IEA/RFP-WS, U. Wisc., Feb. 29,2000

Understanding of Mode-locking Phenomena in TPE-RX

Recent measurements of the vessel current, mode rotation in the B_t signals, T_{e0} and n_{e0} give a better picture to understand the threshold for the mode to lock, in line with the Fitzpatrick's theory.

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(Acknowledgment to R. Fitzpatrick[2], T. Bolzonella[3], P. Zanca[3] and S. Martini[3], 2: U. Texas, 3: Consorzio RFX)

Outline

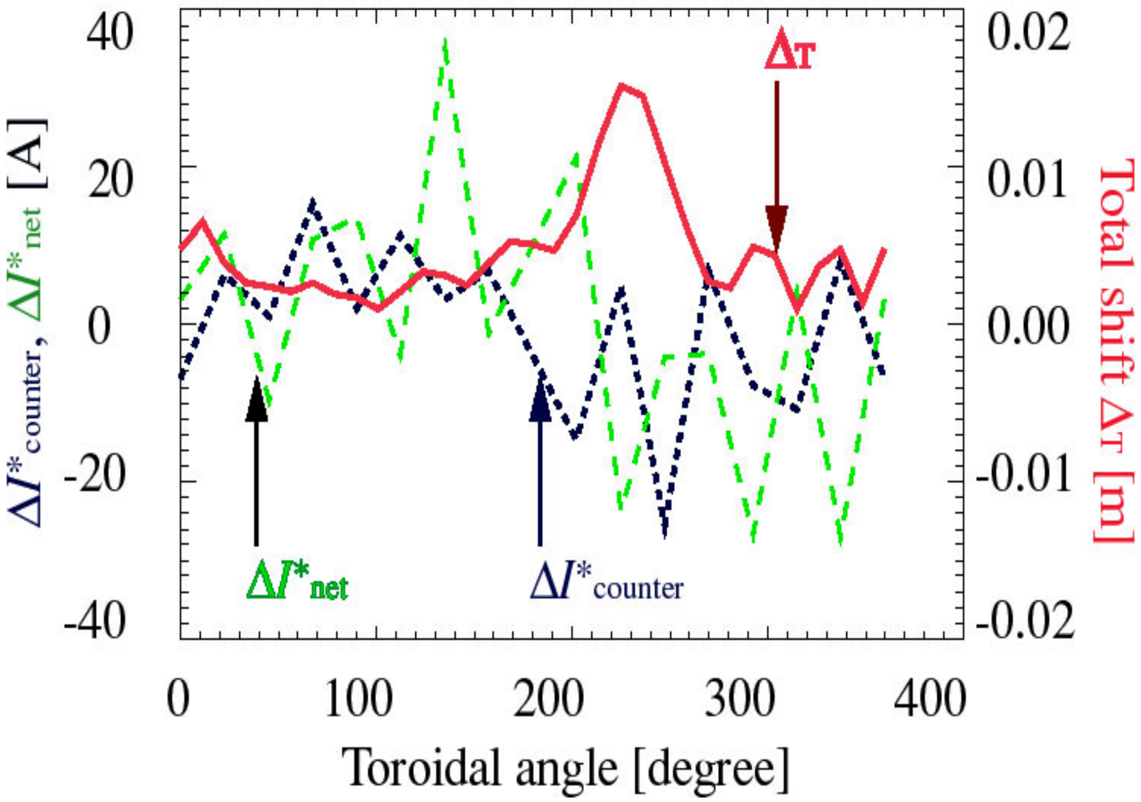
- Introduction
- Locked (LM) and nonlocked (NonLM) discharges
- Diagnostics (B_r and B_t-arrays)
- B_t signals
  - *Raw data, mode amplitude, velocity and spectrum*
- Comparison of T_{e0}, T_i, n_{el}*, β_p and τ_E
- Comparison with Fitzpatrick's threshold
- Summary

Introduction

- Phase- and wall-locked mode (LM) has been observed in many RFPs (RFX, T2, MST, TPE-RX).
- In TPE-RX, typical LM discharges as well as the discharges in which 'slinky' structure disappears exist (NonLM) [Phys. Plasmas 6 (1999) 3824].
- *Two hypotheses* for the cause of the mode locking have been experimentally checked.
  - (1) *Halo current* => O(30-40A). Not the cause but the result of the shift of the plasma column [Koguchi et al., in preparation].
  - (2) *Fitzpatrick's theory* [Phs. Plasmas 6 (1999) 3878] => *Investigated here.*

