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Stability and NICD limits with lower density and higher q_{MIN}

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XP review

June 12, 2007
Princeton Plasma Physics Laboratory

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Stable & fully non-inductive target scenario utilizing only NBI and BS current drive has been identified

Present high-f_{NI} long-pulse H-modes:

I_P = 750kA

$\beta_N < 5.6$, $\beta_P < 1.5$, $\beta_T < 17\%$

l_i = 0.6, q_{min}=1.3, B_T=4.5kG

$\kappa = 2.3$, $\delta_{X\text{-}L} = 0.75$, q*=3.9

Target scenario:

I_P = 700kA

$\beta_N = 6.7$, $\beta_P = 2.7$, β_T =15%

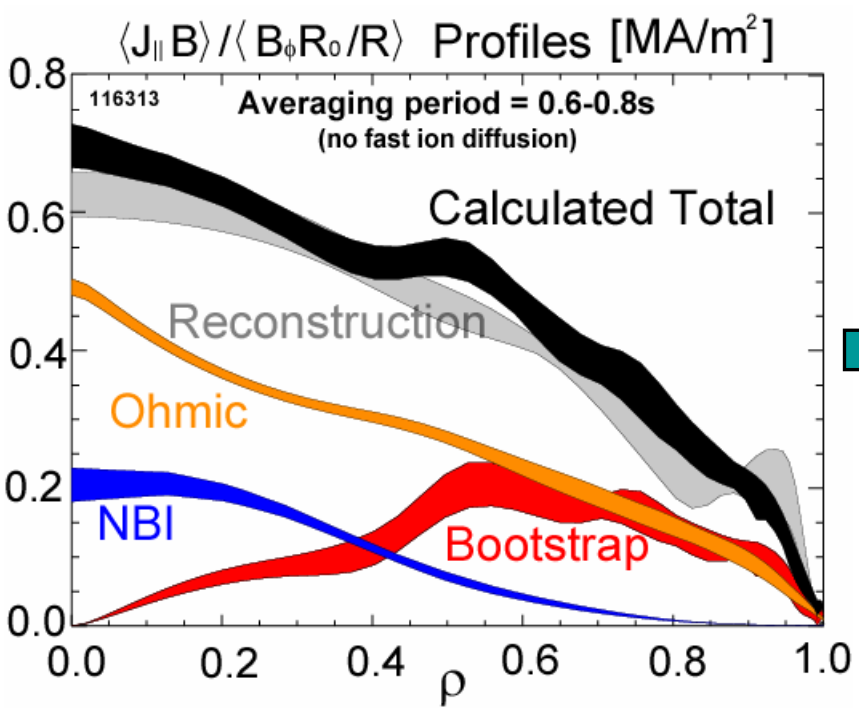
l_i = 0.5, q_{min} = 2.4, B_T=5.2kG

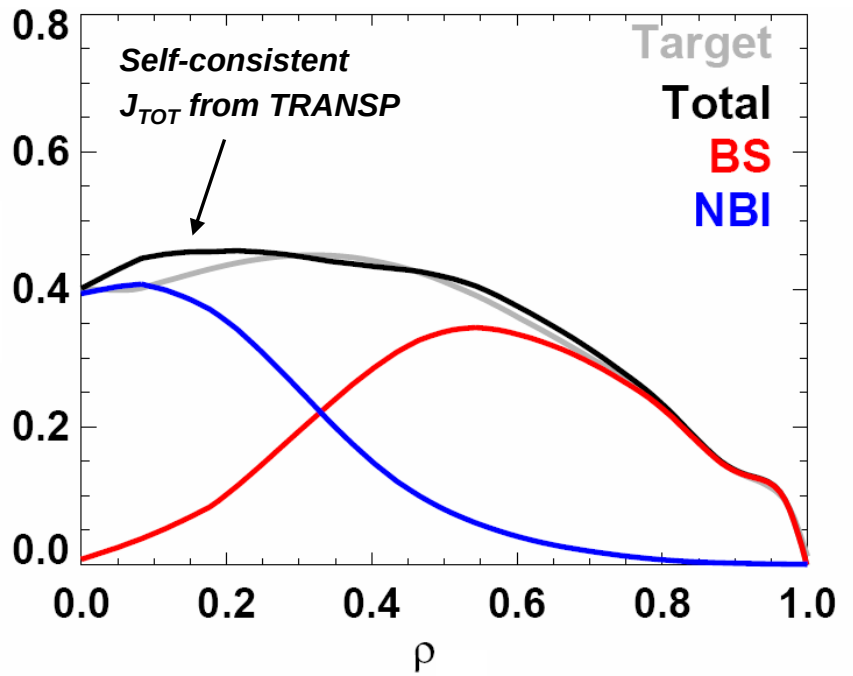
$\kappa = 2.6$, $\delta_{X\text{-}L} = 0.85$, q*=5.6

