Overview of the FTU results

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Abstract. An overview of the FTU results during the period 2000-2002 is presented. Long duration Internal Transport Barriers have been obtained on FTU with combined injection of Lower Hybrid and Electron Cyclotron waves in 5T/0.5MA discharges. The ITB phase lasts about ten energy confinement times and is characterised by an energy confinement time up to 1.6 times the ITER97L-mode scaling. Up to 11keV are achieved at $0.9\times10^{20}m^{-3}$ central density. ITB studies using IBW injection have been also continued up to 8T/0.8MA. The Lower Hybrid system has operated at full power allowing to complete the current drive studies at ITER relevant densities. At these density values the electrons and ions are coupled and an increase in the ion temperature is clearly observed. Preliminary sign of enhanced Current Drive efficiency has been obtained in combined injection of Electron Cyclotron and Lower Hybrid waves at magnetic field values lower than the resonant field. Pellet optimisation studies have been performed in order to test the conditions under which a quasi steady state confinement improvement can be obtained and impurity accumulation can be avoided. Ohmic discharges generally exhibit a confinement time in agreement with the ITER97 L-mode scaling. Transient confinement improvement is observed for duration less than one energy confinement time. Radiation Improved mode studies have been started thanks to the recently inserted boronisation system which has allowed to reduce the radiated power. Confinement improvement with Neon injection has been observed in 6T/0.9MA discharges. Transport studies on profile stiffness and MHD studies of fast reconnection and snakes will be also presented.

1. Introduction

The Frascati Tokamak Upgrade (FTU) (a=0.3m, R=0.93m) is a compact, high magnetic field tokamak aimed at studying confinement, stability and wave-particle interaction physics at ITER relevant parameter by operating up to a magnetic field B=8T and a plasma current

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I=1.6MA. The main upgrades with respect to the last IAEA conference have been the insertion of a boronisation system and of a second Ion Bernstein Wave antenna. The boronisation system has allowed to achieve very clean plasmas and to reduce the radiated power fraction up to level as low as 30%, allowing, in particular, Radiation Improved (RI) mode studies to be started. During the last two years most of the effort has been given to the investigation of internal transport barriers (ITB) with electron heating at high density, i.e. close to reactor relevant conditions. This has been obtained by combined injection of lower hybrid waves, to control the current density profile, and electron cyclotron waves, to produce large electron temperature gradients. Long lasting ITBs can now be routinely produced on FTU with a duration of the order of several confinement times, limited by the duration of the ECRH phase. These discharges exhibit an enhancement of the global energy confinement time over the ITER97 L-mode scaling up to a factor 1.6, in contrast with typical ohmic and L-mode discharges which follow such a scaling. Pellet enhanced performance (PEP) discharges, characterised by very high neutron rates, exhibit transient confinement improved phases, lasting less than one energy confinement time, up to a factor 1.3 above the ITER97 scaling. Pellet optimisation studies have shown that in order to avoid high-Z impurity accumulation (FTU is equipped with a TZM toroidal limiter) in the presence of peaked density profiles, delayed sawteeth must be maintained. This allows a long sequence of PEP mode phases with quasi steady state H factors well above those achieved in gas fuelled discharges.

FTU is equipped with three different RF heating systems which have been extensively used for the production and control of Internal Transport Barriers. The Lower Hybrid (LH) system (8GHz, t_{pulse}=1s) is composed by 6 gyrotrons feeding 6 grills on two FTU windows. The system has operated close to the maximum performance (≈2MW at the plasma). The electron cyclotron resonance heating (ECRH) system [1] (140GHz, t_{pulse}=0.5s) has been working at a maximum power level of about 0.8MW at the plasma (corresponding to two gyrotrons), making use of the launching system capability of injecting power at oblique angle with Current Drive (CD) capability. The system has been employed both for transport studies and MHD mode stabilisation. Synergy studies with combined injection of LH and EC waves have been made in the ITER-relevant upshifted scheme. Encouraging preliminary results with the IBW system at higher power have been obtained.

2. Internal transport barriers studies.

2.1 Long lasting ITBs with combined LHCD and ECRH

Internal Transport Barriers have been observed in the past on FTU using ECRH on the current ramp in B=5.3T discharges [2]. Very high values of the central electron temperature (≈15keV) were observed with the electron thermal conductivity maintaining the value of the ohmic phase, in spite of much larger temperature and temperature gradients. These discharges were characterised by a large value of the radiated power (this was in fact used to produce hollow temperature and current density profiles in the early phase of the discharge) due to heavy impurity contamination. In order to avoid such a problem, scenarios have been developed with simultaneous injection of LH and EC waves both during the current ramp and the current flat top. As in most of the existing experiments, ECRH injection during the current ramp phase delays the current density evolution and allows the formation of broad current density profiles which are subsequently maintained by LHCD during the flat top phase [3]. In this way, long lasting electron ITBs have been obtained [4]. As shown in Fig. 1a the duration of the ITB phase is of the order of 0.25s corresponding to about ten energy confinement times, with the central density reaching $0.9\times10^{20}m^{-3}$ and the central temperature up to about 11keV as confirmed by spectroscopic measurements of heavy-impurity line radiation. After the ECRH phase, the ITB becomes weaker and then disappears possibly due to a change in the current density profile or an increase of the plasma collisionality. In order to achieve steady state conditions, a different ITB formation scheme has been attempted. A plasma target is formed with full LHCD. The EC power is applied during the flat top phase in order to produce an electron ITB (Fig.1b). Again, the ITB duration is limited by the duration of the ECRH phase.

