# Progress on Flowing Liquid Surface PFC Concept Development for NSTX

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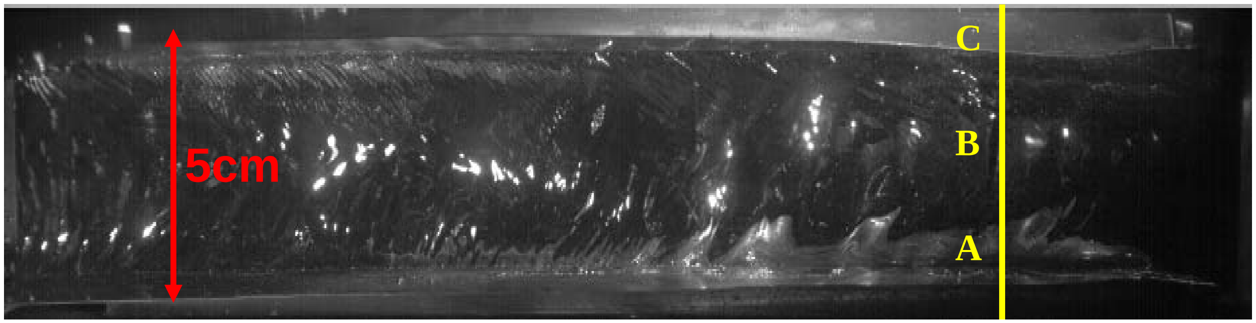
# Outline

- ➢ Summary of Existing Results (V&V)
  - – Numerical results (HIMAG[F]) versus experimental observations
  - – The width effect
- ➢ Numerical Simulation of NSTX Module B
  - – Numerical results for a simple flow geometry
  - – Coupling to the conducting inlet nozzle
- o Initial results of e-beam heating simulation
- ➢ Experimental progress and work to be completed this year

# Both numerical and experimental results show asymmetric free surface height variation in the span wise direction

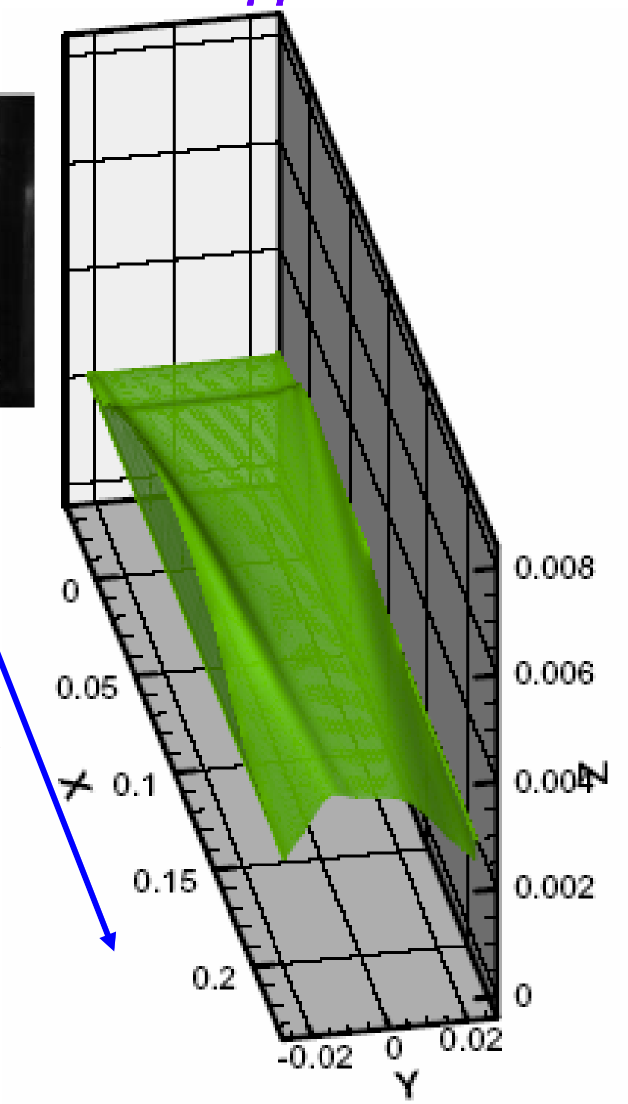
*Decreasing toroidal + locally increasing surface normal fields applied*

2 m/s



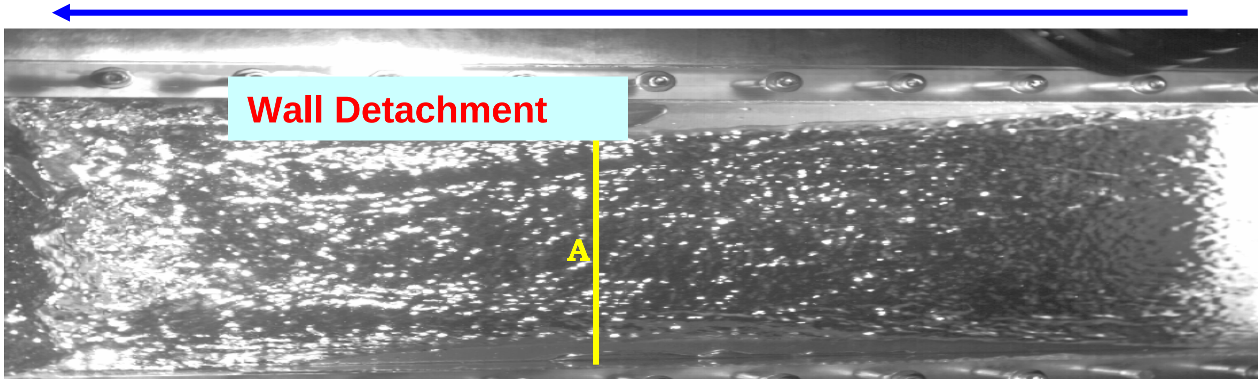

Inductive probe film height at 26cm downstream
A: 6.0mm B: 7.8mm C: 10.0mm

- The toroidal field (strongest at the inlet) plays a 'global' role as it affects the flow in the loop as a whole.
- Surface normal field effects have a 'local' nature. A the exit (strongest surface normal field) a dramatic increase in film thickness is observed.
- Toroidal field modifies the free surface structure (hinting at partial laminarization of the flow). '2-D' column type structures are observed at regions of strong toroidal field.



