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NSTX

Results from MHD XP's 711 and 724

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NSTX Results Review

July 23-24, 2007
Princeton Plasma Physics Laboratory

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ISD XP-711 - Improved break-down scenario for higher q during I_P ramp

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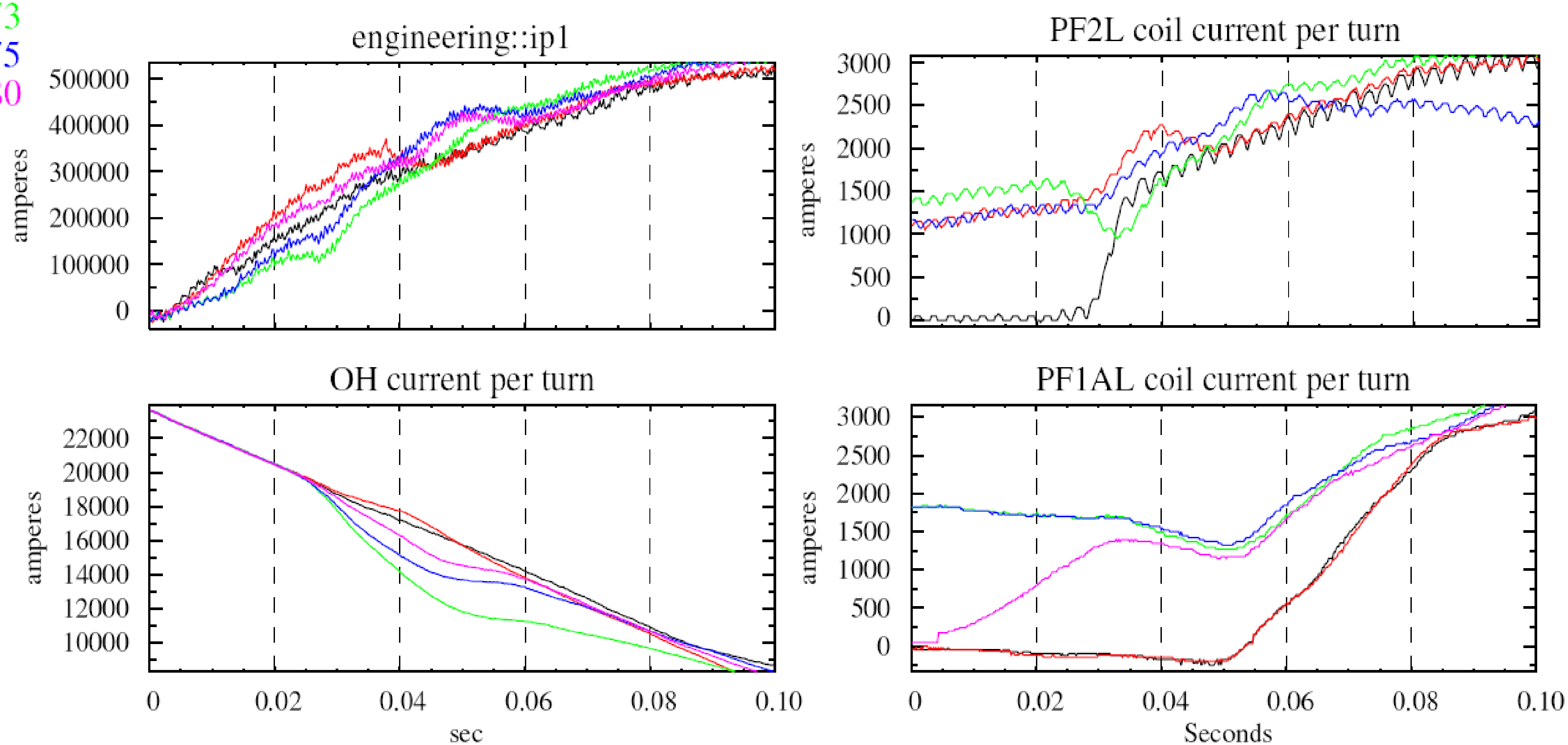
- Found PF2 and PF1A coil currents that can allow stable high elongation and diverted plasma by t=45ms
  - H-mode measured as early at t=65ms for a few shots
- New breakdown incorporated into XP-710 shots
- Starting from XP-711 → XP-710, XP-724 successfully linked PF1B LSN early H-mode with rtEFIT controlled LSN

- New breakdown scenario successful in increasing early safety factor values (demonstrated in XP724, XP710)

Divertor coil currents scanned during breakdown to increase elongation until field-null is degraded or lost

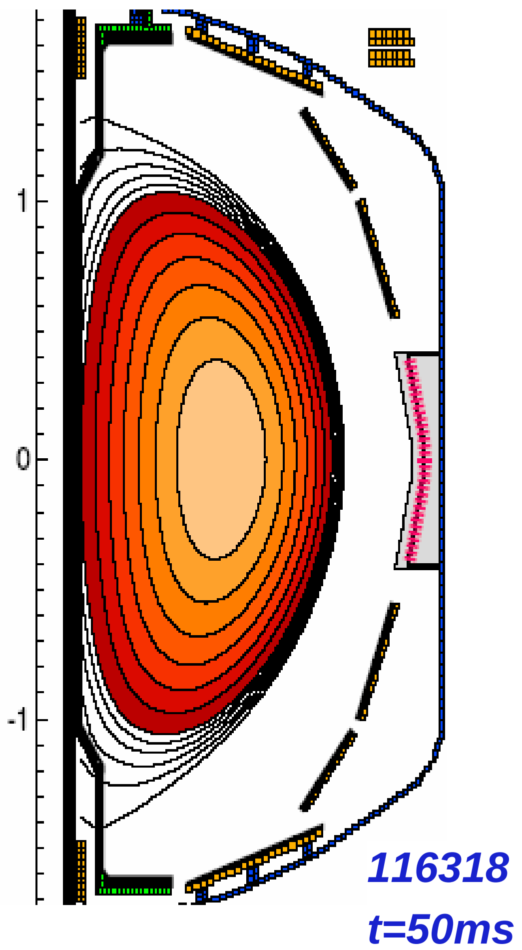
- PF2 and PF1A usually at zero current during breakdown
- I_P actually increased with addition of 1kA of PF2 current
  - Consistent with improved null quality at breakdown
- High PF1A and PF2 eventually degrade null, breakdown lost

