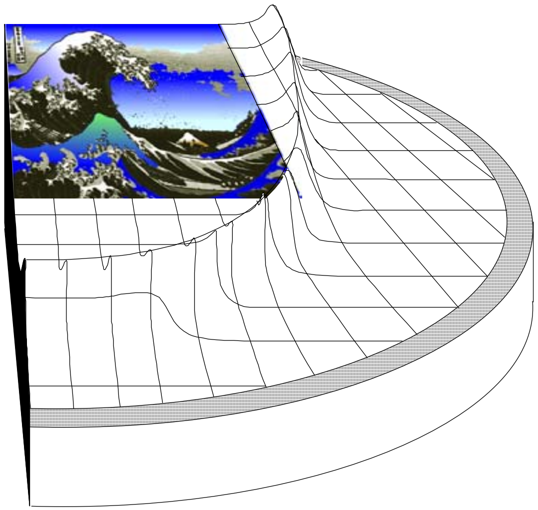
Integrated TSUNAMI Simulations for the Heavy-Ion Point Design



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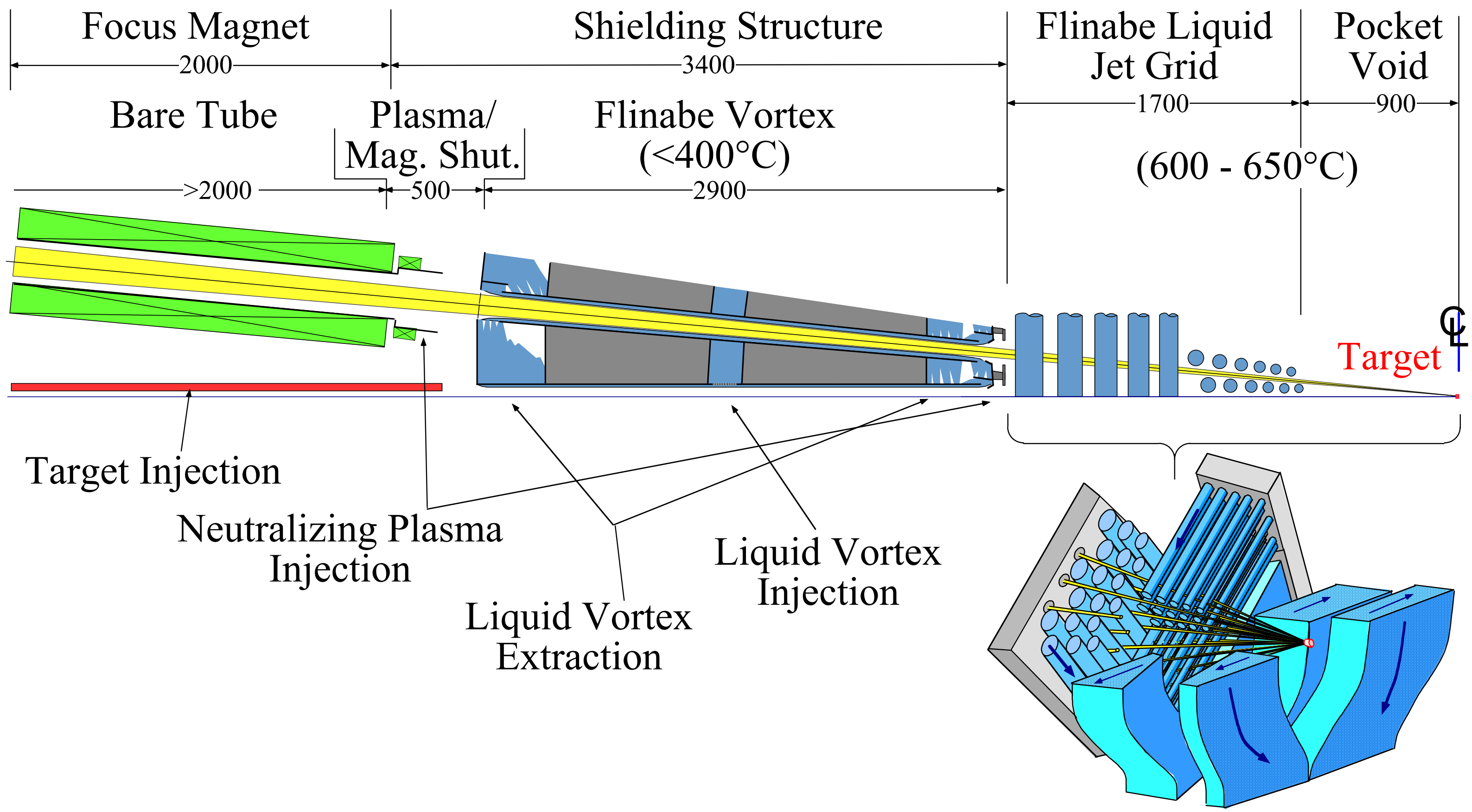
Motivation

