Results of multi-fluid transport simulation in the edge and SOL of NSTX

A. Pigarov

University of California at San Diego

Acknowledge: R.Maingi, T.Rognlien, V.Soukhanovsky, S.Krasheninnikov, D.Stotler

Outline

- In/out asymmetry of radial profiles of Ne and Te and q_{plate}
- Transport coefficients in NSTX vs. DIII-D and C-Mod
- Impurity transport including intermittent convection
- Radiation opacity, plasma flows, Dα profiles

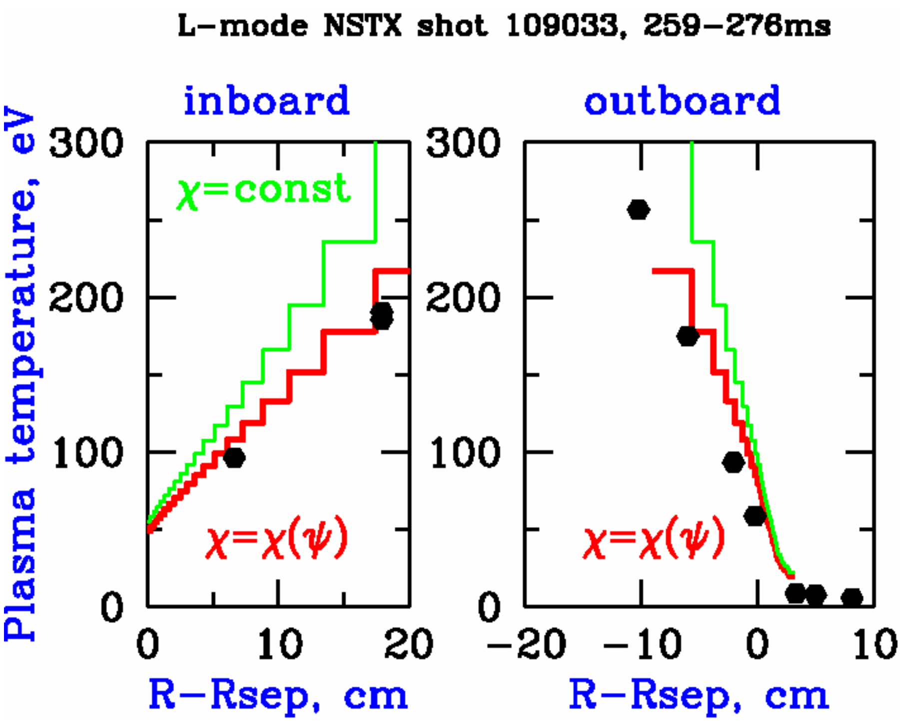
Presented at NSTX Research Results Review, PPPL, Princeton, September 20-22, 2004

Motivation

1) Study the effect of intermittent non-diffusive transport on macroscopic plasma parameters in NSTX, in particular, on in/out asymmetries, main chamber/divertor recycling, impurity sources, radiation, etc.
2) Being a low-B small-R machine, NSTX already provides unique data on edge transport and valuable for cross-tokamak comparison.
3) Compare and contrast NSTX experimental data with edge-physics code **UEDGE**.
4) NSTX diagnostics involved in the UEDGE analysis are Thomson, pressure gauges, CHERS, IRTV, interferometers, Da CCD array. We plan to add simulation of Langmuir and reciprocating probes and bolometer arrays.

Anomalous transport coefficients $D_\perp$, $\chi_\perp$, and $Vconv_\perp$ vary radially in the ψ_N-space

$$\Gamma_\perp(\psi,\theta) = -D_\perp(\psi,\theta)\, \partial n/\partial r + n\, V_\perp conv\,(\psi,\theta)$$



