



Status of 3-D Modeling of Advanced Divertor Configurations in NSTX-U

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Introduction

- Motivation
- Numerical and Analytic Tools
 - EMC3-EIRENE
 - FLARE
 - Multi-Reservoir Particle Balance
- Heat Flux Survey
- Particle Balance Analysis
- Neutral Fueling
- Summary
- Next Steps

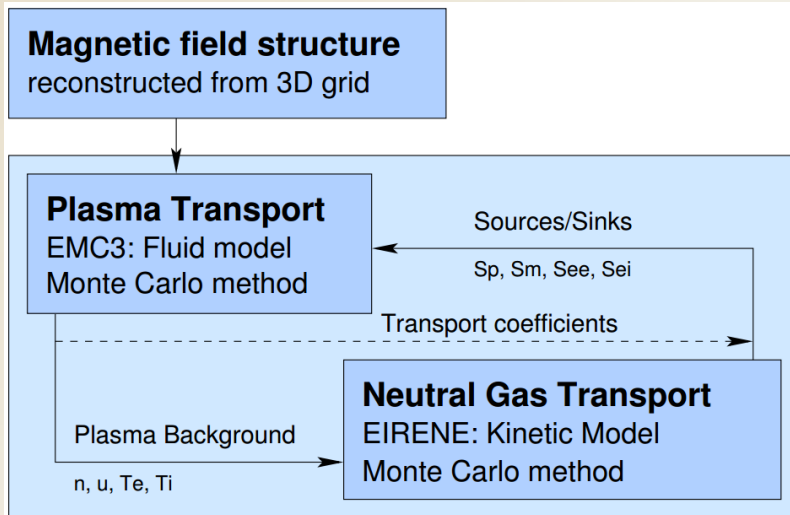


Motivation

- Damaging ELMs present a major problem in future tokamaks
 - Resonant Magnetic Perturbations (RMPs) one possible mitigation strategy
- Steady State heat loads also threaten divertor lifetimes
 - Snowflake and X-Divertors both seek to address this issue
- How do they work **together** and how does that impact **fueling and exhaust**?



