

# **Analysis of lithium jet in LIMITS**

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# JET Calculation Using HIMAG

5 mm diameter round 200C lithium jet

Inlet velocity = 10m/s

Lithium Properties

Characteristic scales:

Velocity = 10m/s

Magnetic field = 1T

Length = 2.5mm

Re=2.23E+4

Ha=207.04

We=323.18

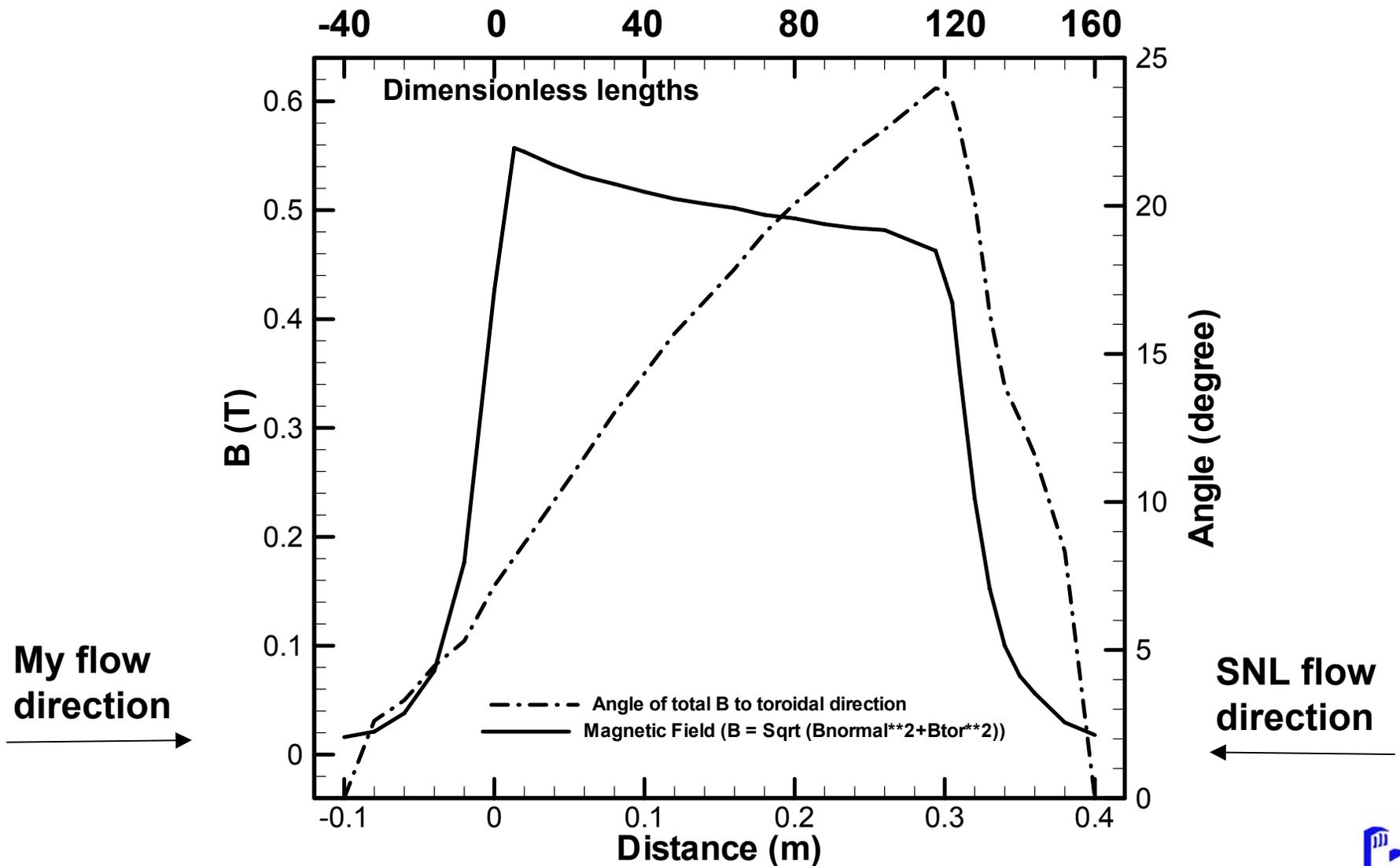
Fr=4077.5

Re=1000

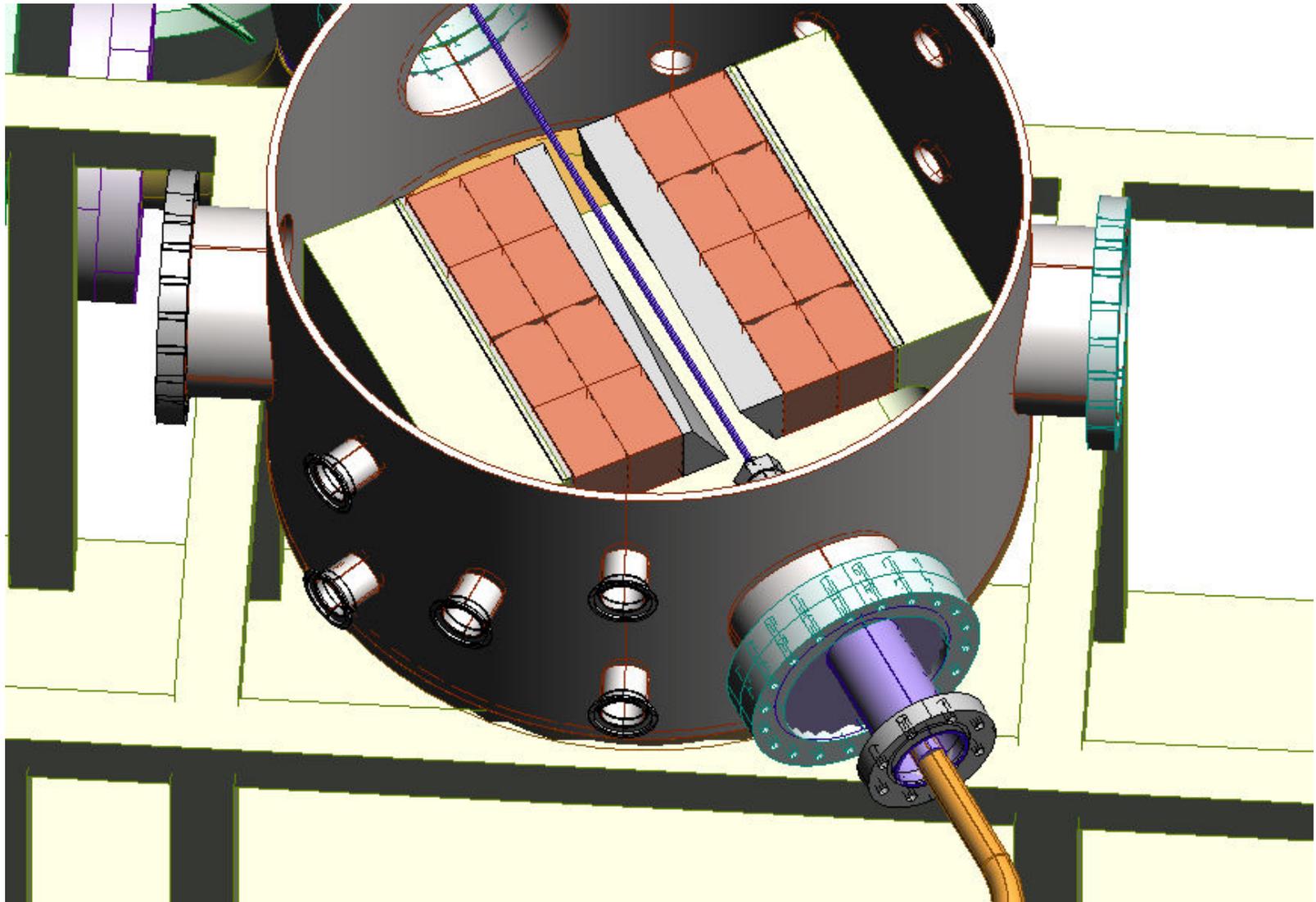
1:3:3

<u>Properties</u>		Lithium (200C)
Composition	Mole %	100% Li
Melting Point, Tm	K	459
Operating Point, T	K	473
Density, rho	kg/m3	510.63
Dynamic Viscosity, mu	kg/m/s	5.73E-04
Kinematic Viscosity, nu	m2/s	1.12E-06
Electrical Conductivity, sig	1/ohm/m	3.93E+06
Thermal Conductivity, k	W/m/K	43.09
Heat Capacity, Cp	J/kg/K	4361.01
Surface Tension, gam	N/m	0.39

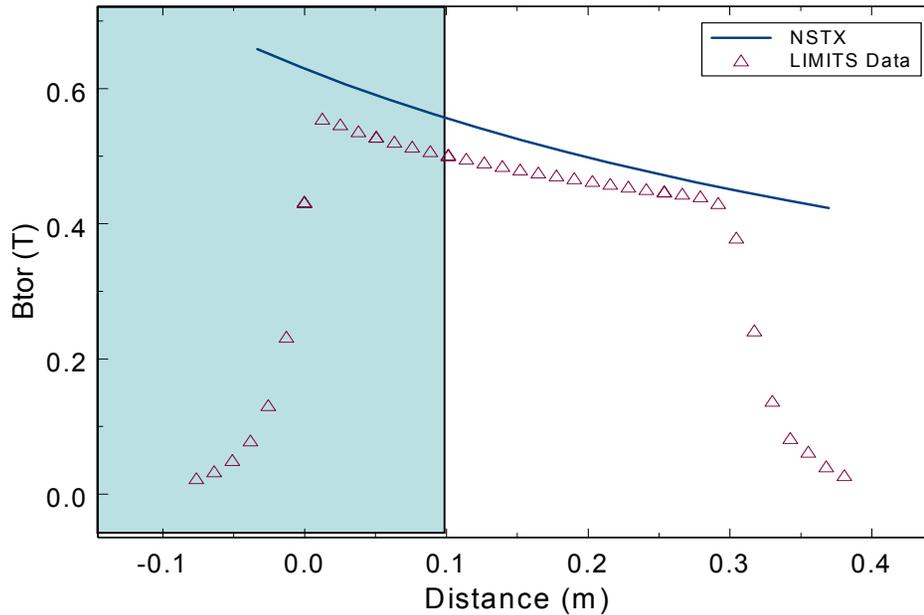
# Limits Field Configuration as a function of distance – magnitude gradient and change in field direction by ~25 degree



