NSTX

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Summary of recent L-H transition studies in NSTX

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R. Maingi Oak Ridge National Laboratory

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UCLA
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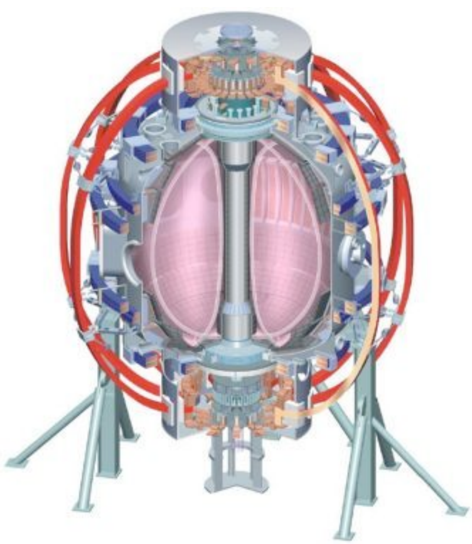
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

H-mode workshop
Princeton, NJ
Sept. 30-Oct. 2, 2009



Culham Sci Ctr
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Several L-H Experiments Run This Year

- *XP909*: P_{LH} smallest at largest R_x (lowest δ) [discussed last]
- *XP922*: P_{LH} increases with I_p
- *XP936*: P_{LH} increases with external applied fields
  - not directly related to rotation profile
- *XP941*: P_{LH} increases with n_e and comparable for deuterium and helium
  - P_{HL} seems comparable, but maybe independent of n_e
- Piggyback: Lithium evaporation reduces P_{LH}
- *XP956*: P_{LH} higher in reversed B_t discharges
  - Lithium seems to have a big effect here also

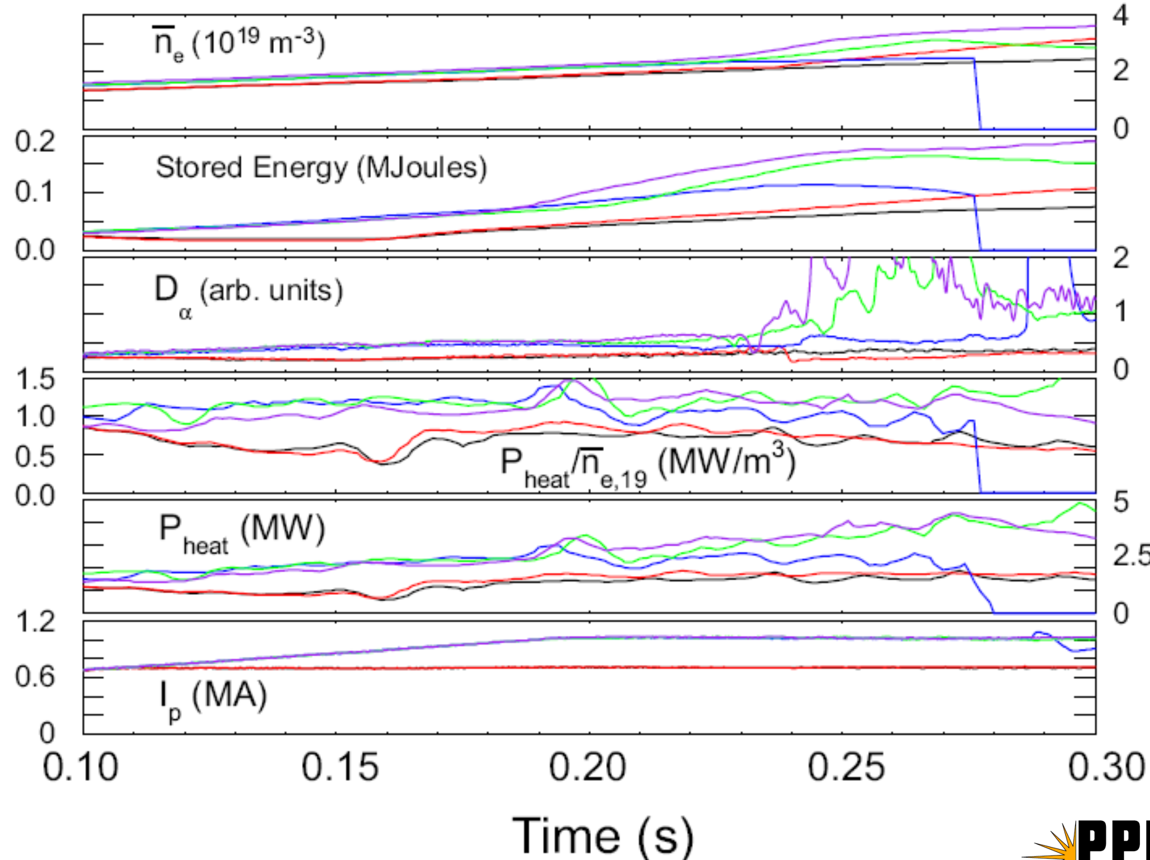
** XP numbers indicate dedicated experiments in 2009*

L-H Threshold Power Increases with Plasma Current in NSTX

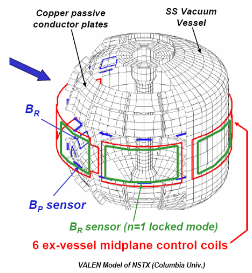
- Evidence for this dependence found several years ago; wanted to confirm
- Need to separate effect of possibly differing n_e
  - Attempt to do this did not succeed this year (MHD events at higher n_e before L-H)
  - However, HHFW expts showed $P_{LH} \sim n_e$
  - Look at both P_{LH} and P/n_e
  - Found P_{LH}/n_e almost a factor of 2 higher for 1 than for 0.7 MA

