LM-MHD free-surface flow experiments in MTOR

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VLT Conference Call

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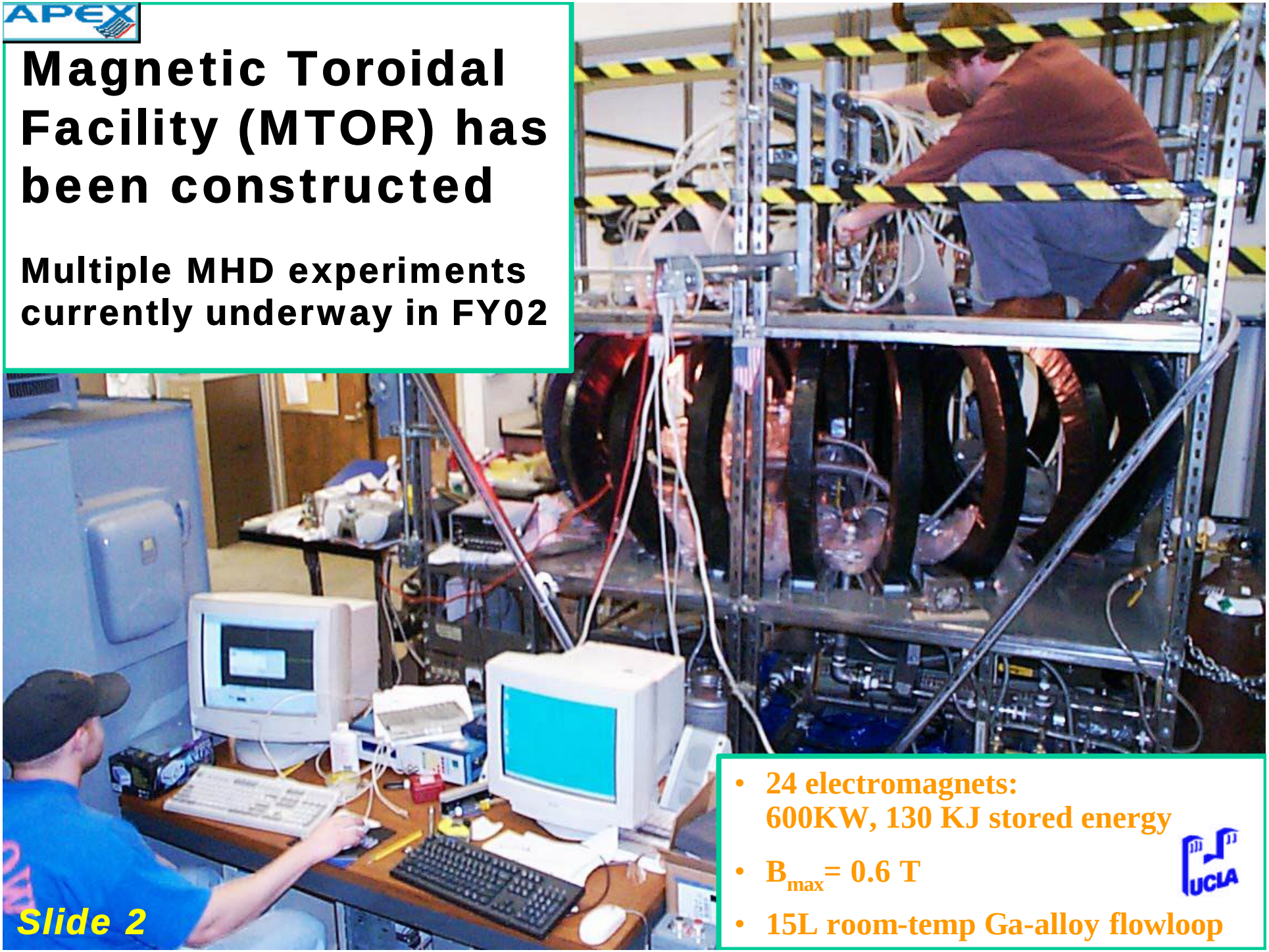
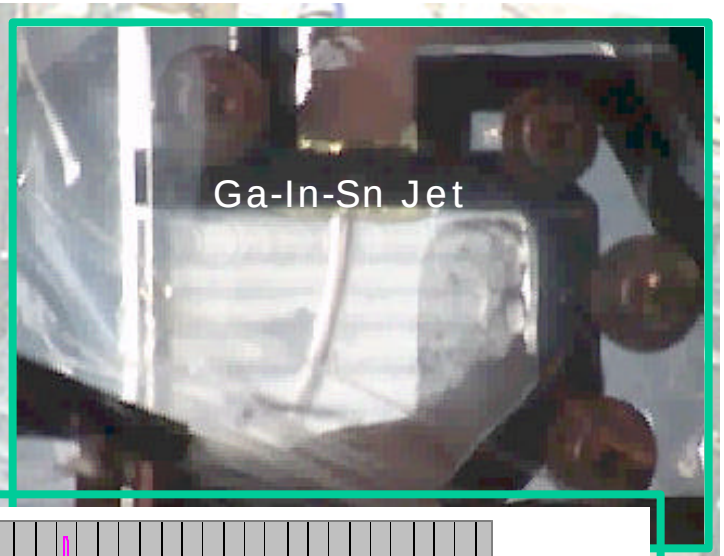
Magnetic Toroidal Facility (MTOR) has been constructed

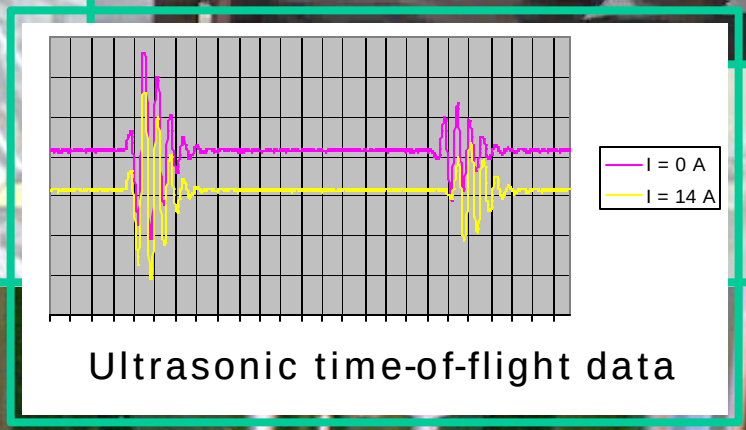
Multiple MHD experiments currently underway in FY02