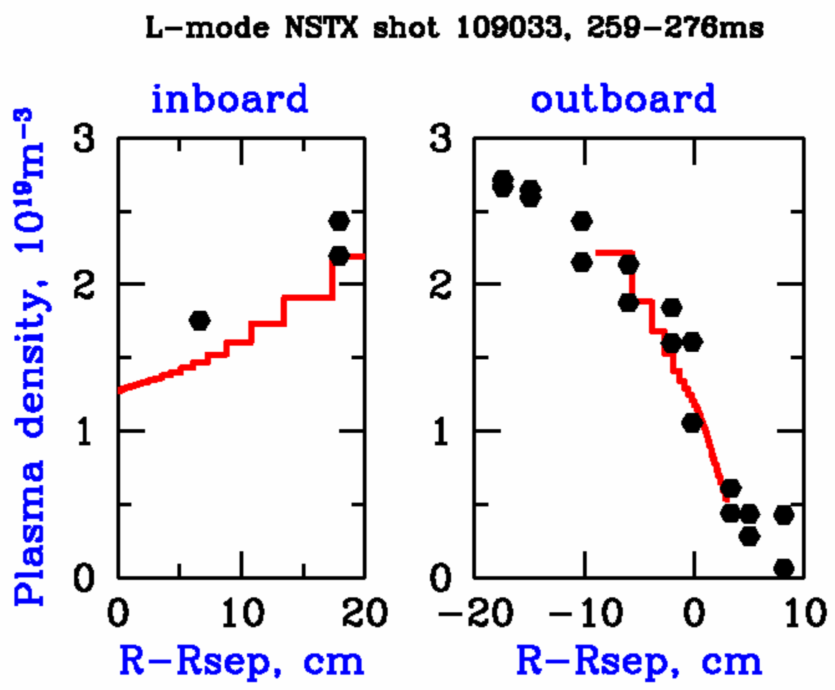
$D_\perp$ is a weakly increasing with ψ . It is typically around 0.6m^2/s at ψ=1.

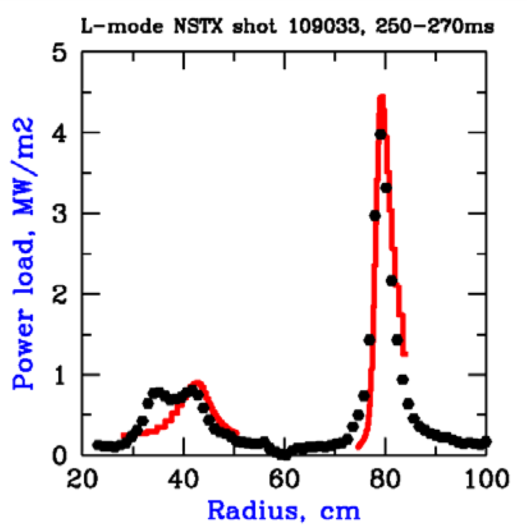
$\chi_\perp$ is strongly decreasing function by factor 2-3. In L-mode, typically χ=15-20 m^2/s at ψ=0.7.

Vconv strongly increases with ψ (in L-mode, from zero at ψ=0.7 to 40m/s at ψ=1 and further to 200m/s at the wall.

Vconv also varies poloidally by 3X and is peaked at outer mid-plane.

Important features of NSTX edge plasma are well reproduced with UEDGE



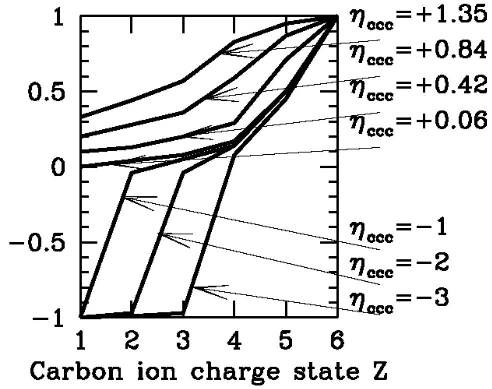


1) Intense gas puff provides deep core plasma fueling at the rate higher than NBI fueling rate consistent with observed core density increase

2) Strong in/out asymmetry in radial plasma profiles and in plasma heat flows

3) Far-SOL shoulders and large mid-plane pressure indicative of significant main chamber recycling

In NSTX, the direction of impurity ion anomalous convection has strong impact on edge plasma