116313
122383
122673
122675
122680

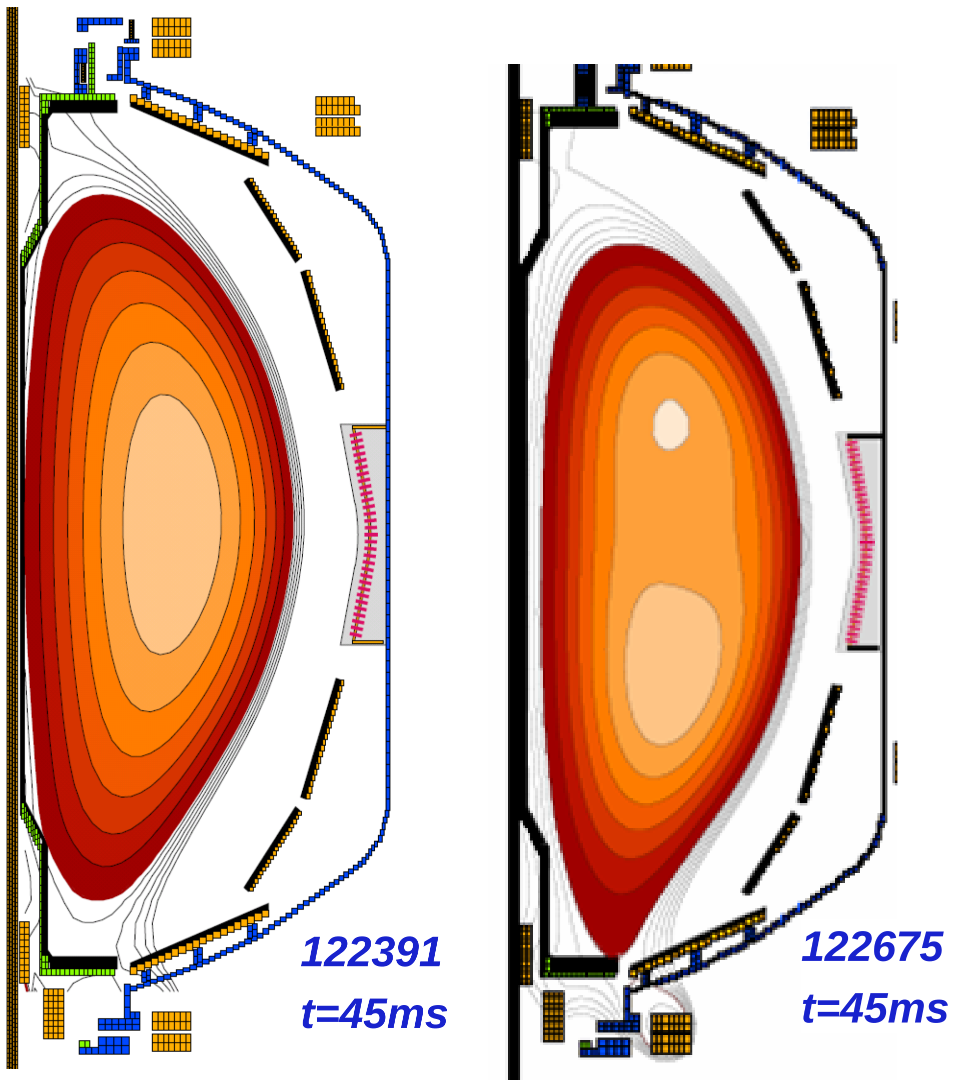


Divertor coil current during break-down enables increased ramp-up elongation and very early diverting

