Modeling of Li experiments in NSTX

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UEDGE model was updated

Fluid 2D transport of all charged states of D, Li and C simultaneously

Sources due to Li evaporation and sputtering at plates and walls

Sources of C at plates/walls that mimics sputtering and evaporation

Atomic physics on Inter-species interaction

Input parameters: ->recycling coefficient at material surfaces
->Distribution of surface temperature on plates (for Li source)

Simulated plasma conditions

NSTX discharges with Li evaporation

Shots: #129041 (3MW) @480ms
#129019 (4MW) @450ms

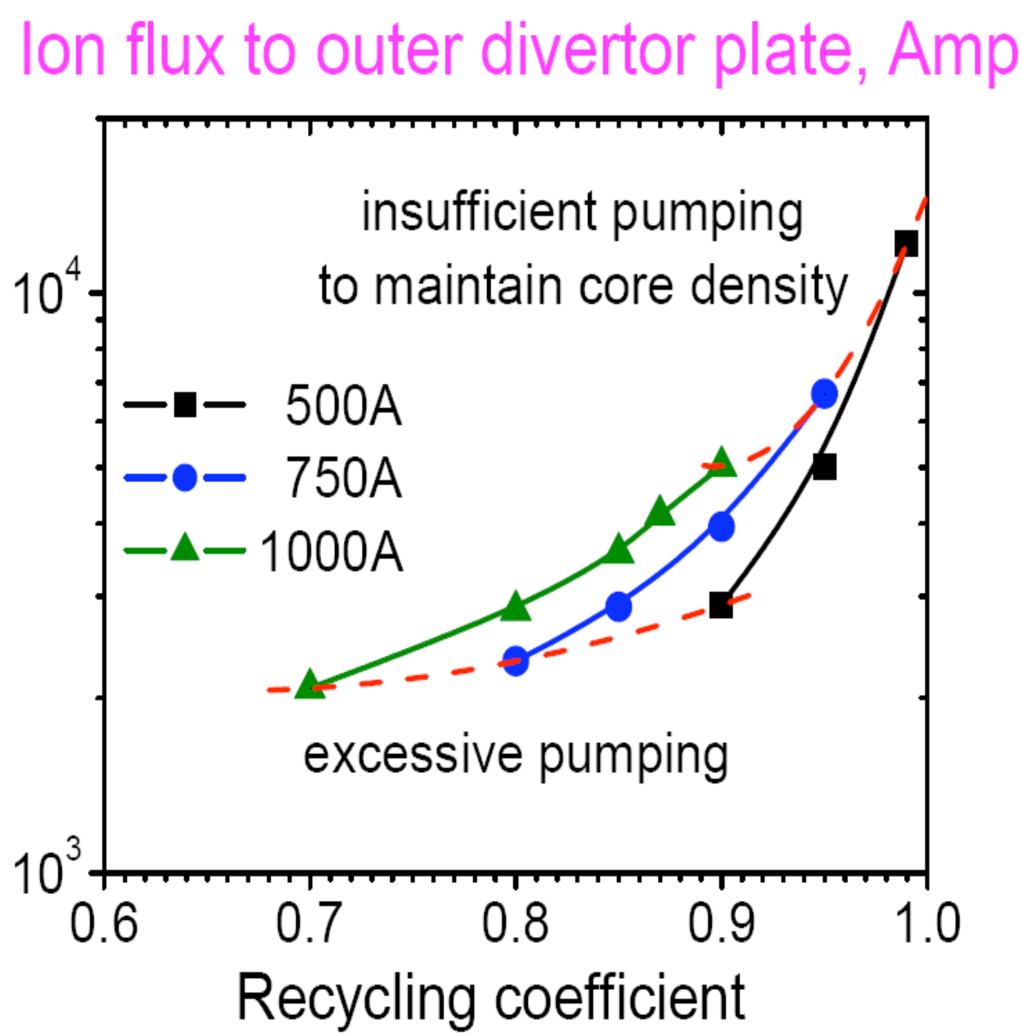
Gas puff = 850 Amp

Core interface density = 5 10^{19} m^{-3}

Ion flux into the core = 50 Amp (according to ne_bar increase rate)

Separatrix density <= 10^{19} m^{-3}

Effect of Li pumping on ion flux



Li pumping substantially decreases the ion flux to plate.

