A near term application of lithium walls to NSTX

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Outline

- Introduction
  - The LTX approach to a nonrecycling wall
- NSTX implementation
  - Power handling limits
  - Particle pumping capability
- Test in CDX-U
- Summary

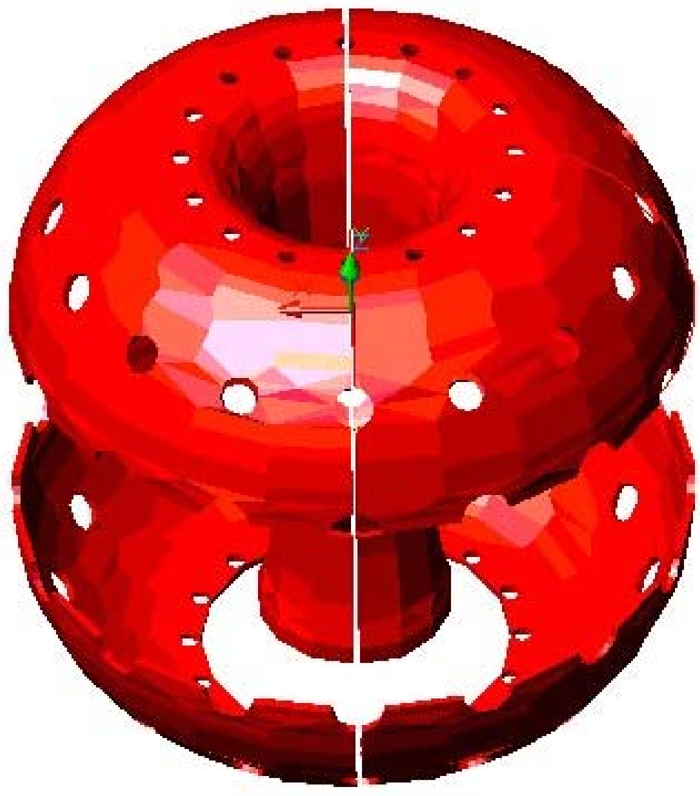
Introduction

- A flowing liquid lithium divertor target for NSTX is being considered
  - Present schedule calls for installation no earlier than 2008
- Lowered recycling *in the near-term* is desirable for NSTX
  - Cryopump
- However, a simple concept for implementing molten lithium walls has been developed for the LTX proposal
  - NOT A FLOWING LITHIUM SYSTEM
  - REQUIRED IN-VESSEL INVENTORY IS VERY SMALL
  - Plasma may transport lithium coatings onto windows
    - » Similar to carbon transport
  - But: no flow of bulk lithium required
- We can use the LTX wall concept to reduce recycling and Z_{eff} in NSTX

Reminder: What is LTX?

