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# Simulations of Edge-Plasmas and Lithium Core Penetration for Low-Recycling Lithium Walls*

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Abstract Submitted
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Sorting Category: 5.9 (Computation/Simulation)

**Simulations of Edge-Plasmas and Lithium Core Penetration for Low-Recycling Lithium Walls**[1] T.D. ROGNLIEN, M.E. RENSINK, Lawrence Livermore National Lab, J.N. BROOKS, Argonne National Lab — The use of lithium for divertor and wall surfaces should substantially reduce the hydrogen particle recycling there. Consequently, the hydrogenic edge-plasmas will have lower densities and higher temperatures than the corresponding standard high-recycling cases. The higher edge temperatures may reduce core turbulence. Simulation results are presented from the 2D UEDGE transport code to quantify the changes in the edge-plasma as the recycling coefficient is varied. Another important issue for lithium walls is the intrusion of lithium ions from evaporation and sputtering into the core plasma. Self-consistent hydrogen/lithium edge-plasma transport calculations are performed to obtain the lithium concentration at the core-edge boundary arising from evaporation (for liquid lithium) and sputtering. Factors setting the allowable wall temperature are discussed. The near-plate sputtering fluxes from the divertor are obtained from the WBC test-particle code, which are then used as input for UEDGE to model the sputtered lithium transport in the remainder of the scrape-off layer.[2]

[1]Work performed for USDOE by Univ. Calif. LLNL and Univ. Chicago ANL under contracts W-7405-ENG-48 and W-31-109-ENG-38.

[2]J. Brooks, T. Rognlien, D. Ruzic, J. Allain, subm. to J. Nucl. Mater.

- [X] Prefer Oral Session
- [ ] Prefer Poster Session

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# Lithium walls and divertor plates can impact core performance

- Possible improvements due to modification of core-edge boundary

  - microturbulence and edge transport barriers

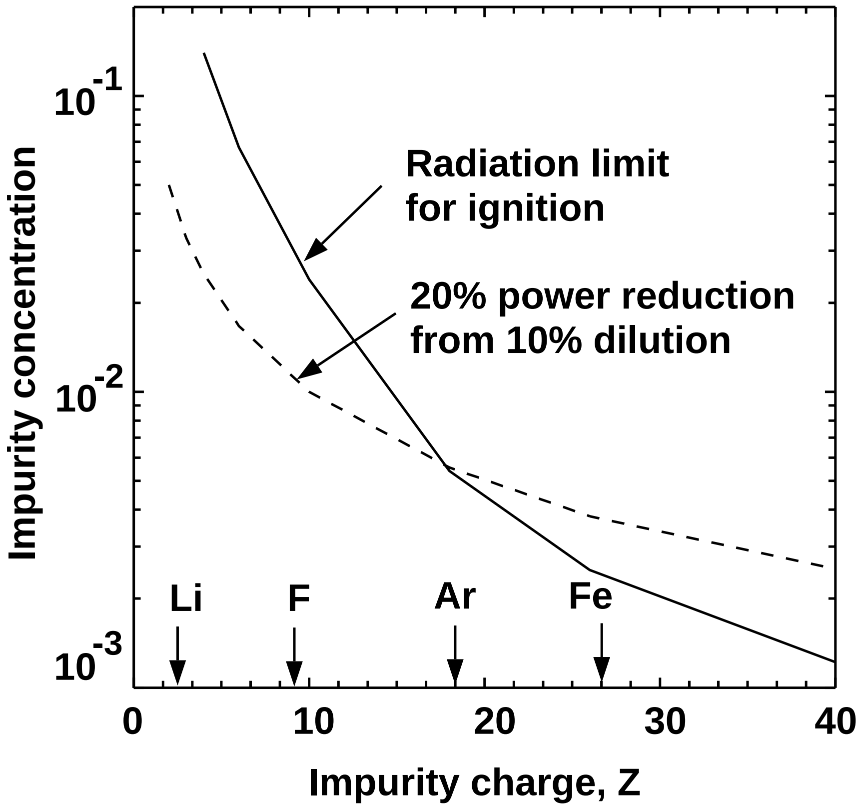
  - MHD stability

  - profiles and bootstrap current

- Possible degradation of core power production due to impurity intrusion

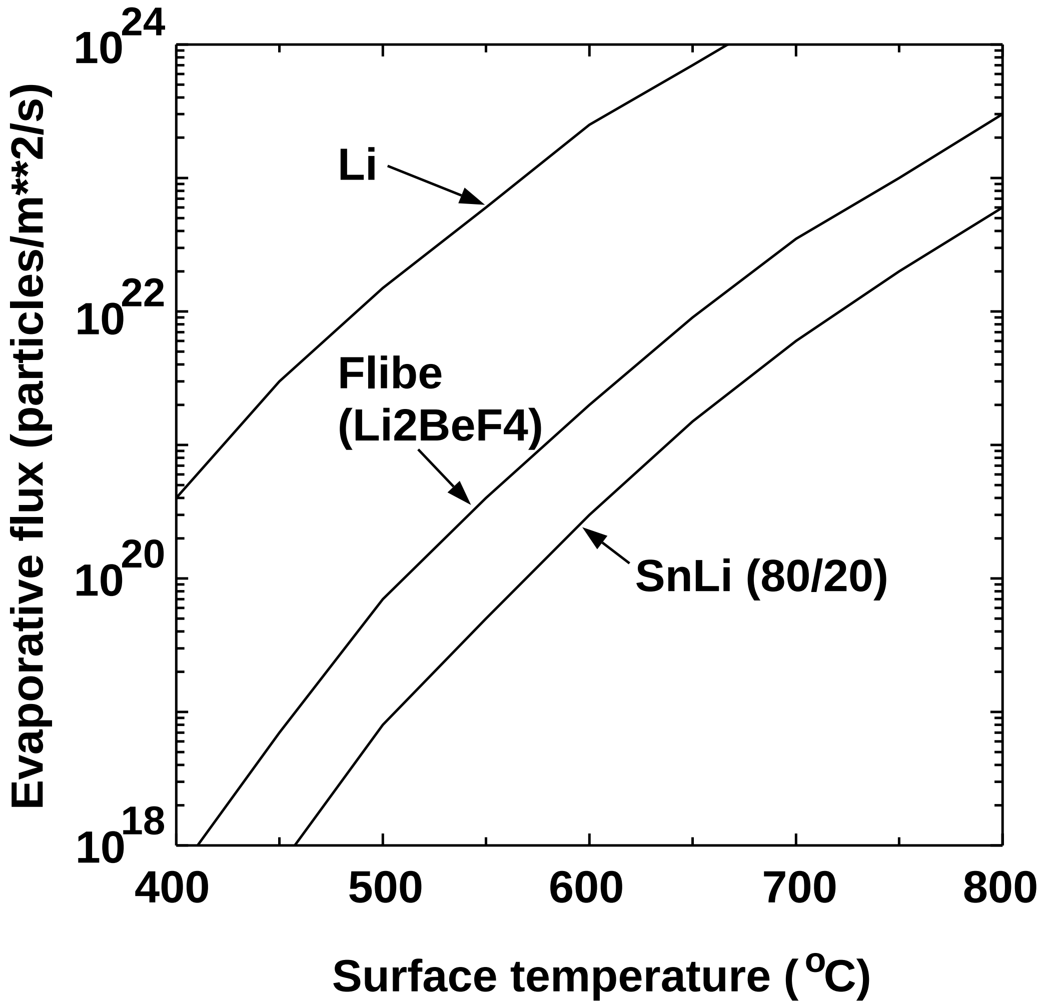
# Core impurity concentration must be below radiation/dilution limits

