News from TDHF

Collaborators	
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Topics *(both concerned with transient states)*

- Density-constrained HF
- α-cluster structure and reactions

Density Constraint

Cusson, Reinhard, Maruhn, Strayer, Greiner, Z. Phys. A320, 475 (1985)

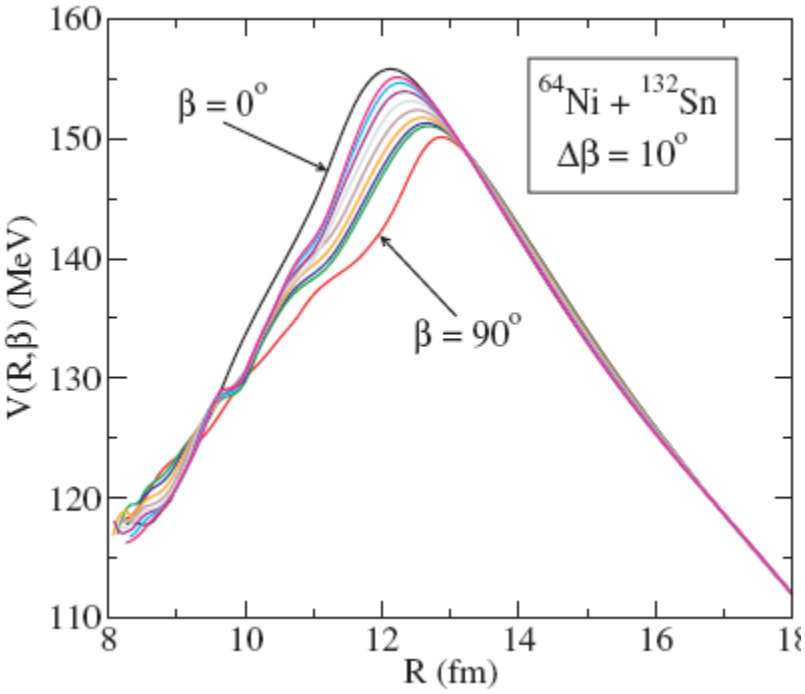
- Take time-dependent density from an unhindered *Skyrme-force* TDHF calculation
- Run static HF calculation with this density as a constraint.
- This produces a local minimal energy, which is associated to a potential V(R), where R is a suitable shape parameter
- The „potential“ thus obtained avoids the arbitrariness of typical constraints, but may be depend on the initial conditions and time
- It may also be used to define a *dynamic effective mass via*

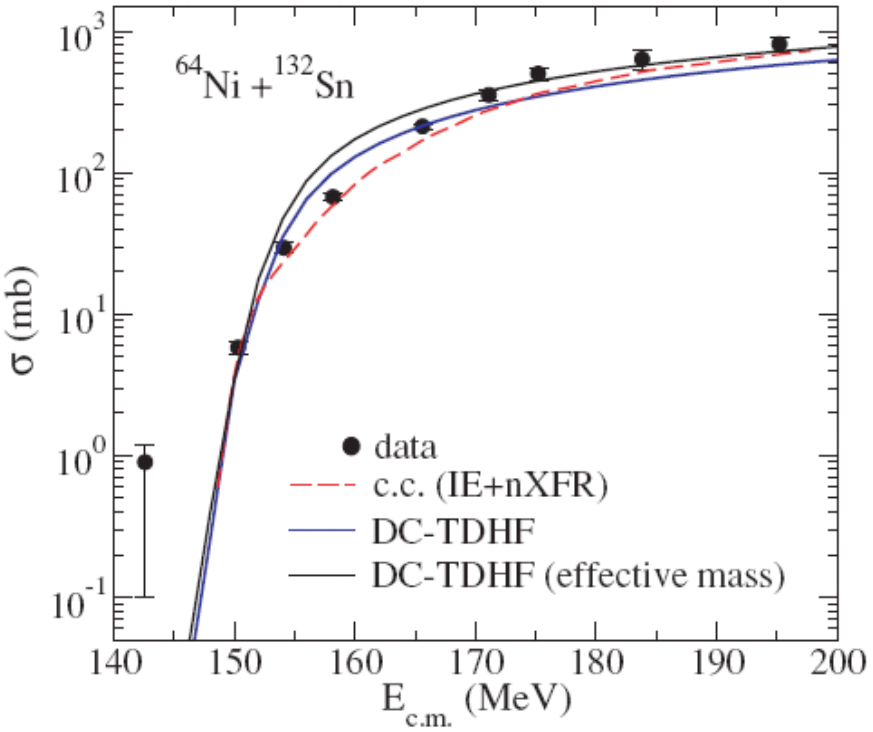
$$E_{cm} = \tfrac{1}{2} M(R)\,\dot{R}^2 + V(R)$$

  which eliminates the arbitrariness in the definition of R.
- In practice the potential was found to agree well with more phenomenological calculations and could be used to even describe sub-barrier effects.
- May also derive excitation energy via