**LIMITS flow is from weak to strong field (outboard to inboard)**

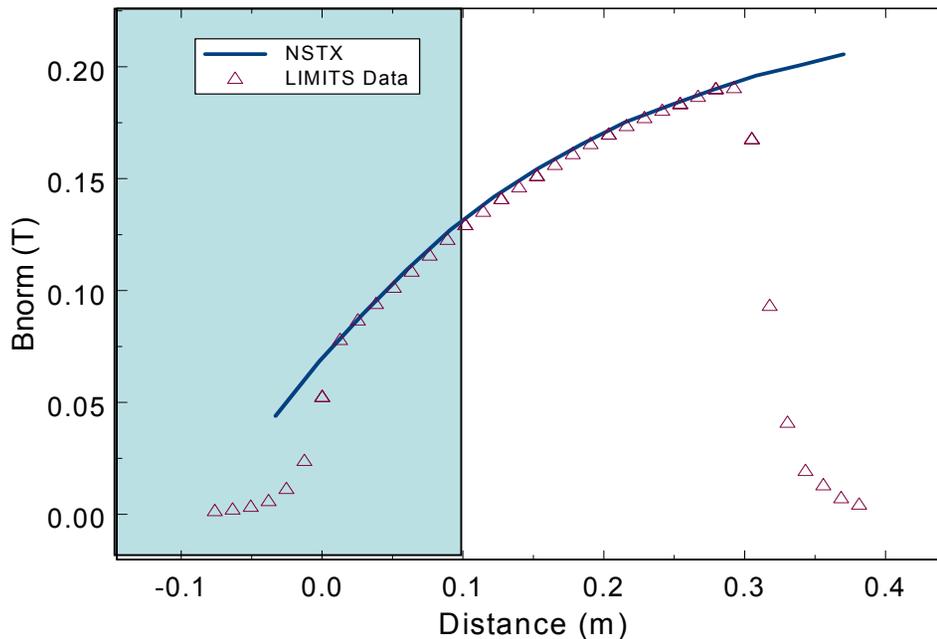


# Field Configuration 1 – Jet flows in from outside the magnet



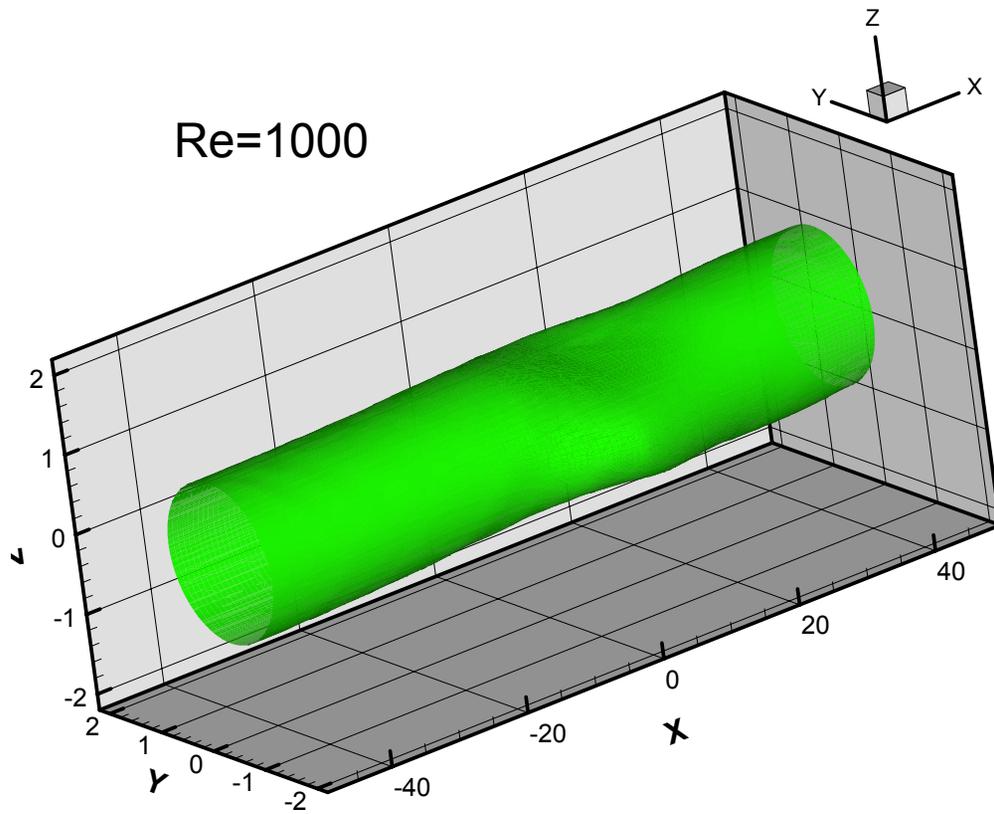
Comparison of the desired toroidal (horizontal) field in NSTX with the measured field in the LIMITS magnet

Calculation area  
In this presentation



Comparison of the vertical field in NSTX with the measured vertical field in the LIMITS magnet.

Re=1000

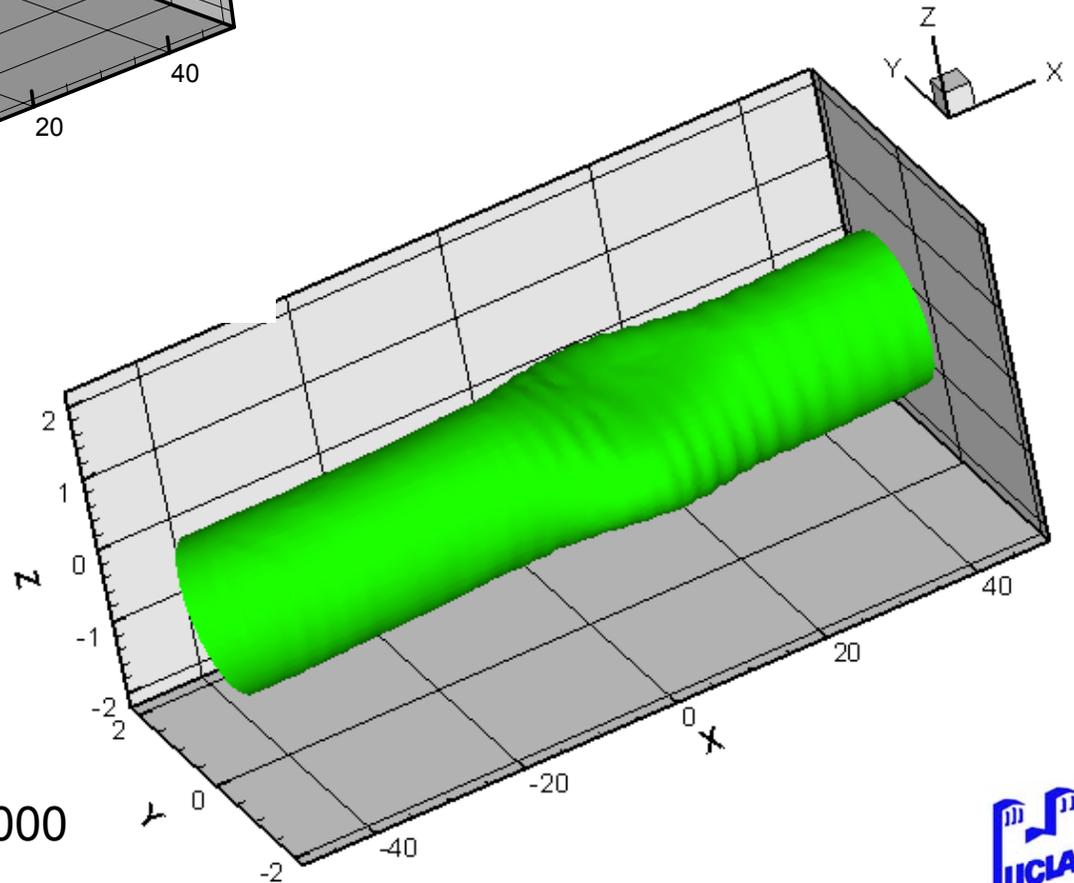


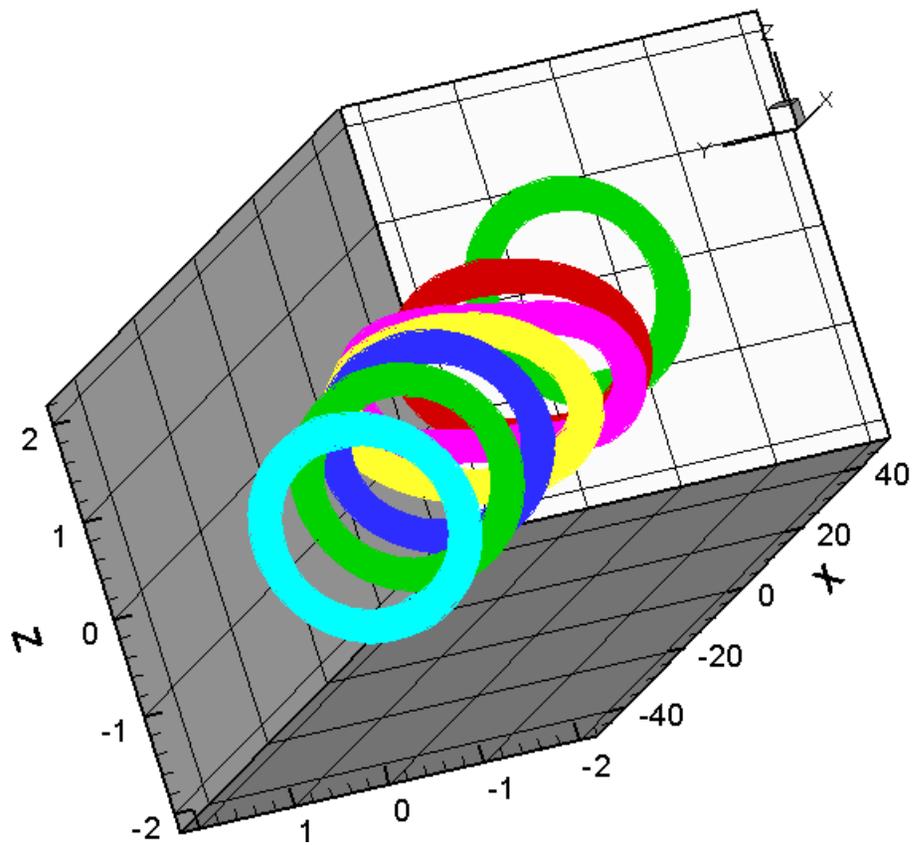
Inlet & outlet have 2.5 times diameters extended regions  
 $\phi=0$  at inlet &  $J_n=0$  at outlet.

