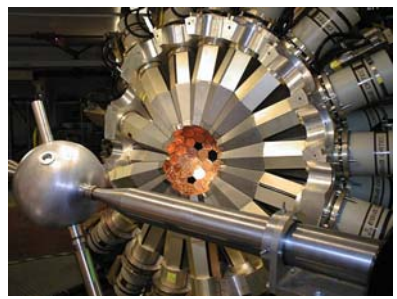
New Results on

Hyperdeformation of Nuclei.

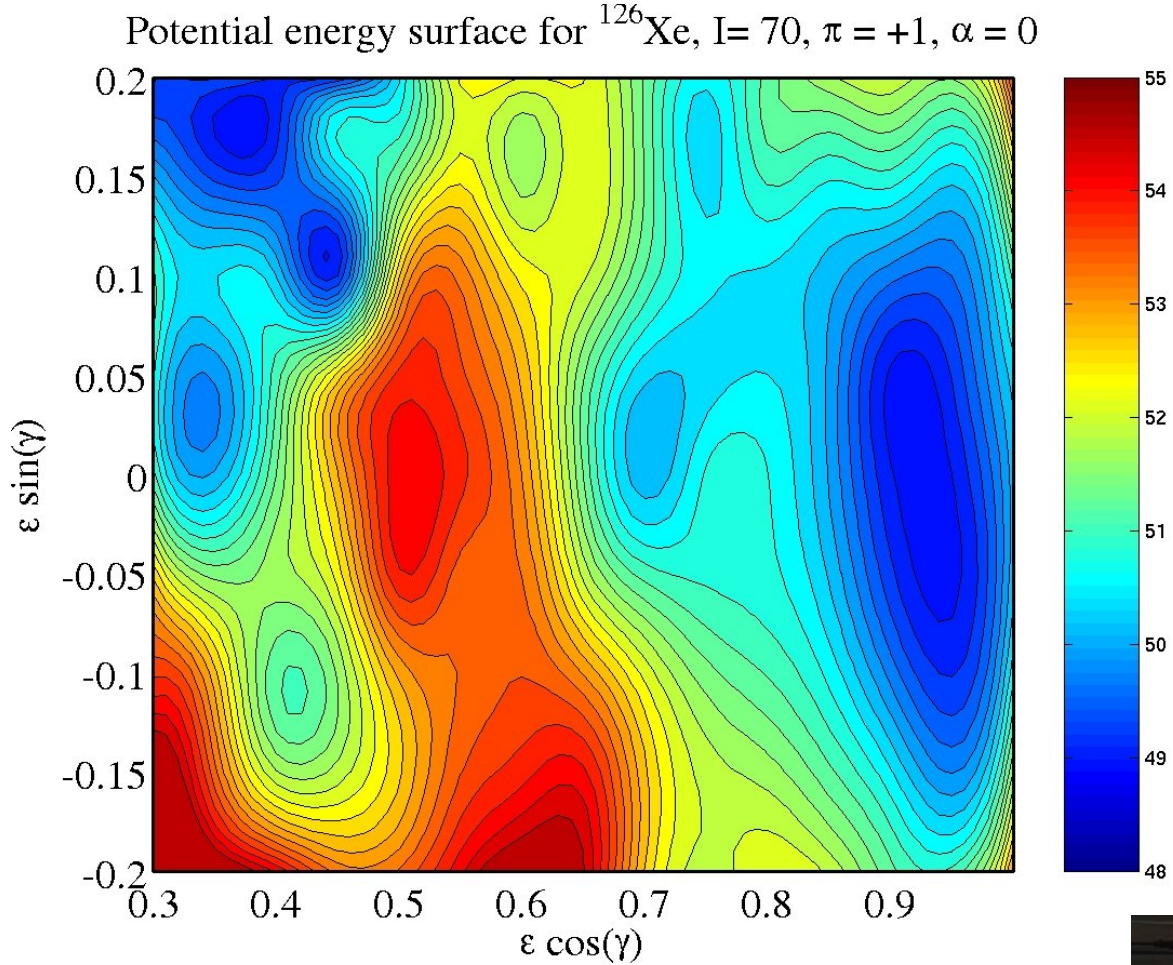
Geirr Sletten for the Canberra, Bonn, Orsay, Berkeley, Argonne, Debrecen and Copenhagen Collaboration.

(Spokesperson Anna Wilson ANU)

- **Experiment in September 2007 with Gammasphere**
- **Previous experiments with Euroball and Gammasphere**
- **Conclusions**

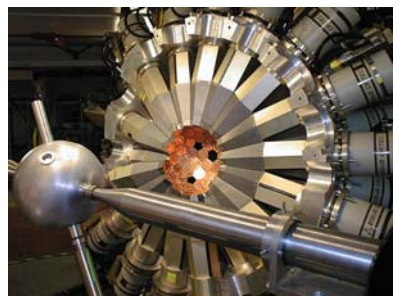


Potential energy surface calculated with the Cranked Shell Model



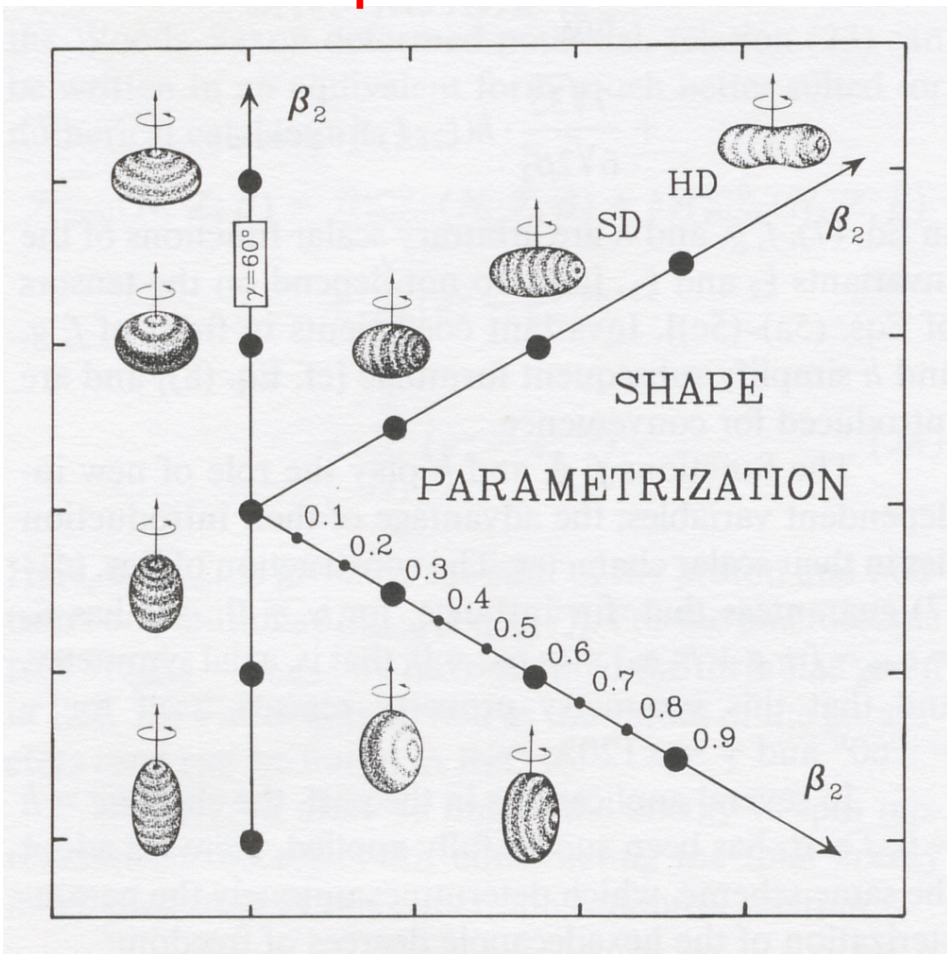
^{126}Xe at 70 ħ

R. Bengtsson, http:www.matfys.lth.se/~ragnar/ultimate.html.



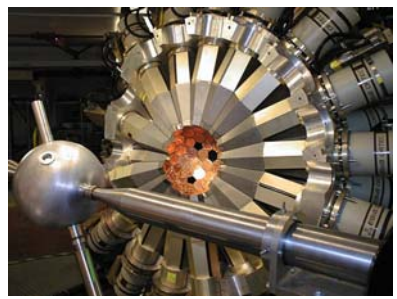
Collective rotation of nuclei

Oblate s.p.



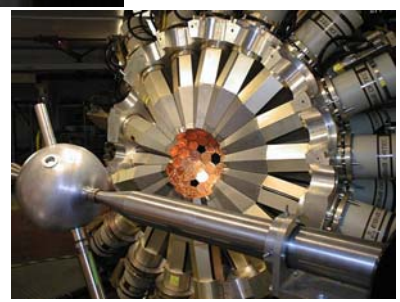
prolate

Collective oblate



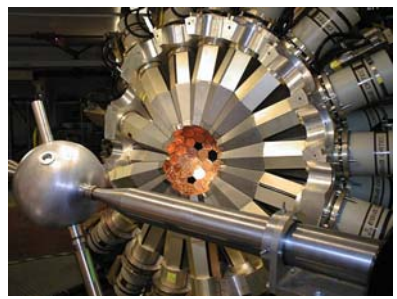
s.p. prolate

Gammasphere @ ANL



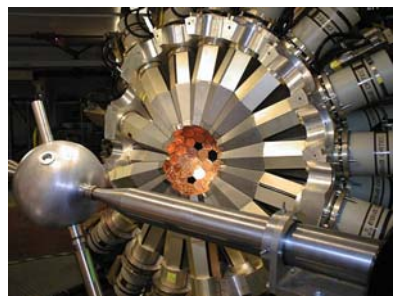
The September 2007 Experiment :

- Fusion reaction at 207 MeV
- ^{80}Se (^{48}Ca, 4n) ^{124}Xe
- Gammasphere with 100 Compton suppressed Ge- detectors.
- 4 particle nano-Amp for 10 days, 30 shifts
- 5 • 10^9 events with 5 fold Ge – supp.coincidences

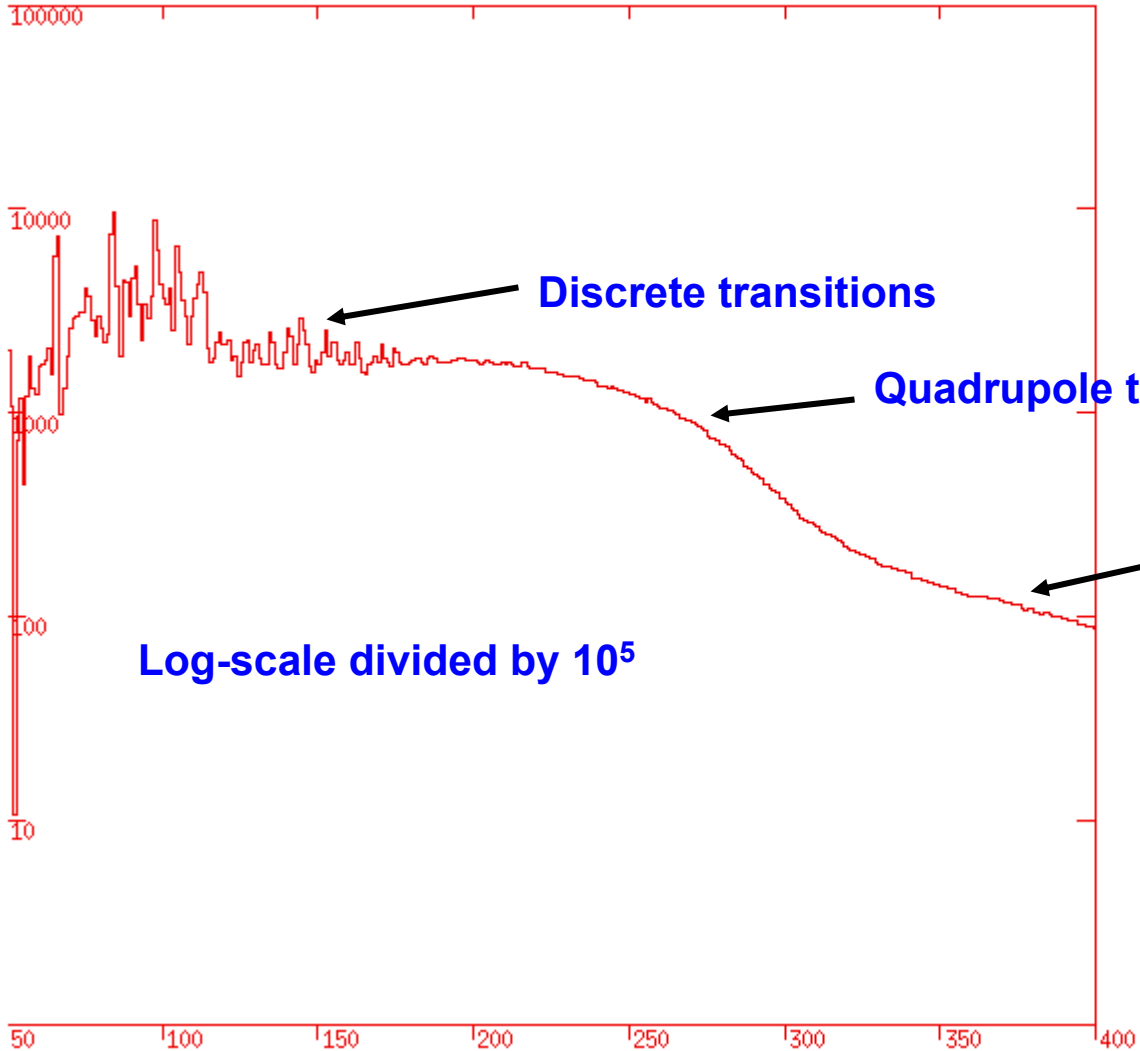


Discrete line analysis.