Inductive current drive is replaced by:

Higher J_{NBI} from higher T_e

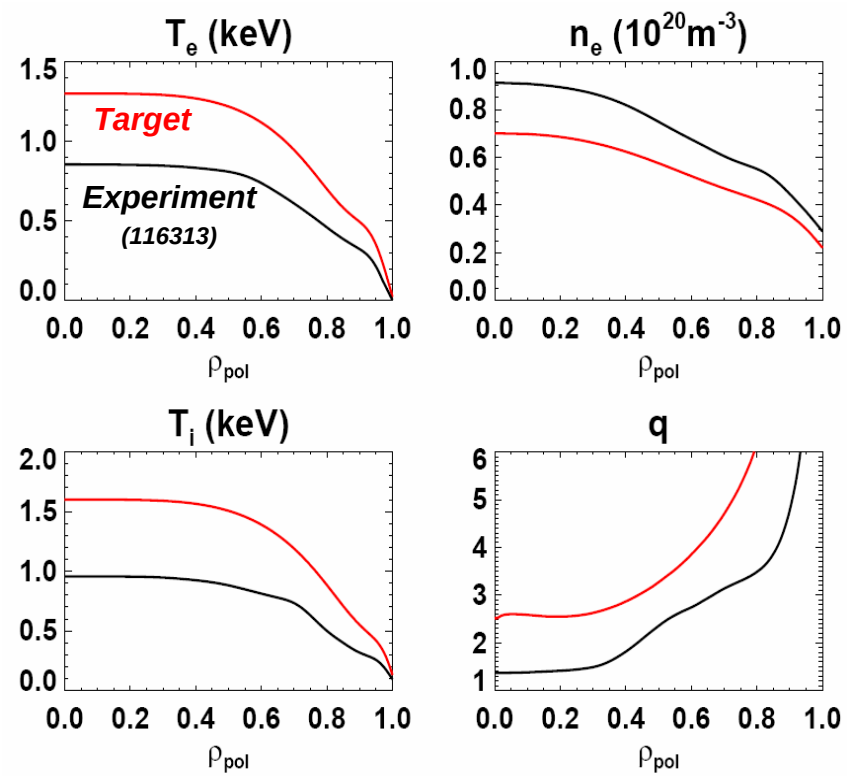
Higher J_{BS} from higher $\beta_{P\text{-thermal}}$





Fully non-inductive scenario requires higher confinement, higher *q*, strong plasma shaping

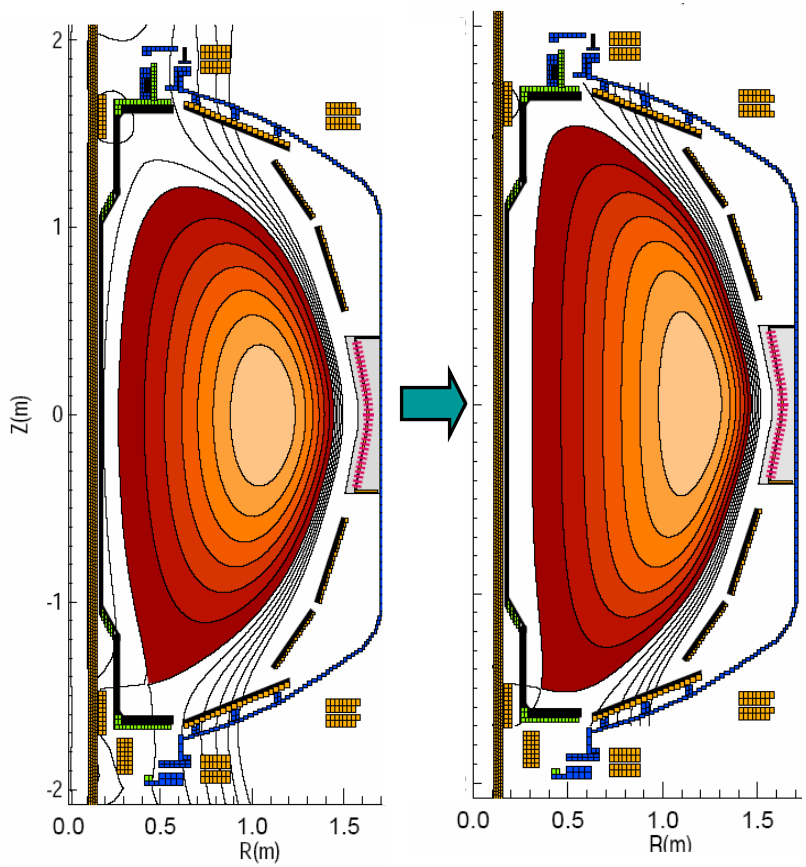
- Need 60% increase in T, 25% decrease in n_e
  - **Lithium for higher τ_E & density control?**
    - **20% increase in thermal confinement**
    - **30% increase in HH_{98}**
  - **Core HHFW heating**
- Want $q_0 \approx q_{min} \approx 2.4 \Rightarrow$ higher with-wall limit



