NSTX-U Supported by U.S. DEPARTMENT OF ENERGY Office of Science

XP Idea: Comparison of material migration with B vs. Li coatings

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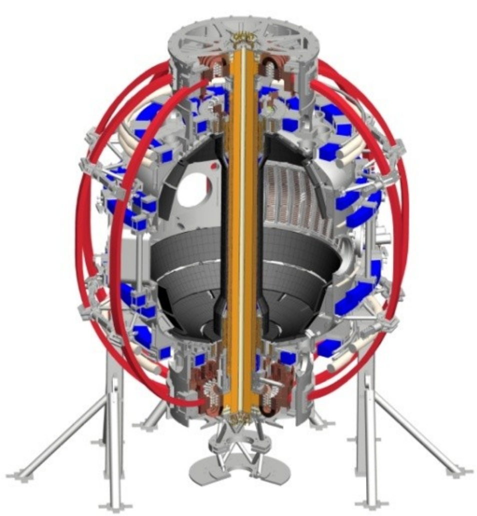

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Goal: Obtain data for development of WallDYN mixed material migration model

- WallDYN provides non-iterative merge of global impurity transport and surface models (K. Schmid JNM 2011)
  - Calculates poloidally-resolved time evolution of mixed material surface concentration and erosion fluxes
- Model basics:

$$\frac{d}{dt}\left(\text{Areal Density}\right) = \text{Incident Flux} * (1 - \text{Reflection}) - \text{Eroded Flux} + \text{Bulk Exchange}$$

Incident Flux: Redistribution matrix paramaterized via DIVIMP

Eroded Flux: Sputter database parameterized via SDTrimSP (TRIM+TRIDYN)

- Needs C/Li/B data to guide development for NSTX-U!
  - Migration patterns are check on redistribution model
  - Migration rates are check on surface model
  - B vs. Li clarifies importance of diffusion into C, specific sputter rates
- Benefit to NSTX-U:
  - Better understanding of B, Li coating lifetimes
  - Tool for interpretation of high-Z tile experiments (milestone R16-2)

Experimental plan

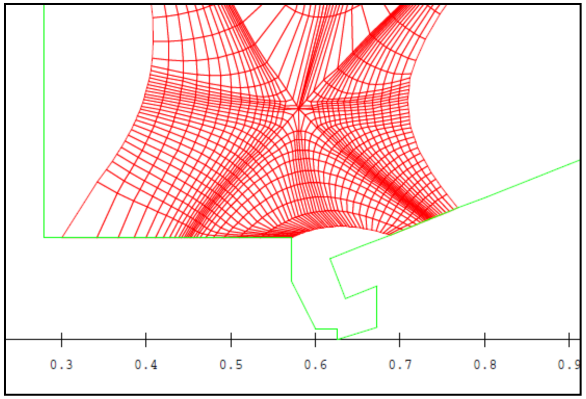
- Two 0.5 day experiments (1 B, 1 Li)
- Large B/Li-zation immediately before XP
- Accumulate 10-15 shots in same nominal plasma shape
- Target plasma: reproducibility is key
  - L-mode
  - Far from stability limits
  - OSP on row 2
  - Strike pt. control necessary
  - Disruption-free (if possible)
- No extra Li between shots
- No He GDC between shots (if possible)
- Run MAPP XPS between shots
- Observe B/Li, C, O erosion flux in lower div. via spectroscopy

