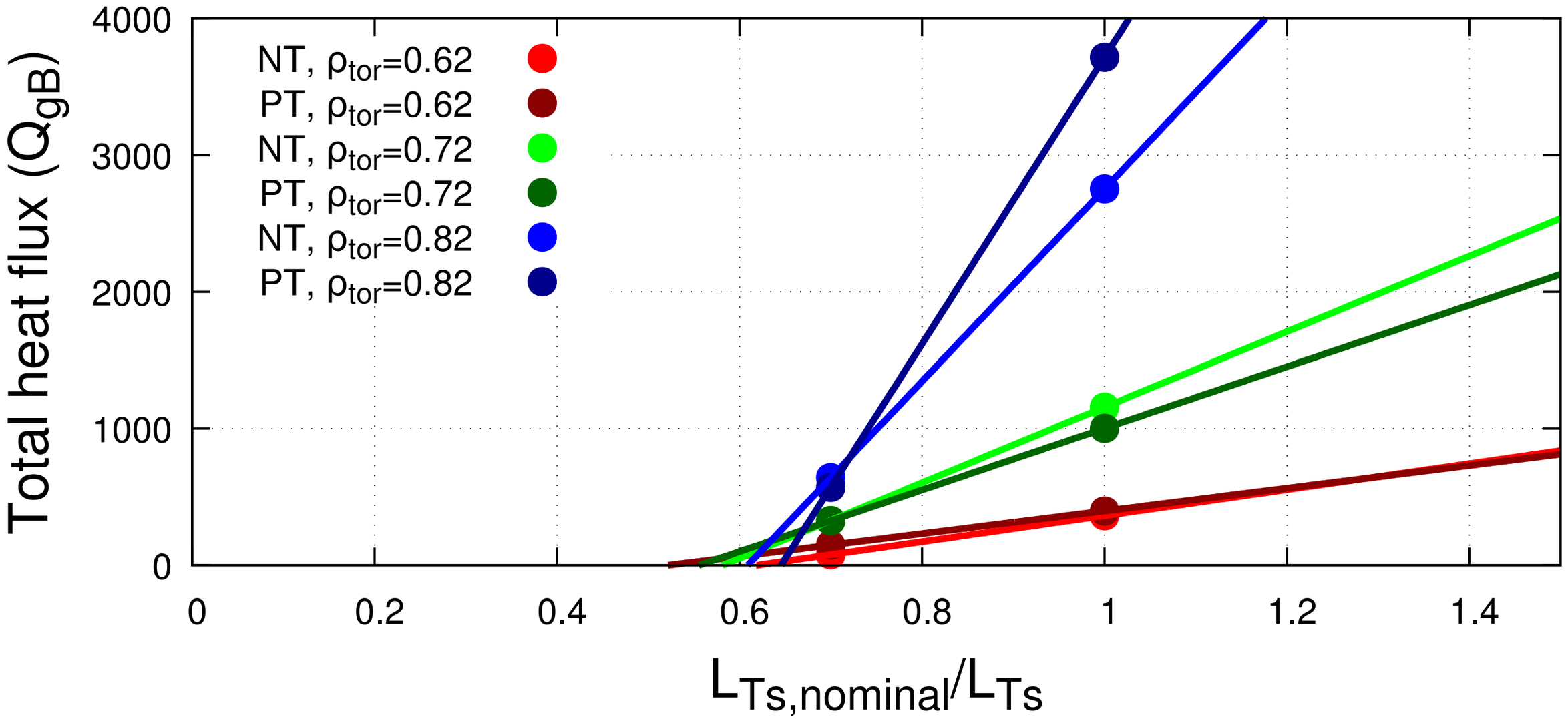
Mostly local gyrokinetic studies of NT versus PT



Justin Ball

2022 Annual TSVV 2 Workshop

30 November 2022

Milestones

Milestone	Description	Participants	Target date
M1.1.3	Perform comprehensive study of critical gradient and stiffness as a function of minor radius using local GK simulations	J. Ball	03.2022
M1.2	Integrate findings from the ERG on global flux driven GK simulations of TCV-like NT discharges (including impurity transport) into this TSVV; specifically comparing trends against the GENE results when possible	P. Donnel, J. Ball	11.2022
M3.2	Validation of trends from GK codes (local and global) using well-diagnosed TCV experiments	J. Ball, O.Sauter, P. Donnel	03.2023
M4.3.1	Perform electromagnetic local GK simulations to test impact at high β	J. Ball, M. Pueschel	03.2023
D1.1	**Report*** on properties of core and pedestal turbulent transport in NT as compared to PT, in particular identifying the important physical effects responsible for the difference	J. Ball, P. Donnel	03.2023
M4.3.2	Perform local GK simulations to extrapolate behavior to reactor scale devices	J. Ball	09.2023

Outline

1. Typically, profile stiffness is pretty similar in NT and PT, while the critical gradients are different

2. Global effects seem to be similar in NT and PT

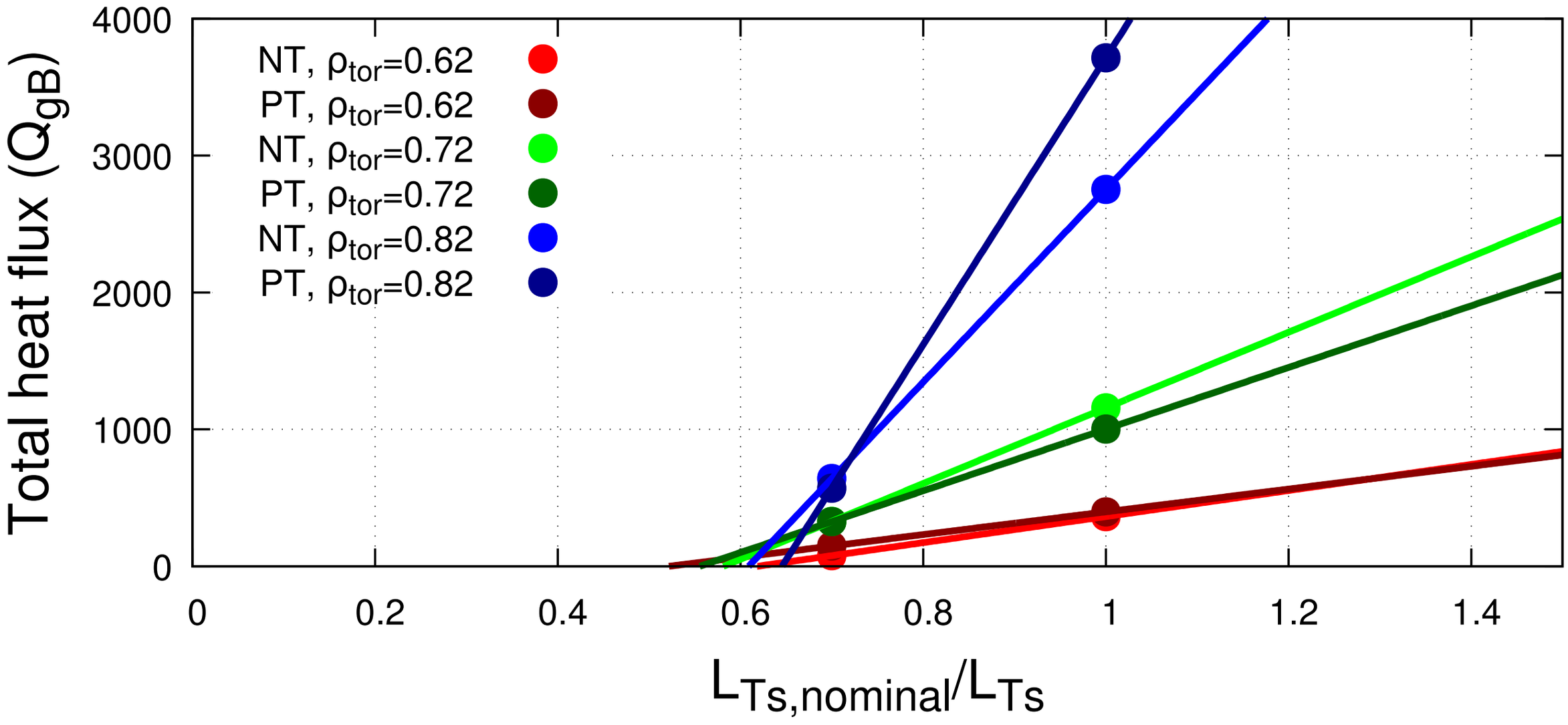
3. The change in transport between PT and NT can depend a lot on tokamak parameters

★ Major trends are independent of the turbulent drive (e.g. ITG, TEM, etc.)

