Observation of Secondary Instability of Magnetic Island in COMPASS High Density Limit Plasmas

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Abstract

In the precursor of COMPASS major Density Limit Disruption (DLD), a secondary instability is observed during $m:n=2:1$ magnetic island evolution. A sinusoidally oscillating signal of $\dot{B}_\theta(t)$ becomes distorted at the onset of this instability, prior to a major DLD. No poloidal or toroidal mode number can be assigned to the secondary instability. A further insight of such secondary instabilities may lead to a better understanding of disruption physics.

Motivation

The next generation of fusion devices will have to operate with high density plasmas as the power gain of a tokamak reactor increases with plasma density. But these plasmas are prone to a complex plasma instability, generally called major Density Limit Disruption (DLD). Disruption results in a sudden loss of energy confinement, and will lead to high mechanical and thermal loads of many GWm^{-2} on ITER and future fusion power plants [1, 2, 3]. The study of major disruptions is of great importance for the future of tokamak reactors as every disruption is undesirable in these reactors and the goal is to decrease its probability of occurrence as close to zero as possible. Disruption is detrimental for ITER, significant for JET but tolerable for smaller tokamaks. Therefore, a smaller device like COMPASS is excellent to study disruptions.

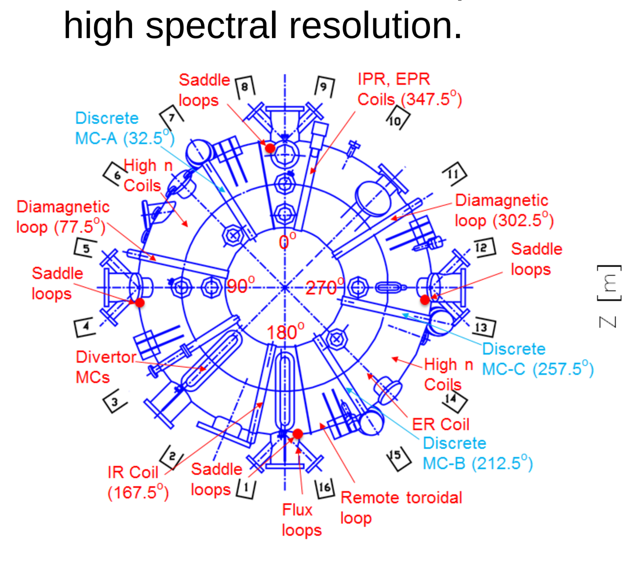
Introduction

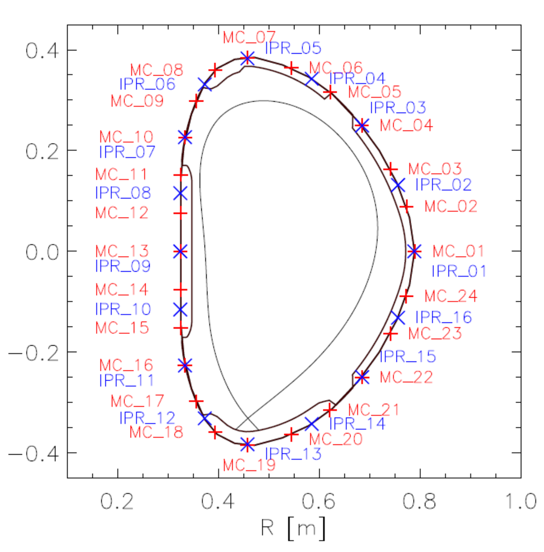
Disruption places a limit on the maximum density, pressure and on the minimum safety factor in a tokamak. DLDs are preceded by a well established sequence of events [1, 2], usually called the precursor of the disruption that starts with the radiative contraction of the current profile caused by increase of electron density with impurity accumulation in the edge. Contraction of the current profile follows, destabilizing MHD modes, mainly an m/n = 2/1 tearing mode (where m and n are the poloidal and toroidal mode numbers, respectively). The linear phase of this MHD instability is rather well understood. However the nonlinear behavior that coincides with large amplitudes reached in the precursor phase of the disruptions, is not well understood [4, 5, 6]. A theoretical model that gained some popularity evoked the overlapping of magnetic islands as capable of creating stochastic field lines that could rapidly conduct electrons and heat in the radial direction [7]. However disruptions are observed without island overlapping. A secondary instability to the magnetic island was found to occur in JET plasmas [8] disruptions. Secondary instabilities have been predicted by theory and studied in different regimes [6, 9]. MHD simulations have predicted the influence of plasma rotation in the developing of secondary instabilities in externally induced magnetic islands [10]. Recently [11] in TCABR density limit plasmas, the natural acceleration of magnetic islands and ions was observed to be quite distinct except at the disruption, where they were equal. The study of the natural flows of MHD modes is very important, since in future large tokamaks like ITER it is expected negligible momentum addition by NBI.

