Fueling of LTX Plasmas with Lithium Plasma Facing Components

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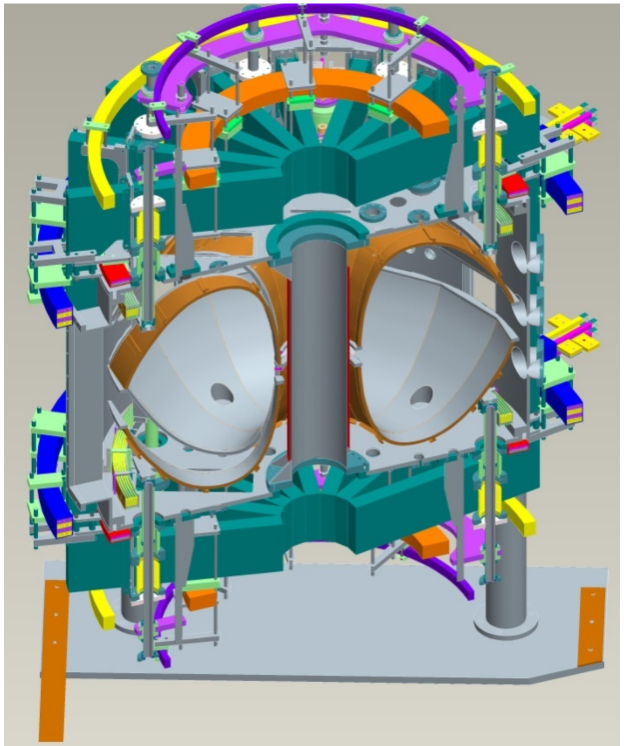
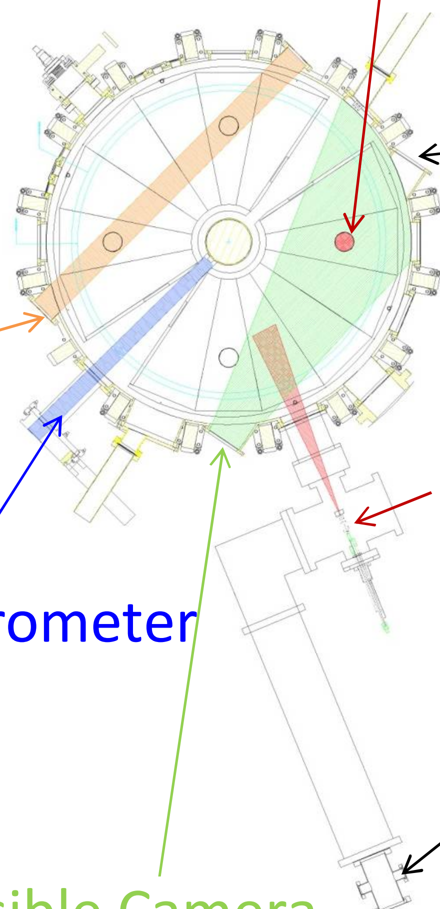
Outline

- Effects of lithium coatings on the fueling of LTX plasmas
- Results from the first LTX lithium campaign
  - Vessel neutral pressure (fast ion gauge)
  - Spectroscopy (Ly_{α} array)
- Future plans: fueling with Molecular Cluster Injection

Lithium Tokamak eXperiment (LTX)





