

An Update on Divertor Heat Load Analysis and Derived Geometry

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OUTLINE

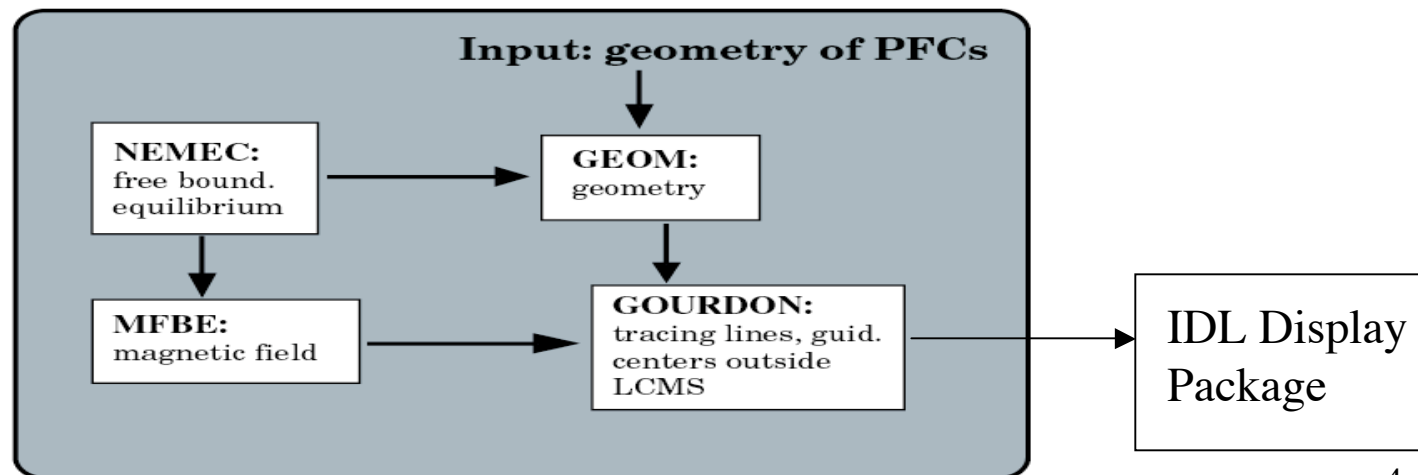
- Update on CS Configurations for divertor study.
- Update on divertor study:
 - Tools update
 - A Systematic Approach for optimizing divertor geometry - an analytic model for plate surface
 - Status of GOURDON/GEOM run on new reference case
- Summary and future work

Status of CS Configurations for Divertor Study

- ARIES/NCSX:
 - NCSX-ARE has been made a reference configuration, because of favorable ϵ loss characteristics. The coil set for NCSX-KZD has been scaled to $R=6.93$ m and $B=6.28$ T to generate free-boundary equilibria with $\epsilon = 4\%$ and 5% .
 - Full 3-D magnetic field maps have been generated using MFBE.
 - Attempt to set up a GOURDON/GEOM run for the 5% ϵ case, with a simple divertor geometry, has met with numerical issues that are being resolved. Need a set of Poincare plots of the field lines.
- ARIES/MHH2:
 - MHH2-K14 is available with a complete set of VMEC-related equilibrium files and optimized coil set data.
 - Full 3-D magnetic field maps with finite beta have been generated.

Status of Tools for Divertor Study

- **Tool for displaying heat load distribution on the plate:**
 - Received IDL program from McGuinness
 - Need some effort to get it into working order
- **GOURDON/GEOM:**
 - Need to remove case-specific elements for proper output of plate and wall heat load
 - Need to run in different mode to obtain Poincare plots
 - Upgrade field line diffusion model

