

Progress on Determining Heat Loads on Divertors and First Walls

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In the Last Project Meeting, We Concluded:

- It is important to self-consistently evaluate the distribution of heat loads on the divertor plates and first wall for the ARIES Pathway power management studies and for designing the TNS device.
- We will use the UEDGE code to calculate heat loads for power fluxes originating in the SOL and divertor region. Previous published results of calculated heat loads on target plates and surrounding walls were presented for
 - ✓ ARIES-AT (w/o impurity), and
 - ✓ FIRE (with impurity injection).

In this talk, we report progress on:

- Work with Tom Rognlien (LLNL) to restore the UEDGE case runs for ARIES-AT.
- Setting up to run ARIES-AT cases with impurity injection, that may help lower peak heat load with a broadened profile.

Collaboration with LLNL on UEDGE

- Spent two days in LLNL in October to work with Tom Rognlien on UEDGE runs for ARIES-AT.
- Obtained the input files for ARIES-AT from Tom.
- Learned to truly run UEDGE, and used specific “knobs” and techniques to reach a convergent solution.
- Set up code to run with impurity (fixed-fraction model) for ARIES-AT.
- Tom wrote a BASIS script to facilitate displaying heat loads on plates and walls.

Tokamak Regions for UEDGE Divertor Analysis

Boundary conditions are set at core boundary, plates and wall.

UEDGE solves set of fluid equations in all regions except the core.

