Power and Particle Control in NCSX

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presented
for the NCSX Plasma Boundary Group
by

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Outline

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- Introduction
- Magnetic configuration
- Power handling
- Particle control
- Impurity control
- Summary and plans

Introduction

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- A key prerequisite for enhanced performance is

neutrals- & impurity control

- In limiter configurations the limiter takes out the heat, while particle- and impurity control is largely accomplished by wall conditioning
- Limiters intercept closed field lines and introduce neutrals- and impurity sources into the confined plasma
- In divertor configurations, neutrals and impurities are controlled by baffling and ‘plasma plugging’ and in addition by wall conditioning
- Divertor baffles intercept open field lines outside the LCMS and provide edge plasma between solid surface and LCMS

Magnetic Configuration in the Plasma Boundary

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- Present experience on Wendelstein7-AS indicates that the most effective location for intercepting power and particles are the top and bottom of the bean-shaped cross-sections at v=0.
- First results on field-line tracing outside the LCMS of NCSX indicate similar trends

- To determine where power and particles leave the confined plasma, i.e. as guidance for the design of the plasma-facing components,
  - **We have started to generate field-line plots outside the LCMS for the top, inside and outside the cross-sections at the start and halfway through the field -period.**
  - **We will generate plots of the interception of energetic particles with the LCMS**

Poincaré Plot for the Li 383 Configuration and Modular Coils

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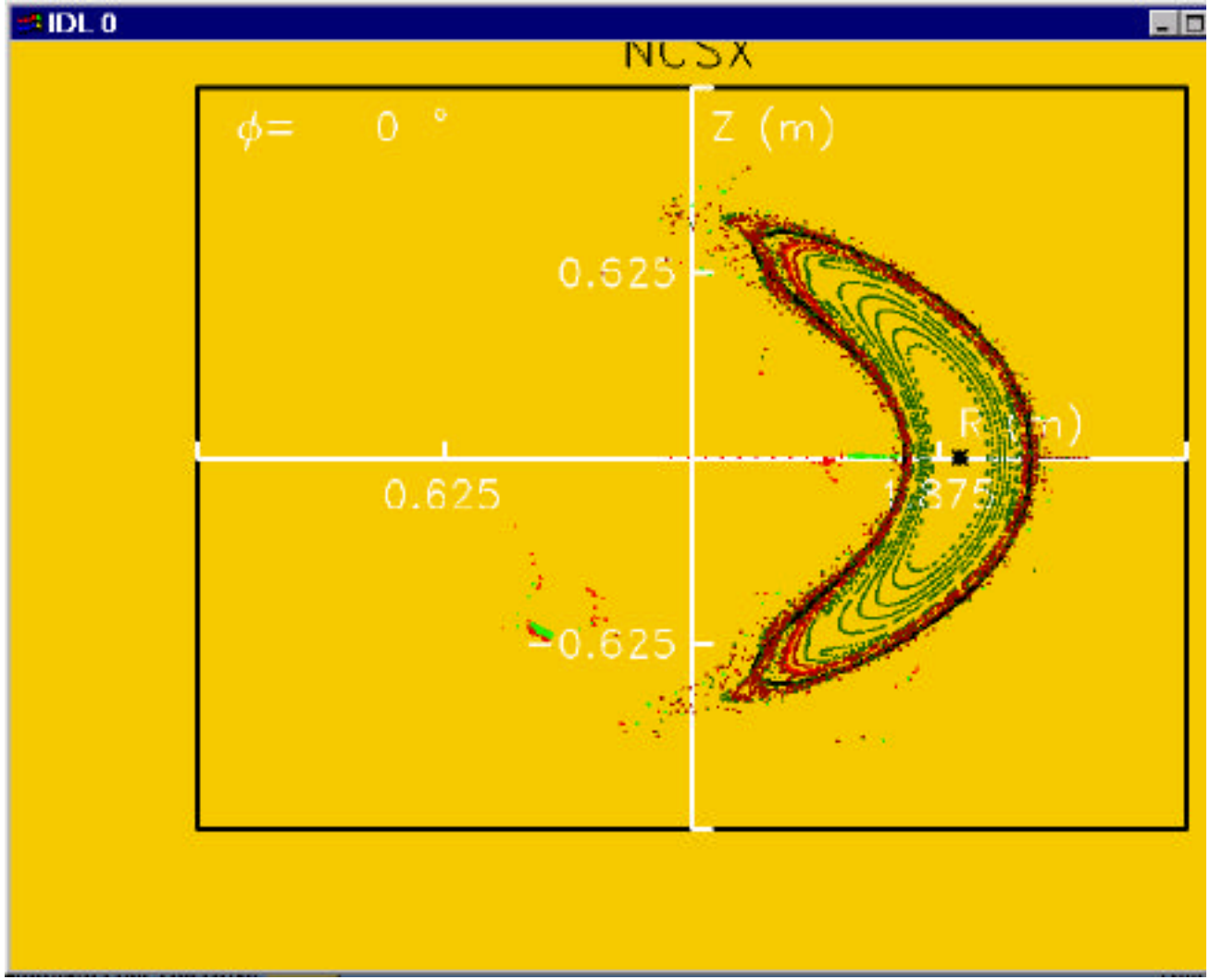