Some Diagnostics of COMPASS

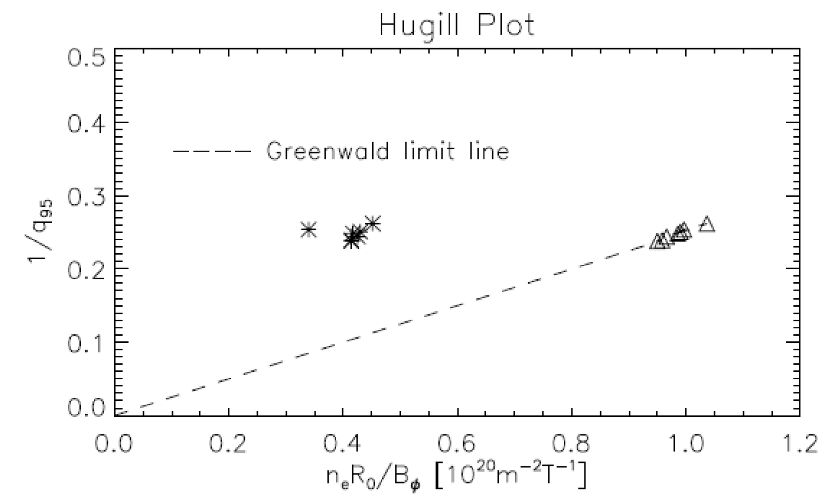
Parameters			
	$R_0 = 0.56\ [m]$	$a = 0.23\ [m]$	$B_t \le 2.1\ [T]$
	$\tau_{pulse} < 1\ [s]$	$\kappa = 1.8$	$I_p(\max) = 360\ [kA]$

- Equipped with ~ 400 magnetic diagnostic coils [12]
  - 3x24 Mirnov coils (MCs) located at TF7 (MC-A), TF15 (MC-B), TF13 (MC-C)
  - Good responsivity of MCs to high frequency (up to 1 MHz)
  - Full poloidal Internal Rogowski (IR) Coil located at TF 1
  - Ring of 16 Internal Partial Rogowski (IPR) coils (TF9)
  - 4 Saddle loops either on HFS or on LFS
- Also equipped with other necessary diagnostic systems like Thomson scattering, SXR, interferometry, reflectometry etc.
- A passive spectroscopic diagnostic system will be available soon, to measure the poloidal and toroidal ion rotation with high spectral resolution.