- Target chamber density control
  - Beam propagation sets stringent requirements for the background gas density
  - Pocket response and disruption
- Beam tube density control
  - Beam propagation requirements
  - Debris deposition in final-focus magnet region may cause arcing with the high space-charged beams and must be alleviated
- Robust Point Design (RPD-2002) motivated new set of gas dynamics simulations

The Robust Point Design (RPD-2002) beam line



Schematic Liquid Jet Geometry

Strategies to prevent debris deposition in the beam tubes (I)

- Design efficient target chamber structures
- Debris should vent towards condensing surfaces (droplets), so that mass and energy fluxes at the entrance of beam ports are as low as possible
- Venting in target chamber has been modeled to determine flux to the beam tubes and impulse load to the pocket (~1200 Pa s)

TSUNAMI

- TranSient Upwind Numerical Analysis Method for Inertial confinement fusion

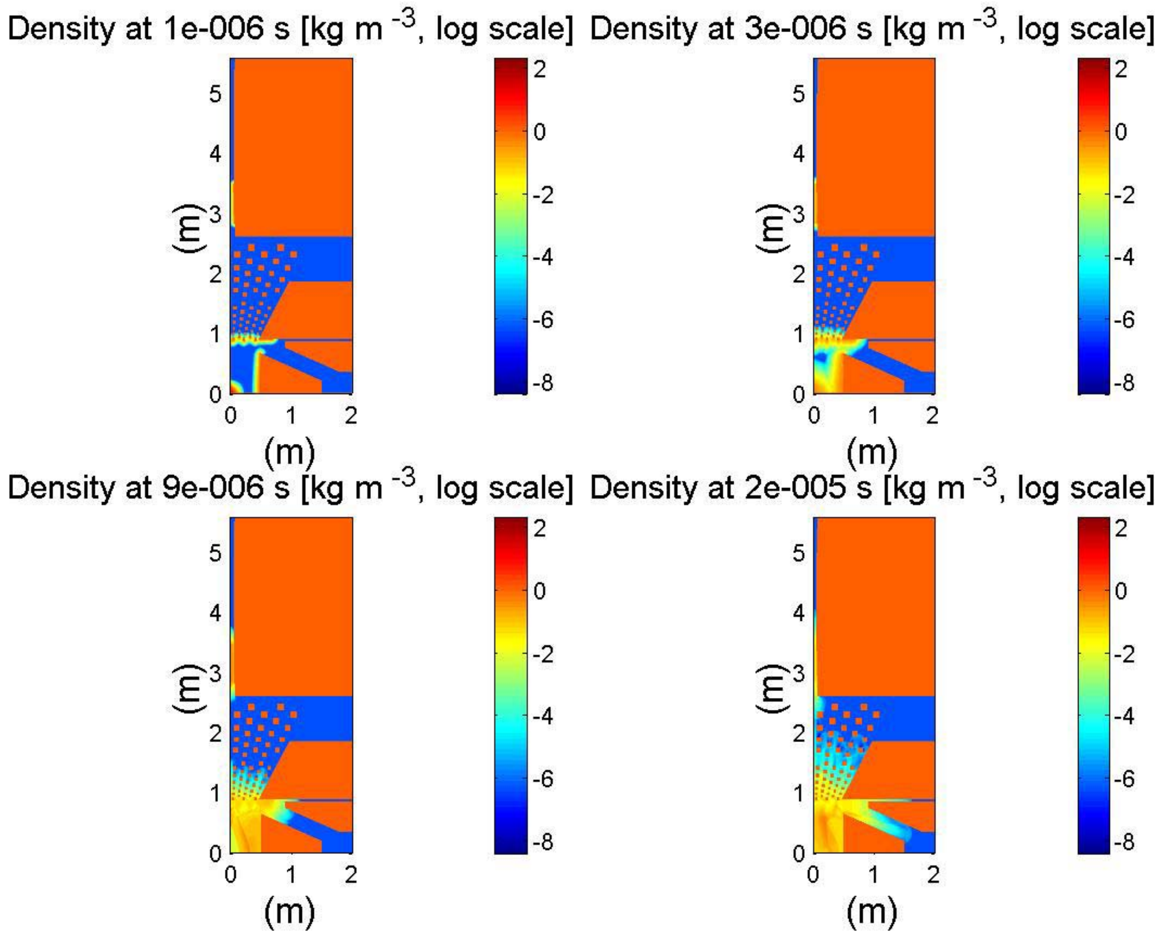
- Provides estimates of the gas dynamics behavior during the venting process in inertial confinement energy systems

