# Liquid Surface Module for NSTX

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**Presented at the NSTX Research Forum**
**at PPPL**

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# Outline

- A joint ALPS and APEX project
- Objective
- Concepts being considered
- NSTX particle fueling rates
- Preliminary analysis of impact
- Module sketches
- Planned experiments
- Tentative project schedule
- Crude budget estimate
- What's next?
- Conclusions

# Participants

- ALIST Working Group from ALPS/APEX Teams searching for innovative liquid surface components for fusion devices.
- M. Ulrickson, R. Nygren, R. Causey, SNL
- R. Doerner, S. Luckhardt, UCSD
- T. Rognlien, M. Rensink, LLNL
- J. Brooks, A. Hassanein, ANL
- B. Nelson, P. Fogarty, R. Maingi, ORNL
- S. Smolentsev, N. Morley, A. Ying, UCLA
- R. Kaita, PPPL

# Objective

- **The objective of this project is to provide NSTX with a tool for particle control.**
- **Specifically, we will provide a module capable of removing about 5 x $10^{20}$ to 5 x $10^{21}$ particles/sec for the full duration of the plasma (~ 5 sec).**
- **A secondary objective is to demonstrate the power handling capability of liquid surfaces in contact with a fusion plasma.**

# Concepts Being Considered

- An outboard limiter module placed at the mid-plane.
  - Easy installation
  - Can be easily retracted for comparison experiments
- A divertor module on the bottom of the machine
  - MHD effects are reduced
  - Small size is possible for the same pumping
  - Harder to retract, maintain, or remove

# Fueling Rate on NSTX (Maingi)

- The average gas fueling rate is 50-100 Torr l/s (3.5-7.0 x $10^{21}$ particles/s).
- The beam fueling rate is about 30 Torr l/s.
- The total particle content of a typical plasma is 5 x $10^{20}$.
- The wall recycling coefficient can be greater than 1 (the wall is supplying particles) or as low as 0.5 (the wall is a sink for particles).

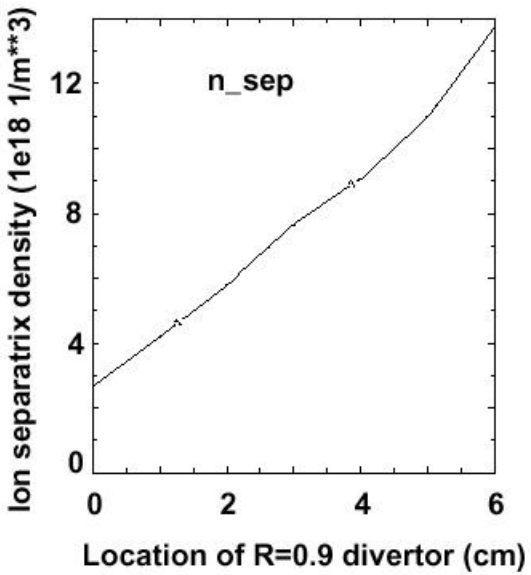
# Particle Pumping Estimate

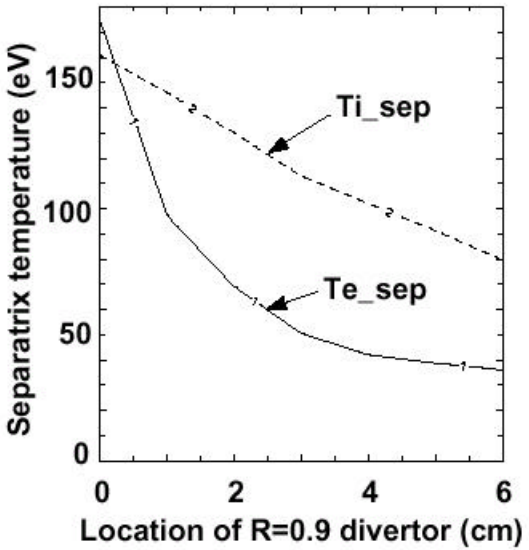
- Upper end estimate
- Recombination coefficient is $10^{-27}$ to $10^{-34}$ $cm^4/s$
- Diffusivity $10^{-4}$ $cm^2/s$, time 0.04 s, Distance 20 mm
- Speed 10 m/s, depth 20 mm, 5 x $10^{24}$ Li atoms/s
- 2% concentration implies $10^{23}$ H/s pumping
- Lower end estimate, assume no diffusion
- Implantation depth 0.1 mm
- Li rate 2.7 x $10^{22}$/s
- 2% concentration implies 5 x $10^{20}$ H/s pumping

