TORE SUPRA

energie atomique • energies alternatives

Collisionality scaling in Tore Supra:
on the uncertainties of global and local energy confinement analysis and what can be done to overcome them

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In 2005, Napa Valley TTF, review on dimensionless scaling laws

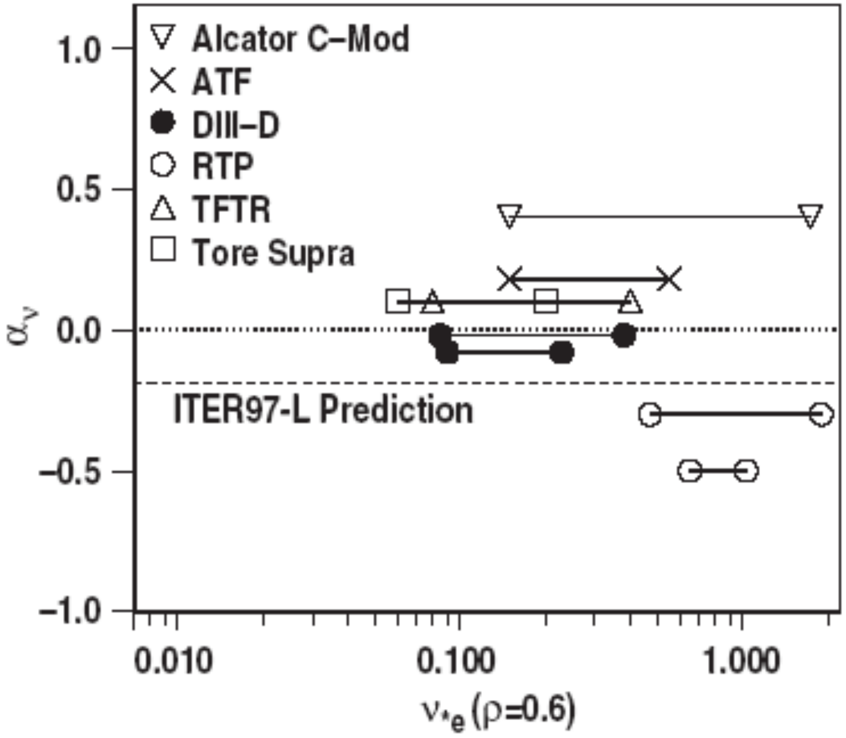
To improve confinement scaling understanding need local dimensionless analysis

- From global scaling to local scaling, $\tau \sim a^2/\langle\chi_{eff}\rangle$ OK if χ_{eff} has same parametric behavior across whole plasma and no stiffness
- Usually not the case: inner, gradient and edge regions respond to different theoretical models
- So need a real local dimensionless analysis based on ρ_*, ν_*, β, ε, κ, δ, q, Z_{eff}, s, T_e/T_i, M, m_e/m_i separating ion, electron and particle transport to be compared with simulation/theory

Still convinced, but since I reallized how difficult it is…

ν* scaling laws in L mode

- Weak dependence of confinement with ν*
  - ITER89-P $$B\tau_E \propto \rho^{*-2.05}\beta^{-0.52}\nu^{*-0.28}$$
  - IPB98-L $$B\tau_E \propto \rho^{*-1.85}\beta^{-1.41}\nu^{*0.19}$$
  - Review by Luce PPCF2008

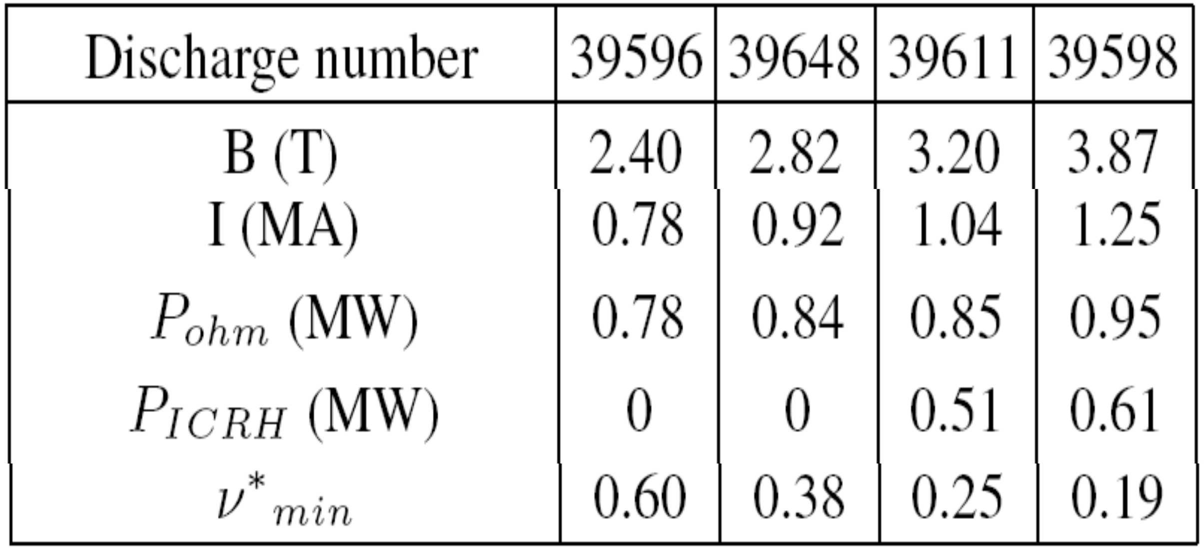


Outline

- Experimental setup
- Global scaling
  - Definitions of τ_E, ν^*
  - Accounting for uncertainties
- Local scaling
- Gyrokinetic simulations versus turbulence measurements
- Conclusion