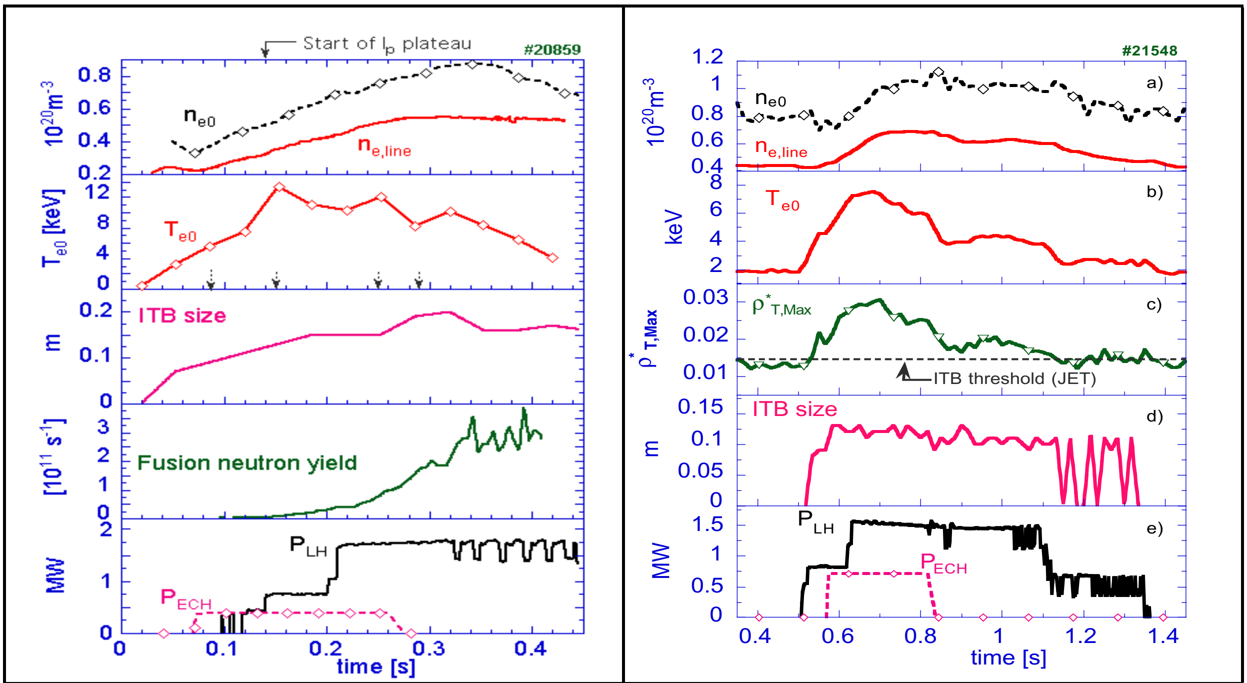

FIG.1a Time evolution of the discharge #20859 with an ITB obtained by ECRH during the current ramp up and LHCD in the flat-top to maintain a broad current profile

FIG.1b Time evolution of the discharge #21548 with the ITB obtained by ECRH during the current flat top on a target discharge with full LHCD.

Transport analysis has been carried out for the discharge shown in Fig. 1a using the JETTO code [5]. The LH power deposition and current drive profiles are calculated by 1-D Fokker-Planck Bonoli code [3]. The ECRH power deposition is calculated by a ray-tracing code. As a result a reduction of the electron thermal diffusivity occurs, more pronounced in the time interval 0.24-0.34s. The code shows the formation of a negative magnetic shear configuration. From the radial T_e profile (Fig. 1c), an ITB expansion is observed, which might be correlated to a broadening of the LH power deposition profile. An improvement of the ion confinement is observed in the time range 0.24-0.34 s. The ion thermal diffusivity in FTU can be often modelled by an anomaly factor of the neoclassical diffusivity. The time evolution of the experimental neutron rate and the experimental ion temperature on axis can be modelled, by reducing the anomaly factor by 60%. It is important to stress that a plasma density peaking is also observed during this ITB phase. The ITB degradation is followed by the onset of MHD m=1, m=2 coupled modes (at t = 0.34 s).

The global energy confinement time shows an enhancement up to a factor 1.6 above the ITER97 L-mode scaling when a threshold value in the parameter $\rho* = \rho_i/L_T$ is exceeded, (ρ_i being the ion sound Larmor radius and L_T the temperature scale length) similarly to what is observed on JET. The maximum $\rho*$ value in the ITB region is considered. As shown in Fig.1d, a transition occurs from pure L-mode scaling to improved confinement when $\rho*$ exceed a threshold value similar to the value observed in JET for obtaining an ITB [6].

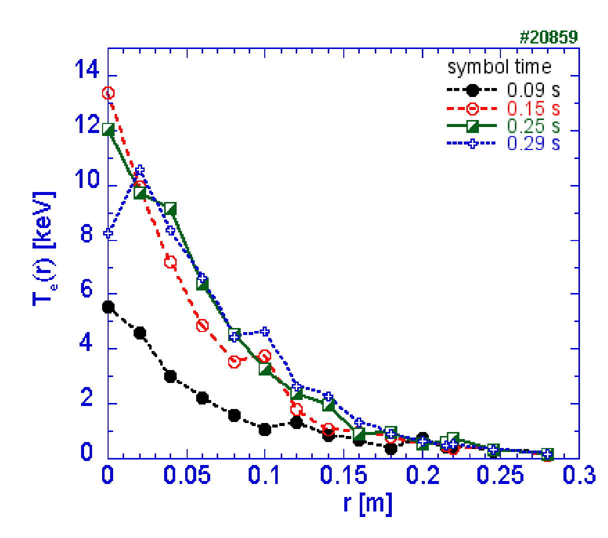

FIG.1c Time evolution of the electron temperature profiles for the discharge shown in Fig.1a

