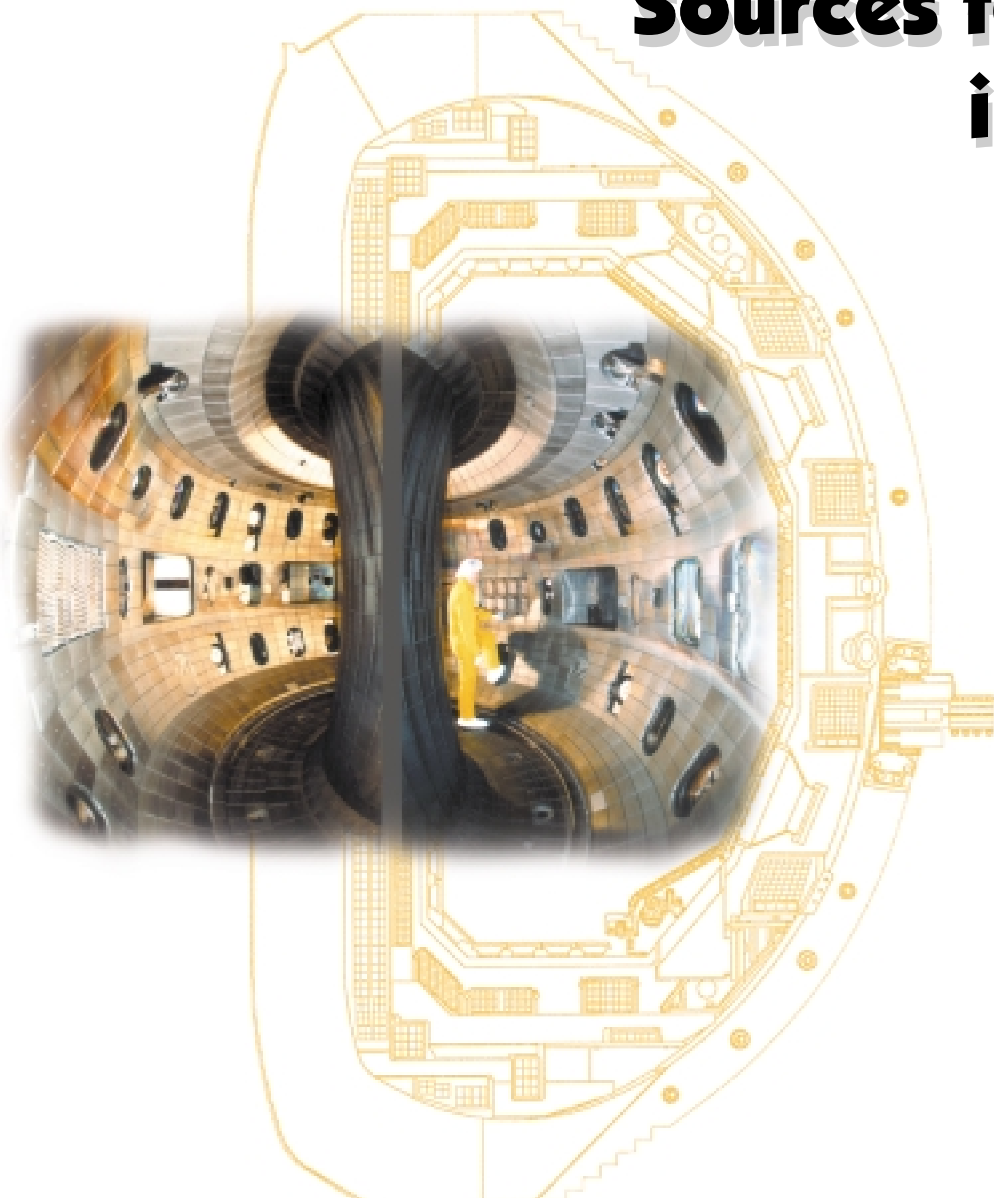
Sources for Carbon Production in the DIII–D Divertors



by
R.C. Isler*
for N.H. Brooks, W.P. West,
and D.G. Whyte†

*Oak Ridge National Laboratory
†University of California, San Diego, California

Presented at
the American Physical Society
Division of Plasma Physics Meeting
Quebec City, Canada

October 23–27, 2000

DIII–D
NATIONAL FUSION FACILITY

2000APS/wj

ornl

Can an understanding of carbon production provide insight to controlling the core content?

