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Experiments with HHFW in NSTX

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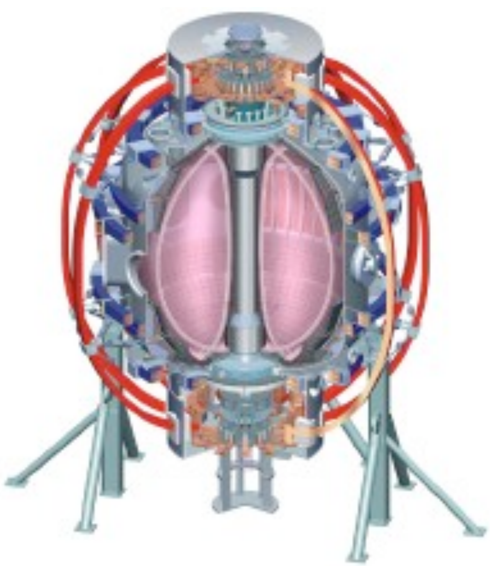

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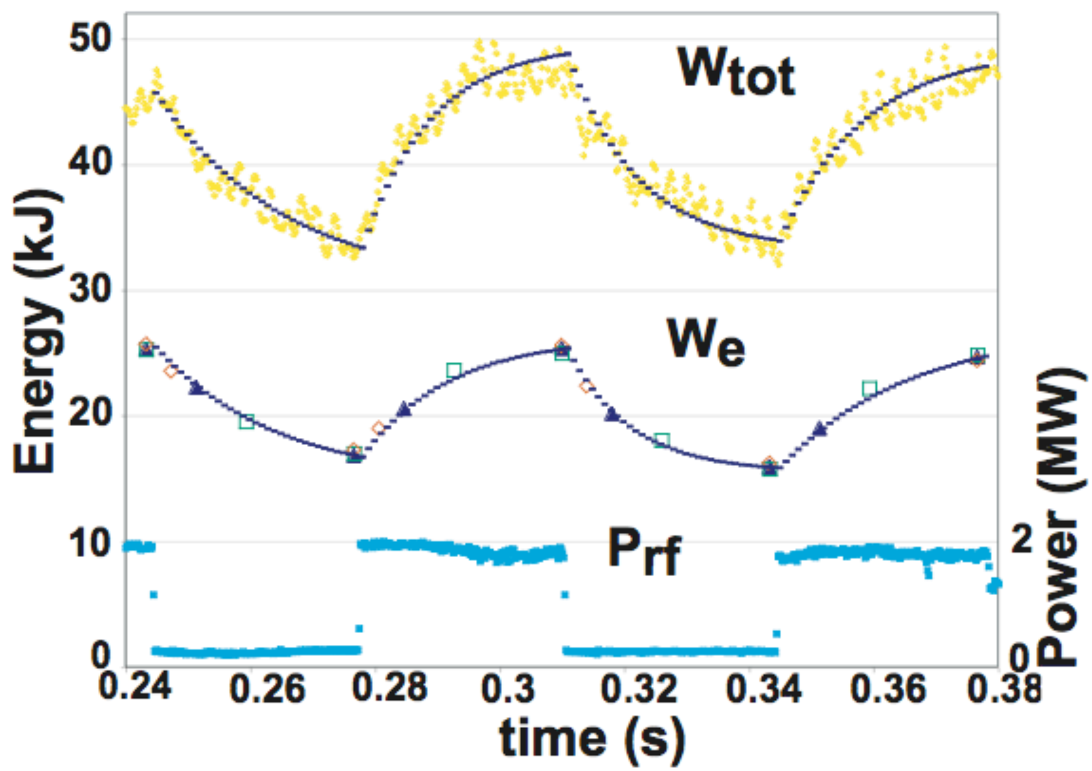
Experiments conducted in 2005 to explore applications of HHFW

- Continue study of heating efficiency versus phase
  - Concentrated on role of misalignment between antenna and B field
  - Performed phase and gap scans at 300 kA and 600 kA plasma current
  - No difference in behavior observed
- Applied HHFW power to Reverse Shear Target
  - Improved electron transport, hence, higher Te target
  - Some electron heating observed but NBI damping still strong
- Applied HHFW power at low current to achieve high Bootstrap fraction H-modes
  - Attempt to achieve overdrive for eventual ST start-up scenario
  - Overdrive may have been achieved transiently
  - Large voltage increase on antenna terminates rf as H-mode forms

