EIGHTEENTH FUSION ENERGY CONFERENCE

SESSION OV5/EX1/TH1

Thursday, 5 October 2000, at 10:40 a.m.

Chair: M. FUJIWARA (Japan)

SESSION OV5/EX1/TH1: Current Drive, Heating and Fuelling
(provided by R. GILL, UK)

Paper IAEA-CN77/OV5/1 (presented by H. Weisen)

DISCUSSION

H. ZOHM: In the ASDEX Upgrade, density pump-out is also observed with ECRH deposited at half radius and without an NTM. This cannot be explained by your proposed mechanism. What happens to particle transport if you deposit ECH at half radius in TCV?

H. WEISEN: The proposed mechanism, which involves a (1,1) island and a displaced core, would indeed only be operative inside the q=1 surface. The particle and energy confinement reduction observed with off-axis ECH in AUG probably does not require an outward directed pinch at all; a diffusivity increase by some other mechanism may be sufficient. Off-axis ECH in TCV has not been observed to lead to large particle losses, however, changes to the density profile have been observed with off-axis ECH as well. A fundamental difficulty in interpreting particle transport is that the underlying processes, in particular, the anomalous pinch which dominates the confinement region, are not understood even in the absence of ECH.

K. TOI: You showed a shot having density pump-out. The hollow density profile and very peaked electron temperature profile are very similar to those observed in low-density ECH plasmas of the CHS heliotron/torsatron. Did you estimate the electron thermal diffusivity χ_e, comparing with the plasma where no density pump-out is observed? Did you find any reduction in χ_e in a density pump-out plasma?

H. WEISEN: Improved electron transport is not a prerequisite for pump-out from the core, but since the most hollow density profiles correspond to the most peaked T_e profiles, a reduction of χ_e in the core would indeed appear to increase pump-out. This observation (see PDP/06) supports the interpretation of core pump-out as neoclassical thermo-diffusion in the presence of locally trapped particles.

F. ENGELMANN: Since you showed that the 3rd harmonic electron cyclotron wave power is absorbed by suprathermal electrons, this power should drive a current and, perhaps, there should be a synergistic effect in the current drive efficiency. Have you looked into this question?

H. WEISEN: Although we do not expect to drive current directly with X3 ECH (perpendicular incidence), synergistic effects due to the preferential absorption of X3 power by suprathermals created by X2 ECCD, may indeed be expected to enhance the driven current. However, in the experiments reported here the driven current fraction was rather small, which makes a direct measurement of the additional driven current (based on loop voltage change) a practical impossibility. Such a measurement may, however, be within the capabilities of specifically designed experiments with full current drive and with feedback controlled zero ohmic input.

Paper IAEA-CN77/OV5/2 (presented by D.A. Kislov)

DISCUSSION

Y. IKEDA: In the TCO, they observed the n_e pumping-out. You observed the H-mode in T-10, where the n_e increased. My questions are: Do you observe the n_e pumping out? What is the main difference of the plasma parameters between H-mode observed and the n_e pumping?

D.A. KISLOV: We have observed flattening of the $n_e(r)$ profile with ECRH power injection. After the transition to the H-mode regime, evolution of the $n_e(r)$ profile indicates the formation of an external transport barrier.

P. VANDENPLAS: In your forthcoming study of τ_E as a function of density, n_e, do you plan to inject neon or argon, as on Textor, to obtain the RI mode?

D.A. KISLOV: Yes, we plan to do it.

D. FRIGIONE: Do you observe any increase of the neutron yield during your PEC?

D.A. KISLOV: Yes, neutron yield increases up to a factor of 10 when the transition occurs.

F.C. SCHÜLLER: In RTP for several years, and now recently in TEXTOR, we have found that ITB’s during off axis ECCD could be related to q-values very close to rational values. Have you looked if the T-10 ITB could be related to specific q-values?

D.A. KISLOV: We do not measure q(r) profiles in T-10. We have not sufficient reasons to relate the region of increased T_e gradient to specific q-values

R.J. TAYLOR: In fluctuation correlation measurements, you may neglect the effects of electric field on particle orbit correlations. How would you include these effects in the interpretation of fluctuation reductions? They are more fundamental than the wave effects.

D.A. KISLOV: So far we have not analyzed the effects you pointed out.

Paper IAEA-CN77/OV5/3 (presented by H. Zushi)

DISCUSSION

E. MARMAR: What materials are used in the plasma facing components of TRIAM 1-M?

H. ZUSHI: Molybdenum limiters and divertor plates, and stainless steel walls without low Z material coating are used.

E. MARMAR: Do you have plans to add active pumping to the device?

H. ZUSHI: For steady-state operation at high power and high density it is indispensable. In TRIAM-1MU several active pumping systems are planned.

G.T. HOANG: How do you explain the LHCD efficiency increasing with injected power?

H. ZUSHI: When ECD occurs, the density, both electron and ion temperatures and driven currents are increased under the same power level. Enhanced $\langle T_e \rangle$ may increase η_{CD} if the gap region is filled. Model calculations, however, show that 70% of the total current is driven by assumed gap waves. Without an assumption of gap waves, if the source particles are given in the gap region, a positive density dependence of η_{CD} is one candidate. We consider that knock-on collisions play a role in creating the source particles. A reduction of prompt loss of energetic electrons is experimentally confirmed by a reduced temperature rise of the limiters in ECD discharges.

