HSX, W7-X and CTH as examples of "non-resonant" divertors

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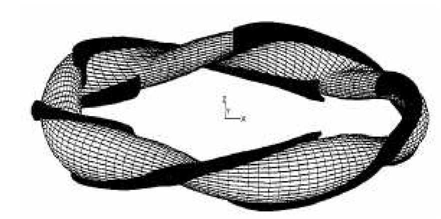
Sherwood Theory Conference, Apr 4, 2016, Madison, WI

Motivation

- Stellarator edges can be strongly dependent on changes in magnetic geometry
  - Island chains can grow/shrink, and move in-out with change in shear
  - Stochastic regions can form
  - Connection lengths can vary greatly
- Options for future reactors
  - Fine control of edge plasma - W7-X (quasi-isodynamic, QI) approach
  - Divertor/wall that is insensitive to changes in β and ι
  - **There is a need for robust divertors design for non-QI stellarators**

What is a non-Resonant Divertor?

- Escaping field lines exit primarily from "toroidal ridges" [1]
- These ridges appear to be a fundamental feature of optimized stellarators, and some unoptimized stellarators as well
- The location of the ridges is insensitive to changes in edge geometry
- **Divertors can be placed in "trough" regions**



Example of "troughs" calculated for W7-X [2]

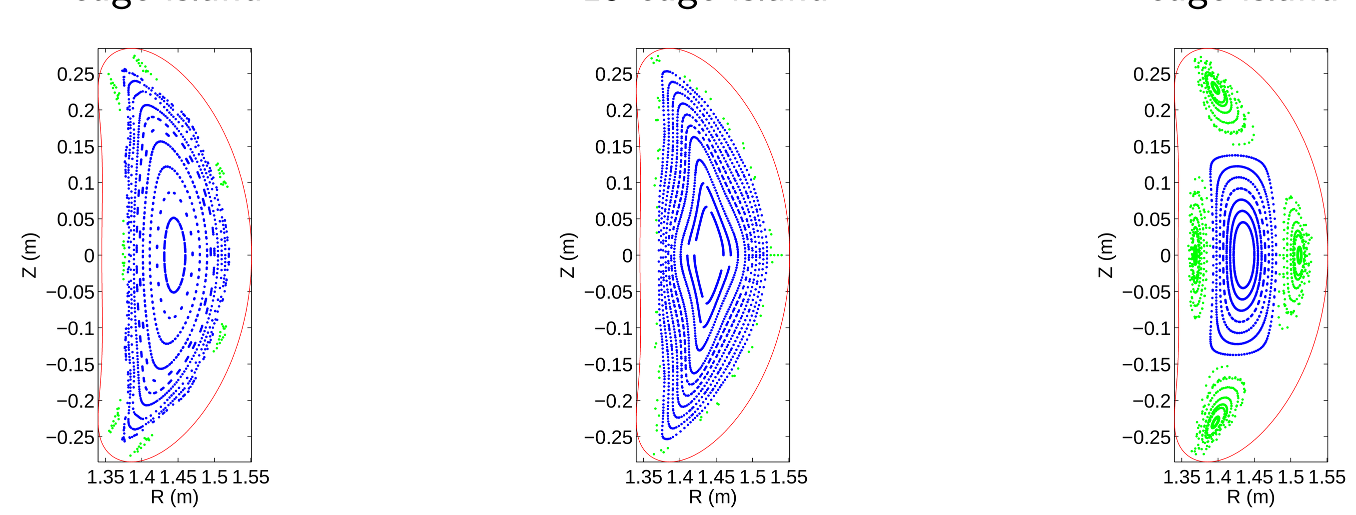
Spiraling method to calculate first exiting line [1]

