# Analysis of Exotic Deformation Parameters in the Actinide Region

K. Mazurek[1], J. Dudek[2], N. Schunck[3]

[1] Niewodniczański Institute of Nuclear Physics, Polish Academy of Sciences, Kraków, Poland

[2] Institut de Recherches Subatomiques and Université Louis Pasteur, F-67037 Strasbourg Cedex 2, France

[3] Departamento de Fisica Teorica, Universidad Autonoma de Madrid, Camtoblanco 28 049, Spain

# Presentation Content

- Macroscopic-Microscopic Method
  - Lublin–Strasbourg Drop (LSD)
  - Shell and Pairing Energies
- Octupole Degrees of Freedom
- Binding Energies
- Summary

# Macroscopic-Microscopic Method

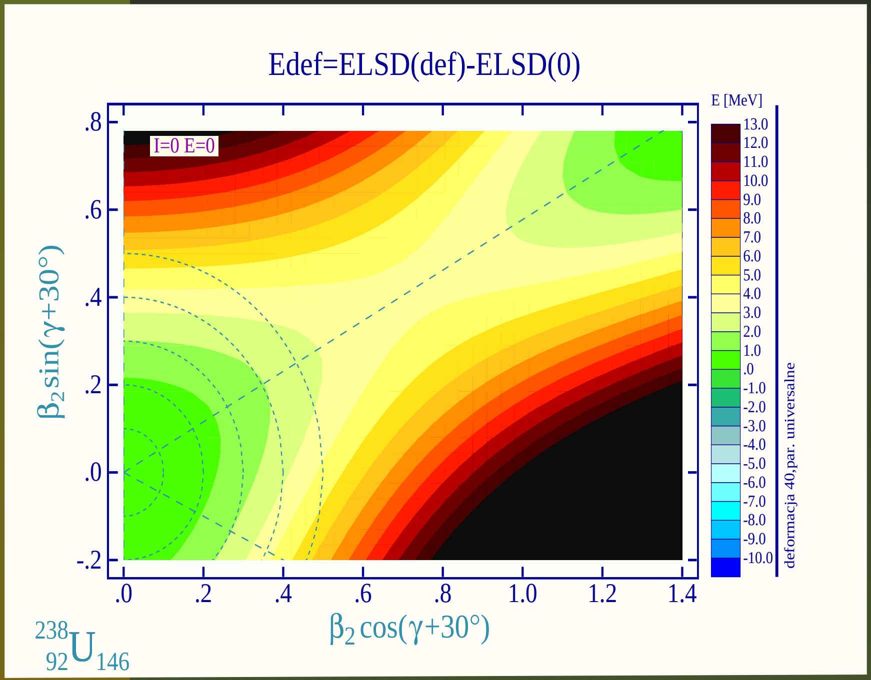
$$M(Z,N;def) = ZM_H + NM_n - 0.00001433Z^{2.39} + E_{LSD}(Z,N;def) + E_{micr}(Z,N;def)$$

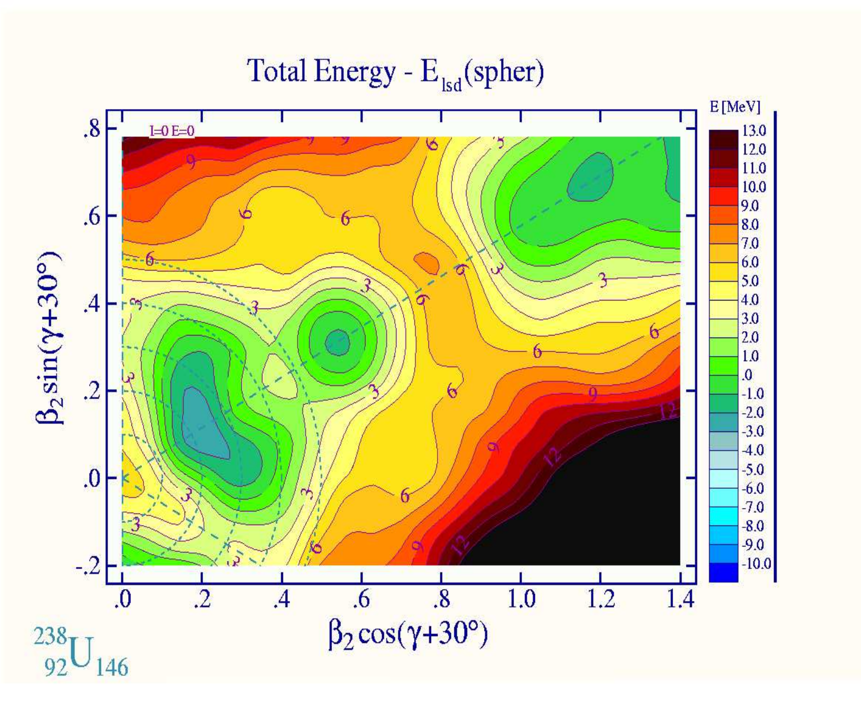
- Microscopic Energy: $E_{micr} = E_{pair} + E_{shell}$
- Macroscopic Energy: Lublin - Strasbourg Drop
  [ K. Pomorski, J. Dudek, Phys. Rev. **C 67**, 044316 (2003)
  J. Dudek, K. Pomorski, N.Schunck, N. Dubray, Eur. Phys. J. **A 20**, 15 (2004) ].

  (A=Z+N; I=(N-Z)/A)

$$E_{LSD} = -15.4920(1 - 1.8601I^2)A + 16.9707(1 - 2.2938I^2)A^{2/3}B_{surf}(def) + 3.8602(1 + 2.3764I^2)A^{1/3}B_{curv}(def) + \frac{3}{5}e^2\frac{Z^2}{r_0^{ch}A^{1/3}}B_{Coul}(def) - 0.9181\frac{Z^2}{A} - 10\cdot\exp(-4.2|I|)$$

# Total Energies: An Example



# Deformation Parameters

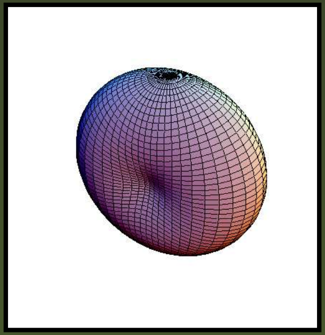
$$\mathcal{R}(\theta, \phi) = R_0 c(\{\alpha_{\lambda\mu}\})(1 + \sum_{\lambda=2}^{\lambda_{max}} \sum_{\mu=-\lambda}^{\lambda} \alpha_{\lambda\mu} Y_{\lambda\mu}(\theta, \phi))$$

# Deformation Parameters

$$\mathcal{R}(\theta,\phi) = R_0 c(\{\alpha_{\lambda\mu}\})(1 + \sum_{\lambda=2}^{\lambda_{max}} \sum_{\mu=-\lambda}^{\lambda} \alpha_{\lambda\mu} Y_{\lambda\mu}(\theta,\phi))$$