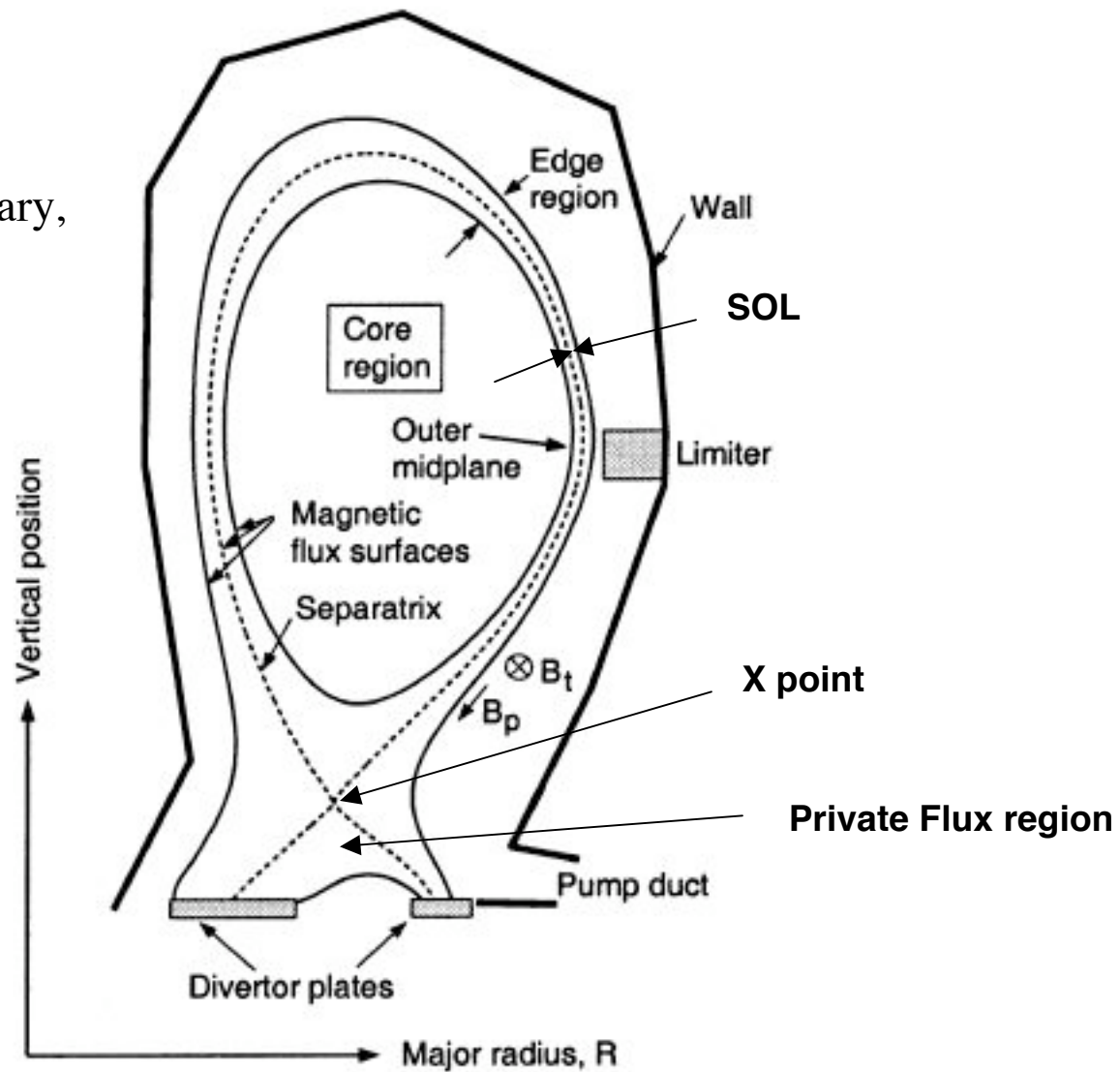


Fig. 1. The poloidal cross-section of a single-null divertor tokamak show various regions and boundaries.

ARIES-AT Example Study with Argon Impurity

- As a start, the impurity density is determined as a fraction of electron density, n_e . In our case, $n_Z / n_e = 0.05\%$.
- Impurity radiation is calculated using an emissivity table based on non-equilibrium coronal results from the MIST code.
- Emissivity depends on :