Present Parameters

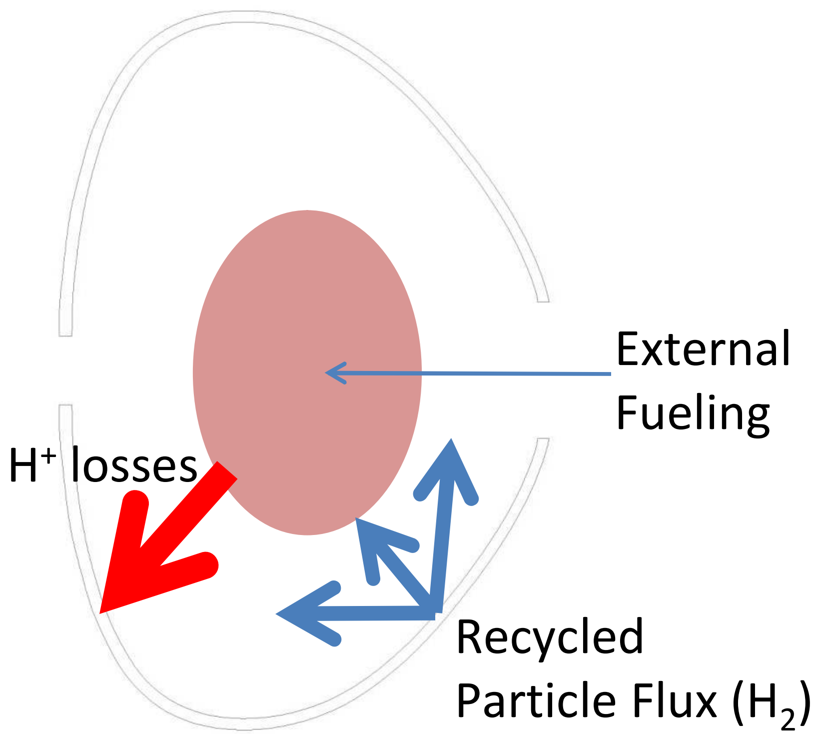
Major radius	0.4 m
Minor radius	0.26 m
Toroidal field	0.21 T
Plasma current	~65 kA
Current flattop	~5 ms

High recycling walls

Large cold wall particle source with poor fueling efficiency.

External fueling a small fraction of total.

Fueling rate and profile are uncontrolled.

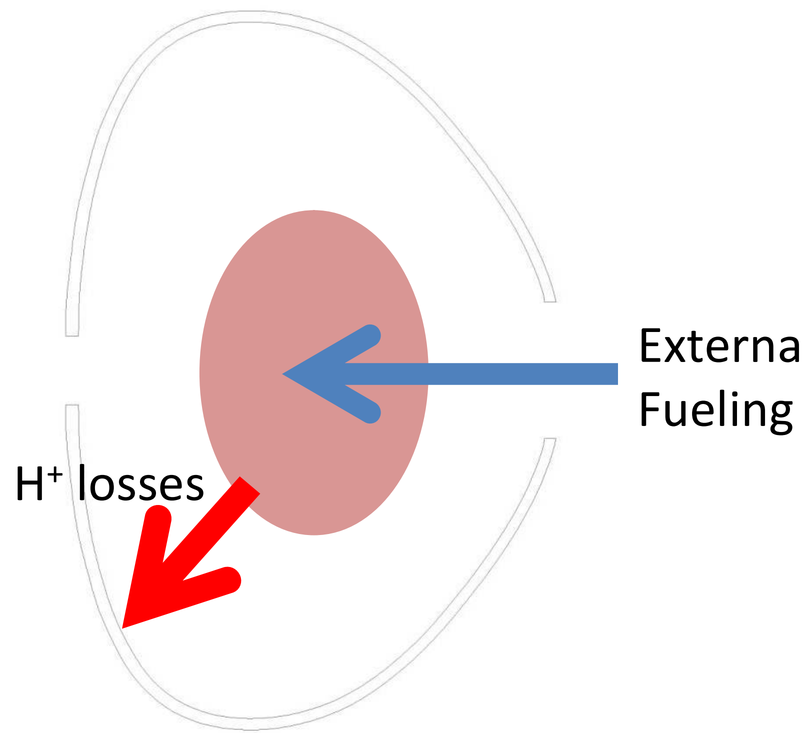


Low recycling walls

Eliminates low-efficiency edge source.