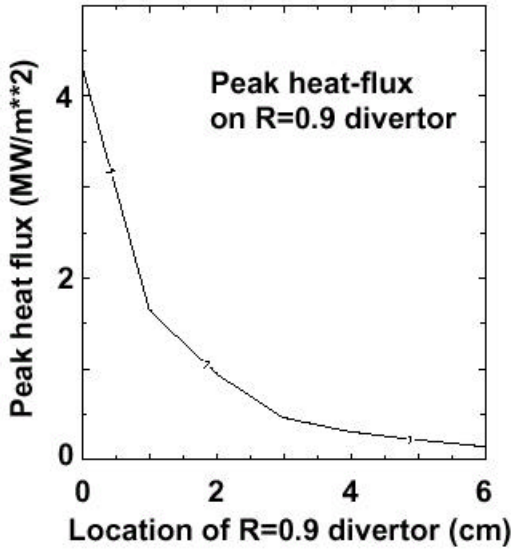
# Preliminary Analysis of Impact

- **The edge plasma has been modeled using the UEDGE code.**
  - **The specified pumping rate increases the edge temperature (100 to 300 eV) and lowers the edge density.**
- **Particle trapping and removal has been studied with the TRIM and TMAP codes and the HEIGTHS package.**
  - **The hydrogen recombination coefficient at a liquid lithium surface is very small ($10^{-27}$ to $10^{-34}$ $cm^4/s$) implying strong trapping of H in a flowing Li layer.**

