# *Effect of Plasma Shape on Electron Heat Transport in the Presence of Extreme Temperature Gradient Variations in TCV*

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# Motivations

- Plasma shape influences stability, confinement, performance

- Aim: Local electron heat transport and global confinement are studied as a function of:
  - plasma shape: triangularity $\delta$
  - $R\nabla T_e/T_e = R/L_{Te}$
    (imposed variations)

- To avoid the strong influence of H-mode edge on:
  - confinement (pedestal height increase with $\delta$)
  - stability of ELMs (strong $\delta$ dependence)
  - ELMs modifying access to ITBs (JET: Rimini, EX/P3-11)

$\rightarrow$ present study in L-mode plasma

# Outline

1 - *$R/L_{Te}$ variations with localised ECH*

2 - *Micro-instabilities*

3 - *TCV and ASDEX-Upgrade vs heuristic model*

4 - *Dependence of $\chi_e$ on micro-instability driving terms*

5 - *Effect of shape and collisionality on $\chi_e$*

# 1. $T_e$-gradient variation experiments with localised ECH

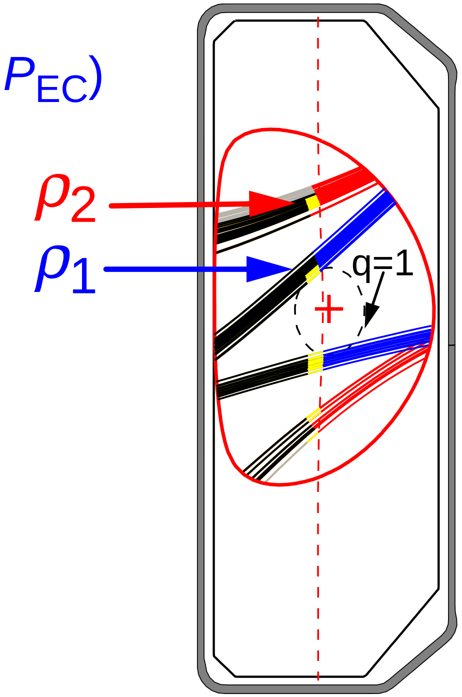
- Dominant EC heating: $P_{EC}$ ~ 0.45-1.8MW, deposited at two radii:

  $\rho_1$~0.35 (> $\rho_{q=1}$, confirmed by sawtooth period increasing with $P_{EC}$)

  $\rho_2$~0.7 (for full EC first-pass absorption)

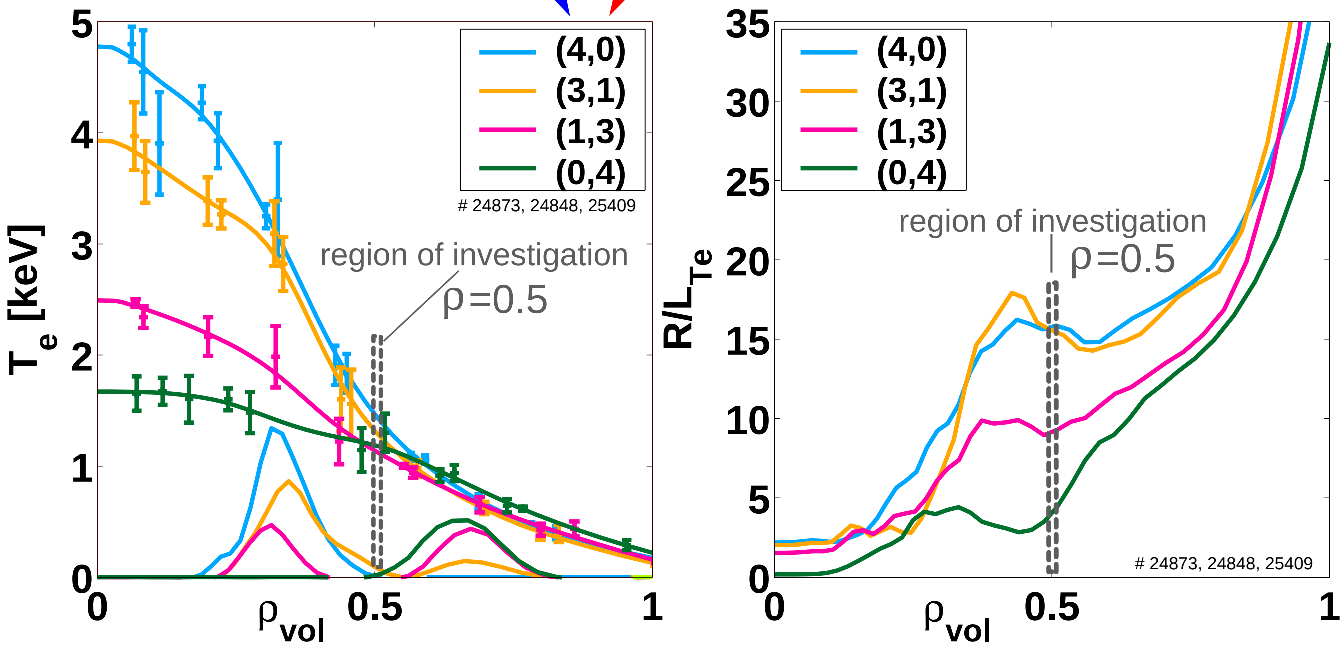
  → $R/L_{Te}$ variation, *constant* edge heat flux

