NINETEENTH FUSION ENERGY CONFERENCE

SESSION EX/W & TH/7

Saturday, 19 October 2002, at 8:30

Chair: M.Q. TRAN (Switzerland)

SESSION EX/W & TH/7: Current Drive and Energetic Particles

Paper IAEA-CN94/EX/W-1 (presented by J.M. Noterdaeme)

Discussion

M. Porkolab: The change in the central toroidal rotation (reduction) during off-axis ICRF heating is similar to that observed in Alcator C-Mod at MIT. Have you also observed formation of a strong density peaking and/or ITB formation at the same time?

J.M. Noterdaeme: No, the results shown were performed in L-mode at a power where you would not yet expect an ITB formation.

Paper IAEA-CN94/EX/W-2 (presented by T. Suzuki)

Discussion

C. Gormezano: Have you measured the plasma rotation with on- and off-axis ECCD?

T. Suzuki: No, the plasma rotation was not measured. Diagnostic NB for charge exchange recombination spectroscopy (CXRS) to measure the rotation increases beam driven current and bootstrap current. For the purpose of accurate measurement of EC driven current, which is a primary purpose of this study, both the beam driven current and the bootstrap current must be reduced as much as possible. Thus, we did not apply the diagnostic NB for CXRS.

W.M. Nevins: The central ECCD efficiency you quote seems low compared with calculations for ITER which predicted $\eta \sim (2–3)\times 10^{19}$ A m^{-2} W^{-1} at $T_e(0) \sim$ 25–30 keV. Do you understand why the JT-60 result is so much lower?

T. Suzuki: We suppose your mentioning higher CD efficiency in ITER is based on the article by R.W. Harvey et al., Nucl. Fusion **37** (1997) 69. We must note that the CD efficiency in ITER is an optimized value over the wave frequency and the injection angle of waves under a toroidal field of 6 T. We must also note that the absolute value of the electron density is also important for higher CD efficiency. The higher n_e gives larger absorption of fast $v_\parallel$ electrons, since the number of electrons with such a fast $v_\parallel$ component increases. To obtain high T_e over 20 keV in JT-60U, the electron density (0.35×10^{19} m^{-3}) was much smaller than that calculated for ITER (15×10^{19} m^{-3}). In a high n_e plasma where waves are absorbed strongly, optimization of the parallel refractive index $N_\parallel$ gives higher CD efficiency. Higher $N_\parallel$ than the JT-60U value of about 0.5 is preferable to obtain higher CD efficiency. Along with the increase of $N_\parallel$, wave frequency should be increased for the same coupling condition. We confirmed that CD efficiency in the linearized Fokker–Planck calculation reaches 2.6×10^{19} A m^{-2} W^{-1} at the same n_e, T_e profile ($T_e(0)$ = 20 keV) as reported by Harvey et al., and uniform Z_{eff} = 1, when we employ a wave frequency of 220 GHz, a toroidal field of 6 T and a higher $N_\parallel$ of about 0.8 in the JT-60U configuration. Thus, the cause of the lower CD efficiency is the insufficient optimization of CD efficiency at high T_e over ECCD conditions.

Paper IAEA-CN94/EX/W-3 (presented by V. Erckmann)

Discussion

M. Porkolab: Congratulations on the beautiful O-X-B mode conversion results. This is one example of connection between fusion research and space plasma physics where similar phenomena were observed more than thirty years ago (the “Z hole” effect.) Do you have any information on the sensitivity of the mode conversion efficiency to edge density fluctuations?

V. Erckmann: The mode conversion efficiency is very sensitive to both the density gradient and the density fluctuation level in the vicinity of the O-mode cut-off layer. We have performed sensitivity studies which show that a high conversion efficiency is obtained only for very low fluctuation levels and small density scale length (steep gradients).

Y.K.M. Peng: Do you have an estimate of the efficiency of conversion from O-X-B at the plasma edge in the W-7AS experiment?

V. Erckmann: The best mode conversion efficiency obtained in W7-AS is about 80%.

Paper IAEA-CN94/EX/W-4 (presented by C.C. Petty)

Discussion

C. Gormezano: When you have done your 2/1 NTM stabilization at $\rho = 0.66$, have you tried to compare your ECCD efficiency with the one needed to stabilize the NTMs?

C.C. Petty: We have not yet developed a reliable technique for measuring the ECCD in the presence of NTMs, but the calculated ECCD current density from the CQL3D code is 2.8 times the equilibrium bootstrap current density at the island location for cases where the 2/1 NTM is completely suppressed. This ratio is in good agreement with the theoretical value needed for stabilization as calculated from the modified Rutherford equation.

Paper IAEA-CN94/EX/W-5 (presented by S. Coda)

Discussion

V. Parail: You conclude that you do not expect any significant deterioration in ECCD efficiency in the case of rather weak EC power. Could you quantify this statement somehow?