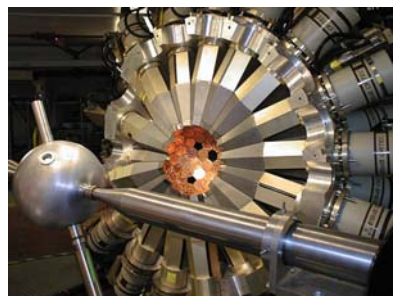
Status after ~ 3 months

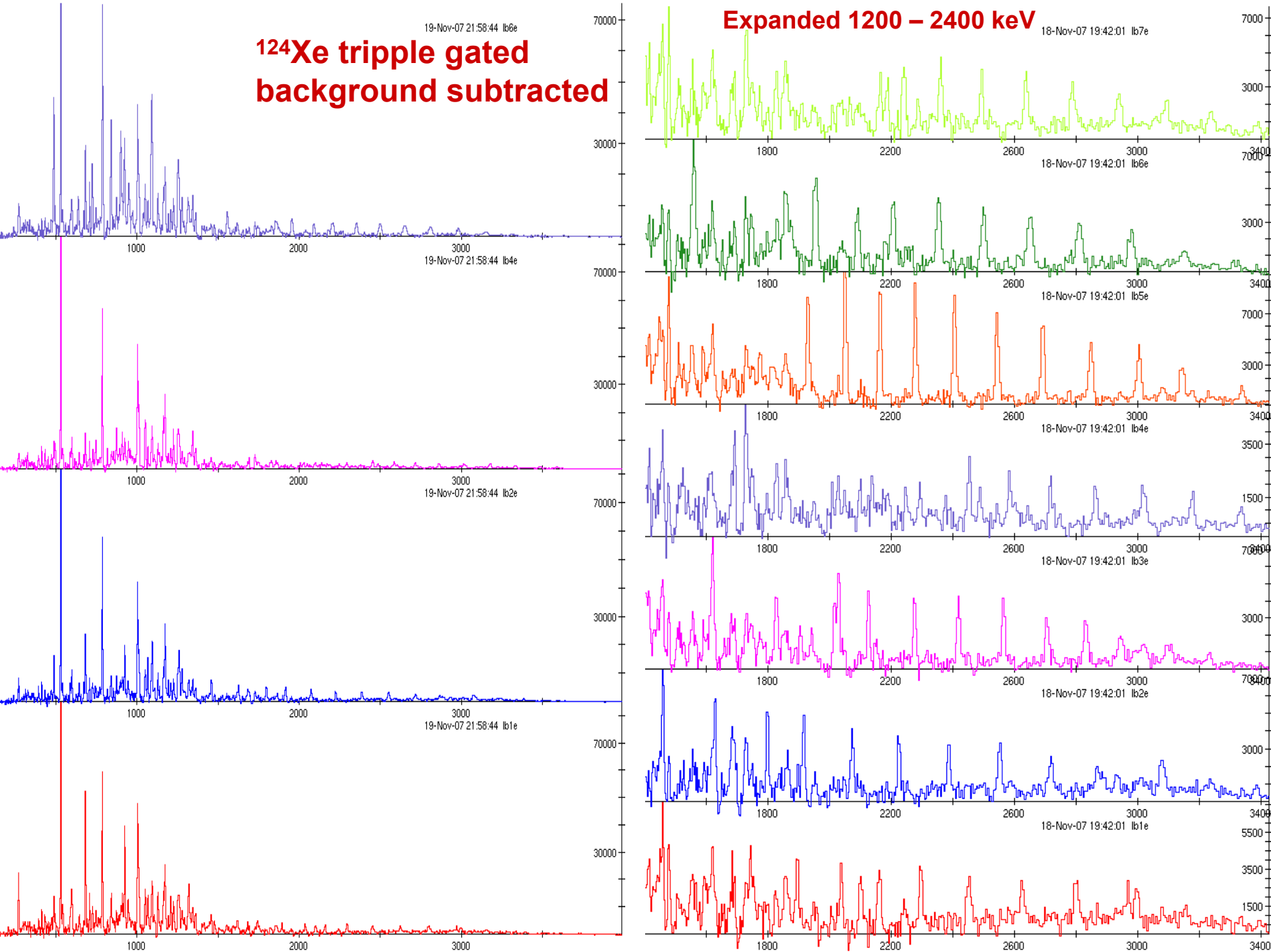


^{124}Xe selected on the 3 lowest lying transitions, unfolded. Spin selection with fold ≥ 16



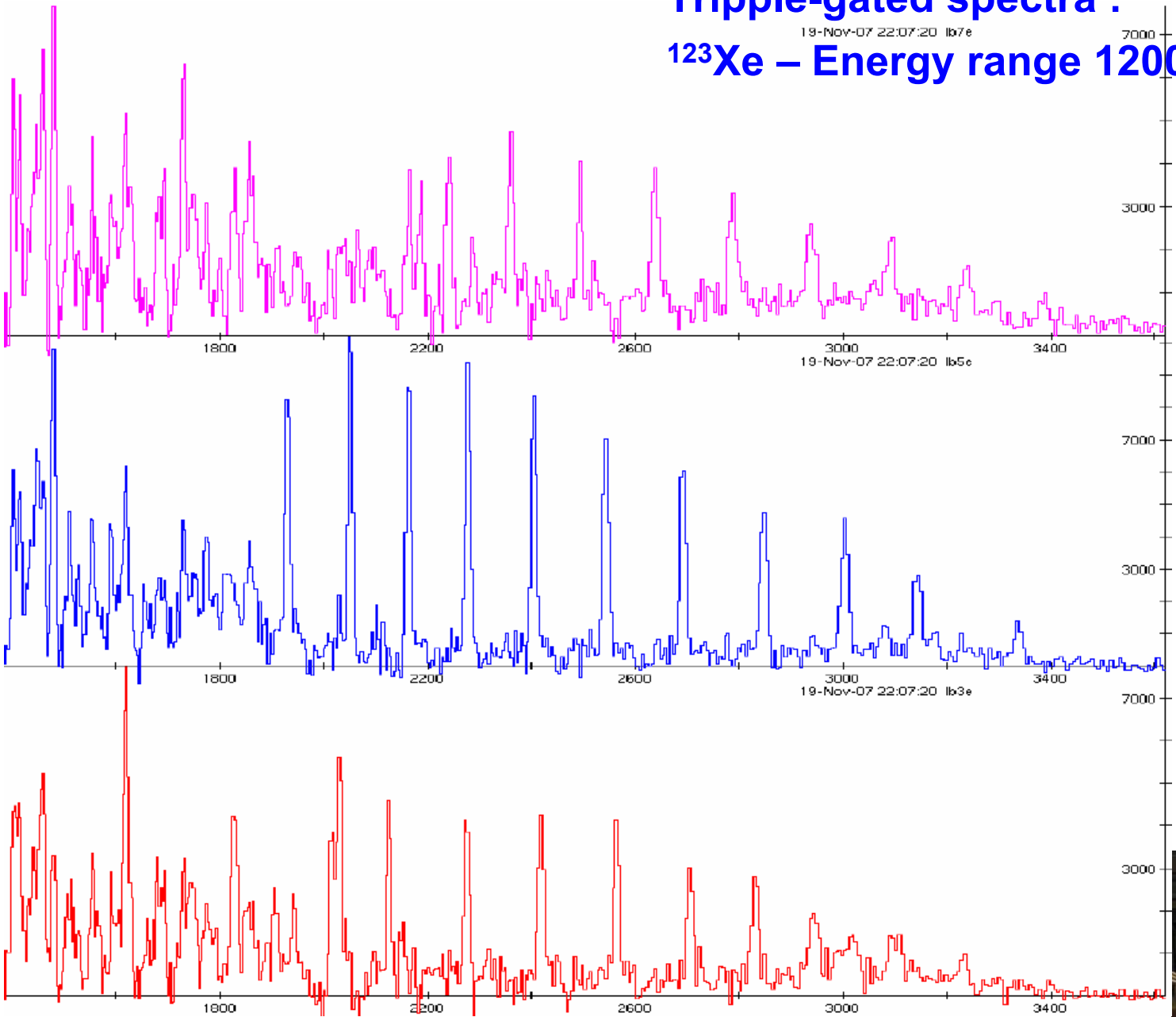
400 E_γ (keV) 3200

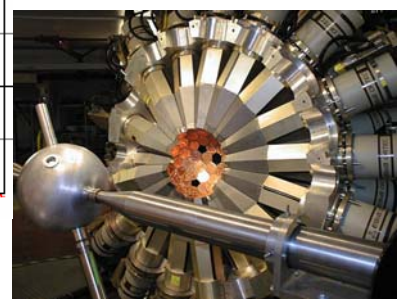



124Xe tripple gated background subtracted
Expanded 1200 – 2400 keV
19-Nov-07 21:58:44 lb6e
19-Nov-07 21:58:44 lb4e
19-Nov-07 21:58:44 lb2e
19-Nov-07 21:58:44 lb1e
18-Nov-07 19:42:01 lb7e
18-Nov-07 19:42:01 lb6e
18-Nov-07 19:42:01 lb5e
18-Nov-07 19:42:01 lb4e
18-Nov-07 19:42:01 lb3e
18-Nov-07 19:42:01 lb2e
18-Nov-07 19:42:01 lb1e

