NSTX

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Planning for NSTX Operation with Reduced Gas Fueling

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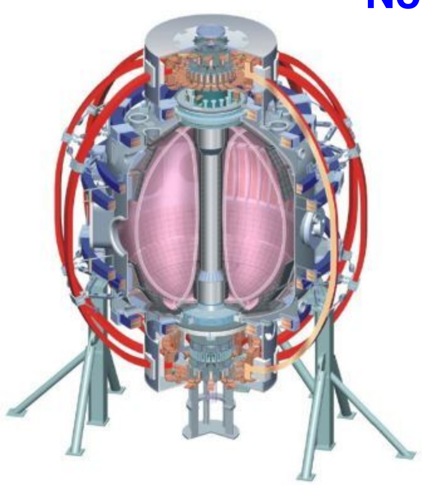

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Goal is density control during I_p flattop during the H-Mode in NBI heated plasmas

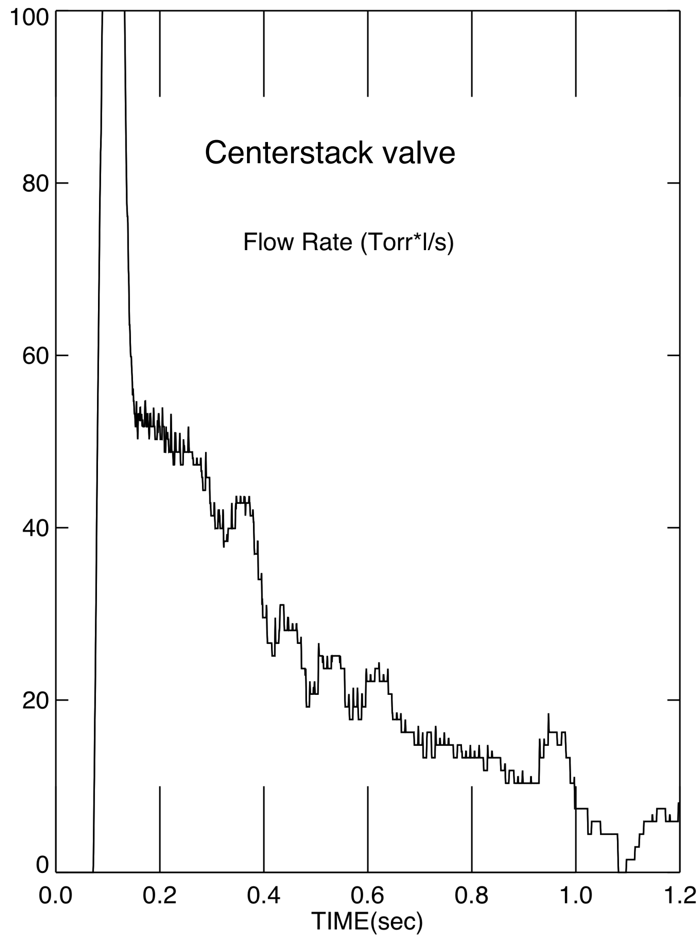
- **NSTX historical density evolution**
  - To avoid MHD, facilitate H-Mode, and keep l_i low, NSTX employs gas fueling from both high- and low-field sides of the plasma
  - NSTX density generally reaches between .6 and 1 times the Greenwald density limit (n_eG) by 1 s
  - The high-field gas valve continues to fuel throughout the discharge as the density rises
- **NSTX-U density goals***
  - Simulations indicate that n_e/n_eG above 0.7 is required for 100% non-inductive current fraction while maintaining $q_{min} > 1$
  - Lower densities are facilitate study of low collisionality regimes
  - NSTX-U has a 3 to 5 times longer pulse length than NSTX

