Monte Carlo Simulations of Neoclassical Energy Confinement

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Monte Carlo Model

- GTC: magnetic coordinates, Hamiltonian guiding center pusher, scalable on massivelly parallel computer, δf methods for both microturbulence and neoclassical studies.
- In this work, we used GTC for full-f Monte-carlo simulations.
- Partiles collide with background plasma
- Heat flux calculated, and thus energy confinement time

$$\tau \equiv \frac{W}{Q}$$

Collision Operators

- Like-species collision

$$C(f) = \frac{\partial}{\partial v_\parallel}(\nu_{s\parallel} f) + \frac{\partial}{\partial {v_\perp}^2}(\nu_{s\perp} f) + \frac{\partial^2}{\partial v_\parallel \partial v_\perp^2}(\nu_{\parallel\perp} f) + \frac{1}{2}\frac{\partial^2}{(\partial v_\parallel)^2}(\nu_\parallel f) + \frac{1}{2}\frac{\partial^2}{(\partial v_\perp^2)^2}(\nu_\perp f)$$

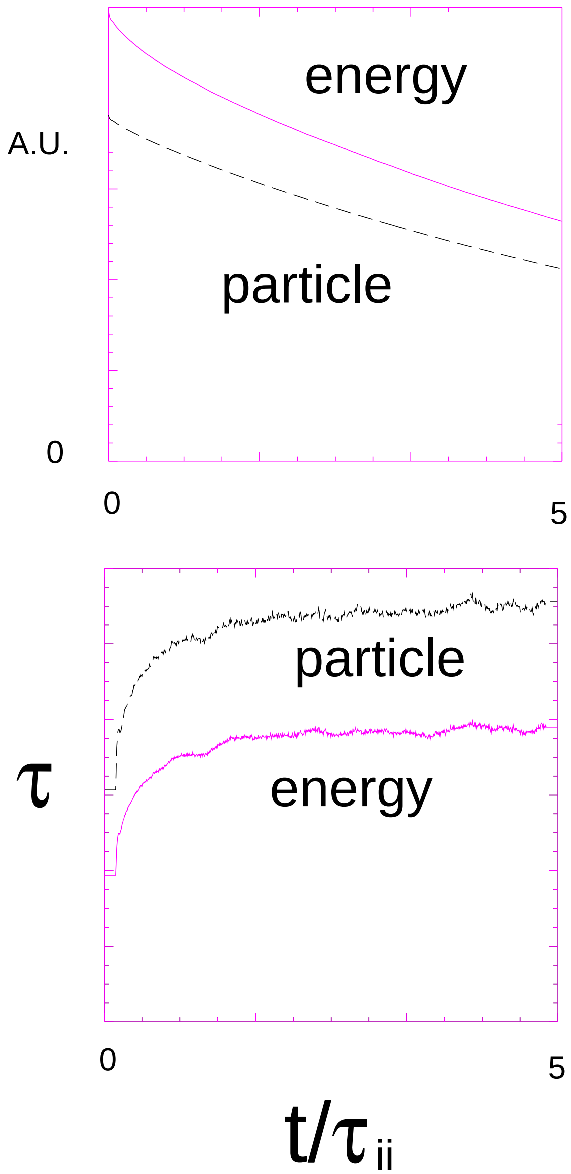
coefficients defined in [*Lin, Tang, Lee, Phys. Plasmas, 1995*]