Physical time = 81ms

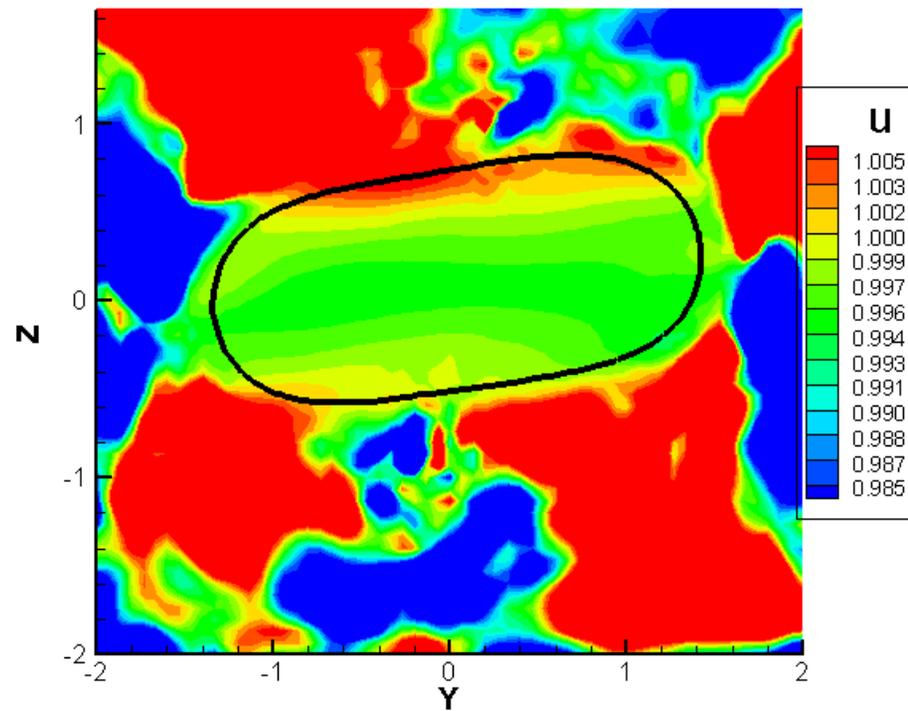
Size factors:  
1:10:10

Re=10,000

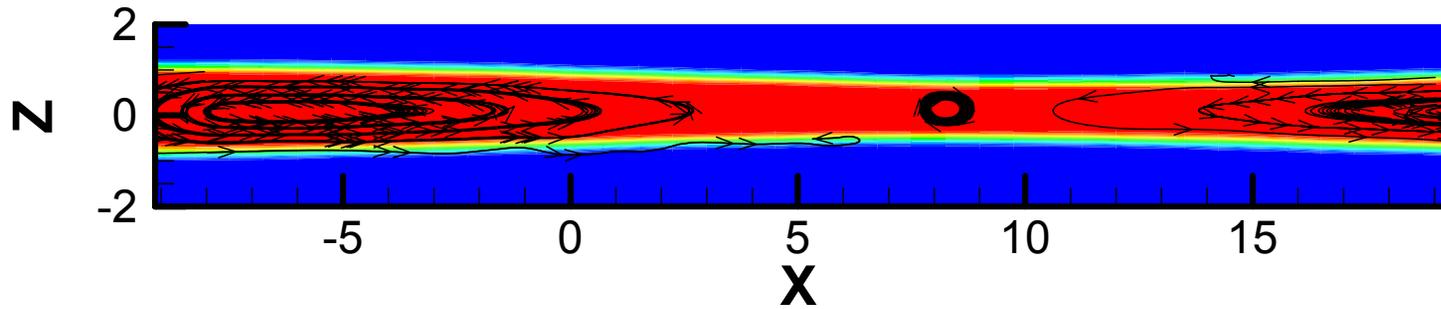




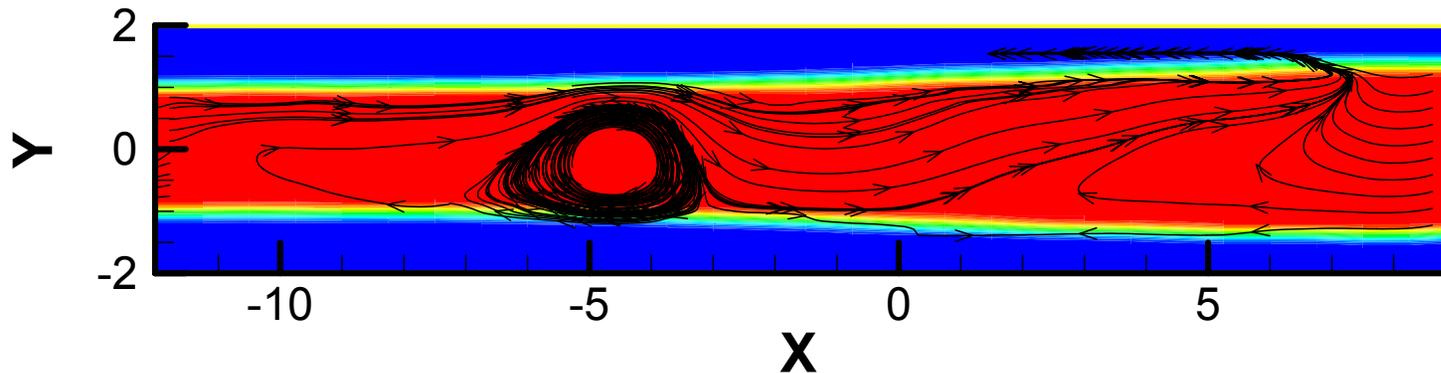
Deformed jet shape at different cross sections along x-axis



Interface shape and axial velocity at  $x=10$  (2.5cm)



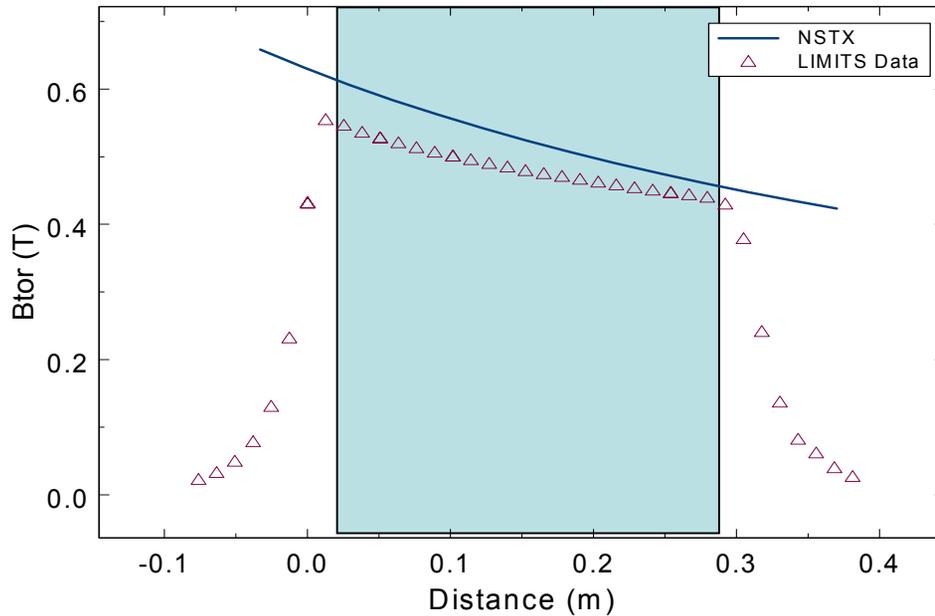
Jx-Jz current streamline distribution at cross section of  $y=0$   
 In which the jet interface shape is also shown, red part is liquid jet



Jx-Jy current streamline distribution at cross section of  $z=0$   
 In which the jet interface shape is also shown, red part is liquid jet

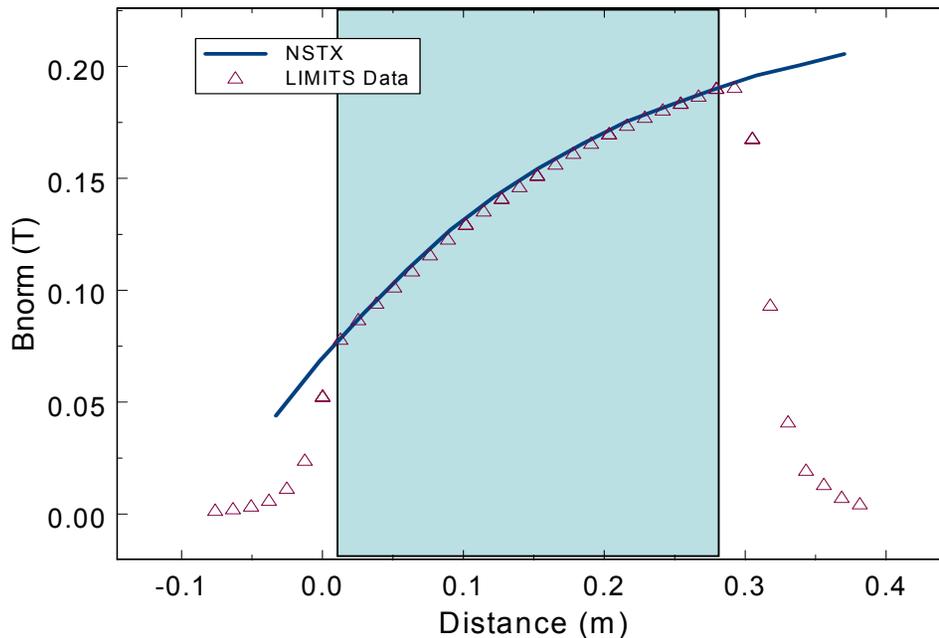
Size factor: 1:1

# Field Configuration 2 – Jet flows initiated in the magnet



Comparison of the desired toroidal (horizontal) field in NSTX with the measured field in the LIMITS magnet

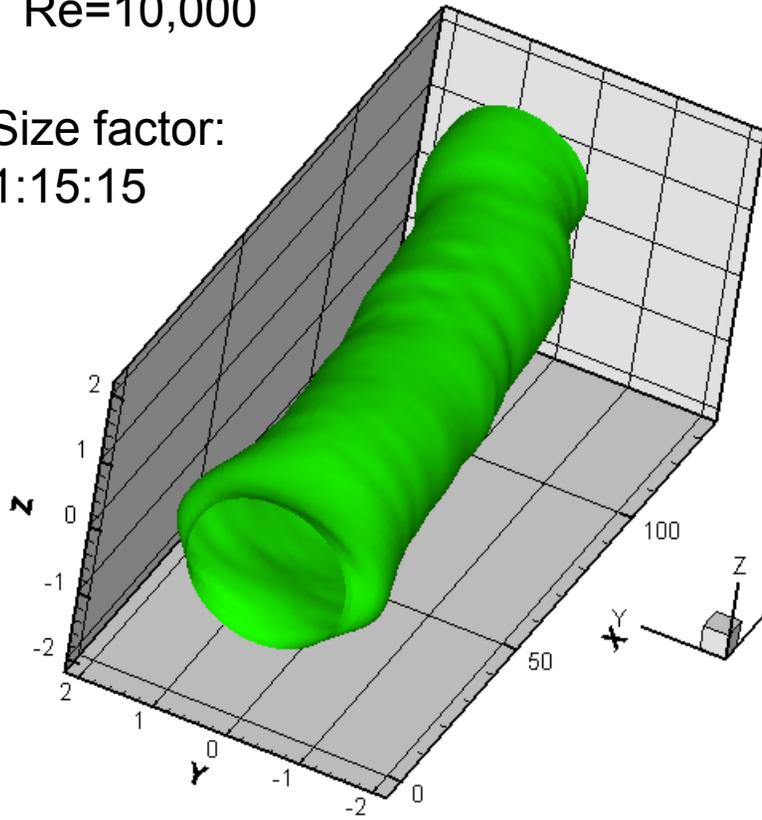
Calculation area  
In this presentation



Comparison of the vertical field in NSTX with the measured vertical field in the LIMITS magnet.