I_p=0.7 MA: P_{LH} ~ 1.6 MW, $P_{LH}/n_{e,19}$ ~ 0.7 MW/m^3

I_p=1.0 MA: P_{LH} ~ 3.1 MW, $P_{LH}/n_{e,19}$ ~ 1.2 MW/m^3

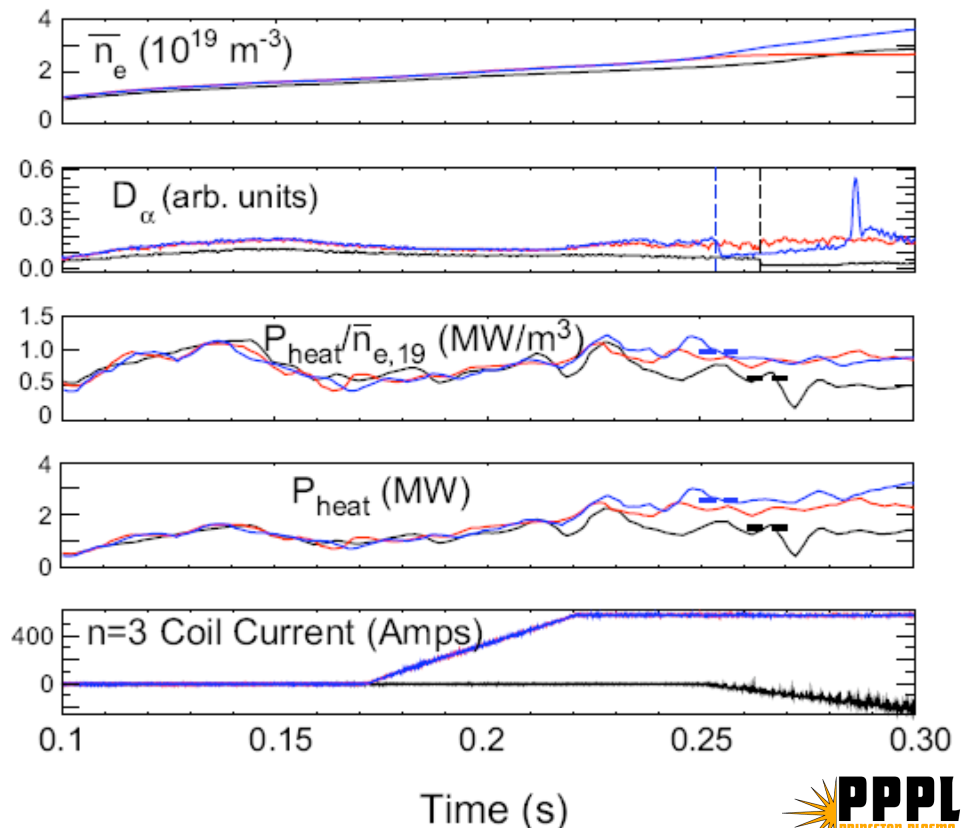


Application of n=3 Fields Results in Significantly Higher P_{LH}



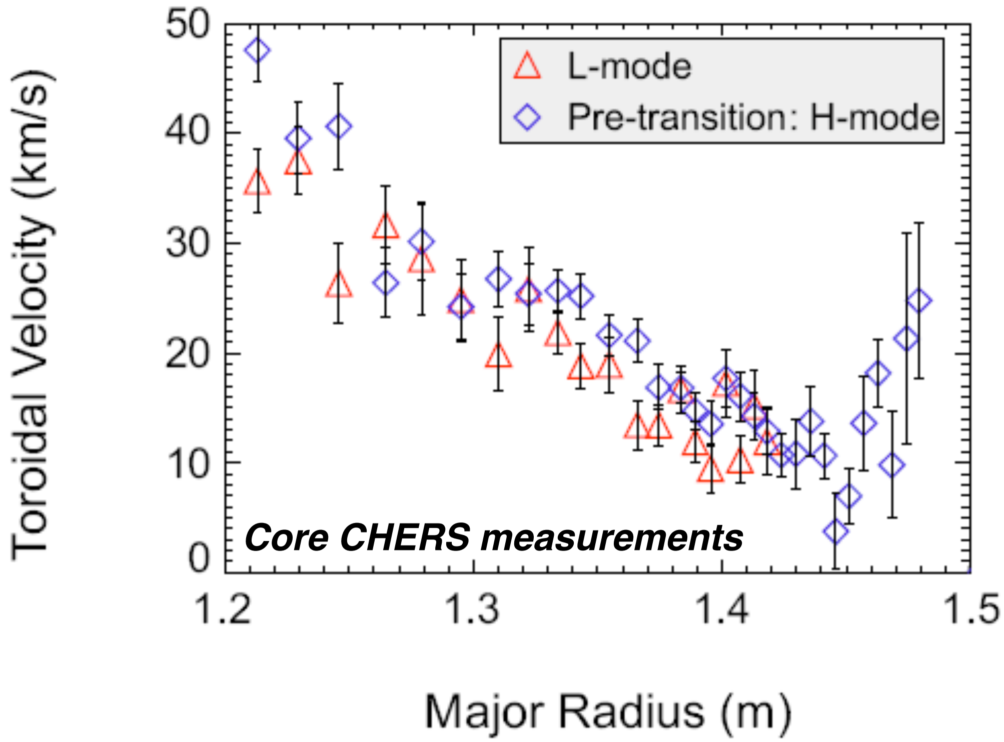
- Motivated by JET ripple, DIII-D torque scan results
- Recent MAST results showed delayed transition with increasing applied field amplitude
- Apply n=3 braking to test effect on threshold power
  - Braking applied prior to L-H transition
- Found P_{LH}/n_e significantly higher with higher applied n=3

P_{LH} increases from ~1.4 to 2.6 MW with higher n=3 current (~65% increase for P_{LH}/n_e)



Rotation Differences Do Not Appear to Play a Major Role

- Any difference in rotation does not appear to be key
  - Consistent with earlier RF vs NBI threshold expts.

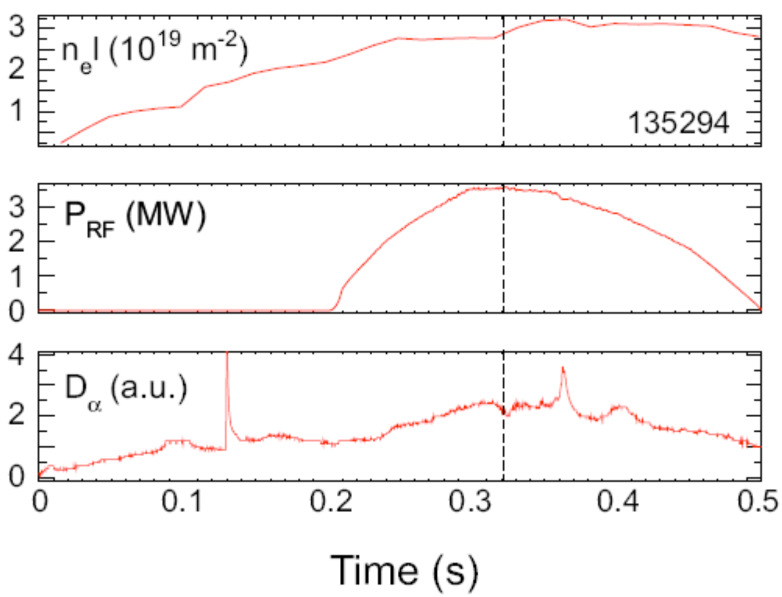


L-H/H-L Power Thresholds in Pure Helium and Deuterium Plasmas Were Explored in NSTX

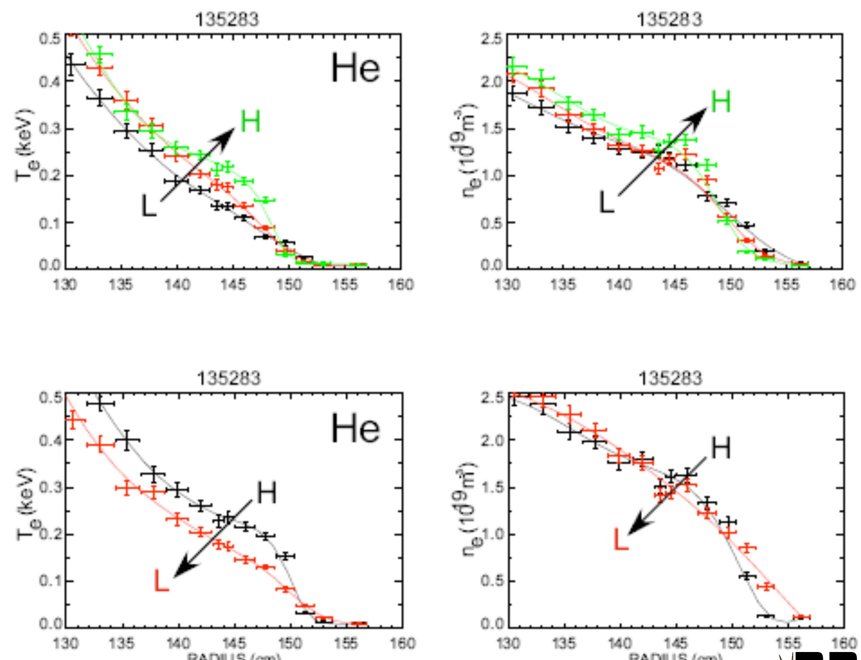
- High Harmonic Fast Waves (HHFW) were used to heat pure helium and deuterium plasmas
- Continuous ramping of HHFW power allowed for "fine" determination of P_{LH} and P_{HL}
- "Perturbation technique" used to determine HHFW electron heating efficiency (<0.16>±0.1)
  - Ion heating efficiency similar
  - In what follows, P_{RF} is taken to be $P_{RF,e}$

Forward or back transitions not always Obvious in D_α signal even for D-plasmas.

