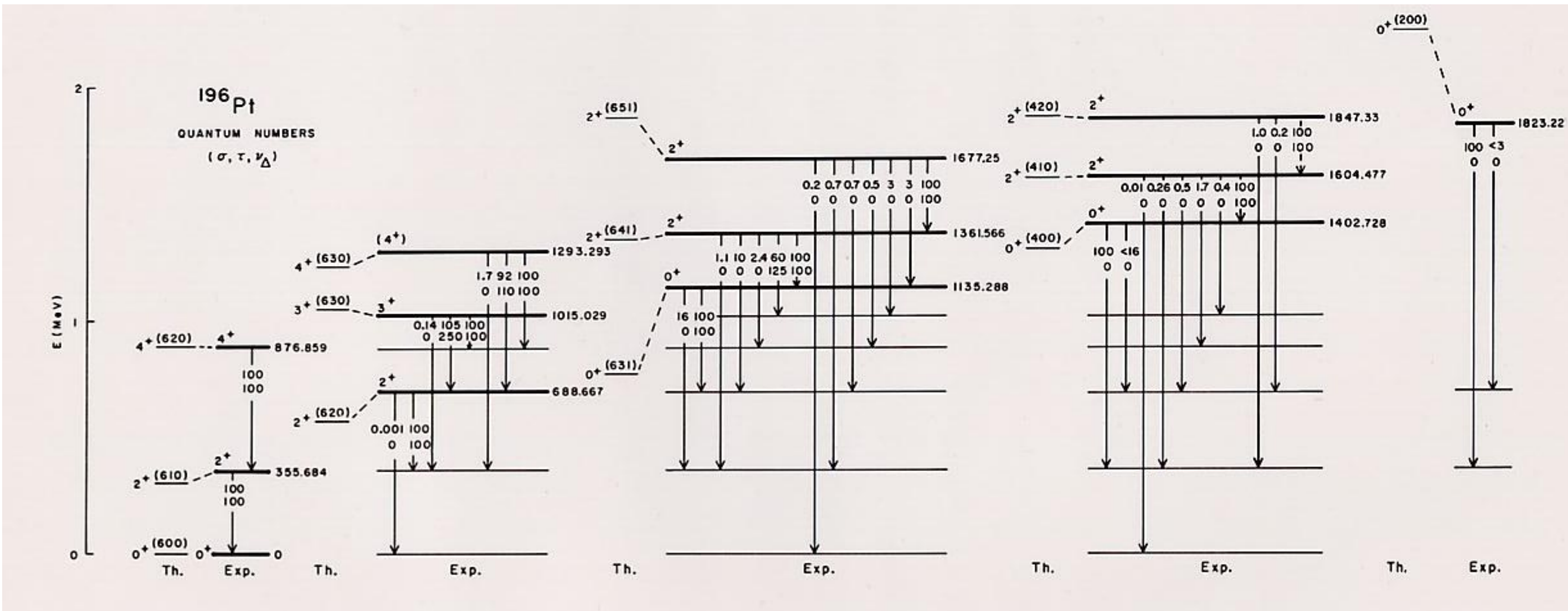
Rutgers University

Beauty in Physics

Celebrating Franco Iachello

O(6) dynamical symmetry of IBA and ^{196}Pt



Level scheme of ^{196}Pt

A. Arima and F. Iachello, PRL **40**, 385 (1978)
J.A.C., R.F. Casten et al. PRL **40**, 167 (1978)

Boson-fermion dynamical symmetry and supersymmetry in Os-Ir-Pt-Au-Hg Nuclei: Tests with transfer reactions

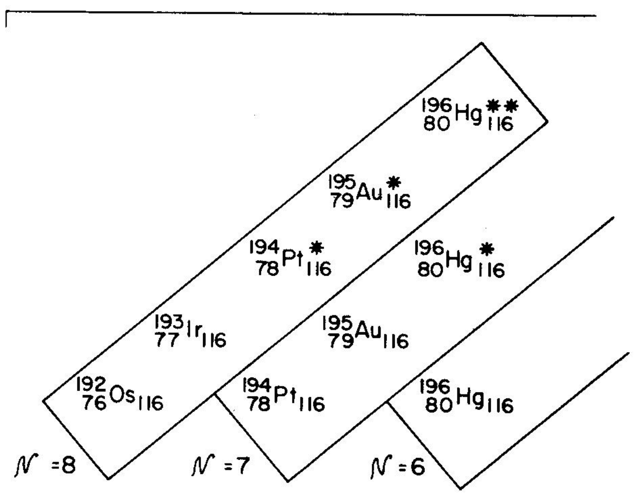


FIG. 9. Schematic diagram of the $n=N+M=8$ supermultiplet of the U(6/4) supersymmetry and the adjacent $n=7$ and 6 supermultiplets.

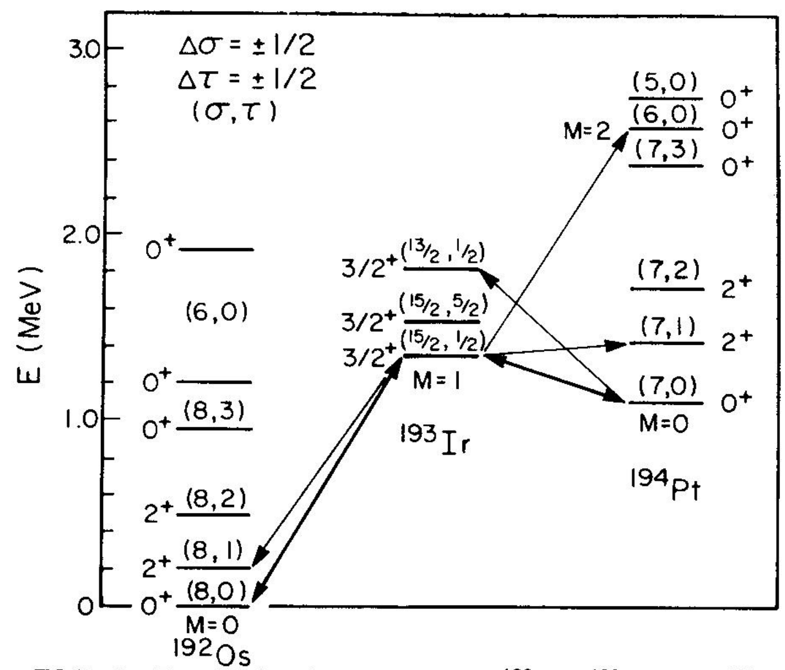


FIG. 8. Partial level diagrams of ^{192}Os, ^{193}Ir, and ^{194}Pt

O(6) + j=3/2 proton

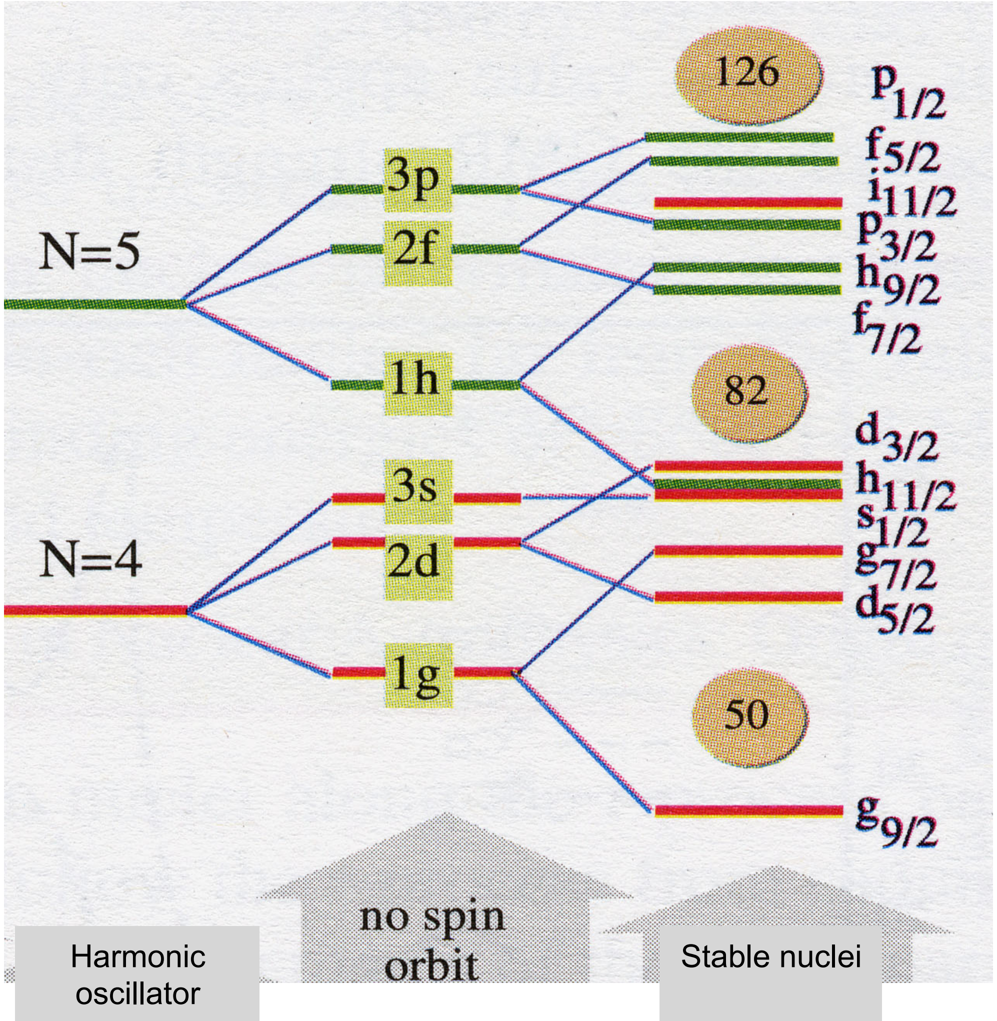
^{194}Pt(t,α) reaction populates $3/2^+$ states in ^{193}Ir with Spin(6) symmetry ratios.

Theory: F. Iachello, PRL **44**, 772 (1981)

Experiment: J.A.C. et al., PRL **46**, 1264 (1981)

^{196}Pt region: Protons 50<Z<82; Neutrons 82<N<126

“Flat” harmonic oscillator potential with positive spin-orbit interaction



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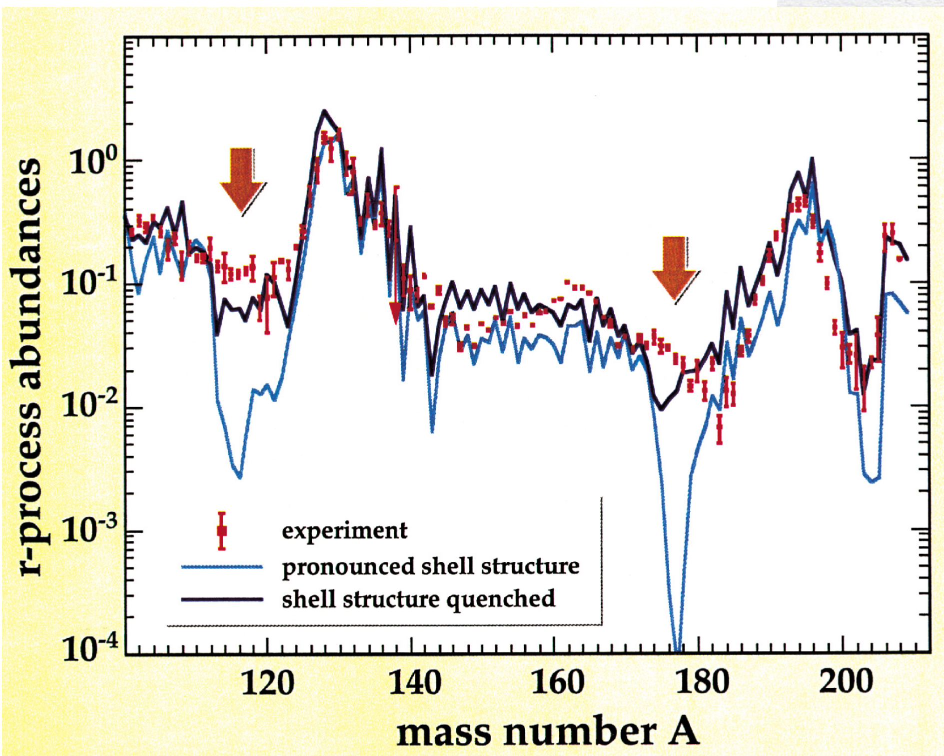
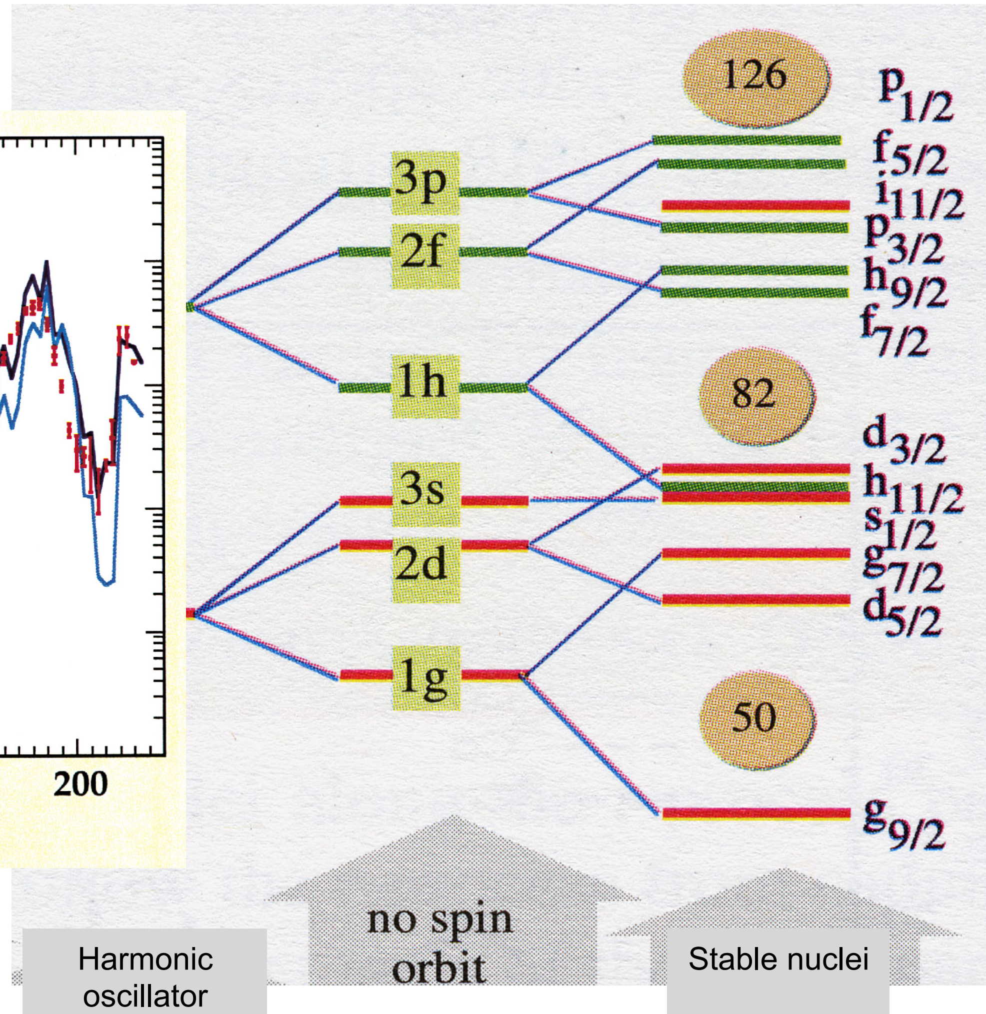
What happens to shell structure away from stability?