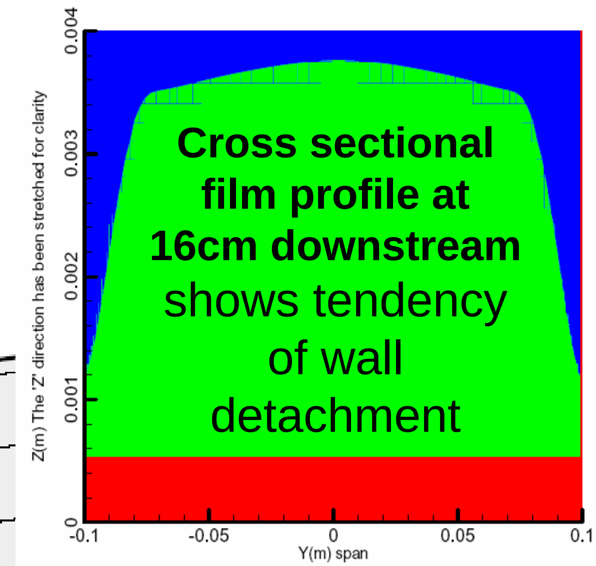

Ga inlet: 3 m/s

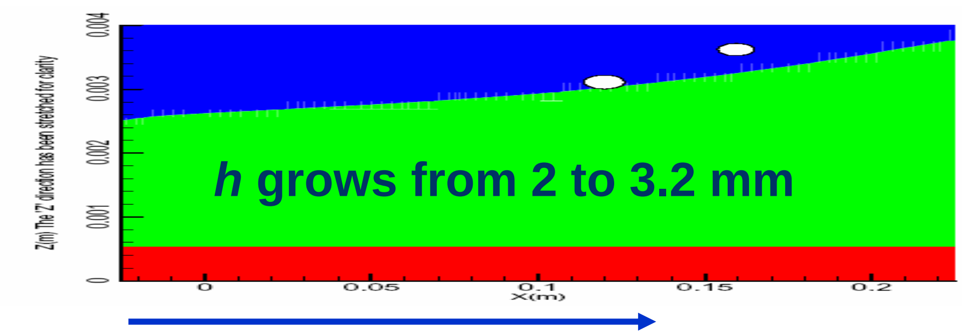
# Numerical simulation showed "wall detachment" as observed in the experiment

