The Dependence of H-mode Energy Confinement and Transport on Collisionality in NSTX*

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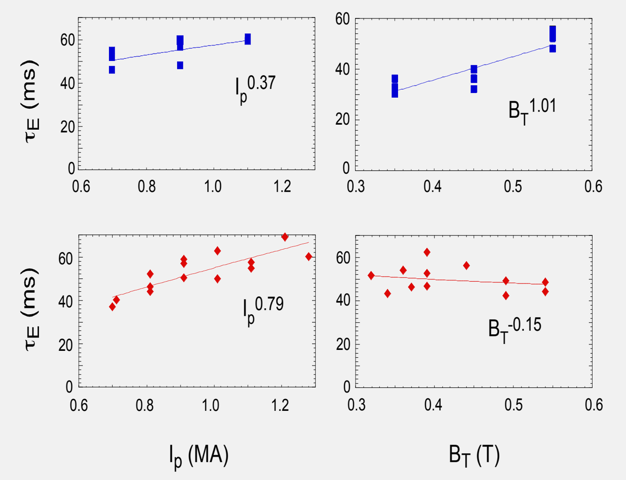
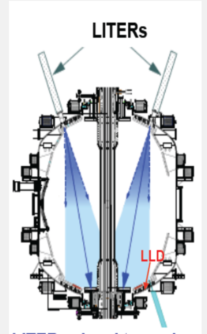
* Work supported by US DOE Contract No. DE-AC02-09CH11466

NSTX has used HeGDC+boronization as well as lithium evaporation for wall conditioning

H-mode confinement scales differently in the scenarios

- Strong B_T, weak I_p scaling in unlithiated discharges
- $H_{98y,2}$ scaling in lithiated discharges





LITERs aimed toward the graphite divertor. Shown are 1/e widths of the emitted distribution.

Can the difference in dimensional parameter scalings be reconciled?

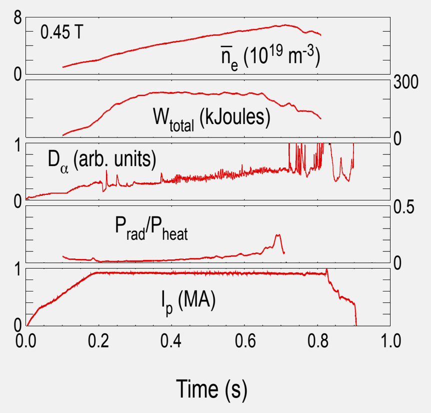
We find that:
- Lithiated discharges generally have lower collisionality
- Collisionality unifies the scalings: ***Strong increase of normalized confinement with decreasing ν^****
- Collisionality changes primarily due to electron temperature profile broadening

In this poster, we will explore the reasons for the strong scaling with collisionality

Two methods were used to change collisionality in NSTX discharges:

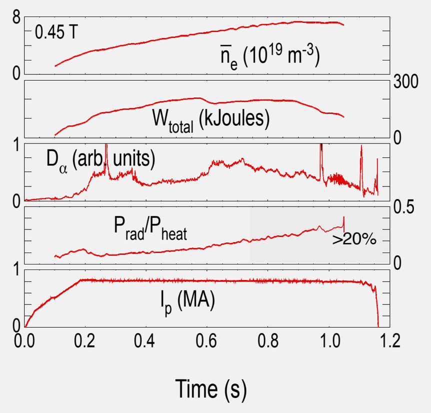
- Vary I_p, B_T at constant I_p/B_T (fixed Li + no Li): Nu scan
- Vary amount of between-shots Li evaporation (fixed I_p & B_T): Li scan

HeGDC+B wall conditioning



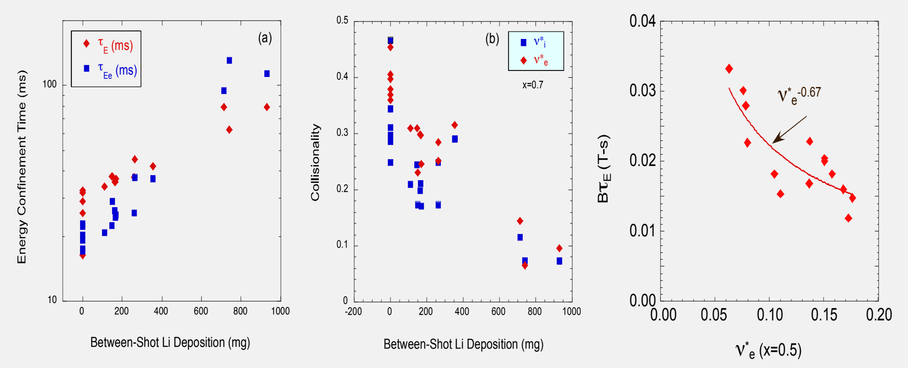
Type V (small) ELMs)