- Solves Euler equations for compressible flows

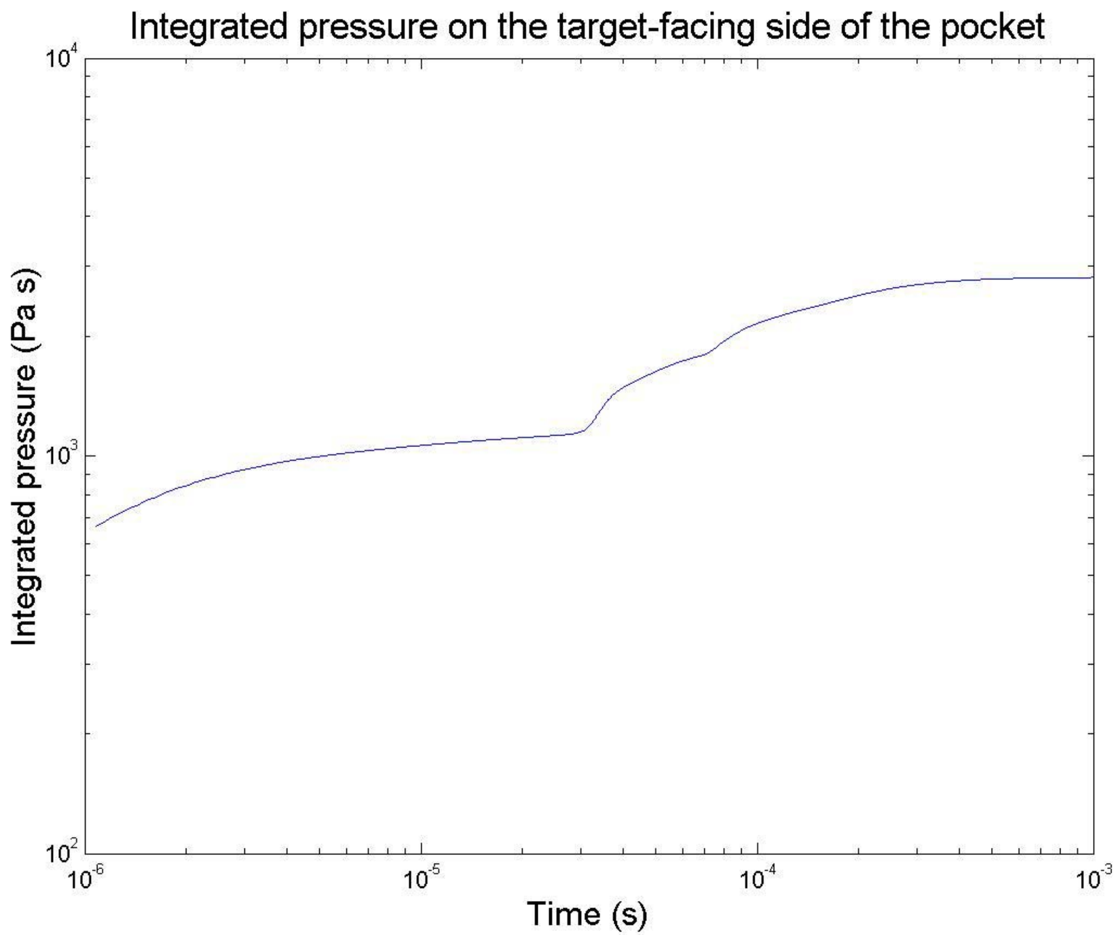
- Real gas equation (adapted from Chen's)