Profile stiffness

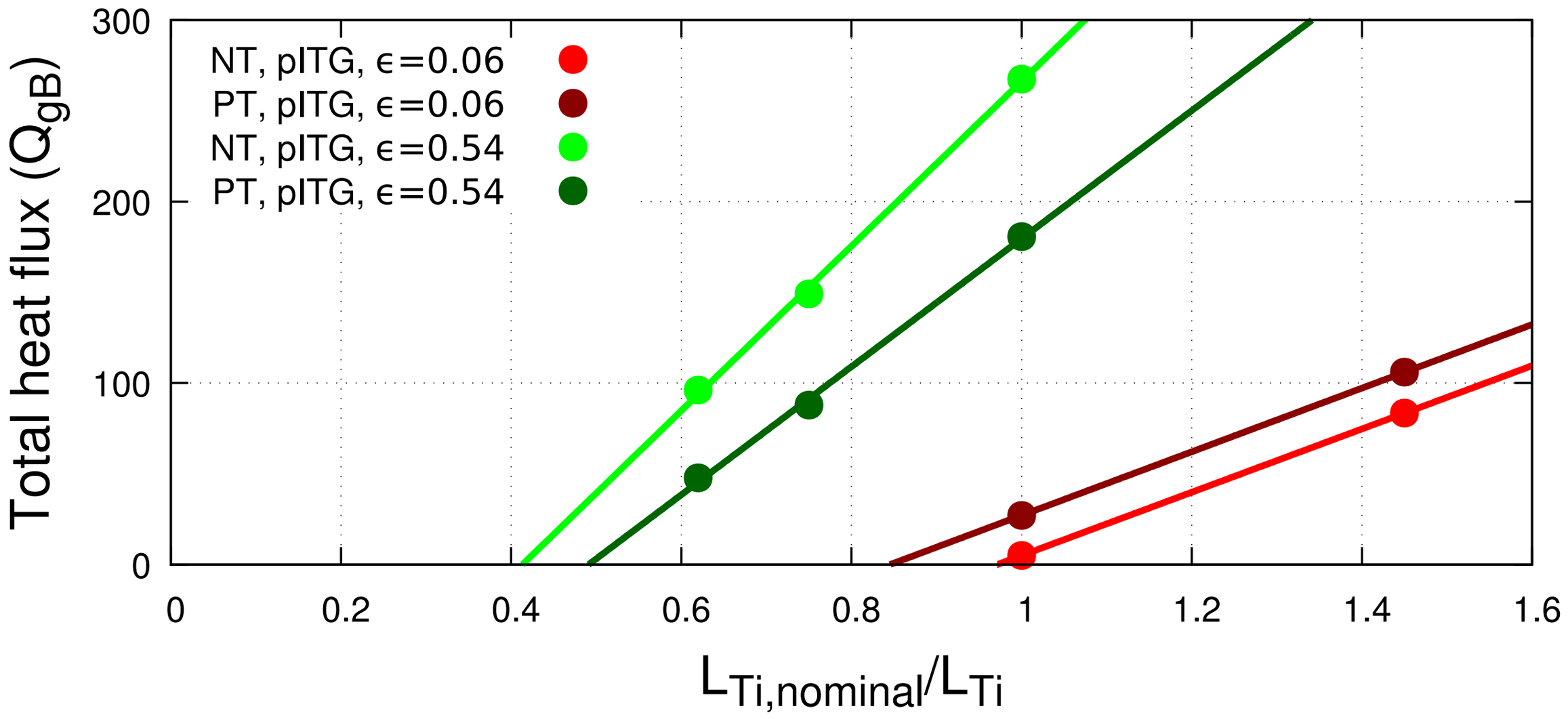
Profile stiffness is similar, critical gradients less so

- Holds well for ITG-dominated EU DEMO scenarios designed to have equal fluxes at nominal gradients



Profile stiffness is similar, critical gradients less so

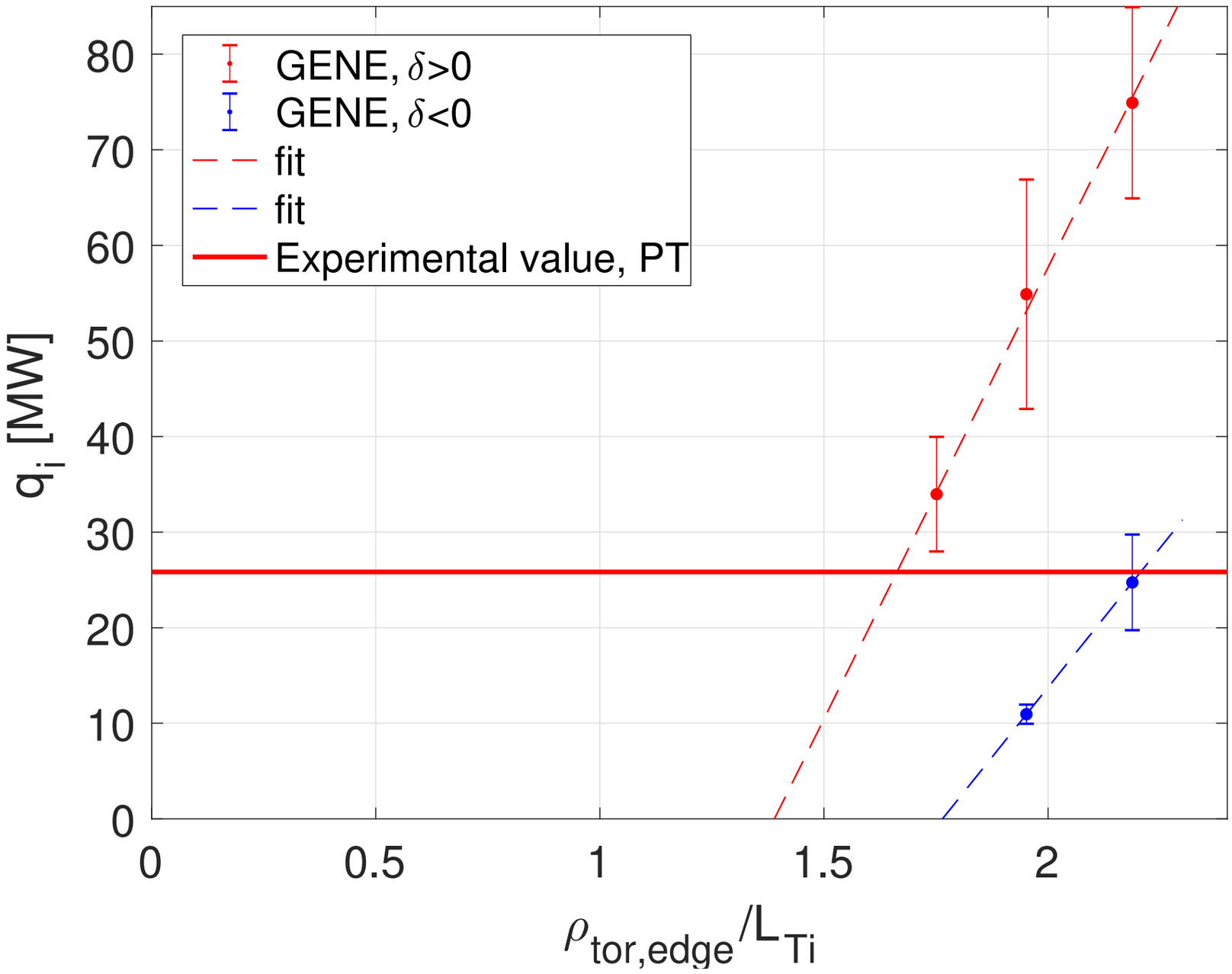
- For idealized geometries with pure ITG drive ($\nabla T_e = \nabla n = 0$) at different aspect ratios



