MeanField4Exp: Examples of service applications: Nuclear shape evolution with spin, impact on the Giant Dipole Resonance Strength - comparison with experiment"

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EURO-LABS Project – MeanField4Exp

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MeanField4Exp

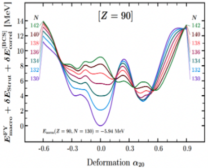
IFJ PAN, KRAKOW, POLAND and IPHC and UNIVERSITY OF STRASBOURG, FRANCE

Logged as Services About Theo4Exp

This website is based on an extensive research program
developed over many years by J. Dudek (IPHC and University of Strasbourg) and his collaborators;
it allows to explore elementary structure properties of atomic nuclei, including shapes, symmetries and excitations,
using **Realistic Phenomenological Nuclear Mean Field Theory Calculations.**

Nuclear Energy Diagrams

Generate Macroscopic-Microscopic Method nuclear energy diagrams.



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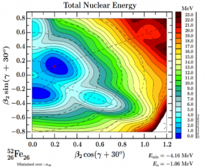
Macroscopic-Microscopic Energy

Generating total energy diagrams according to the Macroscopic-Microscopic approximation.



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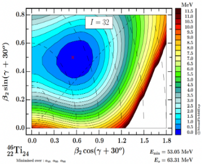
Shape Evolution with Spin

Generating diagrams of shape evolution with spin according to macroscopic energy models.



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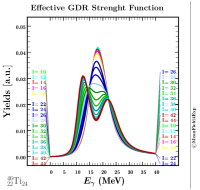
Giant Dipole Resonances (!beta version!)

Generating effective GDR strenght function for given spins and temperature.



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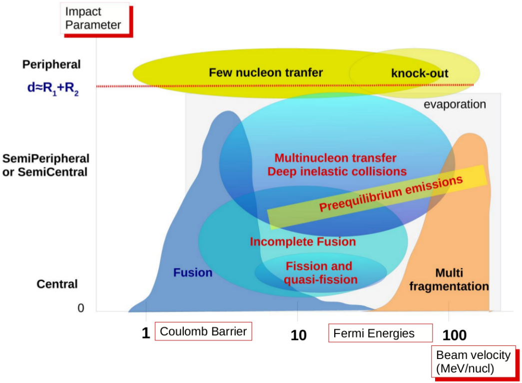
https://meanfield4exp.ifj.edu.pl

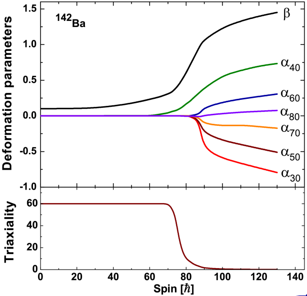
Outline

- Geometrical Symmetry Breaking
- Thermal Shape Fluctuation Model
- Results in MeanField4Exp

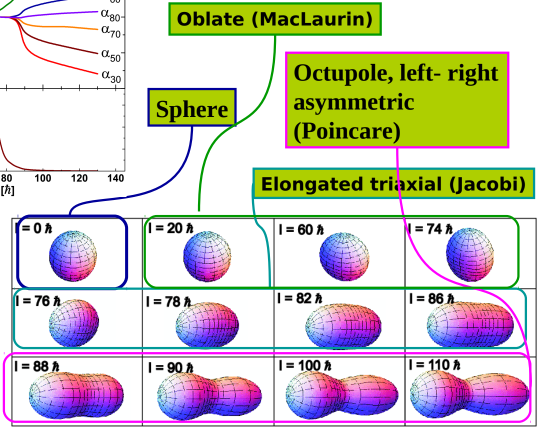


Geometrical Symmetry Breaking

Jacobi/Poincaré Shape Transition

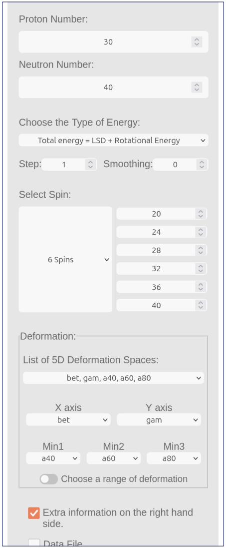


H.Poincare, Acta Math. 7 (1885) 259
A.Maj, K.M., J.Dudek, et al, Int. J. Mod. Phys. E 19 (2010) 532



Theoretical prediction *(for the first time)* of the Poincare shape transition in atomic nuclei