- The quadrupole shapes $\lambda = 2, \mu = -2, 0, 2$

$$\mathcal{R}(\theta,\phi) = R_0 c(\{\alpha_{\lambda\mu}\})(1 + \alpha_{2,-2} Y_{2,-2}(\theta,\phi) + \alpha_{2,0} Y_{2,0}(\theta,\phi) + \alpha_{2,+2} Y_{2,+2}(\theta,\phi))$$

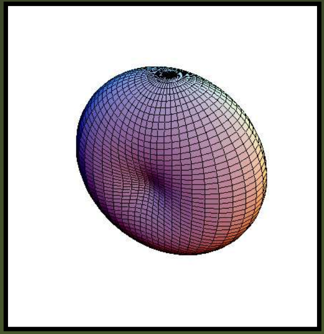


## Deformation Parameters

$$\mathcal{R}(\theta,\phi) = R_0 c(\{\alpha_{\lambda\mu}\})(1 + \sum_{\lambda=2}^{\lambda_{max}} \sum_{\mu=-\lambda}^{\lambda} \alpha_{\lambda\mu} Y_{\lambda\mu}(\theta,\phi))$$

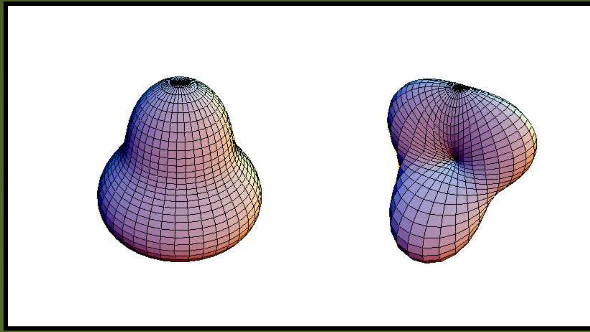
- The quadrupole shapes $\lambda = 2, \mu = -2, 0, 2$

$$\mathcal{R}(\theta,\phi) = R_0 c(\{\alpha_{\lambda\mu}\})(1 + \alpha_{2,-2} Y_{2,-2}(\theta,\phi) + \alpha_{2,0} Y_{2,0}(\theta,\phi) + \alpha_{2,+2} Y_{2,+2}(\theta,\phi))$$

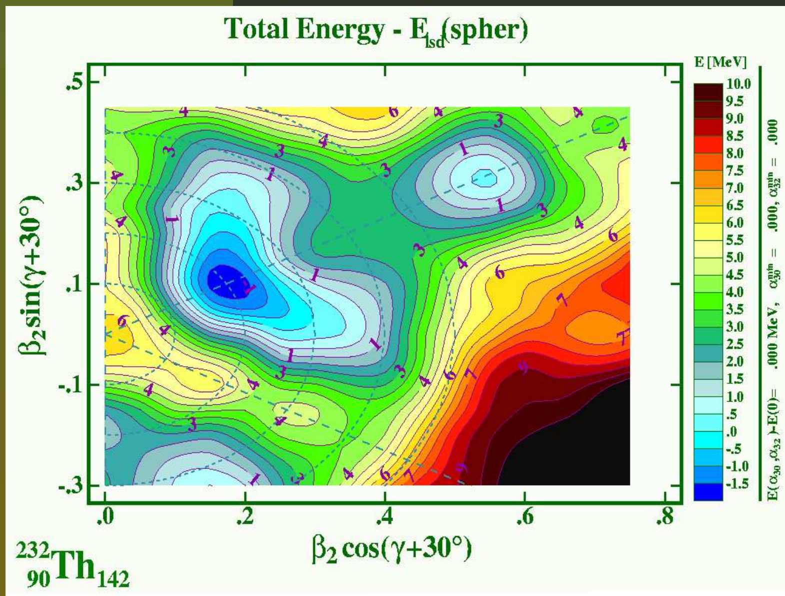


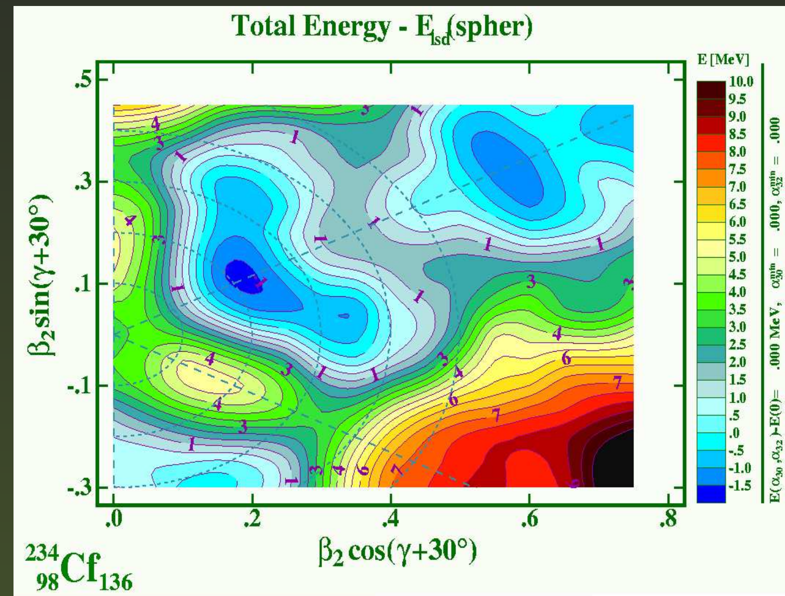
- The octupole shapes $\lambda = 3, \mu = -2, 0, 2$

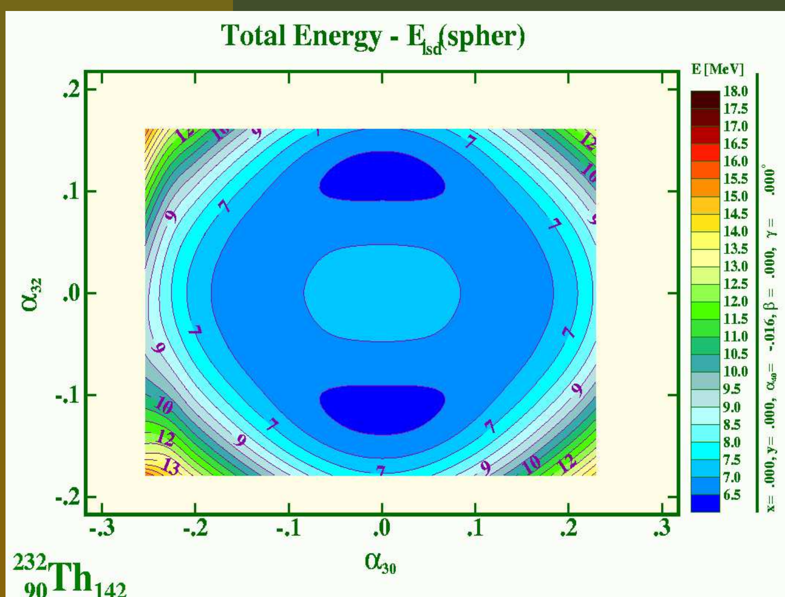
$$\mathcal{R}(\theta,\phi) = R_0 c(\{\alpha_{\lambda,\mu}\})(1 + \alpha_{2,\pm2} Y_{2,\pm2}(\theta,\phi) + \alpha_{2,0} Y_{2,0}(\theta,\phi) + \alpha_{3,\pm2} Y_{3,\pm2}(\theta,\phi) + \alpha_{3,0} Y_{3,0}(\theta,\phi))$$

