Sawtooth and magnetic precursor during NBH discharge on TCV


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Introduction

Study of different heating scenarios in a TCV discharge. Sawtooth instabilities and related magnetic activities are found to be responsible under certain conditions to redistribution of the thermal and injected fast-ion populations.

Equilibrium

- Located close to the vacuum vessel thanks to its size 169 × 302 × 1260mm².
- Neutral particle counts integrated along line of sights from aligned with the NBH injection line to nearly tangential, on the equatorial plane.
- \( \lambda = v_{\parallel}/v_0 \) (pitch angle window as function of CNPA viewline).
- Energy proportion \( \lambda_{\text{max}} - \lambda_{\text{min}} \):
  - \( \lambda_{\text{max}} = 25\text{ keV} \): 73%
  - \( \lambda_{\text{max}}/2 \): 20%
  - \( \lambda_{\text{max}}/3 \): 7%

Neutral particle analyzer

-\( \lambda = v_{\parallel}/v_0 \) for \( q = 1 \) surface, at birth \( \lambda = \gamma_p/v_0 \) = 0.85 and different deuterium fractions.

1. ECRH period

- Sawtooth instability with period ~ 2 ms
- No relevant Mirnov signals on LFS-MID toroidal array
- Magnetic bursts on LFS-TOP and -BOT toroidal arrays
- No CNPA data available

2. ECRH+NBH period

- Sawtooth instability with period ~ 2 ms
- No relevant Mirnov signals on LFS-MID toroidal array
- Magnetic bursts on LFS-TOP and -BOT toroidal arrays
- CNPA counts show no significant changes correlated with the sawteeth

3. NBH period

- Sawtooth instability with period ~ 10 ms
- Magnetic precursor of sawtooth crash on LFS-MID toroidal array: a ballooning \( m/n = 1/1 \) MHD mode occurring on \( q = 1 \) surface, at \( f \approx 2 \text{kHz} \) (Doppler-shifted due to the toroidal plasma flow \( f \approx 25 \text{kHz} \))
- The sawtooth crash is correlated in time with an increase of deuterium neutrals escaping from the plasma ~ 30% for all the energies from thermal up to the injection one
- Magnetic signals cross-correlated with the Correlation Cyclotron Electron Emission [Fontana, Rev. Sci. Instrum. 88, 2017] to obtain the radial shape of the precursor, by assuming:
  i) \( i - B - (B \cdot \delta T) \)
  ii) vacuum approximation from LCFS and the wall i.e. \( i - B \cdot (\delta T)^r \).
- The magnitude of the mode on the \( q = 1 \) is \( \delta B_{\perp,1} = 400 \text{mG} \) and its characteristic width ~ 1 cm

4. Observations

During the ECRH+NBH the sawtooth periods are shorter than during solely NBH. Deposition of power by injected ions is well known to increase the sawtooth growth time [Campbell, Phys. Rev. Lett. 60, 1988]. Here long sawteeth are found only in the NBH window suggesting that the electron heating can affect the sawtooth instability. [Lennholm, Phys. Rev. Lett. 102, 2009] point out that despite the presence of a strong ion pressure an ECCD can shorten the sawtooth period even if the induced current is ~ 0.1\%i_p. In the present case the induced current by ECRH is nearly 1\%i_p, however further analysis is required in order to assess the reliability of the same mechanism on this TCV discharge.

Magnetic precursor of sawtooth crash on LFS-MID toroidal array: a ballooning \( m/n = 1/1 \) MHD mode occurring on \( q = 1 \) surface, at birth \( \lambda = \gamma_p/v_0 \) = 0.85 and different deuterium fractions.

CNPA counts show no significant changes correlated with the sawteeth.