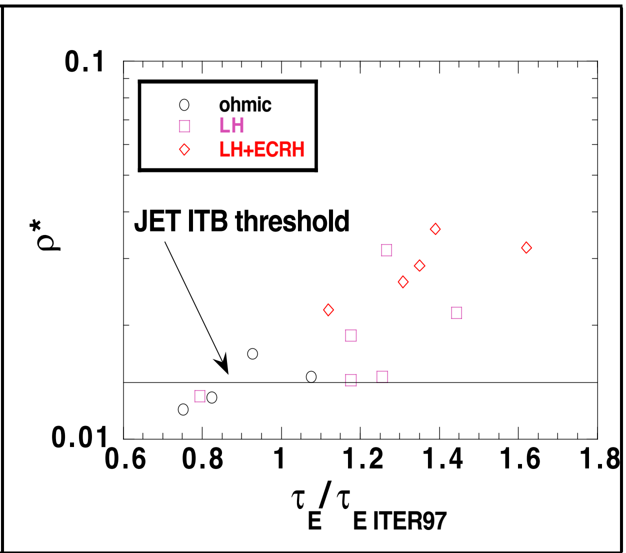

FIG.1d : ρ^* vs $\tau_E/\tau_{ITER\ 97\text{-}th}$: the maximum of ρ^* in the ITB region is used. The threshold value found on JET is also shown.

2.2 Internal Transport Barriers produced by IBW induced sheared flows

The investigation of ITB formation by IBW injection has continued with higher power capability, after the insertion of a second IBW launcher, using higher density, higher plasma current and lower Z_{eff} values than in the 1999 campaign [7]. In H plasmas the IBW absorption layer is located at about one third of the minor radius (at 4 Ω_H); the investigation has been carried out up to 0.4MA/7.9T and simultaneous density and temperature peaking has been observed, as it was found during the 1999 campaign (Fig. 2). Deuterium plasmas have been also investigated up to 0.8MA/7.9T. In these conditions the absorption layer is located more outwards ($r_{abs}/a \approx 0.65$). The experimental results for a D discharge (Fig.2) seems to indicate a larger ITB radius, in agreement with the position of the absorption layer (at $9\Omega_D$). During the IBW injection an increase of plasma density is observed, at constant electron temperature, together with a decrease of Z_{eff}. Transport analysis shows a uniform decrease of the electron thermal conductivity by 20% over the region inside the absorption radius.

3. Radiofrequency heating studies

3.1 Lower hybrid current drive at high density

The FTU LHCD experiment was originally designed in order to demonstrate the feasibility of LH current drive at ITER-relevant densities. During the last two years it has been possible to operate the LH system close to full power. Conditions of full CD have been achieved at higher density, higher plasma current and lower Z_{eff} than before. An example of plasma discharge close to full power for about 1s is shown in Fig. 3a [8].

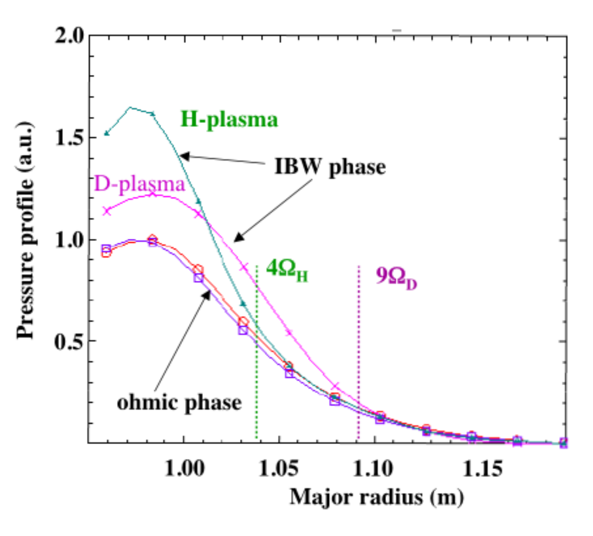

FIG.2 Pressure profile before and after IBW injection in D and H discharges at 0.4MA/7.9T

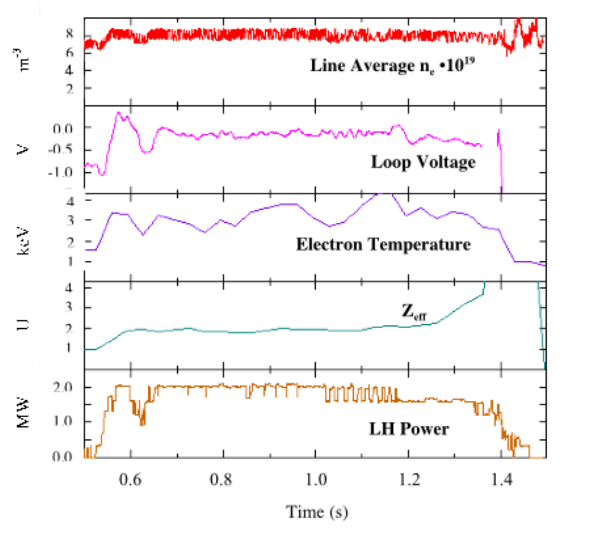

FIG.3a Time evolution of a LHCD discharge at full power. Up to 2MW for 0.8s have been injected at ITER relevant densities.

Following the first tests of the boronisation system, the decrease of the radiated power produced an increase of the heat loads on the stainless steel protection structures of the fast MHD measurements inside the vacuum chamber (MHD "rings"). The resulting increase of the "rings" temperature produced a large Mn evaporation followed by a disruption. During the 2001 winter campaign all the "rings" were dismantled and this problem was eliminated.

