ALPS/APEX Plasma Edge/Plasma Material Interaction Group-2/11/03 Conf. Call Report

- **DiMES 99 Lithium Shot Analysis**

  —Integrated sputtering/transport/redeposition analysis, and comparison with erosion data, atom photon data and 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.

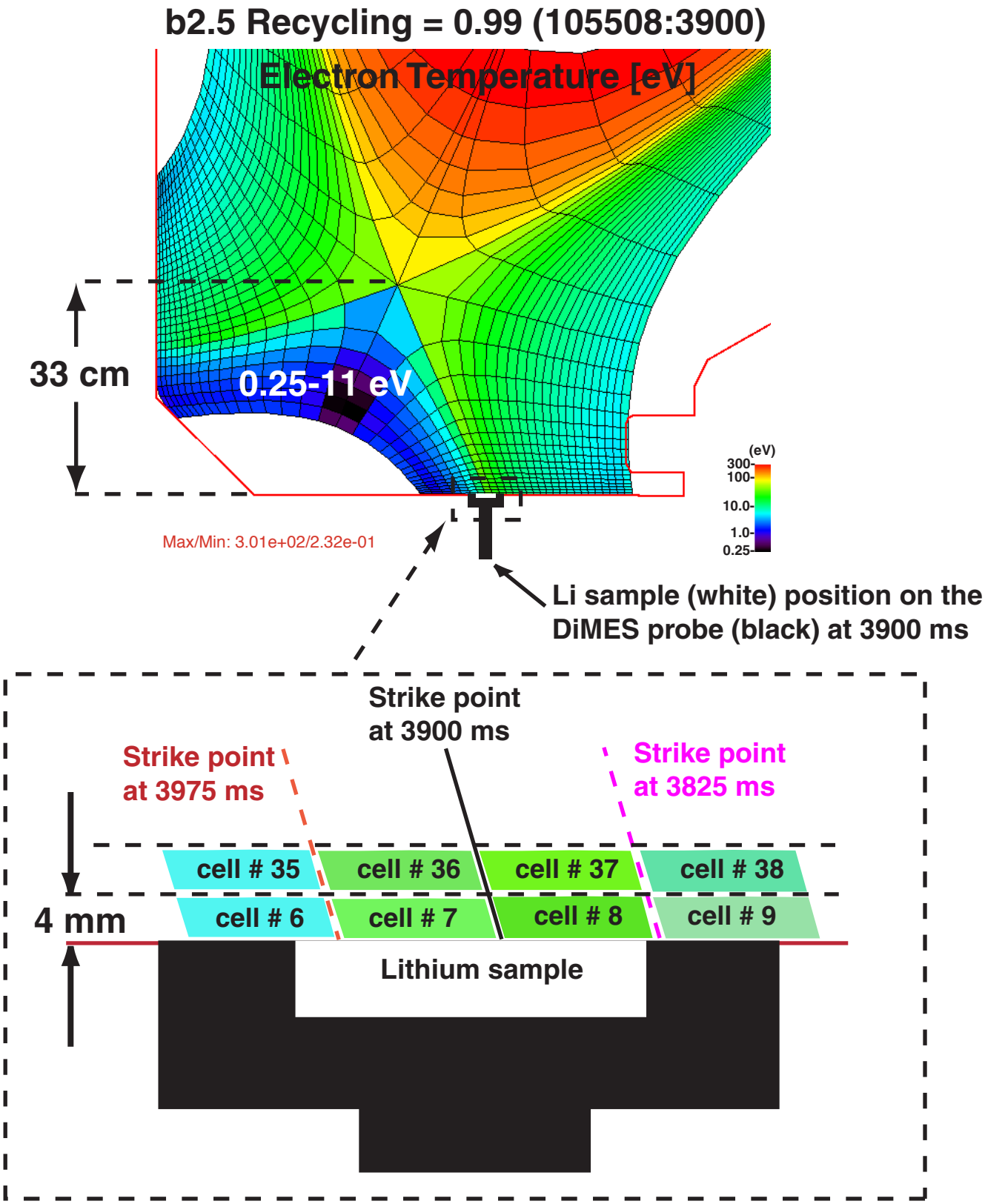
  —Ongoing analysis of lithium sputtering, transport, superheat issues.

- **PMI Science: Liquid Metal, Carbon, ELM's**

  —Molecular dynamics code studies of Li^+ reflection on liquid lithium, Helium trapping, and "soft" surface carbon/hydrocarbon reflection.

  —Surface temperature dependent lithium sputter yields and energy distributions.