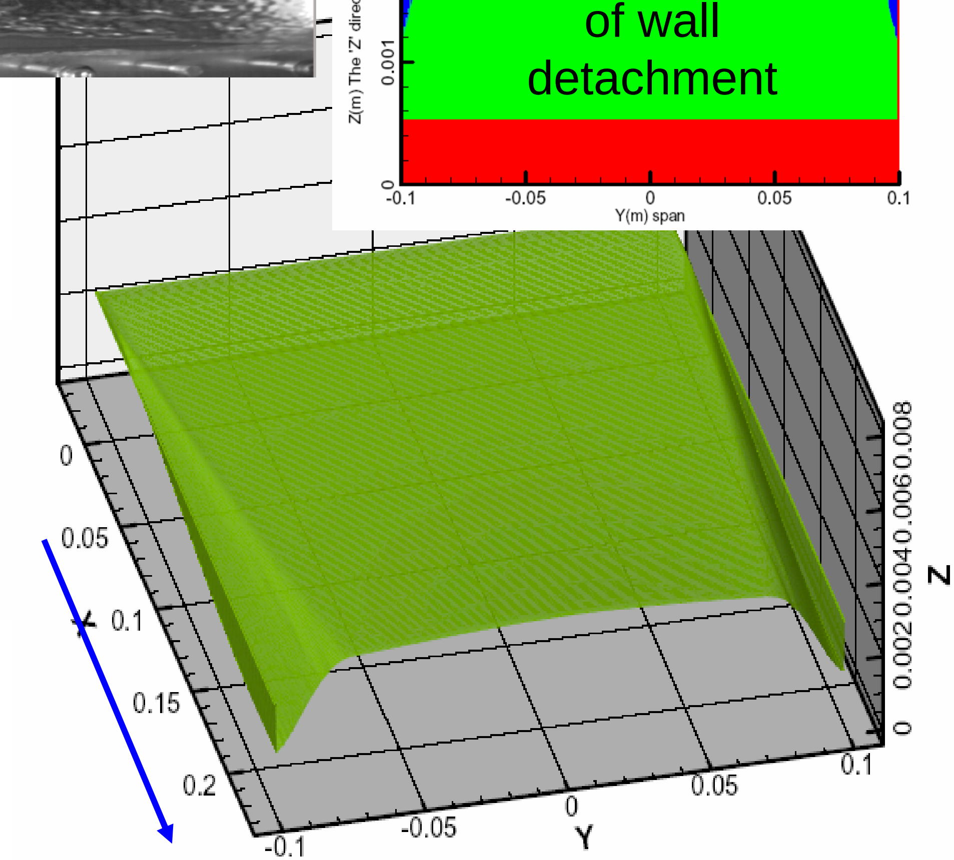



Channel width: 20 cm

3 m/s Ga flow subjected to the NSTX like surface normal field configurations



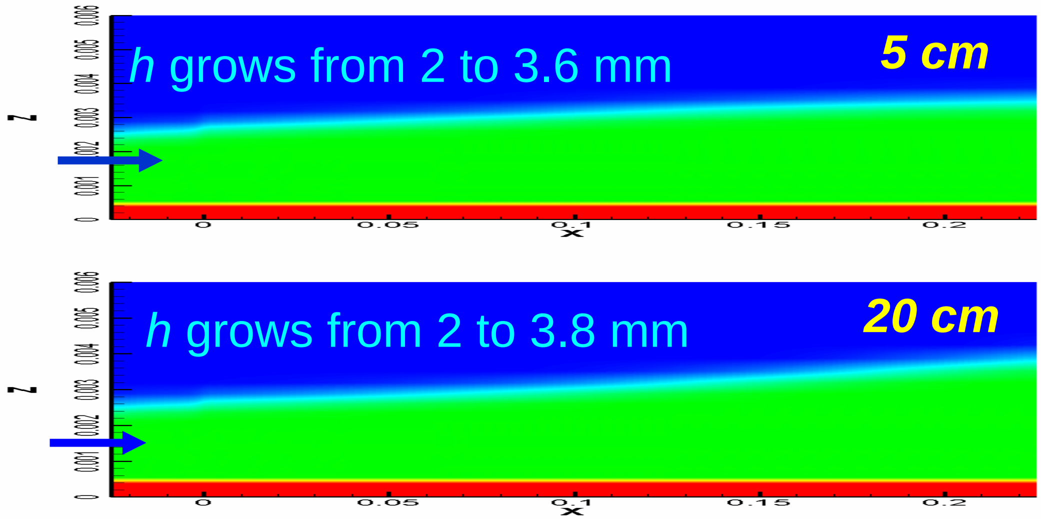



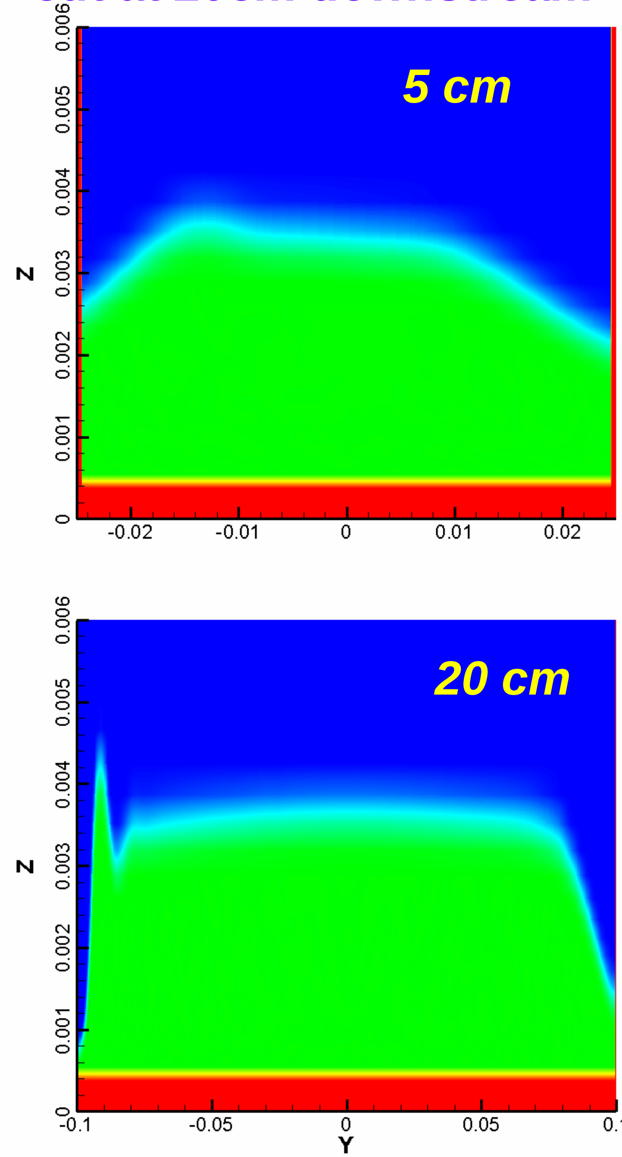

Film height evolution at the channel centerline. The white dots are measurements from the experiment.

# Understanding the width effect

*Film height evolution over 20 cm (at channel centerline)*



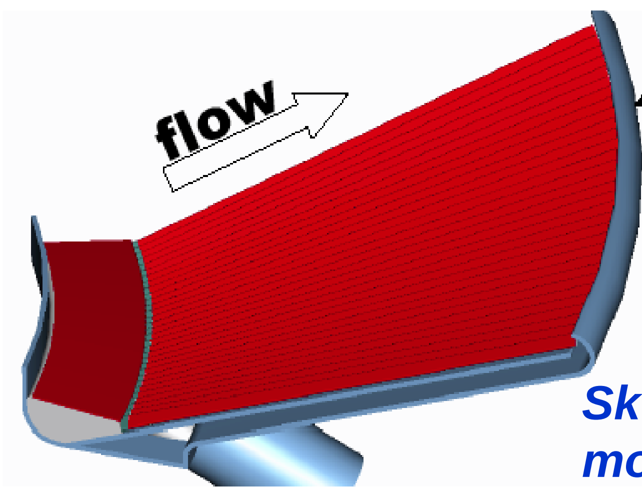

*Span-wise cross section cut at 20cm downstream*



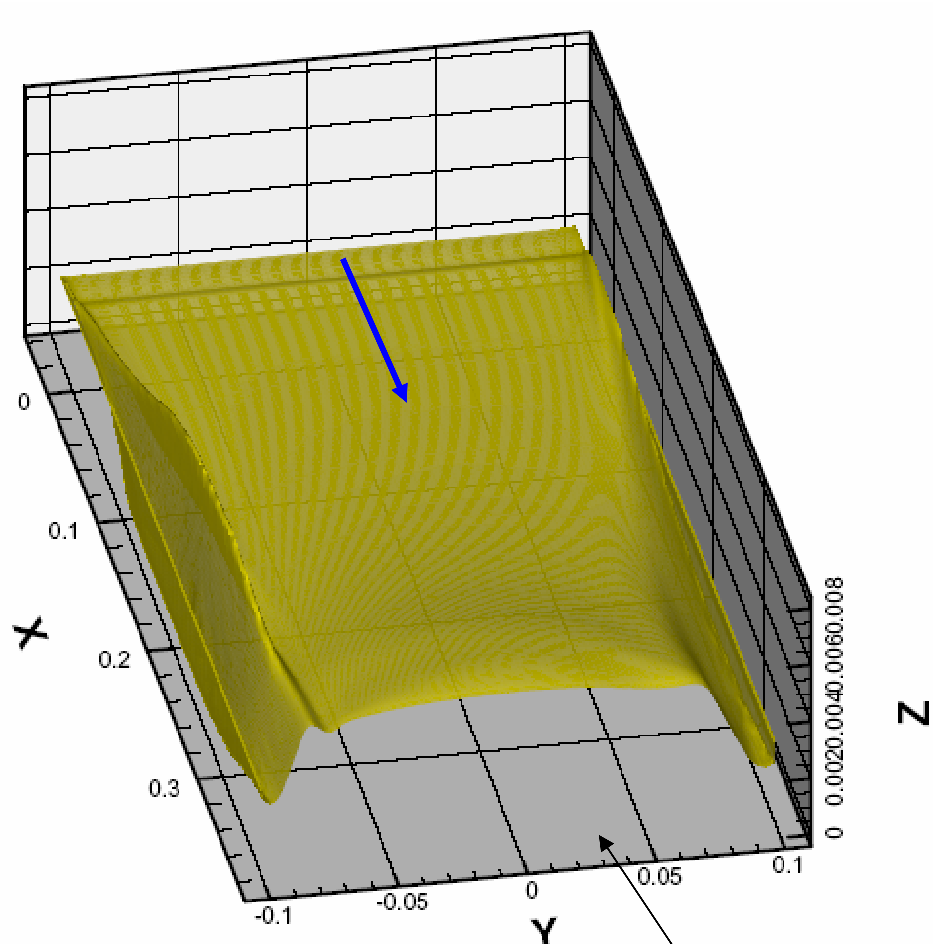

- **The average increase in the film thickness at the centerline is about the same between the two cases.**
- **Span-wise film height variation shows asymmetric for the two cases.**
- **Stronger local MHD effects near the side walls are observed in the wide channel case.**

# Initial Modeling of NSTX Module B

- A 20 cm wide x 40 cm long conducting chute with fluid constraining conducting side walls.
- Lithium is used as the working fluid with an inlet velocity of 10 m/s and an initial film height of 2 mm.
- The flow is subjected to the NSTX toroidal and surface normal field components.
- The flow climbs uphill at a slope of 22$^{o}$.