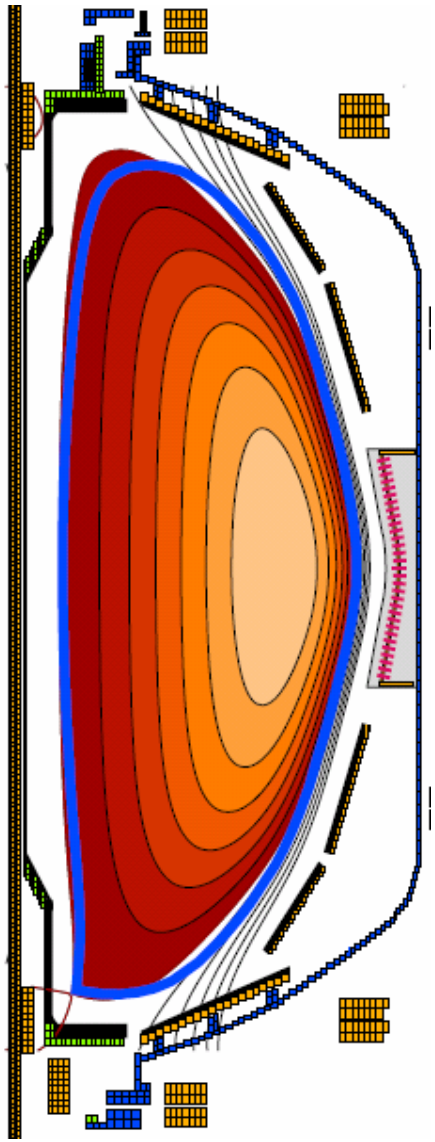
- Higher κ for higher q, β_P, f_{BS}
- High δ for improved kink stability

κ= 2.3, $\delta_{X\text{-}L}$ = 0.75
δR_{SEP} = -1cm

κ= 2.6, $\delta_{X\text{-}L}$ = 0.85
δR_{SEP} = -2mm



Shape achieved in XP710 is very close to target shape



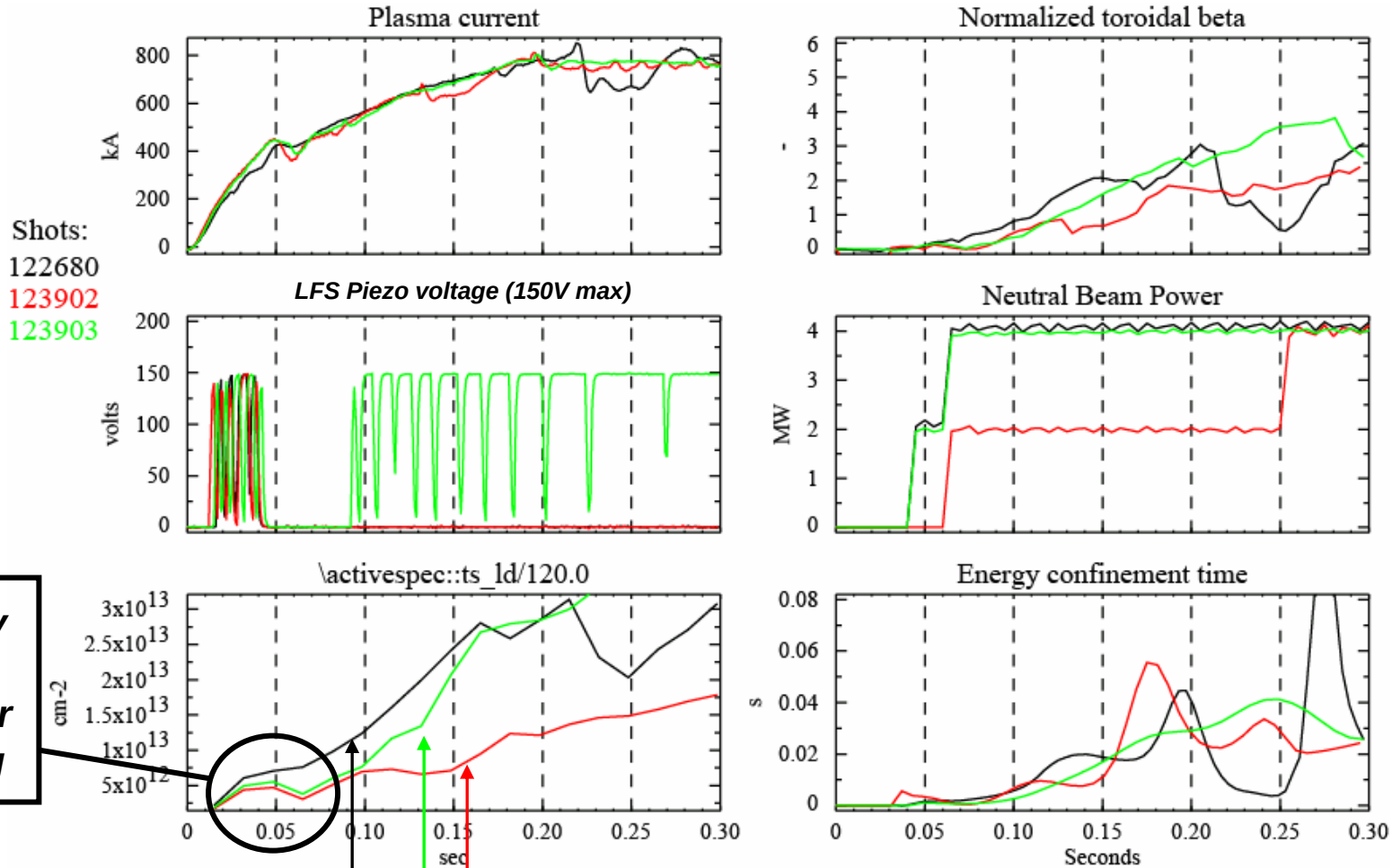
- Plasma shown is target reference
- Blue boundary is 124058 – XP710 using rtEFIT control
- Can we improve shape further?
  - Try increasing upper triangularity
  - Try decreasing lower squareness
  - Do these changes impact ELMs and/or global stability?

