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Particle Simulation of Neoclassical Li^{+3} Transport in Realistic Geometry NSTX

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Simulation performed by Gunyoung Park

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XGC0: Kinetic transport modeling code

- Full-f Particle-in-cell in 3D magnetic field (RMP, ripple)
- Realistic geometry from geqdsk data (wall and separatrix included)
- 3D (in r-space) + 2D (in v-space) ion and electron Lagrangian dynamics with self-consistent 1D E_r evolution
- Electrostatic potential Φ is assumed to be a flux function
- Logical sheath at diverter plates ($J_\perp + J_{||} = 0$ out of a flux tube)
- D/H Neutral Monte Carlo particles with a wall recycling coefficient
- Conserving Monte-Carlo Coulomb and neutral collisions (ionization and charge exchange)
- DEGAS2 is built-in (Stotler)
- Multiple ion species with Hirshman collision operator
- Heat flux from core
- Implementation of anomalous transport modeling: random walk and convection. Independent control of the ambipolar particle and the heat transport on each species
- More self-consistent anomalous transport is to be imported from XGC1.
- XGC-RF contains rf operator

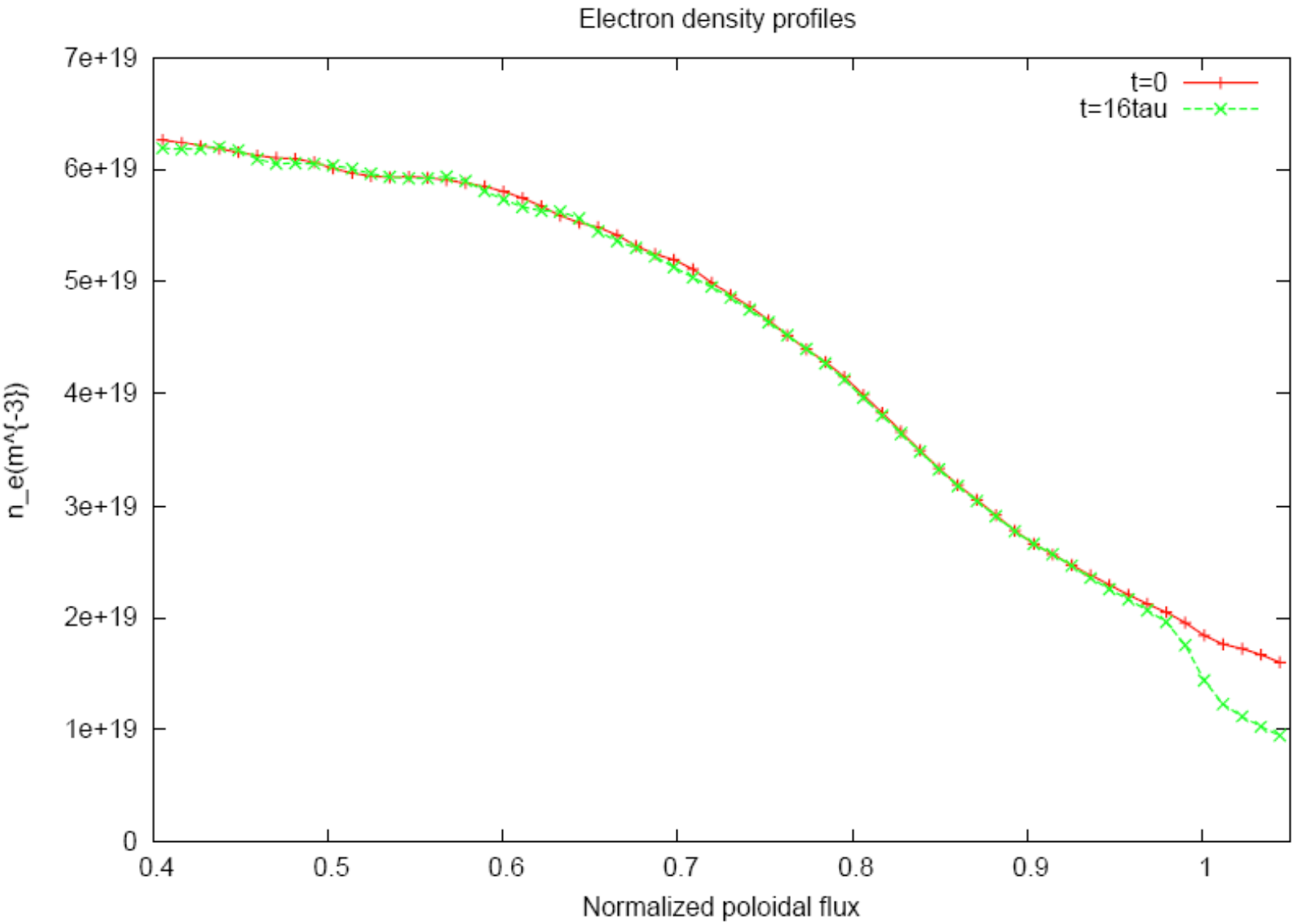
Kinetic neoclassical impurity transport simulation

