NSTX-U Boundary Physics Operations Status Overview

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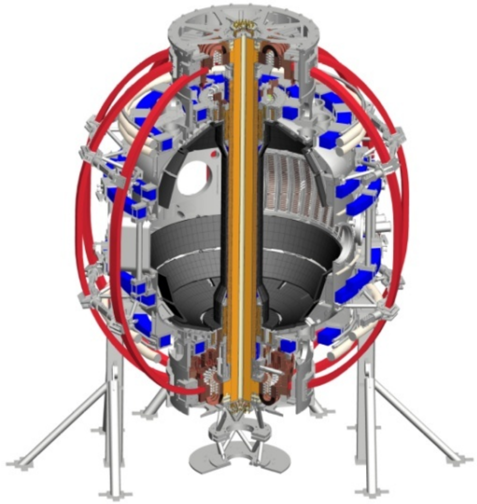
NSTX-U Operations/Diagnostics Status Meeting

January 28, 2015



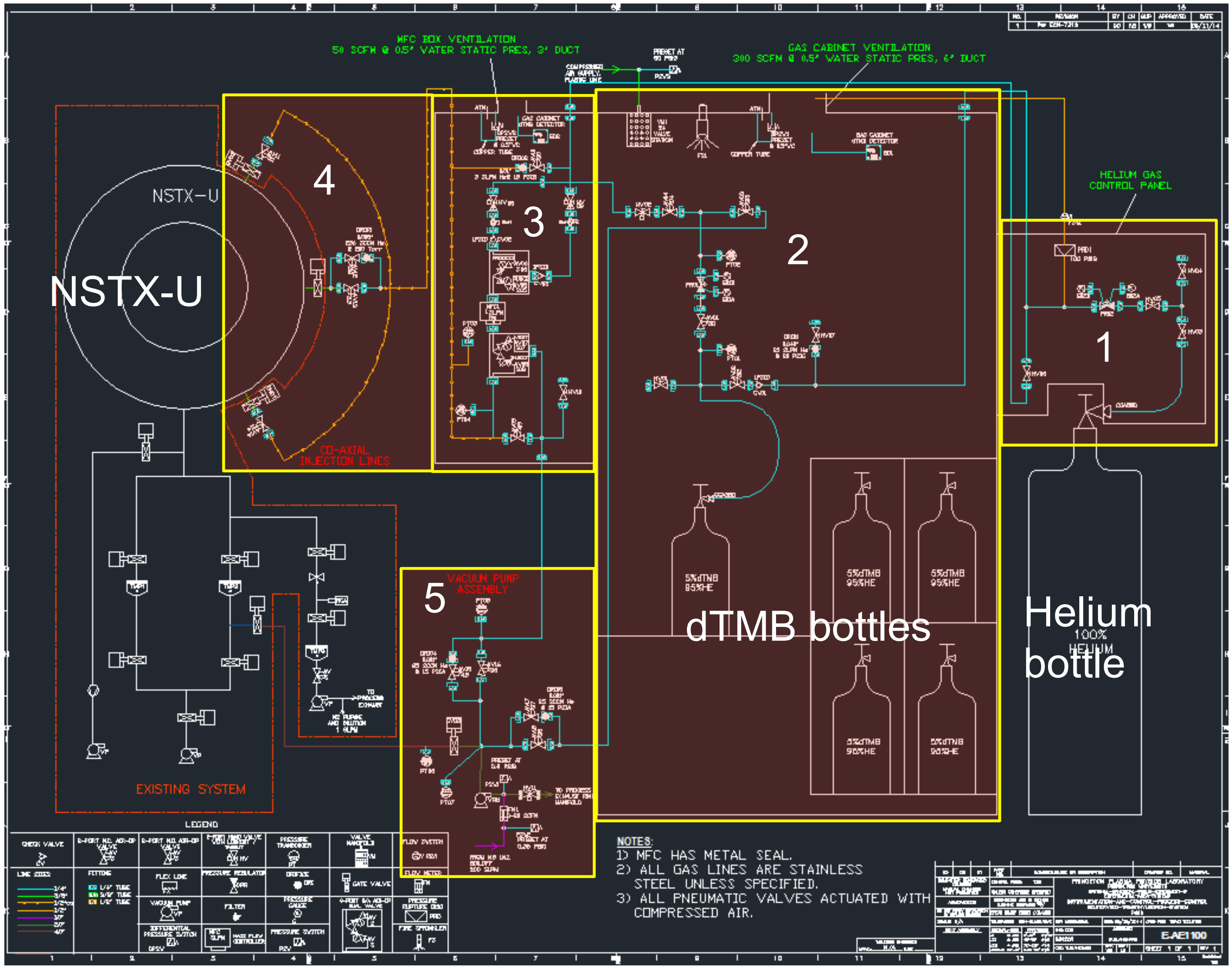
Topics to be covered

1. Systems for conditioning plasma-facing components (PFCs)
   - Deuterated Trimethylborane (dTMB) system
   - LIThium EvaporatoRs (LITERs)
2. Lithium Granule Injector (LGI)
3. Boundary physics diagnostics
   - Langmuir probe (LP) arrays
   - Fast thermocouples (TCs)
   - Materials analysis and particle probe (MAPP)

New system to be available for conditioning with deuterated trimethylborane - dTMB

Five major sub-assemblies:

