NSTX

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Advanced Scenario Development on NSTX

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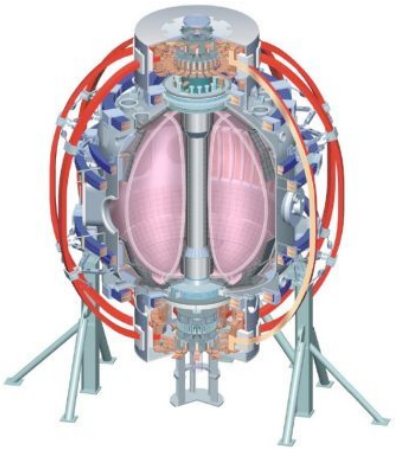
50th APS-DPP meeting
Dallas, TX
November 17, 2008



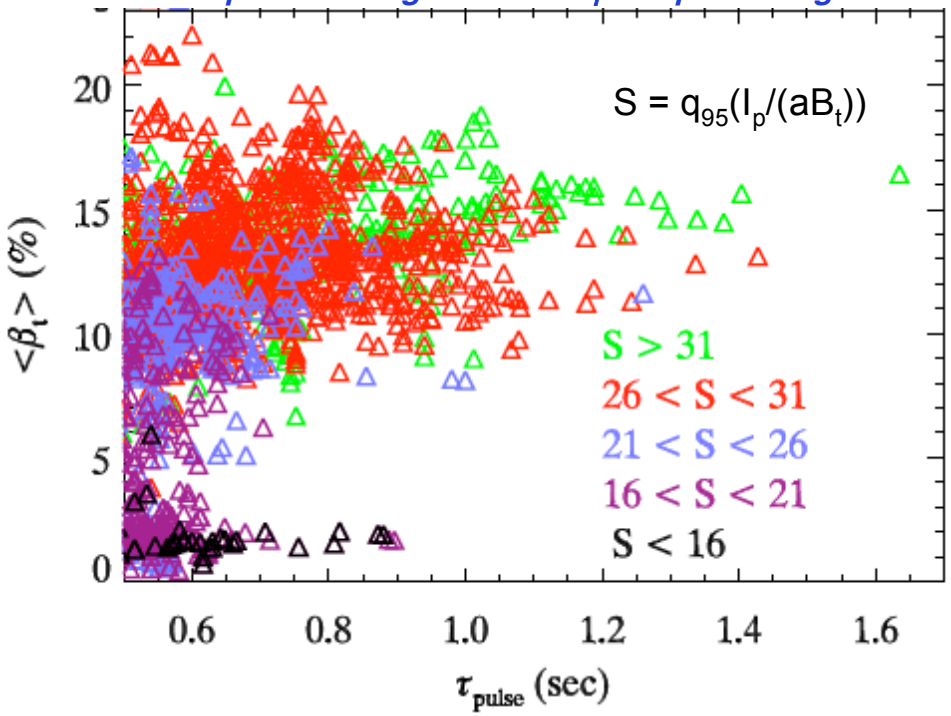
Advanced scenario development incorporates physics understanding to advance ST concept

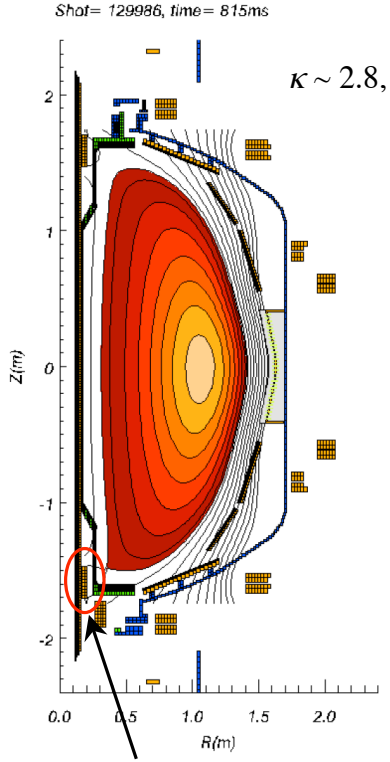
- Based on contributions from topical science groups
  - *MHD - (plasma shaping and RFA/RWM control)
  - *Boundary - (improved performance with lithium)
  - Fast particles and *waves - (HHFW heating during H-modes)
  - Transport and turbulence
  - Solenoid free startup
- Scenario modeling focuses activities towards full non-inductive operation
  - Reduced collisionality increases neutral beam driven current

