



High-Flux Atomic Source for the Project 8 Neutrino Mass Experiment

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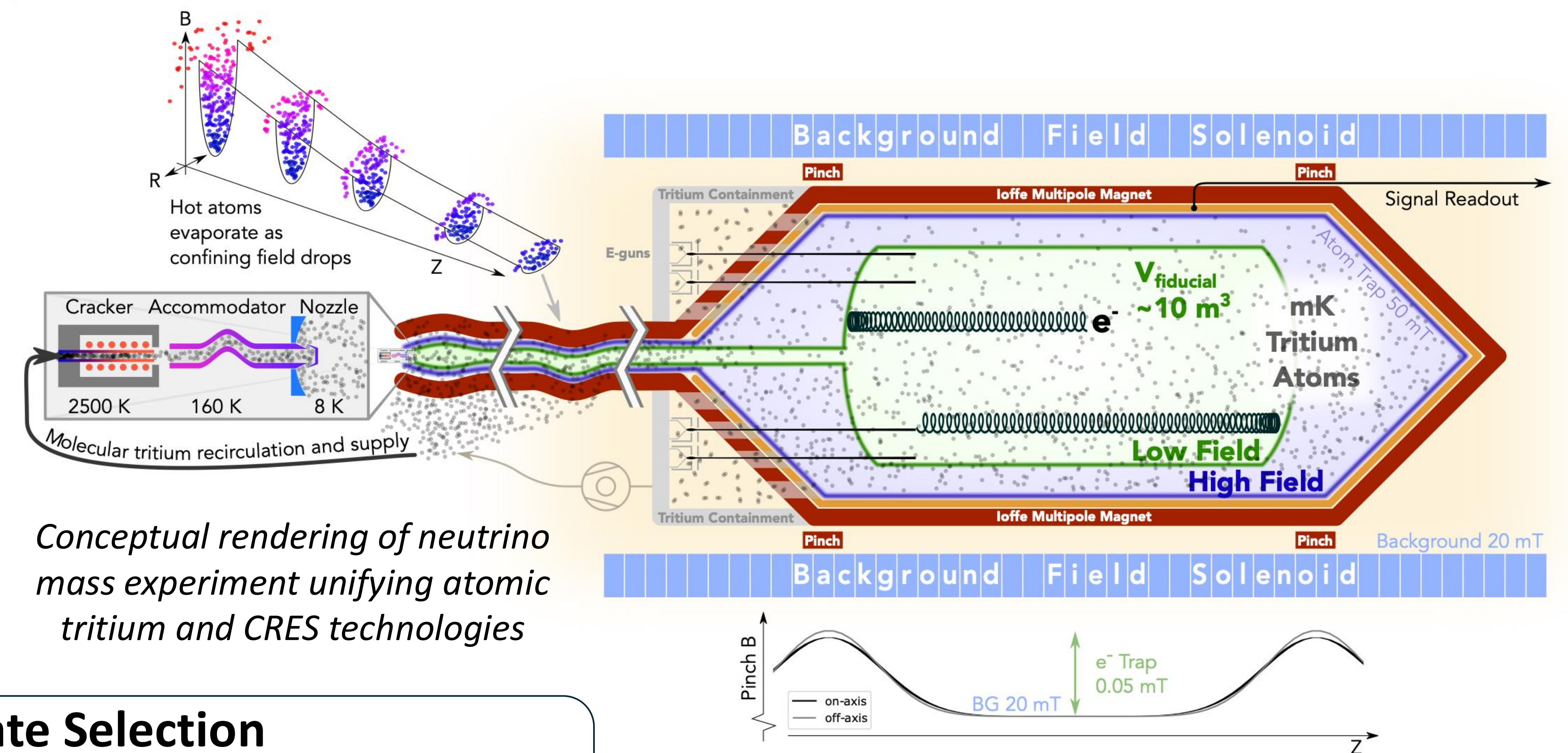
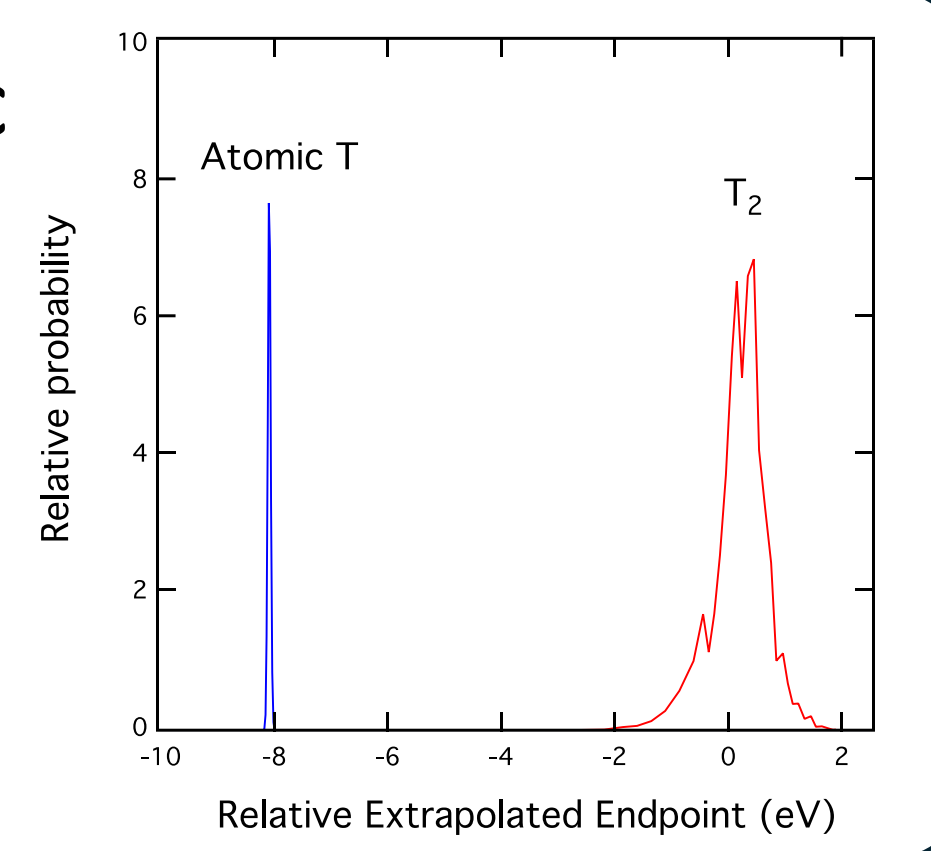
PROJECT 8

Project 8 targets a neutrino mass sensitivity of 40 meV. An intense source of atomic tritium is a key enabling technology to avoid the molecular final state effects.