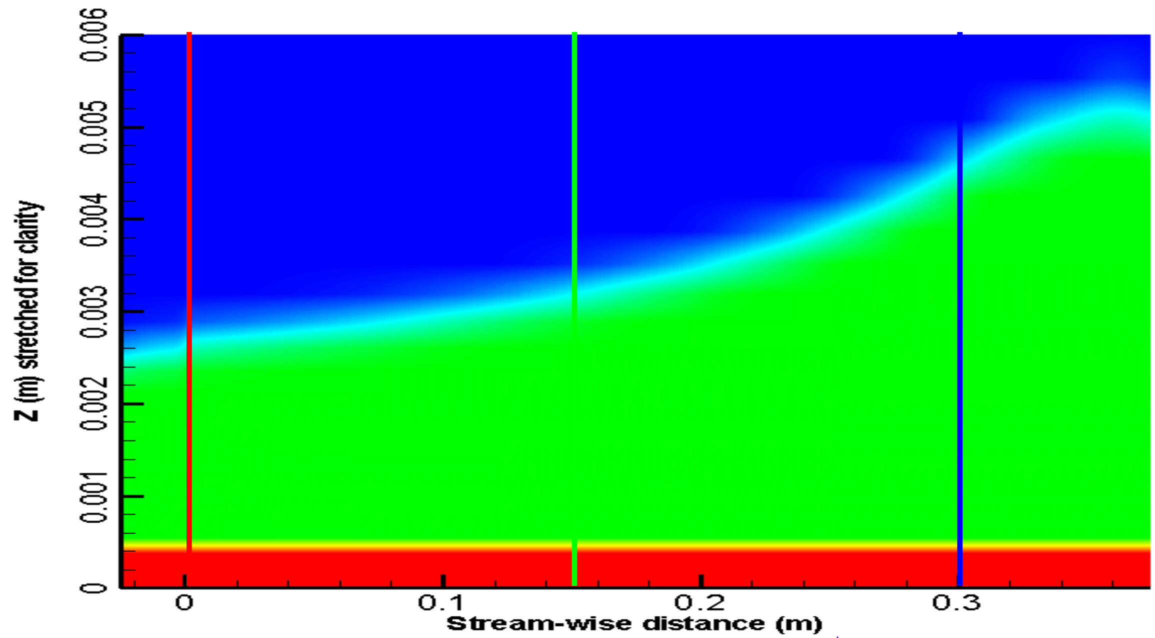

*Sketches of Li flow module for NSTX*

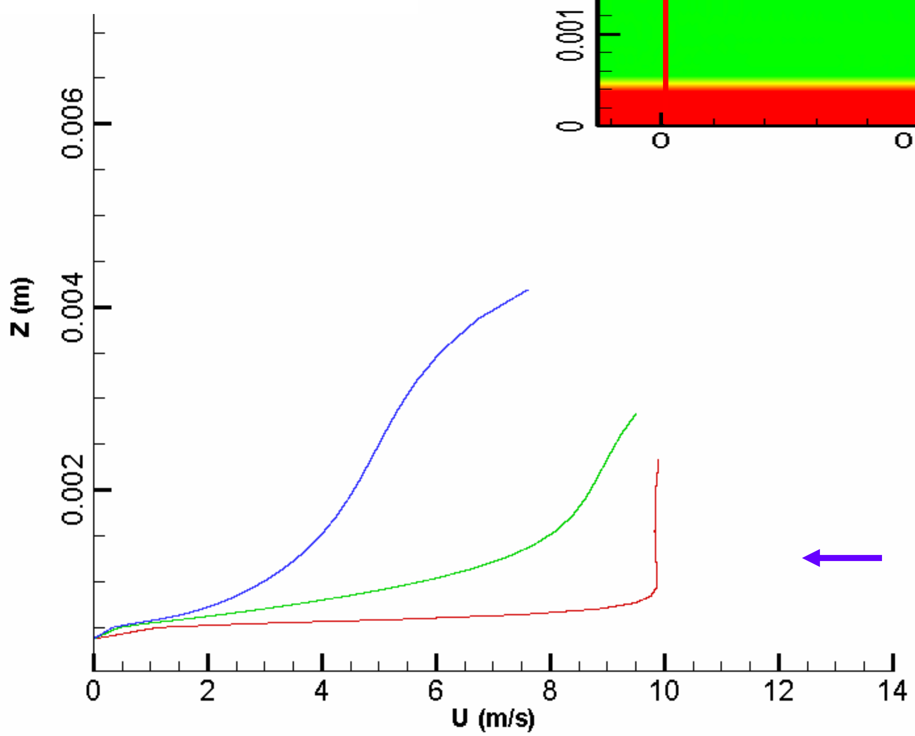



*HIMAG first simulation*

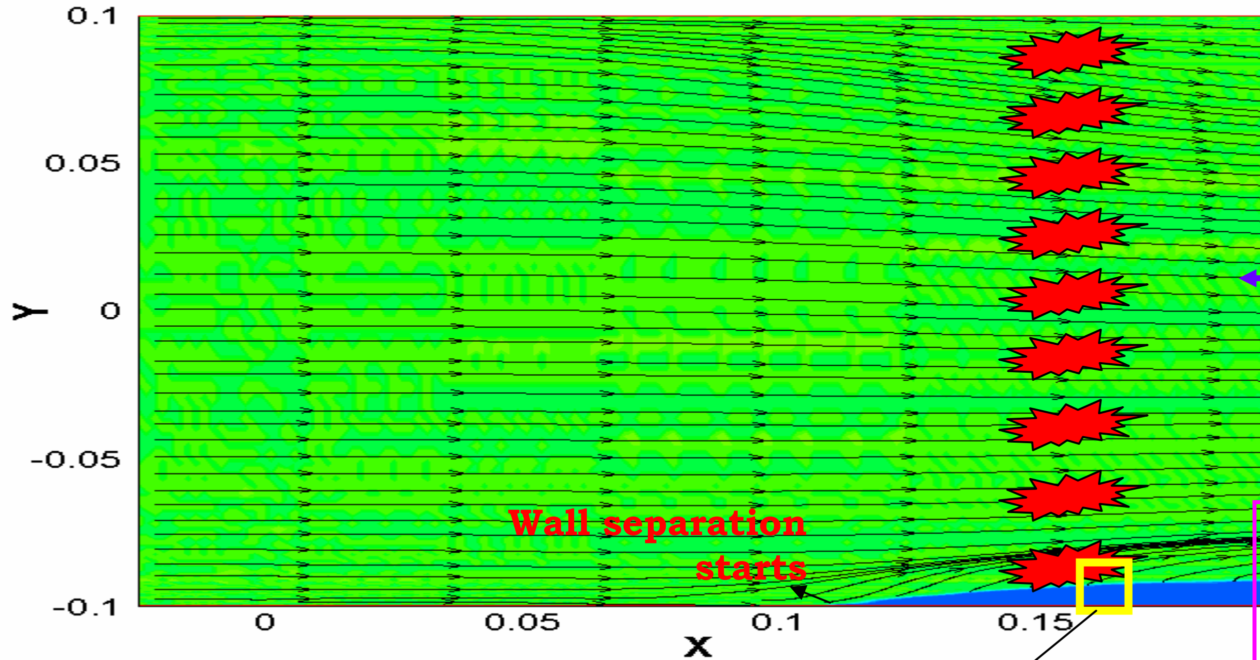
# Some Details on Module B Simulation

**Velocity is about 9 m/s at strike point; It appears adequate for NSTX surface heat flux (~ 7.5 m/s is needed)**



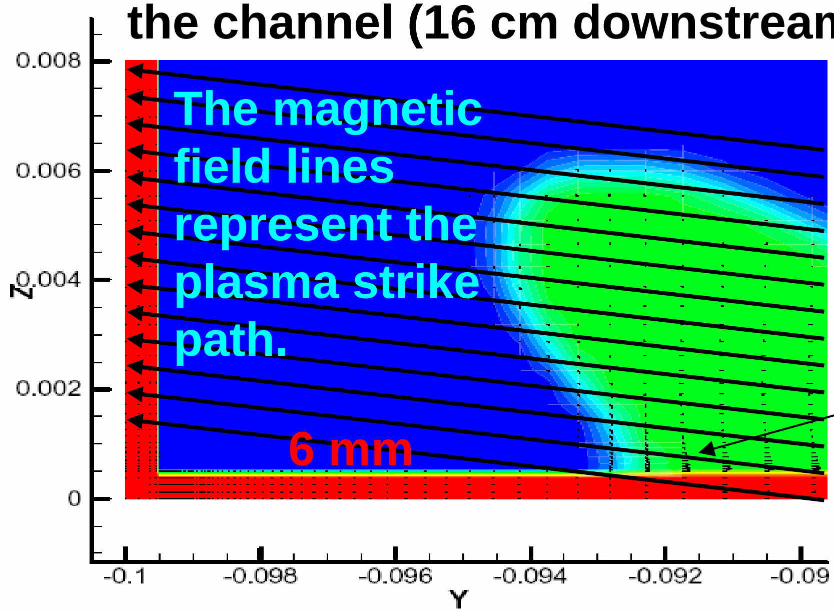

- The stream wise film thickness variation. (section cut at the centerline)
- Stream-wise velocity component with height at three downstream locations (0, 15, and 30 cm).



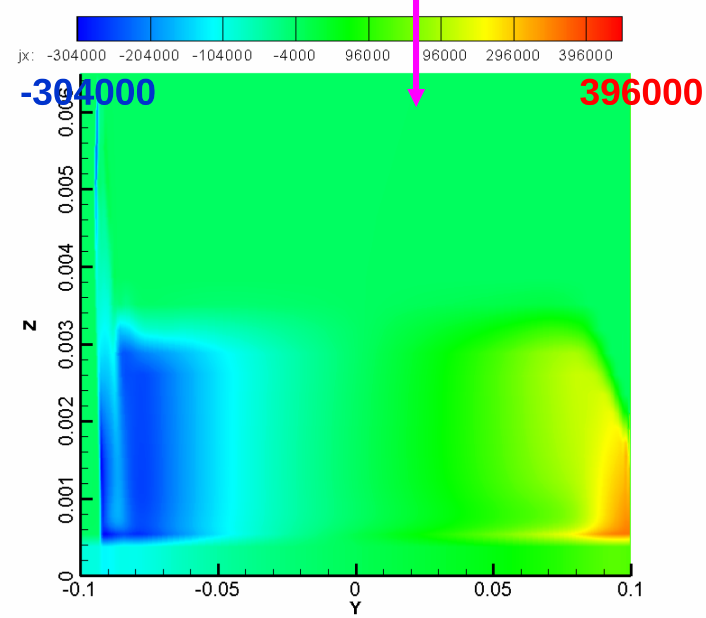

- The flow streamlines show a tendency to pinch in and separate from the walls.
- The cartoon marks the location of the strike point.

