UEDGE Modeling of the Effect of Changes in the Private Flux Wall in DIII-D on Divertor Performance

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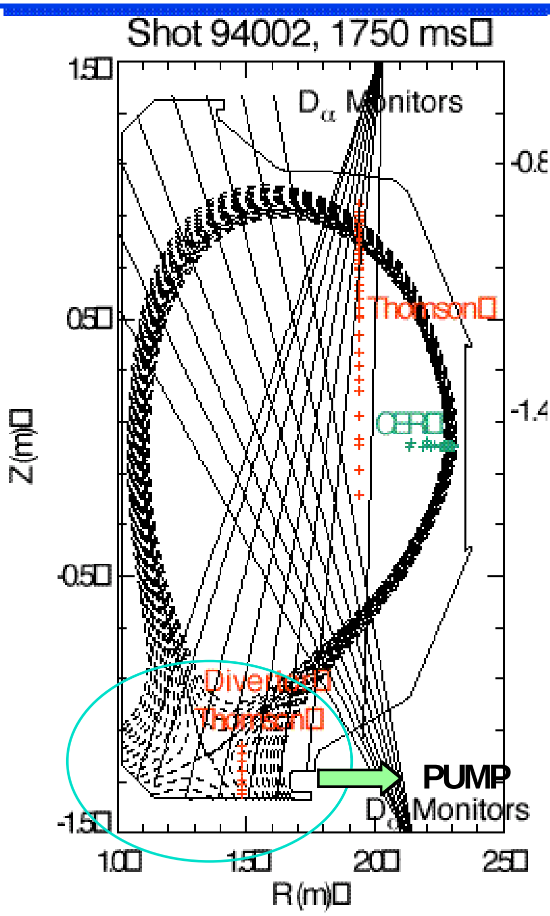
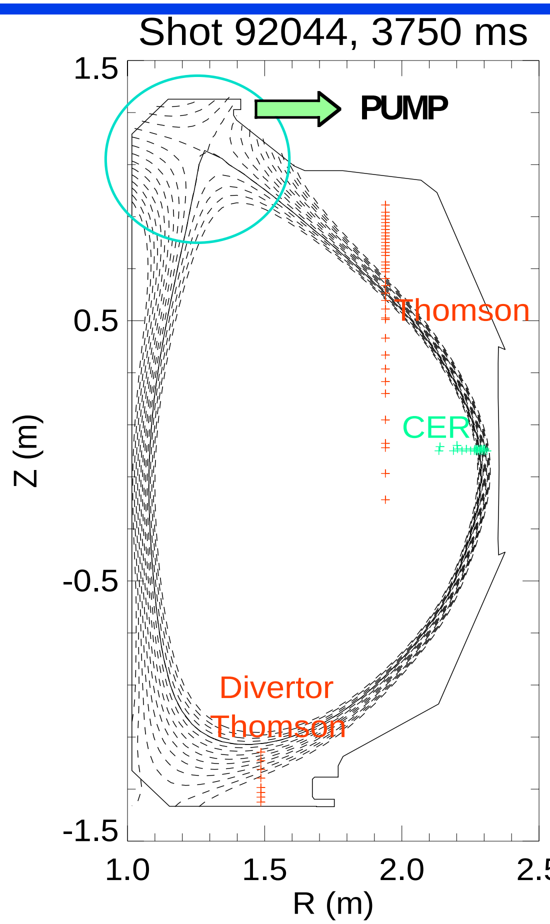
Presented at the APS-DPP Meeting, Nov. 17, 1999

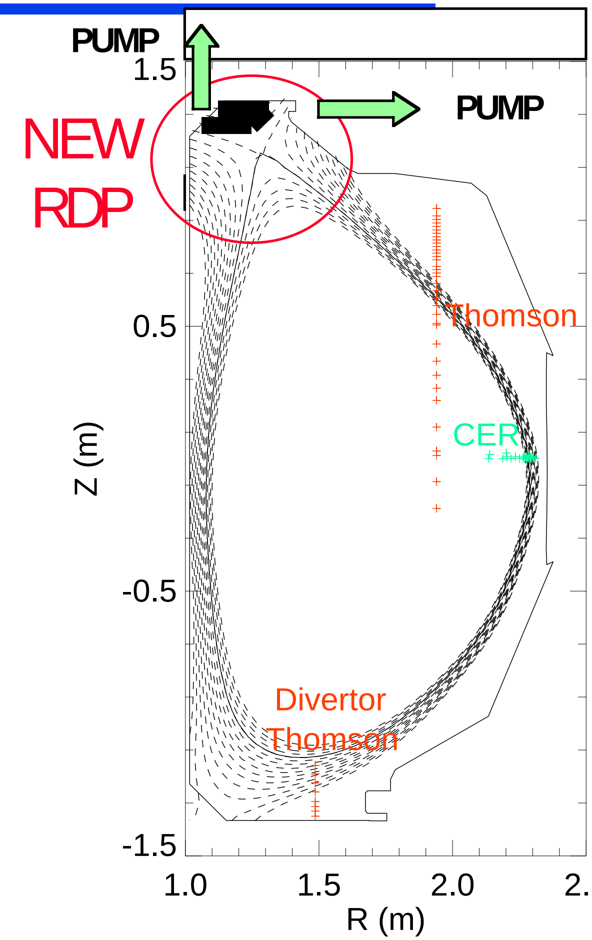
MOTIVATION: determine the effect of changes in the DIII-D upper divertor