 - ✓ electron temperature
 - ✓ charge exchange recombination on neutral hydrogen
 - ✓ impurity lifetime due to convection ($\tau = 1$ s)
- Other assumed parameters are:
 - $P_{\text{core,net}} = 40$ MW [$f_{\text{rad}} = 0.88$]
 - Core ion density = $5 \times 10^{19} \text{ m}^{-3}$
 - $D_i = 0.33 \text{ m}^2/\text{s}$, $\chi_i = \chi_e = 0.5 \text{ m}^2/\text{s}$

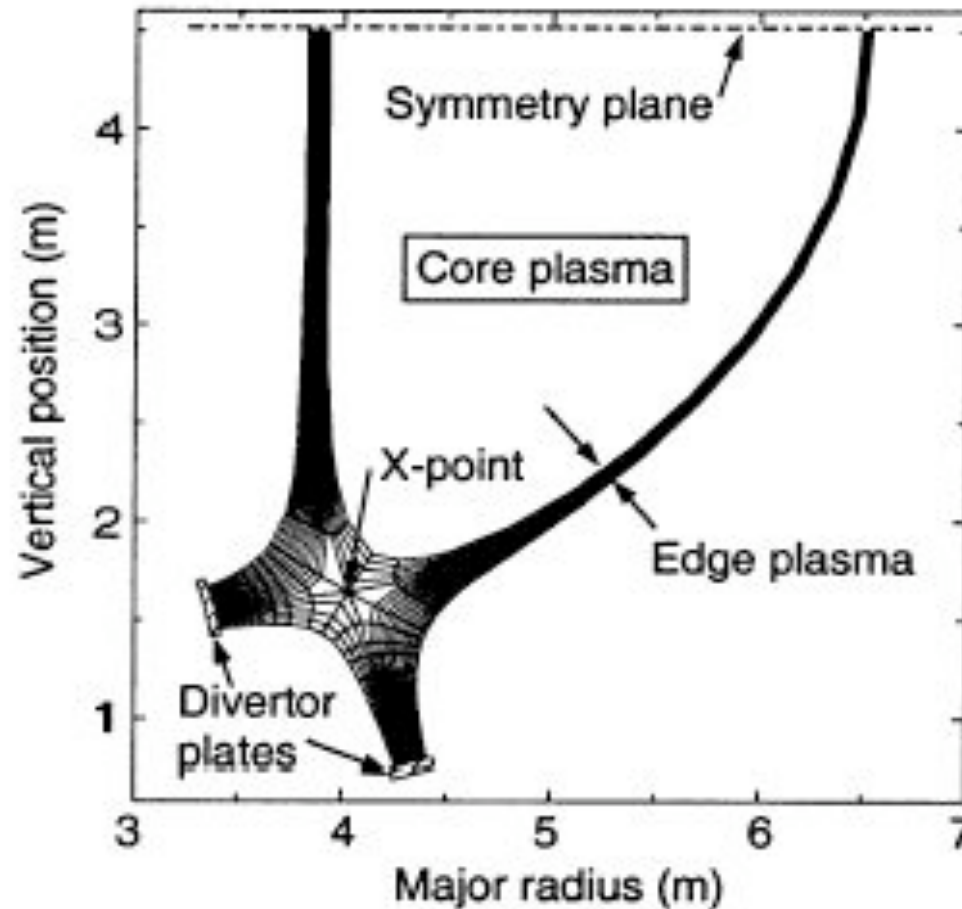
For this case, Divertor Plates are Orthogonal to Field Lines