- 24 electromagnets: 600KW, 130 KJ stored energy
- B_{max}= 0.6 T
- 15L room-temp Ga-alloy flowloop

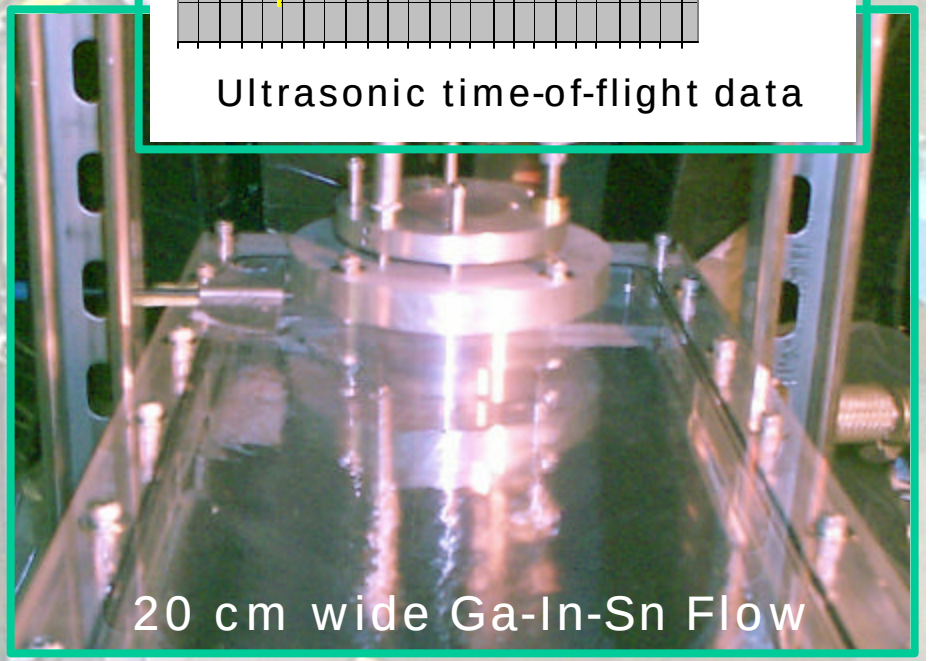
MHD effects on fluid flow and heat transfer are dominant issues for liquid metal walls





Extensive effort was initiated in FY02 and will be a major focus in APEX for FY03/04

1. Serious modeling of 3D MHD Flows with multiple component magnetic fields (no tools currently exist)
2. Intensive experiments on MTOR and LIMITS facilities to provide direct data for design and model validation



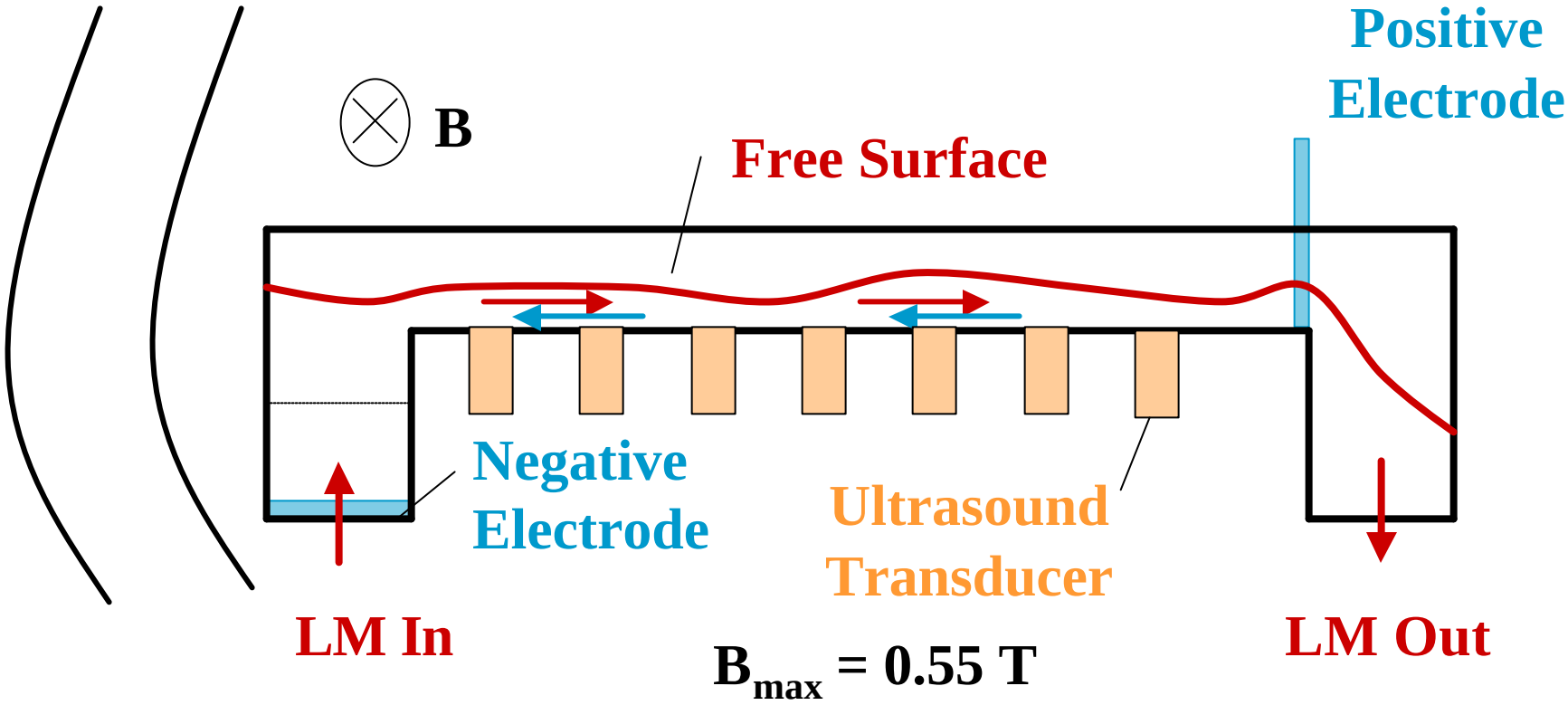
MTOR Facility Objectives

- **Field and gradient effects on drag and stability.** Free surface flows are very sensitive to drag from toroidal field 1/R gradient and surface-normal fields. Complex stability issues arise with field gradients, 3-component magnetic fields, and applied electric currents
- **Geometric Effects.** Including axisymmetry, expanding contracting flow areas, inverted flows, penetrations
- **NSTX Environment simulation** for module testing. Including time varying field effects