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

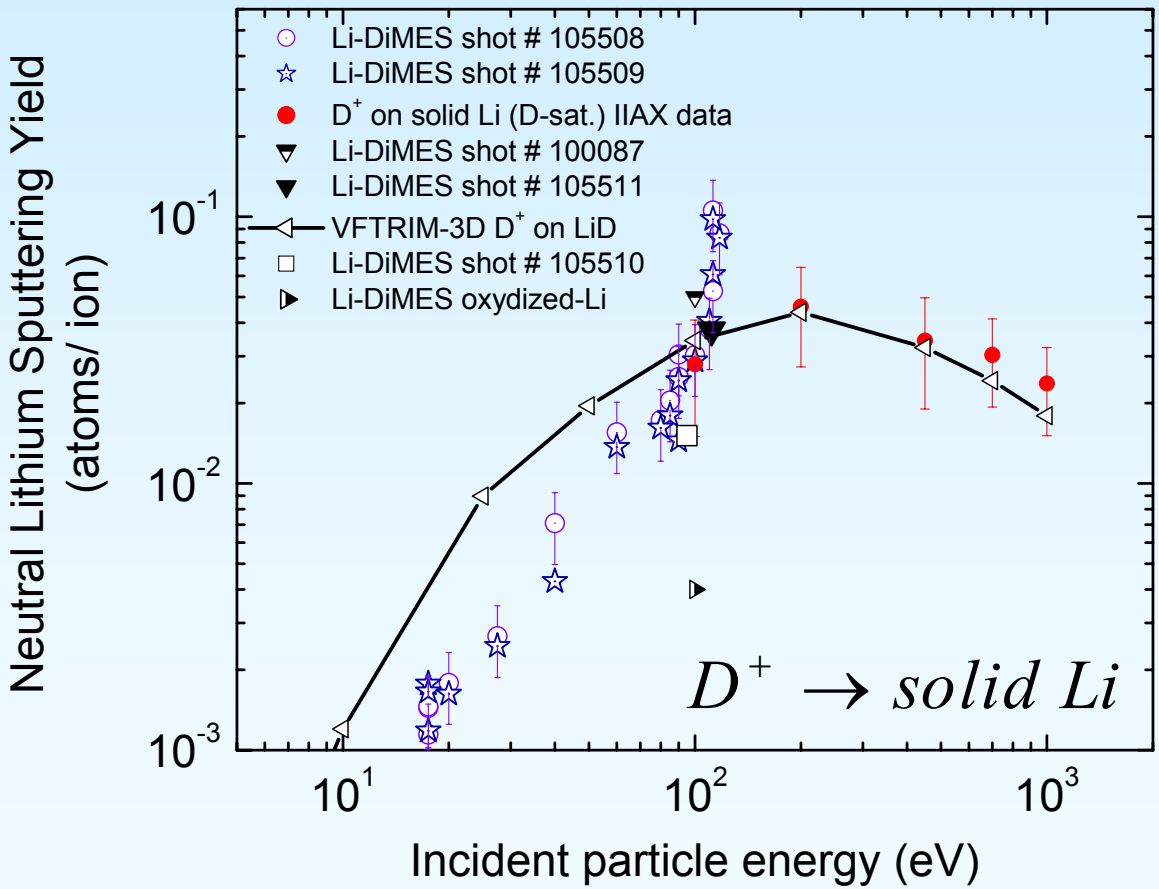


Sweeping the strike point across the Li sample implies that more complex numerical modeling is needed to understand SOL transport

- Using the b2.5 solution for n_e and T_e (recycling coef. R=0.99 at the outer strike point), LiI->LiII ionization rate coefficients from ADAS and the LiI surface normal velocity calculated by WBC (during the OSP sweep from 3825 ms to 3975 ms) we calculate the perpendicular mean free path length (λ_{mfp}) for neutral Li atoms above each simulation cell and D^+ particle flux:
  - cell #6 λ_{mfp} = 5.7 cm, cell #7 λ_{mfp} = 1.8 cm and cell #8 λ_{mfp} = 0.4 cm.
  - the D^+ flux to the solid Li sample peaks in cell #8 at 3.7e22 m^{-2} s^{-1}, and falls rapidly in cell #7 (3.9e21 m^{-2} s^{-1}) and cell #6 (8.5e20 m^{-2} s^{-1}).
- Thus, while sweeping the strike point across the sample has a significant impact on the number of lithium atoms released from the sample (assuming a constant sputtering coefficient) and the depth of penetration into the plasma the two effects somewhat cancel for the case considered.
- Sweeping the strike point across the sample, coupled with relatively large variations in the radial n_e, T_e, c_s and Γ_p profile across the sample (and Δ n_e, Δ T_e variations above the sample) implies that more complex modeling is needed to validate the key physics assumptions.

Measurements and modeling of Li-DiMES sputtering

- Li-DiMES experiments for conditions where the sample surface is in solid phase
- IIAX solid-phase data is multiplied by 1/3 to account for 2/3 ion sputtered fraction since at the plasma boundary the sheath will effectively suppress sputtered ions
- Oxidation of the lithium surface results in significant reduction in sputtering consistent with metal-oxide sputtering theory



(J.P.A.)

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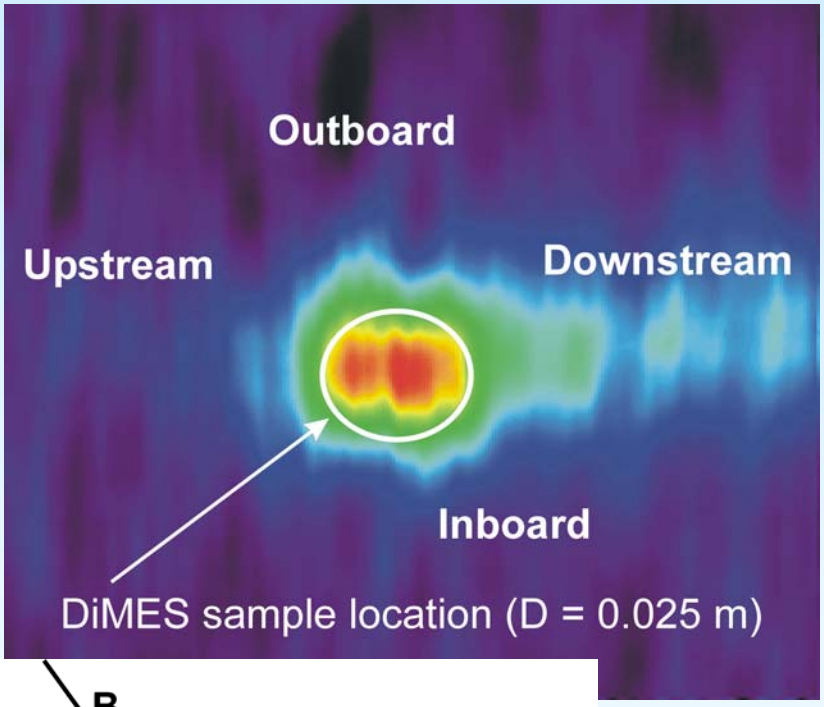
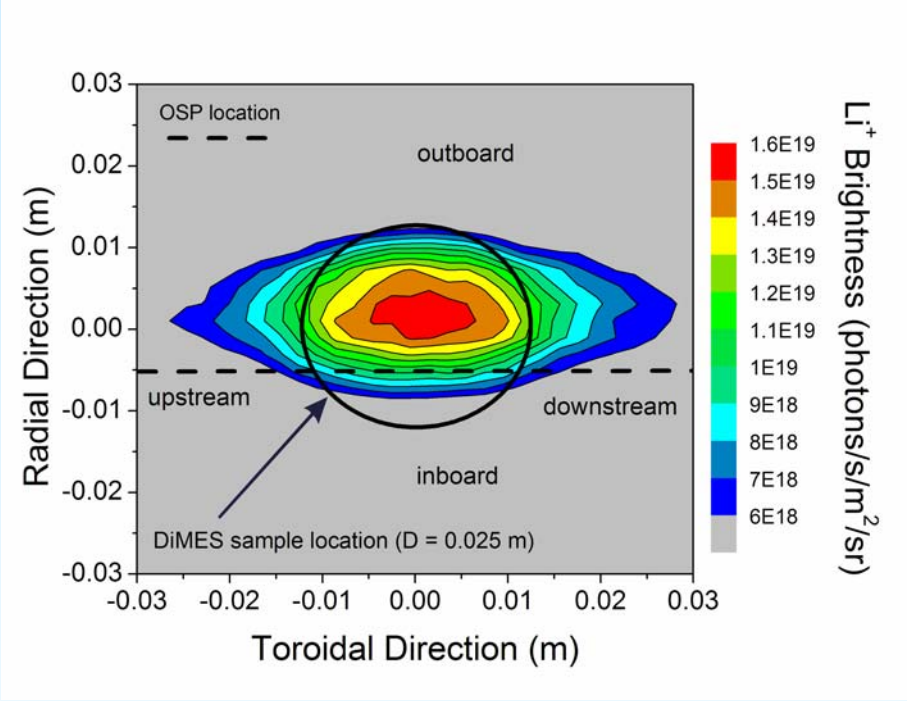
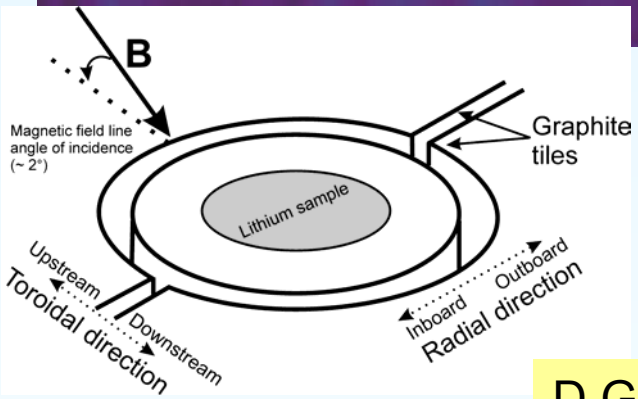
Li-DiMES erosion modeling and measurements for solid-phase Li