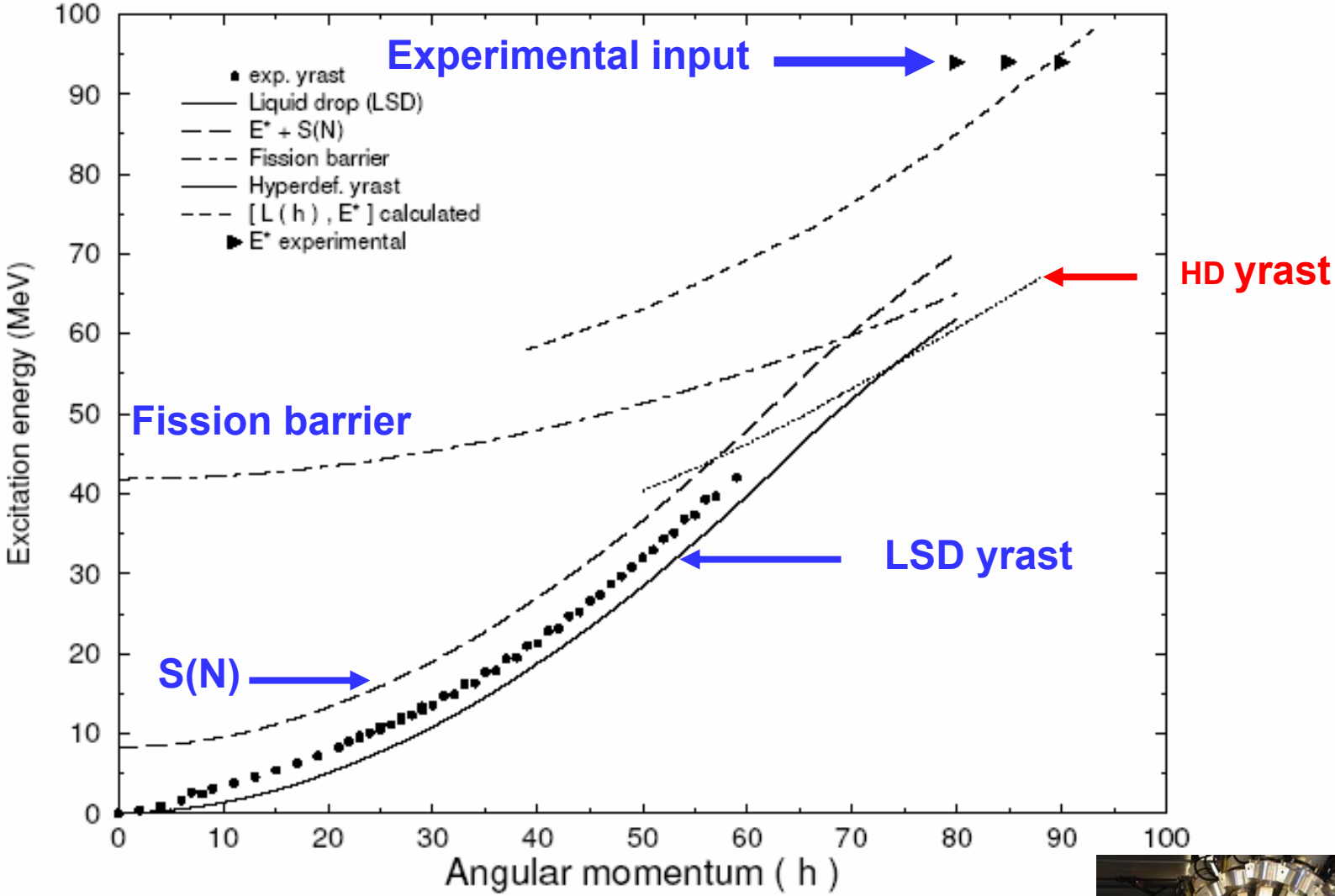
Tripple-gated spectra :

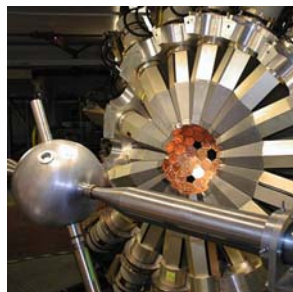
^{123}Xe – Energy range 1200 – 2400 keV





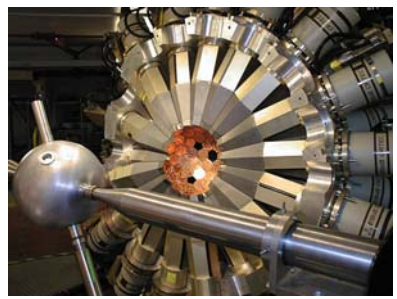
^{126}Xe Yrast Diagramme





Ridge analysis.

Analysis of the quasicontinuum.



Gamma-ray Energy – Rotational Energy – Moment of Inertia - Deformation

$$E_R = \frac{\hbar^2}{2\Im} I(I+1) = A \cdot I(I+1)$$

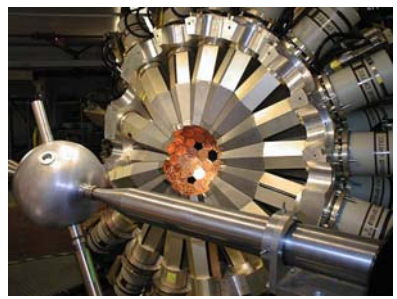
$$E_\gamma = E_R(I+2) - E_R(I)$$

$$E_\gamma = A \cdot (4I - 2)$$

$$A = \frac{E_\gamma}{4I-2} = \frac{\Delta E_\gamma}{8}$$

For a solid ellipsoid with mass M, the ridgid moment of inertia is :

$$\Im_{rigid} = \frac{2}{5} M R^2{}_{av} (1 + 0.31\beta) \qquad \beta = \frac{4}{3}\sqrt{\frac{\pi}{5}}\frac{\Delta R}{R_{av}}$$



Gamma-ray Energy - Kinematic Moment of Inertia

Dynamic Moment of Inertia.

The kinematic Moment :

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

The Dynamic Moment :

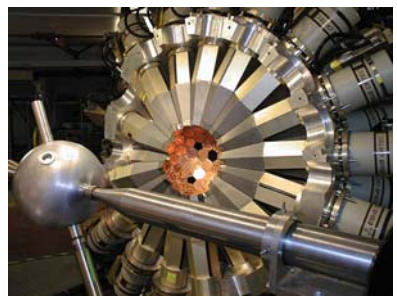
$$\Im^{(2)} = \hbar^2 \left(\frac{d^2E}{dI^2}\right)^{-1} = \hbar \frac{dI}{d\omega}$$

$$\Im^{(2)} = \frac{4\hbar^2}{\Delta E_\gamma}$$

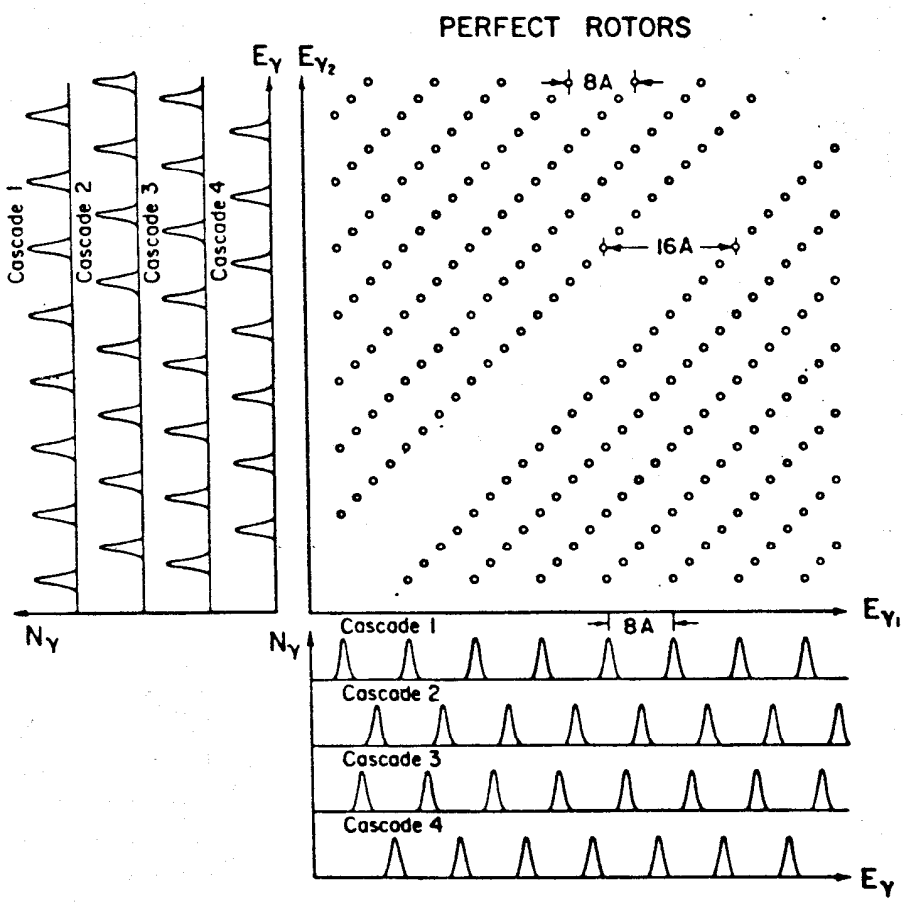
$$\Im^{(2)}(\omega) = \Im^{(1)}(\omega) + \omega \frac{d\Im^{(1)}(\omega)}{d\omega}$$

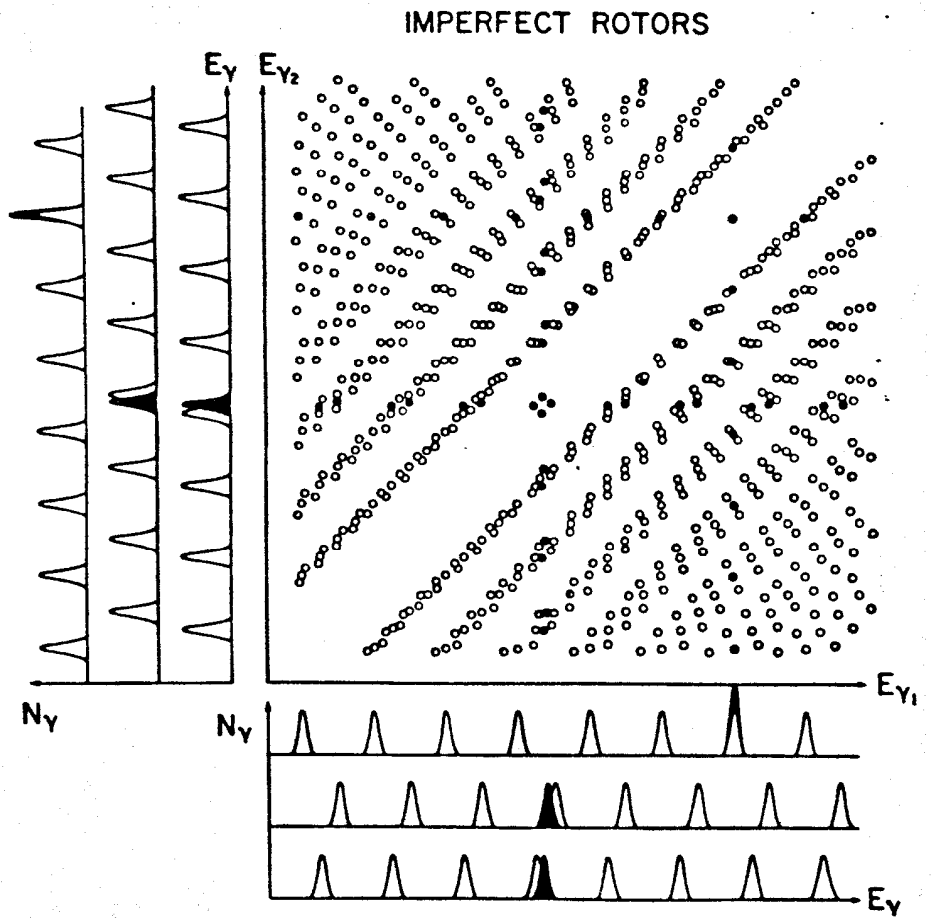
For ridgid body rotation $\Im^{(1)}$ **is constant and :**

$$\Im^{(2)} = \Im^{(1)} = \Im_{rigid-body}$$

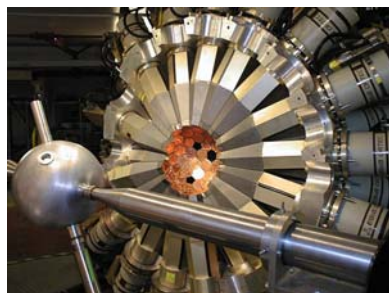


Principle of ridge analysis





$$\Delta E_\gamma = 8A = 8\,\hbar^2/2J$$



Rotational Energy Correlations form ridges in 2D and 3D spectra. Ridges are identified in perpendicular cuts in slices in the 3D cube.

