Single-Particle Spectroscopy of ^{133}Sn via the (d,p) reaction in inverse kinematics

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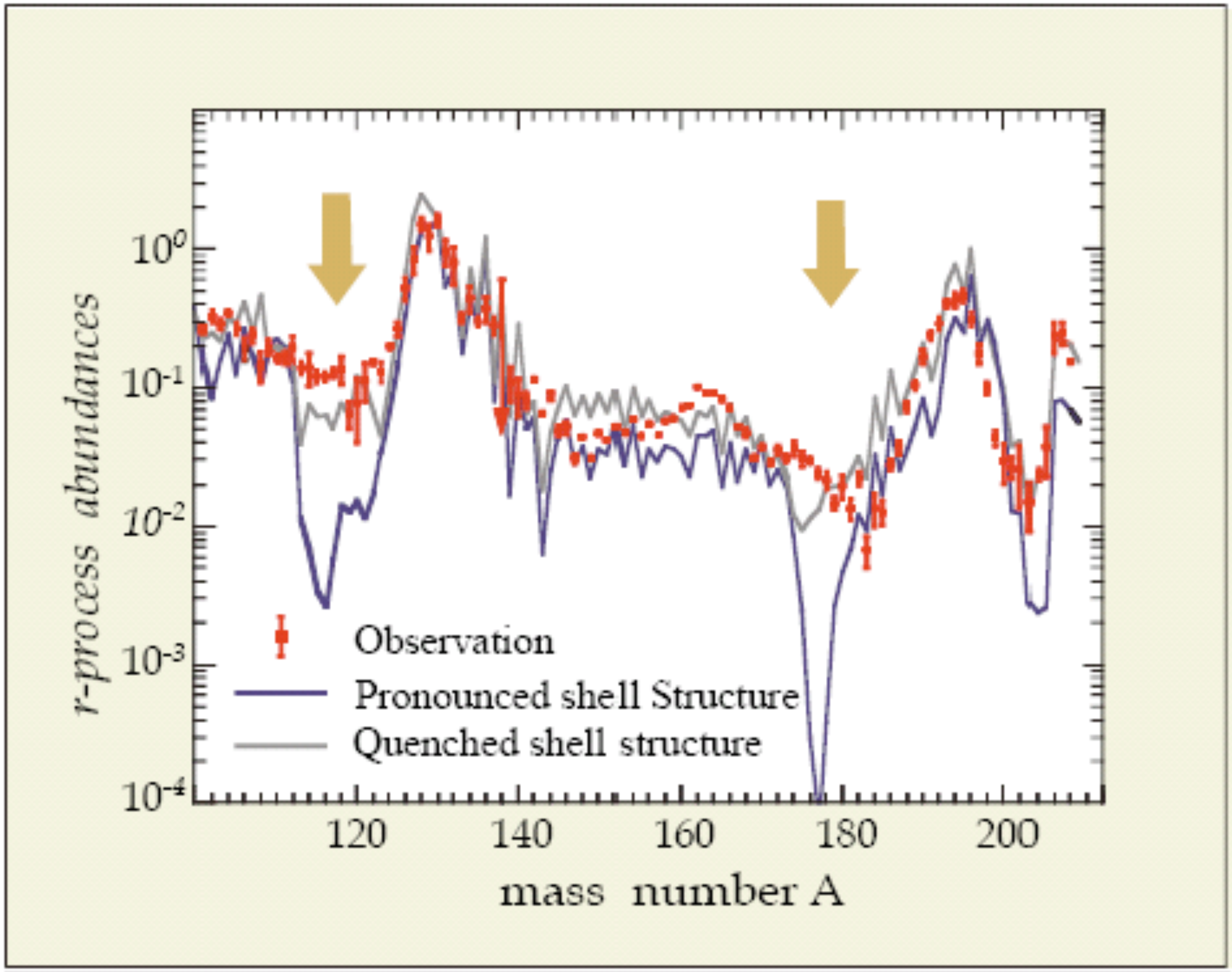
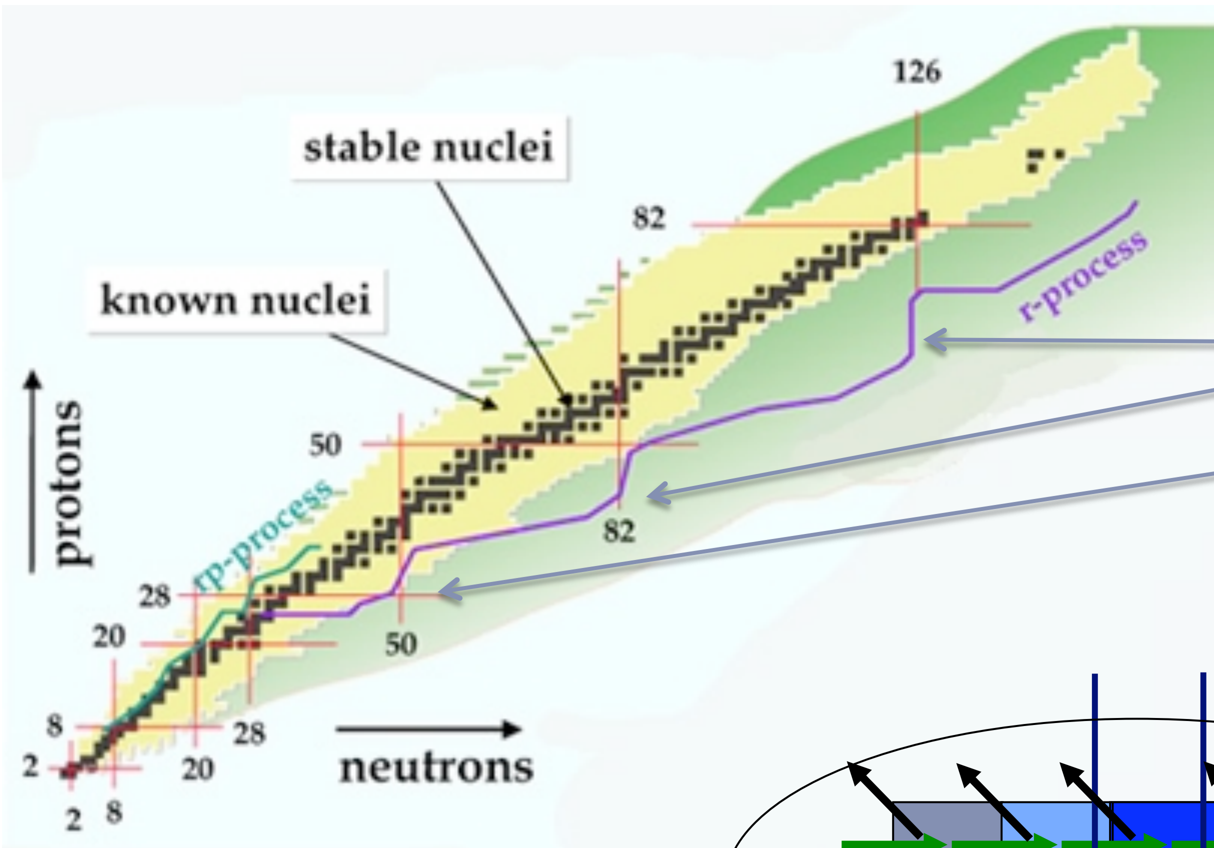
Shell model fingerprints on the galaxy

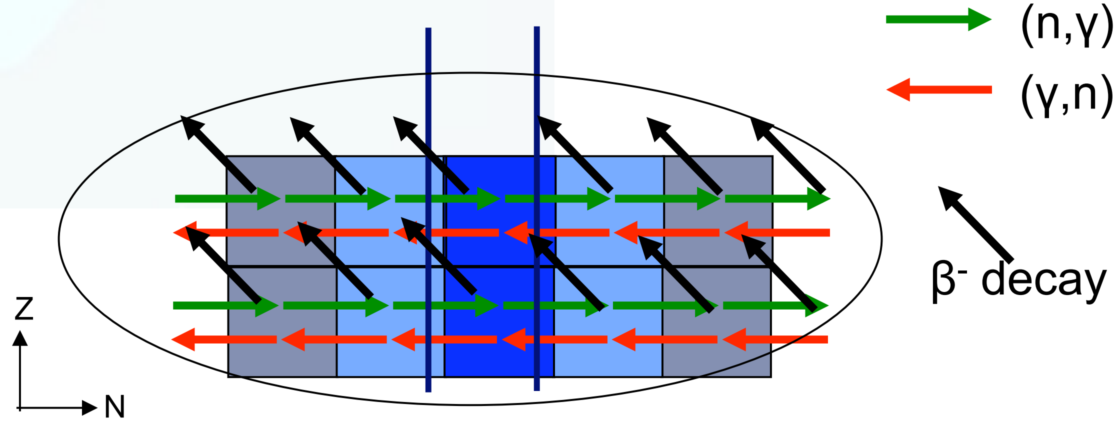


- Pfeiffer, Kratz, Thielemann and Walters, Nuc. Phys. A **693** 282 (2001)