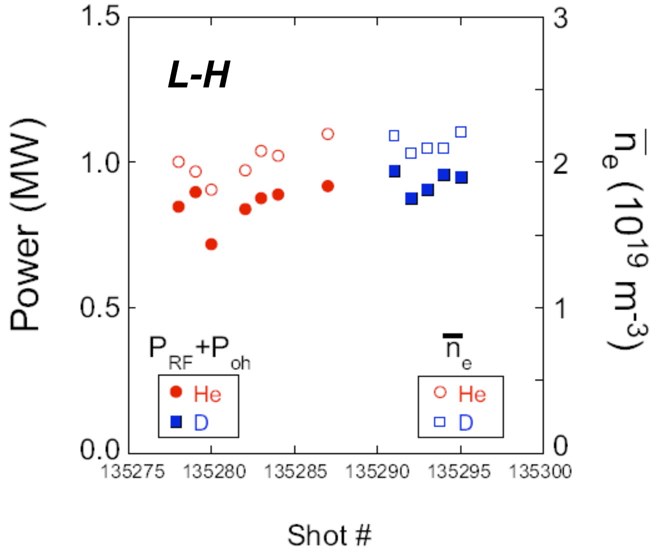
- No D_α indication in He-plasmas

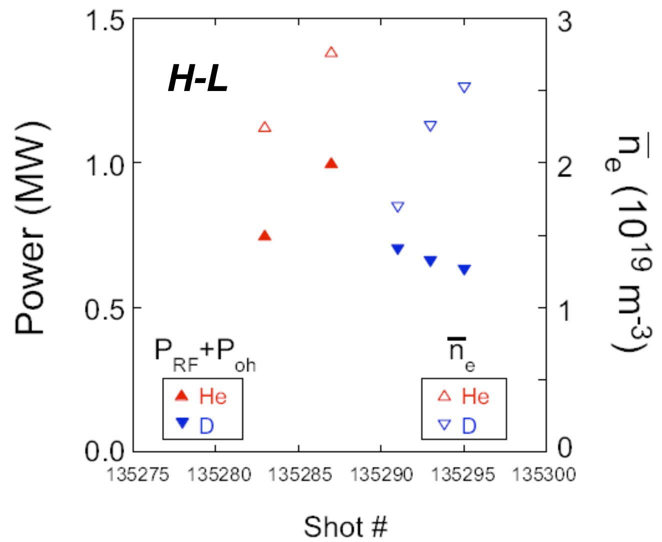


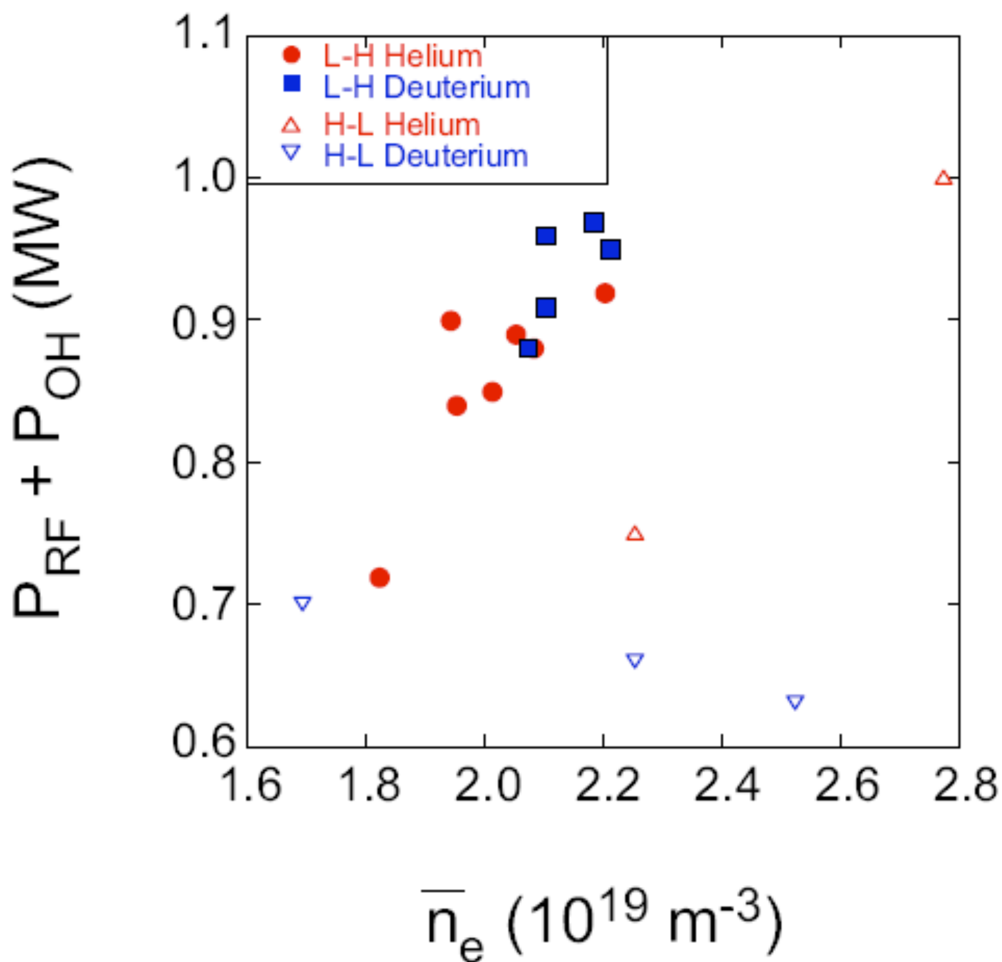
Use change in edge profiles as an Indication of both L-H and H-L transition



L-H Transition Powers Linearly Dependent on Density; Not True for H-L Transitions

