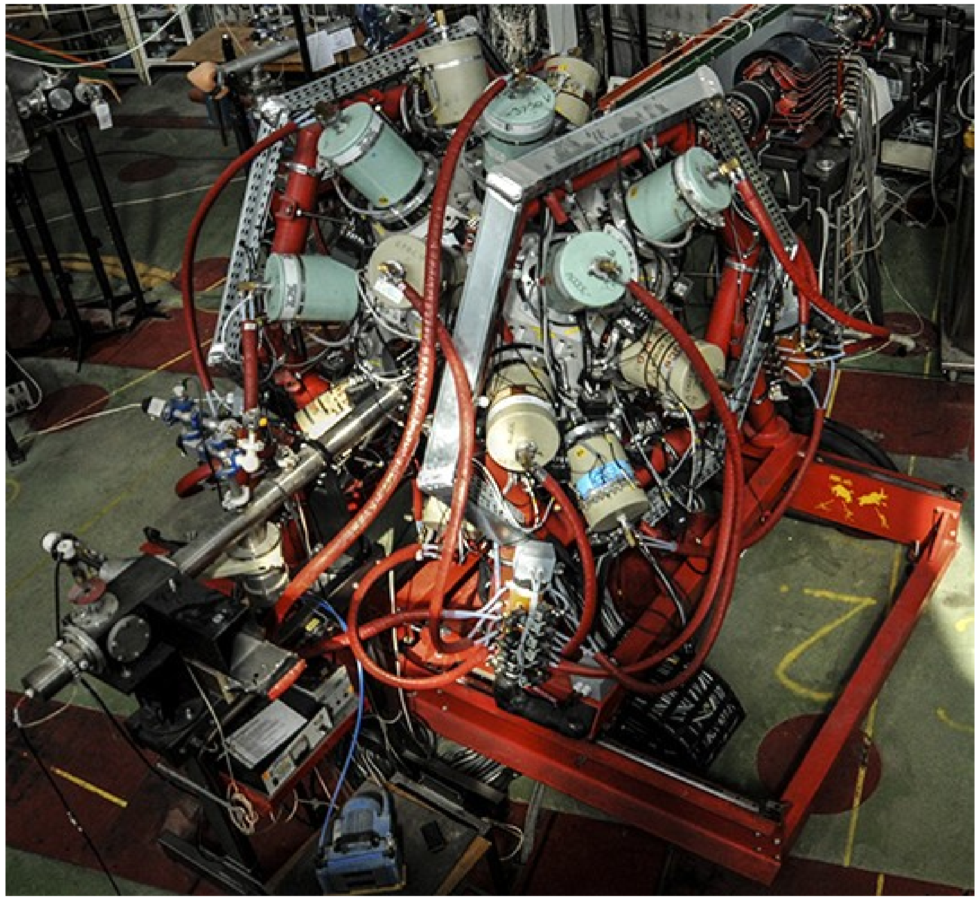
Gamma Spectroscopy
at Heavy Ion Laboratory, University of Warsaw.



central European Array for Gamma Levels Evaluation - EAGLE

J. Mierzejewski et al., NIM ***A 659*** *(2011) 84*

EAGLE: 15 HPGe ACS of 70% efficiency
mechanical frame for 30 Ge ACS

1.Heavy Ion Laboratory, University of Warsaw, 02-093 Warsaw, Pasteura 5a, Poland
2.Nuclear Physics Division, Institute of Experimental Physics, University of Warsaw, Warsaw, PL
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6.National Centre for Nuclear Research, 05-400 Swierk, Otwock
7.Department of Theoretical Physics, Institute of Physics, M. Curie Skłodowska University, Lublin, PL
8.The Henryk Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, PL
9.F. Ioffe Physical-Technical Institute, St.-Petersburg, Russia
10.IRFU/SPhN, CEA Saclay, Gif-sur-Yvette, France
11.Horia Hulubei National Institute of Physics and Nuclear Engineering - IFIN HH, Romania
12.Department of Physics, LUND, Sweden
13.Department of Atomic Physics, Faculty of Physics, University of Sofia "St.Kliment Ohridski" Sofia, Bulga
14.Faculty of Physics, Warsaw University of Technology, Warsaw, PL
15.School of Environment and Technology, Uniwersytet w Brighton, Great Brittain
16.GANIL, Caen, Francja
17. **Division of Nuclear Physics, Institute of Nuclear Research (ATOMKI),H-4026 Debrecen, Hungary**
18. Department of Physics, Royal Institute of Technology (KTH) Stockholm, Sweden
19. Department of Physics, University of Oslo, Oslo, Norway

EAGLE Ancillary Detectors

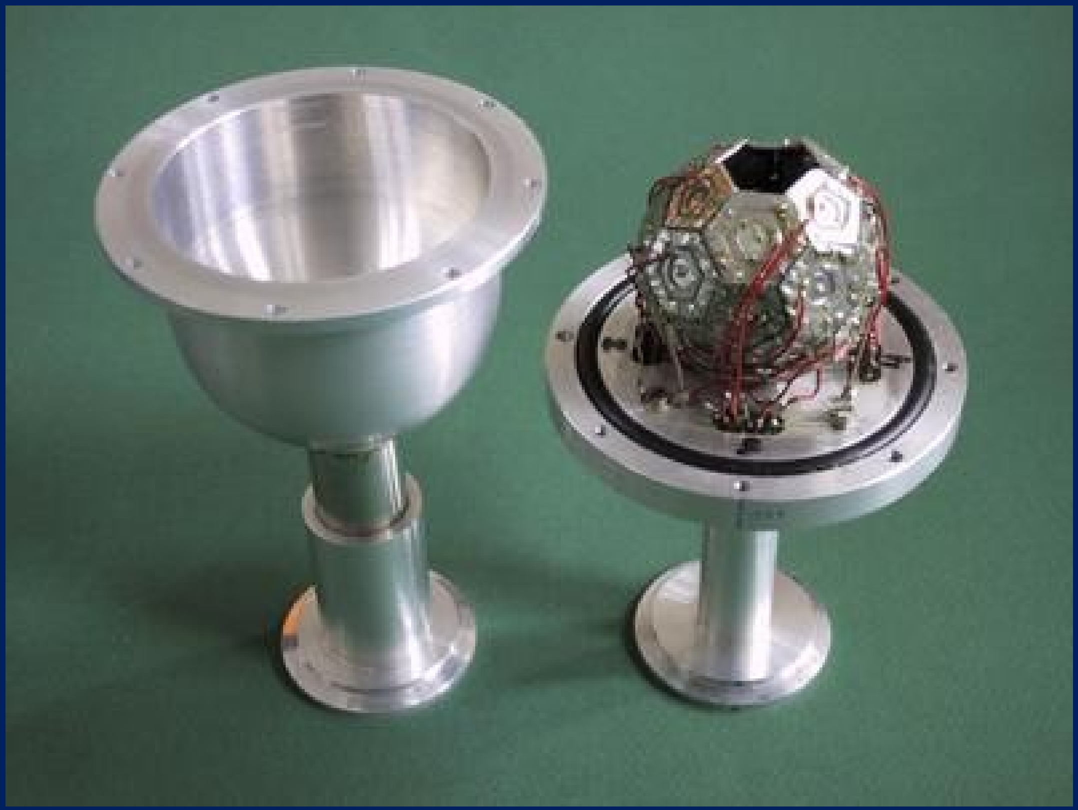
- internal conversion electron spectrometer ULESE
  J. Perkowski, - Univ. of Lodz
- COULEX (48 - max.110 PIN-diodes)
  P.J. Napiorkowski, K. Wrzosek-Lipska HIL UW

- Devald type Plunger C. *Mihai - IFIN-HH Bucharest, A. Tucholski HIL UW*

- 4π Si-Ball for p,α detection *A. Kordyasz, HIL UW*

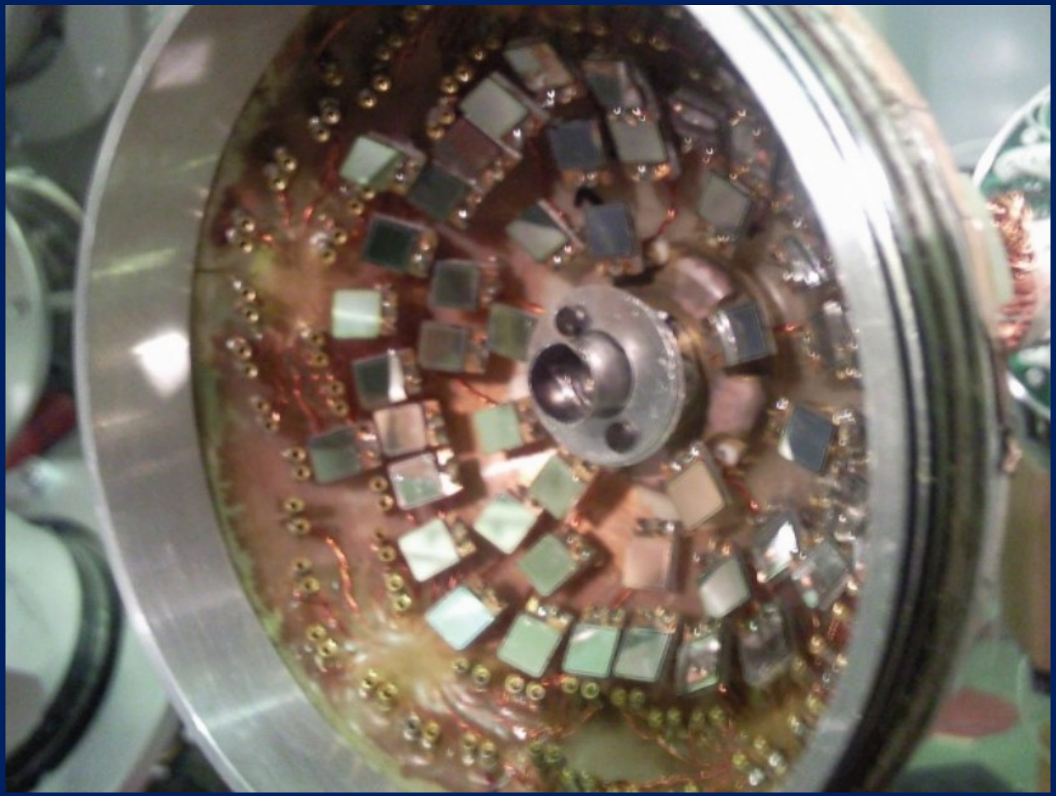
- Recoil Filter Detector *P. Bednarczyk - IFJ PAN,Kraków*

- Multiplicity Filter (60 BaF2)



4π Si-Ball
(A. Kordyasz, HIL UW

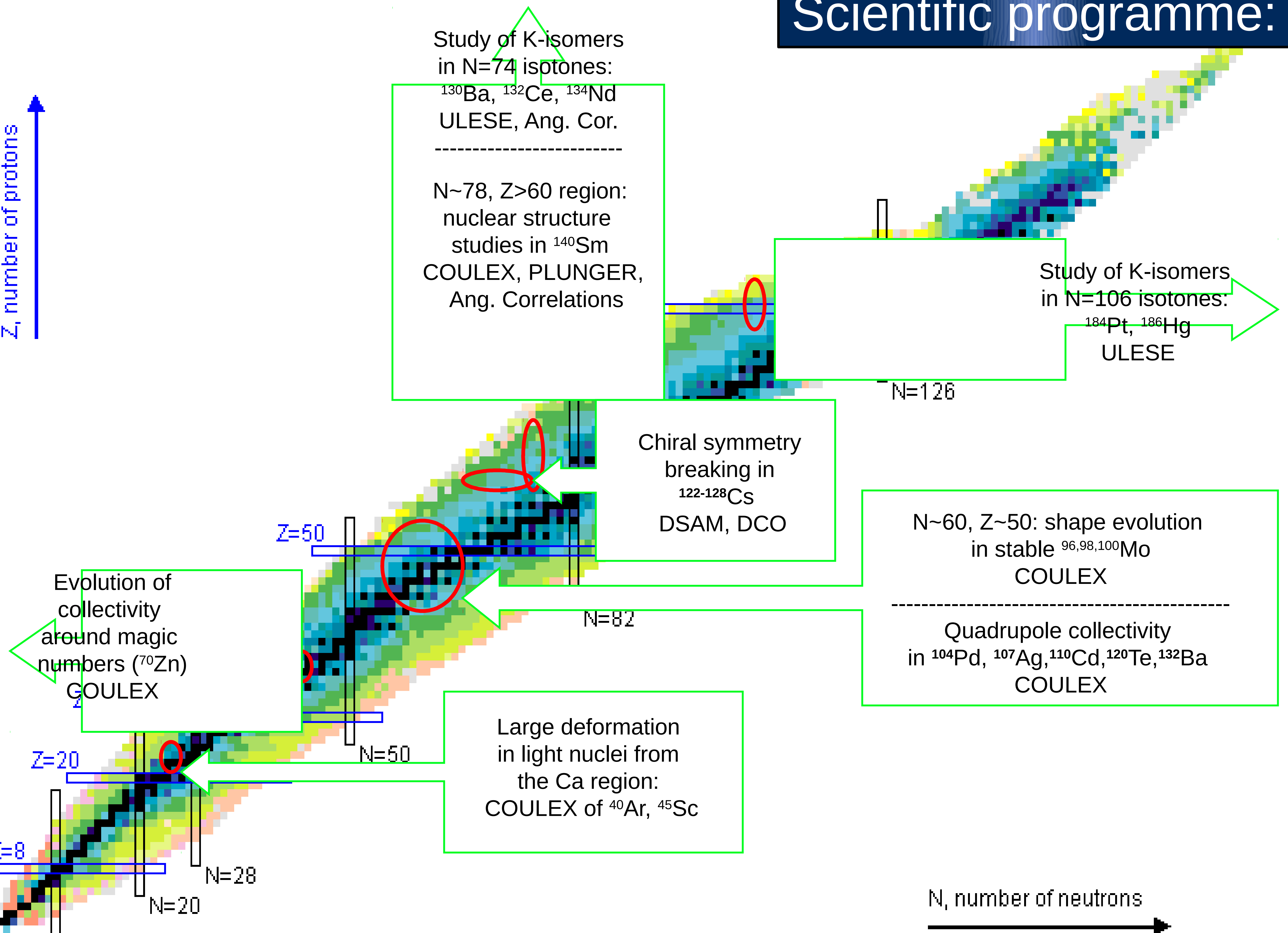
ULESE J. Perkowski
University of Lodz Electron SpEctrometer



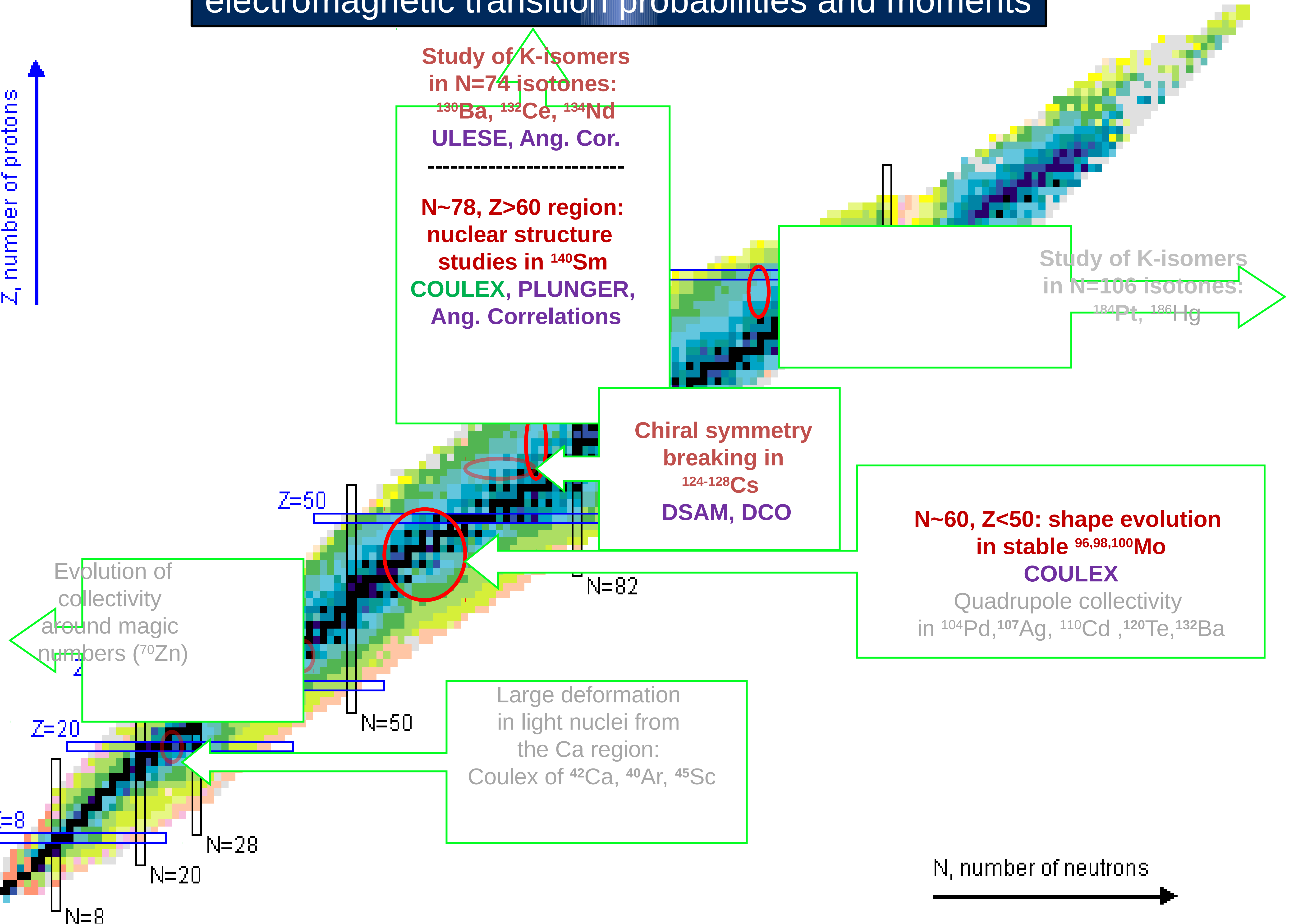
„The Munich chamber” 48 PiN diodes
(max. 110)
P. Napiorkowski, K. Wrzosek-Lipska, HIL

Bucharest -Koln plunger
C. Michai IFIN-HH, A. Tucholski HIL UW

Scientific programme:



electromagnetic transition probabilities and moments



Study of K-isomers
in N=74 isotones:
^{130}Ba, ^{132}Ce, ^{134}Nd
ULESE, Ang. Cor.

