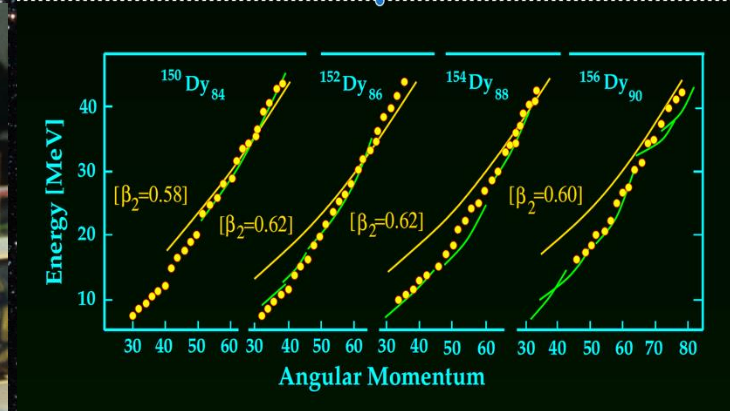
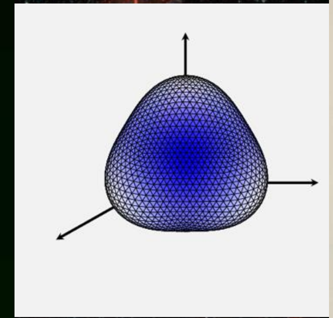
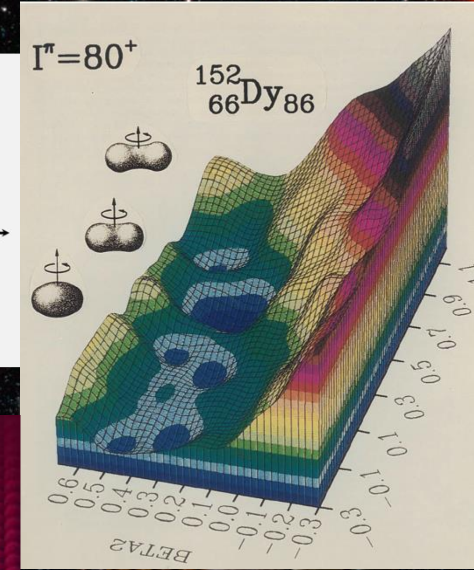
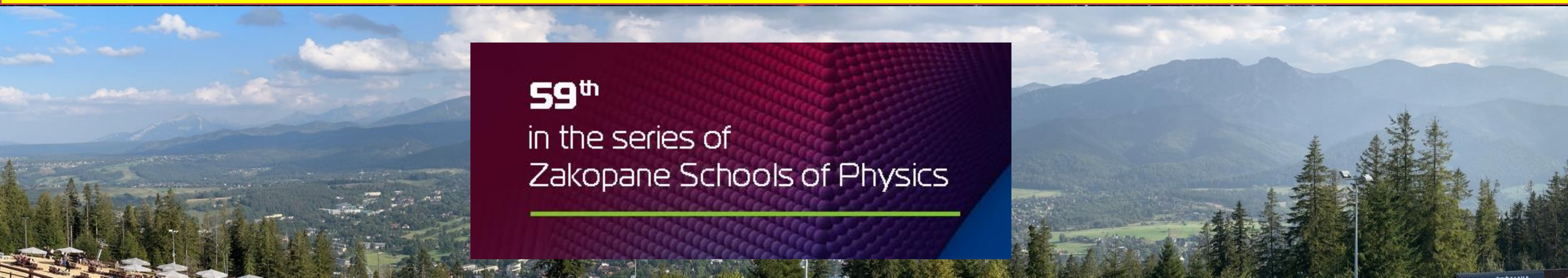






Shapes, Symmetries and Spin at the Extremes in Atomic Nuclei: Reflections on Seminal Contributions of Jerzy Dudek!

Mark A. Riley - Florida State University (+ a few from Jerzy himself ☺)

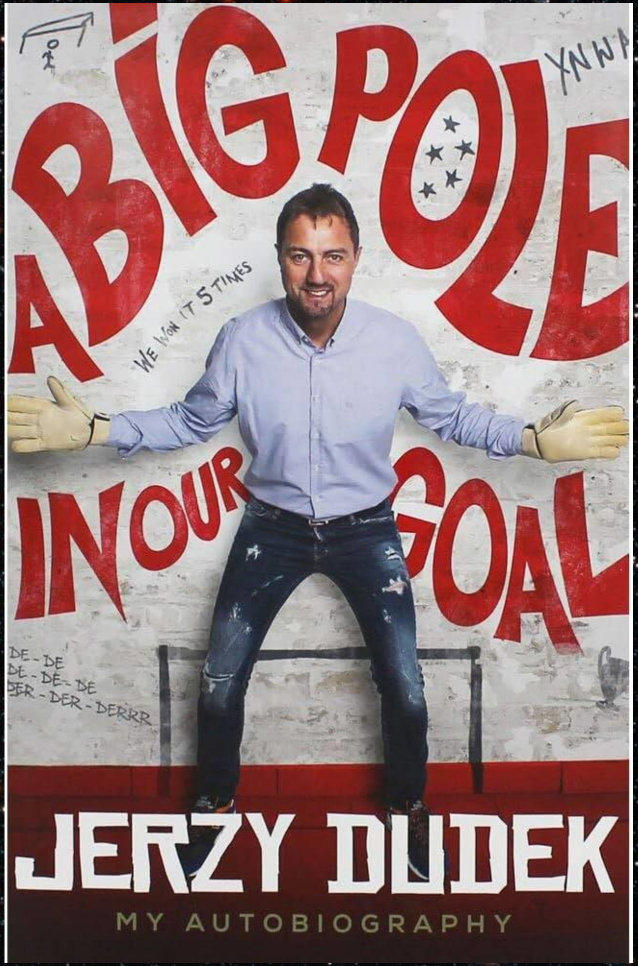


Outline of Talk

- Shapes, Symmetries and Spin.
- Jerzy Dudek is a Grand Master of Nuclear Structure Physics!
- We would not be where we are now without his brilliant 6 decades of input.
- I first met Jerzy/Jurek/Dudek in 1984 at Daresbury Laboratory.
- Let us celebrate his 80th birthday in a special way and make mention of some of his seminal contributions.
- It is also the 40th birthday of the discrete superdeformed band in ^{152}Dy which changed our field forever! Brief SD primer for young folks … It will be back!
- Just celebrated 50 years since Nobel Prize for Bohr, Mottelson and Rainwater.
- I will attempt to combine these three interlinked themes with some history and of my own interactions with Jerzy through the past 40+ years.
- There is spectacular discovery potential in the future to study nuclei at the extremes. May the fun continue!

AI Overview
Jerzy Dudek

- Jerzy Dudek is a Polish former professional footballer goalkeeper, winning the Champions League with Liverpool in 2005.
- He also spent four years at Real Madrid.
- Dudek played 60 times for Poland – 2002 World Cup.
- He settled with his family in **Kraków.**



AI Overview
Jerzy Dudek

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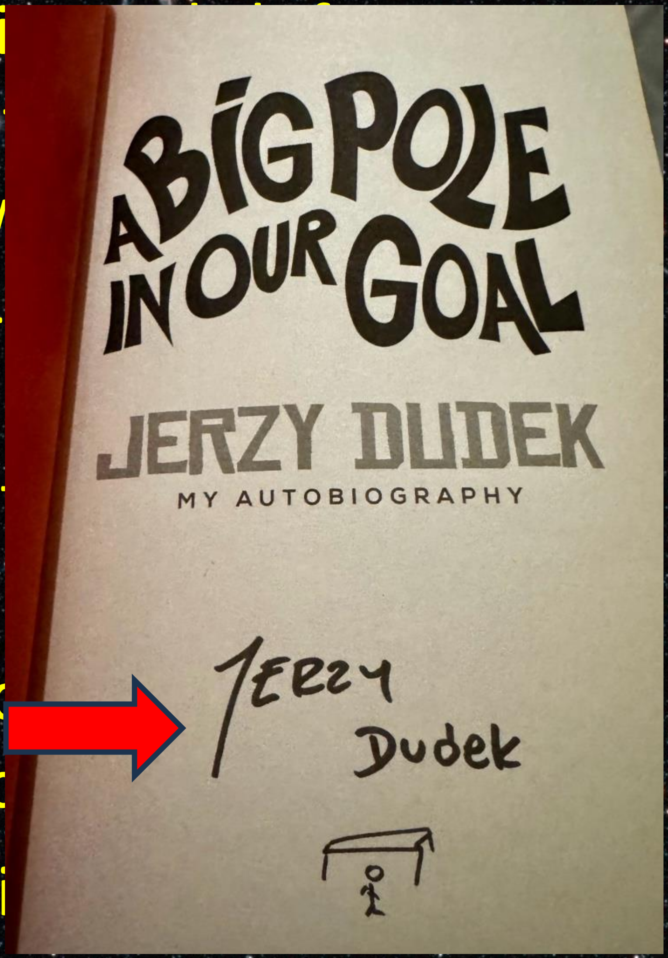
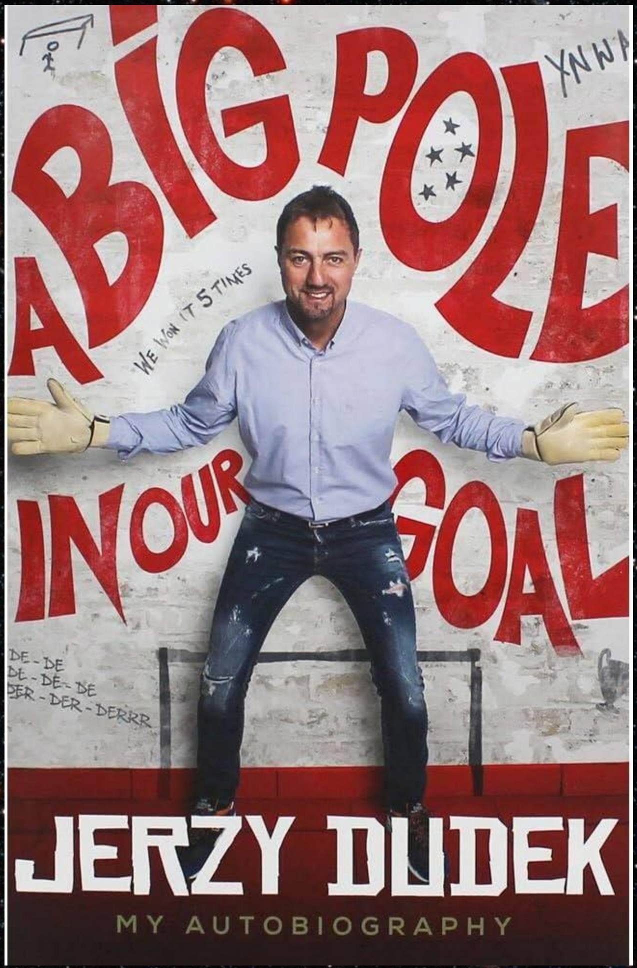




AI Overview

Jerzy Dudek and Nuclear Structure

- Jerzy Dudek is a theoretical physicist recognized globally for his foundational research on the diverse shapes, exotic symmetries, and extreme rotational behaviors of atomic nuclei. Working primarily at the University of Strasbourg and the IPHC in France, his career spans six decades of connecting theoretical models with experimental nuclear physics.
- Local lad! ☺ Master's degree in Theoretical Physics from the Jagiellonian University in Kraków, Poland, and completed his Ph.D. in Theoretical Nuclear Physics at the University of Warsaw, Poland

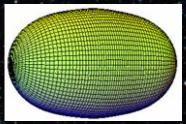
AI Overview
Key Scientific Contributions

Deformed Woods-Saxon Potential Universal Parameter set

- Dudek (along with collaborators like Witold Nazarewicz) optimized and popularized the **axially deformed Woods-Saxon potential** to compute single-particle nucleon energies.

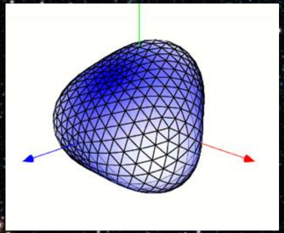
*6 parameters! Truly Universal!

- Compared to older models, Dudek's parameterization was remarkably accurate at describing the subtle nuclear shell adjustments that occur when a nucleus stretches or spins.
- This became the global standard for predicting where new islands of stability and deformed shapes would manifest.



AI Overview
Key Scientific Contributions

- **Super- and Hyper-Deformation:** He developed microscopic theories explaining atomic nuclei that stretch into elongated, highly deformed shapes under extreme rotation or energy.
- **Exotic Point-Group Symmetries:** He pioneered the study of non-standard spatial symmetries in nuclei—such as **tetrahedral and octahedral** point-group symmetries—which affect nuclear stability and shell structures.



VOLUME 88, No. 25 PHYSICAL REVIEW LETTERS 22 June 2002

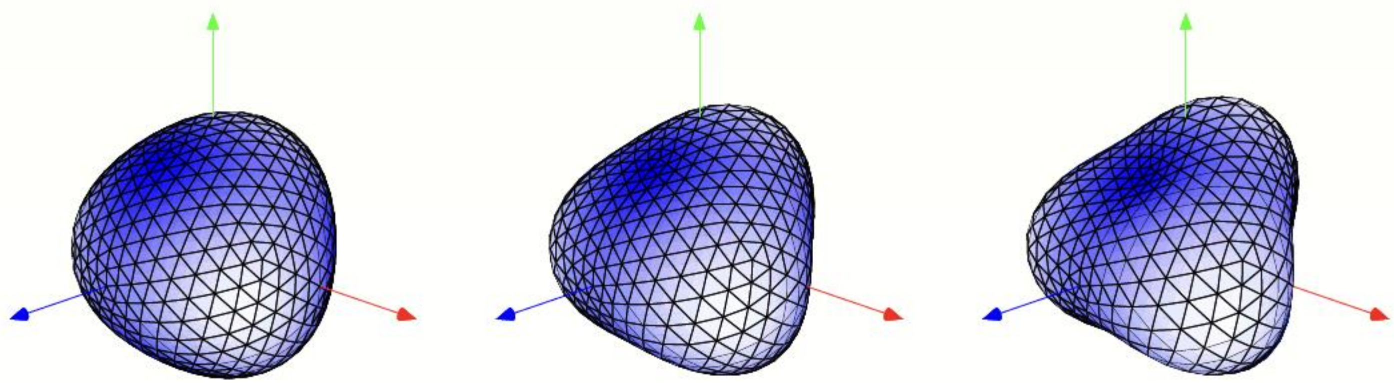
Nuclear Tetrahedral Symmetry: Possibly Present throughout the Periodic Table

J. Dudek, A. Góźdź, N. Schunck, and M. Miśkiewicz

VOLUME 97, 072501 (2006) PHYSICAL REVIEW LETTERS 18 August 2006

Island of Rare Earth Nuclei with Tetrahedral and Octahedral Symmetries: Possible Experimental Evidence

J. Dudek, D. Curien, N. Dubray, J. Dobaczewski, V. Pangon, P. Olbratowski, and N. Schunck



$\alpha_{32} \equiv t_3 = 0.1$ $\alpha_{32} \equiv t_3 = 0.2$ $\alpha_{32} \equiv t_3 = 0.3$

Examples: Nuclear TETRAHEDRAL symmetry shapes

AIP Physics News 2002 & 2006

"Nuclear Pyramids"

Physics News Update http://www.aip.org/pnu/2002/split/593-1.html

AIP American Institute of Physics SEARCH AIP go home contact us | site map

Inside Science Research — Physics News Update

Number 593 #1, June 10, 2002 by Phil Schewe, James Riordon, and Ben Stein
Nuclear Pyramids

"Smallest Pyramids in the Universe"

Smallest Pyramids in the Universe -- Physics News Update 789 http://www.aip.org/pnu/2006/split/789-1.h

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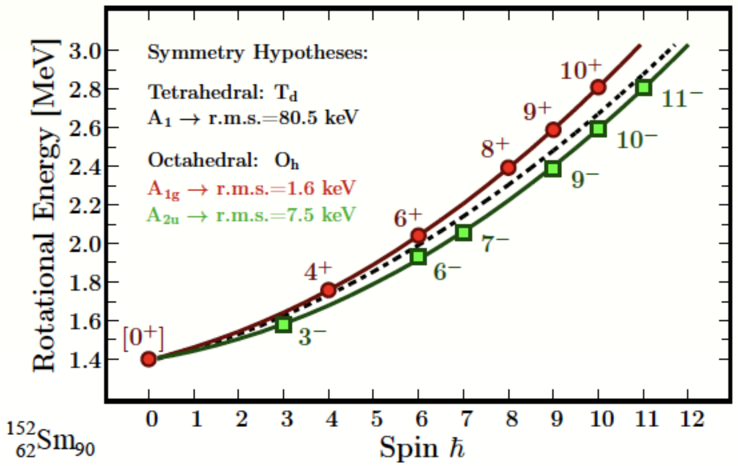
Inside Science Research — Physics News Update

Number 789 #1, August 22, 2006 by Phil Schewe, Ben Stein, and Davide Castelvecchi
Smallest Pyramids in the Universe

Want to know more? Nicholas Schunck or Dudek's talk

• These two sequences represent the coexistence between tetrahedral and octahedral symmetries. Curves represent the parabolic fit and are not meant to guide the eye. This is the first evidence based on the experimental data

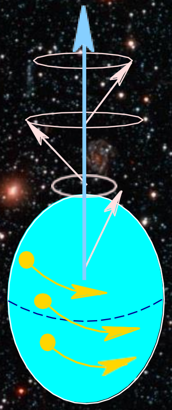
Experimental Results [T_d-*vs.*-O_h]



FROM: **Spectroscopic criteria for identification of nuclear tetrahedral and octahedral symmetries: Illustration on a rare earth nucleus**

J. Dudek et al., PHYSICAL REVIEW C 97, 021302(R) (2018)

AI Overview
Key Scientific Contributions



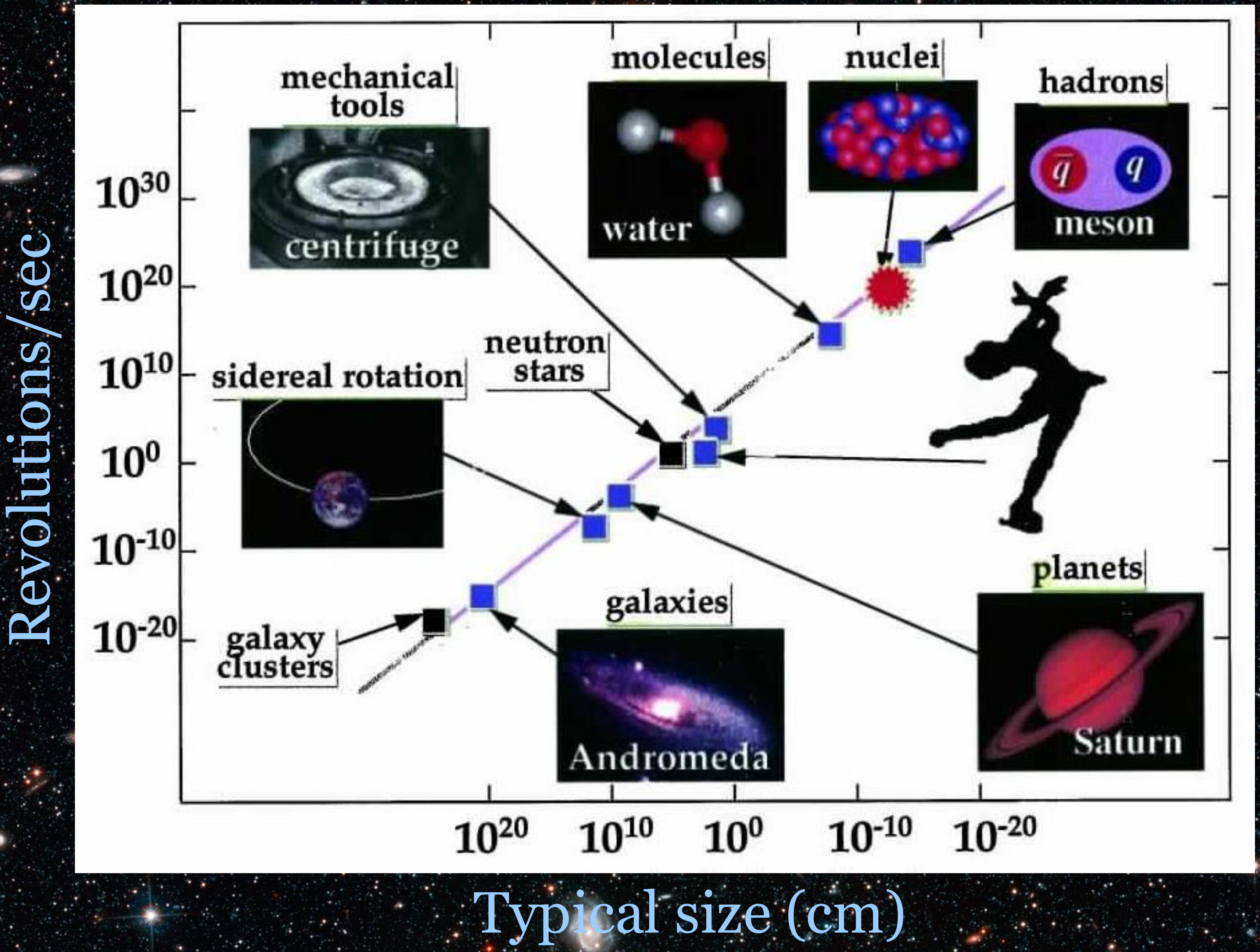
- **Nuclear Isomerism and Rotation:** His work clarified the nature of fission-isomers, yrast-trap isomers (high-spin trapped states), and collective nuclear rotation using mean-field theory.
- **Extreme Conditions:** He investigated how atomic nuclei behave under extreme conditions, including **high spins, high temperatures, and extreme neutron-to-proton ratios (isospins).**

AI Overview
Key Scientific Contributions

- You can read more about his recent lectures on realistic models through the Zakopane 2026 Conference on Nuclear Physics, or explore his co-edited collection on the Focus issue on Nuclear Shapes and Symmetries.

Pushing atomic nuclei to new extremes is what we are about!

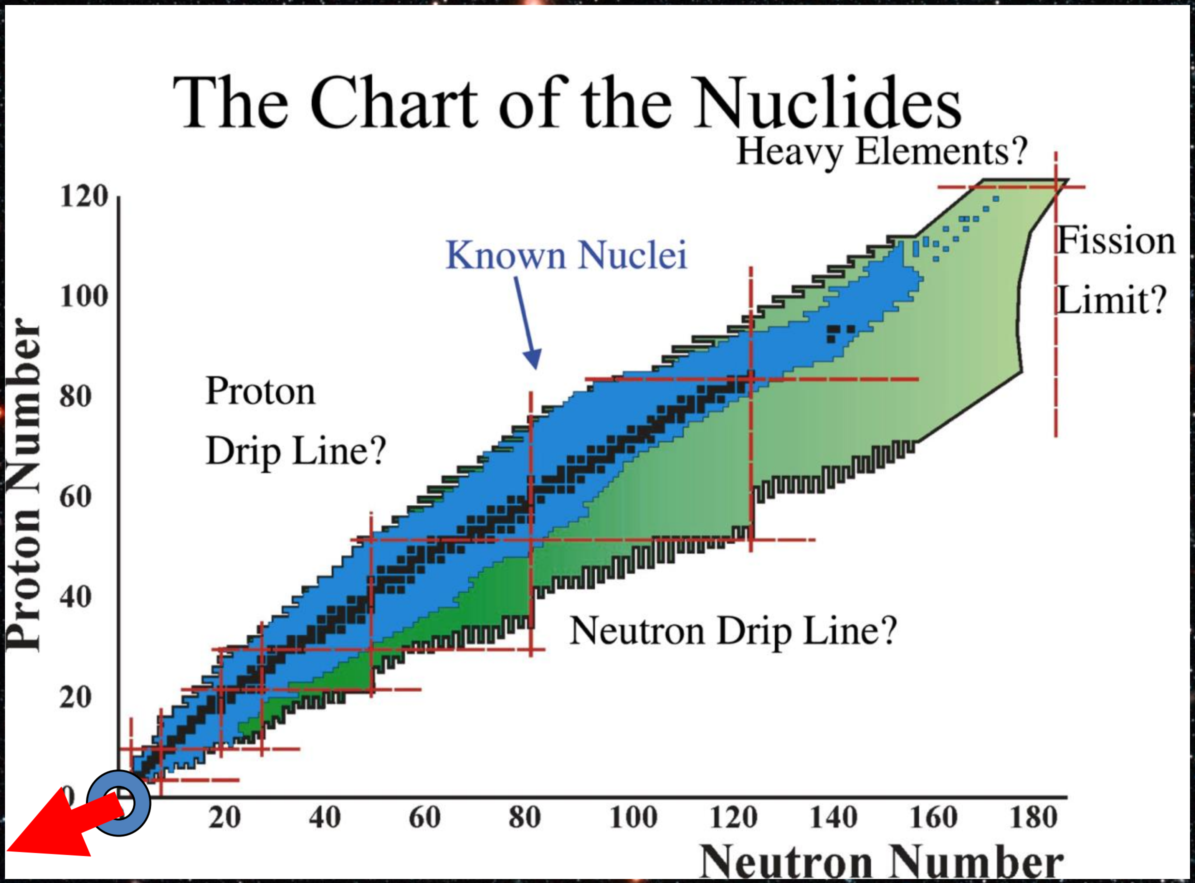
Witek Nazarewicz: Rotations in the Universe



It is fun to look at rotating objects!

It is fun to study rotating objects!

NUCLEI AT THE EXTREMES:



Increasing Angular Momentum and Excitation Energy:

Excellent way to investigate nuclear structure. Remember these studies are ultra-sensitive to what the intruder shells are doing!

ON THE
TRANSMUTATION OF ATOMIC NUCLEI
BY IMPACT OF MATERIAL PARTICLES

I. GENERAL THEORETICAL REMARKS

BY

N. BOHR AND F. KALCKAR

Mathematatisk-fysiske Meddelelser XIV, 10 1937

We must in fact assume that any orbital momentum is shared by all the constituent particles of the nucleus in a way which resembles that of the rotation of a solid body. Denoting by J the moment of inertia, we obtain

MAY 15, 1938 PHYSICAL REVIEW VOLUME 53

On the Rotation of the Atomic Nucleus

E. TELLER, *George Washington University, Washington, D. C.*

AND

J. A. WHEELER, *University of North Carolina, Chapel Hill, N. C.*

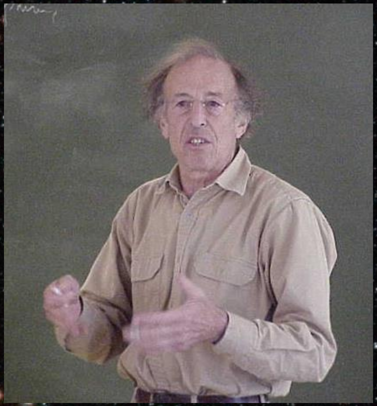
(Received March 23, 1938)

Physical Review 90 (1953) 717 - Letters to Editor

Rotational States in Even-Even Nuclei

AAGE BOHR AND BEN R. MOTTELSON*
Institute for Theoretical Physics, Copenhagen, Denmark

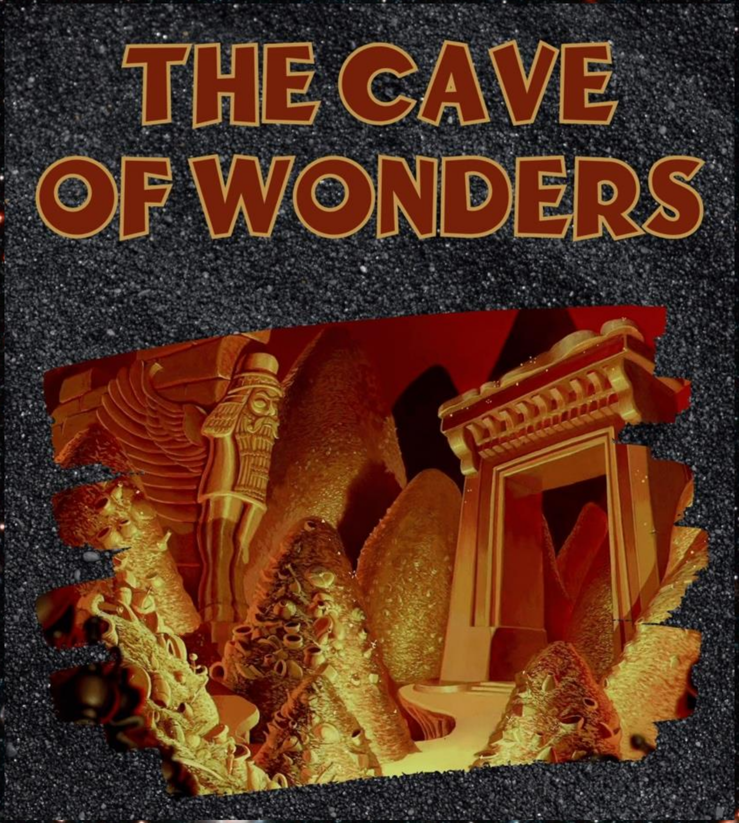
$$E_I = \frac{\hbar^2}{2\mathcal{J}} I(I+1), \quad I = 0, 2, 4, 6, \text{ even parity} \tag{1}$$



Bohr and Mottelson (with Rainwater) were awarded the 1975 Nobel Prize for connecting the single-particle and collective aspects of nuclear behavior into a consistent framework.

Dudek's Aladdin's Cave #1!!!

Perhaps the most important archive for nuclear physics in the world!
Simply Amazing!



Celebrating the 40 year anniversary of the 1975 Nobel Prize to Bohr, Mottelson and Rainwater

PHYSICA SCRIPTA 2016:

Focus issue to celebrate the 40 year anniversary of the 1975 Nobel Prize to Aage Niels Bohr, Ben Roy Mottelson and Leo James Rainwater
Guest Editor: Jerzy Dudek

- Nearly 140 scientists from all over the world accepted our invitation and we have over 60 articles included in this *Special Celebration Focus Issue*!

Phys. Scr. 91 (2016)

IOP Editor-in-Chief to Dudek

- In comparison with two other focus collections, ...
  for a collection on a similar topic,
  it is 6.5, whereas the average citation for your
  collection is 32.8.
- This clearly demonstrates that the collection has attracted significantly higher attention and citations, making a substantial contribution to the journal.

IOP Editor-in-Chief to Dudek

Taking this opportunity, we would also like to ask if <u>you are interested in editing another focus collection with Physica Scripta?</u>

Best regards,
Huan (Harley) Wang

Ms. Huan Wang王欢 |Publisher
IOP Publishing Beijing Office

Celebrating the 40 year anniversary of the 1975 Nobel Prize to Bohr, Mottelson and Rainwater

PHYSICA SCRIPTA 2016:

Focus issue to celebrate the 40 year anniversary of the 1975 Nobel Prize to Aage Niels Bohr, Ben Roy Mottelson and Leo James Rainwater
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OPEN ACCESS
IOP Publishing | Royal Swedish Academy of Sciences Physica Scripta
Phys. Scr. 91 (2016) 123002 (19pp) doi:10.1088/0031-8949/91/12/123002

Invited Comment

High resolution gamma-ray spectroscopy and the fascinating angular momentum realm of the atomic nucleus

M A Riley[1,4], J Simpson[2] and E S Paul[3]

[1] Department of Physics, Florida State University, Tallahassee, FL 32306, USA
[2] STFC Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, UK
...ent of Physics, University of Liverpool, Liverpool, L69 7ZE, UK

...riley@physics.fsu.edu, john.simpson@stfc.ac.uk and esp@ns.ph.liv.ac.uk

...16 April 2016, revised 11 August 2016
...for publication 22 August 2016
...16 November 2016

OPEN ACCESS!! FREE TO THE WORLD! ☺☺☺☺☺

Downloaded over 8560 times!

In 1974 Aage Bohr and Ben Mottelson predicted the different ... deformed nuclei as a function of increasing angular momentum ... up to the fission limit. While admitting their picture was highl... stated '*...with the ingenious experimental approaches that are ... forward with excitement to the detailed spectroscopic studies ... of the spinning quantised nucleus*'. High resolution gamma-ray ... major tool in studying the structure of atomic nuclei and has ... advances over the last four decades. This article will select hig... Niels Bohr Institute, Denmark, and Daresbury Laboratory, UK ... 1980s, some of which have continued at other national laborator... present day. These studies illustrate the remarkable diversity of phenomena and symmetries exhibited by nuclei in the angular momentum–excitation energy plane that continue to surprise and fascinate scientists.

Keywords: Gamma spectroscopy, Detector instrumentation, nuclear structure, collective excitations, single particle excitations, high angular momentum

(Some figures may appear in colour only in the online journal)

Riley, Simpson & Paul, Phys. Scr. 91 (2016) 123002

Physica Scripta. Vol. 10 A, 13–20, 1974

Some Current Themes in Nuclear Research

A. Bohr

The Niels Bohr Institute, University of Copenhagen, Denmark

B. R. Mottelson

Nordita, Copenhagen, Denmark

Received July 3, 1974

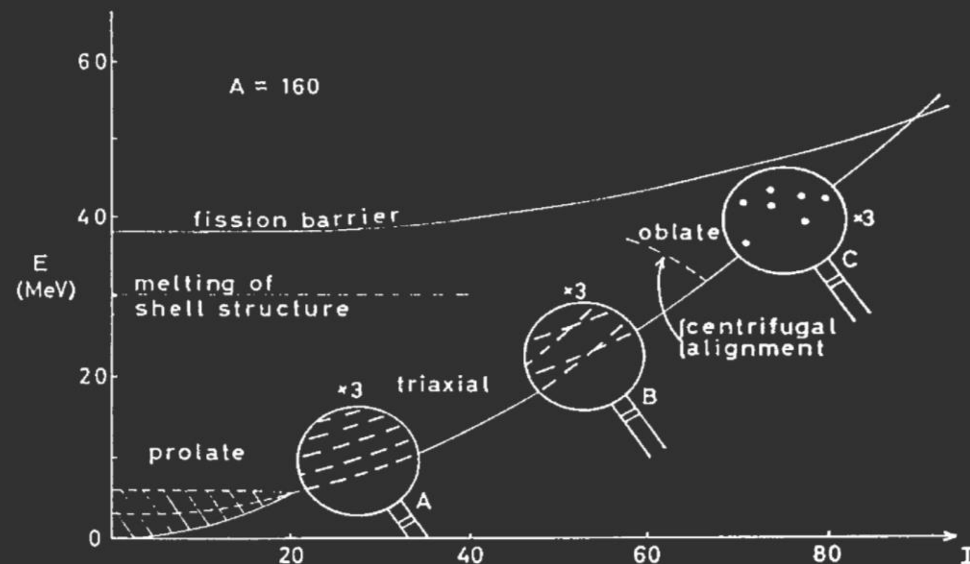
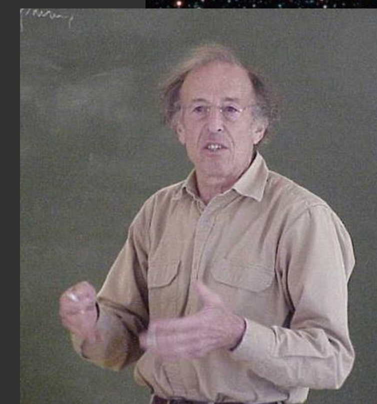
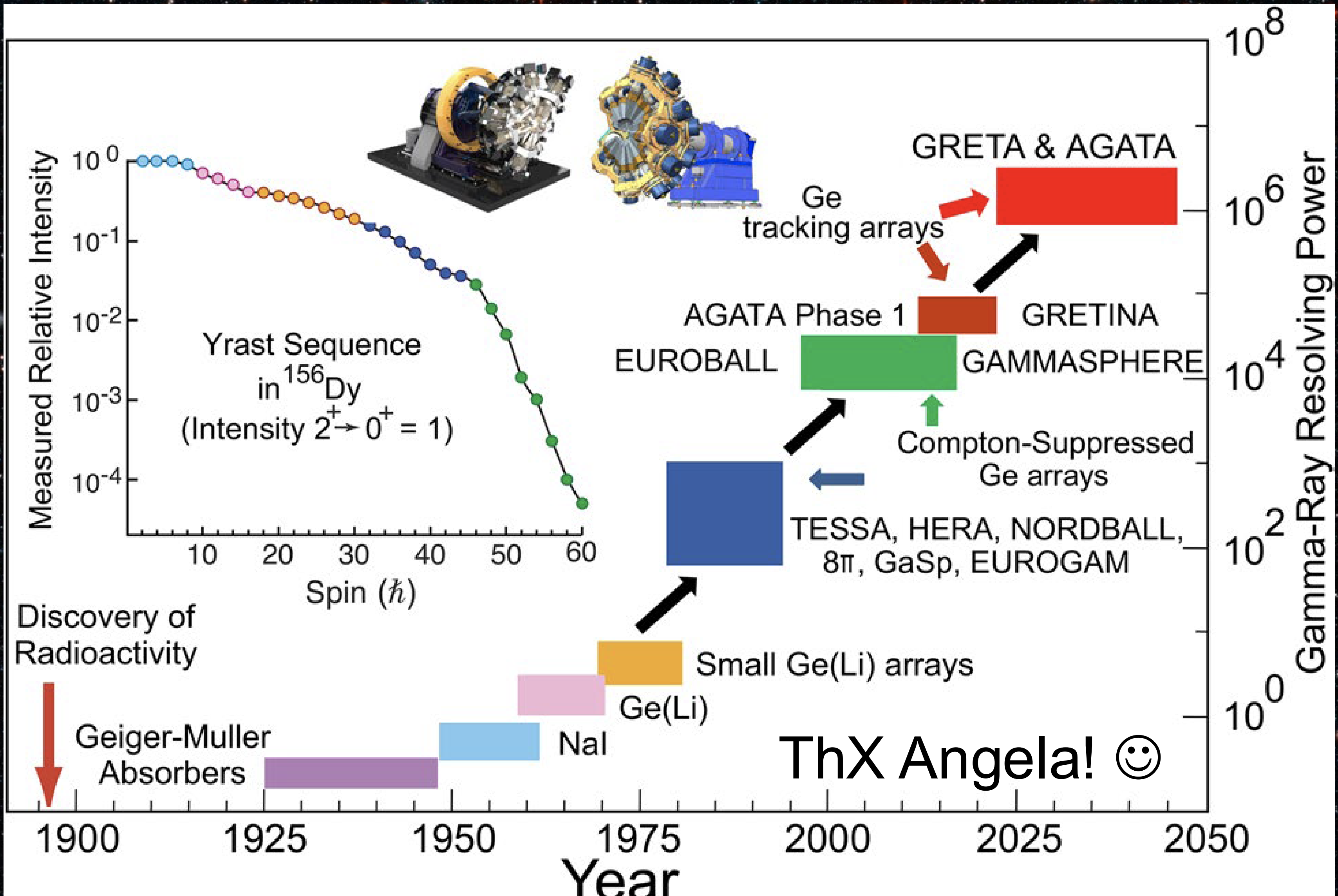


Fig. 11. Nuclear phases a a function of angular momentum and excitation energy (schematic).



The picture sketched in Fig. 11 is admittedly highly conjectural; however, with the ingenious experimental approaches that are being developed, we may look forward with excitement to the detailed spectroscopic studies that will illuminate the behavior of the spinning quantized nucleus.