Profile stiffness is similar, critical gradients less so

A. Mariani, A. Balestri, I. Casiraghi, P. Mantica (2022).

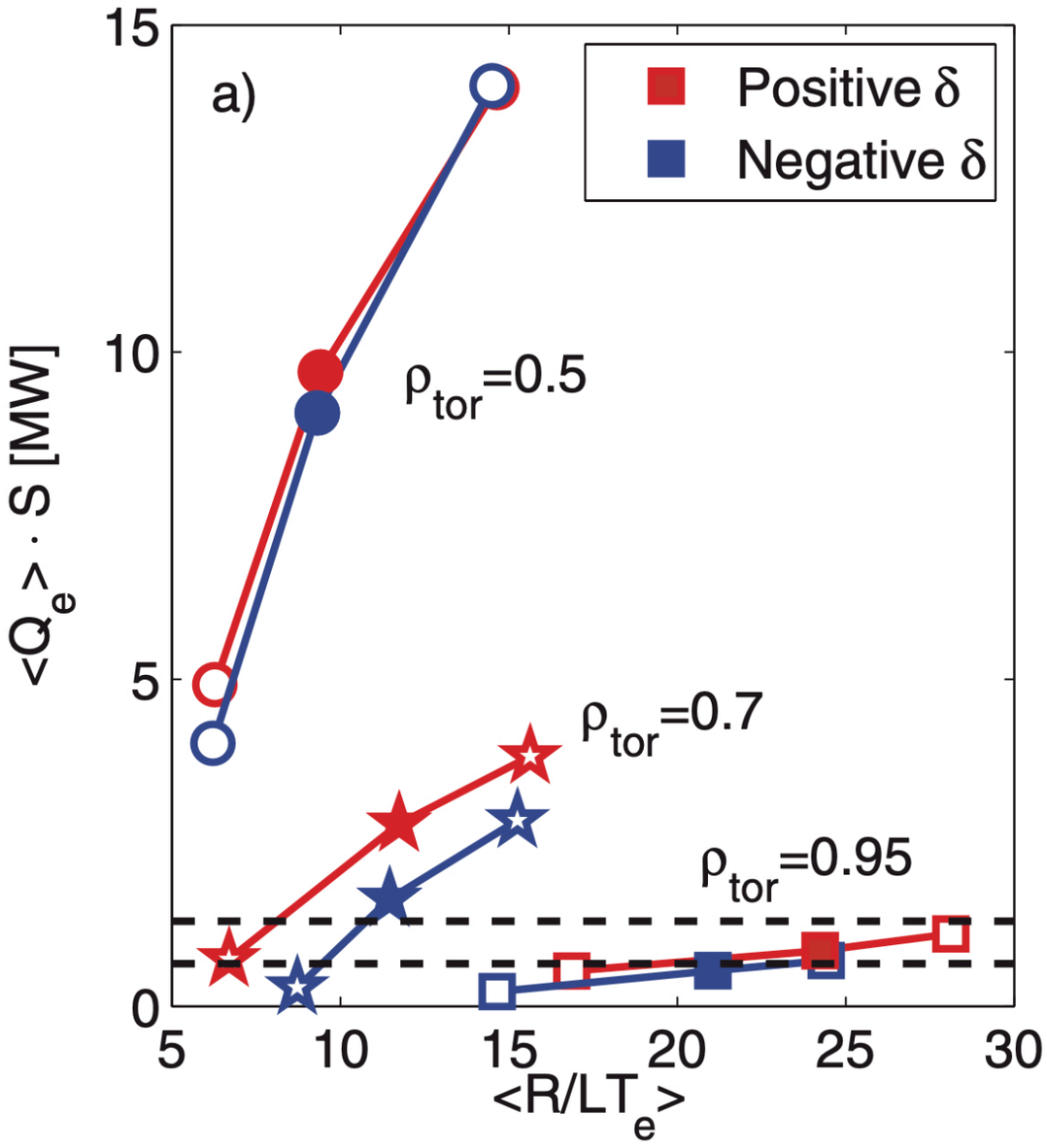
- High-fidelity, realistic DTT equilibria show a minor change in stiffness

