“DIII-D and NSTX Lithium Erosion/Redeposition Analysis”

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ANL

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- **DiMES 99 Solid Lithium Shot Analysis**

  —Integrated sputtering/transport/redeposition analysis of experiment.

  —comparison with erosion data, ltihium atom photon data and lithium ion photon data.

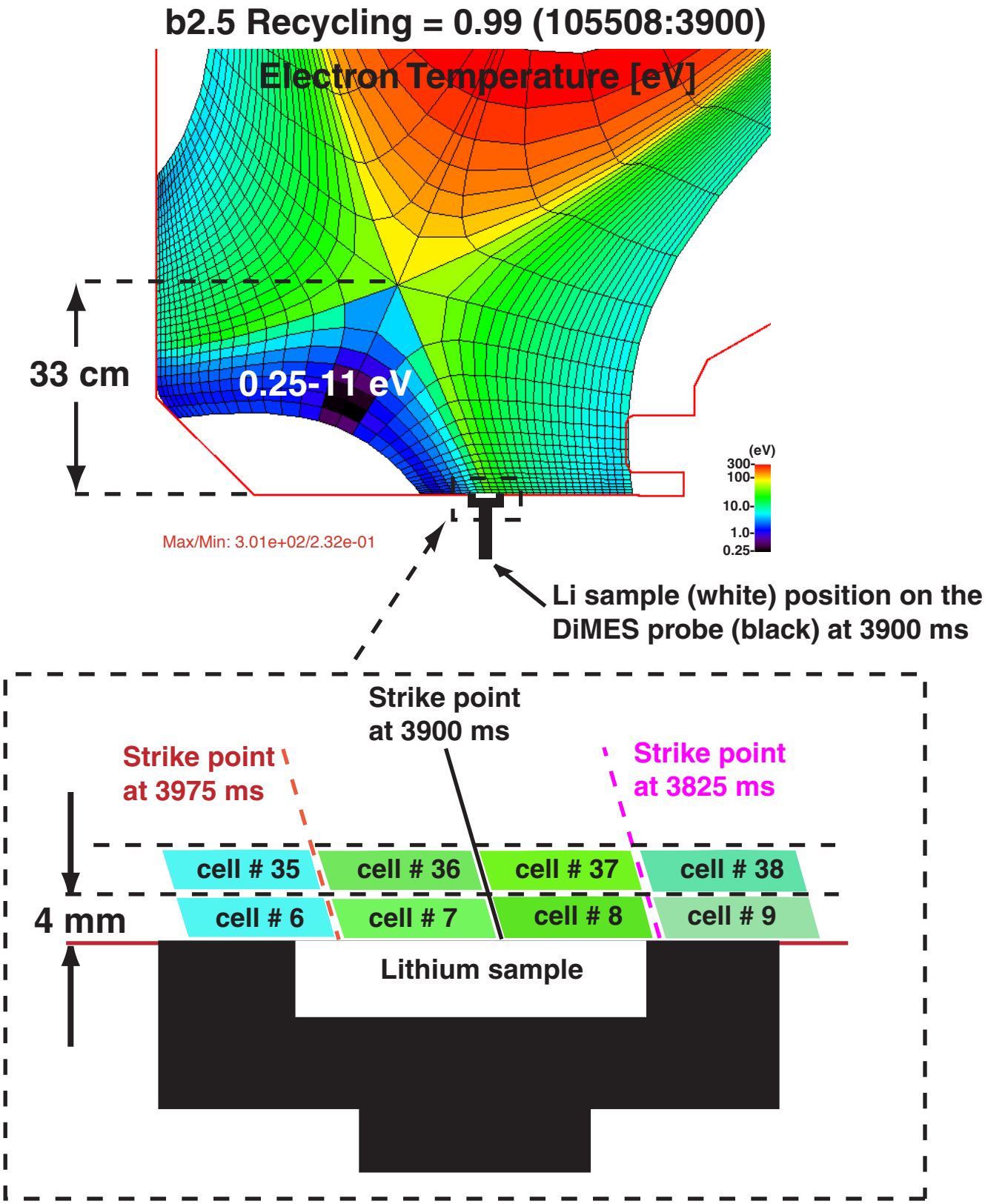
- **NSTX Lithium Divertor Module**

  —New plasma conditions for 1 m toroidal length module.

