Temperature Profile Predictions for NCSX

Goals

- Develop tool for evaluating thermal energy confinement of candidate configurations with self consistent E_r and temperature profiles (presently these are assumed).
- Find optimal density, B_{ref}, R_{ref} for each configuration (at fixed target $<\beta>$).

Methods

- Solve steady state 1-D power balance equations for T_e and T_i.
- Assume a fixed shape for the density profile (may eventually predict this, too).
- Include standard 'transport matrix' and temperature coupling.
- 'Shaing-Houlberg' neoclassical ripple transport, using effective helical ripple from
- Nemov-Kernbichler code NEO; calculates orbit drifts using VMEC field description. finds 'effective' ripple amplitude of muliple-helicity configuration (correct for $1/\nu$).
- Find and use E_r which maintains quasi-neutrality (use ion root when it exists).
- Add axisymmetric neoclassical fluxes (Hinton-Hazeltine, Chang-Hinton).
- Add 'anomalous' transport (Lackner-Gottardi, Mixed-Shear, Culham,...?).
- Neutral beam deposition in axisymmetric geometry (try a few cross sectional shapes).
- Assume temperatures at outer boundary condition; core will be insensitive ??

Nested loops of iteration planned for SURVEY optimizer.

- Find E_r, transport matrix, equilibrium temperature profiles (standalone code).
- Vary the line average density to find the optimum.
- Vary B_{ref} & R_{ref} (2-D scan); find P_{heat} required to reach target $<\beta>$.

Current Status

- NEO has produced a (profile) figure of merit for helical ripple transport.
  - axisymmetric and anomalous transport must be added to get total fluxes.
  - says LI383_328 is best of current contenders, but II379_328 is 20-50% better.
  - Modified NEO to read Bmns... files with Long-Poe Ku's new format.

- Houlberg's subroutine for neoclassical ripple transport installed.
  adding Crume, et al., modification of the collisionless de-trapping, or ν, regime.

- KAPISN - axisymmetric neoclassical χ_i - (from SNAP) installed.