Experimental setup

- Since: $\beta \propto n_e T_e B^{-2}\,,\ \rho^* \propto \sqrt{T_e} B^{-1}\,,\ \nu^* \propto q n_e T_e^{-2}$
- To keep β and ρ^* fixed, one gets: $\nu^* \propto B^{-4}$
- At the lowest B, ohmic discharge, then choose 3 B at which ICRH can be coupled: 2.4 T, 2.8T, 3.2T and 3.9T
- At the lowest B and I_p, Greenwald fraction maximized to optimize Doppler reflectometer measurements: $nl = 4.5.10^{19} m^{-2}$

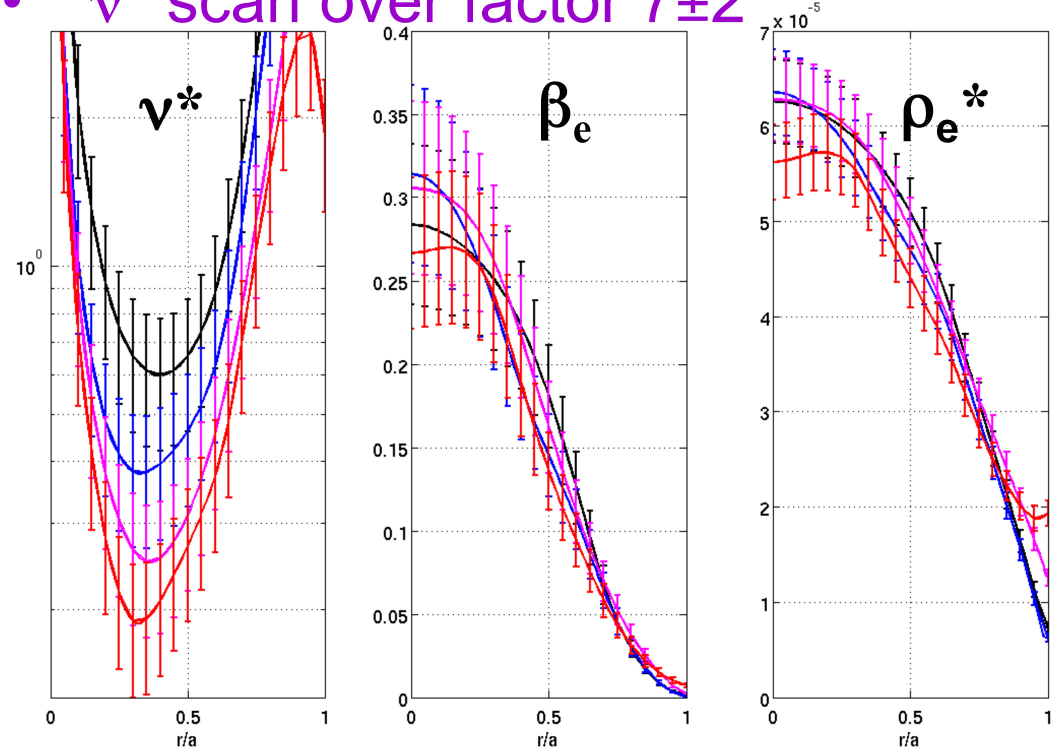


Discharge number	39596	39648	39611	39598
B (T)	2.40	2.82	3.20	3.87
I (MA)	0.78	0.92	1.04	1.25
P_{ohm} (MW)	0.78	0.84	0.85	0.95
P_{ICRH} (MW)	0	0	0.51	0.61
$\nu^*{}_{min}$	0.60	0.38	0.25	0.19

Uncertainties on dimensionless parameters

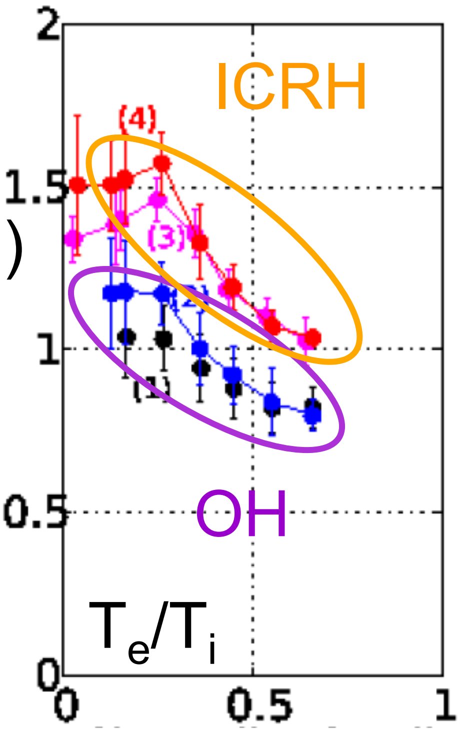
Data	n_e	T_e	B	q	ρ^*	β	ν^*
uncertainty	10%	10%	5 %	20%	7%	17%	30%

