Introduction to KSTAR MHD Research Activities

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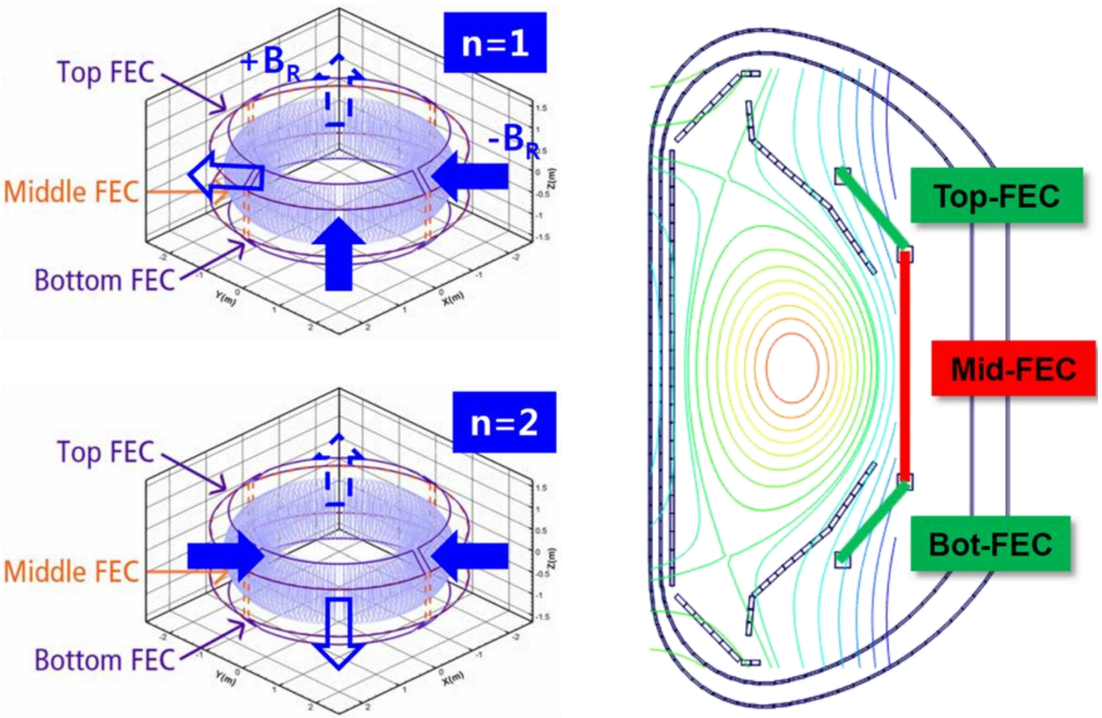
Contents

Error Field Study (NTV effects)

NTV Effect on Error Field Penetration

Jayhyun Kim (NFRI)

FEC Coil Con figuration



Y. M. Jeon, IAEA FEC 2012, EX/3-3

n=2 (even) + n=1

Port	L	P	D	H
	0°	90°	180°	270°
Top	+	-	+	-
Mid	-	+	+	-
Bot	+	-	+	-

n=2 (odd) + n=1

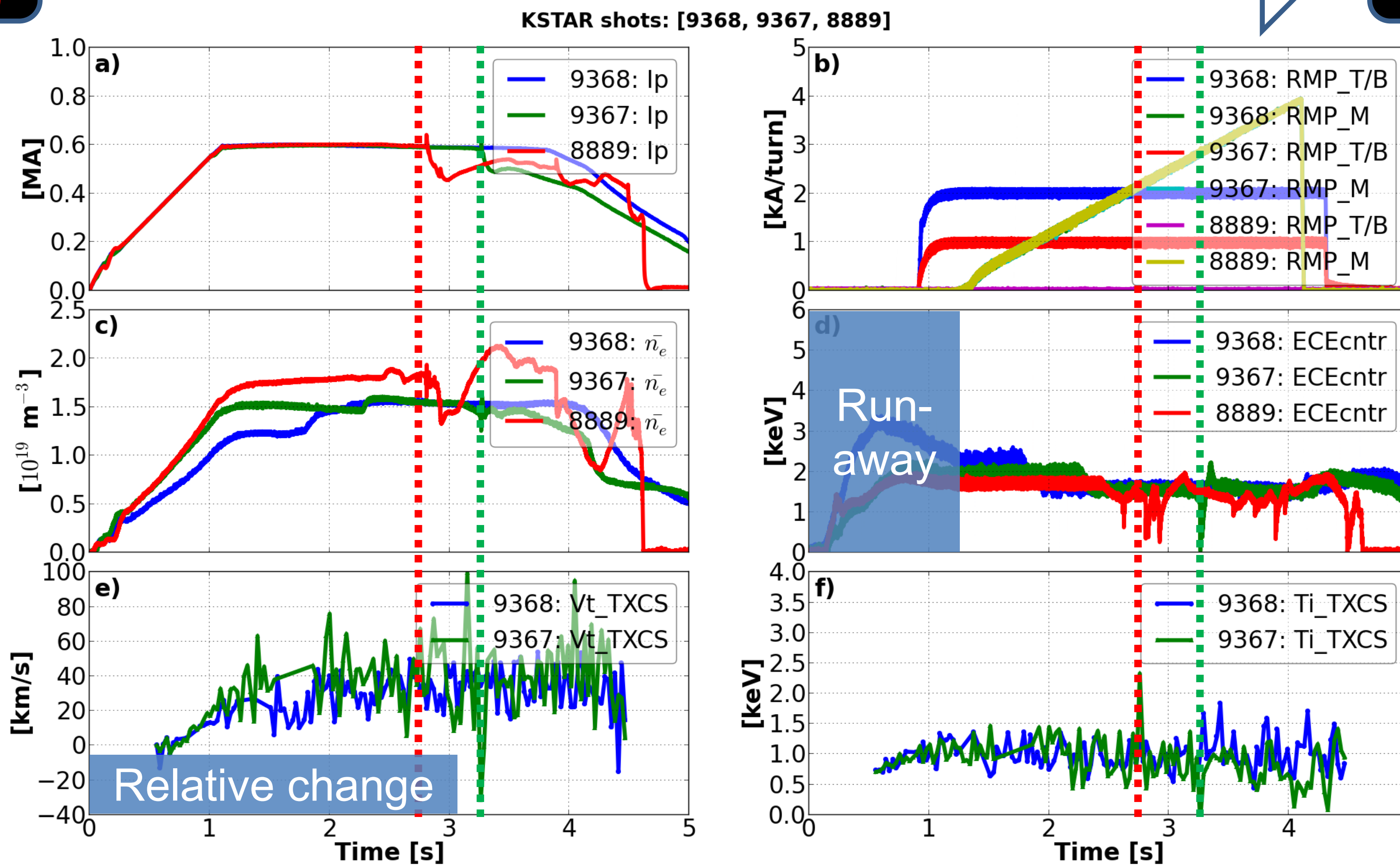
Port	L	P	D	H
	0°	90°	180°	270°
Top	+	-	+	-
Mid	-	+	+	-
Bot	-	+	-	+

- All the coils are internal thus NA field could be effectively coupled to plasmas.
- n=1 or 2 field is applicable per each row with various toroidal phase.
- Three rows of FEC coils can provide various poloidal magnetic spectra.

Higher n=2 even field discharge is less susceptible to final locking by n=1 field.