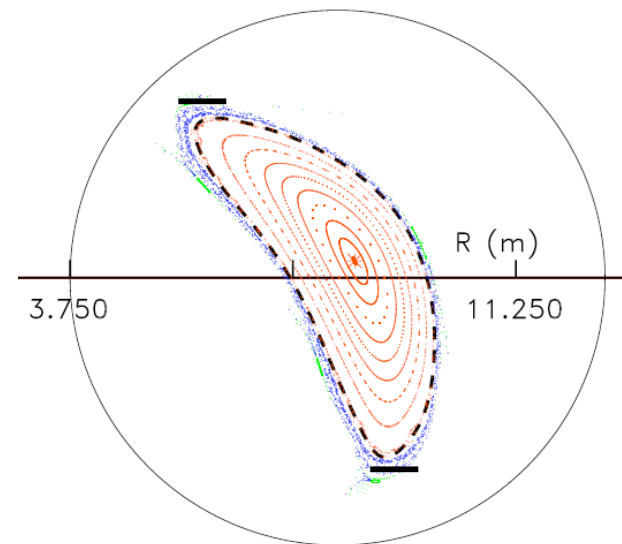
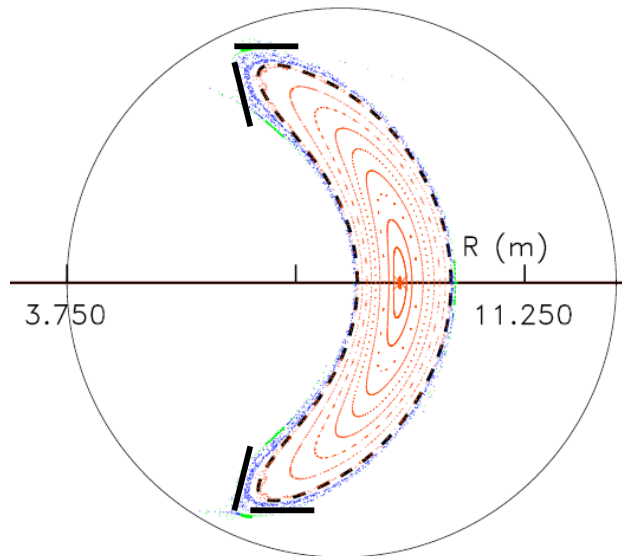


Main Objectives of Divertor Design

- Achieve **low peaking factor** for heat flux on the target (<10)
 - Maximize load spreading
 - Achieve uniform heat load distribution
- **Minimize the surface area** of the divertor plate so coverage of first wall area is limited to below 10%.

Criteria for Plate Location

- **Maximum load spreading:** Region with large flux expansion
Larger distance from LCMS
- **Minimum surface area:** Region with large number of field line crossings; closer to LCMS
- Regions outside LCMS with sharp surface curvature appear suitable for this purpose:



Criteria for Plate Surface Topology

- **Maximal load spreading** : Surface should be conformal to LCMS to ensure grazing field line incidence on plate.
- **Small surface area**: Surface can be made inwardly convex to capture more field lines with minimal plate area, i.e., tilting the plate away from conformal surface