- Plasma shape during I_P ramp with old breakdown

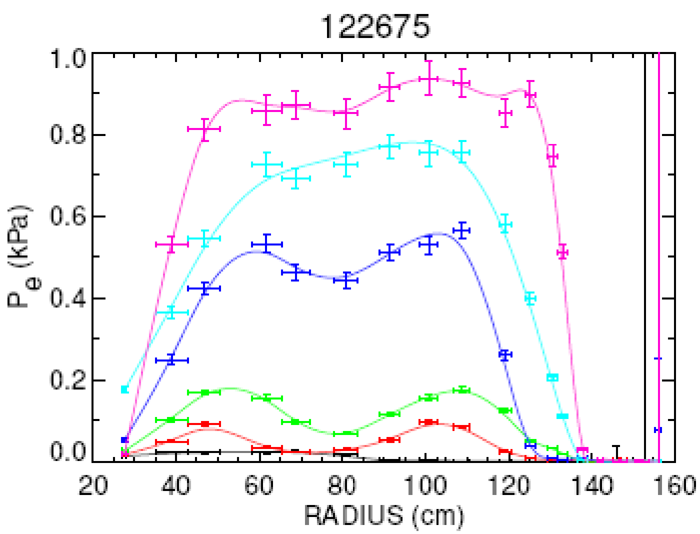


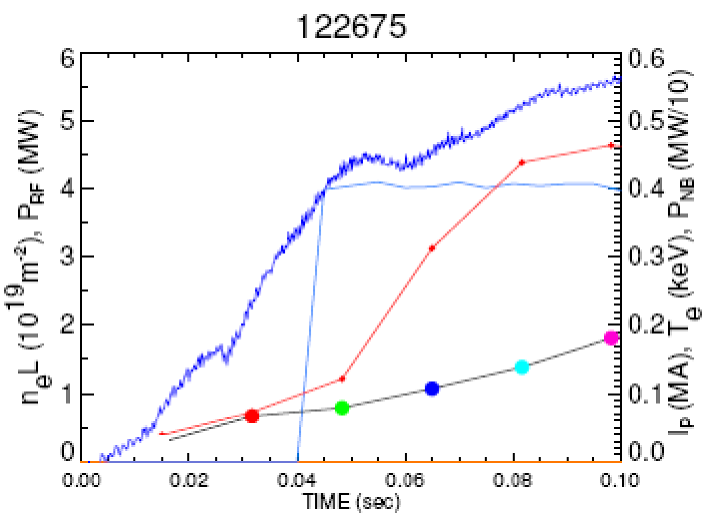
- Plasma shape w/ new breakdown

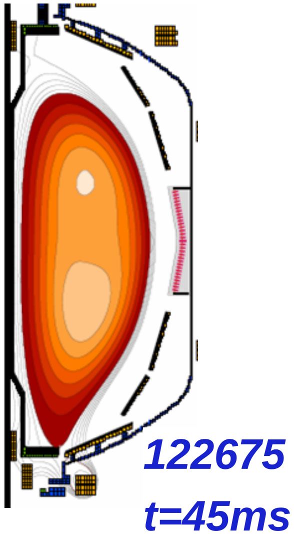


Very early H-mode possible with early diverting

- Found PF2 and PF1A coil currents that can allow stable high elongation and diverted plasma by t=45ms
- H-mode measured as early at t=65ms for a few shots
  - Very early H-mode initially not reproducible due to radial position oscillation from t=40-100ms (no H-mode when inner gap is small)
  - Reliable early H-mode (70ms) eventually obtained
  - But, power threshold higher than in previous years (up to 6MW)
    - Due to increased He, lower density, or metallic impurities?

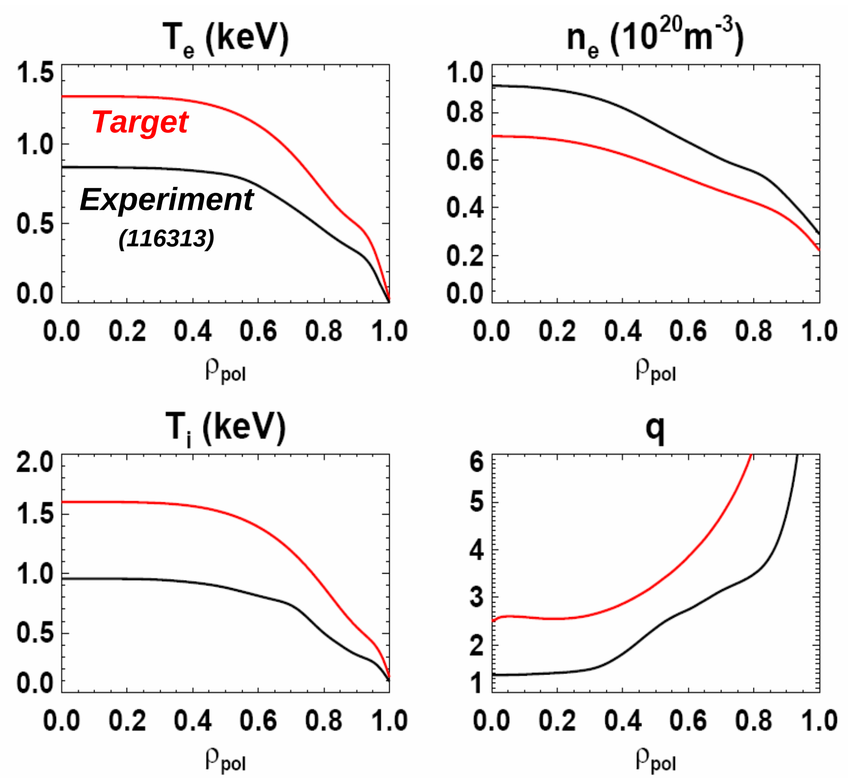






XP-724 motivation: Fully non-inductive scenario requires higher confinement, higher *q*, strong plasma shaping

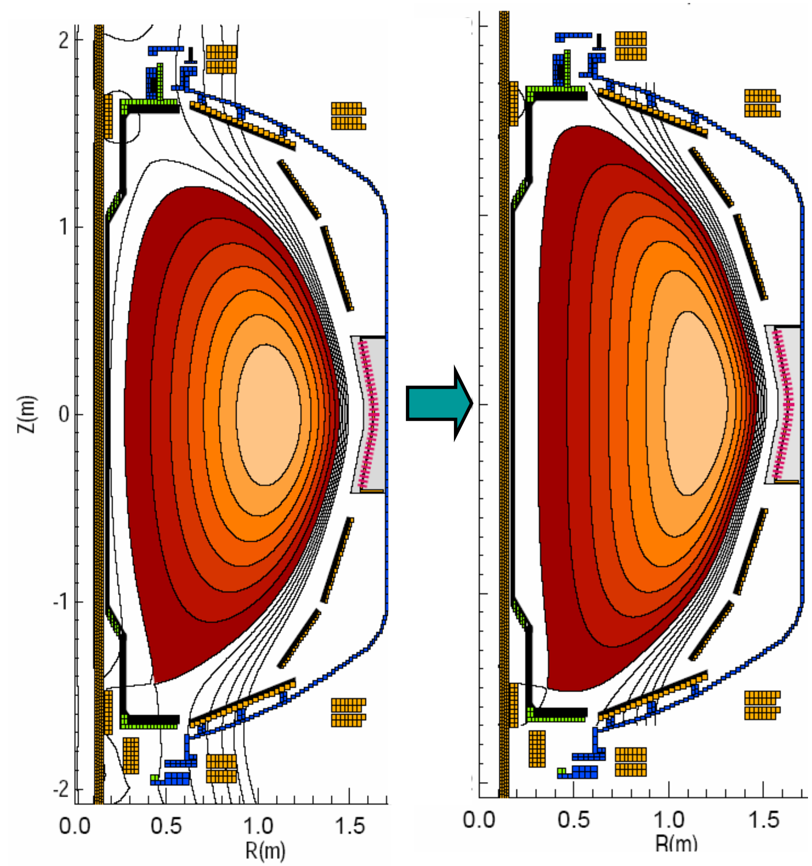
- Need 60% increase in T, 25% decrease in n_e
  - **Lithium for higher τ_E & density control?**
    - **20% increase in thermal confinement**
    - **30% increase in HH_{98}**
  - **Core HHFW heating**
- Want $q_0 \approx q_{min} \approx 2.4 \Rightarrow$ higher with-wall limit



