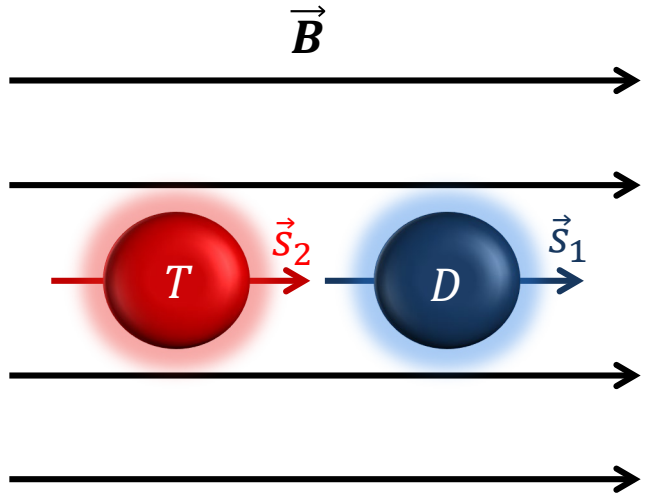
Spin-polarized fuel can double the fusion power & reduce tritium inventory

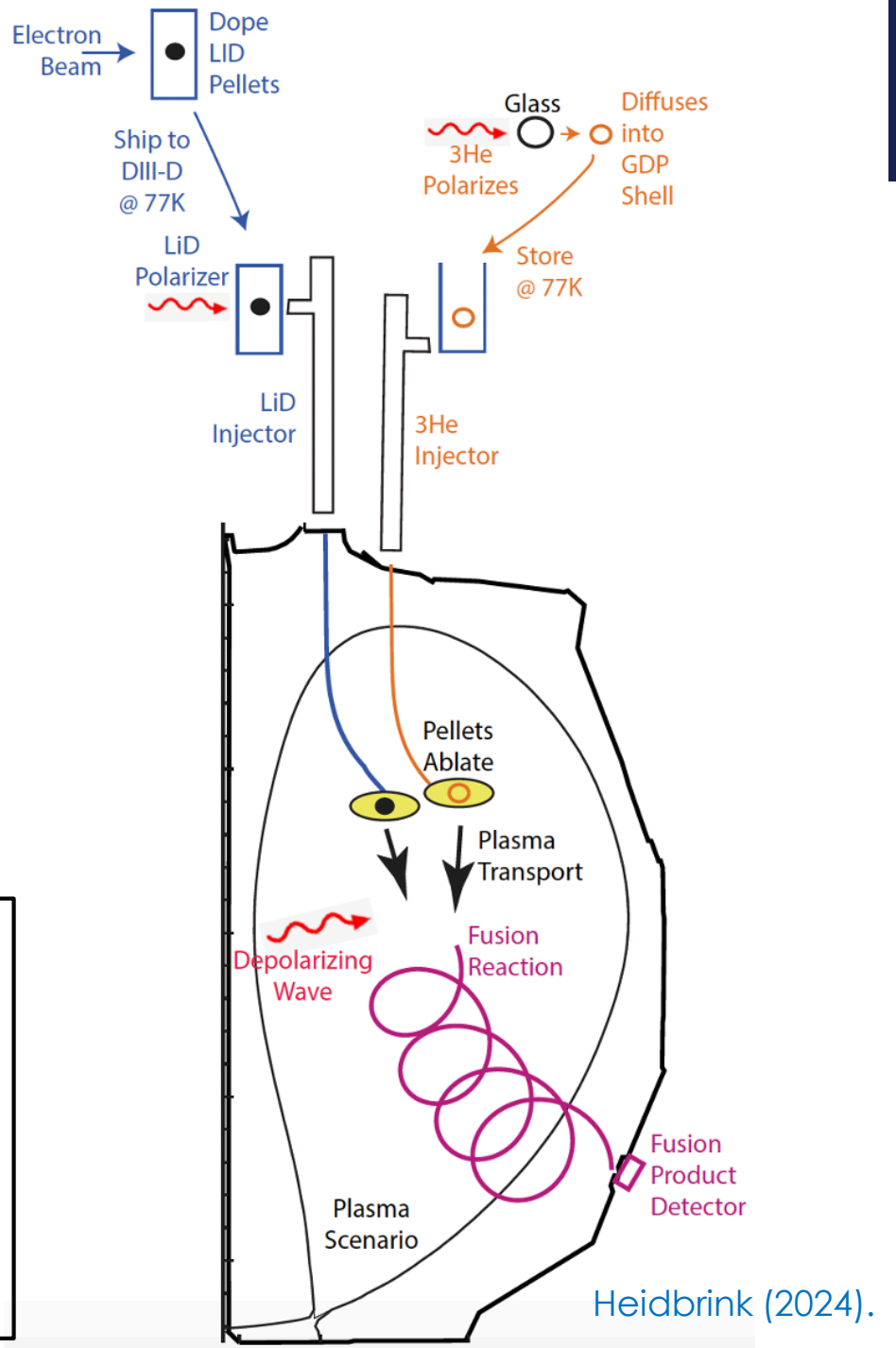
- The D-T fusion cross section is 50% larger when the D & T nuclear spins are aligned with the field Additional heating by the extra alphas → a factor of two increase in fusion power
- Higher reaction probability → less circulating tritium
- Theoretically, depolarization lifetimes are long but are they?
- DIII-D experiments using D-^{3}He as a proxy for D-T can test relevant depolarization mechanisms



