Investigations on the breaking of left-right symmetry in light nuclei - the Poincaré instability

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The Menu

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  a reminder of a famous publication
- **Modified Funny-Hills parametrisation**
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Breaking of left-right symmerty -

a reminder of a famous publication

ANNALS OF PHYSICS 82, 557–596 (1974)

Equilibrium Configurations of Rotating Charged or Gravitating Liquid Masses with Surface Tension. II*

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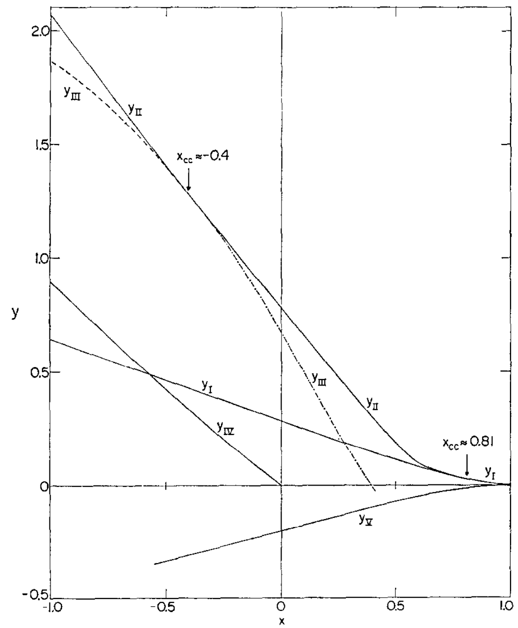
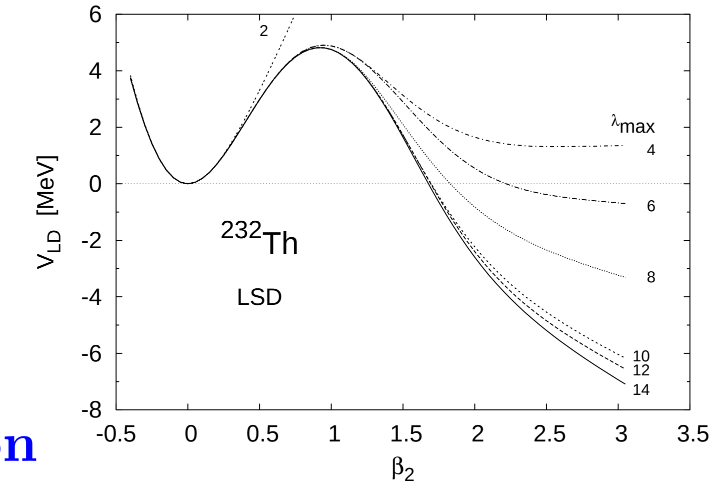


FIG. 2a. Various critical rotational parameters y in their dependence on the fissility parameter x. Triaxial shapes appear between y_I and y_{II}. Saddle shapes are stable against reflection asymmetric distortions to the right of the dot–dashed portion of y_{III}. Triaxial shapes are unstable against asymmetry between the dashed portion of y_{III} and y_{II}. The critical curves y_{IV} and y_V will be discussed in future installments of this series of papers.

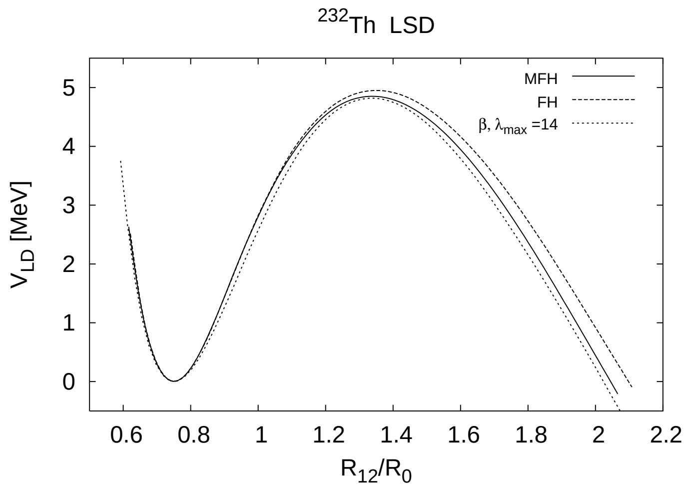
Modified Funny-Hills Shape parametrisation