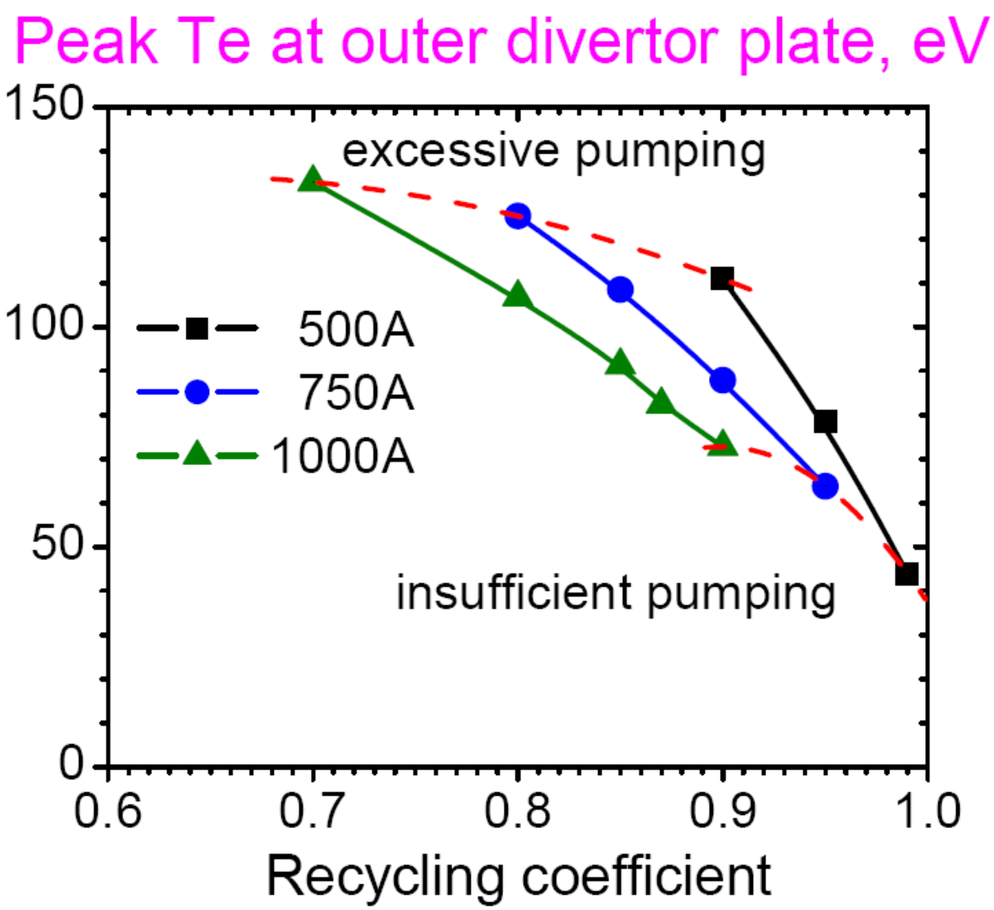
For R~0.8, ion flux is ~2KAmp, comparable to ion flux on wall

If ~20% of D+ is pumped by Li coating, the gas puff rate should be >800Amp

High values of recycling coefficient may be inconsistent with core density at given gas puff rate

Low Recycling Regimes

Effect of Li pumping on divertor temperature



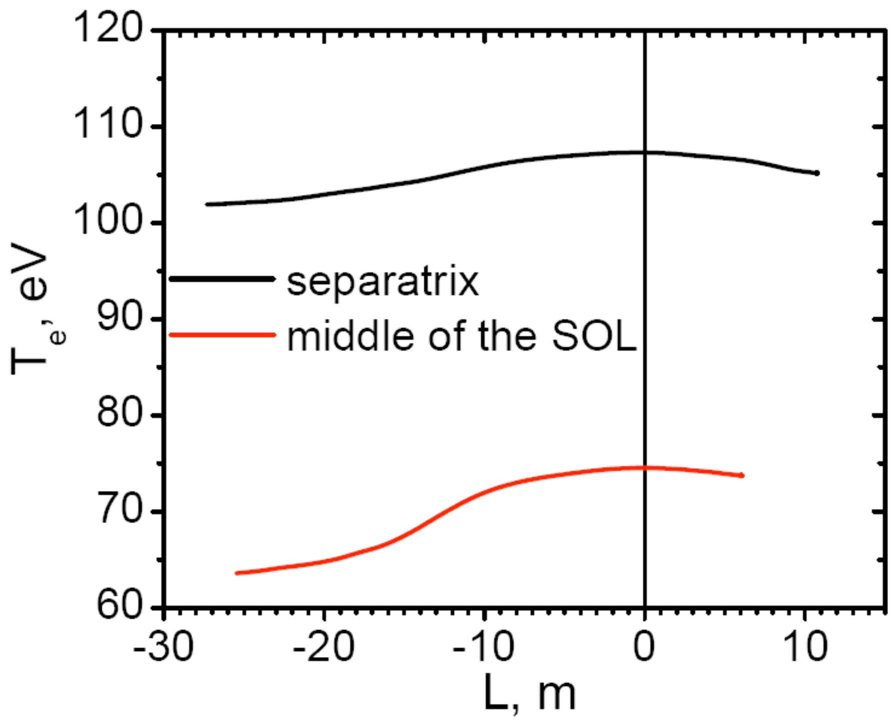
Electron temperature at plate is peaked near separatrix

The higher the Li pumping (smaller R), the higher is the peak Te at plate

For R<0.95, Te>50 eV !

