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NSTX

Stability and pulse-length limits with reduced fueling and higher q_{MIN}

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Presented by:

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ISD group review

June 1, 2007

Princeton Plasma Physics Laboratory

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%

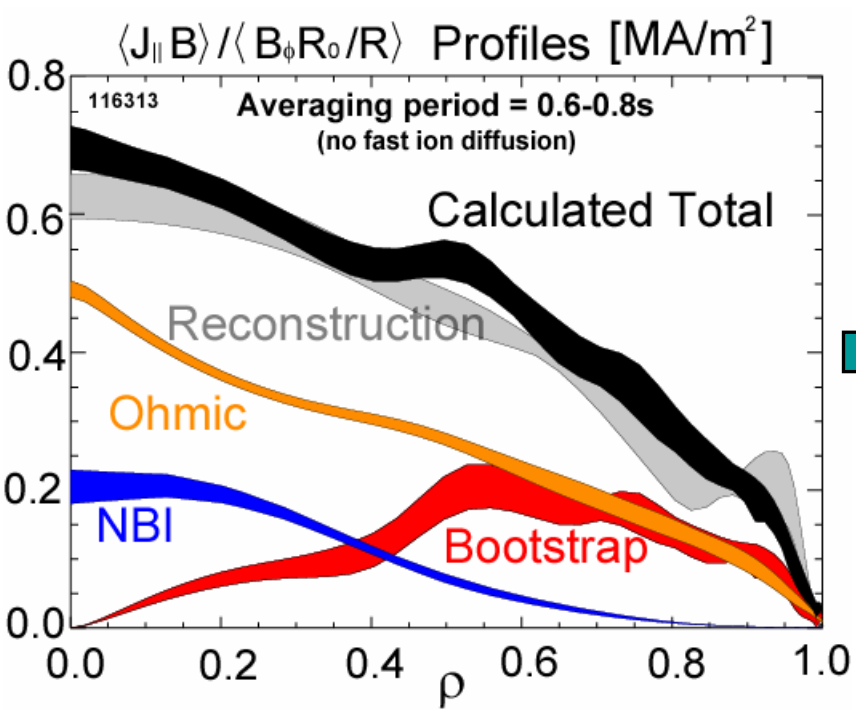
l_i = 0.5, q_{min} = 2.4, B_T=5.2kG

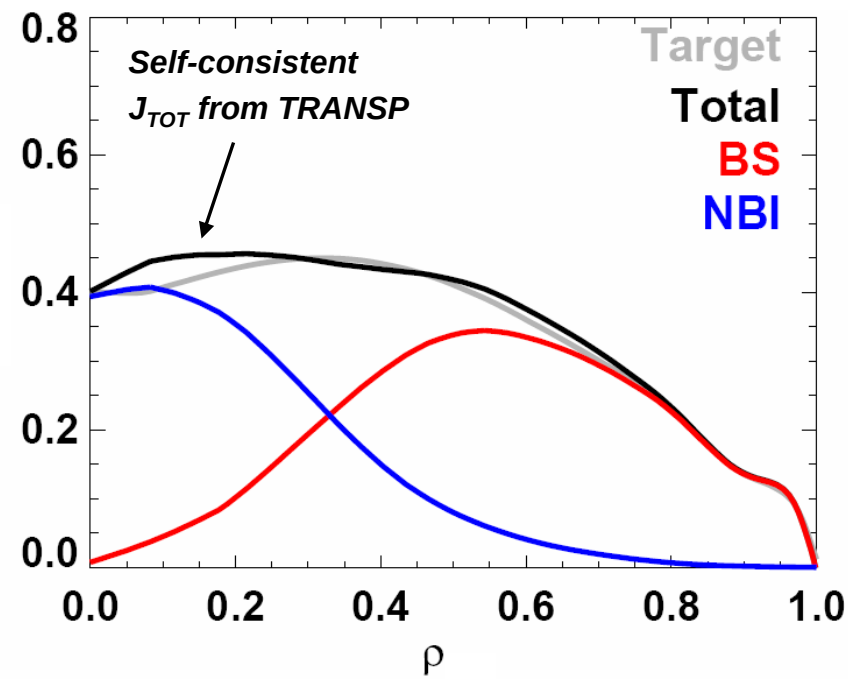
$\kappa = 2.6$, $\delta_{X\text{-}L} = 0.85$, q*=5.6

