Assessment of 3D Field Effects on the Properties of the Snowflake Divertor

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in collaboration with

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NSTX-U Research Forum

Divertor and Scrape-Off Layer

Topical Science Group

Princeton Plasma Physics Laboratory – PPPL

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Main Goals

- **Use the snowflake divertor to validate/improve the physics models in some MHD and transport codes (TRIP3D, SURFMN, M3D-C^1, NIMROD, EMC3-Eirene, ELITE, GATO, BALOO, NTVTOK)**
  - Provide a better understanding of the effect of 3D fields on tokamak plasmas

- **Compare measured particle and heat deposition pattern on divertor plates with those simulated using the transport code EMC3-Eirene**
  - The simulations will be run on grids generated using TRIP3D and MHD codes: M3D-C^1 and NIMROD (include plasma response to 3D fields)

- **Provide a better insight into the edge MHD stability by challenging the present models (ELITE, GATO, BALOO) using snowflake diverted plasmas**
  - SF diverted plasmas are expected to have a larger edge magnetic shear (enlarge the peeling-balooning stability boundary)

- **Study the effect of the divertor geometry on the NTV torque (NTVTOK)**

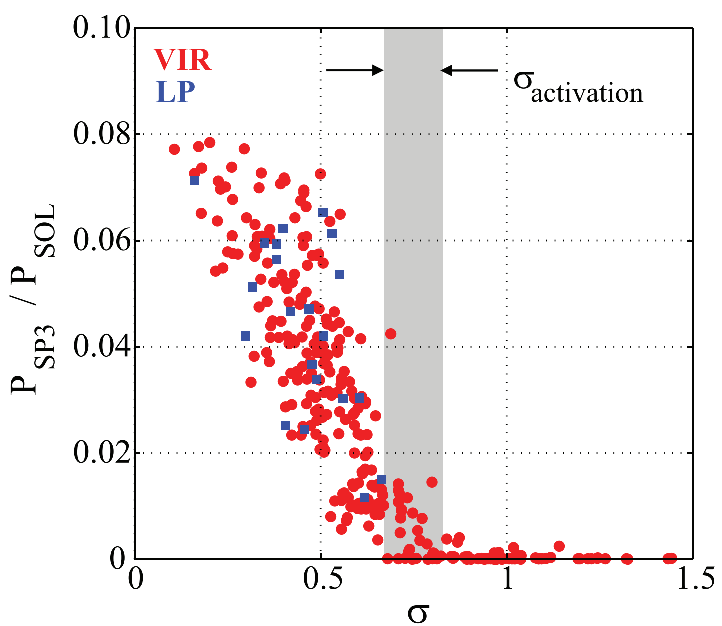
Previous Studies on TCV Suggest the Existence of an Enhanced Cross-Field Transport in the Snowflake Divertor

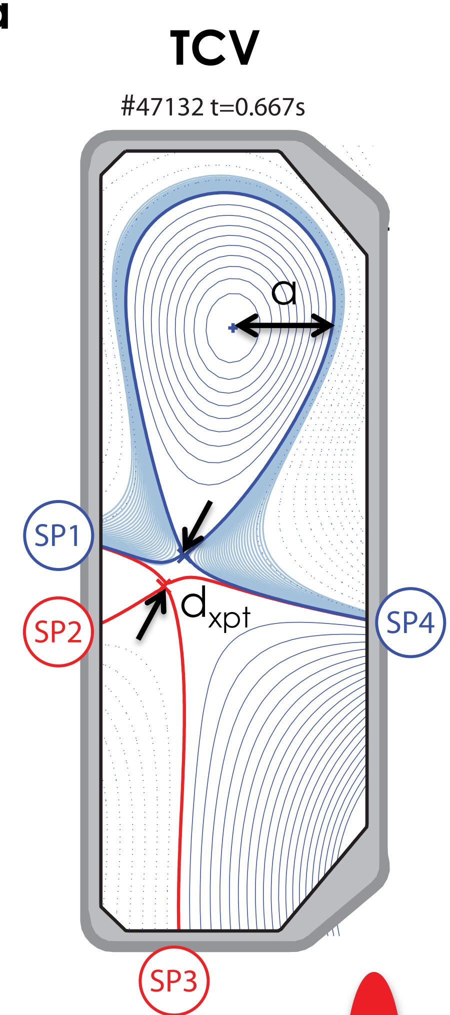
- **Heat flux measurements at secondary strike points of a SF+ indicate transport across the primary separatrix**

