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Simulation of High-Intensity Mercury Jet Targets

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Mercury Target Simulation Program

- FronTier MHD, a 3D code with explicitly tracked interfaces of multiphase / free surface fluids has been developed and used for mercury target simulations. New SPH code is in progress
  - Compressible and incompressible MHD regimes
  - Homogenized and discrete bubble models for cavitation
  - Realistic equation of states

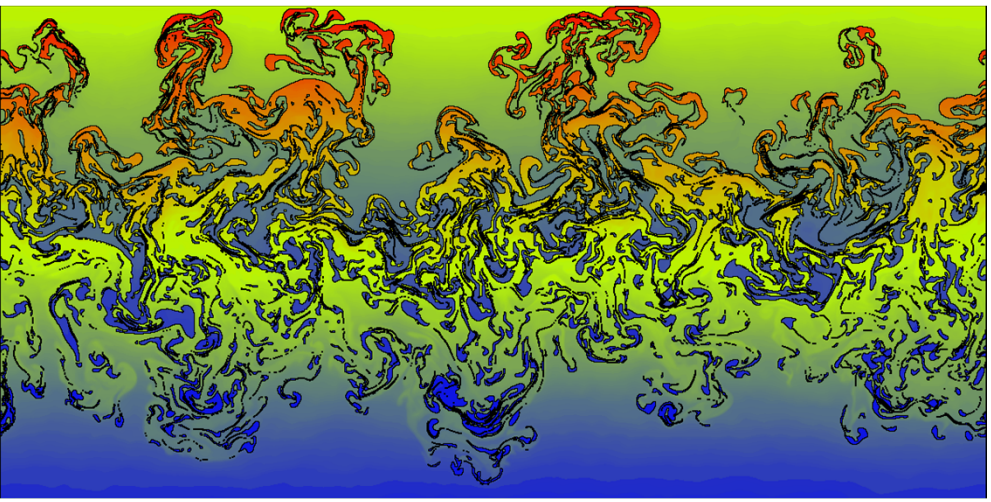
- Simulation studies focus on
  - Distortion of mercury jets entering solenoid magnets
  - Disruption of mercury targets interacting with proton pulses
  - Benchmark with MERIT experimental data
  - Studies of the muon collider vs. neutrino factory targets

FronTier simulation of high speed jet cavitation and breakup

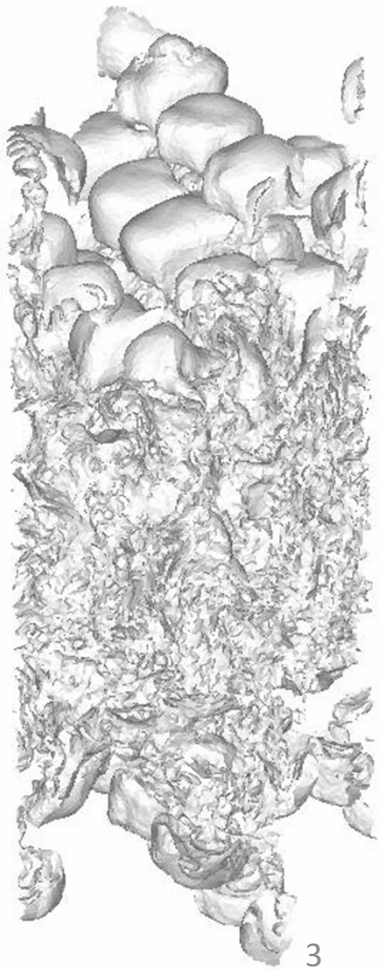
The ***FronTier*** Code

FronTier is a parallel 3D multiphysics code based on front tracking

- Explicit tracking of material interfaces in free surface / multiphase flows
- Physics models include
  - Compressible fluid dynamics
  - MHD
  - Flow in porous media
- Realistic EOS models, phase transition models
- Exact and approximate Riemann solvers
- Adaptive mesh refinement

