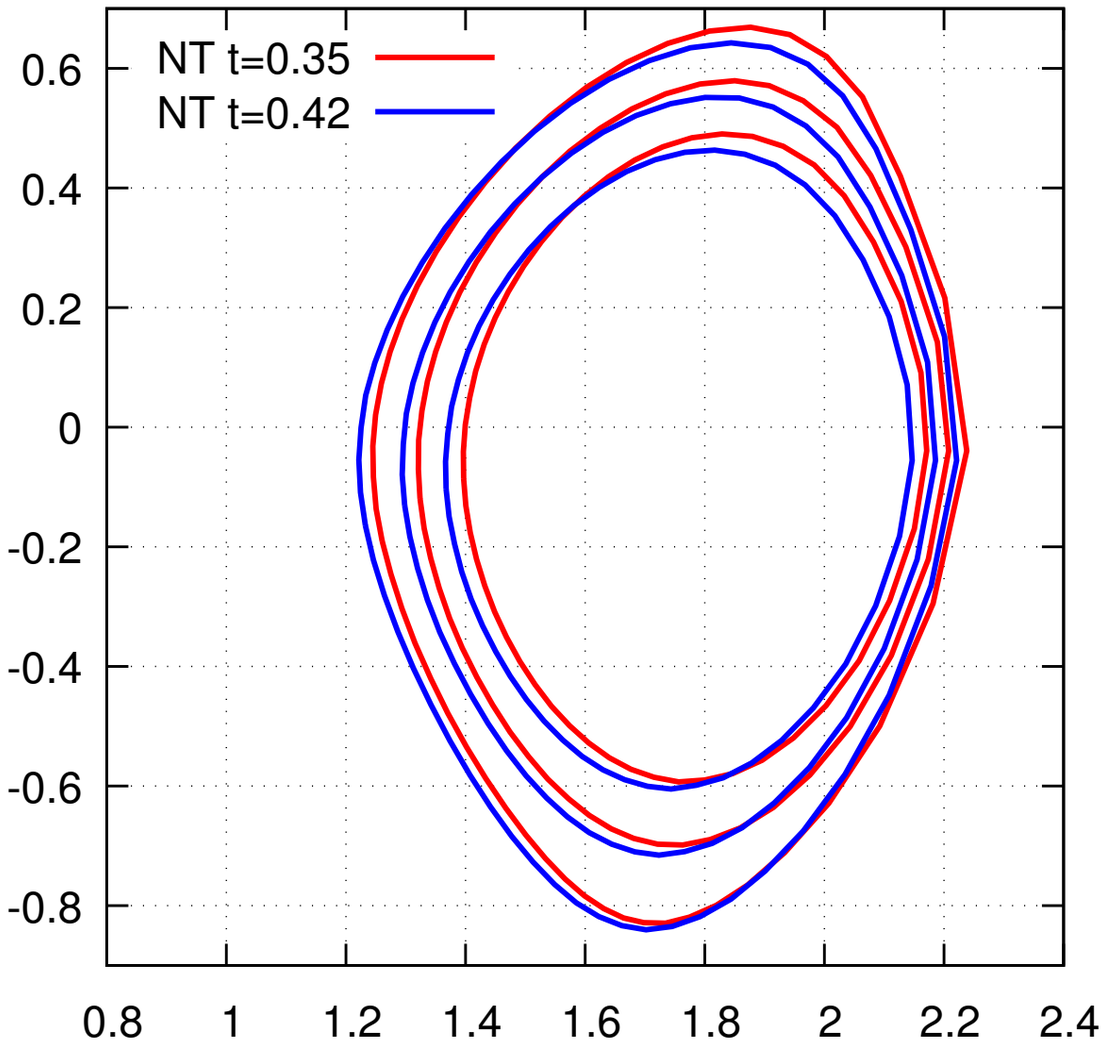
# Physics insights into NT core turbulence




Justin Ball

2021 Annual TSVV 2 Workshop

2 December 2021

# Milestones

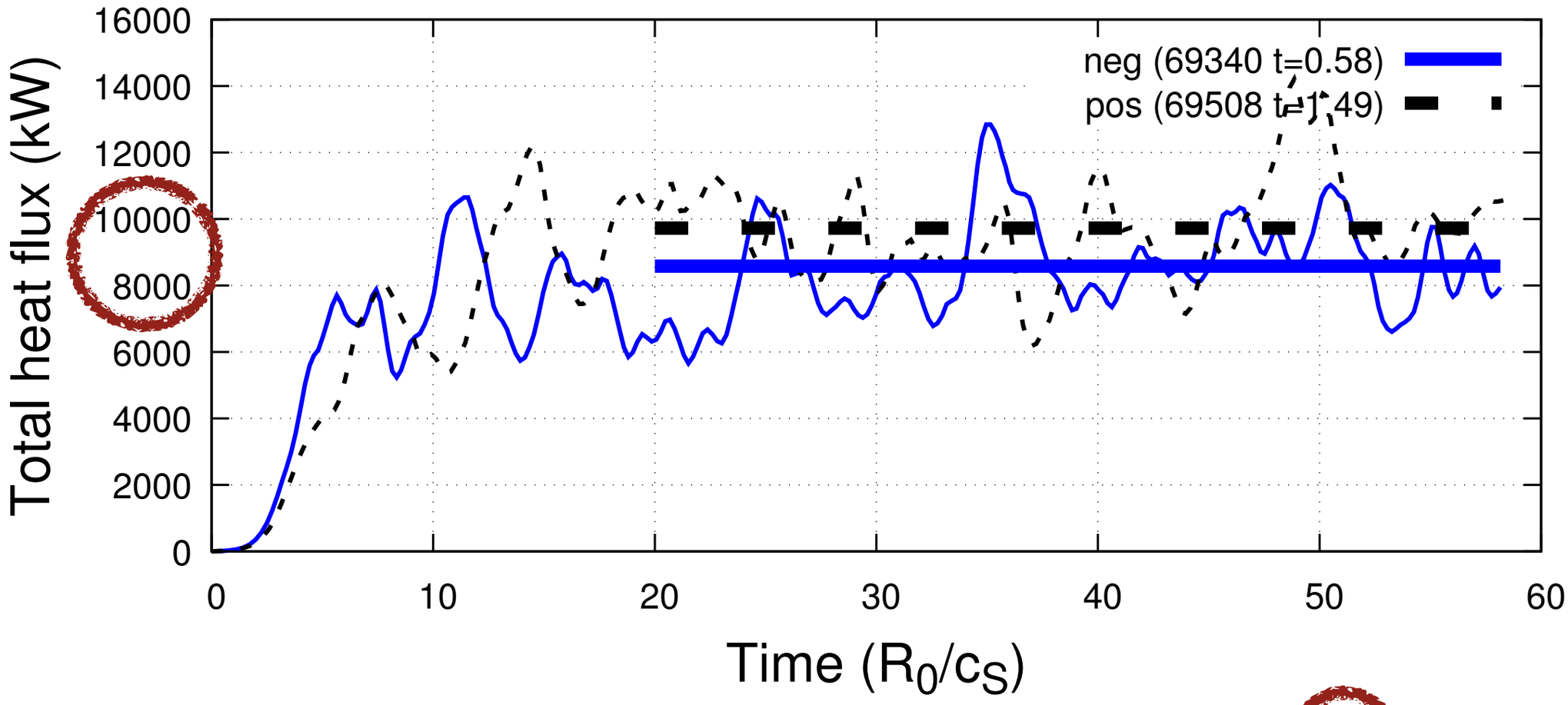
| Milestone | Description | Target date |
|---|---|---|
| **M1.1.1** | Use local electrostatic GK simulations to assess magnetic equilibria and plasma profiles for consistency with design objectives | 5.2021 |
| **M1.1.2** | Perform local electrostatic GK simulations of PT and NT equilibria and swap individual geometric coefficients and plasma parameters to identify the dominate terms | 11.2021 |
| **M1.1.3** | Perform comprehensive study of critical gradient and stiffness as a function of minor radius using local GK simulations | 3.2022 |

