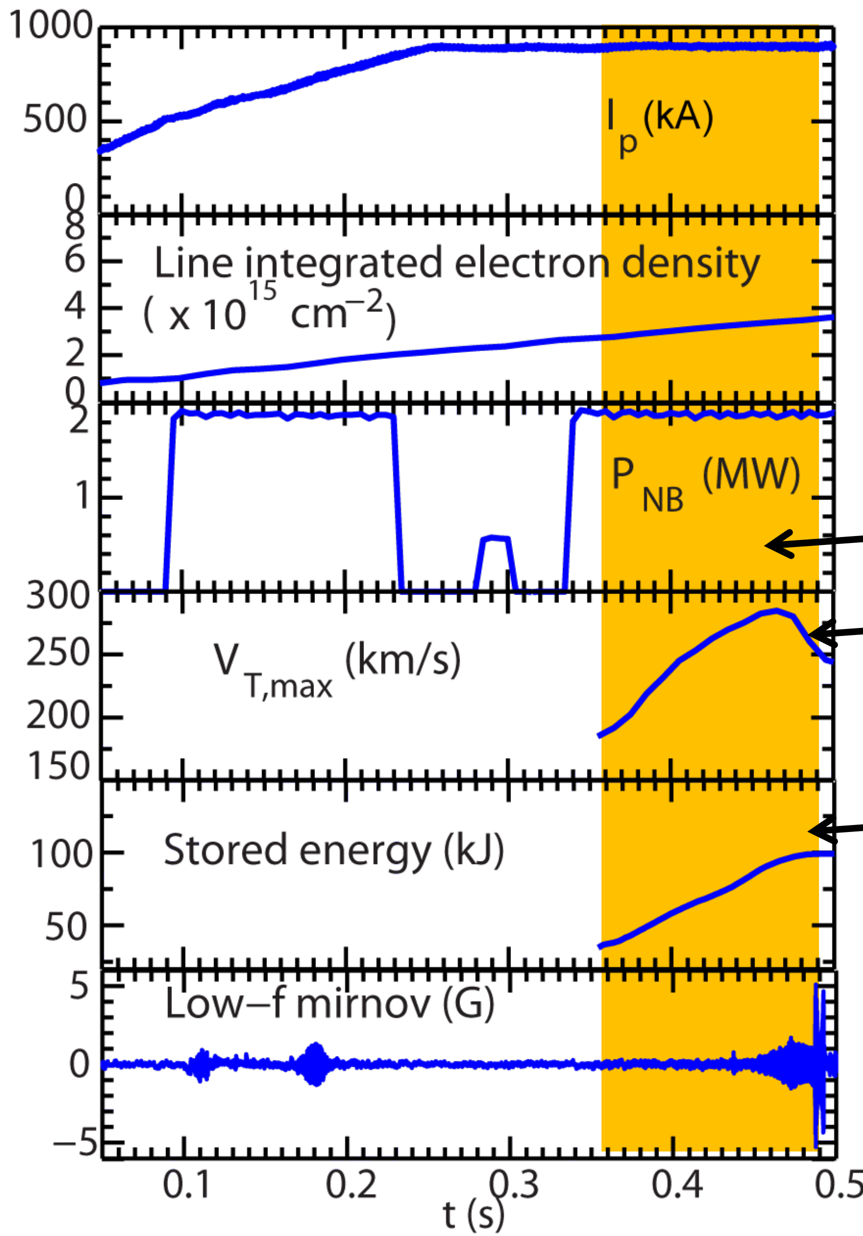
Plasma Stored Energy Increases as Plasma Spins up in a Set of NSTX NBI-heated L-mode Plasmas



