TC-12: H-mode transport at low aspect ratio

Collisionality scan of confinement and transport in MAST H-mode

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ITPA Meeting on Transport and Confinement 5-7 October 2009, Princeton

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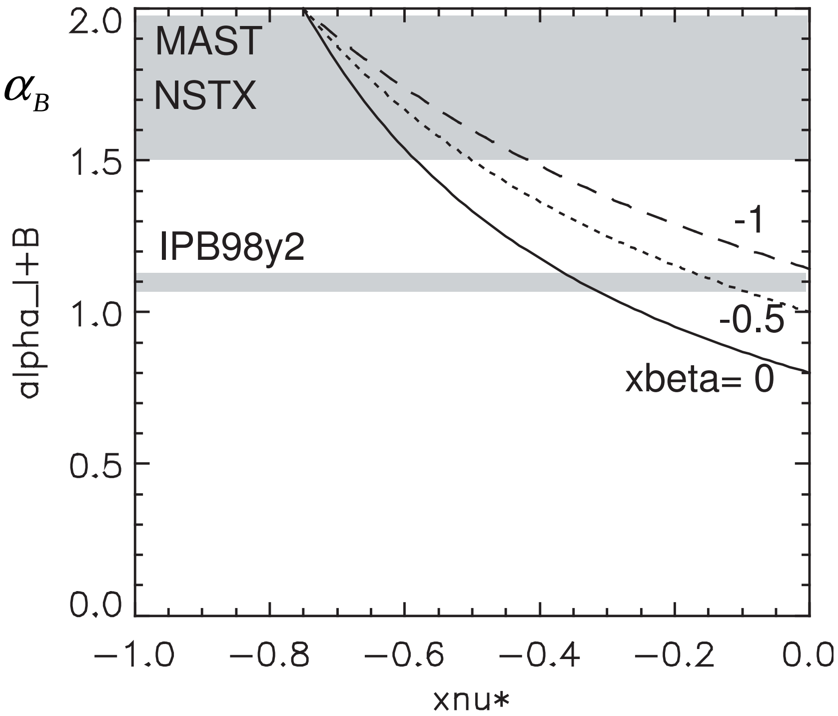
Total field exponent ($\alpha_{Ip}+\alpha_{BT}$) in engineering scaling in STs suggests stronger ν^* scaling