In the modular coil configuration, the field lines outside the LCMS are concentrated at the top and bottom of the bean.

This provides an opportunity for effective divertor baffling.

Divertor Baffles / Limiters for the Li 383 Configuration

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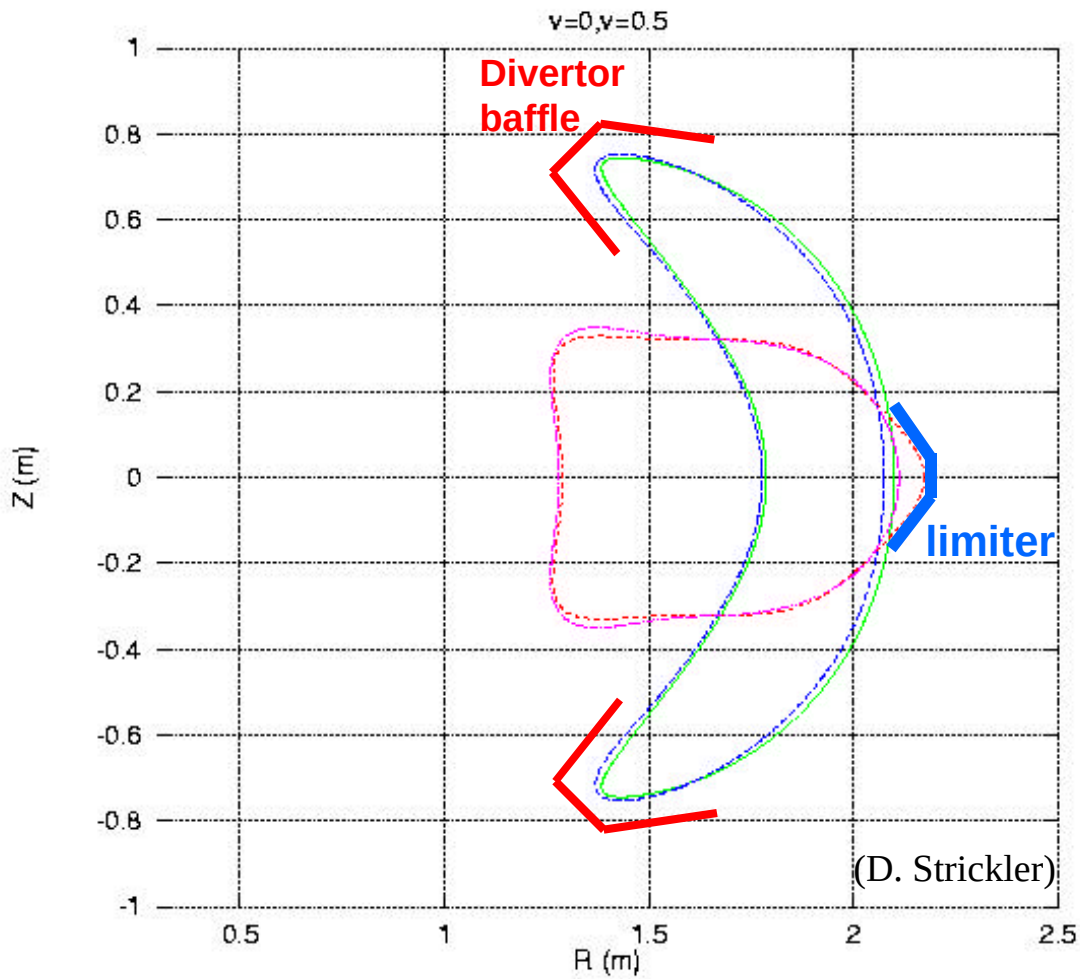