- Anomalous transport is off → Neoclassical
- Simulation domain: ψ_N=0.4 to wall in realistic g_eqdsk geometry (g124439.00497)
- No ripple and RMP
- 5 species: D^{+1}, e^- , D^0, C^{+6}, Li^{+3}
- C^{+6} and Li^{+3} are born at fixed fraction to n_e.
- Large initial C density fraction (5% and 10%) and small Li fraction (1/3%)
- Radial transport speeds are calculated from assumed initial profile
- Instead of using DEGAS2, a built-in simplified neutral Monte Carlo model is used for this simulation .
- Self-consistent E_r-$v_{||}$ with the impurity and edge effects (wall, X-point, neutral, pedestal, etc)

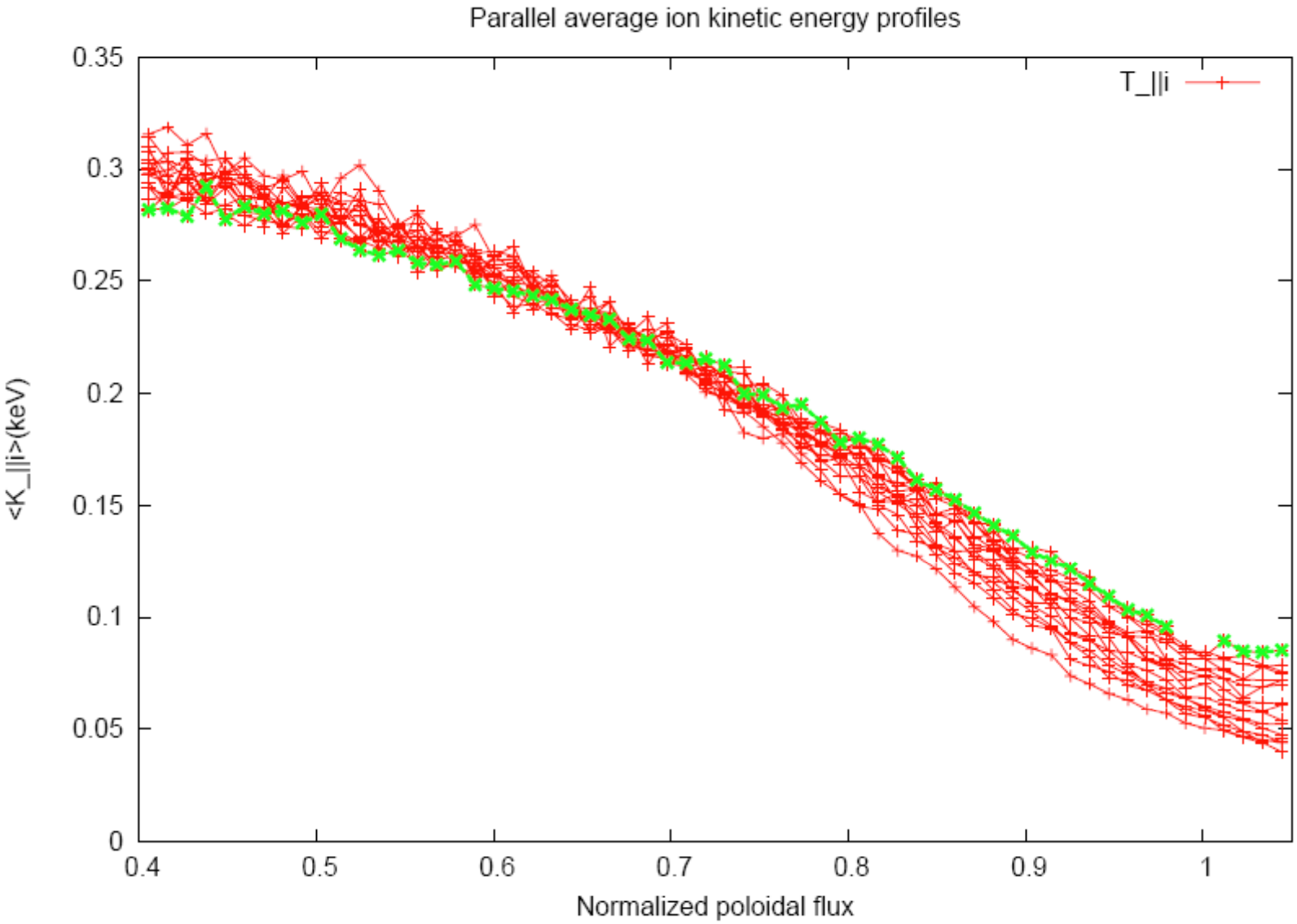
Analytic theories are not easy for C and Li impurities