Evolution of detector systems ☺

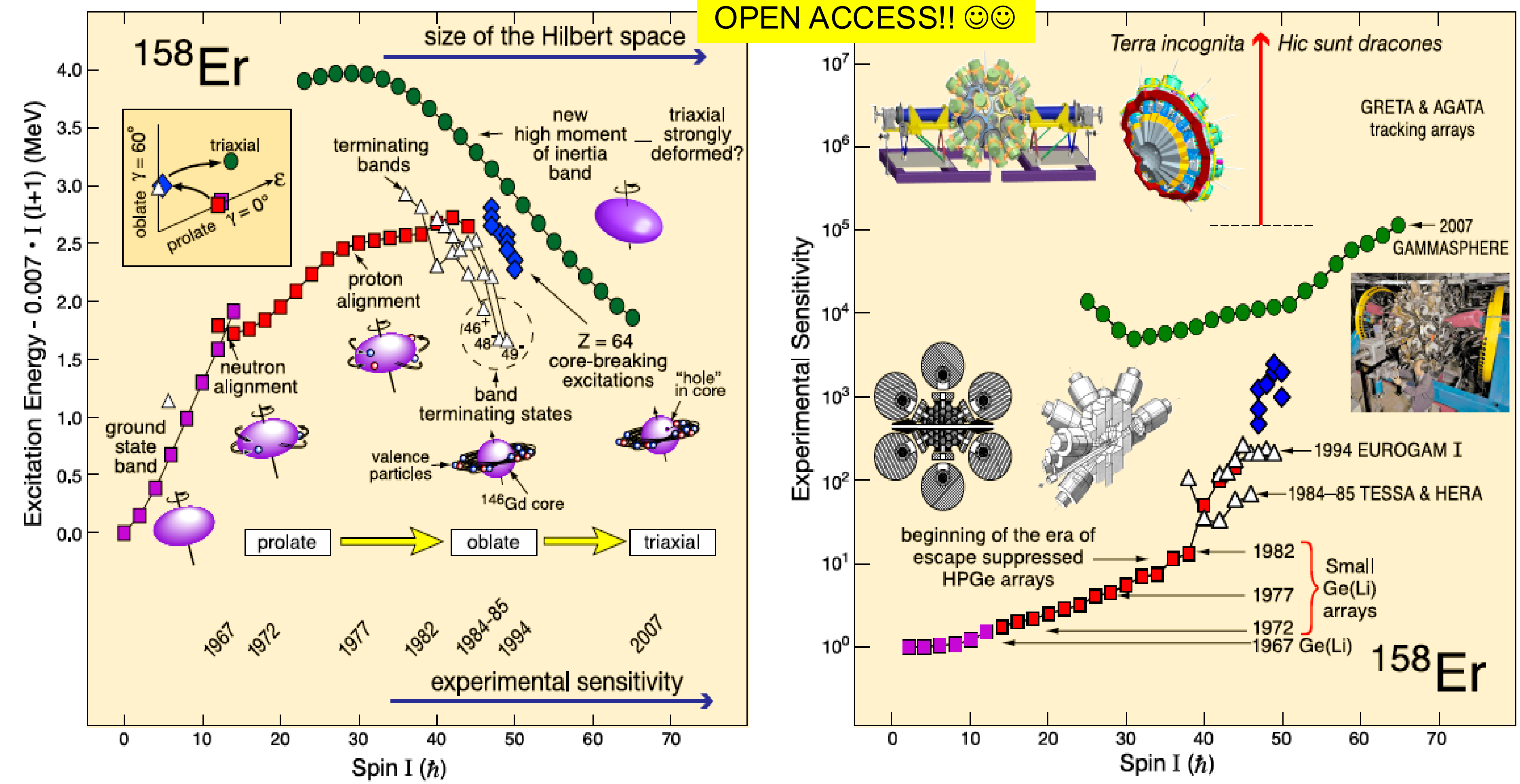
Wyss & Riley, Nuc. Phys. News Vol.32, No.2,2022

(with brilliant help from John Simpson and Augusto Macchiavelli)

Evolution of Gamma-Ray Spectroscopy Through the Decades

- New Detector Systems ⟷ New Physics
- Riley, Simpson and Paul, Phys. Scr. 91 (2016)

OPEN ACCESS!! ☺☺



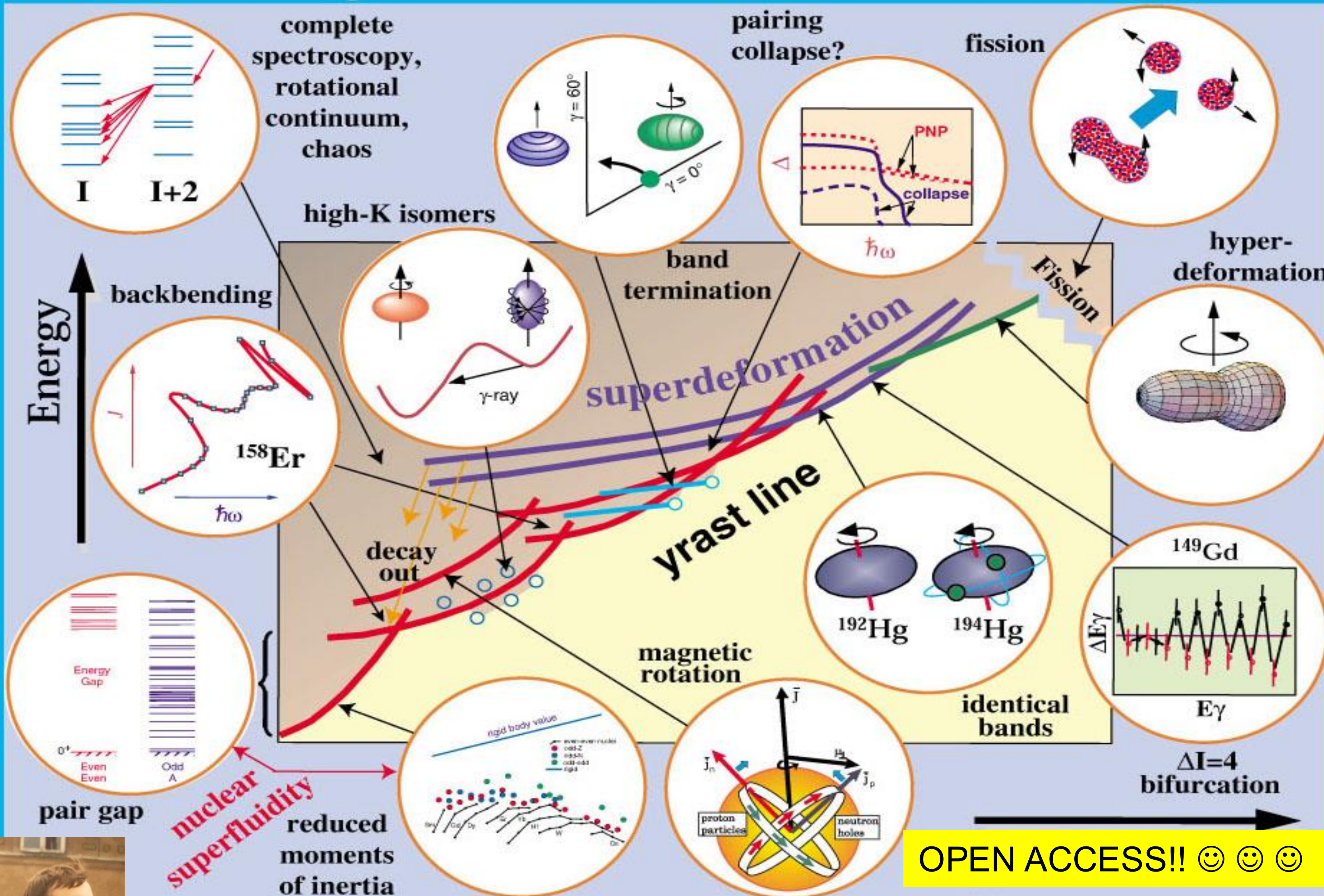
The Importance of Discovery Potential!

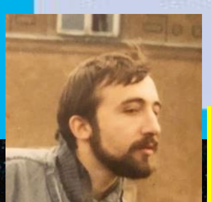
LOT OF THESE MOMENTS!!

Novel instrumentation always forms an explosive "discovery" mixture!

NEW PHYSICS!!!

The Angular Momentum World of the Nucleus



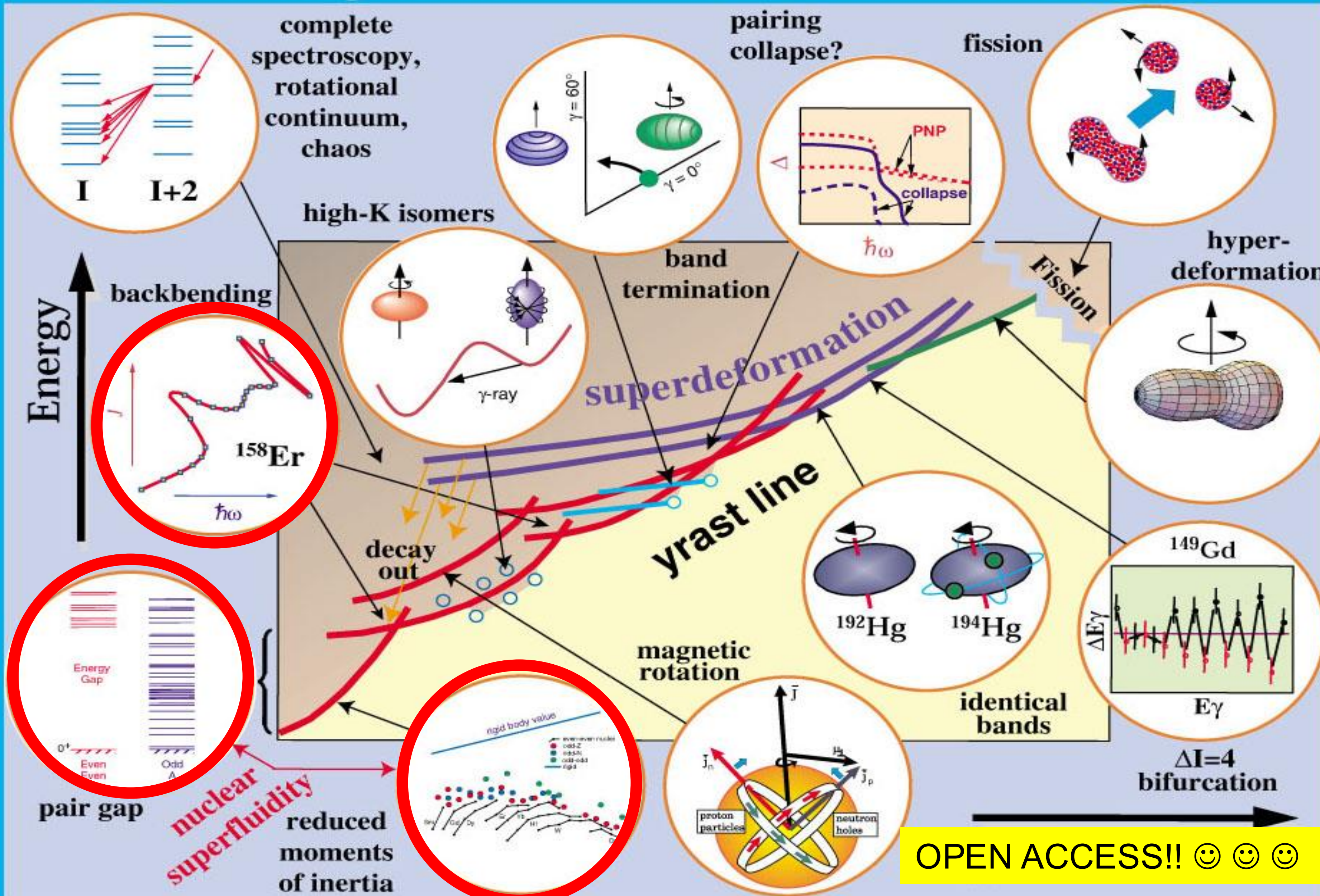


OPEN ACCESS!! ☺ ☺ ☺

Riley, Simpson & Paul, Phys. Scr. 91 (2016) 123002

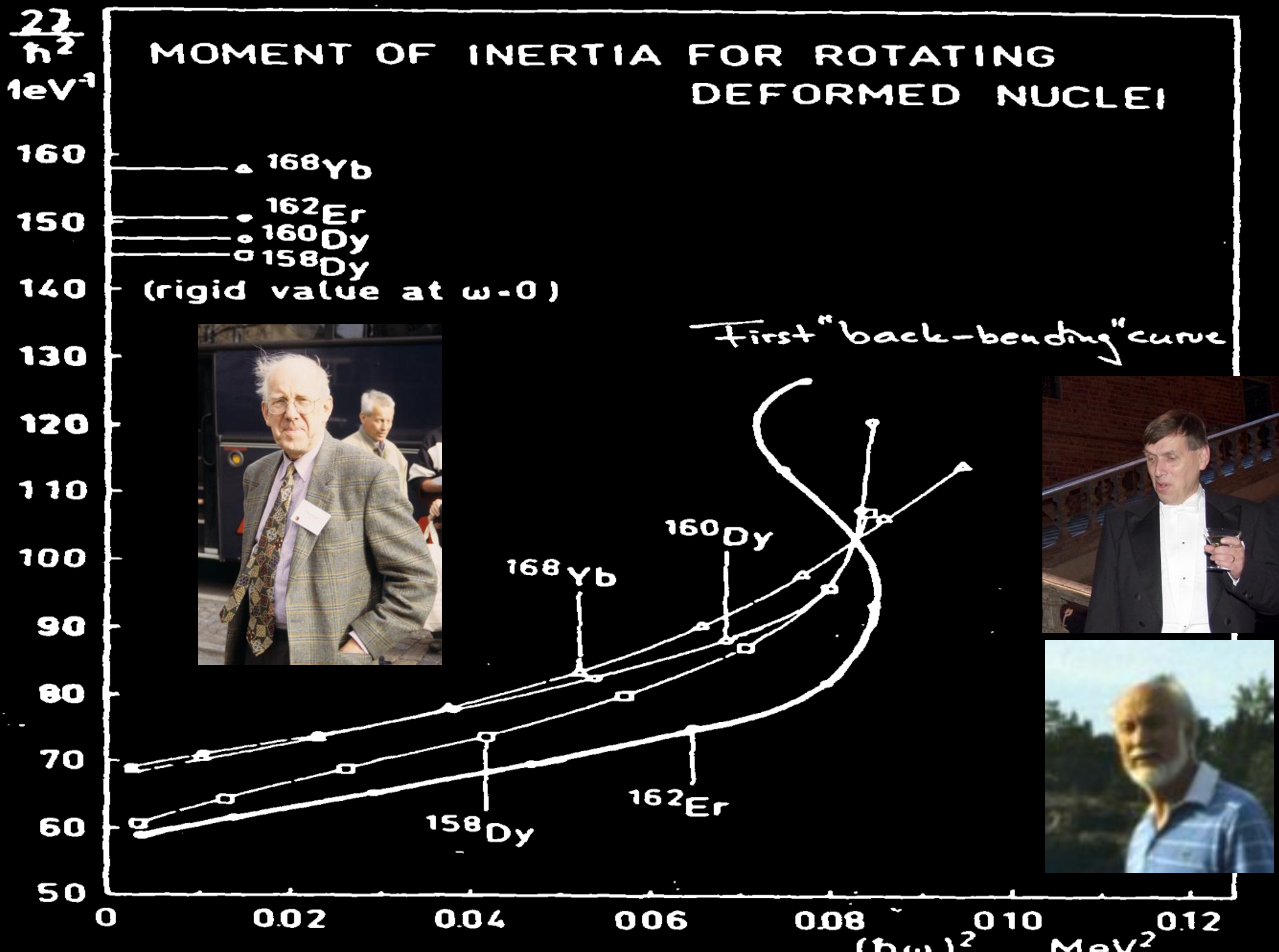
70’s, EXCITING TIMES:
Warsaw Group led by Syzmanzki form strong interactions with Lund and Copenhagen with spectacular results and creation of future Jedi Masters!

The Angular Momentum World of the Nucleus



OPEN ACCESS!! ☺ ☺ ☺

Riley, Simpson & Paul, Phys. Scr. 91 (2016) 123002



A. Johnson, H. Ryde and S.A. Hjorth
Nuc. Phys. A179 (1972) 753

BLEGDAMSVEJ 17, 2100 KØBENHAVN Ø
TELEFON: (01) TRia 1616
TELEGRAMADR.: PHYSICUM, KØBENHAVN

16 October, 1970

Dear Arne and Hans,

Thank you for the preprint of your note which indeed makes a very exciting story. It appears that you have rather convincing evidence for the occurrence of something quite remarkable for angular momentum values in the region $I \approx 16$; this is exhibited, perhaps, even more dramatically in a plot of the moment of inertia as a function of the rotational frequency (see the enclosed figure). The frequency is defined by the canonical relation appropriate for an axial symmetric rotor

$$\omega = \frac{dE}{d\sqrt{I(I+1)}}$$

or

$$\omega^2 = 4I(I+1)\left(\frac{dE}{dI(I+1)}\right)^2$$

In the last expression, the energy derivative is taken from the observed transition energies

$$\left(\frac{dE}{dI(I+1)}\right)_{I(I+1) = I_1^2 - I_1 + 1\,*} = \frac{E(I_1) - E(I_1 - 2)}{4I_1 - 2}$$

The moment of inertia is also defined in terms of the derivative of the observed energy

$$\frac{2\mathfrak{I}}{\hbar^2} = \left(\frac{dE}{dI(I+1)}\right)^{-1}$$

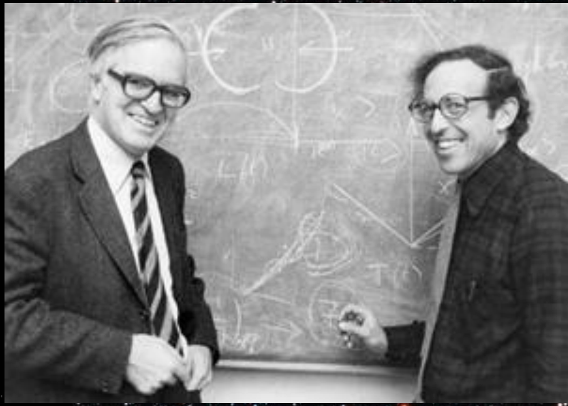
Another interesting feature of your data concerns the value of $\mathfrak{I}$ at the singular point. If the pairing correlation were to completely disappear, one would expect $\mathfrak{I} = \mathfrak{I}_{rig}$. However, since the transition frequency for neutrons and protons may be quite

$$* = \tfrac{1}{2}(I_1(I_1+1) + (I_1-2)(I_1-1))$$

different, the value of $\mathfrak{I}$ is likely to be somewhat below $\mathfrak{I}_{rig}$ after the first transition.

We send our compliments and best wishes for continued successful hunting in this exciting field.

Aage   Ben
A. Bohr   B. Mottelson



Ben and Aage in 1970

1.D.1:
1.D.2

Nuclear Physics A183 (1972) 257—284; © North-Holland Publishing Co., Amsterdam

CORIOLIS EFFECTS IN THE YRAST STATES

F. S. STEPHENS † and R. S. SIMON
Sektion Physik, Universität München, München, Germany ††

Received 19 November 1971

Abstract: We have investigated the Coriolis effects at high angular momentum in a system consisting of two (or four) particles in the $i_{\frac{13}{2}}$ orbital coupled to a deformed core. As the angular momentum is increased in this system, we find that the particles tend to decouple from the core and add their angular momenta, ultimately $2j-1$ for two particles, directly to that produced by the rotation of the core. In our calculations, enough energy is gained in this partial decoupling so that somewhere between $I = 10$ and $I = 20$ these states become lower in energy than those involving just rotation of the initial system. Such a change in the character of the lowest-lying, or yrast, level in this spin region is consistent, in so far as we can tell, with existing experimental data on rotational-level spacings and de-excitation cascades.

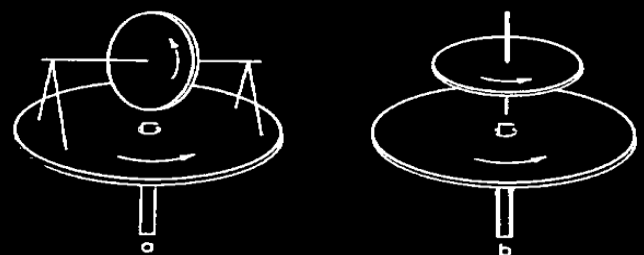
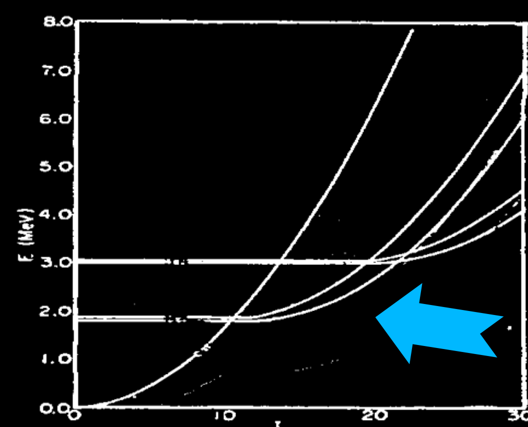


Fig. 4. The Coriolis effects on a spinning wheel constrained to turn with a turntable (a) tend to produce the configuration shown in (b).



Stockholm Band

Fig. 6. Excitation energy versus angular momentum for a doubly even rotational nucleus.

1.D.1:
1.D.2

Nuclear Physics A183 (1972) 257—284; © North-Holland Publishing Co., Amsterdam

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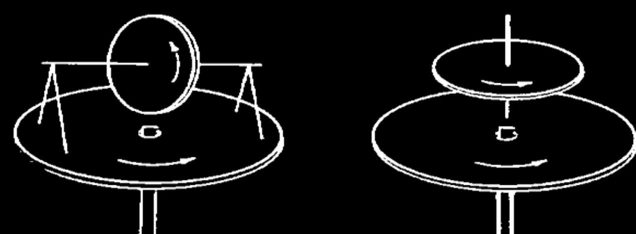

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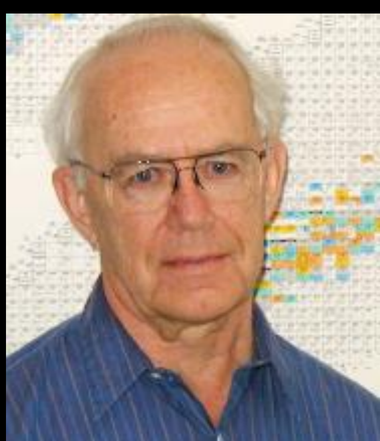


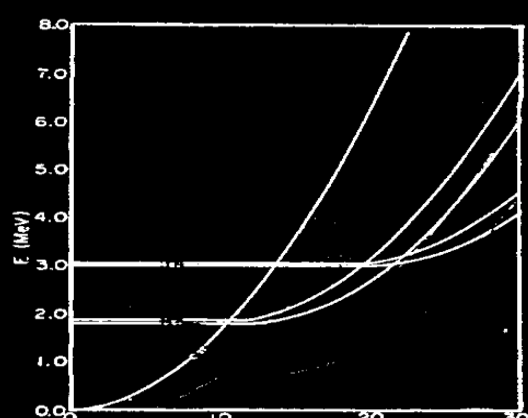
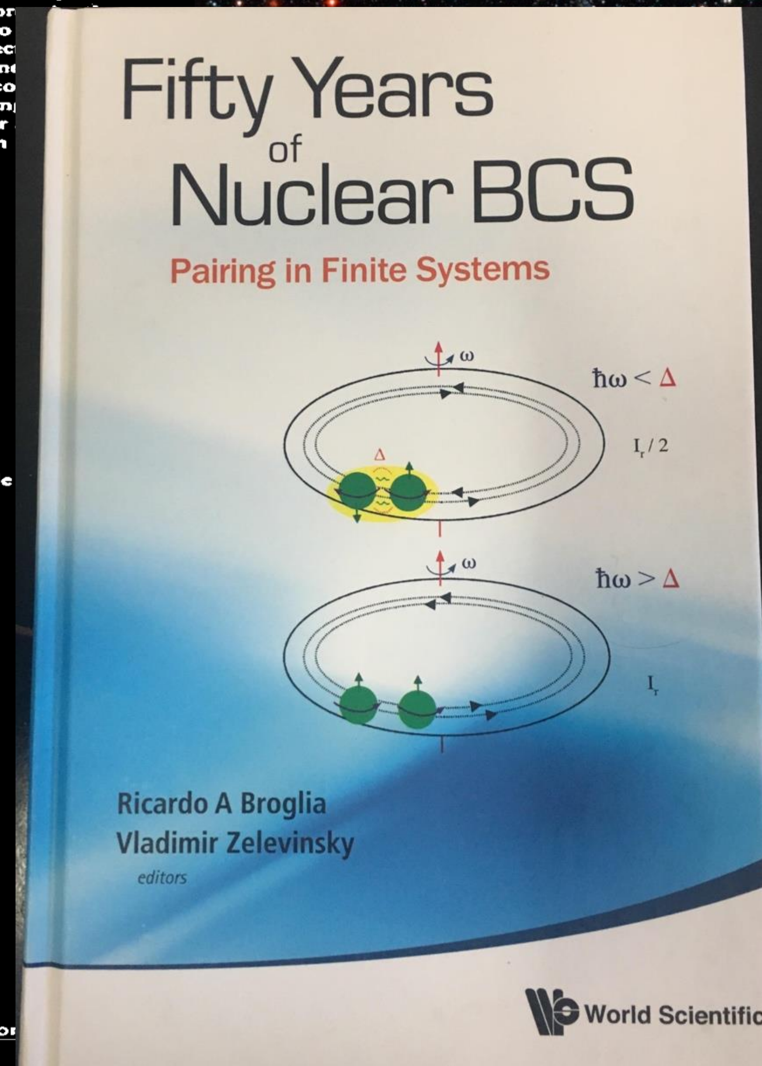
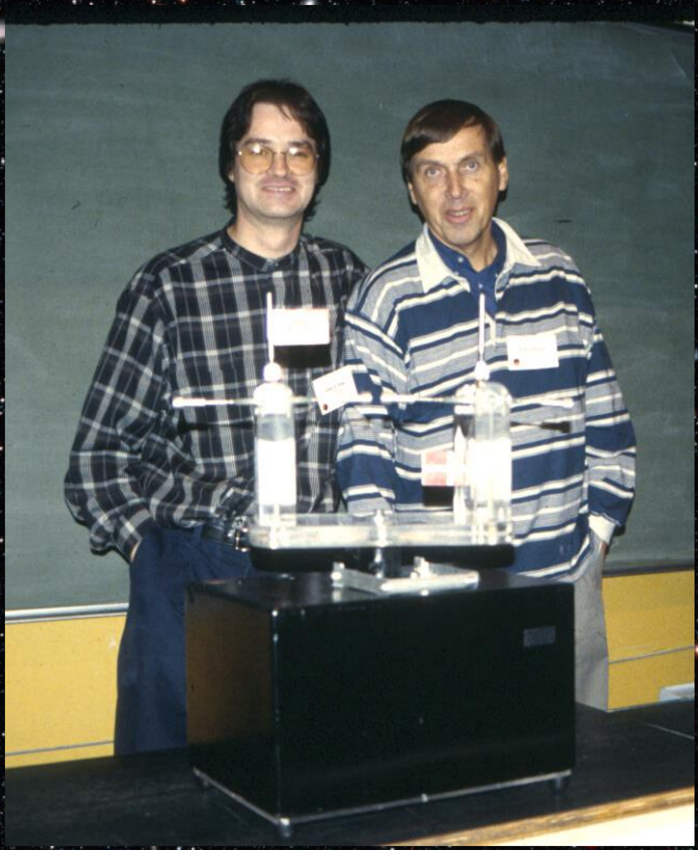
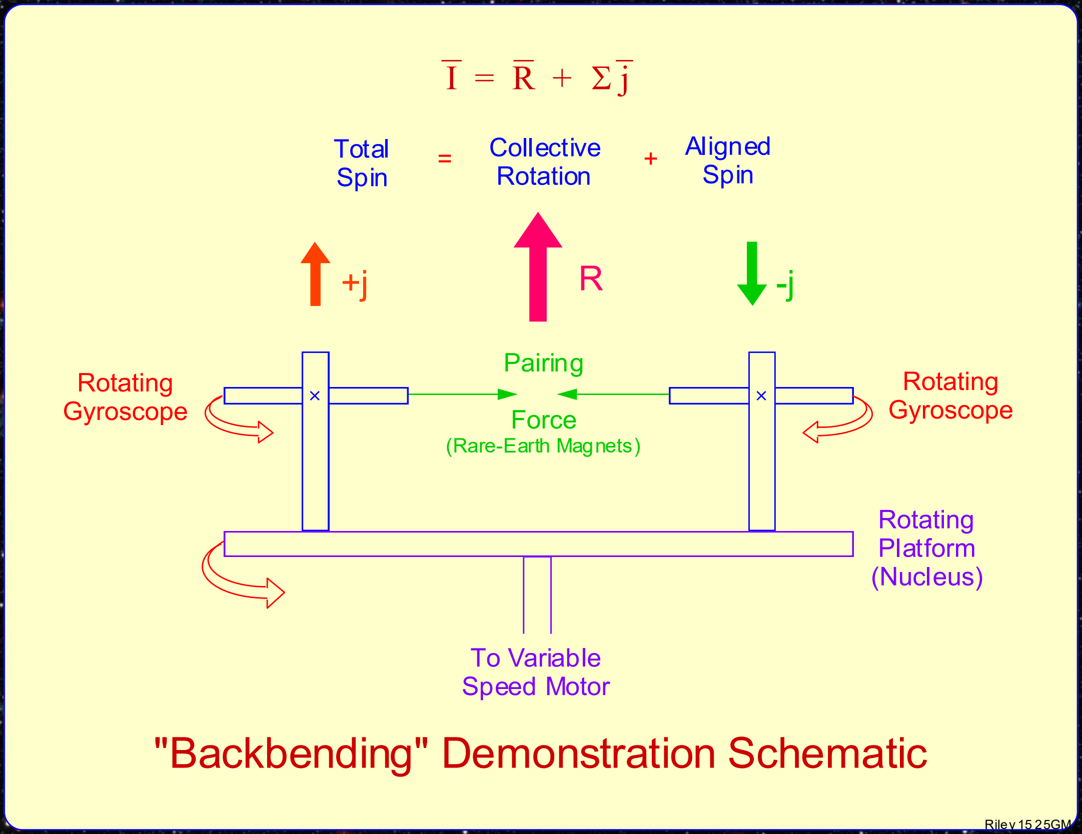


Fig. 6. Excitation energy versus angular momentum for a doubly even rotatior



The Backbender at NBI in 1997 with Arne.





- Available for download at www.physics.fsu.edu/TheBackBender

- Or via Open Access journal:
- Riley, Simpson & Paul, Phys. Scr. 91 (2016) 123002

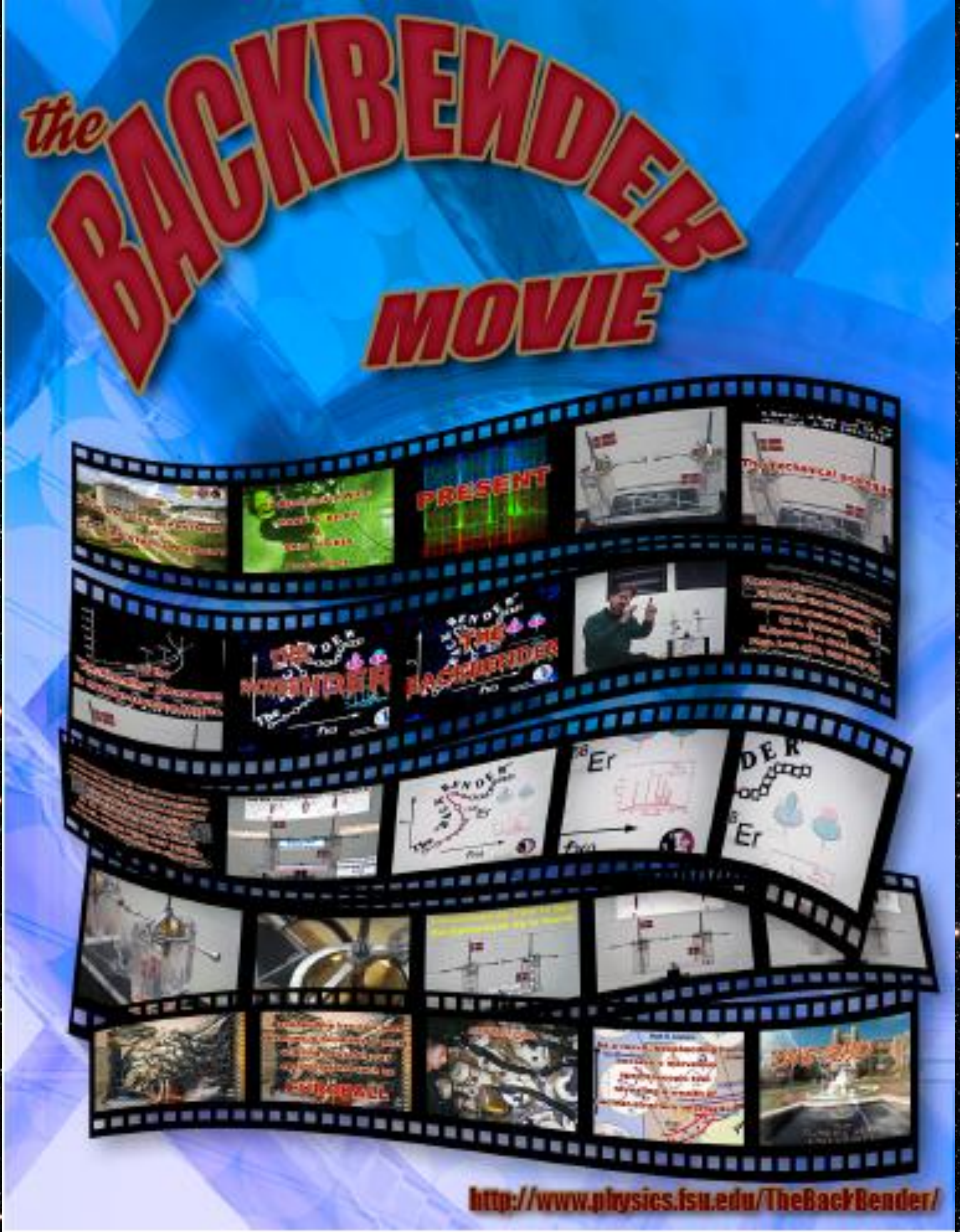


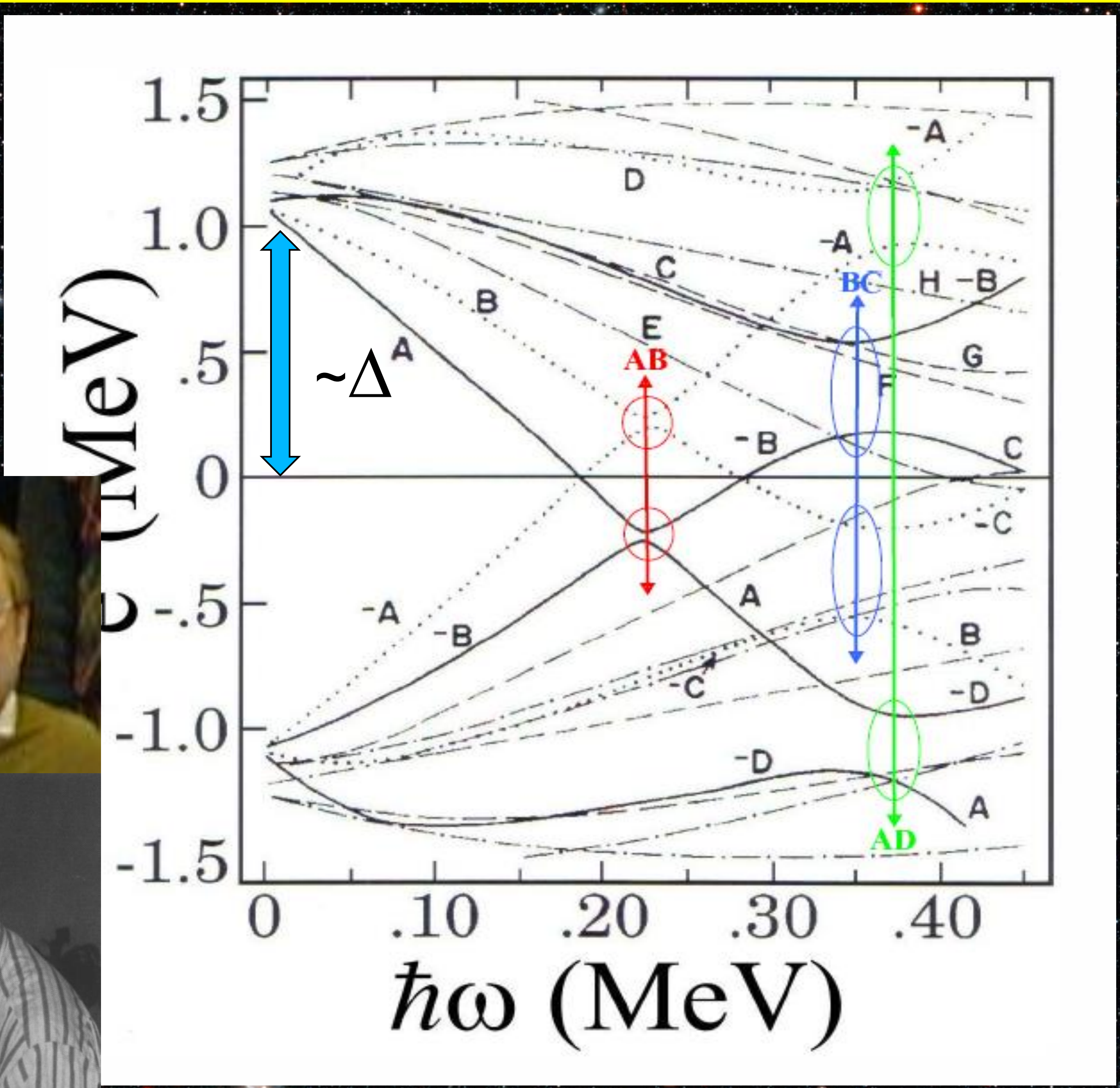
Fig. 14: A short movie about backbending or rotational alignment in nuclei [77] can be downloaded and viewed at http://www.physics.fsu.edu/TheBackBender [78]. It con-

Cranked Shell Model Quasi-particle diagram or Spagetti plot!

To understand BACKBENDING!

Bengtsson and Frauendorf also Dudek and Nazarewicz:

Lund, Rossendorf, Warsaw, NBI



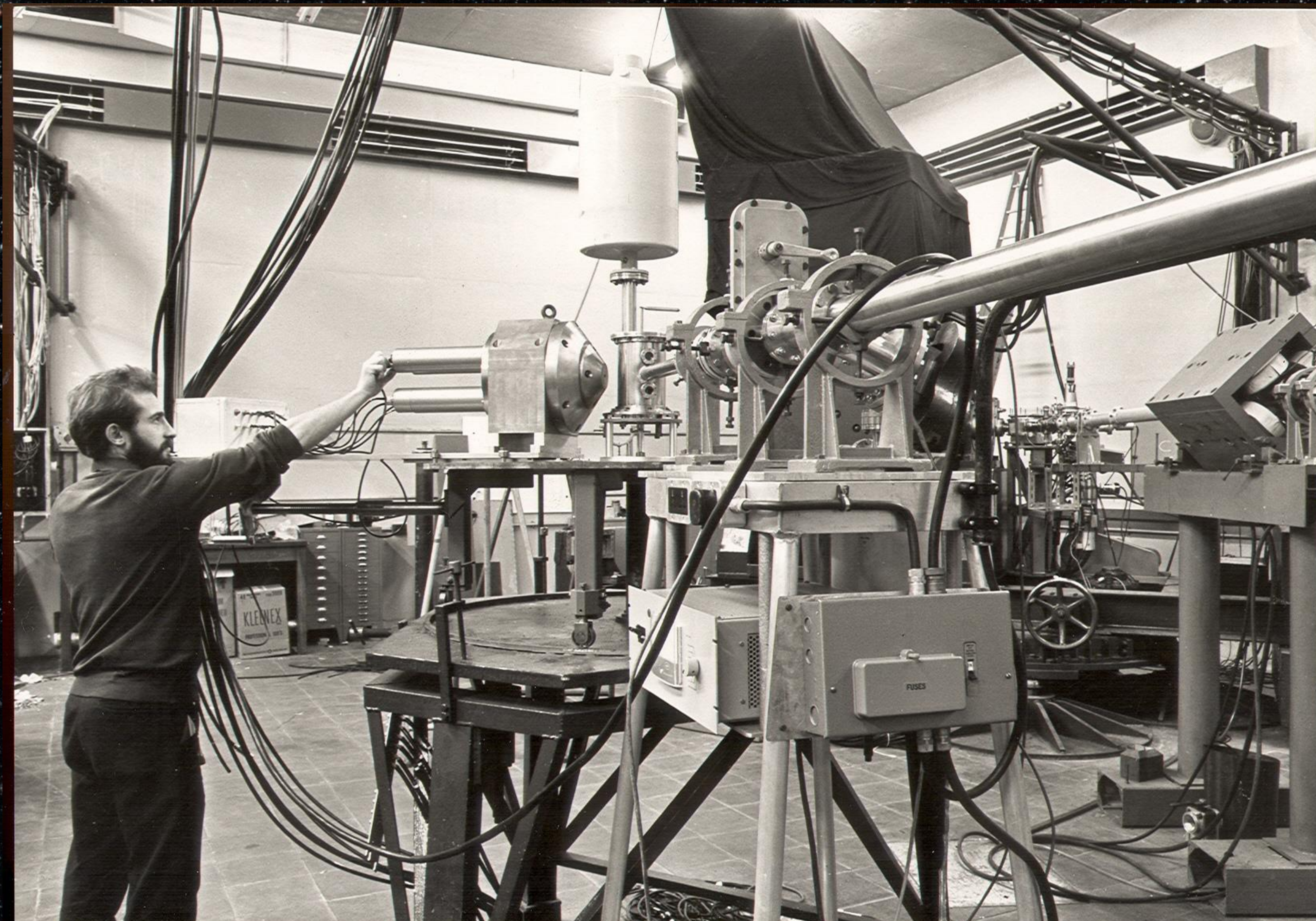
Al* Dudek at Daresbury for first time 1984 ☺

In **1984**, prominent Polish theoretical nuclear physicist **Jerzy Dudek** spent time as a visiting scientist collaborating with experimentalists at the **Nuclear Structure Facility (NSF)**

His visit coincided with a landmark period in nuclear physics history:

This collaborative bridge in 1984 between Dudek's structural calculations and Daresbury's high-resolution gamma-ray spectroscopy is **widely recognized as a foundational moment** that kicked off the global race to study superdeformed nuclei throughout the late 1980s.