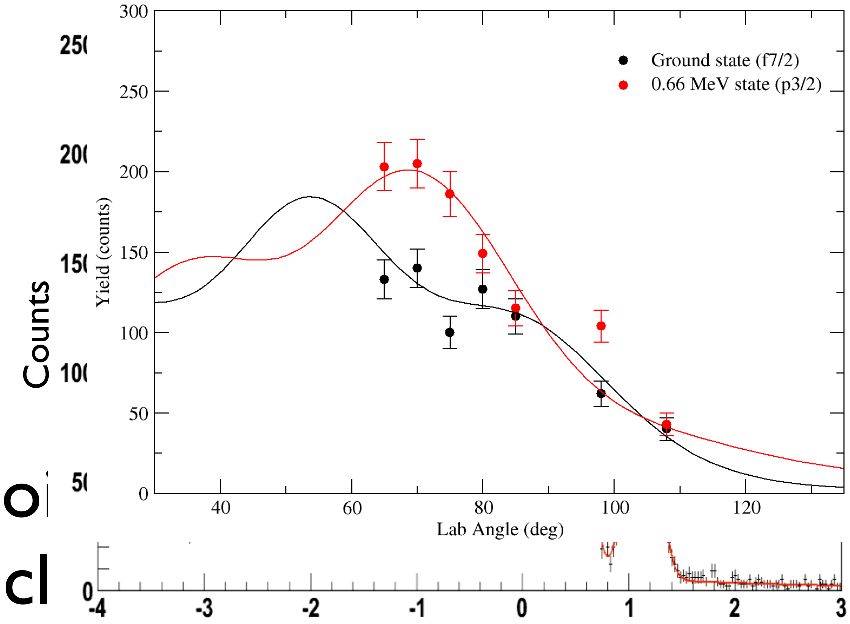
The rapid neutron capture (r-)process



large deviations in r-process path at shell closures

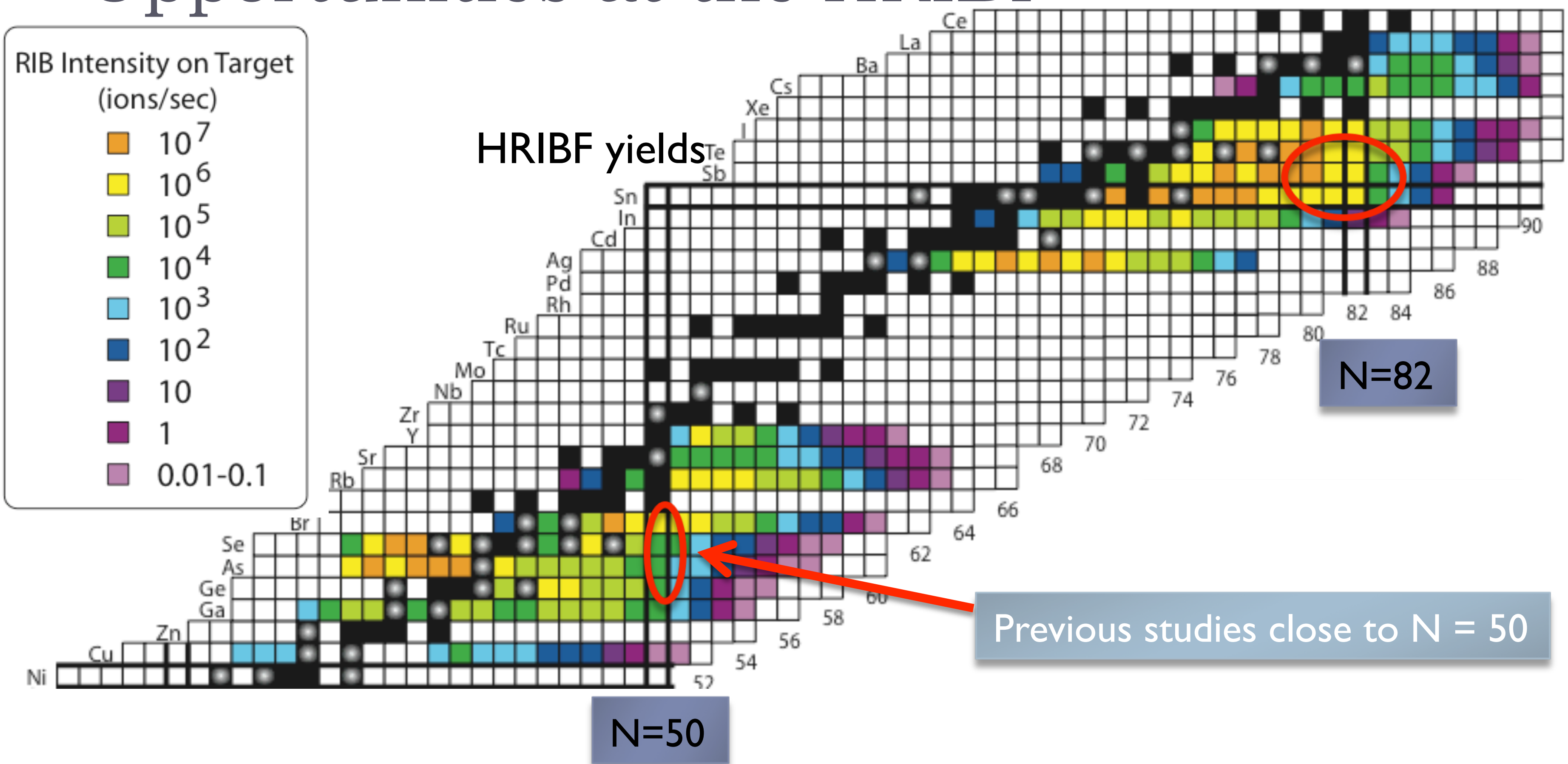


What we can learn from transfer reactions



- Q-value
  - mass.
  - excitation energies.
- Angular distributions of reco
  - ℓ-value of transferred nucl
  - combined with calculations gives spectroscopic factor.

Opportunities at the HRIBF



J.S.Thomas et al

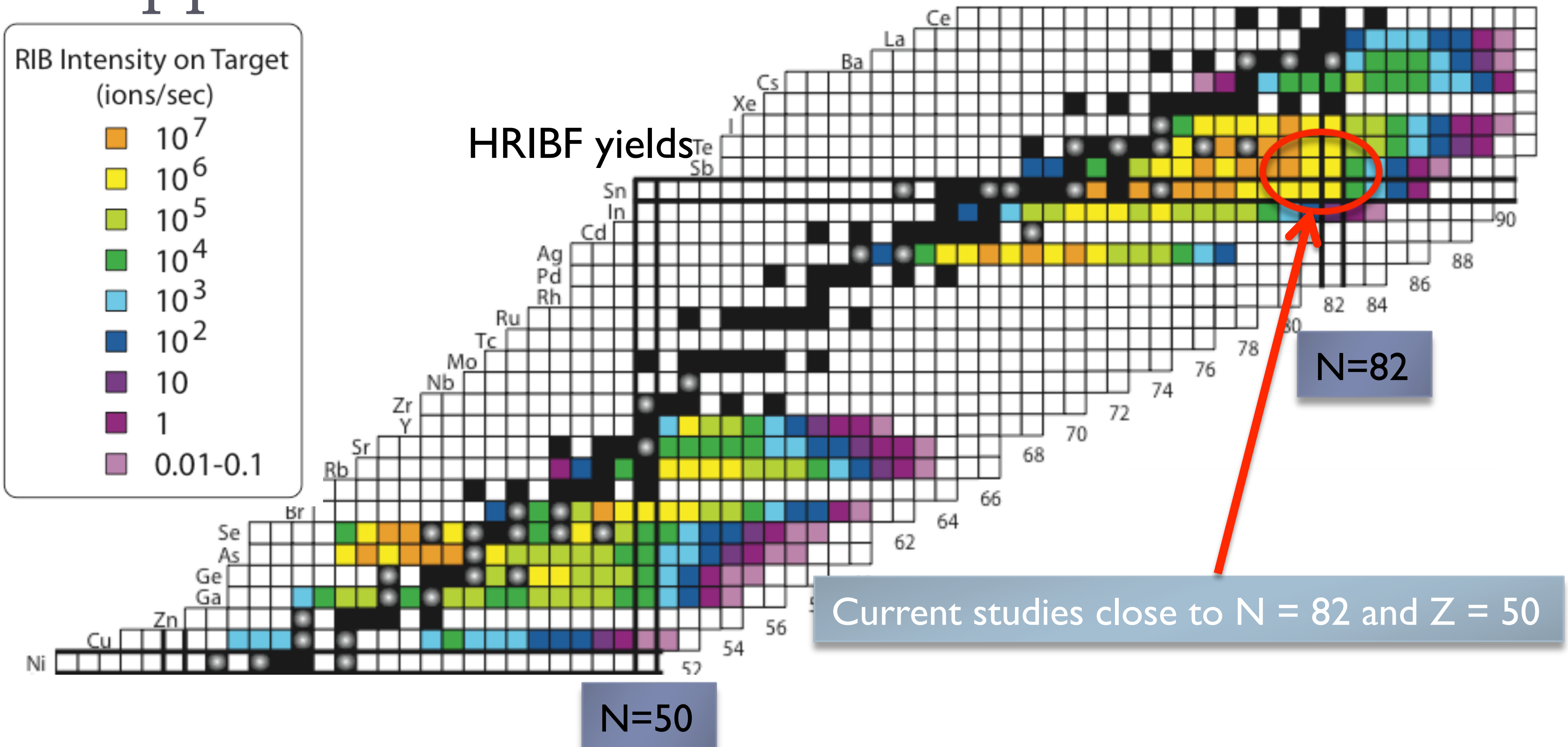
Phys. Rev. C **71**, 021302 (2005)