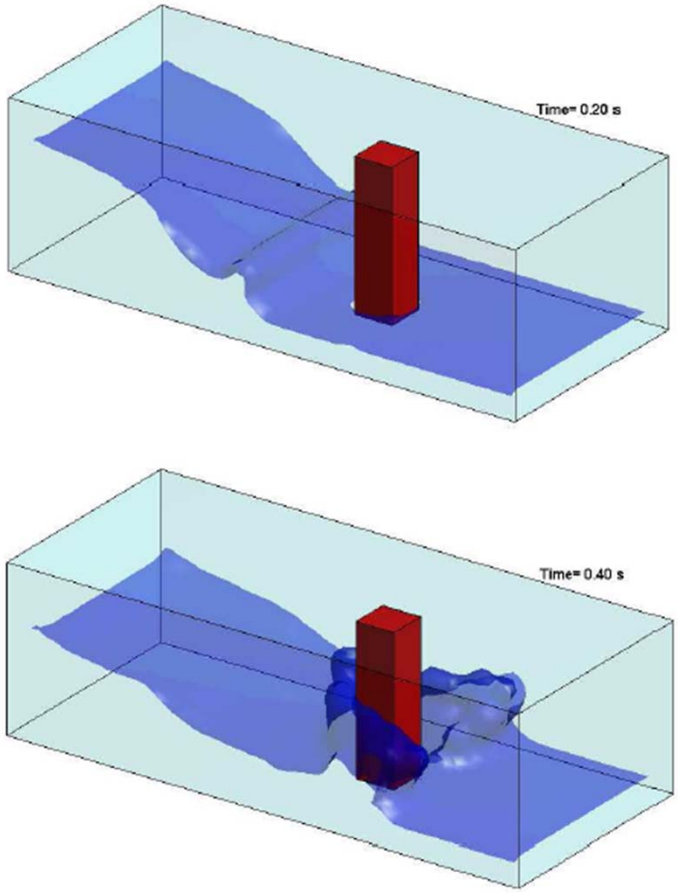


Turbulent fluid mixing.
Left: 2D
Right: 3D (fragment of the interface)



New Smoothed Particle Hydrodynamics (SPH) Code

- A new code for free surface / multiphase MHD flows is being developed based on SPHYSICS from U. of Manchester
- SPH is a Lagrangian method based on particles
- Several smoother particle kernels, Riemann solvers, MUSCL-based schemes
- Advanced time stepping (Predictor-corrector, Verlet scheme, symplectic schemes)
- Easily adaptable to GPU architectures
- Complementary code to FronTier



MHD Simulation of the mercury jet interaction with proton pulses

- Performed simulations of initially cylindrical and elliptical jets interacting with proton pulses in magnetic fields
- Simulations predicted cavitation and surface filamentation
- Magnetic field reduced the amount of cavitation and velocity of filaments
- Reasonable agreement with MERIT experiments on disruption velocities