- Huge variety of nuclear shapes (g.s. $\Longrightarrow$ scission point)
- Only a very few relevant deformation parameters
  - Expansion in spherical harmonics



  - Funny-Hills (FH) parametrisation

$$\varrho_s^2(u) = \begin{cases} R_0^2 c^2 \left(1 - u^2\right) \left(A + \alpha u + B u^2\right) & , B \geq 0 \\ R_0^2 c^2 \left(1 - u^2\right) (A + \alpha u) \exp\left(B c^3 u^2\right) & , B < 0 \end{cases}$$

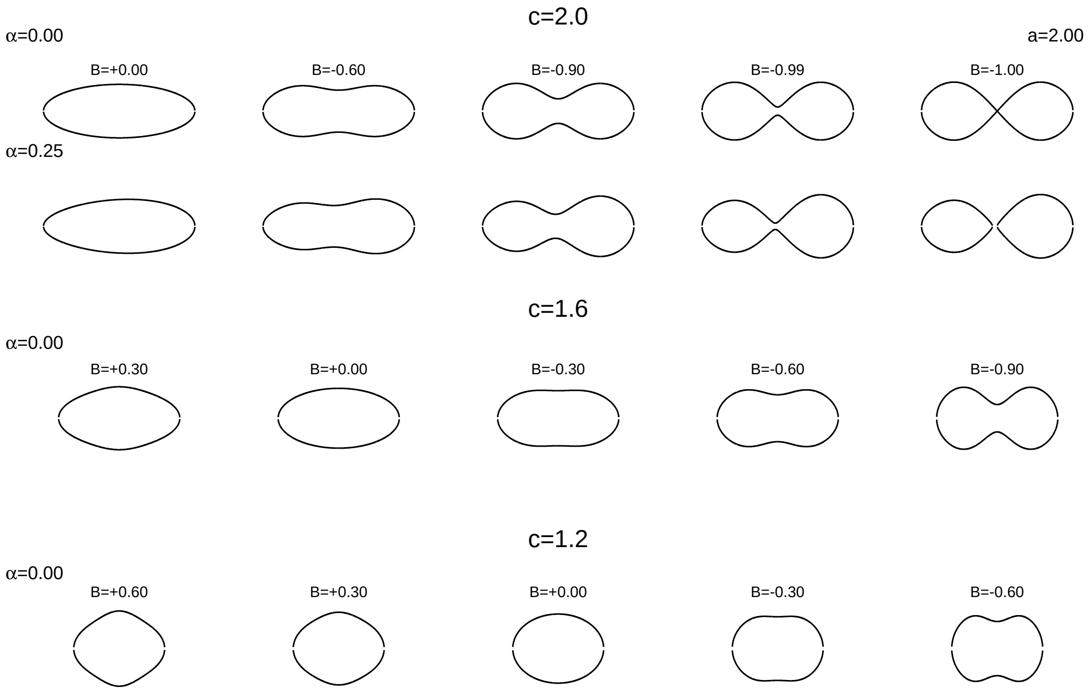


- **Modified Funny-Hills shape parametrisation**

$$\varrho_s^2(z) = \frac{R_0^2}{c\, f(a,B)}\,(1-u^2)\,(1+\alpha u)\,(1-B\,e^{-a^2u^2}) \;\;,$$

where

$$f(a,B) = 1 - \frac{3\,B}{4\,a^2}\left[e^{-a^2} + \sqrt{\pi}(a - \frac{1}{2a})\,\mathrm{Erf}(a)\right]$$



