Comparison of Enhanced Confinement L–Mode Regimes in JET and DIII–D With Impurity Seeding

by

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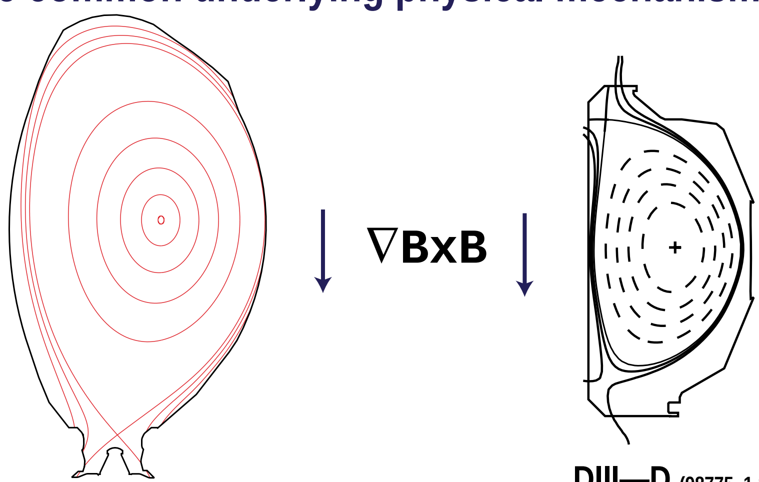
MOTIVATION

- **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)**
- **JET,DIII—D and TEXTOR have demonstrated energy confinement equivalent to H—mode, H_{97Y} ~ 1, with an L—mode edge and impurity seeding**
- **Establishing similar discharges in DIII-D and JET can provide size scaling and further elucidate the common underlying physical mechanisms**



JET (53154, 44.8 S)

DIII—D (98775, 1.16 S)

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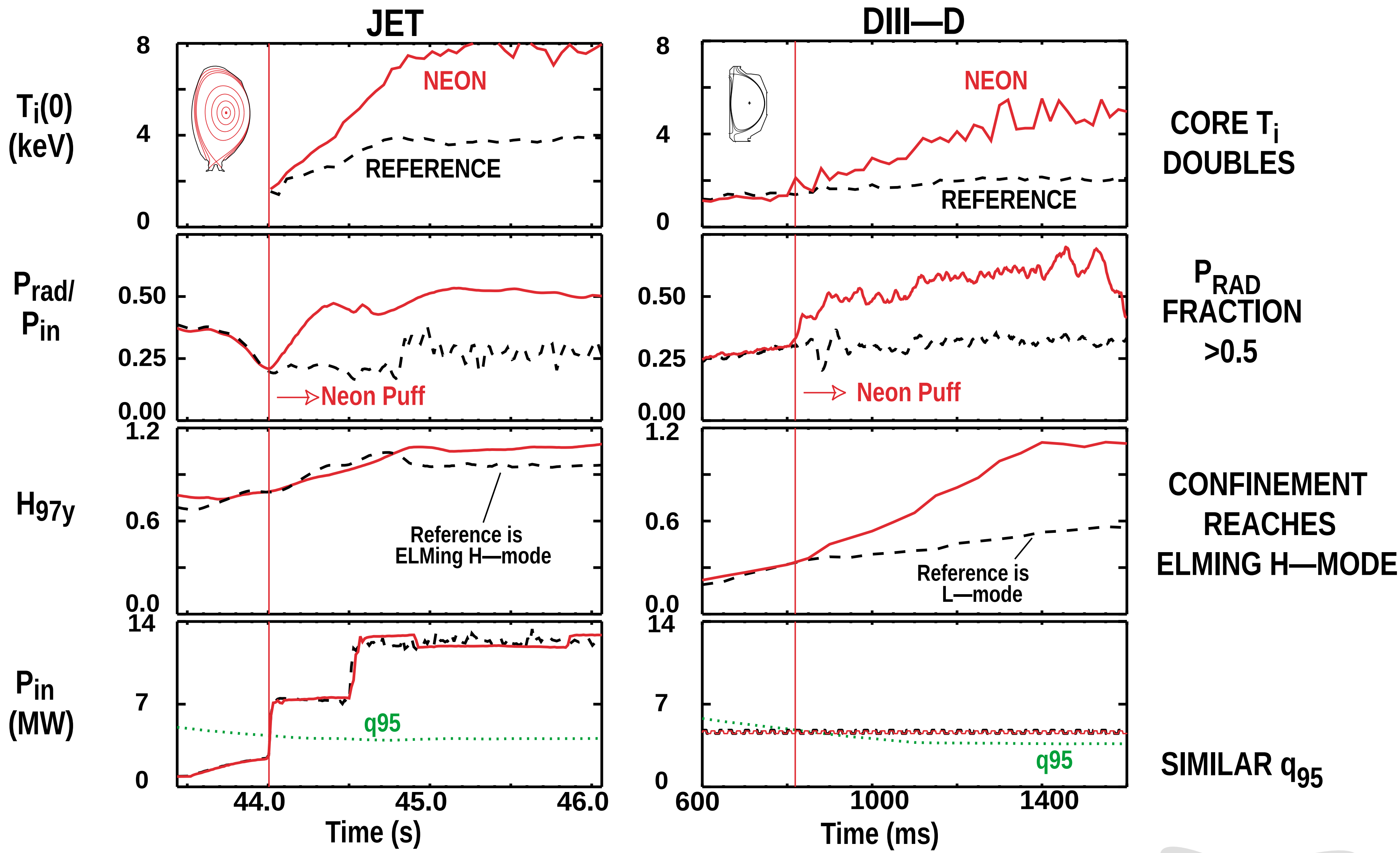
BOTH JET AND DIII—D EXHIBIT SIMILAR TEMPORAL RESPONSE WITH NEON SEEDING