$$E_{cm} = \frac{m}{2}\int \frac{j^2}{\rho}\,\mathrm{d}^3 r + V(r) + E^*$$

^{64}Ni + ^{132}Sn Fusion Cross-Section



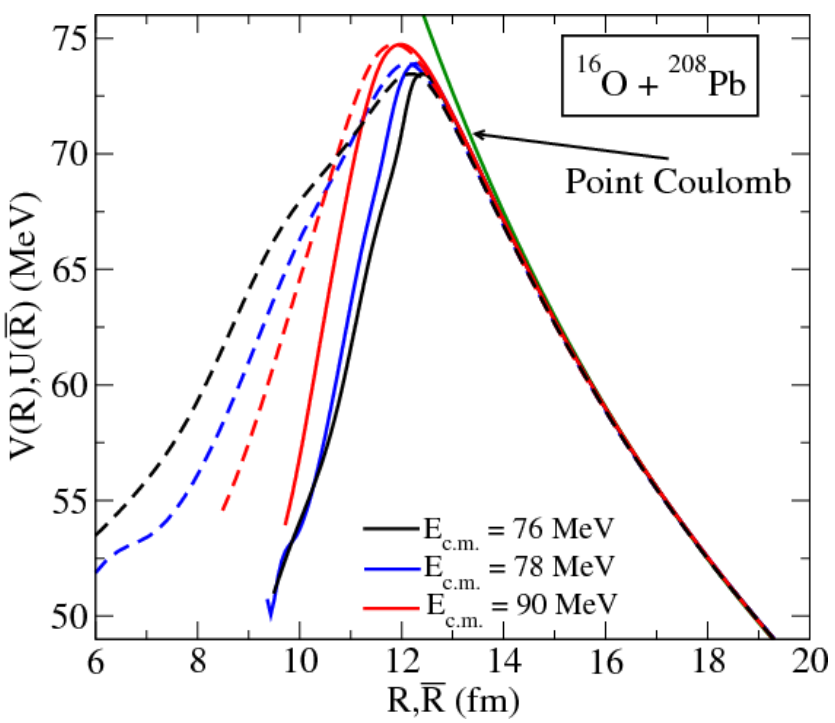


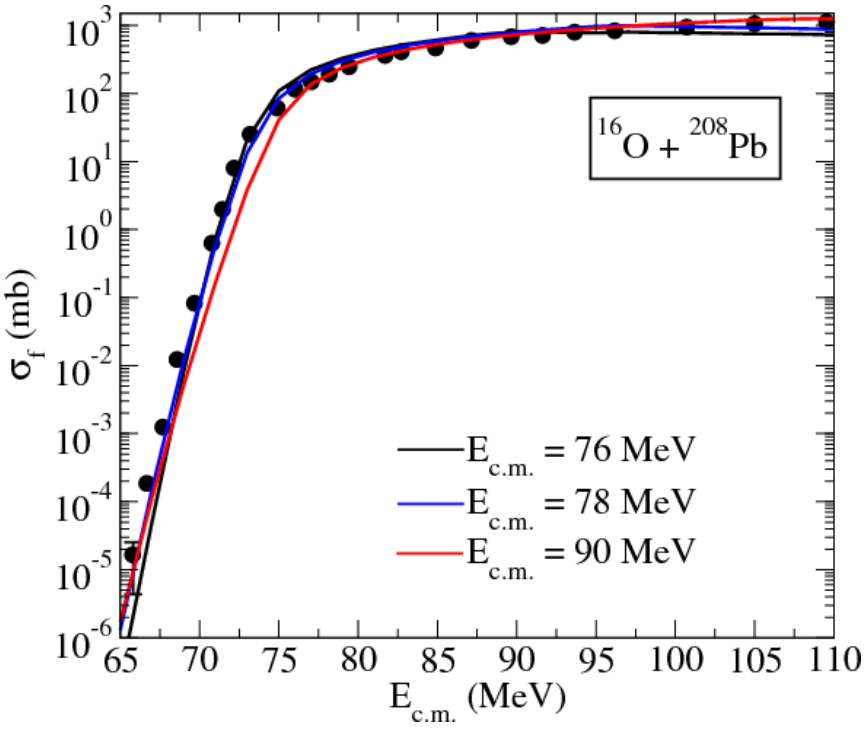
$$\sigma_f\left(E_{c.m.}\right) = \int_0^1 \mathrm{d}\cos(\beta) P(\beta) \sigma\left(E_{c.m.}, \beta\right)$$

Umar and Oberacker, *Phys. Rev. C* **76**, 014614 (2007)

Exp. Data and c.c.
J.F. Liang *et al.*,
PRL 91, 152701 (2003)
PRC 75, 054607 (2007)

$^{16}O + ^{208}Pb$ Fusion Cross-Section





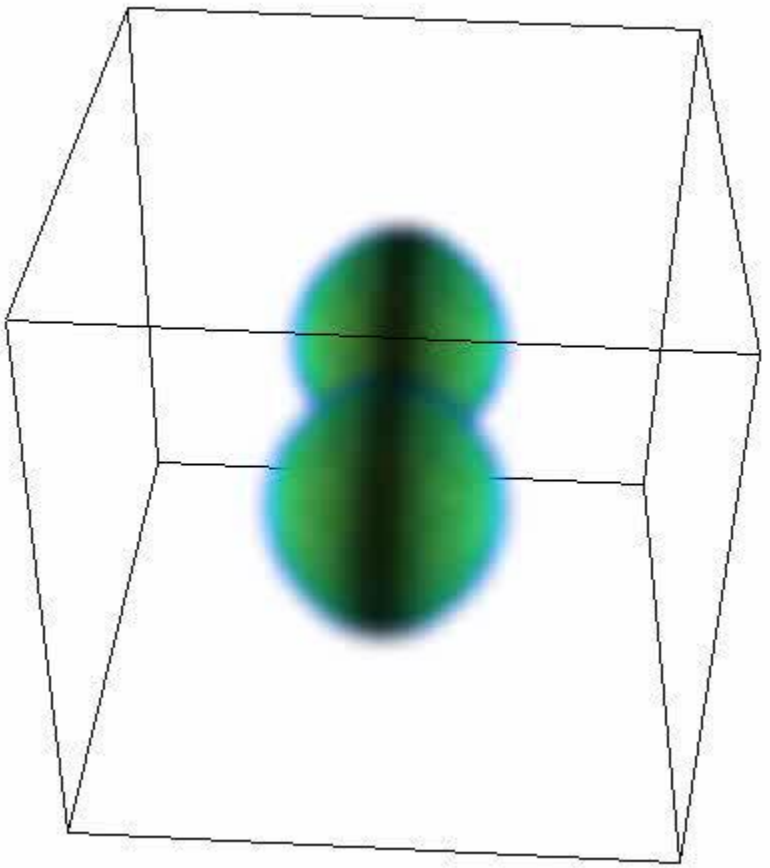
Umar, Oberacker, *EPJA* **39**, 243 (2009)
Exp. data from M. Dasgupta *et al*., Phys. Rev. Lett. **99,** 192701 (2007).

$^{238}U + ^{238}U$ (Paul Stevenson)

Sly6

E_{cm}=1200 MeV

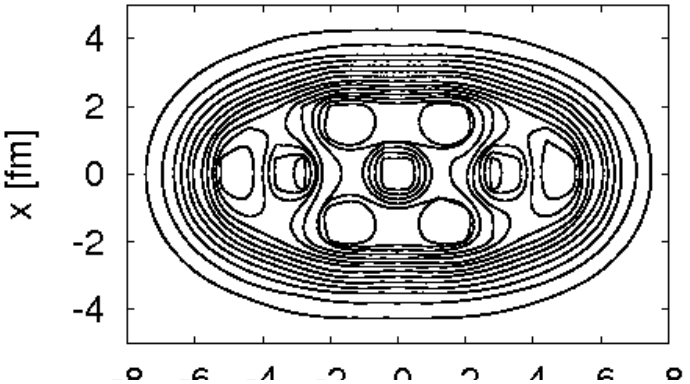
b=3 fm



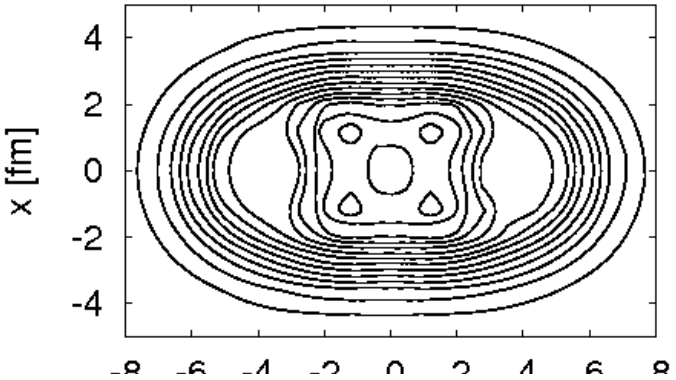
Fragment: A=59.1, Z=22.1, N/Z=1.67
Uranium: N/Z=1.59

