Pedestal modification via lower hybrid waves

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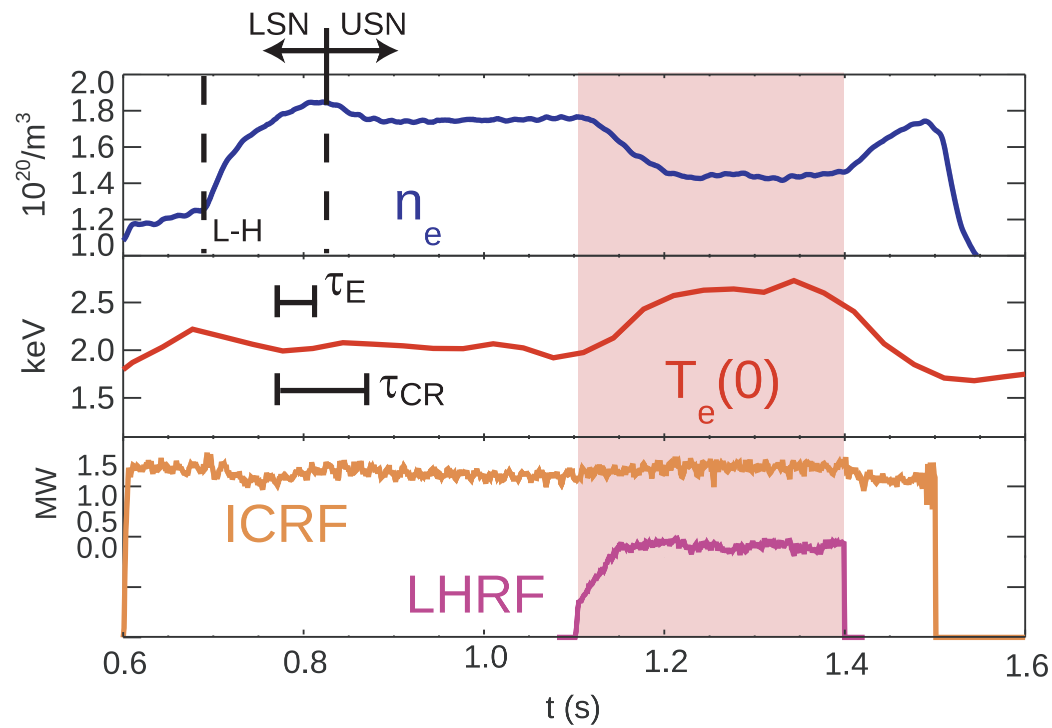
Alcator C-Mod

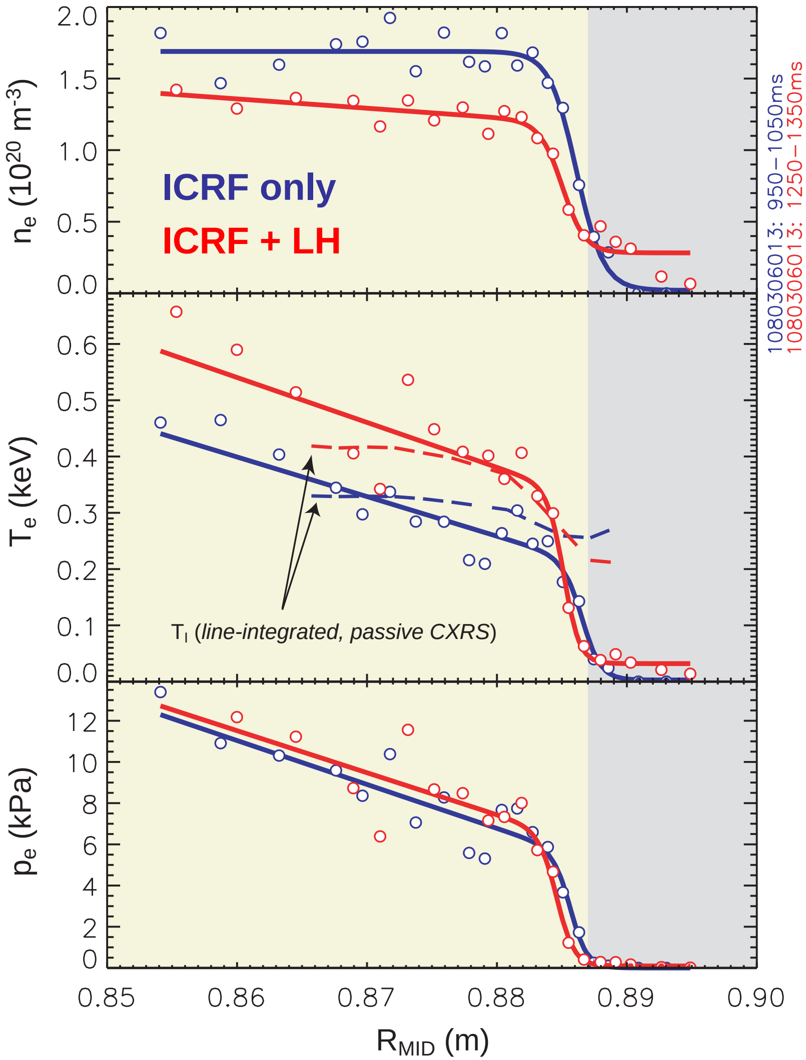
EDA H-mode target demonstrates clear response to LHRF

