Gamma rays at ATLAS - the evolution of techniques and physics

ATLAS 25th Anniversary Celebration

Lee Riedinger

University of Tennessee

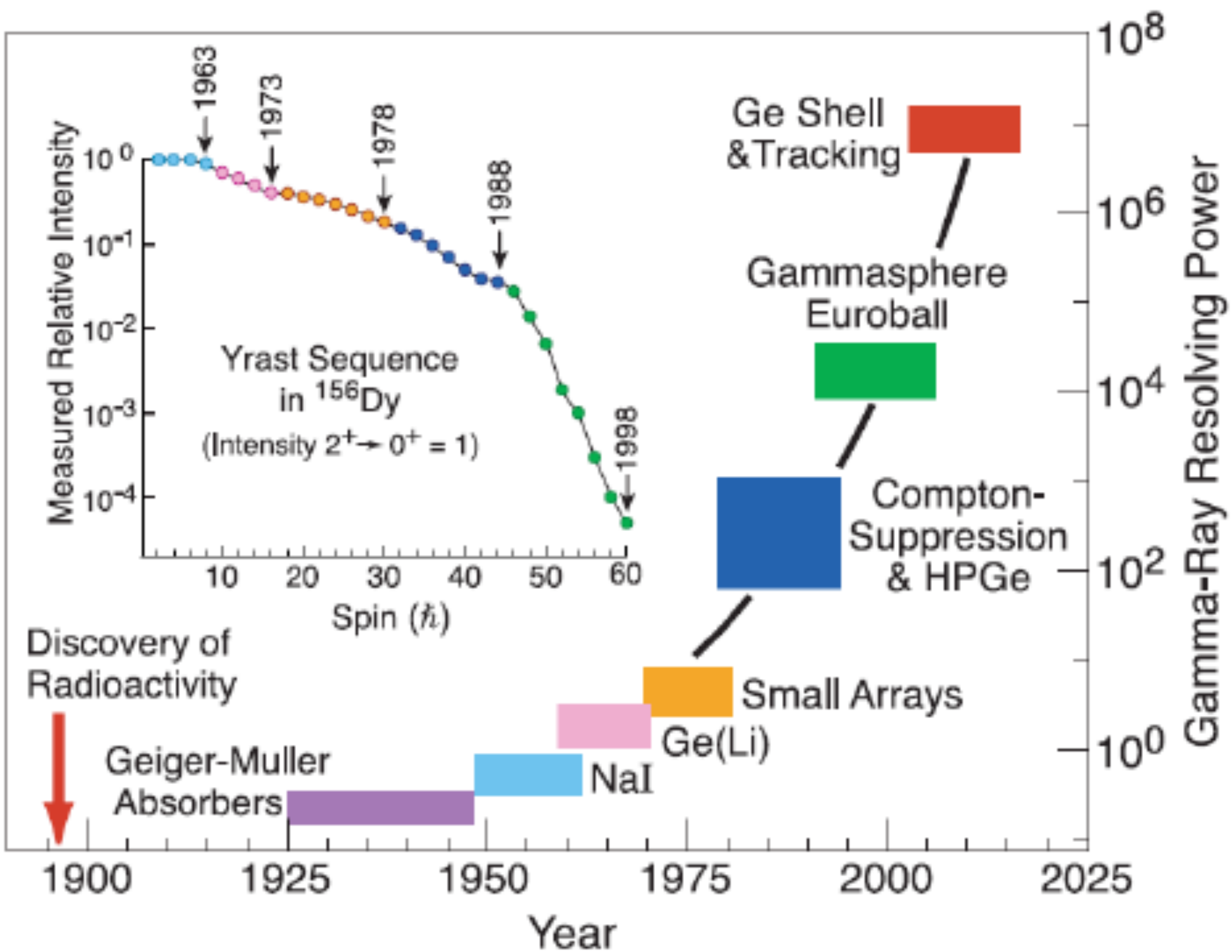
October 22, 2010

Outline

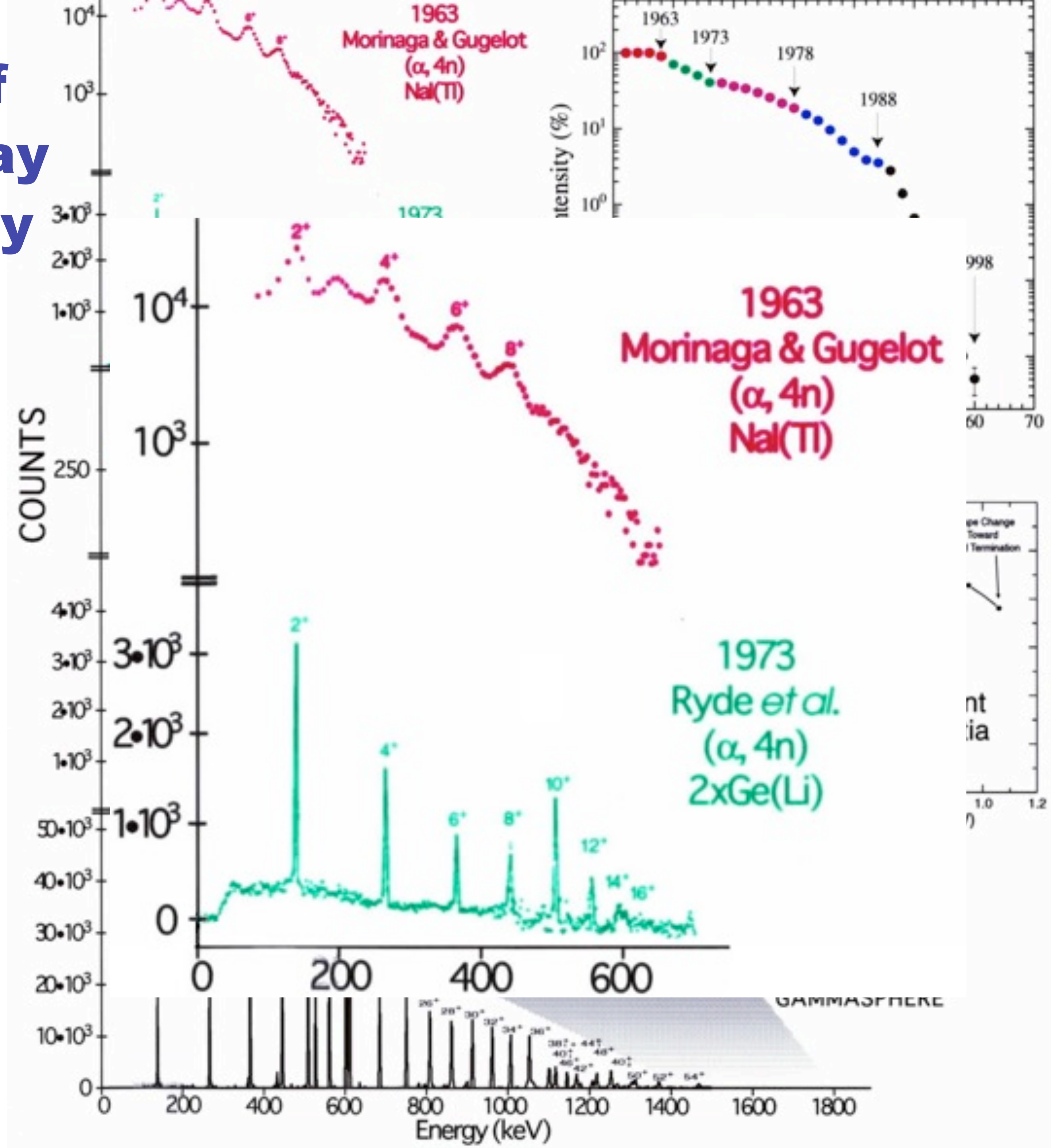
- The γ-ray instruments at ATLAS
- The people
- The physics
- The future

ATLAS

Huge progress in 25 years in resolving power of γ-ray detector systems

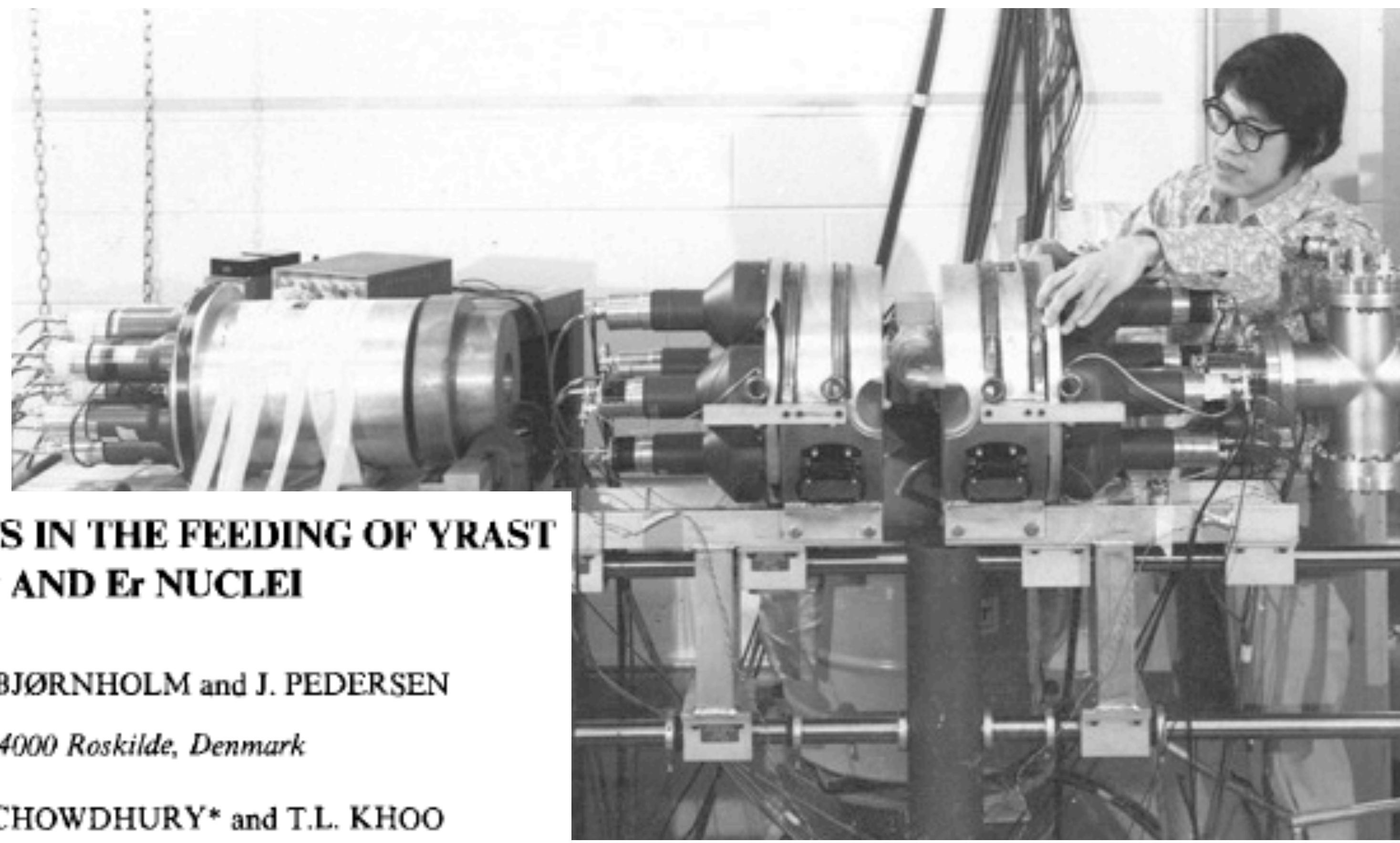


Evolution of high spin γ-ray spectroscopy



Early ATLAS γ-ray experiments

- **1983 - use array of NaI counters plus one Ge detector**
- **Population of yrast and near-yrast levels in Gd, Dy, and Er nuclei investigated in (HI,xn) reactions through γ-ray intensity measurements**
- **Clear difference between non-rotor (N < 86) and rotor nuclei (N > 86)**
- **I_{sat} is independent of bombarding energy when it becomes sufficiently high**



NUCLEAR STRUCTURE EFFECTS IN THE FEEDING OF YRAST STATES OF Gd, Dy AND Er NUCLEI

J. BORGGREEN, G. SLETTEN, S. BJØRNHOLM and J. PEDERSEN

Niels Bohr Institute, Risø, 4000 Roskilde, Denmark

R.V.F. JANSSENS, I. AHMAD, P. CHOWDHURY* and T.L. KHOO

Argonne National Laboratory, Argonne, Illinois 60439, USA

and

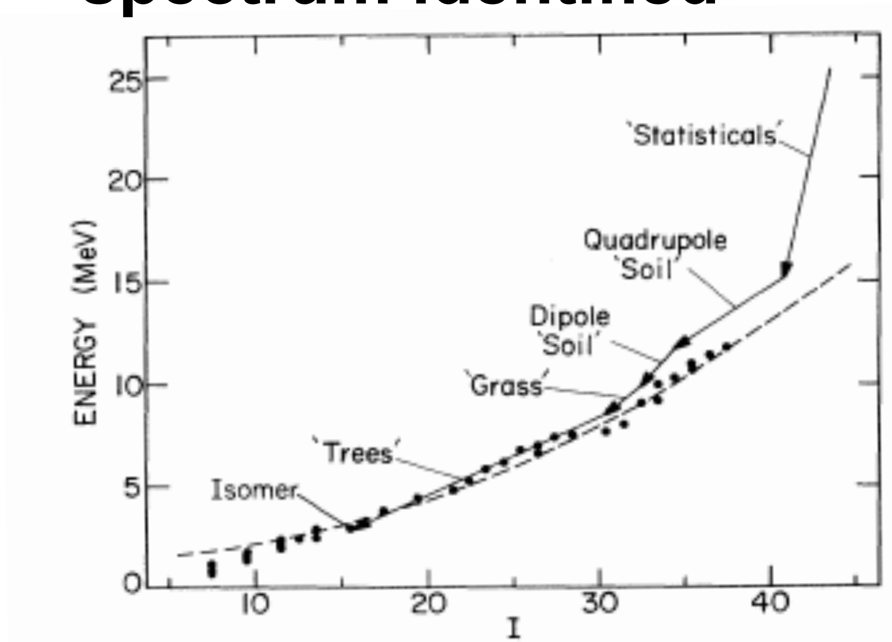
Y.H. CHUNG and P.J. DALY

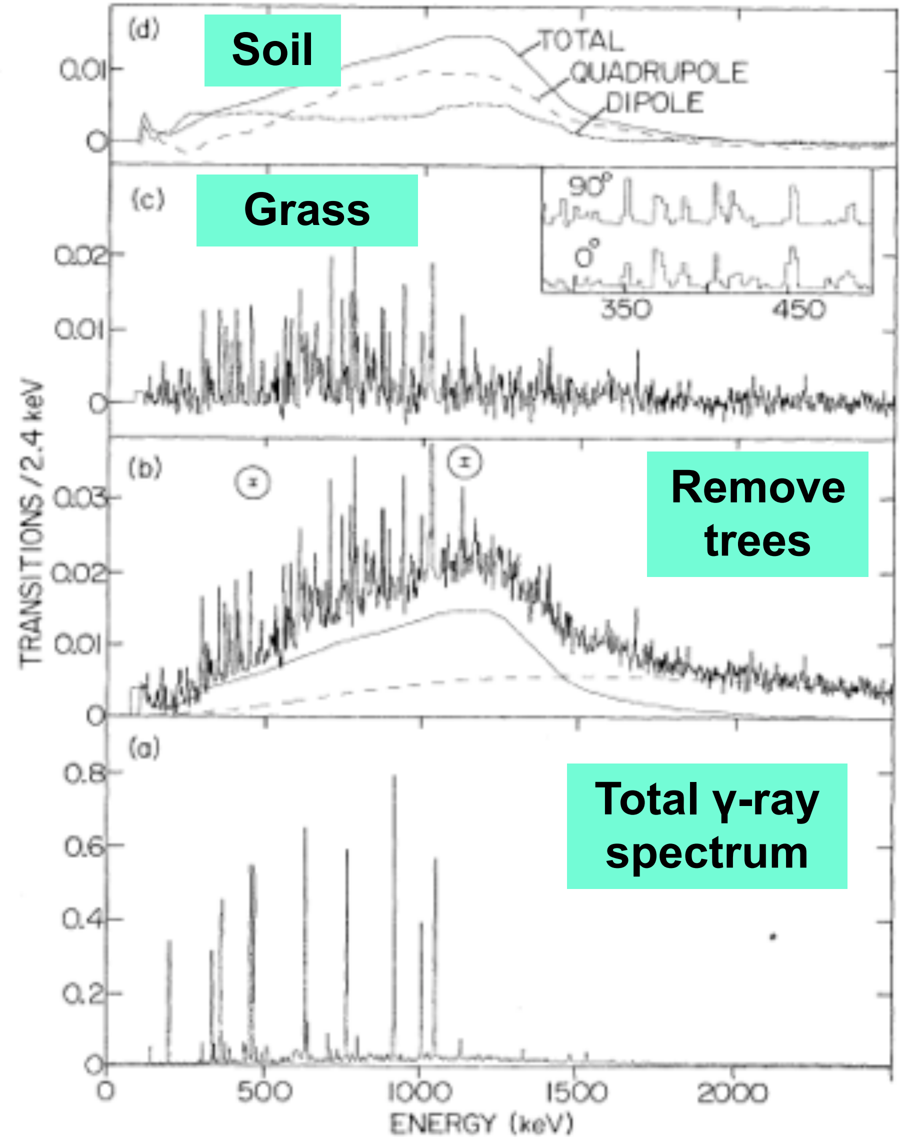
Nucl. Phys. **A443**, 120 (1985)

ATLAS

1985 - 2 Compton suppressed Ge and 12 NaI

- $^{120}Sn(^{37}Cl,4n)^{153}Ho$
- Four components of γ-ray spectrum identified





D. C. Radford,[a] I. Ahmad, R. Holzmann, R. V. F. Janssens, and T. L. Khoo
Argonne National Laboratory, Argonne, Illinois 60439

PRL **55**, 1727 (1985)

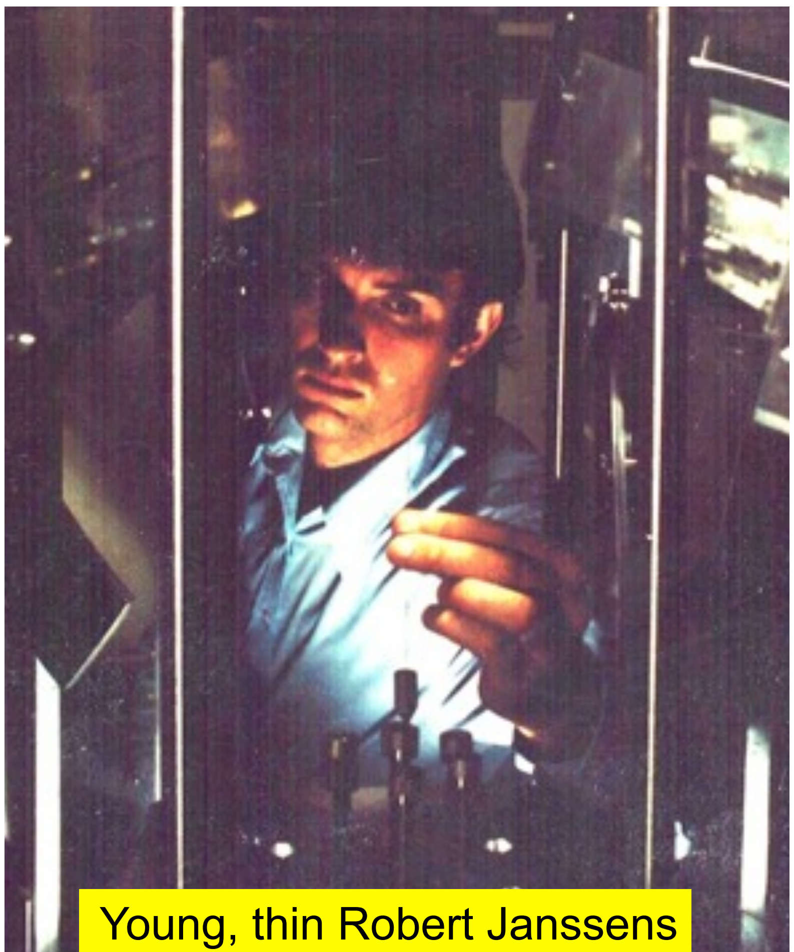
M. L. Drigert and U. Garg
University of Notre Dame, Notre Dame, Indiana 46556

and

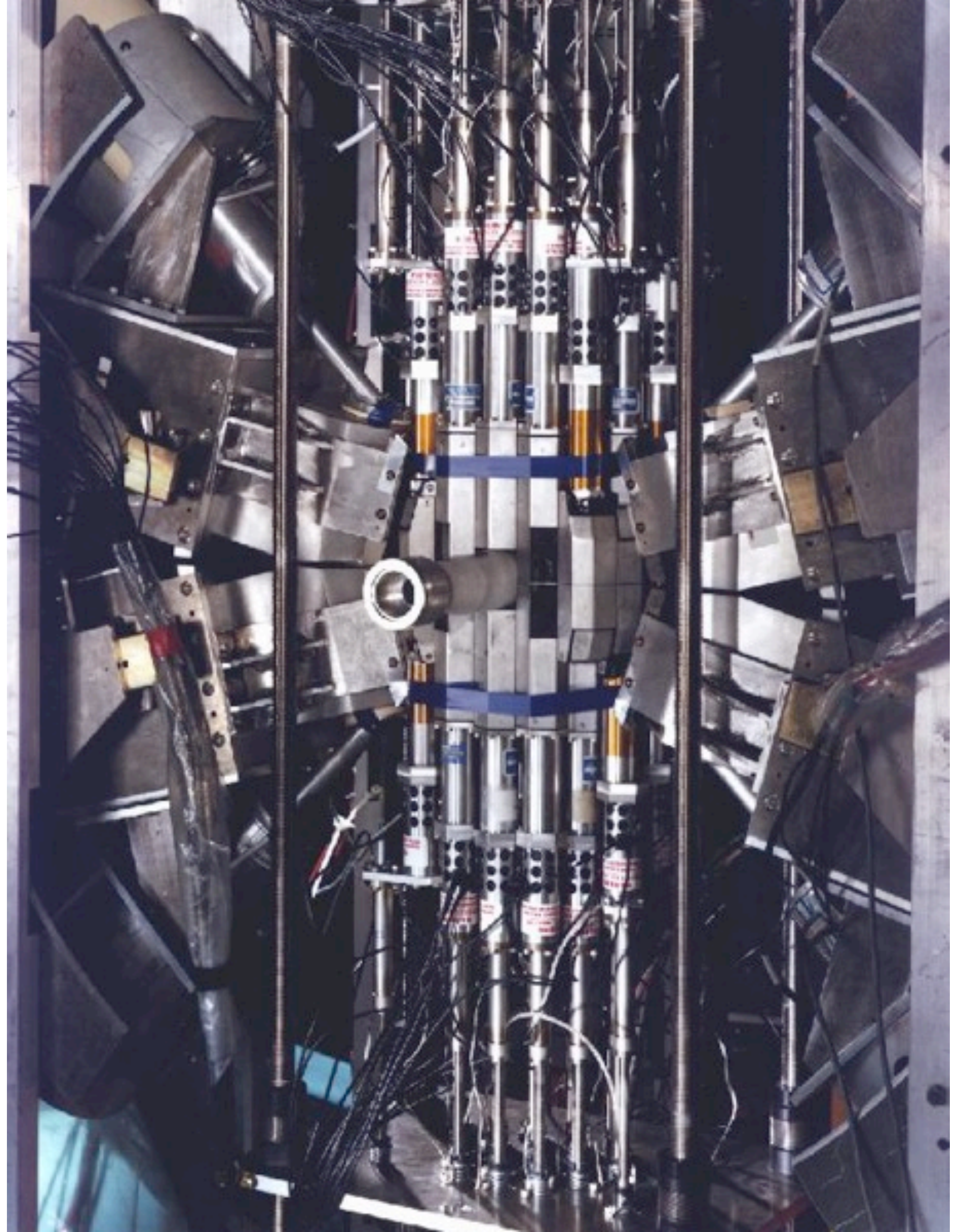
H. Helppi
Lappeenranta University of Technology, Finland

