# Direct reactions with exotic beams of neutron-rich nuclei near $^{132}$Sn

Jolie A. Cizewski

Department of Physics & Astronomy

Rutgers University

# Collaboration
## RIBENS/Center of Excellence

**Rutgers University** J.A.C., R. Hatarik, P.O'Malley, Steve Pain, T. Swan

**ORNL** D.W. Bardayan, J.C. Blackmon, F. Liang, C.D. Nesaraja, D. Shapira, M.S. Smith

**Univ. Tennessee** K.Y. Chae, Kate L. Jones, Z. Ma, B.H. Moazen

**Tennessee Tech** Ray Kozub, J.Shriner, D.Sissom

**ORAU** C. Matei

**University of Surrey** J.S. Thomas

**Colorado School of Mines** K. Chipps, L. Erikson, R.J. Livesay

**Ohio University** A. Adekola

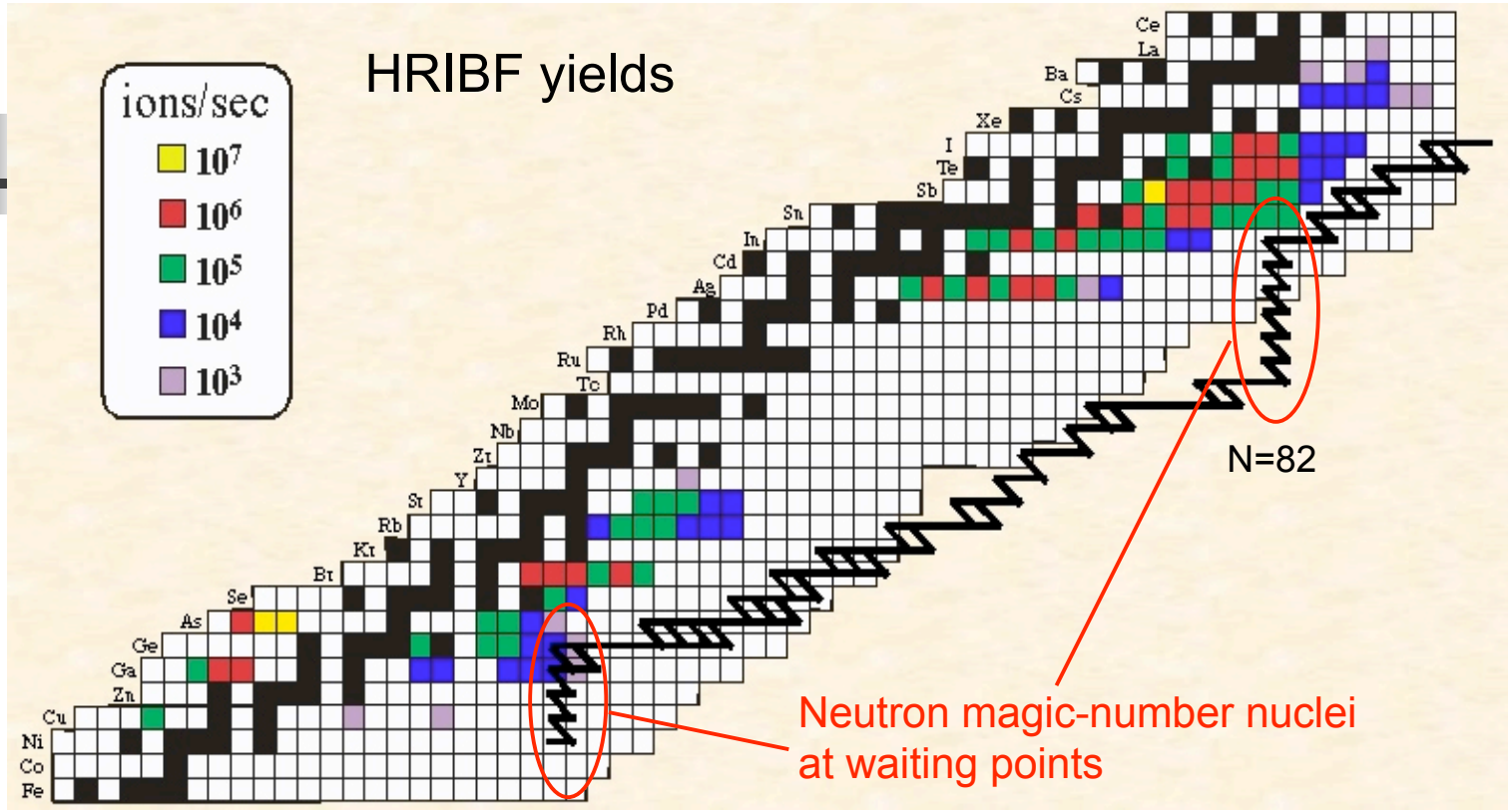
**Warsaw** W. Krolas

Funded in part by the U.S. DOE Office of Science & NNSA/SSAA and the National Science Foundation.



UNIRIB University Radioactive Ion Beam Consortium | CENTER OF EXCELLENCE FOR RADIOACTIVE ION BEAM STUDIES FOR STEWARDSHIP SCIENCE | THE STATE UNIVERSITY OF NEW JERSEY RUTGERS

# Measuring (d,p) on Rare Isotopes near Shell Closures




## Measure (d,p) reaction with unstable beams

- Measure single-neutron energies + spec. strengths
- Provide data to understand r process nucleosynthesis



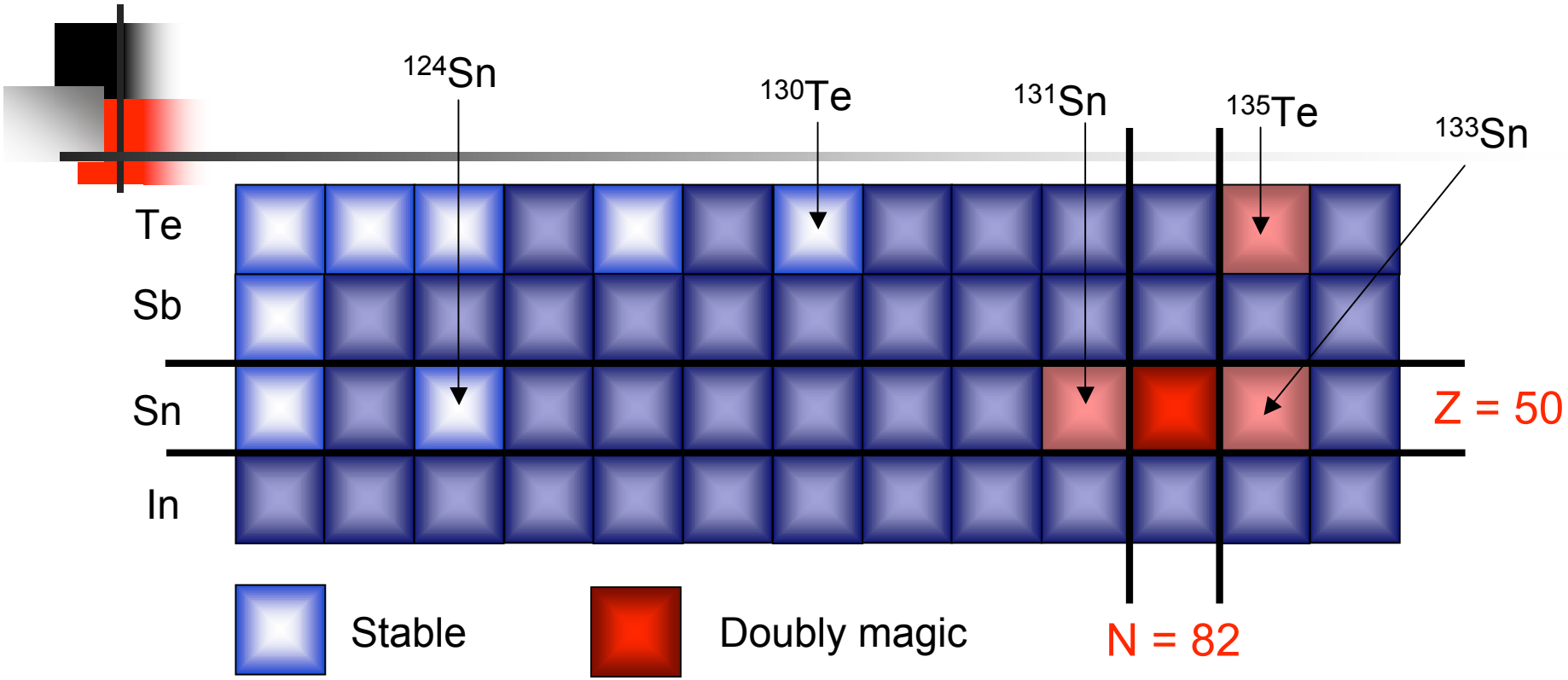
UNIRIB University Radioactive Ion Beam Consortium