Numerical and Analytic Tools

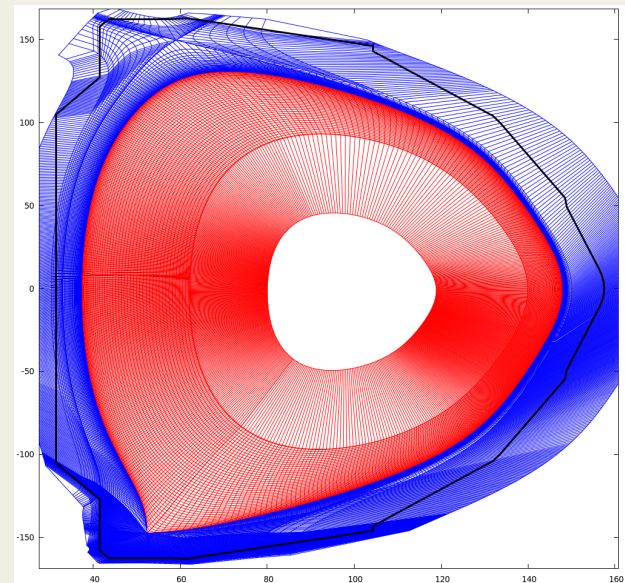


- **EMC3-EIRENE**

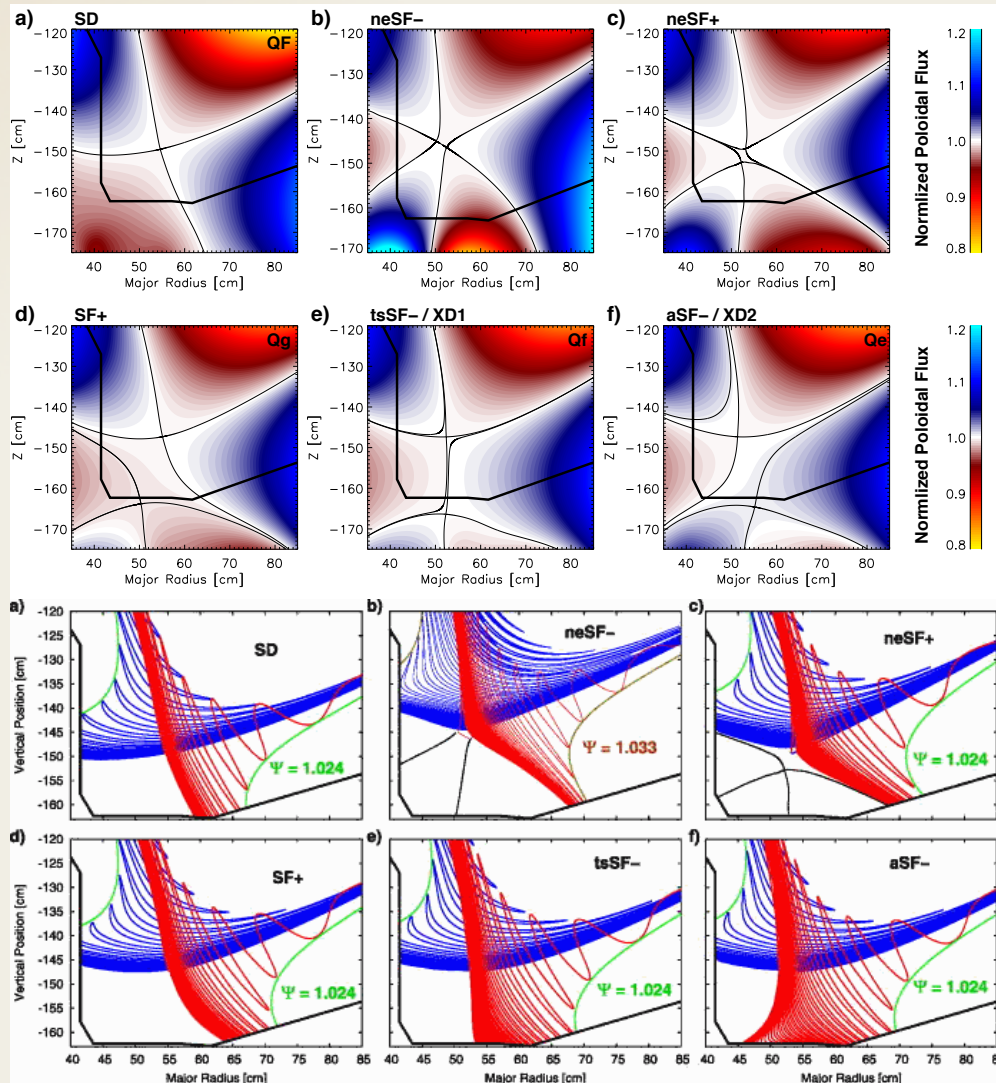
- Coupled 3D plasma fluid and kinetic neutral transport code
- Enhanced set of post processing tools developed-- specifically a Zone Resolved Particle Balance

