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L-to-H power threshold comparisons between NBI and RF heated plasmas in NSTX

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Abstract

Recent experiments on the National Spherical Torus Experiment (NSTX) have focused on investigating important dependencies of the power threshold for the L-to-H mode transition, P_{LH}. These experiments are motivated by recent results from MAST and ASDEX- Upgrade[1], which show a reduction of P_{LH} in double null configuration compared to single null configuration with the ion ∇B drift towards the lower X-point. The role of magnetic configuration (double null, lower single null, upper single null) on P_{LH} was investigated for both NBI heated and RF heated plasmas. Furthermore, the height of the X-point was found to be an important parameter in establishing H-mode in Ohmic, NBI, and RF heated plasmas, as investigated previously on JET[2]. At fixed configuration (e.g. balanced double null), it appears that P_{LH} is similar for discharges that are NBI heated to those that are RF heated. This is surprising since neutral beam injection (NBI) heats partly the core plasma ions and imparts a large amount of toroidal rotation to the plasma, while RF heating predominantly heats plasma electrons in the core and imparts little toroidal rotation. Indeed the NBI heated discharges have a higher T_i/T_e ratio and more toroidal rotation in the core. However, measurements reveal that despite these differences, the stored energy in the plasma is similar in the two cases, as are the edge parameters (T_e, n_e, T_i, v_T, E_r). This confirms that edge plasma conditions are likely to be most important in determining the L-to-H transition, and that in NSTX the transition is relatively insensitive to the two primary heating mechanisms since they impart energy largely in the core.

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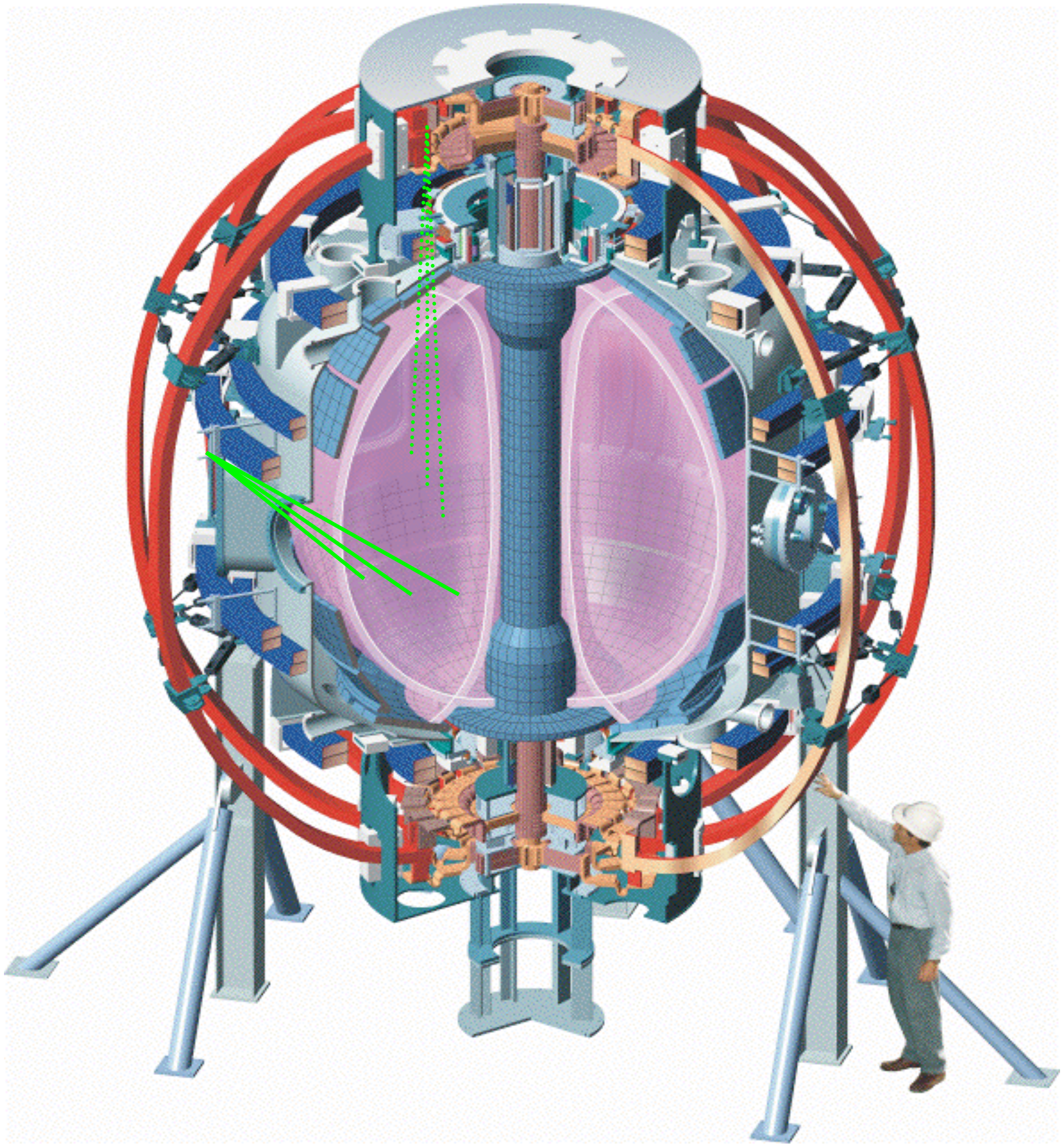
[1]H. Meyer, *et. al.*, 2006 Nuclear Fusion **46** 64.
[2]Y. Andrew, *et. al.*, 2004 PPCF **46** A87.

Outline

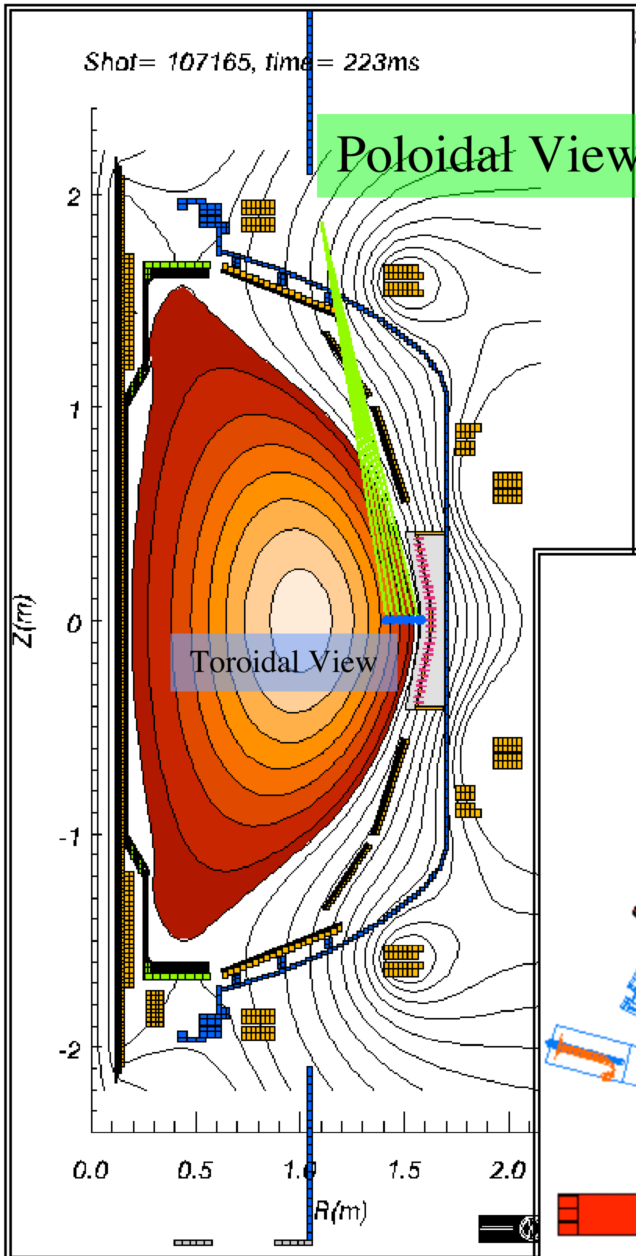
- NSTX and diagnostic summary
- P_{LH} results
  - Shape scan with NBI heating
  - Shape scan with RF heating
  - NBI v. RF comparison
    - DN configuration in detail
- Summary
  - Future work