1. Helium control panel
2. dTMB gas cabinet
3. Master Flow Control (MFC) box
4. Coaxial injection lines
5. Vacuum pumping assemblies

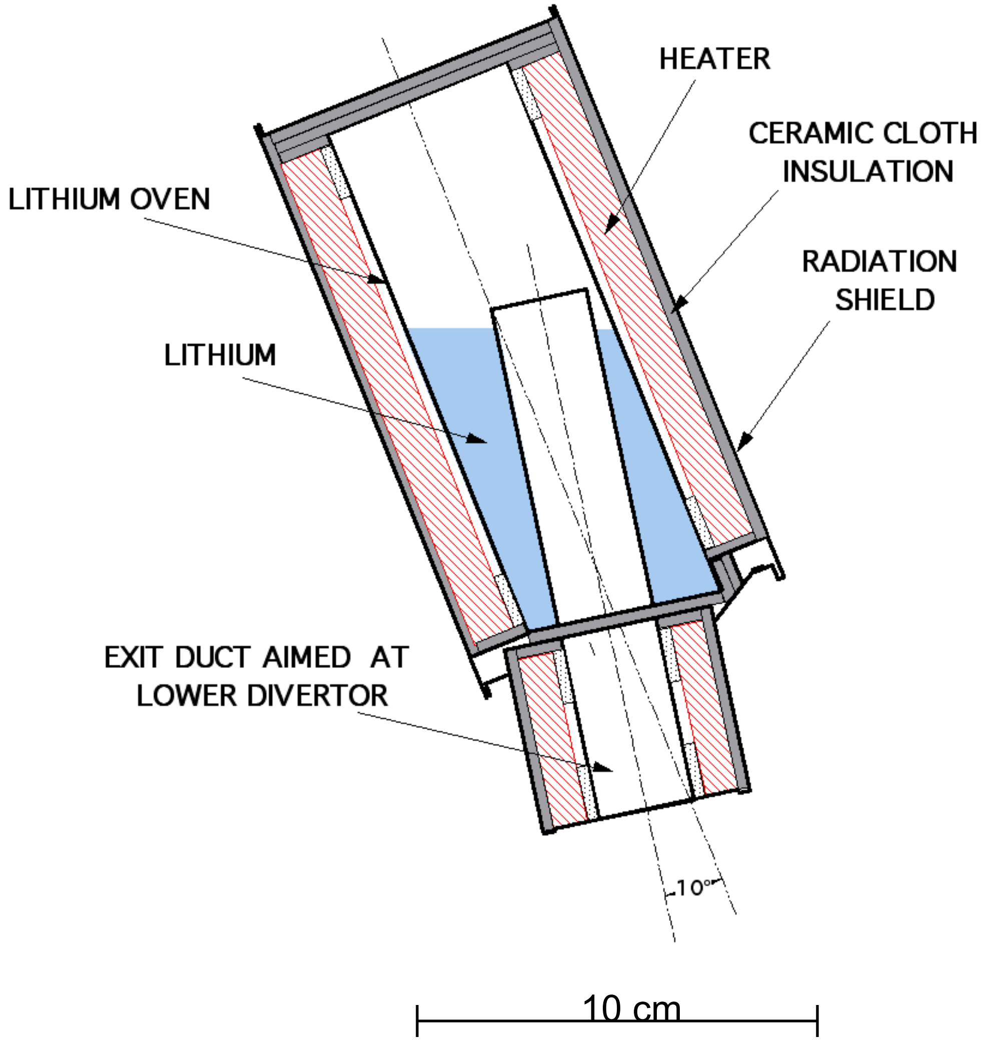


- D. Cai, dTMB System Final Design Review, September 17, 2014

dTMB procedure well-established but schedule issues persist

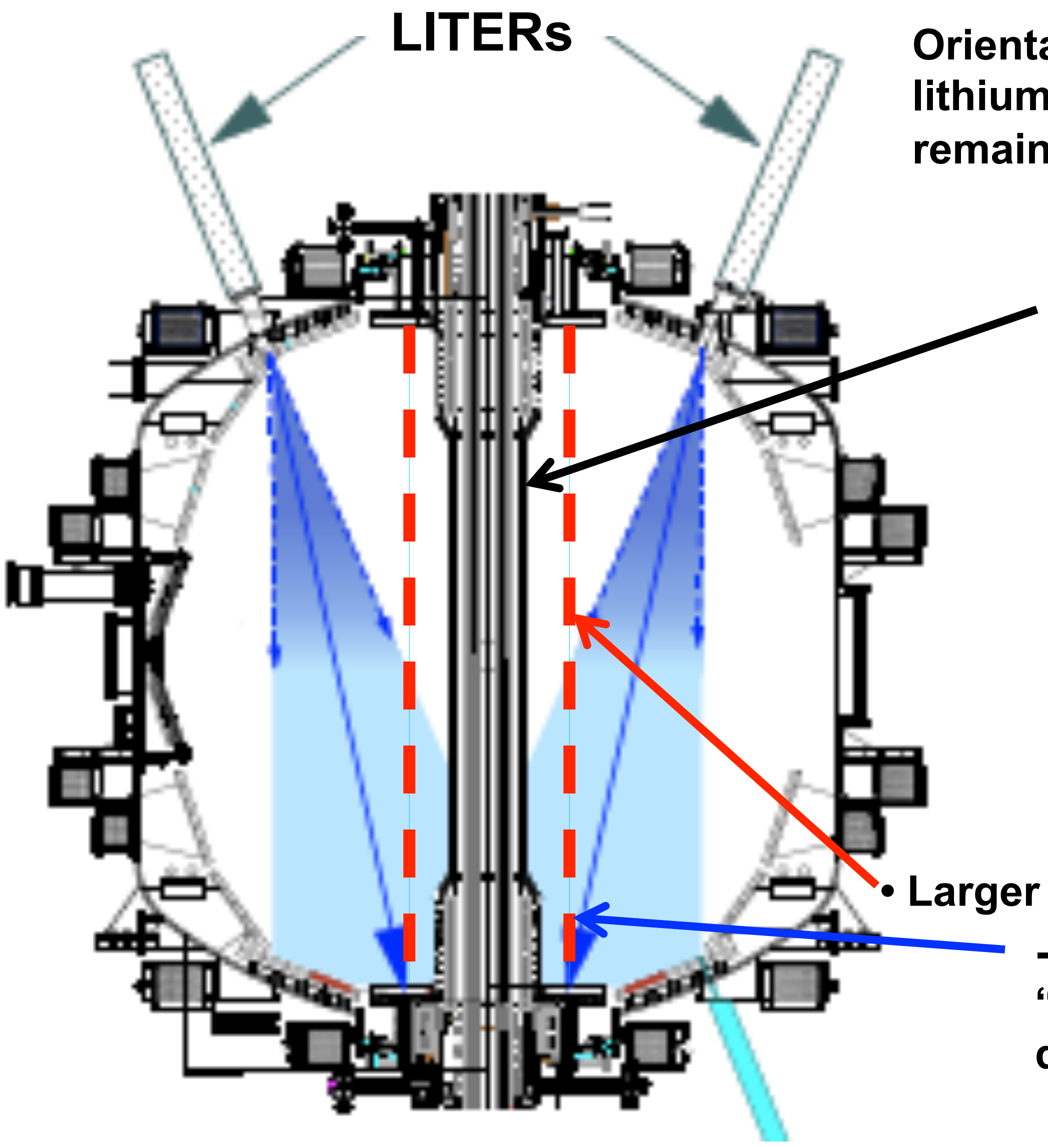
1. **Procedure:**
   - Initiate helium glow discharge cleaning (He-GDC) initiated – system also allows "between shots" GDC
   - Add gas mixture of 95% helium and 5% deuterated trimethyl boron (dTMB) - $B(CD_3)_3$ - to gas feed for He-GDC – three carbon atoms for every boron atom