Optimized shape control has enabled access to advanced regimes on NSTX

- NSTX has achieved record values of plasma shaping
  - Technology improvements allow control of plasmas with record elongation
  - PF coil enhancements enable achievement of high triangularity
  - rtEFIT developed in collaboration with GA enables reliable plasma shape control
- Improvements in performance clearly associated with plasma shaping
- 2008 NSTX combines high shaping with high β_N giving longest pulse to date
  - Non-axisymmetric control also important
- Many shots now limited by available TF flattop

Plot of pulse averaged toroidal β vs. pulse length





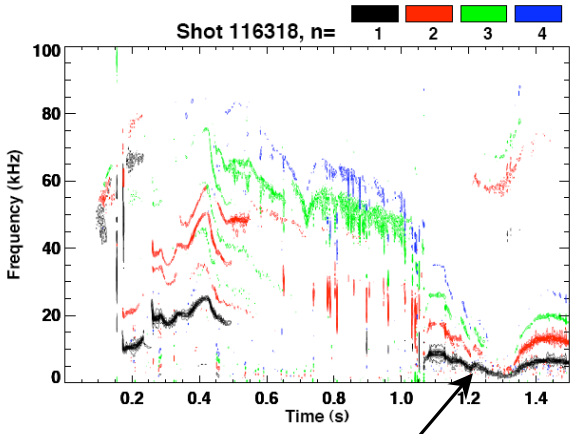
$\kappa \sim 2.8$, $\delta = 0.8$, $S \sim 40$

2008

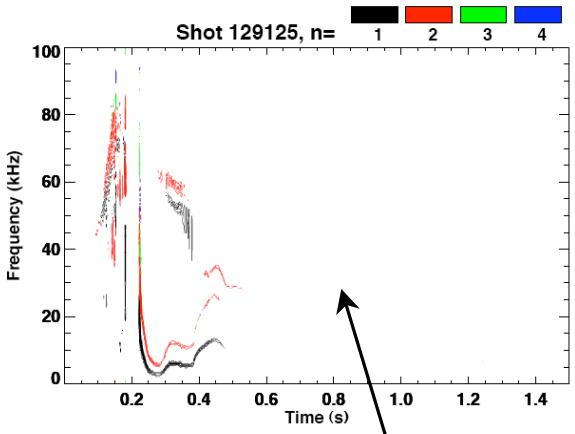
- ***PF1A coil upgraded***

n=1 RFA/RWM control combined with n=3 error correction increases β and extends pulse

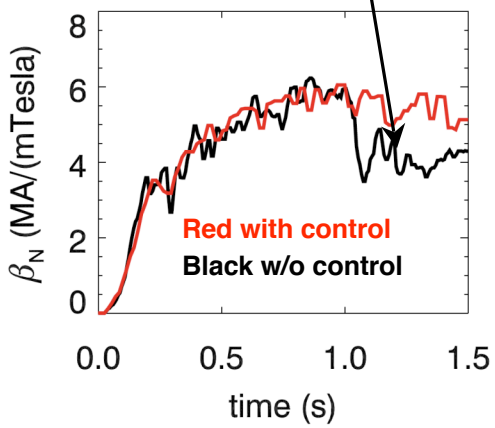
- ***MHD spectrogram w/o n=1 feedback and n=3 correction***