$$\alpha_I + \alpha_B$$



$$\tau_E B_T \propto \rho_*^{-3} \beta^{x\beta} \nu^{x_\nu}$$

$$\tau_E \propto I_p^{\alpha I} B_T^{\alpha B}$$

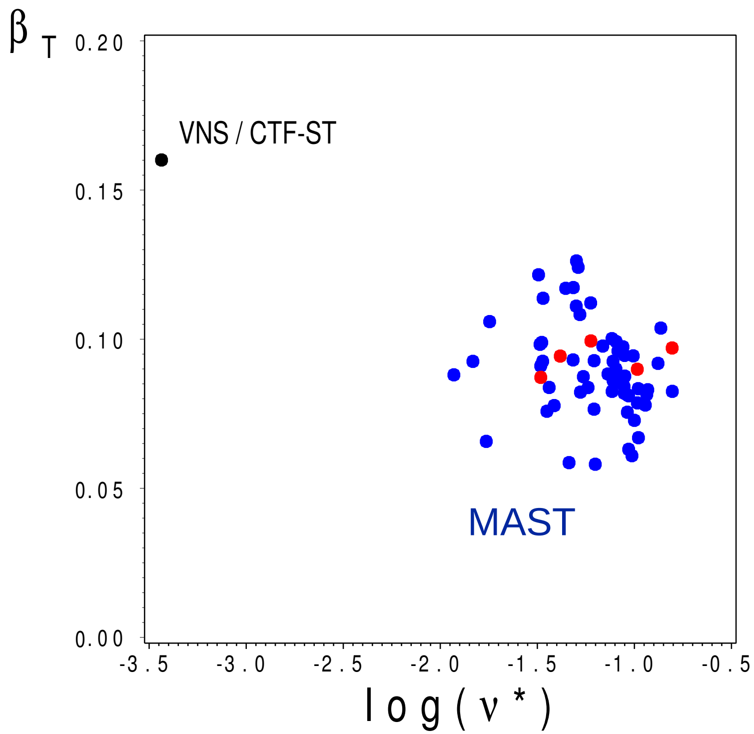
$$\alpha_I \sim 0.6$$

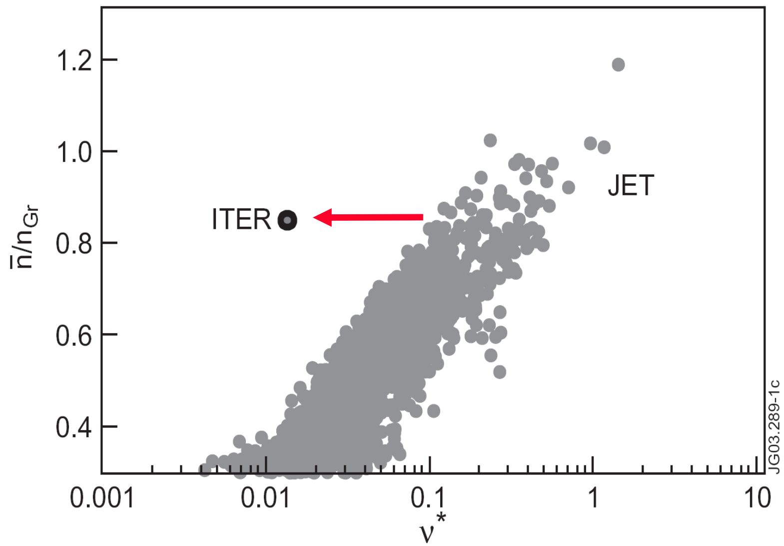
$$\alpha_B \sim 1-1.4$$

S Kaye Nucl. Fusion 2007

MV Nucl. Fusion 2009

Extrapolation along ν_* for spherical and conventional tokamaks





MV PPCF 2004

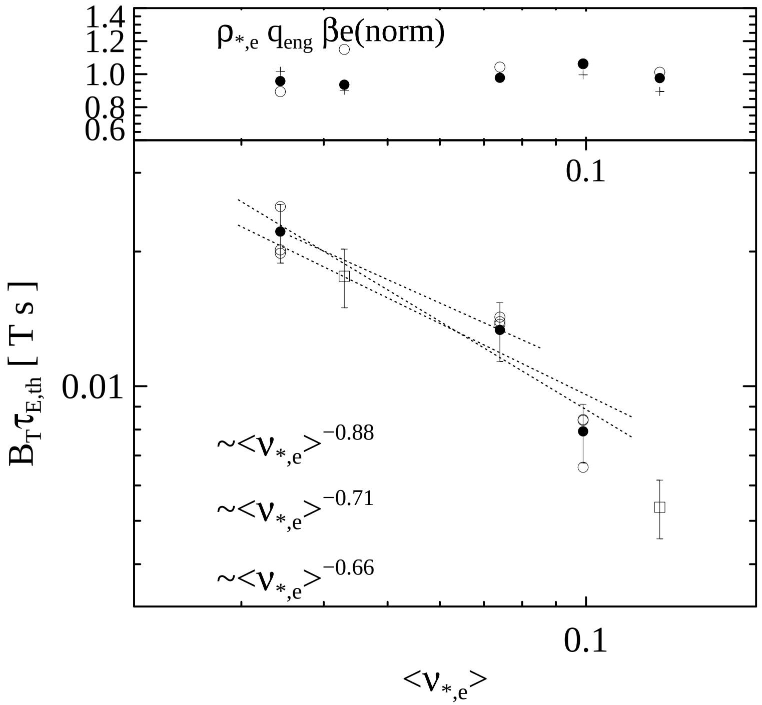
Extrapolation to the Volume Neutron Source CTF-ST is mainly along collisionality

Extrapolation from JET 3T plasmas with constant n/n_{Grw} involves 7x reduction in collisionality.

