# EXPERIMENTAL GOALS AND METHOD

- Goal: Determine experimentally the influence of cross-section shape on energy transport in L mode and H mode

- Method: While changing the elongation, hold fixed:
  - Toroidal field at geometric center
  - Minor radius
  - Density profiles in normalized radius
  - Temperature profiles in normalized radius
  - Toroidal rotation profile in normalized radius

  and to compare with theory
  - q profile in normalized radius

  or to compare with global scalings
  - Plasma current

- Note: Since densities are large and no uncertainty analysis has been performed, only one-fluid power balance results are shown

# FLUX-AVERAGED EQUATIONS GIVE SIMPLE FORMULAS FOR THE EFFECT OF CROSS SECTION CHANGES

- **By definition:**

$$\overline{q_H} \equiv -n\bar{\chi} \frac{\partial T}{\partial \hat{\rho}} \frac{1}{\rho_b} \qquad\qquad P \equiv \frac{\partial V}{\partial \rho} \overline{q_H} \quad .$$

**($\rho_b^2$ is the boundary value of the normalized toroidal flux). The change in diffusivity when the cross section is varied with $n(\hat{\rho})$, $T(\hat{\rho})$ constant:**

$$\frac{\bar{\chi}_2}{\bar{\chi}_1} = \frac{\bar{q}_{H2}}{\bar{q}_{H1}} \frac{\rho_{b2}}{\rho_{b1}} = \frac{(P_2/H_2)}{(P_1/H_1)}$$

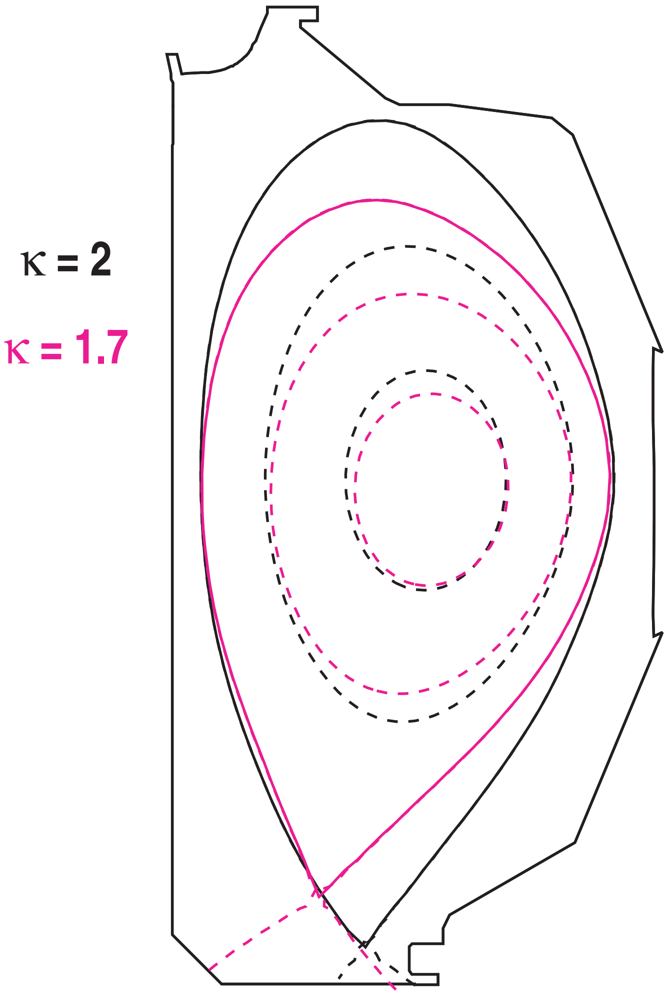
**where $H \equiv \partial V/\partial \rho \; (4\pi^2 R_o \, \hat{\rho} \, \rho_b)$.**

- **The change in global confinement can be estimated by $\tau = \rho_b^2/\bar{\chi}$. Then**

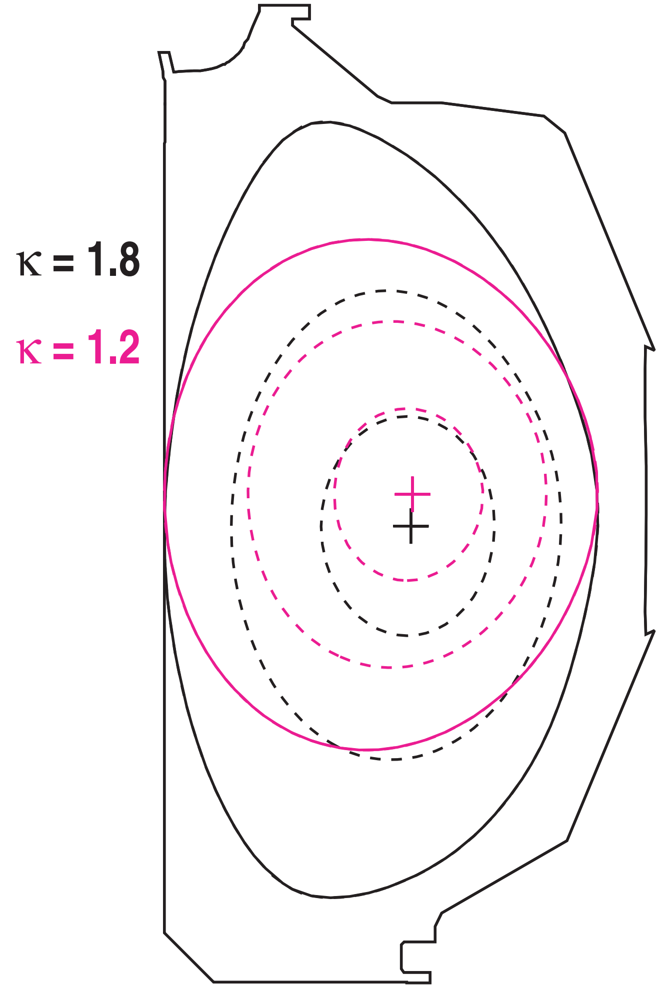
$$\frac{\tau_2}{\tau_1} = \left(\frac{\rho_{b2}}{\rho_{b1}}\right)^2 \frac{\bar{\chi}_1}{\bar{\chi}_2} \quad .$$