Start of a Revolution: Late 70's early 80's
First Escape Suppressed Spectrometer at Liverpool



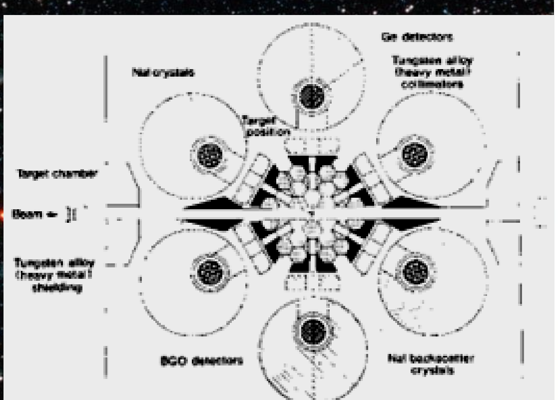
John Francis Sharpey-Schafer helped change everything!

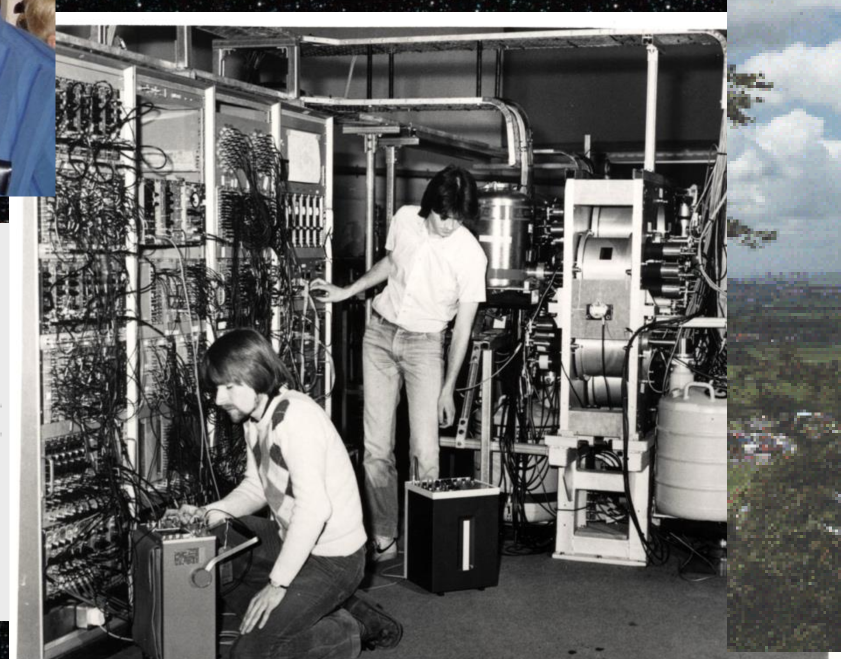
Start of a Revolution: Late 70's early 80's
First Escape Suppressed Spectrometer at Liverpool

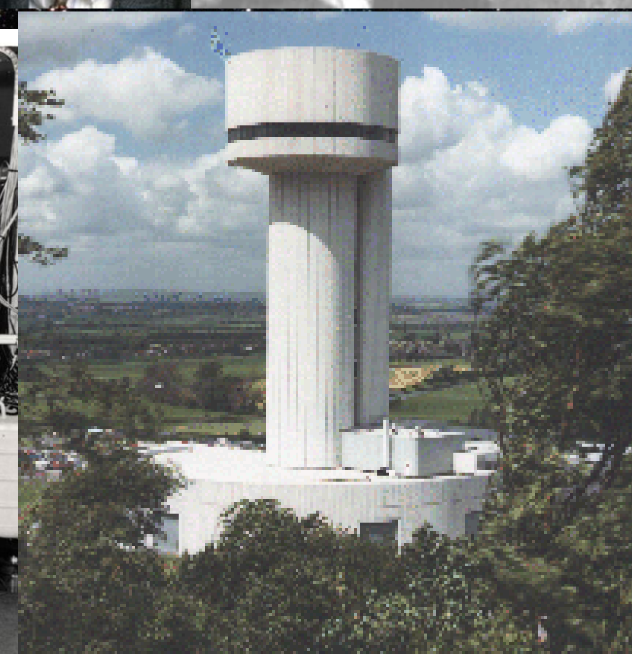
John Francis Sharpey-Schafer helped change everything!

First experiments at Daresbury, Er-158 and Dy-152, proposed Sharpey-Schafer and Twin

1983 (Liverpool + NBI)
TESSA2
6 ESS + 50 element BGO ball
Plus a ^{48}Ca beam!

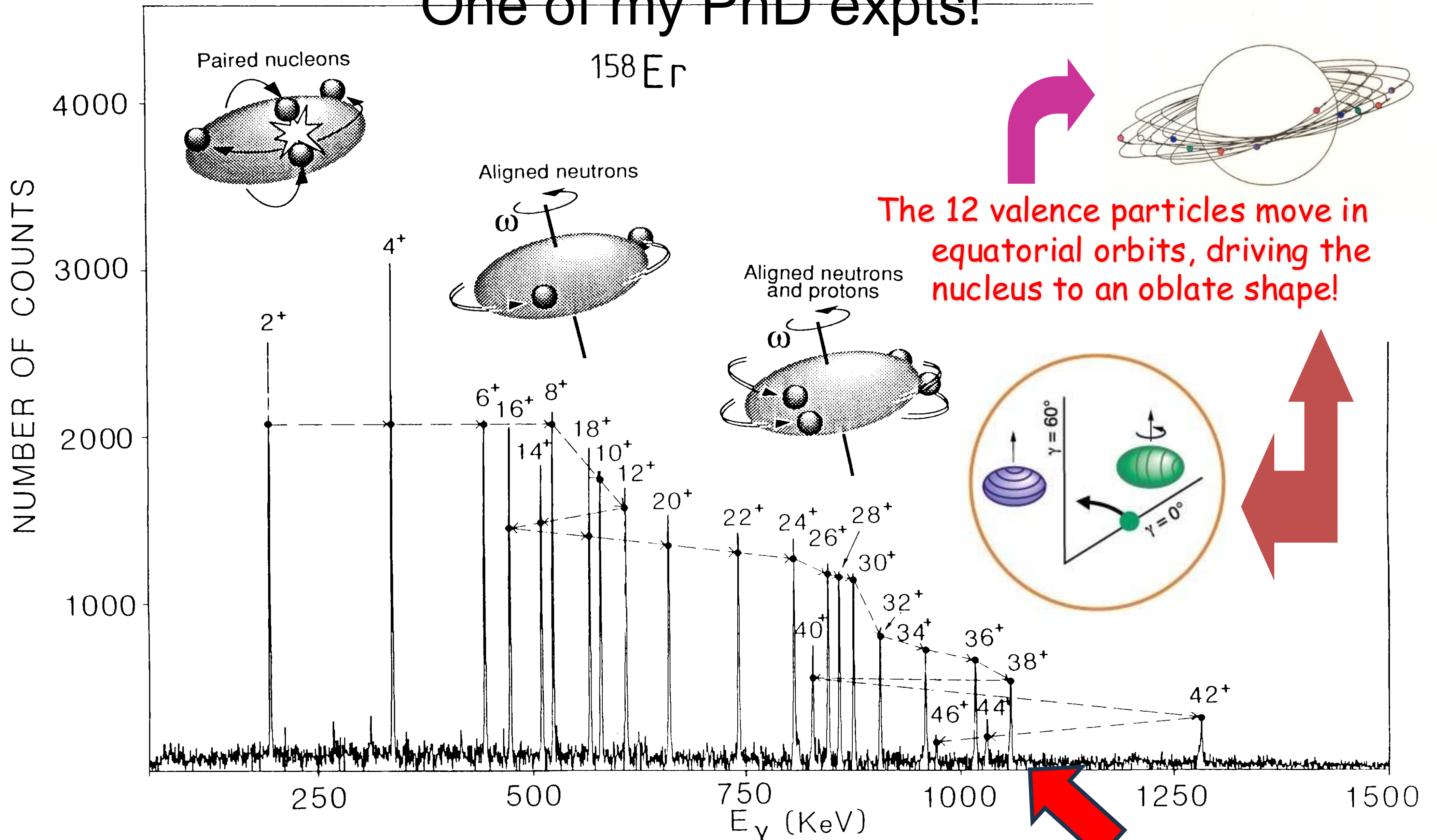






^{158}Er expt at Daresbury -Sharpey-Schafer et al - Mid-80's

One of my PhD expts!



The 12 valence particles move in equatorial orbits, driving the nucleus to an oblate shape!

Simpson, Riley, JFSS et al., Phys. Rev. Lett. (1984) – prolate-oblate shape change
LBL group, P.O.Tjom et al., PRL 55 (1985) 2405 – beautiful lifetime measurements

^{158}Er expt at Daresbury - Sharpey-Schafer/Riley/Simpson/Mid-80's

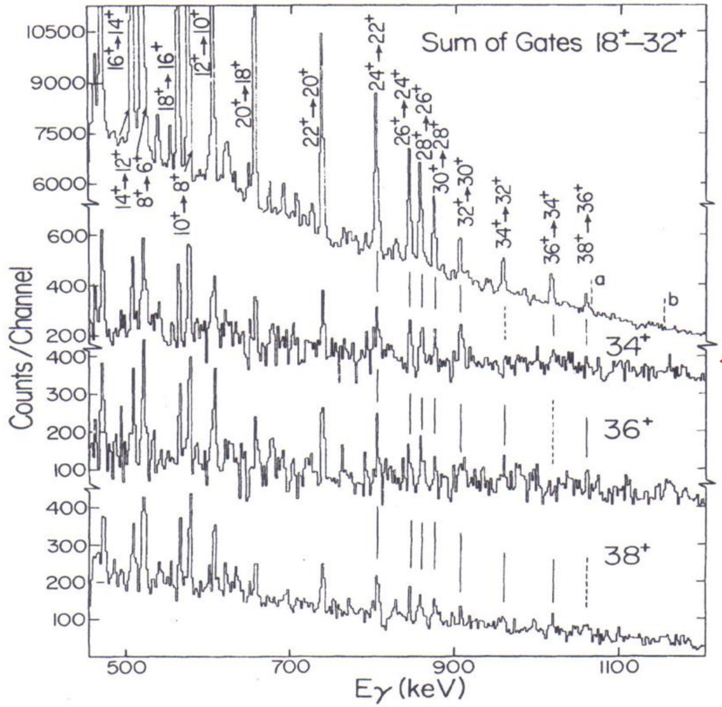
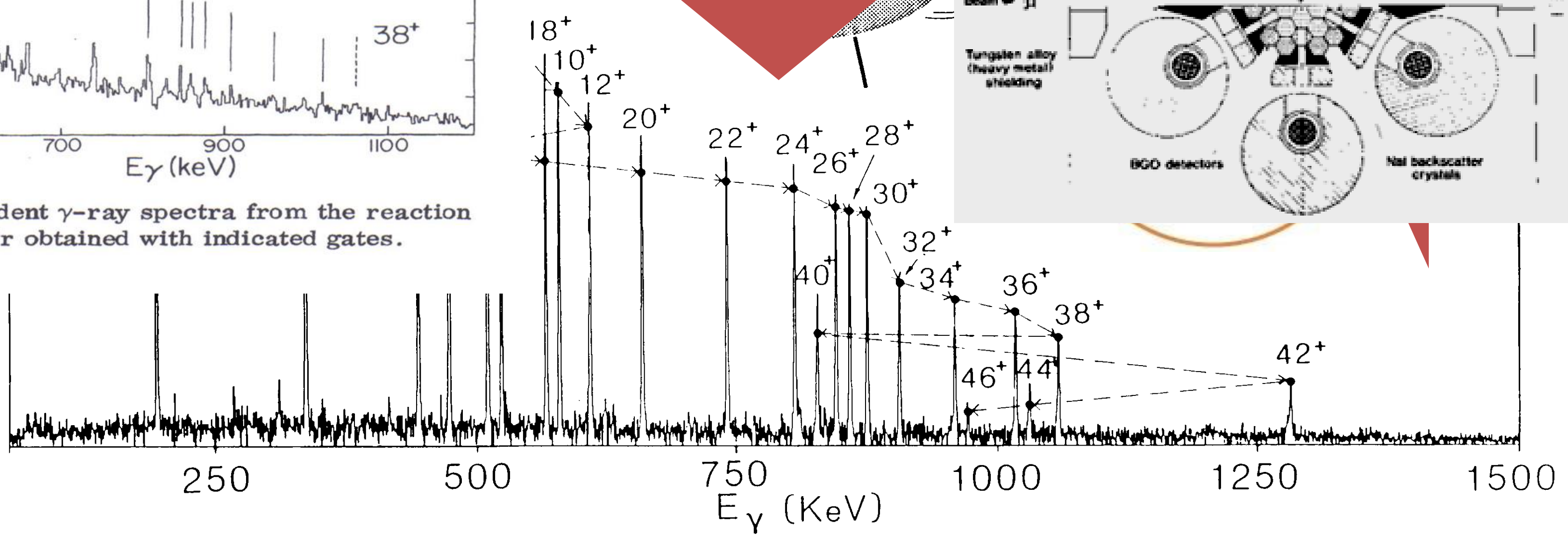
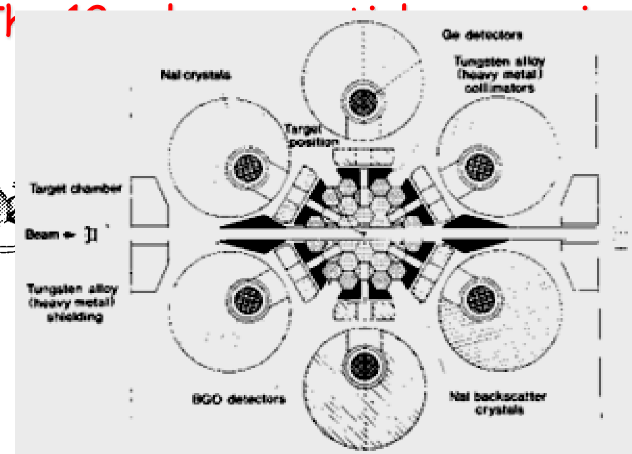


FIG. 1. Coincident γ-ray spectra from the reaction ^{122}Sn(^{40}Ar, 4n)^{158}Er obtained with indicated gates.

^{158}Er

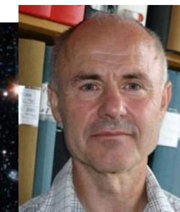
The Compton Suppression Revolution!!!





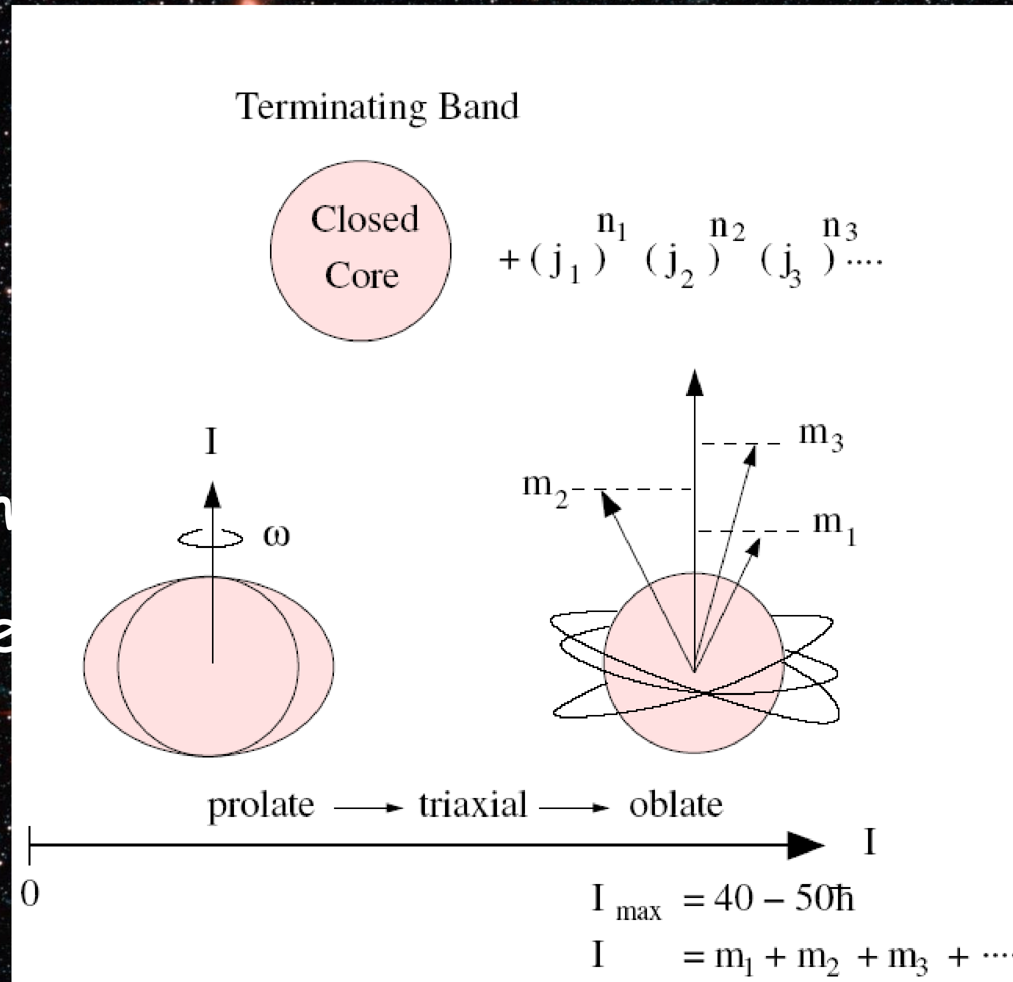
(keV)

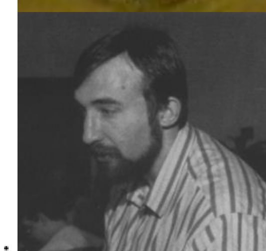
Simpson et al., Phys. Rev. Lett. (1984) - prolate-oblate shape change
LBL group, P.O.Tjom et al., PRL 55 (1985) 2405 - beautiful lifetime measurements
T.Bengtsson and I.Ragnarsson, Physica Scripta T5 (1983) 165
Ragnarsson, Xing, Bengtsson and Riley, Phys. Scripta 34 (1986) 651



1980's Band Termination near N = 90

- Band termination occurs when the valence nucleons outside ^{146}Gd core are fully aligned with the axis of rotation.
- In these rare-earth nuclei a prolate to oblate shape change occurs.
- Beautiful work at ANL with ^{154}Dy, ORNL too on ^{158}Yb and LBL on $^{156,158}Er$.





T.Bengtsson and I.Ragnarsson, Physica Scripta T5 (1983) 165

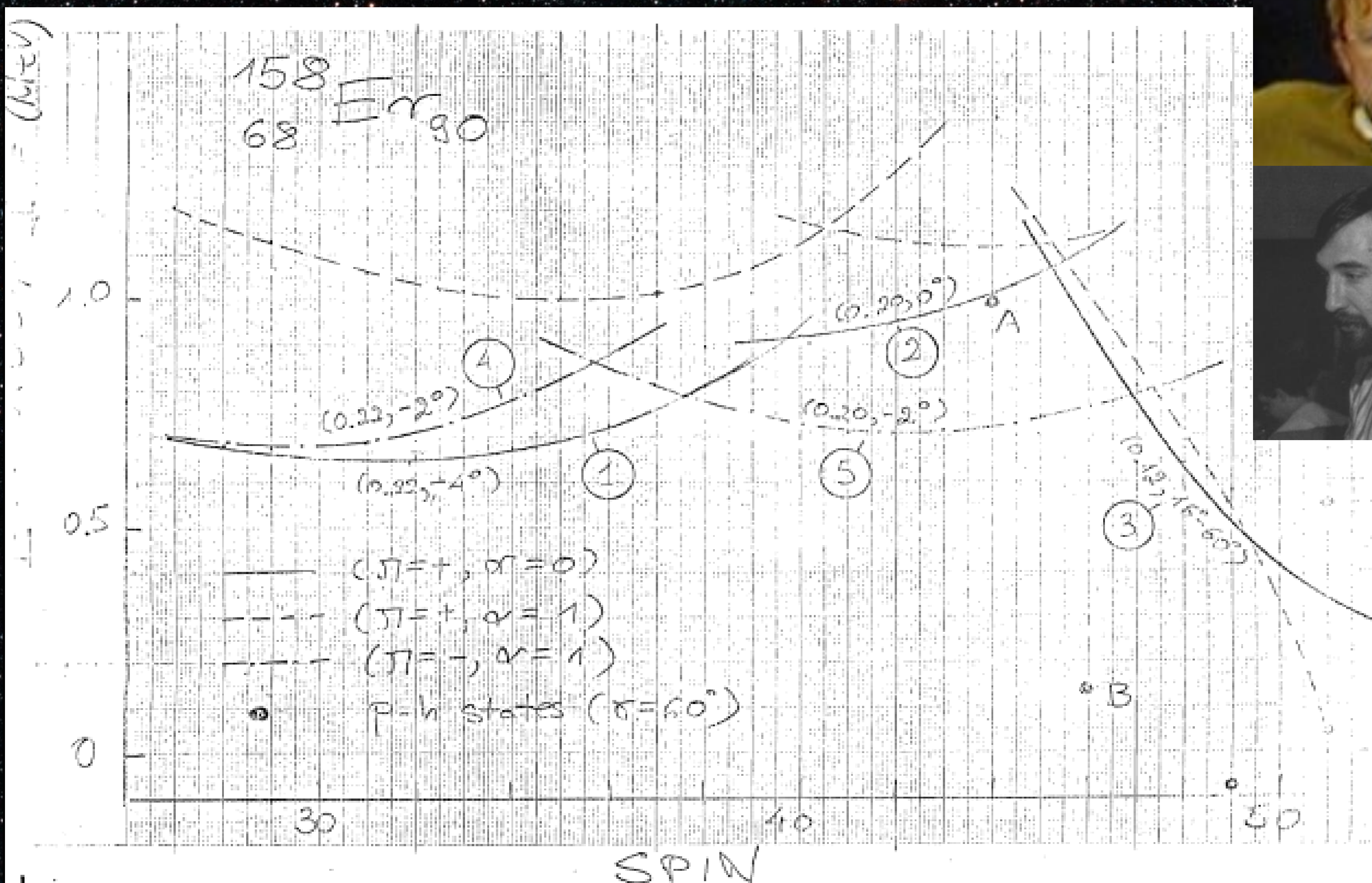
I. Ragnarsson, T. Bengtsson, W. Nazarewicz, J. Dudek, and G. A. Leander; PRL 54, (1985) 982

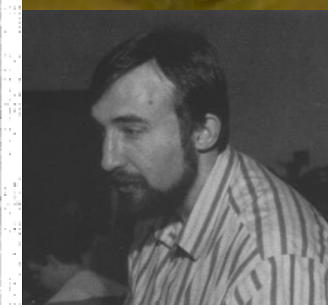
I. Ragnarsson, T. Xing, T. Bengtsson and M.A. Riley, Phys. Scripta 34 (1986) 651.

Early 1985: Witek and Jerzy remind me that fabulous calculations on ^{158}Er come from Poland too!

Original hand drawings for the famous 1985 article

Phys. Rev. C31 (1985) 298 *** more of this paper later ***





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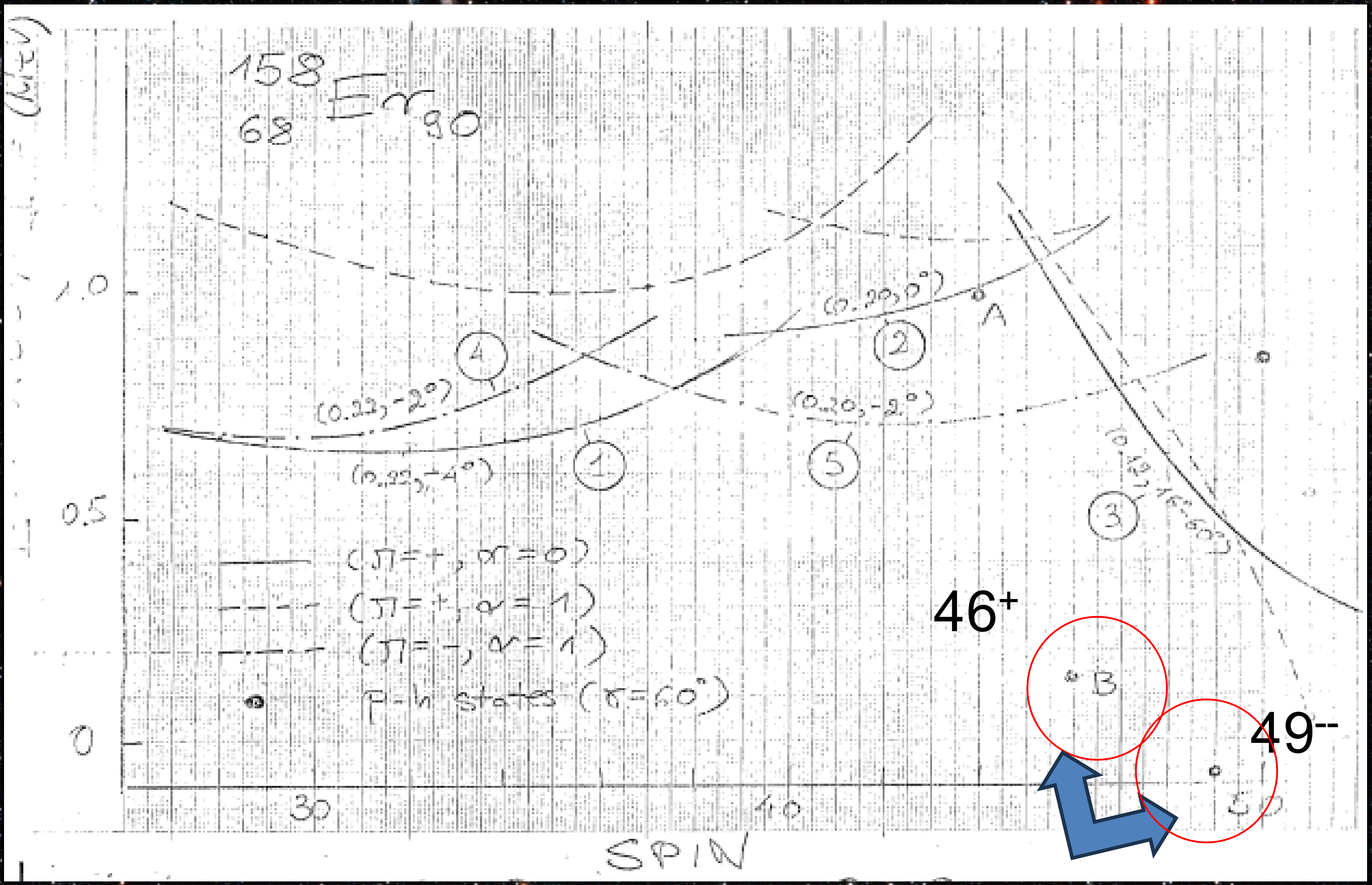
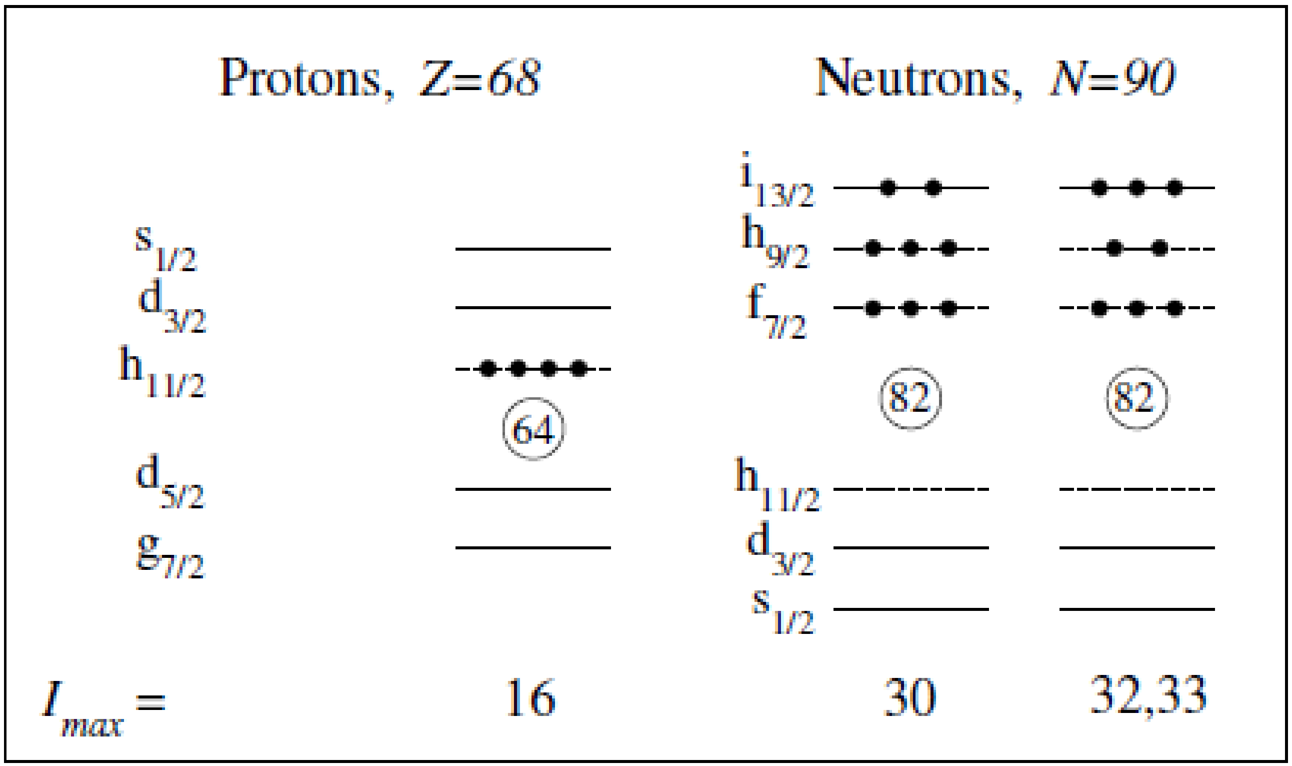
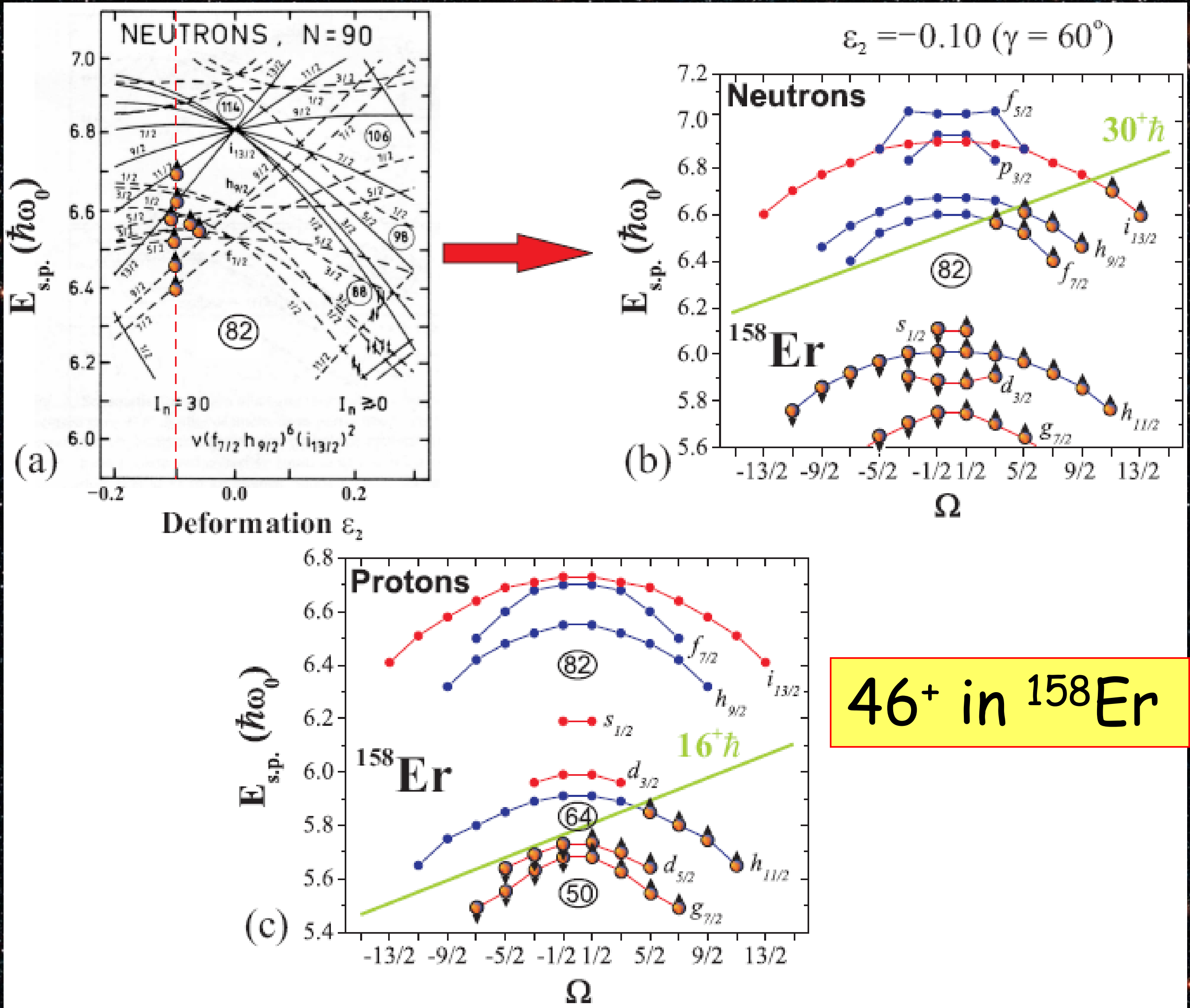


^{158}Er: Filled orbitals relative to ^{146}Gd core.