# Outline

- **Matching the experimental heat flux for TCV equilibria**
- Swapping geometric coefficients for DEMO equilibria
- DEMO equilibria with hybrid electrons
- Preliminary DIII-D simulations

# Issue with simulations of TCV equilibria

- Previously, there was a factor of >10x discrepancy with experimental results




| Description | Constants of comparison | Machine | Discharge | Time (sec) | elong | delta | betaN | P_nbi (kW) |
|---|---|---|---|---|---|---|---|---|
| Diverted, PT | Ip, betaN, ne | TCV | 69508 | 1.49 | 1.43 | +0.28 | 1.12 | 735 |
| Diverted, NT | Ip, betaN, ne | TCV | 69340 | 0.58 | 1.42 | -0.28 | 0.97 | 362 |

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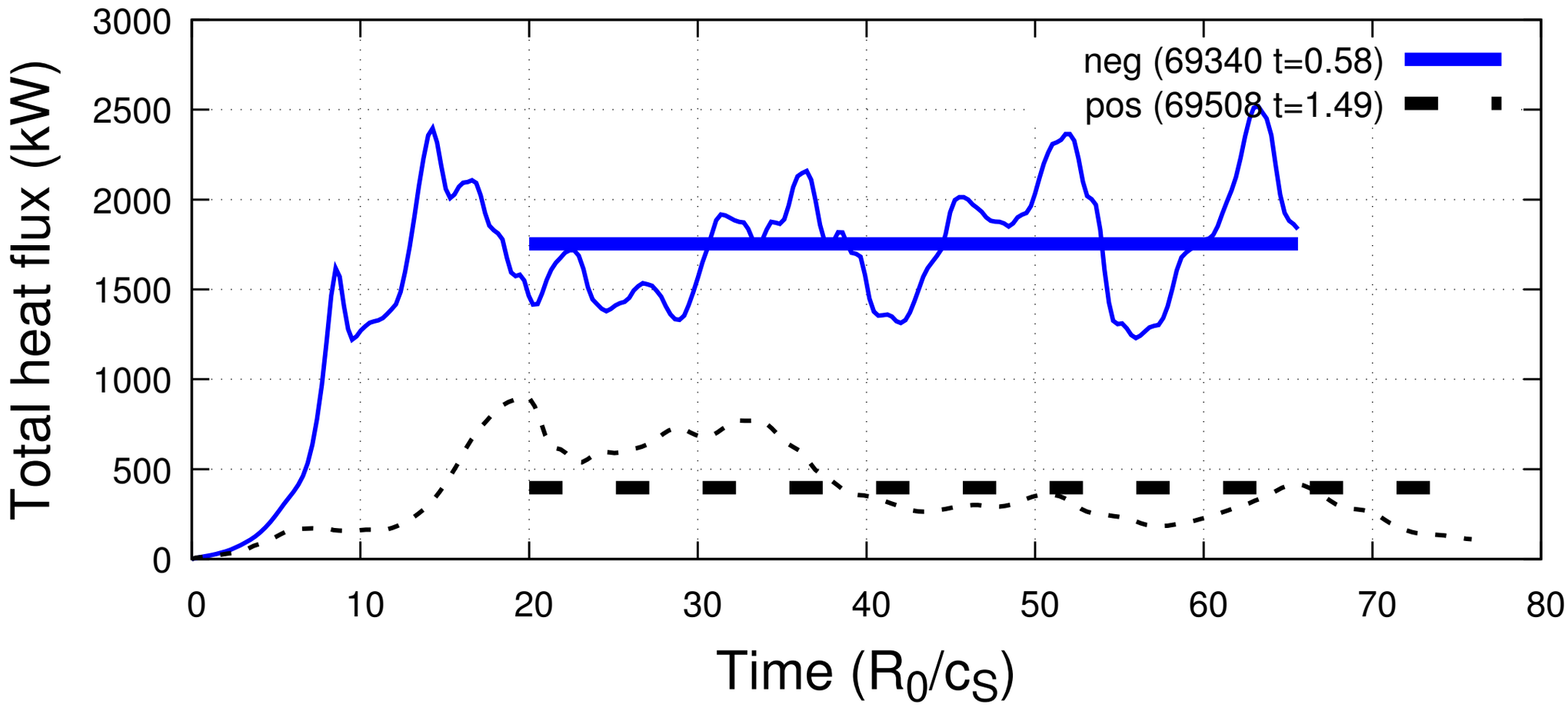
# Simulations of TCV equilibria

- Largely resolved by including collisions

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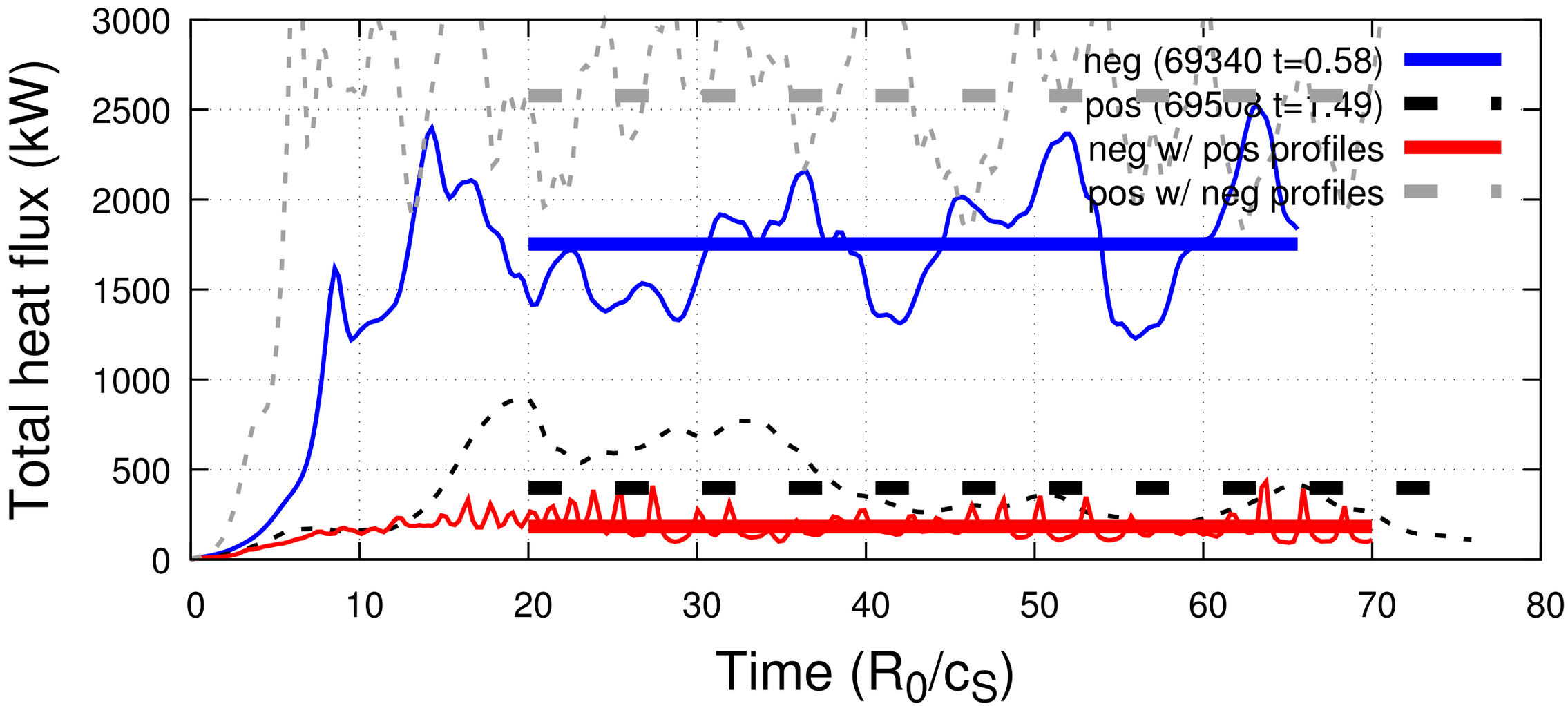
# Simulations of TCV equilibria