The NSTX Facility

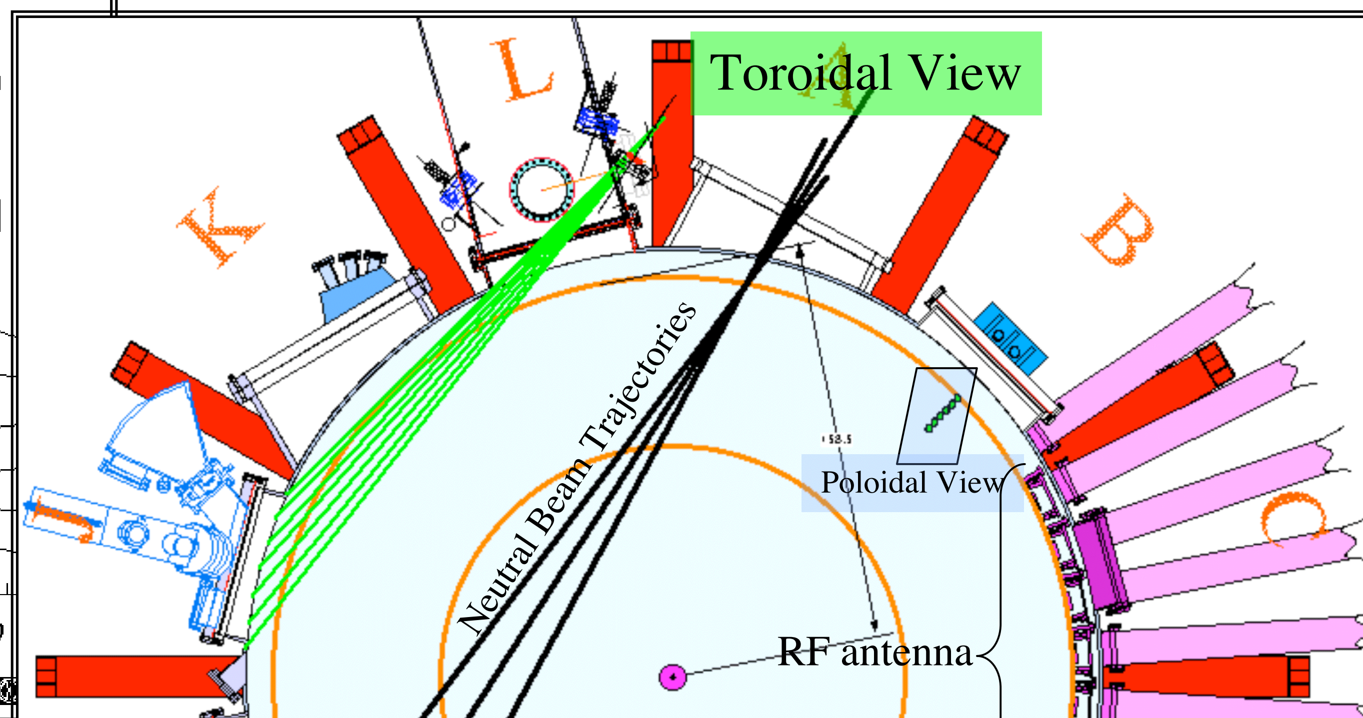


- $R \sim 0.85$ m, $a \sim 0.65$ m
- $I_p < 1.2$ MA
- $B_T < 0.6$ T
- Pulse length ~ 1 sec
- He or D_2 fueled
- active shape control
  - LSN, USN, DN, limited
- Neutral Beam Heating
  - < 7 MW
  - Co-current injection
- RF Heating
  - < 6 MW
  - 30 MHz, High Harmonic Fast Wave

The Edge Rotation Diagnostic (ERD)



- 10 ms time resolution
- 7 toroidal and 6 poloidal sightlines cover 140 to 155 cm at the outboard midplane.
- Sensitive to intrinsic emission light of C III, C IV, and He II.
- Measures velocity, temperature, and brightness of edge ions.
- Spectral resolution of 0.22 Å/pixel with 75 μm slits.
- T.M. Biewer, *et. al.*, Rev. of Sci. Instrum. **75**, 650 (2004)
  - http://w3.pppl.gov/~tbiewer/ERD_RSI.pdf



Reprints

Electronic copy available at: http://w3.efda.jet/~tbiewer/EPS06poster.pdf

Lowest P_{LH} in DN and highest in U-SN

NBI heated: $I_p = 0.6$ MA, $B_t = 0.45$ T

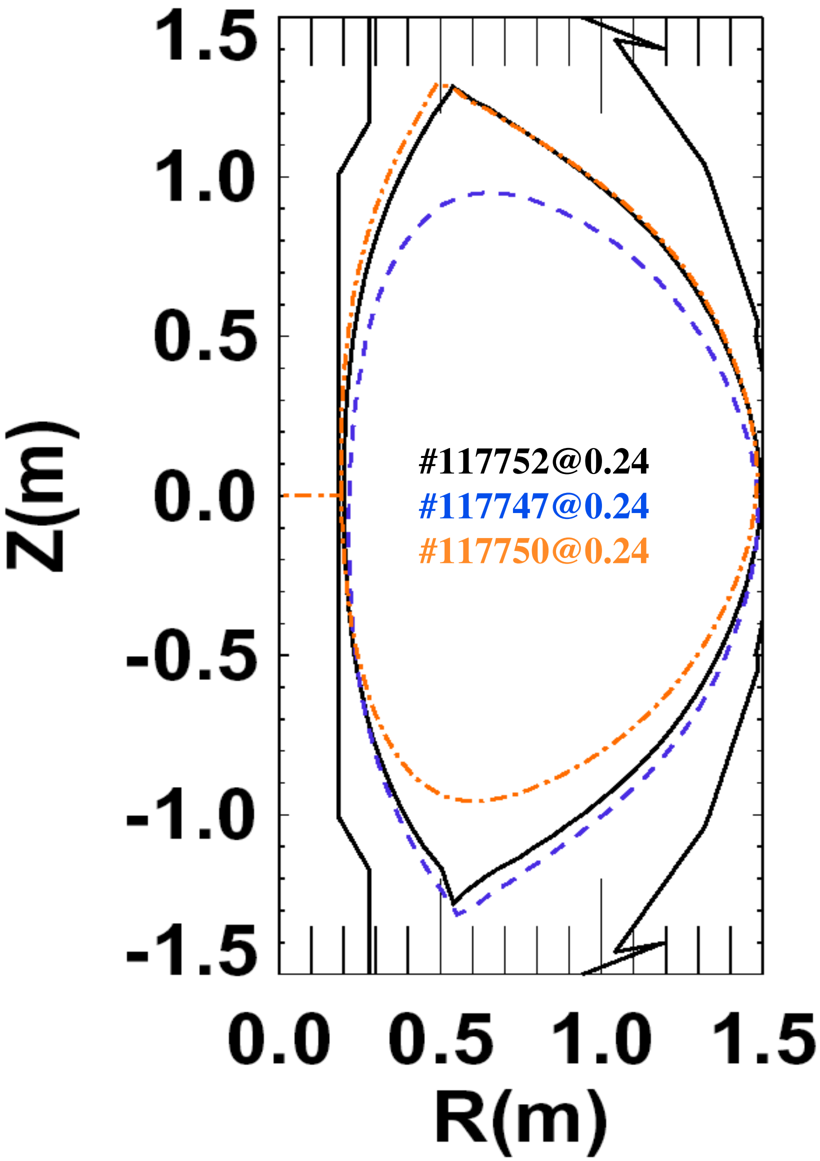
Pulse	Conf.	$d_{r,sep}$ [mm]	κ	δ_u	δ_l	P_{NBI} [MW]
117752	DN	0	2.0	0.49	0.47	0.6
117747	L-SN	-20	1.76	0.35	0.52	1.1
117750	U-SN	14	1.72	0.55	0.35	4.0