- **Power distribution to secondary SPs of a SF+ increases with decreasing σ** [H. Reimerdes, PPCF 2013]
  - EMC3-Eirene simulations indicate the existence of an enhanced cross-field transport in the null-point region of the SF divertor [T. Lunt, PPCF 2014]

Slope: Measure of cross-field transport

$\sigma_{activation}$: Typical scale length of the transport process

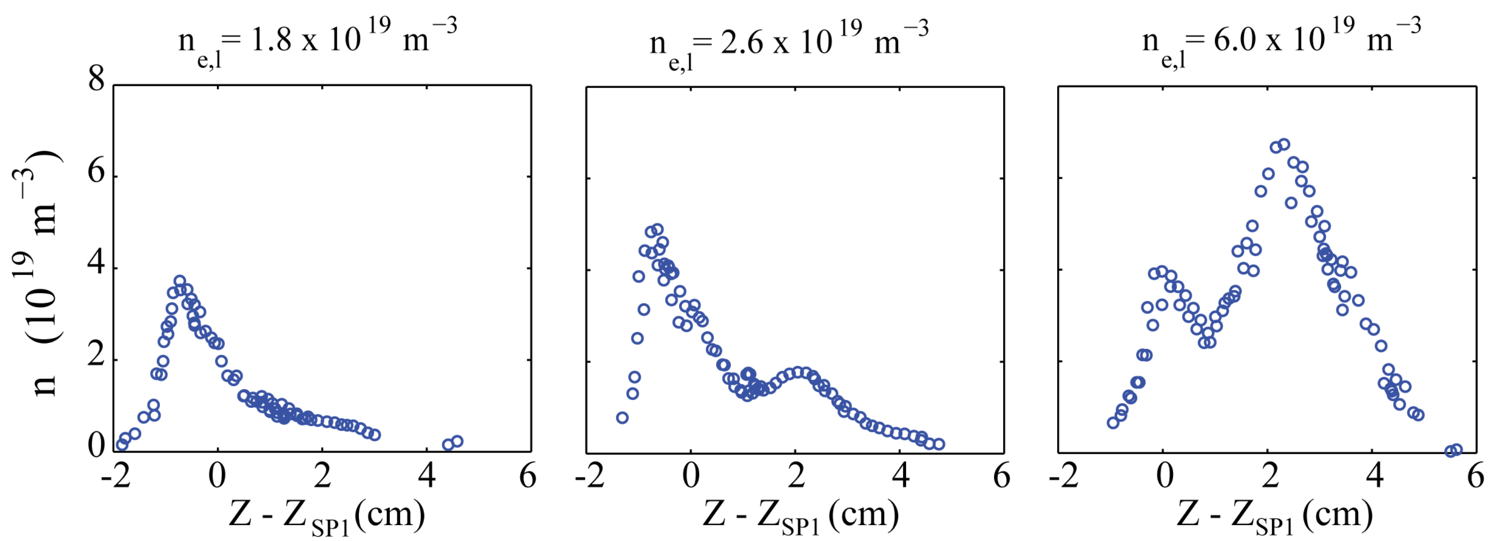




$\sigma = d_{xpt} / a$

The E x B Drift Explains Most of the Measurements Obtained During TCV Snowflake Diverted Discharges

- **Several mechanisms have been proposed to explain such an enhanced cross-field transport**
  - Destabilization of flute-like interchange ("churning") modes [D.D. Ryutov, Phys. Scr. 2014]
  - Shock waves in the divertor region [D.D. Ryutov, Contrib. Plasma Phys. 1996]
  - E x B particle drift [G.P. Canal, to be submitted to NF]
- **The E x B drift provides a better explanation for most of the experimental observations, e.g. double-peaked density target profiles**