An example of a full LH current drive discharge with I= 0.50 MA and B= 7.2T is shown in Fig. 3b. The launched $n_{||}$ spectrum has a maximum at $n_{||}$ =1.52. The peak and average density are 1.3×10^{20} m^{-3} and 0.75×10^{20} m^{-3}, respectively. The electron temperature increases from 2keV in the ohmic phase to 6.0÷4.5 keV in the auxiliary heated phase. At these density values the electron-ion coupling is large and ion heating is observed from the large increase of the neutron rate. The neutron yield increases by a factor six corresponding to an ion temperature increase of 0.25 keV. Relatively low impurity content is maintained in these conditions: Z_{eff} increases from Z_{eff} =1.7 during the ohmic phase to Z_{eff} =2.7 during the LH phase. Note that at higher densities Z_{eff} remains below two during the LH phase. The current drive efficiency achieved in these discharges is $\eta_{CD}=0.23\times10^{20}$ $AW^{-1}m^{-2}$ and taking in account the Z_{eff} correction reaches the value of $\eta_{CD}=0.28\times10^{20}$ $AW^{-1}m^{-2}$. The LHCD efficiencies observed on FTU show a clear dependence on the average electron temperature $<T_e>$ when the correction for the impurity content is accounted for [9]. In Fig. 3c the value of the LHCD efficiency extrapolated to Z_{eff}=1 is plotted vs. $<T_e>$ for various devices showing that values in the range $\eta_{CD}=0.3\times10^{20}$ $AW^{-1}m^{-2}$ are achieved in a domain relevant to ITER.

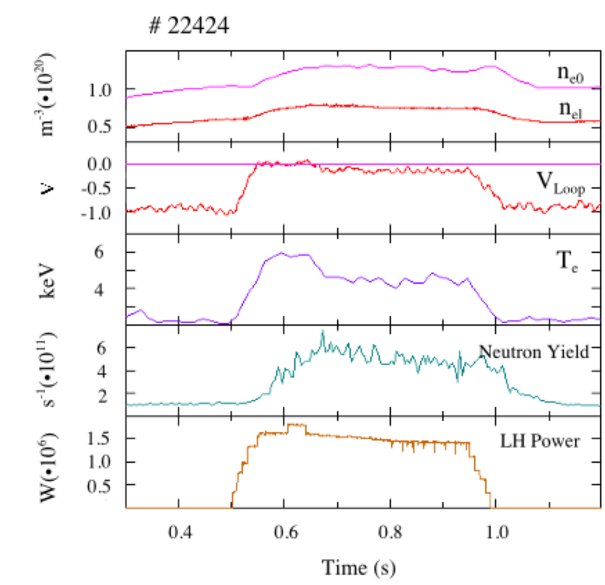

FIG 3b Full LHCD discharge at ITER relevant densities.

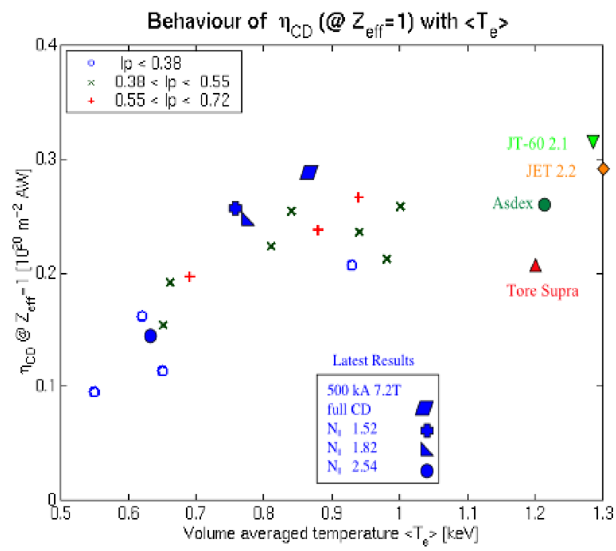

FIG.3c LHCD efficiency vs. average electron temperature.

3.2. Synergy studies in combined injection of LH and Electron Cyclotron waves

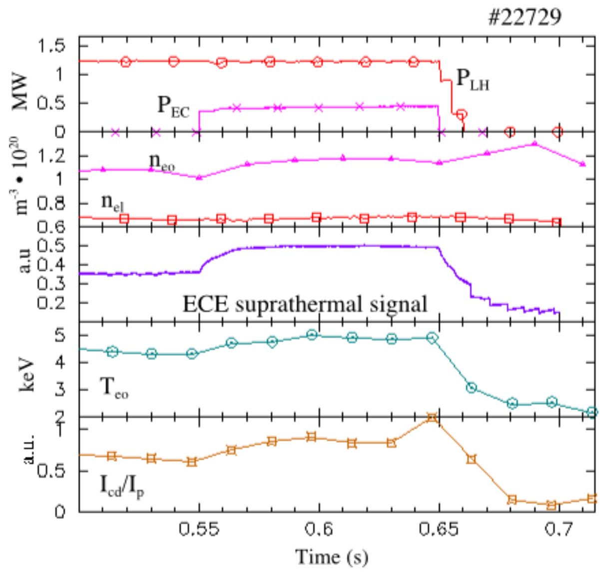

FIG.3d Time behaviour of main plasma quantity in case of down-shifted EC absorption experiment (shot #22729) at 7.2 T/0.5MA (EC bulk resonance (5 T) outside the plasma), $Z_{eff}\approx 3$ and full LHCD.