- Electron-ion collision

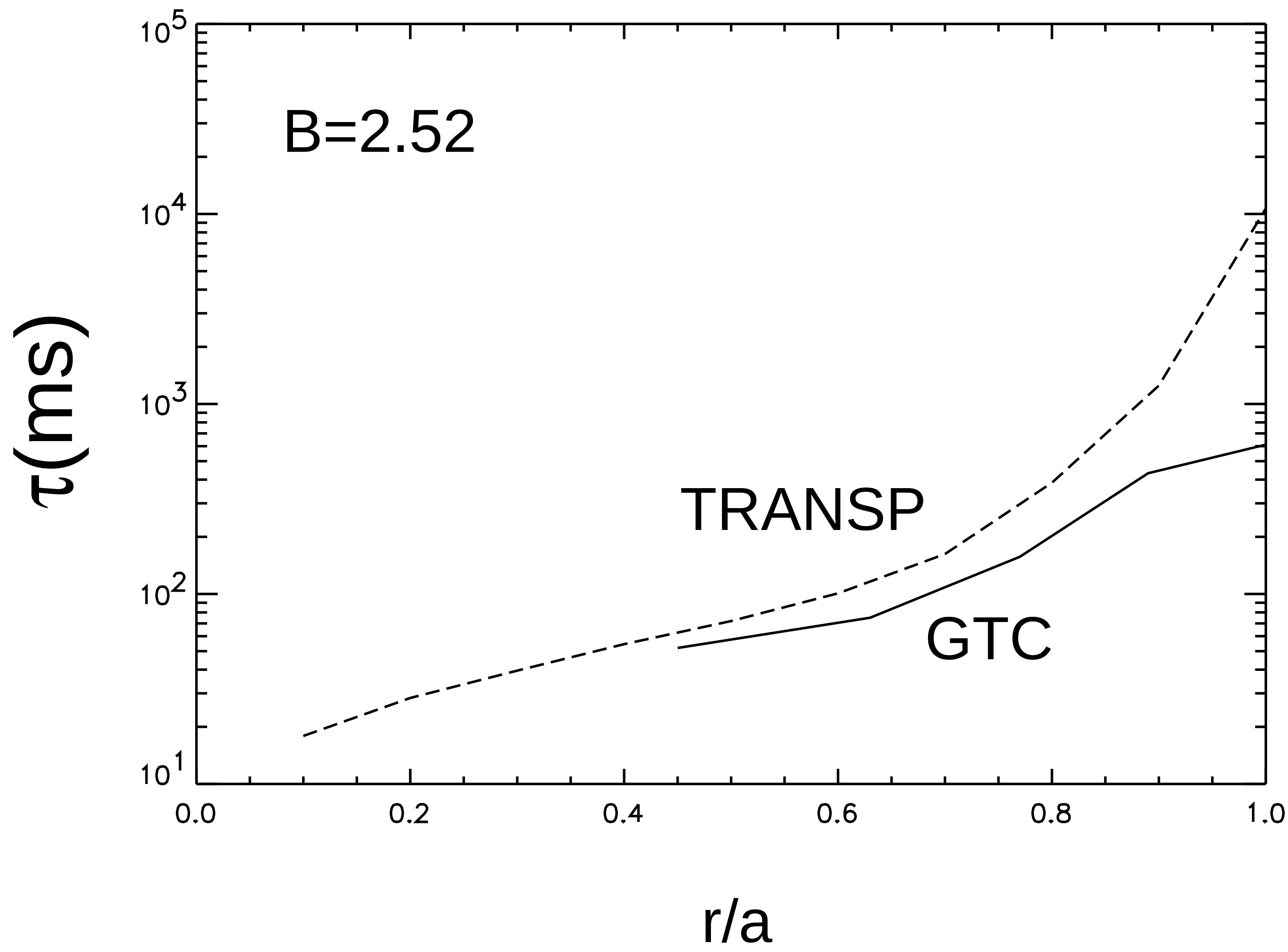
$$C = \frac{3\pi^{1/2}}{4\tau_{ei}}(\frac{v_e}{v})^3 \frac{1}{2}\frac{\partial}{\partial \xi}(1-\xi^2)\frac{\partial}{\partial \xi}, \quad \xi = \frac{v_\parallel}{v}, \quad v_e = \sqrt{\frac{2T_e}{m_e}}$$

