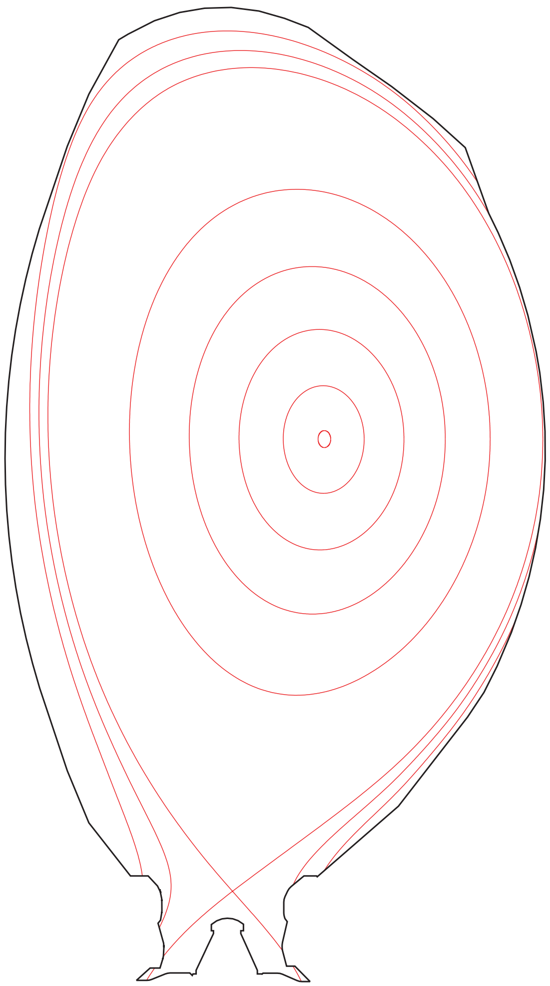
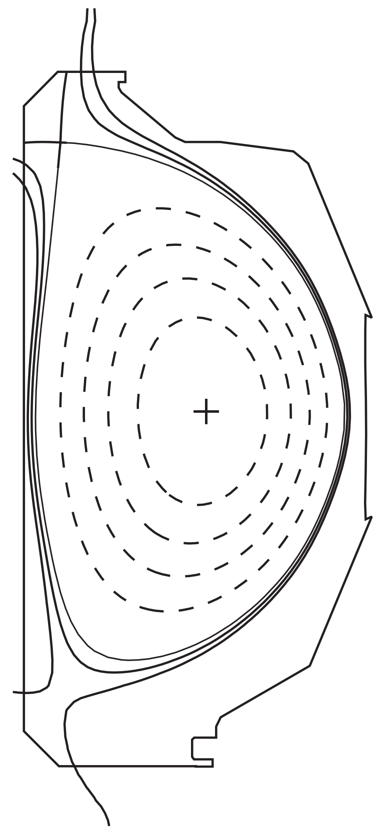
MOTIVATION

- Discharges with impurity seeding can radiate a significant power fraction inside the LCFS, reducing peak heat fluxes to plasma facing surfaces
- Reduced power flow across the LCFS can allow L–mode operation by remaining below the L–H power threshold, eliminating transient heat pulses (ELMs)
- DIII–D and TEXTOR results have shown that energy confinement equivalent to H–mode, $H_{97Y} \sim 1$, can be achieved with an L–mode edge
- Establishing similar discharges in JET can provide size scaling and further elucidate the common underlying physical mechanisms

COMPARISON OF NEON SEEDED L–MODE DISCHARGES IN DIII–D AND JET CAN PROVIDE SIZE SCALING DATA



JET (53154, 44.8 S)



DIII–D (98775, 1.16 S)

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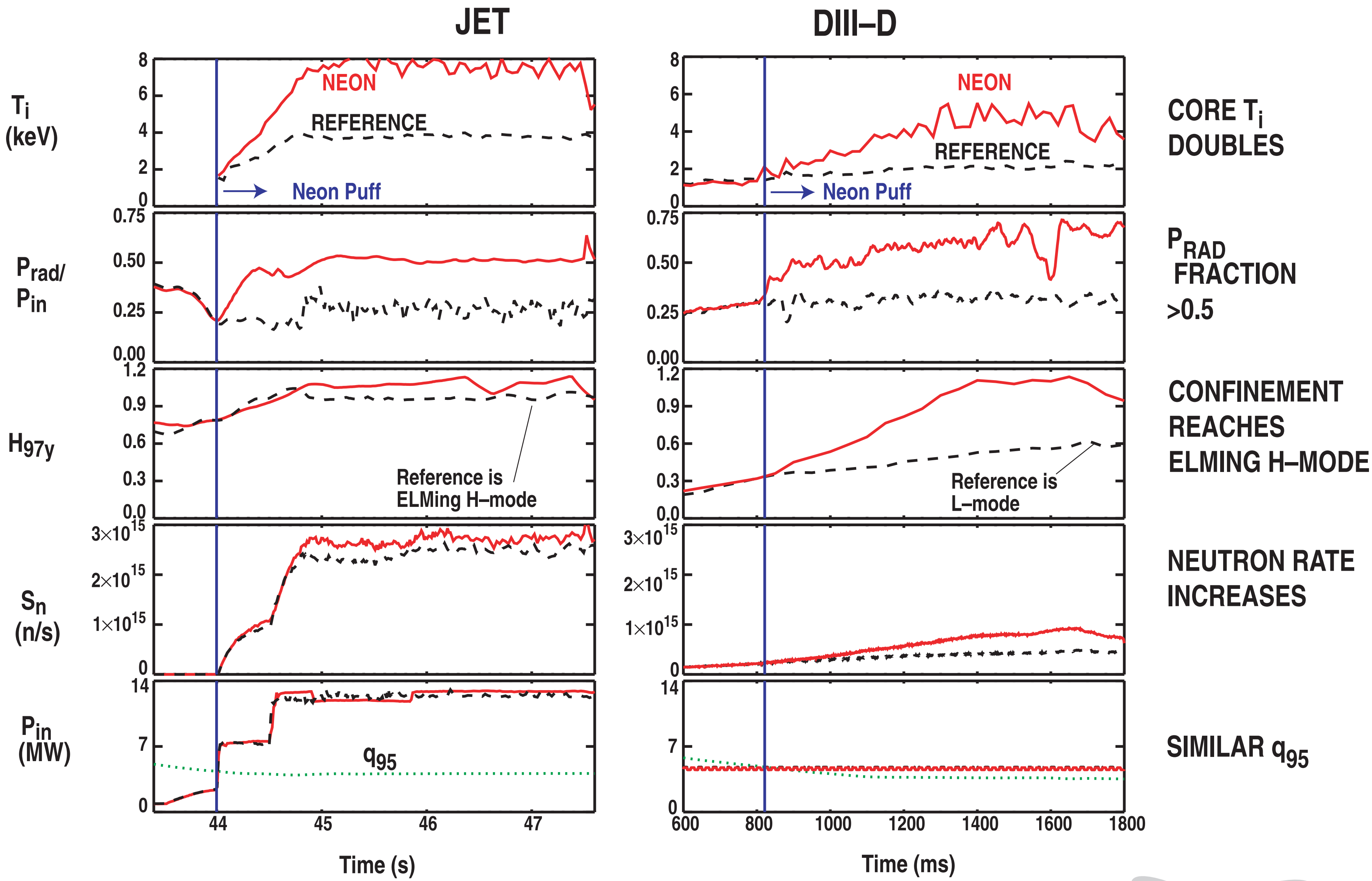
BOTH JET AND DIII–D EXHIBIT SIMILAR TEMPORAL RESPONSE WITH NEON SEEDING