- **FLARE**

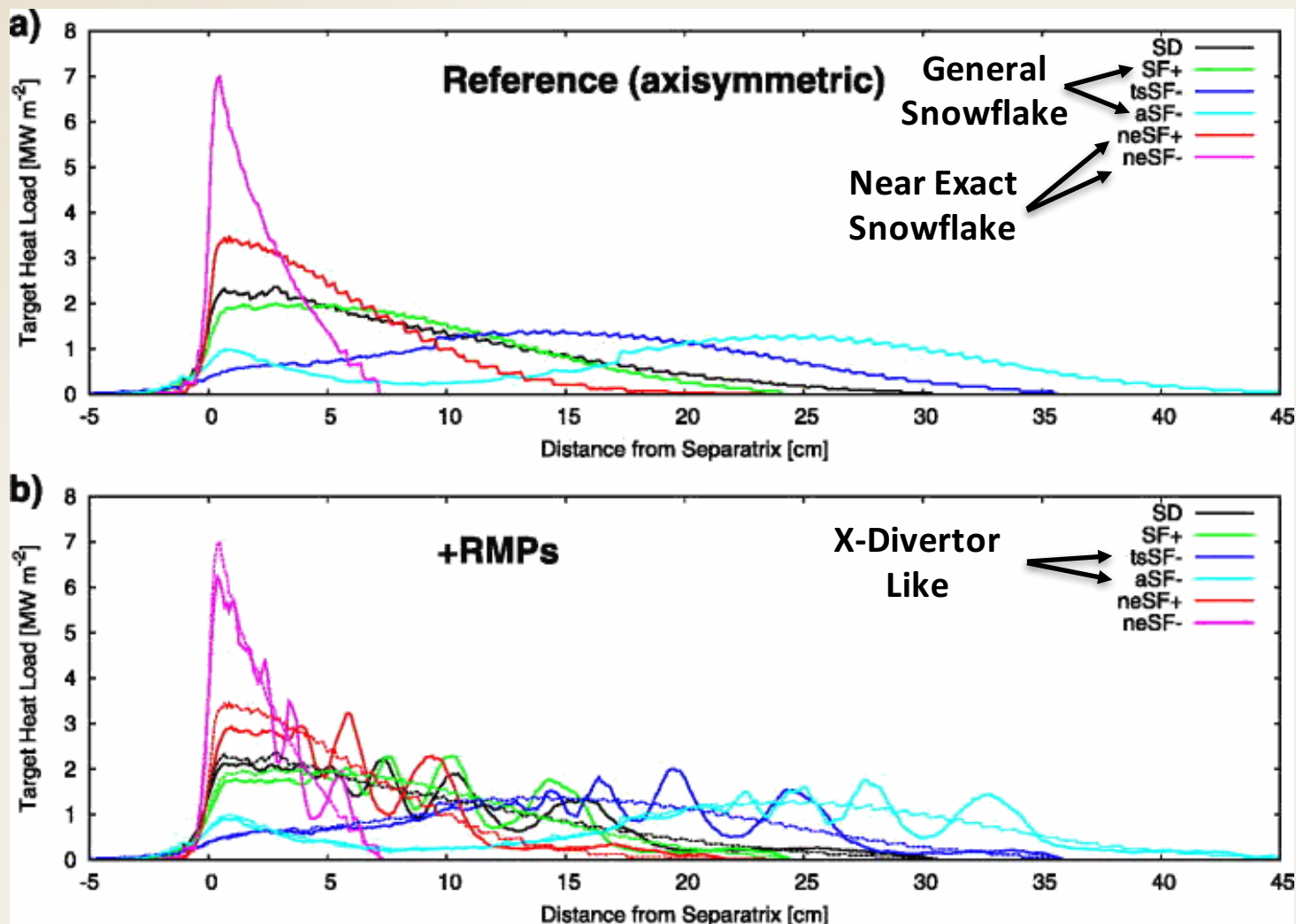
- Field Line Analysis and Reconstruction Environment
- Grid generator for EMC3-EIRENE
- Magnetic analysis toolbox



First Systematic Assessment of Major Advanced Divertor Configurations at NSTX-U with EMC3-EIRENE



Peaked heat loads in Near Exact Snowflake, lowest heat loads in X-Divertor like configurations. RMP fields don't impact toroidal average.





Numerical and Analytic Tools

- Global particle balance analysis

$$\cancel{\frac{dN}{dt}} = -\frac{N}{\tau} + \Phi_{REC} + \Phi_{Ext Fuel} - \Phi_{Ext Pump}$$

- Multi-Reservoir particle balance analysis

CORE: $\cancel{\frac{dN_{core}}{dt}} = -\frac{N_{core}}{\tau_{core}} + \phi_{core}$

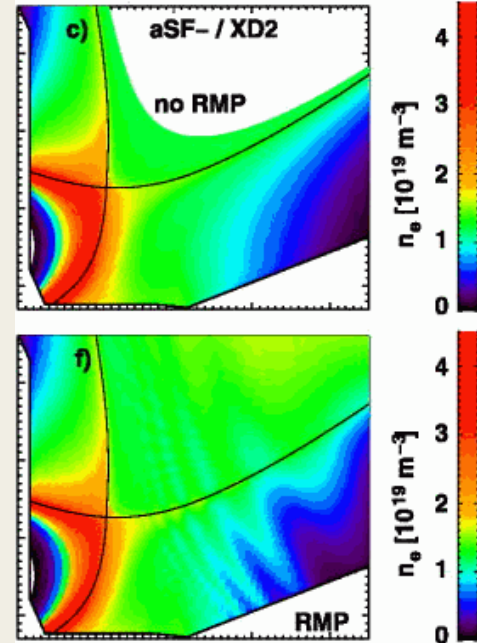
SOL: $\cancel{\frac{dN_{SOL}}{dt}} = -\frac{N_{SOL}}{\tau_{SOL}} + \phi_{SOL} + \frac{N_{core}}{\tau_{core}}$