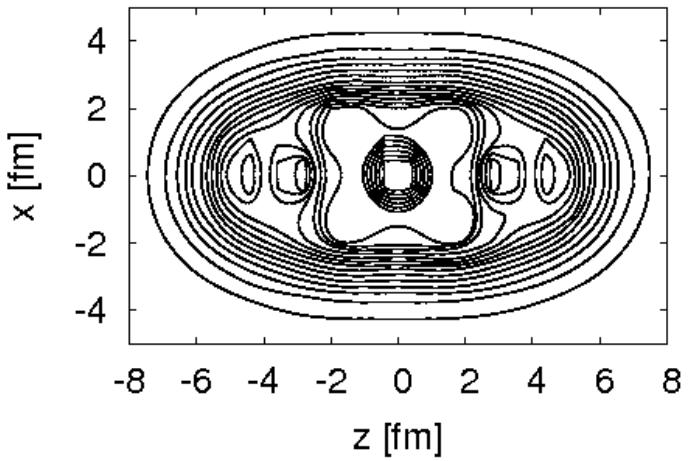
3α Chain Configurations in ^{20}C similar structures seen in ^{12}C and ^{16}C

SkI3

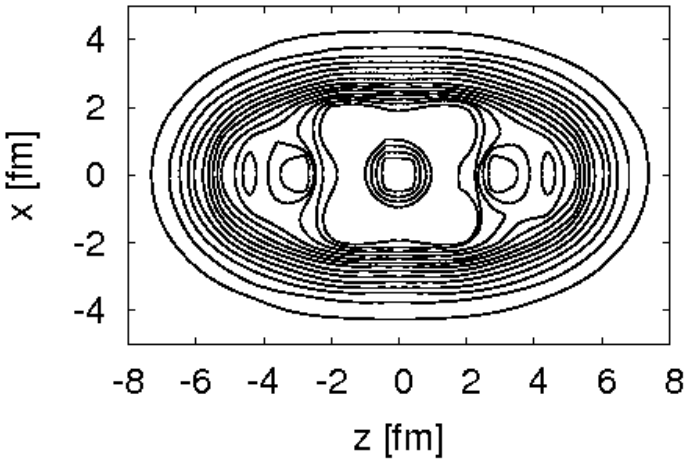


SkI4





Sly6



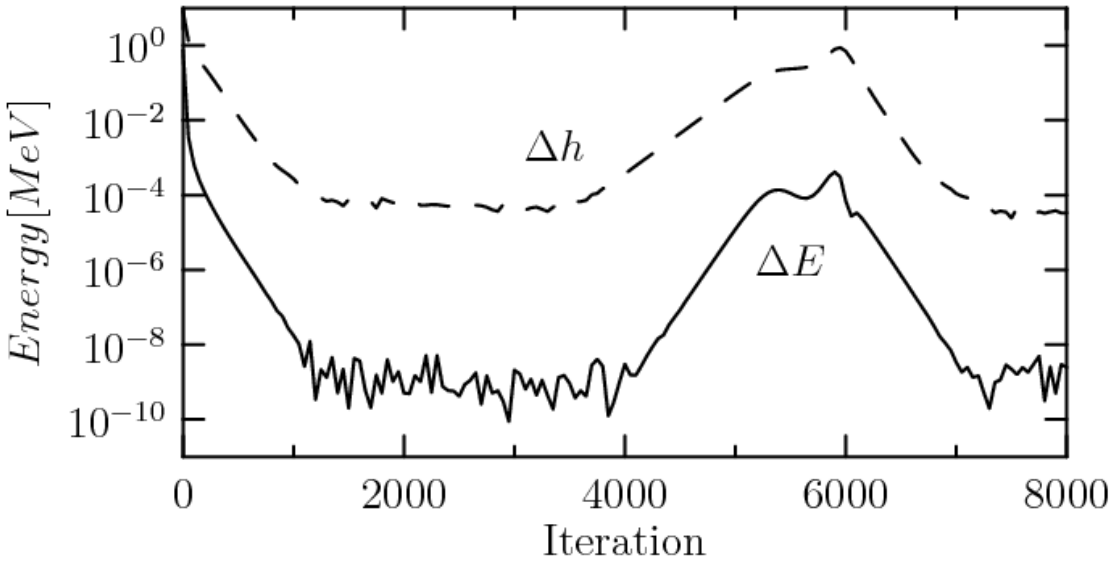
SkM*

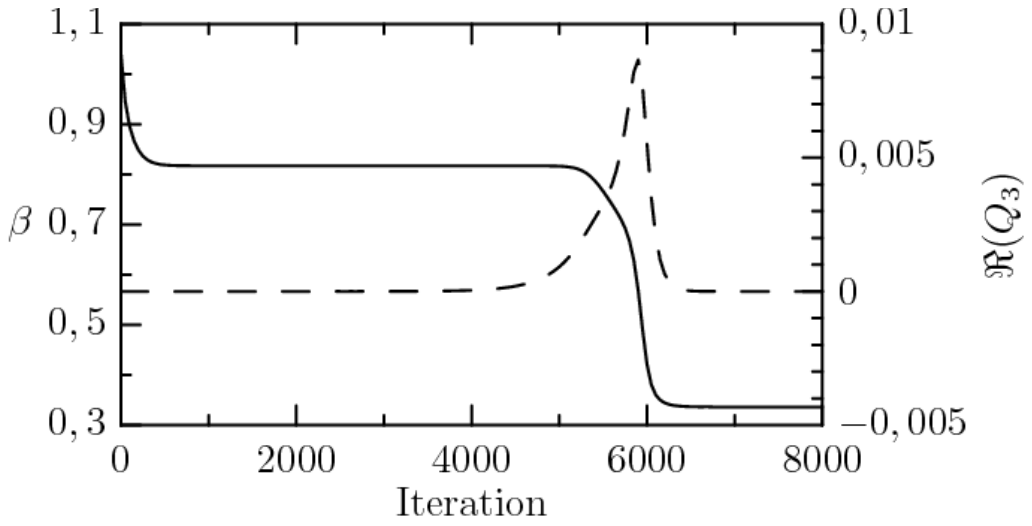
Convergence Behavior in Chain Configurations