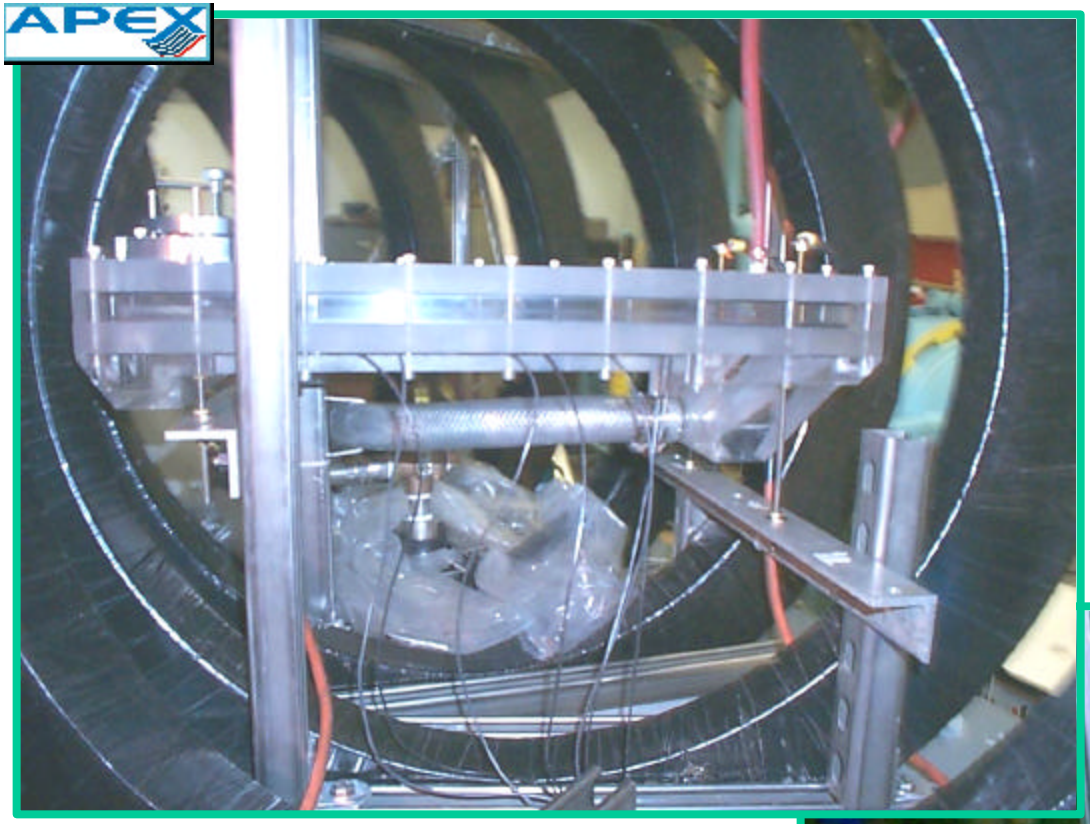
Initial Experiments in MTOR

- Inclined plane with magnetic propulsion
- Flux concentrators
- Free jet
- Recirculating cell
- Soaker Hose (not discussed here)

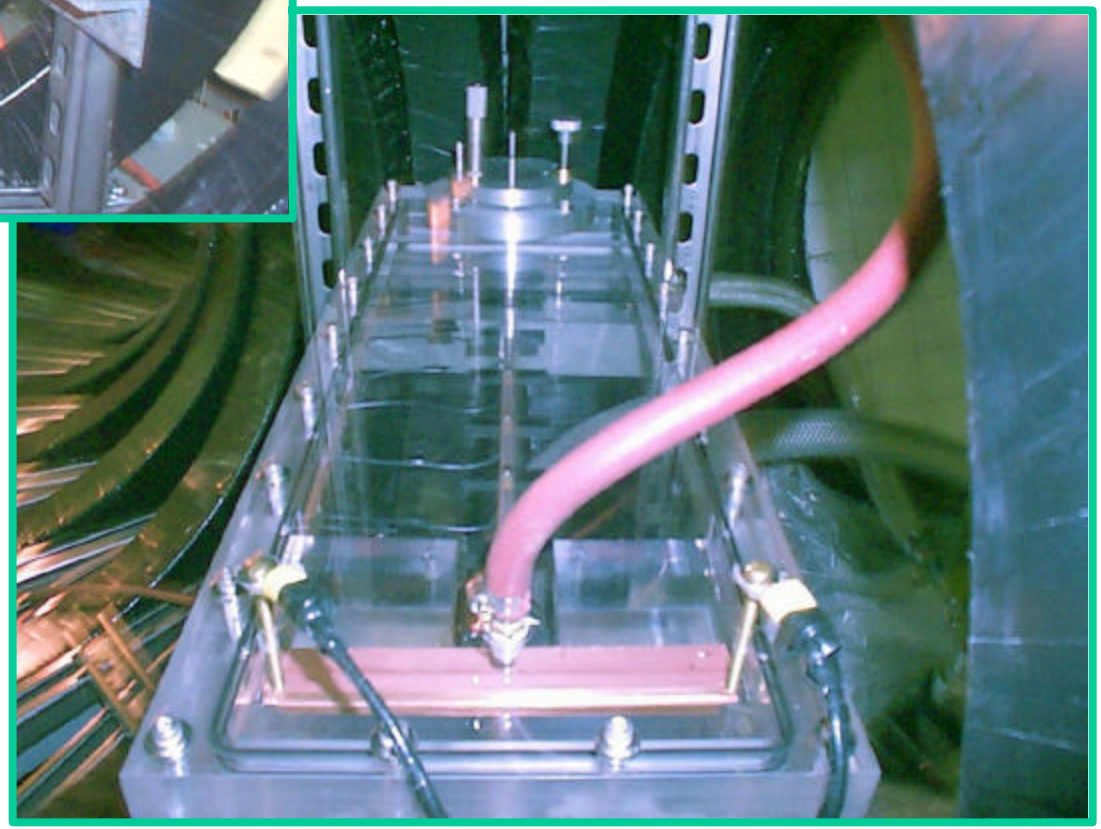
Flow Experiments on Inclined Plane with Magnetic Propulsion