CENTER OF EXCELLE
RADIOACTIVE ION BEA
FOR STEWARDSHIP

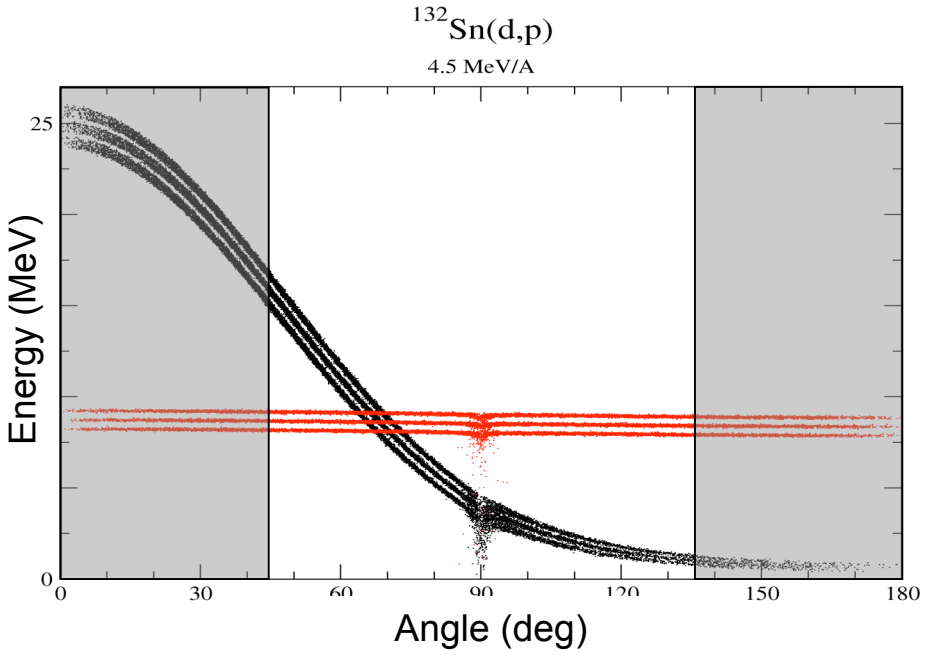
# Transfer measurements around $^{132}$Sn

**Double shell closure Z=50, N=82**

$^{132}$Sn(d,p)$^{133}$Sn, $^{130}$Sn(d,p)$^{131}$Sn and $^{134}$Te(d,p)$^{135}$Te measurements completed



# $^{132}$Sn(d,p) kinematics @ 4.7 A-MeV

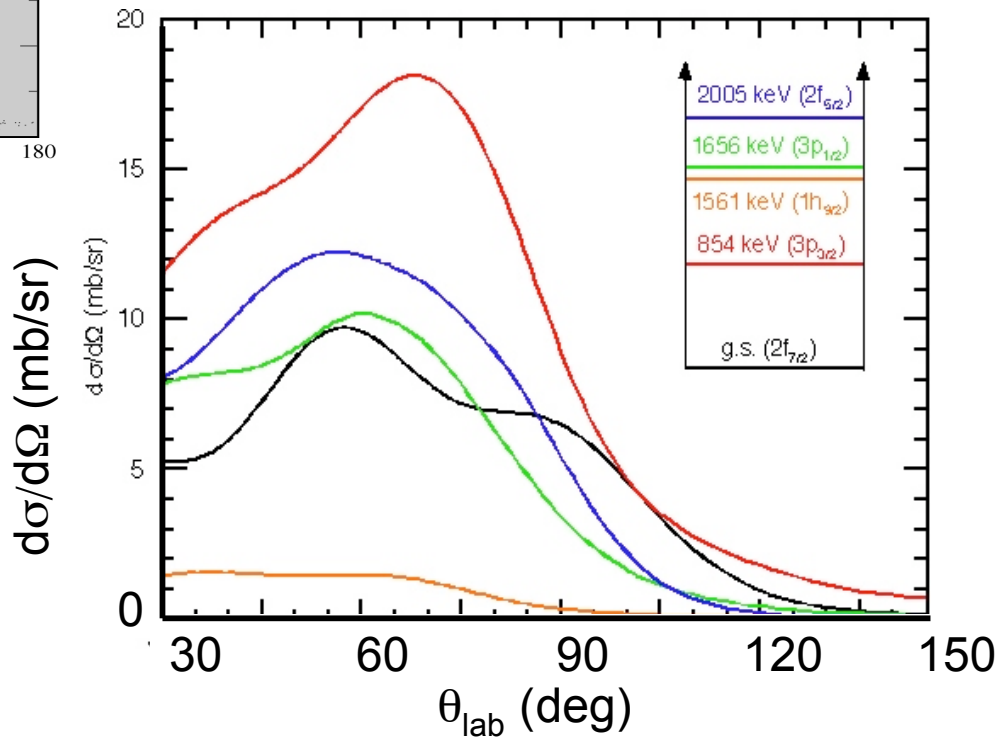



Forward $\theta_{c\text{-}o\text{-}m}$ ↔ backward $\theta_{lab}$

At backward $\theta_{lab}$ cross section very small and $E_{proton}$ very small.

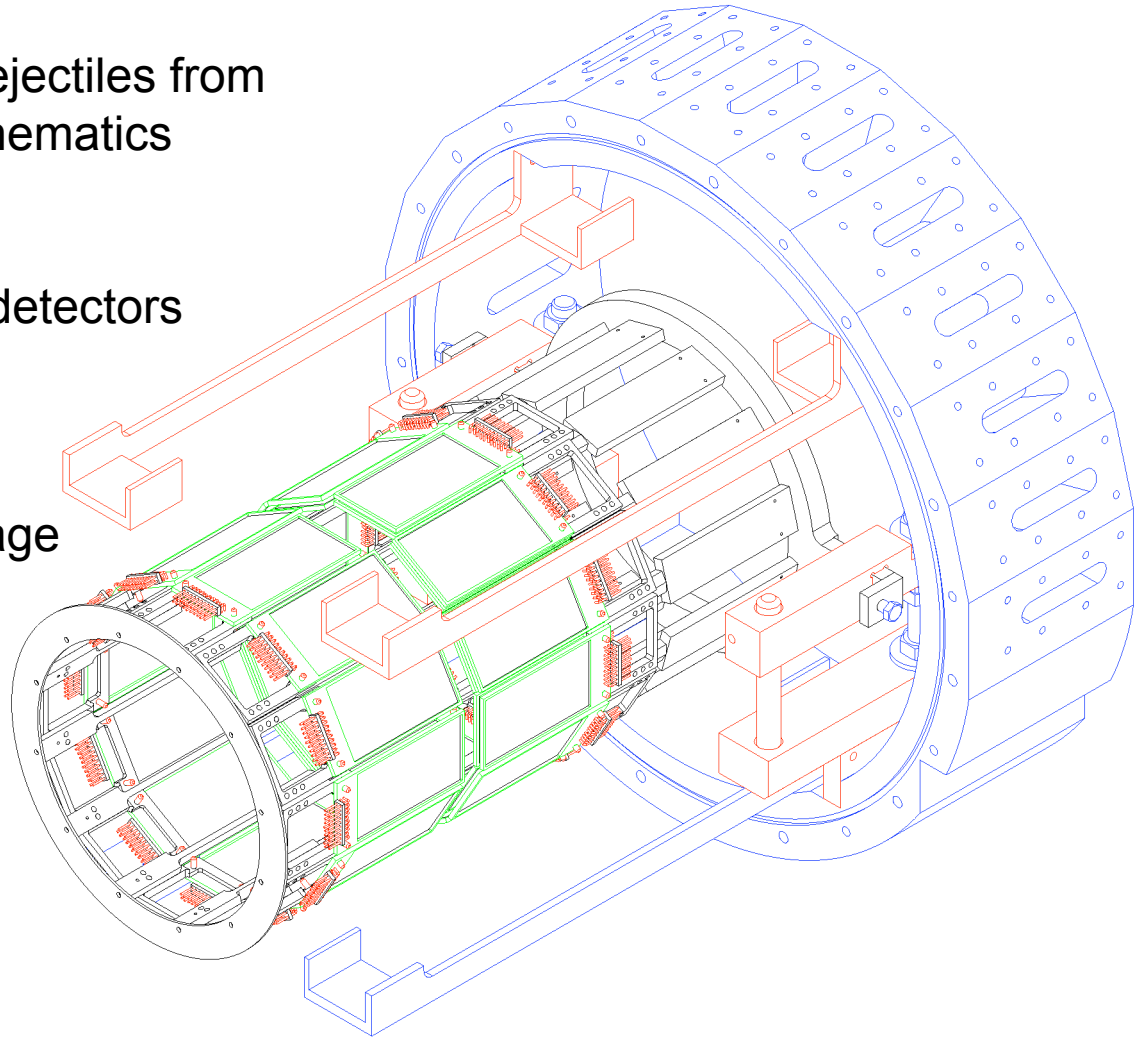
At forward $\theta_{lab}$ $E_{proton}$ rises quickly with angle ($dE/d\theta$ is large).

Want to measure around 90°.