N~78, Z>60 region:
nuclear structure
studies in ^{140}Sm
COULEX, PLUNGER,
Ang. Correlations

Study of K-isomers
in N=106 isotones:
^{184}Pt, ^{186}Hg

Chiral symmetry
breaking in
$^{124-128}Cs$
DSAM, DCO

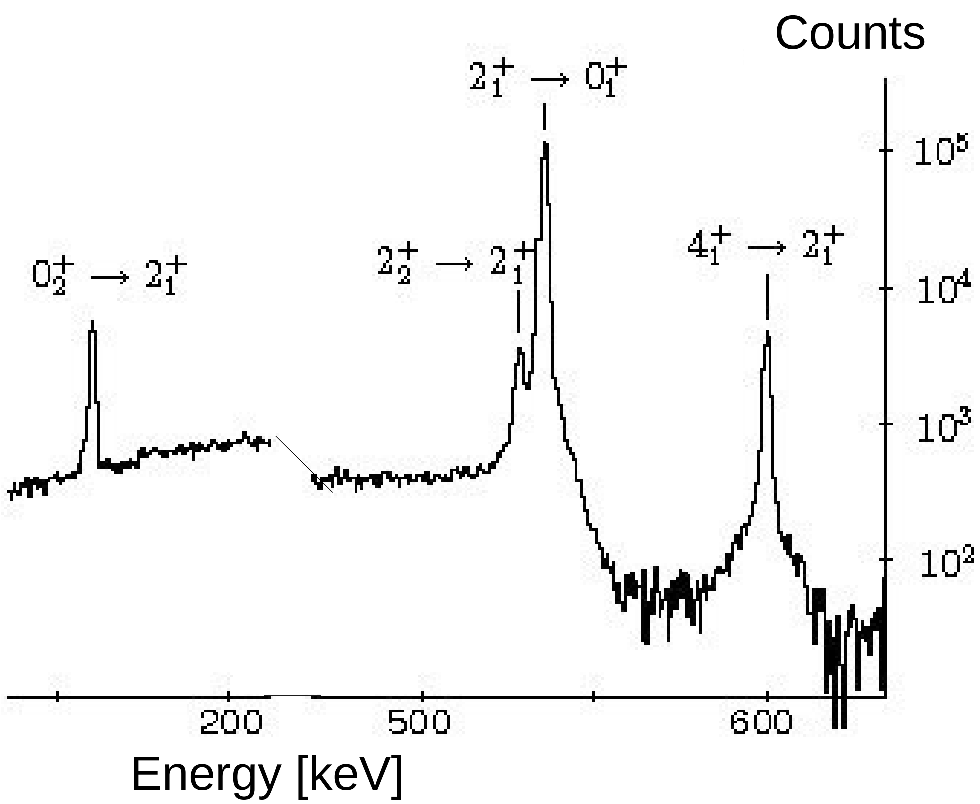
N~60, Z<50: shape evolution
in stable $^{96,98,100}Mo$
COULEX
Quadrupole collectivity
in ^{104}Pd, ^{107}Ag, ^{110}Cd, ^{120}Te, ^{132}Ba

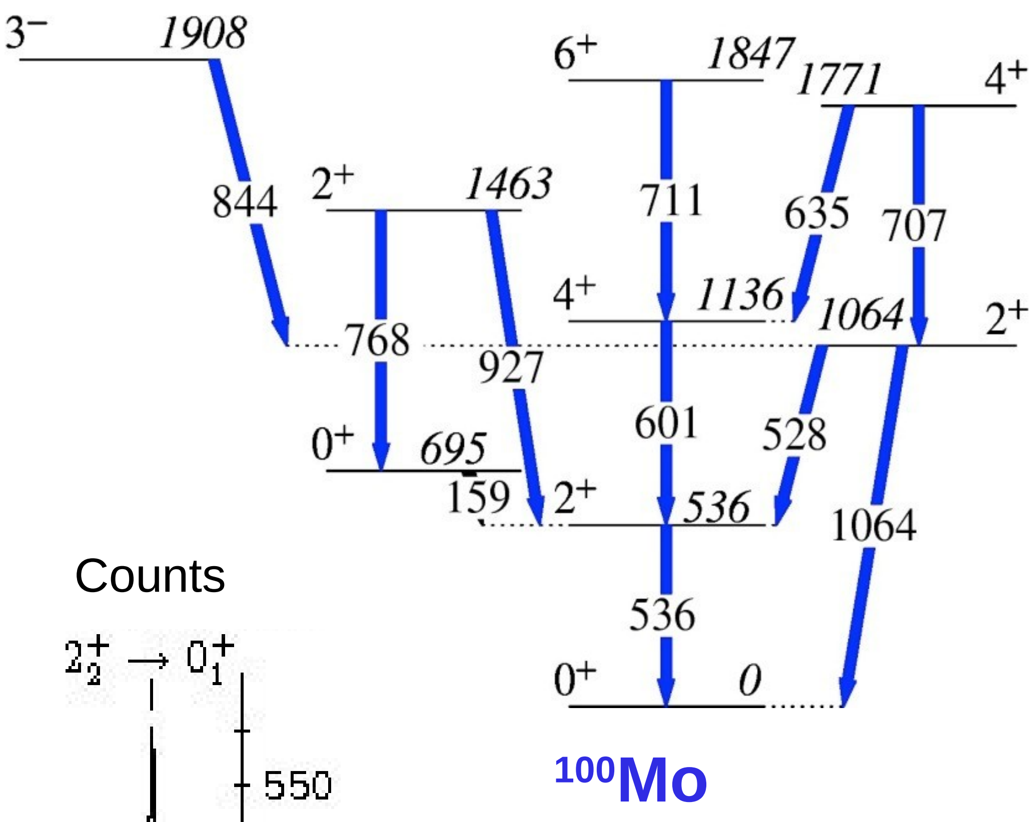
Evolution of
collectivity
around magic
numbers (^{70}Zn)

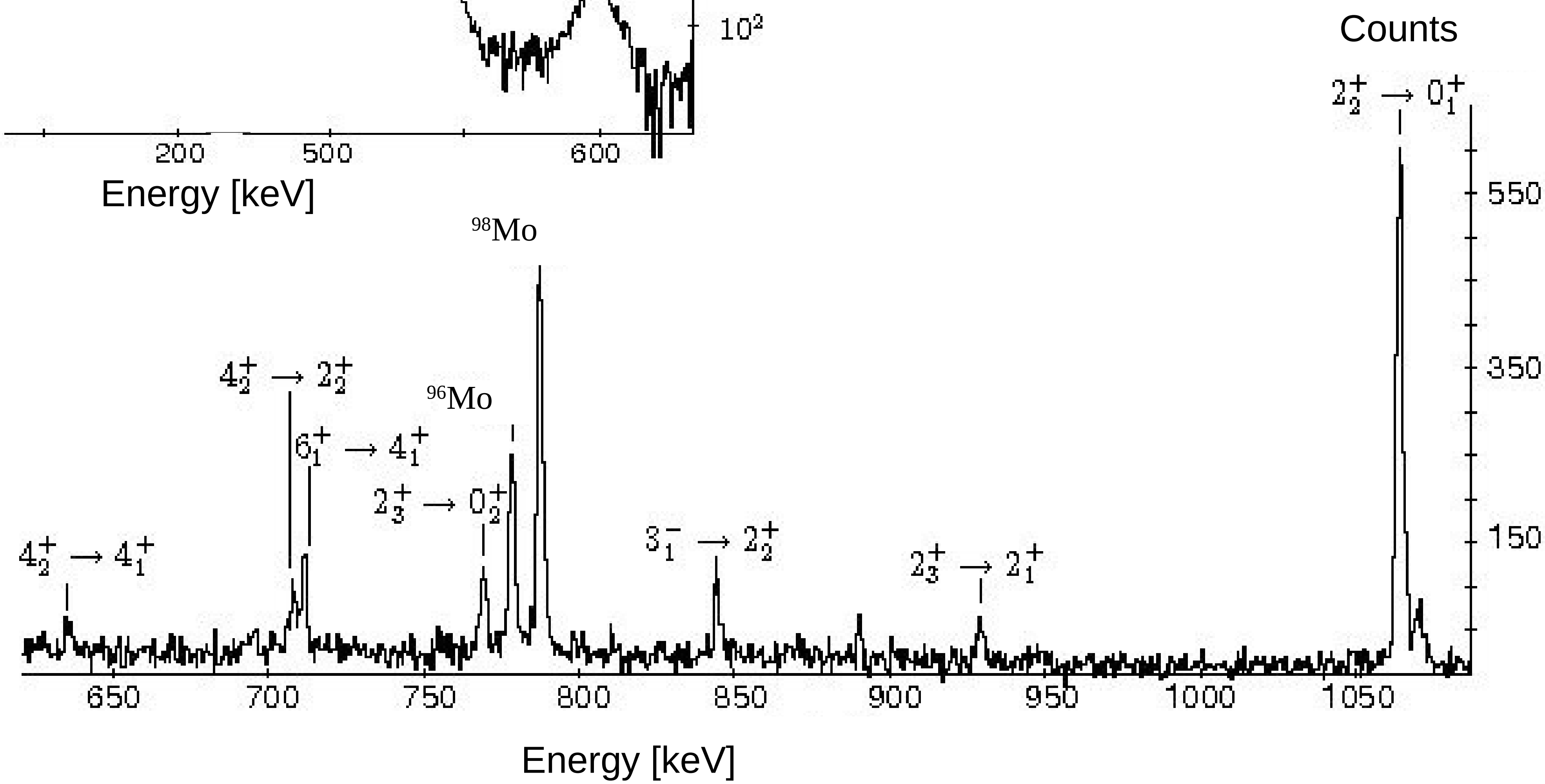
Large deformation
in light nuclei from
the Ca region:
Coulex of ^{42}Ca, ^{40}Ar, ^{45}Sc