  → $T_e$ variation, *variable* edge heat flux




- Three triangularities: $\delta$ = -0.2, 0.2, 0.4

  nb. of gyrotrons at $\rho_1$ and $\rho_2$ (1 gyro = 0.45MW)




$\delta$ = 0.2, $q_{95}$ ~ 5

$P_{EC}$ =1.8MW,

$q_e^{edge}$ ~ 0.16 MW/m$^2$

$R/L_{Te}$ variation by a factor of 4

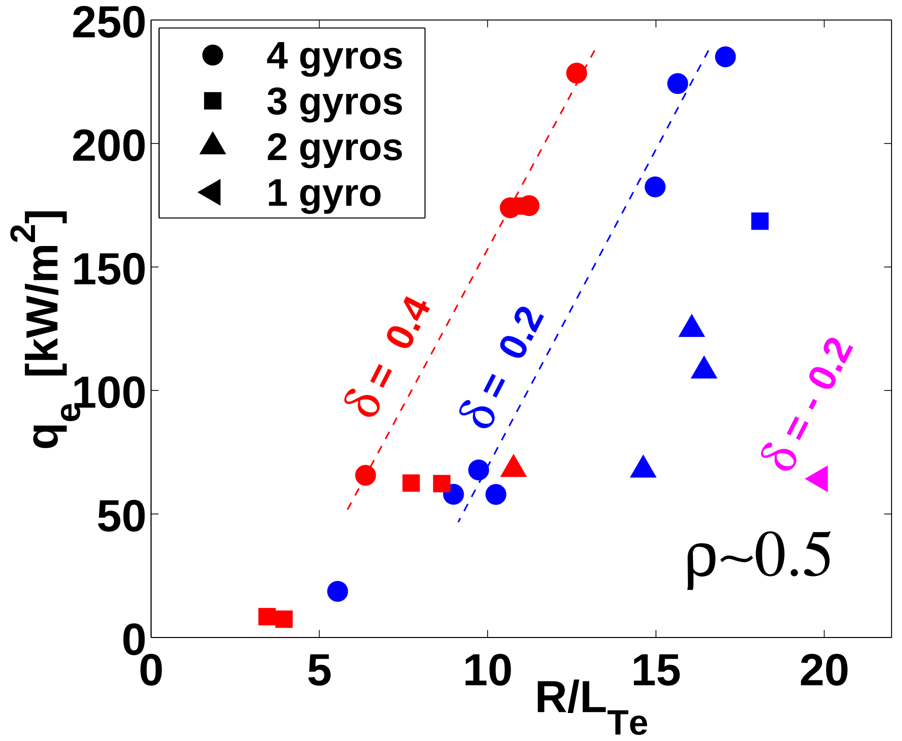
# Local heat transport and global confinement with triangularity