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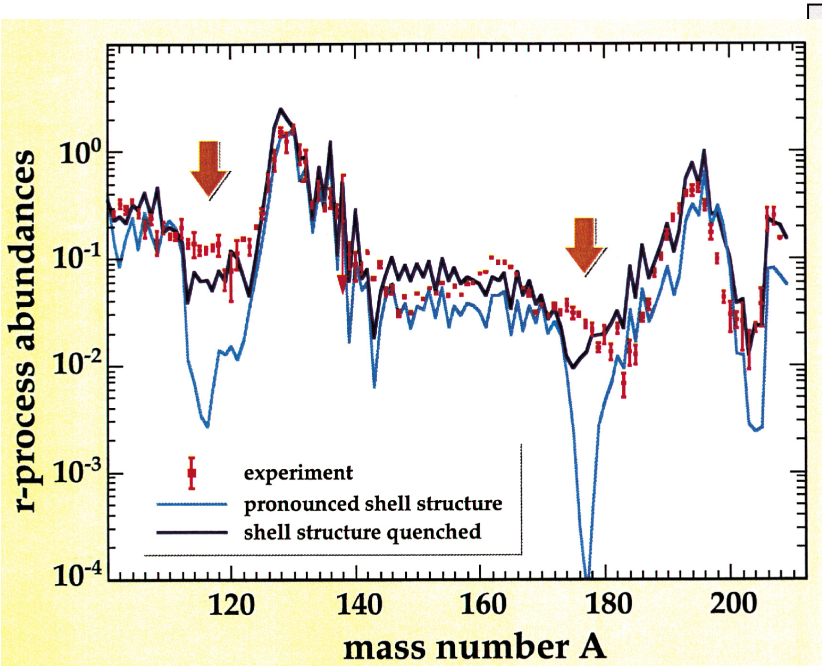
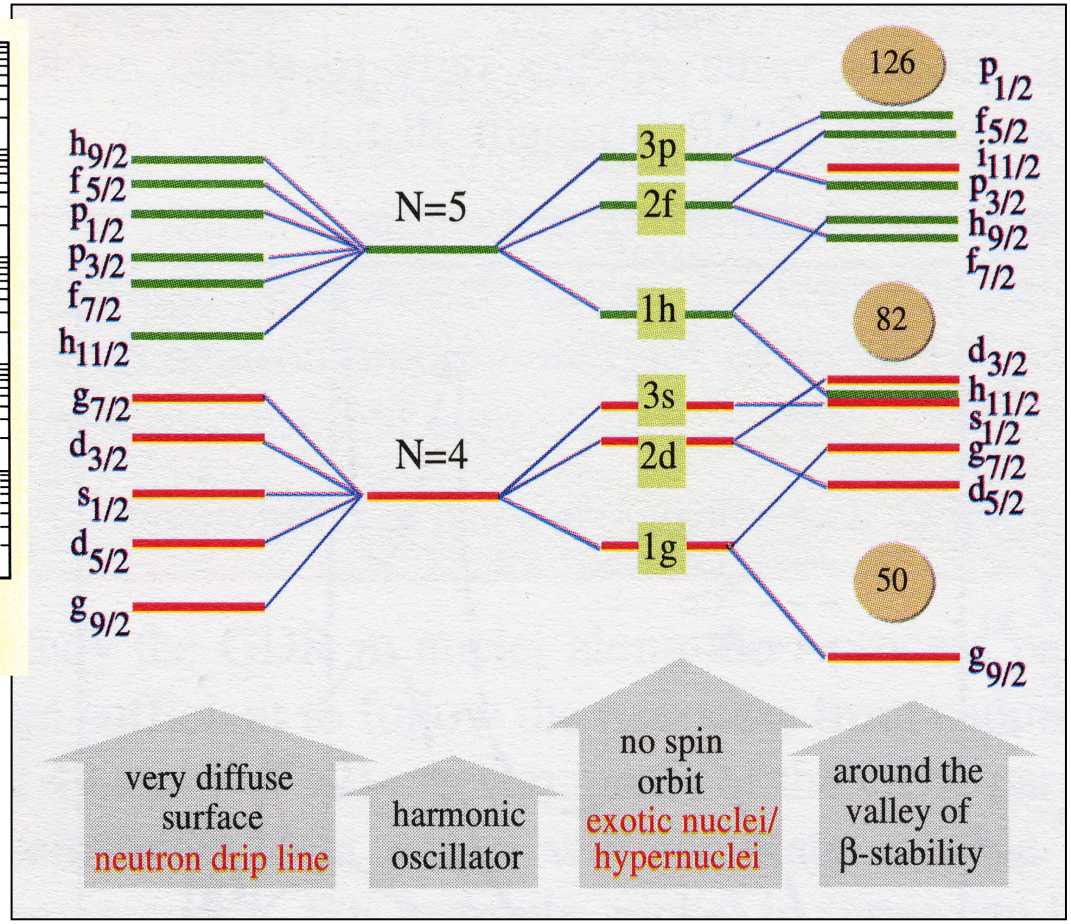
Evolution of nuclear shell structure





Probe neutron-rich nuclei with beams of rare isotopes

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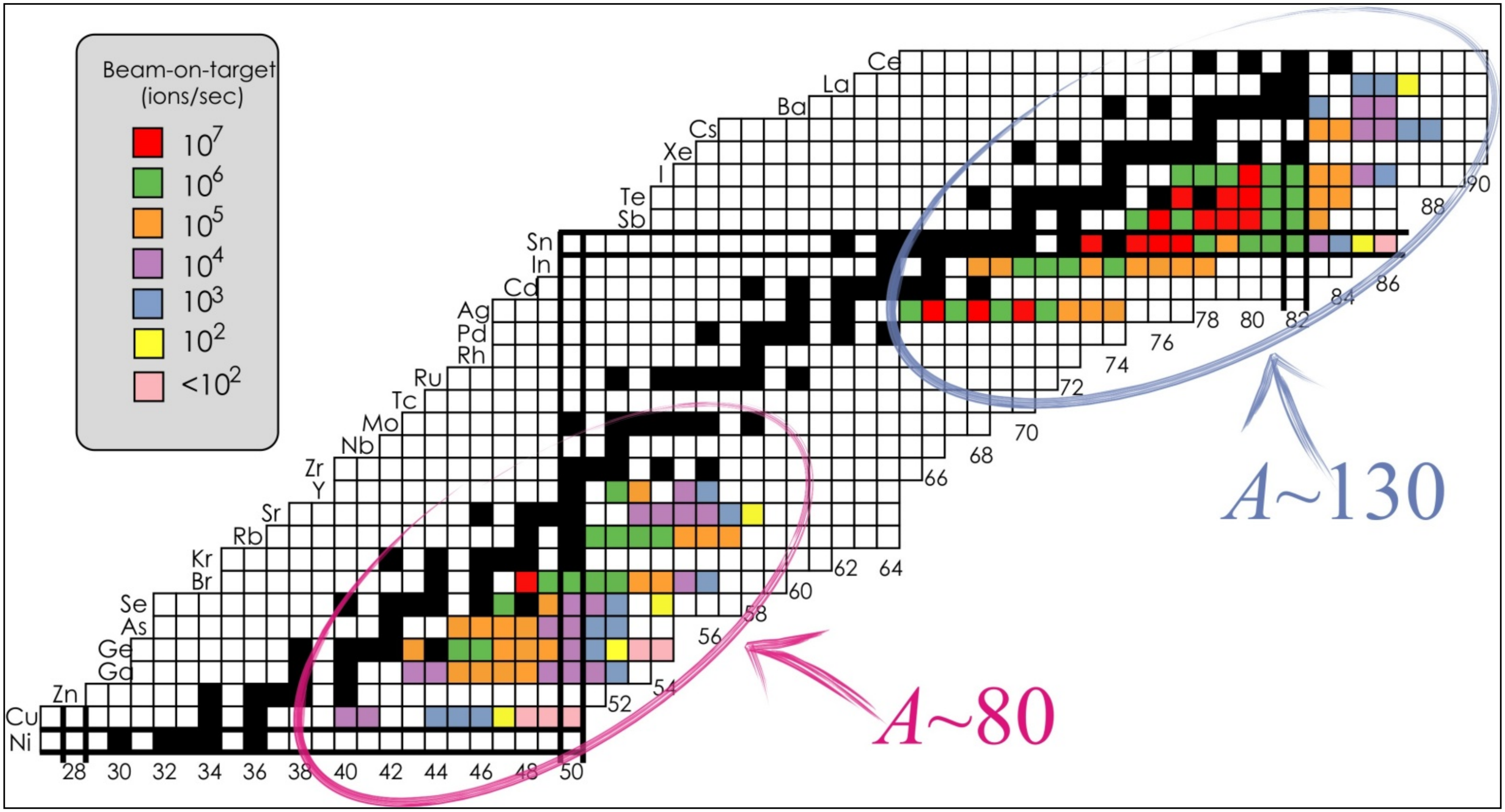
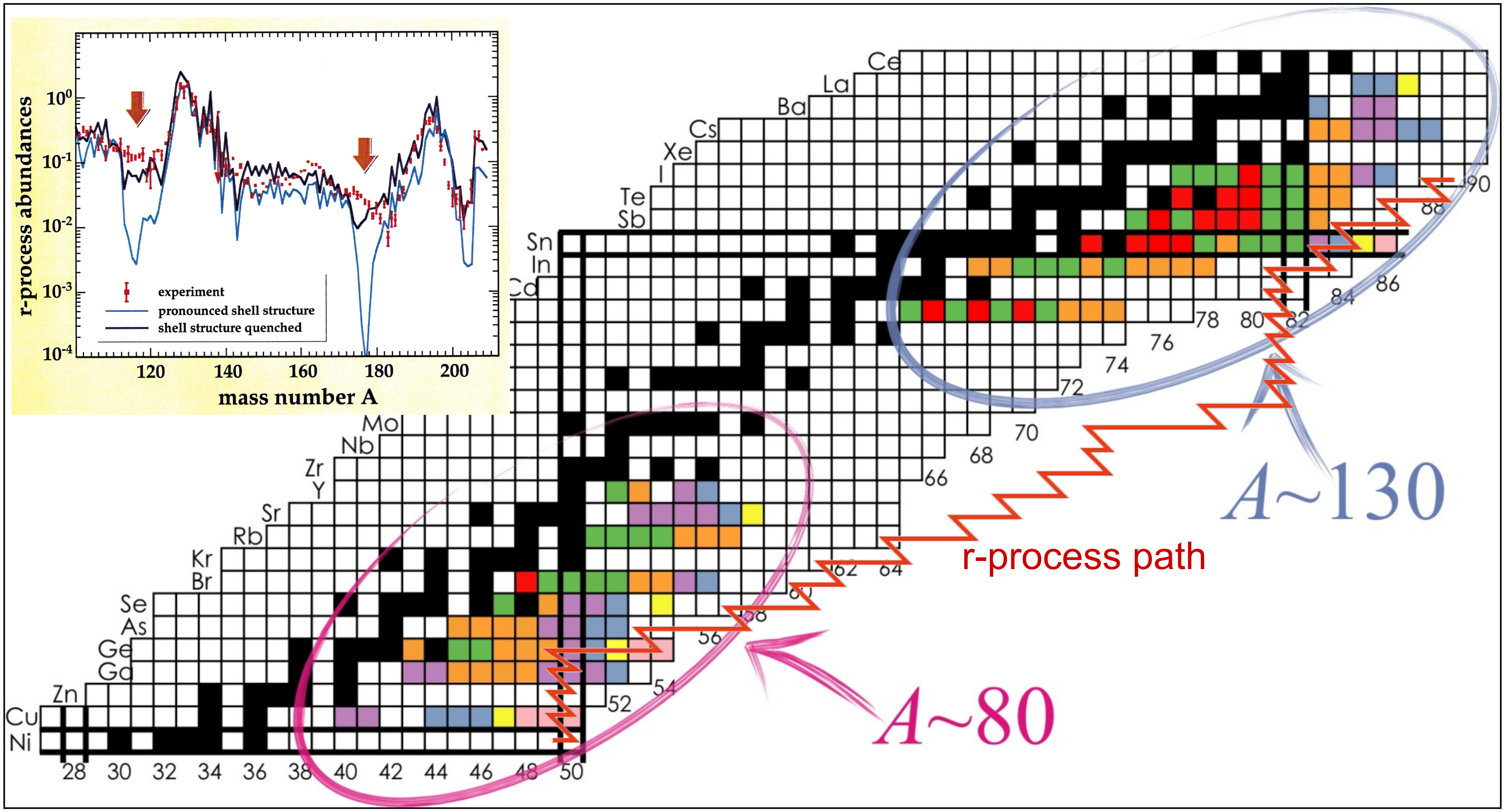
Spectroscopy of Neutron-rich Nuclei at HRIBF