- Negative triangularity is still stabilizing, holding the profiles constant



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- DEMO equilibria with hybrid electrons
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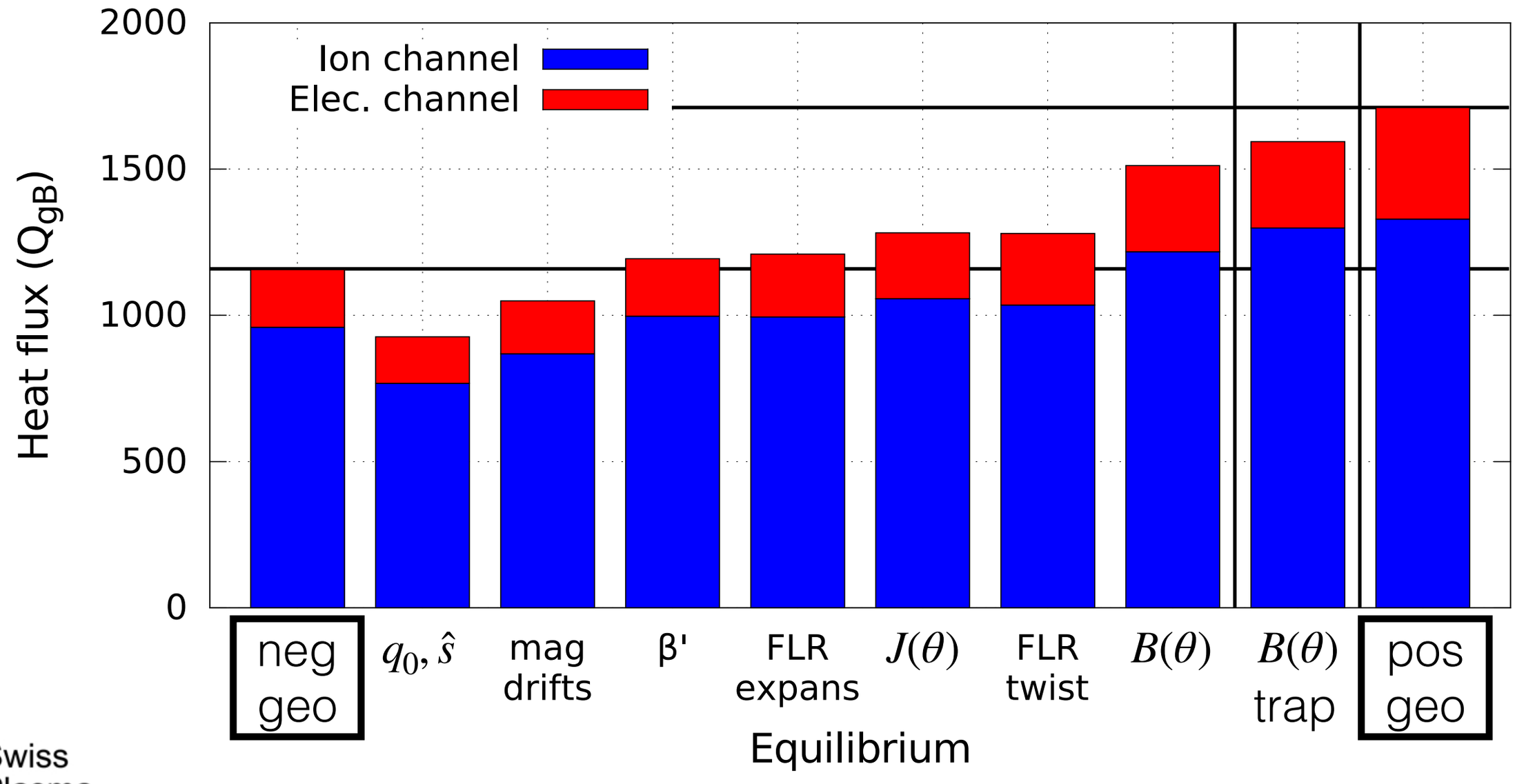
# DEMO equilibria with ITG-driven turbulence

- When preparing to repeat geo. coeff. swapping with TCV equilibria, I discovered a bug in particle trapping simulation