   - Perform GDC for ~160 minutes or about until 90% of gas bottle containing 10g of dTMB consumed
   - Results in film on order of tens of nanometers consisting of boron, carbon, and deuterium resulted
2. **Schedule issue:**
   - Gas line installation delayed by several weeks due to welding for unexpected neutral beam piping repair

LIThium EvaporatoRs – LITERS – be used to direct lithium vapor with same exit ducts as used on NSTX



- Capacity: 90 g Li
- Oven Temp: 600-680°C
- Rate: 1mg/min - 80mg/min

Larger diameter center stack means new lithium deposition pattern on PFCs



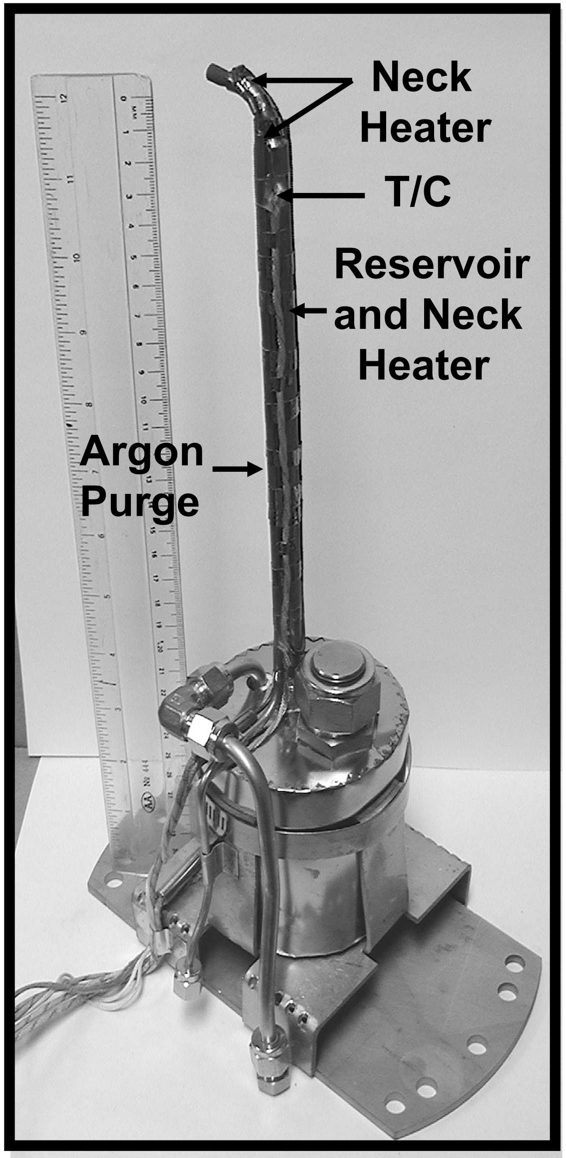
Orientation of exit tubes for lithium evaporators – LITERs – to remain unchanged for NSTX-U