R&D ongoing towards:

- Dissociation
- Cooling and State Selection
- Trapping

Atomic tritium has a magnetic moment arising from unpaired spins, enabling magnetic guiding and trapping



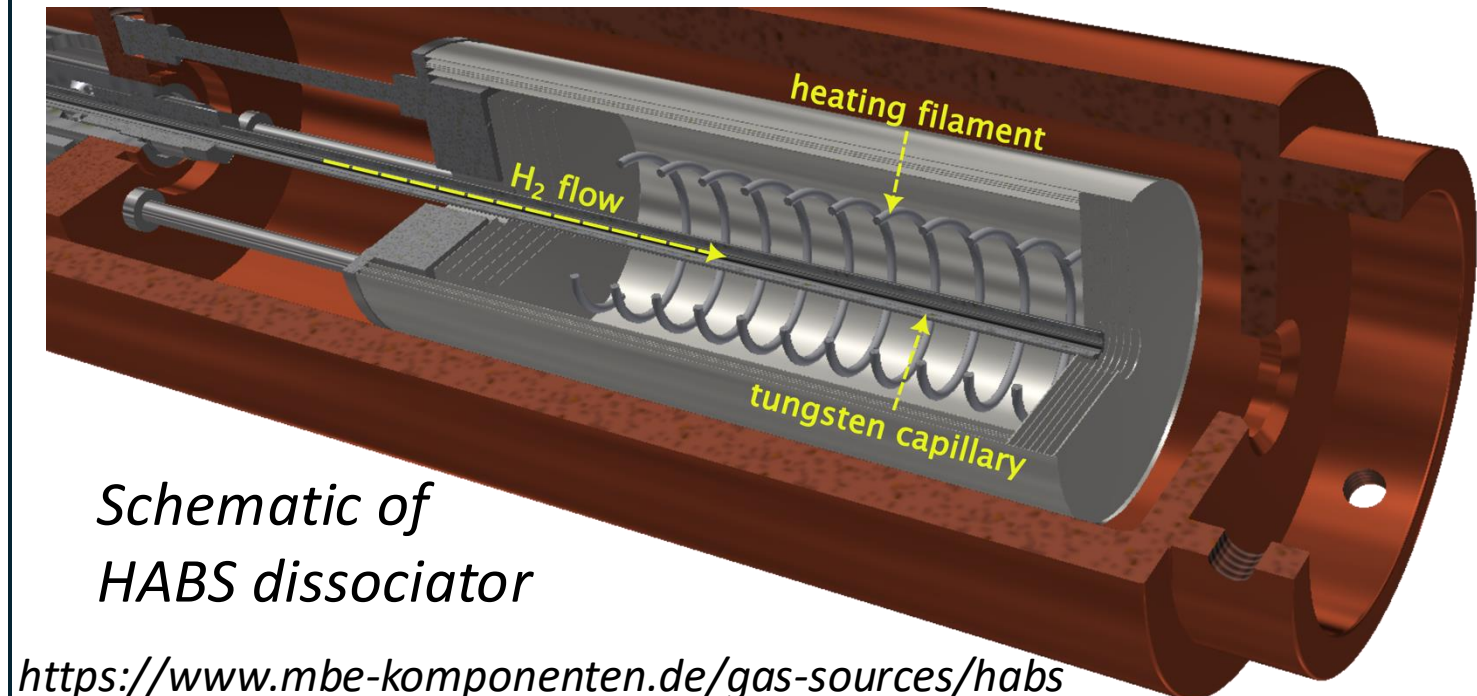
Conceptual rendering of neutrino mass experiment unifying atomic tritium and CRES technologies

Dissociation

Target "hot" atom production of $>10^{19} s^{-1}$ by splitting molecular T₂. Exploring thermal and RF cracker designs.

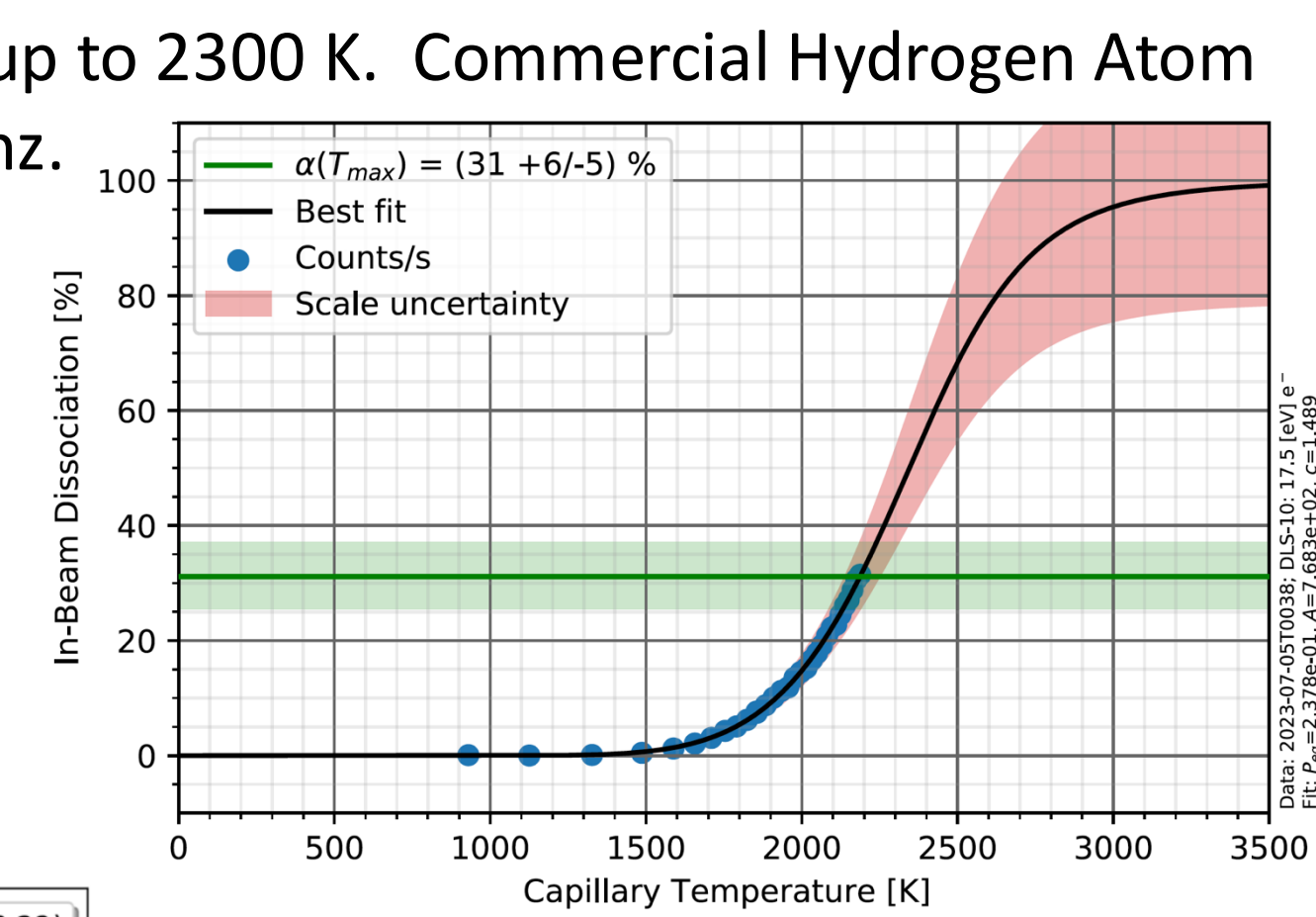
Thermal Cracker

Hot tungsten capillary dissociates molecules on surface up to 2300 K. Commercial Hydrogen Atom Beam Sources (HABS) operating at Washington and Mainz.