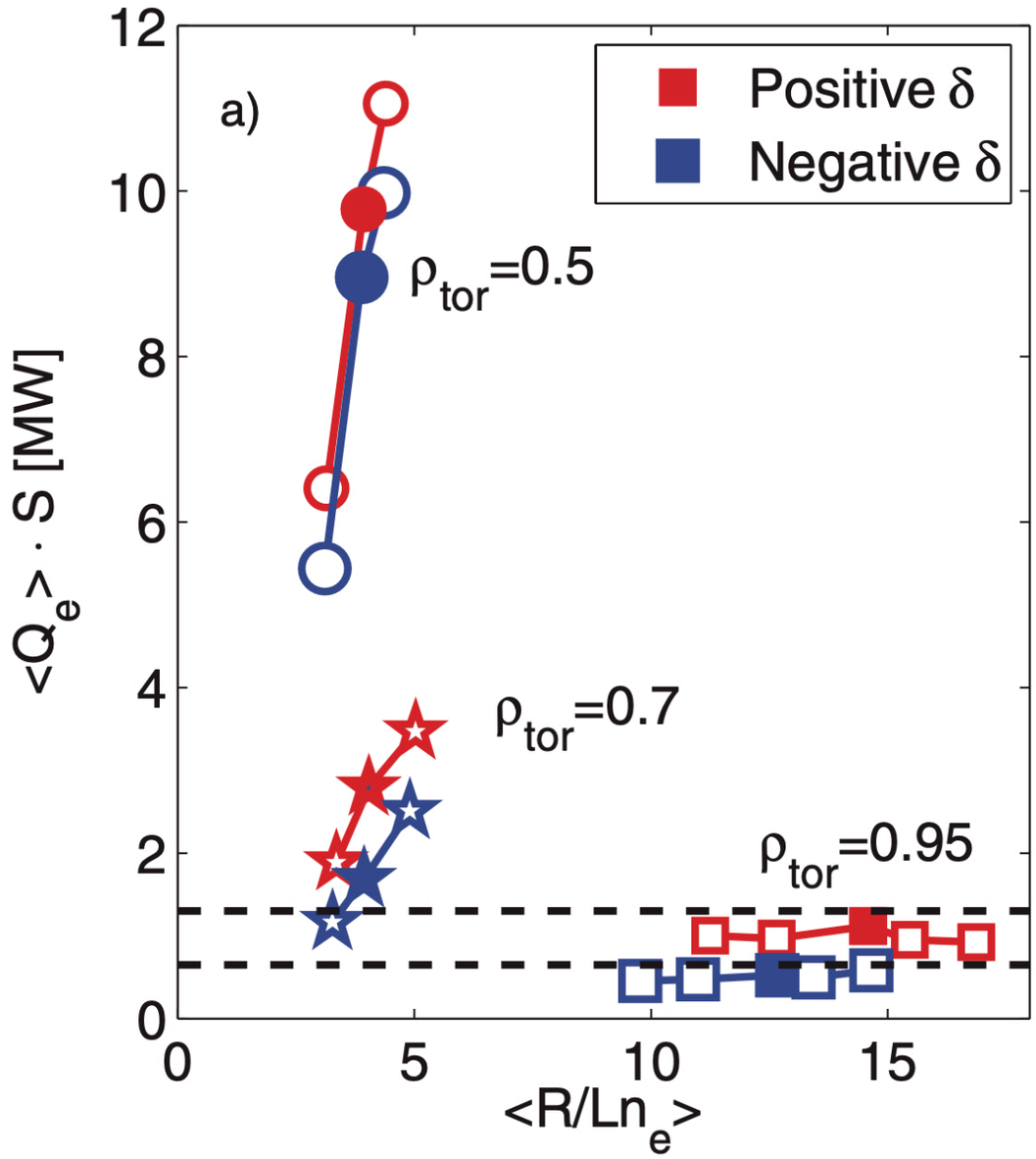


Profile stiffness is similar, critical gradients less so

G. Merlo, et al. *PPCF* (2015).

- Consistent with original Merlo paper for TEM-dominated TCV discharges





Global effects

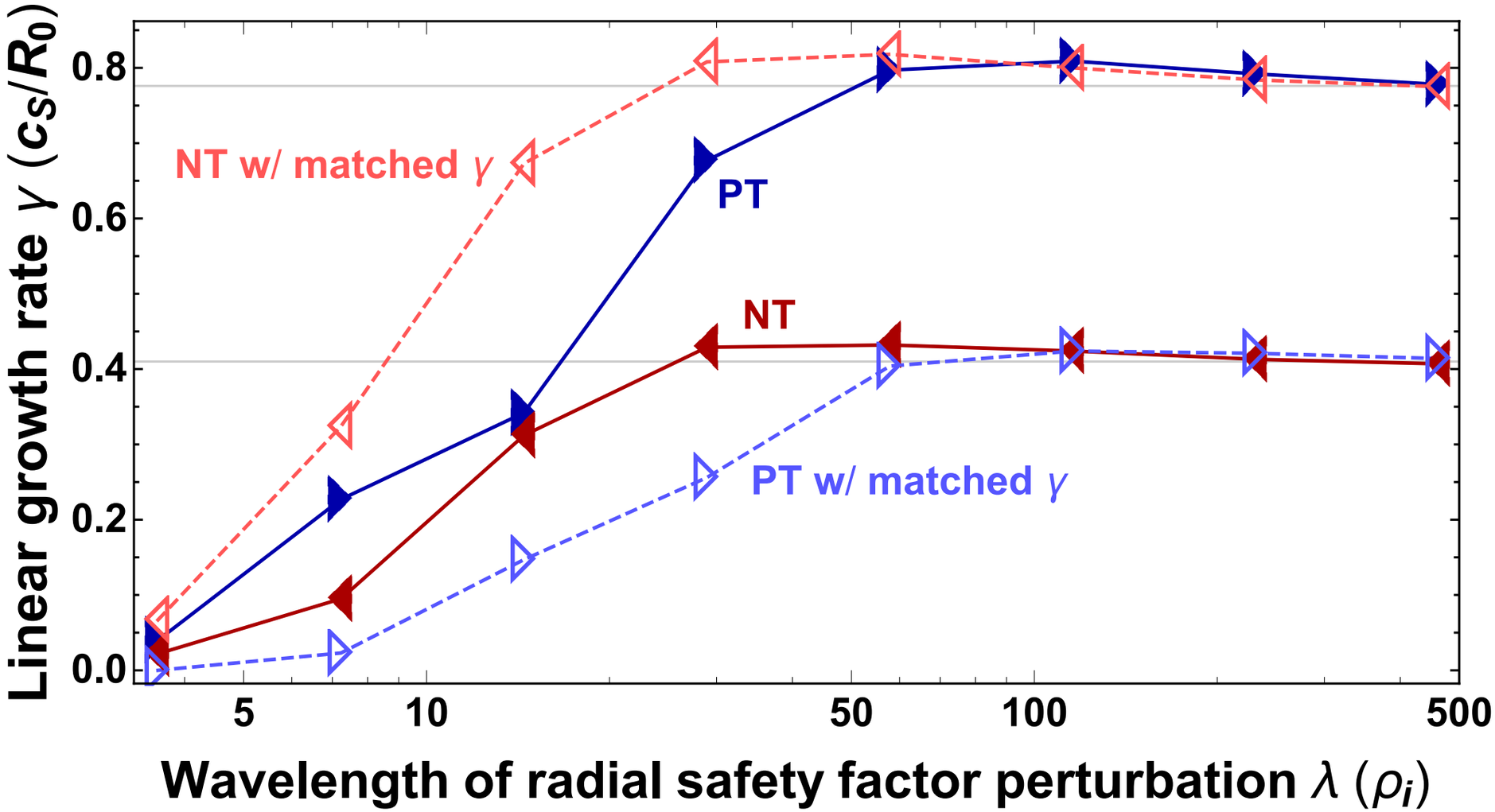
Linearly global effects are *less* important in NT

J. Ball, et al. *PPCF* (accepted) arXiv:2208.11984.

J. Duff, et al. *Phys. Plasmas* (2022).

- Important for scaling up to a NT power plant

- Used idealized ITG-dominated CBC simulations with novel flux tube domain feature non-uniform radial profiles



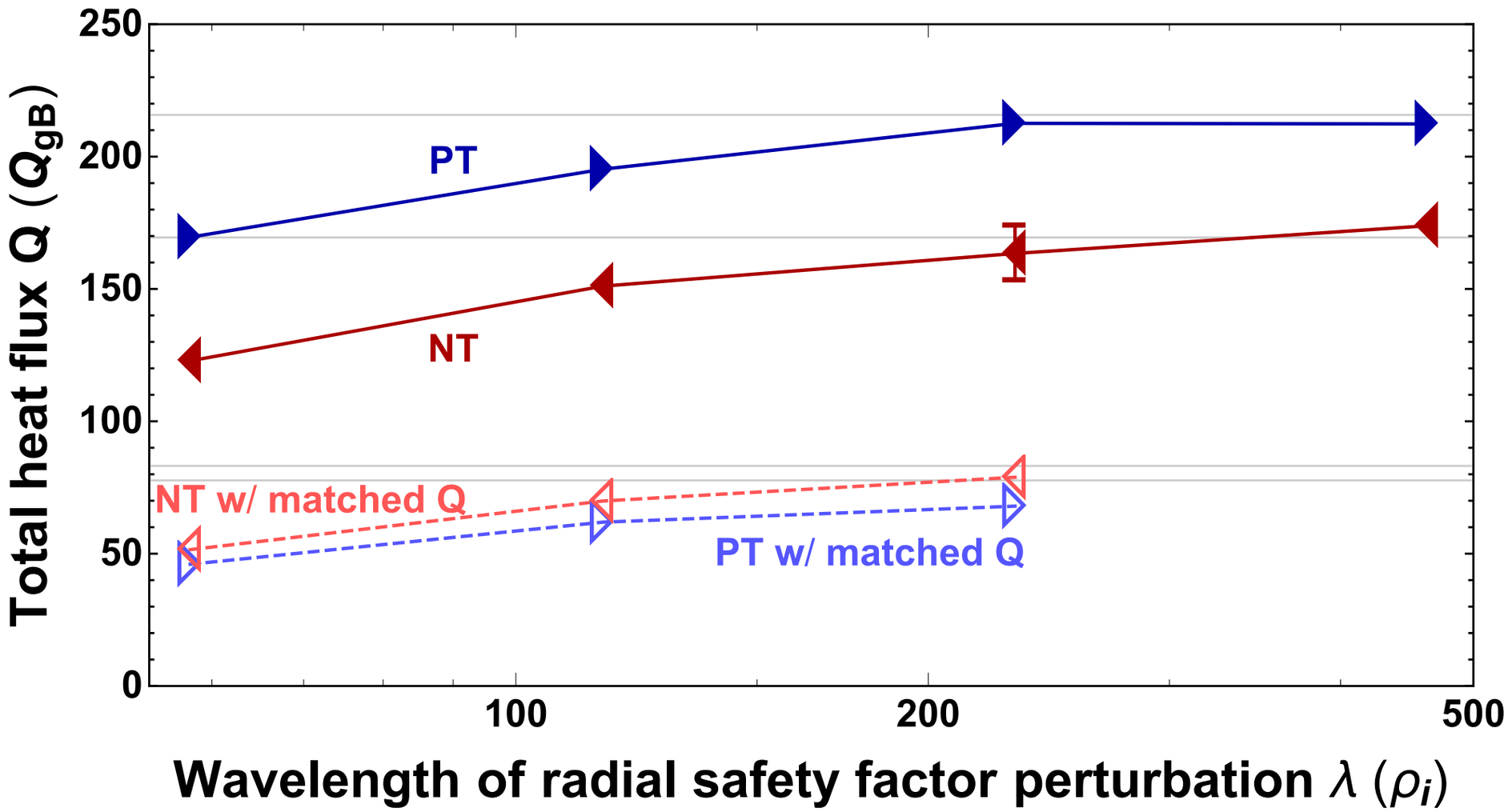
Nonlinearly global effects are similar for PT and NT

J. Ball, et al. *PPCF* (accepted) arXiv:2208.11984.

G. Merlo, et al. *PPCF* (2021).

- Not obvious how to reconcile with Merlo paper that used TEM-dominated TCV discharges