- Higher κ for higher q, β_P, f_{BS}
- High δ for improved kink stability

κ= 2.3, δ_{X-L} = 0.75
δR_{SEP} = -1cm

κ= 2.6, δ_{X-L} = 0.85
δR_{SEP} = -2mm



ISD XP-724 - Stability and NICD limits with lower density and higher q_{MIN}

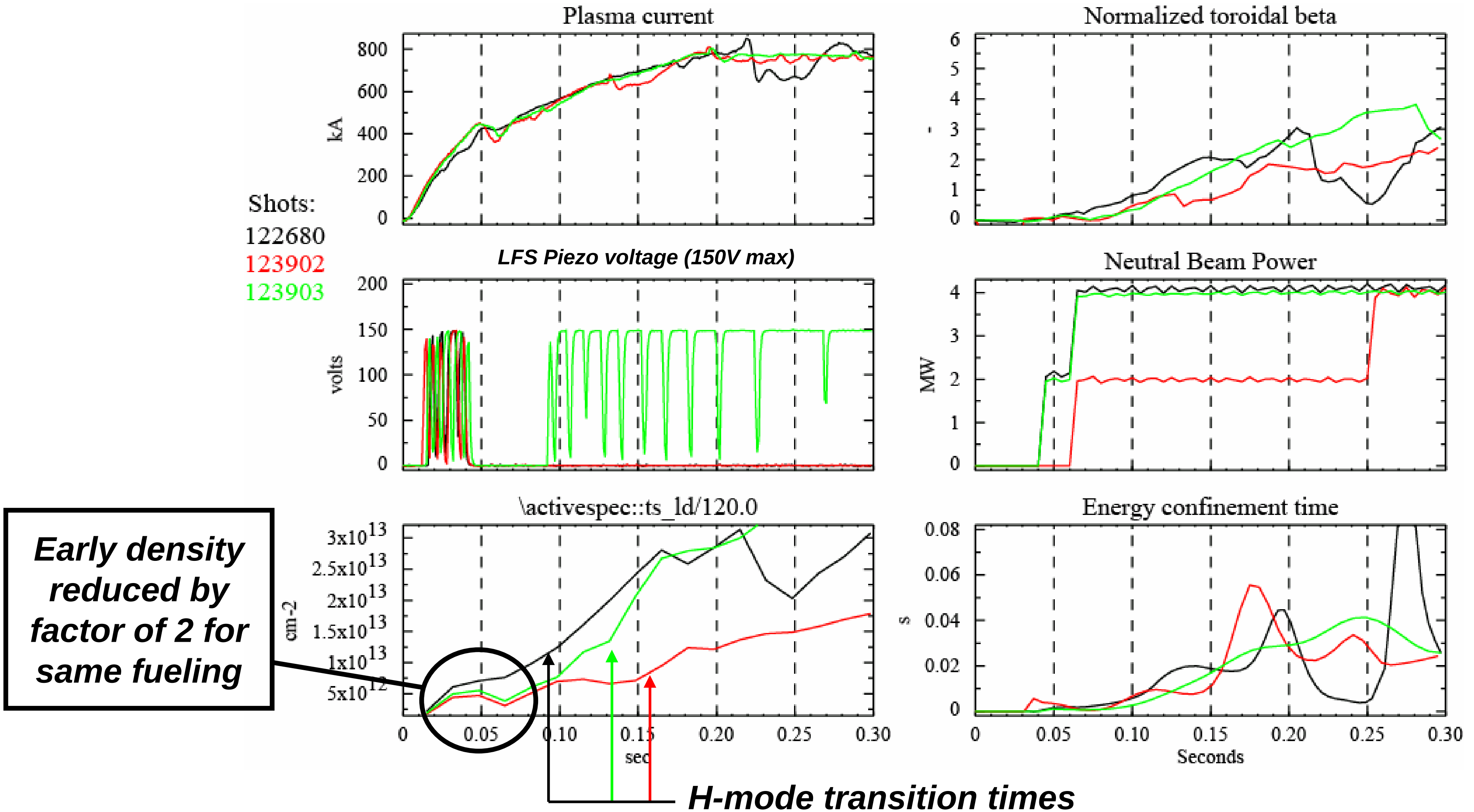
- Demonstrated confinement increase with LITER
  - Reduced internal inductance, higher elongation, etc
- Demonstrated significant density pumping with LITER
  - Obtained at highest evaporation rates = 35-40mg/s
  - But, we did not use these high rates for most experiments
    - LITER ran out of Lithium and had to be refilled during run
    - Concern over iron impurities coincident with LITER operation
    - Not enough time to develop fueling of very low density discharges
- q_{min} elevated with high-κ breakdown + LITER
- Resultant q profile apparently unstable - likely 2/1 NTM
  - Poloidal beta limited to < 1.4 (not a β_N limit)
  - But need to determine eigenstructure for mode identification

High LITER evaporation rates (30-40mg/min) with 7 min He glow can significantly increase D pumping

Black → reference discharge w/o LITER from 2007

Red → with 35mg/min LITER (different beam programming unfortunately)