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

D.G. Whyte, J.N. Brooks and J.P. Allain

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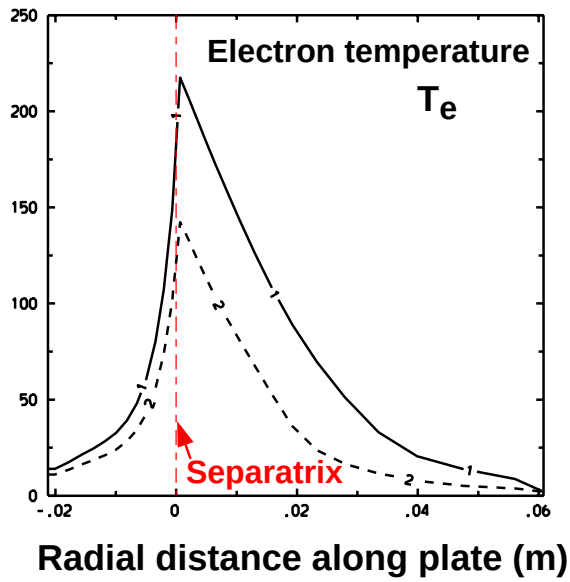
University of Illinois at Urbana-Champaign

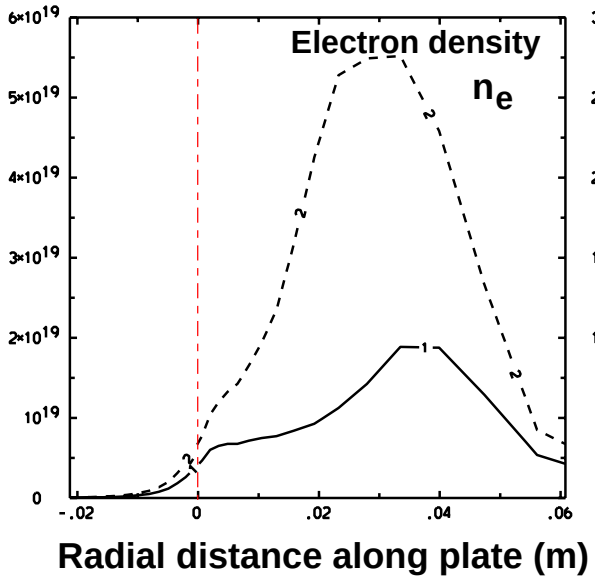
Divertor profiles with larger module shows biggest change in lower plasma density

