Theoretical prediction of effective GDR width at high spins from the thermal shape fluctuation model

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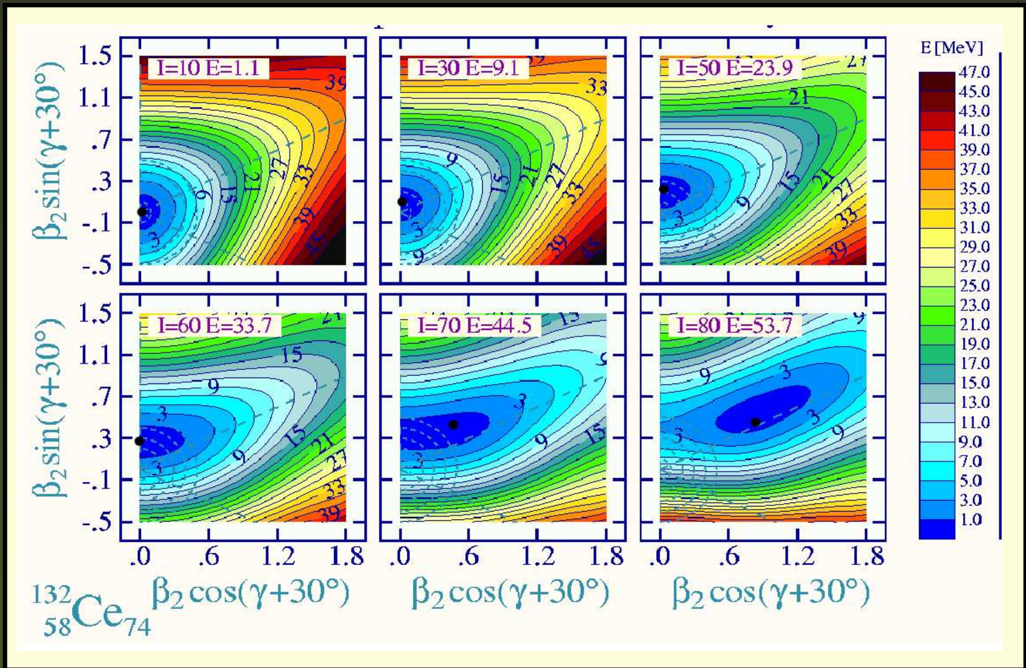
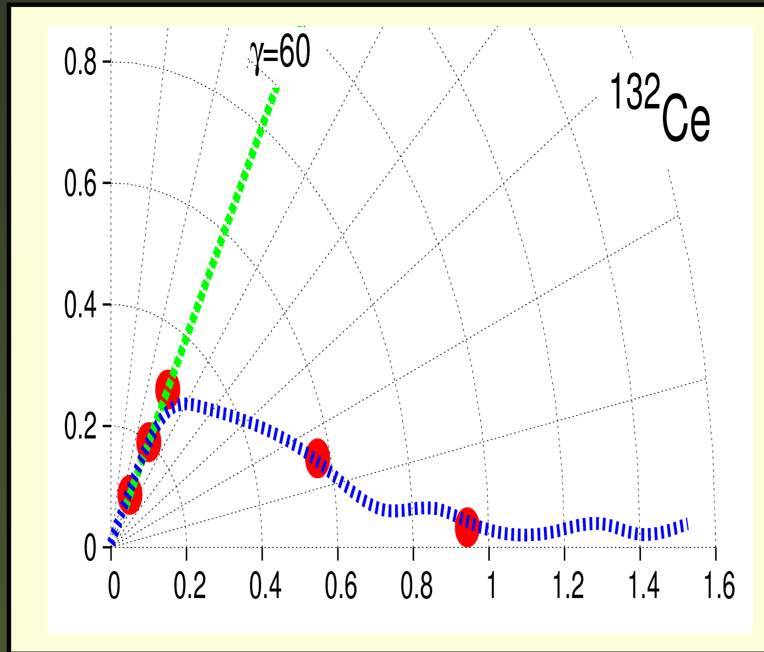
Macroscopic Energy: Lublin-Strasbourg Drop

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)



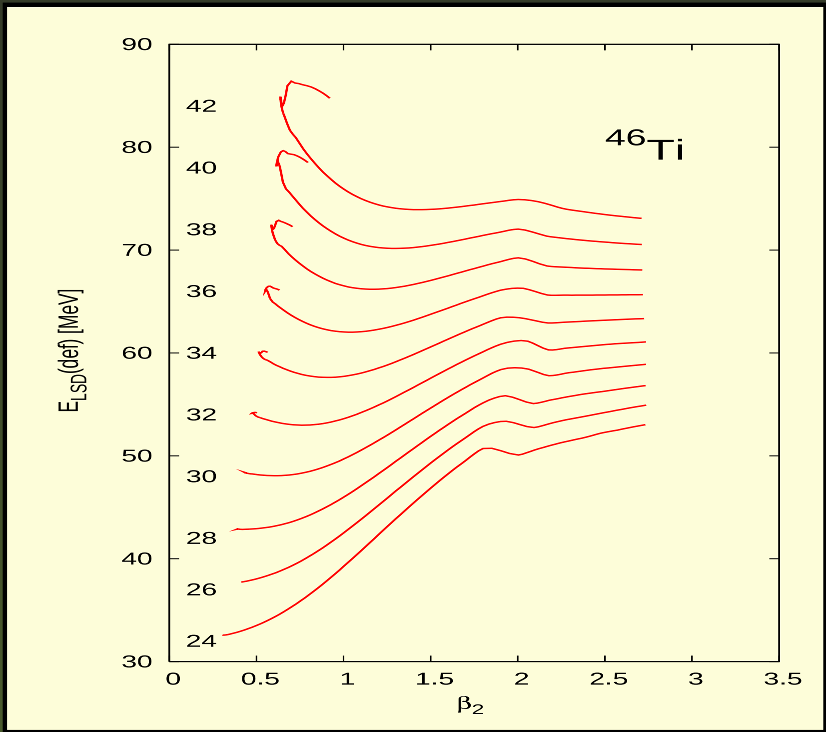


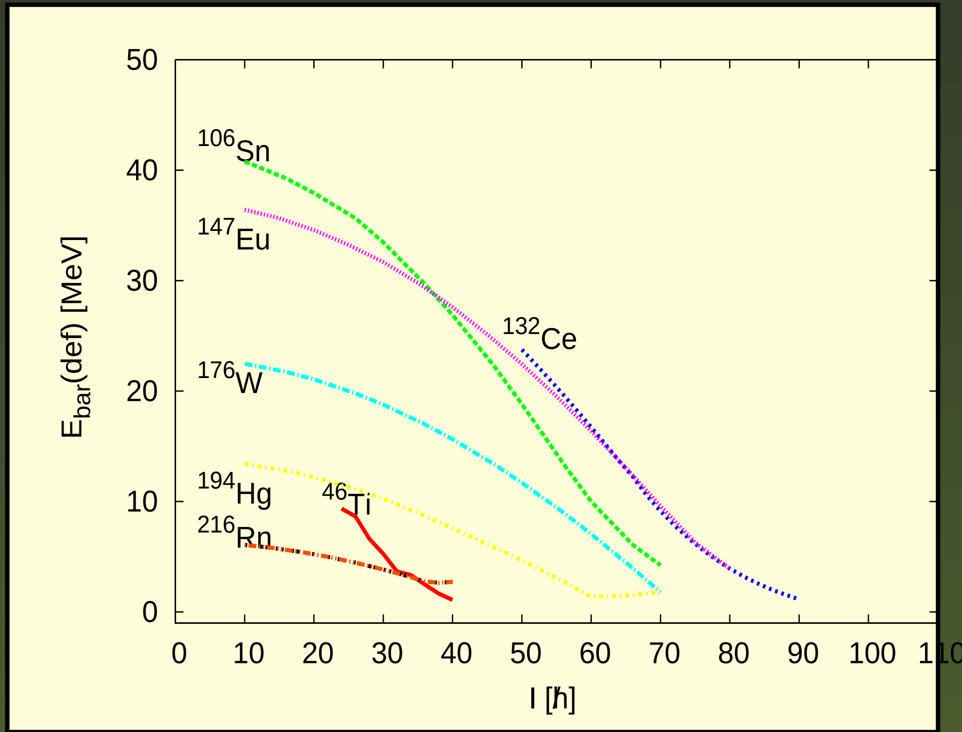
$$E_{LSD} = -b_{vol}(1-\kappa_{vol}t^2)A + b_{surf}(1-\kappa_{surf}t^2)A^{2/3}B_{surf}(def)$$

$$+b_{curv}(1+\kappa_{curv}t^2)A^{1/3}B_{curv}(def) + \frac{3}{5}e^2\frac{Z^2}{r_0^{ch}A^{1/3}}B_{Coul}(def)$$