Inductive current drive is replaced by:

Higher J_{NBI} from higher T_e

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

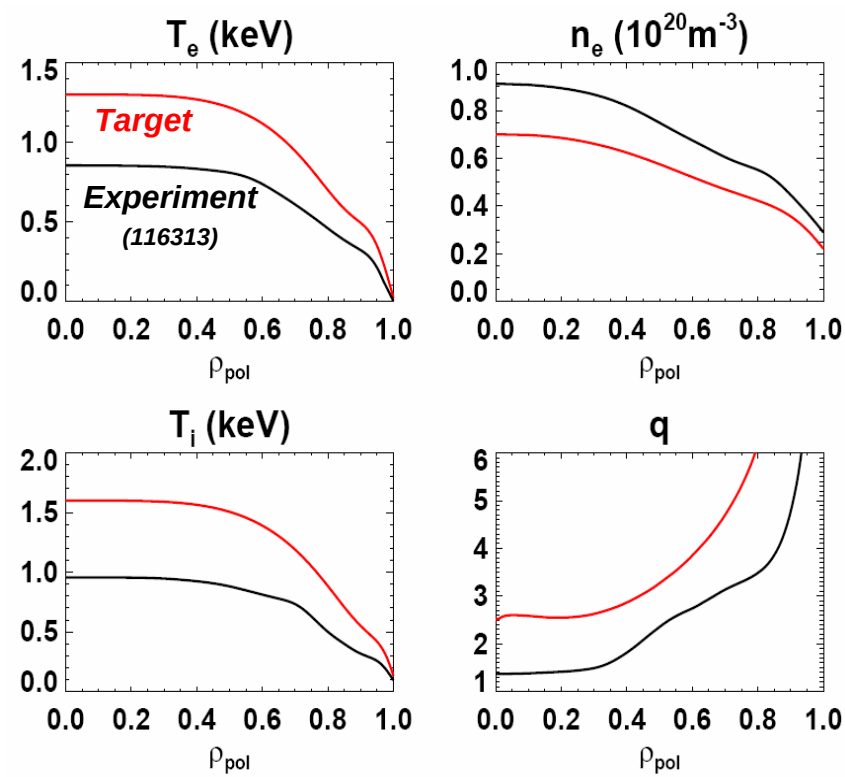




Fully non-inductive scenario requires higher confinement, higher *q*, strong plasma shaping

- 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**

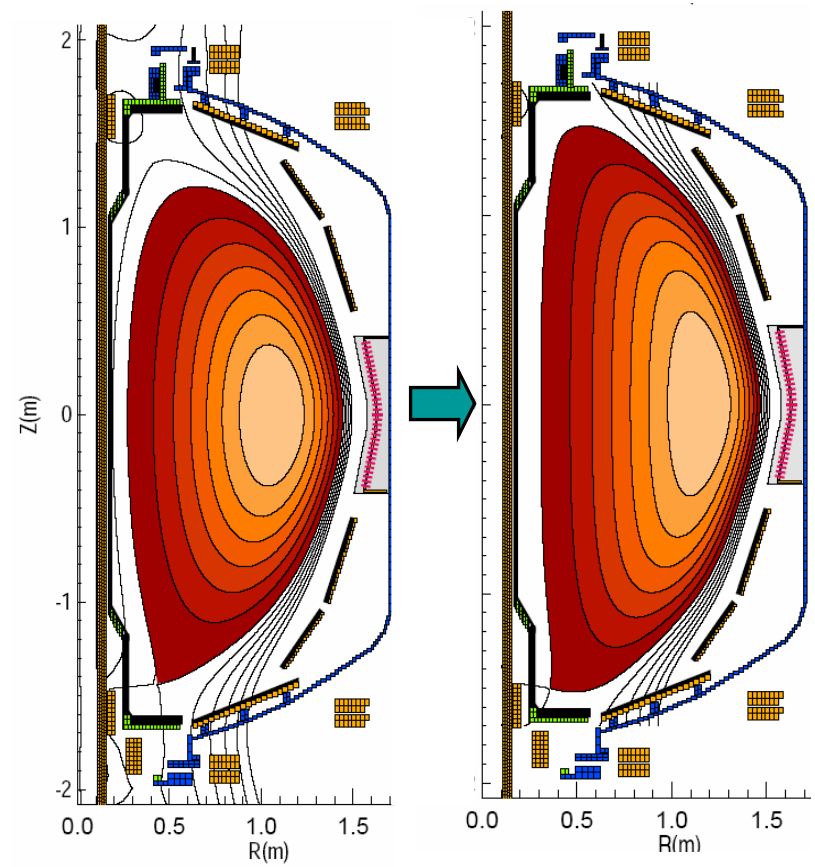
- Want $q_0 \approx q_{min} \approx 2.4 \Rightarrow$ higher with-wall limit



