



Science & Technology
Facilities Council

Mercury Beam Dump Simulations

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1st joint meeting of EUROnu WP2 (Superbeam) and NF-IDS target
15-17 December-2008

Mercury beam dump design from NUFACT Feasibility Study

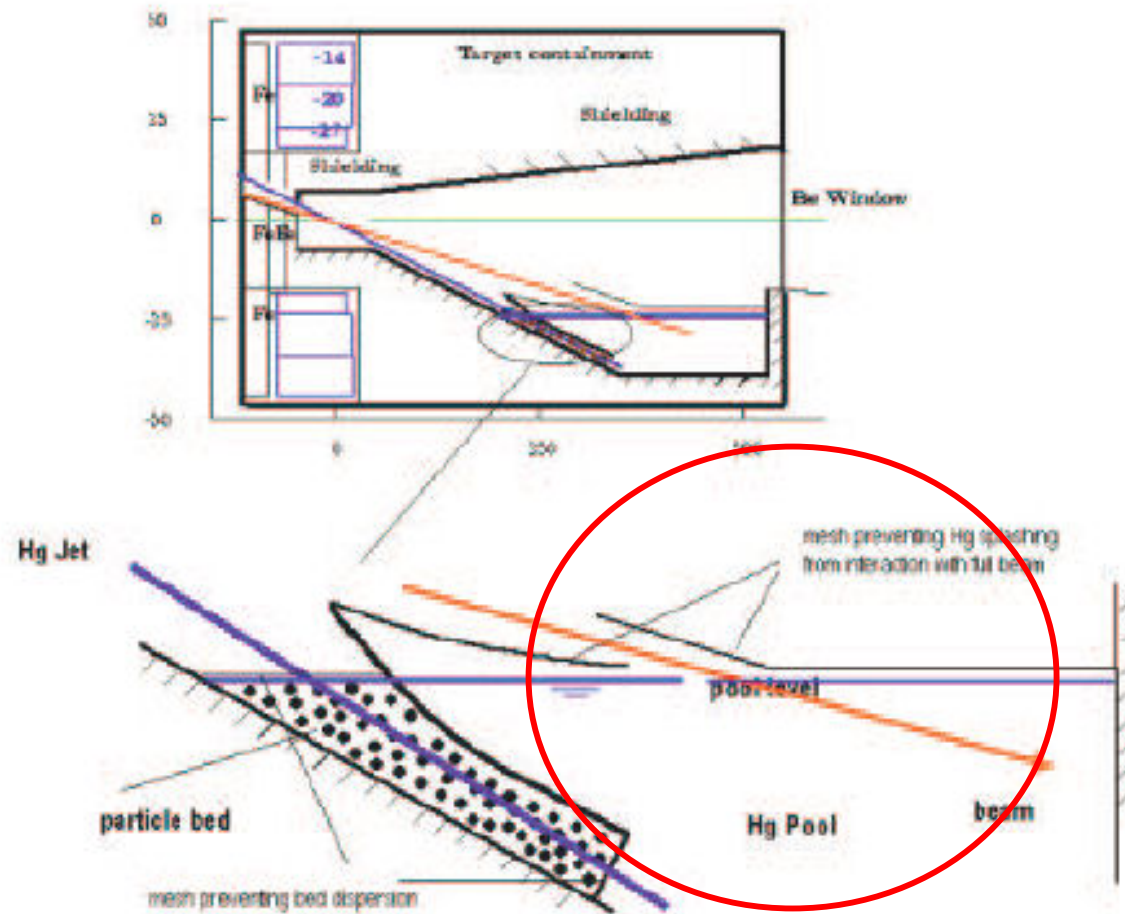


Figure 3.36: Schematic of the mercury pool that serves as the proton beam absorber.