Coulomb Excitation of ^{100}Mo

^{32}S scattered at 112° – 154°



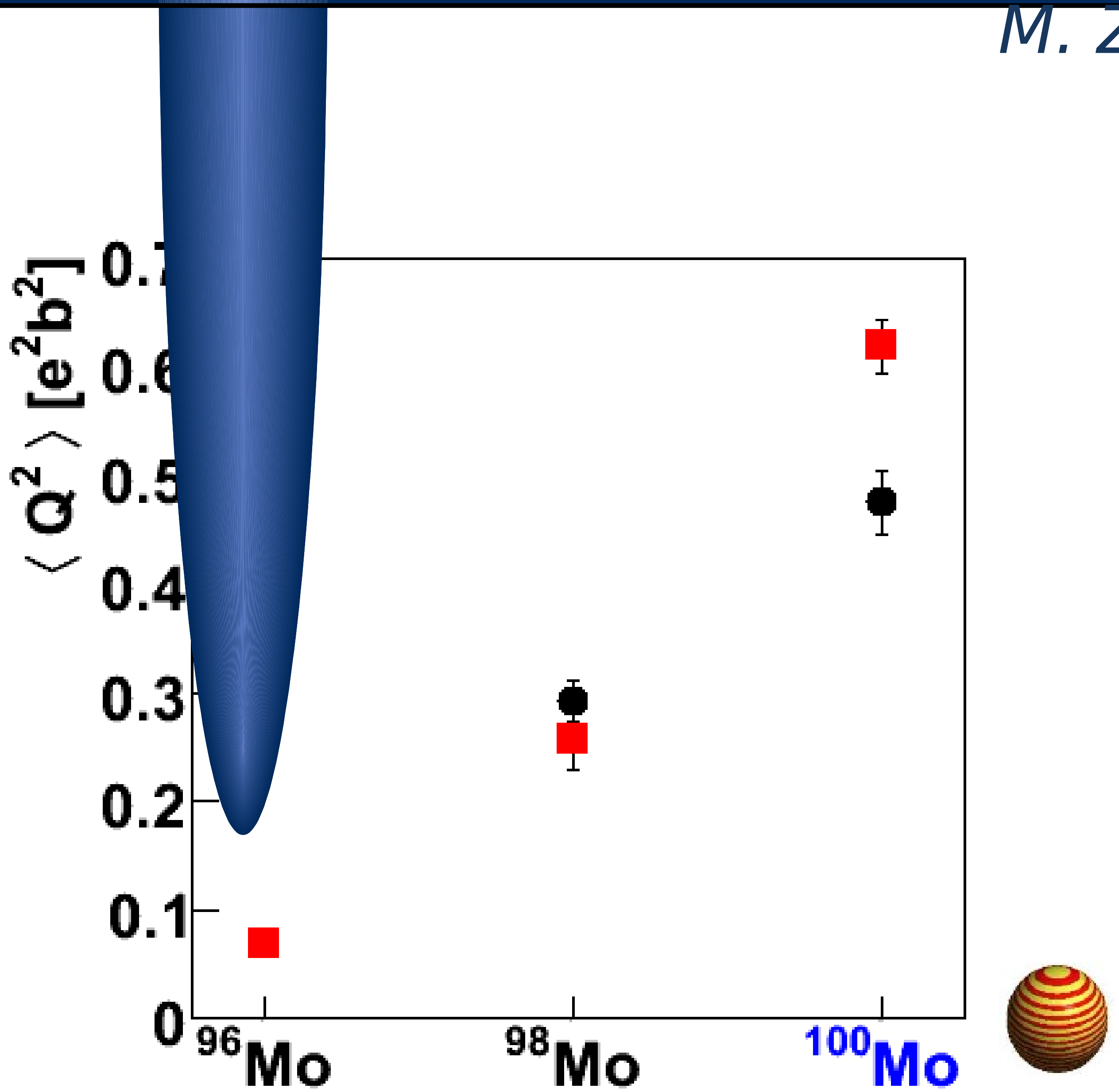


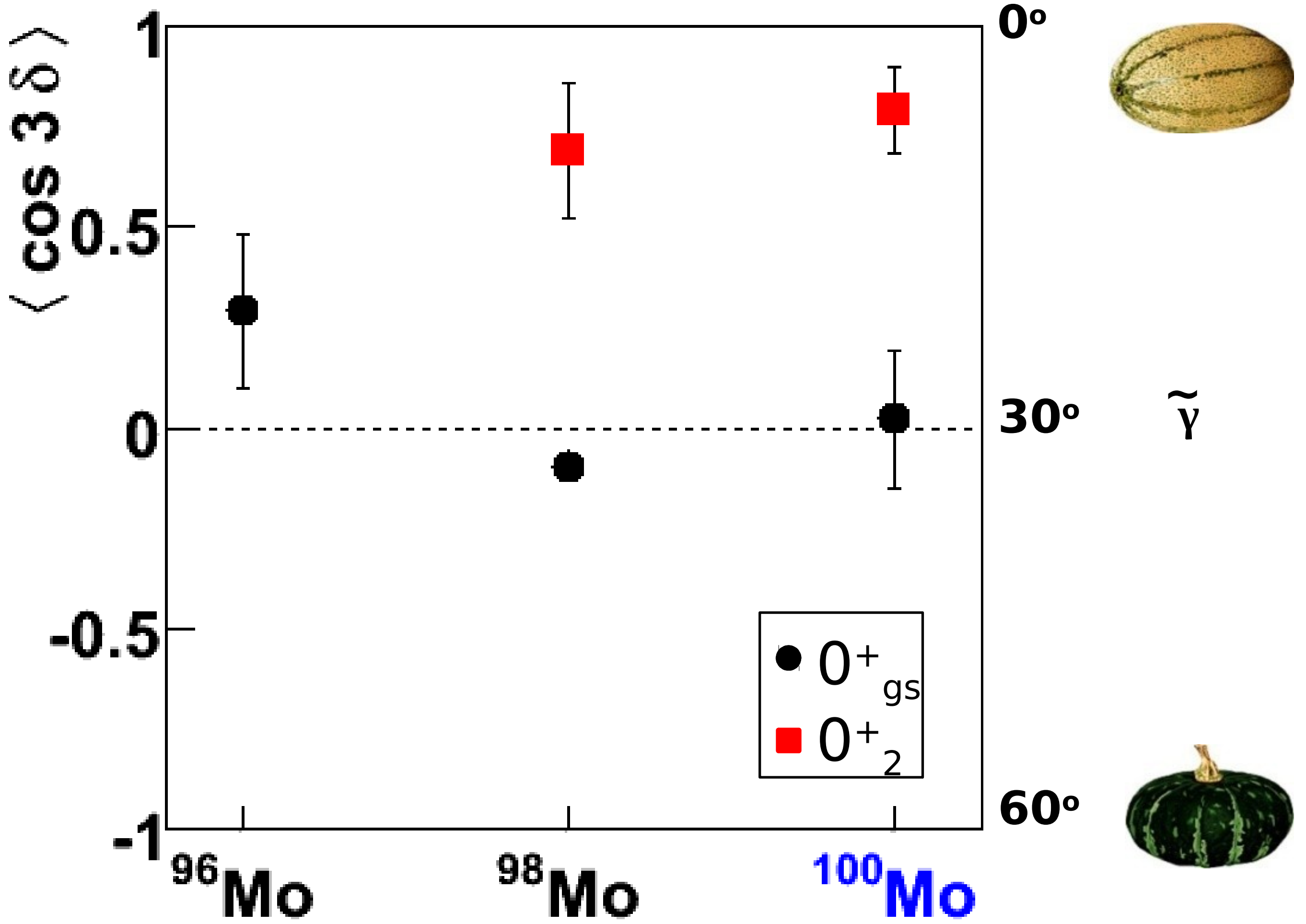


K. Wrzosek-Lipska, et al.
PRC 86 (2012) 064305

Shape evolution of $^{96-100}$Mo

M. Zielińska et al., Nucl. Phys. A 712 (200
K. Wrzosek-Lipska et al., PRC 86 (201

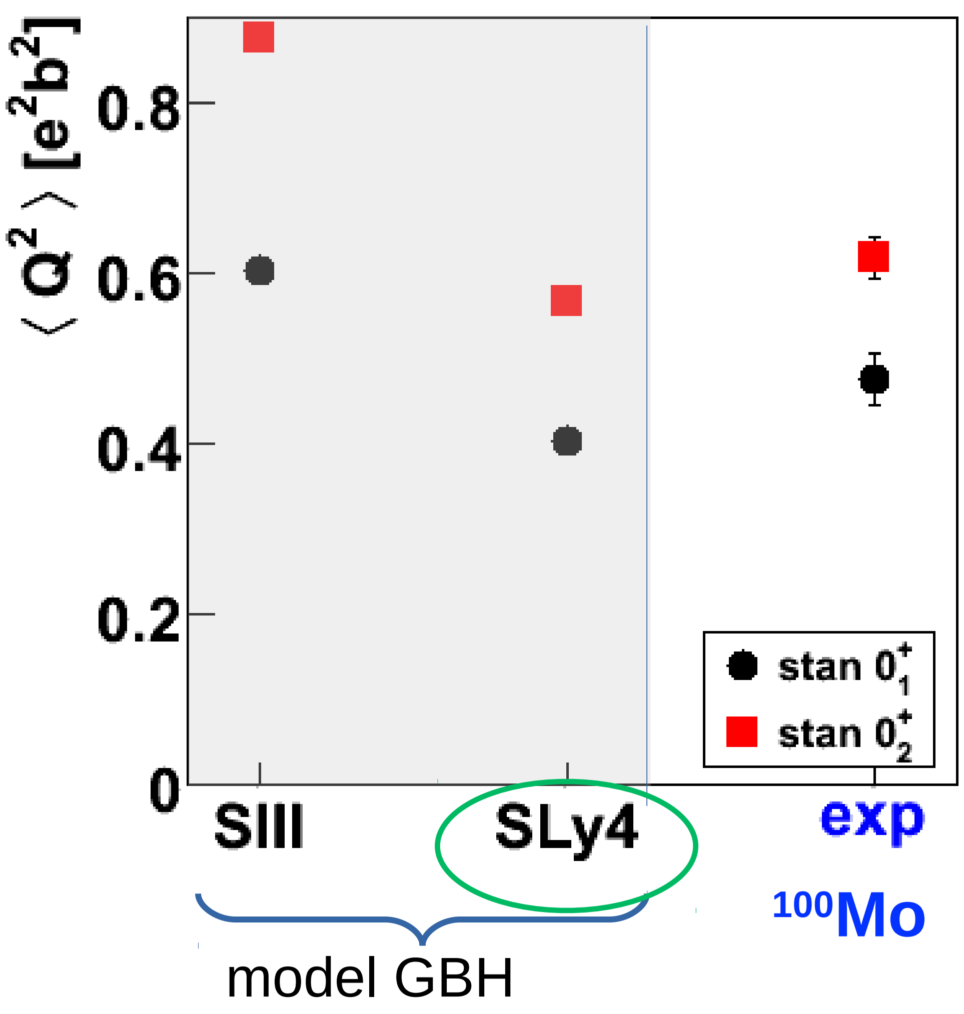


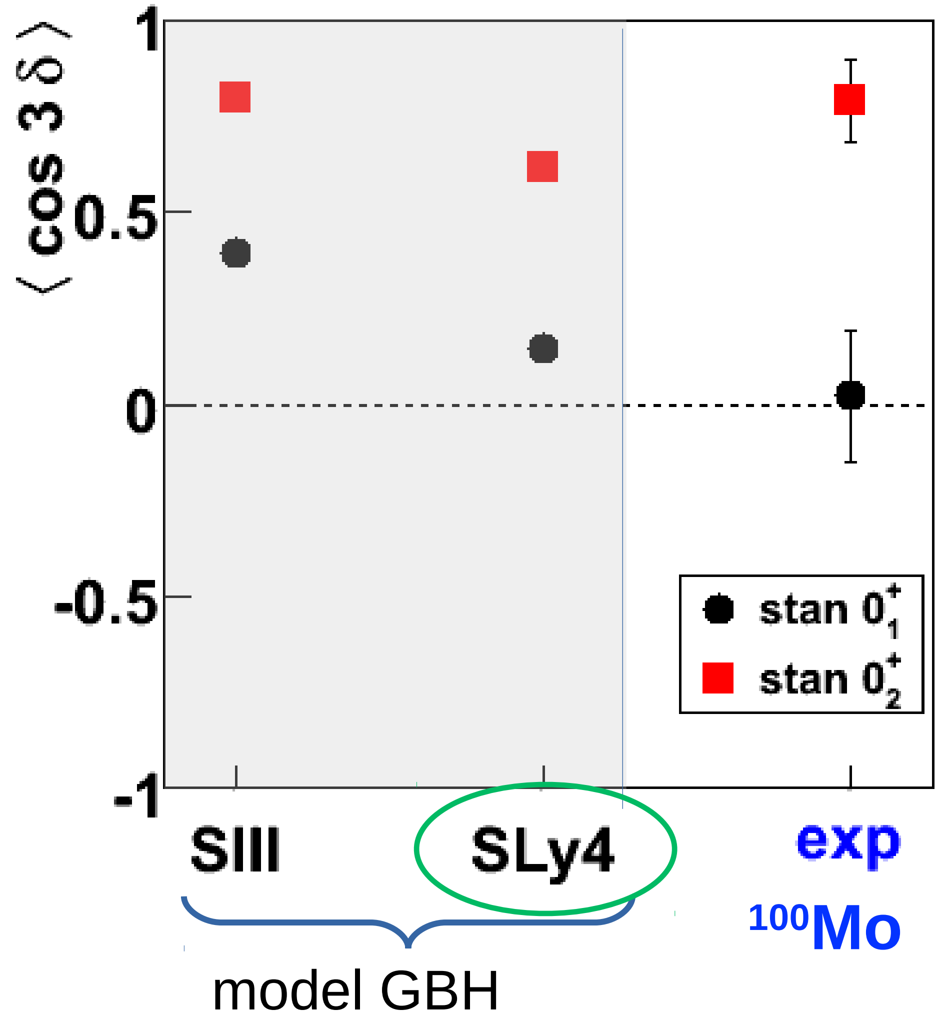


coexistence of the deformed ground state with a spherical 0^+_2
rmation of 0^+_2 state is increasing with N; ground state of the Mo isotopes
e coexistence in ^{98,100}Mo manifested in a different triaxiality of 0^+_1 and 0^+_2

Courtesy K. Wrzosek-Lipska

Deformation of ^{100}Mo: theory vs. experiment





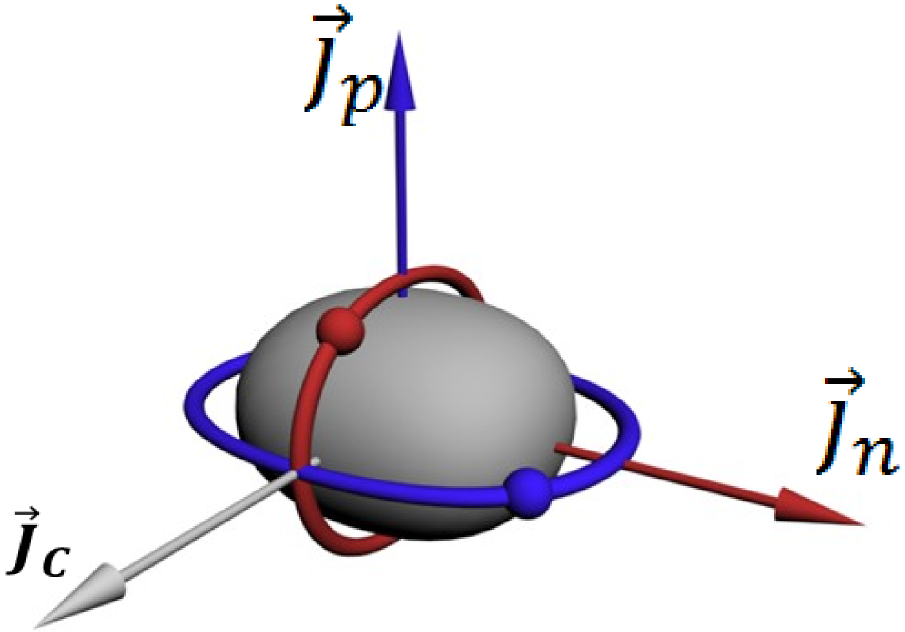
GBH - **G**eneral quadrupole collective **B**ohr **H**amiltonian (5 dimentional **B**ohr **H**.)

UMCS Lublin + U. Warsaw

L. Próchniak, S. G. Rohoziński, *J. Phys. G: Nucl. Part. 36 (2009) 123101,*

L. Próchniak Int. J. Mod. Phys. E19 (2010) 705

nuclear chirality - Time reversal spontanous symmetry breaking



3 components:
- **Even-even core**
- **Odd proton**
- **Odd neutron hole**

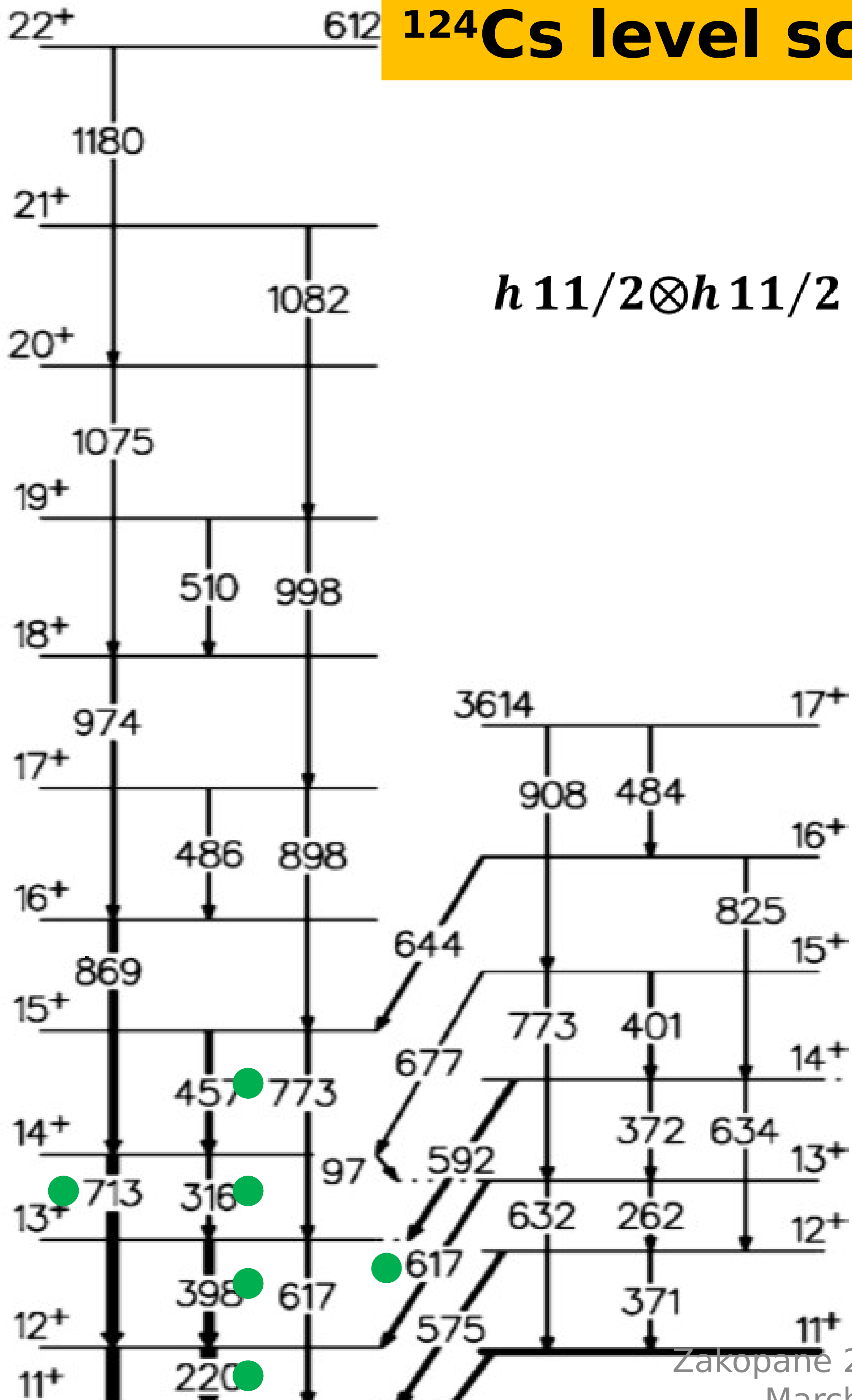
We need these angular momentums to be perpendicular