Experiments to measure the lifetime in the DIII-D tokamak are funded

Deliverable	Institution*
1. Make polarized D	Jefferson Lab
2. Make polarized ^{3}He	University of Virginia
3. Inject fuel into tokamak	Oak Ridge N.L.
4. Create suitable plasma	UCI
5. Diagnose polarization	UCI

*In collaboration with General Atomics

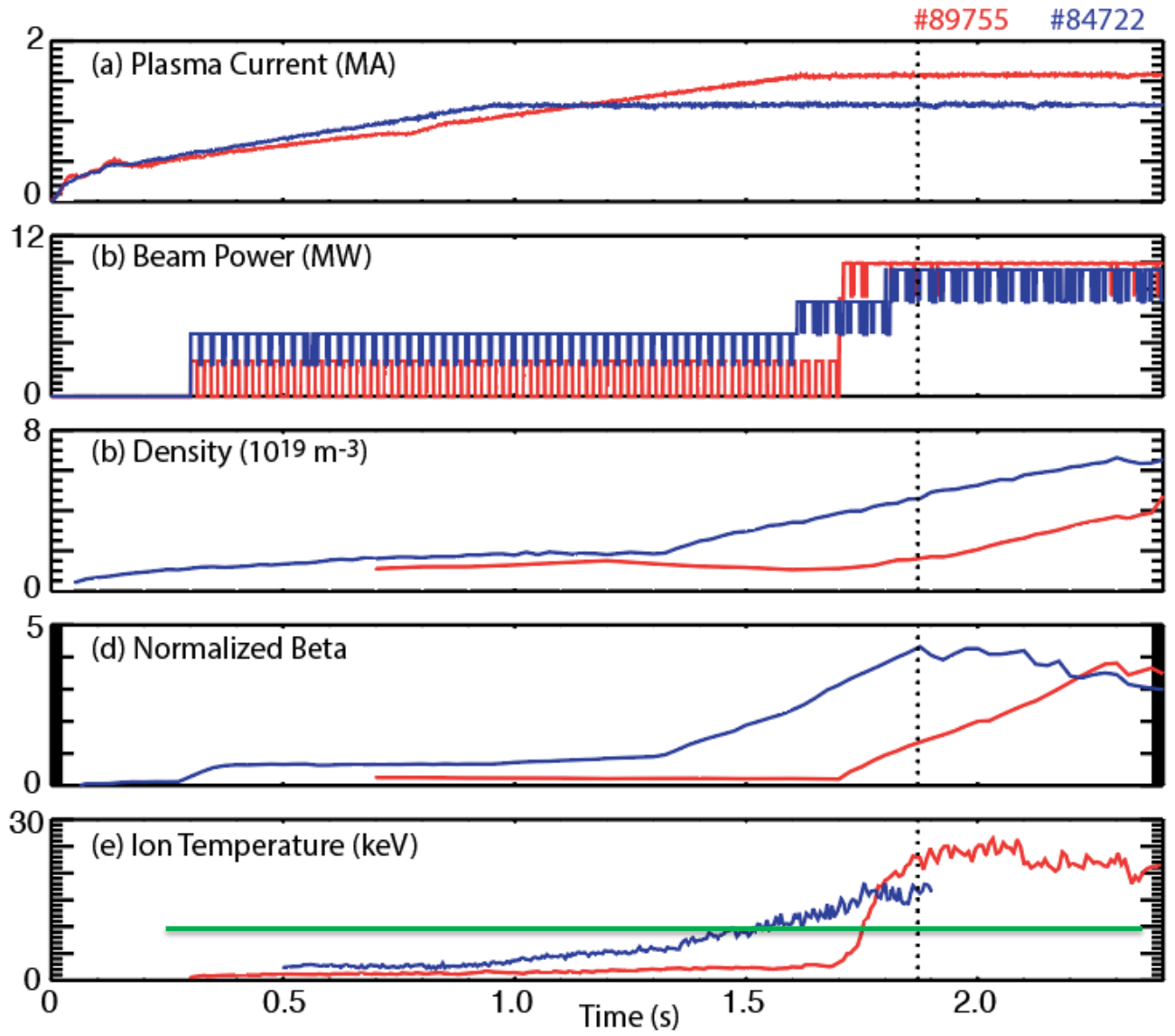


Heidbrink (2024).

1) **"Polarized Fusion and Potential *in situ* Tests of Fuel Polarization Survival in a Tokamak Plasma,"**
L. Baylor et al.,, Nucl. Fusion **63** (2023) 076009.
2) **"Conceptual design of DIII-D experiments to diagnose the lifetime of spin polarized fuel"**
A.V. Garcia, W.W. Heidbrink and A.M. Sandorfi, Nucl. Fusion **63** (2023) 026030.
3) "**A research program to measure the lifetime of spin polarized fuel"**
W.W. Heidbrink et al., Frontiers of Physics (2024) in press .

Can DIII-D make a High T_i plasma with a metal wall?

- Most sensitive polarization cross section is for thermonuclear D-^{3}He reactions
- Need $T_i \sim 10$ keV for adequate fusion rate
- Must use H beams & inject two pellets
- JET & ASDEX-Upgrade struggled to recover low-density, high T_i regimes after wall changed



Garcia (2023).

[1] Burrell, PPCF (1998).

Recycling at a W wall will depolarize the nuclei → limits maximum measurable lifetime

- **Inhomogeneous static magnetic fields during injection** ✓
  - Gradients too long to cause depolarization
- **Hyperfine interactions during ionization** ✓
  - Neutral ground state has no interaction
  - Few % loss for ^{3}He [1]
- **Binary Coulomb collisions** ✓
  - Spin-spin, spin-orbit and quadrupole moment interactions predicted negligible [2]
- **Electromagnetic waves** ✓
  - Microturbulence too low in frequency
  - Ion cyclotron waves problematic
- **Wall interactions** **Limited by particle confinement time**
  - High depolarization rates at metal walls [3] (but low for carbon or SiC)

[1] Baylor, NF (2022)
[2] R.M. Kulsrud et al., Nucl. Fusion **26** (1986) 1443.
[3] Greenside, Journal of Vacuum Science & Technology A 2, 619 (1984).