Open Divertor
Lower Single Null
[used for validation]



RDP or Closed Divertor
Upper Single Null



Private Flux Region Dome
In the new RDP

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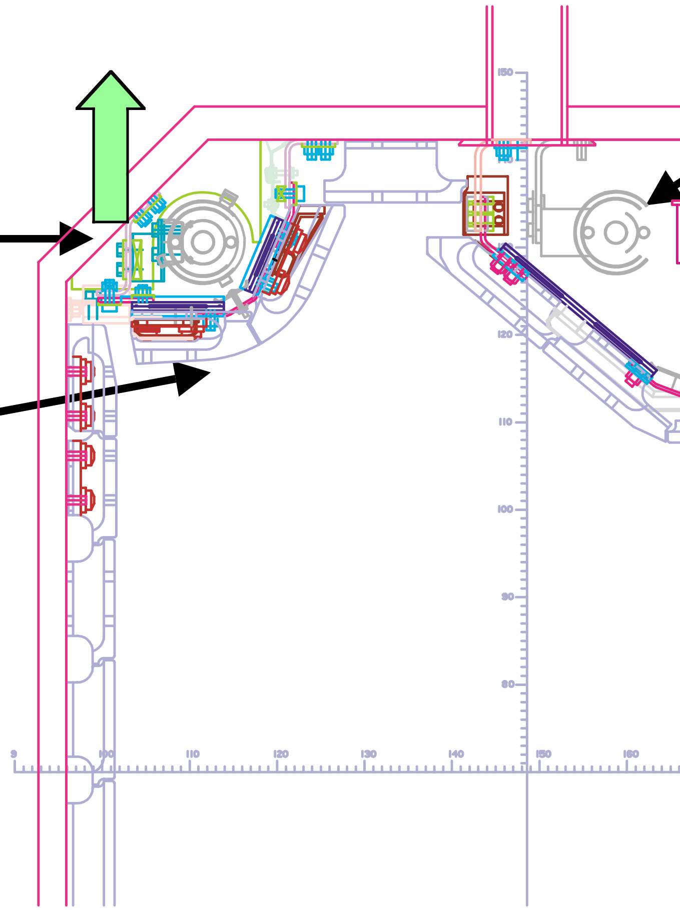
Upper divertor (RDP) now has a dome in the private flux region and a pumped inner leg

The new RDP



METHOD: simulate the SOL and divertor plasma with the UEDGE code

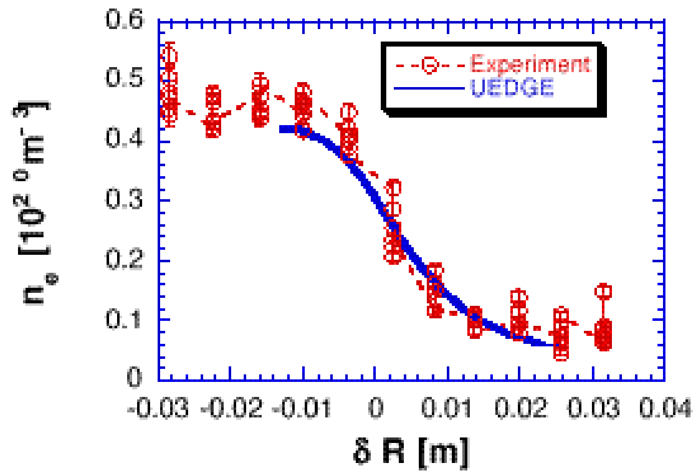
- **UEDGE solves equations for ion continuity, energy and momentum on 2-D domain, simulating the plasma from:**
  -- 96% flux surface to limiter surface in radial direction,
  -- plate to plate in poloidal direction
- **Hydrogenic ion fluid (Braginskii equations)**
- **Navier Stokes fluid equations for neutrals**
- **Collisional-radiative hydrogenic rates**
- **Turbulence-driven perpendicular (radial) transport**
- **Carbon source is physical and chemical sputtering from walls, using Univ. Toronto model [Davis & Haasz, J. Nucl. Mater. 241-243, 37,1997]**
- **Force balance equations for 6 ionization states of carbon**
  -- diffusive neutral carbon fluid
  -- non-equilibrium coronal impurity radiation

