FTU – 2014 – C1 – week 24

Topic	EC 1 EC 2 RdO 1 RdO 2 PIC	EC	LH	Inj	Li	Experiment 1 Experiment 2	Date
M10 **M10**	**G. Granucci** **G. Granucci** A. Romano W. Bin G. Pucella	Y Y	--- ---	--- ---	--- ---	**EC Assisted Breakdown** **EC Assisted Breakdown**	10/06/2014 Tuesday
M10 **M06**	**G. Granucci** **G. Ramogida** W. Bin G. Artaserse C. Mazzotta	Y Y	--- ---	--- ---	--- ---	**EC assisted breakdown** **FTU – H**	11/06/2014 Wednesday
M03 **M13**	**G. Pucella** **W. Bin** G. Calabrò V. Cocilovo P. Buratti	Y Y	--- ---	--- ---	--- ---	**MHD limit cycles** **MARFE stabilization**	12/06/2014 Thursday
M04a **M04a**	**G. Pucella** **G. Pucella** G. Ramogida G. Calabrò O.D'Arcangelo	--- ---	--- ---	--- ---	--- ---	**DL low BT** **DL low BT**	13/06/2014 Friday

M10 EC Assisted Breakdown

10/06/2014 (Early & Late)
11/06/2014 (Early)

Scientific Coordinator: G. Granucci
Deputy: S. Garavaglia

Scientific Team: W. Bin, S. Garavaglia, G. Granucci, D. Ricci

Related external tasks or contracts
F4E GRANT 346 ended but with possible extension, F4E GRANT 161

Past experiments on which the current experiment is based
First tests in 2009
Ohmic campaign in 2012 (to be compared with the result with EC power)
1 partially day with EC power in 2013

M10 Background, goals and experimental strategy

Background

The EC assisted breakdown will be applied for the ITER plasma start-up. FTU is in the unique condition to be able to reproduce, in field, polarization and injection angle the ITER conditions. In particular it is possible to test the real effectiveness of mode conversion at inner wall reflection (for injection angle around 20°) that is at the basis of the positive results expected for ITER. A 0D code to predict the required power for EC assisted breakdown (BKD0) has been developed at IFP and used on the old FTU data and on data from AUG.

Goals

Completion of polarization conversion efficiency vs injecting toroidal angle study. Assisted EC start-up in presence of strong radial field (V + H) at low electric field. Investigation of runaway generation at start-up X2 vs O1 effectiveness comparison (ITER initial strategy). Extension E/p operational window in ITER like configuration. Validation of BKD0 code at low pressure & high EC power (<800kW)

Experimental strategy

Completion of oblique injection angle scan to compare results with or without inner wall reflection. Using P8 new launcher for refined toroidal angle. Error field scan with different EC power at low V_loop to verify positive/negative effect on breakdown. After selection of good data in O1 from database, try to obtain similar results at 2.5T with X2 polarization mode: toroidal inj. scan 0° - 20° - 24° (no inner wall reflection), pressure scan at low voltage, 2 power level.

M10 Pulse plan

Pulse Plan

Polarization conversion at inner wall>>>Oblique injection angle
Zero at 5.3 T
5.3 T / ECRH 400kW P8 Upper 20º t=0 / Vloop=8V (no commutation)
5.3 T / ECRH 400kW P8 Upper 24º t=0 / Vloop=8V (no commutation)
5.3 T / ECRH 400kW P12 L1 20º t=0 / Vloop=8V (no commutation)
5.3 T / ECRH 400kW P12 L1 10º t=0 / Vloop=8V (no commutation)

Minimum low field target
5.3 T / ECRH 400kW P12 L1 20º t=0 / Vloop=2V
Repeat 6) [optimization]
Zero at 2.5 T
2.5 T / ECRH 400kW P12 L1 20º t=0 / Vloop=2V
Repeat 9) [optimization]
Repeat 9) [optimization]

Vertical error field scan at minimum low field target
5.3T /400kW/Vloop_min for Bvscan (100G)
5.3T /400kW/Vloop_min for Bvscan (step ± 50G)
5.3T /400kW/Vloop_min for Bvscan (step ± 50G)
5.3T /Vloop_min/BV max at 800kW
2.5T /400kW/Vloop_min for Bvscan (100G)
2.5T /400kW/Vloop_min for Bvscan (step ± 50G)
2.5T /400kW/Vloop_min for Bvscan (step ± 50G)
2.5T /Vloop_min/BV max at 800kW

14	Program
2	Zero
0	Recovery
3	Repeat

G. Granucci

M06 FTU H – mode

11/06/2014 (Late)