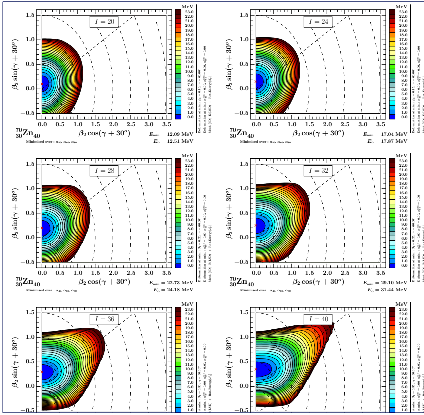
MeanField4Exp: Shape Evolution with Spin



User Specifications:

- Nucleus (Z, N) values
- The choice of the Macroscopic Energy Model:
  - Lublin- Strasbourg Drop
  - Myers - Świątecki Model
- The spin values I_n, $n \leq 6$
- Choice of deformation:
  - selecting main x-axis

$\alpha_{\lambda\mu} \in [\text{min.}, \text{max}]$



MeanField4Exp: 3D Nuclear Surface

3D Nuclear Surface

Select the Symmetry:

None

a20 Value: 0.15

Add Element Remove Element

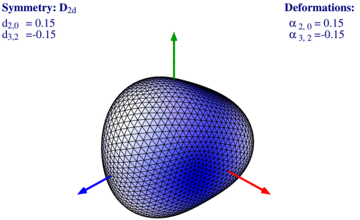
Generate

Instructions for formatting the drawing

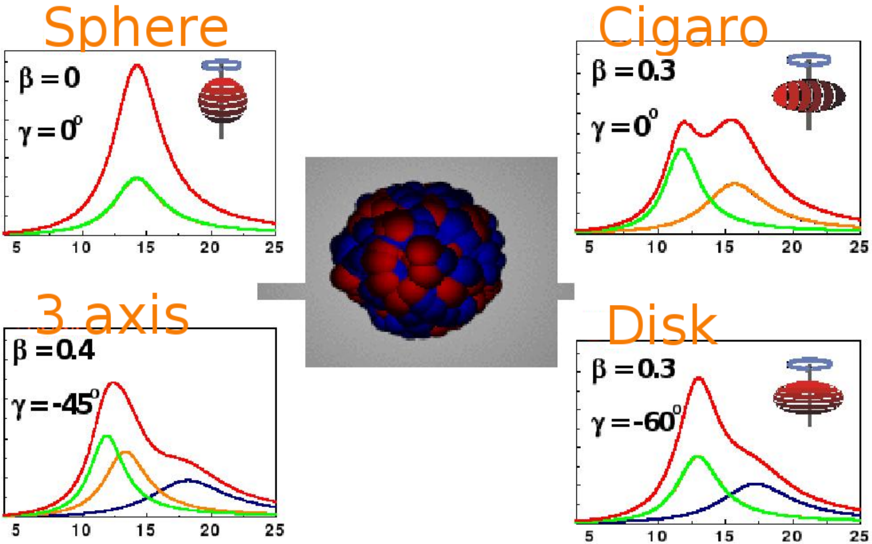
This page allows you to create nuclear surfaces based on specified deformation parameters, utilizing an expansion in terms of spherical harmonics $Y_{\lambda\mu}(\vartheta, \varphi)$.

$$\Sigma : R(\vartheta, \varphi) = R_0 C(\alpha) \left[1 + \sum \alpha_{\lambda\mu} Y_{\lambda\mu}(\vartheta, \varphi)\right] \qquad (1)$$

This expression represents the distance from the center of the reference frame to the points on the surface. $\alpha_{\lambda\mu}$ represents the nuclear deformation parameters, eg. $(\lambda = 2)$ quadrupole, $(\lambda = 3)$ octupole, and $(\lambda = 4)$ hexadecapole.



Giant Dipole Resonance - GDR



Giant Dipole Resonances Measurement

M. Ciemała et al. Phys. Rev. C 91, 054313 (2015)

PHYSICAL REVIEW C **91**, 054313 (2015)

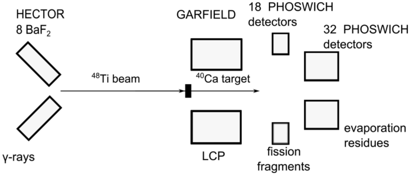


FIG. 1. Schematic view of the experimental setup in the ^{48}Ti + ^{40}Ca $\rightarrow$ ^{88}Mo* experiment.

