The Dynamics of Hot Nuclei Studied With Antiproton-Induced Fission

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Fission dynamics of hot nuclei has been investigated using fission of ^{238}U by stopped antiprotons. The experiment was carried out at the LEAR storage ring of CERN [1]. The experimental multiplicity values M_{pre} and M_{post} of neutrons emitted before and after fission, respectively, are shown in fig. 1 as a function of the mass loss of the fissioning hot compound nucleus compared to the target nucleus. This mass loss is a measure for the excitation energy (Δm = 1u corresponds roughly to 10 MeV excitation energy). The results were obtained by measuring the energy spectra of the neutrons emitted at various angles to the fission axis.

The experimental neutron multiplicity data for pre- and post-scission emission were analyzed in the framework of the cascade-evaporation-fission (CEF) model. This model takes all stages of antiproton annihilation on heavy nuclei correctly into account: the fast stage of the intranuclear cascade, the evaporation from compound nuclei before fission, the fission process including the descent from saddle to scission points, and the evaporation after the separation of the fission fragments [2].

The fission probability and pre- and post-scission neutron multiplicities averaged over the ensemble of residual nuclei have been calculated in the framework of the standard version of the CEF model [2]. The results of such type of calculations confirm the fact that the statistical model underestimates the ratio of pre- to post-scission neutrons (see fig. 1, dashed curves). The newly developed version of the CEF model [3], taking into account the fission dynamics, includes such dissipative effects as a transient delay time τ_{f}, a saddle-to-scission descent time τ_{SSC} and Kramers' factor for the fission rate [4], depending on the value of the nuclear viscosity. Inclusion of the above mentioned dynamic effects in the model calculations leads to a much better description of the experimental data [3,5] (see fig. 1, solid curves).

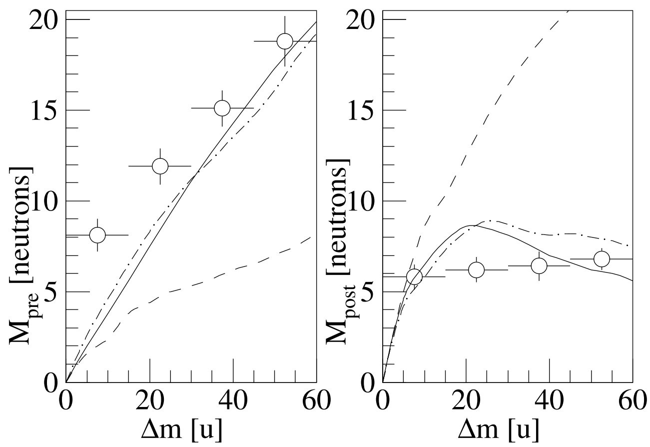

Fig. 1: Comparison of calculated pre- and post-scission neutron multiplicities (curves) with the measured multiplicities (data points) as a function of mass loss. The dashed curve is calculated with the statistical model without dynamical effects. The dashed-dotted curve stands for a calculation taking into account the viscosity following the approach by Kramers [4] (γ=0.7). The solid curve is calculated with the assumption of a finite saddle-to-scission transient time $\tau_{\mathrm{SSC}} = 10^{-20}$s.

The theoretical analysis shows for the first time that the dynamical effects play a crucial role in antiproton-induced fission, that fission of hot nuclei is underdamped (the nuclear friction coefficient γ <1) and that the saddle-to-scission time is about 10^{-20}s. The values of the nuclear viscosity, the transient and saddle-to-scission times obtained with antiprotons can be compared with the corresponding values extracted from heavy-ion data [5].

References

[1] W. Schmid, Ph.D. thesis, TU München, 1996
[2] P. Hofmann *et al.*, Phys. Rev. **C49** (1994) 2555
[3] W. Schmid *et al.*, submitted to Phys. Rev. **C**
[4] H. A. Kramers, Physica **7** (1940) 284
[5] A.S. Iljinov *et al.*, to be published.