- ***MHD spectrogram with n=1 feedback and n=3 correction***

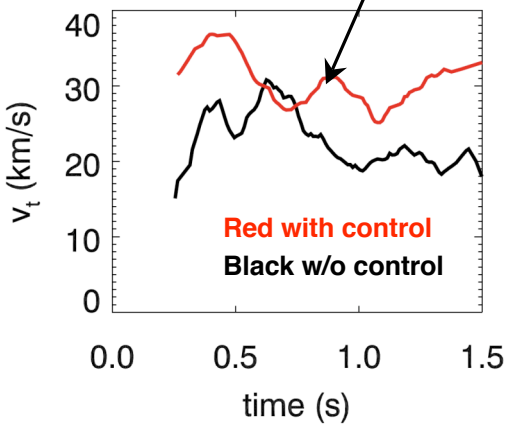


n=1 mode drops β



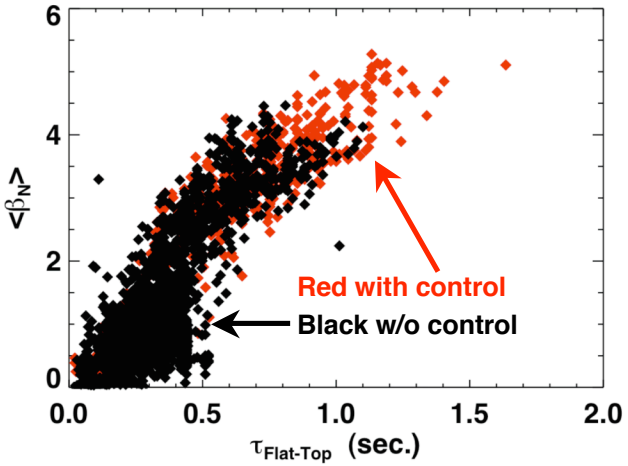
No MHD, β and rotation maintained

CHERS v_t at R = 139cm

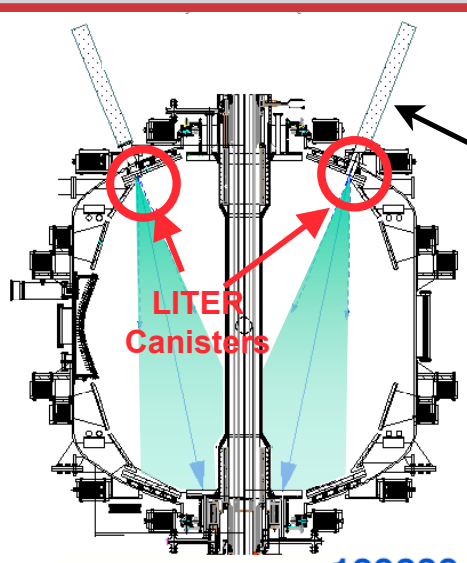


- Non-axisymmetric feedback algorithm has been developed using unique feedback training scheme
  - Prevents onset of MHD modes
  - Plasma rotation is maintained throughout discharge
- Control statistically raises β and increase pulse length