RF Power Absorption and Incremental Confinement Obtained from Power Modulation

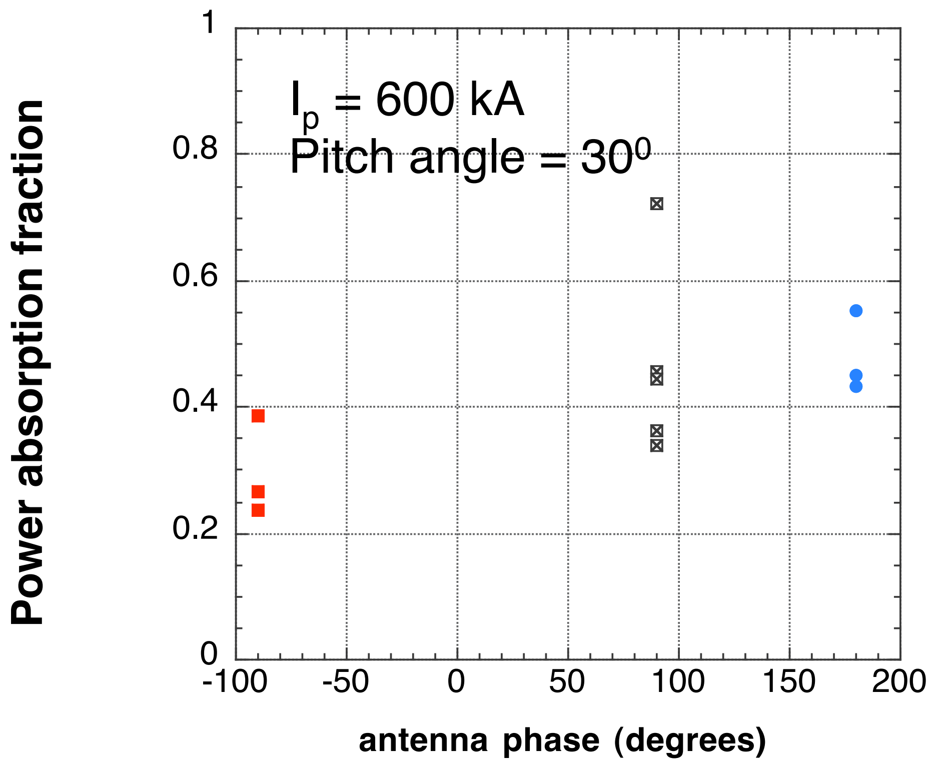
k_T (m^{-1})	%Power absorbed
14	80
+7	70
-7	55
+3	<20

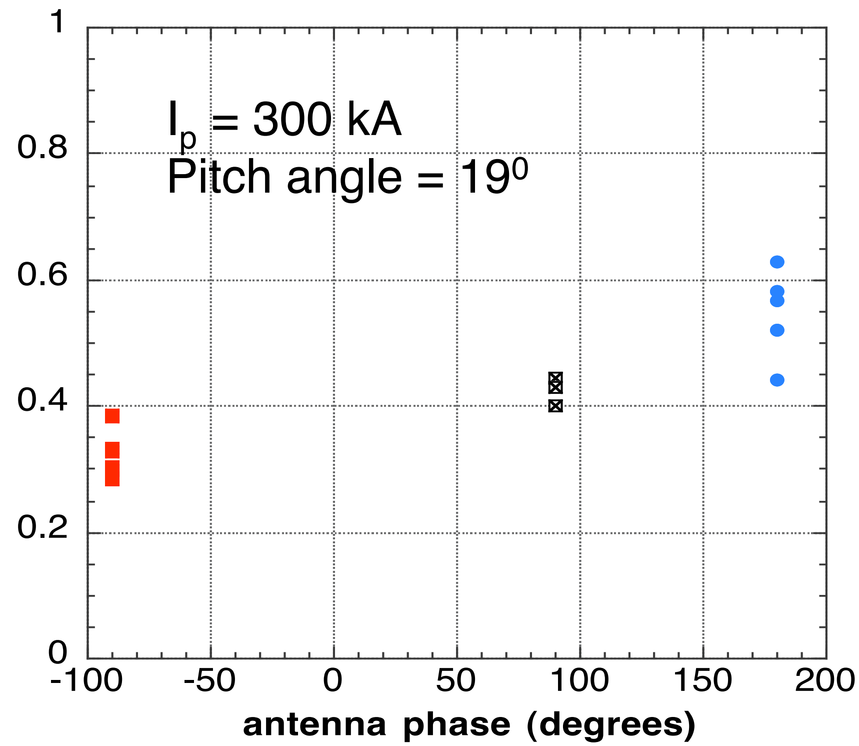


Parametric decay into surface waves appeared to explain some of these differences

In 2005 look at field pitch angle to explain differences especially between co and counter

Pitch angle is not an important factor for heating efficiency and differences between phases