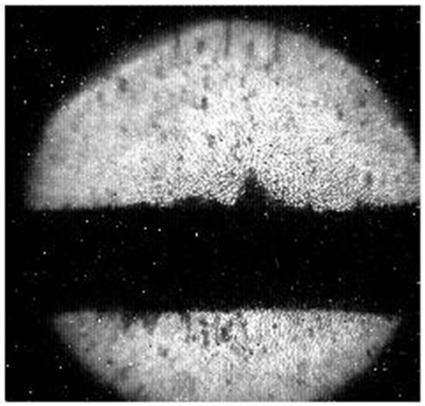
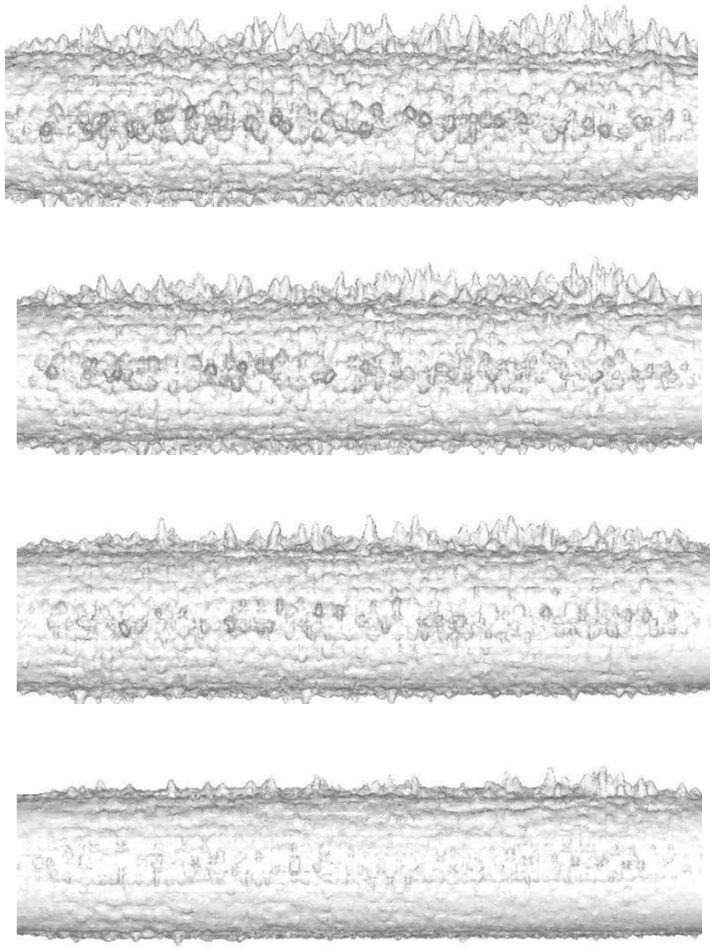


