Recent results from LTX and near-term plans

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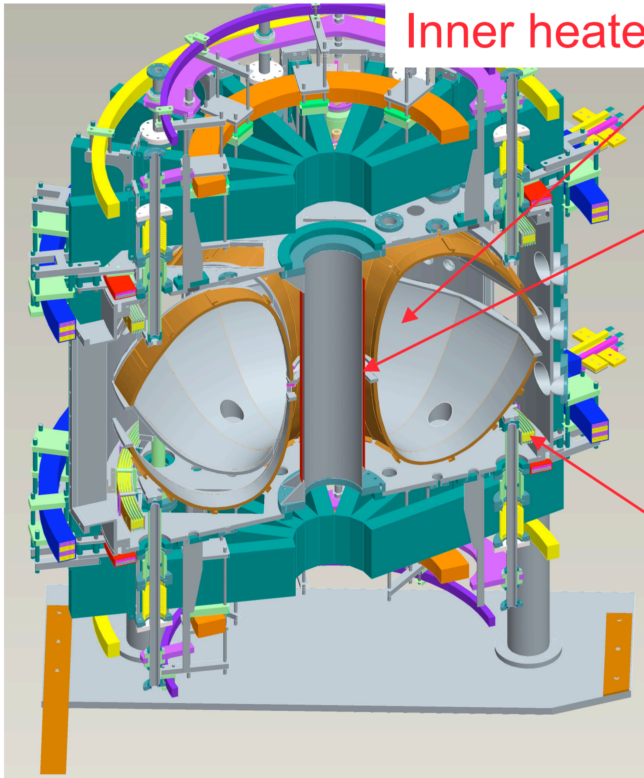
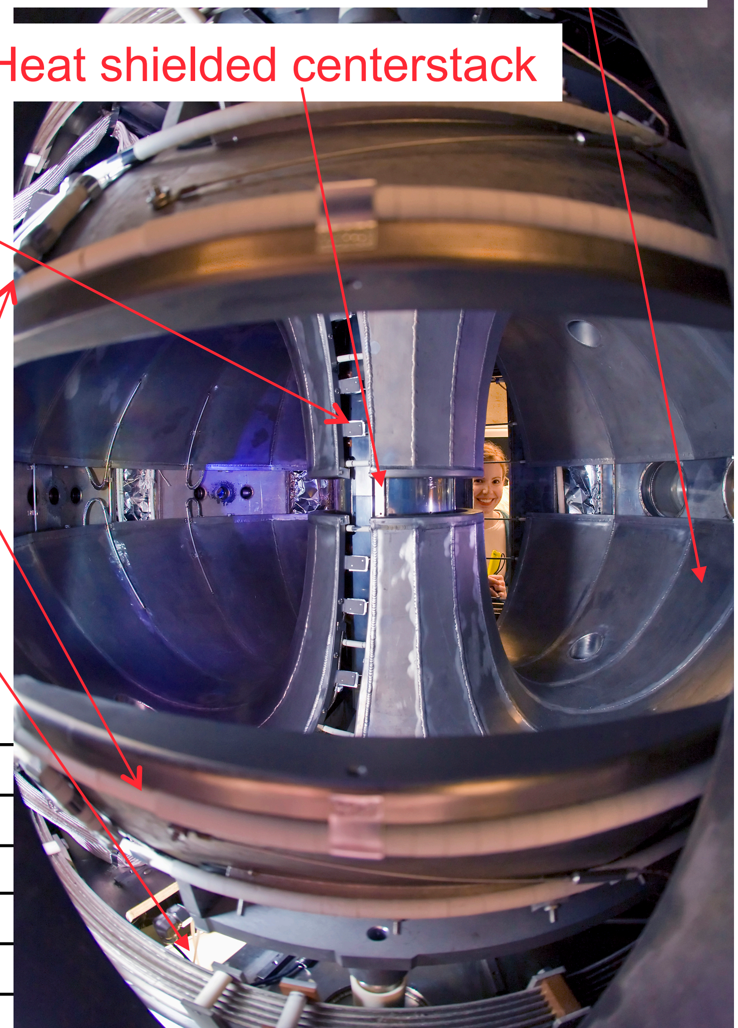
Outline

- LTX overview
  - Shell and heater systems
  - Fueling systems
  - Recycling diagnostics
  - 2010 lithium evaporation system
- Results with evaporated coatings
  - Cold walls
  - Hot walls and discussion
- Near-term plans

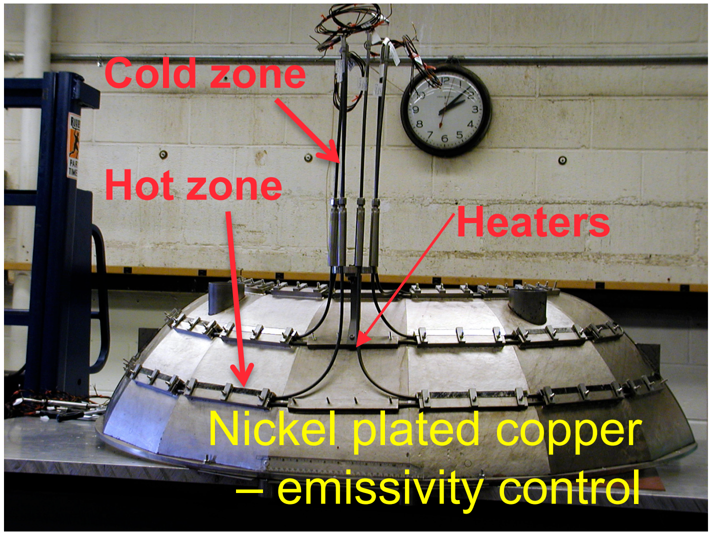
LTX has a full, 5 m^2 heated, conformal wall