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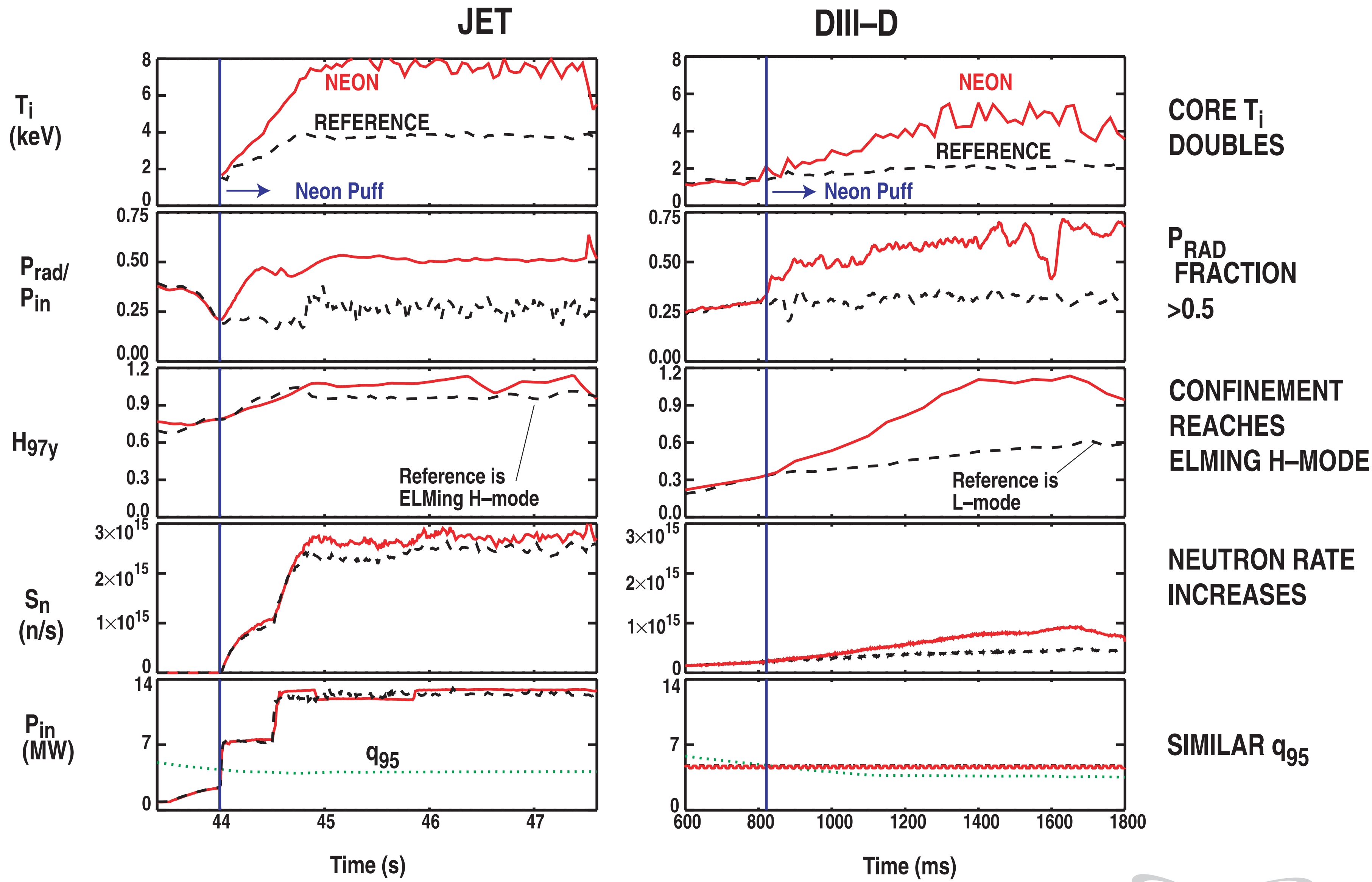