Shot=141716

Center-stack limited L-mode plasma with B_T =5.5 kG

Time range of interest

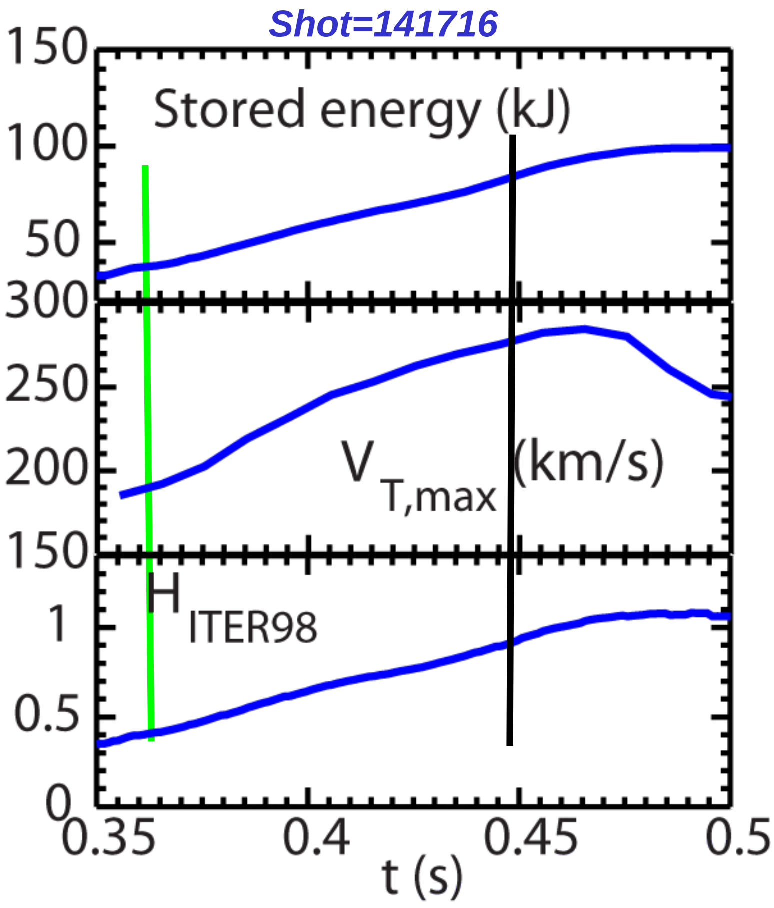
Measured by CHERS

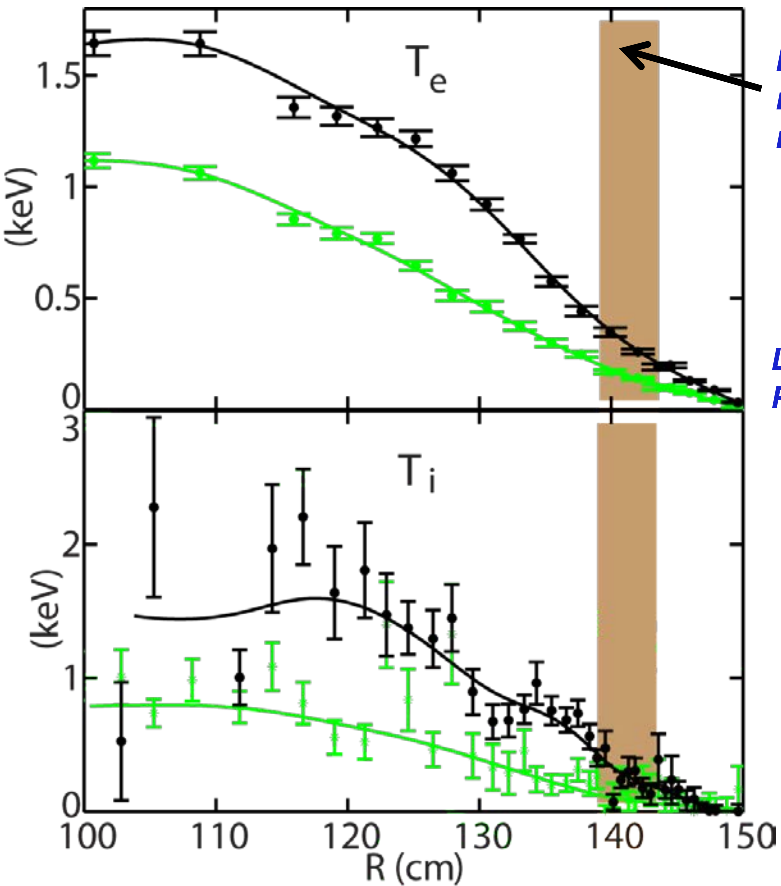
From TRANSP

Ren et al., NF 2013

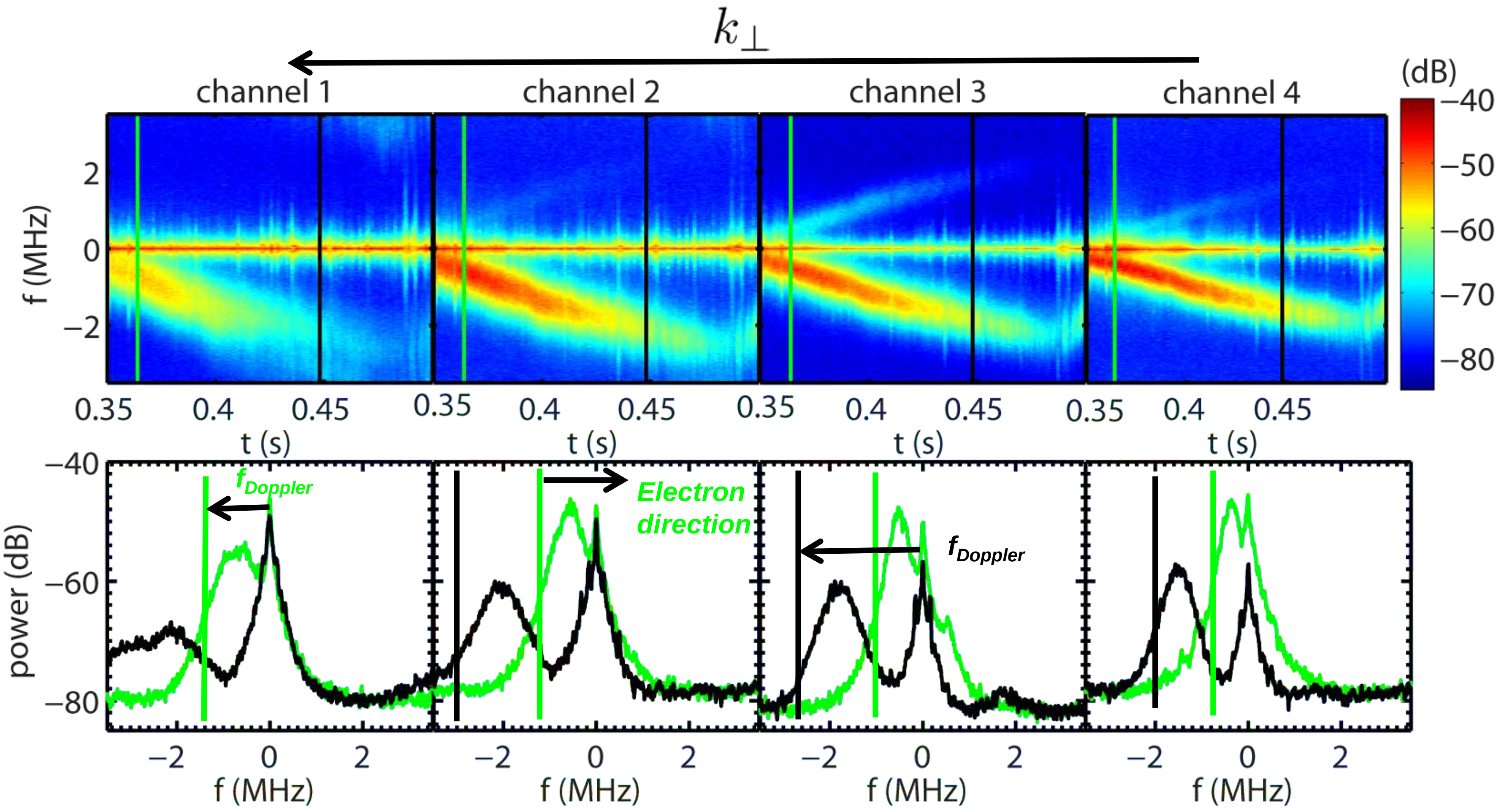
L-mode Plasma Confinement Reaches that of the H-mode of Conventional Tokamaks