  —Revised flowing lithium surface temperature for high power case.

  —Ongoing analysis of lithium sputtering, transport, superheat issues.

Solid lithium sample positions between 3825 ms and 3975 ms during DIII-D shot 105508



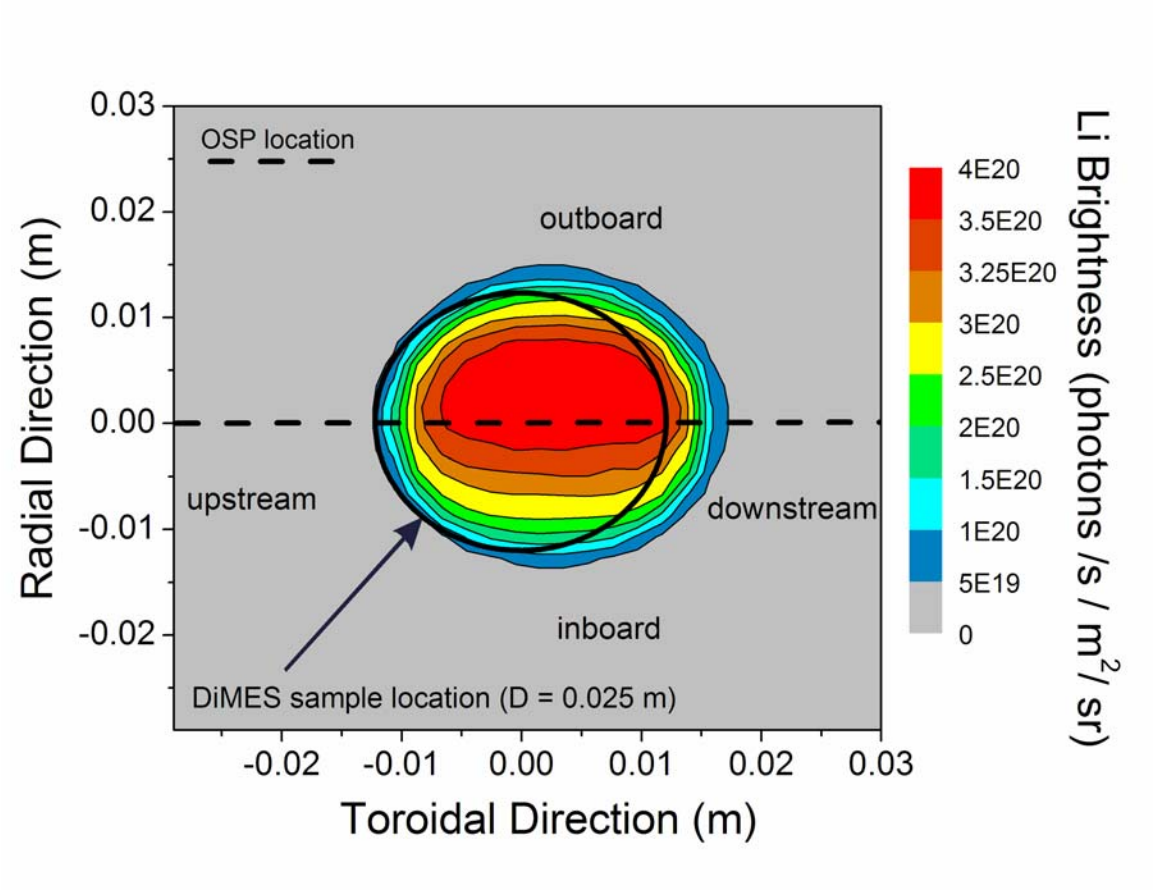


Figure 10. Calculated Li I 671 brightness from DiMES Li sample with outer strikepoint (OSP) on DiMES sample center. Computations done with WBC/REDEP model using L-mode plasma conditions listed in Table 1.