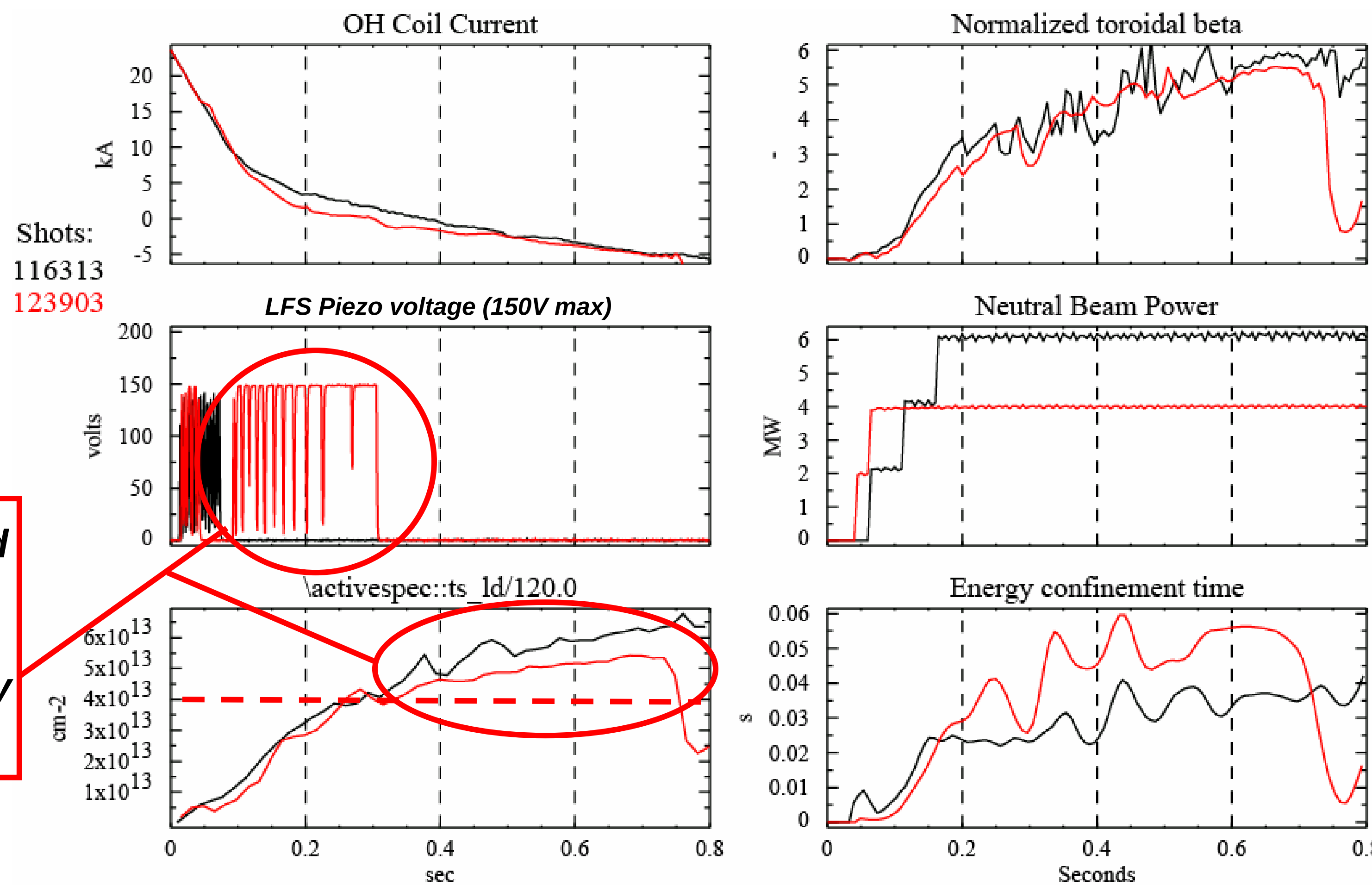
Green → Strong LFS fueling needed in I_P ramp to match reference



LITER → Achieve same β_N and flux consumption of previous long-pulse discharges with 1/3 less NBI power (using NBI A+C) and at lower density

Black → w/o LITER - 2005 long-pulse discharge at 750kA and 4.5kG

Red → with LITER, same β_N → 5-5.5 with 2 sources → τ_E = 35ms → 55ms

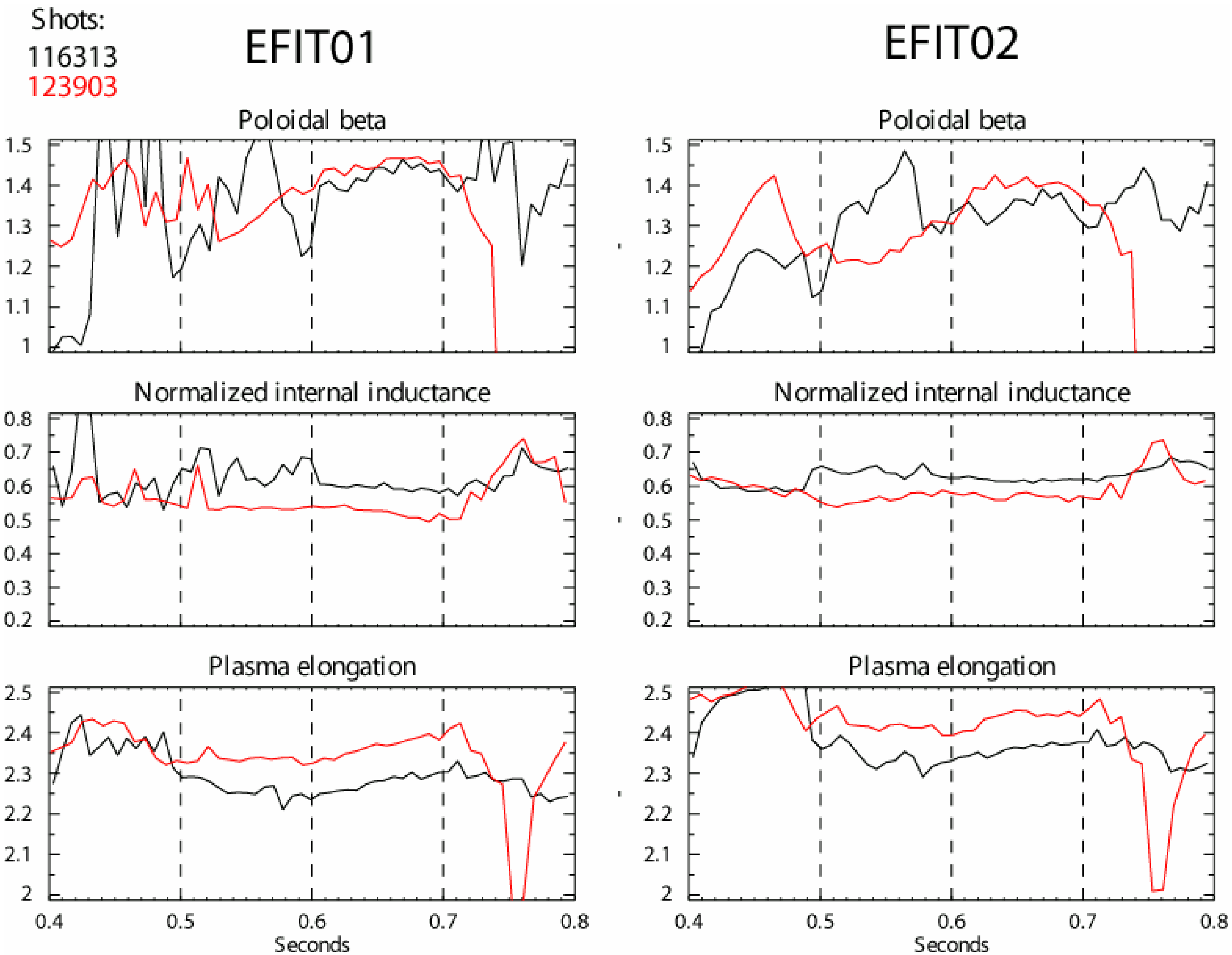


Note lower n_e and slower rate of density rise with much higher early LFS gas fueling