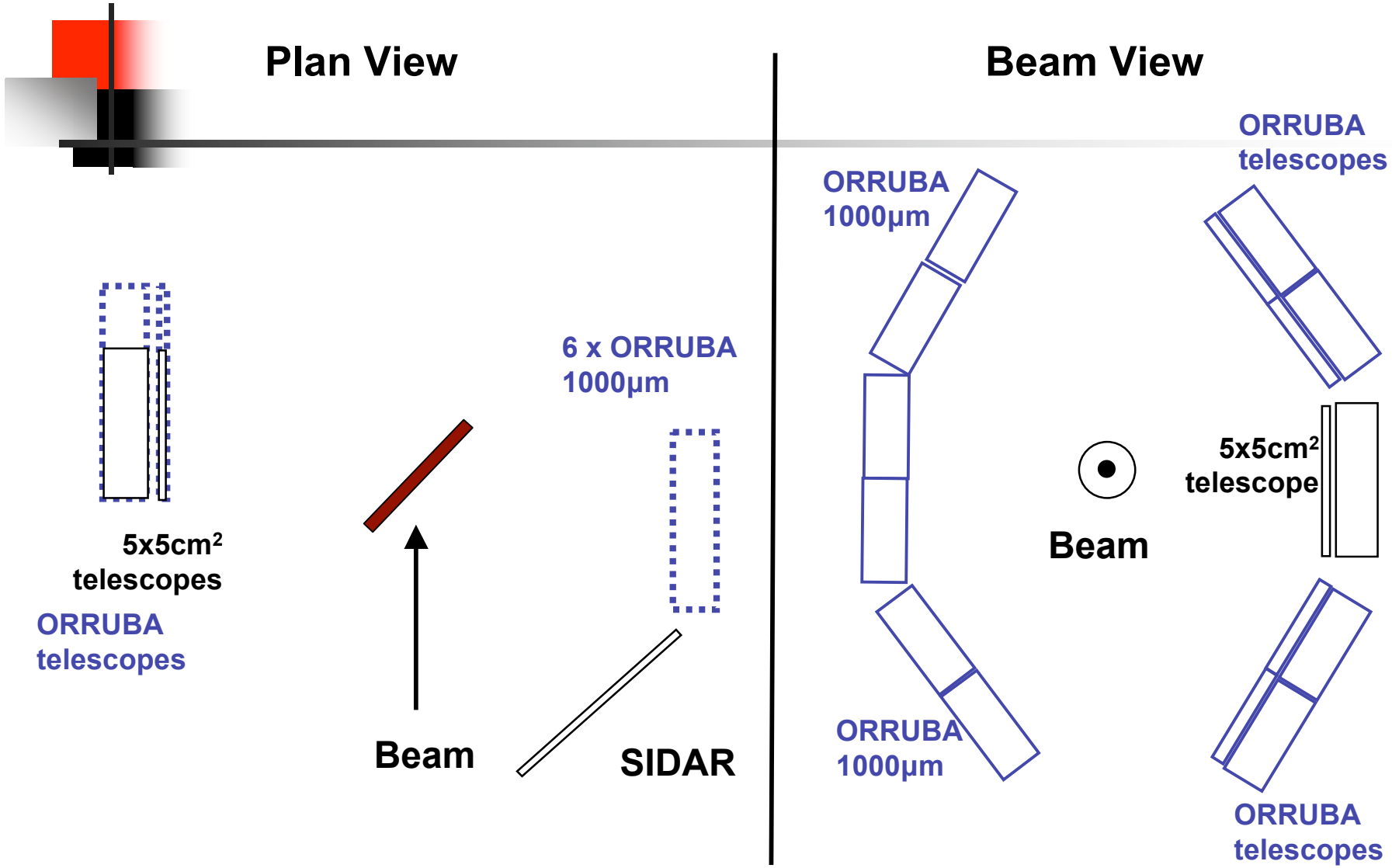


# ORRUBA: Oak Ridge Rutgers University Barrel Array

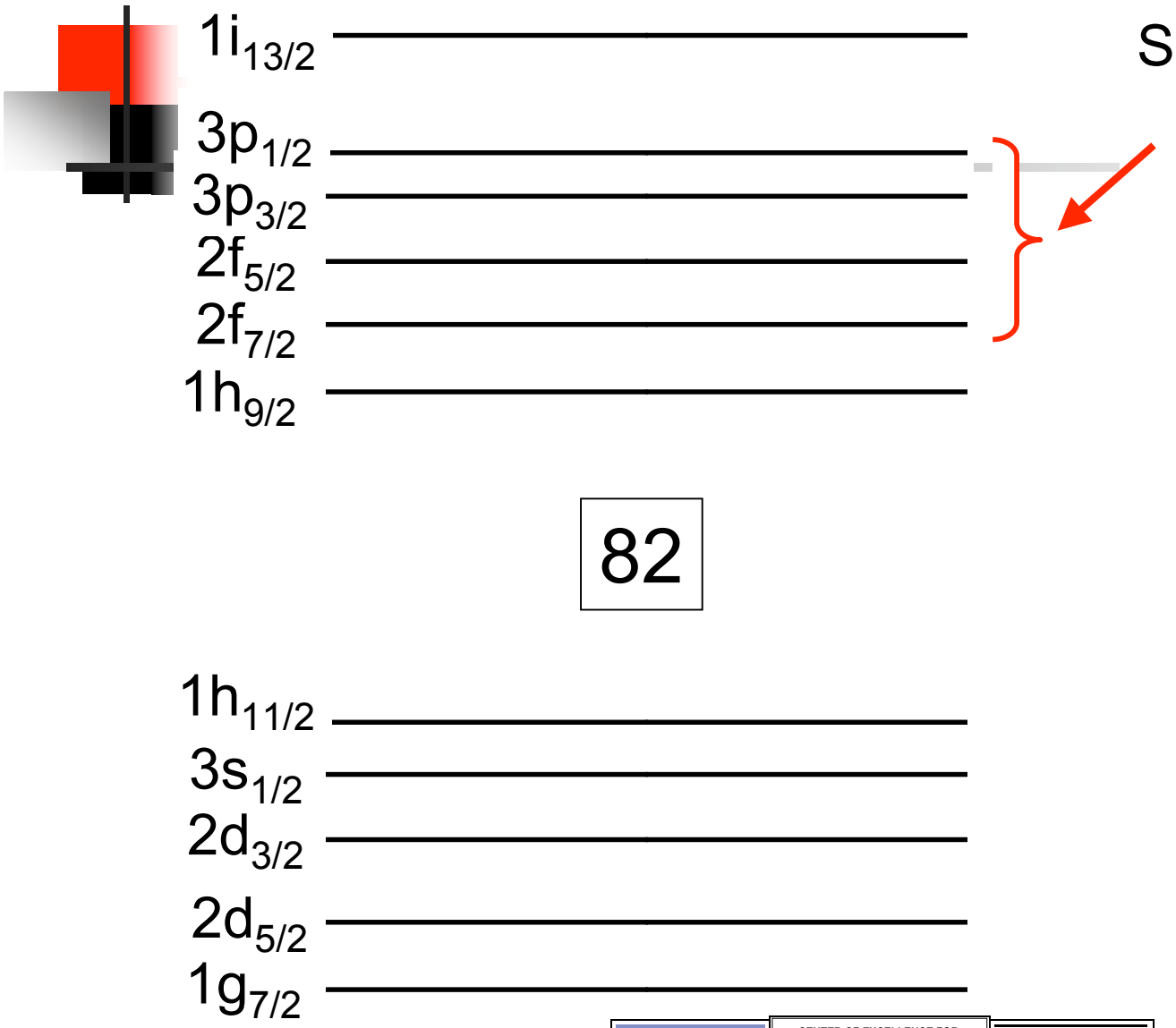
- Flexible design for measuring ejectiles from transfer reactions in inverse kinematics
- Resistive and non-resistive Si detectors (1000μm, 500μm and 65μm)
- ORRUBA gives ~80% $\phi$ coverage over the range 47° →132°
- 288 electronics channels (conventionally instrumented)