Power modulation experiments performed at 600 kA and 300 kA

Parametric decay strongest for -7 m^{-1} and weakest for ±14 m^{-1}

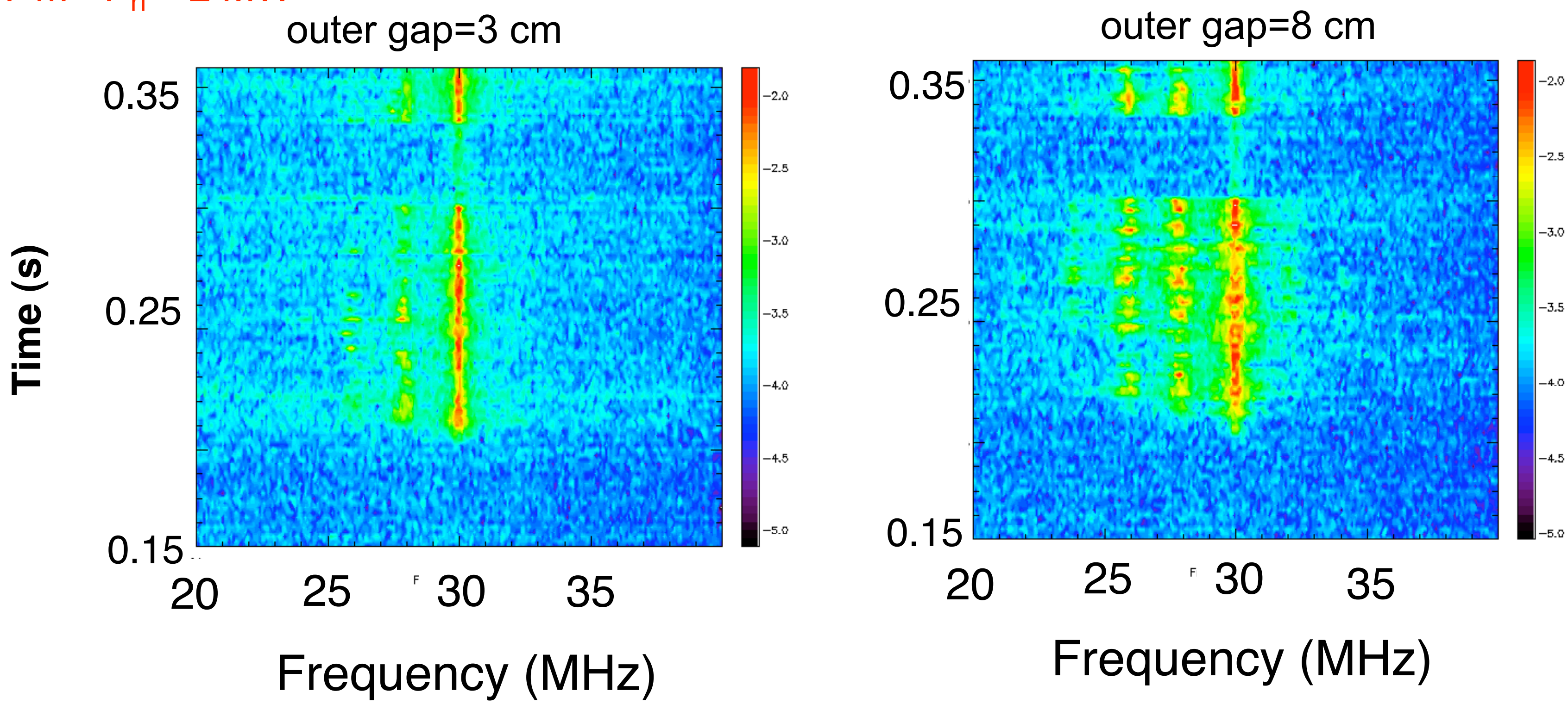
Possible Loss Processes in Edge Plasma

NSTX

- Ion heating through parametric decay
  - Observed in 2004, confirmed with improved time resolution in 2005
- Excitation of surface waves, near field and far field, can cause power deposition in sheaths and through collisions in the periphery of the plasma
  - Magnetic pitch angle (shear) effects (2005)
  - Surface waves (propagating along field)
  - Reactive waves (evanescent along field)
  - Have observed phase dependence of neutral pressure in antenna

Parametric decay now observed with time resolution using edge probe and microwave reflectometer