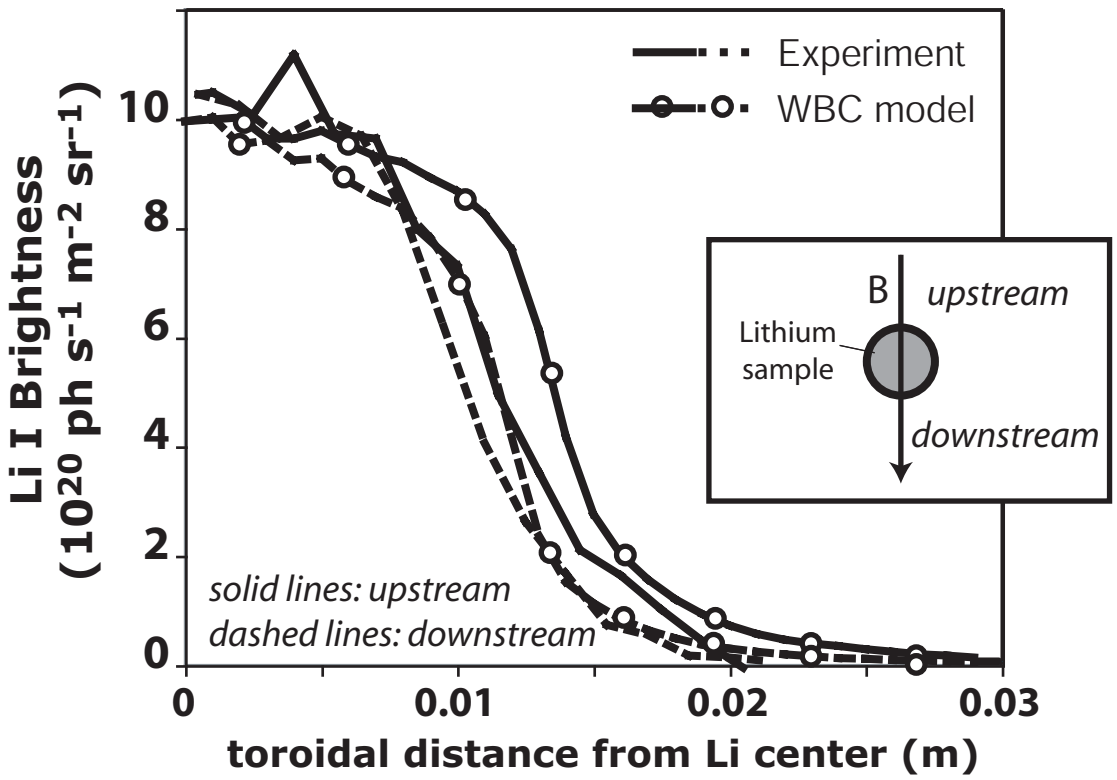
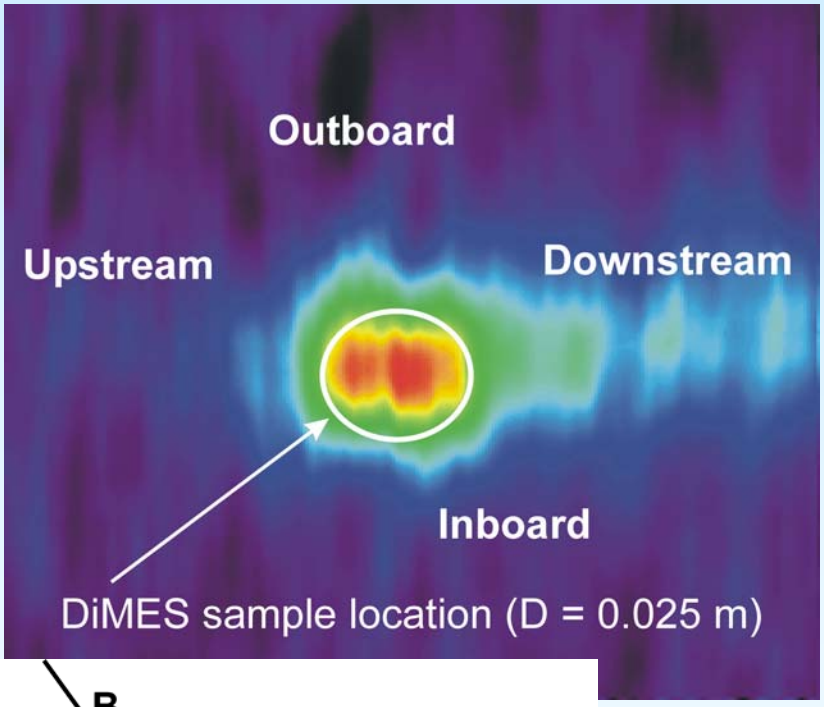