Lithium wall conditioning



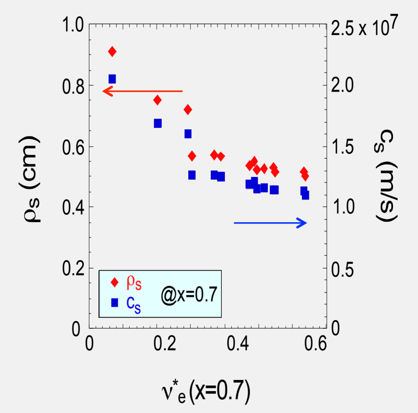
Type I or No ELMs
Choose toi when $P_{rad}/P_{heat} < 0.20$

The strong dependence of global confinement on between-shot Li deposition and collisionality is straightforwardly prominent in the **Li Scan**

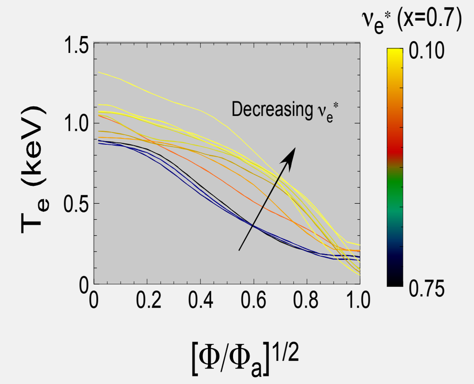


Not all dimensionless variables are fixed across range of ν^*

ρ^* ($=\rho_s/a$, a constant) changes across range of collisionality

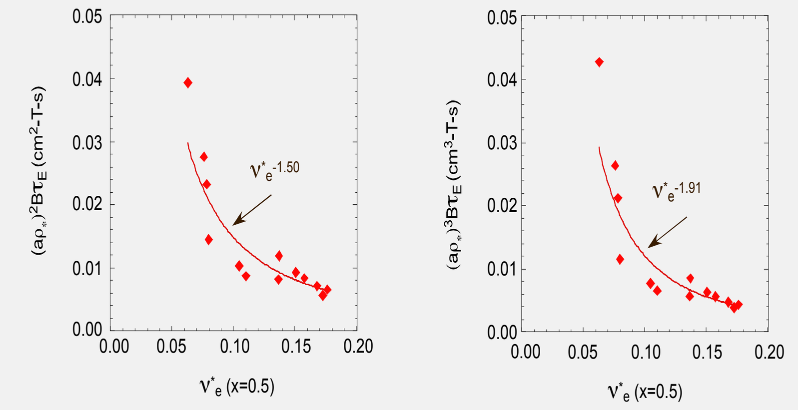


Primarily due to T_e profile broadening



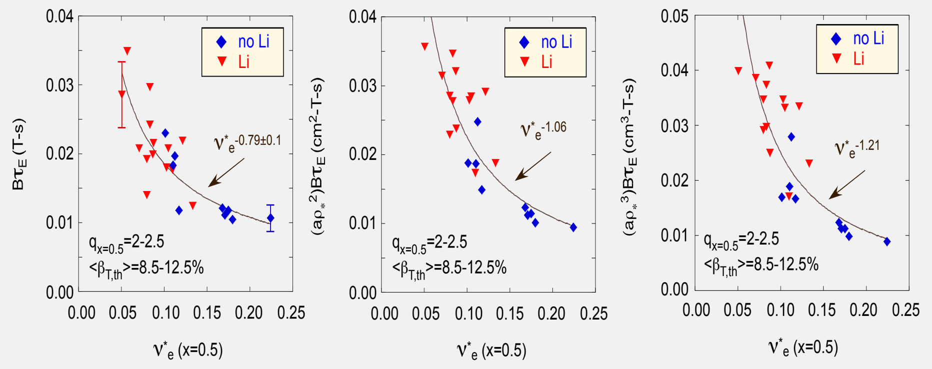
Dependence on ν^* even stronger when confinement normalized by ρ^* trends

- ***Express confinement scaling in terms of dimensionless parameters***
  $\Omega\tau_E = B\tau_E = \rho^{*\alpha} f(\nu, \beta, T_e/T_i, \kappa, q, ...)$ where α = -2 for Bohm and α = -3 for gyroBohm scaling
  - ***NSTX HeGDC+B discharges found to be consistent with gyroBohm (Kaye, 2006)***
    - ***For the Li scan, B, q, <β>, κ, a … constant for all discharges***