$$R_{\text{strike}} = 3.4 \text{ m (inner); } 4.3 \text{ m (outer)}$$

$$\Psi_{\text{core boundary}} = 0.97$$

$$\Psi_{\text{separatrix}} = 1.001$$

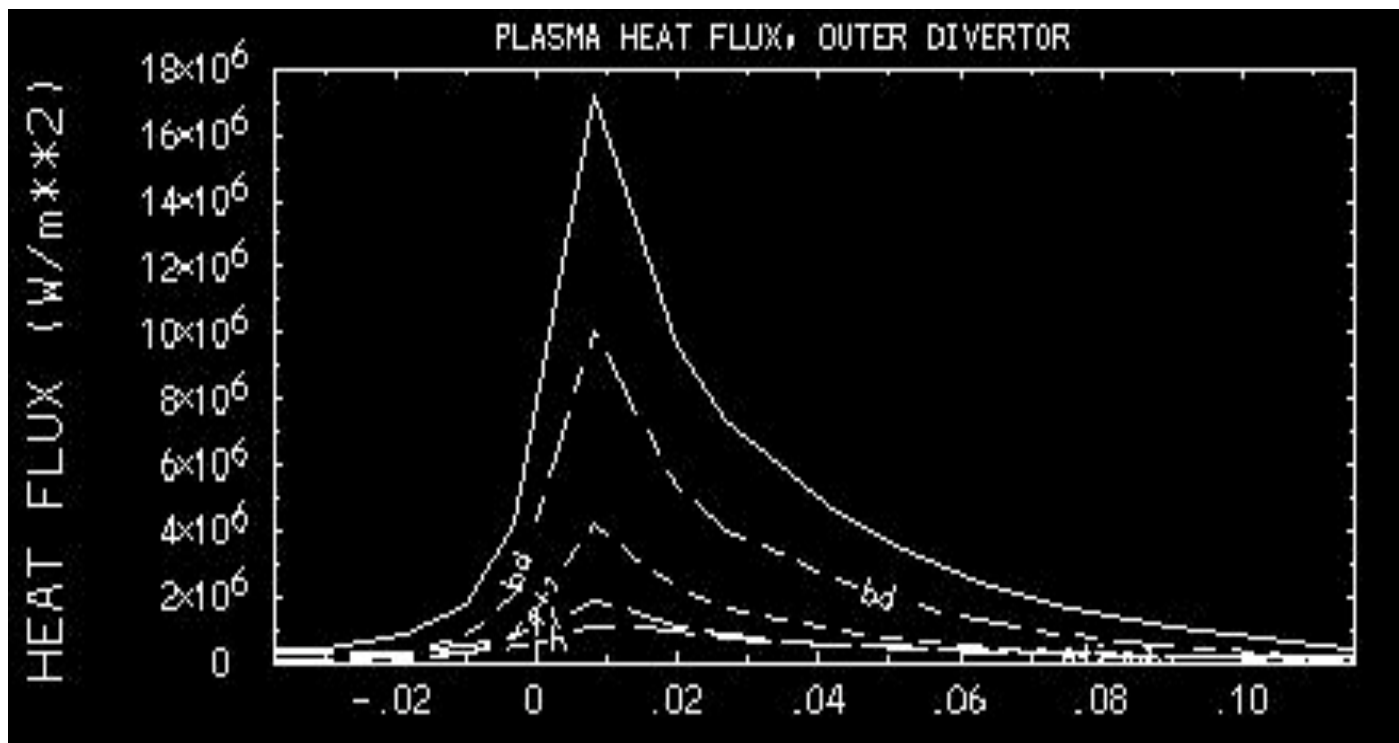
$$\Psi_{\text{wall}} = 1.10$$



Calculated Heat Flux to Outer Divertor Plate

- Peak heat flux = 17 MW/m^2 @ 40 MW input power

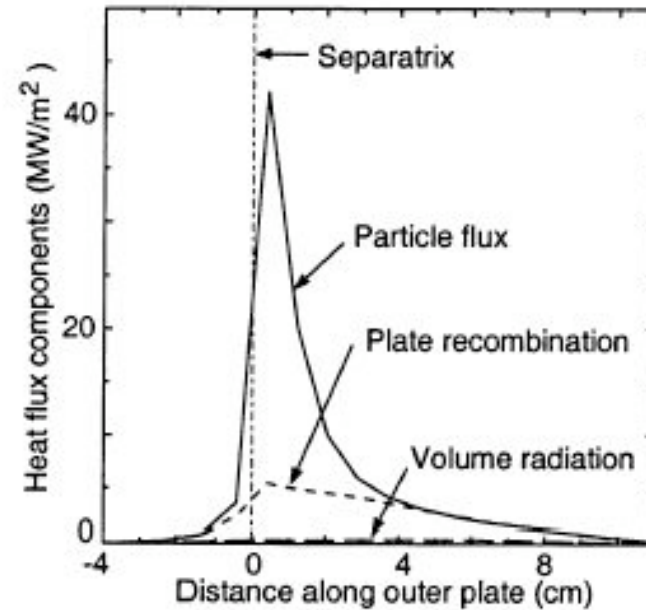
Labels: **solid**: total; **bd** : particle flux; **e+i** : plate recombination;
ri : impurity radiation; **rh** ; hydrogen radiation



Distance along Outer Plate (m)

Corresponding ARIES-AT Case with No Impurity

- Net core power input = 80 MW
 $f_{\text{rad}} = 0.77$
- Peak heat flux = 47 MW/m²

