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Simulation of High Power Mercury Jet Targets using Smoothed Particle Hydrodynamics

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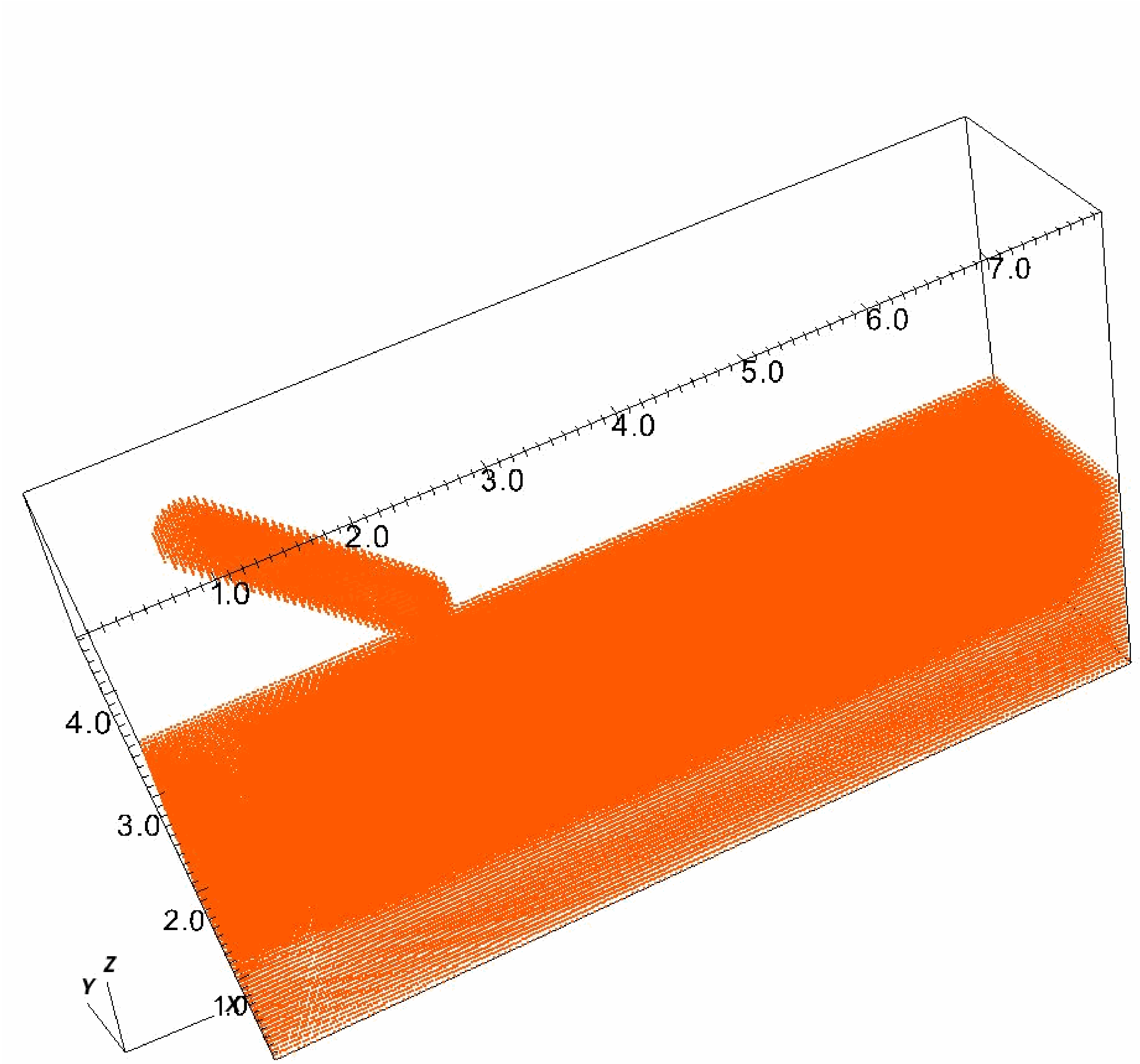
Benefits of SPH

- Exact conservation of mass (Lagrangian code)
- Natural (continuously self-adjusting) adaptivity to density changes
- Capable of simulating extremely large non-uniform domains
- Robustly handles material interfaces of any complexity
- Scalability on modern multicore supercomputers

New Smoothed Particle Hydrodynamics (SPH) code

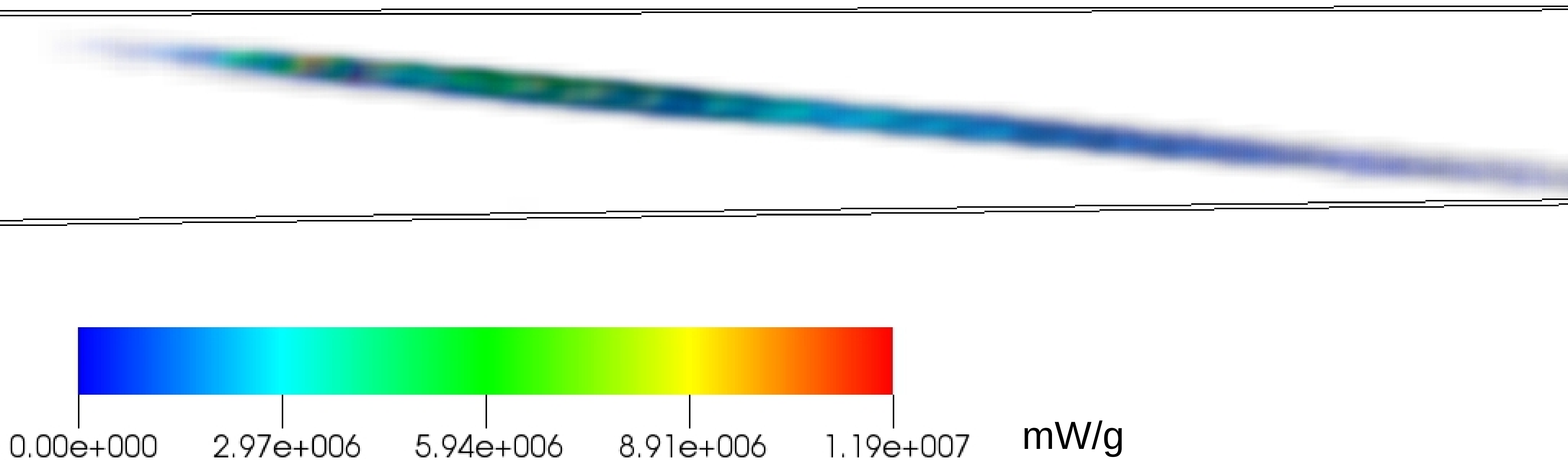
- New SPH code has been developed in our group using C++ modular structure
- Several smoother particle kernels
- Riemann solvers, MUSCL-based schemes (to be completed)
- Time stepping
  - Predictor-corrector
  - Verlet scheme
  - Symplectic schemes
- Currently MHD and physics models related to high energy density physics are being added