1986 - ANL-ND array

- Argonne/Notre Dame γ-ray facility at ATLAS
- 8 Compton-suppressed Ge spectrometers
- An array of 14 BGO scintillators



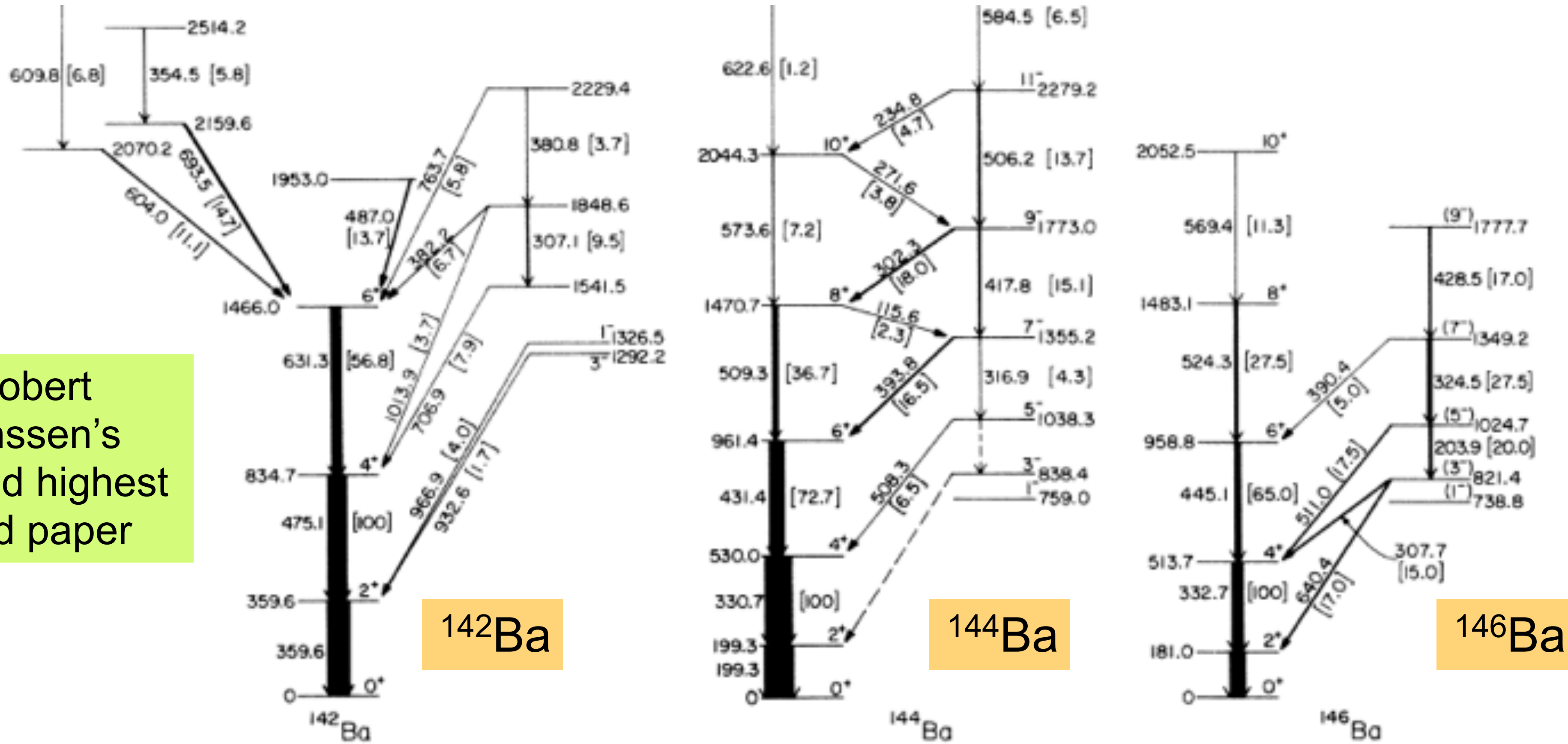
Young, thin Robert Janssens



1986 - octupole shapes in heavy Ba

- **First paper of work with the ANL - ND BGO array**
- **First work with a ^{252}Cf fission source**
- **Pioneering work - led to all later work on n-rich nuclei from prompt fission**

Robert Janssen's second highest cited paper



Octupole Deformation in Neutron-Rich Barium Isotopes

W. R. Phillips,[a] I. Ahmad, H. Emling,[b] R. Holzmann, R. V. F. Janssens, and T.-L. Khoo
Argonne National Laboratory, Argonne, Illinois 60439

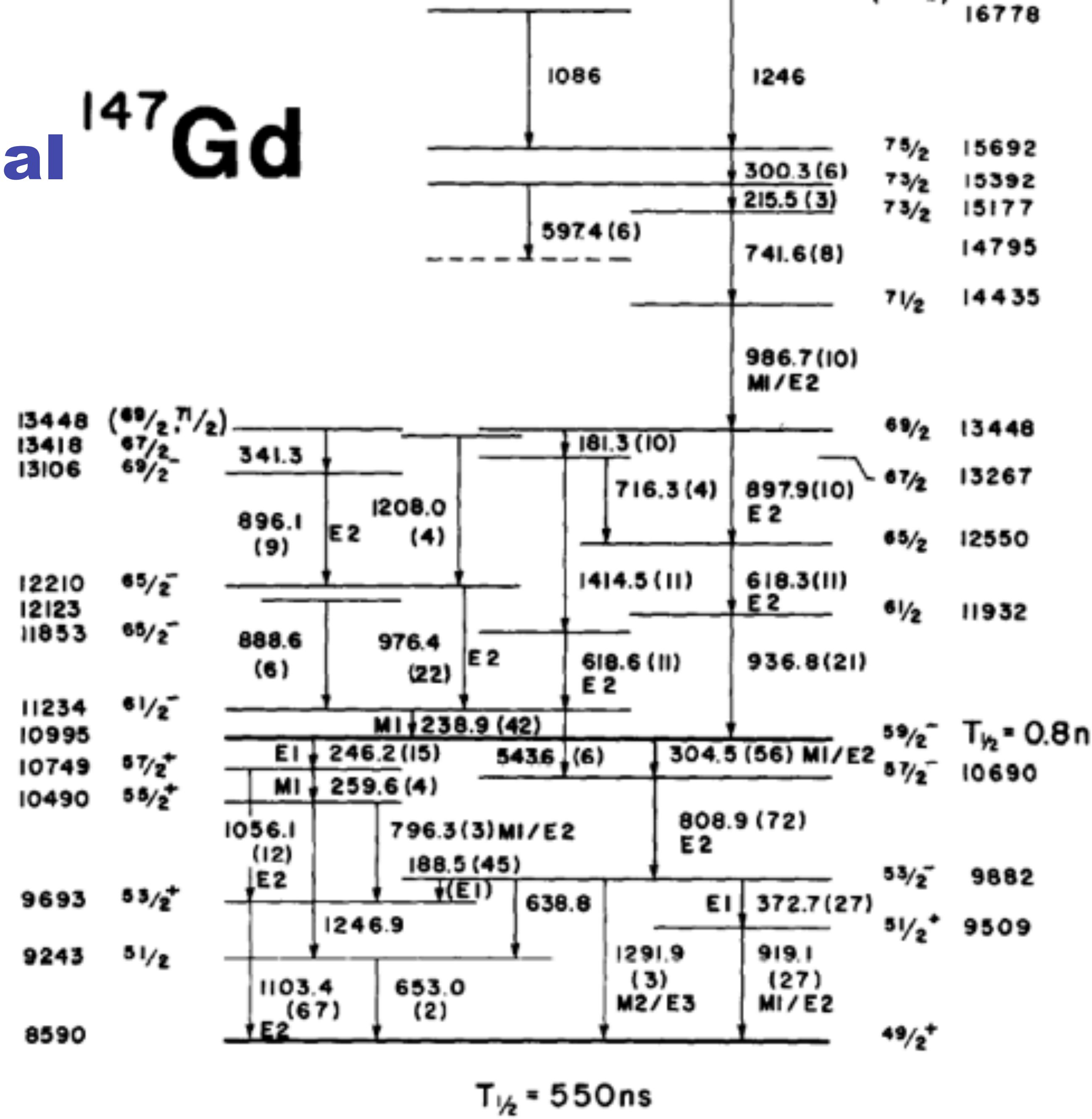
and

M. W. Drigert
University of Notre Dame, Notre Dame, Indiana 46556

PRL **57**, 3257 (1986)

ATLAS

1987 experiment with 4 Ge and 14 NaI



- **Record for highest spin state yet seen at that time - 79/2**
- **Pulsed beam: ^{122}Sn(^{30}Si,5n)**
- **States built on 550 ns isomer of 49/2$^+$**
- **No collective states seen**

J. BORGGREEN, G. SLETTEN, S. BJØRNHOLM, J. PEDERSEN and A. DEL ZOPPO[1]

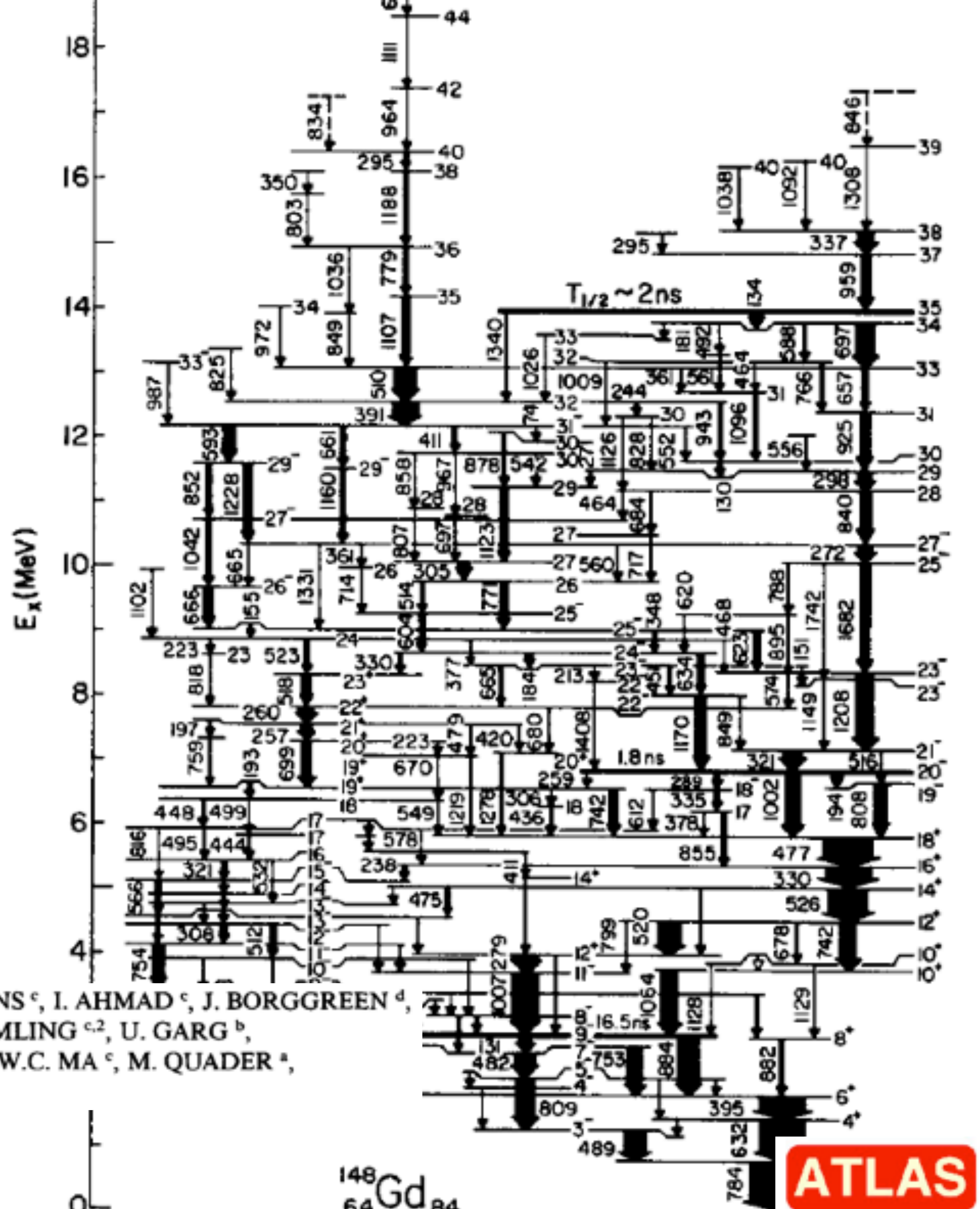
Niels Bohr Institute, Risø, 4000 Roskilde, Denmark

D.C. RADFORD[2], R.V.F. JANSSENS, P. CHOWDHURY[3], H. EMLING[4], D. FREKERS[5] and T.L. KHOO

NP **A466**, 371 (1987)

1987 - ^{148}Gd to spin 44

- ANL-ND array
- ^{116}Cd(^{36}S,4n)
- Power of new array - most complicated level scheme ever put together
- Single-particle states up to I = 38
- A few fast E2s above 38
- A tour-de-force for γ-ray spectroscopy

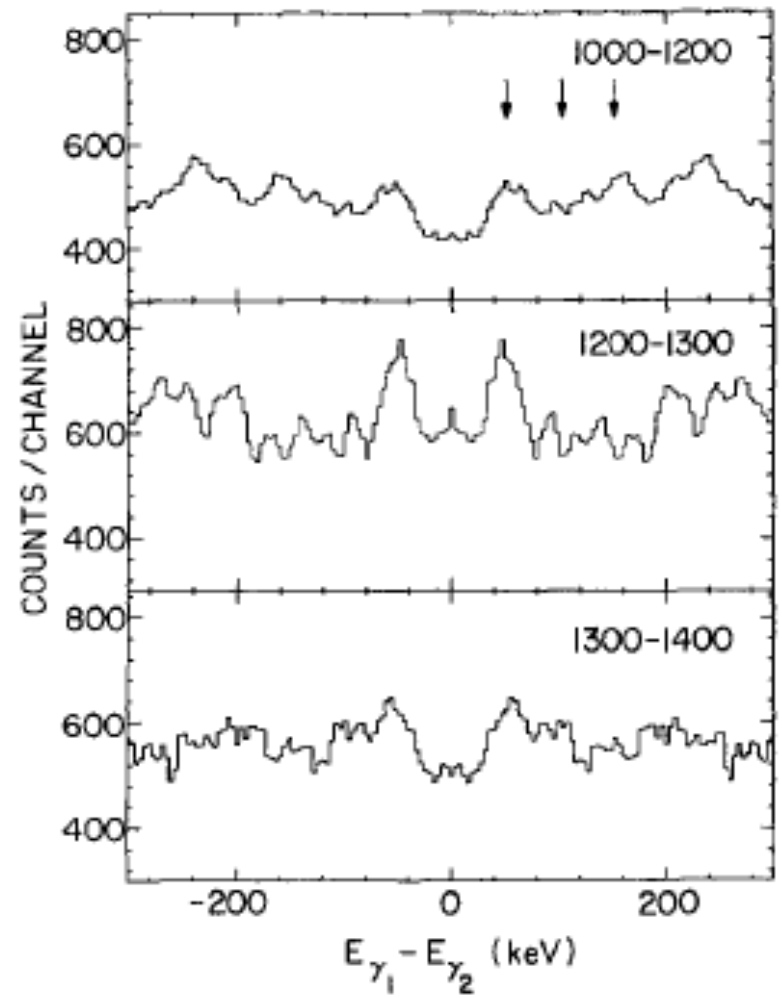


Phys. Lett. **194B**, 468 (1987)

M. PIIPARINEN [a,1], M.W. DRIGERT [b], R.V.F. JANSSENS [c], I. AHMAD [c], J. BORGGREEN [d],
R.R. CHASMAN [c], P.J. DALY [a], B.K. DICHTER [c], H. EMLING [c,2], U. GARG [b],
Z.W. GRABOWSKI [a], R. HOLZMANN [c], T.L. KHOO [c], W.C. MA [c], M. QUADER [a],
D.C. RADFORD [e] and W. TRZASKA [a]

Superdeformation in ^{148}Gd

- γ-γ transition energy correlation measurements were performed using ANL-ND array
- A broad first ridge was observed for $1.00 < E_\gamma < 1.42$ MeV
- Moment of inertia consistent with superdeformation in ^{148}Gd
- The results can be explained by cranked Strutinsky calculations



Now 9 SD bands seen

M.W. DRIGERT [a,1], R.V.F. JANSSENS [b], R. HOLZMANN [b], R.R. CHASMAN [b], I. AHMAD [b], J. BORGGREEN [c], P.J. DALY [d], B.K. DICHTER [b], H. EMLING [b,2], U. GARG [a], Z.W. GRABOWSKI [d], T.L. KHOO [b], W.C. MA [b], M. PIIPARINEN [d,3], M. QUADER [d], D.C. RADFORD [e] and W. TRZASKA [d]