Small Te (<20eV) may mean small Li pumping

Low Recycling results in Sheath-limited outer divertor plasma regimes



Because of low upstream density and high Te, the electron mean free path is small

$mfp(m)=2\ 10^{10}\ [T(eV)]^2/<ne(cm^{-3})>$

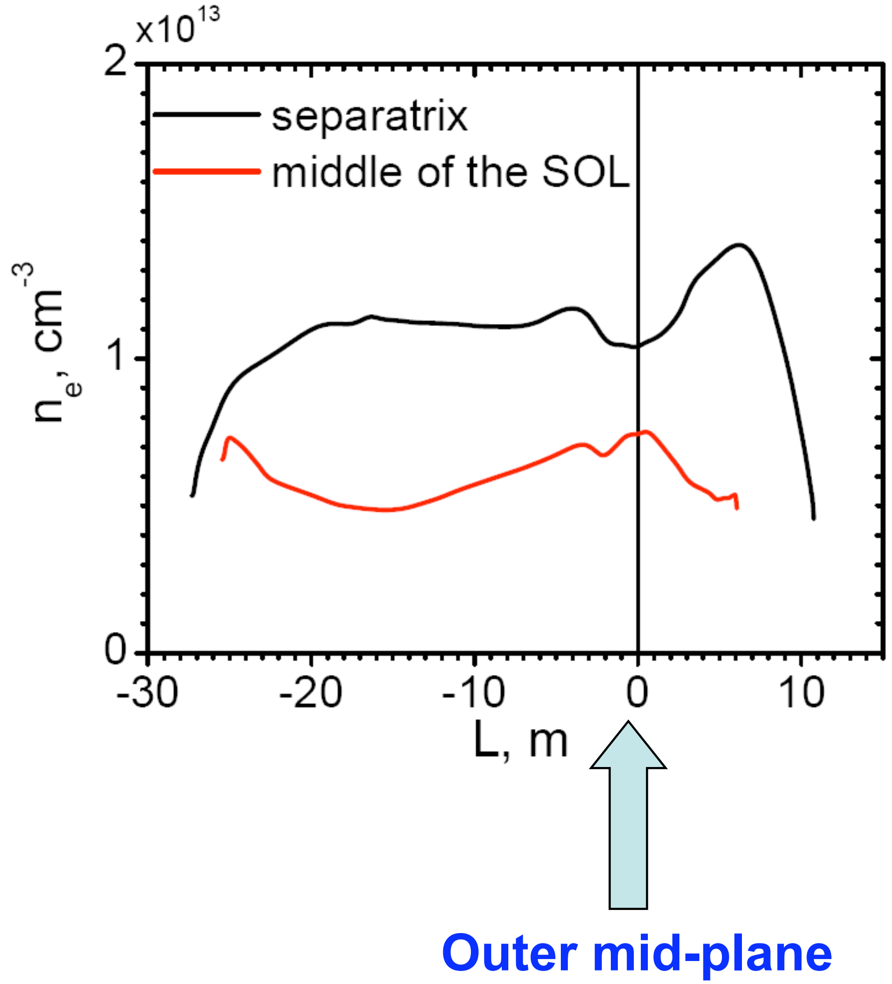
For Te=100eV ne=10^{13} cm-3
mfp=20m

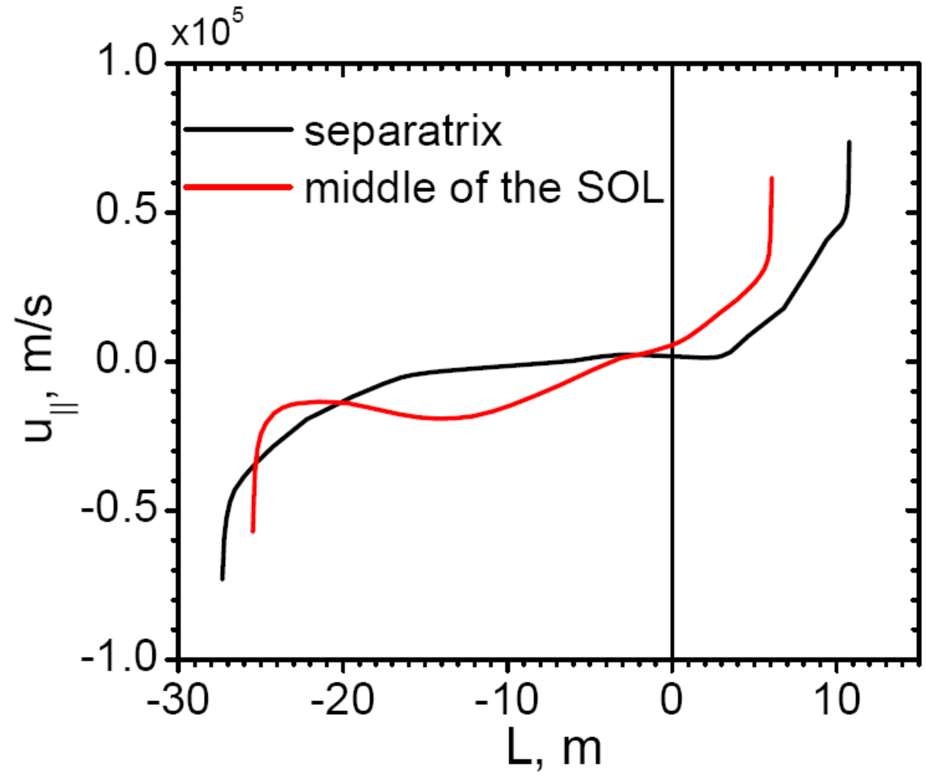
Mfp exceeds the connection length to the outer divertor plate and mid-plane (10m)