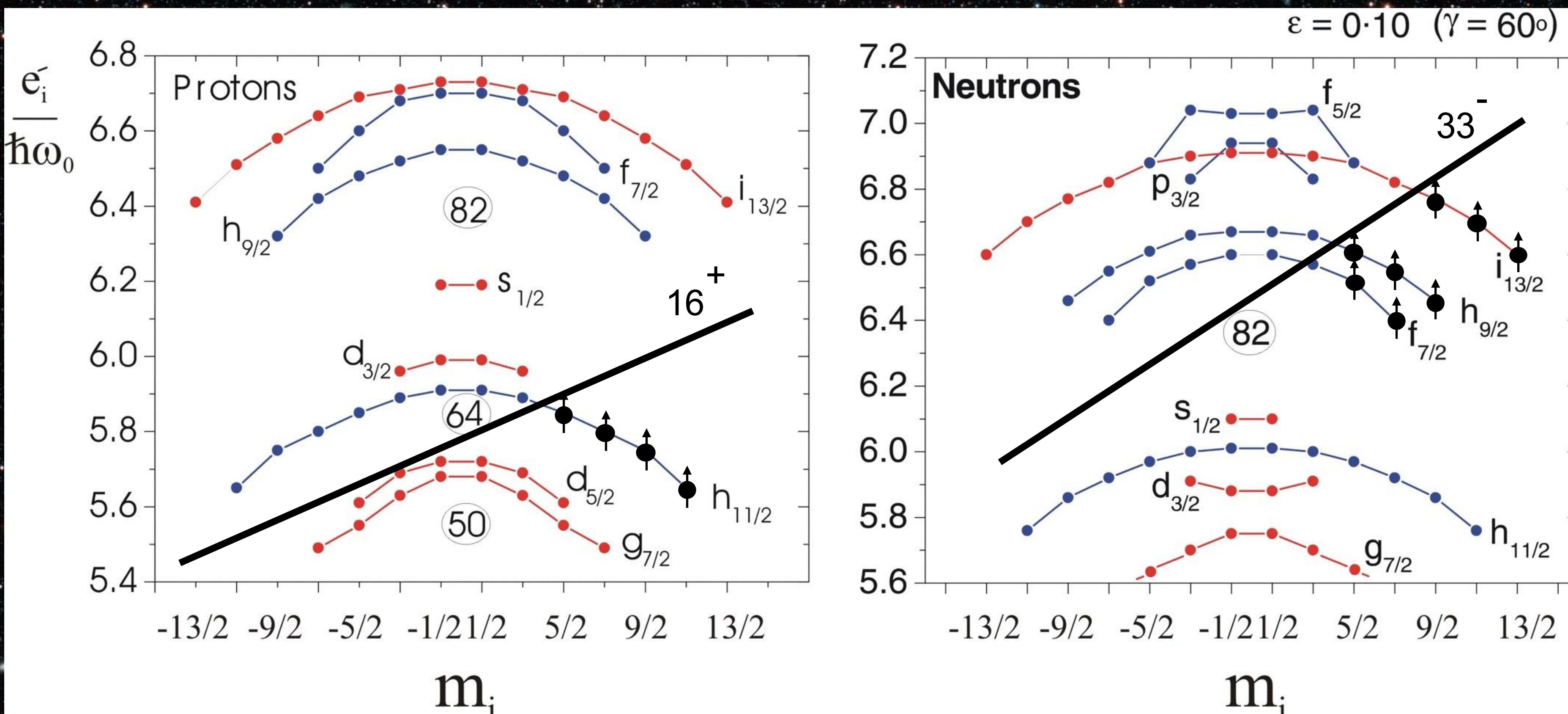


Titled Fermi Surfaces – Used to great effect in late 70's by Dudek and Warsaw/Lund collaboration group in explaining high spin yrast traps in rare-earth nuclei



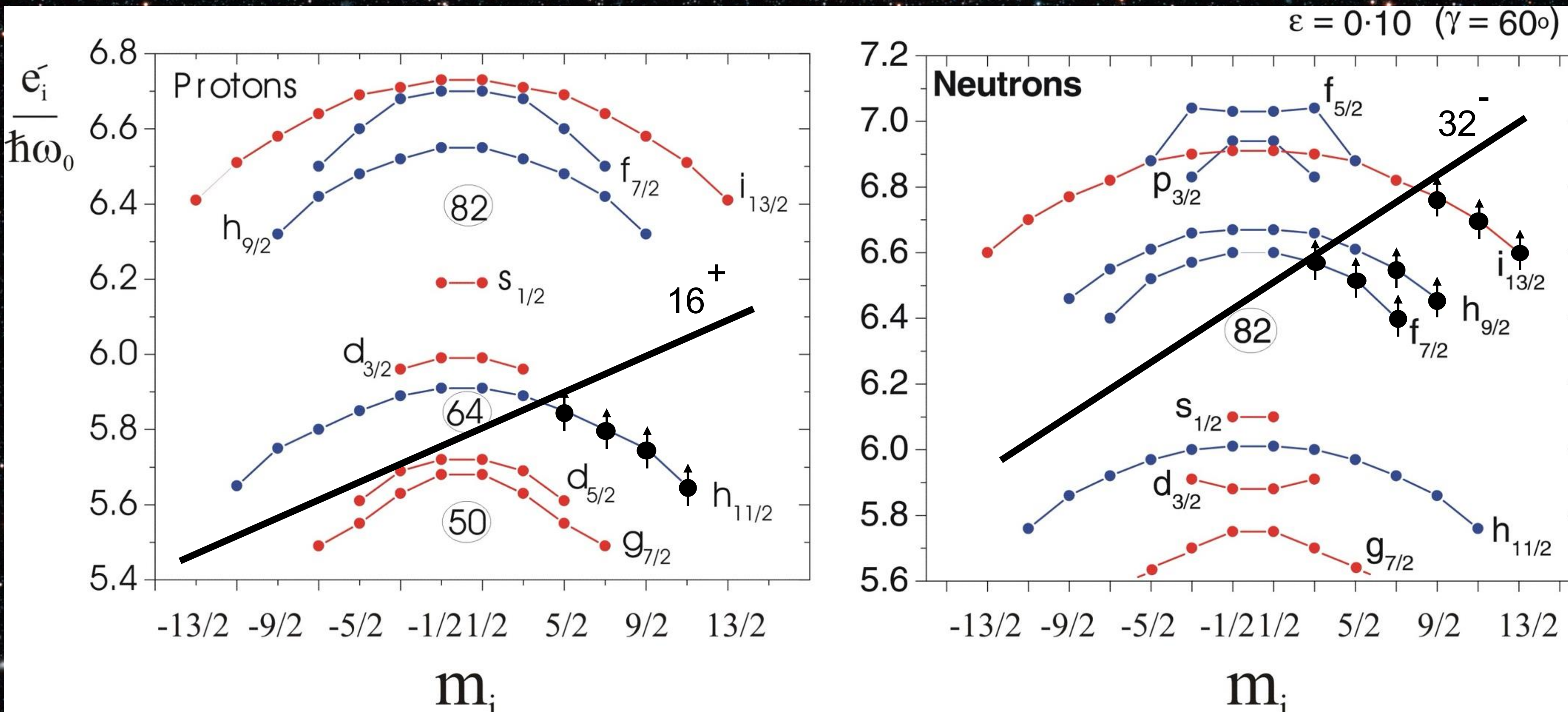
46^+ in ^{158}Er

Favored BT States and the Tilted Fermi Surface Method. Predicted Negative parity states. e.g. 49^- (-,1)



$\pi[(h_{11/2})^4]_{16+} \otimes \nu[(h_{9/2}, f_{7/2})^5 (i_{13/2})^3]_{33-}$

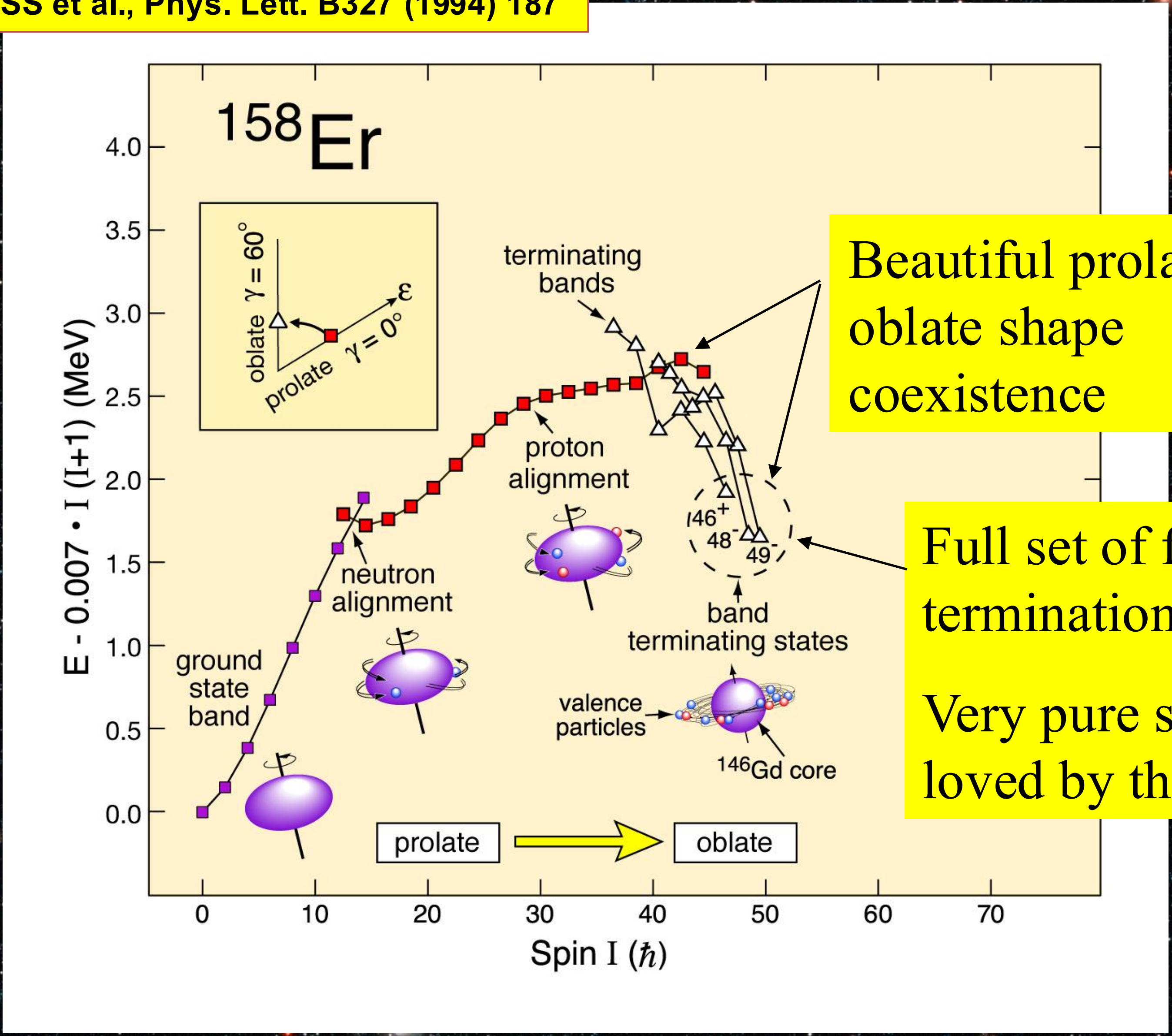
Favored BT States and the Tilted Fermi Surface Method. Predicted Negative parity states. e.g. 48^- (-,1)



$\pi[(h_{11/2})^4]_{16+} \otimes \nu[(h_{9/2}, f_{7/2})^5 (i_{13/2})^3]_{32-}$

10 years later (1994)
- ^{158}Er again at Daresbury but now with EUROGAM (37 ESS)

Simpson, Riley, JFSS et al., Phys. Lett. B327 (1994) 187



Beautiful prolate – oblate shape coexistence

Full set of favored terminations!

Very pure states – loved by theorists

Warsaw Group and K Conservation and Selection Rule ☺

- Dudek or Jurek
- Witek
- Jacek
- Marek
- Wojtek

While at Daresbury (84/85), Dudek (and Nazarewicz in Lund) created seminal systematic predictions of high-spin shape evolution of rare-earth nuclei

PHYSICAL REVIEW C VOLUME 31, NUMBER 1 JANUARY 1985

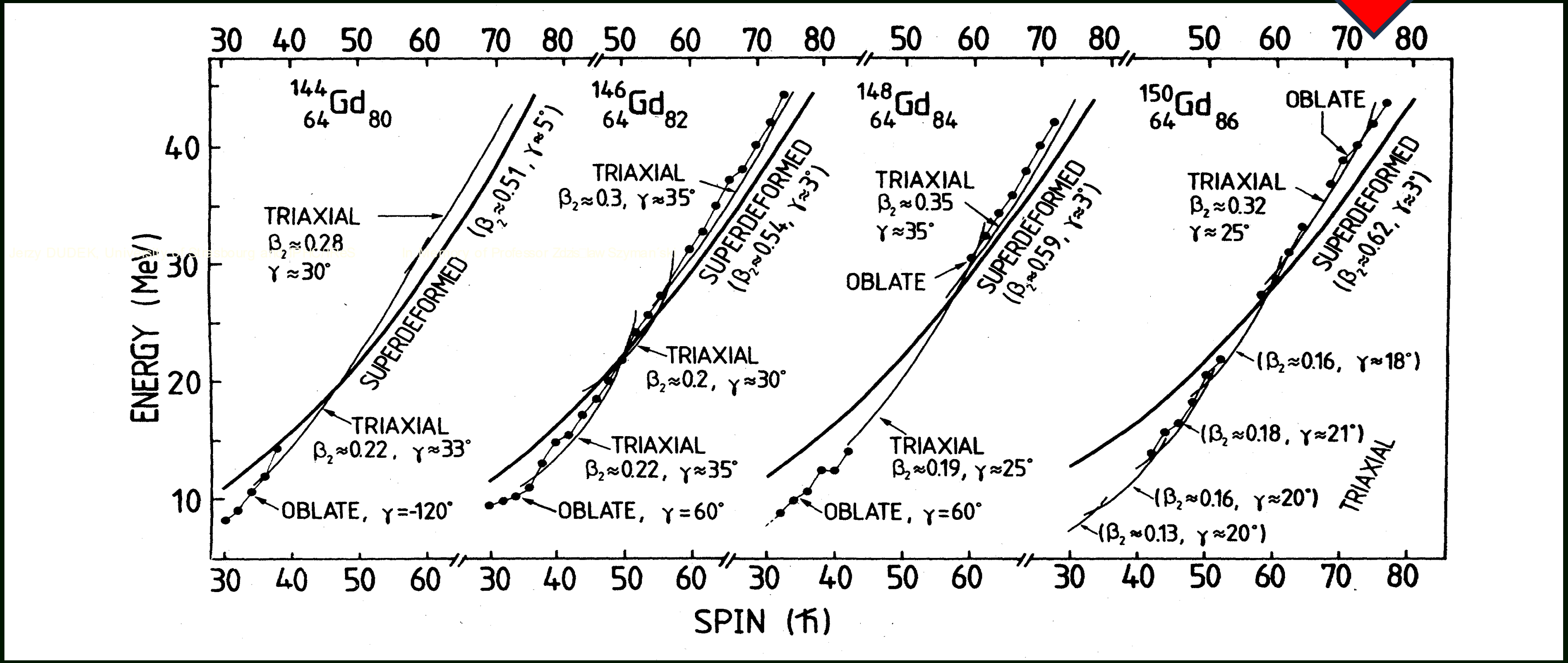
Shape evolution in the transitional gadolinium, dysprosium, erbium, and ytterbium nuclei

J. Dudek
Centre de Recherches Nucl´eaires, F-67037 Strasbourg Cedex, France

W. Nazarewicz*
Department of Mathematical Physics, Lund Institute of Technology S-22007
Lund, Sweden
(Received 25 June 1984)

Shape evolution in $I \geq 30\,\hbar$ high-spin states of $^{144-150}$Gd, $^{150-156}$Dy, $^{152-158}$Er and $^{154-160}$Yb is predicted theoretically within the cranking approximation using the generalised Strutinsky method. A comparison with available experimental data is provided.

Idea for Paul Fallon's thesis expt in late 80's



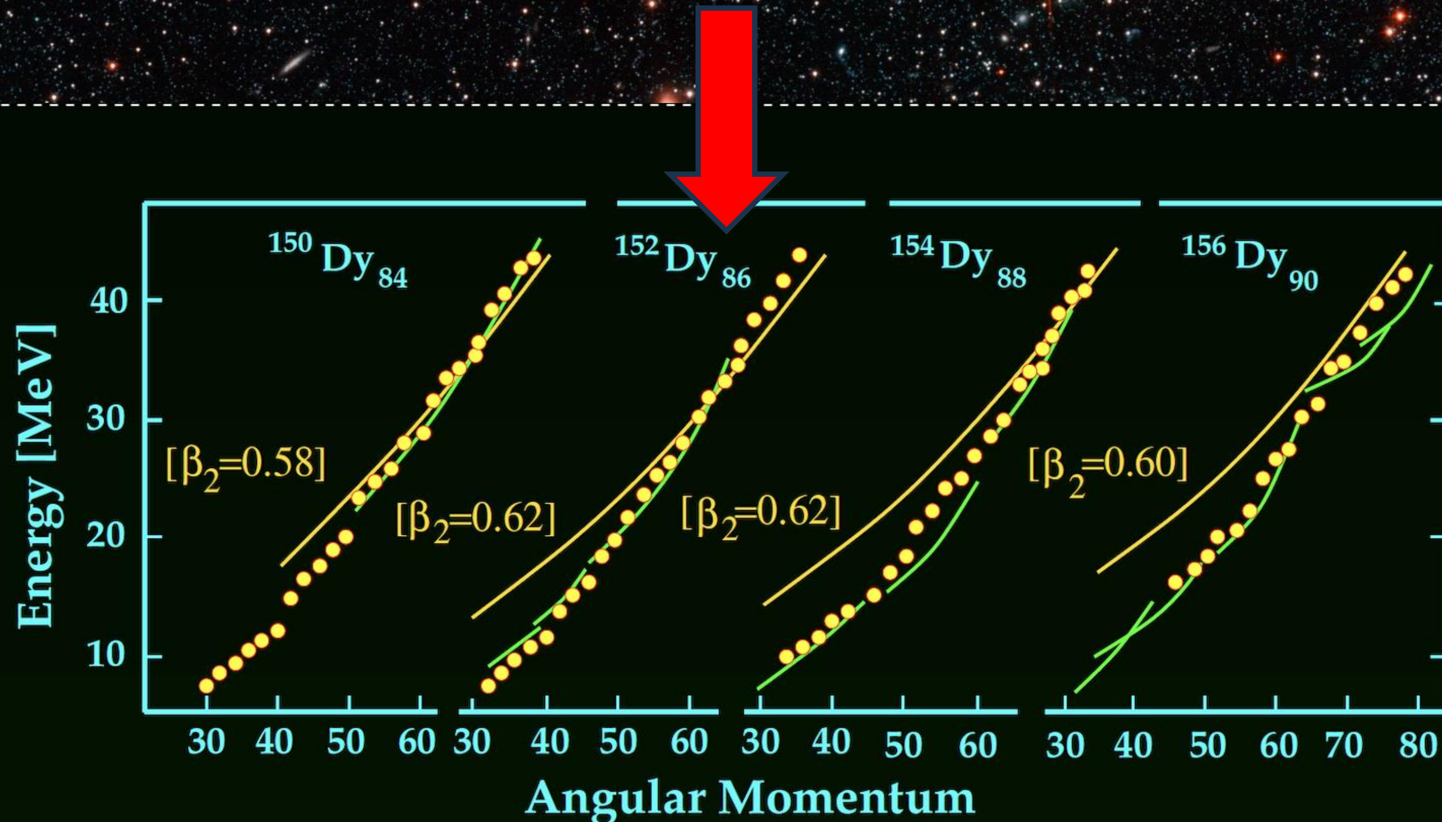
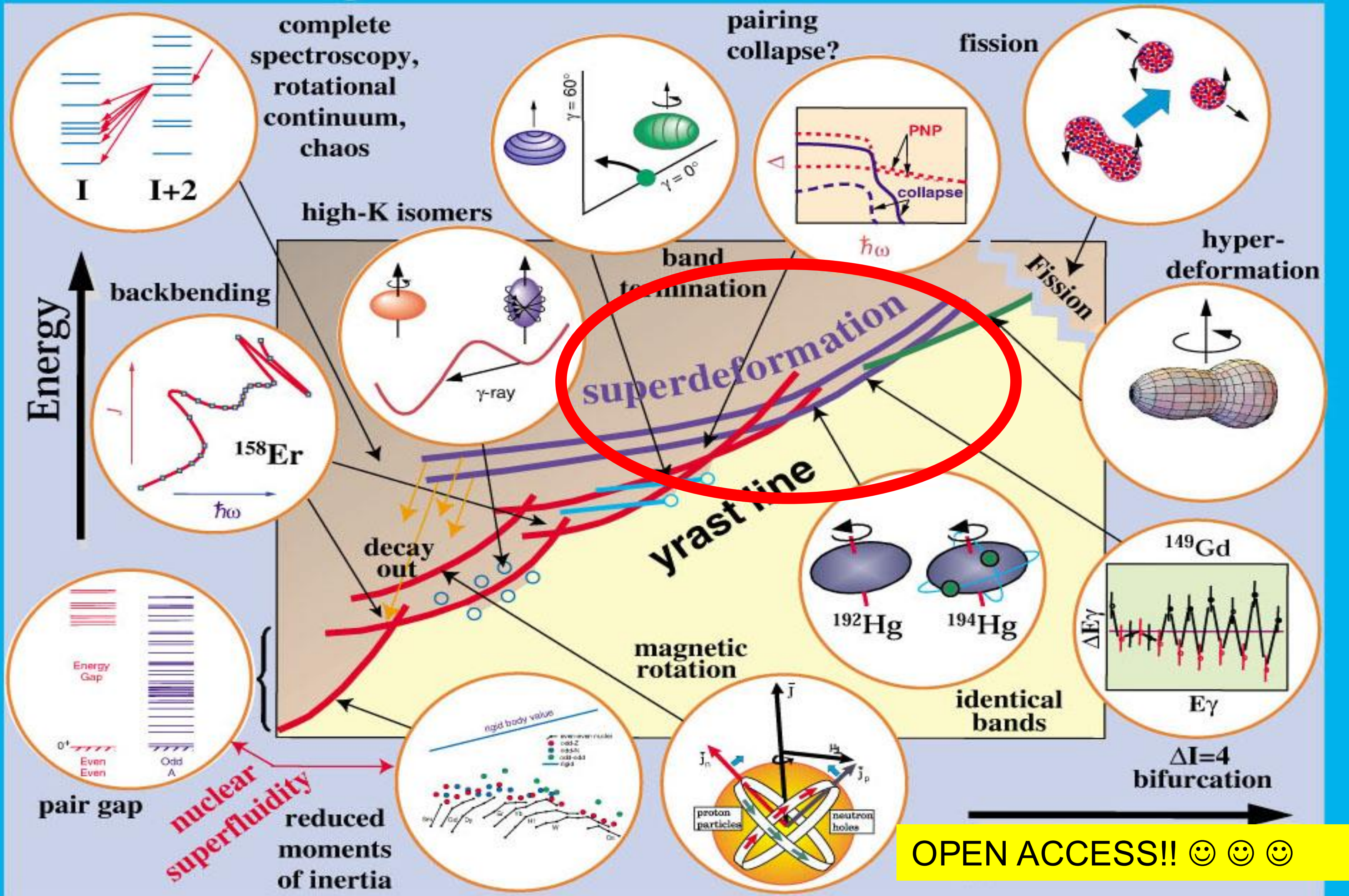


Figure: *Predicted competition between the super-deformed, together with normal-deformed (in particular triaxial) and non-collective states, the latter marked with circles.*

SUPERDEFORMATION!

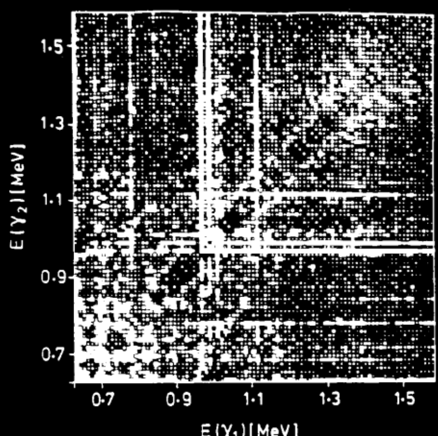
The Angular Momentum World of the Nucleus



Riley, Simpson & Paul, Phys. Scr. 91 (2016) 123002

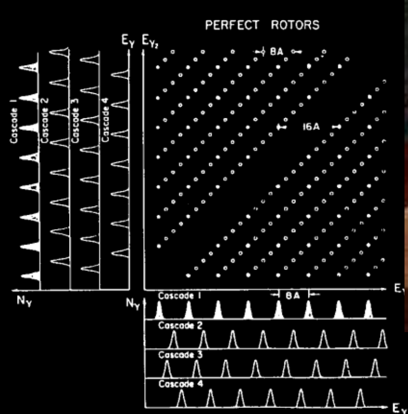
Most Famous Rotational Structure EVER!

Superdeformed Band in ^{152}Dy: (Twin, Nyako, JFSS et al)



The γ-ray energy correlation spectrum of $E_{\gamma 1}$ against $E_{\gamma 2}$ for ^{152}Dy obtained using TESSA2. The horizontal and vertical stripes are discrete γ-rays below spin 40ħ. The superdeformed structure is identified by the two parallel ridges close to the $E_{\gamma 1} = E_{\gamma 2}$ 45° diagonal.

Exptal data: Note the diagonal "ridge" structure expected for a highly collective rotor, Nyako et al. PRL (1984)



VOLUME 52, NUMBER 7 PHYSICAL REVIEW LETTERS 13 FEBRUARY 1984

Observation of Superdeformation in ^{152}Dy

B. M. Nyakó,[a] J. R. Cresswell, P. D. Forsyth, D. Howe, P. J. Nolan, M. A. Riley, J. F. Sharpey-Schafer, J. Simpson, and N. J. Ward
Oliver Lodge Laboratory, The University of Liverpool, Liverpool L69 3BX, United Kingdom

and

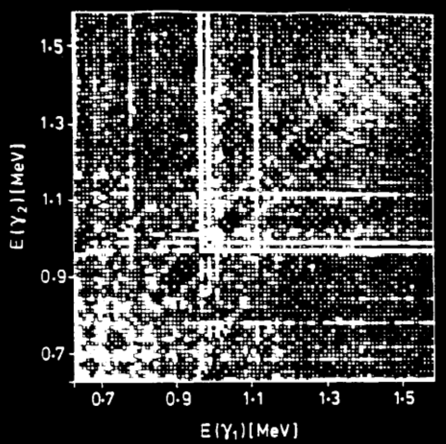
P. J. Twin
Science and Engineering Research Council, Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

(Received 15 November 1983)

High-resolution, low-background, two-dimensional γ-ray energy correlations $E(\gamma_1)$ vs $E(\gamma_2)$ have been measured at high spin in ^{152}Dy with the spectrometer TESSA2. Ridges characteristic of rotational behavior are observed for γ-ray energies $0.8 \leq E(\gamma) \leq 1.35$ MeV. The separation of the ridges gives a dynamical moment of inertia $\mathscr{I}_{band}^{(2)} = (85 \pm 2)\hbar^2$ MeV^{-1} indicating a quadrupole deformation of $\epsilon \approx 0.51$ for a rigid body assuming $\gamma = 0$.

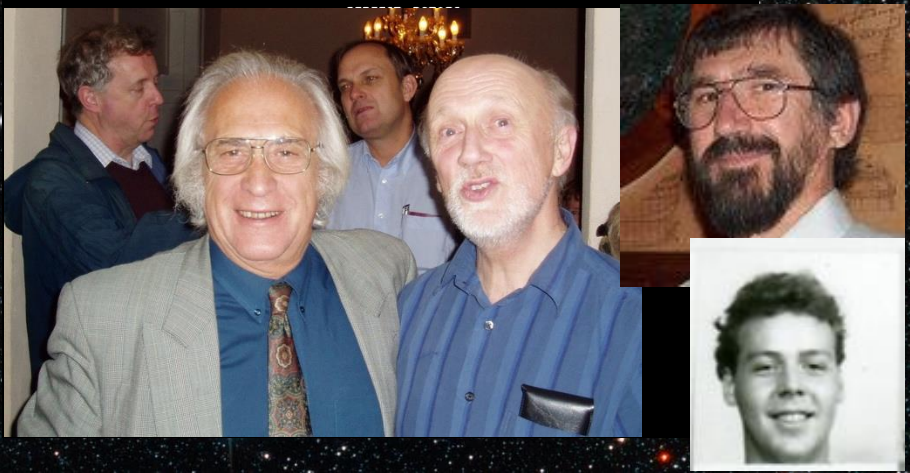
Most Famous Rotational Structure EVER! Superdeformed Band in ^{152}Dy: (Twin, Nyako, JFSS, Bentley et al)

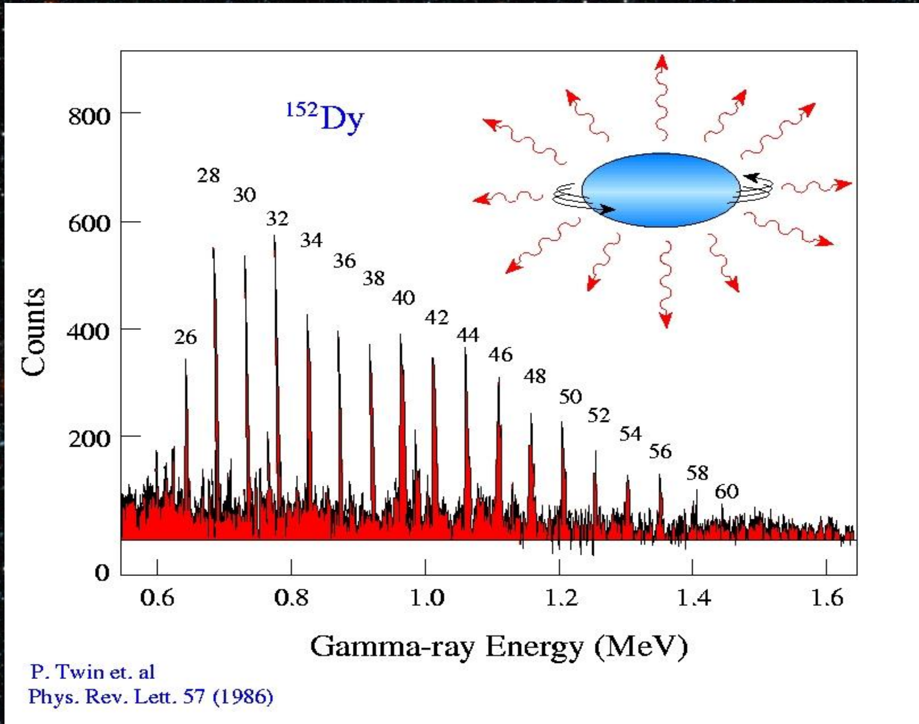
Exptal data: Note the diagonal "ridge" structure expected for a highly collective rotor, Nyako et al. PRL (1984)



The γ-ray energy correlation spectrum of $E_{\gamma 1}$ against $E_{\gamma 2}$ for ^{152}Dy obtained using TESSA2. The horizontal and vertical stripes are discrete γ-rays below spin 40ħ. The superdeformed structure is identified by the two parallel ridges close to the $E_{\gamma 1} = E_{\gamma 2}$ 45° diagonal.

Then 2 years later (after detector upgrade TESSA3) the first discrete high-spin SD band revealed itself to the human race!





Most Famous Rotational Structure EVER! Superdeformed Band in ^{152}Dy: (Twin, Nyako, JFSS, Bentley et al)

VOLUME 59, NUMBER 19 PHYSICAL REVIEW LETTERS 9 NOVEMBER 1987

Intrinsic Quadrupole Moment of the Superdeformed Band in ^{152}Dy

M. A. Bentley, G. C. Ball,[a] H. W. Cranmer-Gordon, P. D. Forsyth, D. Howe, A. R. Mokhtar, J. D. Morrison, and J. F. Sharpey-Schafer
Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 3BX, United Kingdom

P. J. Twin, B. Fant,[b] C. A. Kalfas,[c] A. H. Nelson, and J. Simpson
Science and Engineering Research Council, Daresbury Laboratory, Daresbury, Warrington WA4 4AD, United Kingdom

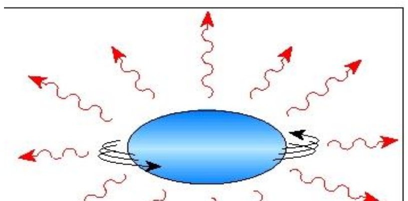
and

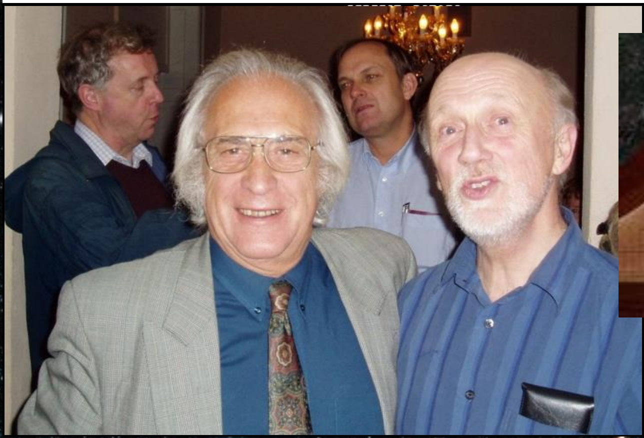
G. Sletten
Niels Bohr Institutet, DK-4000 Roskilde, Denmark

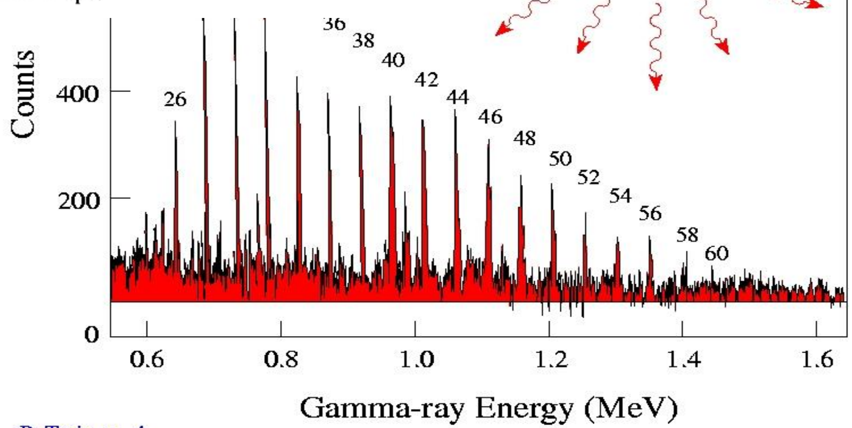
Q_0=19 +/- 3 e.b

(Received 9 February 1987; revised manuscript received 3 June 1987)

The attenuation of the Doppler shift has been measured for γ rays emitted from the superdeformed states in the nucleus ^{152}Dy, recoiling in a ^{108}Pd target and its gold backing. The transitions from the high-spin members of the superdeformed band are fully shifted, indicating feeding times of not more than a few femtoseconds. The partially shifted low-spin transitions yield a quadrupole moment of $19 \pm 3\ e \cdot b$, in excellent agreement with the value expected for a superdeformed shape.

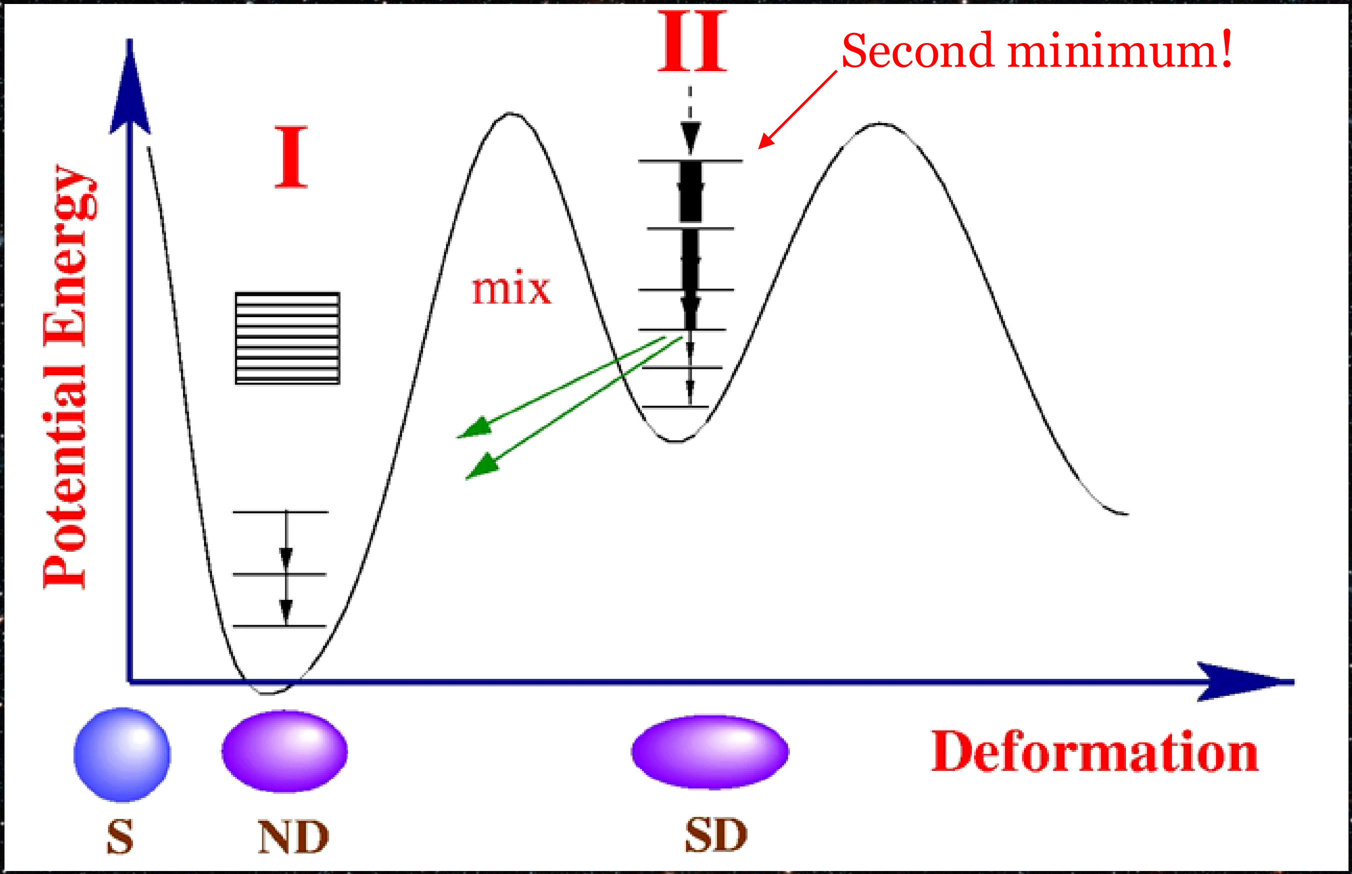






P. Twin et. al
Phys. Rev. Lett. 57 (1986)

The Nucleus at Extreme Deformation



Second minimum in the nuclear potential energy!

Extremely deformed nucleus - 2:1 prolate (football shaped)

Let us investigate this brave new world! Surprises galore!!

Nuclear Superdeformation – A Major Discovery

"Top unexpected physics discoveries of the last five years!"

PHYSICS TODAY December 1991

Daniel Kleppner
Lester Wolfe Professor
of Physics at MIT

High temperature superconductivity

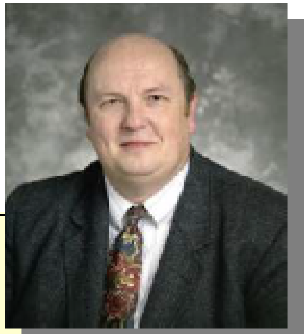
Atom cooling and atom optics

Large-scale structure of the universe

Supernova 1987A

Superdeformed nuclei

Buckyballs



J. Garrett
"Superdeformation - Nuclear Physics' Supernova"

B. Mottelson
…one of Nuclear Structures finest hours ..

Slide stolen from Paul Fallon

J. Phys. G: Nucl. Part. Phys. 17 (1991) 481–510. Printed in the UK

Gamma-ray spectroscopy of superdeformed states nucleus ^{152}Dy

M A Bentley†, A Alderson‡, G C Ball§, H W Cranmer-
P Fallon‡, B Fant||, P D Forsyth‡, B Herskind¶, D How
C A Kalfas*, A R Mokhtar‡, J D Morrison‡○, A H Nels
B M Nyakó#, K Schiffer¶□, J F Sharpey-Schafer‡, J Sim
G Sletten¶ and P J Twin‡

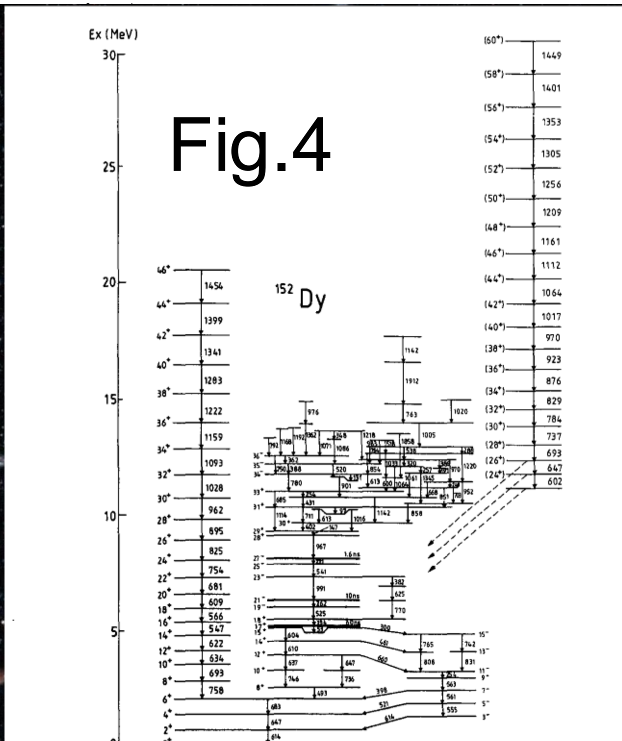
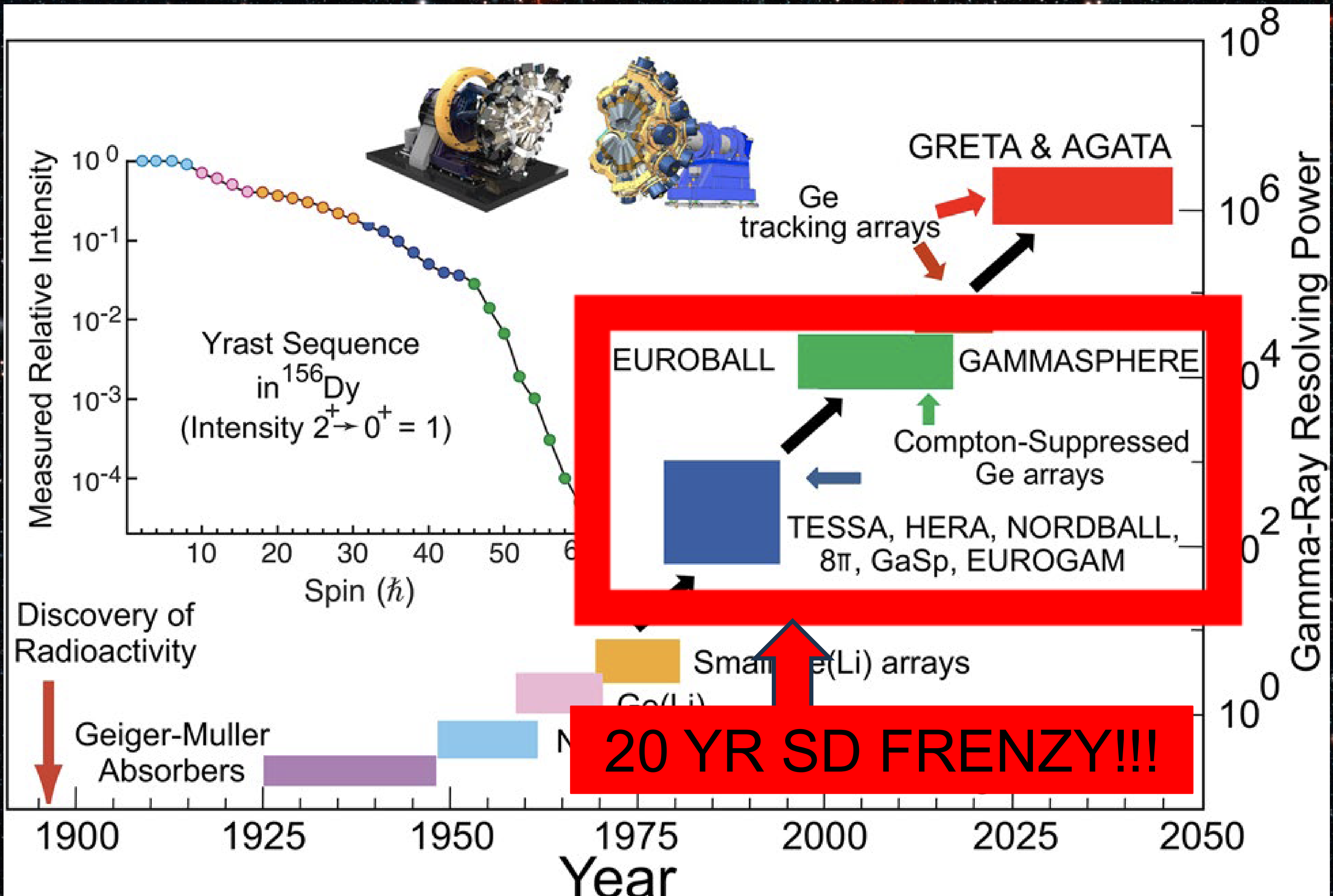


Figure 4. The ^{152}Dy decay scheme showing the coexistence of three distinct structures. On the left-hand side, a prolate rotational band is built on the ground-state band (Nyakó *et al* 1986) with a low deformation ($\beta_2 \sim 0.3$, $\gamma \sim 25°$). In the centre of the level scheme, an oblate single particle structure is shown ($\beta_2 \sim 0.1$, $\gamma = 60°$) up to spins $\geqslant 36\hbar$ (Howe 1986). On the right-hand side is the superdeformed band ($\beta_2 \sim 0.6$, $\gamma = 0°$) extending up to a spin of $60\hbar$. (The values of β_2 and γ are taken from Dudek 1987.) The link between this band and the known scheme is not observed.