ν_* scan: global energy confinement

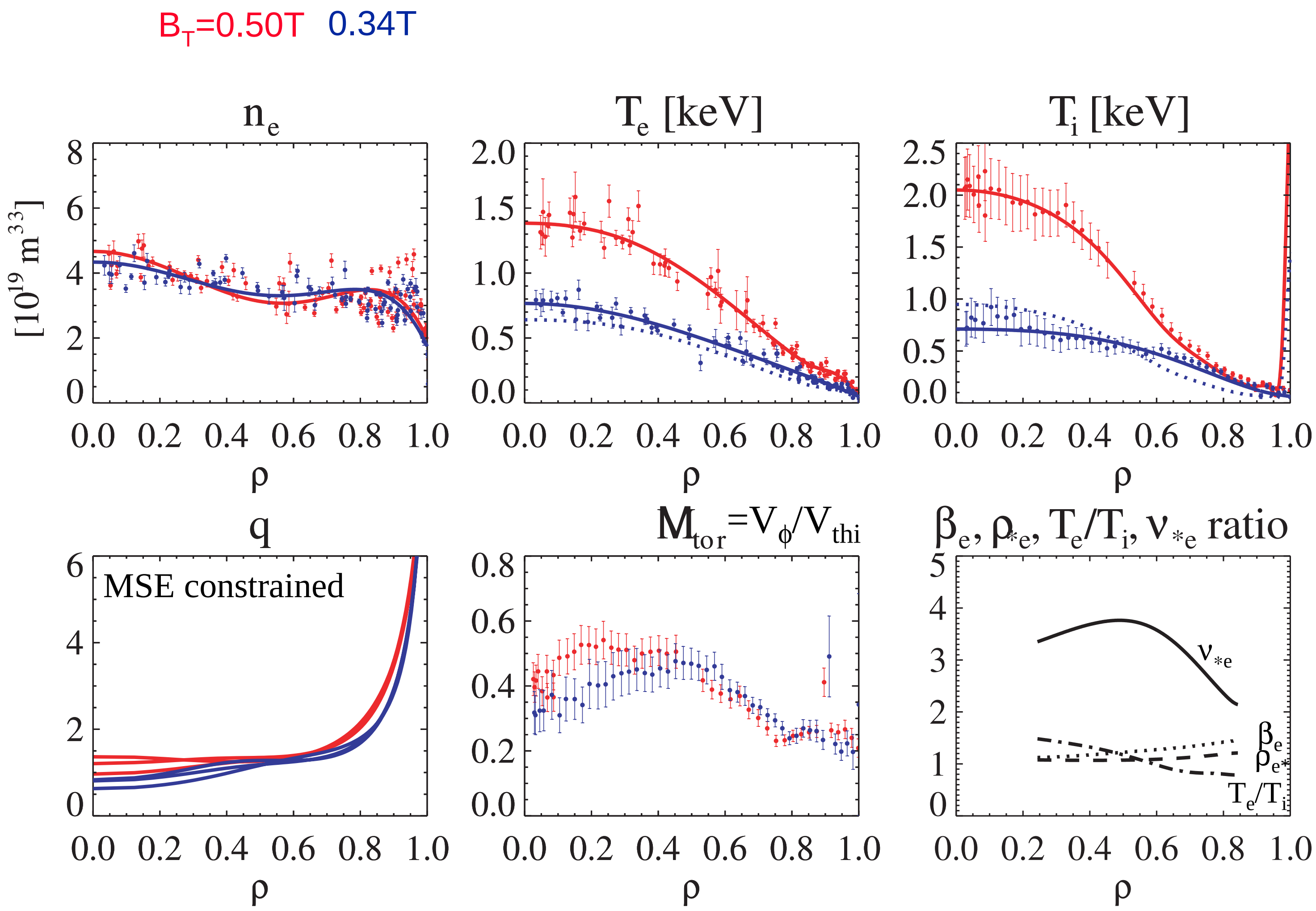
$$\tau_E B \propto \nu^{x_\nu} F\left(\underbrace{\rho_*, \beta, q}_{const}, M, T_e/T_i \ldots\right) \qquad n \propto B^0 \qquad T \propto B^2$$