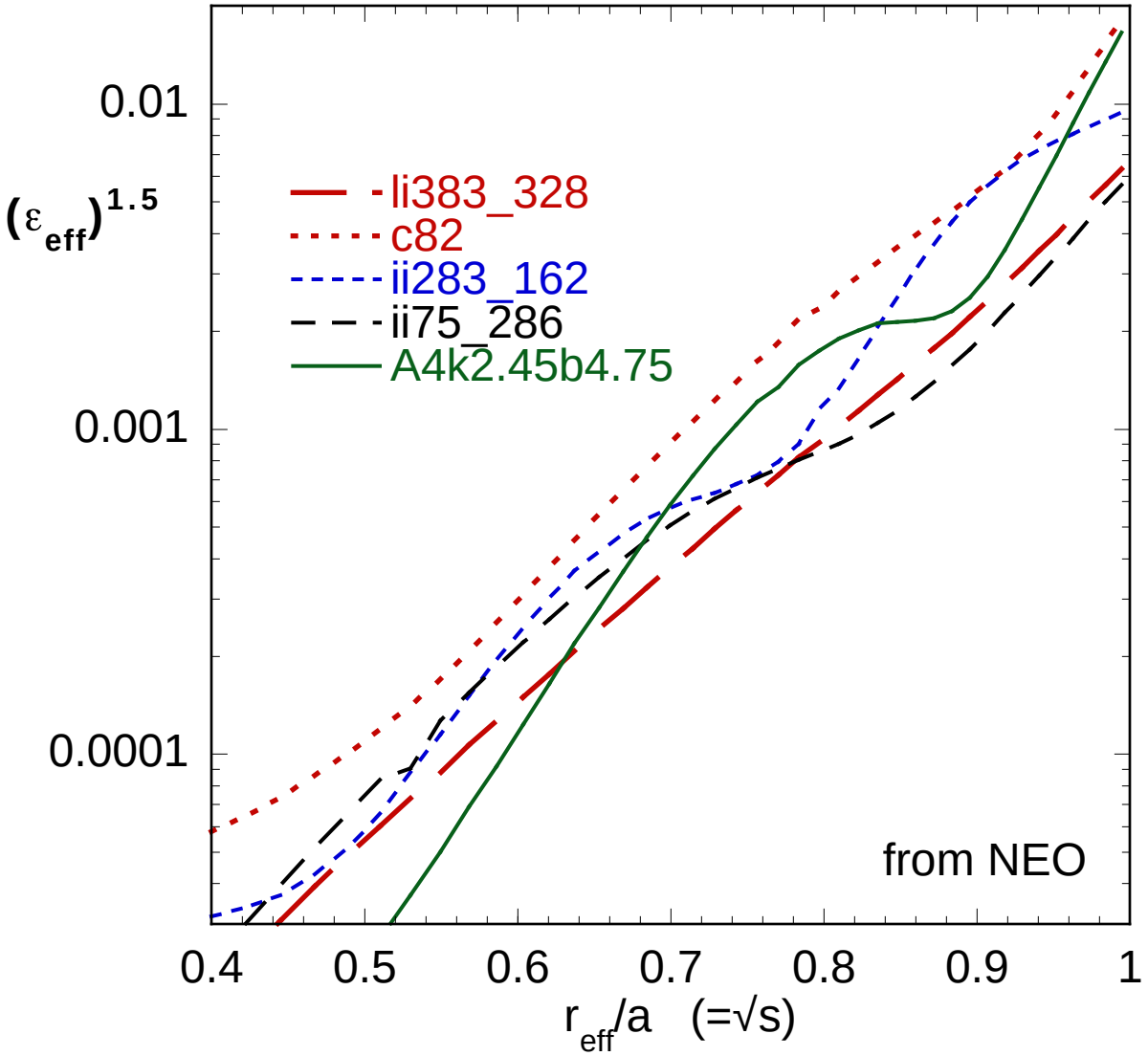
- Root-finding subroutine for E_r is working.

- Temperature prediction routine written; initial tests have no convergence problems.
  - need ~100 radial grid points for accurate solution.