Initializing with three Gaussian a‘s + molecular neutrons, an excited transitory state appears as an apparently converged configuartion for 1000‘s of iterations. Sometimes convergence indicators are as good as for the ground state.

$$\Delta h = \frac{1}{A}\sum_{k=1}^{A}\sqrt{\langle\phi_k \mid \hat{h}^2 \mid \phi_k\rangle - \langle\phi_k \mid \hat{h} \mid \phi_k\rangle^2}$$

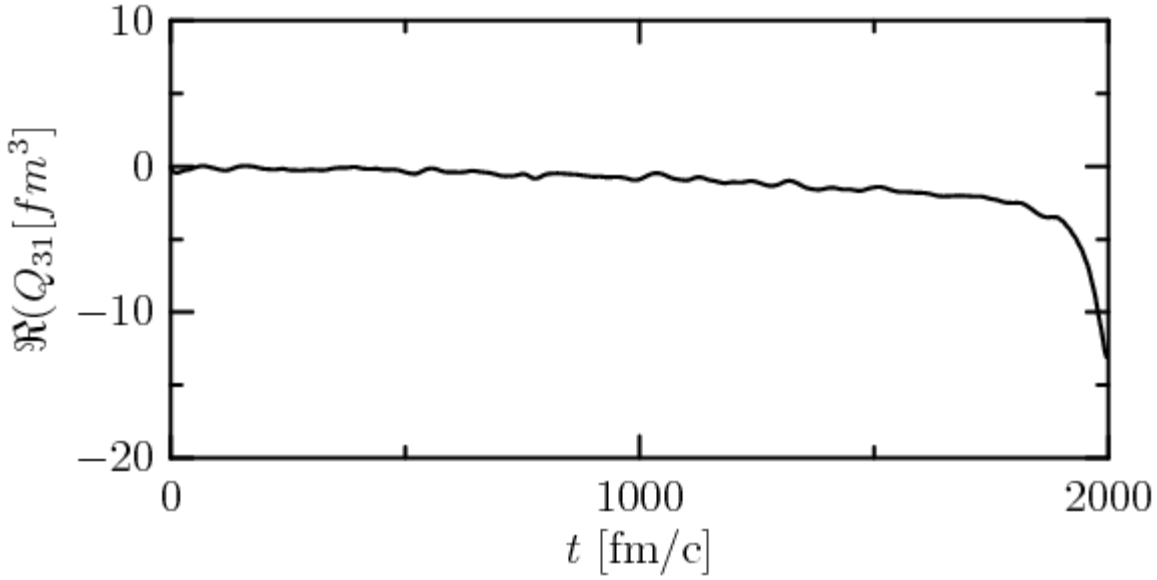
Subsequently, there is rapid conversion to the ground state via triaxial shapes.



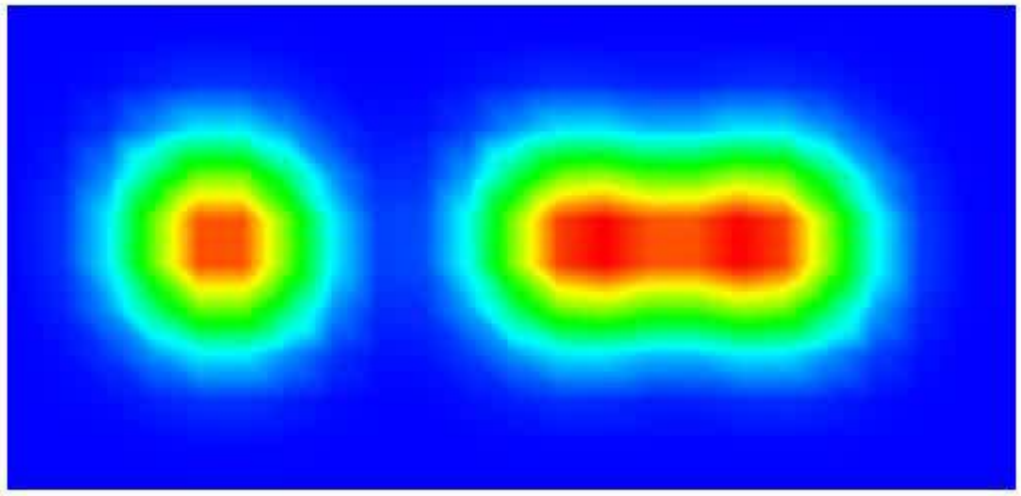


Properties

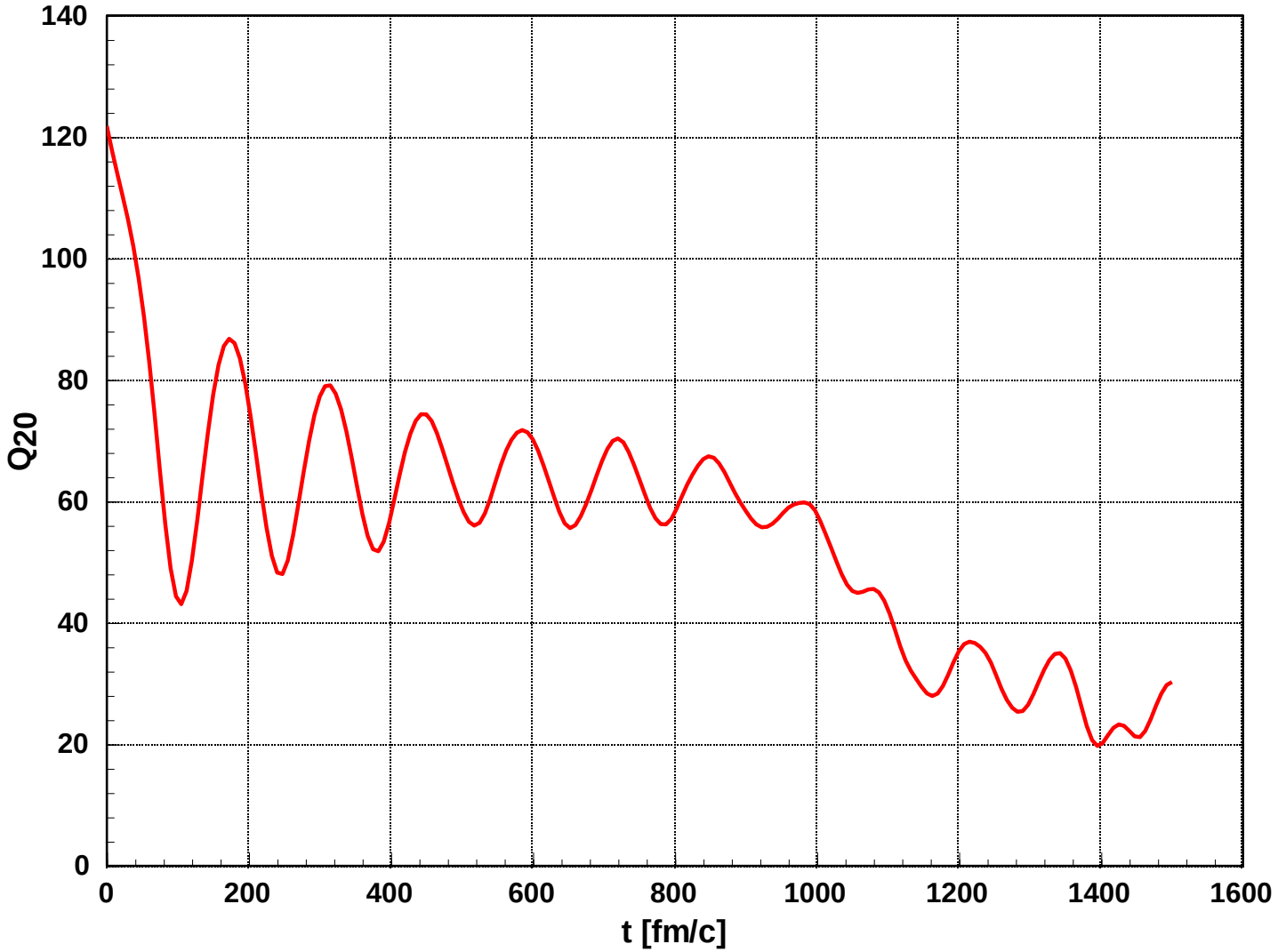
Force	$\Delta h \times 10^6$	n	E_B (g.s.)	E*	β_2
SkI3	21	>50000	113.37	14.48	0.851
SkI4	14	12000	108.11	14.71	0.824
Sly6	22	19000	109.73	14.95	0.837
SkM*	23	9000	128.67	17.06	0.823



