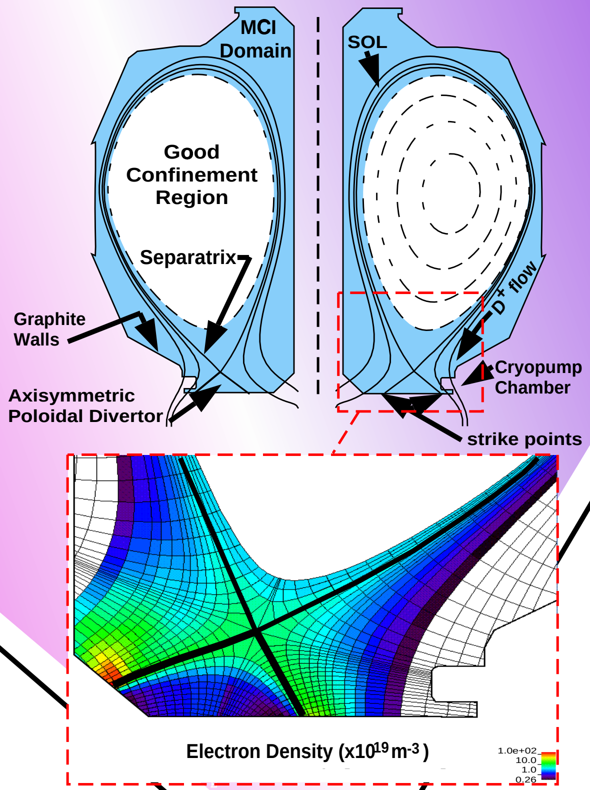

Atomic and molecular carbon production and transport studies in the DIII-D divertor and SOL with a Monte Carlo impurity transport code

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A Monte Carlo impurity transport code is used to understand how intrinsic carbon impurities reach the DIII-D core plasma

Goal

- Identify the primary points of origin of core penetrating carbon using a Monte Carlo code that incorporates realisitc sputtering, molecular dissociation and impurity transport models.