Inclined-Plane Test Section

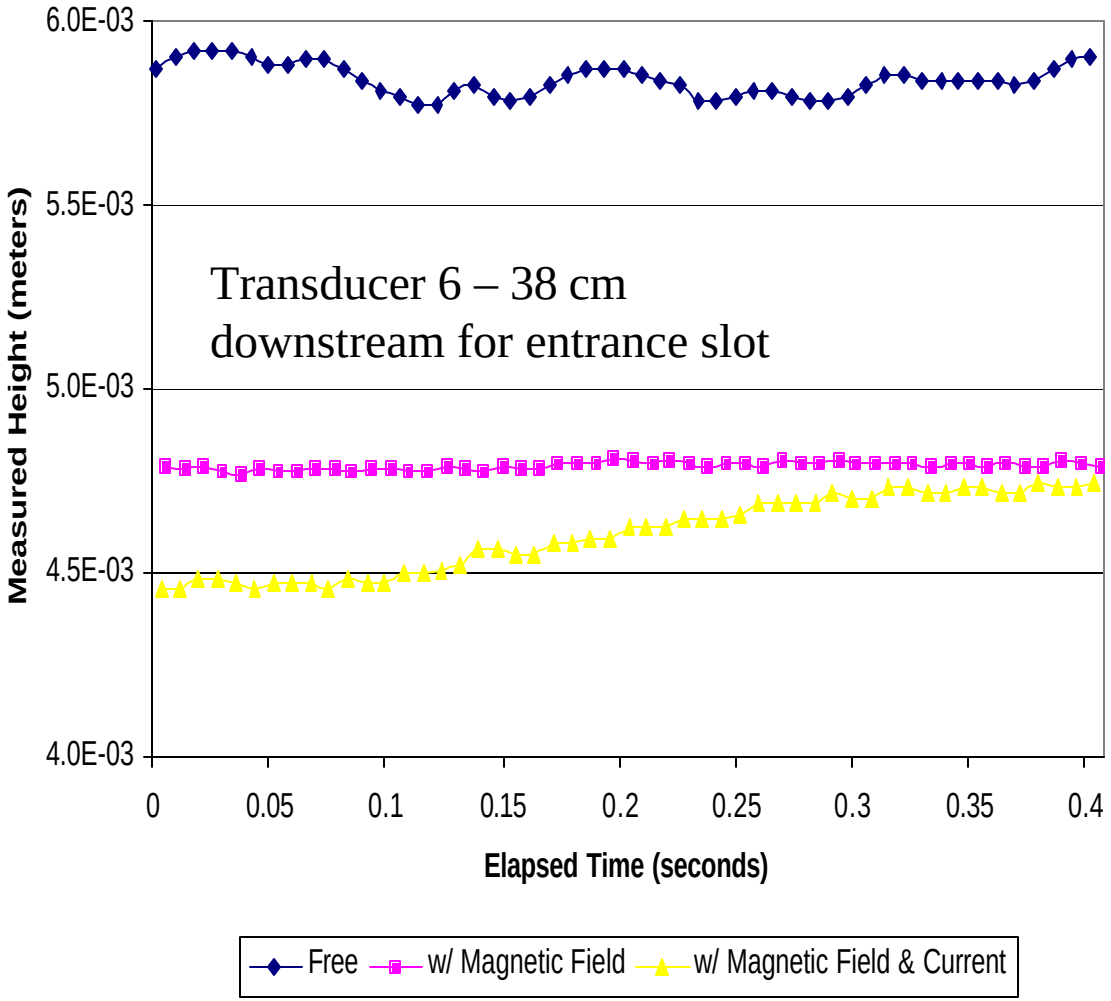


- 150 A available for MP
- Walls are insulated and does not wet Ga alloy



- Flow area: 20 cm x 60 cm
- Flow is enclosed with Argon cover gas
- 7 Ultrasonic Transducers
- Variable inclination +5 to –15 deg

Film height response to toroidal field and magnetic propulsion current



B field acts to laminarize flow – **Reducing flow resistance and eliminating surface waves**

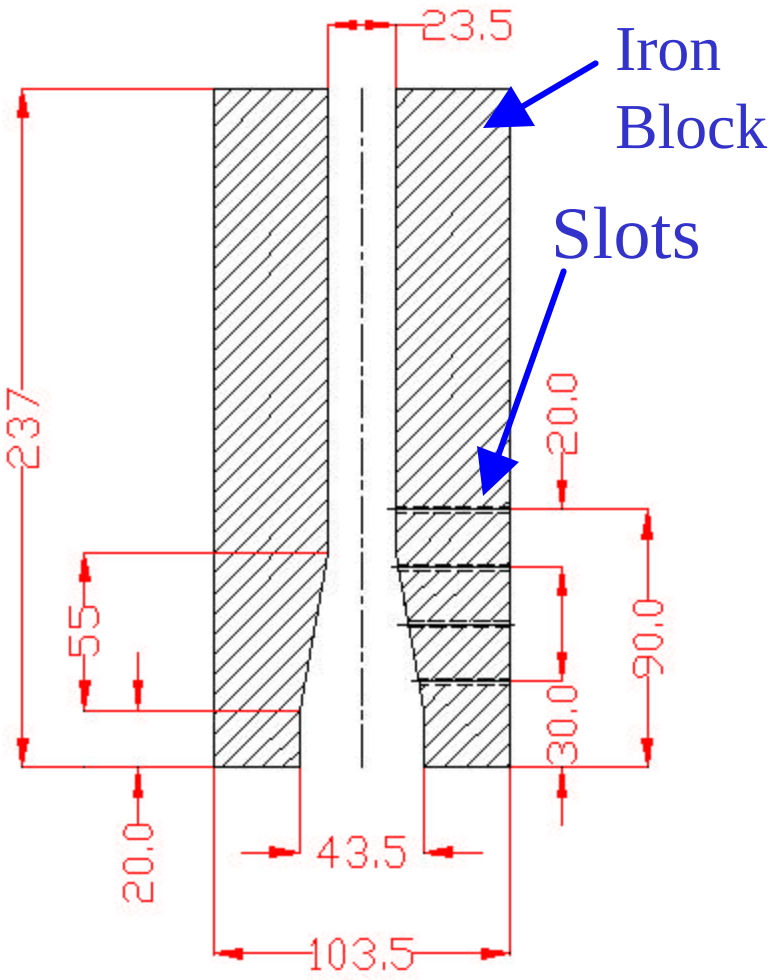
MP current acts to accelerate flow, but low frequency instabilities return