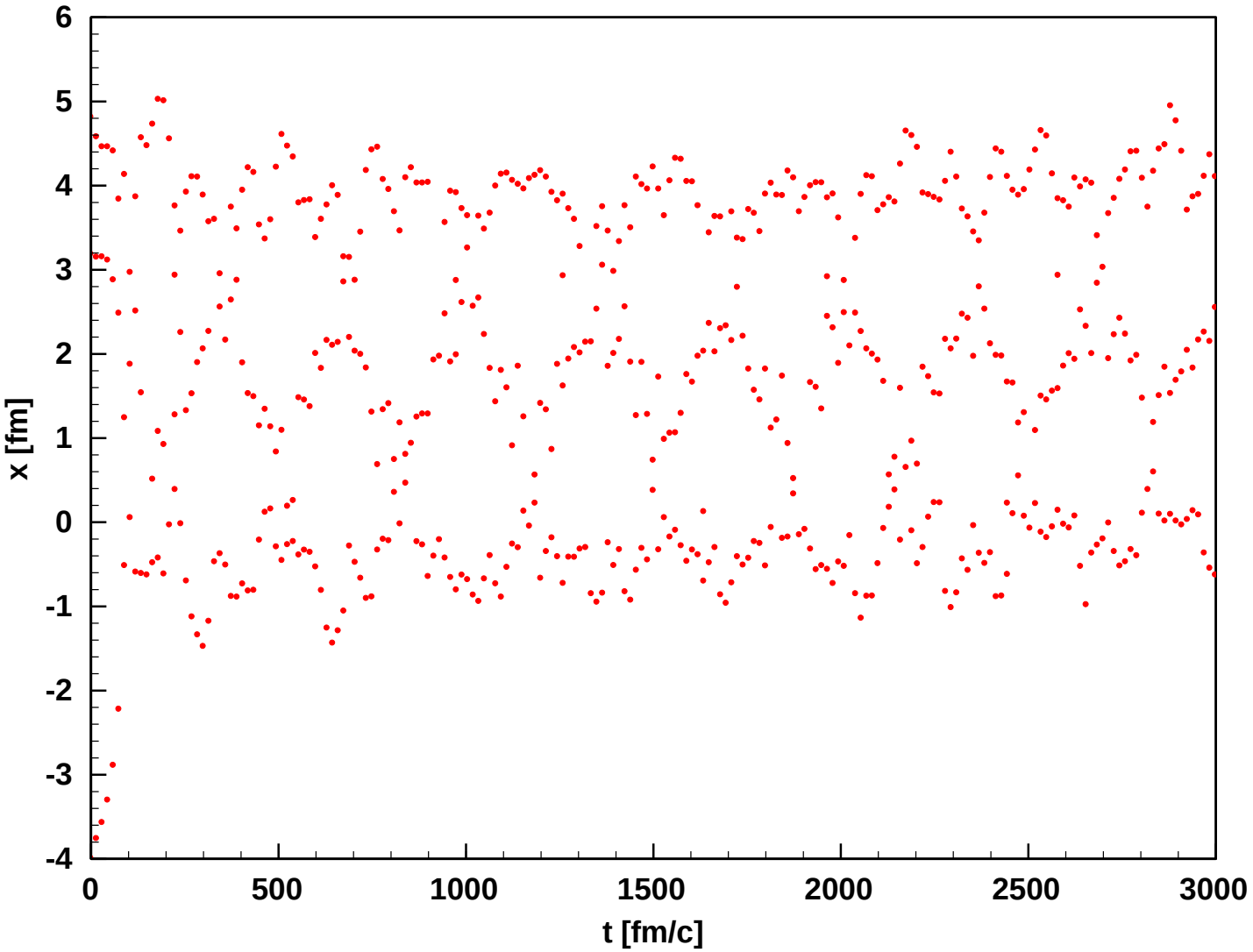
The Reaction $^{4}He + {}^{8}Be$
$b=0.2$ fm, $E_{cm}=2$ MeV