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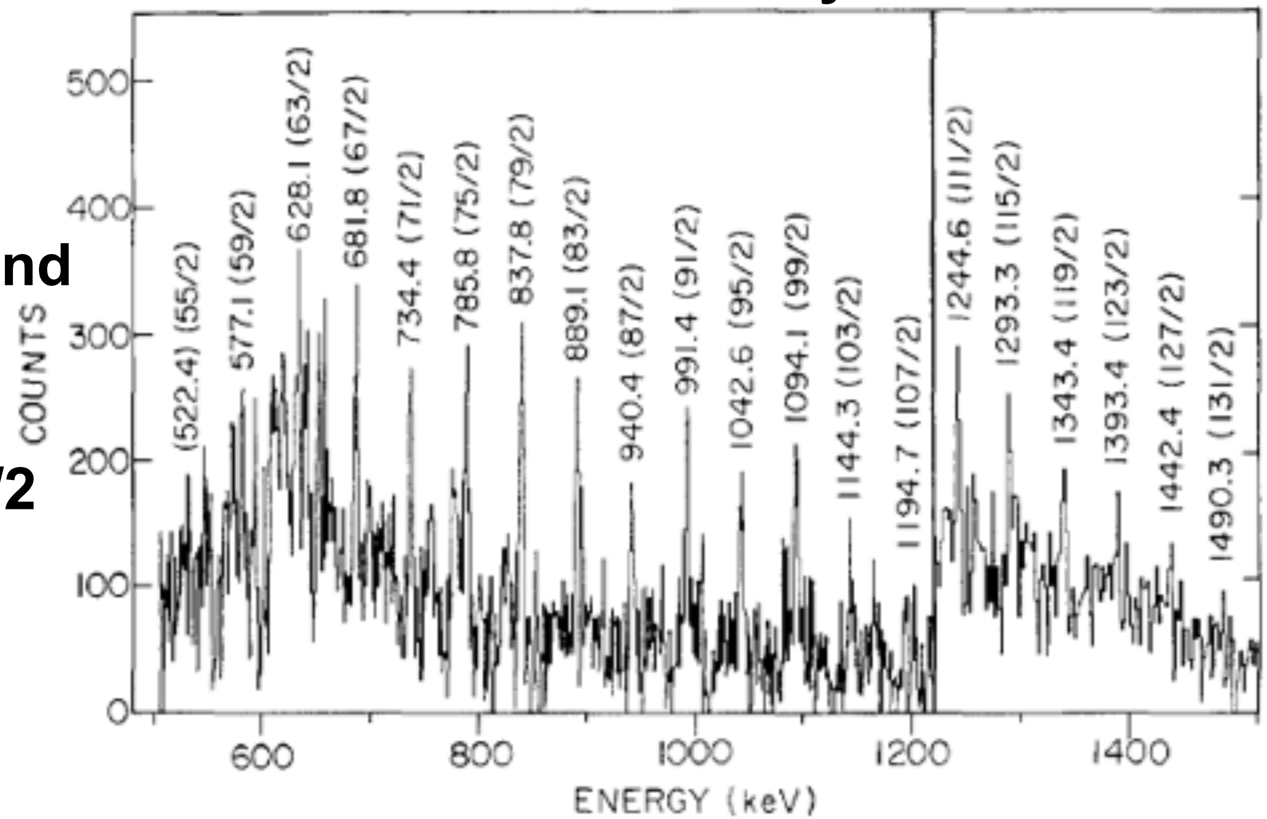
[d] *Purdue University, West Lafayette, IN 47907, USA*
[e] *Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada KOJ IJO*

Phys. Lett. **B201**, 223 (1988)

ATLAS

1988 - superdeformation in ^{151}Dy

- ANL-ND array
- First discrete line SD band seen at ATLAS
- Showed that the dynamic moment of inertia could be very different from that in ^{152}Dy and is sensitive to configuration
- Important for expanding on first SD band seen (^{152}Dy) and showing that this is not an isolated structure
- Highest spin is around 131/2
- Intensity around 1%



Now 5 SD bands seen

G.-E. RATHKE [a], R.V.F. JANSSENS [a], M.W. DRIGERT [b], I. AHMAD [a], K. BEARD [c], R.R. CHASMAN [a], U. GARG [c], M. HASS [a,1], T.L. KHOO [a], H.-J. KÖRNER [a,2], W.C. MA [a,3], S. PILOTTE [d], P. TARAS [d] and F.L.H. WOLFS [a]

[a] *Argonne National Laboratory, Argonne, IL 60439, USA*
[b] *Idaho National Engineering Laboratory, EG & G Idaho Inc., Idaho Falls, ID 83415, USA*
[c] *University of Notre Dame, Notre Dame, IN 46556, USA*
[d] *Université de Montréal, Montreal, Quebec, Canada H3C 3J7*

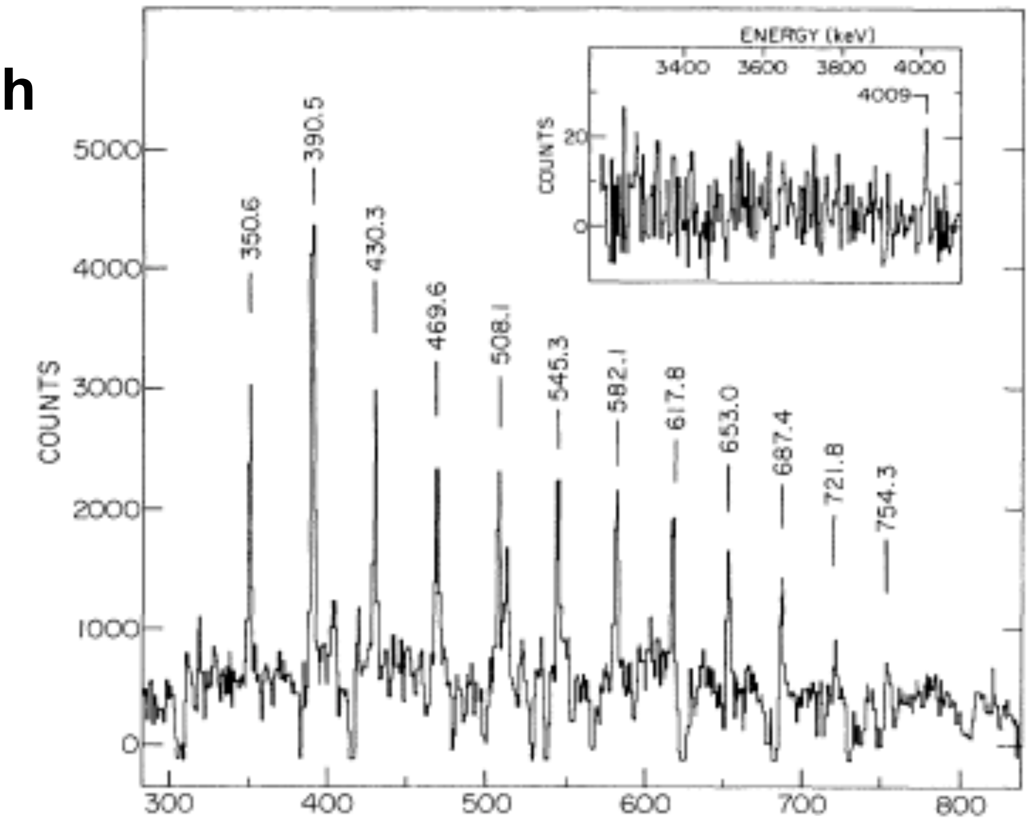
Phys. Lett. **B209**, 177 (1988)

ATLAS

1989 - a new region of superdeformation - ^{191}Hg

- **Discovery of a new SD region with the first SD band in ^{191}Hg - 12 transitions**
- **Axis ratio of 1.65:1 (β_2 ~ 0.5)**

Now 4 SD bands seen



E. F. Moore, R. V. F. Janssens, R. R. Chasman, I. Ahmad, T. L. Khoo, and F. L. H. Wolfs
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D. Ye, K. B. Beard, and U. Garg
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M. W. Drigert
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Ph. Benet and Z. W. Grabowski
Purdue University, West Lafayette, Indiana 47907

J. A. Cizewski

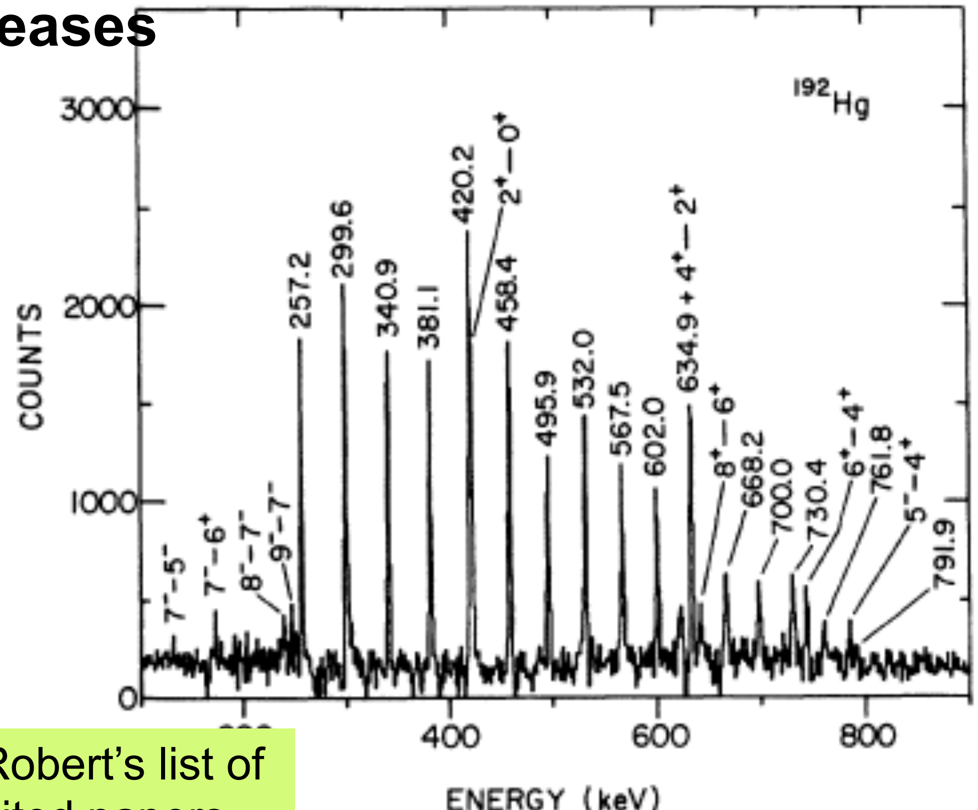
#5 on Robert's list of most cited papers

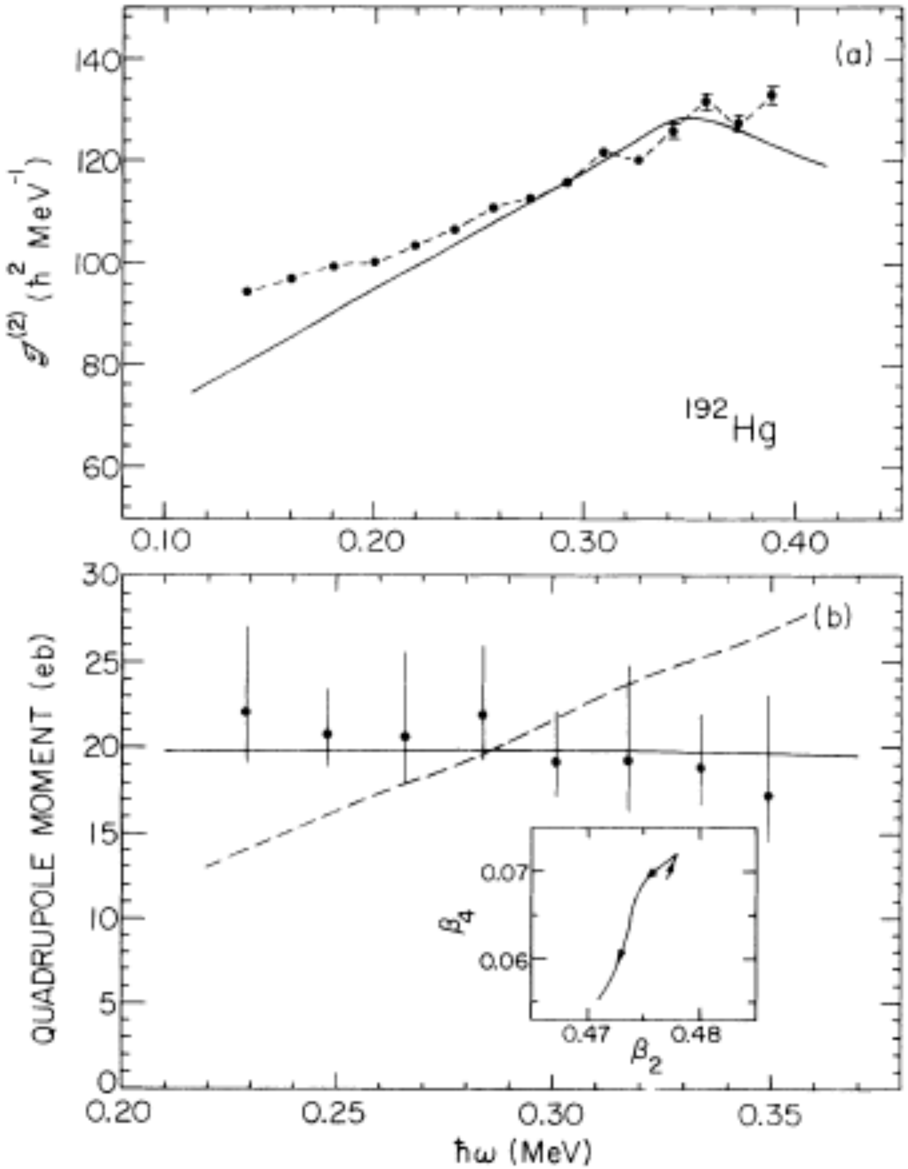
PRL **63**, 364 (1989)

Superdeformed band in ^{192}Hg

Now 3 SD bands seen

- **First DSAM measurement on a SD band - Moore et al., PRL 64, 3127 (1990)**
- **Q_t = 20 eb, constant over band - shape stays constant as moment of inertia increases**





#11 on Robert's list of most cited papers

D. Ye,[a] R. V. F. Janssens,[b] M. P. Carpenter,[b] E. F. Moore,[b] R. R. Chasman,[b] I. Ahmad,[b] K. B. Beard,[a] Ph. Benet,[c] M. W. Drigert,[d] P. B. Fernandez,[b] U. Garg,[a] T. L. Khoo,[b] S. L. Ridley,[b],* and F. L. H. Wolfs[b]

[a]*University of Notre Dame, Notre Dame, Indiana 46556*

[b]*Argonne National Laboratory, Argonne, Illinois 60439*

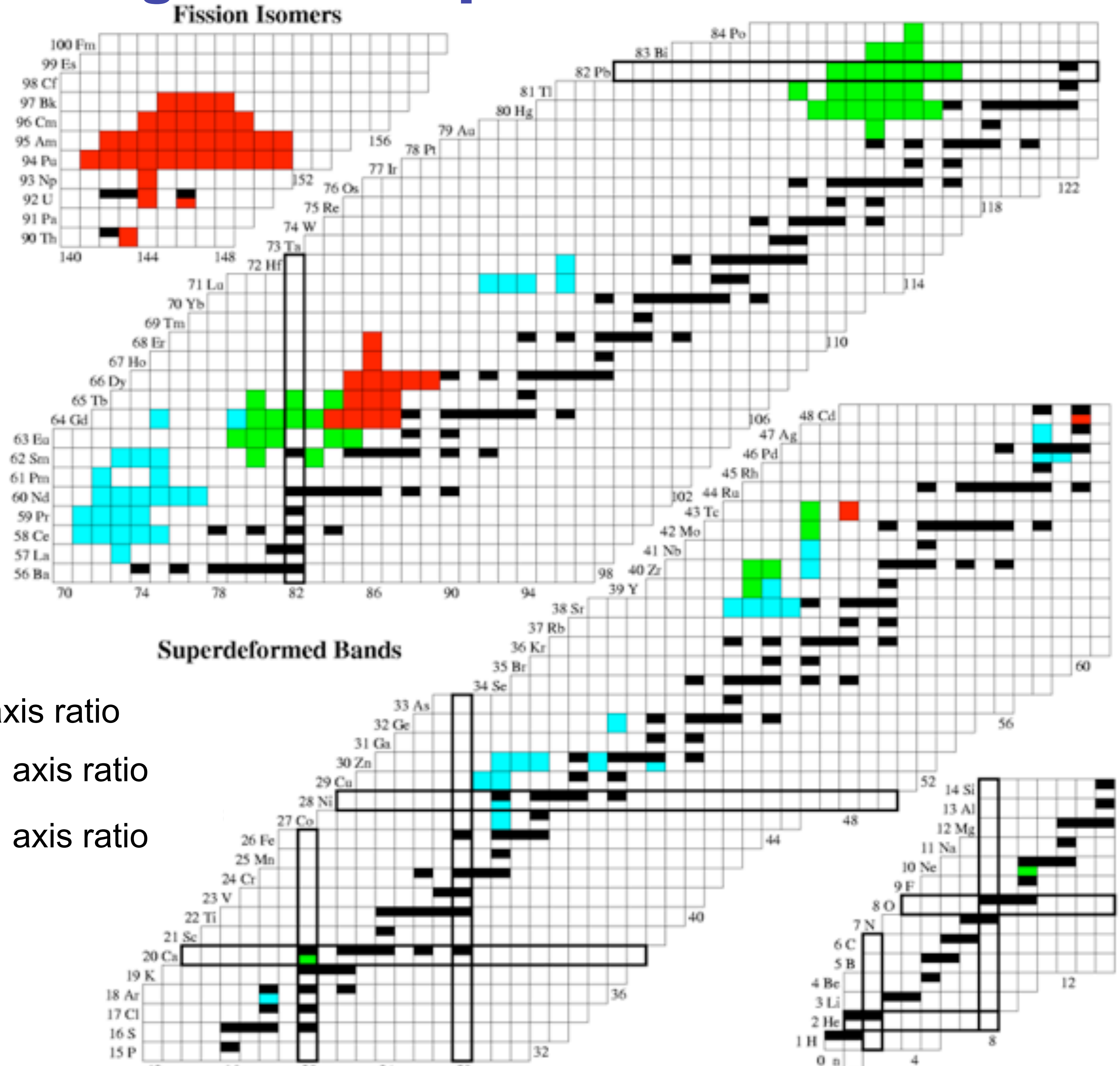
[c]*Purdue University, West Lafayette, Indiana 47907*

[d]*Idaho National Engineering Laboratory, EG&G Idaho Incorporated, Idaho Falls, Idaho 83415*

PR **C41**, R13 (1990)

ATLAS

Regions of superdeformation



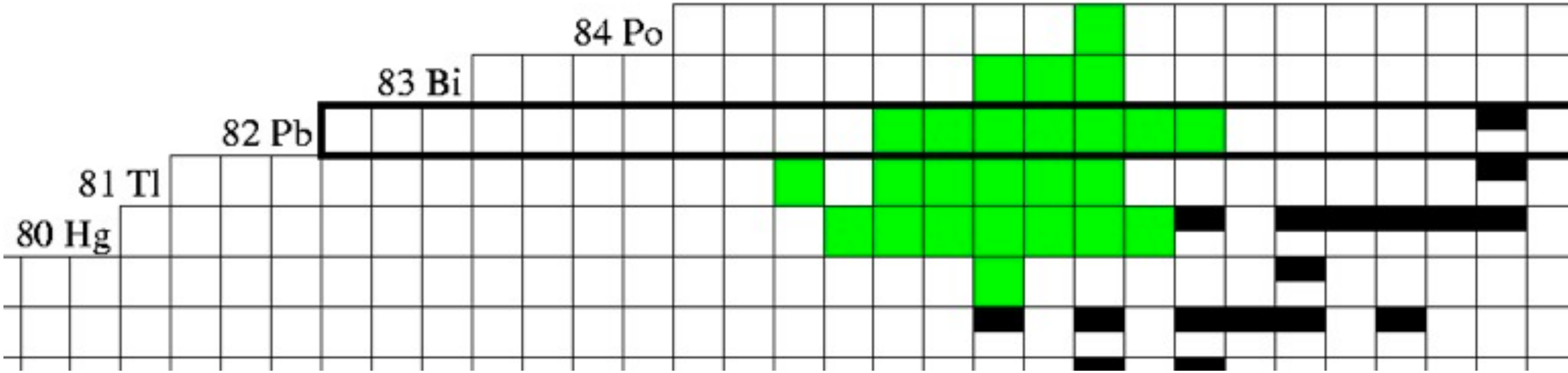
2:1 axis ratio

1.7:1 axis ratio

1.5:1 axis ratio

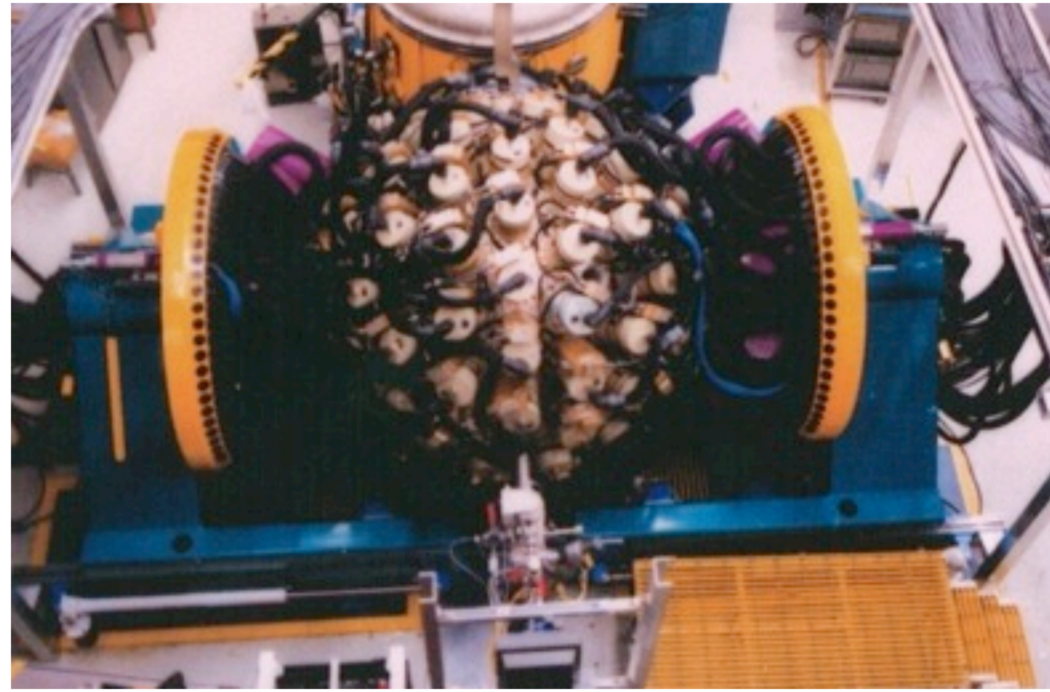
ATLAS

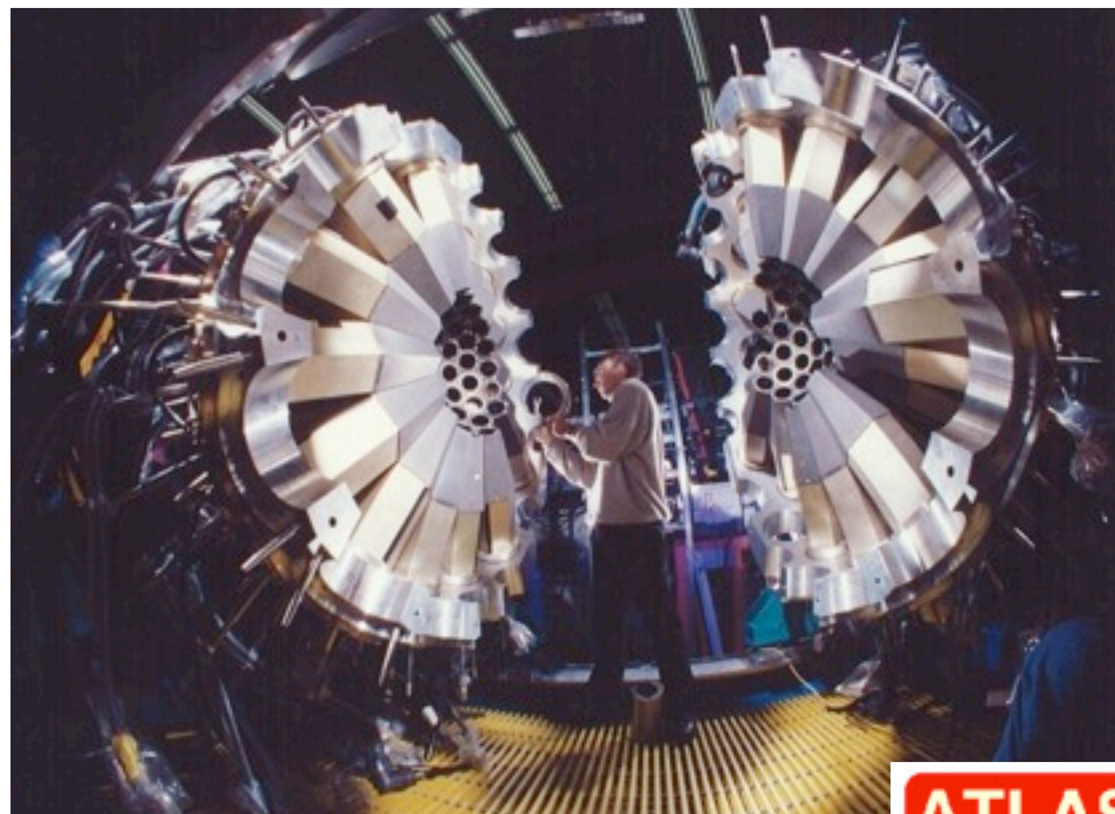
Wide region of superdeformation around ^{192}Hg