Mechanisms	Products (measured)
† physical sputtering →	C I
† chemical sputtering →	CD_4 → CD
	C_2D_y, C_3D_y → C_2, CD
† sublimation →	C I, C_2, C_3
†radiation enhanced sublimation →	C I

- Measure fluxes: Γ = emission x loss rate/excitation rate

  Γ = I S(T)/X(T) (uncertain by factors of 2)

- Measure kinetic and rotational temperatures

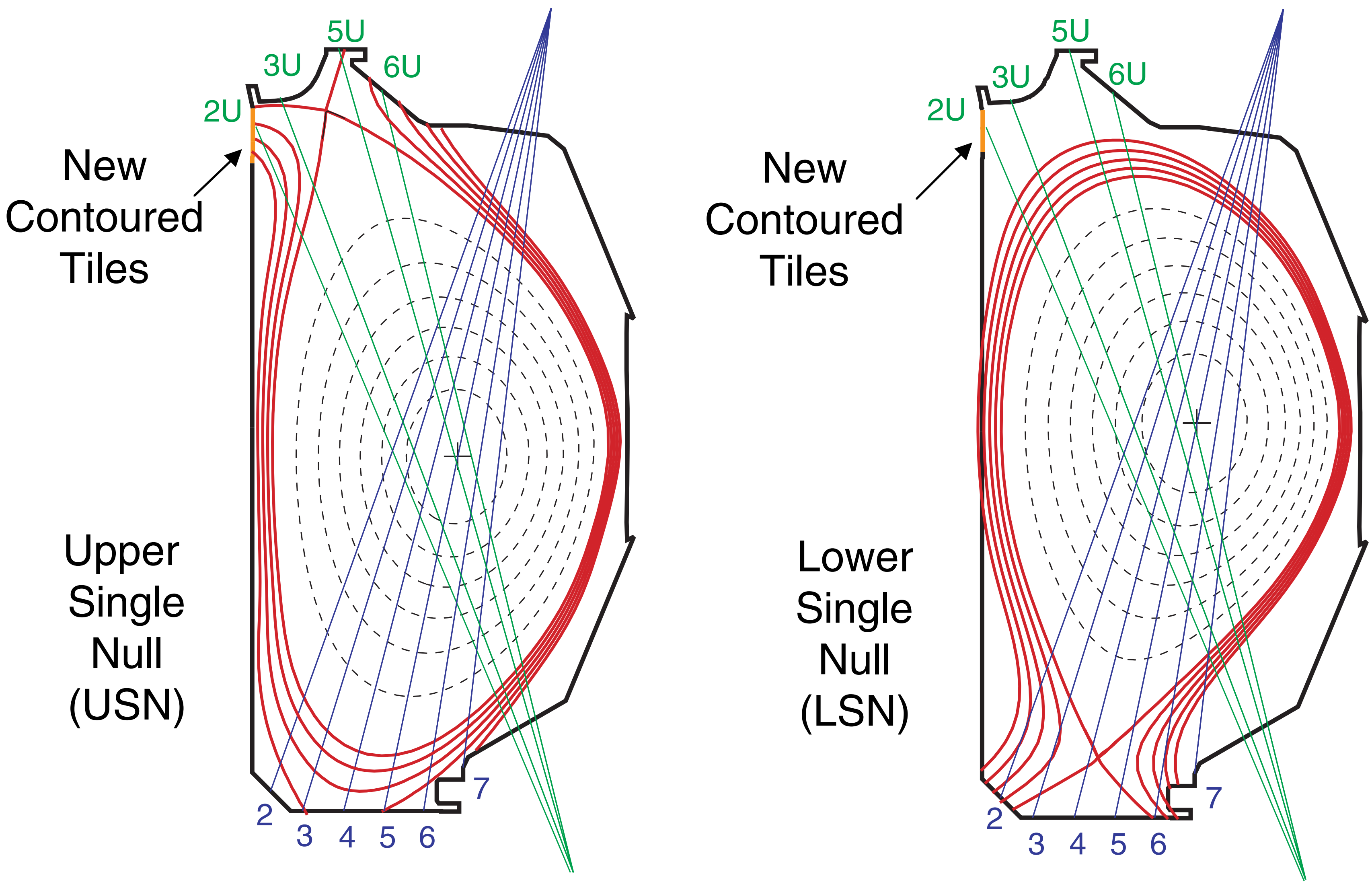
The conventional picture of carbon release for DIII-D divertor conditions

- Spectroscopy indicates electron and ion temperatures near the target are in the range of 5 - 10 eV, so ion energies should be below the threshold for physical sputtering.

- Chemical sputtering should be dominant in this temperture range and produce more C_2D_y and C_3D_y than CD_4.