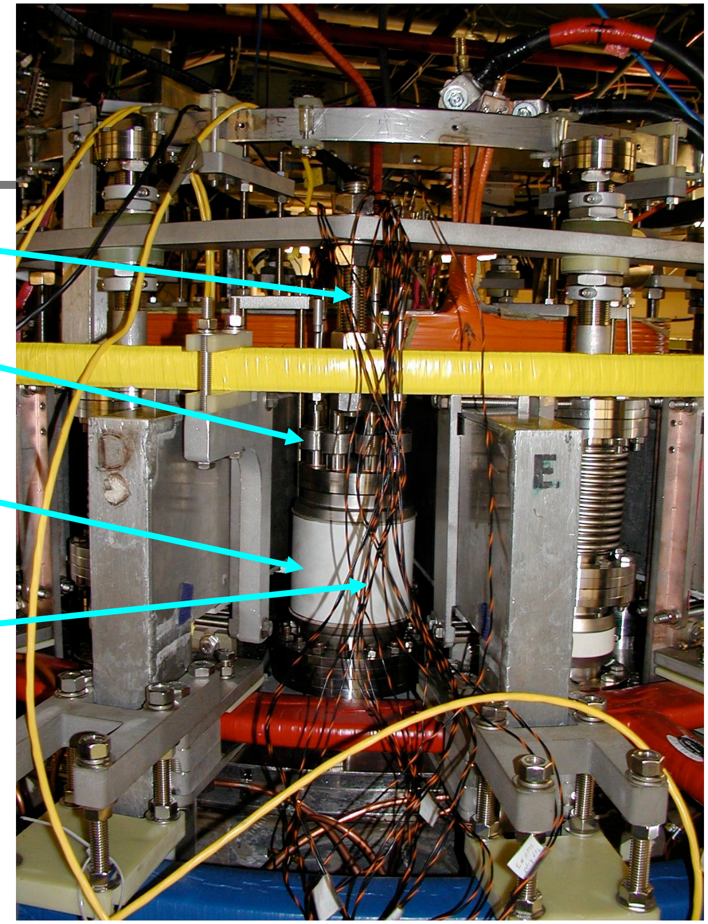


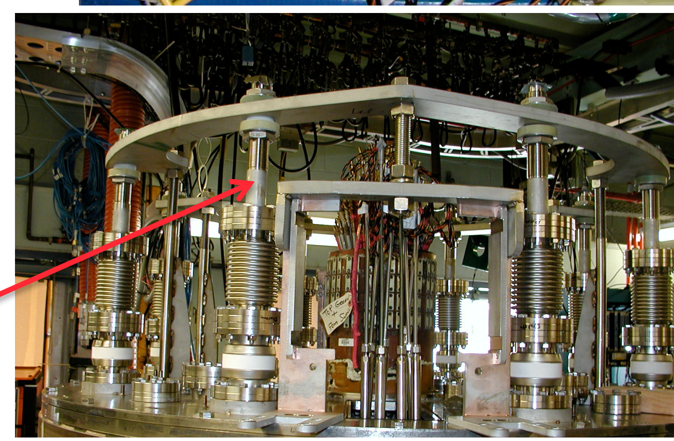


Parameter	CDX-U	LTX
Major radius	0.34 m	0.4 m
Minor radius	0.22 m	0.26 m
Toroidal field	0.21 T	0.34 T
Plasma current	100 kA	400 kA
Current flattop	5 ms	>100 ms
Ohmic flux	30 mV-s	160 mV-s (centerstack maximum: 225 mV-s)
Wall temp.	20 °C	400 °C now, ~ 600 °C future

Robust operation of LTX heaters to 300 °C demonstrated



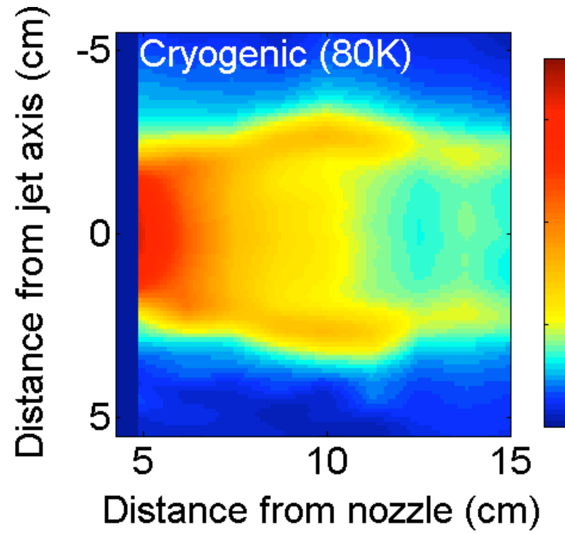




- Detail of full shell support structure

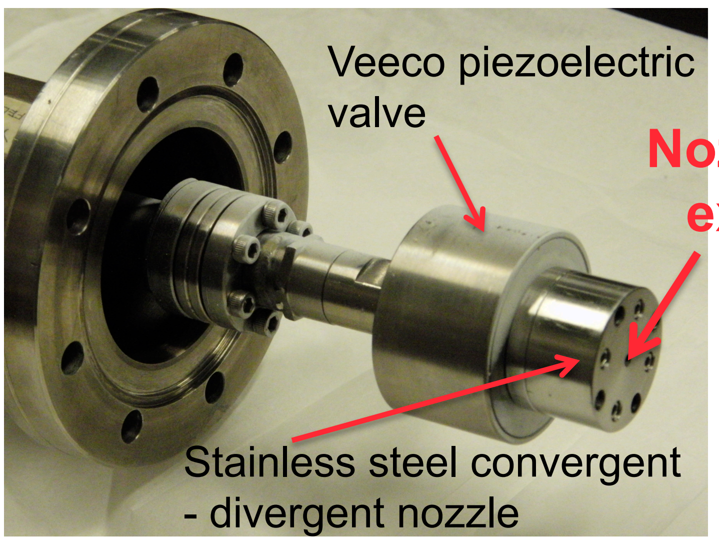
Recycling source being replaced by active fueling

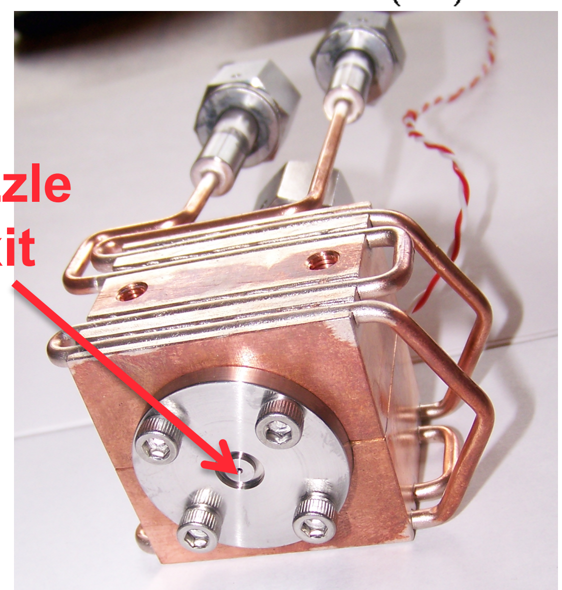
- Molecular cluster injector for LTX
  - Precooled (82K) gas condenses through nozzle exhaust
    - Forms clusters
  - Less expansion of jet
  - High fueling capability
  - Millisecond response
- Combined with existing supersonic gas injector



