Single and Multi Helical States in TPE-1RM20

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Different Dynamo Activities in Low and High Θ

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Low Θ (~1.5) (Low Ip/<Bt>)
Continuous Activities
Multi-Mode Structure (m=1/n=multi)

High Θ (~2.0) (High Ip/<Bt>)
Intermittent and Discrete Events
Large scale relaxation (energy loss)
 *=> Growth of a single mode
                    (m=1/n=single)
 => Mode Coupling(m=0 & 1)
 => Multi-Modes (m=0 & 1/n=multi)
 => Release of Magnetic (Plasma) Energy =>*

Good Confinement in a Single Helical State

F

1.2

Low Θ

High Θ
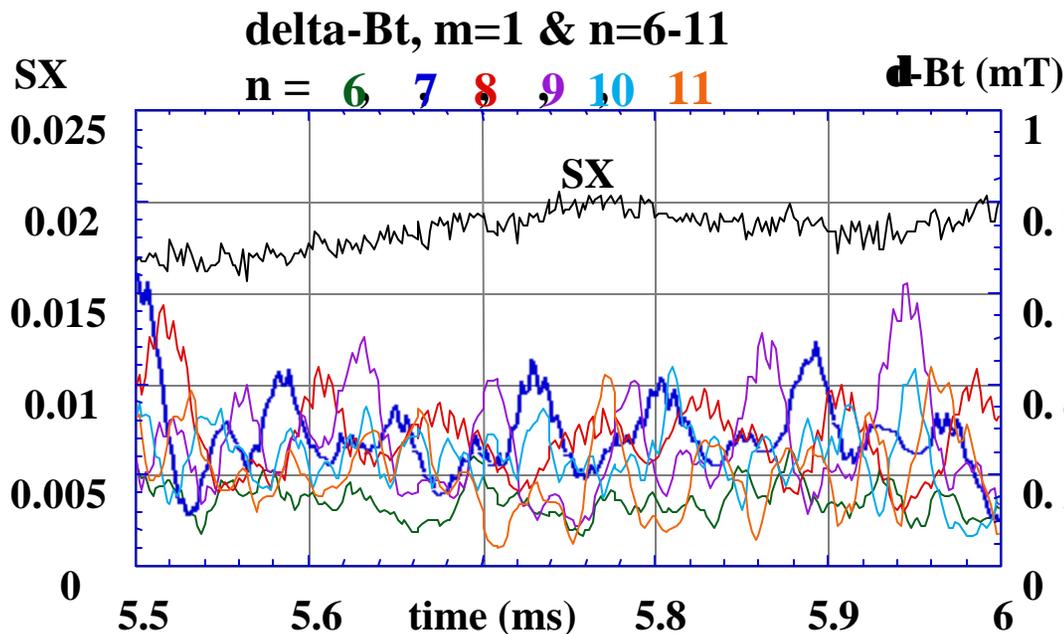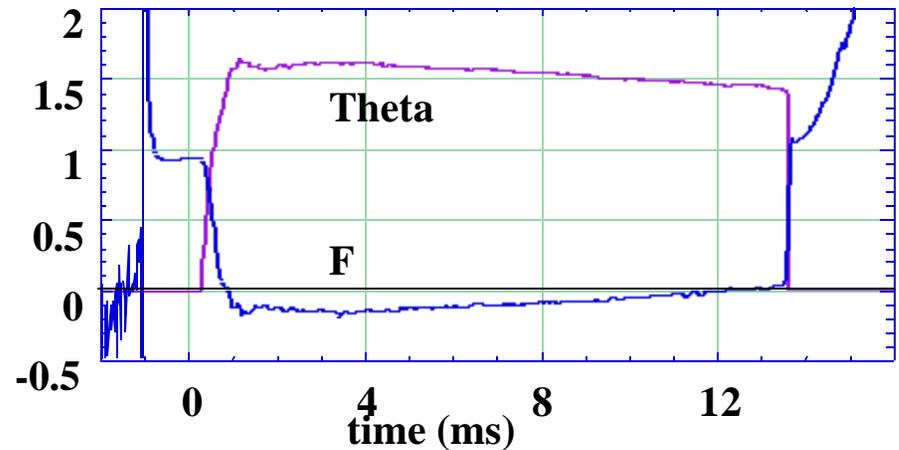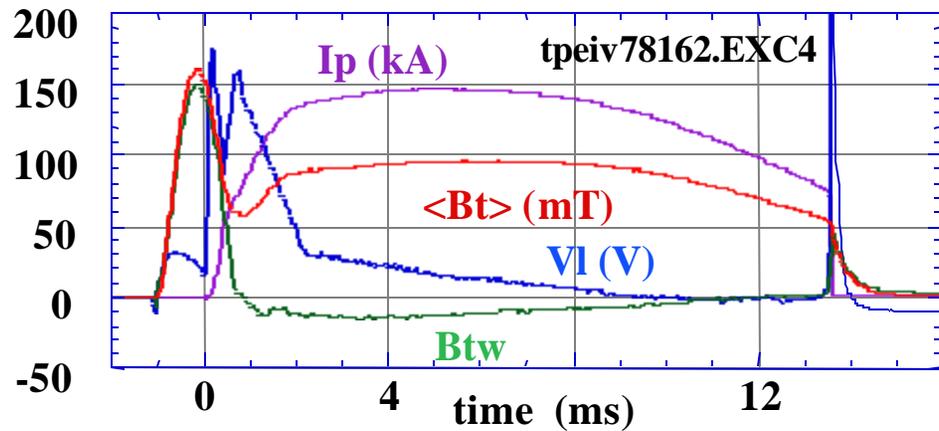
Theta
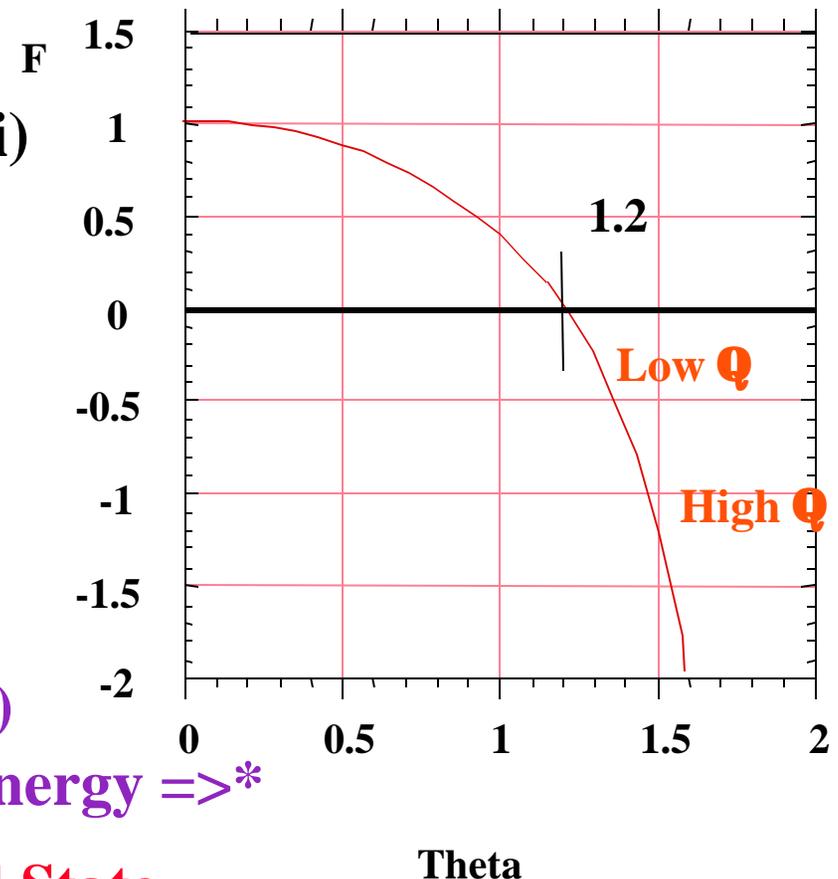
Dynamo Activities in Low Q
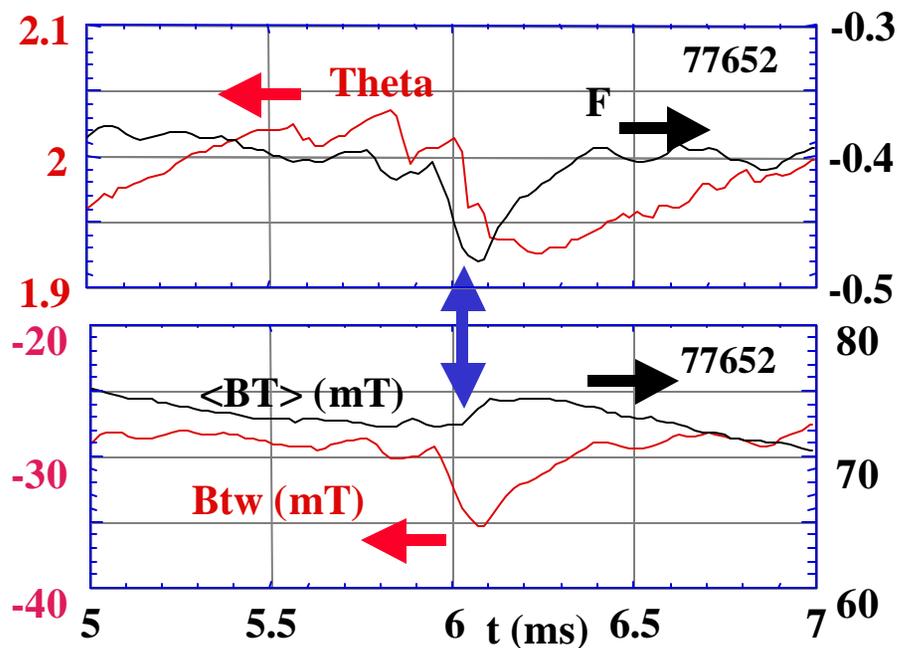## Cyclic growth (oscillation) of m=1/n=7-10 modes
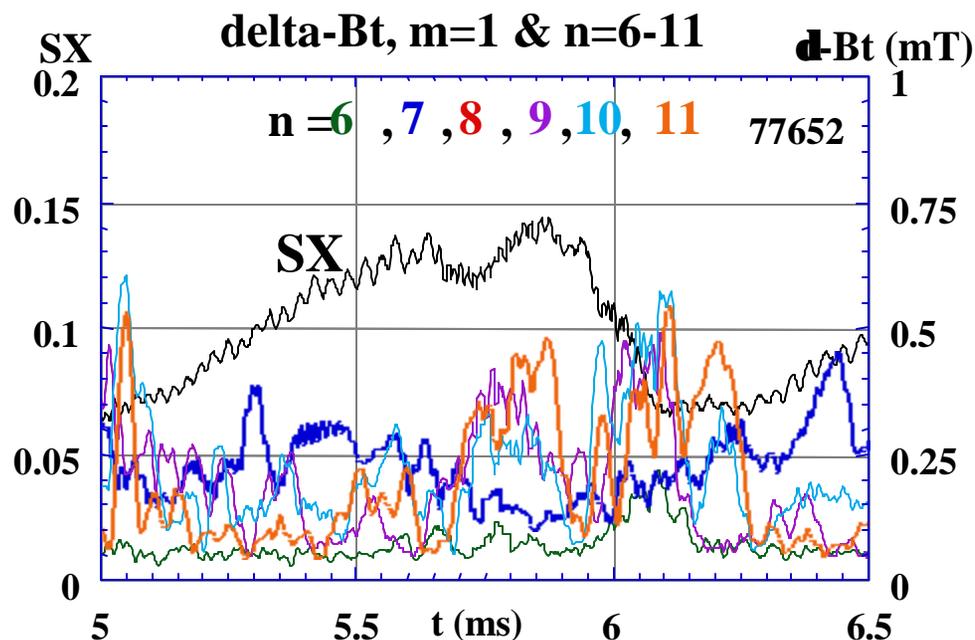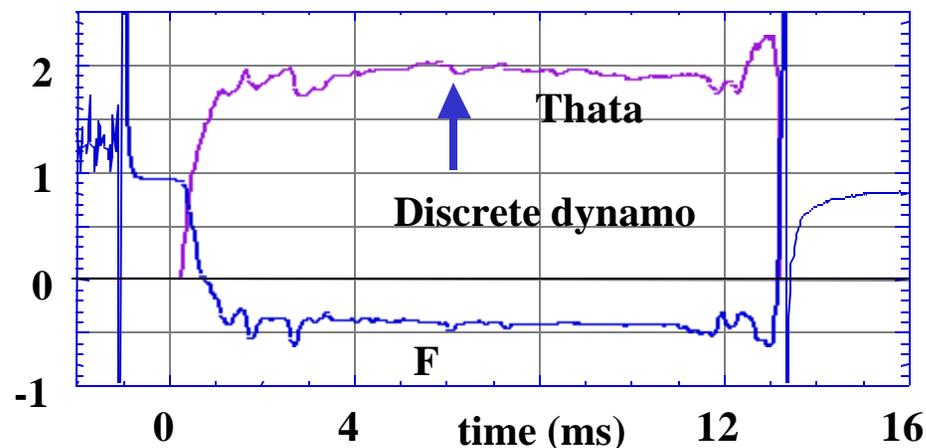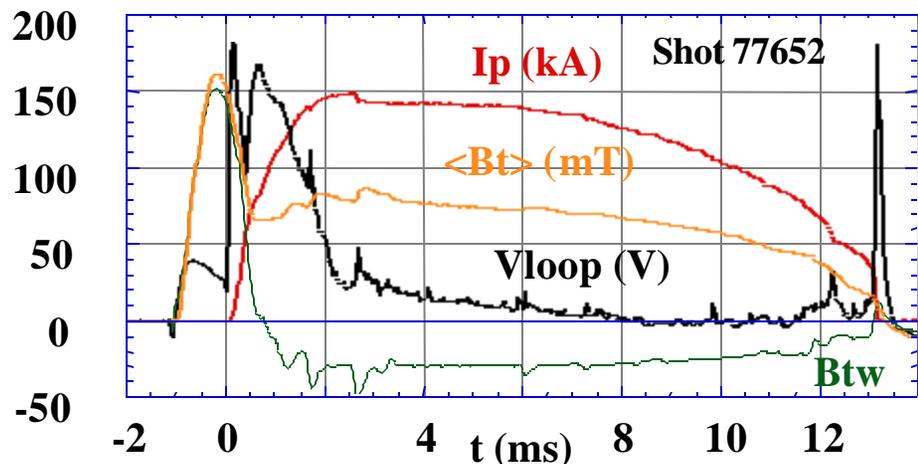## They grow one after another (in TPE-1RM20)