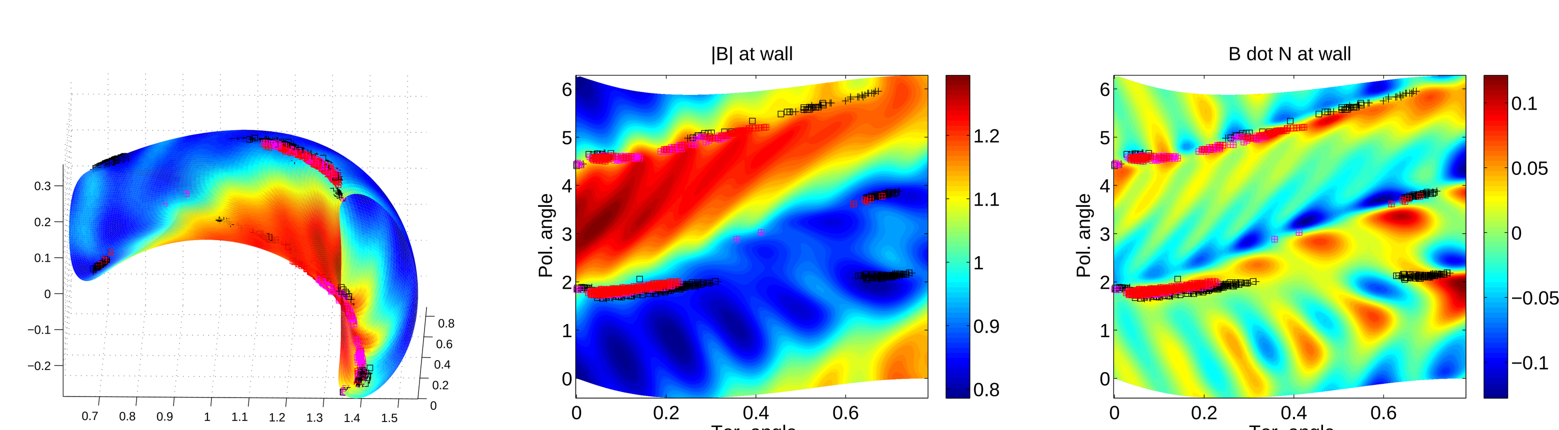
- Start lines **inside** LCFS
- After distance $\Delta\phi$ move line radially outward Δ_r
- Take limit as $\Delta\phi \to \infty$ and $\Delta_r \to 0$
- Calculate strike points on a "witness surface": in this case, move a characteristic flux surface uniformly outward some distance
  - This witness surface is not the actual machine wall, or designed divertor
- **Calculate strike points for different machine geometries as edge configurations are varied**

HSX

HSX: four field period, quasi-helically symmetric stellarator. Many edge configurations easily numerically accessible.

Standard: $n = 8$, $m = 7$ edge island | **Small island**: $n = 16$, $m = 15$ edge island | **Large island** $n = 4$, $m = 4$ edge island