- Modest ICRF heating
  - H-mode triggered in LSN
  - Shift to USN with cryopumping used to obtain minimum possible density prior to lower hybrid turn-on ($n_{||}$=2.3)
- Results include:
  - *Core density reduction*
  - Substantial increase in core T_e
  - Net increase in W_P
  - Effect sustained for multiple τ_E, τ_{CR}



- Data and modeling suggests relatively low current drive (f_{CD}<4%) in this target

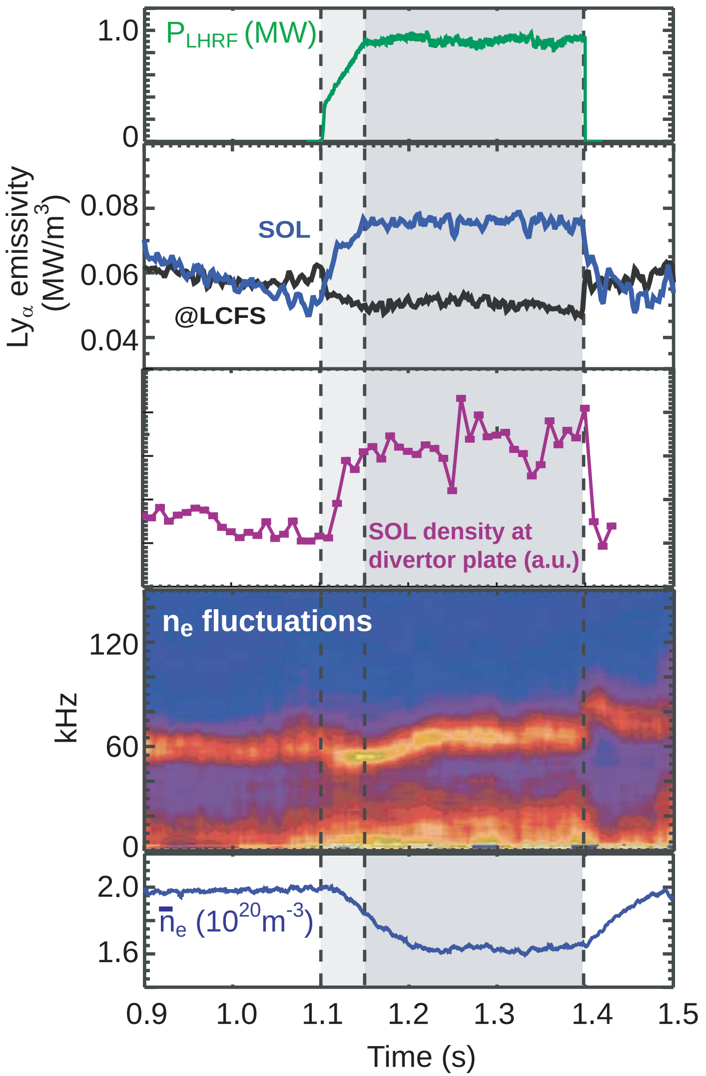
Significant modification to pedestal profiles leads to global change



- Steady state n_{PED} reduction is observed: as much as 30% in 600kA discharges
- Relaxation of n_e gradient, boost in SOL n_e
  - *Beneficial for LH coupling, wave penetration into core plasma*
- T_{PED} increases by up to 50%
  - *Beneficial for LH damping in core*
- Pressure pedestal nearly invariant, with p_{PED} constant or slightly increasing
- ~50% increase in D_{eff} at LCFS
- Pedestal collisionality drops from ~4 to ~1 in this case (ν^*_{95})
  - EDA H-mode is maintained throughout

Time behavior shows effects propagating in from edge

- Prompt edge response observed upon application of LH
  - Changes in Ly_α emissivity profile indicate fast changes in edge/SOL profiles
  - Divertor probes measure prompt increase in particle flux
  - Changes in QCM observed
- Global density decrease continues after initial edge modification
- H-modes stay in EDA H-mode throughout LH phase
- QCM mode characteristics altered → more particle transport drive?