Gas density in MCI jet exceeds $10^{16} cm^{-3}$

Supersonic Gas Injector



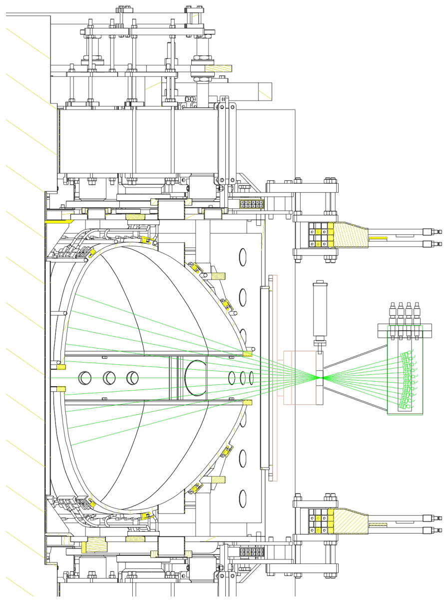


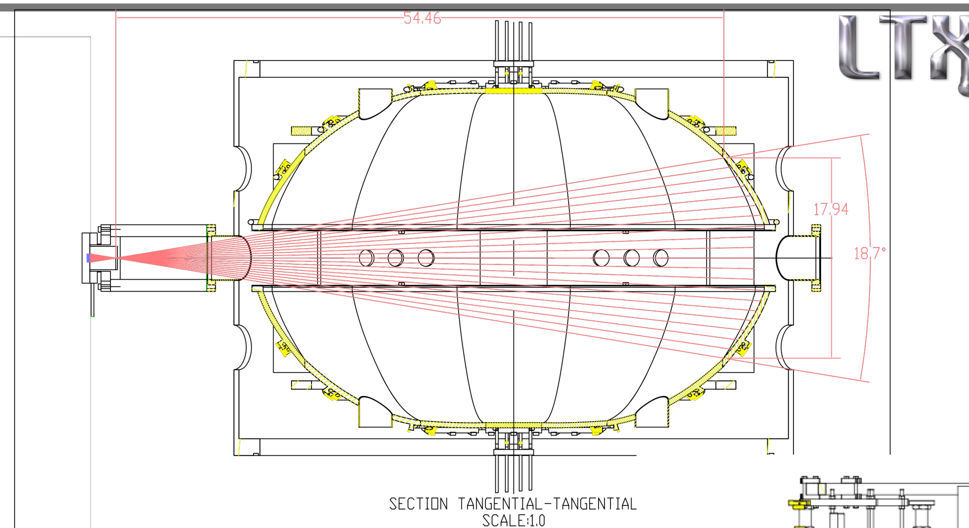
Molecular Cluster Injector

→ Talk by D. Lundberg, Session IIB

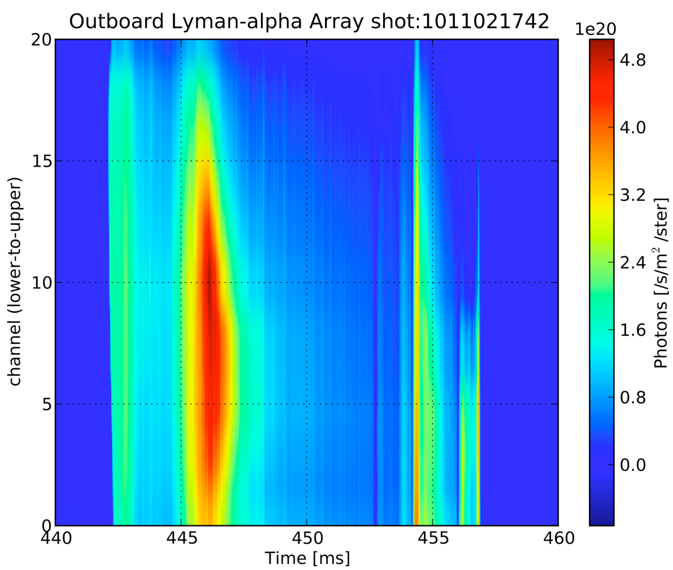
Recycling measurements employ Lyman-α arrays

- Lyman-α array viewing shell high-field (inner) side

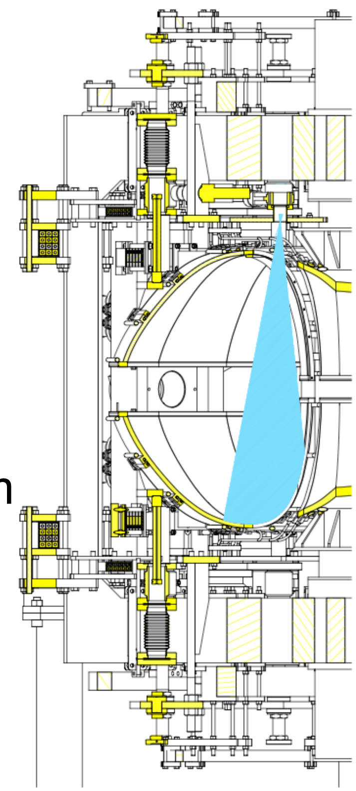




- View of shell low-field (outboard) side through tangential port (array developed by K. Tritz, JHU)