Phys. Rev. C **76**, 044302 (2007)

Fission fragment beams

Production via p-induced fission on U gives access to n-rich nuclei close to N=50,82

Opportunities at the HRIBF



r-process close to shell closure

✧Low level density

✧Small capture cross section

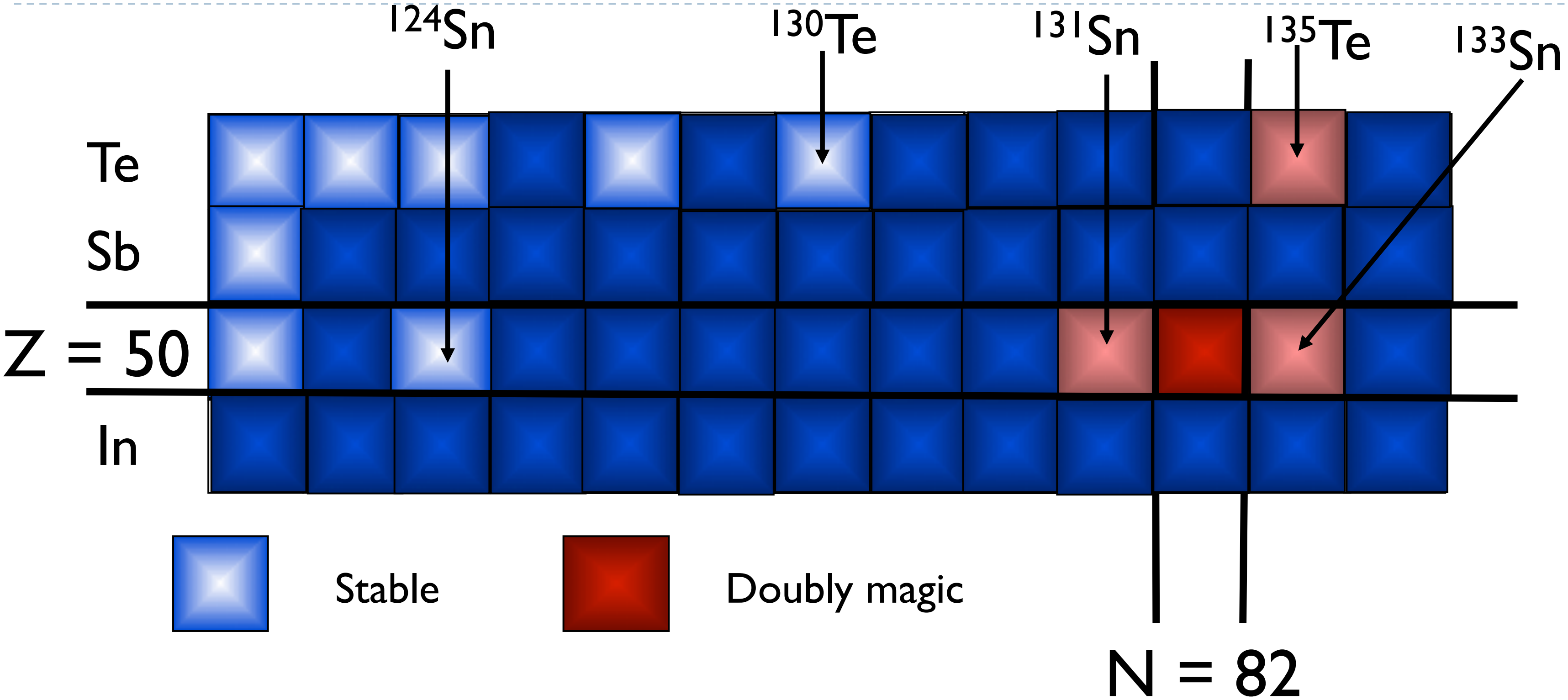
✧Statistical model not reliable

✧Direct capture important

Fission fragment beams

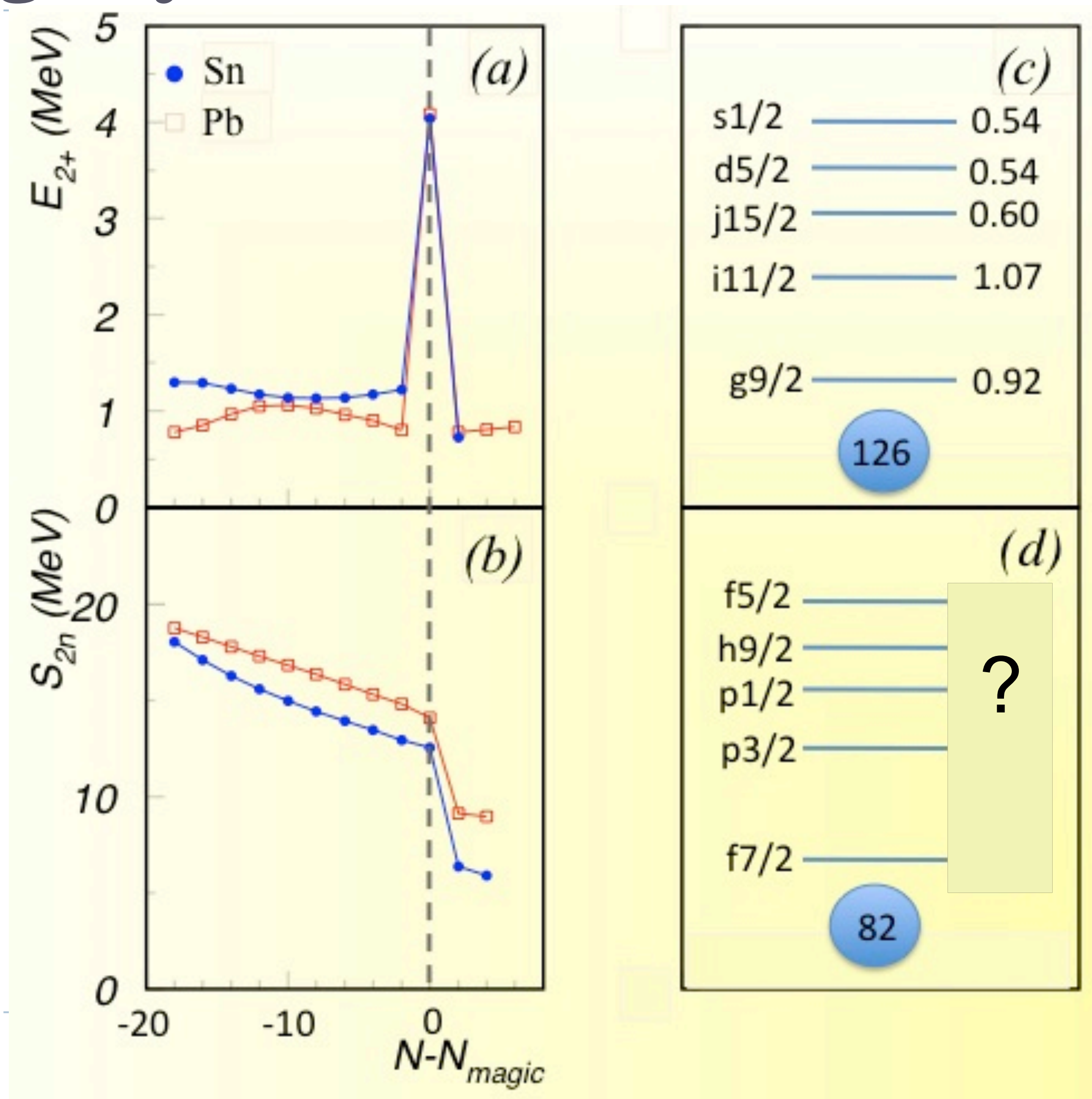
Production via p-induced fission on U gives access to n-rich nuclei close to N=50,82

Transfer measurements around ^{132}Sn



Neutron transfer e.g. (d,p), sensitive probe of single-particle structure. Can extract energies, ℓ-values and spectroscopic factors. Reaction is selective.

Magicity of ^{132}Sn



What is a Spectroscopic Factor?