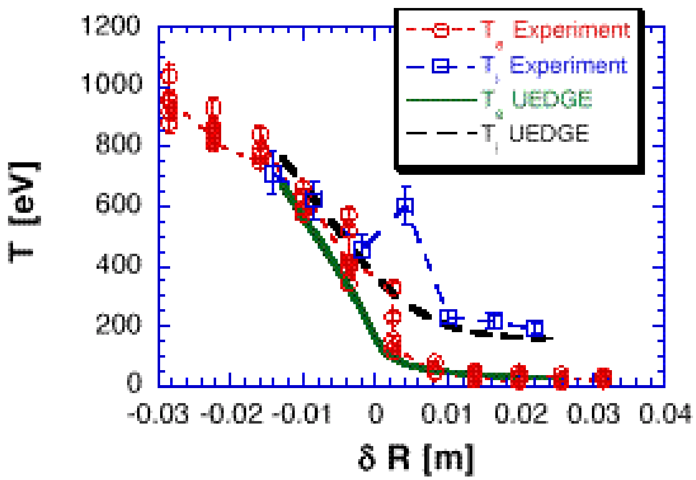
VALIDATION: simple radial transport model agrees with midplane n_e and T_e profiles

- **UEDGE uses <u>constant</u> turbulence-driven radial diffusion coefficients:**
  $D_\perp$ = 0.1 m²/s
  $\chi_i = \chi_e$ = 0.4 m²/s

- **Radial profiles match experimental results for the lower single null plasmas shown**

- **These and many other results indicate that UEDGE models the DIII-D experiment well**





SUMMARY of our SIMULATIONS for the new RDP

- 1) Core carbon density (and hence Z_{eff}) increases with increasing carbon yield
- 2) Core carbon density increases with core heating power
- 3) The radiation fraction is much less than that for similar lower single null plasmas
- 4) Inner and outer pumping is not independent.

Specific UEDGE assumptions for new RDP divertor modification simulations

- **Density at 96% surface specified; n_e(core) = 2.7×10^{19} m^{-3}**
- **Radial power across 96% surface in ions and electrons specified**
- **Particles removed in two ways:**
  1) neutral albedo at the plate, A_P = 0.98, simulates cryopumping at baffle entrances
  2) neutral albedo at walls A_w = 0.97 (wall pumping)
- **Spatially constant particle and thermal perpendicular diffusivity**
- **Carbon sputtered from walls (as fraction of Davis & Haasz model)**

We examine the effect of changing carbon yield on core impurity density in <u>new RDP</u>