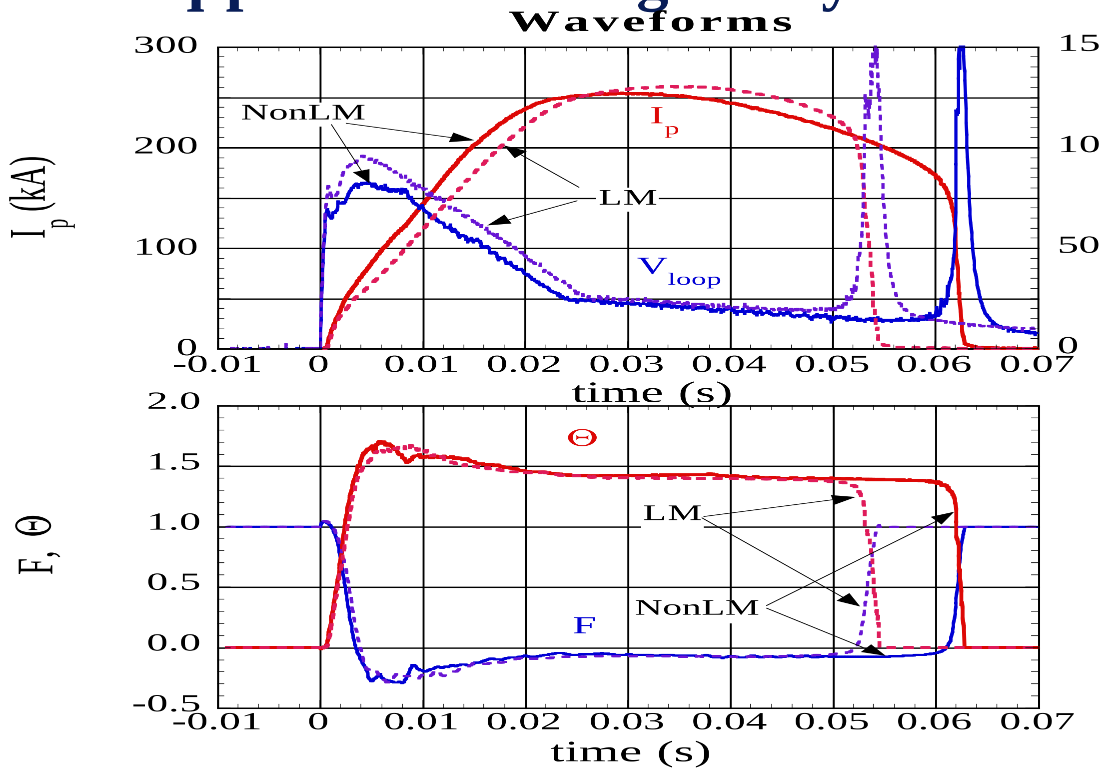
Vessel Current Measurement

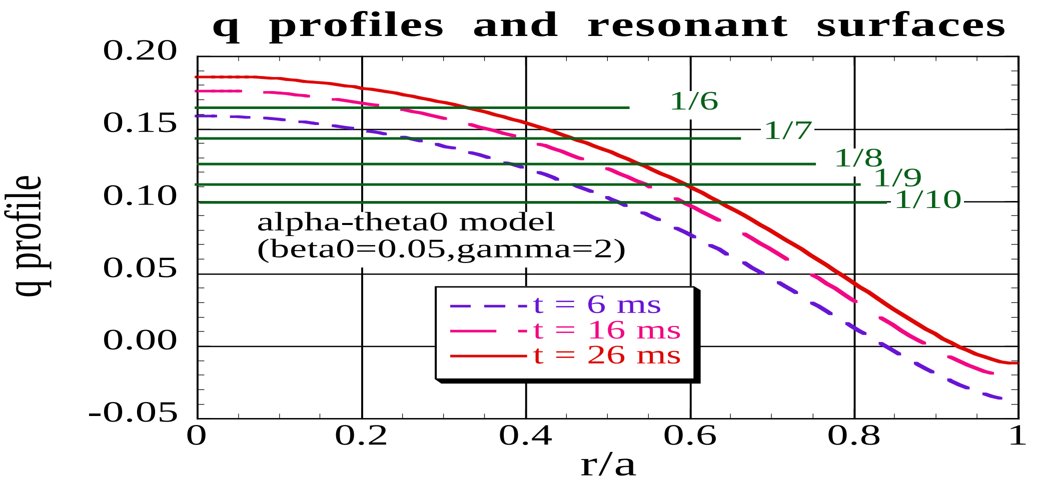
- **Toroidal distribution of the vessel current was directly measured in order to check if a significant amount of the halo current is formed.**
- **The result showed that the vessel current is 30-40 A, which is much weaker than what is expected to form the halo current, and is an order of the ion saturation current as a result of the local shift of the plasma column.**



LM and NonLM Discharges

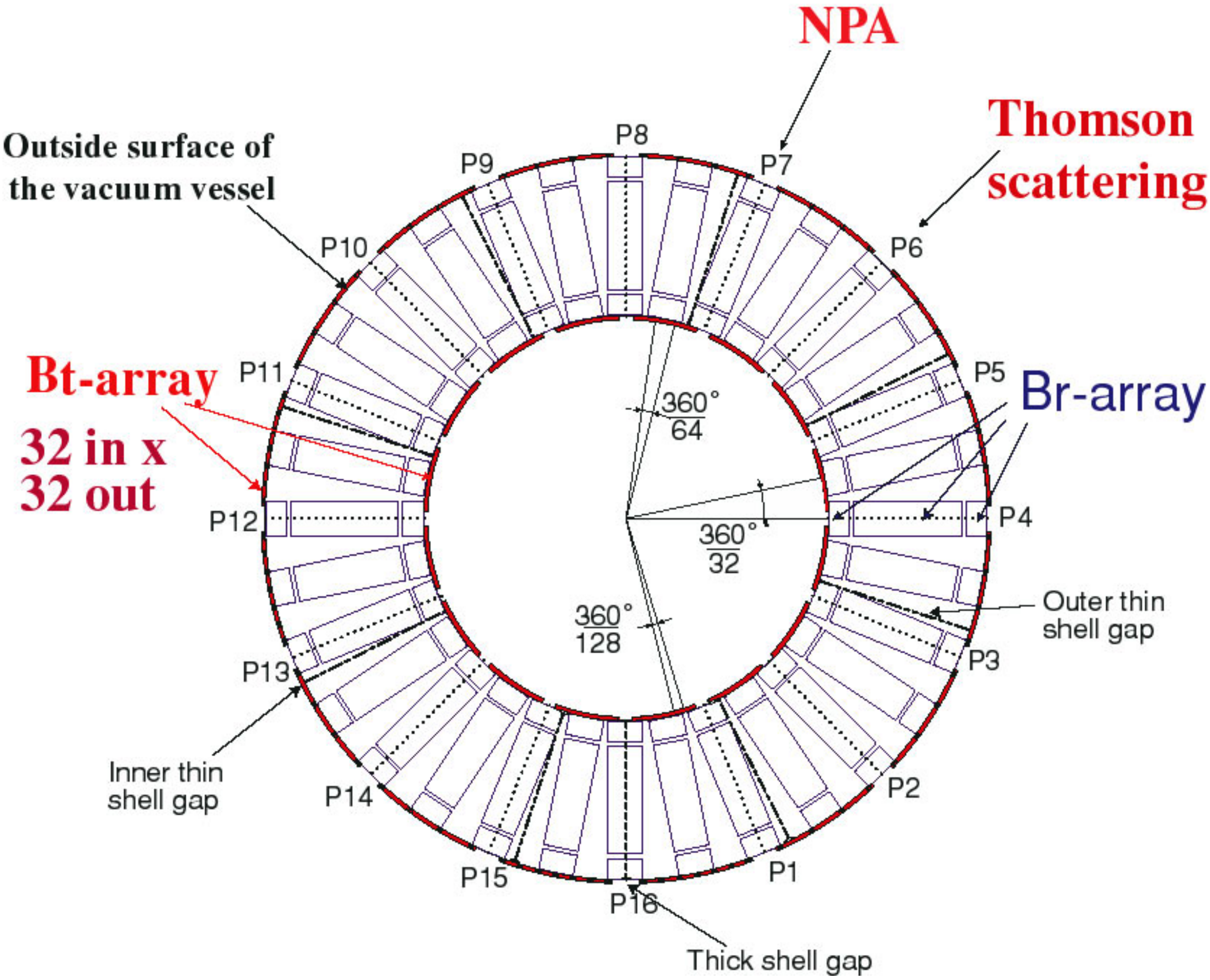
- **LM and NonLM is compared in detail at I_p = 250 kA, Theta = 1.4 and F = -0.1.**
- **Note that values of (F, Theta) are almost the same between LM and NonLM so that the q-profiles do not globally differ.**