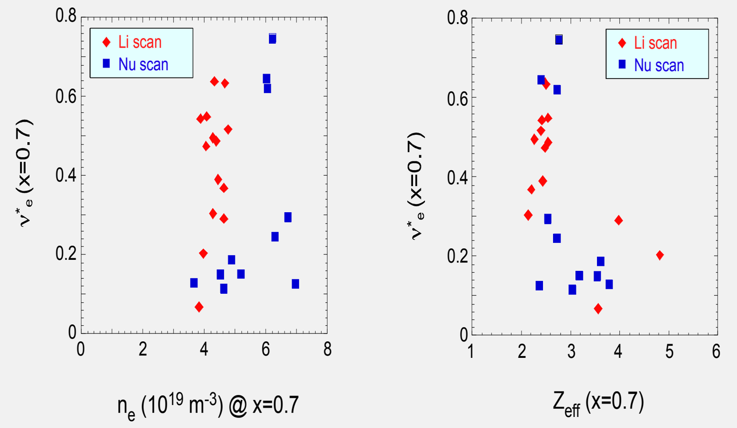
Strong dependence of normalized confinement on n^* also in "Nu Scan"

- q, β vary strongly in **Nu Scan** (also constant a)
  - Constrain data to $q_{a/2}$ = 2-2.5 and <β_T> = 8.5-12.5%

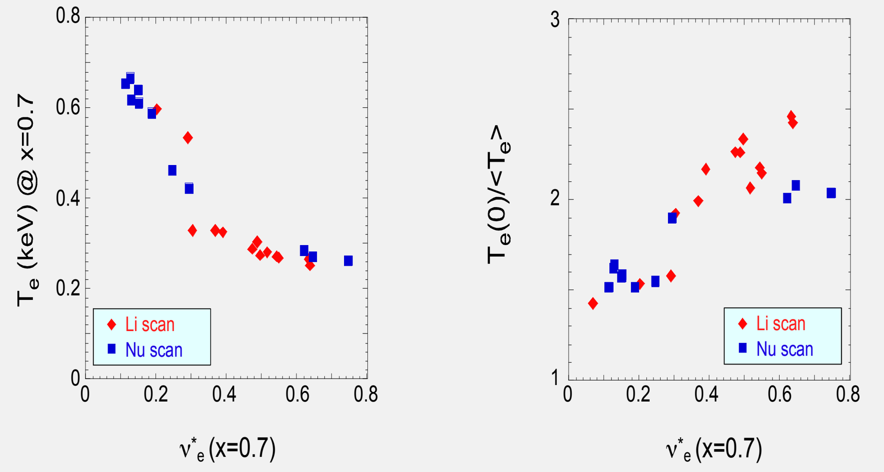


n_e and Z_{eff} variations do not control the variation in ν^*

Would expect a linear dependence between parameter pairs if they were controlling factors ($\nu^* \sim n_e Z_{eff}$)

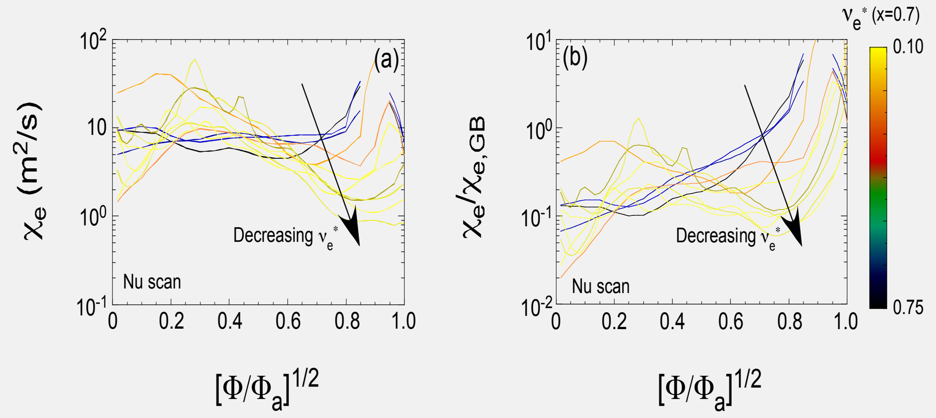


The variation in T_e and T_e profile broadness is the reason ν^* (and ρ^*) varies ($\nu^* \sim 1/T_e^2$)



The T_e broadening reflects a strong reduction in electron transport with decreasing collisionality in the outer region of the plasma