Impact of wall change on Spin Polarized Fusion research program

1. **Likely adverse impact on ability to achieve a high ion temperature scenario with H beams**
2. **Most metal walls will limit our ability to measure long polarization lifetimes**

Impact of wall change on DIII-D EP physics program

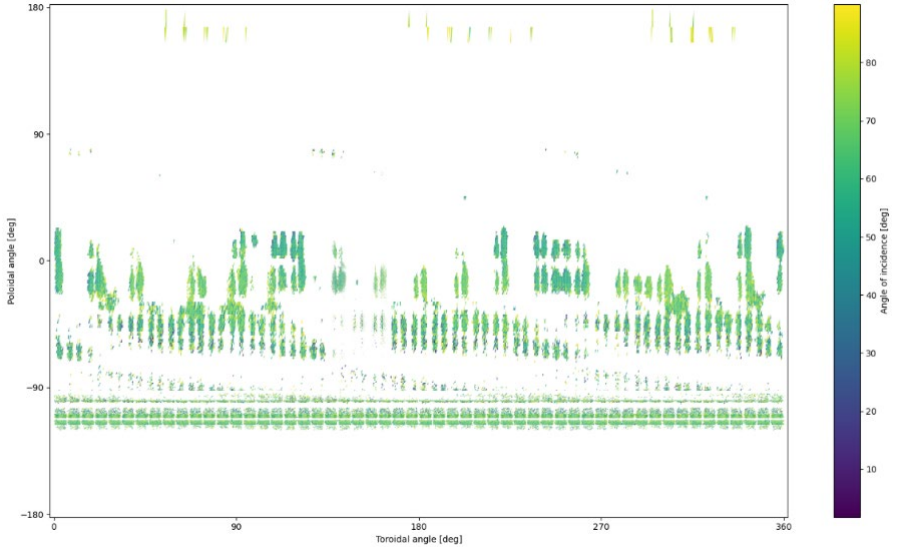
Opportunity

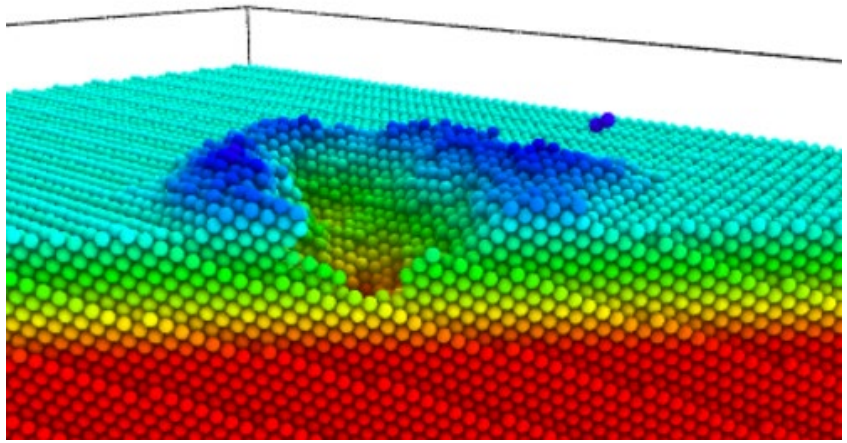
- Fast ion loss sourcing of W is a significant concern for new ITER baseline
  - DIII-D EP program is well equipped (both numerically and experimentally) to address this important issue if a W wall is chosen

Adverse impact of metallic wall

- Large fraction of DIII-D EP experiments use inner wall limited L-mode plasmas, often with high power and low density (likely will no longer be possible)
- All high frequency magnetic probes will need to be replaced (currently use graphite tile as part of pickup loop)

Fast ion wall loading in ITER





An illustration of result of 150 keV W atom colliding with a W layer releasing tens of W atoms