**Axial current contours.**
**Span-wise cross section cut at 16*cm* downstream.**

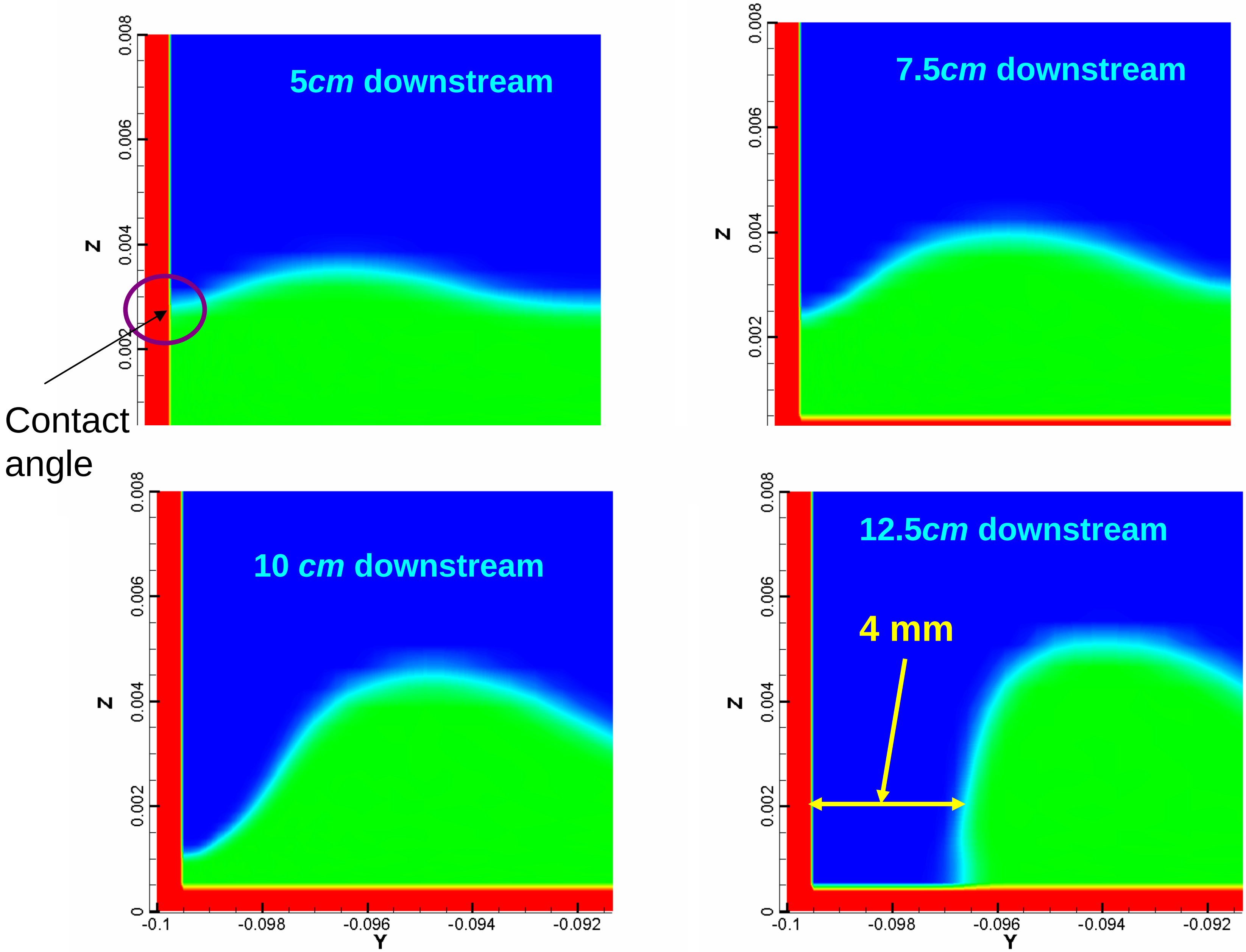
**A blown up view of the left part of the channel (16 cm downstream)**




**The cross sectional currents are shown.**

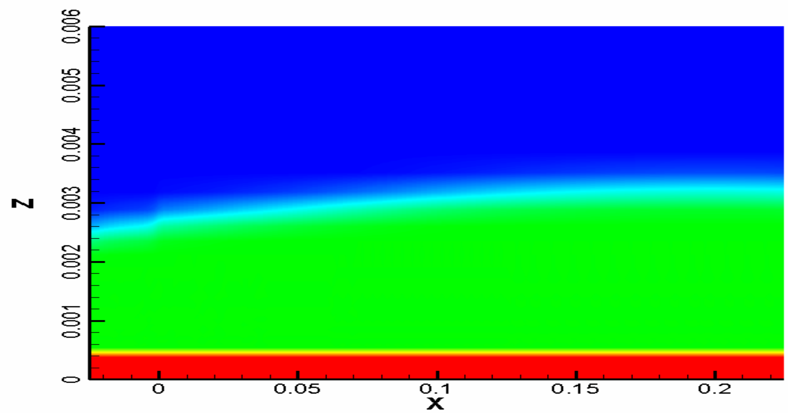


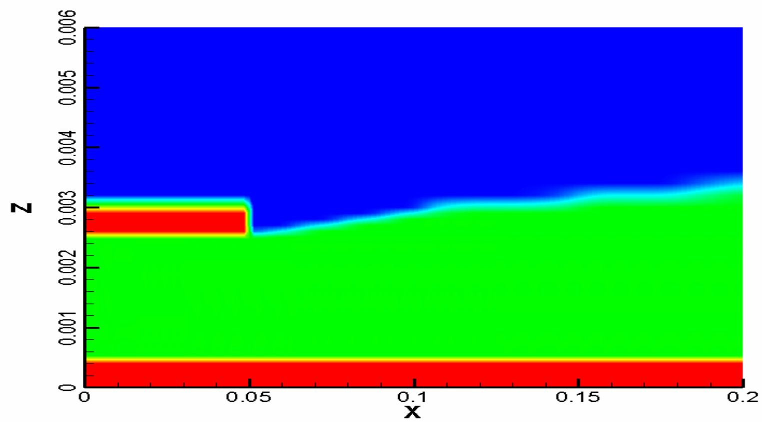
# Lithium flow evolution at the far left corner before and after detachment



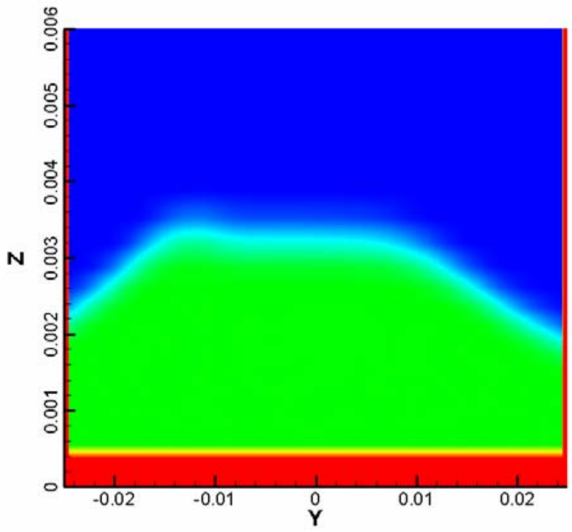
# Effect of Conducting Injecting Nozzle

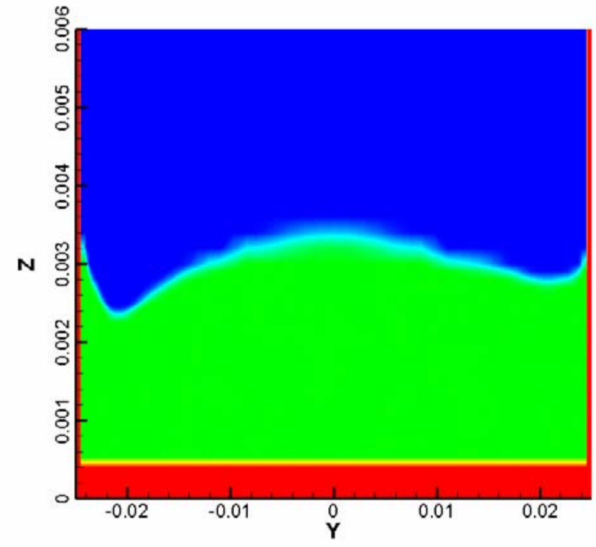
**Stream-wise cross section cut at the channel center-line shows a similar stream-wise variation of film thickness.**