$$-C_4\frac{Z^2}{A} - 10\cdot\exp\left(-4.2|t|\right)$$

Fission barriers for different spins





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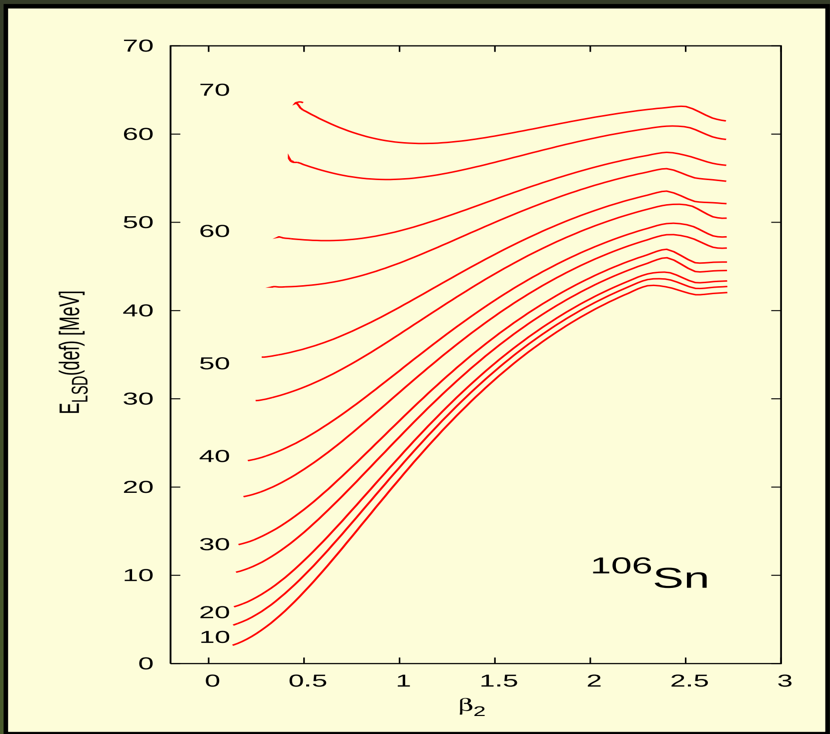
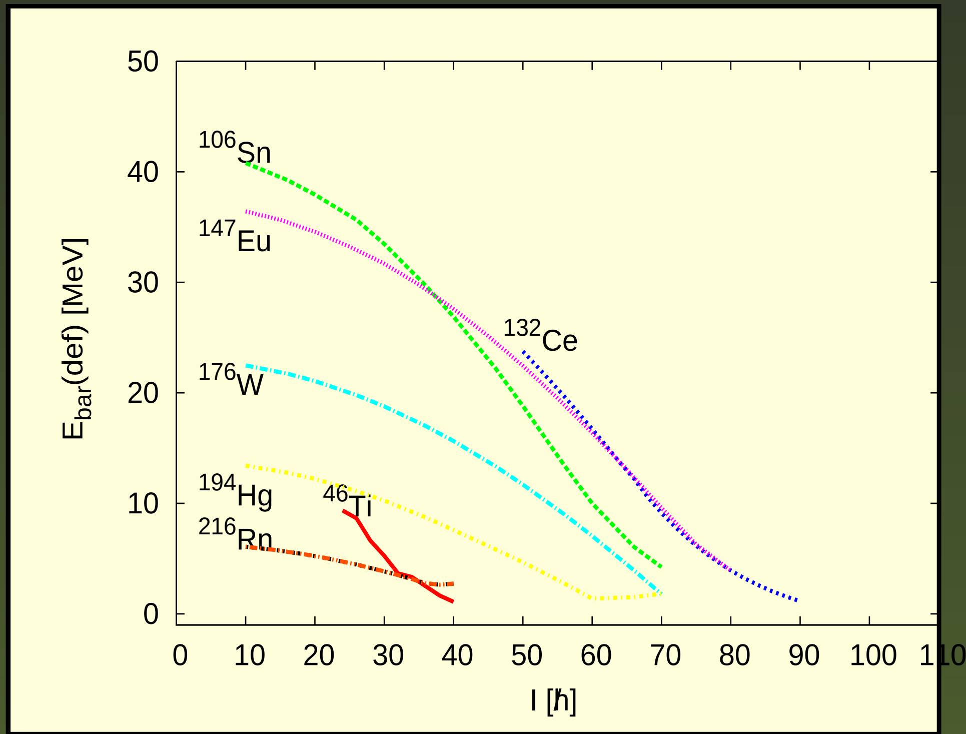
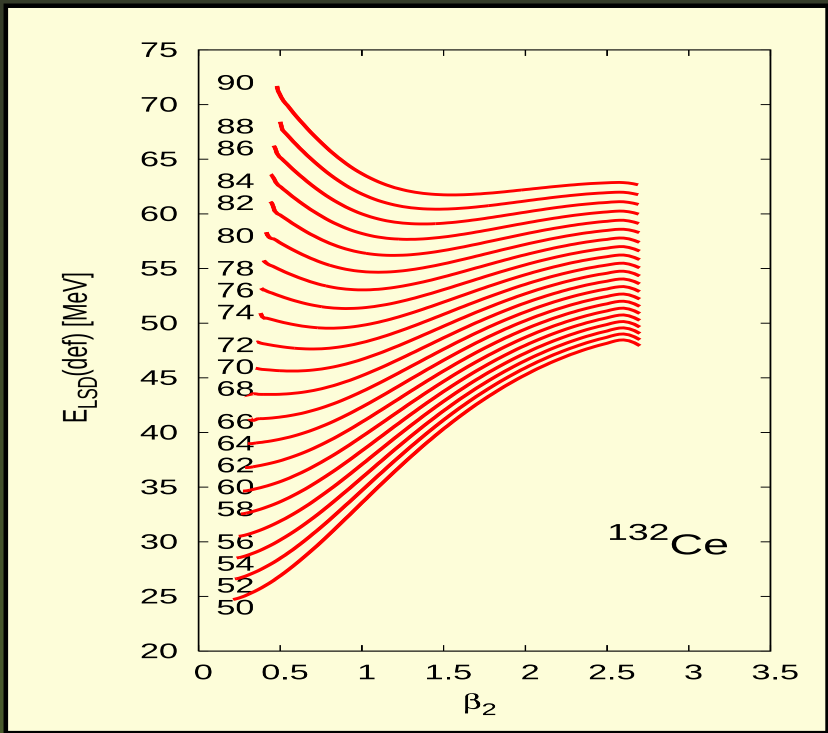
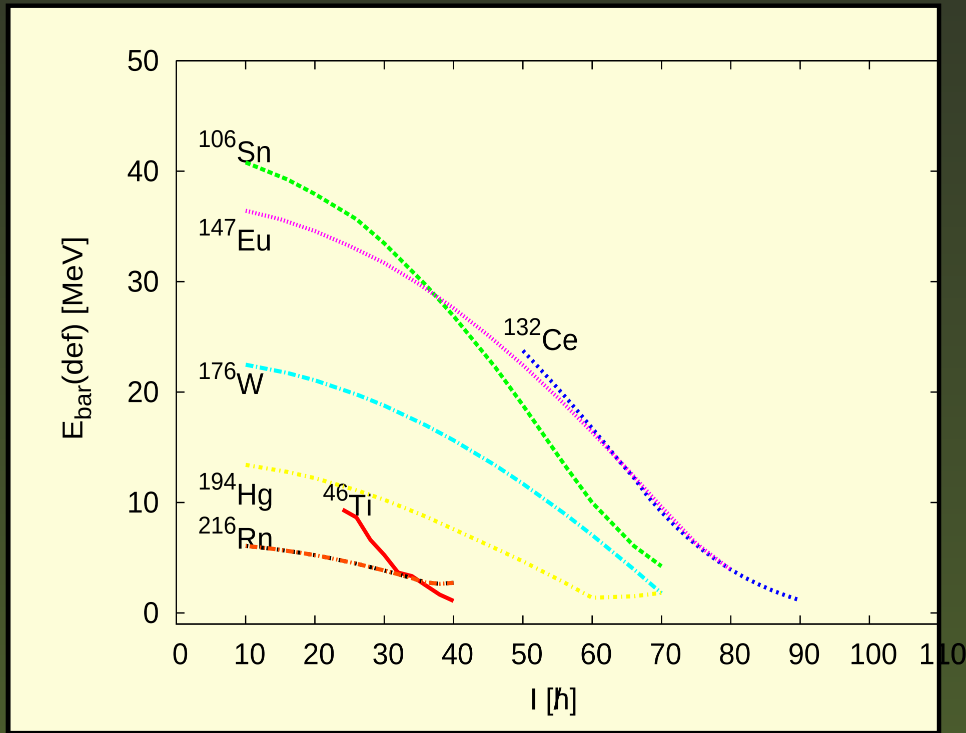