SPH simulation of mercury jet dump (3D)



SPH Simulations of Mercury Jet Interaction with Protons

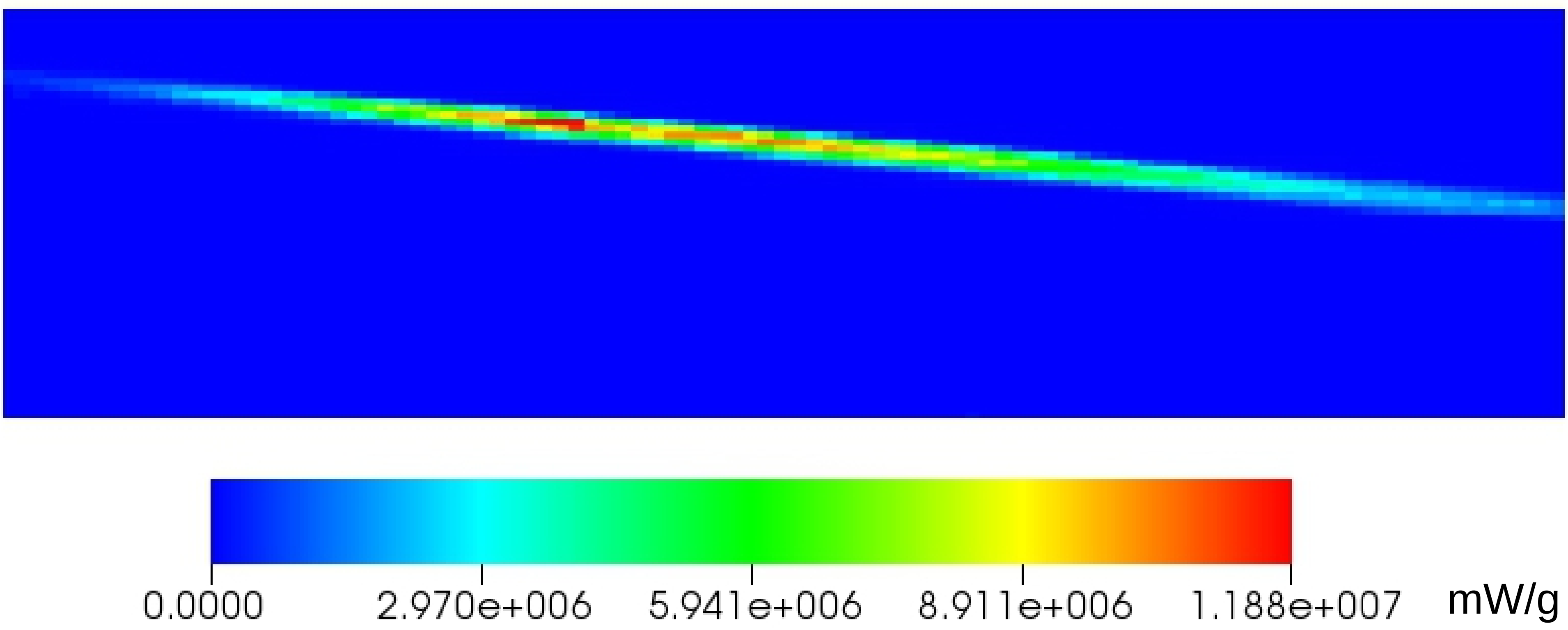
Energy Deposition for NF / MC



- Image: 3D volume rendering
- The number of incoming protons have been normalized to 4MW
- To obtain correct pulse structure
  - for MC, the energy is divided by 15
  - for NF, the energy is divided by 150
- x-range: [-0.4, 0.3] cm, y-range: [-3,2.9] cm, z-range: [-75.0, -0.2] cm