(chance to see spontaneous time-reversal symmetry breaking)

Effect expected in odd-odd nuclei within A ~ 130 region

Courtesy Tomasz Marchlewski

^{124}Cs level scheme



$h11/2 \otimes h11/2$

Lab system

Visible partner bands with similar properties:

-Level energies

Relative transition probabilities proportional to line thickness

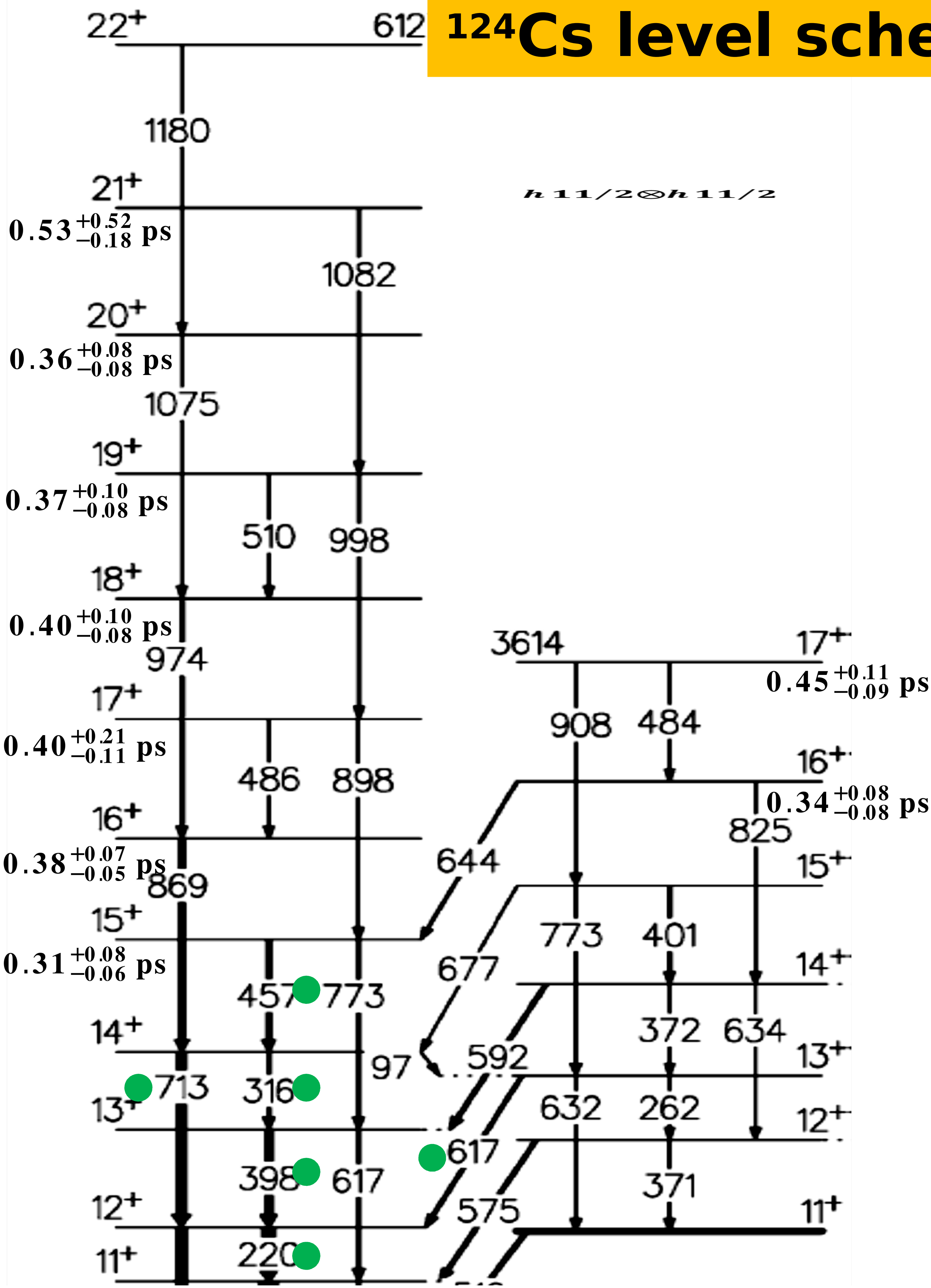
Energy separation in $^{124-128}$Cs Isotopes around 150-200 keV
lifetime results from the DSA experiments –Warsaw cyclotron
Partner bands populated in fusion evaporation reaction

configuration $\pi h_{11/2} \otimes \nu h_{11/2}^{-1}$

E.Grodner et al.,
*^{128}**Cs** as the best example revealing the chiral symmetry breaking phenomenon*
Phys. Rev. Lett. 97 (2006) 172501

E.Grodner et al.,
*Partner bands of ^{126}**Cs** – first observation of chiral EM selection rules*
Physics Letters B 703 (2011)

^{124}Cs level scheme



^{114}Cd (^{14}N, 4n) ^{124}Cs

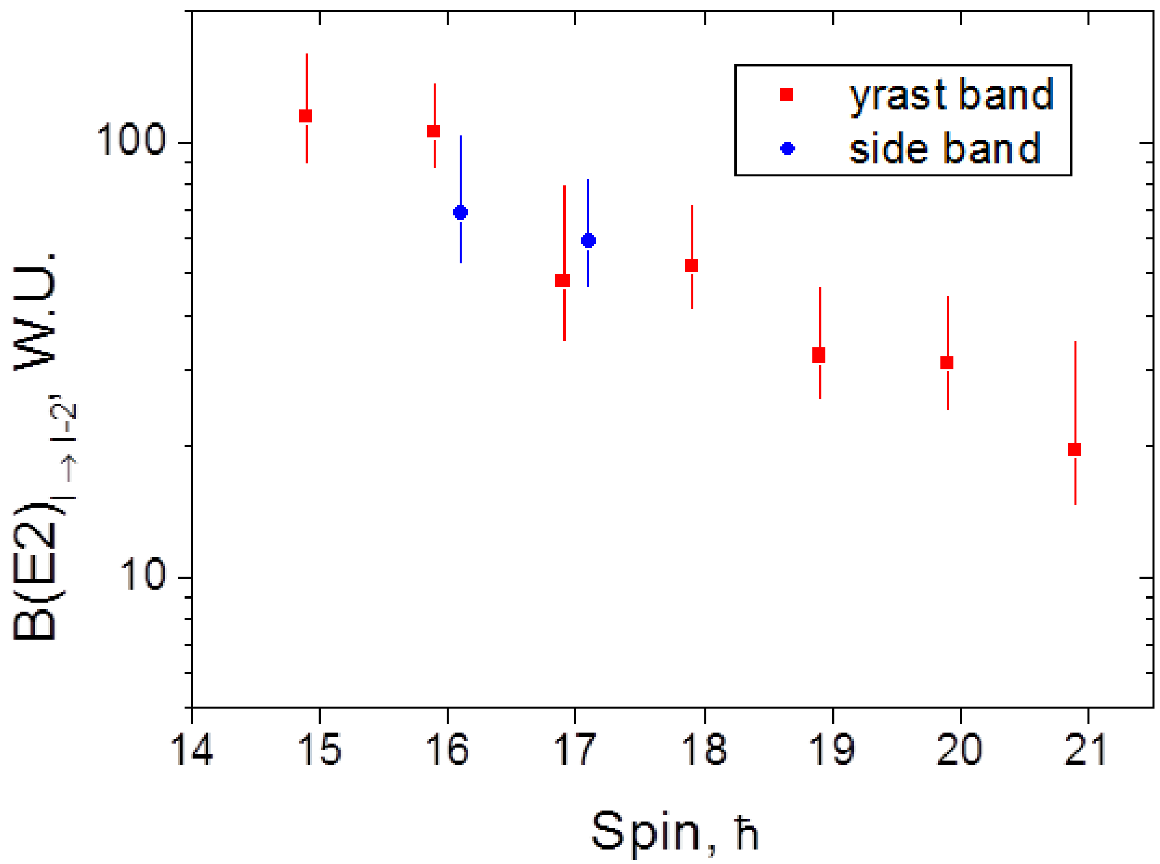
DSAM, DCO

Visible partner bands with similar properties:
- **Level energies**
- **Transition probabilities**

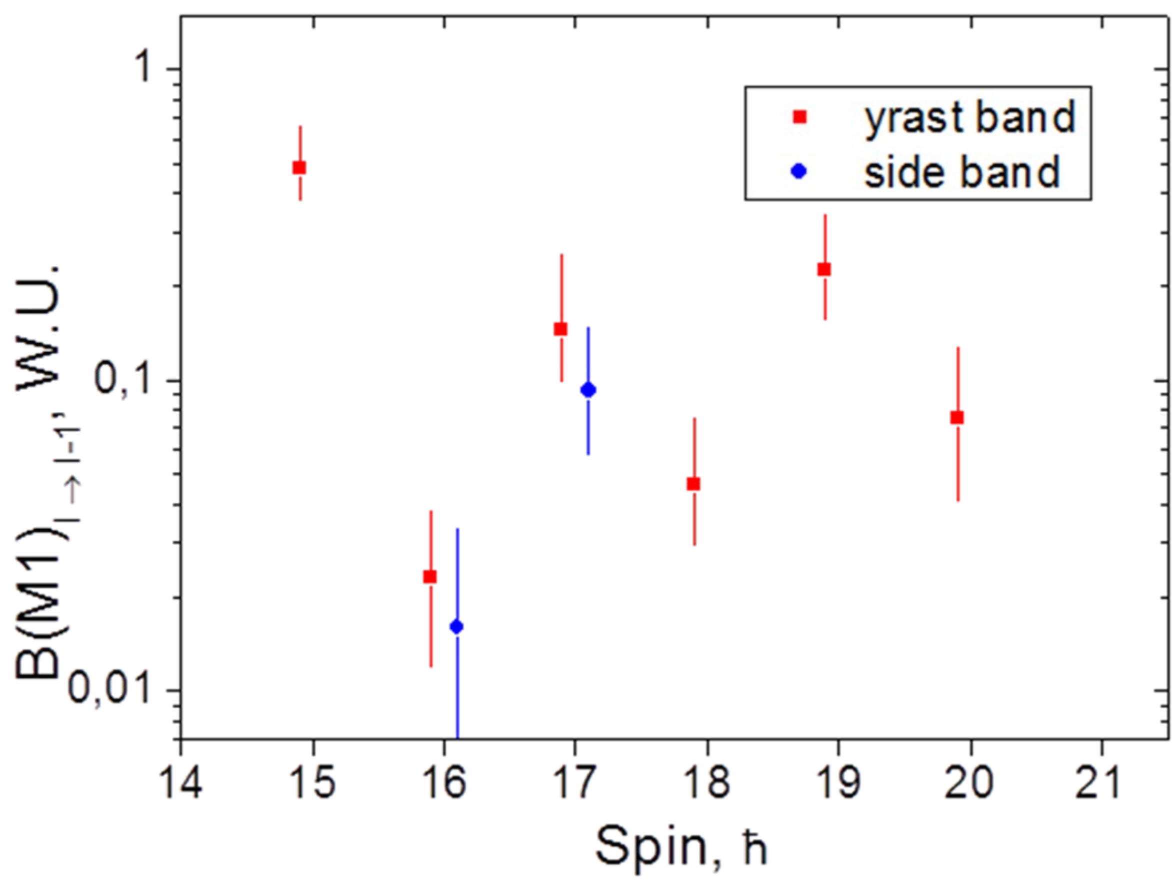
Known lifetimes presented

Relative transition probabilities proportional to line thickness

courtesy Tomasz Marchlewski

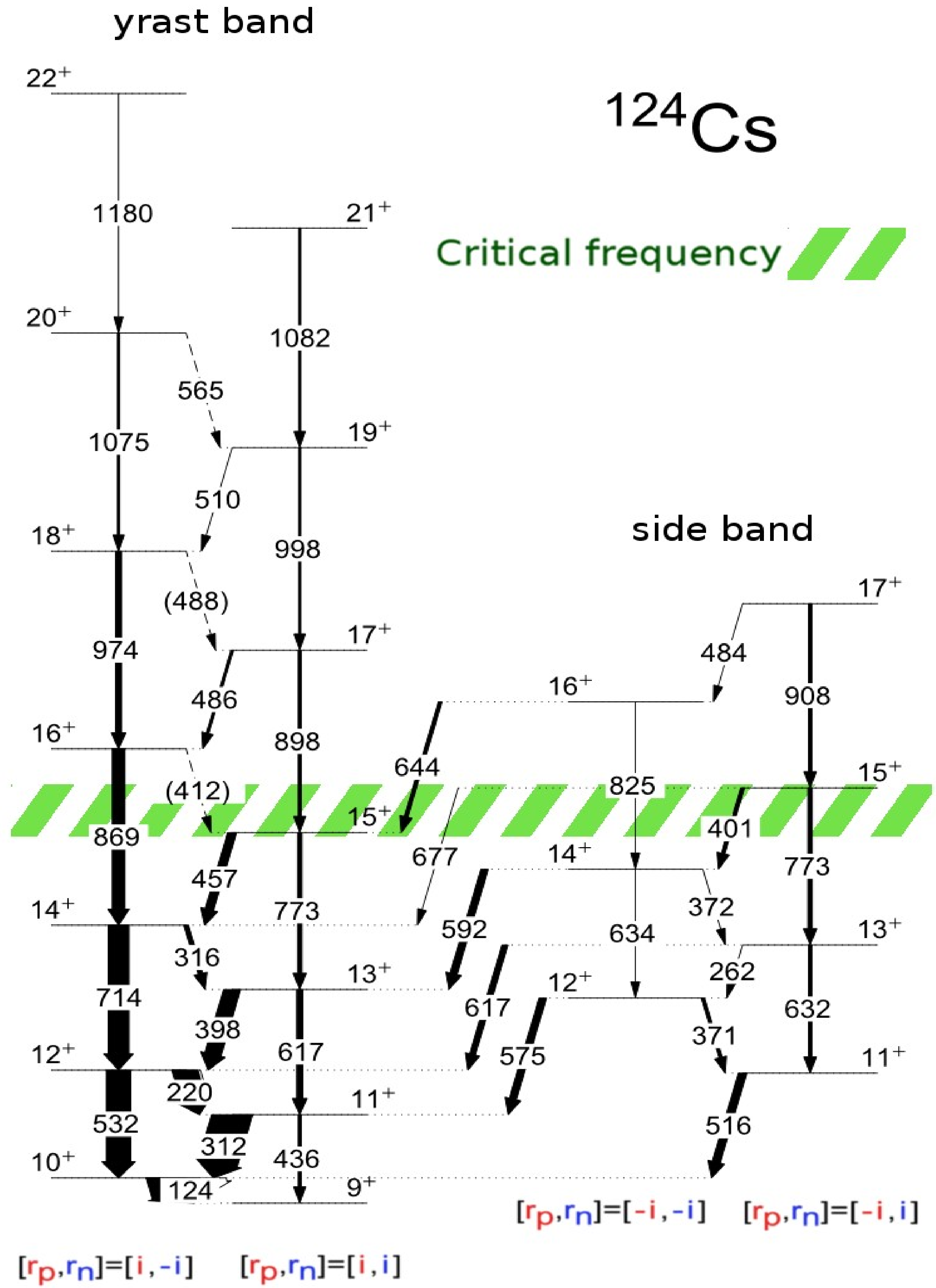


Reduced E2 and M1 transition probabilities are the same in partner bands



we can see staggering

T. Marchlewski,..,J. Samorajczyk et al.


yrast band
^{124}Cs
Critical frequency
side band
22+
21+
20+
19+
18+
17+
16+
15+
14+
13+
12+
11+
10+
9+
1180
1082
1075
565
510
998
(488)
974
486
898
(412)
869
644
825
677
484
908
401
773
457
773
592
634
372
316
714
262
632
617
398
617
575
371
220
532
312
436
516
124
[rp,rn]=[i,-i]
[rp,rn]=[i,i]
[rp,rn]=[-i,-i]
[rp,rn]=[-i,i]