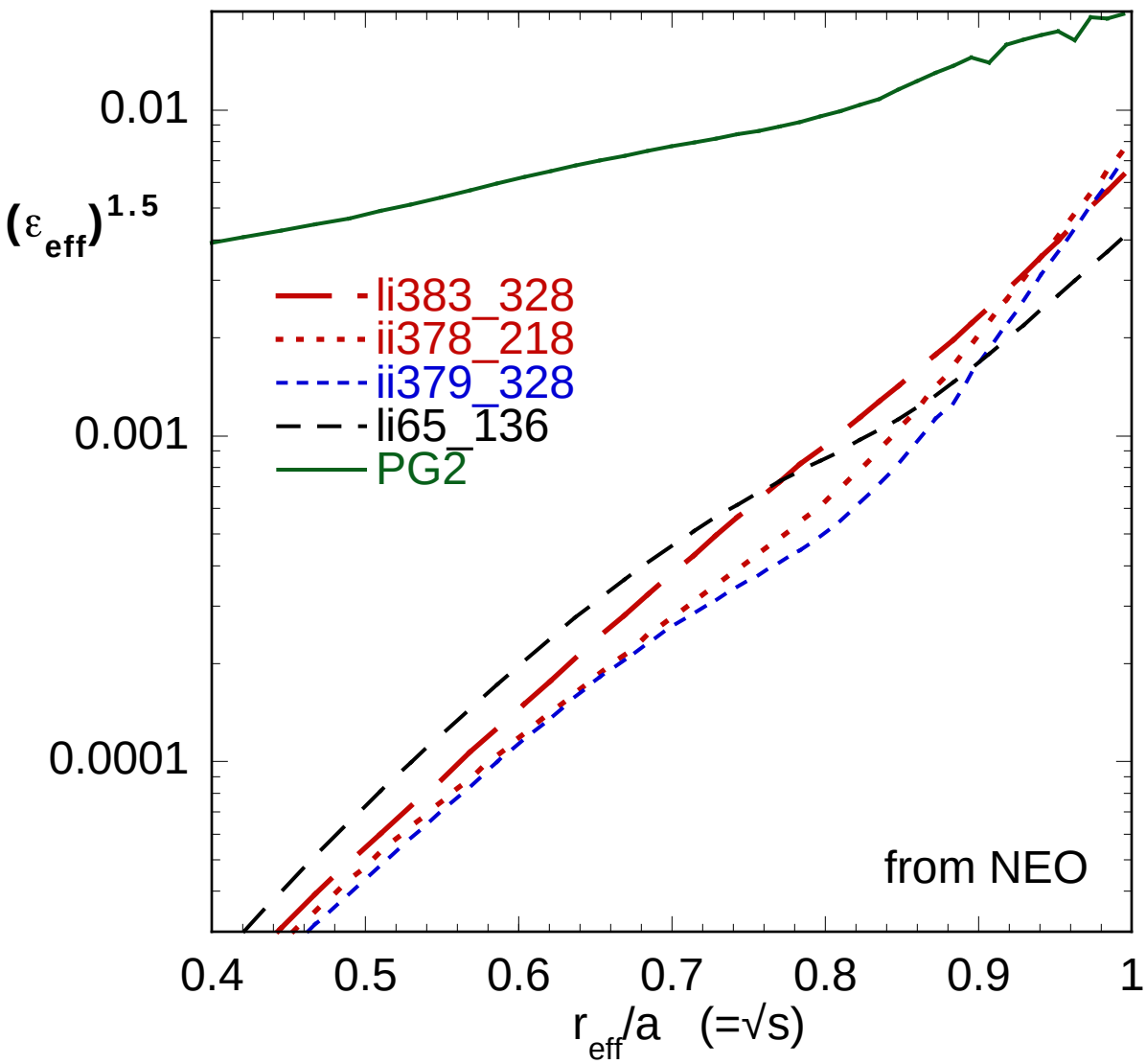
- SURVEY has nested loops for optimal density and 2-D scans over B_{ref} & R_{ref} .

- Proposed a simple fit for fast-ion orbit losses; needs to be tested by D. Spong.