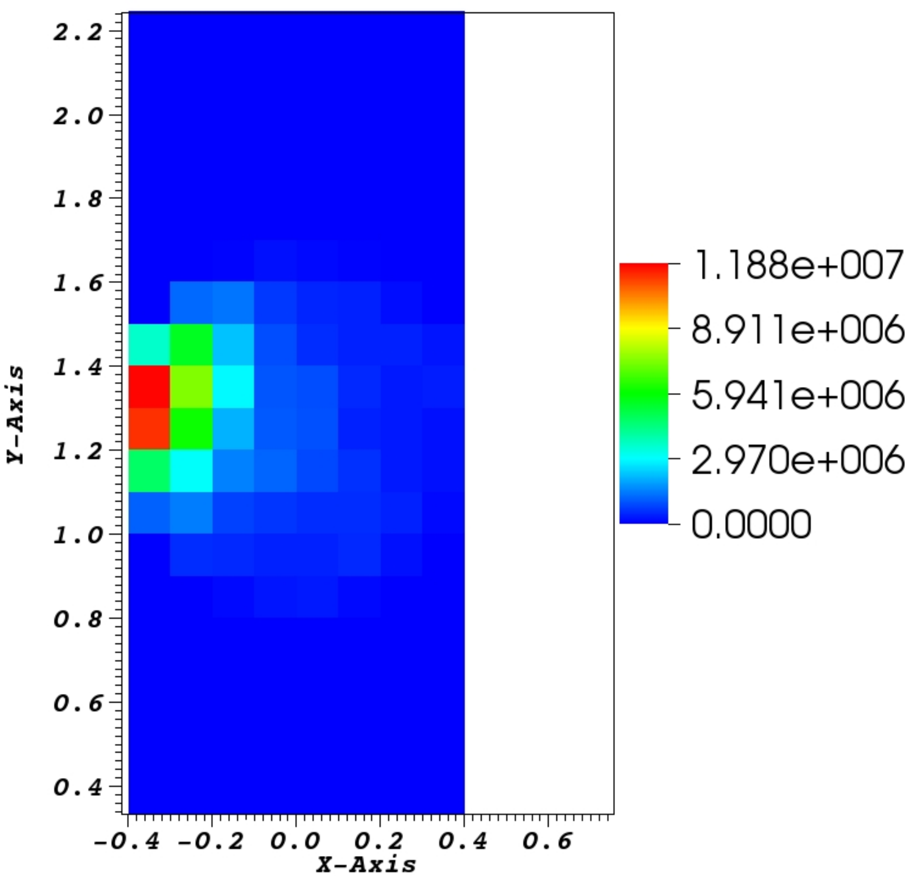
Energy Deposition for NF / MC

Slice of data parallel to y-z plane at x = -0.4 (containing the maximum energy deposition)



Energy Deposition for NF / MC

Slice of data parallel to x-y plane at z = -50.0 (containing the maximum energy deposition)

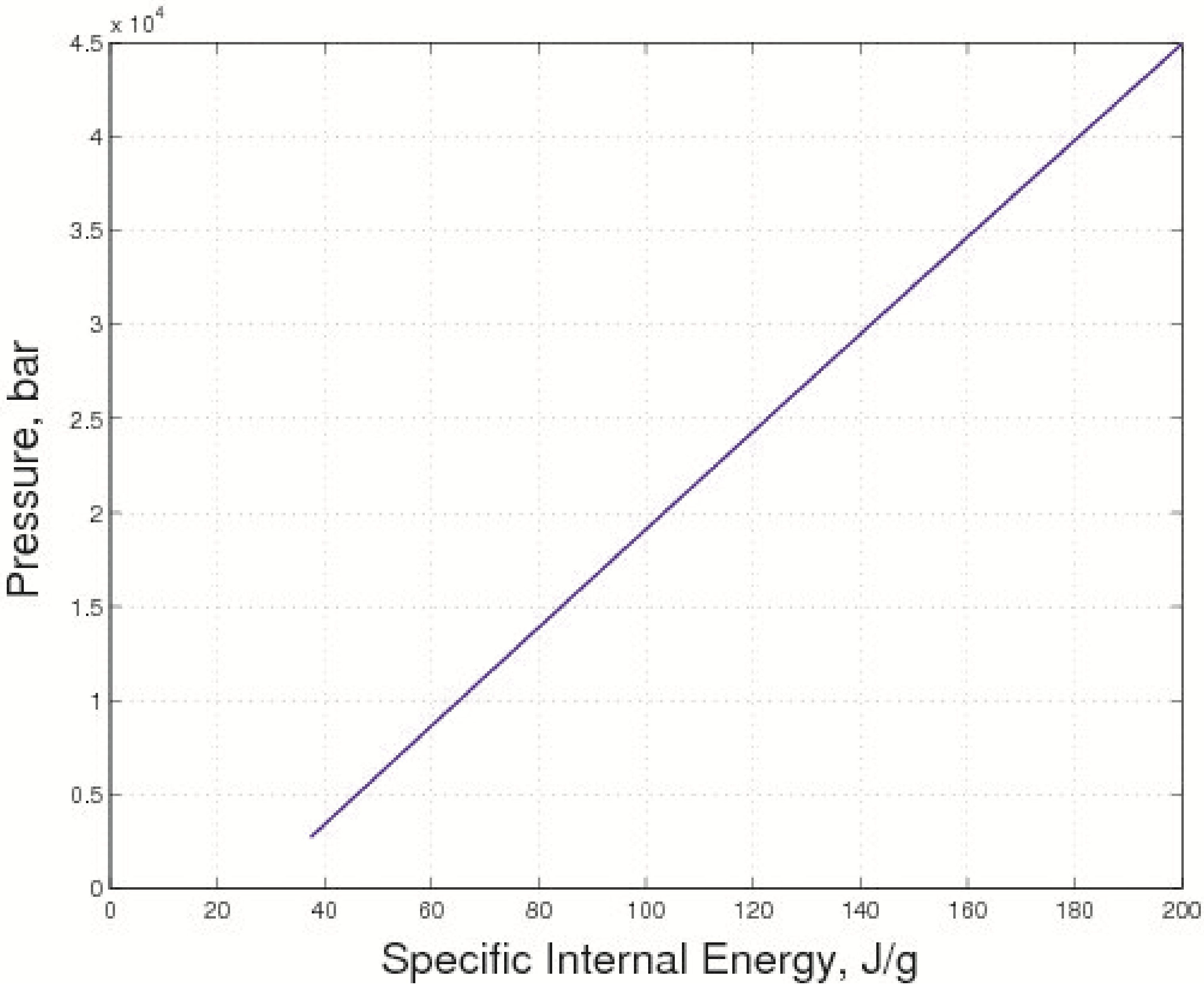


Peak energy deposition values:

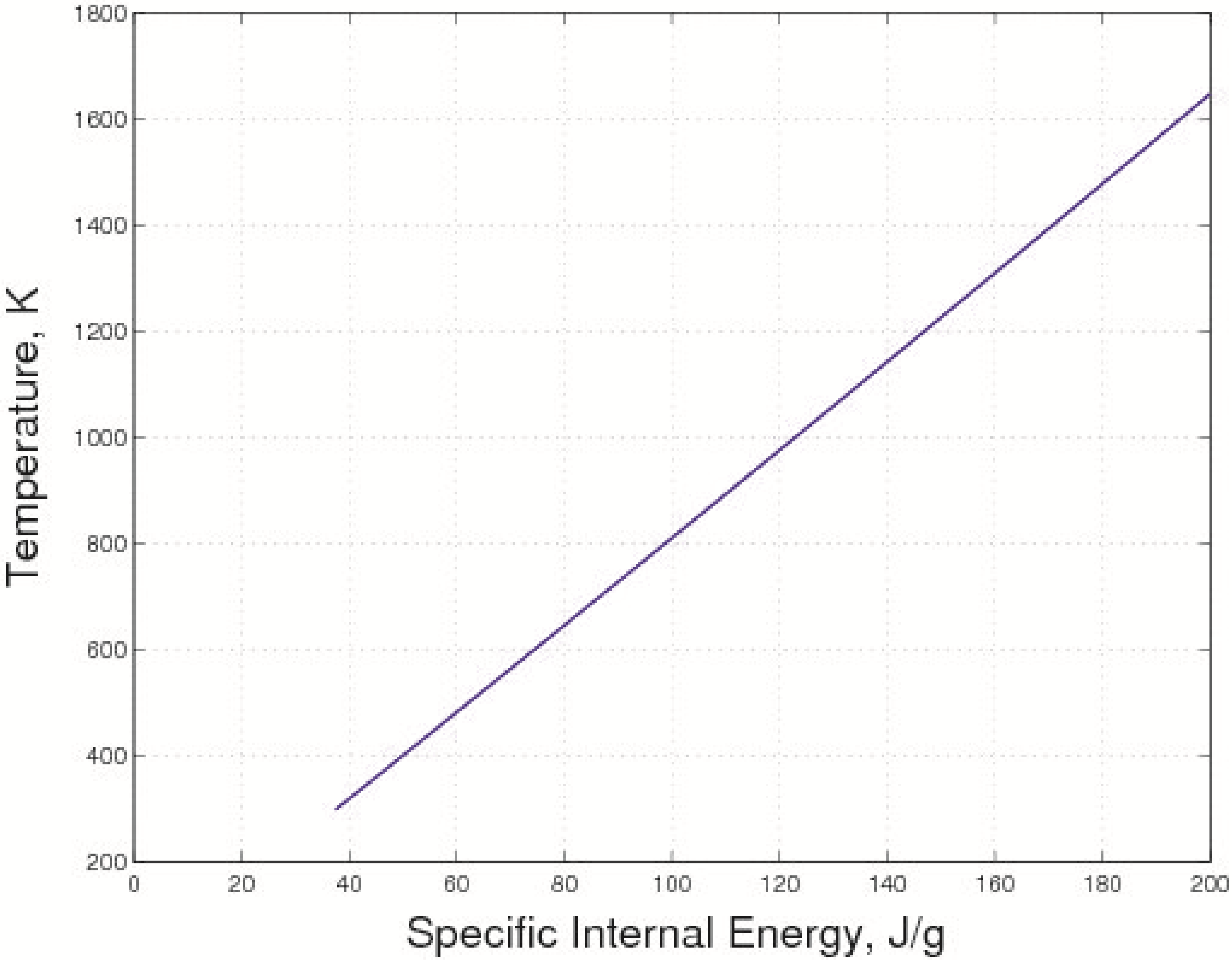
NF: 79 J/g

MC: 790 J/g

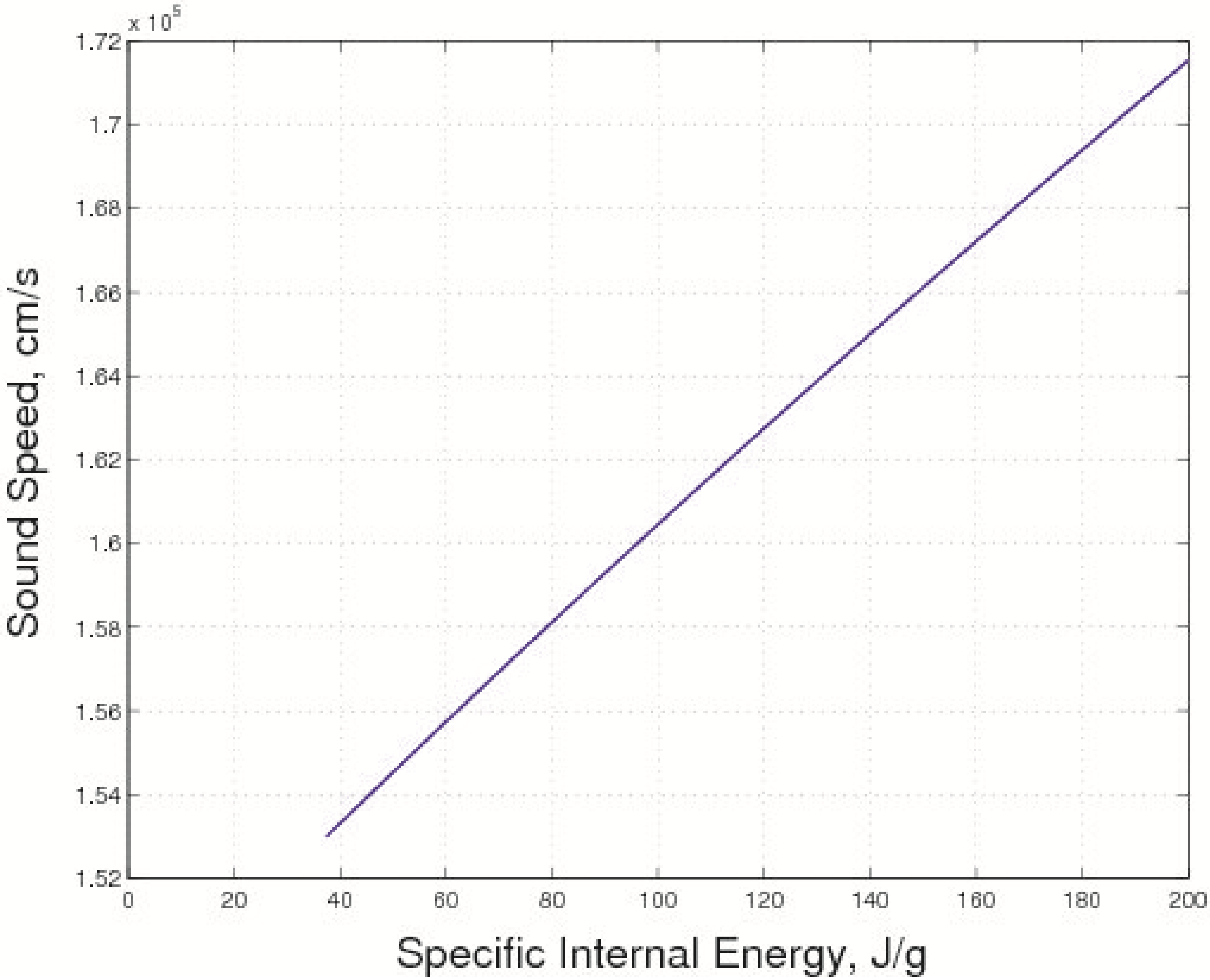
Increase of Pressure by Isochoric Energy Deposition (SESAME data)



