The effect of liquid lithium PFCs on plasma performance in CDX-U

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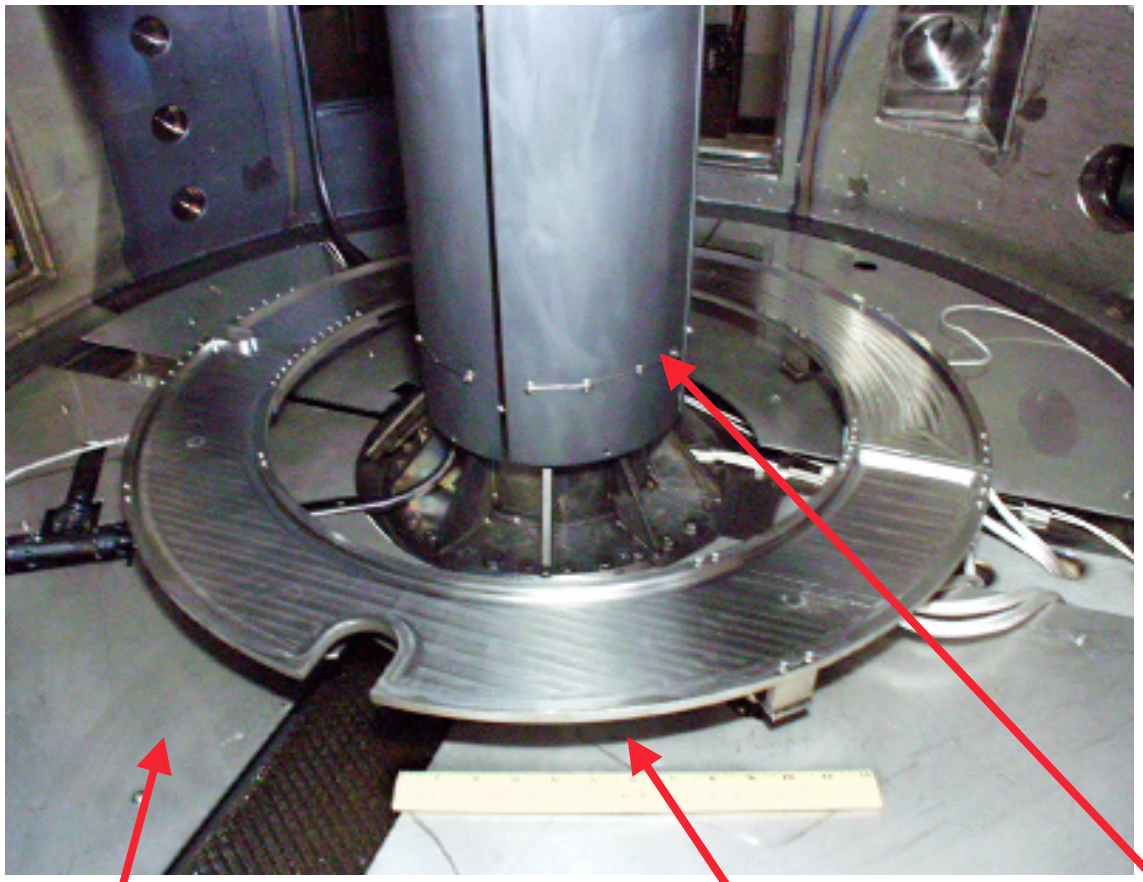
Goals of the CDX-U lithium experiments

- Effects of liquid lithium PFCs on plasma operations in a tokamak
  - Recycling and fueling
  - Impurity reduction
  - Performance enhancement
  - Radiation losses and core lithium accumulation
- Practical implementation of liquid lithium systems
  - Safety issues
  - Impact on diagnostics and heating systems
  - Motion of the liquid during PF ramps, disruptions, halo current strikes
  - Cleanup: 
- Present system is a full toroidal liquid lithium belt limiter
  - Experiments will continue through 2003.

