NSTX-U

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Potential NSTX Contributions to JRT13

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ECC Meeting
4/13/12

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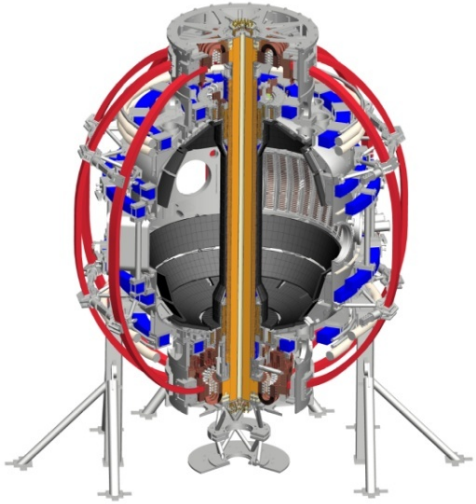

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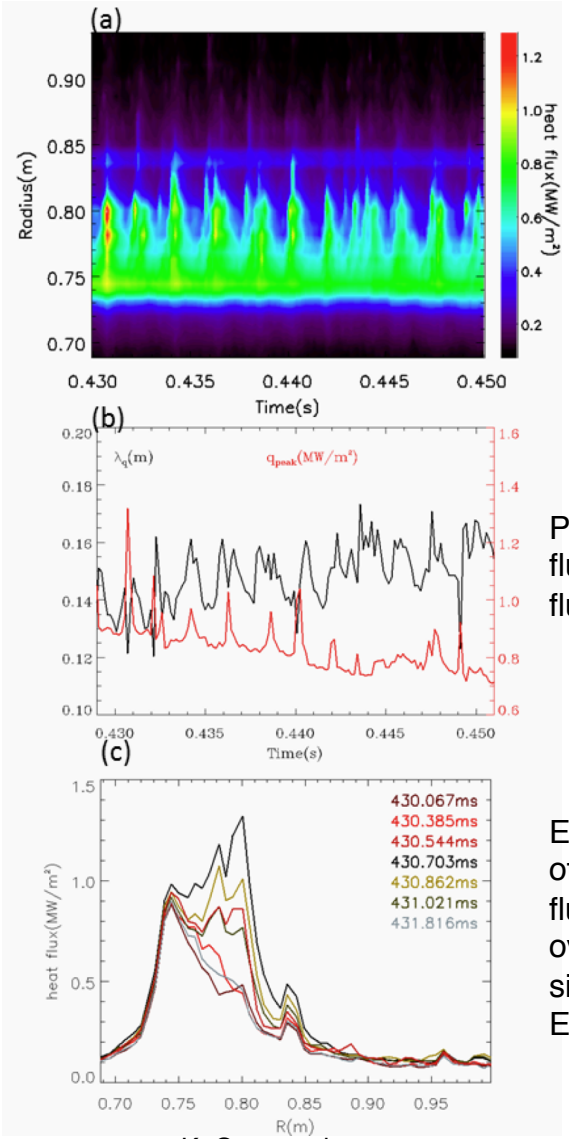
Overview

- Original intention was that NSTX would collect targeted data during the operation period July 2011-February 2012.
  - TF magnet failure during machine commissioning.
- NSTX last collected data in Oct. 2010.
- Internal NSTX discussions have identified the following potential contributions:
  - Heat flux measurements during type-V ELMs.
  - Further study of type-V ELM regime access conditions.
  - Occurrence of 'EHOs' and the potential to actively drive them.
  - Modifications to particle and heat transport w/ 3D fields.
    - Not RMP ELM suppression.
  - Search for I-mode in the database.
  - Other…EPH, Lithium application, IPEC+NTV

Type-V ELM Regime Heat Fluxes

- Type-V ELM regime is a small ELM regime with high-performance.
  - Observed in many high-performance, high-β_N discharges in NSTX.
  - Previous work showed that the energy loss during these ELMs was <1%.
    - Could not tell how much less due to limit of equilibrium reconstruction.
- Work by K.F. Gan, J.-W. Ahn has resolved the divertor heat flux footprint using fast-IR.
- q_{peak} increased by ~20% typically, sometimes up to 50%.
- λ_q increased by 20%, with impulsive energy going to larger major radius.
- Compared to true ELM-free cases, λ_q increased by ~300%
- If extrapolable, this regime may be favorable for ITER/ FNSF.

