Edge Plasmas, Edge Radiation, and Liquid-Wall Temperature Limits*

T.D. Rognlien and M.E. Rensink
Lawrence Livermore National Lab

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Topics

1. Geometry and profile effects for Sn ARIES CLiFF design

2. Liquid module for C-MOD

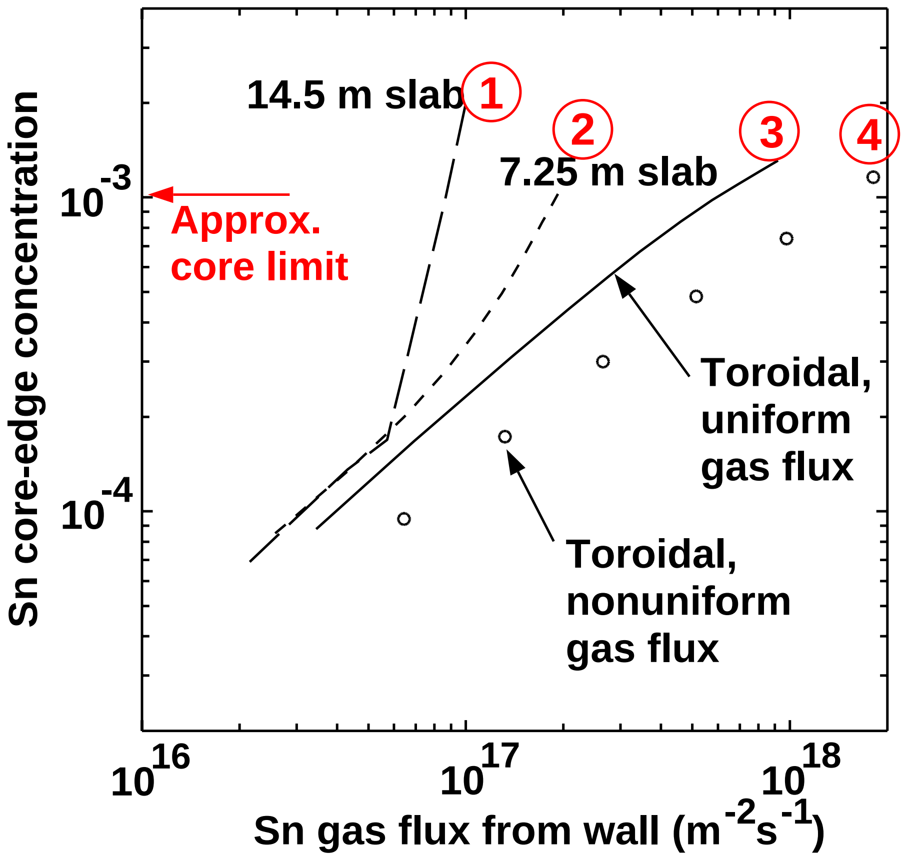
3. Impact of divertor plate location/orientation

4. Scaling studies for impurity intrusion

5. Results for spheromaks

Sn tokamak impurity-based wall-temperature limits show substantial model sensitivity