Re=10,000

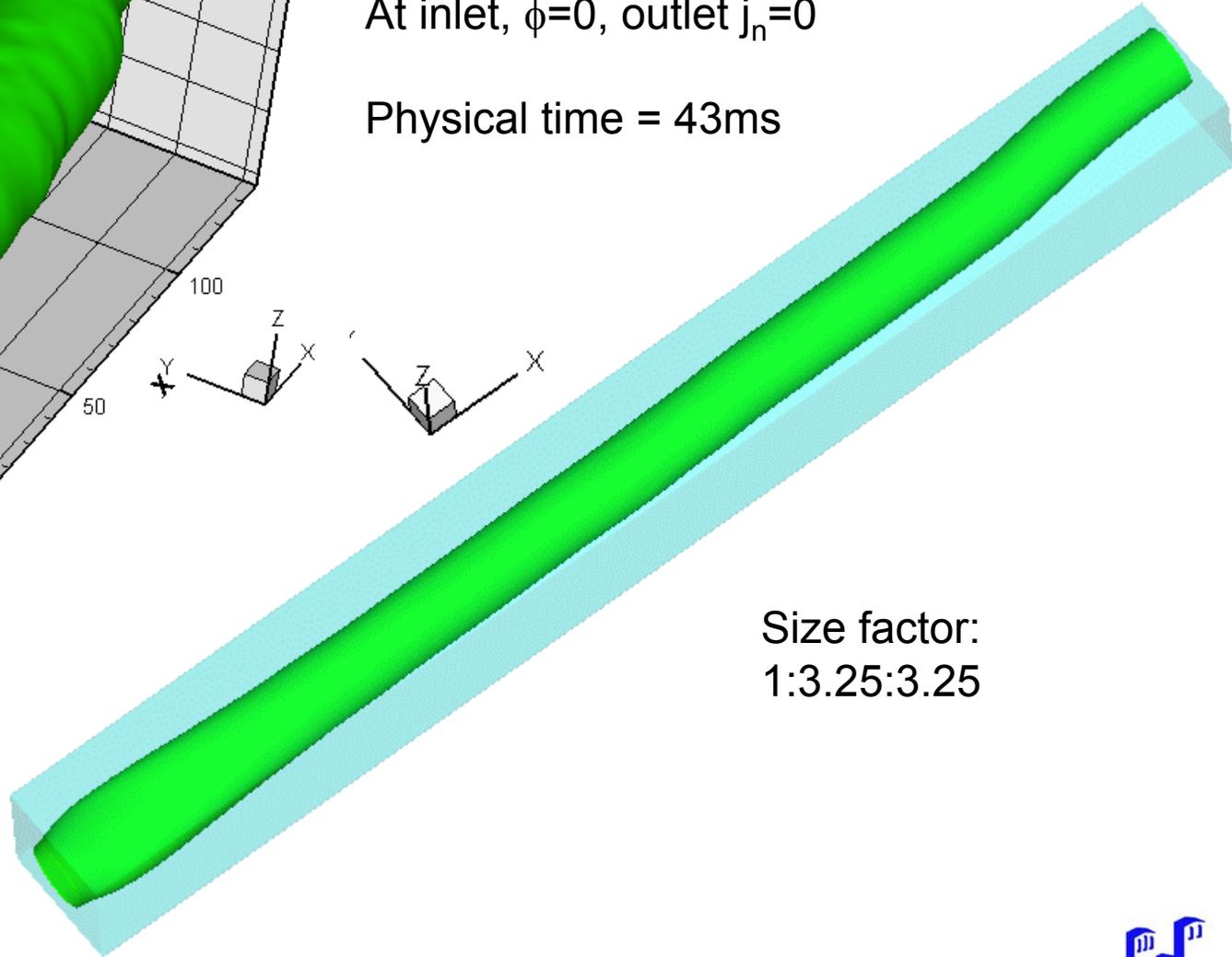
Size factor:  
1:15:15



Inlet & outlet have 4 times diameter extended regions. MHD forces ON at inlet and outlet

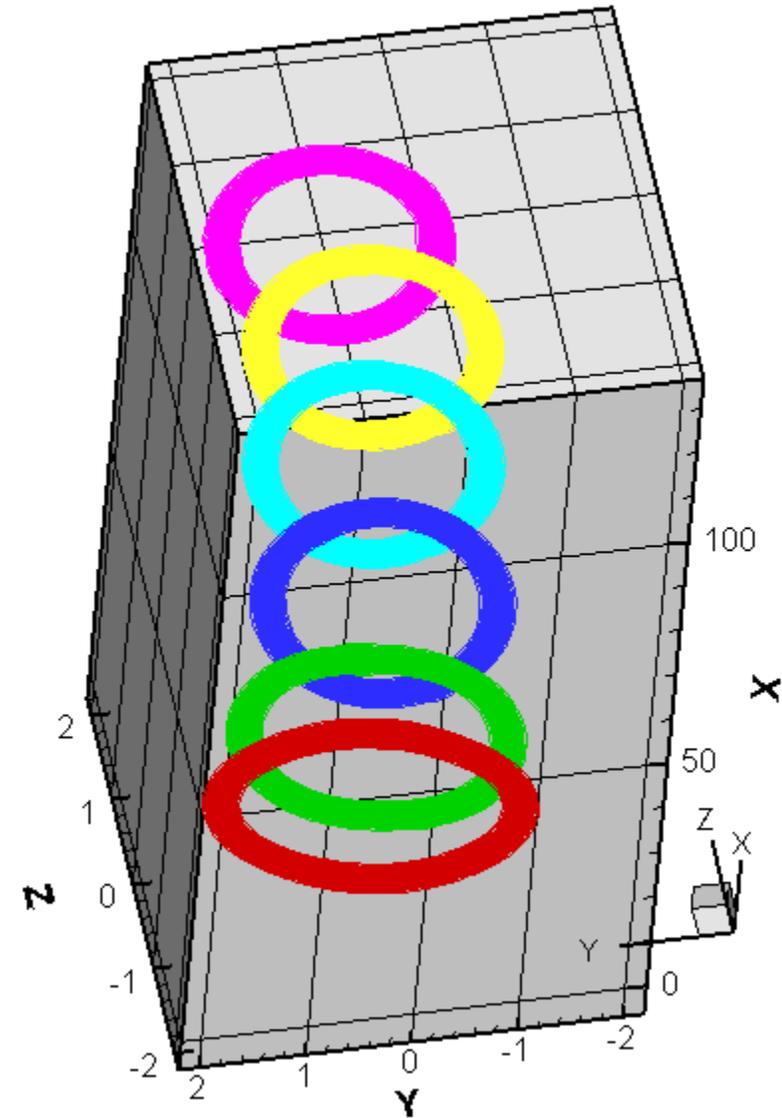
At inlet,  $\phi=0$ , outlet  $j_n=0$

Physical time = 43ms

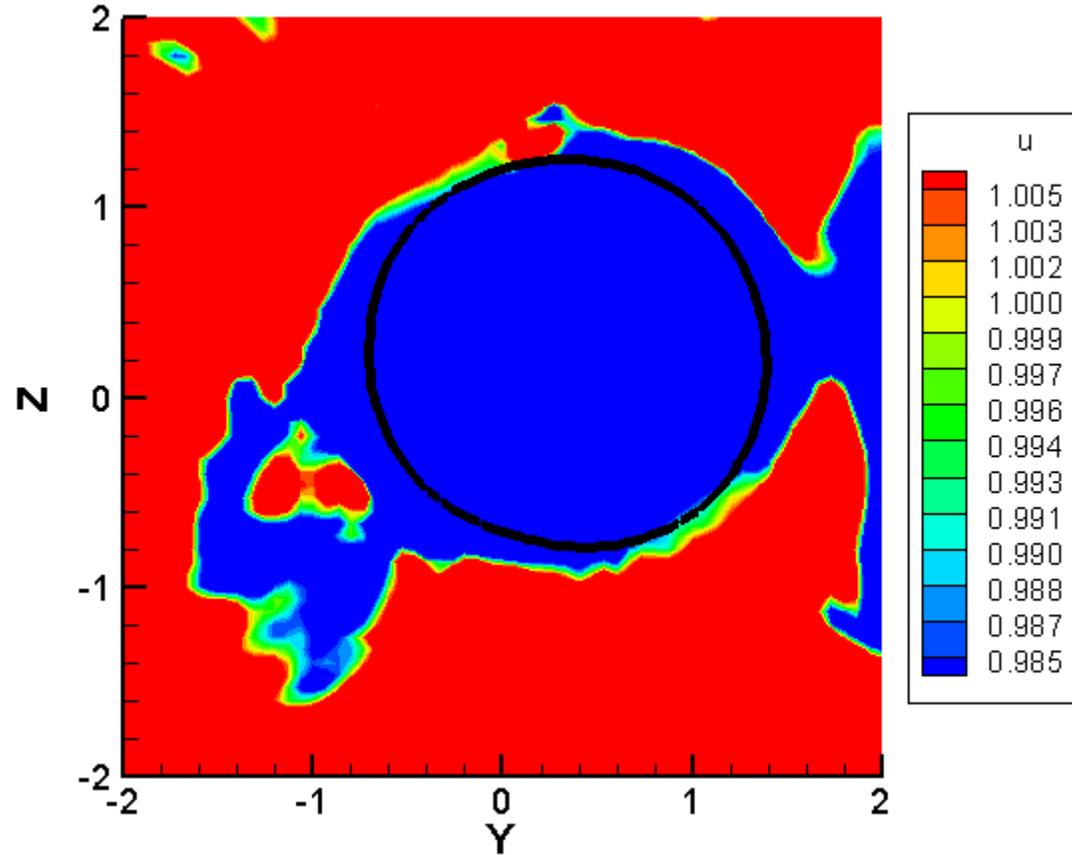


Size factor:  
1:3.25:3.25

## MHD forces ON at inlet and outlet

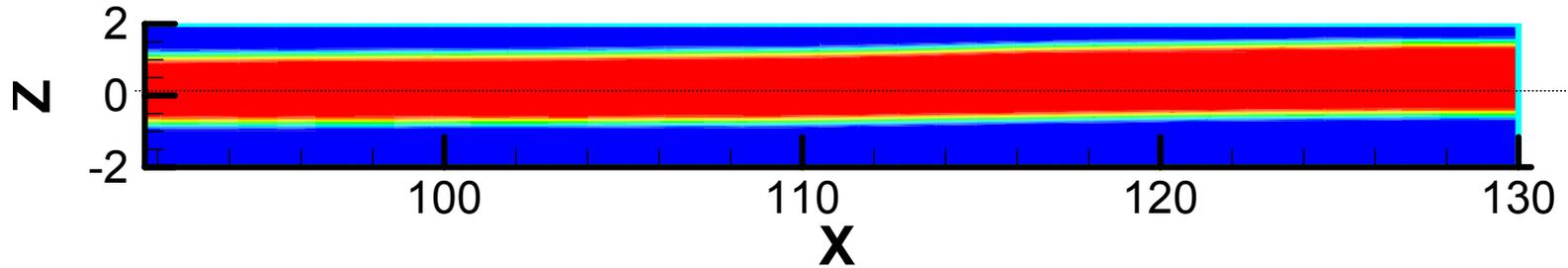


Deformed jet shape at different cross sections along x-axis



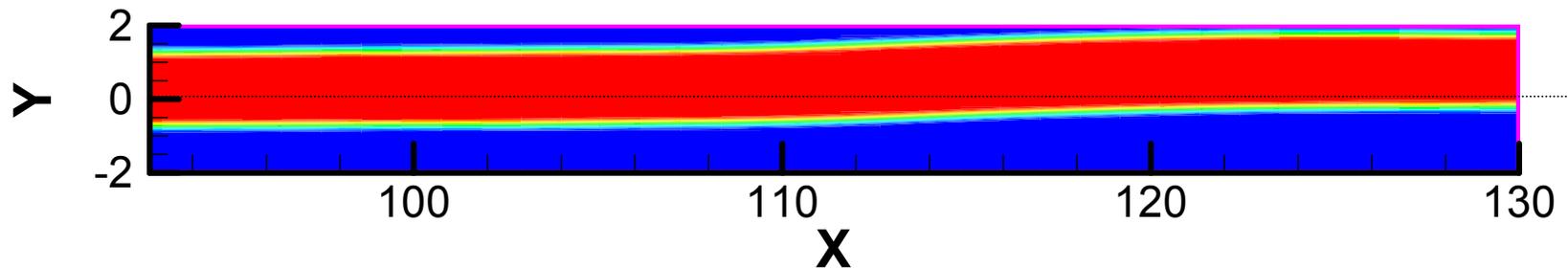
Interface shape and vector of  $J_y - J_z$  at  $x = 99$  (24.6cm), near the outlet