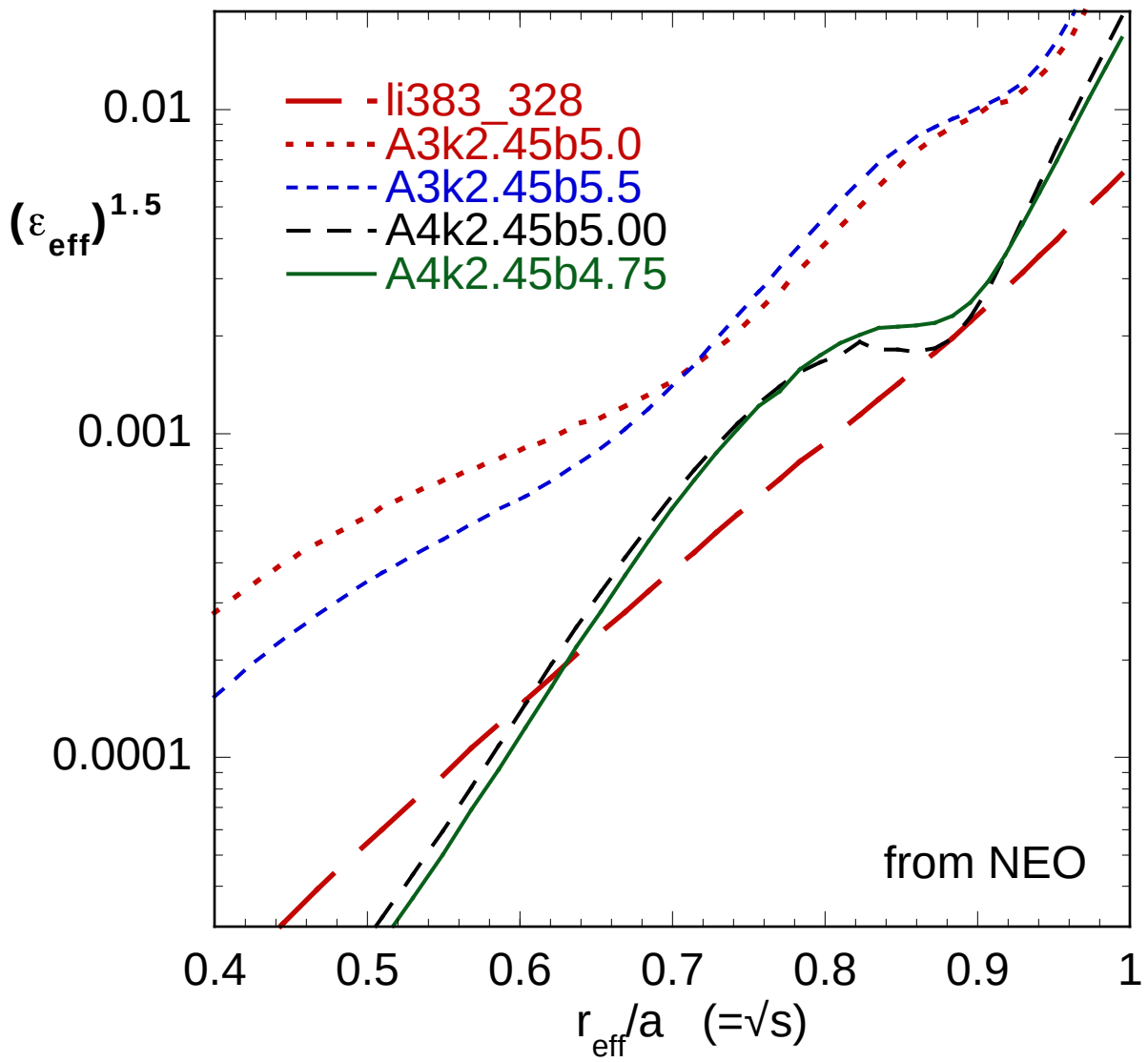
Helical Transport Reduced
li383_328 2-3 times lower than c82