- Specific Example

$$\left|{}^{11}\mathrm{Be(g.s.)}\right\rangle = A_{2s_{1/2}} \left|{}^{10}\mathrm{Be(g.s.)} \otimes 2s_{1/2}\right\rangle + A_{1d_{5/2}} \left|{}^{10}\mathrm{Be}(2^+) \otimes 1d_{5/2}\right\rangle + \ldots$$

- Nuclear Reaction Theory

s.p. radial overlap function

$$S_{\ell sj} = \left|A_{\ell sj}\right|^2$$

Spectroscopic Amplitude

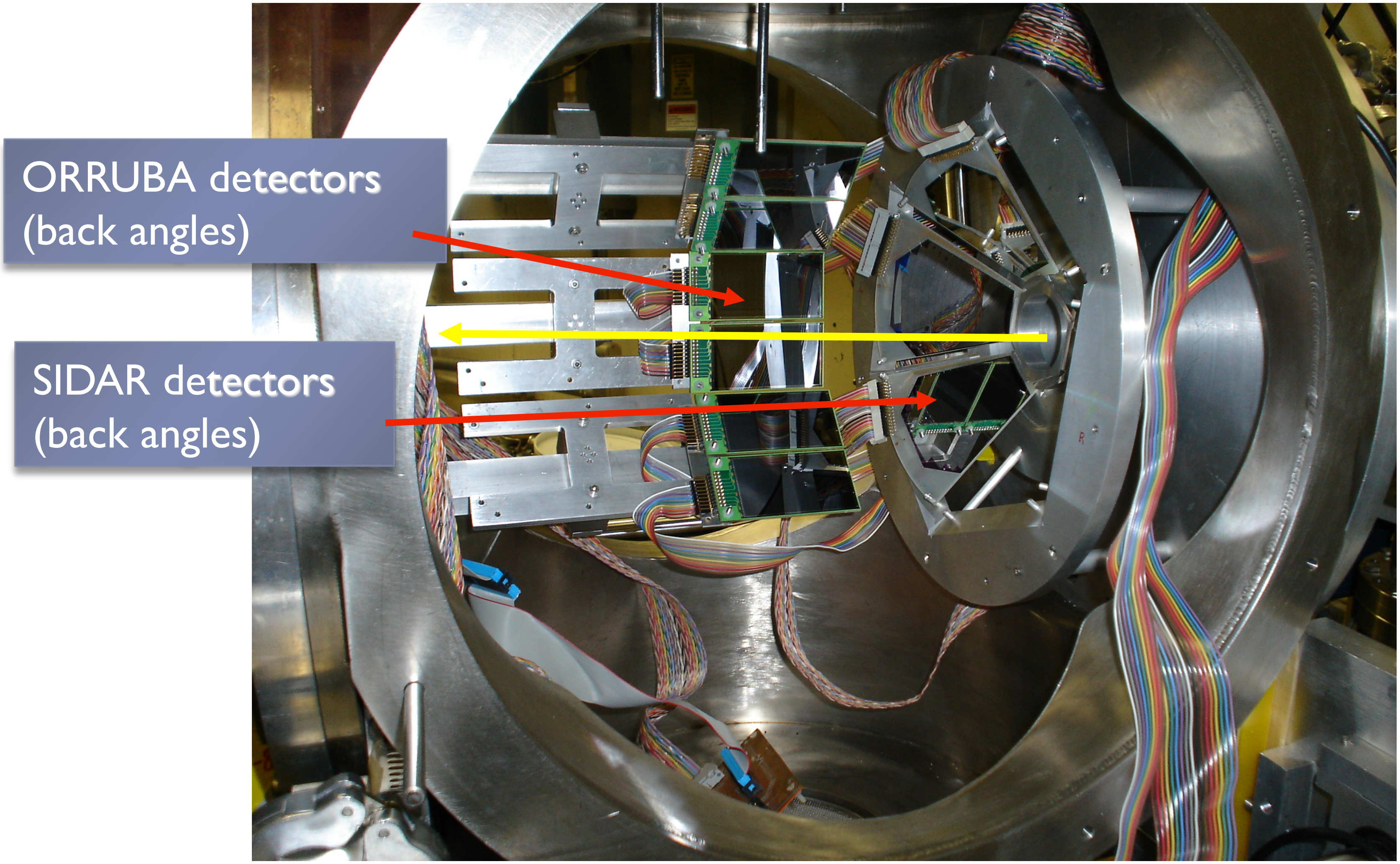
$$u_{\ell sj}(r) = A_{\ell sj} v_{\ell sj}(r)$$