Mercury beam dump design from NUFAC Feasibility Study

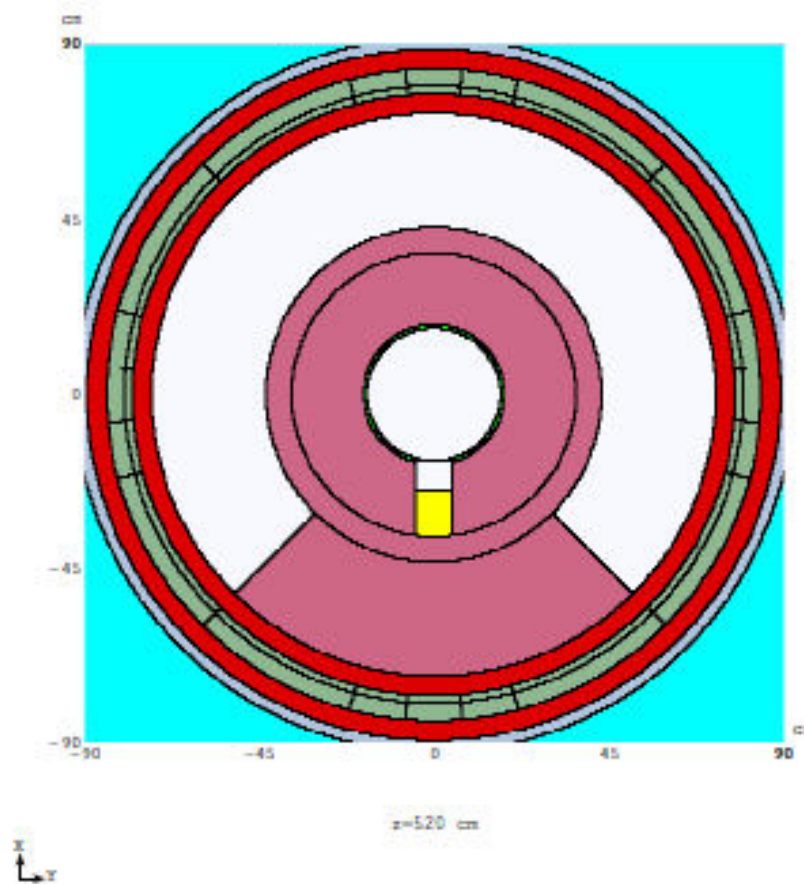


Figure 3.13: Transverse section of the target system at $z = 5.2$ m, showing the mercury pool that serves as the proton beam absorber.



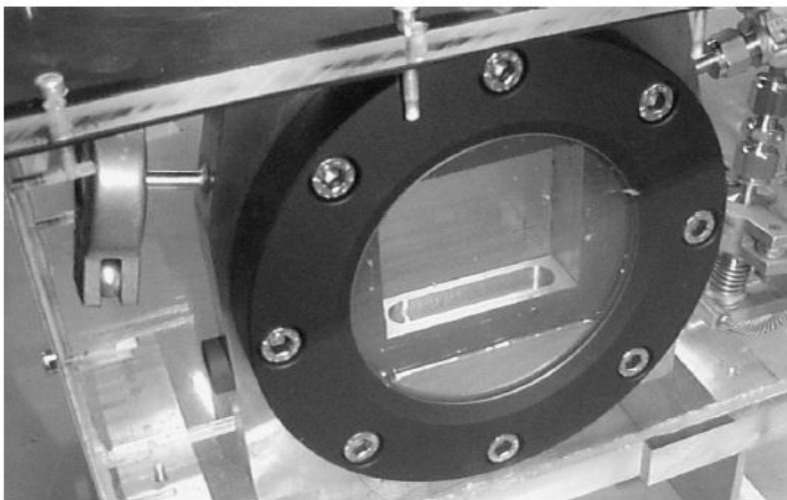


Figure 1. Trough target. The trough is excavated in a steel frame, with the viewing windows on both sides. The steel frame is placed in a second confinement.