# DEMO equilibria with ITG-driven turbulence

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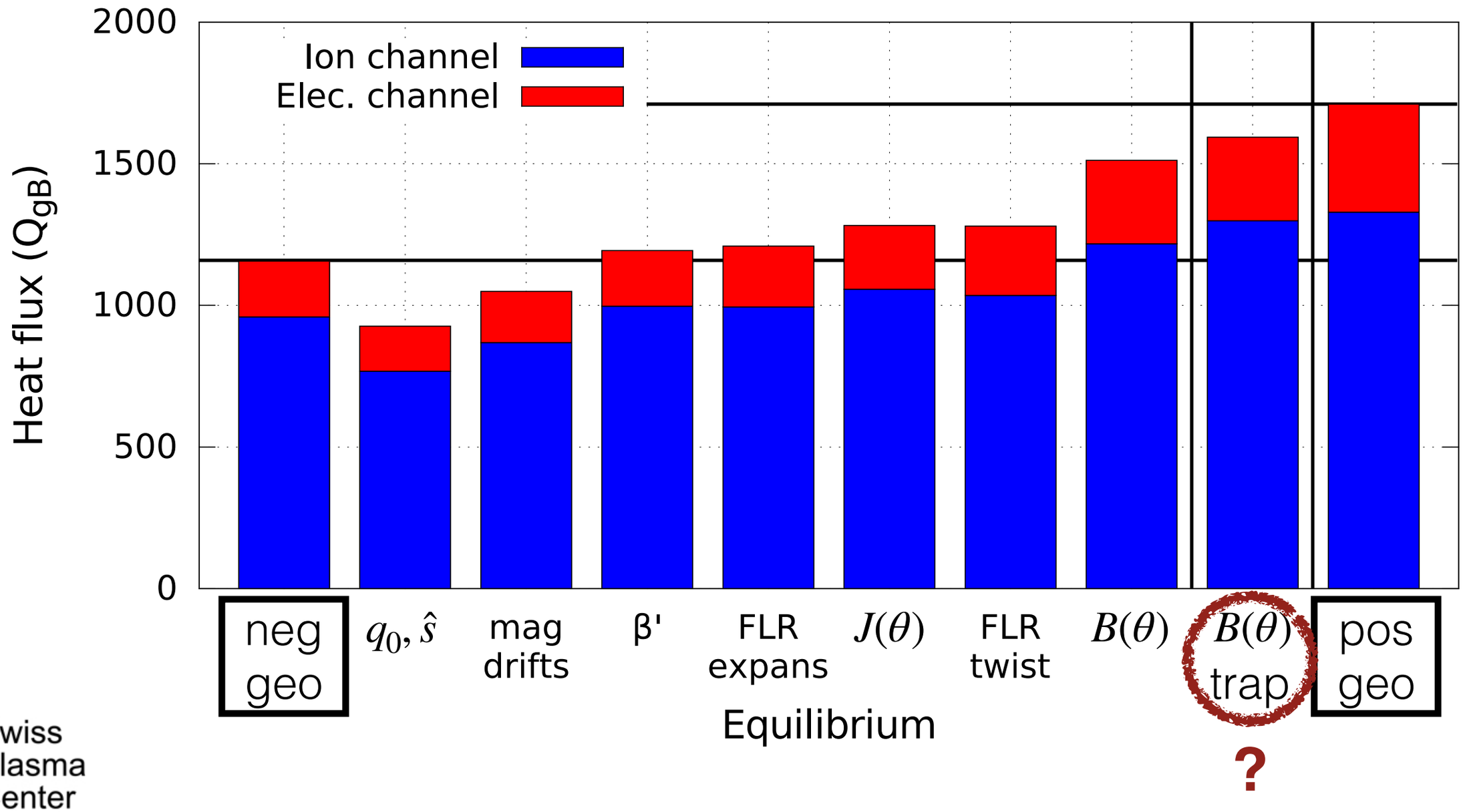
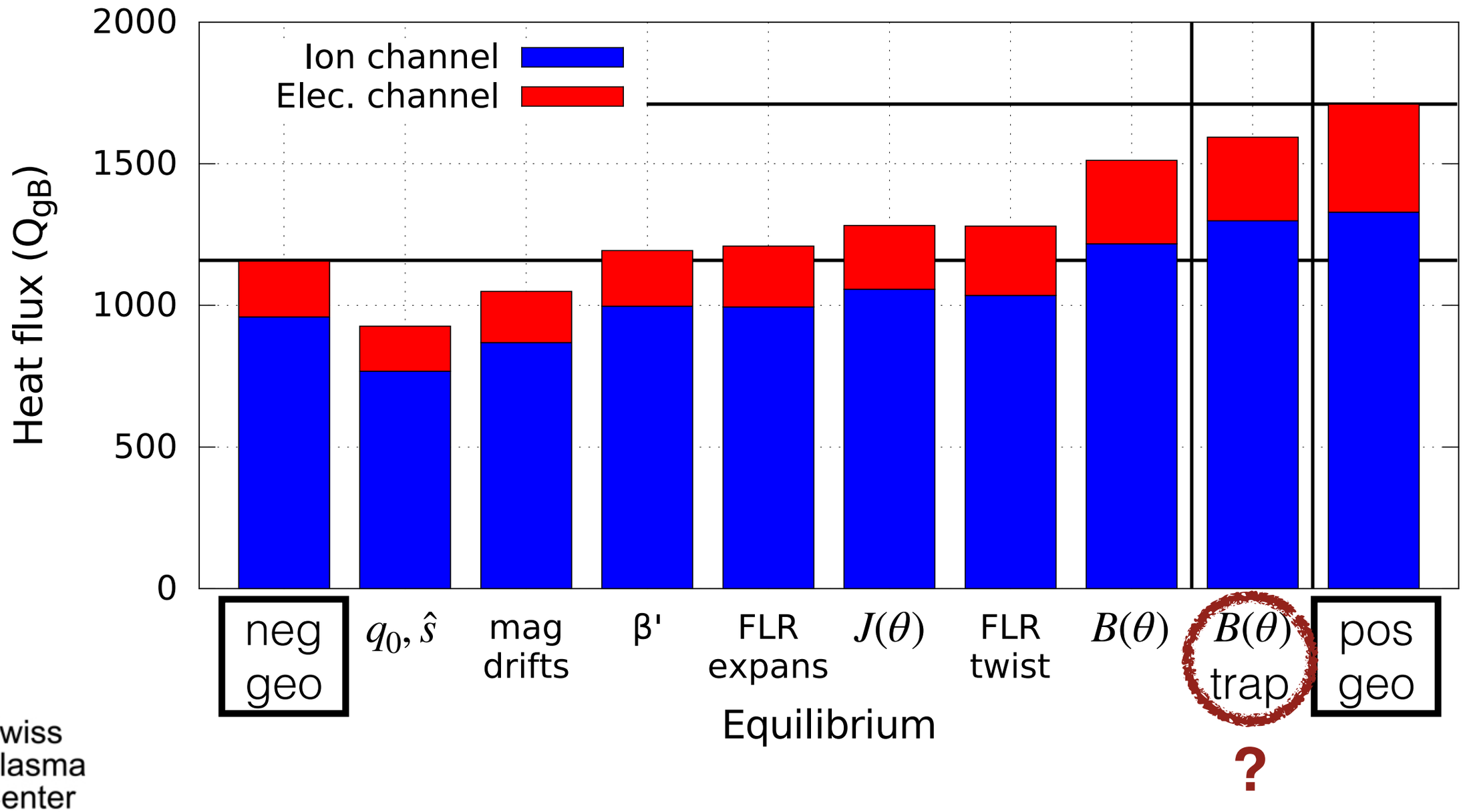


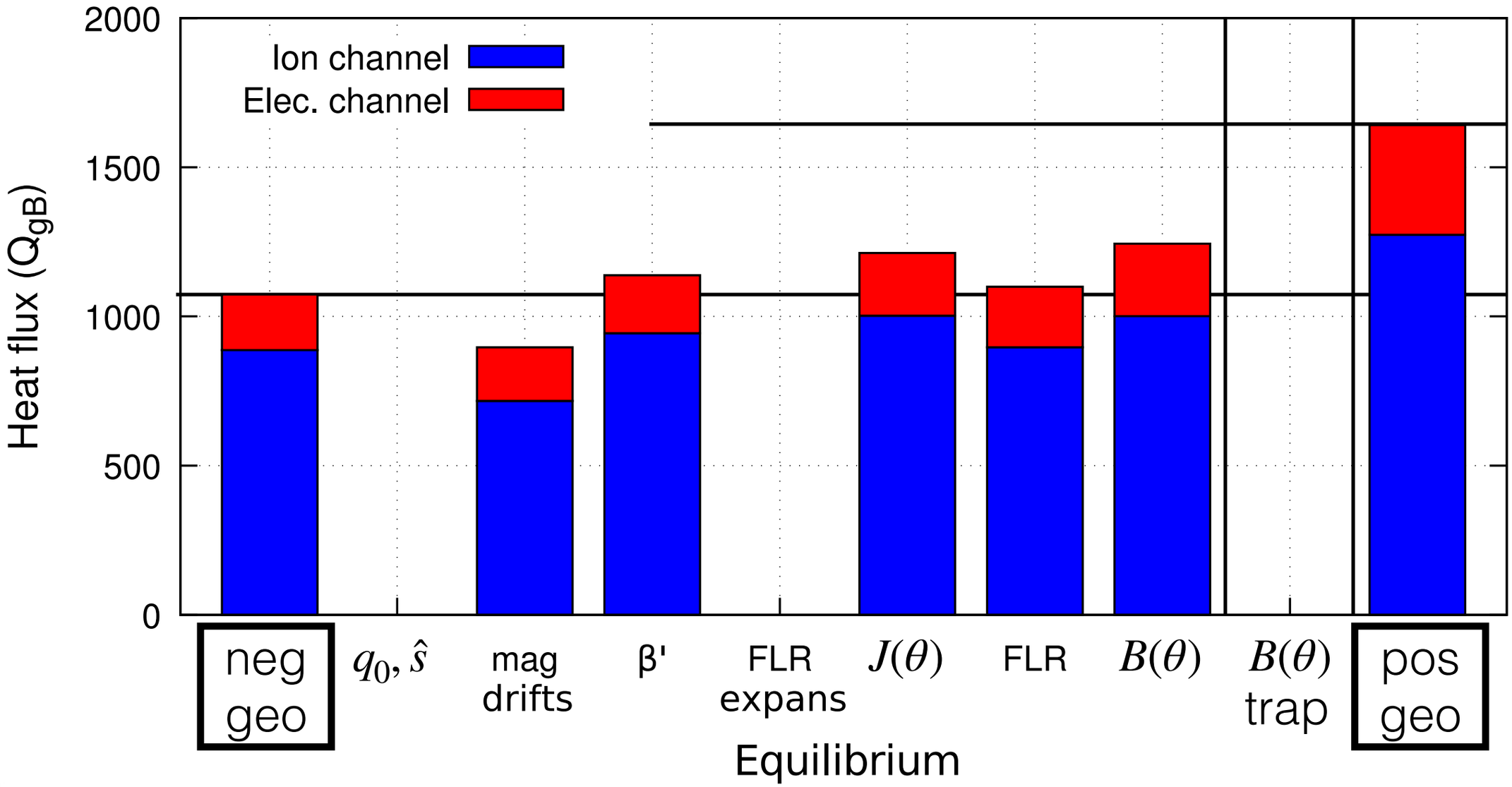
# DEMO equilibria with ITG-driven turbulence