Potential Contribution: Determination of the compatibility of this discharge regime w/ heat flux requirements of next-step devices.
Theory question: Can we model the evolution of these ELMs with extended MHD?



Heat flux vs. radius and time.

Peak heat flux and heat flux width

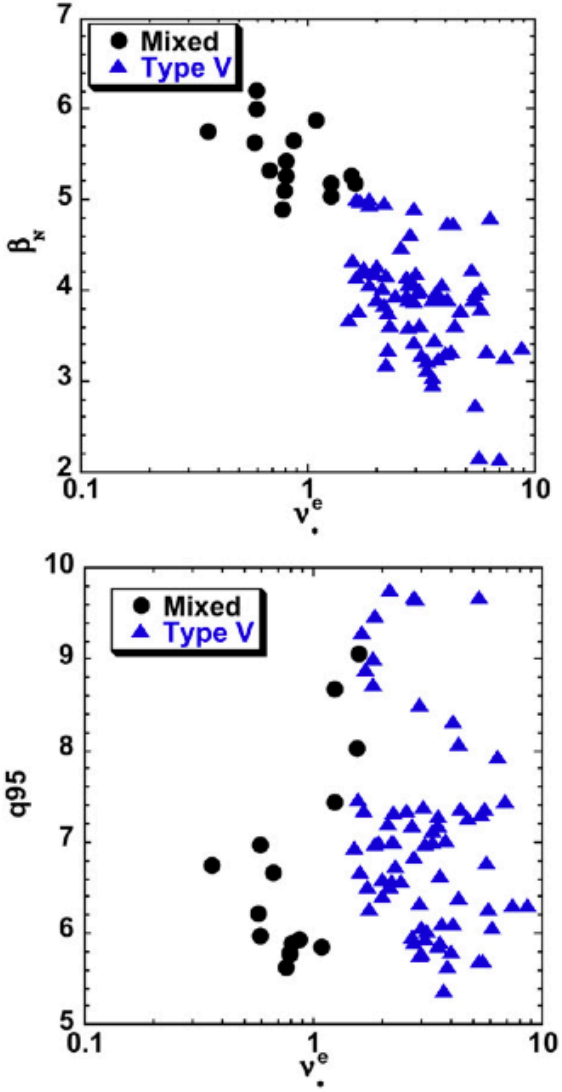
Evolution of heat flux profile over a single ELM.

K. Gan, et al.,

Type-V ELM Regime Access Conditions

- If type-V ELMs have good characteristics, then we wish to know how these regimes extrapolate.
- Historically, these regimes are found at higher pedestal collisionality, in somewhat biased-down discharges.
  - More recent work has found cases down to ν^*~0.5
- Need to better understand the access conditions for these instabilities.
  - Triangularity and elongation.
  - dr-sep
  - Beta and Collisionality