- for Phase I the baffles will provide mechanical baffling and enhanced re-ionization
- for later phase, room for pumping might be needed

- an alternative to divertor baffles is a set of modular outboard limiters (one per FP)
- this would have to be combined with some wall armor to protect the wall from energetic particles

3-D View and Poloidal Cut of Possible Divertor Baffle

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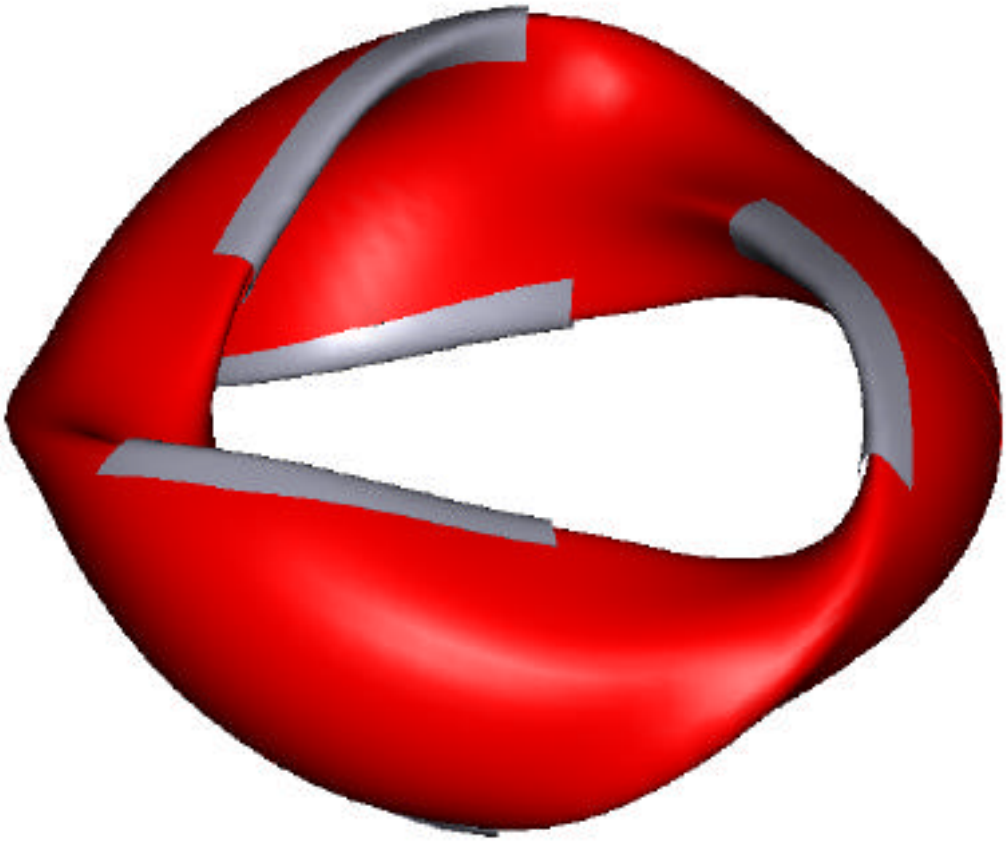

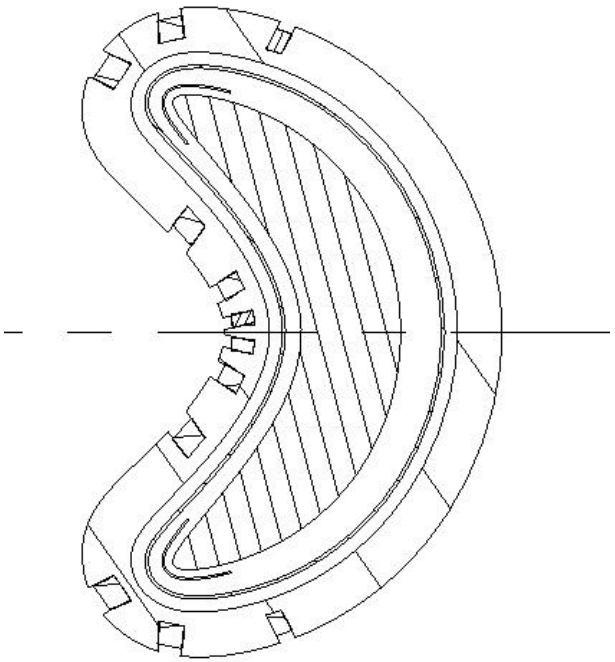

B. Nelson

Initial Power Handling Considerations
Example: Divertor

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- Divertor baffle is toroidally discontinuous (one top/bottom pair per FP)
- Toroidal extent needs to be worked out in detail
- Assuming for now a toroidal extent of 1.5 m per per field period
- For 3 field periods and top and bottom baffles: total length = 9 m
- For this case the baffle surface facing the plasma is: ~ 6 m^2
- Designing for 80% of the power intercepted by baffles: 9.6 MW
- Average power density: 1.6 MW/m^2
- With a peaking factor of 3, maximum power density: ~ 5 MW/m^2