A Strategy for Optimizing Divertor Plate Geometry

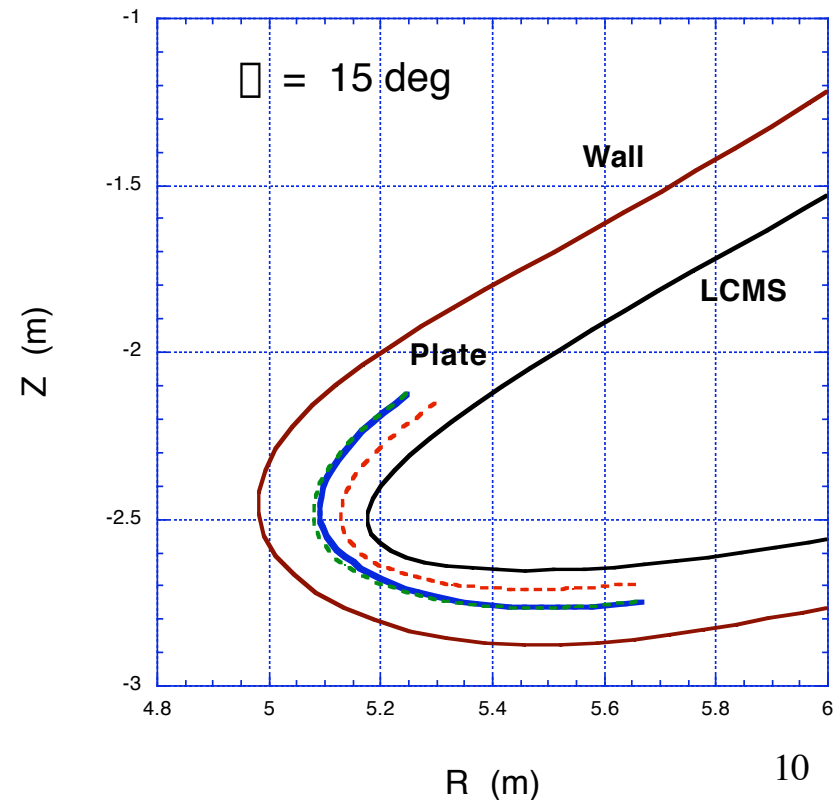
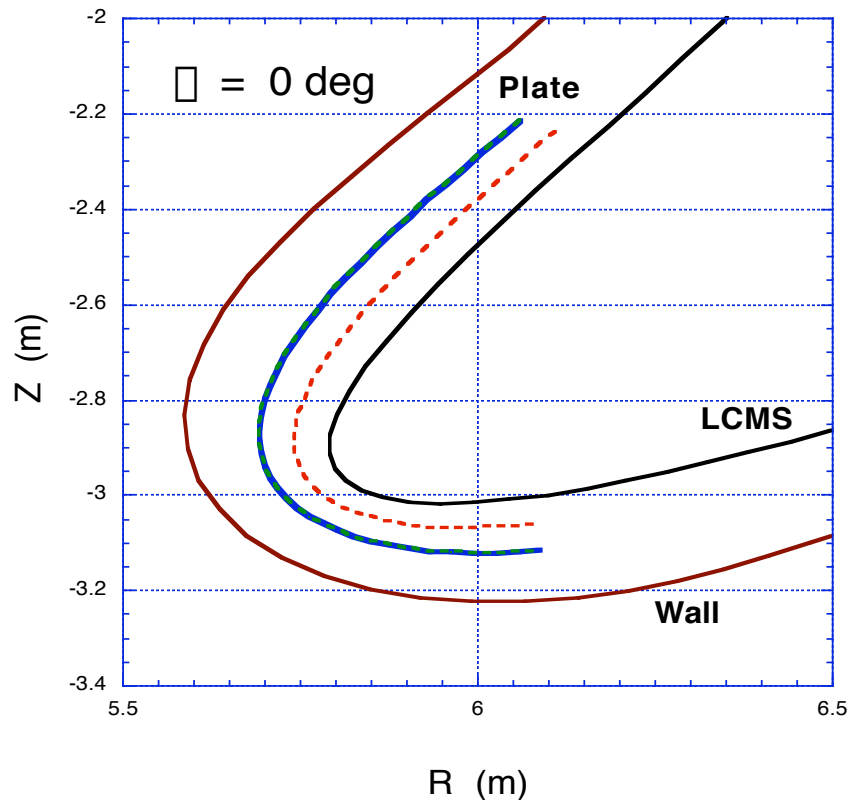
- Divertor geometry is determined by a large number of parameters:
 - Distance of plate from LCMS
 - Location of center of plate (toroidal and poloidal angles)
 - Size of plate surface (toroidal and poloidal extent)
 - Number of plates per field period and their locations
 - Shape (topology) of plate surface (Conformal or not?) ; many shape parameters may be required.
- Propose to use an analytical model to specify the divertor plate geometry (location and surface shape) and by varying parameters to optimize the plate performance in terms of low load peaking factor and small surface area.

An Example Divertor Plate Geometry

(based on NCSX-ARE case with $R = 6.93$ m)

- This plate is located at $\varphi_0 = 30^\circ$, $\varphi_0 \approx (-113)^\circ$ -- $(-143)^\circ$, with $\Delta\varphi = 60^\circ$, $\Delta\varphi = 40^\circ$, between the $d = 5$ cm and $d = 10$ cm surfaces. It covers half of each field period.
- The surface is inwardly convex from the $d = 10$ cm surface and peaks at (φ_0, φ_0) with an offset distance of 5 cm.