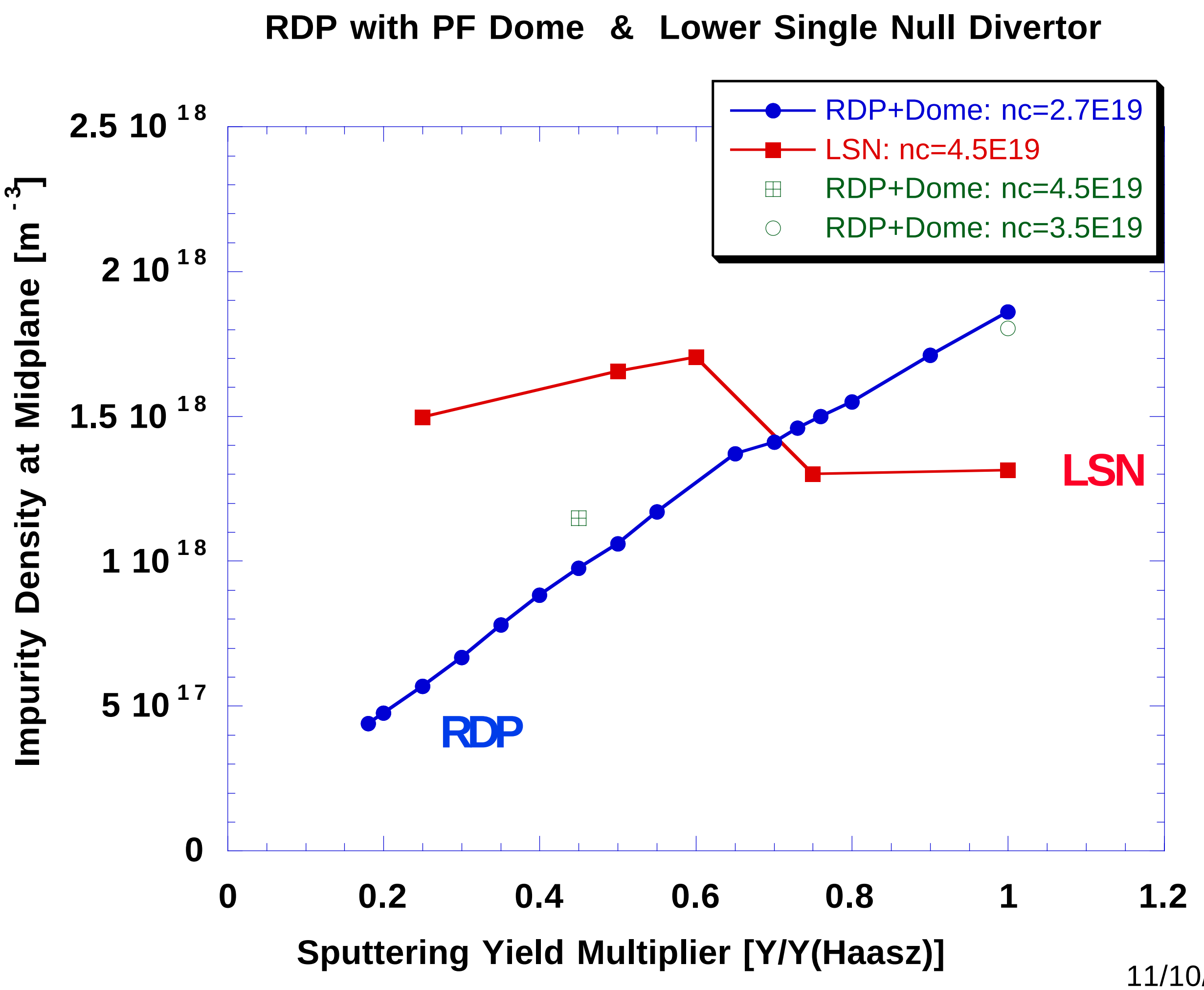
- **WHY? Experiments on DIII-D show a nearly constant core impurity concentration as the lower divertor apparent yield has decreased in seven years of operation [see D. Whyte's poster this session]**

- ## UEDGE Modeling Results:

- **Lower Divertor: Impurity density remains nearly constant as the carbon yield is lowered {<u>agrees with experiment</u>} [see G. Porter, et al. and also P. West, et al. at this session]**

- **Upper Divertor (New RDP+PF Dome): Impurity density decreases as carbon yield is lowered {<u>new prediction</u>}**

KEY RESULT: Core impurities insensitive to sputtering with lower divertor, but not RDP