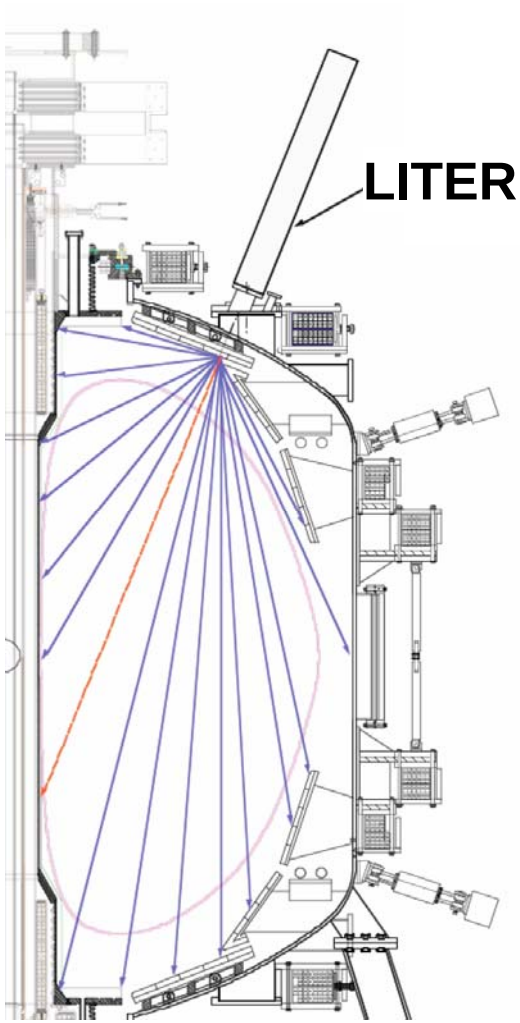
- Higher κ for higher q, β_P, f_{BS}
- High δ for improved kink stability