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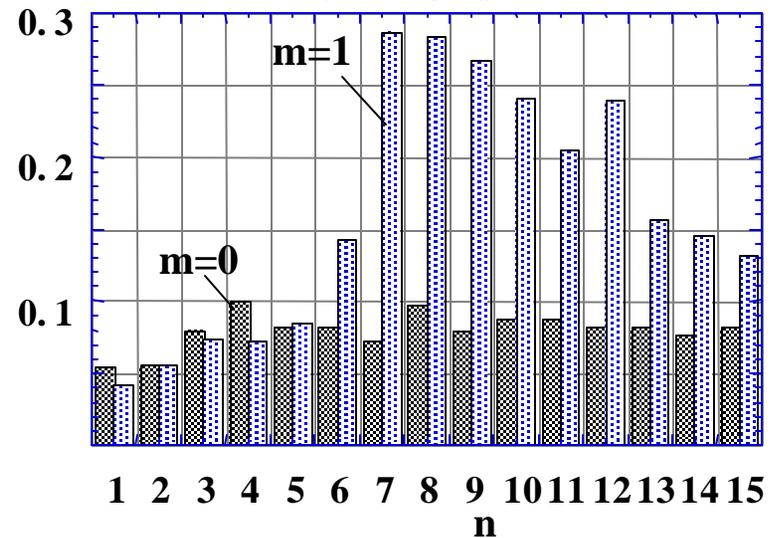
Dynamo Activities in High Θ
Growth of a single mode, m=1/n=7 (resonant at center)
Discrete & Intermittent   (in TPE-1RM20)