Thermal shocks and magnetohydrodynamics in high power mercury jet targets

J Lettry, A Fabich, S Gilardoni, M Benedikt, M Farhat and E Robert

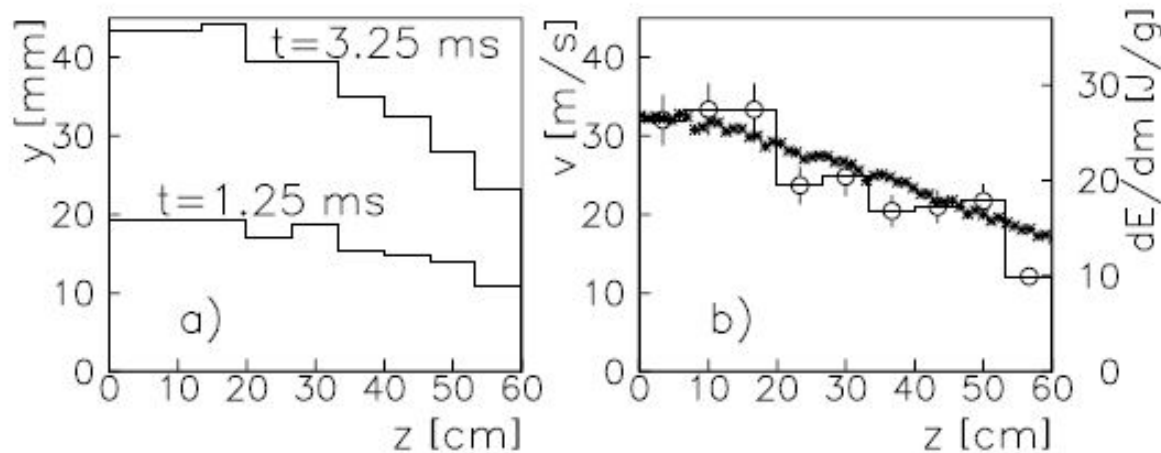
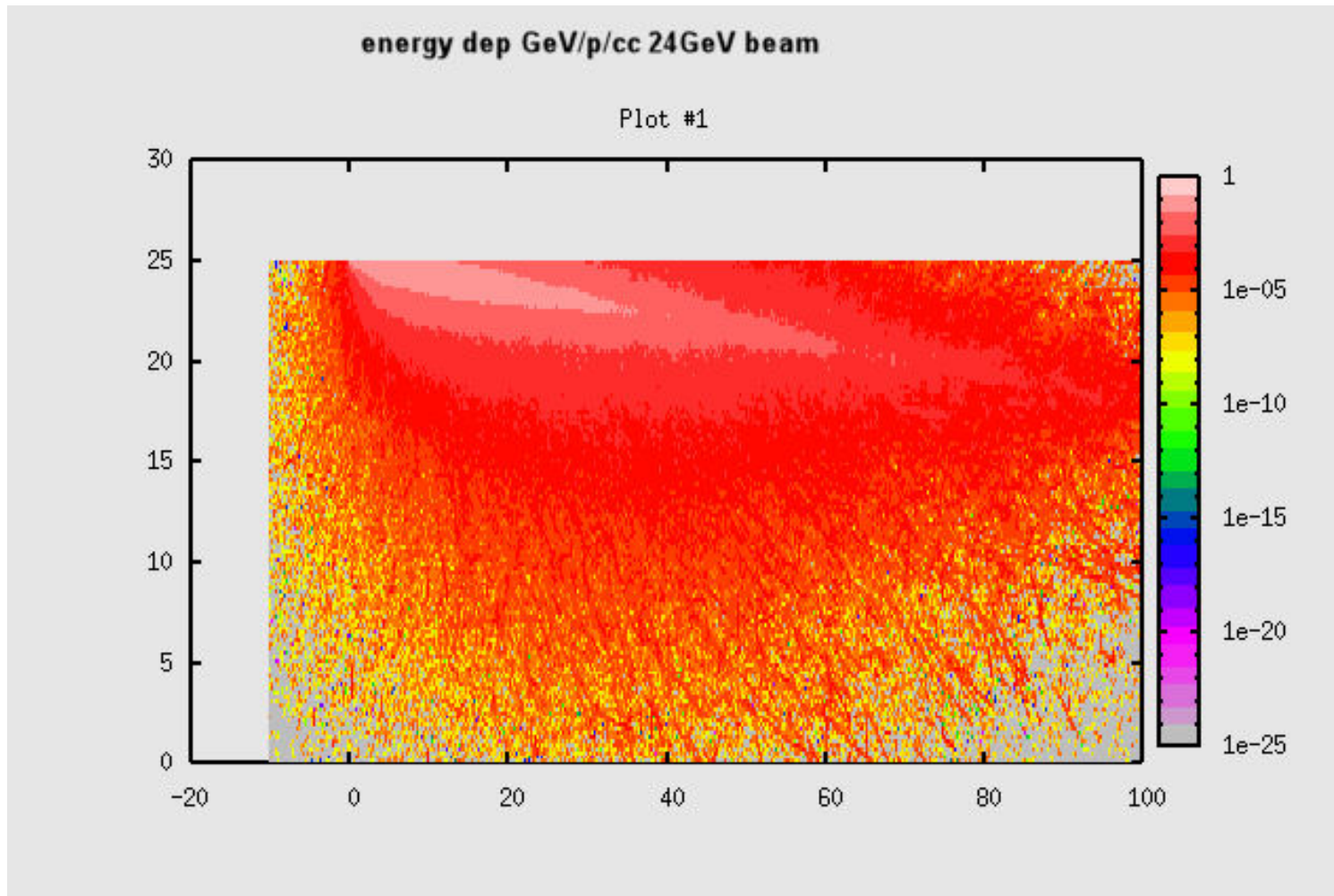