**If the diffusivity is independent of cross-section shape, then $\tau \propto \rho_b^2 \sim \kappa$**

## Shape variation for H–mode elongation scans




## Shape variation for L–mode elongation scans

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# CONCLUSIONS

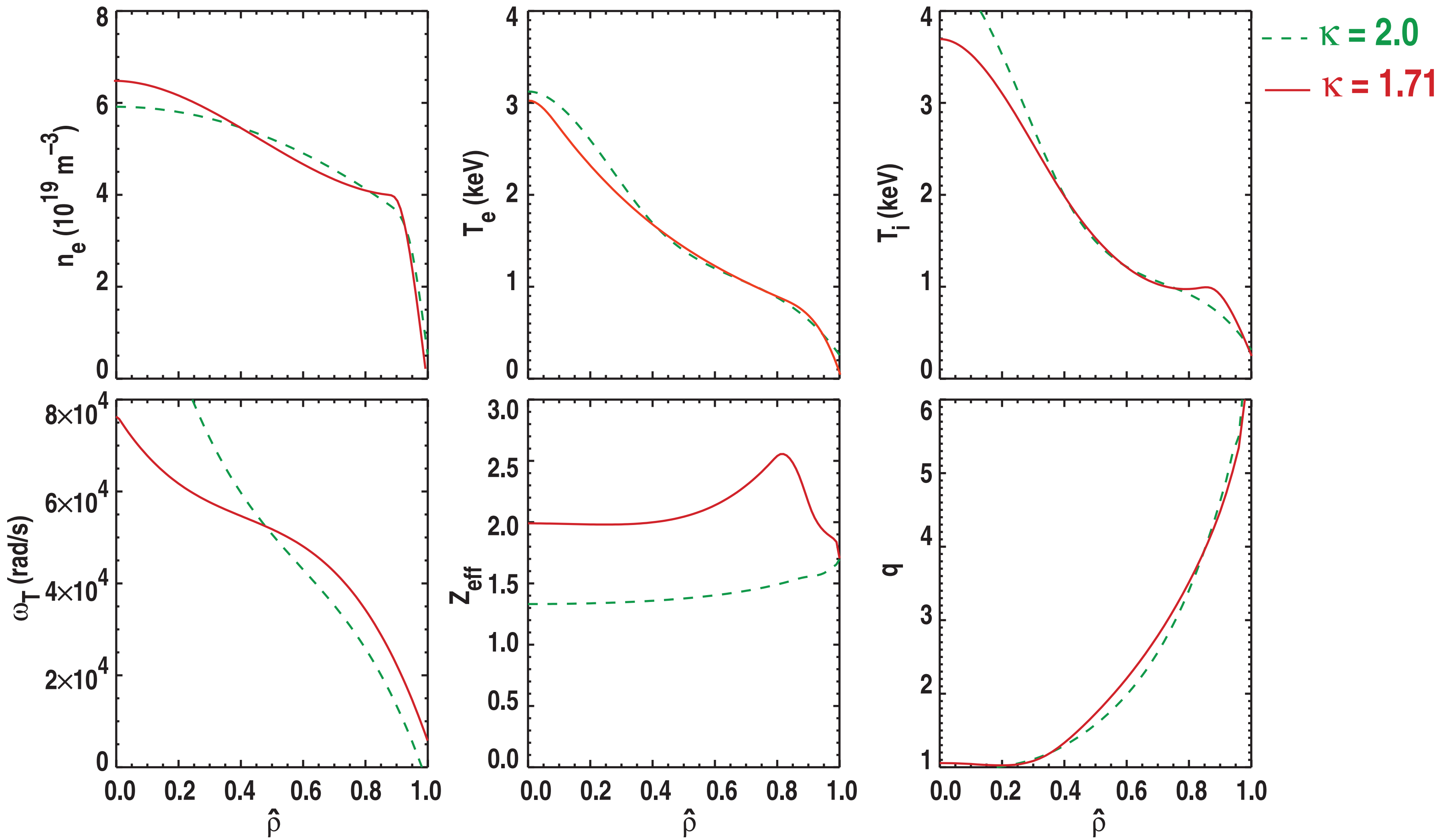
- Characterizing the cross-section shape effects using $\kappa$, and the effect on diffusivity as a power law $\chi \propto \kappa^a$, there is a strong influence of shape on transport: $\alpha = -(1.5\text{–}2.0)$