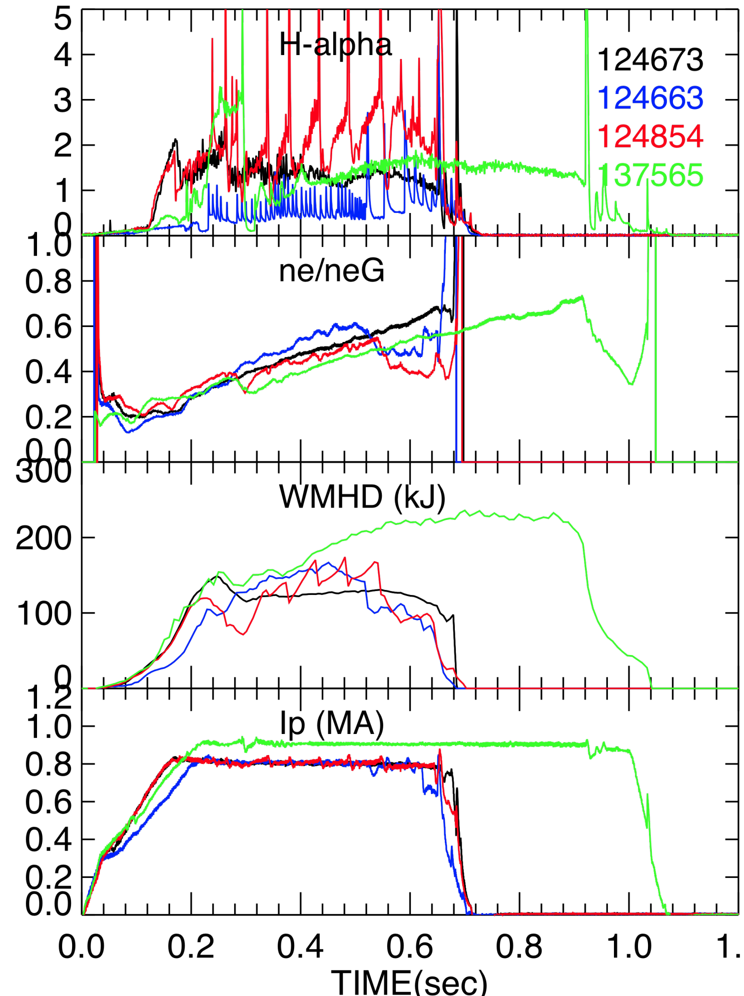
**S. Gerhardt invited talk Friday morning*

Fueling and early H-mode are important tools for overcoming constraint of small solenoid

- The small solenoid limits the available V*s
  - Reach Ip flattop quickly
  - Apply early heating to reduce resistive losses
  - Achieve H-Mode early to reduce resistive losses
  - Keep l_i low to extend pulse duration
- Avoidance of deleterious MHD and beta limits
  - Strong shaping can be accomplished only with low l_i
  - Need broad pressure profiles
  - Low density leads to early MHD which limits plasma performance
- Use of gas fueling has been an important tool to achieve these NSTX goals
- Little operational effort has been spent to find an alternative to gas fueling

With or without Li conditioning and with or without ELMS, the density in NSTX rises through the current flattop*