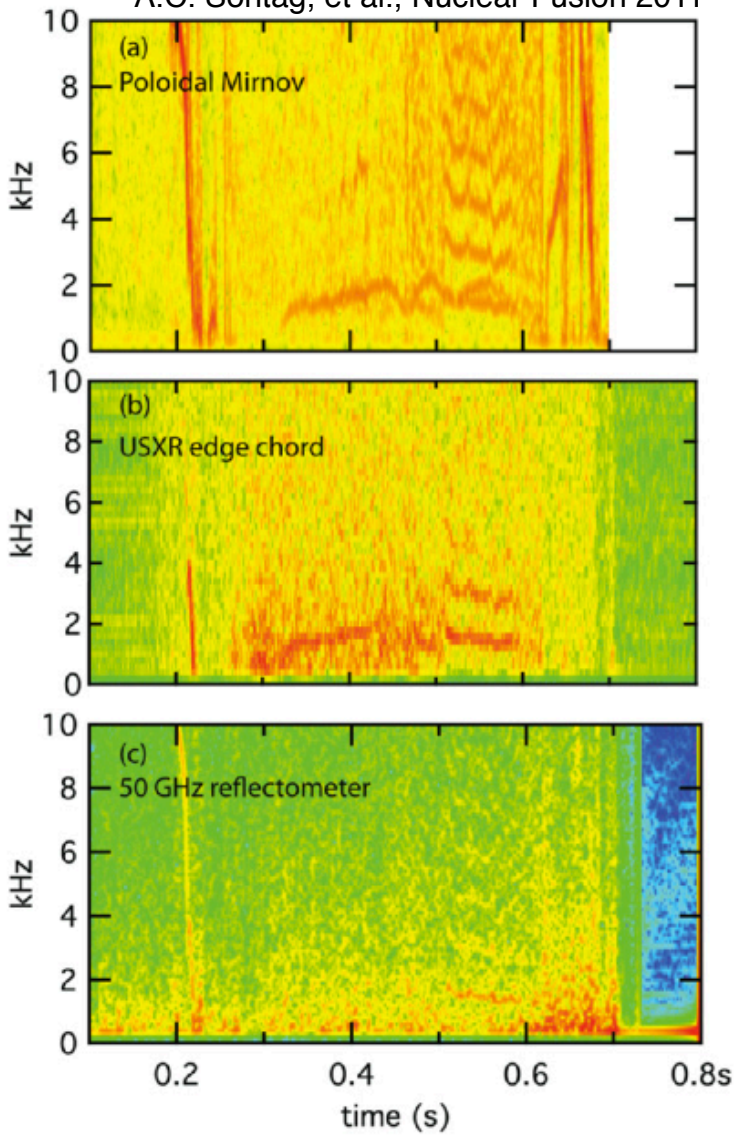
Potential Contribution: Improved prediction of the existence regime of these ELMs, including projection to ITER or FNSF
Theory question: Can we model the linear stability of these ELMs?