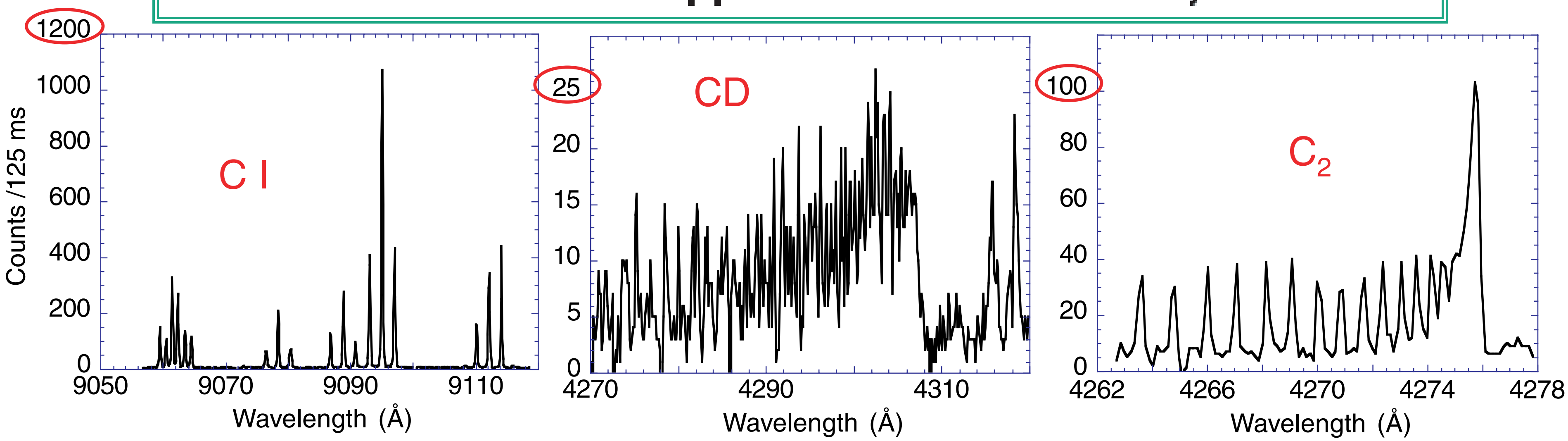
Flux measurements are not totally consistent with this picture.