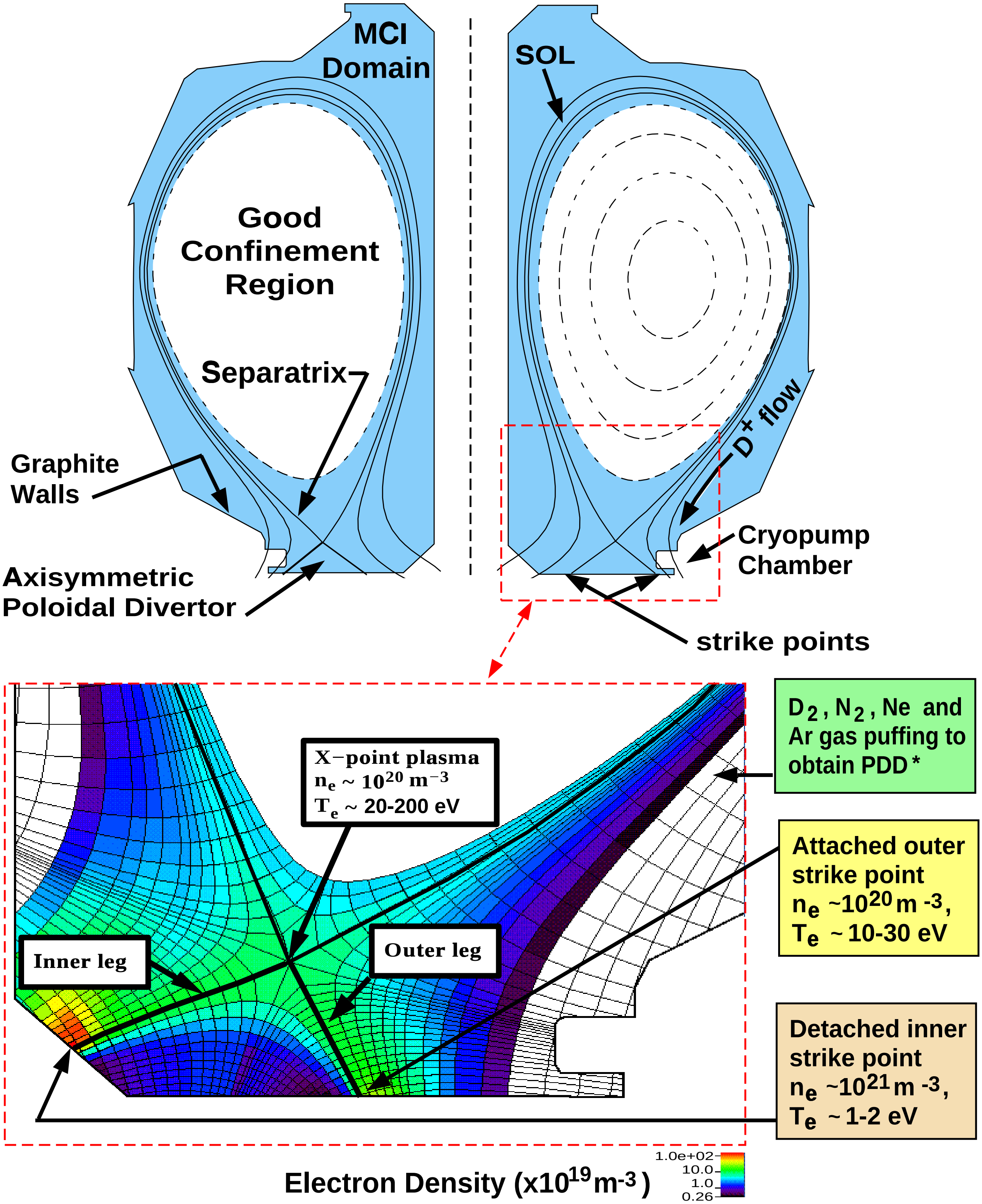
Approach

- Fluid background plasma solutions used to specify the divertor sputtering flux and divertor/SOL transport properties.
- Physical and chemical sputtering models generate carbon neutral launch properties at each target plate.
- Molecular dissociation physics modeled for chemically sputtered carbon.
- Core carbon penetration tallied as a function of source location and the type of sputtering process used to produce the carbon.
- Wall contributions assessed and compared to divertor sources.

Conclusion

- Experimental benchmarking of individual models being used for the background plasma, sputtering, molecular dissociation and impurity transport is essential in any edge modeling code.
  - systematic benchmarking of MCI's physics models has allowed us to select the best possible set of models for DIII-D simualtions of carbon penetration into the core.

The MCI computational domain extends from the 95% flux surface to the DIII-D walls



MCI Domain

Good Confinement Region

Separatrix

Graphite Walls

Axisymmetric Poloidal Divertor

SOL

D^+ flow

Cryopump Chamber

strike points

X−point plasma
$n_e \sim 10^{20}\ m^{-3}$
$T_e \sim$ 20-200 eV

Inner leg

Outer leg

D_2, N_2, Ne and Ar gas puffing to obtain PDD*

Attached outer strike point
$n_e \sim 10^{20}\ m^{-3}$,
$T_e \sim$ 10-30 eV

Detached inner strike point
$n_e \sim 10^{21}\ m^{-3}$,
$T_e \sim$ 1-2 eV

Electron Density ($x10^{19} m^{-3}$)

* PDD => Partially detached divertor

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Carbon simulation results are generally very sensitive to the sputtering physics used

Sputtering models are a key part of the MCI simulations process

$$Y_{TOT} = Y_{PHY} + Y_{CHEM}$$

Six physical and three chemical sputtering models are available in MCI

Smith78 [1]

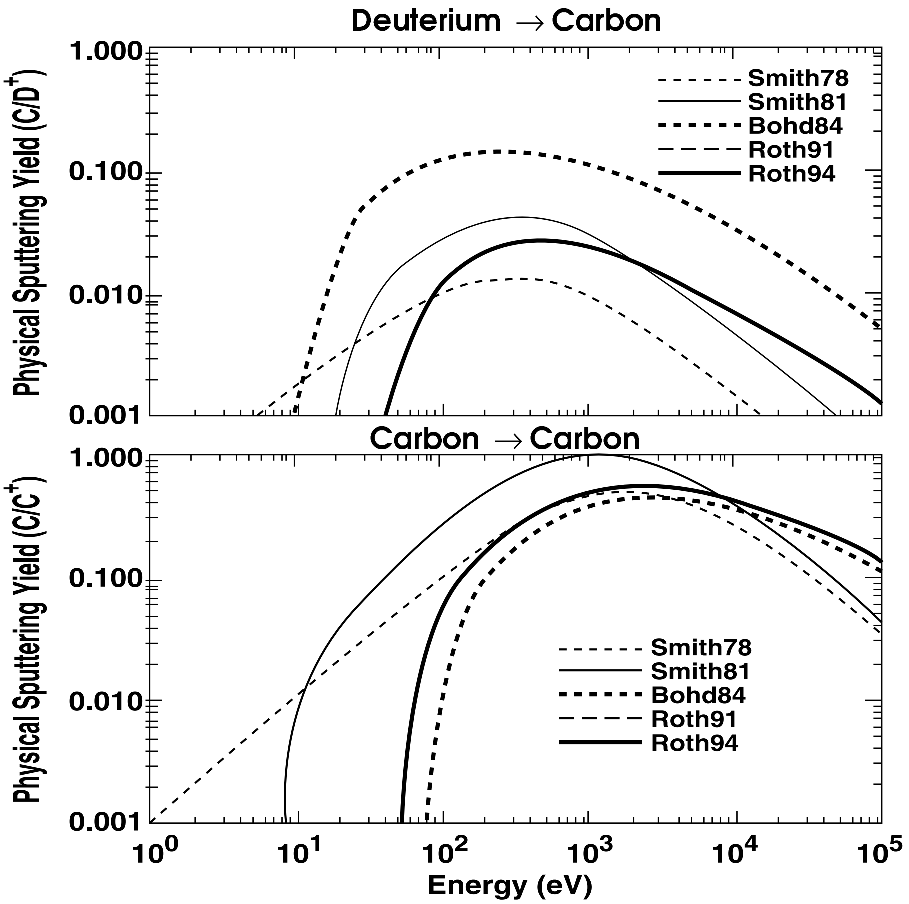
Smith81 [2]