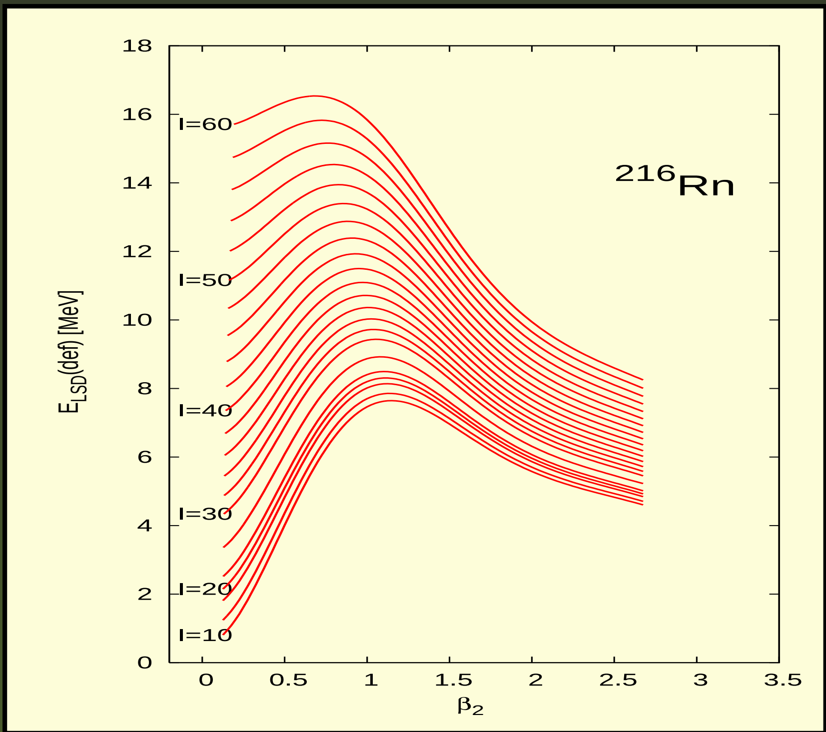


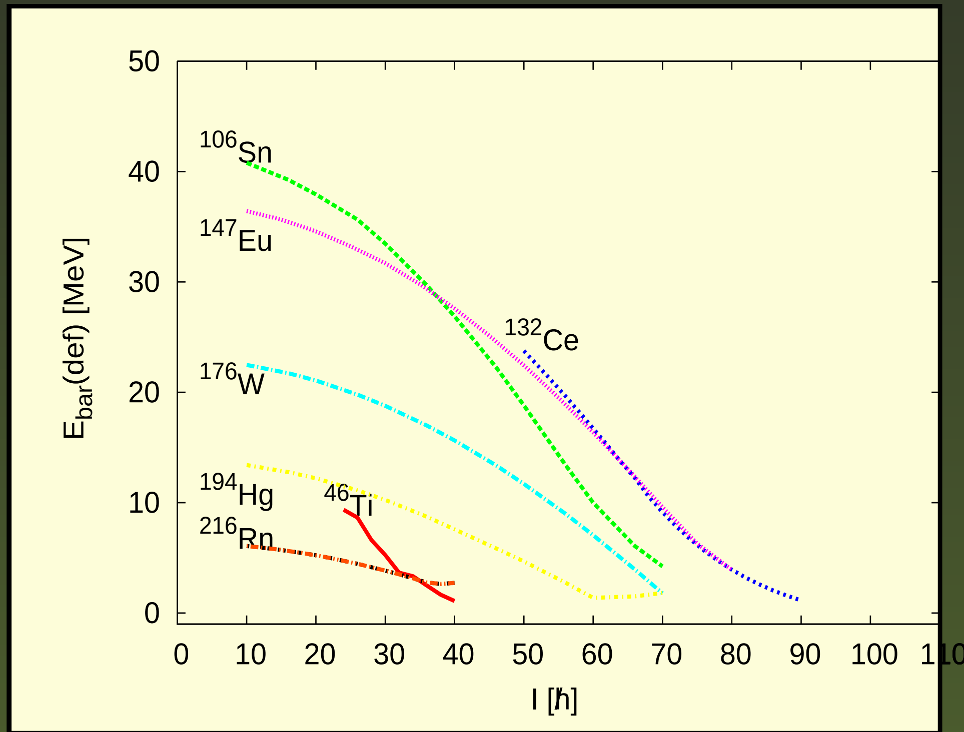
Fission barriers for different spins



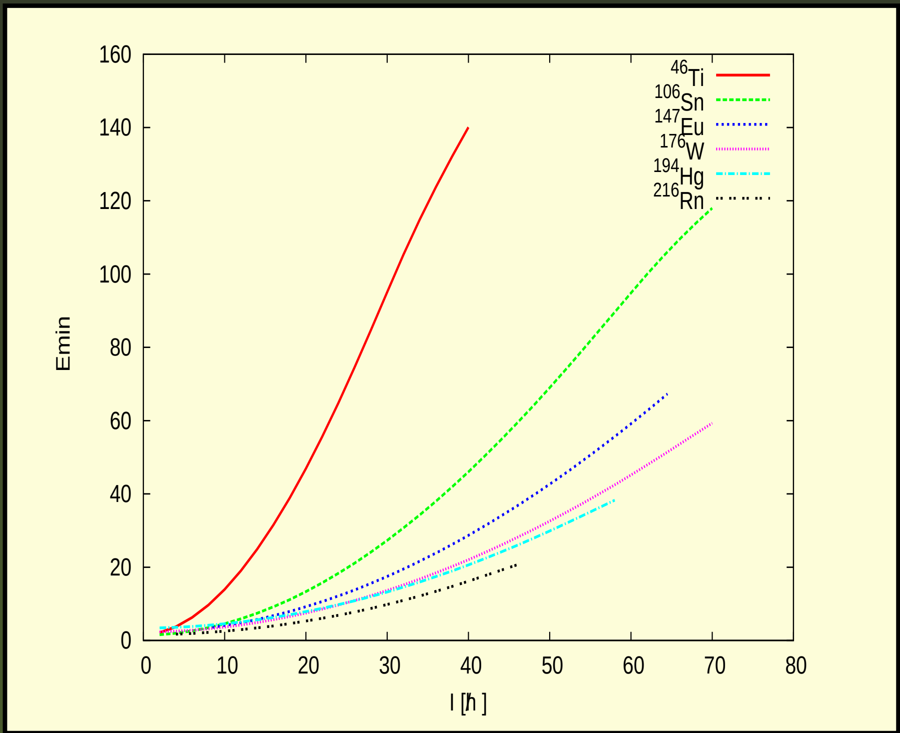


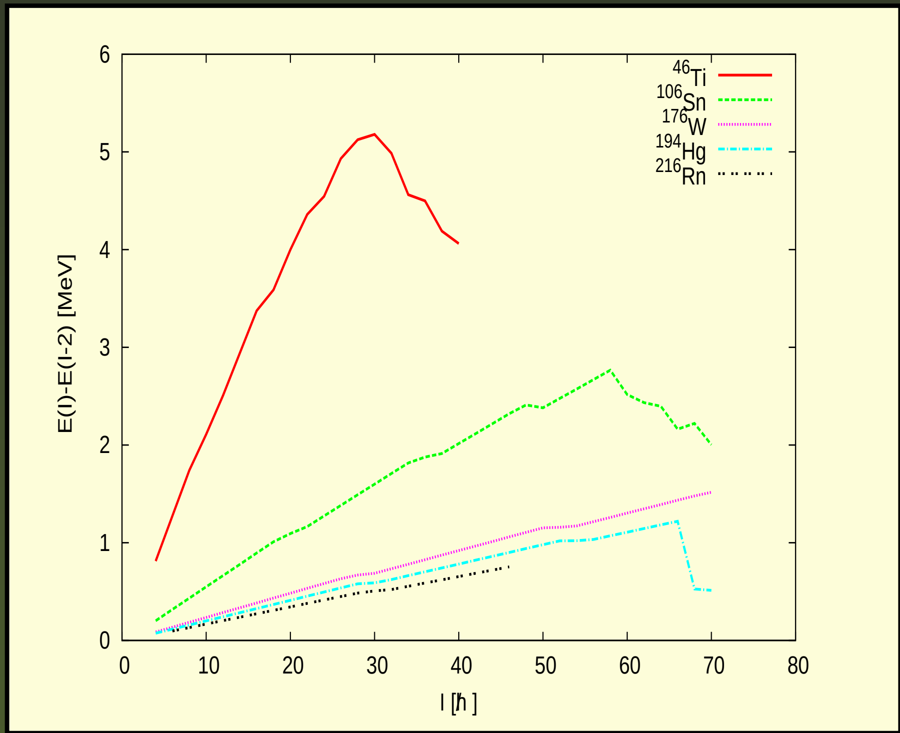
Fission barriers for different spins



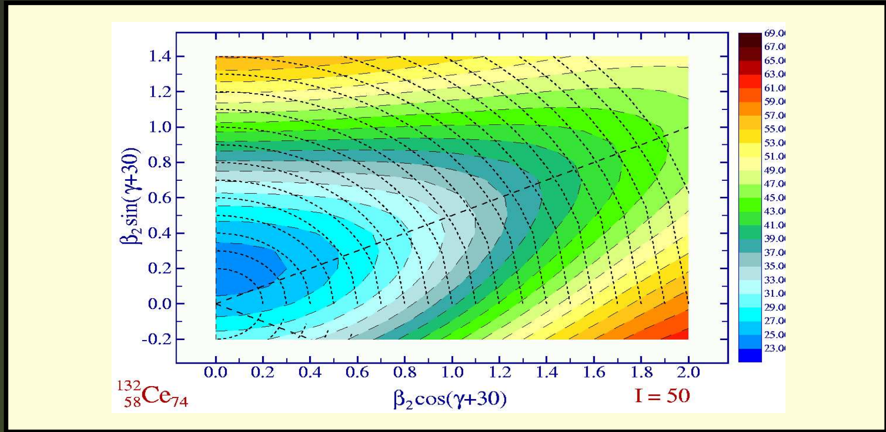


Effect of Giant Backbending



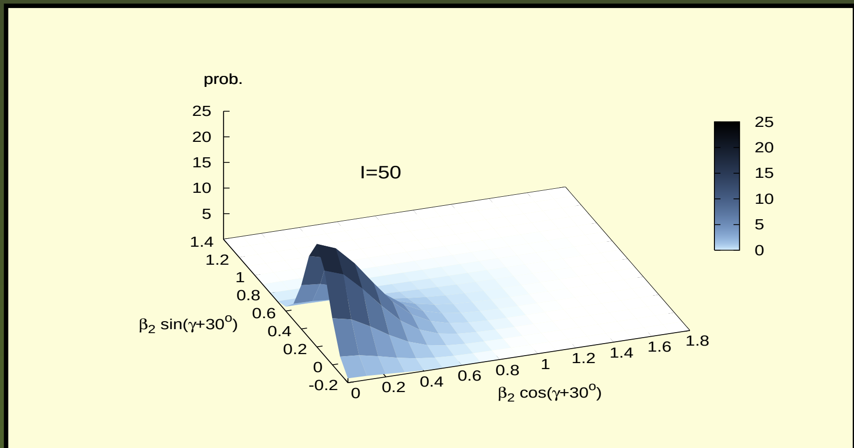


Probability of Nuclear Shape

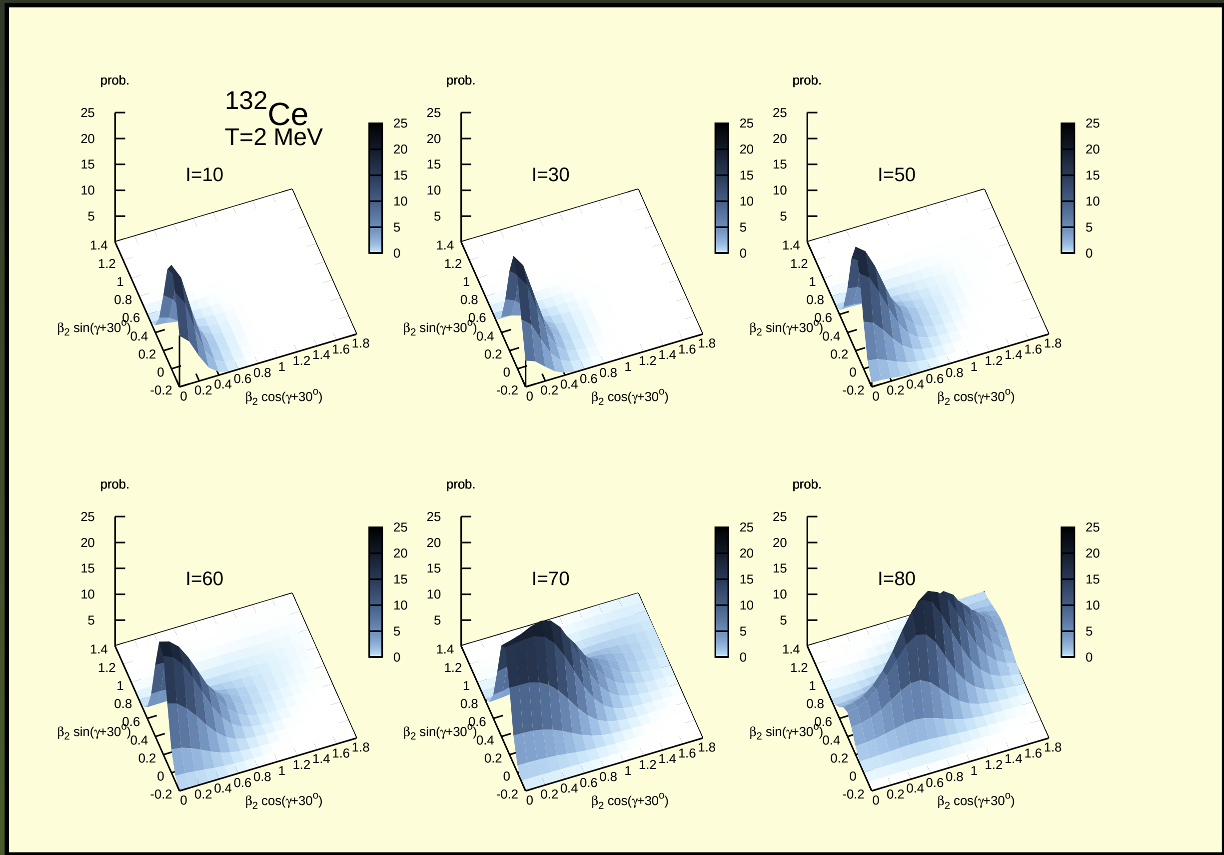


$$P(I;T) \sim exp\{-F(T)/kT\}$$

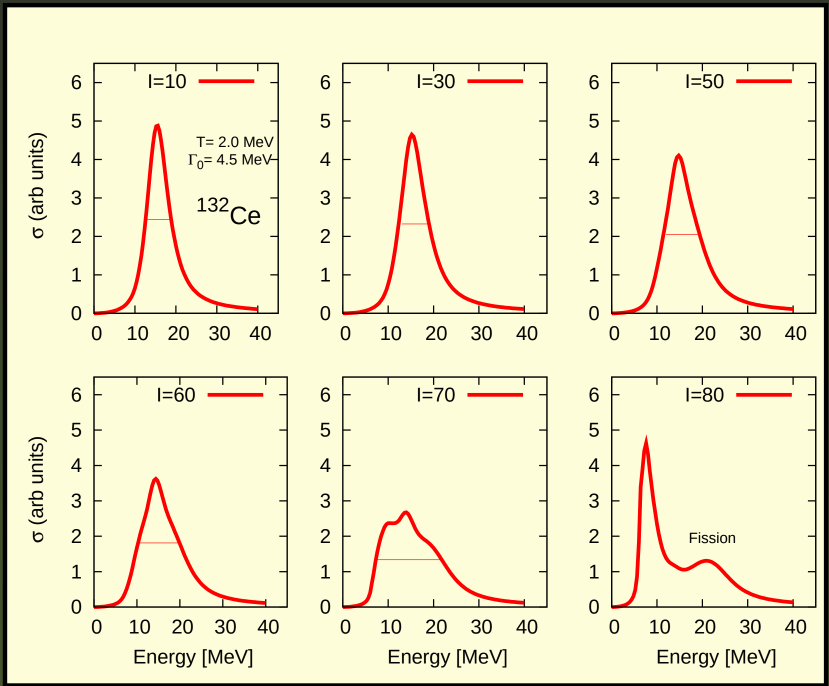