$k_T = -7\ m^{-1}$ $P_{rf} = 2$ MW



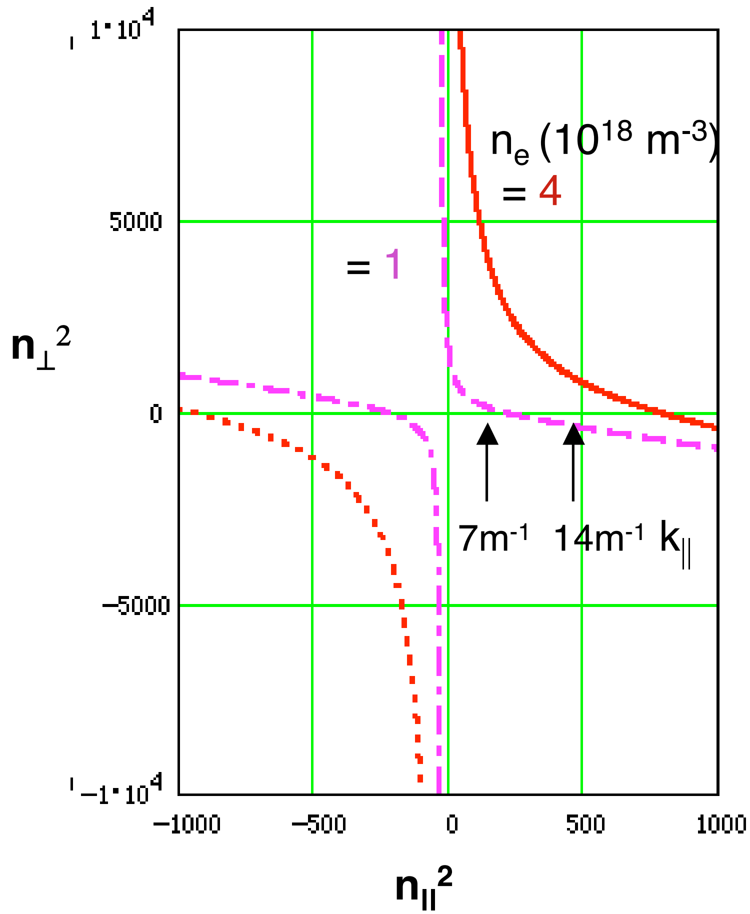
Density fluctuation spectra from edge reflectometer