- More trustworthy/realistic than linear results

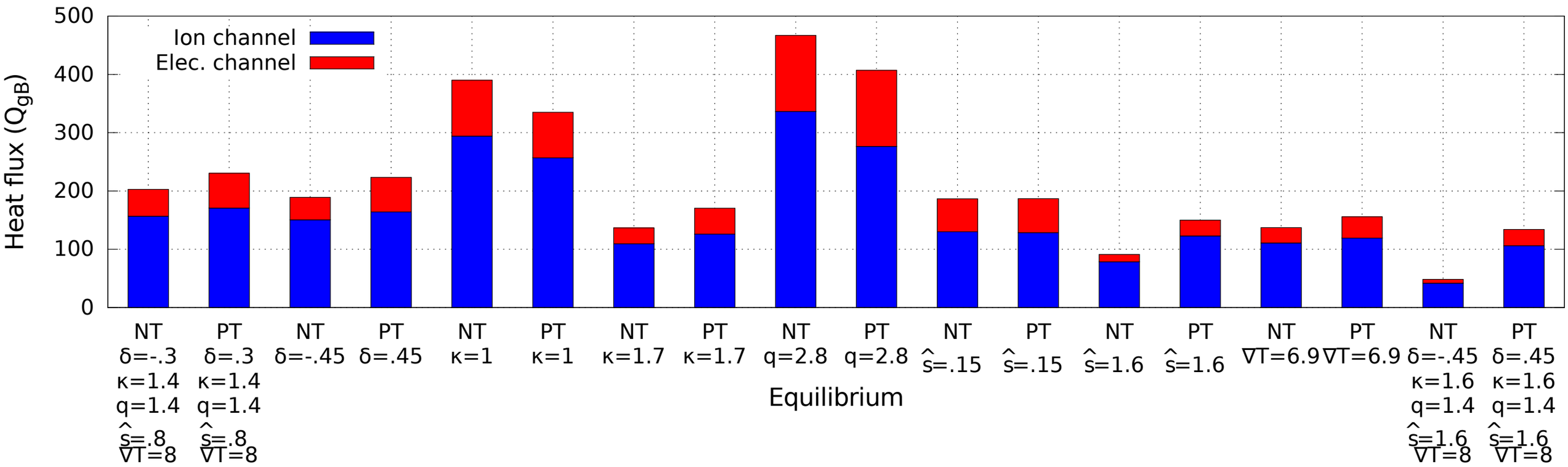


Parametric dependence

Parametric dependence of benefit from NT

- Performed a large multi-dimensional scan to test for interesting parametric dependencies and maximize beneficial effect of NT

- Idealized Cyclone Base Case (i.e. ITG driven) without collisions

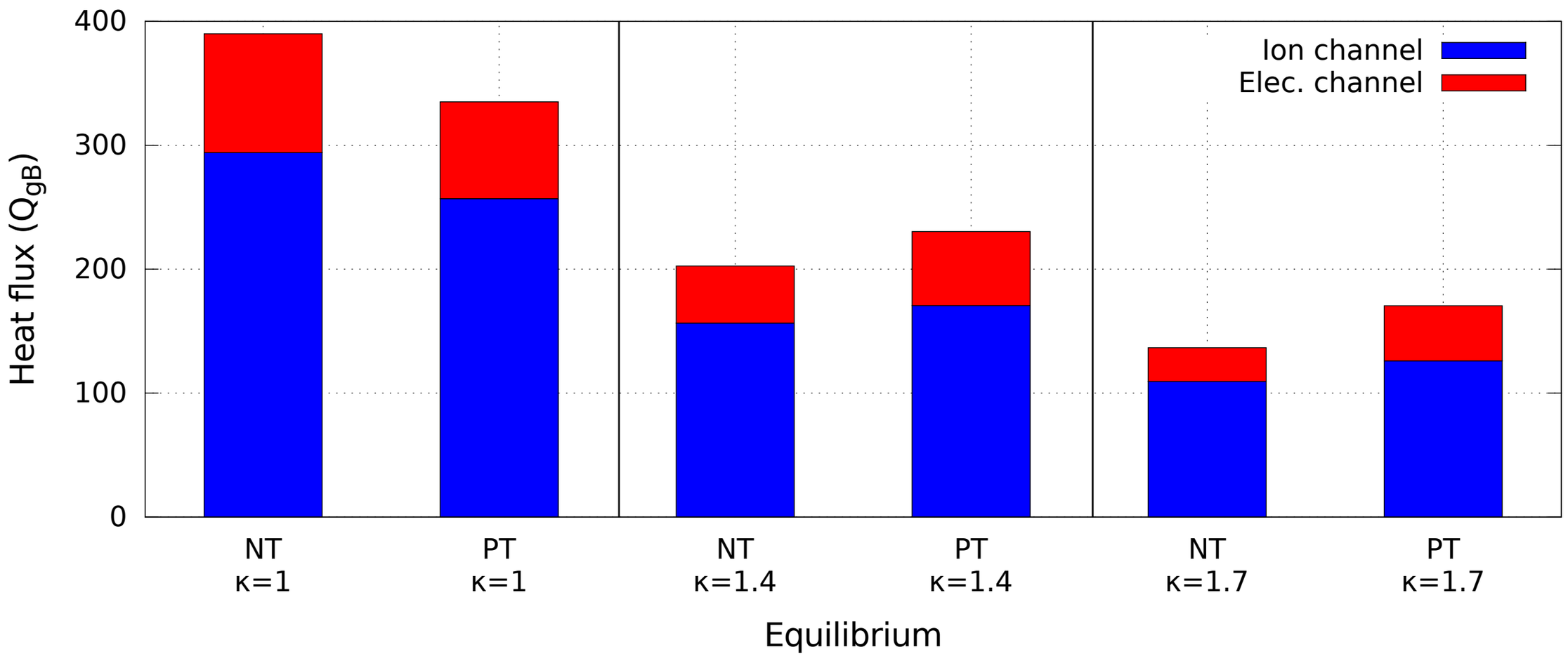


Parametric dependence - Elongation

L. Porte, et al. *Private Comm.* (2022).

- Increasing elongation enables NT to be more helpful

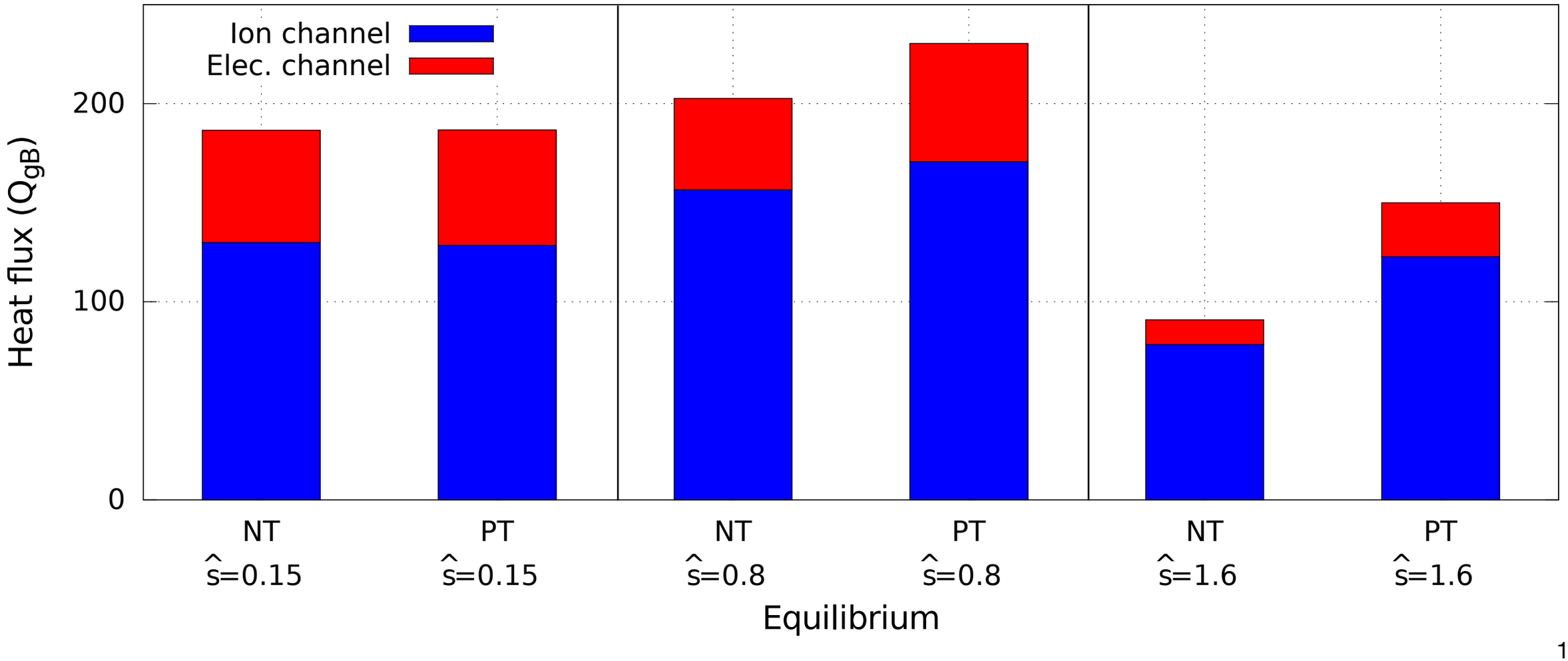
- Consistent with rumors from experiment