- **83 SD bands seen in this region**
- **All have an axis ratio of around 1.7:1, lower than in the ^{152}Dy region (2:1)**

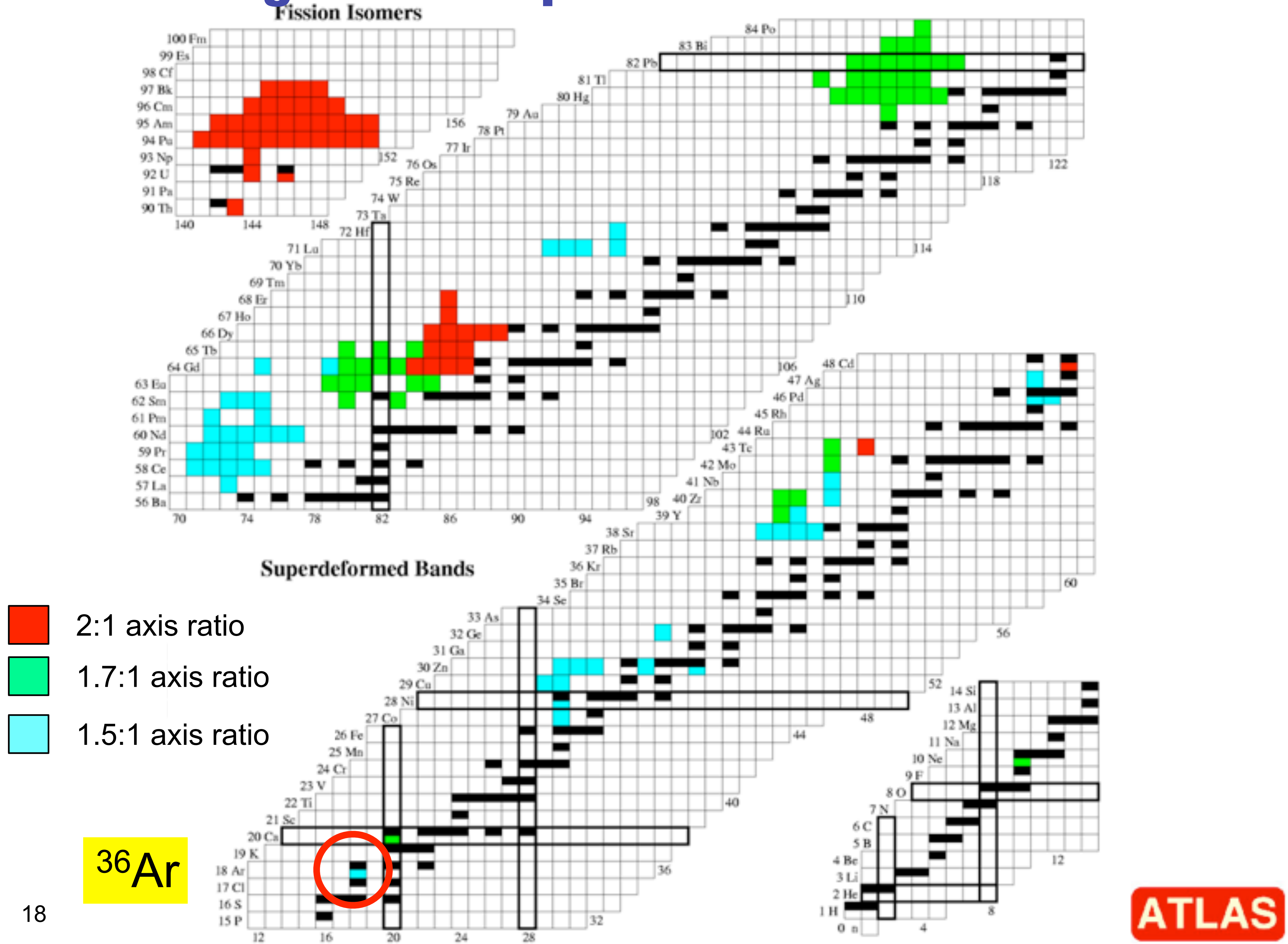
The age of Gammasphere





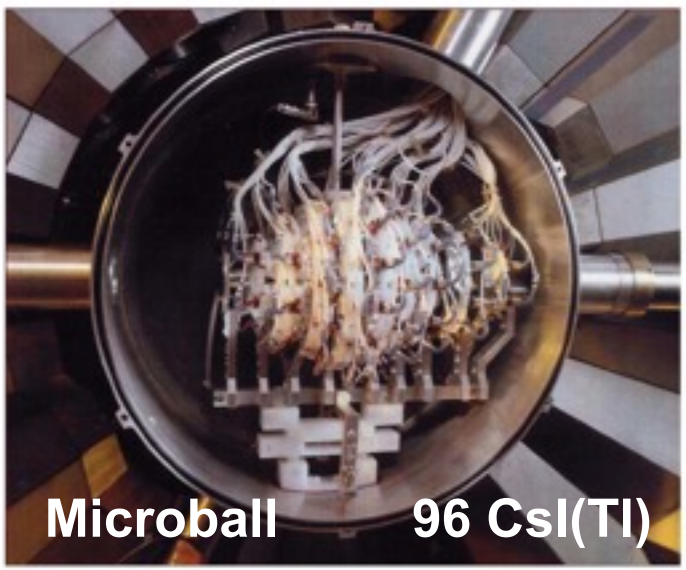
ATLAS

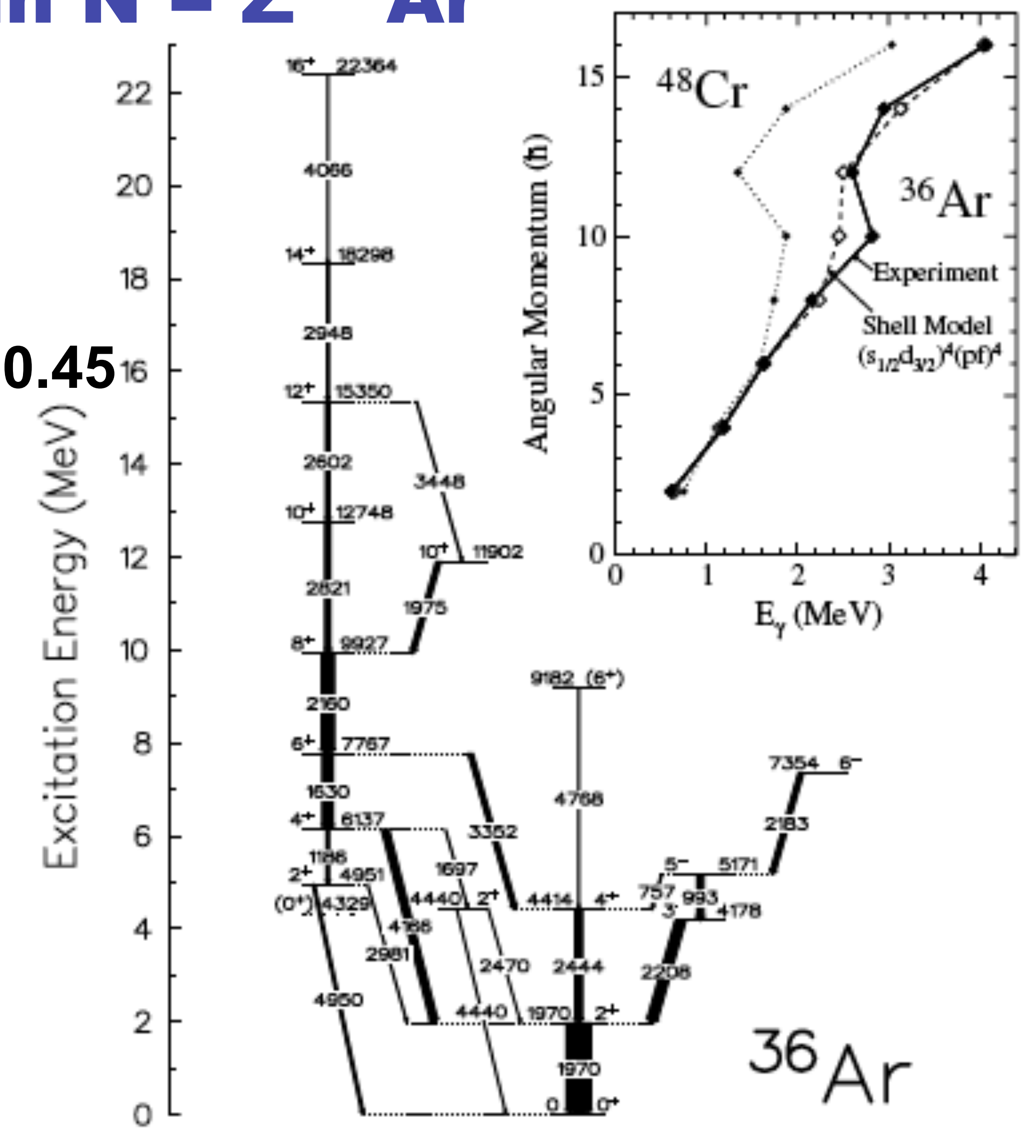
Regions of superdeformation



2000 - superdeformation in N = Z ^{36}Ar

- Lightest nucleus with SD band
- Linked to known low-spin states
- Up to high-spin termination at I = 16
- Four pf-shell orbitals occupied, $\beta_2 \sim 0.45$
- ^{24}Mg(^{20}Ne, 2a)^{36}Ar
- Gammasphere + Microball





C. E. Svensson,[1] A. O. Macchiavelli,[1] A. Juodagalvis,[2] A. Poves,[3] I. Ragnarsson,[2] S. Åberg,[2] D. E. Appelbe,[4] R. A. E. Austin,[4] C. Baktash,[5] G. C. Ball,[6] M. P. Carpenter,[7] E. Caurier,[8] R. M. Clark,[1] M. Cromaz,[1] M. A. Deleplanque,[1] R. M. Diamond,[1] P. Fallon,[1] M. Furlotti,[9] A. Galindo-Uribarri,[5] R. V. F. Janssens,[7] G. J. Lane,[1] I. Y. Lee,[1] M. Lipoglavsek,[5] F. Nowacki,[10] S. D. Paul,[5] D. C. Radford,[5] D. G. Sarantites,[9] D. Seweryniak,[7] F. S. Stephens,[1] V. Tomov,[9] K. Vetter,[1] D. Ward,[1] and C. H. Yu[5]

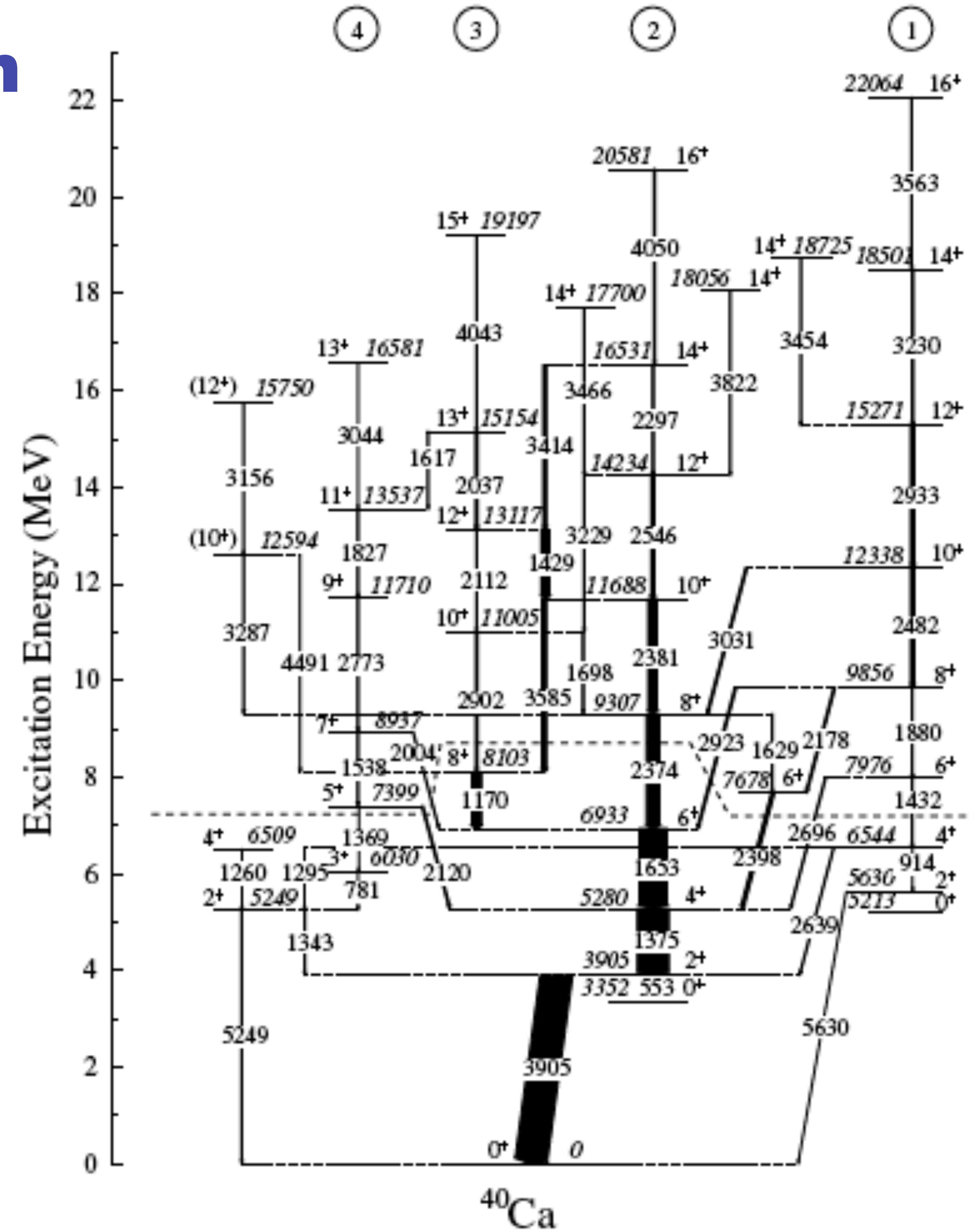
#14 on Robert's list of most cited papers

PRL **85**, 2693 (2000)

ATLAS

2001 - superdeformation in doubly magic ^{40}Ca

- $^{28}Si(^{20}Ne,2\alpha)$
- **Gammasphere + Microball**
- **Measured lifetimes and deduced Q_t = 1.8 eb**
- **Band 1: β_2 = 0.59**
- **Mainly 8p-8h excitation: $(\pi f_{7/2})^4\ (\nu f_{7/2})^4$**



#13 on Robert's list of most cited papers

PRL **87**, 222501 (2001)

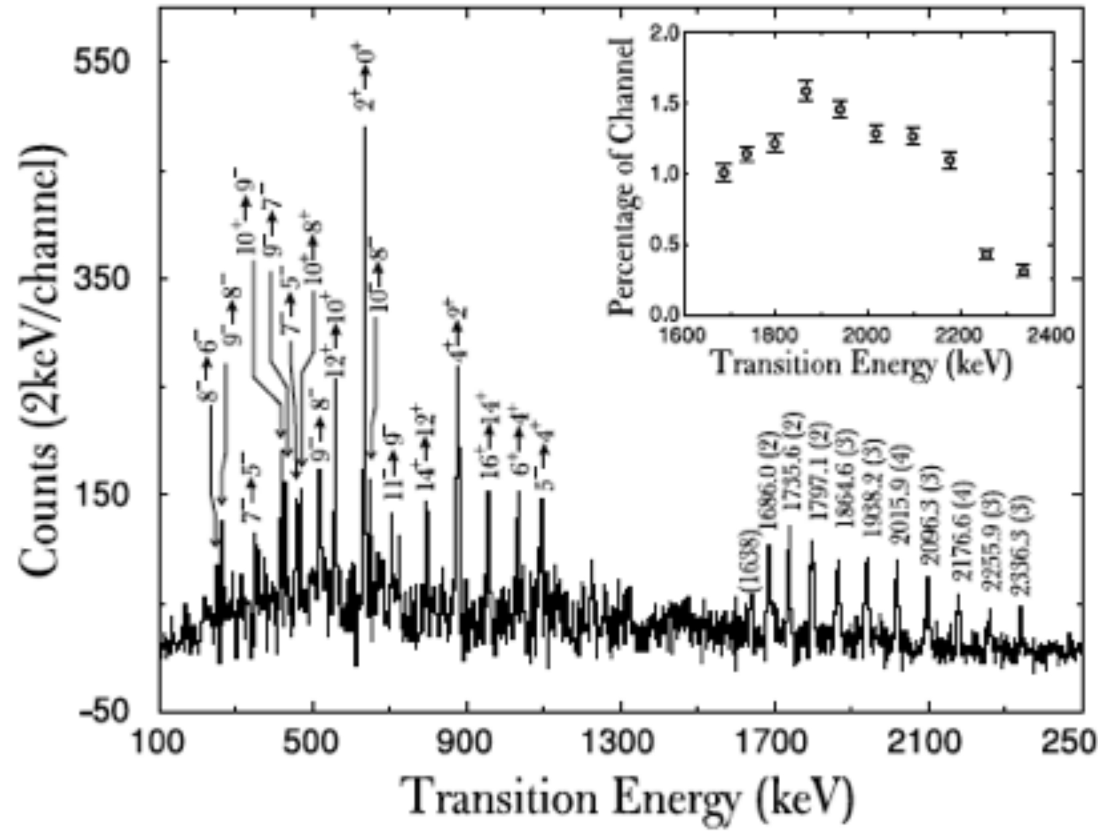
E. Ideguchi,[1] D. G. Sarantites,[1] W. Reviol,[1] A. V. Afanasjev,[2,3,4] M. Devlin,[1,*] C. Baktash,[5] R. V. F. Janssens,[2] D. Rudolph,[6] A. Axelsson,[7] M. P. Carpenter,[2] A. Galindo-Uribarri,[5] D. R. LaFosse,[8] T. Lauritsen,[2] F. Lerma,[1] C. J. Lister,[2] P. Reiter,[2] D. Seweryniak,[2] M. Weiszflog,[7] and J. N. Wilson,[1,†]

2001 - superdeformation in ^{108}Cd

- ^{64}Ni(^{48}Ca,4n)
- **Major-to-minor axis ratio larger than 1.8:1 - among most deformed structures identified in any nucleus**

TABLE I. The measured quadrupole moments and deduced major-to-minor axis ratios, x, for SD bands in different mass regions.