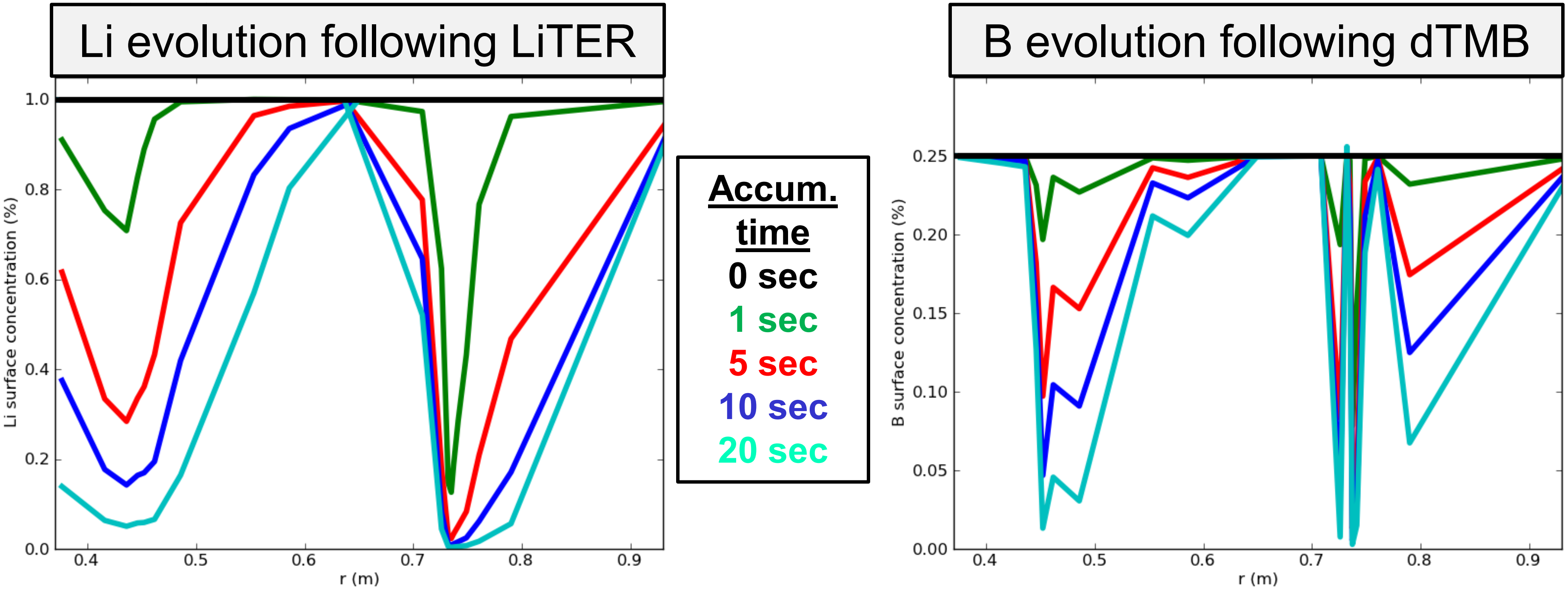
Why not H-mode?

- ELMs are hard to model
- Want to isolate surface variables in this XP
- See following XP idea

Key data: MAPP and divertor spectroscopy

- Diagnostics needed to constrain OEDGE plasma reconstruction: Langmuir probes, EFIT, TS, CHERS
- Surface composition and erosion flux directly comparable to WallDYN





Preliminary WallDYN results (from NSTX) → Plenty of tweaks to be added!

XP Idea: ELM effects on mixed material migration

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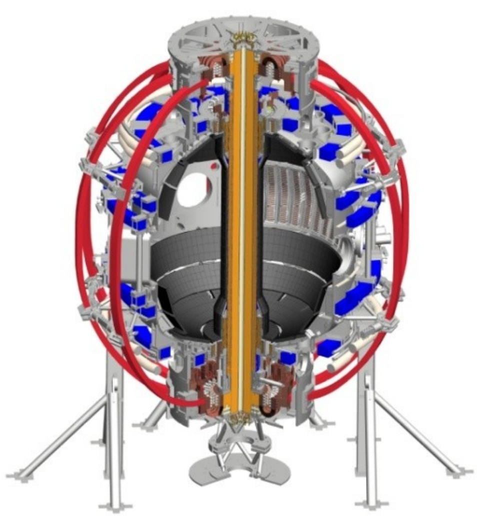
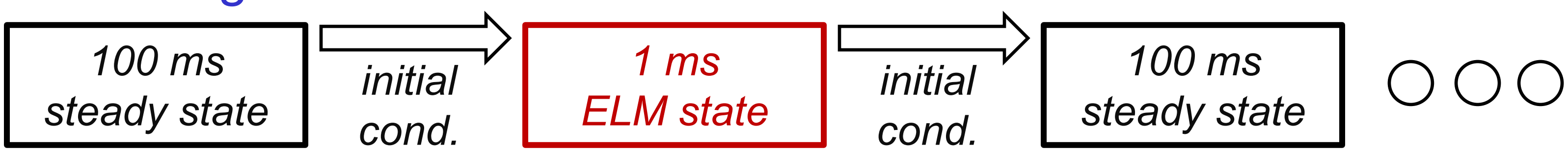


