True ternary fission of superheavy nuclei

- **Clusterization and shape isomeric states of heavy nuclei**
- **Ternary fission of superheavy nuclei**
- **Ternary quasi-fission of giant nuclear systems**
- **Summary and hint at experiments**

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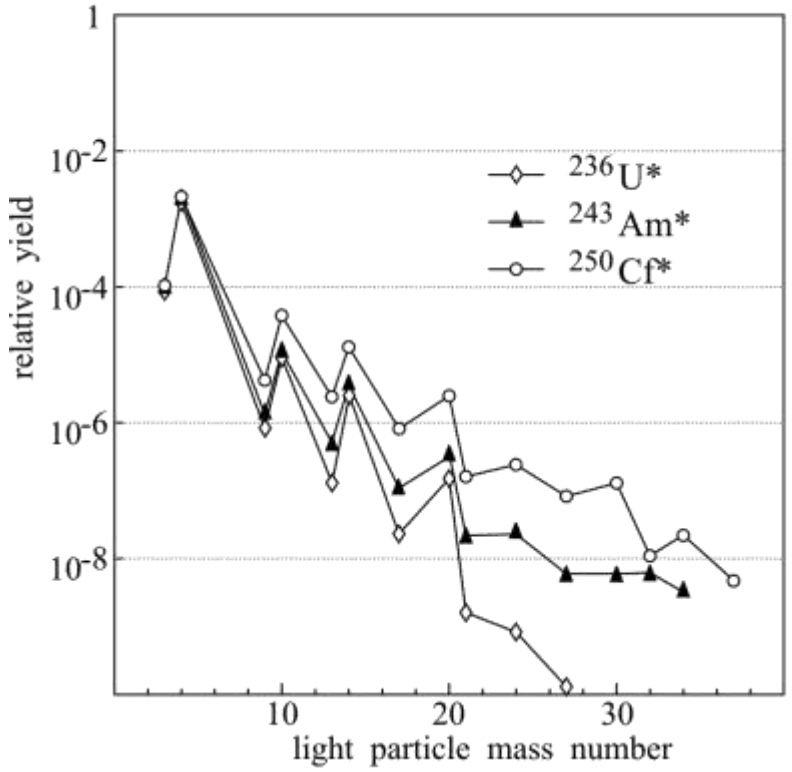
for Seminar on Fission VII, Het Pand, 20 May 2010

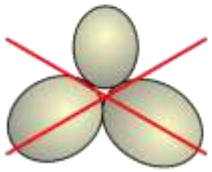
LP accompanied fission and True ternary fission

Yields of **ternary particles** in the (n_{th}, f) reactions with thermal neutrons (relative to binary fission).
F. Gönnenwein et al., *Seminar on Fission: Pont D'Oye IV*



True ternary fission:
"a simultaneous decay of a heavy nucleus into three fragments of not very different mass".
[C. Wagemans, in *The Nuclear Fission Process*]
Such decays of low excited heavy nuclei have not yet been unambiguously observed.

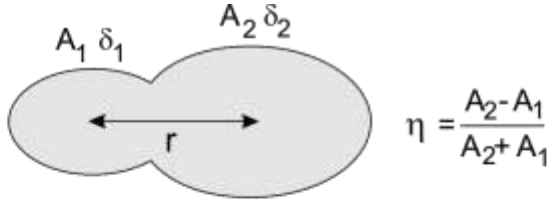
History:
W. J. Swiatecki, *Int.Conf.on Peaceful Uses of At.Energy, Geneva, 1958.*
H. Diehl and W. Greiner, *Nucl. Phys. A* ***229****, 29 (1974).*
A. R. Degheidy and J. A. Maruhn, *Z. Phys. A* ***290****, 205 (1979).*
H. Schulheis and R. Schulheis, *Phys. Lett. B* ***49****, 423 (1974).*
X. Wu, J. Maruhn, and W. Greiner, *J. Phys. G* ***10****, 645 (1984).*



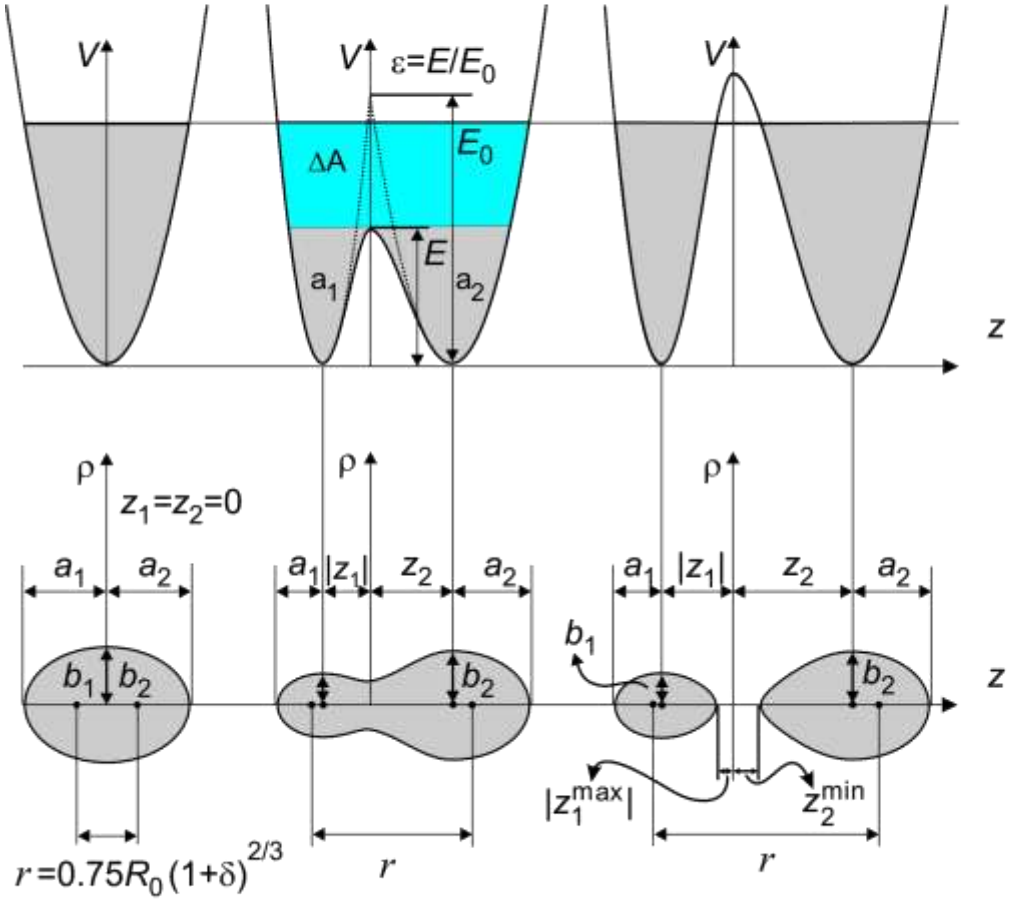
oblate (triangle)