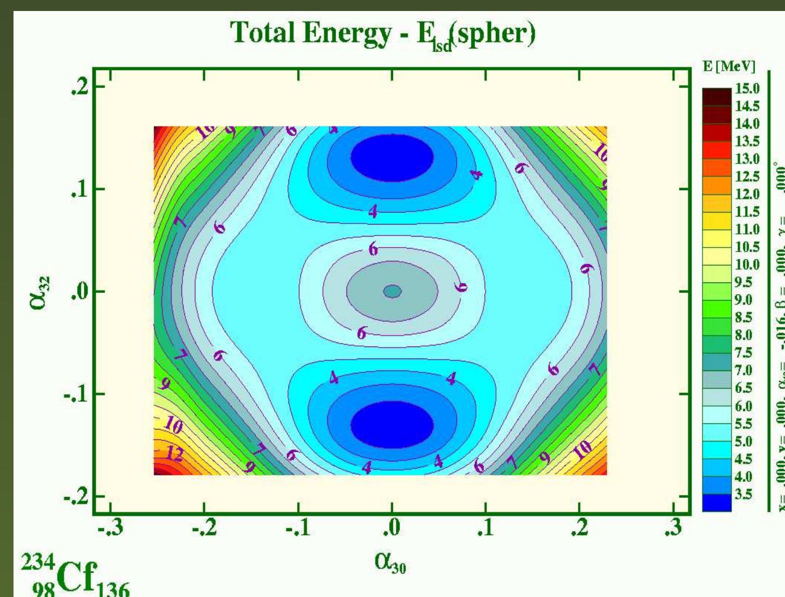


# Total Energies: Non-Axial Octupole Projections

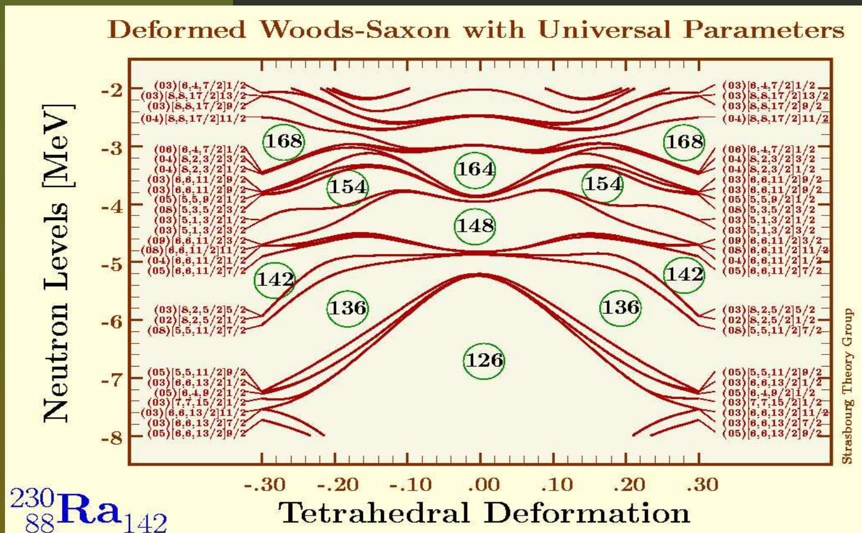


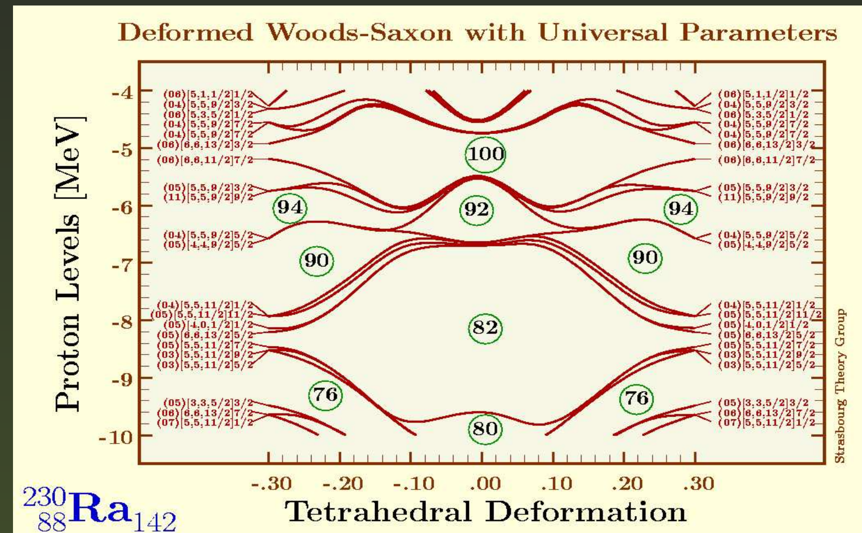



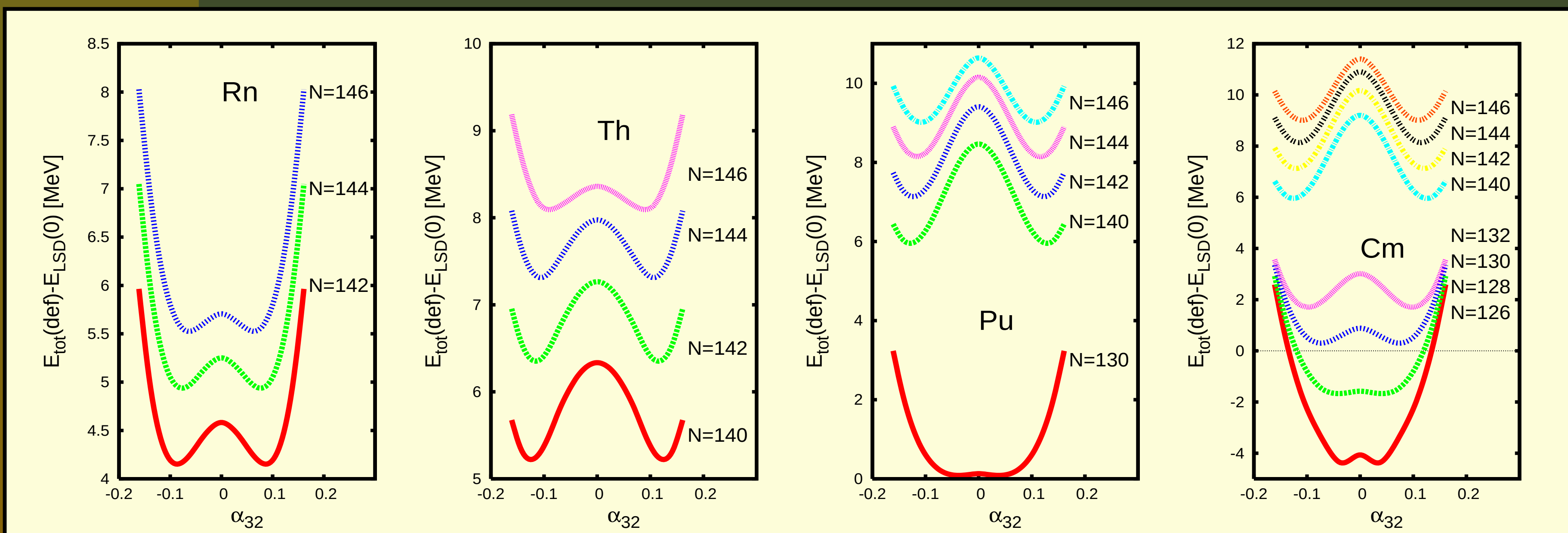



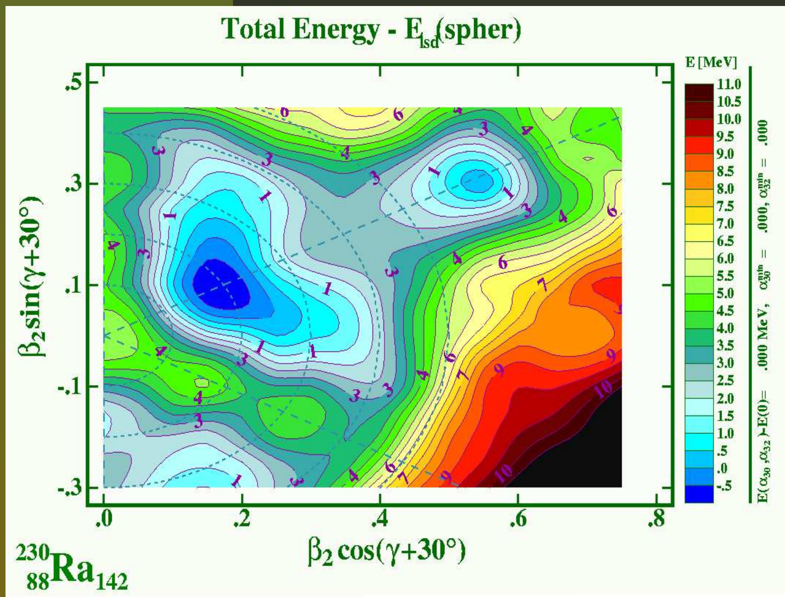
# Tetrahedral Symmetry: $Y_{\lambda,\mu}$ : $\lambda = 3, \mu = -2, 0, 2$