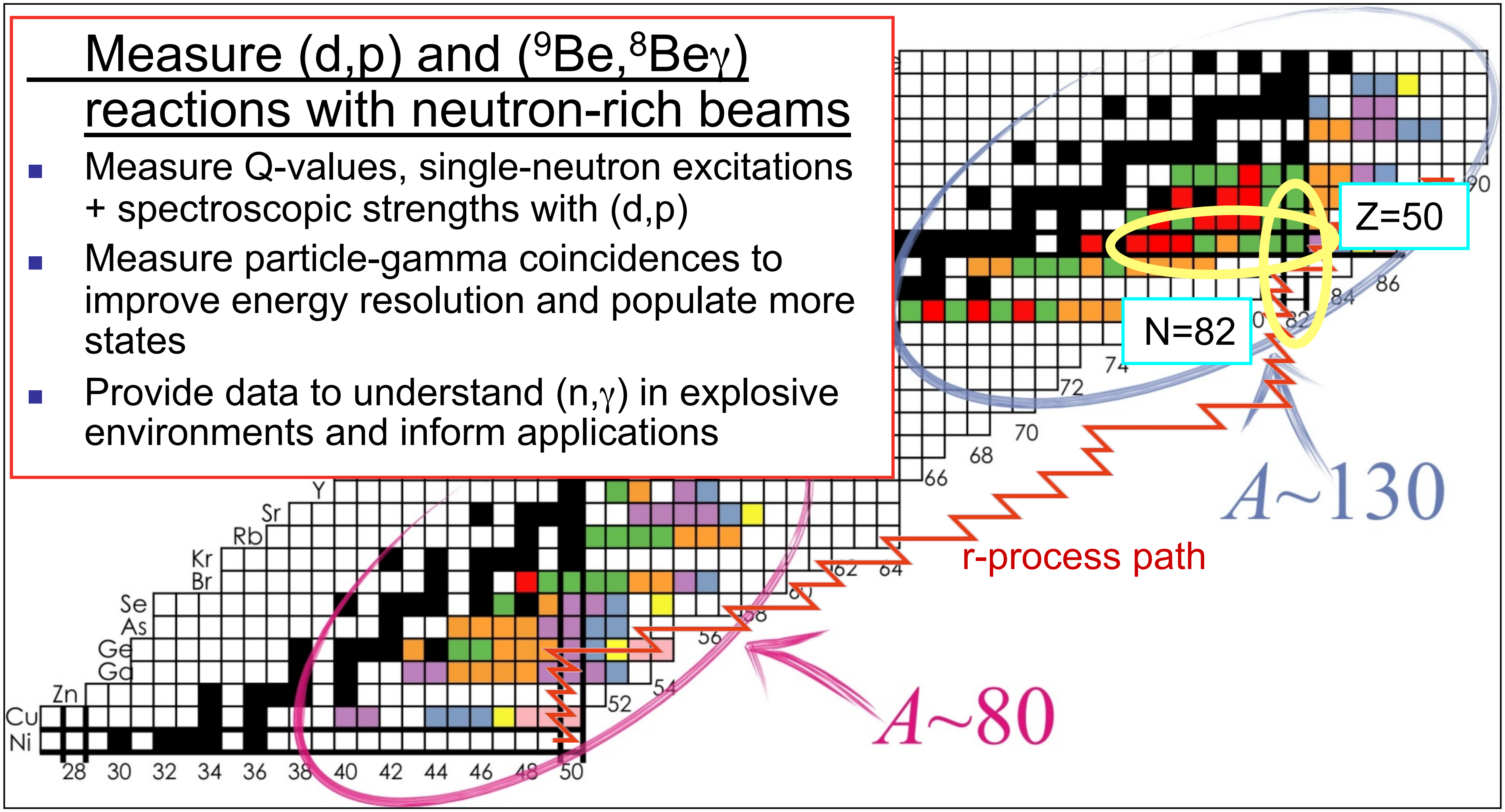
Spectroscopy of neutron-rich nuclei at HRIBF



Neutron transfer reactions with neutron-rich nuclei

Measure (d,p) and (^{9}Be,^{8}Beγ) reactions with neutron-rich beams

- Measure Q-values, single-neutron excitations + spectroscopic strengths with (d,p)
- Measure particle-gamma coincidences to improve energy resolution and populate more states
- Provide data to understand (n,γ) in explosive environments and inform applications



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A≈130 (d,p) and (^{9}Be,^{8}Beγ) Collaboration

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Univ. Tennessee: S. Ahn, K.Y. Chae, R. Kapler, Kate L. Jones, B.H. Moazen, S.T. Pittman, K.T. Schmitt

Tennessee Tech: Ray L. Kozub

Michigan State Univ: Filomena Nunes

ORAU: W. A. Peters

Louisiana State University: J.C. Blackmon, M. Matos

University of Surrey: S. Hardy, T.P. Swan, J.S. Thomas, G.L. Wilson

Colorado School of Mines: K.A. Chipps, L. Erikson, R. Livesay

Ohio University: A.S. Adekola

UNAM: E. Padilla-Rodal

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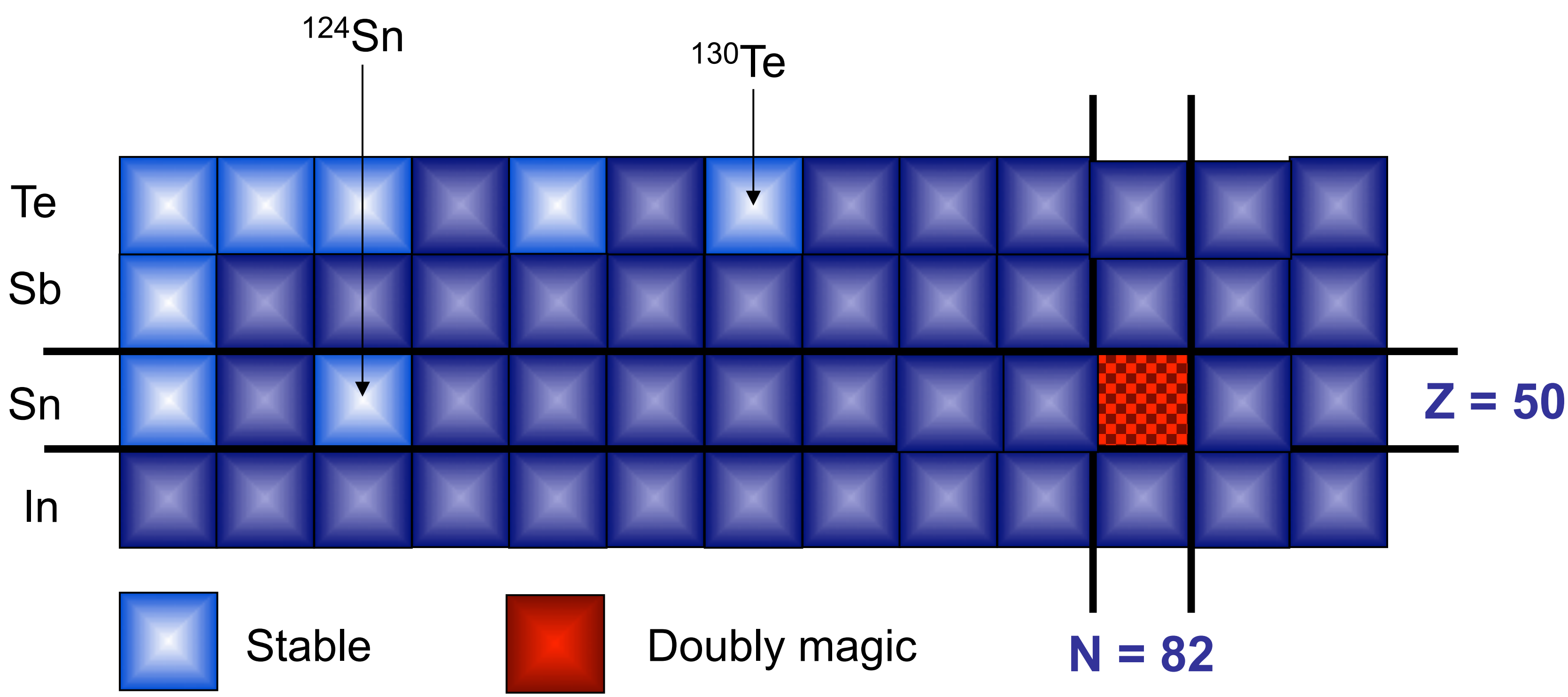
E

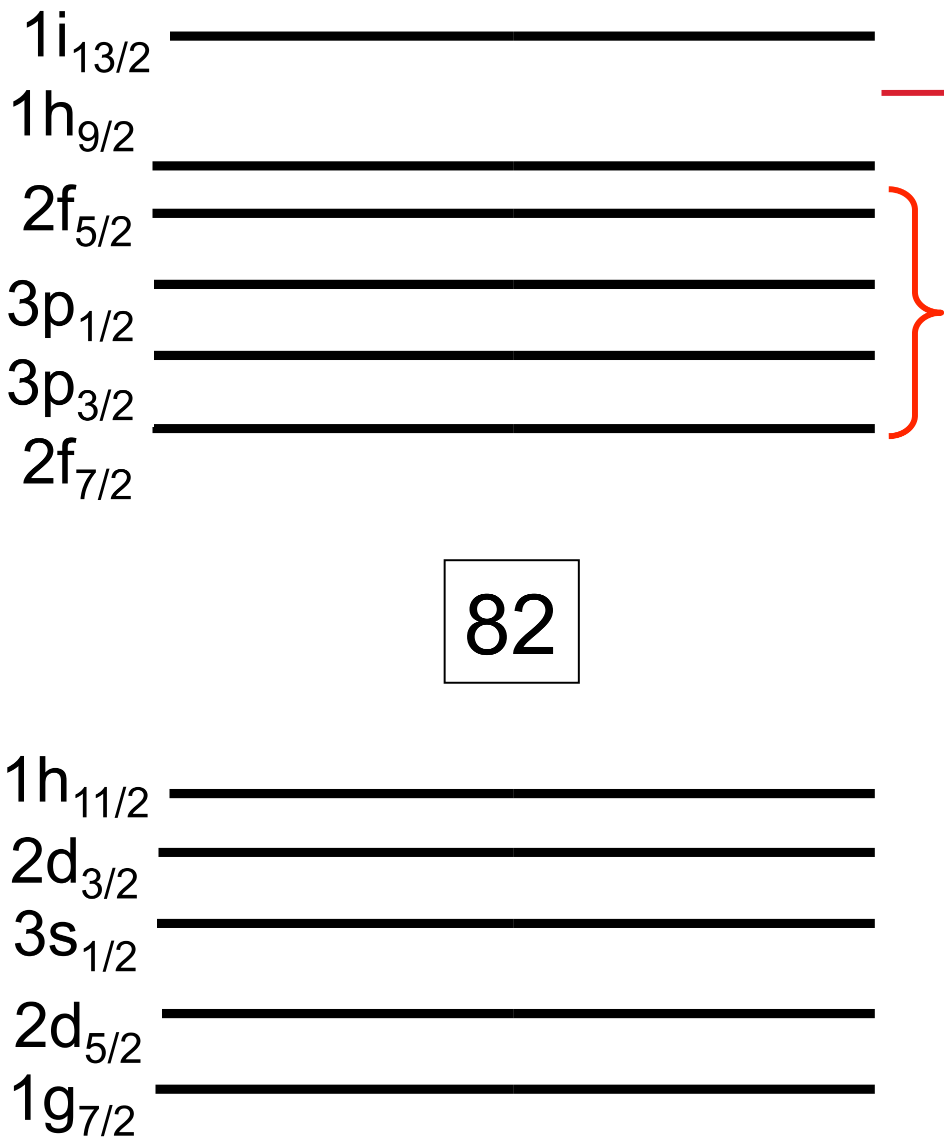
^{132}Sn Z=50, N=82

Nuclear reaction & structure studies

Beams of neutron-rich ^{132}Sn
$t_{1/2}$=40s

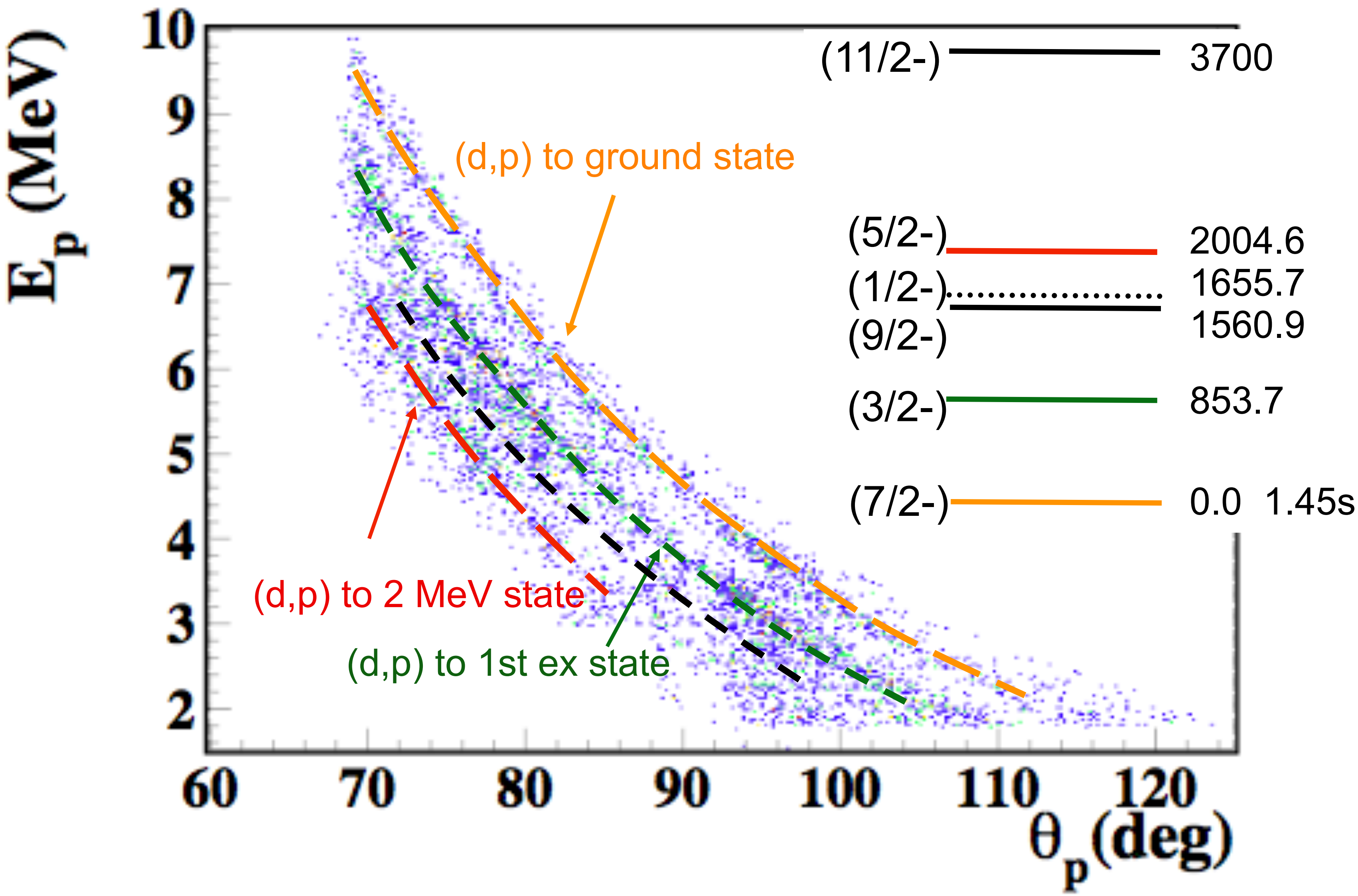


Sn (d,p): what should expect to see?



Should be strongest in N=82 (d,p) (ℓ =1 and ℓ =3)

$^{132}Sn(d,p)$ data



K.L. Jones et al.