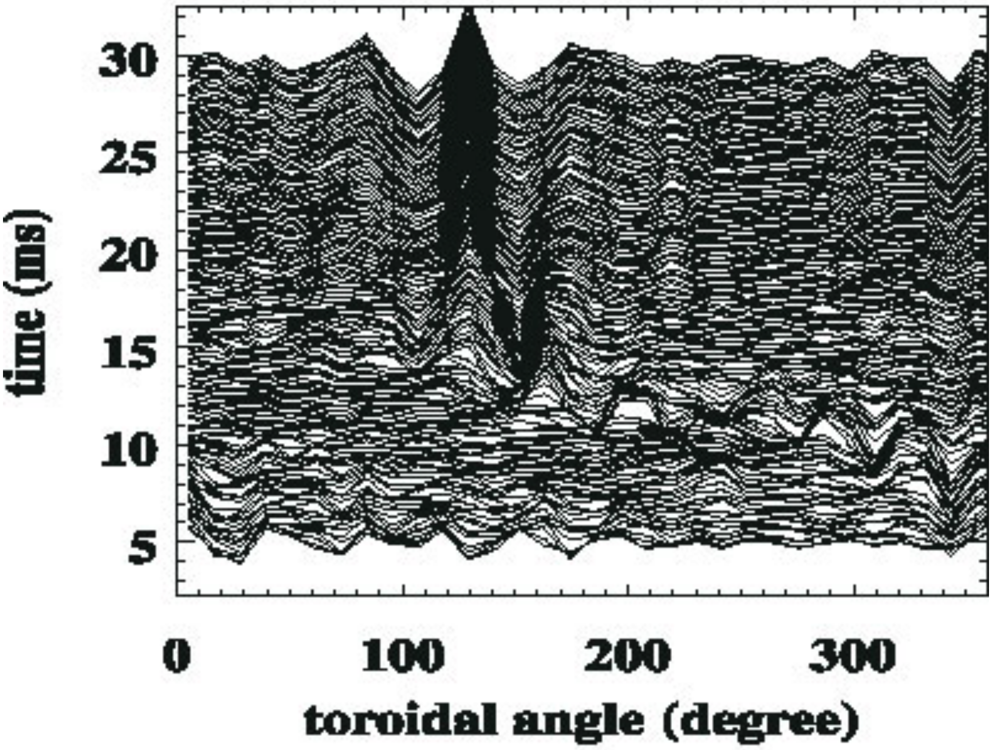
Diagnostics

- **Br** => good for the reconstruction of the LCFS [P. Zanca and S. Martini, Plasma phys. Control. Fusion 41 (1999) 1251].
- **Bt** => larger than Br at the edge and good for studies on MHD activities in general (including mode rotation).