- Braginskii collision time

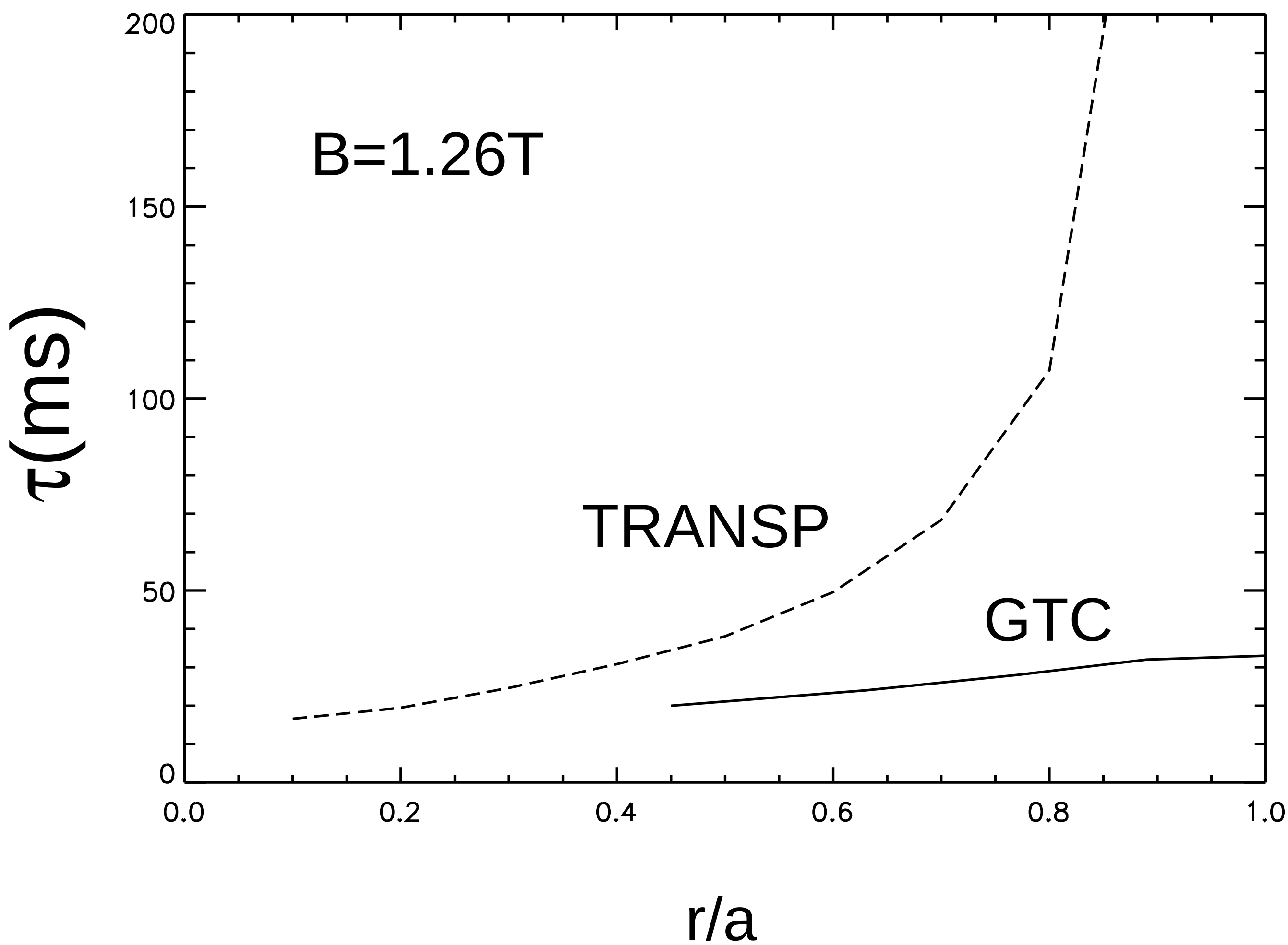
$$\tau_{ii} = \frac{3 m_i^{1/2} T_i^{3/2}}{4\pi^{1/2} Z_{eff} n_e \ln \Lambda}, \quad \tau_{ei} = \frac{3 m_e^{1/2} T_e^{3/2}}{4(2\pi)^{1/2} Z_{eff} n_e \ln \Lambda}$$