- n=1 field is gradually increased to cause the final locking.
- n=2 even field is constantly applied during n=1 field increase.

Early locking | #8889 (no n=2) > #9367 (n=2, 1 kA/t) > #9368 (n=2, 2 kA/t) | No locking



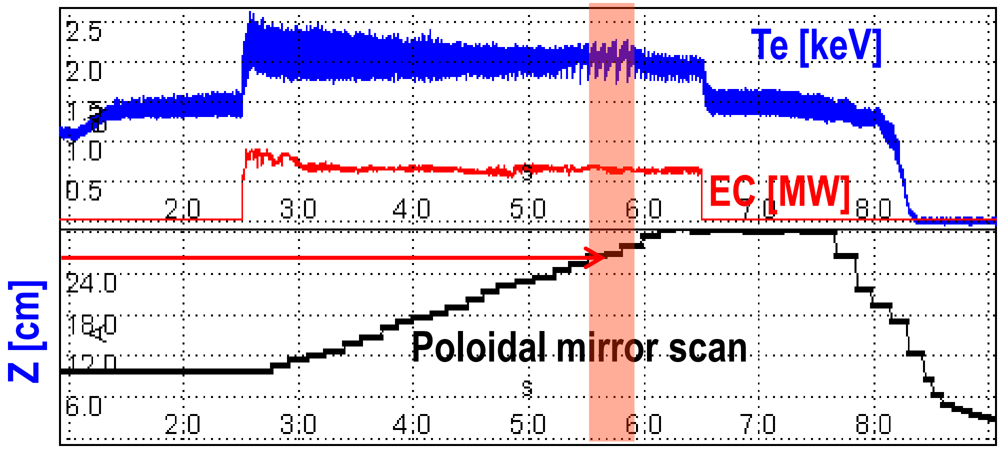
Sawtooth Control

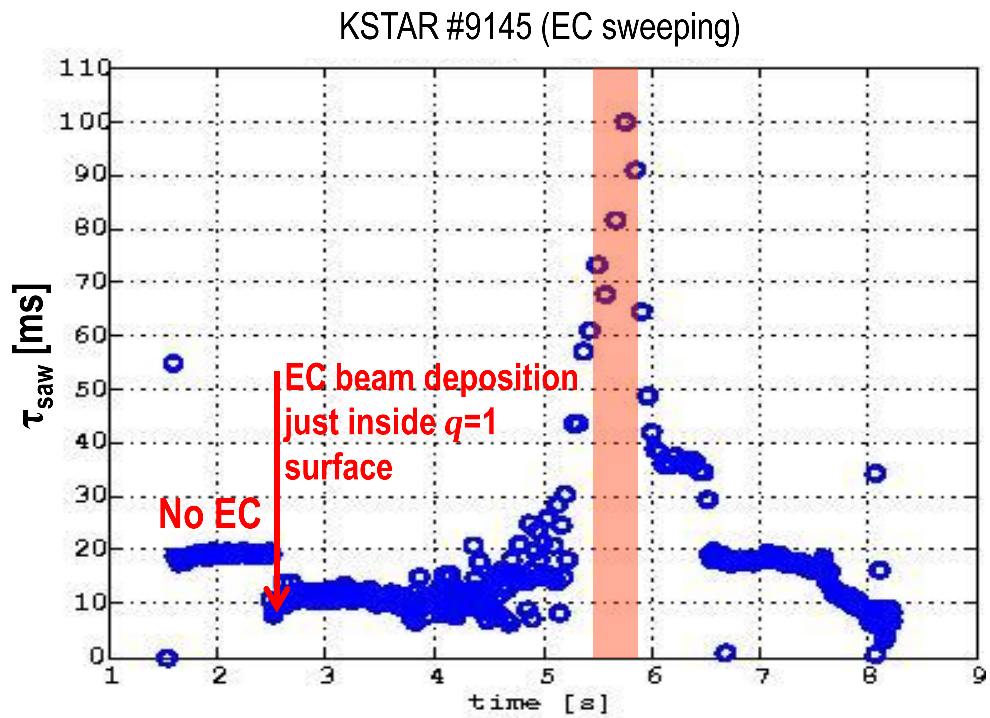
Locking by Modulated ECCD Injection

JinHyun Jeong (NFRI)
DooHyun Kim (CRPP – EPFL)

Locking by Modulated ECCD Injection

- The optimal location for stabilization of sawtooth was determined with a EC beam poloidal scan (EC beam deposition just outside q=1 surface)