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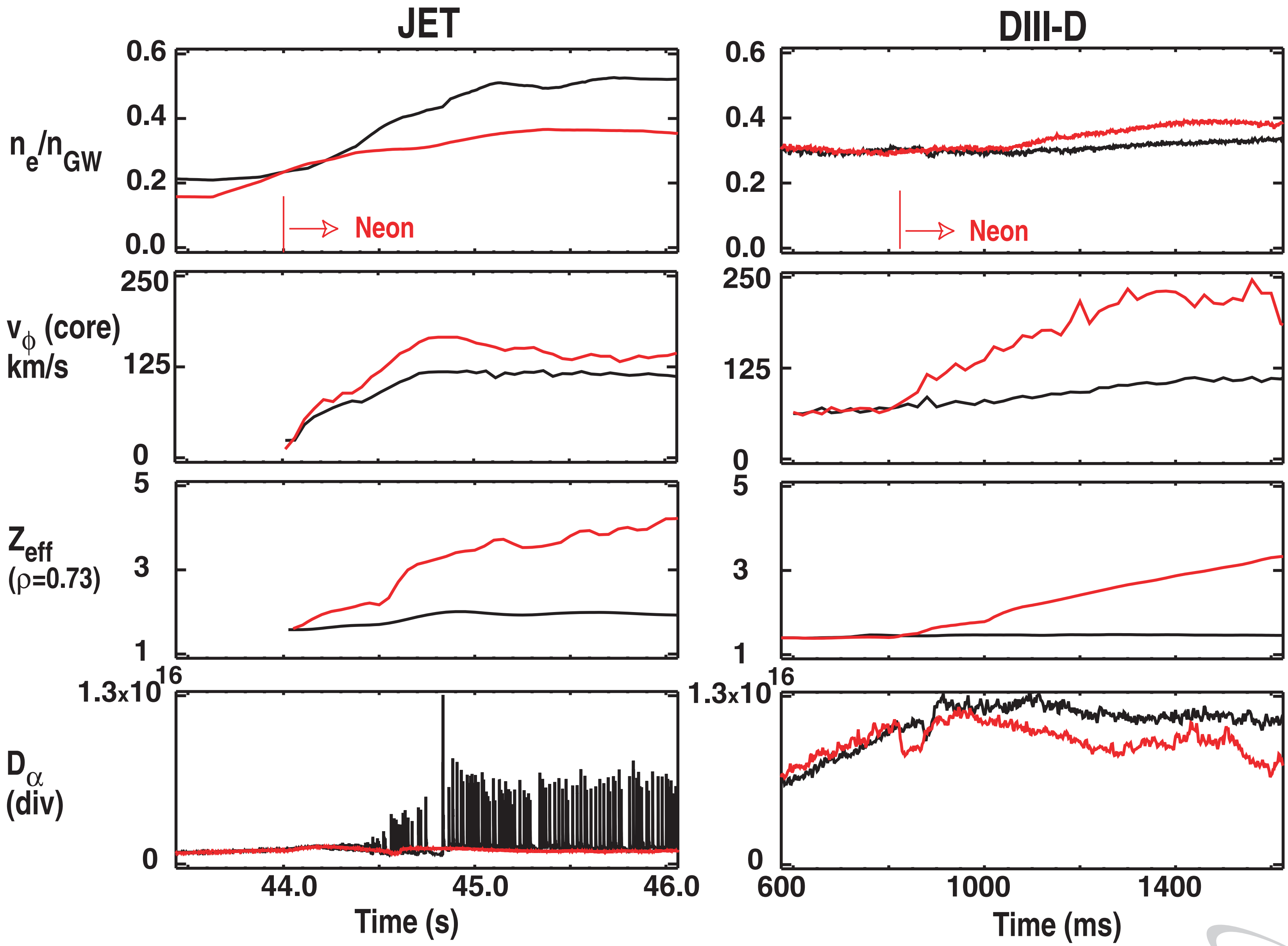
TOROIDAL ROTATION INCREASES IN NEON SEEDED DISCHARGES WHILE n_e IS COMPARABLE