Core Sn concentration for 4 case with increasing detail for CLIFF



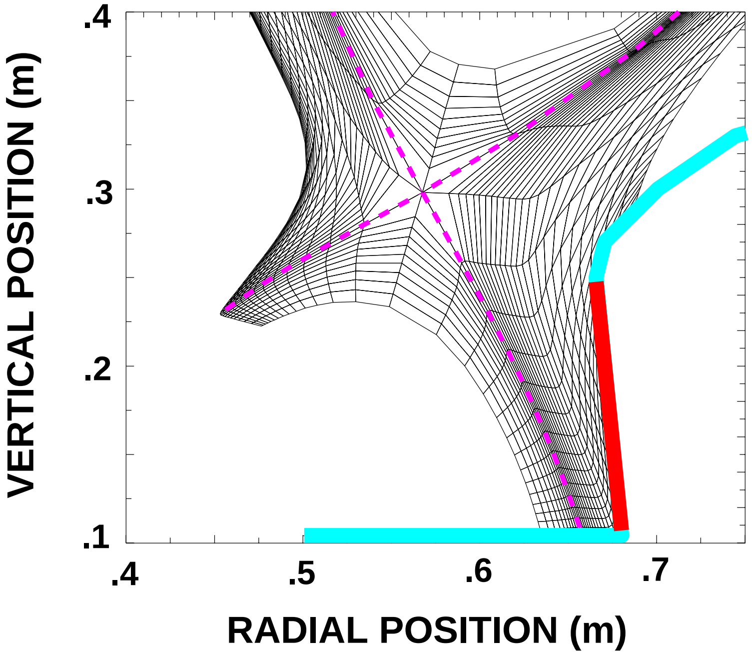
Corresponding wall temperature limits

Case	1	2	3	4
T_w [K]	1010	1030	1070	1100

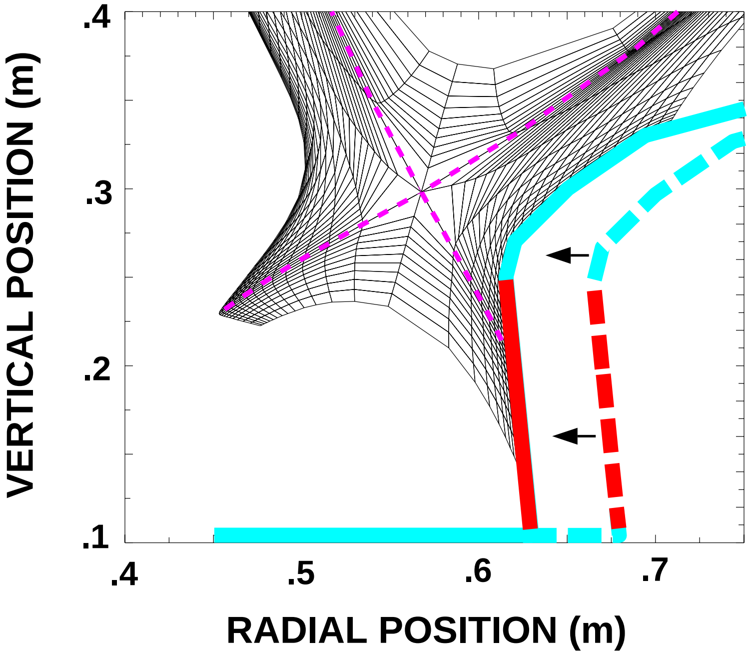
Particle Pumping Rate in C-Mod is Controlled by Strike Point Position