# UEDGE Modeling Results (LLNL)



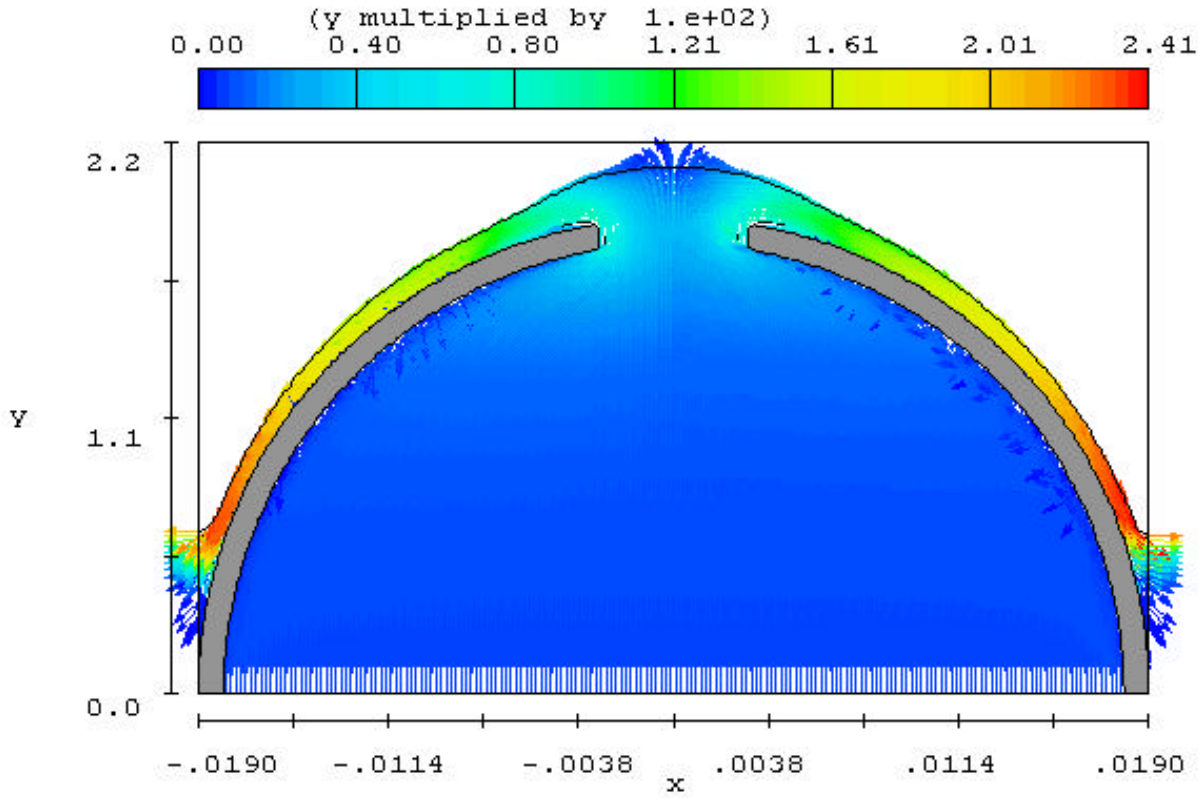



# Preliminary Analysis of Impact

- **MHD effects on several flow options have been evaluated by UCLA.**
  - **For flow over a backing plate MHD effects are reasonable if the backing plate is resistive enough (the flow thickening is <50%)**
  - **For the soaker hose concept, the currents required to drive the flow were excessive (>25 kA).**

# Soaker Hose Analysis (UCLA)




Bx=-0.15, By=0, and I/A=1.5e6



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# Flow on a Backplate Analysis (UCLA)