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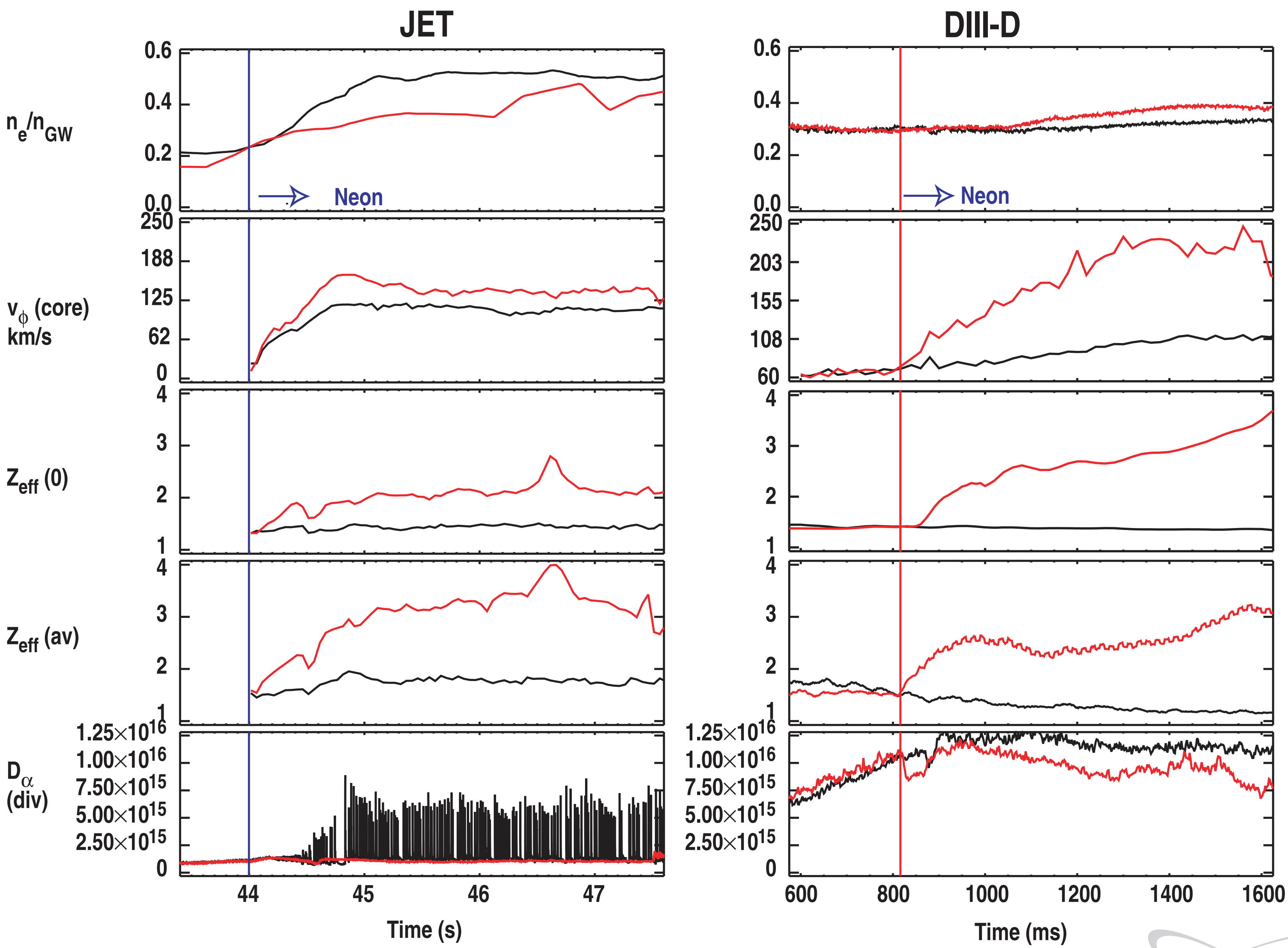
COMPARISON OF JET AND DIII–D L–MODE NEON SEEDED DISCHARGES (continued)



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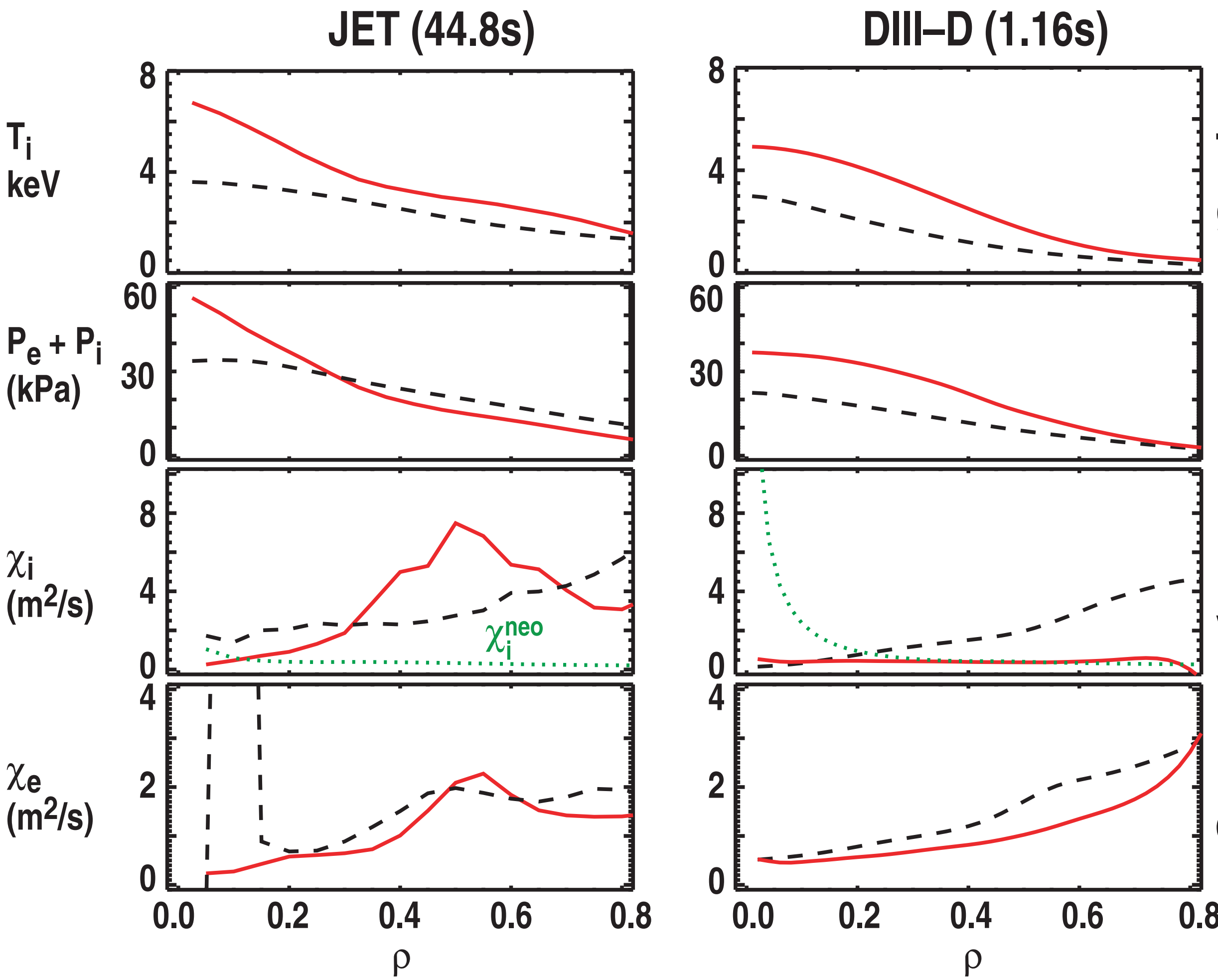
PROFILE DIFFERENCES BETWEEN NEON AND REFERENCE DISCHARGES OCCUR IN DIFFERENT REGIONS



T_i and thermal pressure gradients steepen for ρ <~ 0.35 (JET) and ρ <~ 0.6 (DIII–D)