- ***ISD Goal: try to achieve constant $\bar{n}_e$ in flat-top ($4x10^{19}m^{-3}$) using shoulder and SGI fueling***

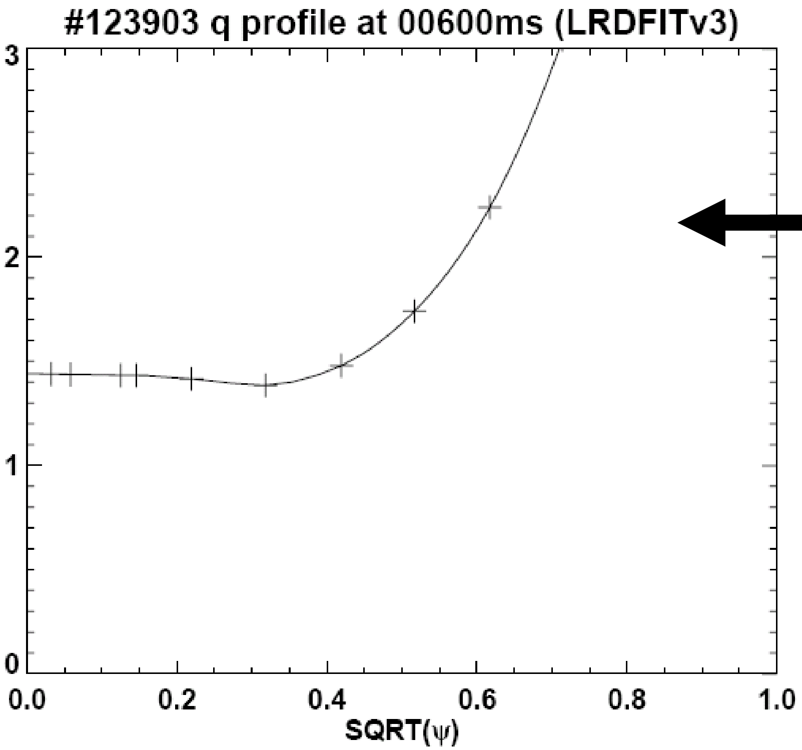
LITER → Achieve lower l_i and higher κ compared to reference

Black → w/o LITER - 2005 long-pulse discharge at 750kA and 4.5kG
Red → with LITER, l_i decreases 10-20% → κ = 2.35 → 2.45 (goal is 2.6)



- ***ISD Goal: try to achieve κ = 2.6 LSN at high β_N and high δ***

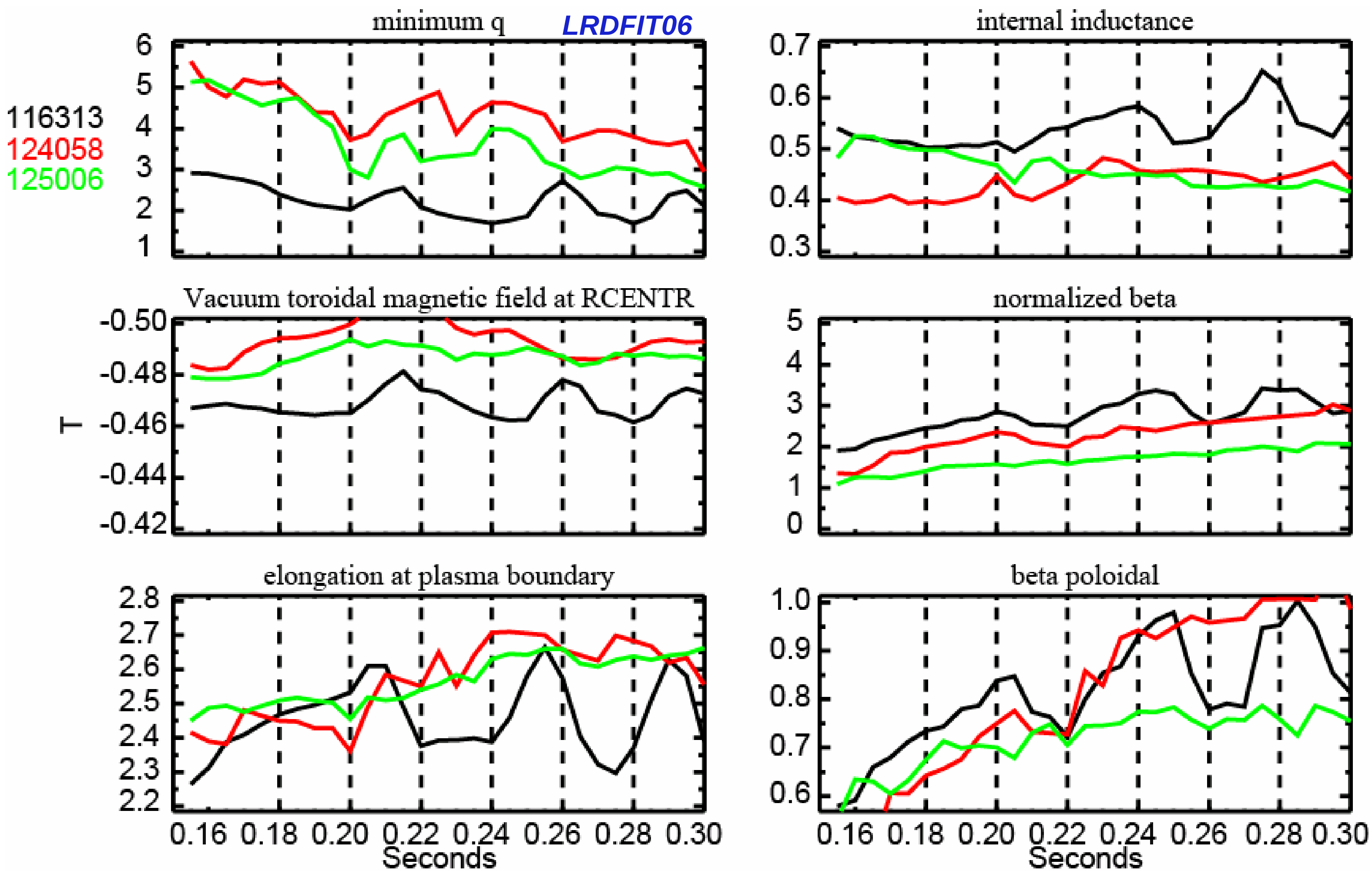
LITER shots that achieve high β_N have $q_{min} \rightarrow 1.3$ with nearly monotonic q profile



- High β_N LITER shots similar to high β_N shots of 2005 which had $q_{min} < 1.5$
  - High shear at q=2 surface beneficial for TM stability?
- Shots avoid low-f tearing activity during high β_N phase.