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 LITER (different beam programming unfortunately)

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



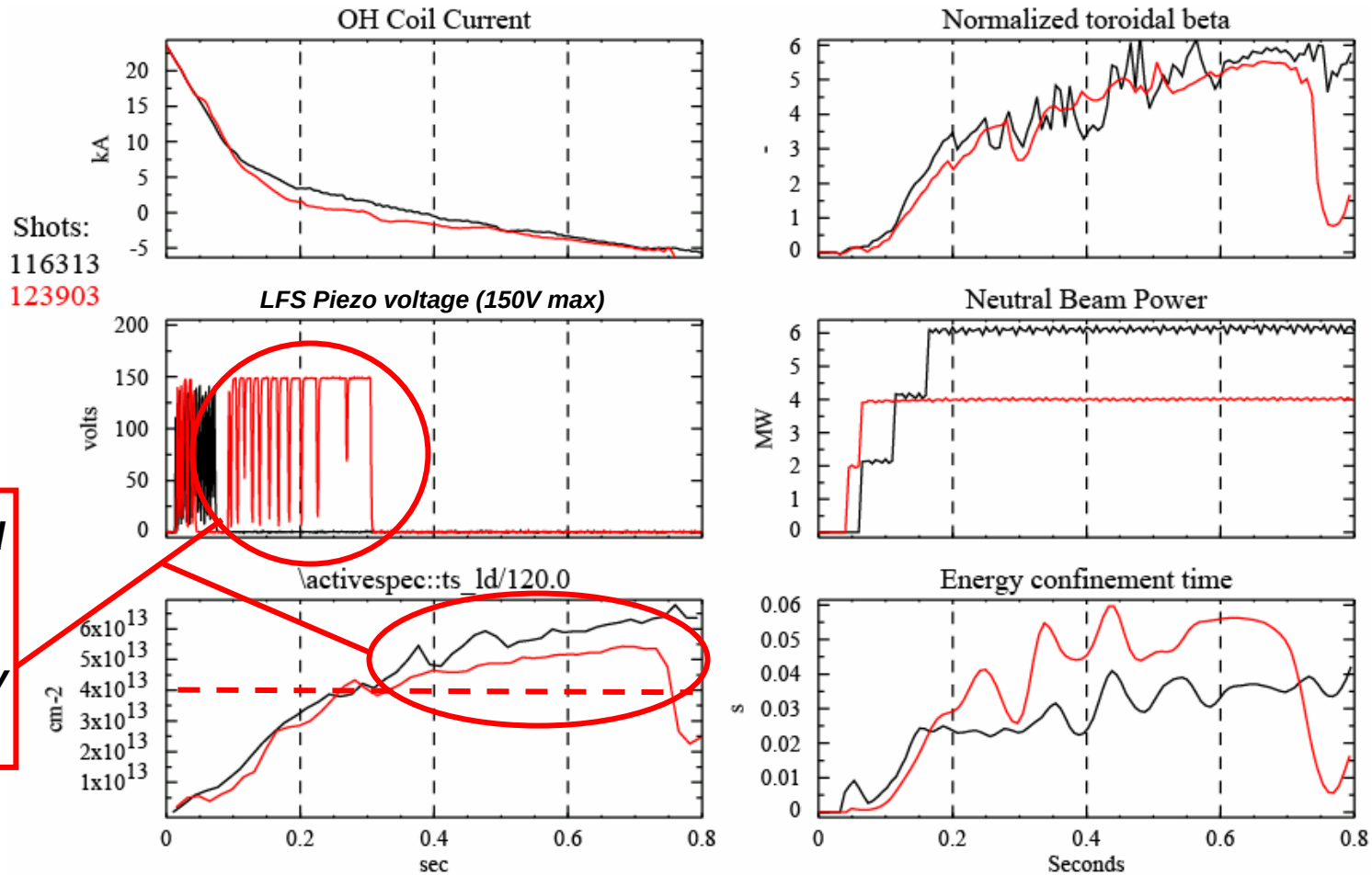
Early density reduced by factor of 2 for same fueling