Ion thermal diffusivity is less than neoclassical values in the core

Electron thermal diffusivity exhibits only small changes

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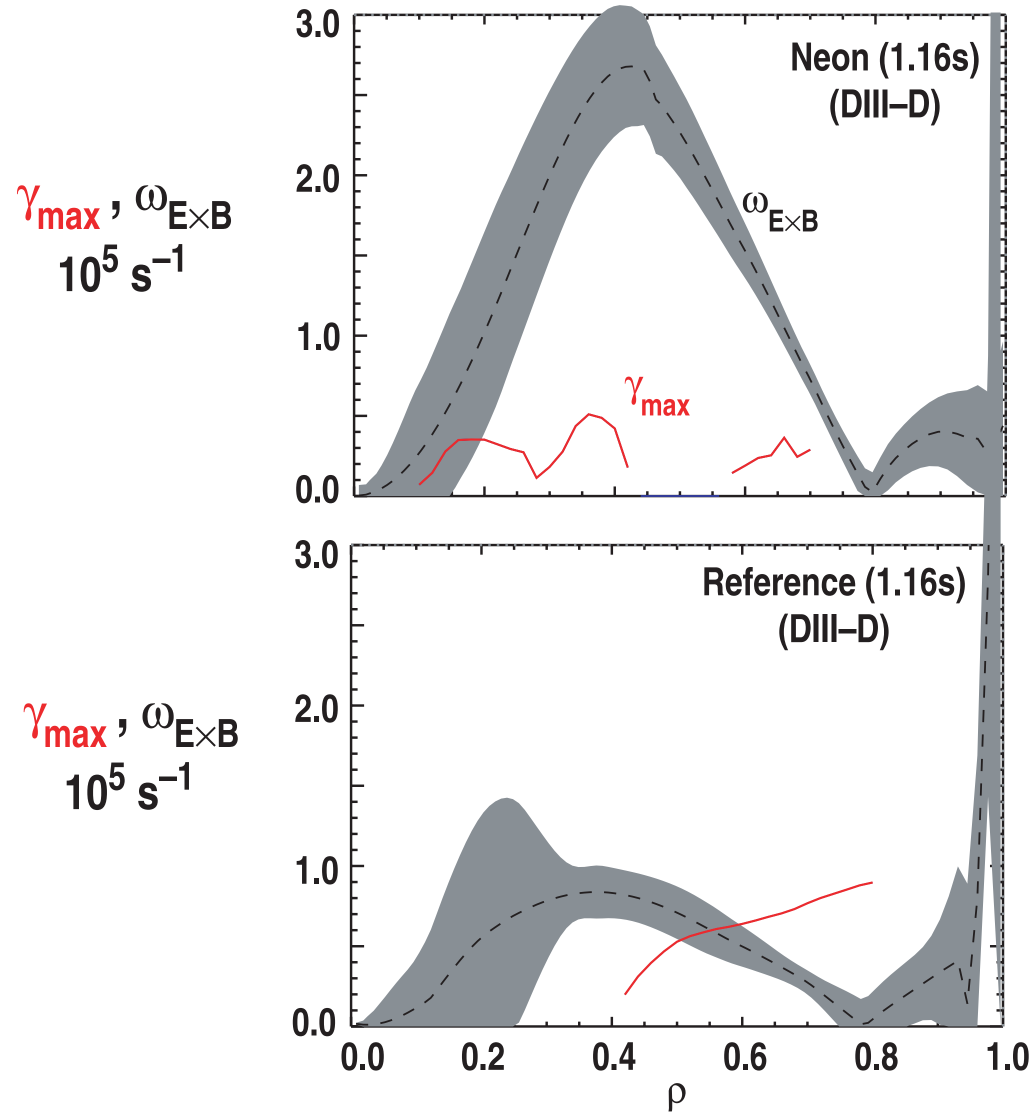
REDUCTION IN ION TEMPERATURE GRADIENT (ITG)–MODE GROWTH RATES CAN EXPLAIN χ_i REDUCTIONS IN JET AND DIII–D

- Reductions in low k ITG–Mode microturbulence in other tokamaks (TEXTOR and DIII–D) have been identified as the mechanism leading to increases in energy and particle confinement
- Impurity seeding can act in a synergistic manner to reduce ITG growth rates
  - Growth rate of turbulence is a function of mass and decreases with increasing impurity concentrations
  - Introduction of impurities acts as a trigger to reduce turbulence
  - Reduction in turbulence leads to improved transport and larger E×B shear
  - Increased E×B rotational shear further stabilizes microtrubulence creating a positive feedback loop

MAXIMUM GROWTH RATE FOR LOW k TURBULENCE IS REDUCED WITH NEON INJECTION IN DIII–D WELL BELOW THE E×B SHEARING RATE, ALLOWING ITG MODE SHEAR STABILIZATION



γ_{max} is well below the ExB shearing rate, allowing ITG mode shear stabilization. Maximum reduction in density fluctuations (BES) is observed for ρ ~ 0.6-0.7