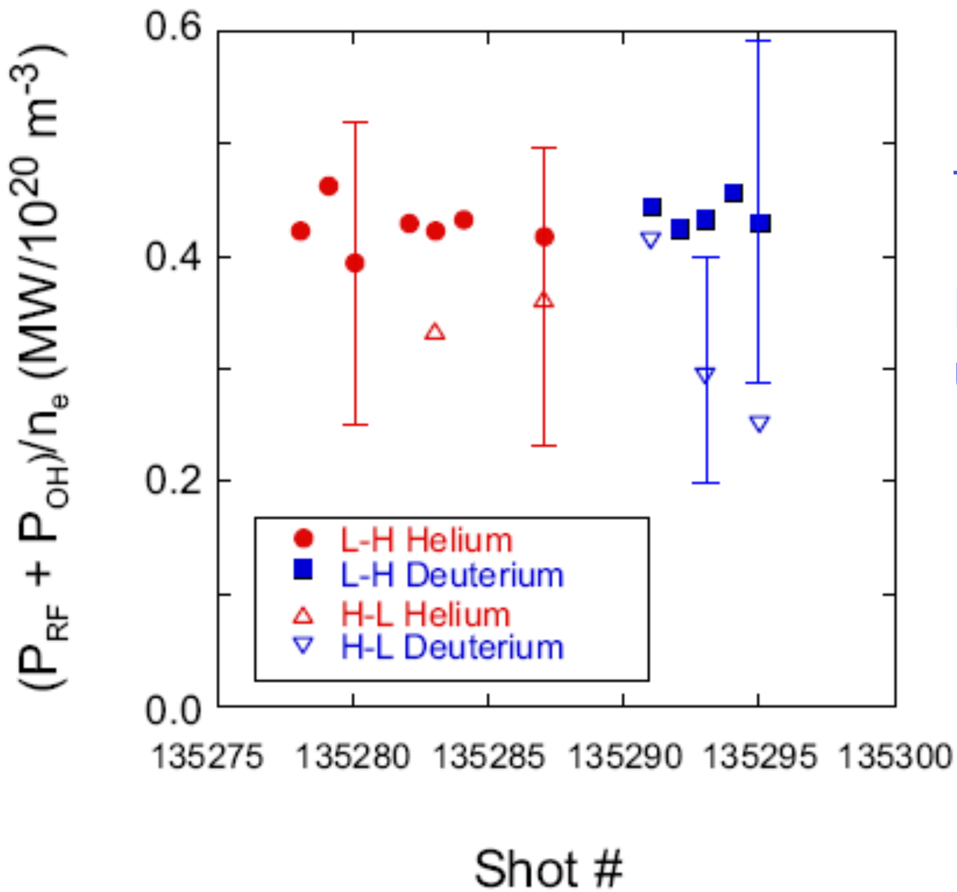






L-H Power Thresholds for He and D Similar

H-L power thresholds lower, indicating some hysteresis

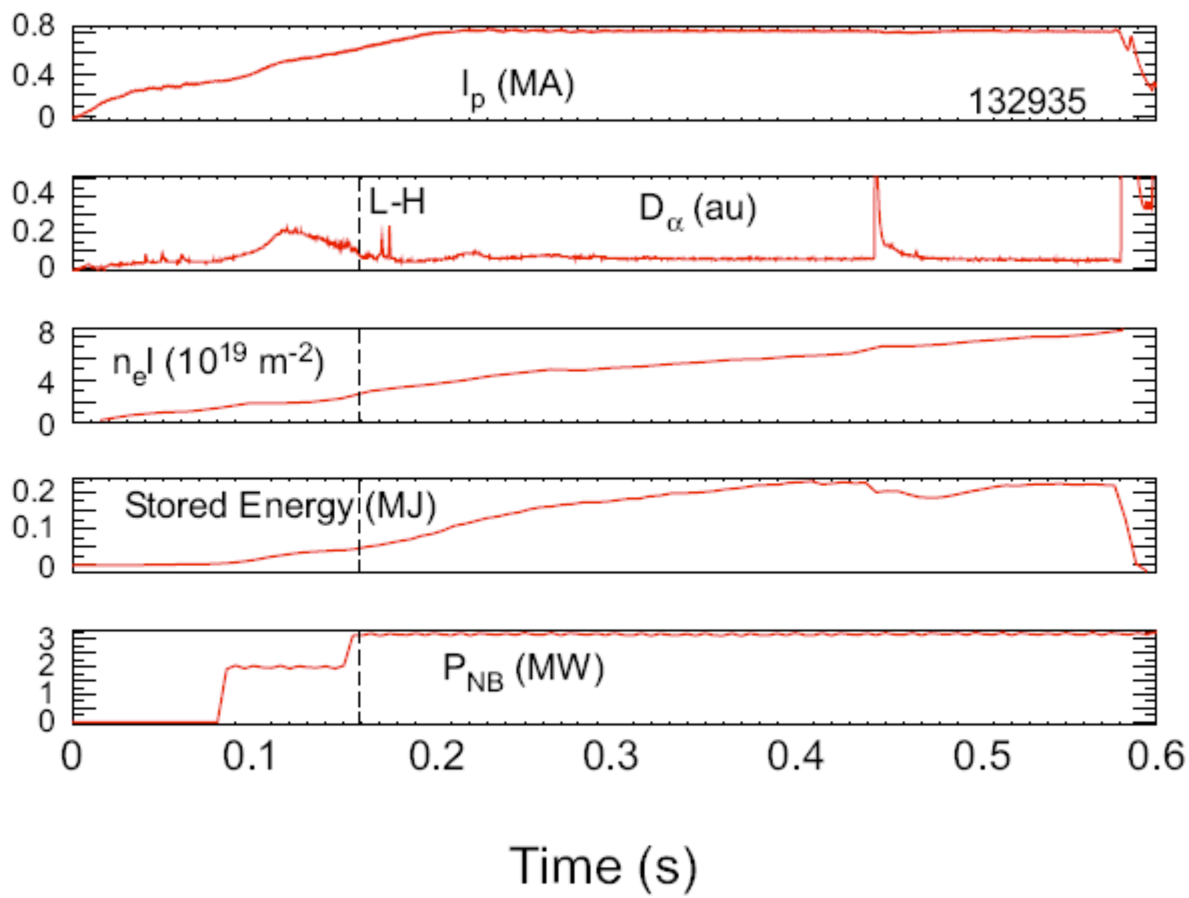


Normalize $P_{RF} + P_{OH}$ by density for comparison

Large error bars due to uncertainty in heating efficiency!

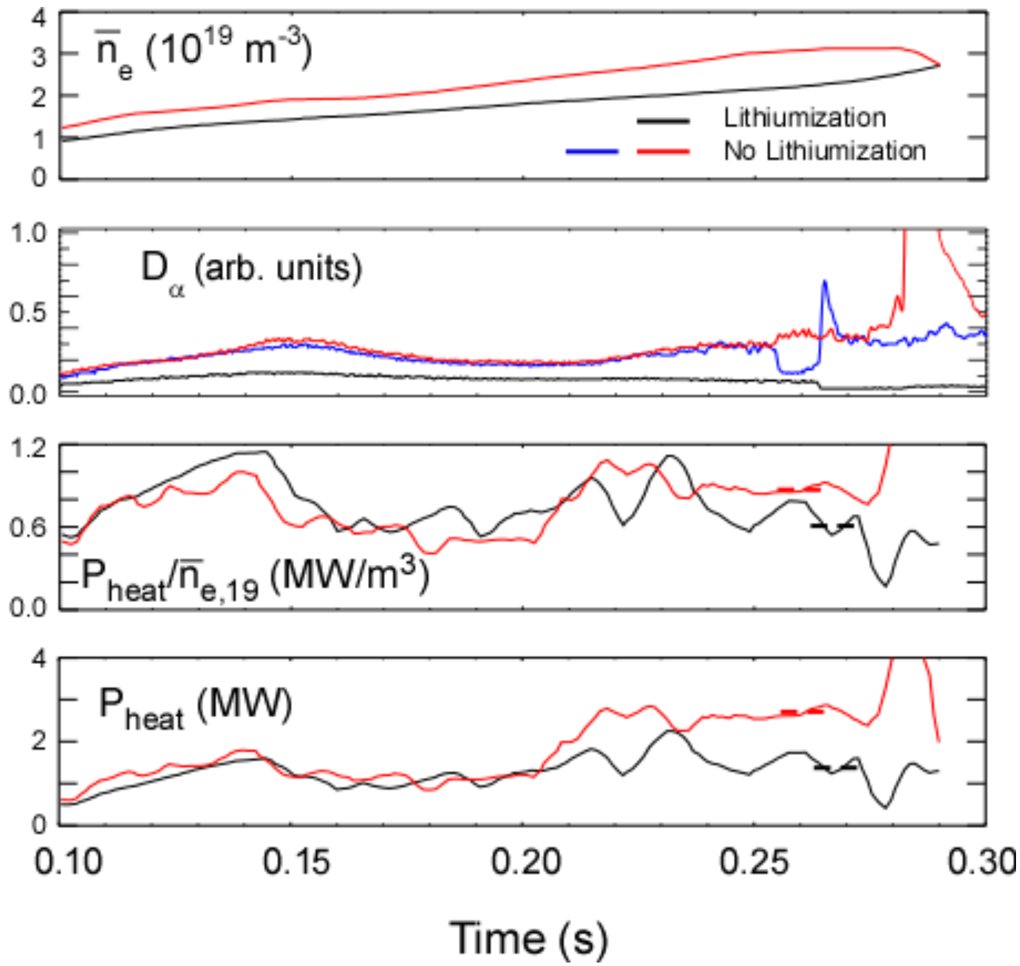
Lithium Evaporation Produced Plasmas with Long ELM-free Durations in 2008 and 2009

- 200 mg of Lithium evaporated between shots
- P_{NB} from 2 to 6 MW (H-mode accessible with P_{NB}<2 MW with Lithium)



Lithium Evaporation Led to a Significant Reduction in L-H Power Threshold

P_{LH} ~ 2.7 MW NBI without Li evaporation (P_{heat}/n_e~0.9 MW/10^{19} m^3)
~ 1.4 MW NBI with Li evaporation (0.6 MW/10^{19} m^3)



- $P_{LH} \propto n_e$ from HHFW expts
- Normalize P_{LH} by n_e due to density differences between plasmas with and without Li evaporation

XP956: Reversed TF Results

- D^+ plasmas with NBI used in this study
- USN vs LSN, no Li vs Li @ 200 mg/shot (4 cases)
- Have not yet done TRANSP calcs for P_{heat}, etc.
- Li has very strong effect, even in unfavorable ∇B drift direction