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Mode Variation at Dynamo Event in High Q
N spectrum of d-Bt, m=0 & 1, n=1-15

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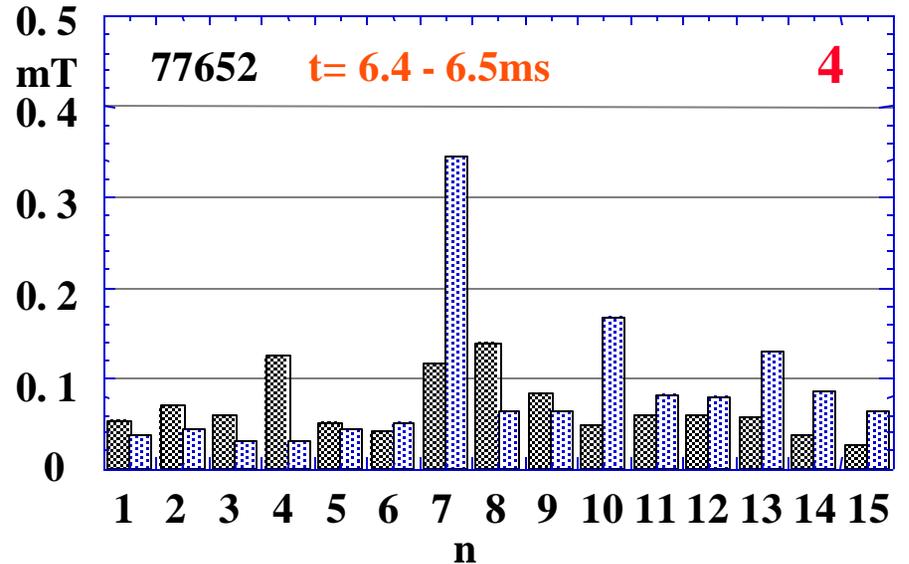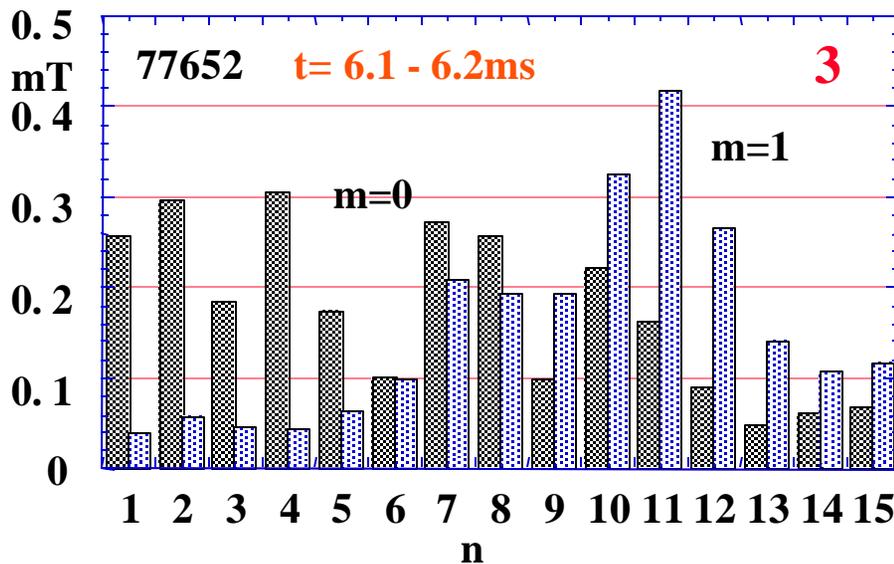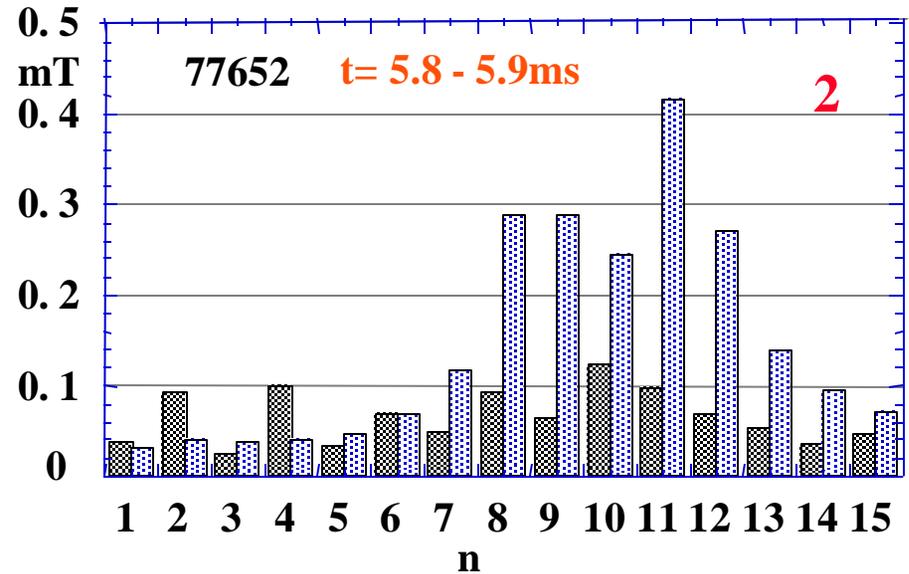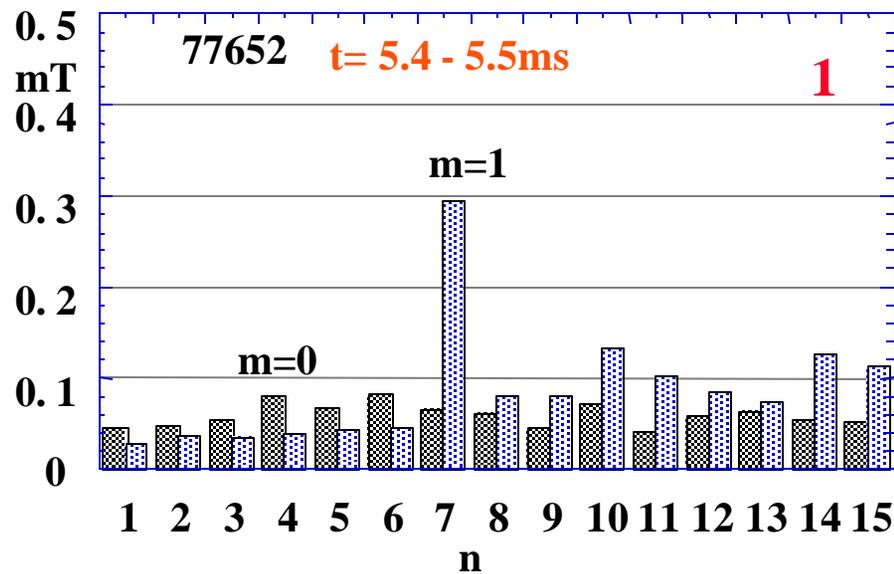
Trajectory on F-**Q** diagram for Discrete Dynamo
One Event in High **Q** Case
Clockwise Rotation