**Span-wise cross section cut at 20*cm* downstream, showing the span-wise variation of film thickness.**

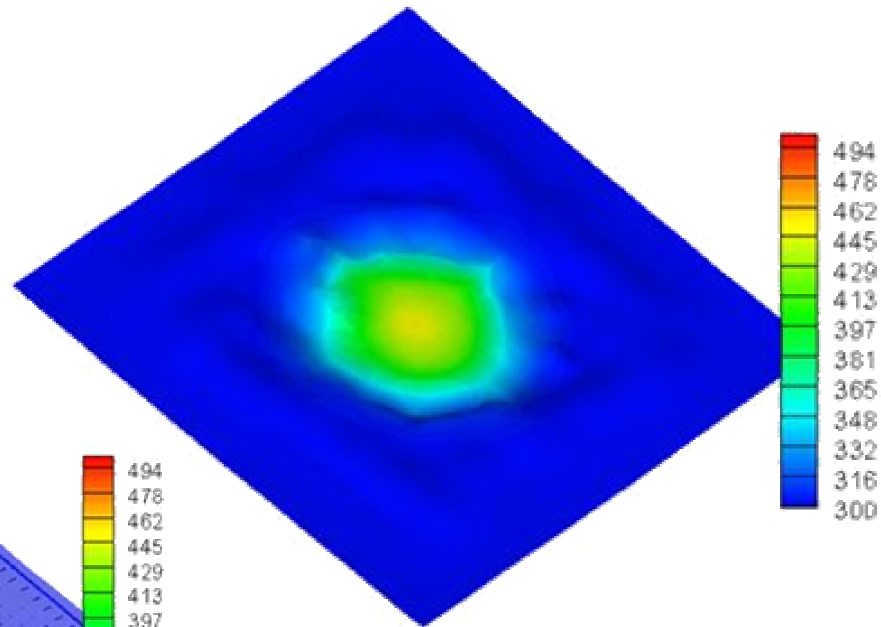


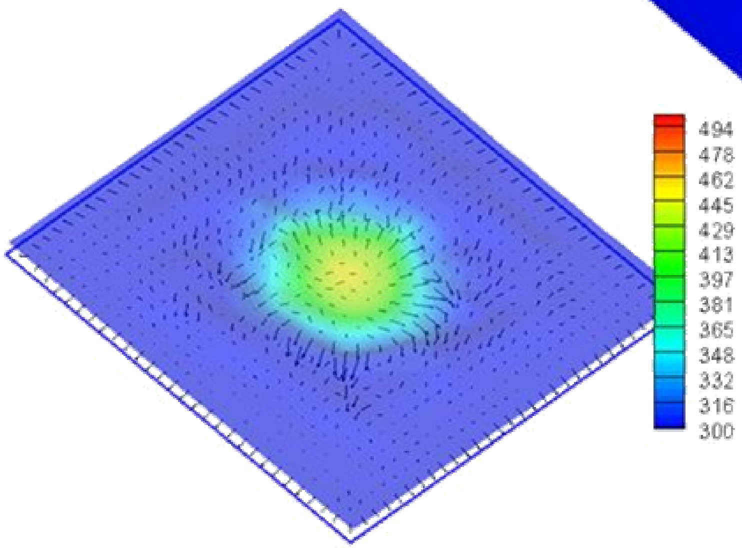
# Simulation of e-beam heating of liquid lithium surface

**.3 A, 1.2kW, 12 mm diameter e-beam on Li surface initially at 300C for 40 ms**

**(no MHD forces included)**




**Surface ripples indicating motion due to surface tension variation with temperature**




**Surface velocity vectors showing outward motion of the liquid in near surface region**

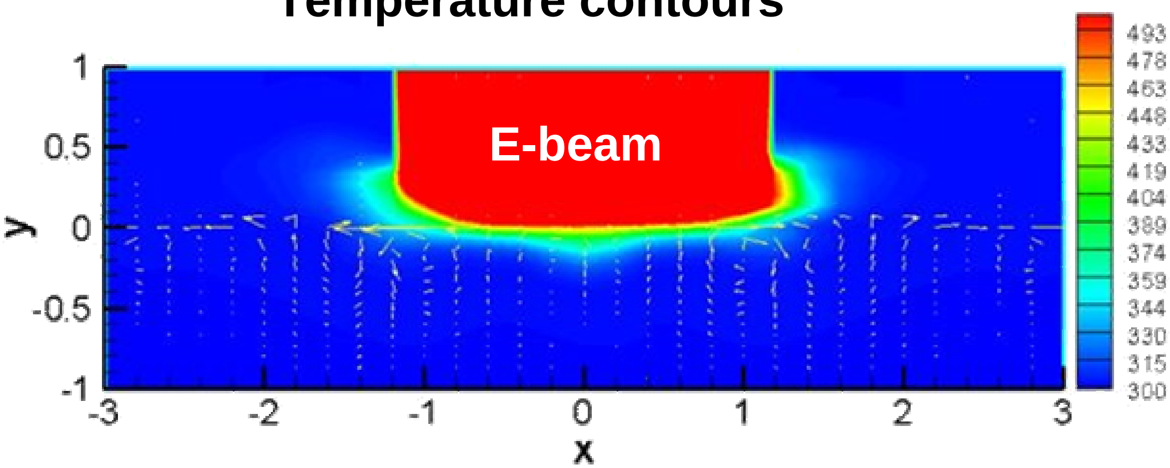
# Important effect for jets, droplets and waves on films that present small normal-incidence targets

- Convection driven in jets and droplets that have local normal incidence may help reduce maximum surface temperature
- Similar phenomena expected for surface waves on films
- More analysis of droplets/jets/films with MHD needed