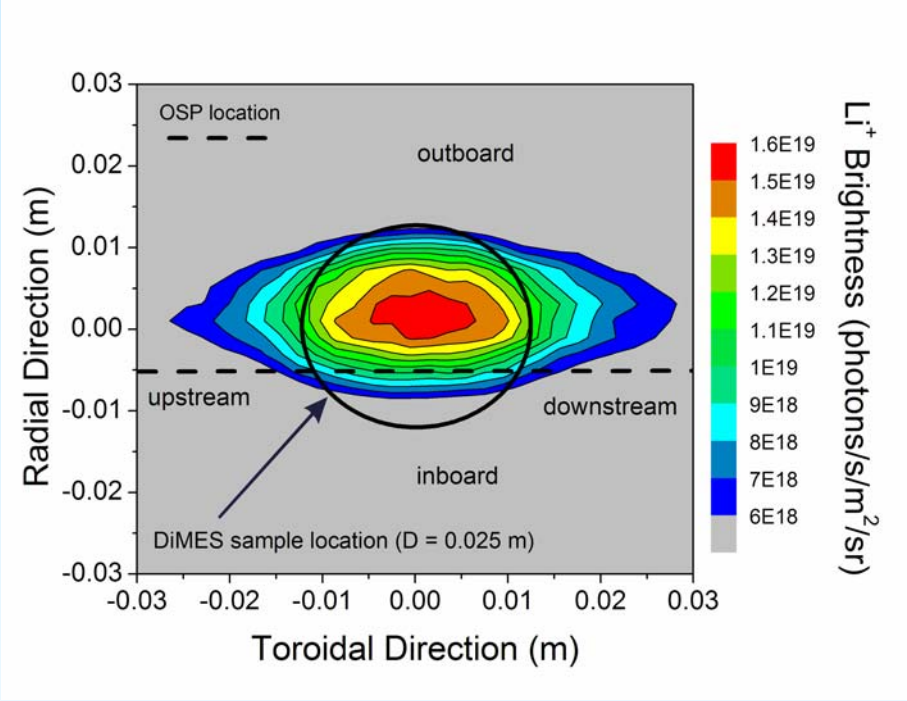