🟦 divertor tiles

🟥 liquid Li



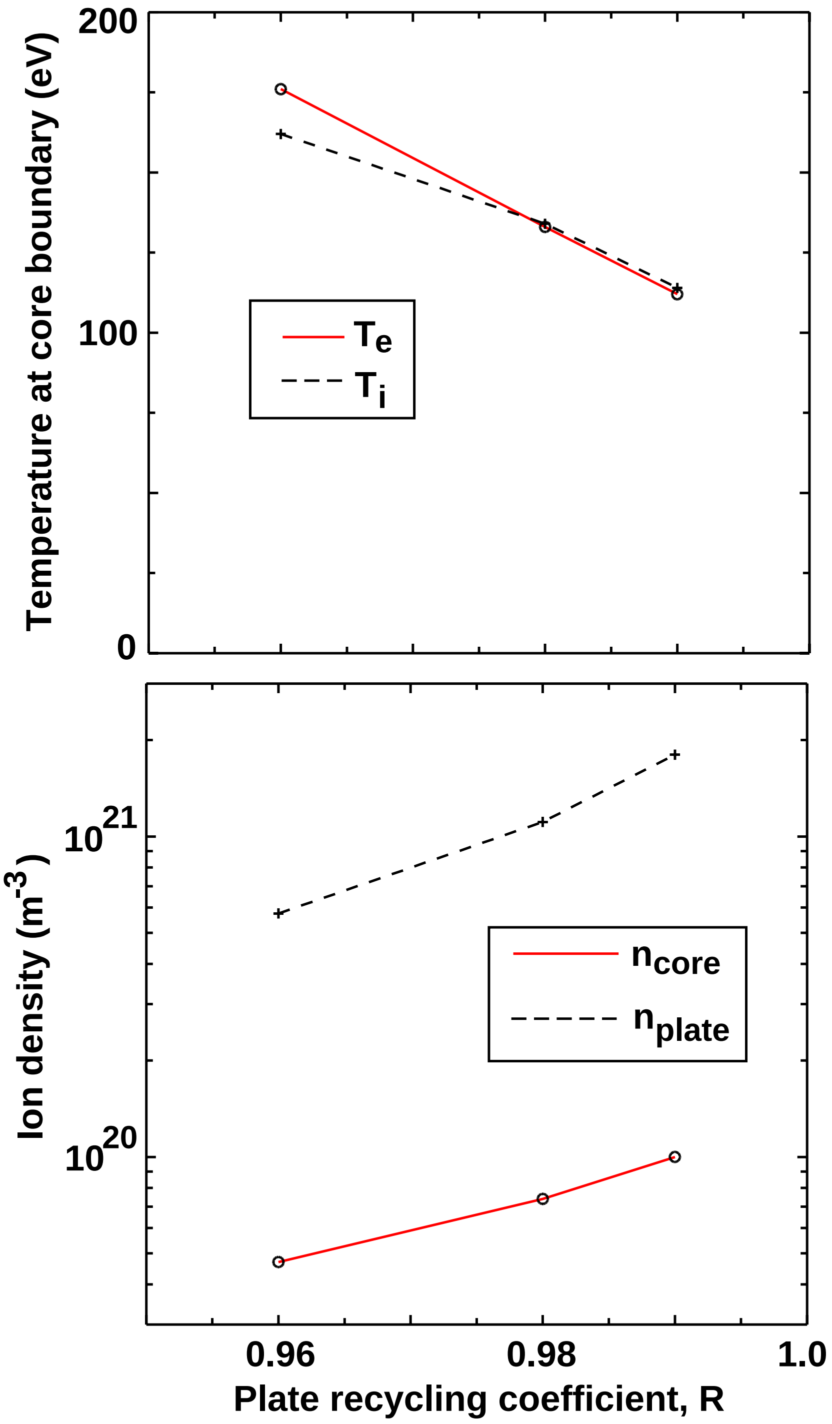
weak pumping configuration



strong pumping configuration

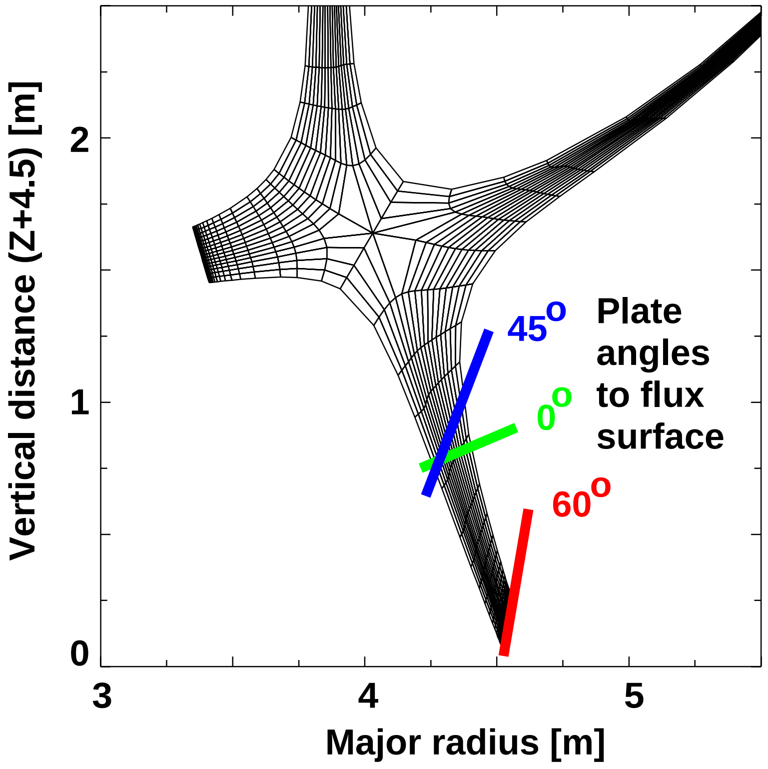
Pumping C-Mod plasma through plate R increases core-boundary temperature

Decreasing plate density with decreasing R lowers pumping efficiency - depends on details