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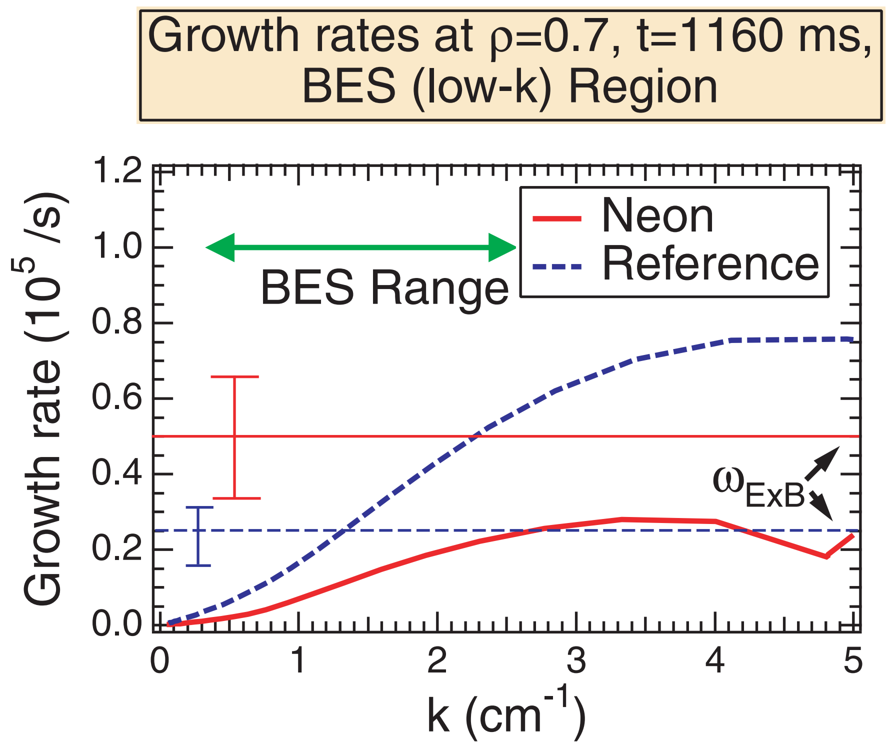
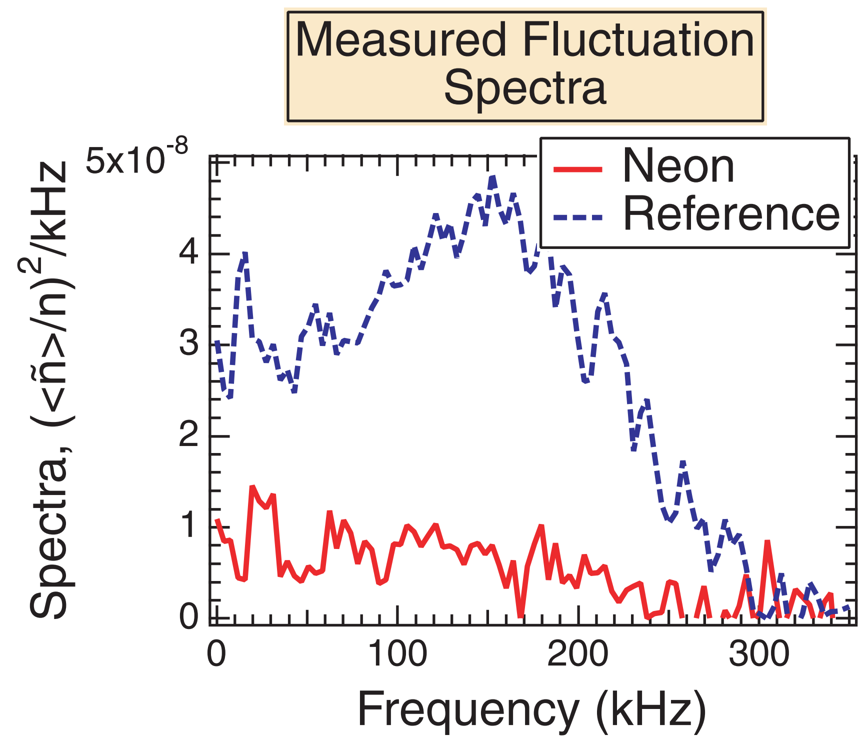
GKS CALCULATIONS OF LINEAR STABILITY GROWTH RATES FOR DIII-D DISCHARGES SHOW SIGNIFICANT REDUCTION AT LOW-k





- ExB shearing rates exhibit opposite behavior, increasing in neon shot, further suppressing turbulence:

Neon: $\gamma_{lin} < \omega_{ExB}$, Reference: $\gamma_{lin} > \omega_{ExB}$

G.R. McKee

GLJ eps00f11a

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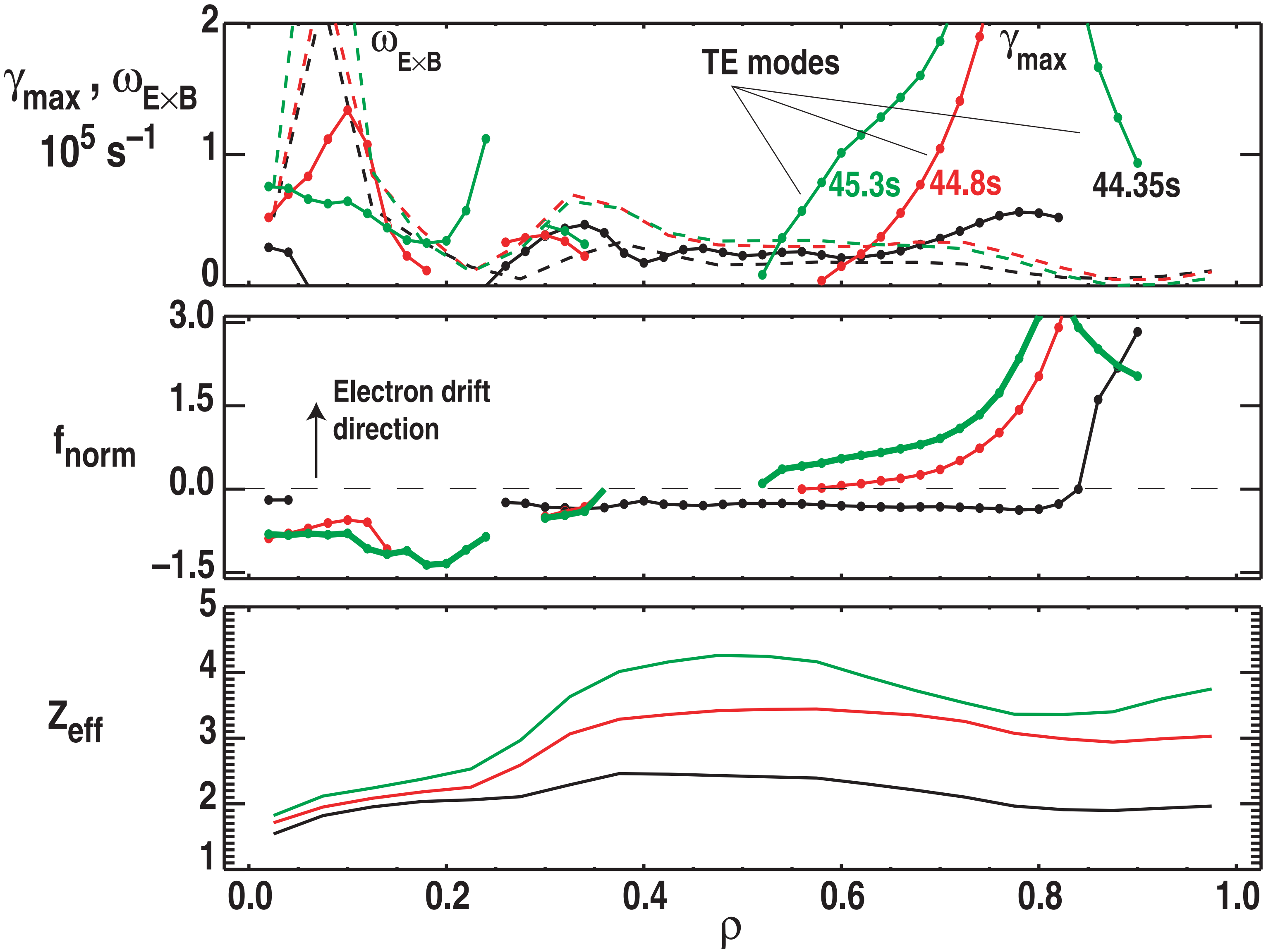
REGION OF ITG STABILIZATION IS REDUCED IF Z_{eff} BECOMES TOO LARGE