FUELING: $\Phi_{REC} = \phi_{SOL} + \phi_{core}$



$$\tau_{core} = \frac{N_{core}}{\phi_{core}}$$

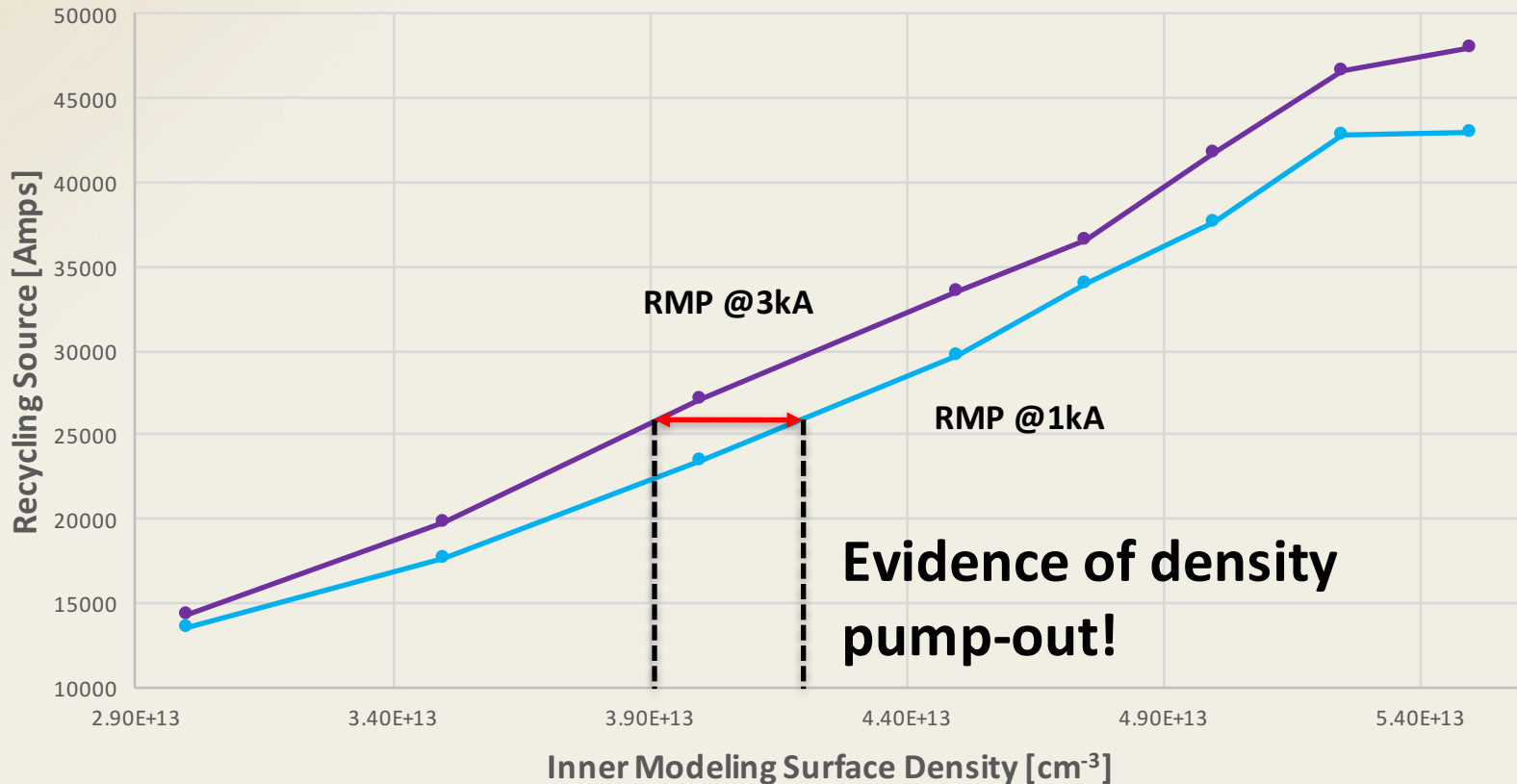
$$\tau_{SOL} = \frac{N_{SOL}}{\phi_{SOL} + \phi_{core}}$$





Reduced Global Particle Confinement in Modeling Domain with Increasing RMP Strength in Tilted Symmetric Snowflake Minus