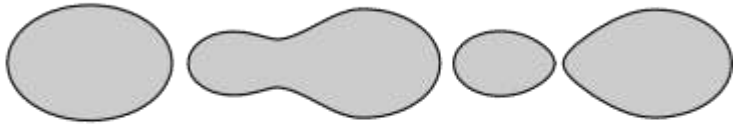
prolate

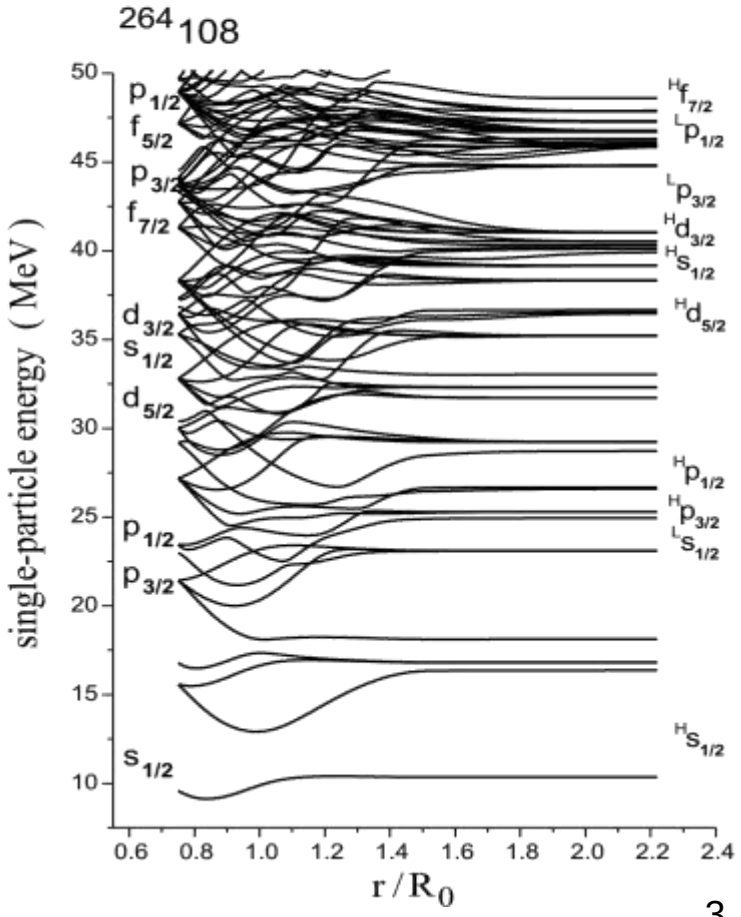
Two-Center Shell Model



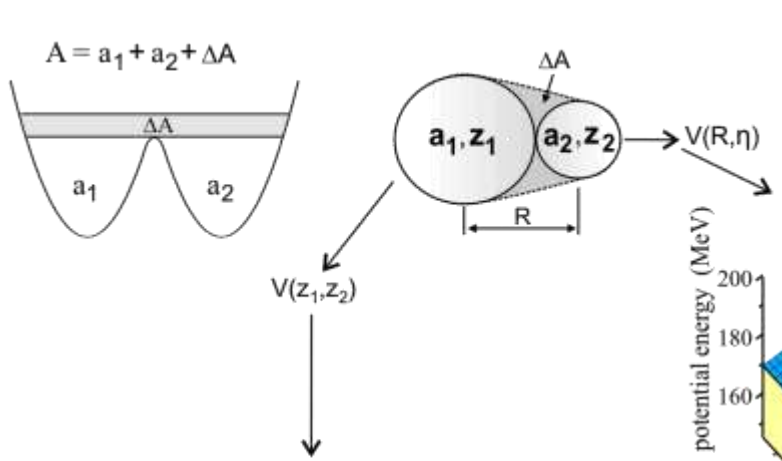
$$\eta = \frac{A_2 - A_1}{A_2 + A_1}$$

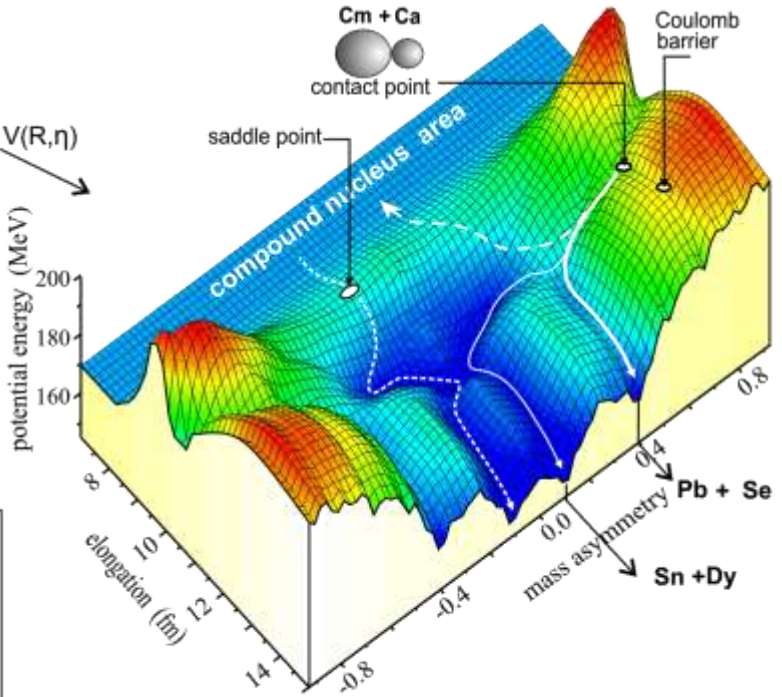


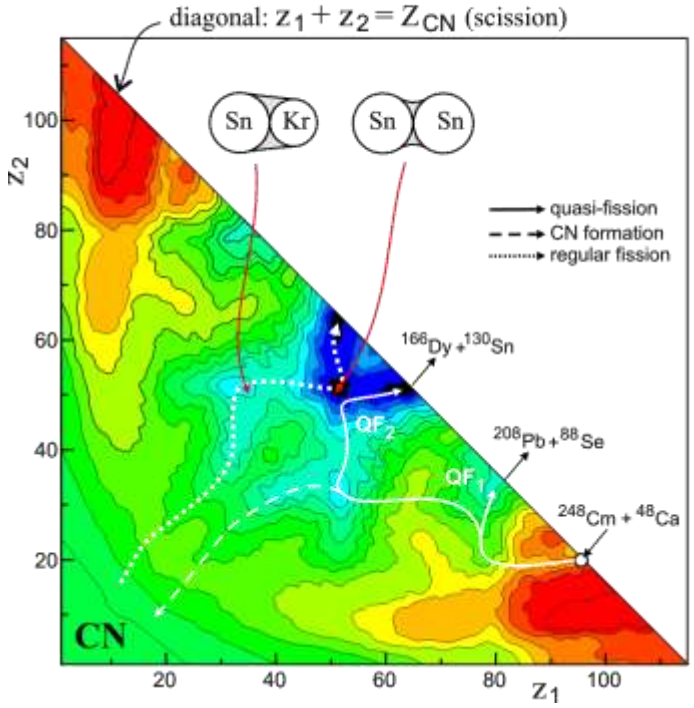


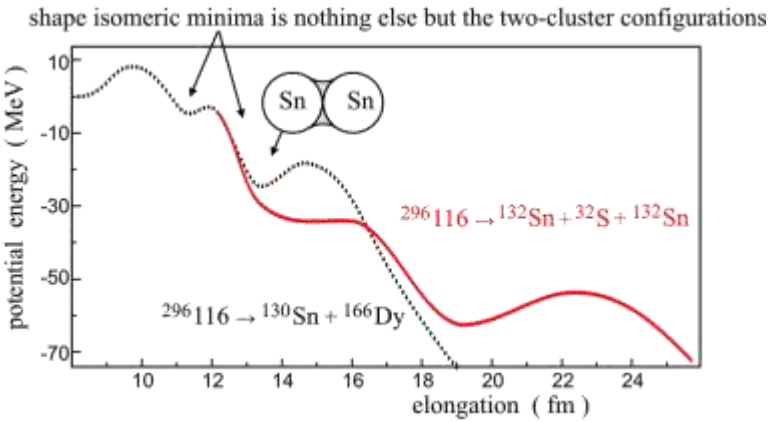