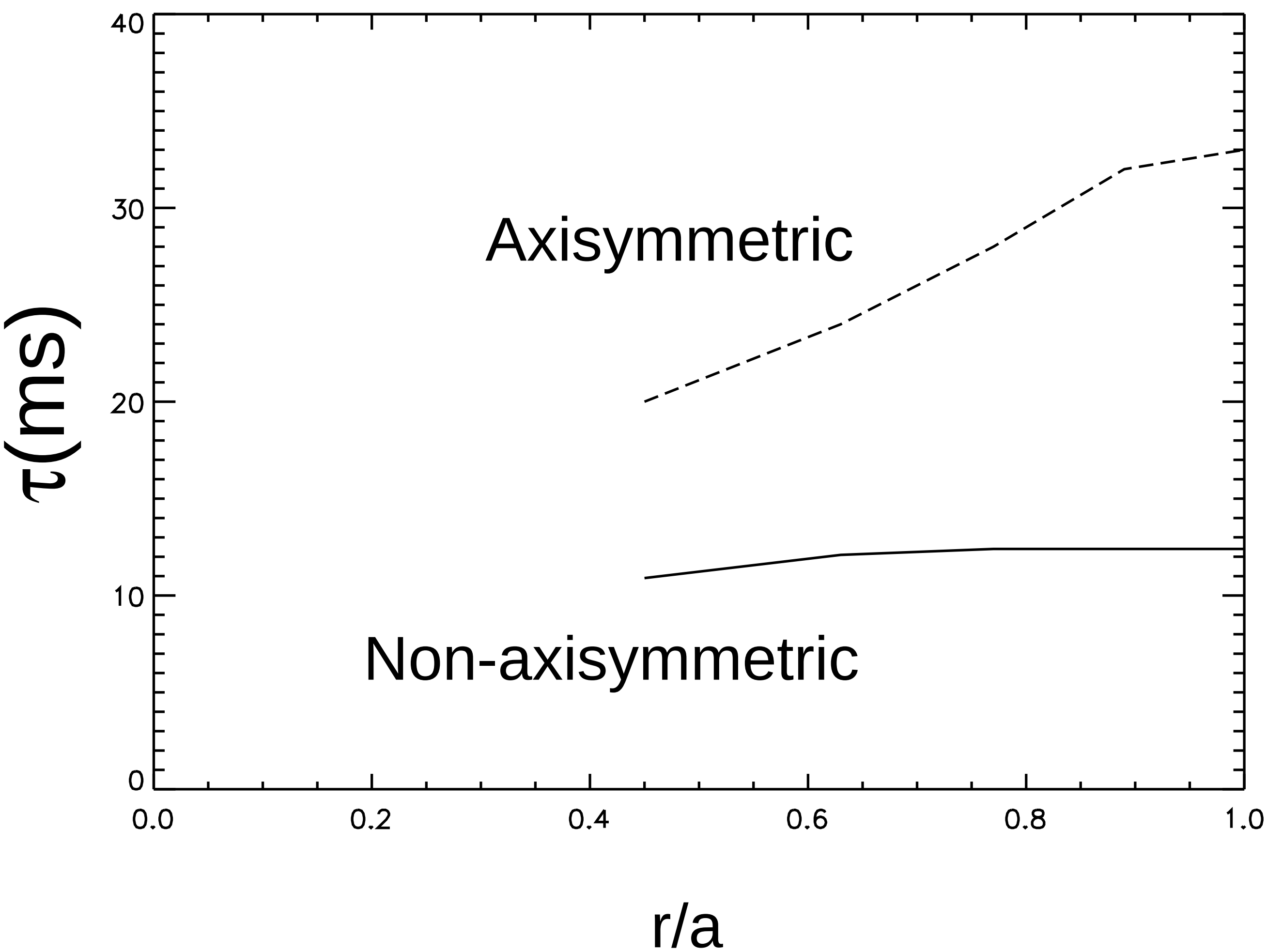
Calculation of particle and
energy confinement time