Synergistic effects between LH and EC radio-frequency waves open the possibility of combining the most interesting features of the two heating schemes, namely a high current drive efficiency for LH waves and a very localised, tuneable, and effective heating for EC waves. FTU is equipped with both LH and EC systems and can perform such an investigation at ITER relevant density values. Clear macroscopic effects were reported at the last IAEA Conference: a substantial temperature increase was obtained with P_{LH} up to 0.9 MW, P_{EC} up to 0.75 MW, B=7.2 T (cold EC resonance outside the vacuum vessel) and central plasma density up to 0.7×10^{20} m^{-3} in the reported domain of studies [10]. The synergy LHCD-EC is characterised by a substantial damping of the EC wave on the energetic LHCD produced electrons at a magnetic field at which the thermal electrons are not in resonance with the EC wave. Energetic electron tails are enhanced and a consequent increase in electron temperature and current drive is observed. Up to 60 to 70% of EC power is estimated to be absorbed in this process. Two distinct regimes have been investigated in FTU. In the so called down-shifted regime the operating magnetic field is above the resonant value for EC absorption (B=5T). The EC waves (O-mode, outer perpendicular launch) cannot interact with the bulk electrons, whereas they can be absorbed by the supra-thermal electrons tail induced by LHCD, because the relativistic mass down-shifts the resonance frequency. In the up-shifted regime, the operating magnetic field is below the resonant value. The wave can be absorbed in the inner part of the discharge but, before thermal absorption takes place, the wave is damped on the fast electron population. The first scheme allows to widen the FTU heating flexibility. The second scheme is of direct relevance for ITER.

The case of up-shifted EC absorption has been performed at 5.2T/0.6MA. The EC wave is launched with an angle of 30° with respect the magnetic field ($n_{\|EC} = 0.5$). The 700 kW of EC injection produce the stabilisation of the MHD activity, a clear indication of a modification of the current profile. The current driven fraction is increased, during the EC phase, by about 50 kA, more than a factor five larger than the value expected from thermal absorption (8 kA) and a factor 2.5 larger than the prediction of a simplified model of the suprathermal interaction (20 kA). The suprathermal EC absorption cannot be measured due to the presence of the thermal resonance in the plasma, the calculated theoretical data is 15%. The average $n_{||}$ value of the launched LH spectrum is $n_{||}$ =1.82. The impurity content corresponds to Z_{eff} = 2.7 in the ohmic phase with Z_{eff} increasing up to 6.7 during the RF injection. The upshifted scheme will be studied in detail when the new Fast Electron Bremsstrahlung emission cameras will allow a good determination of the fast electron density, which was not available in the 2000/2002 campaign.

The downshifted scheme is very reproducible The evolution of the main plasma quantities in case of down-shifted EC absorption experiment is shown in Fig.3d. The central magnetic field is 7.2 T and the plasma current is 0.5MA. A clear increase of central temperature and of the fraction of current driven are observed. The behaviour of ECE signal evidences the increase of supra-thermal population, as expected by theory. The overall EC absorption, estimated from the residual radiation in the chamber, is 80% The EC wave is injected in perpendicular direction (respect to the magnetic field) an the LH launched $n_{\|}$ is peaked at 1.82. Note that full non inductive CD was achieved in these conditions.

4. Transport studies

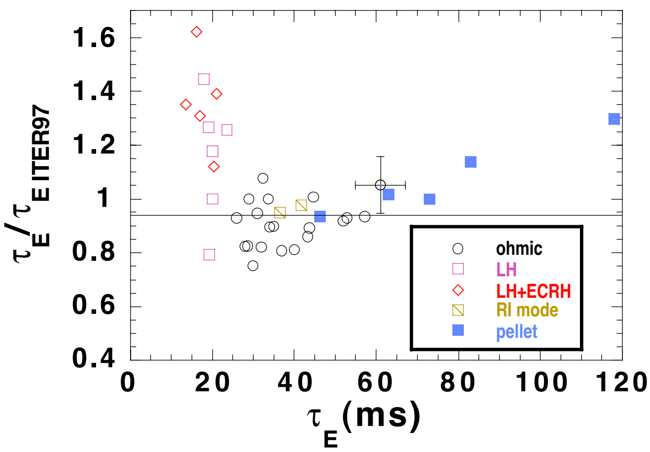

FIG.4a Ratio of τ_E (energy confinement time as calculated from transport analysis) to $\tau_{ITER\ 97\text{-}th}$ vs τ_E.

4.1 Global energy confinement

Over the last five years different confinement regimes, ranging from ohmic and L-mode plasmas to PEP and ITB plasmas were investigated in FTU. Transport analysis has been performed using EVITA [11] or JETTO [5] codes. The database contains 20 recent FTU discharges with typical plasma parameters in the range: B=5.2-7.2 T, I=0.35-1.2 MA, $n_e(0)=0.5\text{-}7.3\times10^{20}$ m^{-3}. Some discharges contribute with more points to the database, each point corresponding to a different heating scheme (for example LH or LH+ECRH): the typical heating power is P_{LH}=1.5-2.1 MW and P_{EC}=0.4-0.7 MW. A summary of FTU results on the global energy confinement is shown in Fig. 4a. The ohmic and L-mode discharges are generally in agreement with the ITER97 L-mode scaling. Discharges with an ITB have an energy confinement time up to 1.6 time the ITER97 scaling. The pellet discharges exhibit a time averaged confinement slightly above the ITER97 scaling, whereas gas fuelled discharges exhibit a confinement lower than the ITER97 scaling. Transient phases with enhancement factors up to 1.3 are observed but with the enhanced phase lasting less than one τ_E.