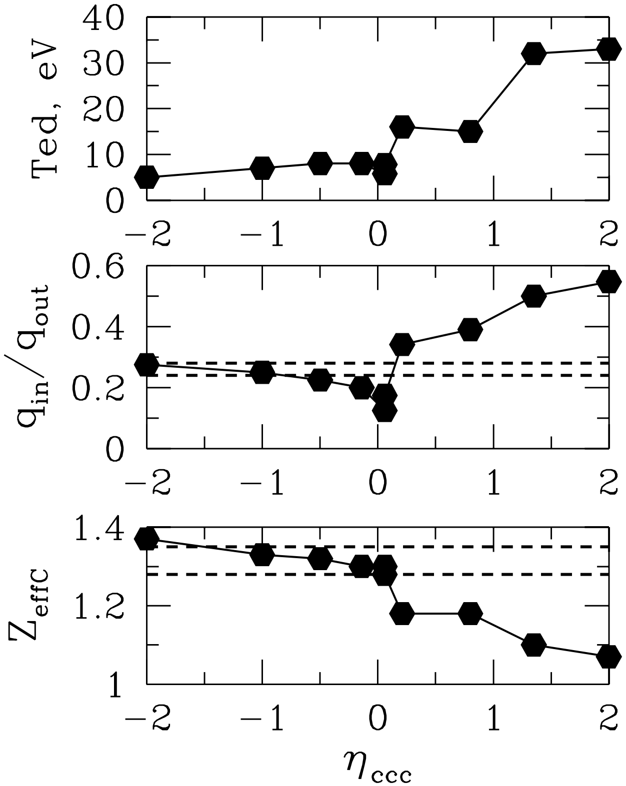


Velocity of impurity ion with charge state z:

$$\mathbf{Vconv(\psi,\theta, z) = V^{[D+]}conv(\psi,\theta)\ A(z)}$$

-1<A<1 is the amplitude factor, **A(6)=1**

Continuous parameter: η_{CCC}=A(1)+A(2)+A(3)



The weaker the carbon atom penetration into SOL, the stronger should be the inward impurity ion convection

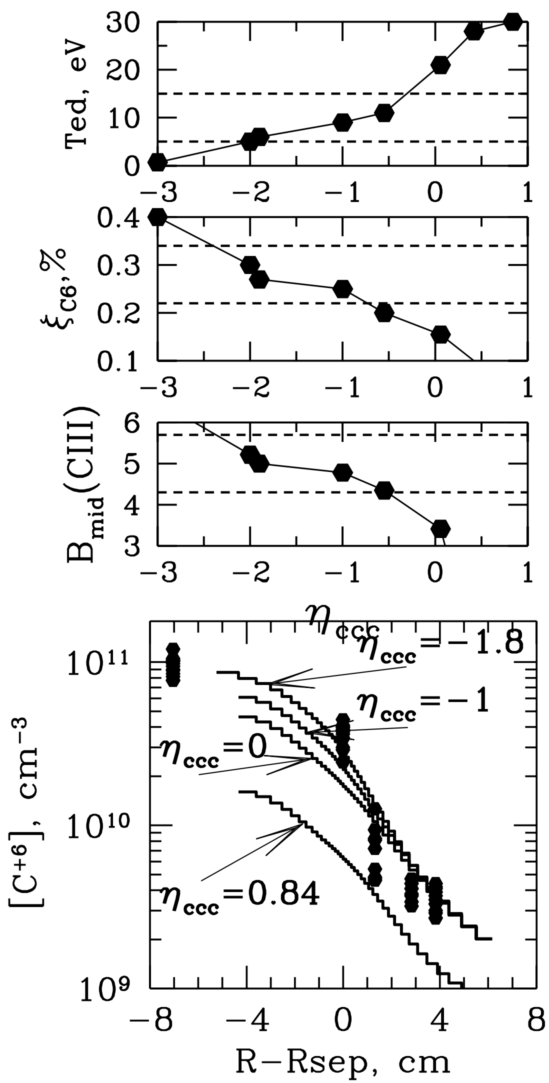
The more ion charge states are directed inward, the closer is the divertor to detachment.