Radiation limits from
Summers & Hellermann, '93




- For Z < 18, dilution sets the limit on concentration
- For Flibe, the Z=9 fluorine component has the highest Z, giving a concentration of ~0.01
- For Li, fuel dilution places a concentration limit of ~0.03

# Liquids have wide range of evaporation rates

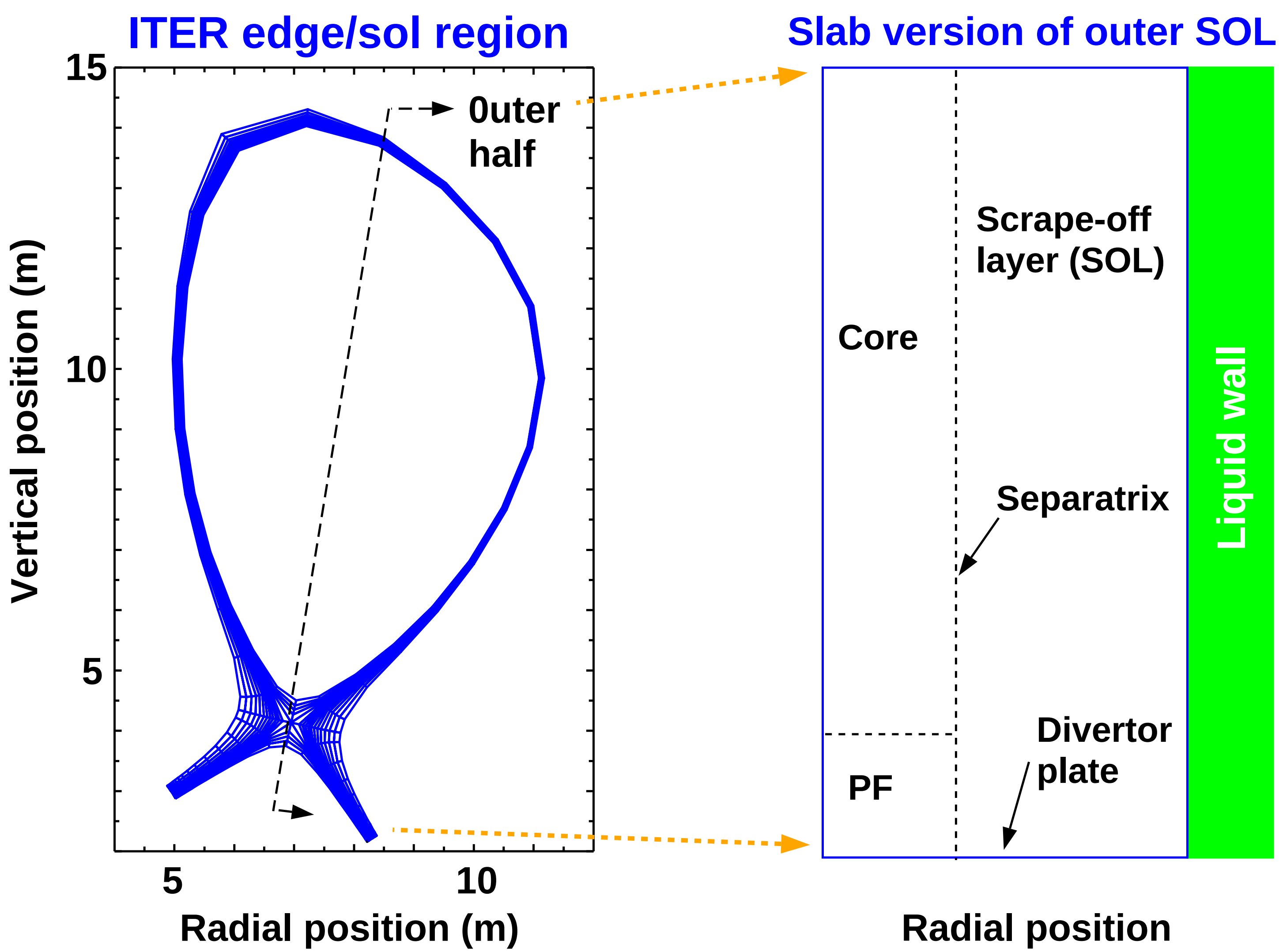



Li is low recycling, conducting
Flibe is high recycling, weakly conducting
SnLi is high recycling, conducting