- Changes in cross-section shape at fixed current will be strongly affected by the change in q. It is necessary to maintain fixed q to isolate the effects of cross-section shape on energy transport

- The constant current scans can be qualitatively reconciled with the constant q scans using $\chi \propto q^2$ as measured in DIII–D H–modes

- No theoretical understanding of such a strong dependence on cross-section shape is available at this time

# PROFILE MATCH FOR CONSTANT q H–MODE SCAN

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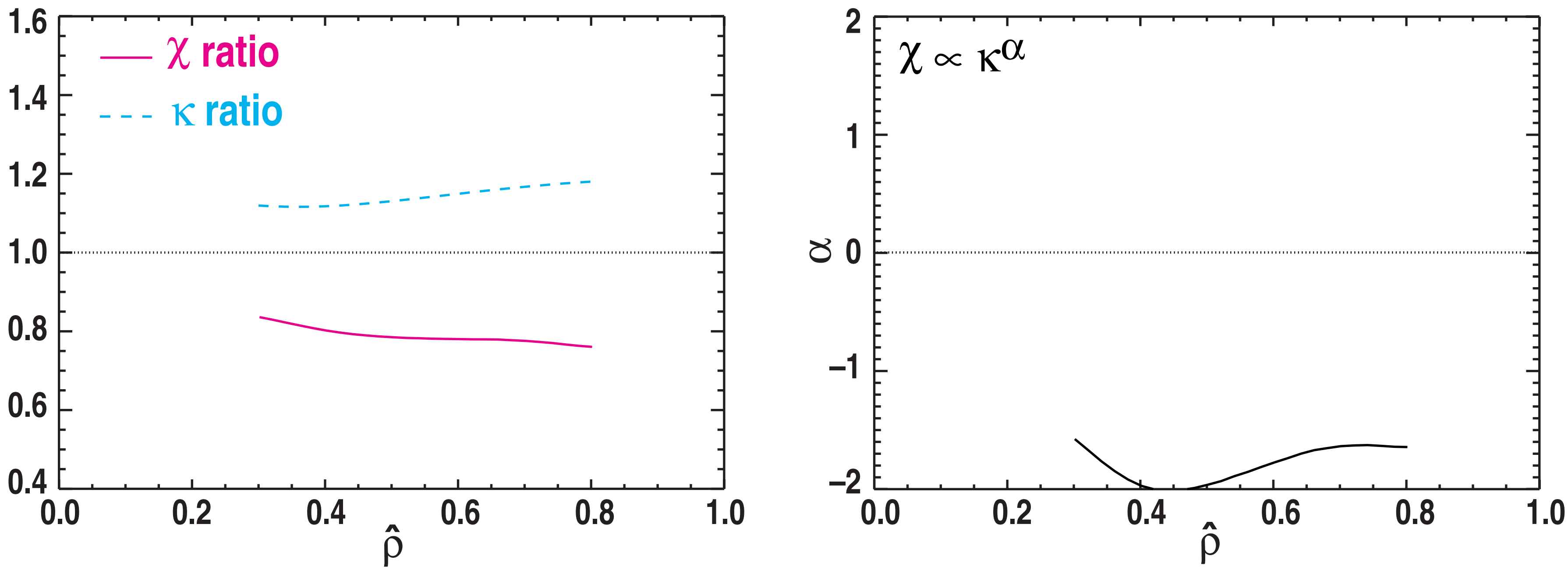
# POWER BALANCE RESULTS FOR CONSTANT q H-MODE SCAN