	22769	22777	22664
$a[m]$	0.580	0.580	0.582
$R_{geo}[m]$	0.816	0.808	0.816
$B_T[T]$	0.340	0.428	0.500
$I_p[kA]$	592	738	886
q_{eng}	2.3	2.3	2.3
$\bar{n}_e[10^{19} m^{-3}]$	3.2	3.7	3.3
$W_{th}[kJ]$	41	65	84
$W_{th}/\bar{n}_e \times B_T^{-2}$	1.1	0.93	1.0
$P_{\mathrm{NBI,INJ}}$ [MW]	3.0	3.3	3.3



Maximum B_T range in H-mode is 0.34-0.50T, giving factor of 4.6 ν_*- scan
Mismatch in ρ_* is 10%, equivalent to exponent error of 0.2
With ρ_* and β correction exponent is ~0.71

Matching local parameters in ν_* scan



High ν_* shot is sawtoothing but separate study shows small effect of s/t

No ν_*- M_{tor} correlation

Correlation ν_* - T_e/T_i

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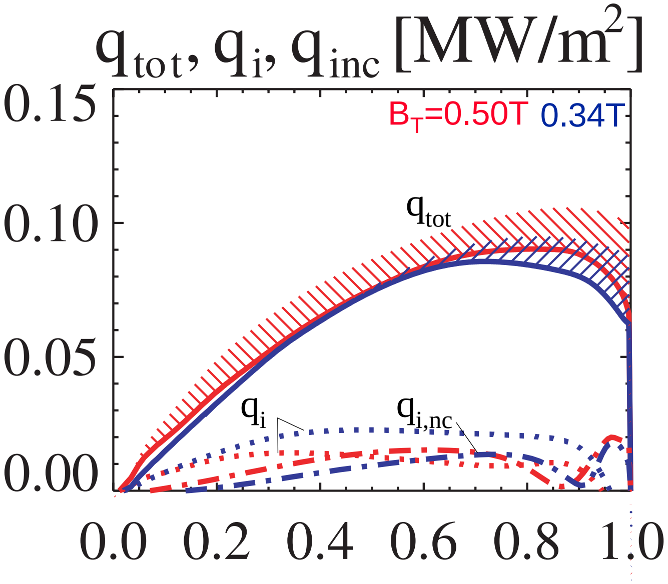
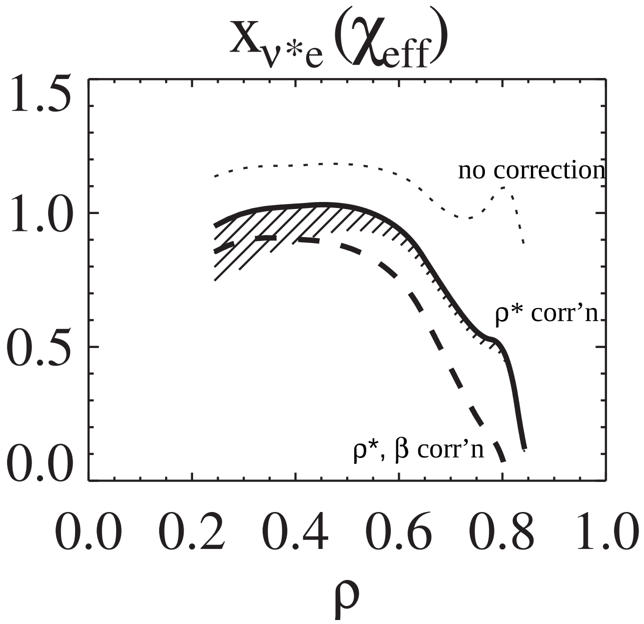
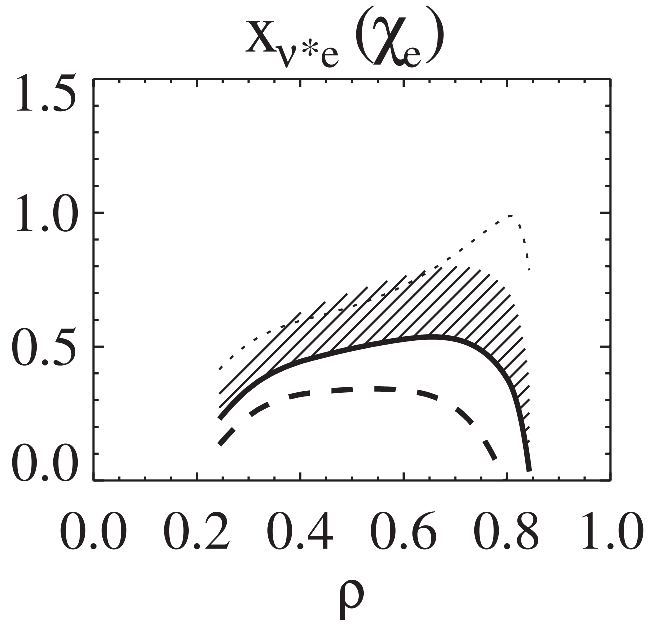
Local heat transport analysis