$$F(T) = E_{LSD}(I) - T(I)S(I,T)$$

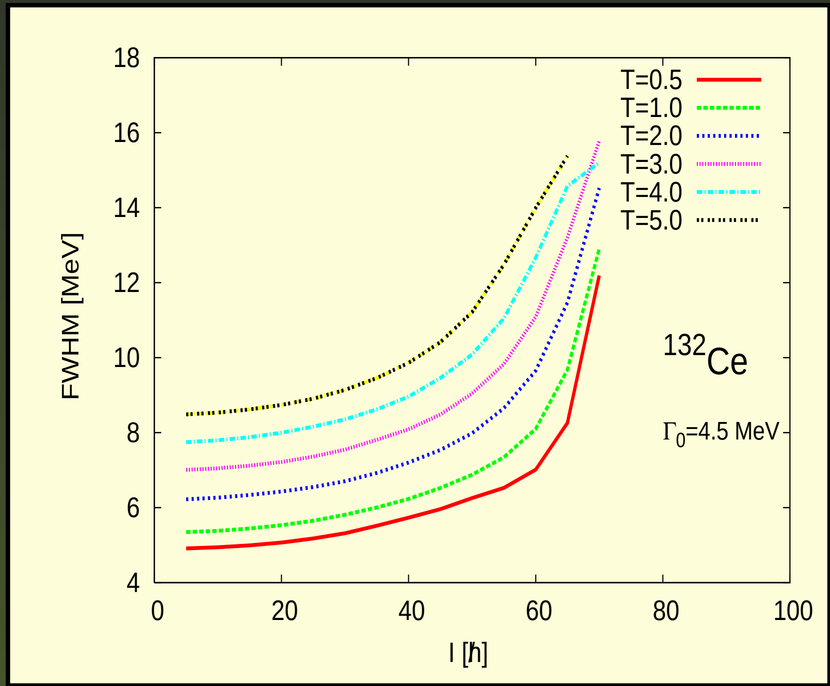


Probability of Nuclear Shape



Effective GDR Shapes



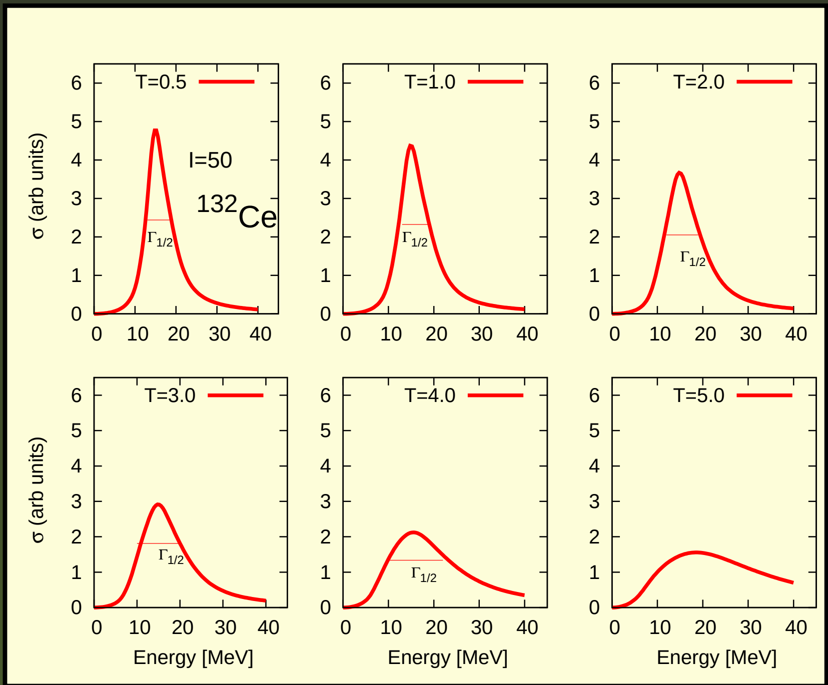


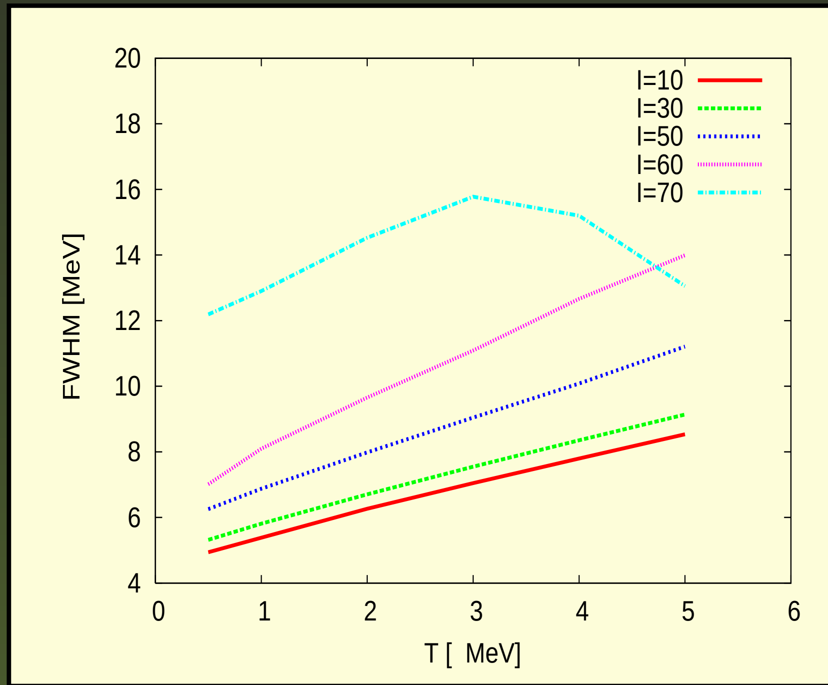
$$\sigma(E_\gamma, T, I) = \sum_{(x,y)} p(I;T) \sum_{k=1}^{5} f_k(E_\gamma)$$

$$f_k(E_\gamma) = \frac{\sigma_k \Gamma_k E_\gamma^2}{(E_\gamma^2 - E_{GDR,k}^2)^2 + E_\gamma^2 \Gamma_k^2} \quad ; \quad \Gamma_k = \left(\frac{E_{GDR,k}}{E_{GDR}}\right)^{1.9} \cdot \Gamma_0$$