Cases

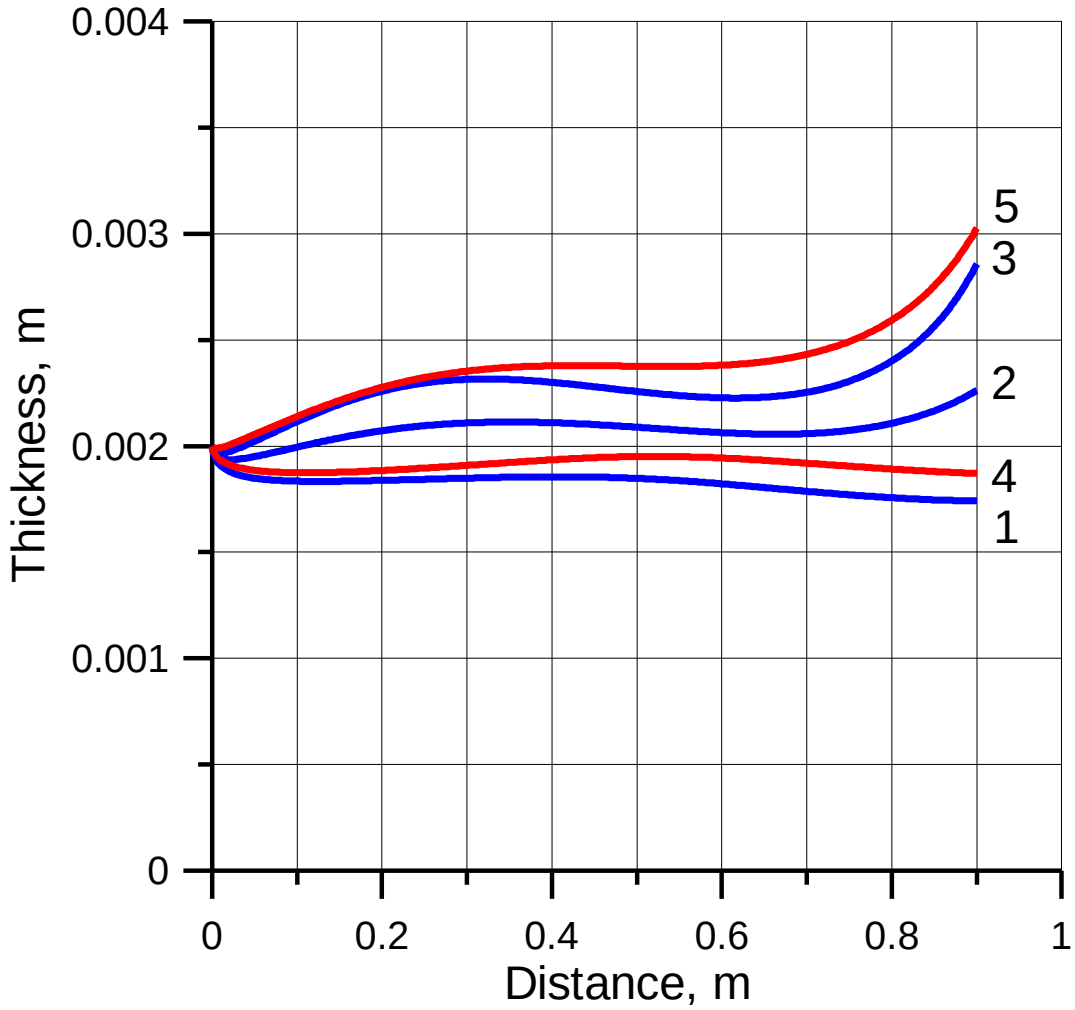
1) 5 m/s, isolated

2) 5 m/s,0.5 mm walls

3) 5 m/s, 0.5 mm side, 1.0 mm back wall

4) 10 m/s, isolated

5) 10 m/s, 0.5 mm side, 2.0 mm back wall



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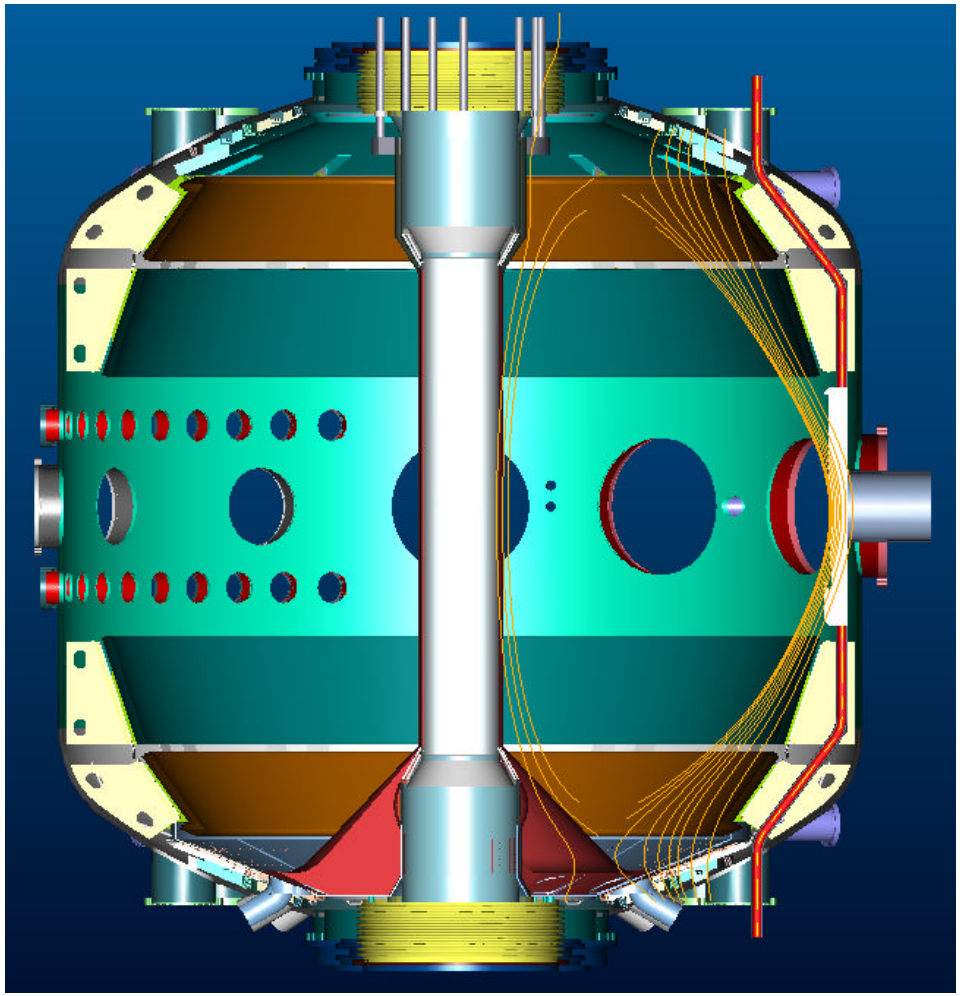
# Module Sketches (ORNL)