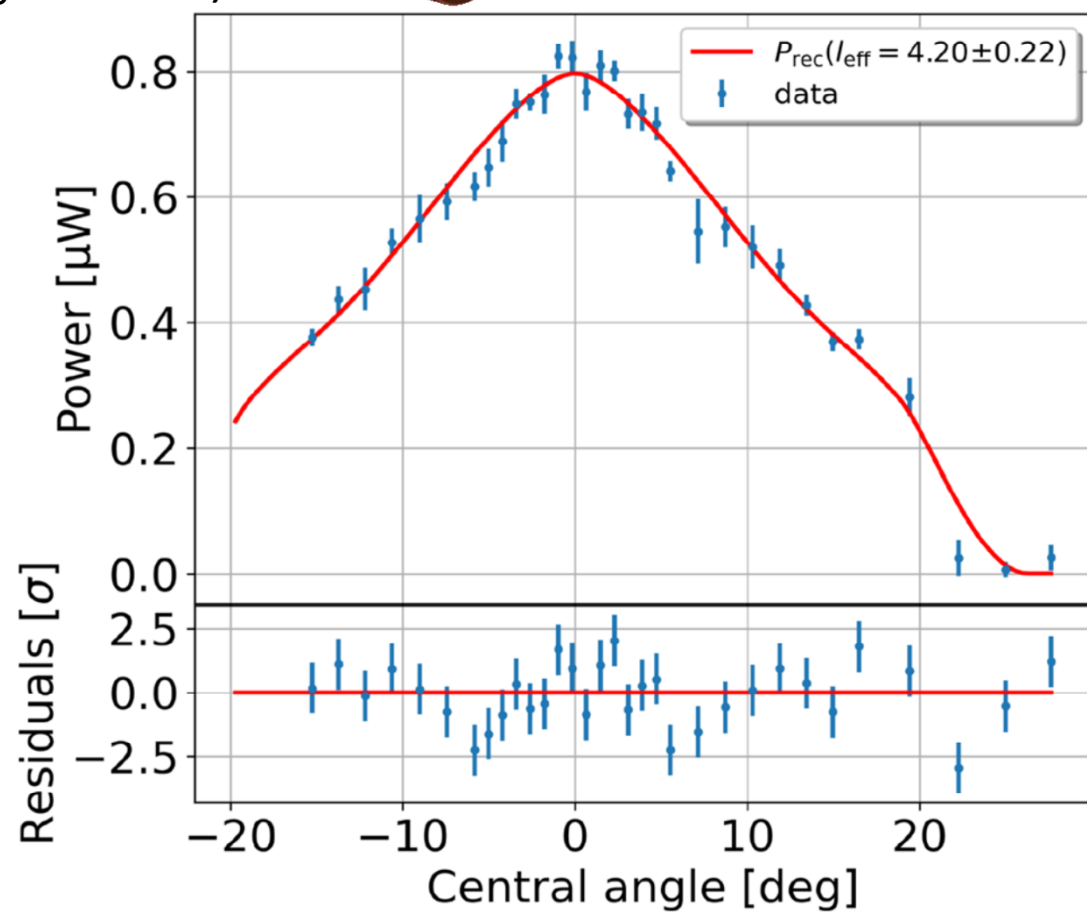


Schematic of HABS dissociator

<https://www.mbe-komponenten.de/gas-sources/habs>



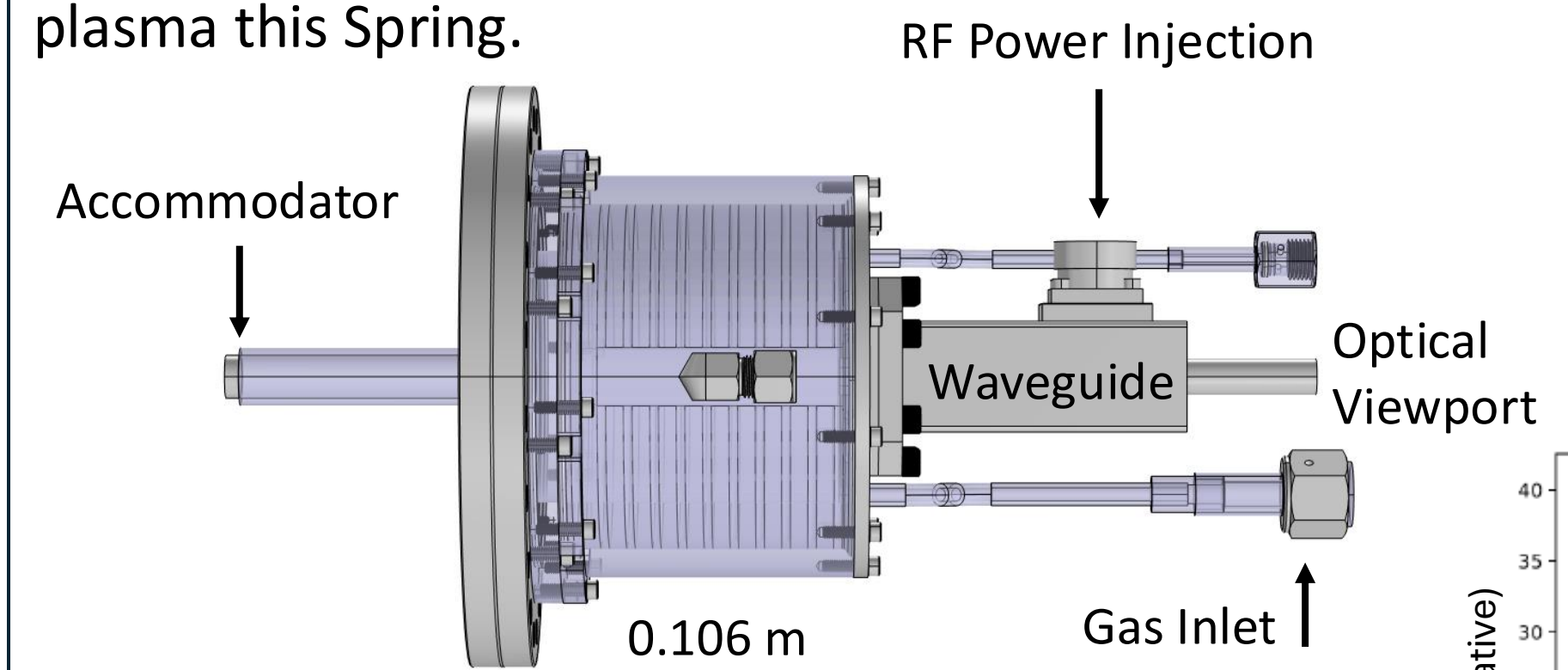
Mass spectrometer scan of hydrogen dissociation efficiency at 1 sccm flow