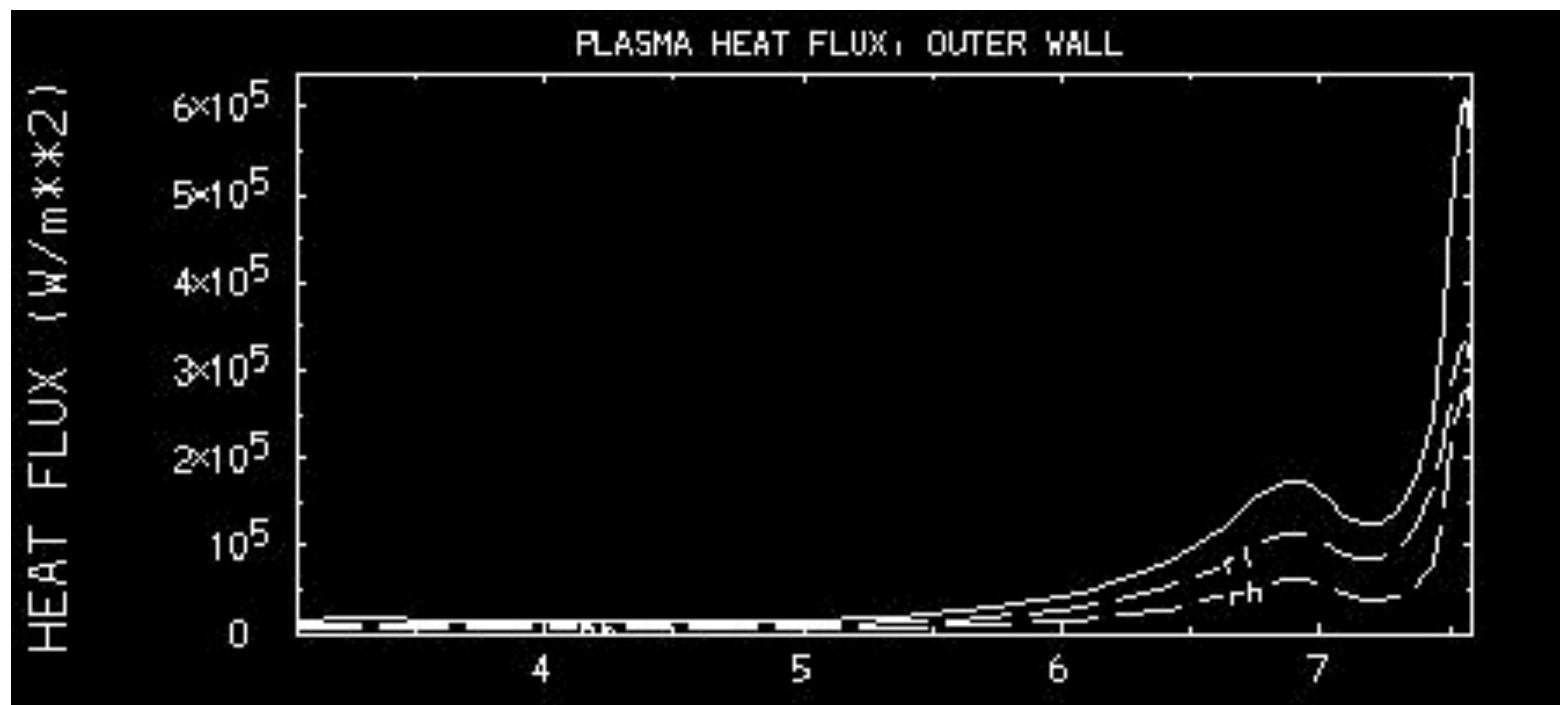


Comparison to Case with Impurity

- The case with impurity has peak heat load that is less than half that for the no-impurity case.
- The case with impurity appears to have a broader heat load profile.