CDX-U lithium tray limiter installed Spring 2001

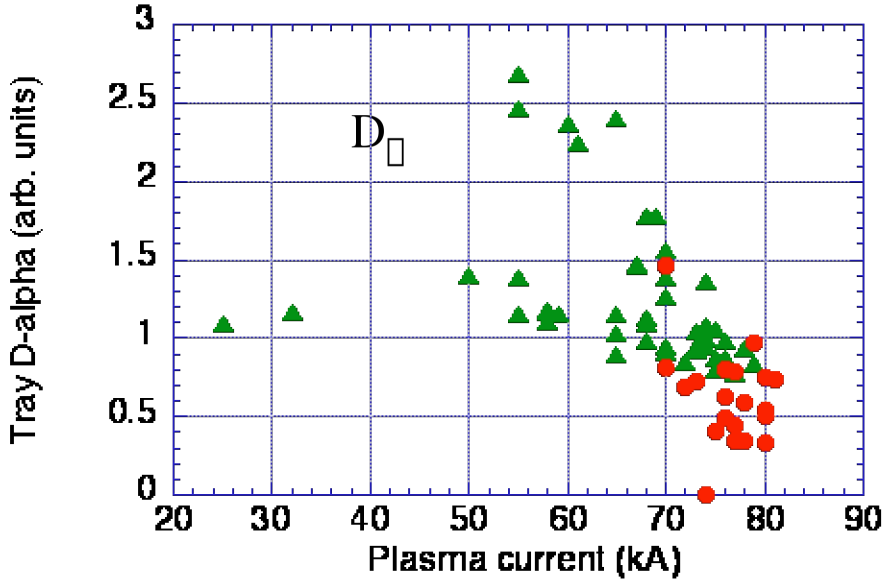


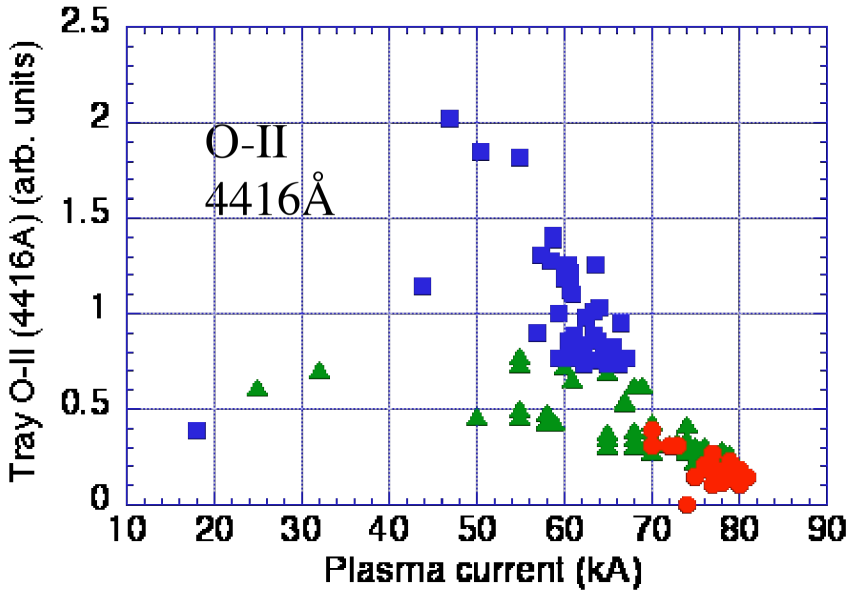
- Discharges run on bare SS tray to establish baseline prior to lithium filling
- 34 cm major radius, 10 cm wide, 0.64 cm deep
- Fabricated in two halves with a toroidal electrical break
  - -Isolated from vessel
  - -Halves connected to electrical feedthroughs
- Heaters beneath for temperature control up to 400°C. Typ. ops 200 - 250°C
- TiC coated heat shield on center stack
- Heat/lithium shield between tray and lower vacuum flange
- Tray temperature monitored with thermocouples around edge

Liquid lithium PFCs reduce $D_{\square}$, oxygen emission

● Liquid lithium in tray (250° C)
▲ Cold lithium in tray
■ Bare stainless steel tray

- $D_{\square}$ data not available for the bare stainless steel tray



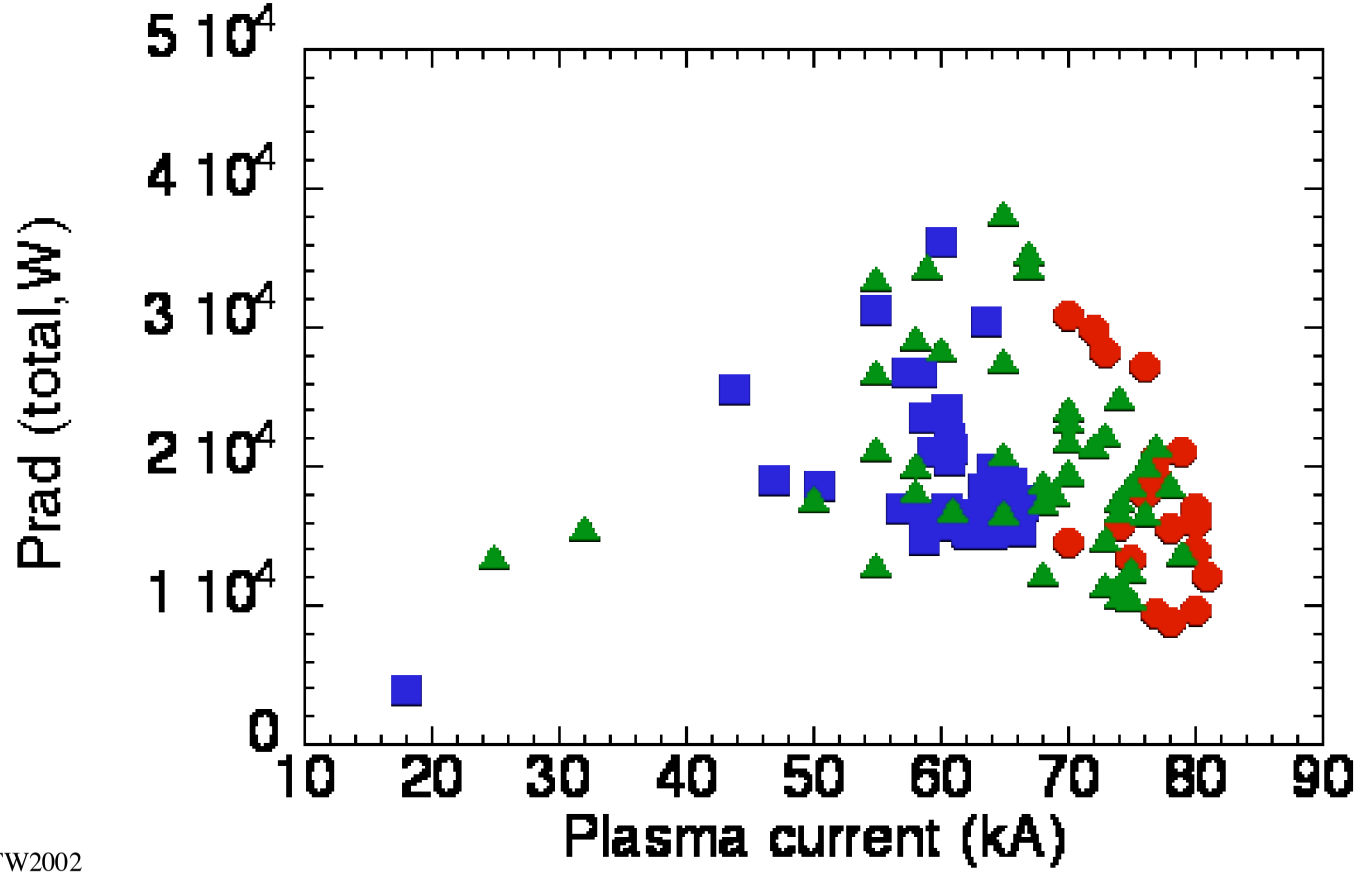


Data from the ORNL tray filterscope

Total radiated power is slightly reduced for discharges limited on liquid lithium