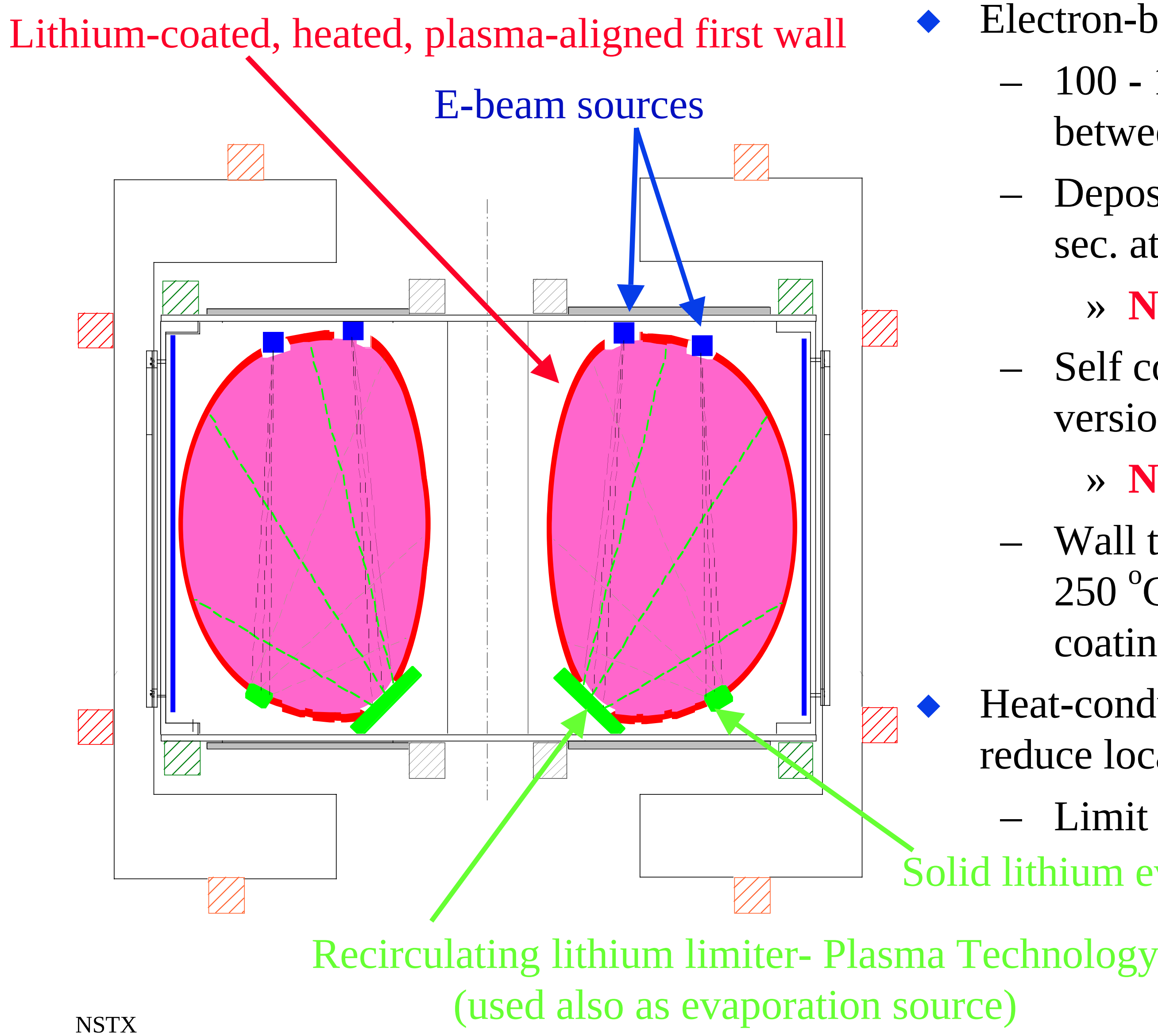
- Goal: an ST with <10% global recycling
- Approach: modify CDX-U to accomplish the LTX objectives
  - R=40 cm, a=26 cm, κ=1.55, B_T=4 kG, I_p <400 kA (50 msec flattop)
- Install a low recycling wall
  - Capacity for full discharge duration plasma particle inventory
  - *Renewed* every discharge
- Employ lithium wall technology: thin films
  - Recoated between discharges
  - Plasma-aligned, heated wall (W or Mo sprayed copper shell)
  - Poloidal field, control system upgraded

Conformal molybdenum- or tungsten-sprayed cast chrome copper shell will form wall in LTX



- LTX shell would be 1 cm thick chrome copper, heated to 200 - 250C.
  - Plasma-facing side would be flamesprayed moly or tungsten (6-7 mils)
  - Heating in LTX would use resistive elements
  - No shell cooling
- **Construction is similar to the NSTX stabilizing plates**

In LTX an e-beam system would deposit lithium on the tungsten (moly) coated copper wall *before every discharge*



- Electron-beam deposition
  - 100 - 1000 Å coating applied between discharges
  - Deposition rates of 1000 Å /40 sec. at 1 m radius *demonstrated*
    - » **NSTX relevant approach**
  - Self contained, insertable version also under development
    - » **NSTX relevant approach**
  - Wall temperature of ~ 200 ^{o}C - 250 ^{o}C will keep lithium coating molten
- Heat-conducting copper shell will reduce local temperature excursions
  - Limit evaporation