breaking axial symmetry

supose ellipsoidal shape $\perp$ to z axis

and introduce the non-axiality parameter

$$\eta = \frac{a_y - a_x}{a_y + a_x}$$

assume that η is independent of z

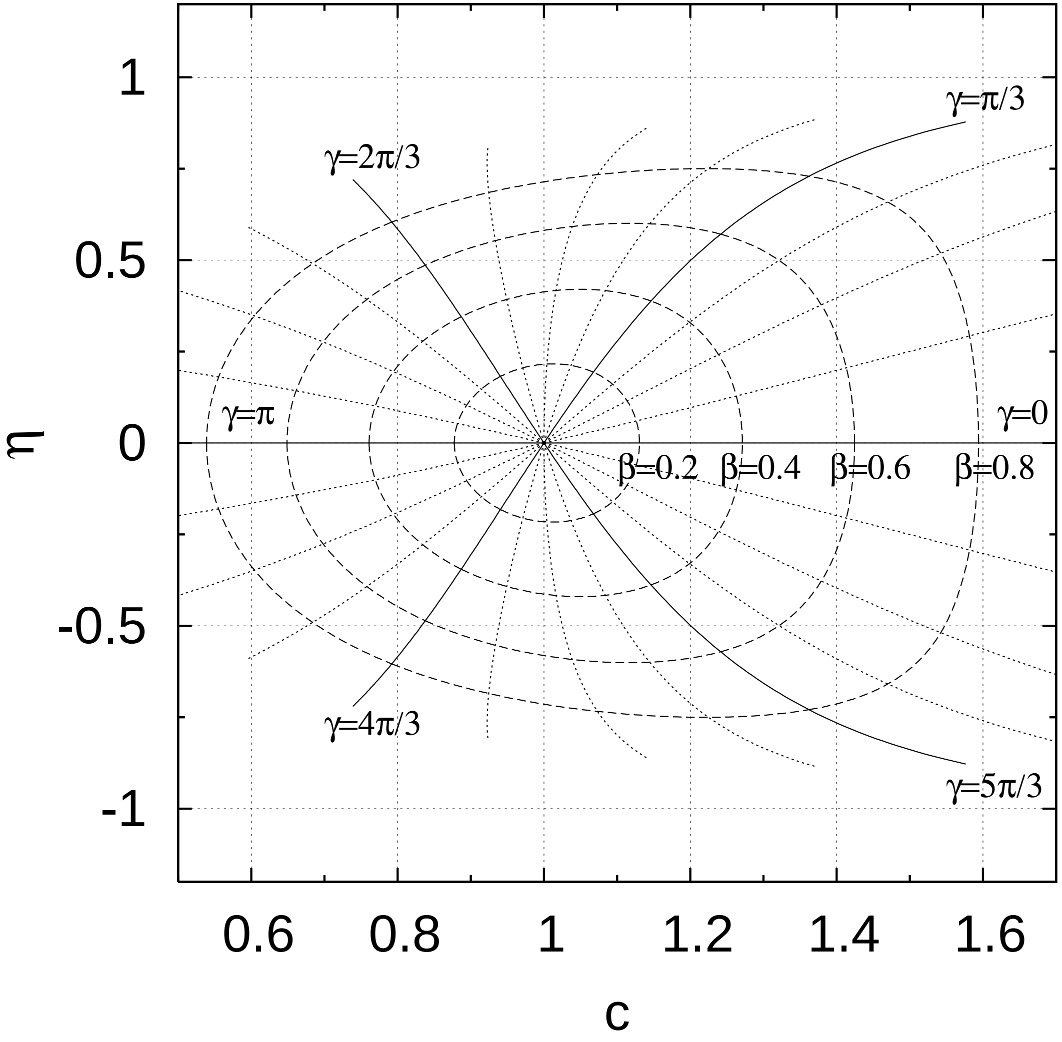
$$a_x(z) = \varrho_s(z) \left(\frac{1-\eta}{1+\eta} \right)^{1/2}$$

$$a_y(z) = \varrho_s(z) \left(\frac{1+\eta}{1-\eta} \right)^{1/2}$$

volume conservation then leads to

$$\widetilde{\varrho}_s^2(z,\varphi) = \varrho_s^2(z) \, \frac{1-\eta^2}{1+\eta^2+2\eta\cos(2\varphi)}$$