Region of $W_{E\times B}$ stabilization decreases at later times and region for TE modes is growing

Neon seeding begins at 44.0 s (#53154)

V_ϕ (core), S_n are maximum at 44.8

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FOR BOTH DIII–D AND JET, MHD CAN LIMIT PEAK PERFORMANCE AND DURATION

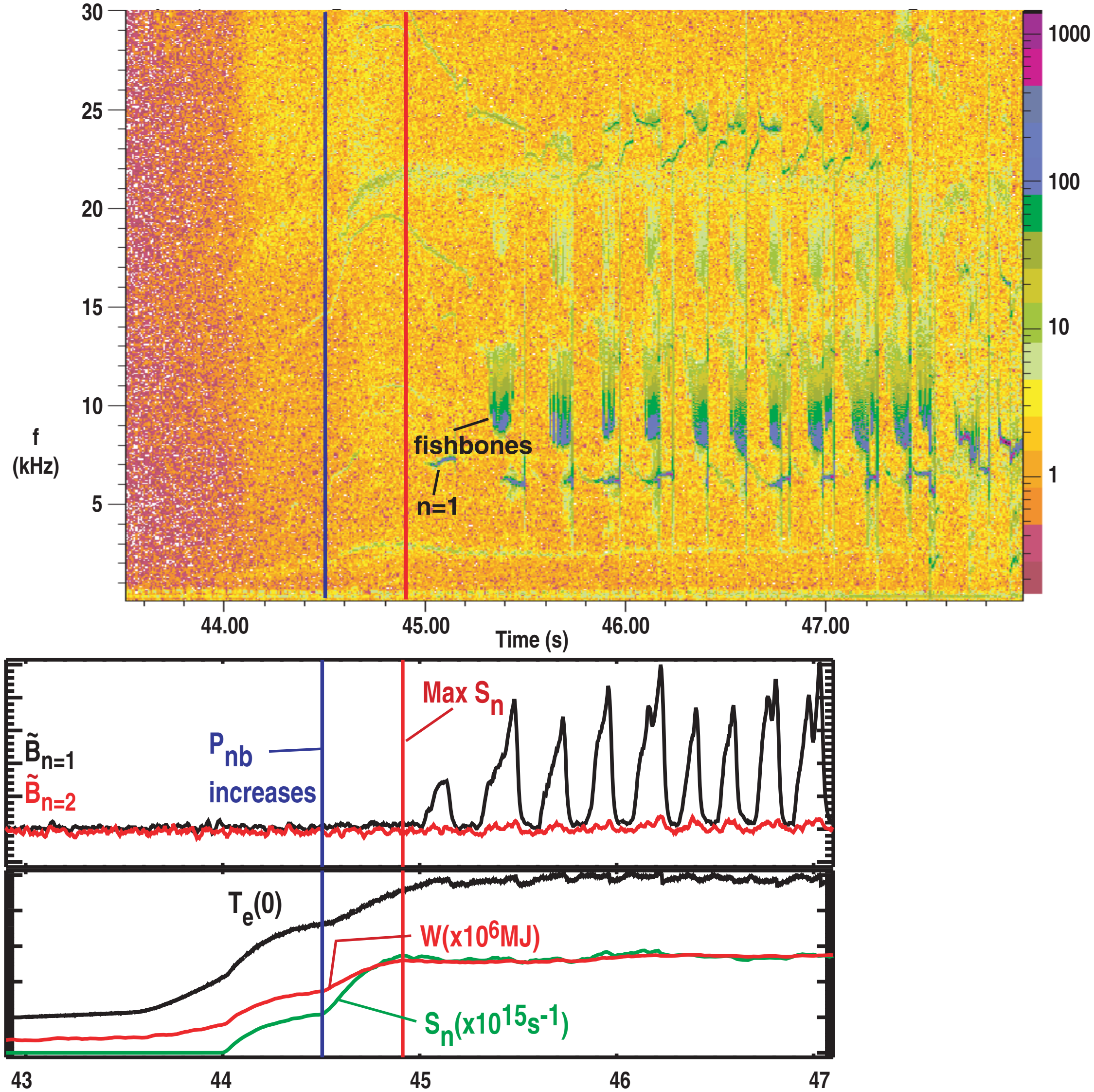
JET

- Low H–mode power threshold makes ELM avoidance more difficult
  - Must inject neon coincident with beams
- n=2 tearing modes (Koslowski, P3.010) and sawteeth can limit the high performance phase
- To date, operational space is limited for tearing mode avoidance
  - Discharge evolution is not reproducible and affects the onset of tearing modes
  - ICRH minority heating provides some benefit
- Sawteeth can be minimized by LHCD
  - n=2 modes have not been simultaneously reduced
  - n=2 MHD activity with LHCD may be due to non-optimum shape
- Discharge development is required to optimize both n=1 and n=2 MHD and extend the duration

DIII–D

- Sawteeth couple to the 3/2 rational surface producing seed islands
- $\Delta r'$ (TEAR code) becomes increasingly unstable. m/n=3/2 islands grow, producing neoclassical tearing modes (Brennan, P3.044)

