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Low I_p HHFW Heating & Current Drive Experiments

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Three low I_p HHFW XPs in support of research milestone R(12-2)

WPI & SFSU TSG Meetings
NSTX Research Forum
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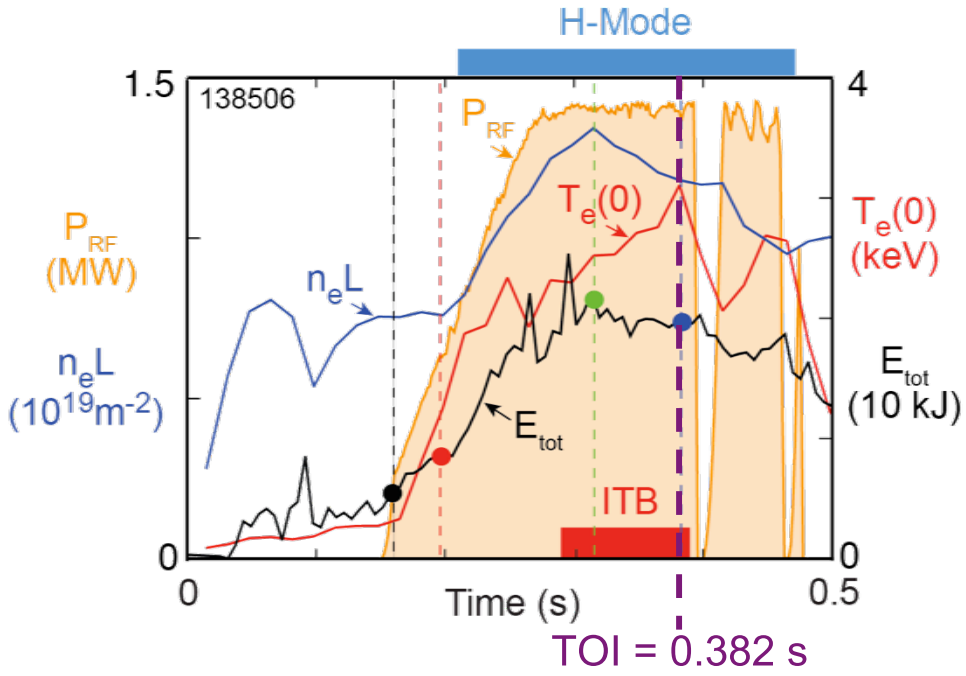
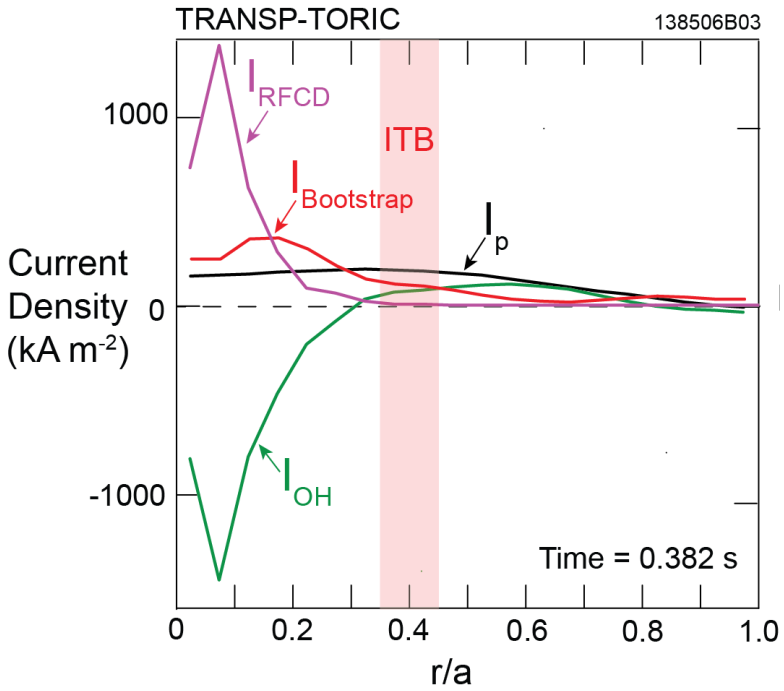
Low I_p Fully Non-Inductive HHFW H-Mode: Description/Background

- I_p = 300 kA HHFW H-mode in 2010 achieved f_{NI} ~ 65% with P_{RF} = 1.4MW:
  - ITB formed during H-mode
  - Positive feedback between ITB, high $T_e(0)$ and RF CD
  - Result obtained after 3-4 hours of running XP1009





- Propose to continuing XP1009 with P_{RF} ~ 3-4 MW to achieve f_{NI} ~ 100%
  - Some work may needed to further improve plasma position control
  - Repeat at I_p = 250 kA

Low I_p Fully Non-Inductive HHFW H-Mode: Experimental Approach/Plan

Plan:

- 1. Setup I_p = 300 kA deuterium discharge similar to shot 138506 and couple k_ϕ = -8 m^{-1} RF power from 150 to 450 ms:
  - Increase P_{RF} to 3-4 MW, while adjusting lithium evaporation rate, gas injection rate and outer gap to optimize RF coupling [10 shots]
- 2. Reduce I_p to 250 kA and couple 3-4 MW of k_ϕ = -8 m^{-1} RF power:
  - Adjust lithium evaporation rate, gas injection rate and outer gap to optimize RF coupling [10 shots]
- 3. Adjust RF pulse to start as soon as I_p reaches the flattop value. Then use open loop OH programming to provide no ohmic drive after $I_p$reaches the ~ 200 kA (at a~ 25 ms) [5-10 shots]

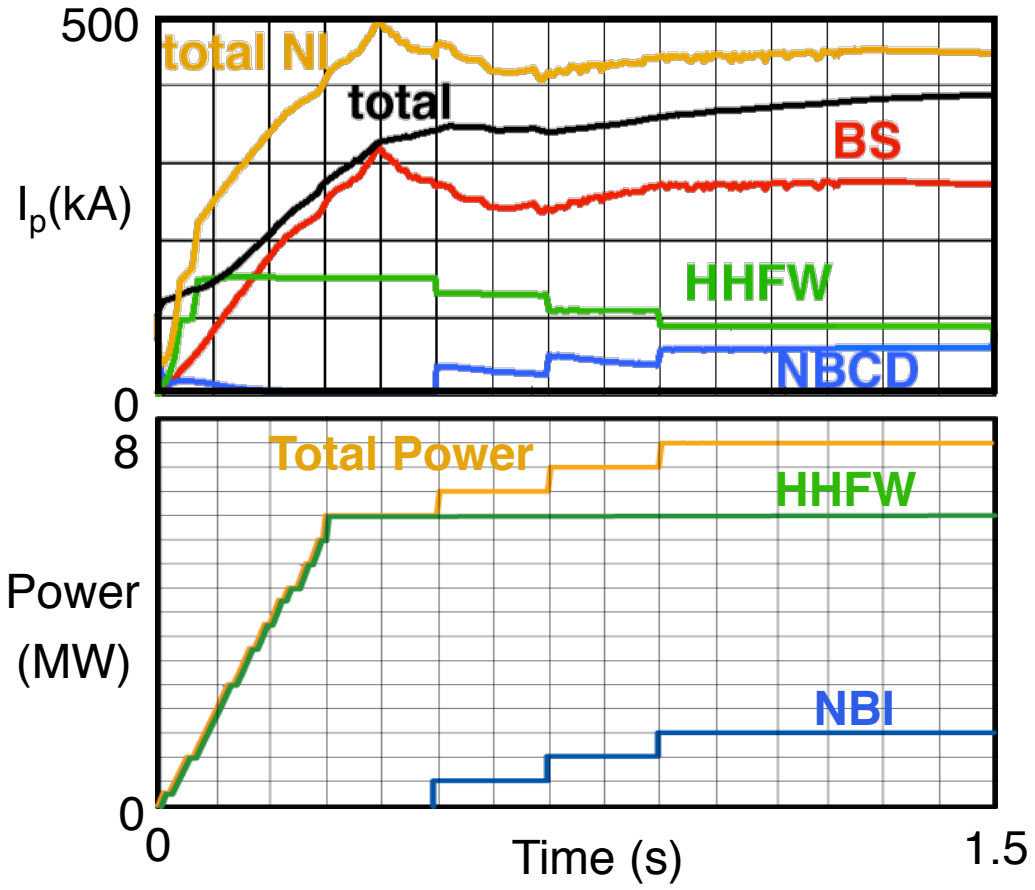
Machine Time: 1.5 days requested, 1 day minimum needed

Operational Requirements: P_{RF} = 3-4 MW with k_ϕ = -8 m^{-1} current drive phasing & establish good plasma position control at I_p = 250-300 kA

Key Diagnostics: MPTS, MSE-LIF

Analysis/Modeling: TORIC-TRANSP, GENRAY-ADJ

HHFW Ramp-up from I_p = 250 kA to I_p = 400 kA: Description/Background



- TSC simulation predicts 5-6 MW of k_ϕ = -8 m^{-1} HHFW can ramp I_p to ≥ 400 kA
- Propose applying P_{RF} ≥ 5 MW to an I_p = 250 kA flat top inductive plasma and ramping I_p to 400 kA with bootstrap and RF CD
- Begin with I_p = 250 kA HHFW H-mode developed in XP1009
- If I_p reaches ≥ 400 kA add NBI source A

HHFW Ramp-up from I_p = 250 kA to I_p = 400 kA: Experimental Approach/Plan

Plan:

- 1. Setup an ohmically-heated I_p = 250 kA deuterium discharge. Add k_ϕ = -8 m^{-1} HHFW power, coupled from 150 to 450 ms:
  - Increase P_{RF} to 5 MW, adjusting lithium evaporation rate, gas injection rate and outer gap to optimize RF coupling [15 shots]

- 2. If I_p reaches at least 400 kA add 2MW of neutral beam power from source A and attempt to ramp I_p above 400 kA [10 shots]