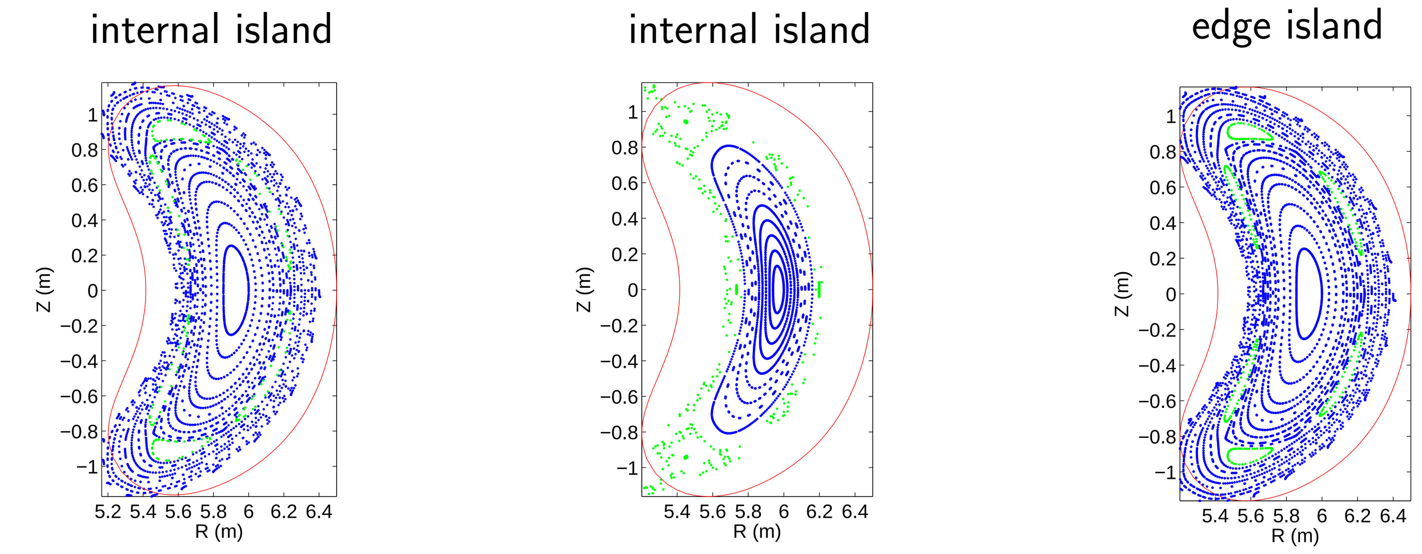


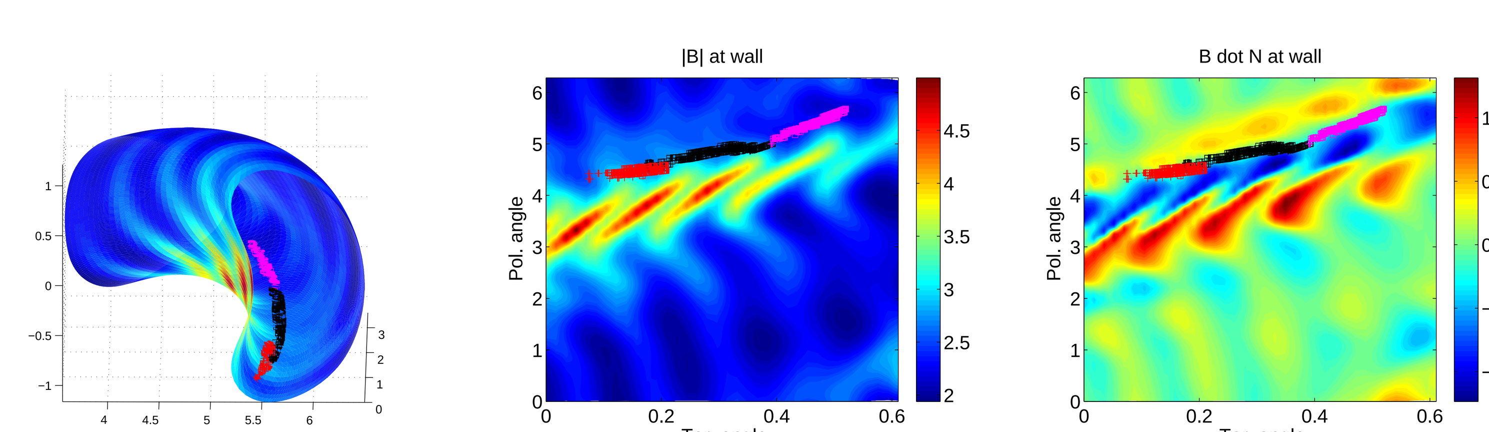
Strike points are independent of configuration for HSX

W7-X

W7-X: 5 field period, QI stellarator. The actual divertor is designed to take advantage of edge islands with an "island divertor" [3].