# $^{132}$Sn(d,p) detectors

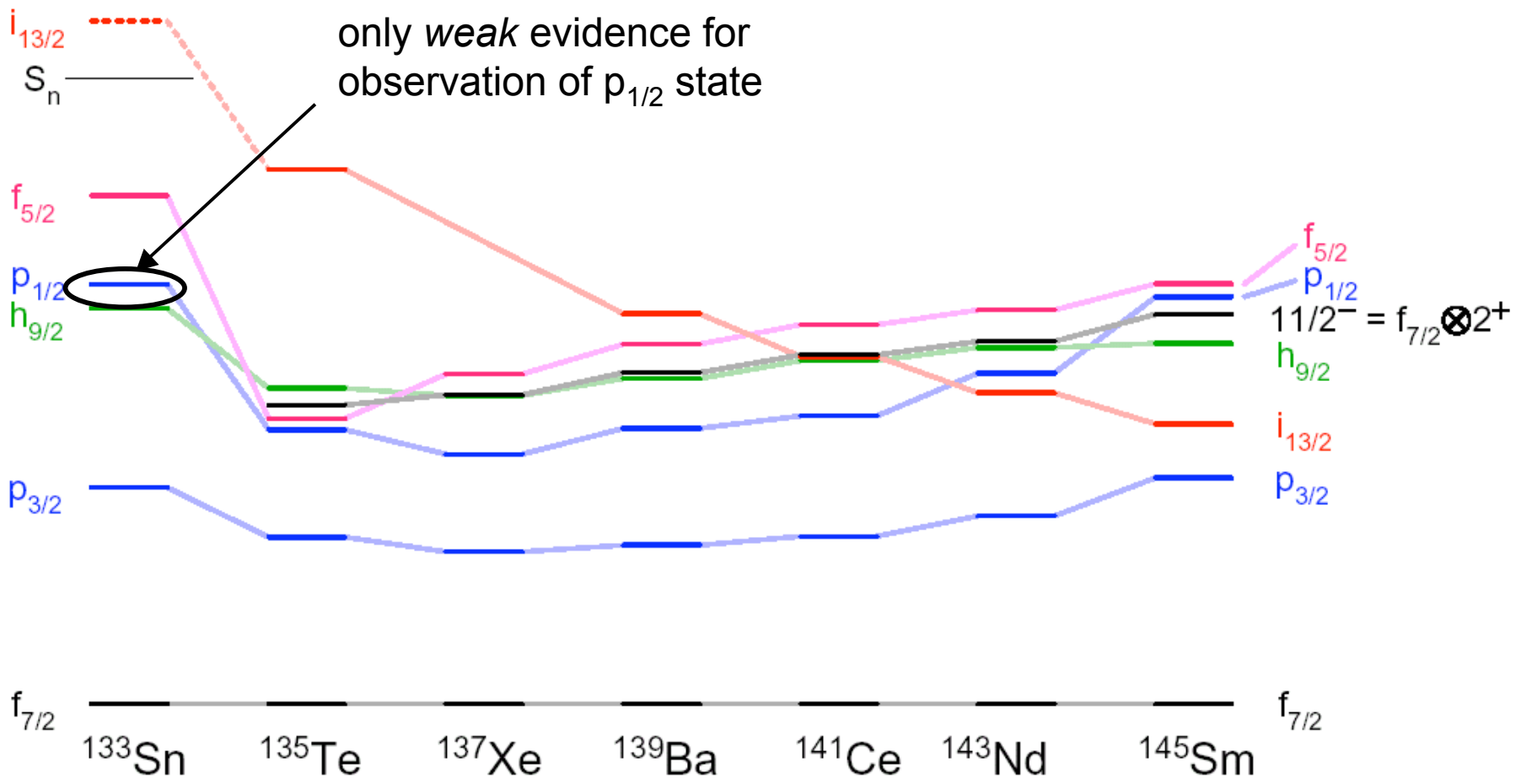


# N=82 (d,p): What should one expect to see?




Should be strongest in N=82 (d,p) ($\ell$=1 and $\ell$=3)

