NSTX

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Study of Neoclassical Transport of High Z impurities

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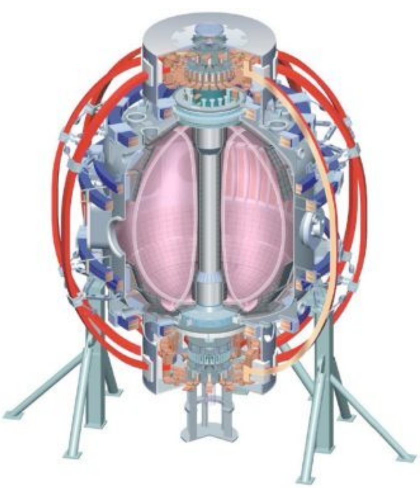
TK Gray, AG McLean and R Maingi
ORNL

NSTX Research Forum
Princeton, NJ
December 1—3, 2009



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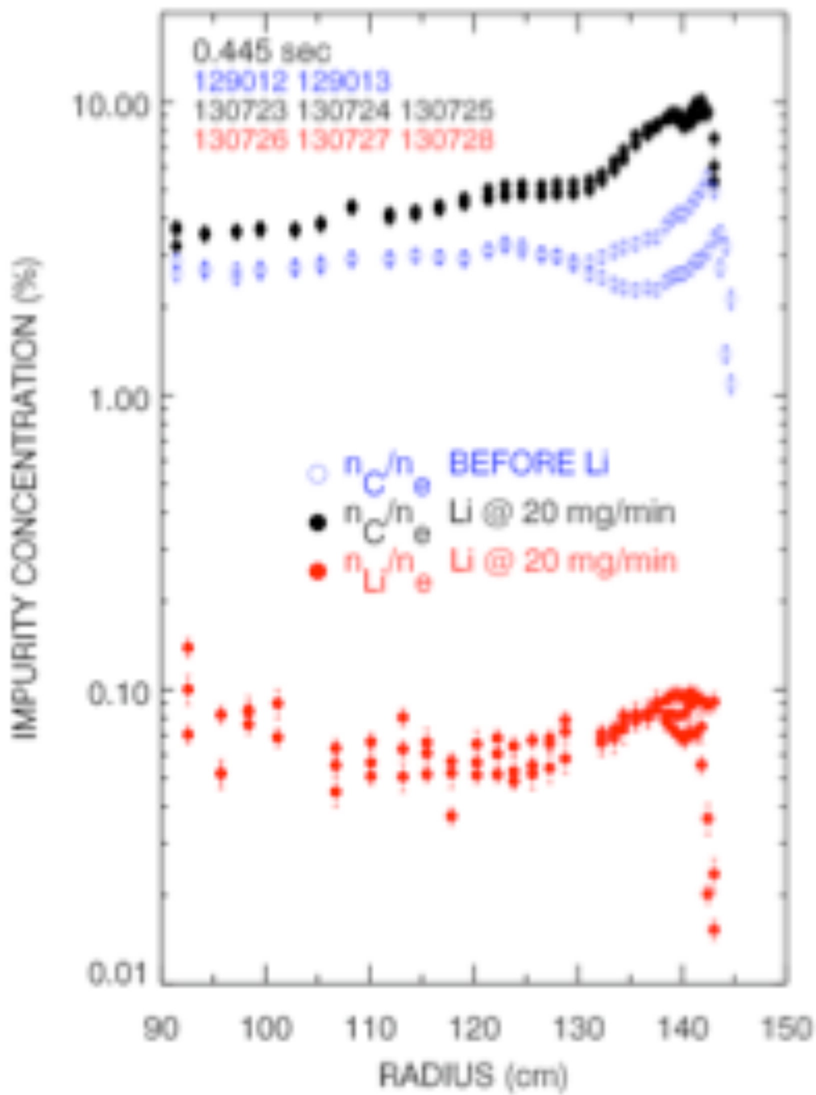
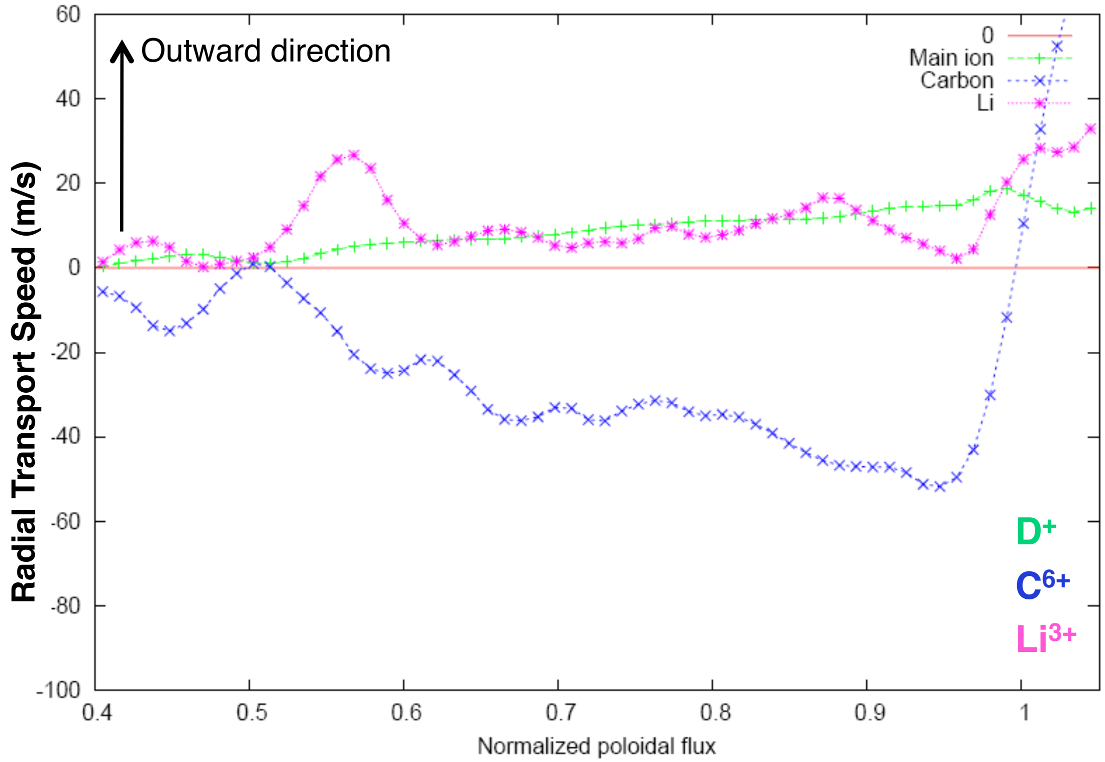
Understand the mechanism by which high Z impurities accumulate in NSTX discharges (R11-3)