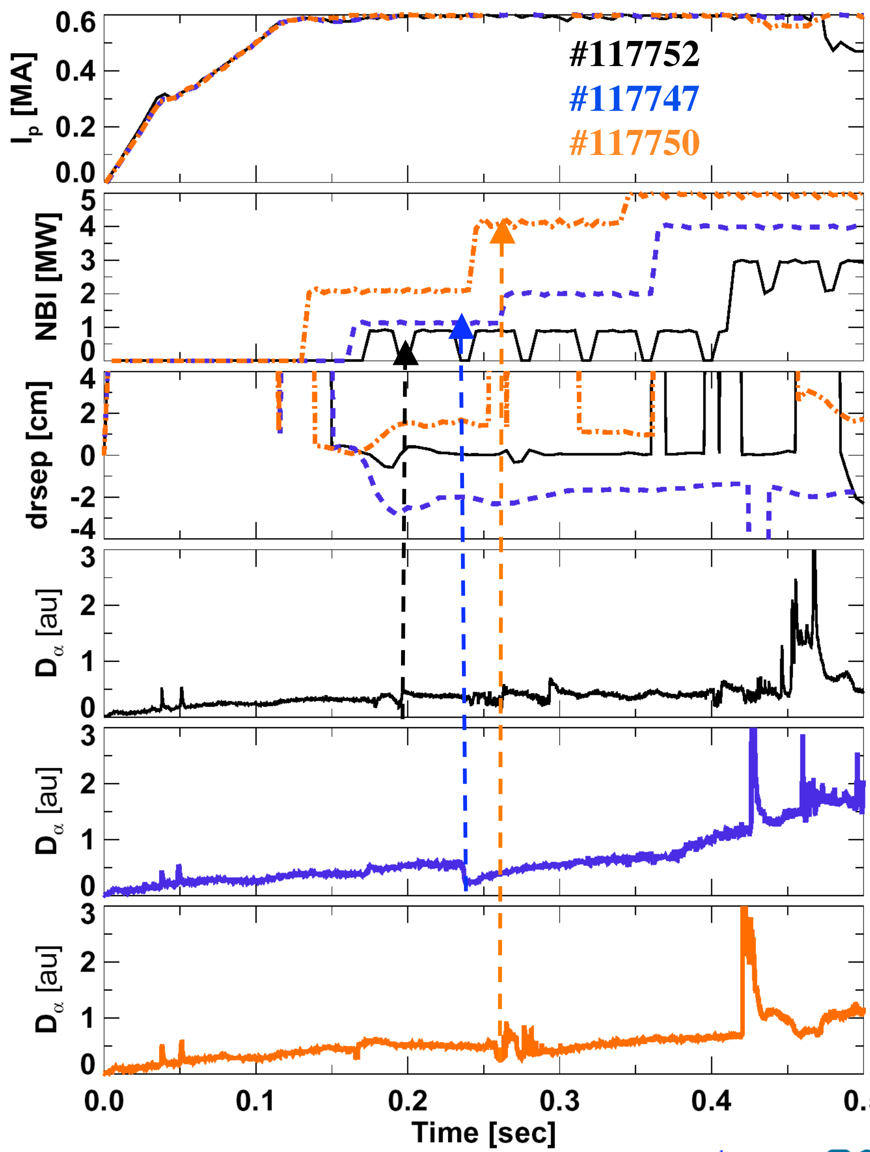
RF heated: $I_p = 0.6$ MA, $B_t = 0.45$ T

Pulse	Conf.	$d_{r,sep}$ [mm]	κ	δ_u	δ_l	P_{RF} [MW]
117767	DN	0	1.98	0.49	0.48	0.6
117776	DN	0	1.97	0.50	0.47	1.1
117777	L-SN	-5	1.89	0.36	0.45	1.7 – 2.2
117782	L-SN	-17	1.86	0.27	0.45	2.7

Ohmic: $I_p = 0.9$ MA, $B_t = 0.45$ T, -24 mm $< d_{r,sep} < 0$ (117754, 117756)

NBI heating: P_{LH} lowest in balanced DN ($d_{r,sep}$~0)