P_{inj}	USN	LSN
No Li	2.5 – 3.0 MW	2.9 – 3.2 MW
Li	0.4 – 0.6 MW	1.15 – 1.75 MW

↑

Similar to LSN with normal TF

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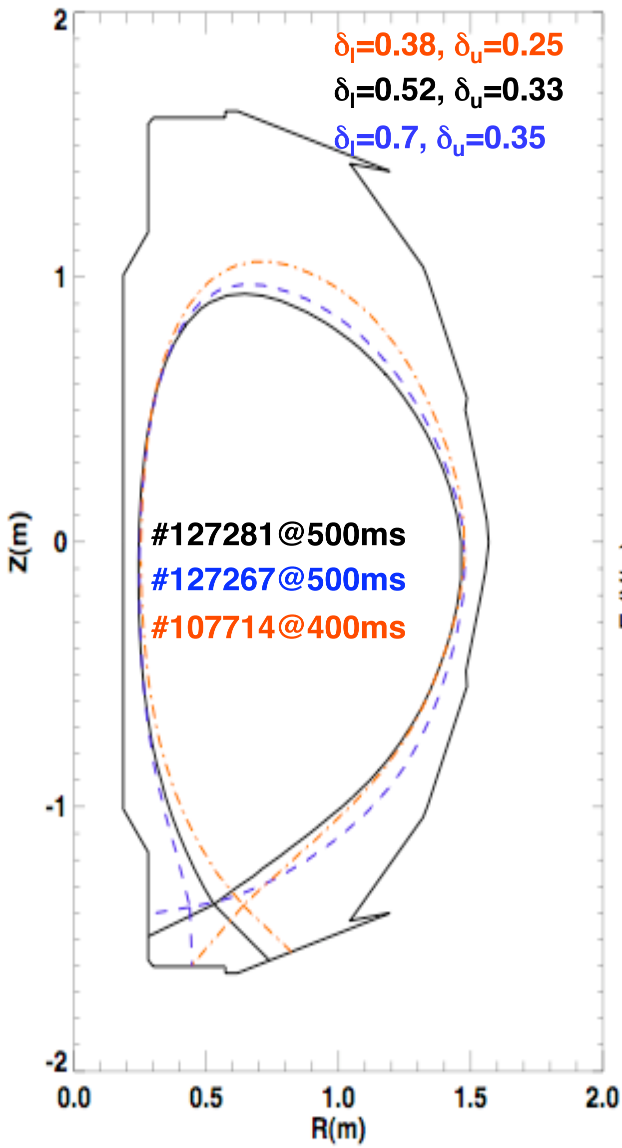
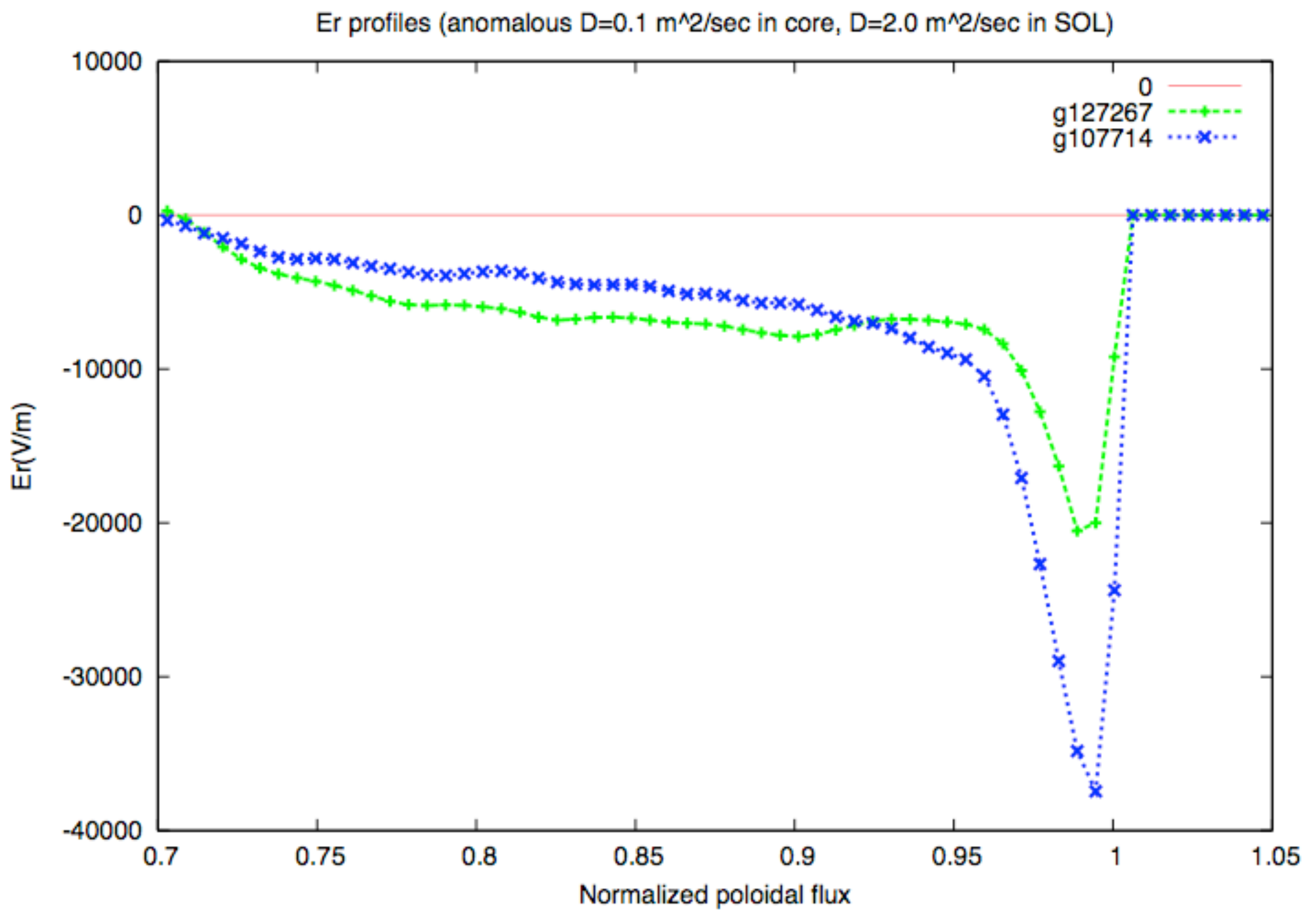
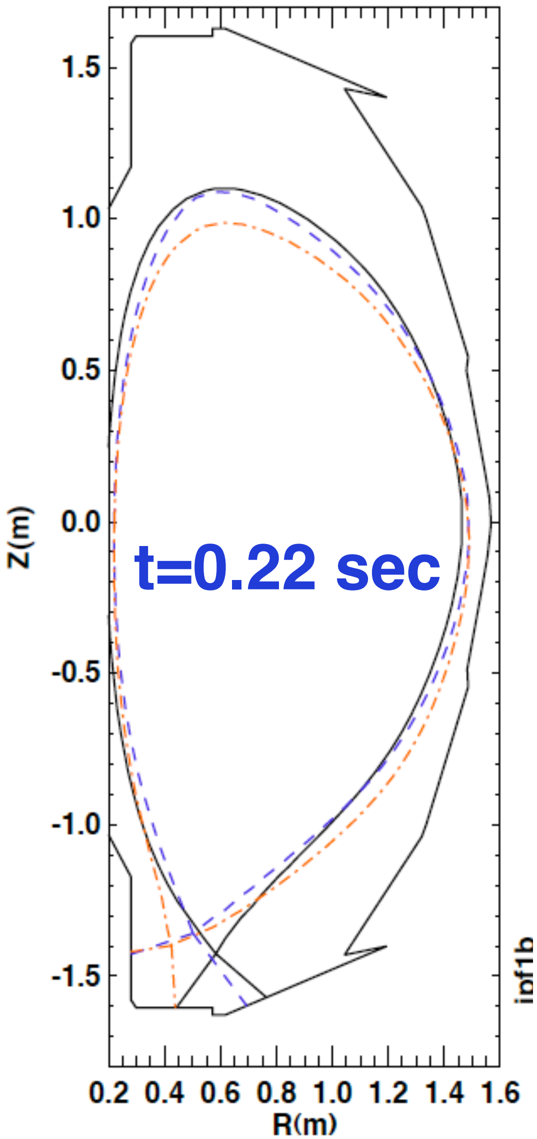
XGC code calculations showed strongest ion loss (and E_r/E_r') near X-point at large Rx – motivated XP909