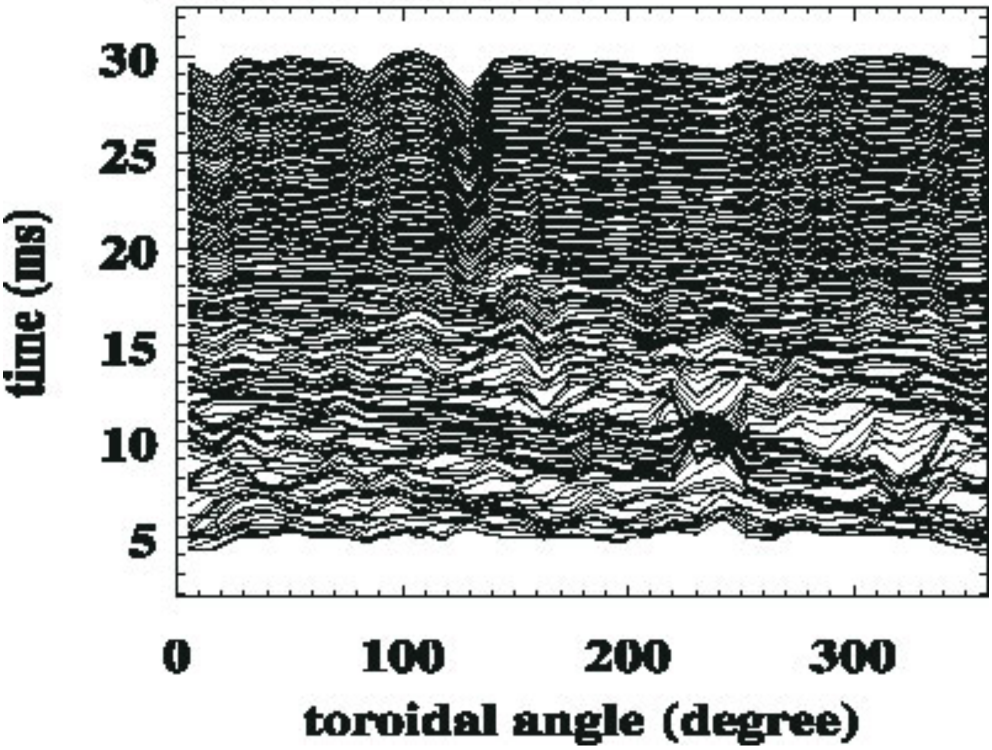


Bt Array Signals in LM

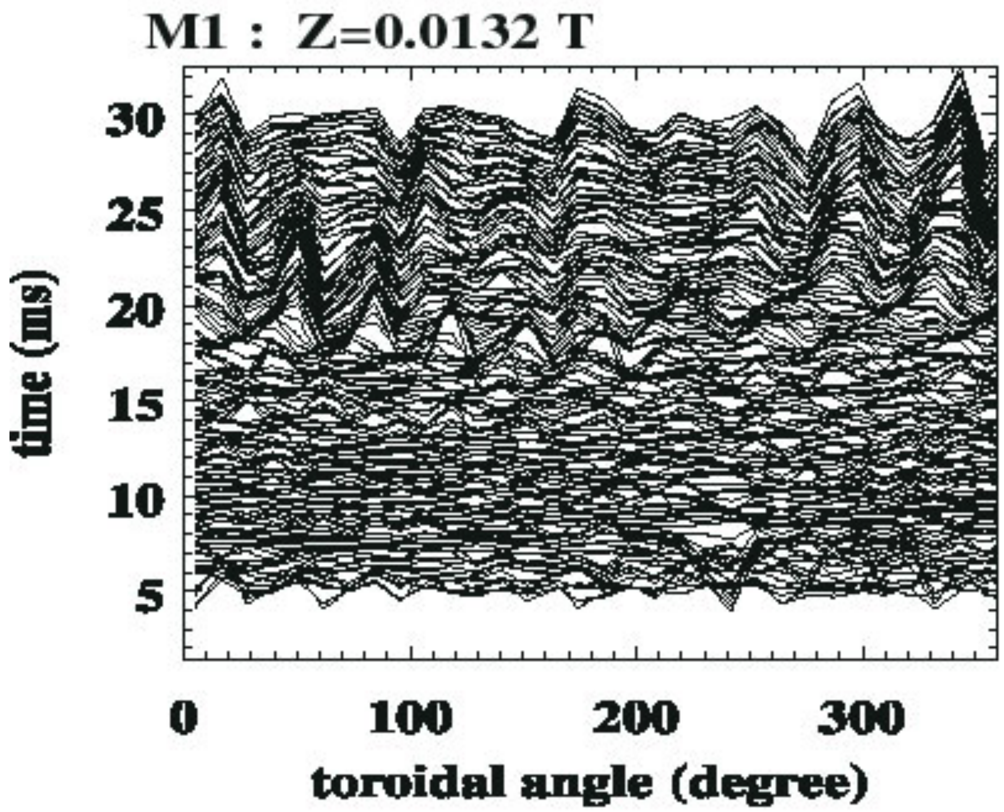
M1 : Z=0.0299 T

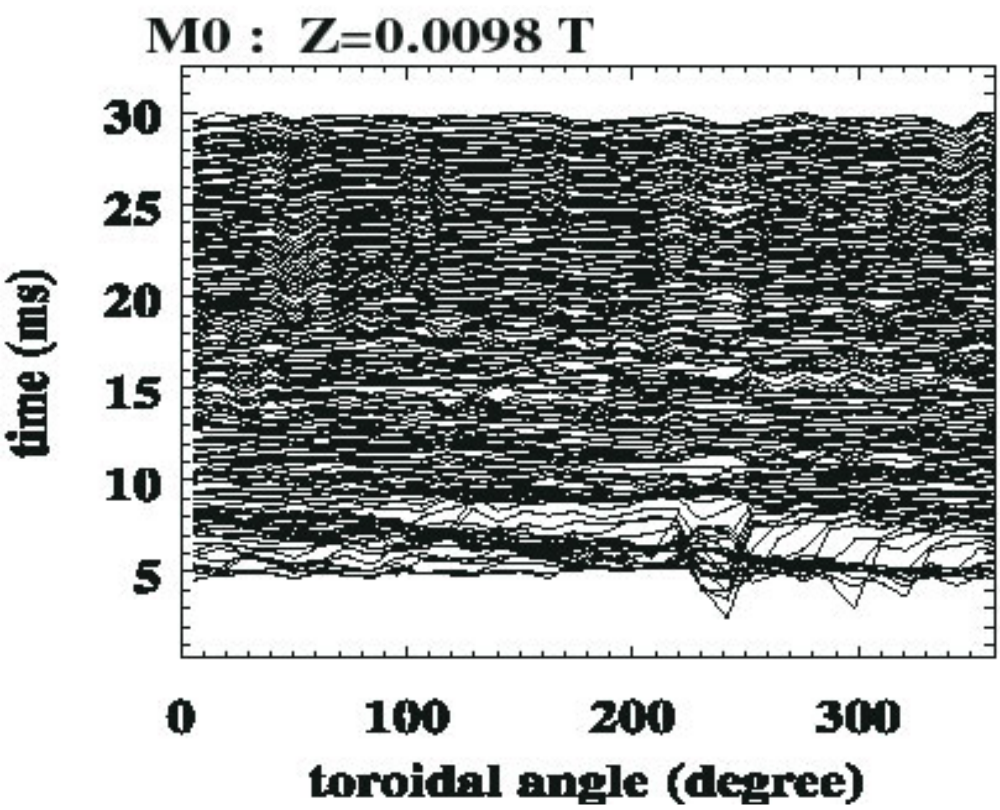


M0 : Z=0.0122 T