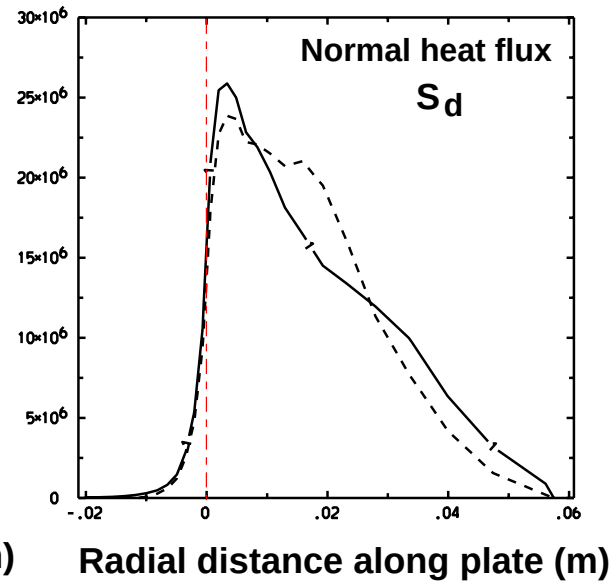
Legend

——— **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**

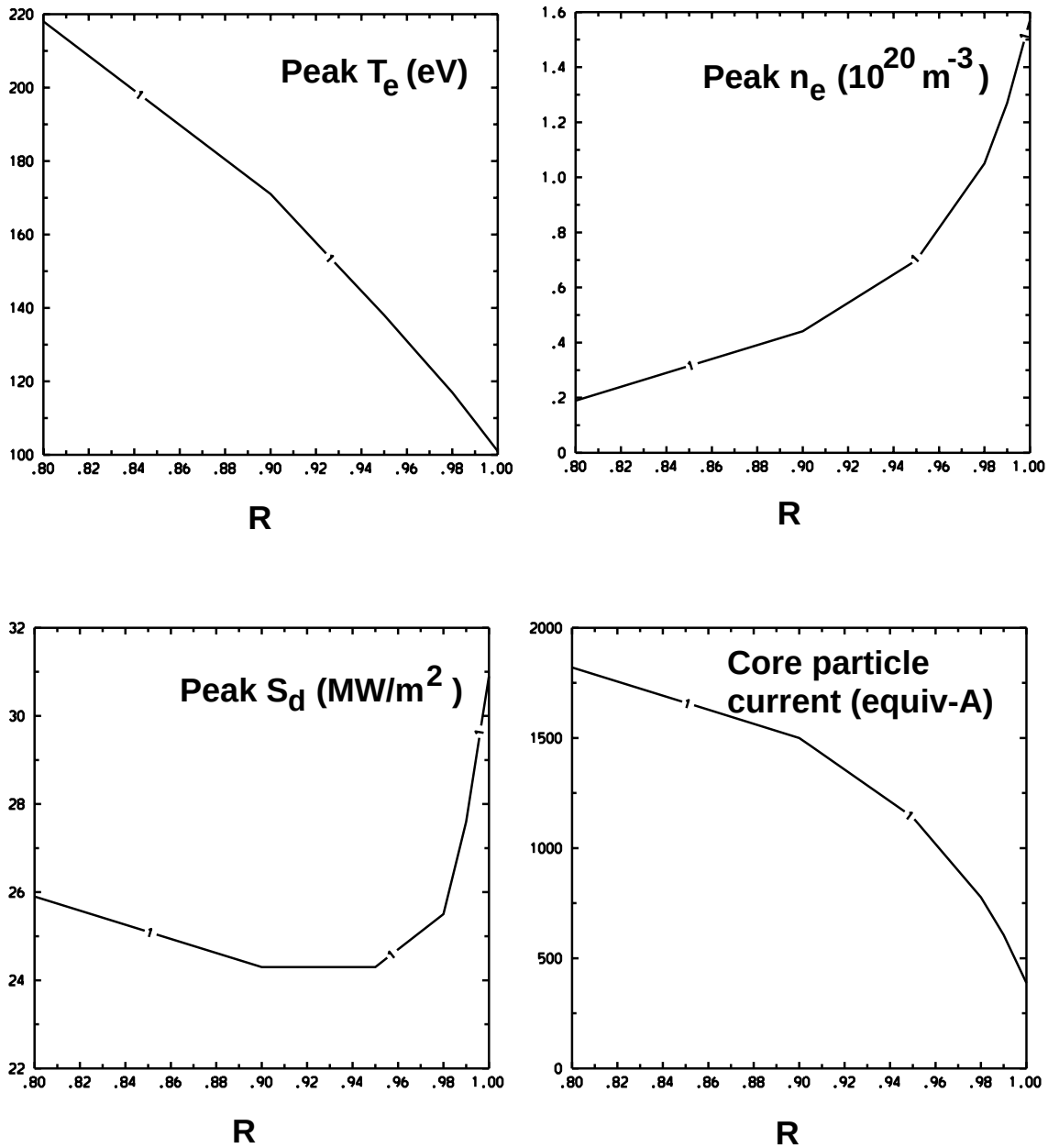




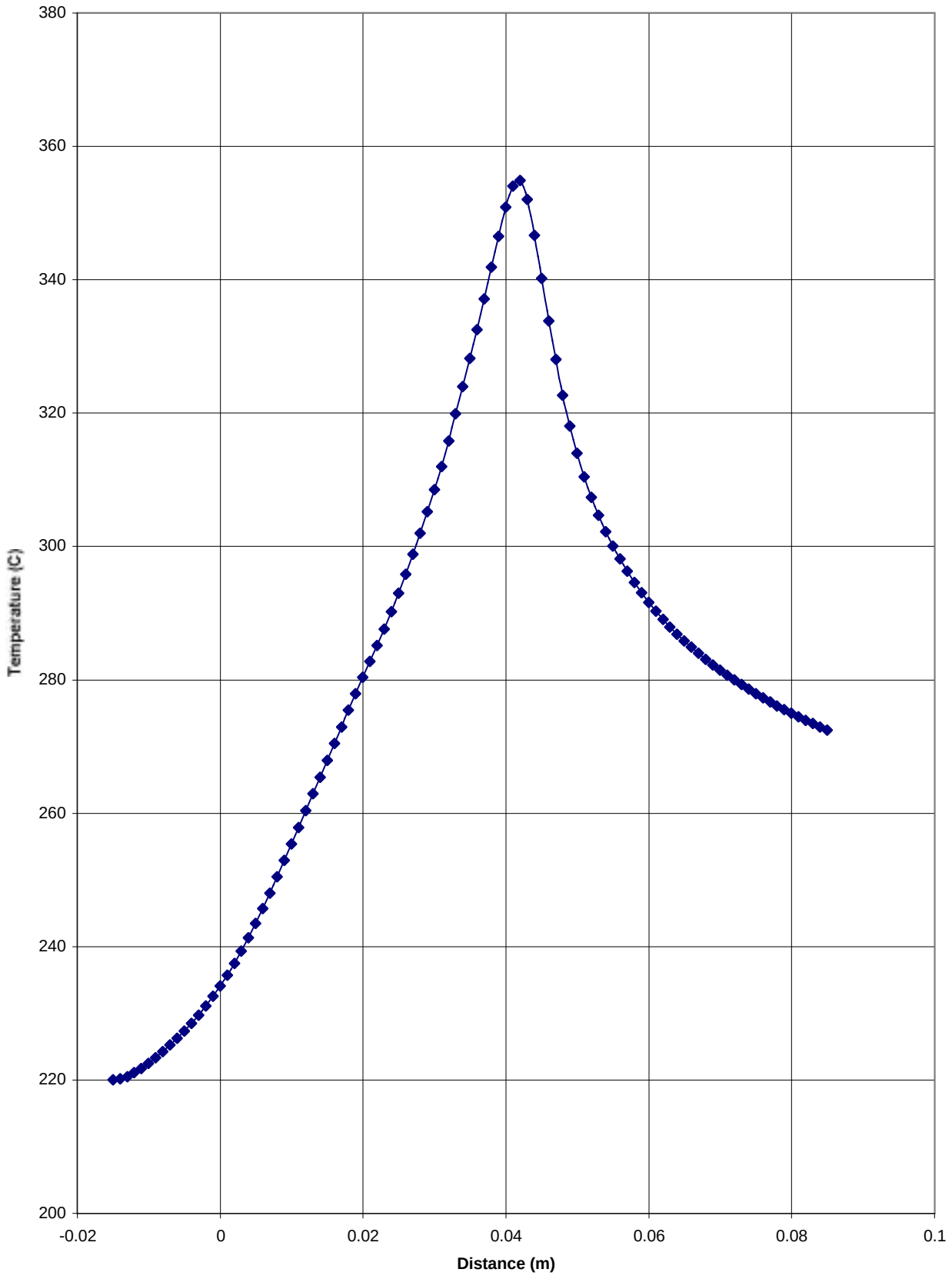


Peak plasma parameters varying with the recycling coeff., R, on outer divertor module