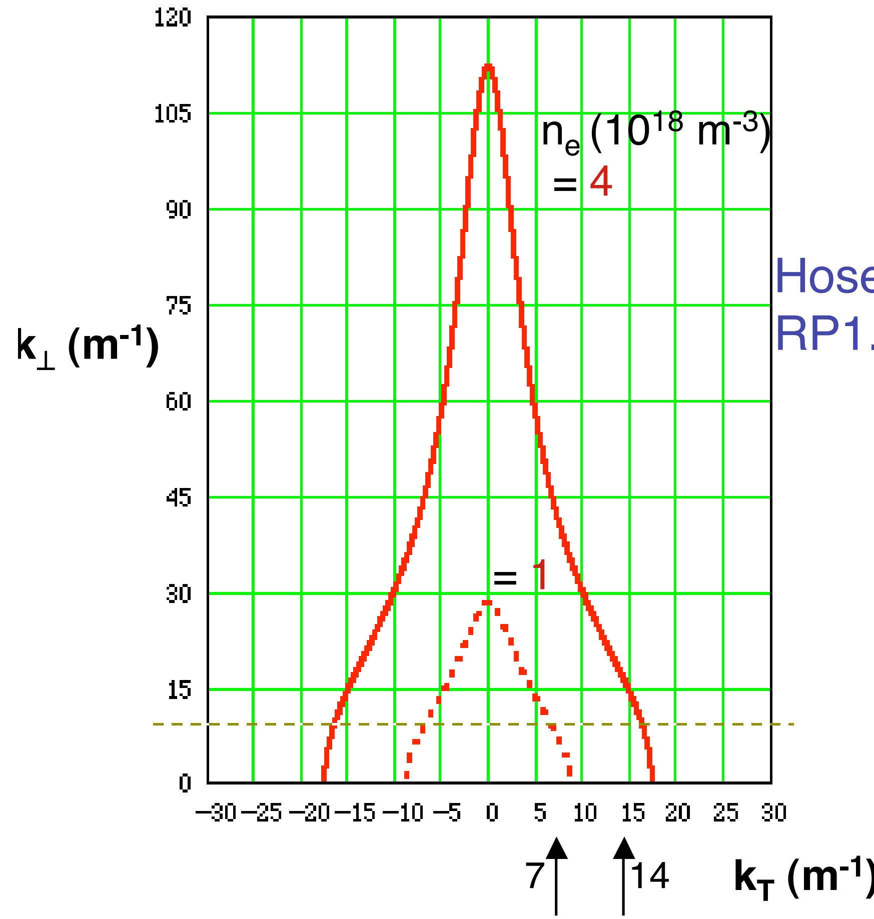
Wilgen RP1.00037

Larger gap, hence lower edge density yields stronger decay as expected by theory

Wave propagation in the surface plasma is enhanced at lower k_T

NSTX

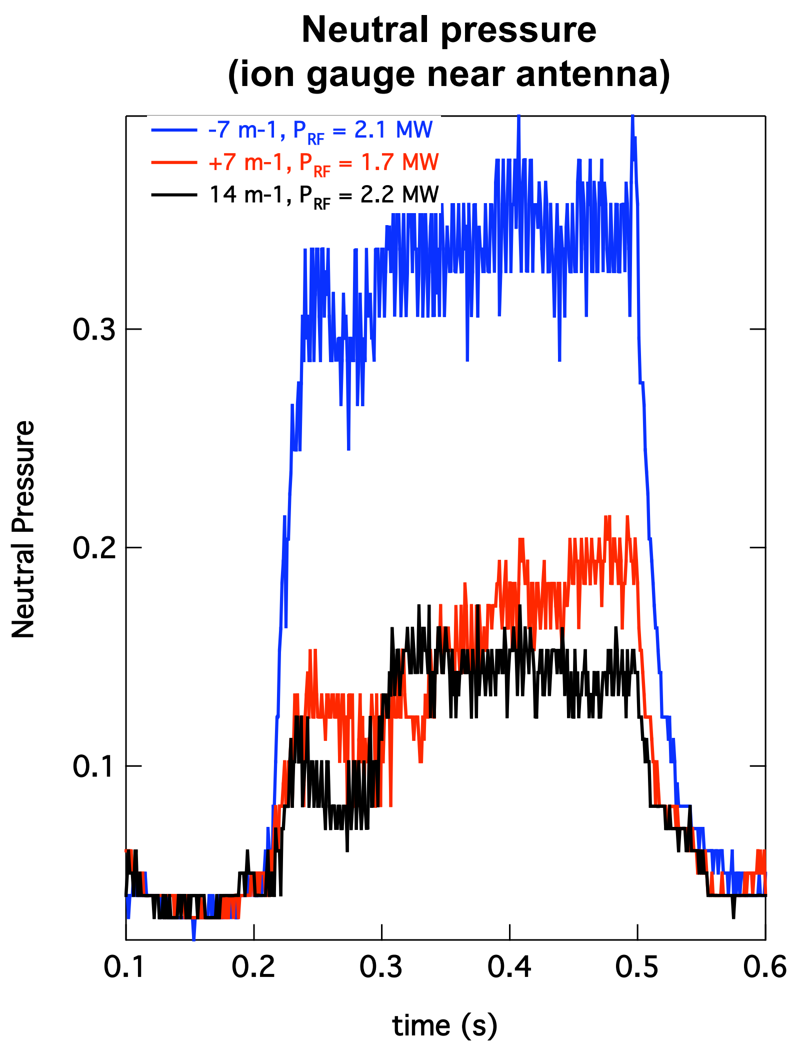


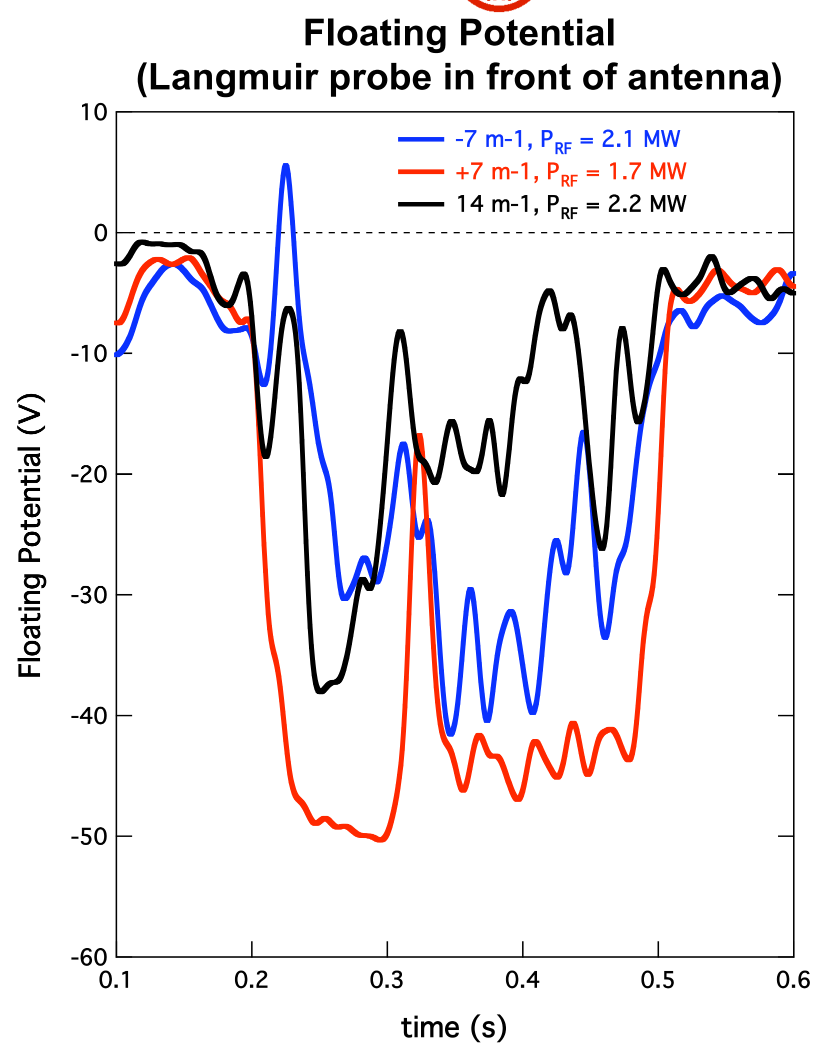


Hosea
RP1.00036

- Fast Waves propagate at lower density and reach much higher $k_\perp$ at a given density for lower k_T
- "Surface wave" fields are enhanced at lower k_T and should contribute to greater power loss through parametric decay, sheath damping and collisions

