NSTX National Spherical Torus Experiment • PROGRAM HIGHLIGHTS

MARCH 2000

Equilibrium Properties of Ohmically Heated Plasmas in NSTX

During its first operational period from September 1999 to January 2000, experiments were conducted in the National Spherical Torus Experiment (NSTX) to establish the range of plasma cross-section shapes available for future research. One of the primary research goals of NSTX is to investigate the effects of plasma cross-section shaping on magnetohydrodynamic (MHD) stability for low aspect-ratio plasmas. During these experiments, the toroidal plasma current and the radial and vertical position of the plasma within the vacuum vessel were controlled by real-time feedback of the currents in a group of the poloidal field coils. The shape of the plasma cross-section was controlled by pre-programming currents in the coils at the top and bottom of the vessel.

The evolution of the plasma equilibrium was analyzed with an automated version of the EFIT code [L.L. Lao, *et al.*, Nucl. Fusion 25 (1985) 1611] which calculates an MHD plasma equilibrium consistent with the data from more than 70 magnetic measurements. These include the currents in the coils, the plasma and the structure surrounding it, and the magnetic flux and local magnetic field at many locations surrounding the plasma. Because of the low toroidal resistance of the vacuum vessel wall and the stabilizing conductors close to the plasma, the induced currents must be included in the analysis. The application of EFIT to NSTX has been a collaborative project between Princeton Plasma Physics Laboratory, Columbia University and General Atomics.

For these experiments, NSTX was operated with a vacuum toroidal magnetic field B_0, of 0.3 T at the center of the vacuum vessel cross-section, and plasma current, I_p, up to 1.0 MA and plasma pulse lengths up to 0.5 s at lower currents. The plasmas were heated resistively by the current flowing in the plasma and fueled by deuterium gas puffing. Figure 1 illustrates the evolution of some of the main

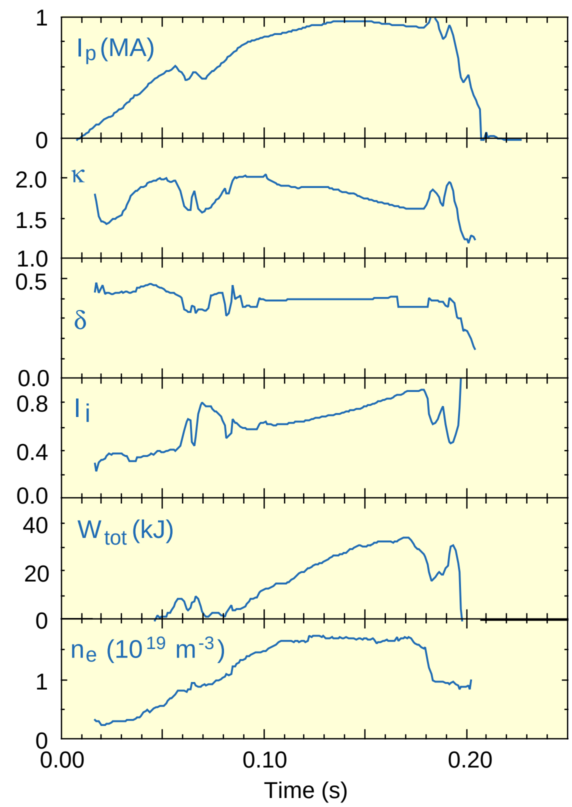

Figure 1: Evolution of plasma parameters for an NSTX ohmic discharge. The interval between EFIT analyses is 1 ms.

About NSTX

NSTX is a new national magnetic fusion experimental facility, located at the U.S. Department of Energy's Princeton Plasma Physics Laboratory, to test the physics principles of the innovative Spherical Torus (ST) confinement concept. The ST concept promises new opportunities for exciting scientific discoveries toward an optimized confinement system and an affordable energy development path. The NSTX National Research and Facility Operations Teams have produced exceptional results since the start of experimentation in 1999 and continue striving to improve in expertise and capability to produce high-quality scientific results and excellent plasma performance. For additional information, please contact: Information Services, Princeton Plasma Physics Laboratory, P.O. Box 451, Princeton, NJ 08543 (609-243-2750); e-mail: pppl_info@pppl.gov or visit our web site at: http://www.pppl.gov plasma parameters for a shot which reached 1 MA in plasma current. Three parameters of the plasma configuration are important for its stability: the elongation, κ, which is the ratio of the height of the plasma cross-section to its width, the triangularity, δ, which is a measure of the displacement of the highest and lowest points on the cross-section towards the major axis, and the internal inductance parameter, l_i, which is a measure of the distribution of plasma current over the cross-section. The thermal energy stored in the plasma, W_{tot}, reached 35 kJ, with an input power of 2 MW, corresponding to an energy confinement time, τ_E, of 15 ms. The line average electron density, n_e, is measured by a microwave interferometer.