Major parameters are matched at

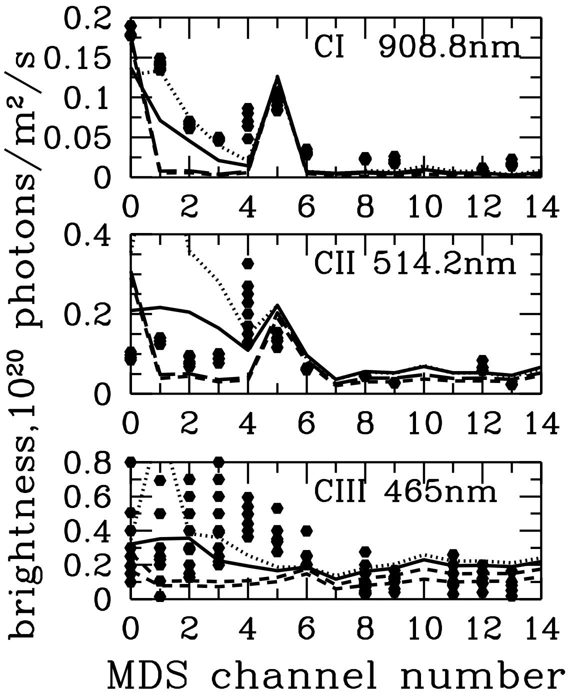
$-2<\eta_{ccc}<-0.5$

ie low charge states are convected inward

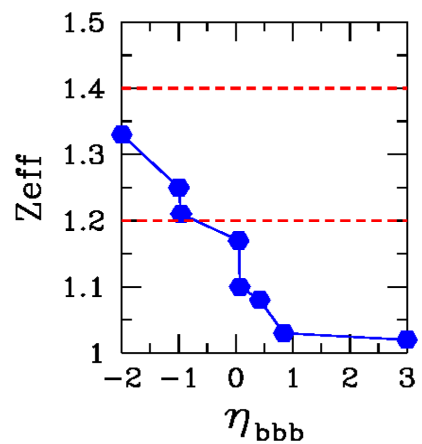
The same convective impurity model has been successively applied to simulate DIII-D and C-Mod



DIII-D



C-Mod

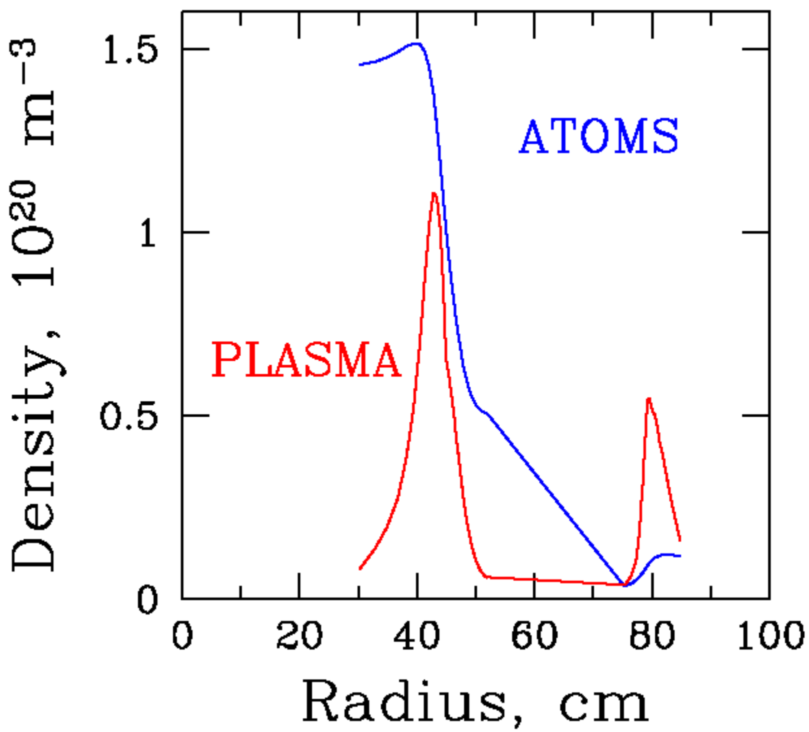


The best fits to measured L-mode data:

$-2<\eta_{CCC}<-0.5$

for a wide range of discharge densities

In NSTX, inner divertor plasma is predicted to be strongly opaque to Ly-α radiation