Flow interrupter and/or current sensor needed for inclined plate test section

- **Current sensor** - Need to determine total applied current going through the test section. Need to upgrade current to 600 A capability
- **Flow interrupter** - Want to keep applied current constant, and have total current available for drive

Paddle-wheel flow interrupter

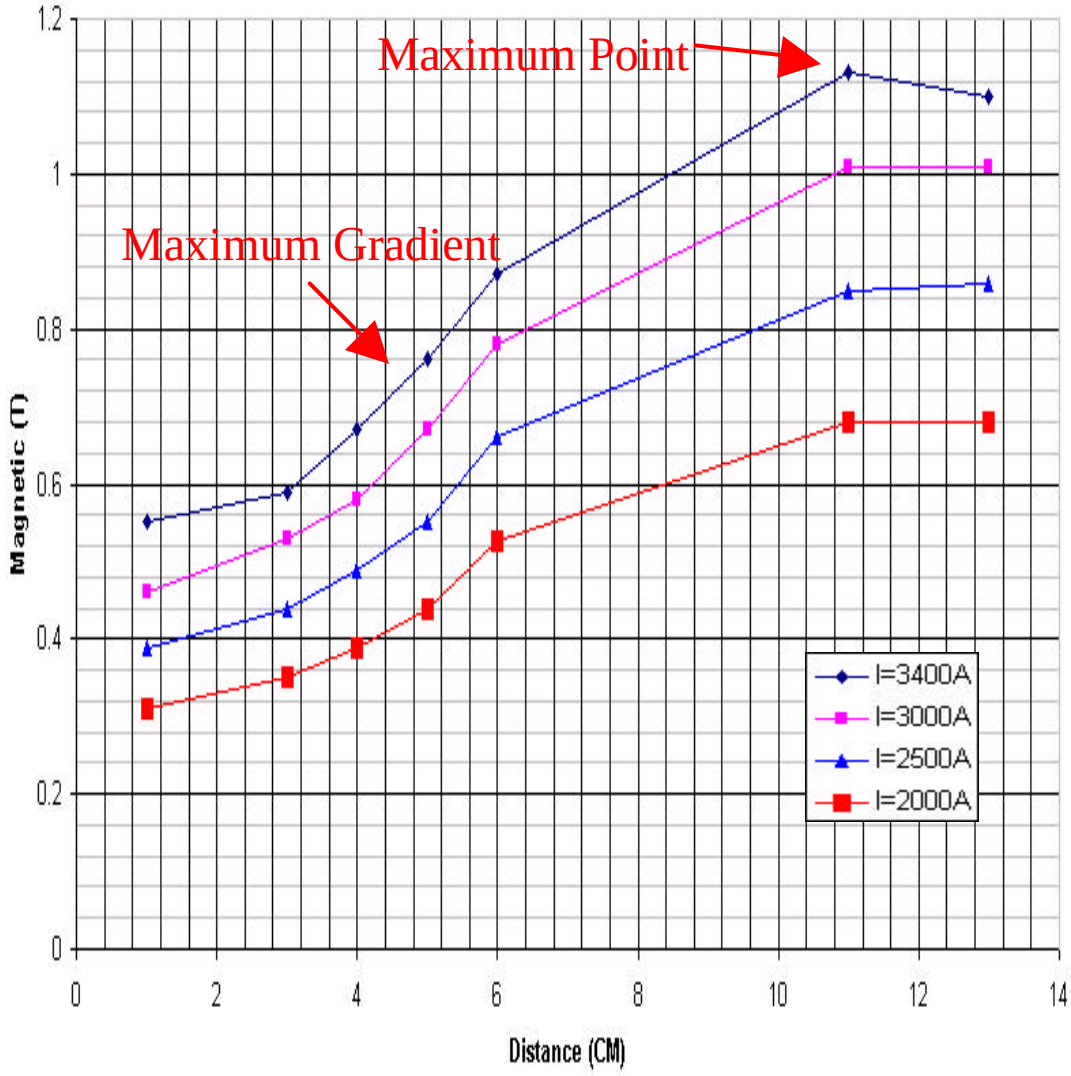
LM Jet test for NSTX module simulation



Unit: mm

- Jet flow is introduced into the high field region between flux concentrators
- The concentrator assembly includes a pair of large iron circle disks (not shown), which grasp the flux and redistribute it into a small iron block
- The field strength depends on the distance between the pair
- Visualizations slots are cut in the iron block to view displacement of jet