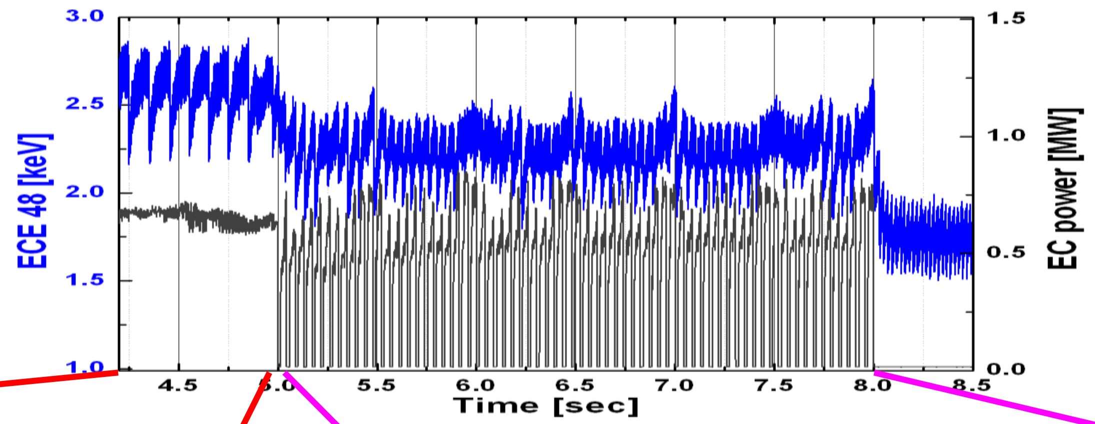


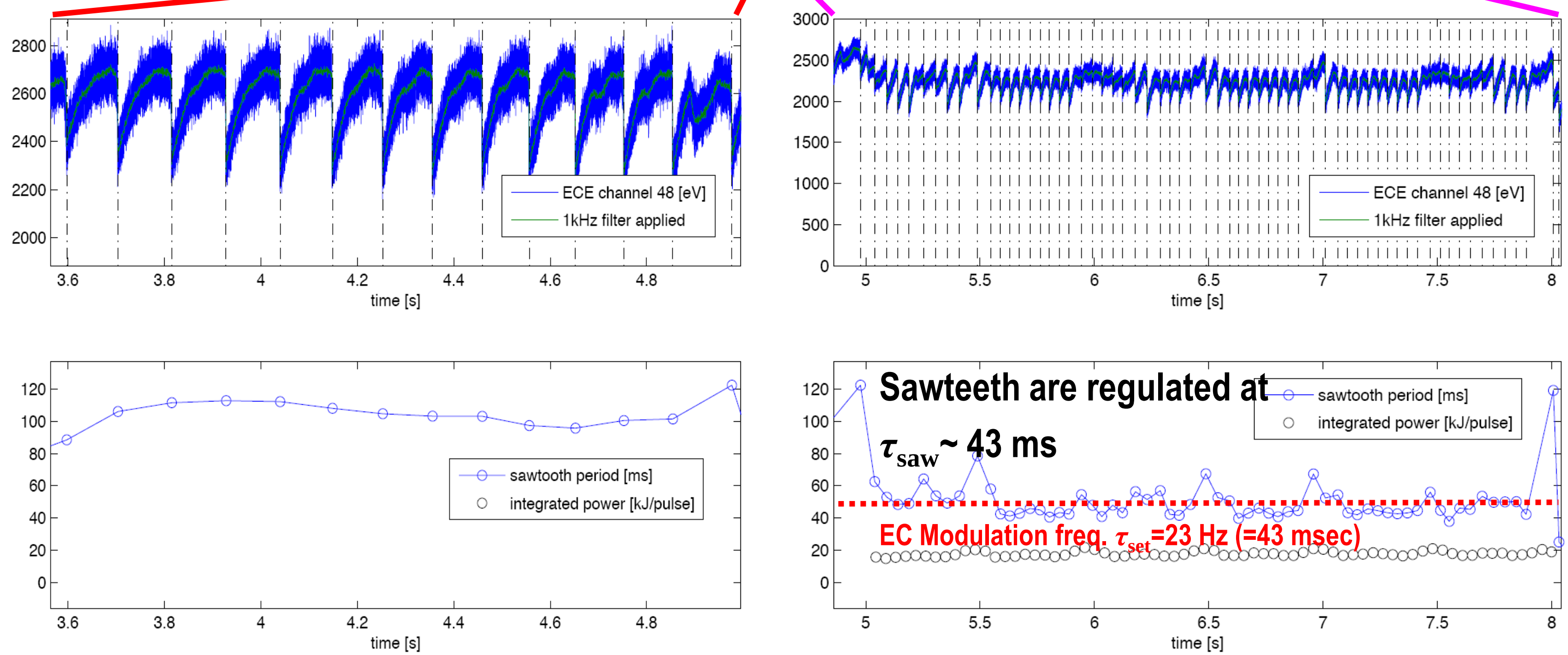


Locking by Modulated ECCD Injection

(#9215)

❖ EC injection
- z=26 cm from mid-plane
- τ_{set}=43 msec (=23 Hz with 70 % duty)





NTM Control

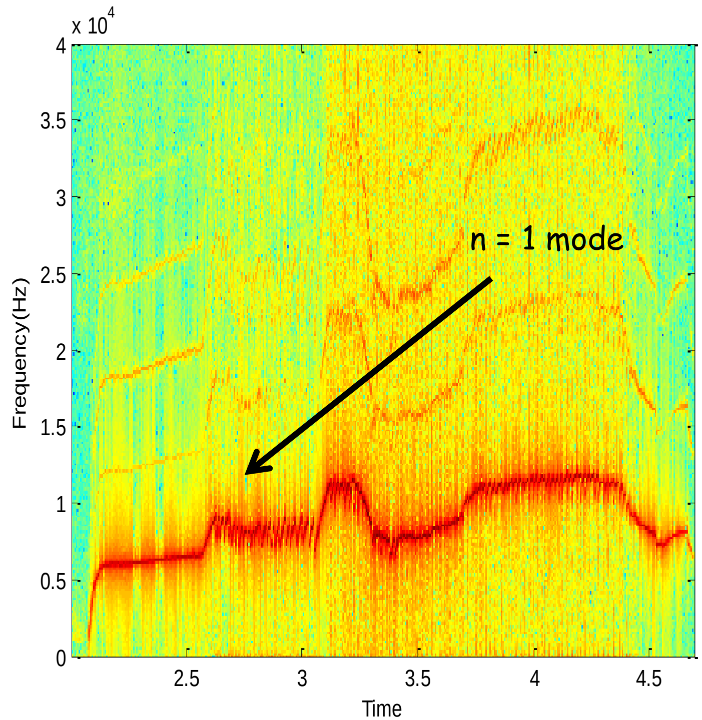
M. Jeong, M.H. Woo (NFRI)
M. Kim (SNU)

Motivation

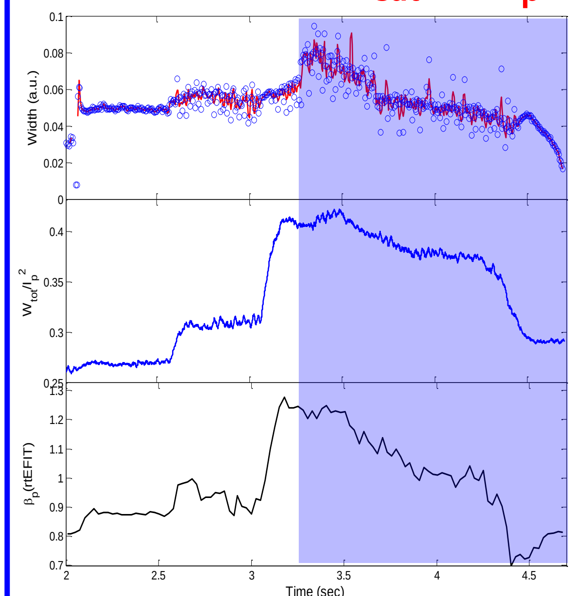
First Observation of NTMs - KSTAR

After first observation of NTMs,

NTM/TM like instabilities are frequently appeared.



Spectrogram of tearing modes (#8016)