PHYSICAL REVIEW C **91**, 054313 (2015)

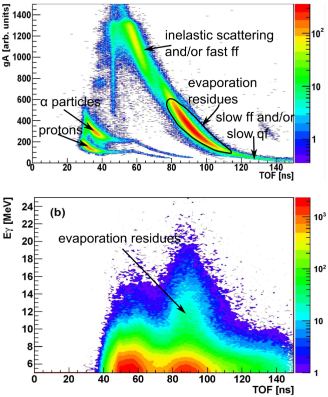
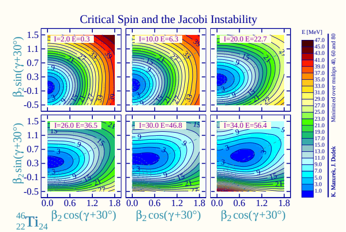
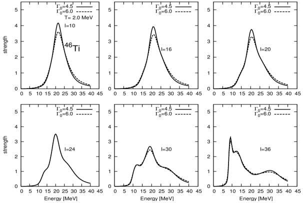


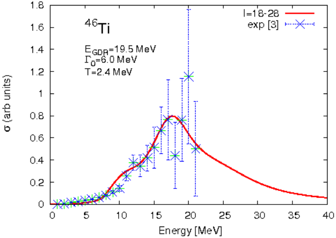
FIG. 4. (Color online) (a) 2D plot of the gA parameter (ΔE energy deposit) and ToF (time of flight) dependence for one of the 32 phoswich detectors, with indicated regions for different reaction products [e.g., particles, evaporation residues, fission fragments (f)f, quasifission fragments (qf), etc.]. (b) 2D plot of the γ-ray energy (E_γ) in HECTOR versus the ToF for heavy fragments in the phoswich detector. The data are for the 300 MeV reaction.

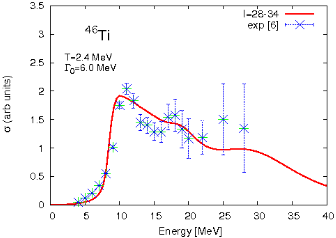
Geometrical Symmetry Breaking

Jacobi Shape Transition Evidence





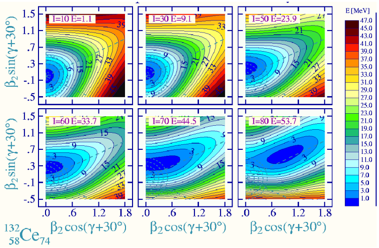


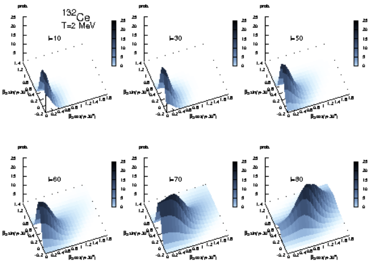


Experiment: A. Maj et al., Nucl. Phys. A 731, 319 (2004).

Thermal Shape Fluctuation Model - GDR

[K. Pomorski, J. Dudek, Phys. Rev. C 67,044316(2003)]. (A=Z+N; t=(N-Z)/A)





The macroscopic energy:

Lublin - Strasbourg Drop

$$
\begin{aligned}
E_{LSD}(Z,N;def) &= b_{vol}(1-\kappa_{vol}t^2)A \\
&+ b_{surf}(1-\kappa_{surf}t^2)A^{2/3}B_{surf}(def) \\
&+ b_{curv}(1+\kappa_{curv}t^2)A^{1/3}B_{curv}(def) \\
&+ \frac{3}{5}e^2\frac{Z^2}{r_0^{ch}A^{1/3}}B_{Coul}(def) - C_4\frac{Z^2}{A} \\
&- 10\cdot\exp(-4.2|t|)
\end{aligned}
$$

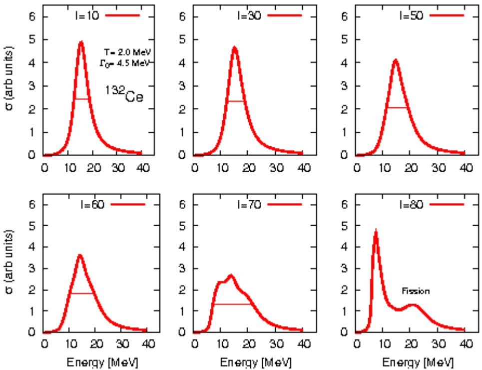
Free energy

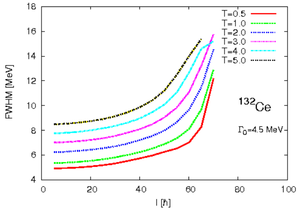
$$F(T) = E_{LSD} + \frac{I(I+1)}{2\mathcal{J}(def)} - TS(def, I, T)$$