Nucleus	Q_0 (eb)	x
^{36}Ar	$1.18^{+0.09}_{-0.09}$	$1.55^{+0.04}_{-0.04}$
^{60}Zn	$2.75^{+0.45}_{-0.45}$	$1.54^{+0.10}_{-0.10}$
^{82}Sr	$3.54^{+0.15}_{-0.14}$	$1.47^{+0.02}_{-0.02}$
^{91}Tc	$8.1^{+1.9}_{-1.4}$	$1.85^{+0.21}_{-0.14}$
^{108}Cd	>9.5	>1.8
^{132}Ce	$7.4^{+0.3}_{-0.3}$	$1.45^{+0.02}_{-0.02}$
^{152}Dy	$17.5^{+0.4}_{-0.2}$	$1.85^{+0.02}_{-0.01}$
^{192}Hg	$17.7^{+0.8}_{-0.8}$	$1.61^{+0.03}_{-0.02}$
^{236}U	32^{+5}_{-5}	$1.84^{+0.14}_{-0.14}$



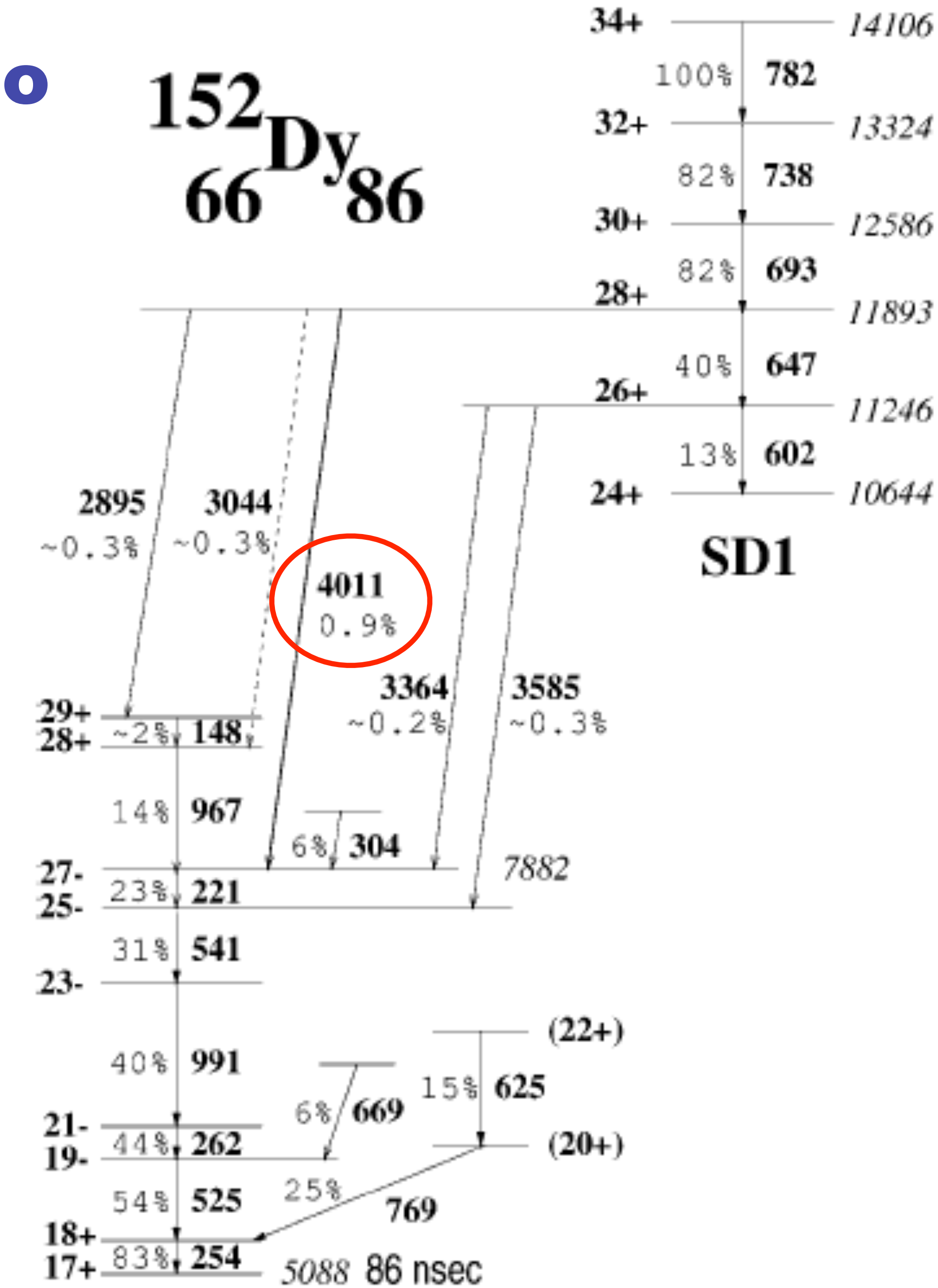
R. M. Clark,[1] P. Fallon,[1] A. Görgen,[1] M. Cromaz,[1] M. A. Deleplanque,[1] R. M. Diamond,[1] G. J. Lane,[1,*] I. Y. Lee,[1] A. O. Macchiavelli,[1] R. G. Ramos,[1] F. S. Stephens,[1] C. E. Svensson,[1,†] K. Vetter,[1] D. Ward,[1] M. P. Carpenter,[2] R. V. F. Janssens,[2] and R. Wadsworth[3]

PRL **87**, 202502 (2001)

ATLAS

2002 - linking an SD band to yrast states

- A real breakthrough in SD physics
- First experiment done at ATLAS with follow-up when GS was back at LBNL
- Excitation energy, spin, and parity of the yrast SD band in ^{152}Dy firmly established
- Measured a 4011-keV single-step transition from yrast SD level to the I = 27$^-$ yrast state



Now 6 SD bands seen

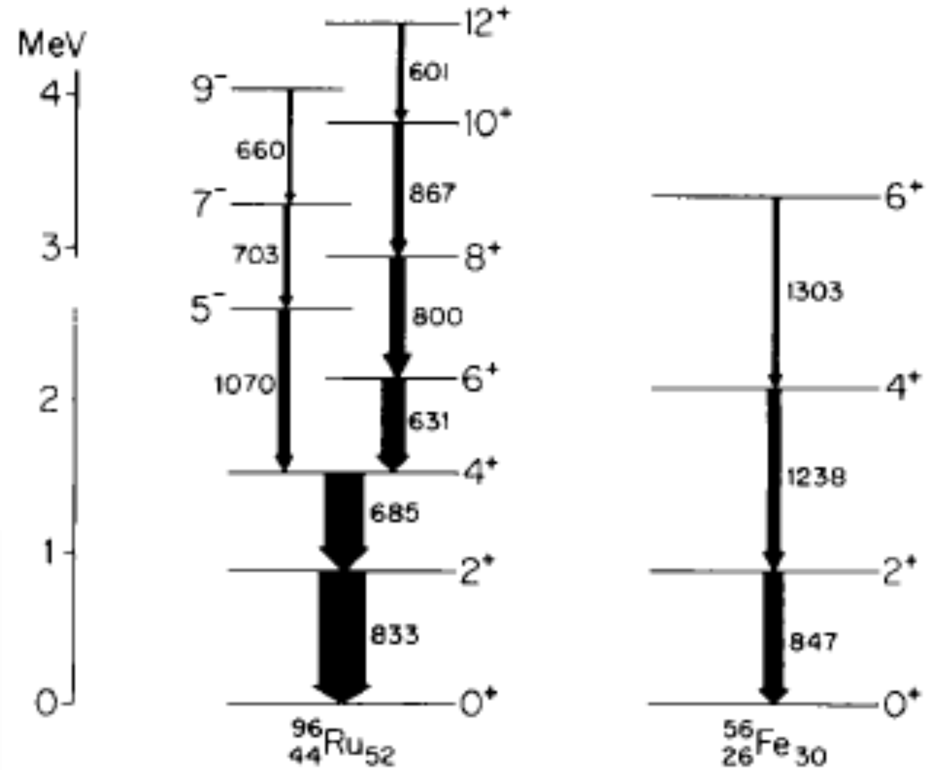
PRL **88**, 42501 (2002)

T. Lauritsen,[1] M.P. Carpenter,[1] T. Døssing,[2] P. Fallon,[3] B. Herskind,[2] R.V.F. Janssens,[1] D.G. Jenkins,[1] T.L. Khoo,[1] F.G. Kondev,[1] A. Lopez-Martens,[4] A.O. Macchiavelli,[3] D. Ward,[3] K.S. Abu Saleem,[1] I. Ahmad,[1] R. Clark,[3] M. Cromaz,[3] J.P. Greene,[1] F. Hannachi,[4] A.M. Heinz,[1] A. Korichi,[4] G. Lane,[3] C.J. Lister,[1] P. Reiter,[1,5] D. Seweryniak,[1] S. Siem,[1] R.C. Vondrasek,[1] and I. Wiedenhöver[1,6]

ATLAS

1990 - new technique - use of deep inelastic scattering for spectroscopy

- Inelastic and transfer reactions in ^{92}Mo + ^{60}Ni - a dozen products were identified and studied, target like and projectile like
- Showed the potential of deep inelastic reactions for spectroscopy of n-rich nuclei
- ANL-ND array
- This has become a very popular technique used by many



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Chemistry Department, Purdue University, West Lafayette, IN 47907, USA

R.V.F. Janssens, T.L. Khoo, W.C. Ma [3]
Physics Division, Argonne National Laboratory, Argonne, IL 60439, USA

and

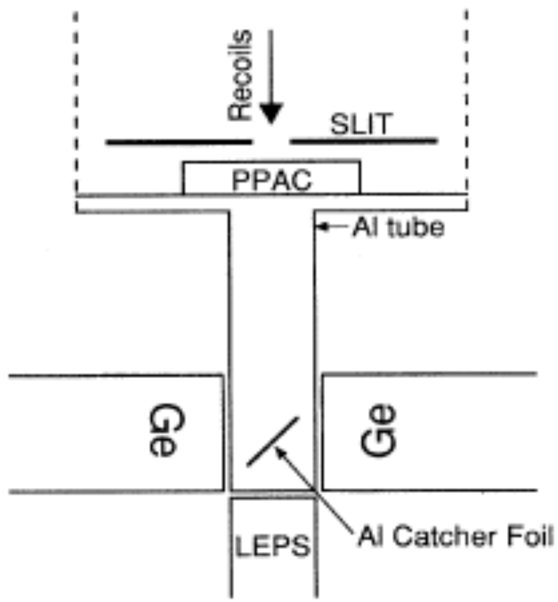
M.W. Drigert
Idaho National Engineering Laboratory, Idaho Falls, ID 83415, USA

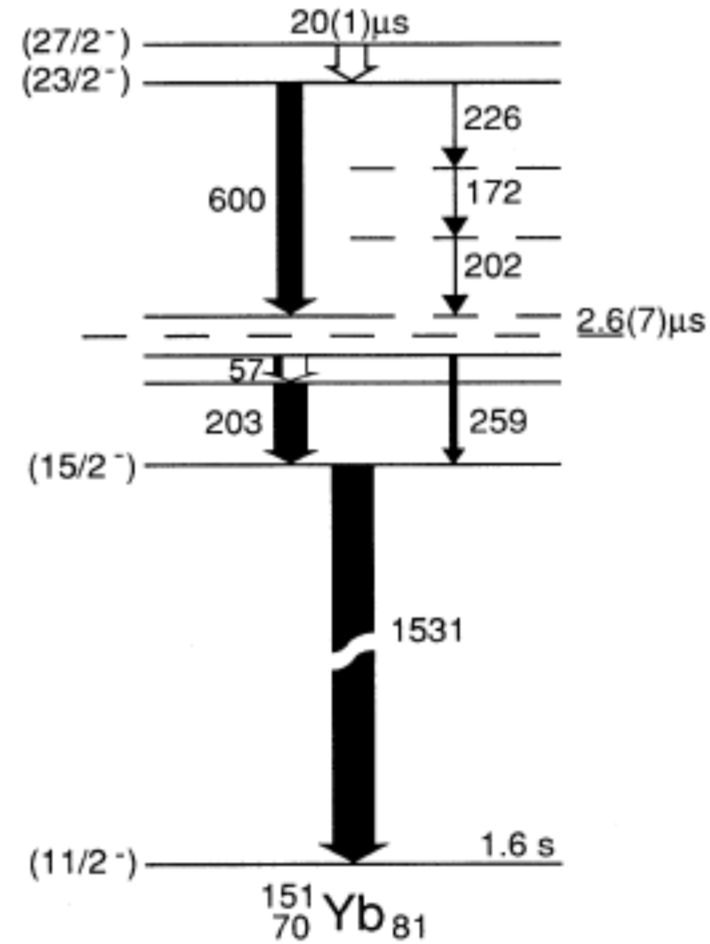
Phys. Lett. **251B**, 245 (1990)

ATLAS

1993 - new technique - Fragment Mass Analyzer

- First spectroscopy at FMA focal plane
- ^{58}Ni bombarding ^{96}Ru making ^{154}Hf*
- 3 Ge counters in back of FMA
- Study of yrast isomers in ^{151}Yb (N = 81)





D. Nisius, B. Fornal, I. G. Bearden, R. Broda,* R. H. Mayer, Z. W. Grabowski, and P. J. Daly
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C. N. Davids, I. Ahmad, B. B. Back, K. Bindra,† M. P. Carpenter, W. Chung,‡
D. Henderson, R. G. Henry, R. V. F. Janssens, T. L. Khoo, T. Lauritsen, Y. Liang, and F. Soramel§
Argonne National Laboratory, Argonne, Illinois 60439

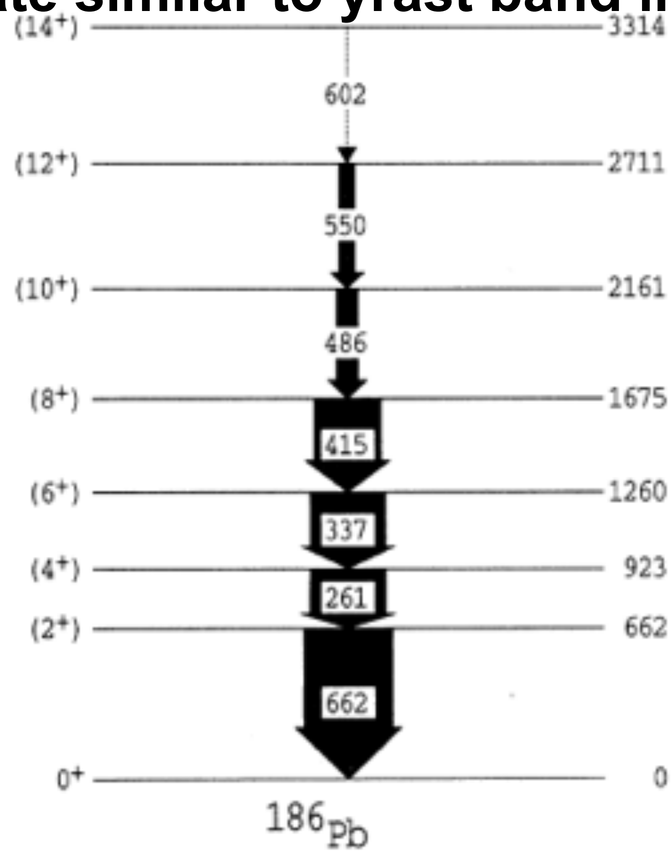
A. V. Ramayya
Vanderbilt University, Nashville, Tennessee 37235

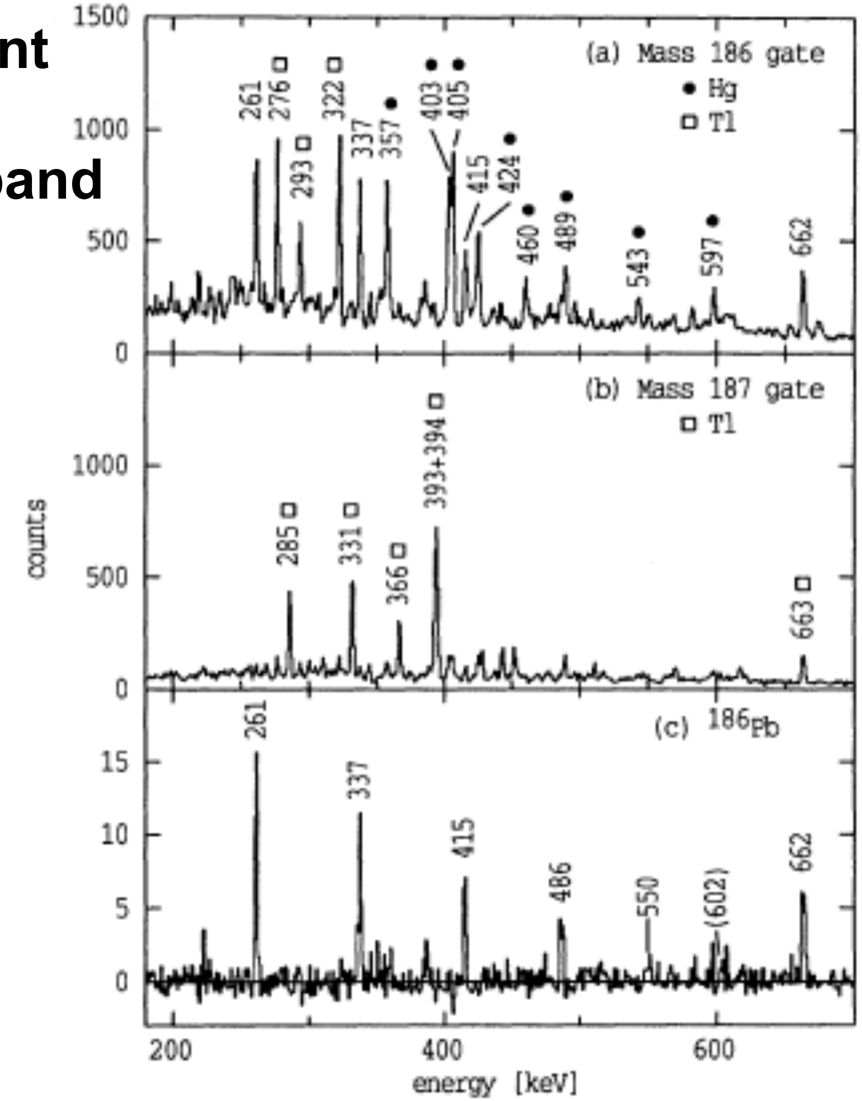
PR **C 47**, 1929 (1993)

ATLAS

1993 - ANL-ND array in front of FMA

- **First paper with ANL-ND γ-ray facility in front of FMA**
- **Provided mass identification of deformed band seen earlier - prolate deformation in Pb**
- **Band looks prolate similar to yrast band in isotone ^{184}Hg**





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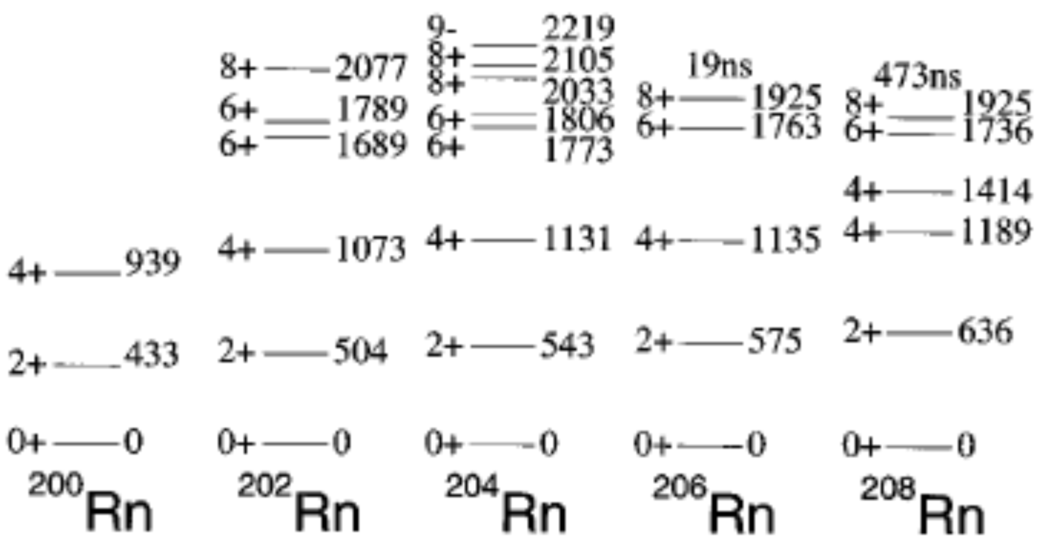
G. D. Dracoulis
Department of Nuclear Physics, RSPhysSE, Australian National University,

