Low I_p HHFW Heating & Current Drive Experiments

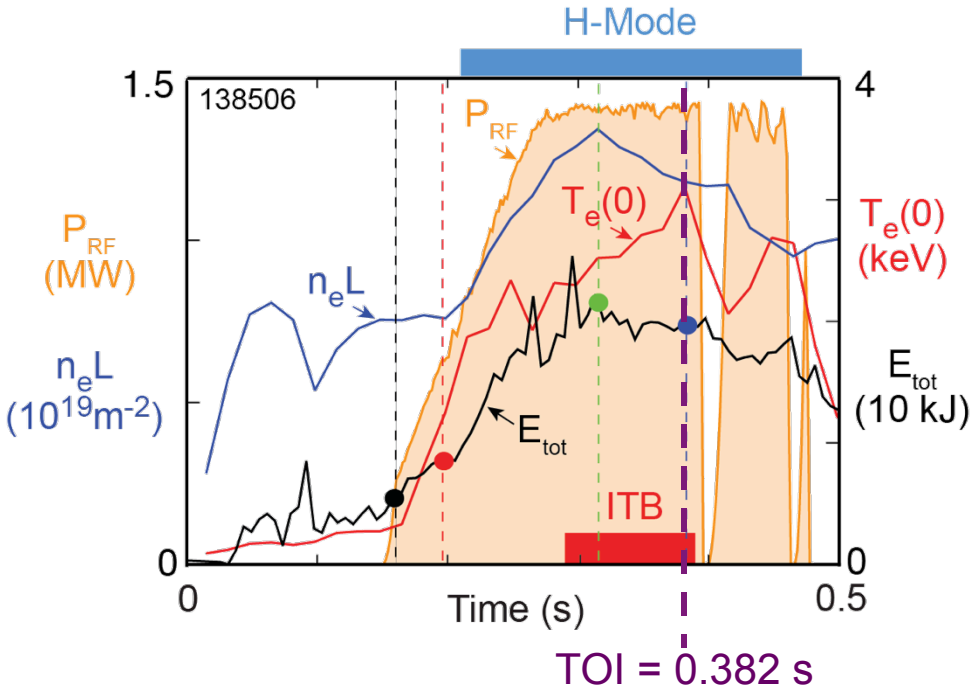
G. Taylor

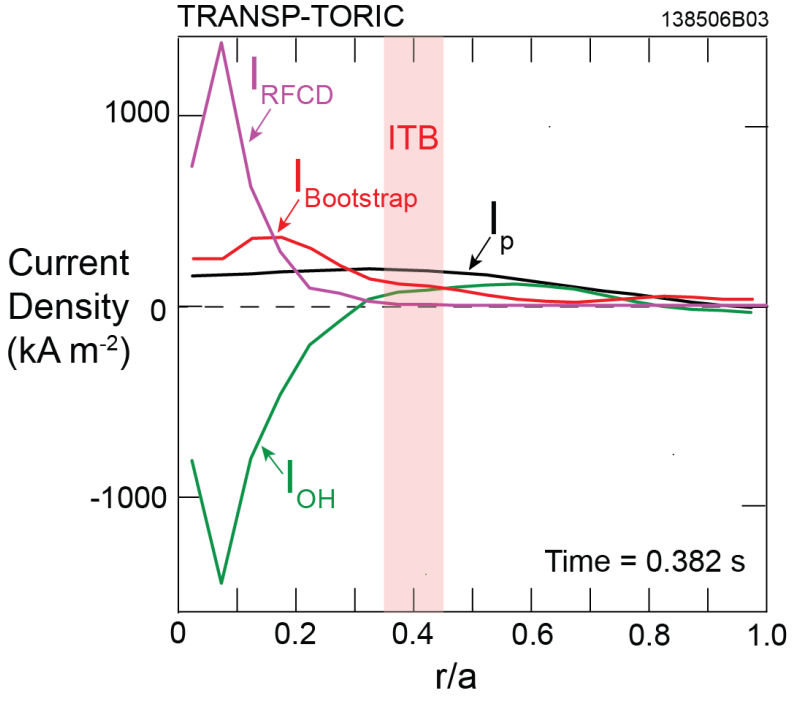
- **Three proposed experiments:**
  - ***Low Plasma Current, Fully Non-Inductive, HHFW H-Mode Plasmas***
  - ***HHFW Ramp-up of Inductively Initiated Plasma from 250 to 400 kA***
  - ***HHFW Heating of CHI-Only Discharges***
- **Experiments should be discussed by SFSU and WH&CD TSGs, but only formally submitted to SFSU TSG for consideration**