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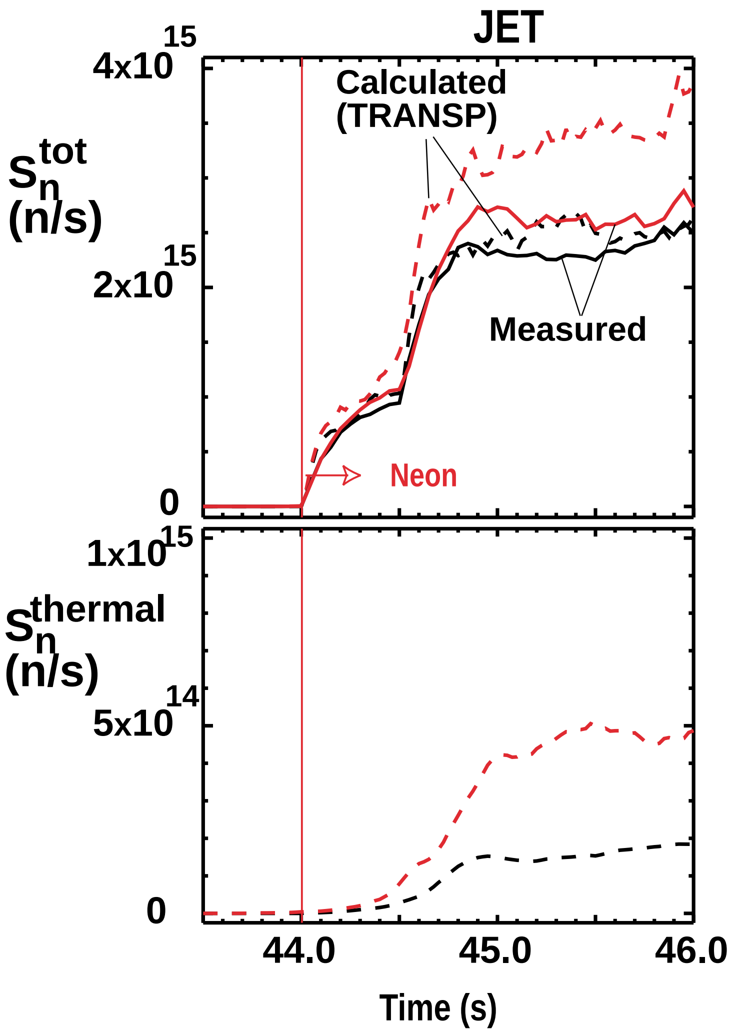
NEUTRON RATES ACTUALLY INCREASE WITH NEON SEEDING