- β and ρ^* vary within uncertainties
- ν^* scan over factor 7±2



•T_e/T_i and Z_{eff} vary more than uncertainties.

With ICRH higher Z_{eff} (2 vs 1.6) and T_e/T_i

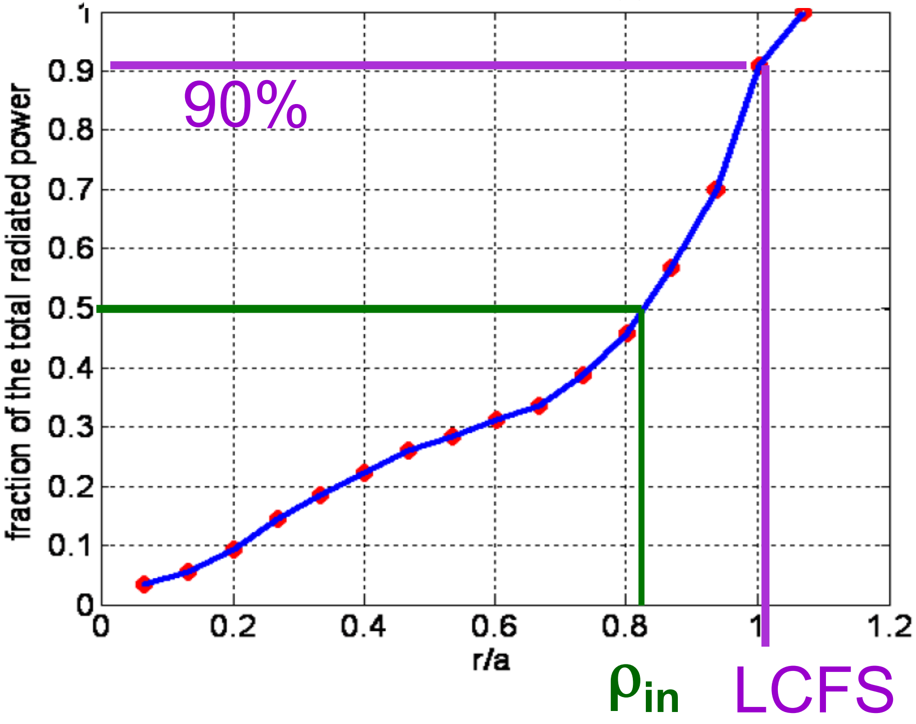


Global scaling: definitions

$$\tau_E^{tr} = \frac{W}{P_{trans}} \qquad P_{trans} = P_{abs} - P_{rad}^{in}$$

- In Tore Supra limited discharges P_{rad} in LCFS up to 90% total
- Surface inside which radiative losses can be neglected (less than 20% of absorbed power) as in Perkins 1993