Scientific Coordinator: G. Ramogida
Deputy: G. Calabrò

Scientific Team: L. Boncagni, G. Calabrò, D. Carnevale, F. Crisanti, G. Mazzitelli, G. Ramogida

Related external tasks or contracts

Enabling Research project: MST2 (Resp.: B. Esposito)

Past experiments on which the current experiment is based

M03 – M06

Number of good pulses: 5

M06 Background, goals and experimental strategy

Background

Power exhaust is one of the main issues to be tackled to achieve steady state operation of future reactors. In the last years liquid metals have demonstrated to be a possible candidate to improve the situation. In 2013, first elongated FTU plasmas heated by 650 kW of ECRH have been obtained with the new actively Cooled Liquid Lithium Limiter (CLLL), that will enable sustaining up to 10 MW/m^2. These discharges aim at investigating the access to H-mode. No L-mode to H-mode transition was observed so far, consistent with the threshold being above the injected power at BT = 5.5T . Neither damage on CLLL nor plasma pollution were observed despite the CLLL was located near (~1cm) the Last Closed Magnetic Surface.

Goals

Experimental study of heated elongated plasma, considering discharges with a lower value of the toroidal magnetic field (2.7T) to reduce the power requirement for accessing H-mode, thus having the possibility to study the impact of Edge Localized Modes (ELMs) on the CLLL used as first limiter.

Experimental strategy

Ohmic and heated high elongated plasmas will be studied with the CLLL at different position (+0cm, +1cm and +2cm) at low-medium plasma electron density in order to access H-mode. Comparison with circular plasma discharges in the same operational conditions will be performed.

M06 Pulse plan

10	Program
2	Zero
0	Recovery
0	Repeat

Pulse Plan

- *RESTART*: test the 2.7T/200kA with high elongation in ohmic

1) Zero at 2.7T
2) 2.7T/200kA "elongated" (combination of pulse #38049 (2.7T/250kA)
3) "circular with I_p ramp-up optimized" and
#37869 (5.5T/200kA) "D-shaped during the I_p flat-top")

- *EXPERIMENTAL DAY 04/06/2014: Compare circular and D-shaped plasma at 2.7T, heated pulses with no CLLL*

3) Zero at 2.7T
4) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 1gyr for 50m
5) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 1gyr for 200ms
6) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 2gyrs for 200ms
7) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 3gyrs for 200ms
8) 2.7 T/200 kA (circular target), n_e =0.3x10^{20}m^{-3}, ECRH = max for 200ms

- *EXPERIMENTAL DAY 25/06/2014: Compare circular and D-shaped plasma at 2.7T, heated pulses with CLLL=1cm*

9) Zero at 2.7T
10) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 1gyr for 200ms
11) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 2gyrs for 200ms
12) 2.7 T/200 kA (elongated), n_e =0.3x10^{20}m^{-3}, ECRH = 3gyrs for 200ms
13) 2.7 T/200 kA (circular target), n_e =0.3x10^{20}m^{-3}, ECRH = max for 200ms

G. Ramogida

M03 MHD limit cycles

12/06/2014 (Early)

Scientific Coordinator: G. Pucella
Deputy: P. Buratti

Scientific Team: P. Buratti, E. Giovannozzi, G. Pucella

Related external tasks or contracts

Enabling Research project: CfP-WP14-ER-01/ENEA_RFX-02 2014
Budget and Resources: 1.3 ppy + 2 keuro mobility (Frascati+Milano)

Past experiments on which the current experiment is based

M03 - MHD limit cycles (2012 - C2)
Number of obtained pulses: 19

M03 Background, goals and experimental strategy

Background

In 2011 dedicated density limit experiments were performed on FTU. All the discharges showed a very similar MHD phenomenology: an m/n = 2/1 mode starts during the density ramp-up, grows up to high amplitude and reduces its frequency rapidly just before the disruption, with a final phase characterized by amplitude and frequency oscillations.

Goals

Experimental study of tearing mode complex behaviour in FTU, determining the role of interaction between islands with different helicities and the scaling for transitions between different regimes (saturation, limit cycles, locking) in terms of plasma parameters and mode amplitude. Establish the role of 2/1 – 3/1 mode coupling, the role of error field, the scaling of critical amplitude and how does the mode structure change during cycles.

Experimental strategy

Limit cycles in island frequency-amplitude plane will be studied at different values of the safety factor, in order to vary the interaction with resonant error fields and between islands of different helicity. Local variations of the current density profile that modify in different ways the free energy available to different modes will be induced by means of the 140 GHz electron cyclotron heating system.

M03 Pulse plan

11	Program
2	Zero
4	Recovery
3	Repeat

Pulse Plan

Compare standard q > 3 cases with q < 3 ones (no 3/1 resonance).