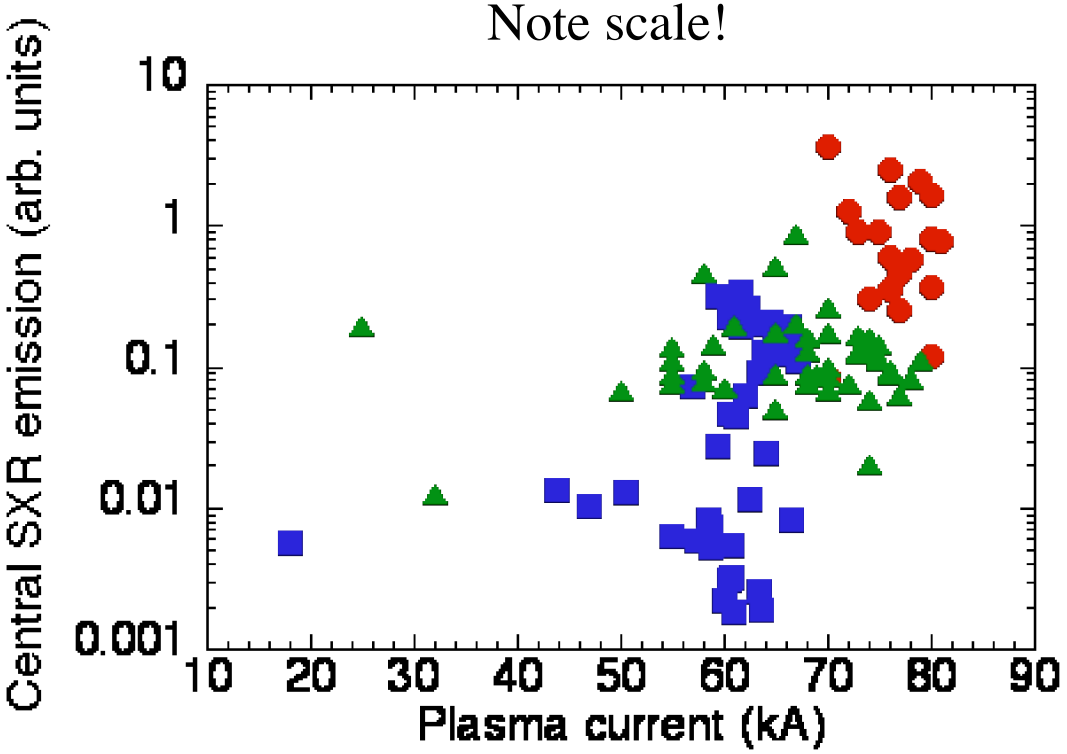
- Data from Johns Hopkins tangential bolometer

● Liquid lithium in tray (250° C)
▲ Cold lithium in tray
■ Bare stainless steel tray

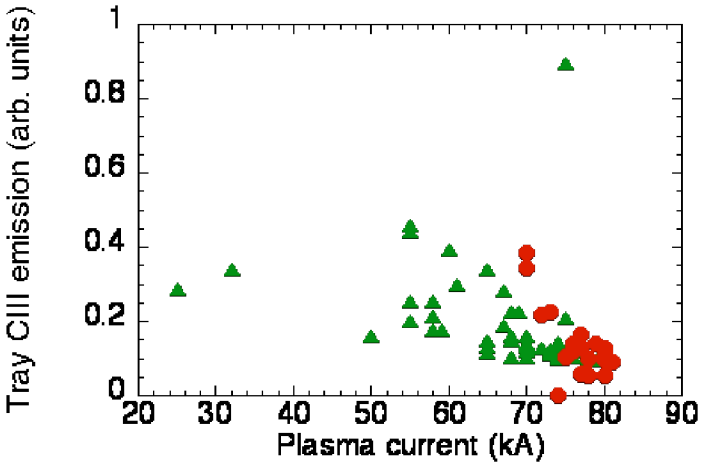


Central soft x-ray emission indicates that plasmas limited on liquid lithium have higher core T_e

Note scale!



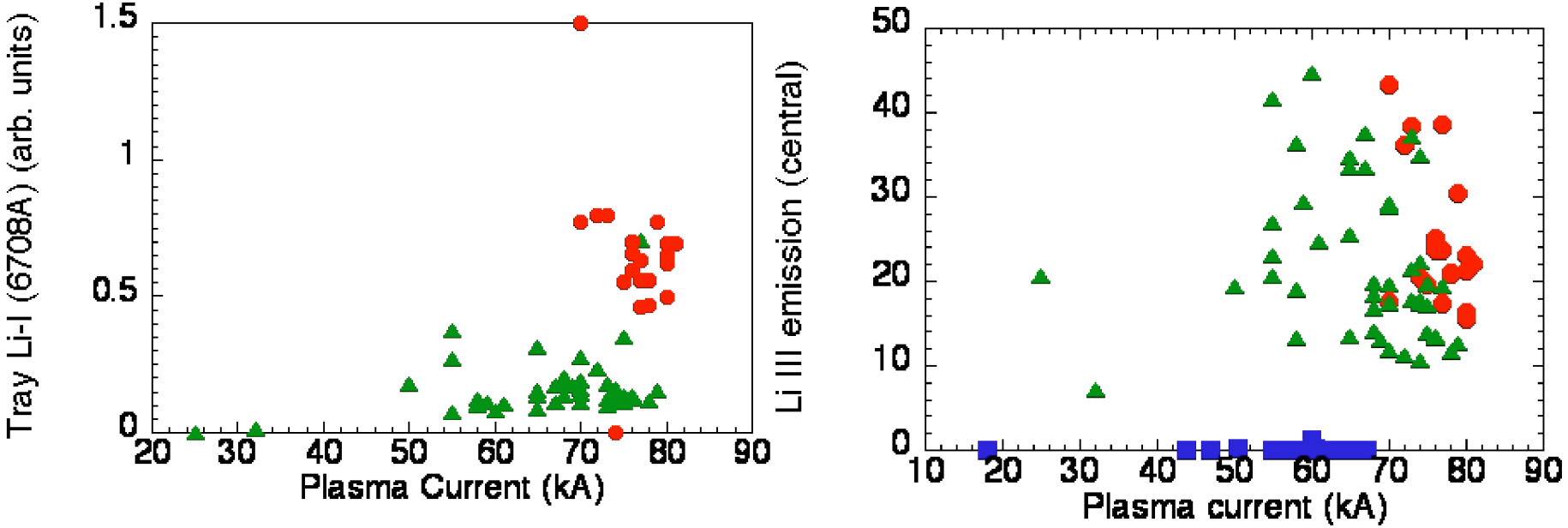
- Edge carbon emission indicates that rise in emission is not due to a carbon influx



● Liquid lithium in tray (250° C)
▲ Cold lithium in tray
■ Bare stainless steel tray