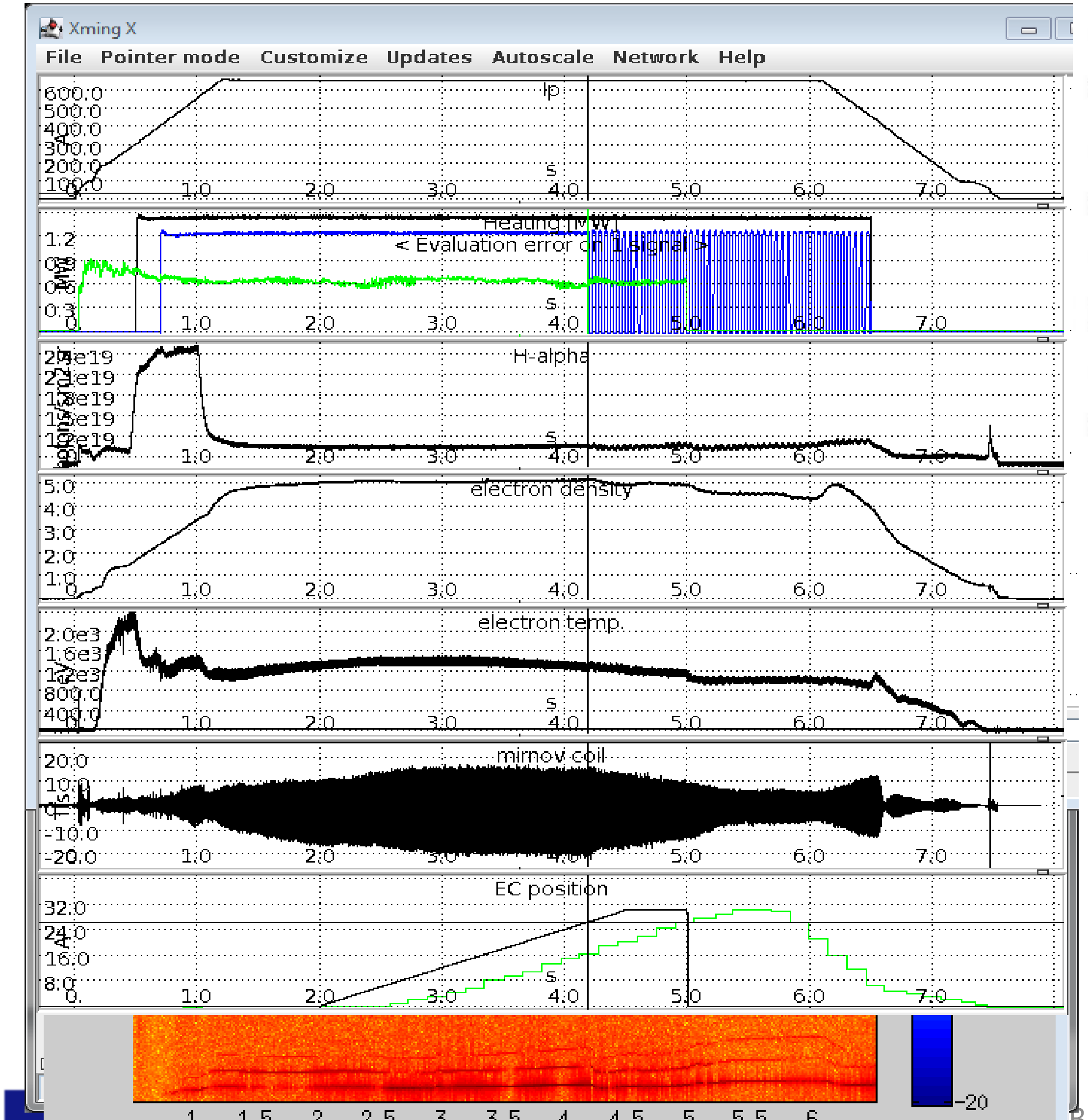


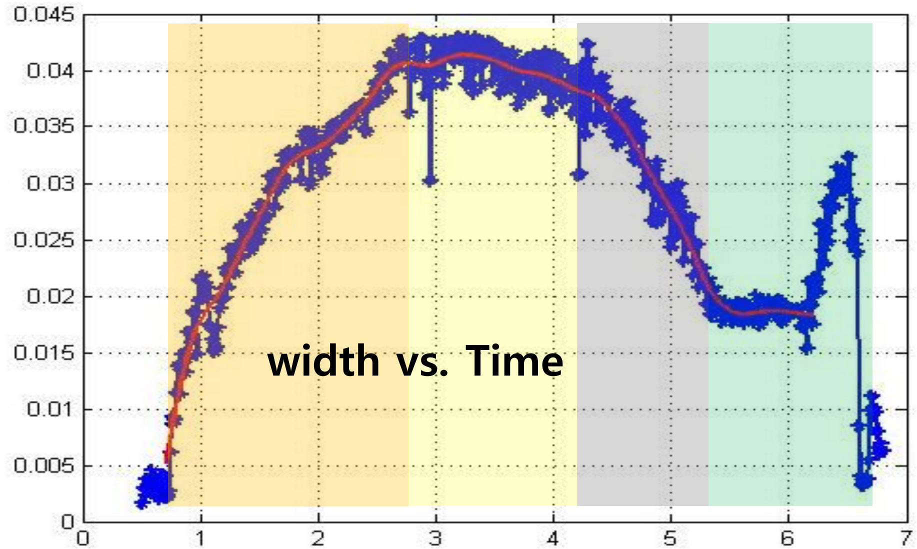
TM spins up at t ~ 2.05 sec (#8016)