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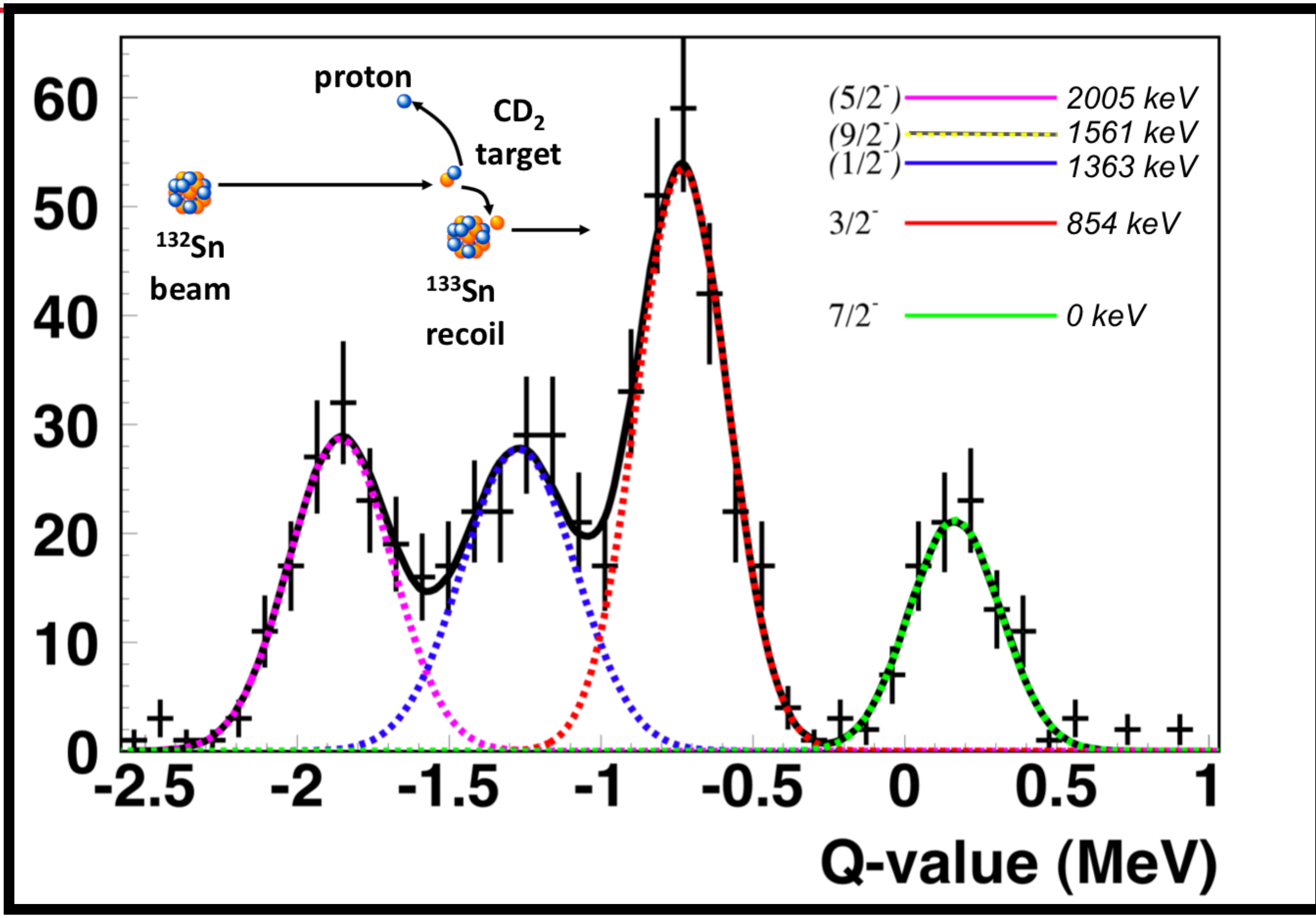
$^{132}Sn(d,p)$ Q-value



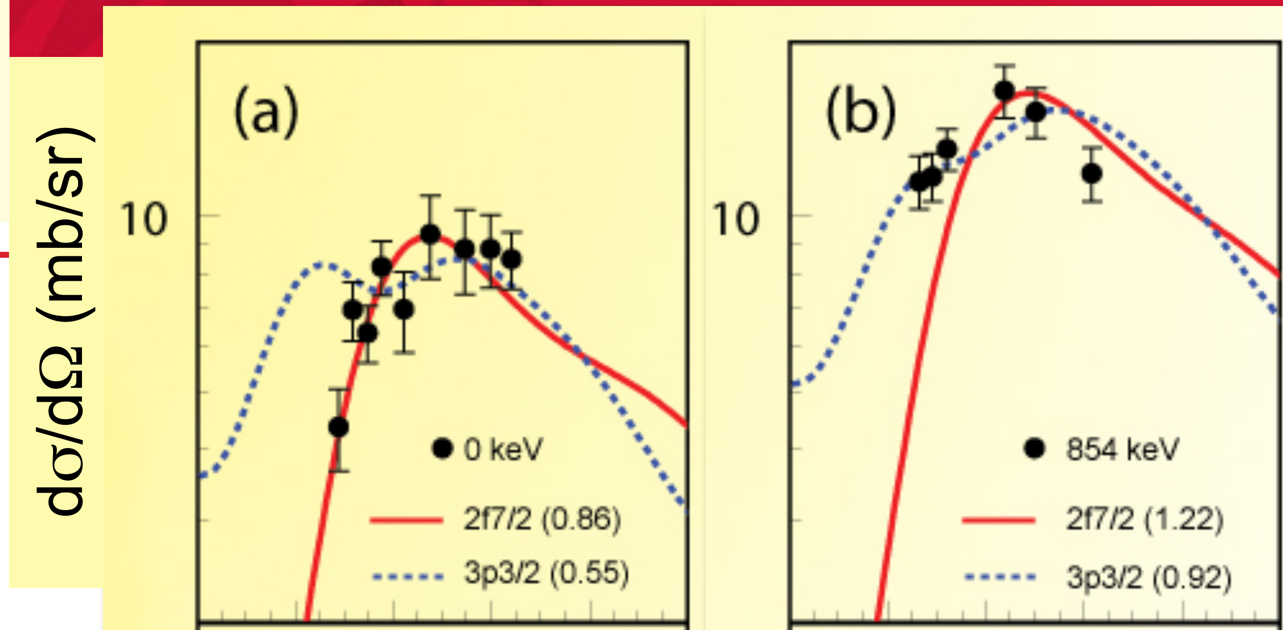
K.L. Jones et al.
Nature, **465**,454 (2010)

(d,p) exp cross sections & spectroscopic factors

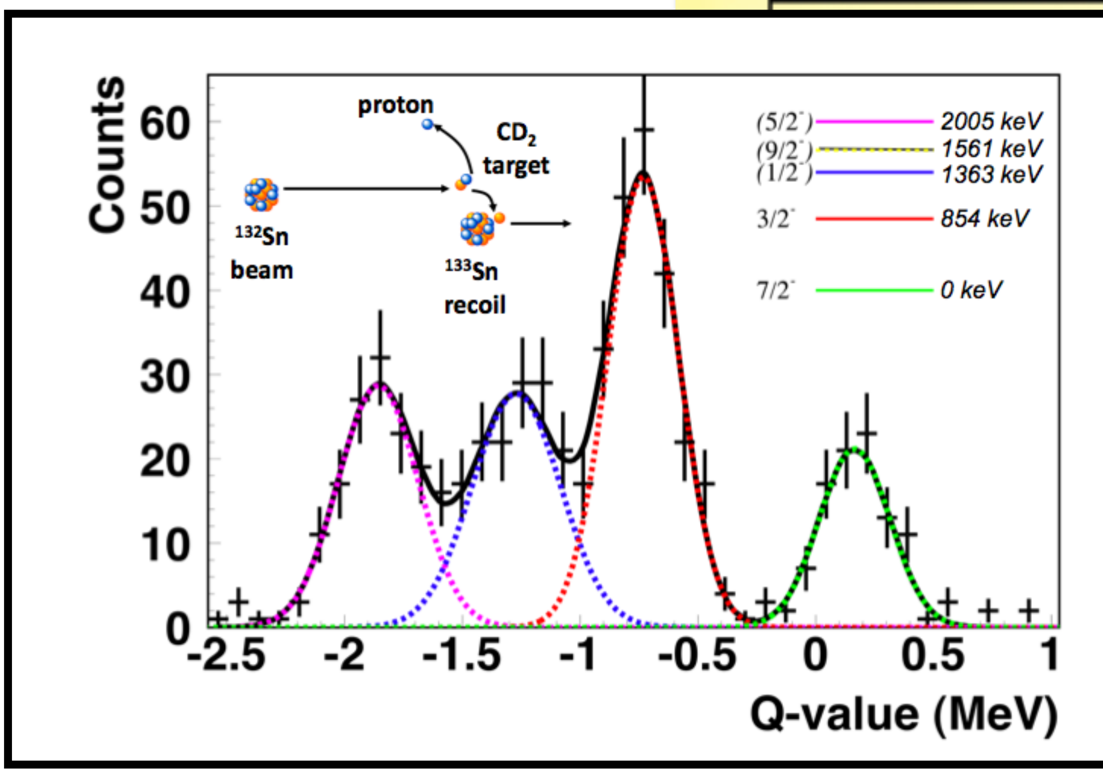
- Absolute exp cross sections ⇐ normalization of data from elastic scattering of deuterons
- Input for theoretical cross sections DWBA
  - Potentials (optical model)
    - Incoming deuteron, outgoing proton, neutron bound state
  - Wave function of the deuteron
  - Wave function of transferred particle, e.g., $2f_{7/2}$ neutron
- Output from theoretical cross sections compared to exp
- (relative) S≈1 ⇒ full spectroscopic strength

$$S = \left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{exp}} \Big/ \left(\frac{d\sigma}{d\Omega}\right)_{DWBA}$$

Angular Distributions



θ(cm) degrees

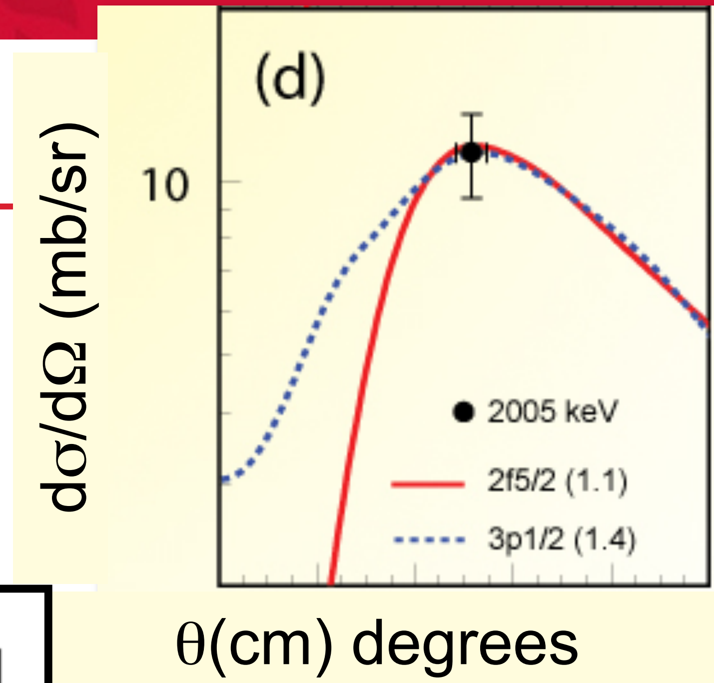


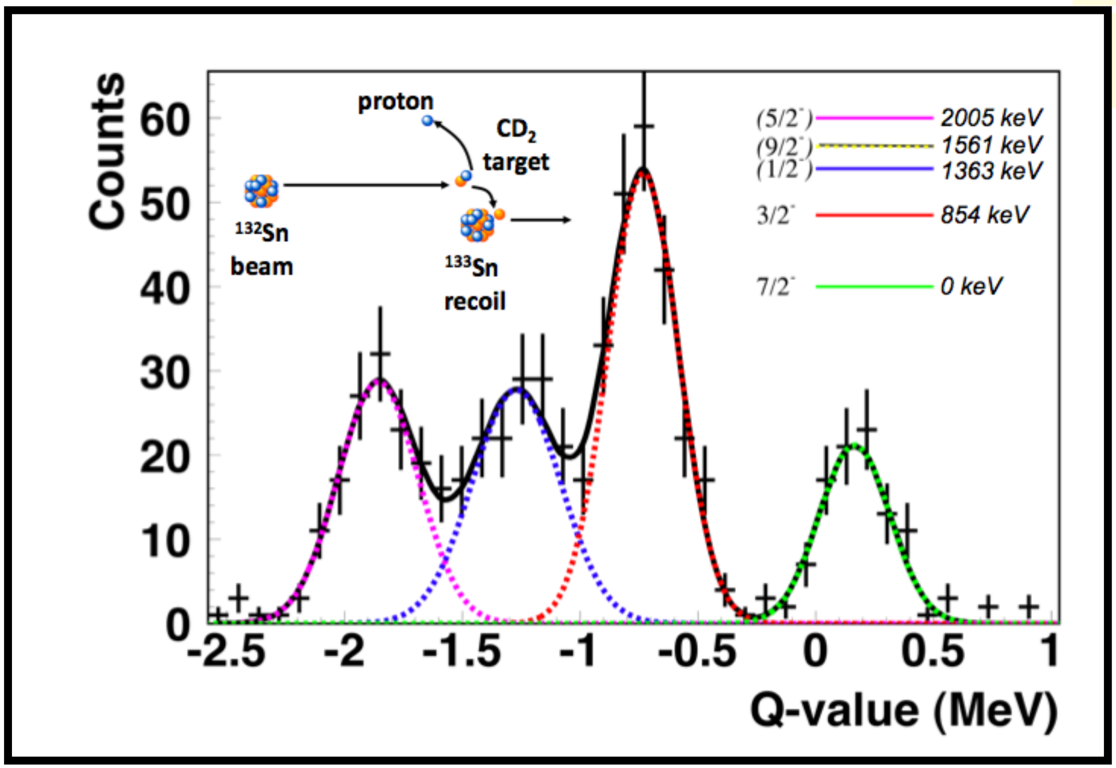
^{133}Sn

ground & 854 keV

K.L. Jones et al.
Nature, **465**,454 (2010)