Edge and core rotation modified on different time scales

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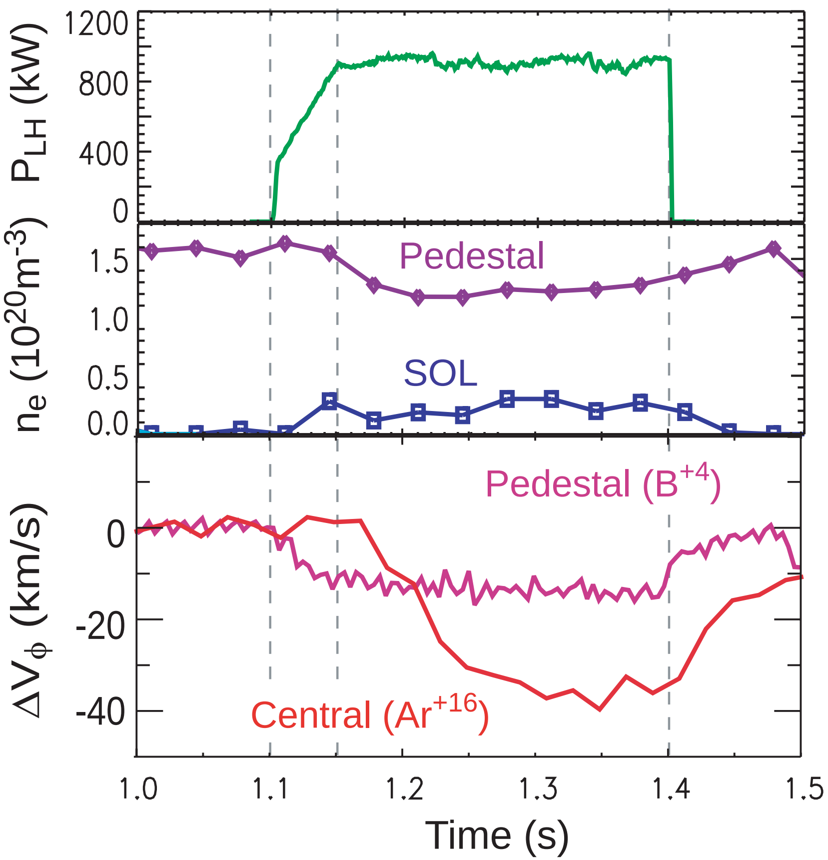
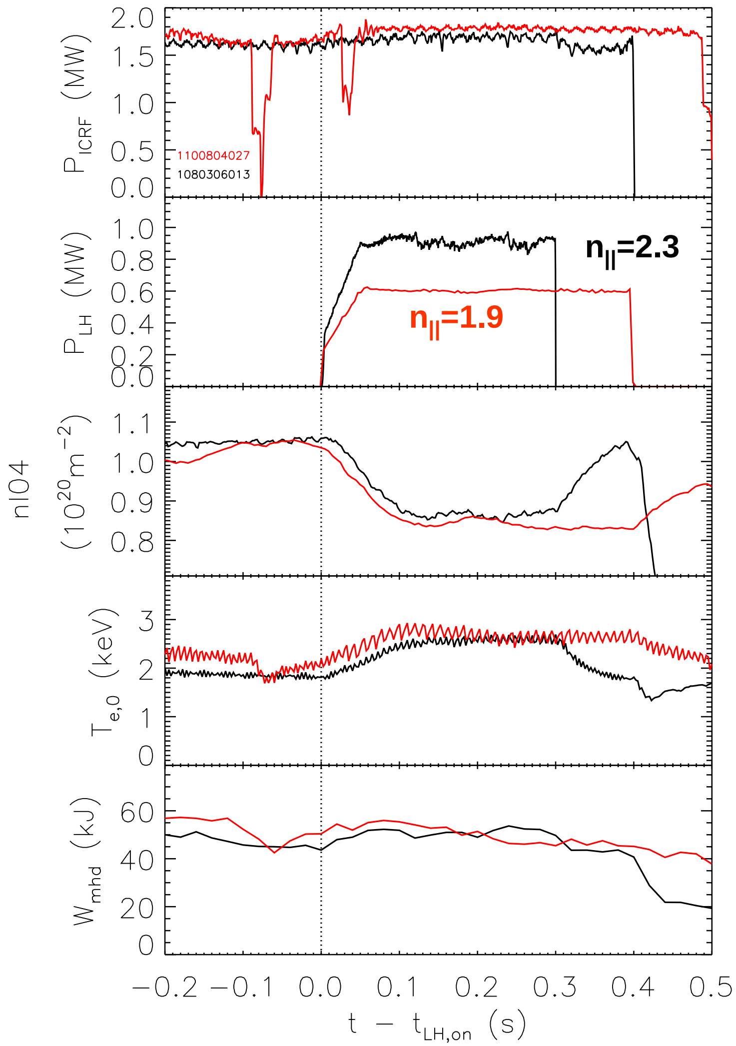