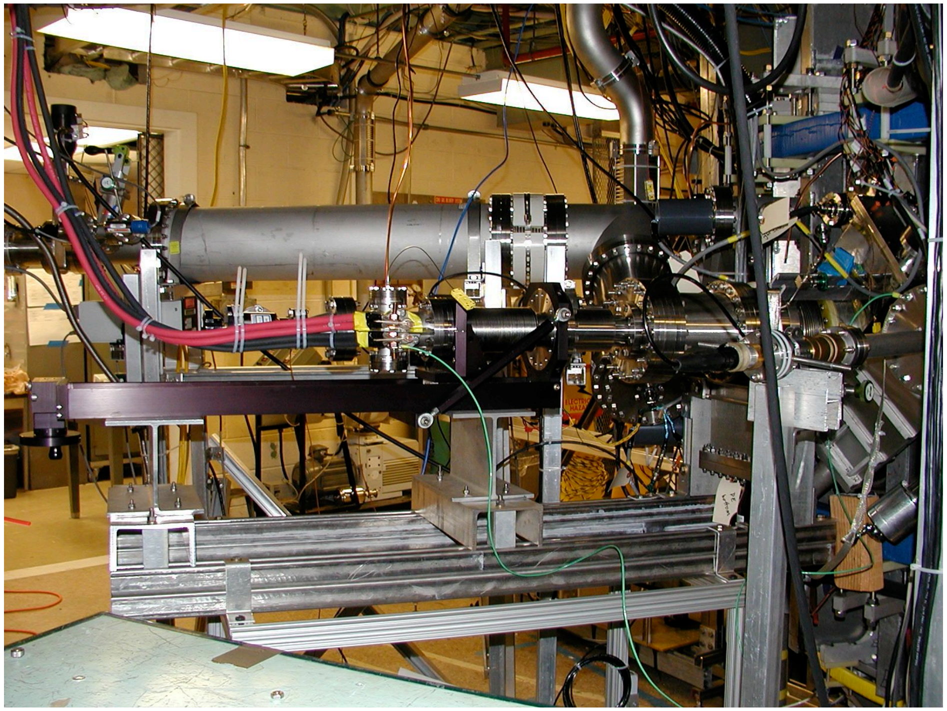


- View of lower molybdenum limiter in lower shell

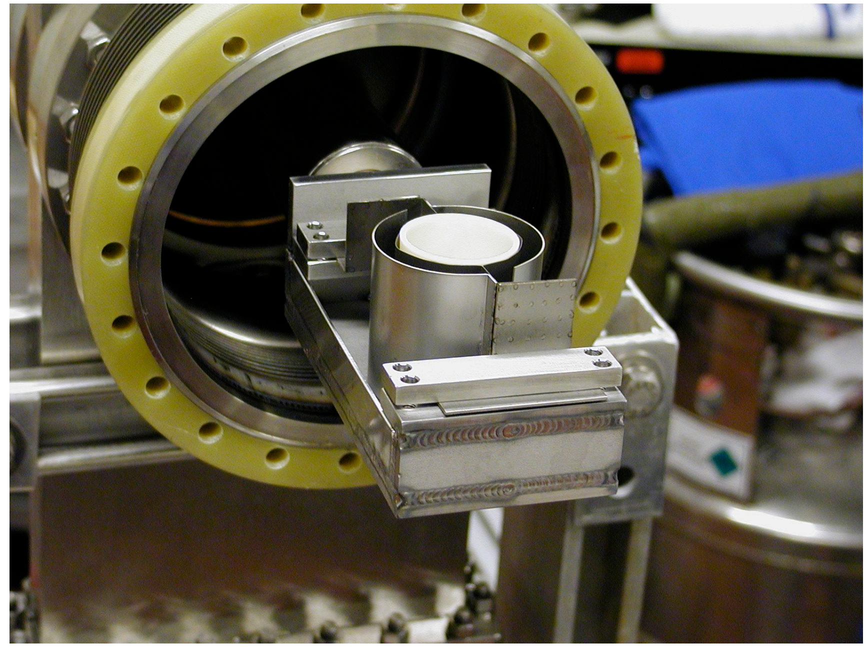


➔Talk by E. Granstedt, Session IIB

New lithium coating systems developed for LTX



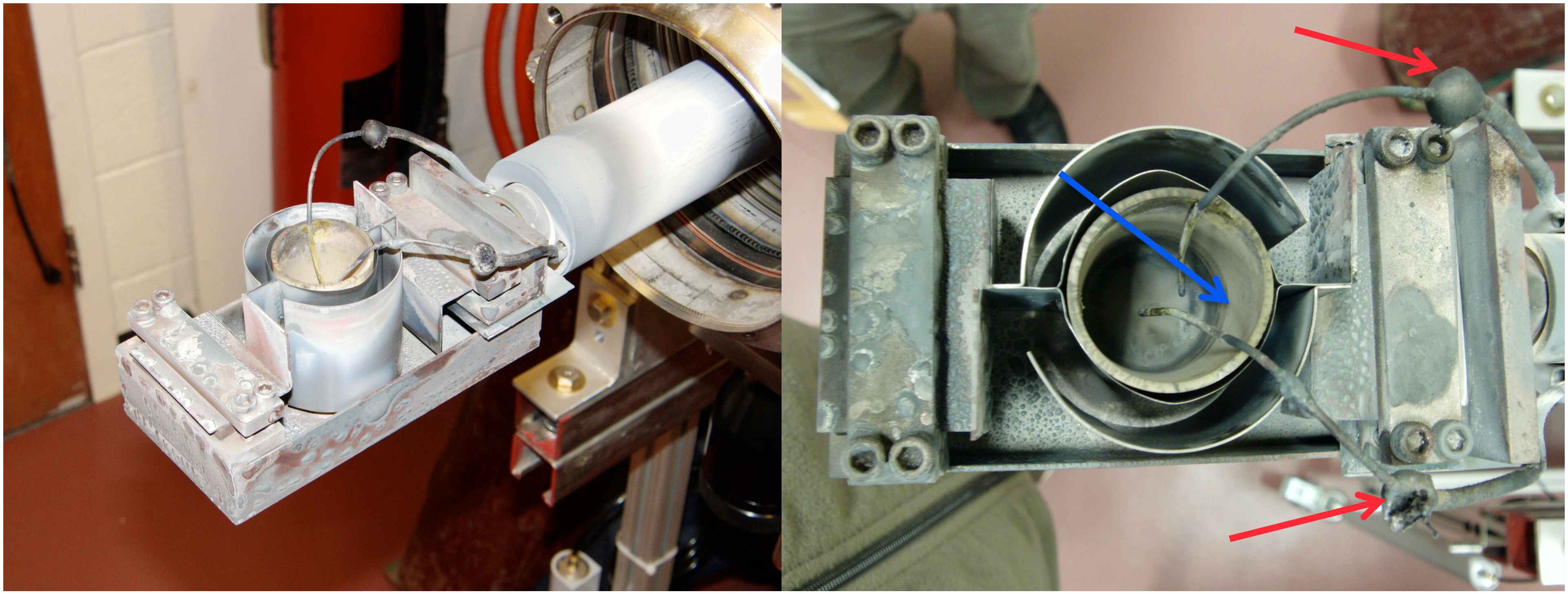
Evaporator (1 of 2) with linear motion stage mounted on LTX



Y_2O_3 crucible, Ta heater
➢Tested to 700 °C

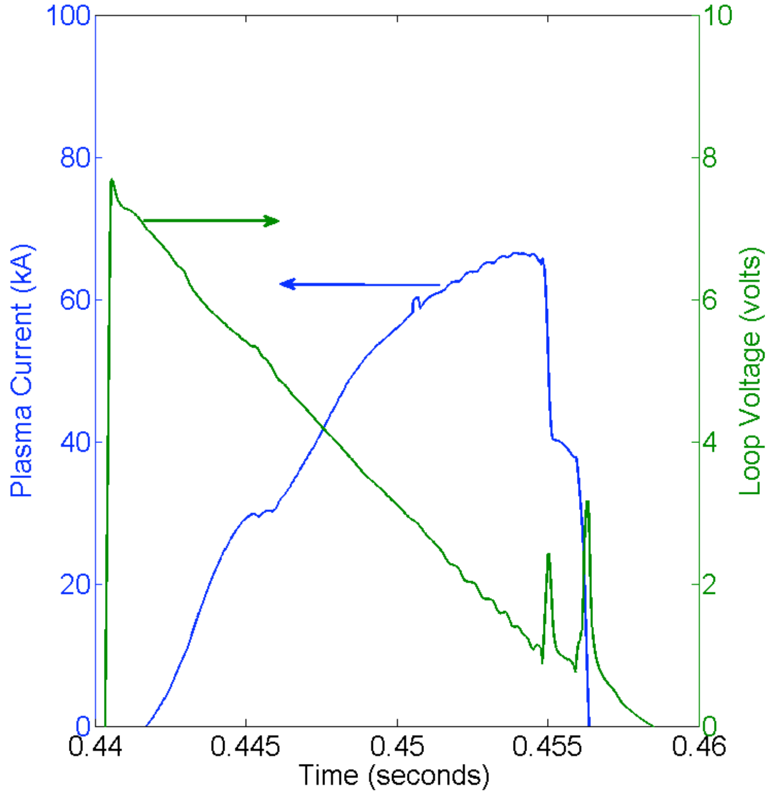
- Two evaporators installed
- LTX lithium experiments have begun
- Total of 10 g evaporated onto walls in first round
  - 44g total lithium evaporated in 2010
  - Sufficient for a 4 micron coating of the entire shell

Crucibles and heaters recycled successfully

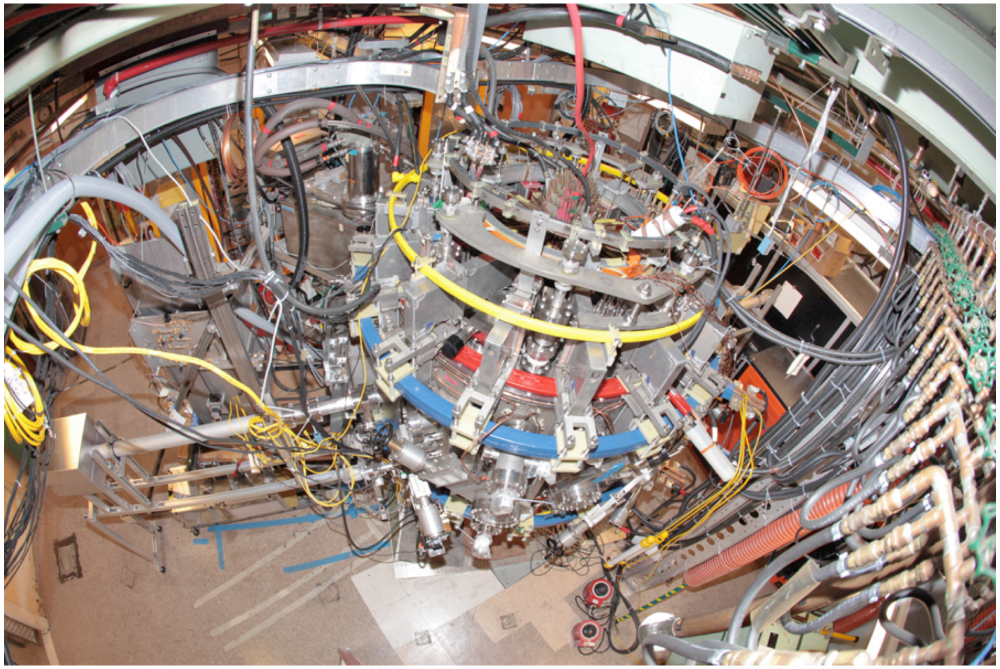


- Cleanup relatively straightforward
- No significant issues with yttria crucibles after 600C operations
  - Lithium did not wet the crucible
  - Thermocouple wetting provided an escape route