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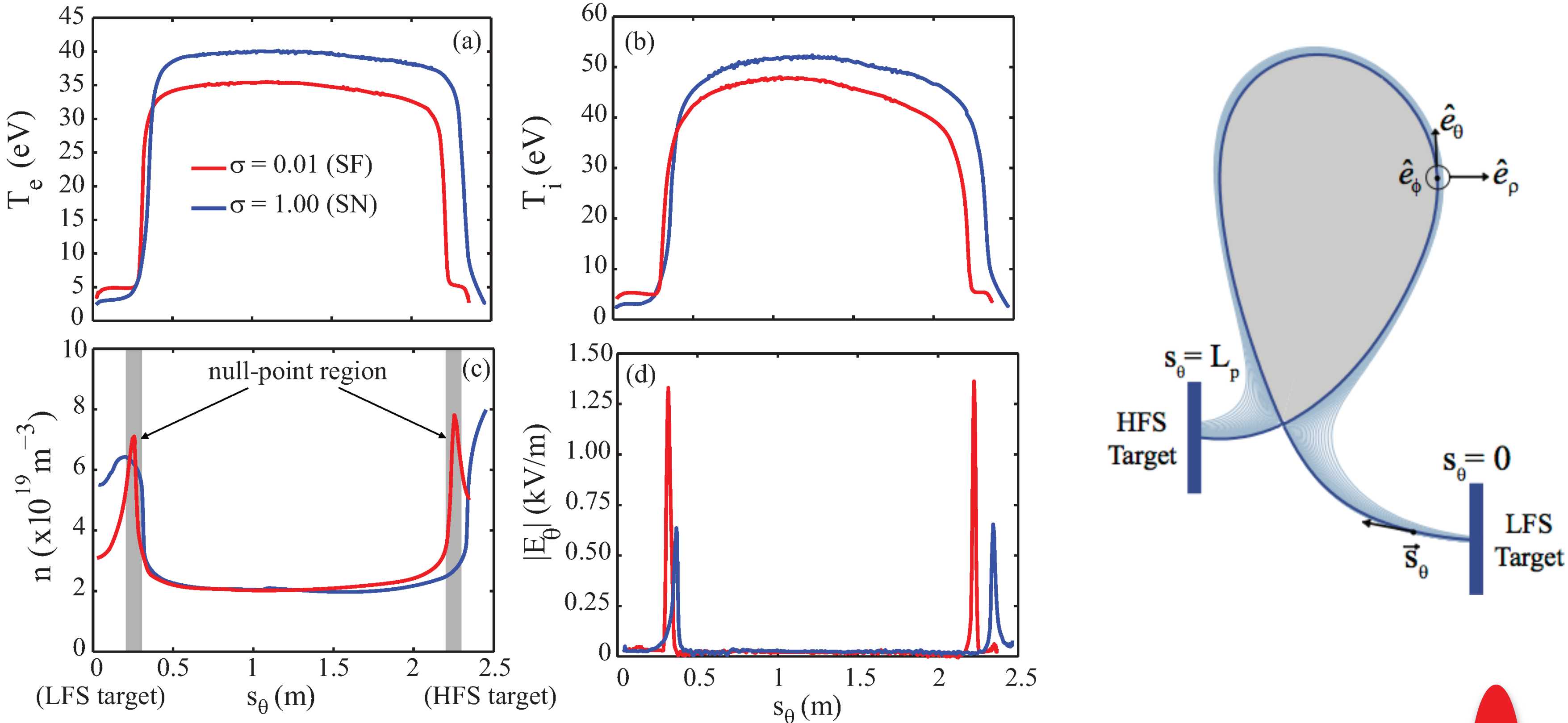
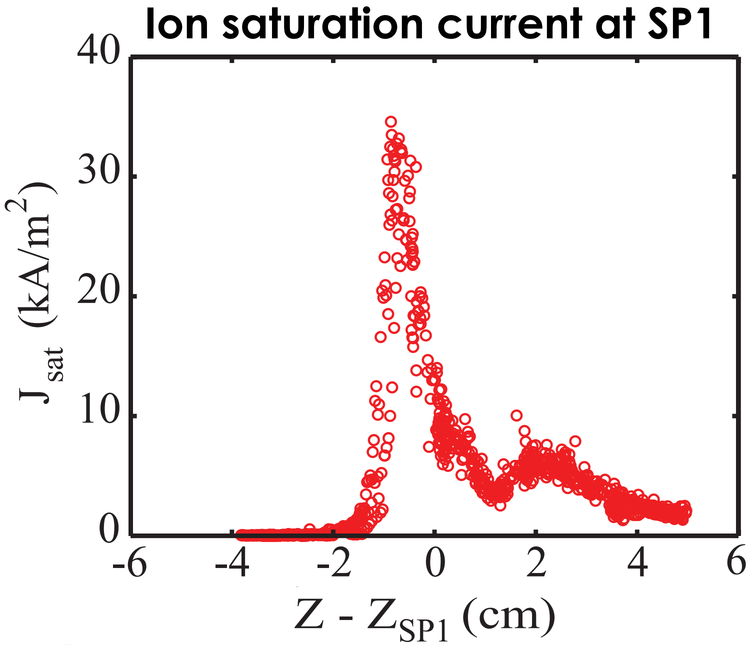
The E x B Drift is Expected to Be Stronger in the Null-Point Region of the Snowflake Divertor