Neutral pressure rise and floating potential change larger for 7 m^{-1} than for 14 m^{-1}

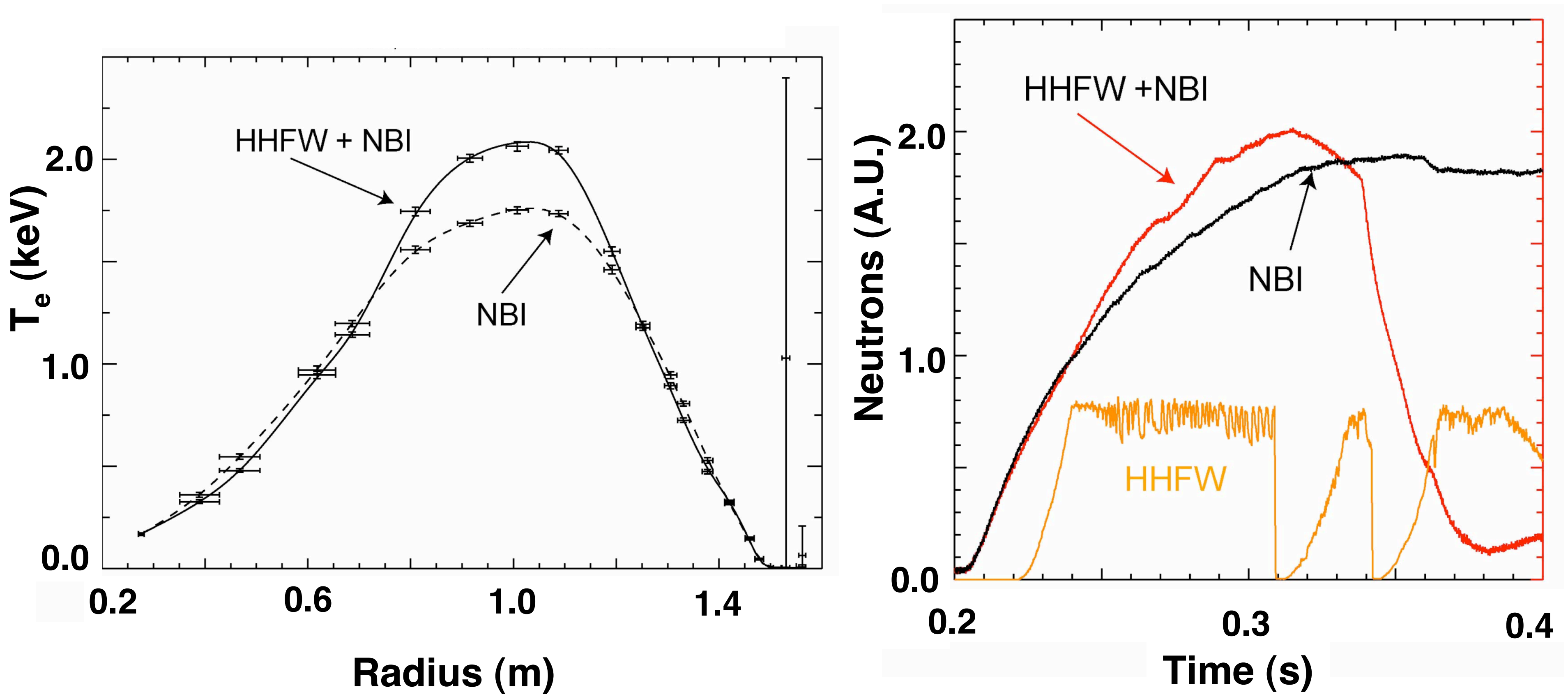




More surface wave at 7m^{-1}?