MHD MAY LIMIT PEAK PERFORMANCE IN JET



BEST NEON DISCHARGES ARE LIMITED BY n=1 MHD AND SAW-TEETH

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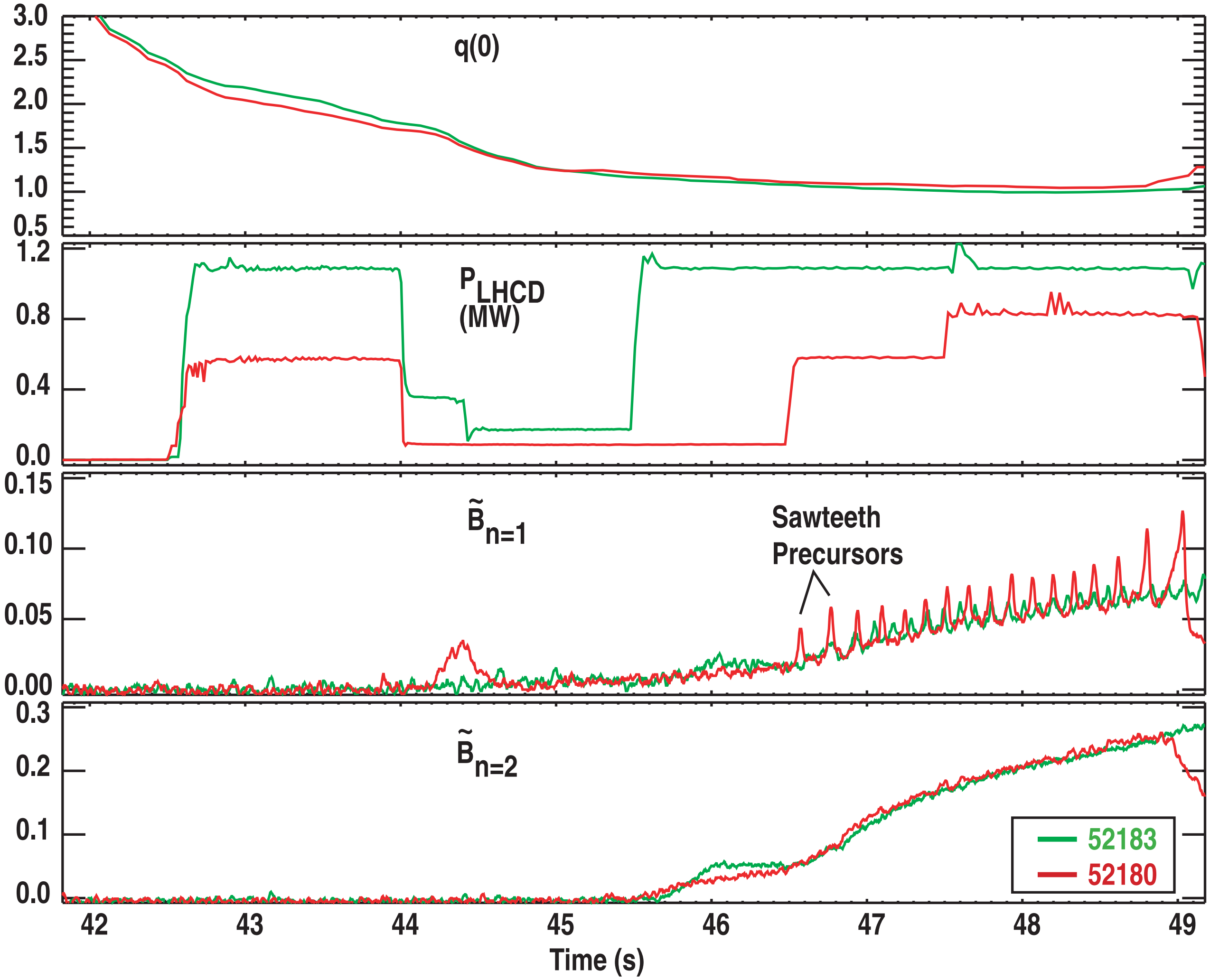
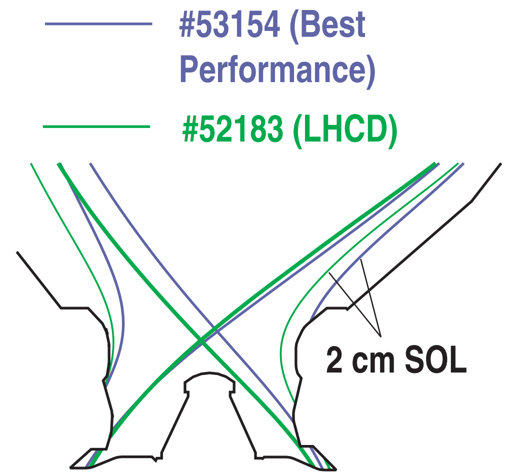
INCREASED LHCD POWER MINIMIZES n=1 MHD ACTIVITY





LHCD Shape has not been optimized for neon seeding

n=2 tearing modes are not reduced with LHCD

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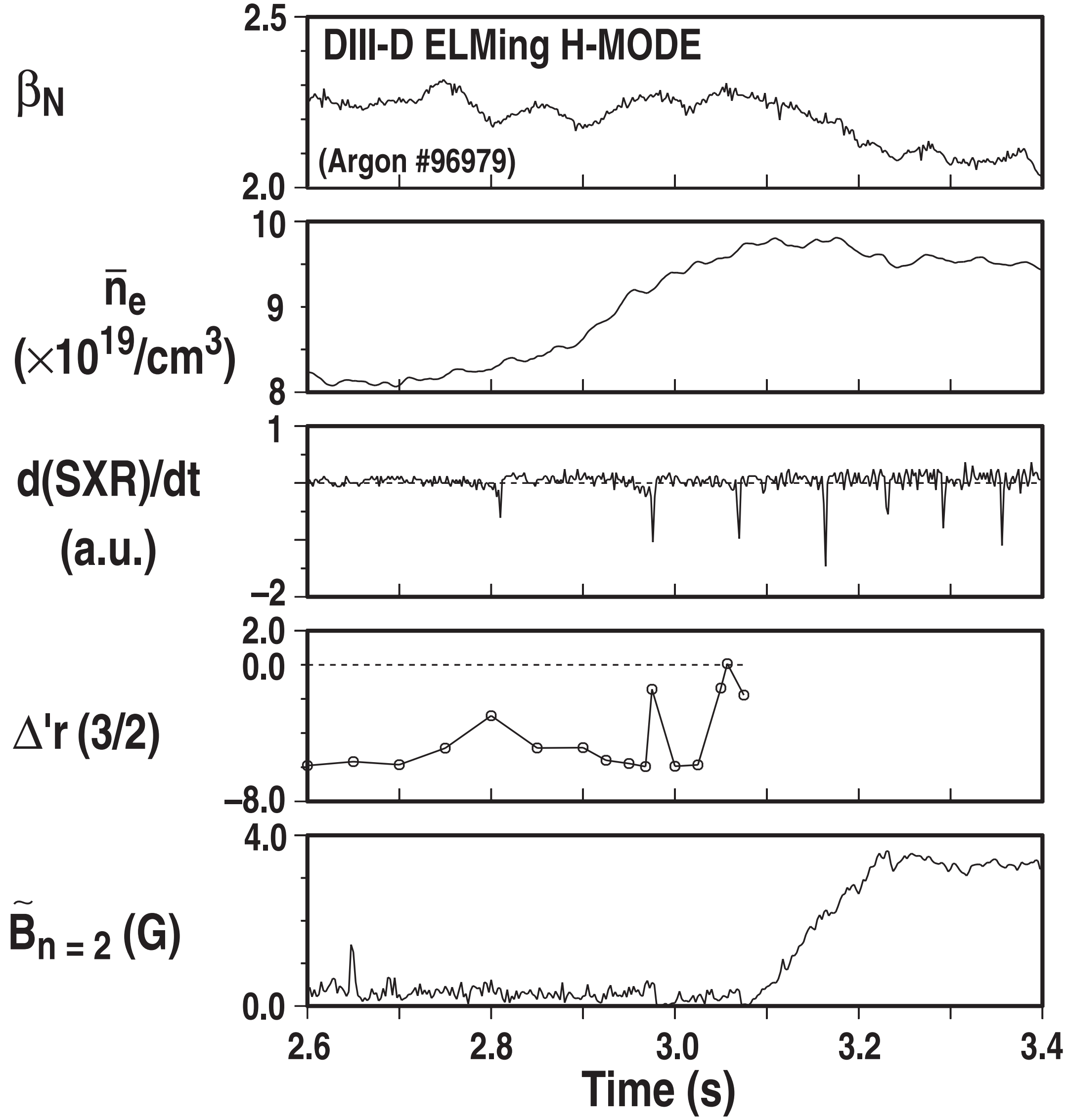
IN DIII–D, BEST PERFORMANCE WITH IMPURITY SEEDING IS USUALLY LIMITED BY m/n=3/2 NEOCLASSICAL TEARING MODES, TRIGGERED BY SAWTEETH