The slices are centered at tilted rotational planes defined by the equation :

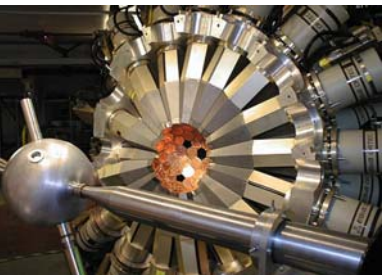
$$E_x - E_z = N(E_z - E_y) \pm \delta / 4$$

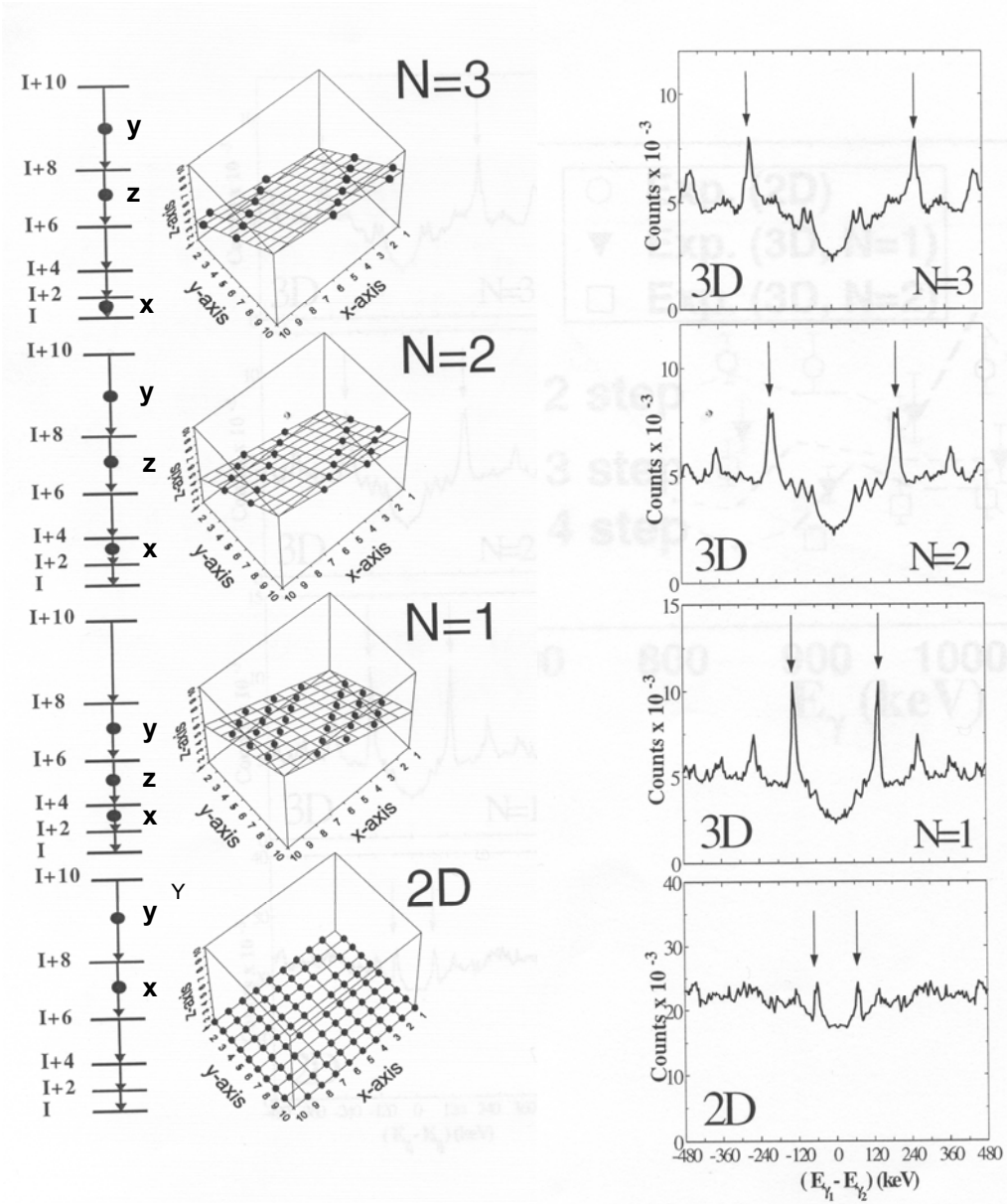
N = 1, 2, 3, ….

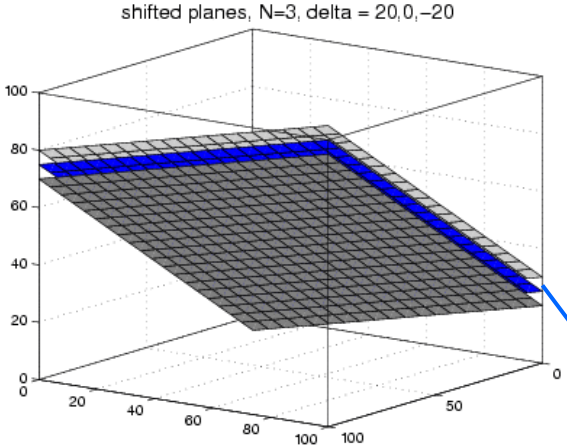
Note the improved peak to total ratio of the ridge cuts in the rotational planes.

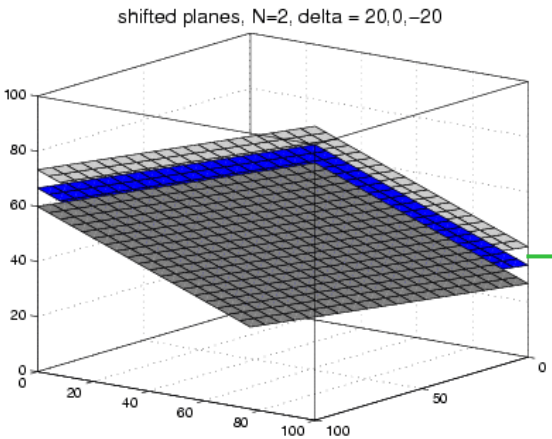
Quality factor of the ridge cuts proportional to

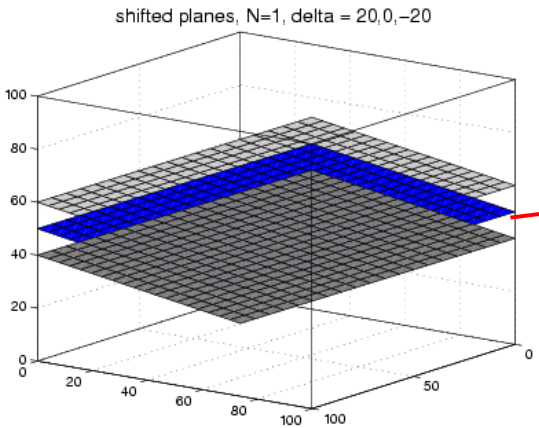
$$q \propto \frac{\Delta E_\gamma}{\delta}$$



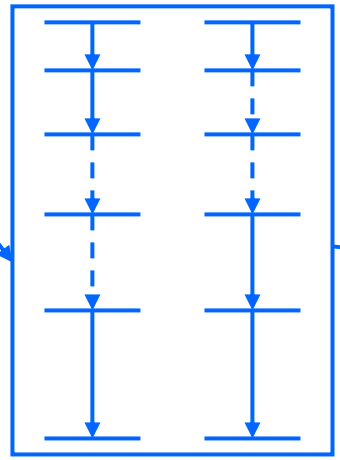




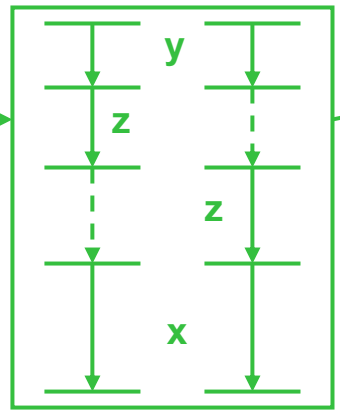




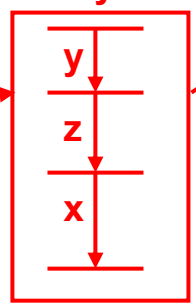
N=3: x+3y-4z = ±δ



N=2: x+2y-3z = ±δ

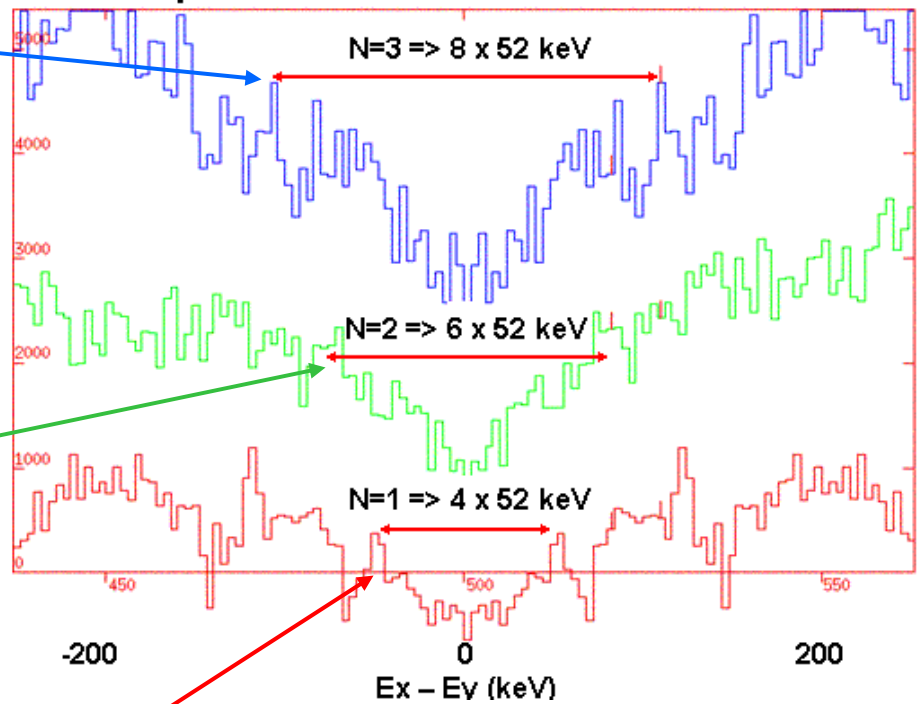


N=1: x+y-2z = ±δ



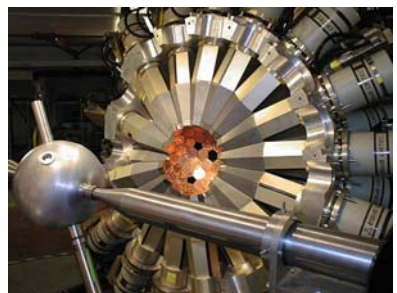
Example from ^{122}Xe – via the (α.2n) channel.
Data from previous EB exp. ^{64}Ni + ^{64}Ni .