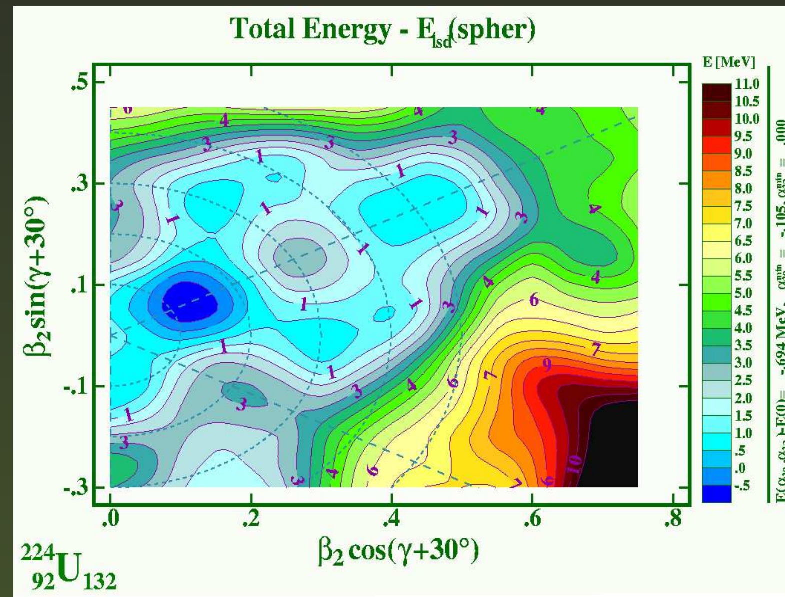


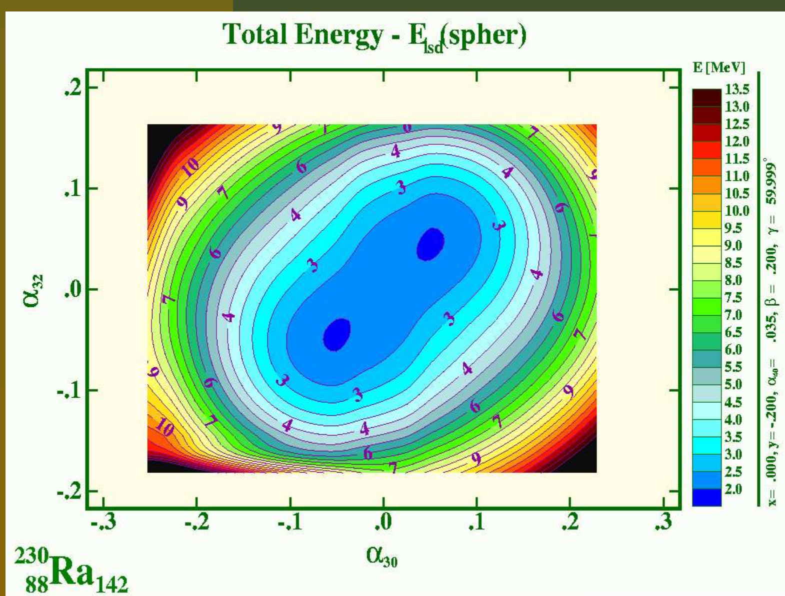



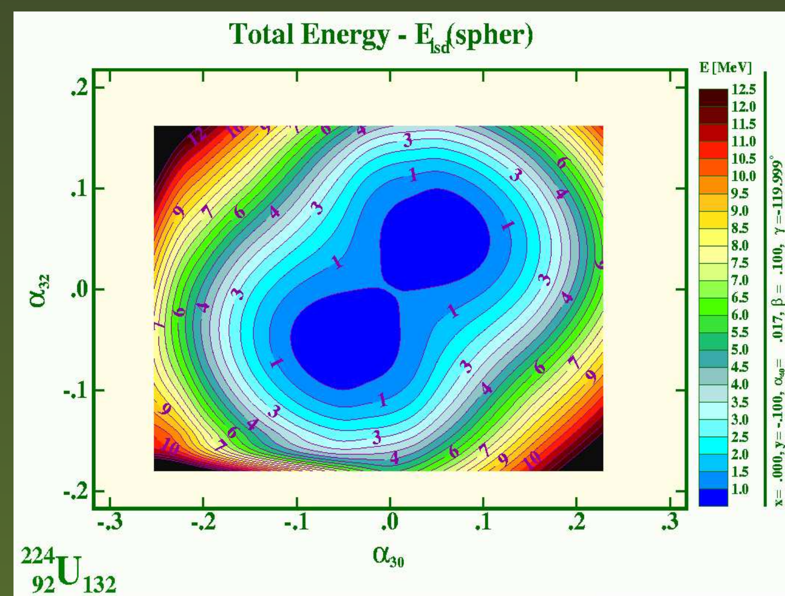



# Examples of Octupole Correlations

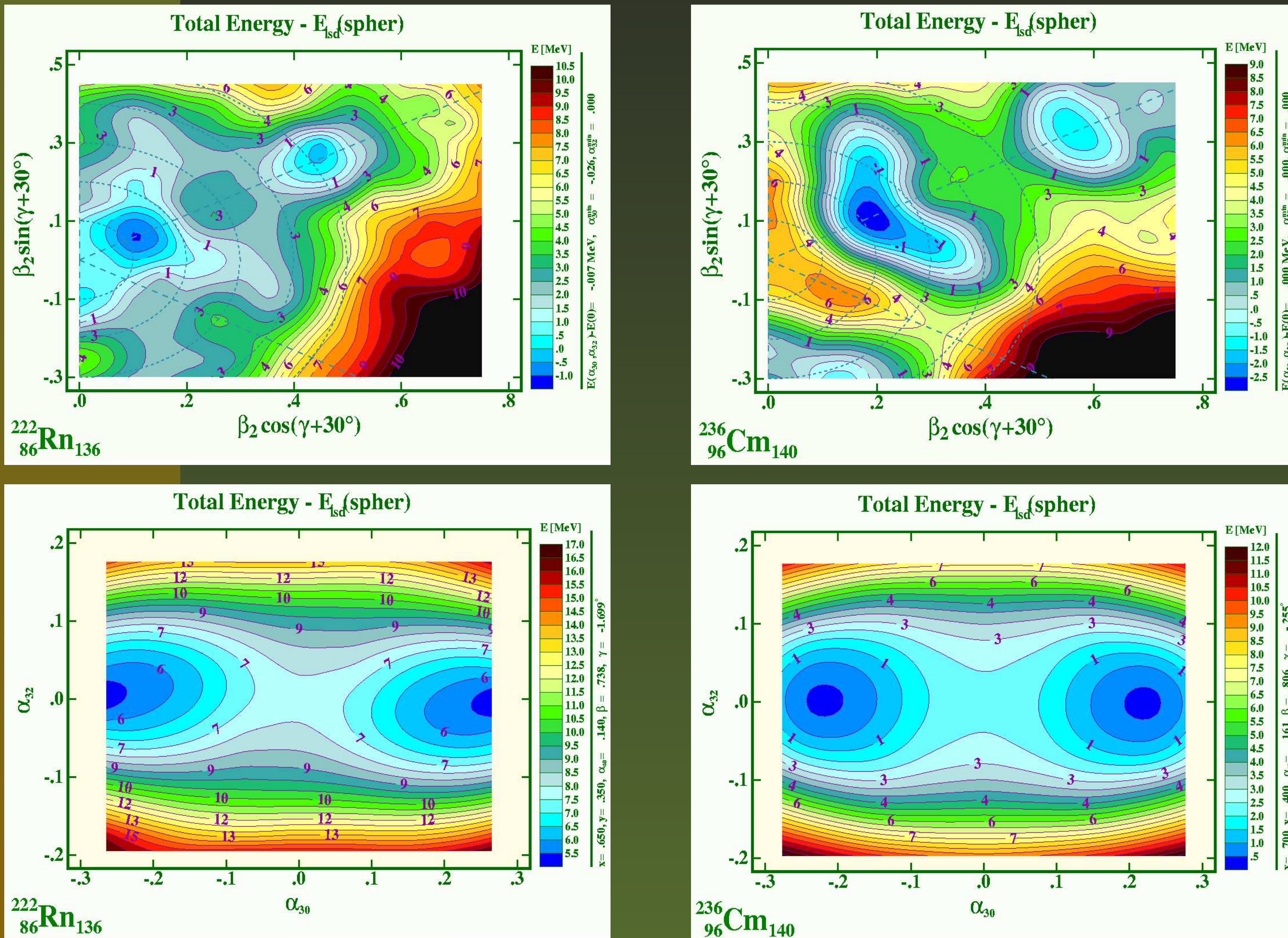


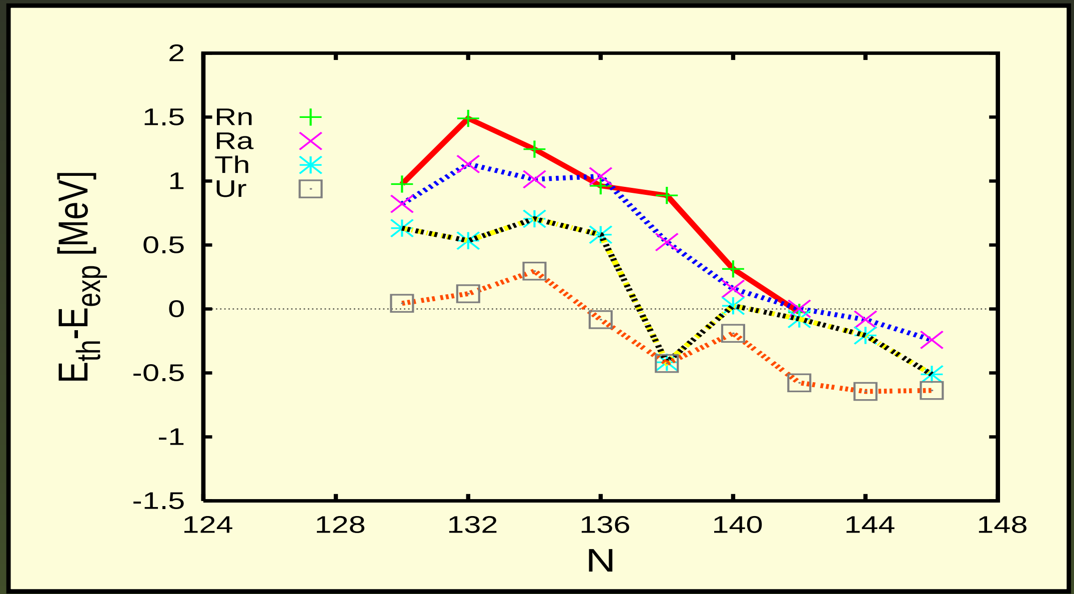