Clusterization and shape isomeric states of heavy nuclei

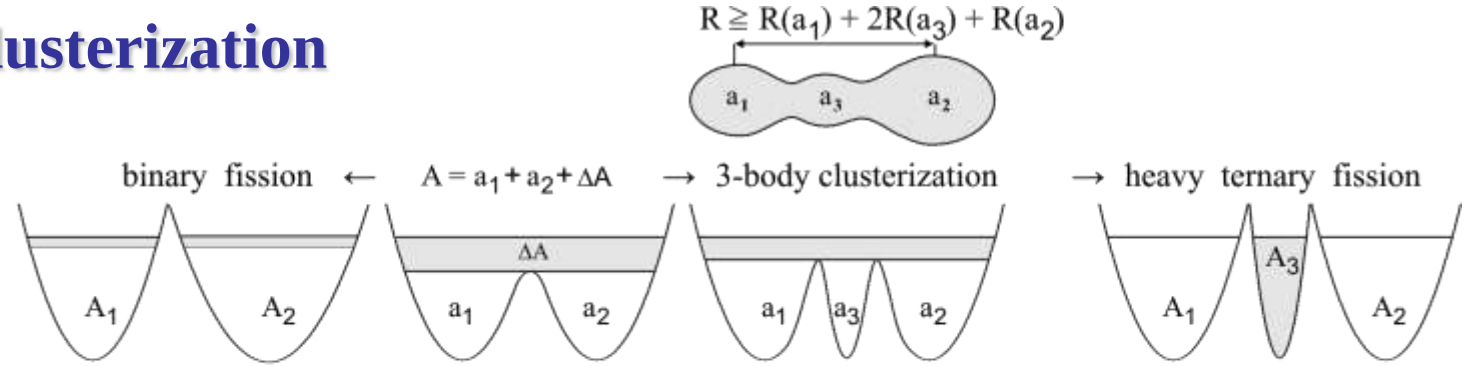


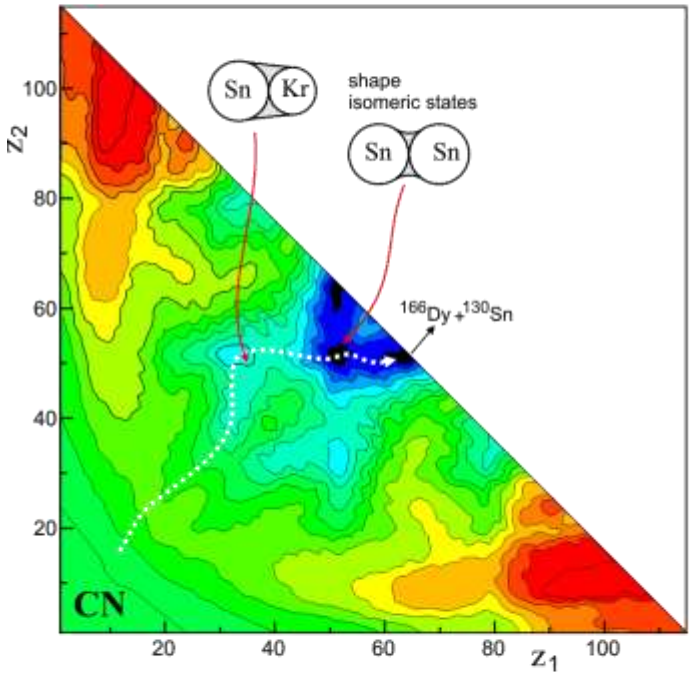


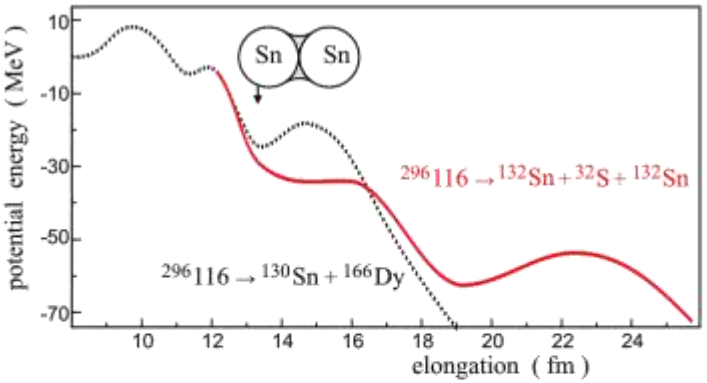


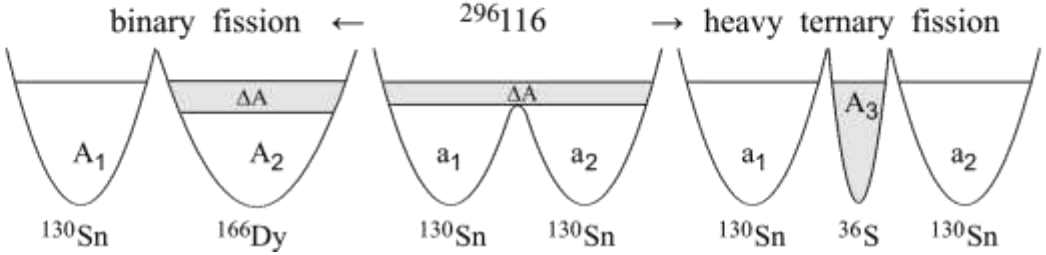


3-body clusterization





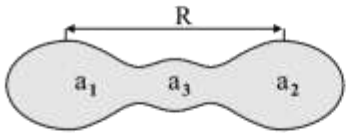




Ternary fission of actinide nuclei is impossible