# Strong deflection along the field is seen near end of computational region



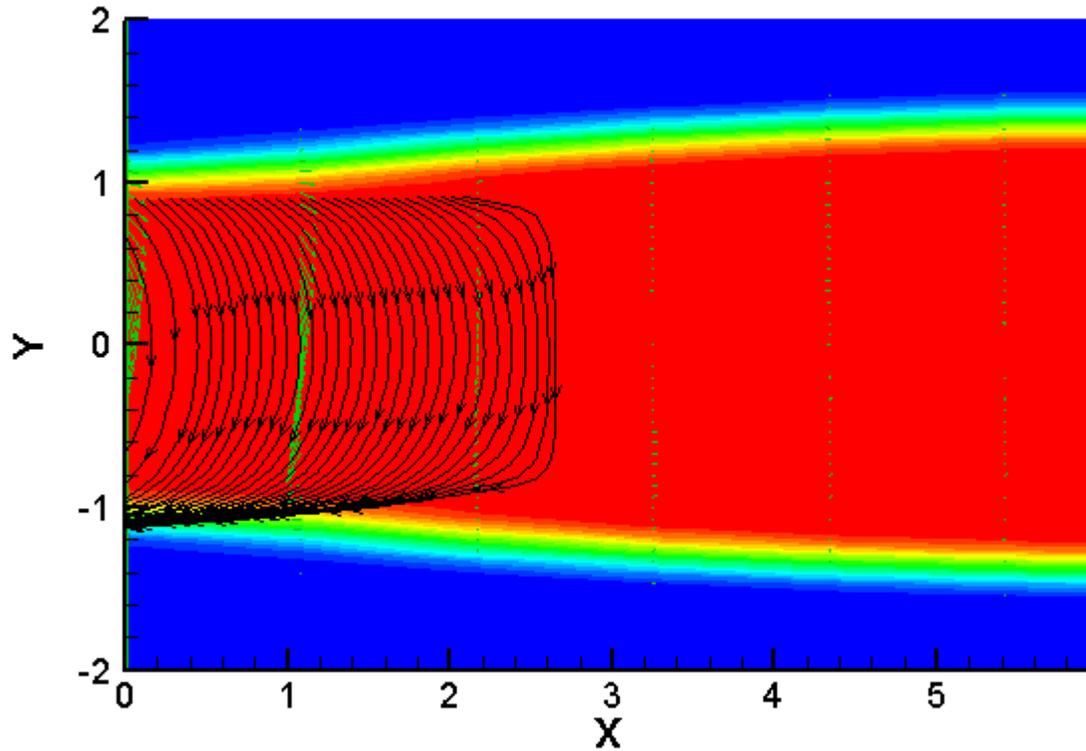
Interface shape at the exit of cross section  $y=1.875\text{mm}$

*MHD forces ON at inlet and outlet*



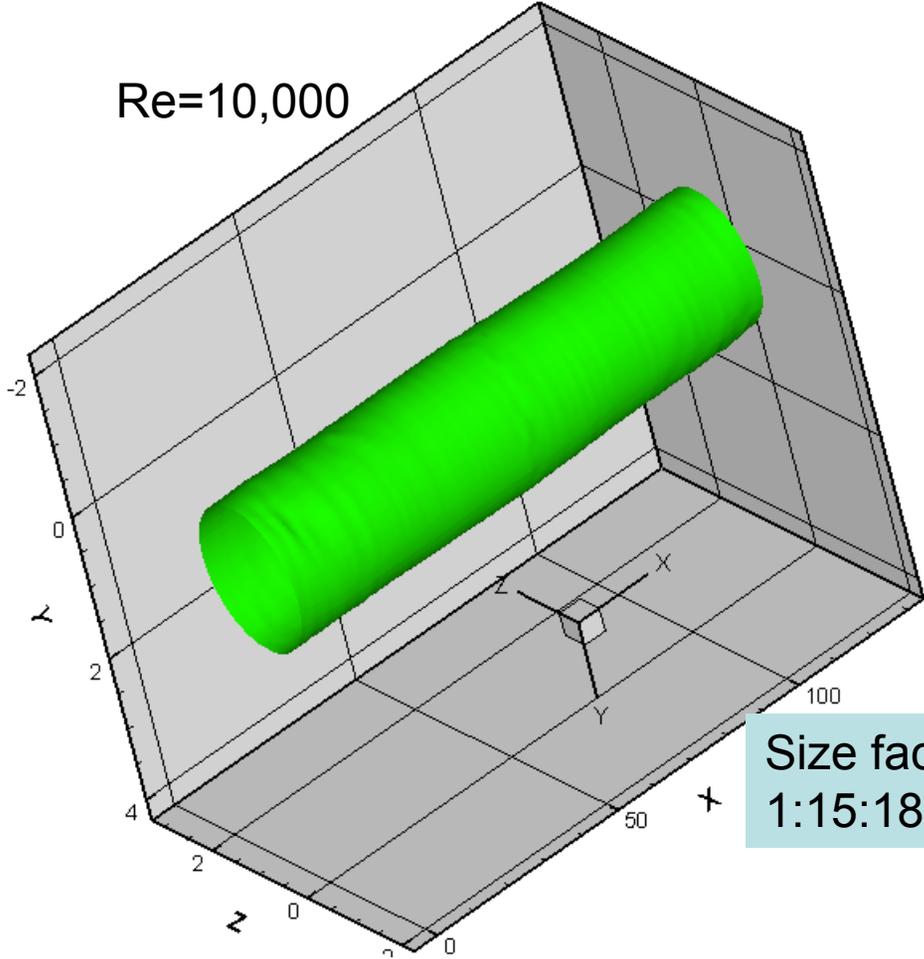
Interface shape at the exit of cross section  $z=1.25\text{mm}$

## MHD forces ON at inlet and outlet



Current streamline at the inlet of cross section  $z=0$ .

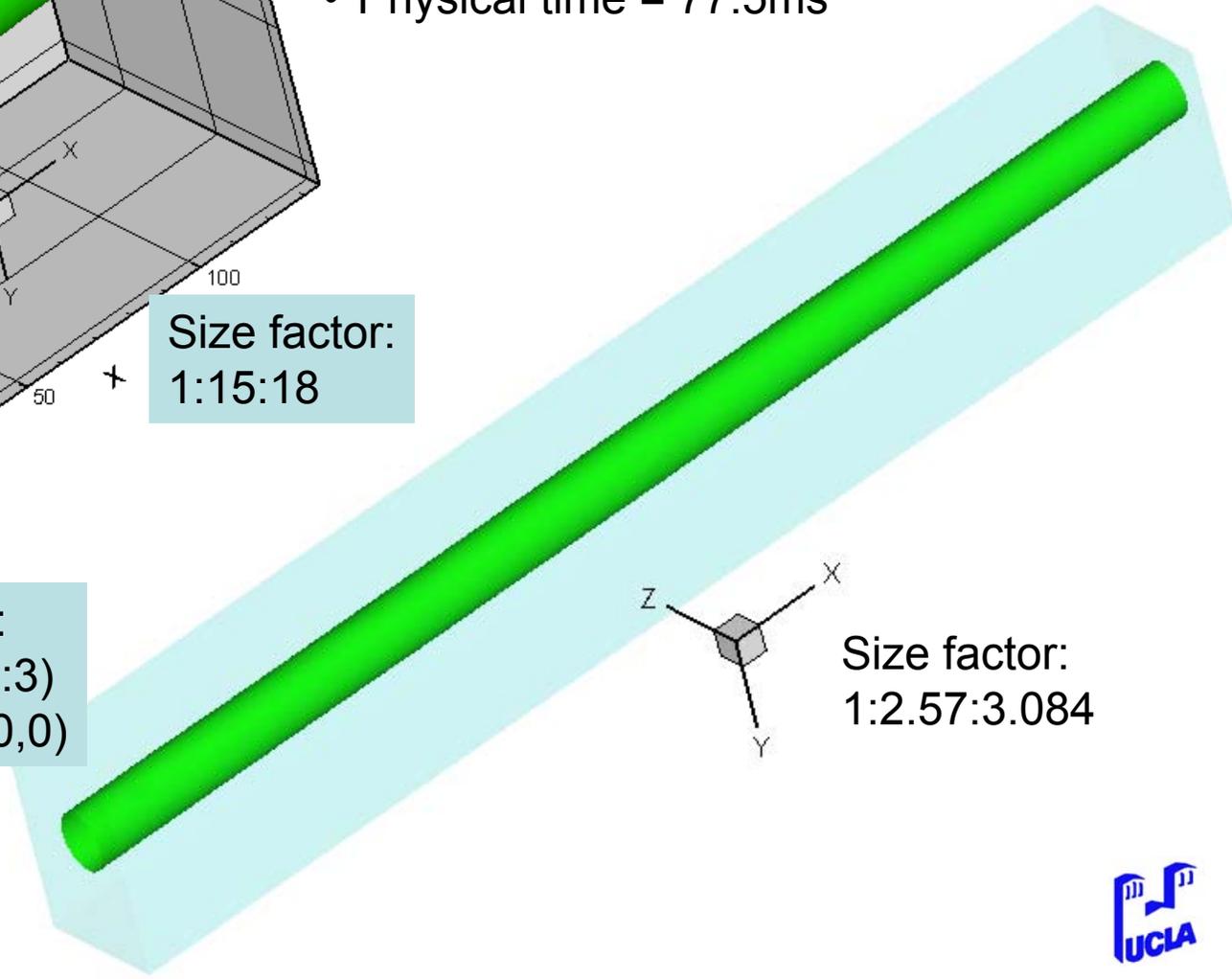
Re=10,000



- Inlet & outlet have 4 times diameter extended regions with MHD force OFF
- At inlet,  $\phi = 0$ , outlet  $j_n = 0$ .
- Physical time = 77.5ms