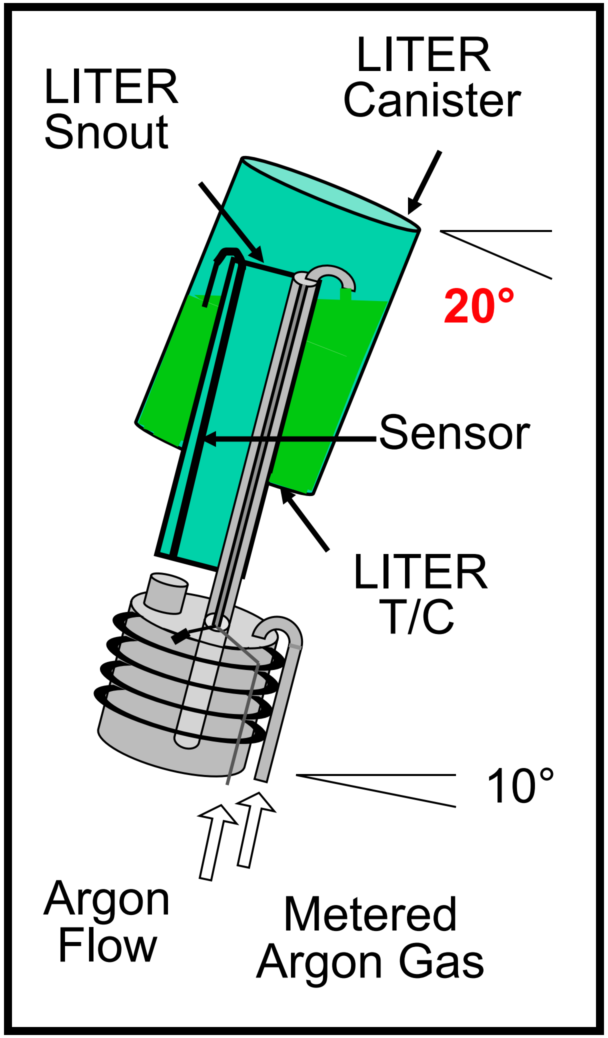
- Larger diameter of new center stack
  - More lithium coverage for "vertical" section of inboard divertor

Re-use of existing LITERs not without challenges

1. LITERs removed at start of outage with torus interface valves – TIVs – left in place
2. Mounting brackets that enable reinstallation without realigning LITERs removed to allow welding of new upper umbrella plate – just finished this week
3. New mounting brackets fabricated but could not be welded into place until completion of umbrella work
   - Each of four LITERs – including two spares – need to be inserted into NSTX-U first for test fit under vacuum
4. Apparatus for loading LITERs - Liquid Lithium Filler liTER or LIFTER - needs to checked and filling procedure updated
   - Modifications to improve safety in progress

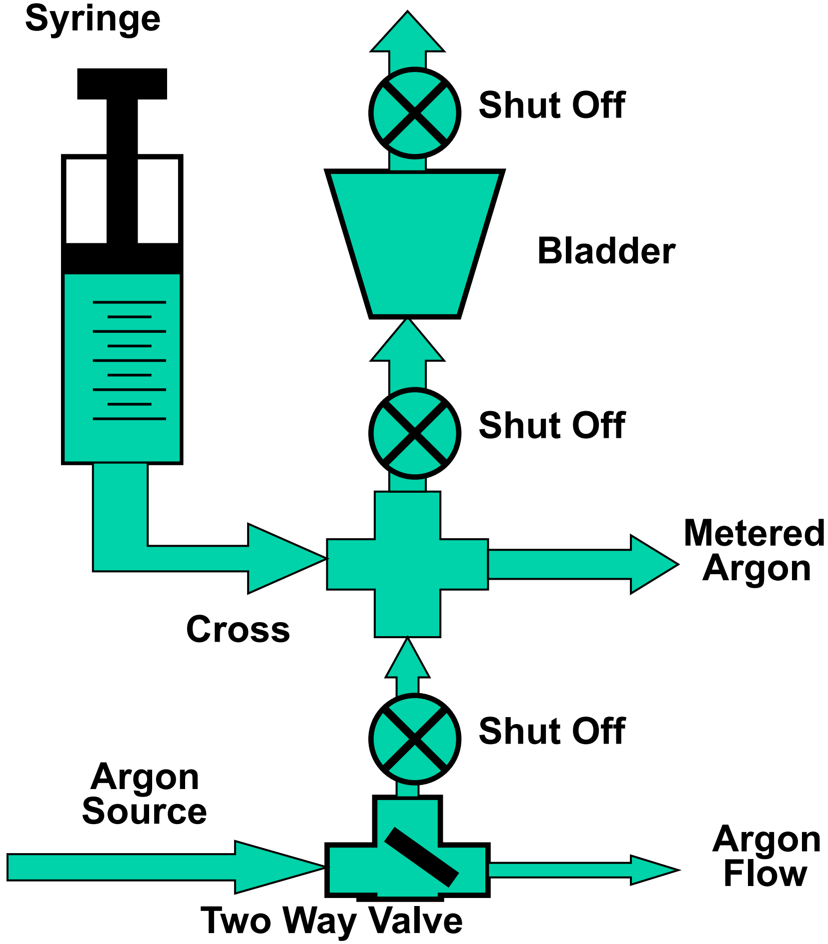
LIFTER originally developed by John Timberlake to increase lithium fill fraction for LITERs