Typical Magnetic Geometries and the Multichordal Divertor Spectrometer Views

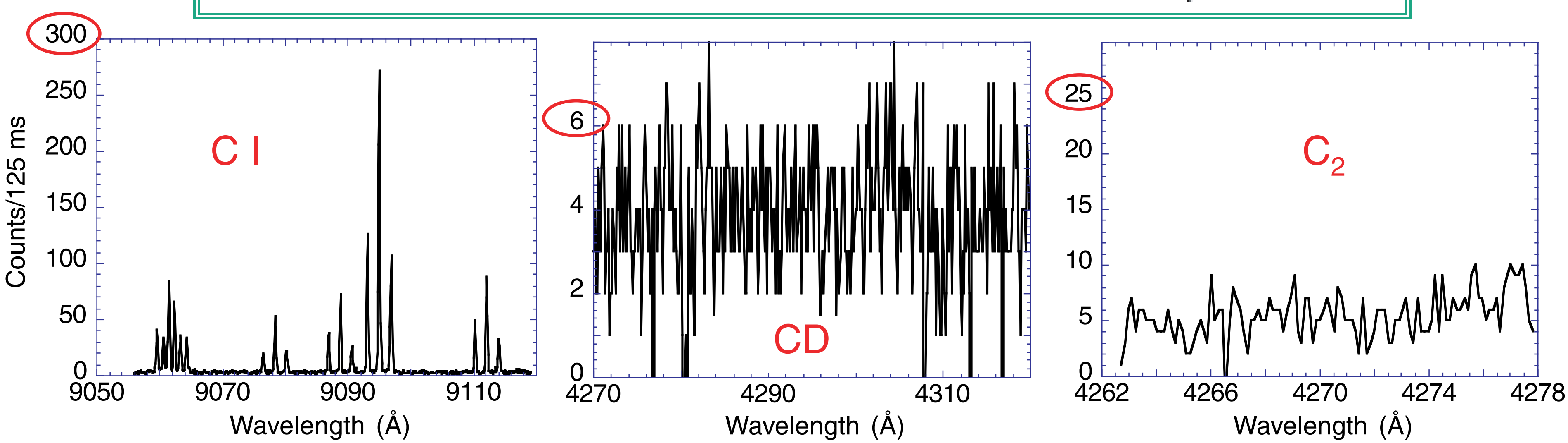


Unconditioned tiles are strong sources of carbon

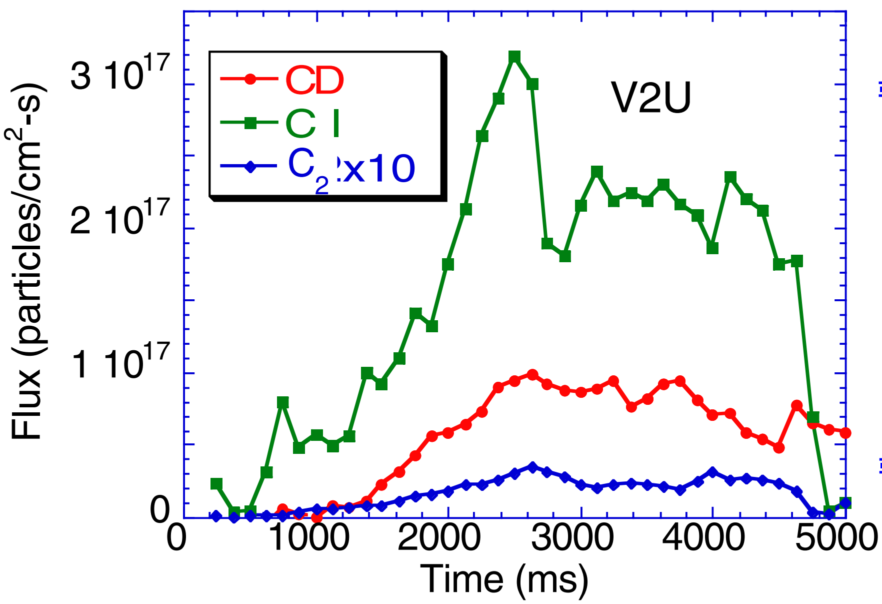
Unconditioned Tiles – Upper Divertor – 9.5 MW, VIEW V2U



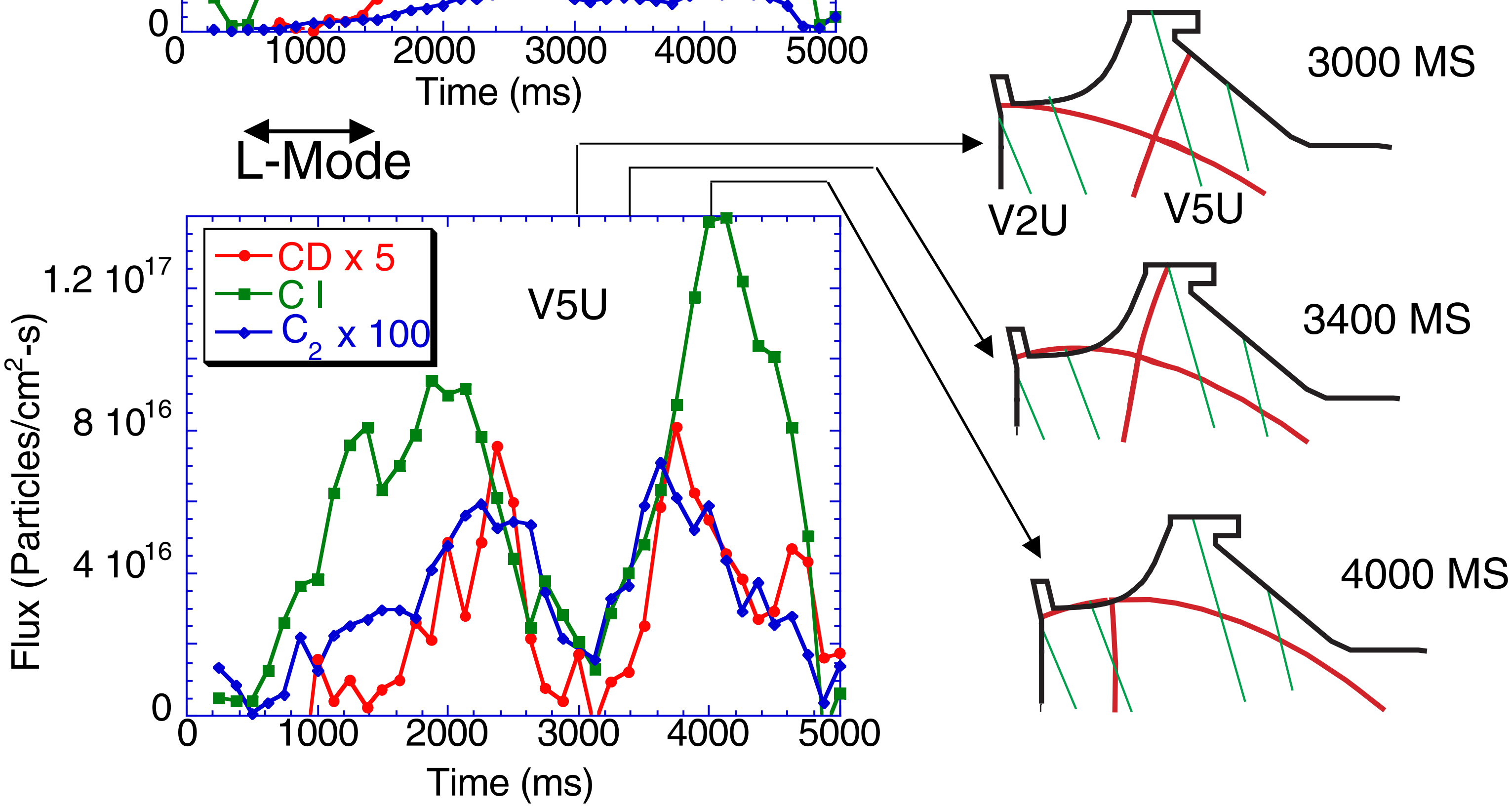
Conditioned Tiles – Lower Divertor – 7.5 MW, VIEW V2