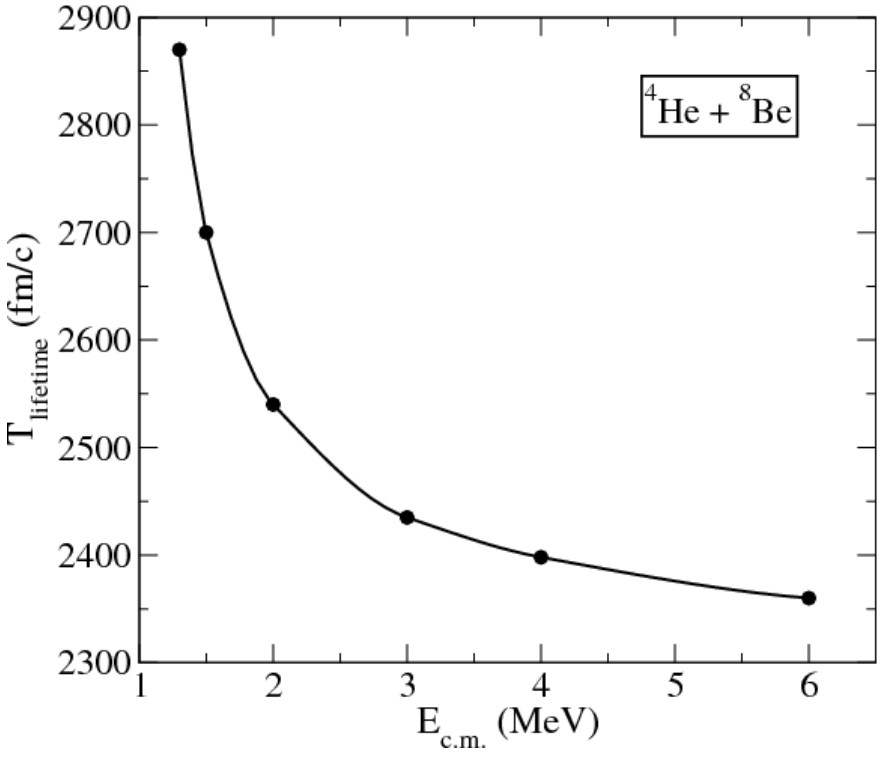
$Q_{20}(t)$ for b=0.2fm

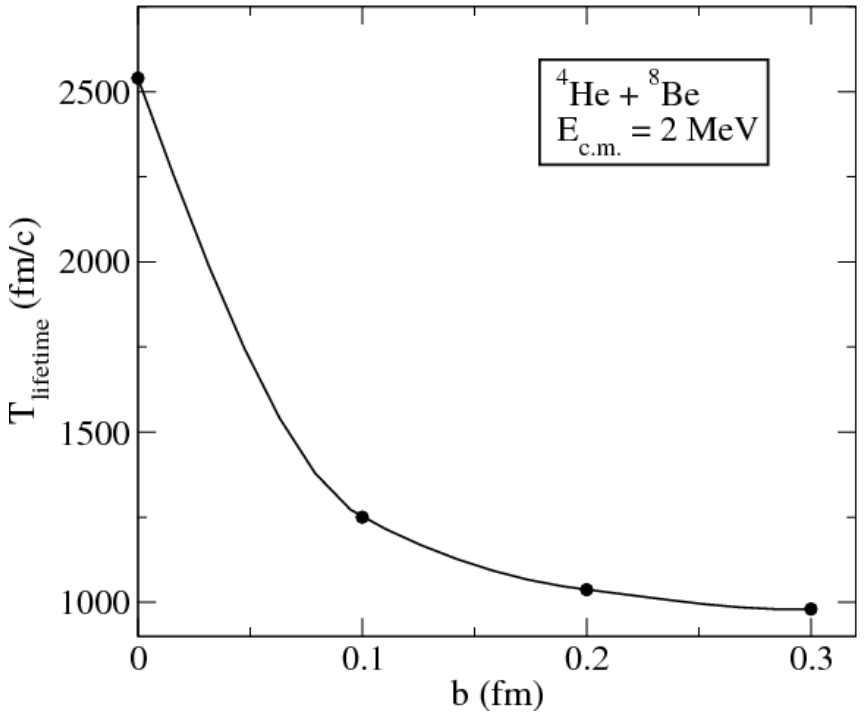


Positions of Density Maxima

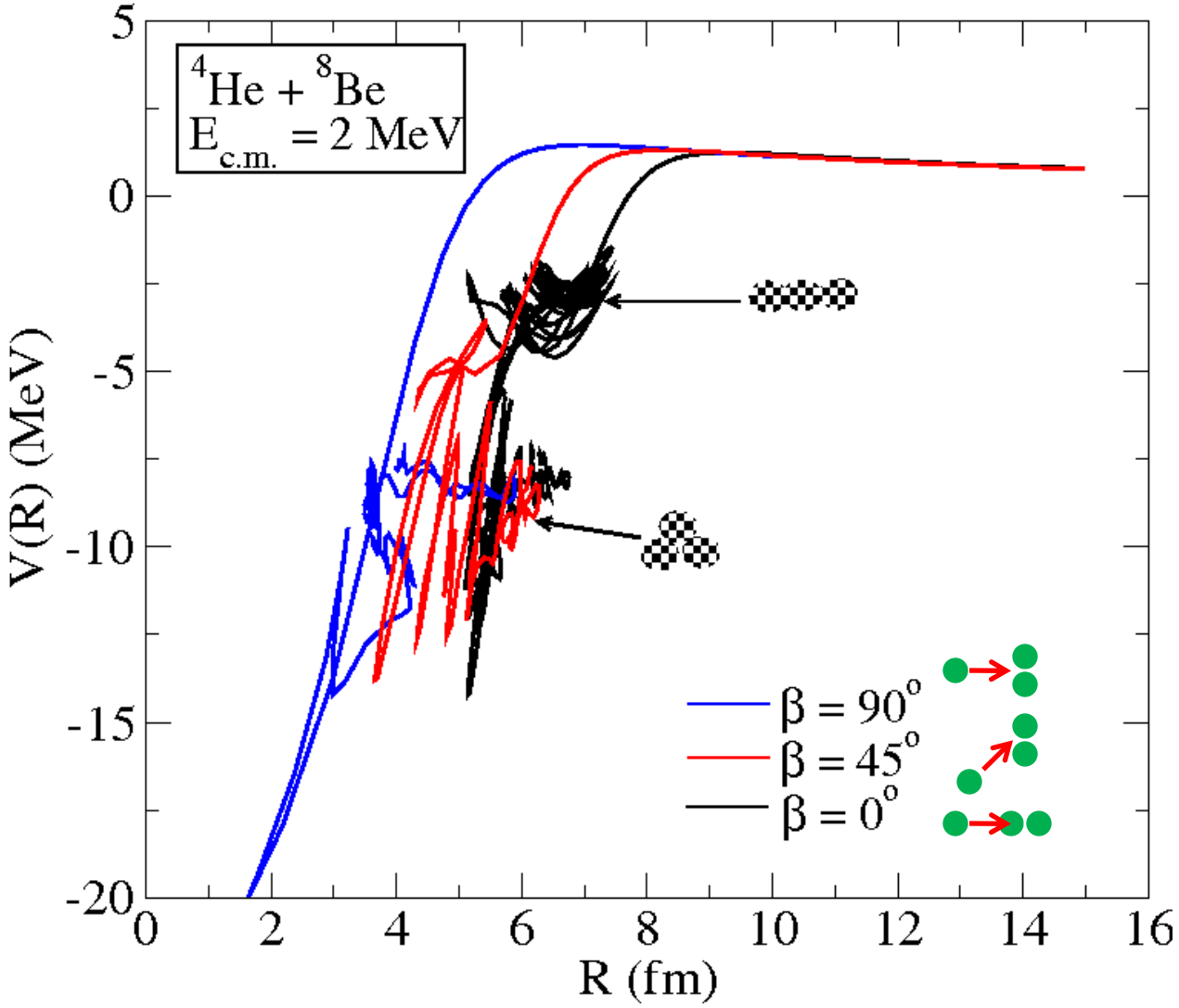


Dependence on b and E_{cm}