Edge, core lithium spectroscopy indicate some lithium influx

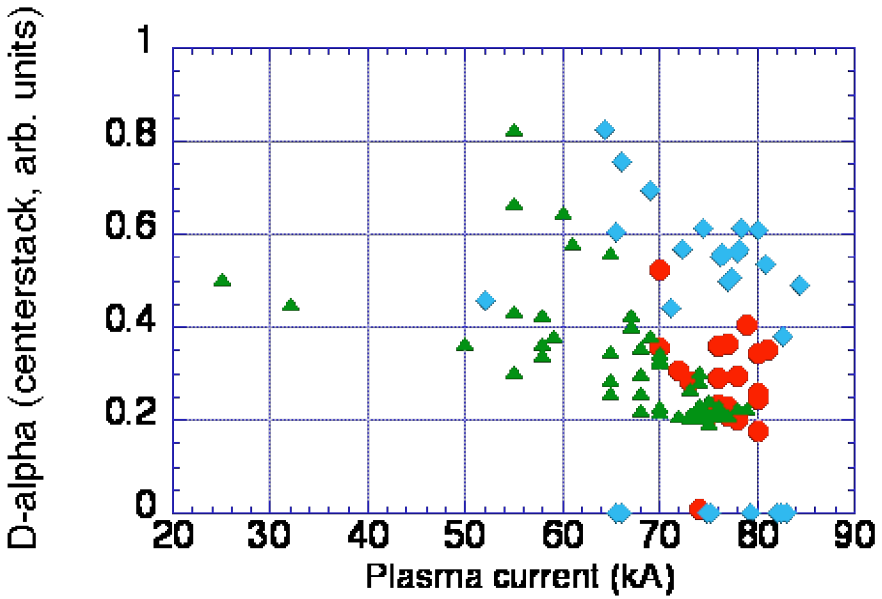
- Core lithium emission does not increase with liquid lithium operation, compared to the solid.
  - T_e increase complicates interpretation

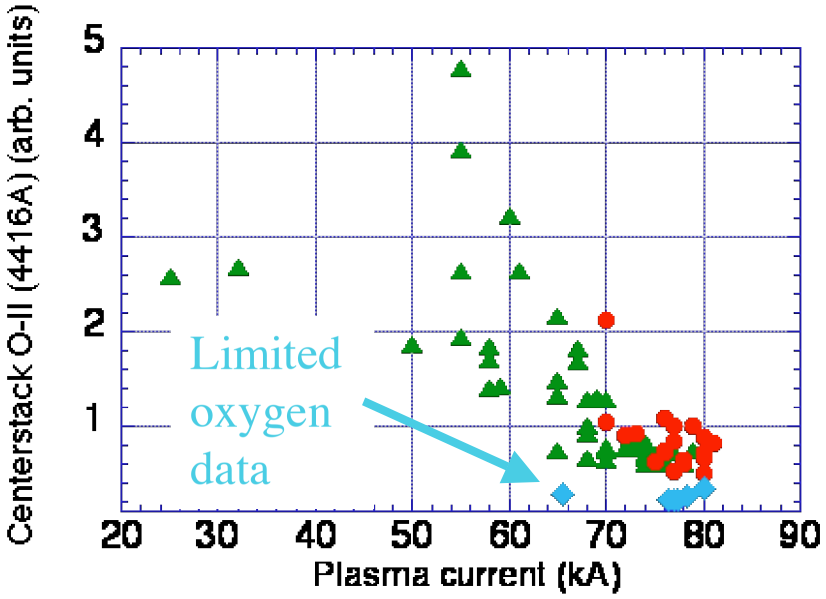


● Liquid lithium in tray (250° C)
▲ Cold lithium in tray
■ Bare stainless steel tray

Vessel interior was coated with lithium during Dec 01 Recycling, impurity results compared with tray data

- Spectroscopy of edge plasma visible light emission at the centerstack indicates that cold, solid lithium coatings saturate in CDX
  - Possible lithium deuteride formation
  - Do not reduce recycling during a discharge
- Cold coating DOES strongly reduce oxygen in discharge