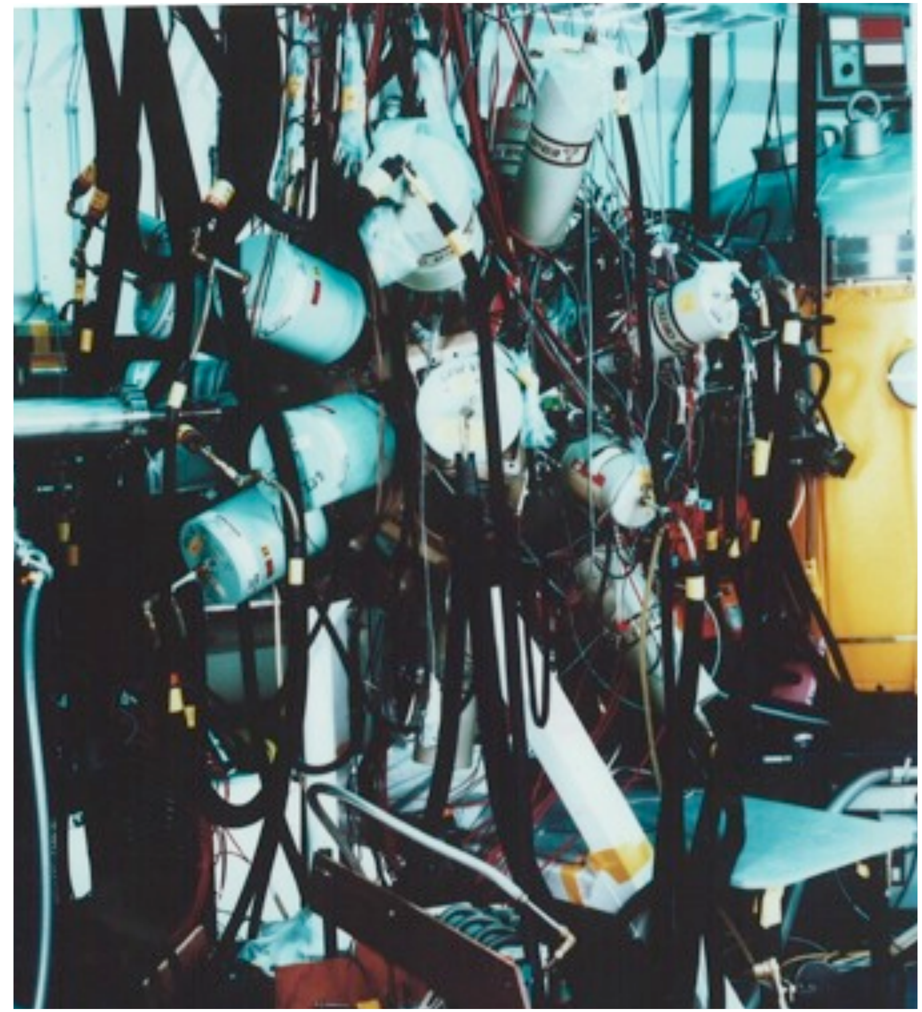
PR **C 48**, R2140 (1993)

ATLAS

1996 - γ array in front of FMA - AYEball

- **First experiment at FMA with the AYEBall array at the target position (ANL-Yale-European array) - 19 Compton-suppressed Ge**
- **Produce ^{200}Rn by ^{176}Hf(^{28}Si,4n) - 5 μb cross section**
- **^{200}Rn not yet deformed**





PR **C 54**, 2296 (1996)

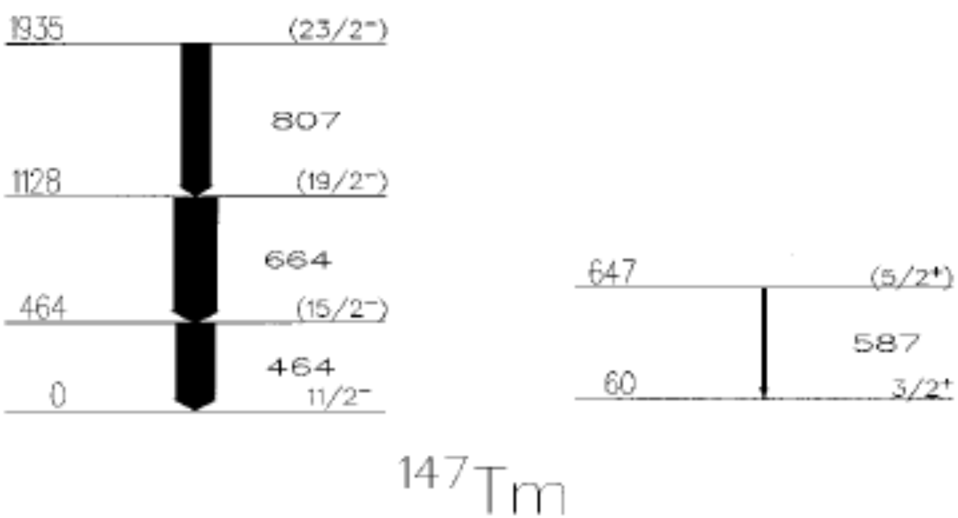
R. B. E. Taylor, S. J. Freeman, J. L. Durell, M. J. Leddy, and A. G. Smith
Schuster Laboratory, University of Manchester, Manchester M13 9PL, United Kingdom

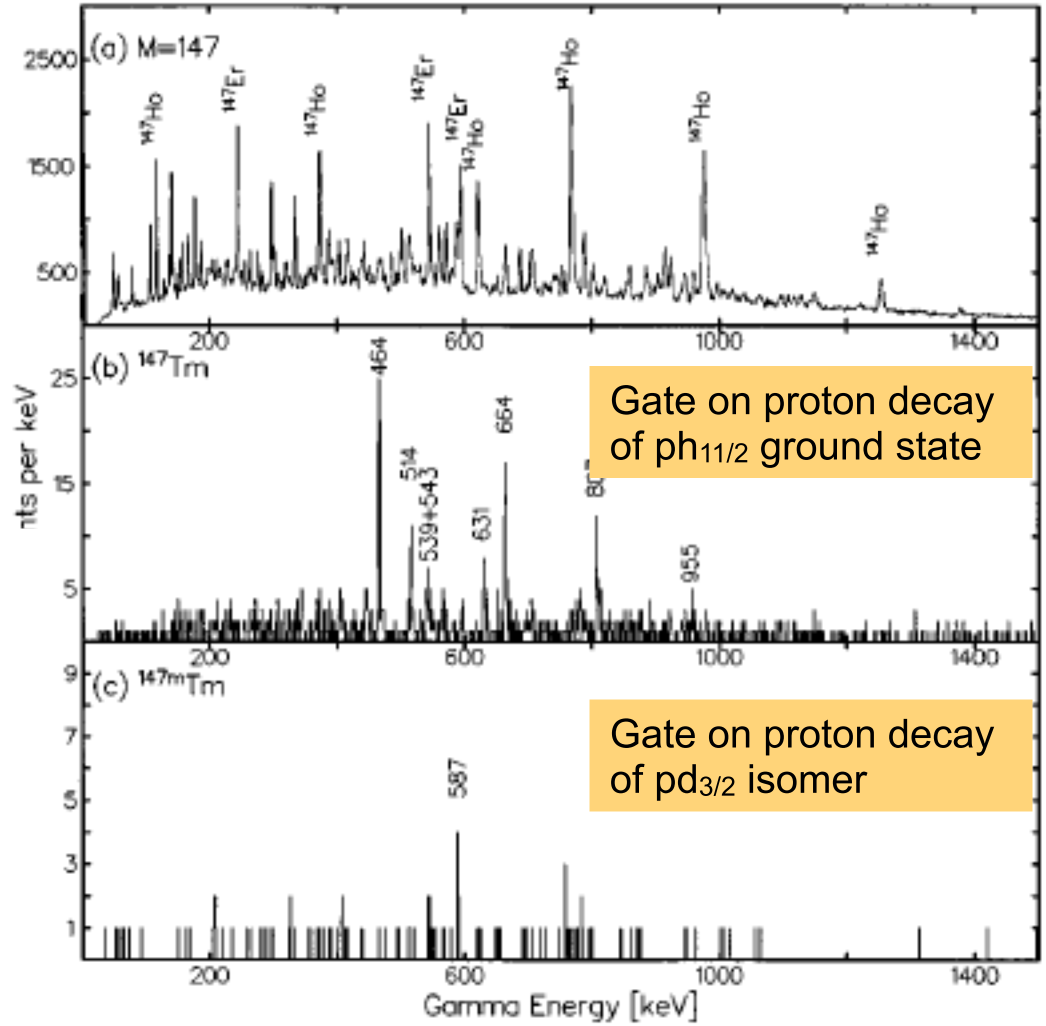
D. J. Blumenthal,* M. P. Carpenter, C. N. Davids, C. J. Lister, R. V. F. Janssens, and D. Seweryniak
Argonne National Laboratory, Argonne, Illinois 60439

ATLAS

1997 - new technique - recoil-decay tagging for γ-ray spectroscopy

- First look at structure of a proton emitter with γ rays - AYEball
- $^{92}Mo(^{58}Ni,p2n)^{147}Tm$
- 16 μb cross section of populating ground state, 2 μb for isomer





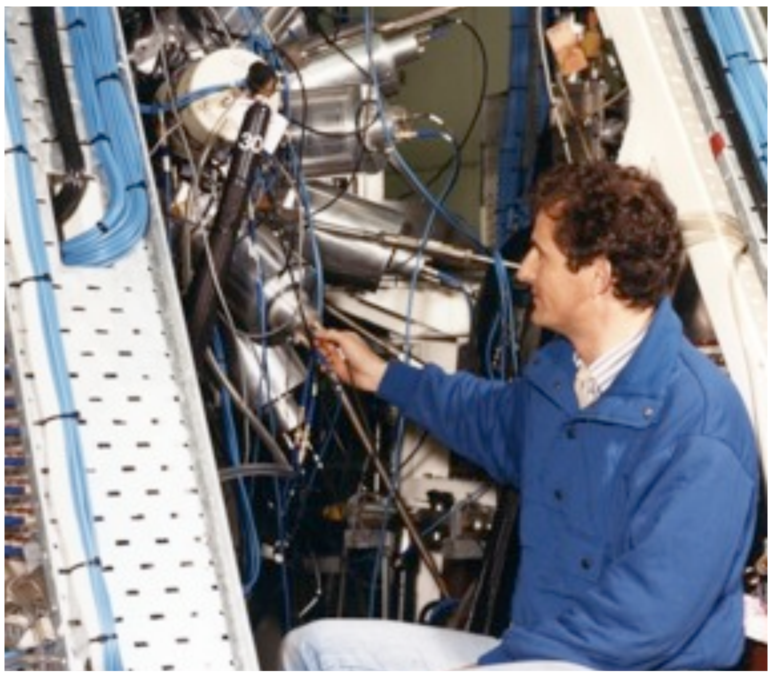
PR **C 55**, R2137 (1997)

D. Seweryniak,[1,2] C. N. Davids,[1] W. B. Walters,[2] P. J. Woods,[3] I. Ahmad,[1] H. Amro,[1] D. J. Blumenthal,[1] L. T. Brown,[1] M. P. Carpenter,[1] T. Davinson,[3] S. M. Fischer,[1] D. J. Henderson,[1] R. V. F. Janssens,[1] T. L. Khoo,[1] I. Hibbert,[4] R. J. Irvine,[3] C. J. Lister,[1] J. A. Mackenzie,[3] D. Nisius,[1] C. Parry,[4] and R. Wadsworth[4]

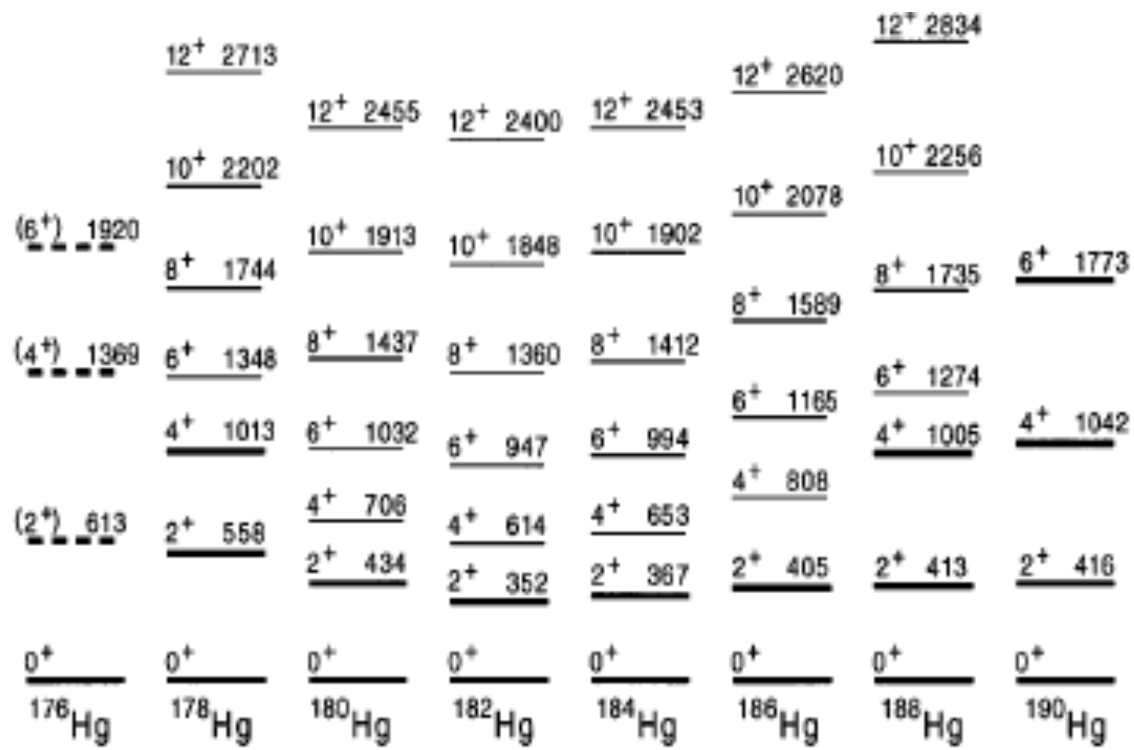
ATLAS

1997 - RDT experiment for light Hg nuclei

- **FMA + AYEball**
- **^{103}Rh(^{78}Kr,pxn) to ^{176,178}Hg**
- **Shape coexistence in the lightest Hg nuclei**
- **Find that prolate minimum is never yrast and that it moves up in energy beyond mid shell**



PRL **78,** 3650 (1997)

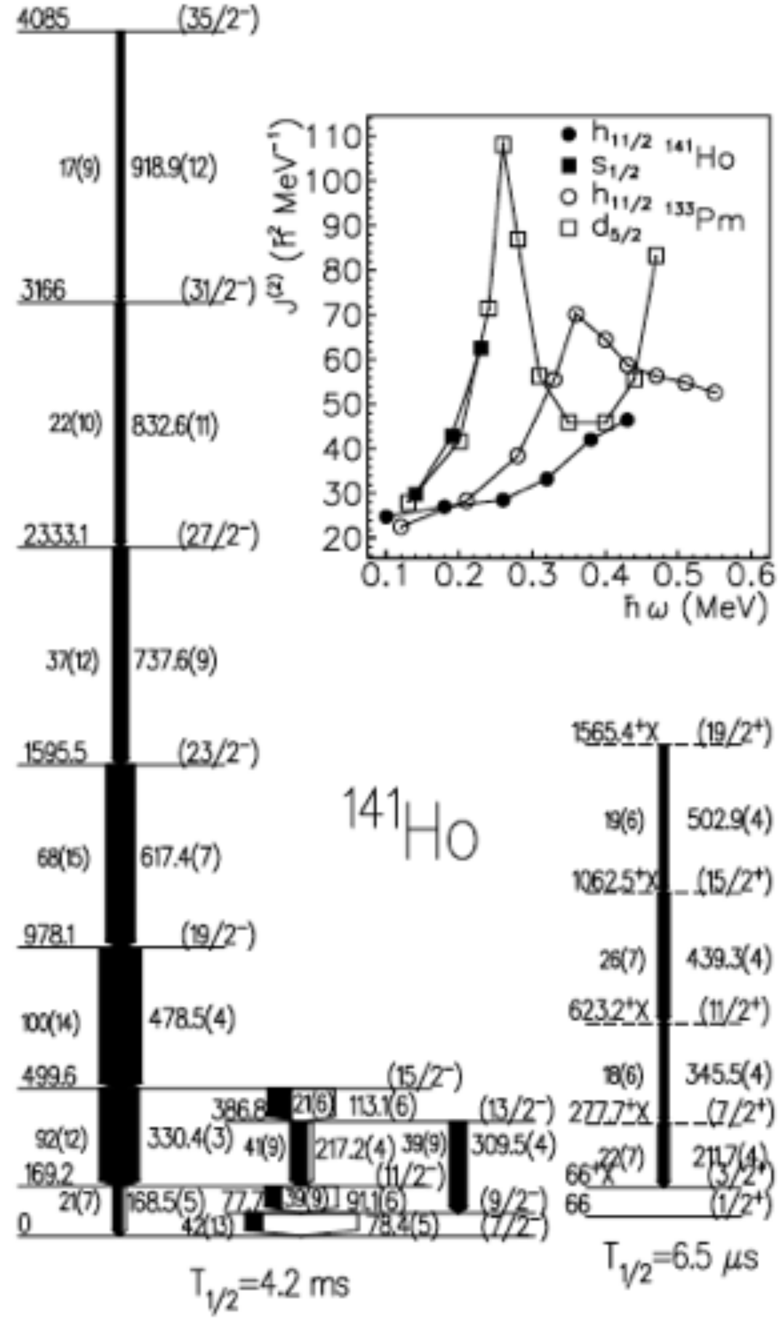


M. P. Carpenter,[1] R. V. F. Janssens,[1] H. Amro,[1,2] D. J. Blumenthal,[1] L. T. Brown,[1,3] D. Seweryniak,[1] P. J. Woods,[4] D. Ackermann,[1] I. Ahmad,[1] C. Davids,[1] S. M. Fischer,[1] G. Hackman,[1] J. H. Hamilton,[3] T. L. Khoo,[1] T. Lauritsen,[1] C. J. Lister,[1] D. Nisius,[1] A. V. Ramayya,[3] W. Reviol,[5] J. Schwartz,[1,6] J. Simpson,[7] and J. Wauter

ATLAS

2001 - rotational bands in proton emitter ^{141}Ho

- **FMA + Gammasphere**
- **^{92}Mo(^{54}Fe,p4n)^{141}Ho**
- **Bands assigned on top of the two p-emitting states**
- **Confirmation of deformed proton emitters via γ-ray spectroscopy in ^{141}Ho**
- **Conclude β_2 = 0.25 for ground state**

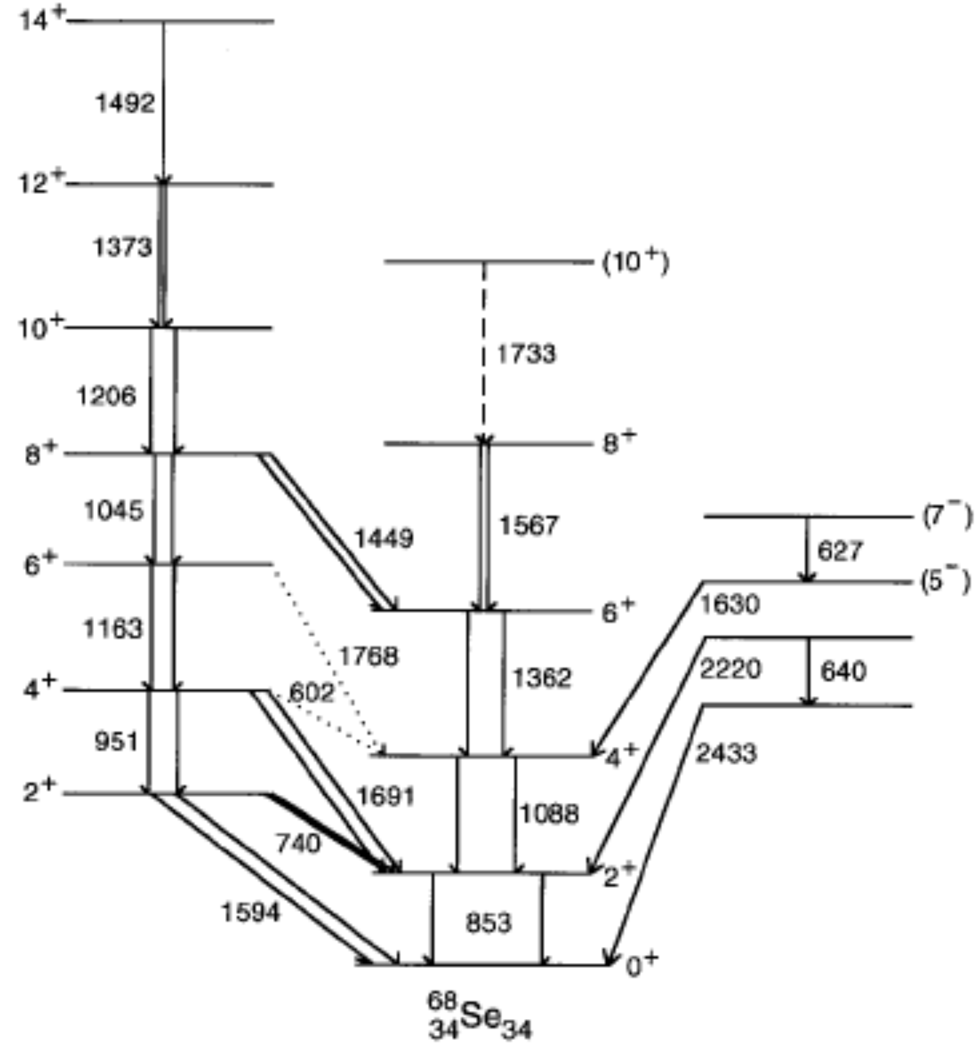


PRL **86,** 1458 (2001)