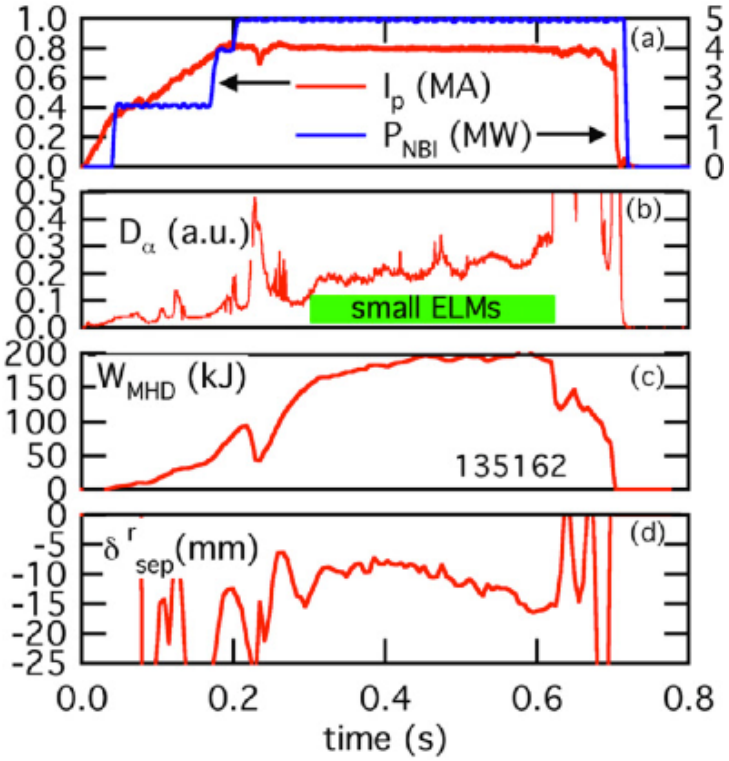
Maingi, Nuclear Fusion 2005

Two Flavors of 'EHOs' Observed in NSTX
1: EHOs During Type-V ELM Regimes

A.C. Sontag, et al., Nuclear Fusion 2011



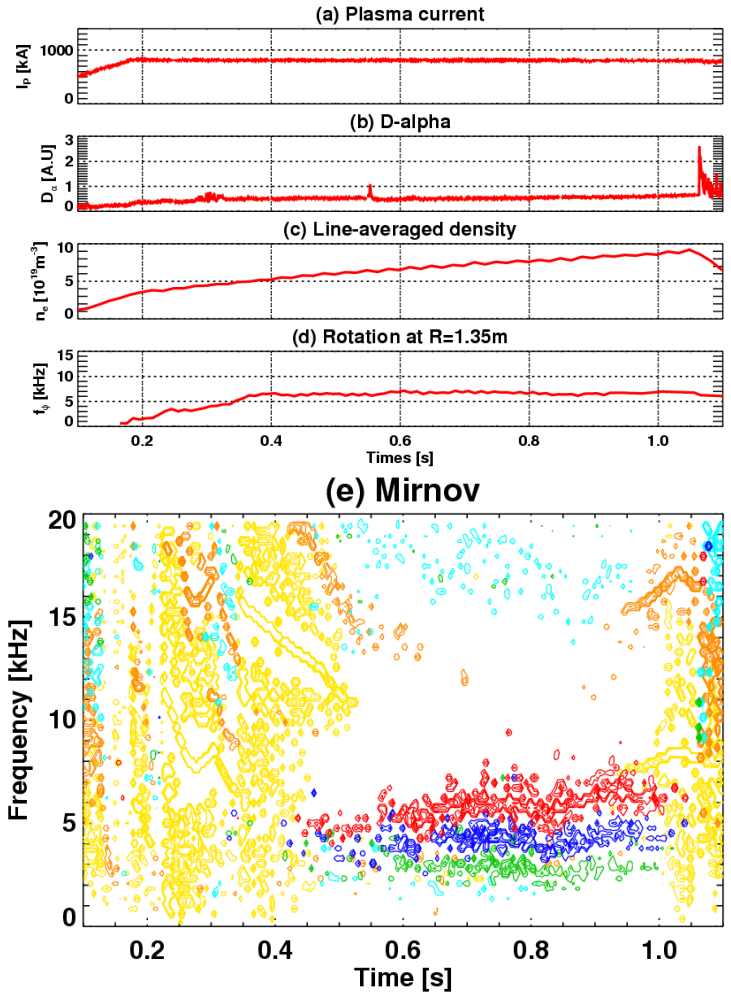
Not suggesting that these are necessarily the same as the QH EHO, only that the are at the edge and have harmonics.



- The EHOs are apparently ubiquitous in the type-V ELM discharges.
  - Similar to the "HRS H-mode" in JFT-2M (Kamiya, et al, Nuclear Fusion 2003).

Two "Flavors" of EHOs Observed in NSTX
2: ELM Free Regime EHOs

EHOs During Lithium Conditioned ELM-Free H-Mode
From J.-K. Park and R. Goldston



n=6
n=5
n=4
n=3
n=2
n=1

- First detected by Fred Kelly
- n=4-6 EHOs were observed in the edge by Mirnov coils tuned for low frequency and low amplitude.
- EHOs are clearest in some optimal operating regimes.
  - 4MW, 0.8MA, 0.4T
  - Would be nice to understand why.
- Generally amplitudes of EHOs are very low, without reduction of density increase.
- Probable FEC paper on this subject.

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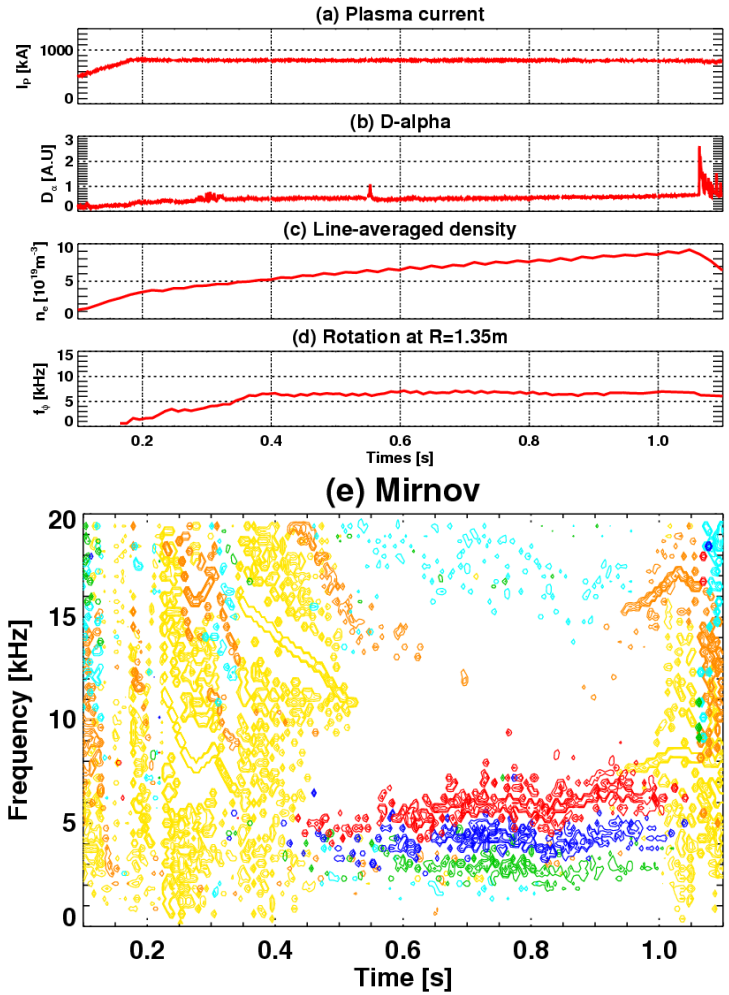