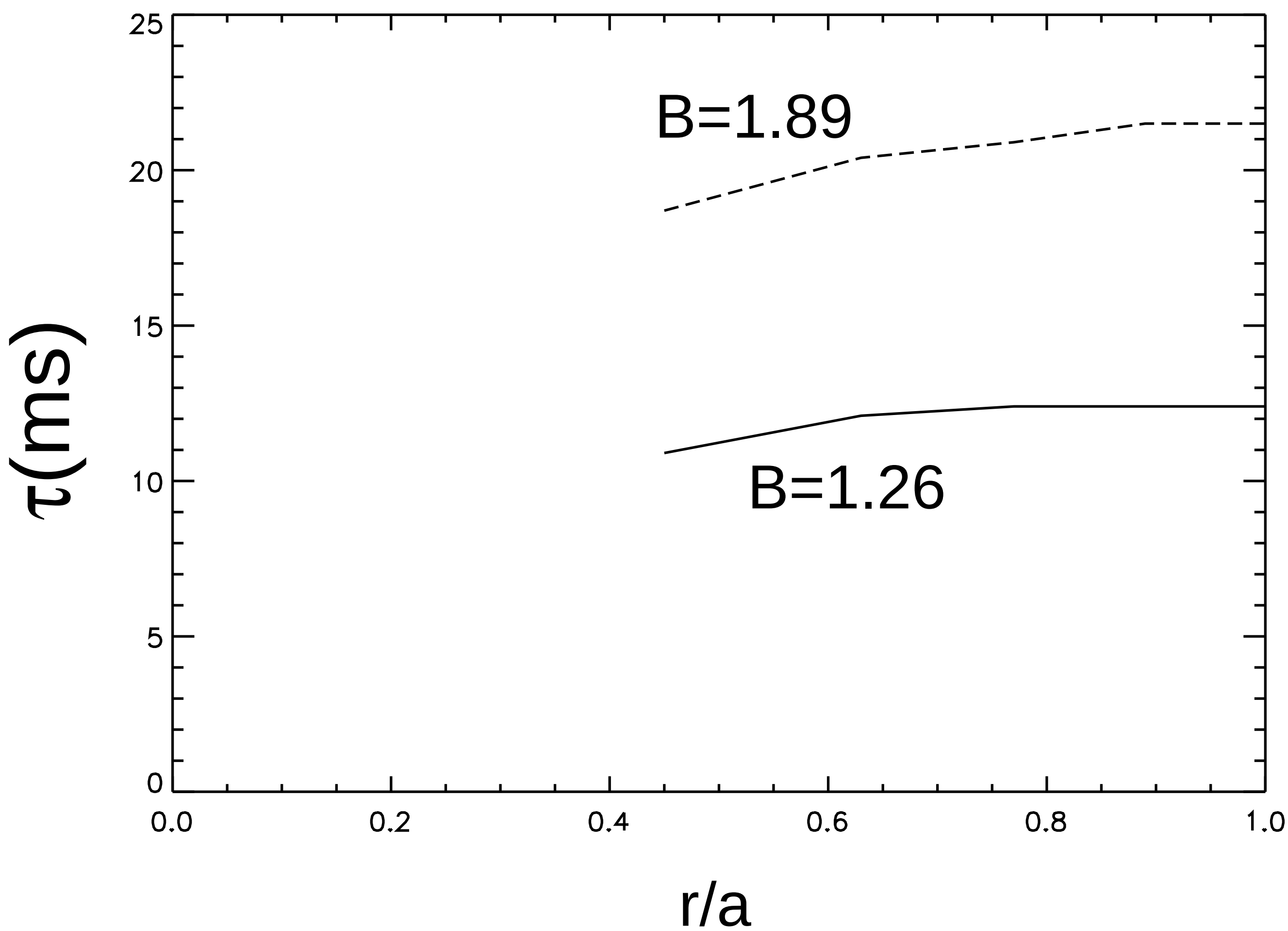
Axisymmetric benchmark



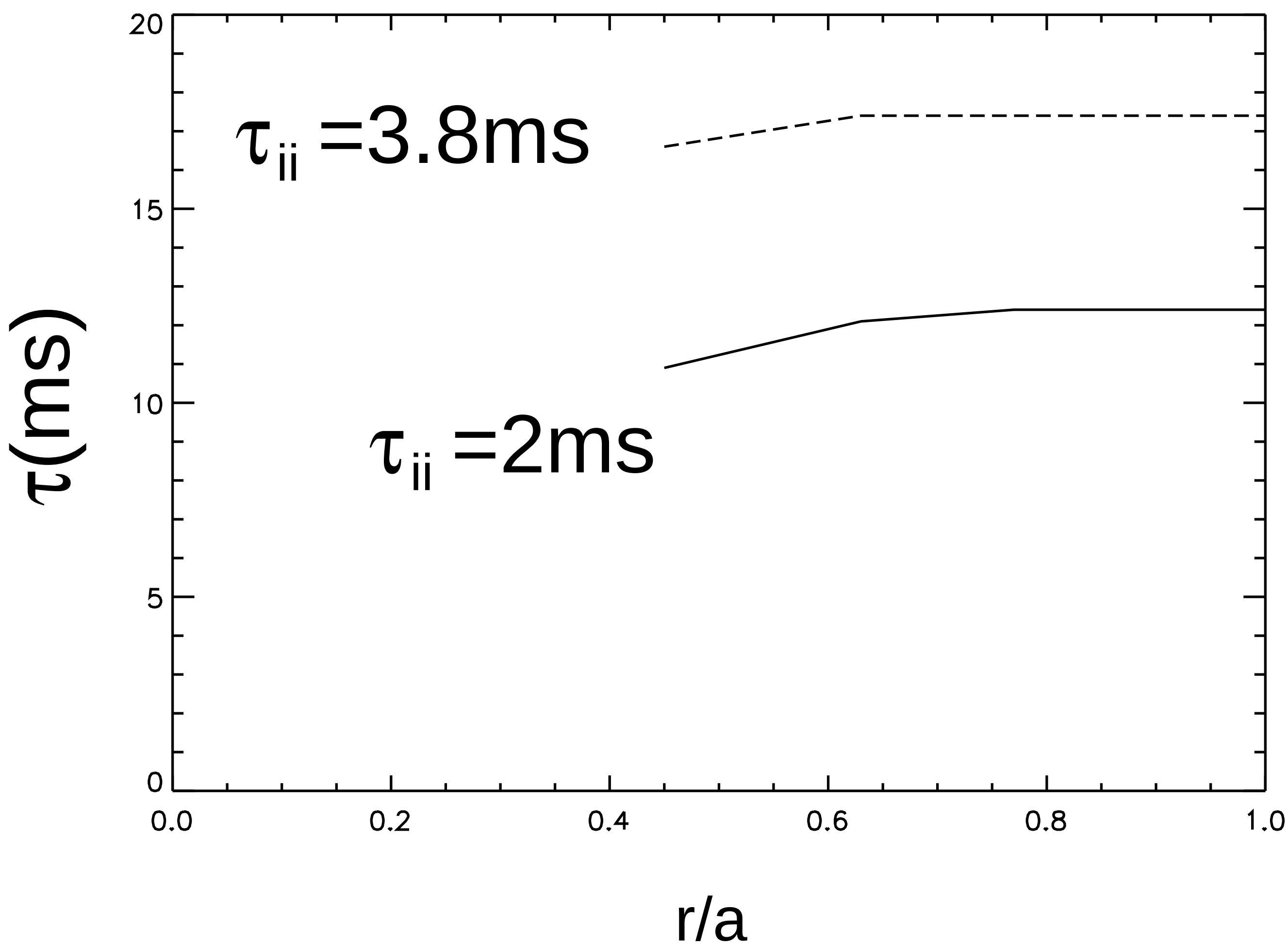
Axisymmetric Benchmark



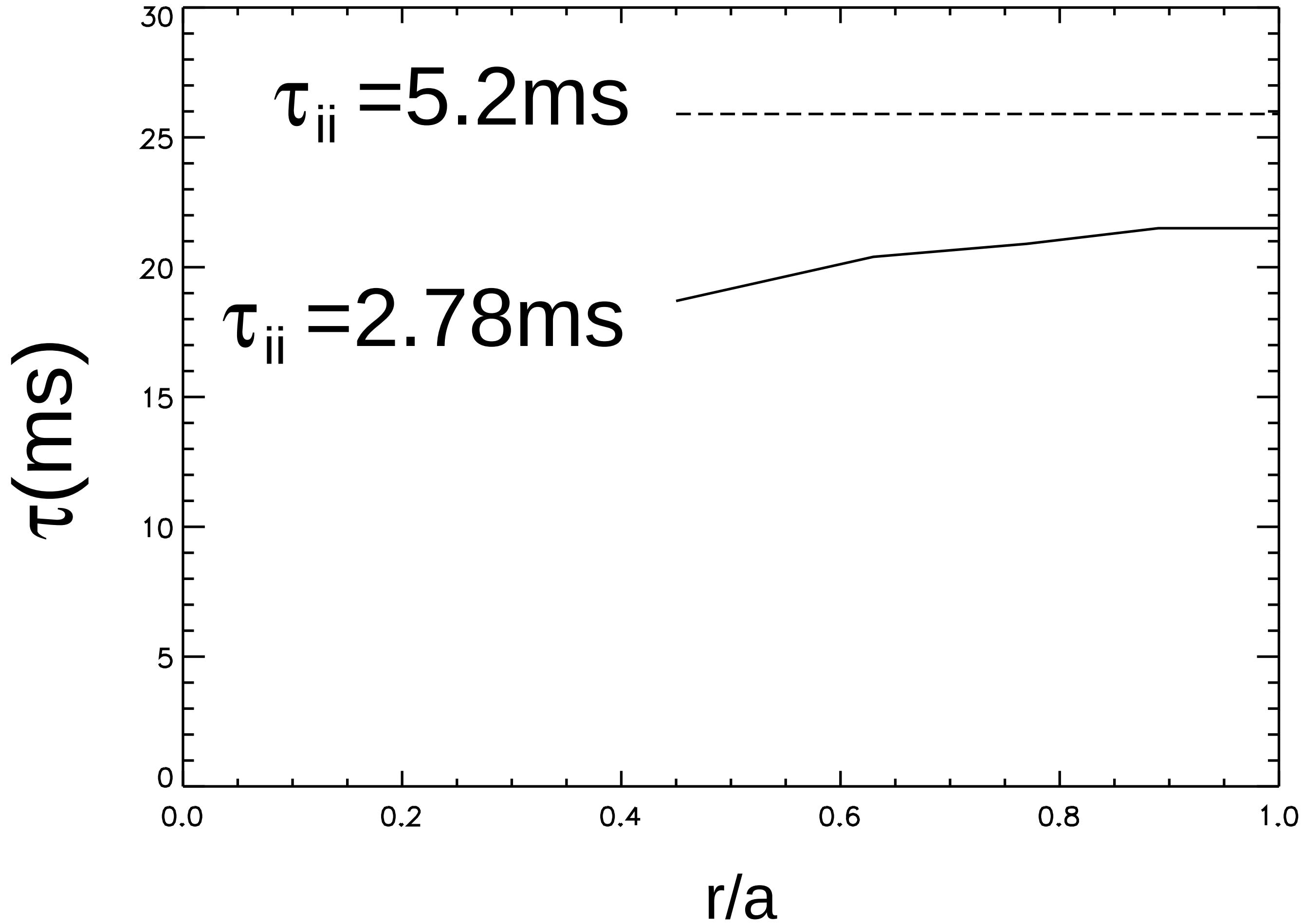
Energy confinement time for E_r=0.0



Non-Axisymmetric