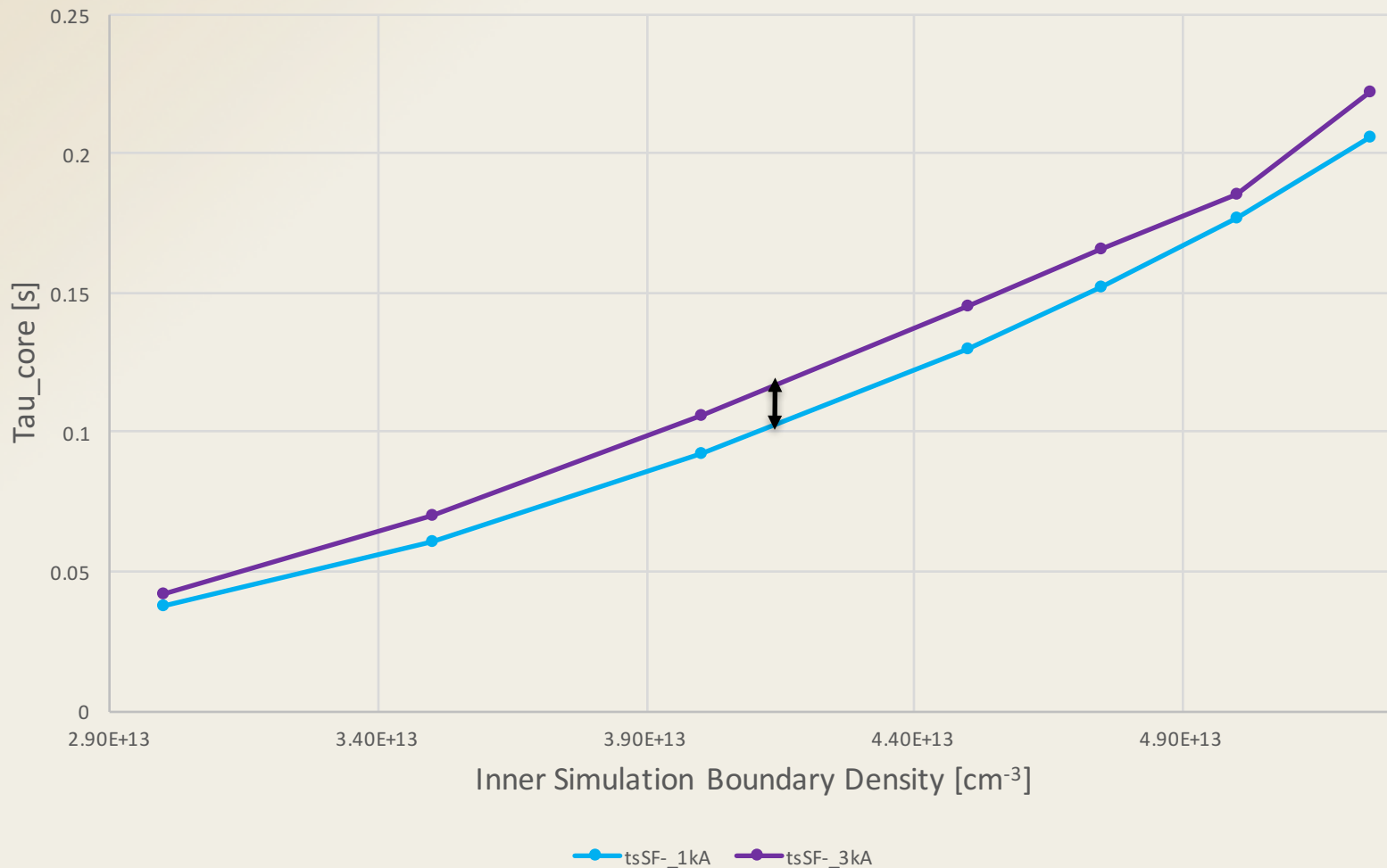
Total Recycling in Tilted Symmetric Snowflake Minus Divertor:
With RMP (@ 1kA and 3kA)



τ_{core} suggests better confinement, not density pump-out!