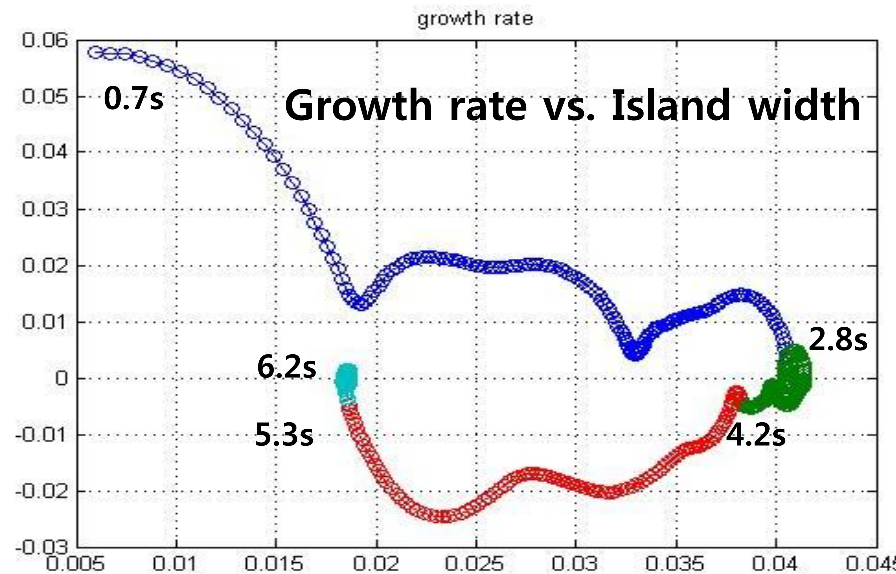
NTM Identification

#9141, 2.6T, 650kA

KSTAR







NTM Suppression by ECCD

L/H transition occurred after partial suppression of NTM

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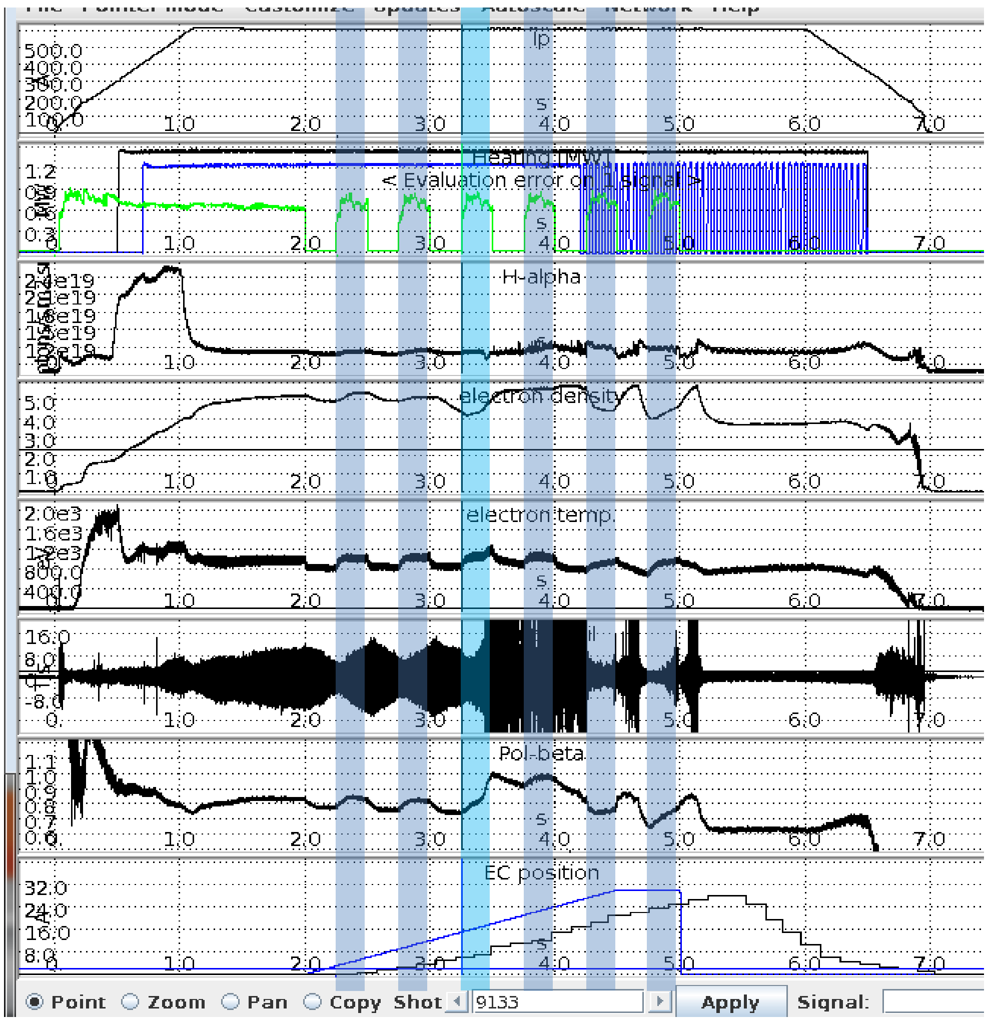
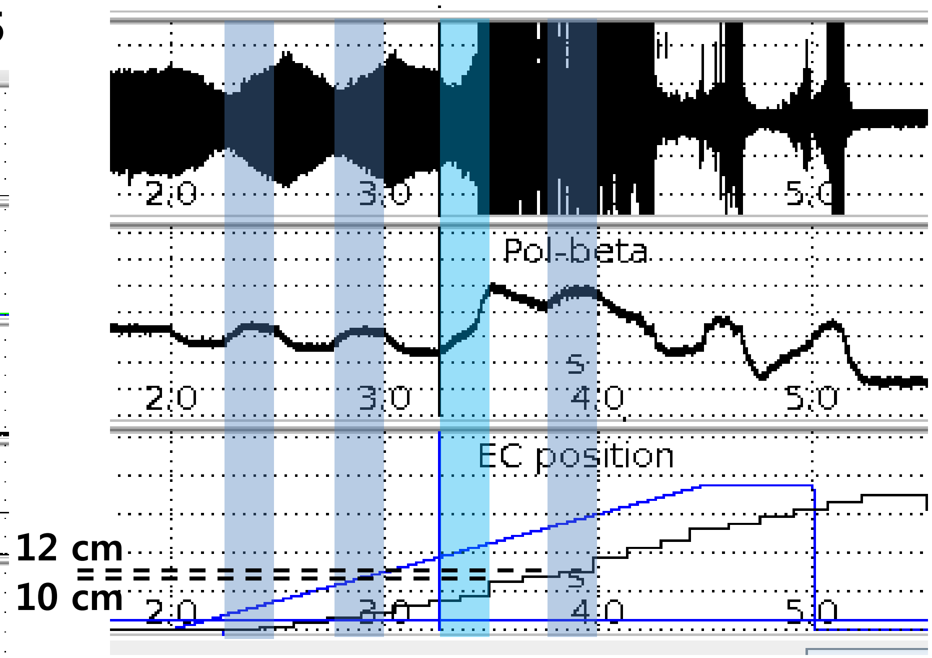
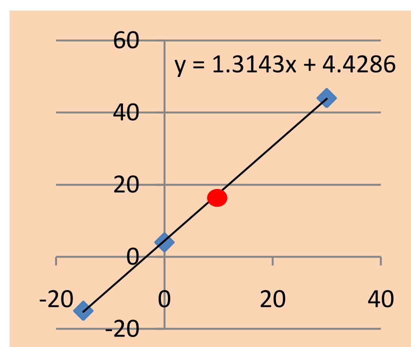
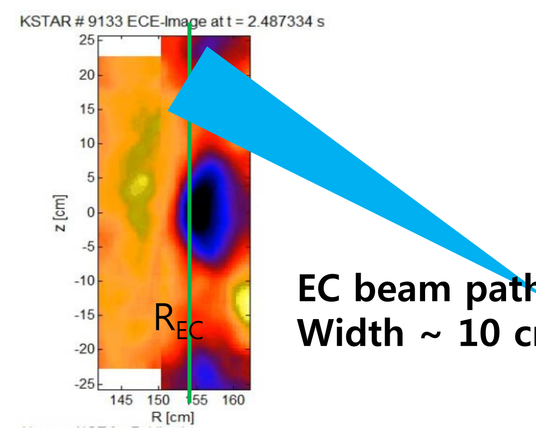
#9133, 2.6T, 600 kA **tor=20deg. z=0-25**









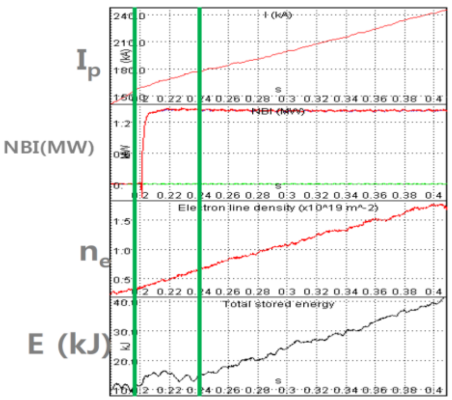
Energetic Particle Physics Research

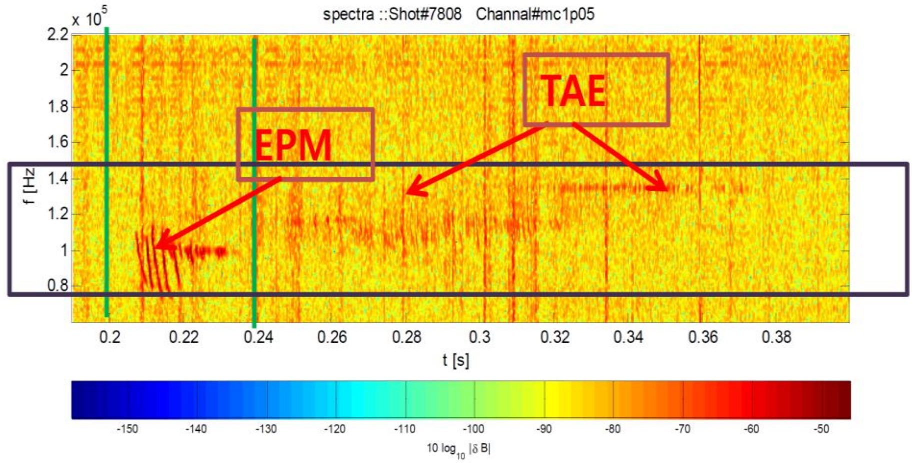
1. Energetic Particle Modes in KSTAR
   Chang-Mo Ryu (Postech)