Bolometry: fraction of P_{rad}

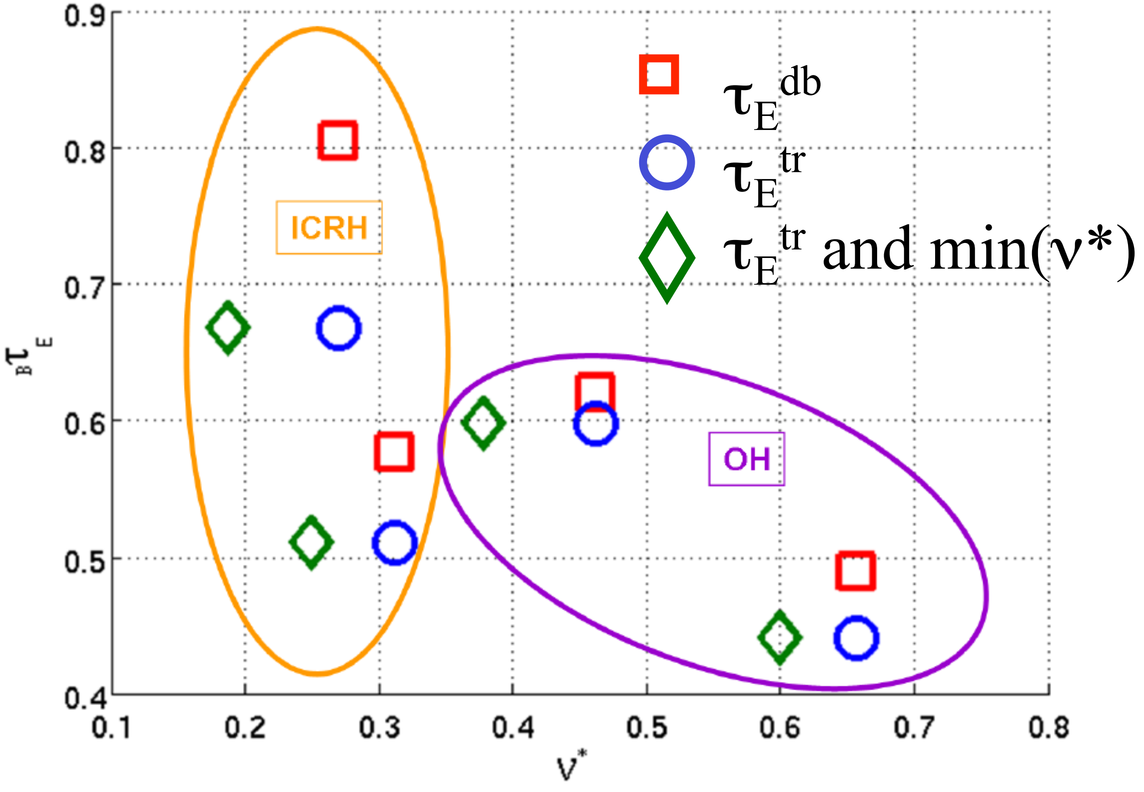


$$\tau_E^{tr} = \frac{W_{th}^{r/a<\rho_{in}}}{P_{abs}^{r/a<\rho_{in}}}$$

$$\boxed{\frac{P_{rad}^{r/a<\rho_{in}}}{P_{abs}} = \frac{P_{rad}^{r/a<\rho_{in}}}{P_{rad}^{tot}} \times \frac{P_{rad}^{tot}}{P_{abs}} < 20\%}$$

Global scaling

- With 20% uncertainty on W_{th} and 10% on P_{abs}



$$\tau_E^{db} = \frac{W_{th}}{P_{inj}}$$

$$\tau_E^{tr} = \frac{W_{th}^{r/a<\rho_{in}}}{P_{abs}^{r/a<\rho_{in}}}$$

$$\boxed{B\tau_E \propto \nu^{*-0.3\pm0.3}}$$

τ_E determination method	α_ν	$\Delta\alpha_\nu$
τ_E^{db}, ν^* at r/a=0.5	-0.42	0.23
τ_E^{tr}, ν^* at r/a=0.5	-0.32	0.26
τ_E^{tr}, min(ν^*)	-0.27	0.19

But…

- From Cordey NF2009 and Gürcan NF2010,need to account for uncertainties on P and W but also for ρ* and β scalings:

$$\boxed{B\tau_E \propto \nu^{*0.0\pm0.7}}$$

$$(\Delta\alpha_\nu)^2 = \frac{1}{\left[\sum_i (x_i - \langle x\rangle)^2\right]^2} \sum_j (x_j - \langle x\rangle)^2$$

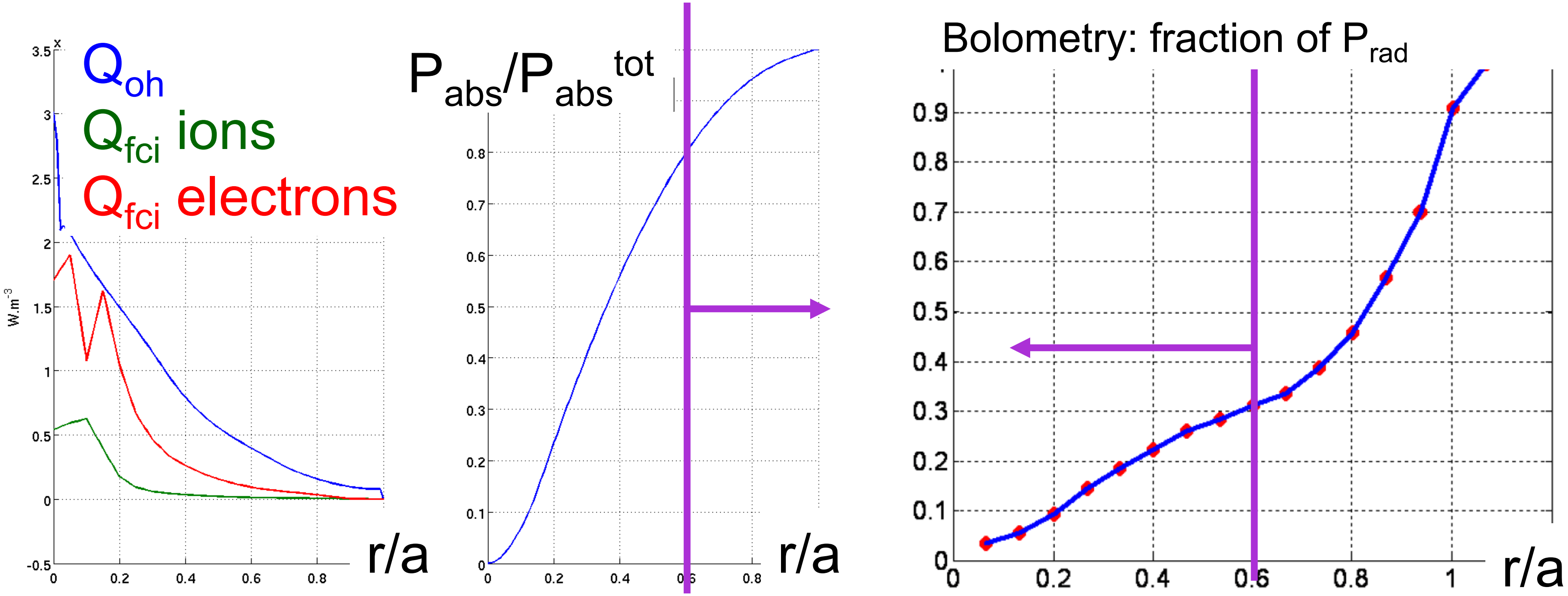
$$\times\left[\left(-2\frac{y_j - \langle y\rangle}{x_j - \langle x\rangle} + \left(1 - \frac{1}{2}\alpha_\rho + 4\alpha_\nu - \alpha_\beta\right)\right)^2 \left(\frac{\Delta W_j}{W_j}\right)^2\right.$$