Neutral density is high **>10^{20} m^{-3}**

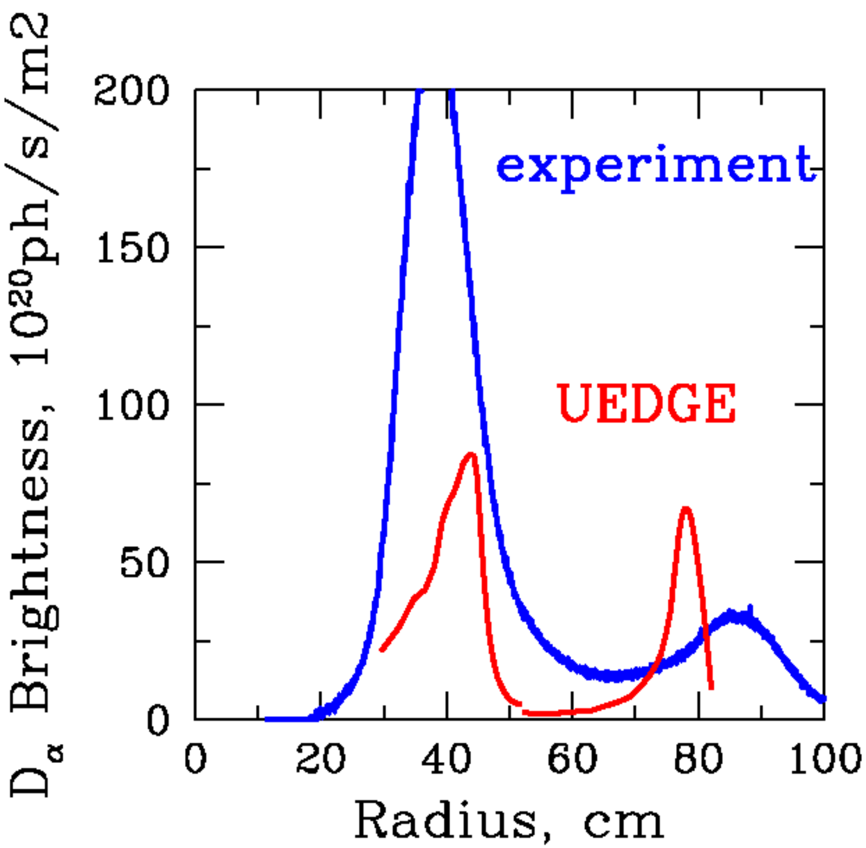
Characteristic size of opaque region **20x5 cm**

Ly-a photon mean free path is **1-2 mm !!!**

Ly-a radiation is strongly trapped and must have an effect on the entire edge plasma region

Same opacities and q_{peak} as expected in ITER can be attained in the NSTX at relatively low discharge densities.

D-α profile is likely affected by Ly-α radiation transport



Interpretation of D-a CCD measurements in NSTX with UEDGE code is challenging

Detachment of inner divertor does not produce the observed strong asymmetries in D-a profile

Ly-a radiation transport as well as the parallel plasma flows (due to fast radial transport and drifts) can affect the in/out asymmetries.

UEDGE improvements and more simulations are needed

Conclusions

O Our multi-fluid simulations of L-mode edge plasma show that fast non-diffusive intermittent plasma transport, which is modeled as anomalous outward convection, is the dominant far-SOL transport mechanism in NSTX (as well as in other tokamaks, e.g. C-Mod and DIII-D).

O In NSTX modeling the best agreement between the calculated and experimental data gives the impurity cross-field transport model in which anomalous cross-field convection dominates in SOL transport, the background plasma ions and high charged impurity ions are convected toward the wall, while the lowest charged impurity states are convected toward the core plasma.

Conclusions (Cont.)

O The following range **$-2<\eta_{CCC}<0.5$** is found for L-mode shots in NSTX as well as in DIII-D, and C-Mod

O Impurities from wall can cause significant contamination of core plasma if SOL impurity transport is fast and non-diffusive

O Core plasma may be fueled by chamber wall recycling even in the inner divertor is detached.

O Inner divertor plasma is opaque to resonance deuterium radiation

O More work is needed to understand the Ly-a radiation transport as well as the parallel plasma flows (due to and fast radial transport and drifts) and their effect on the in/out asymmetry.