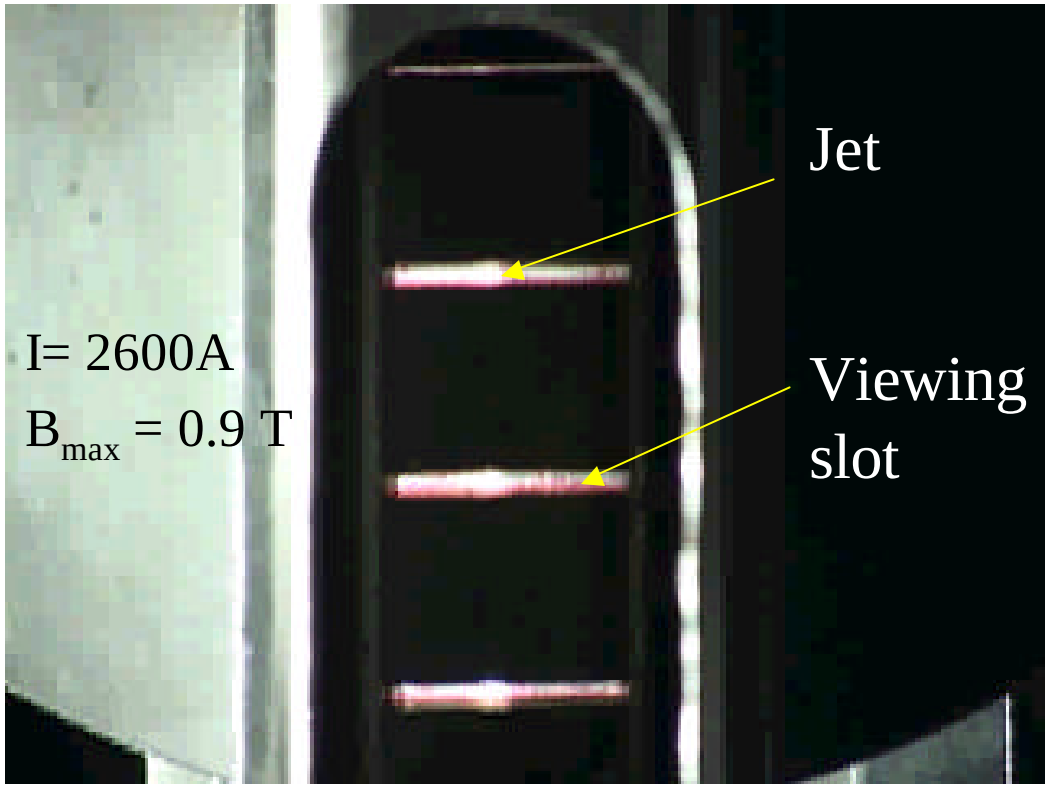
Magnetic Field Strength inside MTOR can be tailored using concentrators

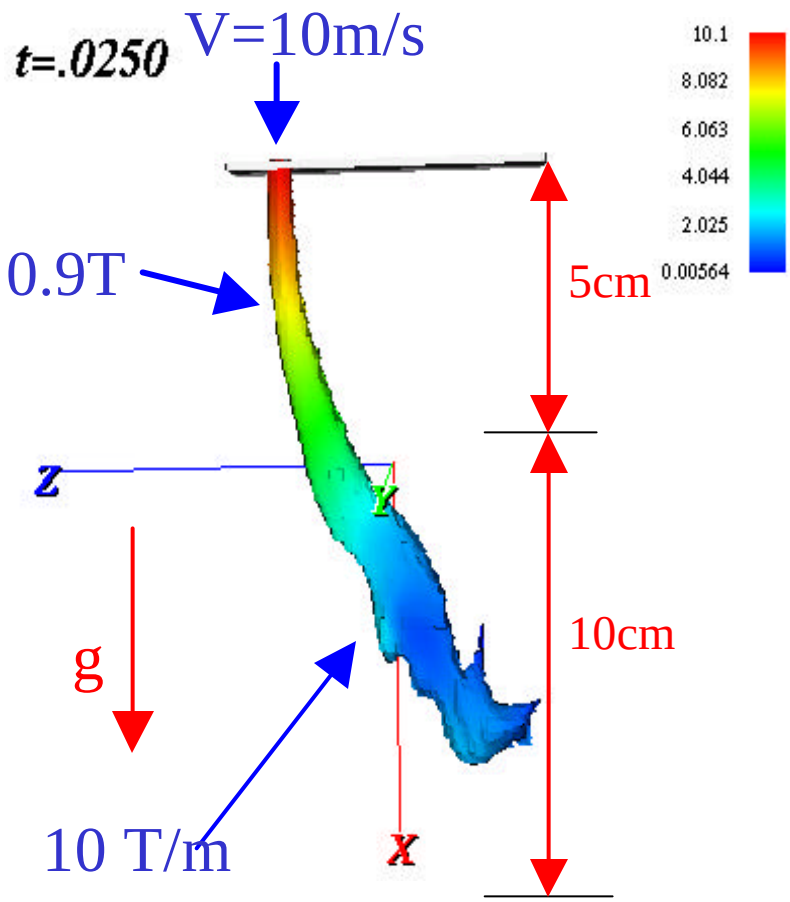


- The magnetic field increases with increasing coil current
- The maximum magnetic field is ~ 1.1T
- The maximum gradient of the magnetic field is ~ 10T/m

Note: Distance means distance along anti-flow direction from bottom of concentrator

