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Predictive Simulations of ITER Including Neutral Beam Driven Toroidal Rotation By: Federico D. Halpern, Arnold H. Kritz, Glenn Bateman, Alexei Y. Pankin, Robert V. Budny, and Douglas C. McCune Received 26 February 2008; accepted 21 April 2008; published online 10 June 2008

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__✓__ 5. This document discloses no possibly patentable subject matter.

☐ 6. This document describes an invention reported as Contractor Docket No. ________ Princeton Univ #:____________DOE Case No_________.

☐ 7. An invention is disclosed for the first time on pages(s) _______________.

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PHYSICS OF PLASMAS **15**, 062505 (2008)

Predictive simulations of ITER including neutral beam driven toroidal rotation

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Predictive simulations of ITER [R. Aymar *et al.*, Plasma Phys. Control. Fusion **44**, 519 (2002)], discharges are carried out for the 15 MA high confinement mode (H-mode) scenario using PTRANSP, the predictive version of the TRANSP code. The thermal and toroidal momentum transport equations are evolved using turbulent and neoclassical transport models. A predictive model is used to compute the temperature and width of the H-mode pedestal. The ITER simulations are carried out for neutral beam injection (NBI) heated plasmas, for ion cyclotron resonant frequency (ICRF) heated plasmas, and for plasmas heated with a mix of NBI and ICRF. It is shown that neutral beam injection drives toroidal rotation that improves the confinement and fusion power production in ITER. The scaling of fusion power with respect to the input power and to the pedestal temperature is studied. It is observed that, in simulations carried out using the momentum transport diffusivity computed using the GLF23 model [R. Waltz *et al.*, Phys. Plasmas **4**, 2482 (1997)], the fusion power increases with increasing injected beam power and central rotation frequency. It is found that the ITER target fusion power of 500 MW is produced with 20 MW of NBI power when the pedestal temperature is 3.5 keV. © *2008 American Institute of Physics*. [DOI: 10.1063/1.2931037]

I. INTRODUCTION

Simulations of ITER discharges, which have been carried out using a variety of integrated modeling codes (see, for example, Refs. 1–10), have predicted a wide range in the fusion performance for ITER. One of the factors contributing to the prediction of the wide range in ITER performance is the stiffness of the anomalous transport model used in the simulations. (Stiffness refers to the rapid growth of the drift-wave turbulence transport with increasing temperature gradients above a threshold temperature gradient.) Transport driven by drift-wave turbulence, which accounts for most of the anomalous thermal transport observed in present day experiments, has been included in the simulations using different anomalous transport models such as the GLF23,[5,11] MMM95,[12] Weiland,[13] and mixed Bohm/gyro-Bohm[14] transport models.

Previously, simulations of similar discharge scenarios were carried out and compared using different transport models in different integrated modeling codes (see, for example, Refs. 2 and 3). It is demonstrated in Ref. 2 that differences in transport model stiffness could explain the disagreement between results obtained with the XPTOR code,[15] using the GLF23 model, and results obtained with the BALDUR code,[16] using the MMM95 model. However, in general, it is difficult to assess the cause of the wide range of predictions for ITER performance when the simulations are carried out in different transport codes using different transport models, different heating sources, and different models for various physical phenomena. For instance, in Ref. 1, ITER simulations were carried out using the MMM95 transport model in the BALDUR code with prescribed auxiliary heating profiles, but with self-consistently evolving temperature, density, and current profiles. In Ref. 5, ITER simulations were carried out using the GLF23 transport model in the XPTOR code with the same prescribed auxiliary heating profiles used in Ref. 1 but without self-consistently evolving the current density and particle density profiles. In Ref. 4, ITER simulations were carried out using the mixed Bohm/gyro-Bohm transport model in the JETTO code with heating profiles computed with the PENCIL code.[17] Furthermore, as a consequence of the transport model stiffness, different predictions for the fusion performance of ITER are obtained with different models for the temperature at the top of the H-mode pedestal.

A recent predictive simulation study[8] has focused on understanding hybrid and steady-state operating regimes in ITER. In another recent paper,[9] the performance of an ITER inductive H-mode scenario is modeled, with a particular emphasis on variations in auxiliary heating as well as reduced performance regimes. Some of the reduced performance regimes considered in Ref. 9 are plasmas with only hydrogen or only deuterium ions, as well as discharges with reduced toroidal field, heating power, or beam voltage.

In the present work, simulations of 15 MA H-mode discharges are carried out using the GLF23 and MMM95 anomalous transport models in the PTRANSP code, the predictive version of the TRANSP[18] code, which has been validated extensively in the analysis of experimental data. The PTRANSP code is used to compute the evolution of the temperature, toroidal rotation, current density profiles, and fusion performance using a choice of models for the magnetic equilibrium, density, sawtooth oscillations, neoclassical and anomalous transport, and the width and height of the H-mode edge pedestal. Objectives of the present work in-

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