4.2 Stiffness

FTU offers the opportunity of testing transport theories based on critical gradients at collisionality values not achievable on other tokamaks. Electron temperature profile response to strong ECRH on FTU tokamak shows all the relevant features of stiffness: in spite of the wide range of different heating schemes (total heating power, difference in the deposition profile between ohmic and auxiliary heated discharges) the temperature gradient length value in the confinement region remains in a narrow range around $1/L_T$=10 m^{-1}(Fig.4b) [12]. In the last two years, modulated ECH was used to investigate temperature stiffness using transient transport techniques. The analysis of the amplitude and phase of the induced temperature modulation has been used using a model for $\chi_{e,HP}$ made by a superposition of step functions The results are shown in Fig. 4c. The $\chi_{e,HP}$ profile is characterised by a double step structure with the intermediate step corresponding to the edge of the region where stiffness is observed. Note that if no reduction in $\chi_{e,HP}$ at r=8cm is assumed, the simulated temperature modulation amplitude does not agree with the measurements. This indicates that an electron temperature gradient driven turbulent transport with a critical value for $1/L_T$ acts also in ohmic conditions. It is important to stress that these results applies to regions where finite magnetic shear is produced. At low magnetic shear, as e.g. during a current ramp, no stiffness of the temperature profile has been observed on FTU [2].

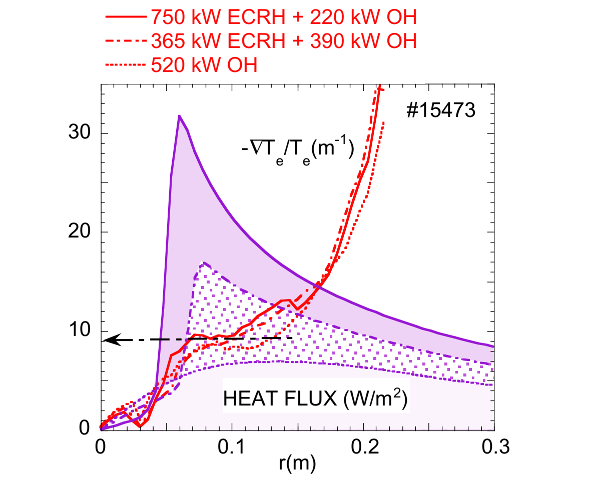

FIG.4b Temperature gradient length vs. radius for the discharge #15473 during the ohmic and auxiliary heated phase.

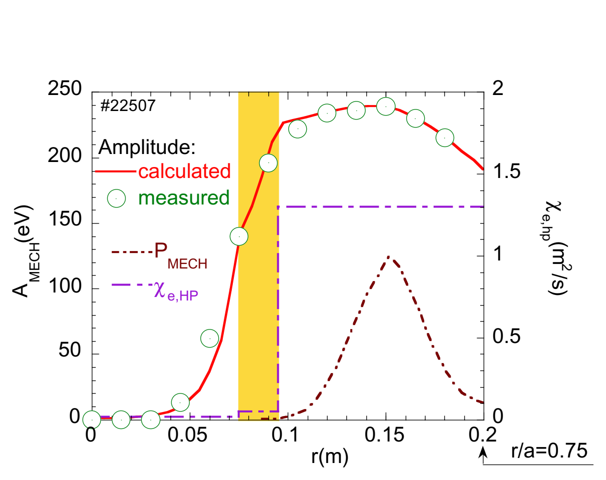

FIG.4c Amplitude of the temperature modulation during modulated ECH vs. radius. The deposition profile and the electron thermal conductivity are also shown.

5. High density regimes

Confinement improvement by density peaking is a well known results of several tokamaks with a possible explanation associated with Ion Temperature Gradient mode stabilisation. However, to obtain steady or quasi steady confinement improvement with simultaneous deep fuelling is not an easy task. At the last IAEA Conference, it was reported the achievement of a quasi steady state enhanced confinement regime with deep pellet fuelling obtained on FTU using a multiple (8 barrel) pellet injector with a maximum speed of 1.6km/s [13]. The density profile following the pellet injection was very peaked with central density values reaching $8x10^{20}m^{-3}$. During the last two years an effort has been made in order to optimise this regime and to understand the conditions to maintain such an improvement in steady state. The interest of this regime is related to the possibility of testing the scaling at high density, high plasma current (I≈1MA), low Z_{eff}, peaked density profiles and edge safety factor around q_a≈3.3.

In order to optimise the performance is crucial to achieve a control of the sawtooth activity as shown in Fig.5 where the time evolution of two discharges is displayed. If sawteeth are suppressed (as in the shot #12744), heavy impurity accumulation in the centre is observed with a substantial increase of the radiated power leading to a disruption (Fig.5a). The best condition is obtained when delayed sawteeth are produced (as in the shot #18598). In the FTU case, this result is achieved by a careful programming of the pellet injection time and by controlling the initial impurity content. In this case impurity accumulation is avoided and the duration of the enhanced confinement phase is limited only by the number of available pellets. Note that the impurity accumulation observed in the shot #12744 requires a modification of the impurity transport coefficients with respect to the pre-pellet phase, whereas in the shot #18598 the average effect of sawteeth maintains the impurity transport basically unchanged. It is apparent from these results that this enhanced confinement regime may be relevant for burning plasma operation provided sawteeth are not completely suppressed. Sawtooth control may be obtained e.g. using RF heating. Some attempt has been made on FTU to combine LHCD with pellets. Although good coupling conditions have been obtained, no clear effects on the plasma have been observed so far due to the high density and the limited available power.