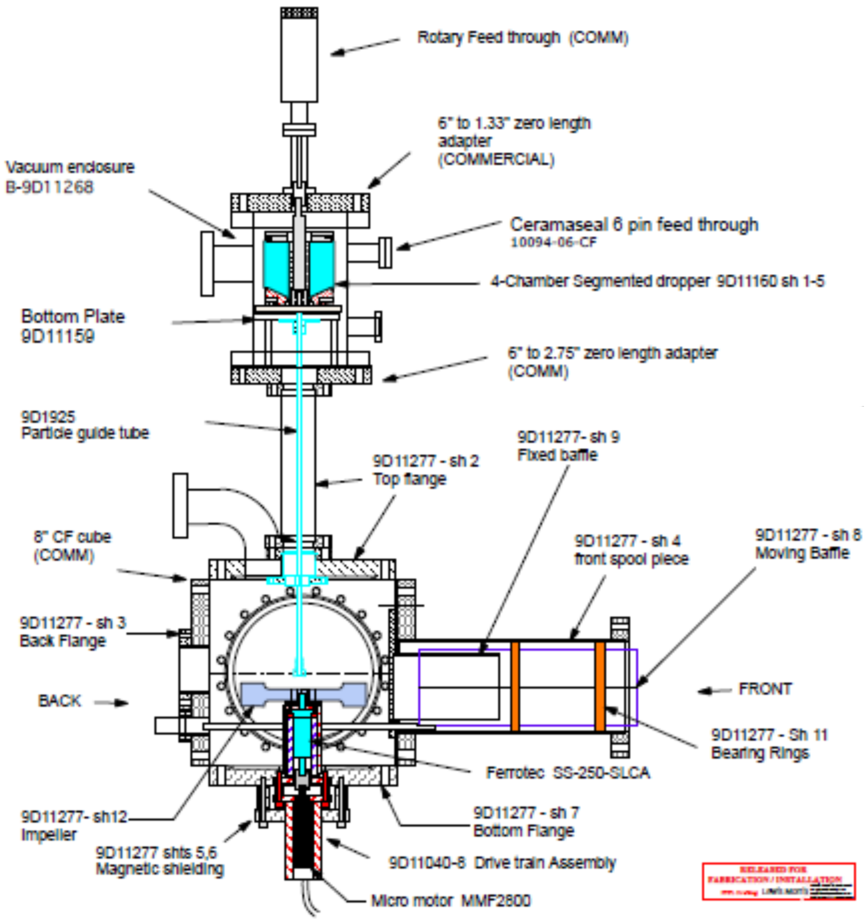


LIFTER issues being addressed

1. Needs more complete documentation
   - Piping & instrumentation diagram (PID)
   - New procedure that includes specification of personal protective equipment (PPE) for liquid lithium handling
2. May also need to replace tubing and plastic components
   - Syringe and bladder in argon propellant gas line that might leak after extended us
3. Backup is to use solid lithium
   - Filling liquid lithium divertor – LLD – no longer required



Lithium Granule Injector – LGI – identical to system presently in use for inducing ELMs in DIII-D plasmas



Available pellet sizes (approximate)
900µm, 700µm, 500µm, 300µm*

Proposed Pellet Composition
Lithium, Boron Carbide*, Graphite*

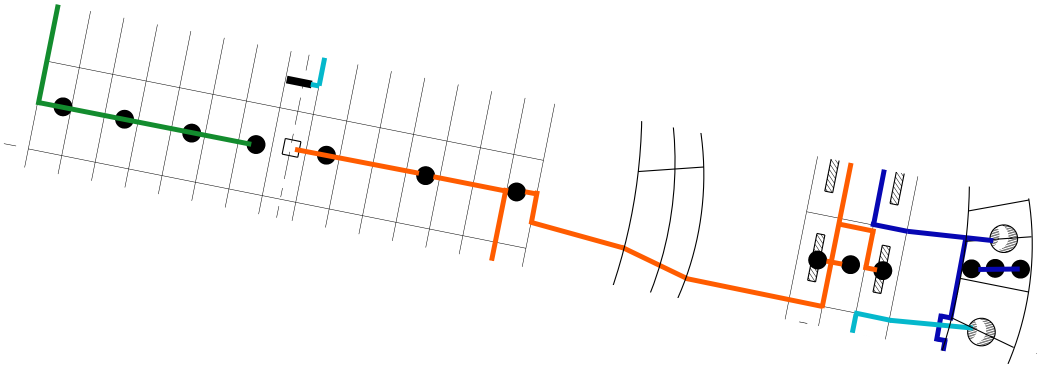
Pellet Injection Velocity
50 – 150 m/sec

Pellet to Pellet Injection Frequency
100 – 500 Hz

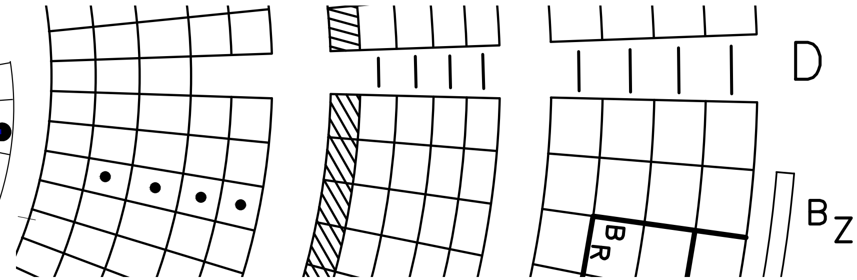
(*Contingent on shop availability for "precision fabrication" of new segmented dropper assembly in order to be ready for FY2015 run)