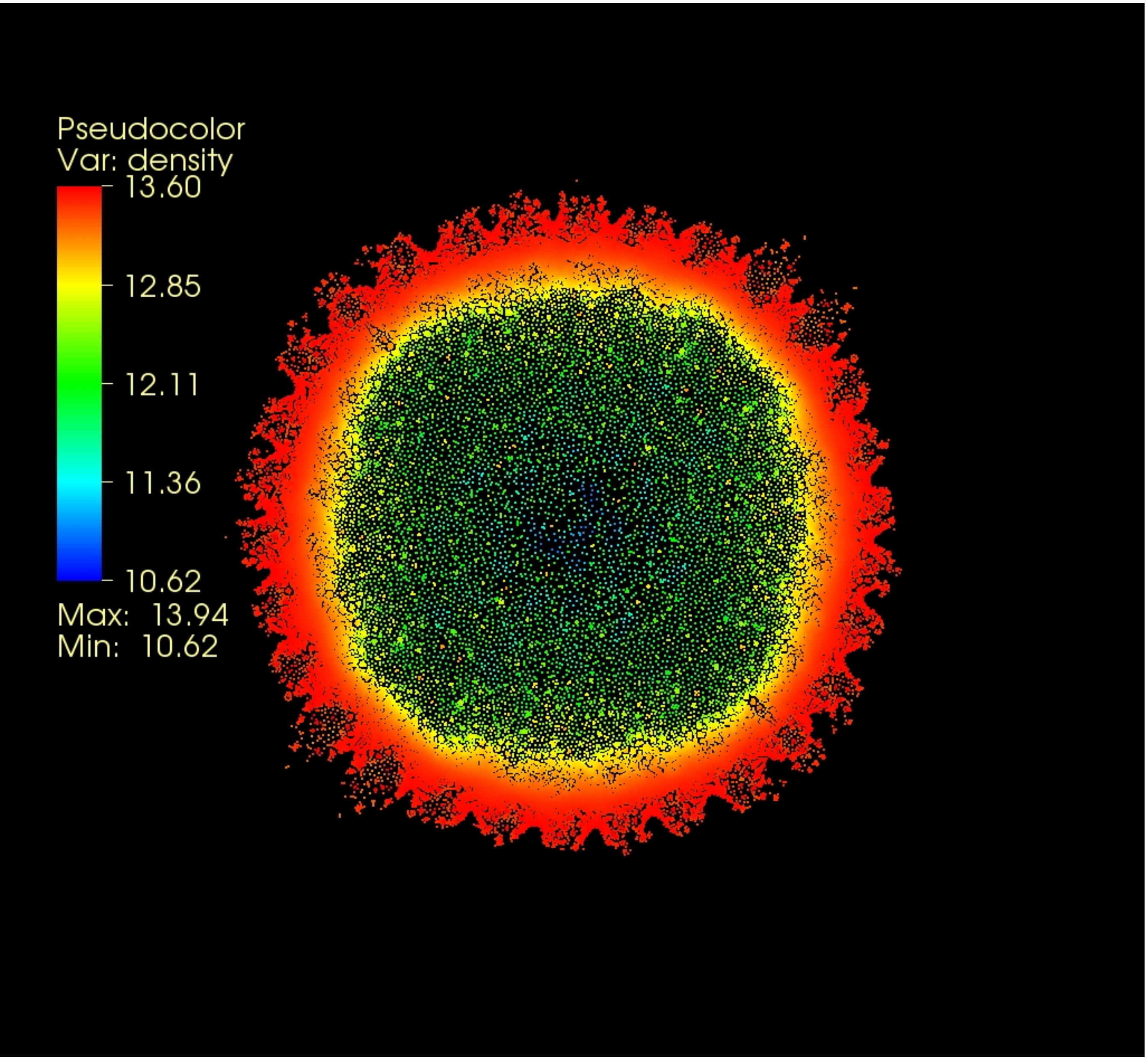
Increase of Temperature by Isochoric Energy Deposition (SESAME data)



Increase of Sound Speed by Isochoric Energy Deposition (SESAME data)