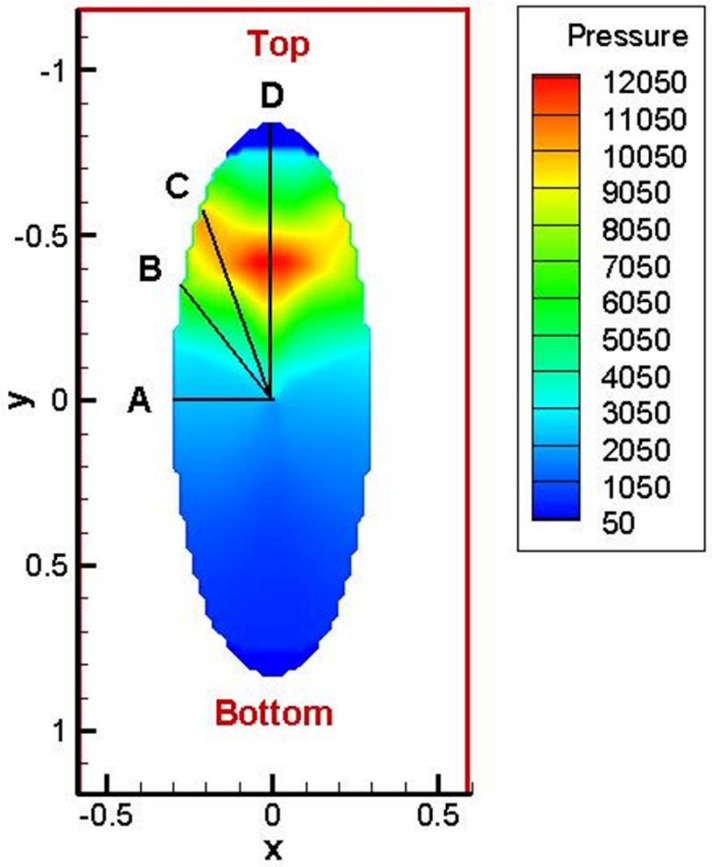
Image from MERIT experiment, B=10T

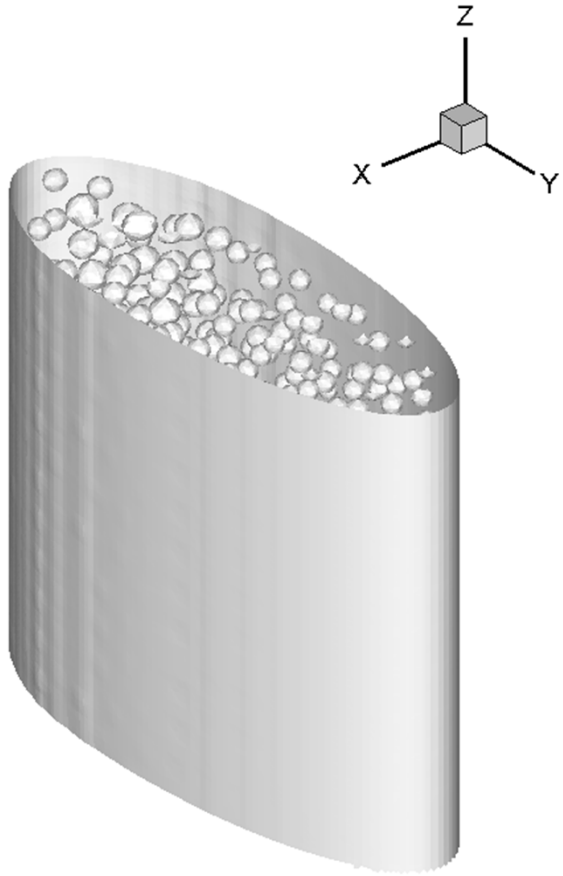


Mercury jet surface at 150 microseconds after the interaction with 12 teraproton pulse

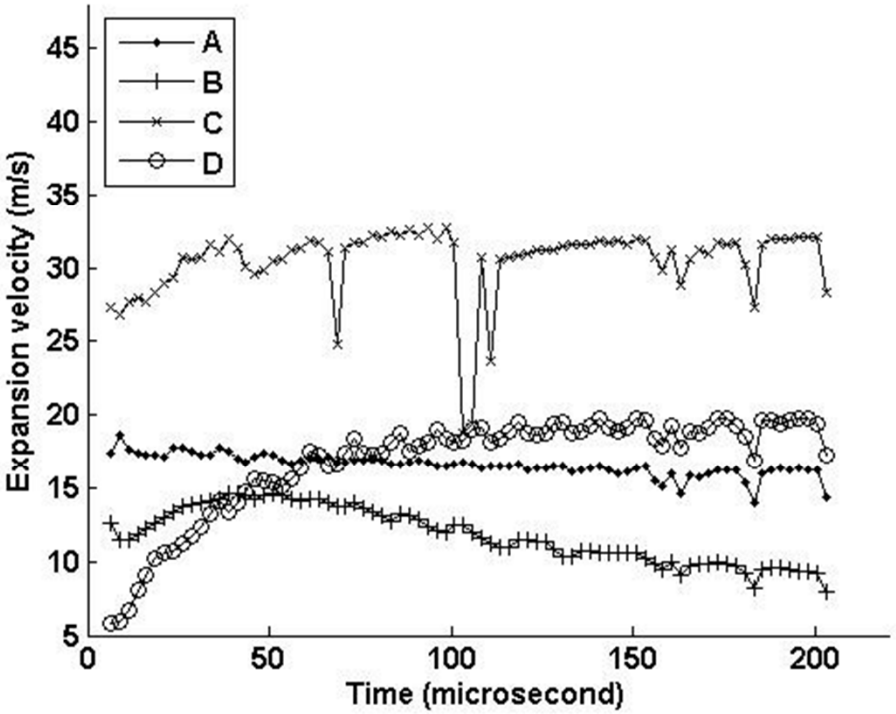
Cavitation and growth of surface filaments

- To obtain the expansion velocity along the jet surface, we evaluate the expansion length in 4 typical positions. 14 GeV, 10 teraproton beam was used for energy deposition calculation