2. Fast Ion Loss associated with 3-D field, Tearing mode
   Junghee Kim (NFRI)

Energetic Particle Modes in KSTAR

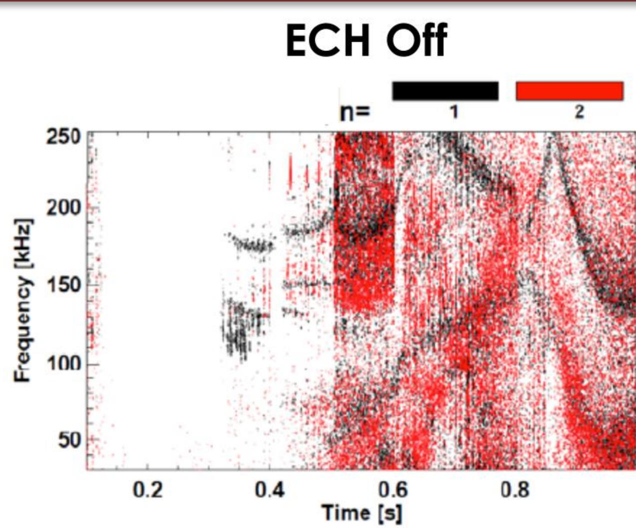
TAE / EPM activities





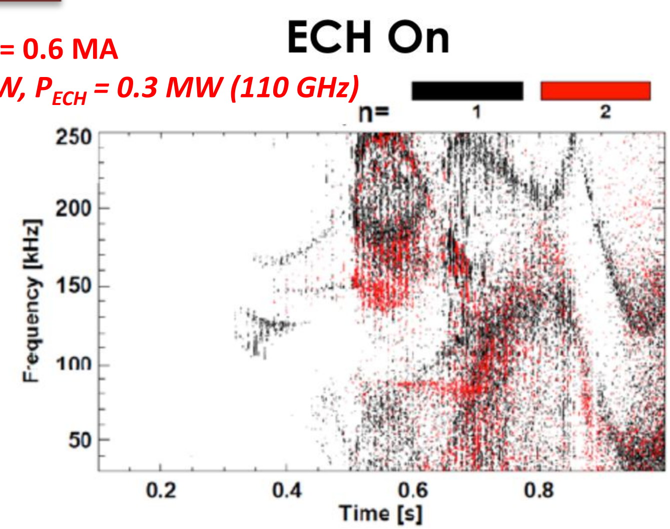
- **Early beam injection** driving EPM with high β_{fast}
- **EPM/TAE** ($q(0)>1$, f=80 ~ 130 kHz)

ECRH effects on Alfvénic modes investigated in KSTAR



B_T = 2.0 T, I_P = 0.6 MA

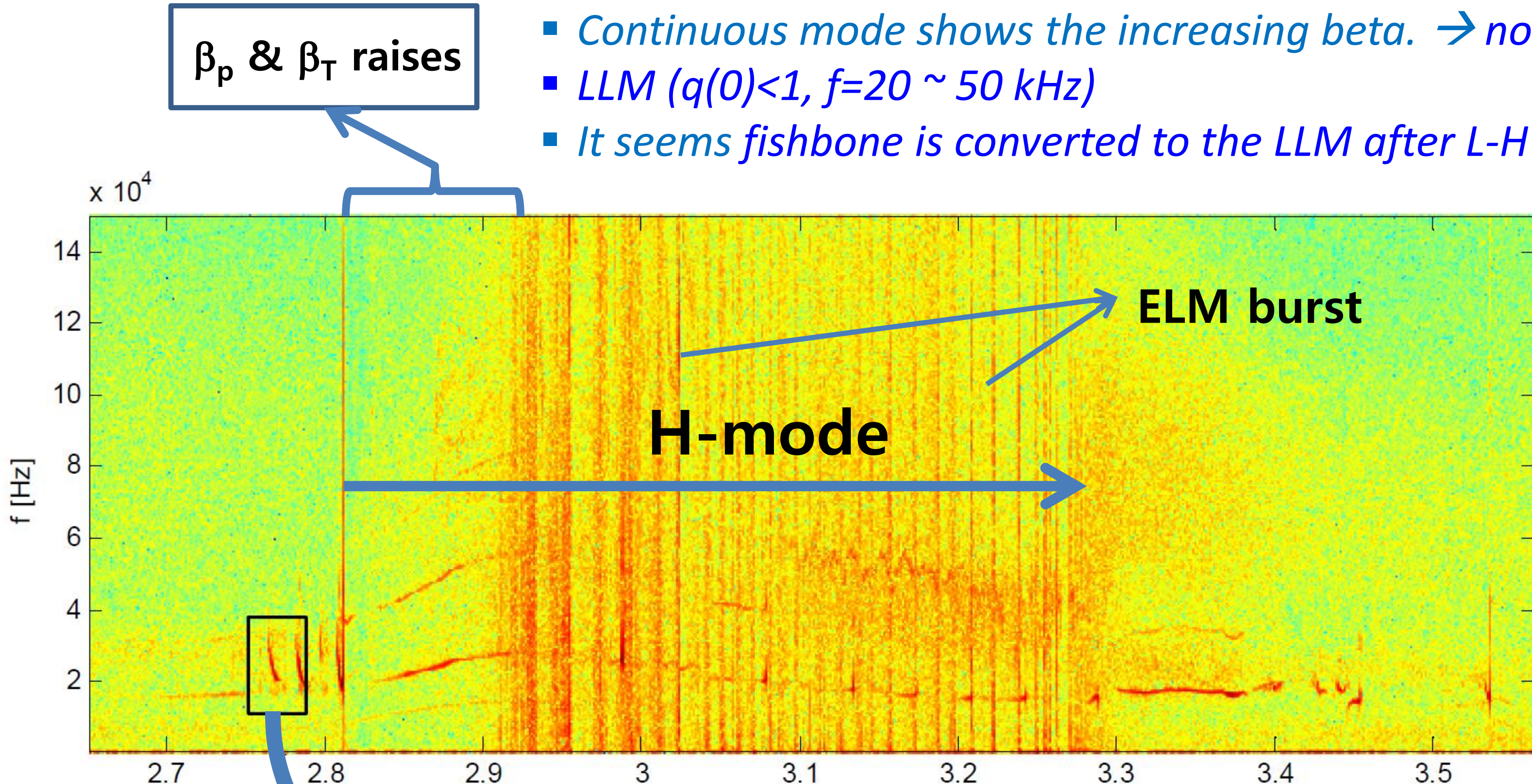
P_{NBI} = 2.7 MW, P_{ECH} = 0.3 MW (110 GHz)

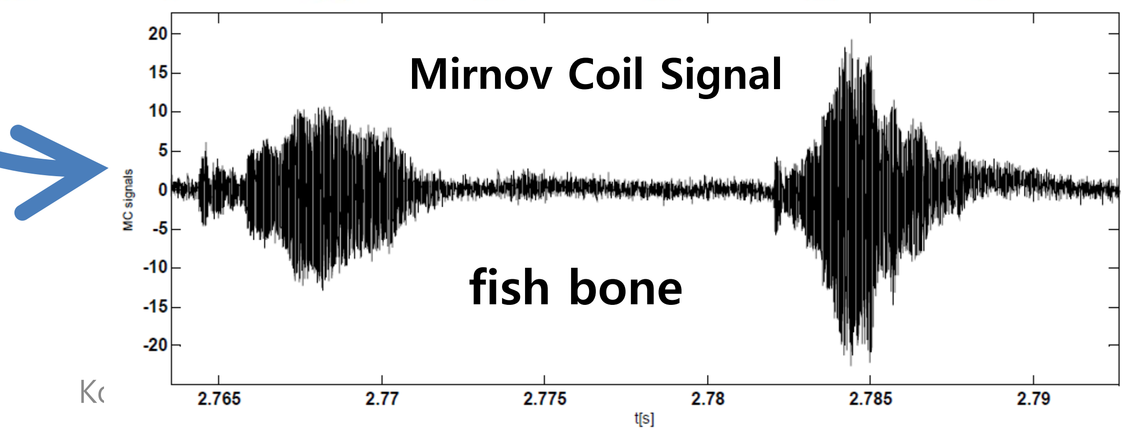


- **n=2 Alfvenic fluctuations are suppressed by ECRH**
- **No complete suppression of n=1 modes: Early high power ECH before NBI will be required.**