II379_328 has lowest effective ripple



li383_328 lower than Ank2 series



Basic Features of Neoclassical Ripple Transport

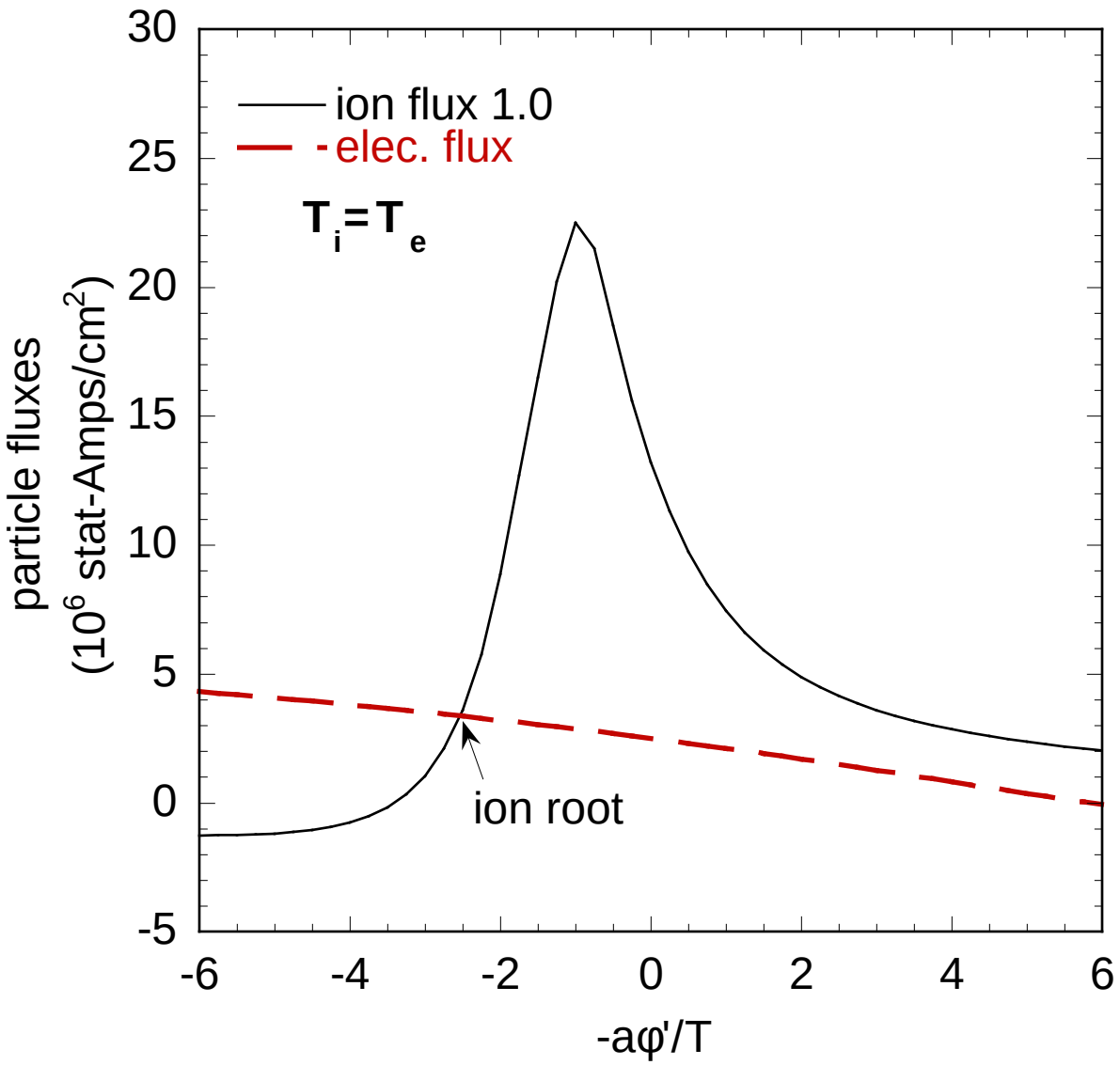
The transport due to helical field ripple has some distinctive characteristics:

- T_e is more important than T_i because electron flux is less sensitive to E_r.
  non-quasi-neutral fluxes force E_r to the point where ion flux = electron flux,
  near an ion root, the electron flux is essentially independent of E_r.