- Transport is reduced with increasing elongation

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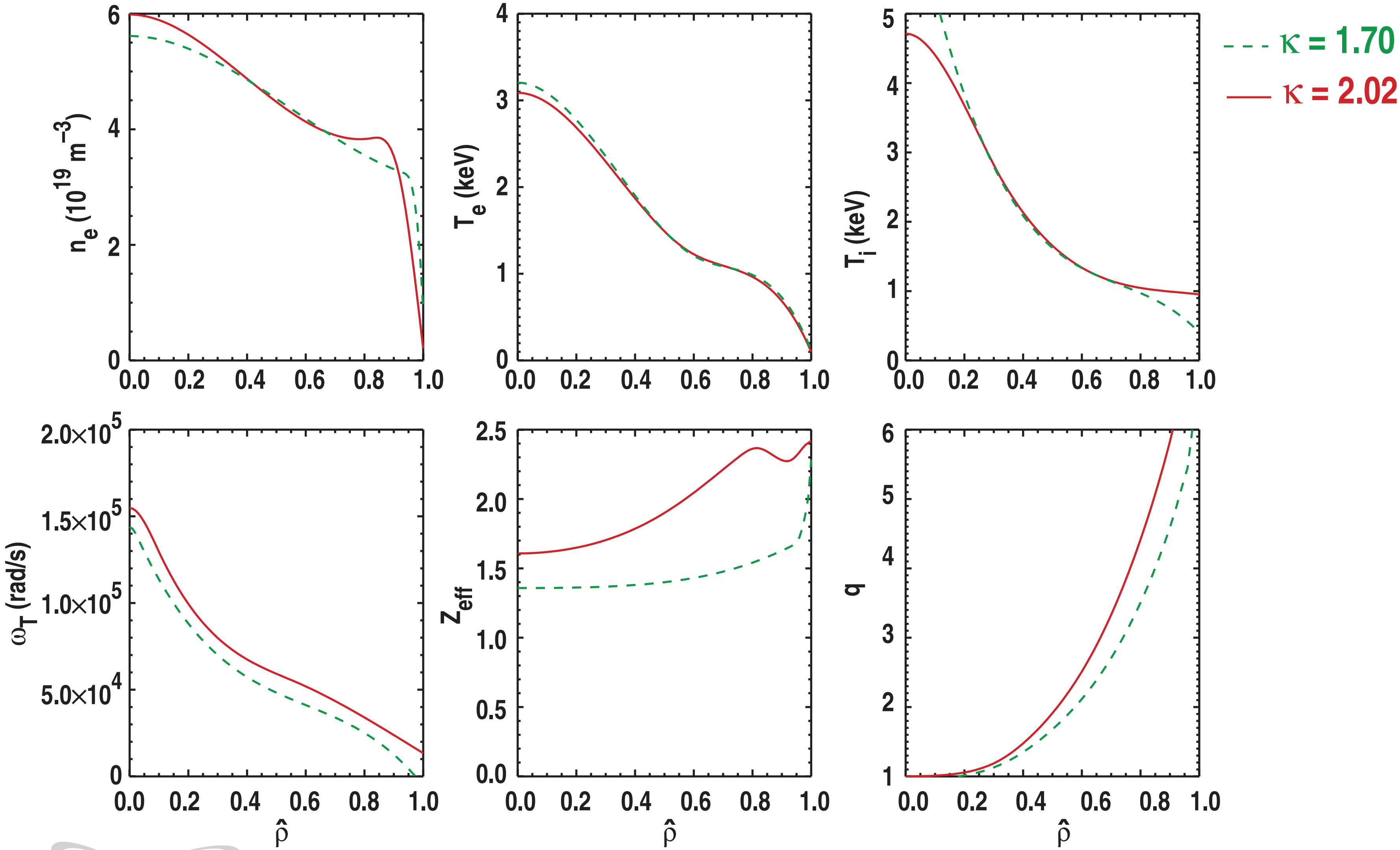
# PROFILE MATCH FOR CONSTANT I H–MODE SCAN

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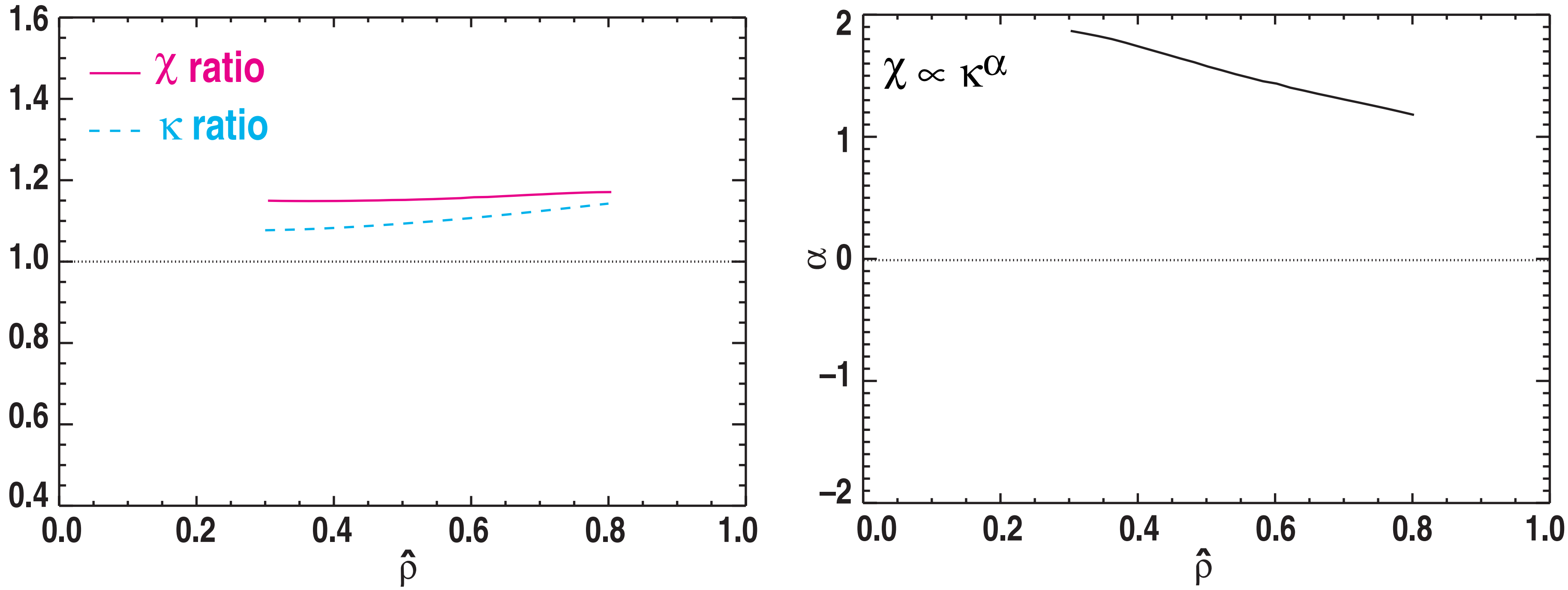
# POWER BALANCE RESULTS FOR CONSTANT I H–MODE SCAN