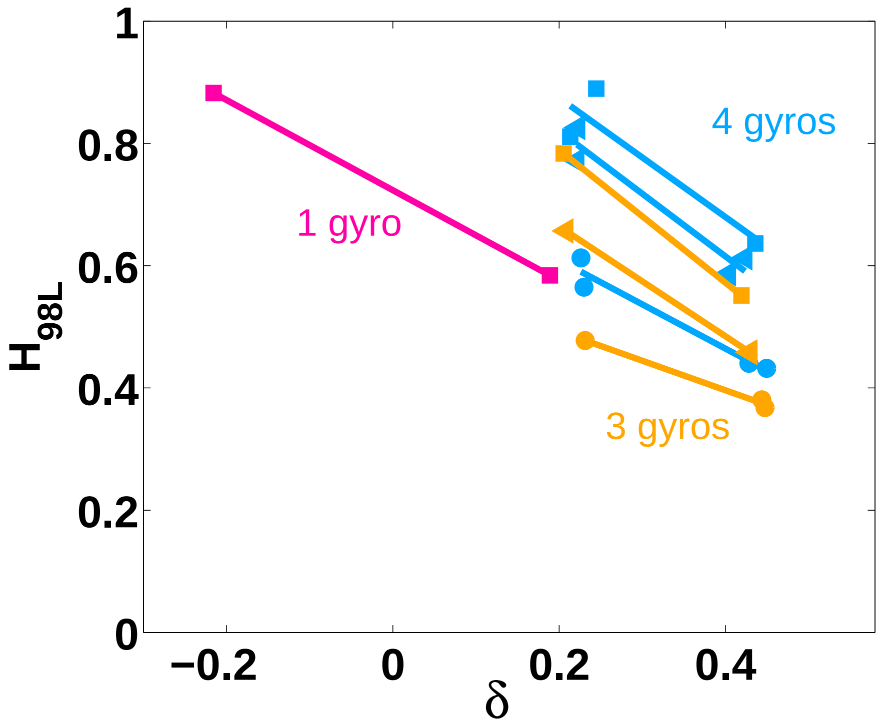
*LOCAL*

- Large range of $q_e$ and $R/L_{Te}$ explored at mid-radius
- Higher $R/L_{Te}$ obtained at the lower $\delta$

*GLOBAL*

- Higher $H_{98L}$ at the lower $\delta$, for any ECH deposition pattern
- Higher confinement for central EC power deposition
- (No significant MHD activity)



# 2. Micro-instabilities: ETG, ITG, TE modes?

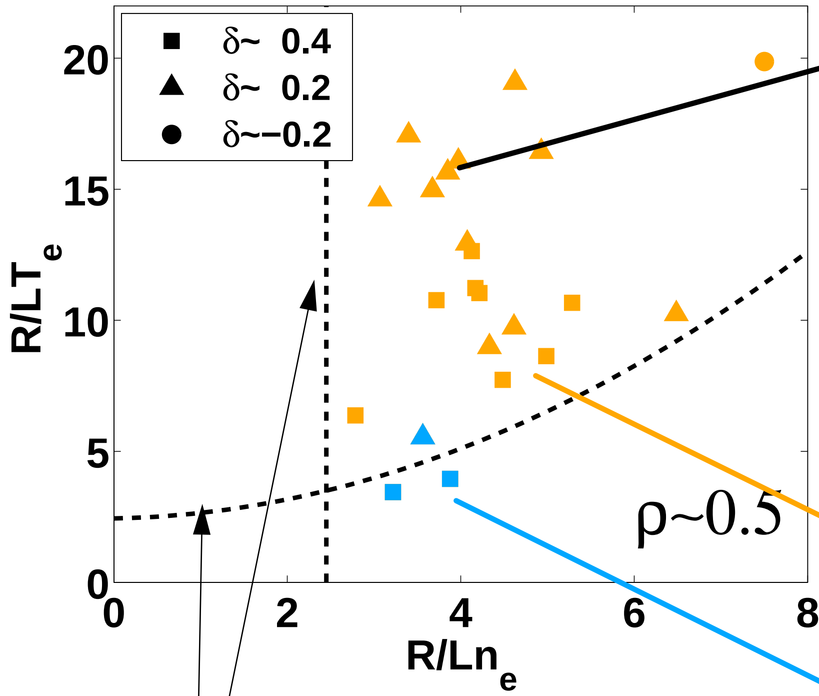
## Parameters at the radius of investigation, $\rho_{vol}$ = 0.53

| | | |
|---|---|---|
| $T_e$ | ~ | 0.6 - 1.3 keV |
| $T_i$ | ~ | 0.2 - 0.5 keV |
| $T_e / T_i$ | ~ | 2 - 4 |
| $f_{trapped}$ | ~ | 0.54 - 0.55 |
| $R/L_{Te}$ | ~ | 4 - 20 |
| $R/L_{Ti}$ | ~ | 4 - 7 |
| $R/L_{ne}$ | ~ | 3 - 8 |
| $n_{e19}Z_{eff}$ | ~ | 3 - 12 |
| $\nu_{eff}$ | ~ | 0.25 - 0.8 |
| $q$ | ~ | 1.5 - 1.9 |
| $s$ | ~ | 1.1 - 1.6 |