Bohd84 [3]

Roth91 [4]

Roth94 [5]

Y=Const.

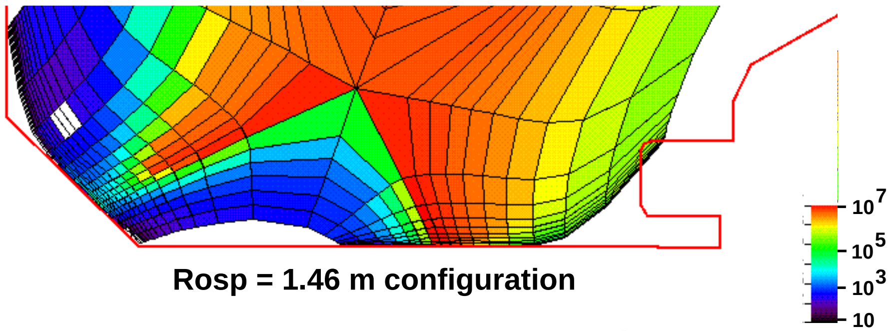


- Chemical sputtering modeled using either Roth96 [6], Roth98 [7] or Haasz97m [8].

- DIII-D benchmarks of MCI simulations [9] using these models indicate the best choice is Roth94 + Roth96.

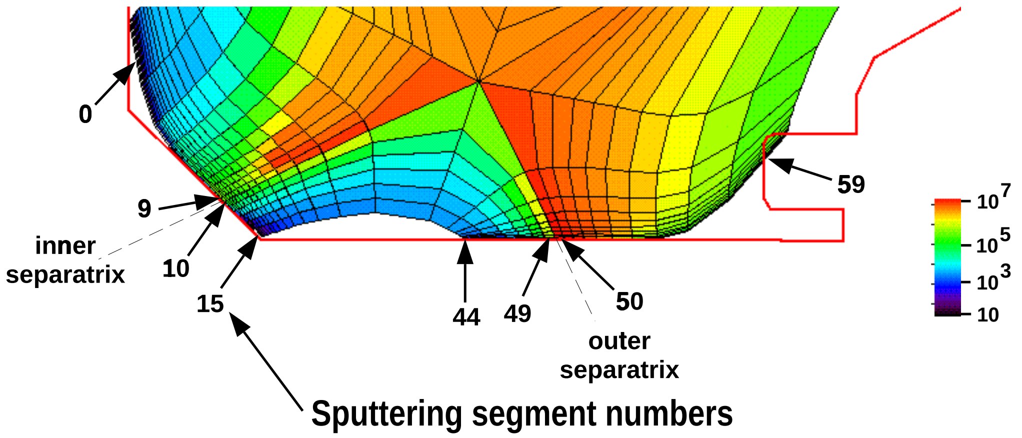
ADAS ionization rates are higher in the divertor than ADPAK resulting in less core carbon