Almost any replacement source has higher fueling efficiency than wall (even puffer) and can be turned off

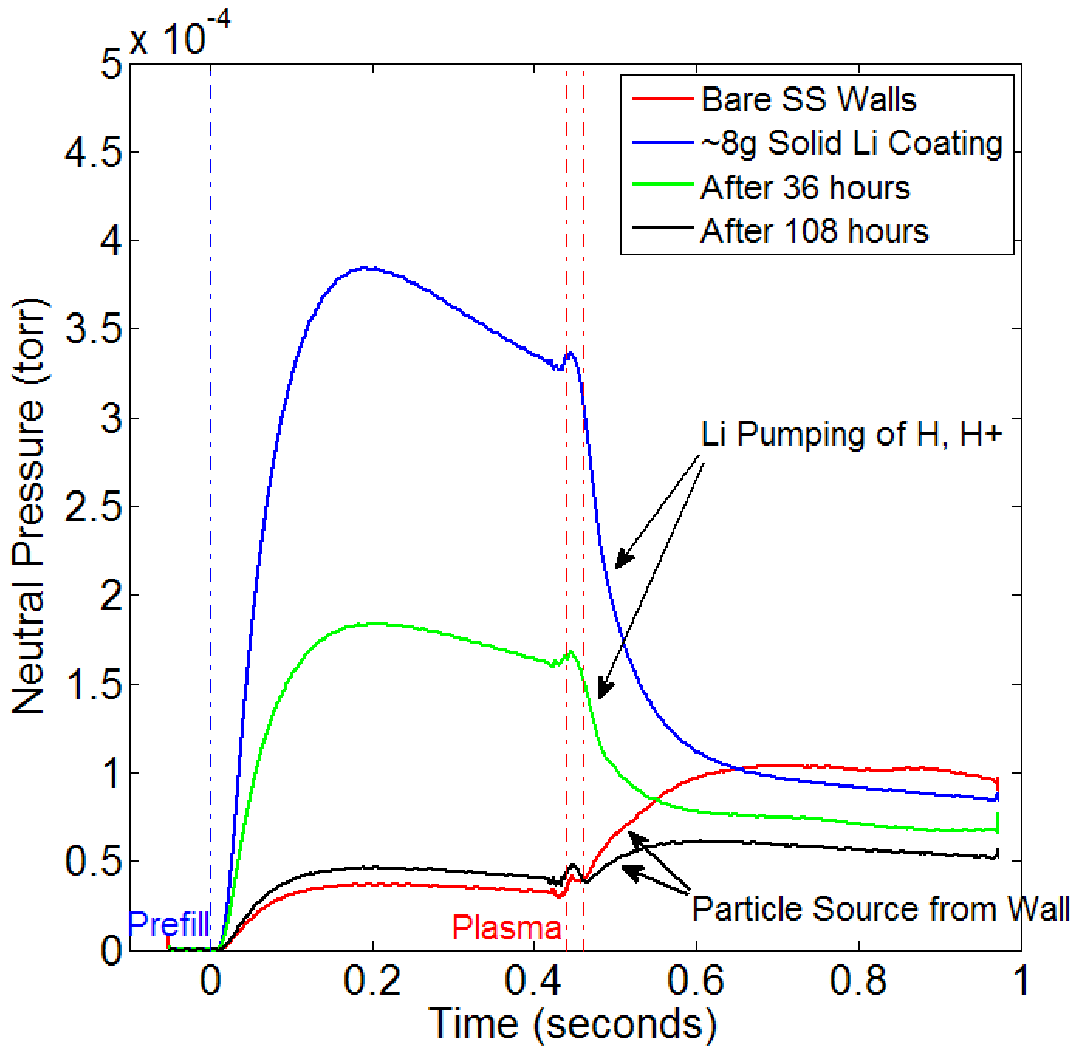
Ideal case is to replace recycled flux with core fueling → control of profile



So with lithium PFC's, we expect…

- Total external fueling requirements to increase
- Evidence of particles absorbed in lithium
  - (H^+ ions/ H_o atoms are pumped by lithium)
- With reduced recycling, edge neutral densities should decrease
  - Neutral emission should be reduced