Perpendicular Cut = 1440 ± 204 keV



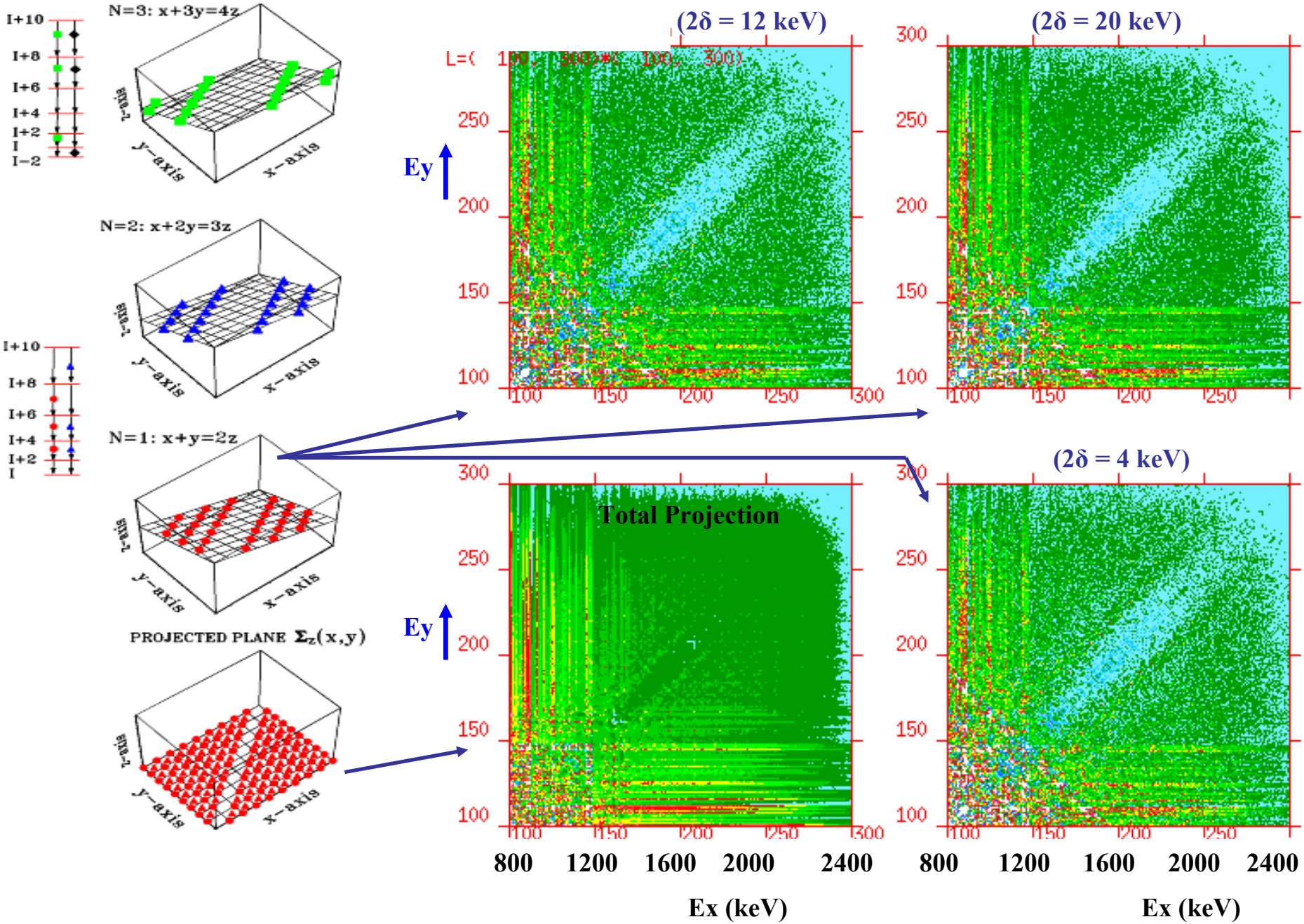
ΔEγ = 52 keV ⟶ $J^{(2)}$ = 76 ħ²/MeV

superdeformed



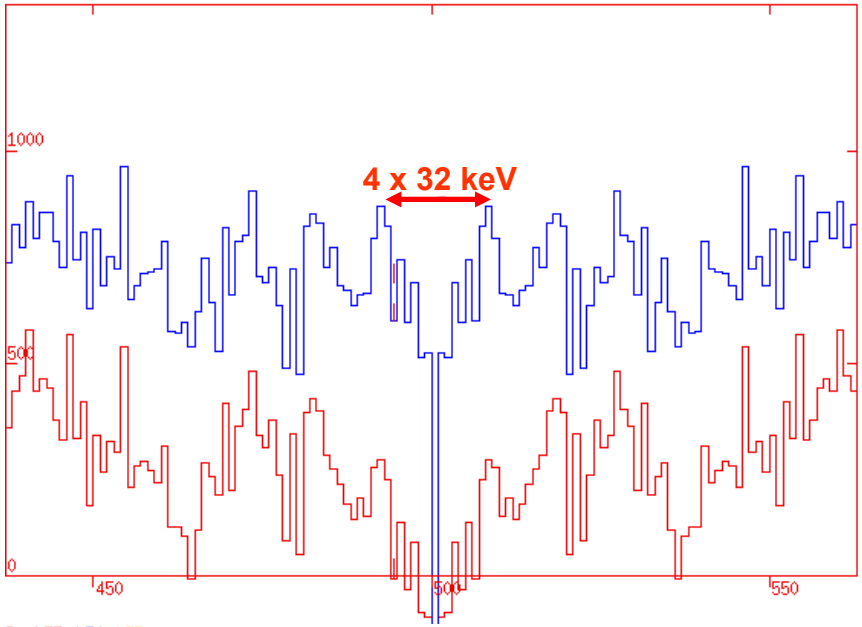
Rotational Plane Mapping (RPM)

RPM on Xe data sorted in a cube N=1 : Ex + Ey – 2Ez = 2δ



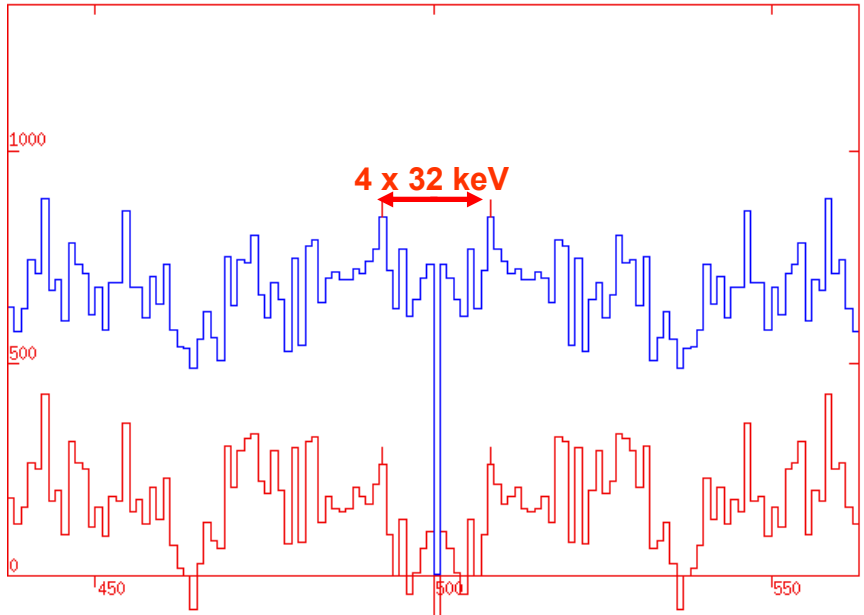
D= b45 b75
F = 2048.
L= 494 H= 494

PCut=1280 ± 164 keV



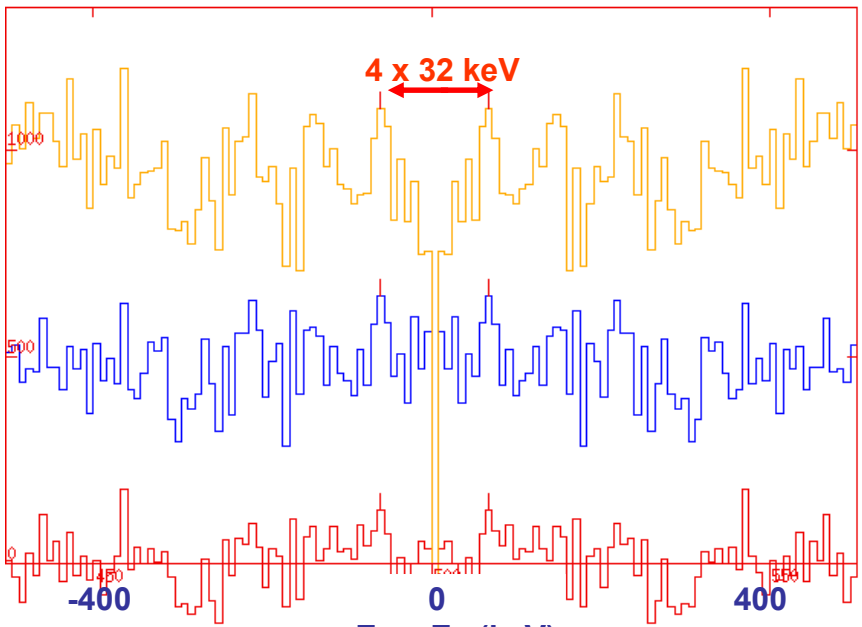
D= b48 b78
F = 2048.
L= 492 H= 508

PCut=1360 ± 164 keV



D= b73 b74 b75
F = 2048.
L= 492 H= 508

PCut=1280 ± 84,124,164 keV

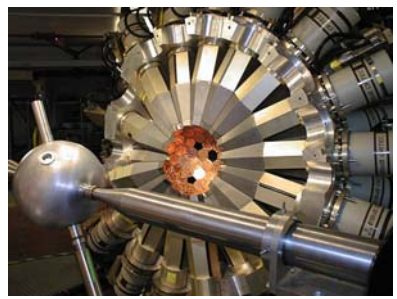


Ex – Ey (keV)

Cuts in Cube gated on ^{124}Xe

$\Delta E\gamma$ = 32 keV ⟶ $J^{(2)}$ = 124 $\hbar^2$/MeV

Hyperdeformed !



