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XP1009 & XP1010: Low I_p HHFW Heating Experiments

G. Taylor
D. Mueller, J.C Hosea, S. Gerhardt, C. Kessel, B.P. LeBlanc, C.K. Phillips, S. Zweben
PPPL
R. Maingi, P.M. Ryan
ORNL
R. Raman
U. Washington

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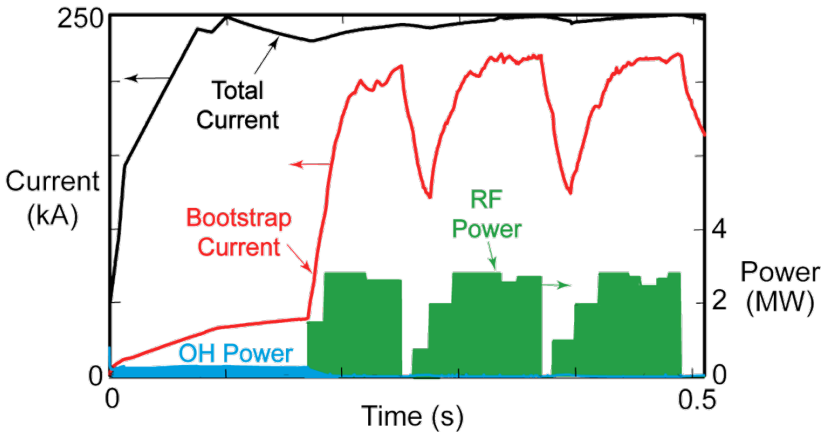
HHFW Heating of Low I_p Plasmas Since 2005 Show Promise, But Also Problems with Plasma Control

2005: (XP-521)

- 60-85% bootstrap current in HHFW heated (k_ϕ = -14 m^{-1}) H-mode D_2 plasmas at I_p = 250 kA
- Transiently produced $V_{loop} \leq 0$ and $dI_{OH}/dt \approx 0$



2007: (XP-731)

- Problem with rtEFIT control at I_p = 250 kA, used 300 kA
- Many trips with k_ϕ = 14 m^{-1}
- Up to 2.7 MW of k_ϕ = -8 m^{-1} heating, produced transient H-mode

2008: (XP-817)

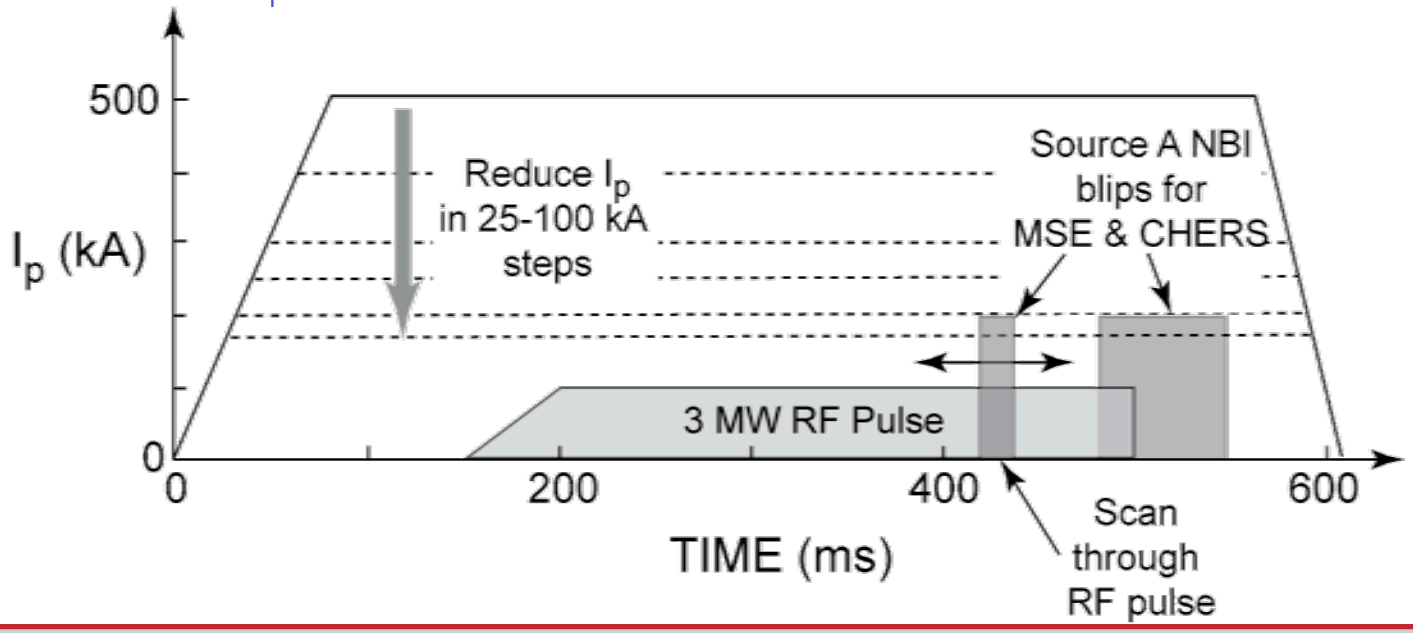
- Li conditioning reduced edge density, improving HHFW core heating, even in CHI start-up plasmas with $n_e(0) \sim 4x10^{18} m^{-3}$