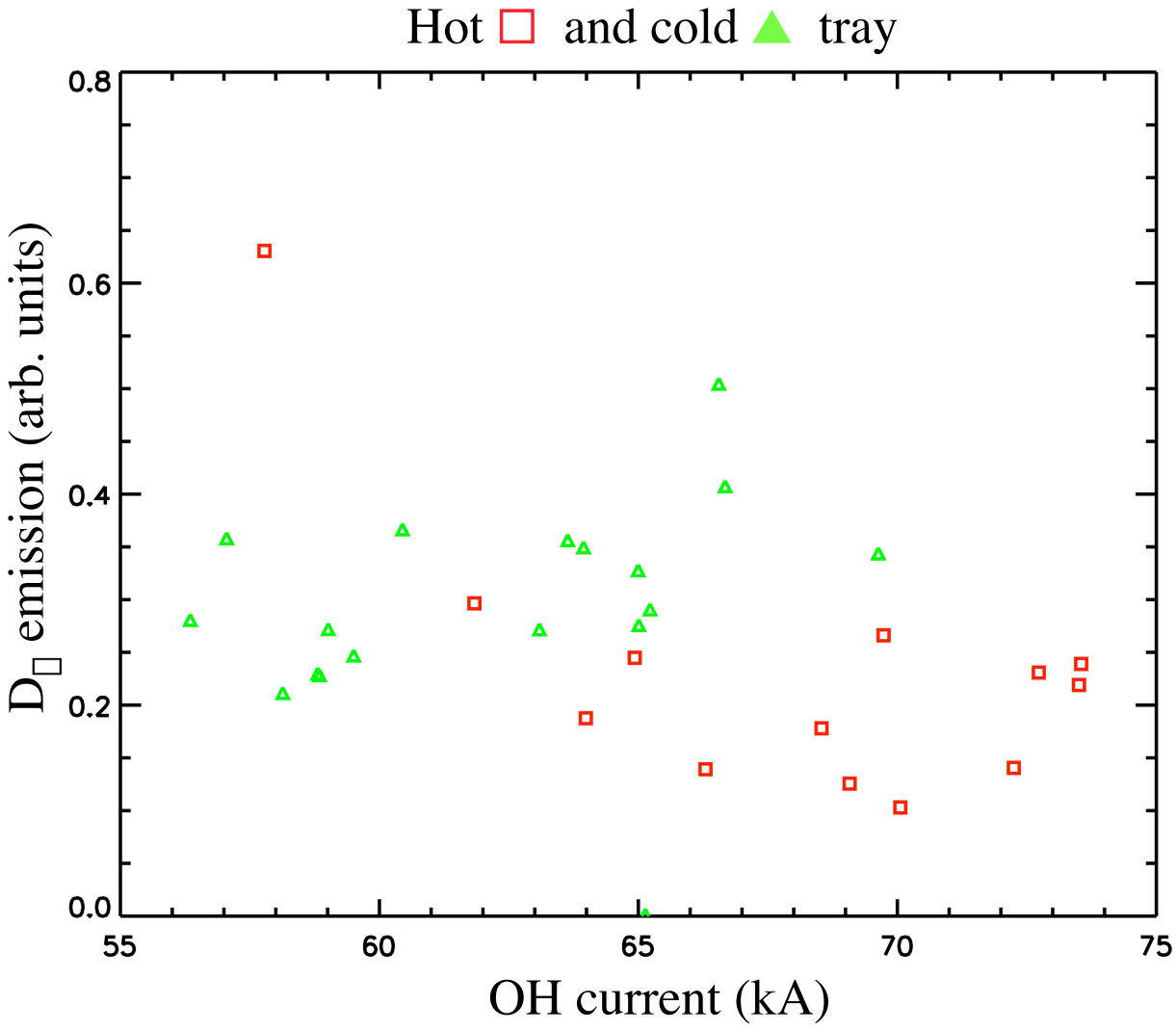
● Centerstack emission with hot tray

▲ Centerstack emission with cold tray

Centerstack emission with coated centerstack (cold tray)

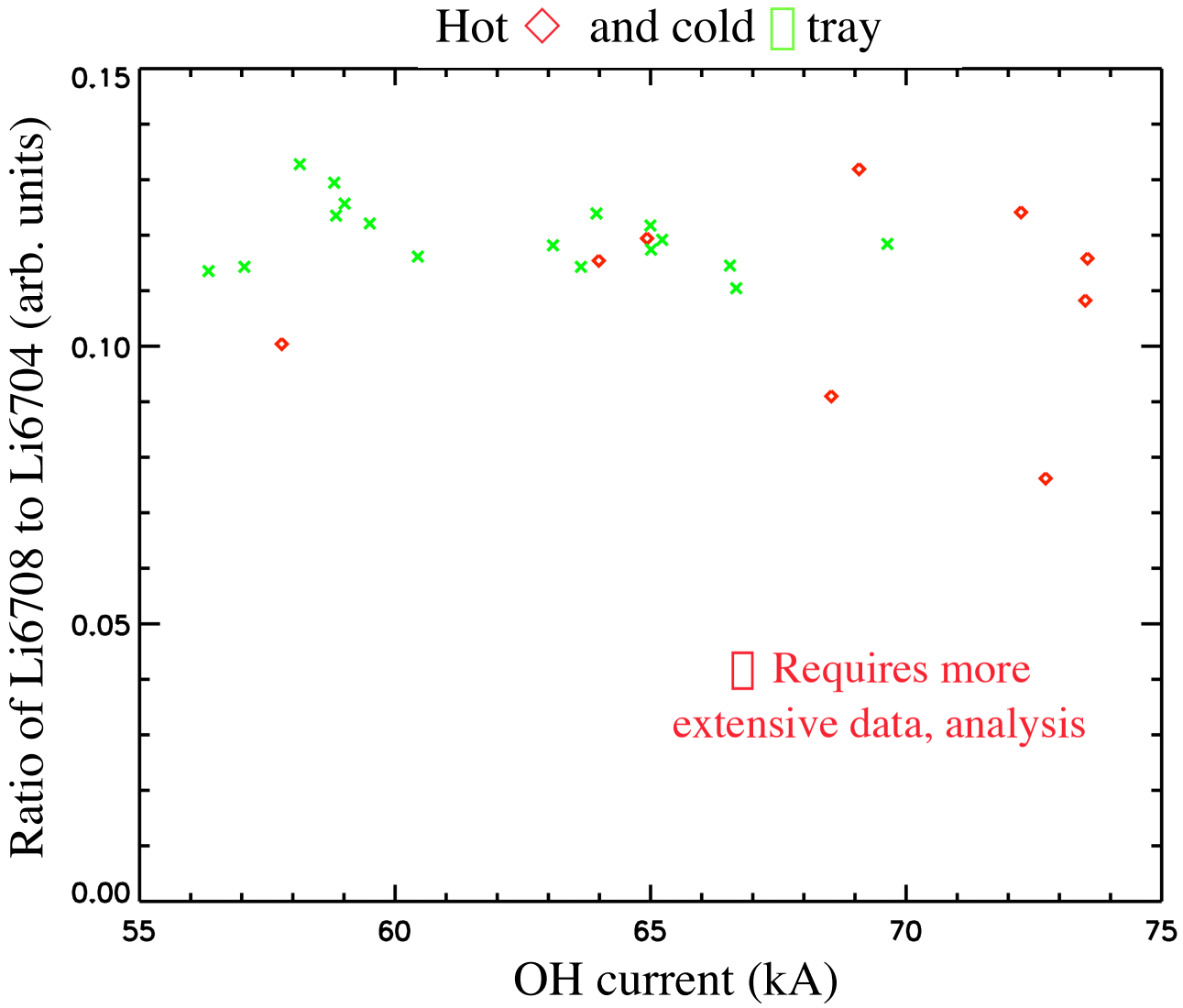
Reduction in tray $D_{\square}$ was less apparent after ~6 months operation

- Data taken after overnight argon glow (original data followed 24 hour glow)



New spectroscopy yields no evidence for an increase in edge T_e local to the tray

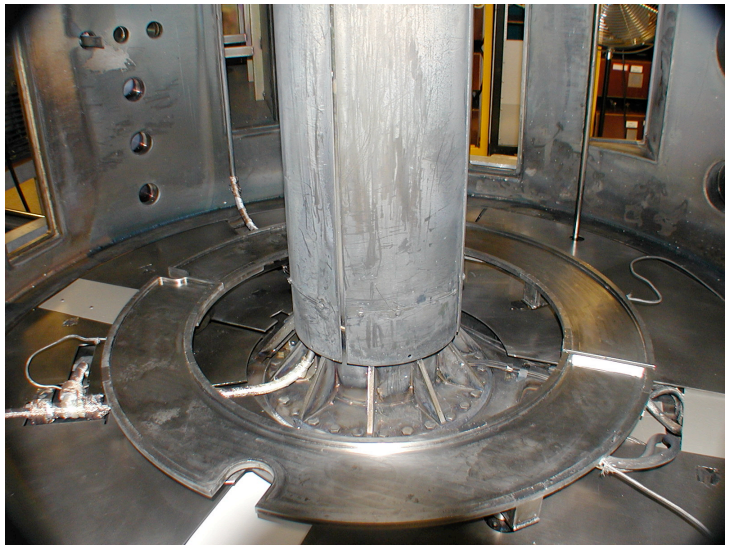
- Lithium 6708/6704 line ratio is sensitive to the electron temperature.