ETG: ETG threshold scales with $Z_{eff}\ T_e/T_i$, ETG mode stable at $\rho$=0.5

# TE modes are most unstable (except at the lowest $R/L_{Te}$)

## ITG-TE modes:




- Pure TE mode thresholds (Weiland model)
  [Nordman, Weiland, NF 1989]

- LORB5 (global lin. gyrokin.)
  [Bottino, PoP 2004]:

$$\frac{\gamma_{d,e}}{\gamma_{\|,i} + \gamma_{d,i} + \gamma_{d,e}} \sim 90\% \quad \text{(n=10, 15, 20, 25)}$$

  TE modes most unstable

- GLF23 (gyro-Landau-fluid)
  [Waltz, PoP 1997]:

  Imposing $\nabla T_i = 0 \Rightarrow \gamma$ increases:
  TE modes most unstable

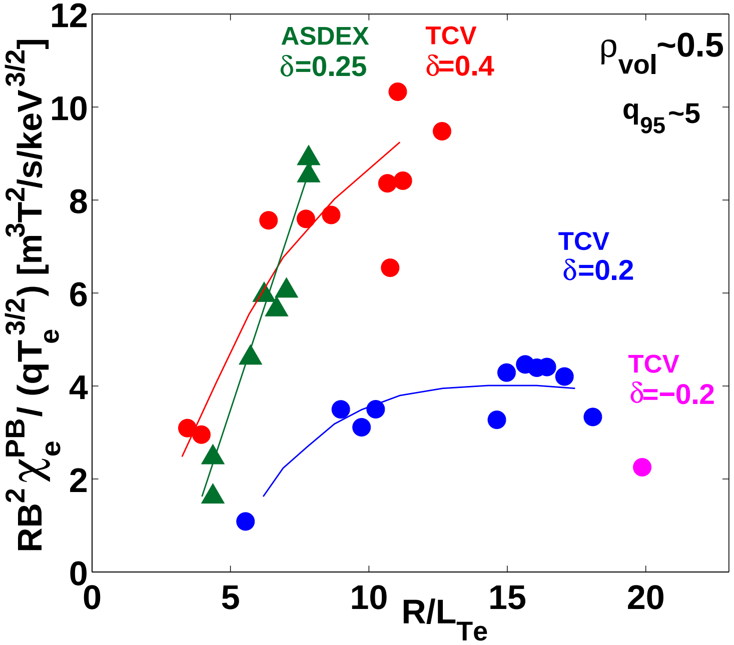
  Imposing $\nabla T_i = 0 \Rightarrow \gamma$ decreases by 75%,
  ITG modes most unstable

# 3. TCV and ASDEX Upgrade versus heuristic electron heat transport model

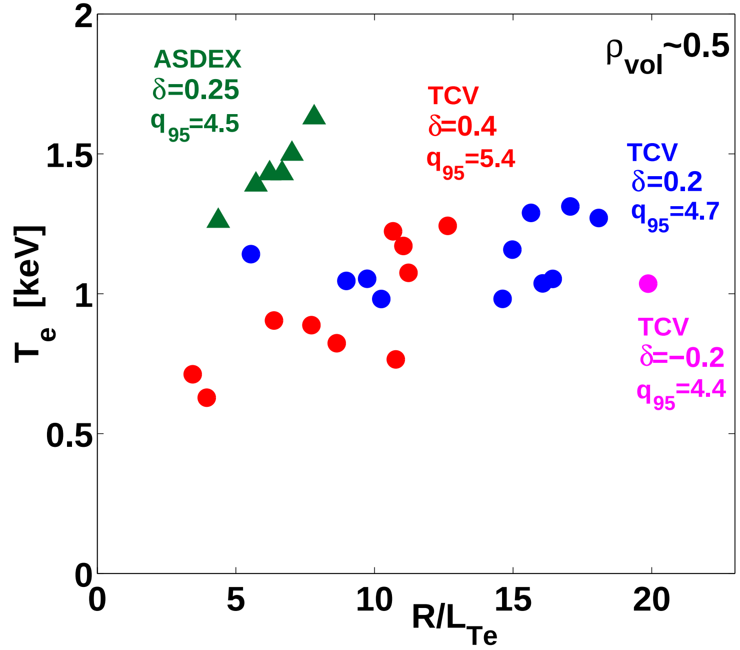
Heuristic conductivity model [Imbeaux PPCF 2001] :

