

Plasma termination by excess fuel and impurities in TJ-II, LHD and W7-X

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Plasma termination by excess fuelling or impurity interaction is a safety relevant event in potential fusion reactors. Sudden termination of plasma operation is an aspect that enters material requirements in terms of released energies, localization and respective time-scales of the plasma terminating event. In tokamaks, such events may lead to disruptions or thermal quenches. While disruptions are not expected in (currentless) stellarator/heliotron operation, thermal quenches are certainly to be illuminated for reactor scale stellarators and heliotrons as well. This report is a study on plasma termination in TJ-II, W7-X and LHD. The confinement in W7-X and LHD allows one to study long-mean-free-path collisionality conditions in the plasma core.

Evidence for stellarator/heliotron specific behavior is given by the spatio-temporal evolution of the electron temperature. After the injection of two fuelling pellets into an LHD discharge, the second pellet induces a cooling of the plasma center leading to a temperature hole after about 100ms (τ_E). It is concluded that the stationary confining field has a beneficial impact. In TJ-II, the peaking of TESPEL particle deposition closer to the centre facilitates plasma recovery. For W7-X, plasma termination due to massive LBO tungsten injection shows energy decay by cooling of the plasma. The electron temperature decays on the time scale of energy confinement (~ 100 ms), while the plasma density remains almost constant (even slightly increasing). The plasma is finally terminated along with a strong increase of radiation representatively shown here as increase of impurity lines due to wall material (iron). Similar evolution of temperature and density is observed after iron impurities terminating ICRH long pulse experiments on LHD.

The systematic comparison of plasma terminating events by cryogenic pellets, induced impurity injection or changes of the heating gives evidence that the observed termination takes place on a time scale corresponding to the energy confinement time. Close to marginal termination, the beneficial effect of stellarator confinement of the vacuum field leads to transient plasmas that are cold in the center but may recover after typically 1s. The findings indicate the benign impact on transient loads in case of plasma termination in stellarators and heliotrons.

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Author: Dr DINKLAGE, Andreas (Max-Planck-Institut für Plasmaphysik)

Co-authors: Dr BUTTENSCHÖN, Birger (Max-Planck-Institut für Plasmaphysik); Prof. SUZUKI, Chihiro (National Institute for Fusion Science); Dr ZHANG, Daihong (Max-Planck-Institut für Plasmaphysik); Dr MOTOJIMA, Gen (National Institute for Fusion Science); Dr FUCHERT, Golo (Max-Planck-Institut für Plasmaphysik); Mr DAMM, Hannes (Max-Planck-Institut für Plasmaphysik); Dr KASAHARA, Hiroshi (National Institute for Fusion Science); Prof. YAMADA, Hiroshi (National Institute for Fusion Science); Dr MIYAZAWA, Junichi (National Institute for Fusion Science); Dr BALDZUHN, Jürgen (Max-Planck-Institut für Plasmaphysik); Dr MCCARTHY, Kieran Joseph (Ciemat); Dr TAMURA, Naoki (National Institute for Fusion Science); Dr DREWELow, Peter (Max-Planck-Institut für Plasmaphysik); Prof. WOLF, Robert (Max-Planck-Institute for Plasma Physics); Prof. SAKAMOTO, Ryuichi (National Institute for Fusion Science); Dr OISHI, Tetsutarou (National Institute for Fusion Science); Prof. PEDERSEN, Thomas Sunn (Max Planck Institute for Plasma Physics); Dr WEGNER, Thomas (Max-Planck-Institut für Plasmaphysik)

Presenter: Dr DINKLAGE, Andreas (Max-Planck-Institut für Plasmaphysik)