Figure 2. Reaction of $\approx 7 \text{ cm}^3$ mercury contained in a 60 mm long stainless steel trough irradiated with a proton pulse of 20×10^{12} 1 GeV protons. a) The height of the Hg-droplets obtained by image processing is averaged over ≈ 7 mm sections, 1.25 and 3.25 ms after proton impact. b) The computed [8, 9] energy deposition (asterisk) on beam axis of the proton pulse is compared to the initial velocities of the Hg-droplets (open circles). The predicted proportionality of the initial velocity to the temperature elevation is confirmed within the precision of the measurement.



Fluka Simulation - Energy deposition in mercury pool with 24GeV beam



How much of the beam energy is absorbed in the beam dump?



Autodyne

Governing equations

Conservation of

- Mass
- Momentum
- Energy

Achieve solution of governing equations with material models

- Equation of state (density = $f(\text{pressure, energy})$)
- Strength/failure model

Solution method

Explicit forward marching scheme with small time step to maintain stability

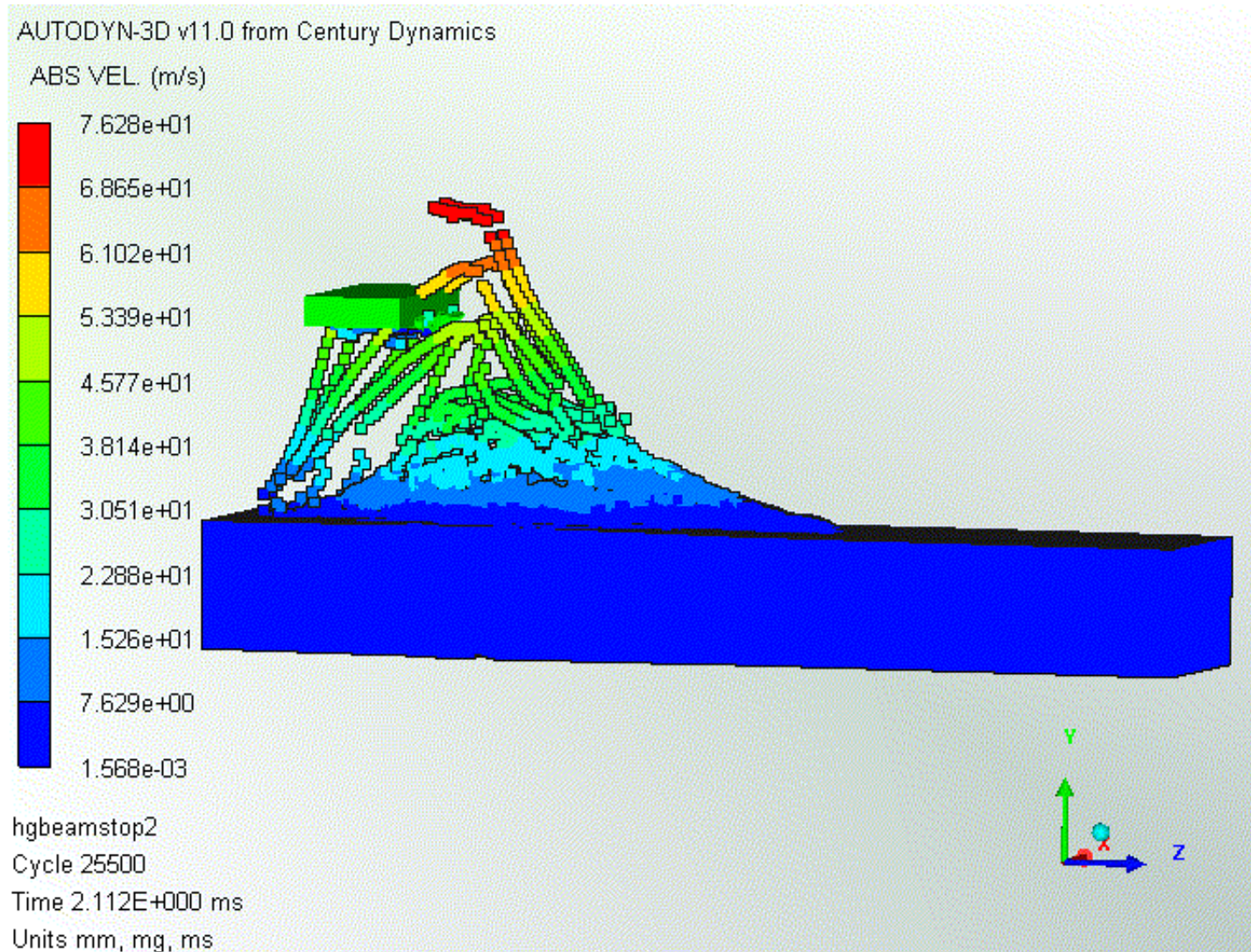
Lagrange or Euler meshing



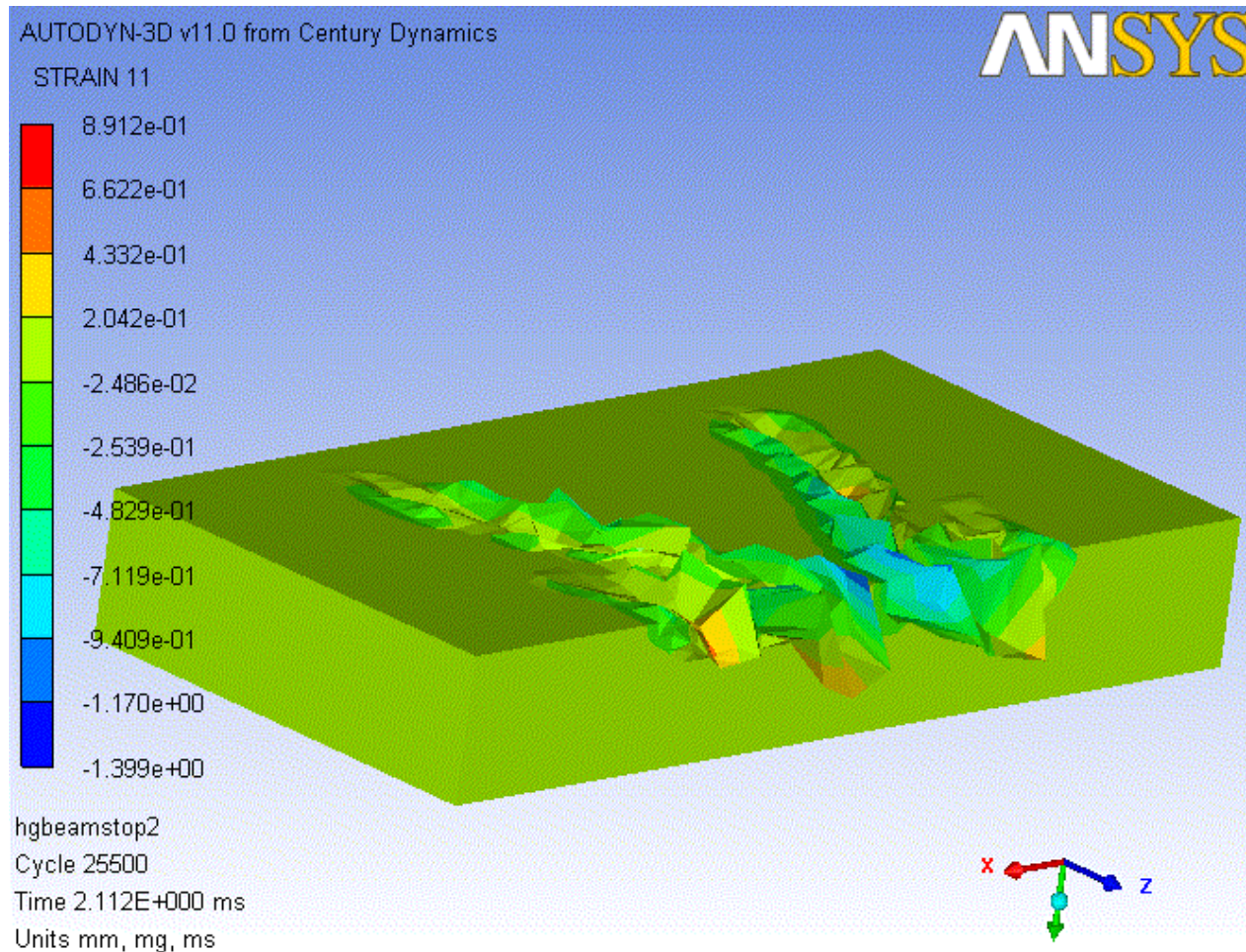
Agitation 'eruption' of mercury pool surface due to 24GeV proton beam