Energetic Particle Modes in KSTAR

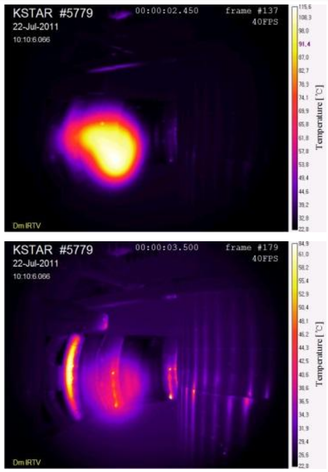
- *Continuous mode shows the increasing beta. → not a NTM.*
- *LLM (q(0)<1, f=20 ~ 50 kHz)*
- *It seems fishbone is converted to the LLM after L-H transition.*



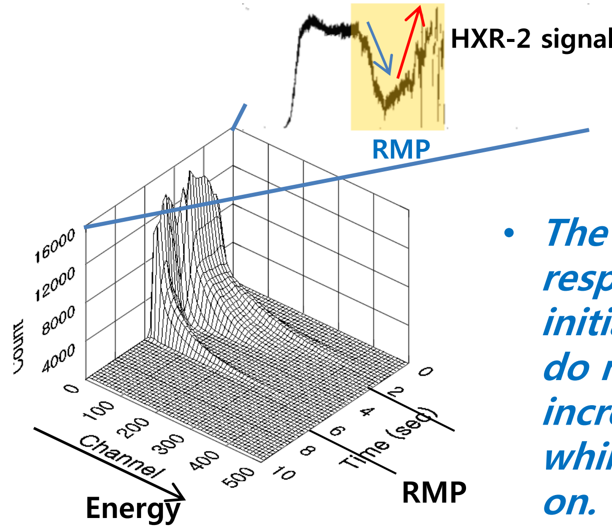


Runaway electron study

Runaway electron suppression (ECRH, RMP)



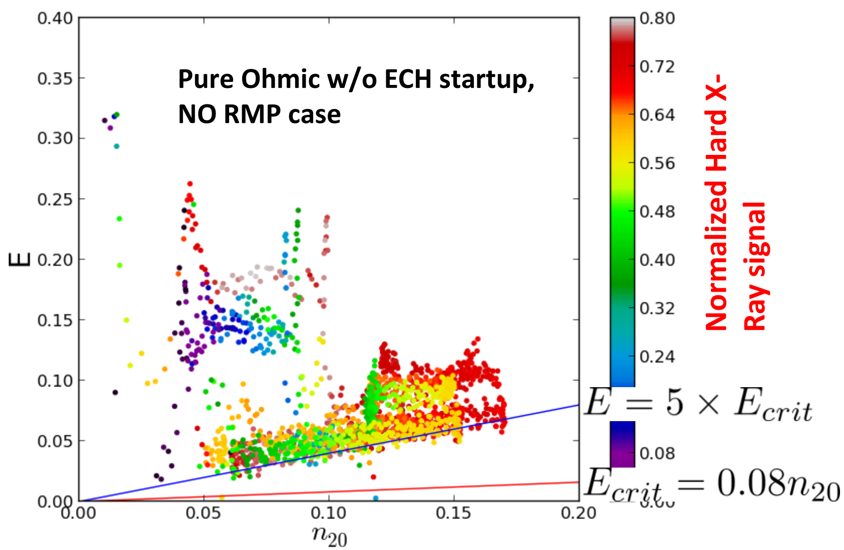
- *RE suppression by the ECRH.*
- *IR synchrotron radiation decreased.*
- *110 GHz ECRH increases T_e which lowered the loop voltage. → The REs decreased in number and energy.*



- *The n=1 RMP may be responsible for the initial decrease but we do not understand the increase during the shot while the RMP was still on.*

$$E_{crit} = \frac{n_e e^3 \ln \Lambda}{4\pi\epsilon_0^2 c2} \sim 0.08 n_{20}$$

Threshold electric field for runaway electron generation



- **Threshold E field for runaway electron is ~ 5 times greater than E_{crit}.**
- **In KSTAR case: n_{crit} ratio of meas/theory ~ 1/5 (0.2)**

n_{crit} meas/theory

Participants in MDC-16:

- FTU (continuation of recent experiments)
  - J. Martin-Solis, B. Esposito
- ~0.1 TEXTOR (recent results from dedicated experiment)
  - R. Koslowski, M. Lehnen
- ~0.2 Alcator C-Mod (only through data mining)
  - R. Granetz
- **~ 0.2** KSTAR
  - J.Kim
- ~0.1 DIII-D (some data mining; dedicated experiments soon)
  - J. Wesley, C. Paz-Soldan
- RFX-Mod (in tokamak mode; flexible error field application)

Disruption Avoidance & Mitigation

1. **Detection of abnormal situation and response to it – VDE (n=0), MHD (n>1), hardware issues**

   Mega-Ampere task force (NFRI)

2. **Development of soft landing control**

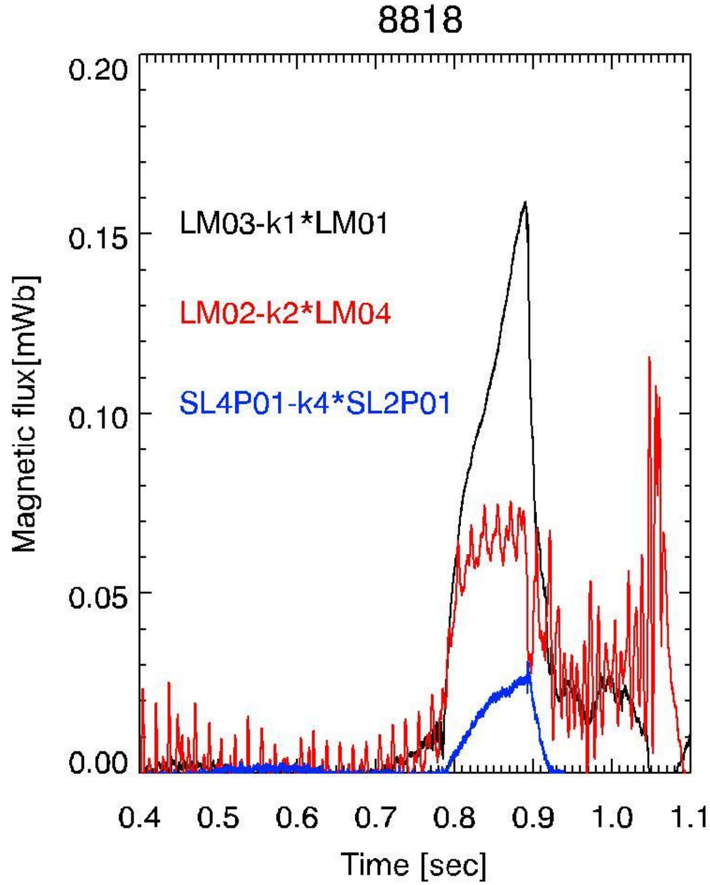
   Mega-Ampere task force (NFR)