Wall condition strongly influences neutral pressure measurements



Bare SS walls

Final neutral pressure actually **increases** after the discharge

- Plasma is liberating material from the wall (R>1)

Fresh lithium

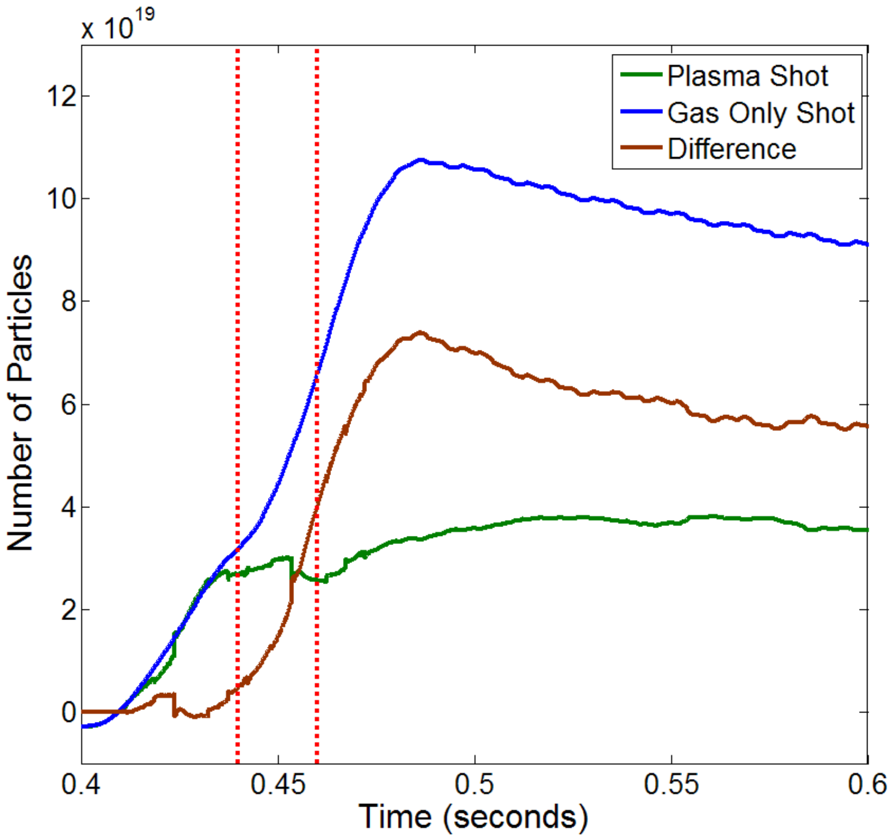
Requires factor of 10 increase in pre-fill pressure to avoid runaway electron formation

Neutral pressure drops after discharge (R<1)

Passivated lithium

Fueling requirements and wall source similar to bare SS case

How many particles is the lithium pumping during a discharge?



H_2 molecules are not pumped by lithium. Difference between "gas only" and "plasma" cases equals amount of H^+ and H_o and absorbed in Li during discharge

Lithium traps ~6-7x10^{19} particles in ~15ms
- 2/3 of the total number of particles injected by the fueling systems