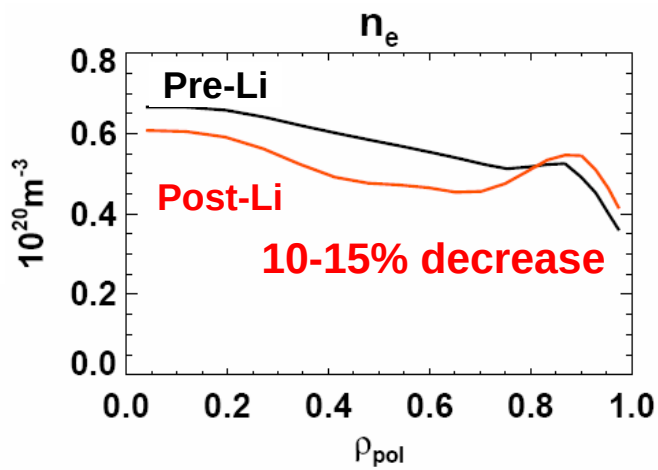
κ= 2.3, δ_{X-L} = 0.75
δR_{SEP} = -1cm

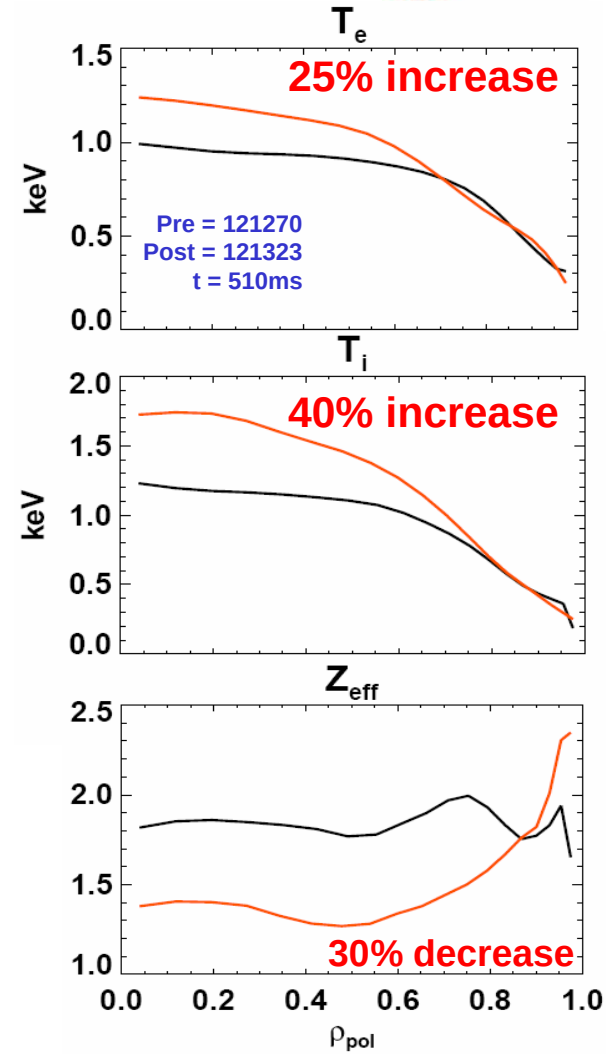
κ= 2.6, δ_{X-L} = 0.85
δR_{SEP} = -2mm



Initial Lithium Evaporator (LITER) experiments in H-mode exhibit improved particle pumping and energy confinement







TRANSP analysis:

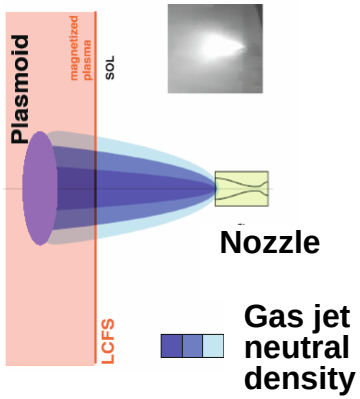
W_{TOT} 20% higher post-Li

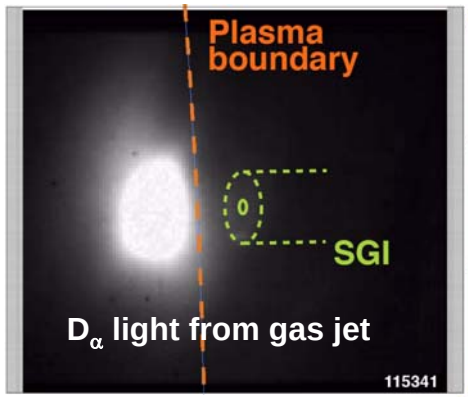
(reaches β-limit w/ same P_{NBI})

