New insights and new puzzles in low-energy fission

Systematic views and global analysis methods

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Layout

- Size of the heavy fragment in asymmetric fission (The unexpected role of Z=54)
- Prompt neutron yields (Evidence for energy sorting, “Maxwell's demon” on the nuclear level)
- Even-odd effect in fission yields (Dominated by the light fragment)
Fission-fragment mass and $Z$ distributions in low-energy fission

Asymmetric fission is strong from $A=226$ to $A=256$. 

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mass distributions
$+$ $Z$ distributions
$\times$ $Z$ distributions in inverse kinematics
Size of the heavy fragment in asymmetric fission - a refined analysis

Unik et al. (1973): $<A_H> \approx 140$.


Analysis on a finer scale: $<Z_H> \approx 54$.

Essential: long isotopic chains from GSI experiment.
Z=54 in the scission-point model

No indication for importance of Z=54 in the scission-point model.
Prompt-neutron yields - energy dependence

Additional excitation energy appears in heavy fragment!
Energy sorting in fission

Scission configuration: 2 nuclei = 2 heat baths with constant (but different) temperatures ($T \sim A^{-2/3}$) and constant total energy in thermal contact. → Energy Sorting

Increased heat capacity due to pairing correlations:

$\rho \sim \exp(E/T)$ (constant nuclear temperature).


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Microscopic processes of energy sorting

Energy transport by particle exchange. 2nd order window formula.

Incomplete energy sorting. (No levels below the gs.)

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Phys. Rev. C 83 (2011) 061601(R)
Even-odd effect in Z yields

Asymmetry-driven even-odd effect: final stage of energy sorting.
New insight into saddle-scission dynamics with the framework of thermodynamics

Experimental signatures:
- prompt neutron yields
- even-odd effect

reveal time scale of different dynamical processes on the descent from saddle to scission.

Even-odd effect in fission is a new kind of nuclear clock which links heat transfer through the neck in the regime of strong pairing correlations with the saddle-to-scission time (building up of an inhibitive Coulomb barrier in the neck).
Conclusion

Systematic analysis of available experimental data and application of general principles of statistical mechanics give new insight into nuclear-structure phenomena in low-energy fission.

Constant position at \( Z=54 \) will be a stringent test for microscopic models.

Evidence for energy sorting from prompt-neutron yields and asymmetry-driven even-odd effect in fission-fragment \( Z \) yields is (qualitatively) explained by statistical mechanics.

Signatures of energy sorting provide a new kind of nuclear clock for the fission process.

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GEFY data base: www.khs-erzhausen.de / http://www.cenbg.in2p3.fr/GEFY