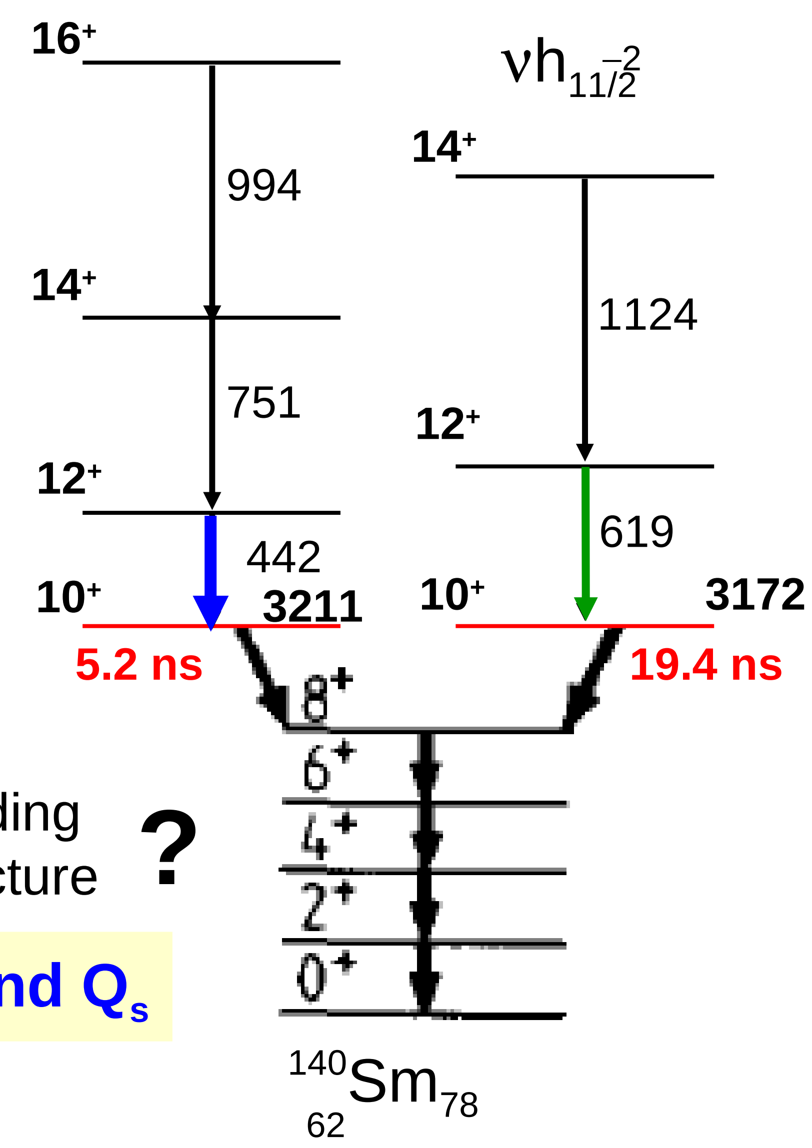
Shape and collectivity of ^{140}Sm

- N~78 and Z>60: region of shape transitions and shape coexistence.
- Two complementary approaches:
  - ➢Low–energy Coulomb excitation with RIB (ISOLDE)

    M. Klintefjord, Univ. of Oslo
  - ➢RDDS lifetime and γ-γ angular correlations measurement at HIL

    Difficulties for RDDS :

two isomeric 10⁺ states



poor understanding of low-spin structure

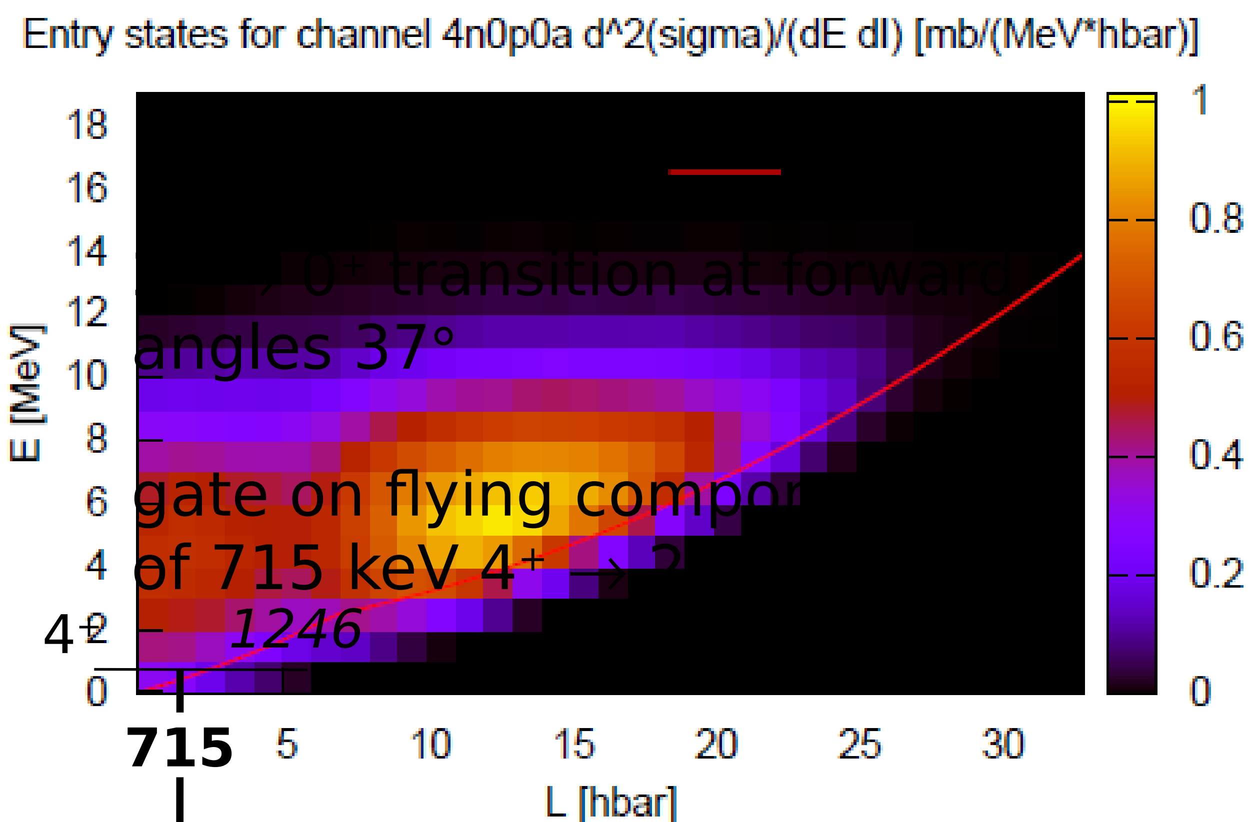
need B(E2) and Q_s

Courtesy of A. Goergen, Univ. Of Os

RDDS lifetime measurement at H

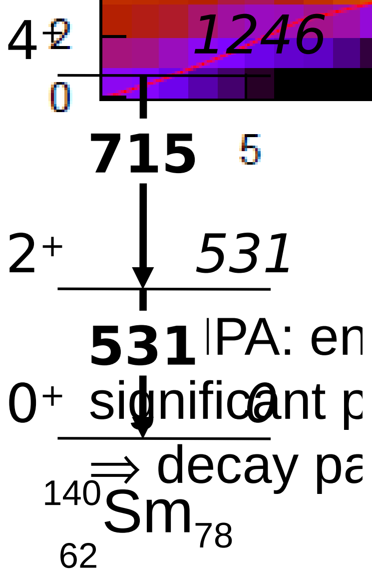
PhD work of F.L. Bello Garrote et al, Univ. Oslo

reaction: $^{124}Te(^{20}Ne,4n)^{140}Sm$ at 82 MeV
(just above Coulomb barrier)

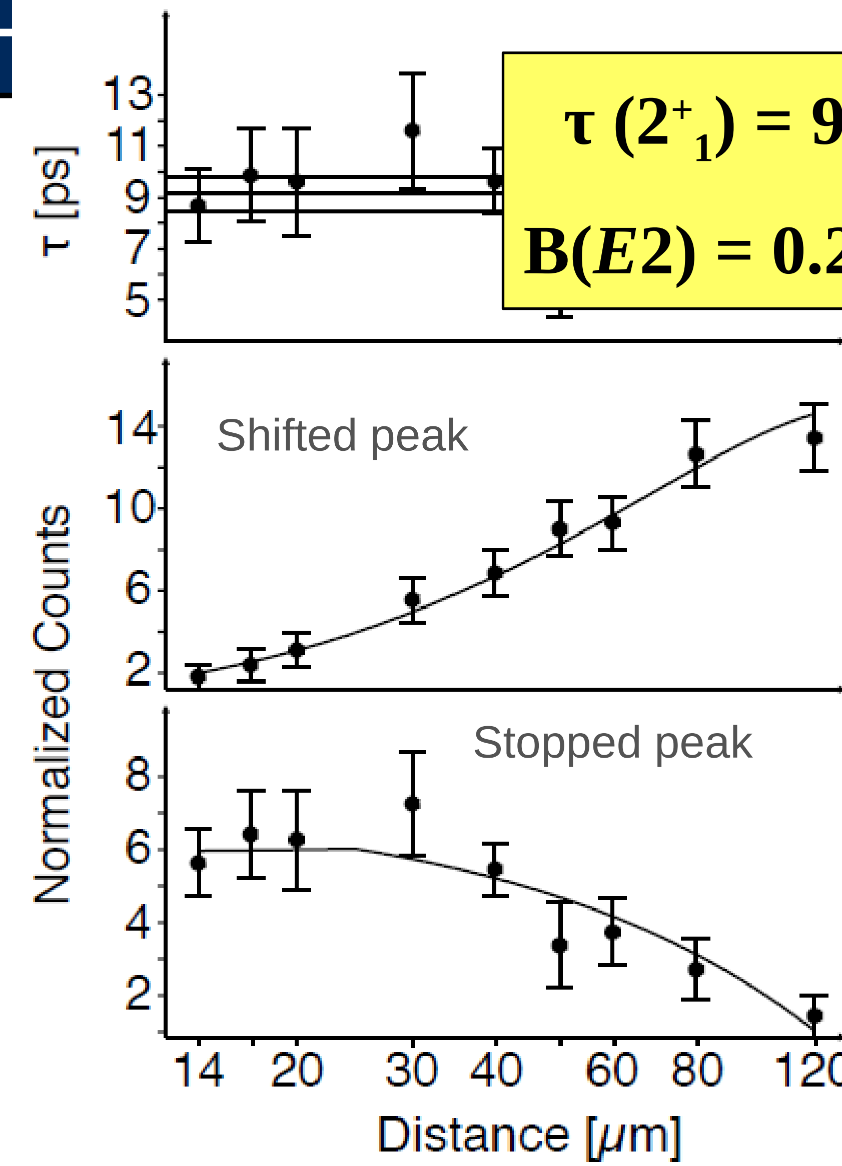


2+ → 0+ transition at forward angles 37°

gate on flying component of 715 keV 4+ → 2+

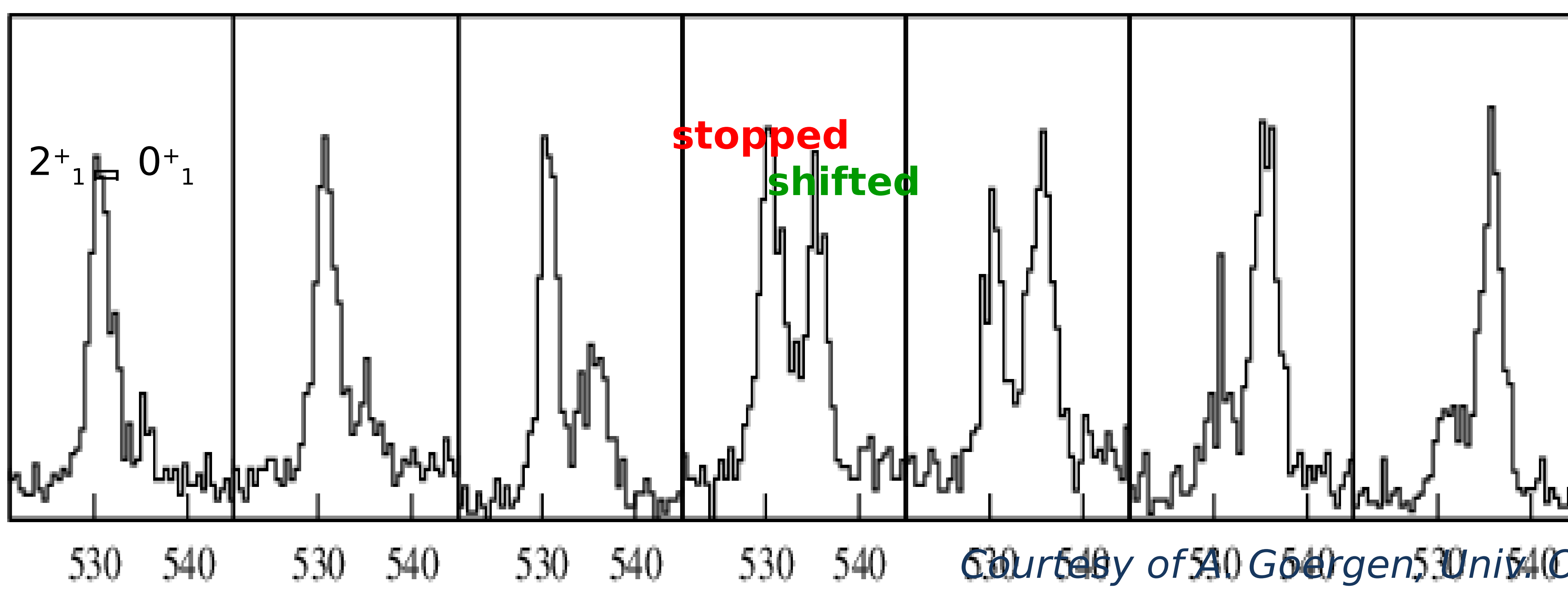


IPA: en
significant p
⇒ decay pa



$\tau(2^+_1) = 9.0(7)$ ps

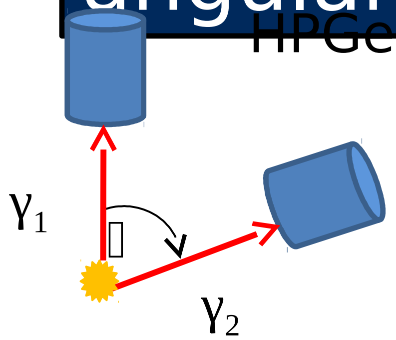
$B(E2) = 0.21(2)\ e^2b^2$



Courtesy of A. Goergen, Univ. Of Os

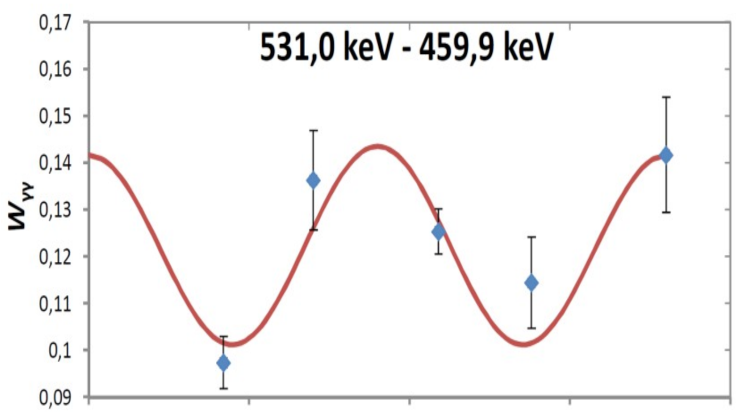
Spin assignment for low-energy states in ^{140}Sm by angular correlations

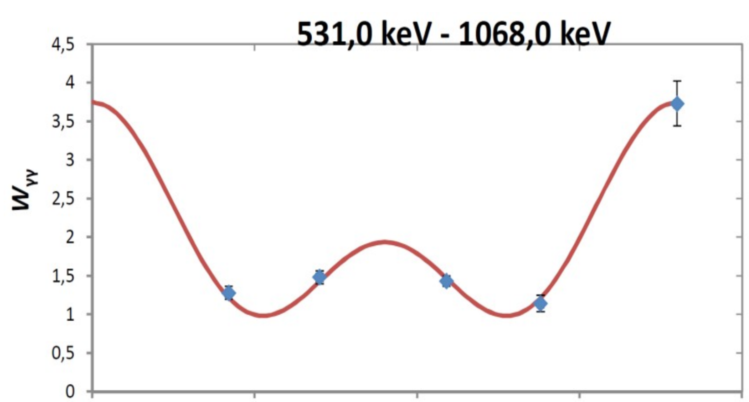
HPGe θ angles: 42°, 70°, 110°, 138°, 180°