Upper divertor fluxes

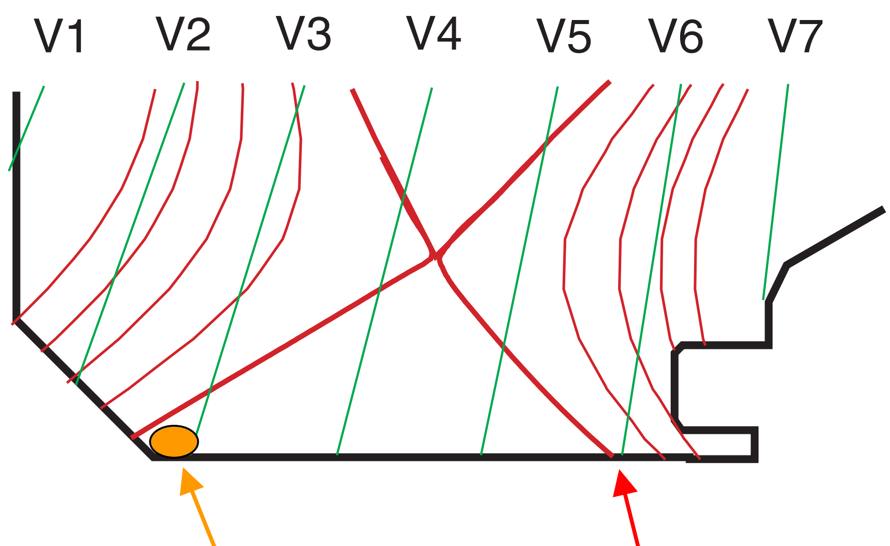


- Calculated molecular fluxes are less than atomic fluxes (5 eV assumed).
- Chemical sputtering of C_2D_y and C_3D_y is negligible.



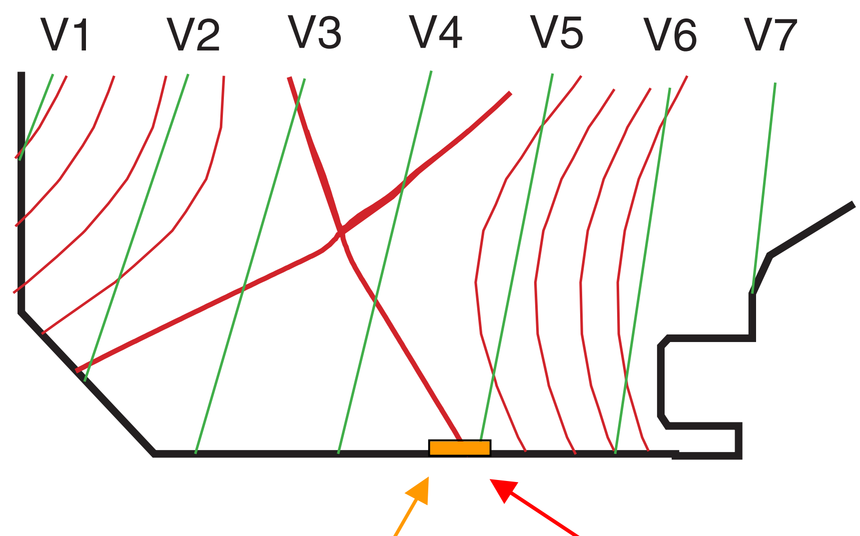
Lower divertor experiments at 9 MW NBI were designed to emphasize