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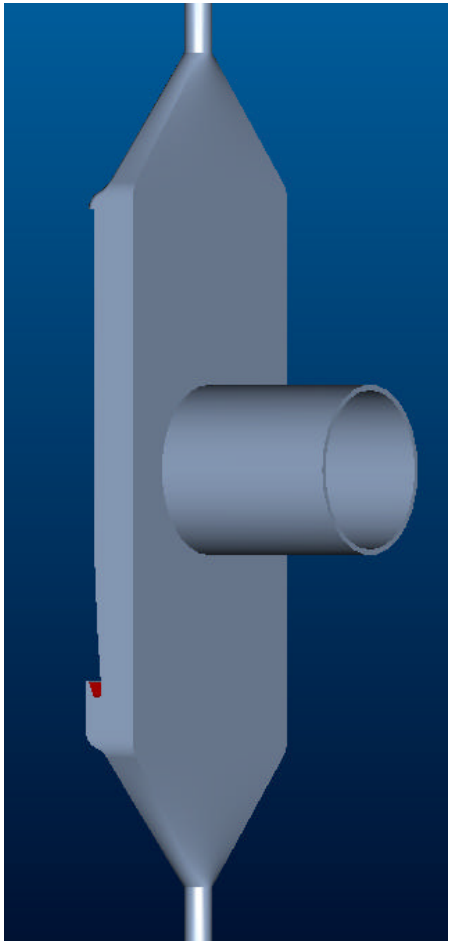