Angular Distributions

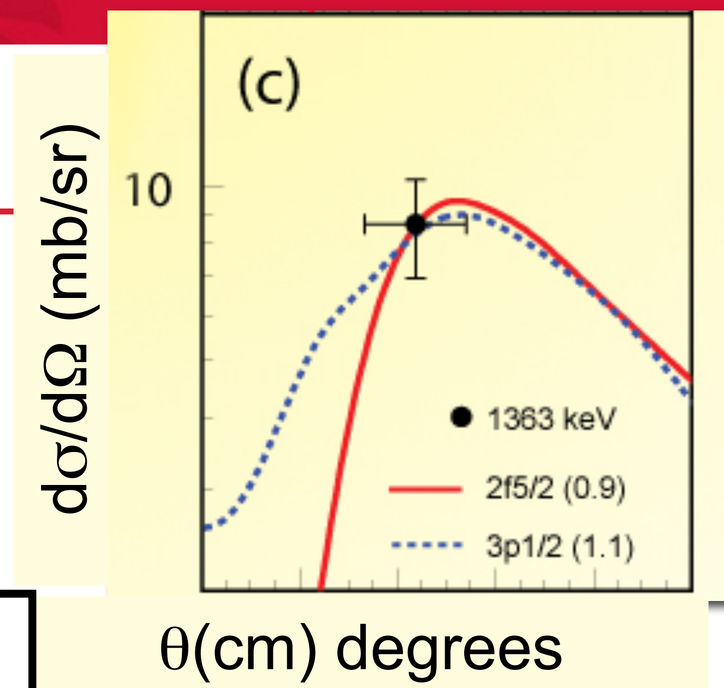


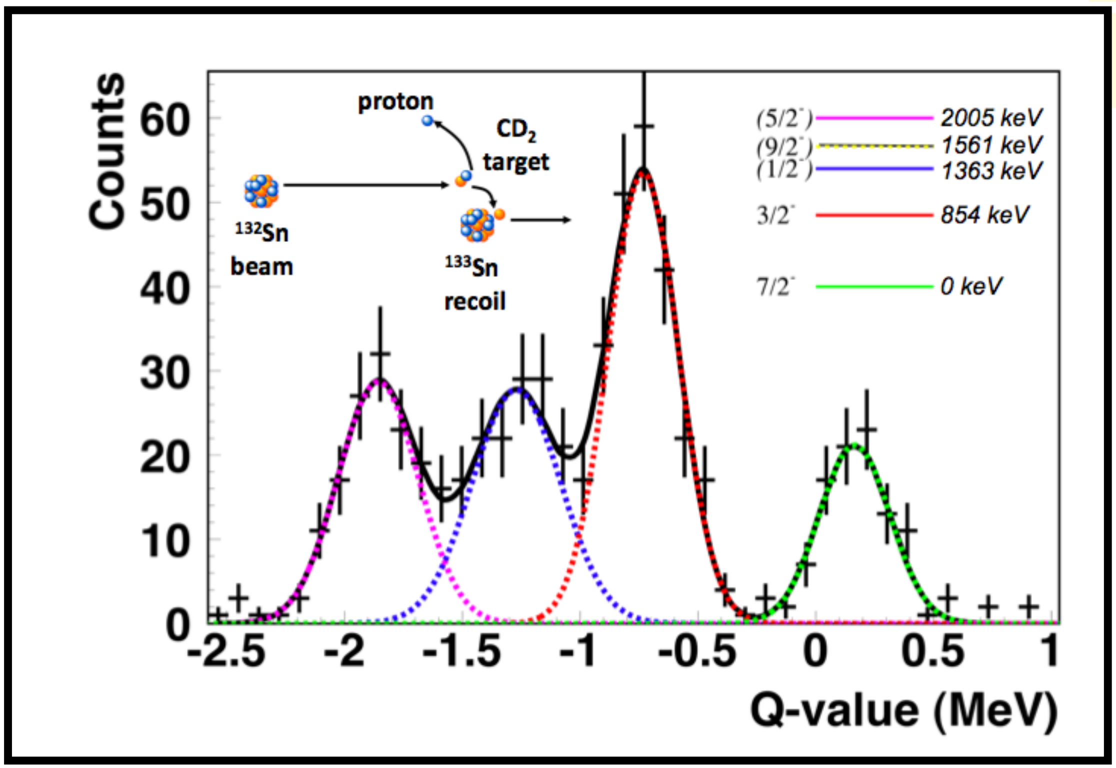


^{133}Sn
2005 keV

K.L. Jones et al.
Nature, **465**,454 (2010)

Angular Distributions



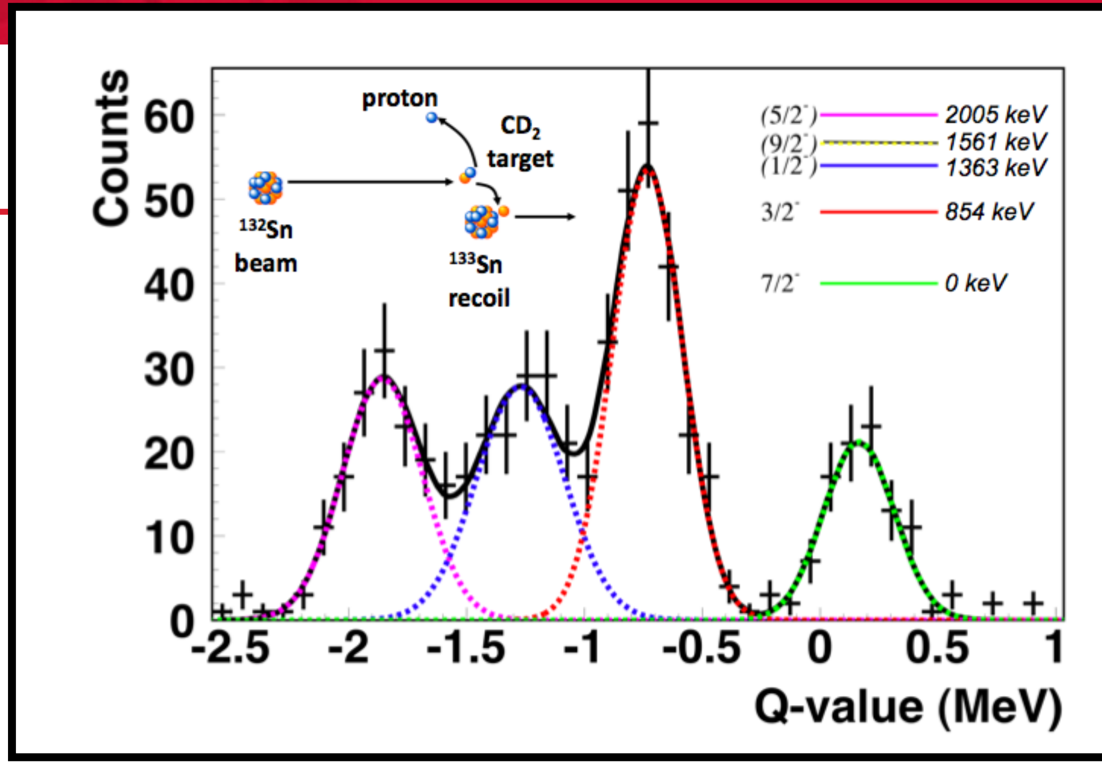


^{133}Sn
1363 keV

K.L. Jones et al.
Nature, **465**,454 (2010)

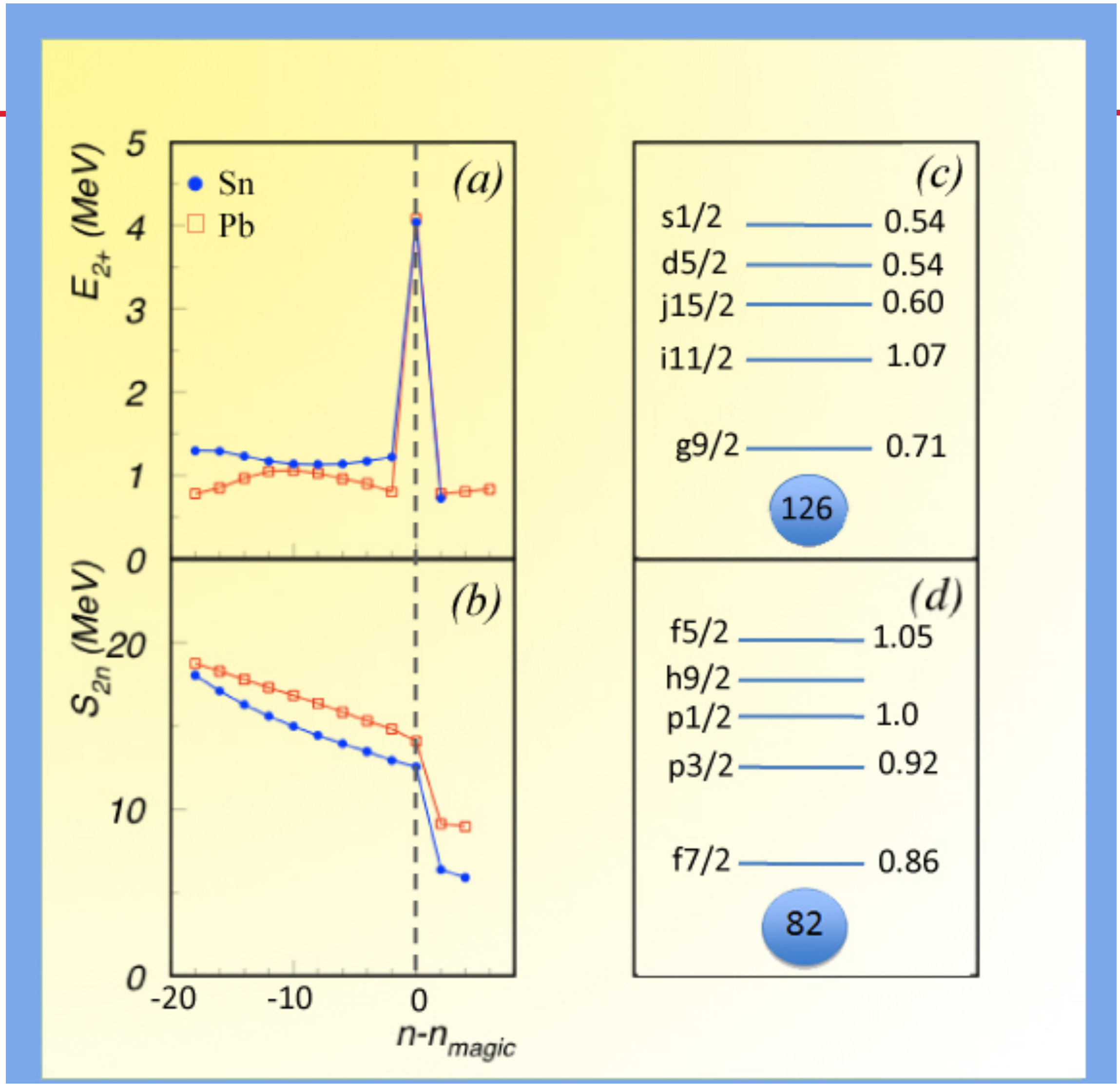
Identified $2f_{7/2}$, $3p_{3/2}$, $(3p_{1/2})$, $2f_{5/2}$ neutron strength in ^{133}Sn

K.L. Jones et al.
Nature, **465**,454 (2010)
Phys. Rev. C **84**, 034601 (2011)



E_x(keV)	J^π	Config	SF (DWBA)	SF (FR-ADWA)	C^2 (fm^{-1})
0	$7/2^-$	$2f_{7/2}$	0.86(14)	1.00(8)	0.64(10)
854	$3/2^-$	$3p_{3/2}$	0.92(14)	0.92(7)	5.6(9)
1363(31)	$(1/2^-)$	$3p_{1/2}$	1.1(3)	1.2(2)	2.6(4)
2005	$(5/2^-)$	$2f_{5/2}$	1.1(2)	1.2(3)	$9(2)\times10^{-4}$

^{132}Sn one of best examples of double-magic nucleus



Modern analysis of SF from ^{132}Sn and ^{208}Pb(d,p)