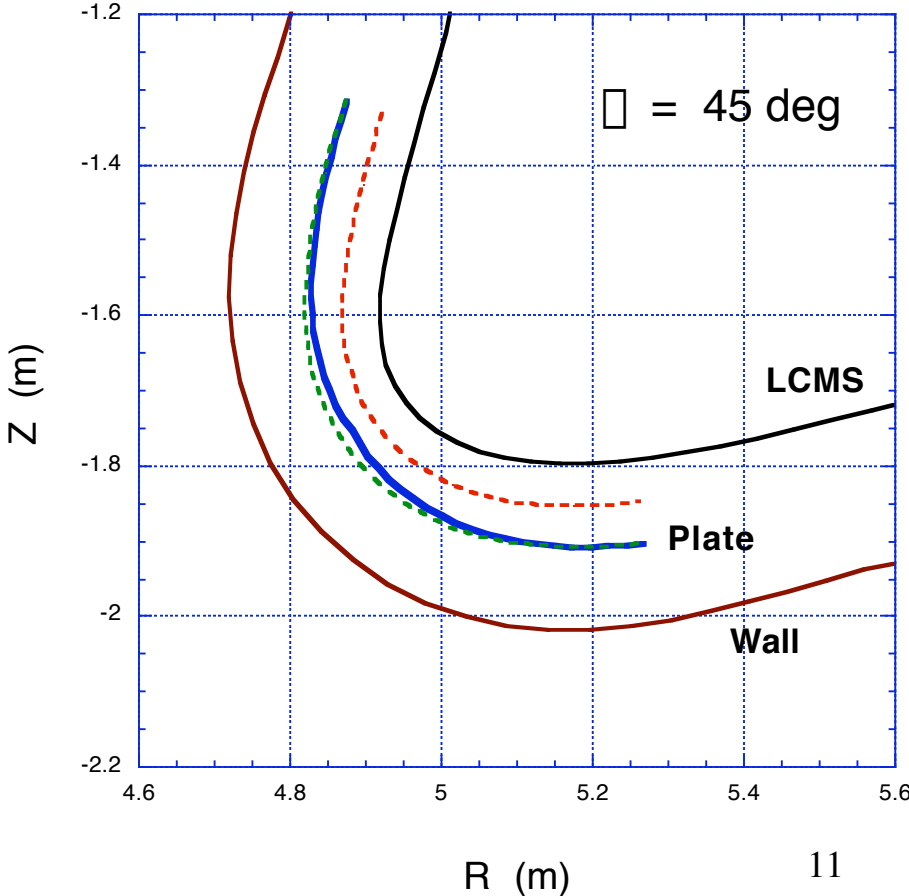
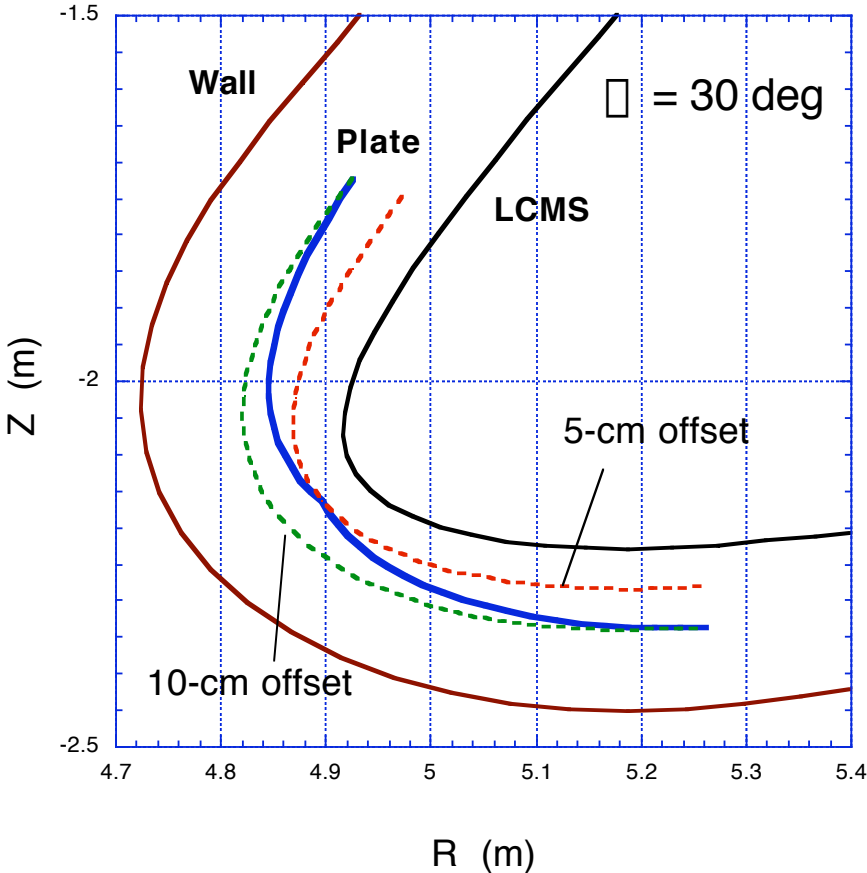
Toroidal Edge