# Outline

- Edge plasma model
- High- and low-recycling hydrogen plasmas
- Wall impurity sources
- Divertor impurity sources
- Summary

## Correspondence between ITER-like geometry and slab model



# Features of the 2-D UEDGE transport code

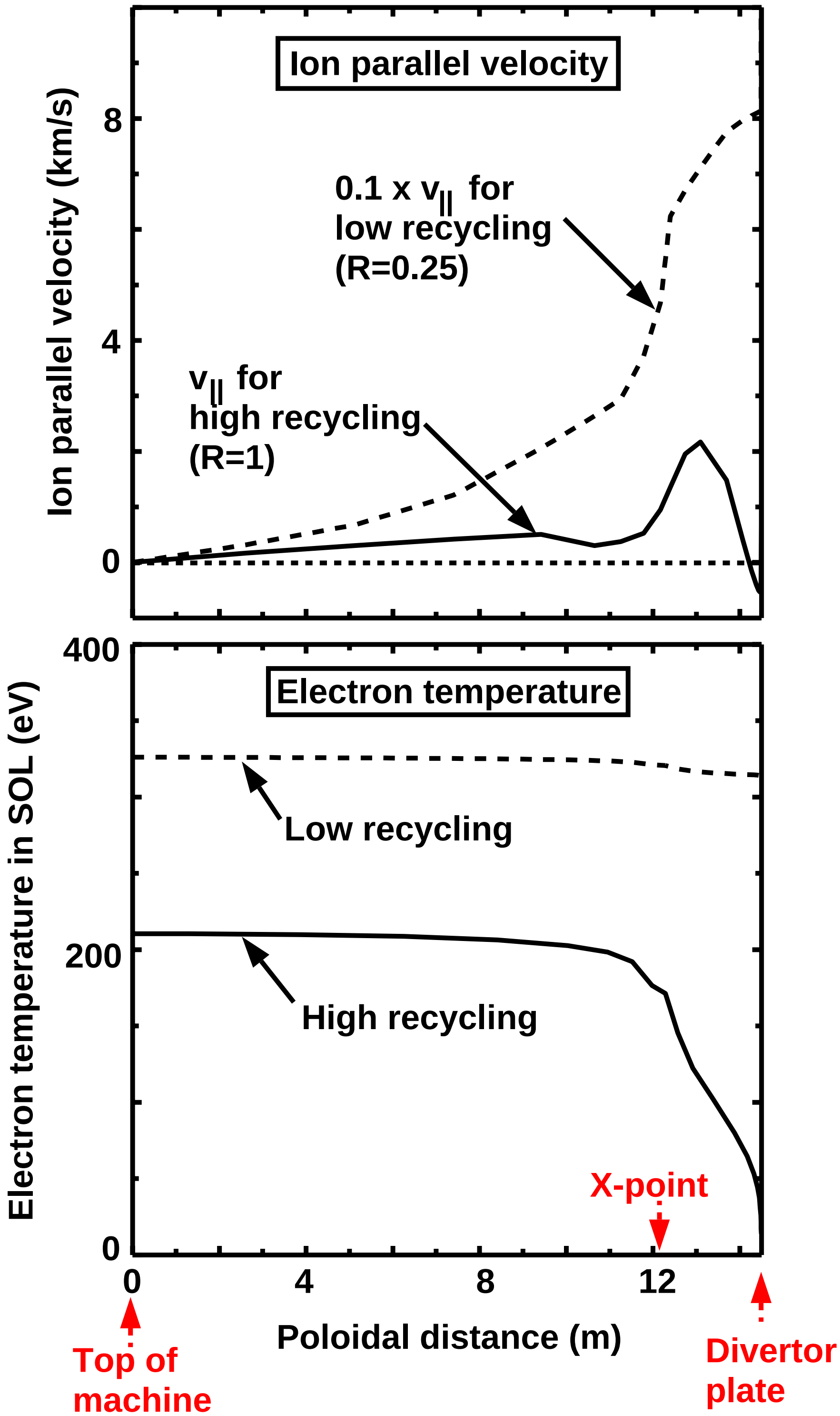
- **Simulates particle and energy flow in the whole edge/SOL region using fluid transport equations**
  - **solve for $n_j$, $v_{||j}$, $T_e$, $T_i$, $n_{gas}$ and $\phi$**
    **($j$ denotes separate ion charge states for impurities)**
  - **parallel transport classical;**
    **radial transport anomalous (from turbulence)**

- **2-D finite-volume, fully-implicit code**
  - **steady-state solutions, or**
  - **time-dependent solutions to assess stability**

- **Special features:**
  - **multi-species impurities**
  - **nonorthogonal mesh - fits divertor structure**
  - **fluid neutrals or Monte Carlo neutrals**