$$\chi / B \propto \nu_{*e}^{x\nu}$$



MC3/TRANSP





χ_{eff} in line with global scaling

χ_e shows weaker ν_* scaling

$$q \equiv -\chi_{eff}(n_e \nabla T_e + n_i \nabla T_i)$$

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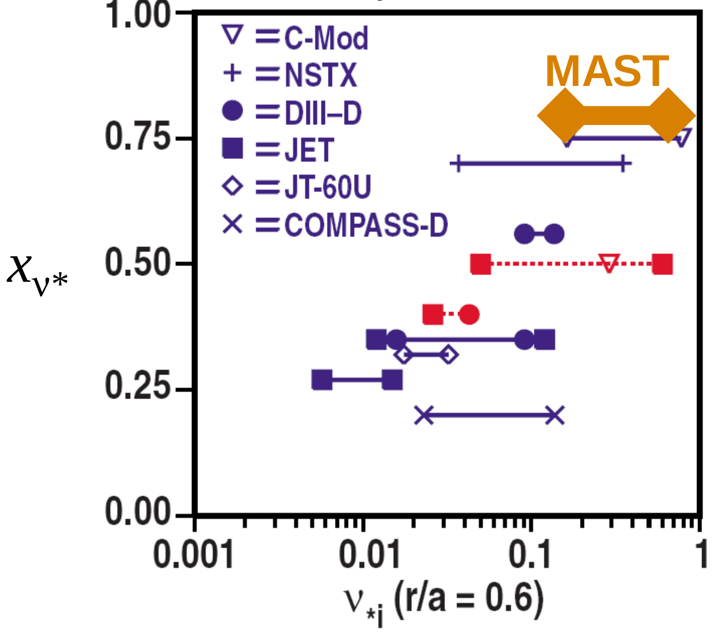
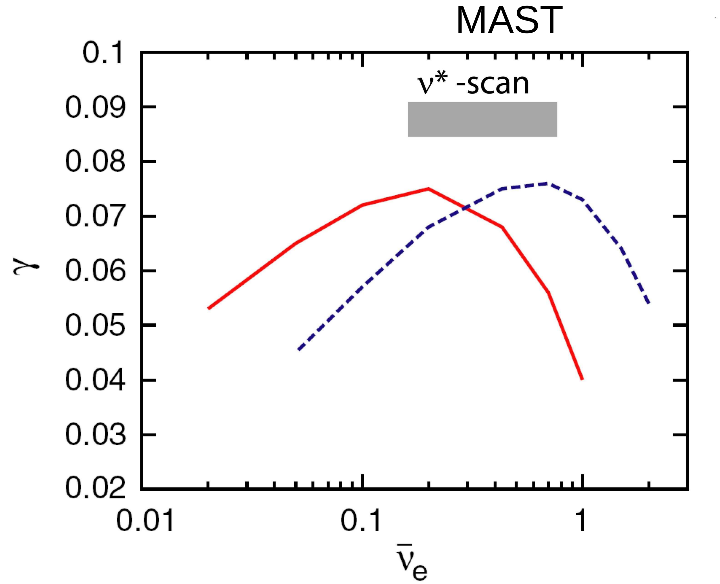
ν_* scaling: comparison with other tokamaks and possible models