r-process (n,γ) sensitivity studies

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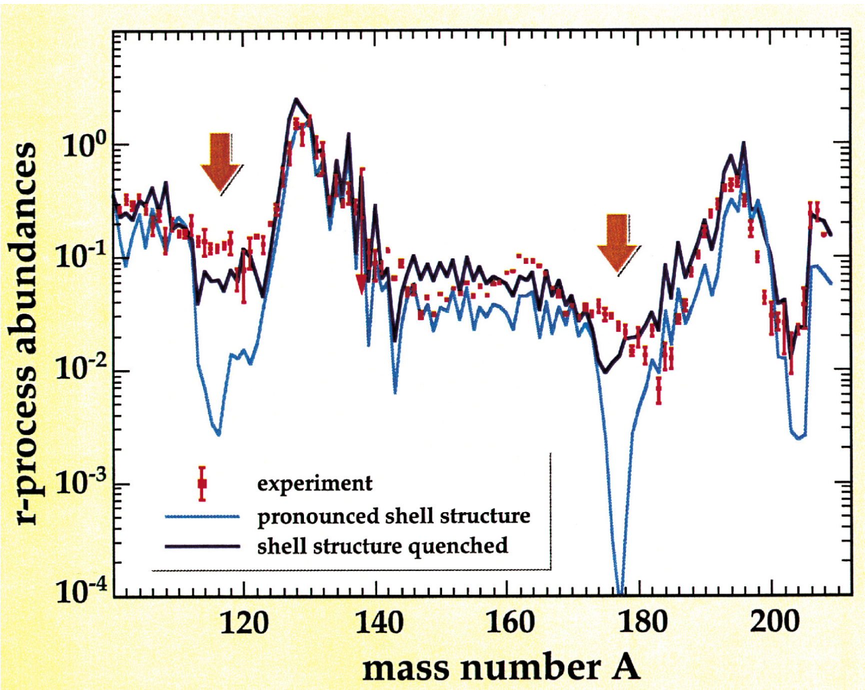
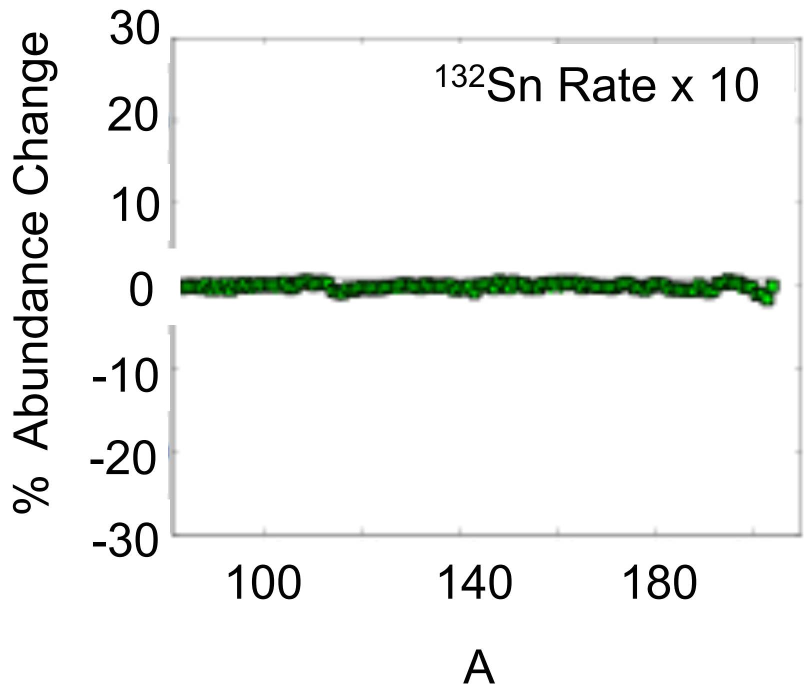
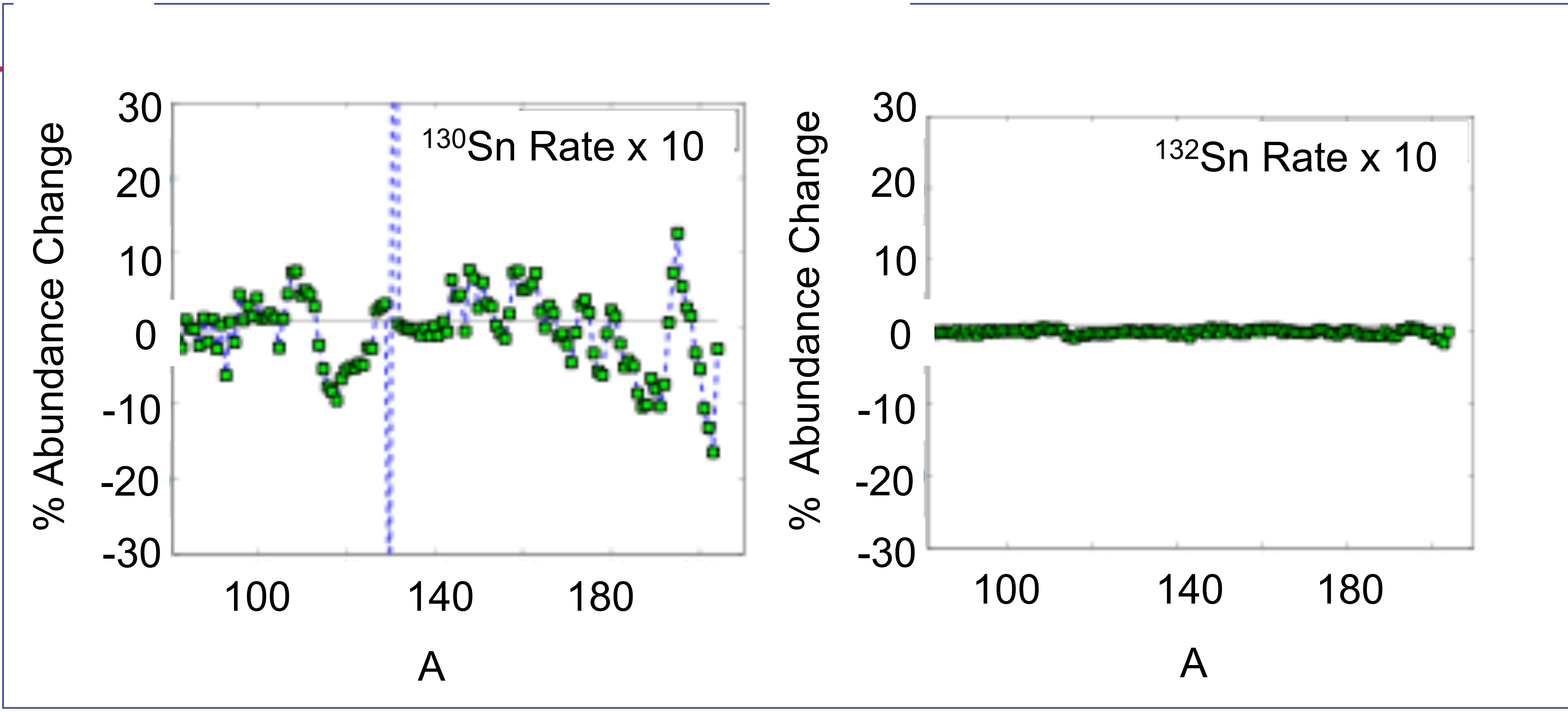




Simulations of the r-process probe **global** sensitivity to ^{132}Sn(n,γ) rate.

J. Beun, *et al.* J. Phys. G 36, 025201 (2009)

r-process sensitivity studies

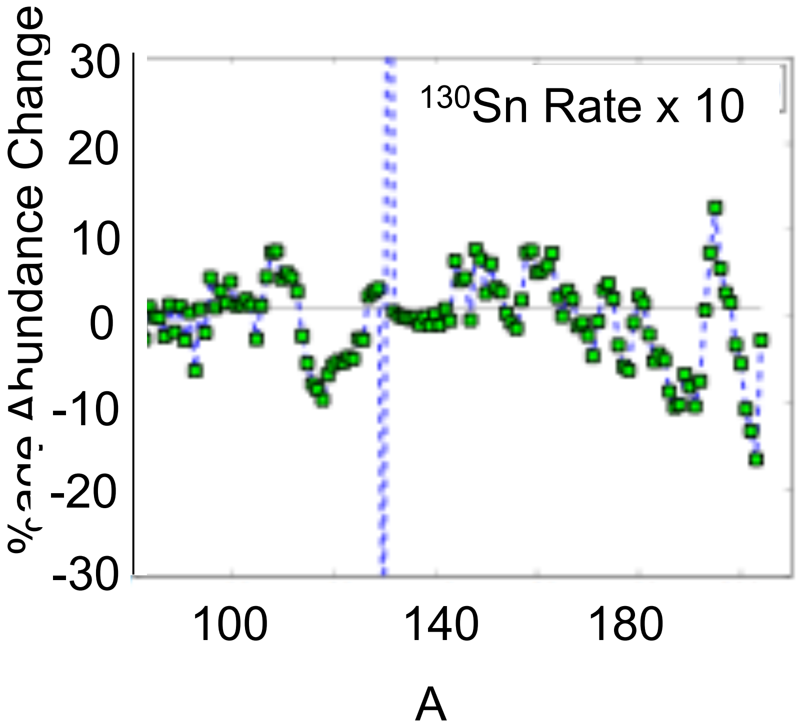


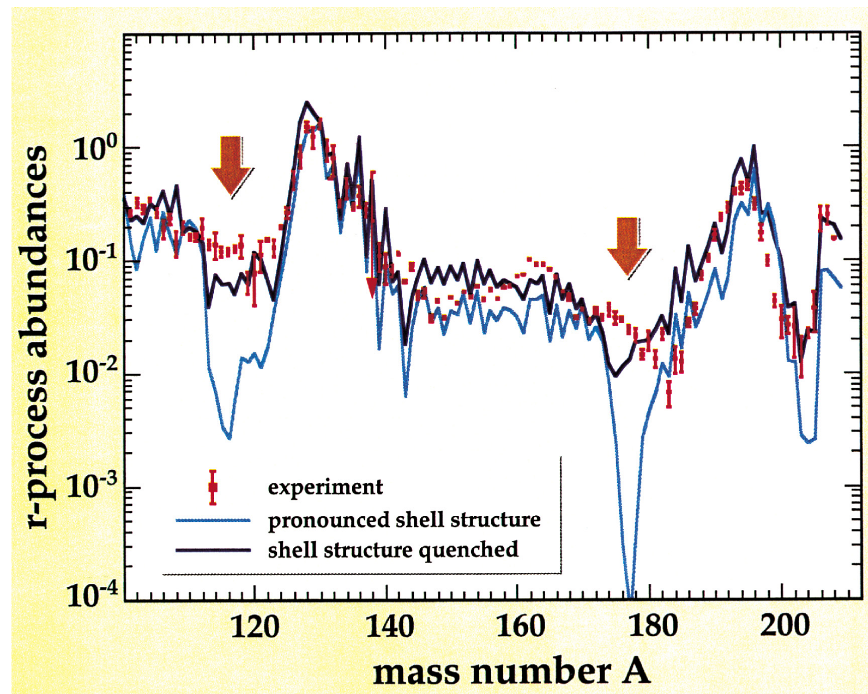
Simulations of the r-process show huge, **global** sensitivity to the $^{130}Sn(n,\gamma)$ rate, in contrast to the $^{132}Sn(n,\gamma)$ rate.

$t_{1/2}(^{130}Sn) = 162s$

J. Beun, *et al.* J. Phys. G 36, 025201 (2009)

r-process sensitivity studies





Simulations of the r-process show huge, **global** sensitivity to the ^{130}Sn(n,γ) rate, in contrast to the ^{132}Sn(n,γ) rate.

$t_{1/2}(^{130}Sn)$ = 162s

J. Beun, *et al.* J. Phys. G 36, 025201 (2009)

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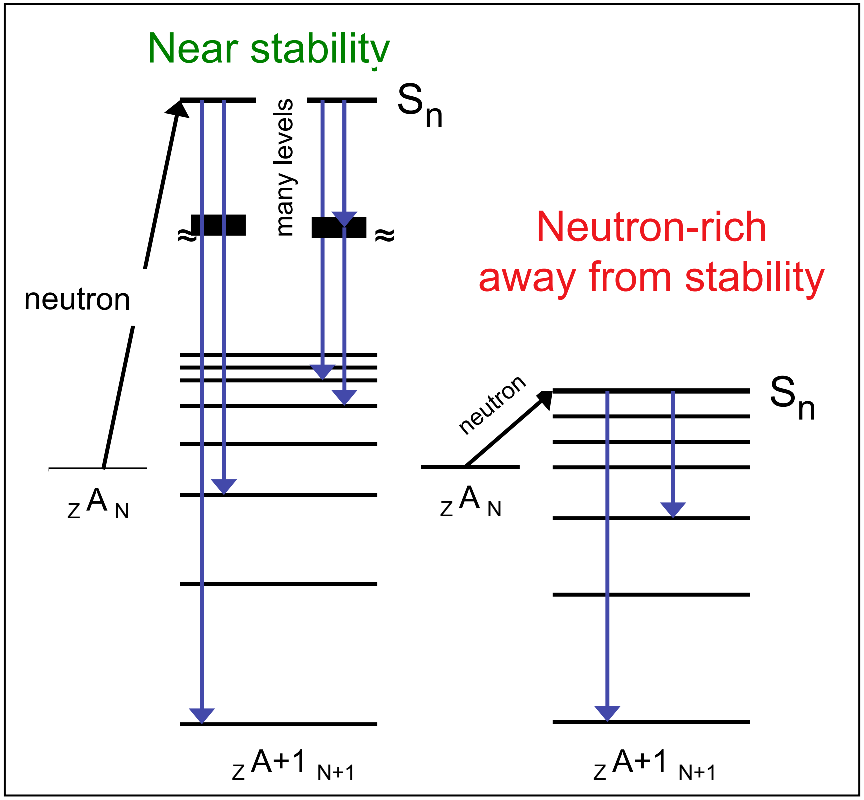
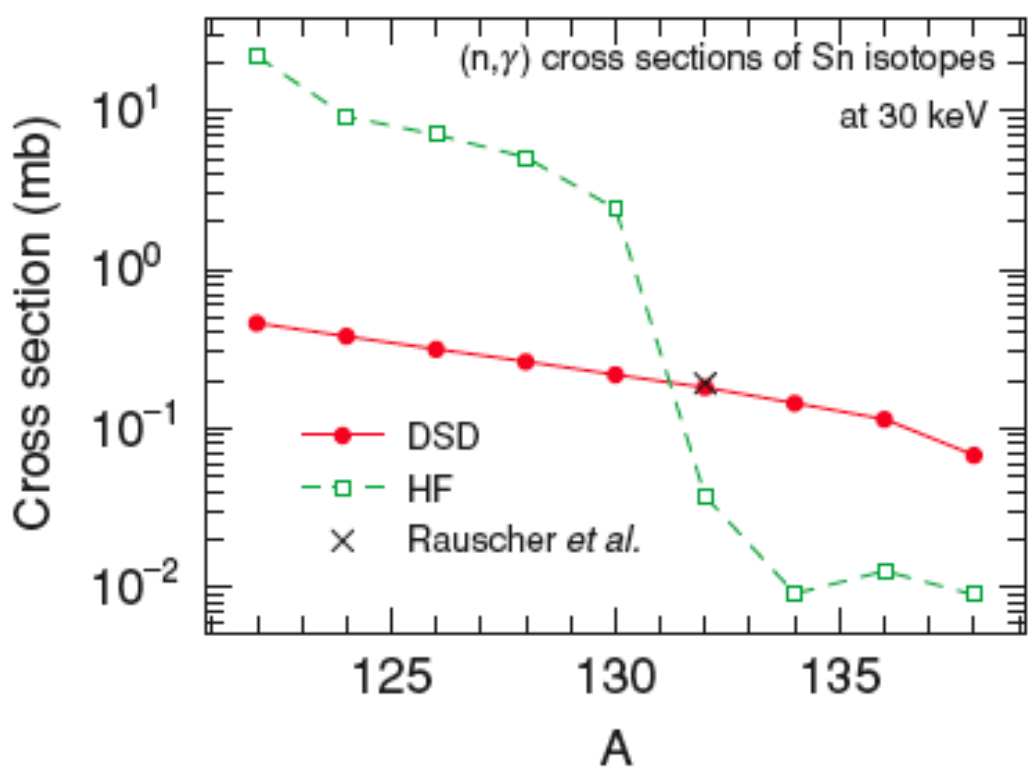
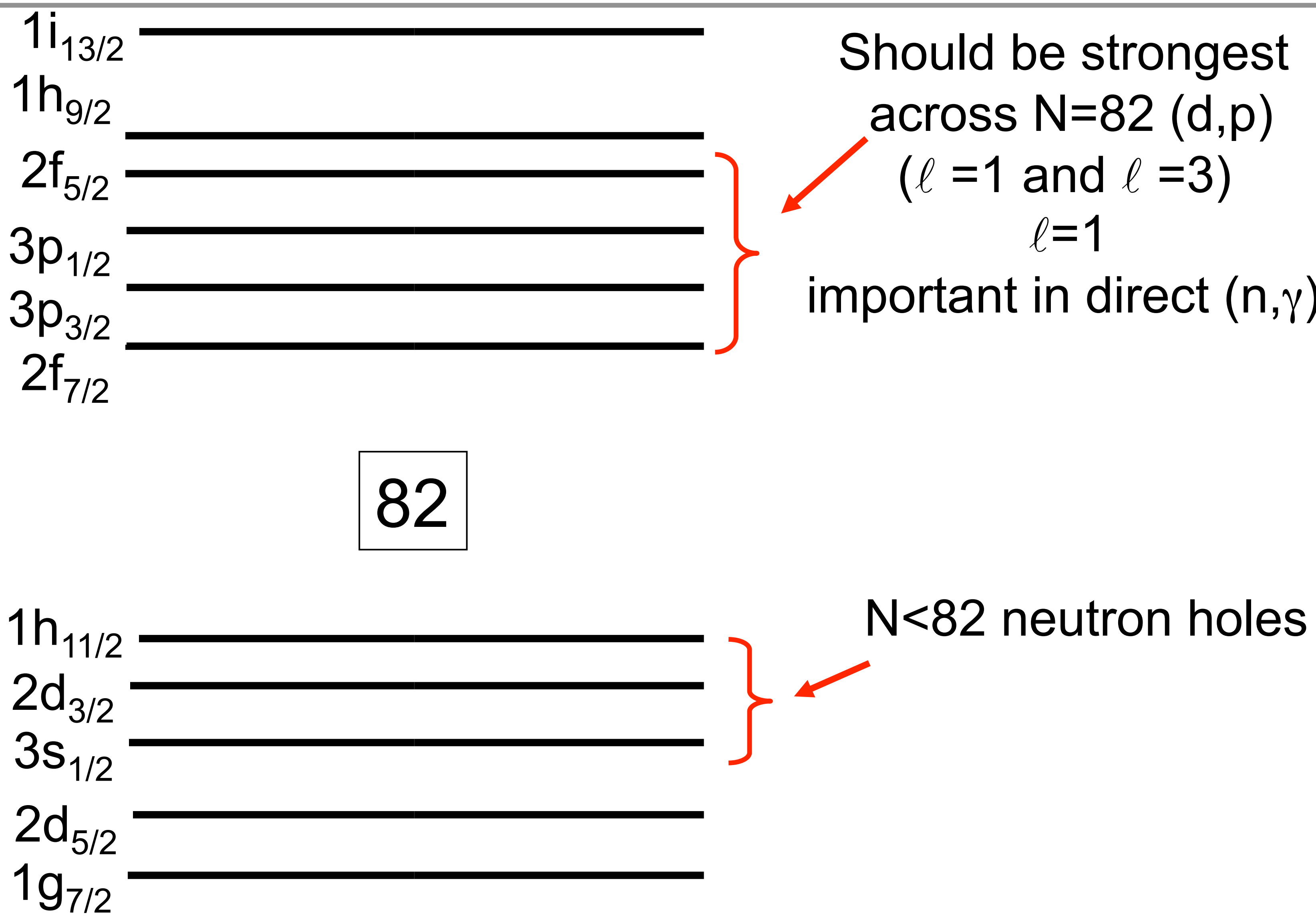
A≈130 Sn σ(n,γ) and sensitivities