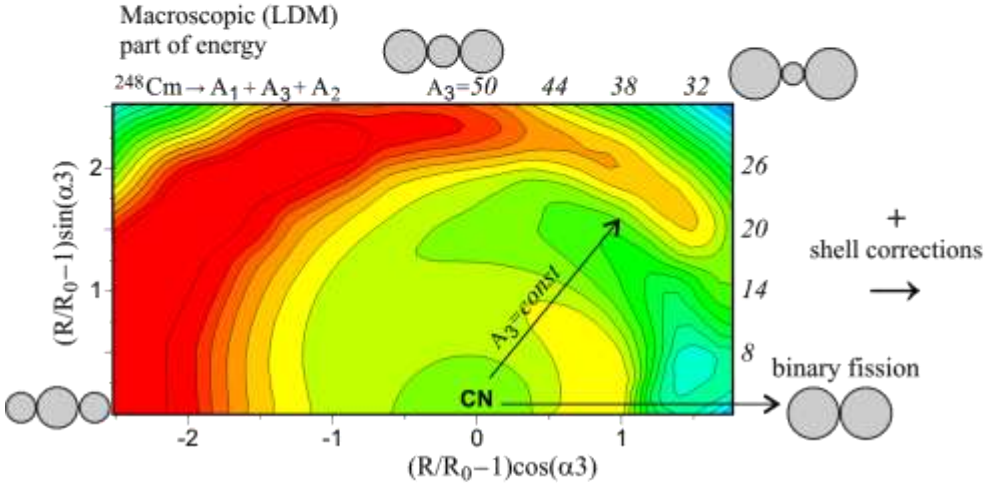
Restrictions: $a_1 = a_2$ and, thus, $A_1 = A_2$

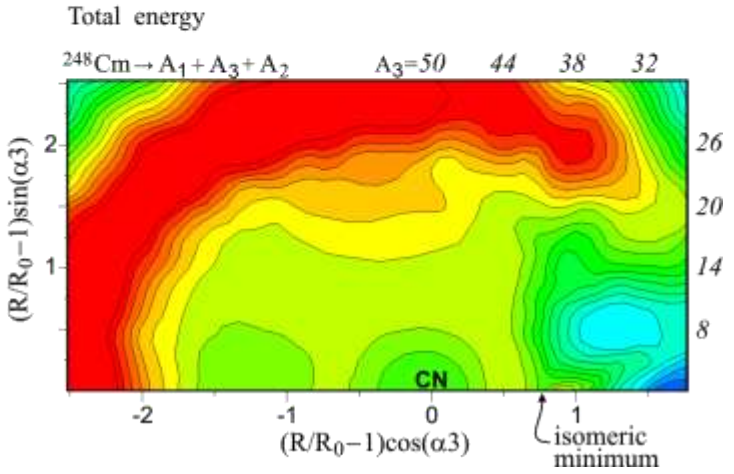
$\delta_1 = \delta_2 = \delta_3 = \delta$



$V(R, A_3, \delta)$

$\alpha_3 = \pi \frac{A_3}{100}$

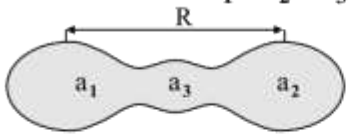




True ternary fission is possible for superheavy nuclei !