- Two-dimensional, axially symmetric pocket

RPD-2002 – TSUNAMI Density Contour Plots



RPD-2002 – Impulse load



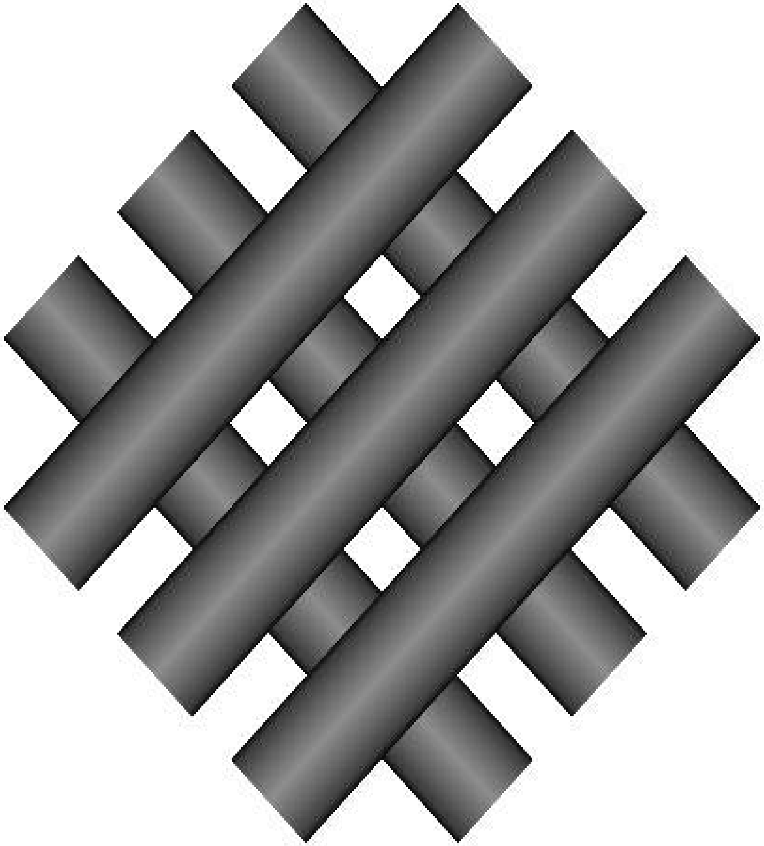
Strategies to prevent debris deposition in the beam tubes (II)

- A new beam tube design:
  - Liquid vortex coats the inside of the beam tube
  - Magnetic Shutters
    - Debris is ionized by plasma plug injected into the beam tube (same plasma at a different density is used to neutralize the beams)
    - Moderate strength dipole diverts debris into condenser