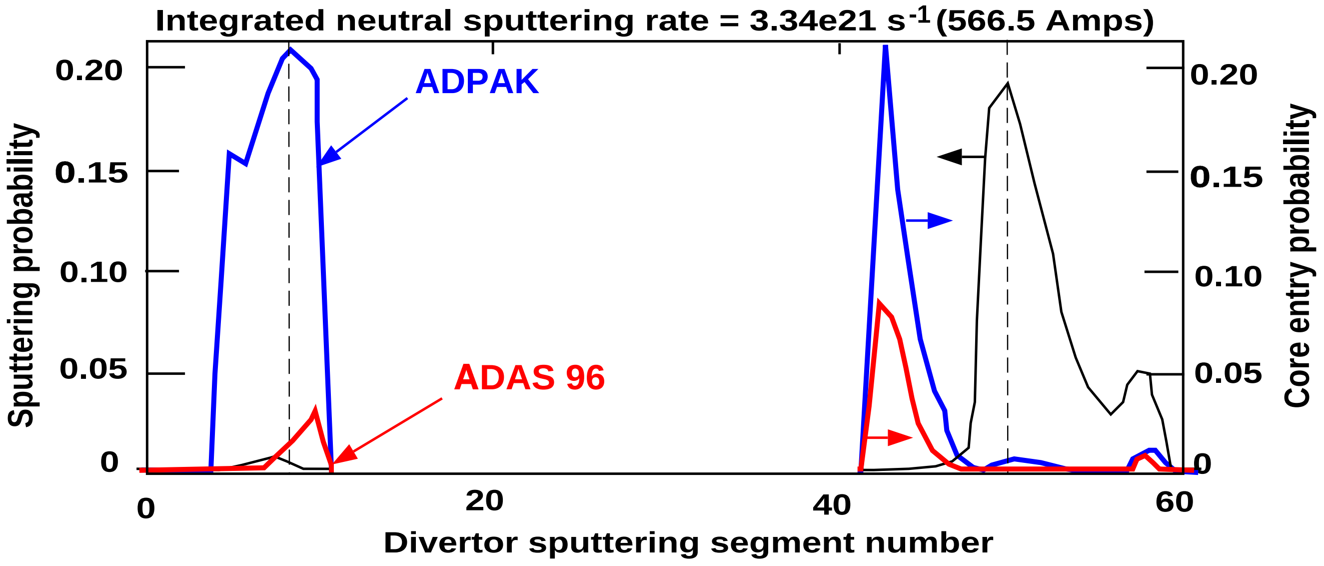
ADPAK CI Ionization rate (s^{-1})



Rosp = 1.46 m configuration

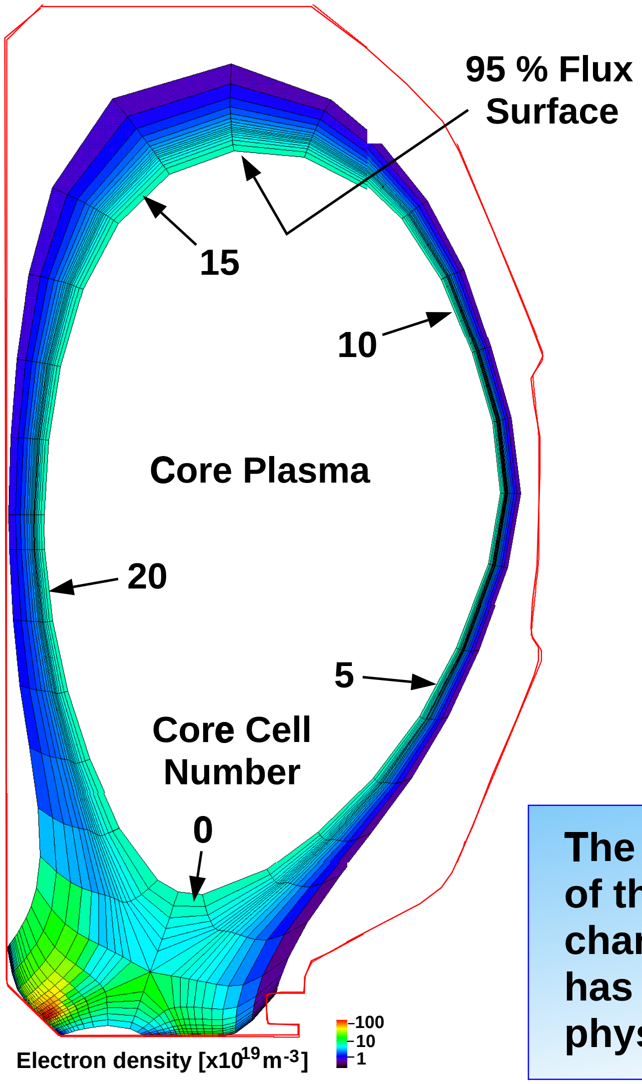
ADAS 96 CI Ionization rate (s^{-1})





- ADAS96 data is more accurate than the coronal, average ion, ADPAK data and thus is preferred for MCI modeling.