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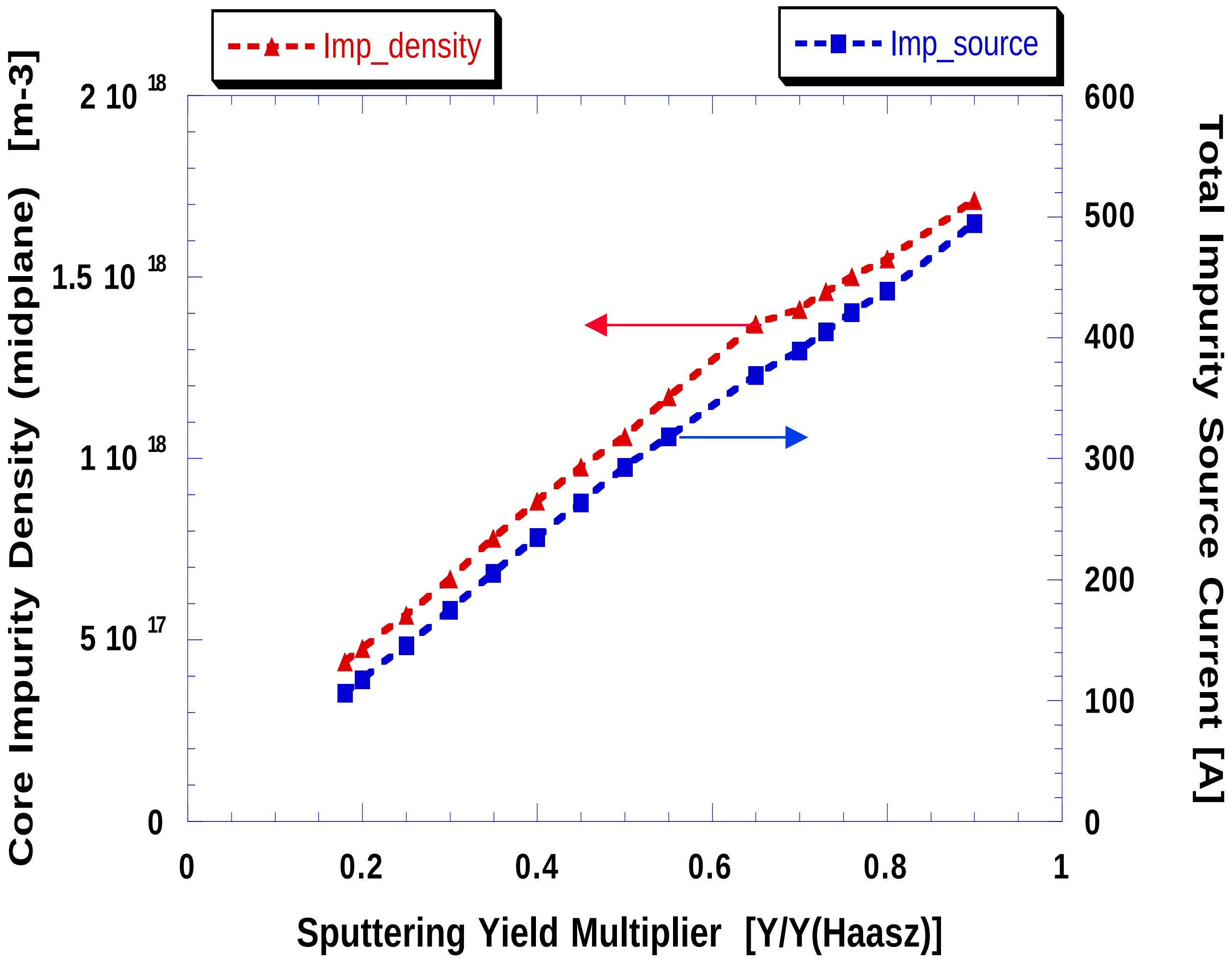
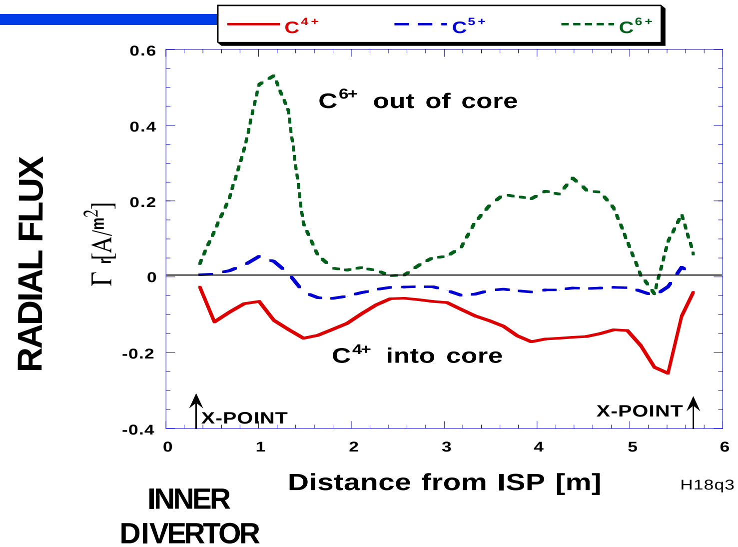
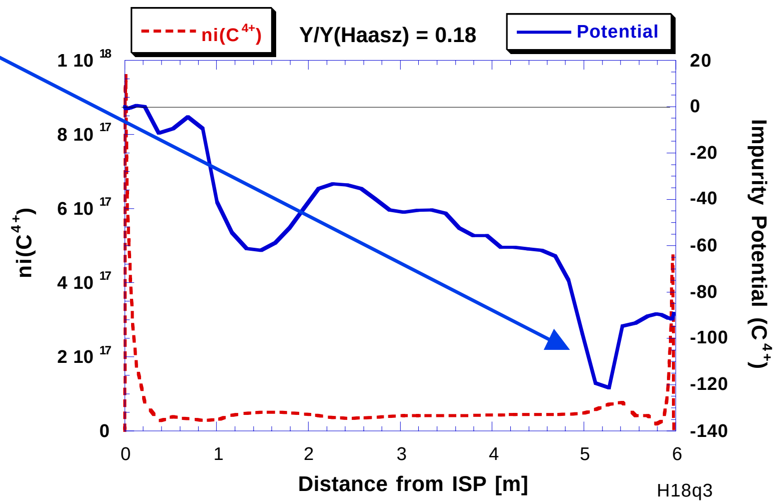
Core impurity density is linear with impurity source strength with new RDP



Is core impurity level much influenced by parallel transport in the new RDP?