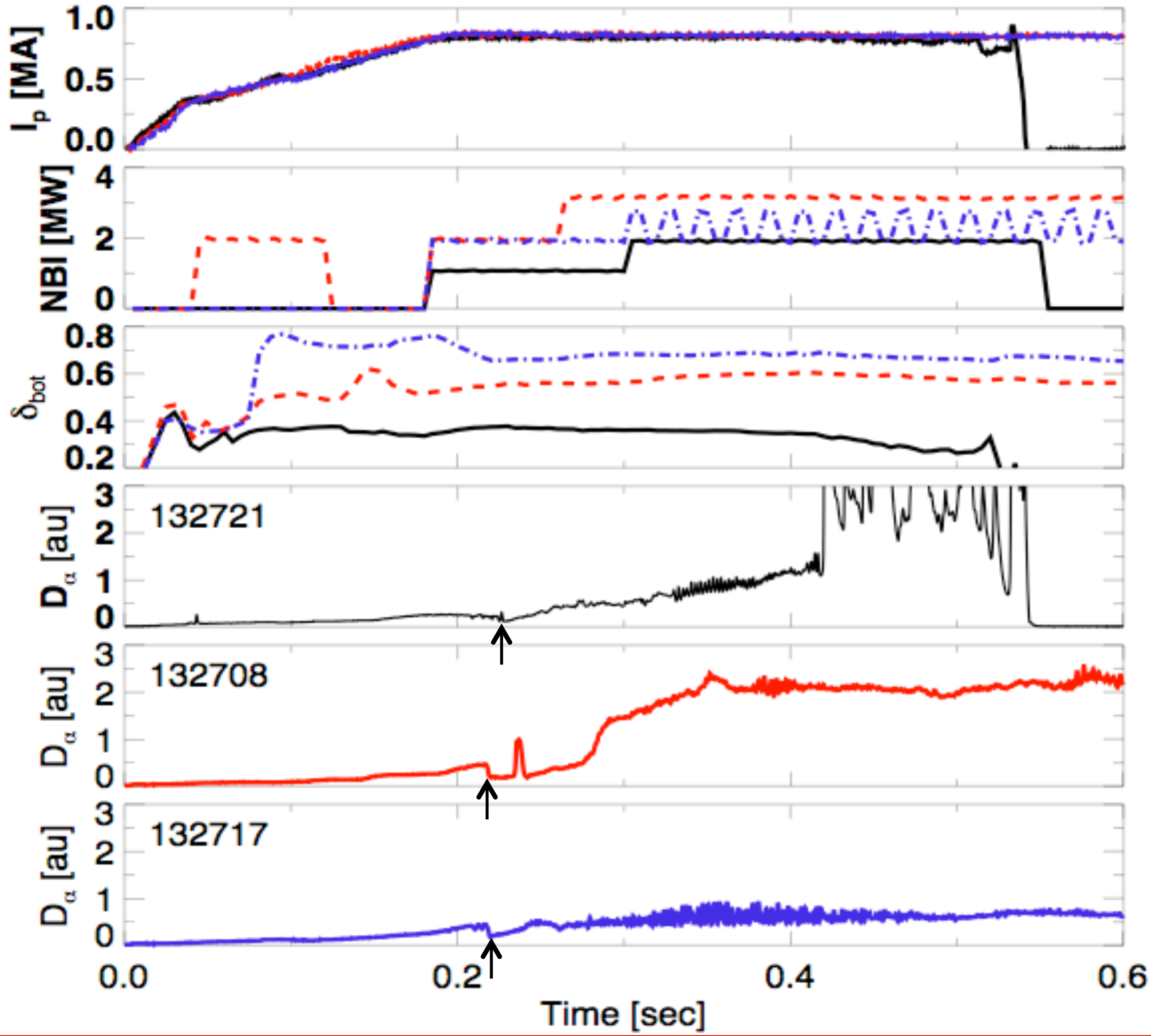




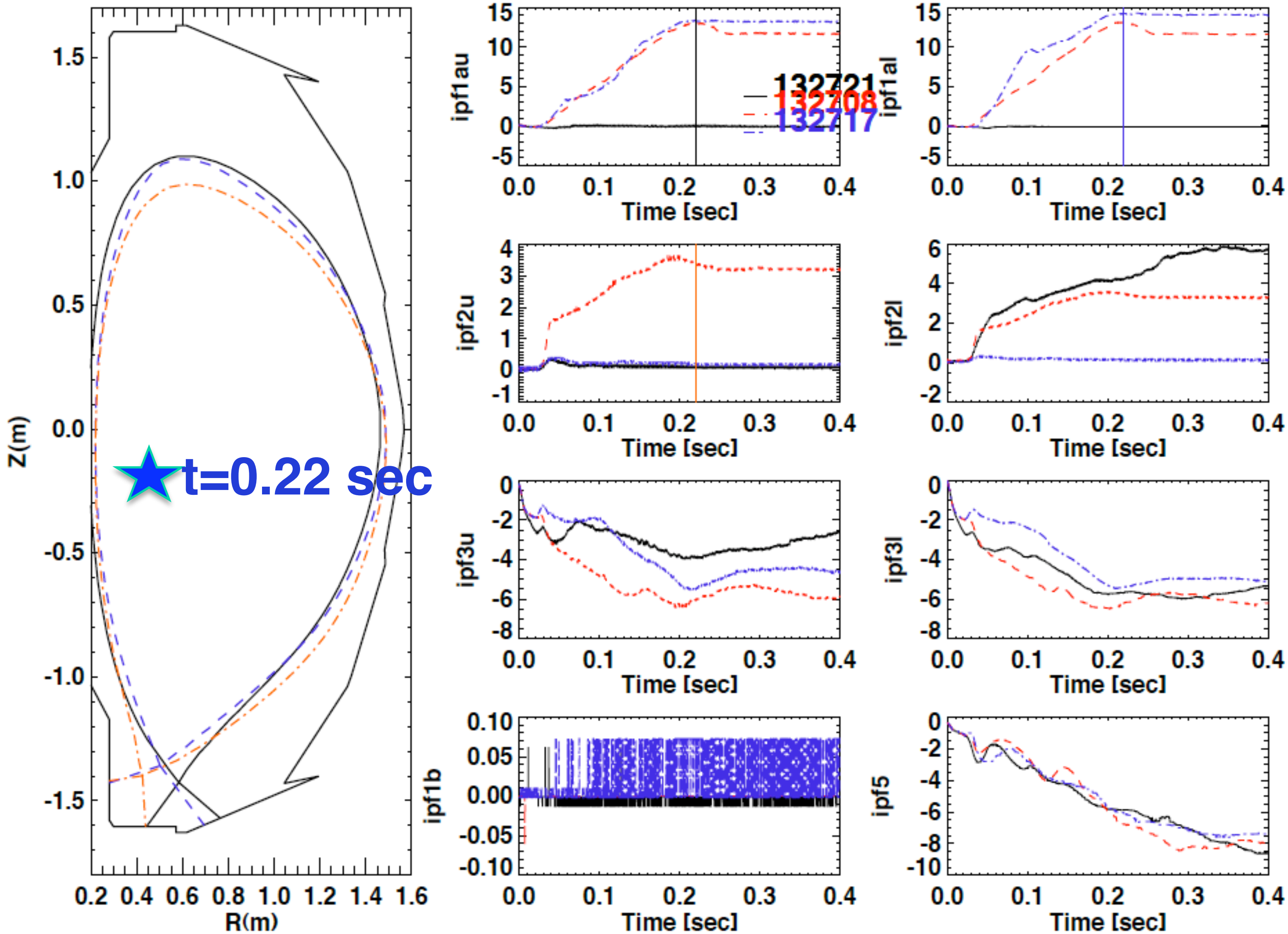
* Courtesy of C.S. Chang, G-Y. Park

P_{LH} lowest at largest R_x (lowest δ)





Three X-point radii and triangularities achieved



κ, bottom gap relatively well matched at 0.2 s, but δ_r^{sep} different
P_{LH}^{NBI} lowest for δ_L~ 0.4 and comparable for higher δ_L