Autodyne simulation

Splash following pulse of 20Terra protons



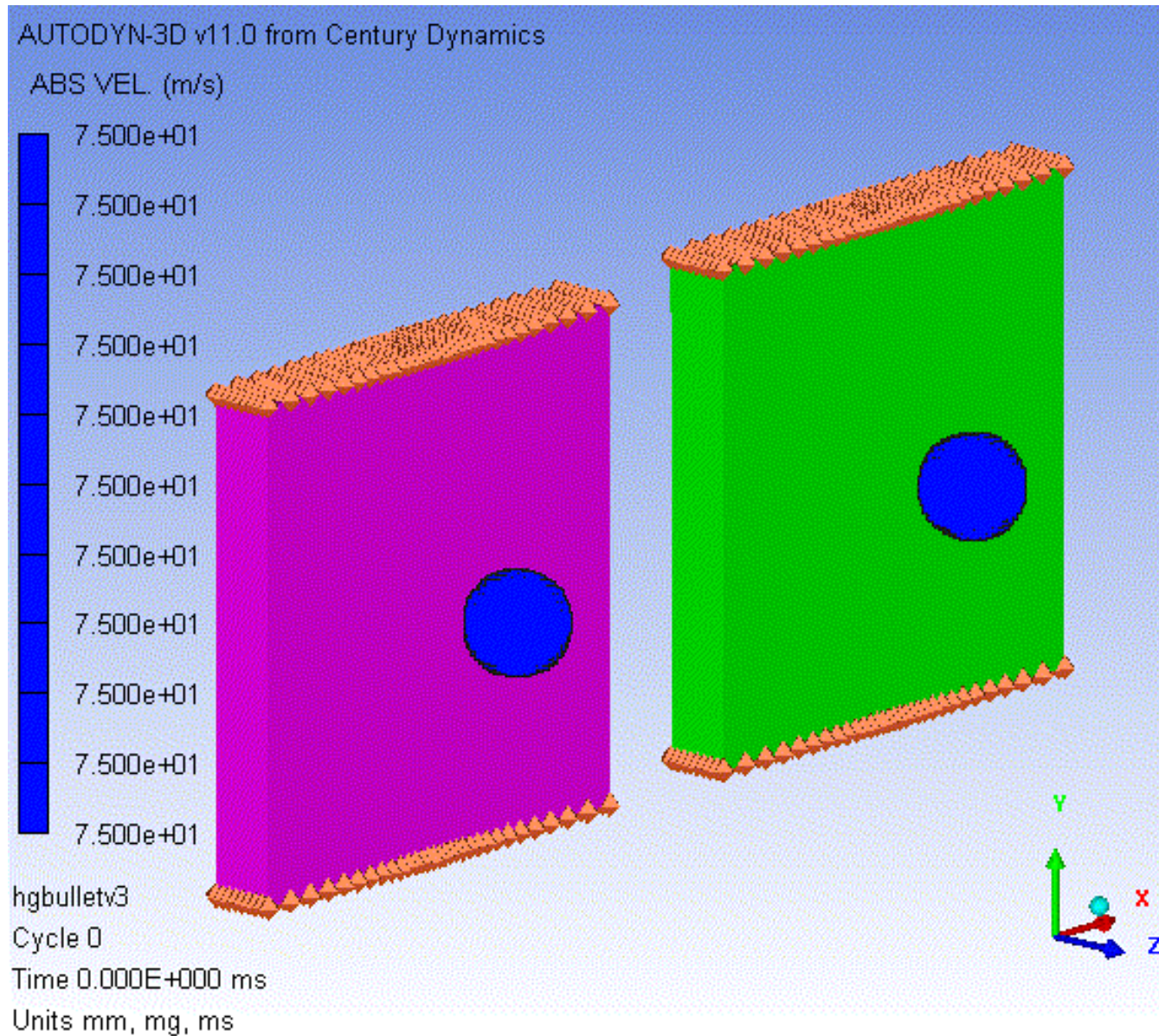
Damage to underside of stainless steel plate fluid - structure interaction model



maybe sprung baffles would be help reduce damage



Damage as a result of high speed impact of a mercury droplet Stainless Steel vs. Ti-6Al-4V