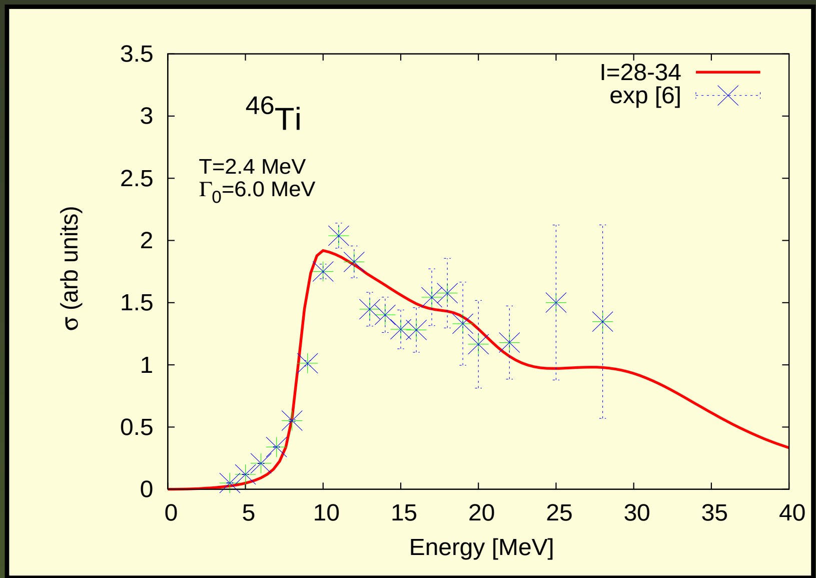
Effective GDR Shapes

Influence of temperature at spin I=50$\hbar$

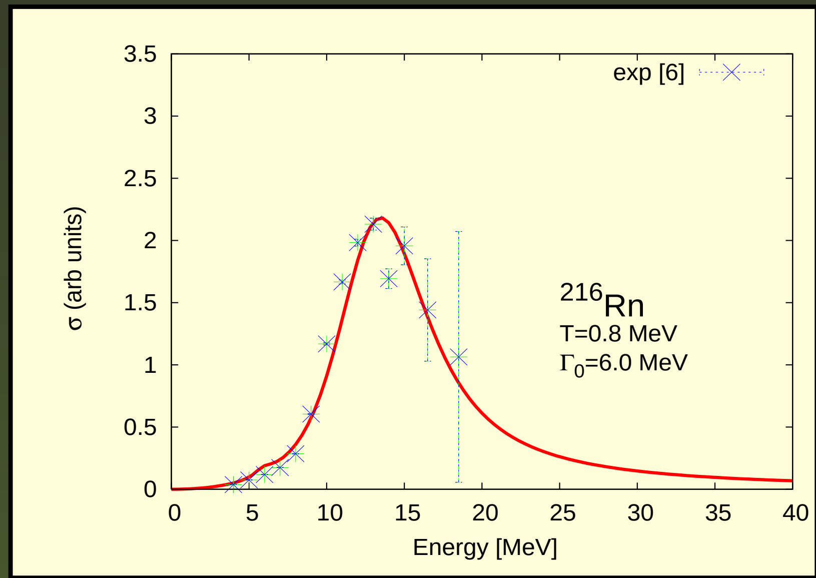




Comparison with Experimental GDR Spectra

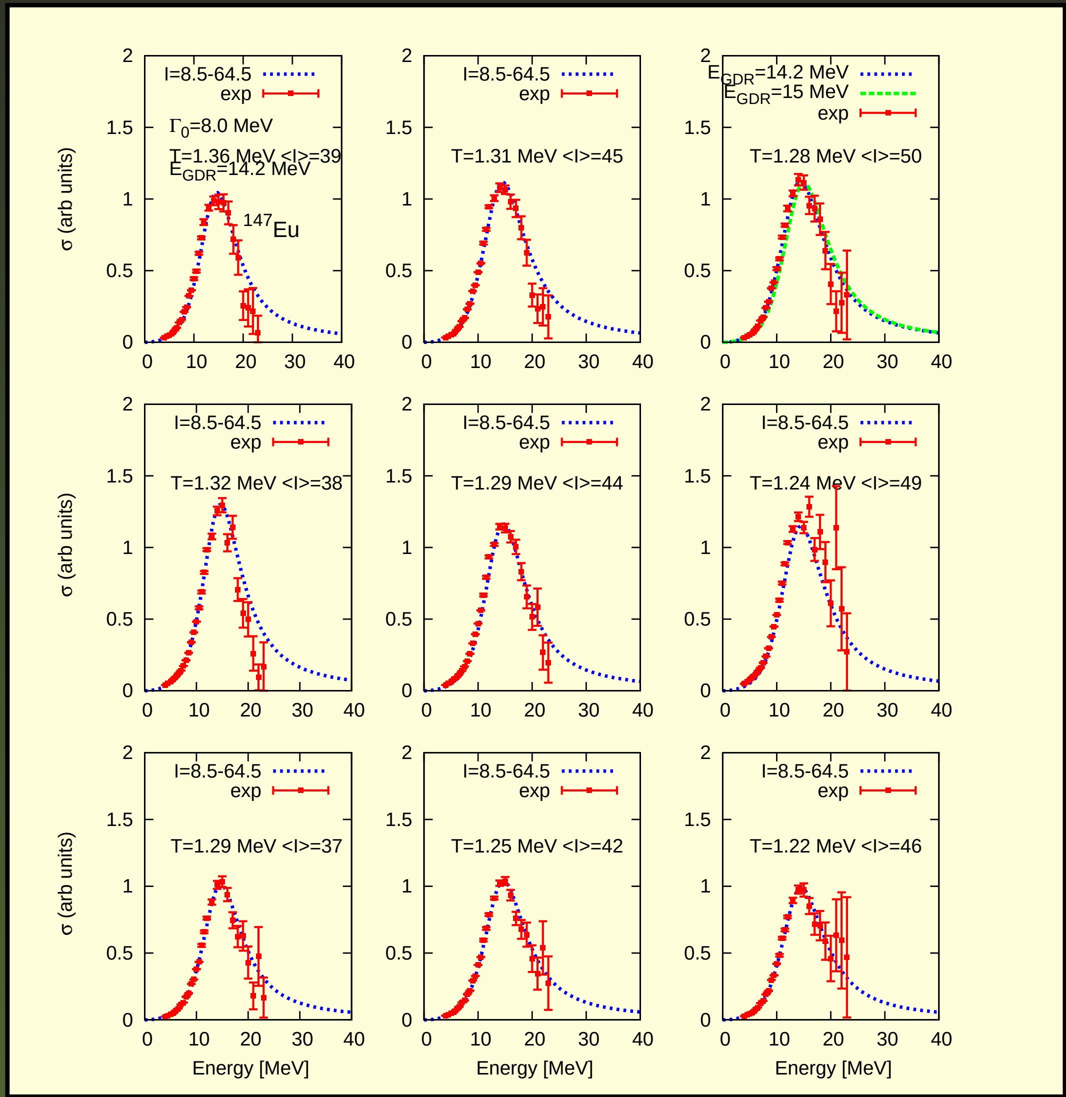


A. Maj et al., Nucl. Phys. **A 731**, 319 (2004)



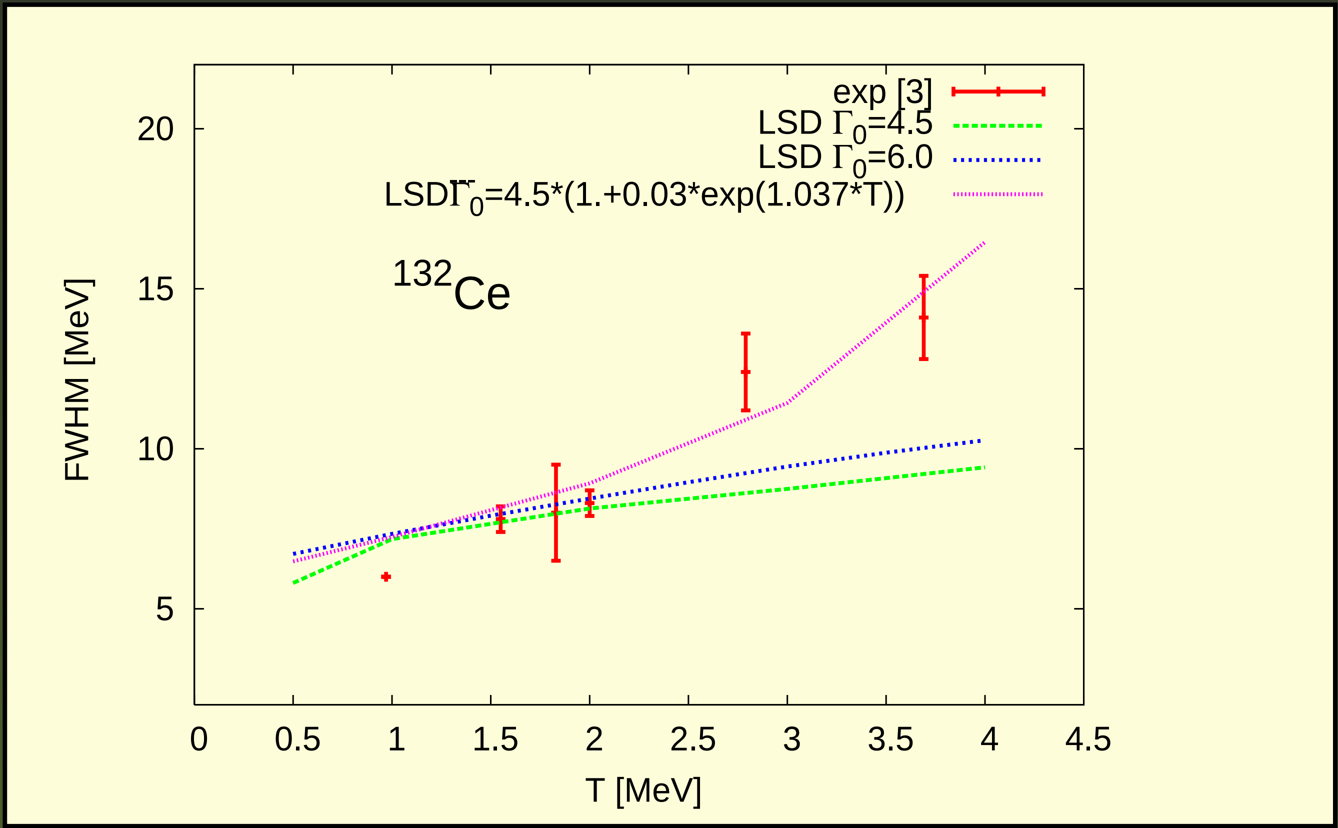
M. Kmiecik et al., Phys. Rev. **C 70**, 064317 (2004)

Effective GDR Shapes at High Spins and Temperatures from the LSD Model



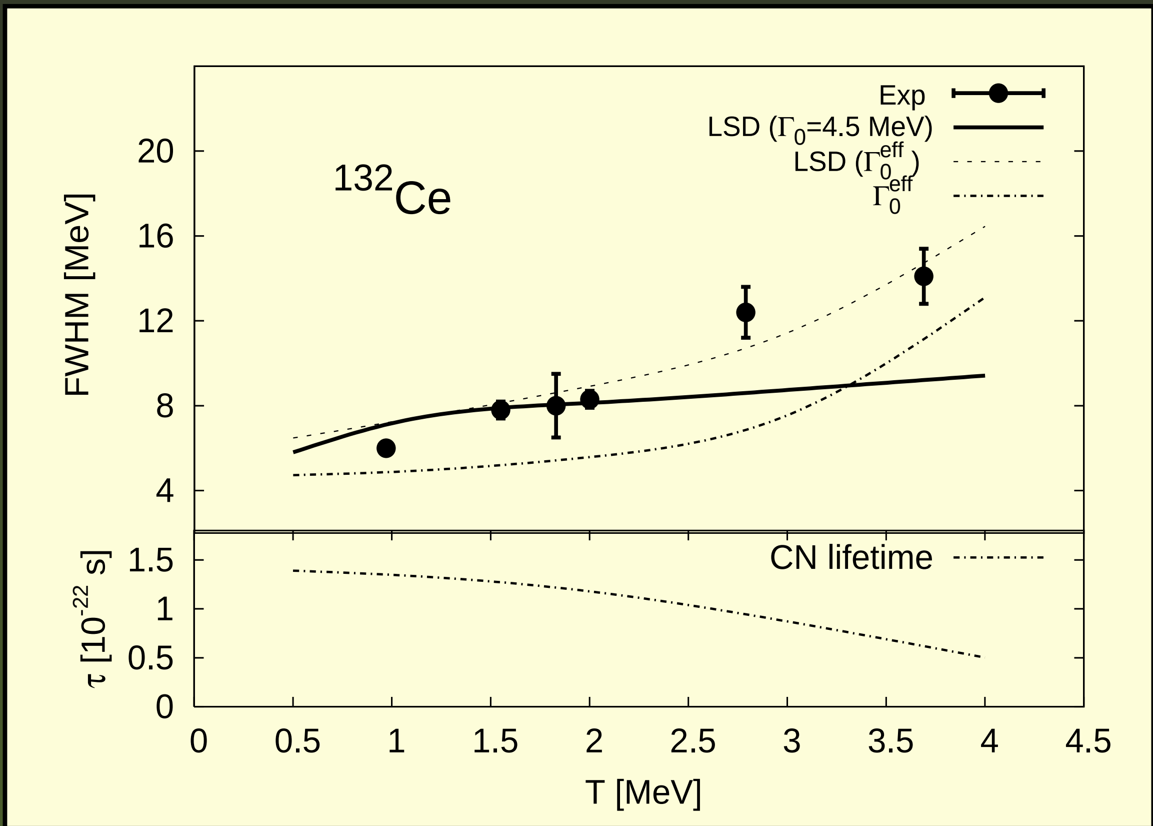
M. Kmiecik et al., Nucl. Phys. **A 674**, 29 (2000)

Comparison with Experimental GDR Spectra



O. Wieland et al., Phys. Rev. Lett. 97,012501 (2006)

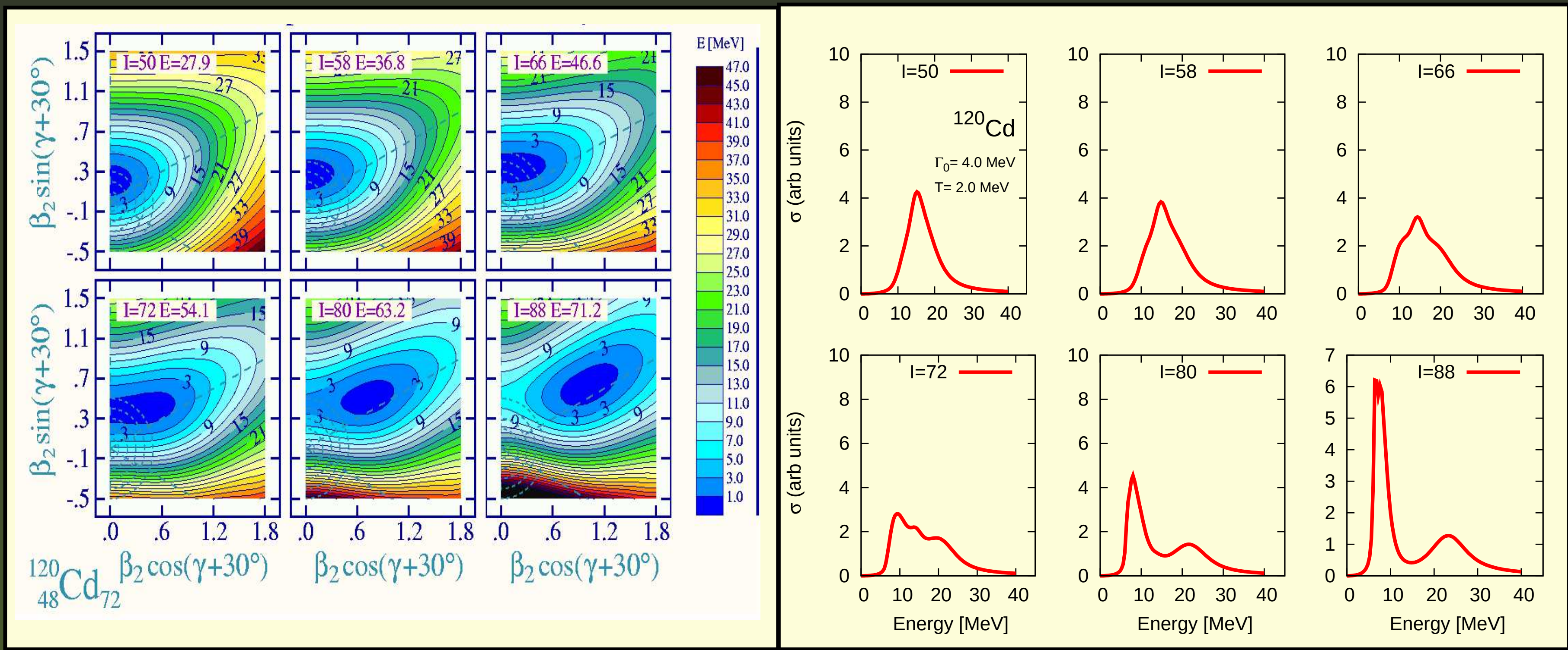
Comparison with Experimental GDR Spectra



$$\bar{\Gamma_0} = \Gamma_0(gs) + \Delta\Gamma_0(T_{CN})$$

$$\Delta\Gamma_0(T_{CN}) \sim e^{\sqrt{E^\star}} \sim e^{\sqrt{aT^2}} = 4.5(1 + 0.03exp\{1.037T\})$$

Effective GDR Shapes at High Spins and Temperatures from the LSD Model



Nuclear level density

1. The most frequent used is formula: $a = \frac{A}{n} \quad n = 8, 9, 10 \ldots$
2. $a_{ign} = c_{vol}\mathrm{A} + c_{surf}\mathrm{A}^{2/3}B_{surf}(def) + c_{curv}\mathrm{A}^{1/3}B_{curv}(def)$
   $+c_{coul}\frac{\mathrm{Z}^2}{r_0^{ch}\mathrm{A}^{1/3}}B_{Coul}(def)$

a) Ignatyuk et al., Yad. Fiz. 21 (1975) 1185 [Sov. J. Nucl. Phys. 21 (1975) 612]