IMPURITY SEEDED ELMING H–MODE AND L–MODE DISCHARGES BOTH ARE LIMITED BY NTMs

n=2 MHD ACTIVITY INCREASES AS Δ'r BECOMES MORE POSITIVE

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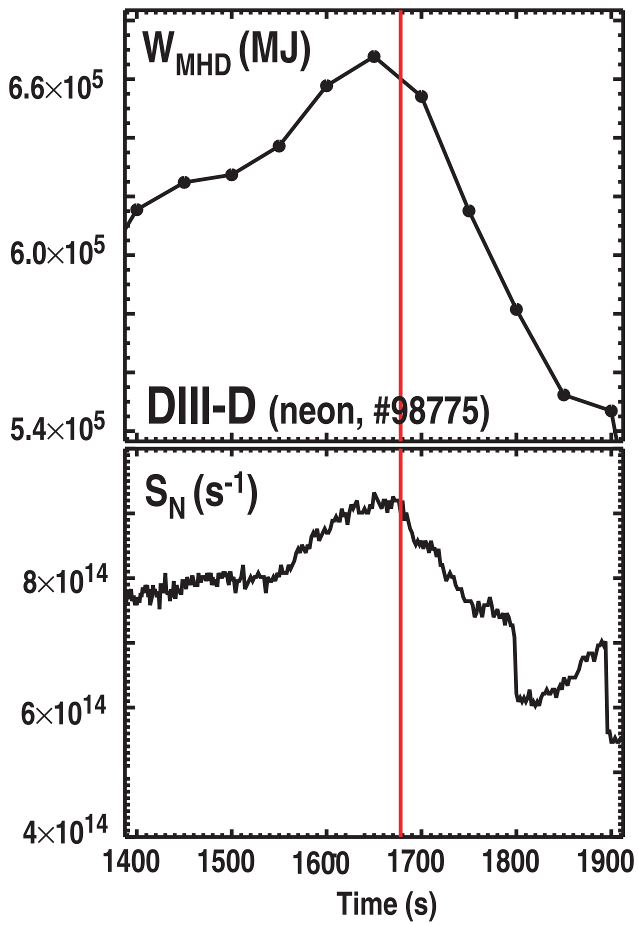
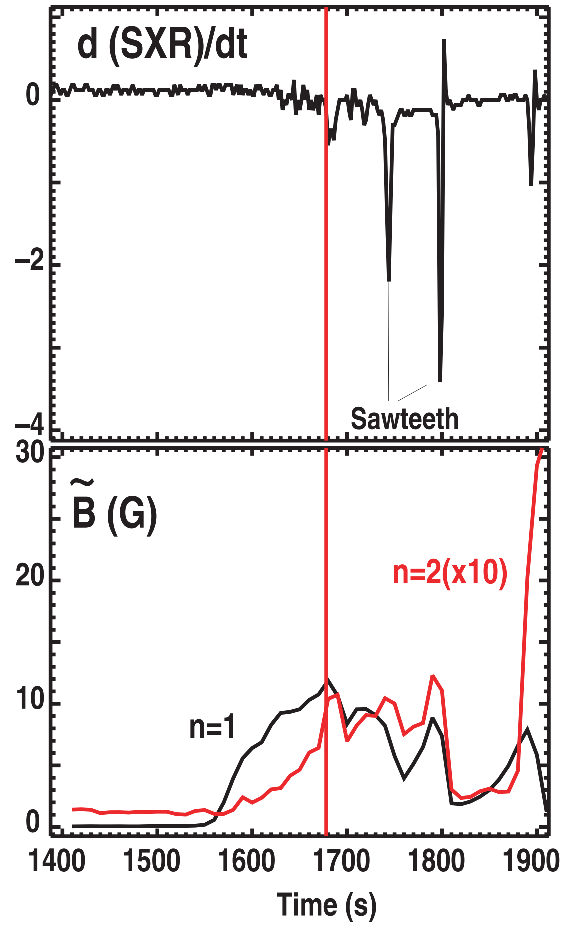
MHD LIMITS PERFORMANCE IN DIII–D NEON SEEDED L–MODE DISCHARGES





n=1 (SAWTEETH) PRECEDE n=2 modes

BOTH n=1 AND n=2 MHD MODES AFFECT CONFINEMENT AND NEUTRON RATE

CONCLUSIONS

- Neon seeded discharges with an L–mode edge and confinement equivalent to ELMy H–mode have been achieved in both DIII–D and JET
  - The temporal evolution of these discharges is similar in both devices
  - When compared to refence (unseeded) discharges, a region of higher ion temperature is observed, up to a factor of 2 in the center
  - Higher plasma pressure extends from the core to $\rho \sim 0.6$ in DIII–D and $\rho \sim 0.35$ in JET
- In both devices, ExB shear stabilization of low k (ITG) modes appears to be the physical mechanism leading to lower thermal diffusivities and higher confinement
  - GKS modeling shows that the region of ITG stabilization is smaller in JET than DIII–D
- MHD tearing modes limit performance in both JET and DIII–D L–mode neon seeded discharges
- Future work will be directed at extending the duration of these neon seeded discharges by reducing MHD, using tools such as ECCD (DIII–D) and LHCD (JET)