# N=83 Systematics



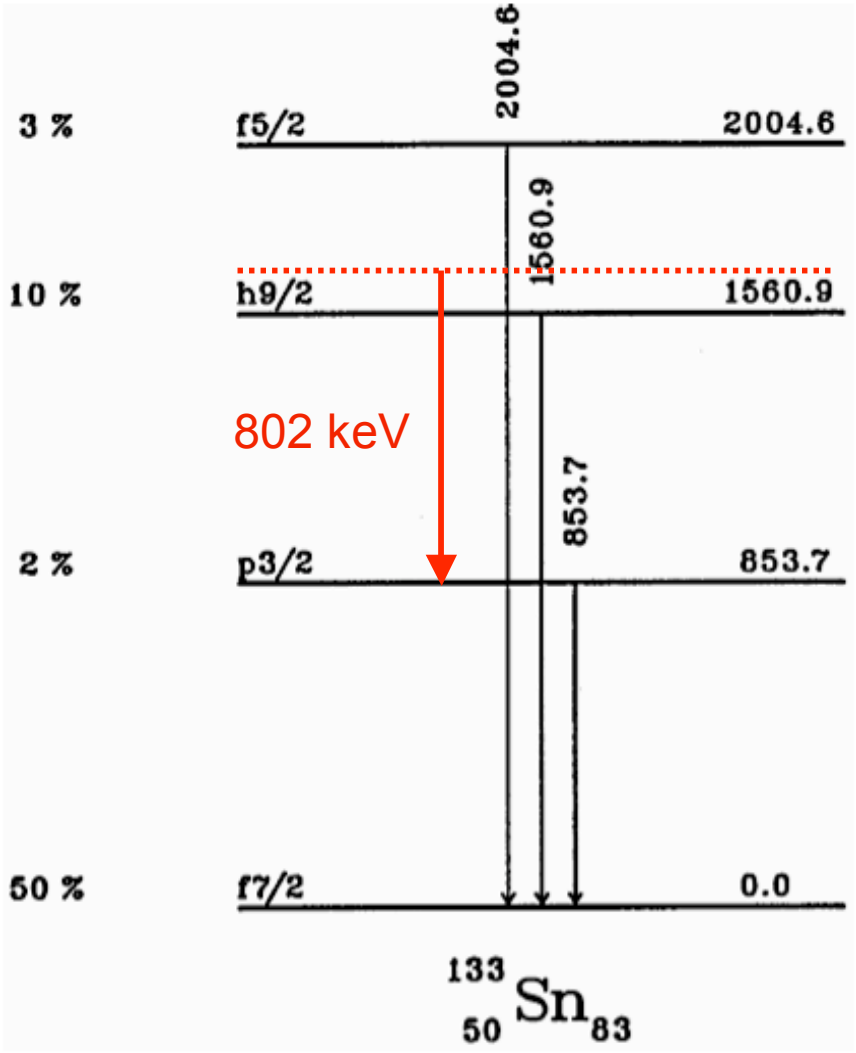
# Location of $p_{1/2}$ state

- Tentatively observed via β-delayed neutron decay

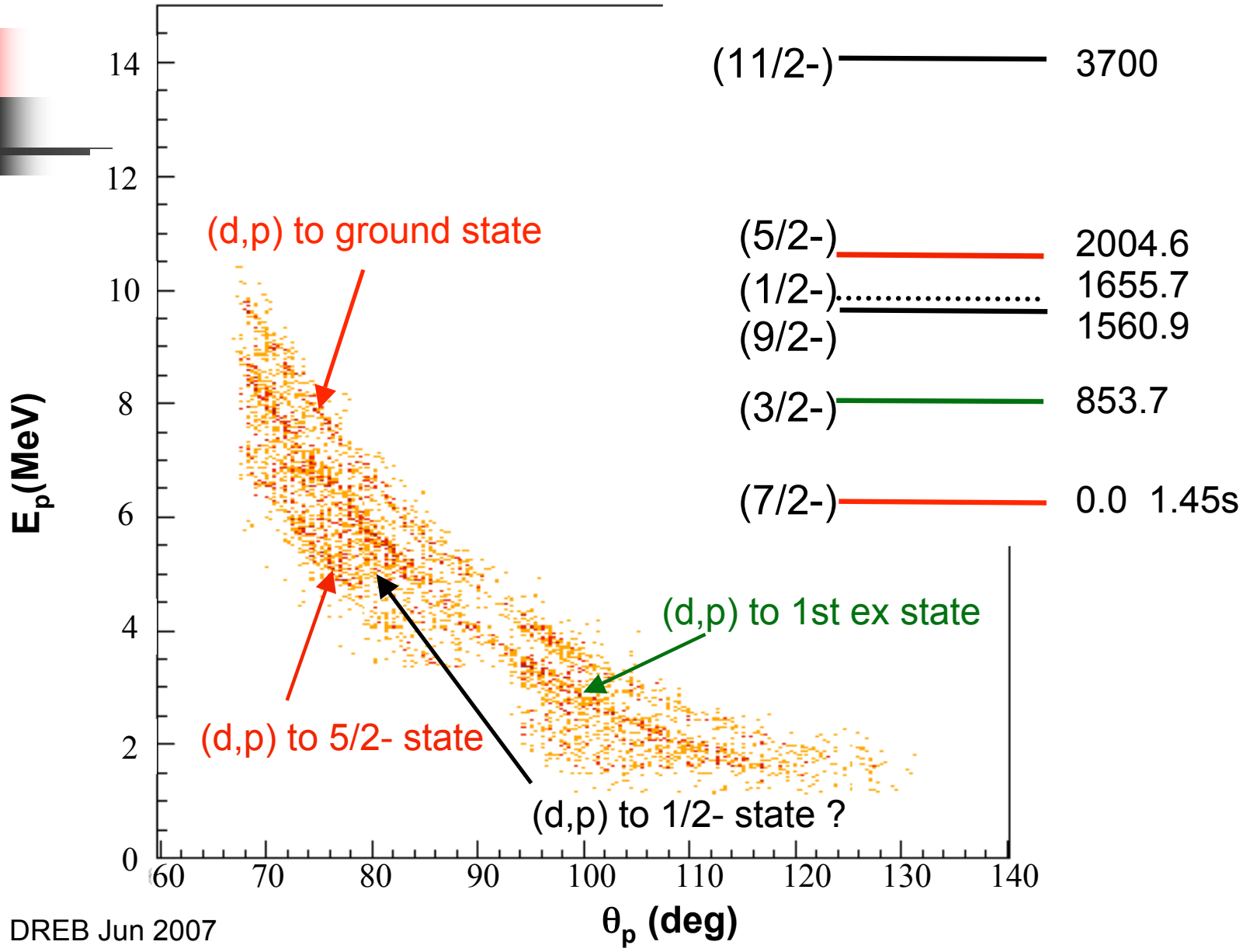
P.Hoff et al PRL **77**, 1020

- Not observed following prompt fission of $^{248}Ca$

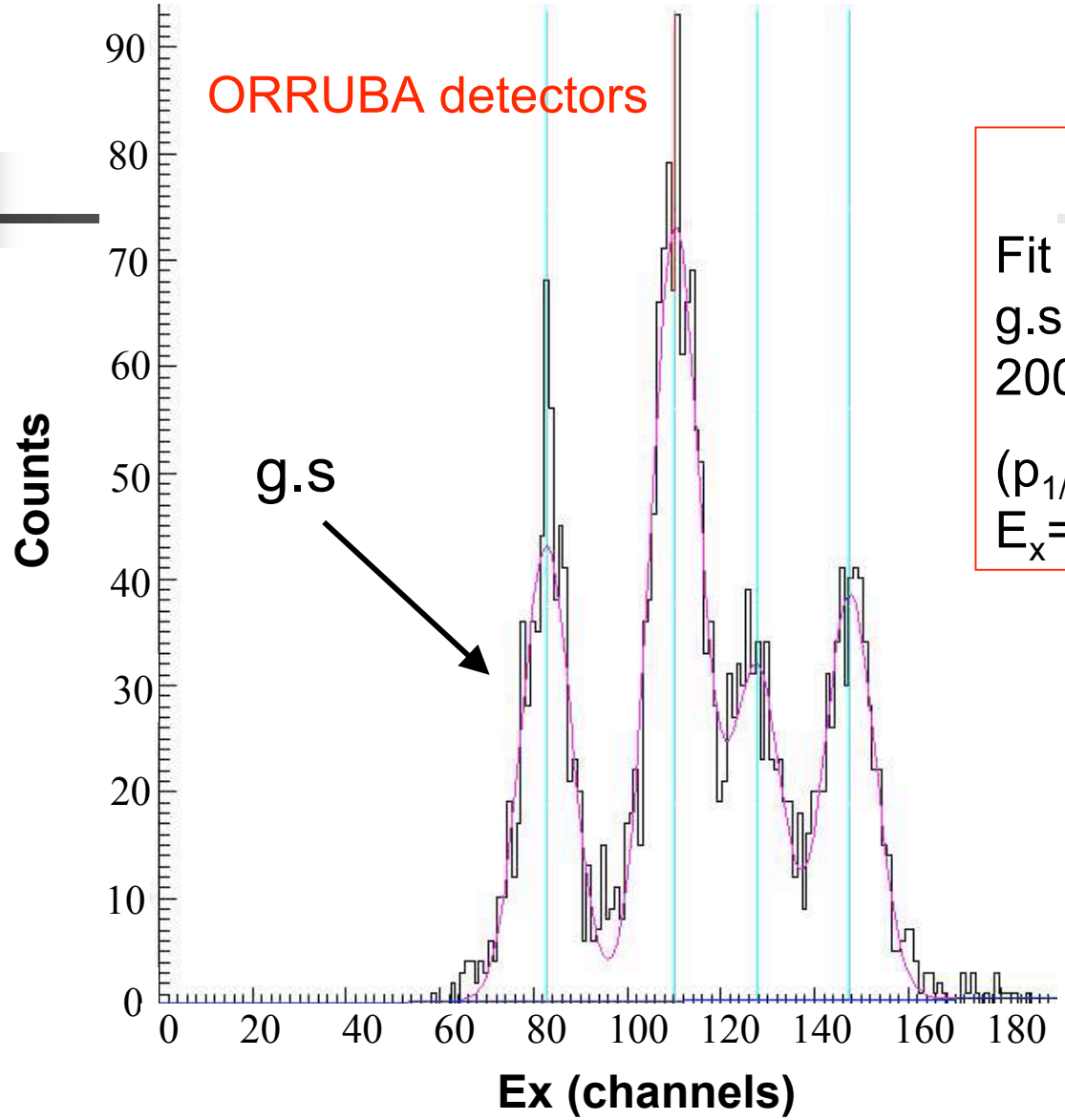
W.Urban et al
Eur. Phys. J. A. **5** 239



# $^{132}$Sn(d,p): "all" ORRUBA detectors



# $^{133}$Sn Excitation Energy

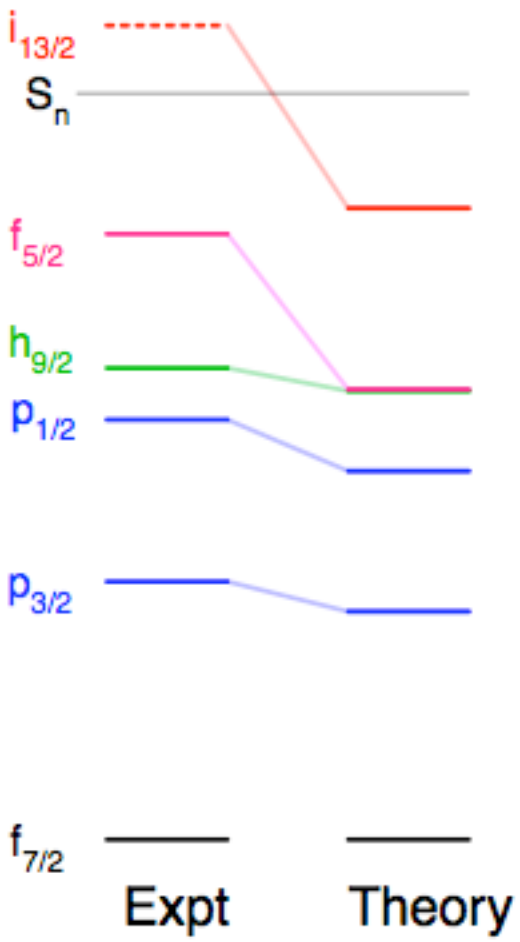



Preliminary

Fit known levels:
g.s., 853.7-keV and 2004.6 keV

($p_{1/2}$) candidate:
$E_x$= 1390 (40) keV

# Single Particle Energies defined




Previously two (unhappy) alternatives:

- SPEs straight from experiment i.e. including the $p_{1/2}$ at 1656 keV.

OR

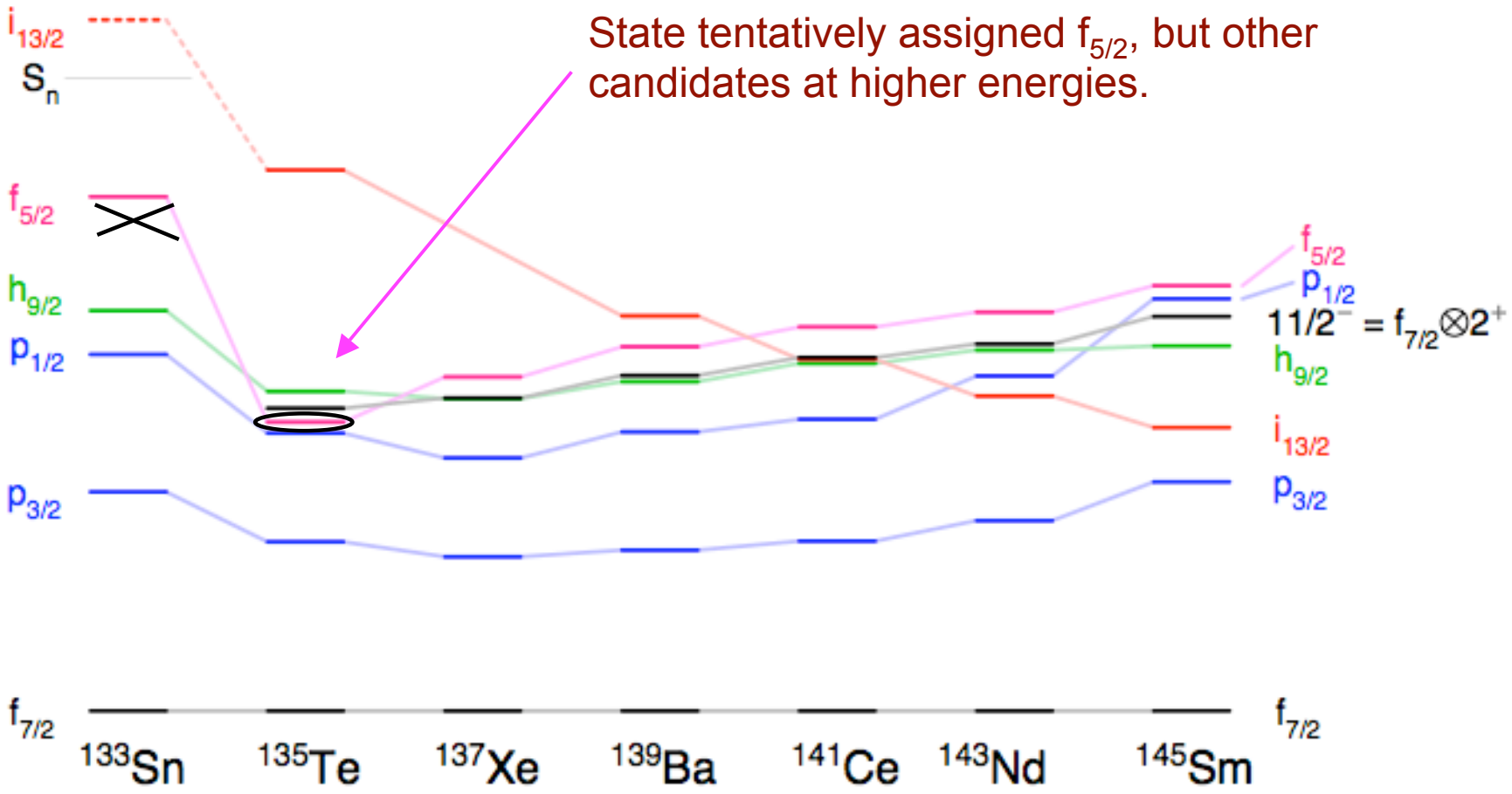
- Extract from states in other nuclei e.g. Z=54, 56 isotones