Normalized WF

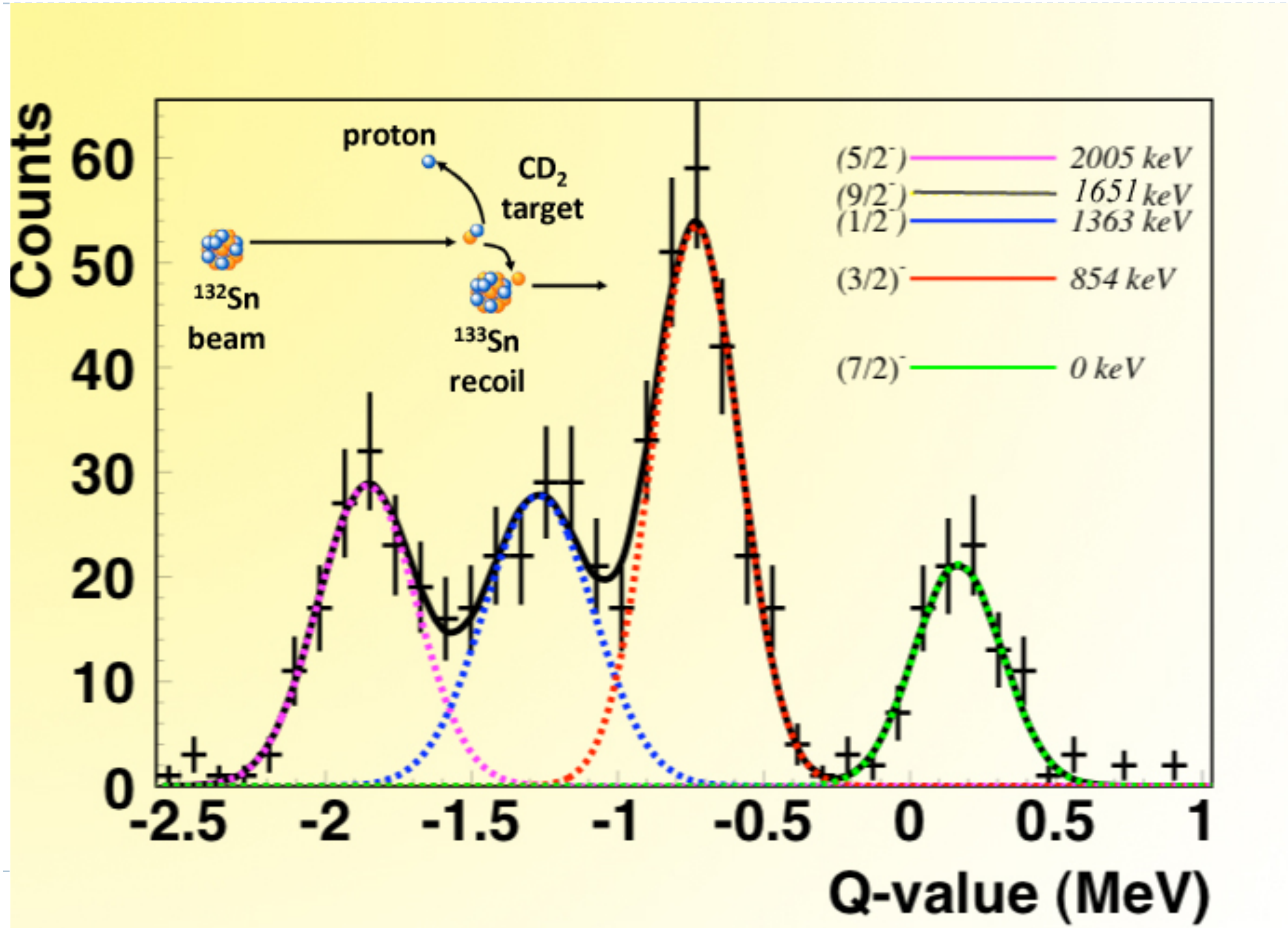
- Nuclear Reaction Experiment

$$S_{lsj}^{\exp} = \frac{d\sigma_{\exp} / d\Omega}{d\sigma_{DWBA} / d\Omega}$$

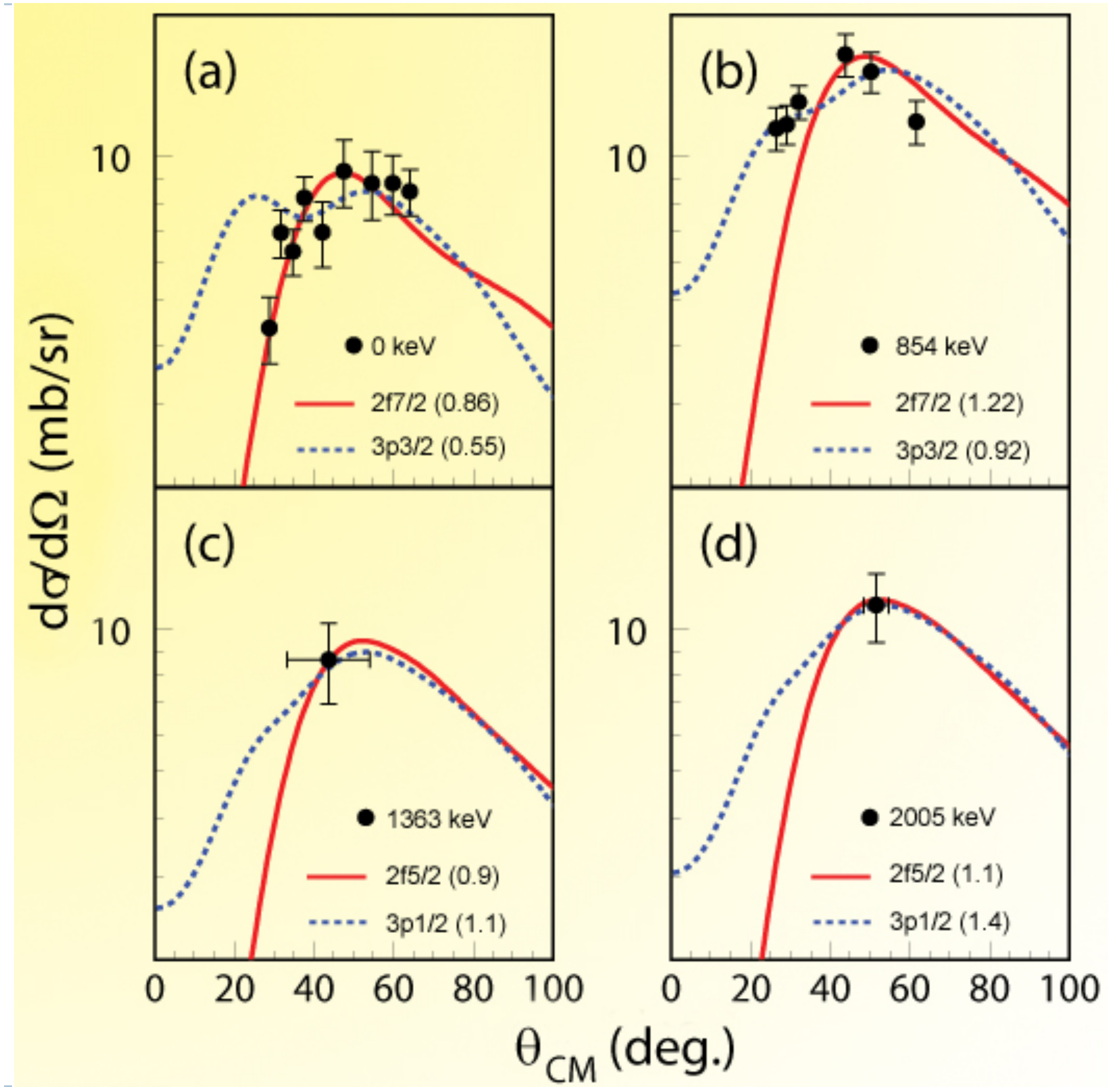
^{132}Sn(d,p) photo



^{133}Sn Q-value spectrum



^{133}Sn Angular Distributions

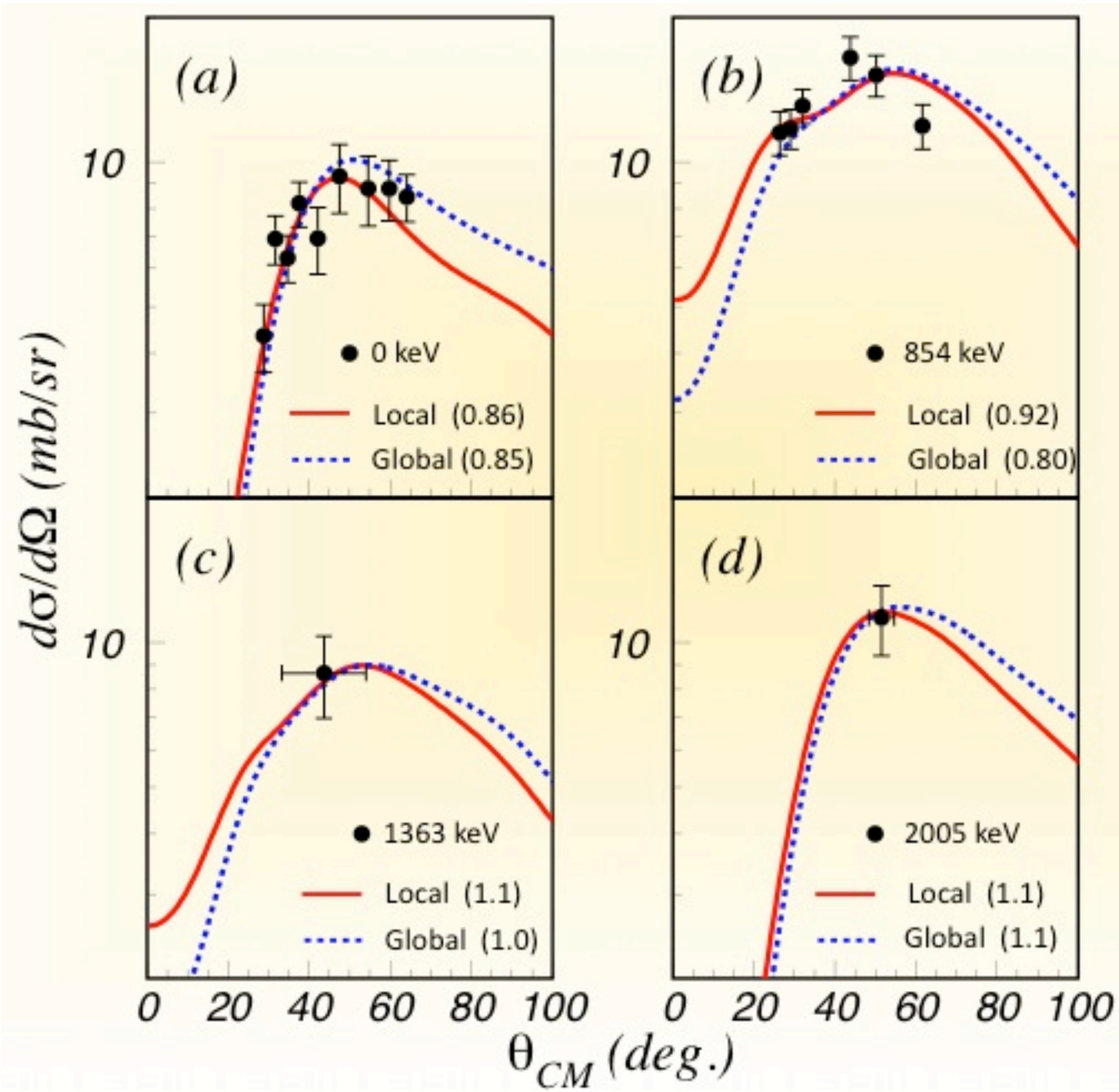


Theory from Filomena Nunes (NSCL)

Values for ^{133}Sn

Ex (keV)	J$^{\pi}$	Configuration	SF	C^2 (fm^{-1})
0	$7/2^-$	$^{132}Sn_{gs} \otimes \nu_{f7/2}$	0.86 ± 0.16	0.64 ± 0.10
854	$3/2^-$	$^{132}Sn_{gs} \otimes \nu_{p3/2}$	0.92 ± 0.18	5.61 ± 0.86
1363±31	$(1/2)^-$	$^{132}Sn_{gs} \otimes \nu_{p1/2}$	1.1 ± 0.3	2.63 ± 0.43
2005	$(5/2)^-$	$^{132}Sn_{gs} \otimes \nu_{f5/2}$	1.1 ± 0.2	$(9 \pm 2)\times 10^{-4}$

Checking optical potentials



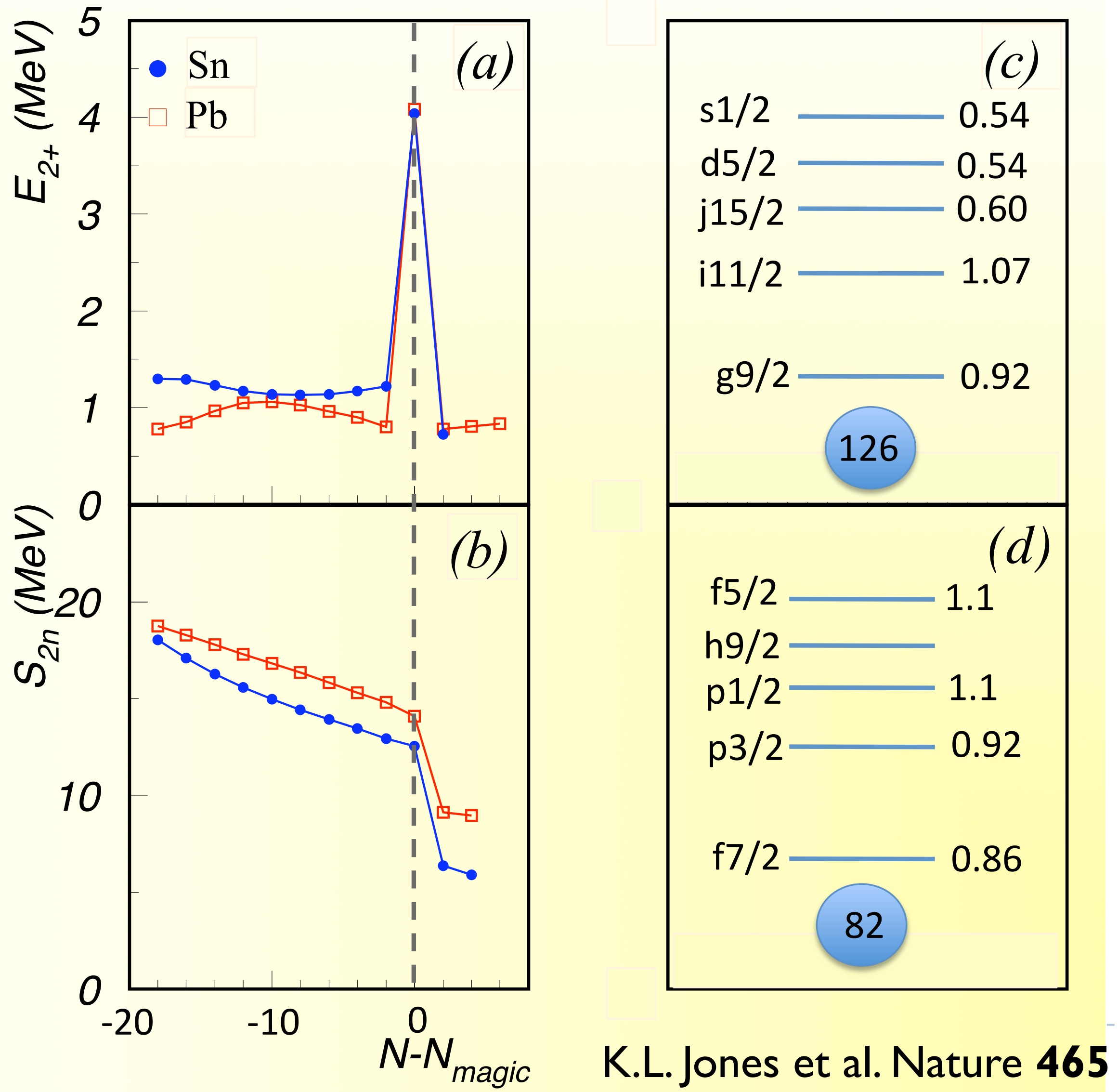
"local" optical potential from Strömich et al Phys. Rev C **16**, 2193 (1977).

