NINETEENTH FUSION ENERGY CONFERENCE

SESSION OV/1

Monday, 14 October 2002, at 10:00

Chair: H. KISHIMOTO (Japan)

SESSION OV/1: Magnetic Fusion Overview 1

Paper IAEA-CN94/OV/1-1 (presented by R. Aymar)

Discussion

C. Newstead: You indicated that you expected the USA to join ITER. Why do you expect this?

R. Aymar: The US fusion community was an active promoter of ITER before the EDA Agreement was signed. It continued during the first period of the EDA to provide ITER with valuable contributions in physics and technology. After the USA left ITER in 1999, the other ITER Parties decided to go on without US participation, and have entered into negotiations to build ITER. It is up to the USA to decide whether to join ITER again. If they do, they will be welcome; if they don't, it will be strange to see the USA staying out of a world programme, which is commonly recognized as the most appropriate next step in the fusion development path.

Paper IAEA-CN94/OV/1-2 (presented by J.G. Jacquinot)

Discussion

R.J. Goldston: Was any effort may to align the limiter plate, taking into account the rippled plasma surface? Is the heat pattern due to parallel heat flux or are there trapped particle effects?

J.G. Jacquinot: The limiter sectors have been aligned vertically from shot to shot with an accuracy of 0.2 mm to ensure even loading of the plates. However, the design does not provide for 3-D shaping to follow the ripple of the magnetic field lines. The heat deposition pattern is dominated by the parallel heat flux but zones loaded with ICRH driven ripple trapped ions and fast electrons from LHCD are clearly identified.

A.S. Kukushkin: You mentioned the effect of density peaking at zero loop voltage. Can you exclude the effect of central fuelling by neutrals?

J.G. Jacquinot: These experiments used only RF heating systems which do not provide any central particle fuelling. The source originating from the charge exchange process is estimated to be negligible.

J.A. Snipes: As you recall, we observed similar oscillations to the 8 Hz fluctuations you showed on JET some time ago that we called Quasi-Stationary Modes. Have you looked at radial field perturbation measurements on Tore Supra?

J.G. Jacquinot: The oscillations seen on Tore Supra show no sign of MHD driven magnetic perturbations.

M. Kikuchi: You mentioned an interesting phenomenon at $V_{loop} \sim 0$. We do not observe such a phenomenon in JT-60U. Do you have any interpretation for such a temperature oscillation?

J.G. Jacquinot: We are exploring the plausible hypothesis of interplay between the local electron heat transport and the current profile generated by LHCD which is itself sensitive to profiles.

Paper IAEA-CN94/OV/1-3 (presented by T. Fujita)

Discussion

T.R. Jarboe: For the current hole profiles, are the profiles predicted to be unstable for ideal or resistive MHD or NTM?

T. Fujita: It is found that the stability for ideal MHD modes is not much affected by the value of q(0) or the existence of a current hole. The stability for resistive modes including NTM in a current hole plasma is under investigation.

X. Litaudon: In the high T_e regime with ECCH (T_e > 26 keV): What are the operating density and the electron thermal transport coefficients? What is the ELM behaviour in the highly non-inductive steady-state regime with ITB?

T. Fujita: The data were obtained by injecting ECH into a low density ($n_e \sim 5 \times 10^{18} m^{-3}$) reversed shear plasma sustained by LHCD. The analysis of the electron thermal diffusivity has not been done yet because of the uncertainty in LH heating power, though a clear T_e ITB in reversed shear existed. In the full non-inductive current drive reversed shear with LHCD, the behavior of ELMs is different from that in inductive positive shear plasmas. The regular giant ELMs are not usually observed but smaller or less frequent ELMs appear.

R.J. Hawryluk: What limits your ability to achieve high β_T in discharges in which the NTM is stabilized by ECCD?

T. Fujita: The beta in which the NTM is stabilized is limited by our available EC power, about 3 MW, at present.

R.J. Buttery: Are you avoiding sawteeth? What triggers the NTM?

T. Fujita: In the high β_P mode plasmas, q(0) is maintained above unity and no sawteeth are observed. The source for triggering NTMs in the high β_P mode plasmas has not yet been identified.