1) Zero at 3.6 T
2) 3.6 T / 500 kA (target q > 3), ne up to tearing mode onset
3) 3.6 T / 500 kA, density limit (ref. 34159, 34162, 34164)
4) Recovery
5) 3.6 T / 700 kA (target q < 3), ne up to tearing mode onset
6) 3.6 T / 700 kA, density limit (the end if cydes are present)
7) Recovery
8) Repeat with different gas (the end if cydes are present)
9) Recovery
10) 3.6 T / 700 --> 500 kA, current ramp-down near density limit
11) Repeat

Local variations of the current density profile induced by means of the 140 GHz electron cydotron heating system.

12) Zero at 5.3 T
13) 5.3 T / 500 kA (target), ne up to tearing mode onset
14) 5.3 T / 500 kA, density limit (ref. 34259)
15) Recovery
16) Target just below density limit
17) Repeat (adjust gas)
18) ECRH deposition scan: q = 1.5 --> 2.5
19) ECRH at q = 2.5
20) ECRH deposition scan: q = 2.5 --> 3.5

G. Pucella

M13 MARFE stabilization

12/06/2014 (Late)

Scientific Coordinator: W. Bin
Deputy: O. Tudisco

Scientific Team: W. Bin, O. D'Arcangelo, L. Figini, C. Galperti, S. Garavaglia, M. Marinucci, C. Mazzotta, A. Moro, G. Pucella, O. Tudisco

Related external tasks or contracts
Enabling Research project: CfP-WP14-ER-01/ENEA_RFX-02 2014
Budget and Resources: 1.3 ppy + 2 keuro mobility (Frascati+Milano)

Past experiments on which the current experiment is based

M13 Background, goals and experimental strategy

Background

In FTU the poloidally asymmetric MARFE instability can be routinely induced and has the peculiarity that it does not degrade the plasma confinement and does not lead to plasma disruption. For this reason FTU represent an ideal test bed to study this kind of phenomenon. Several properties of MARFE have been already demonstrated during the last years in FTU and now are well known. Nevertheless, the effects of the ECRH power on this kind of instability and on the plasma regimes which establish in presence of that have not been studied up to now.

Goals

The goal of the proposal is the study of the effects of the EC waves injection in plasmas where MARFE is established. The first aim is to demonstrate if the ECRH can be used as a tool to prevent or to control this kind of instability and, in particular, to define the proper power threshold to obtain the stabilization as well as to study the effects of different localizations of power deposition. Secondly, the experiment should aim at investigating the effects of the ECRH on the scalings related to MARFE that we know nowadays.

Experimental strategy

One gyrotron will be used to inject ECRH power with the new front steering antenna. To test the effect of the EC wave on MARFE a power deposition will be performed with a flat top line density level higher than the density threshold for which MARFE establishes and lower than the density limit for disruption: 1- on the equatorial plane; 2- from the equatorial plane to the peripheral regions of the plasma.

M13 Pulse plan

Pulse Plan

1) Zero at 4.8 T
2) 4.8 T / 300 kA ne=8.0·1019 flat top, reference Ohmic shot
3) 4.8 T / 300 kA, density ramp-up to find the density limit for disruption (ndisr) and the line average density of MARFE onset (nmarfe) - Ohmic shot
4) 4.8T / 300kA, flat top: nmarfe < ne < ndisr, ECRH from new launcher line-4 (L4_NL) for 300 ms from t=900 ms, poloidally toward the equatorial plane with constant toroidal injection angle ($\beta^*=5°$, with $\theta= 11.6°$, $\phi= 7.1°$)

If in shot 4) ECRH stabilizes MARFE:

5) Density ramp-up to find the density limit for disruption when ECRH is injected to keep MARFE stabilized - ECRH (L4_NL) for 300 ms with the same launching angles as in 4)
6) 4.8T / 300kA, flat top: nmarfe < ne < ndisr, ECRH (L4_NL) for 300 ms, the same toroidal angle as in shot 4) $\beta^*=5°$ and poloidal scan from equatorial plane up, from ($\theta= 11.6°$, $\phi= 7.1°$) to ($\theta= 18.4°$, $\phi= 6°$)
7) 4.8T / 300kA, flat top: nmarfe < ne < ndisr, ECRH (L4_NL) for 300 ms, the same toroidal angle as in shot 4) $\beta^*=5°$ and poloidal scan from equatorial plane down, from ($\theta=11.6°$, $\phi=7.1°$) to ($\theta=6.4°$, $\phi=8.1°$)

If in shot 4) ECRH do not stabilize MARFE:

5-bis) the same as shot 6): 4.8T / 300kA, flat top: nmarfe < ne < ndisr, ECRH (L4_NL) for 300 ms, the same toroidal angle as in shot 4) $\beta^*=5°$ and poloidal scan from equatorial plane up, from ($\theta= 11.6°$, $\phi= 7.1°$) to ($\theta= 18.4°$, $\phi= 6°$)
6-bis) the same as shot 7): 4.8T / 300kA, flat top: nmarfe < ne < ndisr, ECRH (L4_NL) for 300 ms, the same toroidal angle as in shot 4) $\beta^*=5°$ and poloidal scan from equatorial plane down, from ($\theta= 11.6°$, $\phi= 7.1°$) to ($\theta=6.4°$, $\phi= 8.1°$)
7-bis) the same as shot 5) but with injection angles to be defined after shots 5-bis) and 6-bis): density ramp-up to find the density limit for disruption when ECRH is injected to keep MARFE stabilized - ECRH (L4_NL) for 300 ms

4.8T / 350kA:

8) 4.8 T / 350 kA the same as shot 3): density ramp-up to find the density limit for disruption (ndisr) and the line average density of MARFE onset (nmarfe) - Ohmic shot
9) 4.8 T / 350 kA the same as shot 5): density ramp-up to find the density limit for disruption when ECRH is injected to keep MARFE stabilized - ECRH (L4_NL) for 300 ms with the same launching angles as in 4)
10) 4.8 T / 350 kA the same as shot 4): 4.8T / 350kA, flat top: nmarfe < ne < ndisr, ECRH from new launcher line-4 (L4_NL) for 300 ms from t=900 ms, poloidally toward the equatorial plane with constant toroidal injection angle ($\beta^*=5°$, with $\theta= 11.6°$, $\phi= 7.1°$)
11) 4.8 T / 350 kA the same as shot 6): 4.8T / 350kA, flat top: nmarfe < ne < ndisr, ECRH (L4_NL) for 300 ms, the same toroidal angle as in shot 4) $\beta^*=5°$ and poloidal scan from equatorial plane up, from ($\theta= 11.6°$, $\phi= 7.1°$) to ($\theta= 18.4°$, $\phi=-6°$)
12) 4.8 T / 350 kA the same as shot 7): 4.8T / 350kA, flat top: nmarfe < ne < ndisr, ECRH (L4_NL) for 300 ms, the same toroidal angle as in shot 4) $\beta^*=5°$ and poloidal scan from equatorial plane down, from ($\theta= 11.6°$, $\phi= 7.1°$) to ($\theta=6.4°$, $\phi=8.1°$)

11	Program
1	Zero
0	Recovery
0	Repeat

W. Bin

M04a Density limit at low B_T

13/06/2014 (Early & Late)

Scientific Coordinator: G. Pucella
Deputy: O. Tudisco

Scientific Team: P. Buratti, M. Marinucci, C. Mazzotta, G. Pucella, O. Tudisco

Related external tasks or contracts
Enabling Research project: CfP-WP14-ER-01/ENEA_RFX-02 2014
Budget and Resources: 1.3 ppy + 2 keuro mobility (Frascati+Milano)

Past experiments on which the current experiment is based
Density limit experiments (2011 – C1)
Number of obtained pulses: 15

M04a Background, goals and experimental strategy

Background

In 2011 the behavior of the density limit was explored on FTU in a wide range of plasma current (500 - 900 kA) and toroidal magnetic field (4 - 8 T).

Goals

Explore high density FTU plasmas for low toroidal magnetic field and plasma current (B_T = 2.0 – 5.2 T, Ip = 250 – 360 kA)

Experimental strategy

The behavior of the density limit will be investigated over a wide range of parameters in terms of plasma current (from 200 to 360 kA), applied toroidal field (2 – 4 T) and edge safety factor q(a) (>2) on the FTU device. For each (I_P, B_T) configuration the gas injection will be tailored to produce an increasing density up to the disruption for density limit. All discharges will have gas puffing and ohmic heating only and will be performed under clean machine conditions.

M04a Pulse plan

Pulse Plan

1) Zero at 5.2 T
2) 5.2 T / 250 kA density limit
3) Recovery
4) 5.2 T / 360 kA density limit
5) Recovery
6) Zero at 4.0 T
7) 4.0 T / 250 kA density limit
8) Recovery
9) 4.0 T / 360 kA density limit
10) Recovery
11) Zero at 3.0 T
12) 3.0 T / 250 kA density limit
13) Recovery
14) 3.0 T / 360 kA density limit
15) Recovery
16) Zero at 4.0 T
17) 4.0 T / 250 kA density limit
18) Recovery
19) 4.0 T / 360 kA density limit
20) Recovery

8	Program
4	Zero
8	Recovery
0	Repeat

G. Pucella