SESSION CD1

Friday, 23 October 1998, at 8.50 a.m.

Chairman: G. Tonon (France)

PLASMA HEATING AND CURRENT DRIVE 1

Paper IAEA-CN-69/CD1/1 (presented by T. Oikawa)

DISCUSSION

A. BERS: Why does your current drive efficiency for N-NB increase with $T_e(0)$?

T. OIKAWA: Fast ion-carrying current increases with T_e because the slowing-down time of NB fast ions becomes longer. As N-NB in JT-60U has a central deposition (centre CD), a central value of T_e describes current drive efficiency well.

D. MOREAU: Have you made any comparison between P-NBI and N-NBI with respect to the plasma rotation issue, and do you have any experimental data showing the effect of N-NBI on rotation?

T. OIKAWA: It has been observed that momentum input into plasma by N-NB is less than by P-NB. In the case of simultaneous co-injection of N-NB and counter-injection of P-NB, the plasma rotates in the counter-direction, even with higher N-NB power (~ 3 MW) than P-NB power (~ 2 MW).

E.S. MARMAR: What is the maximum contribution to β due to the fast ions from N-NBI on JT60-U? Can N-NBI be used to investigate toroidal Alfvén eigenmode (TAE) physics?

T. OIKAWA: A volume-averaged beta of $< \beta_h > = 1\text{-}2\%$ is expected. TAEs can be investigated with N-NBI and low n TAEs have been observed for $< \beta_h > \geq 0.1\%$. This new result is discussed in paper IAEA-CN-69/EX8/6 by Y. Kusama et al.

M. PORKOLAB: What is Z_{eff} in the N-NBI current drive experiments? And, was proper account taken of a lower Z_{eff} (of the order of 1.6 or less) in the reactor relevant regime?

T. OIKAWA: In our current drive experiments, Z_{eff} is 2-3.5 at relatively low density (E_B ~ 350 keV, $T_e \leq 5$ keV). Higher E_B with higher T_e in a reactor can further improve current drive efficiency and compensate reduction of NB fast ion current by electron drag in lower Z_{eff}. For a reactor case, assessment of N-NB as a current driver at higher density with lower Z_{eff} is needed.

Paper IAEA-CN-69/CD1/2 (presented by F. Rimini)

DISCUSSION

F. DE MARCO: Have you performed experiments close to the Greenwald limit?

F. RIMINI: No, the highest density for these experiments corresponds to only roughly half of the Greenwald limit.

H. KIMURA: You indicate that in the “pure” 2 ω_{CT} case there are 20% fast triton losses and also that TAE modes are observed. Are the losses related to TAE modes?

F. RIMINI: No. The figure of 20% is the estimate for losses due to trapped particle orbits intersecting the limiter.

A. BÉCOULET: In your experiments favouring bulk ion heating, do you have any indications concerning the plasma rotation behaviour?

F. RIMINI: Although we have the data on plasma rotation, this analysis has not been carried out. Thank you for the suggestion.

S. BERNABEI: Do you observe chirping modes during minority heating?

F. RIMINI: No, not in these pulses. Chirping modes were observed in optimized shear discharges.

C.S. CHANG: Have you seen any sign of current drive or rotation generation from the minority heating? For the current drive, off-axis heating can yield an asymmetric $k_{\|}$ absorption from a symmetric $k_{\|}$ spectrum. Thus, in principle, we could expect a minority current drive (as well as rotation).

F. RIMINI: The rotation data have yet to be analysed. Current drive effects with such a low power RF pulse may be very difficult to identify, given the uncertainty in the measurements and the very limited set of pulses in such a scenario.

Papers IAEA-CN-69/CDP/07 and 08 (rapporteured by F.C. Schüller)

DISCUSSION

B. SAOUTIC: Was the stabilization of sawteeth observed during ECCD due to the removal of the q = 1 surface of the plasma, or to a modification of the current density profile at the q = 1 surface?

F.C. SCHÜLLER: The team claims that q_0 is lifted above 1 and therefore no q = 1 surface is present any more in the plasma.

R.J. HAWRYLUK: How does the current drive efficiency vary between on- and off-axis current drive?

F.C. SCHÜLLER: As I have demonstrated in the transparency showing the driven current as a function of the magnetic field and therefore as a function of deposition radius, the current drive efficiency falls quickly with increasing deposition radius. However, as I indicated, that result has to be unfolded with the appearance/disappearance of thermal barriers combined with the strong temperature dependence of the current drive efficiency.

K. HANADA: Are full ECCD discharges obtained?

F.C. SCHÜLLER: No, because the density needed would be so low that the plasma could not be regarded as a standard tokamak discharge. In general, the RTP team performed their investigations with central densities well above $2.10^{19} m^{-3}$ in order to stay in a more relevant regime.