- **Various benchmarks with DIII-D and Alcator C-Mod**

# Edge plasma changes from low to high recycling



# Divertor and wall impurities have different paths

- **Parallel force, $F_{||}$, on an impurity fluid element:**

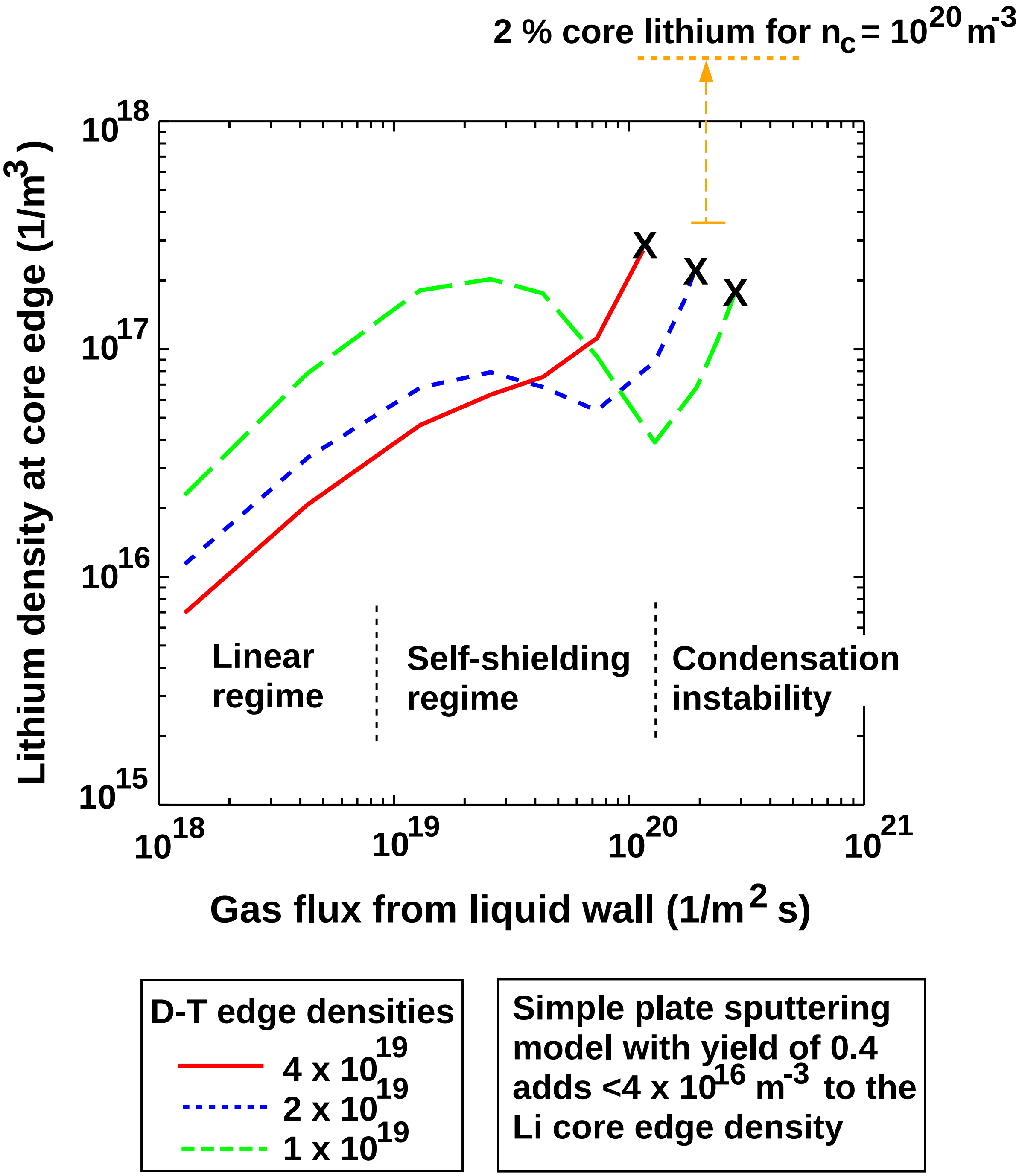
$$\frac{F_{||}}{n_z} = ZeE_{||} + \frac{m_z n_h}{\tau_d n_z}(v_{||h} - v_{||z}) - \frac{\alpha_{e,i}}{1+\lambda/L}\frac{\partial T_{e,i}}{\partial s_{||}}$$

- **Often, first two forces are directed toward the plate, whereas the third (thermal force) is toward the core midplane**

- **Thus divertor plate impurities must "swim" upstream to core, but high recycling and/or large impurity radiation can change forces**

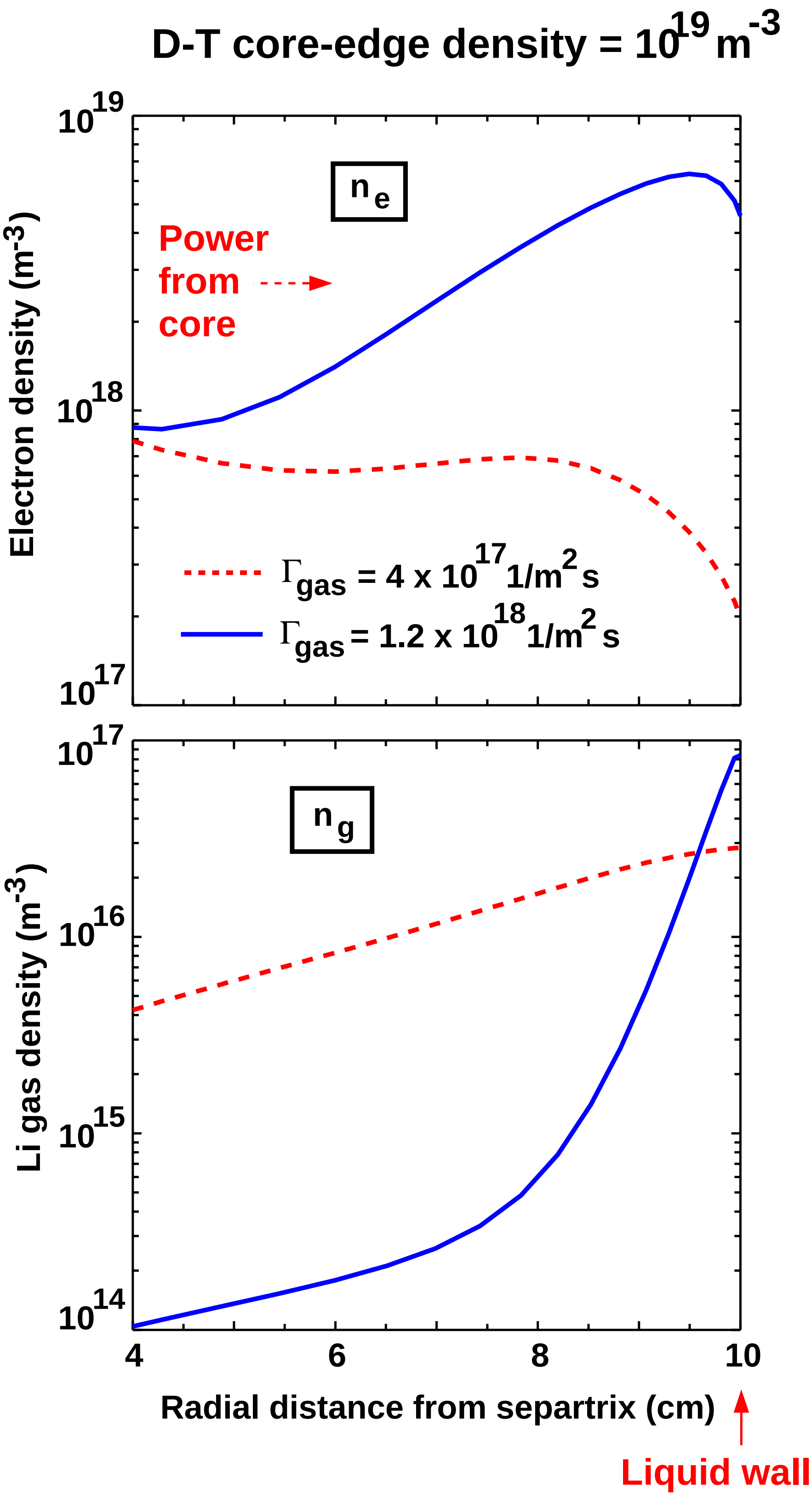
- **In contrast, wall impurities can just diffuse into core region before they are swept to the divertor region (and pumped)**