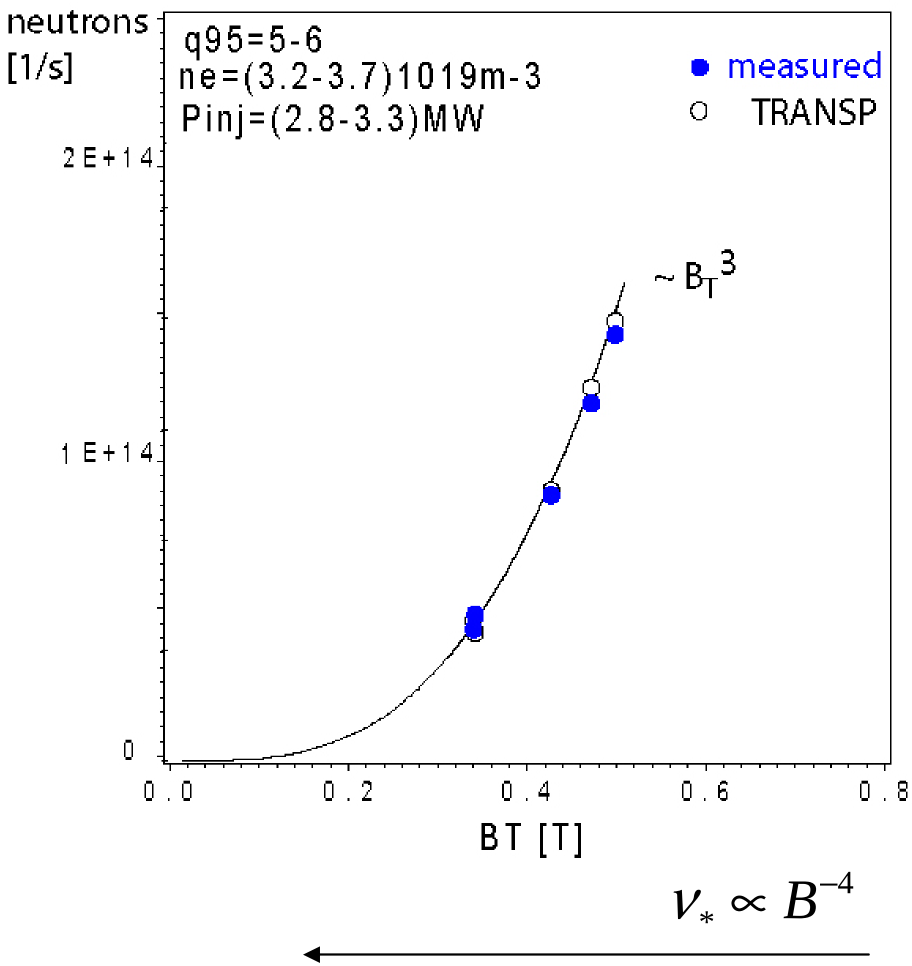
linear GS2 for #6252, r/a=0.6, blue/red: Boltzmann/full ion response.

D Applegate PPCF 2007

Candidate models:

- Collisional damping of zonal flows (Lin 1999)
- Proximity of neoclassical transport
- Microtearing instabilities predict ν*-dependence, but MAST scan lies close to the maximum of linear growth rate. Full nonlinear calculations are planned for more accurate comparisons.

ν_* scaling: neutron rate



TRANSP neutron rate adjusted to measured value by fast ion diffusion 2-4m²/s

Along the ν_* -scan neutron rate depends strongly on B_T.

B_T is the most important engineering variable in the extrapolation to Neutron Source.

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Summary

Factor of four collisionality scan in H-mode in MAST.

Thermal energy confinement time shows stronger collisionality dependence, $B_T\tau_E \sim \nu_*^{-(0.7-0.9)}$, similar to NSTX (S Kaye 2007)

Single fluid effective heat diffusivity is consistent with τ_E scaling, but electron heat diffusivity has weaker ν_* dependence.

Along the ν_* scan, neutron rate displays strong dependence on toroidal magnetic field stressing the importance of raising B_T towards the volume neutron source CFT-ST.