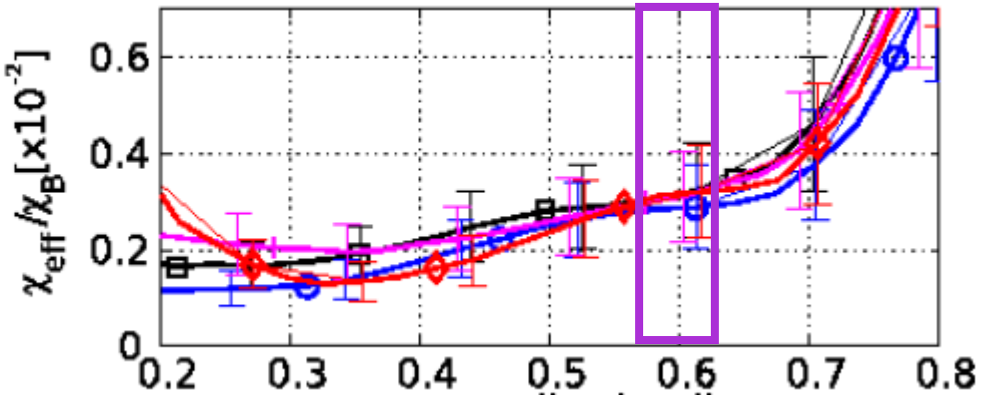
$$\left. + \left(\frac{\Delta P_j}{P_j}\right)^2\right] \qquad (5)$$

assumptions on α_ρ and α_β	α_ν	$\Delta\alpha_\nu$
$\alpha_\beta = 0,\ \alpha_\rho = 0$	-0.32	0.26
$\alpha_\beta = 0,\ \alpha_\rho = -3$ and all 4 ρ^* fixed to its value in #39596	-0.32	0.58
$\boxed{\alpha_\beta = 0,\ \alpha_\rho = -3 \text{ and } \Delta\rho^*/\rho^* = 7\%}$	$\boxed{0.02}$	$\boxed{0.74}$
$\alpha_\beta = -1.41,\ \alpha_\rho = -3$ and $\Delta\rho^*/\rho^* = 7\%,\ \Delta\beta/\beta = 17\%$	0.33	1.34

Local analysis

- Avoid r/a where less than 80% of P_{add} is absorbed and where more than 70% of P is radiated: r/a ~ 0.6