Te at plate is determined by plasma sheath transmission

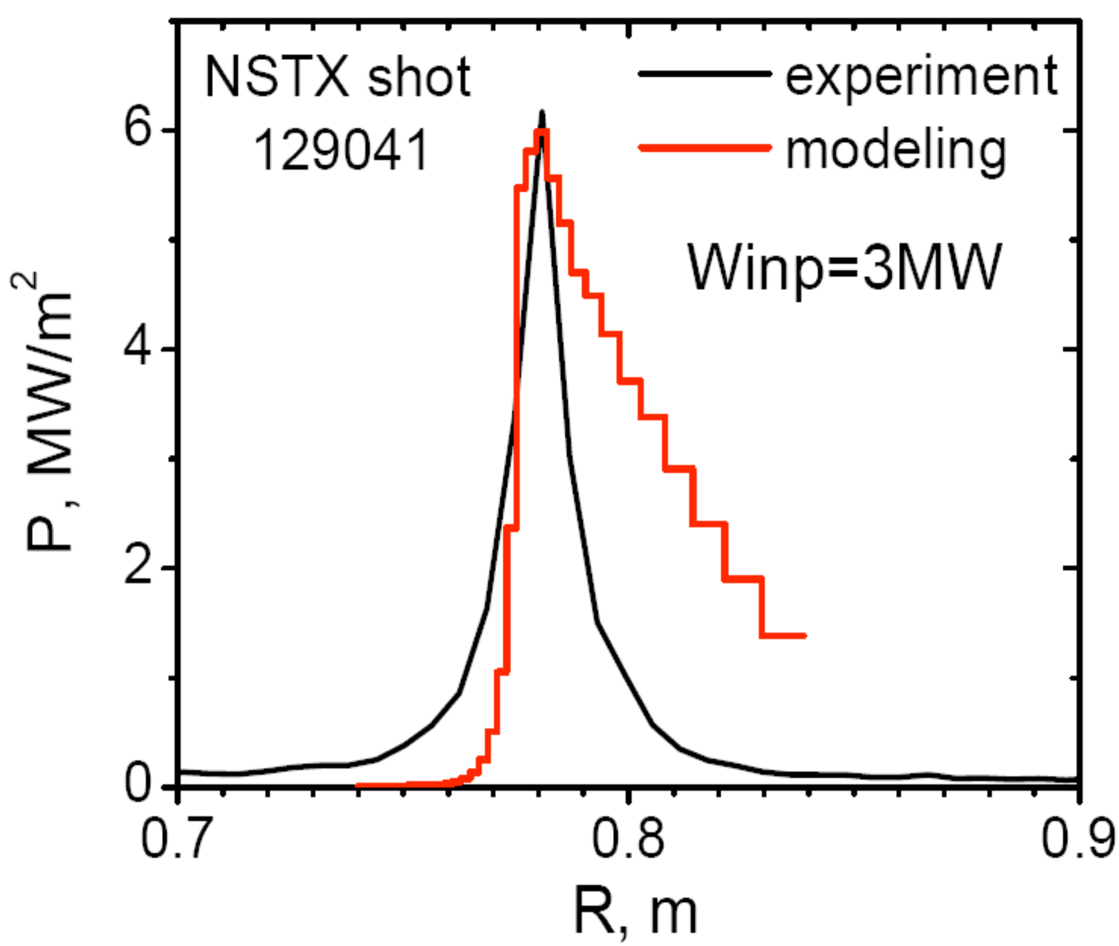
Te distribution along the magnetic field line is rather flat

In LRR plasma density may decrease towards the plate since parallel plasma velocity increases





Heat flux to plate in low recycling regime



Heat flux is from electrons. Flux limited parallel heat conduction

Peak heat flux to outer plate can be consistent with experimental one

Calculated total power is much larger than experimental.