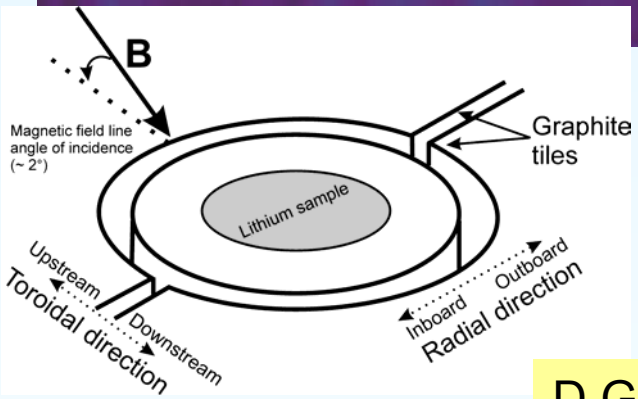
Figure 17. Measured Li I brightness intensity from DiMES Li sample with outer strikepoint (OSP) 3 cm inboard of DiMES sample center for shot # 105511. Computations done with WBC/REDEP model.

Good Code/Data comparison

Li-DiMES erosion modeling and measurements for solid-phase Li







Continued WBC/REDEP modeling of measured Li I and Li II light from Li-DiMES experiments under quiescent plasma conditions showing near-surface ionization of sputtered lithium

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DiMES 99 Li II photon emission, code/data comparison

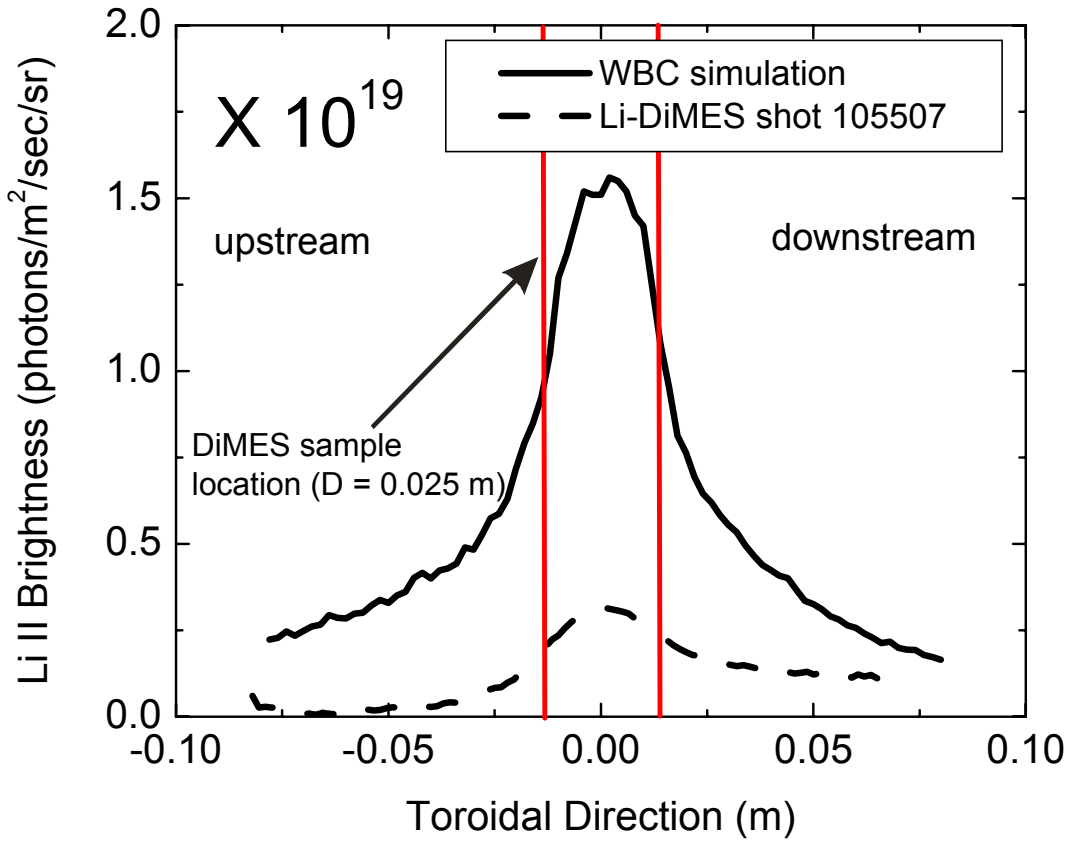


Figure 16. Measurements and WBC simulation of Li II brightness intensity, centered radially on DiMES sample, with outer strikepoint (OSP) 0.5 cm inboard of DiMES sample center.

two problems: a) Code/Data brightness ratio ~ 6/1

b) toroidal asymmetry in data not predicted by code

DiMES 99 Solid Lithium Code/Data Comparision Summary

- **Net erosion- good match. Most important single issue for predictions of ALPS divertor lithium performance.**

- **Lithium atom ionization distances and LiI emission- good match. Thus confirms key point of sputtered lithium confinement to near-surface region.**

- **Lithium ion (LiII) transport and emission-**

  ---Probably OK match right above lithium sample, considering uncertainty in rate coefficient.