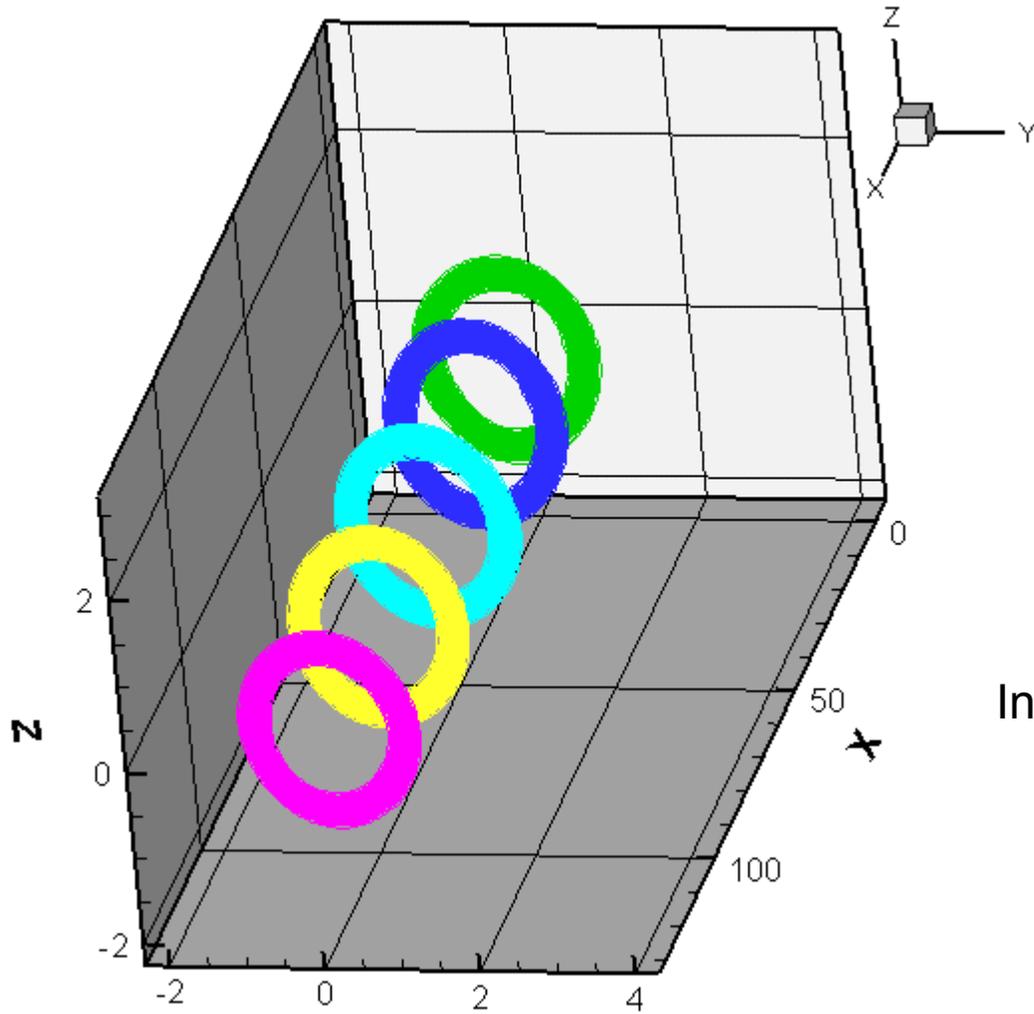
Size factor:  
1:15:18

Computational region size:  
x:y:z = (0~128):(-2~4):(-2:3)  
Inlet jet circle center at (0,0,0)



Size factor:  
1:2.57:3.084

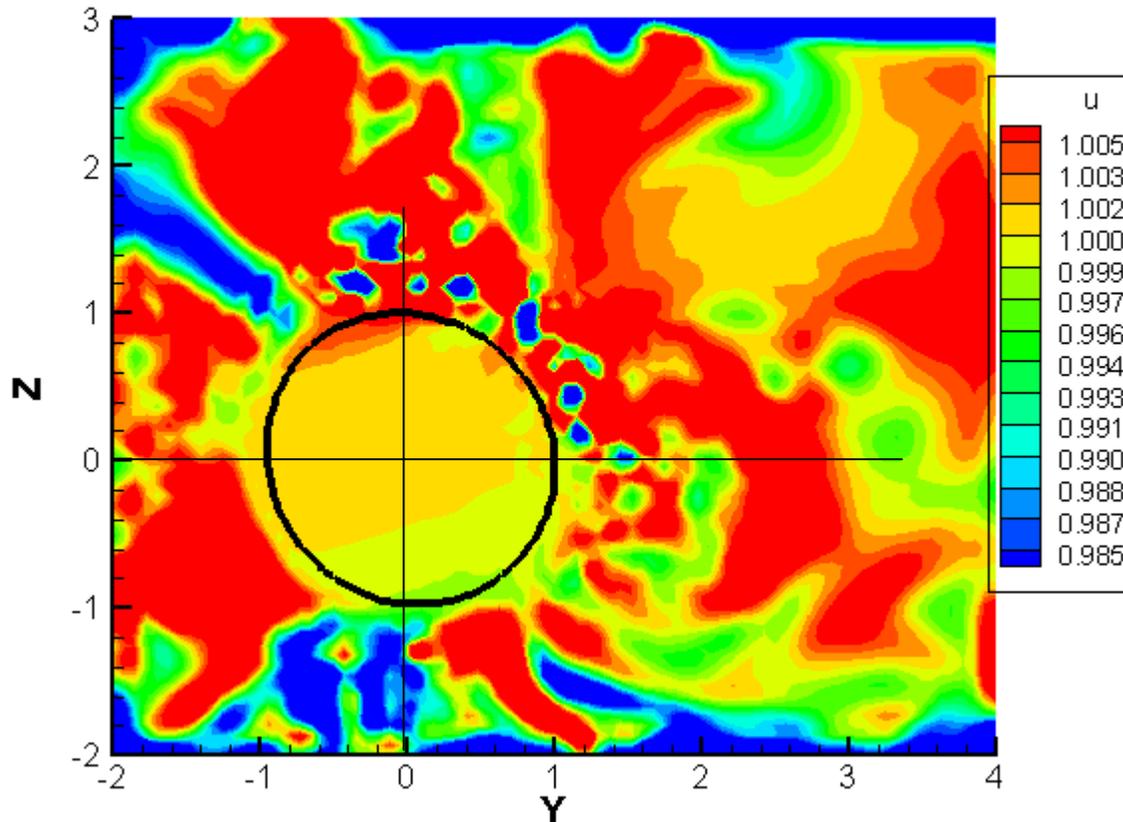
# Correct deformation and no deflection with MHD force OFF at inlet section



Inlet MHD force OFF

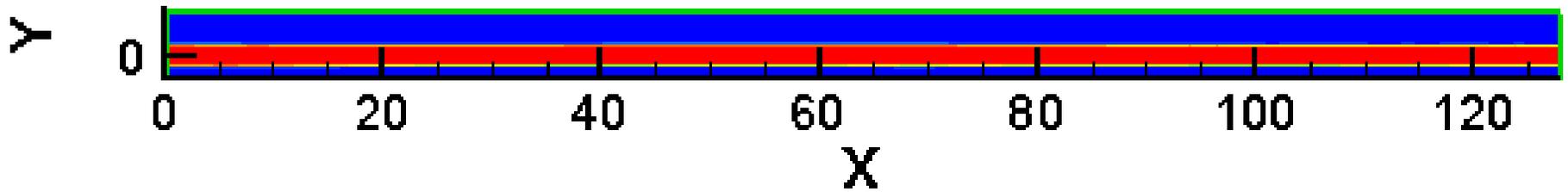
Deformed jet shape at different cross sections along x-axis

# Cross section near exit colored by axial $V$ – Jet is not slowed down or deflected

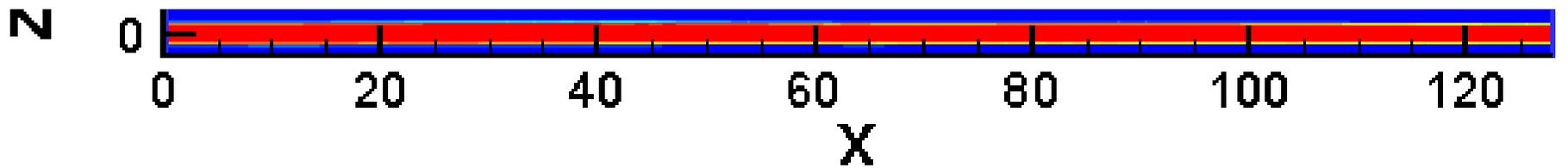


Distribution of velocity  $u$  at one cross section of  $x=150\text{cm}$   
The black solid line is the interface shape of jet at this section

MHD forces OFF at inlet and outlet

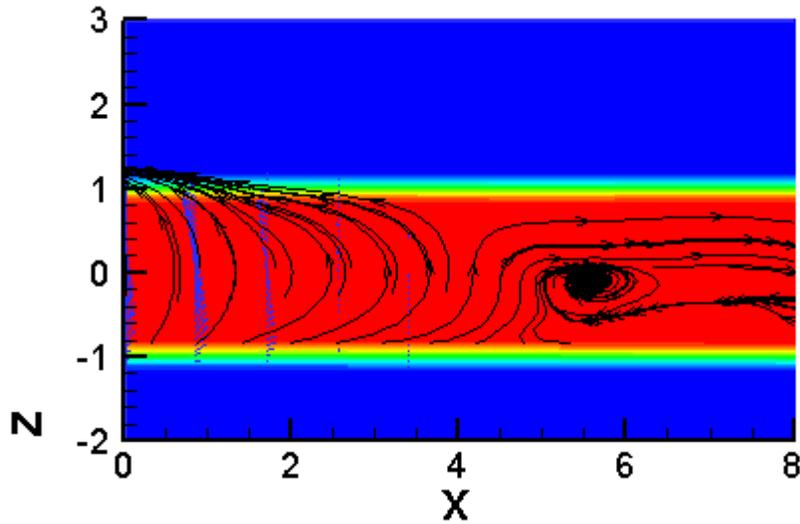


Interface shape at the exit of cross section  $z=0$

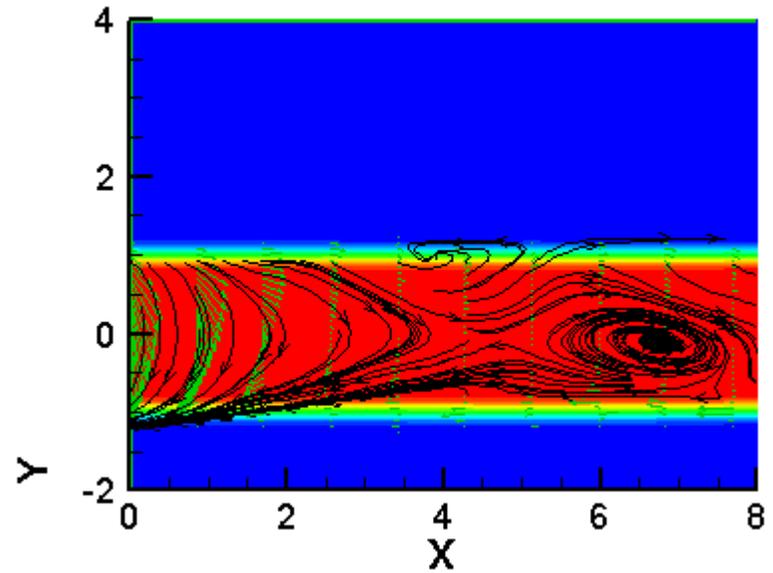


Interface shape at the exit of cross section  $y=0$

# MHD forces OFF at inlet and outlet

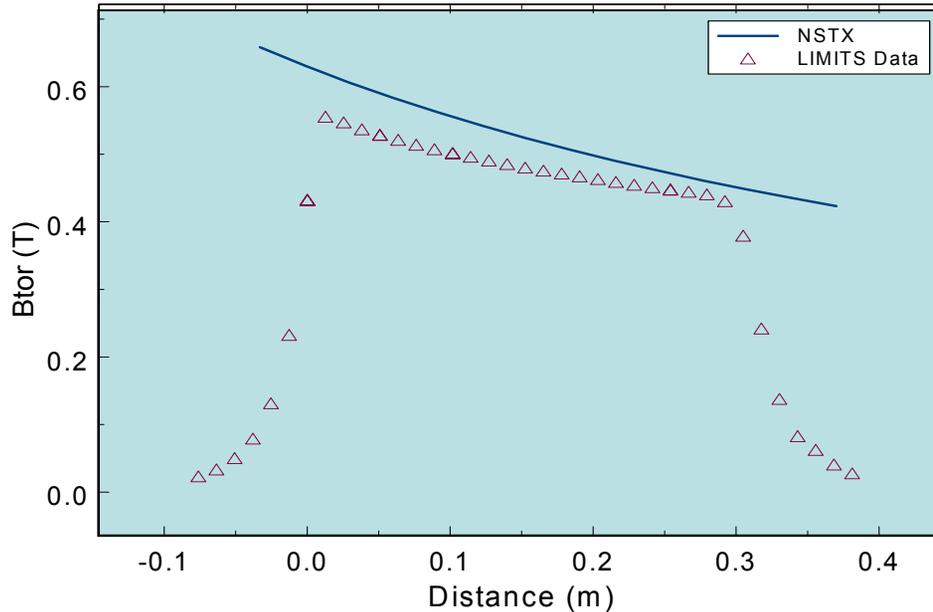


Current streamline at the inlet of cross section  $y=0$ .