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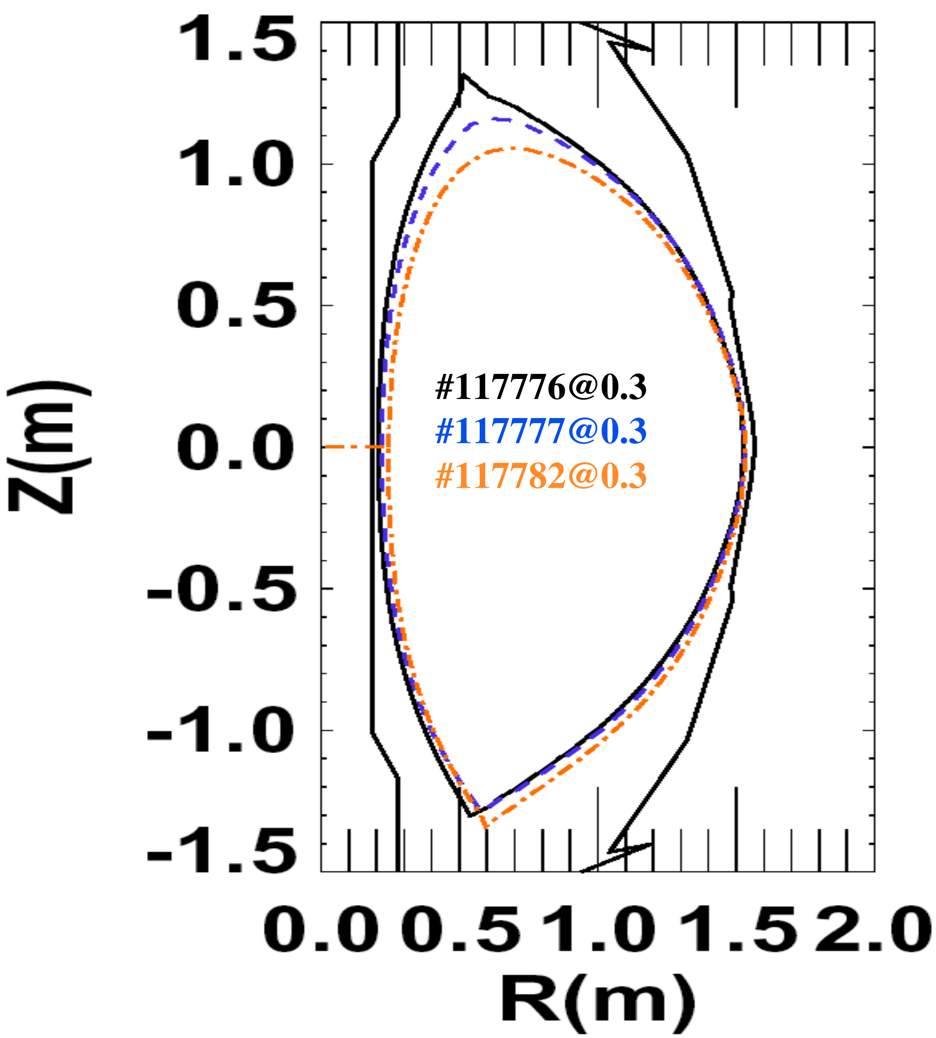
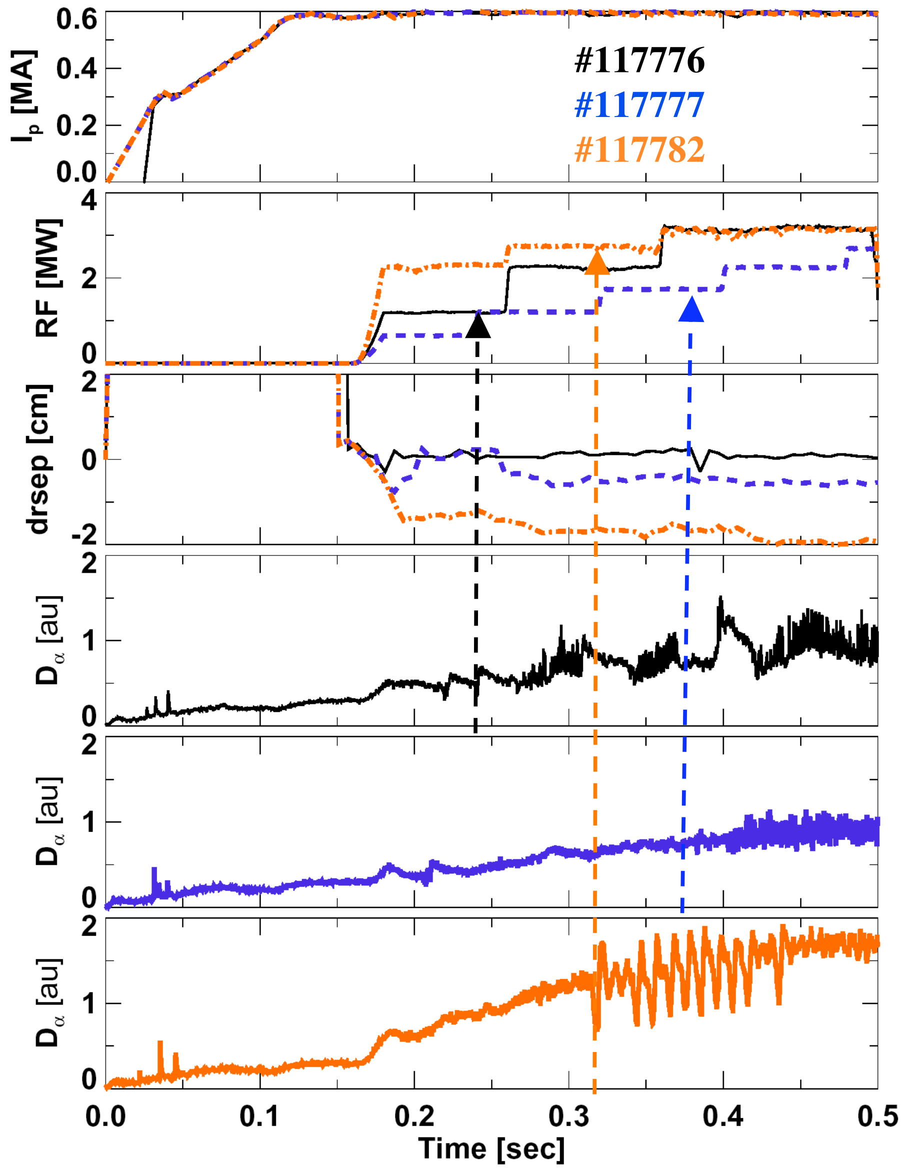
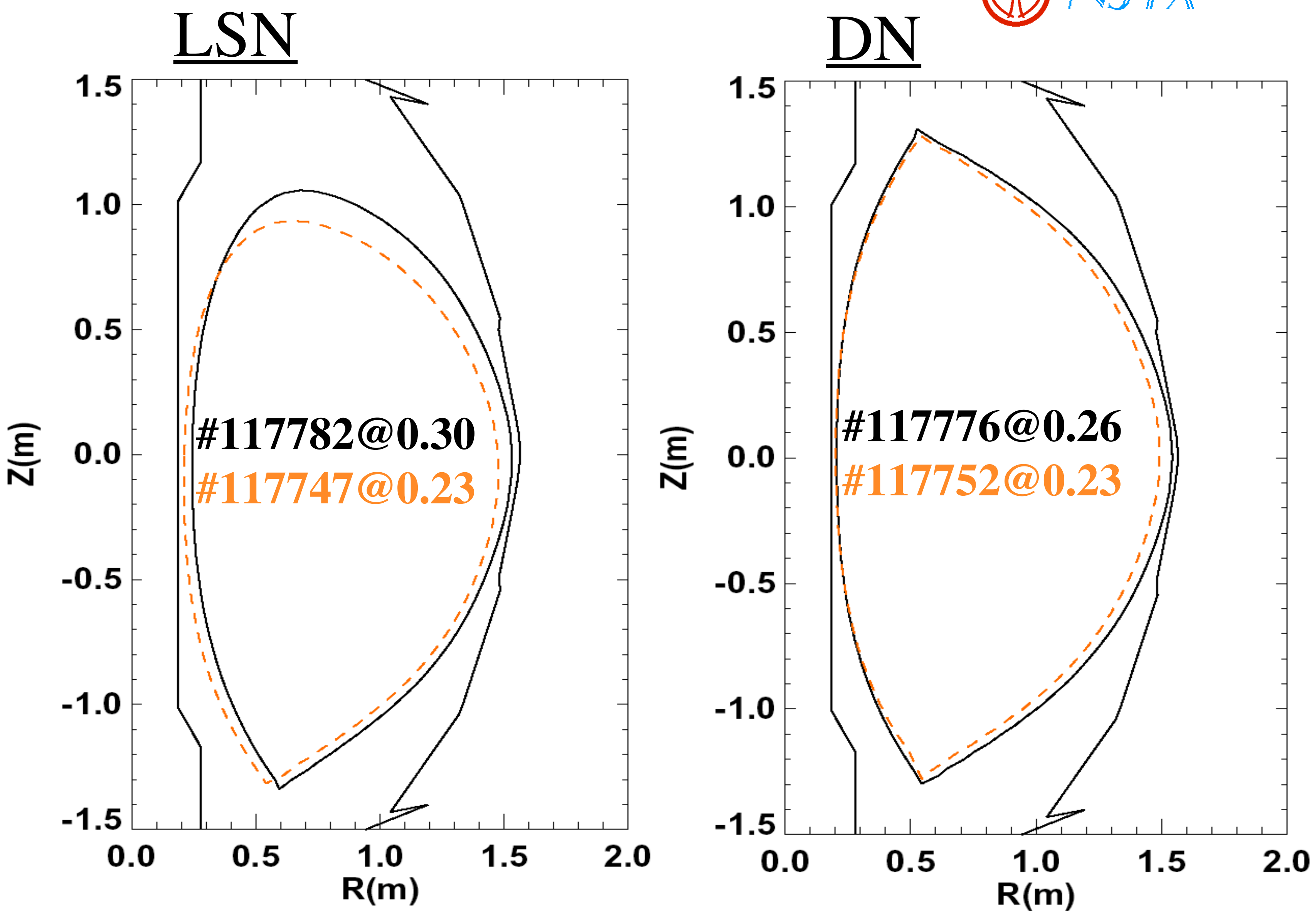
RF heating: P_{LH} increased with increasing $|d_{r,sep}|$