- Fixing it causes a slowly-building high-wavenumber mode that dramatically reduces the time step



# DEMO equilibria with ITG-driven turbulence

- Repeating the $B(\theta)$ simulation gives a somewhat lower result (but within statistical error bars)



# Outline

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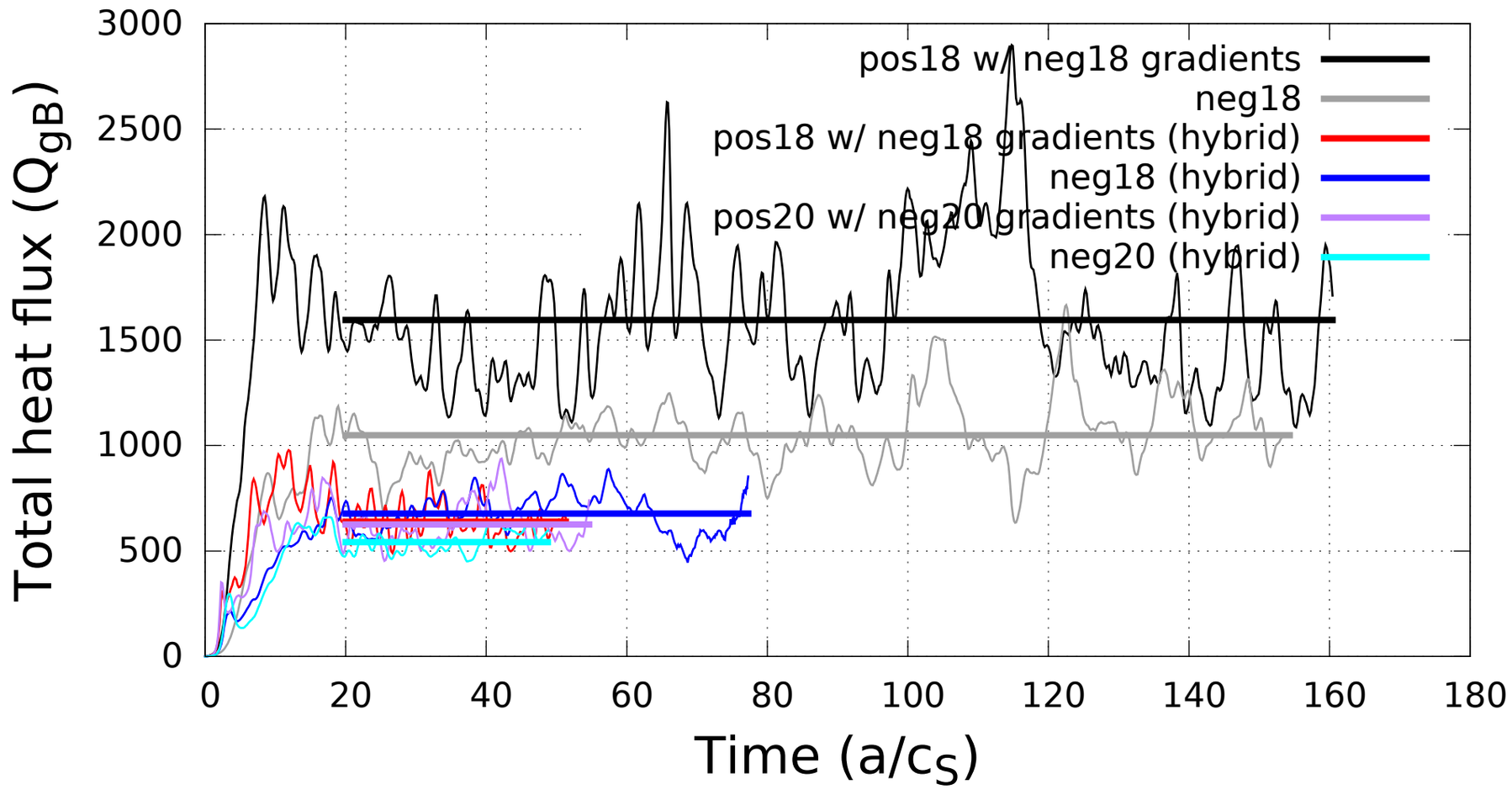
- Swapping geometric coefficients for DEMO equilibria
- **DEMO equilibria with hybrid electrons**
- Preliminary DIII-D simulations

# DEMO equilibria with hybrid electron model

- Hybrid electrons show little difference between positive and negative triangularity

- However, the hybrid negative triangularity simulations show same slowly-building, high-wavenumber mode as before