Granule supply is also issue – arrangements being negotiated for fabrication at the University of Illinois

Additional Langmuir probes installed to increase poloidal coverage in divertor region

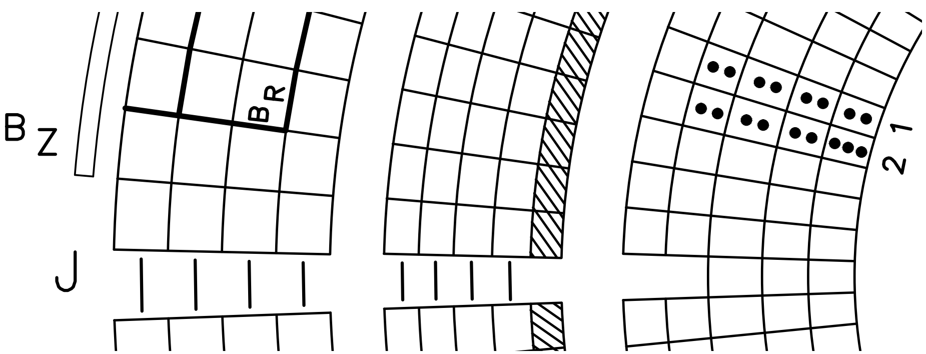


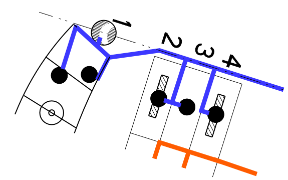
Bay D – Langmuir probe locations on lower half of center stack vertical section and inboard divertor



Bay D – Langmuir probe locations on outboard divertor

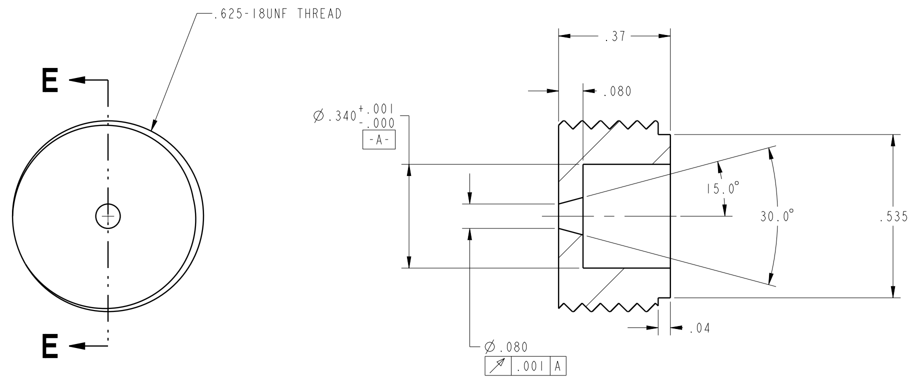
Bay J – Langmuir probe locations on outboard divertor





Bay L – Langmuir probe locations horizontal and vertical sections of inboard divertor

Langmuir probe design same as on NSTX



Probe plug diameters reduced to allow more sensors in PFC tiles

- **Re-use as many cables, bipolar operational amplifier bias supplies and signal generators as possible**
- **Fast thermocouples also reinstalled in new tiles at original locations on NSTX prior to upgrade**

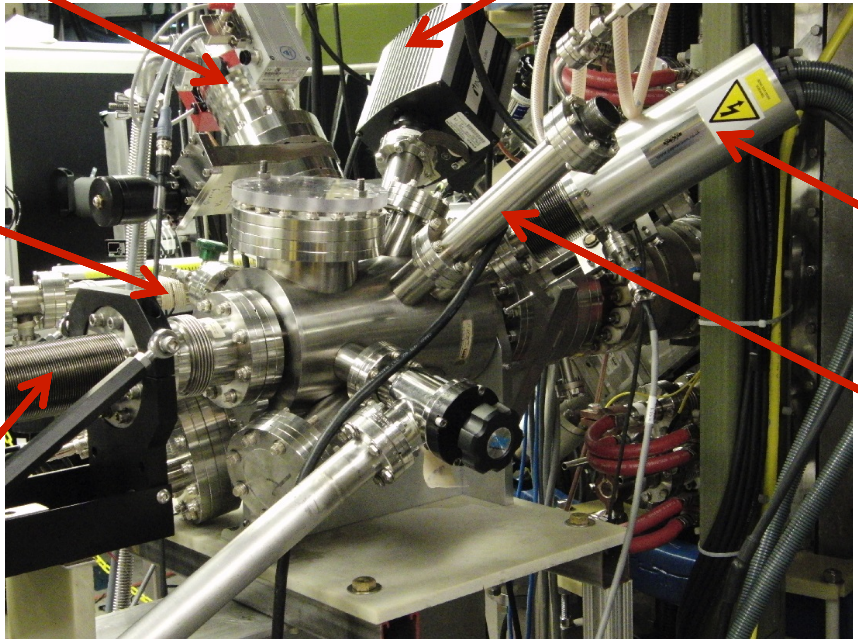
Tips – under protective covers - protrude 1 mm above tile faces