High-κ breakdown scenario + LITER (15-20mg/min) successfully increased q early in discharge

- In first 300ms, q_{min} > 3, l_i = 0.45, κ = 2.6-2.7
  - Previous long-pulse shots (116313) had q_{min} → 2 by t=0.2s



q profile remains systematically elevated w.r.t. previous long-pulse, and evolves toward $q_{min} \rightarrow 1.4$

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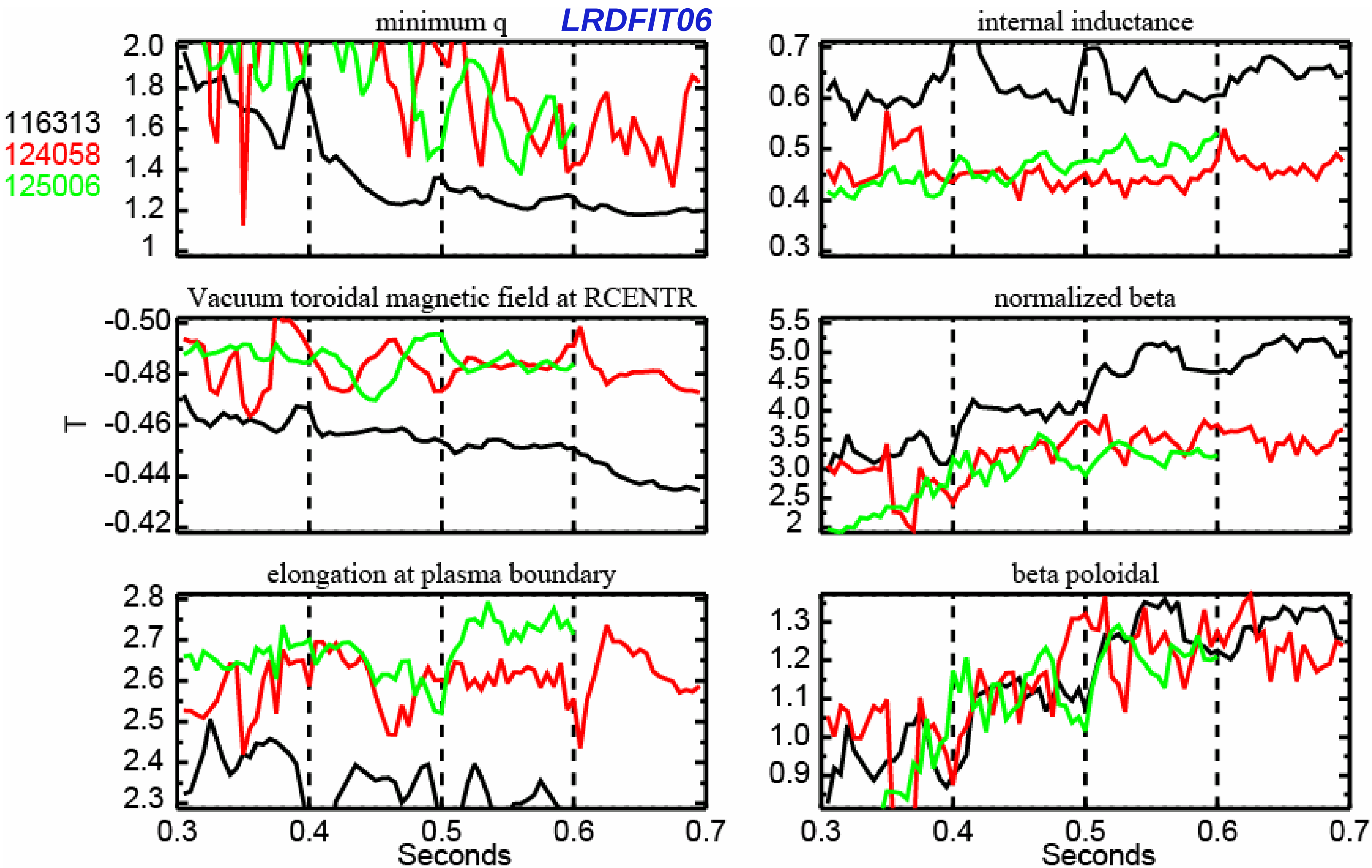
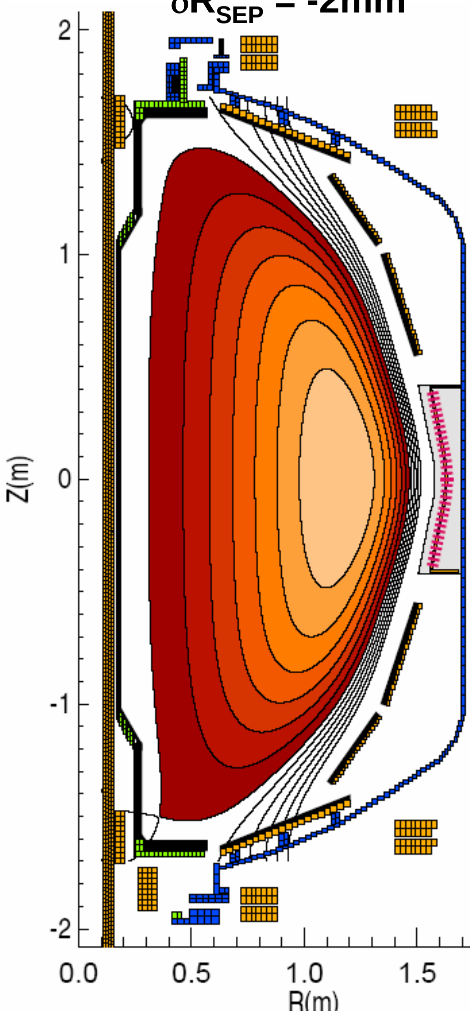
- q_{min} = 2 enters plasma at t=400-500ms, l_i < 0.5, κ = 2.6-2.8