D. Seweryniak,[1,2] P.J. Woods,[3] J.J. Ressler,[2] C.N. Davids,[1] A. Heinz,[1] A.A. Sonzogni,[1] J. Uusitalo,[1] W.B. Walters,[2] J.A. Caggiano,[1] M.P. Carpenter,[1] J.A. Cizewski,[4] T. Davinson,[3] K.Y. Ding,[4] N. Fotiades,[4] U. Garg,[5] R.V.F. Janssens,[1] T.L. Khoo,[1] F.G. Kondev,[1] T. Lauritsen,[1] C.J. Lister,[1] P. Reiter,[1] J. Shergur,[2] and I. Wiedenhöver[1]

2000 - study of N = Z nuclei - shape co-existence

- $^{12}C(^{58}Ni,2n)^{68}Se$
- FMA + Gammasphere
- Two rotational bands seen
  - Ground band consistent with oblate collective rotation
  - Excited band consistent with prolate rotation
- Supports long-standing prediction that ground state with substantial oblate deformation ($\beta_2 \sim -0.3$) should exist in this region



S. M. Fischer

Department of Physics, DePaul University, Chicago, Illinois 60614

D. P. Balamuth and P. A. Hausladen*

Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, Pennsylvania 19104

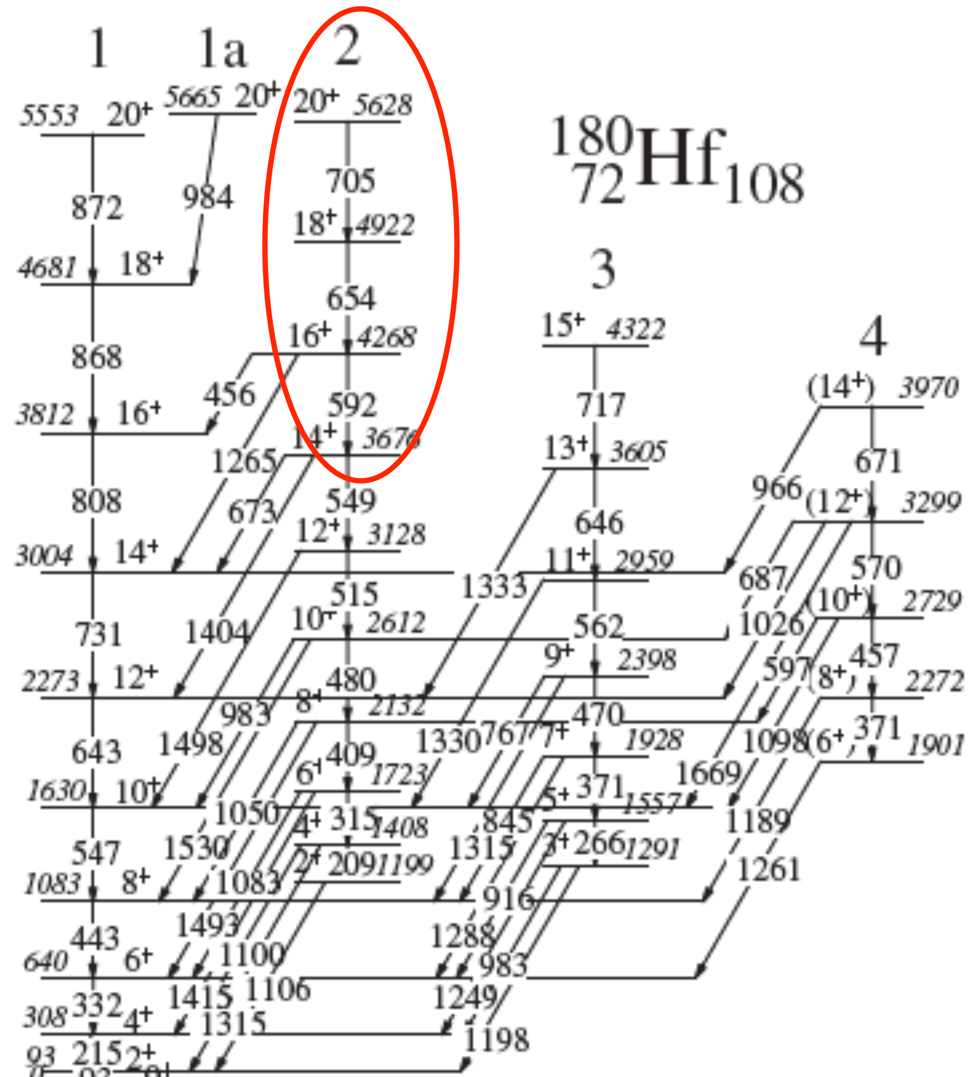
C. J. Lister, M. P. Carpenter, D. Seweryniak, and J. Schwartz

PRL **84,** 4064 (2000)

ATLAS

2008 - collective oblate rotation in ^{180}Hf

- 1300 MeV ^{180}Hf beam on a ^{232}Th target - 25% above Coulomb barrier
- Use CHICO + Gammasphere
- Collective oblate rotation - a long sought-after collective mode



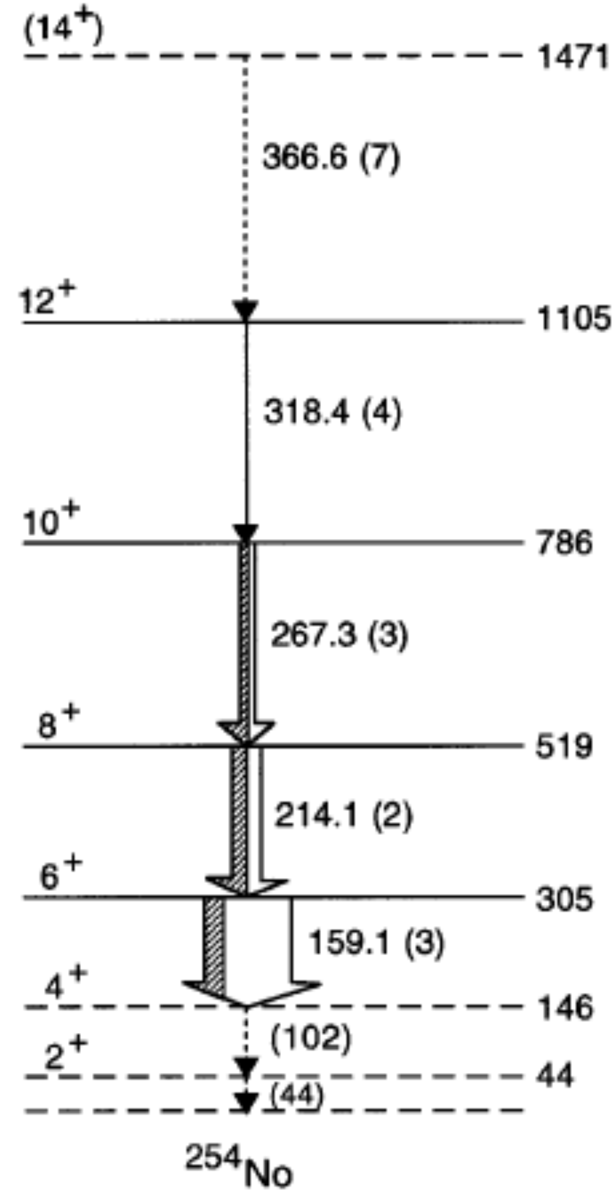
PRL **101,** 182503 (2008)

U. S. Tandel,[1] S. K. Tandel,[1] P. Chowdhury,[1] D. Cline,[2] C. Y. Wu,[2,*] M. P. Carpenter,[3] R. V. F. Janssens,[3] T. L. Khoo,[3] T. Lauritsen,[3] C. J. Lister,[3] D. Seweryniak,[3] and S. Zhu[3]

ATLAS

1999 - actinides - ground state band of Z = 102 ^{254}No

- First spectacular result of Gammasphere + FMA
- Was the start of spectroscopy of actinides worldwide
- ^{208}Pb(^{48}Ca,2n) - 3μb cross section
- Deduced quadrupole deformation $\beta_2 \sim 0.27$
- Survival of ^{254}No to spin 14 means that its fission barrier persists at least up to that spin



#4 on Robert's list of most cited papers

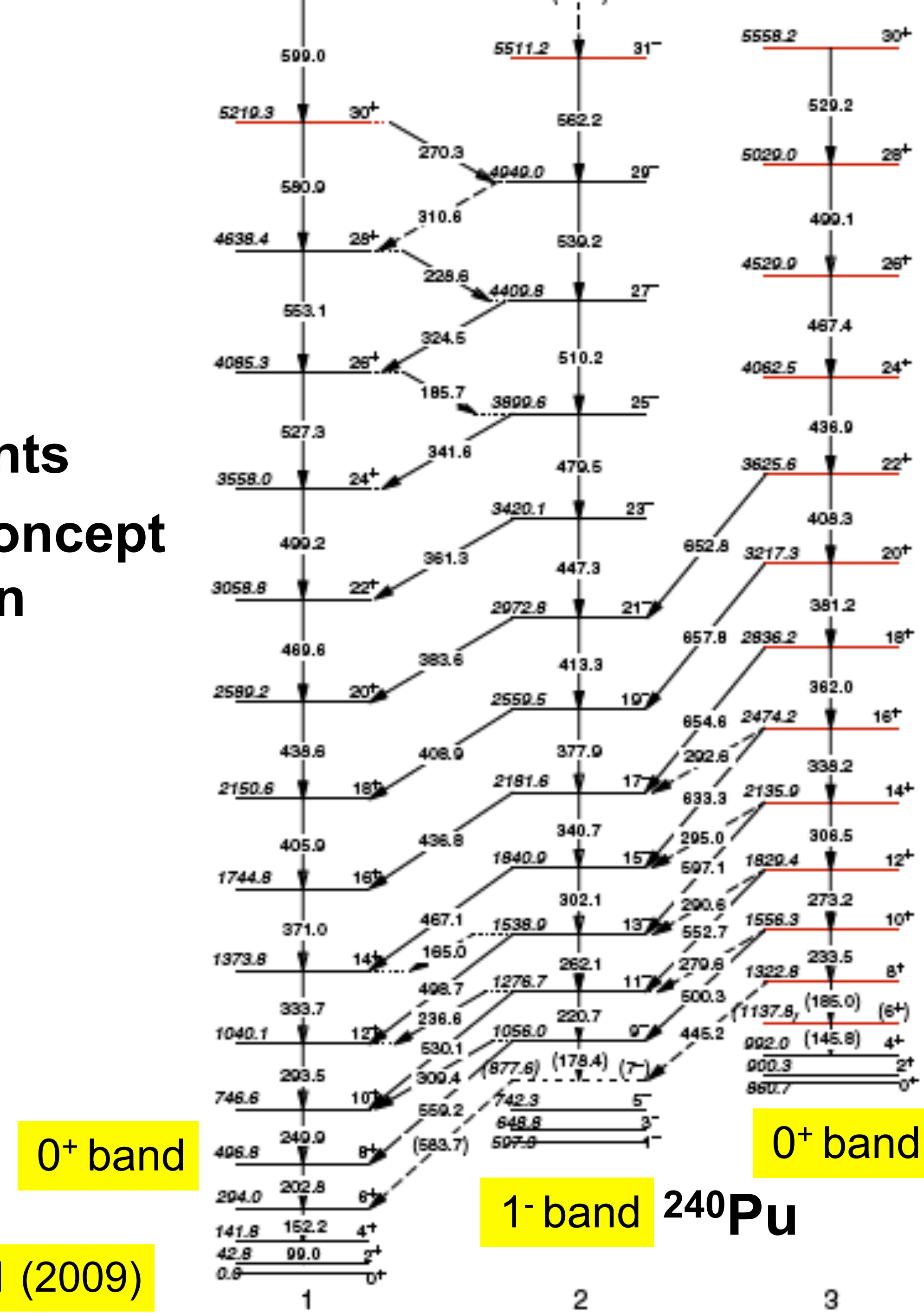
PRL **82,** 509 (1999)

P. Reiter,[1] T.L. Khoo,[1] C.J. Lister,[1] D. Seweryniak,[1] I. Ahmad,[1] M. Alcorta,[1] M.P. Carpenter,[1] J.A. Cizewski,[1,3] C.N. Davids,[1] G. Gervais,[1] J.P. Greene,[1] W.F. Henning,[1] R.V.F. Janssens,[1] T. Lauritsen,[1] S. Siem,[1,8] A.A. Sonzogni,[1] D. Sullivan,[1] J. Uusitalo,[1] I. Wiedenhöver,[1] N. Amzal,[2] P.A. Butler,[2] A.J. Chewter,[2] K.Y. Ding,[3] N. Fotiades,[3] J.D. Fox,[4] P.T. Greenlees,[2] R.-D. Herzberg,[2] G.D. Jones,[2] W. Korten,[5] M. Leino,[6] and K. Vetter[7]

1999 and 2009: unsafe Coulexc of ^{240}Pu

- 1300 MeV ^{208}Pb beam on ^{240}Pu
- Gammasphere
- 1999 - 10^8 events; 2009 - 3 x 10^9 events
- Octupole effects in the actinides - concept of an octupole phonon condensation

PRL **102,** 122501 (2009)

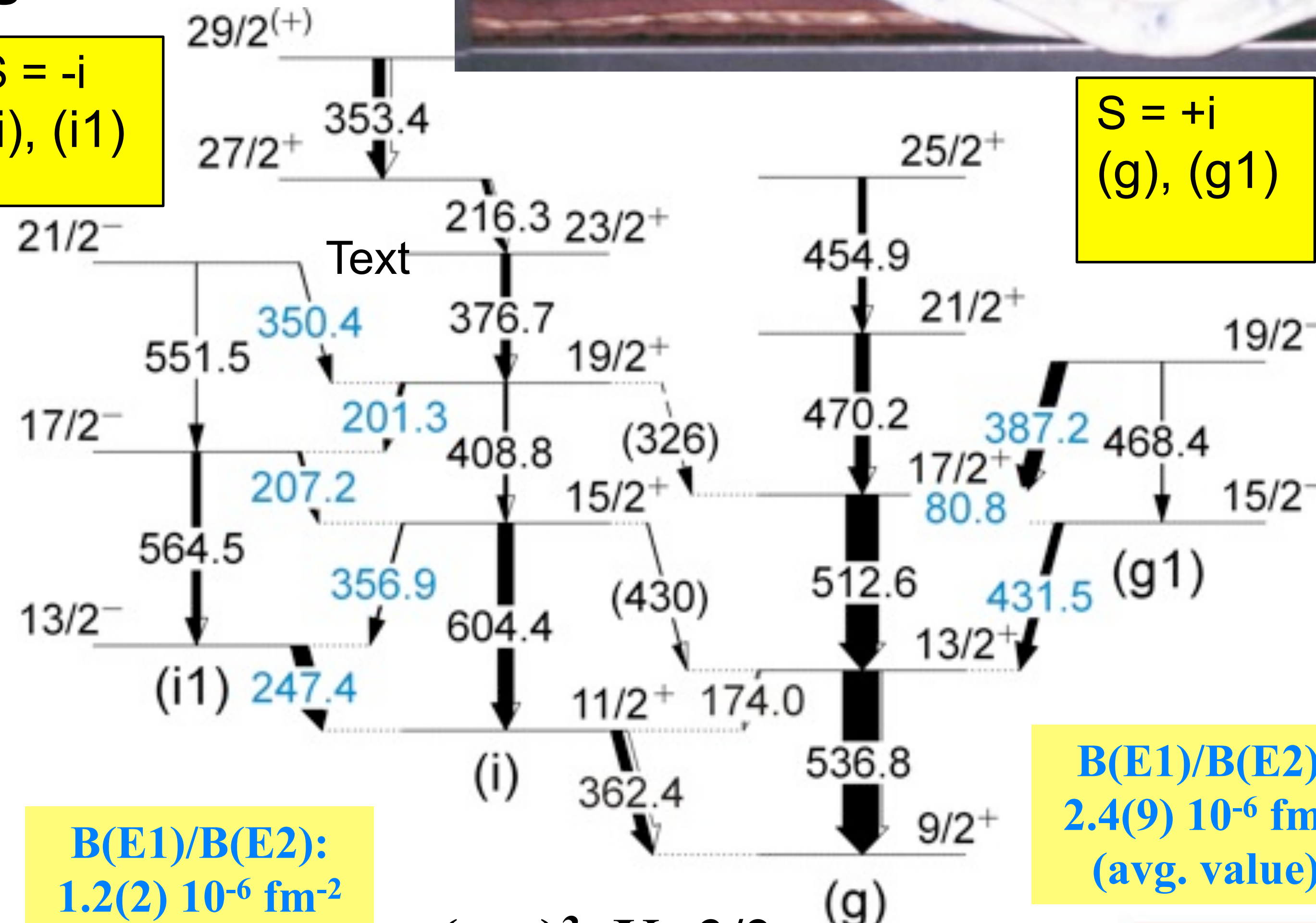


X. Wang,[1,2,*] R. V. F. Janssens,[1] M. P. Carpenter,[1] S. Zhu,[1] I. Wiedenhöver,[3] U. Garg,[2] S. Frauendorf,[2] T. Nakatsukasa,[4] I. Ahmad,[1] A. Bernstein,[3] E. Diffenderfer,[3] S. J. Freeman,[1,5] J. P. Greene,[1] T. L. Khoo,[1] F. G. Kondev,[6] A. L T. Lauritsen,[1] C. J. Lister,[1] B. Meredith,[7] D. Seweryniak,[1] C. Teal,[3] and P. Wilson[3]

2008 - new technique - Hercules - ^{219}Th

- ^{198}Pt(^{26}Mg,5n)^{219}Th
- **Gammasphere + Hercules - needed to pick out weak fusion channel - first excited states seen**
- **Parity doublets assigned at N = 129**

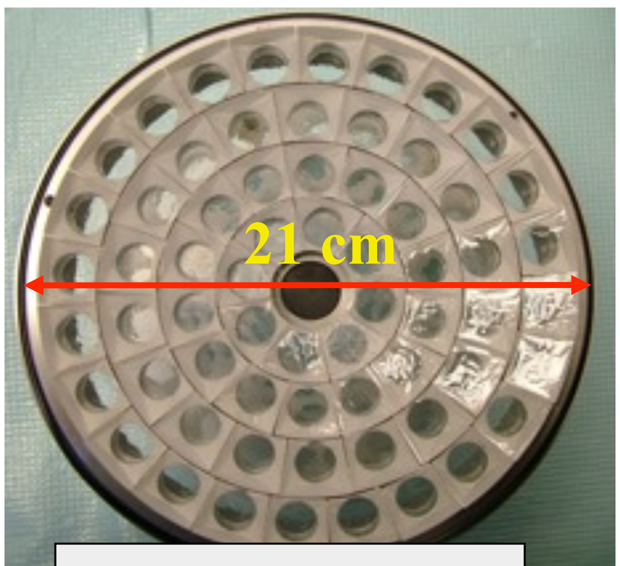
Reviol et al., PR **C80**, 11304(R) (2009)



B(E1)/B(E2):
1.2(2) 10^{-6} fm^{-2}
(avg. value)

$(g_{9/2})^3$, K=3/2

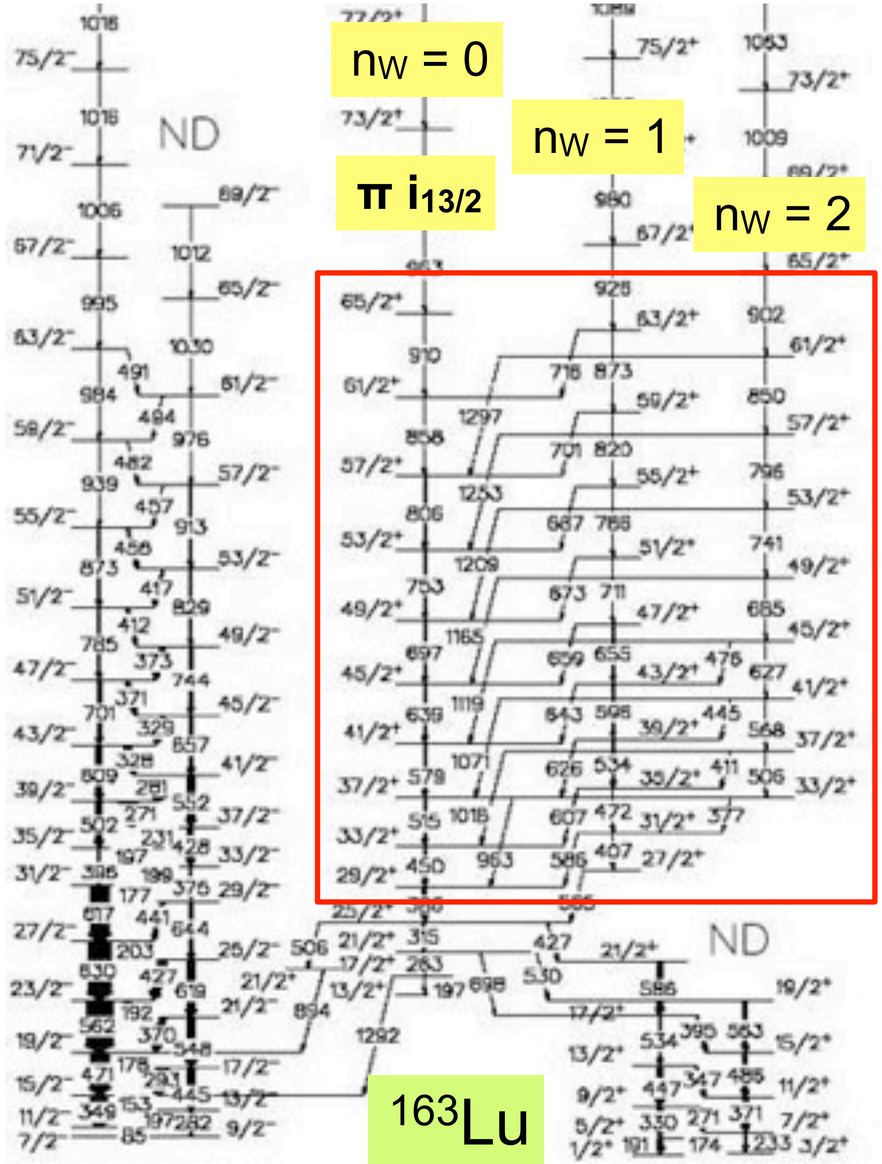
B(E1)/B(E2):
2.4(9) 10^{-6} fm^{-2}
(avg. value)