CALCULATED TOTAL NEUTRON RATES ARE WITHIN 30% OF MEASURED RATES

INCREASE IS HIGHEST FOR THERMAL NEUTRONS

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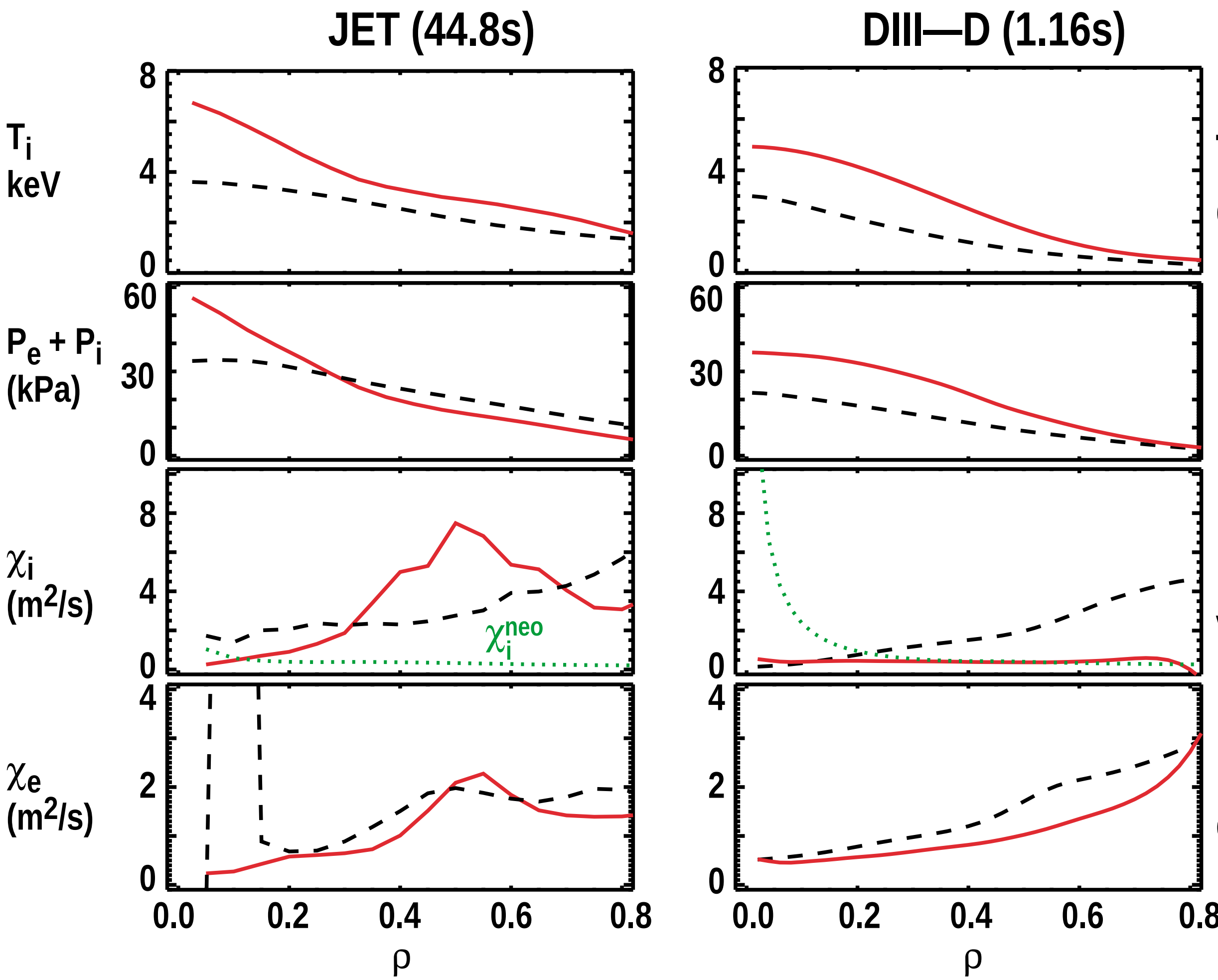
PROFILE DIFFERENCES BETWEEN NEON AND REFERENCE DISCHARGES OCCUR IN DIFFERENT REGIONS



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 when $\omega_{ExB} > \gamma_{max}$ (Waltz's rule)
- 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