Paper IAEA-CN-69/CD1/4 (presented by S. Ide)

DISCUSSION

V.V. PARAIL: You indicate that in your experiment with L-mode plasma the ITB is lost after several seconds of good confinement. How often do you observe such events and do you understand the reason for the loss of the ITB?

S. IDE: I cannot say exactly how often. It occurs relatively frequently, not only in the LHCD cases, but also in the usual NBI cases. Although the events have not been investigated in depth, it seems that the value of the minimum q and/or the relative distance between q-minimum and the ITBs may be responsible. A detailed study of the data and a stability analysis will be carried out.

R.J. HAWRYLUK: Recalling that H. Shirai et al. in paper IAEA-CN-69/EX5/4 characterized the internal transport barriers in JT-60U as parabolic or box-like, how would you describe the transport barriers in your experiments? Also what changes are required to explore control of internal transport barriers in $\beta_N \sim 2$ discharges?

S. IDE: The reversed shear data show that the transport barriers appear to be of the "box" type. More NBI power would be required to raise β_N. However, the heat load to the LHW launchers increases with the increase in NBI power. For the time being, this limits β_N to a value of ≤ 1.23.

Y. PEYSSON: Could you tell us whether, in LH-sustained ITB experiments, the wave absorption takes place in a single- or multi-pass regime?

S. IDE: Although this has not been validated, some fraction of the power may well travel along several paths.

M. PORKOLAB: Can you comment on the role of reversed shear on confinement? How would confinement behave without reversed shear, i.e. at the same plasma parameters, such as current, density, magnetic field, and NBI input power, but <u>without</u> LHCD? In other words, would you still have an ITB without LHCD.

S. IDE: β_N decreased by about 30-40% after the ITBs disappeared, with I_p, P_{NB} and P_{LH} maintained constant. This shows the significance of the ITBs for confinement. It should be noted that the impact of ITBs on confinement may increase with increasing I_p. The role of ITBs does not depend on whether the LHCD is on or off. The point is, however, that without LHCD the ITBs cannot be sustained in steady state.

D. MOREAU: In the experiments where you sustain the ITB in a near steady state, can you comment on the controllability of the LH power deposition profile? Is it essential to use both launchers with different spectra? What are the respective powers in each spectrum and did you vary the power ratio, or vary the launched wave spectrum in one antenna or the other or both of them, to optimize the off-axis power deposition profile?

S. IDE: The position of the minimum q changed when the input power of one launcher decreased. Although this was a chance occurrence, it suggests controllability. From the experimental results demonstrating the sustainment of reversed magnetic shear, we believe that the use of two launchers is necessary. We have tried varying the spectra and the power of each launcher to optimize the system, and the results are currently being analysed.

Paper IAEA-CN-69/CD1/5 (presented by D.A. Hartmann)

DISCUSSION

K. IDA: Ion heating by ICRF has been considered difficult because RF enhances the perpendicular velocity of particles which may escape from the plasma owing to ripple loss. On the other hand, NBI heating does not encounter this problem, provided it is injected tangentially. Is there any difference in ion heating efficiency between NBI and ICRF owing to the difference in the heating mechanism? How sensitive is ICRF heating efficiency to the E_r profile which may enhance or reduce the ion loss due to ripple?

D.A. HARTMANN: The heating efficiency of ICRH for schemes which directly heat the ions is comparable to the NBI heating efficiency when a plasma is heated. The heating efficiency of ICRH is considerably reduced (by a factor of about 2) during plasma sustainment with ICRH only. The dependence on the radial electric field has not been investigated in detail. Typically, there was no significant increase in the absolute value of the negative radial electric field with ICRH during heating. However, the difference in the radial electric field between heating and sustainment has not been checked.

M. MURAKAMI: Regarding the H/D mode conversion scenario you tried, was there any evidence of current drive or RF flow drive?

D.A. HARTMANN: No, because the antenna was operated either in 0 or π phasing and the resulting $k_{||}$ spectrum was symmetric.

R.J. HAWRYLUK: I would like you to put the ICRF results in the context of the high confinement times of ~ 50 ms in W7-AS reported at this conference (paper IAEA-CN-69/OV2/4). I infer from the diamagnetic measurements and ICRF power that the energy confinement time was a few milliseconds. Yet you also conclude that the ICRF heating efficiency is good. How do the ICRF heating experiments differ?

D.A. HARTMANN: The typical energy confinement time of the ICRF plasmas was about 10 ms. The long confinement time discharge on W7-AS is obtained for a certain rotational transform and neutral beam source. We have not tried ICRF operation at those rotational transform values.