- Large mass ratio and/or high Z approximations are problematic.
- Orbit loss effects (X-loss) on E_r, rotation and transport are difficult to handle analytically

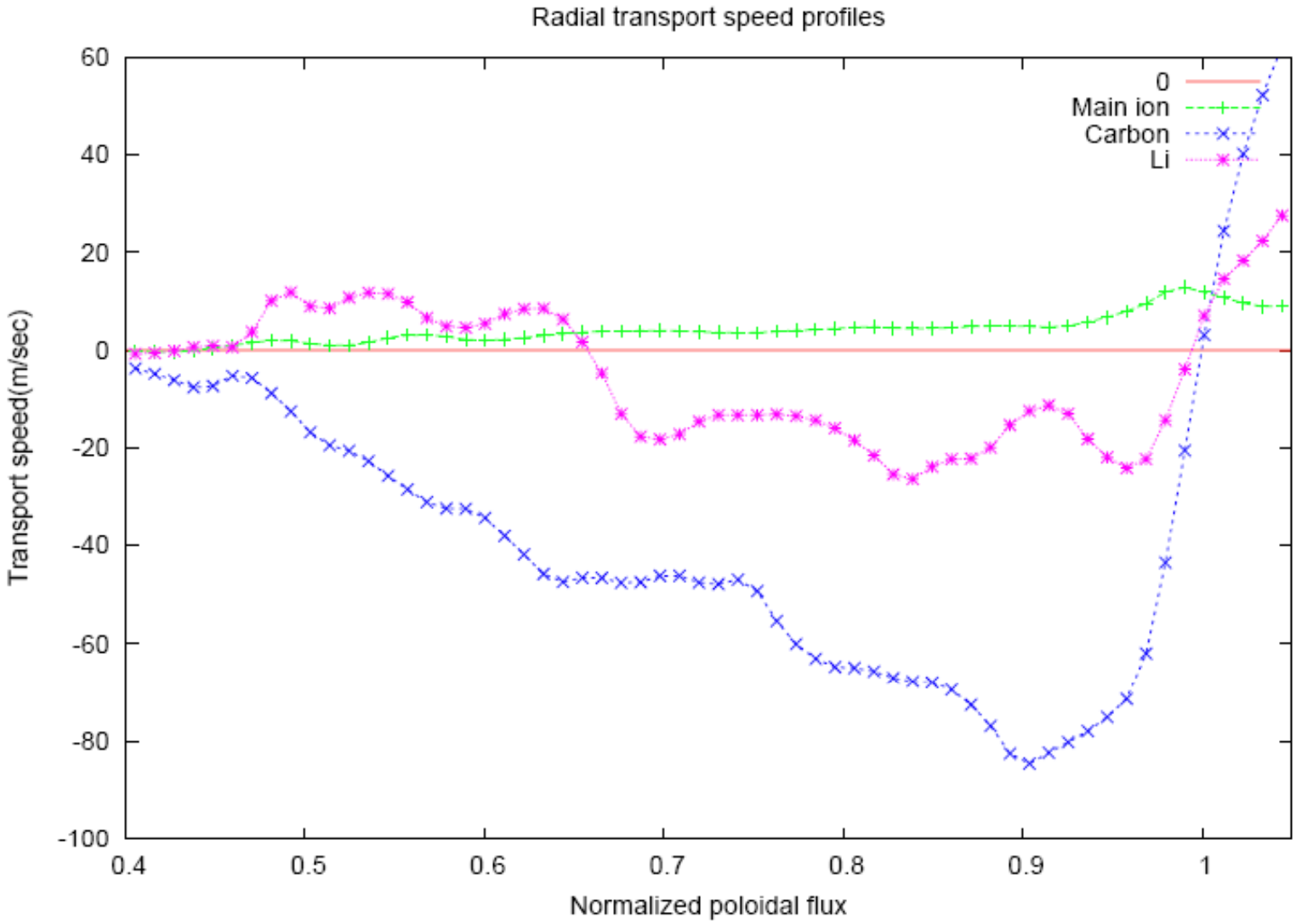