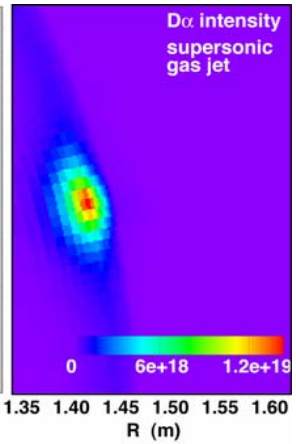
HH_{98y} = 1.07 → 1.25 post-Li

- **L-mode exhibits even larger (20-25%) relative density decrease**

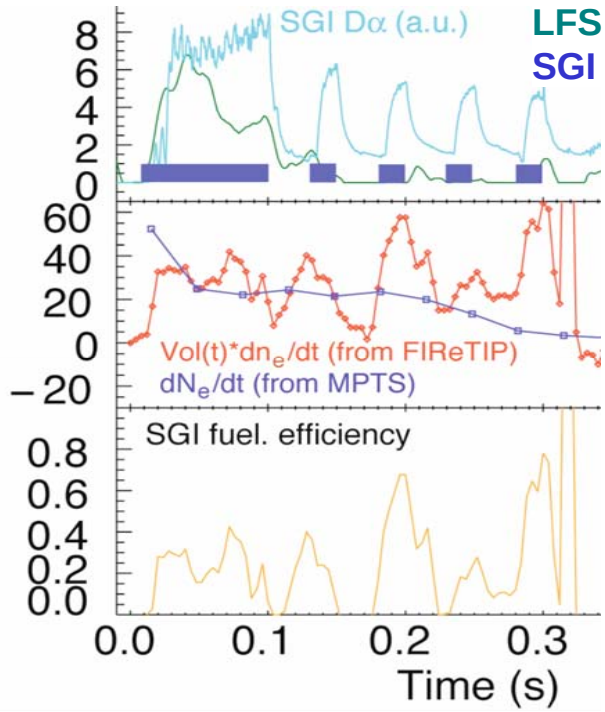
Supersonic Gas Injection (SGI) achieves up to 5 × higher fueling efficiency relative to standard low-field-side gas puff