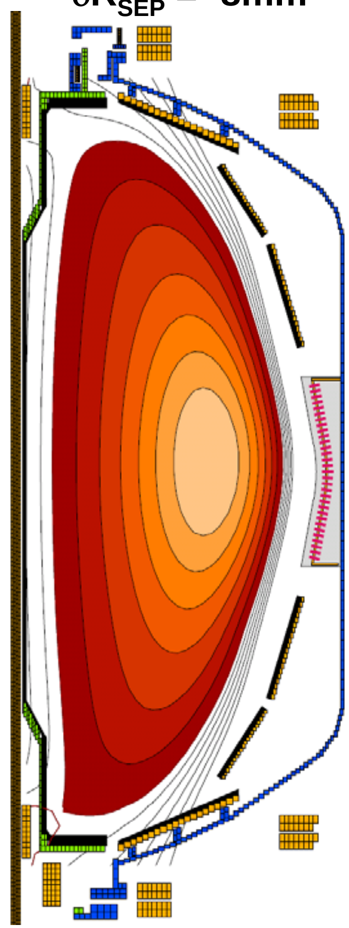
Plasma shape achieved very close to desired target shape

High q_{min} TARGET ***125006, 550ms (LRDFIT06)***

κ= 2.6, δ_{X-L} = 0.85
δR_{SEP} = -2mm



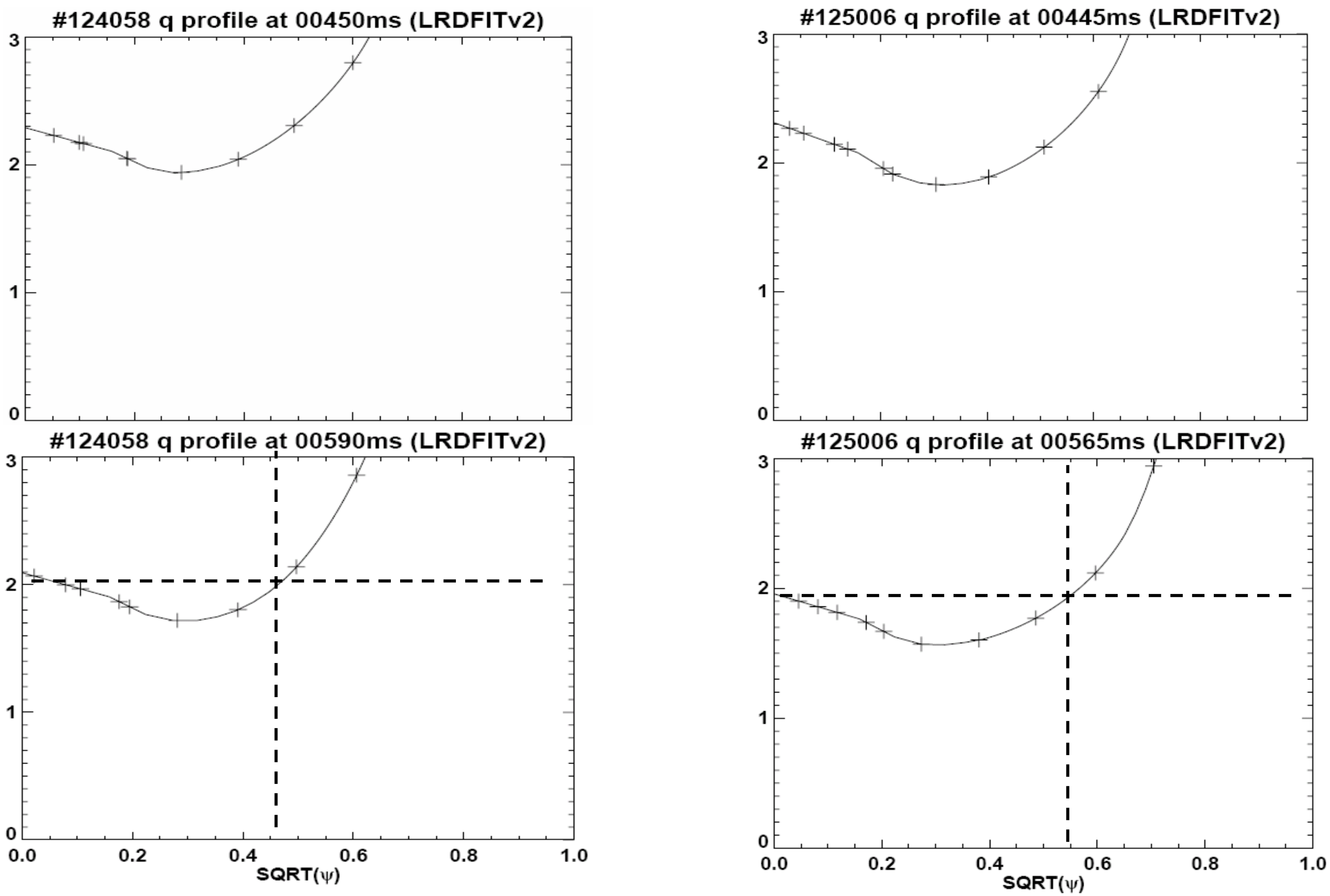
κ= 2.75, δ_{X-L} = 0.85
δR_{SEP} = -8mm



- Shape development needed to match target:
  - Decrease outer gap
  - Increase upper δ
  - Increase squareness

Elevated q_{min} shots from XP710 and 724 (both w/ high-κ breakdown + LITER) have weak q-reversal during high β_P phase

- q_{min} = 2 radius is near ρ_{pol} = 0.45-0.55 late in both discharges
  - Carbon impurity rotation frequency near this radius = 17-22kHz



Core n=1 MHD activity associated with q=2 surface may explain β_P = 1.3-1.4 saturation in high q_{min} discharges

- n=1 mode propagation frequency ≈ 20kHz consistent with rotation frequency near q=2 surface
  - Need to determine eigenstructure of mode – is it **NTM** or other?