J. Bartel, F. Ivanyuk, K. Pomorski, IJMPE E19 (2010) 601



Transformation from (c, η) to (β, γ) in the pure spheroidal case

Lublin-Strasbourg Drop Model

According to the Strutinski theorem

$$E_{\rm tot} = \int \mathcal{H}(\rho)\, d^3r = E_{\rm mac} + \delta E_{\rm mic}$$

with the Lublin–Strasbourg drop

$$E_{\rm mac}(Z,N,def) = a_{\rm vol}\,(1-\kappa_{\rm vol}I^2)\,A \;+\; a_{\rm surf}\,(1-\kappa_{\rm surf}I^2)\,A^{2/3}\,B_{\rm surf}(def)$$

$$+\,a_{\rm cur}\,(1-\kappa_{\rm cur}I^2)\,A^{1/3}\,B_{\rm cur}(def) + \frac{3\,e^2}{5\,r_{\rm o}}\,\frac{Z^2}{A^{1/3}}\,B_{\rm Coul}(def)$$

$$-\,C_4\,\frac{Z^2}{A} - E_{\rm cong}$$

with shell and pairing corrections

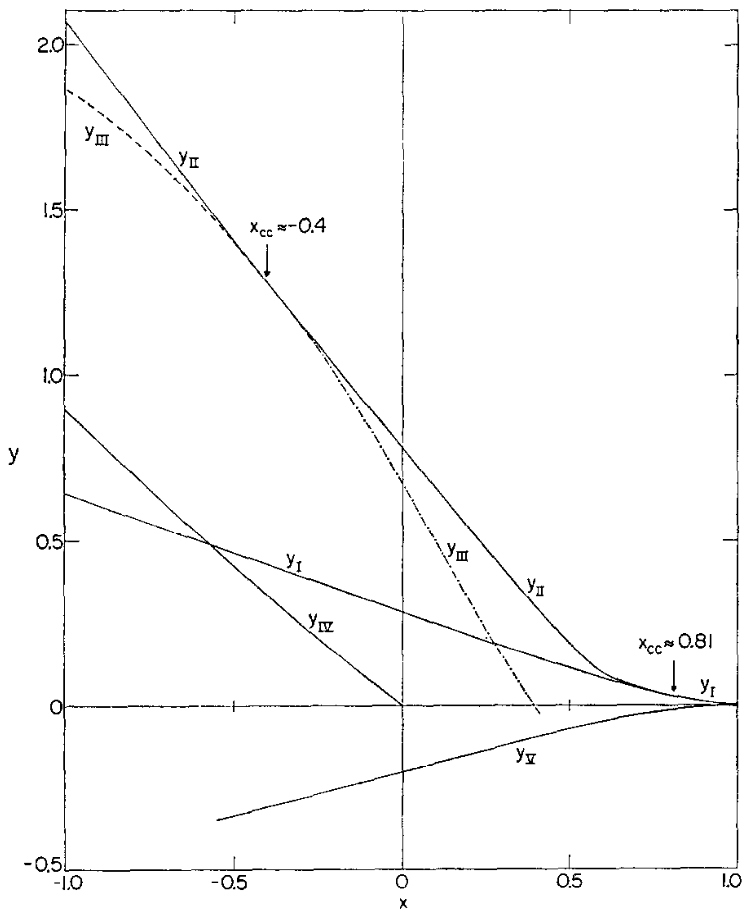
$$\delta E_{\rm shell} = \sum_{\rm occ} \varepsilon_\nu - \widetilde{E}$$

$$\delta E_{\rm mic} = \delta E_{\rm shell} + \delta E_{\rm pair}$$

$$\delta E_{\rm pair} = E_{\rm BCS} - \sum_{\rm occ} \varepsilon_\nu - \langle E_{\rm pair} \rangle$$