# Impurity intrusion has three regimes for Li

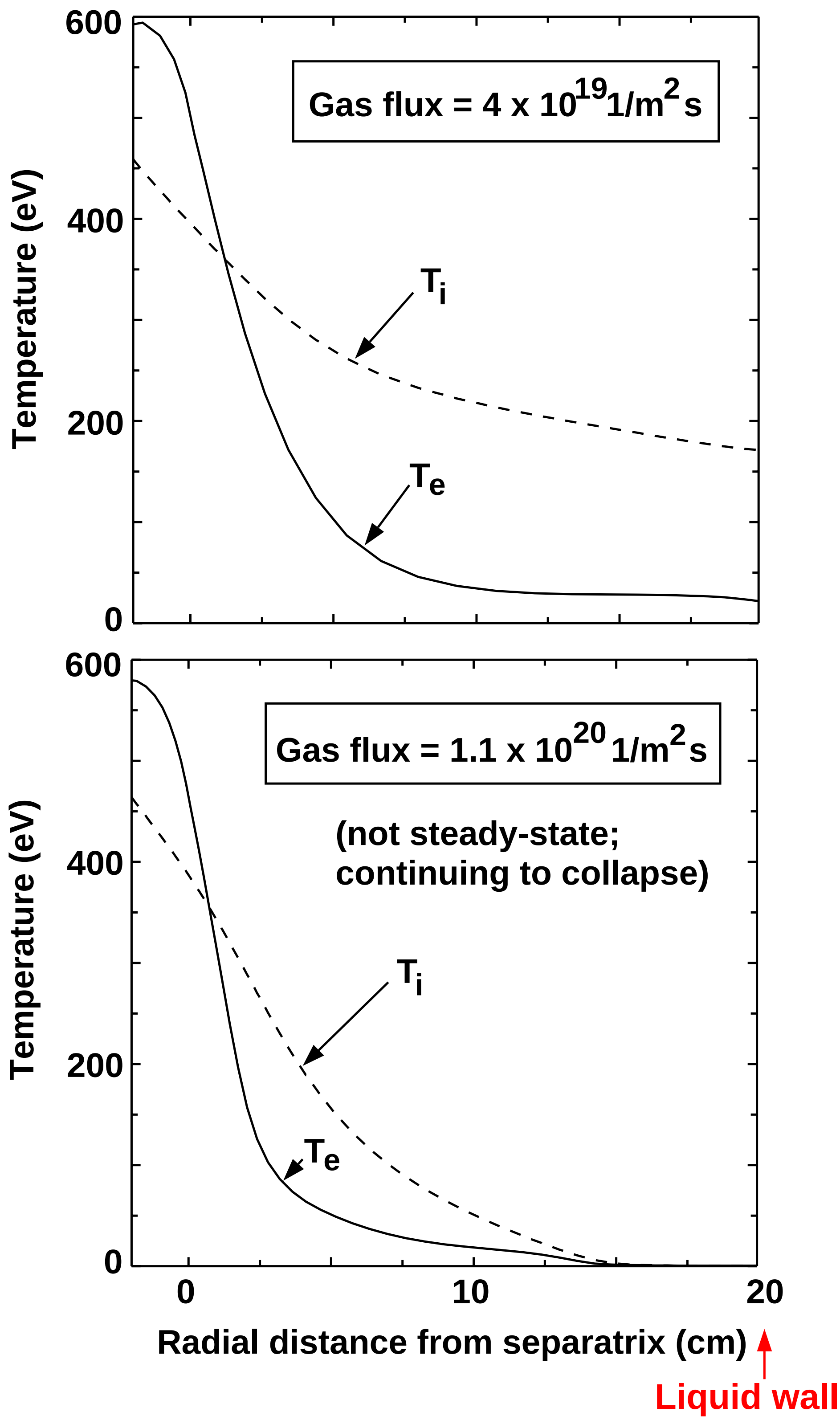



Simple plate sputtering model with yield of 0.4 adds <4 x $10^{16}$ m$^{-3}$ to the Li core edge density