- Both T_i and T_e increase as plasma toroidal velocity increases
- No formation of a transport barrier is observed





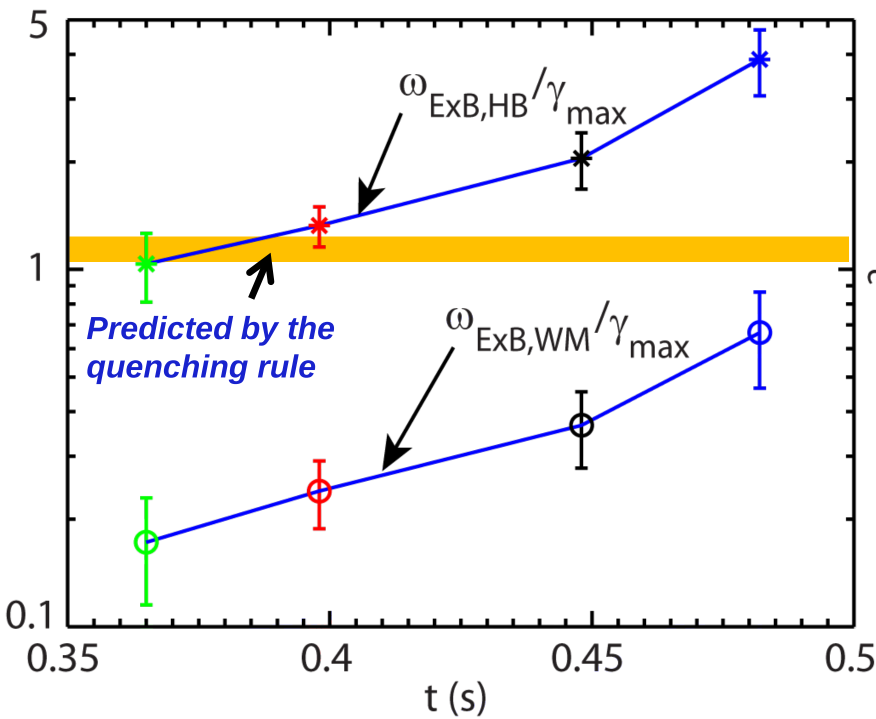
All High-k Channels Saw Decreased Scattering Power as Plasma Spins up