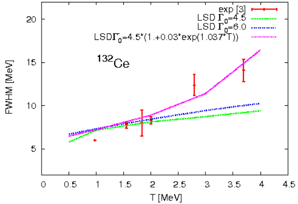
The GDR probability

$$p(def;I;T) = exp\left\{-\frac{F(T)}{kT}\right\}$$

Thermal Shape Fluctuation Model - GDR







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

$$f_k(E_\gamma, (def)) = \frac{\sigma_k \Gamma_k E_\gamma^2}{(E_\gamma^2 - E_{GDR,k}^2)^2 + E_\gamma^2 \Gamma_k^2}$$

$$\Gamma_k = \left(\frac{E_{GDR,k}}{E_{GDR}}\right)^{1.9} \cdot \Gamma_0$$

K. M., M. Kmiecik, A. Maj, J. Dudek,

N. Schunck, Acta Phys. Pol. B 38, 1455 (2007)

Experimental Results - ^{48}Ti+^{40}Ca→ ^{88}Mo

M. Ciemała et al. Phys. Rev. C 91, 054313 (2015)

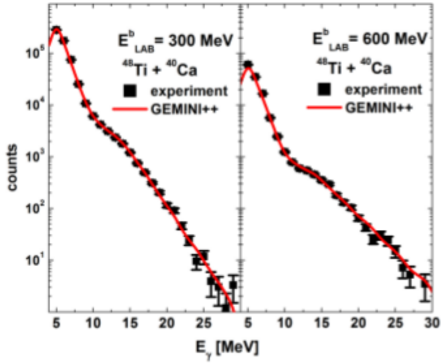


FIG. 9. (Color online) A comparison of the γ-ray spectra from the ^{48}Ti + ^{40}Ca reaction, at the beam energies of 300 MeV and 600 MeV, with the results of the *GEMINI++* fit (see text).

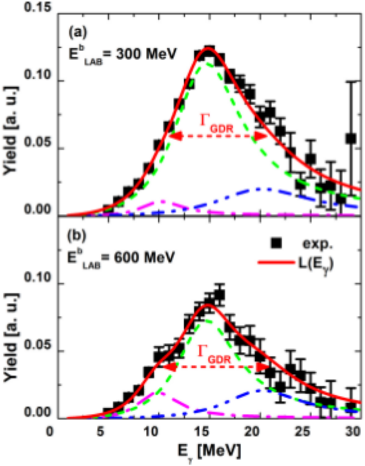


FIG. 10. (Color online) The experimental, $Y_{exp}(E_\gamma)$, and fitted, $L(E_\gamma)$, GDR strength functions for (a) 300 and (b) 600 MeV beam energies.

Thermal Shape Fluctuation Model - Results

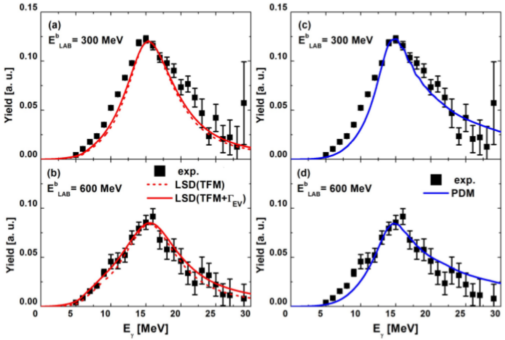
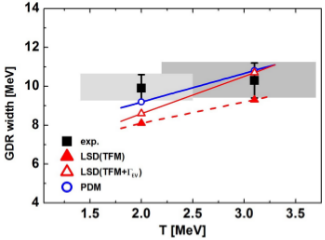
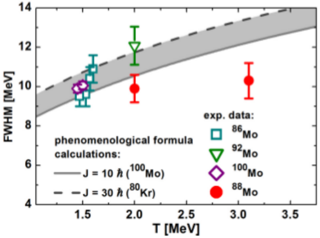
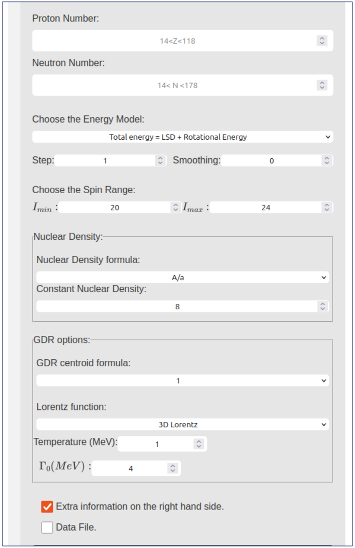