- Transport increases with increasing elongation

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# H MODE GLOBAL CONFINEMENT RESULTS

| | Constant q Scan | Constant I Scan |
|---|---|---|
| $\tau_{th}$ (ms) | 190/135 | 137/128 |
| | 2.0/1.71 | 2.02/1.70 |
| $\rho_b^2$ ($m^2$) | 0.63/0.517 | 0.604/0.513 |
| $H_{98y2}$ | 0.99/1.20 | 1.15/1.20 |
| $\alpha$ | 2.19 | 0.41 |
| I (MA) | 1.08/0.84 | 0.84/0.84 |
| B (T) | 1.93/1.93 | 1.93/1.93 |
| $\bar{n}$ ($10^{19}$ $m^{-3}$) | 5.2/5.1 | 4.7/4.6 |
| P (MW) | 2.69/3.37 | 3.60/3.37 |

($\tau_{th} \propto \kappa^{\alpha}$)

$H_{98Y2}$ is the ratio of $\tau_{th}$ to the H–mode confinement scaling in the ITER Physics Basis

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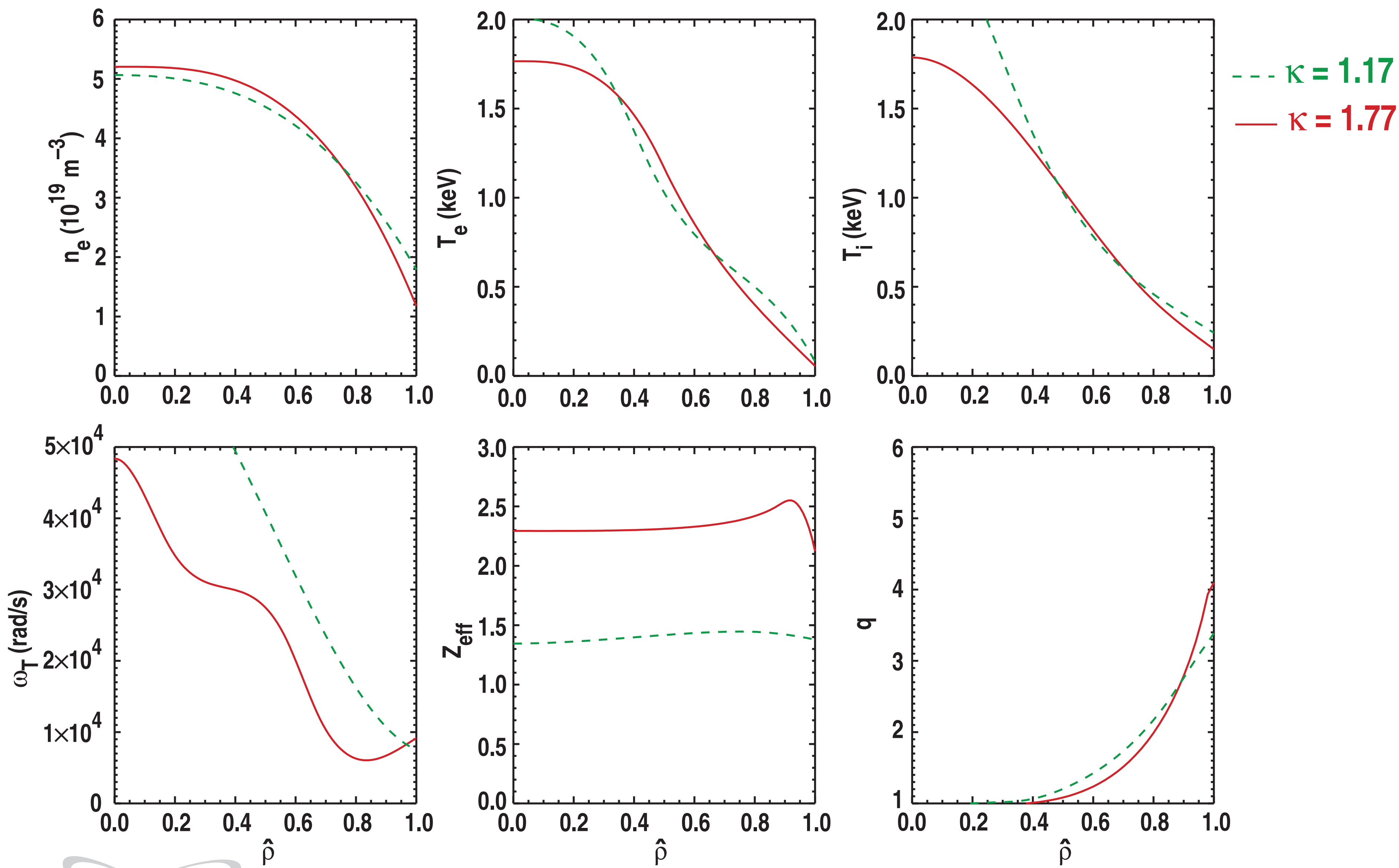
# PROFILE MATCH FOR CONSTANT q L–MODE SCAN