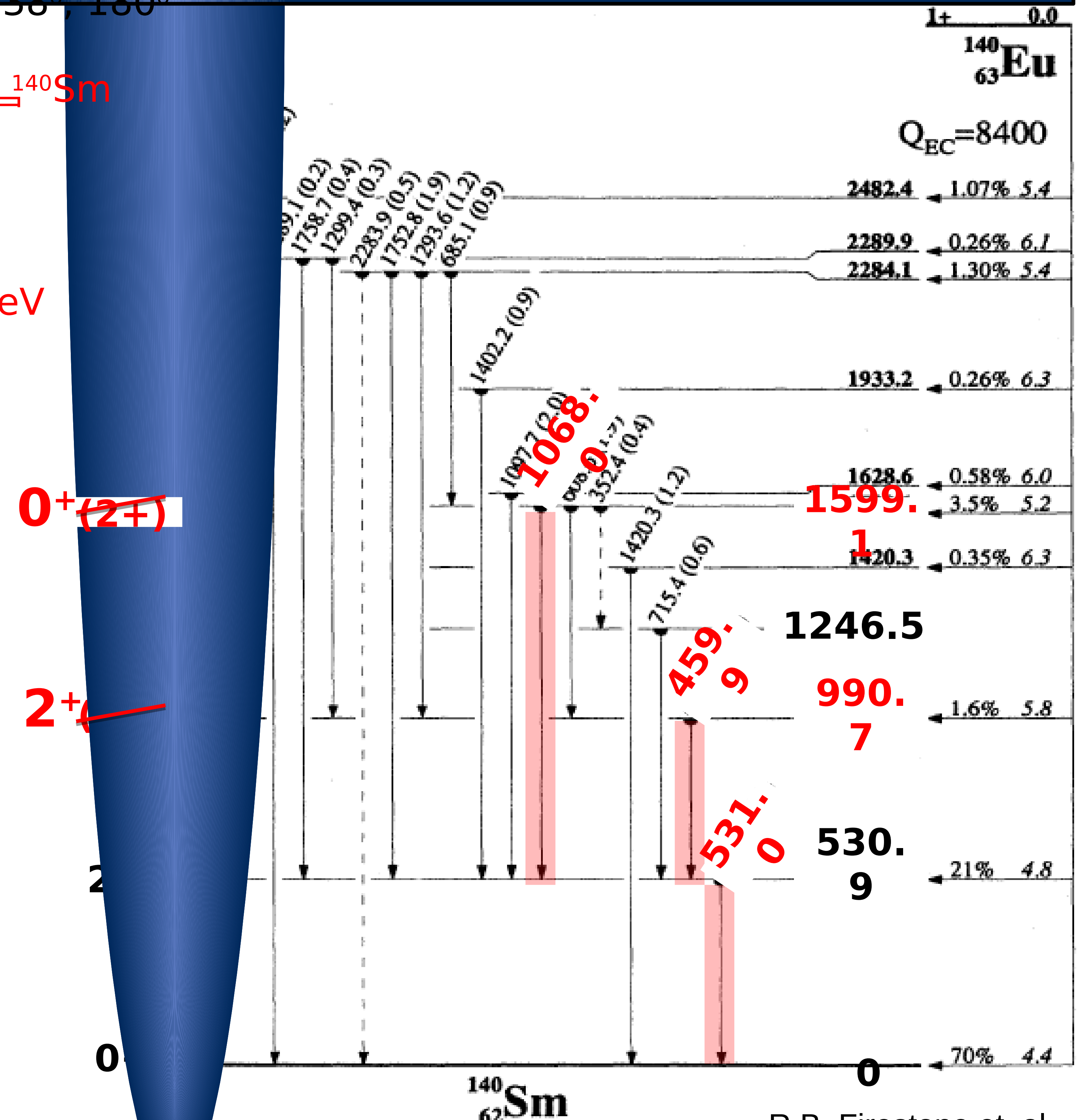


- β decay of ^{140}Gd → ^{140}Eu → ^{140}Sm
- ^{112}Cd(^{32}S, p3n)^{140}Eu

  ^{112}Cd(^{32}S, 4n)^{140}Gd
  beam energy of 155 MeV



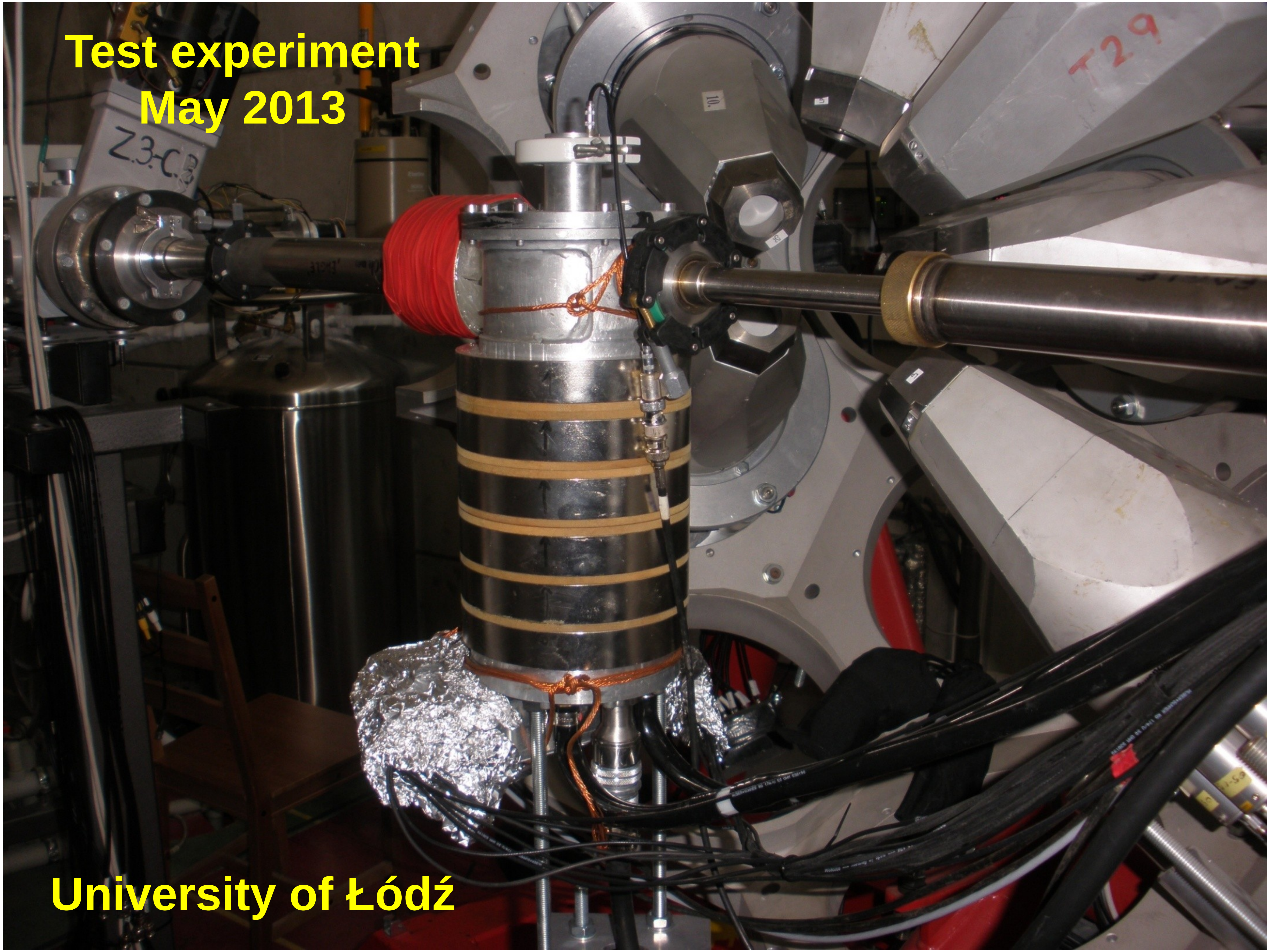




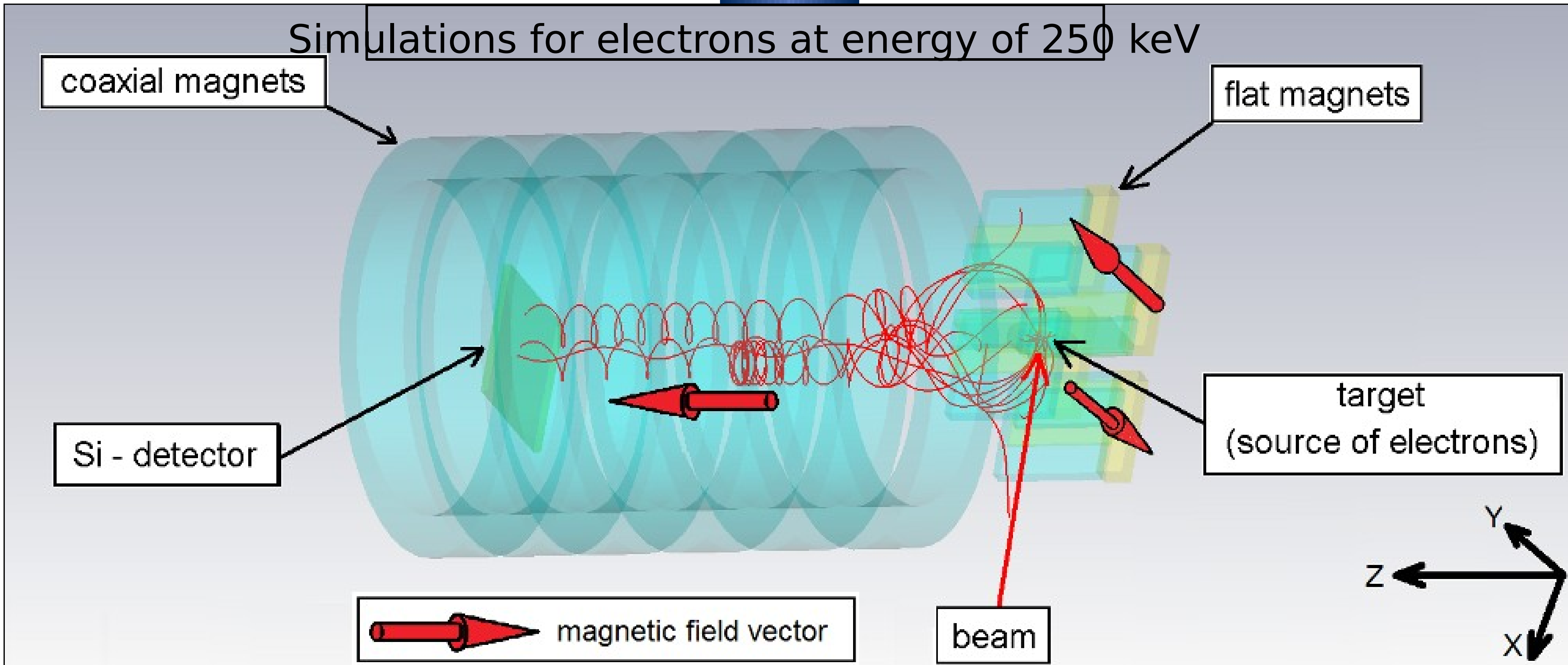
R.B. Firestone et. al.
PRC 43, 1066 (1991)

M. Klintefiord, .. ,J. Samorajczyk et al. A.Ph.Pol. B46(2015) 603

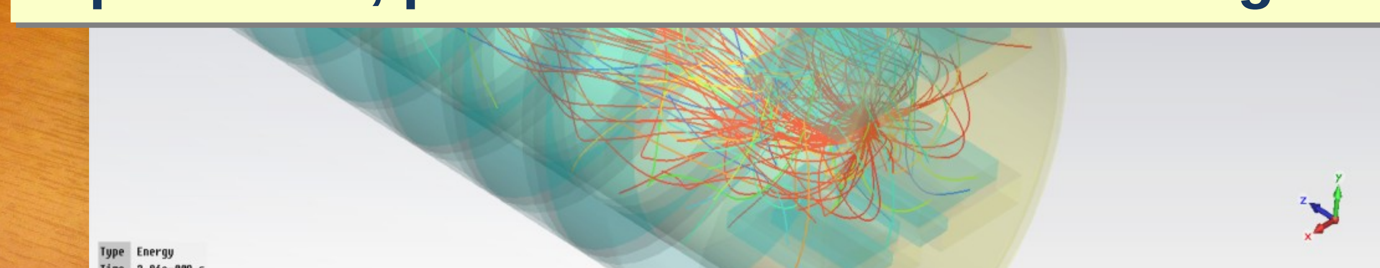
New electron conversion spectrometer - ULESE

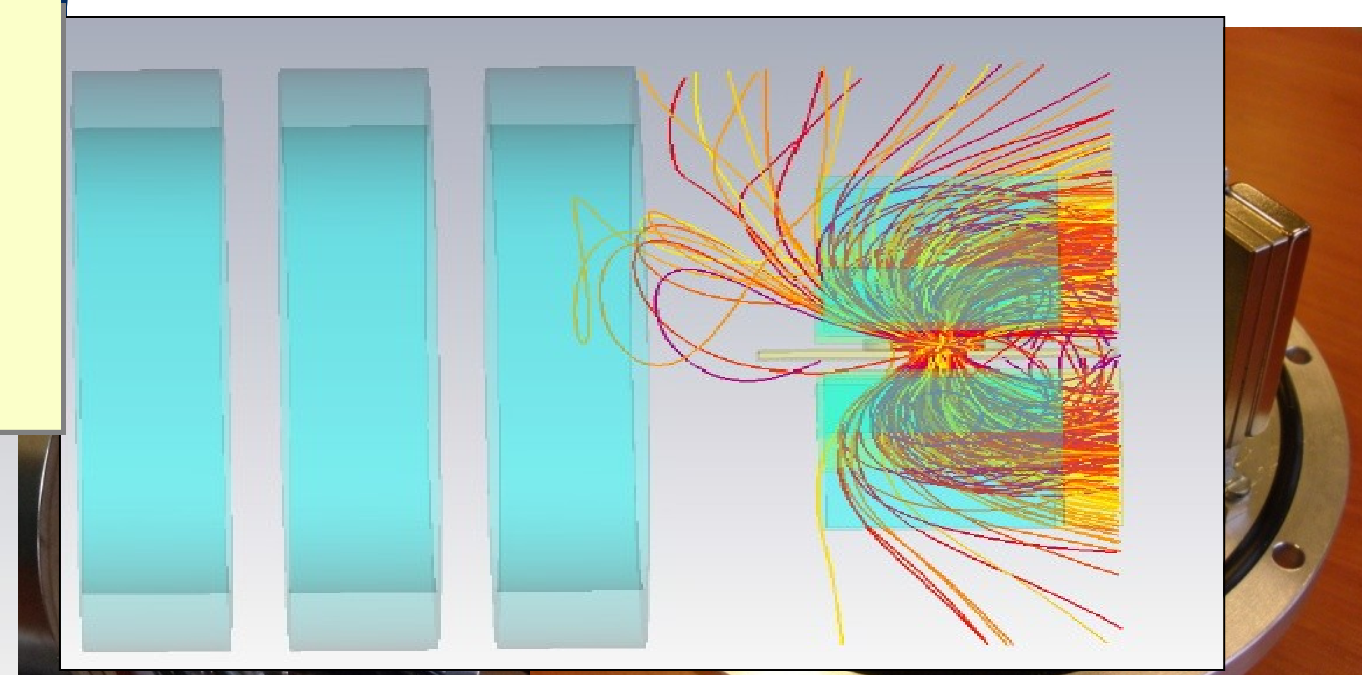


ULESE (University of Lodz an Electron SpEctrometer)