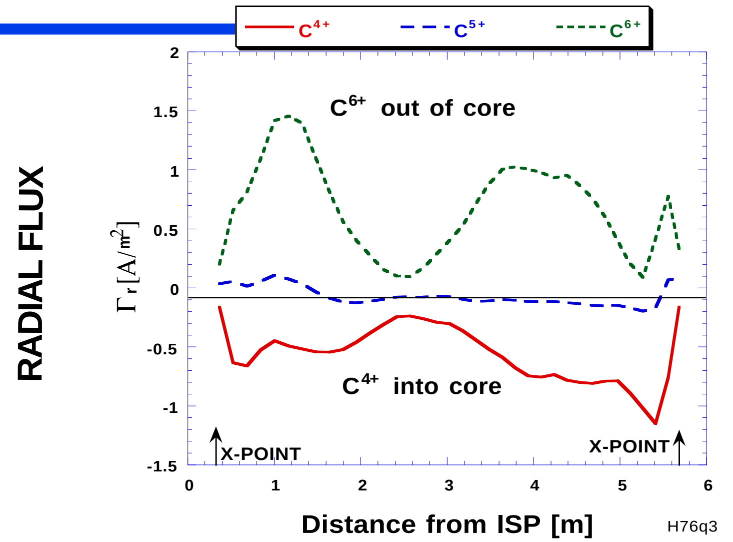
- Carbon is sputtered from ion and neutral impact on all walls:
- Y/Y(Haasz) = 0.18
- C^{4+} flows freely from inner divertor and is attenuated from outer divertor
- There is some C^{4+} accumulation due to local parallel potential wells
- Carbon enters the core as C^{4+} via radial diffusion, and exits as C^{6+}
- The potential integrates the parallel net force, which is a balance between drag and ∇T_i forces