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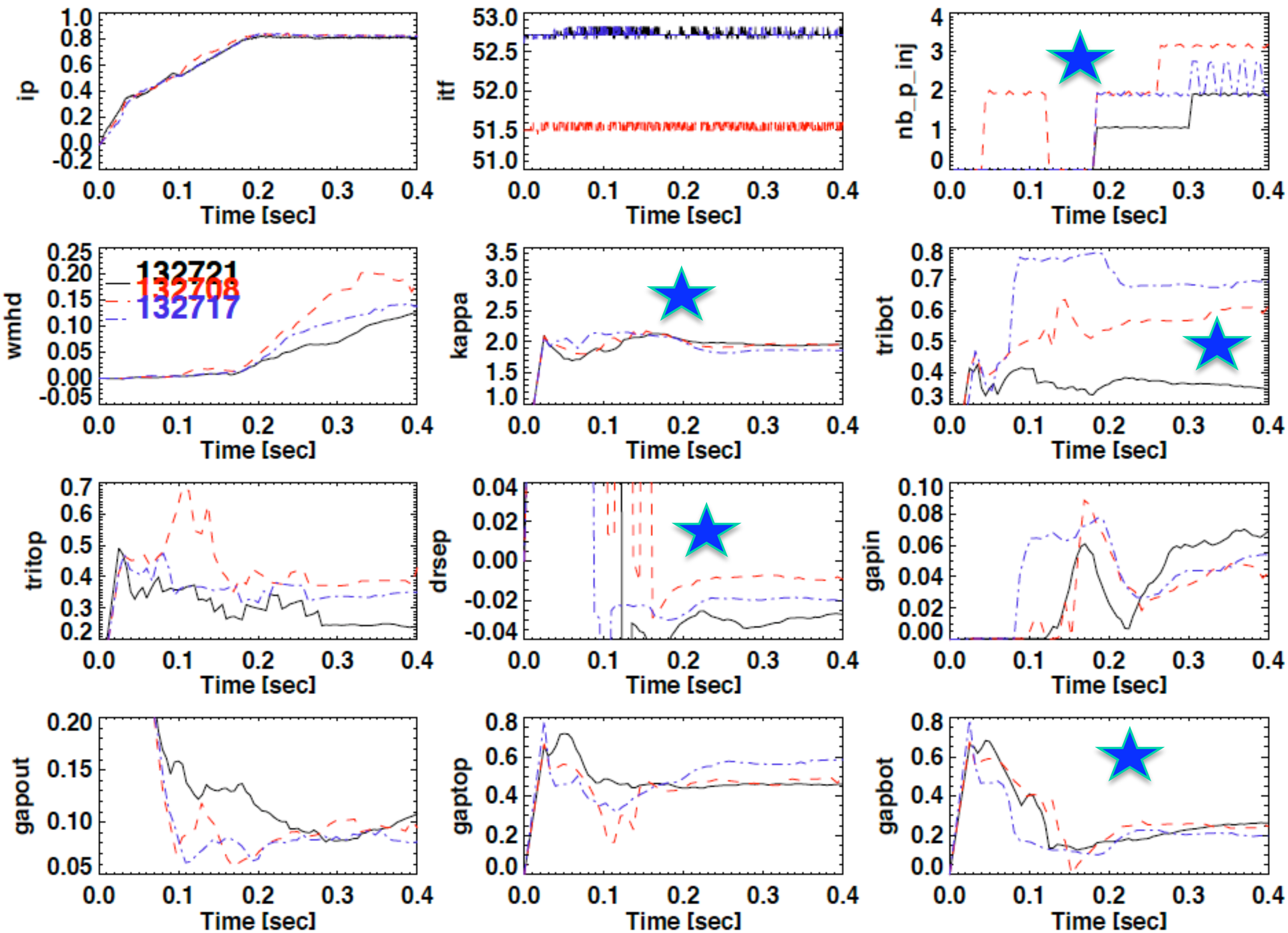
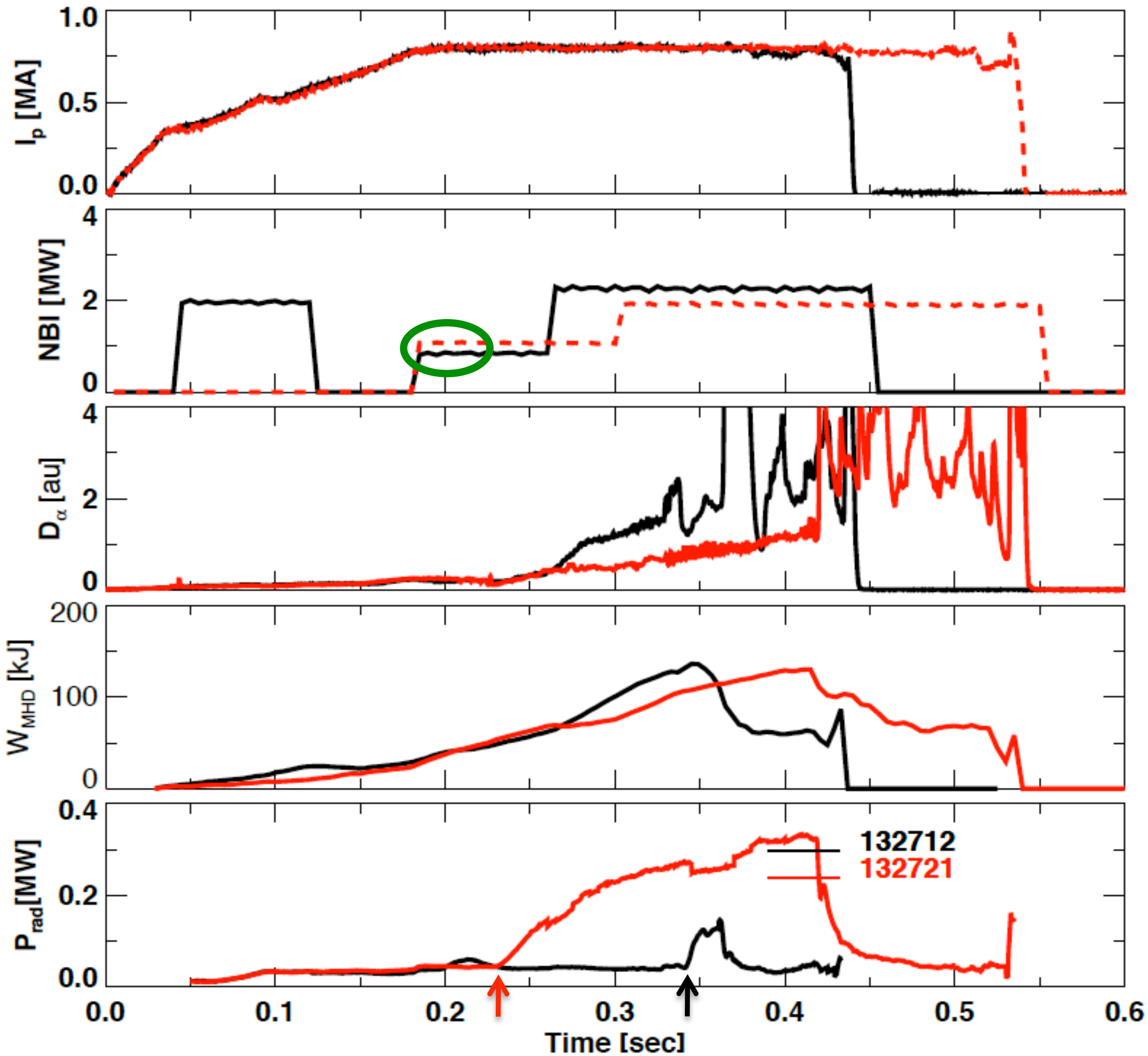
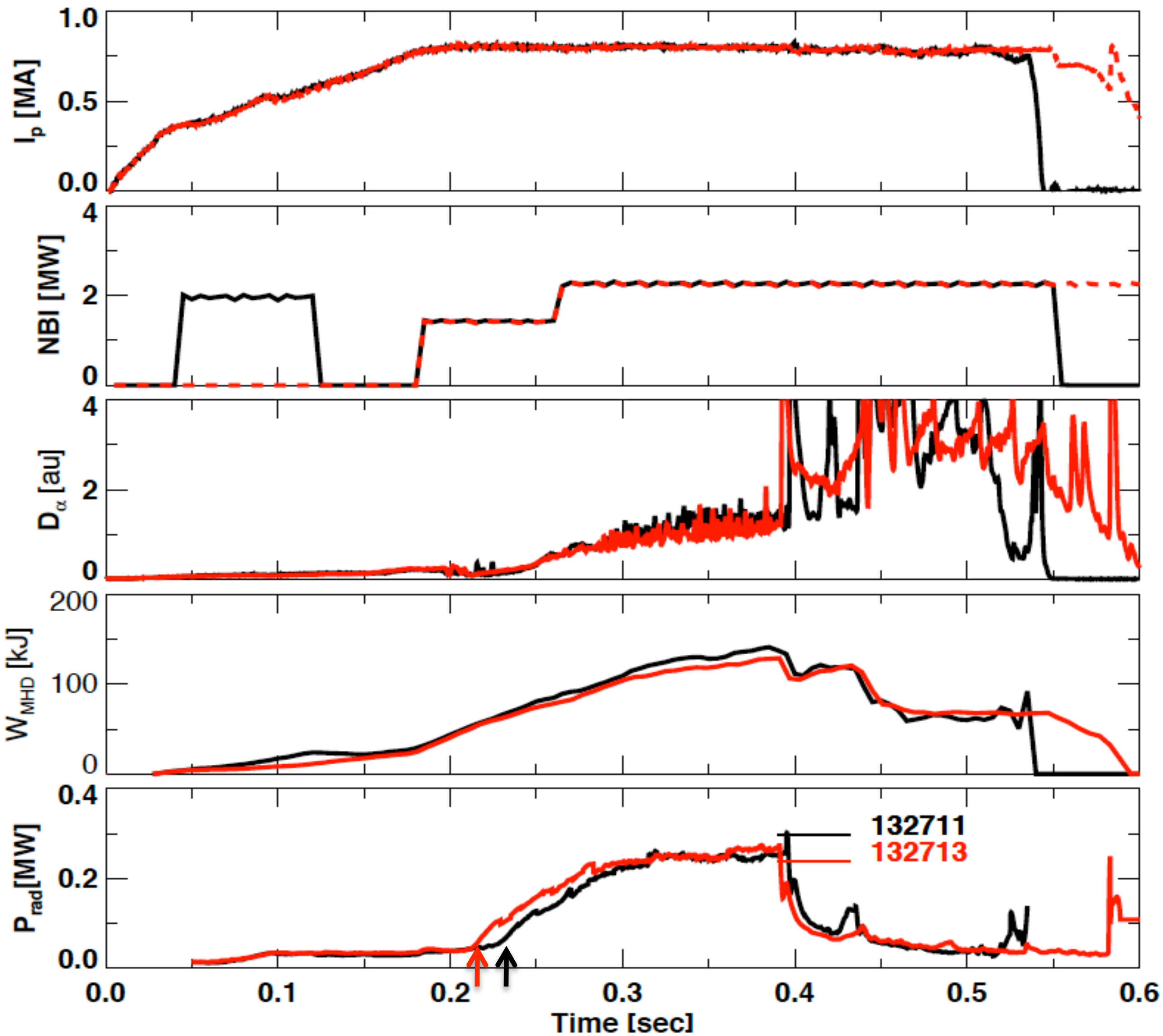