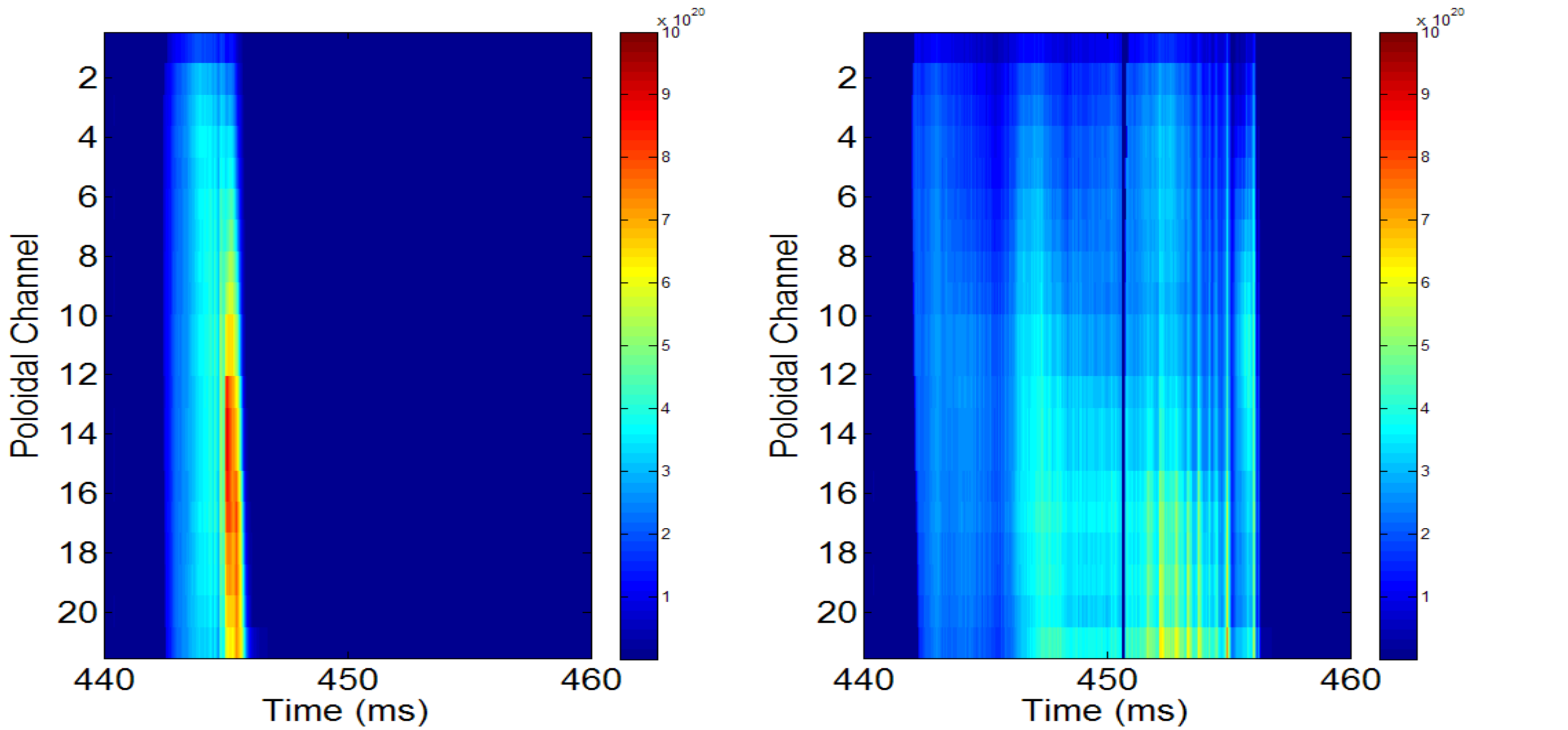
This is **not** the same as R=0.33
(we do not know how many times particles hit the Li wall before sticking)

But clearly R<1

Spectroscopic Measurements Indicate Reduced Edge Neutral Emission With Lithium Coatings

High-recycling case (passivated Li)
$4x10^{18}$ particle pre-fill puff
Ly_α monotonically increases
Plasma collapses in <10ms

Low-recycling case (fresh Li coating)
$3.6x10^{19}$ particle pre-fill puff
Ly_α level lower despite higher pre-fill pressure (implies reduced edge H_o)



(Credit to E. Granstedt for development of the Ly_α array)

What about the other 1/3 of the particles?

