PROFILE EVOLUTION AND PARTICLE TRANSPORT CLOSE TO THE ONSET OF SAWTOOTH OSCILLATIONS DURING THE DENSITY RAMP-UP PHASE IN ASDEX

O. Gehre, V. Mertens, M. Kornherr, E.R. Müller, and G. Becker, H.S. Bosch, H. Brocken, A. Carlson, A. Eberhagen, G. Dodel[1], H.-U. Fahrbach, G. Fussmann, J. Gernhardt, G. v.Gierke, E. Glock, O. Gruber, G. Haas, W. Herrmann, J. Hofmann, A. Izvozchikov[2], E. Holzhauer[1], K. Hübner[3], G. Janeschitz, F. Karger, M. Kaufmann, O. Klüber, K. Lackner, M. Lenoci, G. Lisitano, F. Mast, H.M. Mayer, K. McCormick, D. Meisel, H. Murmann, J. Neuhauser, H. Niedermeyer, A. Pietrzyk[4], W. Poschenrieder, H. Rapp, A. Rudyj, F. Schneider, C. Setzensack, G. Siller, E. Speth, F. Söldner, K. Steinmetz, K.-H. Steuer, S. Ugniewski[5], O. Vollmer, F. Wagner, D. Zasche

Max-Planck-Institut für Plasmaphysik
EURATOM Association, Garching, FRG

Abstract: The evolution of the profiles of electron density and temperature, soft X-ray (SX) and bolometer radiation is investigated in ASDEX discharges close to the onset of sawteeth. For the transition phase these diagnostics show the signature of a strong sawtooth-like collapse, which removes impurities accumulated in the plasma center. A comparison of electron density transport before and after the transition indicates that the bulk plasma transport has not significantly changed and the observed broadening of the density profile is due to the additional relaxation mechanism of sawteeth.

Introduction: The time evolution of the electron density profile is studied in detail during density build-up in ohmic ASDEX divertor discharges. After a flat distribution in the ignition phase, the profile continues to peak till sawtooth activity sets in. Following this event, the profile continuously flattens till the density plateau is reached.

Diagnostics: The transition phase to a sawteething discharge often shows a sudden decay of the central density and a strong broadening of the profile. This behaviour is demonstrated in figs. 1 and 2, which show 3-D-plots of vertical density profiles, measured by HCN-laser interferometry /1/. In fig. 1 the sawteeth already start during the rising phase of the density, while fig. 2 shows an even more pronounced onset at the beginning of the plateau, indicated by the sharp decay of the center of the distribution. A similar decay, after an initial peaking phase, is also observed in the SX radiation. The case of rapid sawtooth onset is confronted with a less common one, characterized by a gradual sawtooth development during which the density profile shows a smooth braodening and no central peaking of the SX radiation is found. In case of no sawtooth development at all, the density and SX profiles continue to peak, generally terminated by a disruption due to a radiation collapse. A comparison of the temporal development of the central SX radiation for these three cases is shown in fig. 3.

[1] University of Stuttgart; [2] Ioffe Institute; [3] University of Heidelberg; [4] University of Washington, Seattle, USA; [5] Inst. for Nuclear Research, Swierk, Poland

The density profiles reached shortly before a distinct transition to the sawtooth phase are characterized by a nearly constant shape, independent of plasma current I_p, toroidal field B_t, dI_p/dt and safety factor q(a). For deuterium plasmas more peaked profiles are found as compared to hydrogen, similar to an investigation made for the density plateau phase of sawteething ASDEX discharges /2/. A faster density rise normally leads to a more pronounced transition at broader profiles.

A 3-D-plot of radial SX profiles measured during the time window of the transition is shown in fig. 4. The strong decay is only seen on channels corresponding to the plasma core within the radius of the q=1 surface. This radius is identified from the inversion point of SX and ECE, when sawteeth have started, and stays constant within measurement resolution. The picture also shows that the transition does not always occur in a single decay but may include a cascade of steps. An Abel inversion of SX channels immediately before the decay gives central emission values, which are at least one order of magnitude higher than bremsstrahlung. Shortly before the transition bolometer profiles show the build-up of a central peak (fig. 5), which vanishes with the onset of sawteeth. The electron temperature profile measured by quasi-stationary YAG scattering before and after the transition is presented in fig. 6. It indicates a pronounced flattening of the central region during the event.

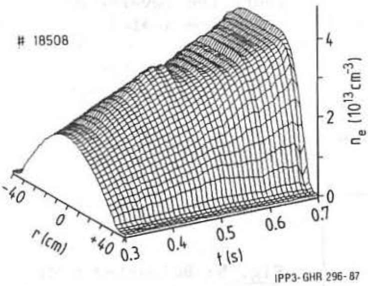

Fig. 1: Time evolution of the electron density profile close to the onset of sawtooth oscillations, transition to the sawtooth regime during the density build-up phase.