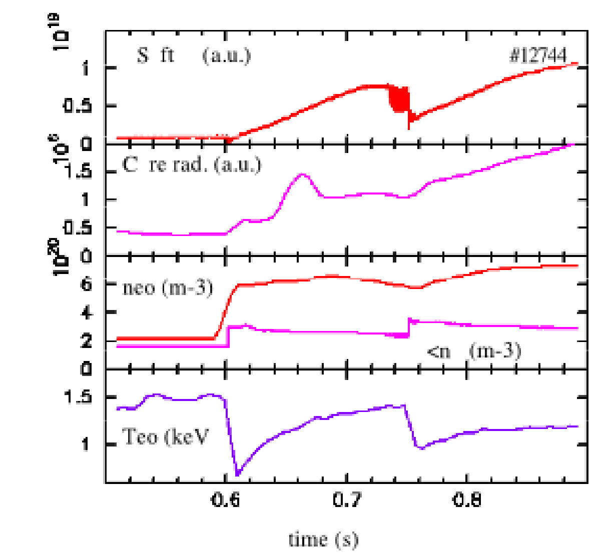

FIG. 5a Time traces for the shot #12744. After the second pellet sawteeth are suppressed and the core radiation increases due to heavy impurity accumulation.

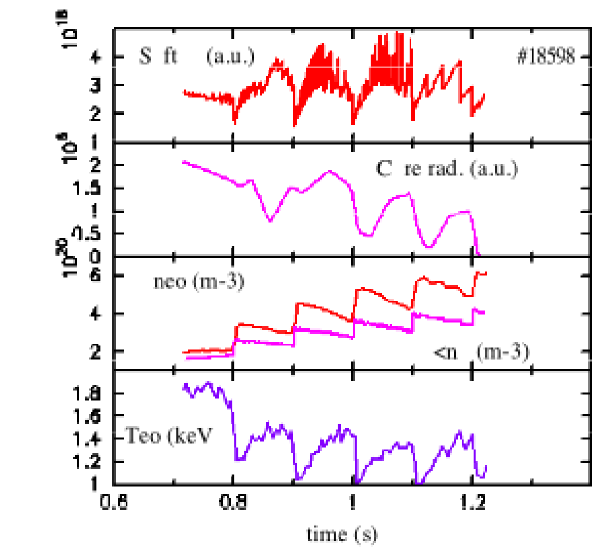

FIG.5b Time traces for the shot #18598. In this case sawteeth are delayed but not suppressed and a quasi steady state is achieved.

Very high central fuelling efficiency is also observed in these discharges. The pellet ablation occurs close to the q=1 surface but in very short time particles drift towards the centre, possibly due to the closeness to the q=1 surface, resulting in a peaked profile.

The power balance analysis has been performed with both JETTO and EVITA codes with similar result. Experimental data are used for the physical quantities except for the ions which are simulated with a neoclassical diffusion coefficient times an anomaly factor adjusted in order to fit the neutron yield. The ohmic pre-pellet phase requires an anomaly factor of about three which reduces to one after the first pellet in #12744 (0.6 s) and after the third (1.0 s) in the #18598. Neoclassical resistivity is always assumed which combined with Z_{eff} deduced from Bremmstrahulung emission, reproduces the measured loop voltage. These discharges exhibit a confinement larger than the value before pellet injection and, when a time average is performed, generally in agreement with the ITER97 L-mode scaling within the error bars. Transient confinement enhancement is observed up to 1.3 times the ITER97 scaling but the duration of such a phase is less than one energy confinement time (Fig.5c).

RI modes have been also produced for the first time on FTU. FTU can extend this regime of operation to high density and high magnetic field. A comparison between a RI mode shot and a reference ohmic shot is shown in Fig.5d. This 6T/0.9MA discharge exhibit the typical saturated ohmic confinement behaviour. With the Ne pulse a significant increase in both the energy confinement time and the neutron yield is observed. The radiated fraction reaches a value of 90% compared to 65% before the Ne pulse. Presently the density range was limited by the number of operating gas valves.

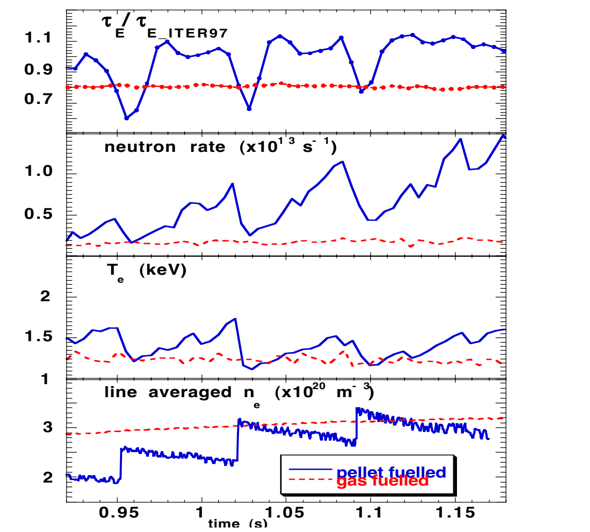

FIG. 5c Time evolution of the temperature, density, neutron rate and energy confinement time normalised to the ITER97 scaling for a gas fuelled and a pellet fuelled discharge.

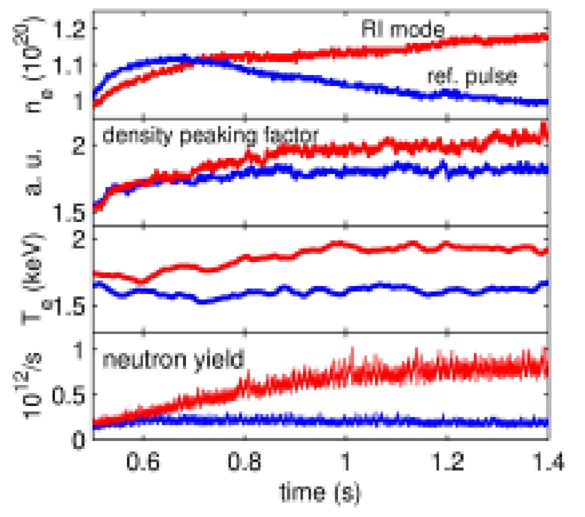

FIG. 5d Time evolution of a discharge exhibiting RI mode behaviour (red) and a reference ohmic discharge (blu).