Ridge cuts with xn channel selection

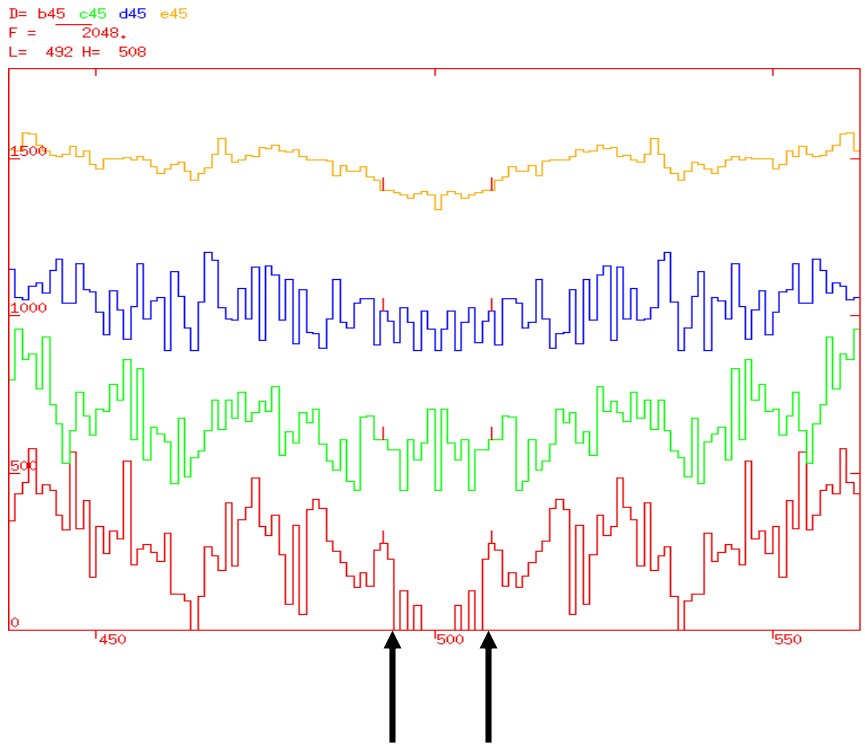
at 1280 ± 164 keV

No selection

6n – ^{122}Xe

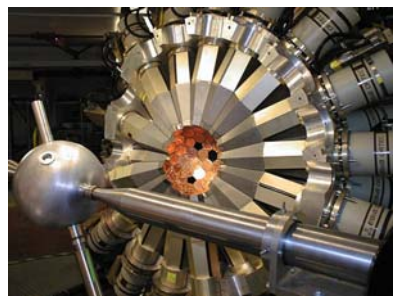
5n – ^{123}Xe

4n - ^{124}Xe

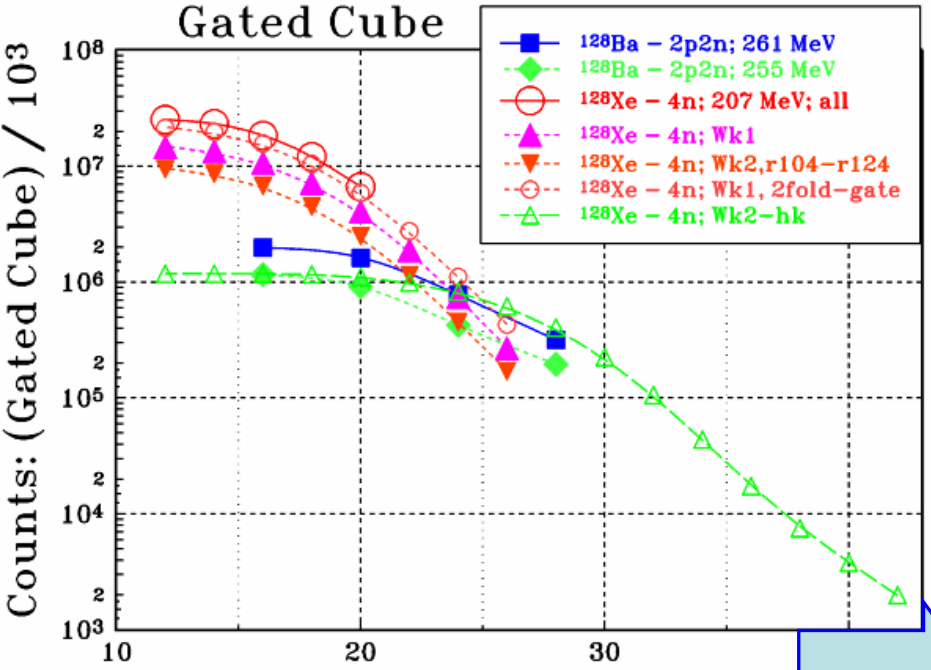


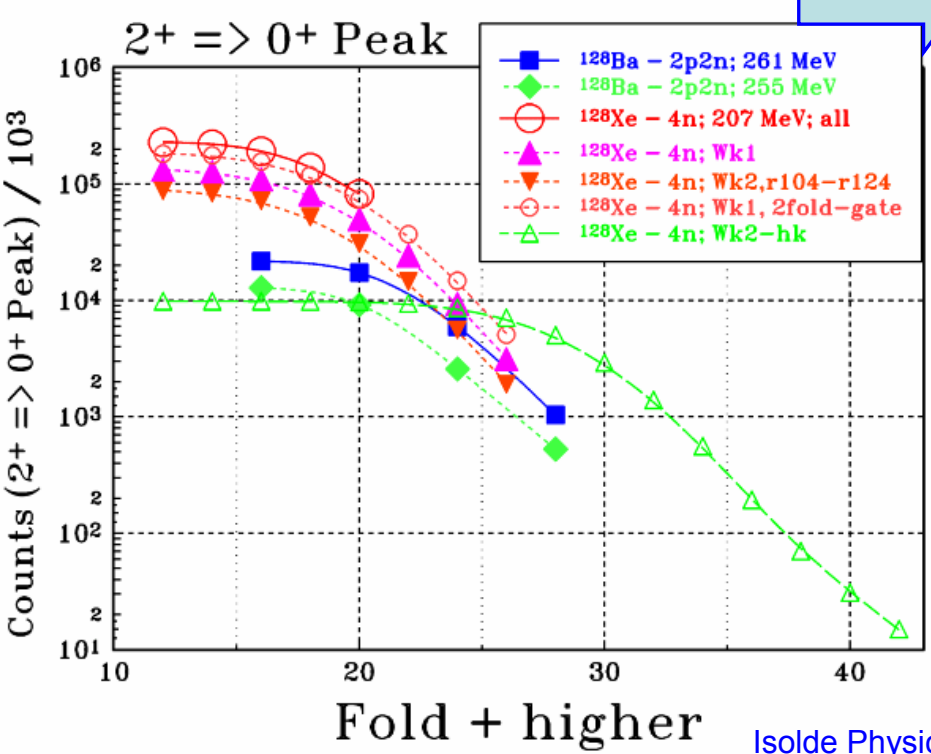
4 x 32 keV

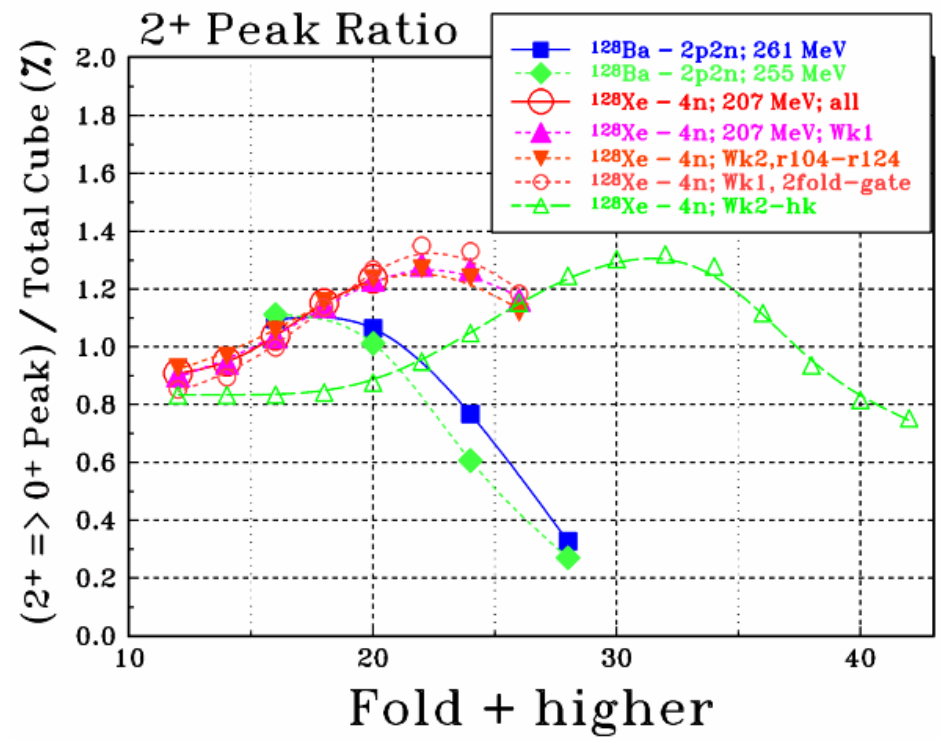
^{124}Xe Hyperdeformed !

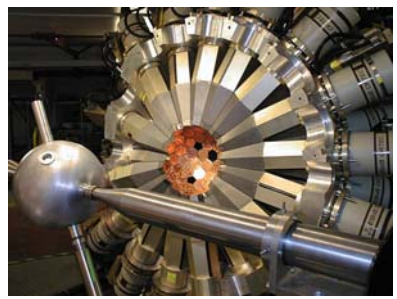


Comparisons of Fold Distributions for the different cases analyzed leading to ^{124}Xe HD Ridge Structures (single–or Gated by 3 low lying peaks)