Sakar and Sakar Phys. Rev. **C64** 014312 (2001).

NOW correct SPE's

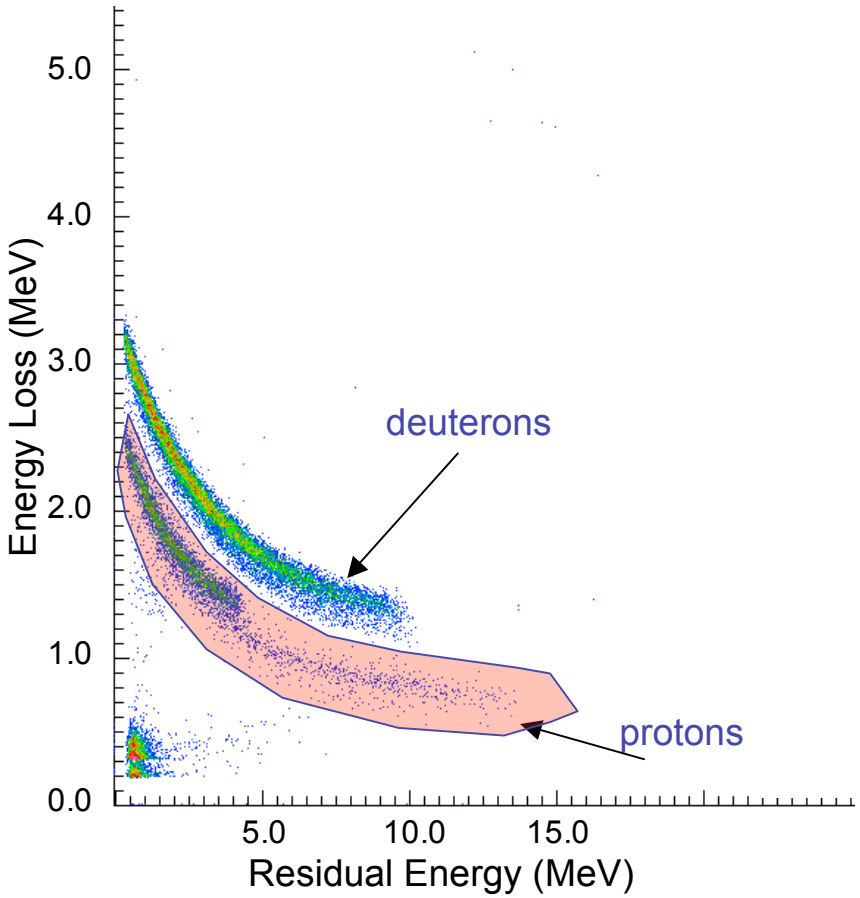
- Calculations of masses, other nuclear properties
- Nuclear astrophysics