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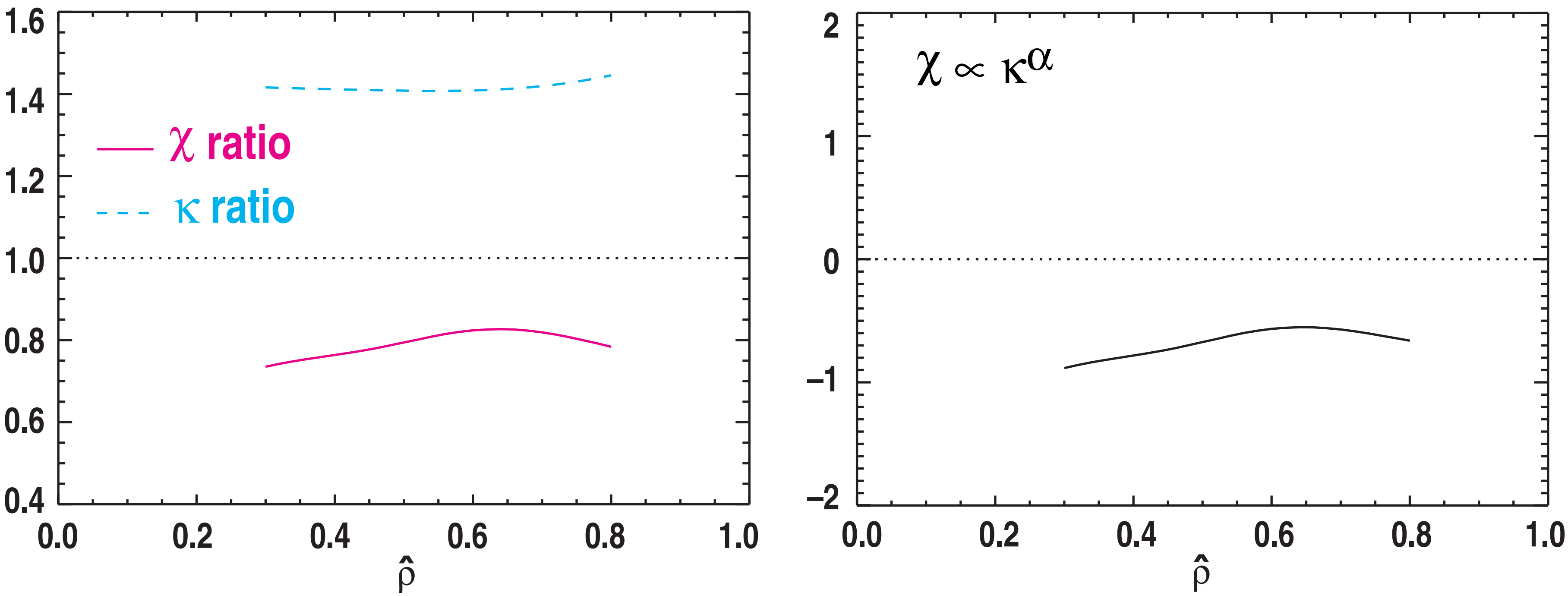
# POWER BALANCE ANALYSIS FOR CONSTANT q L–MODE SCAN

- Transport is reduced with increasing elongation

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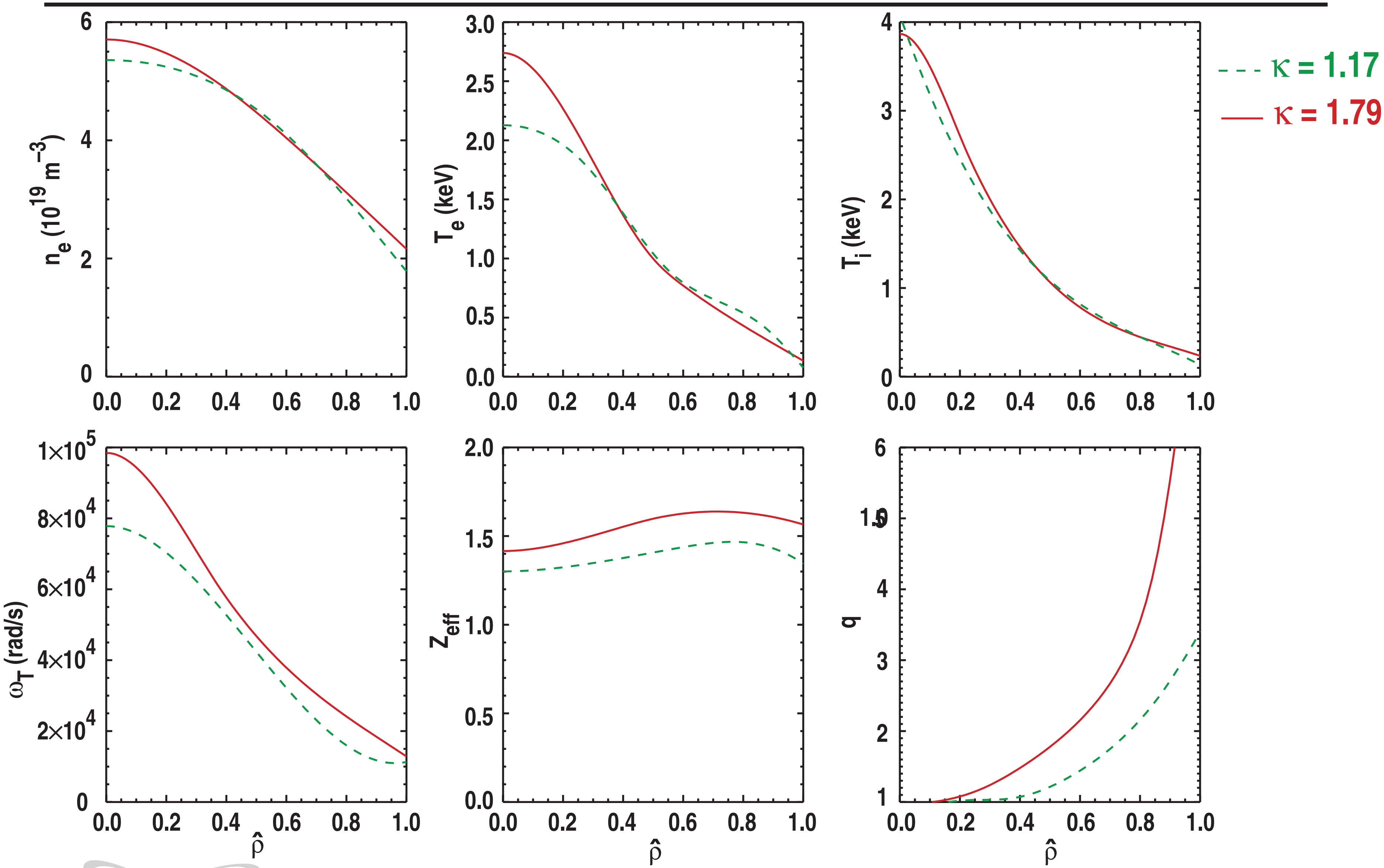
# PROFILE MATCH FOR CONSTANT I L–MODE SCAN