Paper IAEA-CN77/OV5/4 (presented by Jikang Xie)

DISCUSSION

R. CESARIO: What is the mechanism of IBW coupling; mode conversion by FW or direct launch?

J.K. XIE: Our IBW Antenna works by direct launching.

V. PARAIL: Have you used low field side to introduce a supersonic particle flow only, or did you try to do it by using high field side as well?

J.K. XIE: The super sonic beams were used from the low field side and from the top. Not yet used from the high field side.

Paper IAEA-CN77/EX1/1 (presented by C.B. Forest)

DISCUSSION

S. ORTOLANI: You showed that the amplitude of the fluctuations decreases during PPCD and that this is associated with changes of the current profile. Do you measure any changes in the mode spectrum of the fluctuations?

C.B. FOREST: In general, we observe a broad band reduction in internal tearing mode amplitudes when PPCD confinement improves.

V. ANTONI: In RFX we observe strong coupling between MHD relaxation and electrostatic turbulence; do you have similar evidence in MST during PPCD?

C.B. FOREST: No comment.

Paper IAEA-CN77/TH1/1 (presented by F.W. Perkins)

DISCUSSION

K. IDA: The generation of toroidal flow in Alacator-C is in co-direction. However, the generated toroidal flow in other devices is in counter-direction in NBI and ICRF discharges, where the transport barrier exists. The direction of the generated toroidal flow is unique. Can you explain why the generated toroidal flow in Alcator-C is in the co-direction, while the generated toroidal flow in other experiments is in the counter-direction? Is this due to high magnetic field or high density in Alcator-C?

F.W. PERKINS: Our numerical solutions are based on the assumption that minority ion-cyclotron resonance heating is the dominant heating mechanism. The validity of this assumption depends on minority concentration and weakly on density, magnetic field strength, antenna specifics etc. The sense of rotation is determined by Monte Carlo runs, which model both RF energization and collisions, which scatter particles from trapped to passing and back again several times. A simple but rigorous argument which strictly conserves angular momentum is not available. One can note that torque arising from momentum is not available. One can note that the torque arising from lost particles is always counter current. Our code is in accord with that.

C,S. CHANG: Following the RF-heated ions all the way until they are thermalized is a good exercise, but not necessary because collisional radial transport is automatically ambipolar with no extra torque. The only torque comes from RF resonance.

F.W. PERKINS: It is necessary to follow all Monte-Carlo particles to zero energy to get a rigorous answer. Truncation of calculation before a particle has lost most of its energy leads to a truncation error that can be only evaluated by another series of Monte-Carlo runs.

C,S. CHANG: Trapped and passing ions react to ICRH in the opposite way. They have a cancellation effect. Strong tall generation yields counter rotation and stronger passing generates co-rotation. If you consider all the phase space contribution, you may find that high field side heating in C-Mod may still give you a co-rotation.

F.W. PERKINS: Our ICRF heating Model 2 lets the code select which particles are to be energized. Model 2 as well as Model 1 provide almost the same non-dimensional rotation curves (see figs. 2 and 3).

R. TAYLOR: I appreciate the basic ideas of momentum balance. All the ideas you refer to are correct about the momentum balance. But all this has been worked out intellectually by Shaing ten years ago and by Taylor experimentally. You need to acknowledge this!

F.W. PERKINS: This paper addresses a different issue from the work of Taylor and Weynants, who have used electrodes or direct orbit loss of particles to create a net neutralizing radial current and $j_r B_\theta R$ torque. This torque lies in the counter-current direction for direct orbit loss. The subject addressed in this paper concerns creation of rotation in a situation where no net torque is applied to the plasma.

B. COPPI: There are experimental observations that a theory of spontaneous rotation phenomenon have to account for. These include: the existence of rotation in the absence of injected heat, that is with ohmic heating only; the inversion of the direction of rotation in the transition from the L confinement regime to a regime of enhanced confinement; the increase of the rate of rotation with the total thermal energy content of the plasma. How is your theory dealing with these issues?

I should point out that the theory that we have developed links rotation to the intrinsic and transport properties of the plasma column. In particular, it provides a coherent explanation for these points. In this context, the effect of ICRH is to increase the ion pressure gradient that, according to this theory, is deemed to be responsible for the rotation.

F.W. PERKINS: The theoretical model presented does address the points raised by Professor Coppi. (1) The paper shows that central plasma rotation is the sum of a core contribution and a boundary value. Rotation in ohmically heated plasmas can be understood in terms of a boundary condition which changes from L-mode to H-mode. A theoretical derivation of the boundary condition for H-mode lies outside the scope of this paper. (2) As above, a change in boundary condition from L-mode to H-mode could invert the sense of rotation. (3) Equation (13) gives the final result which has the scaling properties mentioned by Professor Coppi in this question and in his manuscript THP1/17.

In brief, this work provides a framework to combined core physics and boundary conditions and finds that the core can generate plasma rotation comparable with that observed.