Physical sputtering or Sublimation



Outer strike point at V6 location

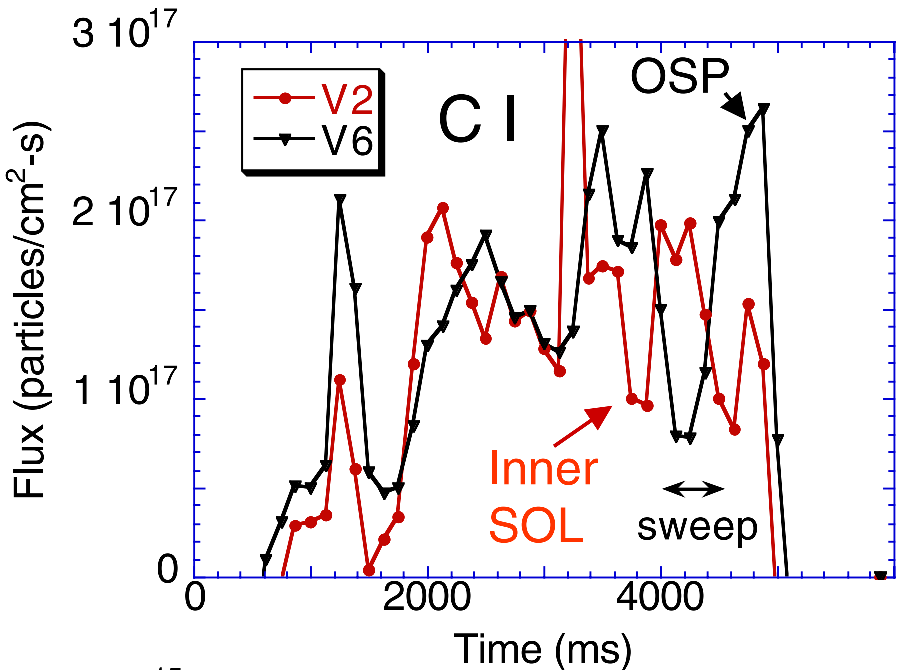
Hot spots observed Where 45° tile meets floor



Outer strike point at V5 location

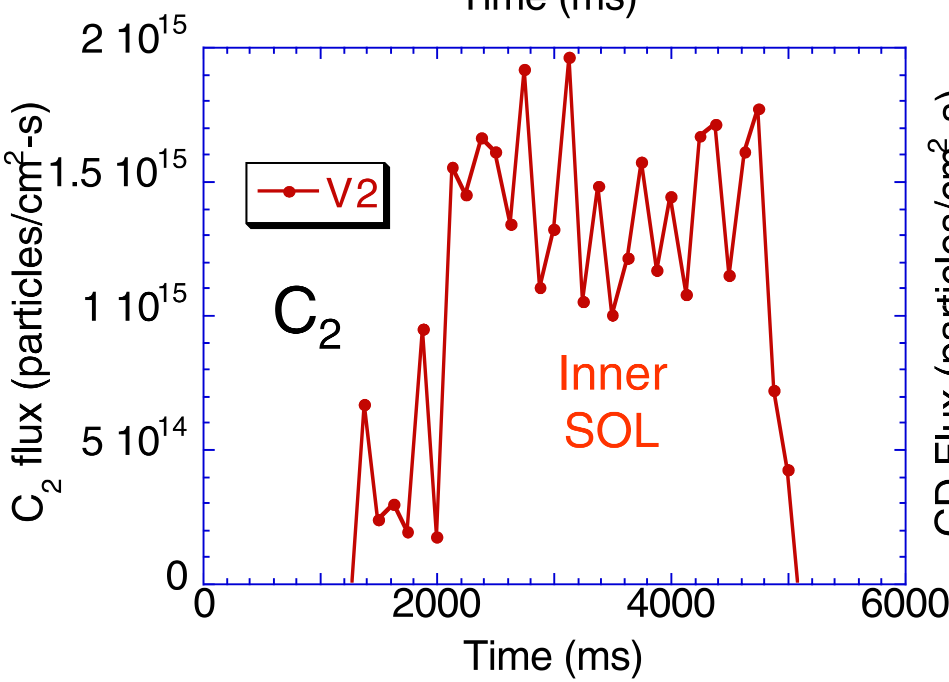
Carbon test sample protrudes 700 microns