$$\chi_e = \chi_o + \lambda \cdot q \cdot T_e^{3/2} \left((R/L_{Te})-(R/L_{Te})^{crit}\right) \cdot H\left((R/L_{Te})-(R/L_{Te})^{crit}\right)$$

*Gyro-Bohm normalised heat diffusivity*



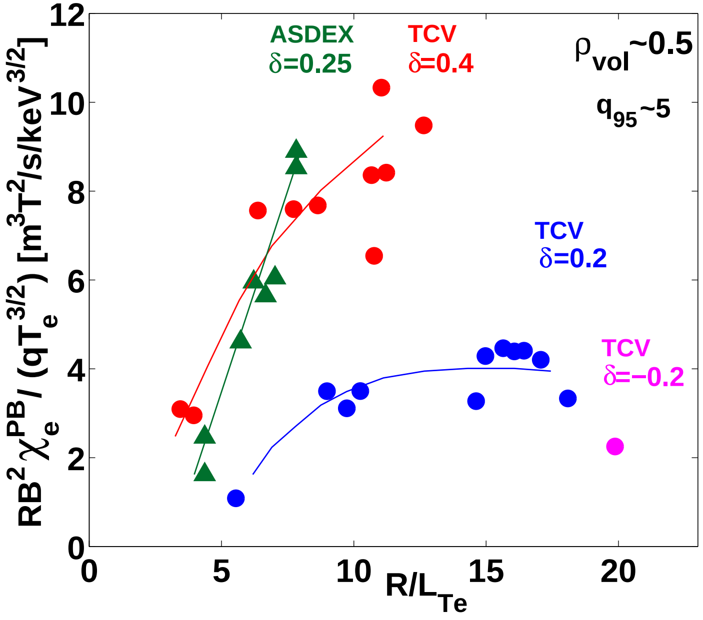

*Large range of $R/L_{Te}$ and $T_e$ data*



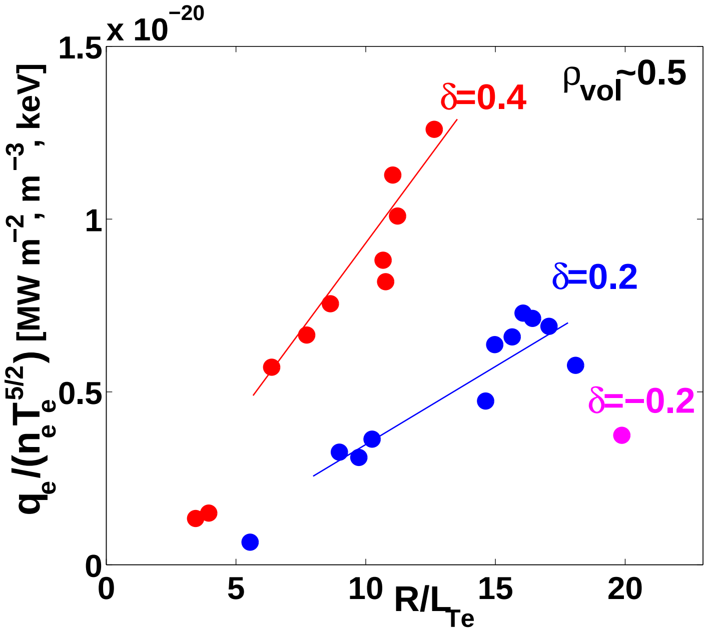

- Excellent agreement for AUG data
- TCV data scattered: due to the large range of $R/L_{Te}$ *and* $T_e$ explored?
  $T_e^{3/2}$ and $R/L_{Te}$ dependences may not be fully adequate
- Saturation of $\chi_e(R/L_{Te})$ at high $R/L_{Te}$