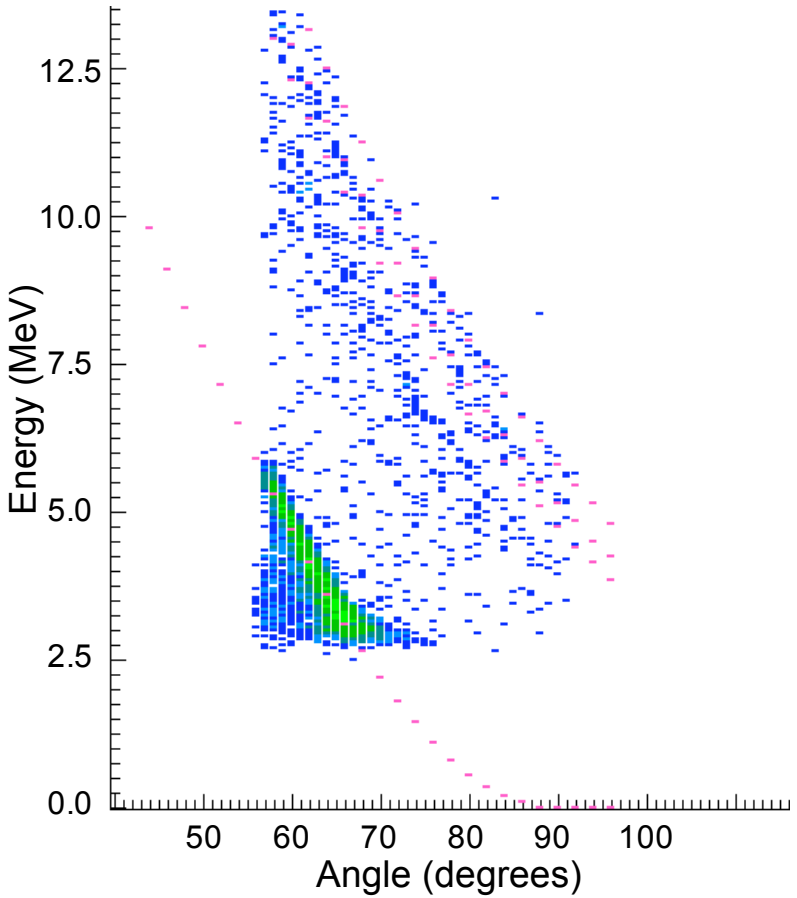
# Revised N=83 systematics



# $^{134}$Te(d,p) Kinematics

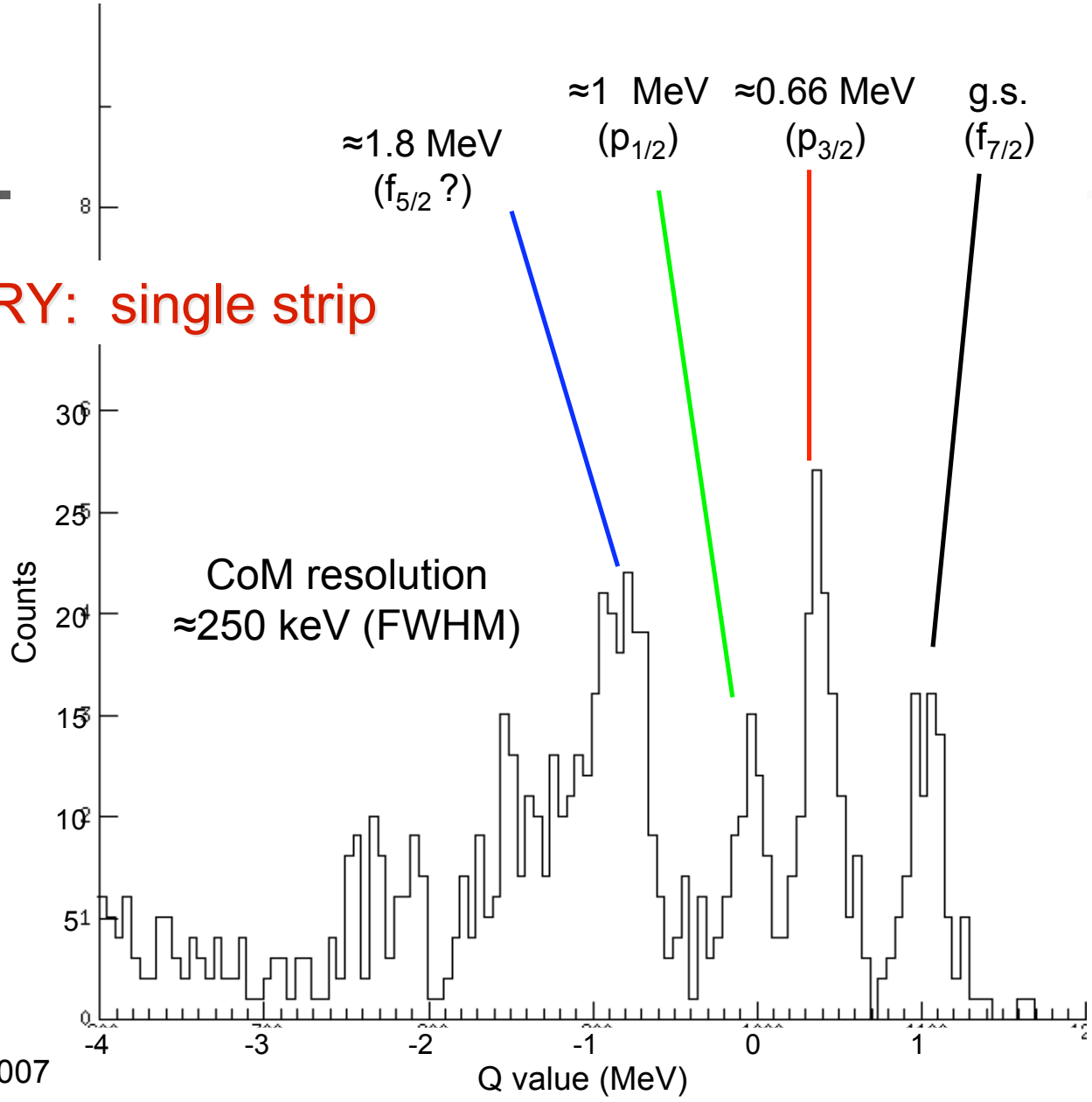
Single strip



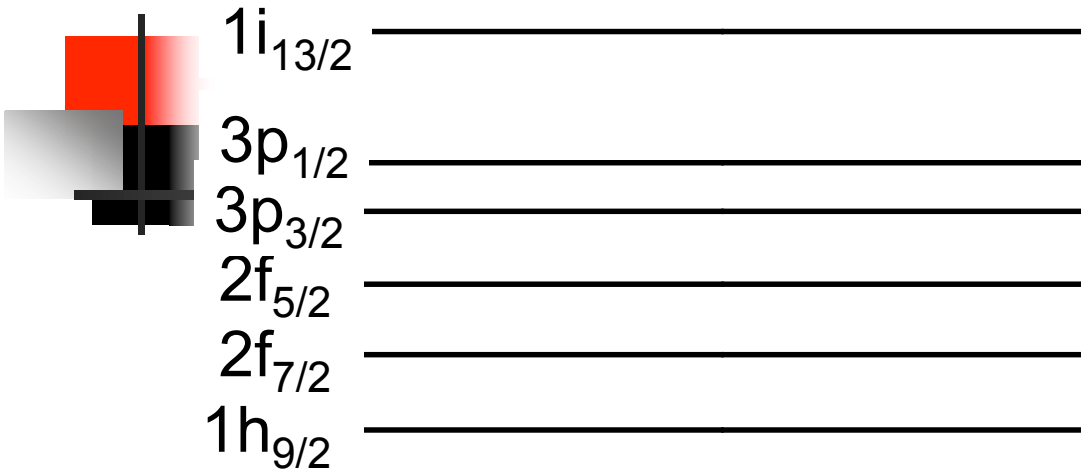



# $^{134}$Te(d,p): Q-value spectrum

PRELIMINARY: single strip

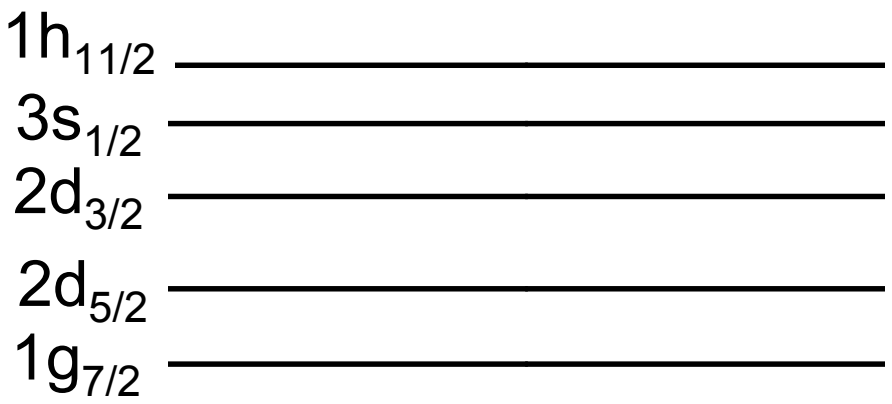


# $^{130}$Sn(d,p): What should one expect to see?




Should be strongest in $^{130}$Sn(d,p)$^{131}$Sn ($\ell$=1 and $\ell$=3)

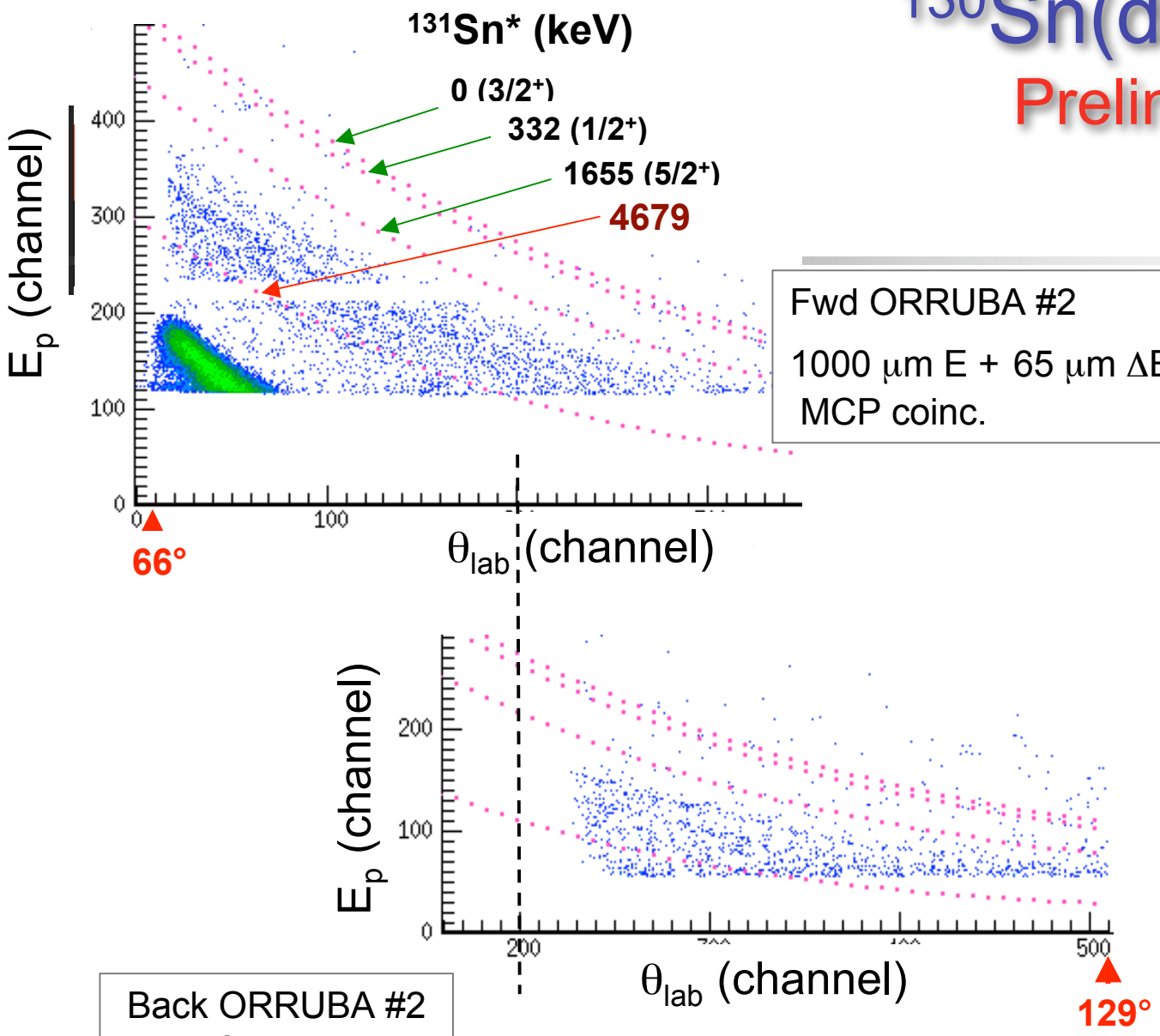
82




Two neutron holes in $^{130}$Sn$_{80}$(g.s.); some population of low-lying hole state(s) in $^{131}$Sn

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

## Preliminary




Fwd ORRUBA #2

1000 μm E + 65 μm ΔE

MCP coinc.

Back ORRUBA #2

MCP coinc.