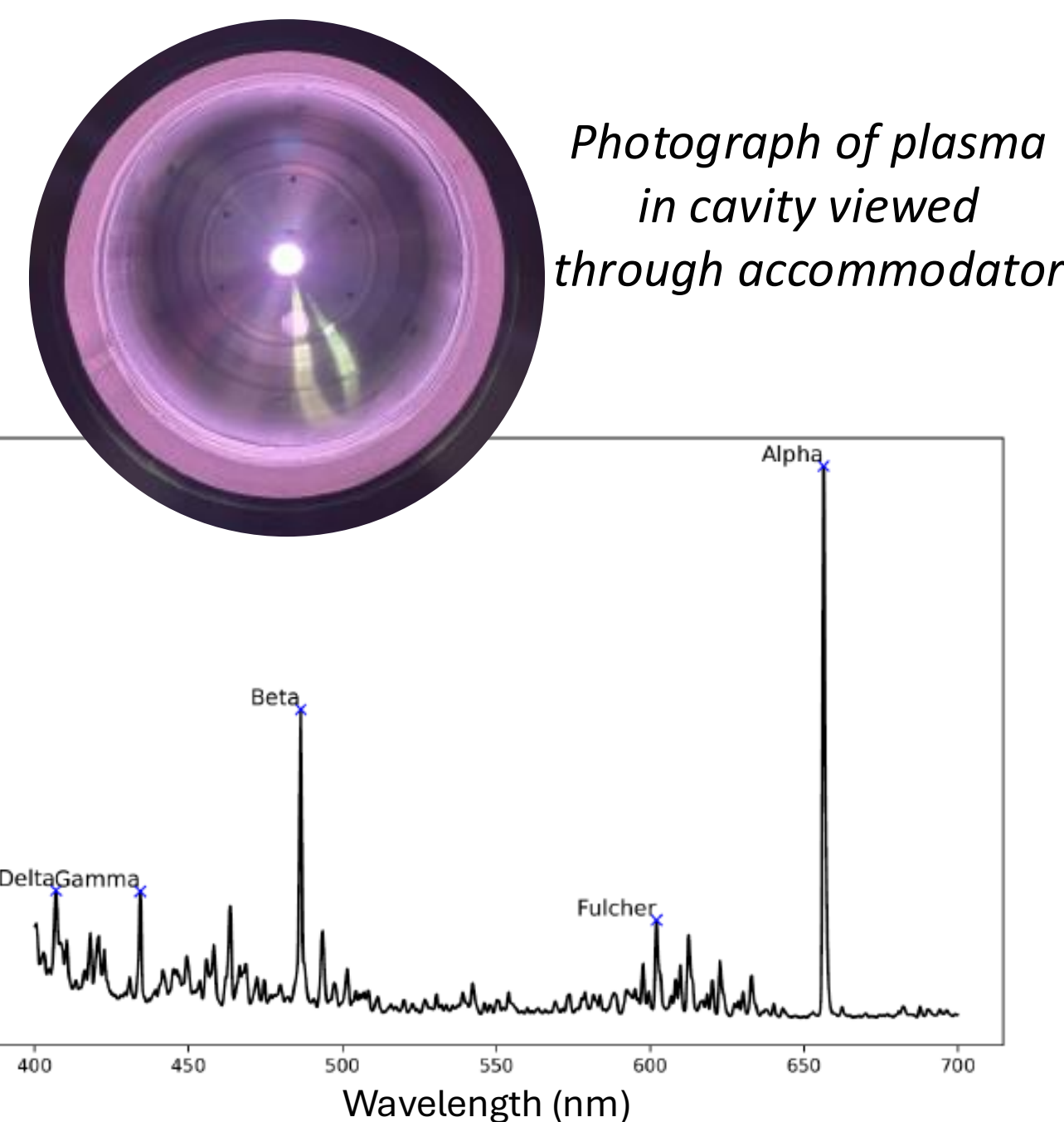
Wire detector developed as additional diagnostic; enables measurement of beam profile
Eur. Phys. J. D 79 (2025) 60

RF Cracker

Custom design using resonant cavity driven by 2.45 GHz RF matched to TE111 mode. Tuned to the electron cyclotron resonance (ECR) condition with 0.9 T magnetic field. Operating at Indiana with first plasma this Spring.