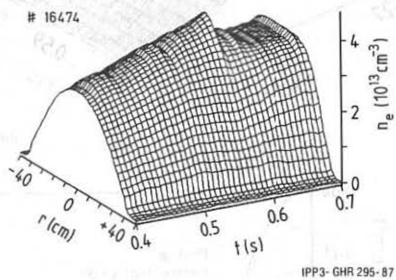

Fig. 2: As in fig. 1, but with more pronounced transition at the beginning of the density plateau.

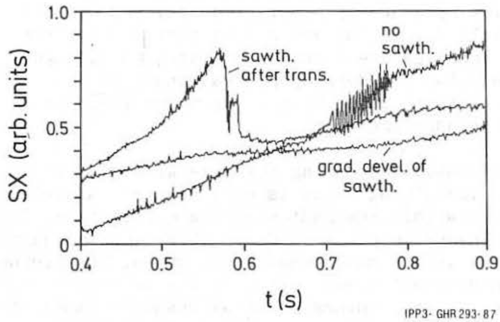

Fig. 3: Temporal development of the central SX radiation for a rapid sawtooth onset as compared to the cases of gradual sawtooth development and no sawteeth.

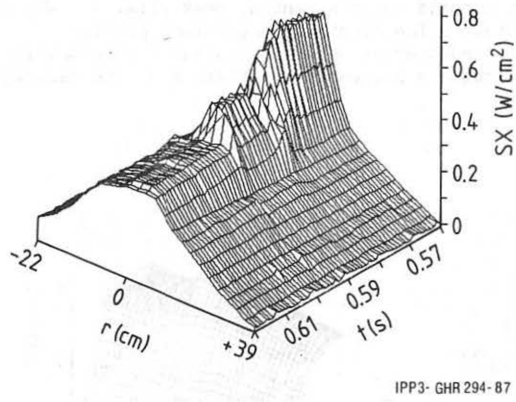

Fig. 4: SX radiation profiles during the transition to the sawtooth regime, showing a strong decay in the plasma core region.
(note the reverse of the time scale)

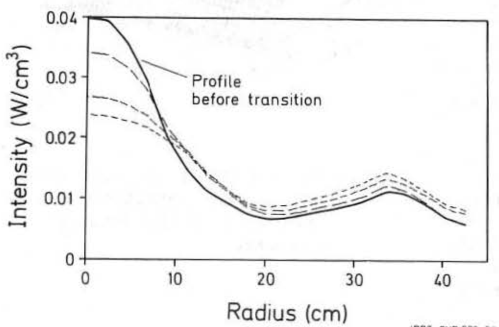

Fig. 5: Bolometer radiation profiles showing the build-up of a central peak before the transition. The solid curve gives the profile reached immediately before the onset of sawteeth.

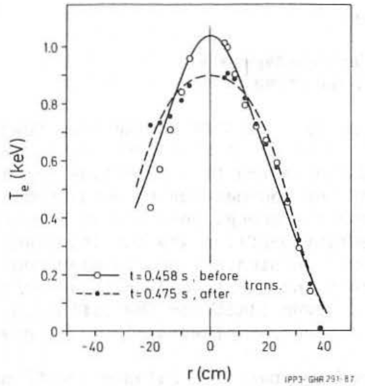

Fig. 6: Electron temperature profiles measured shortly before and after the transition to a sawteething discharge, indicating a pronounced flattening of the central region.

In summary, the transition to the sawtooth regime shows the signature of a strong sawtooth-like collapse, removing metal impurities from the center of the discharge, which have accumulated there during density build-up. No m=1 precursors are found, however, and the strong MHD activity seen during this phase, which was not studied in detail, does not allow to exclude a more complicated instability with higher mode numbers. The connection to impurities is supported by experiments, where krypton pulses were injected into the plasma. With increasing krypton content, indicated by higher initial levels of central SX radiation, the onset of sawteeth is shifted to later times and MHD activity during the transition increases. At too high impurity content no sawteeth develop and the discharge disrupts.

Transport: Electron density transport has been investigated shortly before and after the collapse. Using the continuity equation in cylindrical geometry, fluxes have been calculated neglecting sources. These fluxes in the plasma core region can be interpreted in terms of a model of electron transport consisting of diffusive and convective driving terms:

$$\Gamma(r) = -D(r) \cdot n'(r) - n(r) \cdot v(r).$$

The fluxes analyzed in the phase without sawteeth and, after the transition, averaging between sawtooth crashes, could be described by the same set of values for D and v. This indicates that the bulk plasma transport has not significantly changed after sawtooth onset. The observed broadening of the density profile is attributed to the started sawtooth activity, balancing the counteracting inward fluxes.

References:

/1/ Gehre, O., Course and Workshop on "Basic and Advanced Fusion Plasma Diagnostic Techniques", Varenna 1986, to be published.

/2/ Gehre, O., Becker, G., Eberhagen, A., and ASDEX team, Proc. 13th Europ. Conf. on Controlled Fusion and Plasma Heating, Schliersee 1986, EPS Europ. Conf. Abstr. 10 C, part I, p. 220-223.