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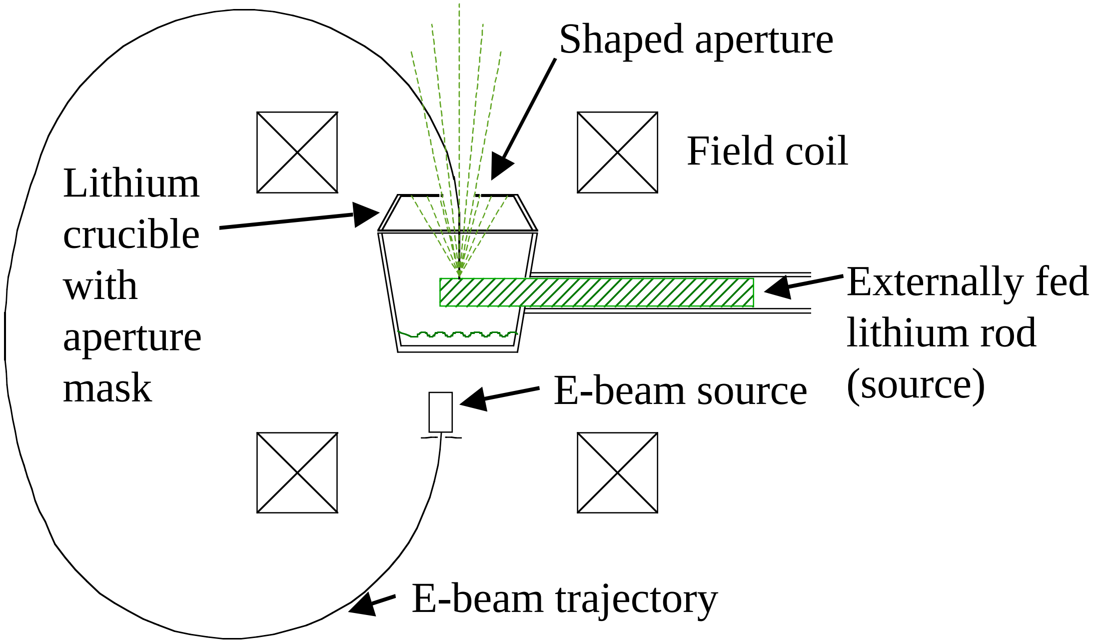
Self-contained deposition source is under development

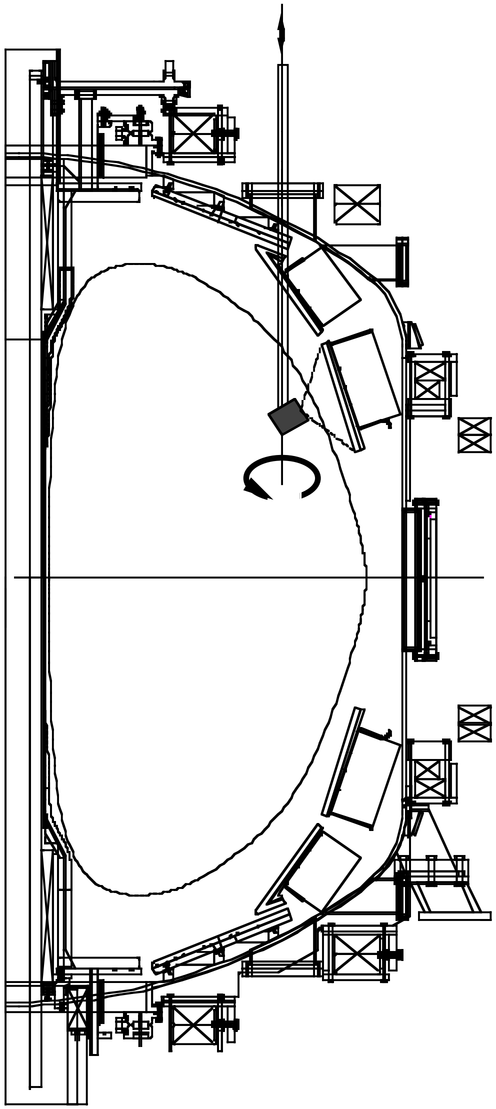


- Electromagnetic version of commercial (permanent magnet) source now in use
  - Allows adjustment of power density by varying ratio of coil currents
- Beam power densities of 250 MW/m^2 attainable
- Shroud crucible or physically scan source to produce desired deposition pattern
  - Defocussed beam can heat/clean aperture
- **Adaptable to NSTX (*or even ITER*)**

Graded approach to low recycling in NSTX

- First step: lithium pellet injection
  - Utilize lithium-carbon chemistry to reduce recycling
- Second step: heavier lithium coating of the carbon tiles
  - Utilize an LTX-like e-beam coater
- Third step: Install a *single* new passive plate
  - Flame sprayed moly over chrome copper
  - Apply lithium coatings between shots
- Finally:
  - Expand lithium coated passive plate system
  - Liquid lithium jet divertor (ALIST system)
- Important caveat for first two steps:
  - Edge of NSTX is NOT as hot as TFTR.
  - Sheath potential is much lower.
  - Ion implantation range is shallower.
    - It is possible that lithium pellets and even the coating will not have as dramatic an effect on recycling as in TFTR