Energy landscapes in light nuclei

studied nuclei: ^{44}**Ti** , ^{64}**Zn** , ^{76}**Se** , ^{80}**Kr** , ^{84}**Sr** , ^{88}**Mo**



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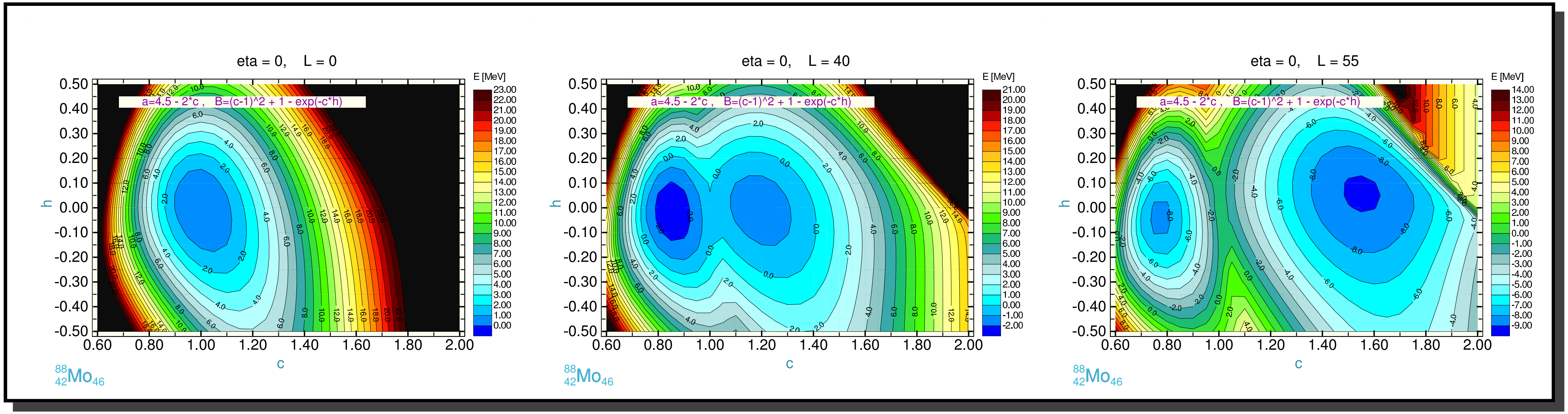
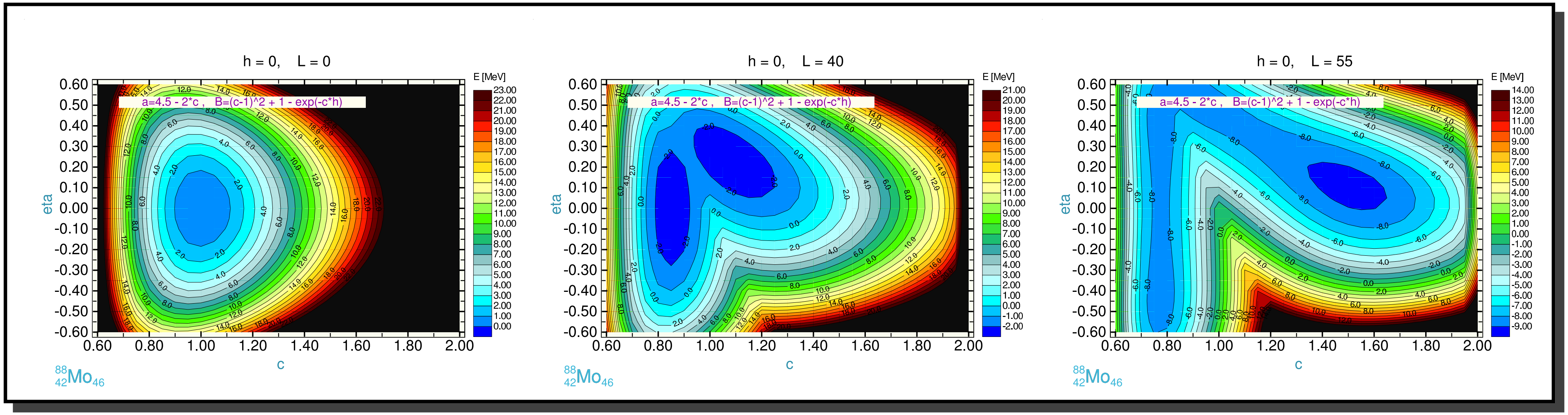
Instability against reflexion asymmetry when $x \leq 0.4$ for $L = 0$, decreasing for $L > 0$