- ELM-free NSTX lithium discharges show a large increase in impurity accumulation during the discharge
  - C, O and heavy metals (Fe)
- Multiple mechanisms by which impurities could be accumulating
- Predicted by XGC0 modeling of edge plasma
  - Neoclassical transport only
    - Anomalous transport is turned off
  - Preliminary results provided by CS Chang (publication forth coming)



Proposed Transport Mechanism from XGC0

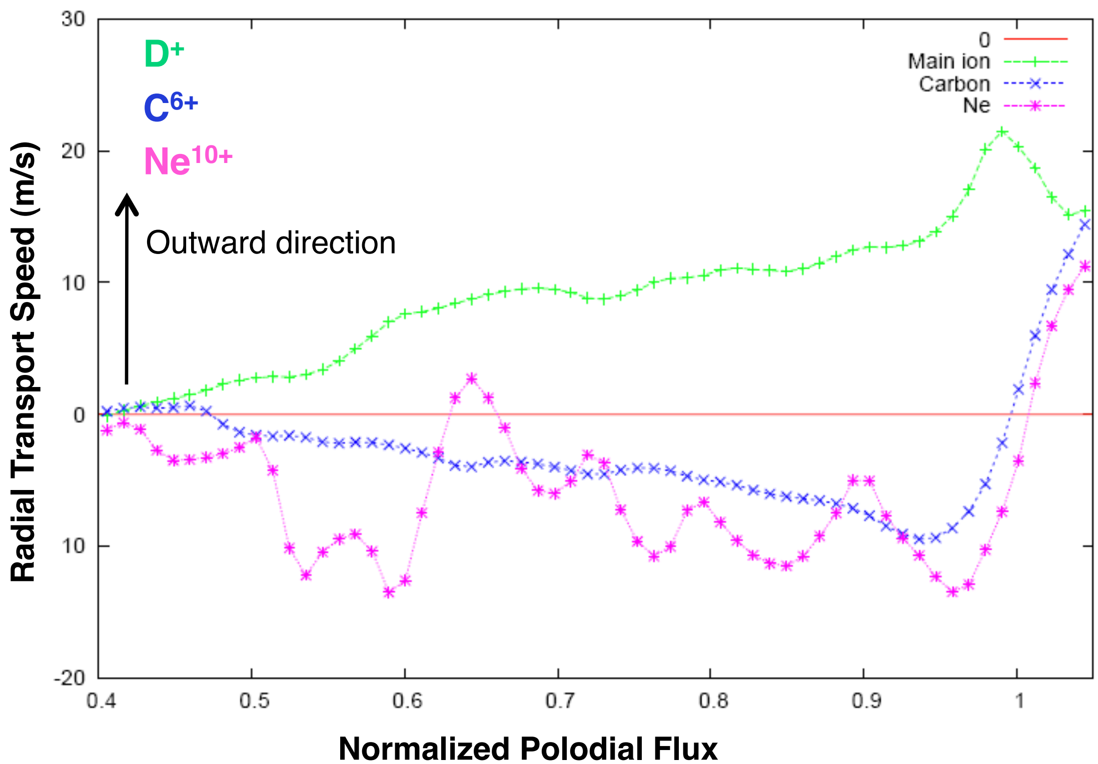
- Momentum exchange between heavy and light ions
  - Lighter species see the heavier impurities species as another pitch-angle scattering source
    - Acts to enhancing the radial outward transport of light ion
  - For the heavier species, collisions with the lighter species result in drag force without much pitch-angle scattering
  - Due to momentum conservation, the heavier species move inward



The result is that lighter Li^{3+} ions act to "push" C^{6+} into the core

The Addition of Neon Impurity Ions Act to Retard the Radial Transport of C to the core