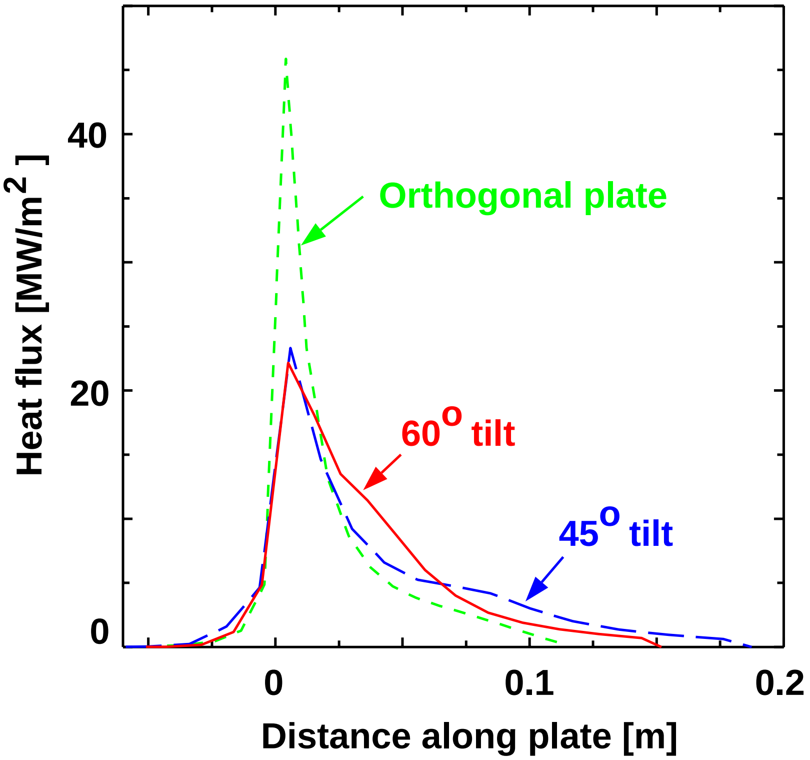
Options for (liquid) divertor-plate orientation show reduction of CLIFF peak heat-load

3 divertor plates for ARIES-AT



For analysis of divertor/wall integration

Corresponding plate heat fluxes



Simple 1D model displays important processes and trends

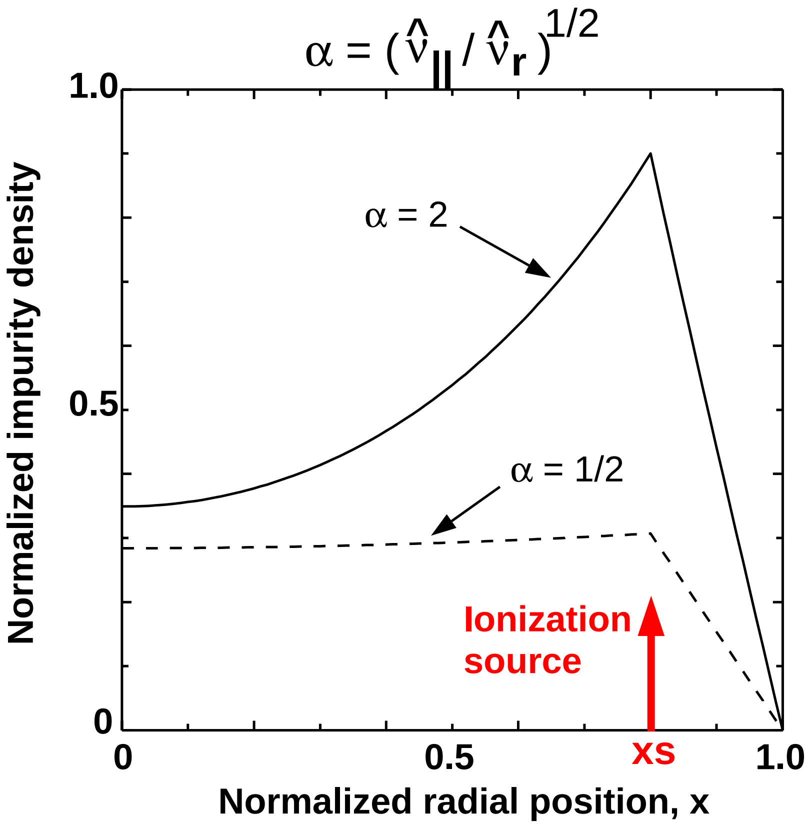
Consider radial diffusion D, ionization source S, & axial loss

$$-D\frac{d^2n}{dr^2} = S\,\delta(r-rs) - \nu_{||}n \quad ==> \quad -\hat{\nu}_r\frac{d^2N}{dx^2} = \delta(x-xs) - \hat{\nu}_{||}N$$

where $x = r / r_{wall}$.