Sn(n,γ) vs A
Chiba, et al. PRC **77**, 015809 (2008)

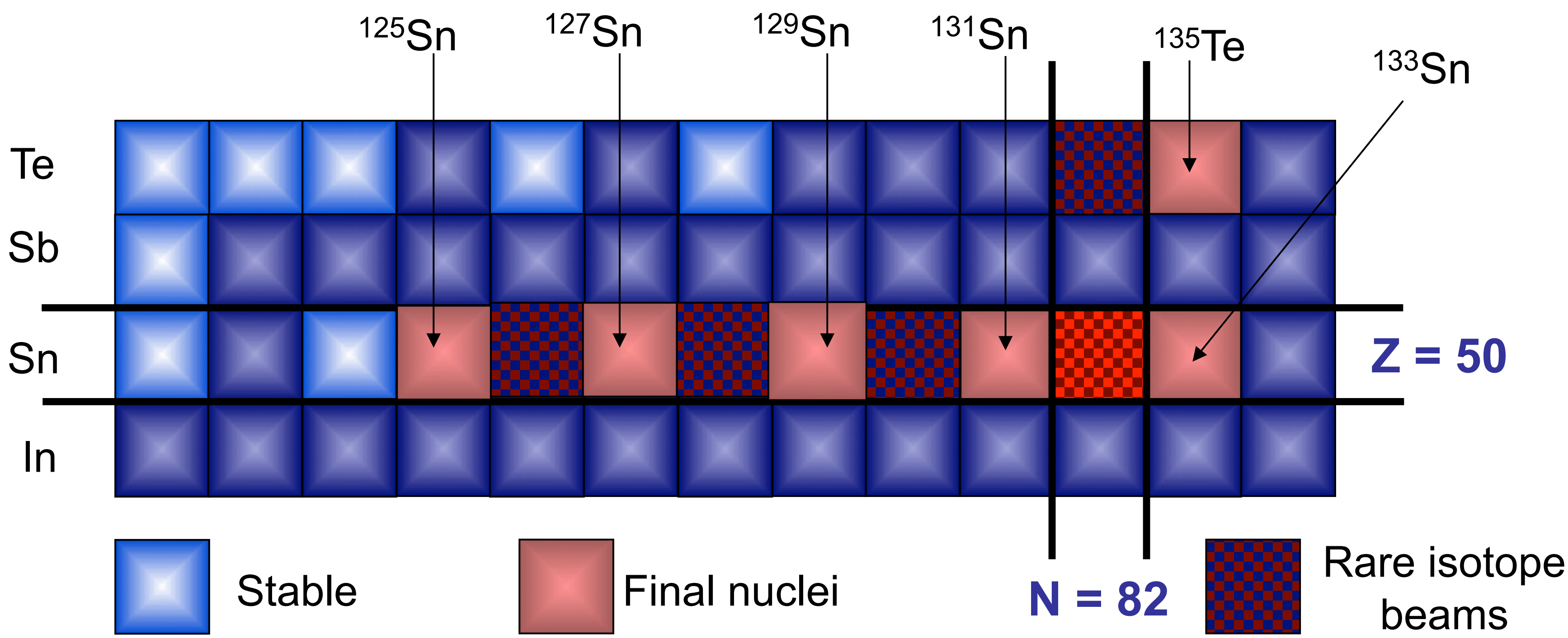
N<82 (d,p) what should expect to see?



Near ^{132}Sn Z=50, N=82

Nuclear reaction & structure studies

Neutron transfer A(d,p)A+1 reactions
Neutron transfer A(d,t)A-1
Neutron transfer + gamma A(^{9}Be,^{8}Beγ)A-1



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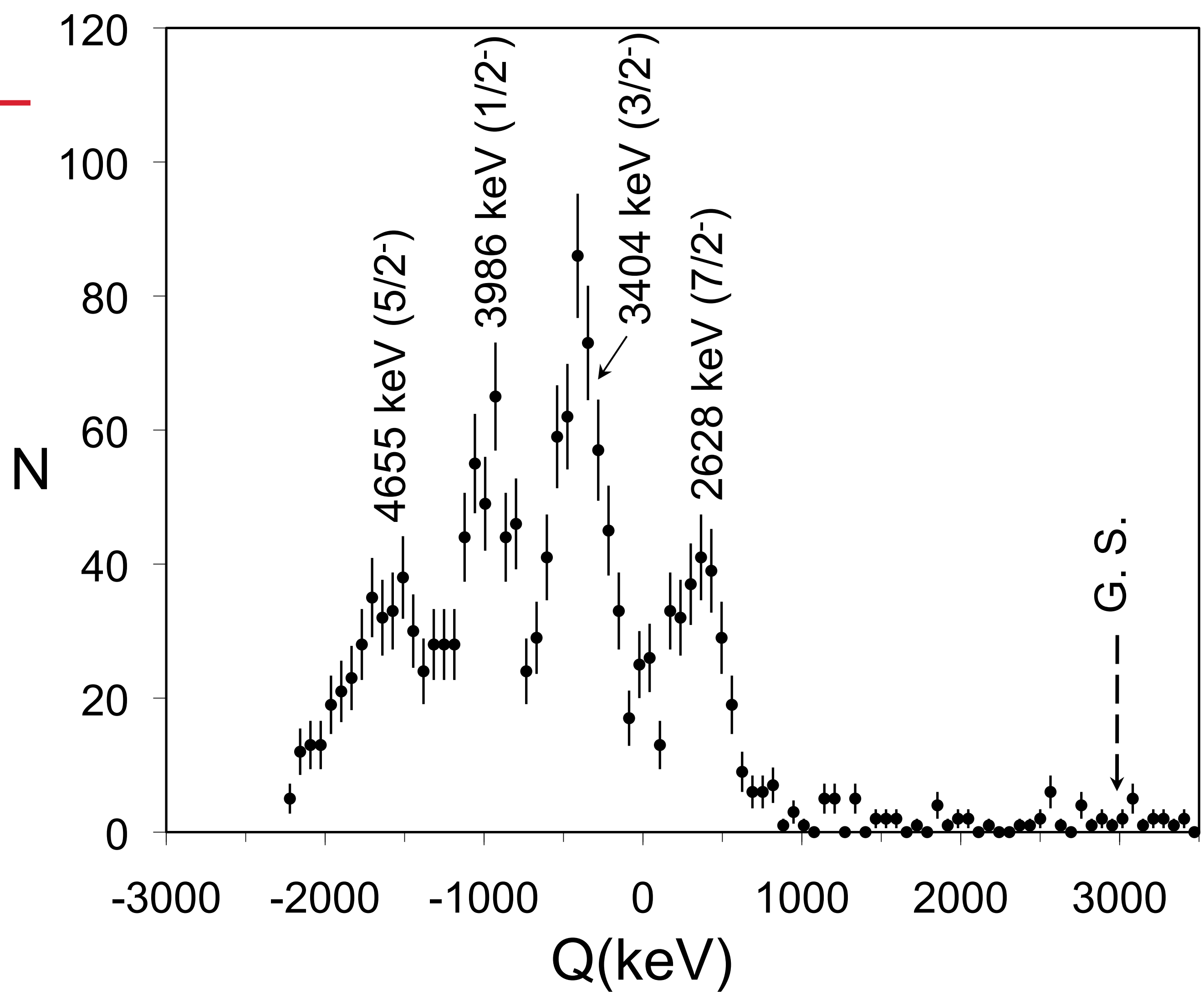
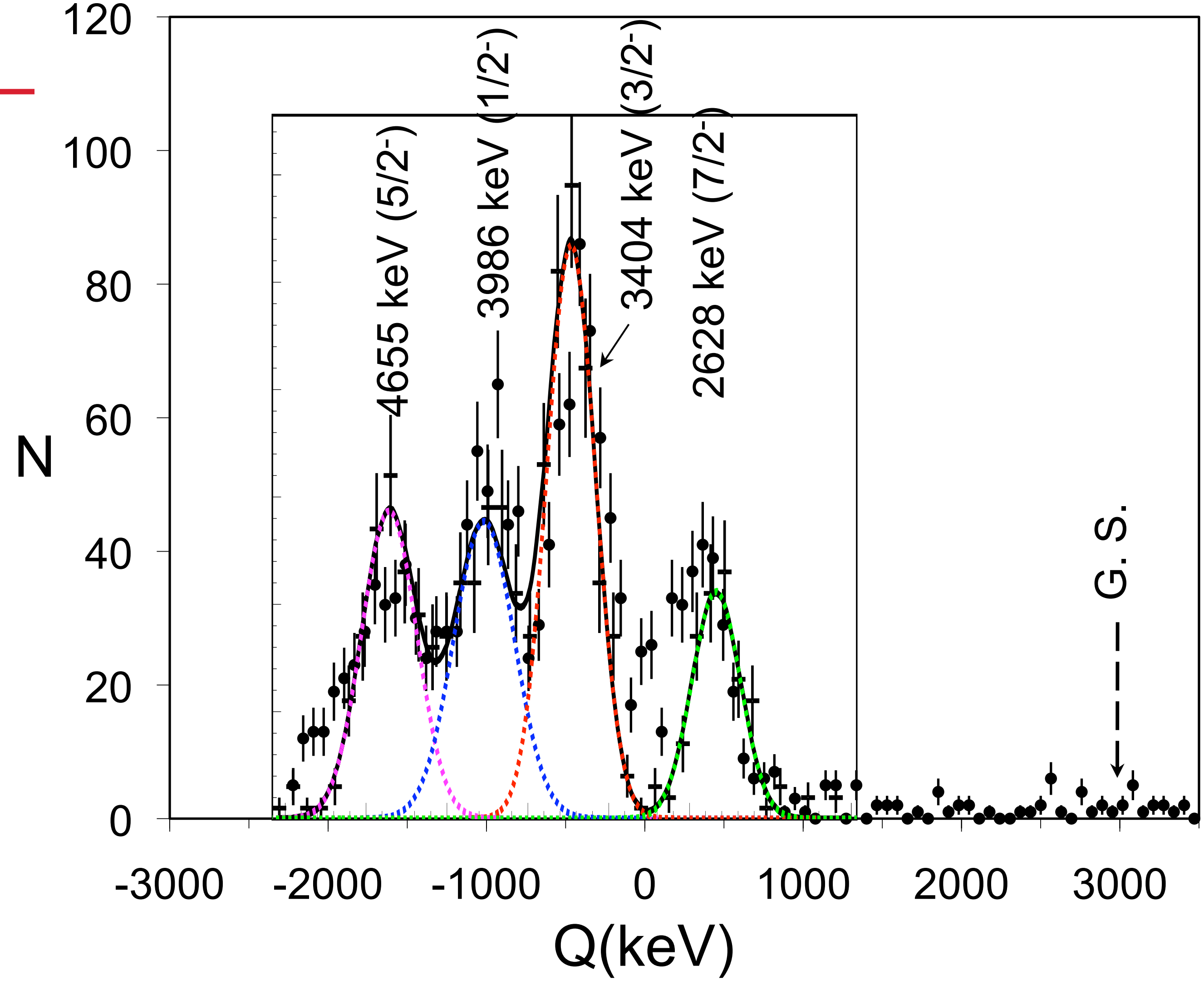
$^{130}Sn(d,p)$