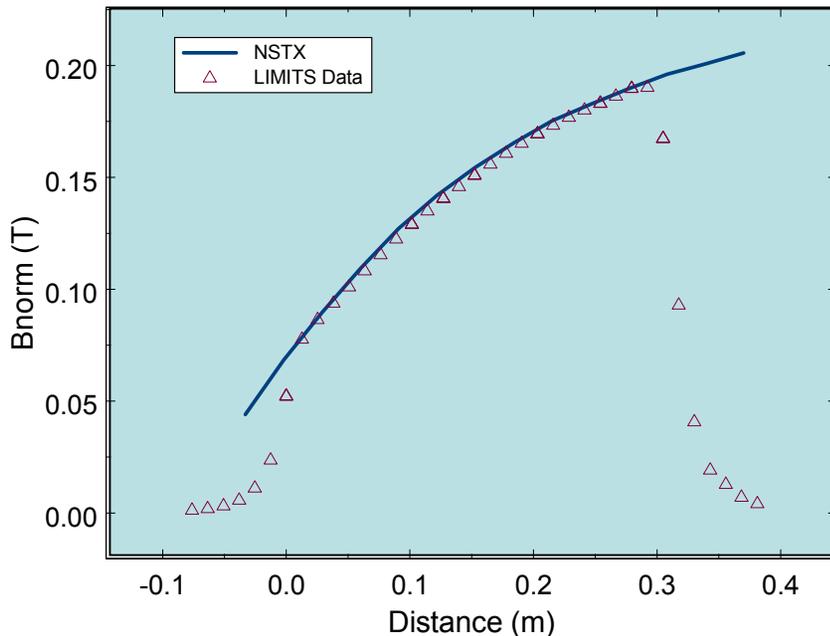
Current streamline at the inlet of cross section  $z=0$ .

# Field Configuration 3 – Jet flows through whole LIMITS magnet



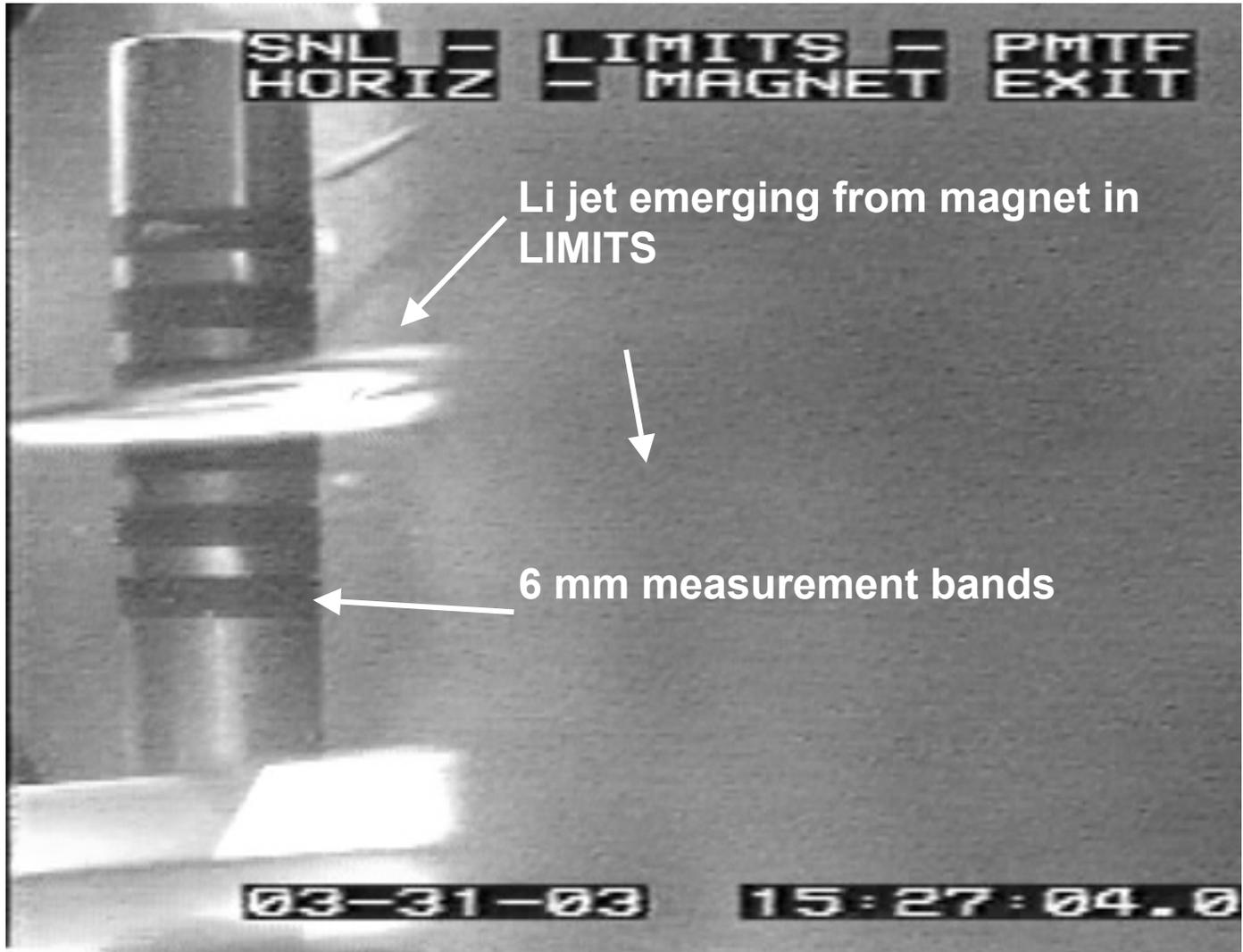
Comparison of the desired toroidal (horizontal) field in NSTX with the measured field in the LIMITS magnet