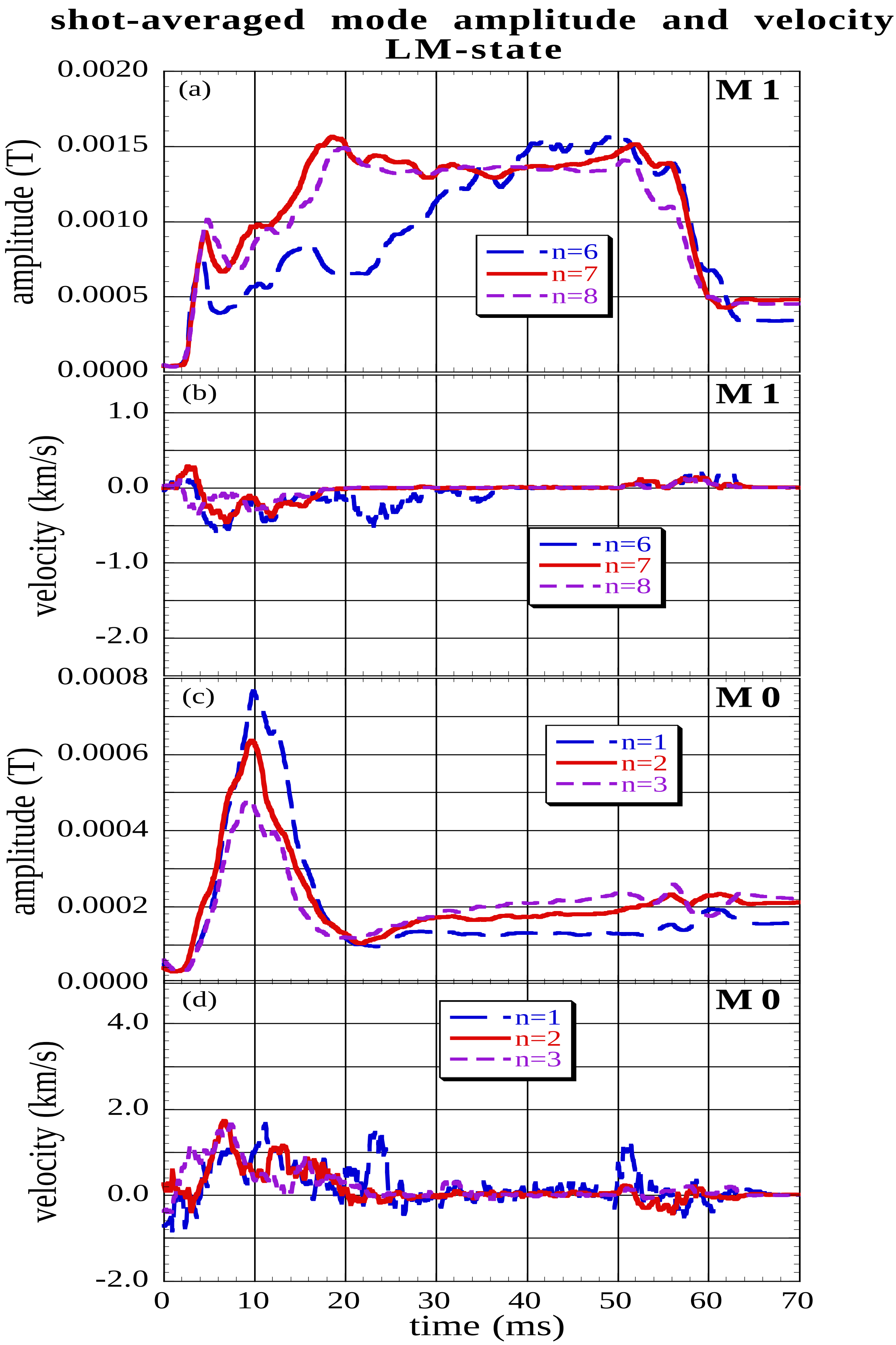


Bt Array Signals in NonLM

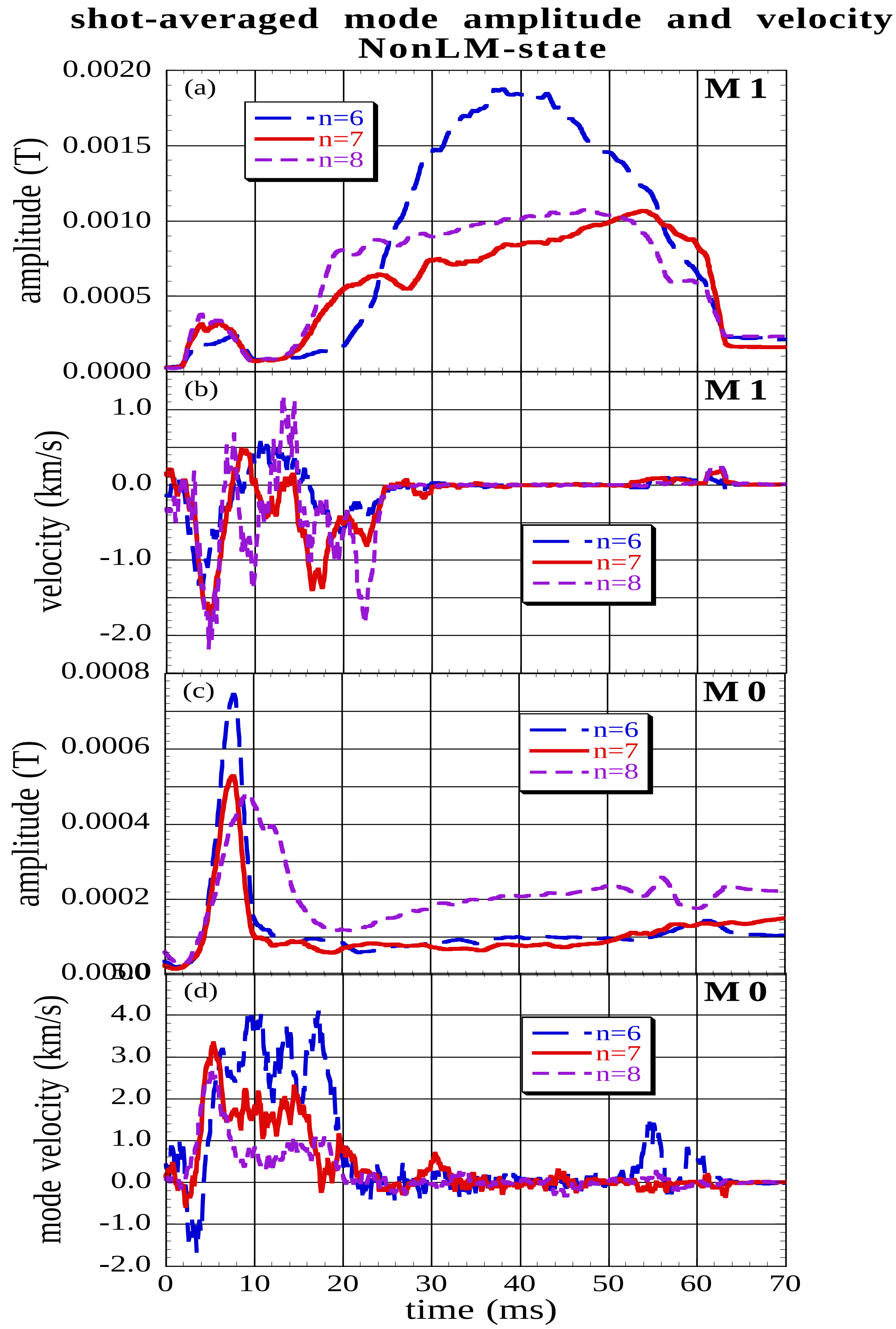




Mode Ampitude and Velocity (LM)

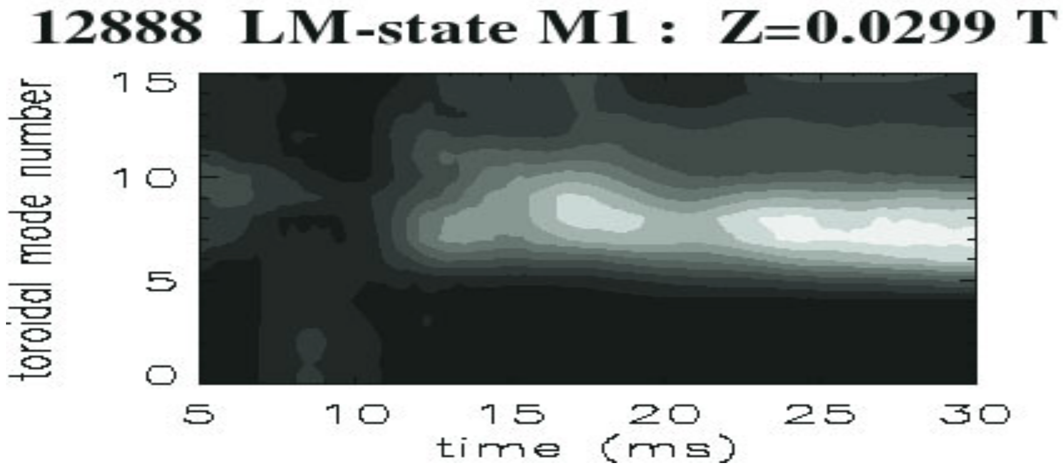


Mode Ampitude and Velocity (NonLM)