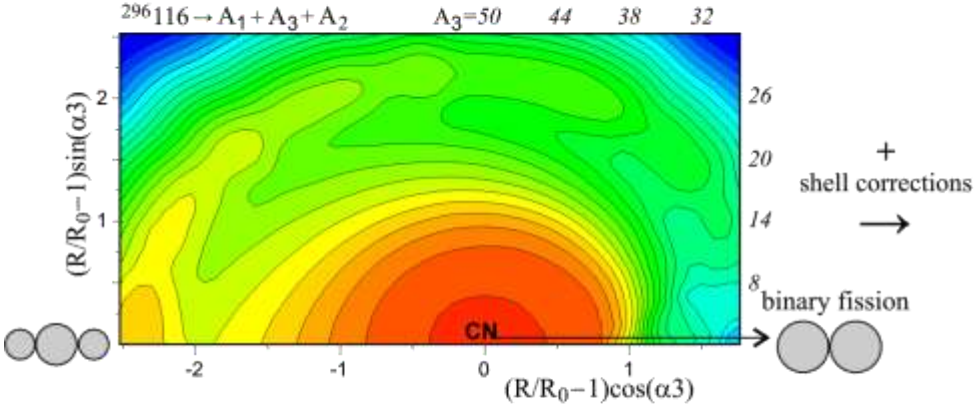
Restrictions: $a_1 = a_2$ and, thus, $A_1 = A_2$