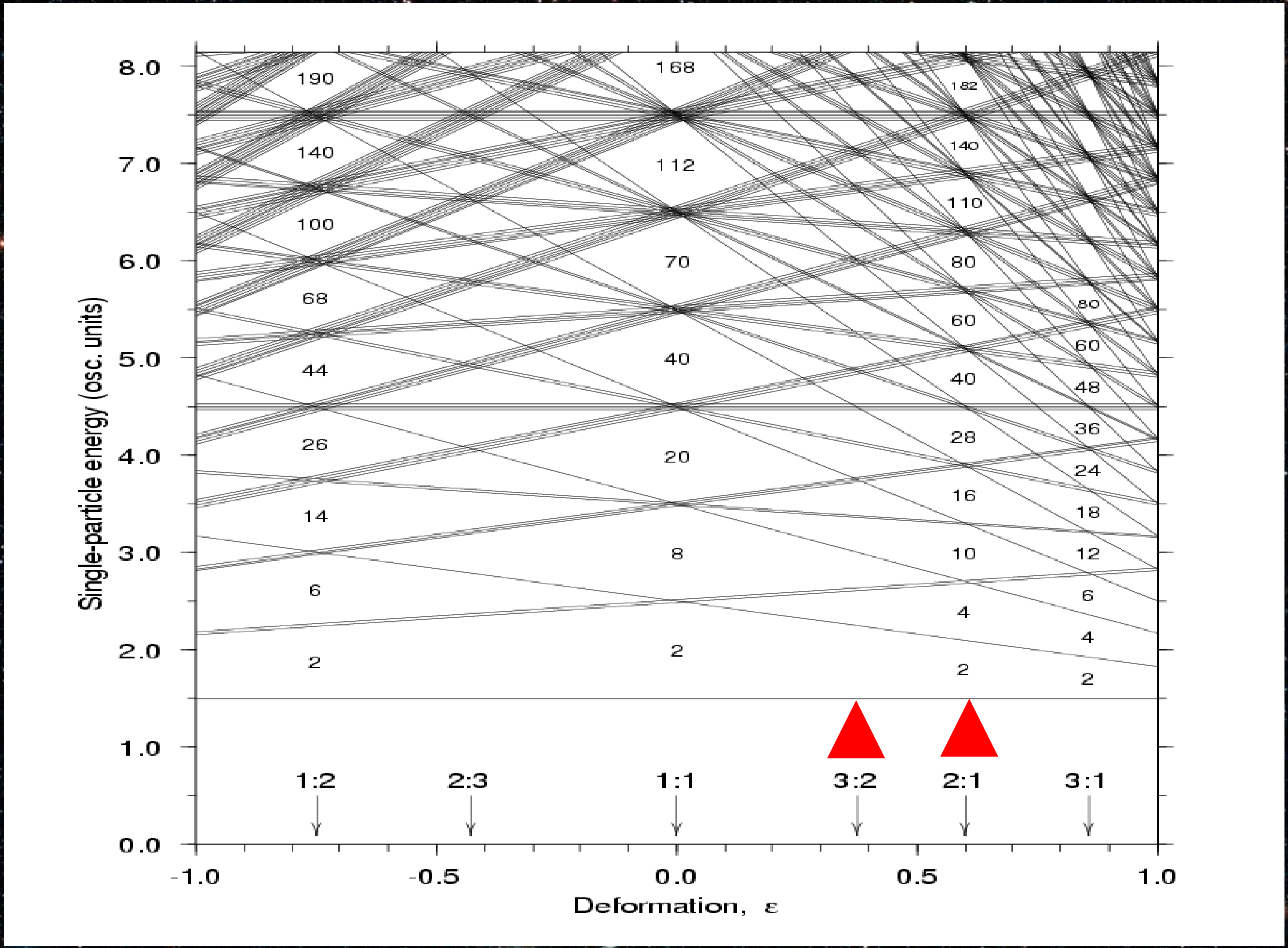


Evolution of detector systems ☺

Wyss & Riley, Nuc. Phys. News Vol.32, No.2,2022

(with brilliant help from John Simpson and Augusto Macchiavelli)

Nuclear Superdeformation

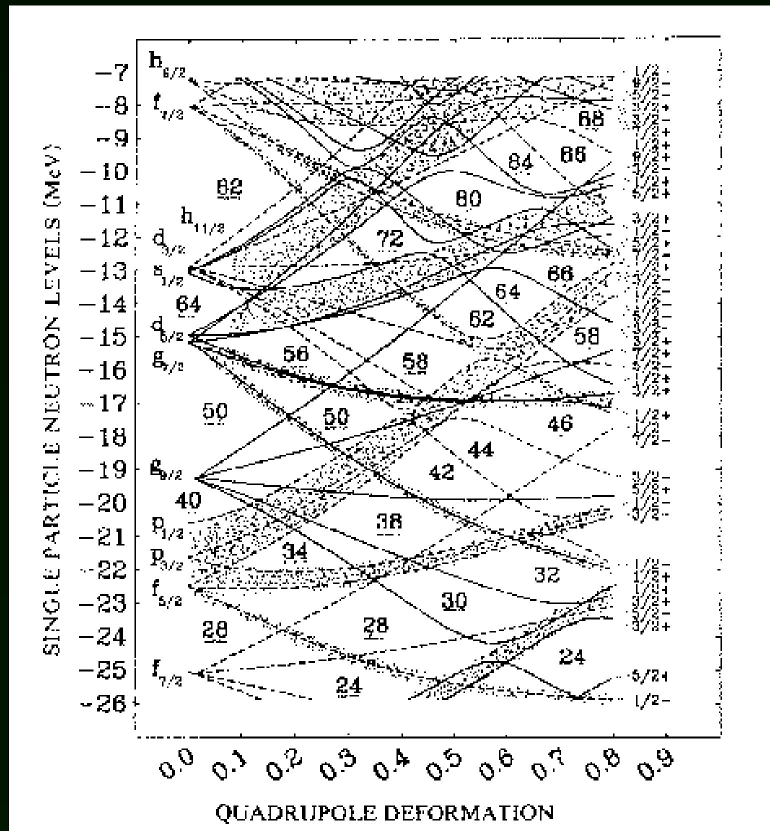


Harmonic oscillator

VOLUME 57, No. 7 PHYSICAL REVIEW LETTERS SEPTEMBER 1987

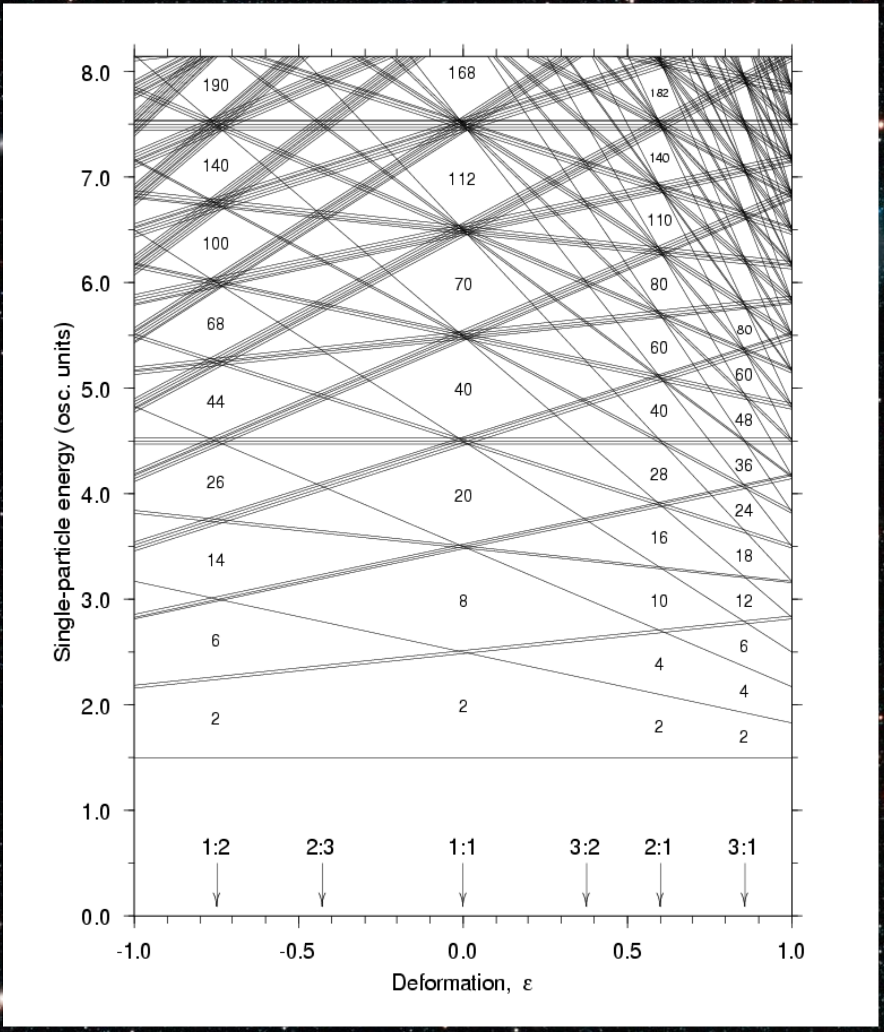
Abundance and systematics of nuclear superdeformed states; relation to the pseudospin and pseudo-SU(3) symmetries

J. Dudek, W. Nazarewicz, Z. Szymański, and G. A. Leander

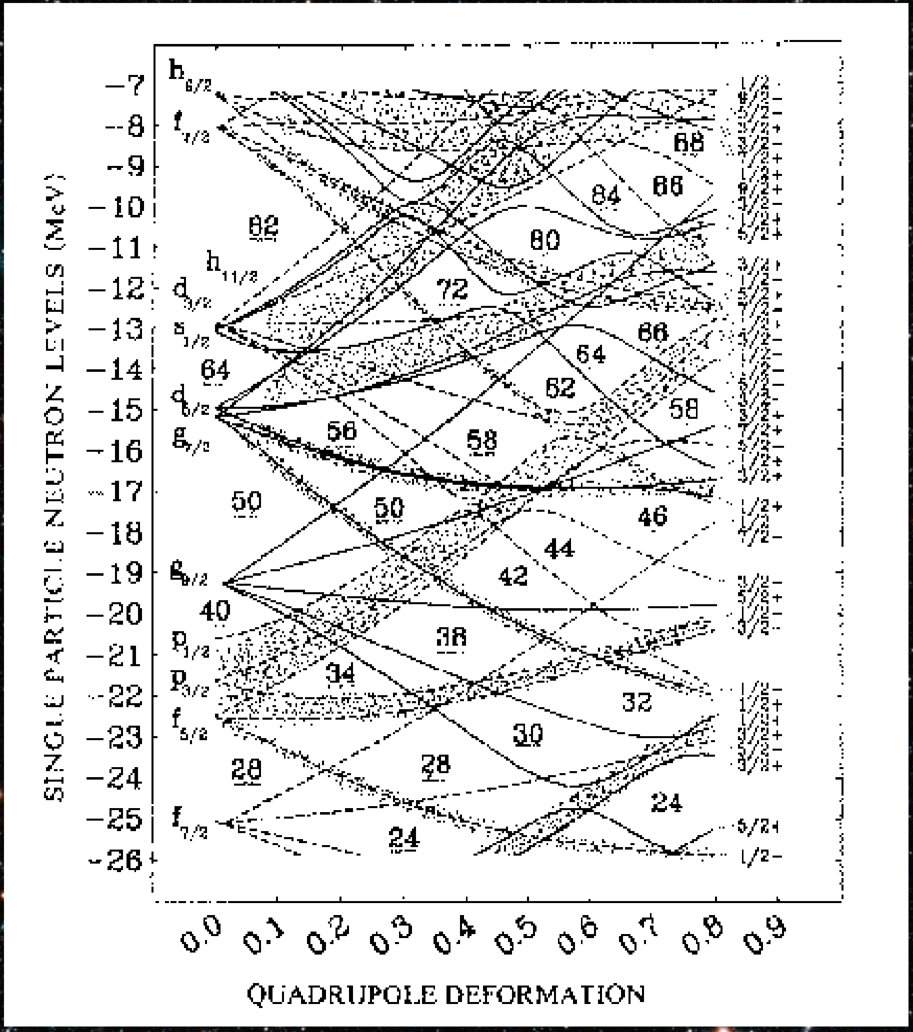


Superdeformation

shell structure



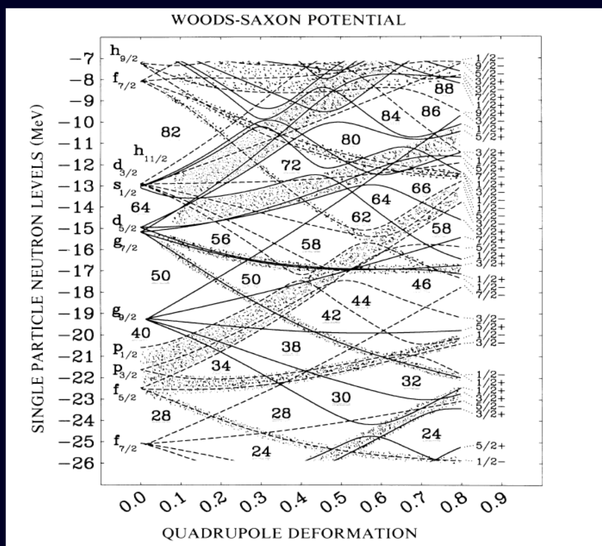
Harmonic oscillator



Wood Saxon potential

Read the Figure - and Write in Words What It Says ...

SU(3) Multiplets



Theoretical Predictions for SD's

1. Existence Z=28, 30, 32
2. Absence Z=34, 36

3. Existence Z=38, 40, 42, 44, 46
4. Absence Z=48, 50, 52, 54, 56

5. Existence Z=58, 60, 62, 64, 66
6. Absence Z=68, 70

7. Existence Z=72
8. Absence Z=74, 76, 78

9. Existence Z=80, 82, ... Actinide

Tools Document 70 / 135

Read the Figure - and Write in Words What It Says ...

Experimental Situation

Z=28, Ni, N=30
Z=30, Zn, N=30, 32, 32, 34 absent, 38 (!)

Z=32, 34, 36, absent

Z=38, Sr, N=44
Z=40, Zr, N=44, 46
Z=42, Mo, N=46
Z=44, Cd , absent
Z=46, Pd, N=58, 60

Z=48, 50, 52, 54, 56, absent

Z=58, Ce, N=72, 74
Z=60, Nd, N=72, 74, 76
Z=62, Sm, N=74, 76, 78 absent, 80
Z=64, Gd, N=80, 82, 84, 86
Z=66, Dy, N=86, 88
Z=68, Er, N=86

Z=70, Yb, absent

Z=72, Hf, N=96

Z=74, 76, 78, absent

Z=80, Hg, N=110, 112, 114
Z=82, Pb, N=112, 114, 116

Theoretical Predictions for SD's

1. Existence Z=28, 30, 32
2. Absence Z=34, 36
3. Existence Z=38, 40, 42, 44, 46
4. Absence Z=48, 50, 52, 54, 56
5. Existence Z=58, 60, 62, 64, 66
6. Absence Z=68, 70
7. Existence Z=72
8. Absence Z=74, 76, 78
9. Existence Z=80, 82, ... Actinide

But do shell gaps persist with rotation in ^{152}Dy?

YES! ☺

e.g. Dudek et al:

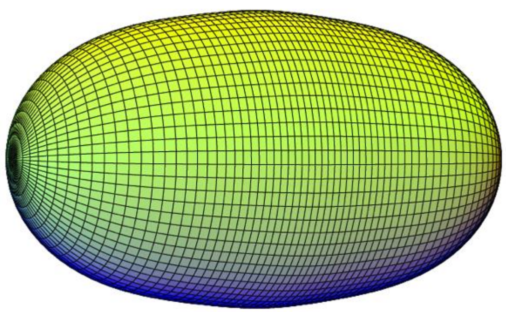


Fig. 1. The superdeformed nucleus ^{152}Dy, according to the measurements of ref. [8] has the quadrupole moment $Q_2 = 17.2$ eb. The corresponding deformation $\alpha_{20} = 0.61$ and $\alpha_{40} = 0.11$ obtained, *e.g.*, from the calculations with the Woods-Saxon potential as in ref. [9] reproduces the measured dynamical moments and the quadrupole moment. The shape presented in the figure corresponds to the above deformation.

the introduction. Below, just a few selected aspects will be mentioned that we consider particularly relevant also in the hyperdeformation context.

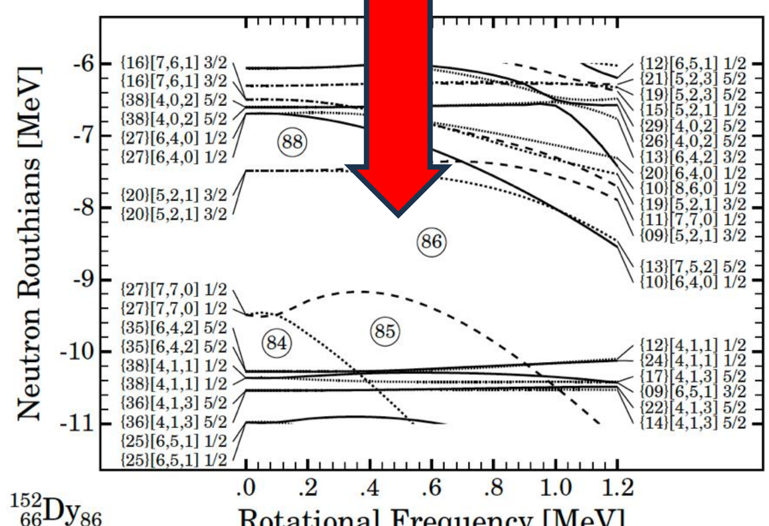


Fig. 2. The neutron single-particle levels as a function of the rotational frequency. The results correspond to the superdeformed nucleus ^{152}Dy at the equilibrium deformation calculated using the deformed Woods-Saxon potential. The numbers in curly brackets give the percentages of validity of the attached Nilsson labels.

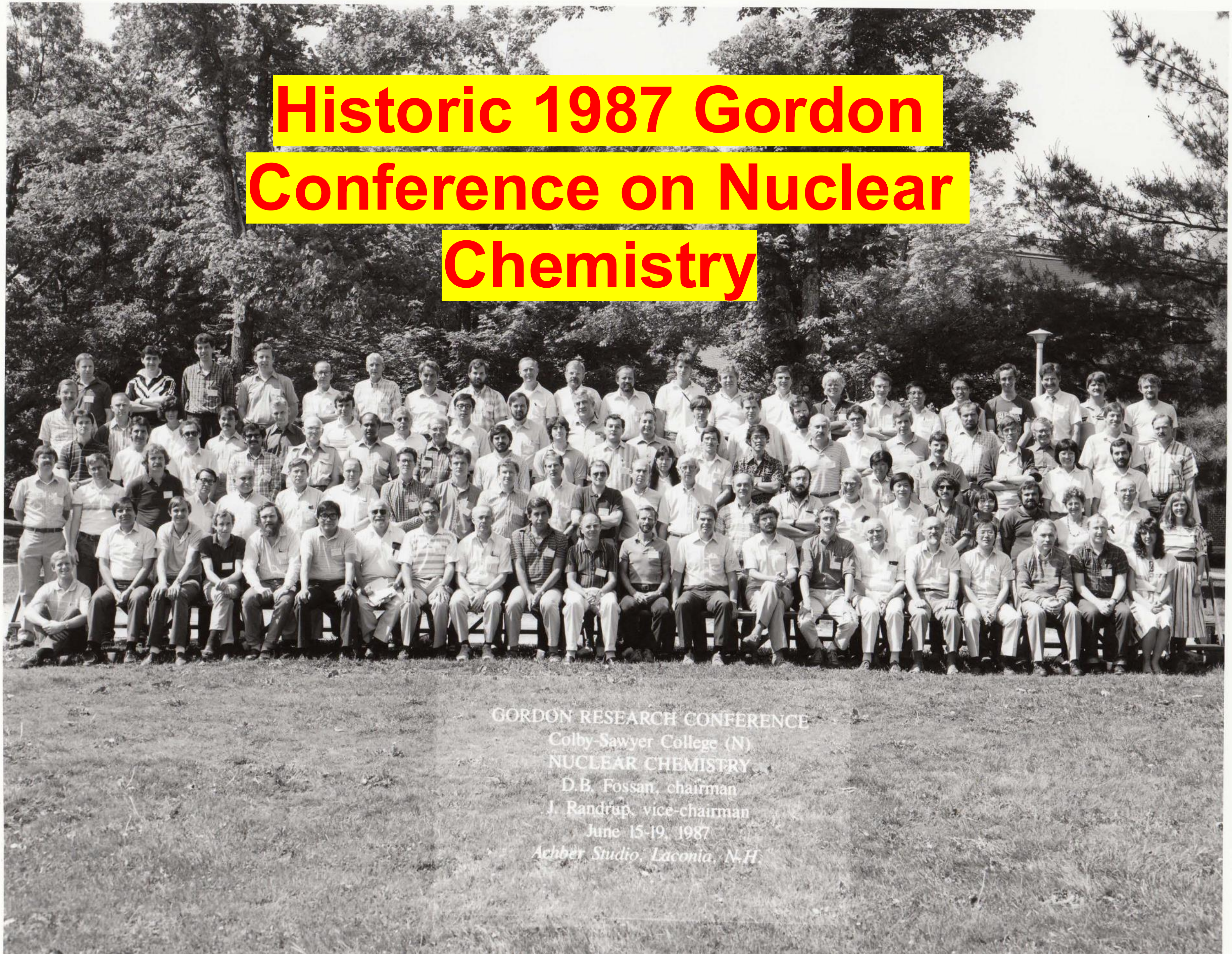
1987: Dudek goes West!
ORNL/JIHIR, TN

Our house in Oak Ridge 1987, Dudek, Bent Herskind, Klaus Schiffer, Alison, her mum and Daniel. FAMILY!!!

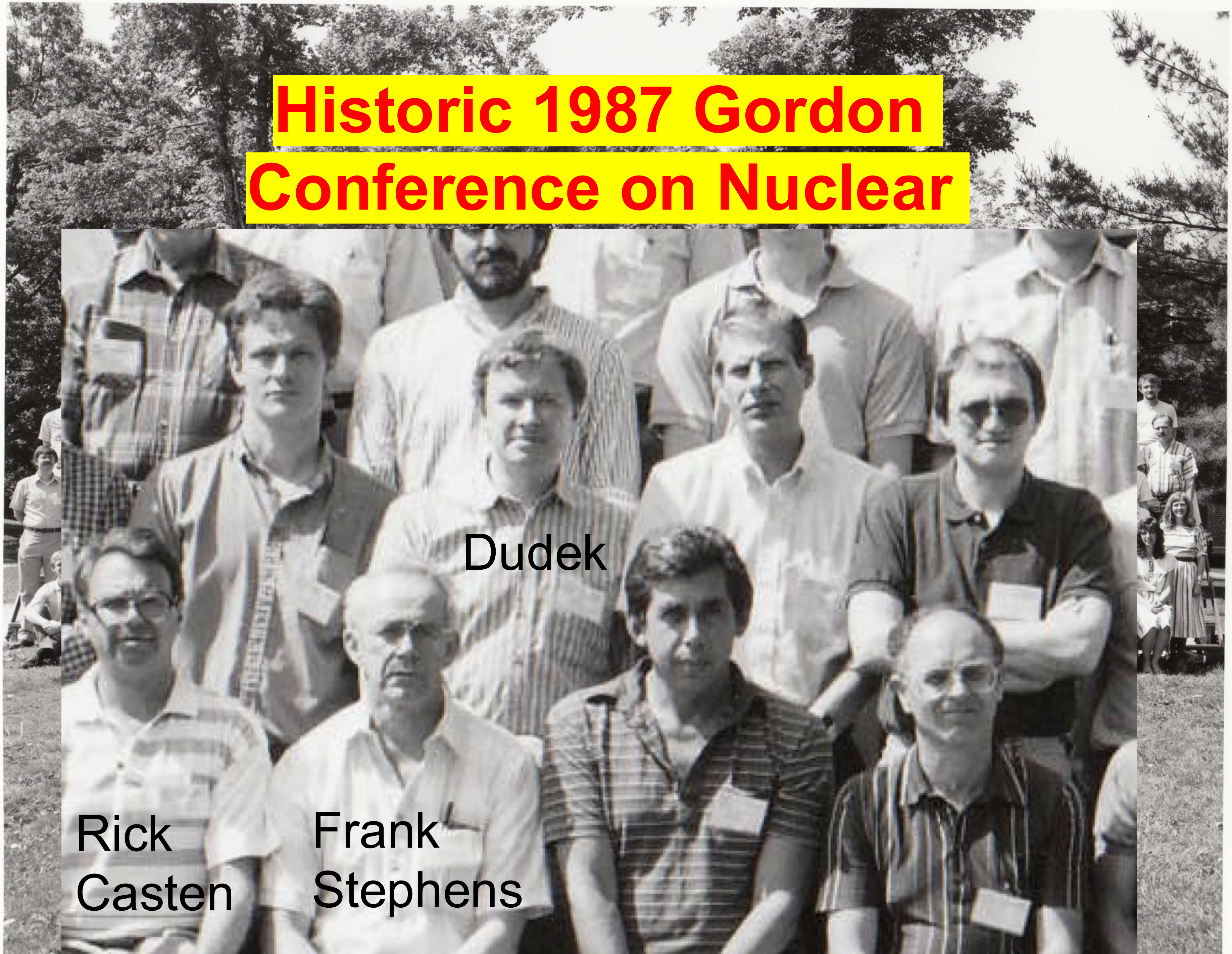
Our house in Oak Ridge 1987, Dudek, Bent Herskind, Klaus Schiffer, Alison, her mum and Daniel. FAMILY!!!

Our house in Oak Ridge 1987, Dudek, Bent Herskind, Klaus Schiffer, Alison, her mum and Daniel. FAMILY!!!

Historic 1987 Gordon Conference on Nuclear Chemistry



Historic 1987 Gordon Conference on Nuclear



1987 Legendary Gordon Conference meeting: A Woodstock Moment!

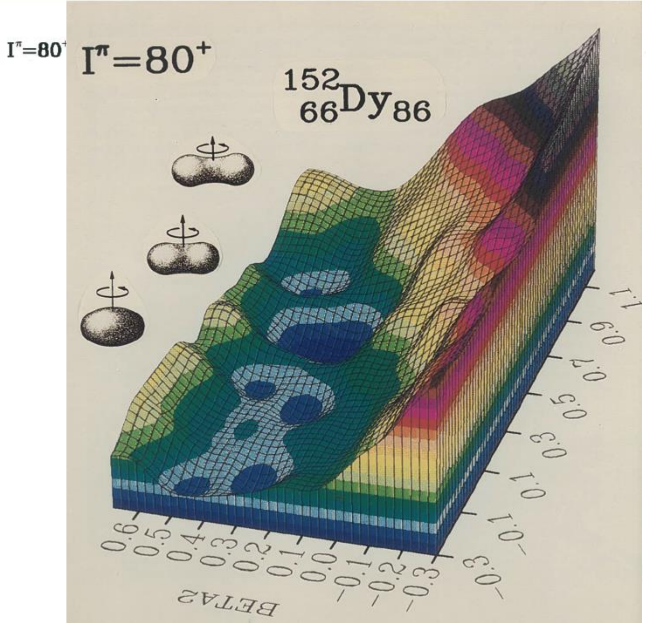
- Discovery of Superdeformation main theme of conference
- Frank Stephens proposes next generation array GAMMASPHERE!
- Dudek at epicenter of extra sessions devoted to making the physics case.

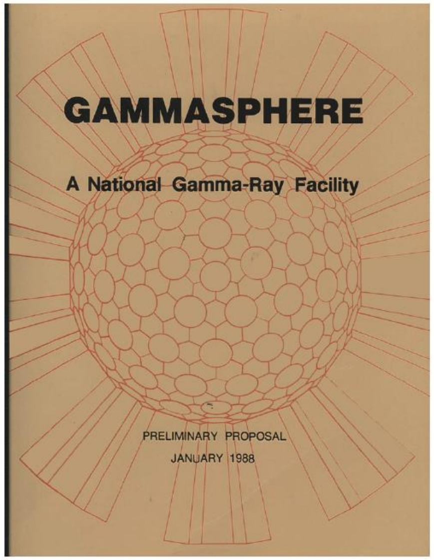
Summary and Conclusions (2)

Physics Issues from the Gordon-Conference Series
Main Lines in J. Dudek Gordon presentations (GEMINI)

Gordon

- **1987: Theoretical Framework of Super-deformation, ^{152}Dy,**
- **1991: From Super-deformation to Hyper-deformation,**





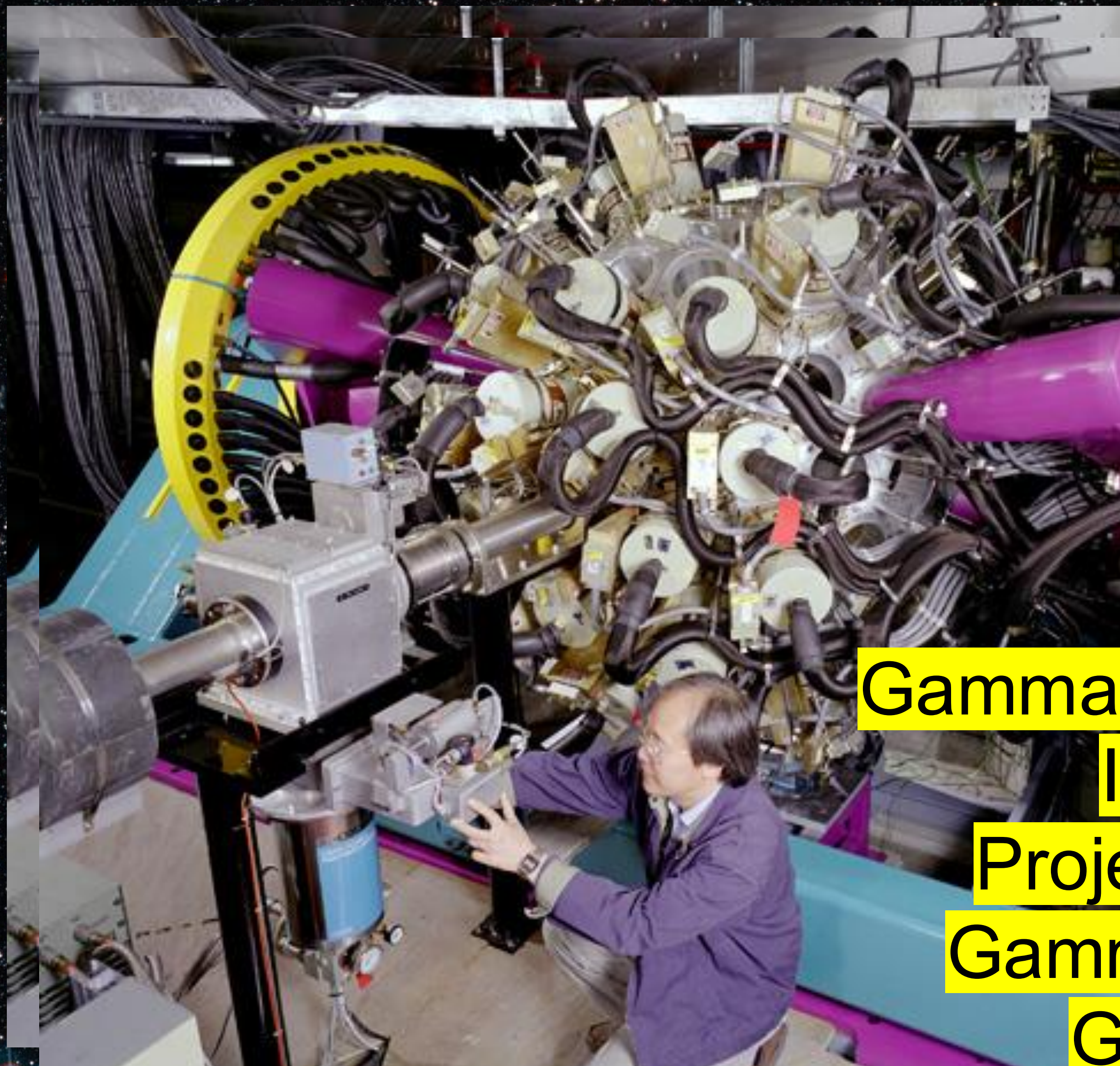
Dudek plot on the front page of the original proposal

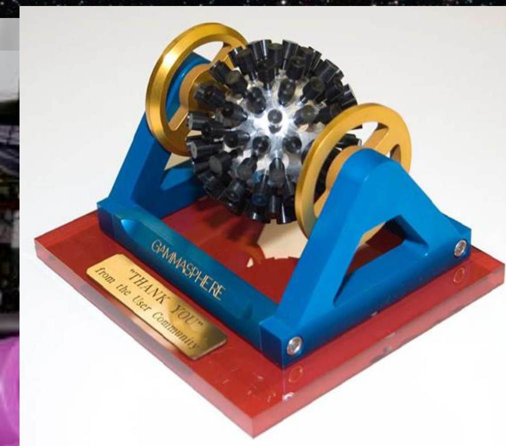
I was the one posting them off to Frank Stephens!

Like Adam, I was Dudek's chauffeur for a year (1988)! To-from Strasbourg for job interviews! HE GOT THE JOB!

AND mid-90's WE GOT: GAMMASPHERE!☺

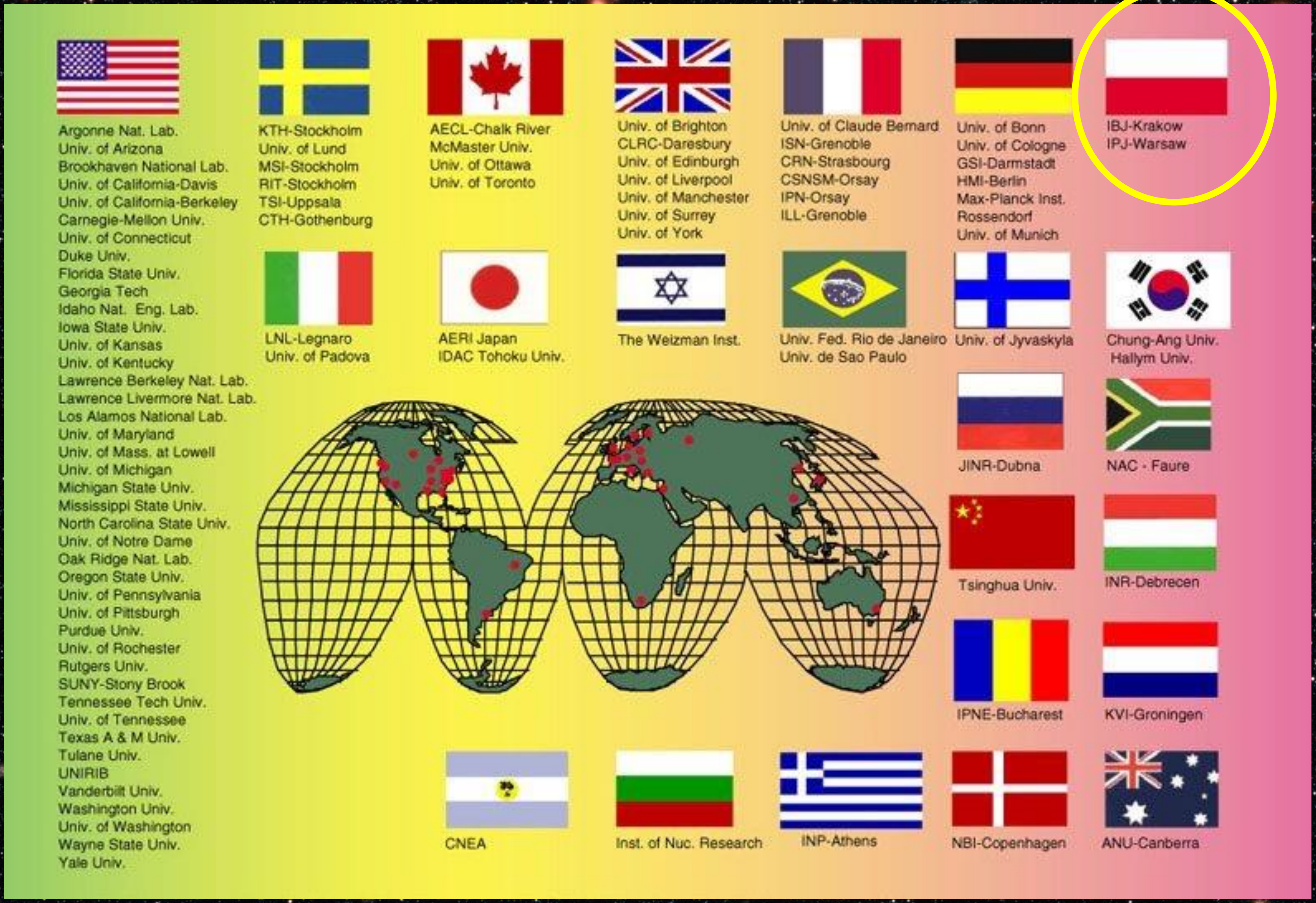
(AND EUROPE GOT EUROBALL! ☺)





Gamma Grand Master
IY LEE!
Project Leader:
Gammasphere &
GRETA!!!

The GAMMASPHERE Collaboration



~100 institutions, ~25 nations

The GAMMASPHERE Collaboration

Similar for Euroball: We are a global community! A FAMILY!

~100 institutions, ~25 nations

GAMMASPHERE TURNS BRUCE BANNER INTO THE HULK!

Universal Pictures presents The Hulk, directed by Ang Lee, opening June 20, 2003.

Credit: ILM/Universal

BIG BANG THEORY TV SHOW!