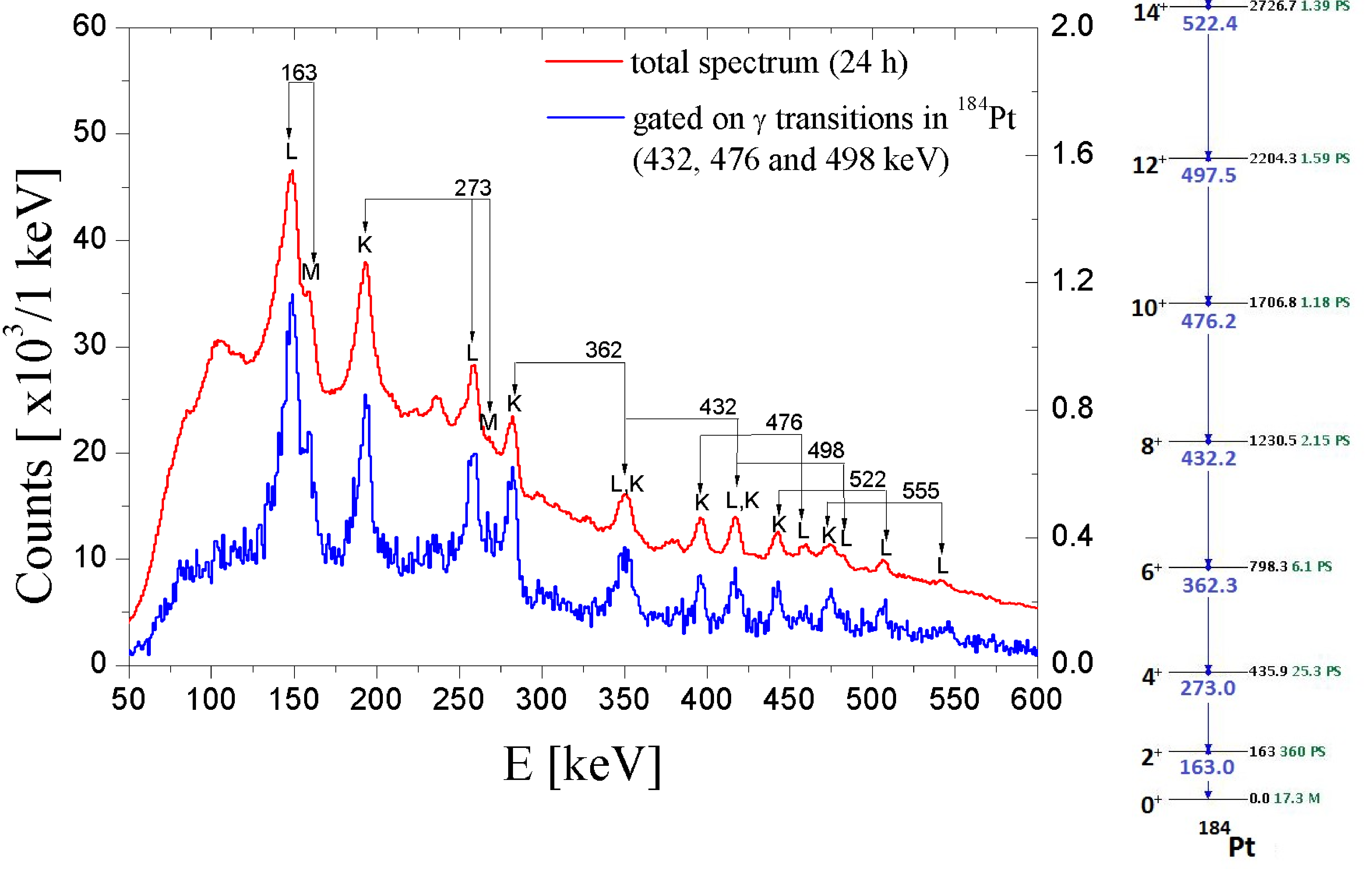
- **high efficiency ⇒ up to 9% at 300 keV**
- **good energy resolution ⇒ ~ 1% at 500 keV**
- **good suppression of delta electrons, positrons, photons emitted from the target**





J. Perkowski et al., Rev. Sci. Instr. 85 (2014) 043303

"In-beam" spectra from the $^{14}N + ^{175}Lu$ reaction



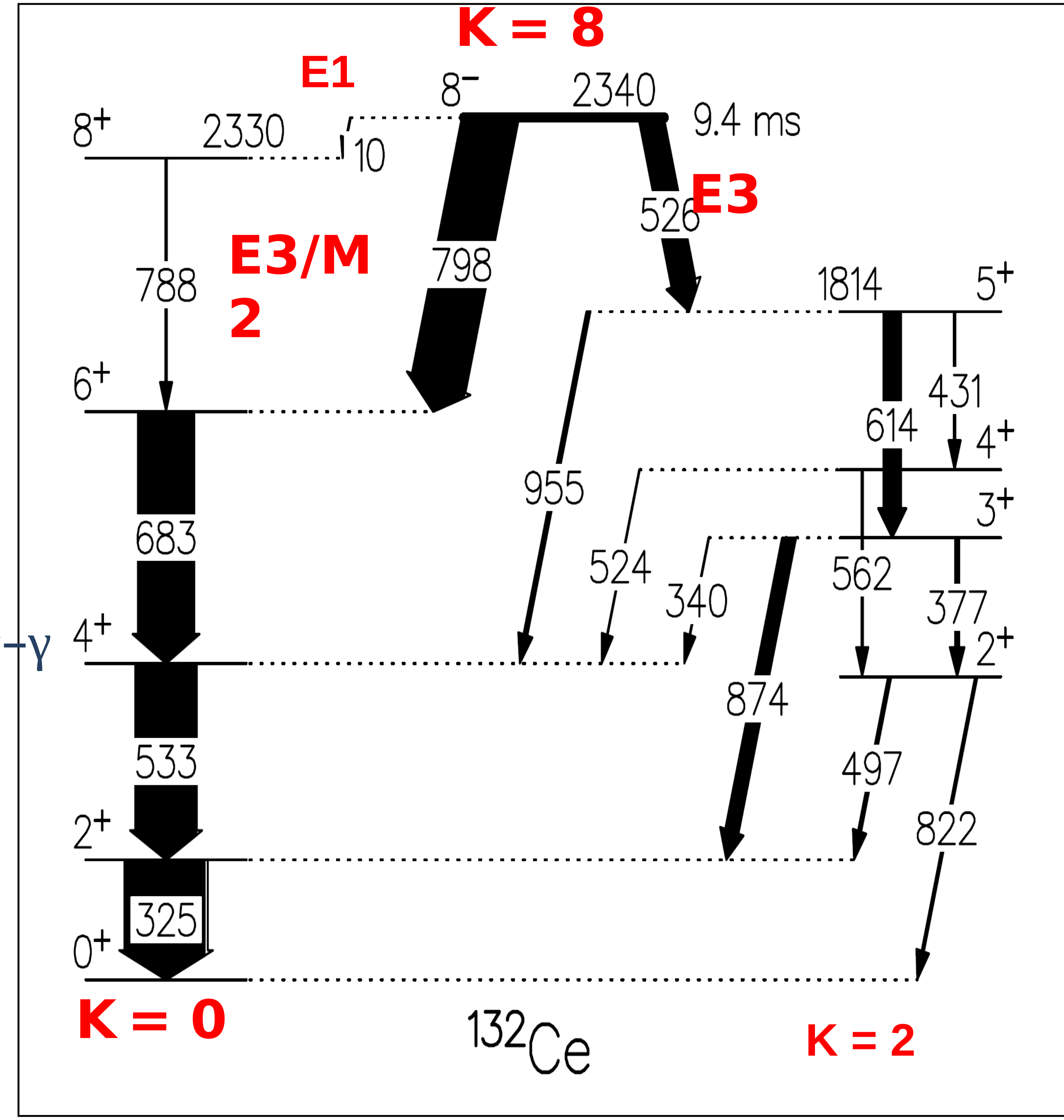
Study of the $K^\pi = 8^-$ isomers with e-γ spectroscopy

otivation: violation of the
-selection rule ($|\Delta K| \geq \lambda$) for
lectromagnetic transitions.

roperties of the decay of the
$^\pi = 8^-$ isomeric states in
=74 (**^{130}Ba, ^{132}Ce, ^{134}Nd**)

tipolarities taken from e–γ and γ–γ

ortant role of triaxiality

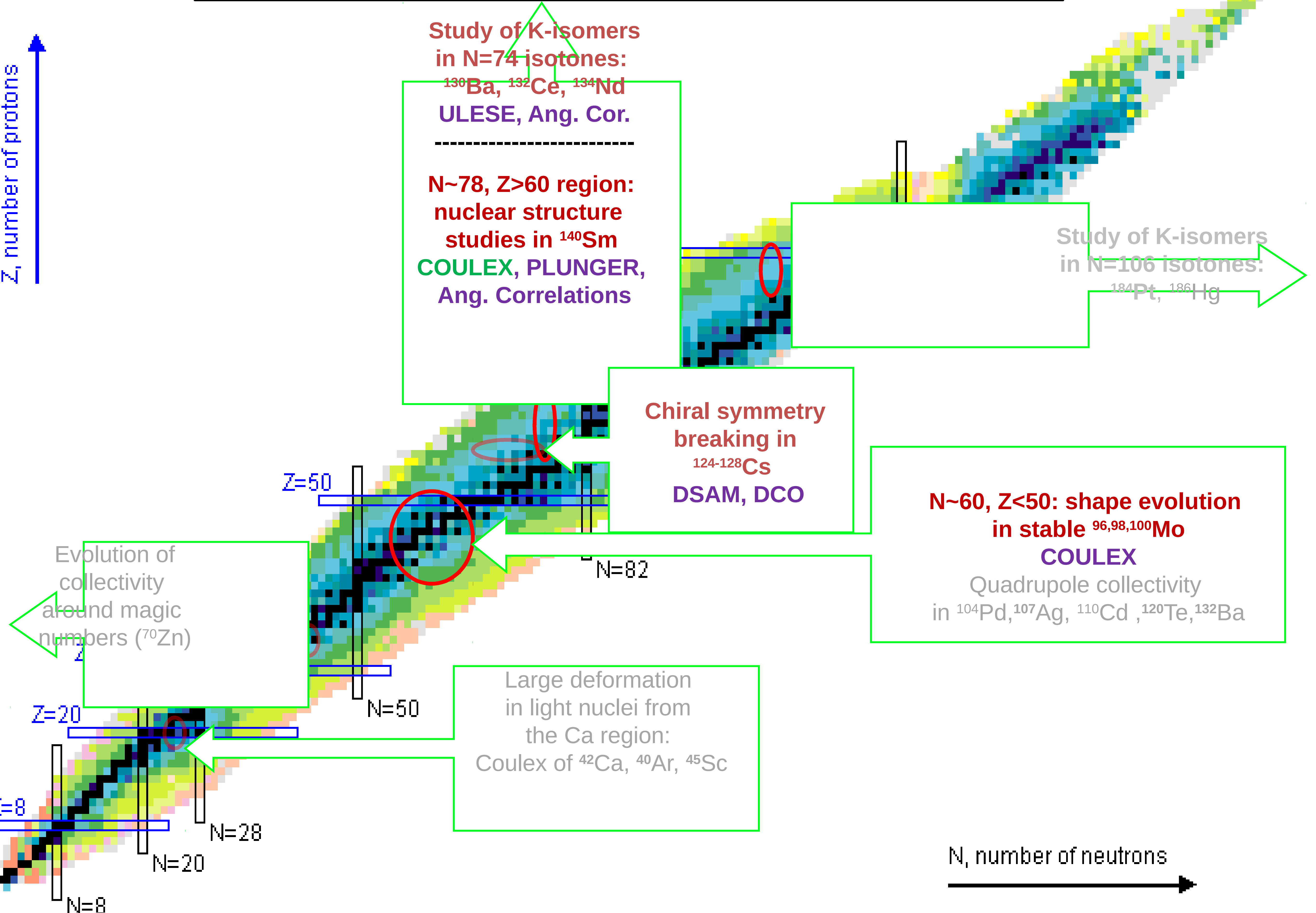


D-F model and I(E3(526)/I(E3(798)

iality γ(5+) - γ(6+) = 4(1)∘

J. Perkowski et al., EPJ A 42 (2009) 37
J. Perkowski et al., APP B 43 (2012) 2

electromagnetic transition probabilities and moments



SUMMARY

- > 60 persons in EAGLE collaboration
  from about 20 Institutions
- ~ 30 working hard

Chirality - E. Grodner, T. Marchlewski

COULEX - P. Napiorkowski, K. Wrzosek-Lipska

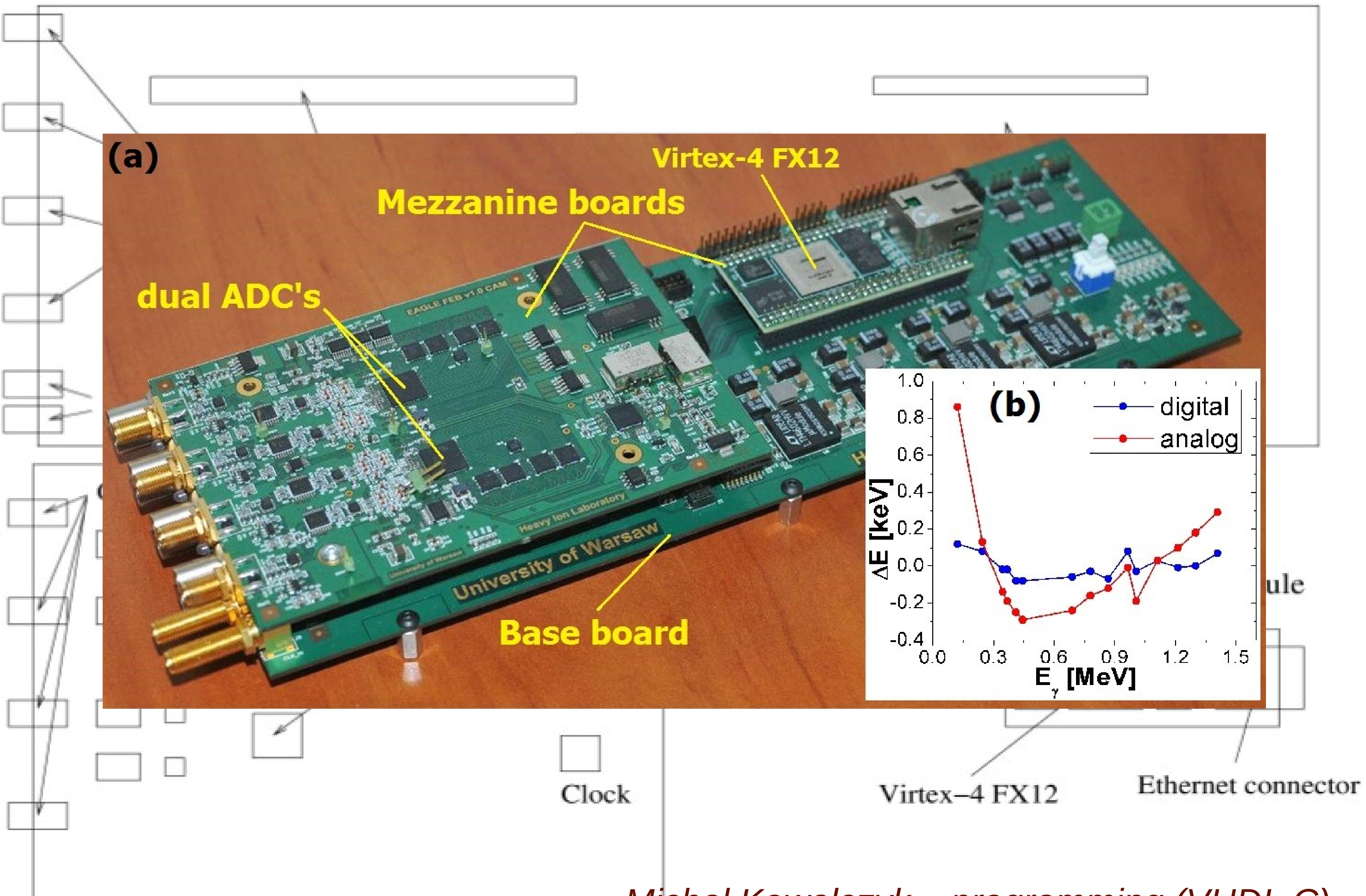
K-isomers - J. Perkowski, J. Samorajczyk