Low recycling is main chamber + gas puff recycling regime

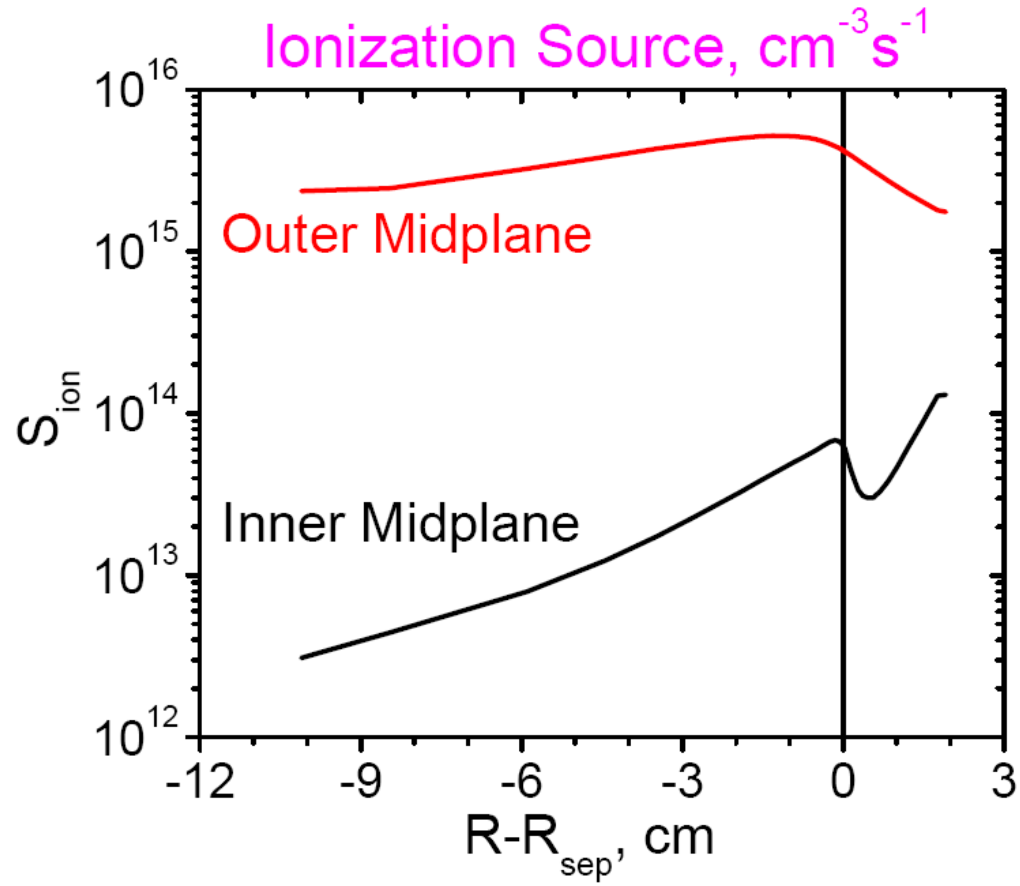
Gas puff rate = 800 Amp

Ion flux to outer wall
=1600 Amp

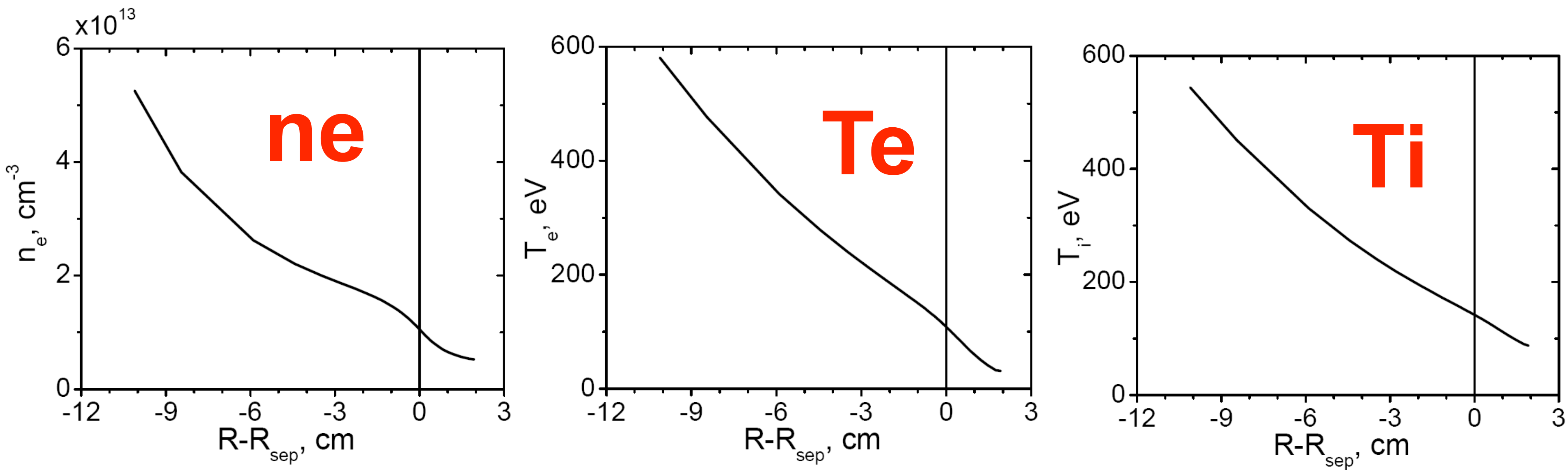
Ion flux to divertor plates =
3000+1800 Amp

Comparable!