Every serious physicist has the ATLAS beam list and Gammasphere on his wall

BIG BANG THEORY TV SHOW!
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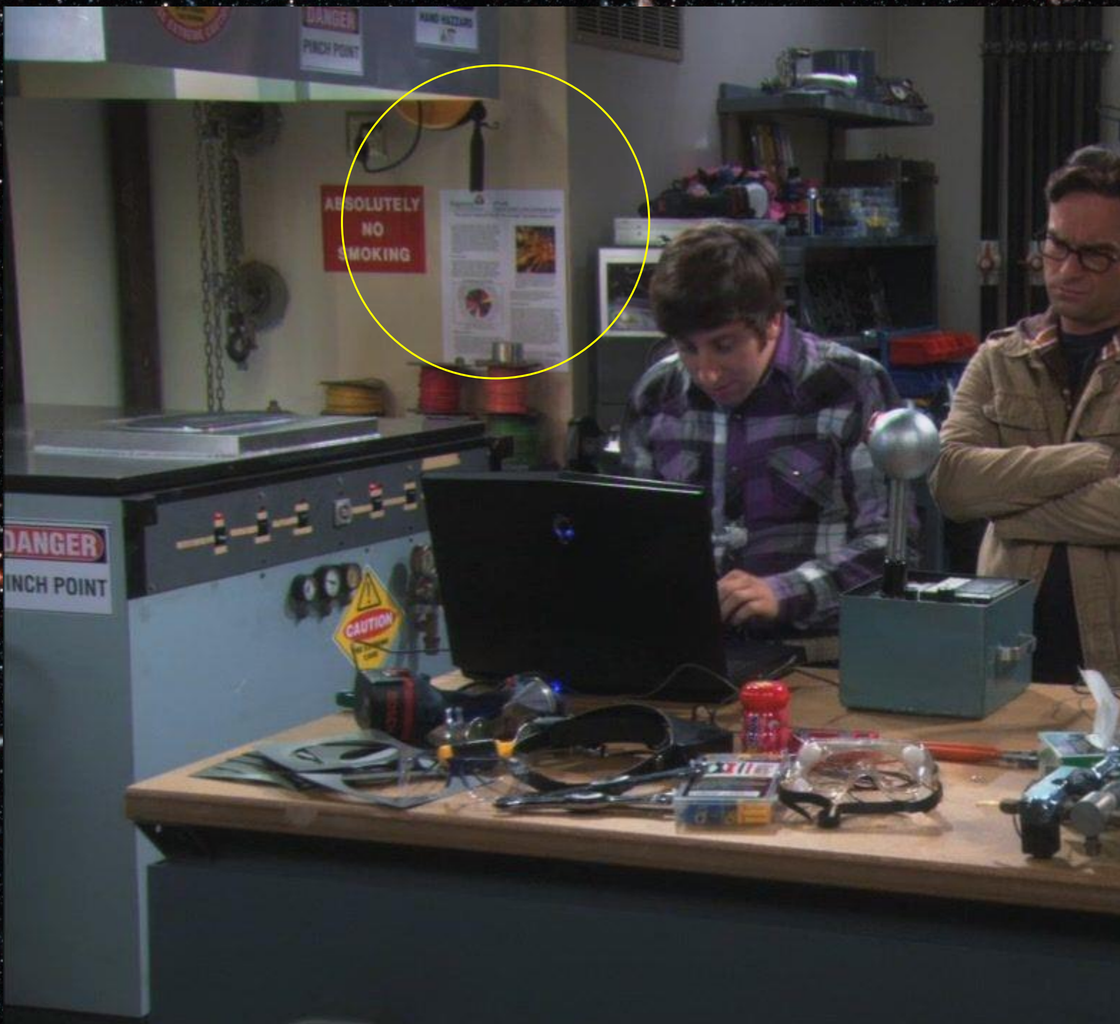
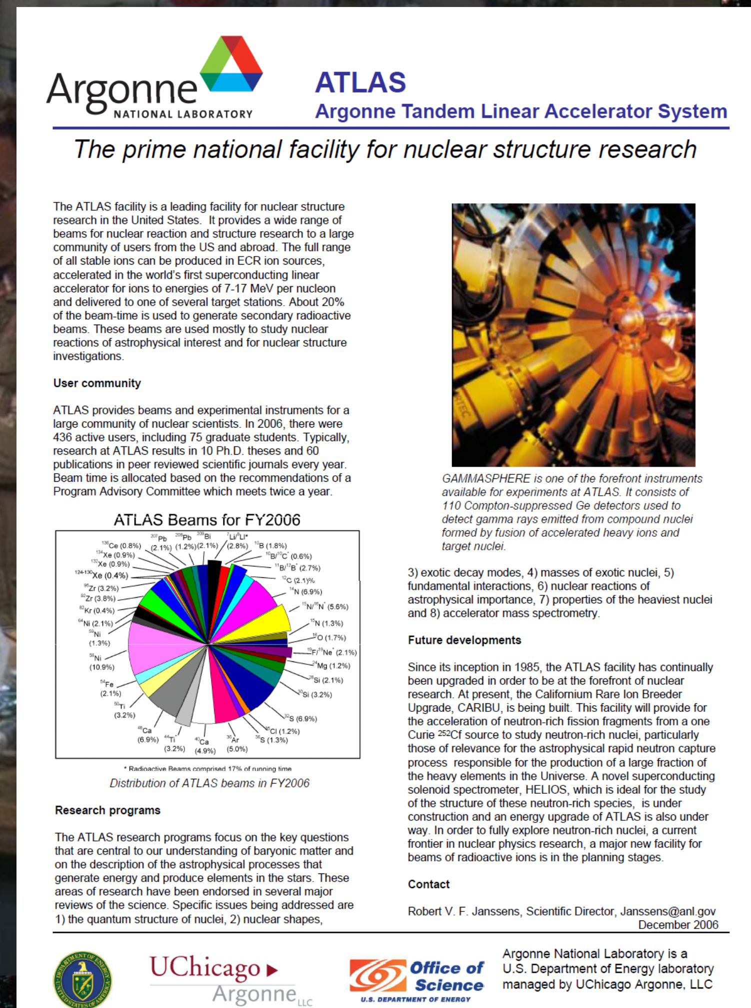




Argonne NATIONAL LABORATORY

ATLAS
Argonne Tandem Linear Accelerator System

The prime national facility for nuclear structure research

The ATLAS facility is a leading facility for nuclear structure research in the United States. It provides a wide range of beams for nuclear reaction and structure research to a large community of users from the US and abroad. The full range of all stable ions can be produced in ECR ion sources, accelerated in the world's first superconducting linear accelerator for ions to energies of 7-17 MeV per nucleon and delivered to one of several target stations. About 20% of the beam-time is used to generate secondary radioactive beams. These beams are used mostly to study nuclear reactions of astrophysical interest and for nuclear structure investigations.

User community

ATLAS provides beams and experimental instruments for a large community of nuclear scientists. In 2006, there were 436 active users, including 75 graduate students. Typically, research at ATLAS results in 10 Ph.D. theses and 60 publications in peer reviewed scientific journals every year. Beam time is allocated based on the recommendations of a Program Advisory Committee which meets twice a year.

ATLAS Beams for FY2006

^{136}Ce (0.8%)
^{134}Xe (0.9%)
^{132}Xe (0.9%)
$^{124-130}$Xe (0.4%)
^{96}Zr (3.2%)
^{92}Zr (3.8%)
^{82}Kr (0.4%)
^{64}Ni (2.1%)
^{59}Ni (1.3%)
^{58}Ni (10.9%)
^{54}Fe (2.1%)
^{50}Ti (3.2%)
^{48}Ca (6.9%)
^{44}Ti* (3.2%)
^{40}Ca (4.9%)
^{36}Ar (5.0%)
^{36}S (1.3%)
^{35}Cl (1.2%)
^{32}S (6.9%)
^{30}Si (3.2%)
^{28}Si (2.1%)
^{24}Mg (1.2%)
^{19}F/^{19}Ne* (2.1%)
^{16}O (1.7%)
^{15}N (1.3%)
^{15}N/^{16}N* (5.6%)
^{14}N (6.9%)
^{12}C (2.1)%
^{11}B/^{12}B* (2.7%)
^{10}B/^{10}C* (0.6%)
^{10}B (1.8%)
^{7}Li/^{8}Li* (2.8%)
^{209}Bi (2.1%)
^{208}Pb (1.2%)
^{207}Pb (2.1%)

* Radioactive Beams comprised 17% of running time

Distribution of ATLAS beams in FY2006

Research programs

The ATLAS research programs focus on the key questions that are central to our understanding of baryonic matter and on the description of the astrophysical processes that generate energy and produce elements in the stars. These areas of research have been endorsed in several major reviews of the science. Specific issues being addressed are 1) the quantum structure of nuclei, 2) nuclear shapes, 3) exotic decay modes, 4) masses of exotic nuclei, 5) fundamental interactions, 6) nuclear reactions of astrophysical importance, 7) properties of the heaviest nuclei and 8) accelerator mass spectrometry.

GAMMASPHERE is one of the forefront instruments available for experiments at ATLAS. It consists of 110 Compton-suppressed Ge detectors used to detect gamma rays emitted from compound nuclei formed by fusion of accelerated heavy ions and target nuclei.

Future developments

Since its inception in 1985, the ATLAS facility has continually been upgraded in order to be at the forefront of nuclear research. At present, the Californium Rare Ion Breeder Upgrade, CARIBU, is being built. This facility will provide for the acceleration of neutron-rich fission fragments from a one Curie ^{252}Cf source to study neutron-rich nuclei, particularly those of relevance for the astrophysical rapid neutron capture process responsible for the production of a large fraction of the heavy elements in the Universe. A novel superconducting solenoid spectrometer, HELIOS, which is ideal for the study of the structure of these neutron-rich species, is under construction and an energy upgrade of ATLAS is also under way. In order to fully explore neutron-rich nuclei, a current frontier in nuclear physics research, a major new facility for beams of radioactive ions is in the planning stages.

Contact

Robert V. F. Janssens, Scientific Director, Janssens@anl.gov
December 2006

UChicago Argonne LLC
Office of Science U.S. DEPARTMENT OF ENERGY

Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

VOLUME 57, NUMBER 7 PHYSICAL REVIEW LETTERS 18 AUGUST 1986

Observation of a Discrete-Line Superdeformed Band up to $60\hbar$ in ^{152}Dy

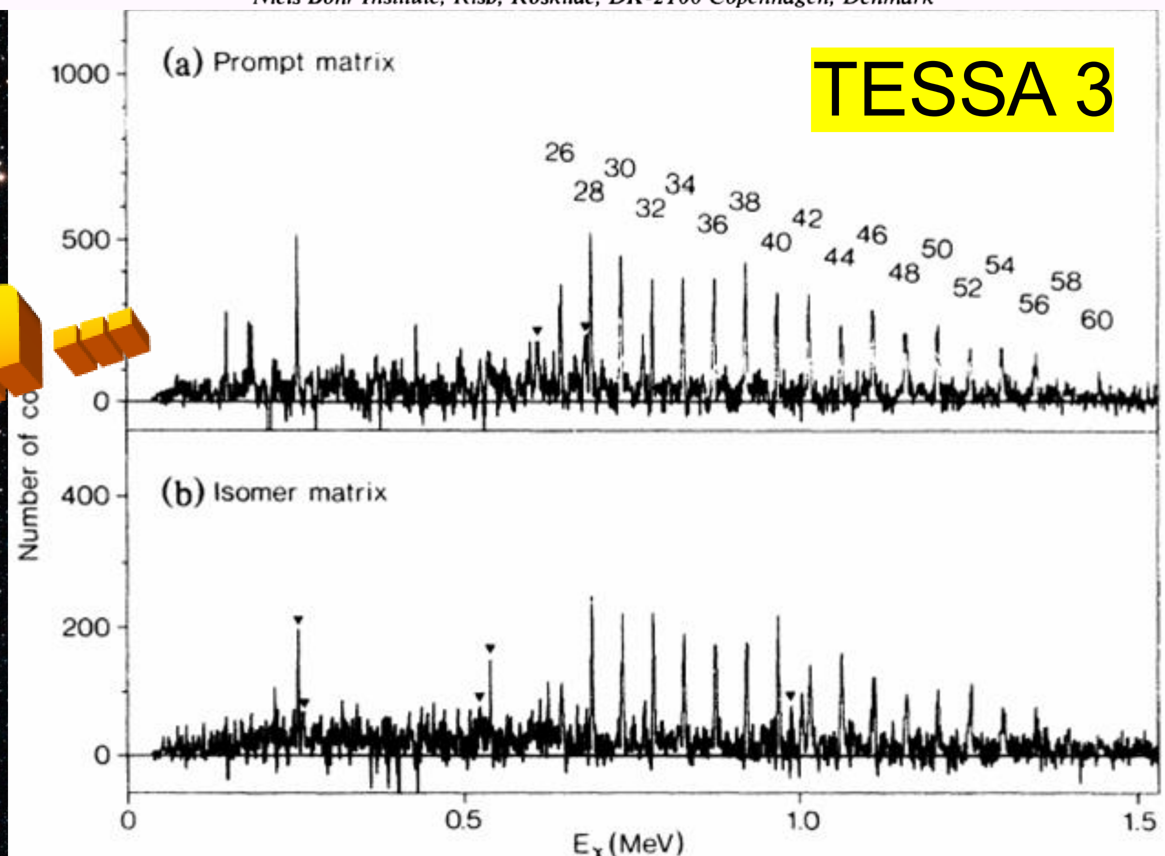
P. J. Twin, B. M. Nyakó,[(a)] A. H. Nelson, and J. Simpson
Science and Engineering Research Council, Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

M. A. Bentley, H. W. Cranmer-Gordon, P. D. Forsyth, D. Howe, A. R. Mokhtar, J. D. Morrison, and J. F. Sharpey-Schafer
Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 3BX, United Kingdom

and

G. Sletten
Niels Bohr Institute, Risø, Roskilde, DK-2100 Copenhagen, Denmark

Then ...



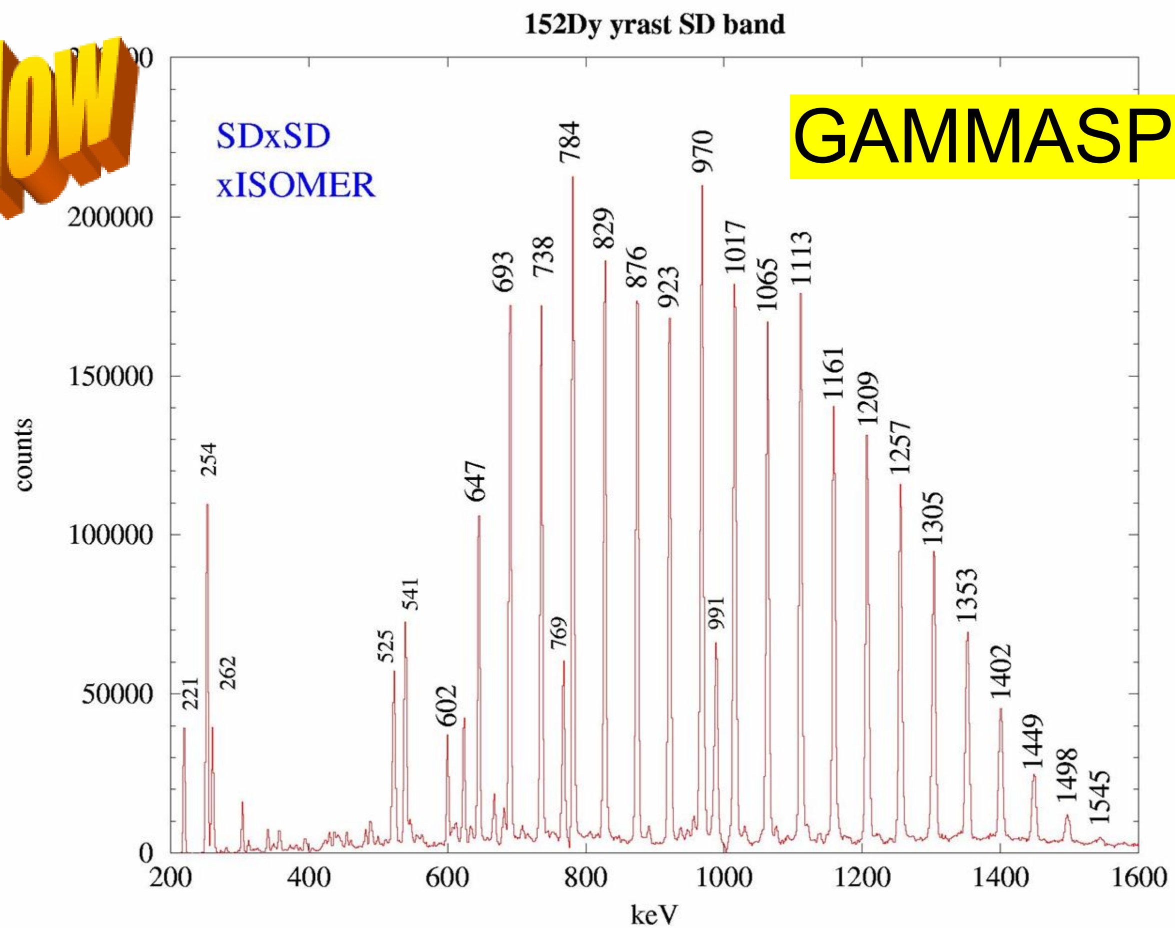
Slide from Augusto

VOLUME 88, NUMBER 4 PHYSICAL REVIEW LETTERS 28 JANUARY 2002

Direct Decay from the Superdeformed Band to the Yrast Line in $^{152}_{66}Dy_{86}$

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]

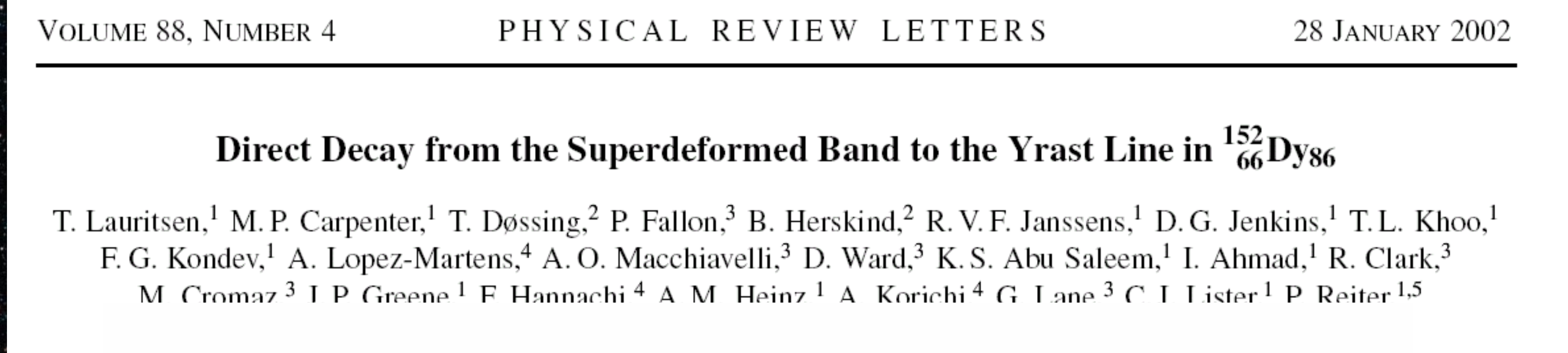
...and Now



GAMMASPHERE

Slide from Augusto

^{80}Se + ^{76}Ge @ 311MeV and ^{108}Pd + ^{48}Ca @ 191MeV



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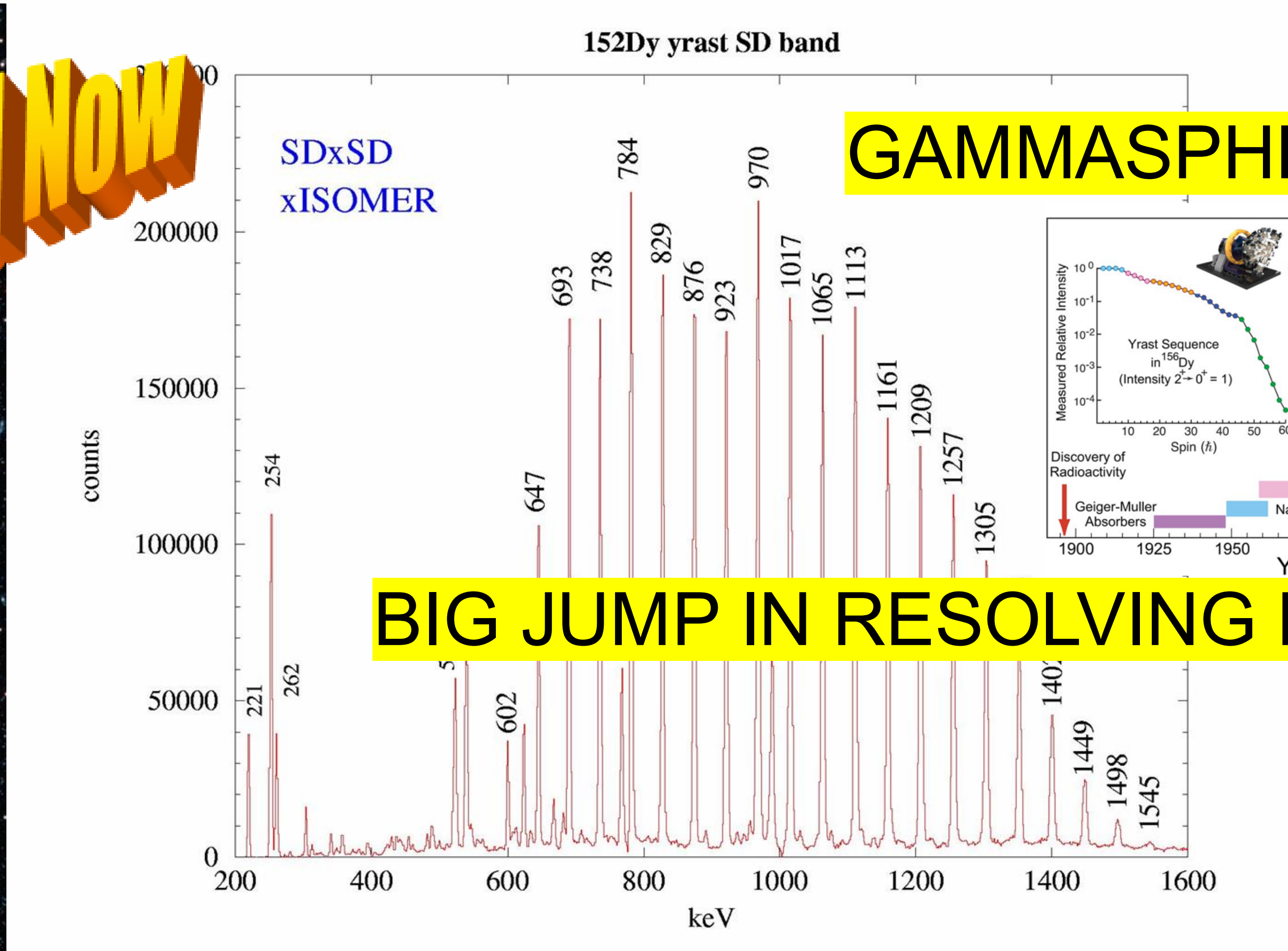
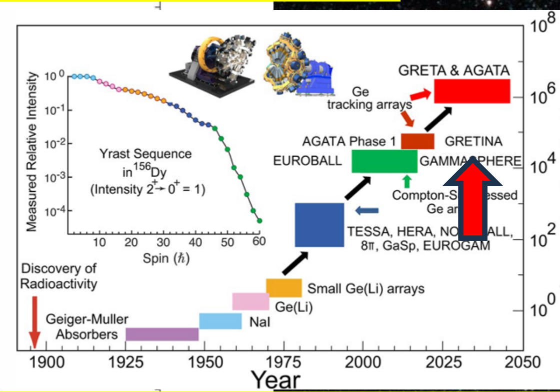


GAMMASPHERE

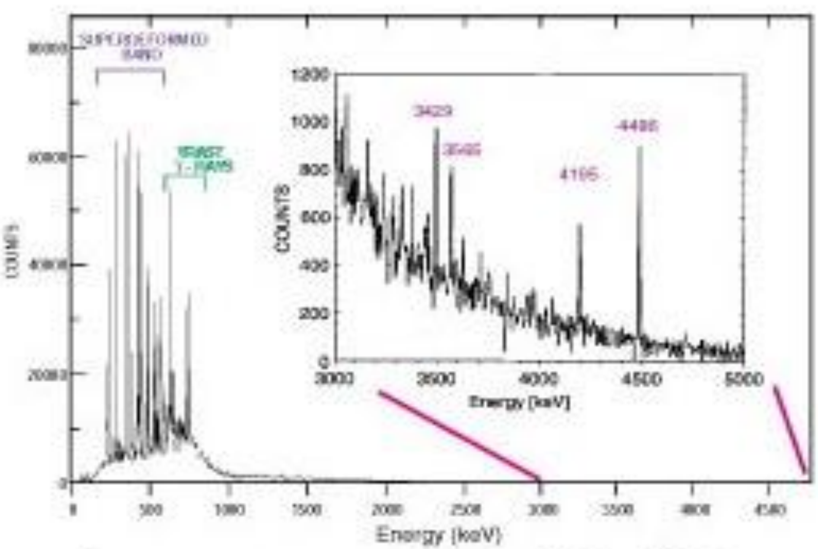


BIG JUMP IN RESOLVING POWER!!

Slide from Augusto

^{80}Se + ^{76}Ge @ 311MeV and ^{108}Pd + ^{48}Ca @ 191MeV

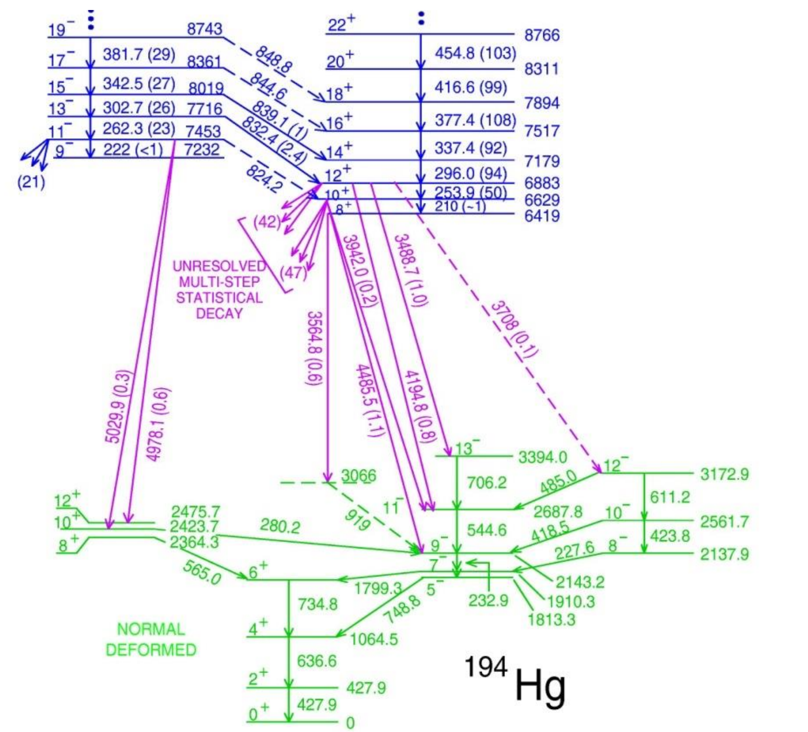
Direct links between high spin superdeformed and normal energy minima finally observed



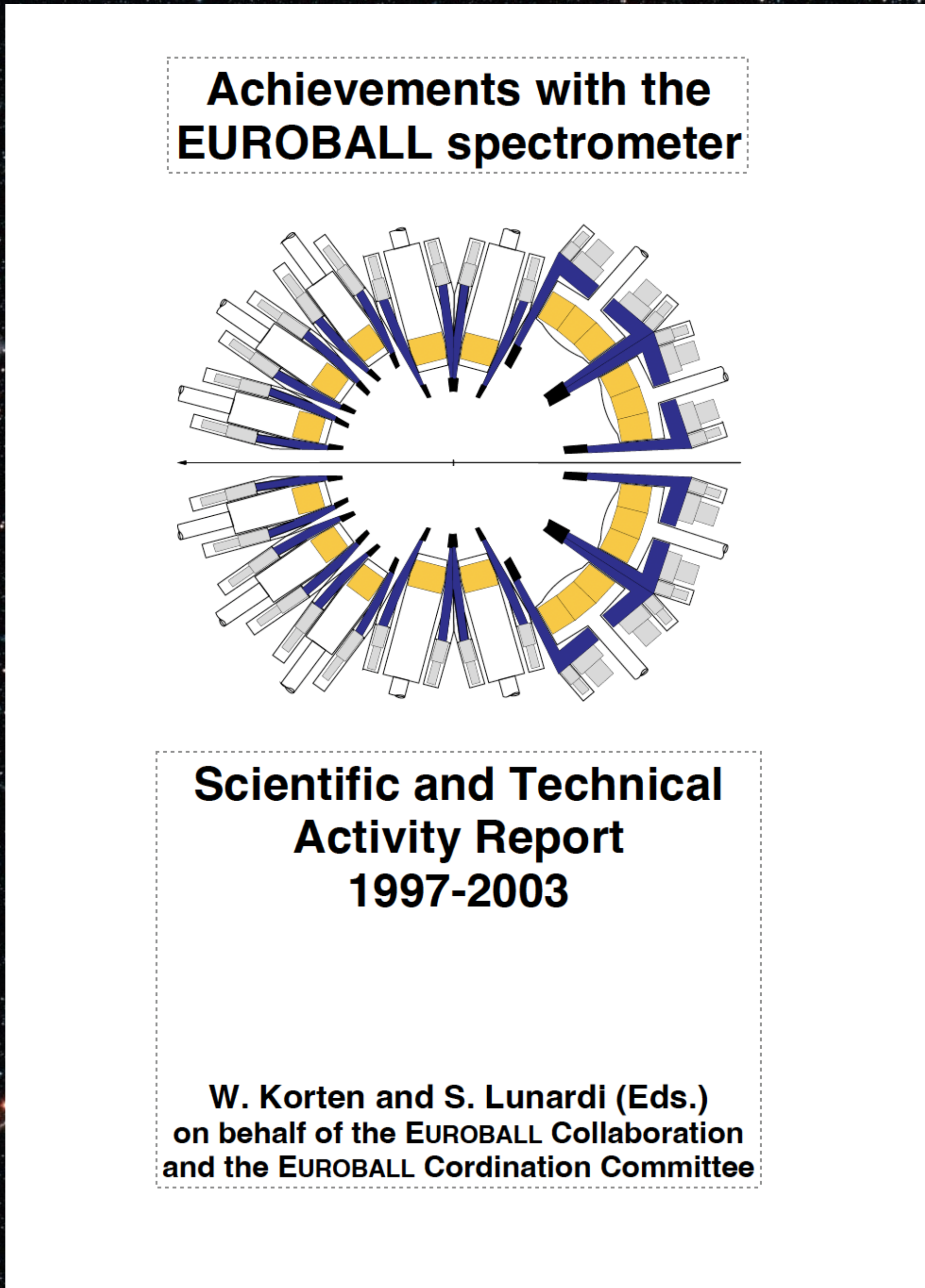
Gamma ray spectrum for band 1 in ^{194}Hg showing the weak direct one-step discrete high energy (3.4 - 4.5 MeV) decays linking the superdeformed and normal deformed minima.

And ^{152}Dy: T.Lauritsen et al., PRL 88 (2002) 042501

Khoo et al, PRL 76(96)1583



This observation unambiguously defined the excitation energies, spins and probable parities of superdeformed bands in the A = 190 region for the first time.


Achievements with the EUROBALL spectrometer

Scientific and Technical Activity Report 1997-2003

W. Korten and S. Lunardi (Eds.)
on behalf of the EUROBALL Collaboration
and the EUROBALL Cordination Committee

FANTASTIC RESULTS FROM EUROBALL TOO!!!

Dudek was obviously influential in the spectacular physics performed back home in Europe too! ☺

Table of Superdeformed Nuclear Bands and Fission Isomers

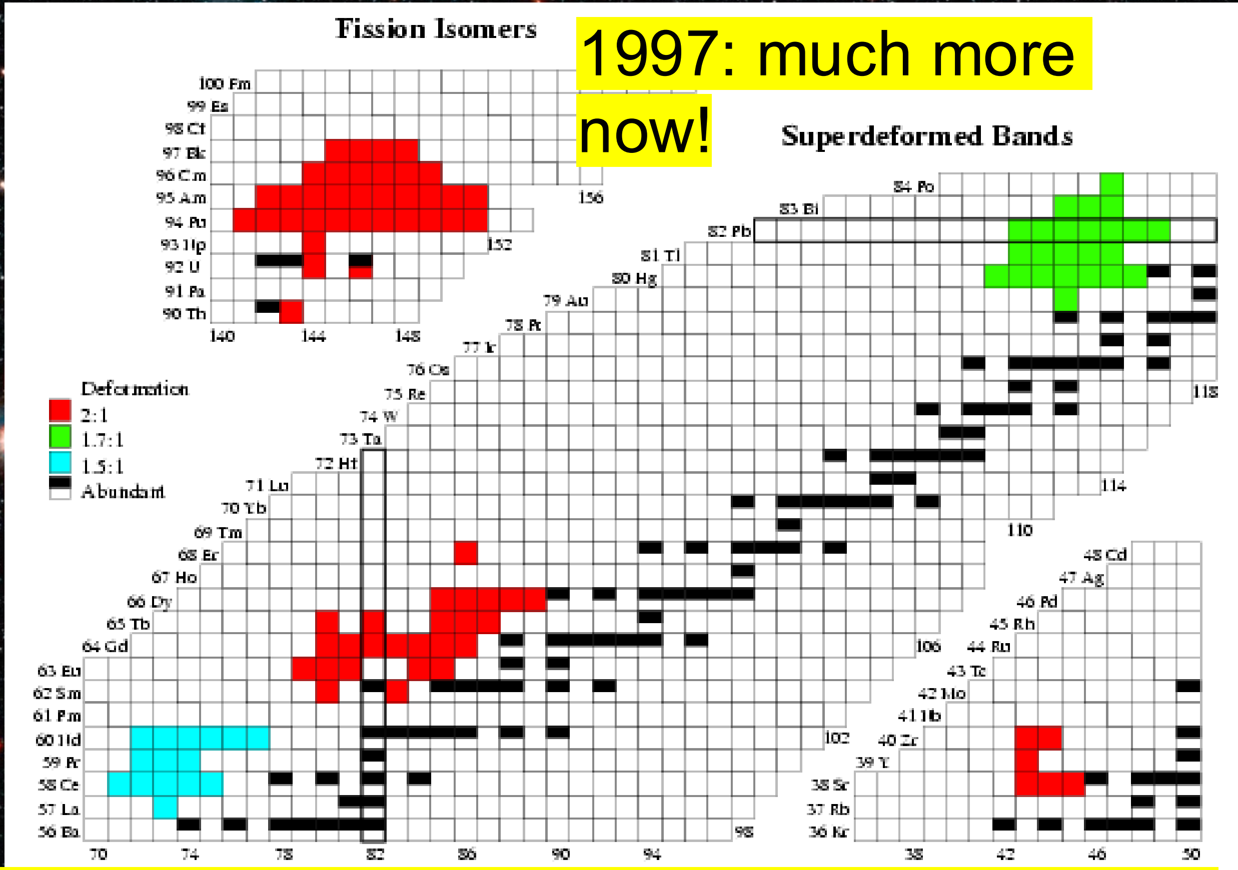
WWW Edition. Updated June, 1997

by Balraj Singh, Richard B. Firestone, and S.Y. Frank Chu

Feast of Spectroscopy!!! Known Regions of Superdeformation (as Dudek's predictions)

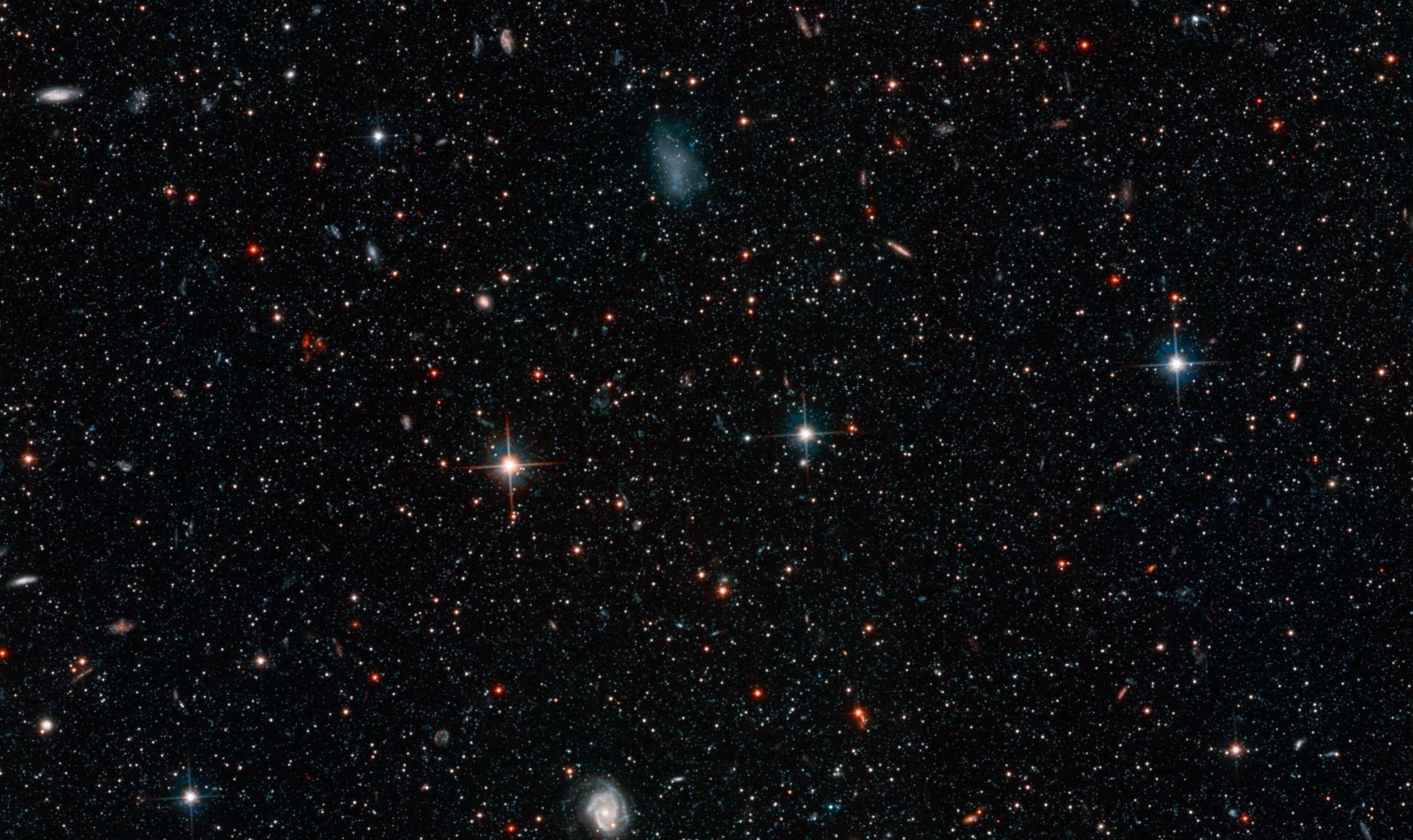
- >500 SD bands now known!
- Each region is unique!
- Amazingly rich spectroscopy!
- But only a couple LINKED! ☹
- - so no I, Π or Ex!

1997: much more now!

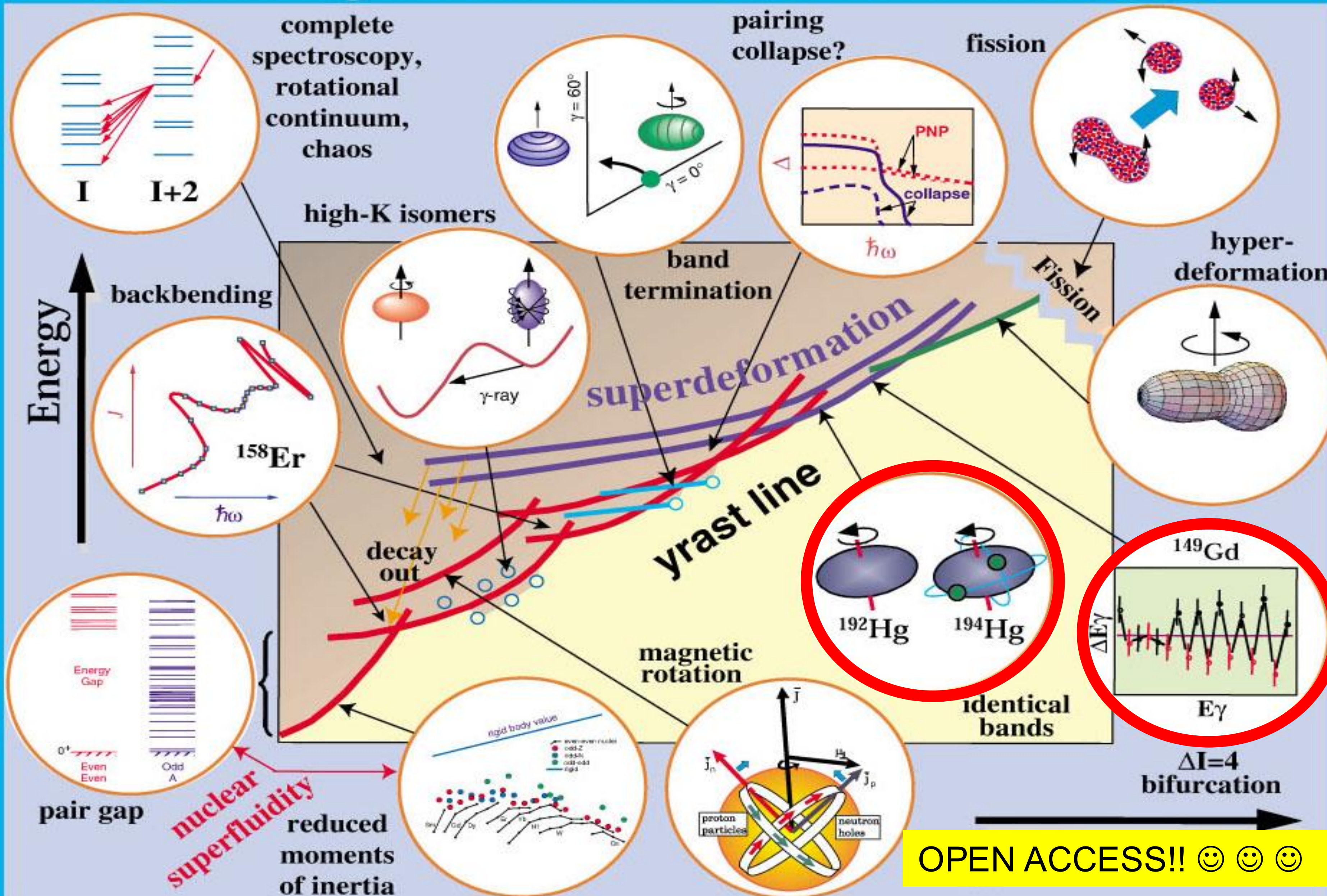


ESSENTIAL TO SOLVE IDENTICAL BANDS & C4 STAGGERING MYSTERIES

1990 Then things became even more super-strange in SD nuclei!



The Angular Momentum World of the Nucleus



OPEN ACCESS!! ☺ ☺ ☺

Riley, Simpson & Paul, Phys. Scr. 91 (2016) 123002

1990: Identical Superdeformed Bands in Different Nuclei!