Schematic of ECR dissociator apparatus



Dissociating plasma verified by atomic Balmer emission

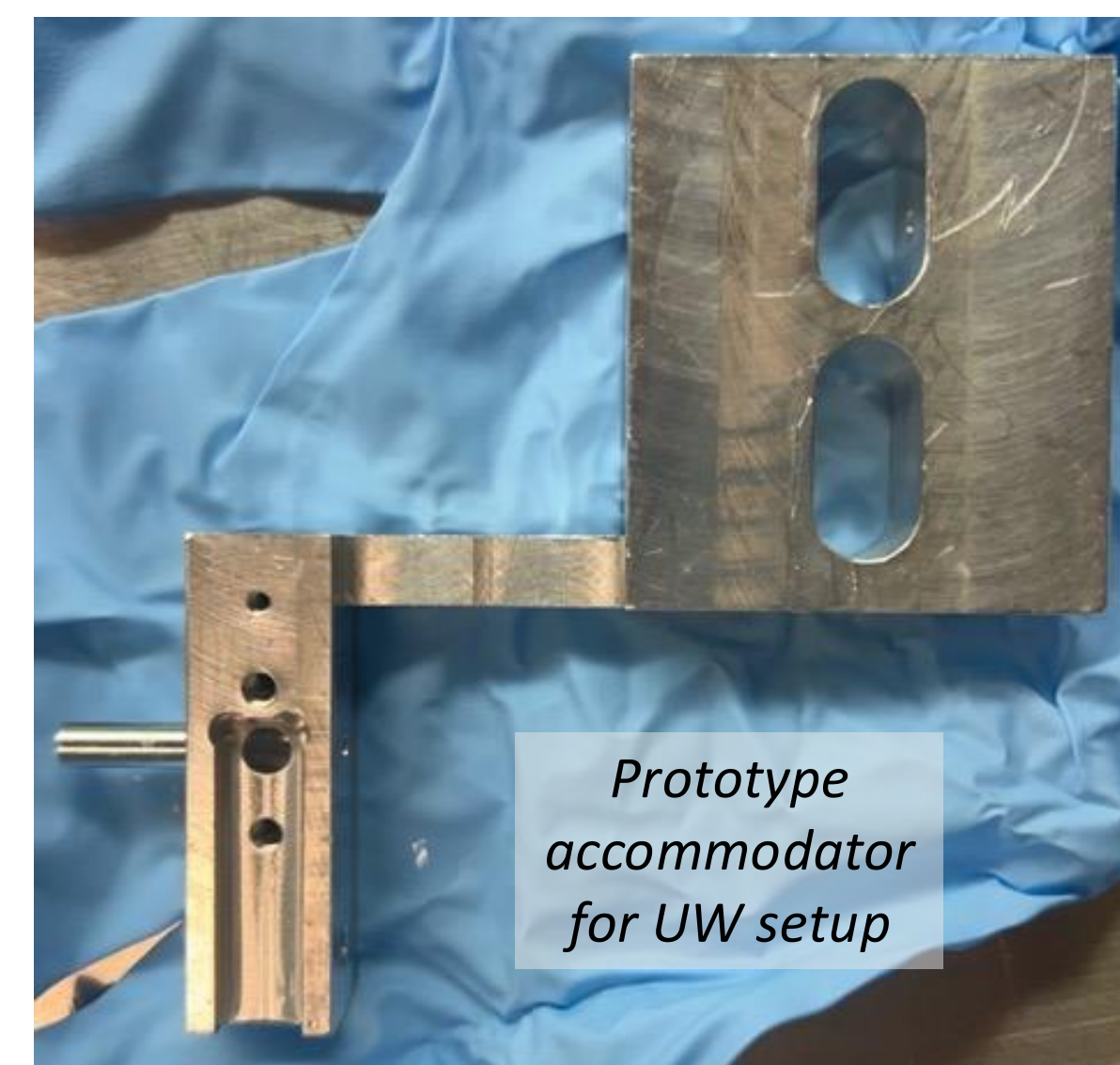
Cooling and State Selection

Cool atomic beam in stages down to trappable temperatures, while minimizing loss. Select only long-lived trappable atomic state.

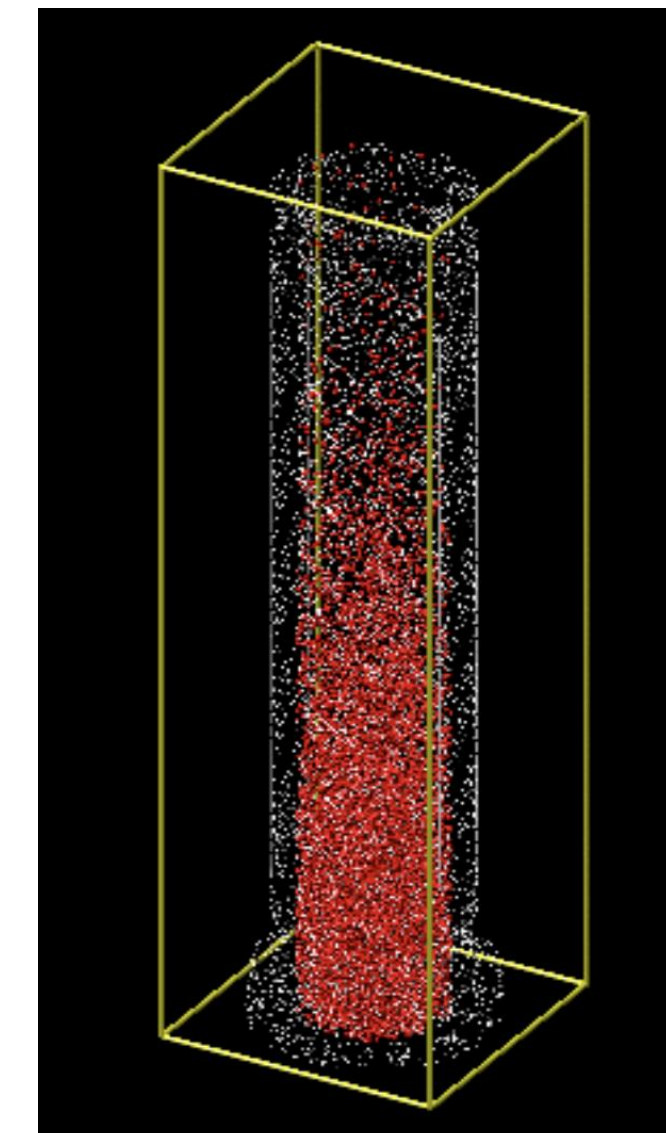
Surface Collisions

First stage targeting cooling down to ~30 K by collisions on cold surfaces. Optimize material and temperature to minimize surface-catalyzed recombination loss.

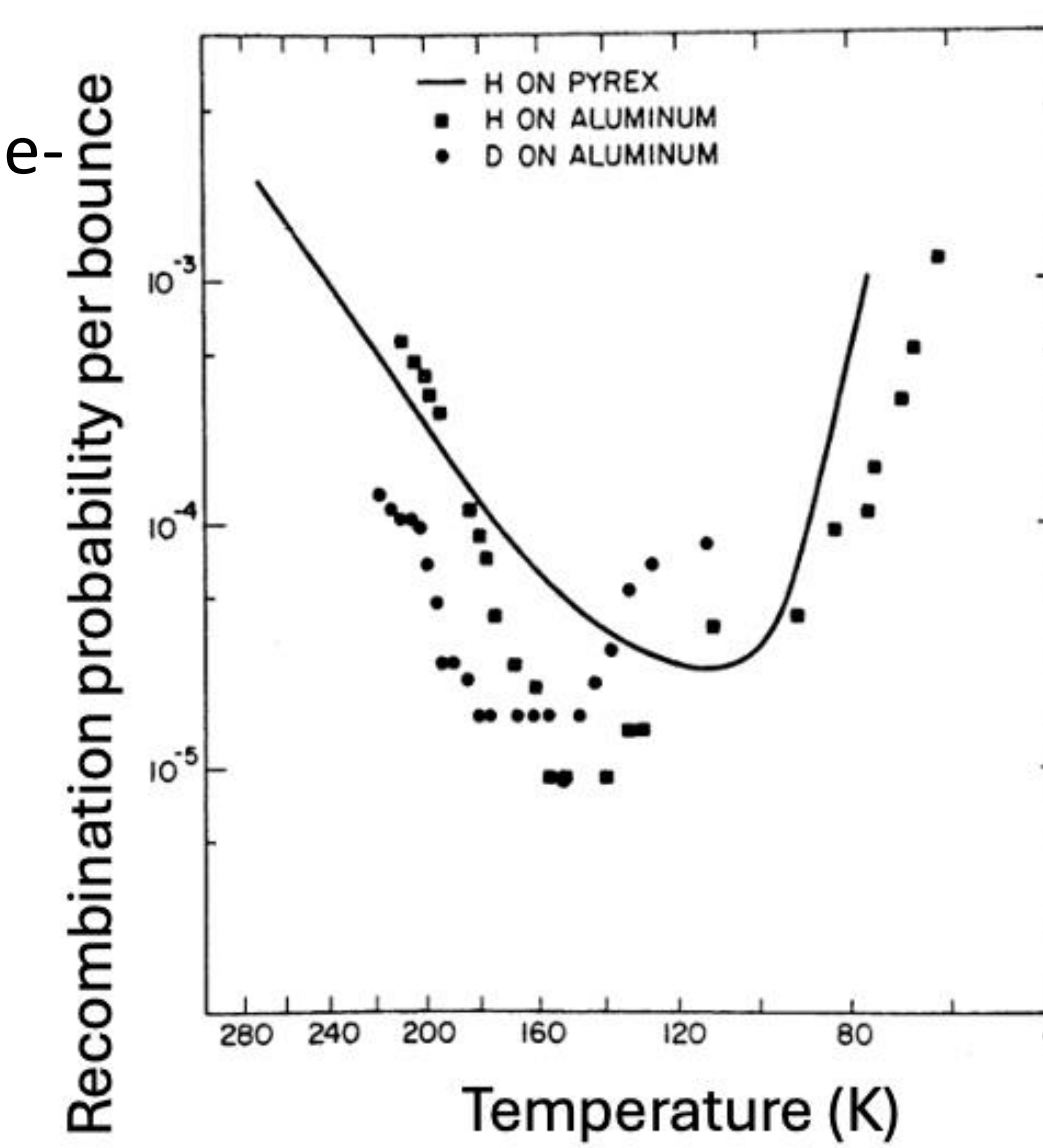
Simulations and/or prototyping ongoing at Berkeley, Indiana, Mainz, and Washington.