  ---Not good match with toroidal transport of some lithium ions. Not highly significant for lithium performance, but at least of academic interest regarding plasma collision theory.

NSTX Lithium Module
Erosion/Redeposition Analysis

*REDEP/WBC code simulation of 8 cm poloidal by **100 cm toroidal** flowing lithium module.*

*Using 2-D plasma parameters/profiles from UEDGE **Case sn_45** (Rognlien); Core power into the SOL = 6.0 MW. Peak power ~ 25 MW/m^2*

Temperature-dependent lithium sputtering model (Allain).

*Lithium surface temp. from SNL (Ulrickson et al.) with 10 m/s flow. **Peak T_s = 358 °C**.*

*Li^+ sputtered transport model with **MOLDYN computed** (Alain, Alman) lithium reflection and charge state parameters. Net atom sputtering ~ Y/2, for total yield "Y".*

Li atoms sputtered self-consistently from entire module surface by D^+ sputtering and self-sputtering.

VFTRIM-3D/random-collision-cascade sputtered velocity distribution.

ADAS rate coefficients (Evans, Whyte) for electron-impact ionization of Li-I, Li-II, Li-III particles

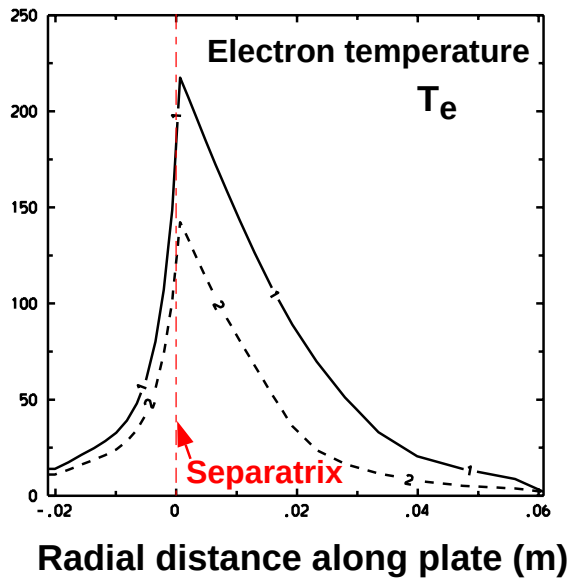
[100,000 particles launched per simulation]

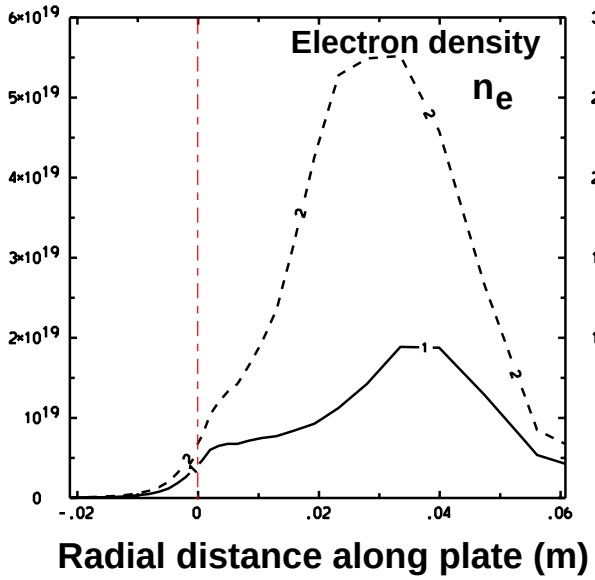
Divertor profiles with larger module shows biggest change in lower plasma density