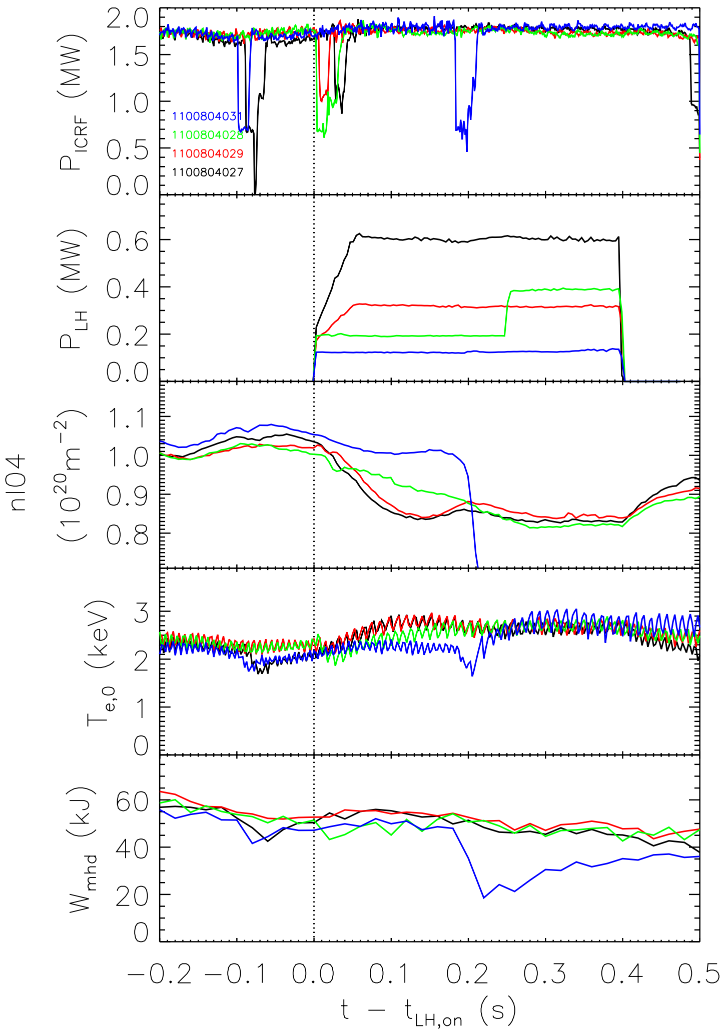
- Natural pedestal toroidal rotation *co-I_P* in H-mode
- LHRF introduces a counter-I_P *change* in pedestal toroidal rotation
  - Precedes most other pedestal modification
  - followed ~100ms later by change in central V_{tor}
- Is the pedestal rotation influencing the transport?

Recently H-mode modification was extended to lower $n_{||}$



- EDA H-mode density reduced to similar plateau during LH flattop
- Lower LH power was used with same (perhaps improved) effectiveness
- Improved coupling was obtained with reduced $n_{||}$ in the newer experiment
  - *Provided immediate test of whether core accessibility matters (it doesn't)*

Obtained a LH power scan in 600kA EDA H-modes



- Effect previously observed over narrow range of P_{LH} (mostly 800—950kW)
- In new experiment, flattop LH power was varied by a factor of ~5x
- Initial dn/dt, final n, fairly insensitive to P_{LH}, down to ~300kW
- Reduced pump-out rates seen at 120—200kW
- Control shot with P_{LH}=0 had an early H-L transition

Outstanding questions

- Behavior of EDA H-mode plasmas can be dramatically impacted by application of lower hybrid waves
  - Still early stages of evaluation; current experiments are exploring range of effect at varied P_{LH}, $n_{||}$, plasma characteristics
  - Demonstrated that core wave accessibility is unnecessary
  - Determined that effect is insensitive to total LH power, at or above about 300kW
- Effects, though mysterious, are generally beneficial
  - LHCD is more efficient in low density, high temperature targets
  - Application of LH directly produces an edge effect which promotes core coupling!
- Measurements, and promptness of edge effects, suggest a direct interaction of LH waves with pedestal/SOL
  - *Direct effect of waves on transport?*
  - *Electron heating effect?*
  - *Direct momentum input?*