$\delta_1 = \delta_2 = \delta_3 = \delta$



$V(R, A_3, \delta)$ $\alpha_3 = \pi \frac{A_3}{100}$

Macroscopic (LDM) part of energy

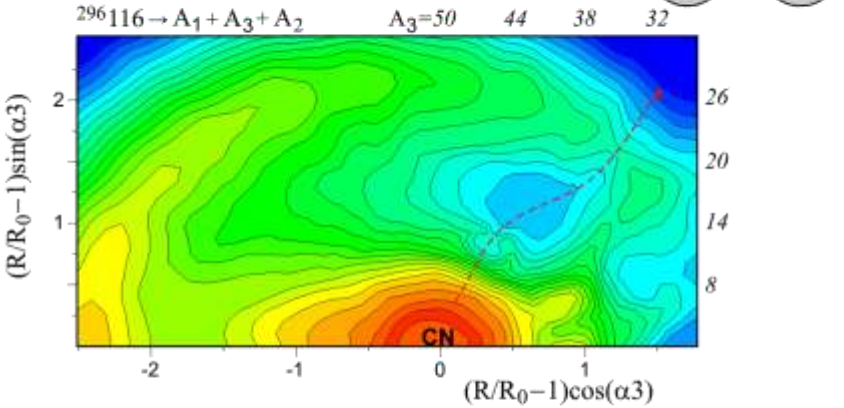


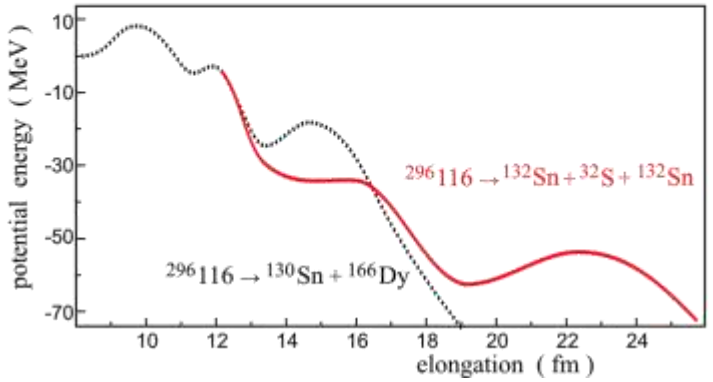
\+ shell corrections →

binary fission