^{152}Dy	^{151}Tb*
693	692
738	738
784	783
829	828
876	876
923	922
970	970
1017	1016
1064	1063
1112	1112
1161	1160
1209	1207
1256	1256
1305	1305
1353	1353

^{192}Hg	^{194}Hg*	^{194}Pb
258	262	256
300	303	298
341	343	340
381	382	380
421	420	420
459	458	458
496	495	496
532	532	532
568	567	568
602	601	603

Back to back PRL's, Bryski, Fallon et al PRL 64(90) 1650 & Nazarewicz, Twin, Fallon, Garrett PRL 64 (90) 1654

At first many thought it was a case of mistaken identity. Faulty experimental work!

Many new cases followed.

35 yr veteran of nuclear physics, "most amazing set of numbers he had ever seen."

<u>Heroic?</u> New insight? Pseudo-spin alignment or

<u>Non-Heroic?</u> : Chance cancellations between pairing & deformation effects?

1990: Identical Superdeformed Bands in Different Nuclei!

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1209	1207
1256	1256
1305	1305
1353	1353

^{192}Hg	$^{194}Hg^*$	^{194}Pb
258	262	256
300	303	298
341	343	340
381	382	38
421	420	42
459	458	4
496	495	4
532	532	5
568	567	5
602	601	6

Back to back PRL's, Bryski, Fallon et al PRL 64(90) 1650 & Nazarewicz, Twin, Fallon, Garrett PRL 64 (90) 1654

<u>Heroic?</u> New

<u>Non-Heroic?</u> : Chance cancellations between pairing & deformation effects?

1990: Identical Superdeformed Bands in Different Nuclei!

^{152}Dy : ^{151}Tb*	
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At first many thought it was a case of mistaken identity. Faulty experimental work!

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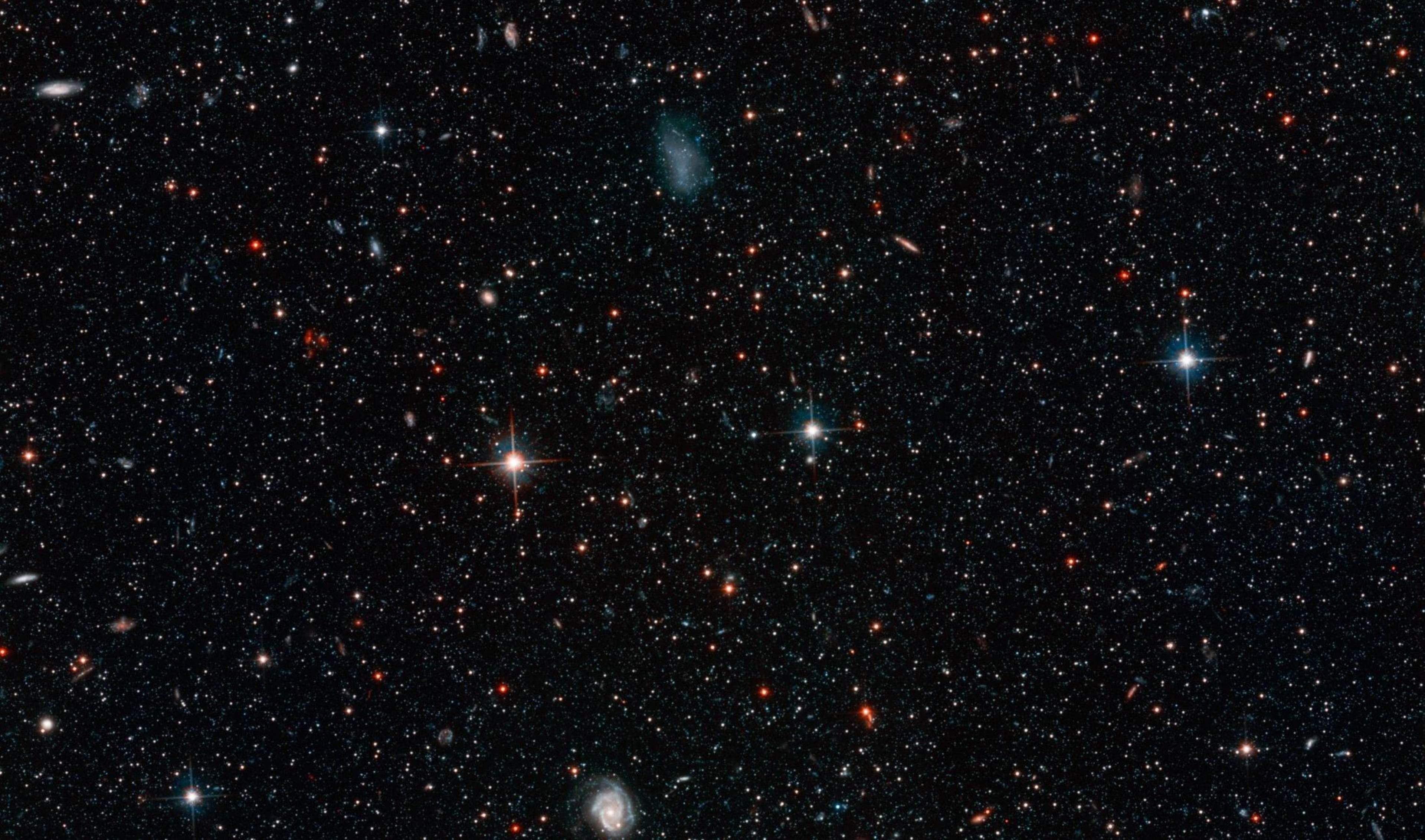
35 yr veteran of nuclear physics, "most amazing set of numbers he had ever seen."

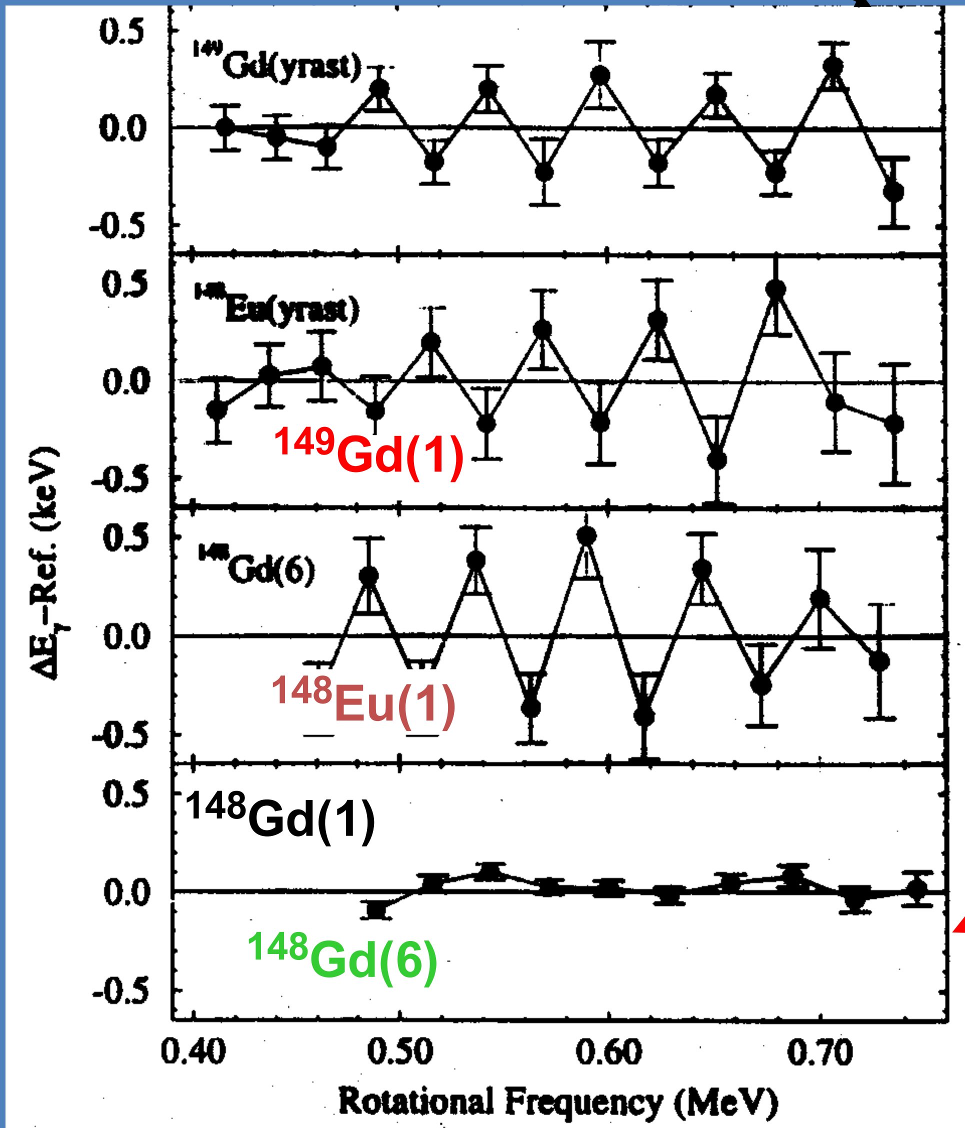
Heroic? New insight? Pseudo-spin alignment or pairing & deformation effects?

Dudek: Degeneracies imply symmetries!

Then 1997 things became even more super-strange ….. MEGA-STRANGE!!



IDENTICAL BANDS ARE OFTEN FOUND IN NEIGHBORING NUCLEI



Classic GS expt by Haslip et al., PRL 78(97)3447

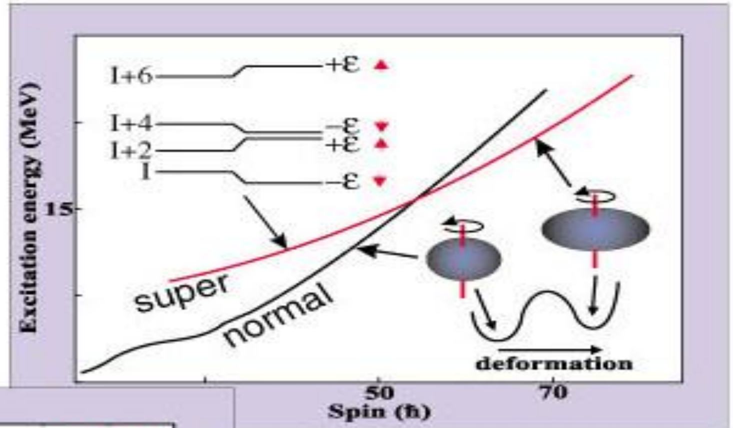
Lots of new bands!

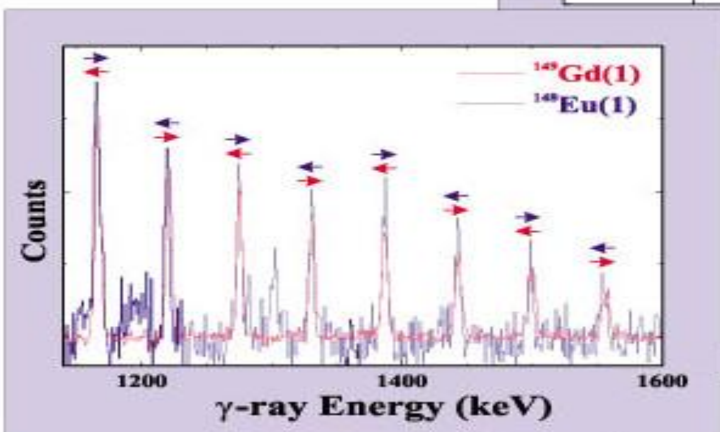
We can use other bands as a reference!

See also Haslip et al., PRC 58(98)R2649 for systematic survey

ΔI=4 Bifurcation in Identical Superdeformed Bands

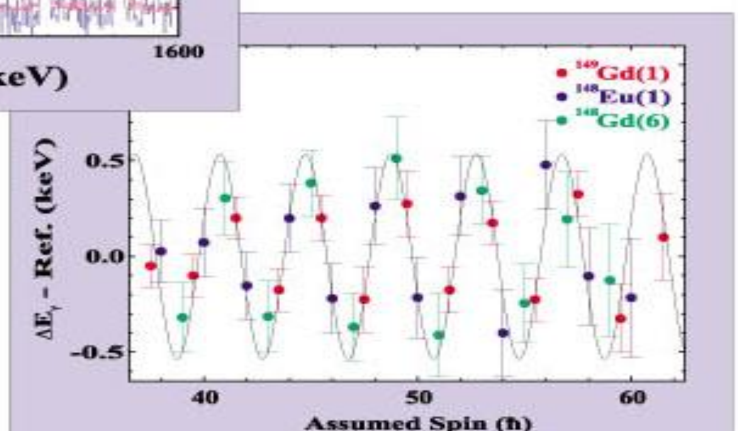
ΔI = 4 bifurcation occurs when alternate levels in a superdeformed band are perturbed by one part in a million, in opposite directions.

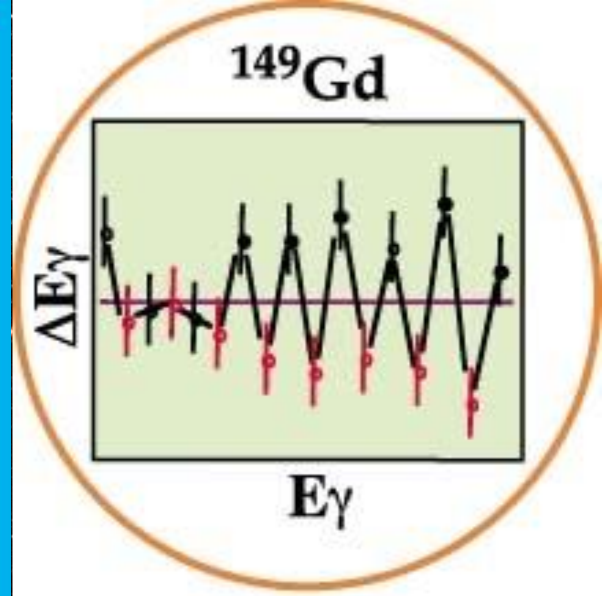




The transitions in these neighboring nuclei are nearly identical, but the direction of the tiny shift is reversed.

When the small shifts in three bands are plotted as a function of spin, they show a remarkable correlation which is not understood at this time.

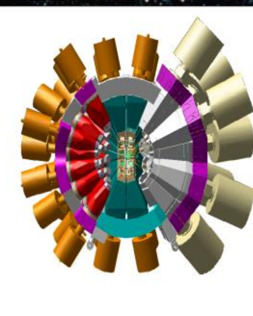


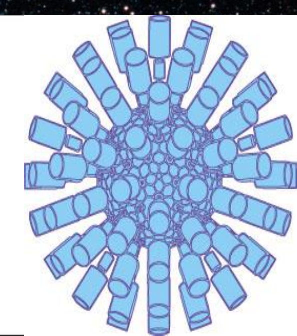


Flibotte et al, PRL 71 (93) 4299

Haslip *et al*., PRL 78, 3447 (1997).

Haslip et al., PRC 58 (98) R2649





Dudek published a significant number of papers on these topics, e.g.

- **"Abundance and Systematics of Nuclear Superdeformed States: Relation to the Pseudospin and Pseudo-SU(3) Symmetries"** (1987) *Authors:* J. Dudek, W. Nazarewicz, Z. Szymanski, and G. A. Leander,

  Physical Review Letters, 59, 1405.
- "Additivity of Quadrupole Moments in Superdeformed Bands: Single-Particle Motion at Extreme Conditions" (1996) Authors: W. Satuła, J. Dobaczewski, J. Dudek, and W. Nazarewicz,

  Physical Review Letters, 77(26), 5182.
- “Time-odd components in the rotating mean field and identical bands”, J. Dobaczewski and J. Dudek,

  Acta Phys. Pol. B 27, 45 (1996)
- [Y]4-type symmetry effects in nuclei pro's and contra’s, Dudek, J. Dobaczewski, J. Luo, W.D., Bouguettoucha, A., Li, X.

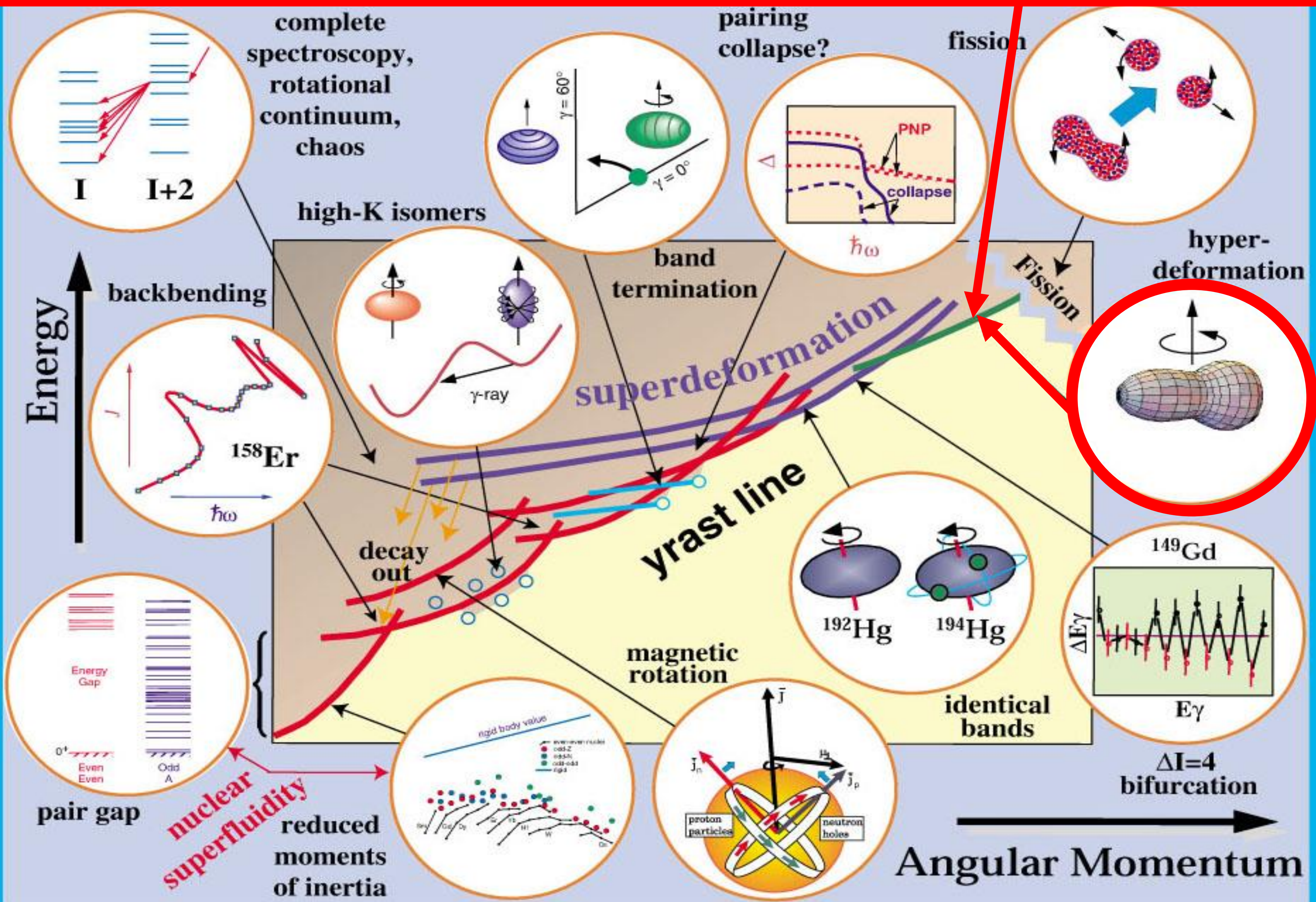
BUT STILL VERY MUCH A MYSTERY!


TO BOLDLY GO

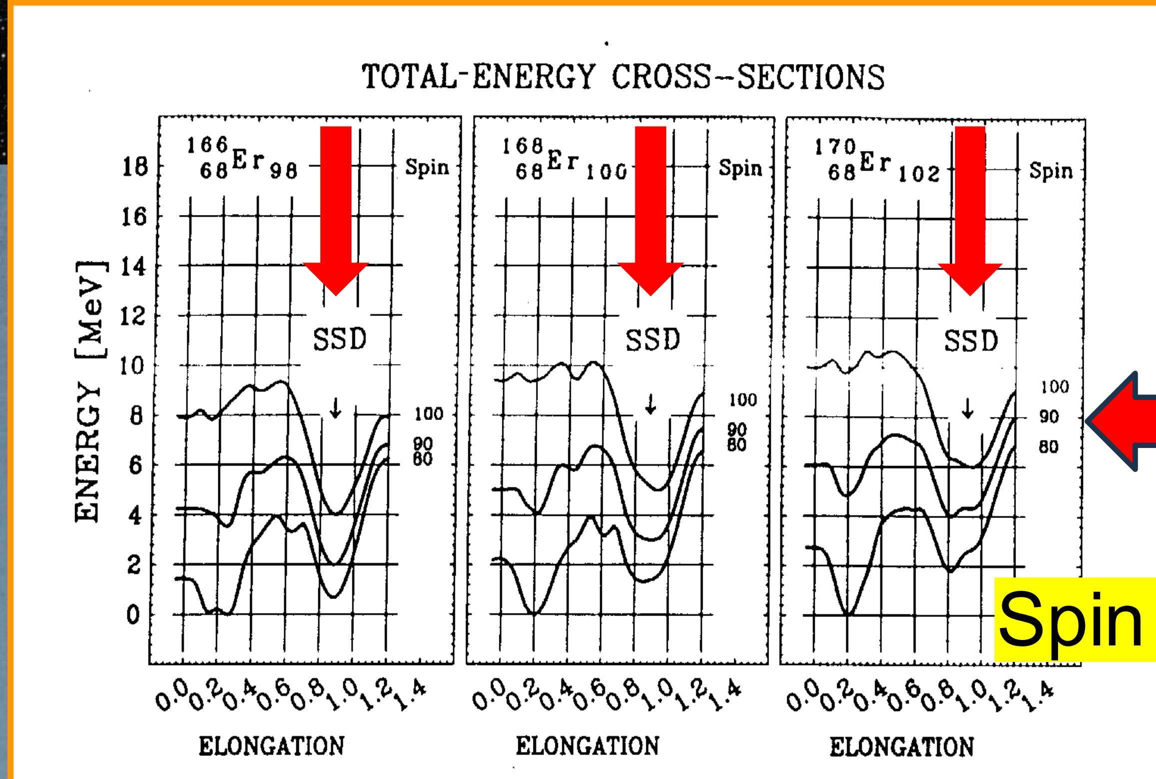
1988: HYPERDEFORMATION PREDICTION AT THE HIGHEST SPINS!

"Prediction of hyperdeformed nuclear states at very high spins" (1988),
J. Dudek, T.R. Werner, and L.L. Riedinger,
Physics Letters B, Volume 211, Issue 3, p. 252-258.

The Great Quest to observe Hyperdeformation at Ultra-High Spins



Reprinted from
Atomic Data
and
Nuclear Data Tables
Vol. 50, No. 2, March 1992



Spin 100!!

!

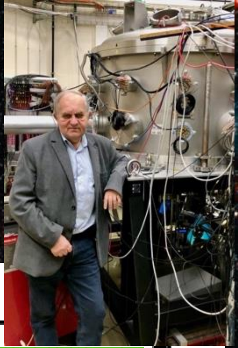
SHAPE COEXISTENCE EFFECTS OF SUPER- AND HYPERDEFORMED CONFIGURATIONS IN ROTATING NUCLEI WITH $58 \leqslant Z \leqslant 74$

T. R. WERNER and J. DUDEK

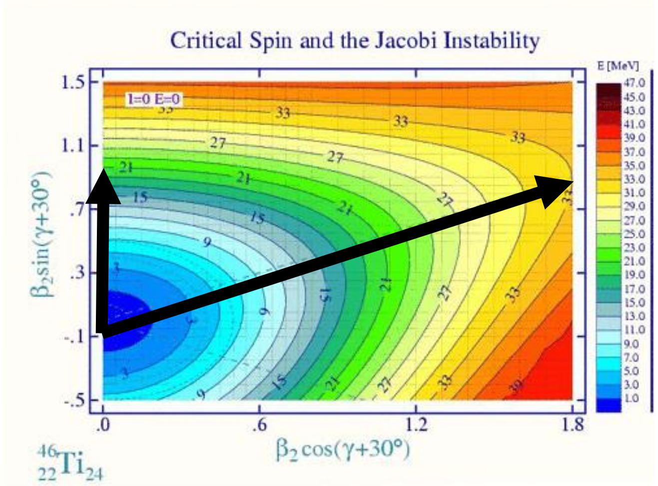
Centre de Recherches Nucléaires
IN2P3-CNRS/Université Louis Pasteur
BP 20, F-67037 Strasbourg Cedex, France

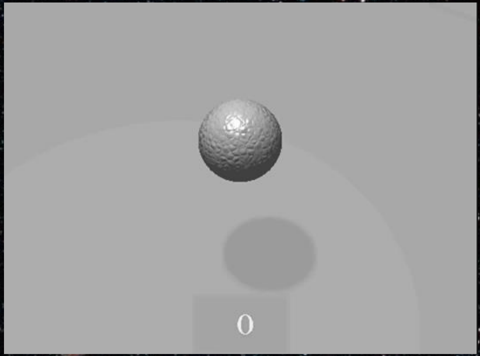
Ben Mottelson story?

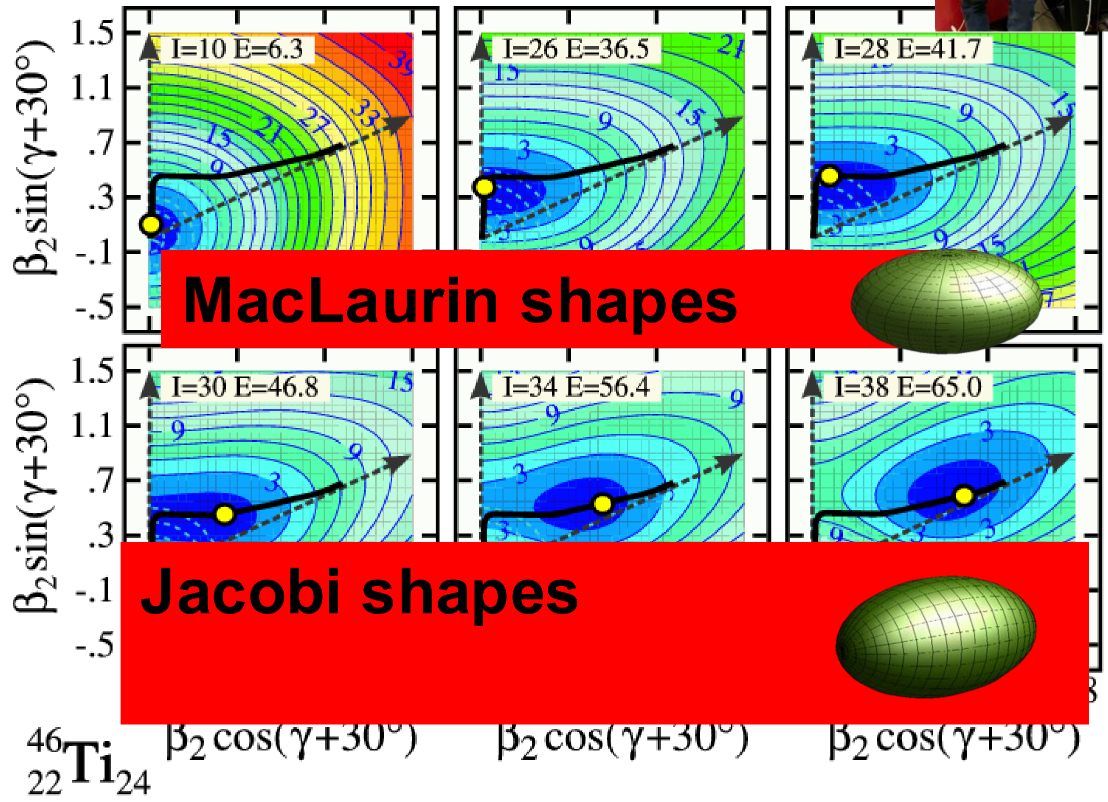
Jacobi Shapes! Slide from Adam's SSNET 2017 talk: ☺
Adam and Dudek worked closely together on this topic!



Expected shape evolution for ^{46}Ti in LSD model





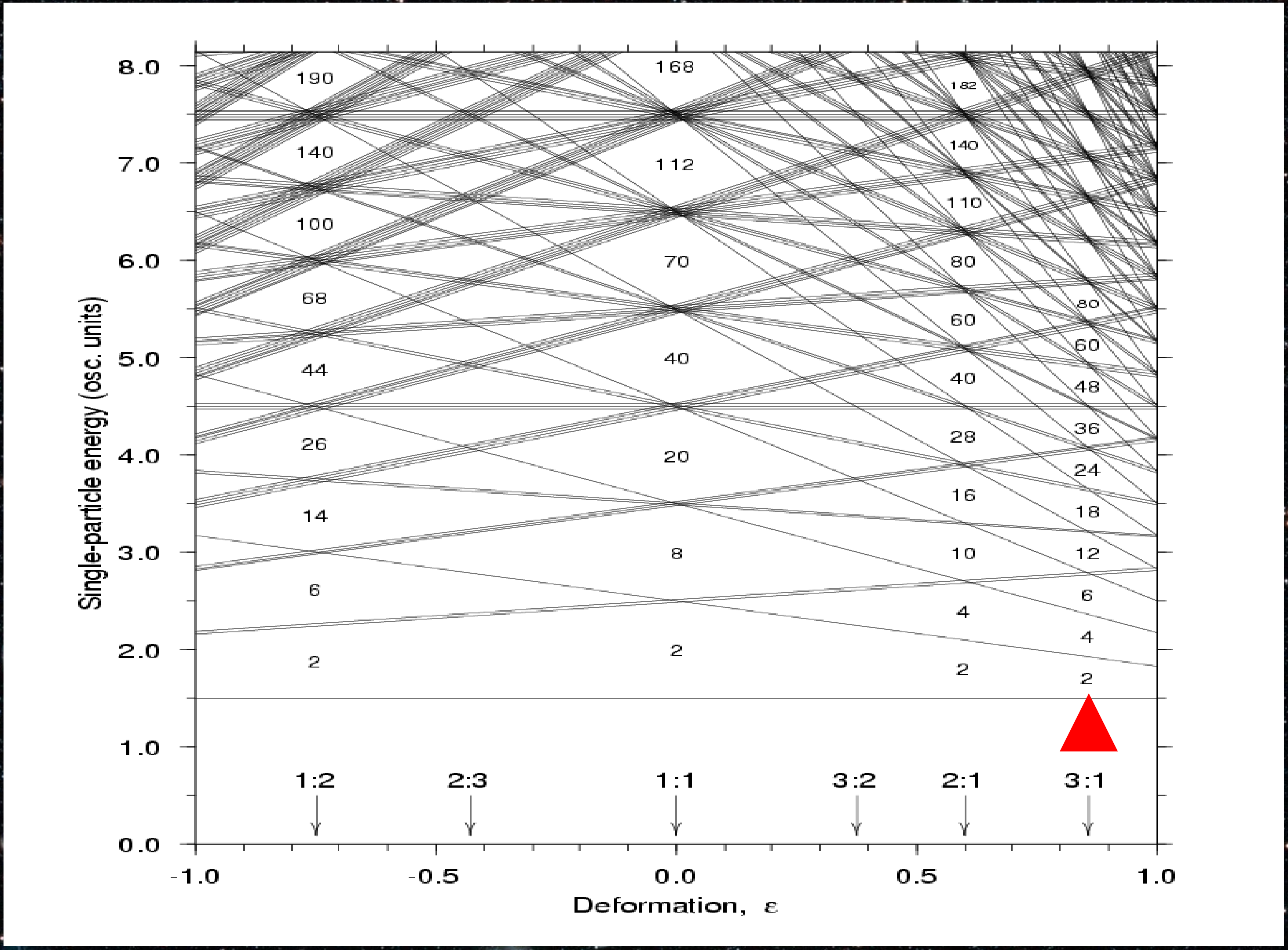


Shape evolution: Sphere➔disc➔tri-axial elipsoid➔❾cigar" (➔fission)

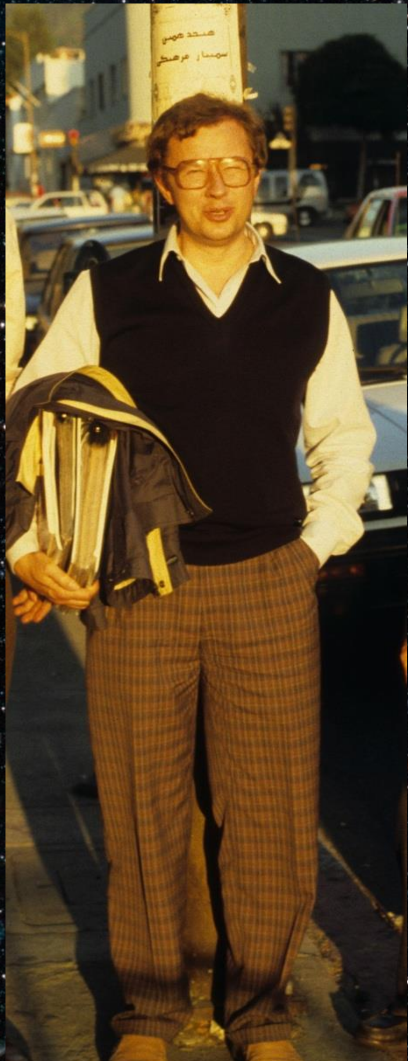
ADAM to comment!

Shell Structure

Nuclear Hyperdeformation



Harmonic oscillator



DUDEK'S INFLUENCE CONTINUES

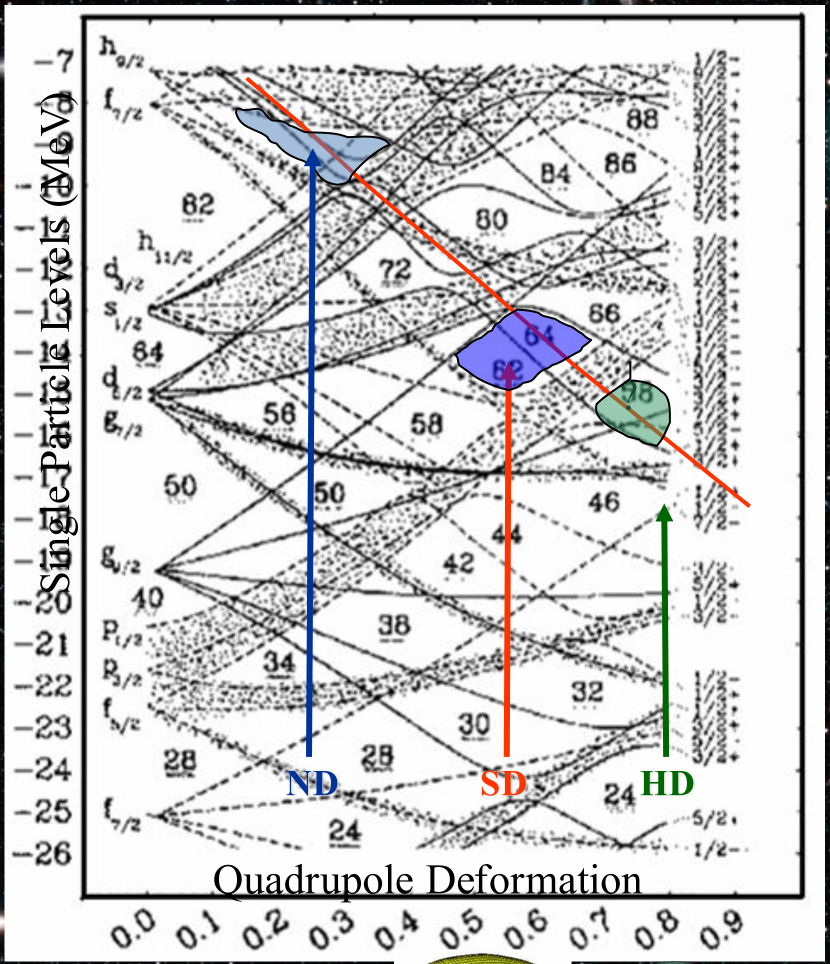
HISTORY REPEATS!

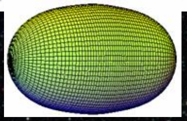
Hyperdeformation at ultra-high spins part of GRETA and AGATA proposals!

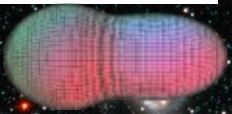
ADVANCED GAMMA TRACKING ARRAY

Can ultra-high spin hyperdeformed nuclei exist?