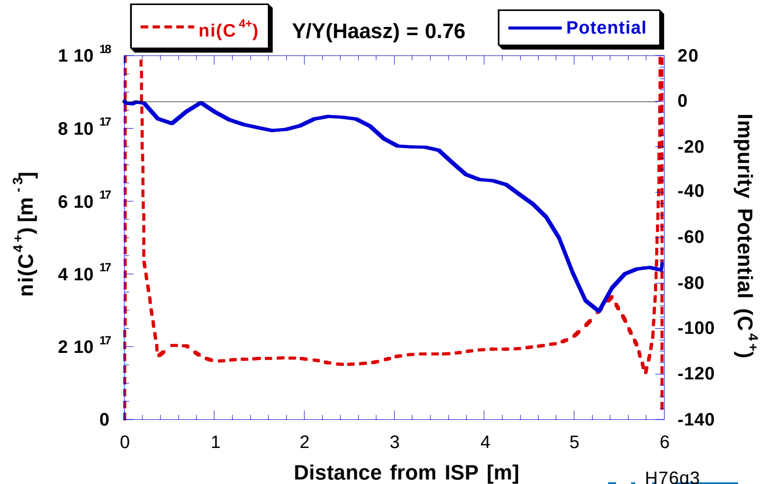




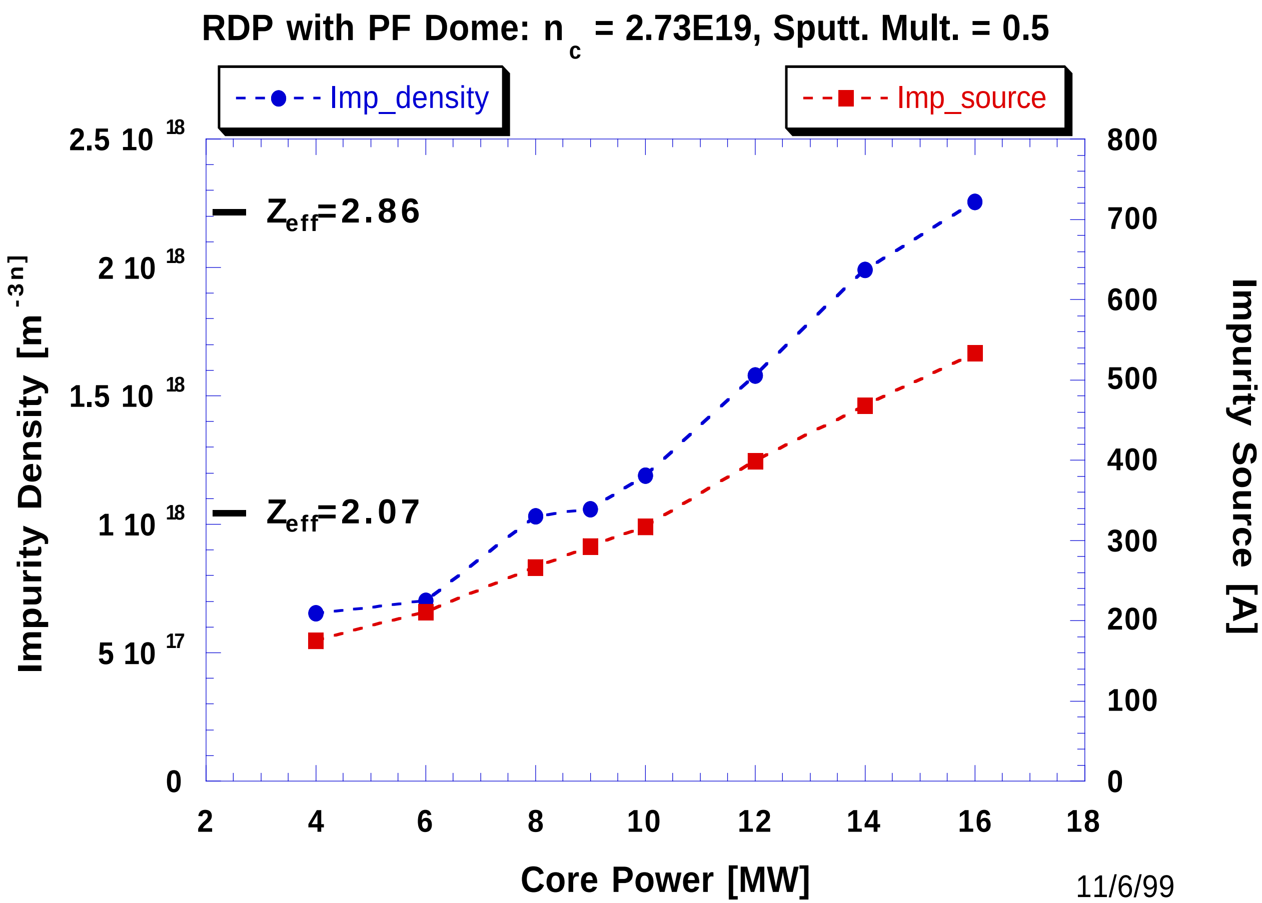
Potential is not changed by higher sputtering yield in new RDP

- **Carbon is sputtered from ion and neutral impact on all walls:**
- **Y/Y(Haasz) = 0.76**
- **As before, carbon enters core as C^{4+} via diffusion, and exits as C^{6+} (at much larger values than for low yield)**
- **But the parallel potential is not much changed from lower sputtering yield value, implying transport is not changed.**
- **Therefore the higher core carbon density is dominated by the higher carbon source current, not parallel transport forces.**