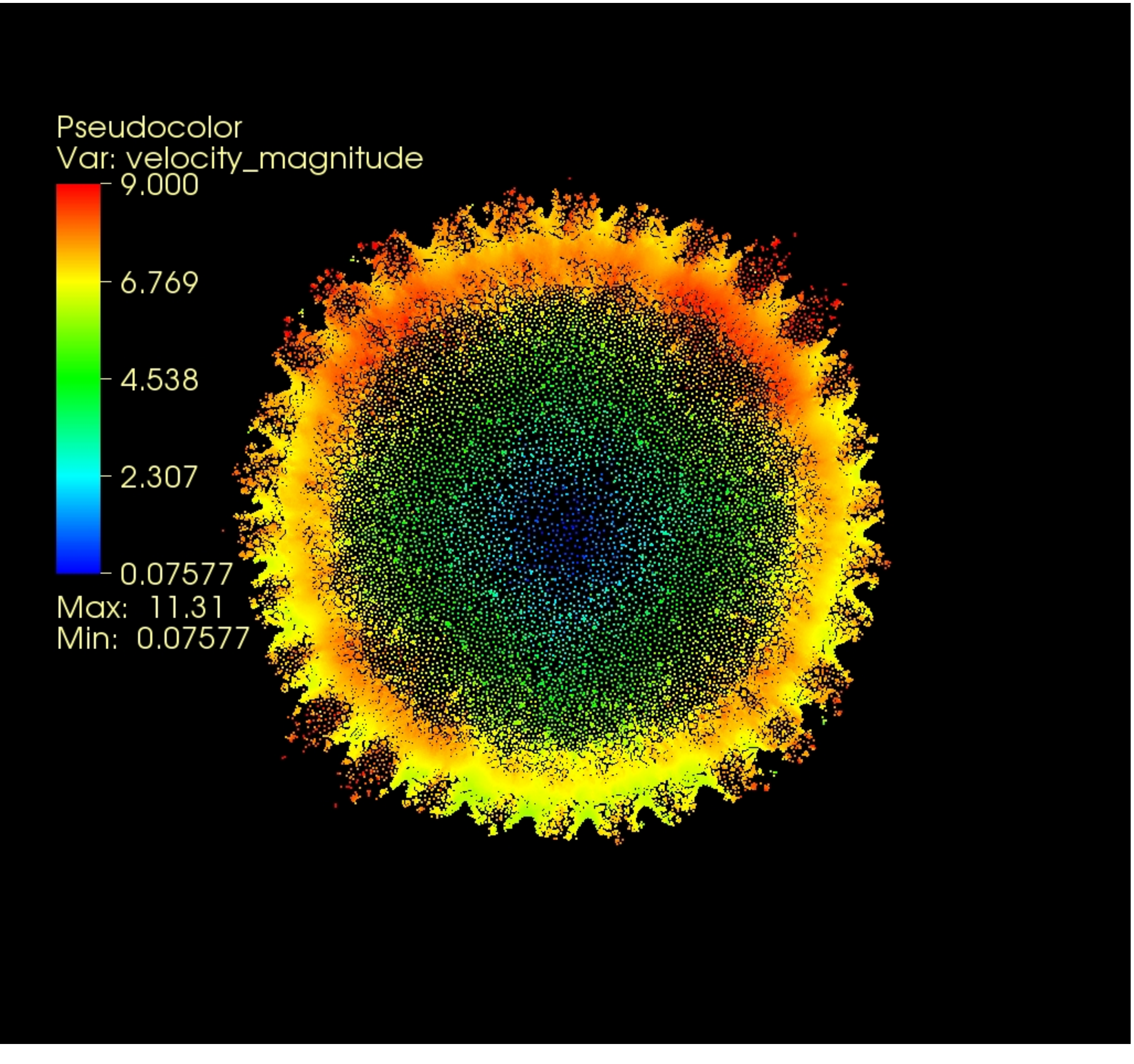
2D simulation of the MC target



Density, g/cc

SPH simulations show surface spikes and fine structure of the cavitation zone

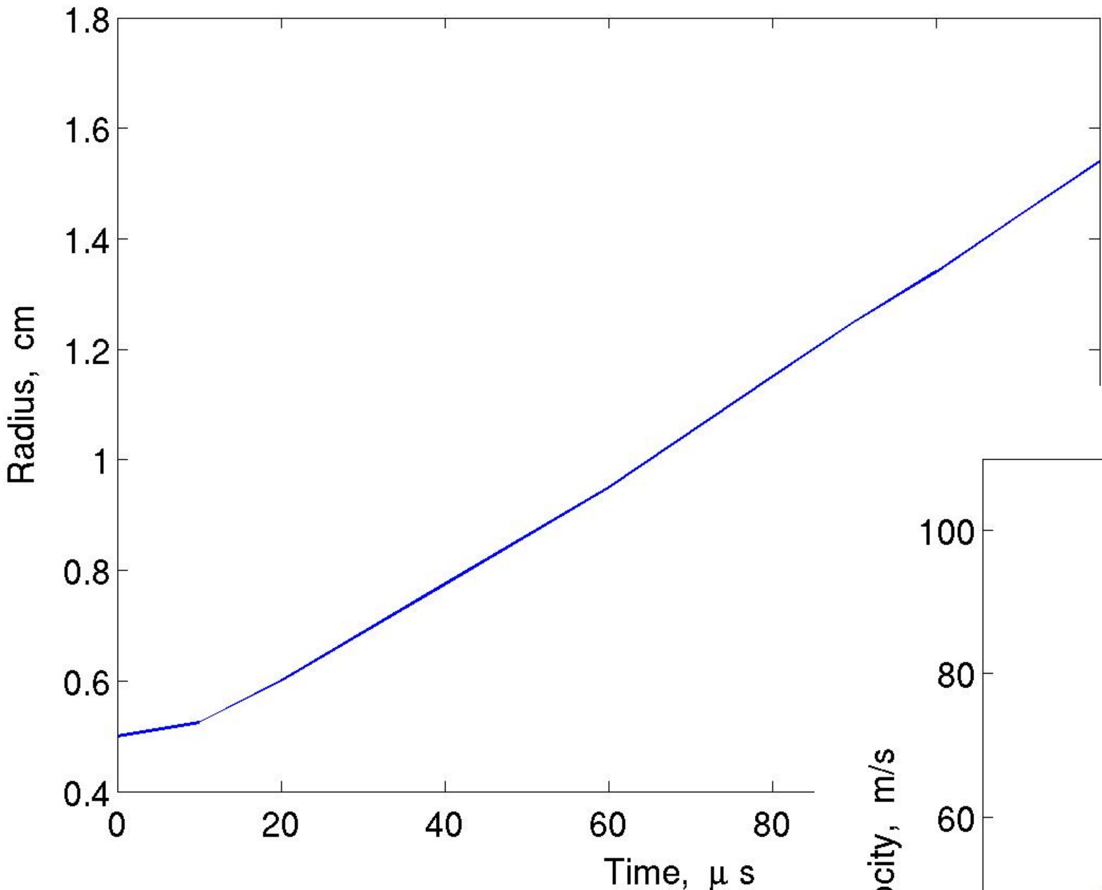
2D simulation of the MC target

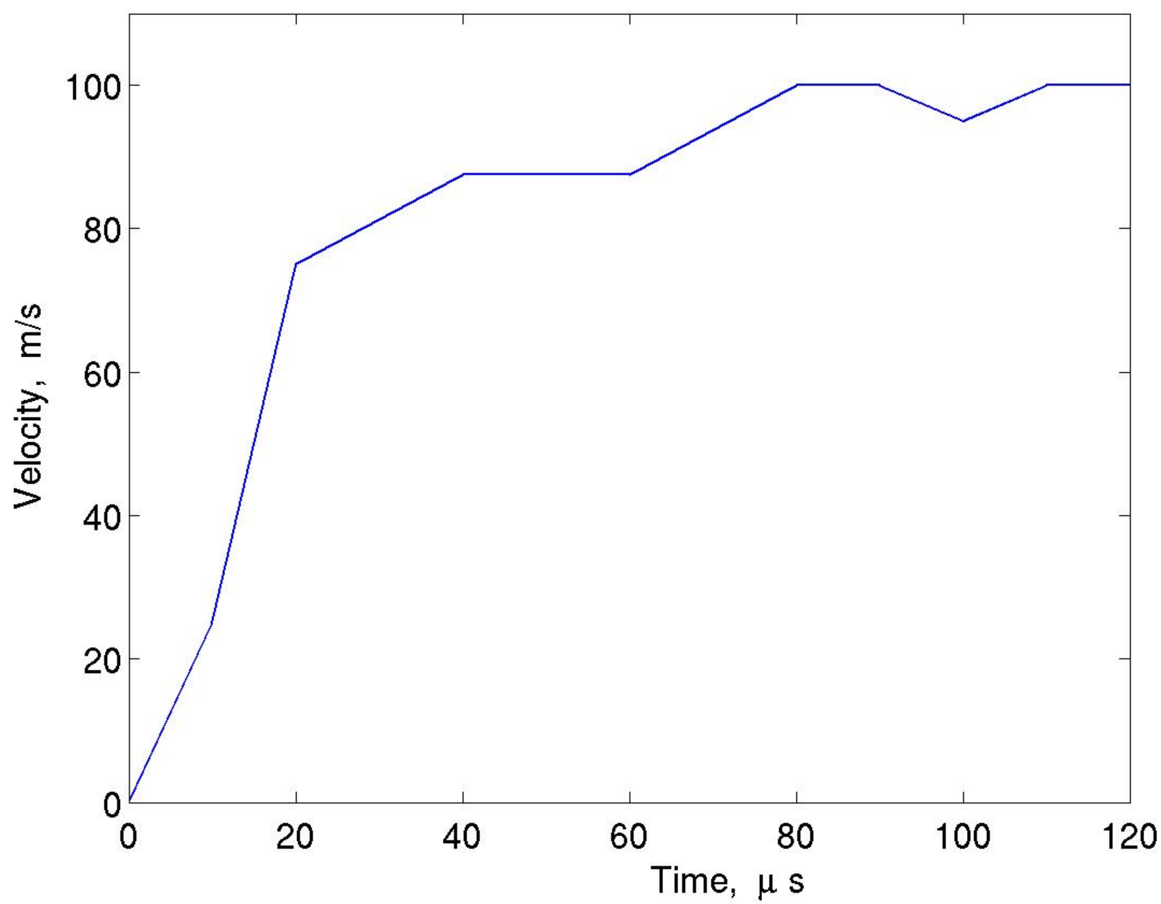


Velocity,

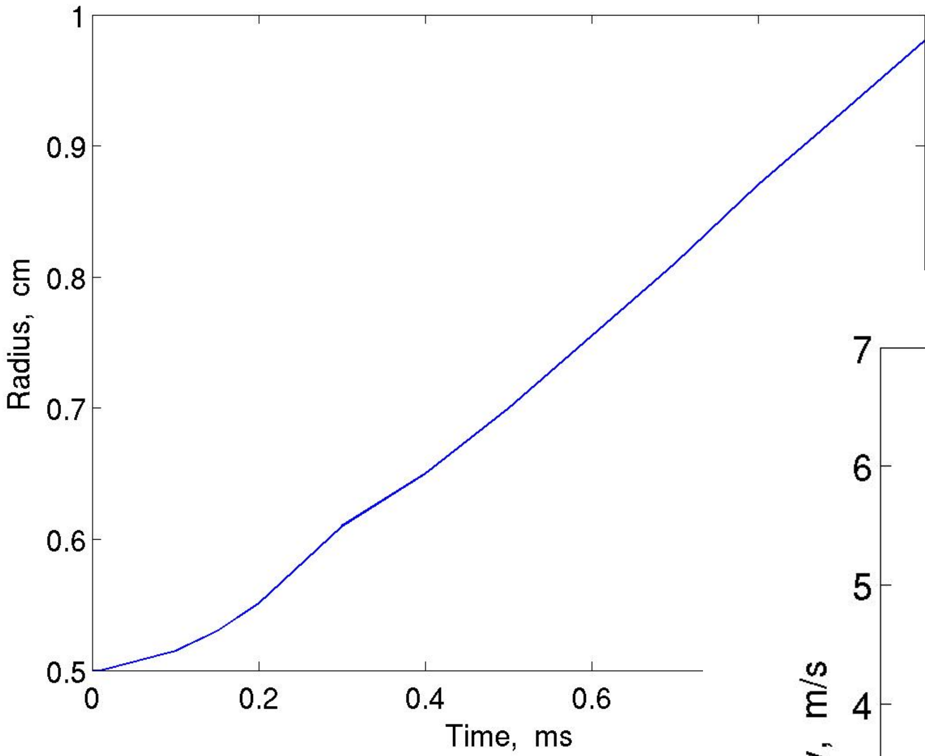
x 10 m/s

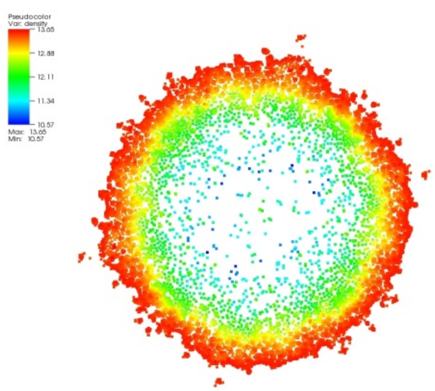
2D simulation of the MC target

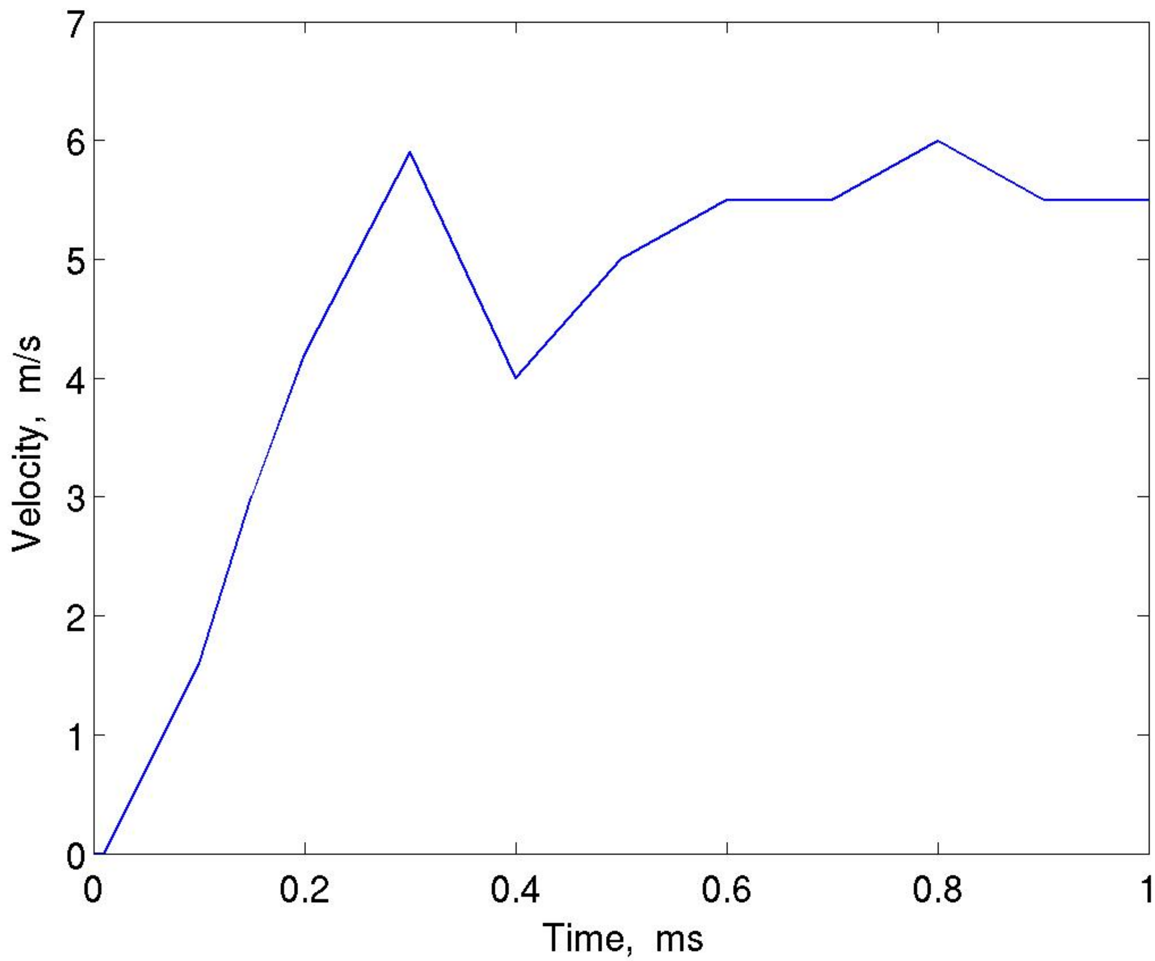




2D simulation of the NF target







Summary

- Developed new smoothed particle hydrodynamics code for free surface hydrodynamic flow (MHD part will be completed soon)
- Performed simulations for the target program of MAP collaboration
    - 3D simulations of the entrance of spent mercury jets into the mercury pool
    - 2D simulations of the interaction of mercury jets with protons
- Mercury accelerated to velocities of about 5.5 m/s (NF) and 95 m/s (MC)
    - The specific internal energy of the normal state was not added to the energy deposition in reported simulations (more critical to NF than MC)
- Refined 3D simulations are currently running without issues but the progress is slow as the code is not parallel yet
    - Parallelization (for both clusters and GPUs) and MHD module are current main priorities
    - Parallelization for GPUs will enable fast simulations of large 3D problems on workstation-size GPU machines