NSTX case with ncore = $4 \times 10^{19} m^{-3}$, Pcore = 6 MW



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



HEIGHTS Simulations of Plasma/liquid Interactions

- **HEIGHTS package is developing 3-D Molecular Dynamics (MD) capabilities to study important issues of plasma/liquid interactions**

- **MD simulation is to study:**

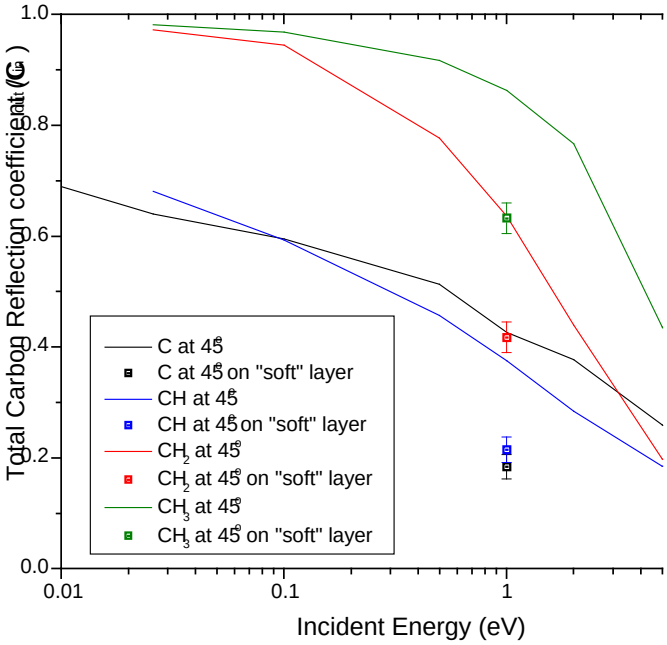
  - **He diffusion in liquid surfaces**
  - **Mechanisms of enhanced liquid sputtering**
  - **Bubble formation dynamics and growth**
  - **H-isotope diffusion/retention in liquid surfaces**

- **Initial results show that simulation of He diffusion coefficient in liquid Lithium is in agreement with limited experimental data and theory**

- **HEIGHTS continues to improve models of plasma/liquid-solid interactions during ELMs in different devices.**

MD Modeling of Hydrocarbons

- Developed a “soft” H:C surface
  - Formed by deposition of thousands of hydrocarbons on a graphite surface
  - Emulates a redeposited carbon layer in a tokamak
    - Larger H:C ratio than for hydrogen implanted in graphite to saturation
    - Lower density
    - Carbon is less strongly bound at the surface
- MD modeling is in progress using this new surface, to be compared to previous results using a graphite surface implanted with hydrogen to 0.4 H:C
  - Preliminary results show reflection is lower on the “soft” surface



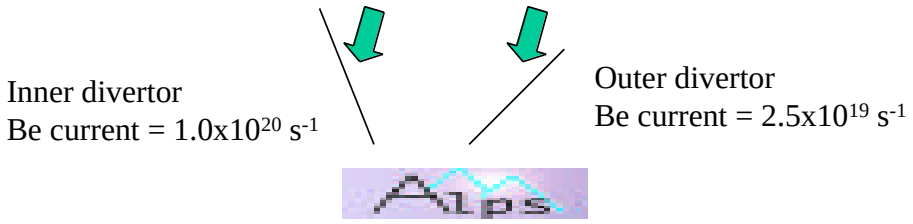
(D.A.)

MD Modeling of Lithium

- Current liquid lithium potential is for bulk
- Approximation of Li reflection coeff. and charge state at 0.3, 2 eV and 20°, on liquid Li at 200 and 450 °C is in progress with this potential
- A more rigorous approach will be pursued in the future, adding to the current potential the term for the structure-independent potential energy, U_0

NSO/FIRE Modeling

- UEDGE plasma solution from Rognlien/Rensink was modified
  - Mesh extended out to first wall, plasma zones filled in
  - Modeled ion flux to first wall, including diffusive and anomalous transport
- DEGAS2 used to calculate fluxes to first wall
- Sputtering of Be from first wall calculated with VFTRIM-3D
- Transport of sputtered Be to divertor calculated with WBC+
- Be flux to divertor goes to ANL for mixed material erosion analysis



Progress on Whole-Device Edge-Plasma Simulations

T.D. Rognlien and M.E. Rensink, LLNL

D.P. Stotler, PPPL

ALPS Electronic Meeting

February 11, 2003

Topics

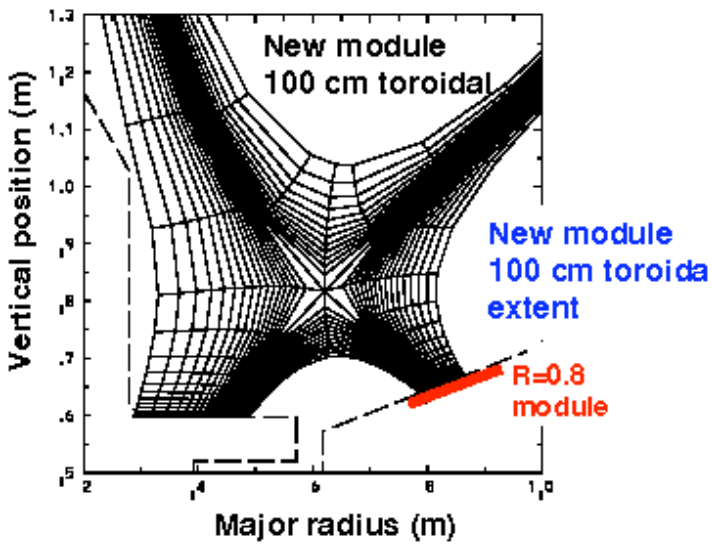
- **Edge-plasma characteristics for NSTX module (LLNL)**

- **Highly radiating edge-plasmas for APEX CLIFF liquid-wall tokamak (LLNL)**

- **Determining properties of edge-plasma turbulence via simulation of Gas-Puffing Imaging (GPI) diagnostic (PPPL)**