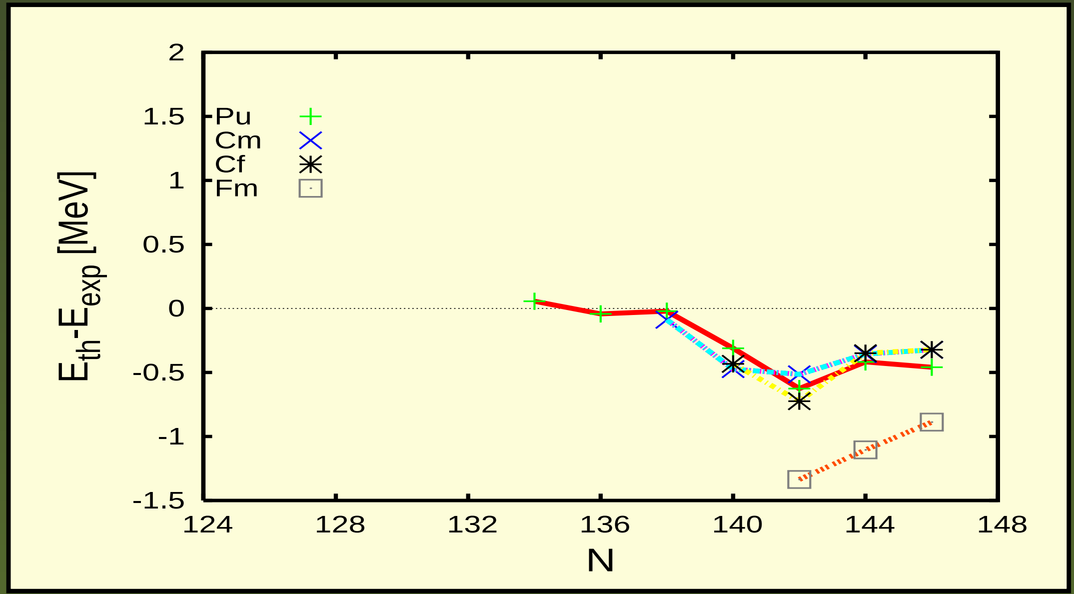



# Very Large Deformations, Superdeformation ...

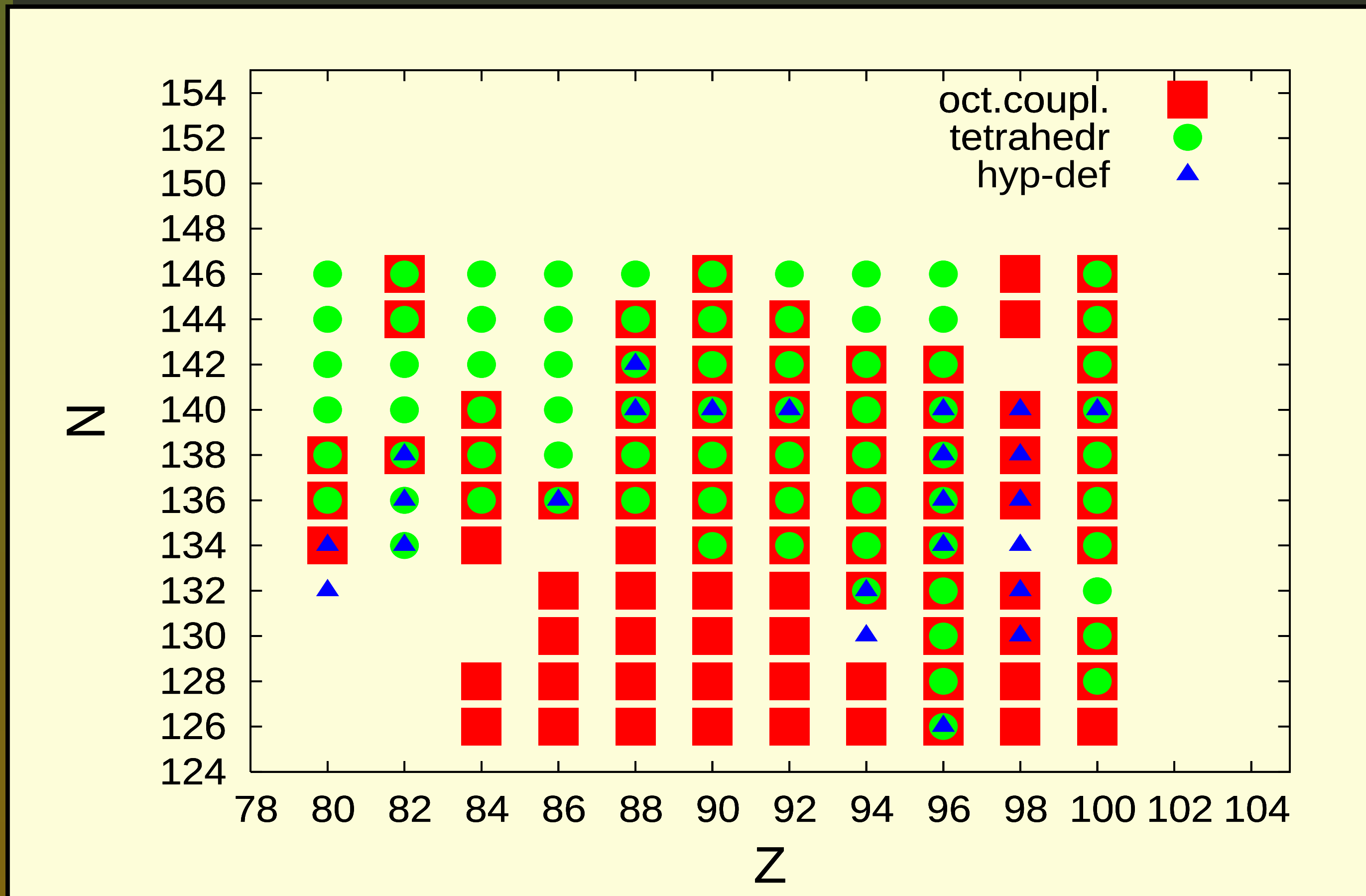


# Binding Energies



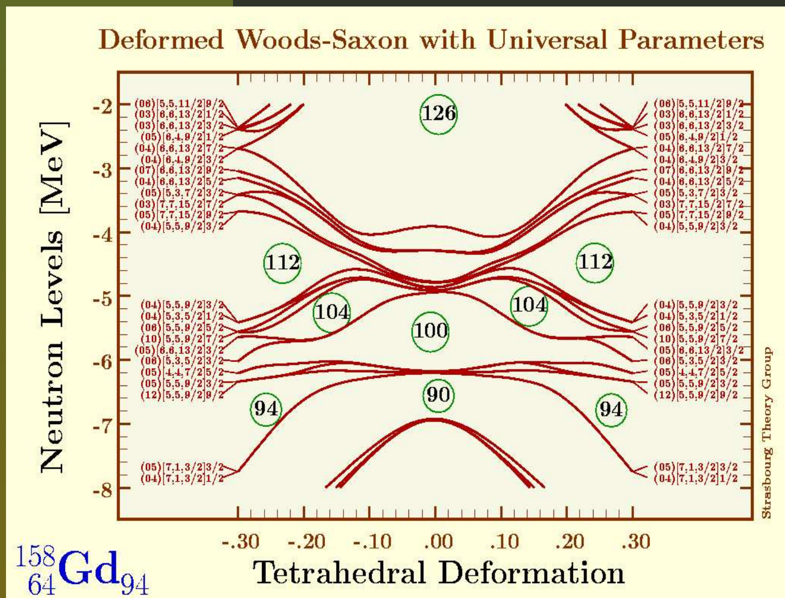



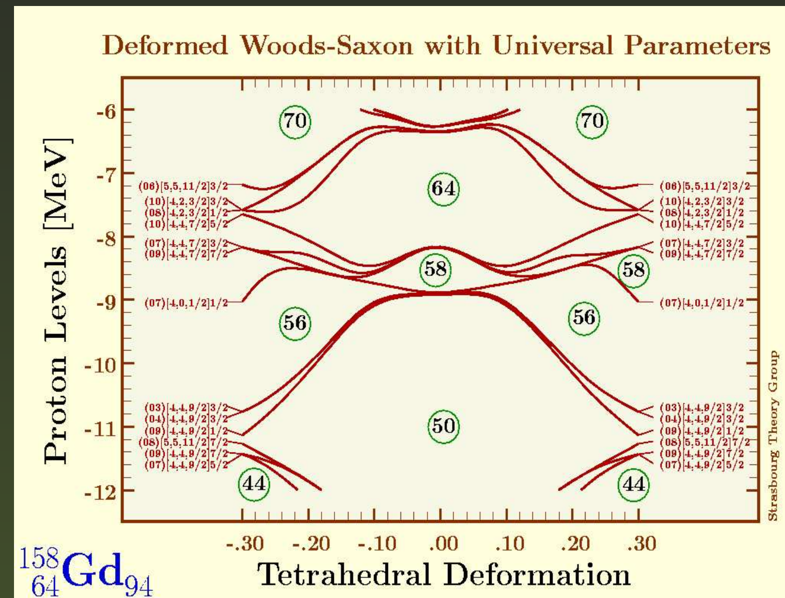