H-mode transition times

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

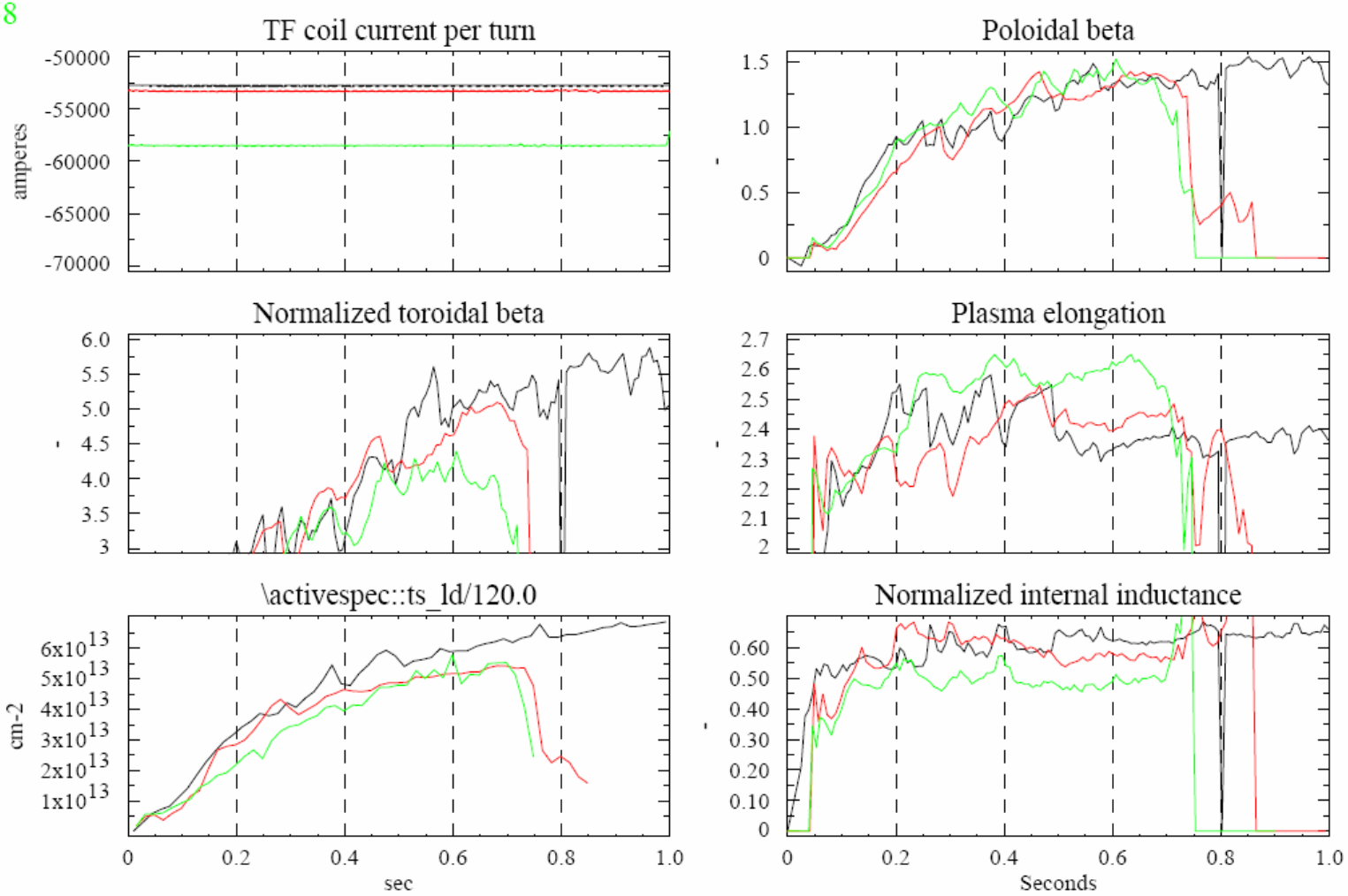


Note lower n_e and slower rate of density rise with much higher early LFS gas fueling