Prototype accommodator for UW setup



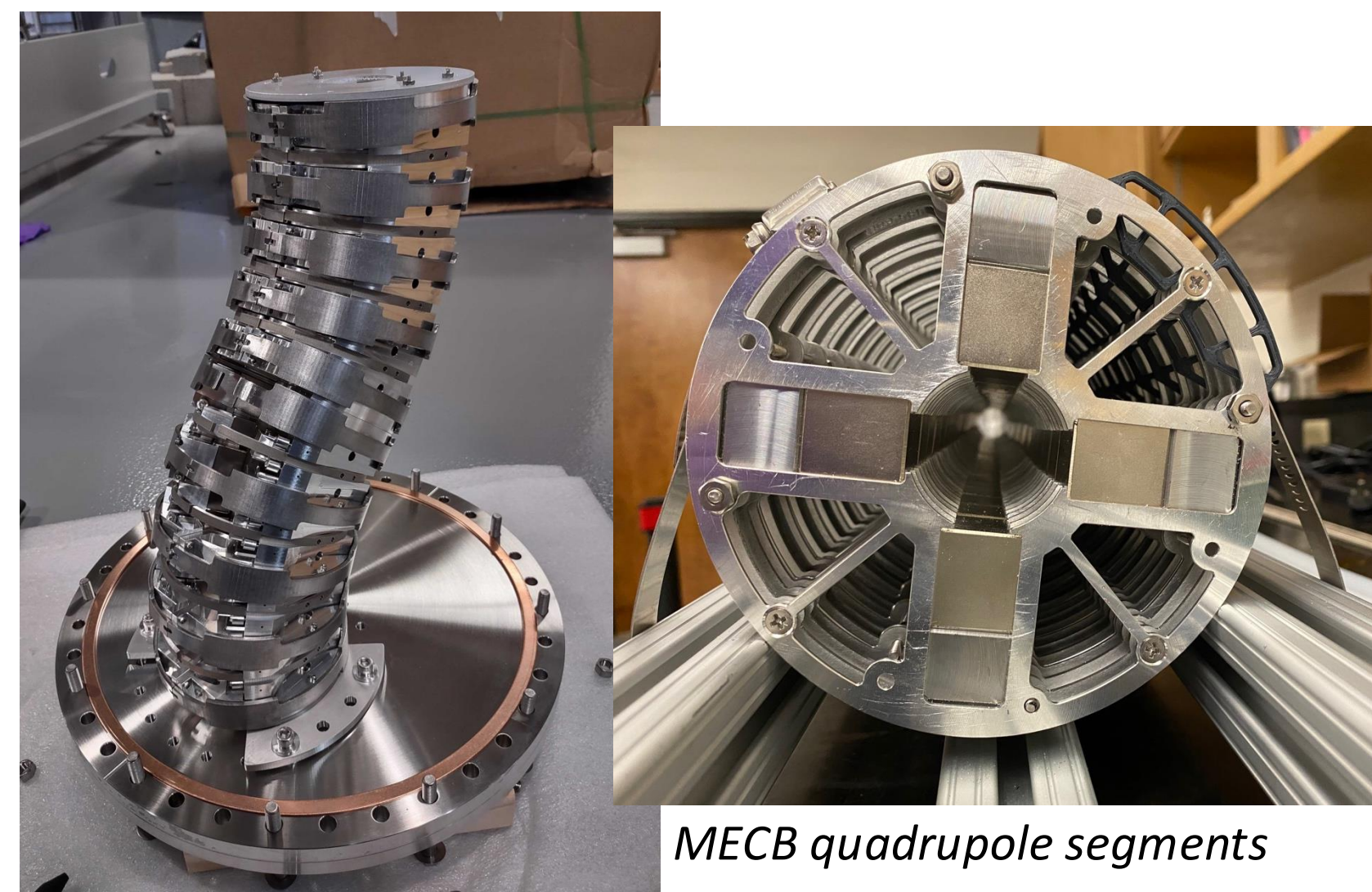
Simulation of atom transport in cooled accommodator