**Heated layer is very thin**

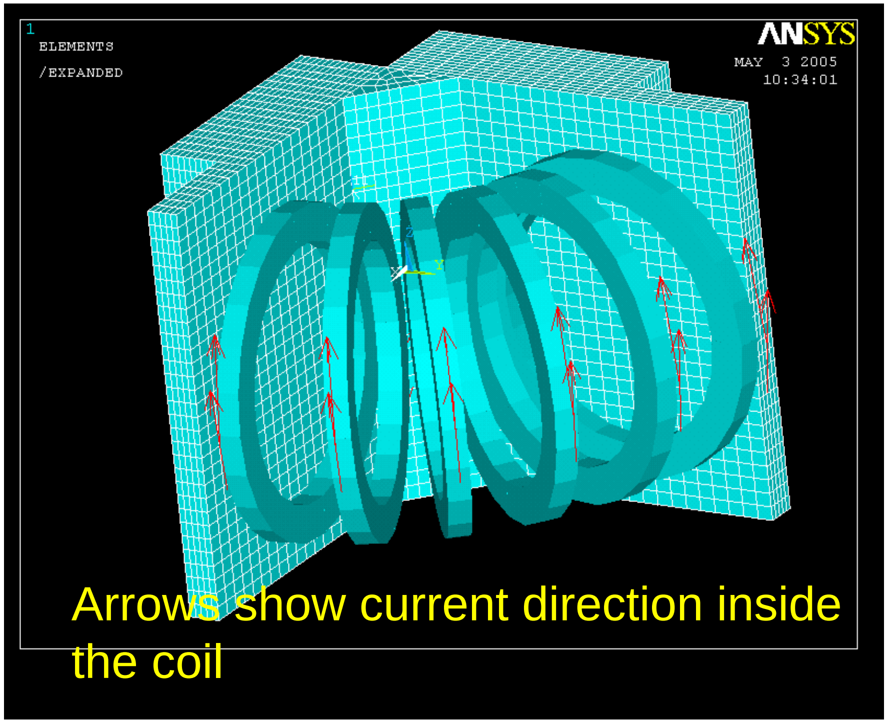
**Strong velocity away from the hot spot ~ 0.25 m/s peak velocity in the liquid after just 40 ms**

**Temperature contours**

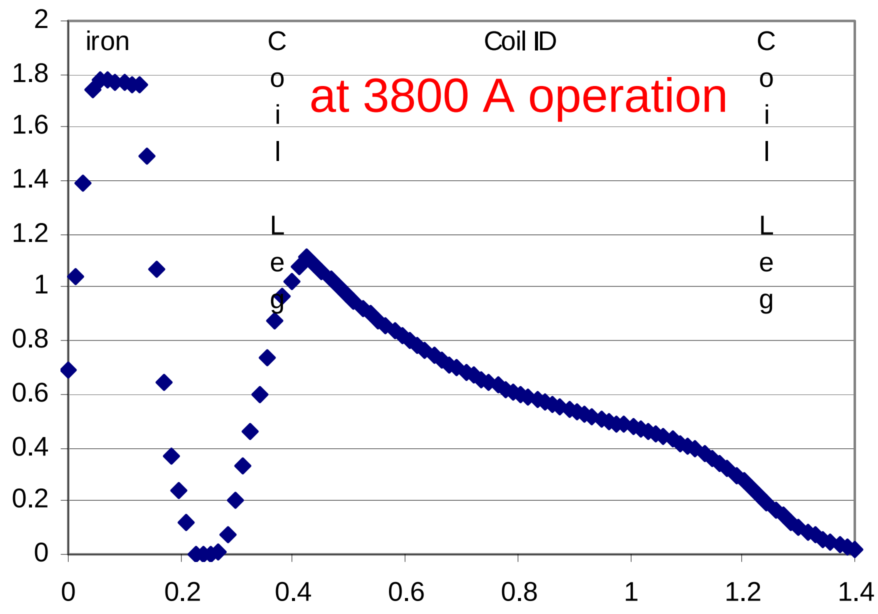


# Experimental Progress

- The toroidal field generating facility (MTOR) is being enhanced to carry higher currents to generate the required toroidal field without the use of iron flux concentrators.
- This will allow for space to carry out toroidal field tests on the 20*cm* wide channel



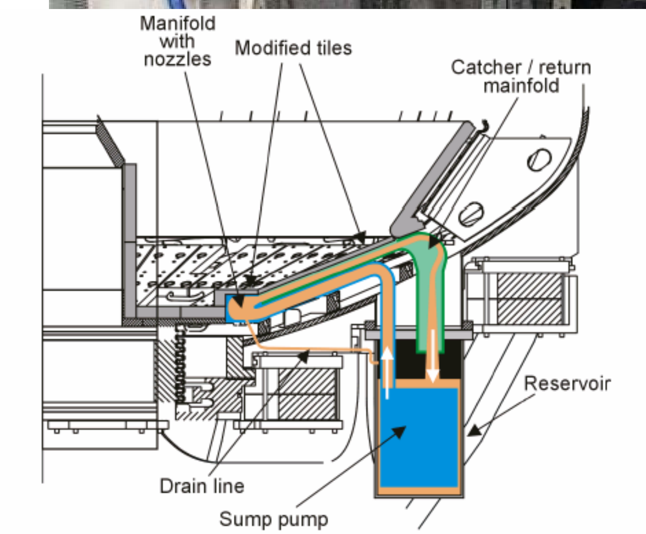

ANSYS modeling of the modified magnetic torus section.

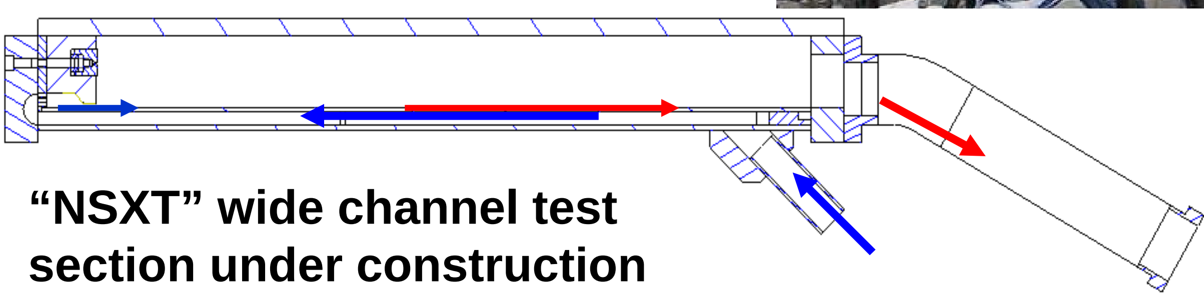



Calculated field as a function distance from symmetry axis at coil mid plane.

# MTOR
# Upgrade underway

**Utility services serve both Q-tours and Jupiter II BOB magnets**



**“NSXT” wide channel test section under construction**


**BOB**

**JUPITER II magnet (2T)**

# Remaining work to be completed this year

- Numerical modeling
  - Flow simulations to aid in the designs for a flowing liquid surface module under NSTX divertor geometry and magnetic field conditions.
  - Enhance computational capabilities to address plasma current and momentum flux effects, addition of surface heat flux effects and temperature calculations and addition of simple turbulence models
- Experimental effort
  - Complete wide channel free surface flow simulations under the scaled NSTX gradient toroidal field
  - Complete a magnet assembly, which provides the NSTX-like gradient surface normal field, by using an array of permanent magnets