Materials Analysis and Particle Probe – MAPP – provides *in situ* information on PFC surfaces

Turbopump

Residual gas analyzer

Hemispherical analyzer and microchannel plate detector



X-ray source (Mg Ka, Al Ka)

Ion source (He, Ne, Ar)

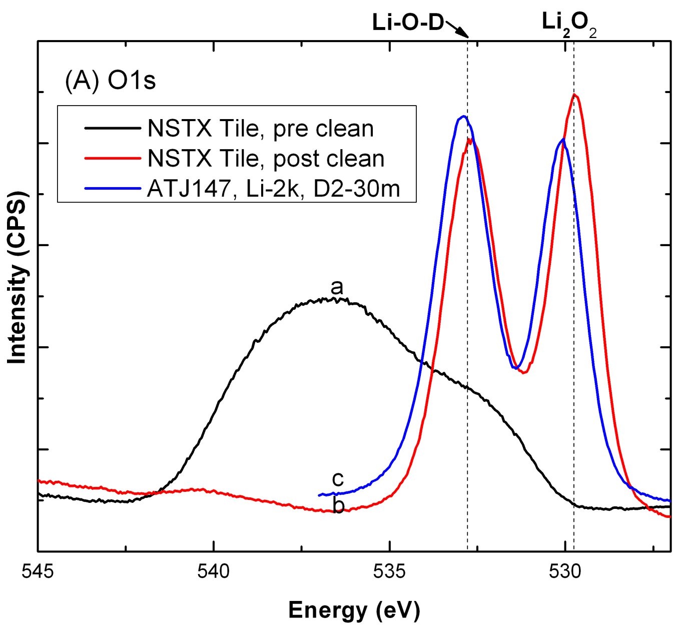
Translation bellows with attached rotary feedthrough

Analysis Technique	Fundamental Information	Status
X-ray photoelectron spec. (XPS)	Elemental/chemical state analysis	Operational
Thermal desorption spec. (TDS)	Binding E of surface volatiles	Operational
Low-E ion scattering spec. (LEISS) Direct Recoil Spectroscopy (DRS)	Impurities with LEISS and H with DRS in forward scattering geometry	In development

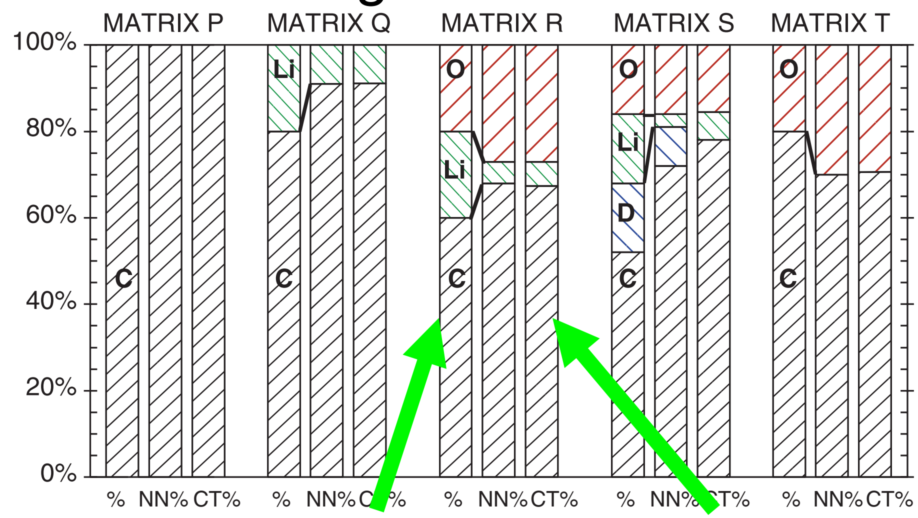
Need to correlate PFC characteristics with "good" plasma conditions

Detailed surface analysis and QCMD modeling explain behavior of lithium-coated NSTX PFCs

- Post-run surface analysis of NSTX tiles detect complexes involving lithium, oxygen, and deuterium



- Quantum-classical molecular dynamics modeling indicates that oxygen dominates bonding of incident deuterium



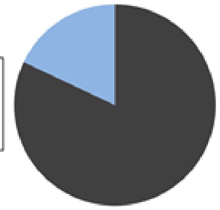
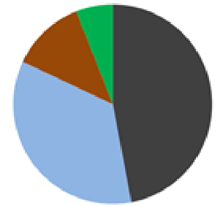
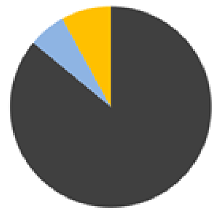
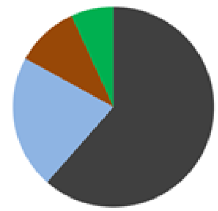
Atomic composition of matrix

Fraction of D sharing charges with matrix constituents

MAPP expected to make such studies easier because PFCs can be analyzed immediately after exposure to plasmas