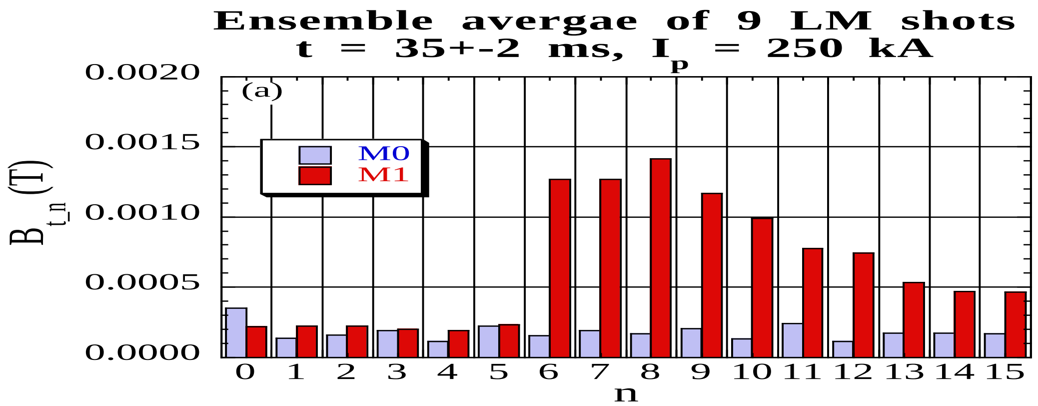


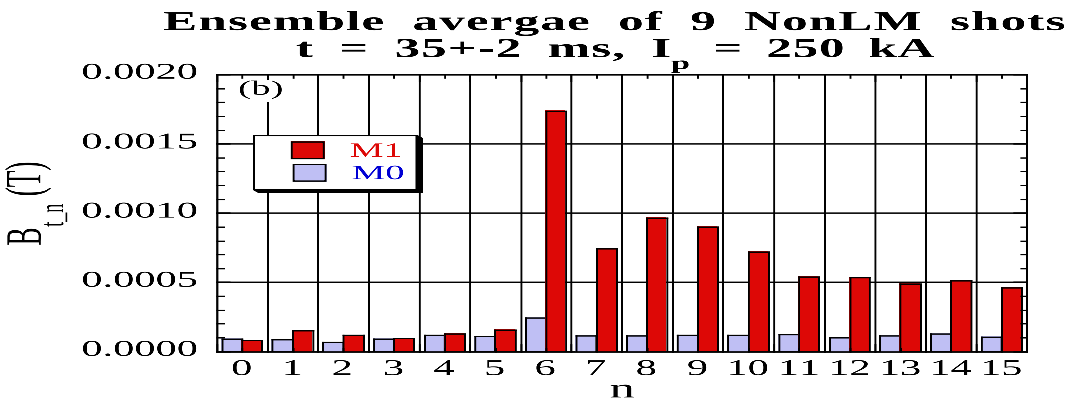
Toroidal Mode Spectrum

- Near-axis resonant modes (m=1/n=8,7) are growing in the LM case during the current- rising phase.