Divertor is still opaque to
neutral penetration from
plate,
but SOL is transparent



Radial plasma profiles in LRR

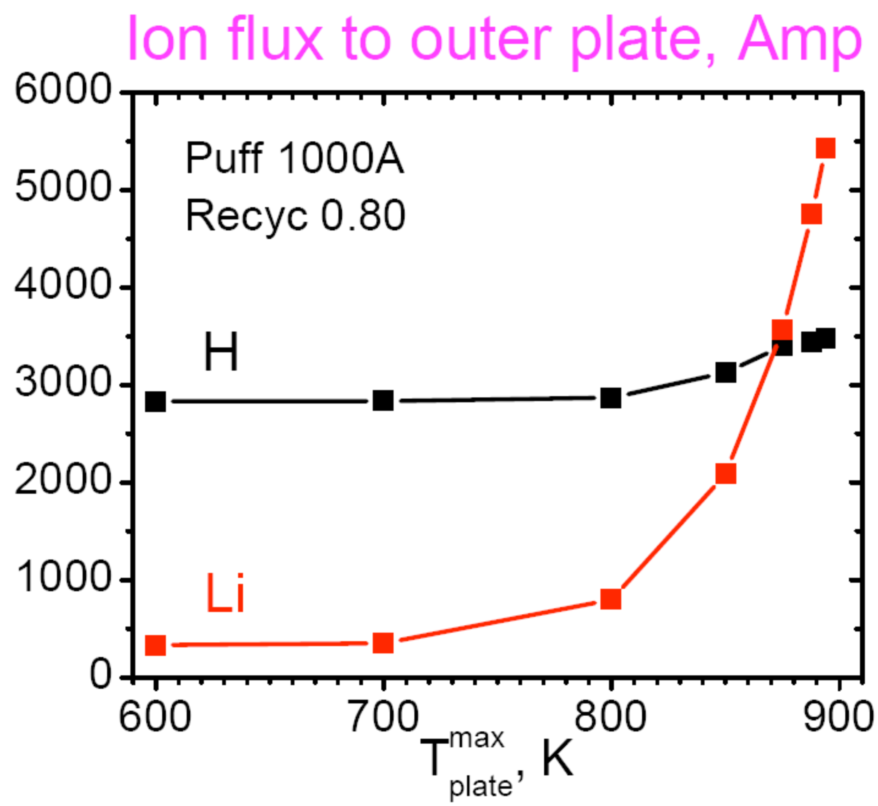


Calculations were done Low Recycling Regime for shot 129041.

Separatrix density is maintained at 1019m-2 level by gas-puff and main chamber recycling

Experimental data show much lower density ne~5 $10^{18}m^{-3}$ and lower Te<50eV and much higher Zeff near separatrix, starting at about R-Rsep~ -3 cm.