n=6
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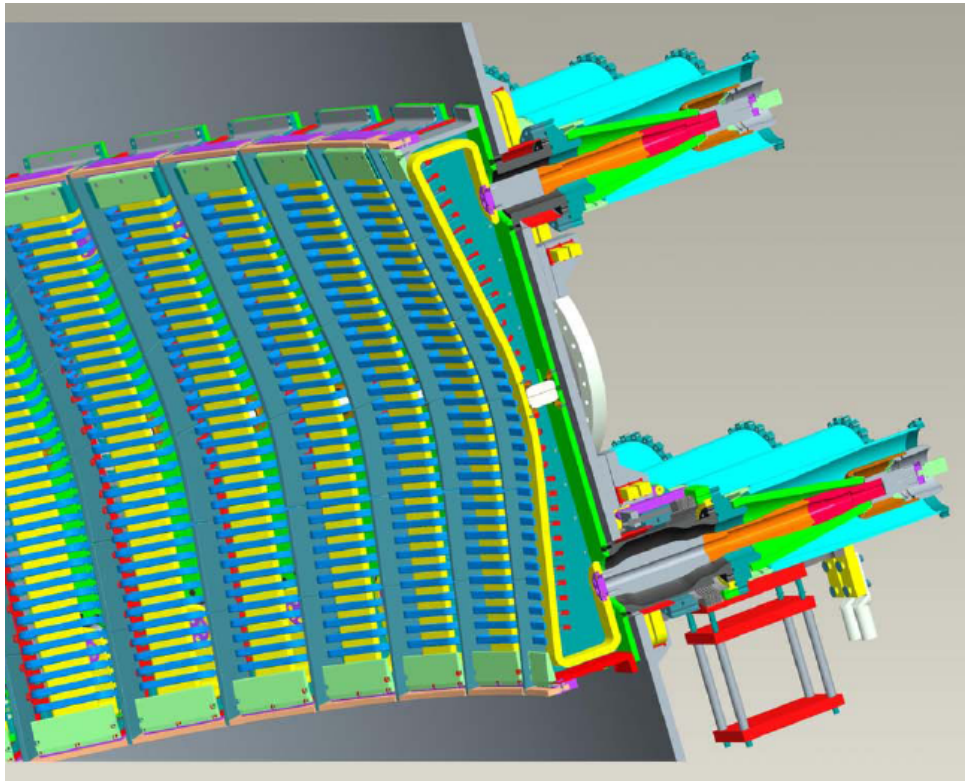
n=1