Numerical simulation predicts more jet deflection than experiment observation

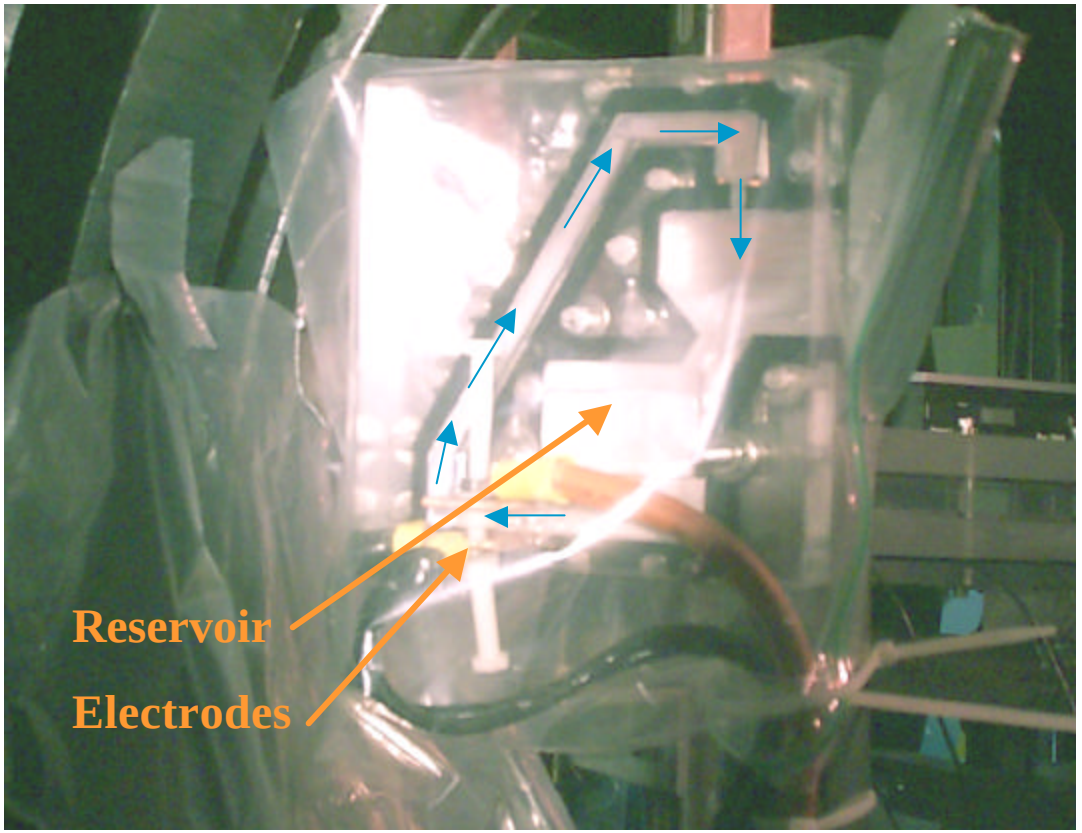




http://www.fusion.ucla.edu/apex/meeting18/07172002_PowerPoint.avi
http://www.fusion.ucla.edu/apex/meeting18/Jet-high-quality.avi

Recirculating cell test for CMOD module simulation

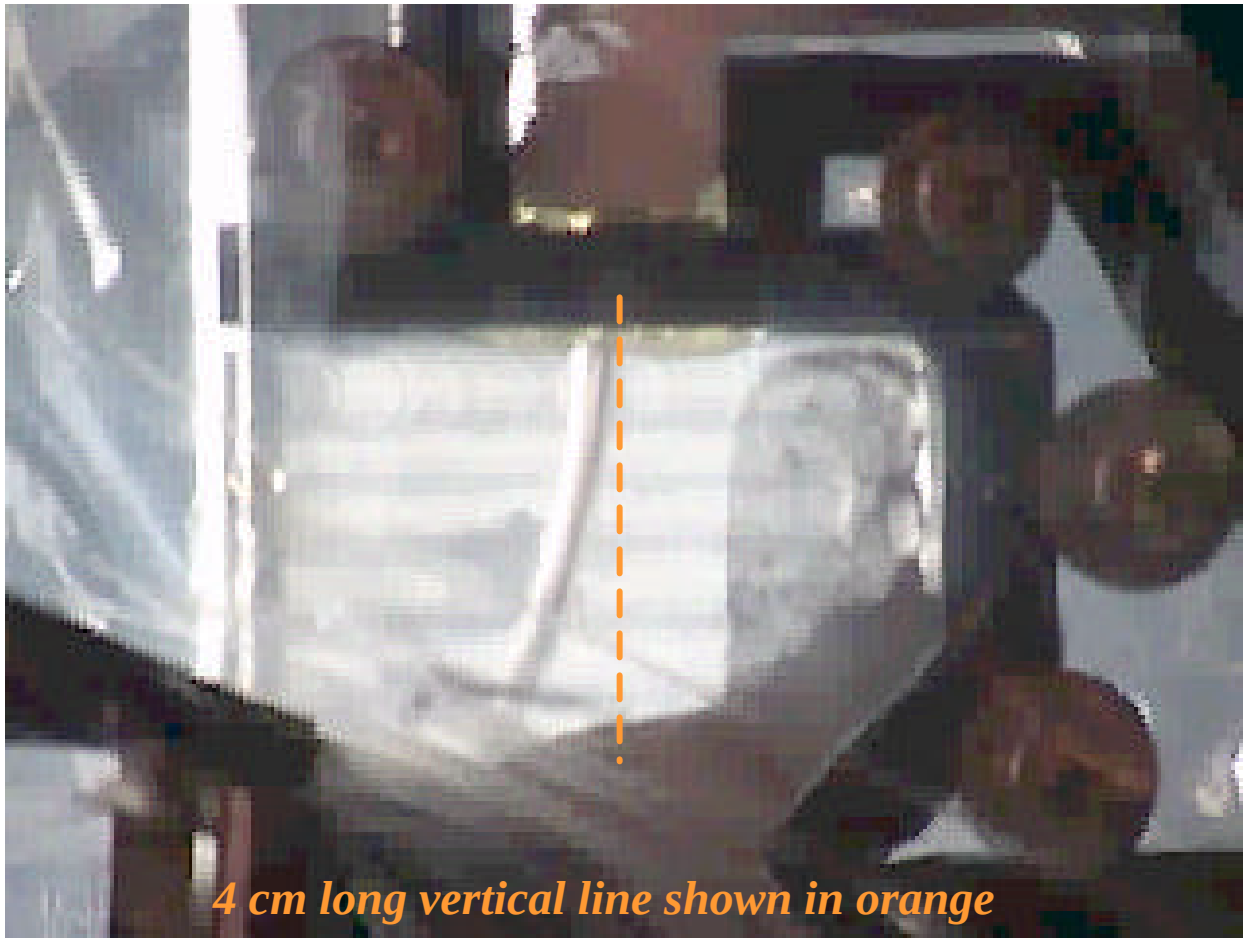
- Based on ORNL idea for CMOD, compact in-situ conduction pump working off toroidal field
- Test cell is acrylic, with copper electrodes, 0-170 A of applied current, and B = 0.55 T



