Edge program on HSX

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1. HSX Experimental edge measurements with Langmuir Probes

2. Resilient divertors for QS stellarators

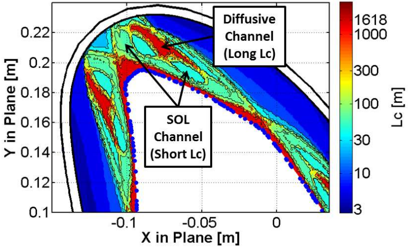
1. HSX Experimental edge measurements with Langmuir Probes

2. Resilient divertors for QS stellarators

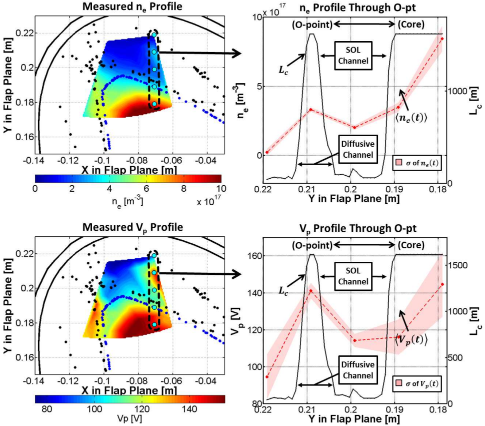
HSX edge is heterogenous, with regions of long and short L_c field lines

HSX edge parameters

- Density: $\sim 10^{12}$ cm^{-3}
- T_e: 20-80 eV
- Island width: $\sim$ 2 cm
- Island extent: $\sim$ 6-7 cm



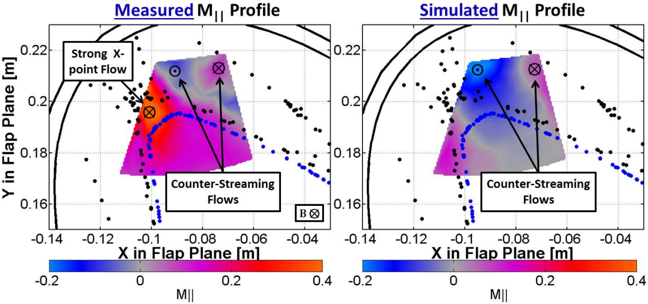
Density and electrical potential measurements show clear effect of island topology



A.R. Akerson PPCF **58** 084002 (2016)

- Density peak not found in simulation
- Electric potential not present in simulation model
- Analysis of density profiles give local diffusivity, $D \approx 0.03$ m^2/s

Counter-streaming flows detected, but additional flow source is present



Additional flow near x-point is not present in simulation
Thought to arise from a distributed particle source

Edge topology has significant effect on edge plasma parameters

- HSX edge is accessible to detailed probe analysis, difficult on denser and hotter devices
- Results point to additional questions
  - What is the mechanism for the very small local D value?
  - What role do electric potential structures play?
  - What is the distributed source driving the strong flow?
  - Is real in-situ mapping of edge field lines possible?
  - Will perform a dedicated helium campaign

1. HSX Experimental edge measurements with Langmuir Probes

2. Resilient divertors for QS stellarators

Divertor design for quasi-symmetric stellarators is still an open problem

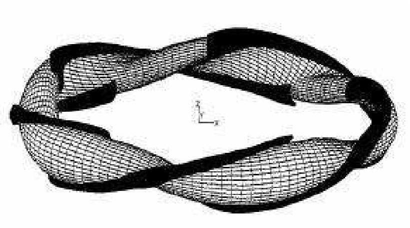
- In torsatrons/heliotrons divertors are defined by helical coils: **Helical Divertors**
- Quasi-ominigenous stellators use islands from low order rational resonances: **Island Divertors**
- Neither of these two approaches are available for Quasi-symmetric stellarators
  - Modular coils prevent attainment of helical divertors
  - Evolving bootstrap current prevents accurate positioning of islands for island divertors

Resiliency - a necessary but not sufficient condition for QS divertors

- Resilience: divertor behavior remains similar as plasma evolves
  - Bootstrap current can modify rotational transform profile
  - Finite pressure can alter flux surface shapes
- Tokamaks and heliotrons are naturally more resilient than modular stellarators because of the relative strength of diverting fields
- The HSX edge displays resilient properties
- Open questions we are thinking about are:
  - **Is HSX resilient?**
  - What features are important for resiliency?
  - What else is needed besides resiliency?