ELMs are a significant but poorly understood driver of material migration

- ELMs enhance erosion due to extrathermal burst of particles
  - Can be primary source of recirculating material in high-Z machines where $E_{steady\text{-}state} < E_{threshold}$
- Highly 3D and time-dependent → Hard to model!
- Options to incorporate ELMs into WallDYN:
  - Stitch together standalone inter-ELM and ELM-state simulations



  - Enhance sputter model by convolving incident particle energy distribution

$$Y = \int Y(E)P(E)\,dE$$

What is ELM state plasma?
What is incident ion/atom energy distribution at each poloidal location?

- Migration data with ELMs isolated would be very useful for model development (including qualitative data)

Experimental plan

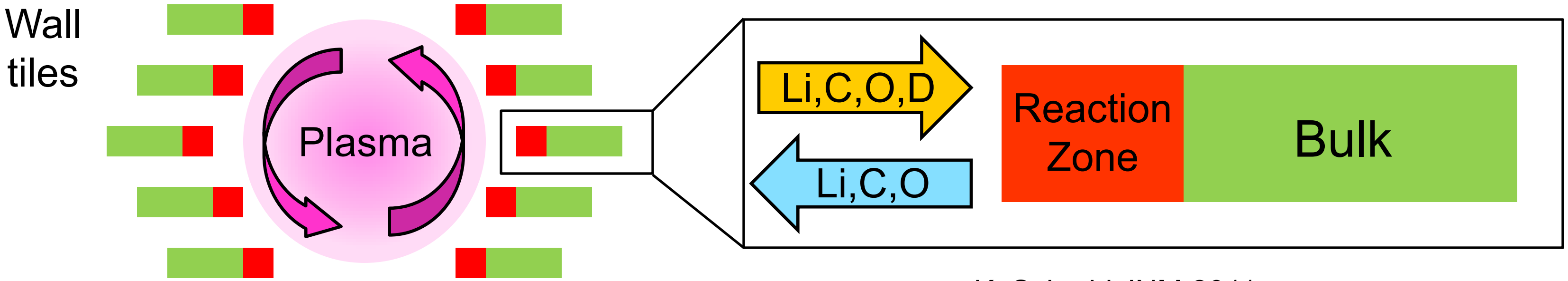
- General observables:
  - C/Li/O erosion rates at multiple locations during discharge evolution
  - Pre- and post-shot elemental composition at MAPP
- Baseline: ELM-free H-mode w/ heavy Li, OSP on row 2
- Using baseline, pace ELMs with LGI (preferred) or RMP
  - f_{ELM} = 10-150 Hz (as time permits)
- Correlate migration rates with f_{ELM}, ΔW, heat/particle flux
- Best data with large Li evaporation, strong strike point control, reproducible discharges
- Requires MAPP XPS, Langmuir probes, TS, CHERS, fast IR thermography, significant divertor spectroscopy/cameras

- Well suited for piggyback on ELM pacing XPs

Backup

WallDYN is a new model to couple time-dependent mixed material surface evolution to global impurity migration

- Calculates time evolution of PFC surface composition, impurity flux (to wall), erosion flux (to plasma)
  - Mixed-material, poloidally-resolved
  - Maintains global material/flux balance