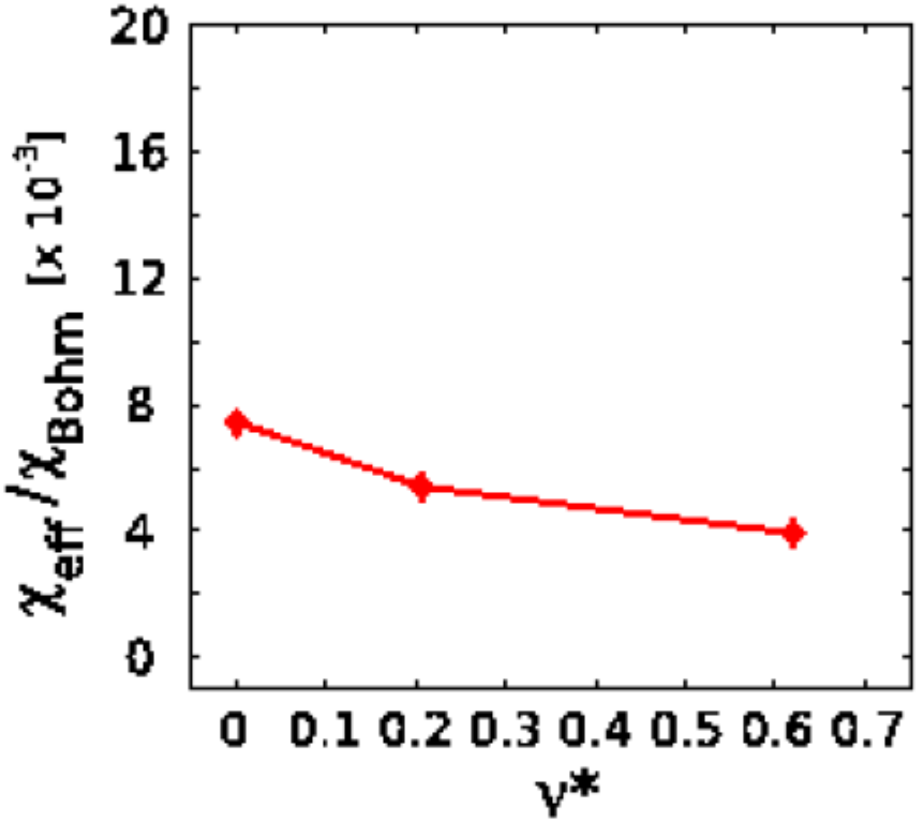




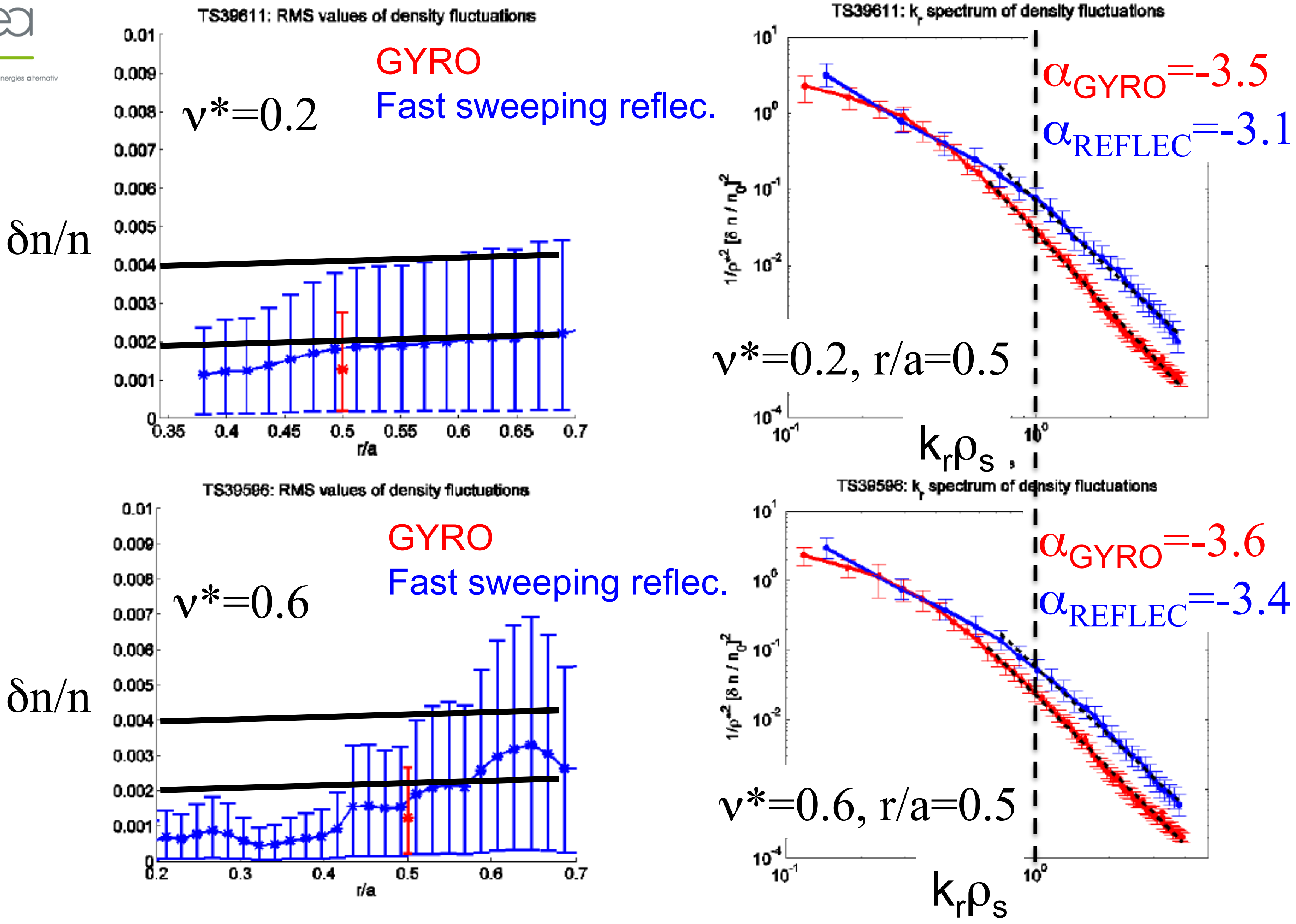
Gyrokinetic modeling

- Linear: ITG modes, need $\nu^*/60$ to see TEM
- Z_{eff} variation affects strongly linear modes
- Despite ITG at rather high ν^*, still detrapping impacts non-linear fluxes: stabilizing impact of ν^*