DREB Jun 2007

CENTER OF EXCELLENCE FOR RADIOACTIVE ION BEAM STUDIES FOR STEWARDSHIP SCIENCE

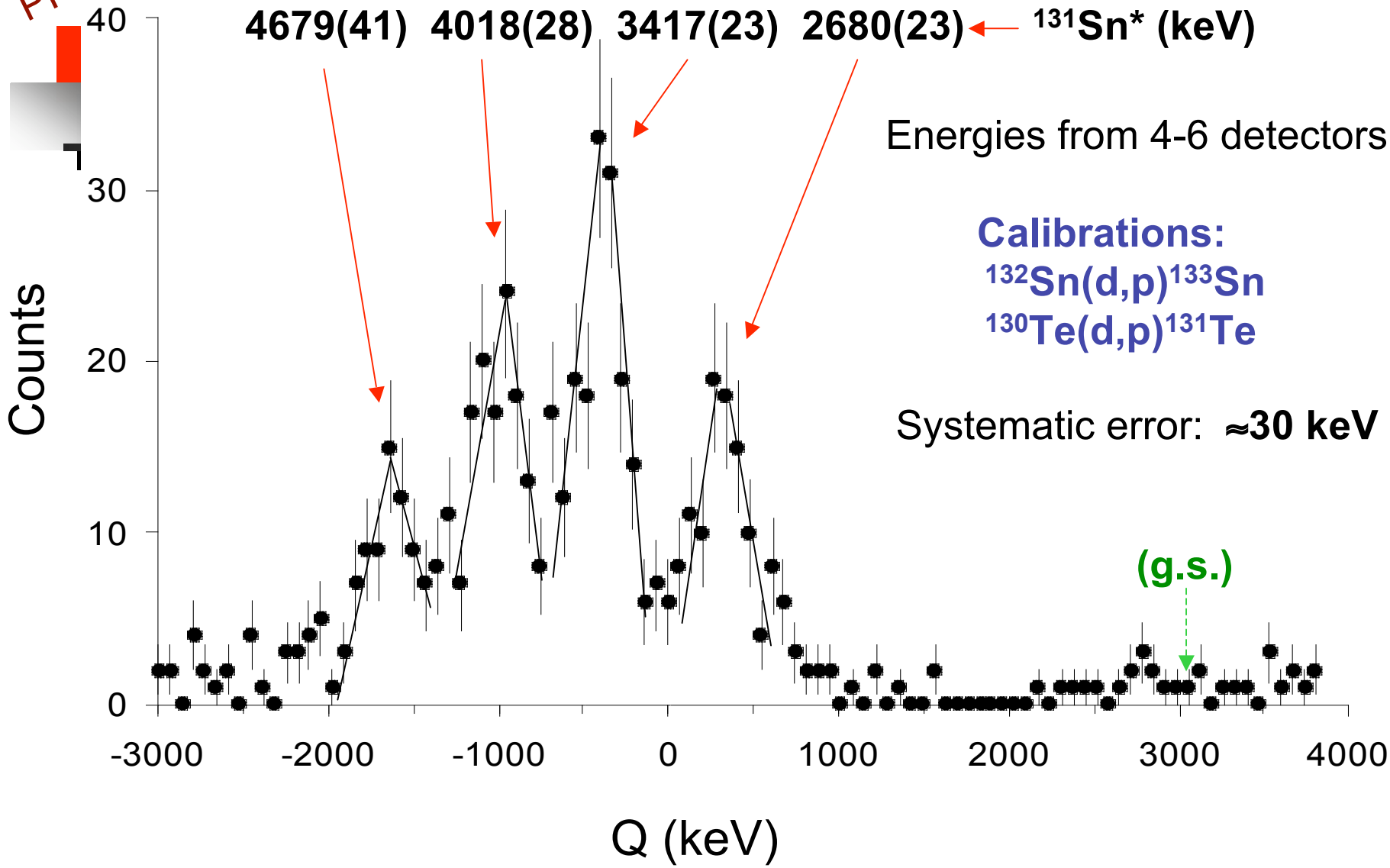
UNIRIB University Radioactive Ion Beam Consortium

THE STATE UNIVERSITY OF NEW JERSEY RUTGERS

PRELIMINARY

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

Fwd ORRUBA #1, MCP coinc., narrow TAC window

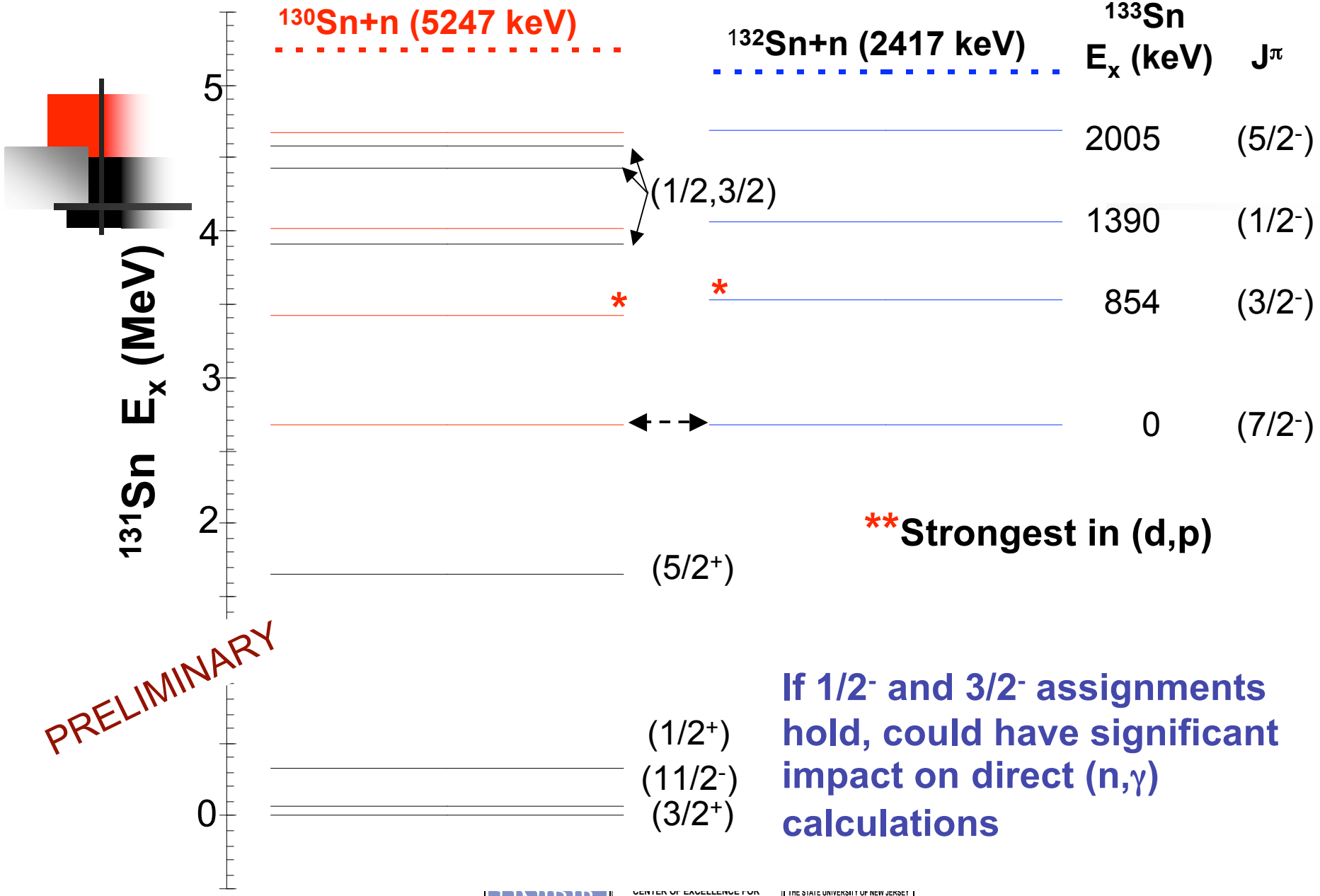





UNIRIB University Radioactive Ion Beam Consortium

CENTER OF EXCELLENCE FOR RADIOACTIVE ION BEAM STUDIES FOR STEWARDSHIP SCIENCE

THE STATE UNIVERSITY OF NEW JERSEY RUTGERS



# Work in progress and to come

- Analysis of all detectors, all experiments
- Angular distributions
  - To support $p_{1/2}$ assignment of 1390-keV state in $^{133}Sn$
  - For all states populated in $^{133}Sn$, $^{135}Te$, $^{131}Sn$
- Spectroscopic factors/ANC's
- Elastic scattering in forward angle detectors

# Summary and Comments

- $^{132}$Sn(d,p):
  - Confirm 3 previously measured states
  - Populate ($p_{1/2}$) state (for first time) at $E_x$=1390(40) keV
  - Better agreement with systematics and theory
- $^{134}$Te(d,p):
  - Candidate for $f_{5/2}$ at ≈1.8 MeV
- $^{130}$Sn(d,p):
  - States above N=82 gap:
  - "Same" spectrum $E_x$>2.6 MeV as $^{133}$Sn

# Thank you

**Direct reactions with exotic beams of neutron-rich nuclei near $^{132}$Sn**

Work supported in part by the
U.S. Department of Energy and
National Science Foundation



UNIRIB University Radioactive Ion Beam Consortium
CENTER OF EXCELLENCE FOR RADIOACTIVE ION BEAM STUDIES FOR STEWARDSHIP SCIENCE
THE STATE UNIVERSITY OF NEW JERSEY RUTGERS