50 75 100 125 150 175 200 225 250 275

Neutron Multiplicities from Fission Induced by Stopped Antiprotons

W. Schmid, T. v. Egidy, F. J. Hartmann, S. Schmid, D. Hilscher [a], D. Polster [a], H. Rossner [a], A. Grabowska [b], J. Jastrzebski [b], W. Kurcewicz [b], A. Trzcińska [b], H. Machner [c], H. S. Plendl [c], J. Eades [d], and S. Neumaier [d]

[a] Hahn-Meitner-Institut Berlin, 14109 Berlin [c] KFA Jülich, 52428 Jülich [d] Cern, CH 1211 Genève 23

Neutron energy spectra from the fission of ^{238}U induced by stopped $\overline{\mathrm{p}}$ were measured by TOF-techniques [1]. The neutrons coincident to both fission fragments were detected under different angles to the fission axis. Simultaneously a mass measurement of the fission fragments was performed. From the anisotropy of the neutron emission the number of the pre- and postscission neutrons was extracted by doing a moving-source-parametrization. The energy spectra of the neutrons were described by 5 Watt-distributions

$$\frac{\mathrm{d}^2 M}{\mathrm{d}E\mathrm{d}\Omega} = \sum_{i=1}^{5} \frac{M_i}{2\,(\pi T_i)^{\frac{3}{2}}} \sqrt{E}\,\mathrm{e}^{-\left(\frac{E-2\sqrt{\varepsilon_i E}\cos\Psi_i+\varepsilon_i}{T_i}\right)}. \quad (1)$$

60000 50000 40000 30000 20000 10000 0

Ψ_i denotes the angle between the direction of the source and the direction of measurement, ε_i is the mean energy per nucleon of the moving source and E the energy of the neutrons. The only moving sources are the two fission fragments, the other 3 sources do not move in the laboratory-system, because the $\overline{\mathrm{p}}$-annihilation occurs at rest. These 3 sources were identified as the intranuclear cascade (INC) emission induced by the annihilation pions, an pre-equilibrium emission (PE) and evaporation (CN) from the compound-nucleus before fission. By performing the parametrization according to eq. (1) one finds for the average number of prescission-neutrons 13.6(8) and for the post-scission neutrons 6.3(6), considering all fission events.

The multiplicities M_i, i=INC,PE,CN,FF1,2 are compared in table 1 for different mass loss windows. Using the mass-loss as a measure of the excitation energy one has an increase of the pre-scission neutron multiplicity while the post-scission multiplicity remains nearly constant. This is a clear indication that fission is slow compared with the emission of neutrons, and mainly the pre-fission emission benefits from an increase of excitation energy. This finding is very similar to the results of heavy-ion experiments [2] which find a nearly constant number of postscission neutrons as a function of excitation energy.

Mass loss [u]	> 45	30–45	15–30	< 15
M_{INC}	4,6(6)	3,6(5)	2,8(5)	1,8(4)
M_{PE}	5,8(7)	4,4(5)	3,1(4)	1,6(3)
M_{CN}	8,4(10)	7,1(7)	6,0(7)	4,7(7)
$M_{FF1,2}$	3,4(4)	3,2(4)	3,1(4)	2,9(3)
M_{pre}	18,8(14)	15,1(10)	11,9(10)	8,1(9)
M_{post}	6,8(6)	6,4(8)	6,2(7)	5,8(7)
M_{Σ}	25,6(15)	21,5(13)	18,1(12)	13,9(11)

Table 1: Multiplicities of neutrons for different mass loss windows.

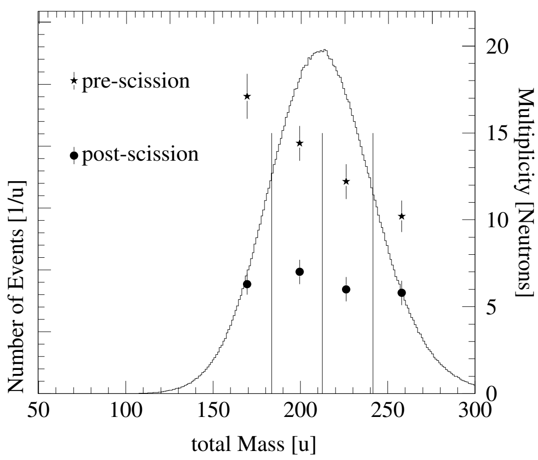

Fig. 1: The picture shows the multiplicities of pre- and postscission neutrons as a function of mass loss for the mass–loss windows given in table 1 and marked by the lines. The curve is the total–mass distribution of the number of the fission fragments.

References

[1] W. Schmid et al., Jahresbericht 1994, p. 34
[2] Mordhorst et al., Phys. Rev. **C43** (1991) 716