An Example Plate Geometry (Cont'd)

- The plate edge coincides with the $d = 10$ cm surface at every point.

Mid-Point



An Example Plate Geometry (Cont'd)

- At the other toroidal edge, the plate surface also coincides with the $d = 10$ cm surface.
- The wall is at an offset distance of 20 cm from the LCMS.

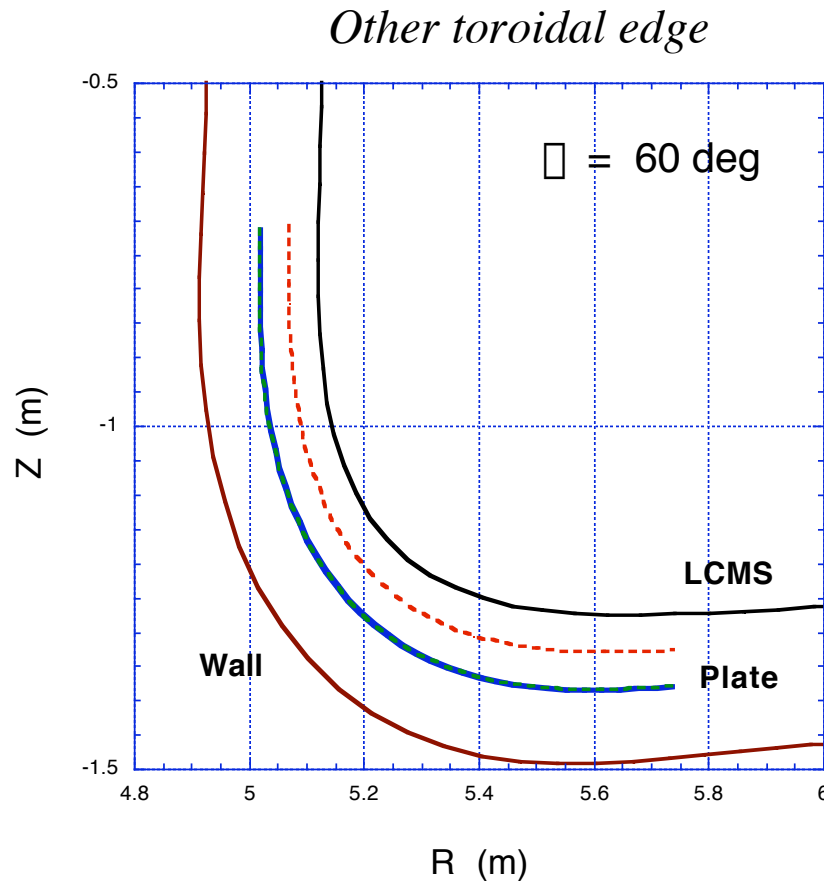
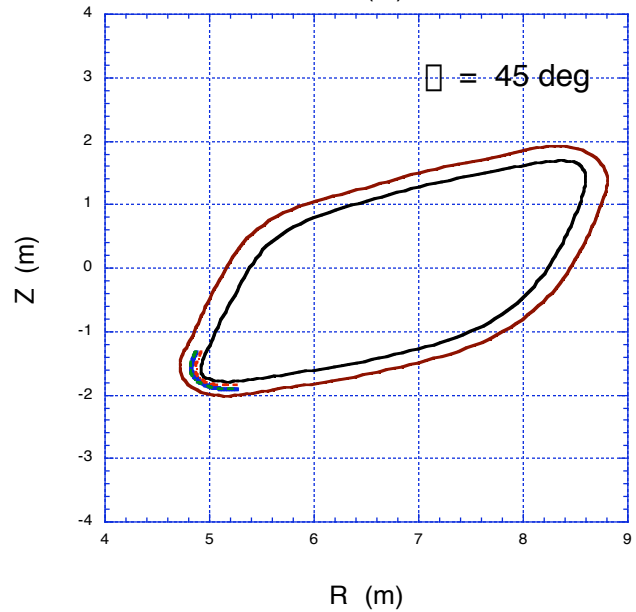
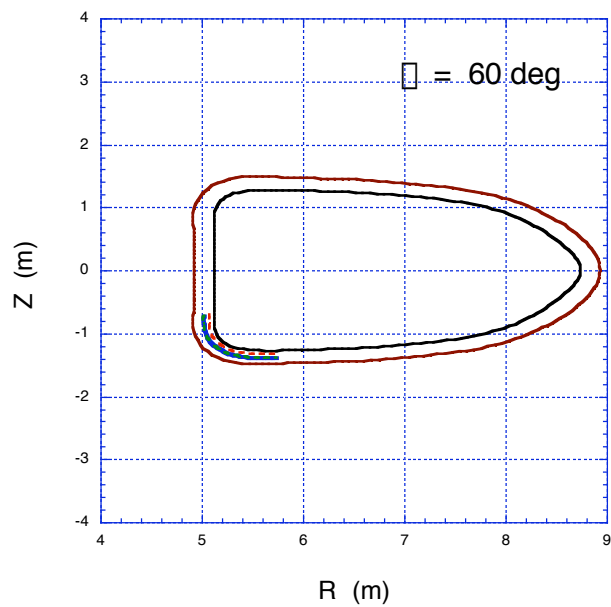
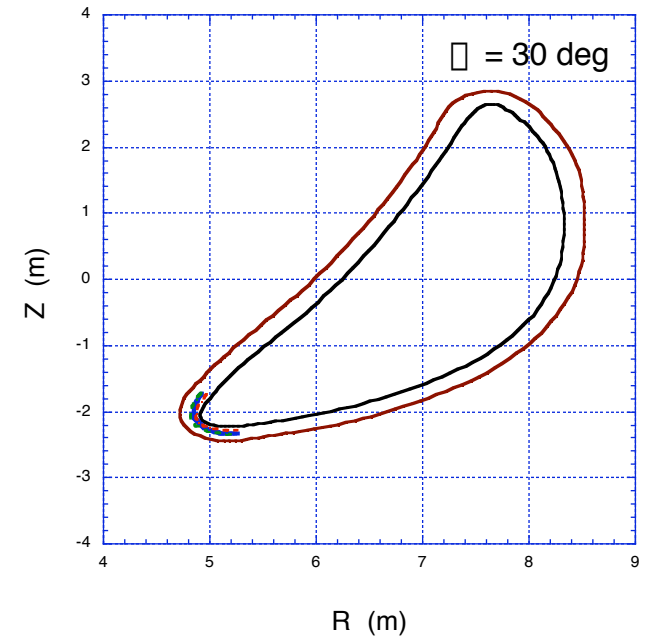
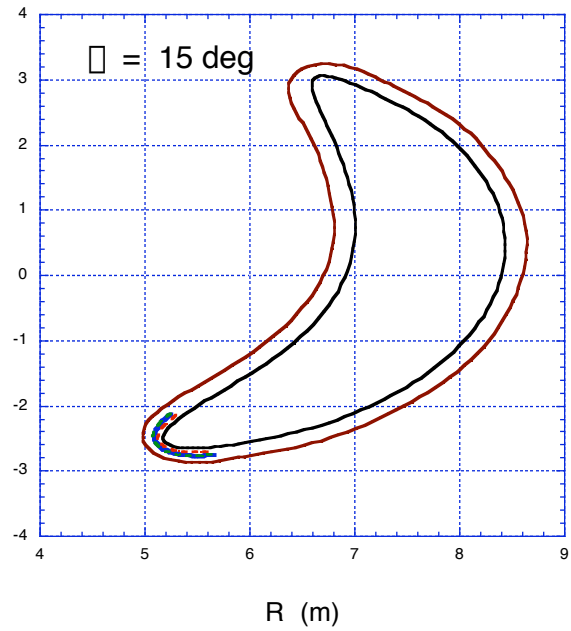
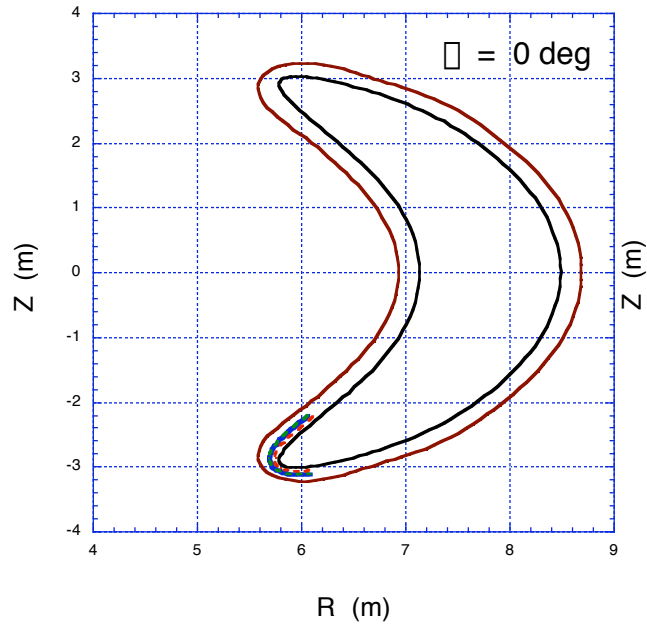