NSTX modeling extended to larger Li module

- **Module extended radially and toroidally**



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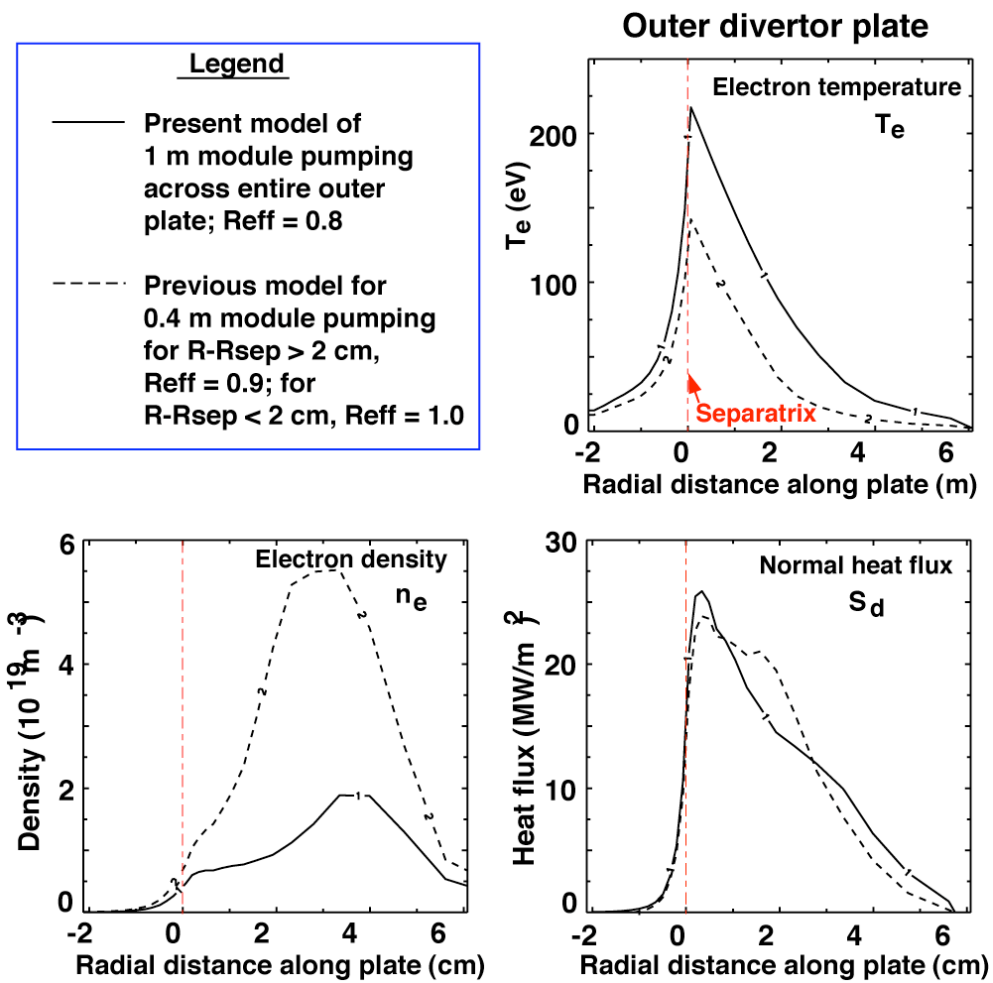
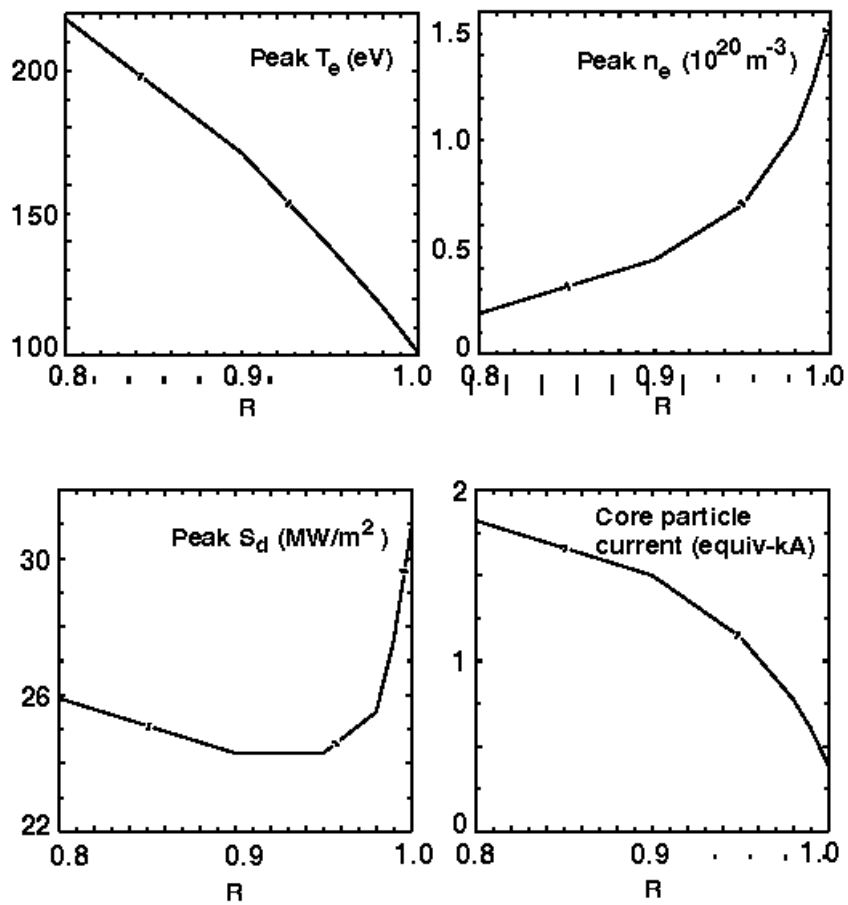


Changing pumping via R impacts edge density

NSTX with $n_{core} = 4x10^{19}\ m^{-3}$, $P_{core} = 6$ MW

- **Minimum toroidally-averaged recycling coeff. R = 0.8 for complete pumping on module**
- **Incomplete pumping characterized by R = 0.8 --> 1.0**
- **Edge-plasma density changes most strongly**