Flowpath marked by blue arrows →

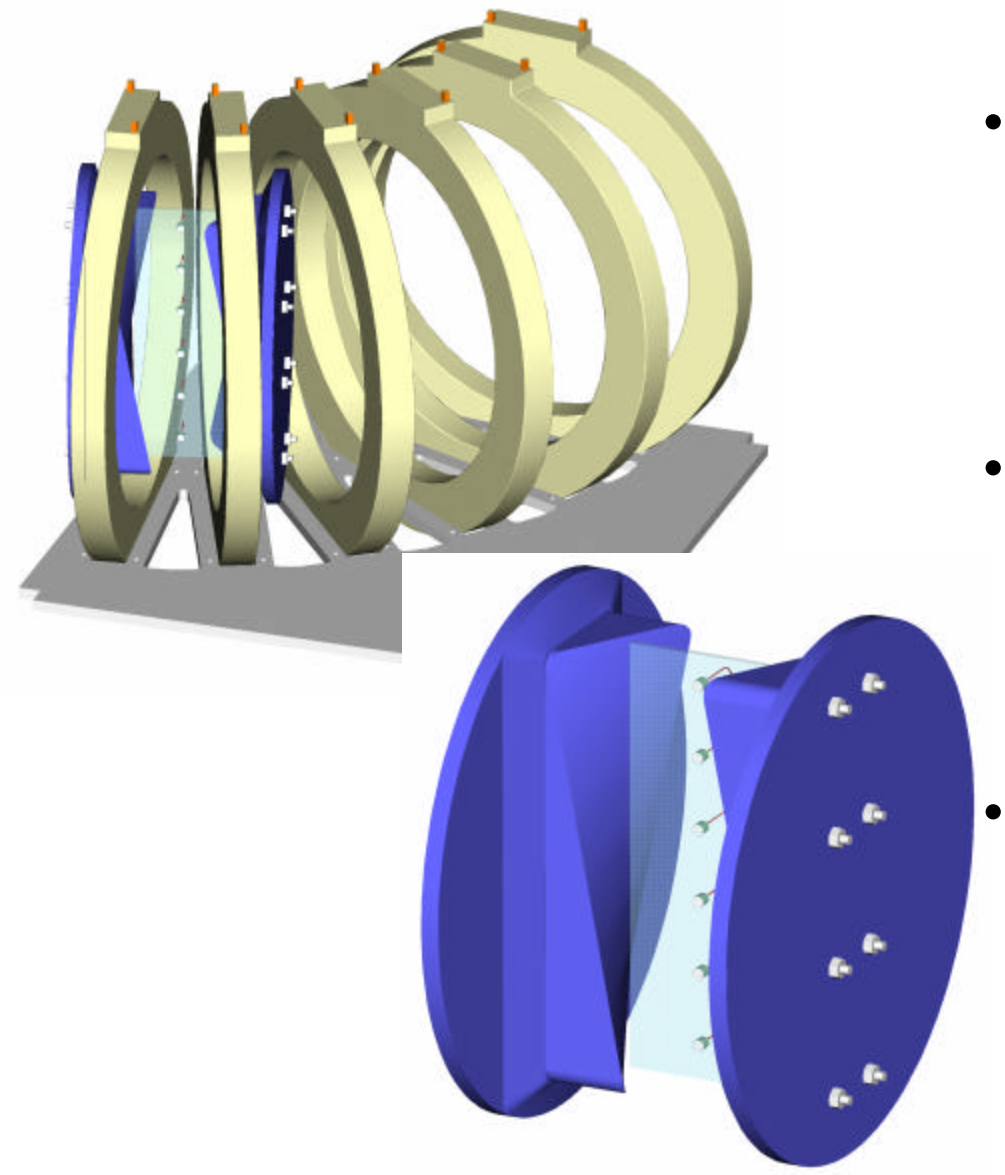
Leakage current bends jet trajectory

- **Some small amount of current is flowing streamwise with the jet.**
- **Jet velocity at nozzle exit roughly 0.5 m/s, accelerates to 1 m/s**
- **Relative resistance of current paths puts: I_{jet} ~ 1 A, $J_{jet} = 8 \times 10^4$ A/m^2, Deflection = 15 mm, Which agrees with experimental findings**
- **In CMOD, must avoid this type of current.**



http://www.fusion.ucla.edu/apex/meeting18/recirc.avi

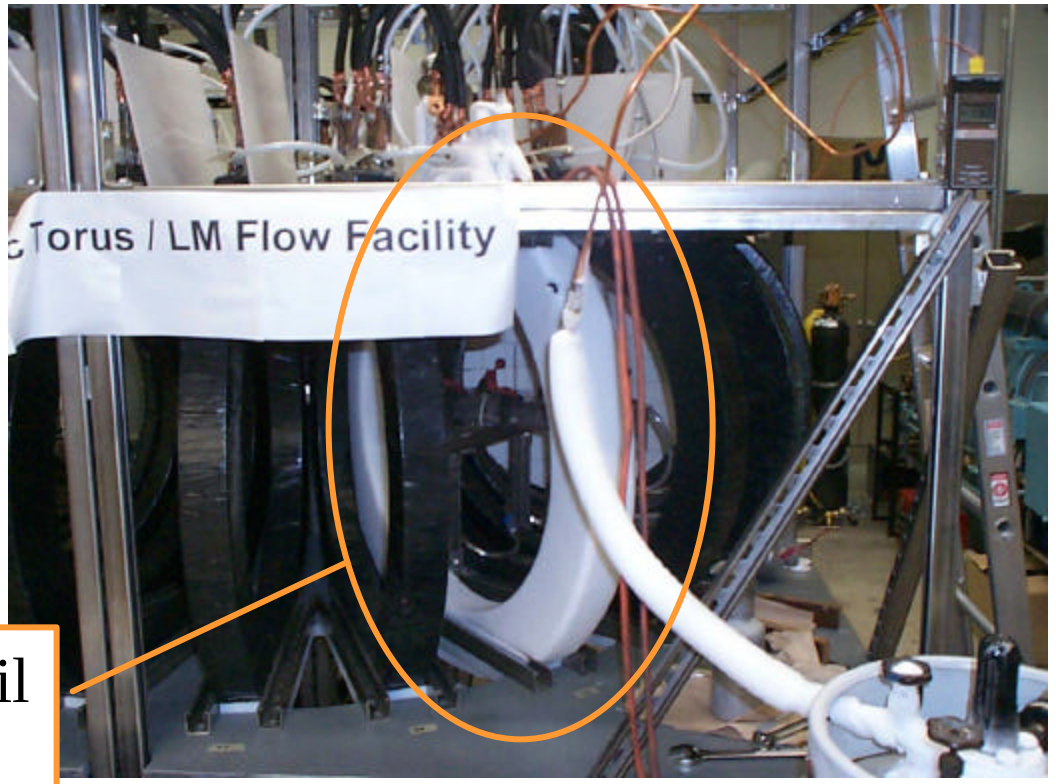
MTOR Improvements
Flux Concentrators for higher field



- **Small iron concentrators producing > 1 T fields and 10 T/m gradients in narrow gap**
- **Bob Woolley visit to UCLA clarified issues for ANSYS calculations of large iron concentrators**
- **Permanent magnets from SNL ordered and awaiting delivery**

Current increase for MTOR coils to double toroidal field

- Visit by Bob Woolley to UCLA in January helped clarify technical issues for higher power
- Various plans for increasing B field will be developed in upcoming weeks



N_2 cooling of MTOR coil down to vapor temp of –45 C gave a factor of 2 increase in conductivity.