# Heuristic modeling: dependence of $\chi_e$ at high $R/L_{Te}$

*Gyro-Bohm normalised heat diffusivity*
*saturation*




*Normalised heat flux*
*linear*

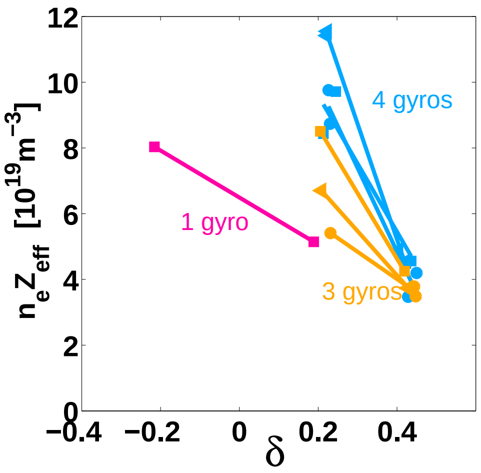



- Local electron heat transport depends on plasma triangularity $\delta$ (L-mode)
- The saturation of the normalised diffusivity $\chi_e(R/L_{Te})$ at high $R/L_{Te}$ , the linear behaviour of a normalised heat flux $q_e(R/L_{Te})$, consistently lead to a heuristic model of the form:

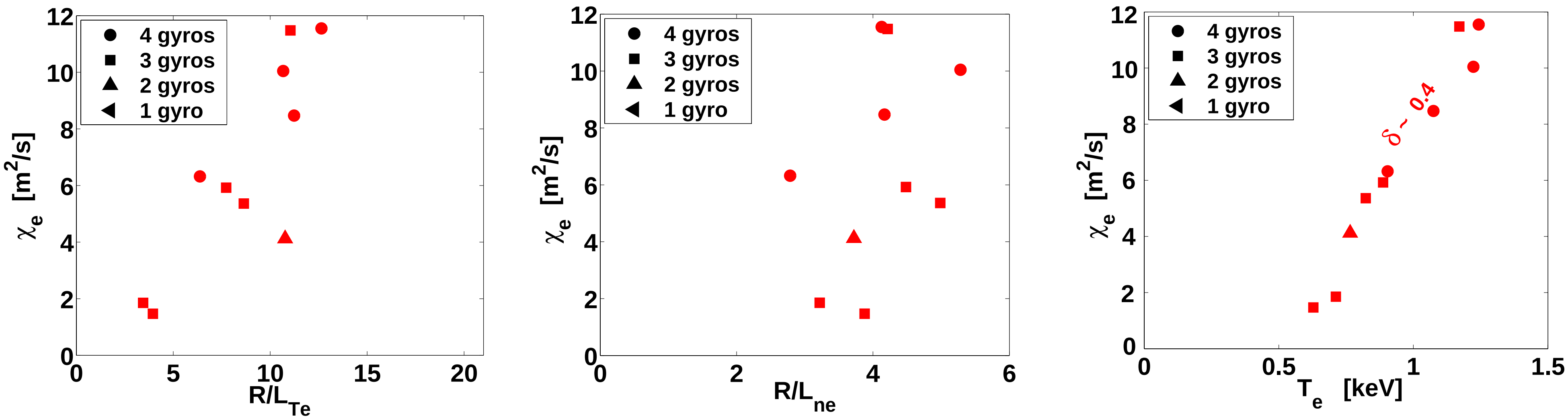
$$\chi_e \sim T_e^{3/2} [(R/L_{Te})-(R/L_{Te})^{crit}] / (R/L_{Te})$$