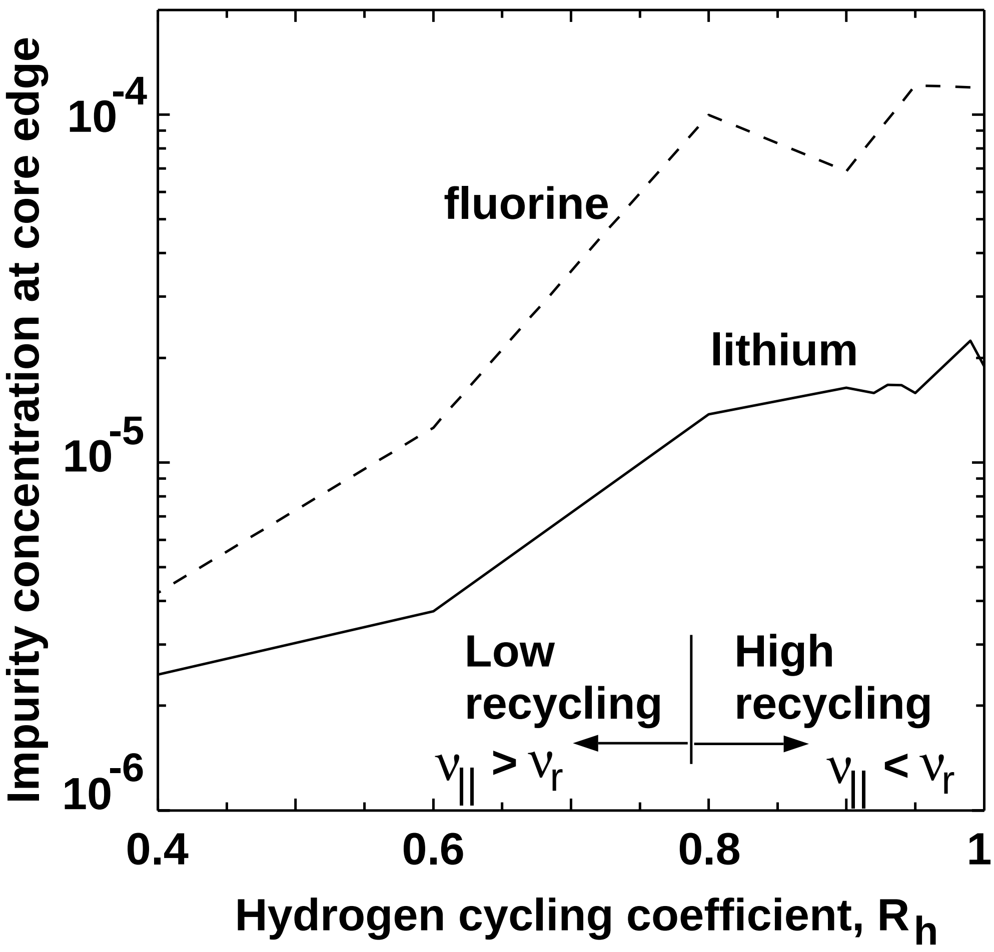
Analytic solution gives profiles and scalings; the core density as source distance from wall,

$$n(0) \sim S(1 - xs)$$



Low hydrogen-recycling regime yields much lower impurity influx to core

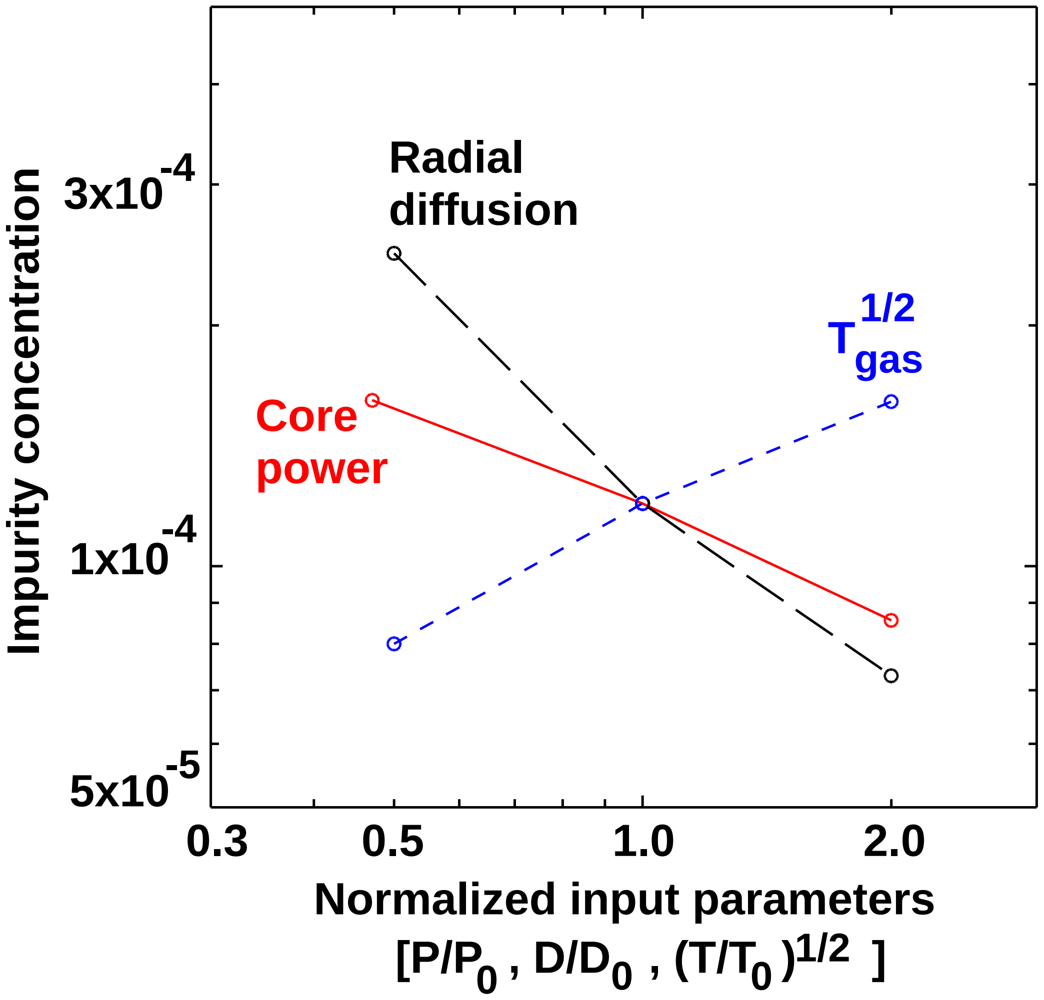
Larger axial flow for smaller R_h gives much better impurity removal