Plate is Located to take Advantage of Flux Expansion

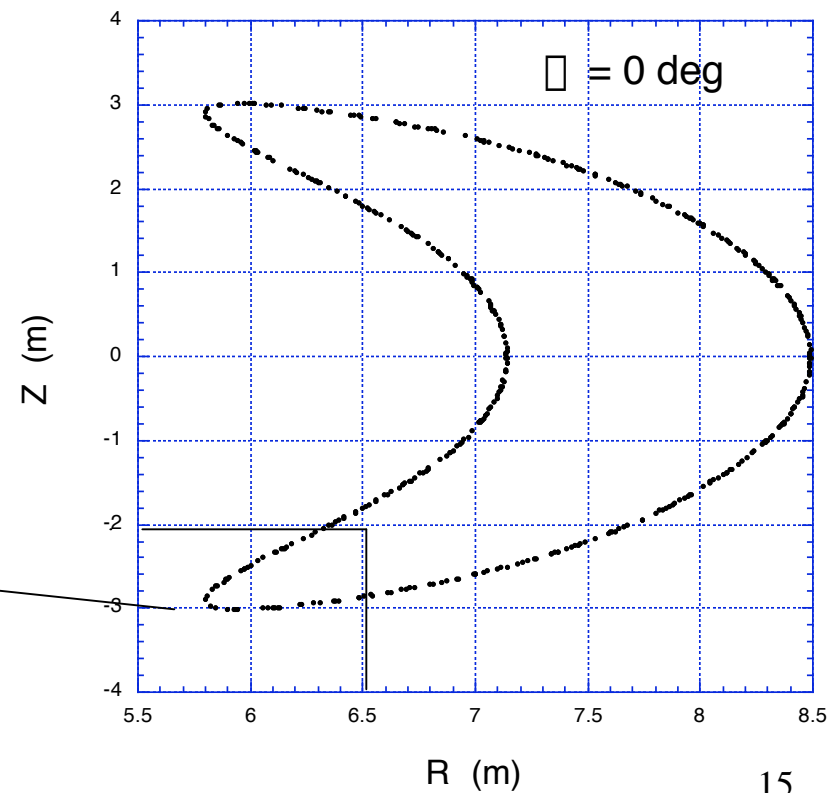
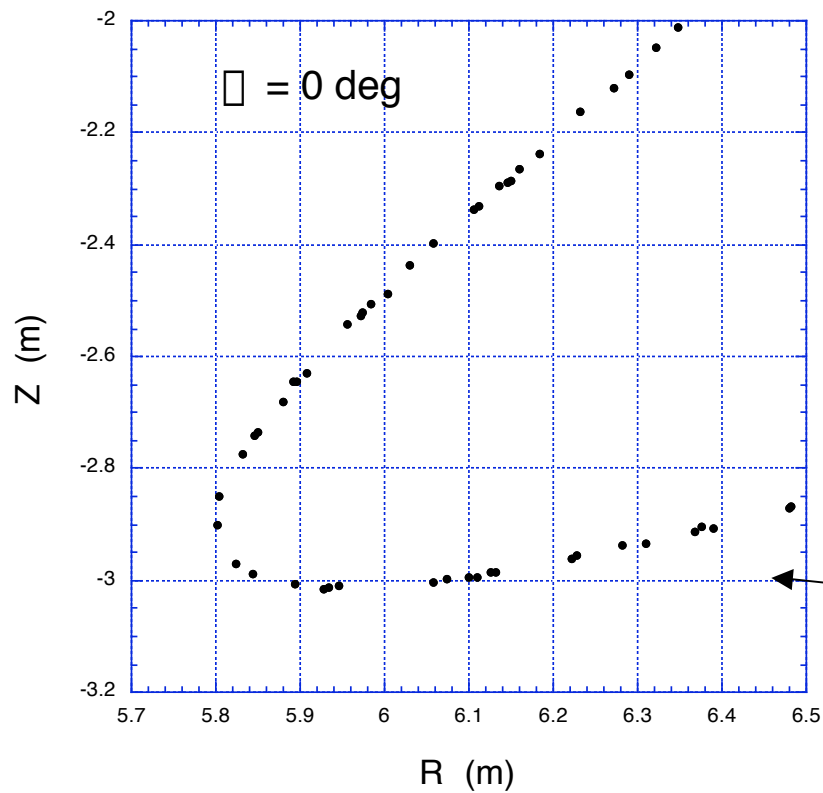