Current LTX status

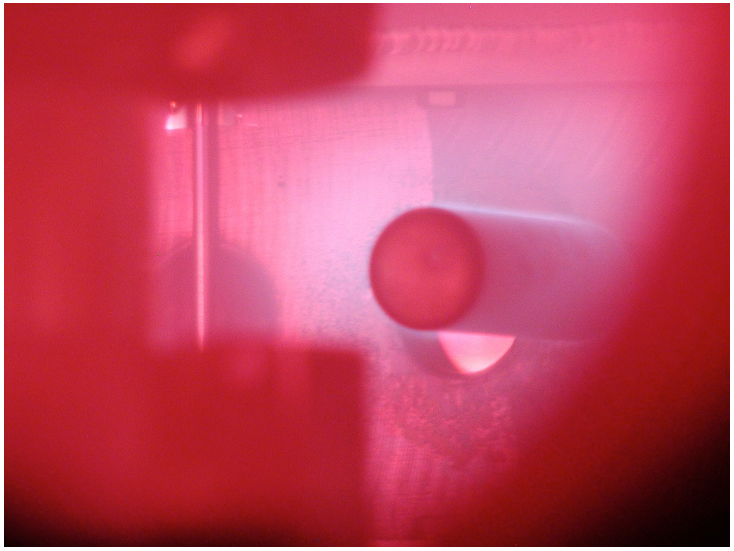


- (Almost) overhead fisheye view of LTX

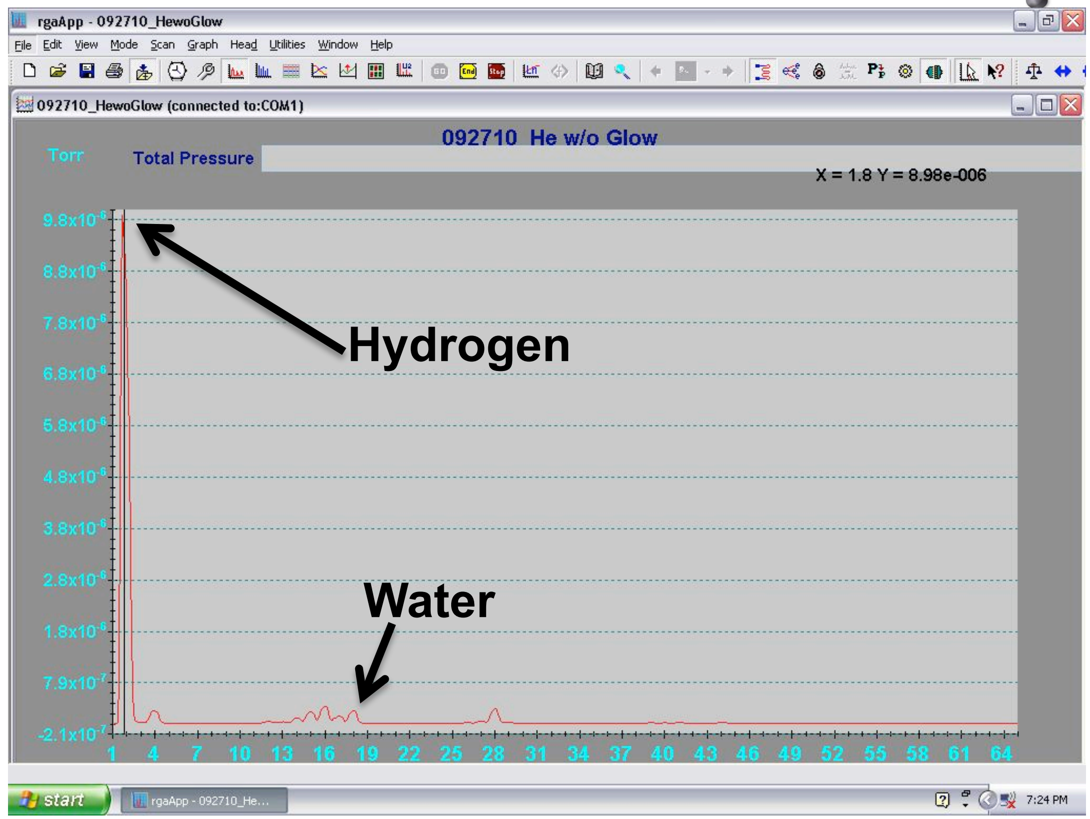


- Plasma current ~70 kA, shot duration ~20 msec
  - Thomson: T_e ~ 50 – 150 eV
- Shells routinely heated to 300 C for bakeout
- Operated with lithium coatings October – December 2010
- Presently vented for maintenance, upgrades: May pumpdown

Lithium initially evaporated into helium glow



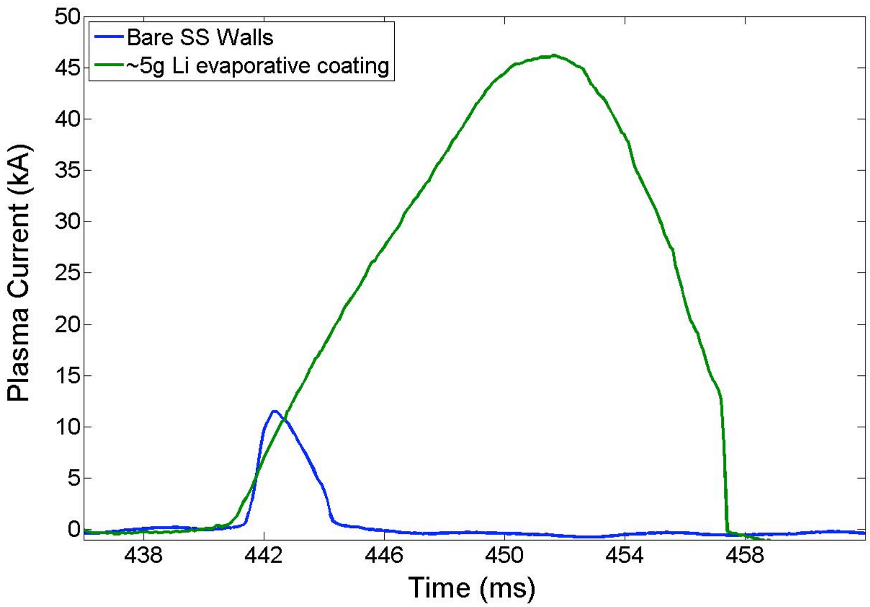
Glow probe head
>Lithium-dominated discharge
>Working gas was helium