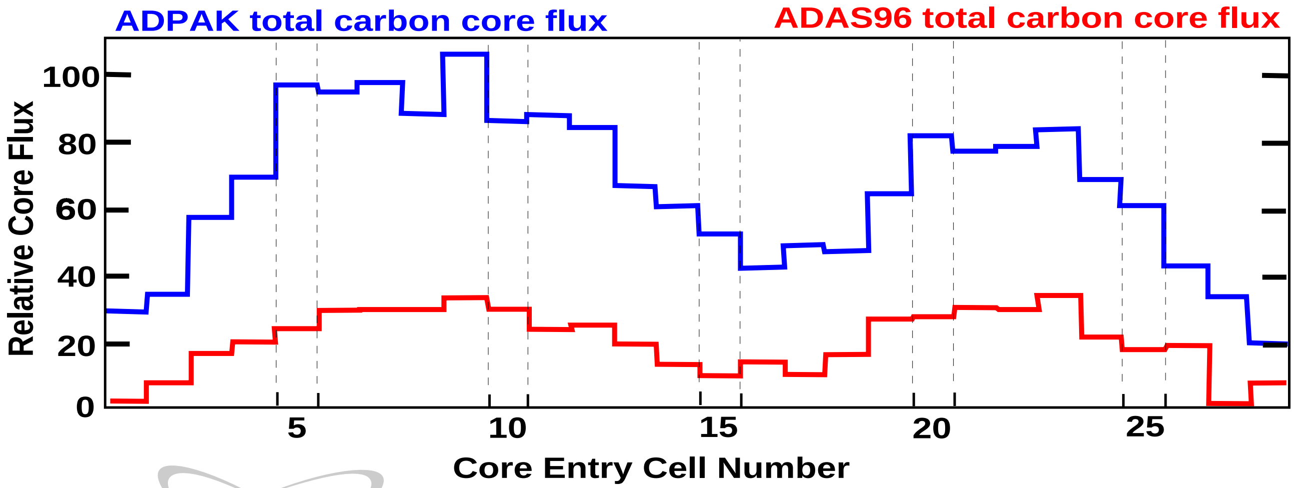
The divertor and SOL transport physics in MCI is relatively insensitive to the atomic data



	ADPAK	ADAS96
Number of Non-recycling particles	443,292	1,563,528
Total Number of core entries	3,670	1,200
Total carbon core density (m^{-3})	9.87e17	1.36e17

Integrated carbon sputtering current = 3.3e21 s^{-1} (566.5A)

The core entry distribution is independent of the atomic data (only the magnitude changes) implying that the atomic data has relatively little effect on the transport physics.