"global" optical potentials:

deuteron Lohr and Haeberli Nucl. Phys. **A232** 381 (1974).

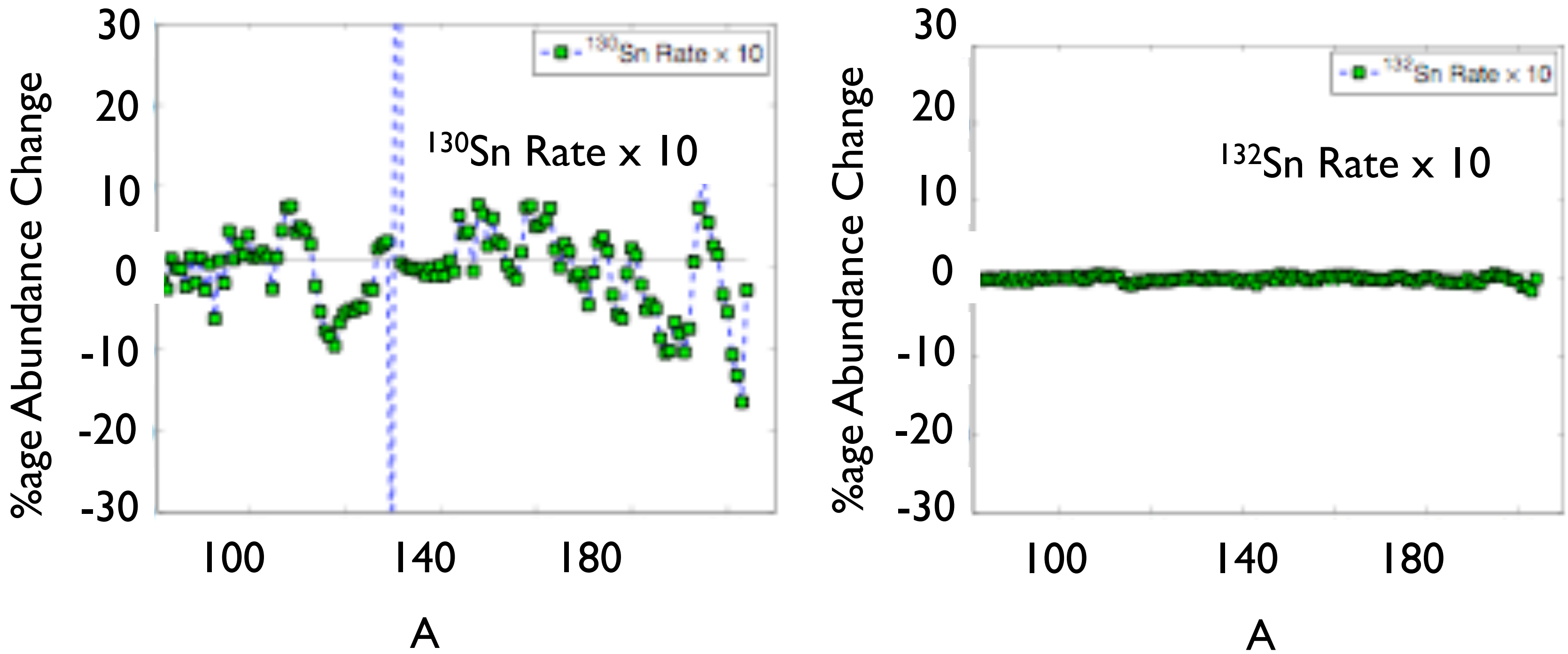
proton Varner et al. Phys. Rep **201** 57 (1991).

Magicity of ^{132}Sn



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

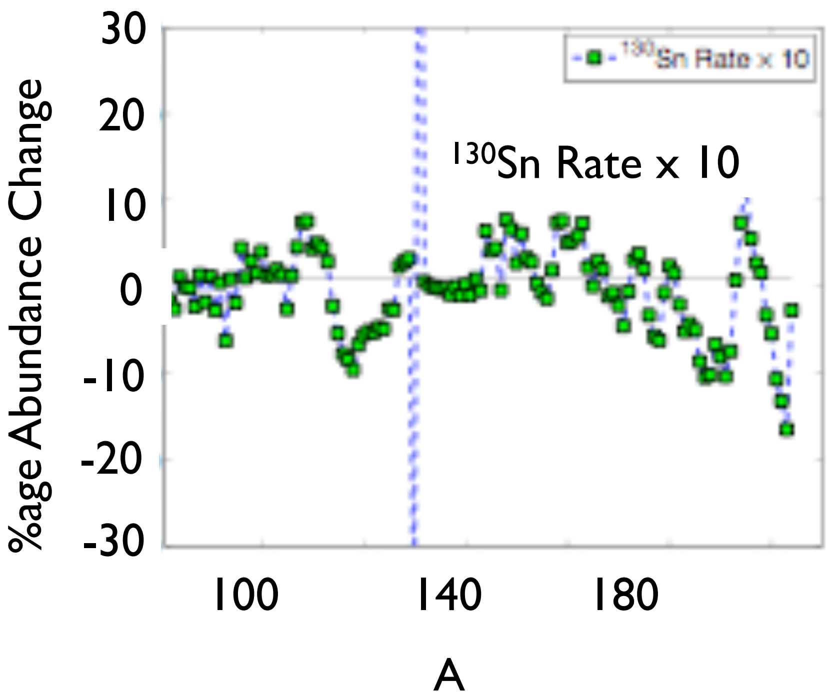
r-process sensitivity studies.

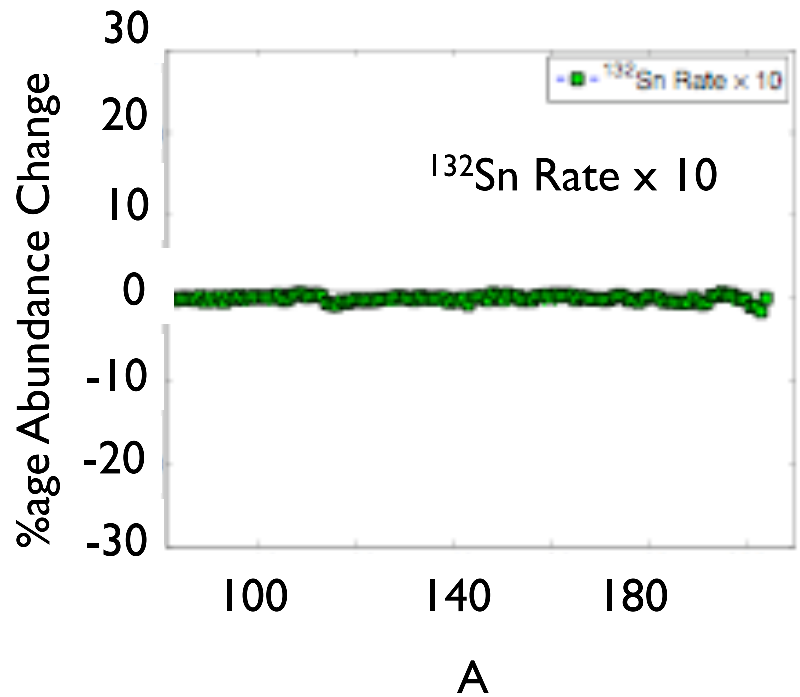


Simulations of the r-process show **global** sensitivity to the ^{130}Sn(n, γ) rate, in contrast to the ^{132}Sn(n, γ) rate.

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

r-process sensitivity studies.