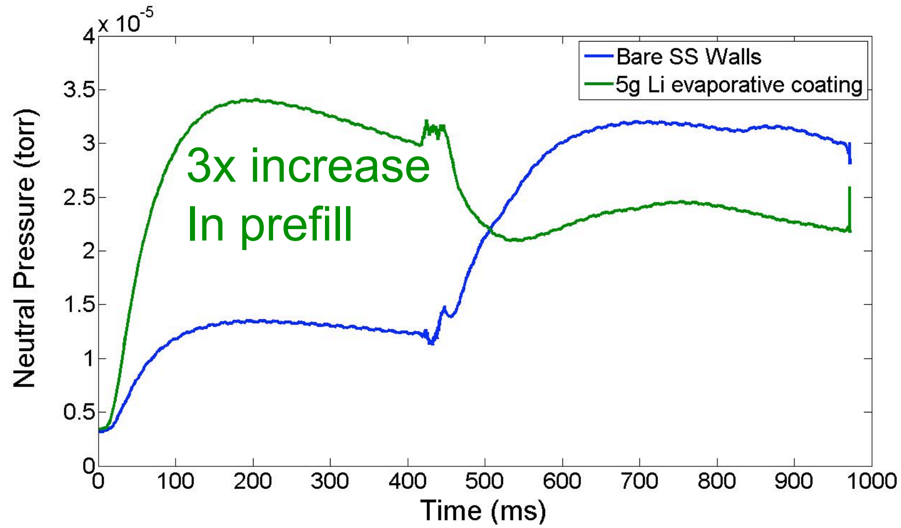
RGA trace indicating lithium gettering of water
>Trace is dominated by liberated hydrogen

- Lithium introduced by evaporation from yttria crucibles at 550 C
- 5 gram load per crucible, 2 crucibles, 1.2 g evaporated in first run

Lithium wall conditioning produced immediate effect on the discharge



Plasma current comparison

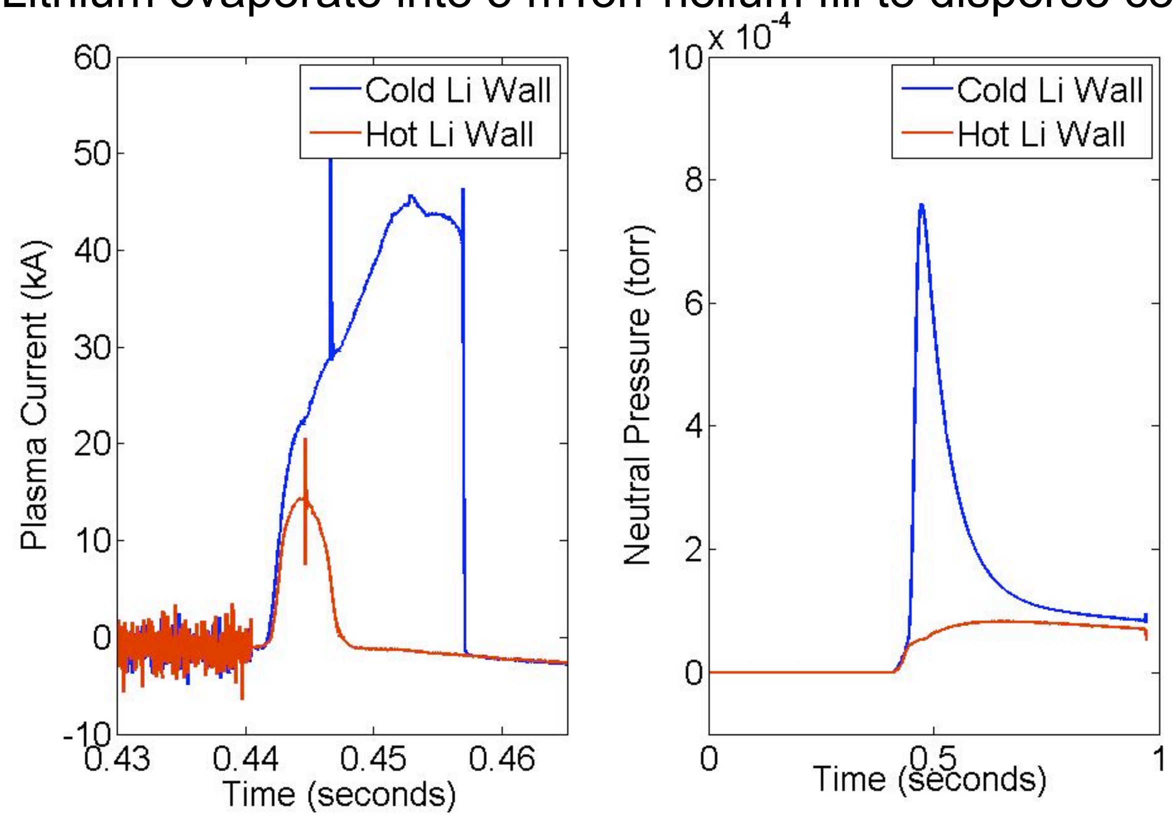


Pressure evolution

- First lithium operation shown – cold shell
- Lithium glow preceded by helium glow with hot (250C) shell for preconditioning
- Discharge current, duration significantly increased after only a few hours of operation following Li glow
- Pressure history demonstrates reduction in recycling

LTX has now been operated with a lithium-coated 300 °C shell

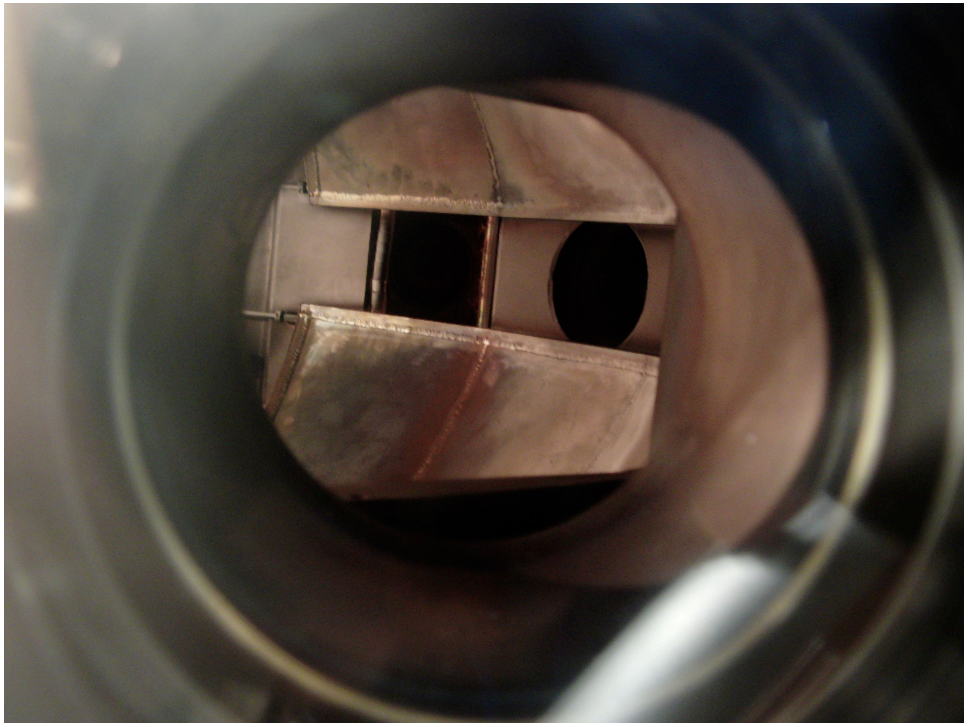
- First full high temperature, high Z wall operation of a tokamak
  - Lithium evaporate into 5 mTorr helium fill to disperse coating