Parametric dependence - Magnetic shear

- Increasing magnetic shear enables NT to be more helpful

- Speculation: low shear enables transition to slab (or less ballooned) turbulence, which is insensitive to shaping

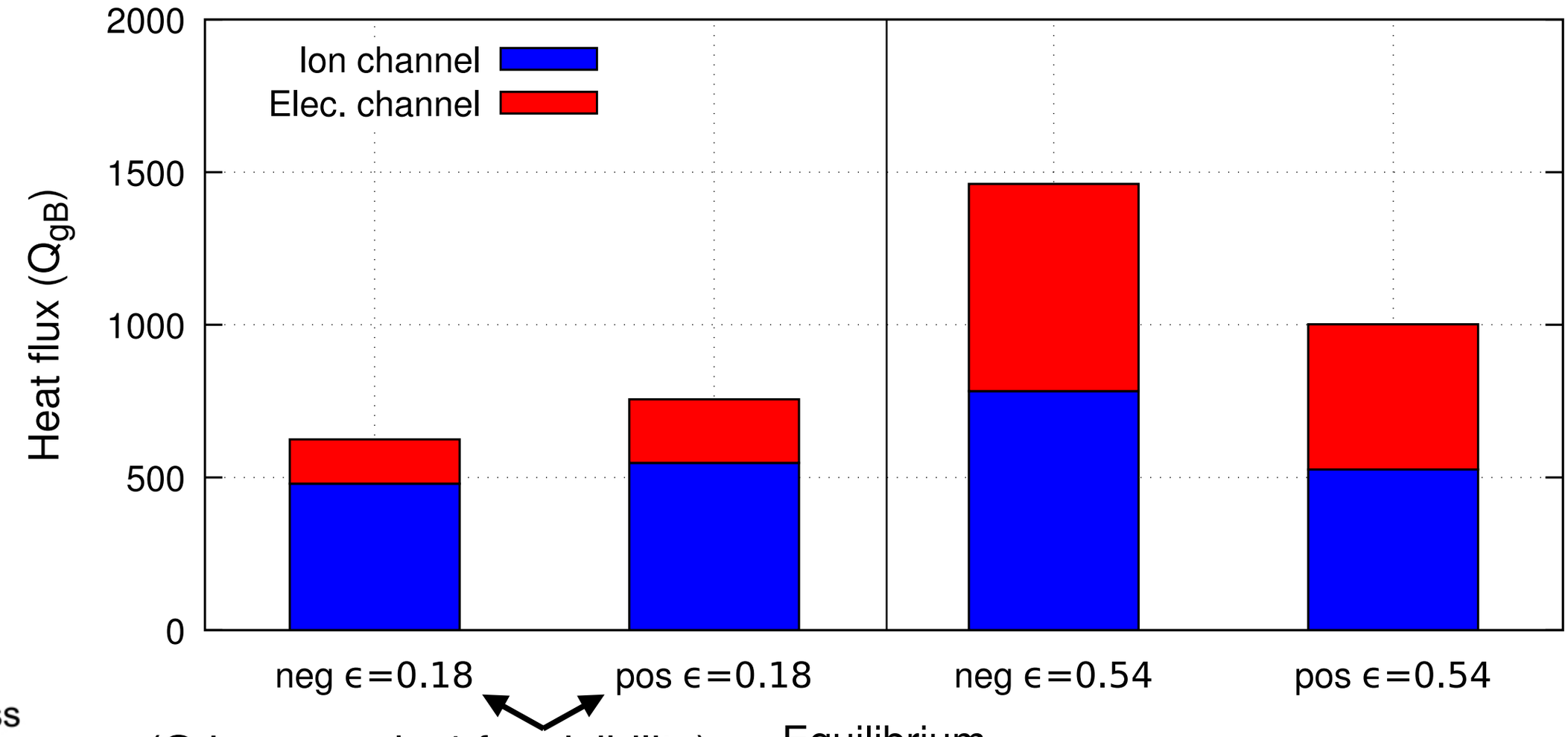


Parametric dependence - Aspect ratio

R. Davies, et al. *PPCF* (2022).

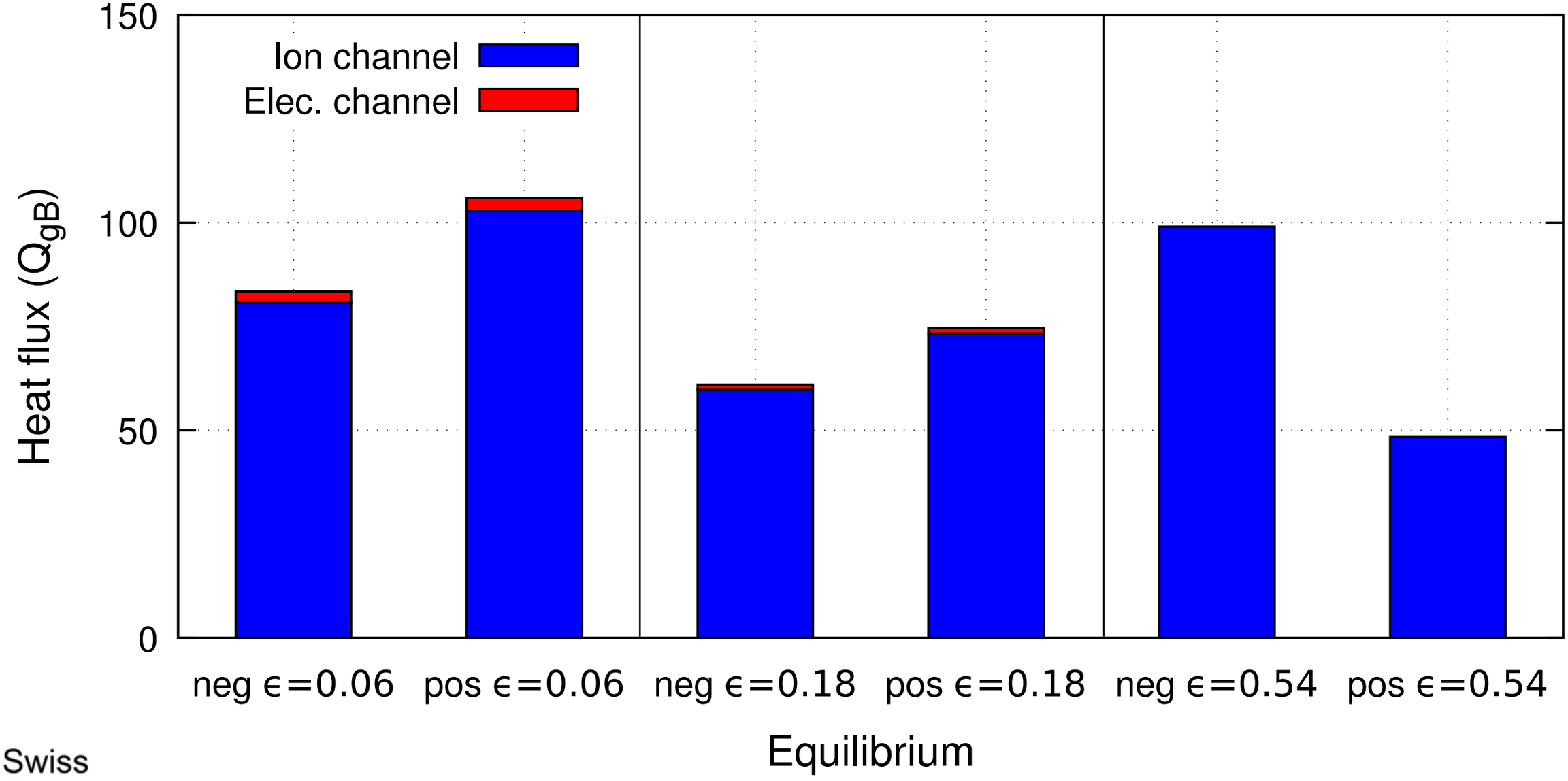
- Unlike at standard aspect ratio, at tight aspect ratios NT appears to worsen confinement

- Consistent with linear study of kinetic ballooning modes by Davies et al.