Low I_p HHFW experiments in WPI TSG contribute to R10-2 milestone in 2010:

- **XP-1009:** HHFW Heating of Low $T_e(0)$, I_p Plasmas (formerly XP-920)
- **XP-1010:** Sustainment of HHFW-Driven 100% Non-Inductive H-Mode Plasmas

XP-1009: HHFW Heating of I_p ~ 200 kA Plasmas - I

- Experimental Approach/Plan:
  - Setup D_2 plasma with I_p = 500 kA, B_T = 5.5 kG [modify 135260], and add k_ϕ = 14 + 18 m^{-1} RF power and to ~ 3 MW, while adjusting Li evaporation rate, gas injection rate and outer gap to optimize HHFW heating efficiency (5-10 shots)
  - Reduce I_p in 100 kA steps to 300 kA while coupling k_ϕ = -8 m^{-1} RF (10 shots).
  - Repeat with k_ϕ = -8 m^{-1} RF (10 shots)



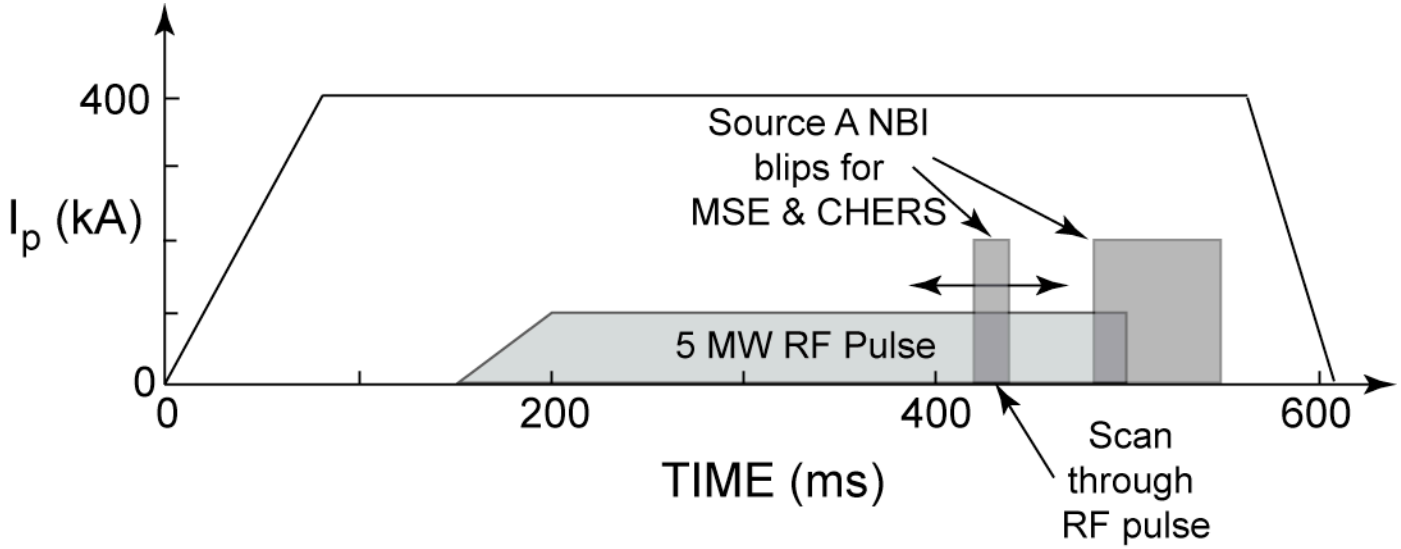
XP-1009: HHFW Heating of I_p ~ 200 kA Plasmas- II