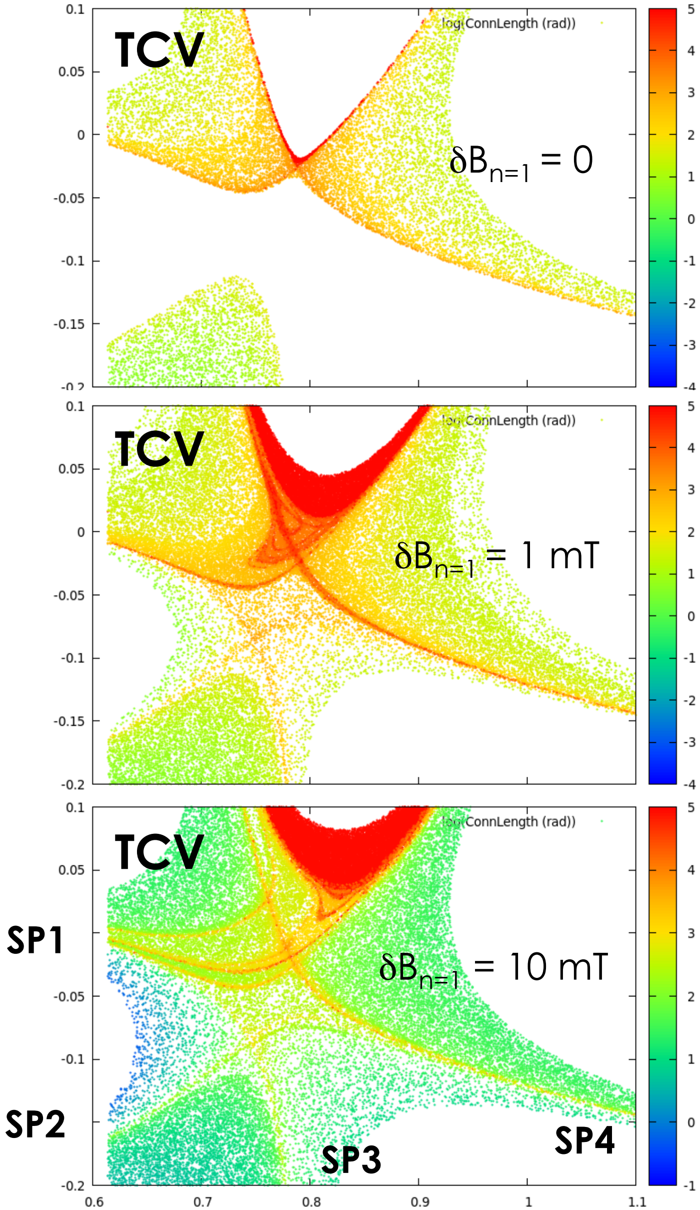
- **Larger poloidal gradients of the kinetic profiles in the null-point region of the SF divertor lead to larger poloidal electric fields**
  - Larger radial E x B particle and heat transport