CDX-U vented for tray cleaning

After vent but before cleaning

After cleaning

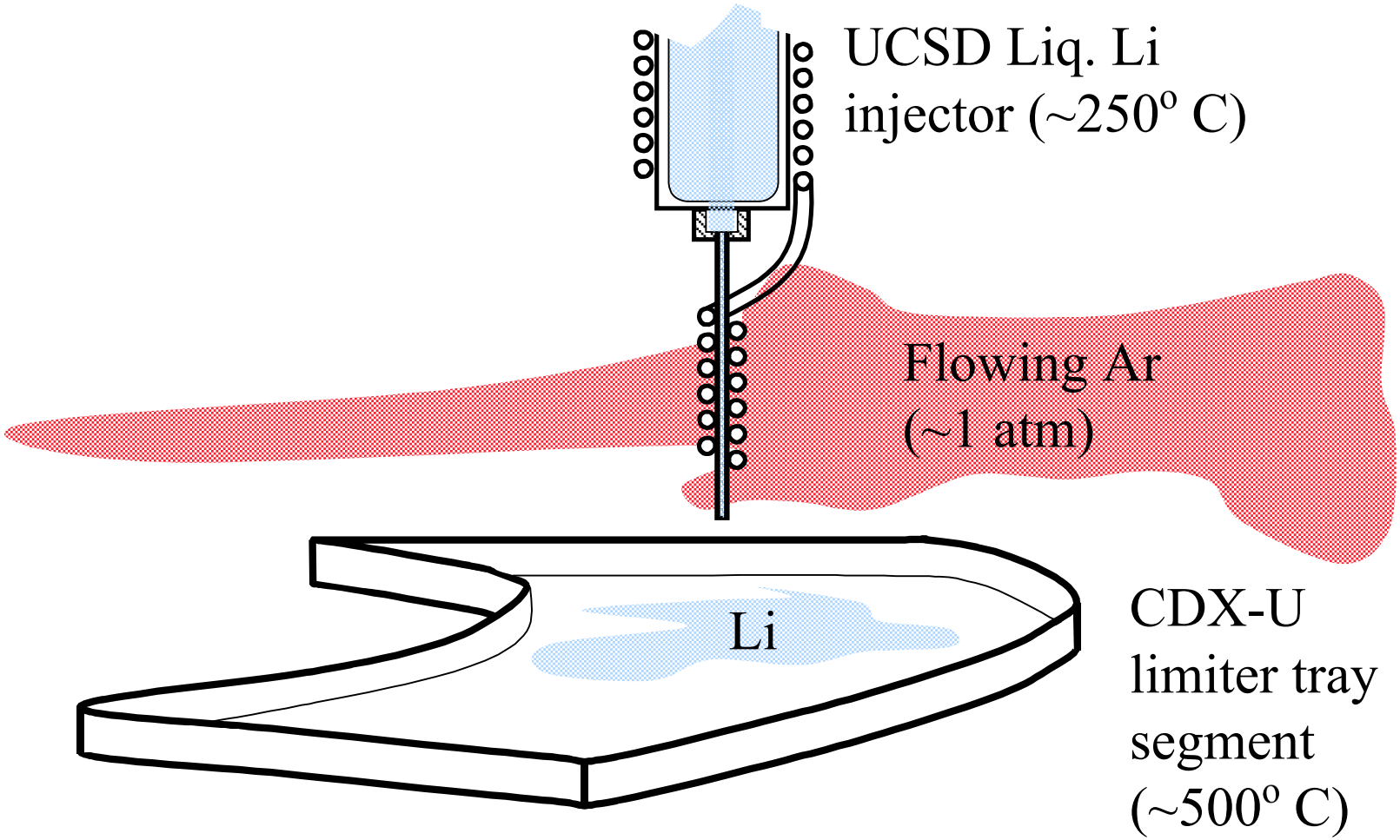


- Prior to vent, sodium hydroxide added to tray in attempt to promote wetting
  - No significant effect on wetting
  - Reaction products obvious on tray
- Air circulated through vacuum vessel for several days
- Lithium hydroxide distribution indicates lithium covered most of tray
- Coating well adhered - reaction between lithium and stainless steel?
  - Complicated by sodium hydroxide experiment

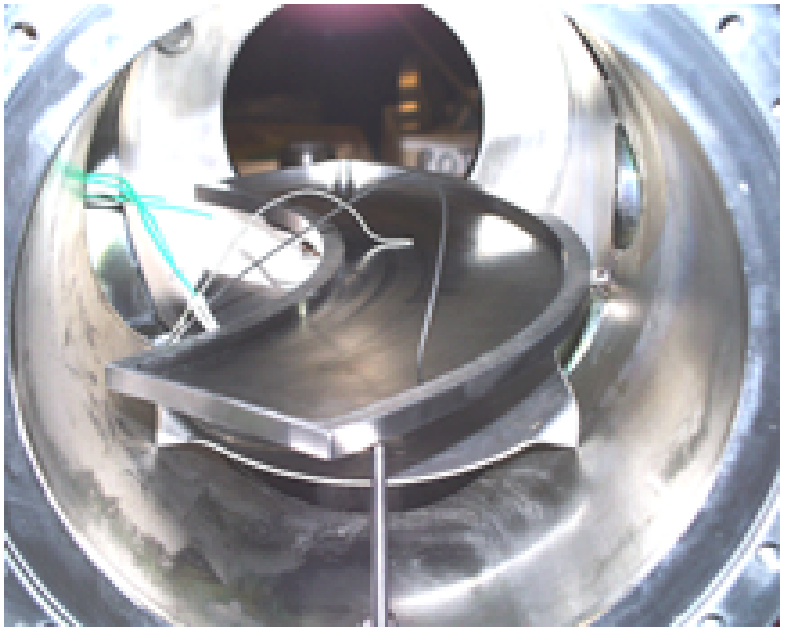
Next step is to achieve more uniform lithium layer in tray by filling with liquid instead of solid lithium