FIG. 17. (Color online) Left: Comparison of the GDR strength functions extracted from the experimental data and the effective model-values based on the macroscopic LSD model with TFM [Eq. (15)] – for the beam energies of (a) 300 MeV and (b) 600 MeV. The theoretical GDR strength functions are estimated with a constant (dashed line) and a temperature-dependent (solid line) intrinsic GDR width Γ_0. Right: Analogous to the left panel comparison of experimentally extracted GDR strength functions to the effective model values based on the PDM [Eq. (24)] for beam energies of (c) 300 MeV and (d) 600 MeV.





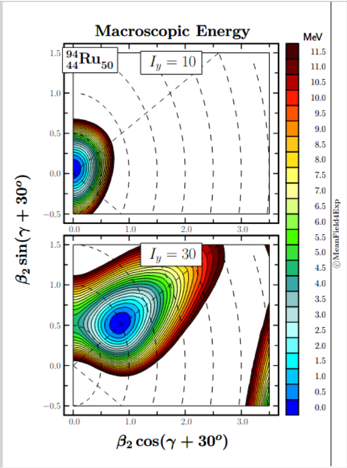
MeanField4Exp: Giant Dipole Resonances

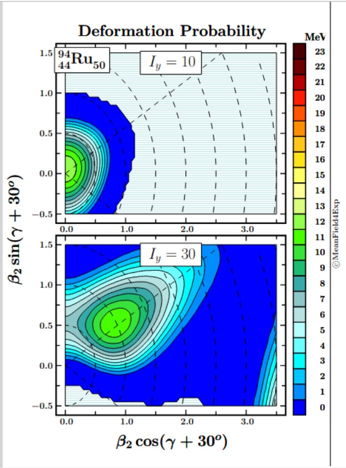


User Specifications:

- Nucleus (Z, N) values
- The choice of the Macroscopic Energy Model:
  - Lublin- Strasbourg Drop
  - Myers - Świątecki Model
- The spin range (I_{min},I_{max}) with step Δ I=2 $\hbar$
- Choice of nuclear level approach (included in Free Energy):
  - Constant parameter (a(A)=A/a)
  - Ignatyuk deformation dependent (a(A)=αA+βA$^{2/3}$)
  - Pomorski deformation dependent (a(A,def))
- GDR options:
  - GDR strenght function centroids $_{GDR}$
  - Lorentz 3D vs. 5D
  - Expected temperature
  - Width of the GDR function Γ_0

MeanField4Exp: GDR Outcome





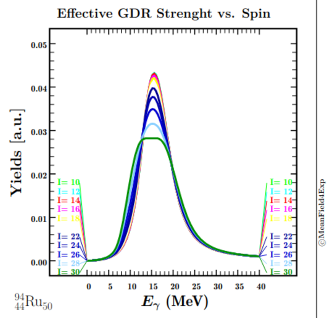
Download the Potential-Energy Surfaces

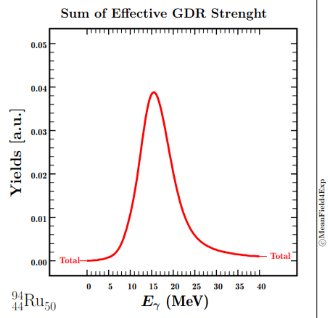
Download the Data File for PES

Download the Probability Maps

Download the Data File for Probability

MeanField4Exp: GDR Outcome





Download the GDR Strenght Function for given Spin

Download the Data File for each Spin

Download the Global GDR Strenght Function

Download the Data File for GDR Strenght Function

MeanField4Exp: Acknowledgments

Experimental Advisory Team

Piotr Bednarczyk

Adam Maj

Michał Ciemała

Hardware and Web Assistance Team

Piotr Kędzierski

Zbigniew Natkaniec