DEGAS 2 Neutral transport modeling reproduces observed features

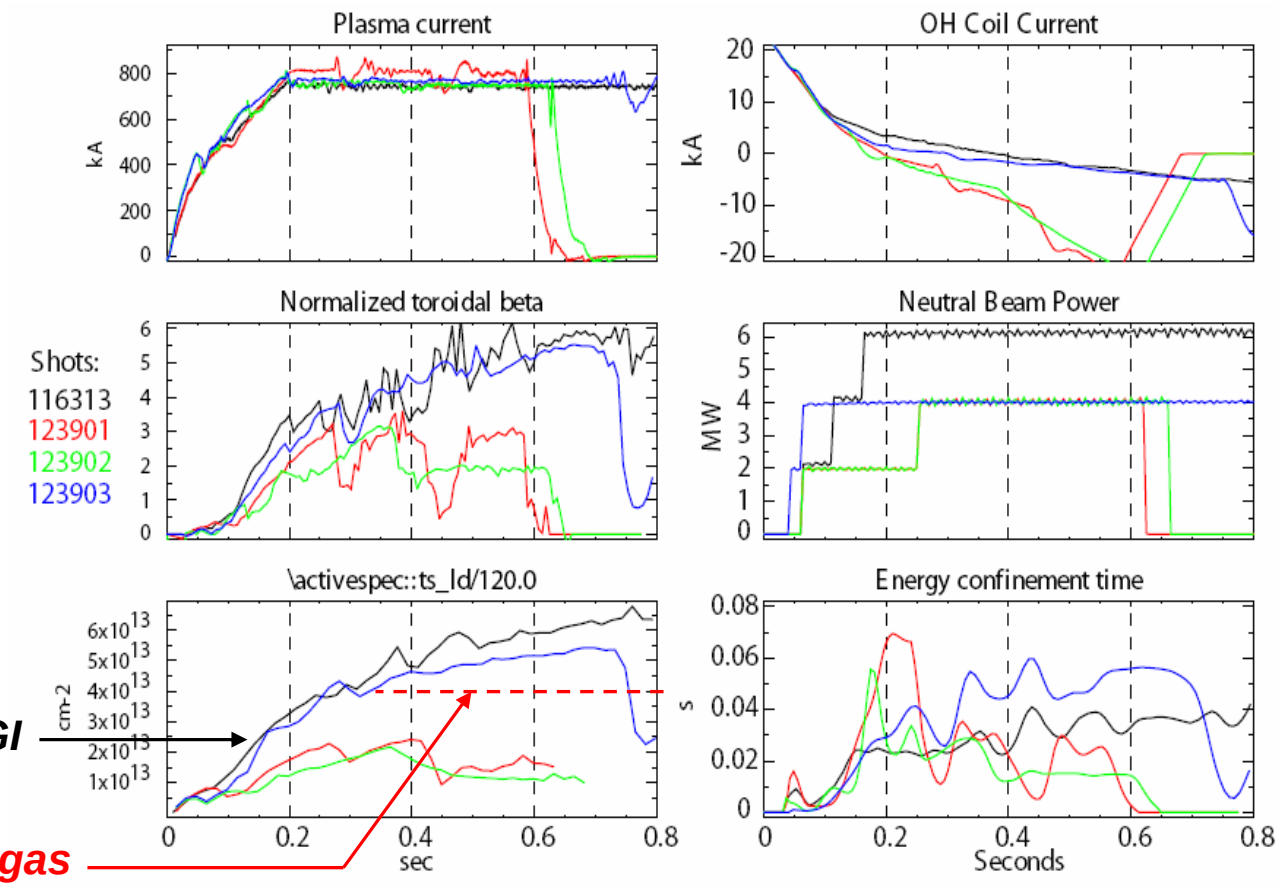


V.A. Soukhanovskii, et al. RSI **75**, 4320 (2004)

- NBI-heated inner wall limited L-mode
  - Pulsed SGI fueling
  - Fueling efficiency = 0.1 - 0.5
    - Compare to LFS gas puff = 0.05-0.1
- H-mode scenarios:
  - SGI changes ELMs from mixed ELM regime (Type I+V) to Type III
  - SGI can replace HFS injector used for H-mode access while providing flow control
- **GOAL: Combine Li & SGI for n_e control**

Using 30-40mg/min Li and 7 min glow, achieved β_N = 5.5 with only NBI sources A & C

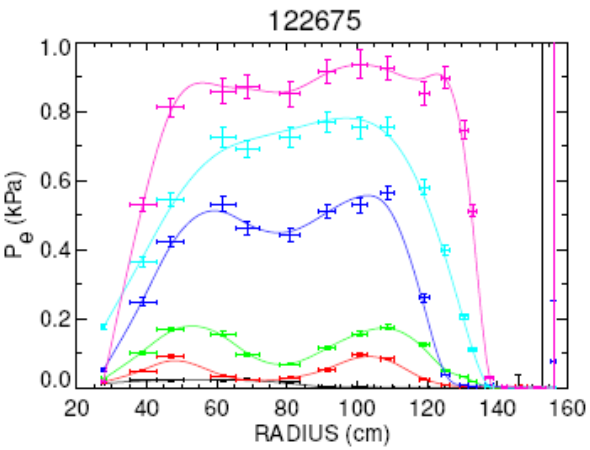
- **Strong LFS gas puffing needed early to raise density**
- **Also used HFS gas at 900T → can SGI slow late rise in density?**
  - ***Can we lower line density to constant 4x10^{19} with SGI (higher NBICD efficiency…)***
  - ***Can NBI-B increase β - what is β limit here?***

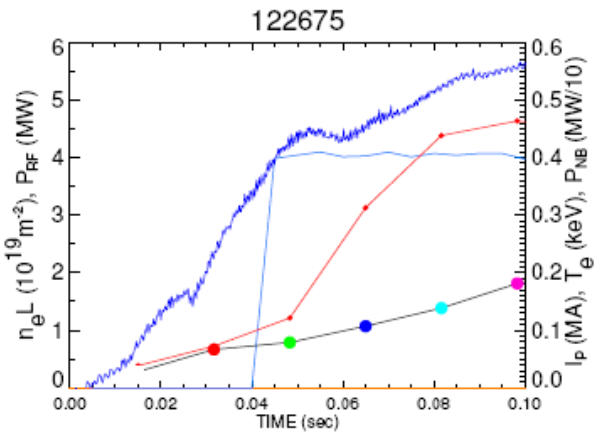


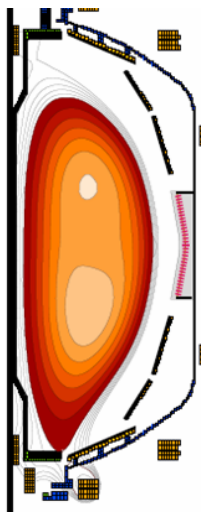
- ***Replace HFS w/ SGI***
- ***Scan SGI and LFS gas***