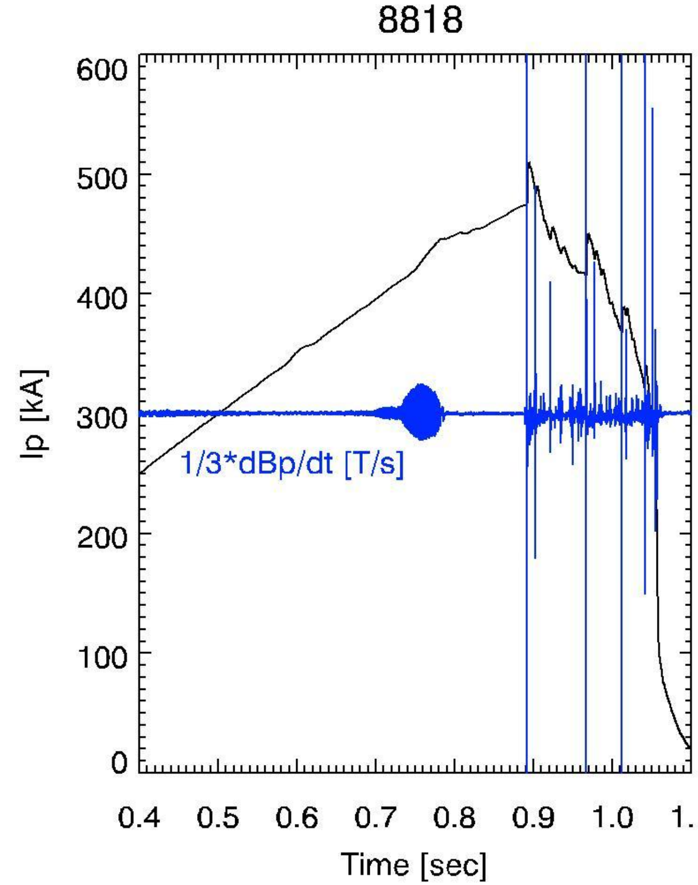
   Acknowledgement to GA control team

Detection of abnormal situation

Signal monitoring during campaign: hard-wired locked mode coil

- Hard-wired paring between 180° opposite LM coils for removal of n=0 component
- Compensation of PF coil action seems to be needed.

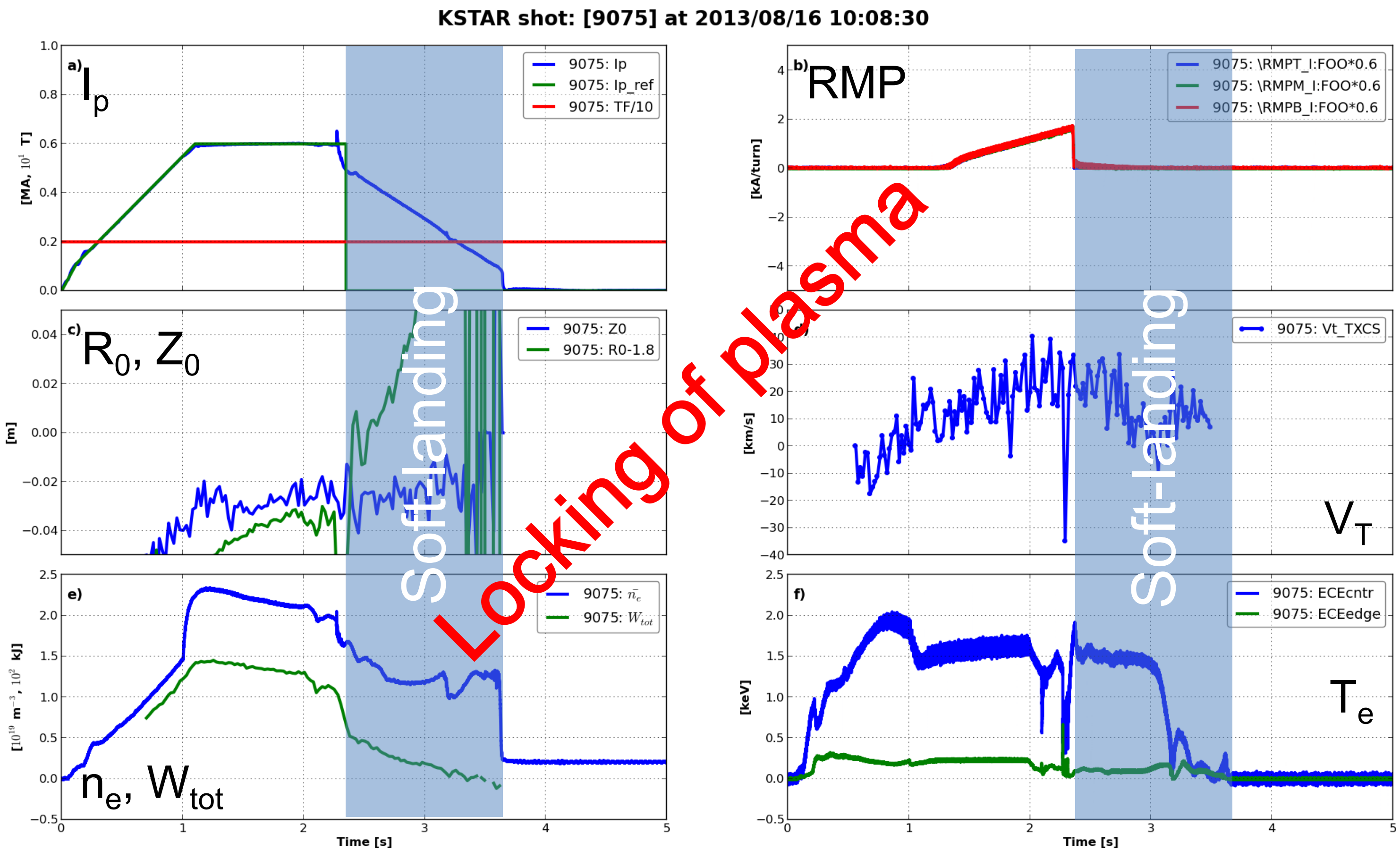




Development of soft-landing control

Development of soft-landing for high I_p and long pulse operation

- Even at the abnormal situation, it is desirable to prevent a sudden drop of I_p.
- Soft-landing algorithm was connected with various kinds of abnormal situations: PFC overheat, NBI fault, VDE, locked mode, and etc.



Plans & Possible Future Collaborations

KSTAR

1. Continue 2013 collaborative experiments (error field, high-beta low rotation, extension of operation window, n=1 instability in high beta plasma)

2. Low q operation under low intrinsic error field: low Bt (robust start-up), moderate/high Ip, shape optimization (low circumference)

3. NTM study and its control (on the way to real time control)

4. Fast Ion Transport (IPEC: plasma response under 3-D field, NOVA-K: Energetic Particle Mode)