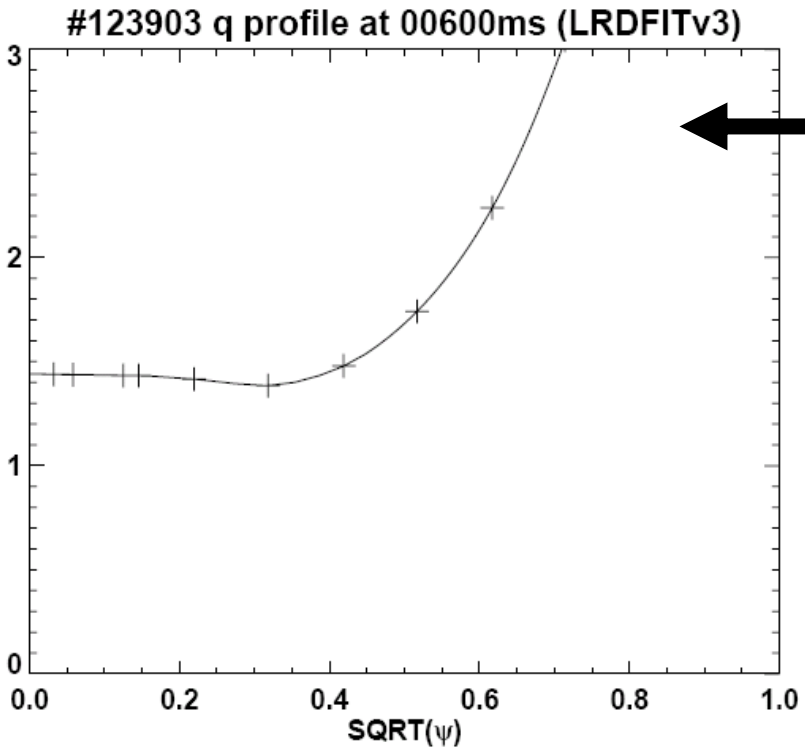
- ***ISD Goal: try to achieve constant $\bar{n}_e$ in flat-top ($4x10^{19}m^{-3}$) using shoulder and SGI fueling***