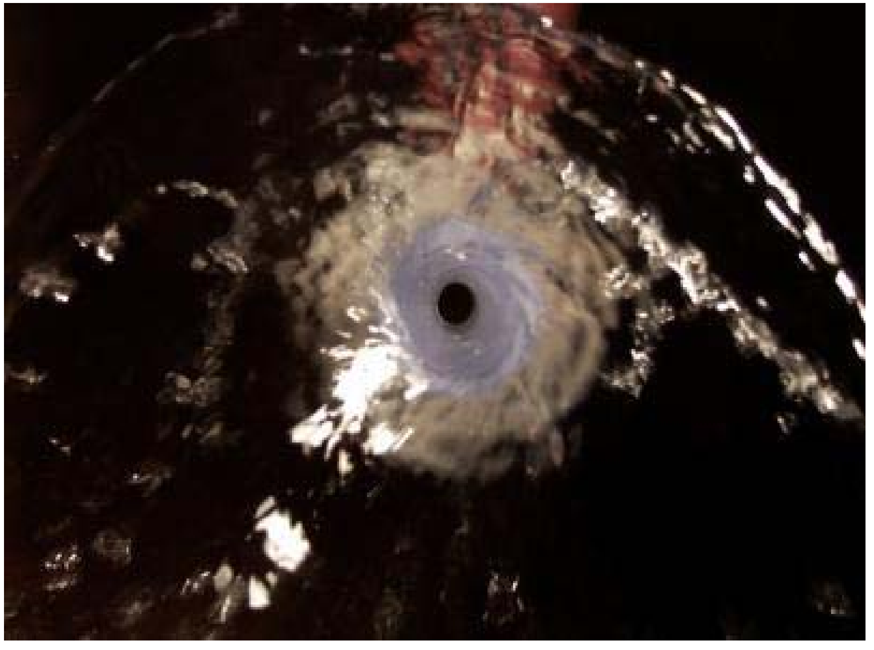
Cylindrical Jet Grids

- Beam access requires multiple round beam ports in the target chamber wall

- Cylindrical jet grids provide a square lattice of jet liquid



Vortex Tubes



- Annular flow in the beam tubes can reduce the apertures in the square lattice to round ports called “Vortex Tubes”

- Stable centrifugal flow provides additional protection in the beam lines

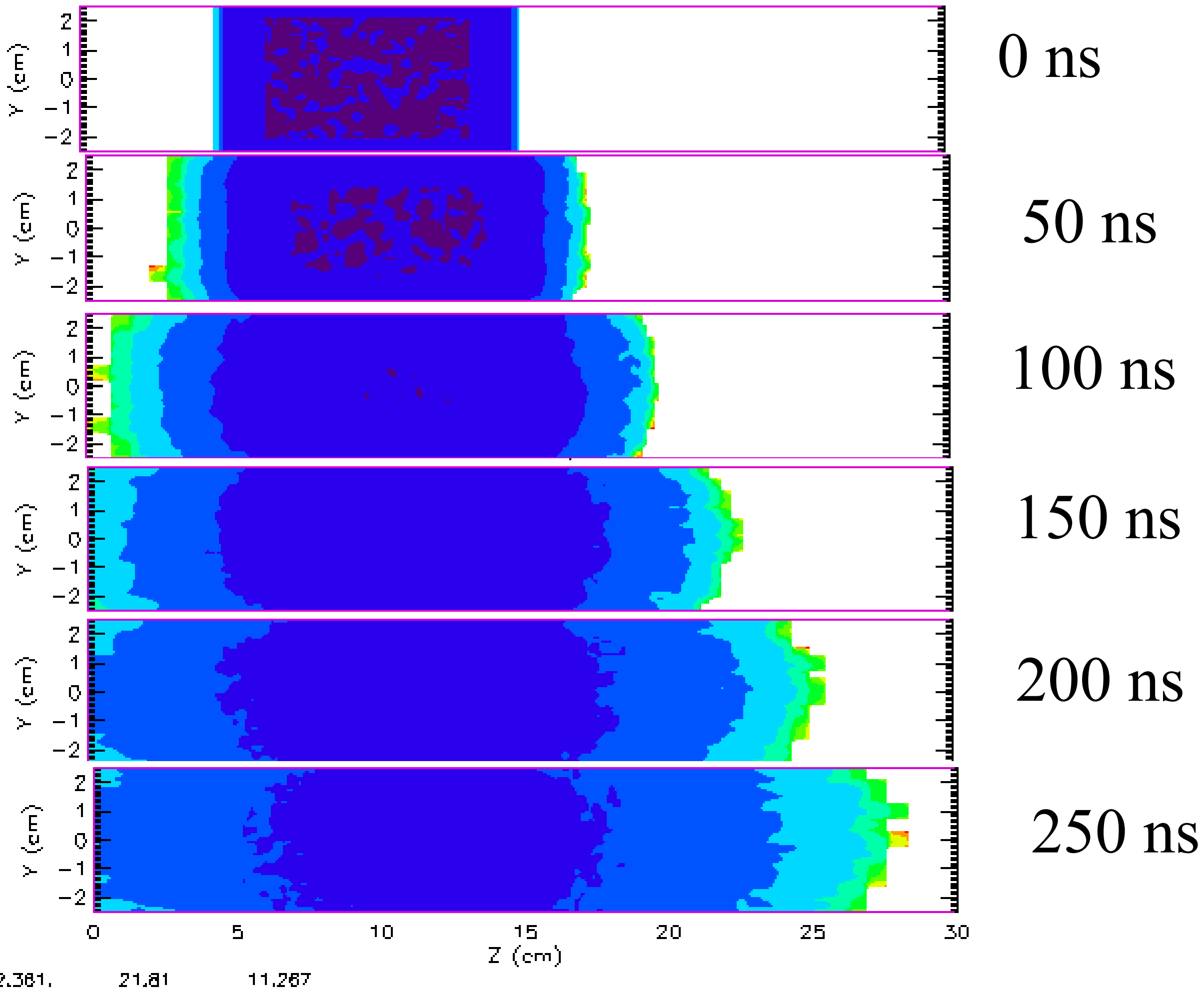
TSUNAMI Predictions up the Vortex Region