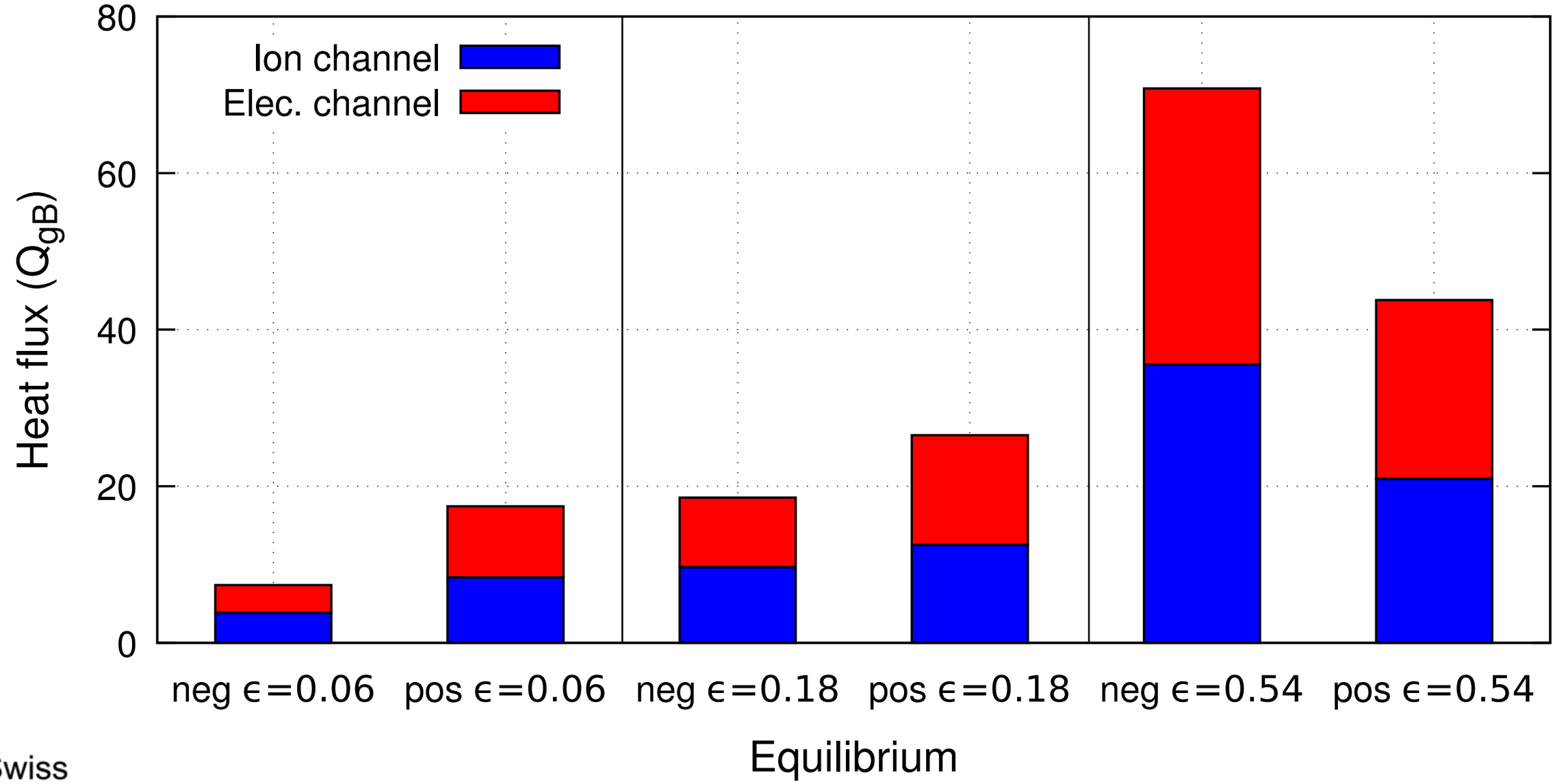
Parametric dependence - Aspect ratio

- Same trend is clearer for pure ITG drive: $\nabla T_e = \nabla n = 0$, while changing $R_0/L_{Ti} = \{10, 6.9, 4.3\}$ for $\epsilon = \{.06, .18, .54\}$ to keep Q approx. constant



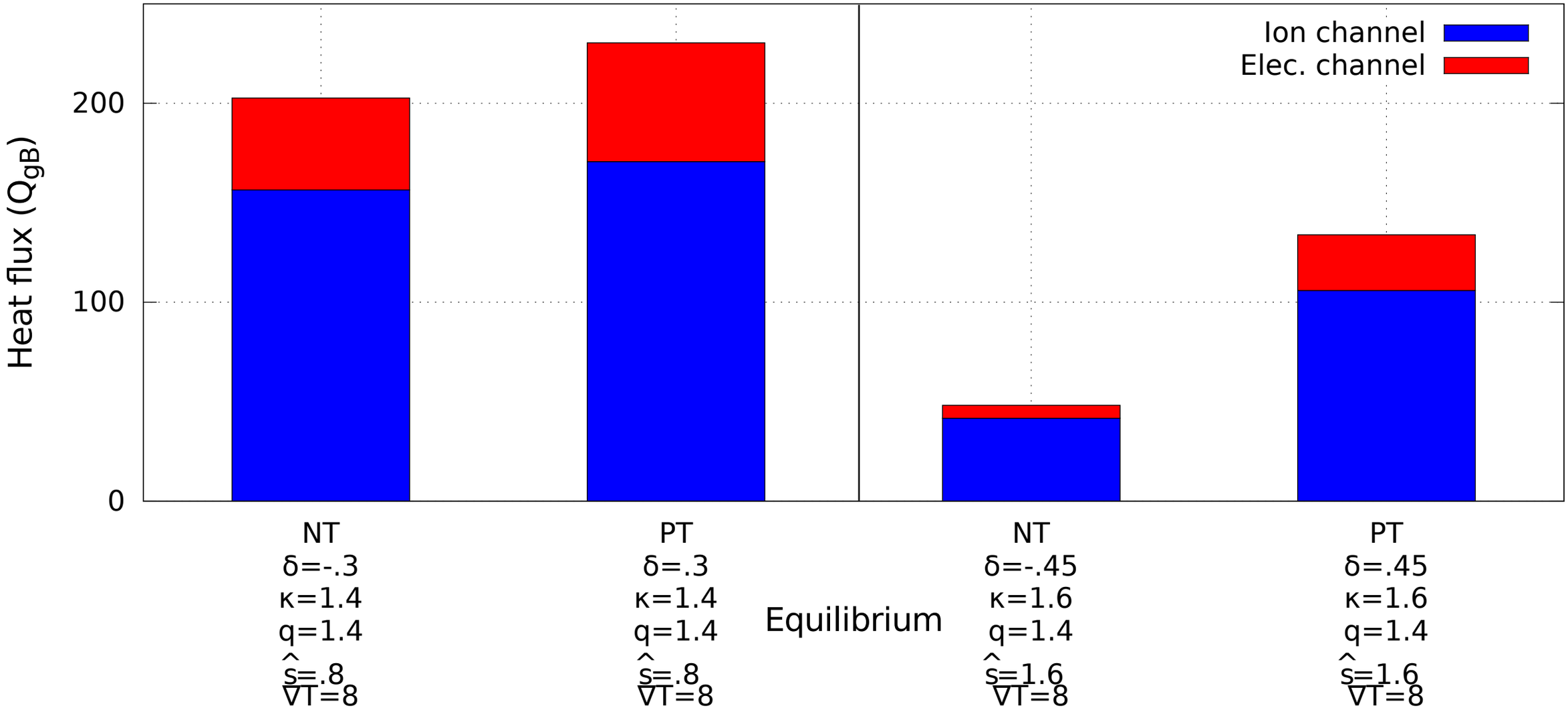
Parametric dependence - Aspect ratio **[poor res.]**

