NSTX National Spherical Torus Experiment • PROGRAM HIGHLIGHTS

AUGUST 2000

Physics Analysis in NSTX

From its humble beginnings in 1992, the NSTX Physics Analysis Division (PAD) has played a crucial role in developing the physics basis for NSTX, laying the foundation for the Research Program and designing experiments to investigate the properties of Spherical Torus plasmas. Areas covered by PAD include discharge scenario development, confinement and transport (including that of the fast ions from neutral beam injection), magnetohydrodynamic (MHD) stability, boundary physics, and radio frequency (RF) heating and current drive. The results of early calculations in these areas fed directly into the engineering design of the device. For instance, the optimum passive plate positions were determined from considerations of plasma stability to vertical motion and to low-n MHD phenomena. Also considered were the expected characteristics of the scrape-off layer plasma to ensure that the passive plates, and other proximate surfaces such as divertor plates and center stack, do not suffer excessive heat loads.

Codes were developed that calculate the magnetic field pattern due to the Ohmic Heating (OH) and Poloidal Field (PF) coils during plasma breakdown to determine the PF waveforms needed to produce a good field null, and thus have successful plasma breakdown. Indeed, the PF waveforms determined by these codes were used during the initial operation period, and plasma breakdown was rapidly achieved. Next it was important to estimate how hot the plasma might become with ohmic and auxiliary heating, and how long the discharges would last. The Tokamak Simulation Code (TSC) indicated that with OH alone, the available flux swing was sufficient to produce 1 MA of plasma current for tens of milliseconds. This was borne out by experiment and used as a basis of calculations for various auxiliary heating scenarios. The results are summarized in Figure 1, which shows the current flattop durations expected for different heating scenarios. Up to 0.5 sec of current flattop, at 1 MA, can be expected.

Confinement and transport calculations indicate a potential suppression of microinstabilities

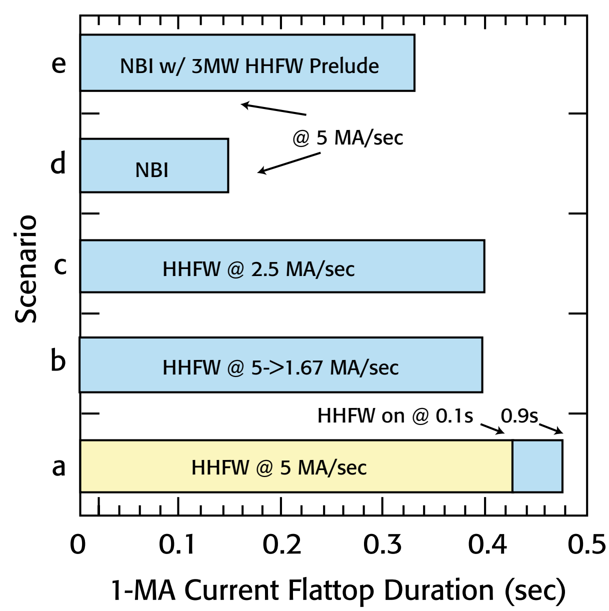

Figure 1. Current flattop duration estimated from the Tokamak Simulation Code.