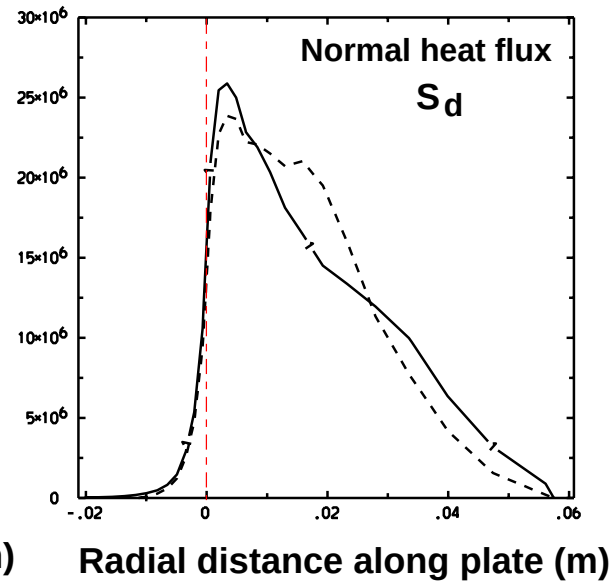
Legend

——— **Present model of 1 m module pumping across entire outer plate; Reff = 0.8**

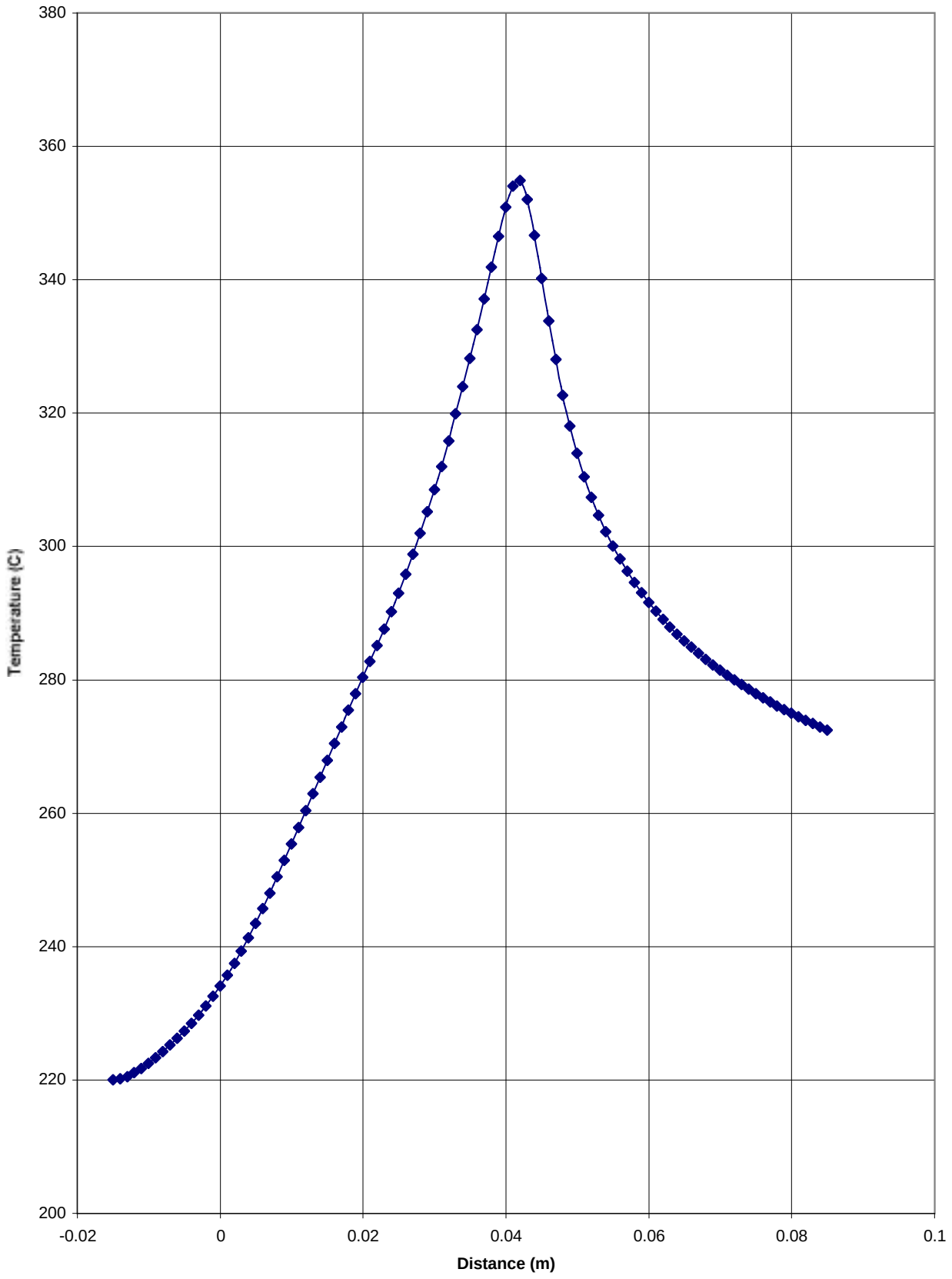
- - - - **Previous model for 0.4 m module pumping for R-Rsep > 2 cm, Reff = 0.9, for R-Rsep < 2 cm, Reff = 1.0**