PLUNGER - C. Michai, A. Tucholski

Theory - L. Próchniak

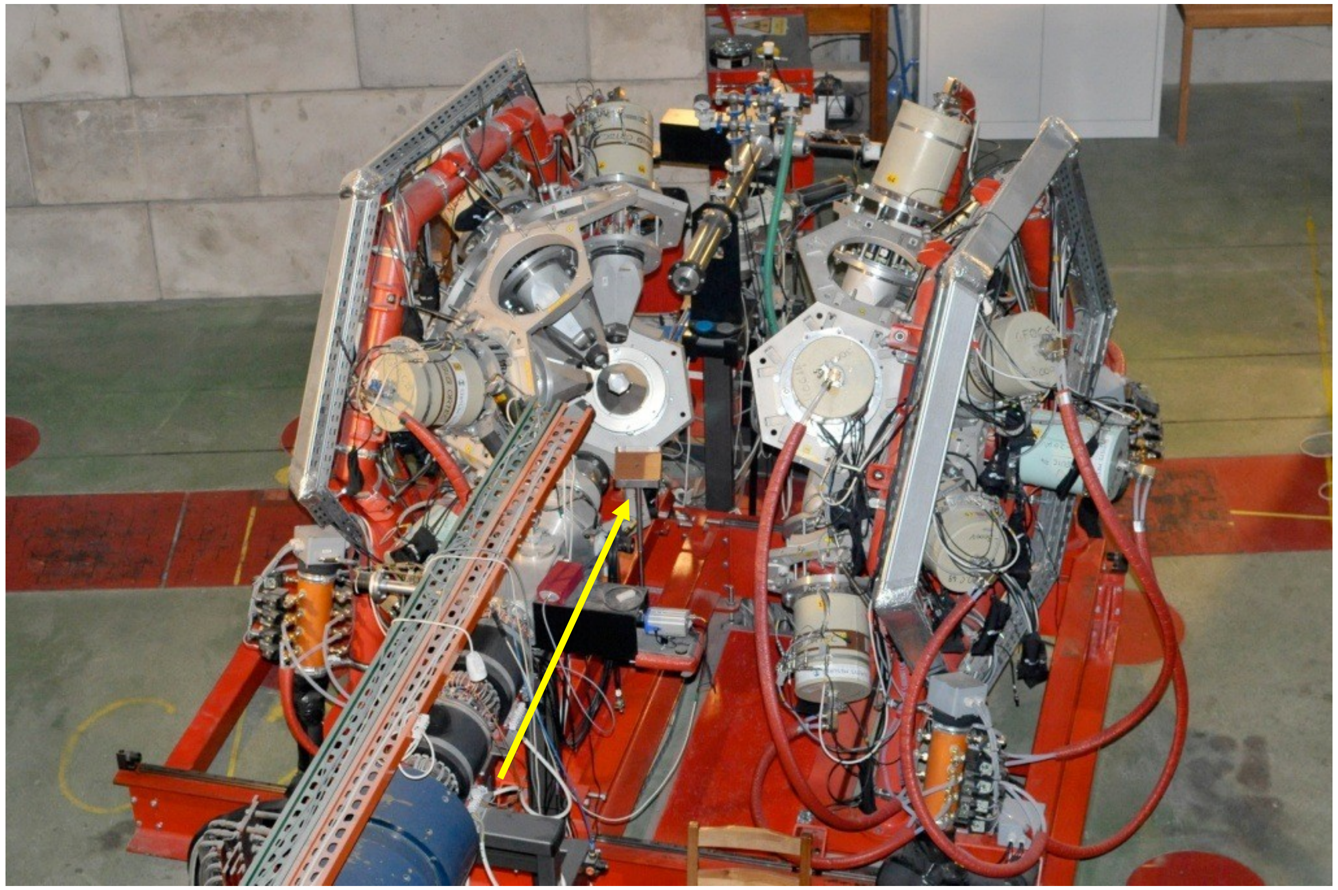
Data Taking system - M. Kowalczyk; W.

New acquisition module for 4 ACS Ge detectors

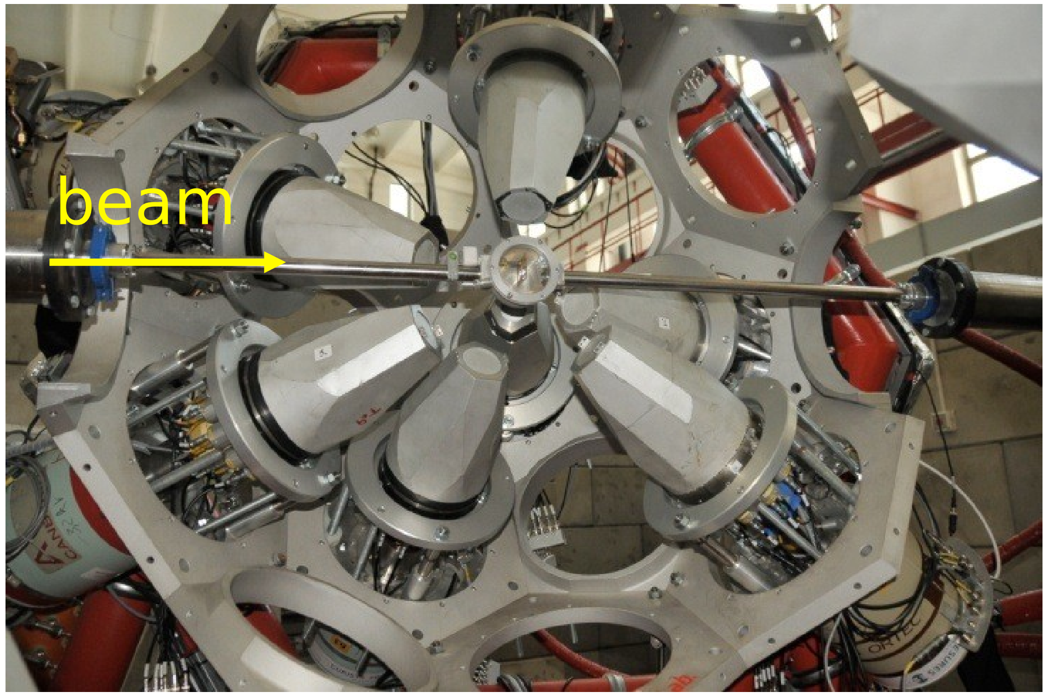


Michał Kowalczyk – programming (VHDL,C)

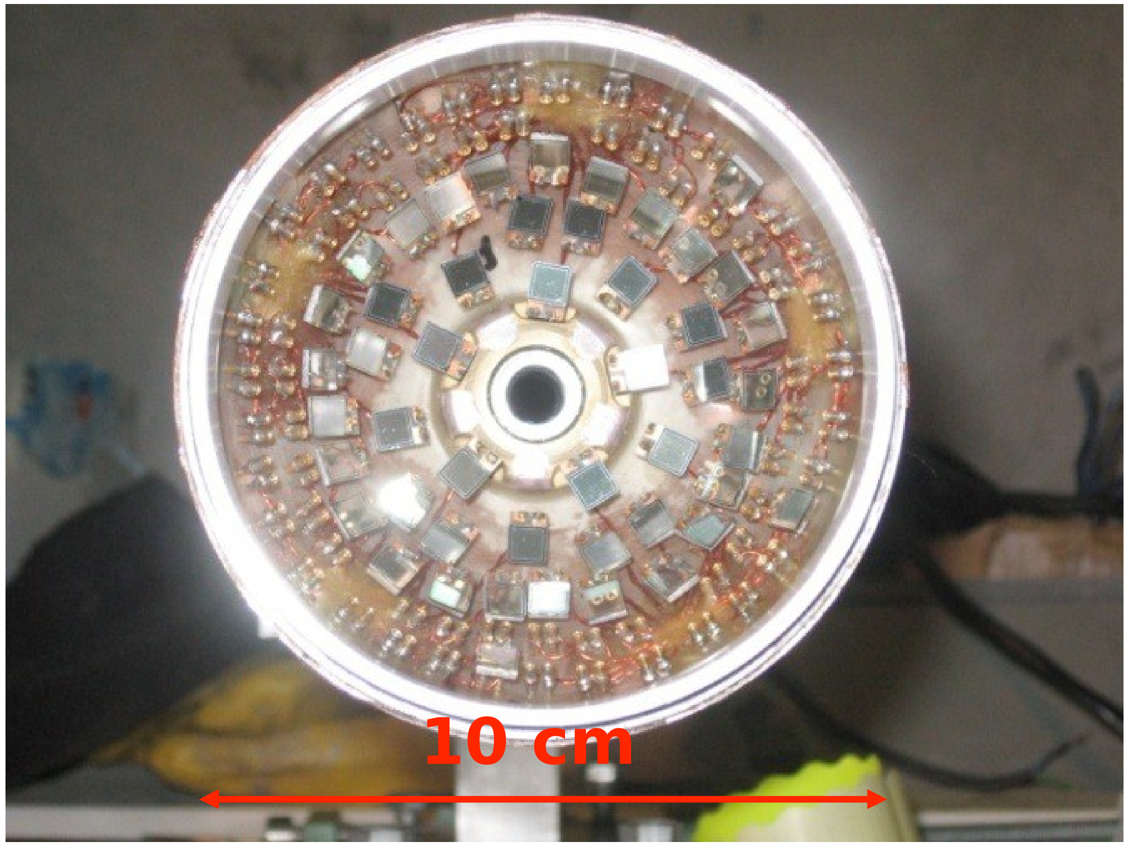
Wojtek Okliński - design + PCB project

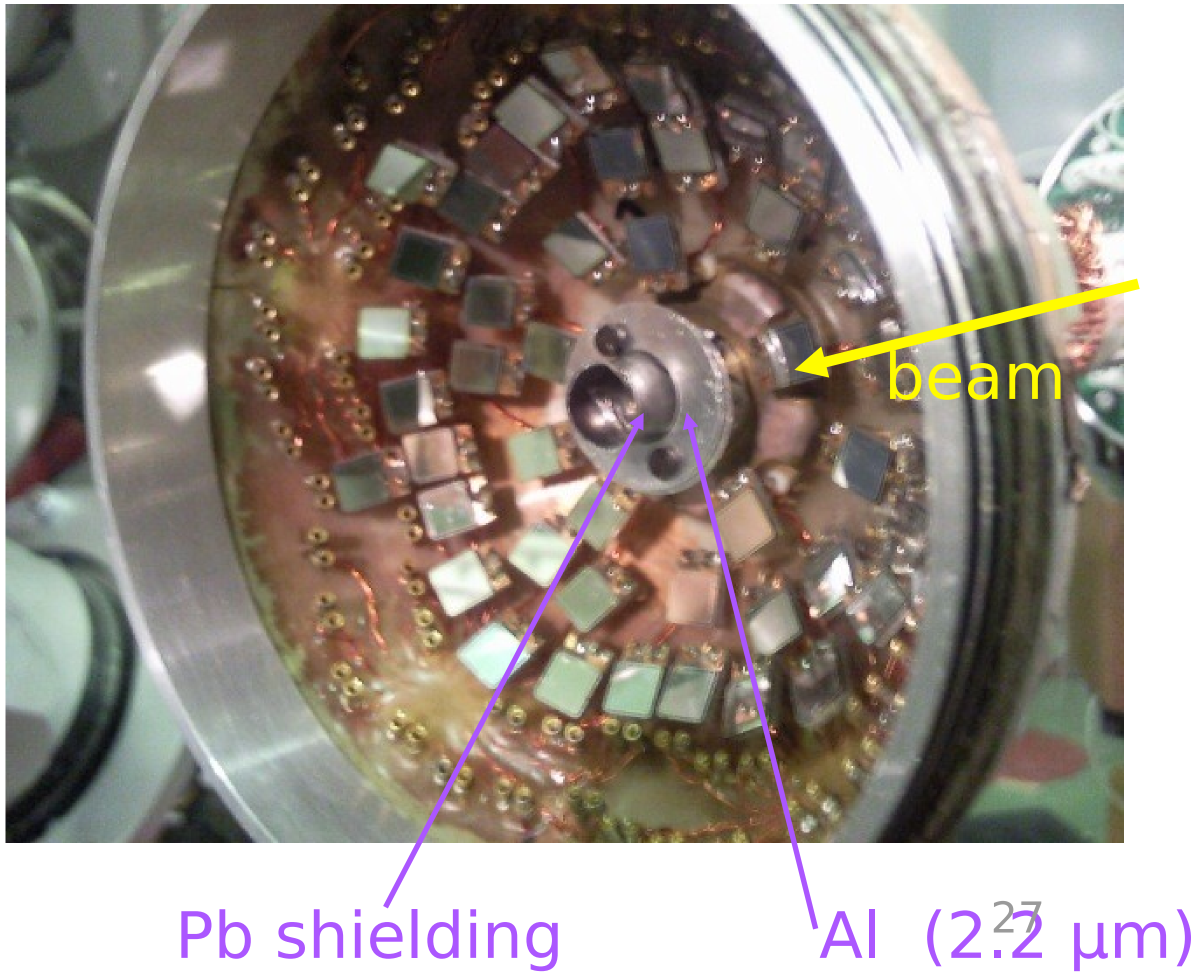


EAGLE: 15 HPGe of 70% efficiency + BGO

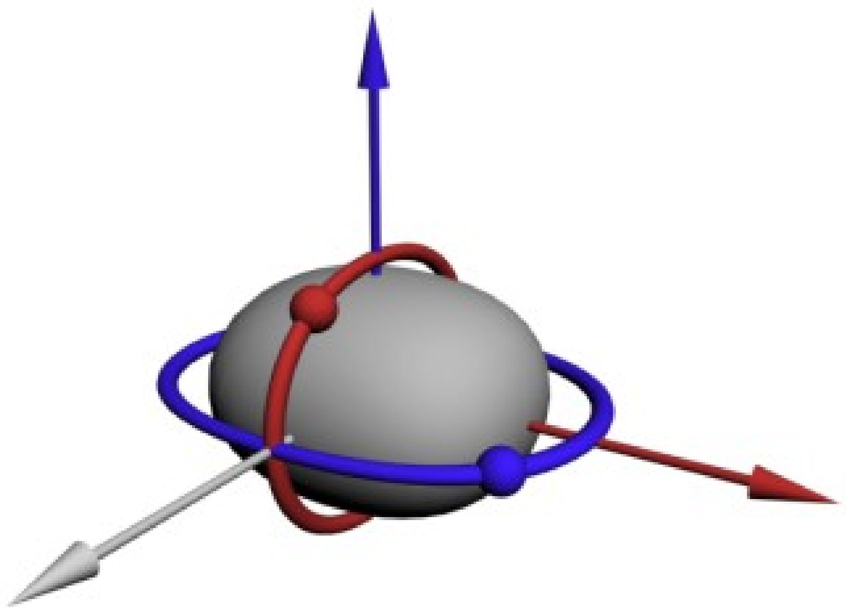


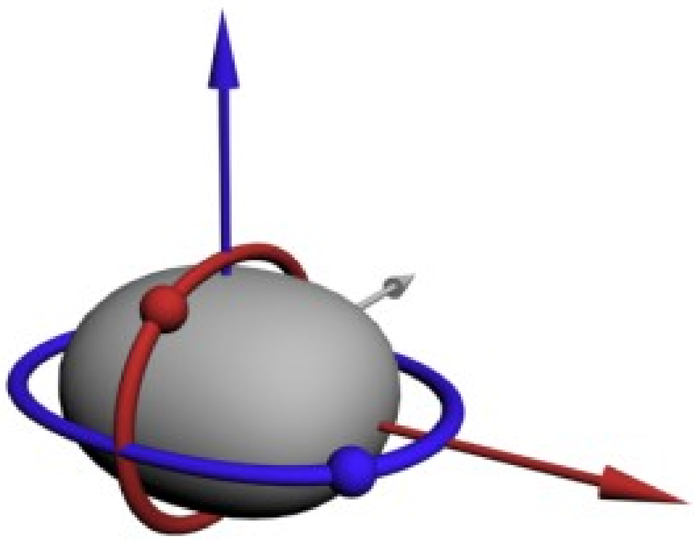
Chamber: 48 Si PiN diodes (0.5x0.5 mm2) at backward angles





Where is time-reversal?





$|\mathrm{L}>$

$|\mathrm{R}>$

$$R_y T|\mathrm{L}> = |\mathrm{R}>$$
$$R_y T|\mathrm{R}> = |\mathrm{L}>$$