# Summary I

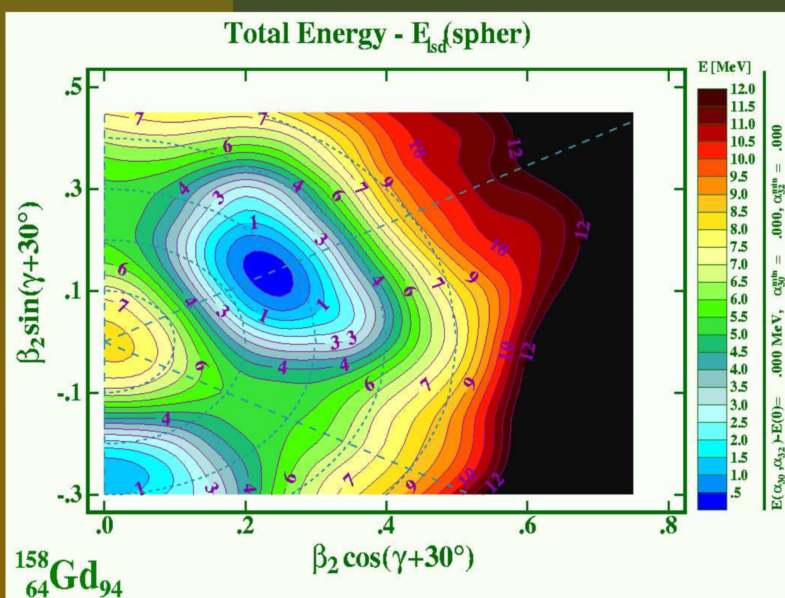


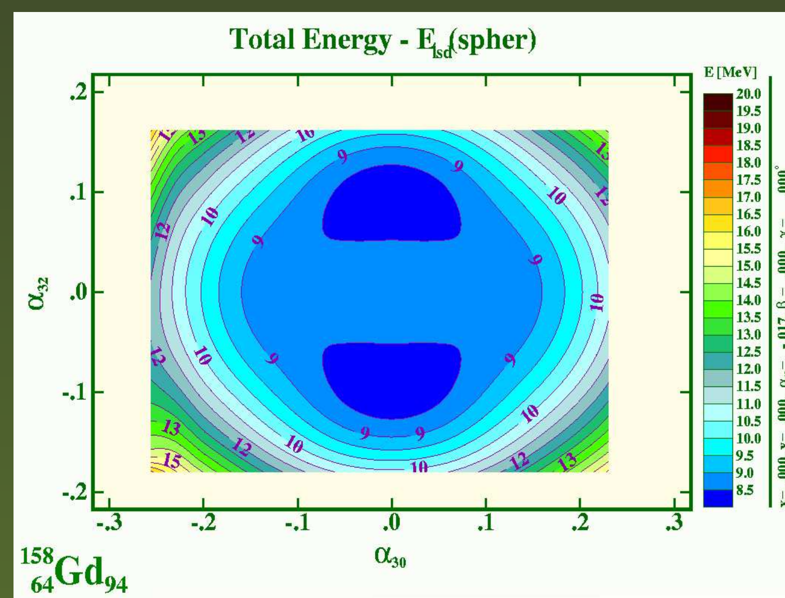
oct.coupl.
tetrahedr
hyp-def
154
152
150
148
146
144
142
140
138
136
134
132
130
128
126
124
N
78 80 82 84 86 88 90 92 94 96 98 100 102 104
Z