- Difficult to remove impurity layer on solid lithium pieces
- Flow over tray surface will improve with liquid lithium
- Liquid lithium still requires special conditions
  - Fill must be performed under flowing argon atmosphere
    - » Minimize lithium hydroxide formation
    - » Inhibit window, vessel coatings
- Other plans:
  - Explore high Mach number gas jets for “core” fueling
  - OH system improvements
  - Implement ESC modeling of equilibria

Schematic of UCSD liquid lithium injector concept

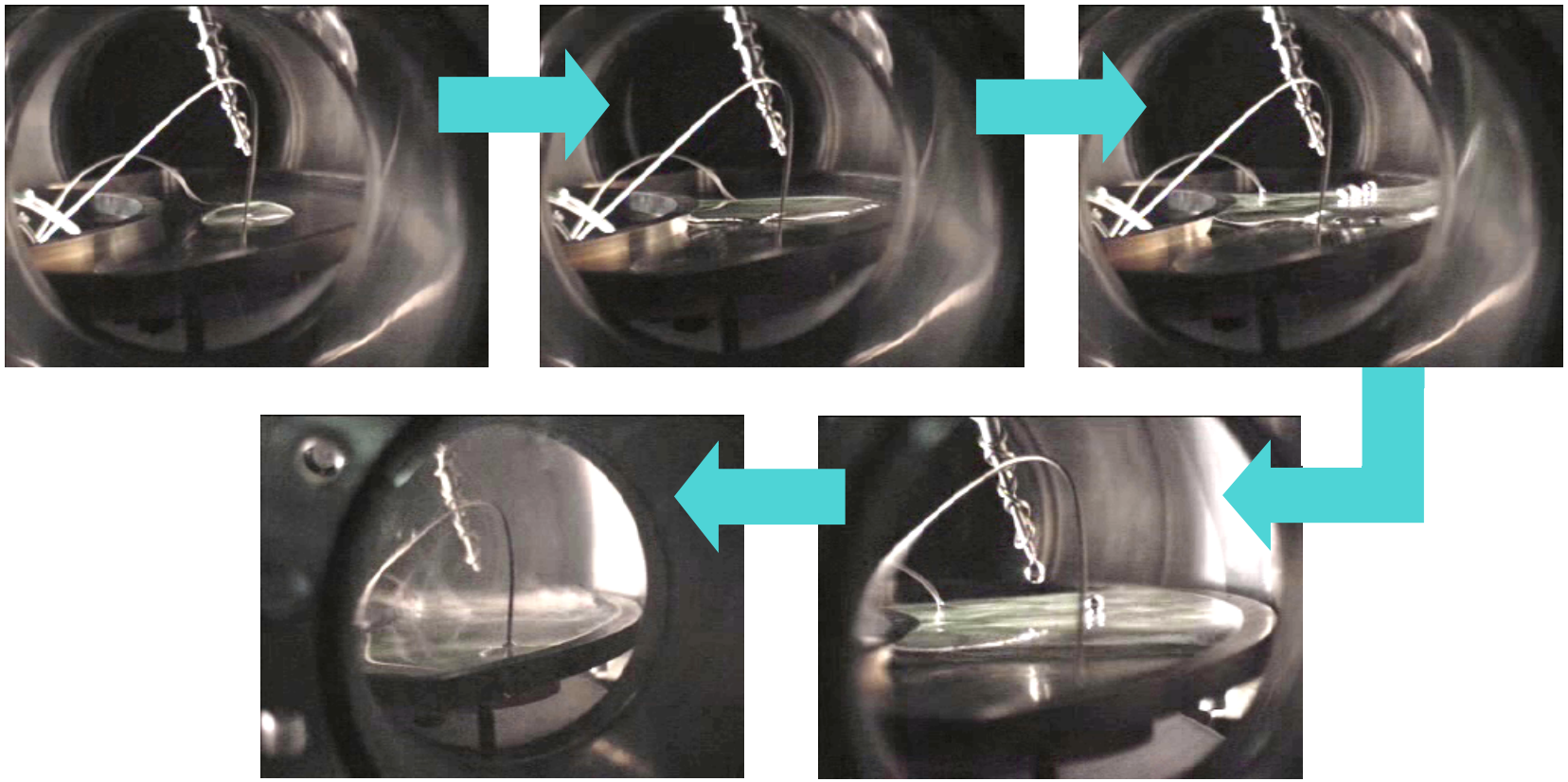


Liquid lithium filling technique demonstrated with mockup of CDX-U limiter tray

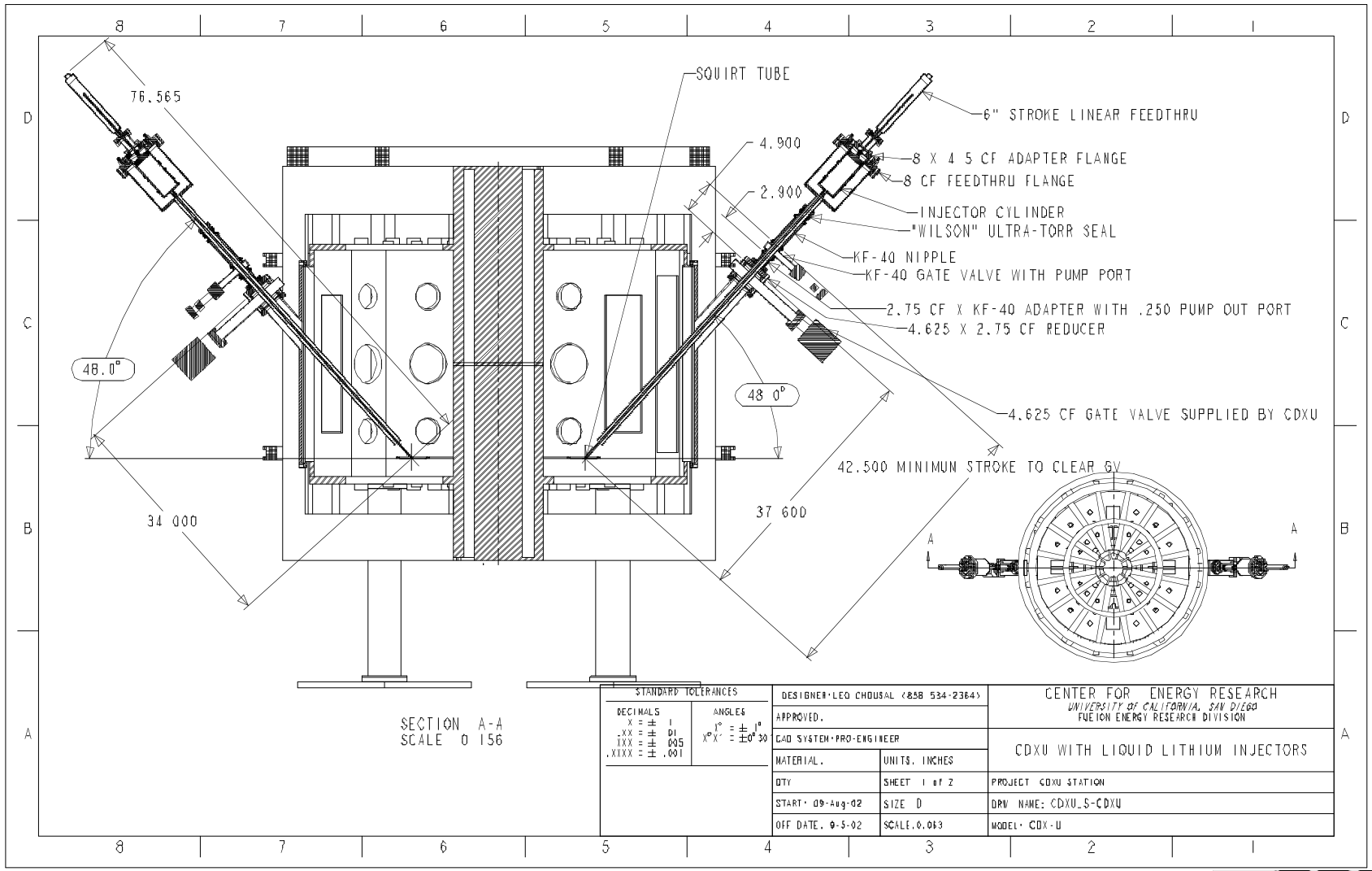


- Mockup has one-fourth of total area of CDX-U limiter tray
  - View from below shows heaters identical to those used in CDX-U tray
- Position of mockup in test chamber at UCSD