Effect of Li evaporation on divertor recycling



Recycling coefficient of Li on Li plate was taken =0.5

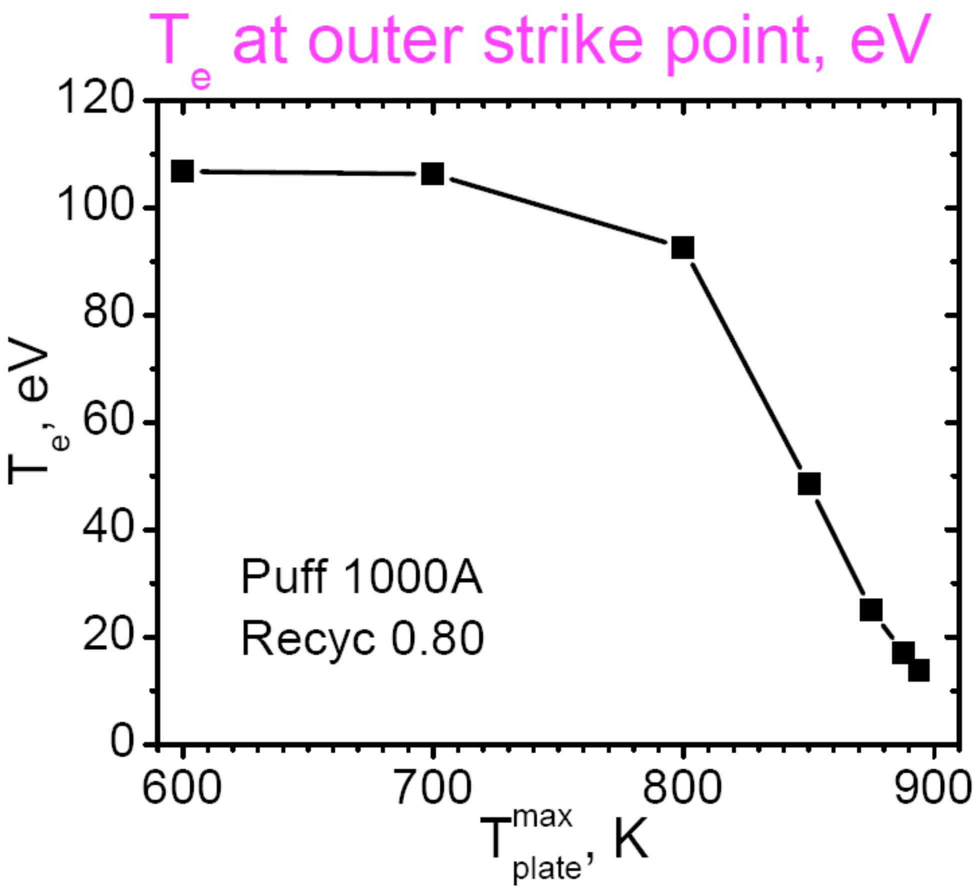
We assume asymmetric Gaussian profile of surface temperature Tplate profile on plate with peak located in the strike point and HWHH to be 2 times wider than that for heat flux.

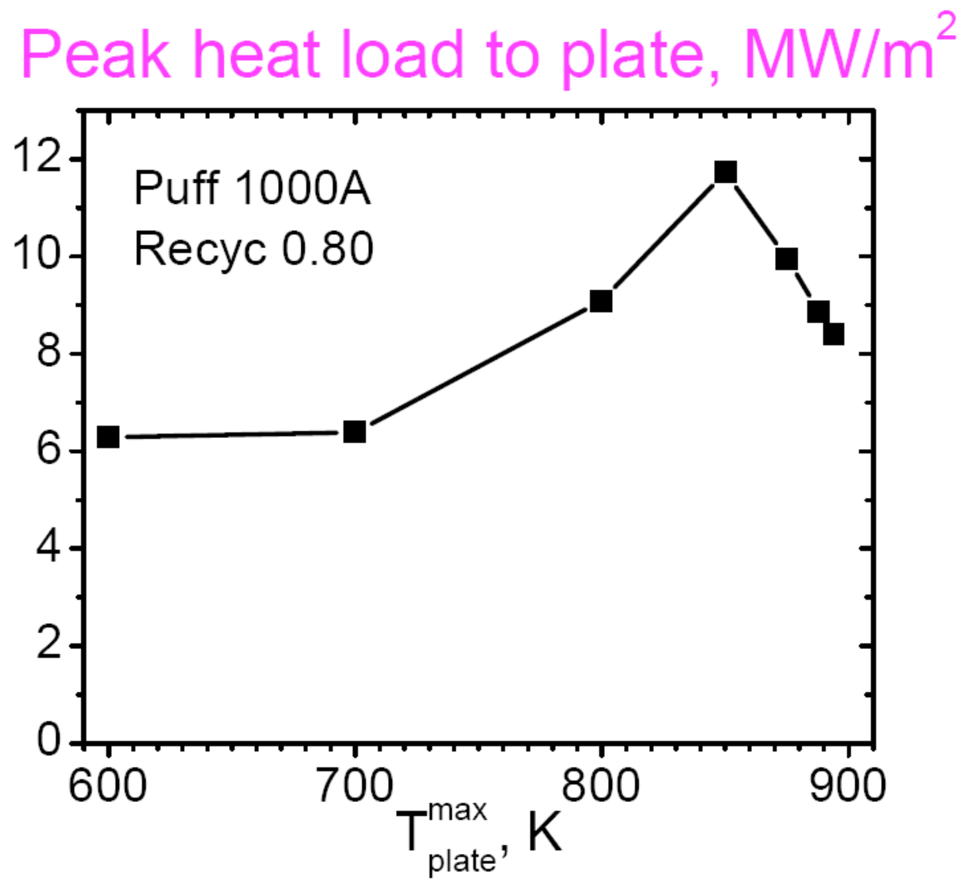
Scan the values of peak Tplate

For low surface temperatues Tplate<850K the Li impurity flux is less than the D+ flux to plate.