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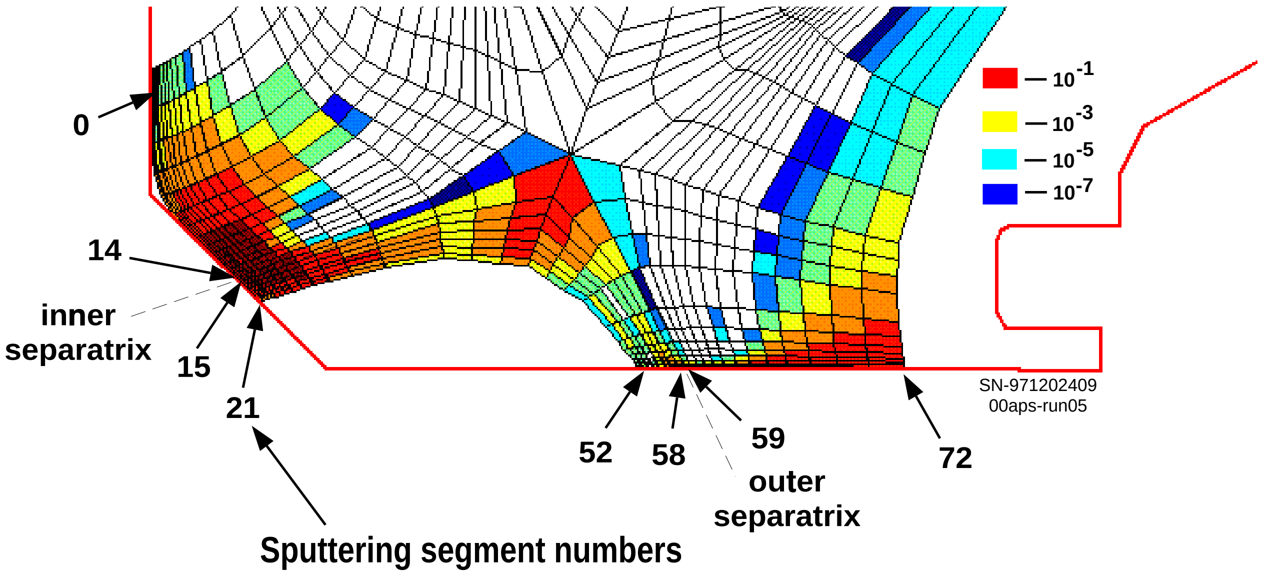
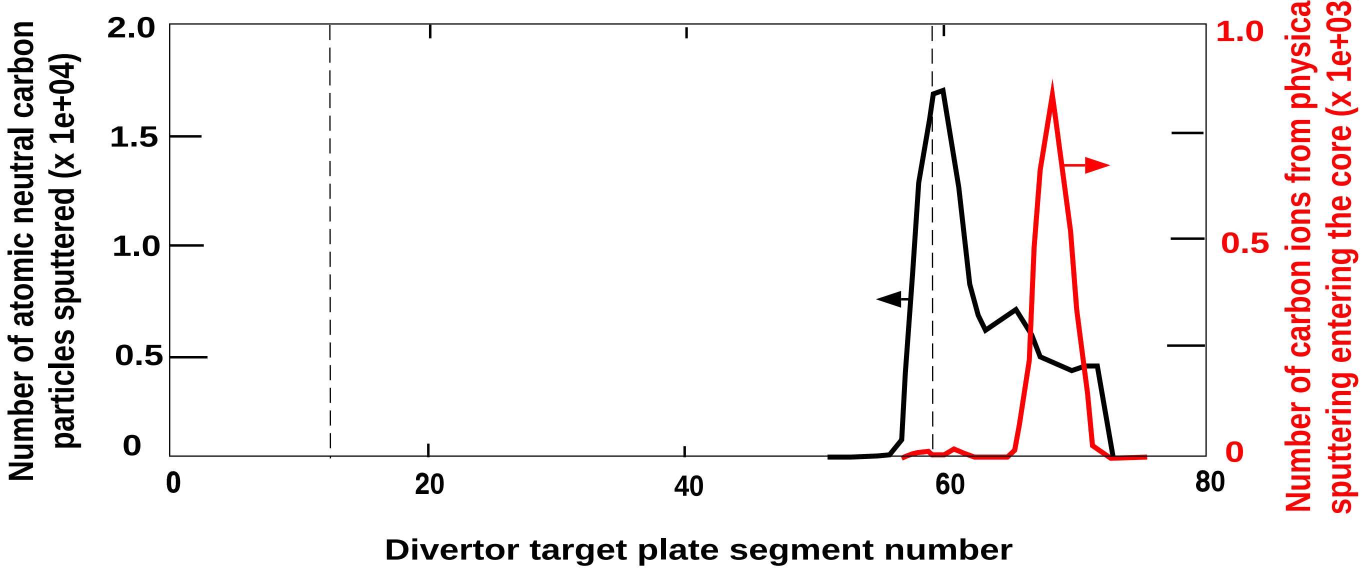
When the plasma is moved away from the outer divertor structure a bypass channel forms for physically sputtered carbon in the outer SOL

CII density calculated by MCI [10^{19} m^{-3}]