Shots in XP710 achieve high β_P=1.5, but $\beta_N \leq 4$

Shots:
116313
123903
124058



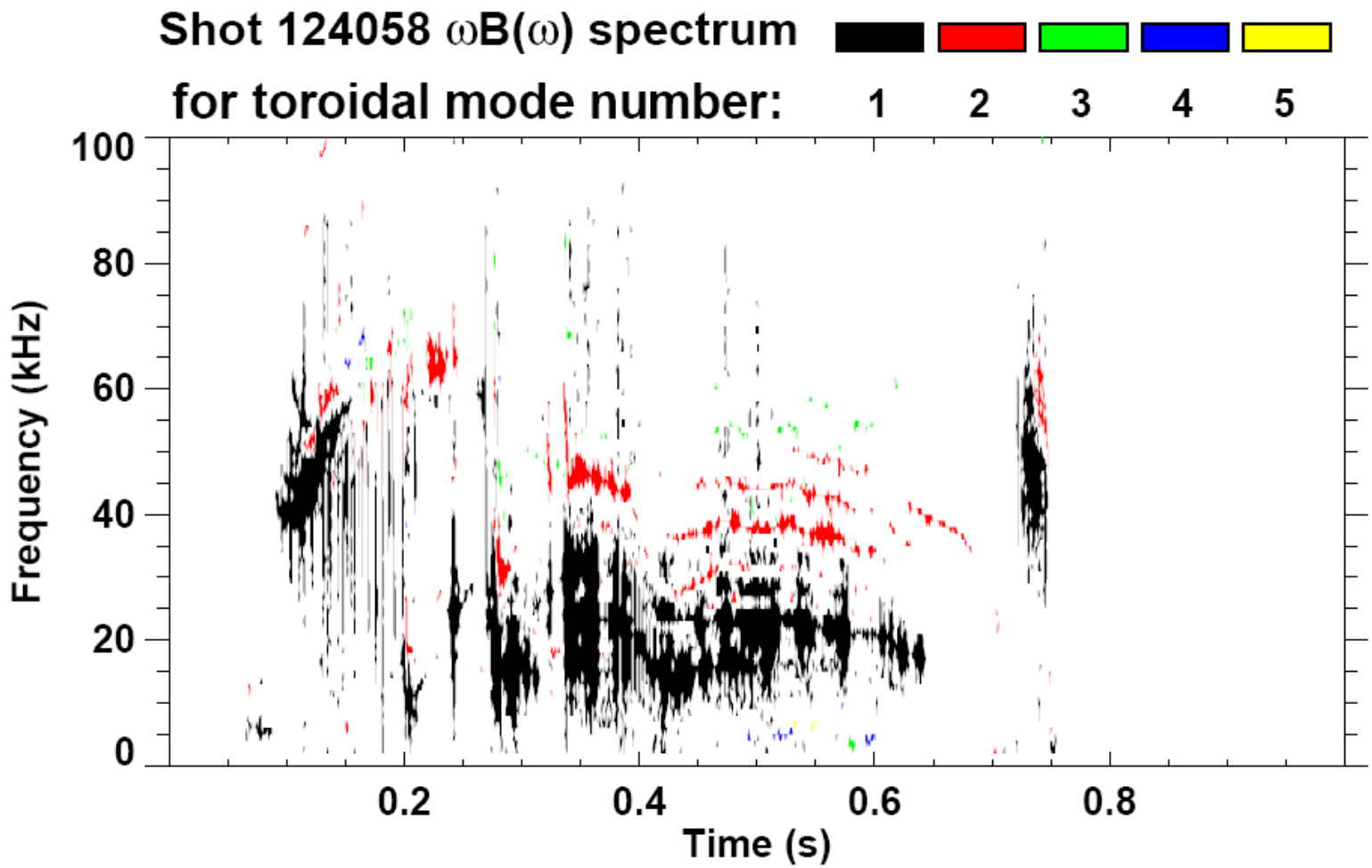
LITER shots with high β_N have q_{min} → 1.3, nearly monotonic



- High β_N LITER shots similar to high β_N shots of 2005 which had $q_{min} < 1.5$
- Higher-κ and B_T LITER shots from XP-710 appear to have $q_{min} \approx 2 \pm 0.4$
  - reconstructions have been challenging for these shots
  - Argues for trying to access $q_{min} > 2$

XP710 confinement likely limited by core n=1 MHD

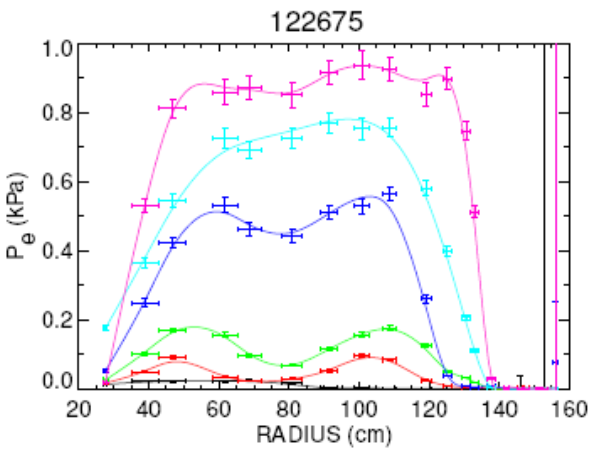
- If this is 2/1 NTM, this argues for trying to increase $q_{min} > 2$
- Earlier H-mode could help to increase q later in shot

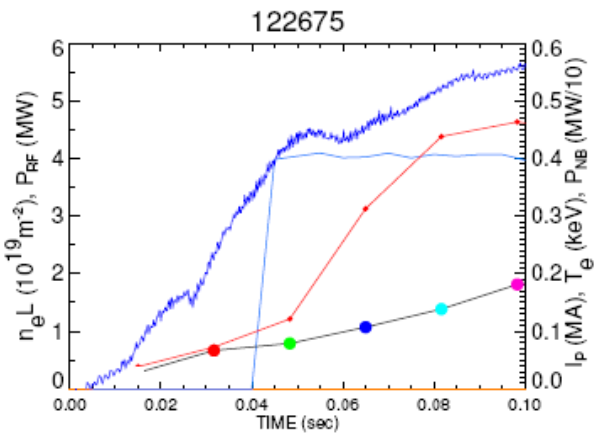


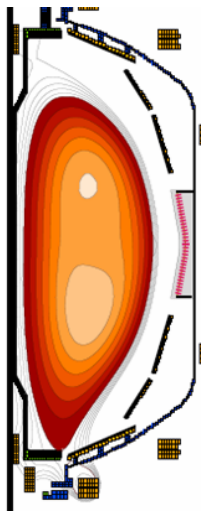
Improved break-down scenario from XP-711 (very early diverting) already incorporated into XP-710 rtEFIT target

- Very early H-mode (t=50-70ms) not yet achieved in XP710

- Very early H-mode observed in XP711, and likely requires PF1B and PF2L to increase radius of strike-point, and/or move X-point closer (but not too close?) to divertor plate.