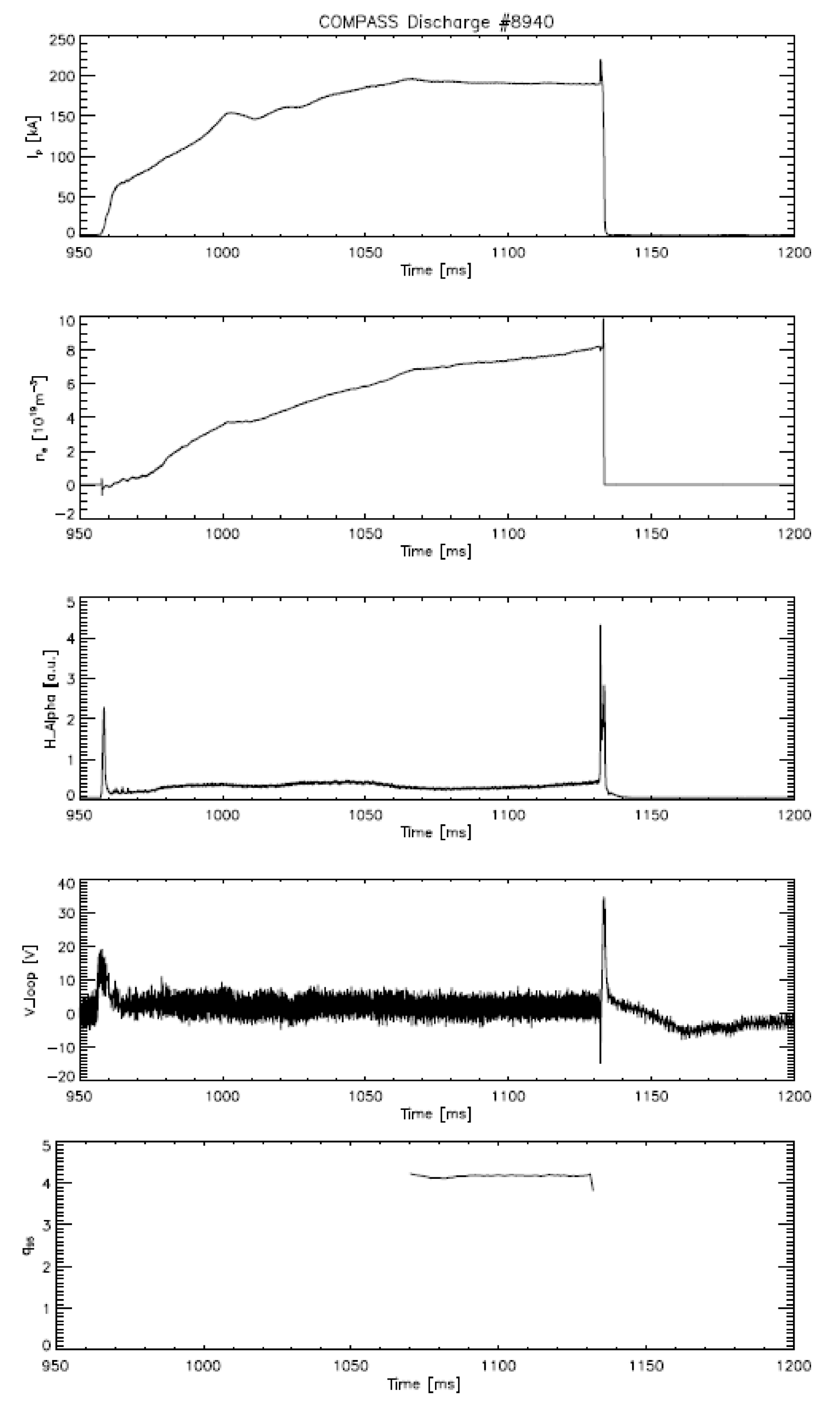




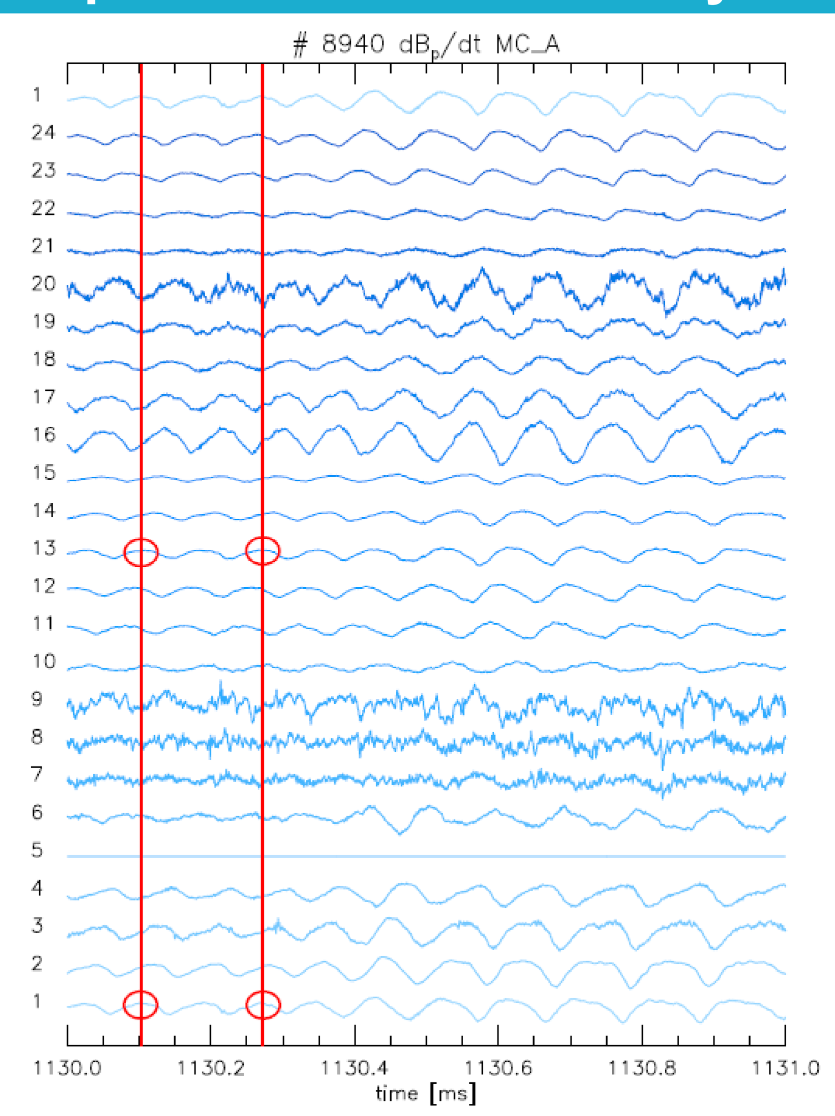
Exp. Results – Hugill Plot

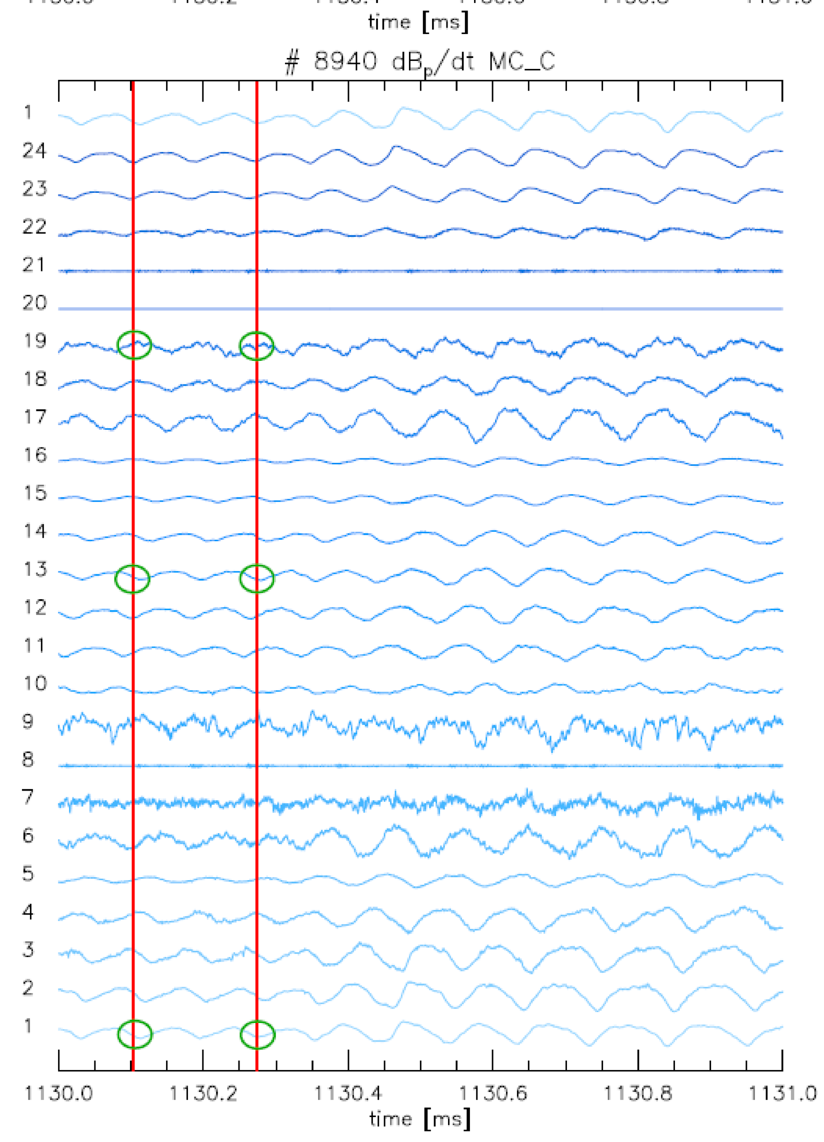


Exp. Results – Discharge # 8940

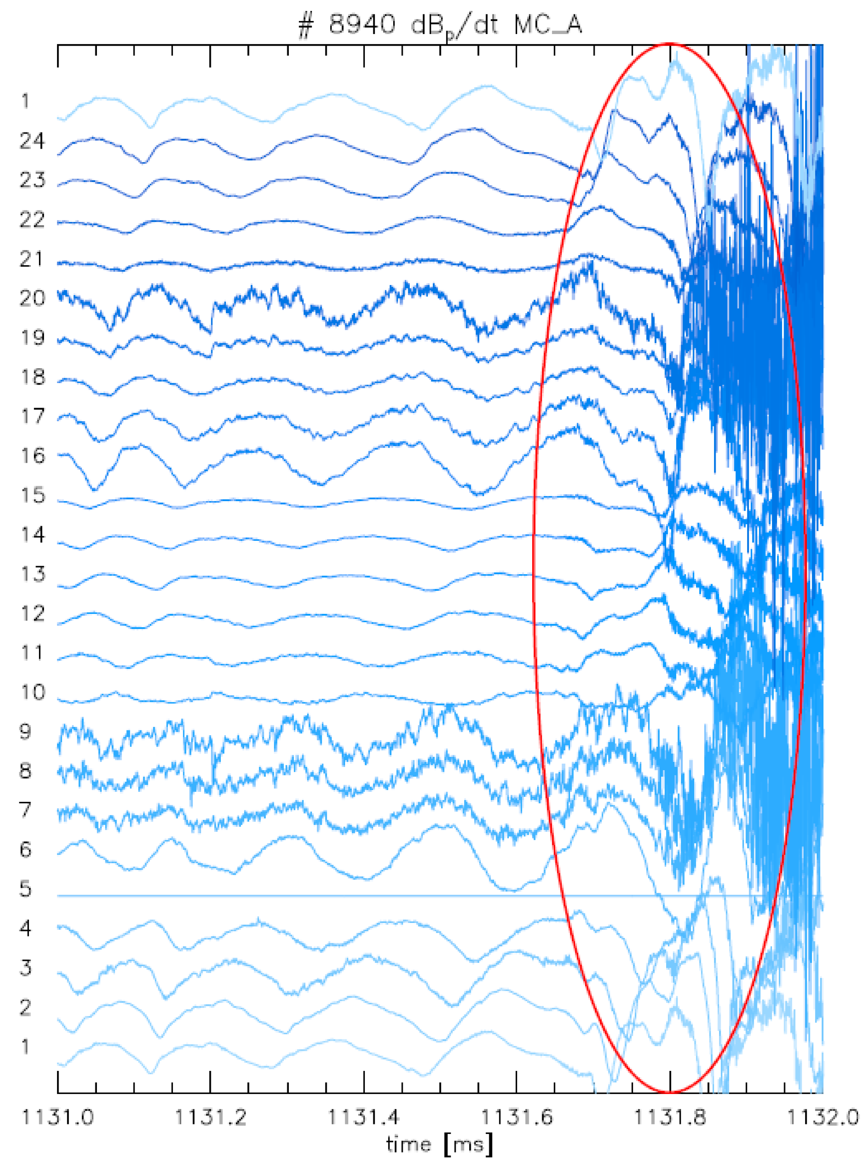