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

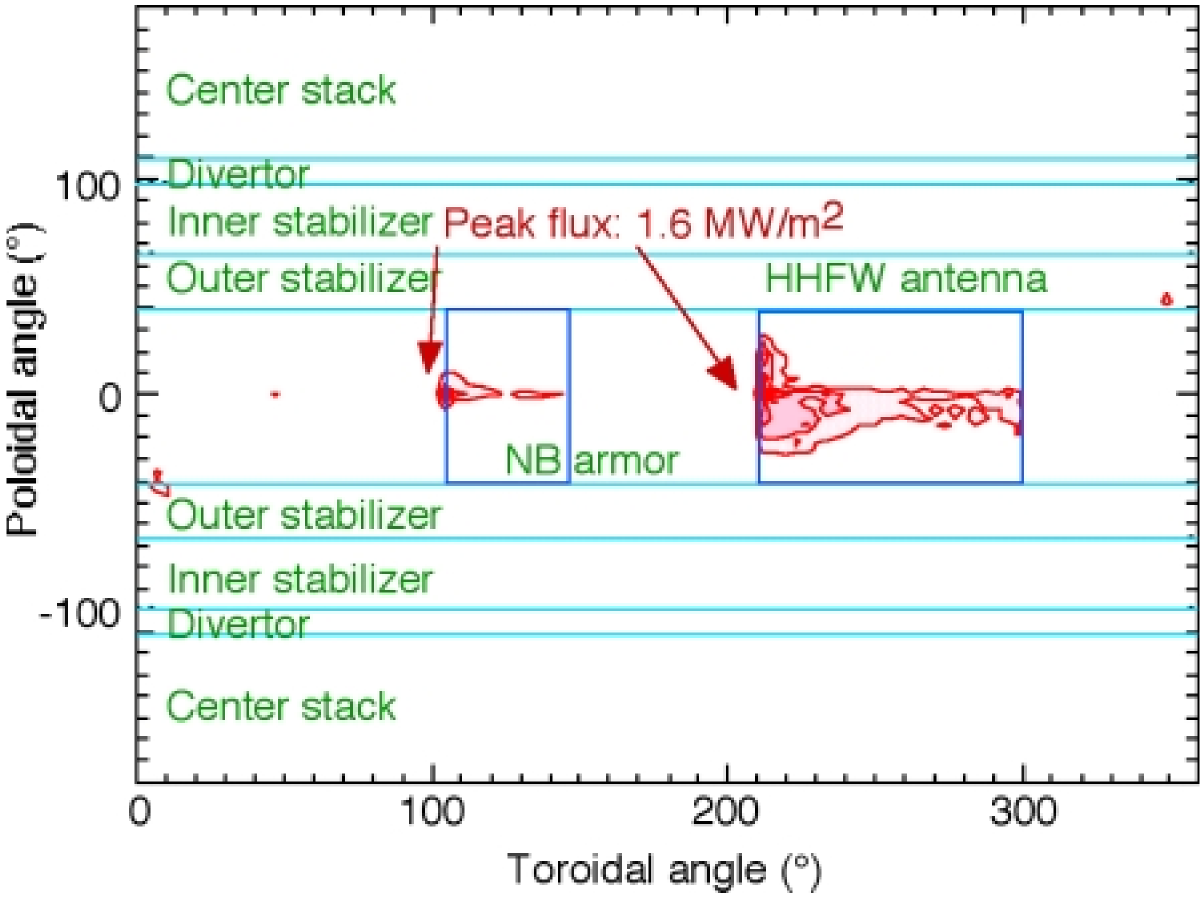

Figure 2. Heat loads on plasma facing components due to fast ion loss.

due both to geometric effects and to large flow shear resulting from NSTX's low magnetic field. MHD stability calculations revealed the effects of the wall on stabilizing low-n modes, and led to the development of a self-consistent set of profiles needed to produce 40% β plasmas. Important to all these calculations were the implications of heating and current drive by both neutral beams and High Harmonic Fast Waves, and the effects of the boundary plasma on heat loads to the plasma facing components.

The NSTX PAD coordinates work for the entire NSTX Research Team in the analysis of experimental data and pursues calculations and theoretical development that support present and future analysis and machine operation. Additionally, the PAD oversaw the development of an advanced Remote Collaboration facility for both control room and meeting access *(May, 2000 NSTX Program Highlights)*. One of the key pursuits in the PAD at present is the configuration of the electrical connections of the passive plates to optimize plasma stability to vertical and low-n instabilities and to optimize the ability to control the plasma through the PF coils. To do this, axisymmetric and fully 3-D stability codes with resistive wall models, developed at a number of fusion facilities, are being benchmarked against one another. This is the first time this has been undertaken for such a wide range of aspect ratios and among so many codes.

PAD is also assessing the validity of classical loss processes of the fast ions from the neutral beams that will be used to heat the plasma. This is needed to understand the confinement characteristics of NSTX plasmas and to determine the potential heat loads from these lost ions. The results of these calculations are shown in Figure 2, indicating that much of the lost power from the fast ions will hit the HHFW antenna at tolerable levels for 0.5 to 1.0 second long pulses. Such calculations, when compared to measurements of the surface temperature with an infrared camera during NBI operation, will aid the decision as to whether active cooling on the RF antenna is needed for multi-second current flattop durations.

NSTX Physics Analysis will determine RF heating and current drive deposition profiles, will apply basic theory with a gyrokinetic treatment to predict and understand transport in the device, and will work toward understanding the role of MHD phenomena in discharge performance. The PAD will also be heavily involved in developing the physics basis for NSTX upgrades and future devices.