K. Schmid JNM 2011

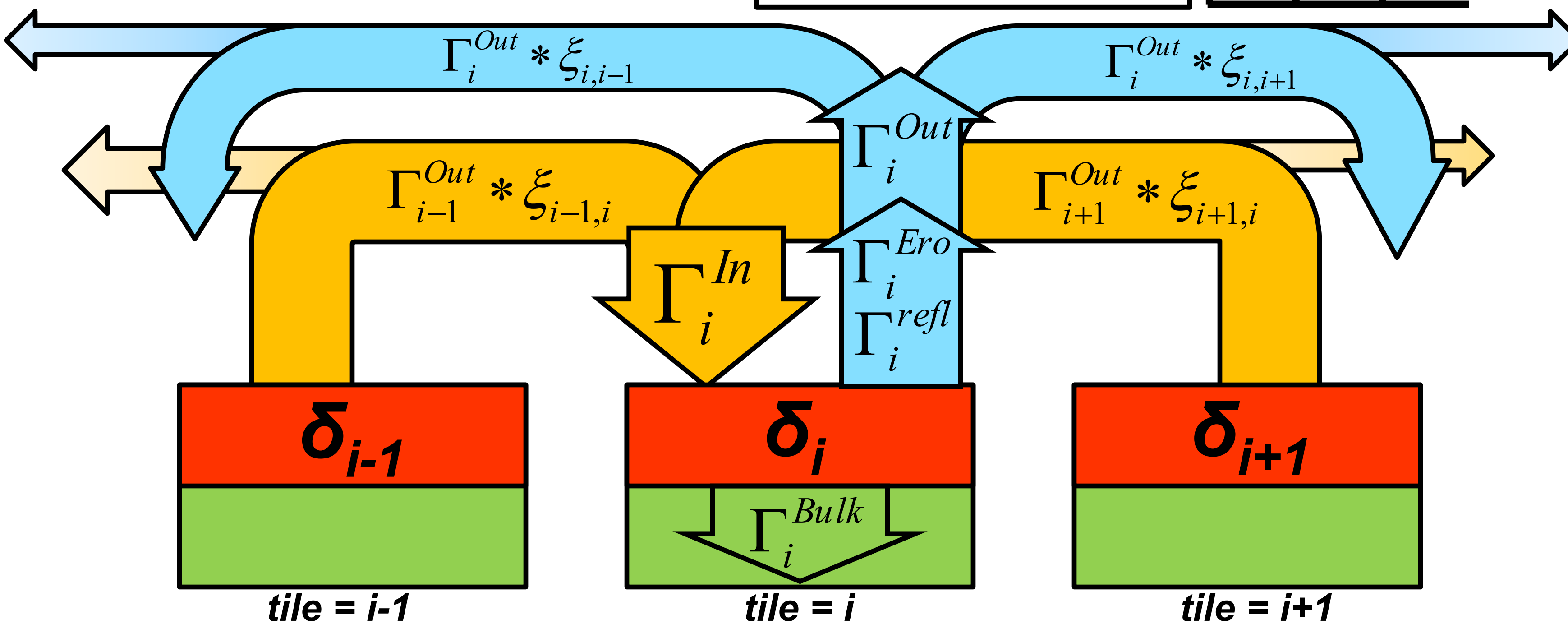
- Plasma model:
  - Time scale of PMI & plasma transport short compared to wall evolution
  - Impurity concentrations do not perturb plasma
  - Plasma transport characterized by redeposition matrix: $\xi_{i,j} =$ % material from tile i transported to tile j
- Surface model:
  - Erosion/deposition occurs homogenously in reaction zone
  - Sputter/reflection yields from composition-dependent parametrizations

WallDYN simultaneously solves a system of equations for surface areal density evolution and impurity influx

Two equations for every wall segment, element, charge state

Redistribution matrix $\xi_{source,destination}$:

$P_{1\to3}$	$P_{2\to3}$	⋰
$P_{1\to2}$	$P_{2\to2}$	$P_{3\to2}$
$P_{1\to1}$	$P_{2\to1}$	$P_{3\to1}$



1 $$\frac{d\delta_i}{dt} = \Gamma_i^{In} - \Gamma_i^{refl} - \Gamma_i^{Ero} + \Gamma_i^{Bulk}$$

2 $$\Gamma_i^{In} = \sum_{tile=1}^{NTiles} \left(\Gamma_{tile}^{Ero} + \Gamma_{tile}^{refl}\right) * \xi_{tile,i}$$

Differential algebraic equation system (~1000 eqs.) solved in Mathematica