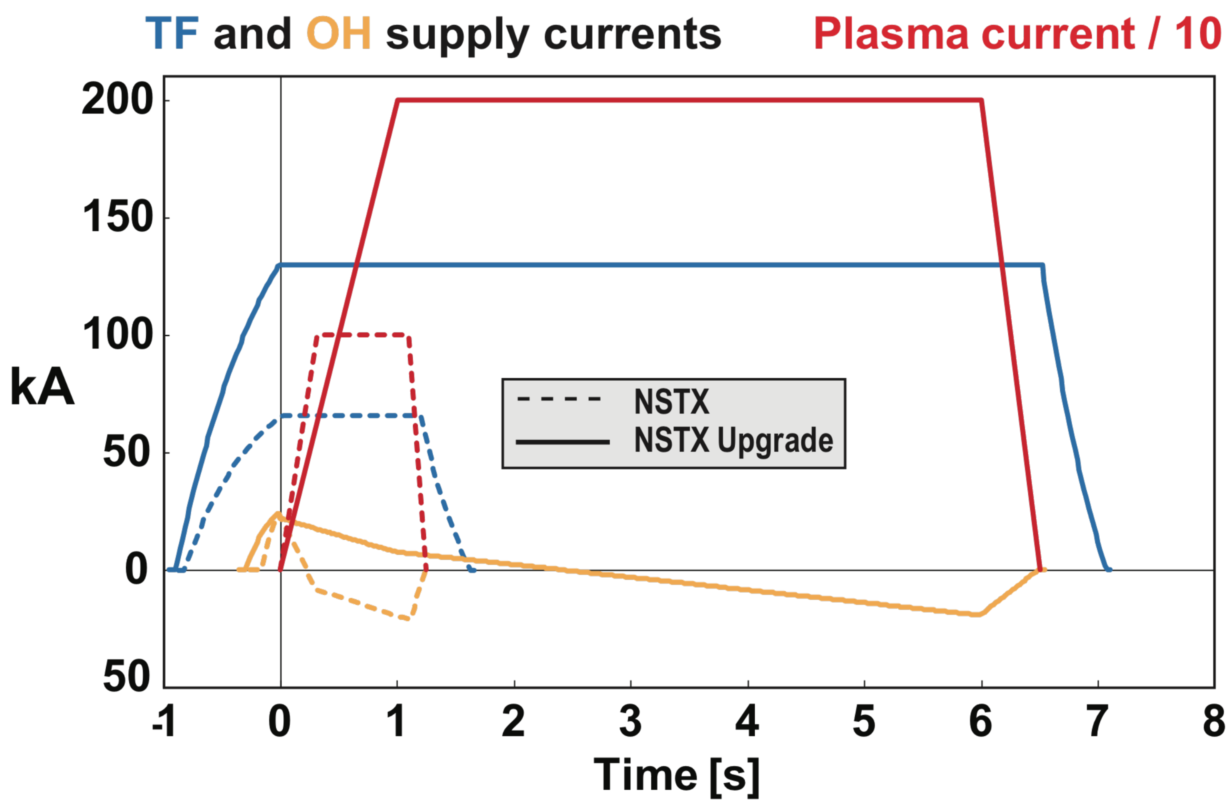


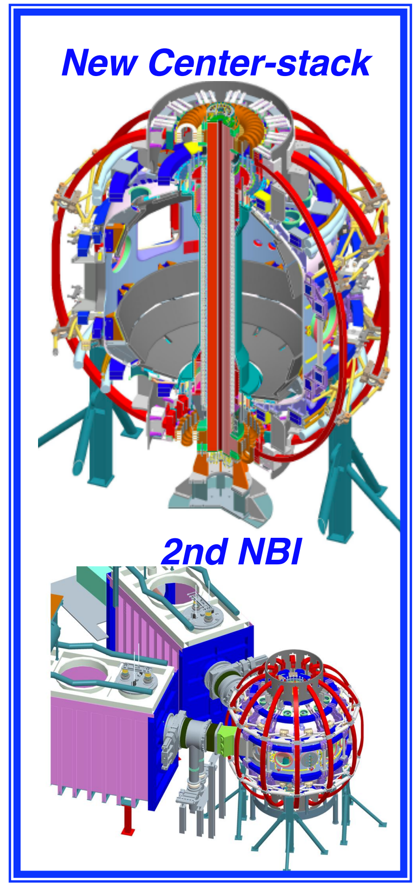
Type V
Normal Type I
Giant Type I
ELM-free

Similar density evolution

***The Greenwald fraction increases when W_{MHD} or I_p is not falling.**
The Radiated power increases throughout the ELM-free discharge to nearly 100% of P_{inj}, and Z_{EFF} (C) increases to 3.5 before the end of the density rise