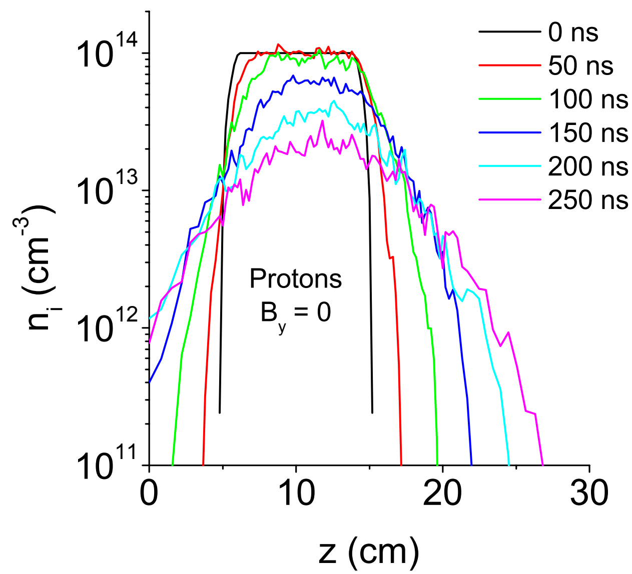
Integrated flux in 1 ms…

Mass = 6.7e-5 kg m^{-2}
Energy = 9.5e4 J m^{-2}

- Debris Average…
  - Molecular density = 1.6e19 m^{-3}
  - Axial velocity = 4.0e4 m s^{-1}
  - Radial velocity = 3.4e2 m s^{-1}
  - Thermal velocity = 9.2e4 m s^{-1}

Magnetic Shutters (MRC simulations)
Test Case: Ion expansion *without* applied B_y-field…