NSTX-U Research Forum
February 2015

Low Plasma Current, Fully Non-Inductive, HHFW H-Mode Plasmas: Description/Background

- I_p = 300 kA RF f_{NI} ~ 65% H-mode with P_{RF} = 1.4 MW in 2010 (XP1009)





- Propose continuing NSTX XP1009 with P_{RF} ~ 3-4 MW, $B_T(0)$ ~ 0.65 T to achieve f_{NI} ~ 100%
  - Some work may needed to further improve plasma position control
  - Repeat at I_p = 250 kA

Low Plasma Current, Fully Non-Inductive, HHFW H-Mode Plasmas; Experimental Approach/Plan

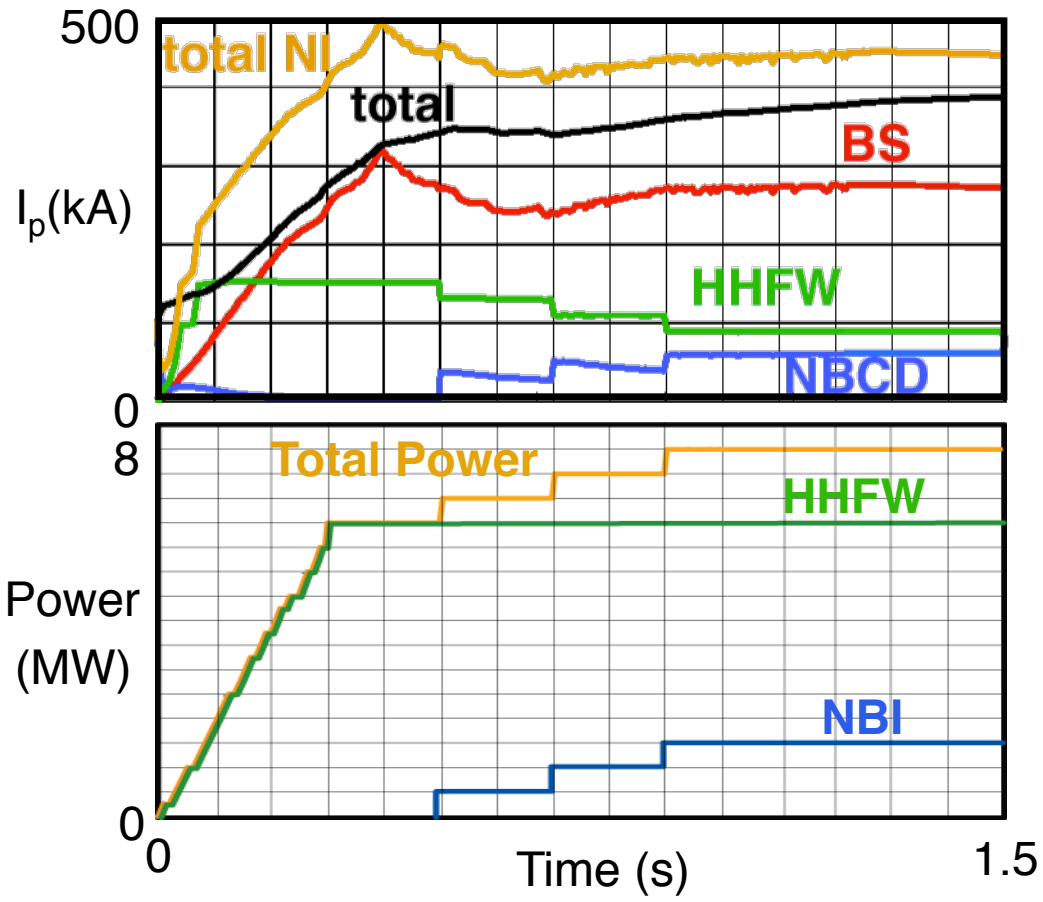
Plan:

1. Setup I_p = 300 kA discharge similar to NSTX shot 138506 from XP1009 and couple k_ϕ = -8 m^{-1} RF power:
   - Start RF heating early and maintain for > I_p relaxation time (~ 200 ms)
   - Increase P_{RF} to 3-4 MW, adjust Li evaporation rate etc.
   - Document q(R) and T_i evolution with MSE and CHERS using 1A NBI blips
2. If I_p = 300 kA discharge is difficult to control at higher RF powers, increase I_p to ~ 350 kA
3. Adjust RF pulse to start as I_p reaches flattop and use open loop OH programming to provide no OH after I_p reaches ~ 200 kA

Machine Time: 2 days requested, 1 day minimum needed, 0 days before Li

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

HHFW Ramp-up of Inductively Initiated Plasma from 250 to 400 kA: Description/Background



- TSC, and recent TRANSP-TORIC, simulationd predict 4-6 MW of k_ϕ = -8 m^{-1} RF power may ramp I_p to ≥ 400 kA
- Heat an inductively generated I_p ~ 250 kA plasma with RF power and ramp I_p to ~ 400 kA
- Experiment requires clamping OH coil current instead of feeding back on I_p
- Shots without RF power will have decaying I_p and when RF power is applied I_p will ramp-up, be sustained or will decay more slowly

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

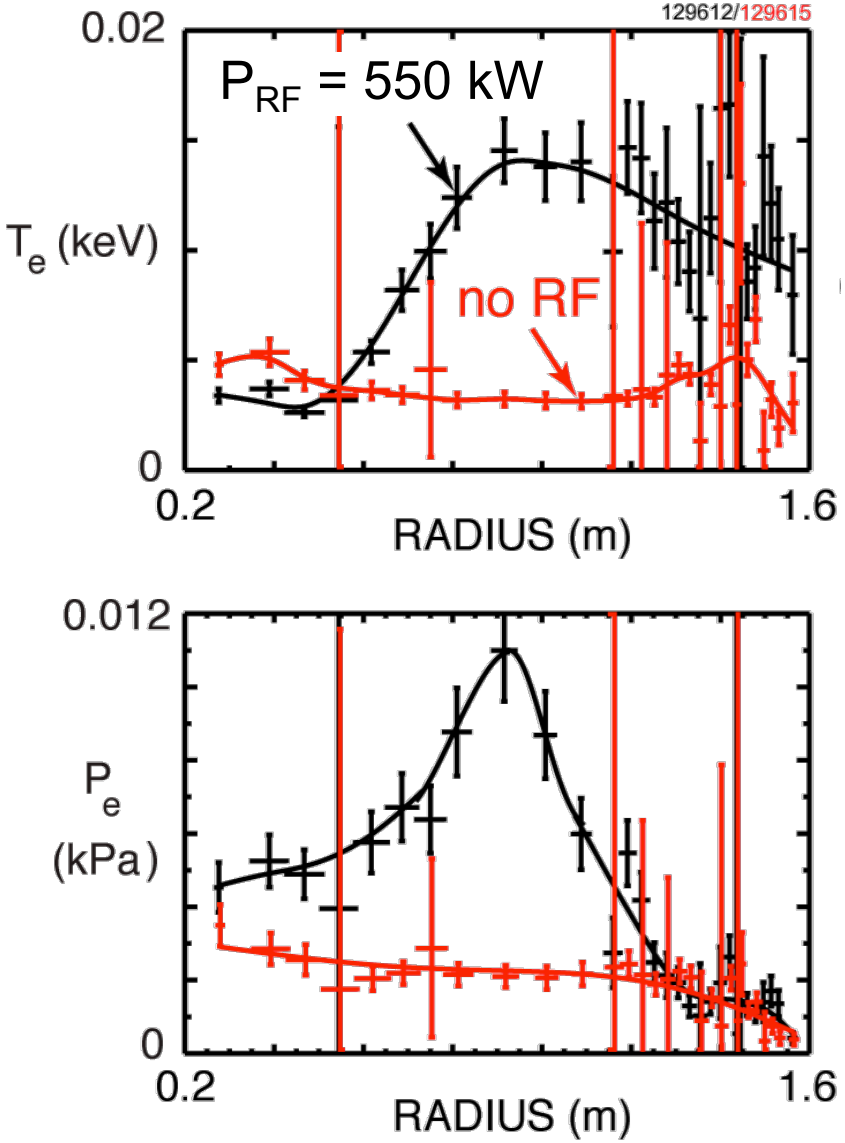
Plan:

1. Setup OH-heated I_p = 300 kA discharge and couple k_φ = -8 m^{-1} RF power from 150 to 450 ms, with a 50 ms RF power ramp-up:
   - Add 50 ms NBI blip for MSE and CHERS at 430 - 480 ms
   - Increase RF power to 3-4 MW, while adjusting the Li evaporation, gas injection and outer gap
   - When reproducible add a second 20 ms NBI blip, scanned from 400 ms to 250 ms over a sequence of 4 shots to q(R) and T_i(R)
2. Reduce I_p to 250 kA and apply 3-4 MW RF power and optimize RF heating efficiency and measure q(r) and Ti as in step (1)
3. Adjust RF pulse to start at beginning of I_p flatop, then use open loop OH programming for no OH drive after I_p reaches the minimum value (< 200 kA at approximately 25 ms)

Machine Time: 1.5 days requested, 1 day minimum needed, 0 days before Li

Operational Requirements: P_{RF} = 4 - 5 MW with k_ϕ = -8 m^{-1} current drive phasing and establish good plasma position control at I_p = 250 kA

HHFW Heating of CHI-Only Discharges:
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:
  - Start HHFW pulse at ~ 100ms when I_p ~ 200 kA and move HHFW pulse progressively earlier
  - Since the HHFW power will be coupled into a very low density plasma HHFW antenna tuning will be set to close to vacuum loading

HHFW Heating of CHI-Only Discharges:
Experimental Approach/Plan

Plan:

1. Develop a CHI plasma target with a well-controlled antenna-plasma gap
2. Couple RF power starting at ~ 100 ms and increase P_{RF} to 2-3 MW:
   - Experiment will start with launches $k_\phi = -8\ m^{-1}$ ($\Delta f = 90^o$) HHFW heating using, using RF tuning settings from NSTX shot 129612
   - Then use $\Delta f = -60^o$ antenna phasing which launches a combination of $k_\phi = -8\ m^{-1}$ and $k_\phi = -3\ m^{-1}$
   - Launching low k_ϕ will start the perpendicular propagation of the fast wave at a low density, reducing the width of the evanescent region between the antenna and the CHI plasma
   - $k_\phi = -8\ m^{-1}$ power will heat the plasma increasing absorption of the $k_\phi = -3\ m^{-1}$ power closer to the antenna
   - $\Delta f = 180^o$ phasing may be tried if the edge > 5x1017m^{-3}
3. Move the start of the HHFW pulse progressively earlier

Machine Time: 1 day requested, 0.5 day minimum needed, 0 days before Li

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