M.C. Zarnstorff: Why did the stored energy drop late in the current hole discharge created without the ohmic solenoid?

T. Fujita: In that discharge the beam power was preprogrammed to decrease during the heating, which resulted in the stored energy drop.

M. Porkolab: From your results with central ECH to control impurity accumulation with ITBs, it seemed that the ITB collapsed as the impurities were pumped out. We have seen similar results on C-Mod unless the central power is kept below a critical level (~ 1 MW in C-Mod). Have you seen similar effects in JT-60 by varying (reducing) central ECH? That way you could maintain the ITB with “acceptable” impurity control.

T. Fujita: In the discharge shown in my talk, the density ITB almost disappeared but the T_i ITB was maintained. We suppose that this is an important point since the temperature ITB without the density ITB is favorable to obtain high energy confinement avoiding impurity accumulation in the reactors. The threshold power of ECH for impurity exhaust has not yet been investigated systematically.

Paper IAEA-CN94/OV/1-4 (presented by J. Pamela)

Discussion

Y. Kamada: The effect of plasma shape on good pedestal performance is quite important. Have you found any dependence of $\Delta W_{ELM}/W_{ped}$ on the plasma shape?

J. Pamela: As shown in the ν^*_{ped} figure the ν^*_{ped} scaling of $\Delta W_{ELM}/W_{ped}$ has been observed in a variety of discharges with moderate or high triangularity. On the other hand, the transition from type I ELMs to mixed type I/type II at high n_{ped} is only observed at high ITER-like triangularity ($\delta \approx 0.45$–0.5). In other experiments (e.g. AUG) type II ELMs occur at moderate triangularity. I_N is quite important to understand the effect of plasma shaping (δ) and magnetic configuration (q_{95}) behind these various behaviours.

Paper IAEA-CN94/OV/1-5 (presented by K.H. Burrell)

Discussion

K. Lackner: Is there anything preventing you from developing reversed shear profiles more towards current hole situations?

K.H. Burrell: Current hole discharges have already been made in DIII-D by using neutral beam heating early in the current ramp. These were presented, for example, at the American Physical Society Division of Plasma Physics meeting in 1998. There is no obvious reason why the electron cyclotron current drive could not be used to supplement this.

S. Ortolani: What is the error field threshold for maintaining rotation and RWM stabilization and how does this extrapolate to ITER?

K.H. Burrell: The error field drag must be balanced against the torque input to determine the plasma rotation. Theory predicts and DIII-D experiments are consistent with an angular rotation speed of the order of 1% of the Alfvén frequency for stabilization of the resistive wall mode. Accordingly, extrapolation to ITER requires knowledge of the factors which govern the plasma rotation, not simply knowledge of the error field.

M. Kikuchi: Achievement of $\beta_N \sim 2 \times \beta_{Nlim}$(w/o wall) is exciting. But the absolute value is rather low. DIII-D has an ability to increase β_{Nlim}(w/o wall) by strong shaping. Are there any difficulties in achieving $\beta_N \sim 2 \times \beta_{Nlim}$(w/o wall) at high β_{Nlim}(w/o wall)?

K.H. Burrell: Most of our experiments on the physics of stabilization of resistive wall modes have been done in plasmas that were designed to have a low no-wall beta limit and a large difference between the no-wall and ideal-wall limits. Theory tells us the same techniques of feedback and rotational stabilization will apply in cases with higher no-wall limits. One example of such a case is discharge 106795 (shown in Fig. 1 of this paper) in which beta was sustained at $\beta_N \approx 4.2$, about 1.5 times the no-wall limit. In this case, beta continues to rise slowly until the onset of a neoclassical tearing mode.

J. Ongena: Could you give typical values of Z_{eff} in QDB and QH discharges on DIII-D?

K.H. Burrell: The Z_{eff} values are in the range of 4 to 6. This is dominated by the contribution from high Z impurities, nickel and copper. If these were not present, the Z_{eff} due to the low Z ions, deuterons and C^{+6}, would be about 2. The high Z ions appear to be produced by interaction of neutral-beam-produced fast ions with some as yet unknown surface in the vacuum vessel. The high Z influx increases with neutral beam power.