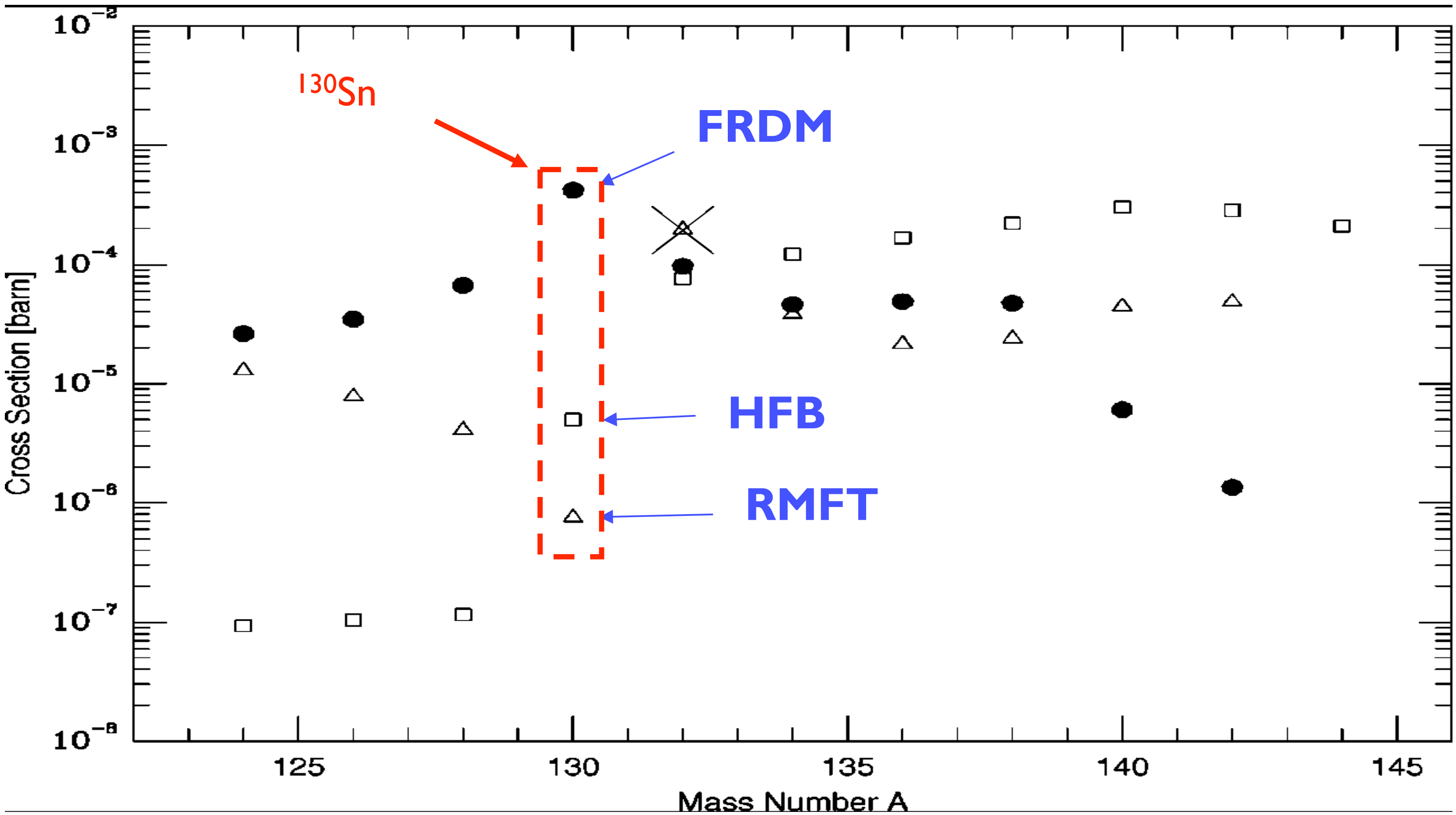


Build up of material at ^{130}Sn, due to long half life (4 min) compared to ^{130}Cd and ^{130}In (~ 1 sec). (n, γ)'s take material out of mass 130 into 131, and also soak up neutrons.

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

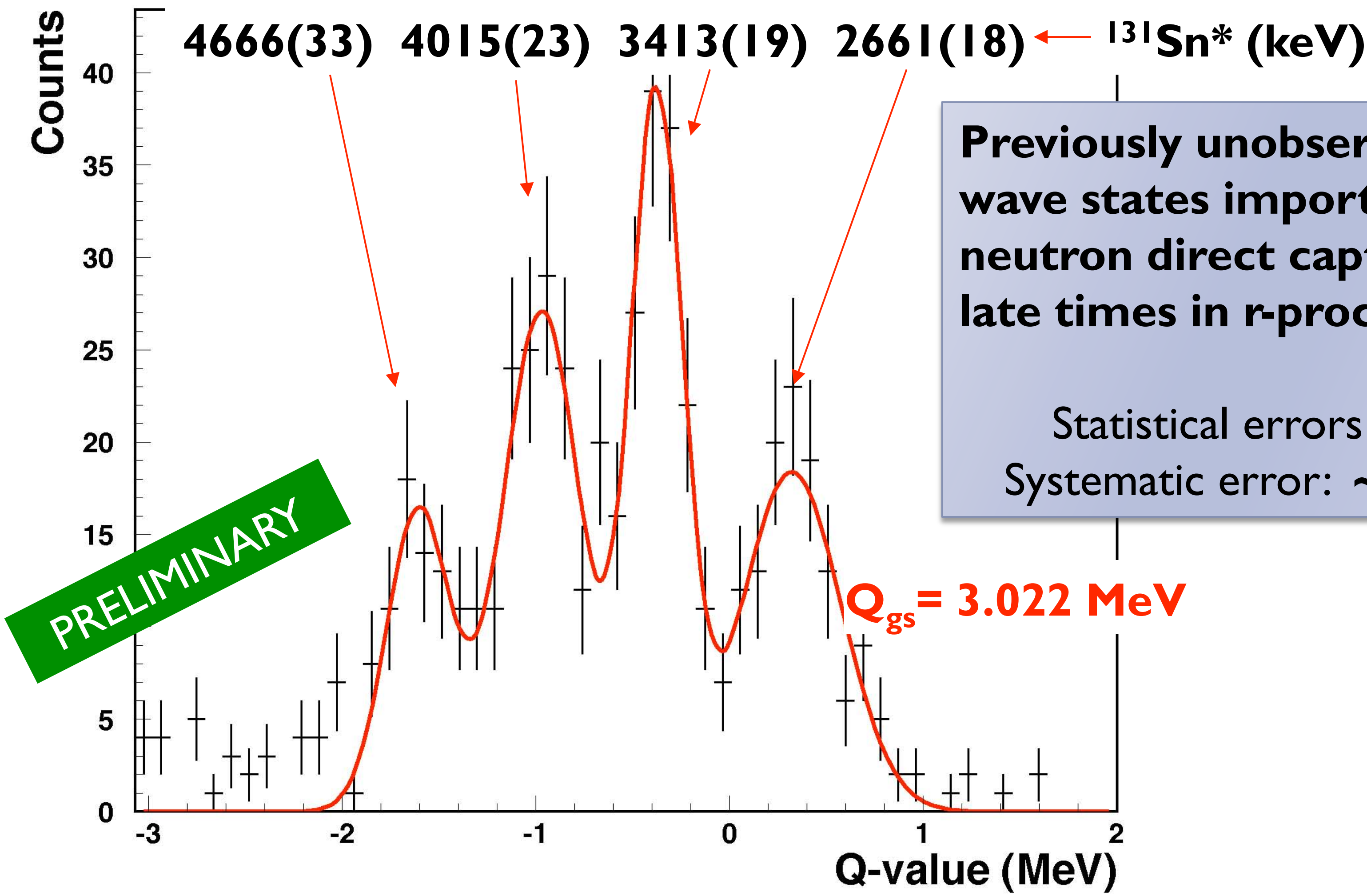
Rauscher *et al.*, *PRC* **57**, 2031 (1998)

Direct Capture on ^{130}Sn



Cross section depends largely on predicted binding energies for 3p s. p. states. No s. p. states identified previously in ^{131}Sn.