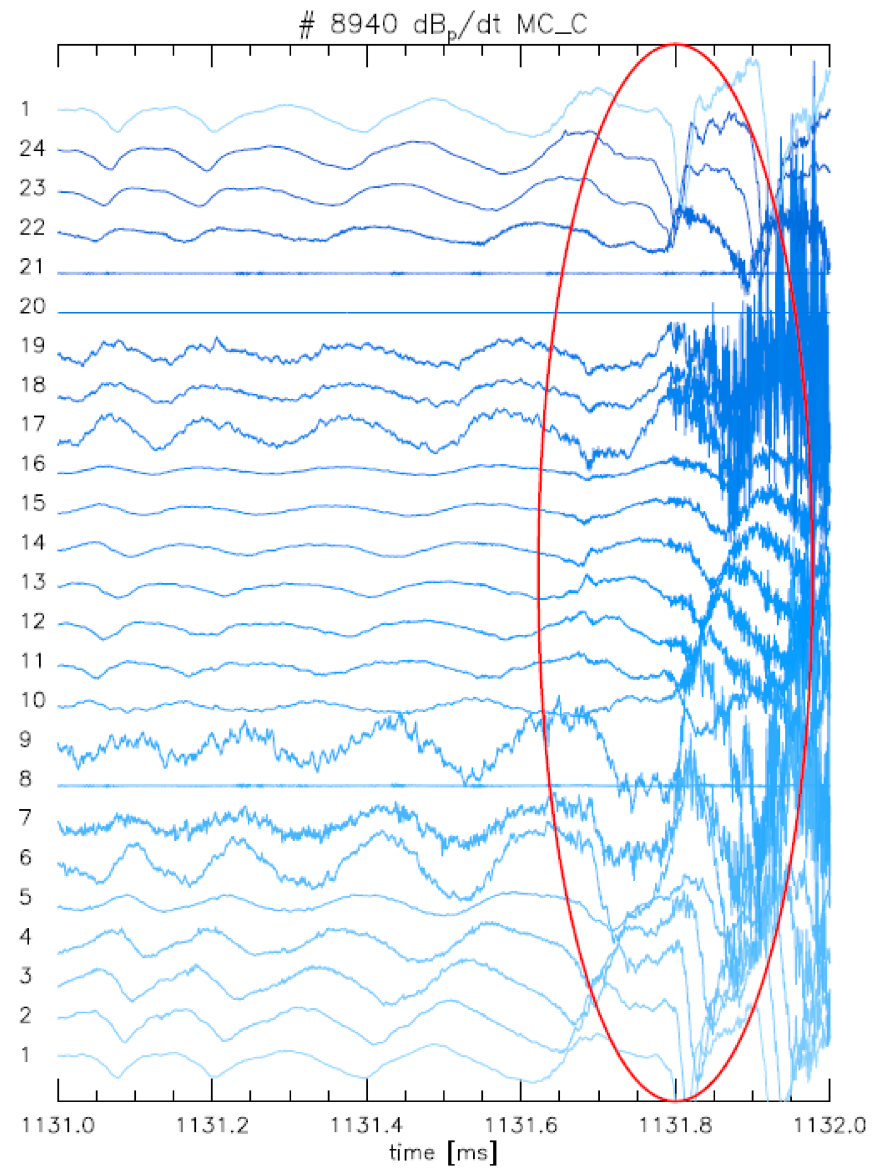
Exp. Results – Mode Analysis





Exp. Results – Secondary Instability





- Mode analysis shows an MHD mode with m=2 and n=1.
- A secondary instability to this m/n = 2/1 magnetic island is observed before COMPASS major DLD.
- No mode numbers 'm' or 'n' can be assigned to this secondary instability.
- Further analysis is in progress.

Future Work

- Experimental study of the natural flows of magnetic islands and ions in COMPASS high density limit plasmas
- Characterize the rotation at the time when the secondary instability is observed
- Study the dynamics of the secondary instability and its role in the disruption to outline a strategy to recover from such events

References

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