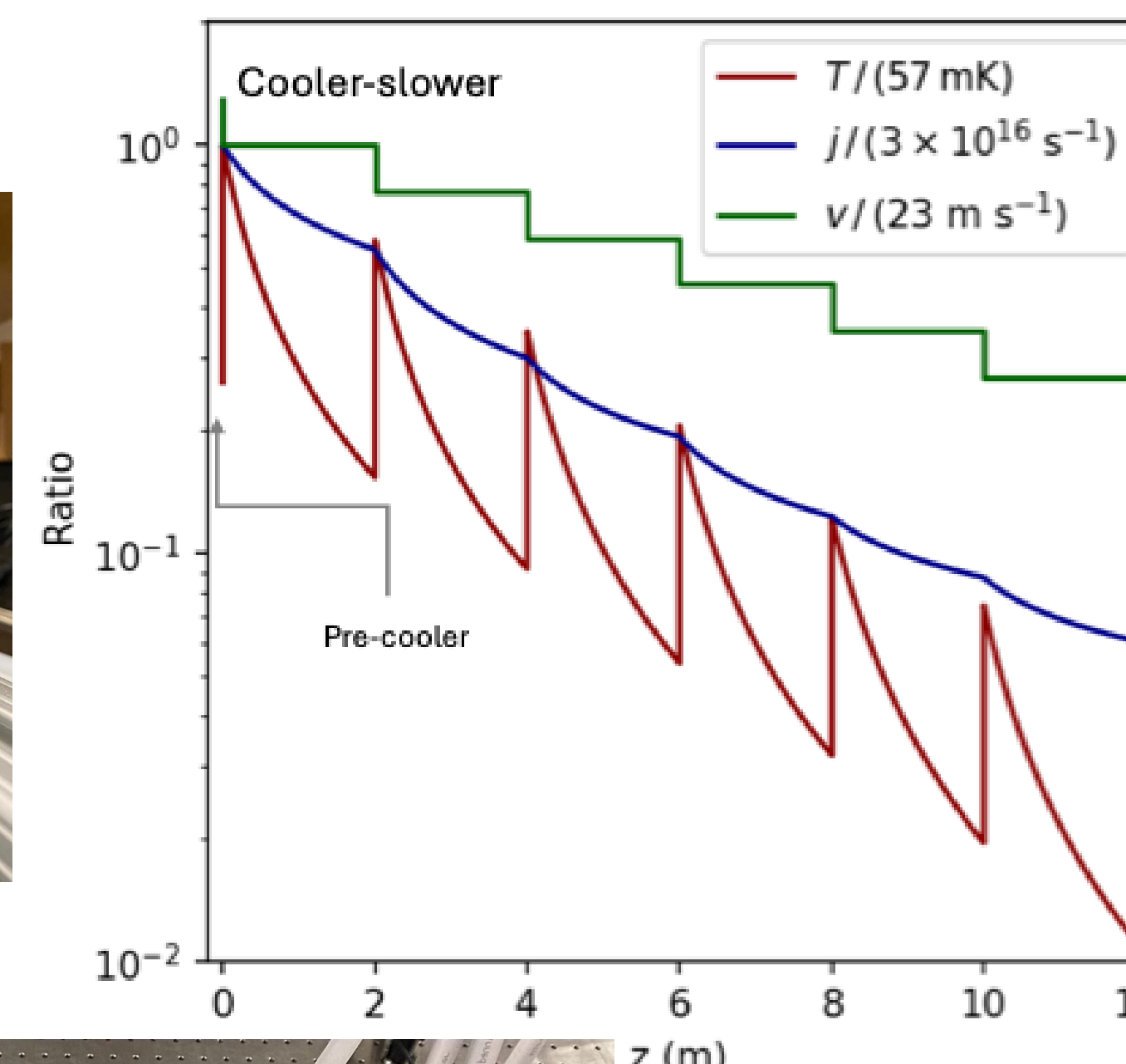
Plot above: Tech. Rep. LA-UR 82-1728 Rev. 3, Los Alamos National Laboratory (1982).

Evaporative Cooling

Final stage targeting cooling down to ~10 mK by evaporative cooling in a magnetic guide. Will consist of transverse cooling sections punctuated by longitudinal slowing by means of field perturbations. Concept published in *Phys. Rev. A* 112 (2025), 033311; Lithium (analog spin system) demonstrator apparatus under construction at Manchester.