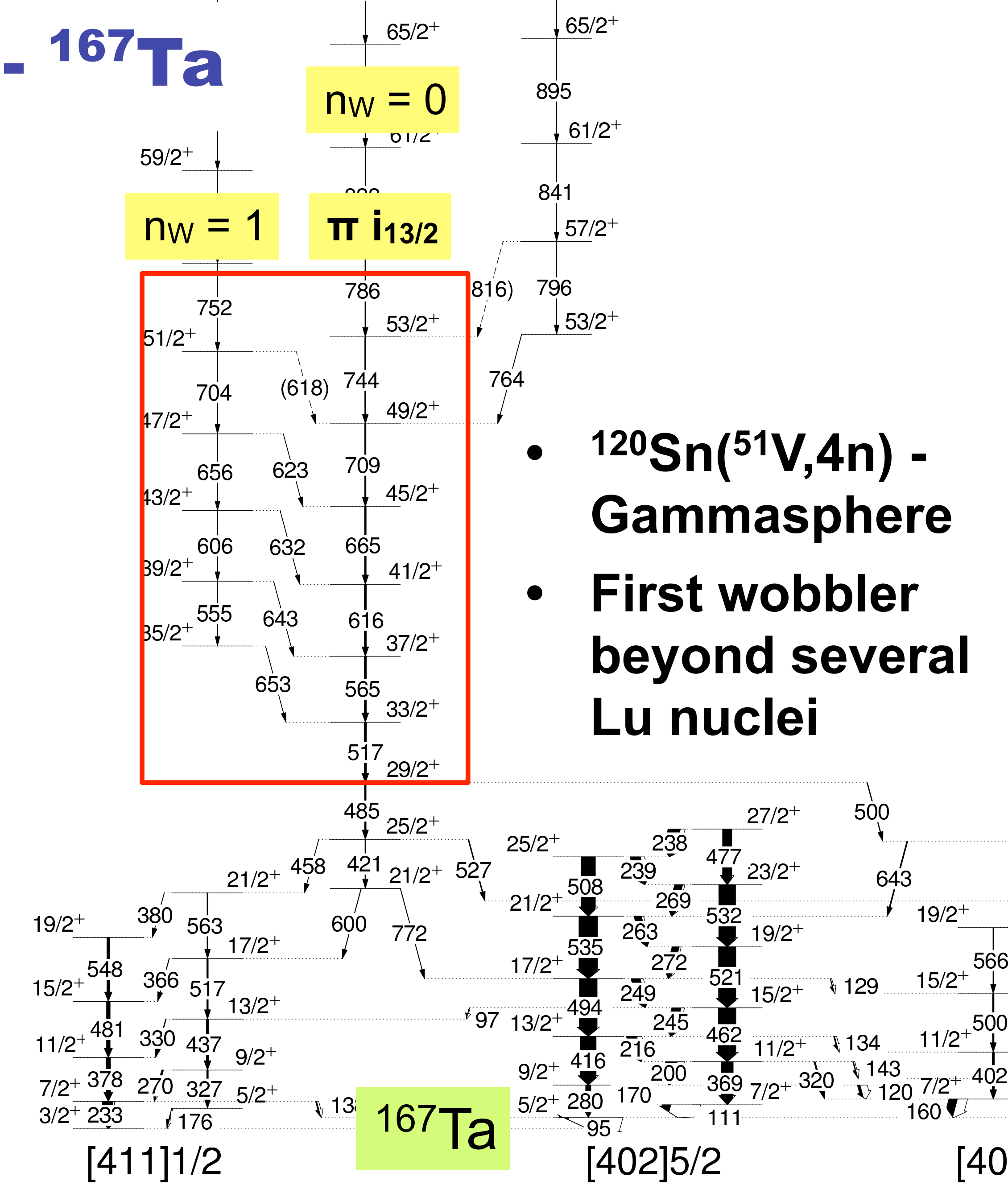


HERCULES
64 fast-plastic det.
D_{target} = 23.2 cm

ATLAS

2009 - triaxial wobbler - ^{167}Ta





- **^{120}Sn(^{51}V,4n) - Gammasphere**
- **First wobbler beyond several Lu nuclei**

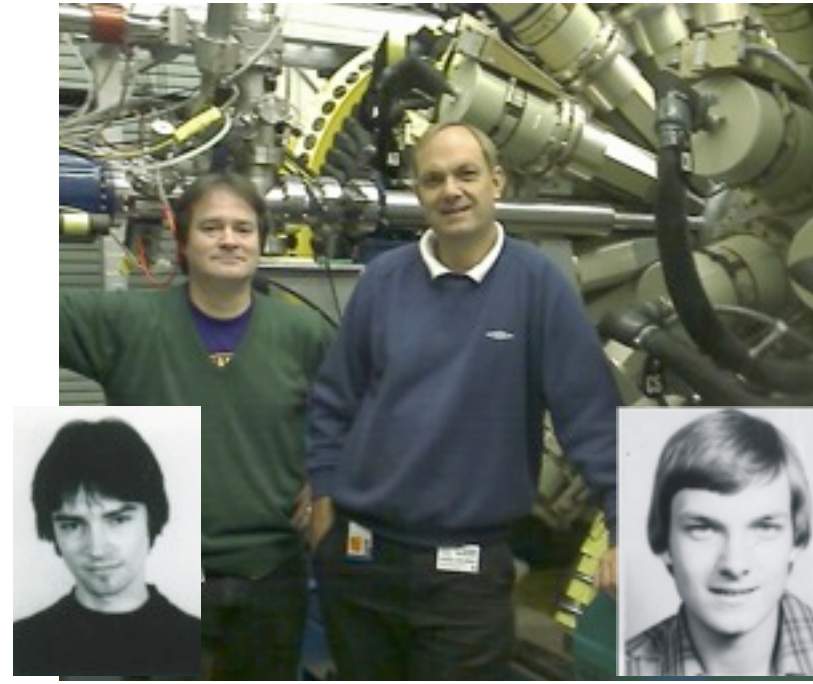
D. J. Hartley,[1] R. V. F. Janssens,[2] L. L. Riedinger,[3] M. A. Riley,[4] A. Aguilar,[4,*] M. P. Carpenter,[2] C. J. Chiara,[2,5,6] P. Chowdhury,[7] I. G. Darby,[3] U. Garg,[8] Q. A. Ijaz,[9] F. G. Kondev,[5] S. Lakshmi,[7] T. Lauritsen,[2] A. Ludington,[1,†] W. C. Ma,[9] E. A. McCutchan,[2] S. Mukhopadhyay,[8] R. Pifer,[1] E. P. Seyfried,[1] I. Stefanescu,[2,6] S. K. Tandel,[7] U. Tandel,[7] J. R. Vanhoy,[1] X. Wang,[4] S. Zhu,[2] I. Hamamoto,[10] and S. Frauendorf[8]

PR **C 80,** 41304(R) (2009)

ATLAS

Ultrahigh-spin spectroscopy of $^{159,160}Er$

- $^{116}Cd(^{48}Ca,4\text{-}5n)^{160,159}Er$
- Gammasphere
- 3.5 x 10^{10} quadruples
- Discrete-line spectroscopy to ultrahigh spin of ~ 60
- Life beyond band termination



J. Ollier and J. Simpson
STFC Daresbury Laboratory, Daresbury, Warrington WA4 4AD, United Kingdom

X. Wang, M. A. Riley, A. Aguilar, and C. Teal
Department of Physics, Florida State University, Tallahassee, Florida 32306, USA

E. S. Paul, P. J. Nolan, M. Petri,* S. V. Rigby, J. Thomson, and C. Unsworth
Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE, United Kingdom

M. P. Carpenter, R. V. F. Janssens, F. G. Kondev, T. Lauritsen, and S. Zhu
Nuclear Engineering Division and Physics Division, Argonne National Laboratory, Argonne, Illinois 60439, USA

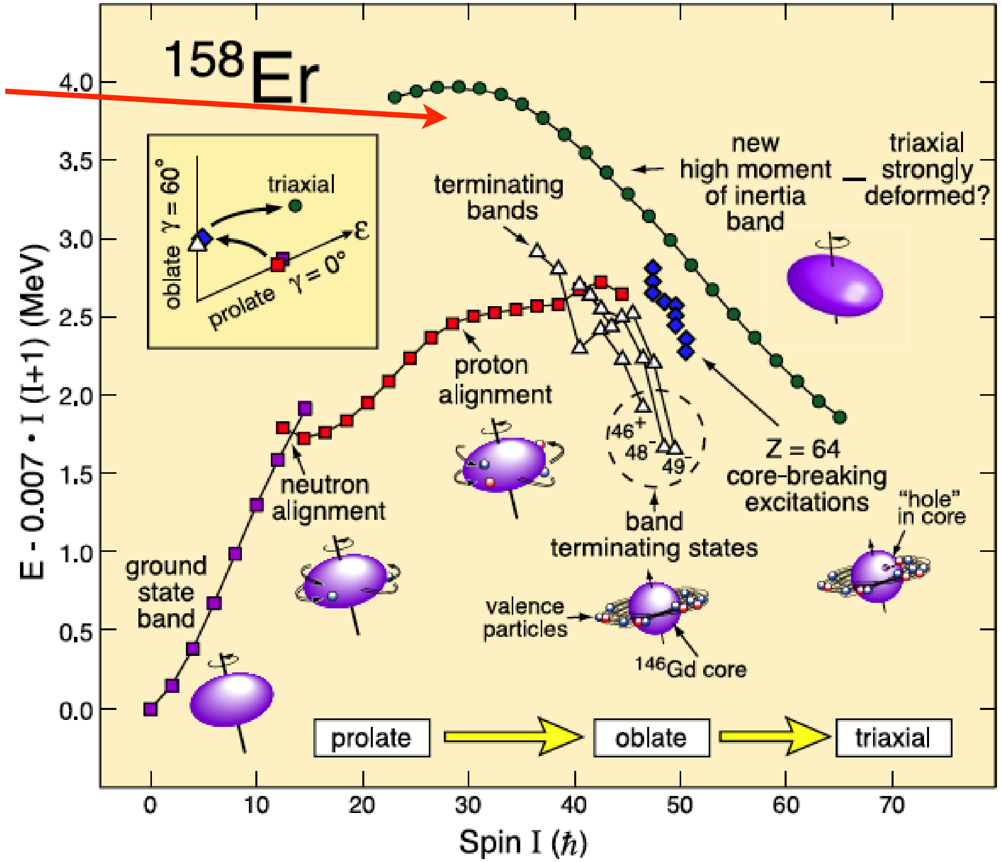
D. J. Hartley
Department of Physics, U. S. Naval Academy, Annapolis, Maryland 21402, USA

I. G. Darby†
Department of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee 37996, USA

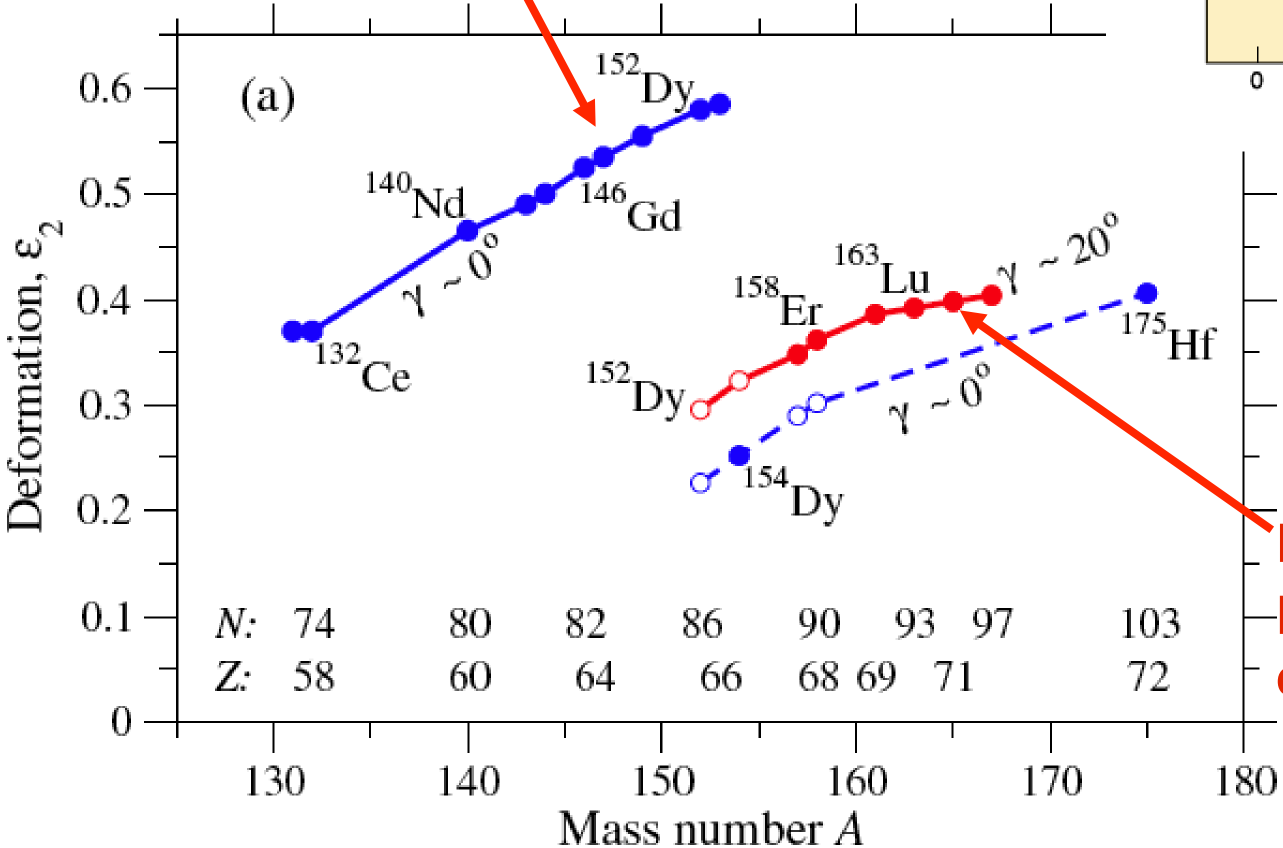
PR **C 80,** 64322 (2009)

ATLAS

New SD band seen in ^{158}Er - maybe this is a triaxial superdeformed state

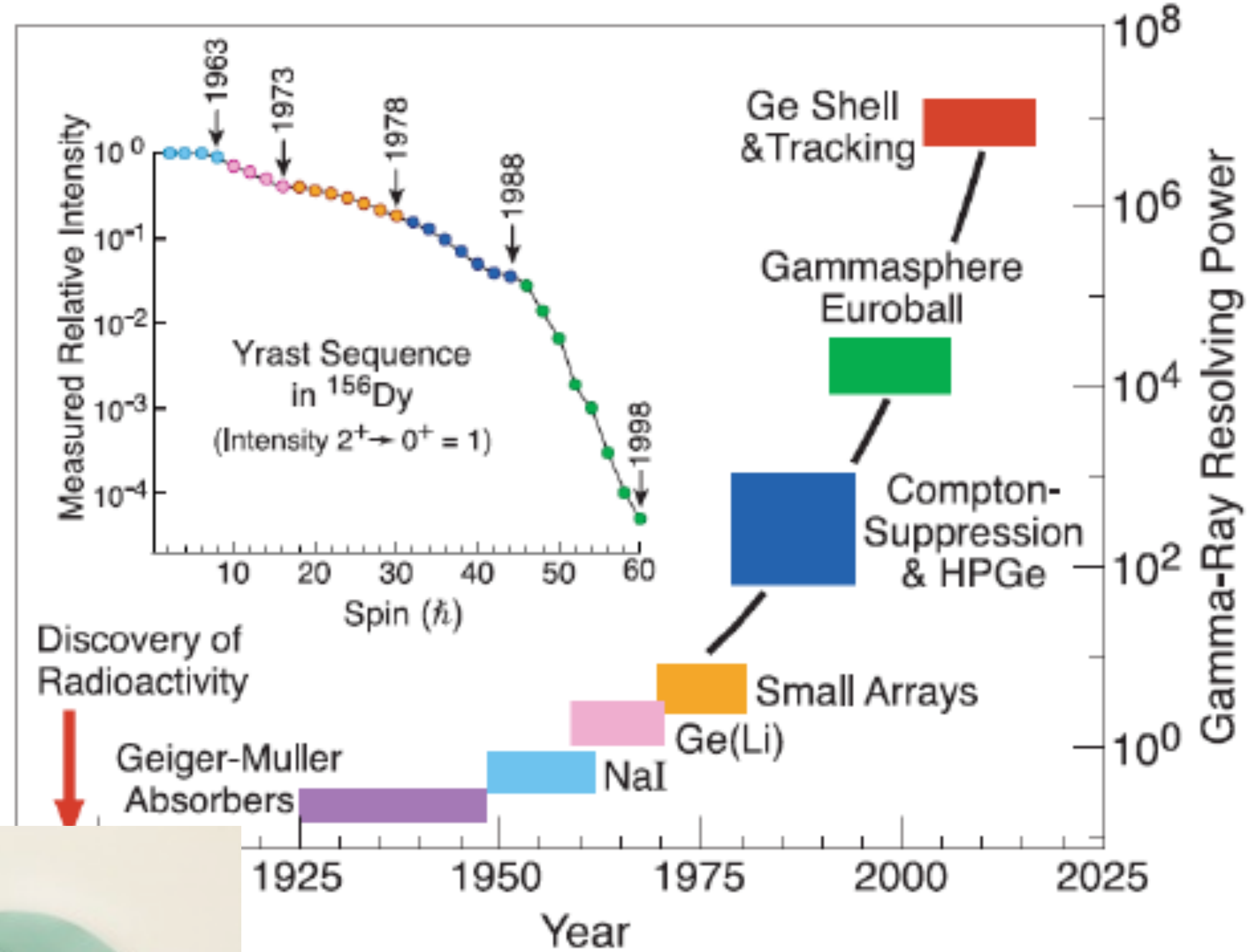


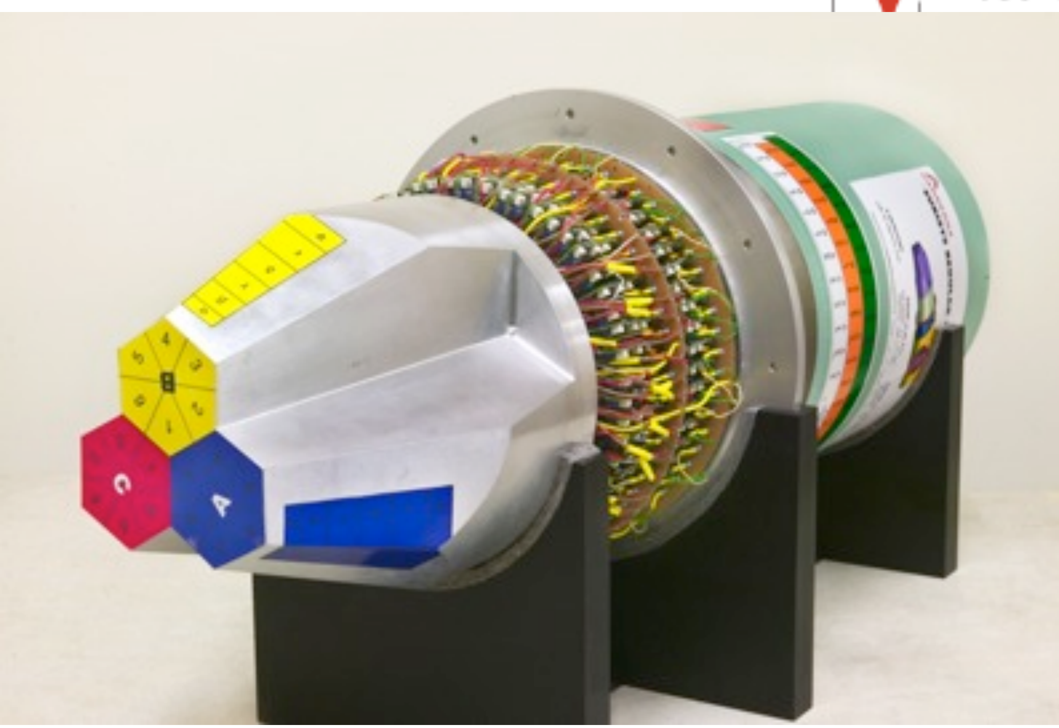
Holes in $\pi g_{9/2}$ [404]9/2 + high-j particles - A. Neusser et al., PRC 70 (2004)



Holes in ν $h_{11/2}$ [505]11/2 + high-j particles, E.S. Paul et al., PRL 98 012501, 2007

Future of γ-ray detection - GRETINA, then GRETA





ATLAS