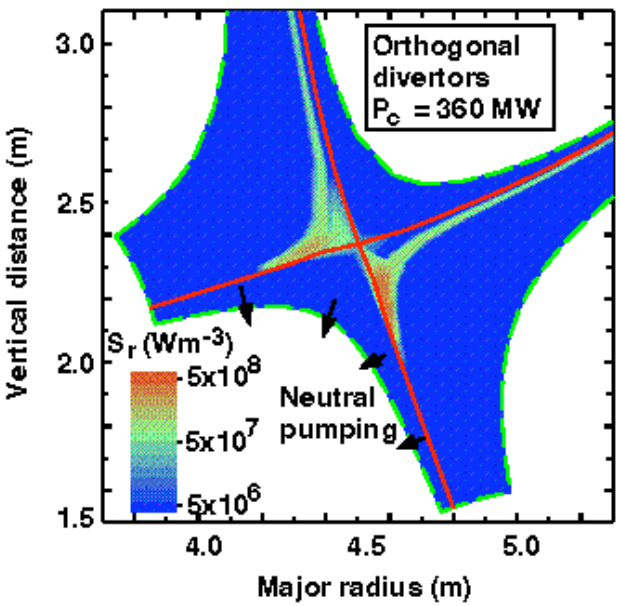
Outer divertor parameters vs. R



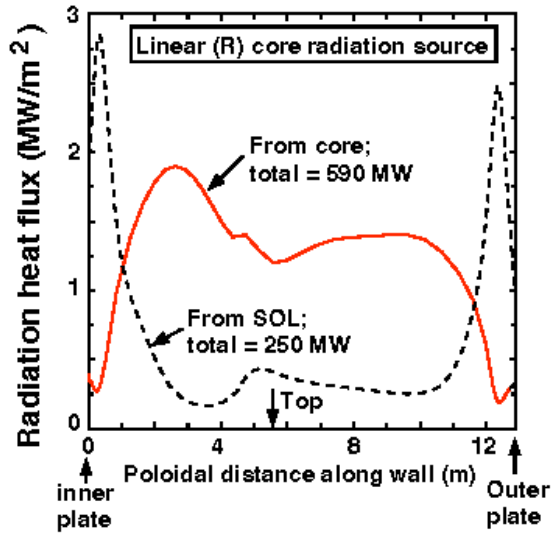
CLIFF wall with flinabe shows effective SOL radiation of core power if edge density ~ 1.5×10^{20}

- Large SOL powers radiated by fluorine from flinabe wall
- Wall and divertor heat fluxes are acceptable
- Stability of detached divertor plasma is key issue
- Helium pumping needs assessment