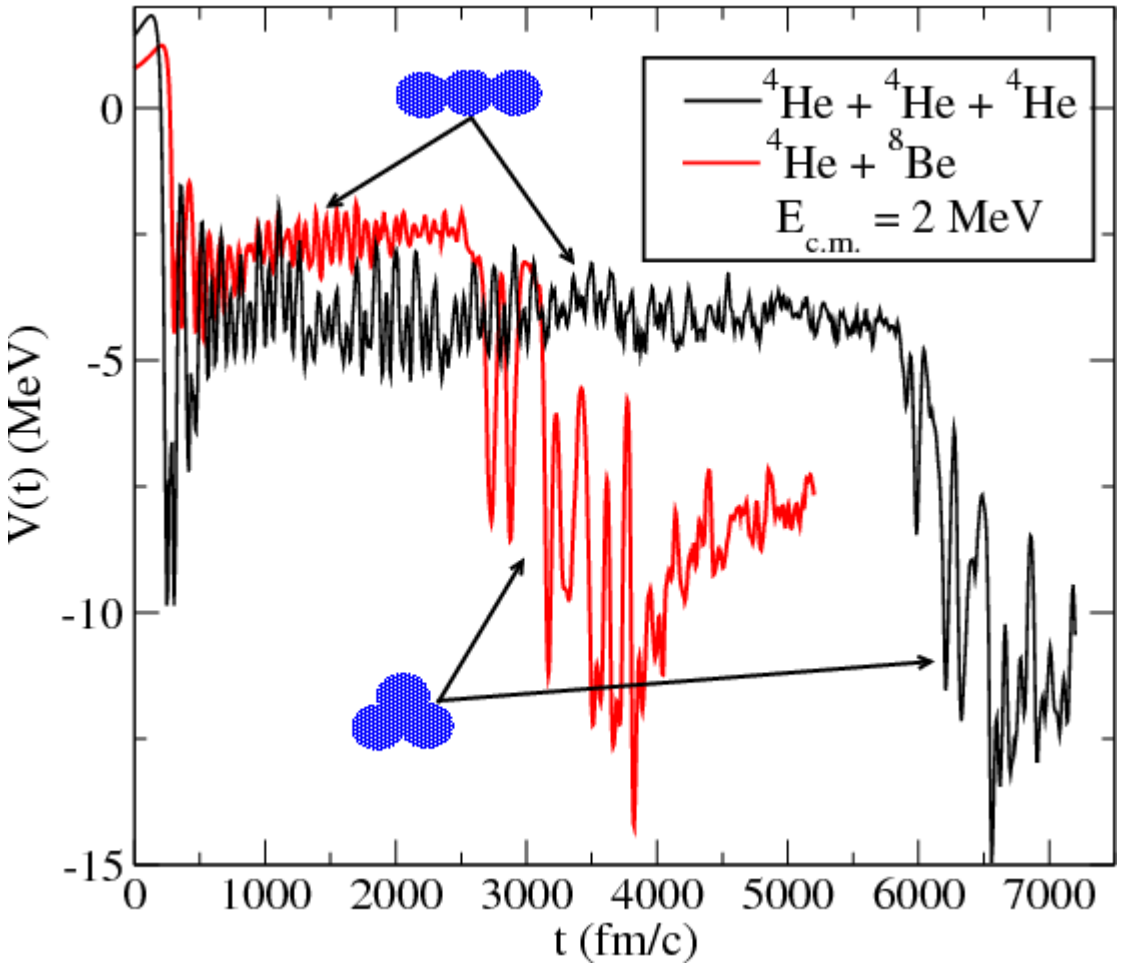


Density Constraint Potential shows Successive Mode Coupling



3α Collision

Comparison of Time Development

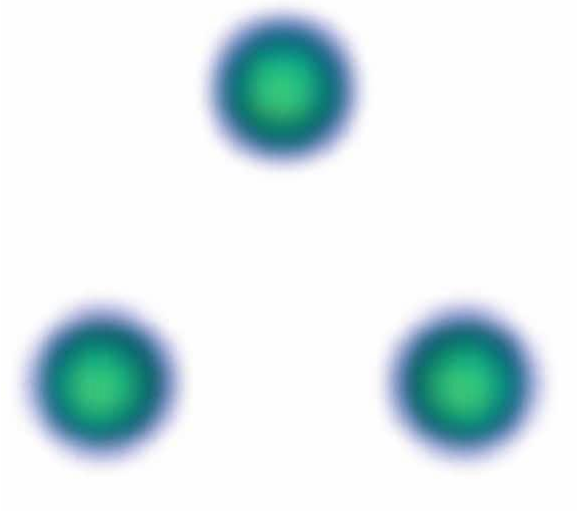


Variations in Triple-α (D. Forster)