GYRO
Local
NL



Weak impact of ν* on δn/n reproduced by non-linear gyro-kinetic simulations (local GYRO)



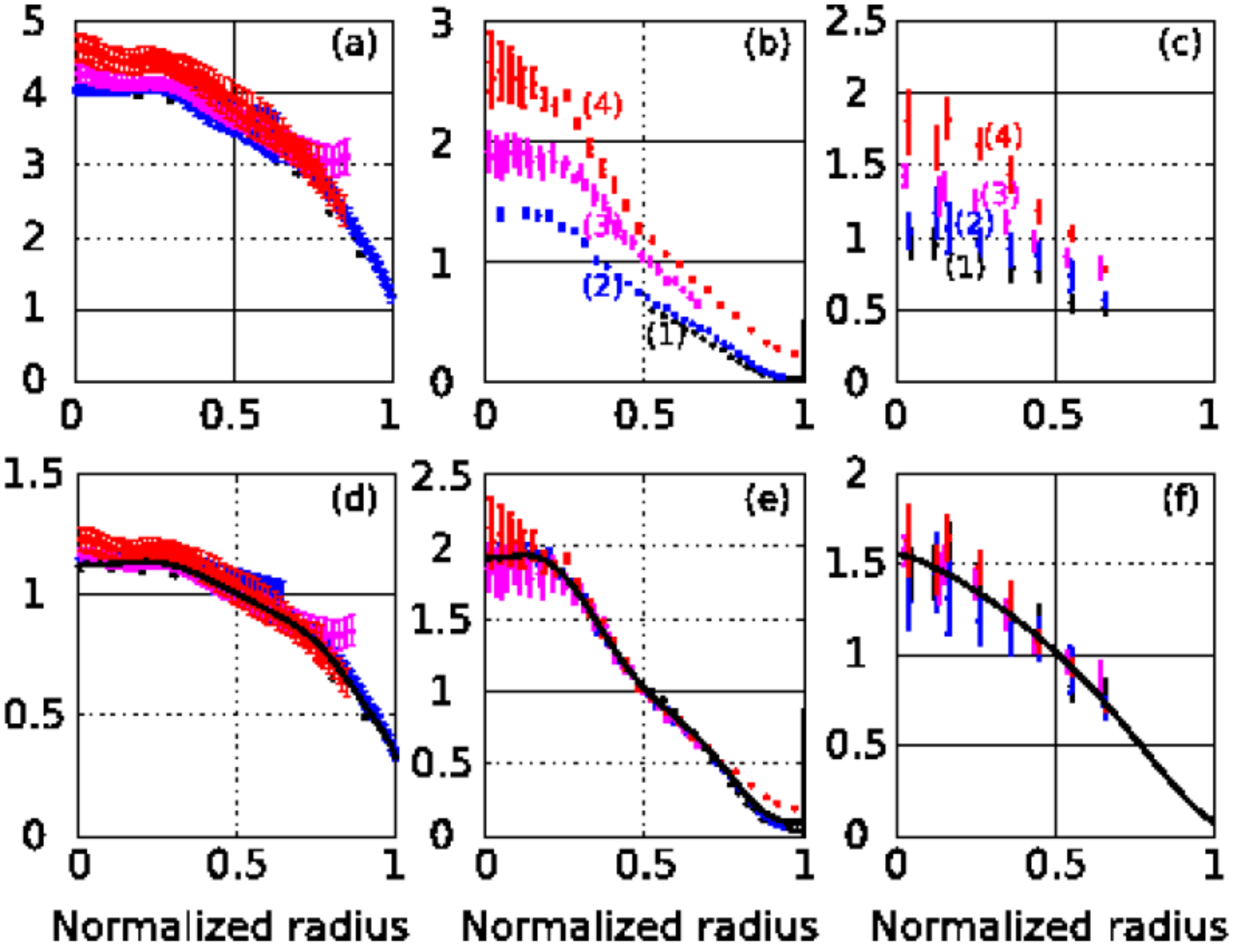
conclusions

- Weak impact of ν* on global and local confinement
- Not possible to resolve more precisely due to underlying gyroBohm scaling, worse if β dependence… Cordey-Gürcan