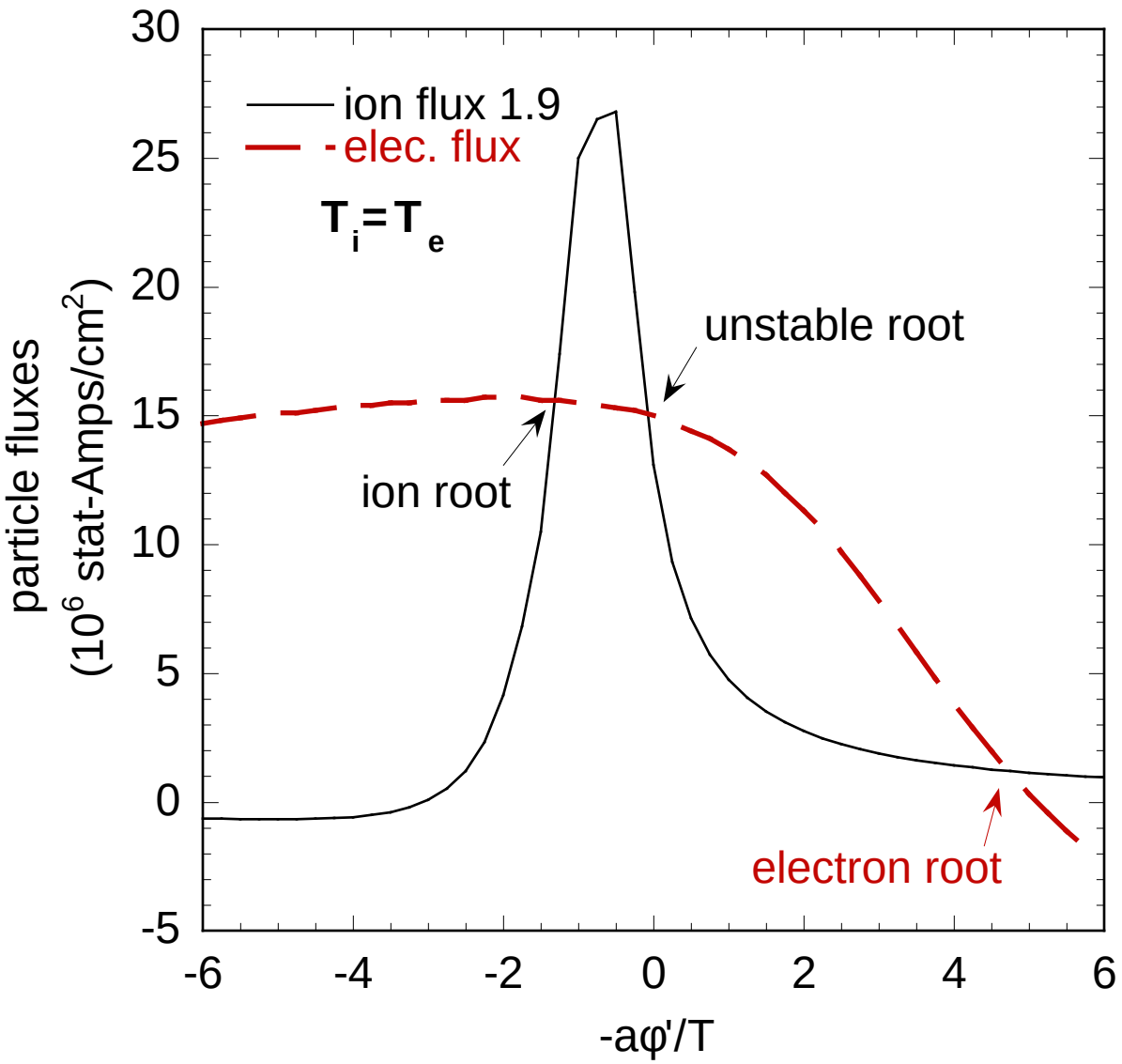
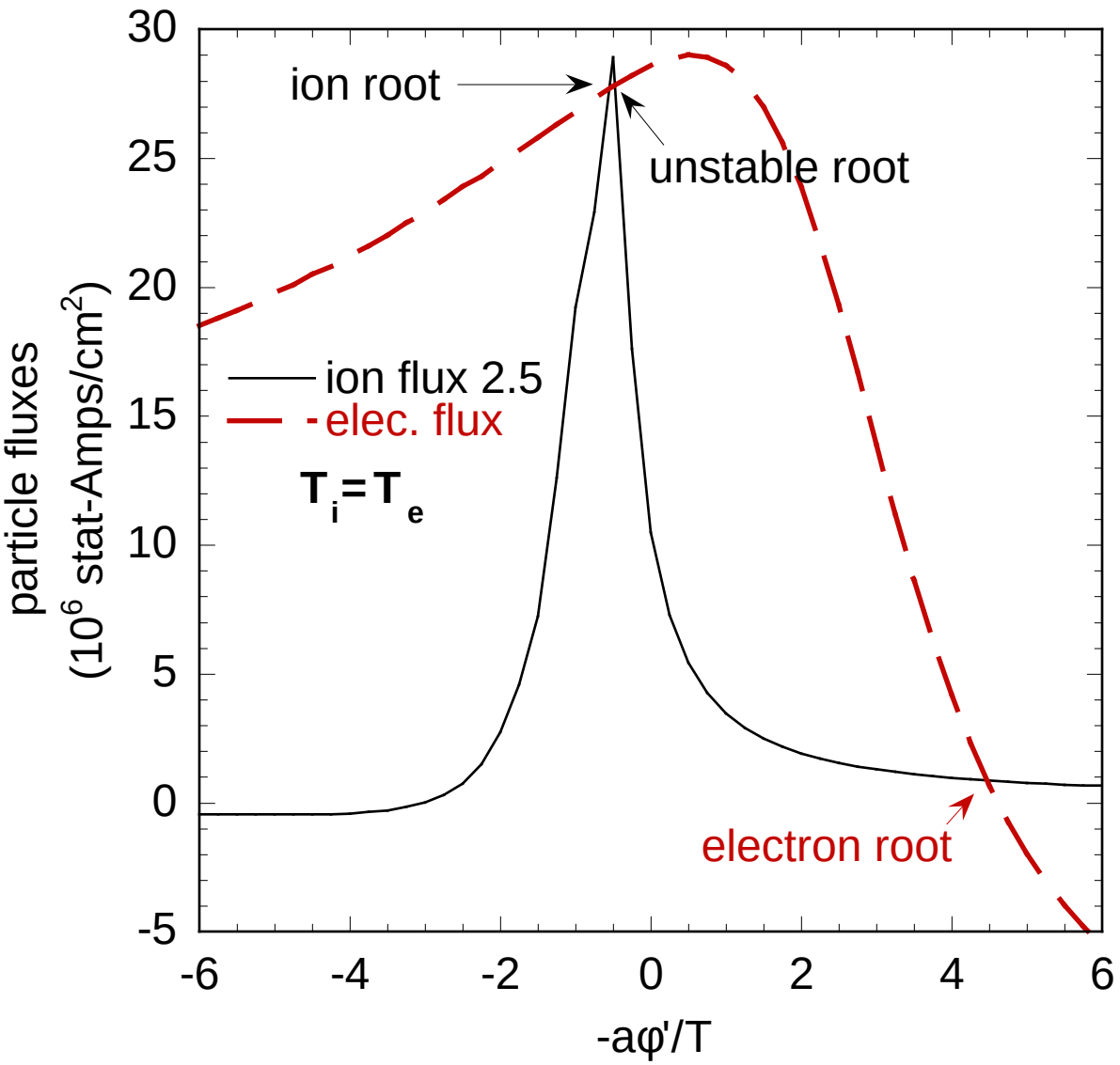
- The electron flux depends strongly on T_e: $\Gamma \sim T_e^{3.5}$; $Q \sim T_e^{4.5}$.
  the ion flux appears to depend mostly on E_r, but T_e is indirectly dominant.
  the ion and electron fluxes (particle and energy) are comparable.
  big τ_E win at high density and slightly lower T_e; neoclassically expect $\tau_E \sim n_e$.

- For high enough T_e (~ 2-4 keV) there is no ion root, and the resulting
  electron root produces a transport barrier.
  The much larger magnitude of E_r strongly reduces all helical transport.
  It might also reduce anomalous turbulence?

Helical Ripple Fluxes; T=1 keV



Helical Ripple Fluxes; T=1.9 keV



Helical Ripple Fluxes; T=2.5 keV