Running GOURDON/GEOM on NCSX-ARE

- The GOURDON/GEOM code has been set up to explore divertor configurations on NCSX-ARE using a simple plate geometry on a conformal surface with 5 cm offset from the LCMS.
- A zone tag map has been generated with GEOM specifying regions of plasma, SOL and divertor, with separate labels for LCMS, wall and plate surfaces.
- A random set of field line starting points has been produced on a surface that is roughly 1 cm inside the LCMS, for toroidal slices at 0°, 30°, and 60°.
- A range of diffusion constants have been used to examine its effect on field line evolution and, eventually, on divertor heat load distribution.

Field Line Starting Points at $\varphi = 0^\circ$ Toroidal Plane

- Points are within 1 cm inside the LCMS.
- A total of 464 starting points have been generated on this plane.



Status of GOURDON/GEOM Run

- A first series of runs with ~ 100 field lines resulting in field lines intercepting either the wall or the divertor plate after only a relatively short distance.
- In many cases, only a fraction of the intersection locations have been successfully calculated.
- Varying the diffusion constant over a wide range (0 - 1 m²/s) does not seem to affect the outcome.
- Possible causes:
 - Calculated LCMS and MFBE-generated field map may not match due to different definitions of toroidal direction.
 - Field is highly stochastic ?
- Need a set of Poincare plots to understand field topology near LCMS.
- Effort is on-going to try to resolve this issue.

Summary

- To optimize the divertor plate geometry (low peaking factor, modest plate area, and uniform load distribution), a systematic approach has been proposed, using a model analytic form for the plate geometry.
- In the approach, various parameters can be varied to optimize the plate configuration. These include:
 - Location of plate center
 - Plate poloidal and toroidal extent
 - Shape of plate surface (many parameters)
 - Plate offset distance from LCMS
- GOURDON/GEOM has been run to do field line tracing on the reference NCSX-ARE using a relatively simple divertor geometry. A zone tag map (GEOM) and a large number of random start points have been generated.
- Efforts are on-going to resolve the encountered numerical issues.

Future Work

- Generally, we need to optimize the divertor configuration to achieve low peaking factor and minimize diveror plate surface area, by following the strategy outlined. Work will be focused on the NCSX-ARE configuration for now.
- Specifically, very near term, we need to resolve the numerical problems when running GOURDON/GEOM for NCSX-ARE.
- We need to update the field line diffusion model in GOURDON.
- On the alpha heat flux issue, we need to calculate alpha particle exit points on LCMS for NCSX-like finite beta equilibrium with favorable loss fraction.
- Finish the incorporation of GYRO into GOURDON/GEOM, and determine the total heat load distribution on divertor plates and the first wall.