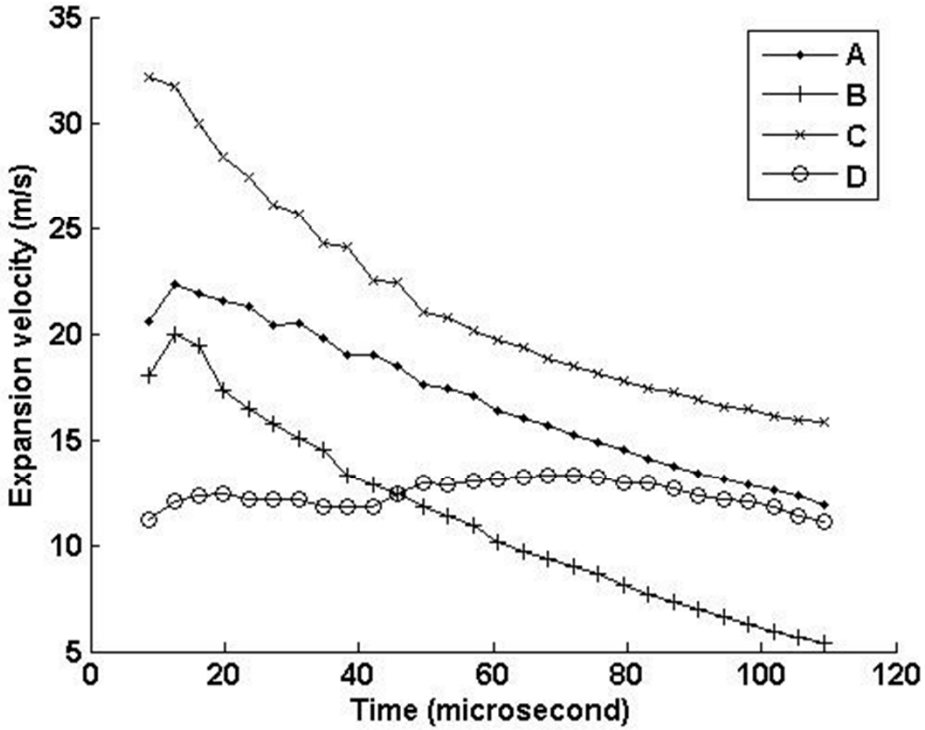




Growth of surface filaments



No magnetic field



B=10T

Muon Collider vs Neutrino Factory

Beam: 8 GeV, 4 MW, 3.125e15 particles/s, r.m.s. rad = 1.2 mm

Muon Collider:

15 bunches / s

66.7 ms interval

208 teraproton per bunch

Neutrino Factory:

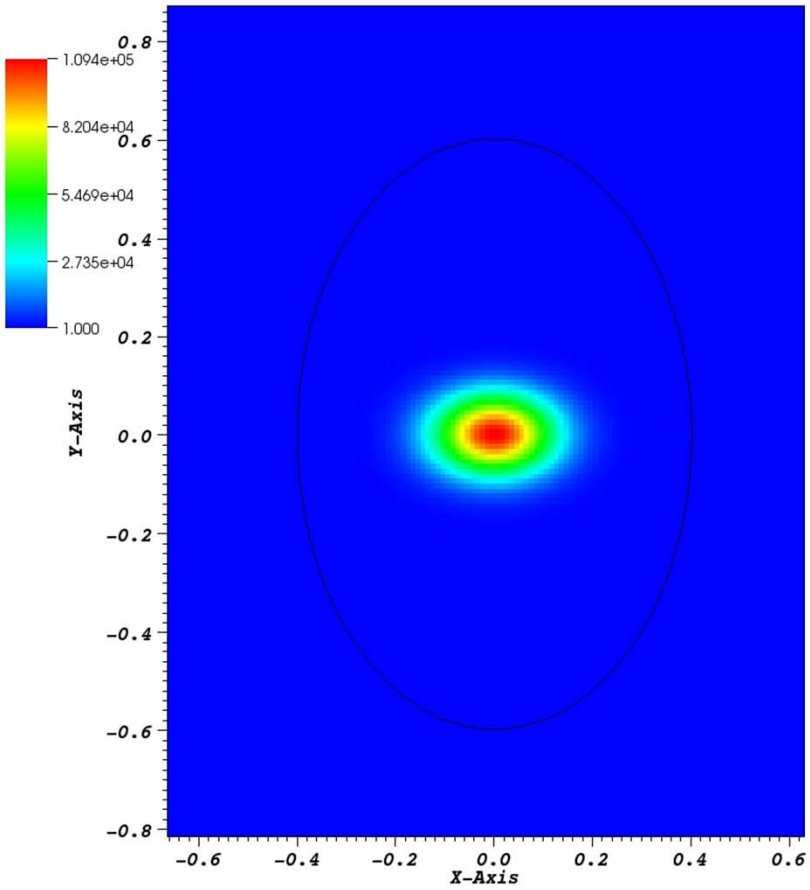
150 bunches / s

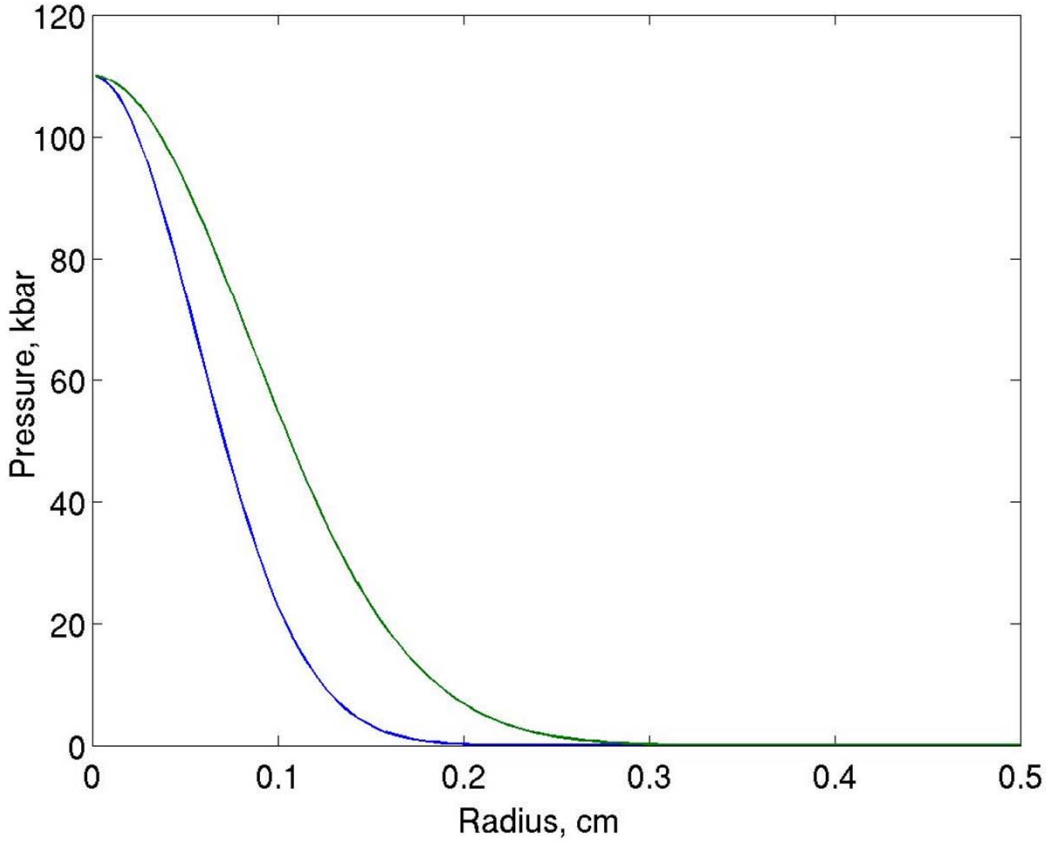
6.67 ms interval

20.8 teraproton per bunch

Maximum pressure (estimate):
Muon Collider: Pmax = 110 kbar
Neutrino Factory: Pmax = 11 kbar