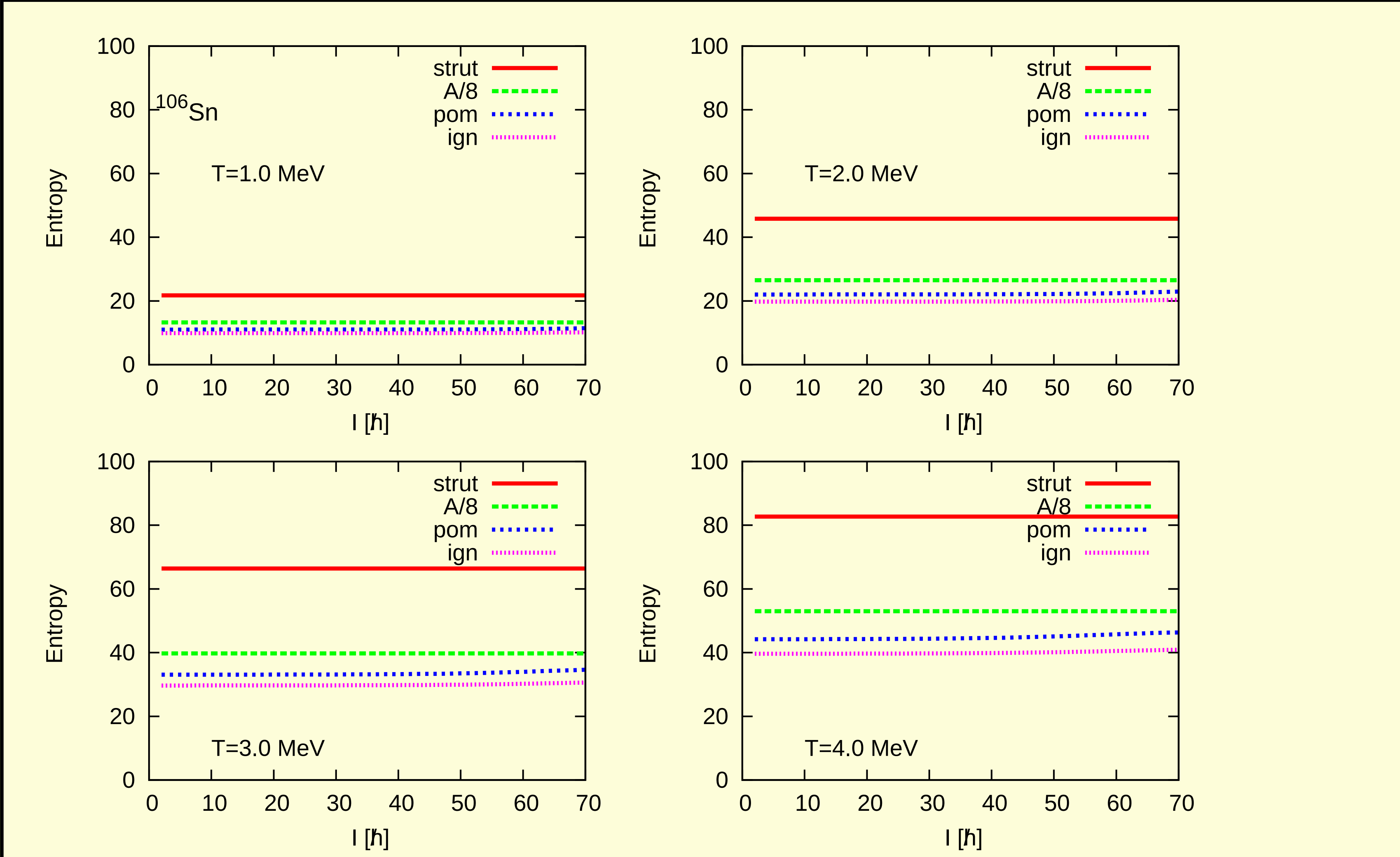
$b_{vol} = 0.073\ \mathrm{MeV}^{-1}, b_{surf} = 0.095\ \mathrm{MeV}^{-1},$
$b_{curv} = 0.000\ \mathrm{MeV}^{-1}, b_{coul} = 0.000\ \mathrm{MeV}^{-1},$

b) K.Pomorski, B.Pomorska, J.Bartel, Int. Jour. Mod. Phys. **E 16** (2007) 566)

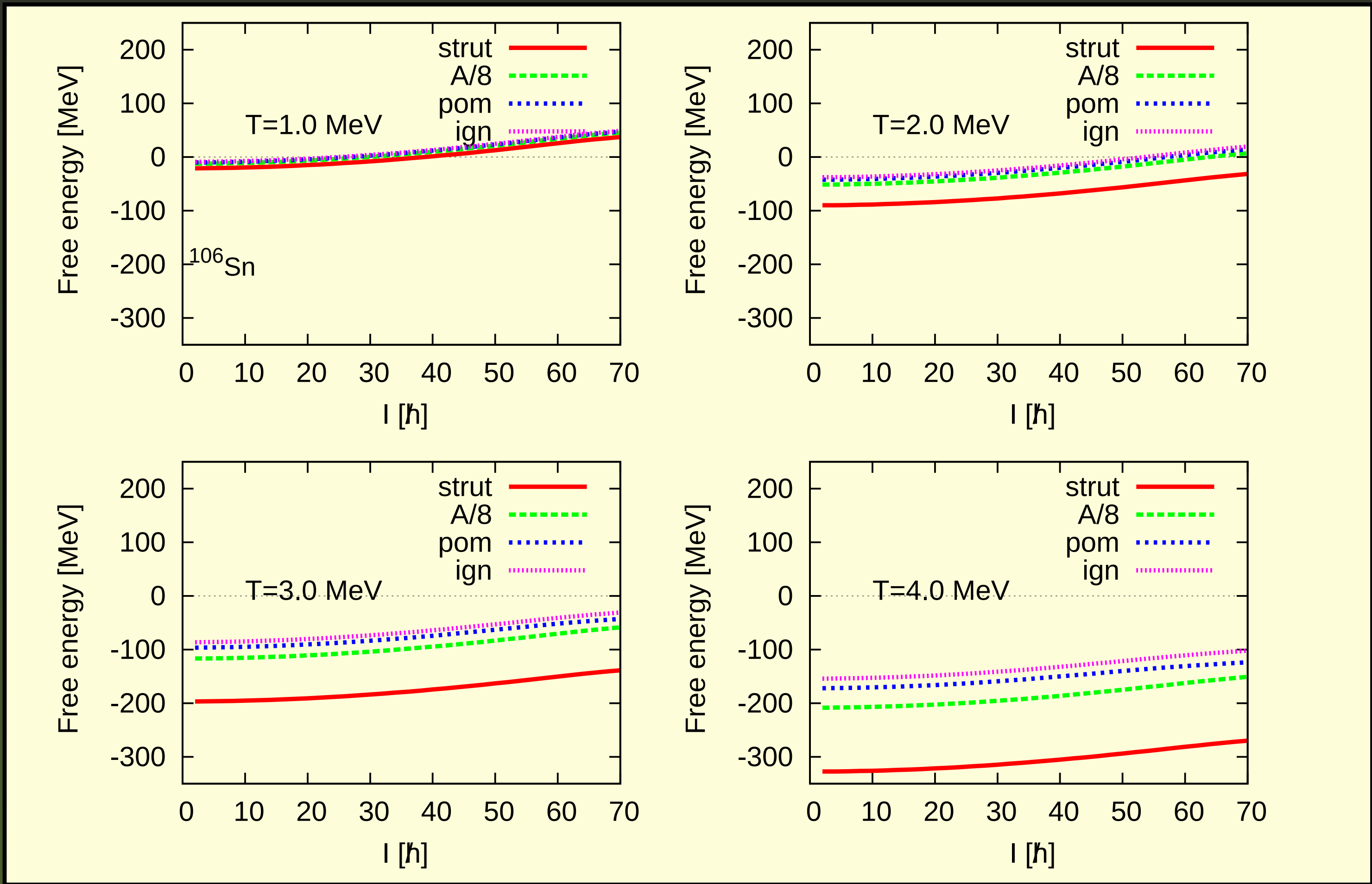
$b_{vol} = 0.090\ \mathrm{MeV}^{-1}, b_{surf} = 0.040\ \mathrm{MeV}^{-1},$
$b_{curv} = 0.280\ \mathrm{MeV}^{-1}, b_{coul} = 0.00146\ \mathrm{MeV}^{-1},$