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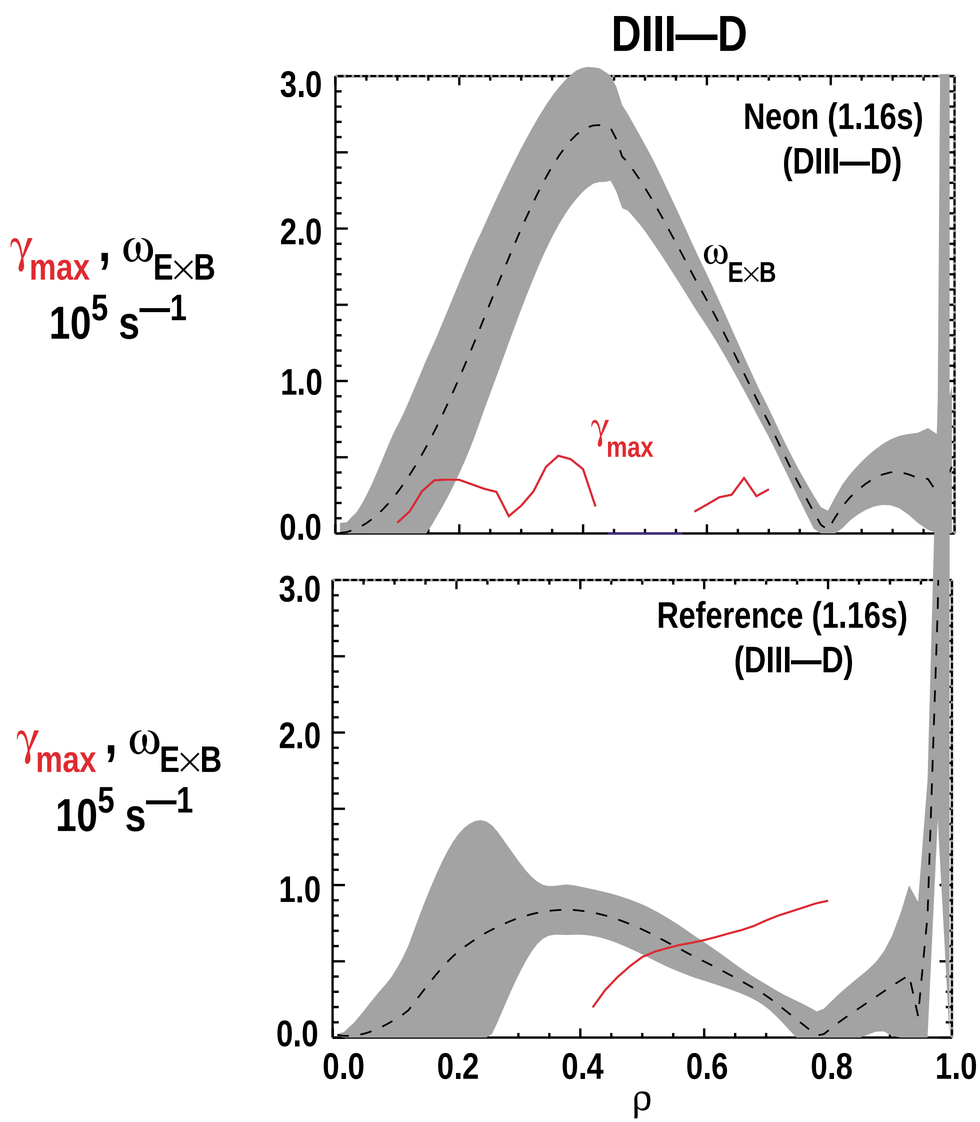
MAXIMUM GROWTH RATE FOR LOW k TURBULENCE IS REDUCED WITH NEON INJECTION IN DIII—D WELL BELOW THE E×B SHEARING RATE, ALLOWING ITG MODE SHEAR STABILIZATION



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 (McKee invited, APS1999)