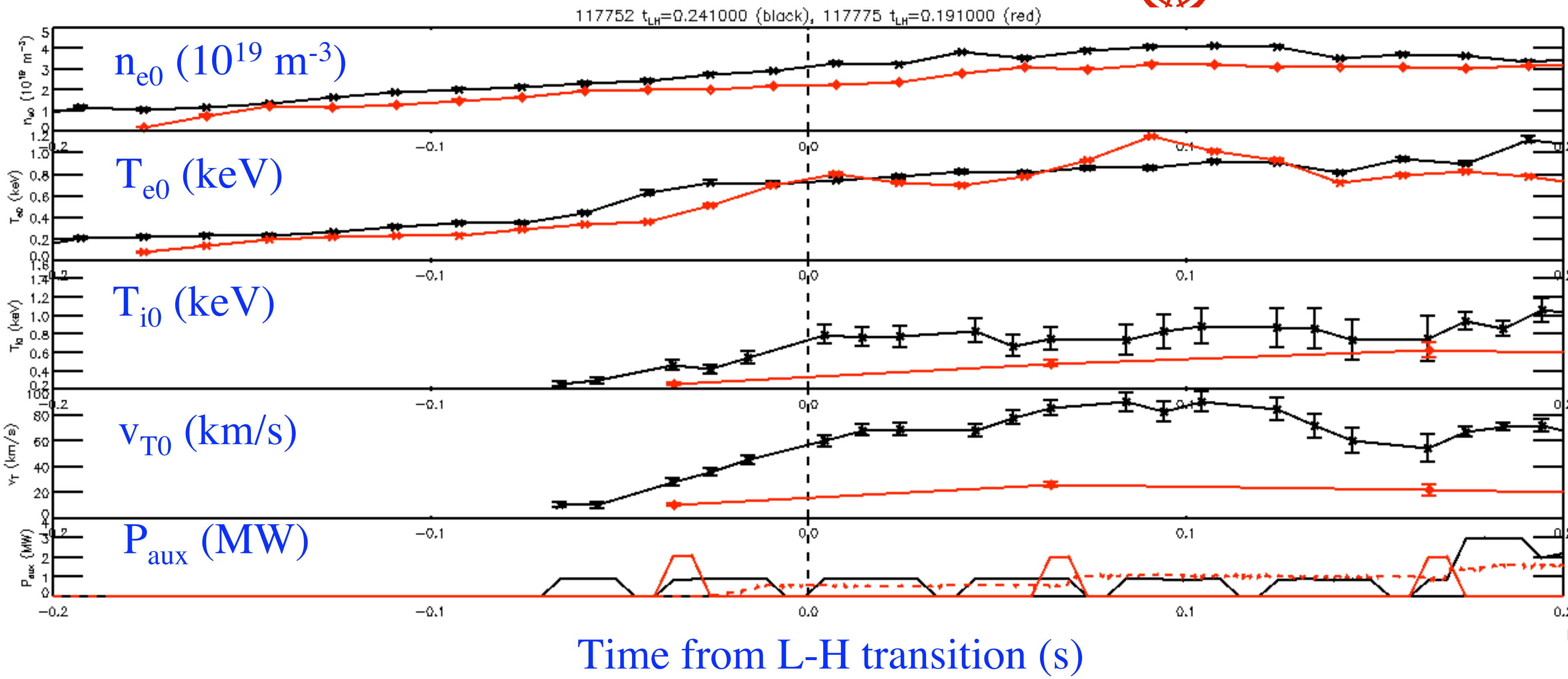




Similar shapes achieved in NBI and RF at time of L-H dithers



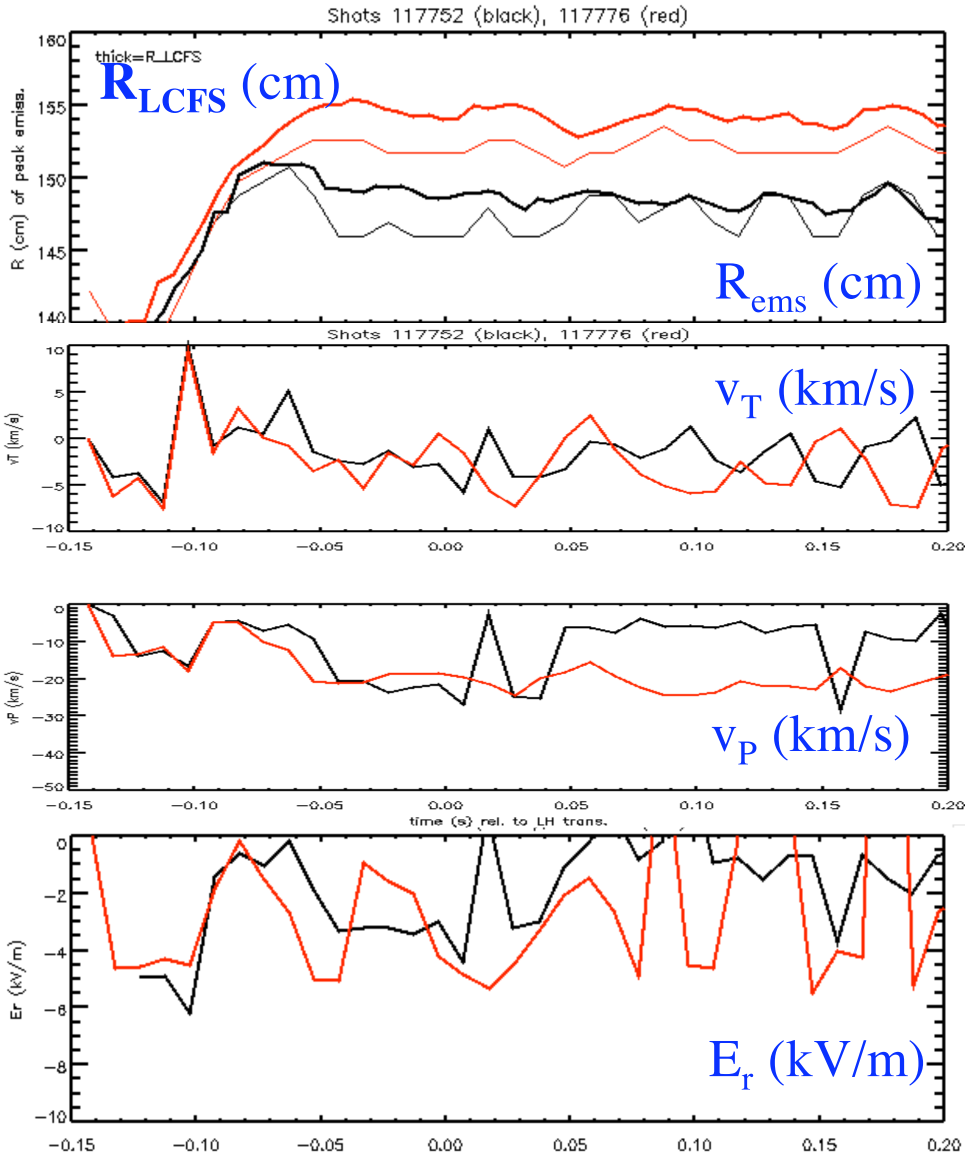
DN: NBI v. RF heated; core v. time



- T_i, v_T measurements made using CHERS
  - 10 ms NBI "blips" in RF heated plasmas