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FT77652_50_70   0.2ms step

t=5ms

Resistive decay of <Bt>

**Decay of
liner current**

t=7ms

**Fast relaxation
in 0.2ms**

relaxed state

F

-0.35

-0.4

-0.45

-0.5

-0.55

Theta

1.85   1.9   1.95   2   2.05
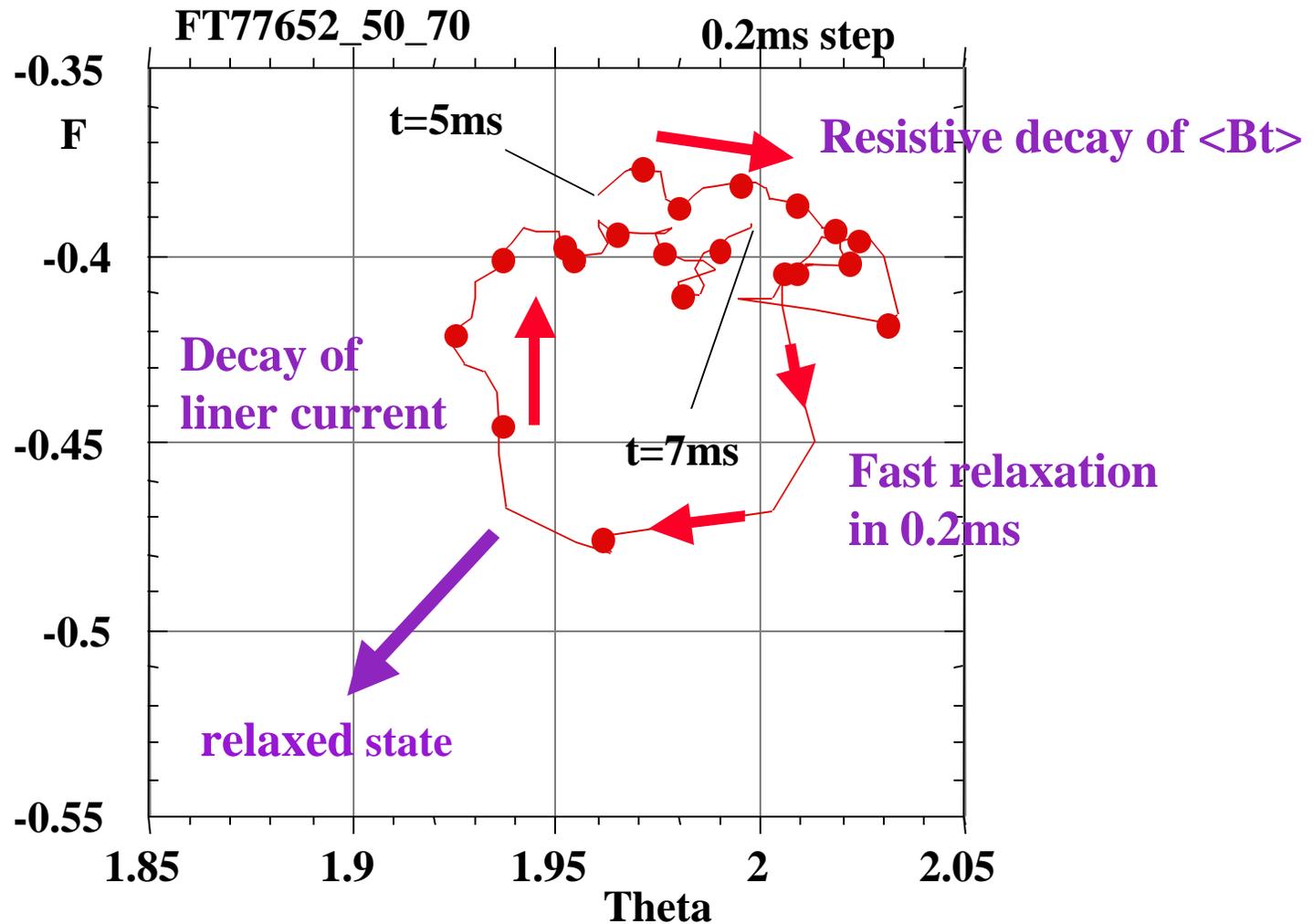
Dynamo effect and confinement in RFP
Comparison between Low and High Q Cases

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Low Q

Multi-Helical Modes State => Island overlapping

Stochastic Magnetic field lines

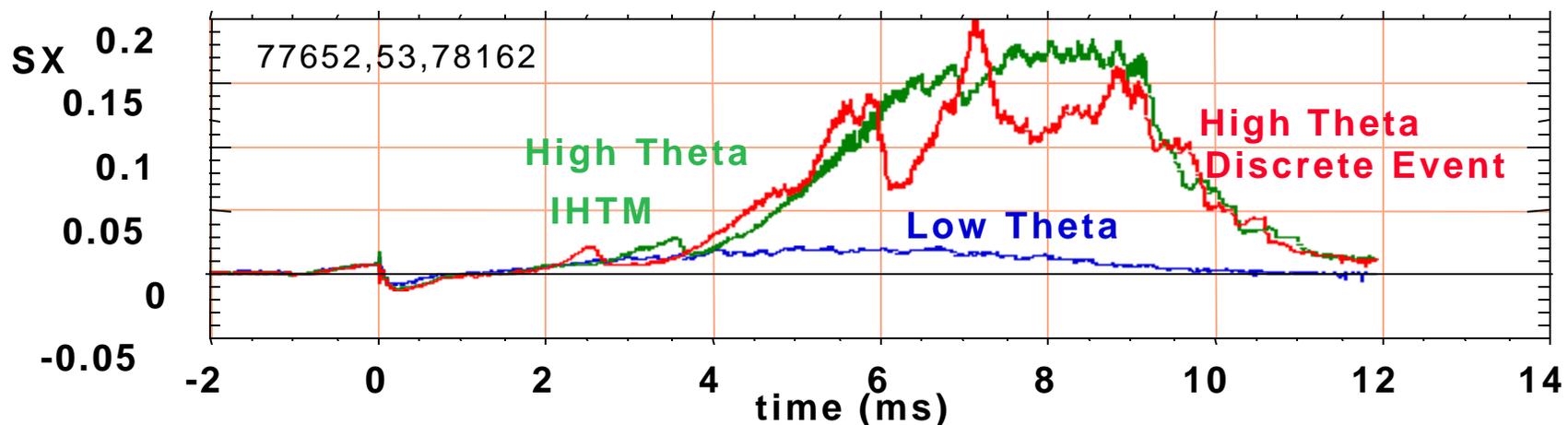**=> Enhancement of Loss, electron loss along field line**

Continuous, Small SX signal

High Q

A Single Helical Mode (good confinement)

Large Multi-Modes, puncture of magnetic surface

Intermittent & discrete large loss, SX sawtooth like crash

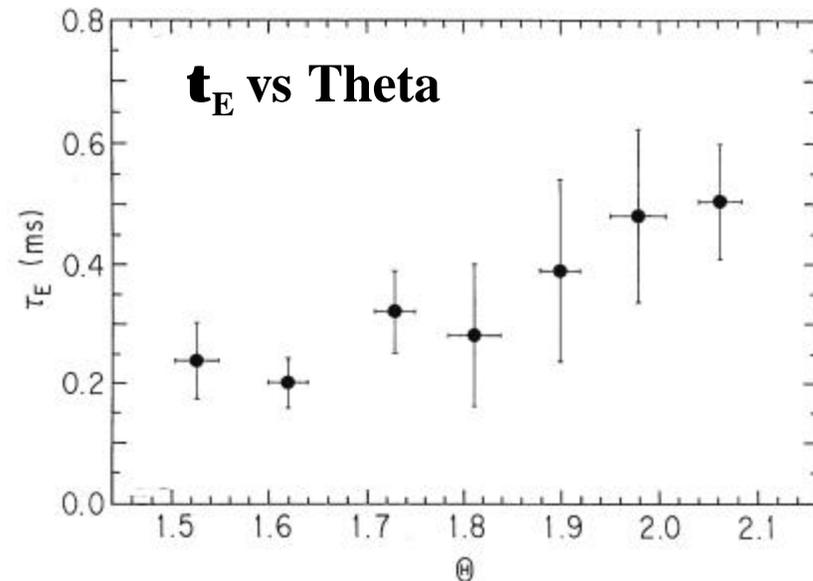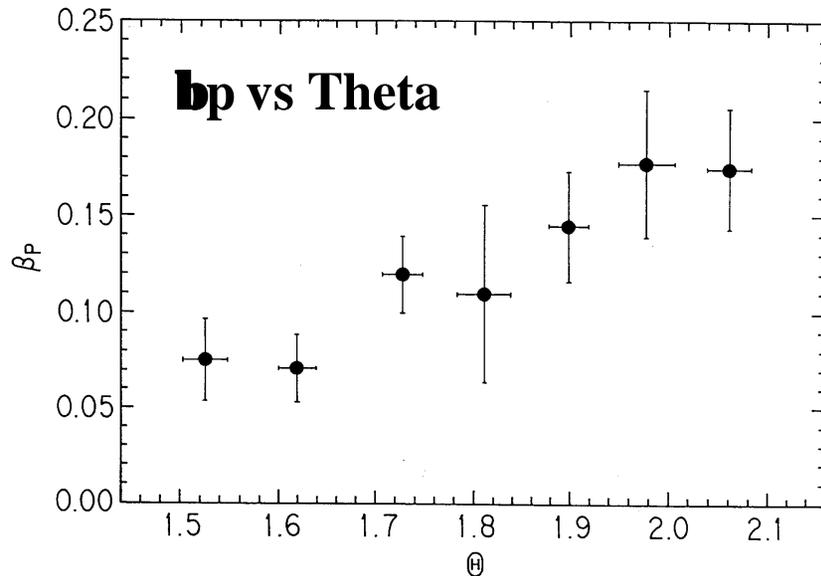# Improved Confinement in High Q Region (TPE-1RM20, Improved High Theta Mode)