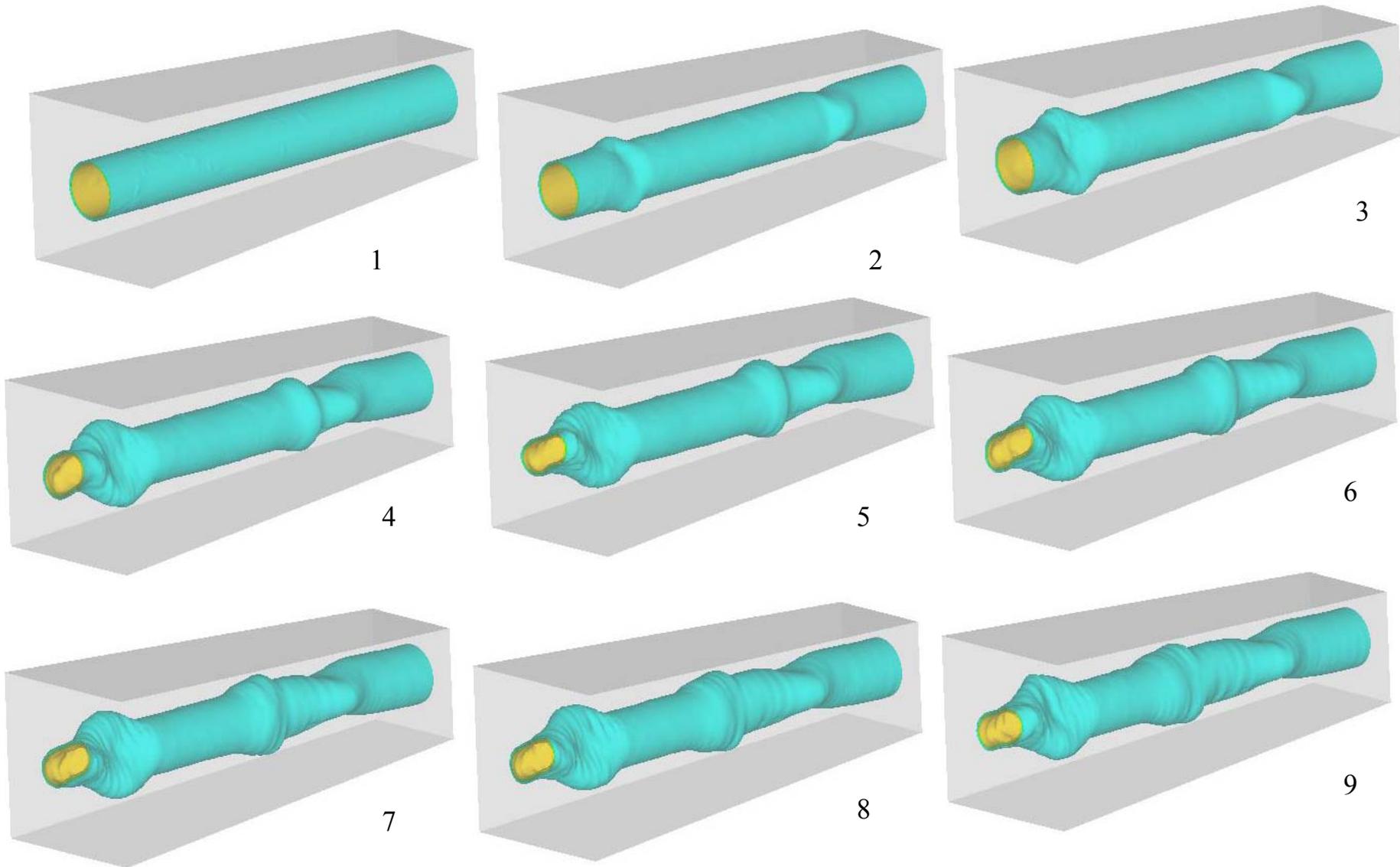
Calculation area  
In this presentation



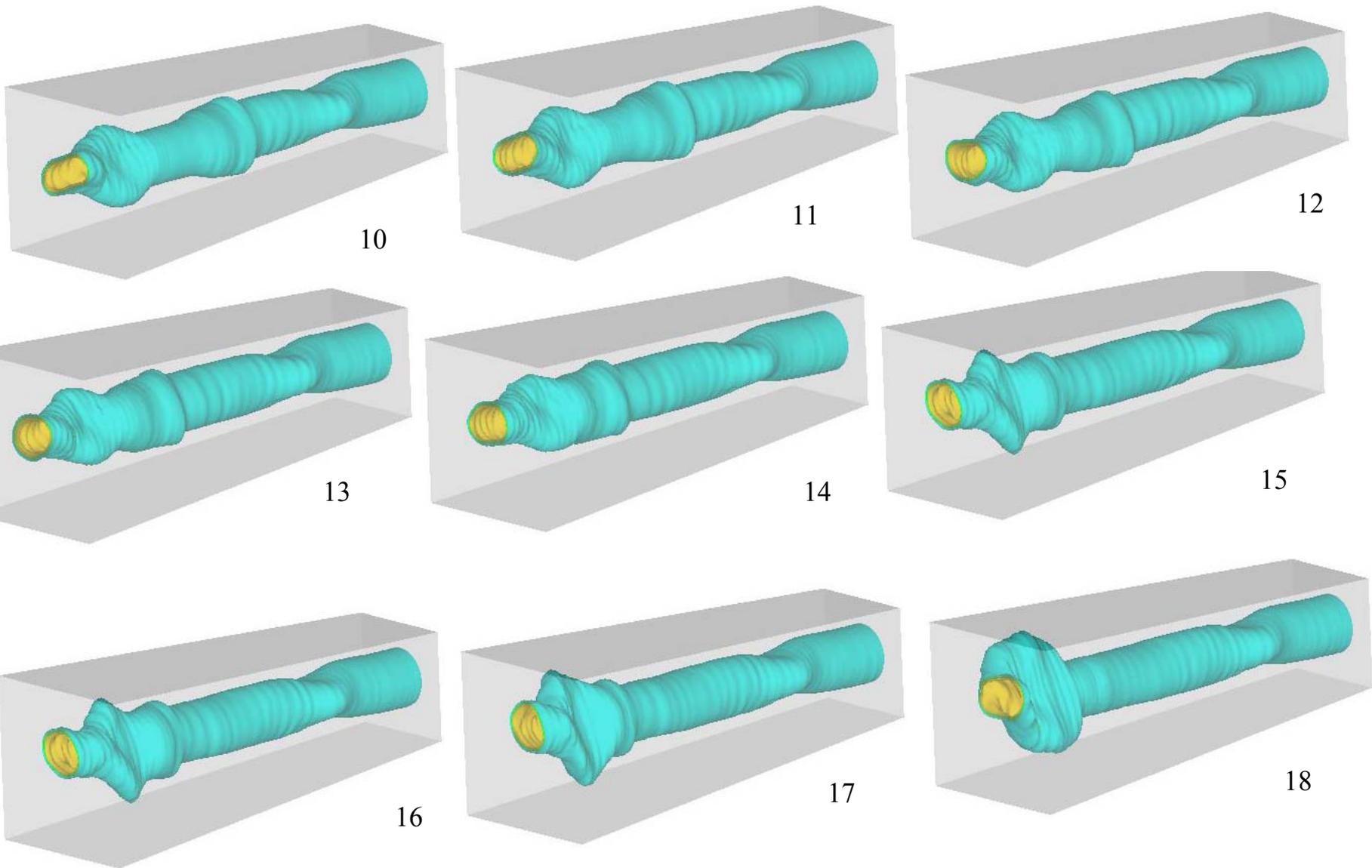
Comparison of the vertical field in NSTX with the measured vertical field in the LIMITS magnet.

**Full length simulation not complete, but preliminary results show deformation and deflection similar to LIMITS images**

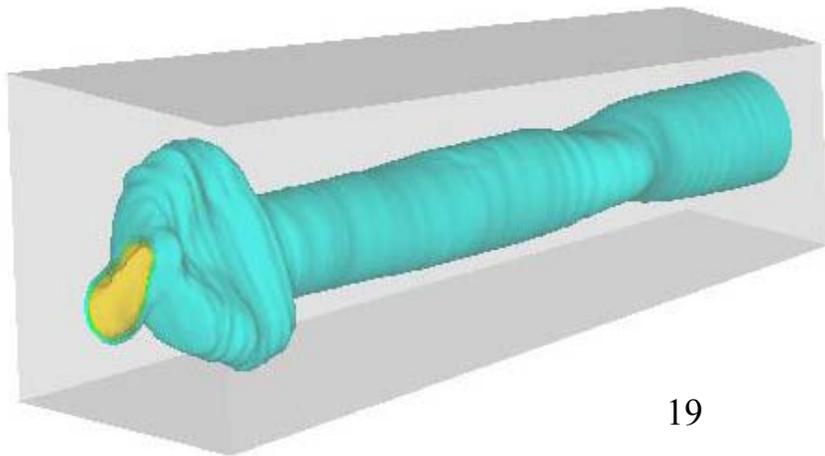




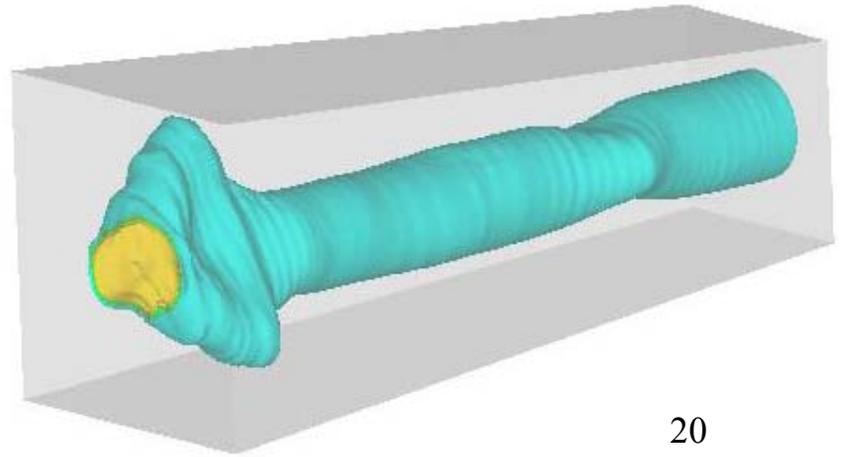
$Re = 10,000$ . Mean speed  $V = 10$  m/s



$Re = 10,000$ . Mean speed  $V = 10$  m/s

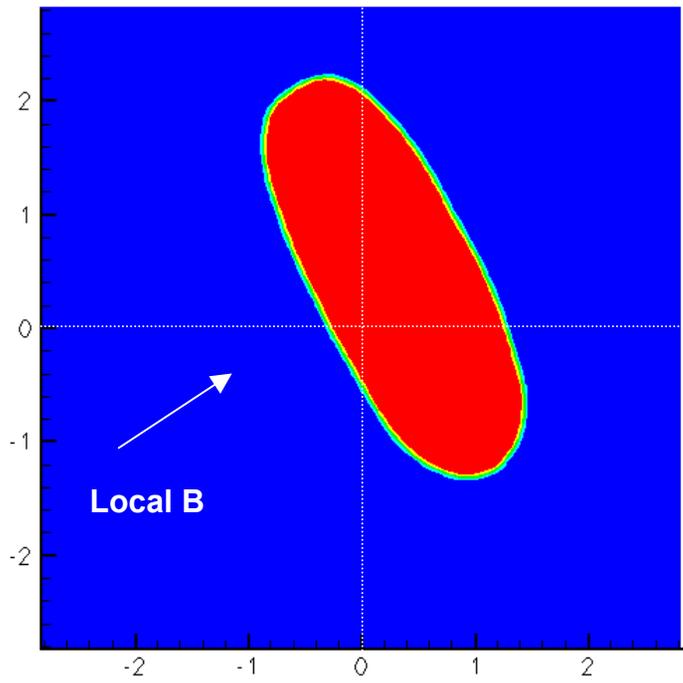


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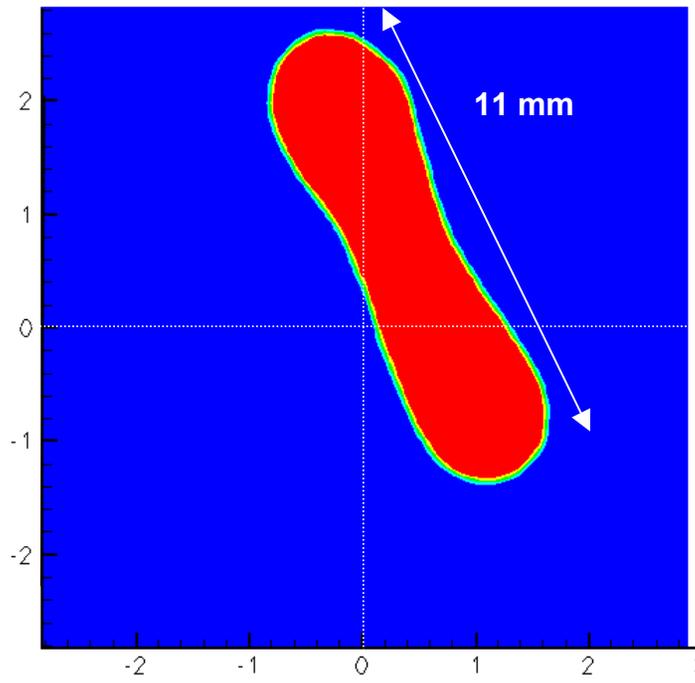


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$Re = 10,000$ . Mean speed  $V = 10$  m/s

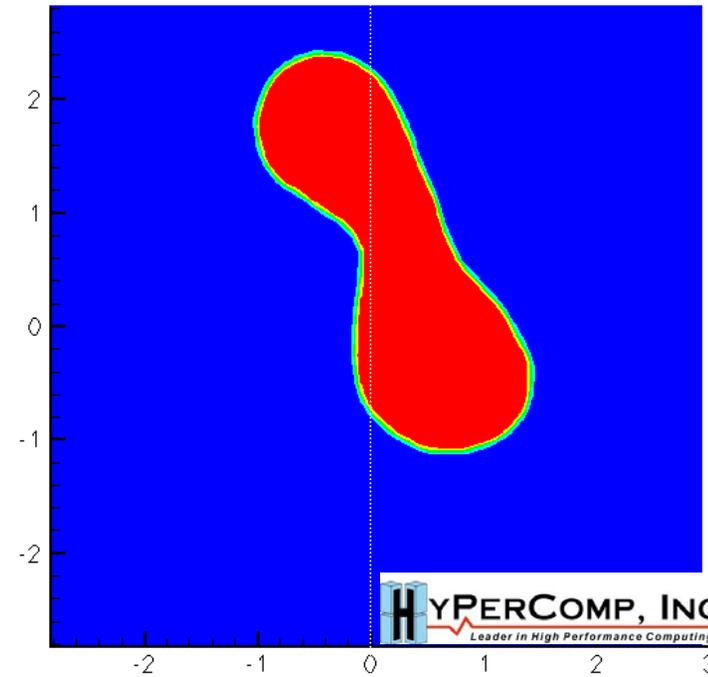


X=130



X=140

X=150



Jet cross section views after the second B-gradient. B-gradient is between  $x=120$  and  $135$

# Summary of LIMITS jet simulation

- Large deformation seen in LIMITS comes from magnet inlet and outlet gradient fields
  - Full LIMITS case at full Re and weak-to-strong-field flow direction still needs to be run
- Initial results for NSTX case with strong-to-weak-field flow direction and jet initiation in the field region shows only small deformation
  - Full NSTX case with conducting nozzle and full Re still needs to be run
  - Addition of anticipated plasma current