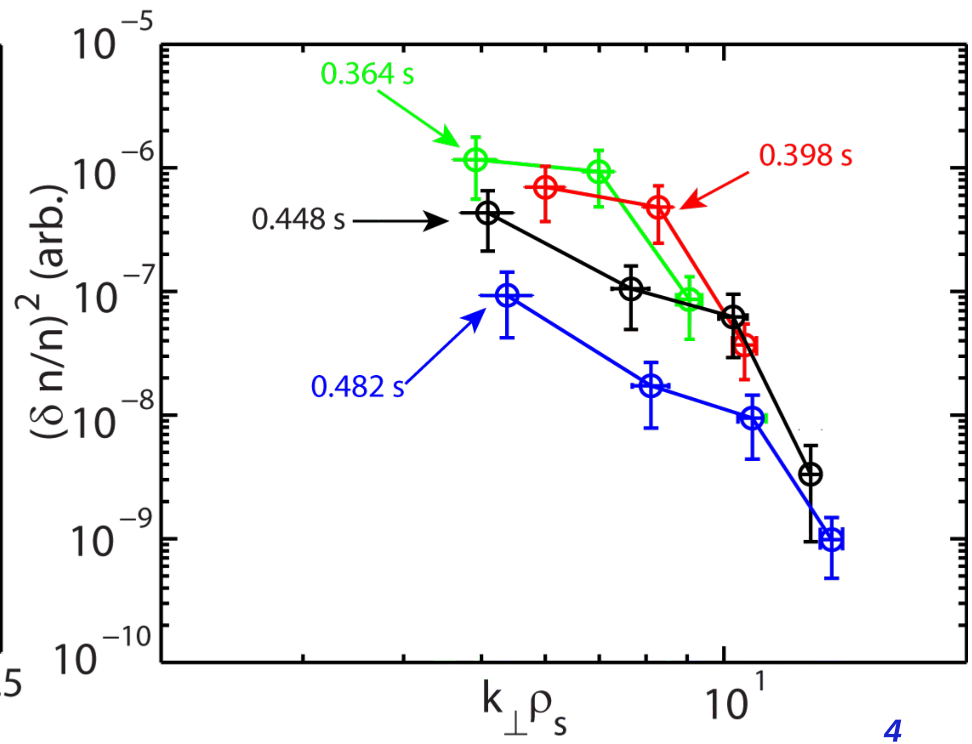


- Plasma rotation leads to large Doppler frequency

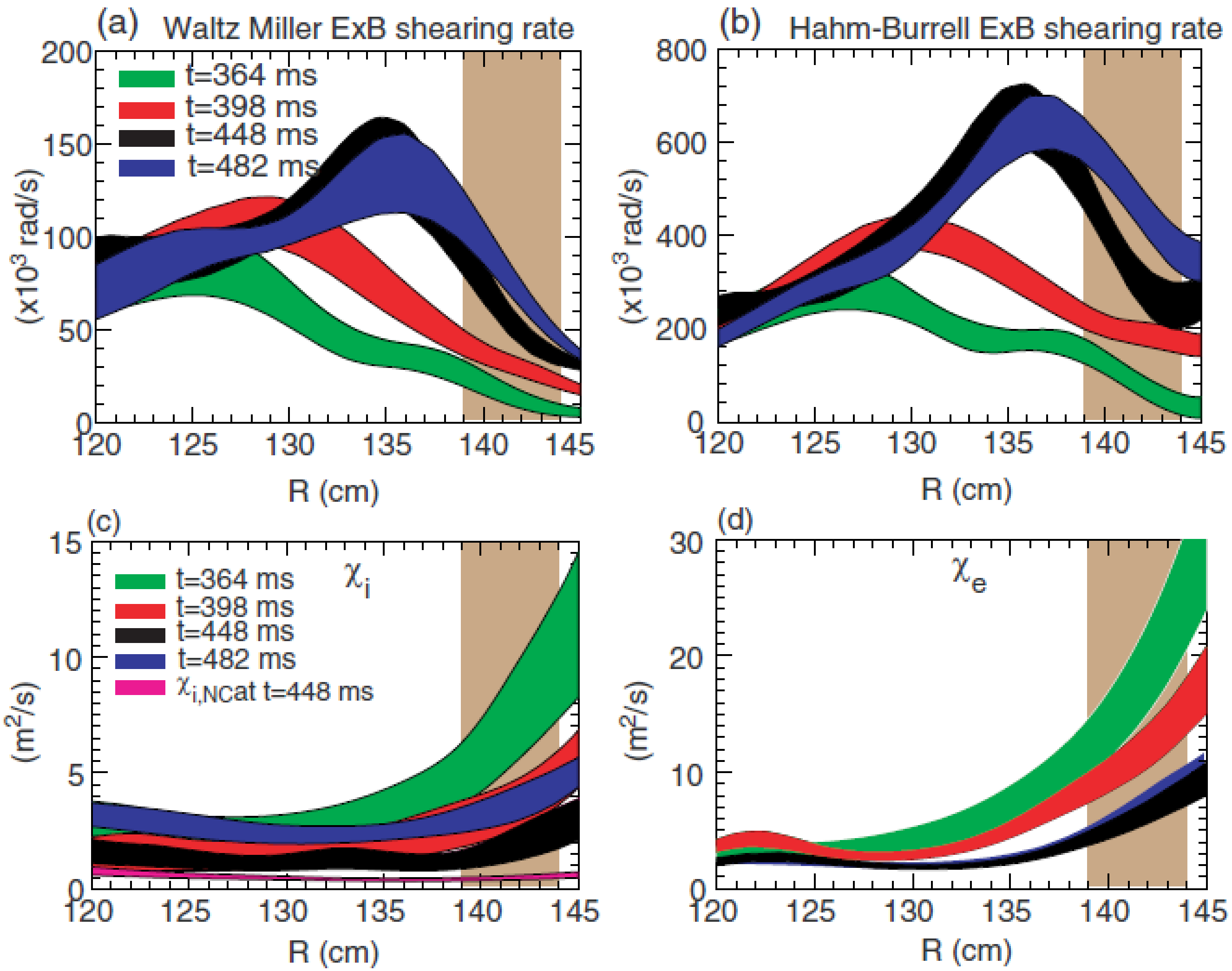
Reduction in Peak Spectral Power in the High-k Measuremen Region is Correlated with Increase in $\omega_{E\times B}/\gamma_{max}$

- Quenching rule for ion-scale turbulence for shaped plasma is shown as $\omega_{E\times B}/\gamma_{max} \approx 1.41(A/3)^{0.6}/(\kappa/1.5)$ *Kinsey et al., PoP 2007*
- $\omega_{E\times B,WM}/\gamma_{max}$ continuously increase to approach 1.1-1.2 predicted by the quenching rule with local A~1.9-2.1 and κ~1.5
  - Correlated with the continuous decrease in the high-k spectral power
  - Consistent with the nonlinear coupling between low-k and high-k turbulence