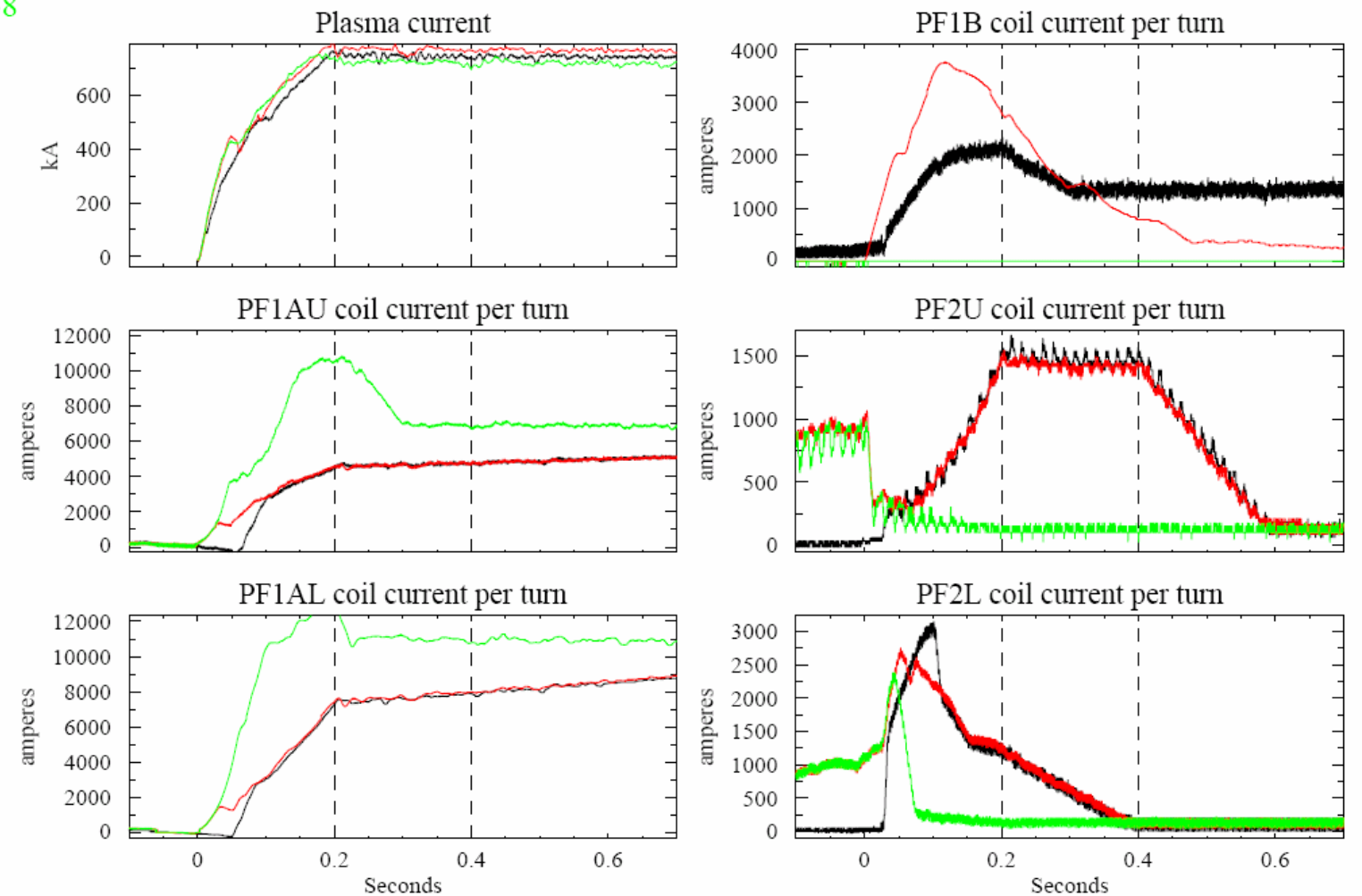


122675
t=45ms

Addition of early PF1B and PF2L coil currents to XP710 target may allow for earlier H-mode access

- Larger outer strike-point radius found to be important during early H-mode development XPs

116313
123903
124058



n=3 error fields are apparently present in NSTX → try n=3 fields in lower density shots for this XP (and n=1 B_R feedback?)

- **Longest shot of XP701 had n=3 w/ good polarity**
- **Good polarity shots have higher Ω_ϕ than w/o n=3**