A rough estimate:

$$x \approx \frac{1}{50}\,\frac{Z^2}{A}, \quad y \approx 2\,\frac{L^2}{A^{7/3}}$$


eta = 0, L = 0
eta = 0, L = 40
eta = 0, L = 55
a=4.5 - 2*c , B=(c-1)^2 + 1 - exp(-c*h)
h
c
E [MeV]
$^{88}_{42}Mo_{46}$


h = 0, L = 0
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eta
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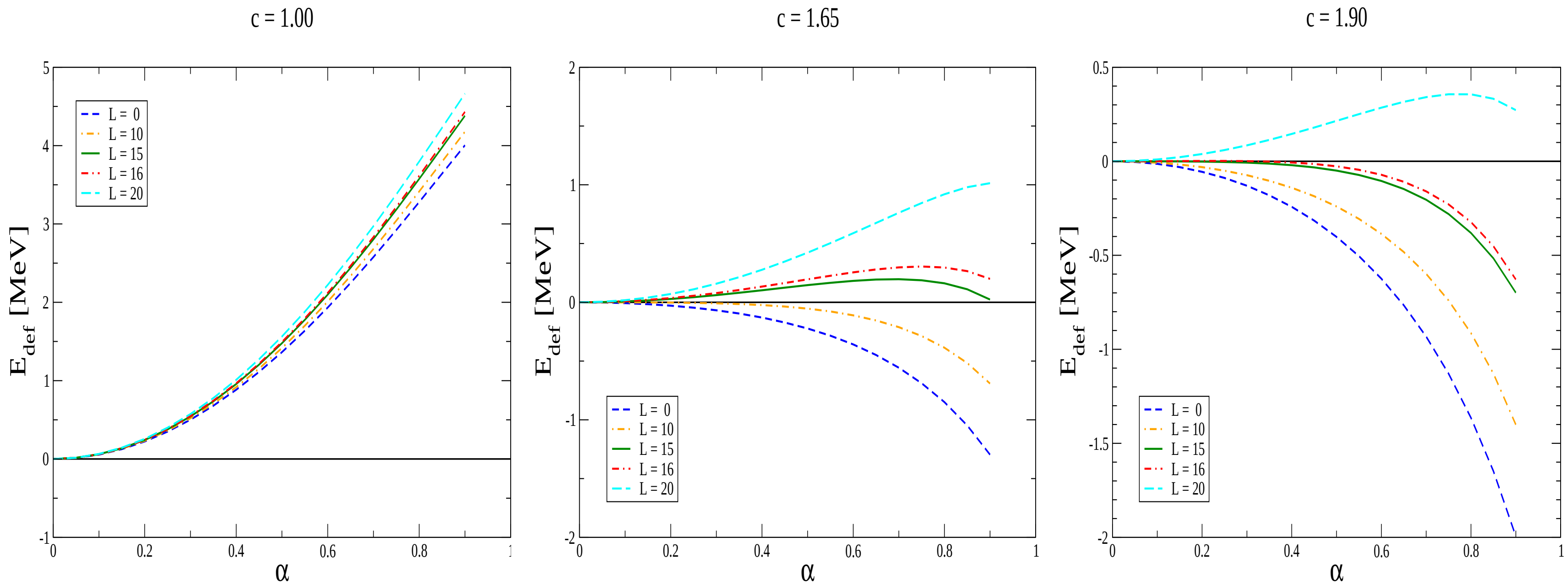
$^{88}_{42}Mo_{46}$