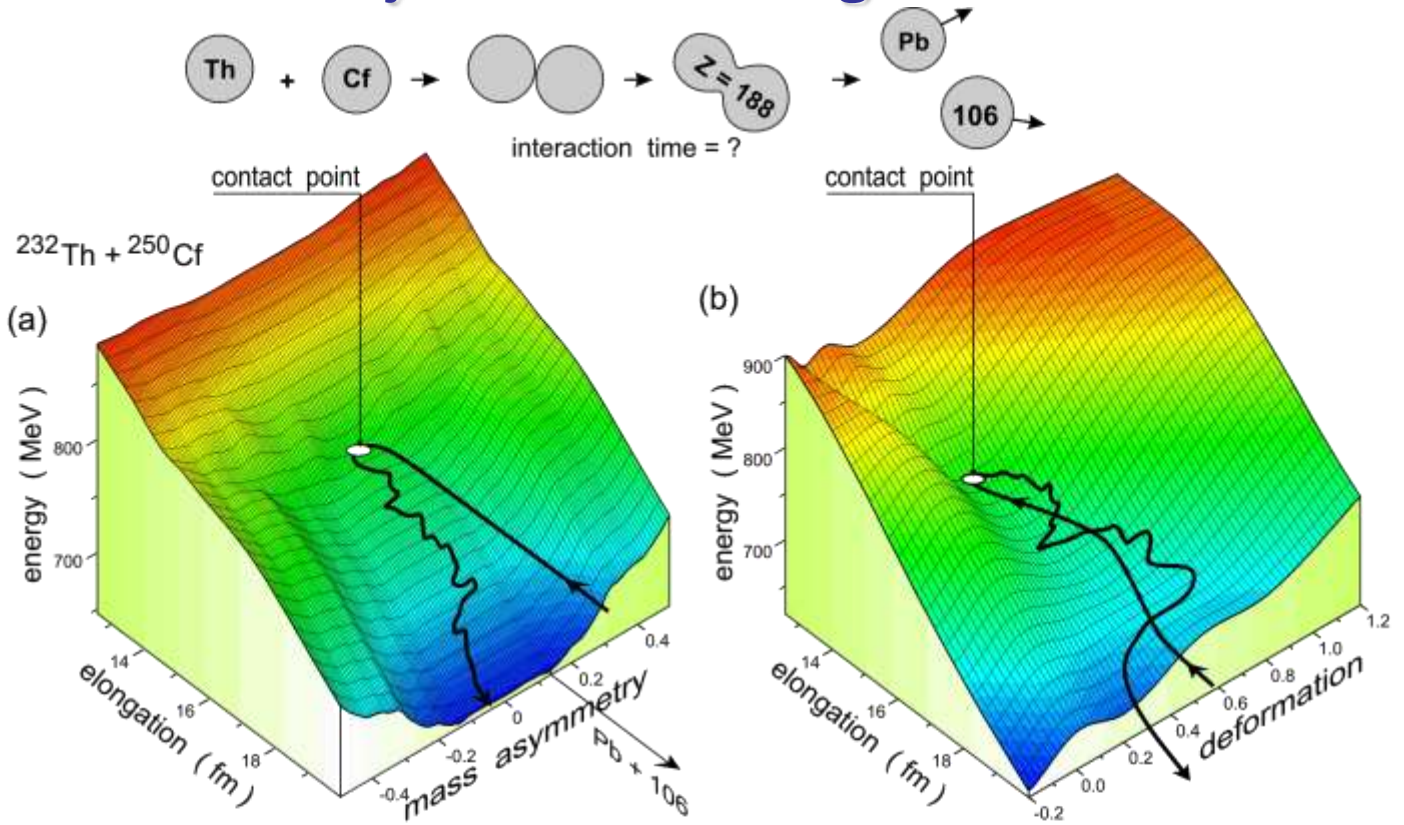
Total energy

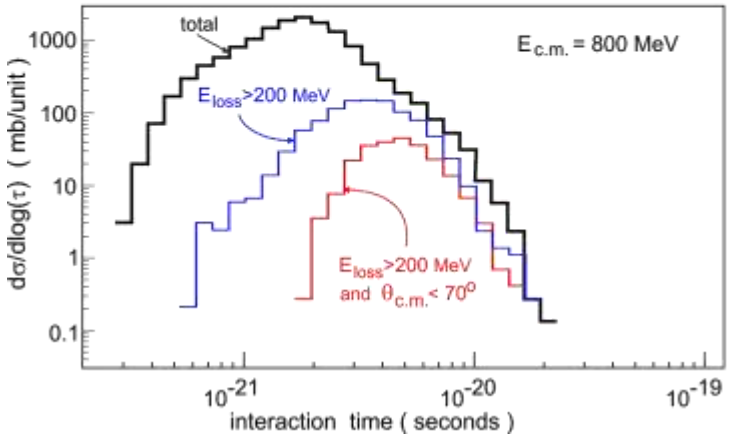
296116 → 132 32 132

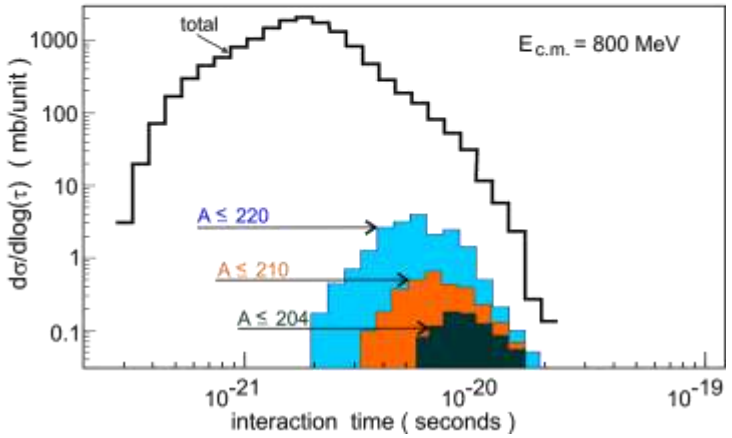




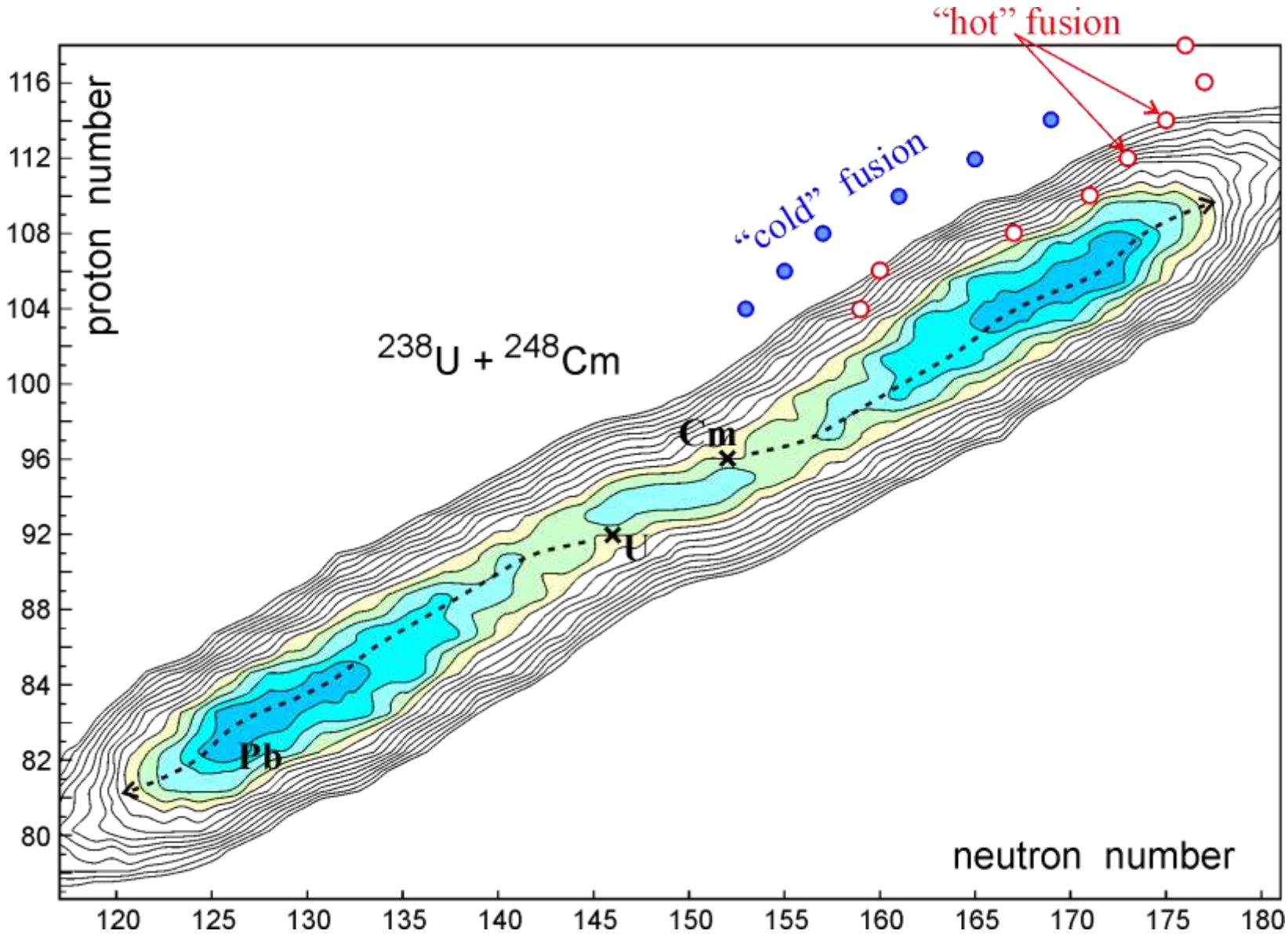
Giant nuclear systems: how long is reaction time?