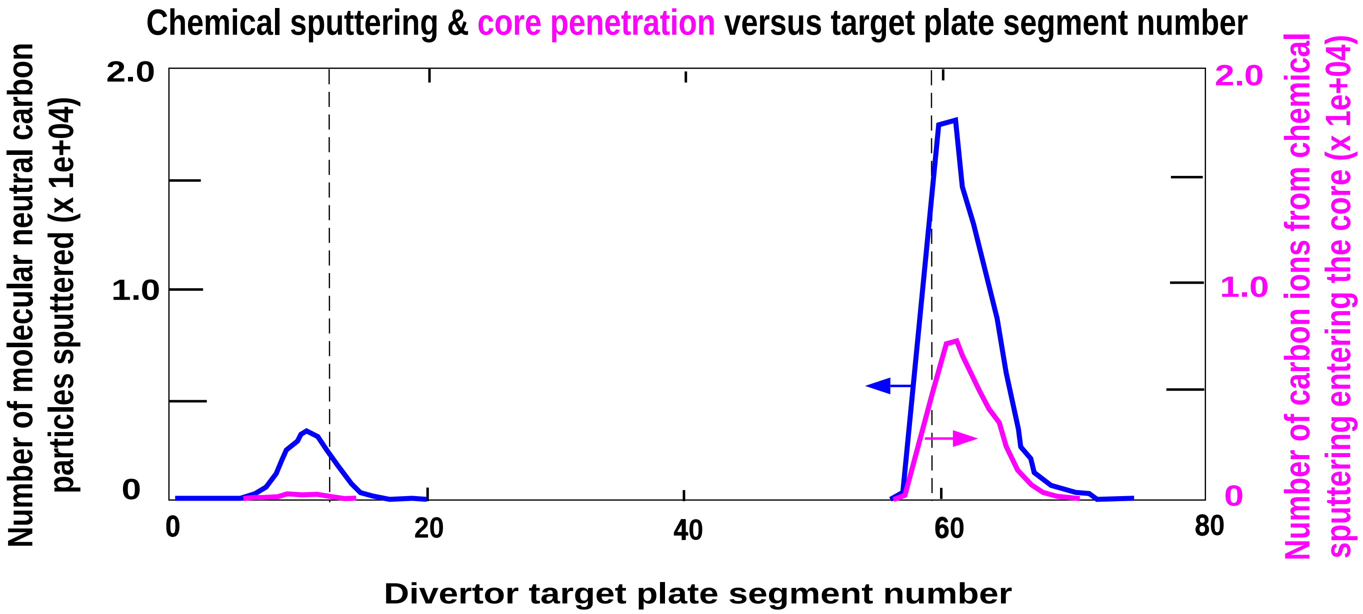


Physical sputtering & core penetration versus target plate segment number



- The integrated neutral carbon sputtering rate from physical and chemical sources is 1.23e21 s^{-1} (197.0 Amps) based on the Roth94 + Roth96 models

Carbon from chemical sputtering near the outer strike point has a high probability of reaching the core with the plasma shifted inward



Chemical sputtering & core penetration versus target plate segment number

- MCI can use either the Alman-Ruzic [10] or the Ehrhardt-Langer [11] dissociation model. Measurements of CH_3 cross sections [12] and MCI benchmarking against PISCES data indicates the Alman-Ruzic model is preferred.

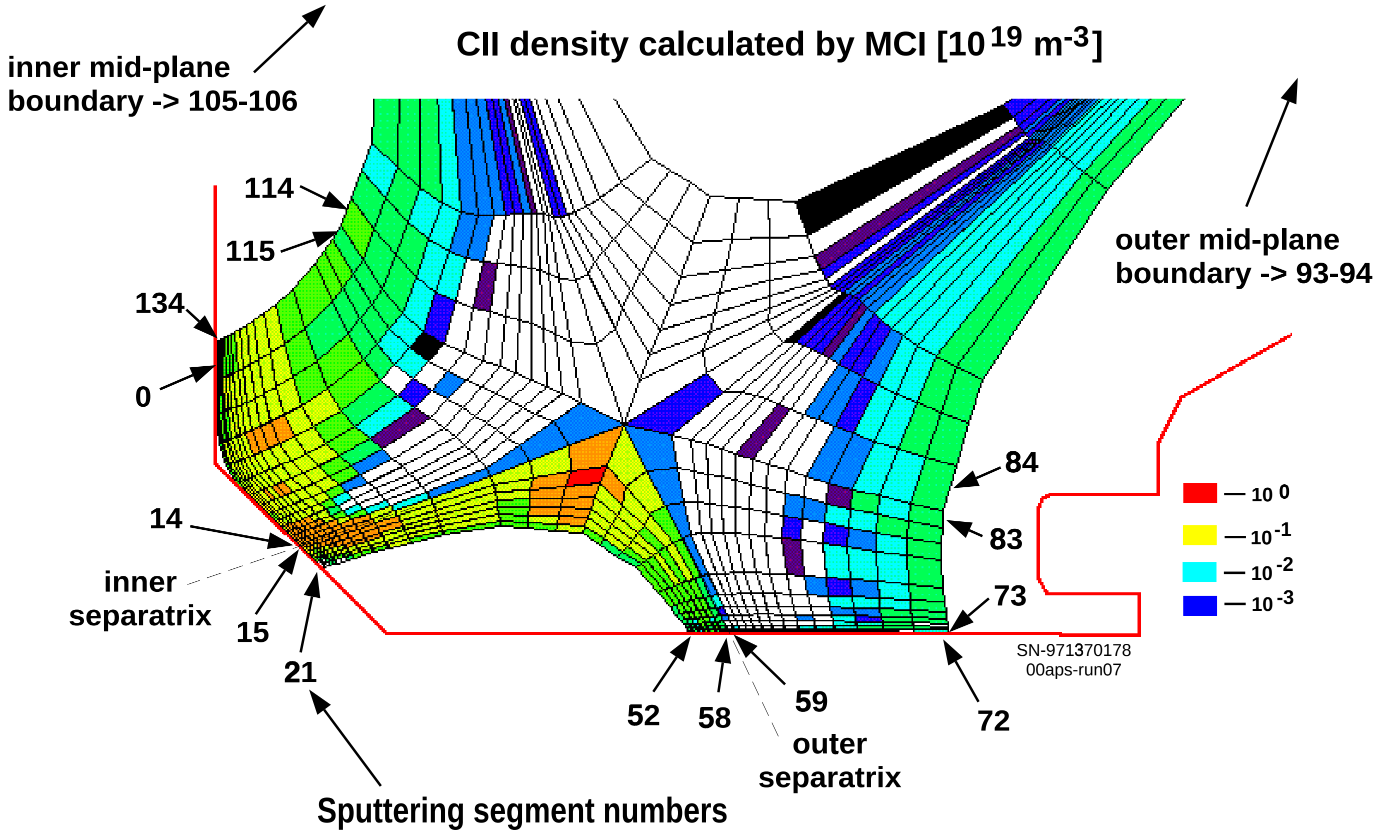
- Preliminary MCI runs suggest that 45-50% of the chemically sputtered carbon from the outer-SOL target plates enters the core.