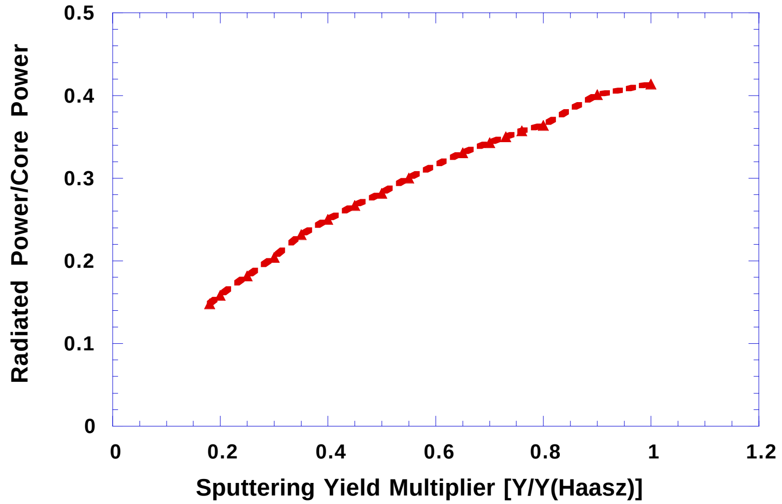


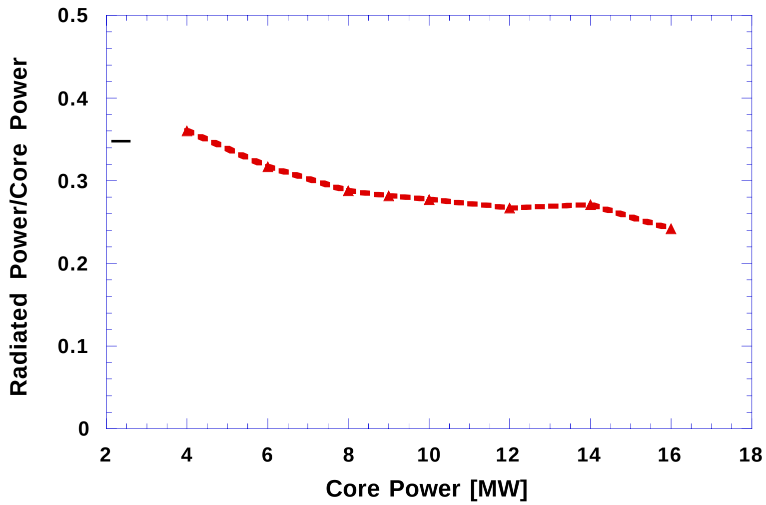
Core impurity density increases with the core heating power in the new RDP



Radiation fraction remains below 40% for the new RDP

- Radiation fraction increases with carbon yield (at fixed core power, P_c = 9 MW)
- Radiation fraction is higher in LSN (usually above 70%)





Radiation fraction remains between 25% & 35% as core power increases (at fixed yield = 0.5)

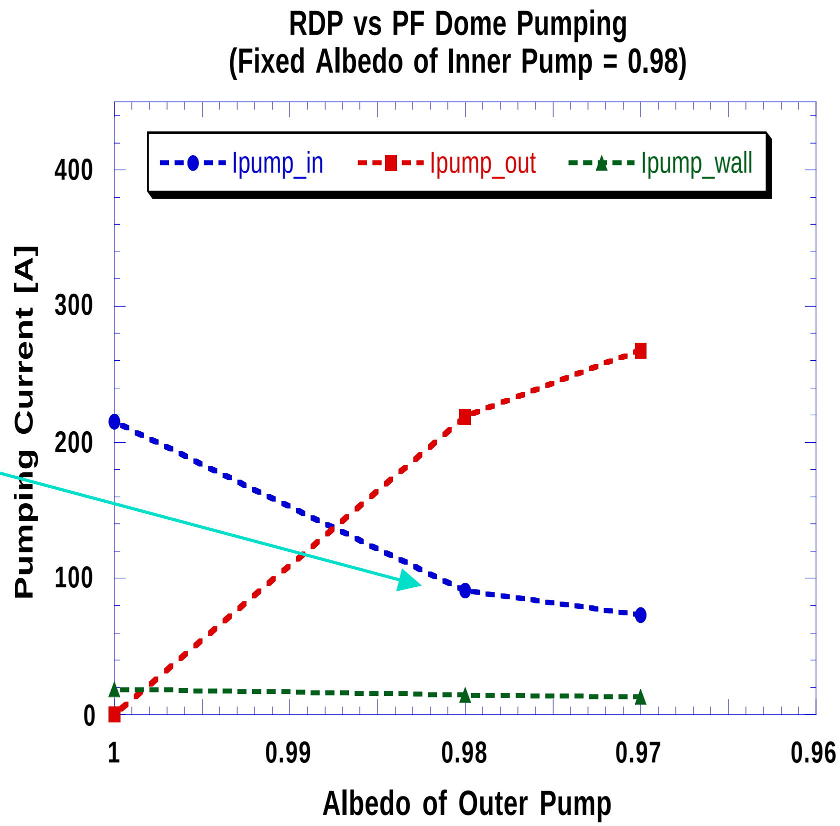
Inner and outer pumping is not independent in the new RDP

- Core density fixed: $n_c = 2.73 \times 10^{19}$
- Core Power fixed: P_c = 9 MW
- Carbon yield multiplier = 0.25

- **Wall pumping is insignificant**

- **The inner pump exhaust decreases as outer pumping eficiency (albedo) increases**

- **For equal albedos, the outer pump is more effective in particle removal**



Core carbon density may be more dependent on wall and plasma conditions in new RDP

- 1) Core carbon density (and hence Z_{eff}) increases with increasing carbon yield, indicating that core carbon can be influenced by wall conditioning.

- 2) Core carbon density increases with core heating power, indicating there may be a problem with high power operation - at low density.

- 3) Radiation fraction is below 40% (less than that for the lower single null plasma with similar parameters)

- 4) Inner and outer pumping is not independent.