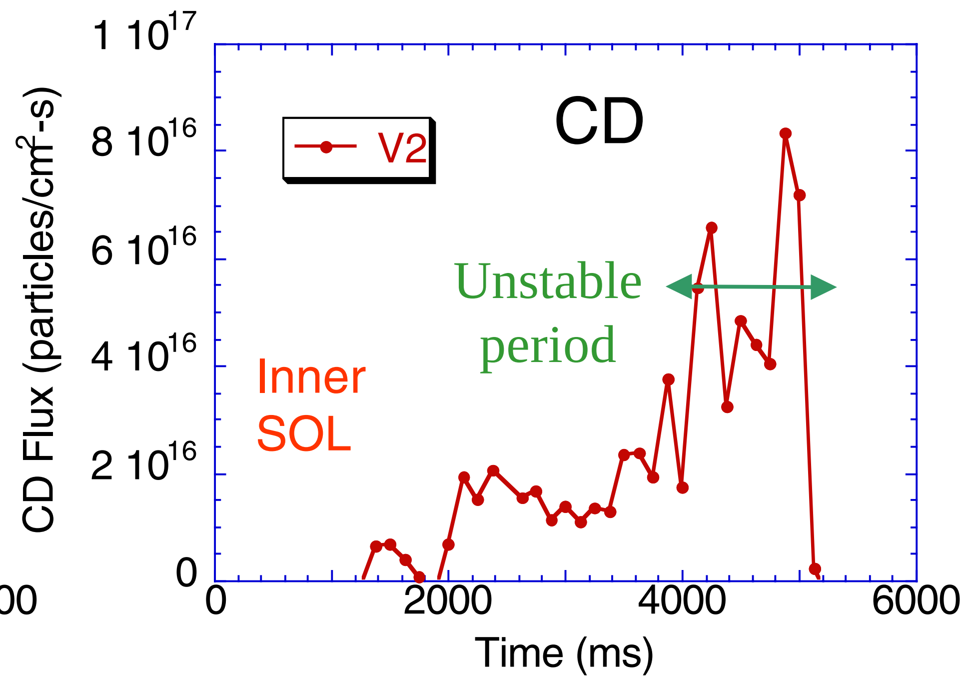
LSN Influxes - 9 MW



- C I is observed on all views
- C_2 appears only on V2 (inner SOL)
- CD appears along V2 and more weakly along V6 (OSP) after 3.8s.