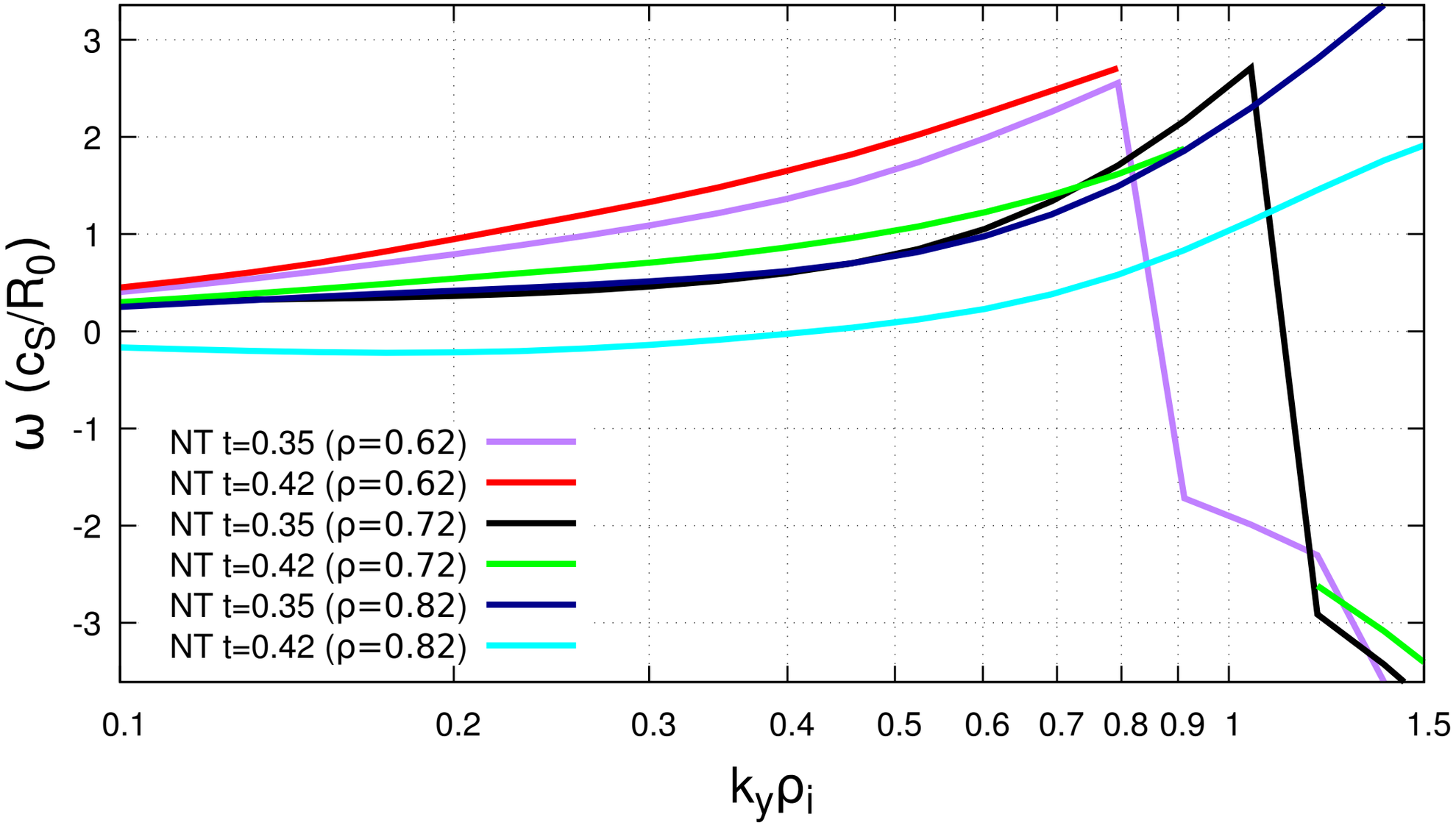


# Outline

- Matching the experimental heat flux for TCV equilibria
- Swapping geometric coefficients for DEMO equilibria
- DEMO equilibria with hybrid electrons
- **Preliminary DIII-D simulations**

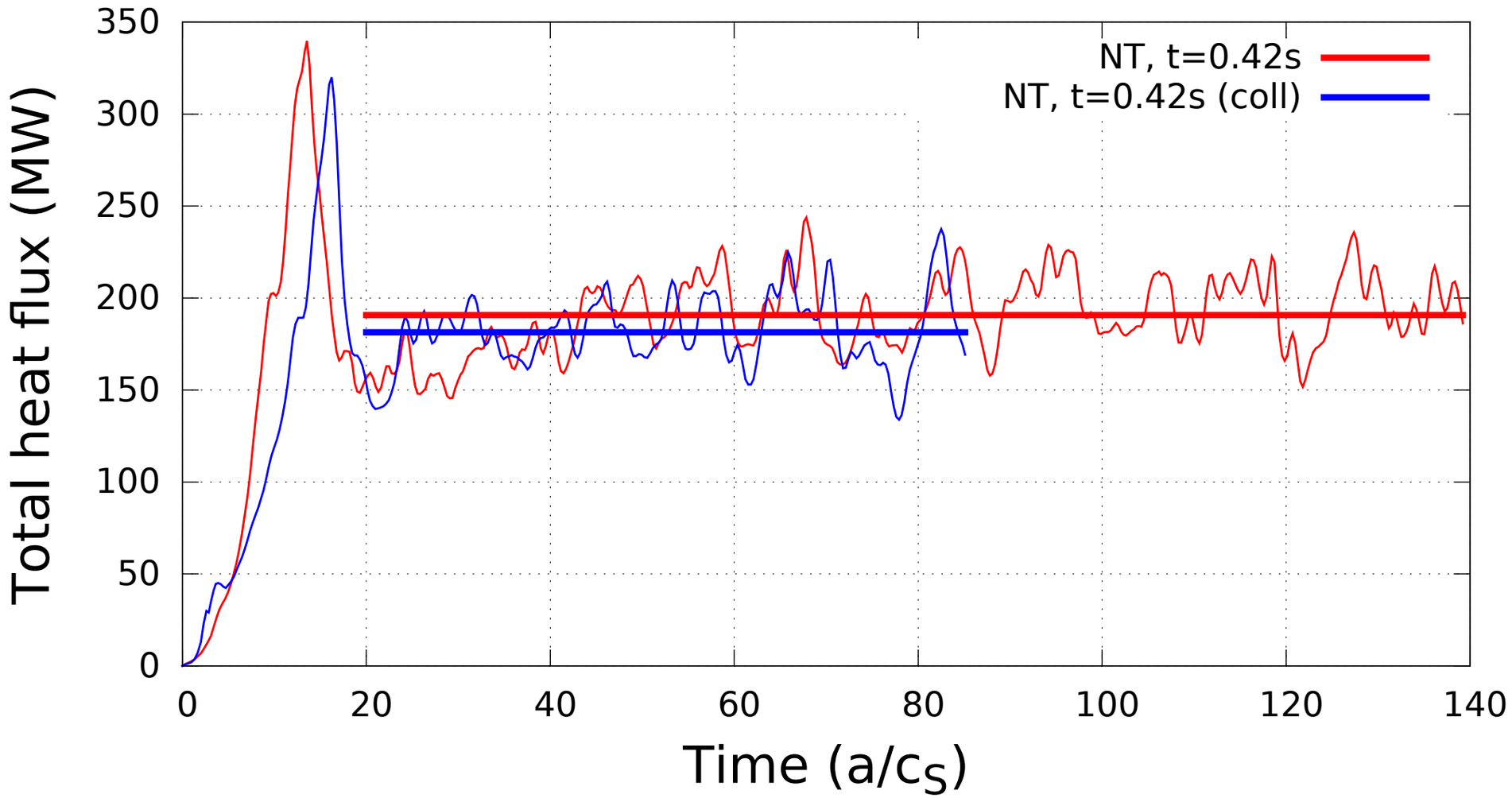
# Preliminary analysis of DIII-D NT equilibria

- Indicates that ITG turbulence is dominant



# Preliminary analysis of DIII-D NT equilibria

- Nonlinear heat flux is x10 too high (again…), even including collisions
  - Potentially due fast ion stabilization from NBI? Under-resolved?