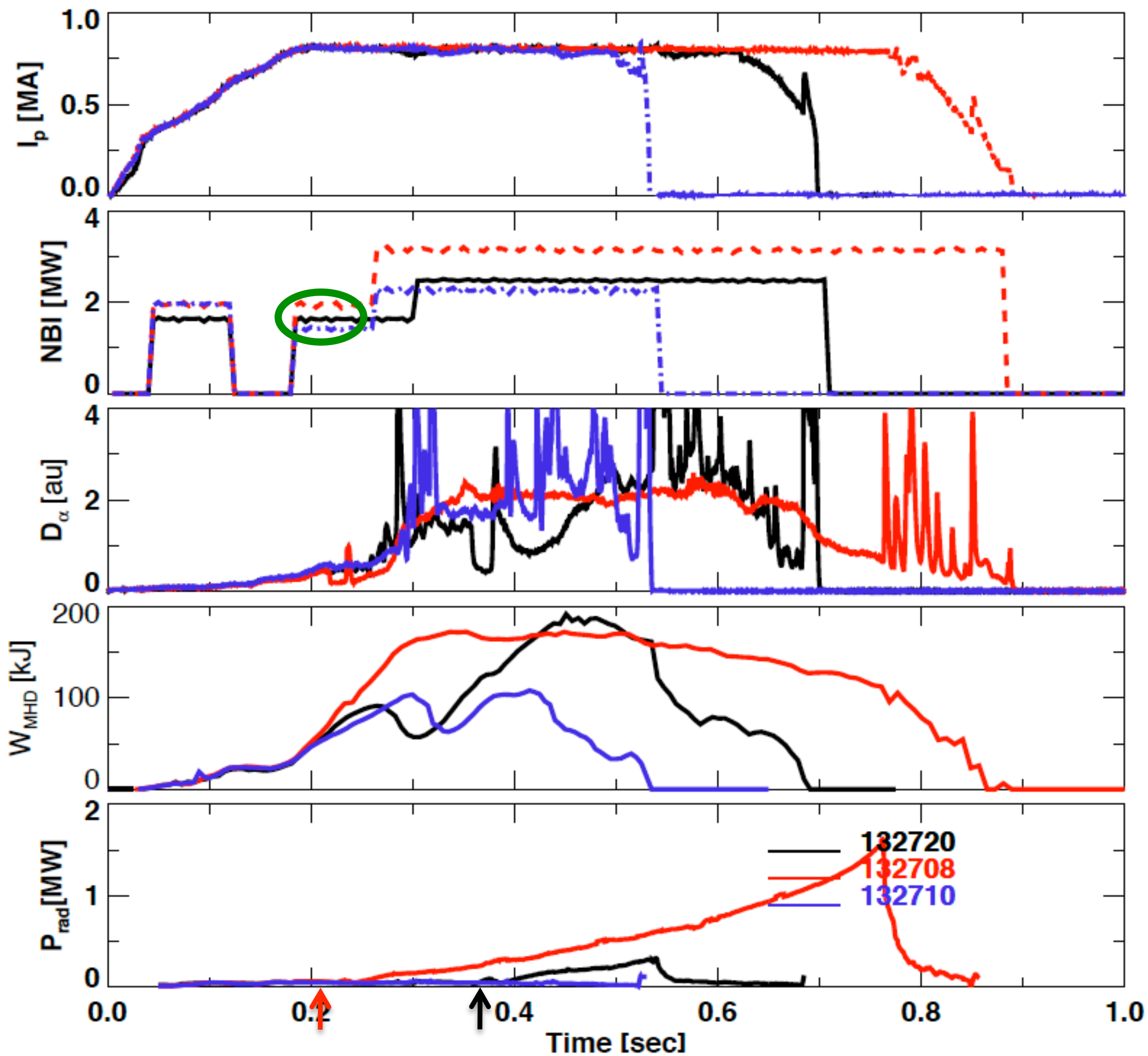
Low δ_L~ 0.4 has P_{LH}^{NBI} < 1.1 MW



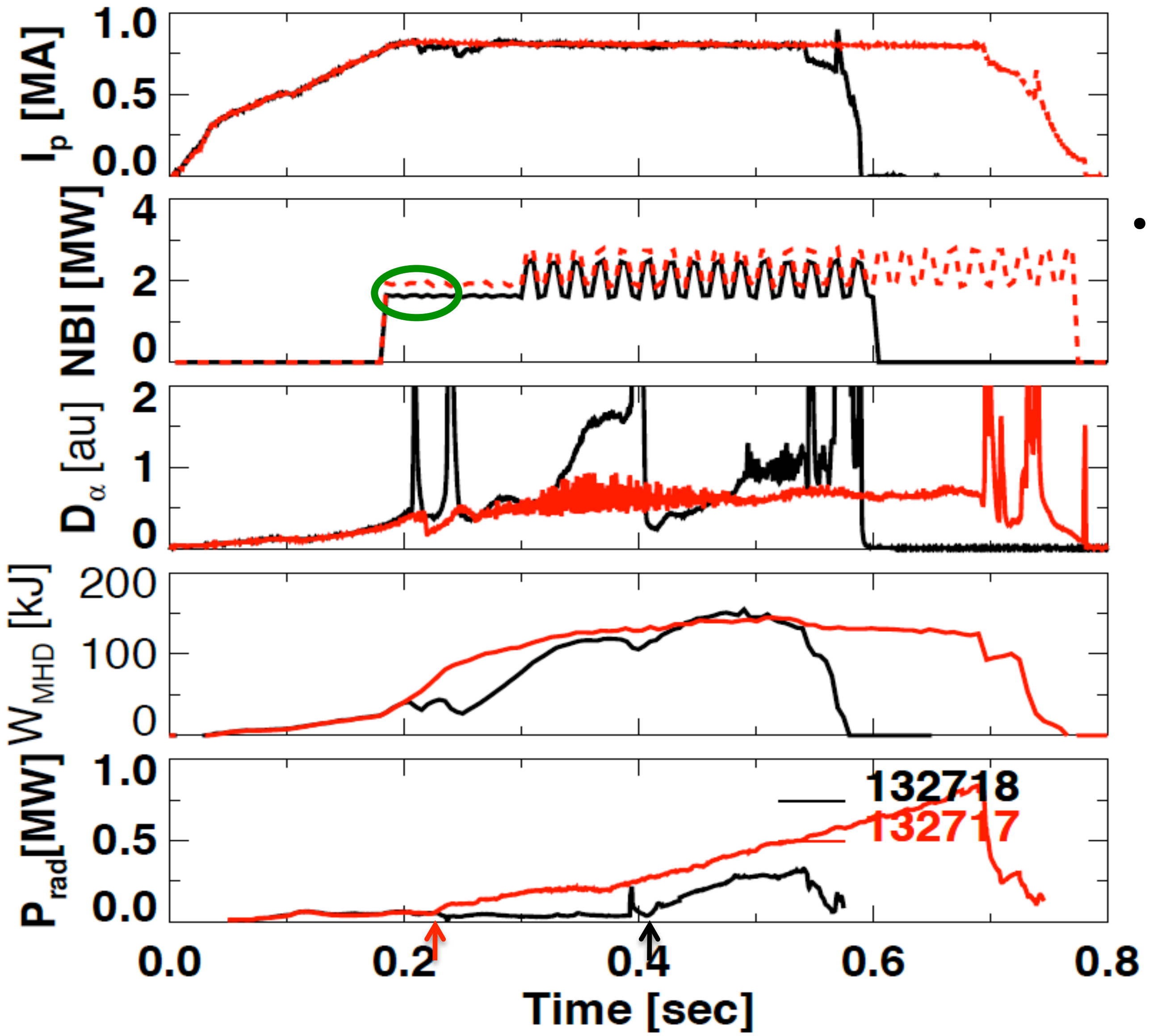
Early heating does not affect P_{LH}^{NBI} (Low $\delta_L \sim 0.4$)



Medium $\delta_L \sim 0.55$ has $P_{LH}^{NBI} \leq 2$ MW



High δ_L~ 0.7 also has $P_{LH}^{NBI} \leq$ 2 MW



- Locked modes affected LH timing in 132718

Poster copies