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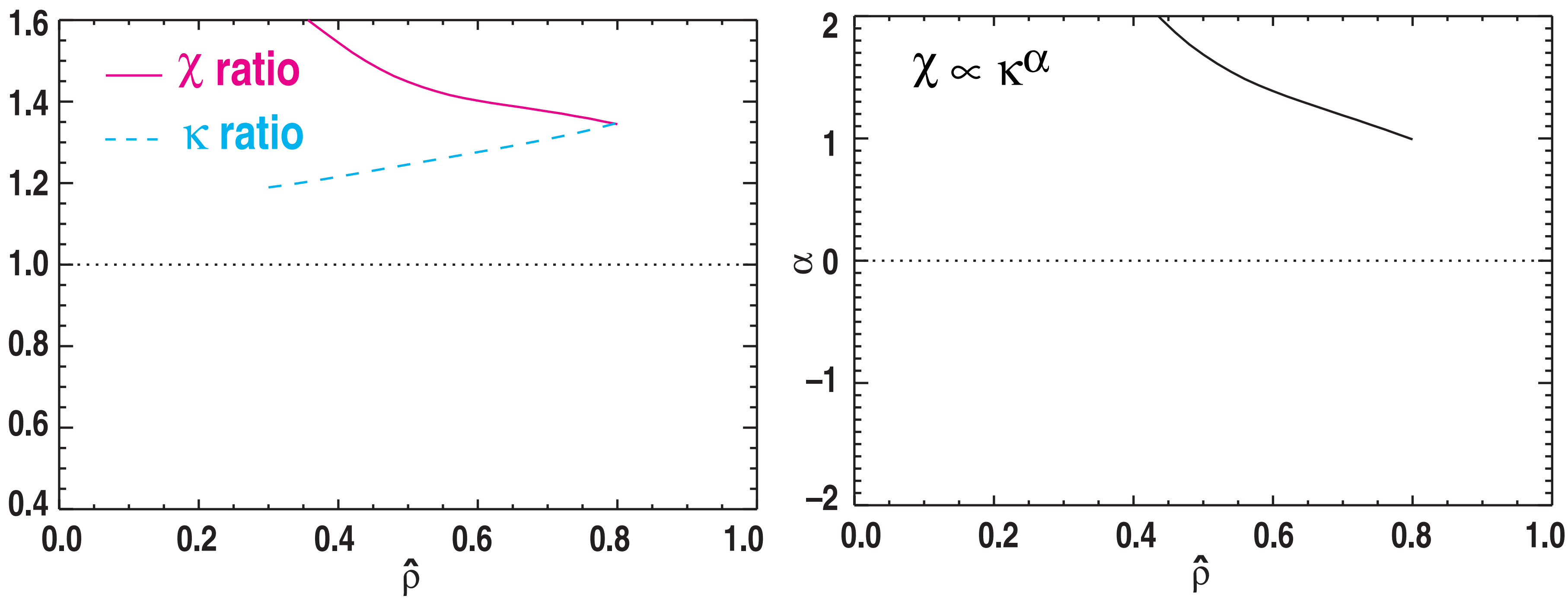
# POWER BALANCE ANALYSIS FOR CONSTANT I L–MODE SCAN