HHFW in RS L-mode Plasma yields small central T_e increase

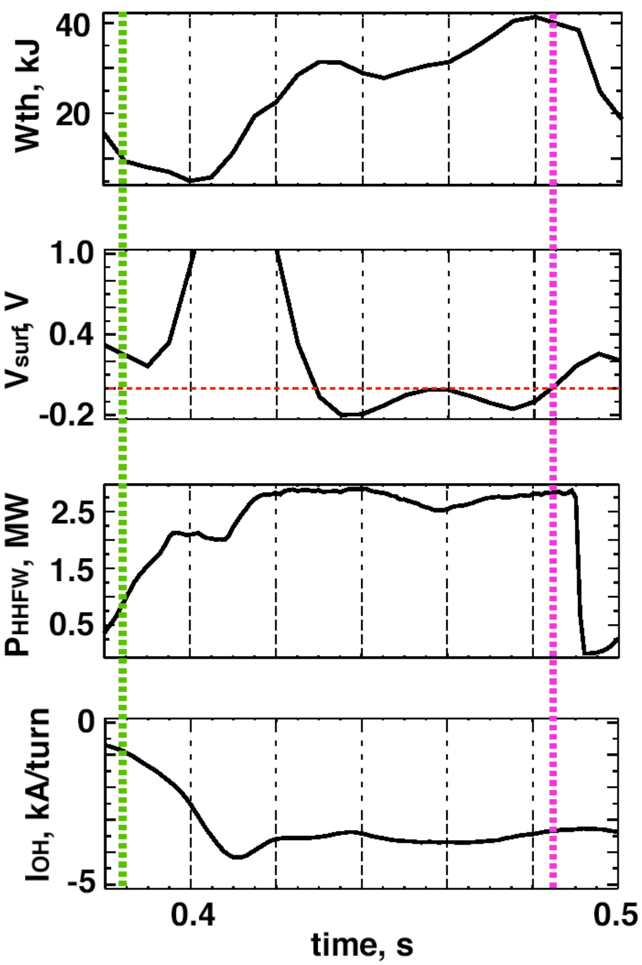
$k_{//} = 14\ m^{-1}\ P_{rf} = 0.75\ MW\ P_{NBI} = 2\ MW$



Neutron increase indicates strong beam ion damping

HHFW Heating Can Induce Strong H-modes at Low I_P and Low T_e resulting in a large Bootstrap current fraction

High T_{ped}, broad $T(\rho)$, and "not-too-high" $T_e(0)$ are best for NS rampup