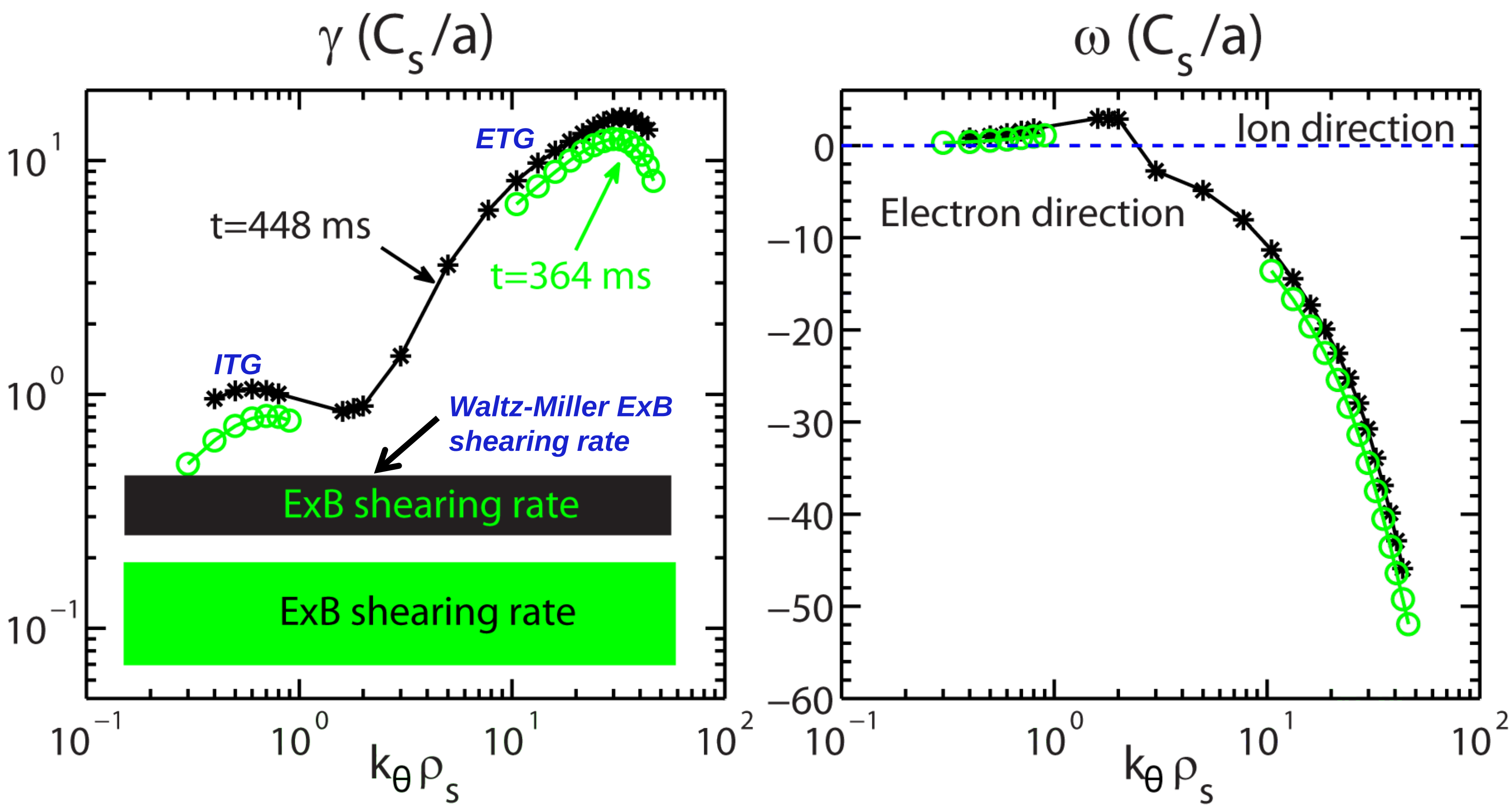


TRANSP Shows Ion and Electron Transport Reduced with Increasing E×B Shear; Ion Transport well above Neoclassical



Linear Stability Analysis Shows that ITG and ETG are both Unstable

- Maximum ITG growth rate is comparable to ExB shearing rate
- Maximum ETG growth rate is more than 10 times larger ExB shearing rate



- Stability Analysis was performed with the GS2 code (Kotschenreuther et al., 1995)

Local ITG/TEM simulations predict substantial heat flux over some region, strongly suppressed by E×B shear