- Same trend is clearer for pure TEM drive: $\nabla T_i = \nabla T_e = 0$, while changing $R_0/L_n = \{4.3,3.0,2.0\}$ for $\epsilon = \{.06,.18,.54\}$ to keep Q approx. constant



Parametric dependence - Optimal parameters

- Leveraging these trends it is possible to dramatically increase the beneficial effects of NT (12% reduction in heat flux to 64% reduction)



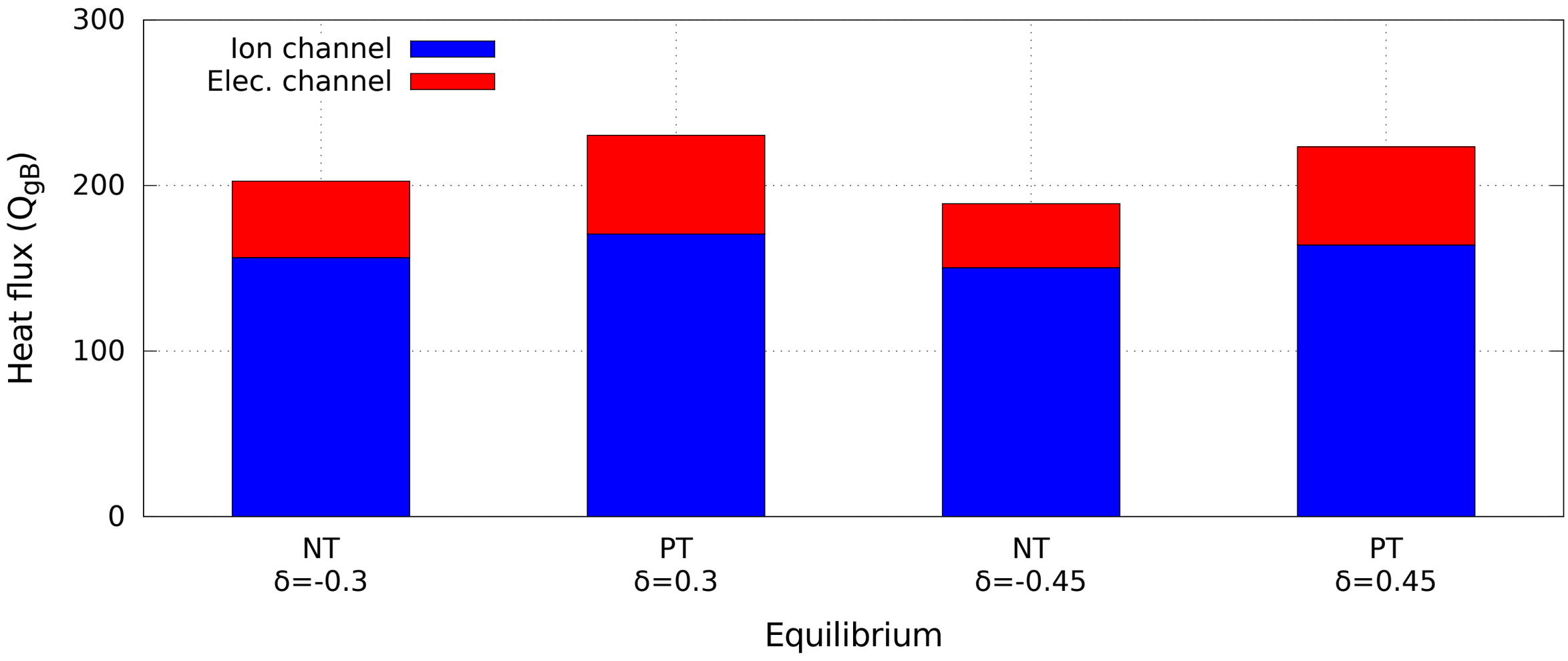
Future plans

- Focus on a basic study of the physical effects underlying the improvements of negative triangularity

All done.

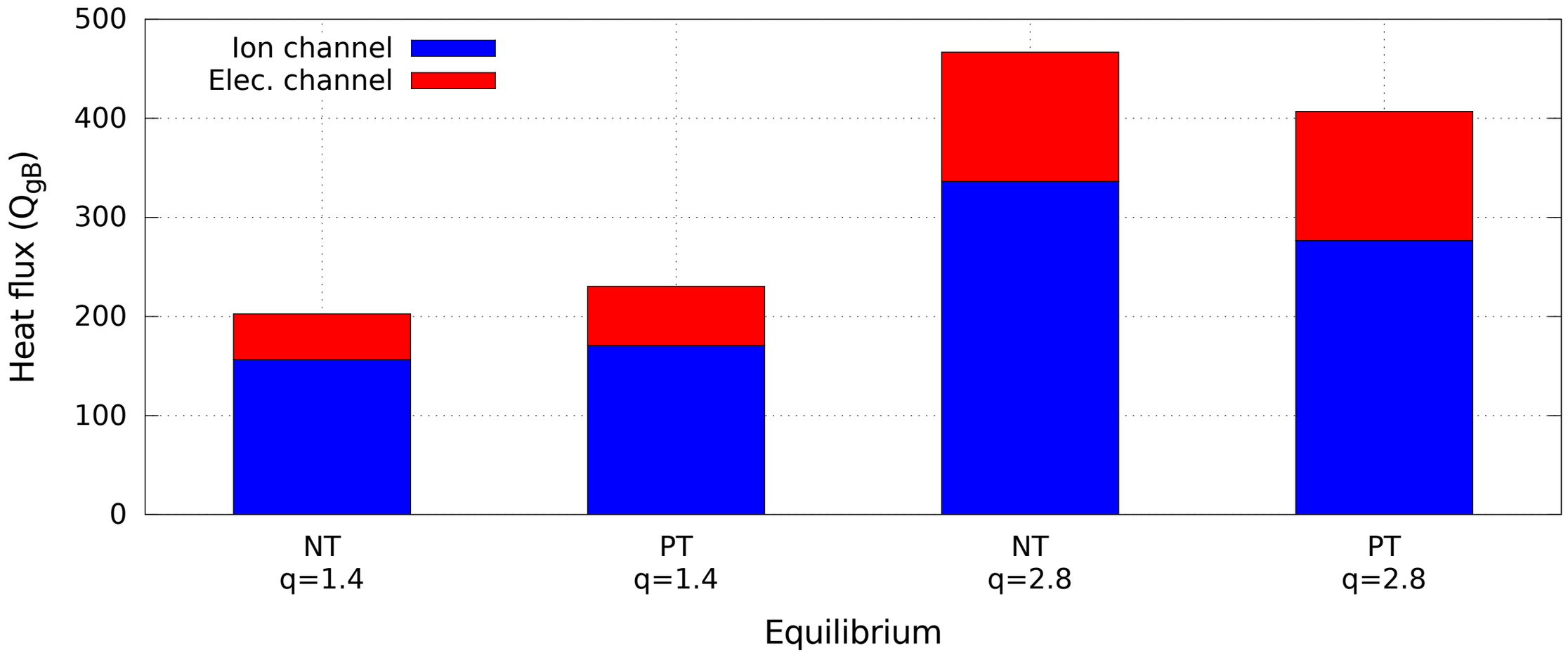
Parametric dependence - Triangularity

- Magnitude of triangularity seems to have fairly small impact, but this is roughly consistent with the fact that $|\delta|$ was only increased by 50%)



Parametric dependence - Safety factor

- Lower safety factor benefits NT



Parametric dependence - Driving gradients

- Strength of driving gradients has little impact