- Transport increases at higher elongation

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# L MODE GLOBAL CONFINEMENT RESULTS

| | Constant q Scan | Constant I Scan | |
|---|---|---|---|
| $\tau_{th}$ (ms) | 90.0/46.2 | 56.6/348.7 | |
| | 1.77/1.17 | 1.79/1.17 | |
| $\rho_b^2$ ($m^2$) | 0.73/0.46 | 0.684/0.462 | |
| $L_{IPB}$ | 0.69/1.12 | 1.23/1.18 | |
| $\alpha$ | 1.61 | 0.35 | ($\tau_{th} \propto \kappa^{\alpha}$) |
| I (MA) | 1.84/0.98 | 0.99/0.97 | |
| B (T) | 1.99/1.99 | 2.00/1.99 | |
| $\bar{n}$ ($10^{19}$ $m^{-3}$) | 4.4/4.2 | 4.5/4.2 | |
| P (MW) | 3.20/4.59 | 5.97/4.58 | |

$L_{IPB}$ is the ratio of $\tau_{th}$ to the L–mode thermal confinement scaling in the ITER Physics Basis

# DISCUSSION

- The discrepancy in the constant q and constant I scans is expected in H mode on the basis of the q scaling measurements on DIII–D ($\chi \propto q^2$) [1]. Such strong and opposing dependences will require a careful error assessment to yield an accurate estimate for the true scaling with shape

- Preliminary anallysis gives a power law dependence of $\alpha \simeq -(1-4)$ for all cases assuming $\chi \propto q^2$ (see figure at right)

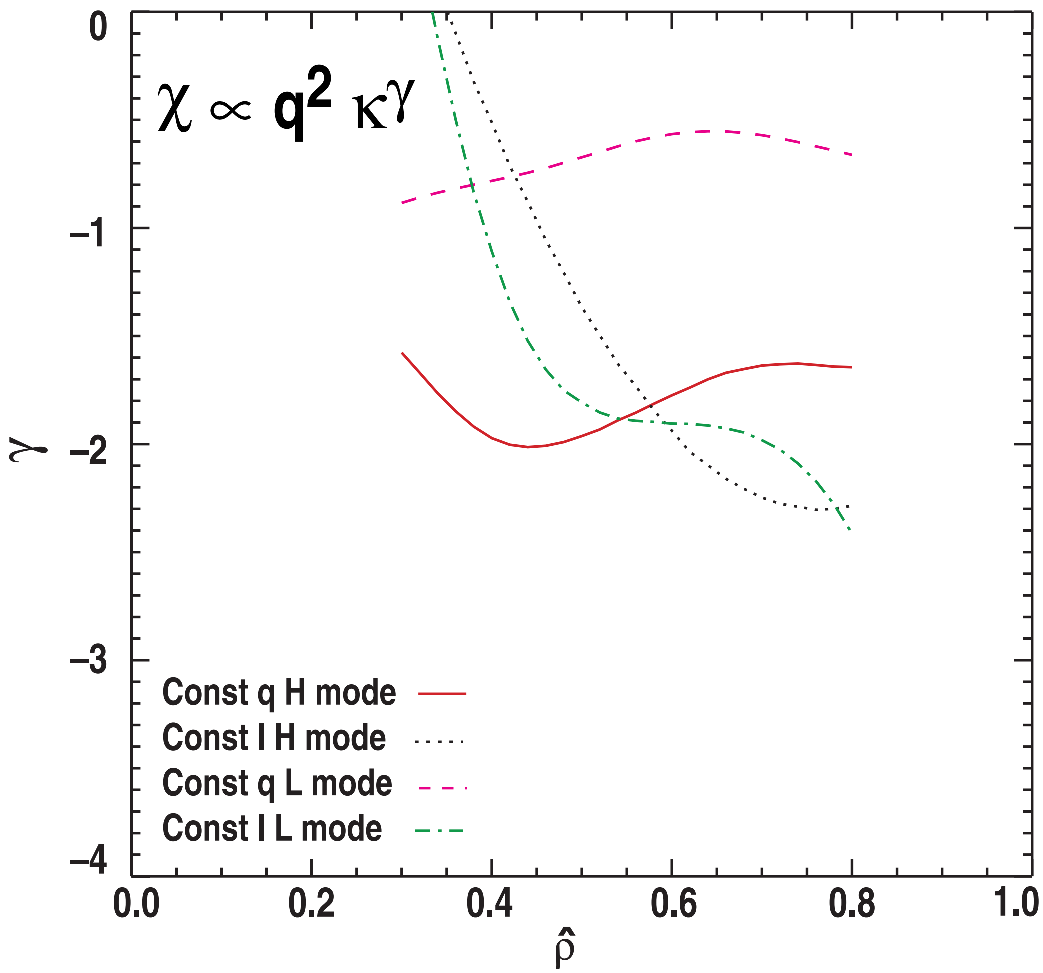
- Such a strong dependence on shape was not anticipated by theoretical calculations (for example [2]). However, physics-based models derived for circular geometry [3] have included strong shaping effects ($\chi \propto \kappa^4$)


[1] C.C. Petty, et al., Phys. Plasmas 5, 1695 (1998).

[2] R.E. Waltz, R.L. Miller, Phys. Plasmas 6, 4265 (1999).

[3] J.E. Kinsey, et al., Physica Scripta 53, 428 (1995).

# PRELIMINARY ASSESSMENT OF CORRECTION OF THE κ SCANS FOR q SCALING




- Main conclusion is that a reasonable q dependence ($\chi \propto q^2$) is in the correct direction and has sufficient magnitude to reconcile the constant q and constant I scans

- Measurement uncertainties may not allow a quantitative correction

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