$N_e(r,t)$ in the simulation



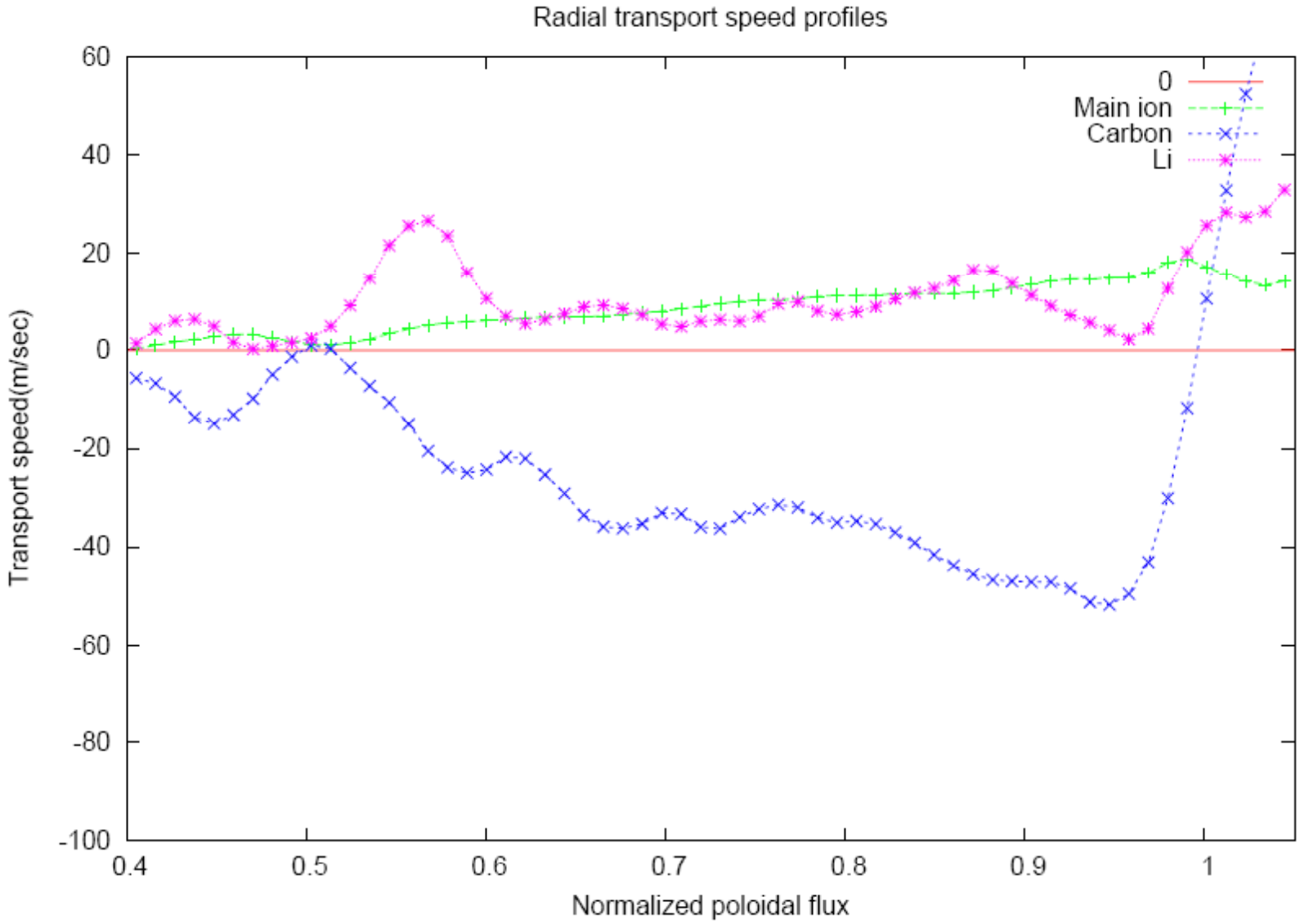
$T_i(r,t)$ in the simulation



At 5% n_C/n_e, Li moves inward at much slower speed than C.