=> ***Inertial cooling during shot and active cooling to remove 5-10 MJ between shots (10 Min.?)***

Energy and spatial distributions of lost beam particles on QA 383

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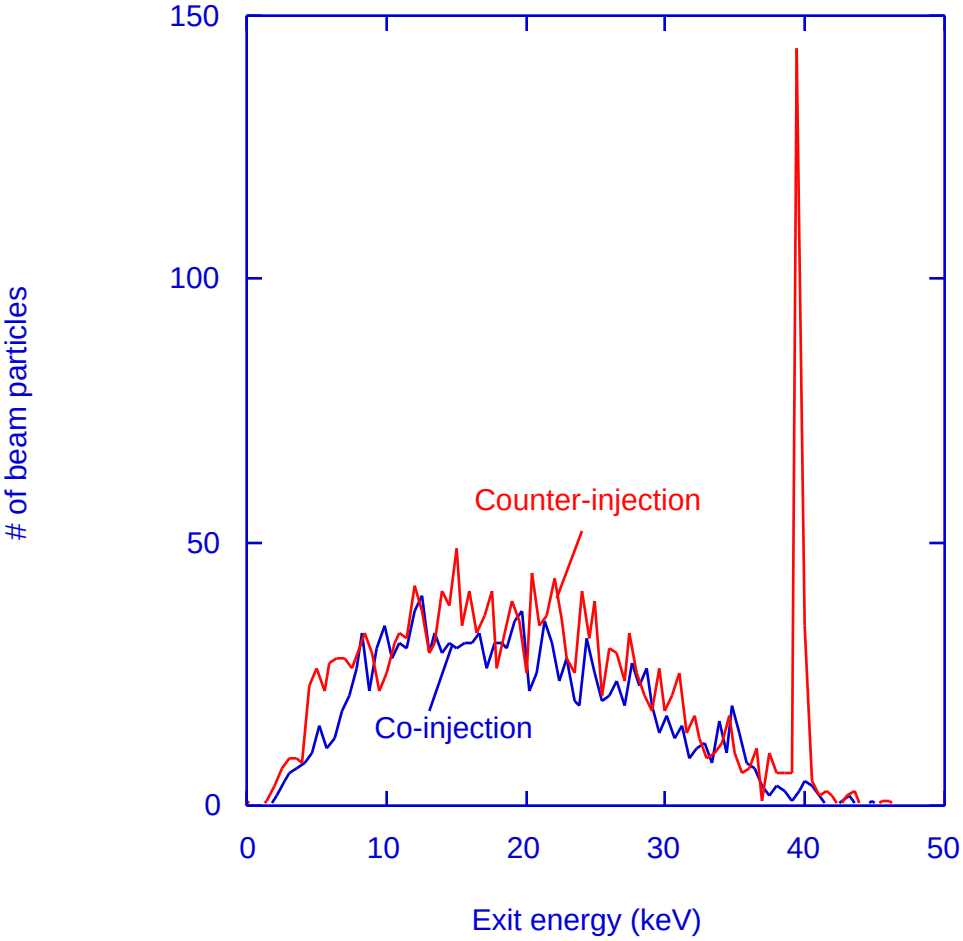