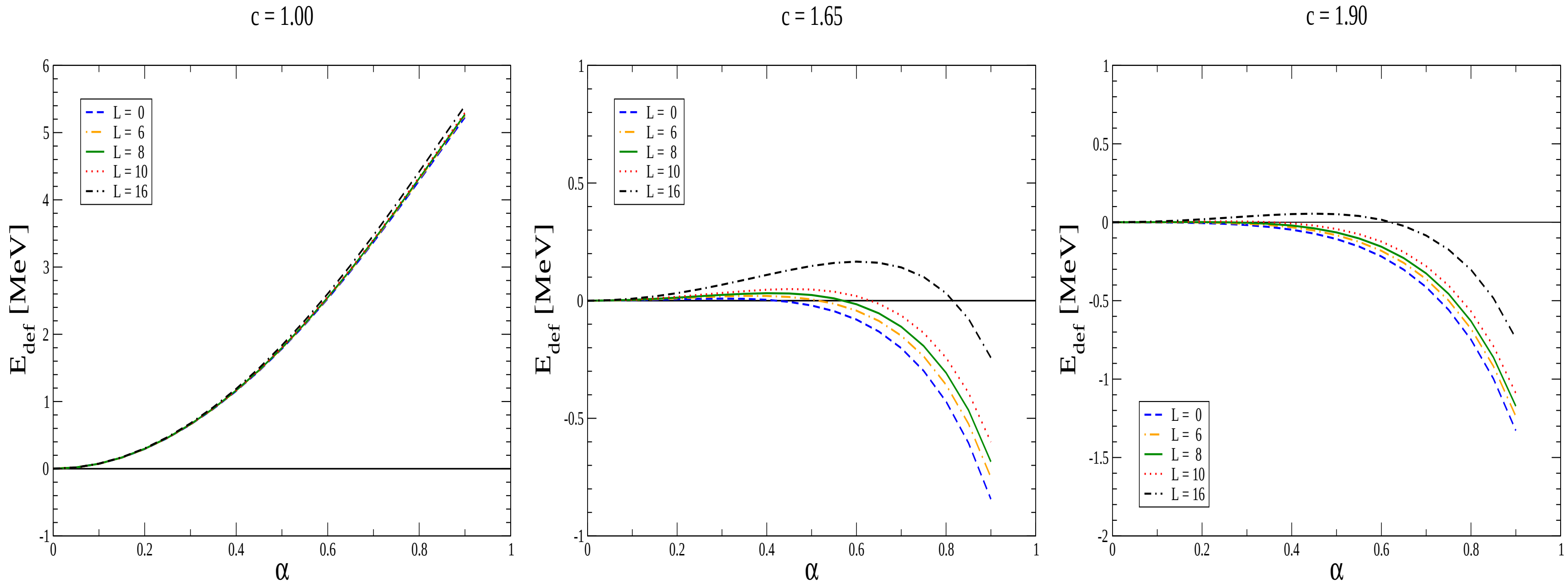
The Poincaré instability

also motivated by the experimental studies of A. Maj & coworkers

(see XVIth Kazimierz workshop 2009, IJMP E19 (2010) 532)