3. Strutinsky-like level density
   $g(\varepsilon) = \sum_{\nu}^{\infty} \delta(\varepsilon - \varepsilon(\nu))$

The nuclear level densities and entropy

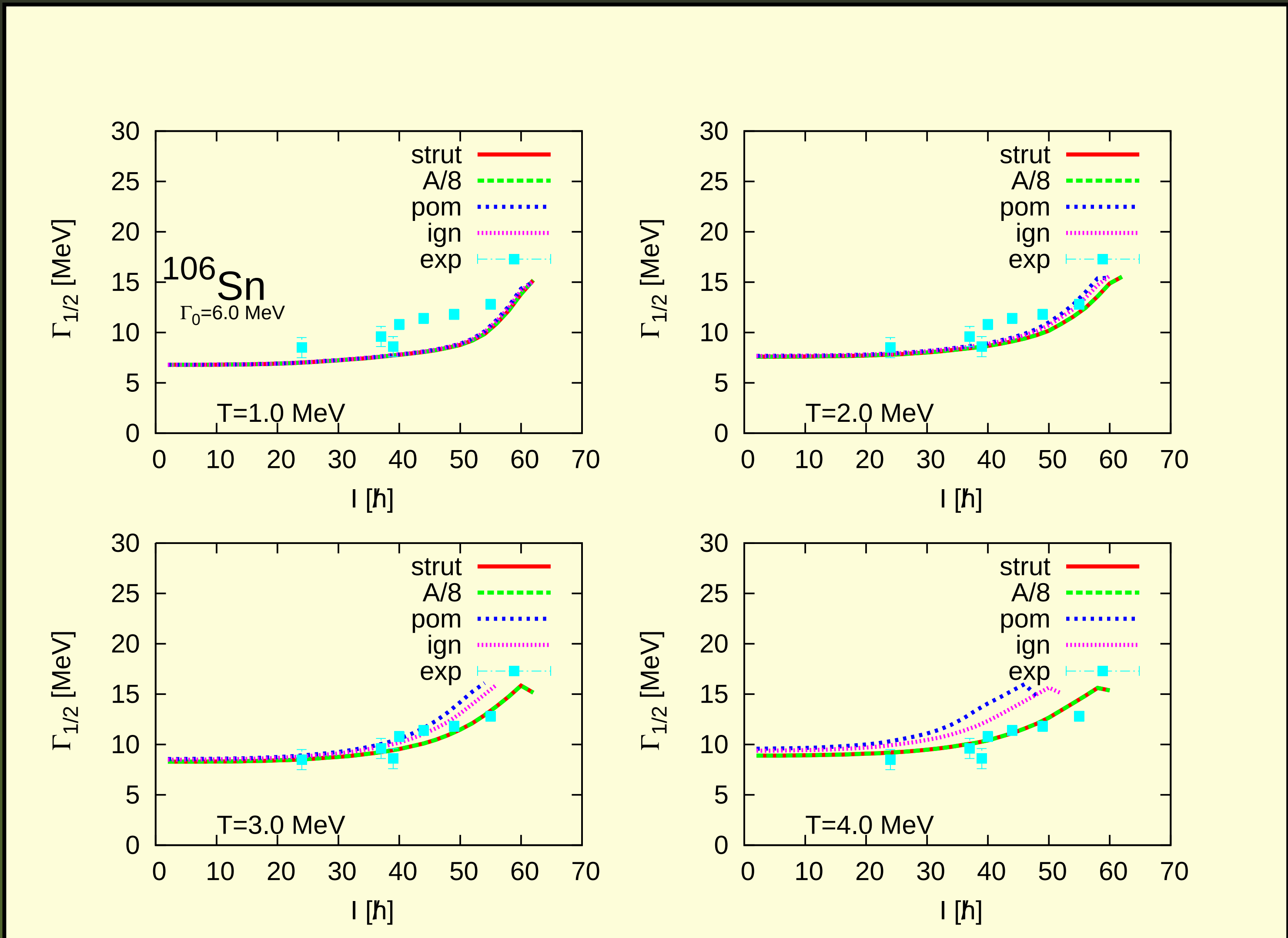


The nuclear level densities and free energy

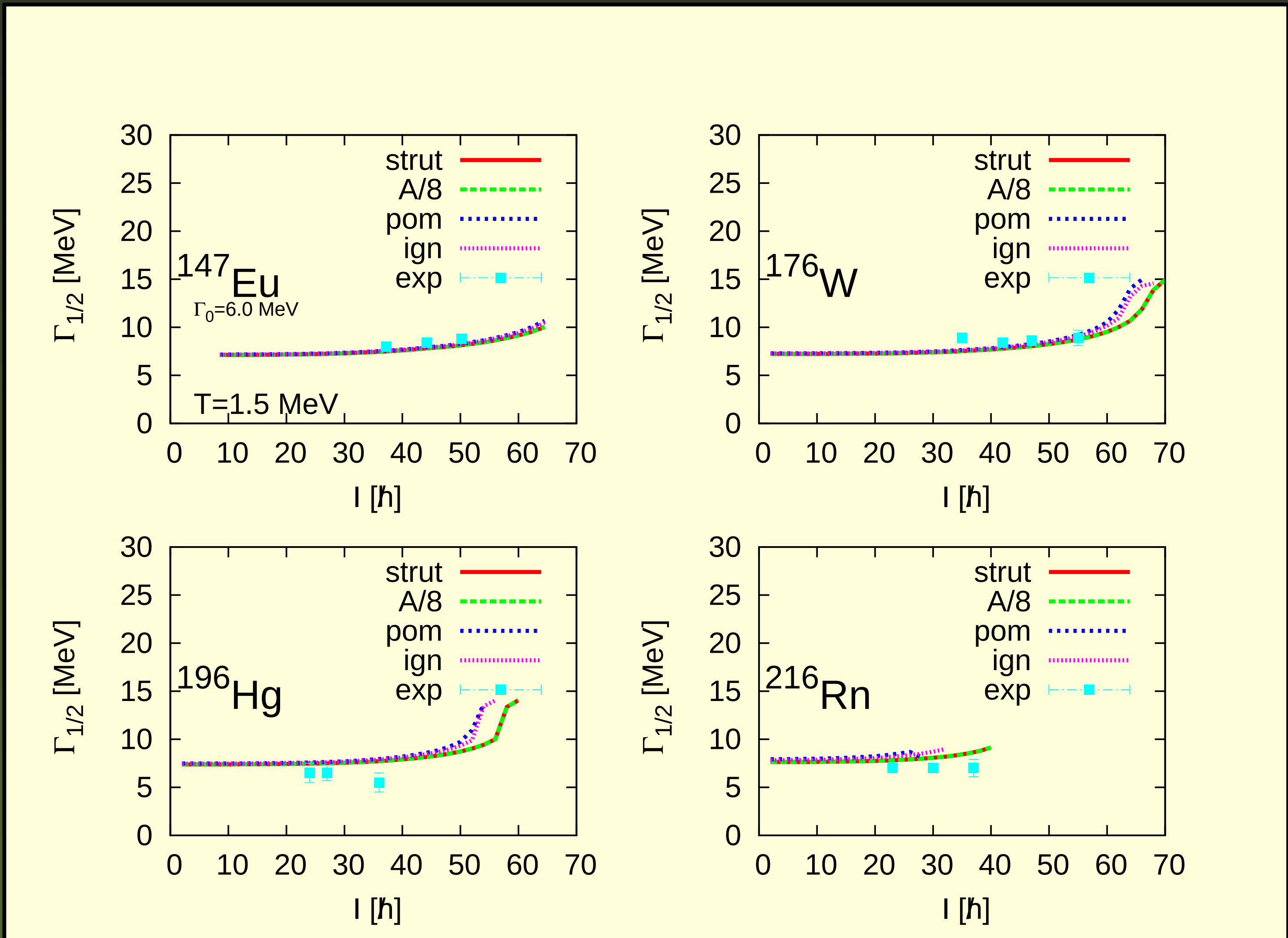


$$F(T) = E_{LSD}((x(\alpha_{40}, \alpha_{60}, \alpha_{80}), y(\alpha_{40}, \alpha_{60}, \alpha_{80})); I) - T(x, y, I)S(x, y, I, T)$$

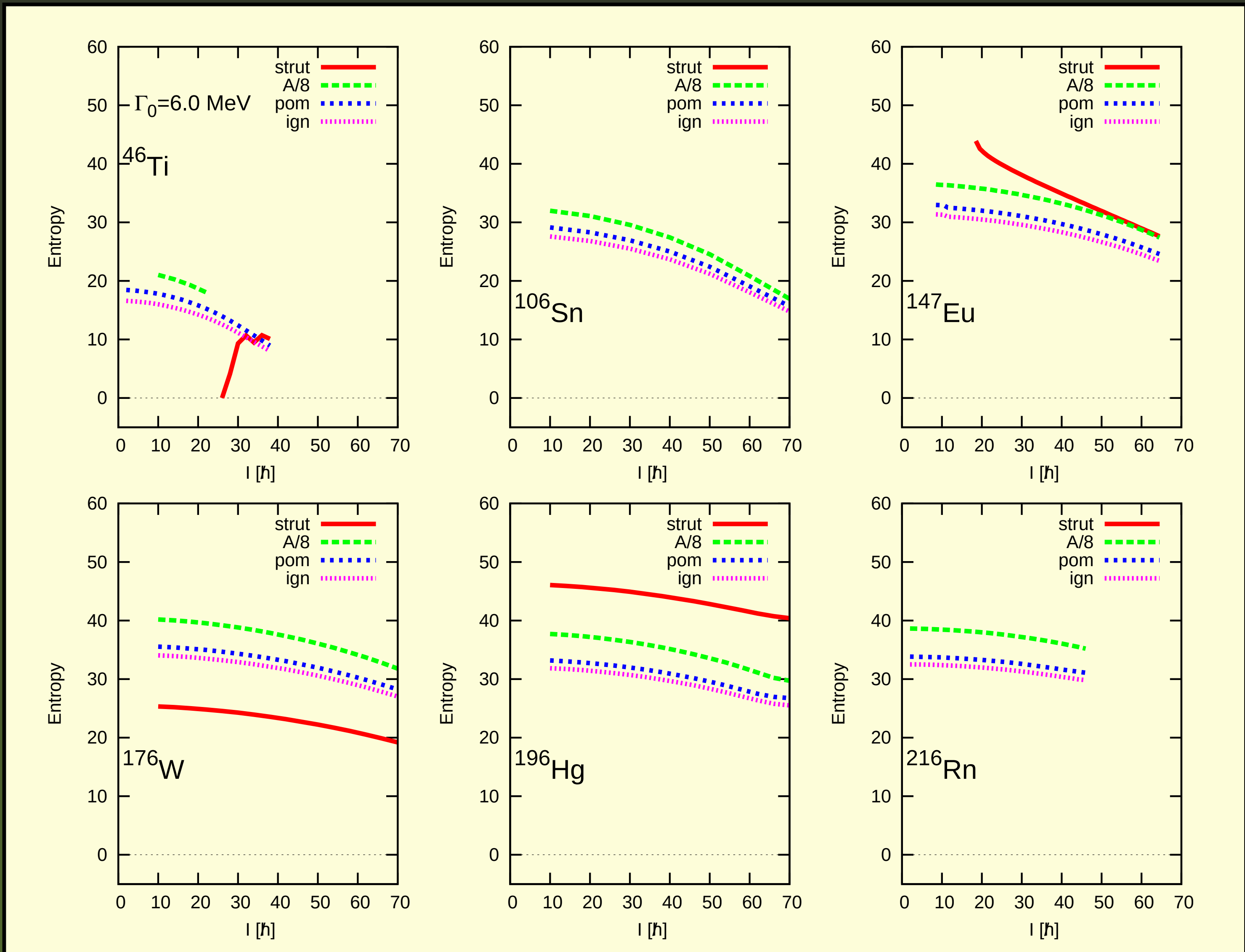
The nuclear level densities and GDR width.



The nuclear level densities and GDR width.



The nuclear level densities for constant excitation energy calculations



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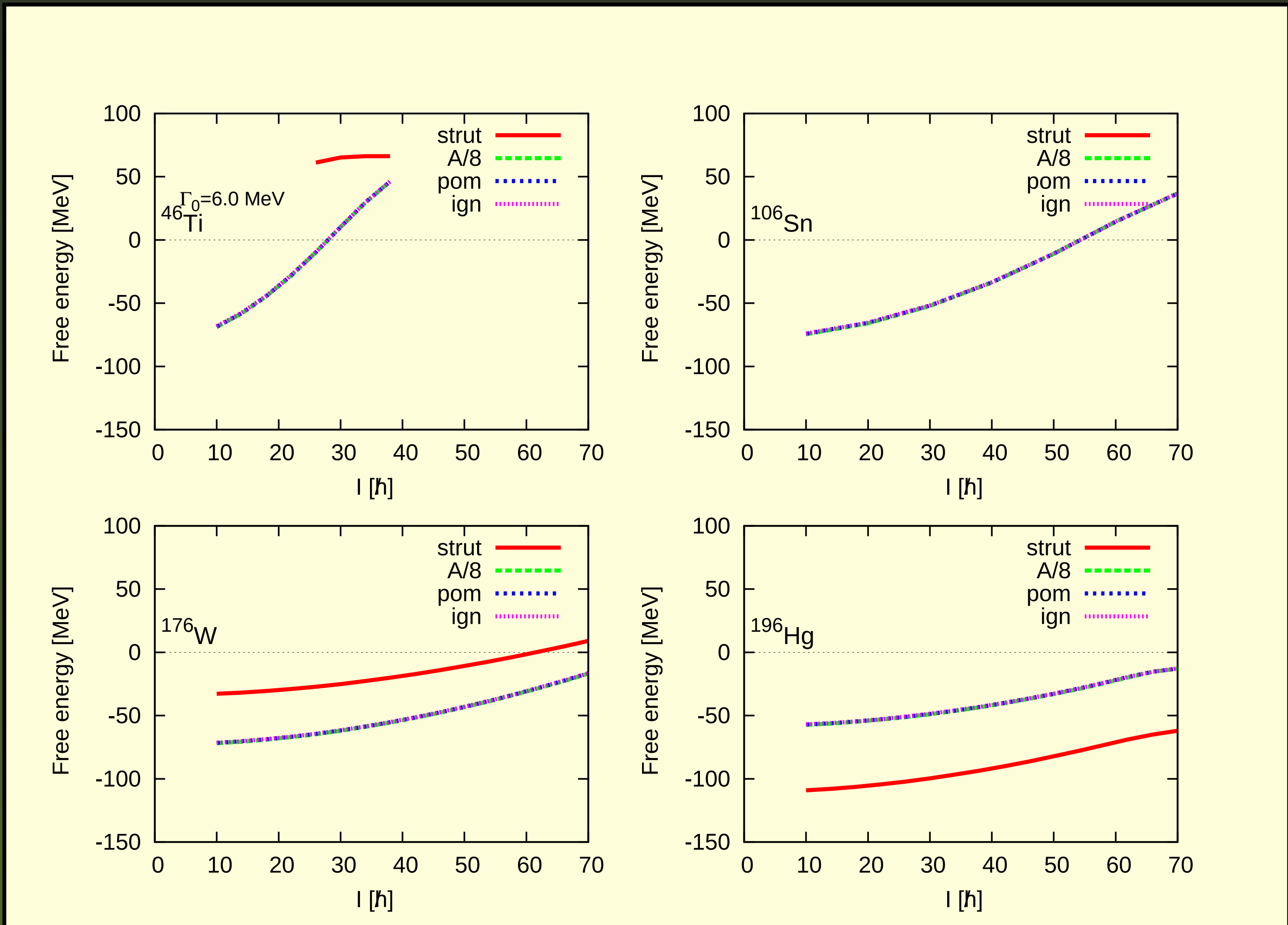