DN: NBI v. RF heated; edge v. time

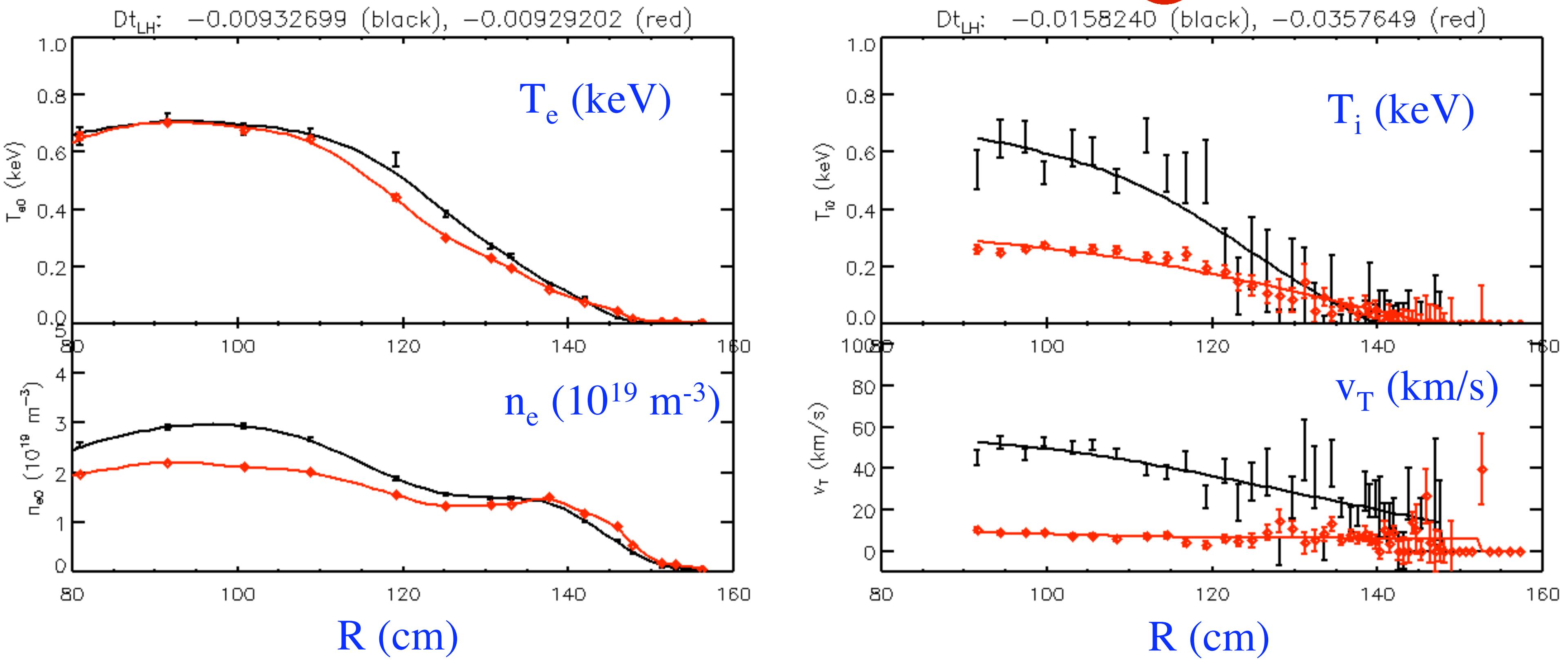
NSTX



Time from L-H transition (s)

- NBI heated pulse has 5 cm wider outer gap.
- Emission peaks inside LCFS (EFIT).
- $(v_T)_{NBI} \sim (v_T)_{RF}$
- $(v_P)_{NBI} \sim (v_P)_{RF}$
- Error in E_r is O(3 kV/m).
- Motion of emission relative to LCFS is O(chord sep.), leads to difficulty in calculating E_r.

DN: NBI v. RF heated; core profiles; L-mode



- During L-mode the core plasmas differ
  - $(T_i/T_e)_{NBI}$~1 but $(T_i/T_e)_{RF}$~0.5
  - $(v_T)_{NBI} > (v_T)_{RF}$