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

- 80% complete (and successful)
- 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 was not reproducible because of radial position oscillation from t=40-100ms (no H-mode when inner gap is small)
- **Desire 0.25-0.5 run days** to achieve reproducible outer gap evolution in LSN and very early H-mode – then couple to rt-EFIT (DND or LSN) after transition







122675
t=45ms

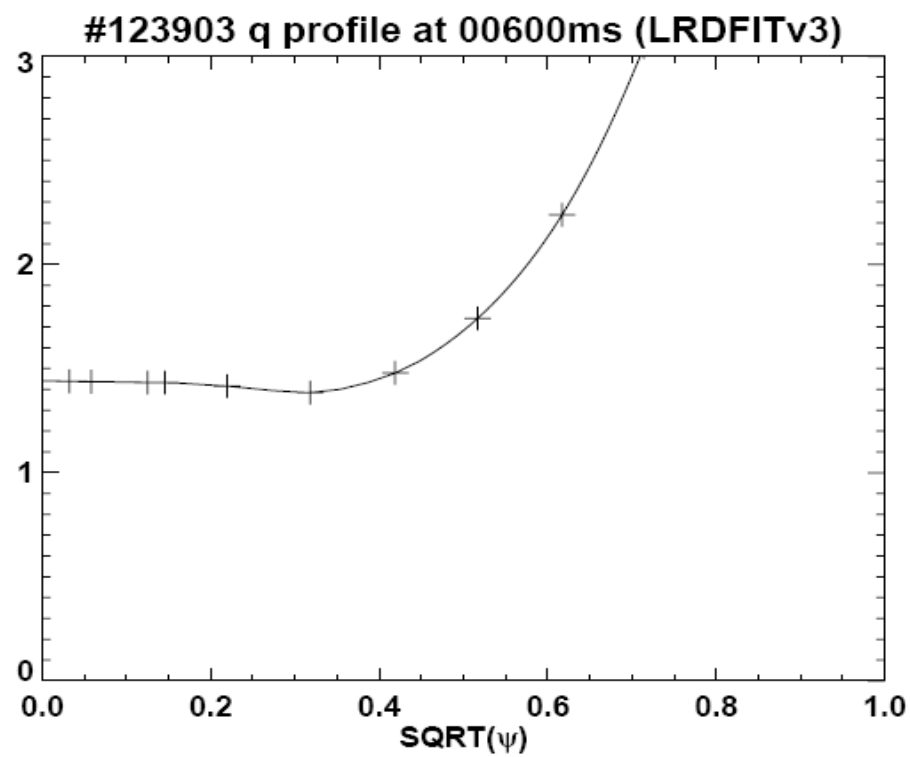
Attempt to generate weakly q-reversed shot with $q_{min} > 2$

- **q reversed early at 250ms**
  - **Cannot get good reconstructions**
  - **May be strongly reversed**
  - **Need more time for LRDFITing…**