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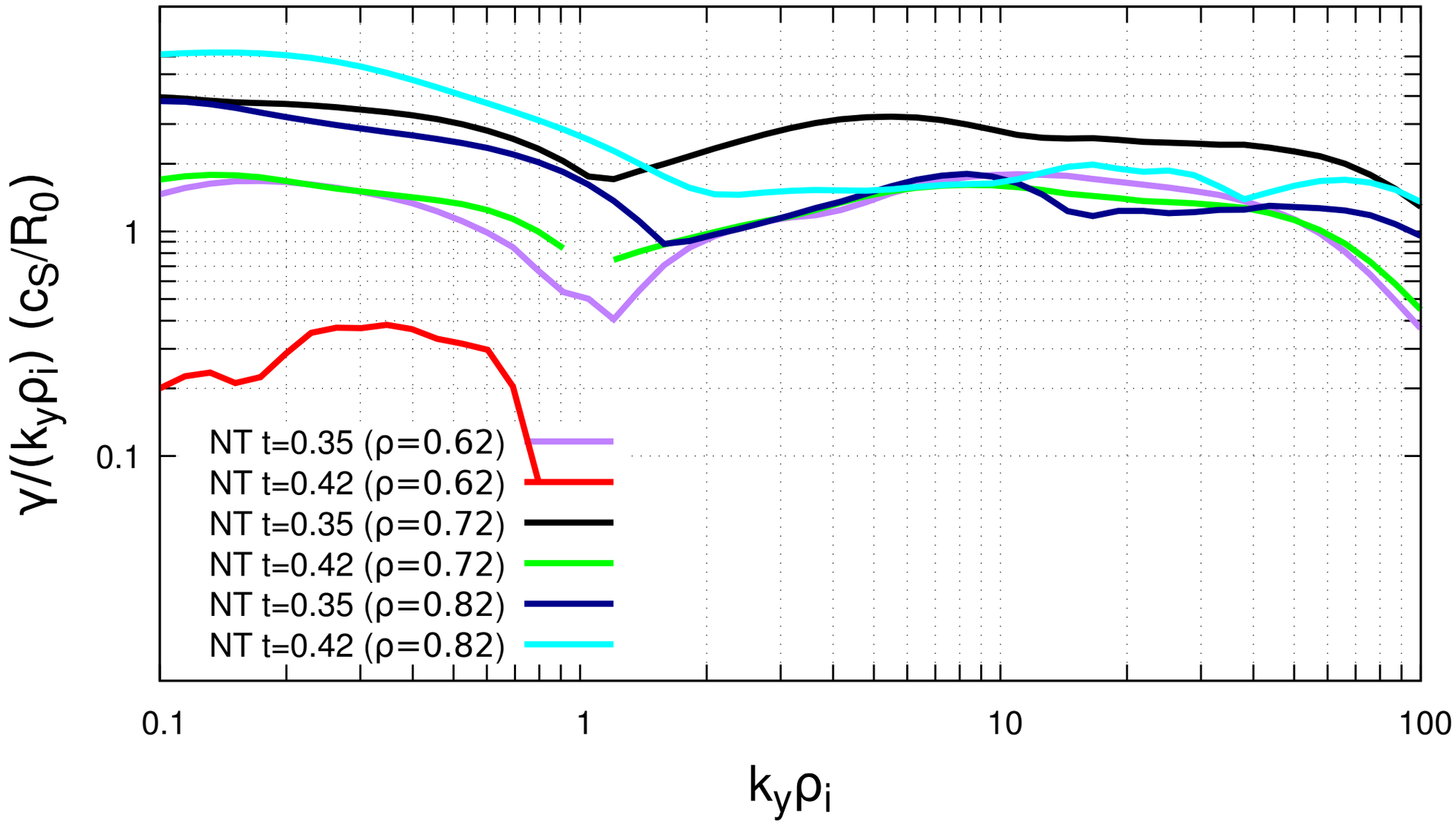
# Takeaways and future plans

- Simulations of TCV equilibria need to include collisions
- Swapping geometric coefficients is on-going
  - DEMO results are less clear than previously thought
    - Repeating with TCV equilibria is underway
  - DIII-D equilibria are ITG dominated
    - Still need a comparable PT equilibrium and to get realistic heat fluxes

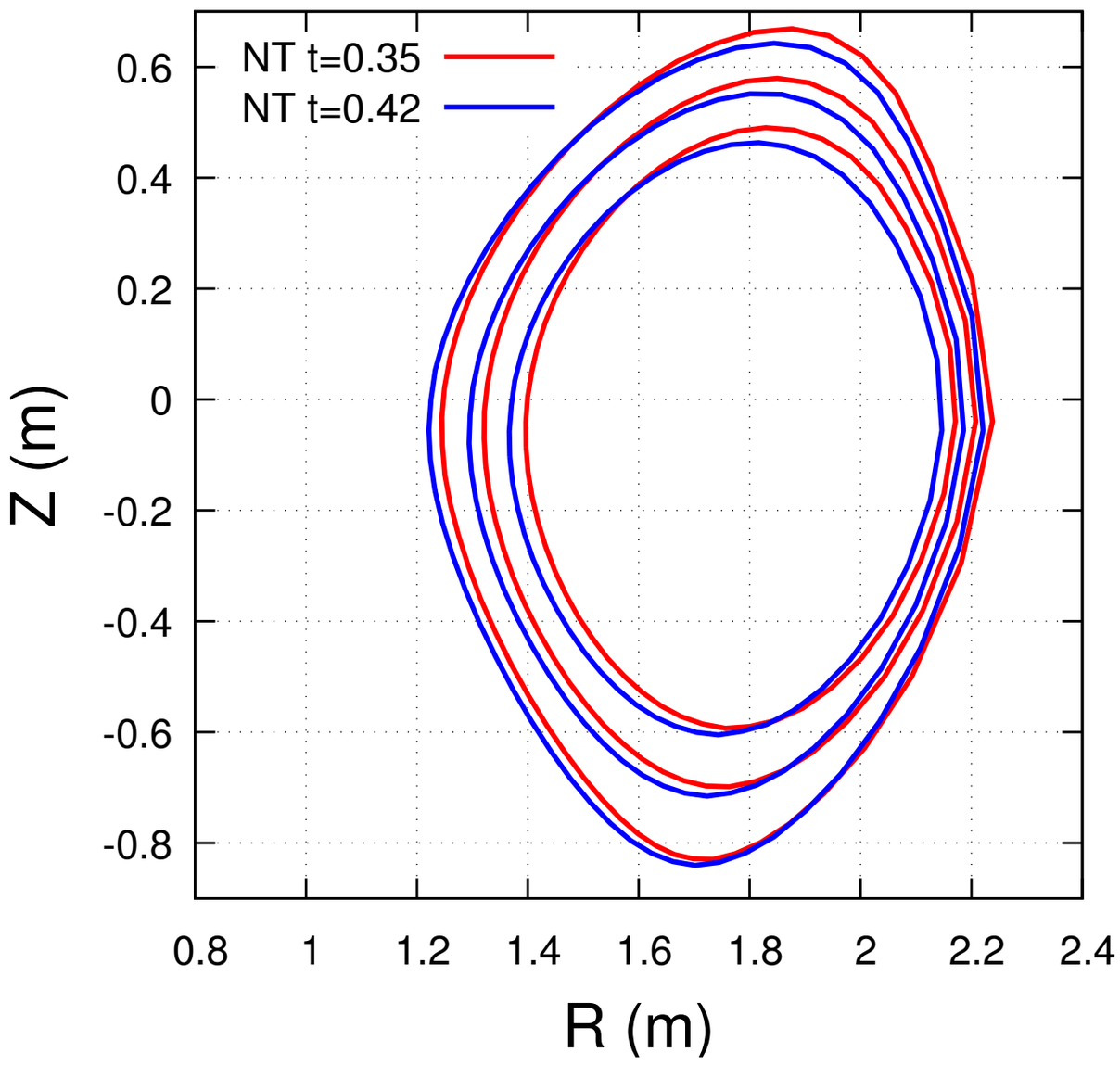
All done.