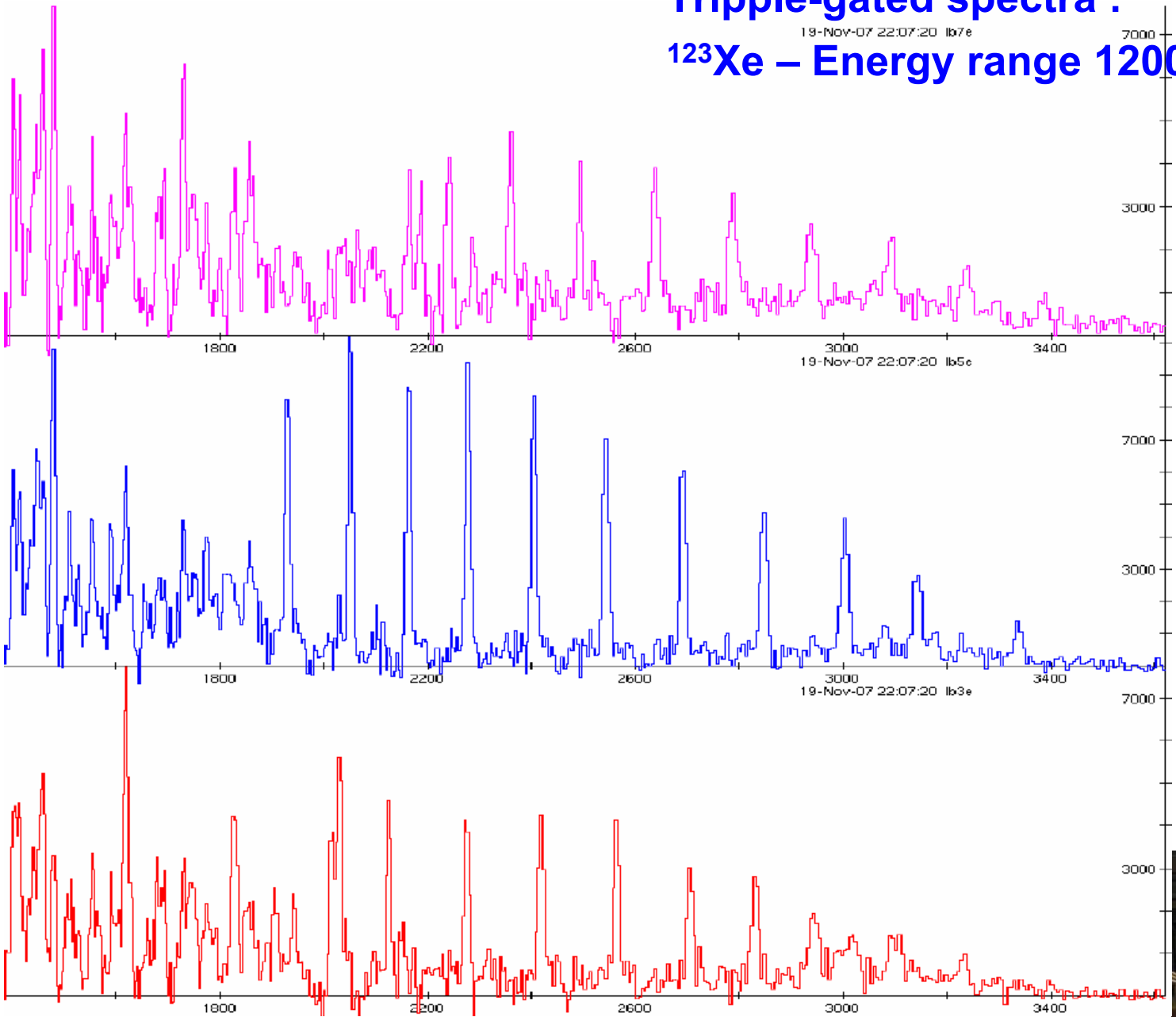


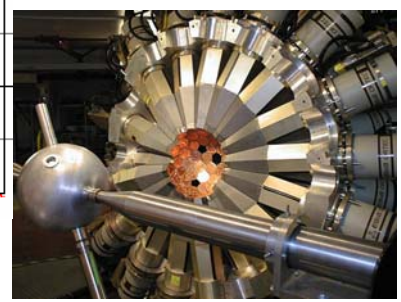




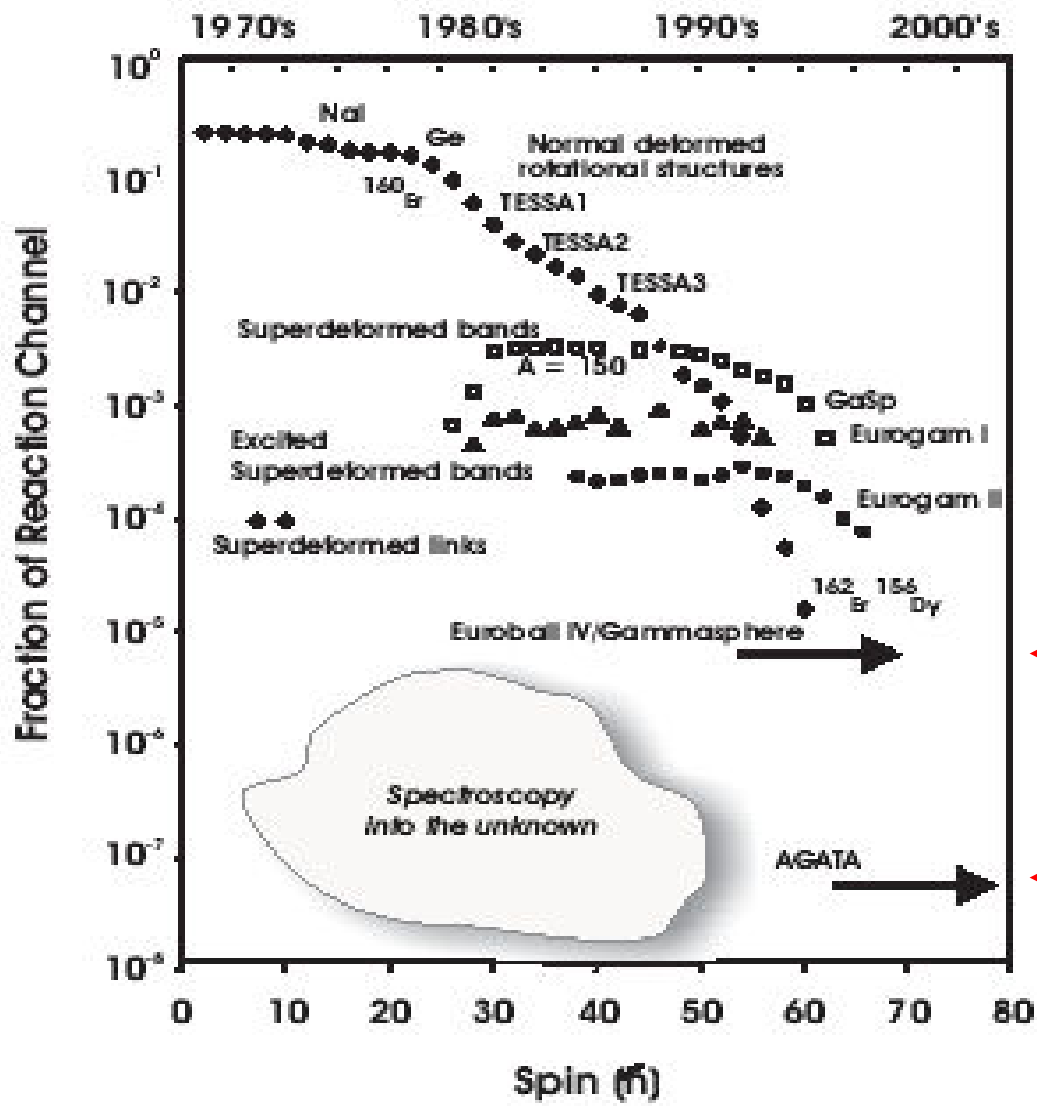
Tripple-gated spectra :

^{123}Xe – Energy range 1200 – 2400 keV



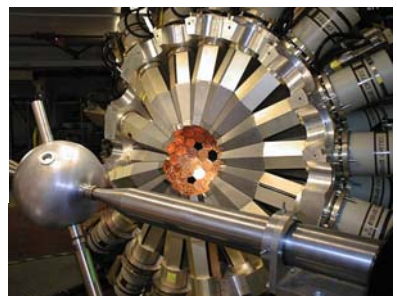


Sensitivity of Gamma-ray detectors vz spin and time.



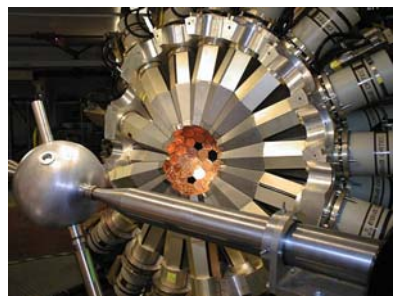
8×10^{-6}

6×10^{-8}



Summary and conclusions.

- Hyperdeformation of ^{124}Xe nuclei at high spin has been identified.
- Analysis of ridge structures indicate a moment of inertia of the rotating nucleus to 124 $\hbar^2$ MeV^{-1} characteristic for a hyperdeformed prolate.
- Discrete line spectra of the hyperdeformed bands are not yet found at the 10^{-6} level of the ^{124}Xe reaction yield.
- Situation analogous to the discovery of superdeformation in 1984/1986, ridges in ^{152}Dy 1984/ discrete lines 1986.
- AGATA at the 10^{-8} level needed ?



Proposal to ATLAS/Gammasphere:

Search for Hyperdeformation in ^{124}Xe and Neighbouring Nuclei.

Awarded 30 shifts.

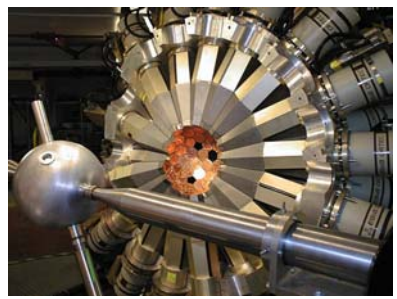
Experimental team:

H. Hübel, B. Herskind, A.N. Wilson, A. Bürger, M.P. Carpenter,

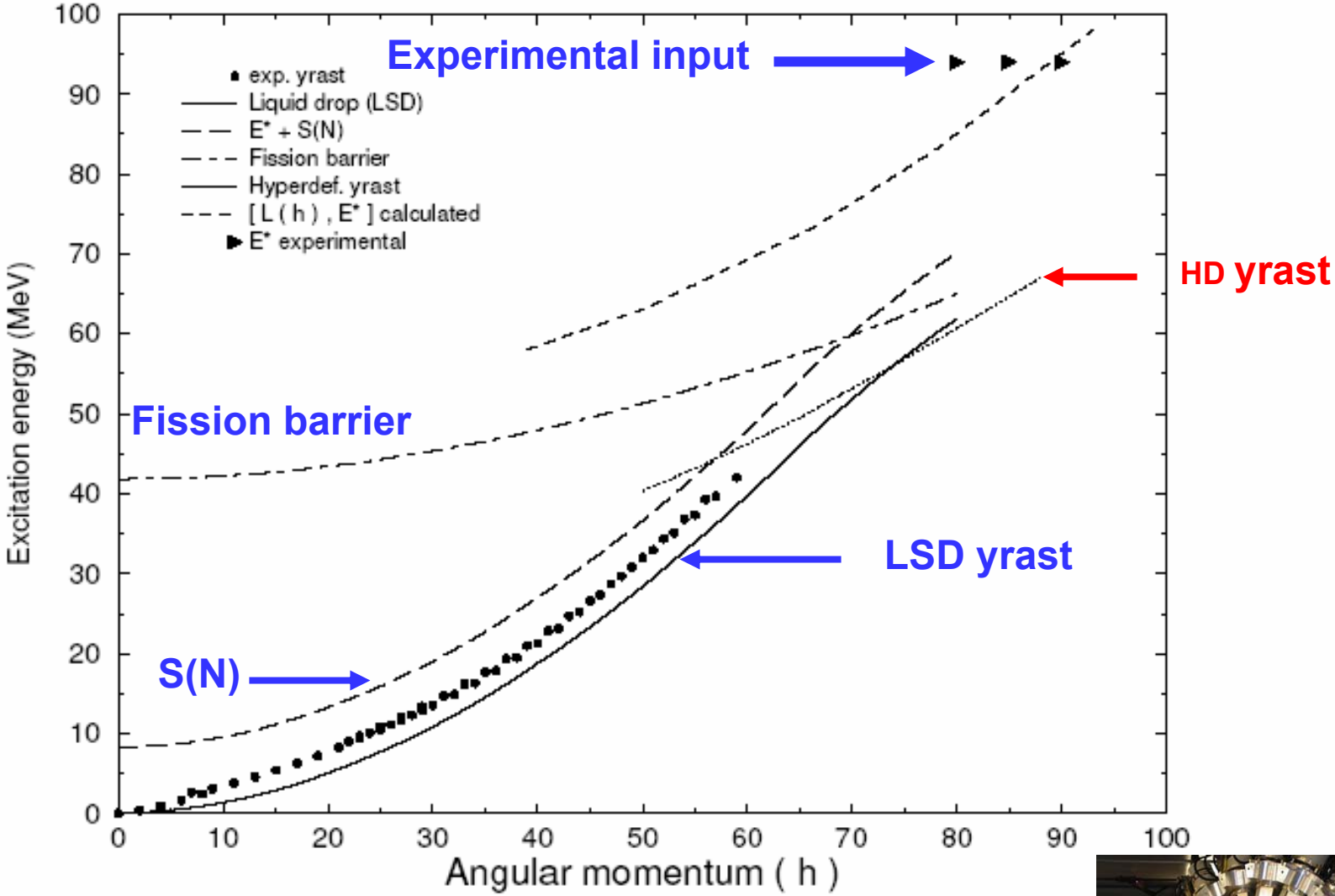
S. Chmel, R.M. Clark, P. Fallon, T.L. Khoo, F.G. Kondev,

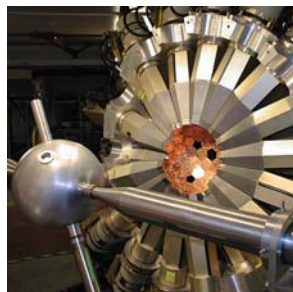
A. Korichi, T. Lauritsen, A.O. Macchiavelli, B.M. Nyakó, G. Sletten,