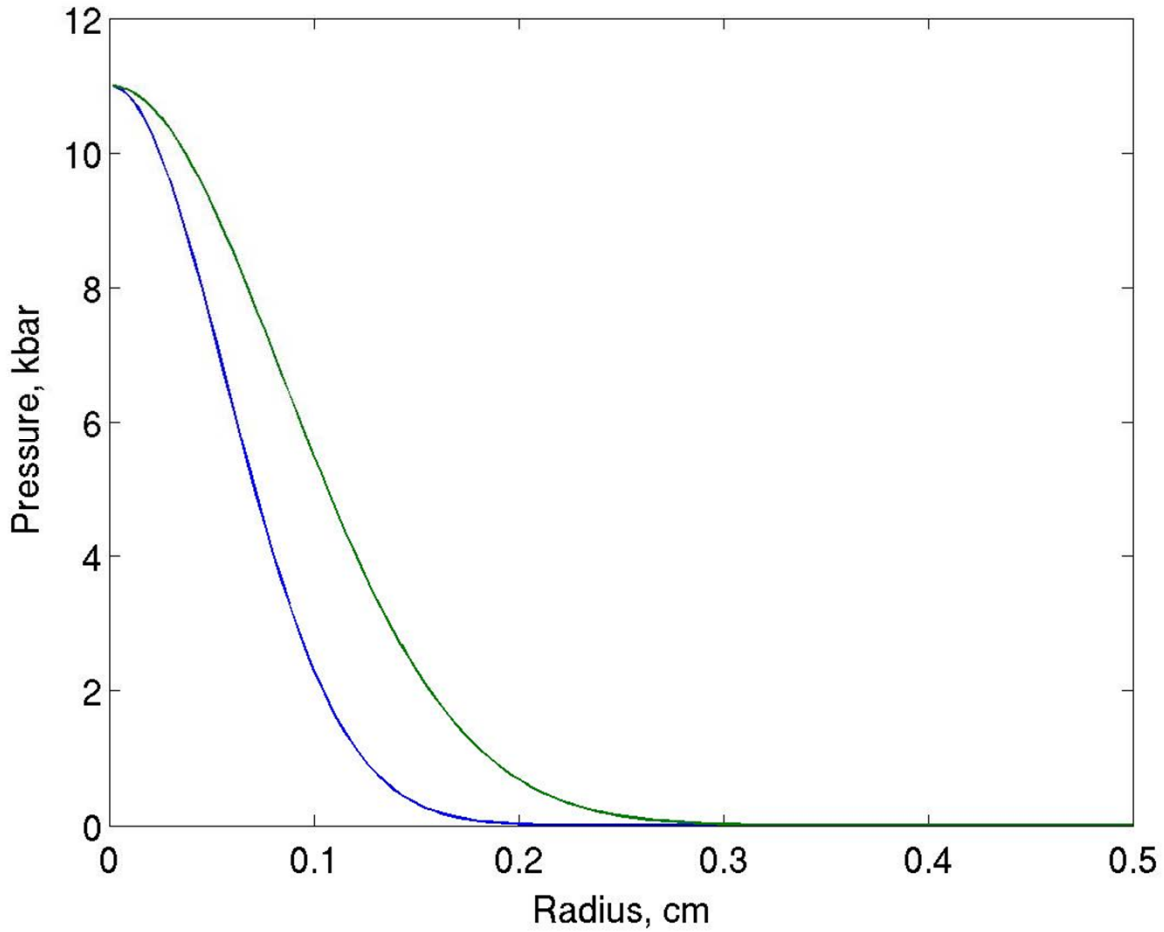
Muon Collider





Jet disruption velocity: 103 m/s

Neutrino Factory



Jet disruption velocity: 25 m/s

SPH simulation of mercury jet dump (3D)