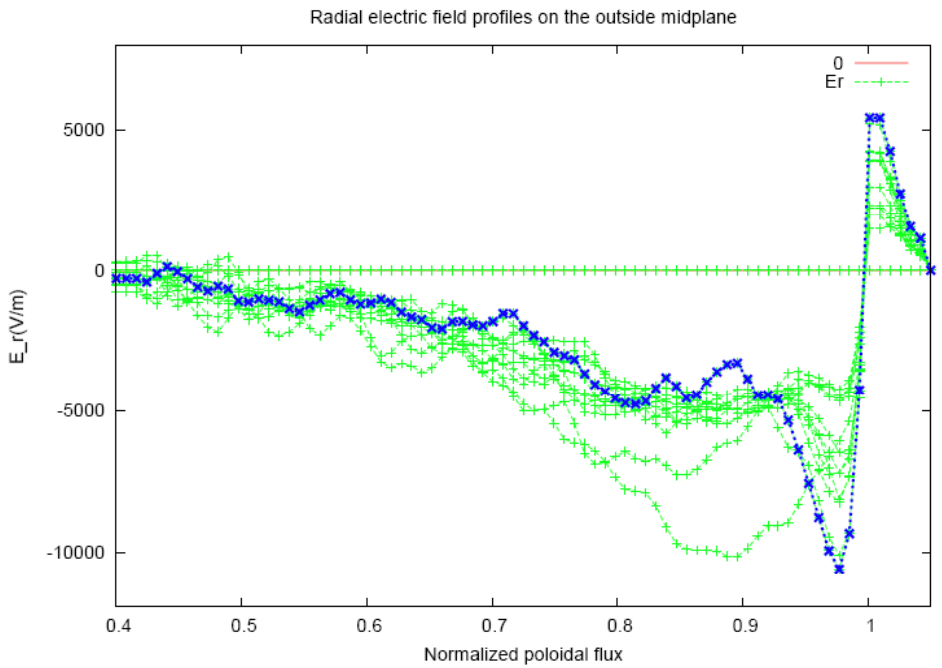


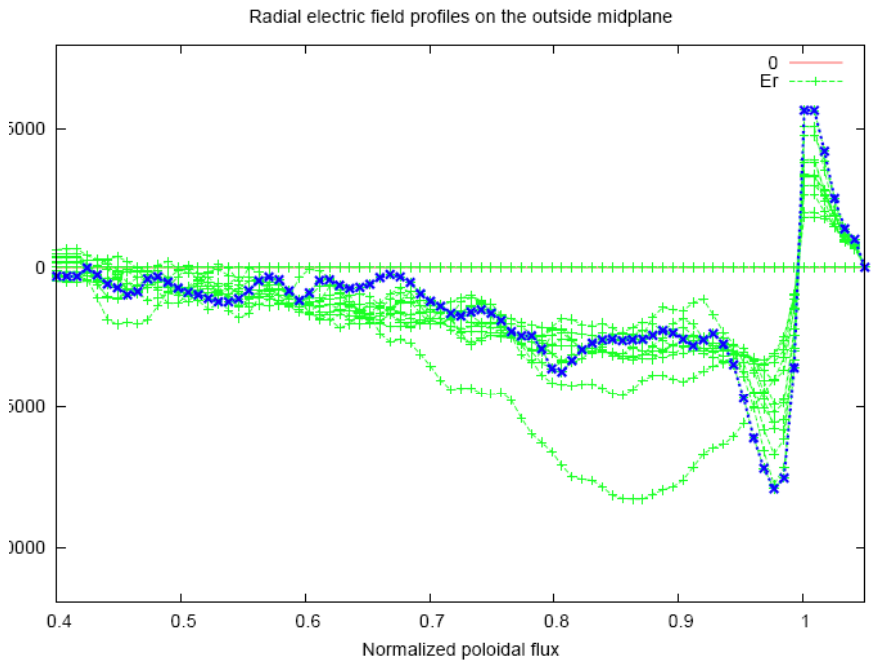
At n_C/n_e=10%, Li even moves outward.



Impurities affect the E_r-well depth.

E_r-well depth at n_C/n_e=10% is weaker than that at 5%
($m^{-1/2}$ vs Z^{-1} in X-loss)





Physics with conclusion

- 5 species full-f neoclassical particle simulation in XGC0: D^{+1}, e^{-} , D^{0}, C^{+6}, Li^{+3}
- Realistic NSTX geometry with separatrix and wall, and heat flux from core

- Neoclassical impurity transport is from momentum exchange between the ion species
- E_r also affects impurity transport (←edge effects)
- For C^{+6}, D^{+1} is the dominant background species
- For Li^{+3}, C^{+6} is the dominant background species
- C^{+6} moves in while D^{+1} moves out.
- Li^{+3} moves out relative to $V_r(C^{+6})$.
- As C^{+6} concentration increases, $V_r(Li^{+3})$ becomes positive

- More detailed experimental comparison to be performed