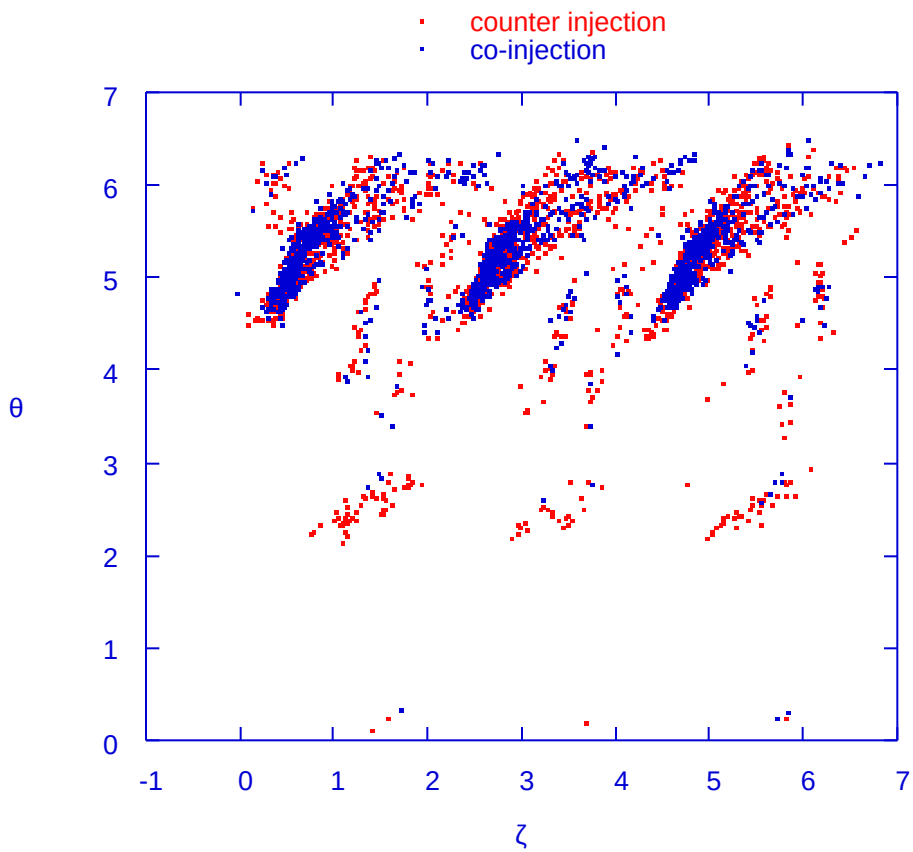

D. Spong

NBI loss patterns for QA 383 on outer flux surface

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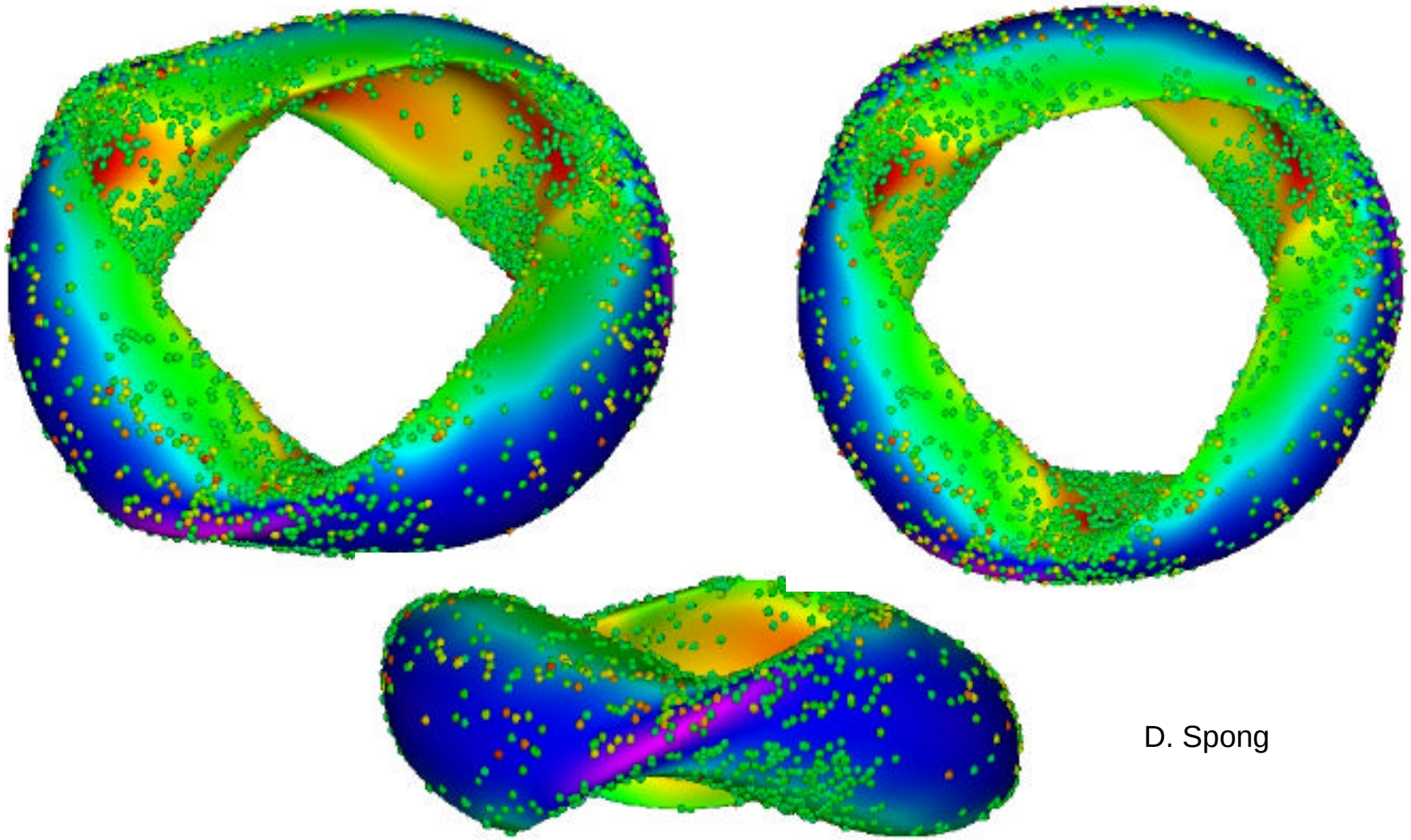