- **Want to vary degree of shear reversal with higher q_{min} target**

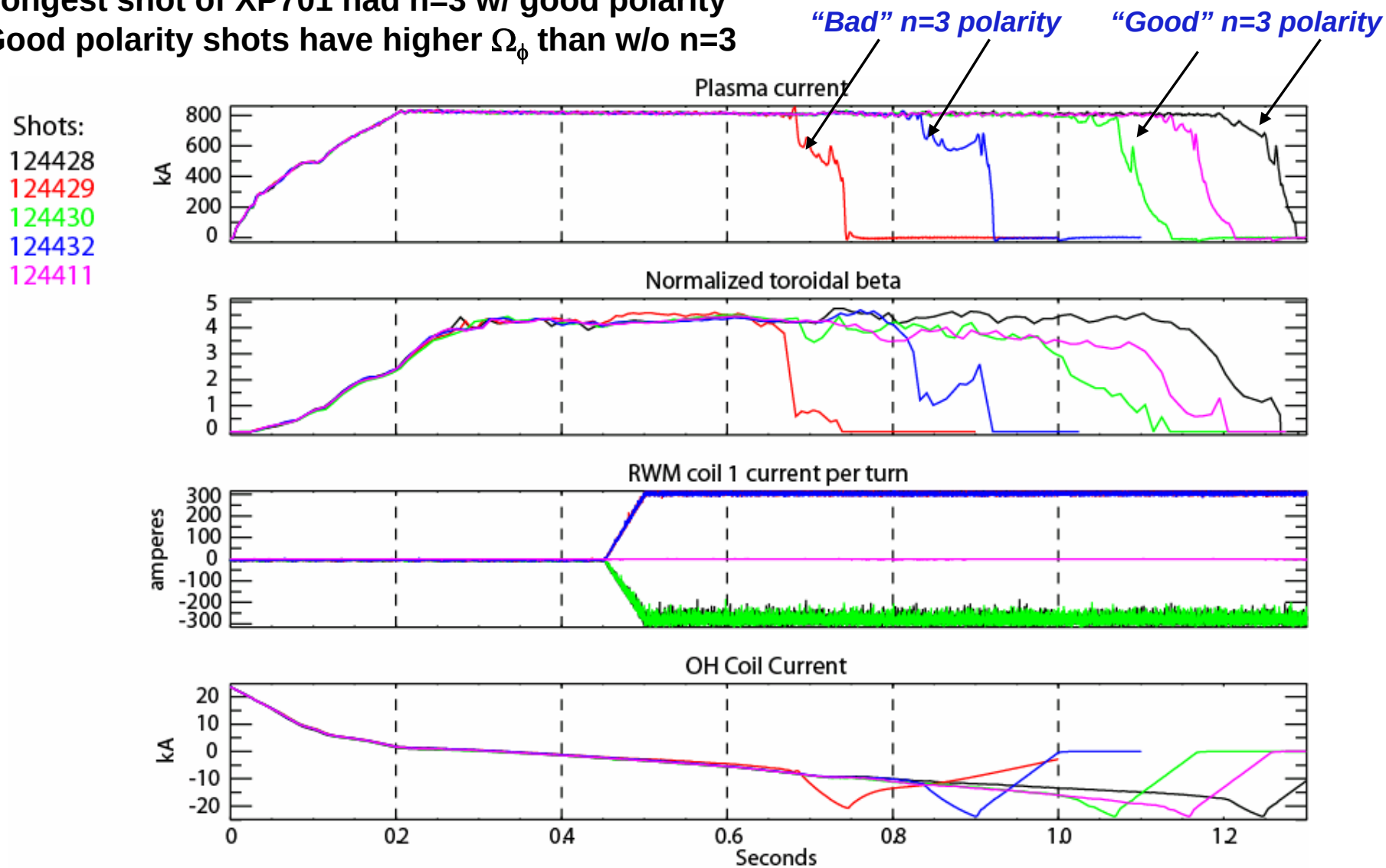
- **Also incorporate results from XP711 with earlier H-mode**

- **q_{min} → 1.3 monotonic in high-β phase**



n=3 error fields may be important for NSTX
→Try n=3 fields in lower density shots for this XP

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



Shot plan – 1 – 1.5 days

1. Obtain very early H-mode if possible – finish XP711
2. Utilize between-shots Lithium for higher τ_E and pumping
   1. Modify early SGI and/or LFS fueling to retain early H-mode access
   2. Scan I_P ramp-rate after H-mode transition to avoid β collapses
   3. Adjust P_{NBI} & timing to avoid β collapses, and/or operate at higher β_N
   4. Scan SGI and LFS gas to vary flat-top n_e – maximize NI current
3. Scan flat-top TF = 4.5kG, 5kG, 5.25kG at fixed I_P = 0.75MA
   1. Determine NI fraction scaling with q* at fixed I_P
4. Scan flat-top I_P = 0.7MA, 0.8MA
   1. Determine NI fraction scaling w/ q* at fixed B_T – use best f_{NI} from #3.
5. Use/adjust EF correction as necessary for highest β_N
   1. Start with n=3 pre-programmed – try 2 amplitudes
   2. try adding n=1 TF EFC