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Suppression of MHD activities in High Q region,
   where the strong activities had been usually observed.
Factor of 2 increase of beta and energy confinement time
   Contribution of the density increase.
   Critical points ; gradual & appropriate decay of Ip & <Bt>

Improved Confinement in a Single Helical State

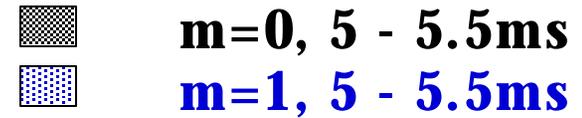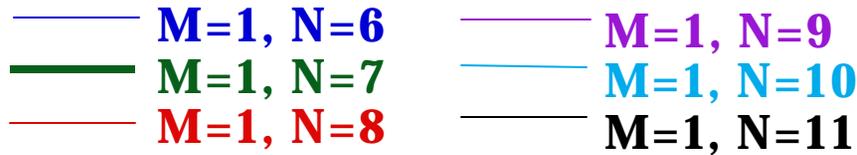## Time variation of m = 1 & N = 6-11 modes
Five times larger dB (m=1/n=7)   still large SX
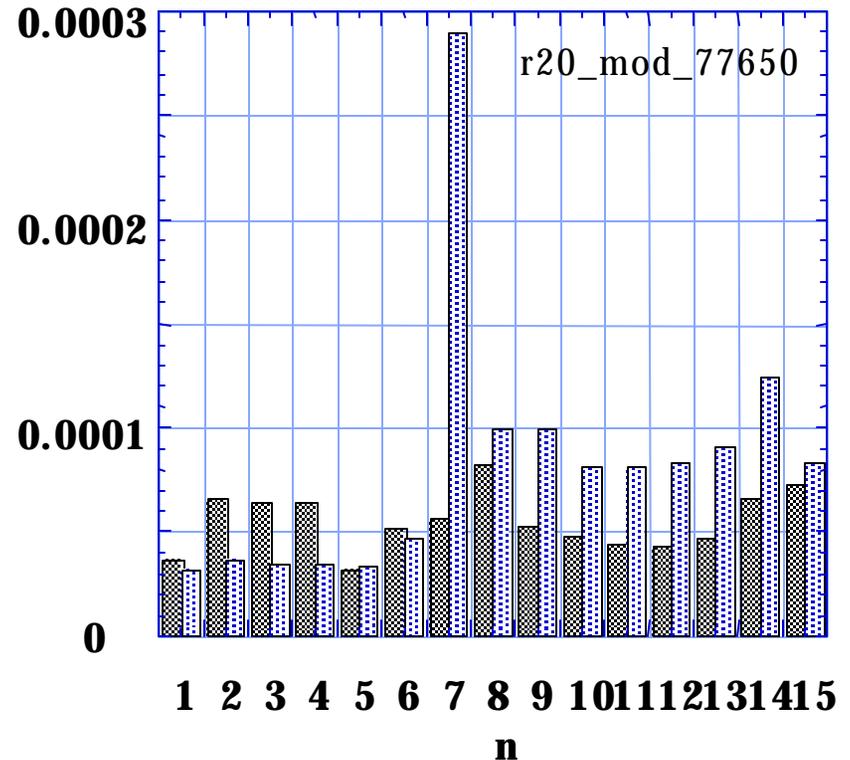## Indicating good confinement even with large dB

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— M=1, N=6   — M=1, N=9   m=0, 5 - 5.5ms
— M=1, N=7   — M=1, N=10   m=1, 5 - 5.5ms
— M=1, N=8   — M=1, N=11

averaged between 32m sec

averaged for t=5-5.5ms
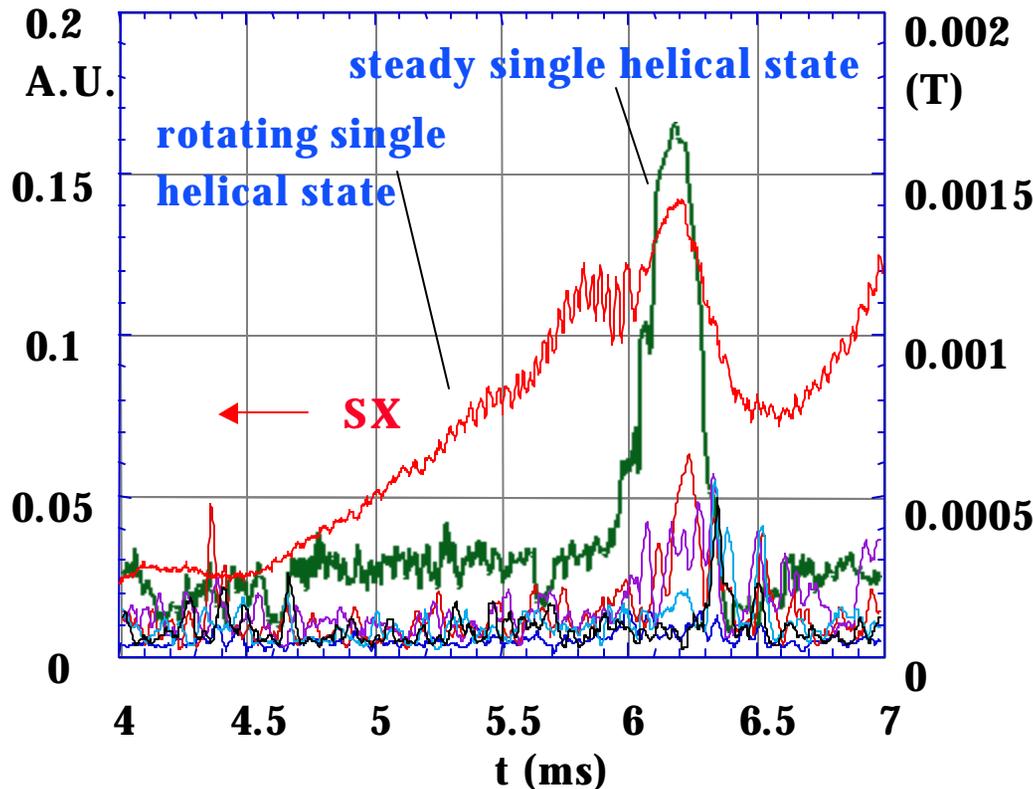
Improved Confinement in a Single Helical State

Time variation of m = 1 & N = 6-11 modes

Concentration to a single mode (m=1/n=7)   increase of SX   ETL

IHTM (Q ~ 2)
Once SX goes up, then stays there even with multi-modes.