$$q_e \sim n_e T_e^{5/2} [(R/L_{Te})-(R/L_{Te})^{crit}]$$

# 4. Dependence of $\chi_e$ on micro-instability driving terms

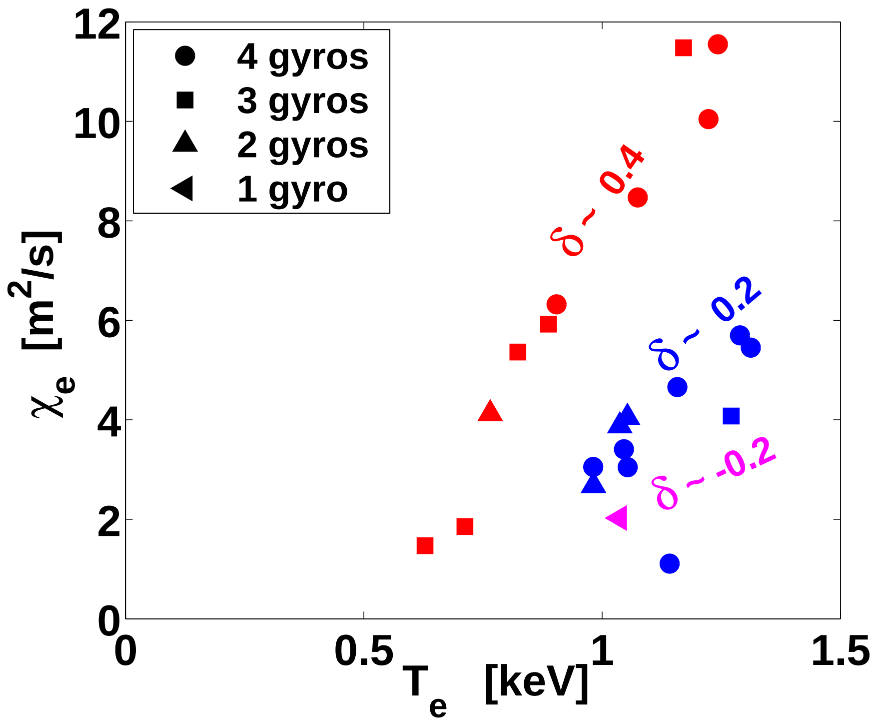


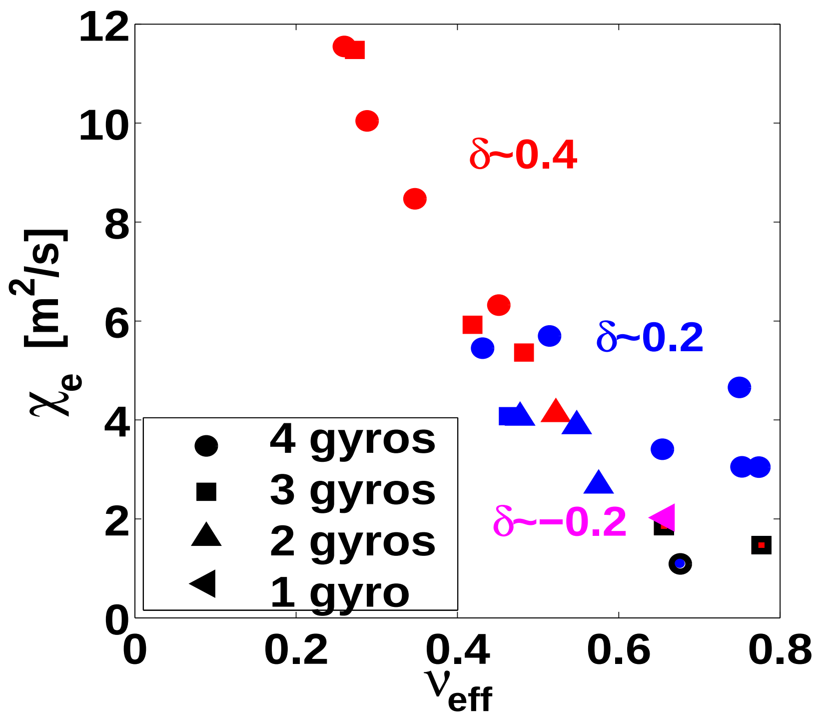

Focusing on
one triangularity $\delta = 0.4$,
where $n_e Z_{eff}$ ~ const.