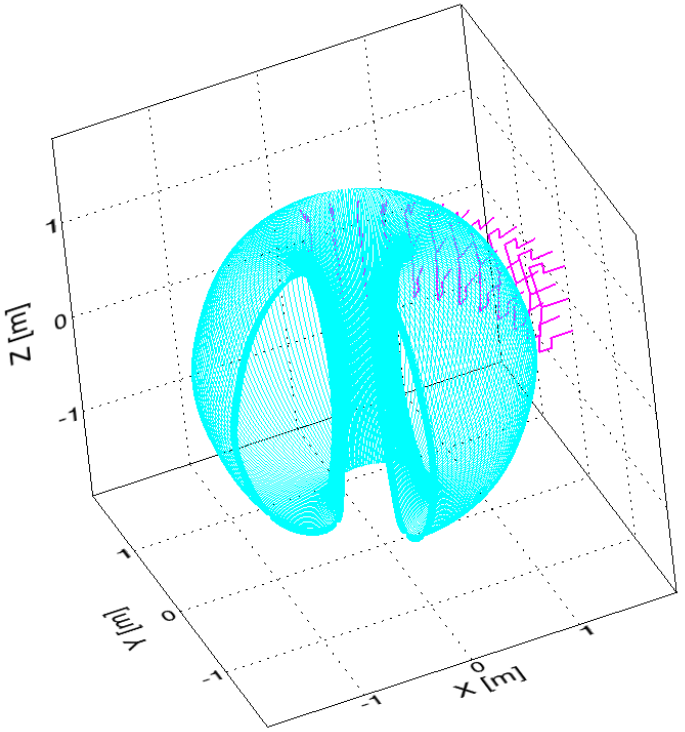
Potential Contribution:
- Understand if the two flavors of EHO are the same mode?
- Can we get a more general understanding of when large-amplitude EHOs may exist?
- Understand the relationship to type-V ELMs.

Theory question: ???

HHFW Antenna Might Be Capable of Driving EHOs

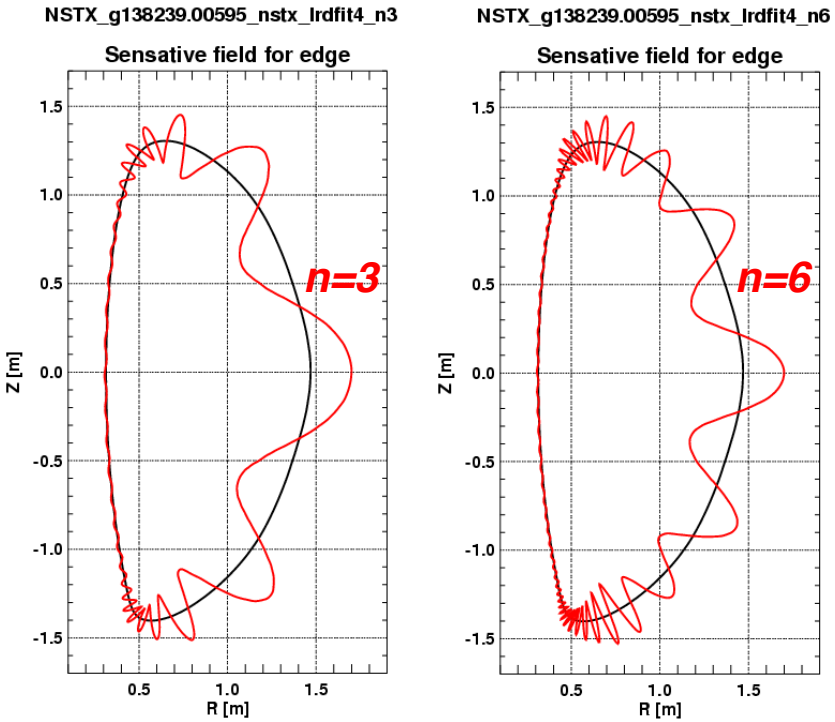
- First suggested by R. Goldston
- Scoping studies by J.-K. Park using IPEC





HHFW Antenna May be Able to Drive EHOs

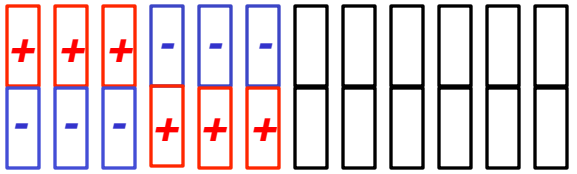
- *For a given toroidal mode number n, there is a field distribution that the plasma is most sensitive to.*
- *Compute the "overlap" of the applied field with the most sensitive field as a measure of efficiency.*