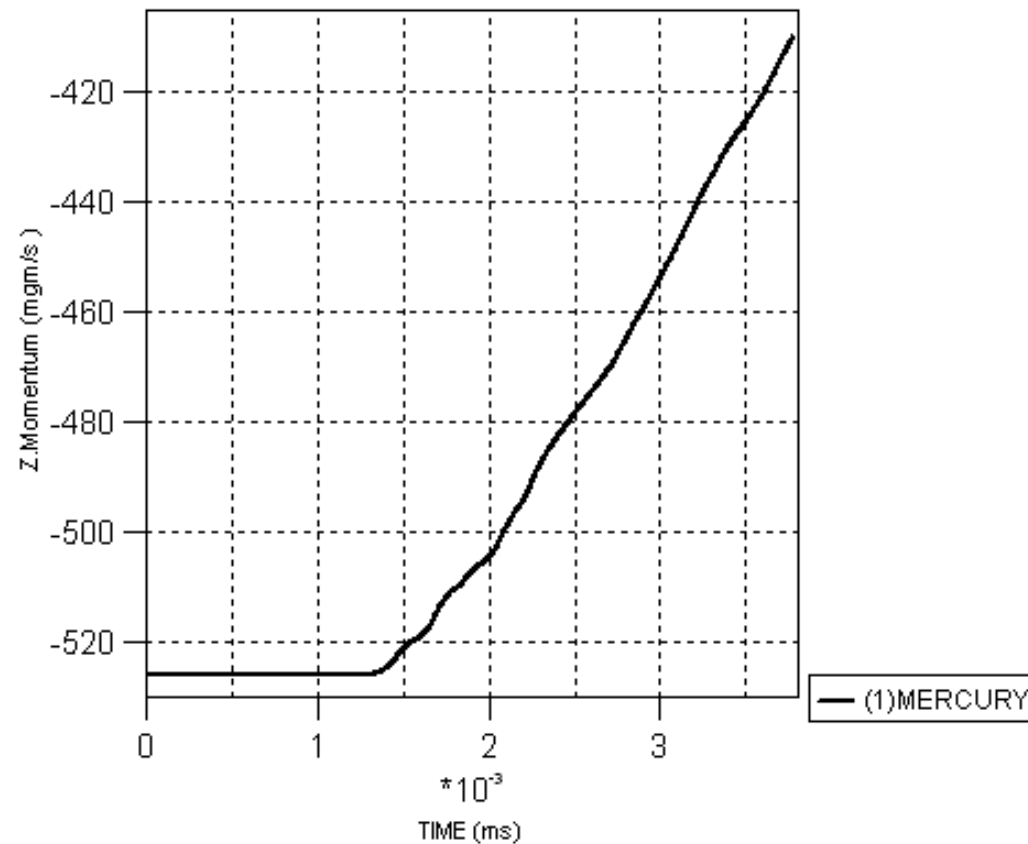


Damage as a result of high speed impact of a mercury droplet