NSTX implementation



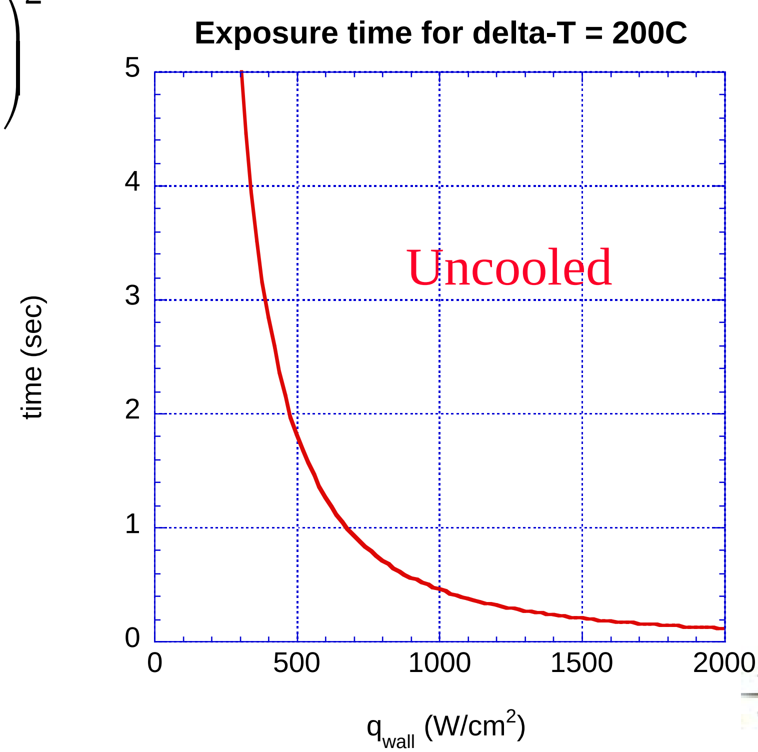
- Replace one of the passive stabilizing plates with a new plate, faced with plasma sprayed tungsten or moly
- Install an insertable e-beam system which can be scanned over the stabilizing plate
- Deposit 1000Å of lithium and withdraw the e-beam system
  - Similar to the insertable getters used in PLT, PBX
  - But time scale is different
    - » Few 10's of seconds for 1000Å coating
    - » Cycle time is dominated by insertion/removal of e-beam.
- Coat before *every shot*
  - 1000 shots ⇒ 0.1 mm accumulation
    - » Accumulation may be limited by evaporation

Power limits: stabilizing plates

- Replacement stabilizing plates: chrome-copper oversprayed with Mo or W, coated with lithium
  - 1000 applications of 1000Å lithium coating: 0.1 mm lithium
  - Underlayment of moly or tungsten: 0.15 mm
  - Neglect temperature differential across the coating+facing
- Temperature rise:

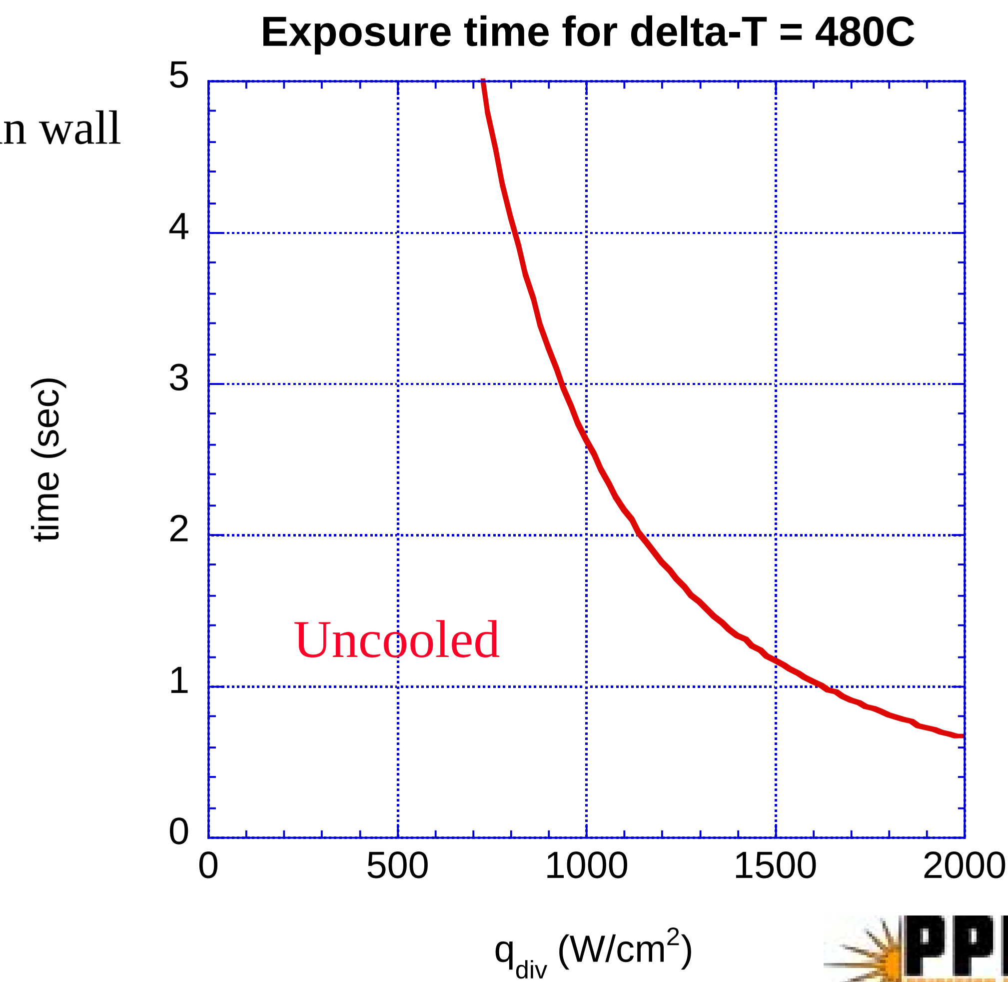
$$\Delta T = 2q_{wall}(W/cm^2)\sqrt{\frac{t}{\pi\kappa\rho_m C_p}}$$

- Or time-to-temperature: $t = 11.4\left(\frac{\Delta T}{q_{wall}}\right)^2$
- For the wall:
  - T_{wall} (initial) ~ 200C
  - T_{wall} (final) < 400C
- *Uncooled* rise
  - Use of active cooling will extend limits