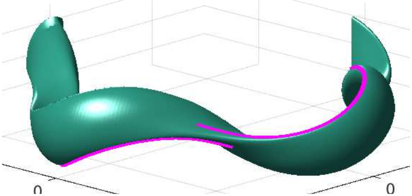
Flux primarily exits from “ridges” into “troughs”

Early W7-X design



Strumberger (NF 1992) uses early designs of W7-X and determines that flux exits the plasma surface in specific region that she refers to as troughs.

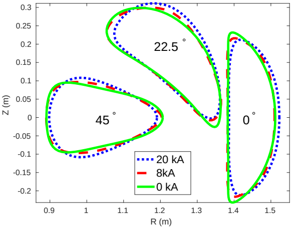
HSX

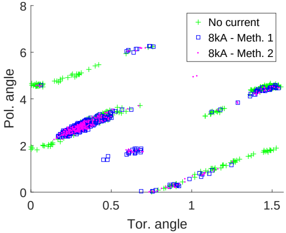


Field lines tend to follow along sharp ridges on the LCFS. Like a poloidal divertor, this defines where particle flux predominantly exits the plasma.
Difference from Tokamaks: Finite toroidal extent

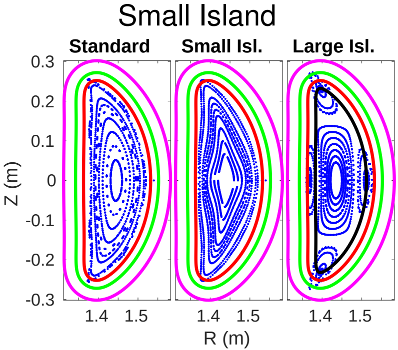
Field line strike-points are robust to changes in plasma current in HSX

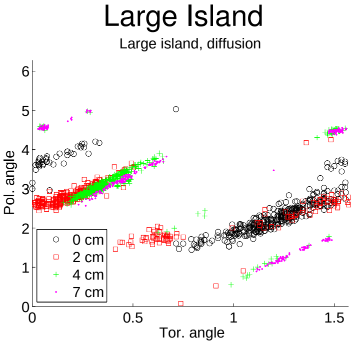
- VMEC equilibria include plasma current
- Caveat: VMEC cannot handle islands: need to avoid low order resonances
- Two methods for calculating magnetic field from VMEC: FIELDLINES (S. Lazerson) and from magnetic potential (M. Cianciosa)





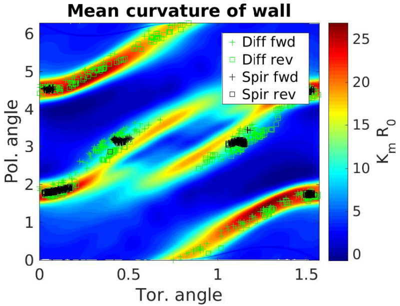
Large island configuration can alter strike point patterns if wall intersects island

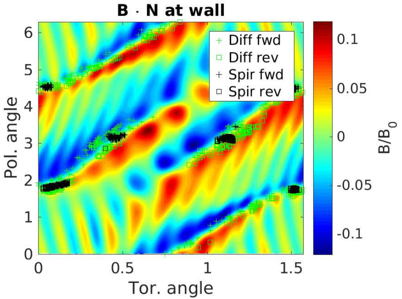




If the islands do not intersect the wall, then strike points for configurations are similar

Strike lines appear on regions of high curvature and along seams in $\mathbf{B} \cdot \mathbf{n}$ at the wall





Wall is generated by stepping out LCFS uniformly in the base configuration

Experimental and theoretical edge studies are ongoing on HSX

- Experimental measurements highlight importance of edge topology
  - Long L_c regions (islands) produce density and potential hills, and constrain parallel flows
  - Edge is accessible to detailed Langmuir probe measurements
  - EMC3-EIRENE simulations are routinely available
- HSX is resilient - useful property for future QS designs?
  - Is resilience guaranteed if islands are not present?
  - If resilience not guaranteed, what determines it? Curvature of LCFS?
  - Are there divertor solutions besides island/helical divertors?
  - Search for good divertor/edge proxies for use in configuration optimization