Standard: $n = 5$, $m = 5$ internal island | **High iota**: $n = 5$, $m = 4$ internal island | **Low island** $n = 5$, $m = 6$ edge island



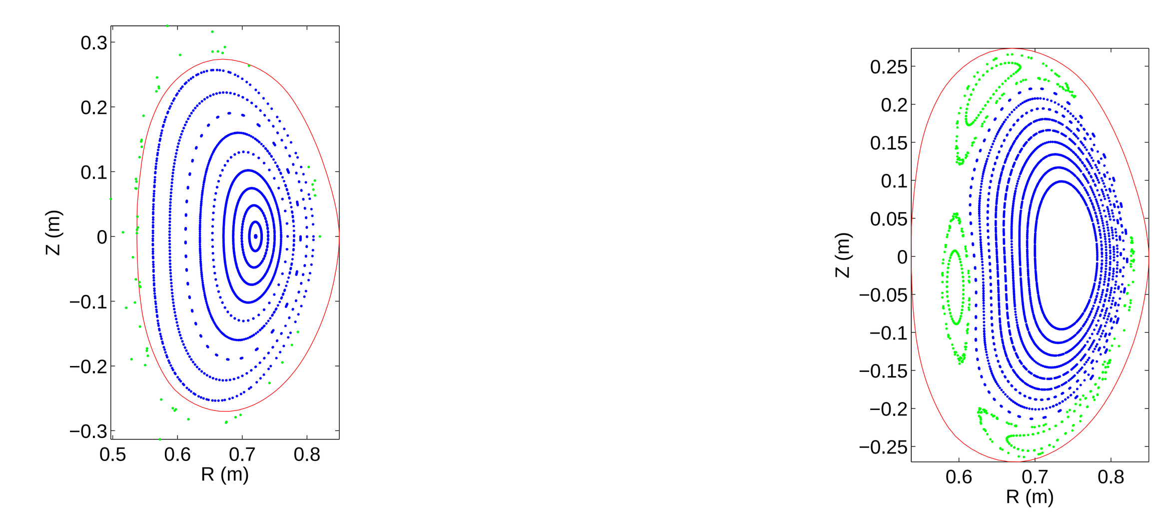


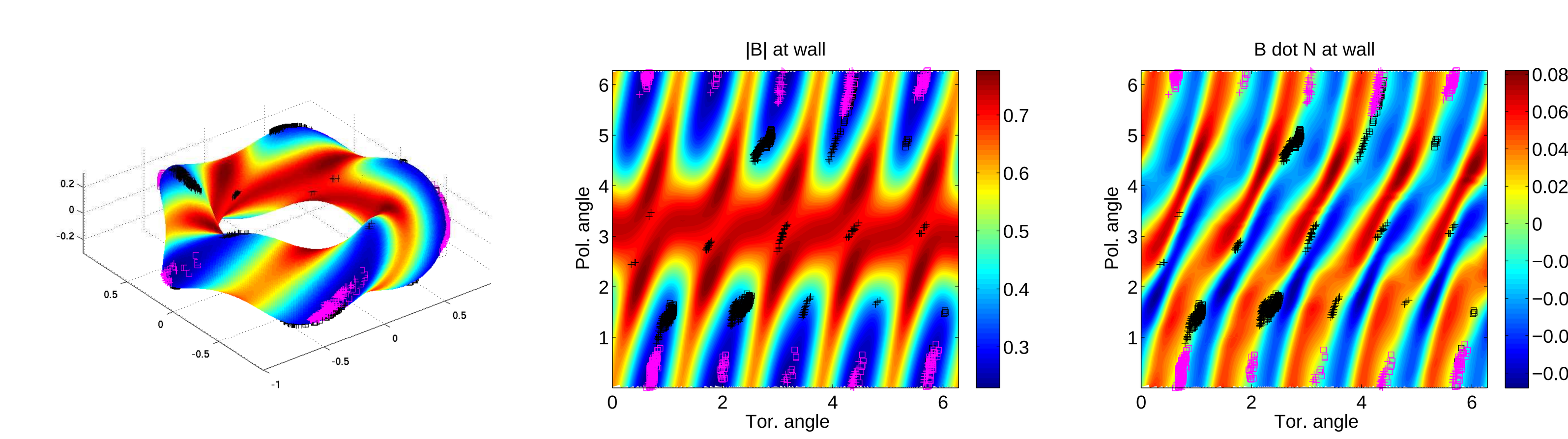
Strike points lie in common trough for W7-X. Toroidal extent is configuration dependent.