R. Maingi: Do you have an idea why counter-NBI is required for QH mode operation, i.e. why do ELMs go away with counter but not co-injection?

K.H. Burrell: One speculation is that the ELM stabilization seen in QH-mode is due to the very deep radial electric field well seen at the edge of QH-mode plasmas. See K.H. Burrell et al., Plasma Phys. Control. Fusion **44**, A253 (2002) for a discussion of these data. Counterinjection makes it easier to produce this well because the beam-induced counter-rotation helps the H-mode edge pressure gradient create a more negative radial electric field.

Paper IAEA-CN94/OV/1-6 (presented by O. Motojima)

Discussion

B. Coppi: Your record confinement results, as you showed, fit a scaling corresponding to the gyro-Bohm scaling. As you pointed out, the same scaling includes relevant confinement results obtained from tokamaks. M. Rosenbluth, R. Sagdeev and I derived this scaling from the theory of ion temperature gradient driven modes in 1967. Is there indirect evidence for this kind of mode in your experiments? On the "practical" side, the gyro-Bohm scaling gives excellent predictions for high field, high density machines such as Ignitor.

O. Motojima: Thank you very much for your question and comment. Right now, we have not enough database to answer your question. It will be an important experimental subject to clarify the mechanism of plasma transport which decides the global scaling law of LHD concerned with the ITG driven mode. For the NBI heated LHD discharges, the shape of the electron temperature is close to parabolic for a wide range of parameter space, i.e. temperature scale length is a function of radius. This may be explained by the critical temperature scale length model based on the ITG instability. In the near term experimental program of LHD, we have a plan to start studies on the fluctuation and turbulence of LHD plasmas, in which we will reveal the detailed transport mechanisms including the ITG mode model.

J.D. Callen: Actually, exceeding the Mercier stability criterion produces feeble instabilities with very small growth rates, which are easily stabilized by non-ideal MHD effects (finite Larmor radius, diamagnetic frequency etc.). Recent calculations have indicated one needs to exceed the Mercier stability criterion by about a factor of two. In your experimental conditions have you exceeded the Mercier criterion by a factor of more than two with no evidence of degradation in plasma confinement?

O. Motojima: This is a very important suggestion and question. Our data points for $\beta > 2.4\%$ are in the low n unstable regime ($D_I \sim 0.2$, namely E + I + H = 0.25), which approximately corresponds to more than a factor of two above the Mercier criterion ($D_I \sim 0$, namely E + I + H = 0.5). In this sense, the answer to your question is yes. An important observation is that even in such a plasma regime, the energy confinement of the LHD plasma is consistent with ISS95 scaling. The maximum β value achieved is now 3.2%. We will try to increase it further. Our final target is over 5%. It is our strong interest to increase the necessary database concerned with your question, and we may answer your question more clearly in the near future.

R.J. Goldston: You told us that 2/1 modes disappeared above $\beta = 2.3\%$. Can you tell us about the evolution of the $\iota = 0.5$ surface? Did the electron transport barrier depend on the plasma position – was it easier to obtain it with low or high orbit losses?

O. Motojima: Thank you very much for your question on this important aspect. As for the first question, with increasing β value, $\iota(0)$ increases and exceeds 0.5. The plasma is shifted outwards and its equilibrium state changes, and the bootstrap current or driven current has a finite effect. Only 20 kA of plasma current in the additional direction (co-direction) at 1 T diminishes the $\iota(0) = 0.5$ rational point. Right now, experimentally we are not sure that the disappearance of the mode exactly corresponds to that of the $\iota = 0.5$ surface. We need to investigate further the dynamics of islands at the rational surface. As for the second question, the iota profile (particularly the position of the $\iota = 0.5$ surface) varies with the position of the plasma axis. This seems to influence the barrier formation. The electric field is supposed to play an important role and this results from the neoclassical effect which has a strong relation with the position of the axis. However, since the ITB is obtained in a wide range of configurations ($3.5 < R_{ax} < 3.75$ m), the effect of orbit losses is not clear at this moment.