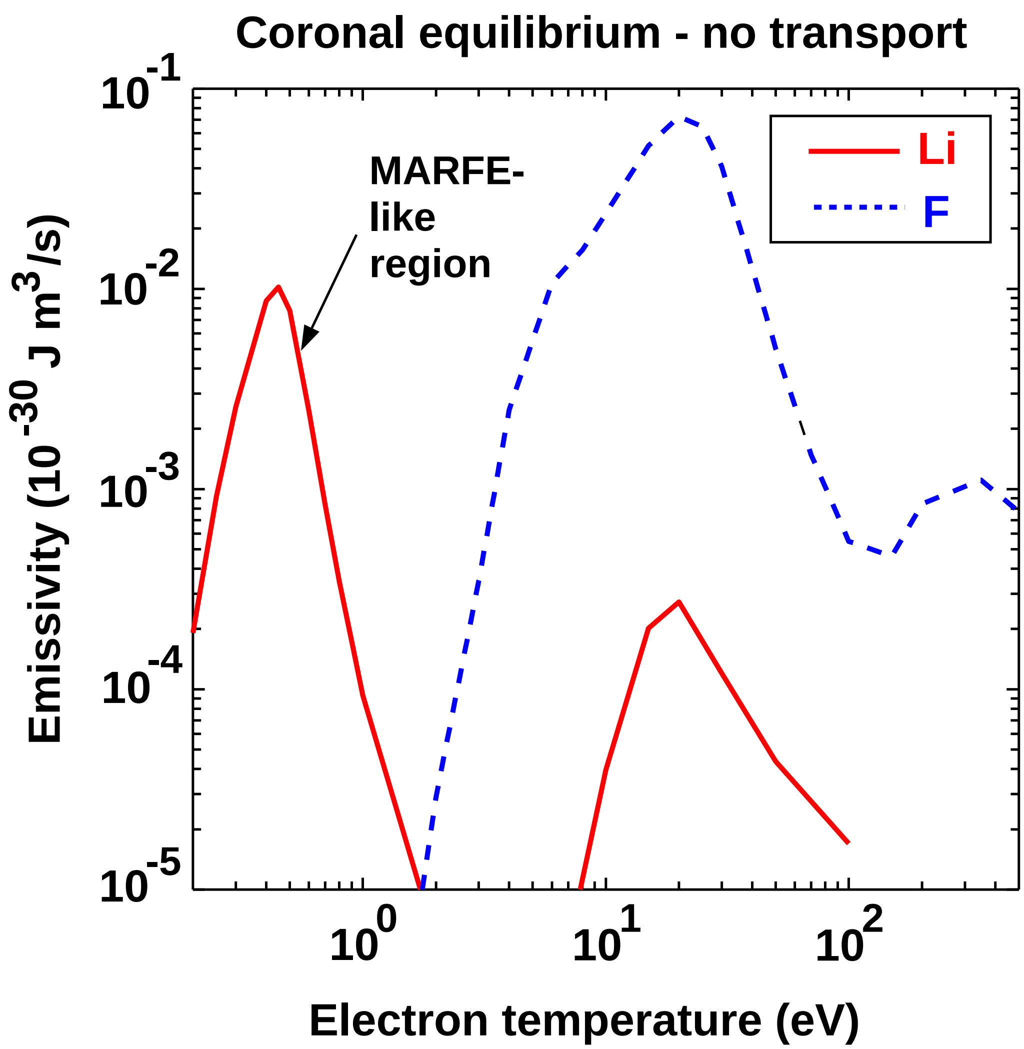
# Dense Li plasma can form to shield core