- No sign of L-mode shortfall, but may occur further out

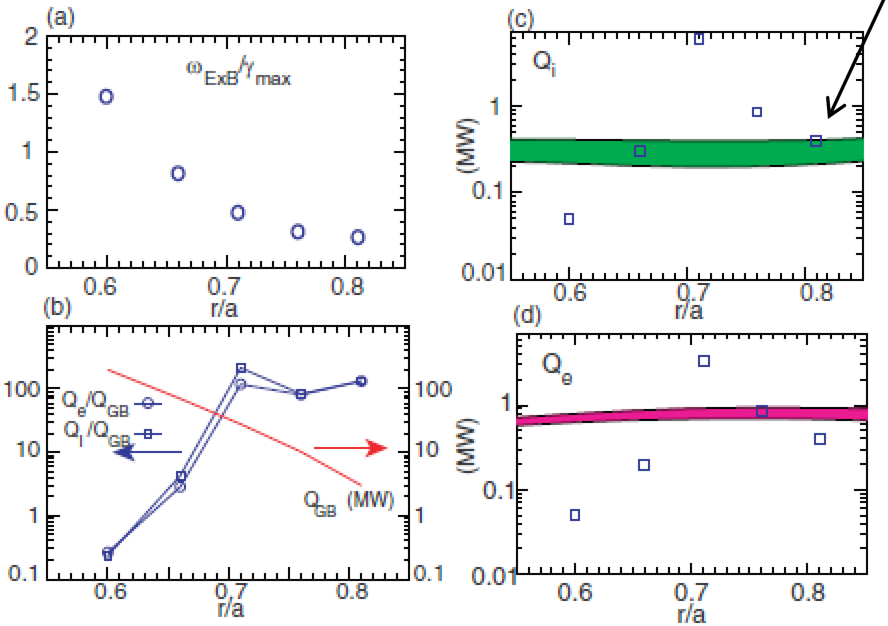


Figure 14. (*a*) $\omega_{E\times B}/\gamma_{max}$ as a function of r/a; (*b*) predicted electron and ion heat flux normalized to the gyro-Bohm unit, Q_e/Q_{GB} (open circle) and Q_i/Q_{GB} (open square) and the gyro-Bohm unit, Q_{GB} (red line); (*c*) predicted (open squares) and experimental (coloured band) Q_i as a function of r/a; (*d*) predicted (open squares) and experimental (coloured band) Q_e as a function of r/a. The vertical width of the bands denotes the experimental uncertainty.

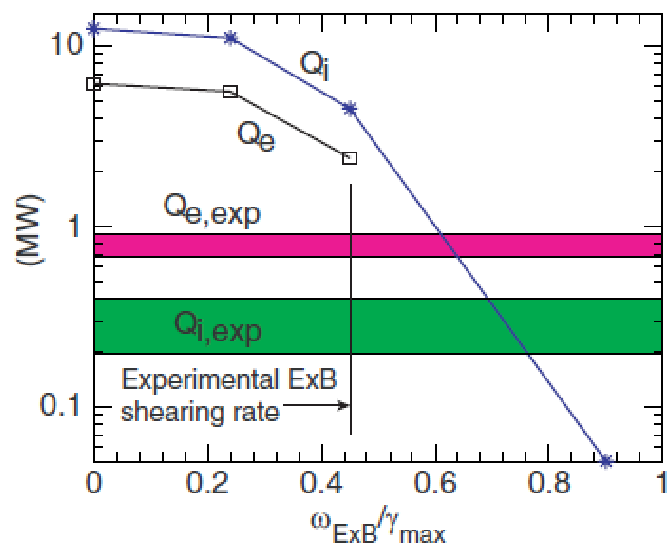
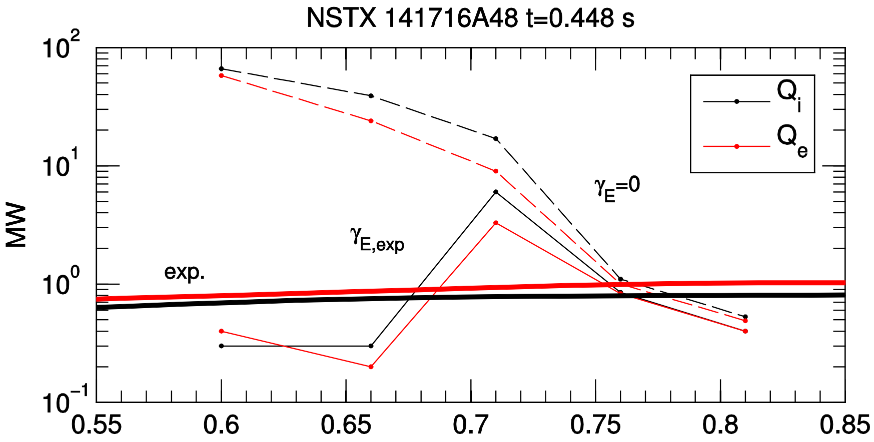
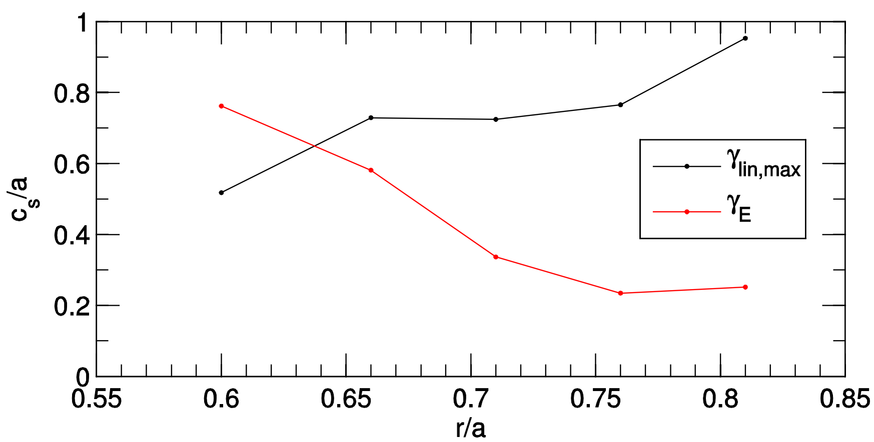


Figure 13. Electron and ion heat flux, Q_e (open square) and Q_i (asterisks), from a $E \times B$ shear scan as a function of $\omega_{E\times B}/\gamma_{max}$. The coloured horizontal bands denote the experimental electron and ion heat flux, $Q_{e,exp}$ (magenta) and $Q_{i,exp}$ (green), and the vertical width of the bands denotes the experimental uncertainty (mainly due to uncertainties in ohmic heating and measured kinetic profiles). Experimental $E \times B$ shearing rate is denoted by the vertical line.