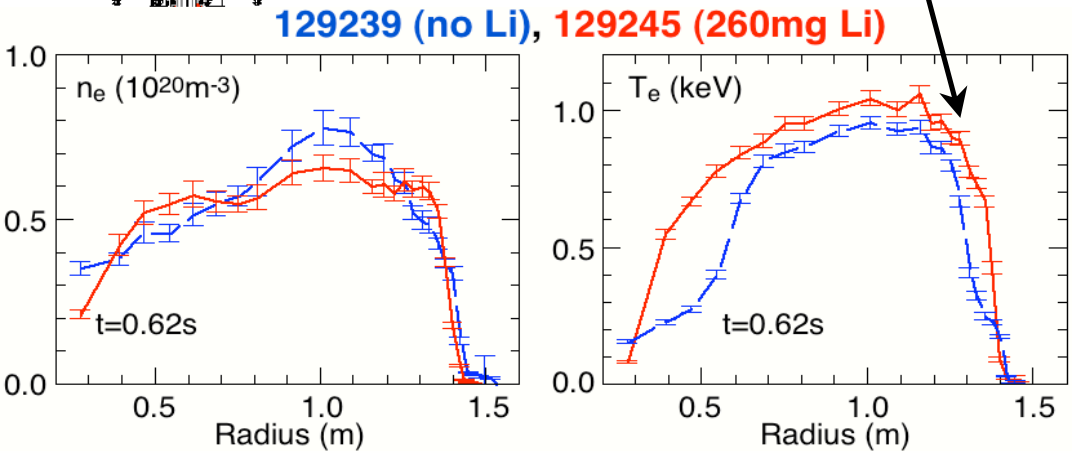
Pulse averaged β_N vs. current flat-top

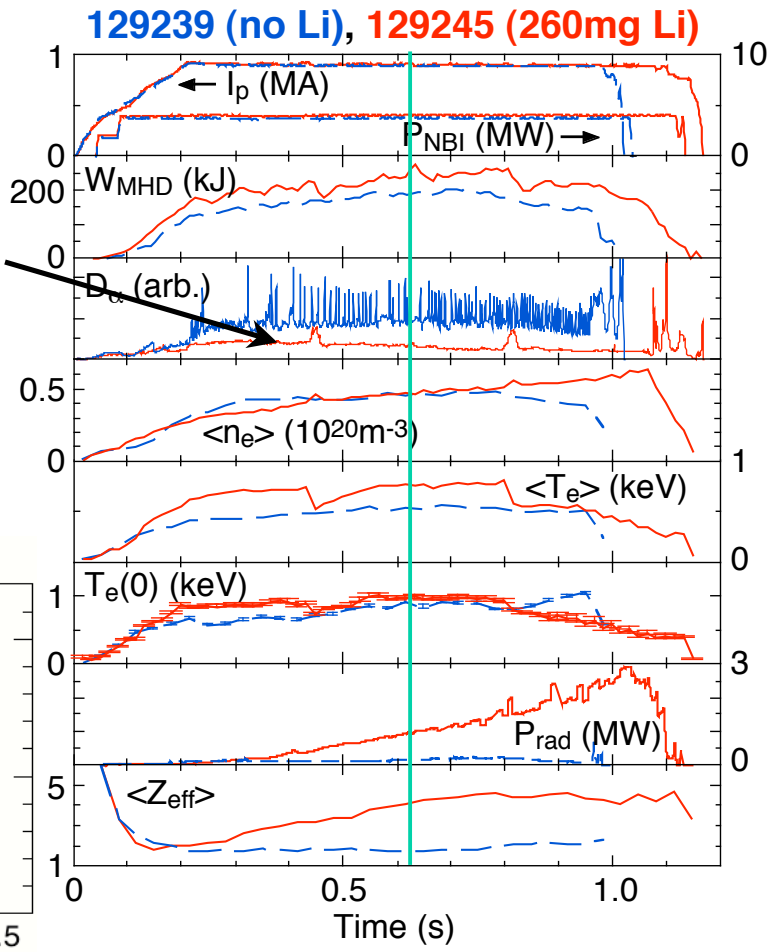


Solid Lithium Coating Reduces Deuterium Recycling, Suppresses ELMs, Improves Confinement



Dual Lithium Evaporators deposit lithium on entire lower divertor, suppressing ELMs, increasing stored energy through the electron channel