During the rapid rise of the plasma current, instabilities frequently occurred, as seen in Figure 1, at about 0.065 s. During these events, which involve redistributions of both the plasma current density, as evidenced by the increase in l_i, and of metallic impurity ions out of the plasma core, as evidenced by data from soft x-ray detectors (not shown). The discharge of Figure 1 finally ends in a series of reconnection events beginning at about 0.18 s.

Limiter, double-null, and lower single-null diverted configurations were produced in NSTX, as shown in Figure 2. Each was sustained at a nominally constant plasma current of approximately 0.6 MA for more than 0.1 s, equivalent to about 5 energy confinement times. Elongations $1.6 \le \kappa \le 2.0$ and triangularities $0.25 \le \delta \le 0.45$ were sustained, while maximum values of $\kappa = 2.6$ and $\delta = 0.6$ were reached transiently. The largest stored energy was attained at the highest plasma current, electron density and plasma volume.

In the next operational period of NSTX, it is planned to implement additional real-time analysis and feedback capabilities for the plasma so that many more features of the equilibrium, such as the position of the boundary relative to several internal components and the location of the divertor strike points, can be controlled simultaneously.

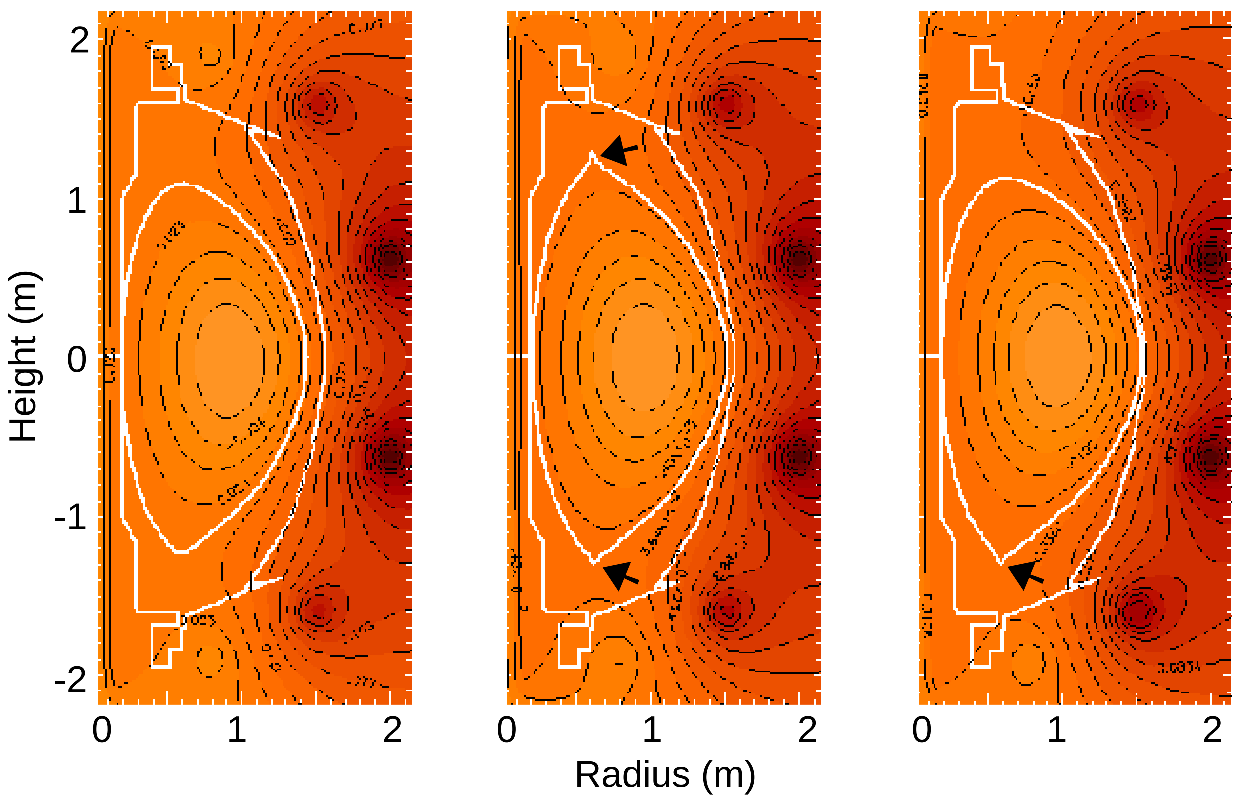

Fig. 2. Poloidal flux contours calculated by EFIT for limited, double-null, and lower single-null diverted equilibria in NSTX. The outer white contours show the cross-section of the plasma-facing wall; the inner white contours are the plasma boundary, i.e. the last closed flux contour inside the vacuum vessel. In the diverted configurations, the arrows show the positions of the null points in the poloidal field on the boundary