Calculated Heat Flux to Outer Wall

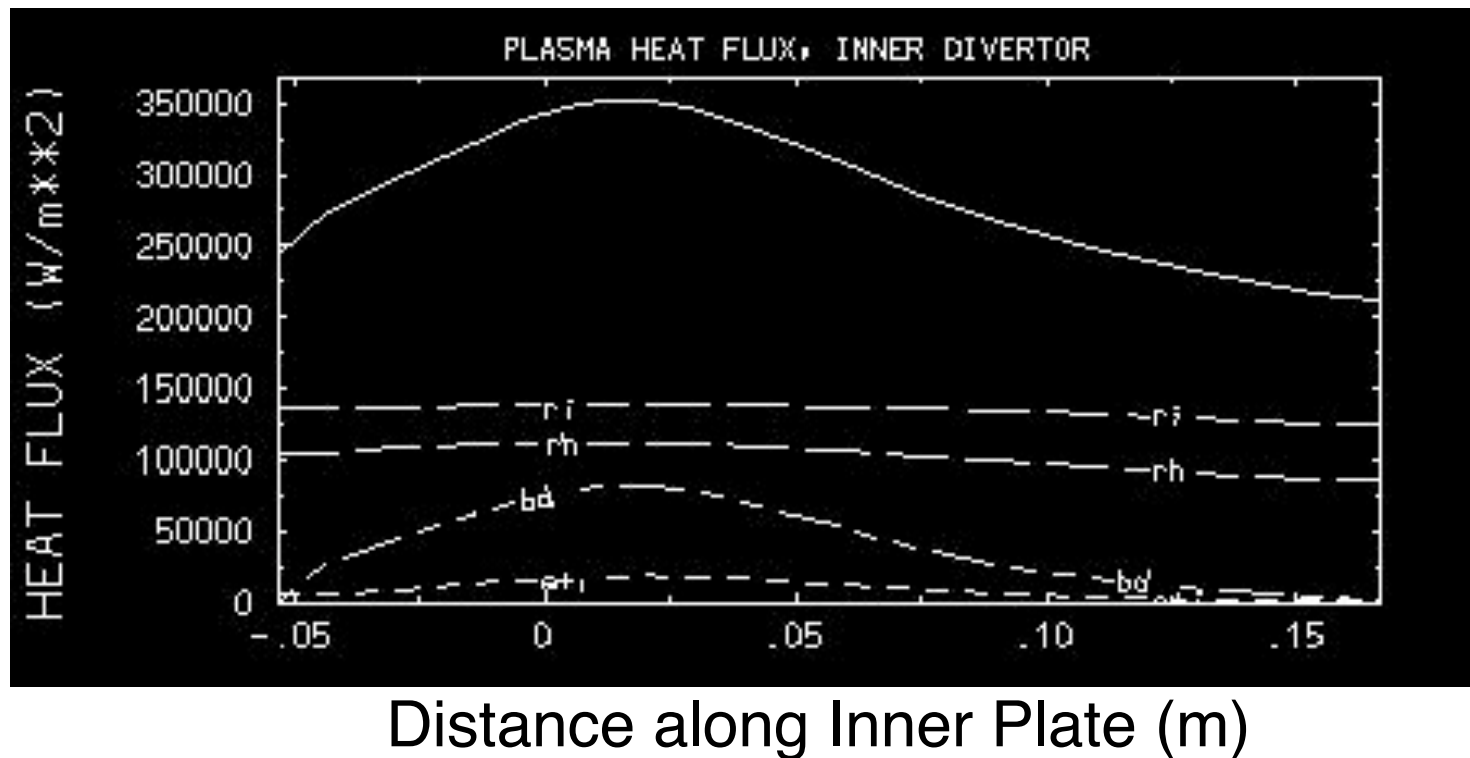
- Peak heat flux = 0.6 MW/m^2
- Labels: **Solid** : total; **ri** : impurity radiation; **rh** ; hydrogen radiation



Distance from OB side to Outer Divertor Plate (m)