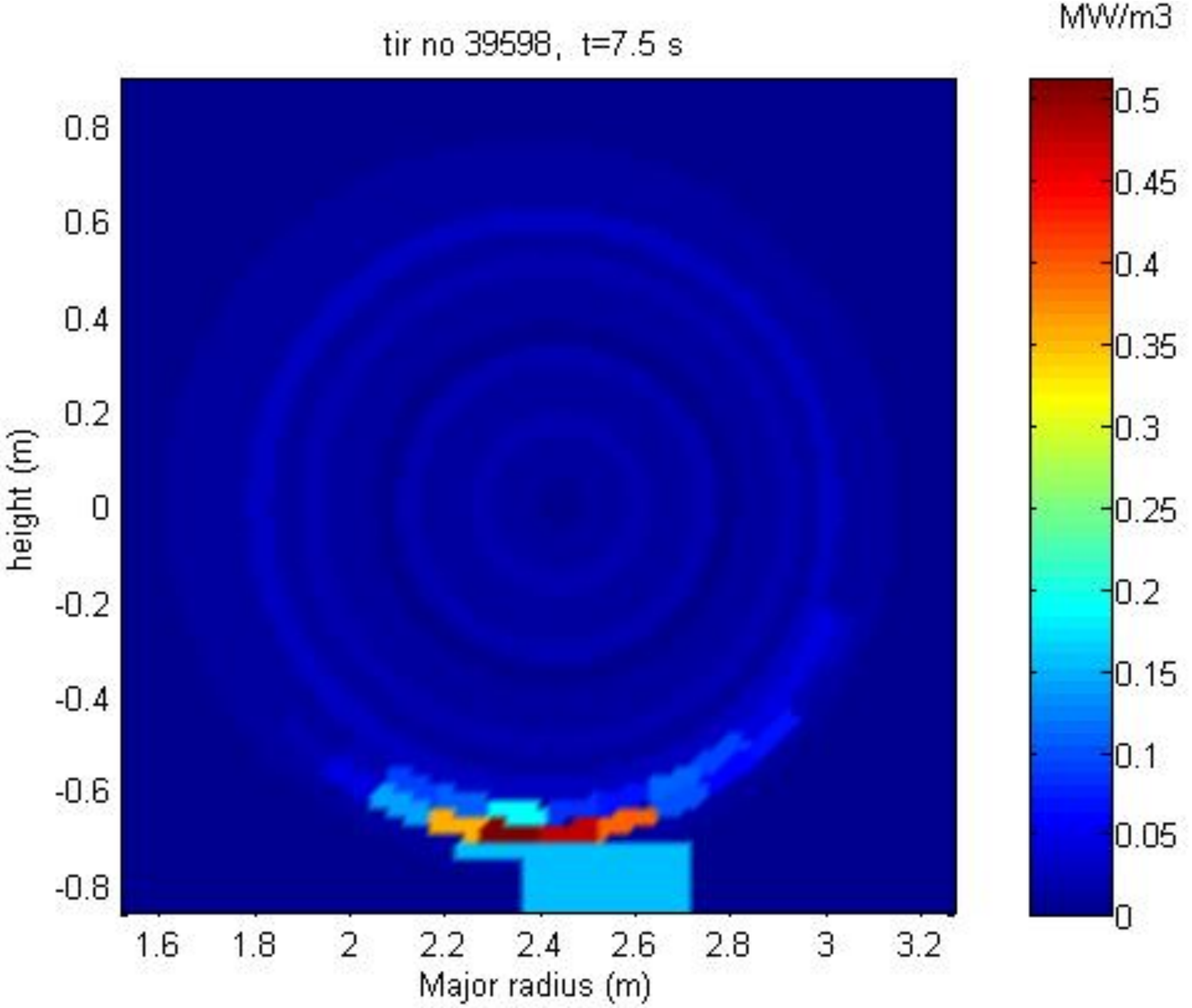
$$\boxed{B\tau_E \propto \nu^{*0.0\pm0.7}}$$

- Local analysis reliability limited in radii
- Density profiles not modified during this scan
- The way to get around: direct NL GK versus turbulent measurements in dimensionless scaling experiments
  - For r/a<0.7: weak impact of ν* on turbulence measurements reproduced by NL local GK
  - For r/a>0.7 see next talk

More details in Bourdelle et al submitted to NF


(a)
5
4
3
2
1
0
0
0.5
1
(b)
3
2
1
0
(4)
(3)
(2)
(1)
(c)
2.5
2
1.5
1
0.5
(4)
(3)
(2)
(1)
(d)
1.5
1
0.5
(e)
2.5
2
1.5
1
0.5
(f)
2
1.5
1
0.5
Normalized radius
Normalized radius
Normalized radius

bolometry


tir no 39598, t=7.5 s
MW/m3
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
height (m)
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Major radius (m)
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2

Plus Zeff and Te/Ti mismatches…

- Hence worth having a look at scaling from 2 OH only

$$B\tau_E = \nu^{*\,-0.9\pm0.6}$$

- Weak dependence in agreement with previous work

Turbulence measurements

- By Doppler at r/a=0.7-0.85 kq
- By fast-sweeping for the whole radius depending on B