CTH

CTH: a five period tokamak-stellarator hybrid with the capability of introducing $n = 1$ perturbations

Standard: No island with a stochastic edge | **Island**: $n = 1$, $m = 3$ edge island

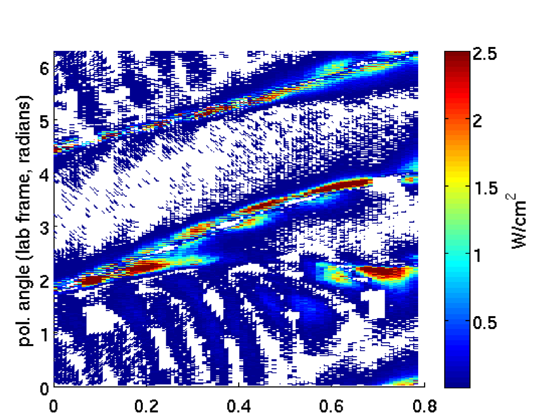




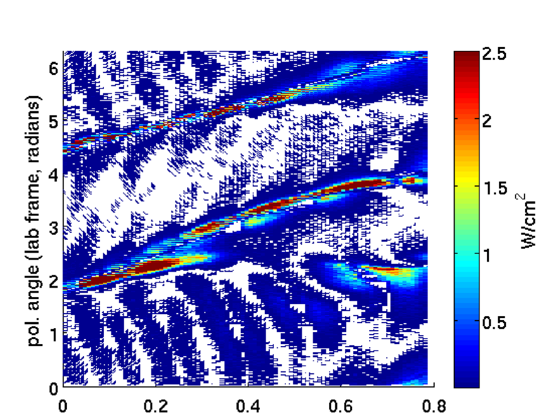
Strike points lie in common trough for CTH. Toroidal extent is configuration dependent.

Resiliency to edge configurations confirmed on HSX using EMC3-EIRENE

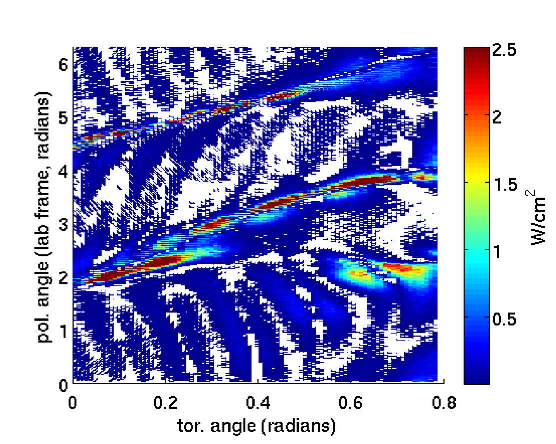
Full 3-D edge simulations of HSX with EMC3-EIRENE indicate that heat fluxes are similar for all three configurations as well.



Standard



Small island



Large island

Conclusions

- All three machines display significant resiliency to changes in edge configurations
- Strike lines always tend to lie on helical "troughs" on the simulated vessels which appear opposite "ridges" on the LCFS
- Different configurations in W7-X and CTH display helical displacements
- Multiple helical troughs are sometimes accessible. Two for CTH, and up to three for HSX

Acknowledgements

Work supported by USDOE-SC0006103. Special thanks to Thomas Sunn Pederson and Oliver Schmitz for useful discussions.

References

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