# Ytterbium Region

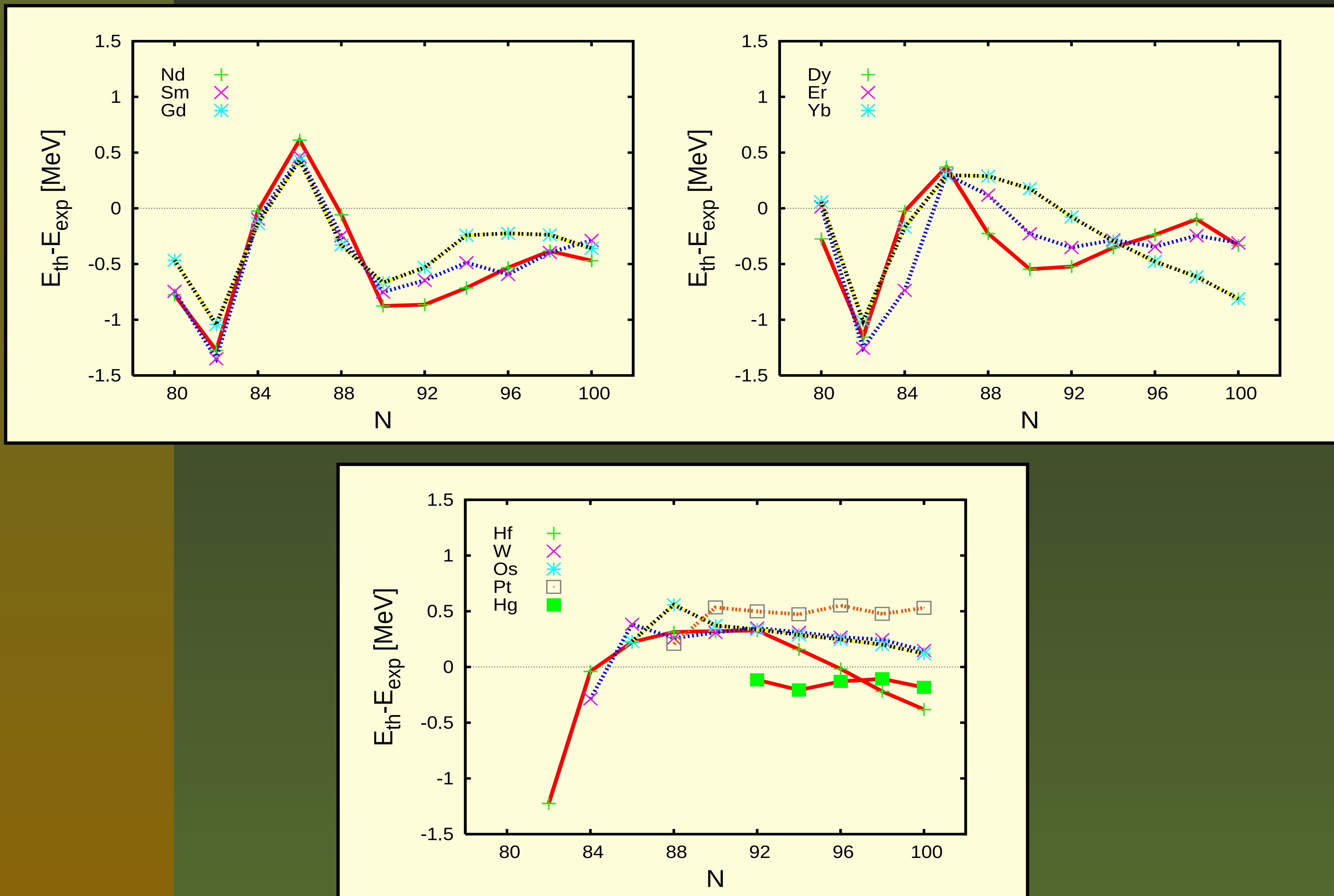


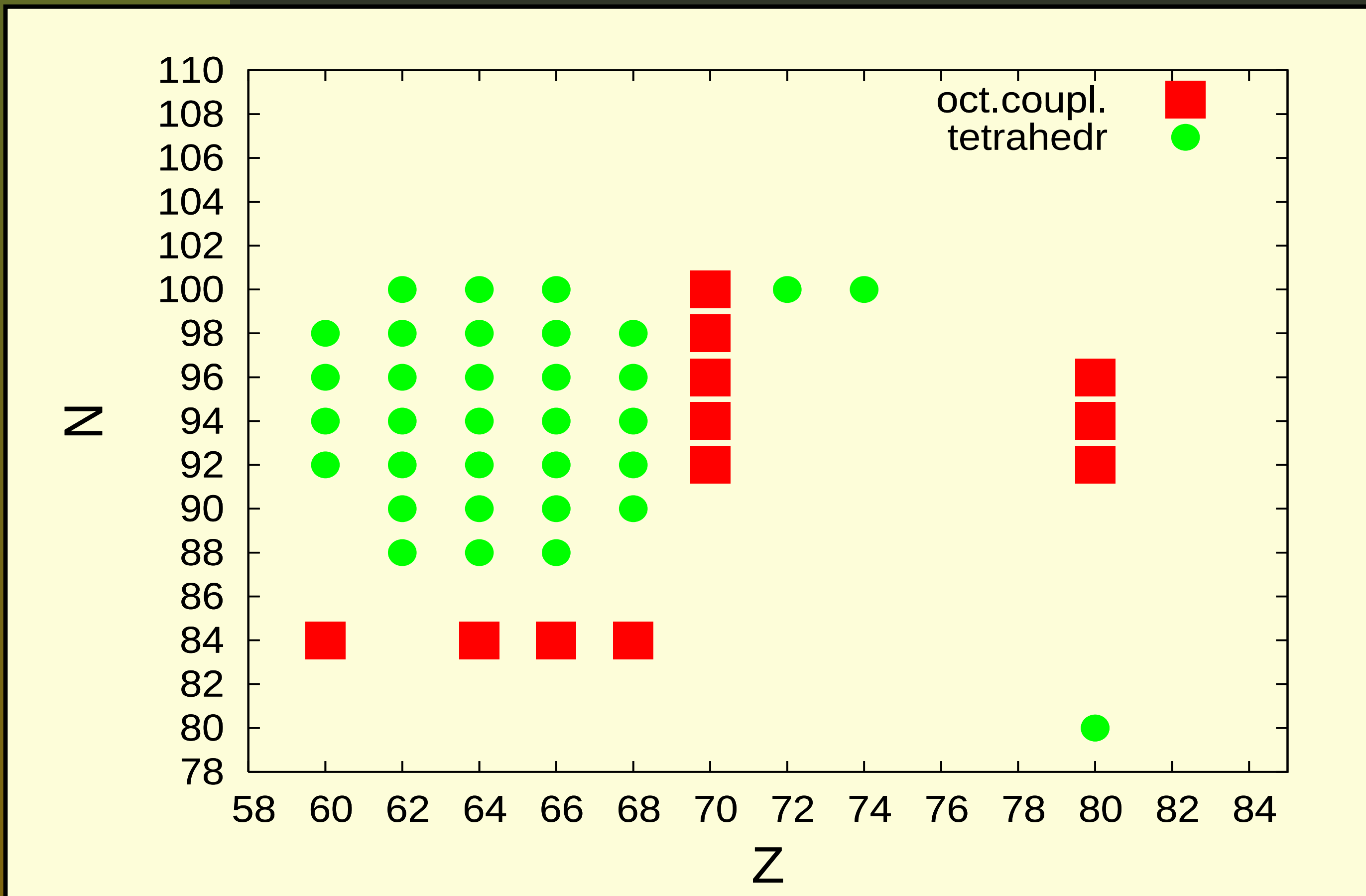



# Ytterbium Region - Binding Energies



# Summary II



oct.coupl.
tetrahedr
N
Z
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
78
58 60 62 64 66 68 70 72 74 76 78 80 82 84

# Conclusions

- The single particle gaps (shell structure) are often very sensitive to $\alpha_{32}$ tetrahedral deformation

# Conclusions

- The single particle gaps (shell structure) are often very sensitive to $\alpha_{32}$ tetrahedral deformation
- For Californium and Fermium isotopes calculations show very large deformation minima correlated with extreme values of $\alpha_{30}$ and $\alpha_{40}$ (in agreement with earlier calculations)

# Conclusions

- The single particle gaps (shell structure) are often very sensitive to $\alpha_{32}$ tetrahedral deformation
- For Californium and Fermium isotopes calculations show very large deformation minima correlated with extreme values of $\alpha_{30}$ and $\alpha_{40}$ (in agreement with earlier calculations)
- Non-axial octupole deformations are predicted around saddle points and at tetrahedral minima i.e. $\forall\, \alpha_{\lambda,\mu} = 0$ except for $\alpha_{3,2} \neq .0$

# Conclusions

- The single particle gaps (shell structure) are often very sensitive to $\alpha_{32}$ tetrahedral deformation
- For Californium and Fermium isotopes calculations show very large deformation minima correlated with extreme values of $\alpha_{30}$ and $\alpha_{40}$ (in agreement with earlier calculations)
- Non-axial octupole deformations are predicted around saddle points and at tetrahedral minima i.e. $\forall\, \alpha_{\lambda,\mu} = 0$ except for $\alpha_{3,2} \neq .0$
- The theoretical binding energies for all even-even nuclei with $Z = 60 - 100$, $N = 80 - 142$ are very close to the experimental ones. The maximum deviations are around $\pm$ 1 MeV