Non-Axisymmetric



Non-Axisymmetric

Non-axisymmetric: E_r Field Dependence

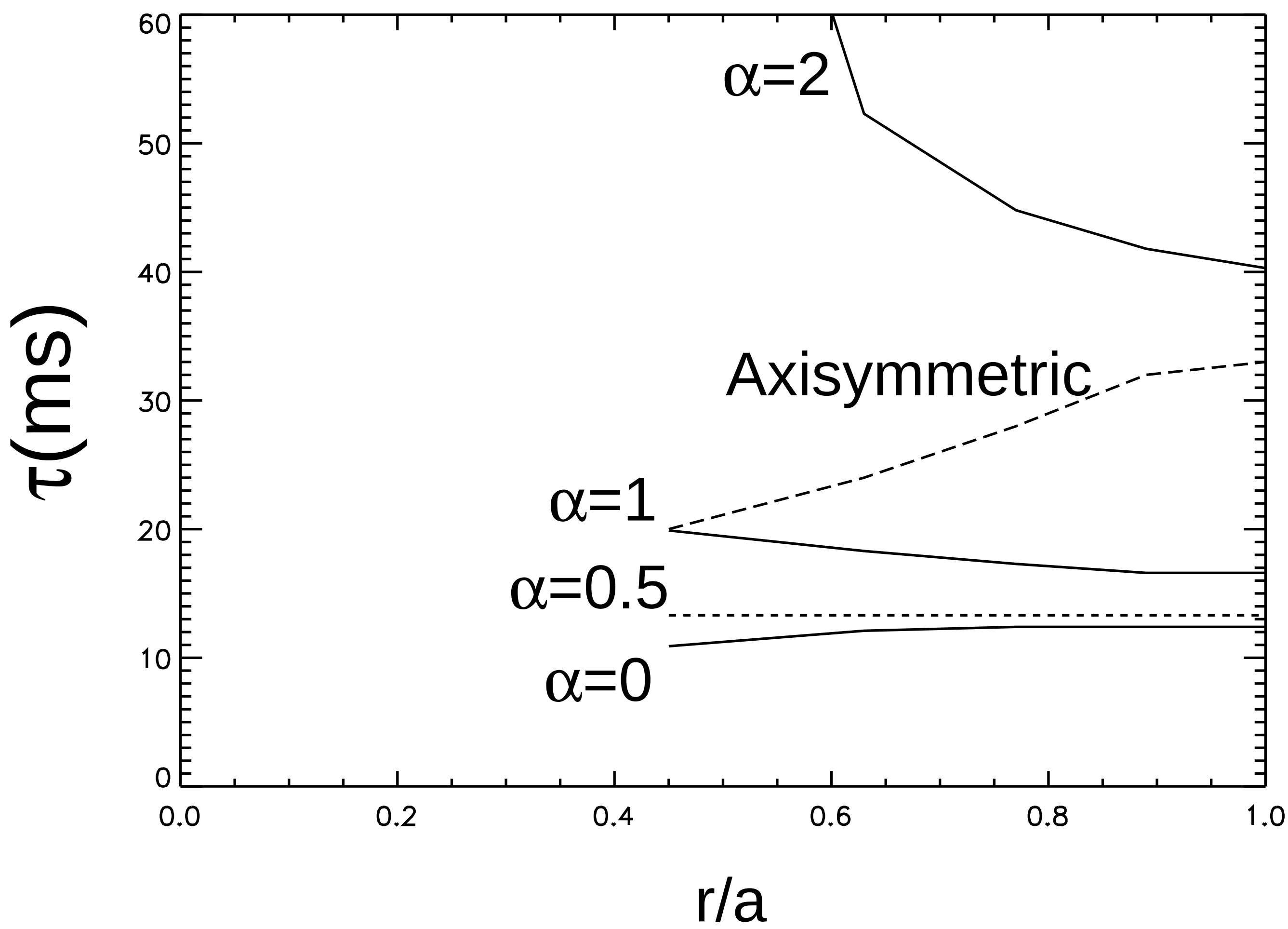
- Electrostatic potential model: rigid rotation

$$\Phi = \alpha \frac{T_{i0}}{e} \frac{\psi}{\psi_{wall}}$$

Poloidal Mach number

$$M_p \equiv \frac{d\Phi/d\psi}{v_{th}/qR} = \alpha \frac{qR}{a^2} \frac{\rho_{i0}^2}{\rho_i}$$

$$\rho_i \equiv v_{th}/\Omega_i, \;\; v_{th} \equiv \sqrt{2T_i/m_i}, \;\; a \equiv \sqrt{2\psi_{wall}/B_0}$$



60
50
40
30
20
10
0
0.0
0.2
0.4
0.6
0.8
1.0
τ(ms)
r/a
α=2
Axisymmetric
α=1
α=0.5
α=0

E_r scan

Next Step

- Temperature dependence
- NB simulations
- δf simulation of electron transport
- Self-consistent E_r