M=1, N=6
M=1, N=7
M=1, N=8
M=1, N=9
M=1, N=10
M=1, N=11

m=0
m=1
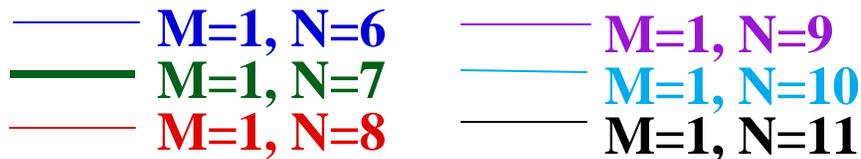
averaged between 32 msec

averaged for t=7.8-8.3ms

r20_mod_77653_030_100.EXC

rotating single helical state

SX

77653

Multi-mode
but small dB level
60% of low Q
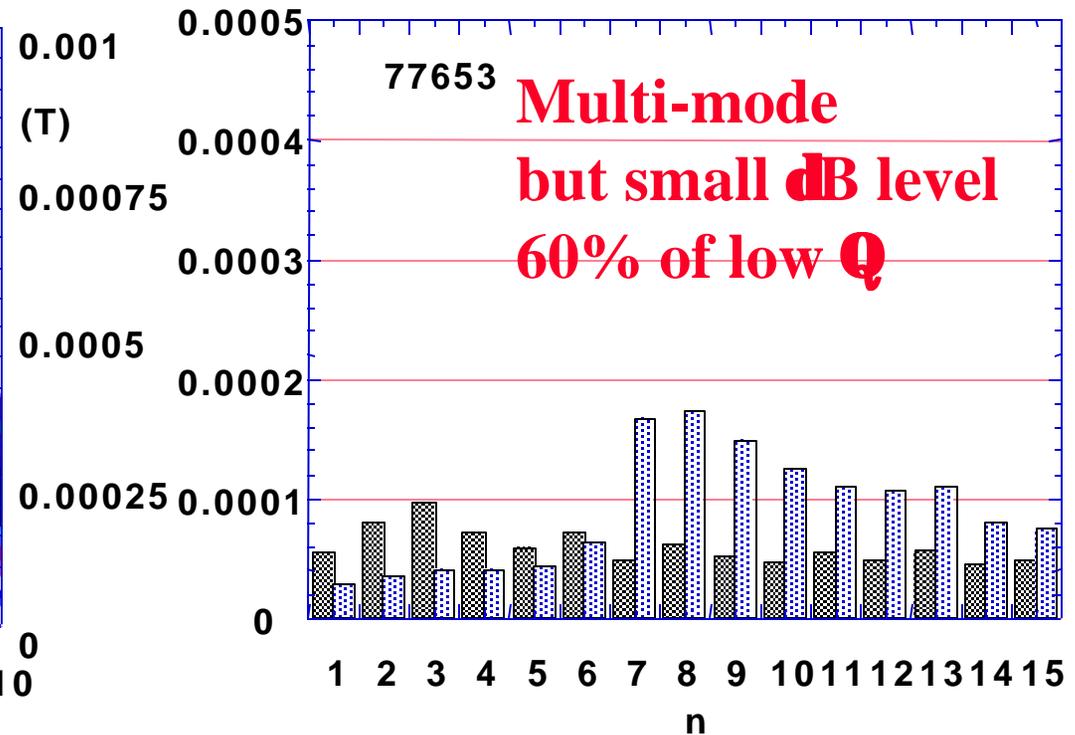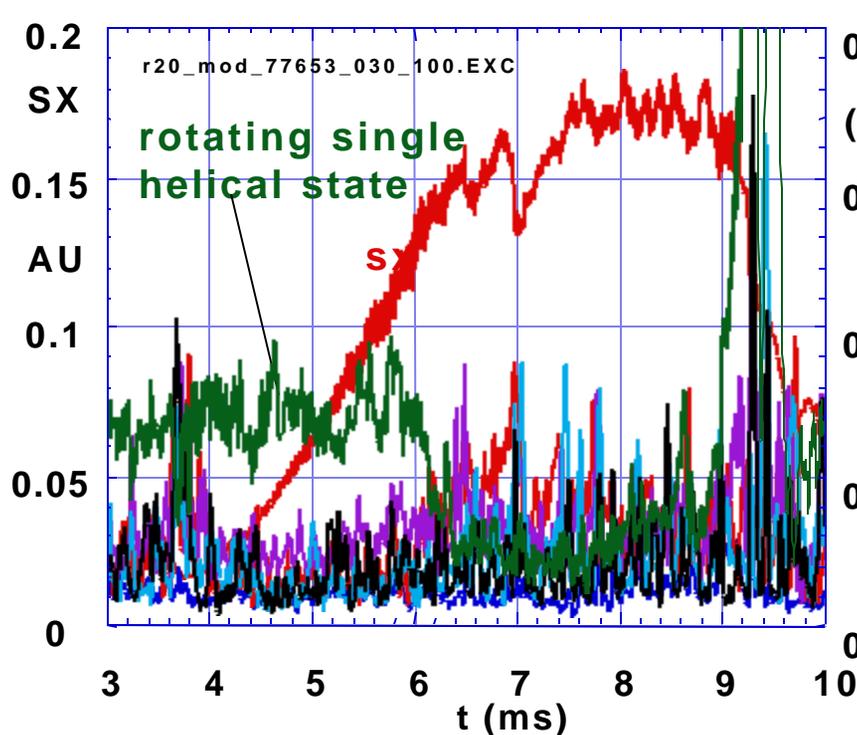
Time variations of δB amplitude
in low and high theta discharges with n mode spectra.
Multi-mode state in both theta values, but smaller in high theta