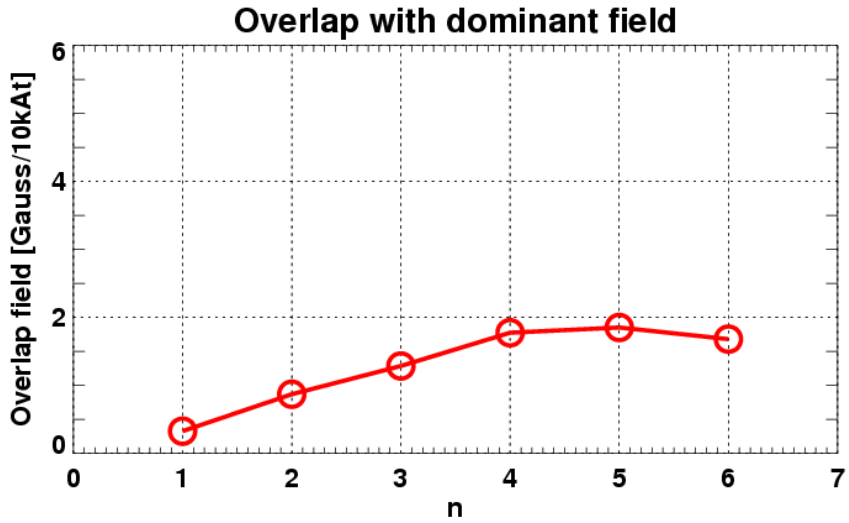


Computed By J.-K. Park w/ IPEC

Potential means of powering the antenna with best coupling to the higher toroidal mode numbers

HHFW Antenna

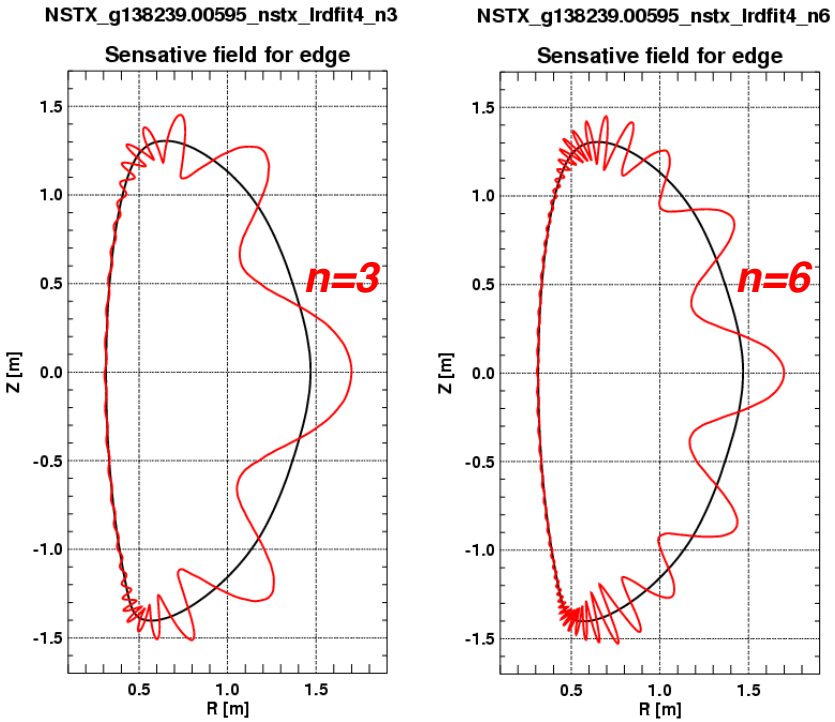




Could be important for NSTX-Upgrade, and future devices that cannot naturally access EHOs

HHFW Antenna May be Able to Drive EHOs

- ***For a given toroidal mode number n, there is a field distribution that the plasma is most sensitive to.***
- ***Compute the "overlap" of the applied field with the most sensitive field as a measure of efficiency.***