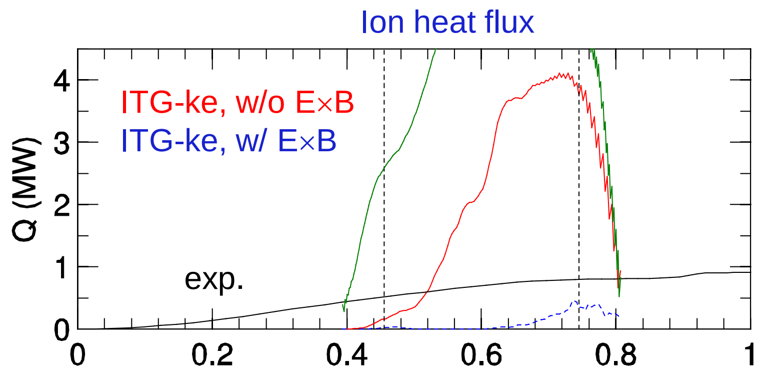
Global effects (turbulence spreading, profile shear) expected to be important for quantitative fluxes

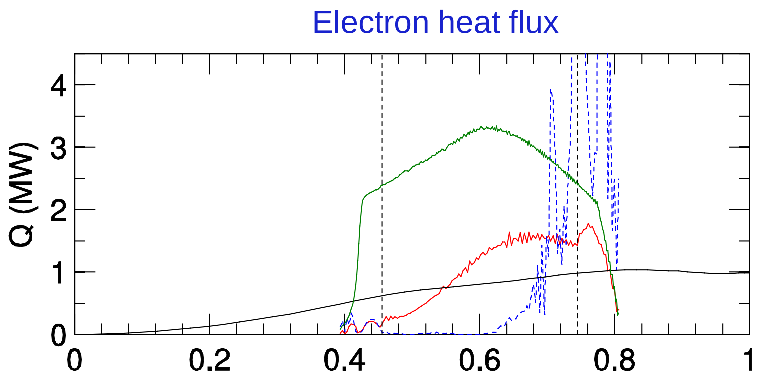
Local GYRO simulations





Global GYRO simulations





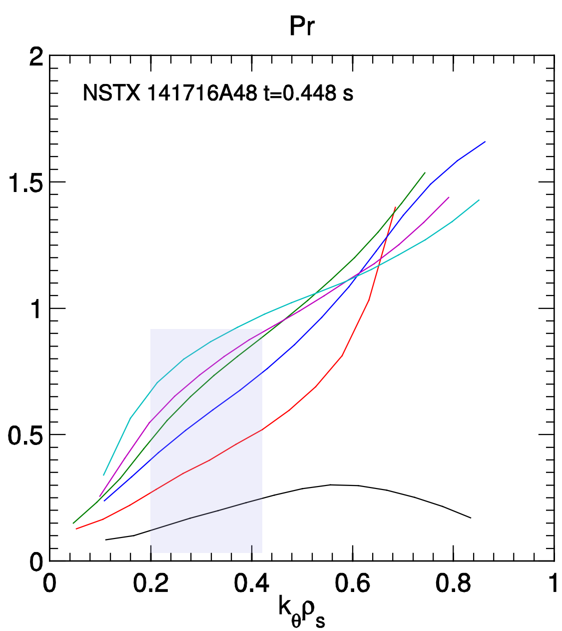
Profile/E×B shear may be important for momentum transport

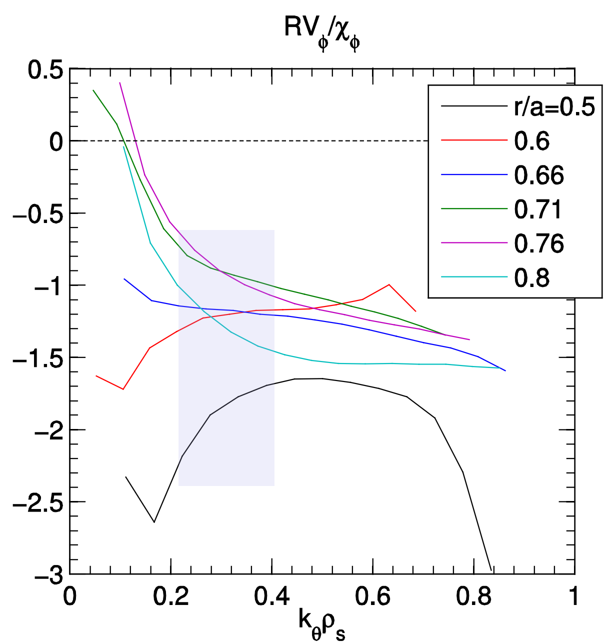
- Quasi-linear runs predict Pr=0.2-0.8, very small pinch (-1)

Assuming $$\hat{\Pi}_\varphi = \hat{\chi}_\varphi \left(\hat{u}' + \frac{RV_\varphi}{\chi_\varphi} \hat{u} \right)$$

$$Pr_{eff} = \frac{\hat{\chi}_\varphi^{eff}}{\hat{\chi}_i}, \quad \hat{\chi}_\varphi^{eff} = \chi_\varphi \left(1 + \frac{RV_\varphi}{\chi_\varphi} \frac{u}{u'} \right)$$