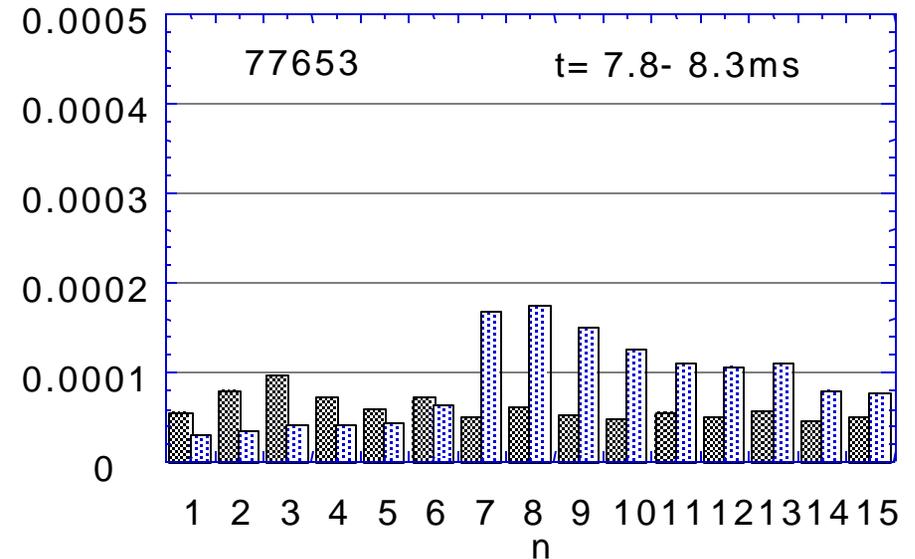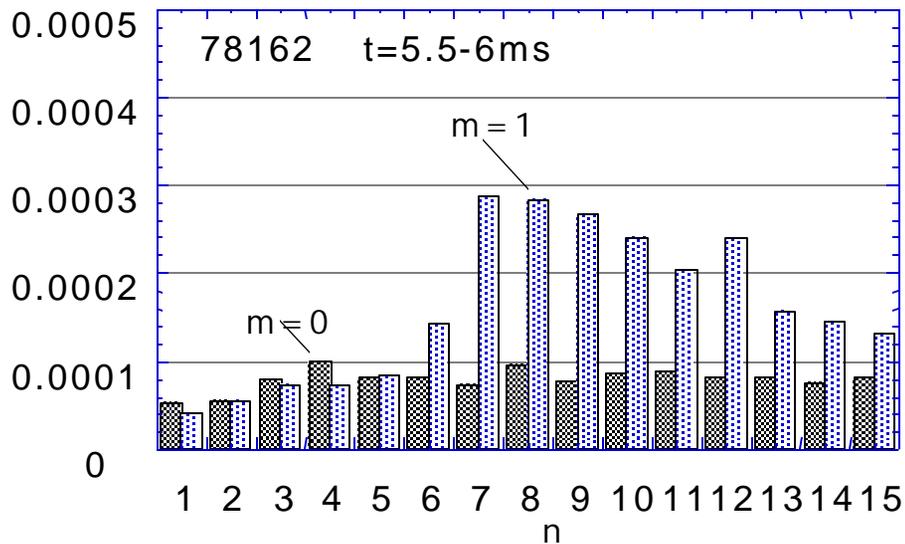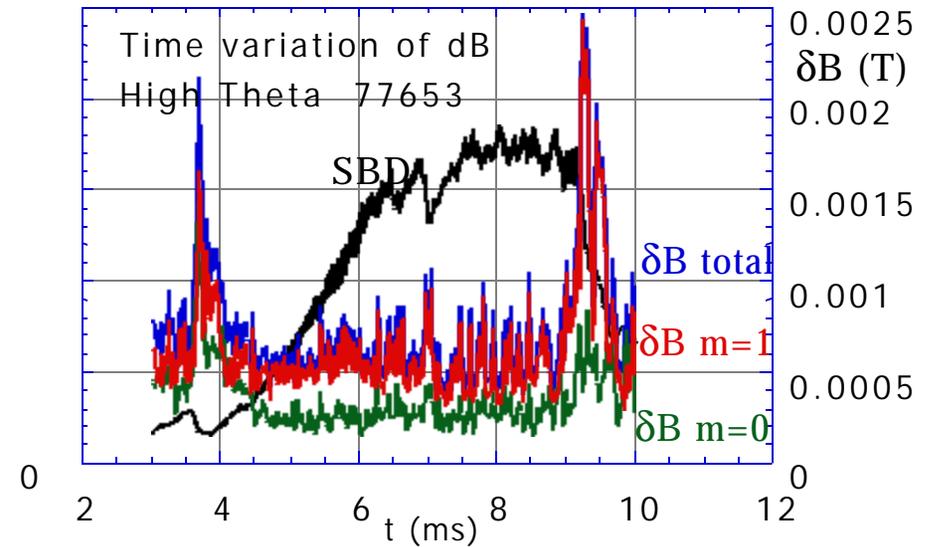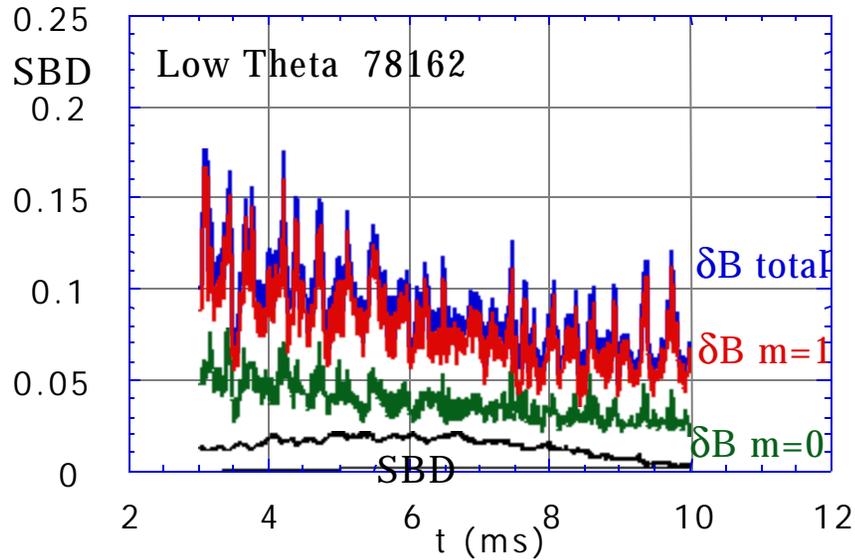
Time variations of δB amplitude
In high theta (IHTM) discharges with n mode spectra.
Improved multi-mode state is observed with reduced δB.
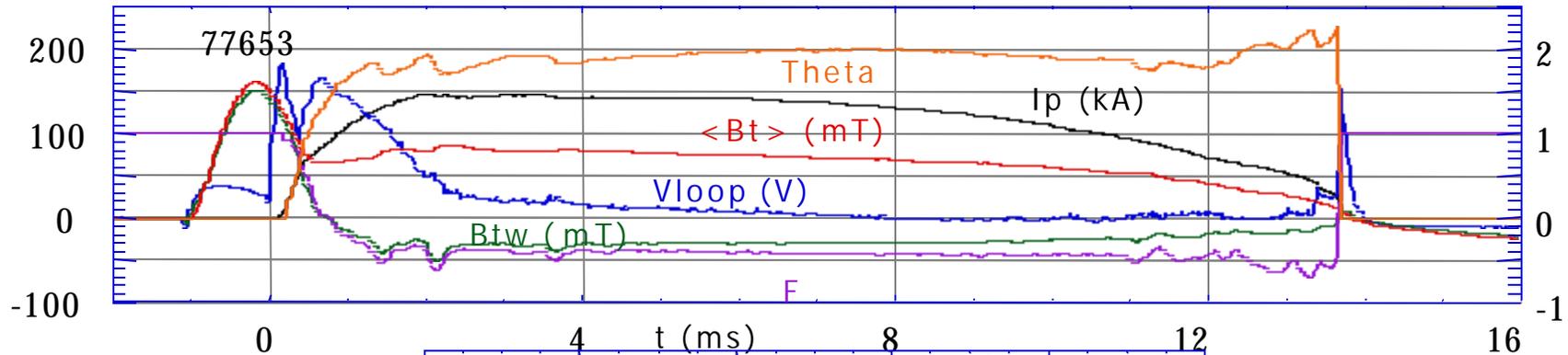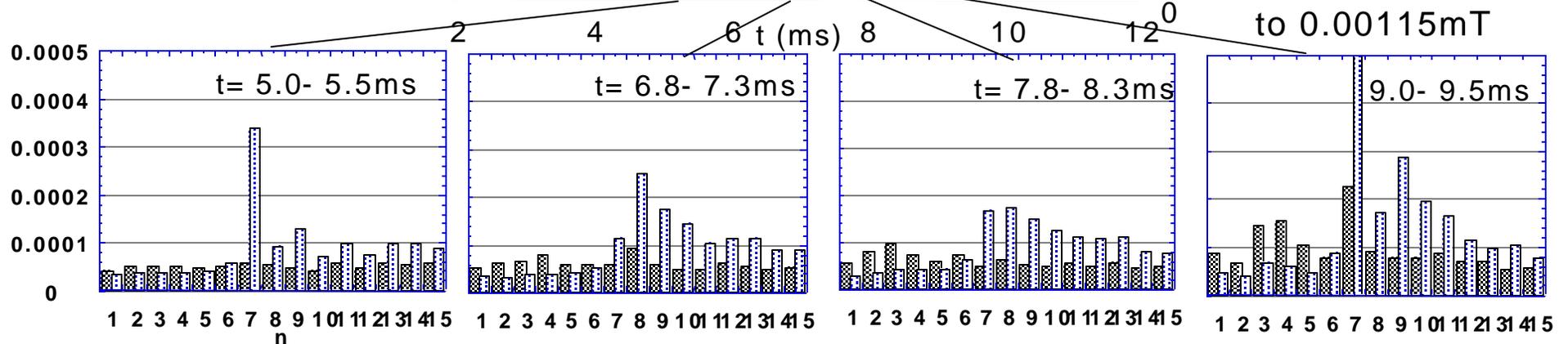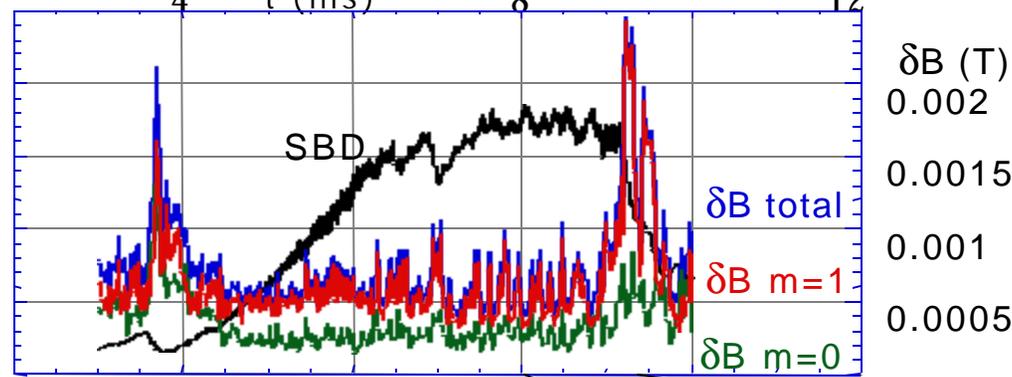
Improved High Theta Mode in TPE-1RM20