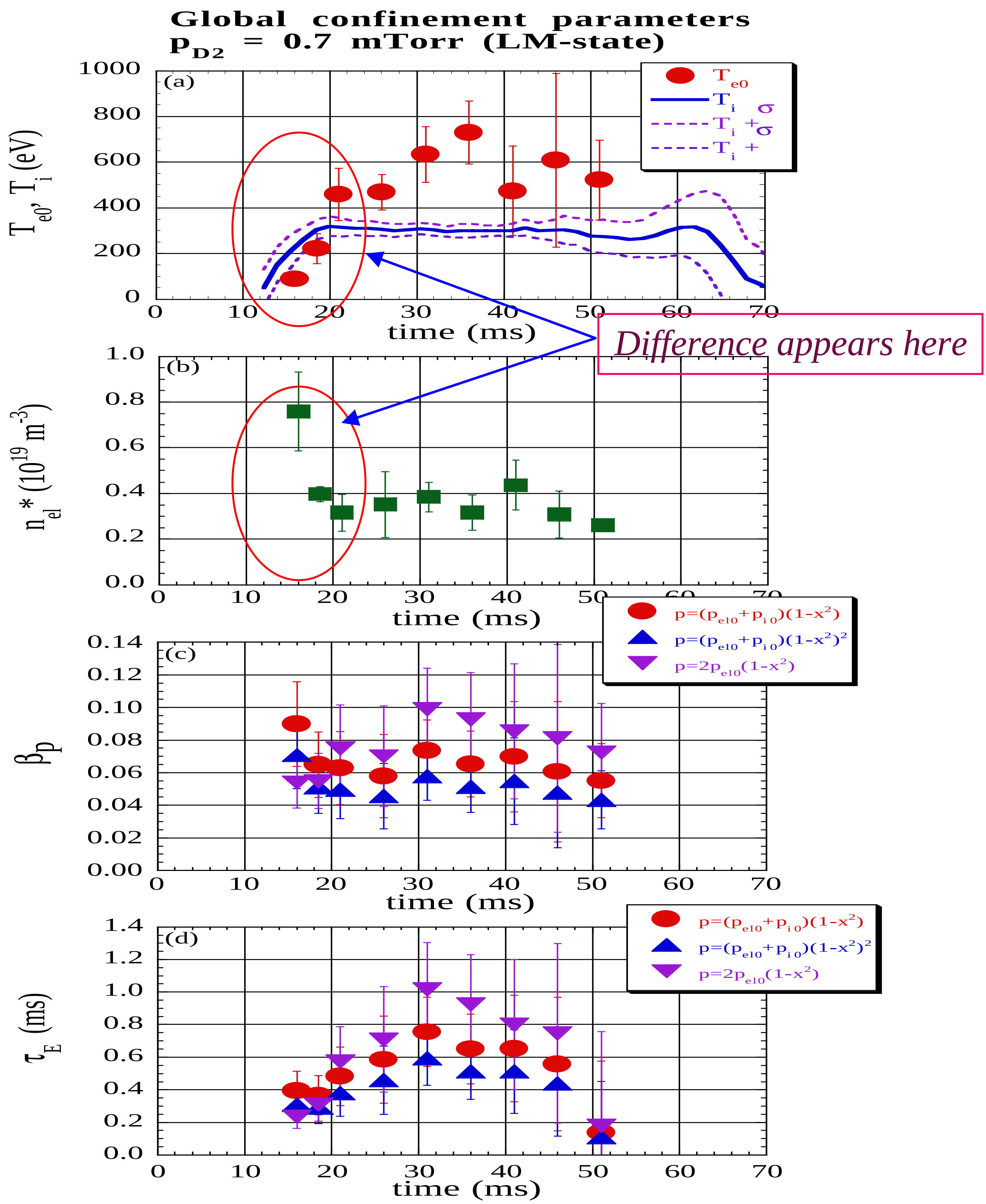


- Shot-averaged spectra at t=35 ms

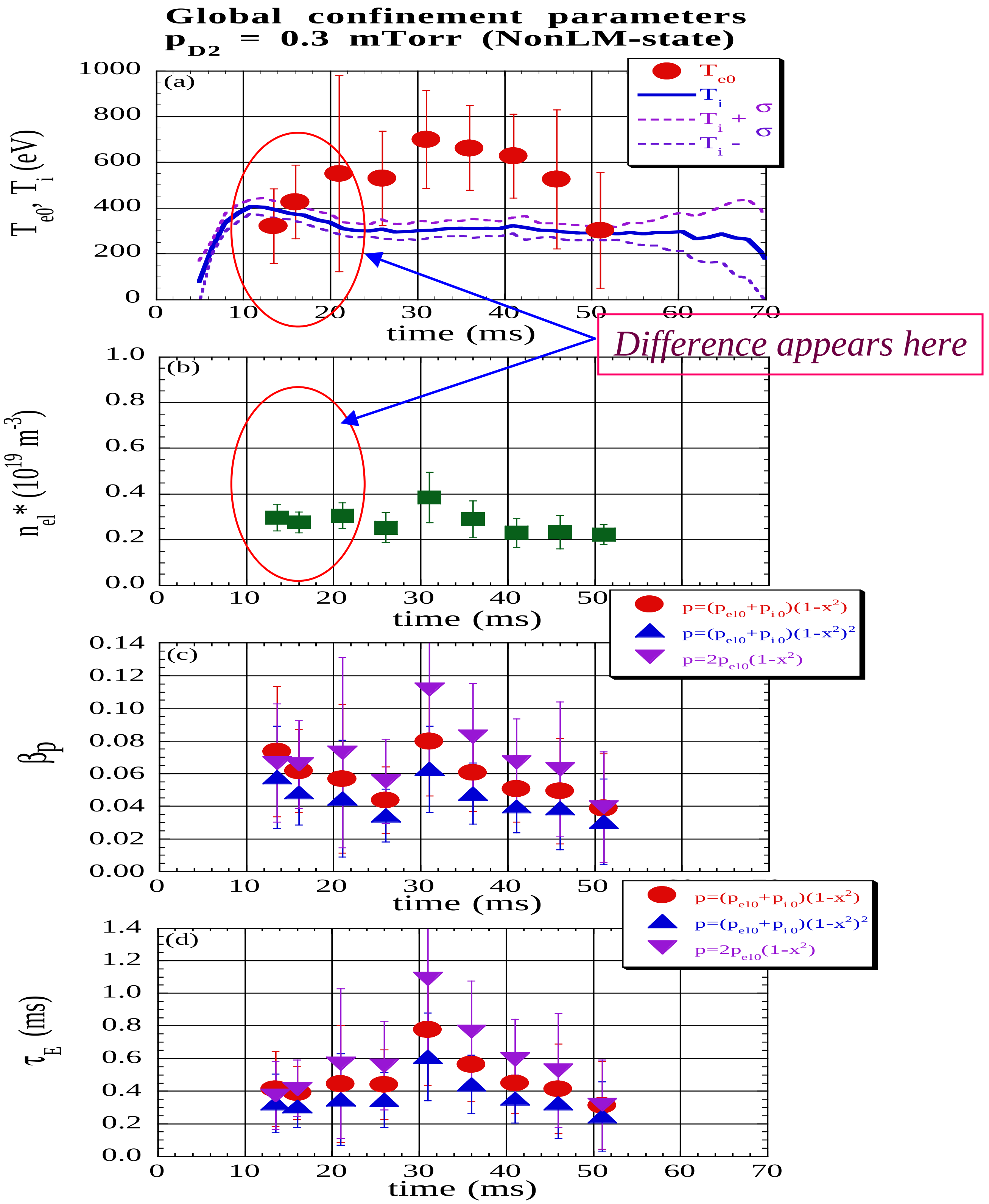




Global Confinement in LM



Global Confinement in NonLM



Fitzpatrick's threshold

$b_{crit}/B = f(\Theta, F) (\tau_b / \tau_f)^{1/2}$

$\approx T_e^{1/2} / I_p$

when a, F, Θ, β_p and τ_E are const.

$\tau_b = 2.5$ ms :

Vessel time constant

$\tau_f = \tau_E / (\tau_A \Omega_0)^2$

$\tau_E = g(T_{e0}, n_{e0}, T_i, R_p, I_p)$:

Energy confinement time

$\tau_A = a (\mu_0 m_i n_{e0})^{0.5} / B_{pa}$:

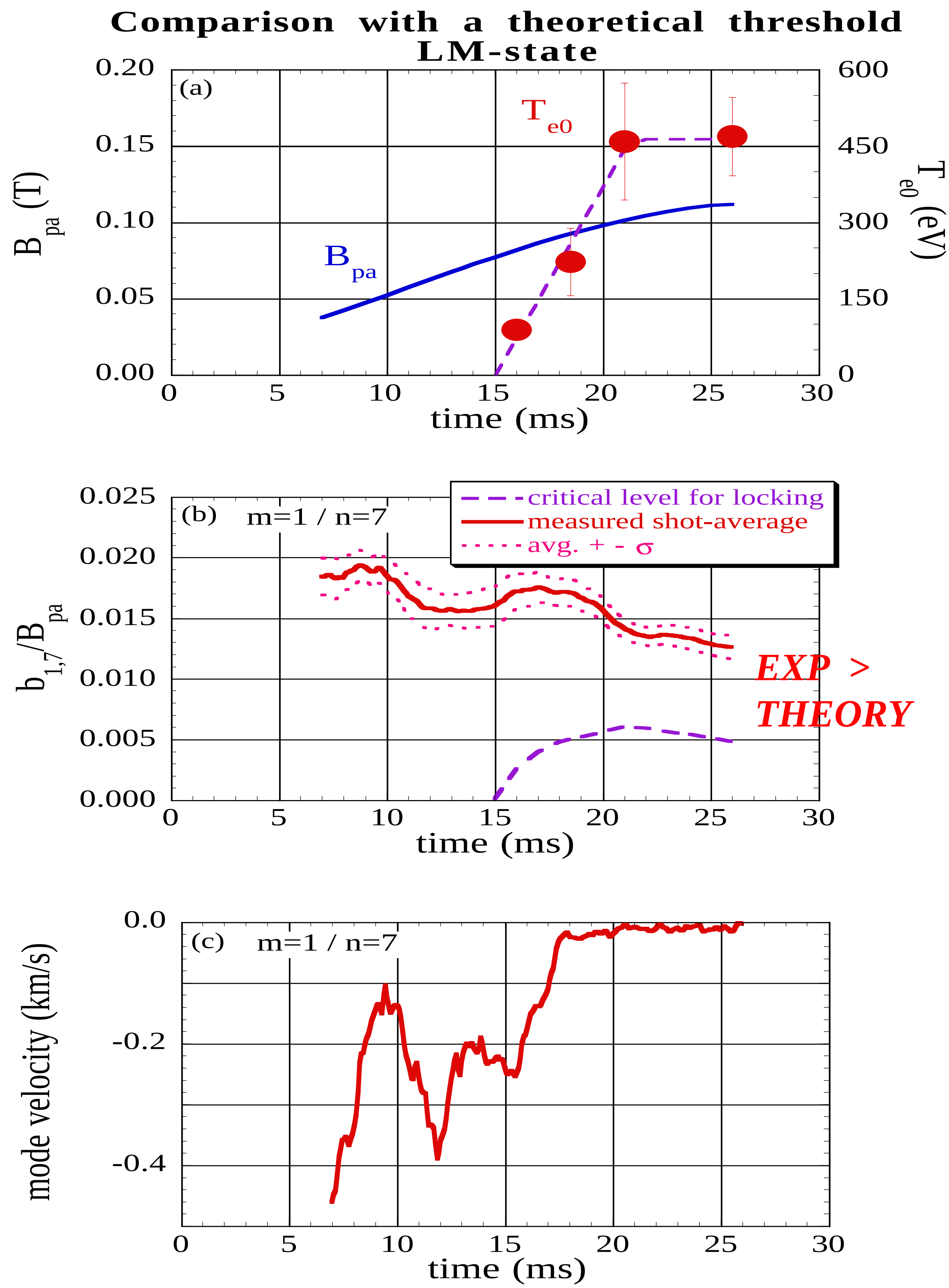
Alfven time

$\Omega_0 = 6(m/n) [T_{e0} / (a^2 B_{pa})]$:

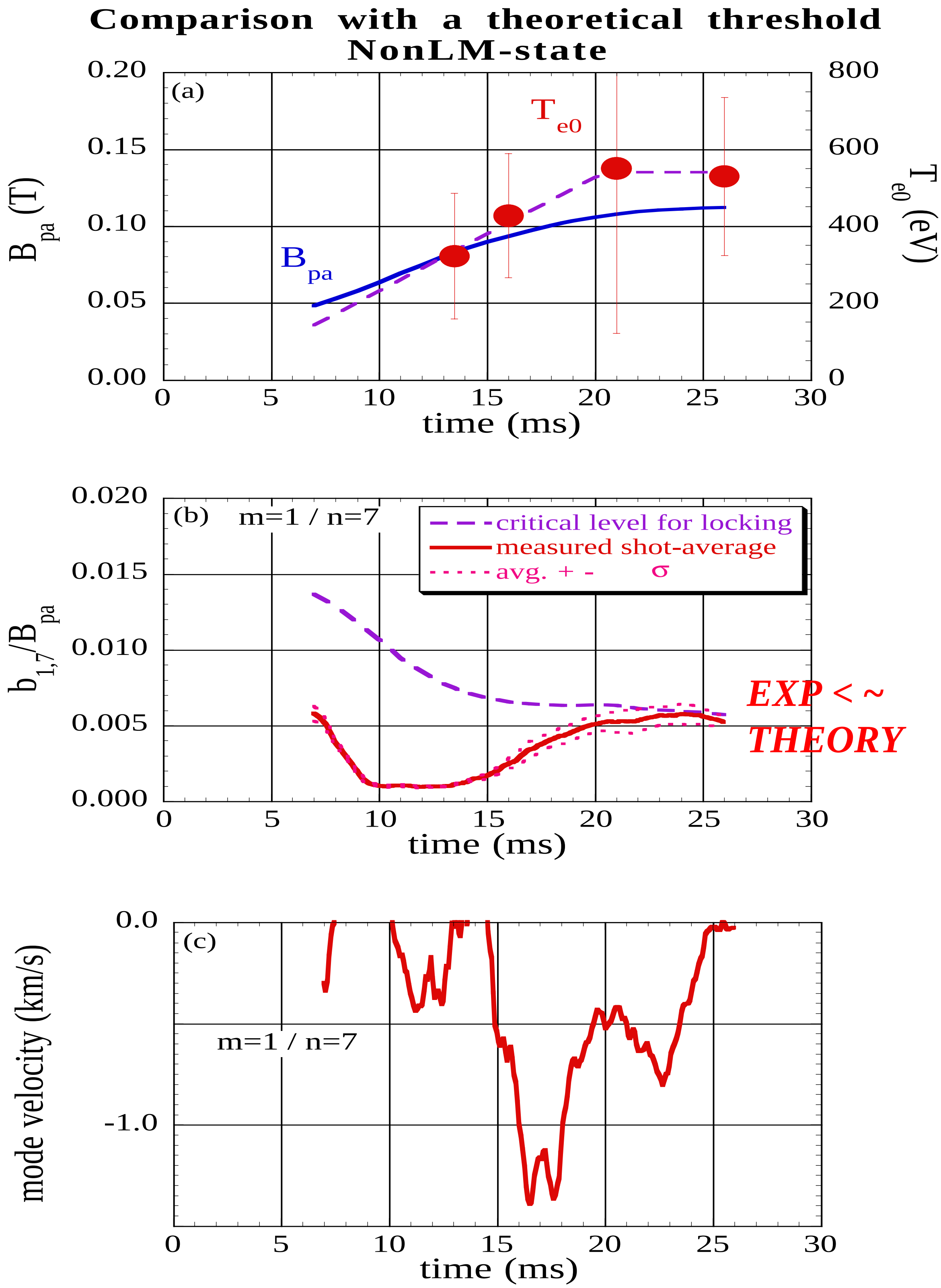
Mode rotation velocity

Evaluation for the experimental values done by Per Brunsell

B_{exp}/B_{pa} and $b_{theo.}/B_{pa}$ in LM



B_{exp}/B_{pa} and $b_{theo.}/B_{pa}$ in NonLM



Summary

Phase- and wall-locked (LM) discharges are compared in detail with the nonlocked (NonLM) discharges in TPE-RX at I_p = 250 kA, with the B_t-array signal and the global confinement properties.

- **Rotation velocity of the modes are larger in NonLM than LM particularly during the current rising phase.**
- **Modes eventually wall-locke in NonLM but the slinky structure disappears.**
- **Global confinement properties at the center of the current flat top are comparable between LM and NonLM.**
- **T_{e0} and n_{el}* differ during the current rising phase, which gives rise to**
  - ***(1) a larger b (S-number related?)***
  - ***(2) a smaller theoretical threshold***

  in the LM-state.