Woods Saxon Potential

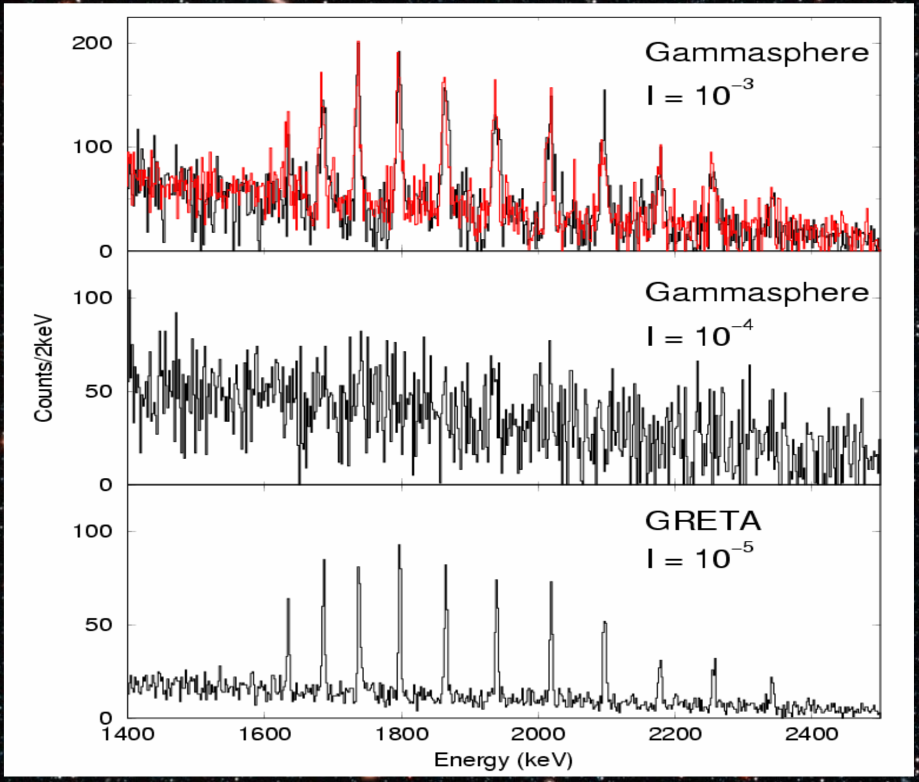






Fusion reactions
- low cross sections
- high γ–ray multiplicity

GRETA/AGATA advantage
- efficiency
- peak-to-background



Extreme spin and deformation

Eur. Phys. J. A manuscript No.
(will be inserted by the editor)

Chapter 4: Exploring the extremes of nuclear deformation (J. Wilson)

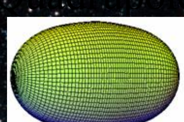
Reflections on the science and impact of Bent Herskind

S. Leoni[a,1,2], A. Maj[3], M. A. Riley[4], J. Simpson[5,a], E. Vigezzi[2], J. N. Wilson[6]

[1]Dipartimento di Fisica, Università di Milano, I-20133 Milano, Italy
[2]Istituto Nazionale di Fisica Nucleare, Milano, I-20133 Milano, Italy
[3]Niewodniczanski Institute of Nuclear Physics PAN, Radzikowskiego 152, 31-342 Krakow, Poland
[4]Department of Physics, Florida State University, Tallahassee, Florida 32306, USA
[5]STFC Daresbury Laboratory, Daresbury, Warrington WA4 4AD, United Kingdom
[6]IJC Lab, CNRS/IN2P3, Université Paris-Saclay, F-91406 Orsay, France

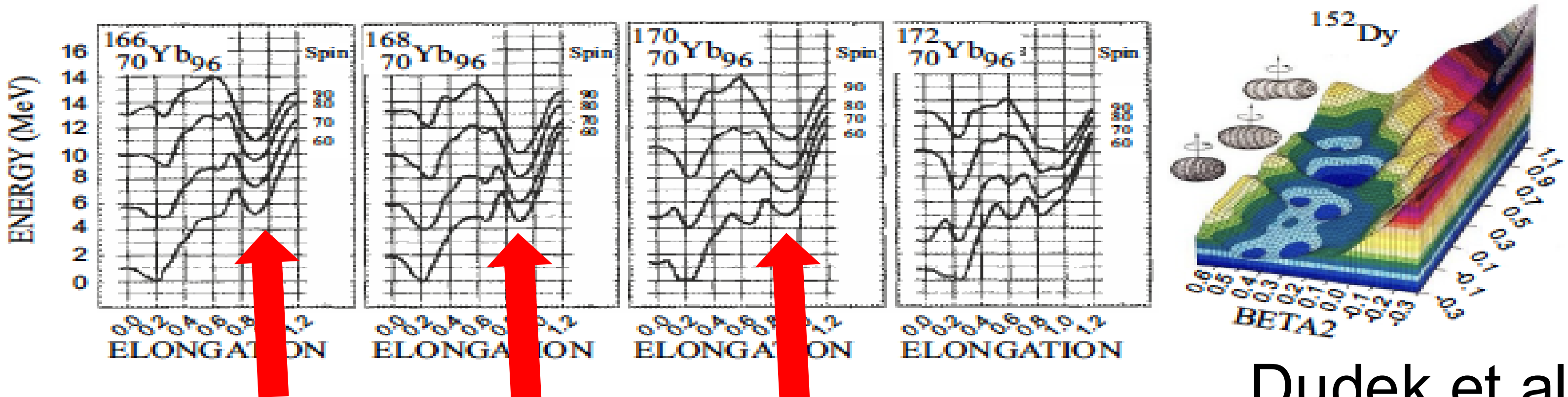
Received: August 22, 2024/ Accepted:

Quadrupole Deformation



Extreme spin and deformation

Chapter 4: Exploring the extremes of nuclear deformation (J. Wilson)



Dudek et al.

Facial is CORRECT: Let us be BOLD: Long focused expts, as pioneered by EUROBALL, with GRETA/AGATA are needed!

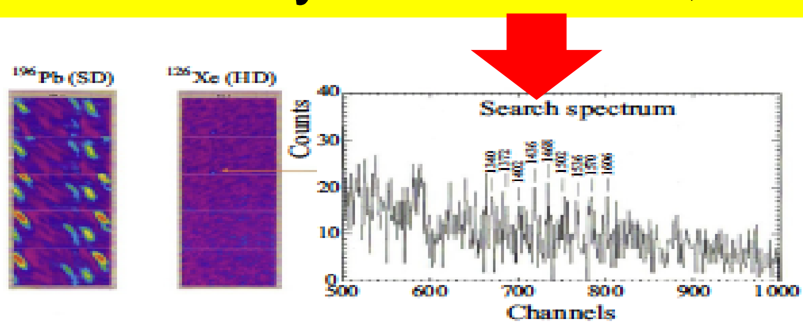


Fig. 17 Visual representation of the statistical significance of candidate bands in the band search space for multiple known superdeformed (SD) bands in ^{196}Pb on the left and HD candidates in ^{126}Xe produced in the ^{48}Ni + ^{82}Se reaction studied with EUROBALL in 2001 on the right. The multiple-gated strongest discrete HD candidate corresponding to the zone of highest statistical significance in the search space (2.3σ) is shown on the far right of this figure.

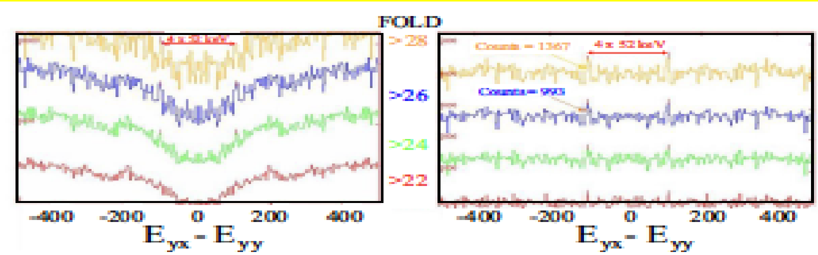
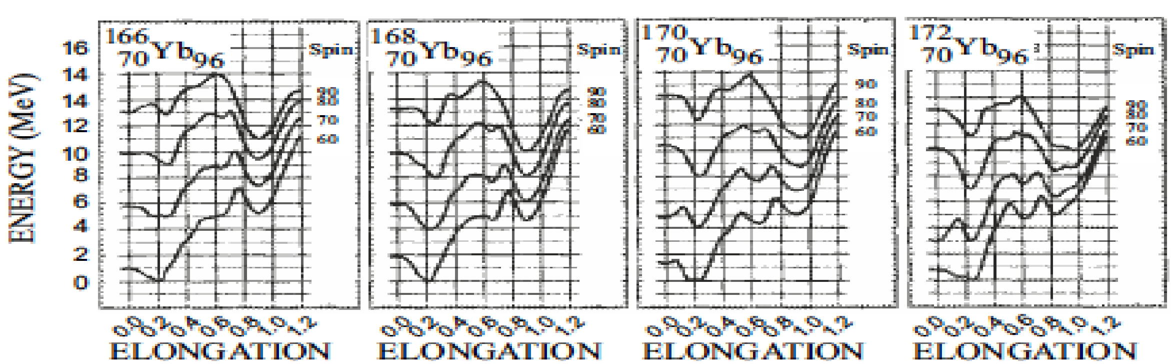
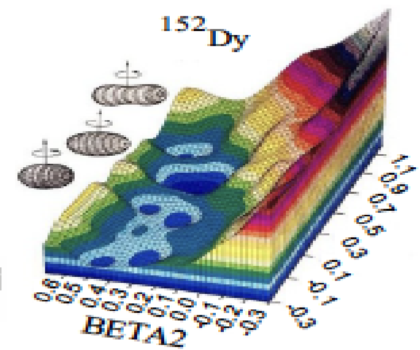


Fig. 18 Ridge spectra as a function of event fold, produced from Bent Herskind's analysis of the rotational planes in the HLHD data set selecting the 2n channel through filtering [89] and charged-particle veto. The right panel shows the difference between the 261 MeV and 255 MeV data for perpendicular cuts to the diagonal at an energy of 1440 keV and width of 102 keV. From [65].

Extreme spin and deformation

Chapter 4: Exploring the extremes of nuclear deformation (J. Wilson)



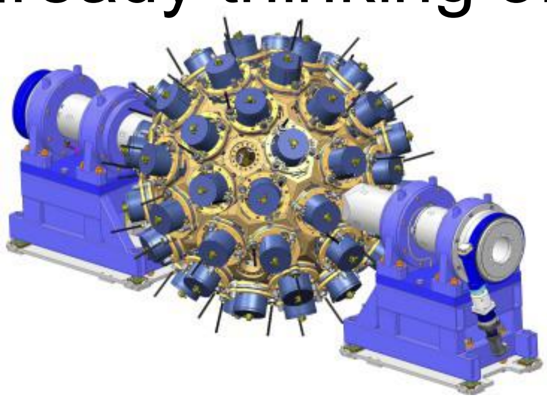


Dudek et al.

Facial is CORRECT: Let us be BOLD: Long focused expts, as pioneered by EUROBALL, with GRETA/AGATA are needed!

Adam already thinking of:

AGATA
ADVANCED GAMMA TRACKING ARRAY



PARIS

Energy (keV)

Extreme spin and deformation

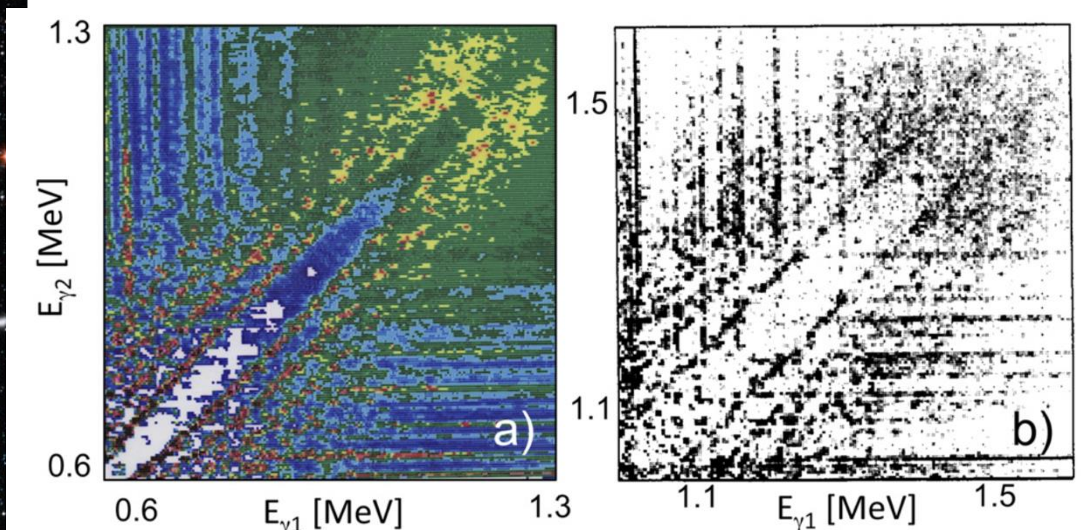
Chapter 2: Warm Nuclei at High-Spin (S. Leoni and E. Vigezzi)

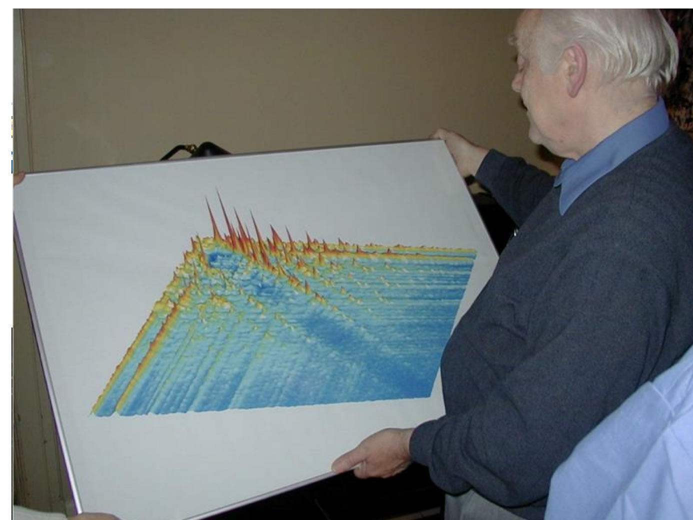
Eur. Phys. J. A manuscript No.
(will be inserted by the editor)

Perhaps as with SD studying the continuum will lead to HD discovery at ultra-high spin?

Reflections on the science and impact of Bent Herskind

S. Leoni[a,1,2], A. Maj[3], M. A. Riley[4], J. Simpson[5,a], E. Vigezzi[2], J. N. Wilson[6]





30 Year Path to GRETA! Thanks Paul!

> 2002 NSAC LRP *"The detection of γ-ray emissions from excited nuclei plays a vital and ubiquitous role in nuclear science .."*

'96

'02

'07

White Paper
'14

'15

23

> 2007 NSAC LRP *"Construction of GRETA should begin immediately upon successful completion of the GRETINA array"*

30 Year Path to GRETA!

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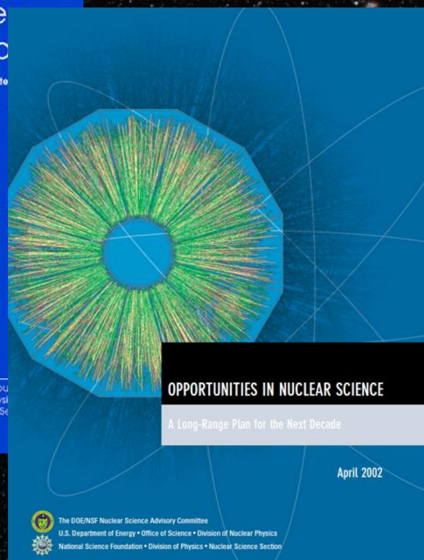
'02



'07

White Paper
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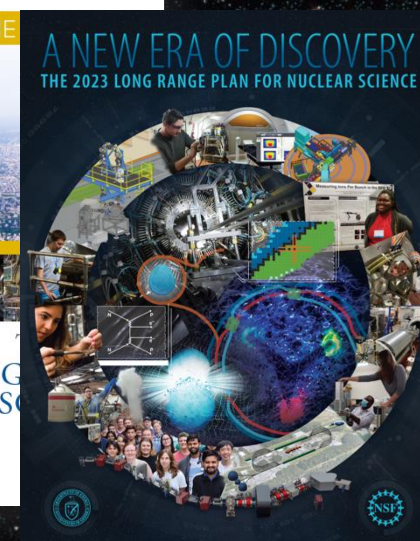
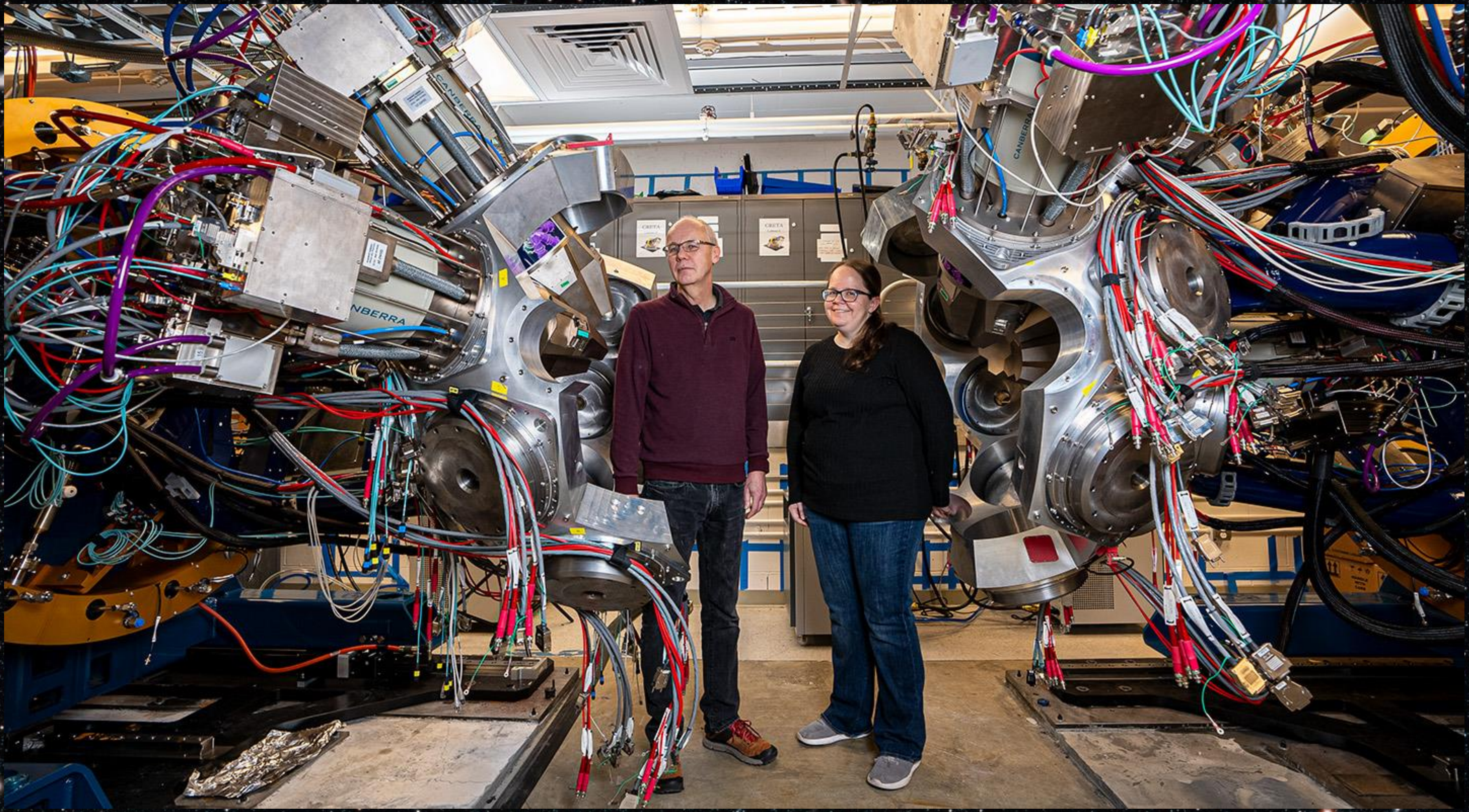


2007 NSAC LRP *"Construction of GRETA should begin immediately upon successful completion of the GRETINA array"*

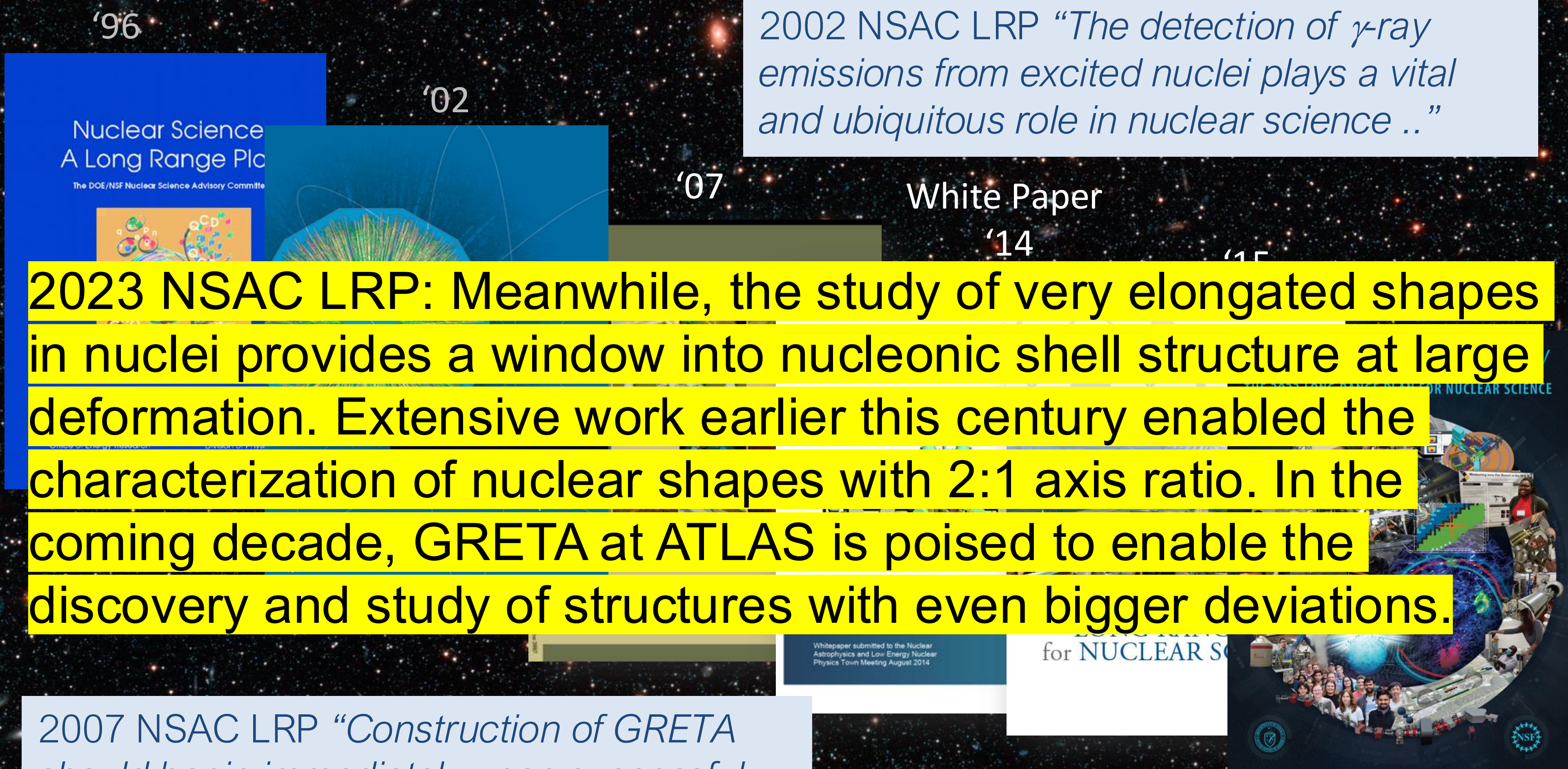
GRETA identified as a key instrument for FRIB!

SUMMER 2026:
AFTER 30 YRS: A FULL GRETA! ☺



30 Year Path to GRETA!

2002 NSAC LRP *"The detection of γ-ray emissions from excited nuclei plays a vital and ubiquitous role in nuclear science .."*



2023 NSAC LRP: Meanwhile, the study of very elongated shapes in nuclei provides a window into nucleonic shell structure at large deformation. Extensive work earlier this century enabled the characterization of nuclear shapes with 2:1 axis ratio. In the coming decade, GRETA at ATLAS is poised to enable the discovery and study of structures with even bigger deviations.

2007 NSAC LRP *"Construction of GRETA should begin immediately upon successful completion of the GRETINA array"*

GRETA identified as a key instrument for FRIB!

30 Year Path to GRETA!

2002 NSAC LRP *“The detection of γ-ray emissions from excited nuclei plays a vital and ubiquitous role in nuclear science ..”*

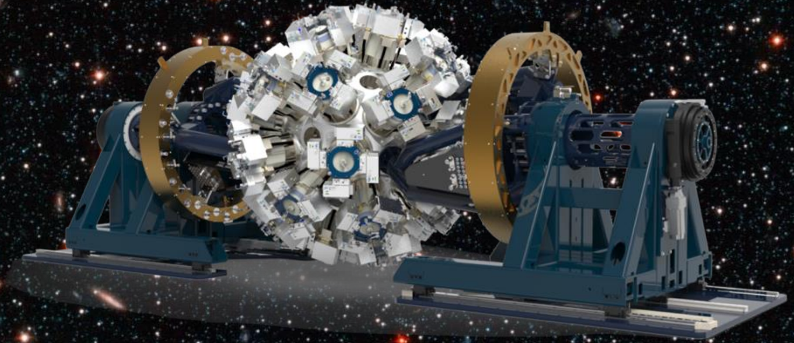
‘96 ‘02 ‘07 White Paper ‘14 ‘15 23

SIMILAR PATH FOR AGATA!! You have many heroes among you who have made it possible for YOU to be performing expts with FULL 4π GRETA/AGATA (+aux dets) in the coming years!!!

THE FUTURE OF HIGH RESOLUTION HIGH SPIN NUCLEAR SPECTROSCOPY LOOKS VERY BRIGHT INDEED!!! ☺

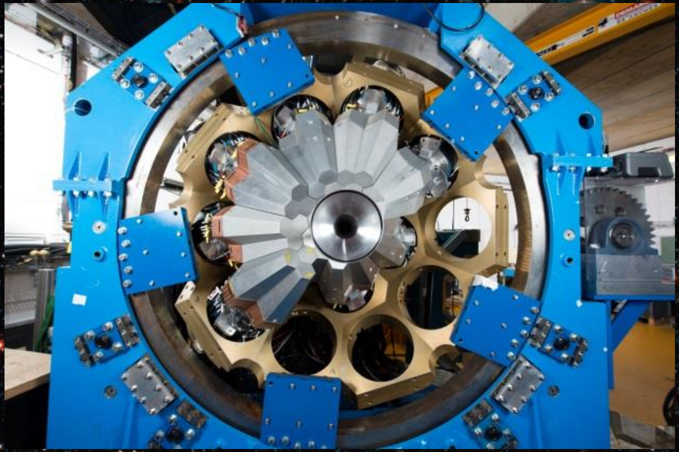
The Gamma-Ray Energy Tracking Array -GRETA

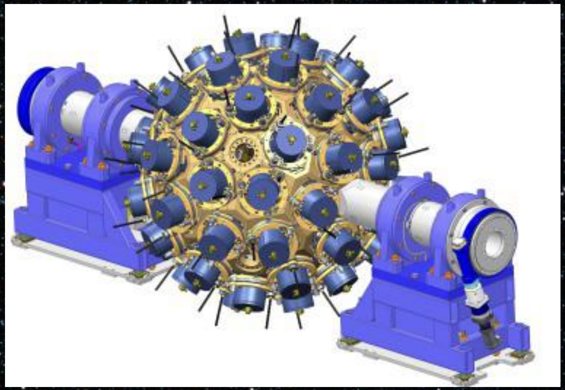
GRETA



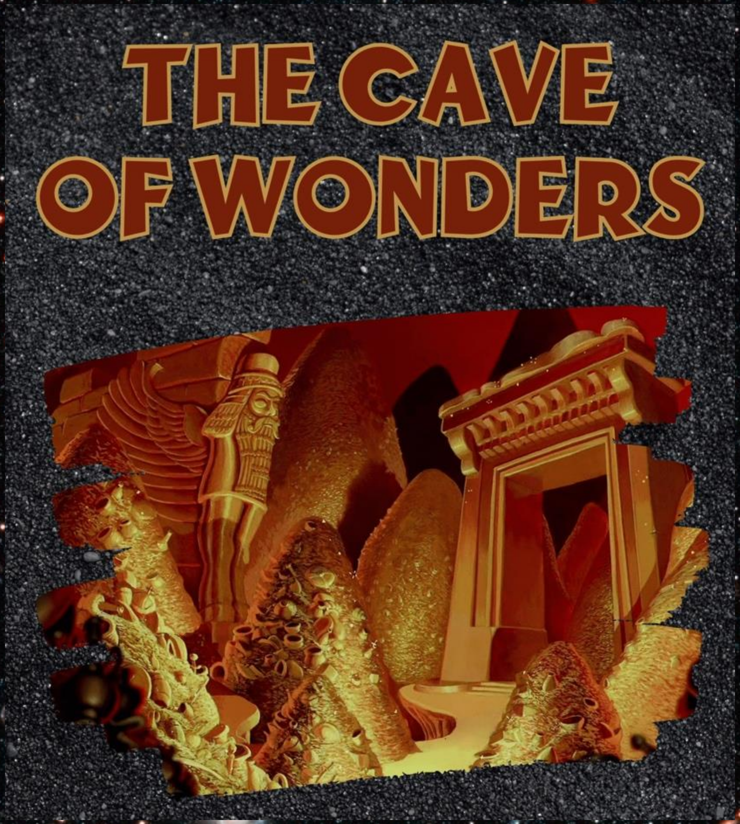
The Advanced Gamma Tracking Array AGATA

AGATA
ADVANCED GAMMA
TRACKING ARRAY





THE THEORIST THAT KEEPS GIVING!!!
IN THE LAST YEAR,
DUDEK et al CREATE
MeanField4Exp website!!!
Aladdin's Cave for Experimentalists!!!



Good News from European Funding Agencies

- **While calculating potential energy surfaces and running other tests for the identification of tetrahedral symmetry we developed many advanced computer codes**

- **We constructed $\sim 5 \times 10^5$ various potential energy 2D projections with the idea of creating an internet site data base**

- **... and there seem to be some good news to shear ...**

- **EURO-LABS has financed our MeanField4Exp proposal of the service based on our computer codes and addressing experimentalists working in nuclear accelerator centres**

- **After 4 years of installation efforts in Kraków the project has just been completed $\longrightarrow$**

Home

MeanField4Exp

IFJ PAN, KRAKOW, POLAND and IPHC and UNIVERSITY OF STRASBOURG, FRANCE

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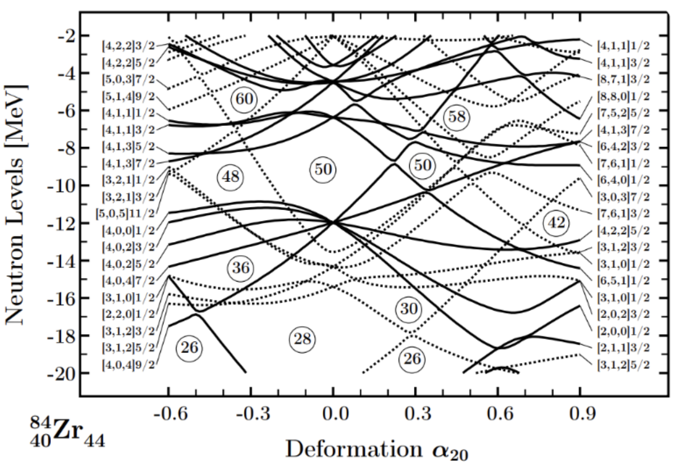
EURO-LABS
EUROPEAN LABORATORIES FOR ACCELERATOR BASED SCIENCES

This website is based on an extensive research program
developed over many years by J. Dudek (IPHC and University of Strasbourg) and his collaborators;
it allows to explore elementary structure properties of atomic nuclei, including shapes, symmetries and excitations,
using **Realistic Phenomenological Nuclear Mean Field Theory Calculations.**

Our Services

Single Particle Energies

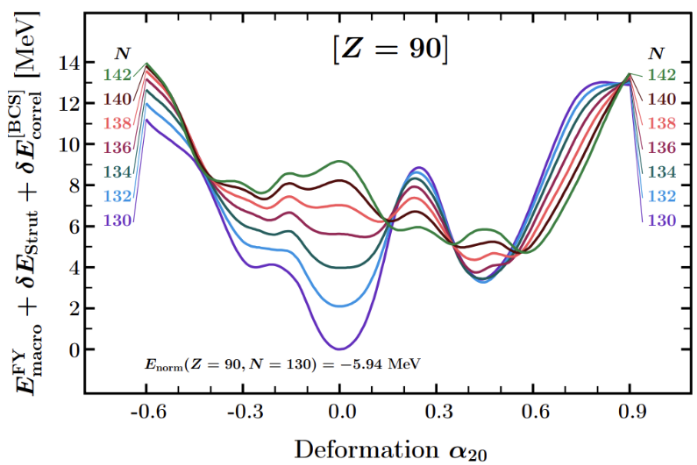
Generating diagrams of single nucleon energies.



Enter

Nuclear Energy Diagrams

Generate Macroscopic-Microscopic Method nuclear energy diagrams.



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Jerzy's Great Gift to us all!

Home

MeanField4Exp

IFJ PAN, KRAKOW, POLAND and IPHC and UNIVERSITY OF STRASBOURG, FRANCE

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This website is based on an extensive research program
developed over many years by J. Dudek (IPHC and University of Strasbourg) and his collaborators;
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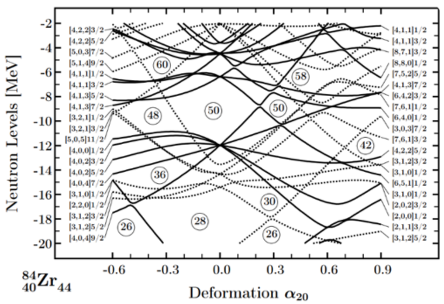

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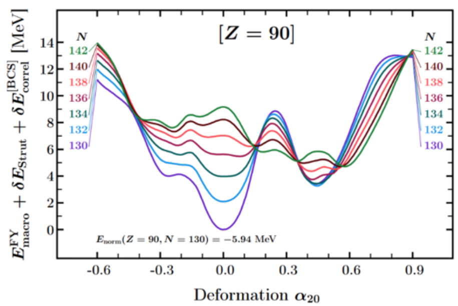
Nuclear Energy Diagrams

Generate Macroscopic-Microscopic Method nuclear energy diagrams.



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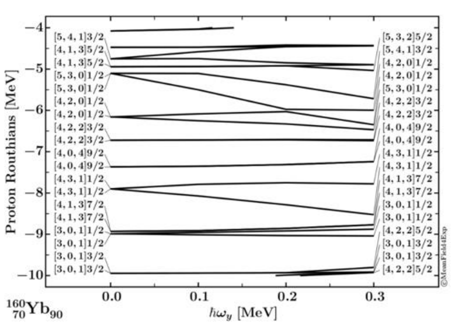
3D Cranking

Create diagrams for single-particle Routhians through the Cranking method.



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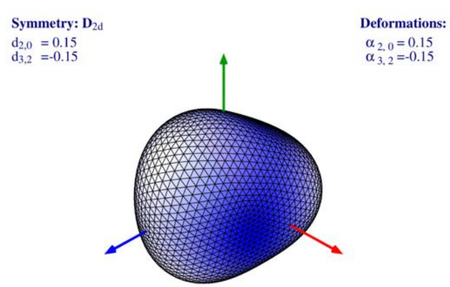
3D Nuclear Surface

Generate 3d diagrams of the nuclear shapes for customized deformations.



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Home Contact Us

MeanField4Exp

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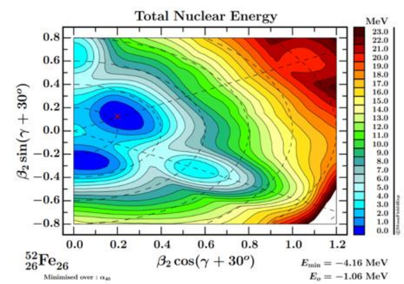
Services About The

Macroscopic-Microscopic Energy

Generating total energy diagrams according to the Macroscopic-Microscopic approximation.



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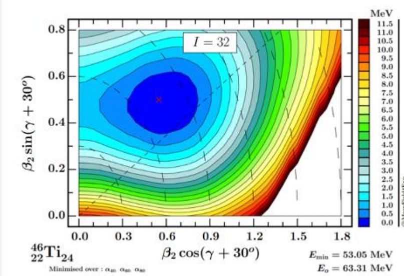
Shape Evolution with Spin

Generating diagrams of shape evolution with spin according to macroscopic energy models.



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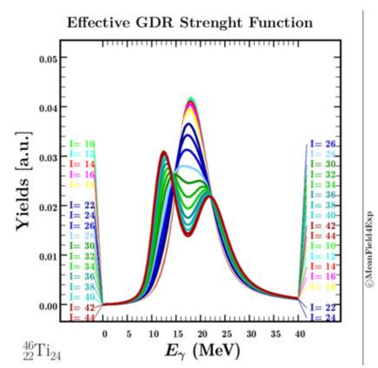
Giant Dipole Resonances (!beta version!)

Generating effective GDR strenght function for given spins and temperature.



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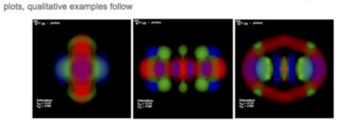
Single Nucleon Probability Density Functions

Description

The nucleonic orbitals [by definition a couple ($E_n, \Phi_n(\vec{r})$) is referred to as orbital] enumerated by integer index, n, define the probability density distributions, $\varrho_n(r) = |\Phi_n(r)|^2$, for either protons or neutrons, according to user specifications, which will result in a 3D plots, qualitative examples follow



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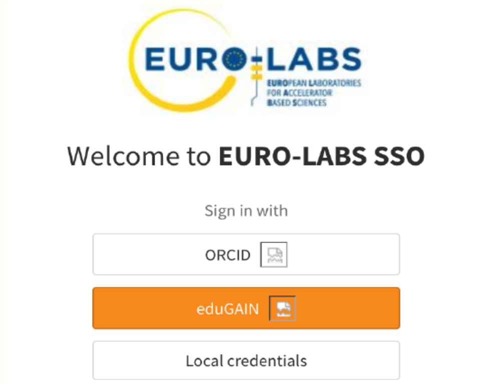
Recent Email Transfer to JD from Professor Maj



From: Sullivan, Conor < C.M.Sullivan@liverpool.ac.uk >
To: adam.maj@ifj.edu.pl
Subject: MeanField4Exp - Fantastic!

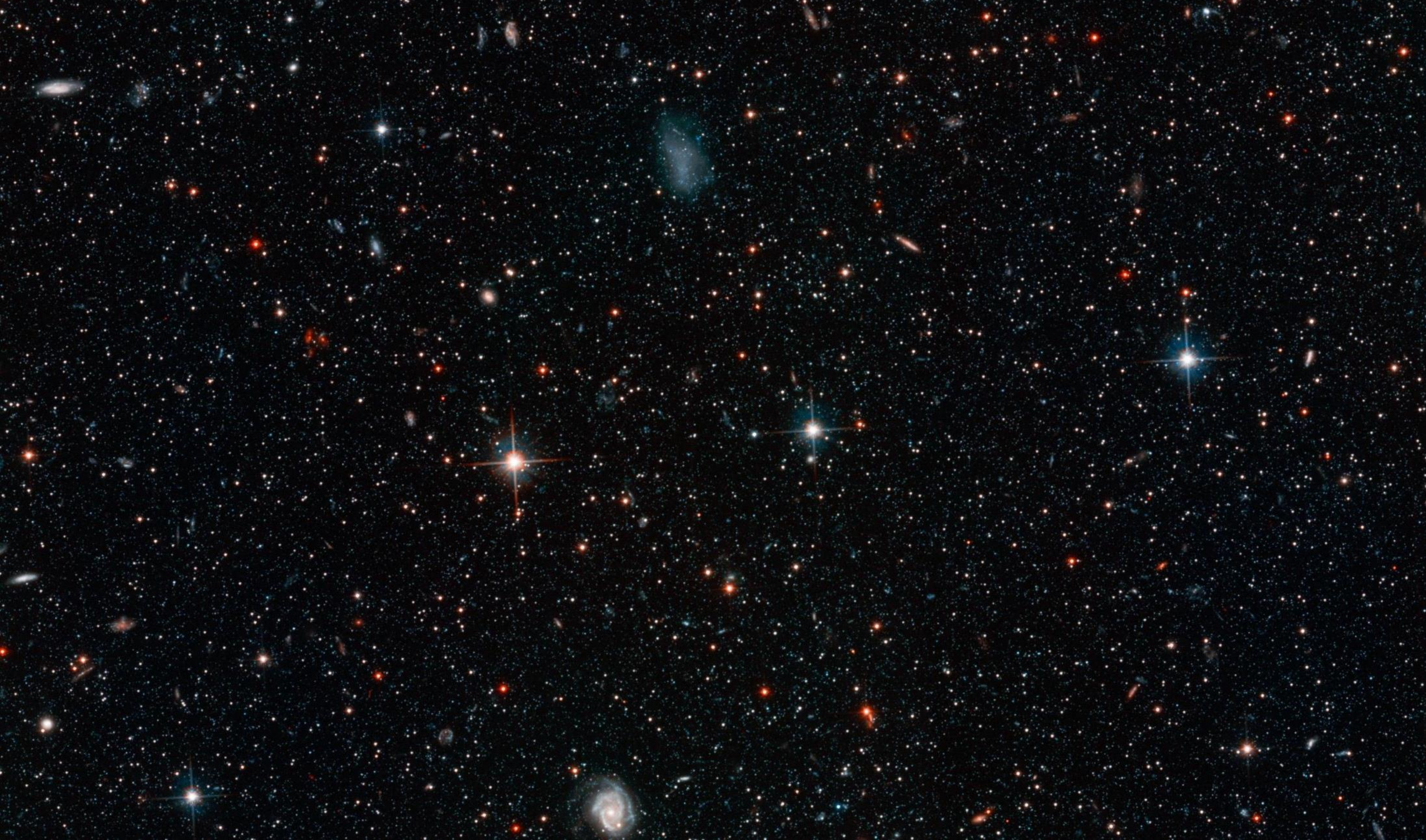
Hi Adam,

Thank you so much for the recommendation on this website.
It's absolutely fantastic and so easy to use!
What a triumph for the collective efforts of Jerzy
and all his collaborators over the years.

Conor

JUST ONE MORE THANK YOU!

☺ ☺ ☺



Shapes and Symmetries in Nuclei: Expt and Theory
SSNET Series of Conferences: Simply Magnificent!!
Thanks Jerzy, Costel, Amel etc ☺☺☺

At Bent Herskind's house in 1989, 3 Month NBI Workshop! Dudek, Geirr Sletten and Alison Riley

HAPPY BIRTHDAY JERZY!
THANK YOU FROM US ALL! ☺☺☺