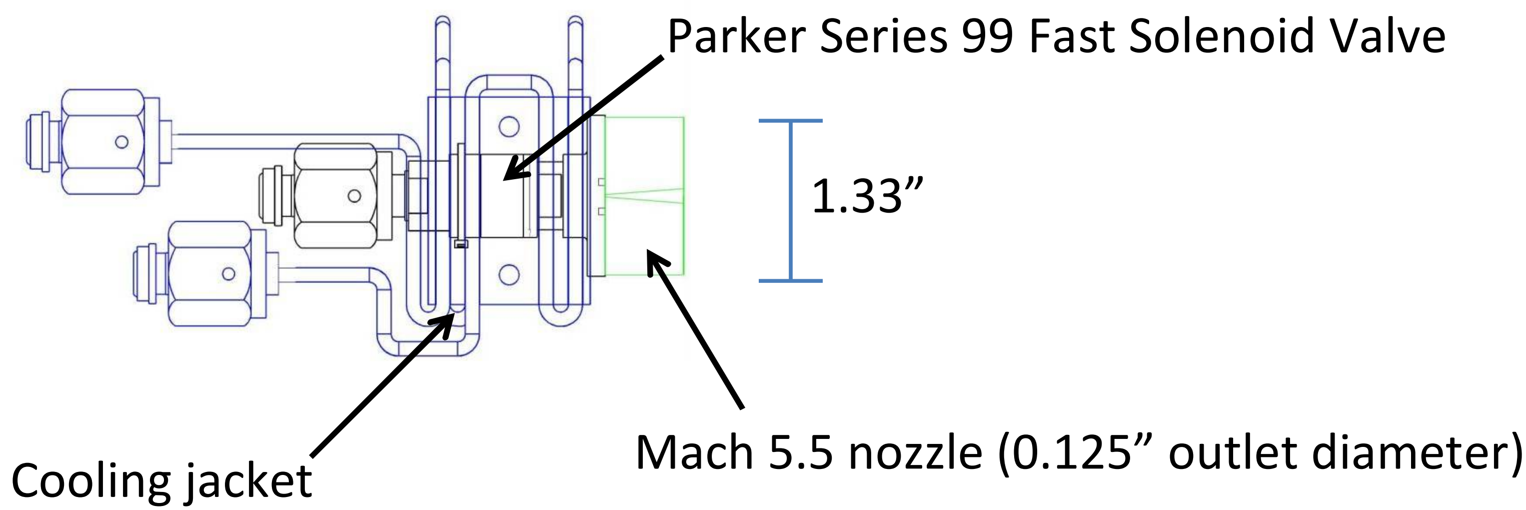
- Not all surfaces are uniformly coated with lithium
  - Gaps in shell, center-stack, etc…
- Particles left over from pre-fill puff
  - Plasma volume is ~1/2 of total vessel
    - Diffuse pre-fill unnecessarily raises the edge neutral density
- Gas puffer has poor fueling efficiency
  - Would like to replace the puffer with directed fueling
    - Minimize stray edge gas
  - Have already reached puffer's maximum fueling rate

Molecular Cluster Injector – a fueling system that creates a collimated, high-density particle source

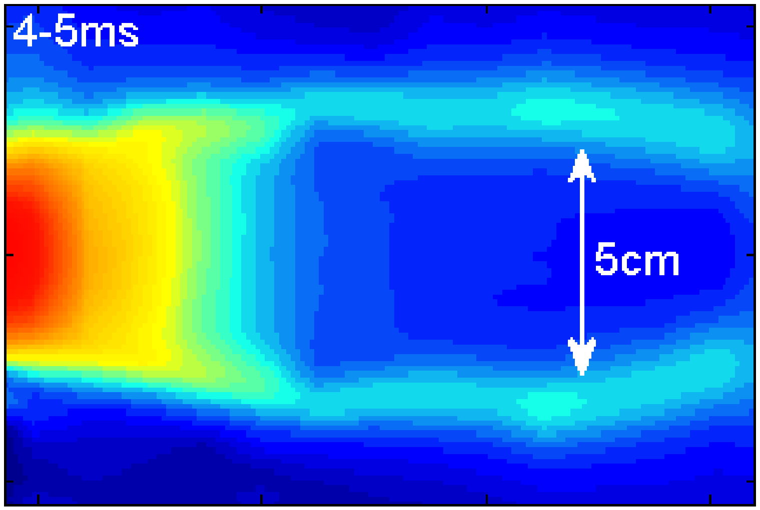
- Cryogenically cooled solenoid valve and supersonic nozzle
  - Cold molecules condense into clusters of a few hundred molecules each
  - Low temperatures, high pressures increase cluster size and number