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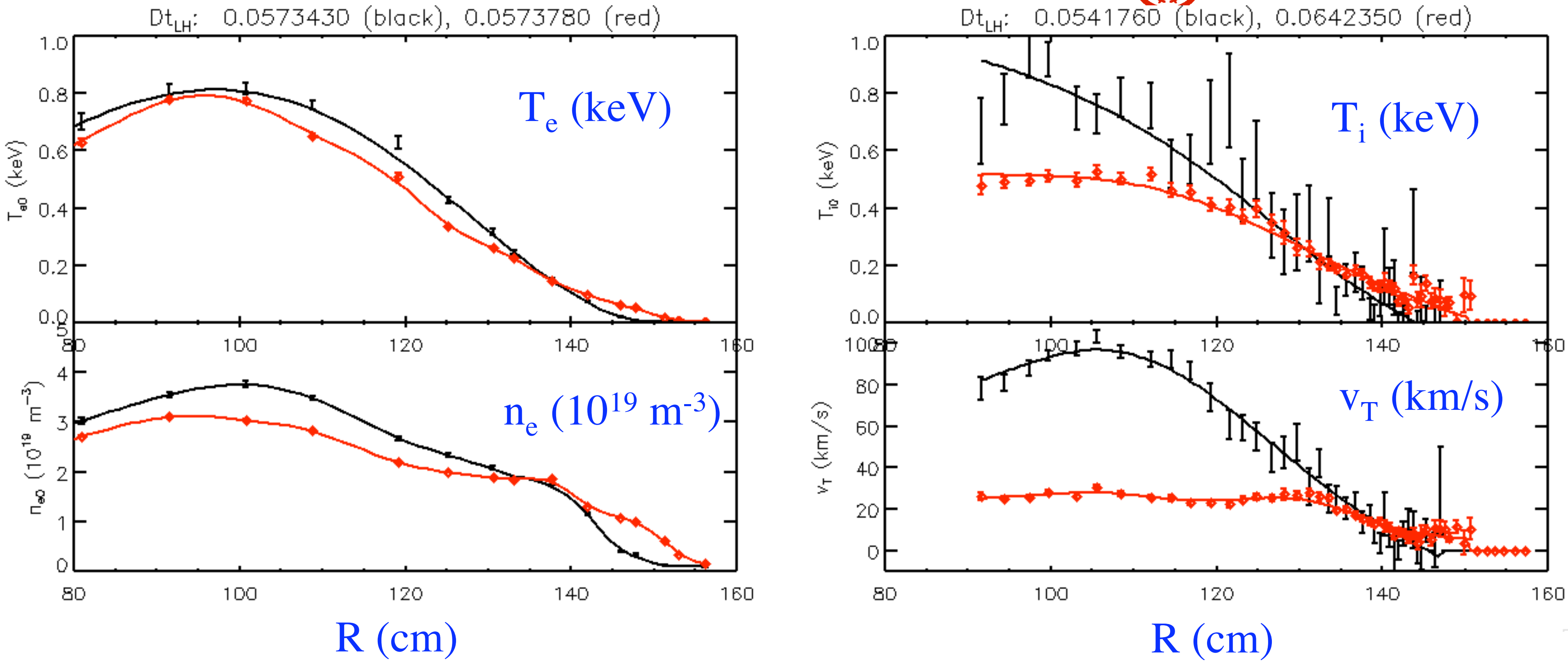
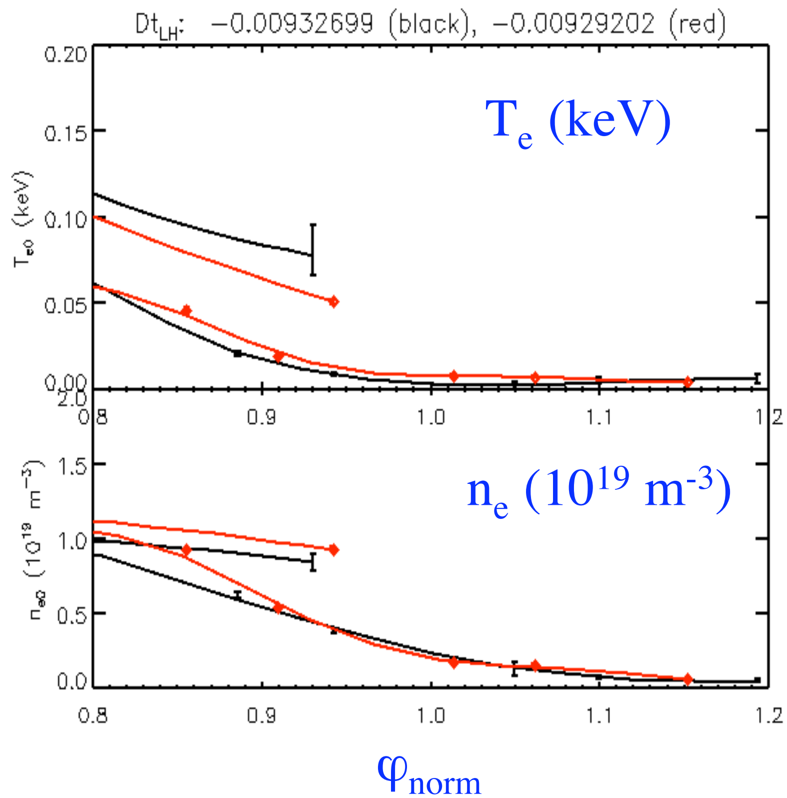
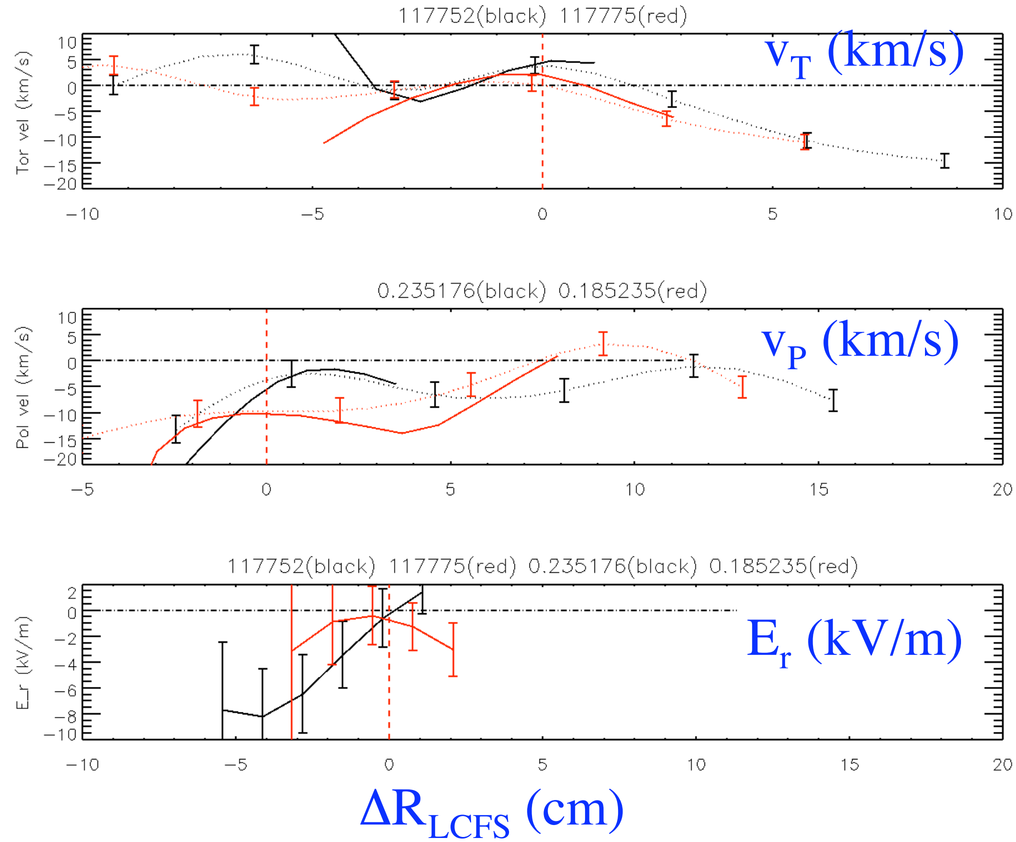
DN: NBI v. RF heated; core profiles; H-mode



- After L-to-H transition
  - T_e, T_i increase for NBI and RF heated plasmas
  - $(v_T)_{NBI} >> (v_T)_{RF}$

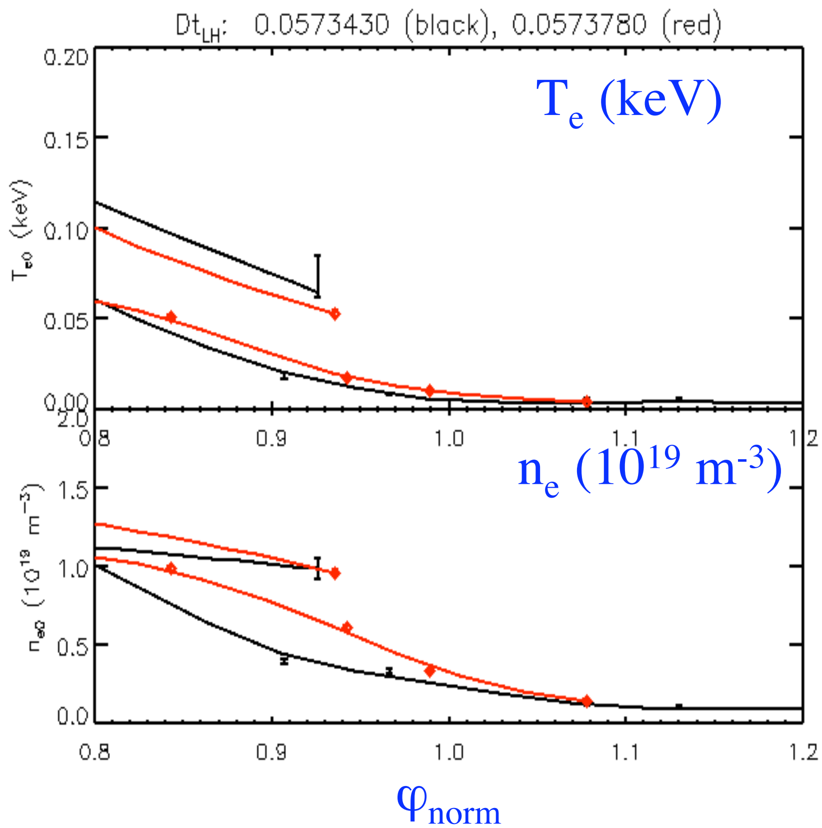
DN: NBI v. RF heated; edge profiles; L-mode