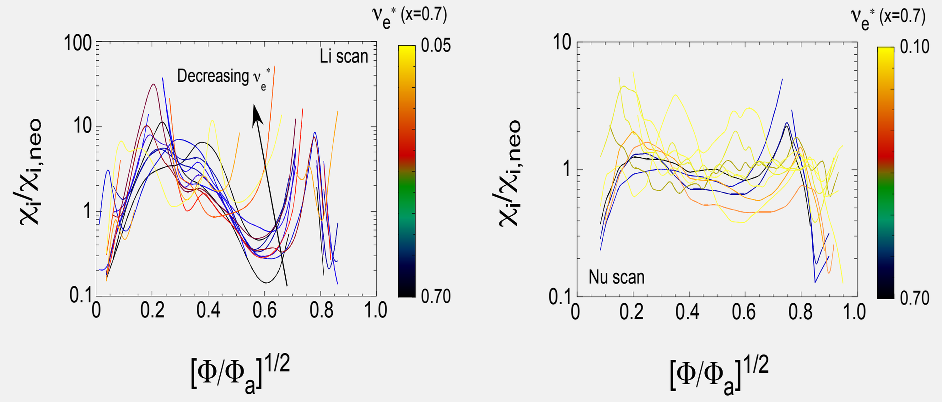
This can be seen in both χ_e and χ_e/χ_{GB}, where $\chi_{GB} \sim \rho_s^2 c_s/a$



Also in Li scan

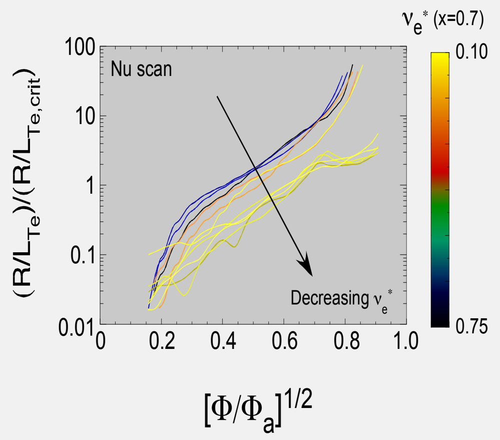
There is a general <u>increase</u> of <u>**anomalous**</u> ion transport in outer regions with decreasing collisionality, but the dependences are more complicated

- Overall increase in $\chi_i/\chi_{i,neo}$ with decreasing collisionality, but there is large scatter even at similar ν_e^*
  ~Neoclassical (NCLASS) ion transport at lowest collisionality (factor of ~2 uncertainty in $\chi_i/\chi_{i,neo}$)
- Ion transport also correlated with rotation shear



High-k ETG becomes more stable for lower collisionality discharges

- Comparison of experimental R/L_{Te} to analytic ETG critical gradient (Jenko et al., 2001) indicates reduction of ETG drive as collisionality decreases
  - Consistent with reduction in electron transport

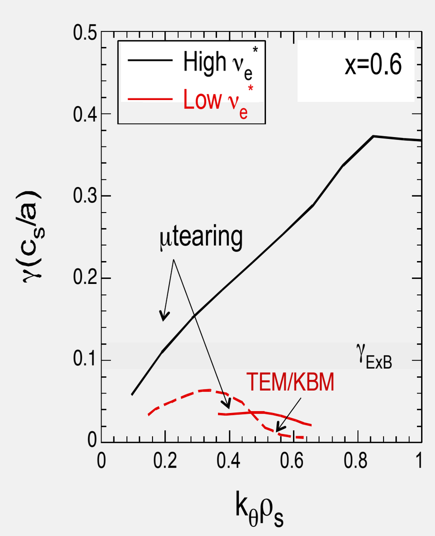


- Linear gyrokinetic indicated ETG completely stabilized for low collisionality discharges
  - Stability due to reduced T_e gradient
- Reduction of high-k turbulence ($k_r\rho_\theta \sim 5 - 30$) at lower collisionality in pedestal region (Canik 2011)

Low-k modes show more complicated dependence

- Linear GYRO calcs indicate microtearing growth dominates low-k spectrum at high collisionality
- At low collisionality, microtearing becomes weaker
  - Consistent with reduction in electron transport going from high to low collisionality
- Low-k hybrid mode (TEM/KBM) predicted to exist at low collisionality
  - Consistent with increase in ion transport
  - Can provide some electron transport
- Mode growth rates near γ_{EXB} at low collisionality
  - Non-linear calculations underway to assess effect on predicted transport levels
- Li scan shows similar result

Nu Scan



Summary and Conclusions

- Collisionality is the unifying parameter in understanding confinement trends in NSTX plasmas
- Normalized confinement shows a strong and favorable dependence with decreasing collisionality
  - Trend is even stronger when Bohm or gyroBohm variation of ρ^* is taken into account
- Improved confinement is governed primarily by reduction in electron transport in outer region
  - Broader T_e profiles with decreasing ν_e^*
  - ETG, microtearing more stable going from high to low ν_e^*
- Ions, however, become more anomalous going from high to low collisionality
  - Hybrid TEM/KBM mode unstable at low ν_e^*
  - Need to assess respective roles of ν_e^* and rotation shear
- **Will be able to explore these trends at even lower collisionality (5x) with more control of the rotation profile on NSTX-U**