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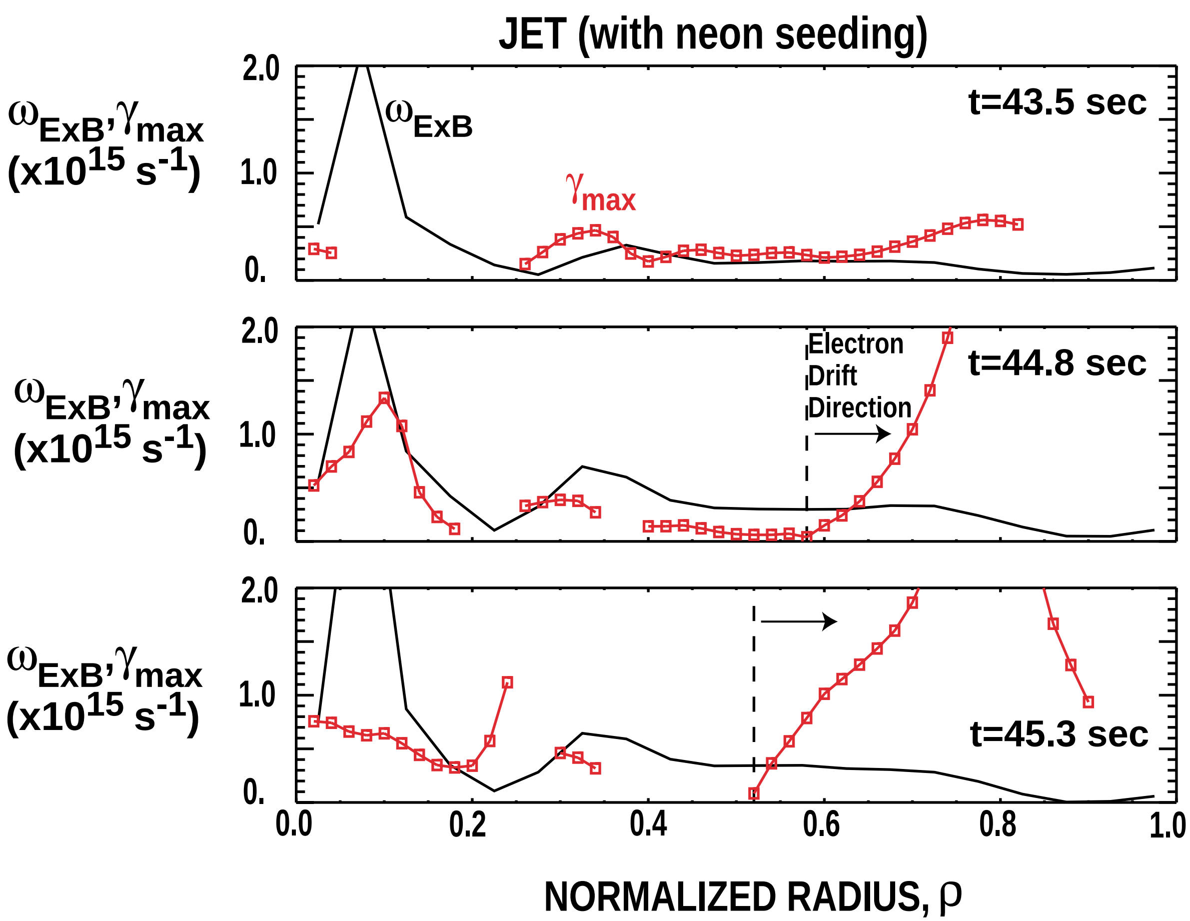
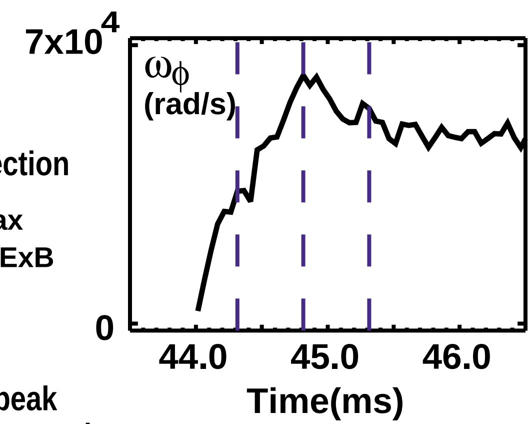
IN JET, GKS ANALYSIS SHOWS THAT NEON SEEDING CAN BE STABILIZING TO ITG MICROTURBULENCE



After neon injection (43.0 sec), γ_{max} approaches ω_{ExB} over much of the profile

At the time of peak core rotation, ω_{ExB} is stabilizing over most of the profile. The TE mode dominates at larger ρ

Later in time the TE mode moves inward and part of the core is no longer stabilized by ω_{ExB} shear.