Hydrogen particle fueling required for low recycling is an important issue; implies low edge density

Core-boundary impurity concentration scales significantly with paramters

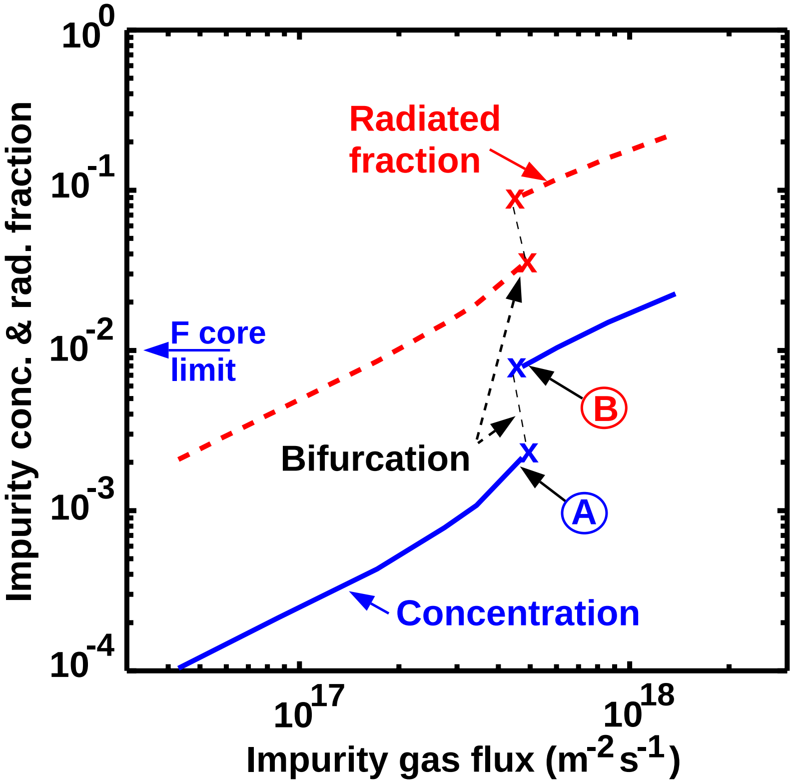
Fluorine case with $R_h = 0.99$



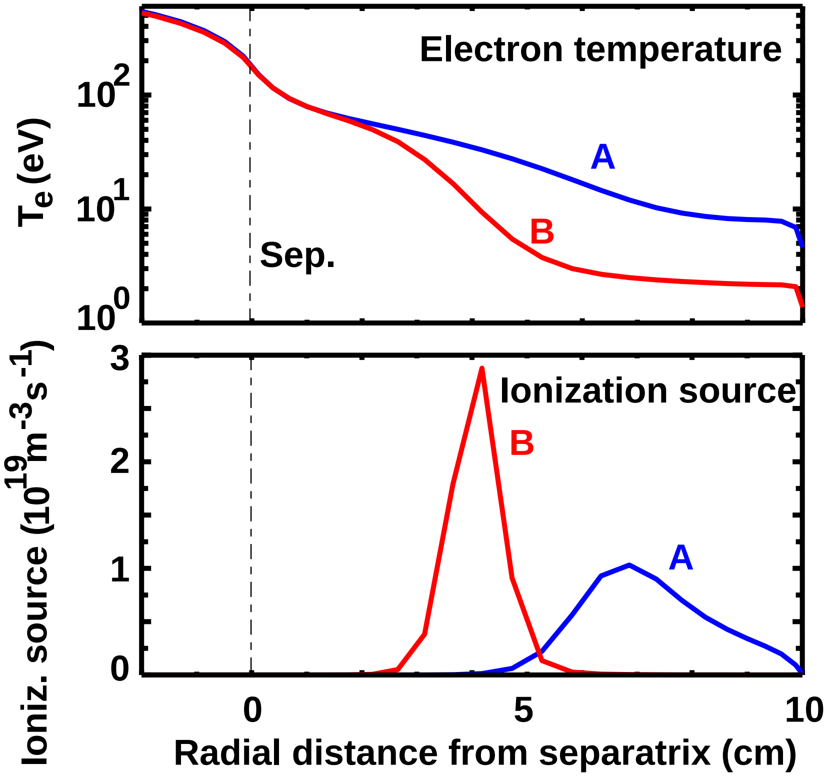
These variations can be understood qualitatively from the 1D model

Core impurity limit with increasing gas flux is coincident with major T_e profile contraction & ionization shift