# Both $T_e$ and $T_i$ collapse near the liquid wall



# Emissivity shows low Te peak for Li

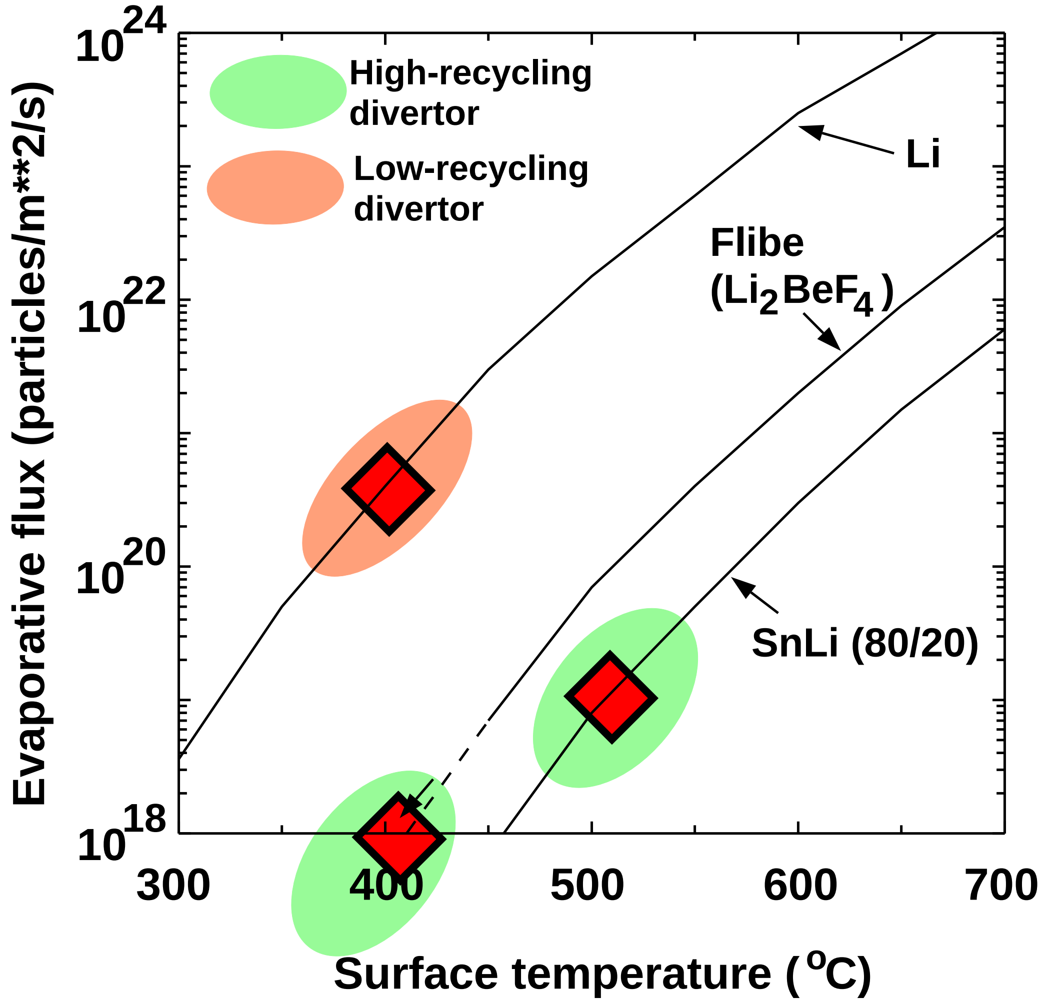



Radiated power = Emissivity x $n_e$ x $n_{imp}$

# Impurity influx sets liquid temperature limits

**Tokamak impurity transport from 2-D UEDGE code**

**Only cases with same wall and divertor material, and no auxillary heating methods**



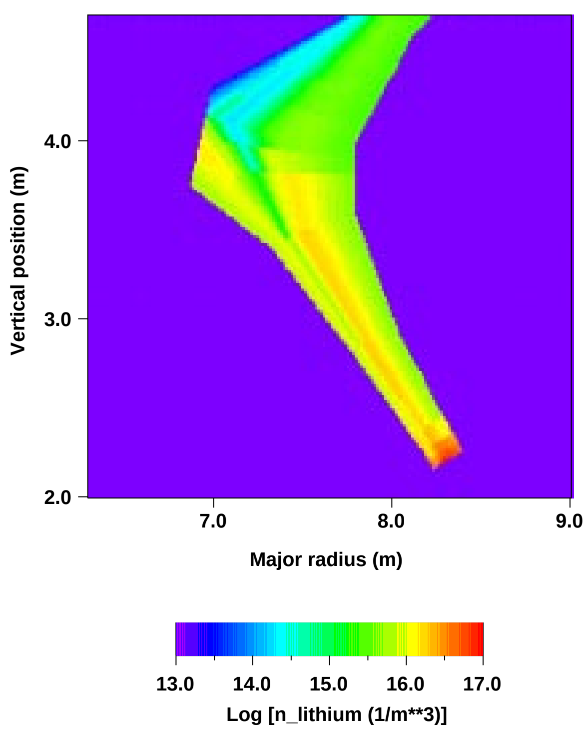
# Divertor impurity sources

**Modeling codes UEDGE+VFTRIM+WBC**

- **realistic geometry and hydrogenic background**
- **angle and energy-dependent sputtering**
- **Monte Carlo impurity ion transport**