- About 5-10% of the chemically sputtered carbon from the inner strike point enters the core through the private flux region.

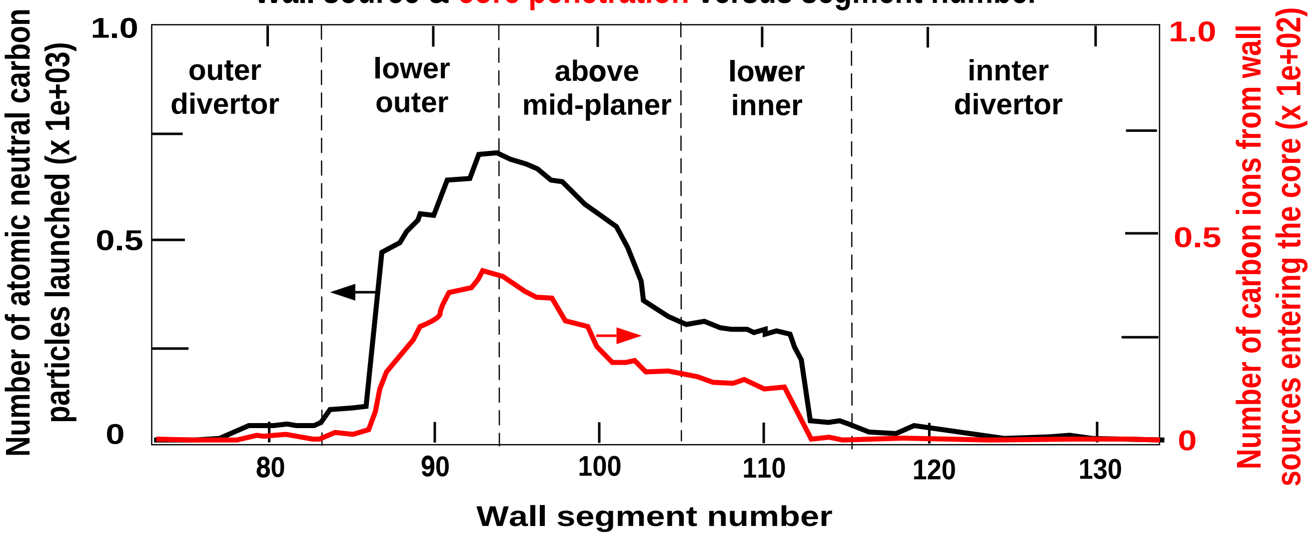
- Molecular dissociation processes provide an relatively efficient pathway for neutral carbon from chemical sputtering to reach the core plasma.

Wall sources increase the SOL CII content and have a 50-60% probability of reaching the core

CII density calculated by MCI [10^{19} m^{-3}]



Wall source & core penetration versus segment number



Carbon generated by plasma interactions with the walls is simulated with a uniform carbon flux at the grid boundary

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Discussion and results

- Monte Carlo simulations of core carbon penetration probabilities in tokamaks require a wide range of models working together.
  - some of these, such as the impurity transport and molecular dissociation models, have been individually benchmarked in PISCES plasmas using MCI (O’Brien, et al., poster HP1.081).
  - others, such as the background plasma and sputtering models have been collectively benchmarked in DIII-D with MCI [9].
  - in addition, MCI simulations have shown that the use of accurate atomic data is crutial for good benchmarking results.
- The MCI benchmarking process has allowed us to select the best combination of models needed to assess carbon production and transport into the core plasma.
- The most significant results from our core penetration studies are:
  - preliminary studies indicate that molecular dissociation increases the probability of core penetration.
  - the position of the plasma with respect to the outer divertor structures strongly affects how physically sputtered carbon reaches the core.
  - physically sputtered carbon sources from the wall have a higher probability of reaching the core than those from the divertor.

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