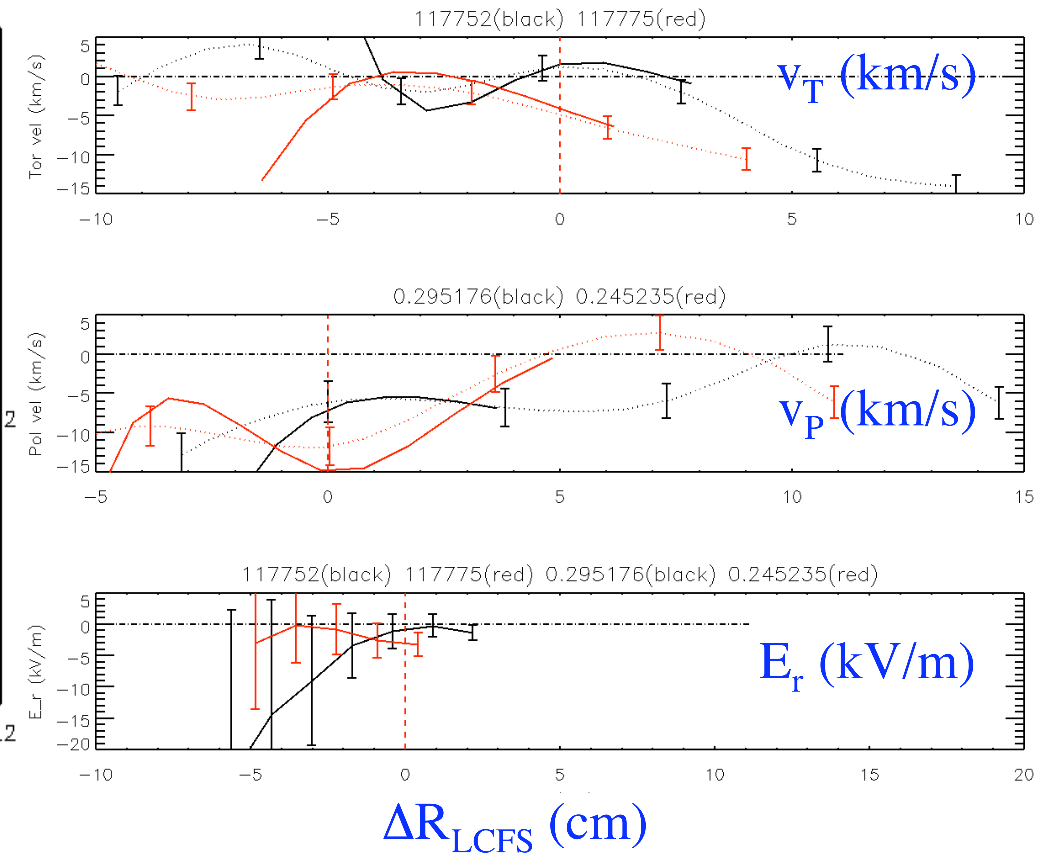




- ERD measured profiles of NBI and RF parameters are within experimental errors prior to H-mode.

DN: NBI v. RF heated; edge profiles; H-mode





- During H-mode less agreement between edge ion parameters, especially v_T

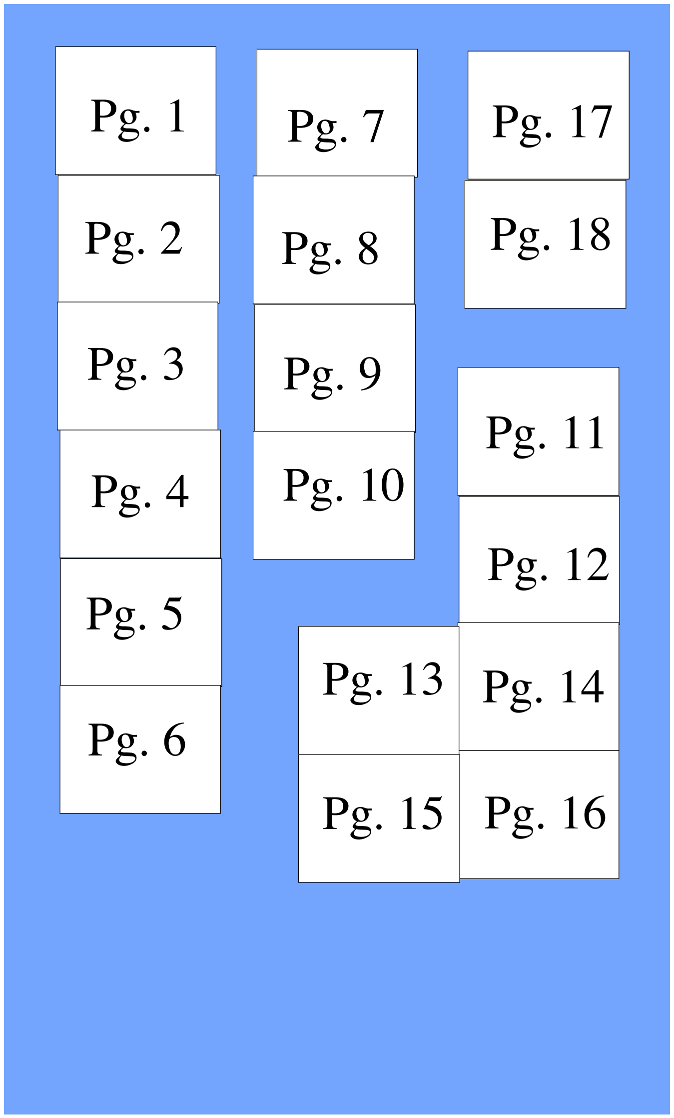
Summary

- Comparisons between NBI and RF heated plasmas find similar P_{LH} for similar magnetic configuration, e.g. LSN, DN.
  - Pre- & during H-mode: $(T_{e0}/T_{i0})_{NBI} \sim 1$, $(T_{e0}/T_{i0})_{RF} \sim 2$
  - Strong plasma rotation not required for H-mode access.
  - Edge: T_e, n_e, T_i, E_r similar for NBI and RF plasmas
- Edge parameters more important for L-H transition than core parameters.
- $(P_{LH})_{DN} < (P_{LH})_{LSN} < (P_{LH})_{USN}$
  - Ion ∇B drift towards lower X-point

Future Work

- Conduct a more thorough examination of edge and scrape-off layer v_θ, v_ϕ, and E_r from Edge Rotation Diagnostic.
- Use LRDFIT04 to get a more accurate location of the separatrix.
- Determine available fluctuation data: reflectometry, correlation reflectometry, gas puff imaging.
- Use TRANSP to get absorbed power.
- Use NCLASS to get linear growth rates; compare to E×B shearing rate.

Poster Arrangement



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