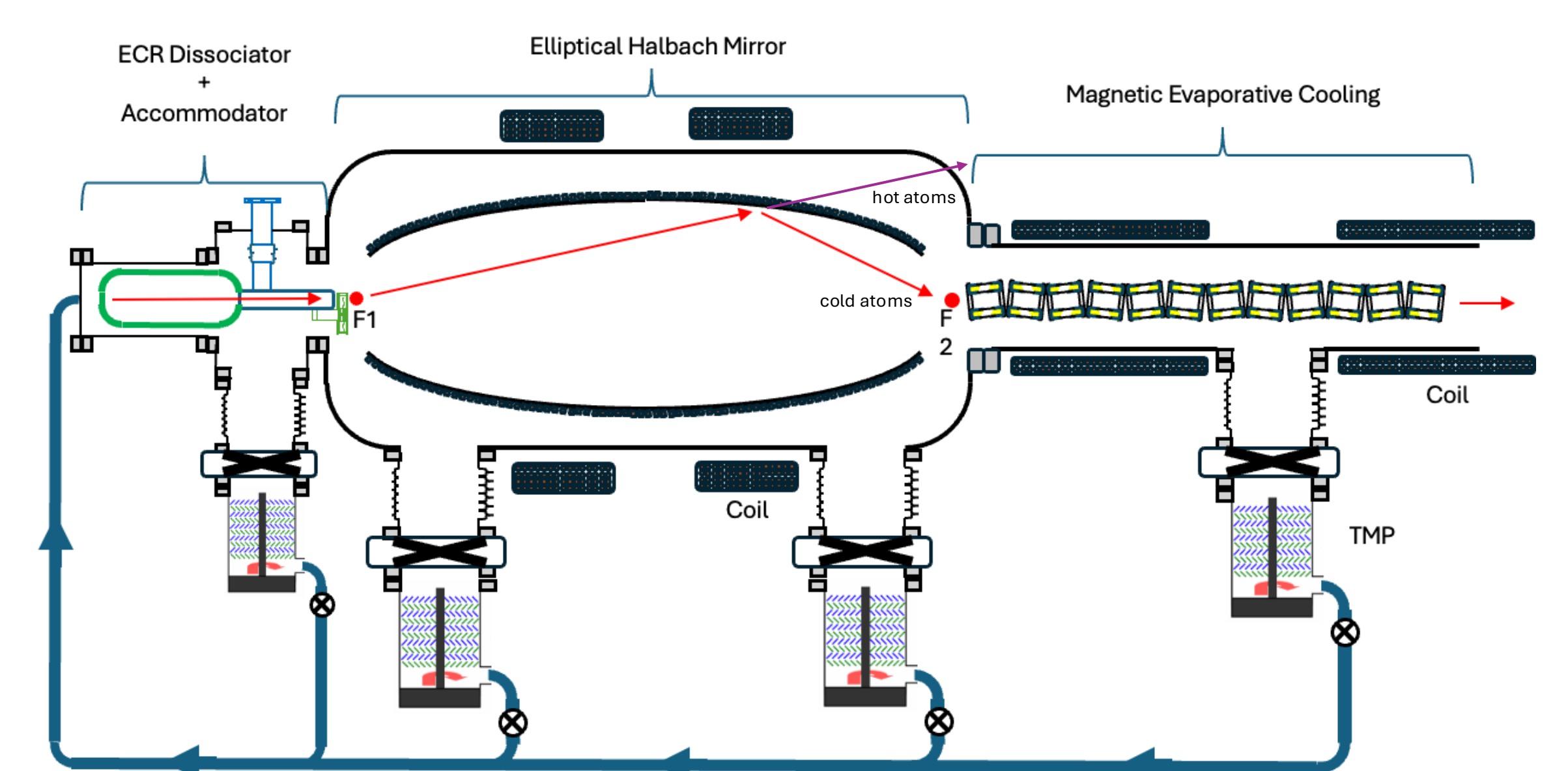


MECB quadrupole segments



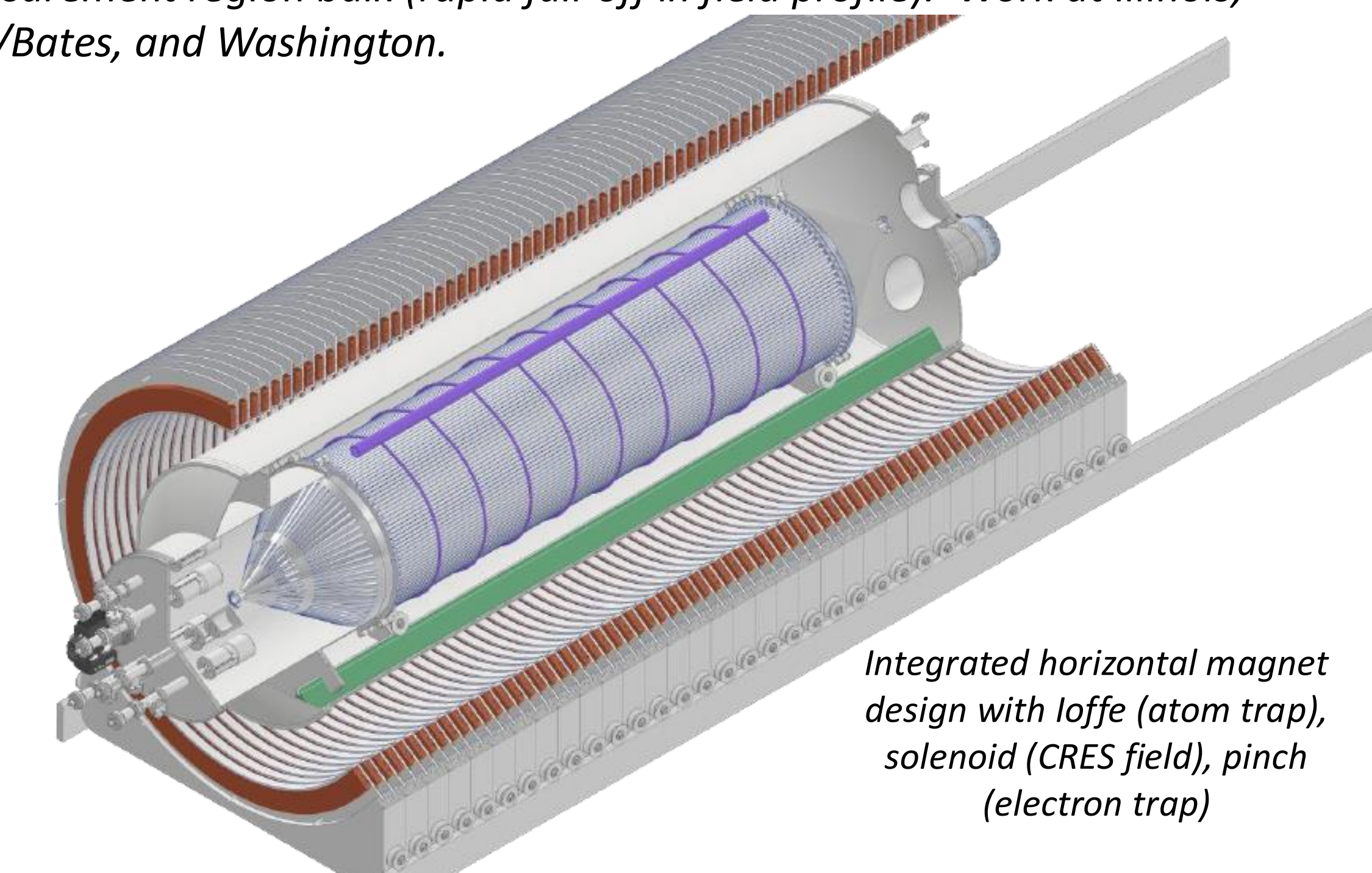
Elliptic Halbach Mirror

Second stage, filtering accommodator output by redirecting low-velocity (guidable) atoms into guide, while hot atoms escape. Selects atoms with temperature ~1 K. System under development at Washington.



Trapping

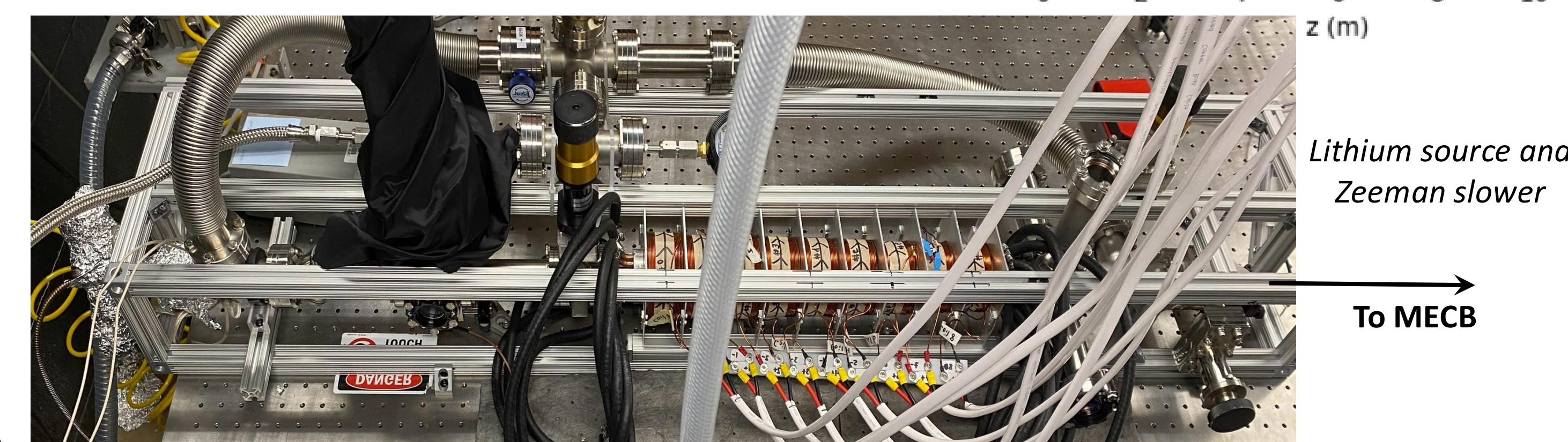
Confine $\sim 10^{17}$ atoms/m³ in CRES measurement region. Requires high-order multipole trap geometry to provide atom trapping (high walls) with CRES measurement region bulk (rapid fall-off in field profile). Work at Illinois, MIT/Bates, and Washington.



Integrated horizontal magnet design with Ioffe (atom trap), solenoid (CRES field), pinch (electron trap)

New T-T scattering calculations motivate choice of horizontal geometry to operate at lower density with decreased spin-flip losses. See *Phys. Rev. A* 112 (2025), 062818.

This work is supported by the US DOE Office of Nuclear Physics, the US NSF, the European Research Council (ERC), the PRISMA++ Cluster of Excellence at the University of Mainz, and internal investments at all collaborating institutions.



Lithium source and Zeeman slower
To MECB