Fluorine for hydrogen recycling R_h = 0.99

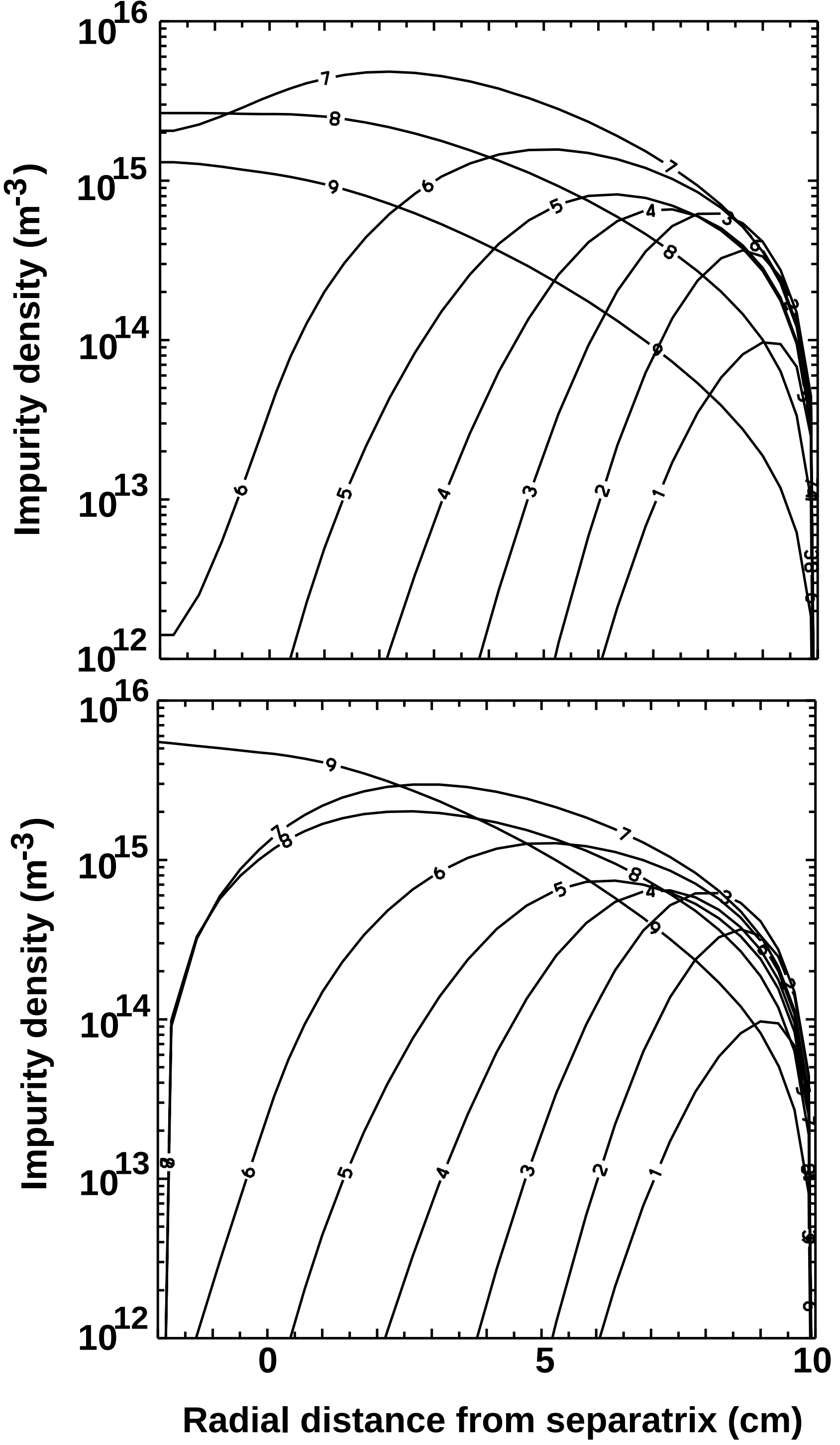


Profiles shift at bifurcation



Two different impurity core boundary conditions give nearly the same F density

Fluorine charge-state profiles



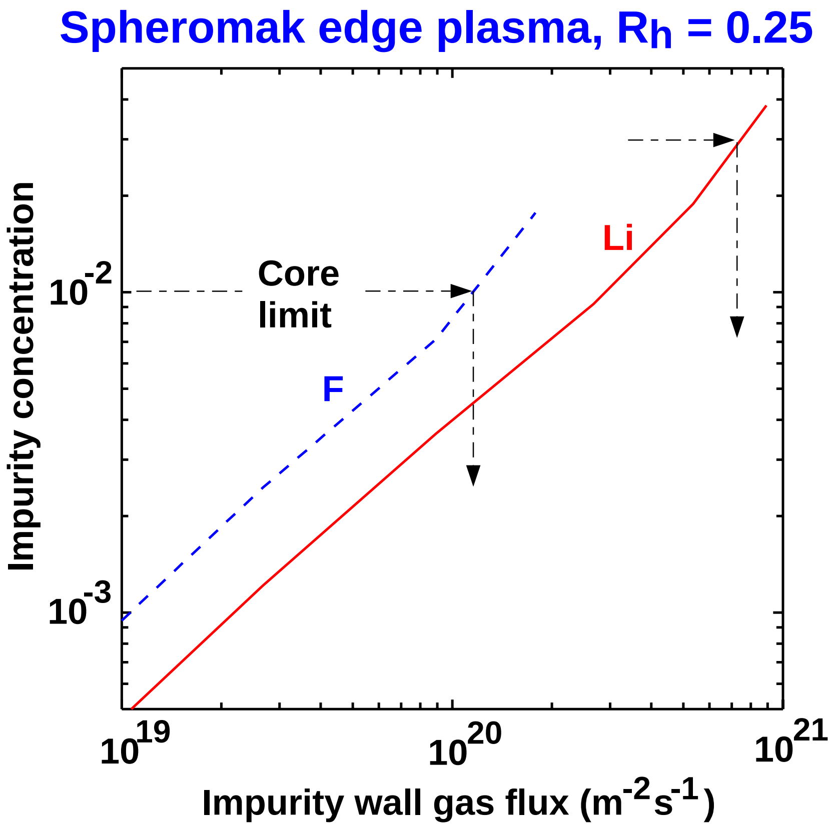
Zero core flux B.C. for all charge states.

Calc. F core edge density is 4.9×10^{15}

Zero density for all states except highest Z from the core; net flux to core is still zero.

Calc. F core edge density is 5.2×10^{15}

Spheromak temperature limits are between those for tokamaks and FRCs



SUMMARY OF LOW-RECYCLING CASES
allowable wall temperatures in degrees C

	Li	Flibe	SnLi
Tokamak	380	480	590
Spheromak	410	520	630
FRC	480	620	720

FRC is compact, high density

Summary

Analysis of wall evaporation for Sn in ARIES (CLiFF) shows temperature limit increases with more detailed geometry and evaporation profiles -- 1100 K max.

Modeling of possible liquid modules for NSTX and C-MOD shows that substantial particle pumping could result without excessive heat loads

Simulation of lithium large-scale lithium influx for the disruptive DiMES shot on DIII-D shows lithium radiation can be much larger than the coronal equilibrium values

Studies of divertor plate orientation for liquid wall / divertor integration shows ~50% heat flux reduction by moderate tilting (~50 deg), and that flux compression via divertor-leg length can be balanced by tilting

Scaling studies help clarify roles of high/low recycling, anomalous transport, core power density, and magnetic geometry

Impurity influx modeling for spheromak - temperature limits are between those for tokamaks and FRCs