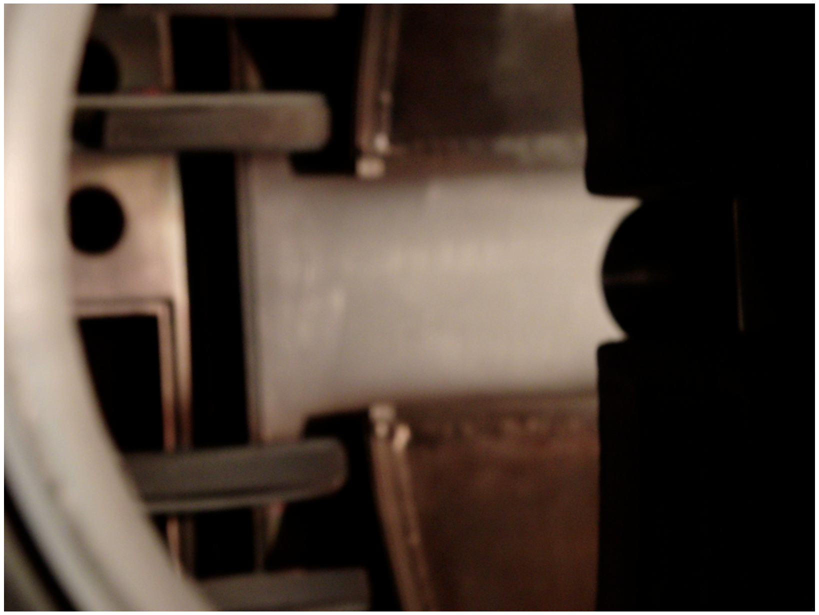


(Warm) cluster injector system, wall puffer employed for fueling with cold lithium walls

- Hot (300 °C) shell with thin lithium coatings does *not* exhibit a significant reduction in recycling
  - "Liquid" lithium is impurity-dominated
  - Relevant to NSTX operation with heated LLD?

Shell interior at 300 °C after 4 g lithium deposition





- Deposition rate ~0.75 g/hour/evaporator; 3 hour evaporation
  - Evaporate into 5 mTorr helium to distribute lithium
  - Est. 1.6 micron average deposition layer
- Lithium coating darkens rapidly
  - Indicative of reactions with background gases
- No visual evidence of metallic surface

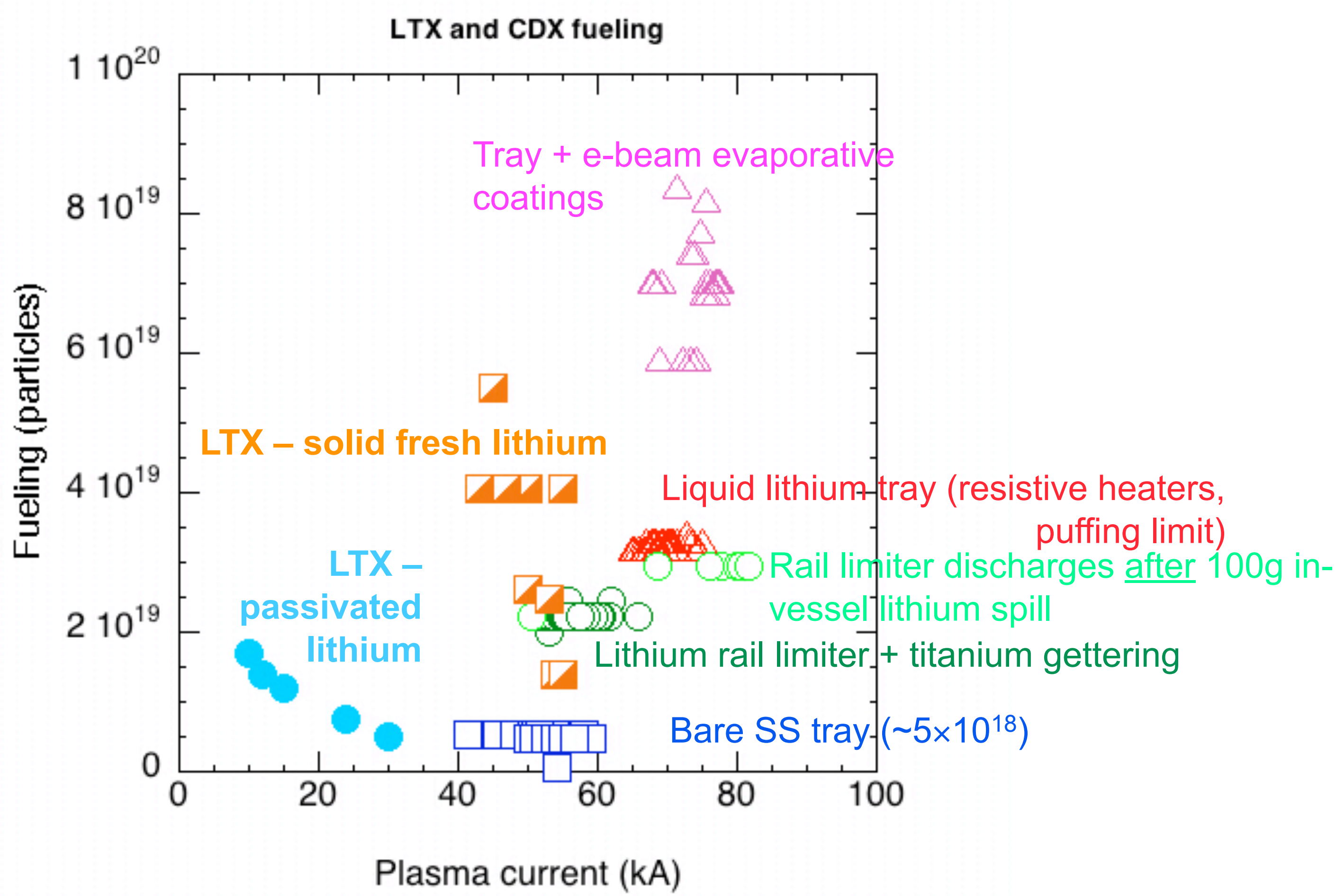
Discussion of hot wall results

- Partial pressure of water during cold wall lithium evaporation was ~ 5×10^{-9} Torr
- Partial pressure of water during the hot wall experiment was ~2×10^{-8} Torr
- With cold walls, improved discharges were obtained for ~48 hours
- With hot walls, no improved discharges were observed
  - Delay between termination of coating and tokamak operations was 1 hour, 15 minutes
  - If the only factor affecting the condition of the lithium coating was background water pressure, coating should have been active for ~12 hours
- Therefore, hot coating passivated more quickly than can be accounted for by background water pressure
- Suspect segregation of oxygen, other impurities to the surface was responsible for rapid passivation
  - C. Skinner, poster session IIB