Molecular sources are minor

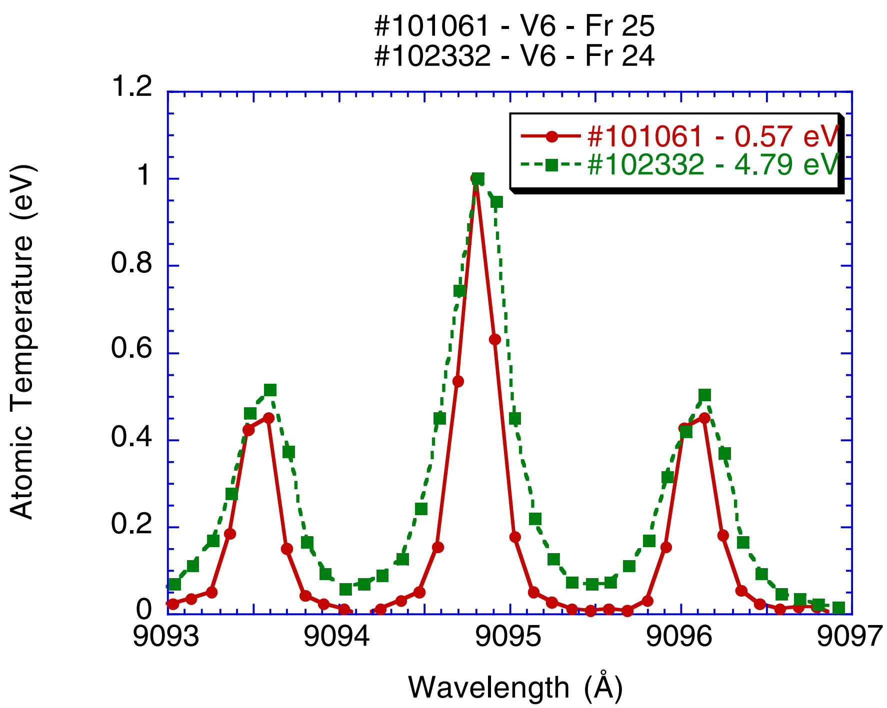


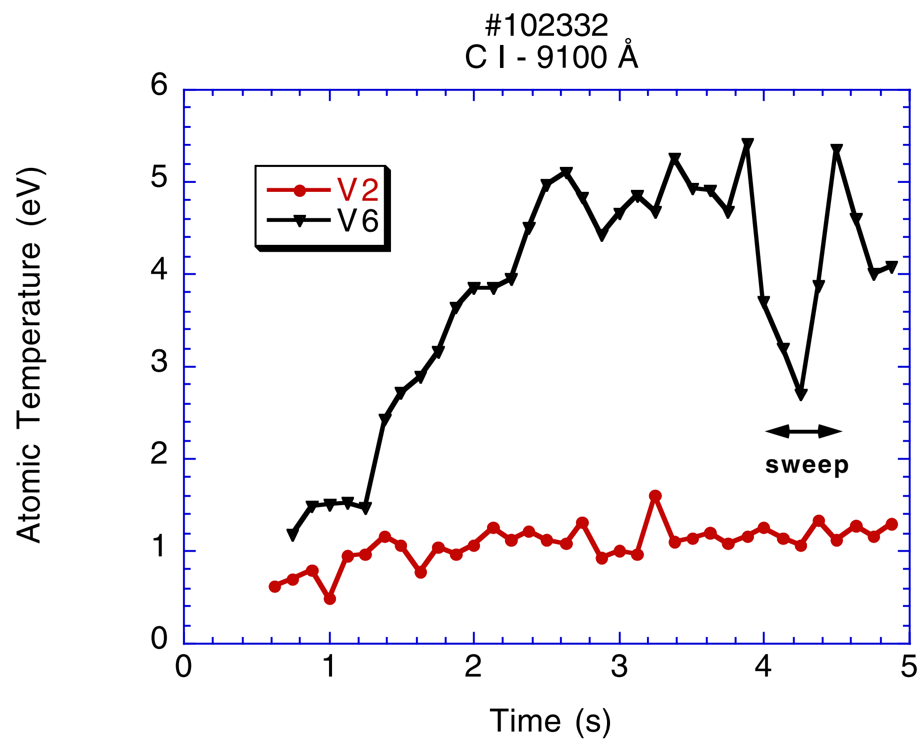


C I Temperatures with 9 MW NBI

•This is the only experiment on DIII-D where we have observed effective C I temperatures greater than 1.6 eV

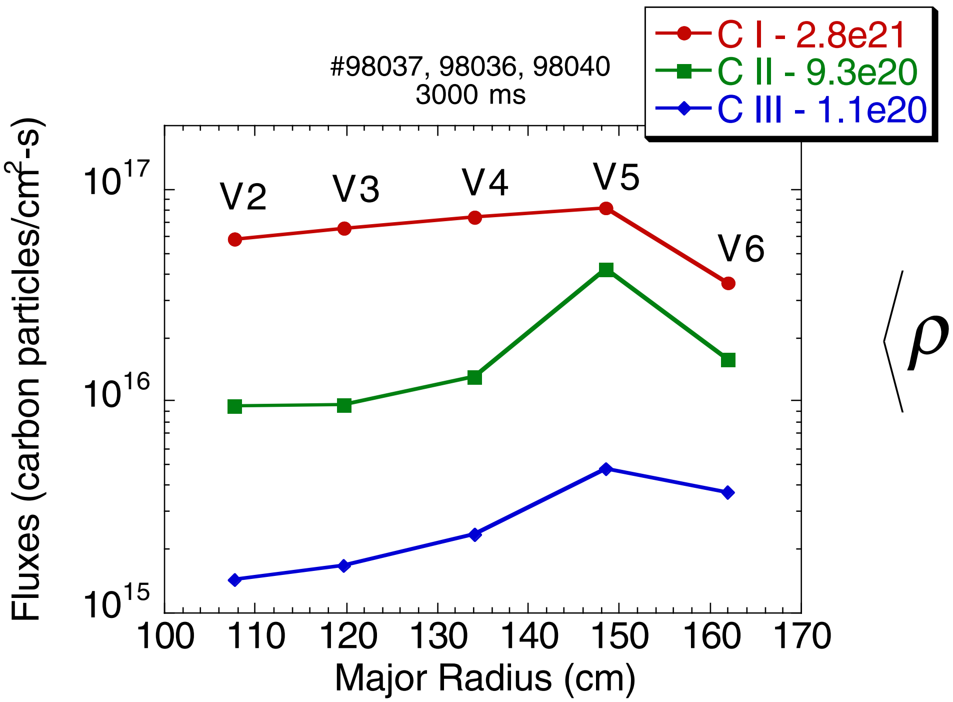
• Does this indicate sputtering? Is Roth's modified sputtering distribution incorrect. Are there phenomena which take place in a tokamak that are not observed in laboratories. Has the C I simply thermalized with deuterons?





Carbon released in the divertor is sufficient to explain the core carbon content

- Carbon ion influxes along the sightlines are reduced as the particles become more highly ionized. Only 4-5% of the neutral influx reaches the C III or C IV stage.
- The reduction with ionization stage is expected owing to the rapid flow (convection) toward the divertor target.



← Integrated fluxes

$$\langle \rho_C \rangle = \frac{\Gamma_{CIII} \bullet \tau_c}{Volume} = 5.5 \times 10^{11} / cm^3$$

Summary

- Carbon release from unconditioned tiles is a factor of 2-4 greater than from conditioned tiles
- C I influx from CD is as much as 40% on unconditioned tiles; it is less than 12% on conditioned tiles. C_2 influxes are negligible.
- These results are not consistent with release through low-impact-energy chemical erosion dominated by C_2D_y and C_3D_y fluxes.
- But, spectroscopy indicates electron and ion temperatures near the target (5-10 eV) are below those necessary to produce physical sputtering.
- The possible role of ELM's in physical sputtering needs to be studied more.