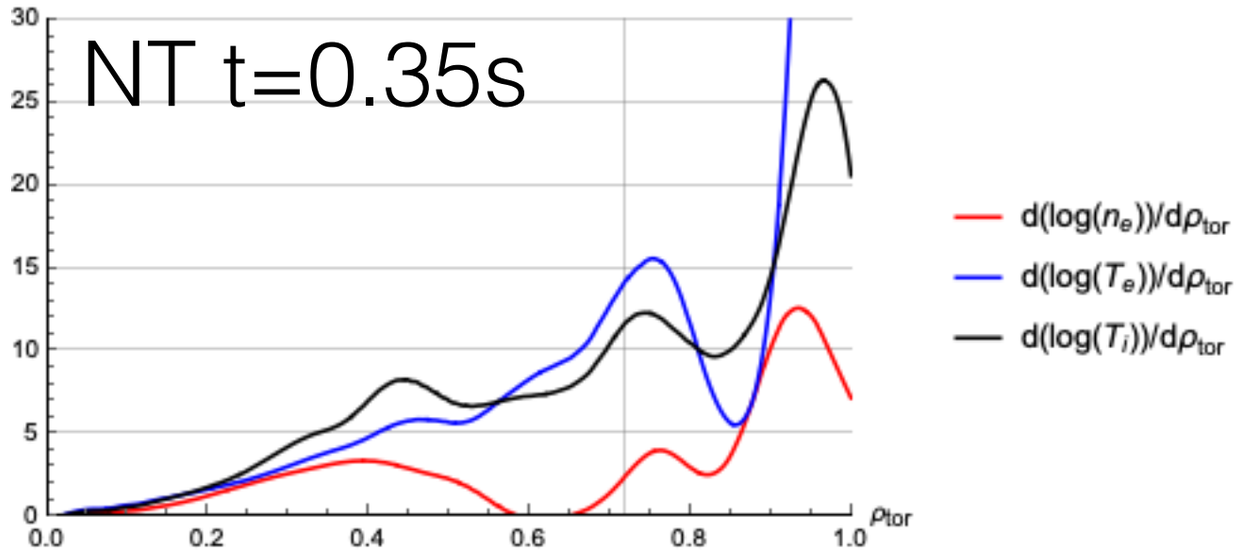
# Preliminary analysis of DIII-D NT equilibria

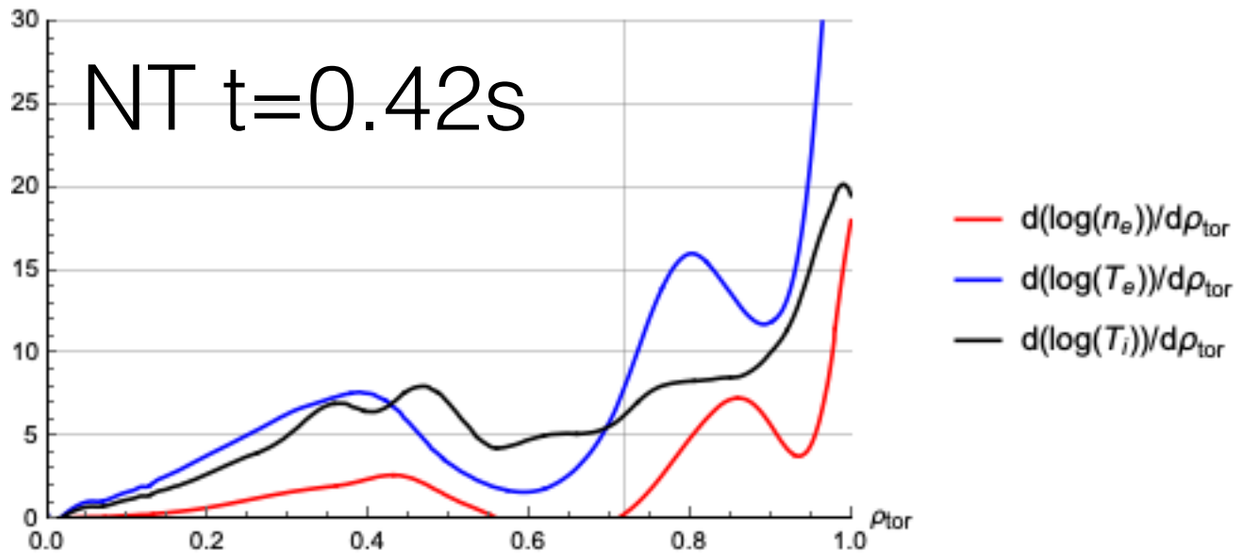
- Indicates that ITG turbulence is dominant



# DIII-D NT equilibria

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# TCV experimental equilibria

| Comp. Num. | Description | Constants of comparison | Discharge | Time (sec) | elong | delta | betaN | P_nbi (kW) | q95 | Ip (kA) | <ne> (x10^19 m^-3) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Diverted, PT | q95, betaN | 69515 | 1.02 | 1.43 | +0.29 | 0.97 | 636 | 3.17 | 242 | 4.0 | not great q95 match |
| 1 | Diverted, NT | q95, betaN | 69340 | 0.58 | 1.42 | -0.28 | 0.97 | 362 | 2.94 | 218 | 3.3 | with Langmuir probes |
| 2 | Diverted, PT | q95, ne, Pheat | 69515 | 1.02 | 1.43 | +0.29 | 0.97 | 636 | 3.17 | 242 | 4.0 | not great q95 match |
| 2 | Diverted, NT | q95, ne, Pheat | 69271 | 1.60 | 1.42 | -0.27 | 1.59 | 612 | 2.90 | 217 | 4.4 | - |
| 3 | Diverted, PT | Ip, betaN, ne | 69508 | 1.49 | 1.43 | +0.28 | 1.12 | 735 | 3.31 | 217 | 4.0 | - |
| 3 | Diverted, NT | Ip, betaN, ne | 69340 | 0.58 | 1.42 | -0.28 | 0.97 | 362 | 2.94 | 218 | 3.3 | with Langmuir probes |
| 4 | Limited, PT | Ip, betaN, ne | 69511 | 1.50 | 1.34 | +0.35 | 1.25 | 1030 | 3.38 | 228 | 3.4 | - |
| 4 | Limited, NT | Ip, betaN, ne | 69273 | 0.85 | 1.29 | -0.29 | 1.30 | 475 | 2.85 | 228 | 3.4 | - |
| 5 | Limited, PT | Ip, Pheat | 69511 | 1.50 | 1.34 | +0.35 | 1.25 | 1030 | 3.38 | 228 | 3.4 | - |
| 5 | Limited, NT | Ip, Pheat | 69273 | 1.70 | 1.26 | -0.26 | 2.02 | 1020 | 2.79 | 226 | 4.6 | - |
| - | Diverted, PT | - | 69515 | 1.58 | 1.43 | +0.34 | 1.84 | 1020 | 3.29 | 239 | 7.1 | in H-mode; no CXRS so Ti=Te |
| - | Diverted, NT | - | 69340 | 1.60 | 1.40 | -0.27 | | | 2.92 | 217 | 5.4 | with Langmuir probes |

# DEMO equilibria with ITG-driven turbulence

- After fixing it, a slowly-building high-wavenumber mode kills simulation