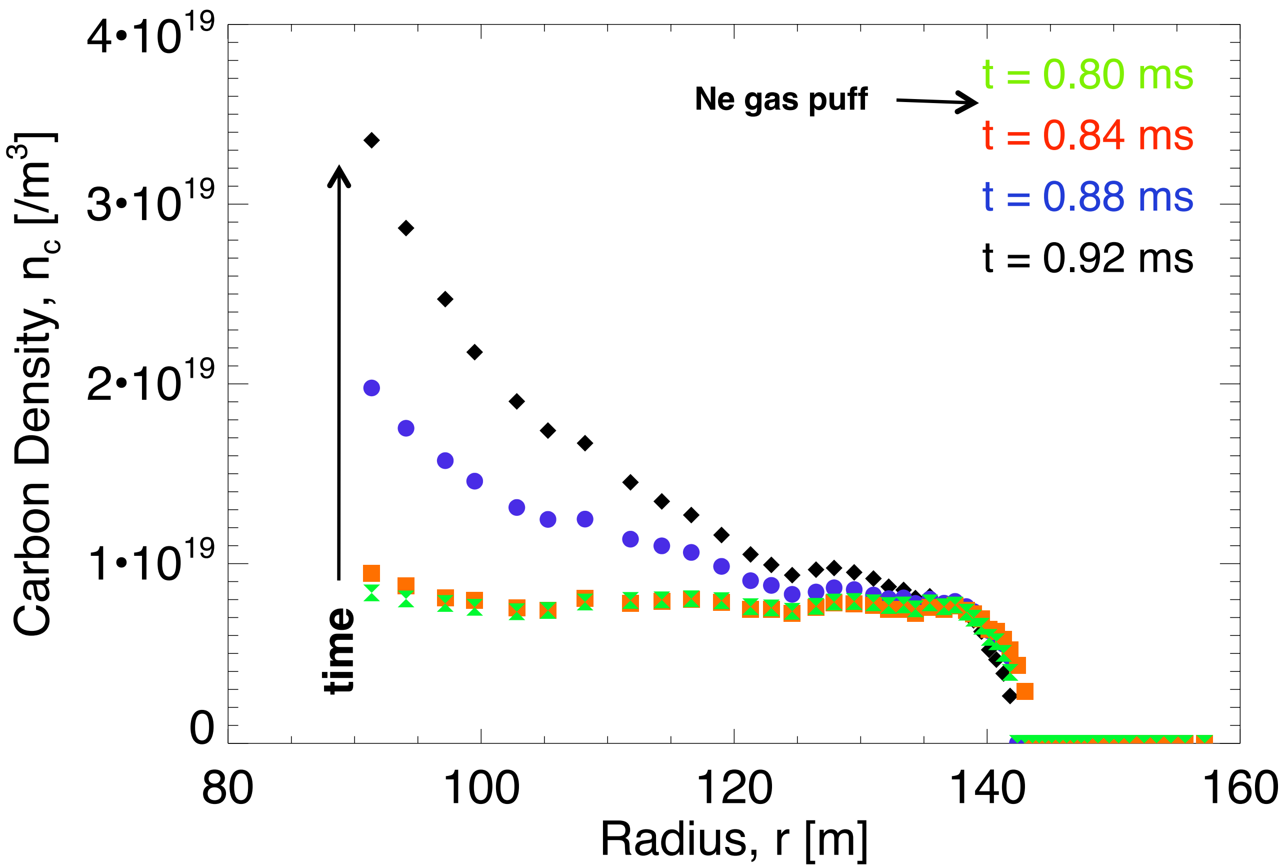
- Net result is a lower concentration of carbon in the core
  - At the cost of adding neon ions
- Goal is to understand the mechanism by which carbon is being transported inward



- This XP can be used to verify XGC0 simulations of impurity transport
  - Lead to a strategy to mitigate core impurities in the future

Preliminary Analysis of JHU Shots Doesn't Look Promising

- D'oH!
- Shot # 134095
  - Large neon puff @ ~ 0.8s
  - Varying amounts of lithium through out XP
- Increase in n_c seen directly after neon gas puff
  - Increased sputtering of graphite due to neon?



~~Propose dedicated XP to study Impurity transport~~

- Supports an integrated Modeling/Experimental Effort in understand impurity transport in NSTX
  - XGC0 model of neoclassical impurity transport
  - Better understanding of the mechanism of high Z accumulation in core plasmas
- Continue to analyze previous data
  - Continue collaboration with CS Chang and XGC folks to refine model
  - Piggyback on XPs this run campaign if anyone else uses high-Z gas puff injection
- Don't typically measure neon with available diagnostics
  - CHERS
    - Look for a reduction in n_C/n_e with gas puffing
    - While Z_{eff} increases or remains constant due to presence of neon
  - SWIFT for change in C ion velocities?

Back-up Slides for XGC0 Details

XGC0: Kinetic transport modeling code
(Courtesy of CS Chang)

– 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
– XGC0 Reference: Park G Y, et al. J. Phys. Conf. Series 78, 012087 (2007)

Kinetic neoclassical impurity transport simulation

- Anomalous transport is off → Purely Neoclassical
- Simulation domain: ψ_N=0.4 to wall in realistic g_eqdsk geometry (g124439.00497)
- 5 species: D^{+1}, e^- , D^0, C^{+6}, Li^{+3} or Ne^{+10}
- C^{+6} and Li^{+3} or Ne^{+10} are born at fixed fraction to n_e.
- Large initial C^{+6} density (10% uniform) and small Li or Ne density (1/3% uniform)
- Initial temperatures are assume to be equal between species.
- Simple neutral-plasma atomic interactions (CX and Ionization)
- Self-consistent E_r-$v_{||}$ with the impurity and edge effects (wall, X-point, neutral, pedestal, etc)

- Radial transport speeds are calculated while the initial profiles are being evolved.