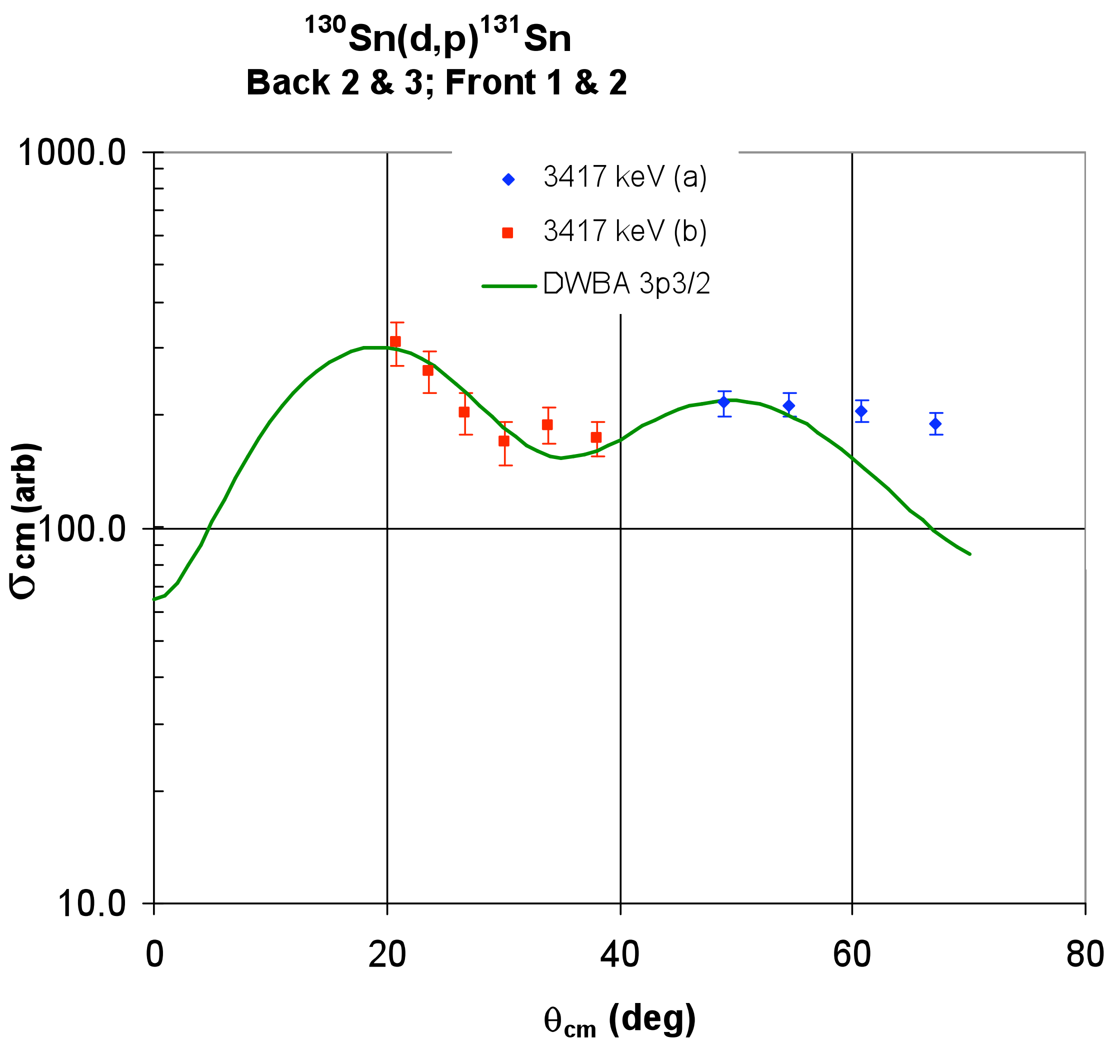
Q-value for 130Sn(d,p)131Sn

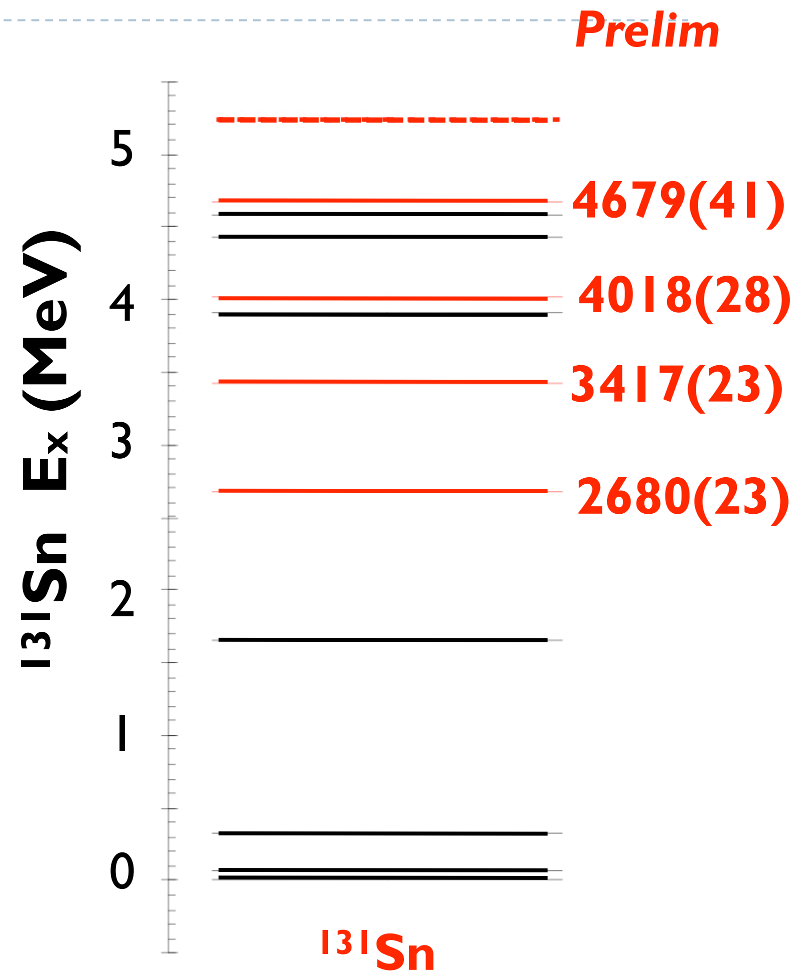


Previously unobserved p-wave states important to neutron direct capture at late times in r-process.

Statistical errors in **( )**.
Systematic error: **~30 keV**

^{131}Sn Preliminary angular distribution



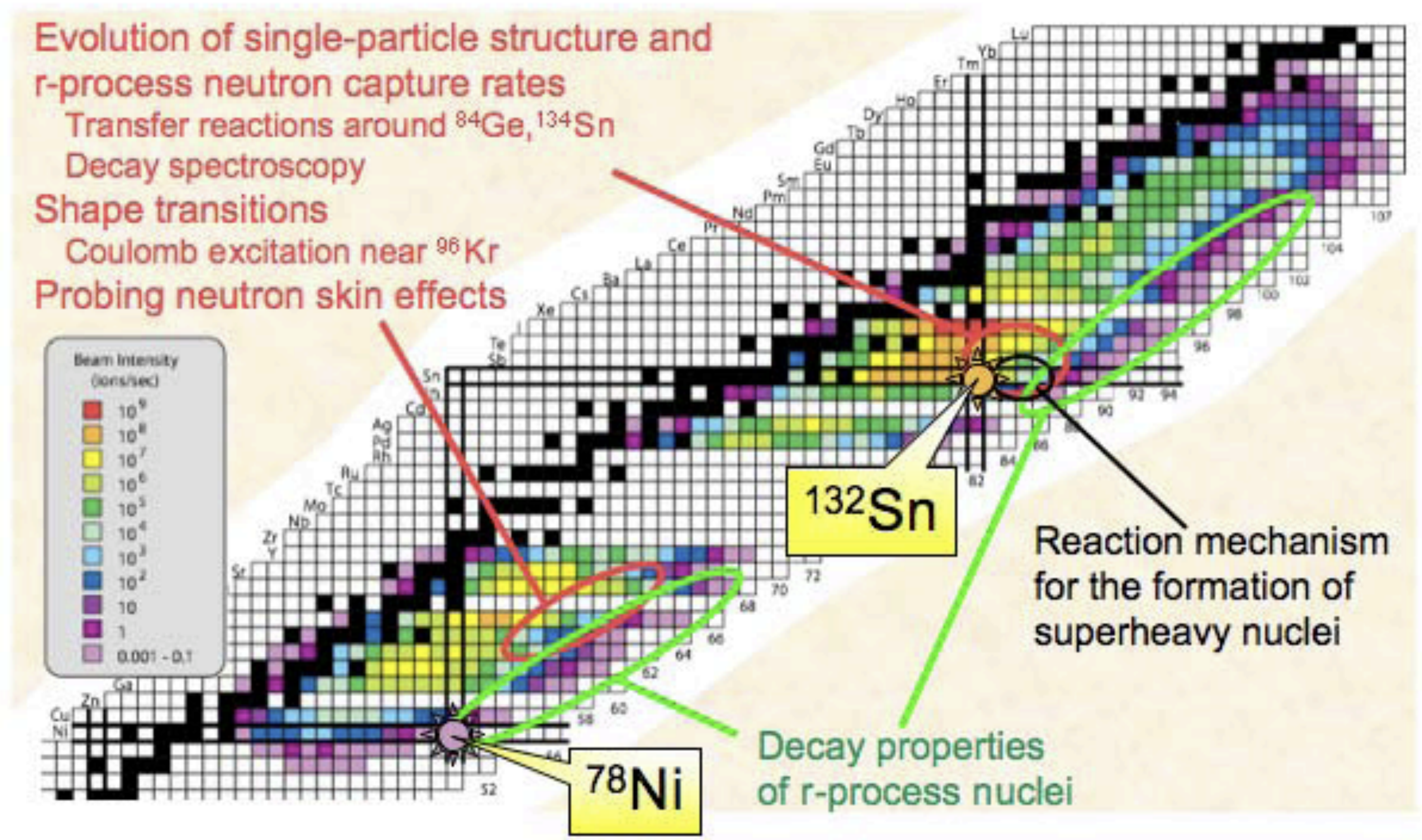


$^{131}Sn(d,p)^{130}Sn$

Near-term future: fission fragments

- (d,p) measurements: ^{126}Sn and ^{128}Sn
  - completing n-rich tin chain
  - understanding systematics
- (d,p) measurement on ^{80}Ge
  - r-process sensitivity to nuclei to the west of the shell closure
- Neutron transfer using (^{9}Be,^{8}Be) on ^{130}Sn
  - pinning down the energies of states in ^{131}Sn

Where next - with HRIBF upgrade



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UND:	J ... a, A. Ro ...
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Surrey:	... Swan, W ... tford, C. Harlin, N. Patterson, J. ... as, S. M. Brown
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Furma ...	A. Gad ...
IFJ PA ...	W. Krolas
EWU:	K. I. Hahn
NSCL/MSU:	F. Nunes

AND the facilities team at the HRIBF

AND YOU for listening