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Neutrals Control

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- The goal is to control the neutrals source :

1. We assume (and need to verify) that thermal and fast particles leave the plasma predominantly at the sharp ridges (Wendelstein)
2. We need to investigate if considerable fractions of particles and power come out elsewhere (we have started this analysis)

- With modular divertor baffles, neutrals are confined mechanically by the baffles and have a finite probability of re-ionization by the boundary plasma
- The goal is to generate local recycling and high-recycling divertor operation with low electron temperatures (high-Z material?)
- This will minimize the build-up of neutral pressure in the vessel
- Divertor baffling will be complemented with state-of-the-art surface pumping
  - **Boronization, Li gettering, other**

Impurity Control

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- Materials
  - **Wall: stainless steel**
  - **High-heat-flux areas: bulk-boronized graphite (high-Z upgrade for high-density phase?)**
- Vessel conditioning
  - **Baking: temperature depends on material, e.g. graphite @ > 300 ^{o}C**
  - **Glow discharge cleaning: H, D, He, other**
- Wall modification
  - **Boronization, Li-gettering, etc.**
    1. Cover wall metals with low-Z coatings
    2. Getter oxygen- and carbon-containing impurities

Impurity Control - cont'd

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- Plasma-surface interactions
  - **Most intense interaction will be at the high flux areas of divertor/limiter (ions)**
  - **A source of similar magnitude - due to the large area - is due to cx sputtering at the wall (neutrals)**
- Divertor baffles should reduce both impurity sources:
  - **Boundary plasma between baffle surface and LCMS will help shield main plasma from impurity source**
  - **Reduction of neutrals will reduce cx fluxes and reduce wall sputtering**
  - **Materials choice and geometry provide additional help**
- Limiter design for minimum effects of plasma interactions:
  - **materials choice and geometry**
  - **wall conditioning**

Summary

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Two options for power- and particle control are being considered:

- Option 1: Modular divertor baffles intercepting power and particle fluxes at top and bottom of the bean-shaped cross-sections
  - **Emphasis will be on neutrals control from the very start**
  - **Power handling should be ok**
  - **Requires knowledge of plasma configuration and fluxes**
- Option 2: Combination of modular outboard (?) limiters and wall armor at locations of energetic particle interception
  - **Emphasis will be on power handling and flexibility**
  - **Neutrals- and impurity-control will likely be inferior to divertor option**

Near-term Plans and Tasks

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- Detailed field line mapping of the plasma boundary
  - **at several cross-sections, launching inside and outside**
  - **For low-beta (vacuum) and high-beta (currents?)**
- Mapping of energetic particle outflow
  - **Estimate particle- and power-fraction**
- Neutrals modeling: approximations with existing tools
  - **Neutrals transport in the baffle regions**
  - **Neutrals penetration in the midplane at various cross-sections**
- Modeling of power and particle fluxes on limiters/divertor baffles
  - **2-D approximation of plasma and fluxes (B2, UEDGE)**

Note: ***Many issues on power and particle handling are similar for NCSX and QOS and can be addressed in similar ways for both devices***