NSTX-U will have a 3 to 5 times longer flattop

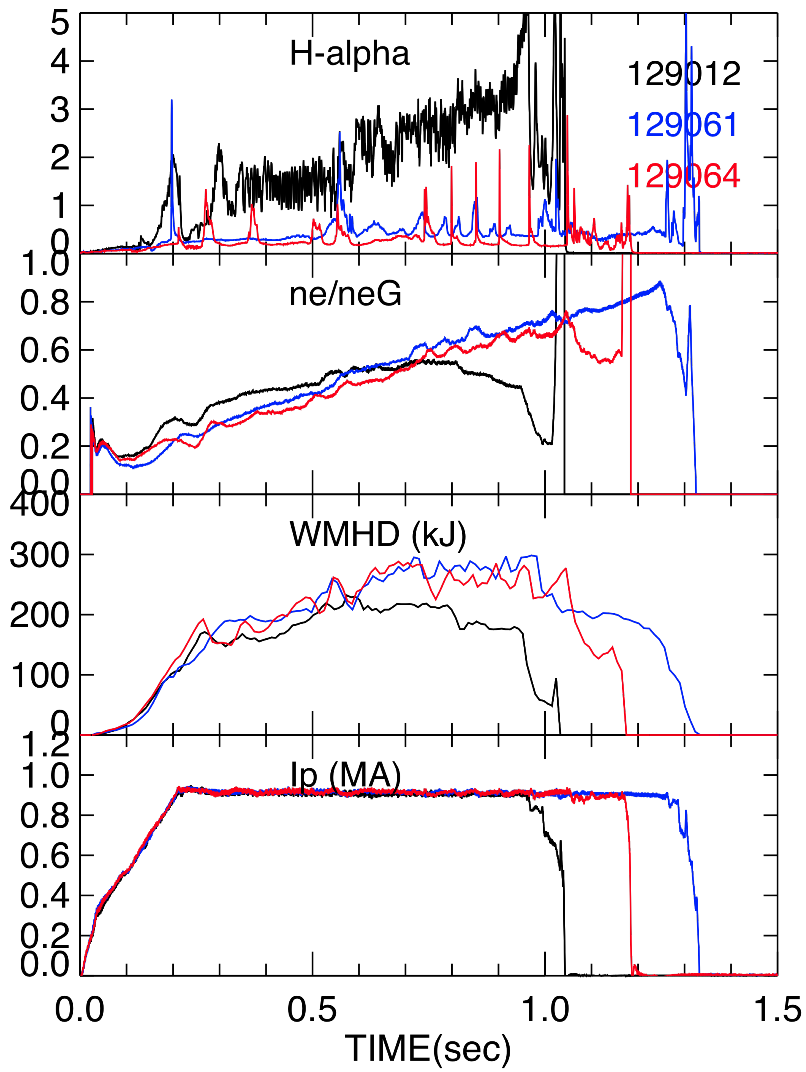




Relative performance of Upgraded NSTX vs. Base:

NBI power increased 2 x
Available OH flux increased 3x, 3-5x longer flat-top
I_P increased 2x, B_T increased 2x at same major radius
Plasma stored energy increased up to 4x (0.25→ 1MJ)

Lithium conditioning lowers the early density, but density increases during the discharge