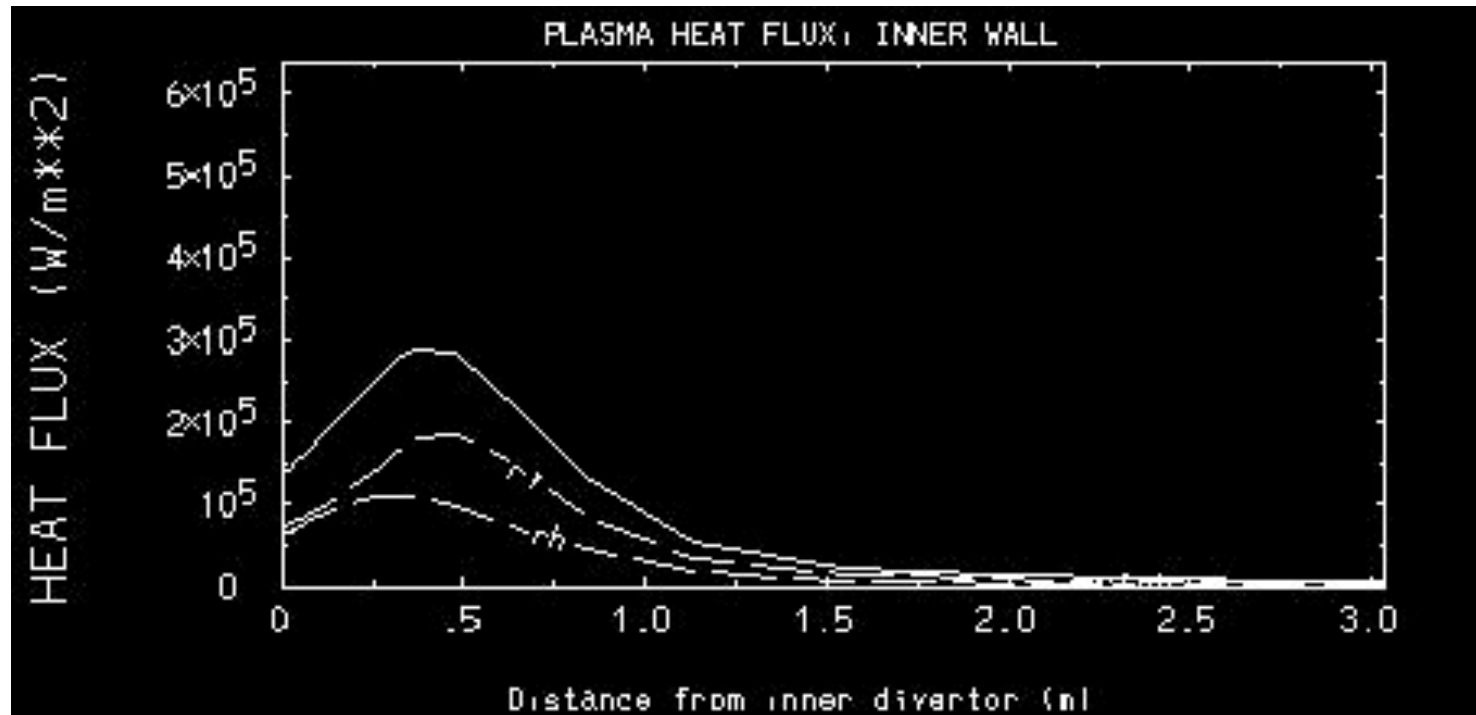
Calculated Heat Flux to Inner Divertor Plate

- Peak heat flux = 0.35 MW/m^2
- The heat flux is much lower and much more broadened than at the outer plate.
Higher flux expansion? Impurity density model?



Calculated Heat Flux to Inner Wall

- Peak heat flux = 0.3 MW/m^2
- Wall heat flux profile is much less peaked than on outer wall.



Summary

- We obtained the necessary input files for us to start looking at power loads at various divertor geometries and side walls, in the presence of impurities, using the UEDGE code.
- We calculated heat loads at the plates and walls for a fixed fraction impurity concentration with plates orthogonal to the field lines. Results are shown to trend in the right direction compared to case without impurity, and at different power input.
- Ability to obtain convergent solutions is sensitive to specific boundary conditions, e.g., core density, and finding a solution can be a time-consuming process. Clearly more practice and further guidance are in order.

Future Work

- Future runs with UEDGE/ARIES-AT will include:
 - ✓ varying impurity concentration
 - ✓ multi-charge-state impurity radiation
 - ✓ impurity injection
 - ✓ tilted plates
- Run VNC software to enable “in situ” interaction with Rognlien when searching for a convergent solution.
- More BASIS scripts for displaying n , T profiles, etc.