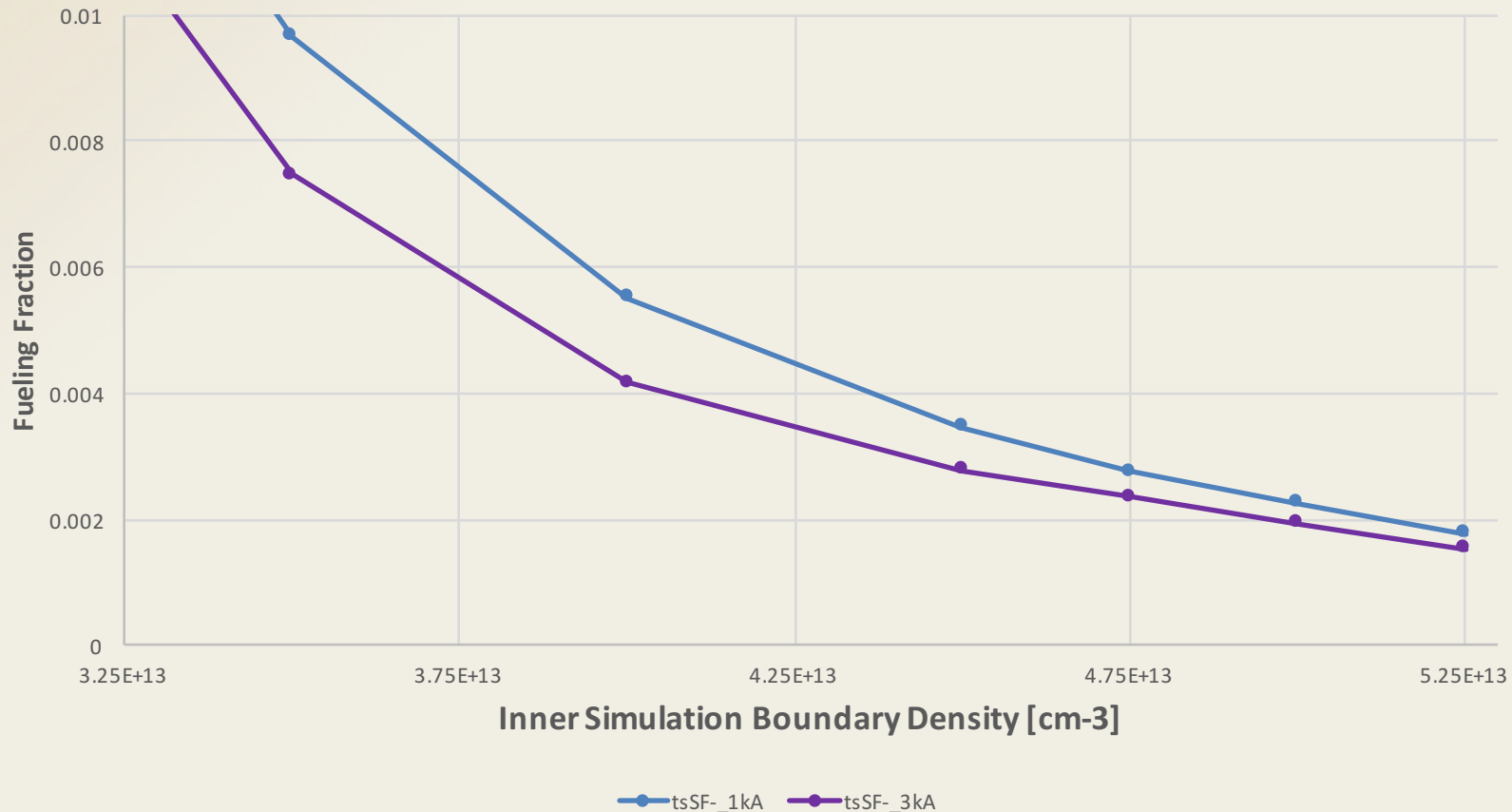
Tau_Core in Tilted Symmetric Snowflake Minus:
With RMP (@ 1kA and 3kA)



Lower Fueling Fraction for 3kA Case Explains Density Pump-Out Without Lower Core Confinement



Core Fueling Fraction Tilted Symmetric Snowflake Minus:
with RMP (@1kA and 3kA)





Summary

- First systematic study of advanced divertor configurations in EMC3-EIRENE
 - Phys. Plasmas **23**, 062517 (2016); <http://dx.doi.org/10.1063/1.4954816>
 - Provides database for exhaust studies
- Evidence of global pump-out with increasing RMP coil current
 - Modeled RMP currents in excess of what was used on NSTX by factor of three
- Global pump-out does not lead to decreased core-confinement => neutral fueling effect does



Next Steps

- Better experimentally constrain EMC3-EIRENE modeling
 - Lithium wall recycling
 - Core fueling
- Investigate role of plasma response and RMP strength
 - Informed by M3D-C1 calculations of plasma response [by Dr. Canal]
 - Comparative study with MAST
 - MAST shows pump-out, but only at much higher RMP currents and with favorable plasma response