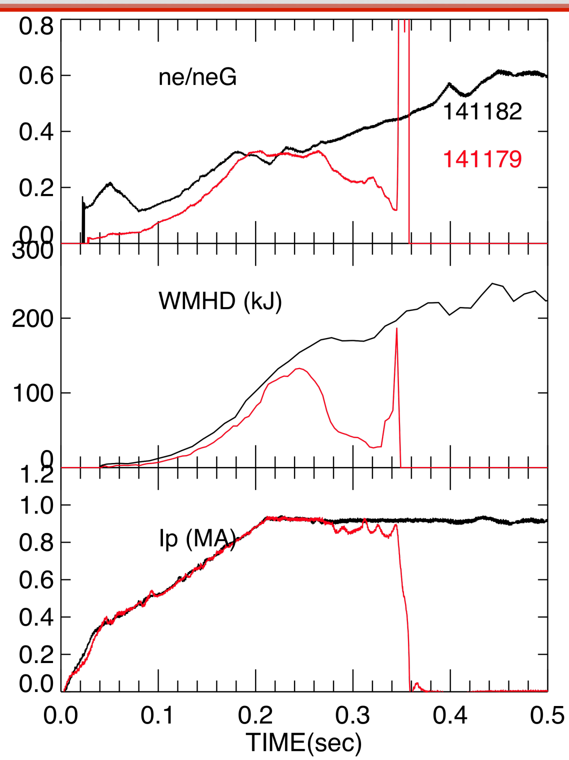
- Black is before evaporating Lithium

- Blue and Red are after Lithium evaporation

- Stored energy is higher in the Li conditioned case

- In all cases the Greenwald fraction increases until W drops.

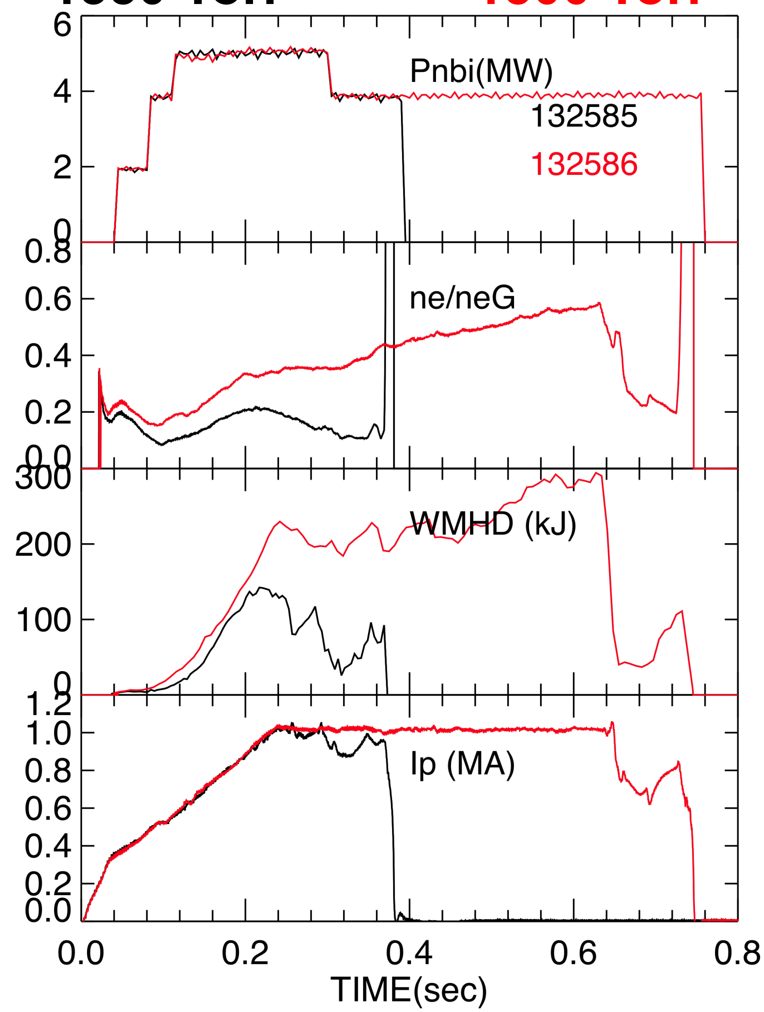
Low fueling results in instability or disruption



TF motion due to OH X TF may → error fields

High-field side fueling plenum pressure:

1350 Torr **1500 Torr**



Two otherwise similar shots

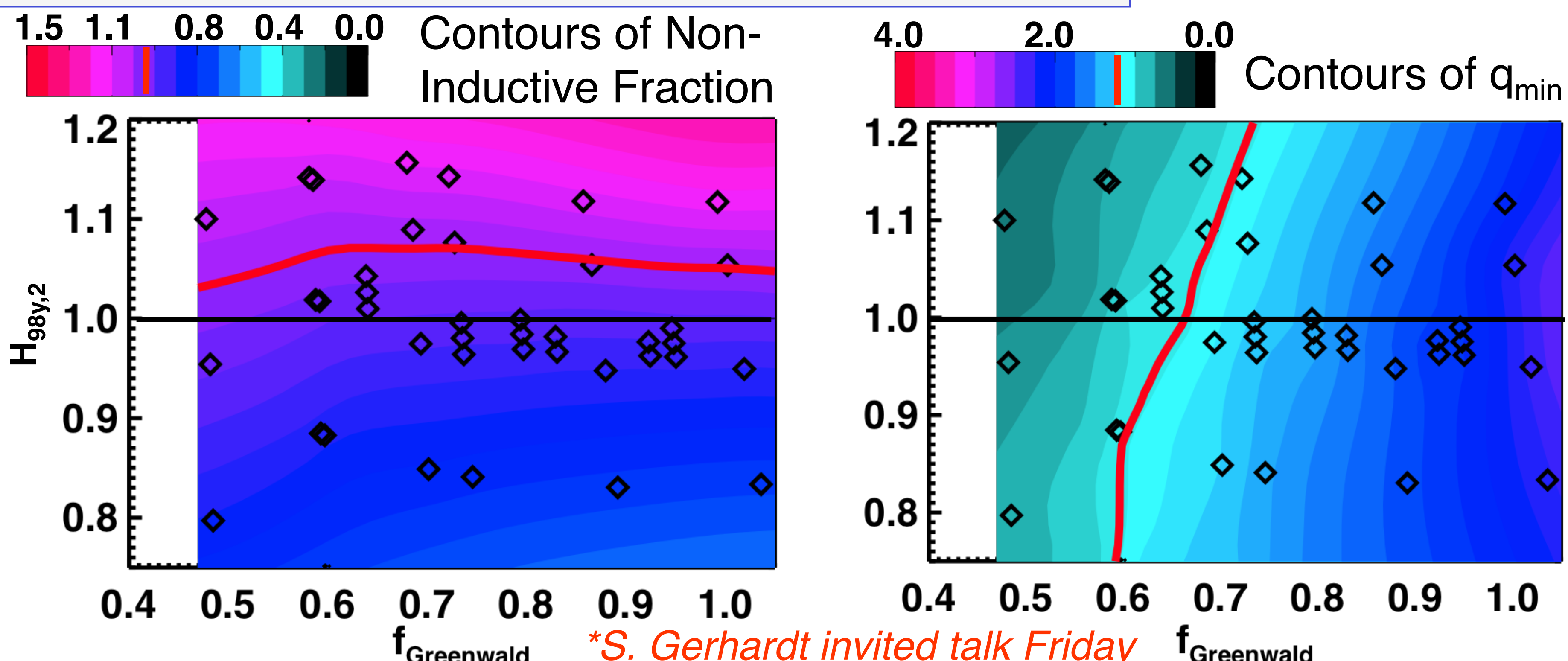
Red had no early gas puffing (and low density)

Black used gas puffing from low field side to increase early density and duration extended to 1.2 s