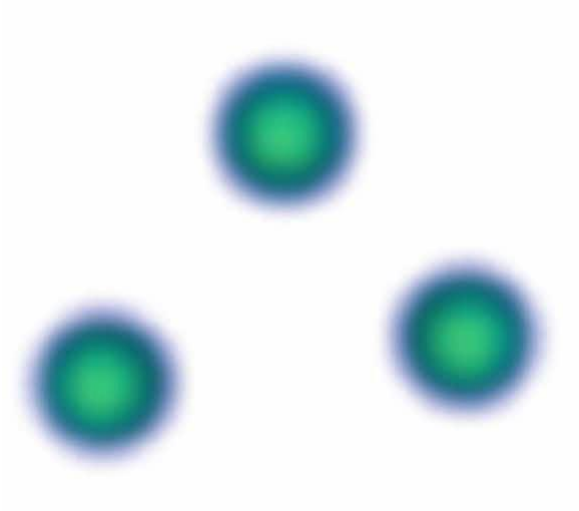
2 MeV

20 MeV

20 MeV

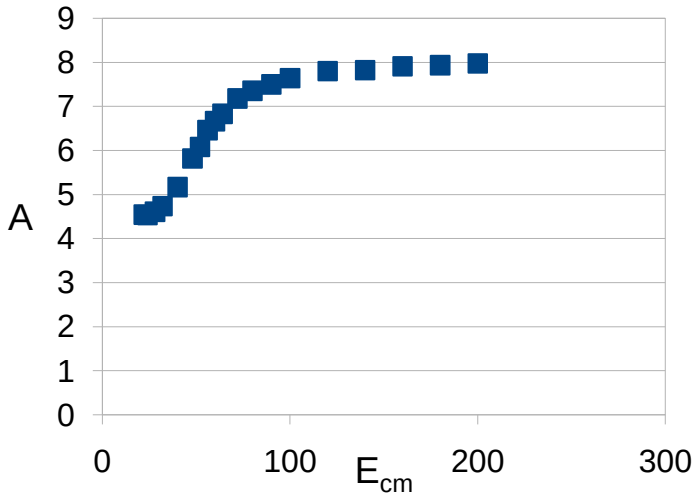


20 MeV



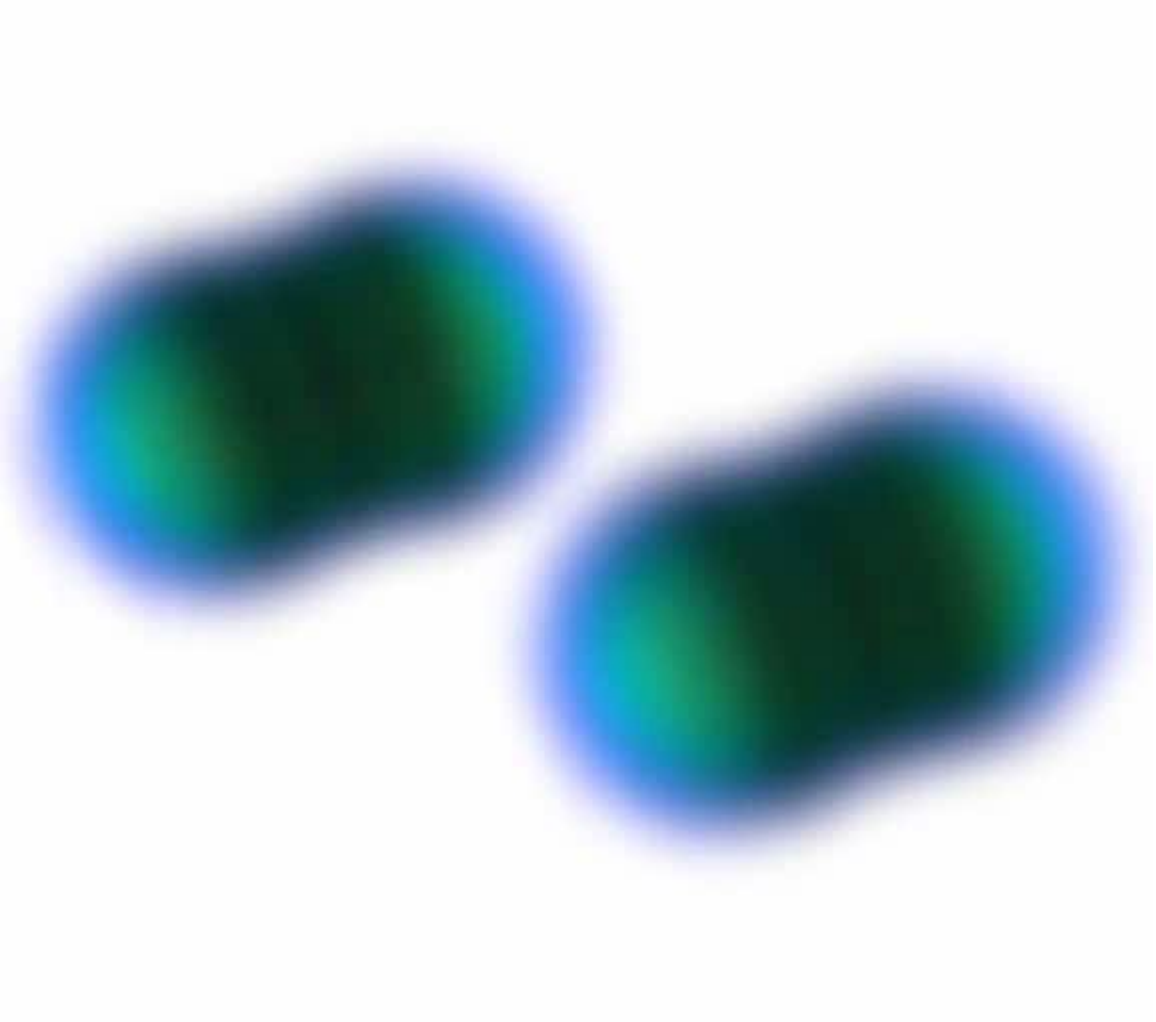
Transparency in Be + Be (M. Stein)

20 MeV



22 MeV

Rotational formation of chain (M. Altmeyer)



Summary

- Density-constrained Hartree-Fock provides an attractive way to calculate potentials and mass parameters that may even be applied to tunneling
- Static Hartree-Fock seems to yield metastable states as well; but seems to eventually always always go to the ground state
- Stability crucially dependent on symmetries
- The superdeformed chain-type states are unstable with respect to a bending deformation, but may be present as resonances
- TDHF shows both such resonances and a triangle-shape state
- THDF dynamics leads to a very complicated coupling of modes

- Open Questions
  - How exactly does TDHF fulfill the Pauli principle?
  - Does adding N-N collisions to TDHF increase or decrease the dissipation?
- Recent Publications

- *J. A. Maruhn, M. Kimura, S. Schramm, P.-G. Reinhard, H. Horiuchi, and A. Tohsaki, "Alpha Cluster Structure and Exotic States in a Self-Consistent Model for Light Nuclei", Phys. Rev. C 74, 044311 (2006).*
- *J.A. Maruhn, N. Loebl, N. Itagaki b, and M. Kimura, "Linear-chain structure of three α-clusters in ^{16}C and ^{20}C", Nucl. Phys. A 833, 1 (2010).*
- *板垣直之, Joachim A. Maruhn, and 木村真明, "中性子の果たす"糊"の効果とαクラスターの結合形態", 日本物理学会誌 64, 840 (2009).*
- *A.S. Umar, J.A. Maruhn, N. Itagaki, and V.E. Oberacker, „Microscopic Study of the triple-α reaction“, Phys. Rev. Lett. 104, 212503 (2010).*
- *A.S. Umar, V.E. Oberacker, J.A. Maruhn, and P.-G. Reinhard, “Entrance Channel Dynamics of Hot and Cold Fusion Reactions Leading to Superheavy Elements“, accepted for Phys. Rev. C*