B. J.Timar and Anna Wilsons student Jeff.

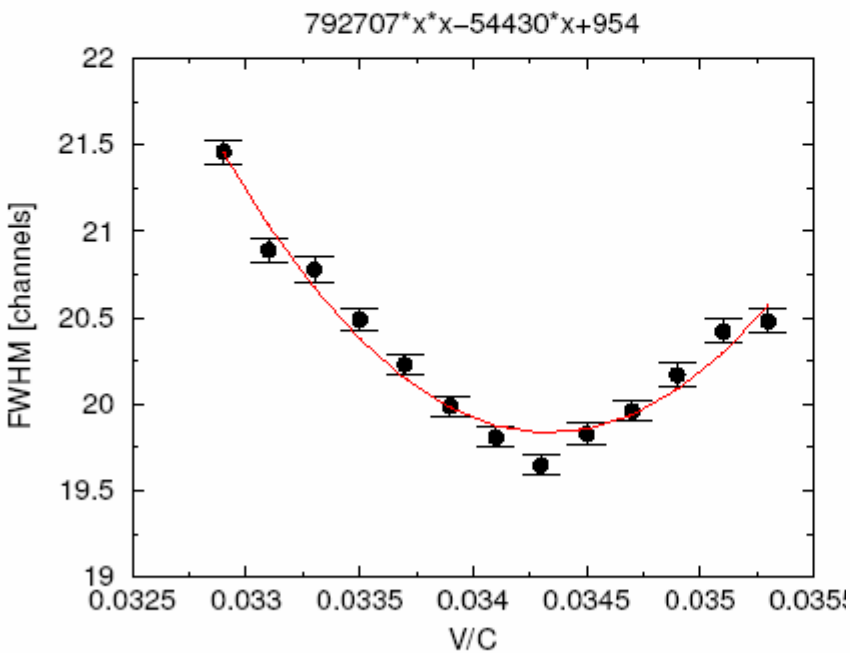


^{126}Xe Yrast Diagramme

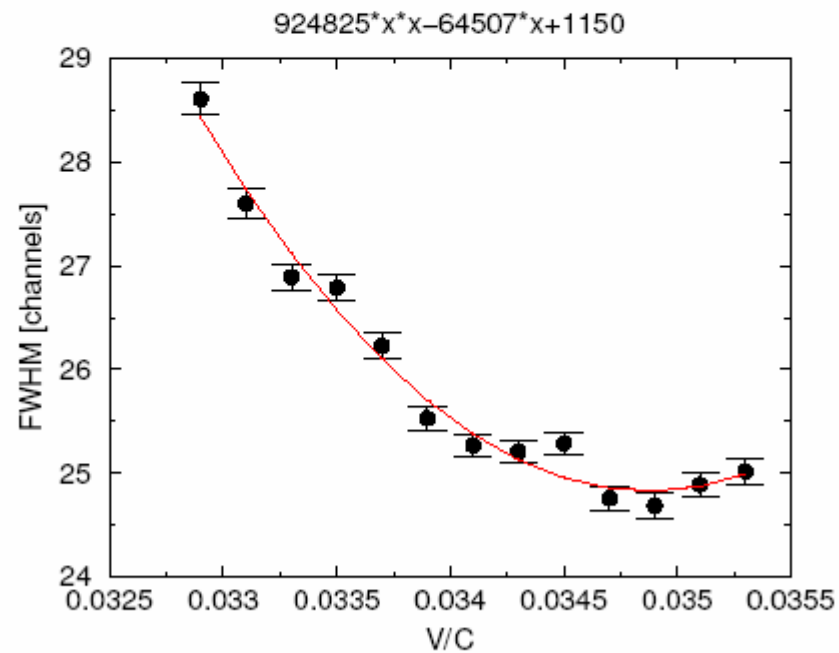




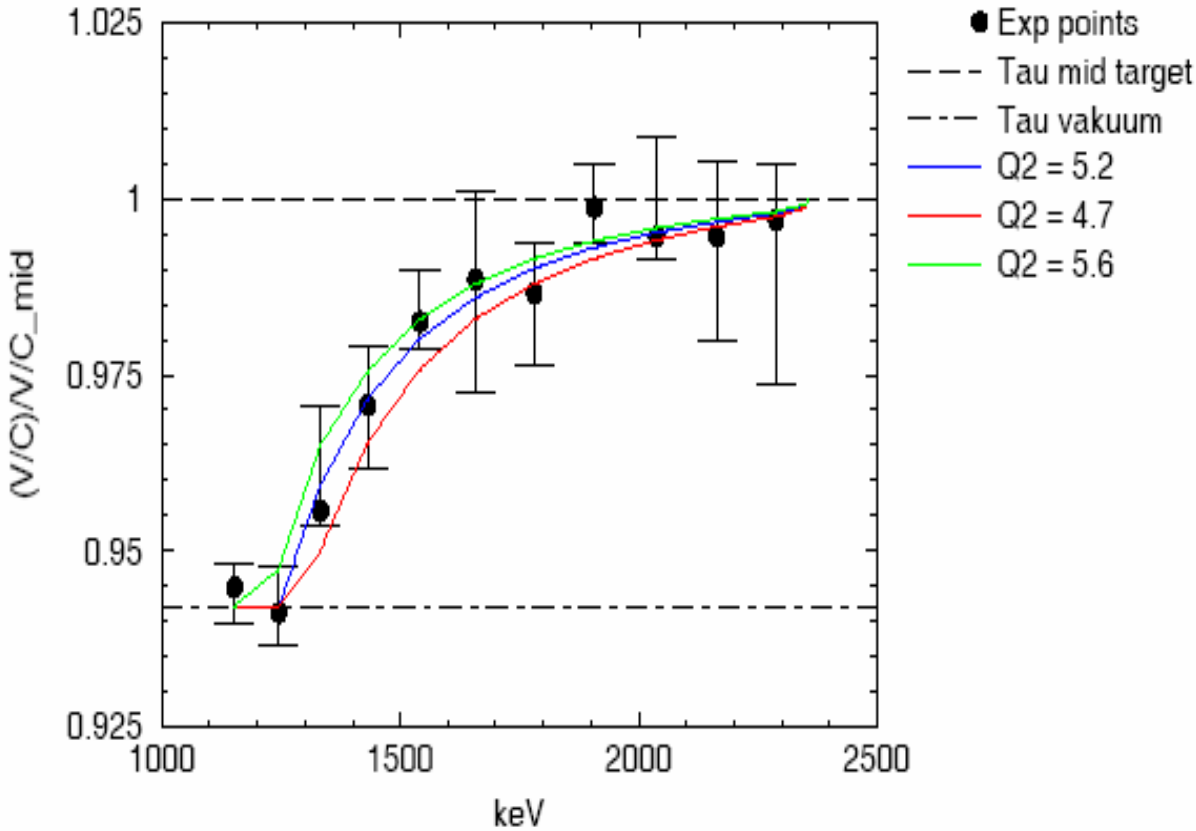
The 36^{-} - 34^{-} 1540 keV transition



The 42^{-} - 40^{-}1907 keV transition



Bormio January 2007


1.025
1
0.975
0.95
0.925
1000
1500
2000
2500
keV
(V/C)/V/C_mid
Exp points
Tau mid target
Tau vakuum
Q2 = 5.2
Q2 = 4.7
Q2 = 5.6

E = 42 MeV

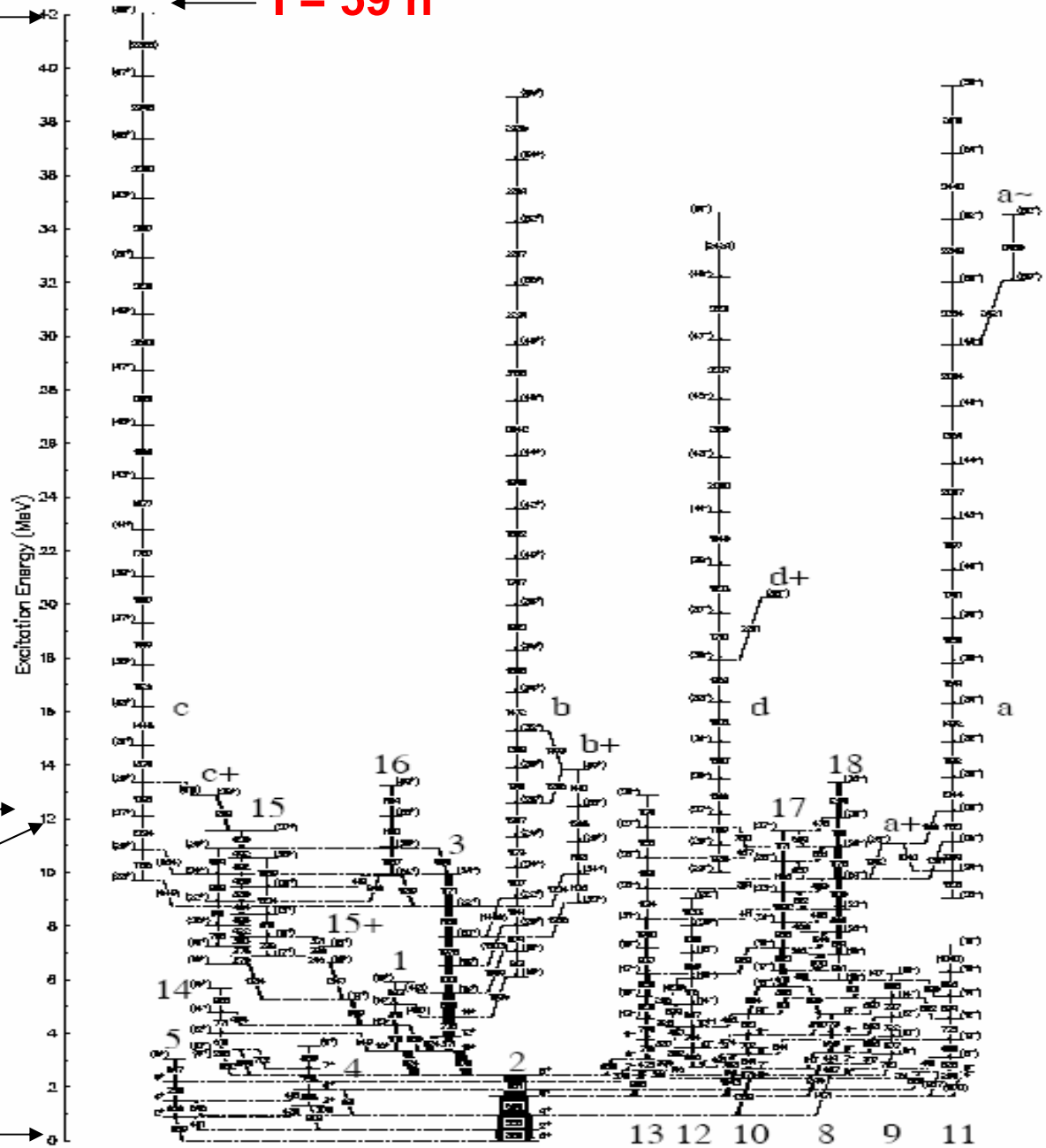
I = 59 ħ

^{126}Xe

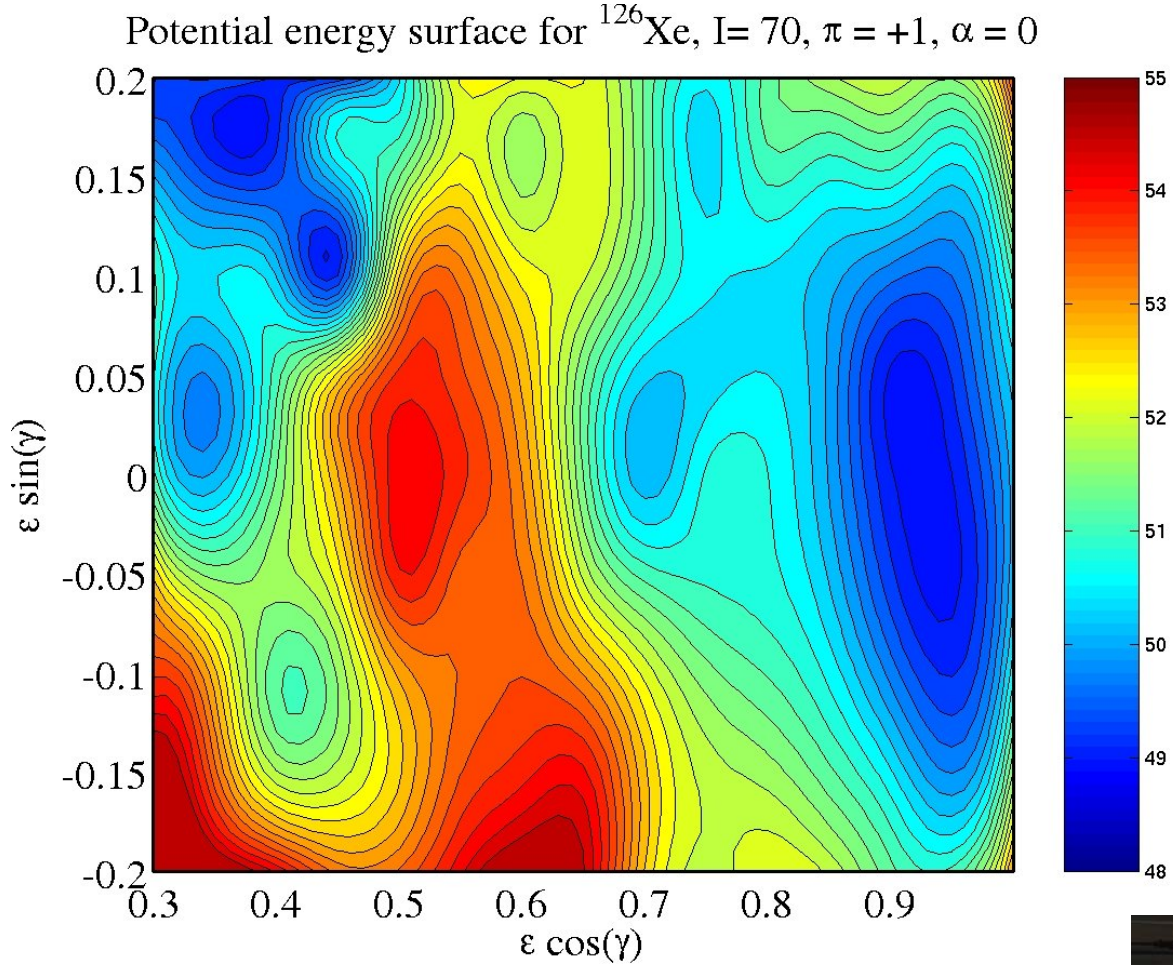
E = 12 MeV

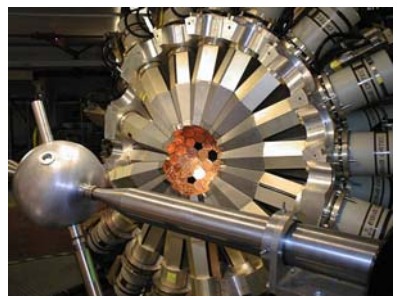
I ~ 24 ħ

E = 0 MeV



Potential energy surface calculated with the Cranked Shell Model



^{126}Xe at 70 ħ

R. Bengtsson, http:www.matfys.lth.se/~ragnar/ultimate.html.