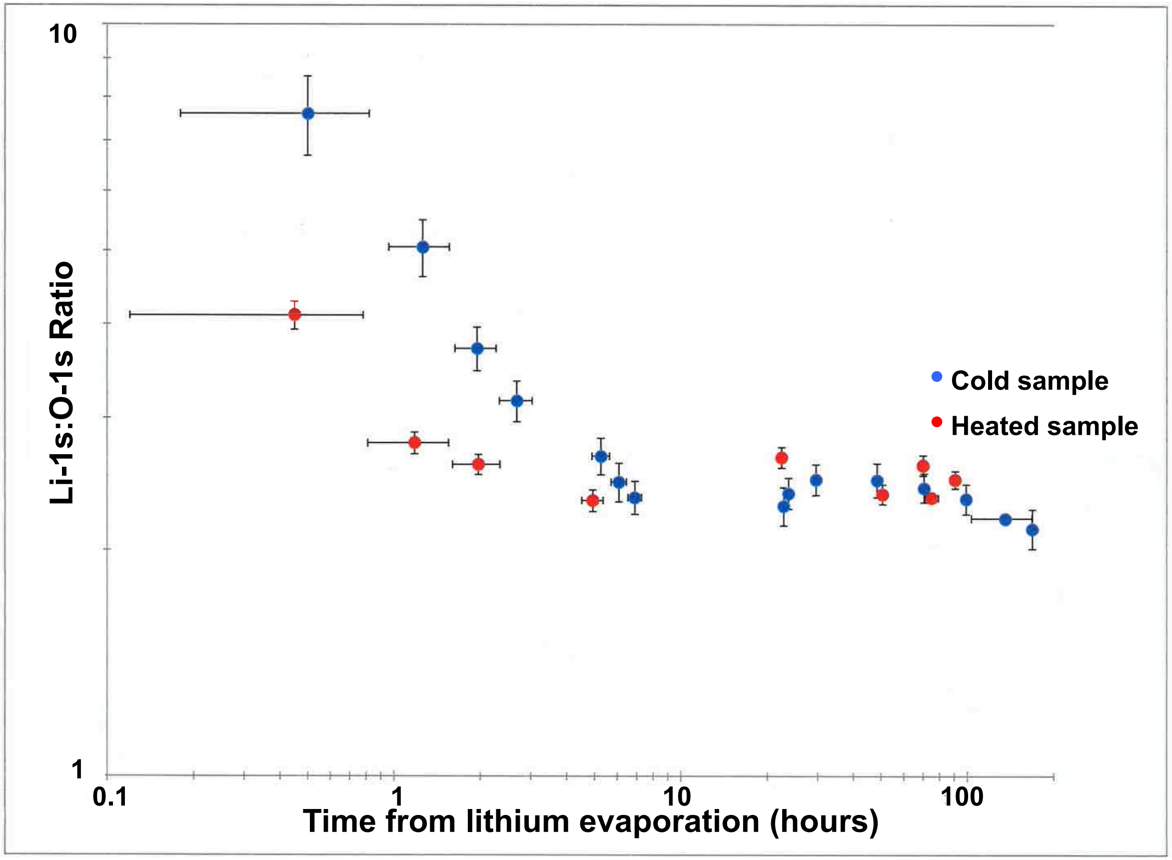
P. Krstic et al. – Phys. Rev. Lett. 110, 105001 (2013)

MAPP data LTX provide information on effects of wall conditioning from samples analyzed before and after GDC

	Pre-Glow	Post-Glow
316 SS	C = 82 ± 2 at. % O = 18 ± 2 at. % 	 C = 47 ± 3 at. % O = 35 ± 2 at. % Fe = 12 ± 1 at. % Cr = 6 ± 1 at. %
Au	C = 86 ± 2 at. % O = 6 ± 2 at. % Au = 8 ± 1 at. % 	 C = 60 ± 3 at. % O = 23 ± 2 at. % Fe = 10 ± 1 at. % Cr = 7 ± 1 at. %

- **XPS analysis of “clean” samples prior to exposure to GDC showed large percentage of carbon**
- **No evidence of gold from XPS analysis after exposure to GDC – possibly from sputtering and redeposition from PFCs during GDC**
- **Suggests complexity of “established” conditioning techniques**

Analysis of MAPP samples coated with lithium suggests mechanism for hydrogen retention long after "passivation"



- XPS analysis shows "equilibration" of lithium oxide formation well before degradation of "cold PFC" plasma performance on LTX
- Suggests role of oxygen in retaining hydrogen in high-Z PFCs

Results from LTX indicate complex PFC picture could also exist for NSTX-U

- Unexpected results obtained on LTX before and after “simple” GDC
  - MAPP data from NSTX-U might similarly show that “boronization” is misnomer for what dTMB actually does to PFCs when “good” plasma performance is achieved
- Unexpected observation of “good” plasma performance on LTX in spite of lithium oxide formation suggests need to re-evaluate what “passivation” means
  - MAPP data from NSTX-U might allow move toward XPs based on what happens when lithium is applied to PFCs rather than empirical quantities like “total evaporated lithium”
- Remaining issues for MAPP on NSTX-U include need to wait for completion of coaxial helicity injection buswork before final installation and drawings to allow placement of cables

Summary

- Goal remains to have following capabilities ready when NSTX-U begins plasma operations
  - dTMB system with He-GDC – also for “between-shots” conditioning – and LITERs
  - More extensive LP array, fast thermocouples and MAPP
- Challenges persist
  - Resources continue to be shared with ongoing upgrade jobs – getting NSTX-U operational is highest priority
  - Limited access to machine due to ongoing construction activities affect installation tasks
  - Resulting “zero sum” situation makes increasing scope and/or requesting additional capabilities inadvisable