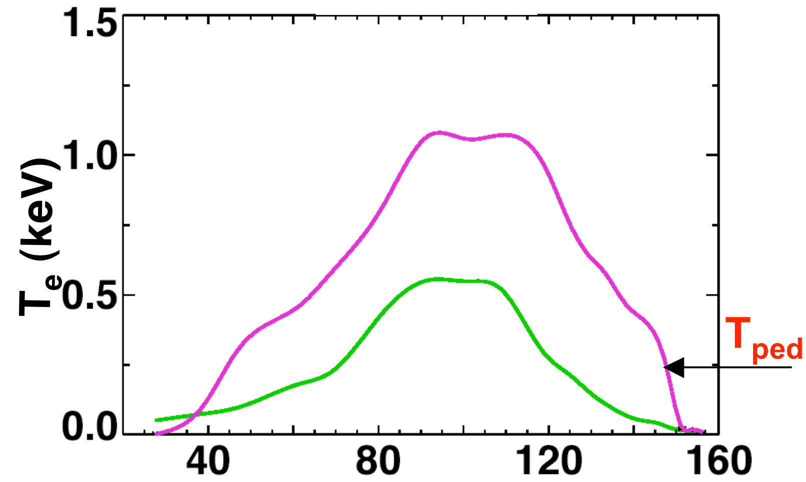


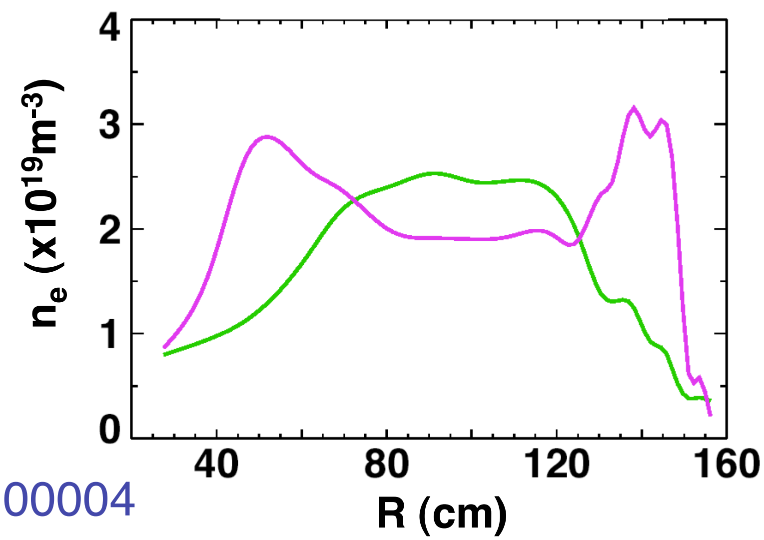
HHFW H-mode

V_{surf} drops below 0

I_{OH} becomes flat

t = 0.385
0.485



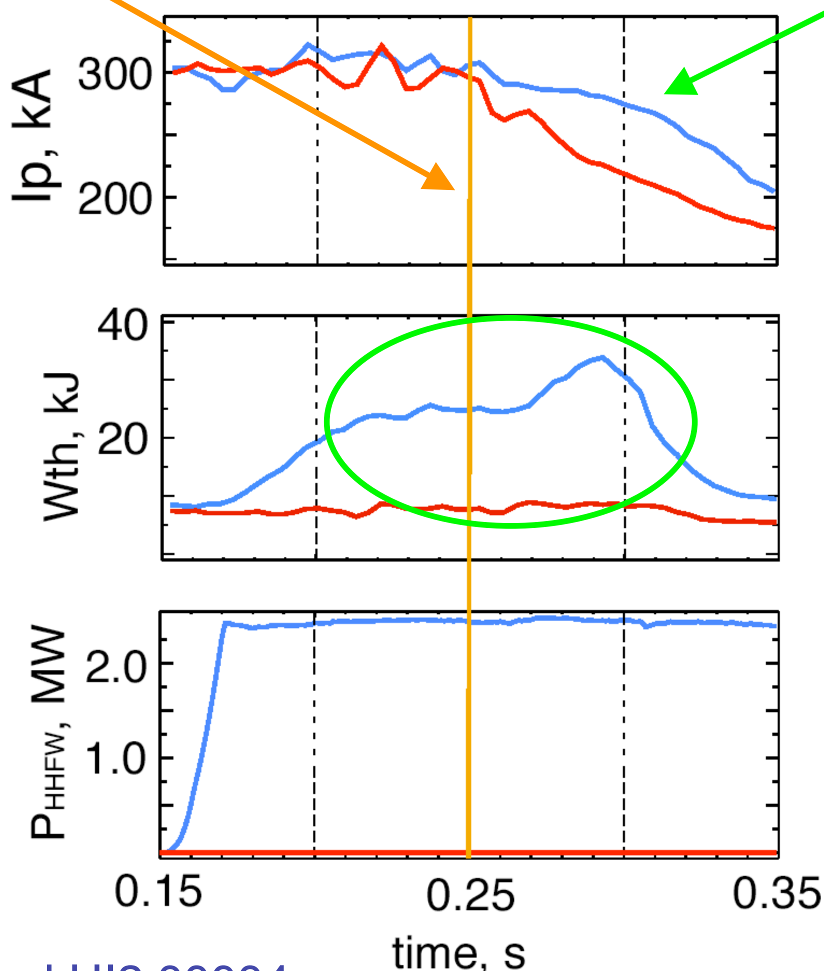


I_P = 250 kA, $k_{||}$ = 14 m^{-1} heating

Kessel UI2.00004

Ohmic Coil Clamp Experiments Show Early Signs of HHFW Current Sustainment

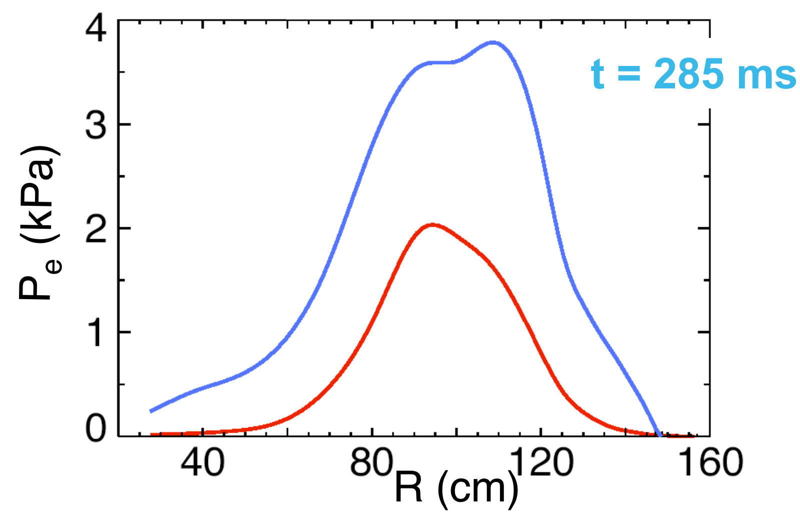
OH Coil Current Clamped



Ip drop after OH clamp is slowed while plasma is in H-mode

H-mode is not sustained, but appears necessary for Ip rampup

Strong pressure increase produces bootstrap current



No HHFW (ohmic)

With HHFW, 7 m^{-1} co-CD

Kessel UI2.00004

HHFW experiments continue to explore application of HHFW to ST's

- Power modulation studies indicate field line angle not implicated in co/counter differences
- Time resolved measurements of parametric decay continue to support role in missing power
- Indications that surface waves may play role (antenna pressure, edge potential)
- Electron heating of high temperature RS target plasmas observed but fast ion damping still strong
- HHFW driven H-modes may be able to drive sufficient bootstrap current to be used in start-up scenarios