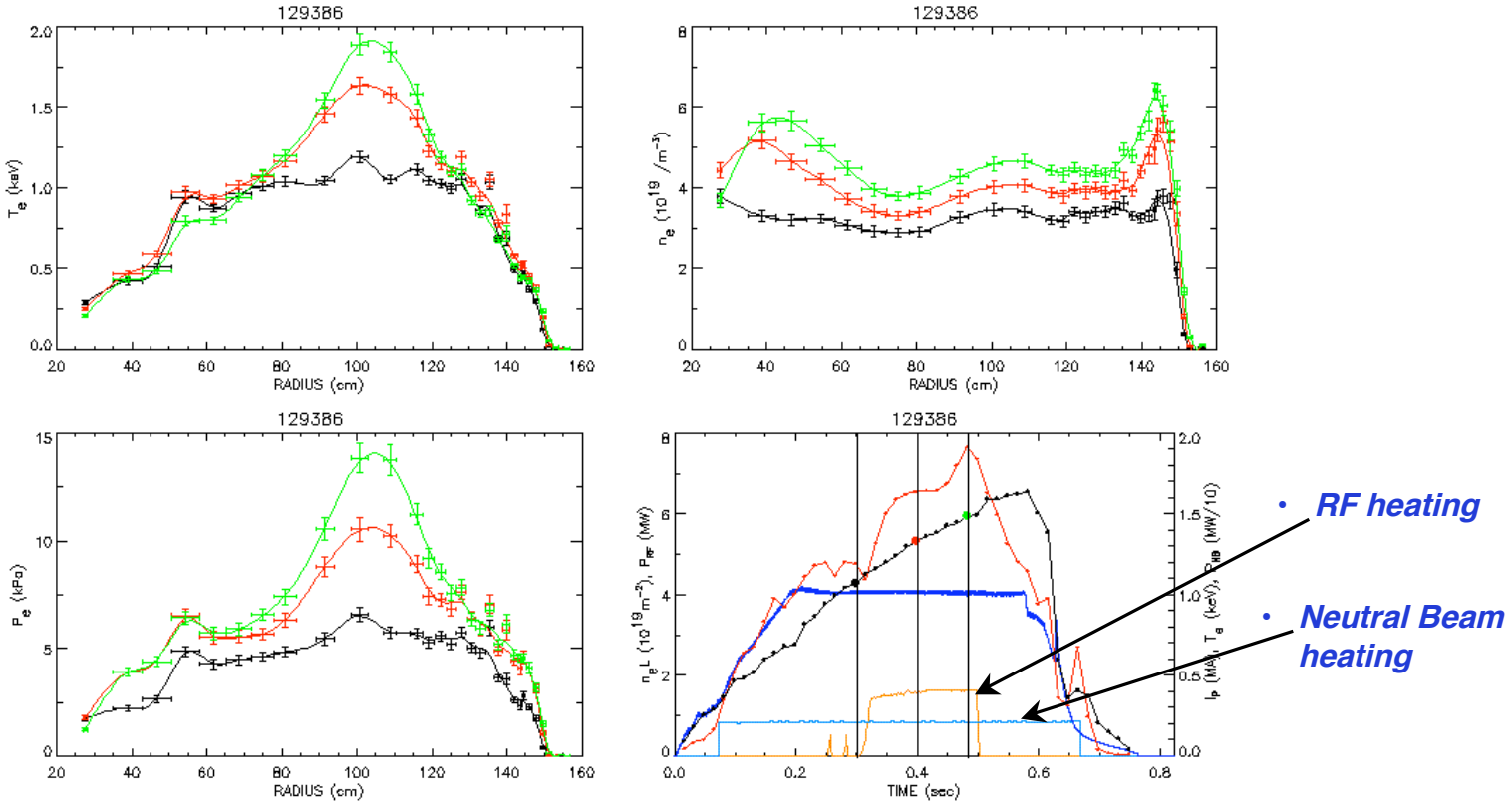




- Without ELMs, impurity accumulation increases P_{rad} and Z_{eff}, *but despite this*
- Broader T_e reduces internal inductance l_i and inductive flux consumption

High toroidal field (0.55T) improves RF coupling in beam heated H-mode plasmas

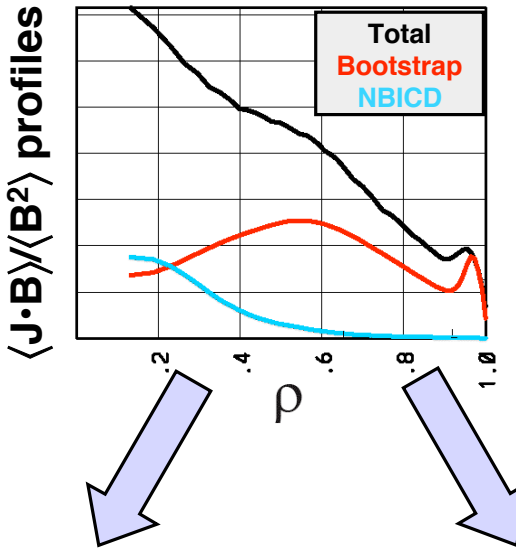
- Able to double central electron temperature during high density H-mode with 1.6MW of RF heating power
  - Lithium coating controls edge density enabling good coupling
- High TF crucial to RF coupling
- Opens many possibilities for manipulating q profile during high performance discharges and controlling ν^*