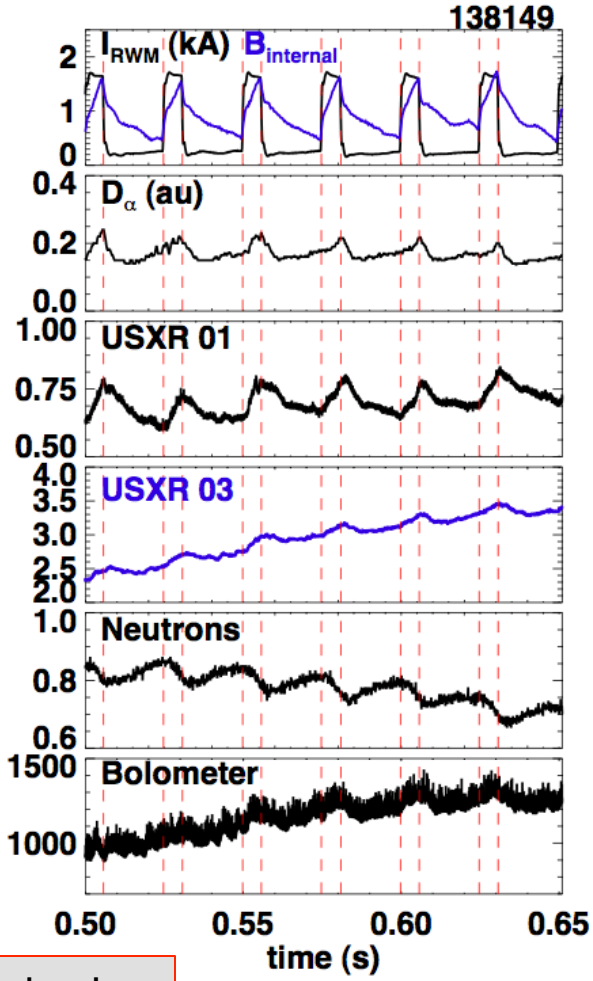
Computed By J.-K. Park w/ IPEC

Potential Contribution:
Collaboration with other devices that might have antennas capable of this drive, including IPEC computational support.

Theory questions:
- Is this overlap criterion for antenna design appropriate?
- If so, for what frequencies?
- Can this be modeled w/ MHD codes?

Particle Transport Changes w/ n=3 Applied Fields

- Large 3D fields can trigger ELMs, but smaller 3-D fields can lead to increased transport.
  - Increased transport evidenced by the change in soft X-ray emission from the pedestal region.
  - Plasma response is determined by the time-scale of field penetration.
  - Unfortunately, no reduction in global impurity accumulation or radiated power.
- Short, high-amplitude pulses make interpretation challenging
  - Field spectrum is changing.
  - Overlap with MPTS times is infrequent.
- Potential future work:
  - Examine additional cases with lower amplitude, longer-duration 3-D field pulses (below ELM triggering threshold). Look for transport response to 3D fields.



J. Lore, et al., 2011 APS

Potential Contribution: Improved understanding of the underlying physics of RMP transport modifications.
Theory Questions: All the standard questions about RMP penetration.

Search for I-Mode in the Database

- NSTX has not yet identified any I-mode cases in the database.
  - But maybe we haven't tried enough?
- Simplistically, I-mode comes about when you raise the L->H threshold and then use strong heating power.
  - Hence the favoring of the unfavorable grad-B drift direction.
- There are some data sets with increased probability of success:
  - In the 2009 reversed-B_T campaign.
  - Other experiments where the L->H power is higher (high X-point,…)
- But no guarantees:
  - High-power L-modes in NSTX are very unstable due to too-large pressure peaking…will work against I-mode formation.
  - C-Mod I-modes are triggered by sawteeth.
    - NSTX essentially never runs with sawteeth.

Potential Contribution:
Additional examples of the I-mode operating space.
Theory questions:???

Other NSTX Contributions

- "Enhanced Pedestal H-Mode" is a high-confinement regime observed when there is a localized edge drag (Maingi, PRL 2010).
  - Results in improved thermal transport & very high confinement.
  - Typically triggered by an ELM (and that ELM can be triggered by 3D fields).
  - Could consider comparison to VH mode if those experiments got run-time on DIII-D.
- Lithium conditioning
  - DIII-D may test a Lithium dropper/slapper at end of FY-12 run, or maybe during FY-13.
  - If discharges meet conditions of JRT, then can compare to NSTX discharges.
    - NSTX ELM-free H-mode typically accumulate impurities, and don't meet the definition of "stationary".
- NTV Calculations
  - IPEC + NTV theory has become a reliable means of calculating NTV.
    - Needs 3D field coils, plasma equilibrium, profiles.
  - (Can be)/(Already is) used for NTV calculations related to QH-mode in DIII-D, C-Mod, ITER.