6. MHD studies

6.1 Internal Kink Mode Behavior with Pellet Injection

As a result of deep pellet injection, macroscopic structures with dominant m=1 poloidal mode number were observed to saturate at large amplitudes and to survive across sawtooth collapses for times exceeding the resistive diffusion period (Fig. 6a). These structures were recognized as m=1 magnetic islands with a very strong soft-x-ray emission from the O-point region as shown in Fig. 6a. The non-linear stability of these islands seems to be due to radiative cooling around the O-point. In some cases the sawtooth activity disappears, and the m=2 sideband of the m=1 island develops an island at the q=2 radius. In these cases the mode frequency decreases or even locks, due to the fact that flux penetration across the q=2 radius gives rise to effective wall braking [14].

6.2 Reconnection studies

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Careful analysis of sawtooth collapses without precursor oscillations in FTU high-density, high current plasmas revealed that the fast collapse is preceded by a purely growing m=1 precursor. The precursor growth rate is similar to the one of the m=1 mode in the semicollisional regime. At the end of the precursor phase the growth rate increases by an order of magnitude, and a final steady state condition is reached in about 15 µs (the typical duration of purely growing and oscillating precursor is 100 µs and 1 ms respectively). Both in the precursor and in the fast collapse phase the plasma core structure is consistent with the one assumed in the Kadomtsev model, i.e the central region undergoes a top-hat displacement leaving room to a crescent-shaped m=1 island. The final (relaxed) configuration can be partly or almost fully reconnected; two (nearly) full reconnection events are typically interleaved by one or two partial reconnection events. In partial reconnection the displacement saturates at a value that is typically below 50% of the q=1 radius; in these cases decaying post-cursor oscillations are observed. In Fig.6b the evolution of temperature contours is shown during the fast collapse phase for a (nearly) full reconnection case. The displacement velocity as evaluated from the slope of temperature contours dramatically increases at t=0.8039 s and then saturates. The final displacement is at least 80% of the q=1 radius, but reconnection is not properly full as a tiny m=1 structure survives. The dashed curve in Fig.6b shows an extrapolation of the precursor exponential growth, while the dot-dashed line is obtained from a non-linear model assuming constant reconnection rate [15].

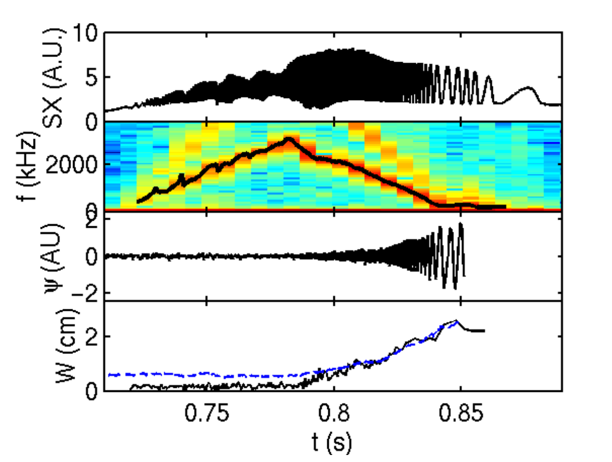

FIG.6a Formation and evolution of an m=1 structure after pellet injection at t=0.7s: a) soft x ray oscillations from impurity accumulation at the island o-point; b) and c spectrogram of this oscillation and of one magnetic coil.

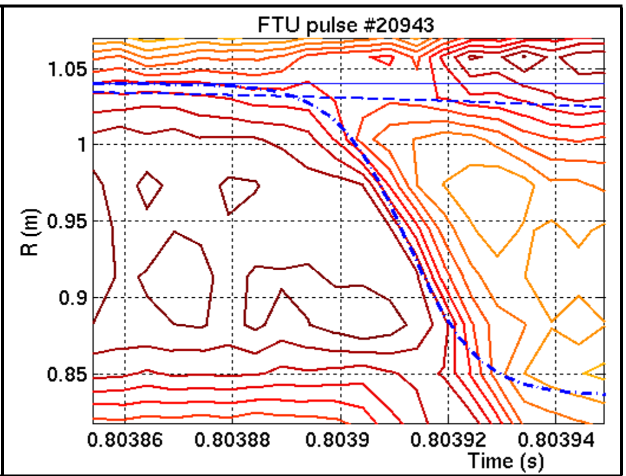

FIG.6b Temperature contours during the fast phase of a main sawtooth collapse. The island o-point is located at R=1.05 m.

7. Future plans

FTU will resume operation at the beginning of 2003. The main objective of the 2003 campaign will be the test and characterisation of the Passive Active Module envisaged as the LH launching structure for ITER. In the second half of 2003 the new scanning CO2 interferometer and the Motional Stark effect diagnostics will be inserted. Experiments will be performed on vertical pellet injection.

The analysis of possible enhancements of FTU has continued. The possibility of a substantial upgrade of FTU in a D-shaped device (FT3) operating up to 8T, 6MA has been investigated, The device equipped with the same diagnostic and auxiliary heating systems of FTU, with the addition of 20MW ICRH power at 70-90MHz, could be inserted in the FTU hall and would make full use of the Frascati site credits. The main scientific aim would be the investigation of collective effects in burning plasmas, by simulating the alpha particle behaviour with the fast ion produced by intense ICRH, and the preparation of ITER scenarios. Thanks to the short construction period (5 years) this device could be a JET-class tokamak (capable of achieving equivalent fusion gain between Q=1 and Q=5) for the accompanying program during the ITER construction period.

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