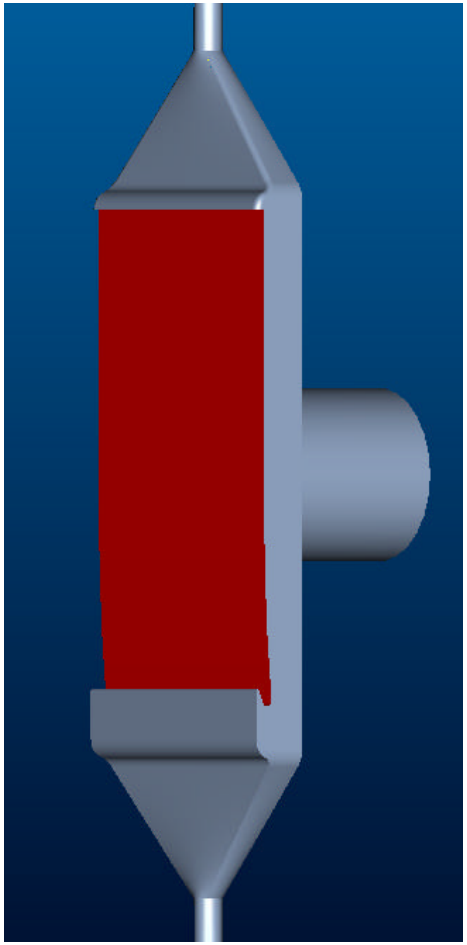

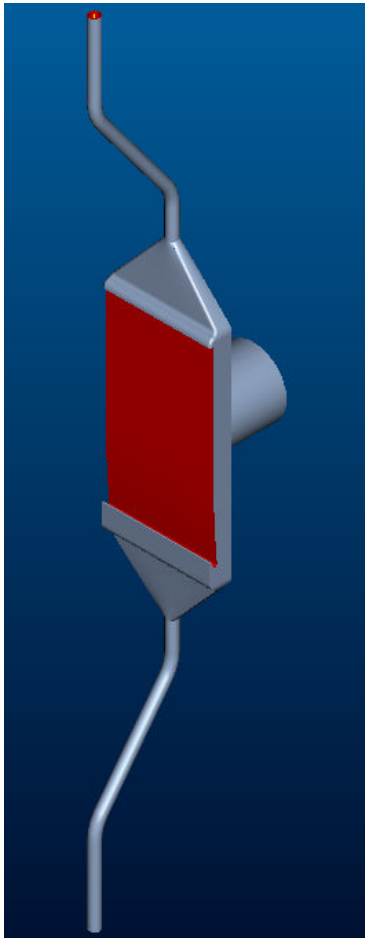

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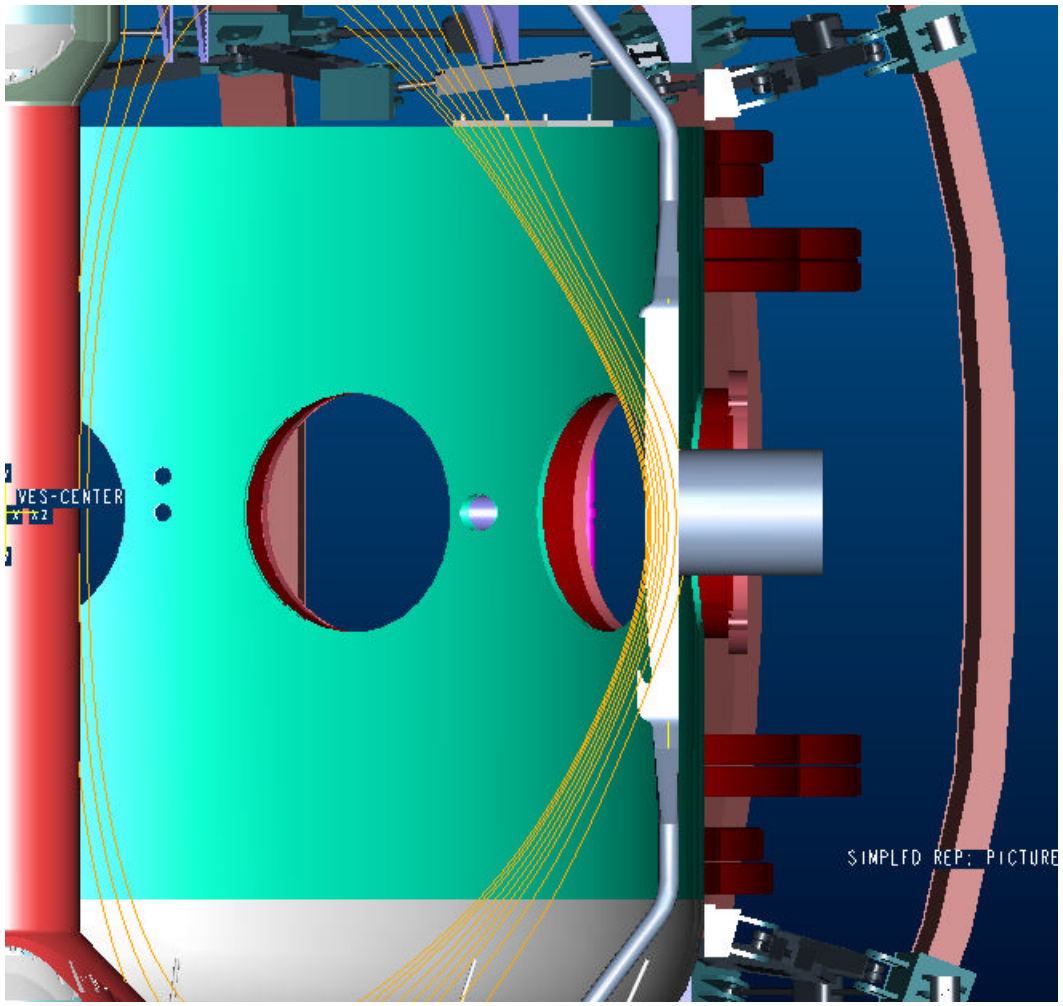