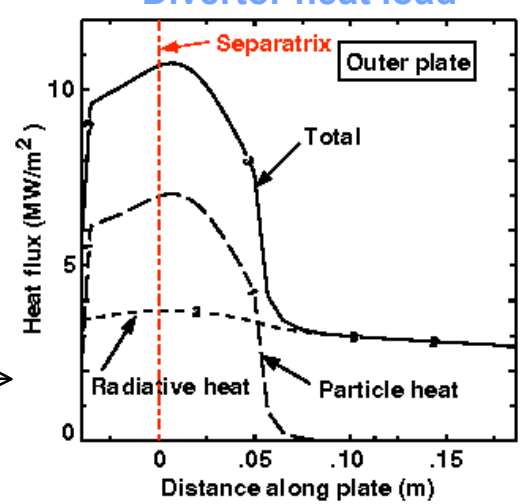
Fluorine radiation



Wall heat load



Divertor heat load

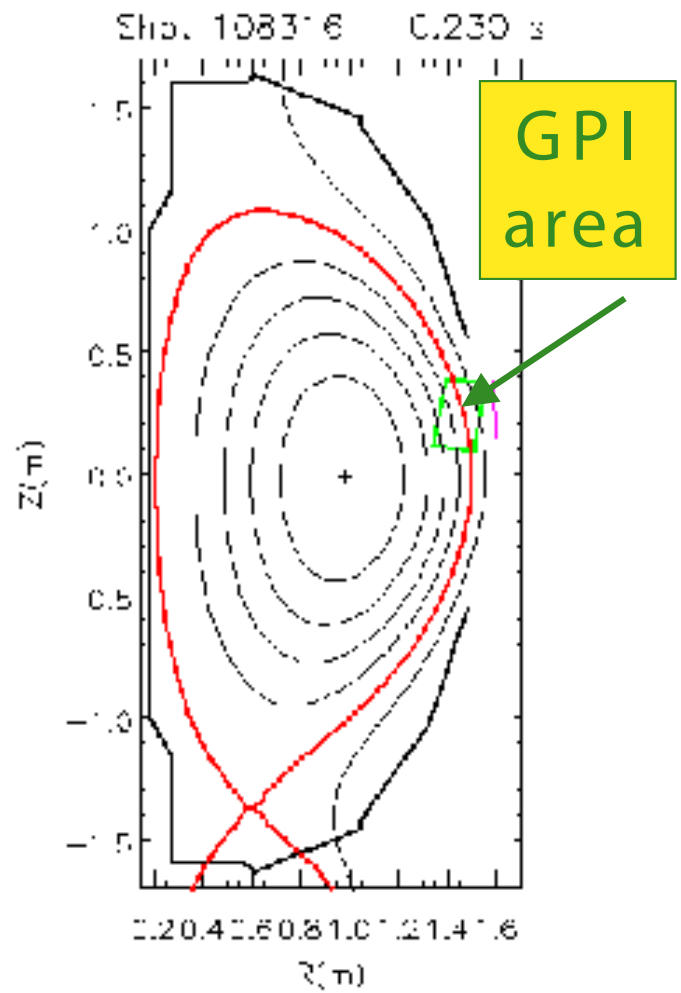


Rognlien
ALPS Feb. '03

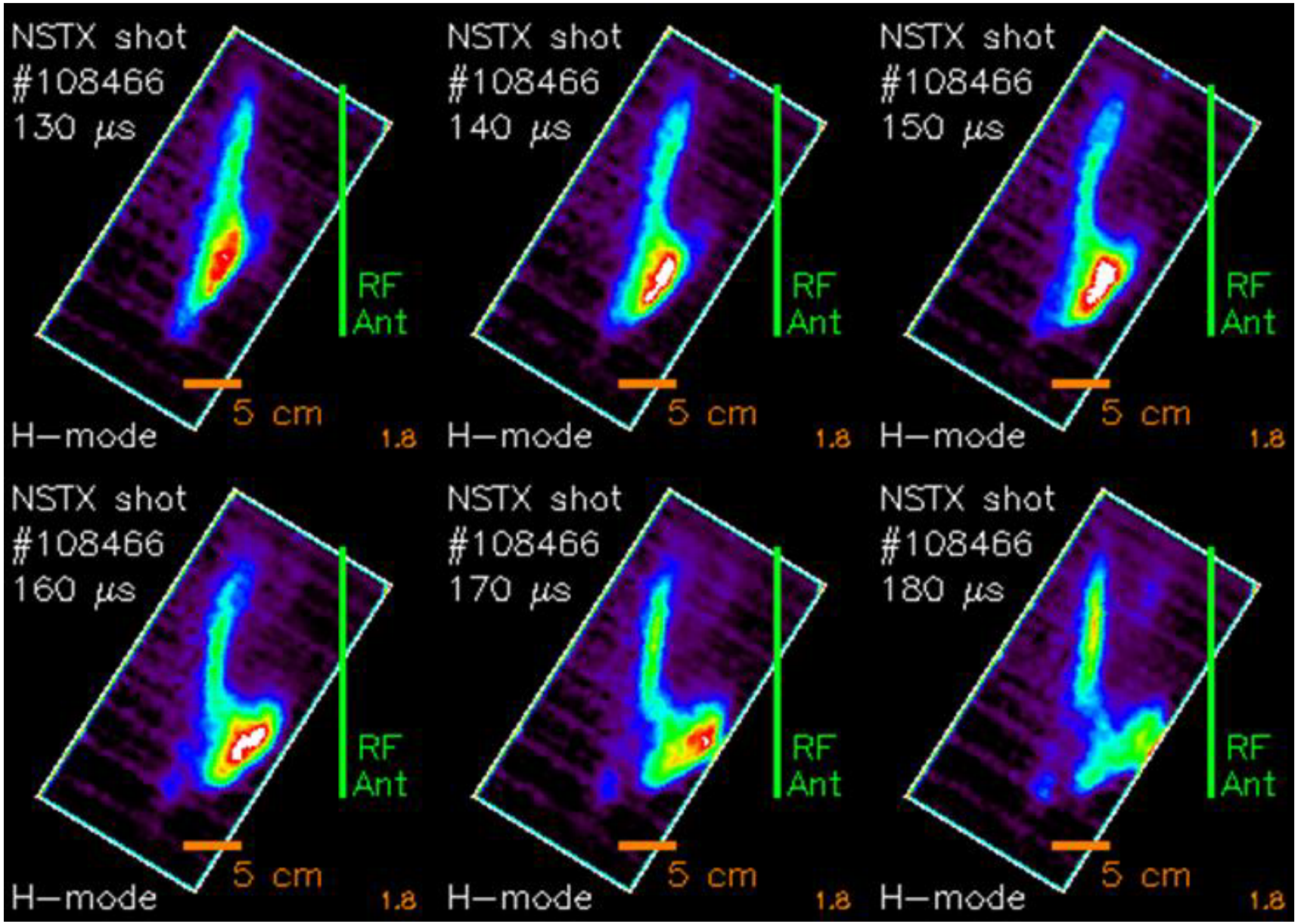
DEGAS 2 Neutral Transport Simulations of NSTX Gas Puff Imaging (GPI) Experiments

D. P. Stotler, PPPL

- Experiments puff gas near outer wall,
- View with fast camera visible emission resulting from electron impact excitation of that gas,
- Use sightline $\parallel \vec{B}$ to see radial & poloidal structure of turbulent plasma.
  - Compare with turbulence measured by probes,
  - And with output from plasma turbulence codes.
- Local emission rate $S = \sum_j n_j f_j(n_e, T_e)$ photons / s,
  - n_j = density of radiating species, f = emission rate,
  - Estimate n_j with neutral transport code using available n_e, T_e data.

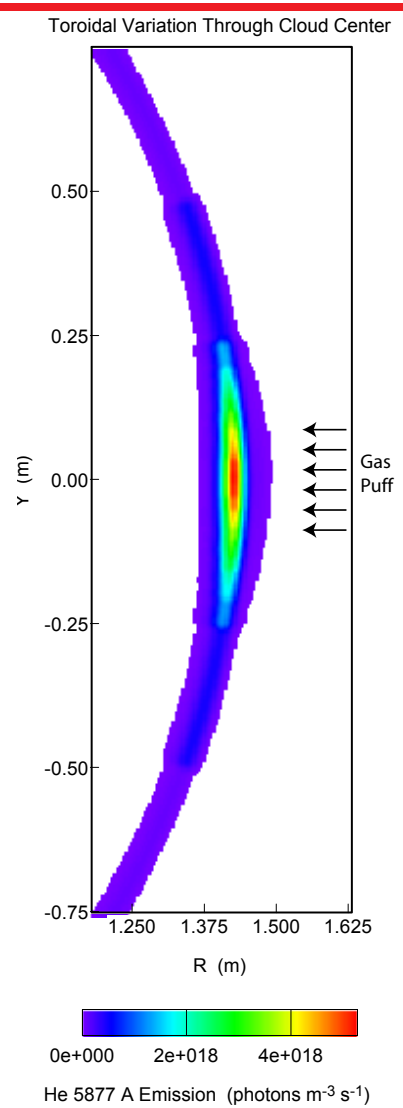


Camera Records Fluctuating Emission for 28 Frames @10μs/frame



Myra & D'Ippolito (Lodestar) Developing Technique for Analyzing "Blob" Motion

- Lodestar technique uses NSTX GPI images & Thomson scattering data to infer 2-D n_e and T_e profiles for each frame,
- Initial effort only factors in n_e, T_e dependence of He atomic emission rate, f_j.
- Will subsequently incorporate DEGAS 2-simulated neutral densities, n_j, to improve inferred n_e, T_e profiles.
  - Continuing to refine 3-D simulations of these experiments (figure).
  - Need 3-D simulation to establish absolute calibration.
- Using these n_e & T_e data, theory can predict blob velocities that can be compared with experiment.



Using Goto's He Collisional-Radiative Model to Compute $f_j(n_e, T_e)$

- Reaction rates newer than those in ADAS model,
- ADAS model treats fewer n and l states.
- However, some data used by Goto has significant uncertainty,
  - E.g., $3^1\mathrm{S} \rightarrow 3^1\mathrm{P}$.
- Goto's code is small and completely portable.
- Currently adding computation & output of energy loss terms to Goto's code.