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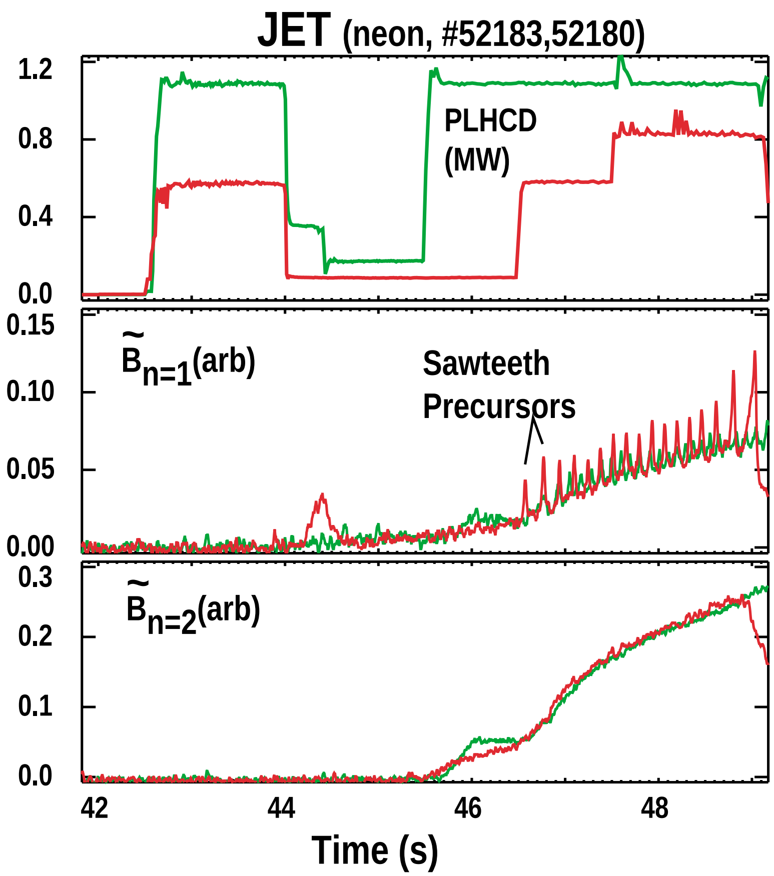
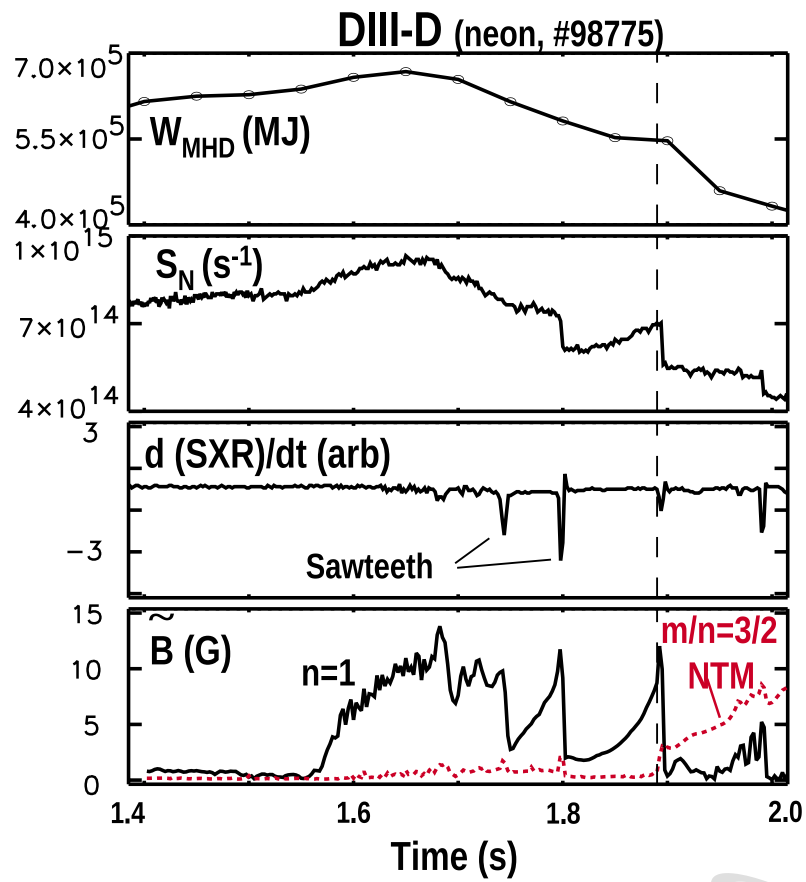
FOR BOTH DIII-D AND JET, MHD CAN LIMIT PEAK PERFORMANCE AND DURATION, BUT LHCD OR ECCD MAY MITIGATE THIS.

In JET, higher LHCD power can reduce n=1 MHD activity



In DIII-D, sawteeth trigger m/n=3/2 NTMs, limiting duration of the high confinement phase. ECCD can be stabilizing (LaHaye, APS 2001 invited)



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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 reference (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 r ~ 0.6 in DIII—D and ρ ~ 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)