δB$_t$(m/n=0/1-15, 1/1-15)

δB$_t$(m/n=1/7)

δB$_t$(m/n=0/1-15)

δB$_t$(m/n=1/high)
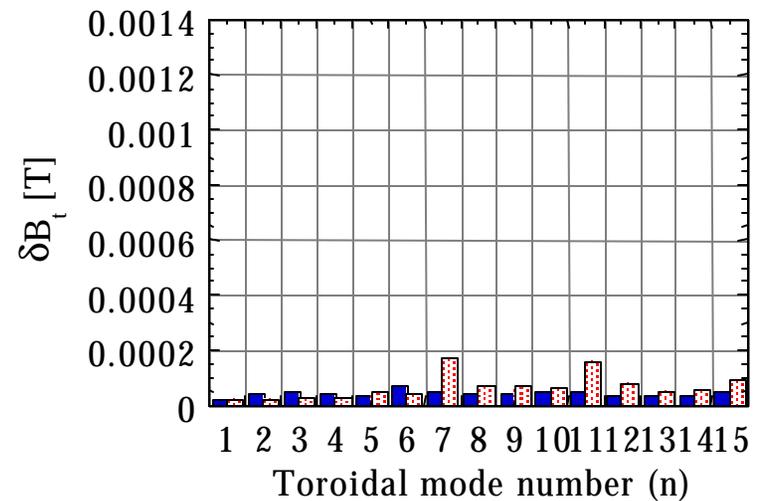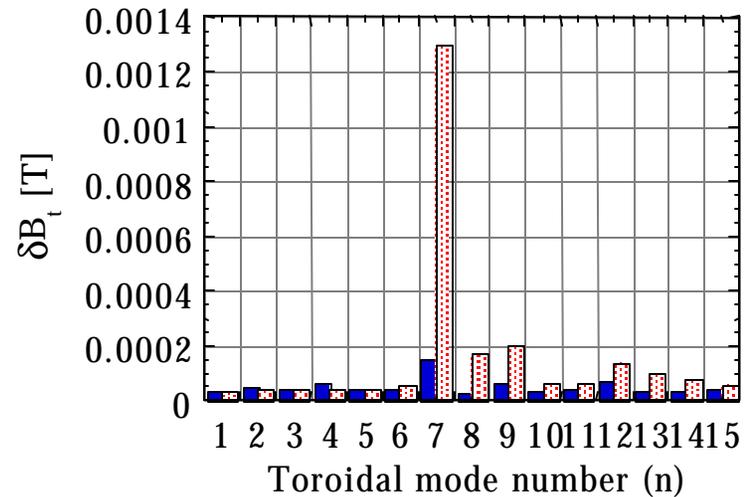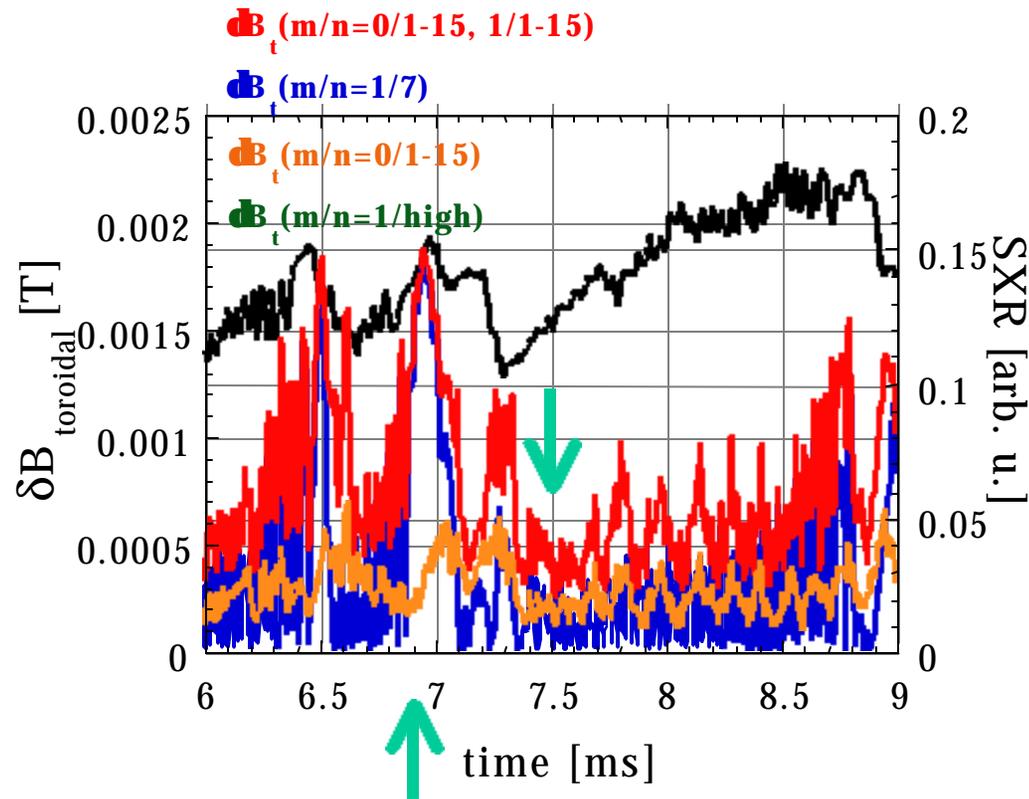
Transition to the all mode suppression state from the single helicity state, triggered by the small sawtooth crash.

H. Sakakita, Y. Hirano et al.; to be presented in Jpn. Energy Conf. at Chubu Univ. (2000).

Comparison of multi & single helical states in TPE-1RM20

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Multi-helical state => globally calm & looks to be stable
in low Θ but small SBD & low beta
mainly observed in low Θ
dB is small in each mode but is large in total

Single helical state => some time with intermittent large crash
large SBD & high beta when without crash
always observed in high Θ
dB is large in one mode but is small in total
SBD is increasing

Multi-helical state => observed in Ip decay phase
in high Θ large SBD & high beta
recently noticed dB is small in each mode and in total

Dynamo effect, Single helical state & Steady state

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Dynamo Effect

=> **Sustaining RFP configuration against resistive decay**
sustaining j-poloidal with V-toroidal
V-toroidal (flux swing) is required.

=> **quasi-steady state, but not complete steady DC state**
even in the single helical state

Single helical state may sustain RFP configuration
without stochastic magnetic field line

=> **improved confinement but not DC state.**

DC operation of RFP requires a certain direct current drive method.

RF ; LHW, Fast W, EBSW, Whisler wave, etc.
NBI
F-Ω pumping
Possibility of Boot strap current is important.
Possibility of dynamo driven by pressure gradient.

Summary

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It is definitely shown that Single Helical state can improve confinement even if the dB amplitude is large (five times larger compared with ordinary cases).
Probably because of the less (non) stochasticity of magnetic field.

Multi-helical state is always observed in low theta, in which there is no large SX crash and violent MHD activities, smooth and continuous. It looks as if it were stable.
Amplitude of individual mode is not large.
However, total dB level is high and SBD is small (large loss?).
Probably because of the stochasticity of magnetic field.

Multi-helical state with small dB level is found in high theta, where the SX signal stays in high level, but doesn't increase, which indicates better confinement than in low theta multi-helical state, but not so good as in the single helical state.