S. Coda: The same diffusivity level that inhibits the nonlinear ECCD efficiency enhancement in the case of TCV would not affect the efficiency significantly in a device like DIII-D, which is already in the linear regime. This was shown by a recent paper by Harvey et al., Phys. Rev. Lett. **88** (2002) 205001. Diffusion would cause some broadening of the current profile, albeit a comparatively modest one in a device of that size. With even larger diffusivities, of course, a deterioration of the efficiency from the linear prediction could occur.

F. Wagner: On Asdex it was observed that non-thermal electrons up to the runaway limit benefited in confinement from the low turbulence level of the H-mode. Is it operationally possible on TCV to carry out comparable studies in L- and H-mode?

S. Coda: No, the low density cutoff ($\sim 4 \times 10^{19}$ m^{-3}) of second harmonic ECH is not compatible with core current drive in H-mode. We have only been able to heat the edge of H-mode plasmas, with limited absorption efficiency and negligible current drive.

W.M. Nevins: Have you compared the fast electron diffusion coefficient with the χ_e for thermal electrons from a power balance analysis? This would shed light on both the prospects for better η_{CD} on ITER and the role of magnetic flutter vs. $E \times B$ convection in anomalous thermal electron transport.

S. Coda: The typical core thermal electron diffusivities are comparable to the estimates I presented for the fast electron diffusivities. It remains to be seen what the relation of the latter is with thermal particle diffusivity; also, we do not yet have direct measurements of fast electron transport in the case of an electron internal transport barrier.

X. Litaudon: Did you measure the non-thermal diffusivity when the EC wave is absorbed inside a thermal electron transport barrier?

S. Coda: We have not performed this measurement yet but we plan to do so by using the short pulse method I presented, with ECE measurements. In our eITBs thus far, most of the ECCD is driven off-axis, i.e. not fully within the eITB.

J. Kesner: In lower hybrid current drive experiments in PBX-M we observed a rapid diffusion of hot electrons that accompanied 3/2 and 2/1 modes. Is this observed in TCV?

S. Coda: The results and simulations I presented are in the absence of MHD modes. More generally, we have not observed any correlation between mode activity and the inhibition of the nonlinear ECCD efficiency enhancement.

Paper IAEA-CN94/EX/W-6 (presented by M. Takechi)

Discussion

C. Gormezano: You recommend a range of q_{min} (2.4–2.7) to avoid dangerous n = 1 AEs. Which parameters (beam energy, density, etc.) can influence this parameter range?

A. Fukuyama: The dangerous range of q_{min} is independent of density and beam energy. The mode amplitude, however, depends on the density and safety factor profiles in the plasma edge region through continuum damping.

D.S. Testa: The theoretical work on RSAEs presented in this paper looks strikingly similar to the theory first presented by S. Sharapov et al. (EPS 2001, APS 2001) and rapporteured at this conference by B.N. Breizman (paper TH/4-3). In particular, a number of theoretical plots are exactly the same. However, you claim yours to be a new theoretical work. Could you explain the differences (if any) between the model of Sharapov/Breizman and yours? Thank you very much.

A. Fukuyama: The main difference is that RSAE is not an energetic particle mode (EPM). This mode exists without fast ions and is destabilized by fast ions. We reported the numerical results at an IAEA Technical Committee meeting in 1999.

Paper IAEA-CN94/TH/7-1Ra & b (presented by N.N. Gorelenkov)

Discussion

R.J. Buttery: How big are the CAEs on NSTX — large enough to explain channeling?

N.N. Gorelenkov: At the moment we do not have enough experimental data to support the idea of energy channeling from NBI ions through GAE/CAEs to thermal plasma ions.

C. Gormezano: In present experiments, TAE induced losses are typically 10% of fast ions/neutrons. When you predict that TAEs will be unstable in ITER, can you give quantitative estimations of the anticipated losses?

N.N. Gorelenkov: It is hard to project the existing experimental and theoretical results to ITER-like burning plasmas. This is because we expect that the transport in ITER may be qualitatively different from the one in present day experimental conditions. The main difference is that in ITER the spectrum of most unstable modes will be shifted to higher toroidal mode numbers. Thus the fast particle transport may be enhanced by the presence of multiple modes. Special dedicated experiments are required on such machines as JET and JT-60U to model high-n number TAE instability in ITER.

A. Jaun: JET observes strong damping of radially extended Alfvén eigenmodes that should have a strong effect also in ITER. Do you recover this dependence and how does it translate to the reactor regimes in your analysis?

N.N. Gorelenkov: We do have the most stable TAEs in ITER due to their radial structure. The damping comes from either the edge or the center, while the drive is mostly localized at r/a=0.6. However, in ITER the spectrum of most unstable modes will be shifted to higher toroidal mode, which allows a more localized solution. In ITER the local drive may be large, so that we expect that the most unstable modes will be nonperturbative ones with a localized mode structure near the localization of the drive.

A. Jaun: In some of the spectrograms you showed, the measurements indicate that non-coherent modes lead to turbulent transport of energetic ions. Do you have experimental evidence of enhanced transport related to this turbulence?

N.N. Gorelenkov: There is no experimental evidence of the turbulent transport of fast particles due to the very limited diagnostics of such transport.