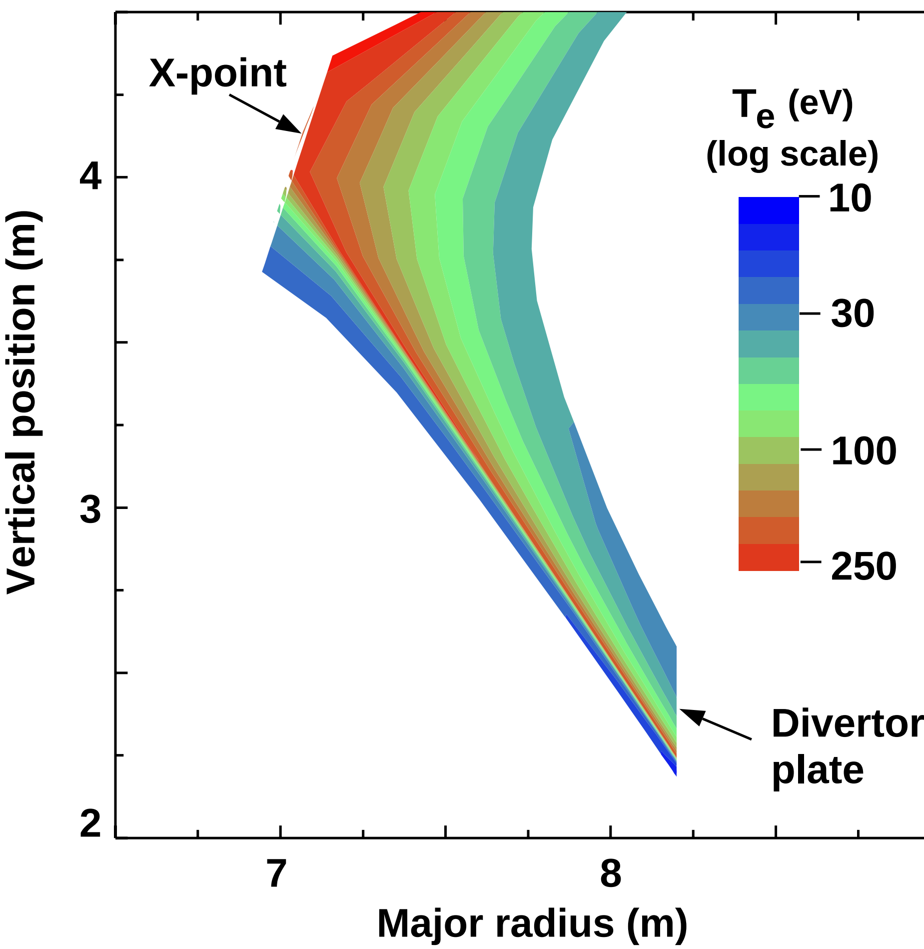
**Issues**

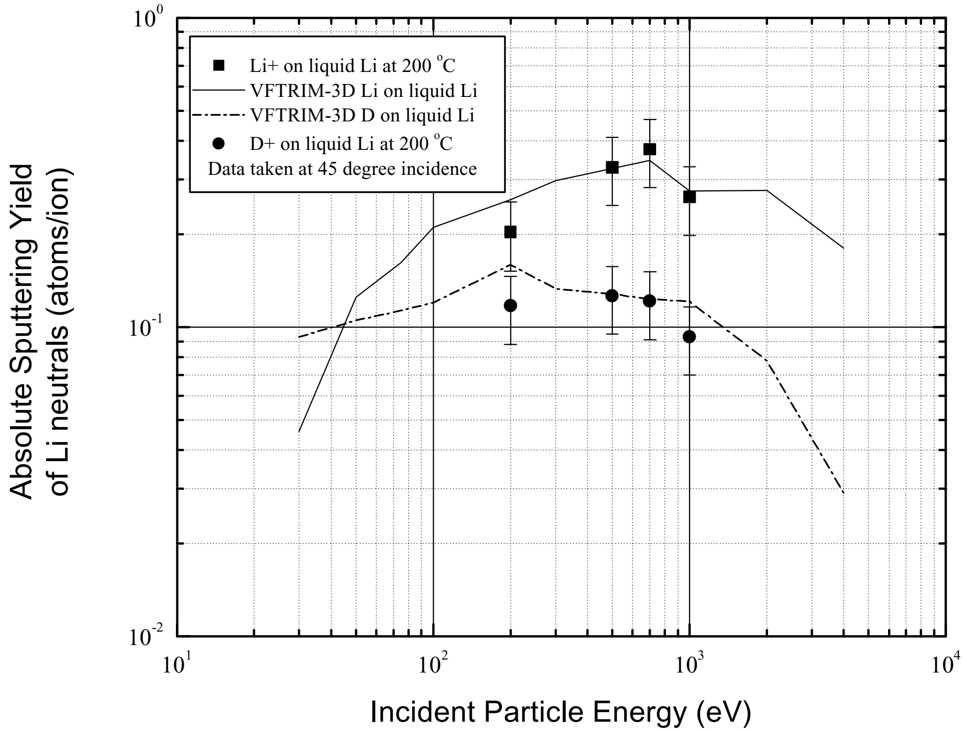
- **Li self-sputtering**
- **core plasma contamination**
- **kinetic effects**



# Low-recycling results in high $T_e$ at the plate

R = 0.5, ncore = 4 x $10^{19} m^{-3}$ , Pcore = 150 MW



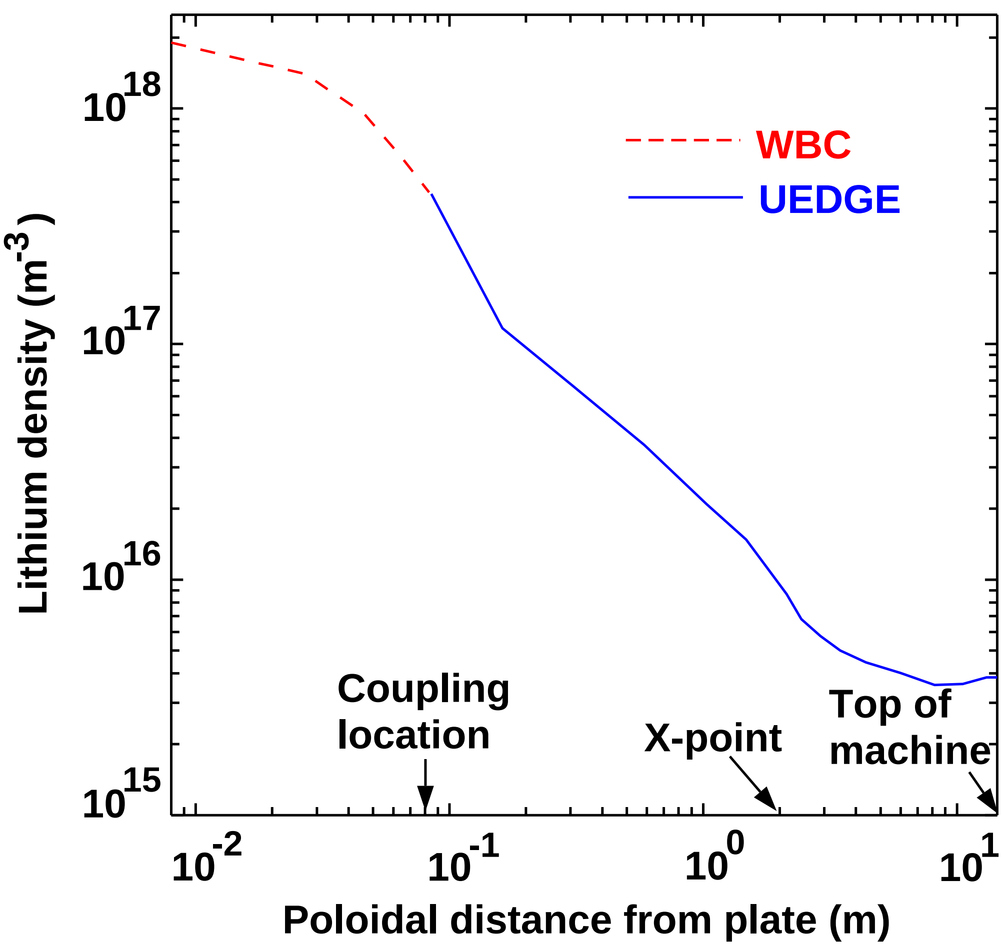


Li+ on liquid Li at 200 °C
VFTRIM-3D Li on liquid Li
VFTRIM-3D D on liquid Li
D+ on liquid Li at 200 °C
Data taken at 45 degree incidence
Absolute Sputtering Yield
of Li neutrals (atoms/ion)
Incident Particle Energy (eV)


Fig. 3

## Coupling UEDGE and WBC gives Li density from plate sputtering in whole SOL region

**ITER geometry with hydrogen recycling R=0.5; effective Li plate sputtering yield = 0.18**



## Summary of impurity modeling

- High- and low-recycling hydrogen plasmas

  - poloidal flow enhanced for low recycling; major impact on impurities

- Wall impurity sources

  - self-shielding by Li plasma helps limit core impurities

  - liquid Li wall temperatures are limited by radiation/condensation instability

- Divertor impurity sources

  - UEDGE/WBC coupling shows low Li core concentration due to sputtering