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# Planned Experiments

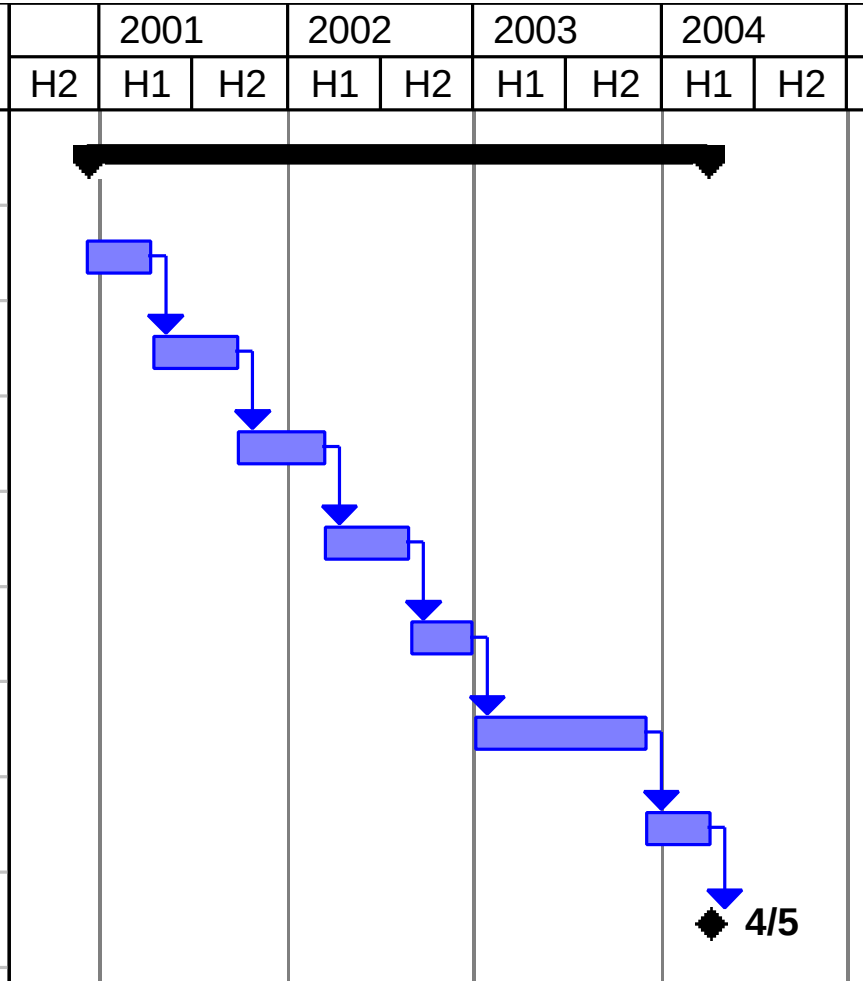
- Comparison of ohmic gas fueled plasmas with and without liquid surface touching plasma
- Comparison of neutral beam heated plasmas with and without liquid surface touching plasma
- Study the impact of liquid surface touching plasma during CHI experiments and pellet fueling
- Effect of the Conducting Shell in Stabilizing NSTX Plasmas with Low Edge Recycling

# Diagnostic Needs

- Use RGA to monitor changes in gas throughput
- Lithium spectroscopy
- Langmuir probes, scanning and fixed
- IR camera for surface temperature profile
- Fast scanning CCD camera
- Wall coupons for Li transport

# Tentative Project Schedule

| ID | Task Name |
|---|---|
| 1 | **Modular Liquid PFC** |
| 2 | Option Assessment |
| 3 | Pre-conceptual Design |
| 4 | Conceptual Design |
| 5 | Preliminary Design |
| 6 | Final Design |
| 7 | Fabrication |
| 8 | Installation |
| 9 | Begin Experiments |



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# Crude Budget Estimate

- An accurate cost estimate cannot be completed until after the pre-conceptual design is completed near the end of FY01.
- We have used rules of thumb from past limiter and divertor designs to estimate the cost of the in vessel hardware. The estimated cost is about $400-500K.
- The cost of the external system will depend strongly on whether the system is once through with no active pumping or has a pump to continuously pump the liquid.

# What's Next?

- A proposal will be made at the NSTX Research Forum (Jan 15-18).
- If the proposal is supported at the forum, we will complete the assessment of the options and conduct pre-conceptual design.
- The plan is to have a module available for use on NSTX in FY03 or 04 if funding is provided. This is before the planned upgrade of the center stack.

# Conclusions

- **Preliminary analysis of the particle removal capability of a flowing liquid lithium surface in NSTX indicates that the entire plasma particle content could be exhausted in 0.1 to 1.0 sec.**
- **A module of about 80 x 40 cm is needed to accomplish this at the outer mid-plane and a module of about 50 x 40 cm is needed in the divertor.**
- **Such a module could be designed, fabricated and installed before the planned center stack upgrade if sufficient funding is available.**