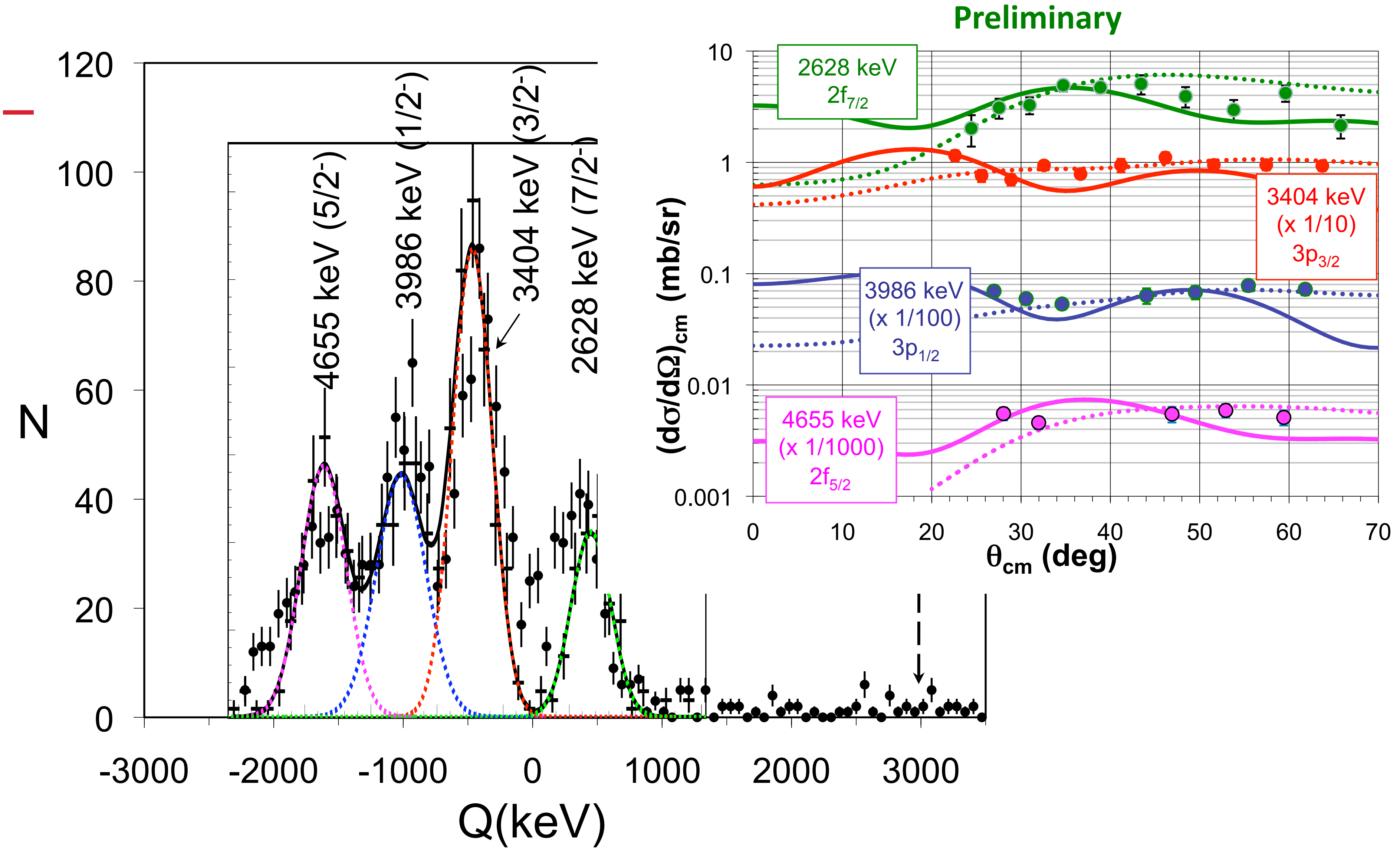
R.L. Kozub, et al.

$^{130}Sn(d,p)$ & $^{132}Sn(d,p)$



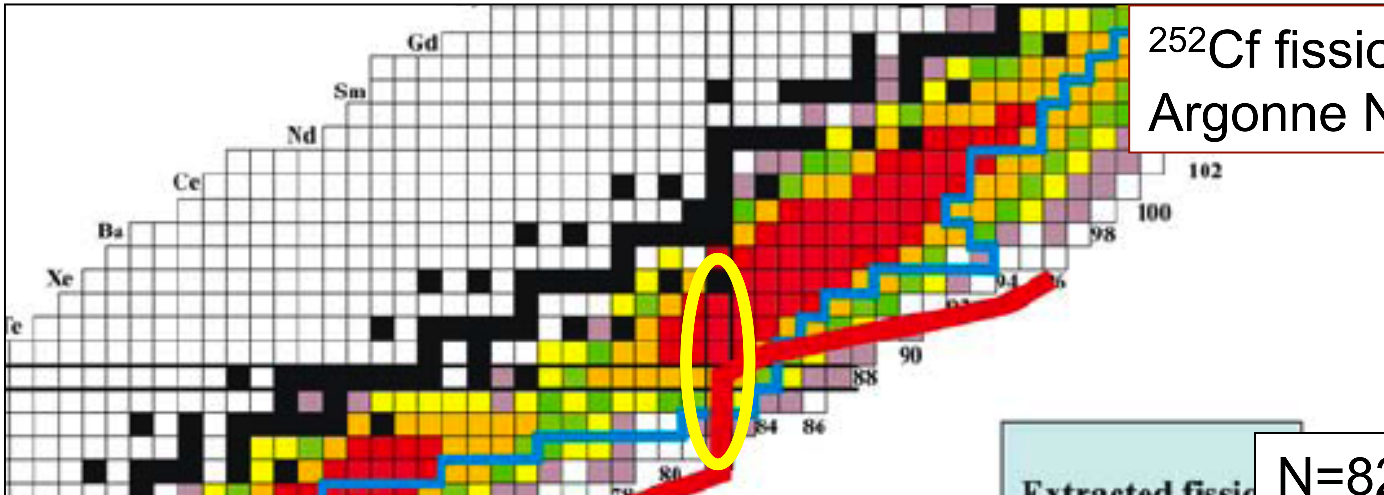
R.L. Kozub, et al.

$^{130}Sn(d,p)$ & $^{132}Sn(d,p)$



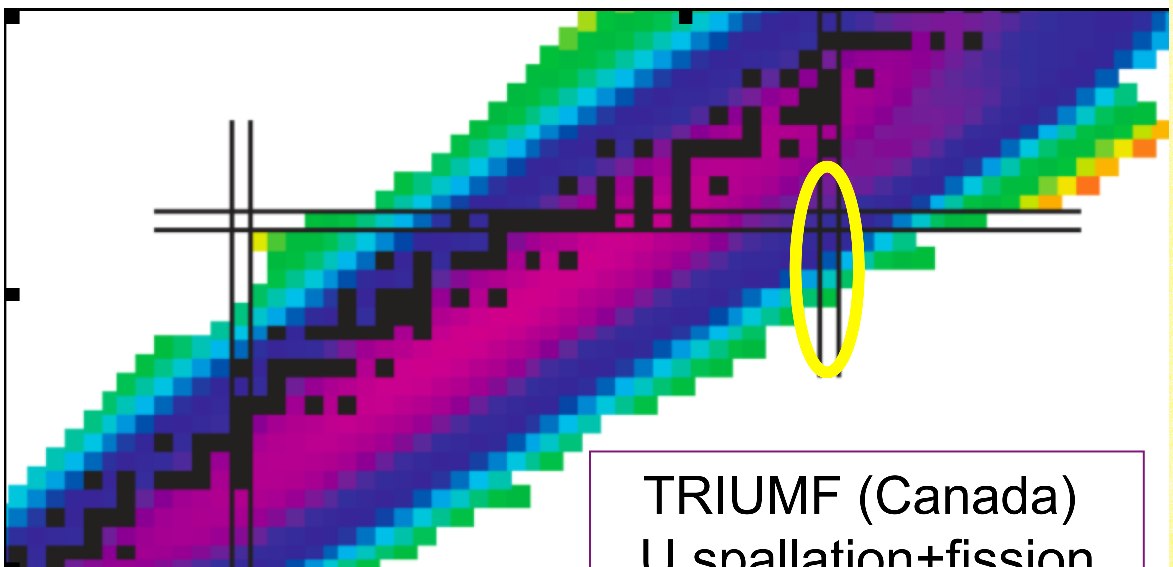
R.L. Kozub, et al.

Many more nuclei can be studied in next few years

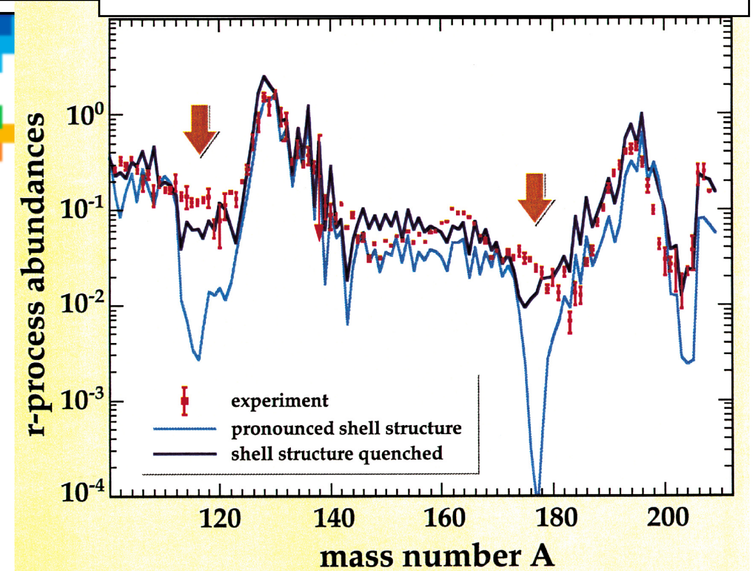


^{252}Cf fission fragments at Argonne National Lab

N=82 neutron-rich studies

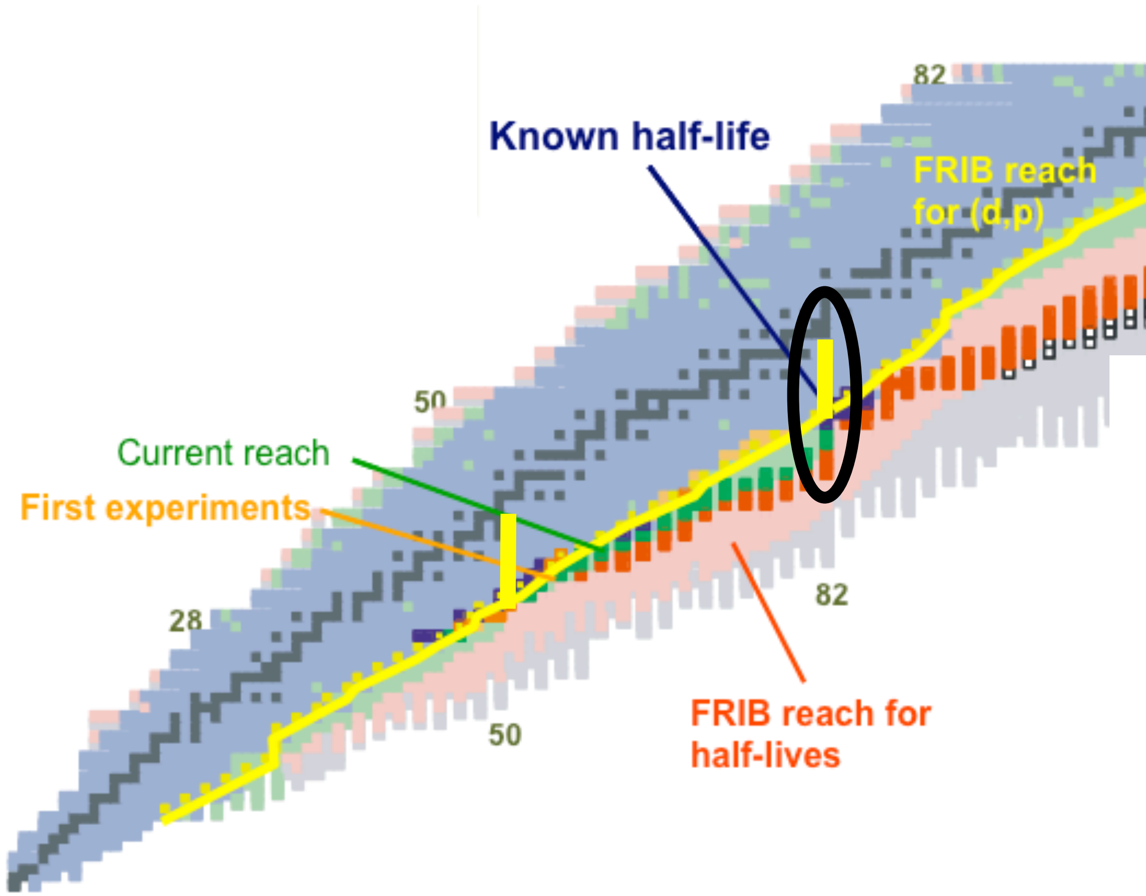


TRIUMF (Canada)
U spallation+fission

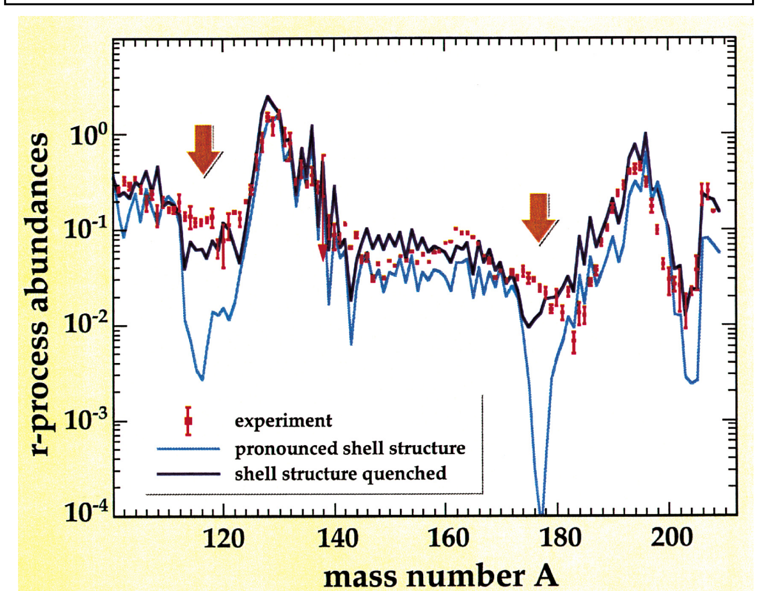


Long term prospects for probing neutron-rich nuclei near N=82 are bright

Facility for Rare Isotope Beams (FRIB) under construction at MSU



Neutron rich nuclei near N=82



Reference: B. Sherrill

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Summary of A≈132 (d,p)

- Measured single-neutron excitations in ^{133}Sn
  - Expected $2f_{7/2}$, $3p_{3/2}$, $3p_{1/2}$, $2f_{5/2}$ states identified with S≈1
  - ^{132}Sn is one of best examples of doubly magic nucleus
- Preliminary analysis of ^{130}Sn(d,p)
  - Sizeable, concentrated ℓ =1 strength at high excitation energies
  - Impact: direct neutron capture strength
- Recent measurements of ^{124,126,128,130,132}Sn (d,p) and (^{9}Be,^{8}Beγ)
  - Gamma-rays to reduce uncertainties in E_x, populate other states, support J^{π} values
  - Similar concentration of (tentative) ℓ=1 strength at high excitation energies
- Near term: studies with n-rich beams and particle-gamma coincidences

Future prospects are bright:

New opportunities for neutron-rich studies in US and abroad

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THANK YOU

Single-neutron excitations near ^{132}Sn

Supported by U.S. Department of Energy NNSA and Office of Nuclear Physics
and National Science Foundation

Happy Birthday Franco!