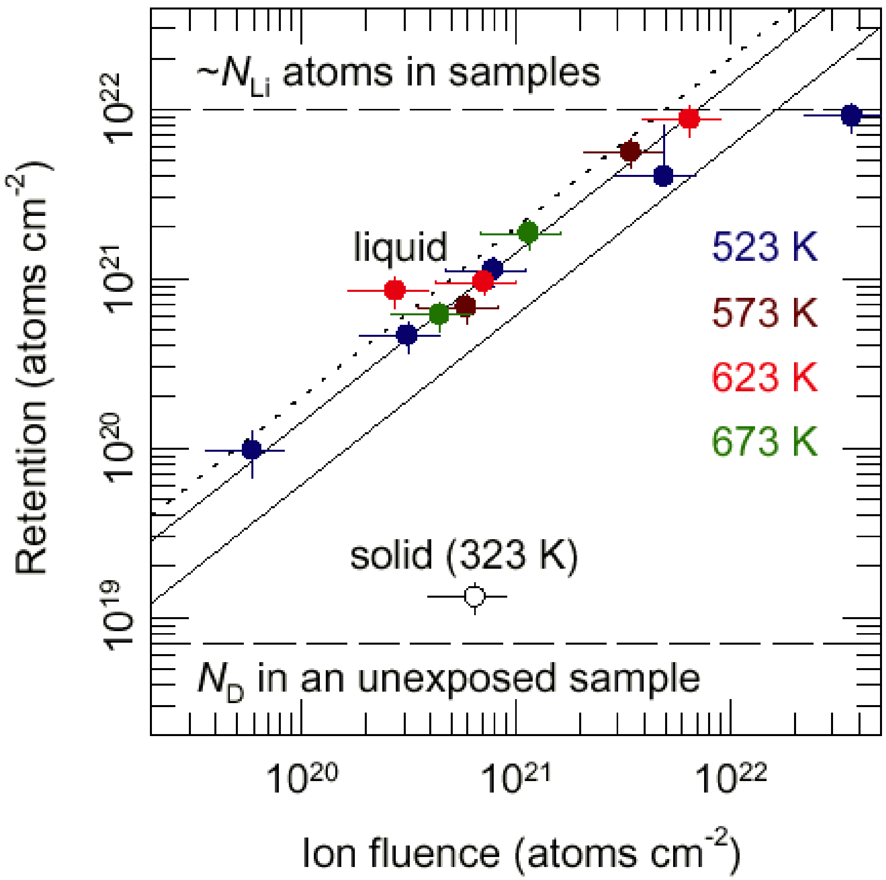


Power limits: divertor target plates

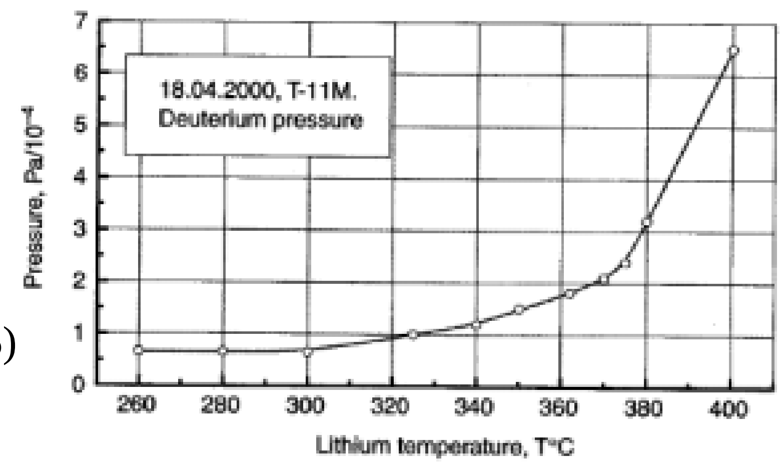
- Previously had not considered this technique for the divertor
- But: coated plate *is* viable in the divertor *if initial condition is solid lithium*
  - T_{wall}(initial) ~ 20C
  - T_{wall}(final) ~ 500C
    - » Higher temp. limit than wall
    - » Much larger ΔT
- *Uncooled rise*
- Sweeping the strike point would enable long discharges
- Present discharges do not require sweeping



High capacity of liquid lithium to store deuterium demonstrated in PISCES-B experiments



- Liquid lithium retains atomic deuterium up to a nearly 1:1 Li:D ratio
  - Deuterium is dissolved in the lithium; *does not form a stable deuteride*
  - High diffusivity precludes large surface concentration
- Coating <u>will not saturate</u> in a discharge
- "Bound" hydrogen can be liberated by heating
  - *Hydrogen (tritium!) retention may not be a problem*