Quasi-linear GYRO predictions

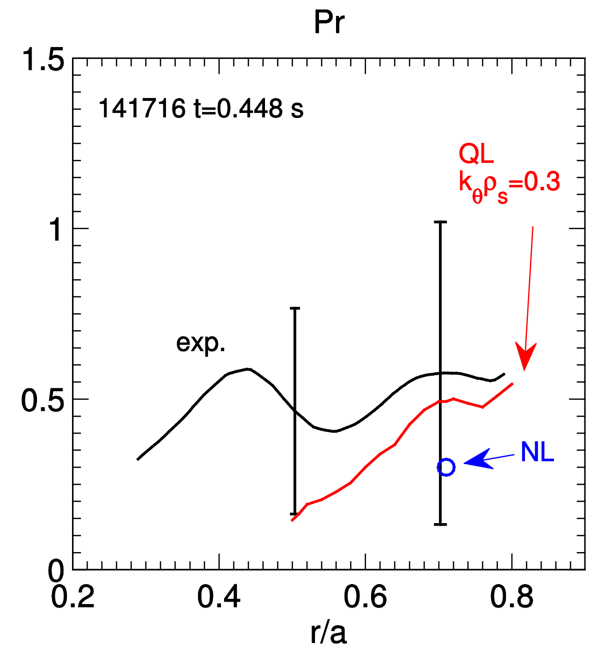




Experimental “effective” Pr

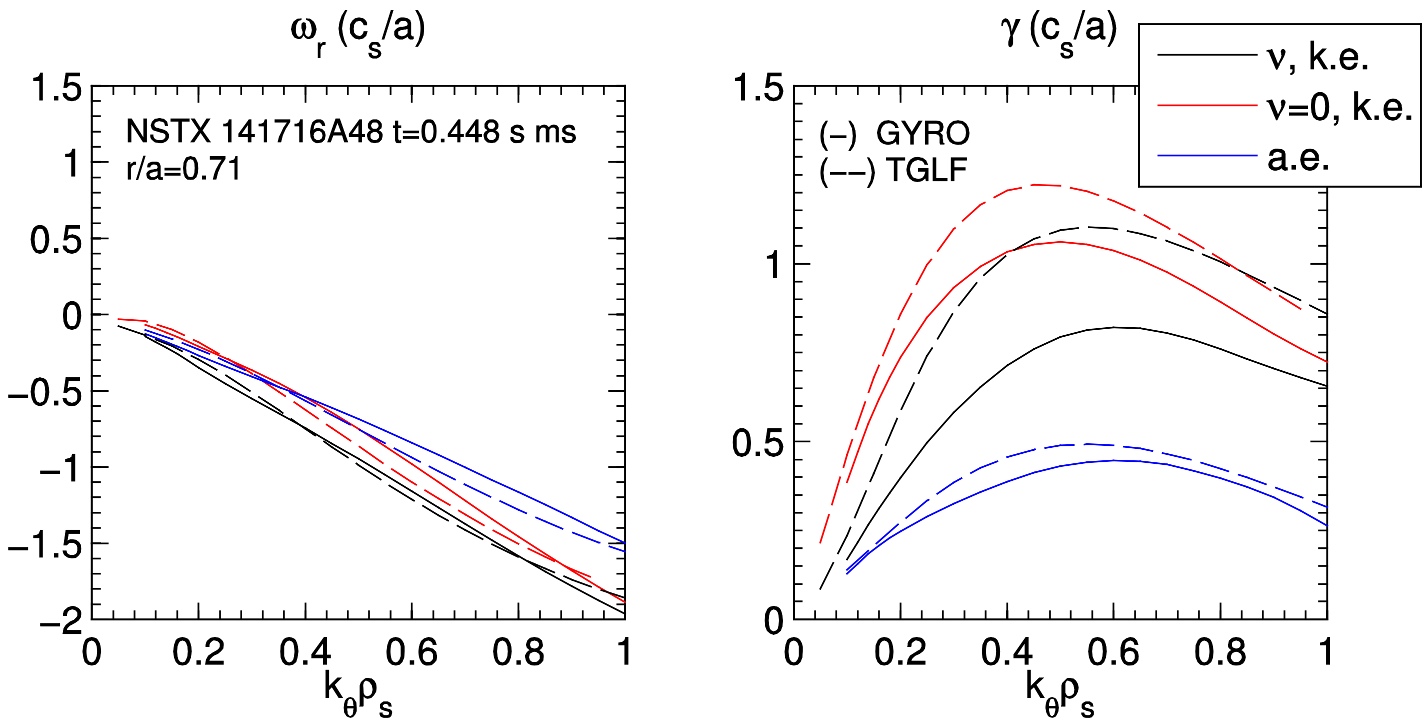
Quasi-linear GYRO predictions

Nonlinear GYRO predictions



This case is also forming the basis for validating TGLF <u>local</u> transport model against <u>local</u> gyrokinetics

- Will need to account for non-local effects if important for quantitative success



NSTX L-mode provides a great place for multi-code gyrokinetic analysis:

- Low beta → electrostatic ITG/TEM is sufficient

1) Quantify impact of non-local effects/turbulence-spreading on thermal transport
2) Investigate profile/E×B shearing contributions to momentum transport
   - Don't have perturbative measurements in NSTX L-modes, but did run an experiment on MAST this year
3) Possibly validate with high-k & BES measurements
4) Investigate if an L-mode shortfall occurs further out
5) Code-code comparison between GTS, XGC-1 (full radius) and GYRO (can't do magnetic axis), all use different numerical algorithms
6) Use for validating transport models like TGLF