  - CDX-U tray and mockup both made of stainless steel

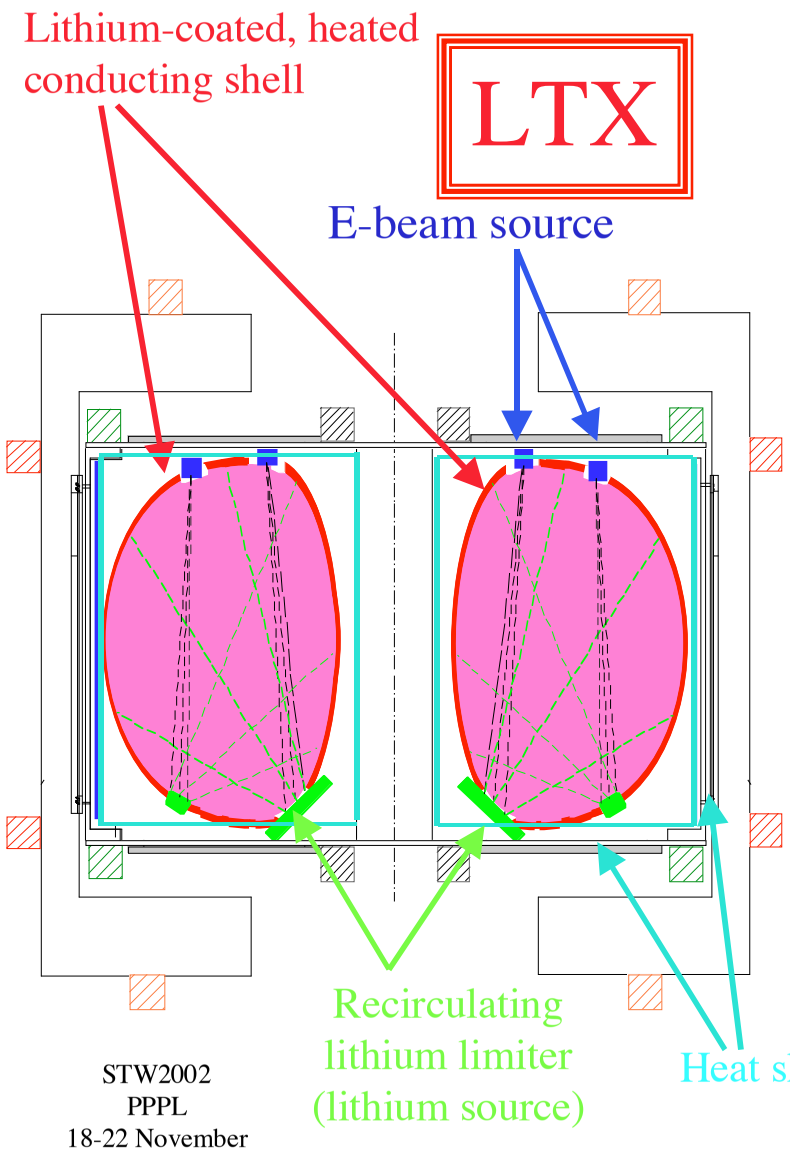
Liquid lithium spreads across surface of CDX-U limiter tray mockup



Liquid lithium will be injected into both halves of toroidal limiter tray from two locations on CDX-U



Summary



- Implementation of liquid lithium PFCs has been shown to be feasible
- Liquid lithium PFCs are found to reduce recycling and impurities
  - Enhanced tokamak performance
  - Effect still observed in CDX-U nearly a year after original lithium loading
- Cleanup, recovery was straightforward
- A new tray was installed earlier this year.
  - New filling technique to be implemented (PISCES-B group, UCSD)
  - New discharge cleaning techniques
- We have further proposed the extension of these experiments to a device with full lithium walls - the Lithium Tokamak eXperiment (LTX)