- Experimental Approach/Plan (cont.):
  - Reduce I_p from 300 kA to ≤ 200 kA in 25-50 kA steps, while maintaining plasma position control so outer gap is 5-10 cm (5-10 shots)
  - At lowest I_p achieved with good plasma control, couple k_ϕ = 14 + 18 m^{-1} & k_ϕ = ± 8 m^{-1} power to ~ 3 MW (15 shots)
  - Perform n_e scan with k_ϕ = -8 m^{-1} heating (5-10 shots)
  - If sufficient CD is observed, adjust RF pulse to start as soon as I_p reaches flattop, then use open loop OH programming to provide no ohmic drive after I_p reaches minimum value (< 200 kA at approximately 25 ms) (10-15 shots)
- 1.5 run days (1 day SFSU & 0.5 days WPI)

XP-1010: Sustainment of HHFW-Driven 100% Non-Inductive H-Mode- I

- Brief Description:
  - Couple ~ 5 MW of HHFW power into an I_p ~ 300-400 kA deuterium plasma
  - Drive plasma into H-mode and use RF heating to generate ~ 100% bootstrap current
- Background:
  - 60-85% bootstrap fraction already achieved with ~ 2.5 MW of k_ϕ = 14 + 18 m^{-1} RF power in an I_p = 250 kA plasma (XP-521)
  - Based on past experiments and modeling 5 MW should be sufficient power to drive plasma into a fully non-inductive H-mode
  - New double end-fed antenna should be capable of coupling ~ 5 MW
  - LLD + LITER's should provide control of edge density for better RF coupling
  - Preceded by XP-1009, and should be run only when ~ 5 MW of RF power has been reliably coupled into deuterium plasma

XP-1010: Sustainment of HHFW-Driven 100% Non-Inductive H-Mode - II



- Experimental Approach/Plan:
  - Setup D_2 plasma with I_p ~ 300-400 kA, B_T = 5.5 kG (5 shots) [use shot from XP-1009]
  - Add 5 MW of k_ϕ = 14 + 18 m^{-1} heating, adjusting Li evaporation, gas injection rate and outer gap to optimize HHFW heating to obtain L-H transition and H-mode sustainment (10 shots)
  - Repeat with -8 m^{-1} heating (10 shots)
- 1 run day

XP-1009/10: Requirements & Analysis

- Diagnostics & Machine:
  - Thomson scattering, MSE, CHERS, SOL reflectometer
  - Need LITERs, but LLD can be maintained in “cold”, solid state
  - Source A NBI blips at 90 keV
- Analysis:
  - GENRAY/CQL3D & TRANSP/TORIC simulations
- Planned Publication:
  - *Nuclear Fusion* or *Physics of Plasmas*
  - Contribute to IAEA presentations