LITHIUM SURFACE TEMPERATURE, 1 m MODULE, 10 m/s FLOW (M.U.)



NSTX Lithium "one meter" module erosion; Key Results

- **Self-sputtering yield peaks at ~ 0.4 (near strike point).**
- **Overall self-sputtering is finite (non-runaway).**
- **Overall lithium sputtering is high, but most lithium confined to near-surface region.**
- **Sputtering superheat is moderate, ~ 1 MW/m^2**
- **Lithium current to SOL/near-surface boundary, ~ 4 % of sputtered current, is moderate.**
- WBC results for sputtered lithium flux leaving near-surface region furnished as source boundary condition for UEDGE analysis of entire SOL Li transport.

REDEP/WBC NSTX Lithium Analysis Summary

Parameter	**UEDGE Case sn-45**
Peak electron temp., Peak heat flux	~220 eV, ~25 MW/m^2
Charge state*	**1.002**
Angle of incidence* (from normal)	**22 ° (12°)**
Energy*	**190 eV (145 eV)**
Redeposition fraction on module	**0.95**
D^+ sputtering fraction	**0.82**
Self-sputtering fraction	**0.18**
Self-sputtering superheat (peak)	**~ 1 MW/m^2**
Fraction of sputtered lithium escaping the near-surface region (0-5 cm from plate)	**0.04**
Sputtered lithium atom current	**1.1 x10^{21} Li/s**
D^+ ion current to divertor	**5.1 x 10^{22} D^+/s**
D^+ ion current to module	**9.5x 10^{21} D^+/s**
Peak Li/D ion density ratio above module	**~ 0.3**

*average value (standard deviation) for redeposited ions

CONCLUSIONS

- DIII-D/DiMES solid lithium experiments being analyzed in detail. **Integration between lab results (PISCES, IIAX etc.), Molecular Dynamic codes, Plasma Diagnostics, Kinetic impurity transport (REDEP/WBC) and Fluid codes (MCI, UEDGE).** Good match between code/data, with exception of LiII radiation.

- New NSTX lithium module erosion/redepostion analysis is encouraging—**ability to handle 25 MW/m^2, low recycle regime power loading, with tolerable lithium plasma contamination.** Also have some margin.

- **Near-future work:**
  - **DiMES *liquid* Li shots**
  - **NSTX higher and lower power cases**
  - **Determination of parameter limits**
  - **Tin and gallium erosion/redeposition analysis**