The Snowflake Divertor is Expected to Be More Sensitive to Non-Axisymmetric Magnetic Perturbations

- **The poloidal field in the null-point region of the SF configuration is lower than that of a lower single-null (LSN) divertor**
  - Non-axisymmetric fields are expected to have a stronger effect on the null-point region of a SF than on a LSN





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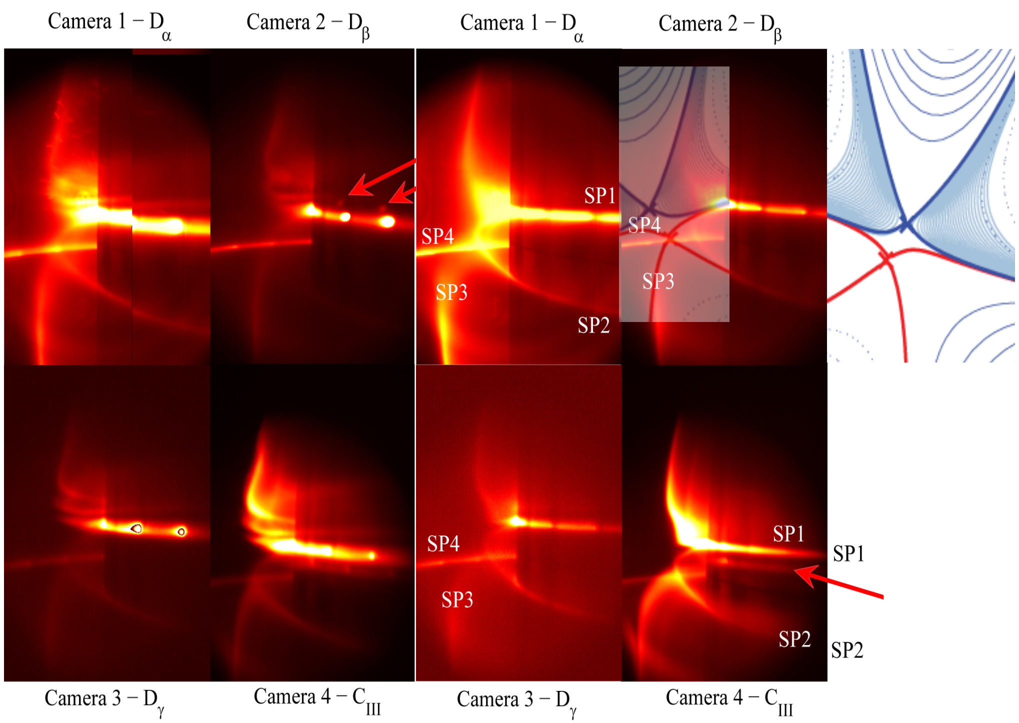
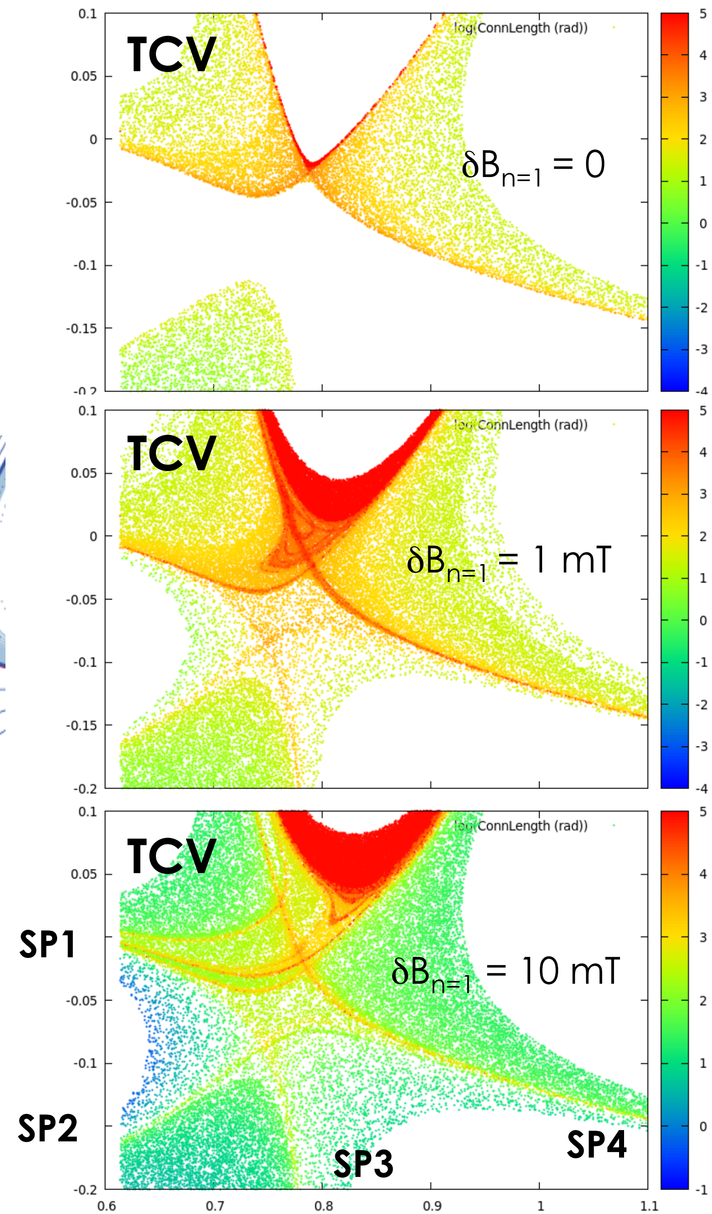
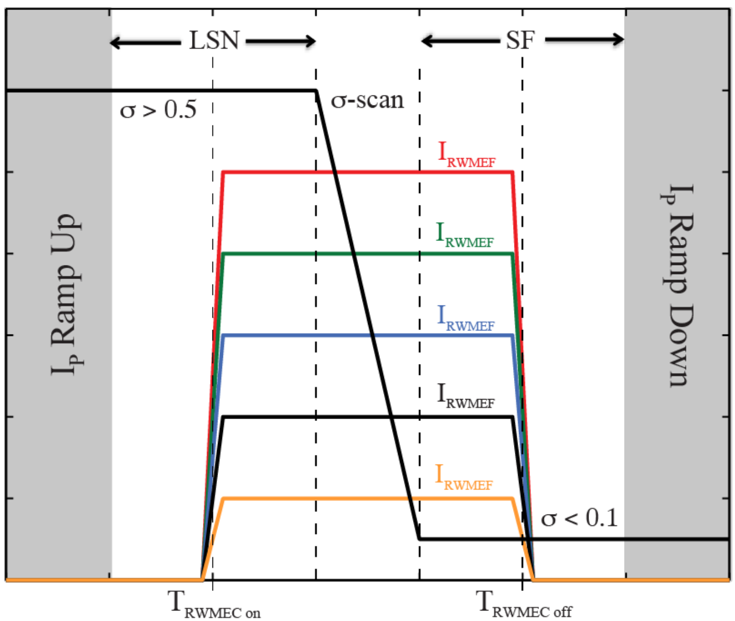




Experimental Plan

- **Develop plasma scenario for σ-scan (Most intense part in this year)**
  - Control of the secondary x-point
- **Carry out discharges with 3D fields in L- and H-mode:**
  - In LSN and SF configurations
  - With various values of current in the RWMEF coils (n = 3)
  - At various values of plasma density
    - **Different SOL regimes: sheath limited, high recycling, cushioning (5 eV > T_e > 1 eV) and detachment**



Desired time trace after the required scenario development

Scenario development could already produce interesting data for model validation