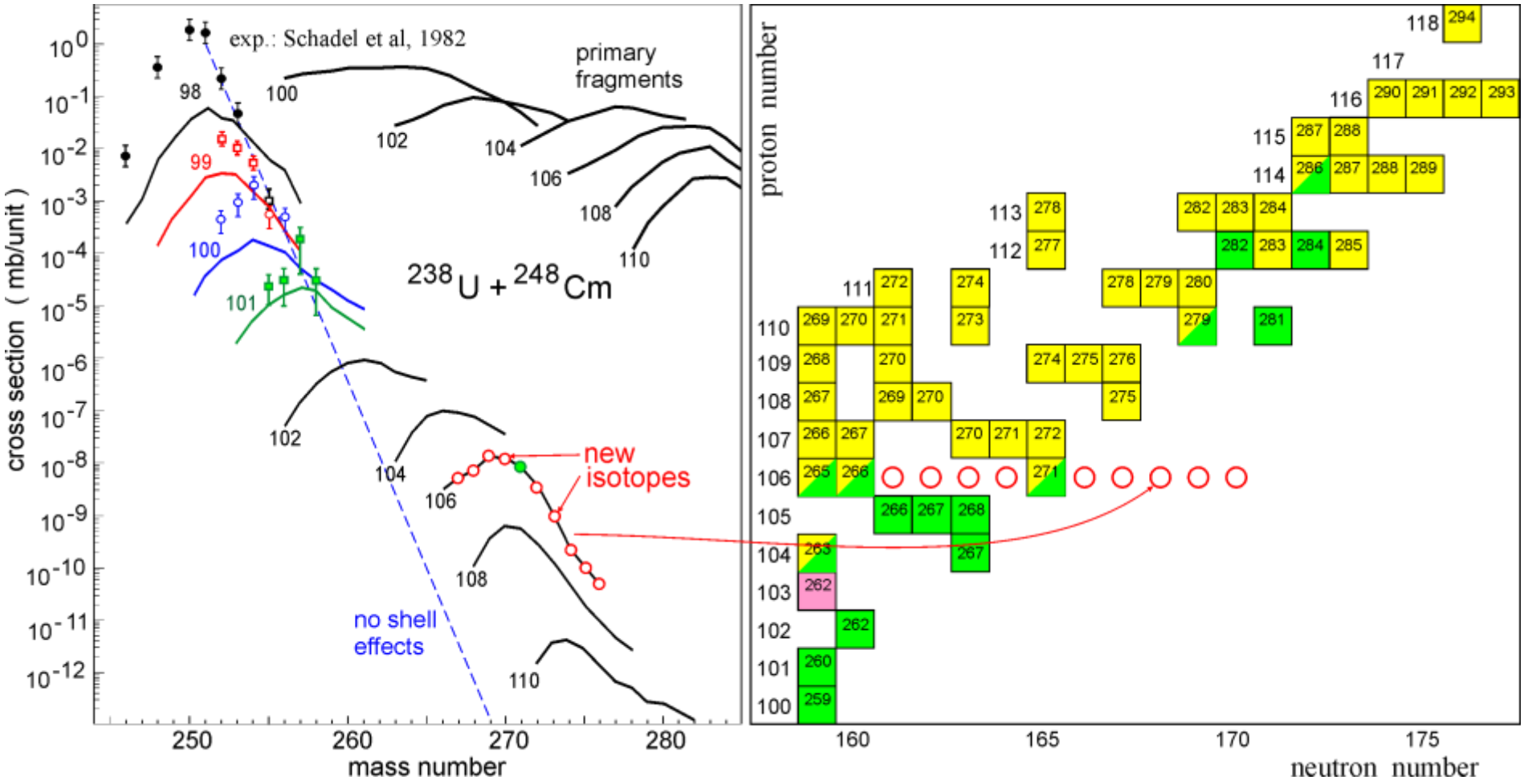




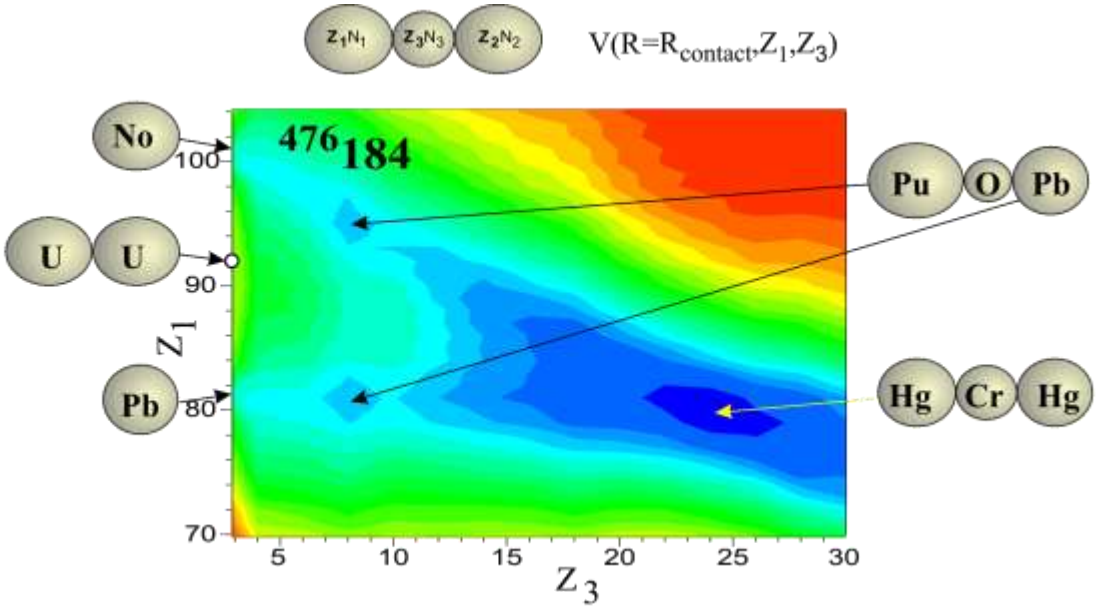
Giant nuclear systems: transfer reactions and production of SHE

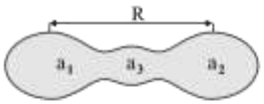


Production of neutron-rich SHE in low-energy collisions of heavy actinide nuclei

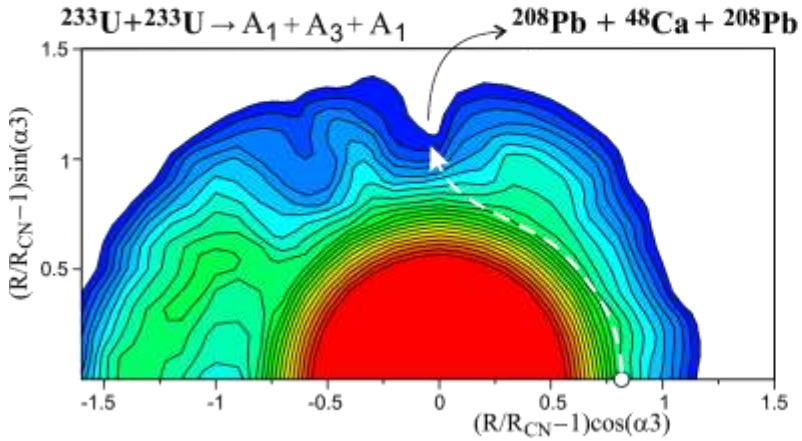


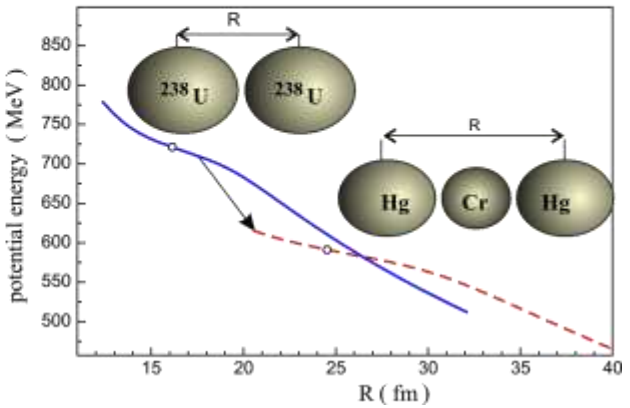
Ternary Quasi-Fission of giant nuclear systems





$V(R,A_3,\delta)$ $\alpha_3 = \pi\frac{A_3}{100}$





Summary

1. **There are only two real heavy nuclear clusters, tin and lead.**
2. **Actinide nuclei have insufficient mass to split onto three heavy clusters.**
3. **Superheavy nuclei have a real chance to split onto tin + something + tin.**
4. **Giant nuclear molecules may decay onto lead + something + lead.**

Two (rather simple) experiments: (1) **Ni + U → Sn + Ca + Sn** (true ternary fission)
(2) **U + U → Pb + Ca + Pb** (true ternary quasi-fission)

Co-authors: Alexander Karpov (Dubna) and Walter Greiner (Frankfurt): *PRC* ***81****, 044608 (2010)*