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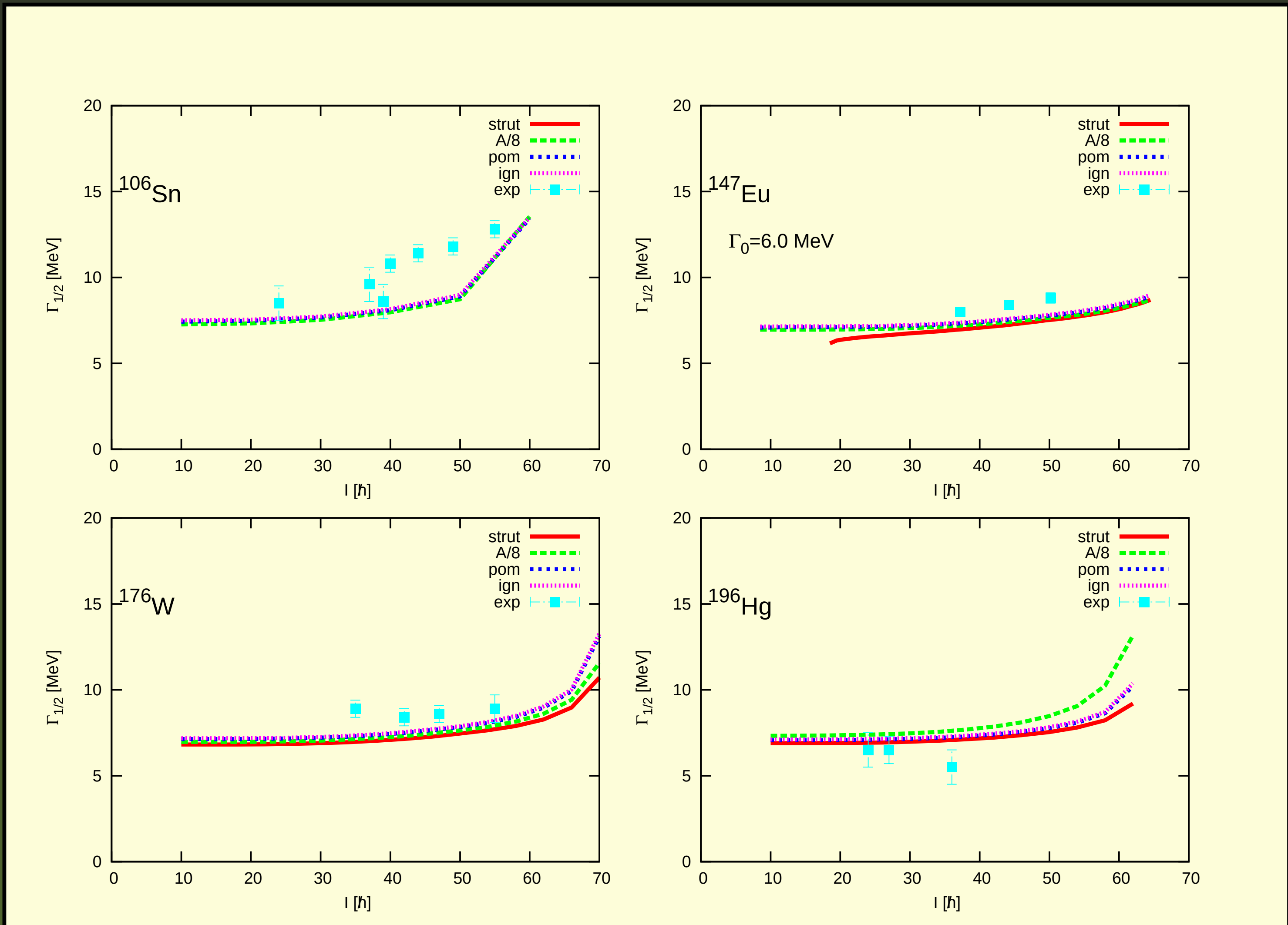

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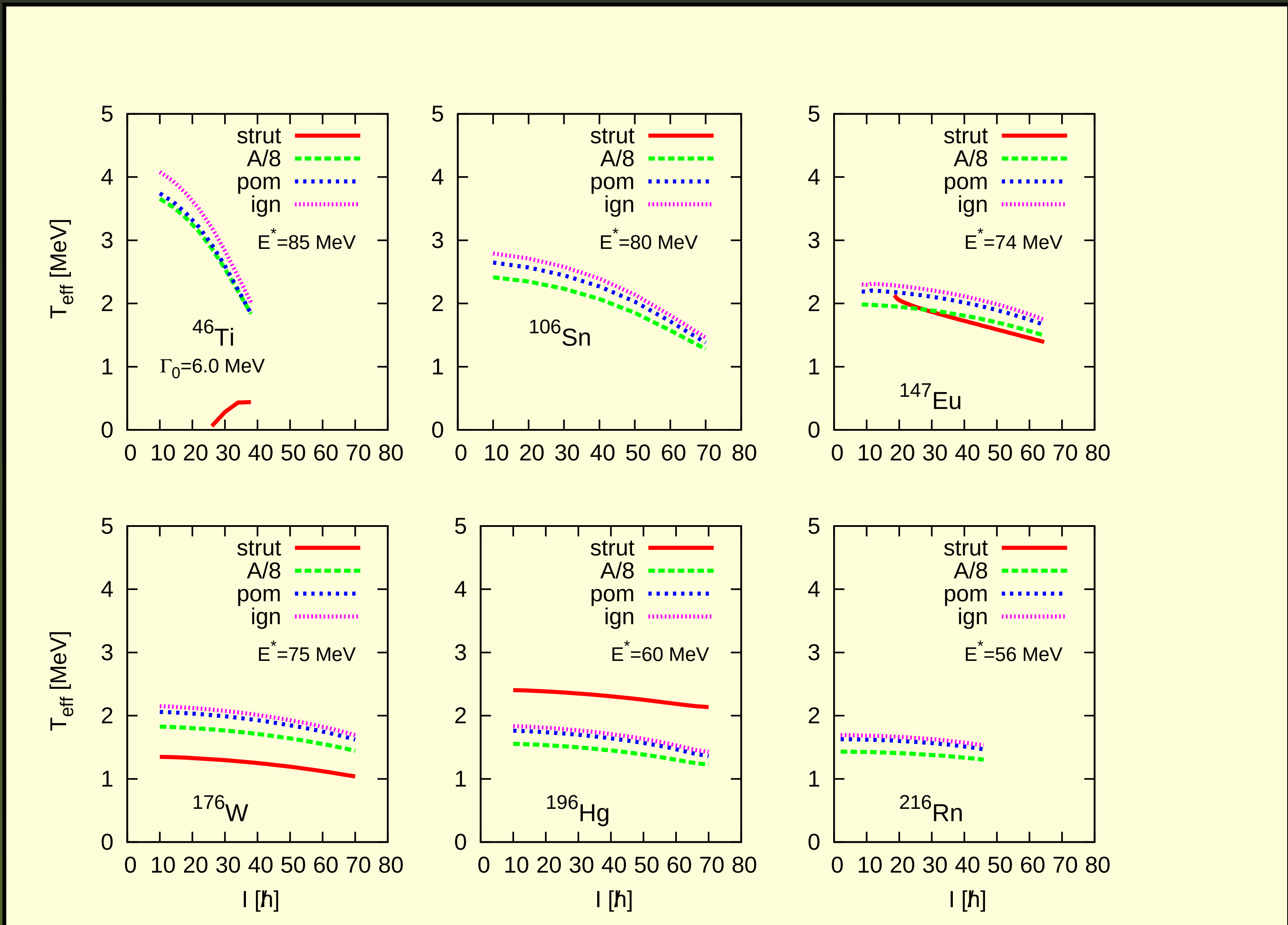
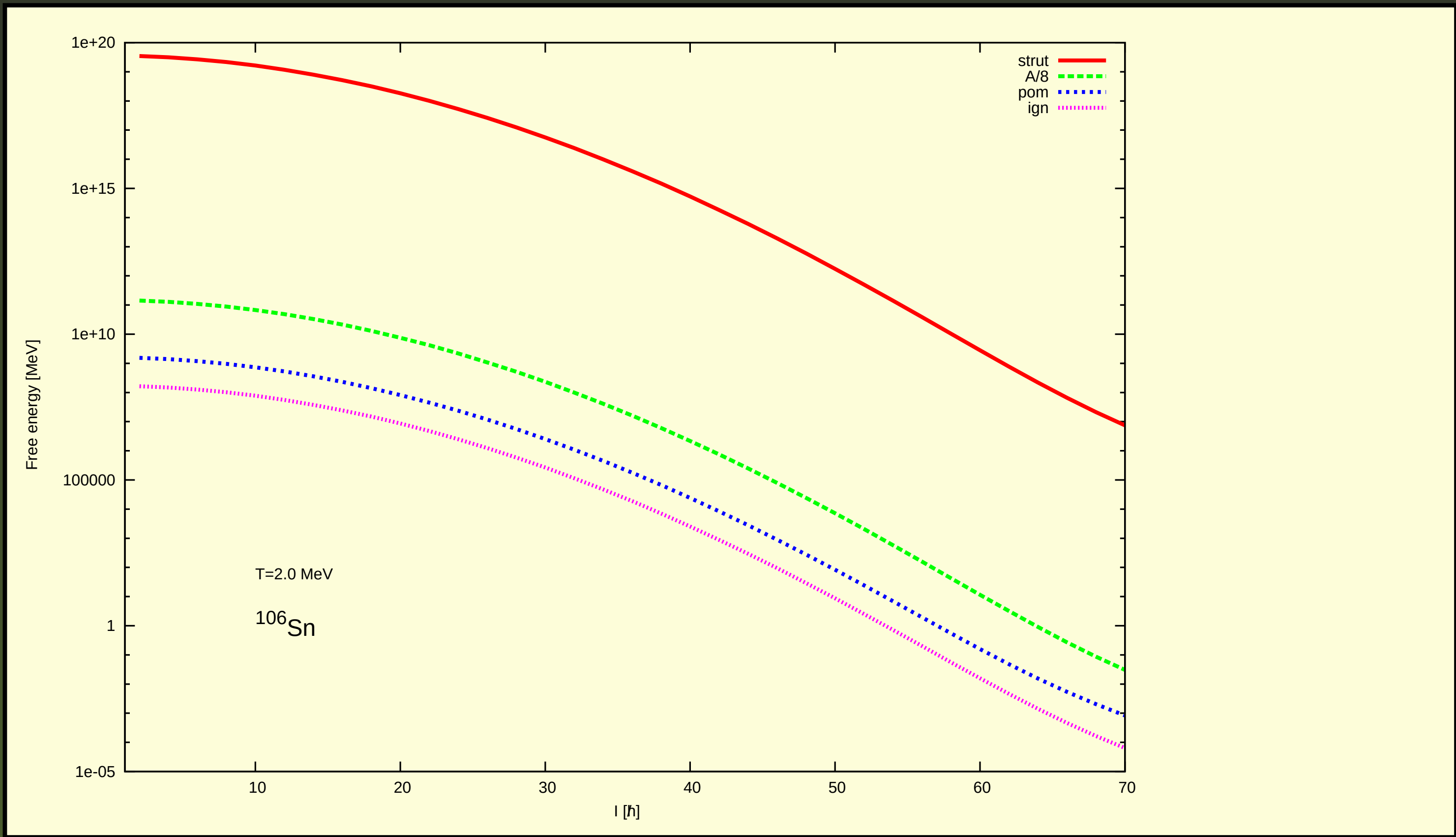


Effective GDR shapes at high spins and temperatures from the LSD model

- The thermal shape fluctuation method based on LSD model correctly describes nuclear shapes up to T=2 MeV for various mass regions.
- The effective Γ_0 increasing with temperature can be connected with decreasing of lifetimes
- If we made calculation for constant temperature the width of GDR strength function is nearly these same for various approaches to the nuclear level densities, only for very high spins differencies are visible.

The nuclear level densities and shape probability



$$p((x(\alpha_{40},\alpha_{60},\alpha_{80}),y(\alpha_{40},\alpha_{60},\alpha_{80}));I;T) = exp\left\{-\frac{F(T)}{kT}\right\}$$