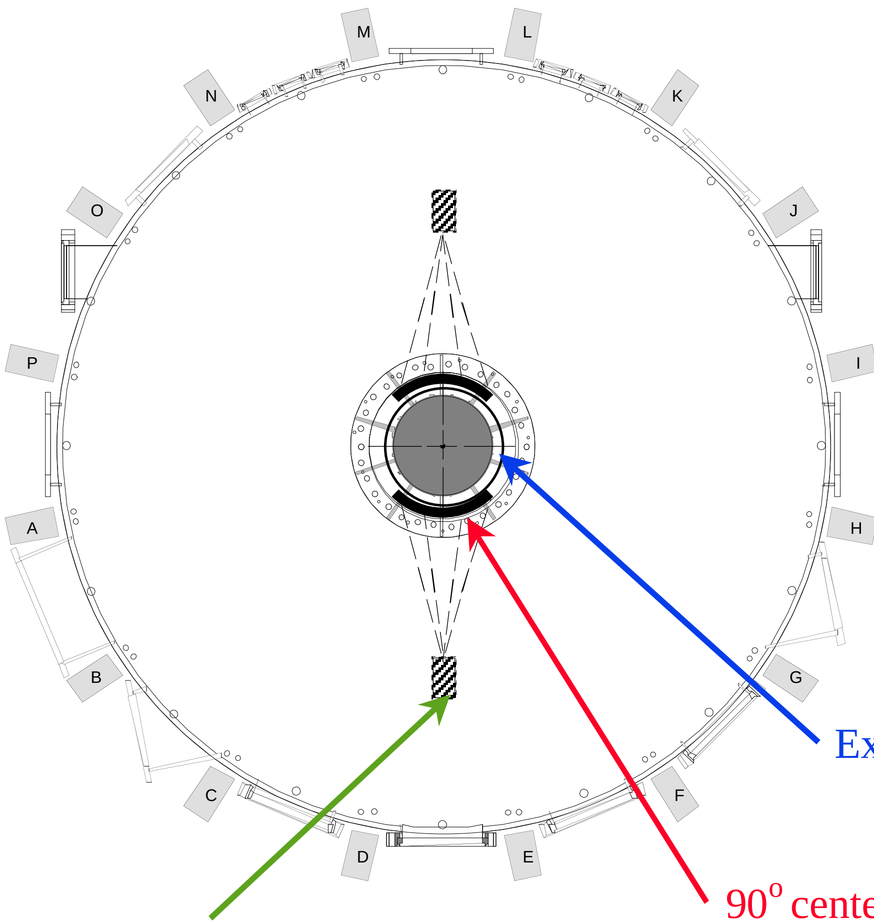


Results from T11-M (PP&CF **44**, 955) showing deuterium desorption vs. capillary lithium limiter temperature

Particle pumping by the lithium coating

- Wall:
  - Area of wall plates is ~1.5×10^5 cm^2.
  - Volume of 1000Å coating: 1.5 cm^3 (~ 6×10^{22} atoms)
  - ~ 6×10^{20} particles in an NSTX discharge
  - Wall has the capacity to pump the discharge for many particle confinement times
- Divertor:
  - Area ~ 3.6×10^4 cm^2.
  - 1.5×10^{22} atoms.
  - Less capacity.
    - » Requires strike point sweeping for partial divertor pumping.
  - Lithium jet system has an advantage in the divertor.

Coated wall will undergo test in CDX-U



Existing passive heat shield

90° centerstack limiter segment
>W or Mo plated copper
>Resistively heated

e-beam lithium source

- Proposed concept test for FY04
- Sources will be vertically scanned to coat ~ 22 × 75 cm (W × H) limiter segments between shots
  - Parked near top of vessel during discharges
- Existing tray limiter will be removed under present plans

Summary

- Lithium coated walls are envisioned for LTX to eliminate recycling
  - Rapid, controlled e-beam application of a 1000Å lithium coating
  - Wall maintained at 200-250C
    - » Deuterium will dissolve in molten lithium
- Coated wall technology is applicable to NSTX
  - Power, particle handling is adequate for wall
  - Can be applied to divertor if strike point is swept
- Lithium coating is low Z
- Lithium coating will pump ALL the water
- Lithium coating will pump the edge plasma
  - Wall coating will be adequate to provide a pumping wall
  - Coating will provide some atomic hydrogen, ion pumping in the divertor
- *Impact on other systems should be minimal*

NSTX reactions

- In general, very favorable.
  - Suggested as possible alternative to cryopump
- Relatively strong advice to install at upper, outer divertor location
- Martin Peng requested a schedule, with the aim of incorporating into the NSTX 5 year plan
  - *Requires discussion here*
- Follow up meeting next week with Martin Peng, Masa Ono, Ed Synakowski
- Costing estimate requested prior to 5 year plan review in June.
- As an aside: the *NCSX* General Requirements Document (now being finalized) also specifies that:
  - *"Materials used inside the vacuum vessel shall be compatible with lithium, in order to facilitate the use of a lithium liner as a possible future upgrade."*
    - » 250 ^{o}C liner for *liquid* lithium

Tentative schedule for discussion

FY03 - Prototype W and Mo coated heated copper plates produced. (This task is presently funded under the lithium walls LPDA project)

>Suggest ALIST explore advanced fabrication techniques for tiles or plates.

- Li coating applied to plates via commercial e-beam system. Adhesion, behavior of coating characterized as a function of temperature, coating thickness. (Again, funded under the LPDA)

FY04 - Centerstack limiter plates for CDX-U designed, fabricated, installed.

- Electromagnet-based deposition system fabricated, installed. **(ALIST participation)**

- Tests of coated-plate system completed in CDX-U. **(ALIST participation)**

- New outer divertor plate designed for NSTX. Prototype tests. **(suggest ALIST lead)**

- E-beam system for NSTX designed. **(suggest ALIST lead)**

FY05 - Outer divertor plates and lithium e-beam coating system for NSTX fabricated and installed. **(suggest ALIST lead)**

FY06 - Outer divertor plates and lithium e-beam coating system for NSTX operational.