- Weak correlation of $\chi_e$ with the TE mode driving terms $R/L_{Te}$ and $R/L_{ne}$, in contrast to GLF23 results
- Strong correlation with $T_e$

# 5. Effect of shape and collisionality on $\chi_e$



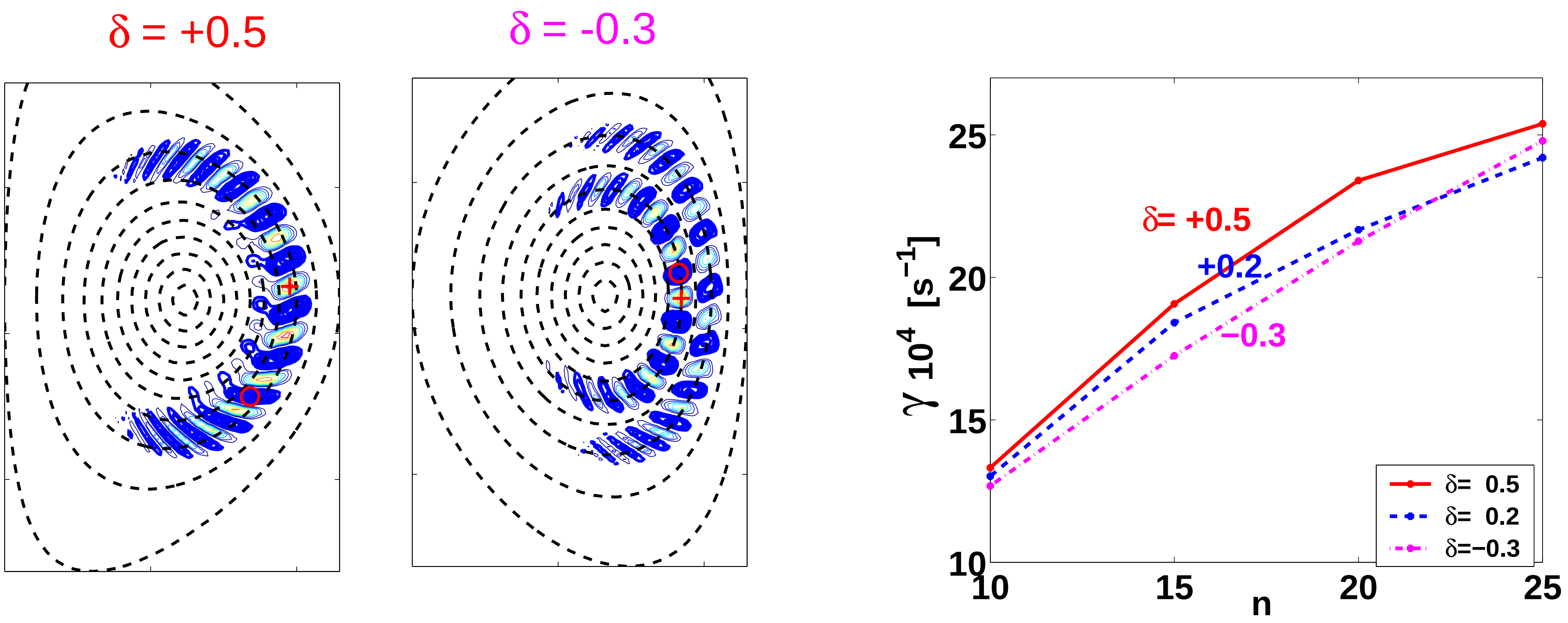

- The heat diffusivity increases with triangularity $\delta$, but collisionality changes with $\delta$.

- Heat diffusivity decreases while collisionality increases (TE mode stabilisation)
- The different $\delta$'s overlay each other
- Does the theory predict a $\delta$-dependence?

# Plasma shape effects in LORB5 simulations

LORB5: linear, global, collisionless, gyrokinetic code

- Varying triangularity $\delta$, while keeping other plasma parameters constant:




- Change of spatial distribution of convective cells (electro-static potential)
- but rather small increase of growth rate $\gamma$ with $\delta$.

# Conclusions

- To determine local electron heat transport properties, an extreme range of $T_e$ and $R/L_{Te}$ has been obtained by varying ECH power and deposition pattern in L-mode
- Reducing triangularity $\delta$
  $\rightarrow$ reduces local electron heat transport and
  $\rightarrow$ increases global confinement
- The gyro-Bohm normalised heat conductivity saturates at high $R/L_{Te}$, specifying the form of the heuristic model
- Strong dependence of $\chi_e$ on $T_e$
- The collisionality $\nu_{eff}$ plays a dominant role in the reduction of the local electron heat transport towards lower $\delta$, through TE mode stabilisation.