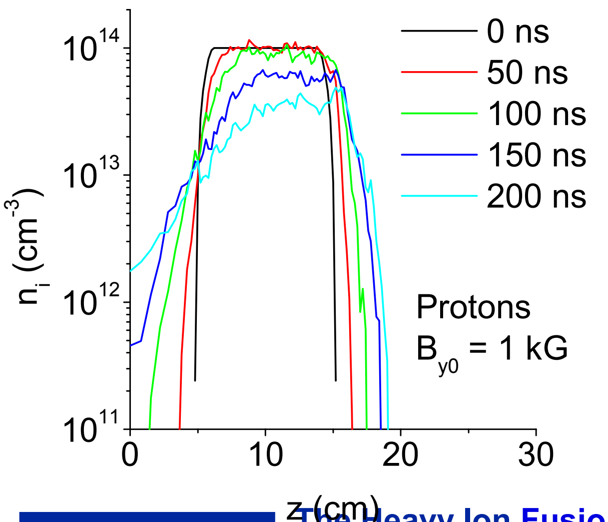


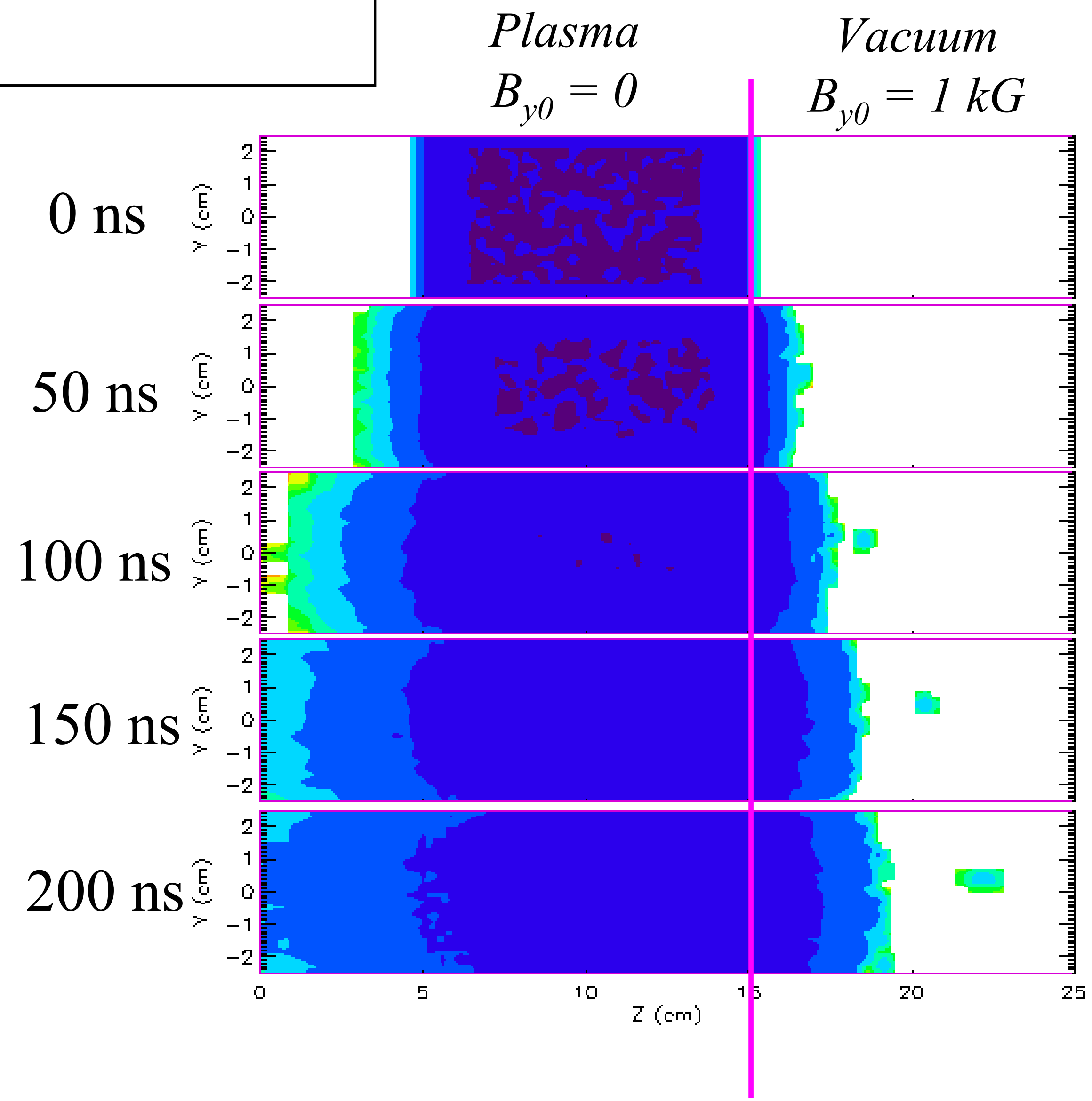
Greater ion expansion into applied B-field is observed in 3D case.

1 kG applied B_y field

$V_{drift} = 9$ cm/μs

$T_e = T_i = 100$ eV





Conclusions

- **TSUNAMI predictions indicate that thick-liquid structures in target chamber should be supplemented by other engineering devices in the beam tubes to prevent debris contamination in the final-focus magnet region**

- **A new beam line:**
  - **Beam tube can be coated with liquid vortex**
  - **Debris can be ionized and diverted by a moderate strength magnetic field**