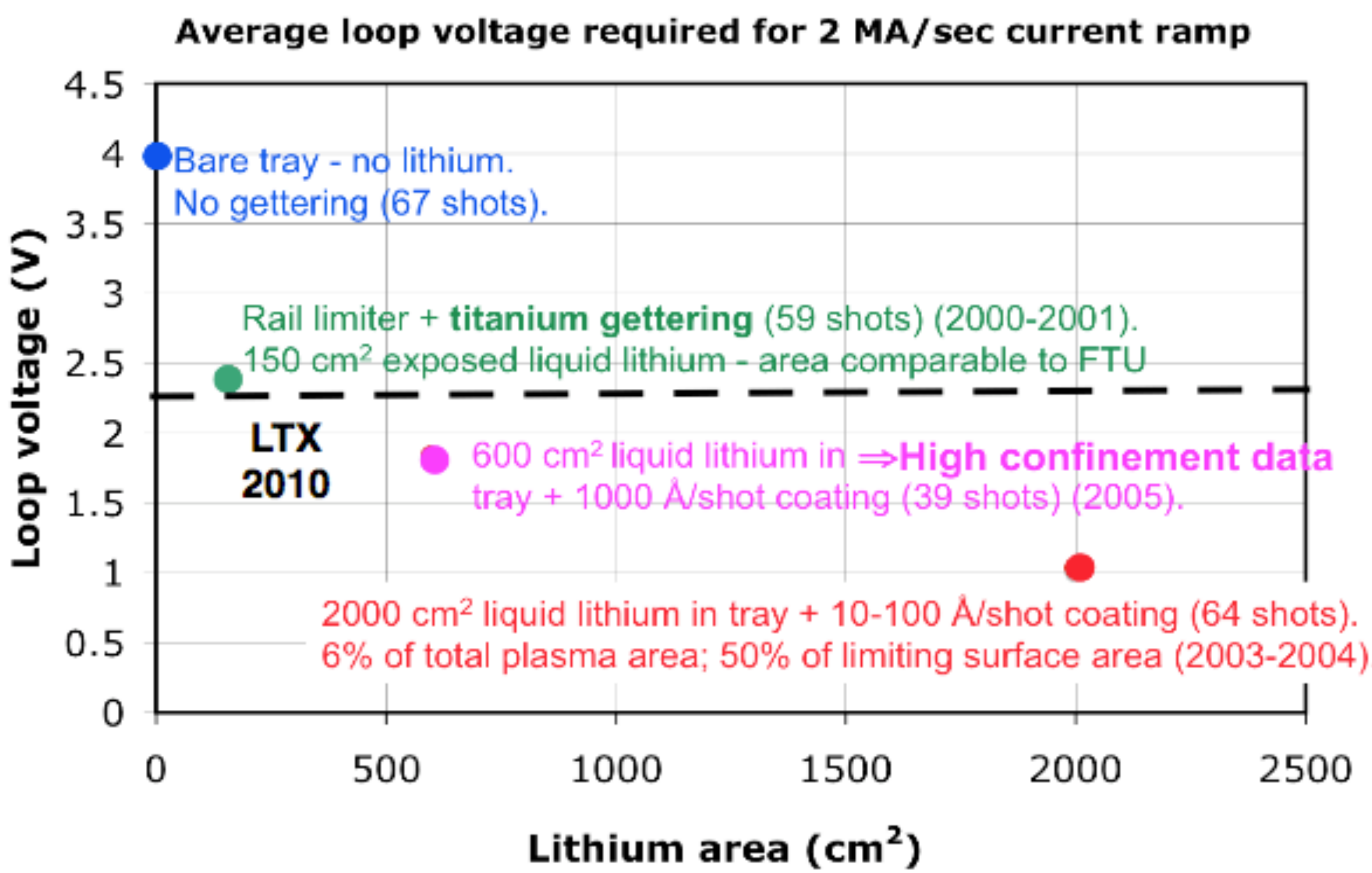
LTX and CDX-U fueling

- Fueling requirements for LTX are approaching CDX-U requirements for low recycling operation
  - LTX: similar shot duration
  - Lower plasma current, density

Total fueling
⇒including
prefill



Loop voltage comparison indicates modestly improved discharge performance with cold wall coatings

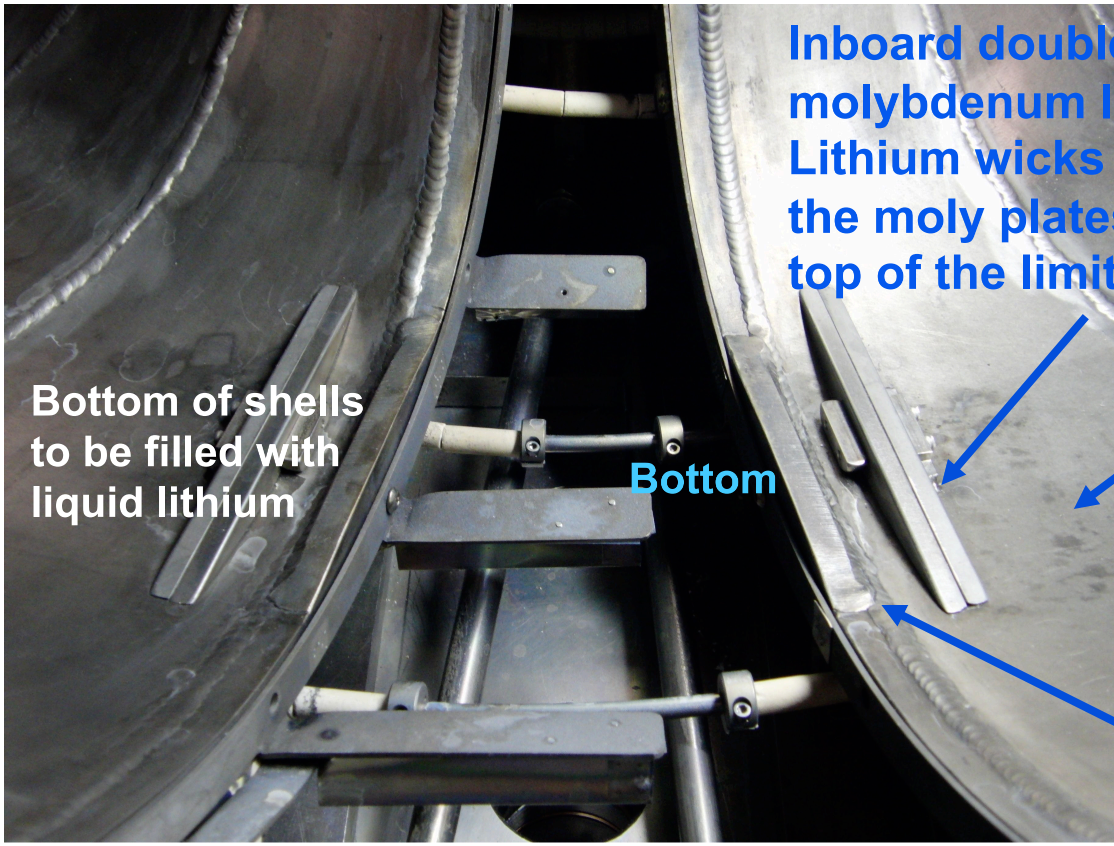


- *Preliminary* result (just a few discharges from LTX)
- Require more discharges, full confinement assessment

Near-term (2011) plans

- Improve vacuum conditions in LTX
  - Adding vacuum vessel bakeout to 120 C
  - Vessel will be cooled during tokamak operations with hot shell
- Increase shell bakeout temperature to 400 C
- Add water pumping
  - Installing two lithium getter pumps
  - Pumping speed for each unit estimated at 2500 L/sec
  - Each pump will employ a heated lithium crucible and a large wall area for lithium deposition
- Summer 2011: begin operations with liquid lithium fills in both lower shells
- Preliminary assessment of confinement with partial liquid lithium walls later this year

Lower shells designed for liquid lithium pools



- Lower shells have welded stainless steel lips to retain lithium
- Double molybdenum limiters are designed to wick lithium
  - Molybdenum limiters extend 2 mm above the stainless steel retention lips