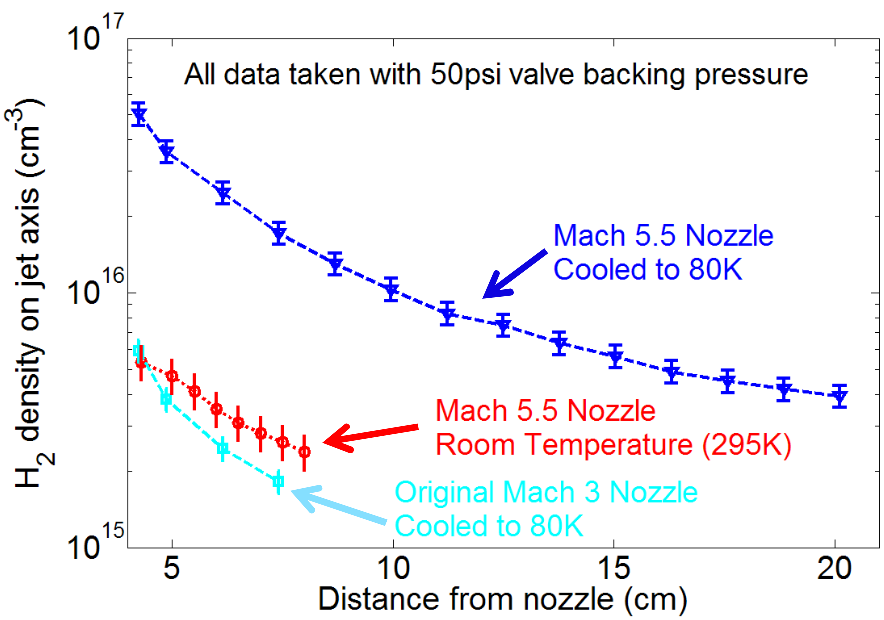
- Clusters expected to penetrate further into plasma than gas-phase molecules
  - Previous results on HL-2A gave some promising indications of this

- Unknown if dominant factor is size of the clusters or total molecular density
  - Cluster size and molecular density are generally correlated → need careful experiments
  - Large clusters as "micro-pellets" versus shielding of inner neutrals in high-density jet



Cluster injector has been optimized for high-density fueling of LTX plasmas





- Improved nozzle design
  - Increased central density by an order of magnitude
- Produces neutral densities of $10^{15\text{-}16}$ cm^{-3} far from the nozzle
  - 1000 X LTX plasma density (strong perturbation to plasma)
- Measured high flow rates $>5\text{x}10^{22}$ particles/s (@250 psi)
  - Rates $>1\text{x}10^{23}$ particles/s should be possible (valve rated to 1250 psi)

Future Plans

- Optimize performance of cluster injector on LTX
  - Maximize fueling efficiency / percentage of core fueling
    - Does this depend on cluster size or just molecular density in the jet?
  - If successful, this fueling system should be of interest to the broader fusion community
    - Cheaper and less complicated than pellet injection
    - High fueling rates available
- Use the cluster injector as a tool to study plasma density profiles with low-recycling walls
  - How does the density profile evolve differently with:
    - Edge fueling?
    - Core fueling?
    - The absence of external fueling?
  - Can we strongly affect the electron density profile via fueling?