Li particle recycling becomes strong when Li stats to substantially sublimate close to 900K

Transition from LRR to HRR and further to MARFE at Li sublimation temperatures





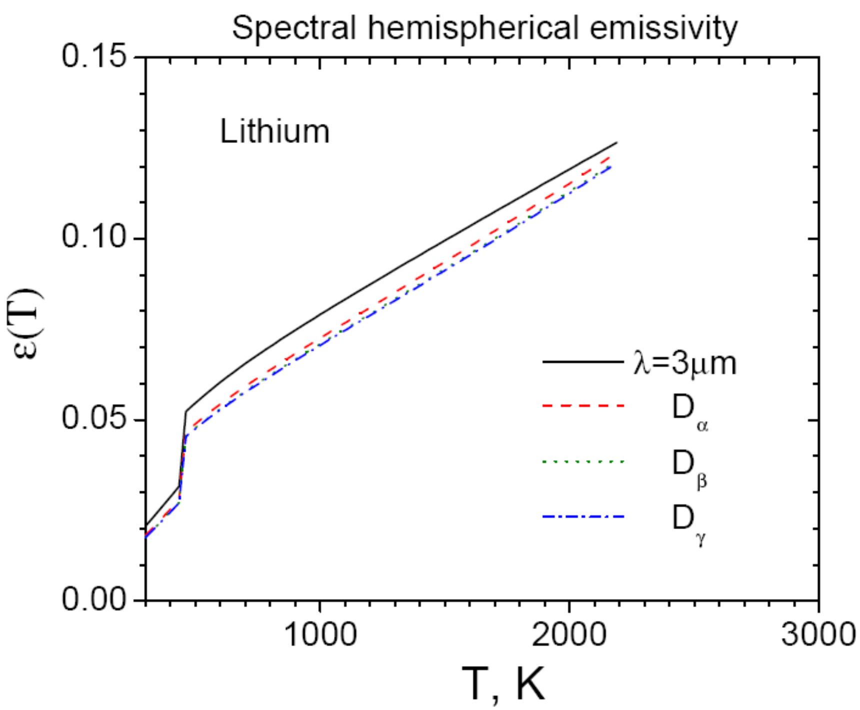
Conclusions

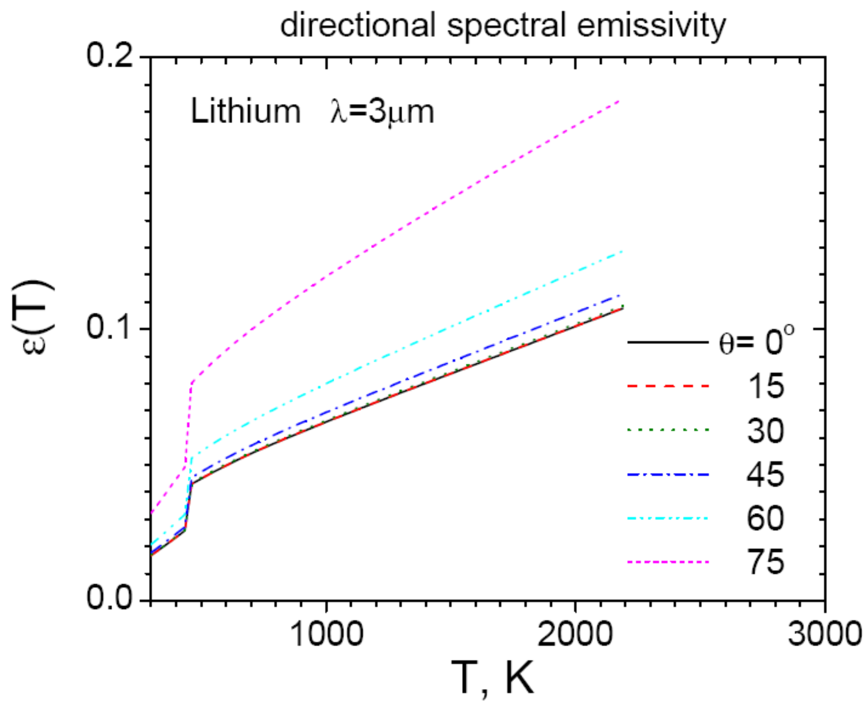
With UEDGE code we self-consistently model the plasma Li and C transport for NSTX divertor coated with Li.

We studied Low Recycling regimes showing the high-temperature and low separatrix density plasma formation in the outer divertor.

We showed that:
- peak heat power loads to plate are dominated by parallel electron heat conduction where that to wall is due to blobby plasma convection
- low upstream plasma densities results in the flat Te profiles along magnetic field lines and in a sheath-limited plasma condiondition at outer plate.
- ion flux to plates is small ~3KAmp for R<0.9 and the recycling is dominated by gas-puff and main-chamber recycle.
- Li impurities originating from Li coatings erosion and evaporation are well retained in the divertor region.
- high peak heat fluxes to plate ~10 MW/m2
- high surface (~900K) temperatures result in divertor transition to high recycling conditions due to excessive Li evaporation.

Li coating emissivity





Thermal emissivity of Li coating strongly increases with surface temperature and viewing angle

Melting of Li causes step-like transition in emissivity

Convolution is needed to determine properly the heat flux profile from surface temperature raise.