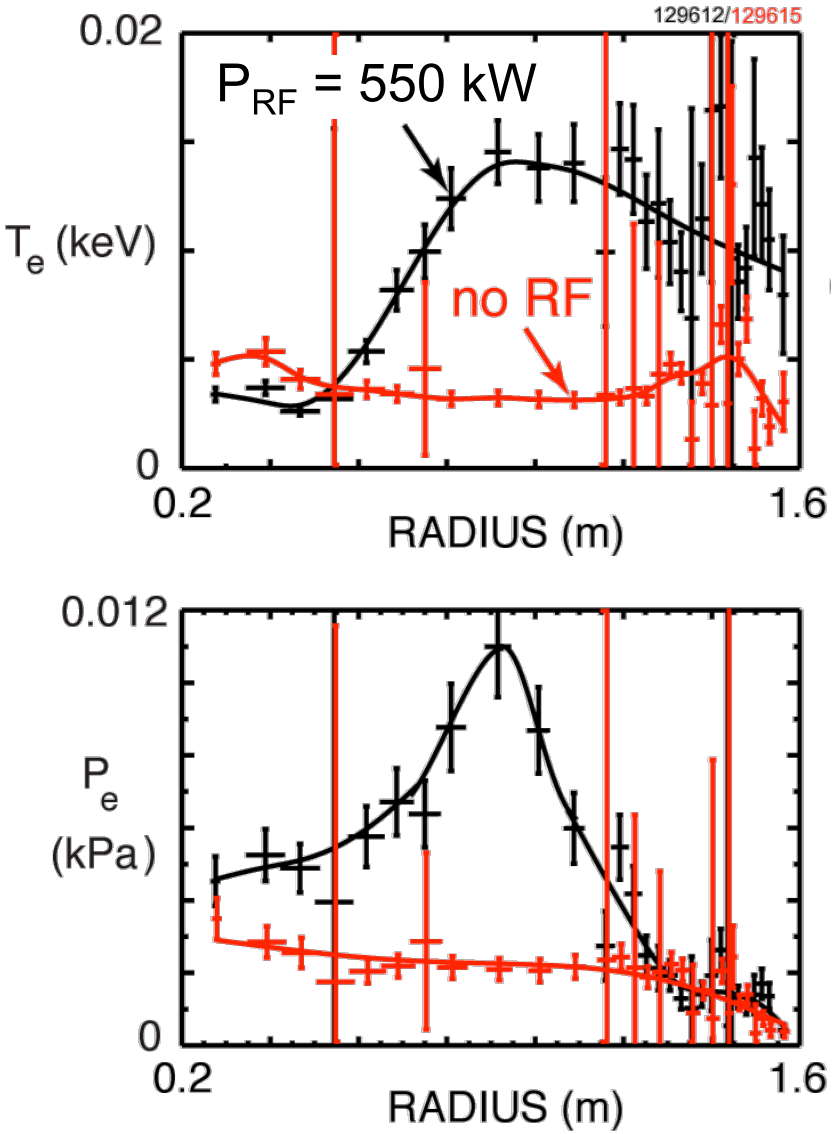
Machine Time: 1 day requested, 1 day minimum needed

Operational Requirements: P_{RF} = 5 MW with k_ϕ = -8 m^{-1} current drive phasing & establish good plasma position control at I_p = 250 kA

Key Diagnostics: MPTS, MSE-LIF, MSE-CIF

Analysis/Modeling: TORIC-TRANSP, GENRAY-ADJ

HHFW Heating of CHI-Initiated Plasma:
Description/Background



- Initial attempts to heat CHI startup plasmas with HHFW in 2008 showed good electron heating but could not maintain coupling:
  - P_{RF} = 550 kW coupled from 10 to 20 ms into I_p ~ 100 kA CHI plasma increased $T_e(0)$ from 3 to 14 eV
- Propose revisiting HHFW-heated CHI plasmas, but probably not until the FY12 run:
  - Start HHFW pulse at ~ 100ms when I_p ~ 200 kA and move HHFW pulse progressively earlier

HHFW Heating of CHI-Initiated Plasma: Experimental Approach/Plan

Plan:

- 1 Develop a CHI plasma target with a well-controlled antenna-plasma gap [5-10 shots]
- 2. Couple k_ϕ = -8 m^{-1} HHFW power starting at ~ 100 ms and increase P_{RF} to 2-3 MW to drive plasma into H-mode and generate off-axis bootstrap current
  - Large change in stored energy and current profile will probably require significant adjustments to the plasma position control [10-15 shots]
- 3. Move the start of the HHFW pulse progressively earlier [10 shots]
- Experiment should be run in FY12 given that the recent NSTX PAC recommended not giving coupling HHFW into CHI high priority in FY11

Machine Time: 1.5 days requested, 1 day minimum needed

Operational Requirements: P_{RF} = 2-3 MW with k_ϕ = -8 m^{-1} current drive phasing & establish good CHI plasma reproducibility to I_p ~ 200 kA

Key Diagnostics: MPTS, MSE-LIF

Analysis/Modeling: GENRAY-ADJ, TRANSP-TORIC