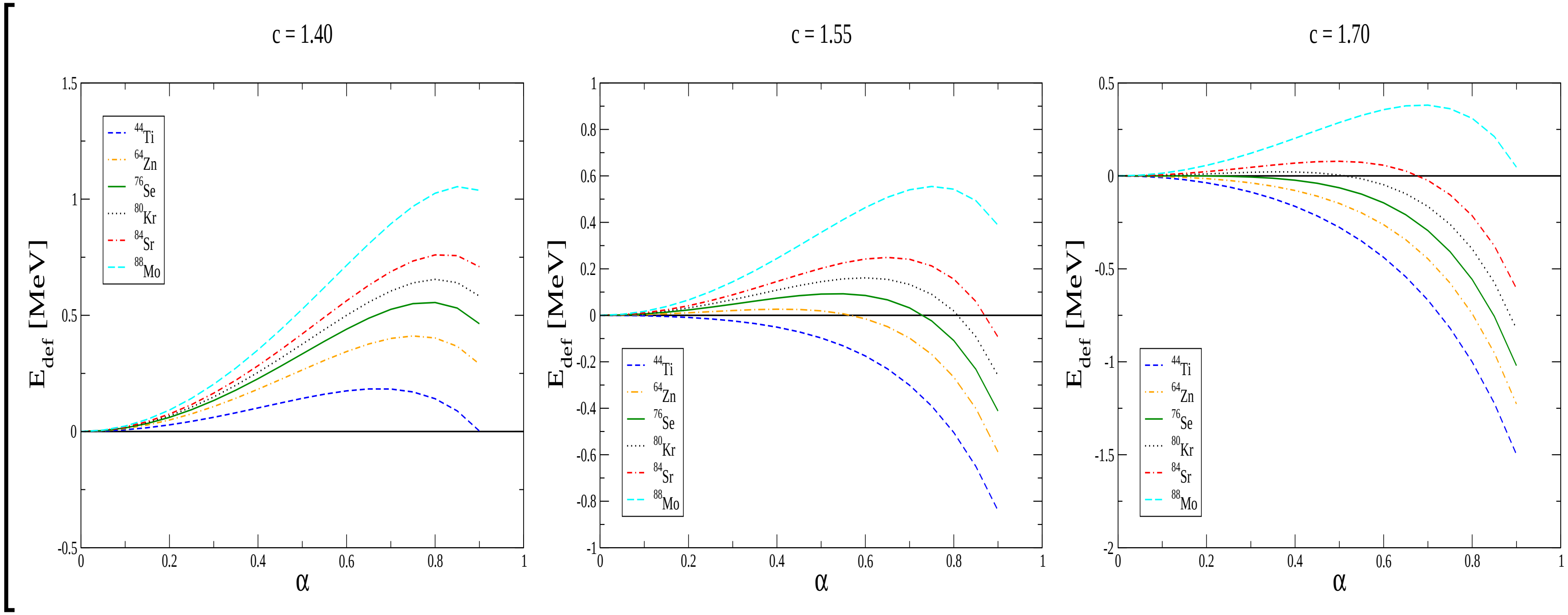
in ^{44}Ti



in ^{76}Se

But $c = 1.65$ is already a pretty large deformation

Study of Poincaré's instability for $L = 0$ at different deformations



Conclusions

- **Modified Funny-Hills (MFH) parametrisation describes nuclear shapes very well (already well known)**

- **Our LDM study with the LSD and the MFH parametrization allows for a systematic study of the Poincaré instability in light nuclei**

- **This instability against left-right asymmetry only present in light nuclei with mass $A \leq 80 - 90$**

- **For higher angular momenta (or higher temperatures) in competion with the fission instability**

- **Higher angular momenta tend to stabilize the nucleus already pointed out by CPS 35 years ago**

- **Finite excitation of nuclei have a practically negligeable effect on the Poincaré instability**