Projections to NSTX-Upgrade Made with Free-Boundary TRANSP*

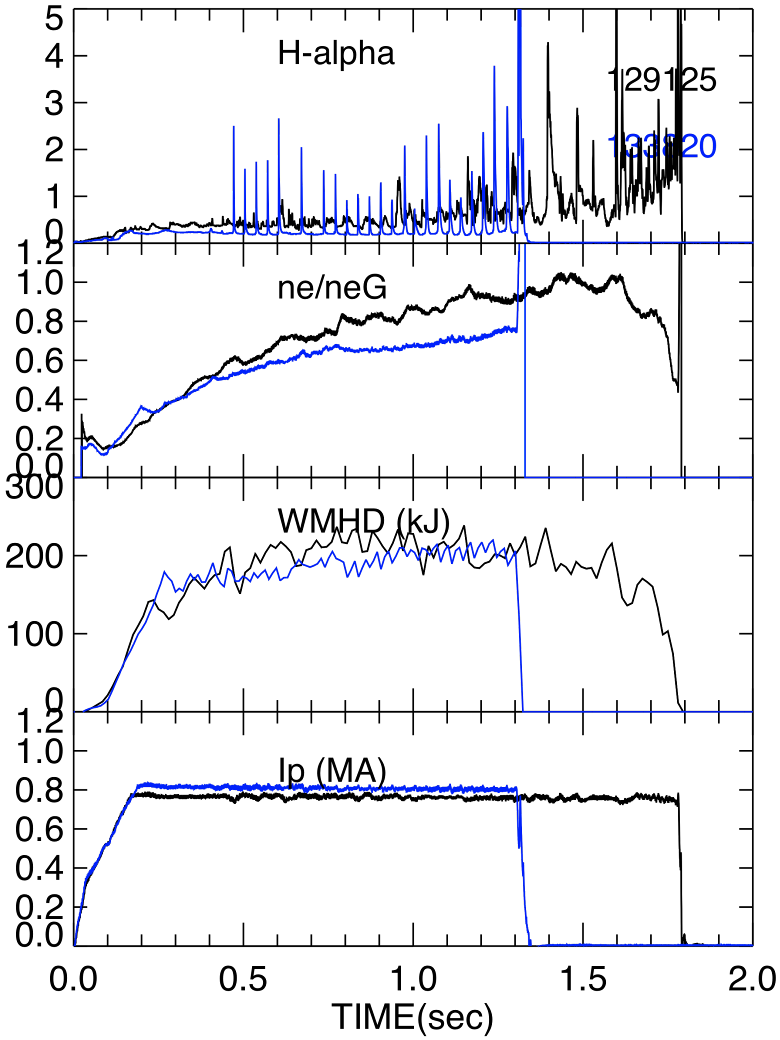
- Profile assumptions
  - Neoclassical theory to predict the ion temperature
  - Scale experimental electron profiles to achieve desired Greenwald density fraction and confinement level
- Equilibria computed with new free-boundary TRANSP
  - Allow the current profile to fully relax

B_T=1.0 T, I_p=1.0 MA, κ= 2.75
Six sources with total P_{inj}=12.6 MW



*S. Gerhardt invited talk Friday

Lithium conditioning with natural or triggered ELMs may provide density control in Upgrade discharge.



- The Black curves are from a discharge taken with moderate Li conditioning
    - Terminated after the end of the TF flattop
- The Blue curves are from a discharge that used RMP pacing of ELMS*
    - Terminated by purposefully ramping I_p down
- NSTX H-Mode discharges with pressure peaking ~ 2.5 have nearly constant n_eG
- The blue curve extrapolates to n_e/n_eG of 1 at 5 s

** Canik, 2010 Nucl. Fus. 50 064016*

Despite heavily constrained operational space NSTX has density control appropriate for NSTX-U

- Li conditioning can lower the early density
- The accumulation of C during heavily Li-conditioned, ELM-free discharges can be ameliorated by triggering ELMS
- NSTX discharges with ELMS typically reach $0.6 < n_e/n_eG < 0.9$ which is appropriate for MHD stable NSTX-U non-inductive sustainment
  - Extrapolation to 5 X longer duration is uncertain, ELM pacing helps
- Further work to explore low density regimes is required to fully exploit NSTX-U capabilities
  - Reduced fueling (New CS should have 2 to 4 times lower error fields)
  - Slower Ip ramp-rate
  - Lower early NBI power
  - Delay onset of H-Mode
  - Possibly cryo-pumps (design study initiated)