Integrated modeling indicates potential path from best NSTX plasmas towards increased f_{NICD} scenarios

TSC modeling
(C. Kessel)

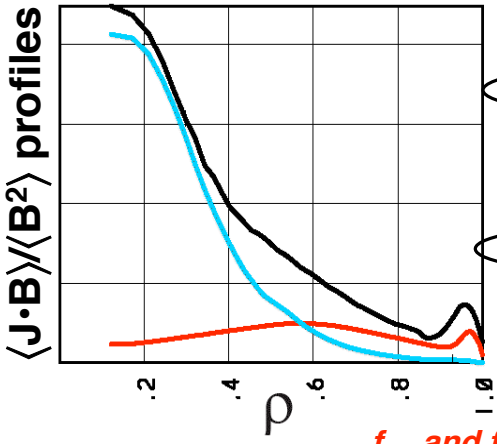
Scenarios have:
I_P=0.68-0.7MA
B_T=5.2-5.5kG



NSTX highest f_{NICD}
$n_{20}(0) = 0.85$
$\kappa = 2.2$
$H_{98} = 1.1$
$\beta_N = 5.7$
$q(0) \approx 1.2$
$f_{BS} = 55\text{-}60\%$
$f_{NBICD} = 10\%$
$f_{NICD} = 65\text{-}70\%$

- *Major extrapolations circled*

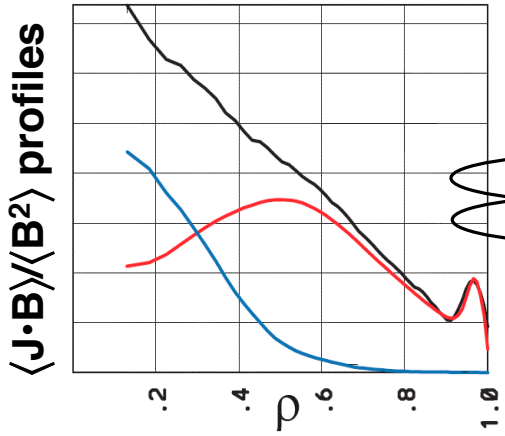
- **Transient, low n_e, high f_{NBICD}**



Low-n_e, high-f_{NBICD}
$n_{20}(0) = 0.36$
$\kappa = 2.2$
$H_{98} = 1.1$
$\beta_N = 5.6$
$q(0) \rightarrow 1$
$f_{BS} = 35\%$
$f_{NBICD} = 55\%$
$f_{NICD} = 90\%$

f_{BS} and f_{NBICD} similar to ST-CTF

- **High density, high-β_N, high-f_{BS}**



High β_N, high-f_{BS}
$n_{20}(0) = 0.75$
$\kappa = 2.6$
$H_{98} = 1.4$
$\beta_N = 6.6$
$q(0) = 1.4$ to 2.4
$f_{BS} = 75\%$
$f_{NBICD} = 25\%$
$f_{NICD} = 100\%$

f_{BS} and f_{NBICD} similar to NHTX

NSTX has made rapid progress towards developing attractive advanced operating scenarios

In particular, NSTX has:

- Combined strong shaping with high β
- Improved MHD stability with n=3 EF correction and n=1 RFA/RWM control
- Improved confinement with suppressed ELMs using Lithium evaporation
- Increased central temperatures in advanced scenarios with HHFW
  - Resulting in longest lasting ST plasma, τ_{pulse} = 1.6s ~ 5-6τ_{CR}
    - β_N > 5 for 3-4τ_{CR}
- Identified a path towards 100% non-inductive sustainment at lower ν^* with integrated scenario modeling

- These results are very encouraging for proposed future STs such as NHTX, ST-CTF as well as ST reactor concepts such as ARIES-AT