Reduction in momentum during impact (1mm diameter)

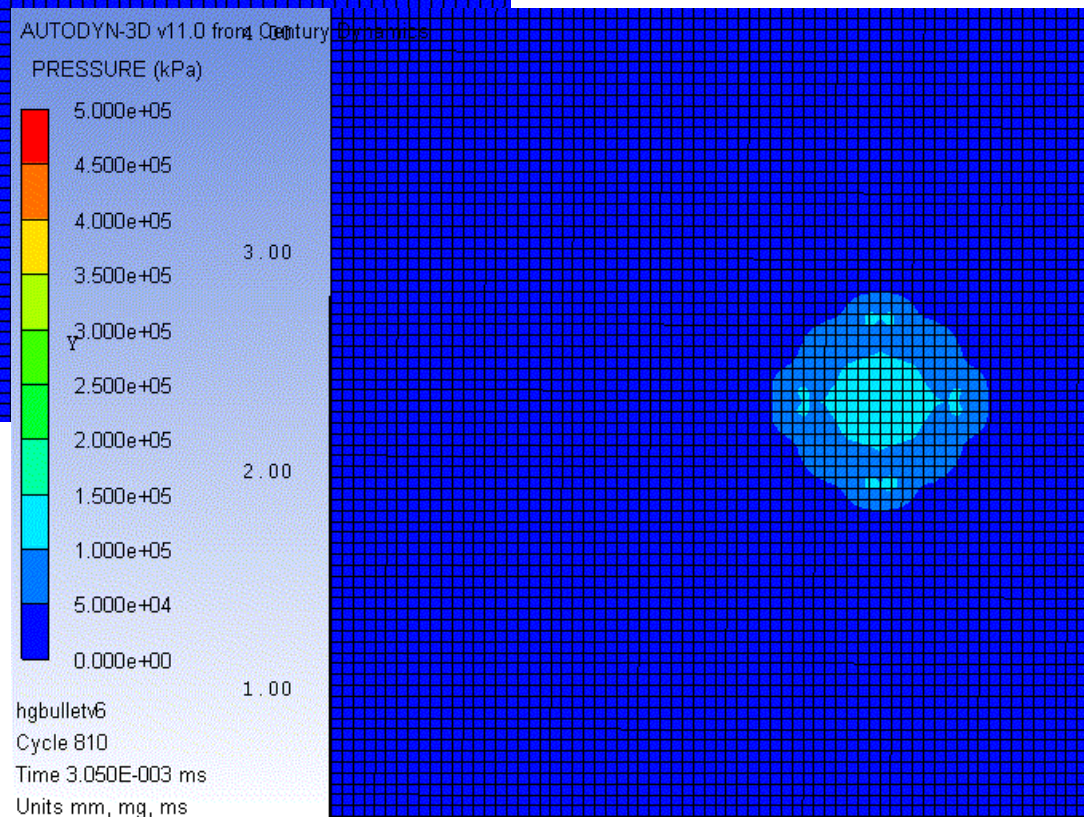
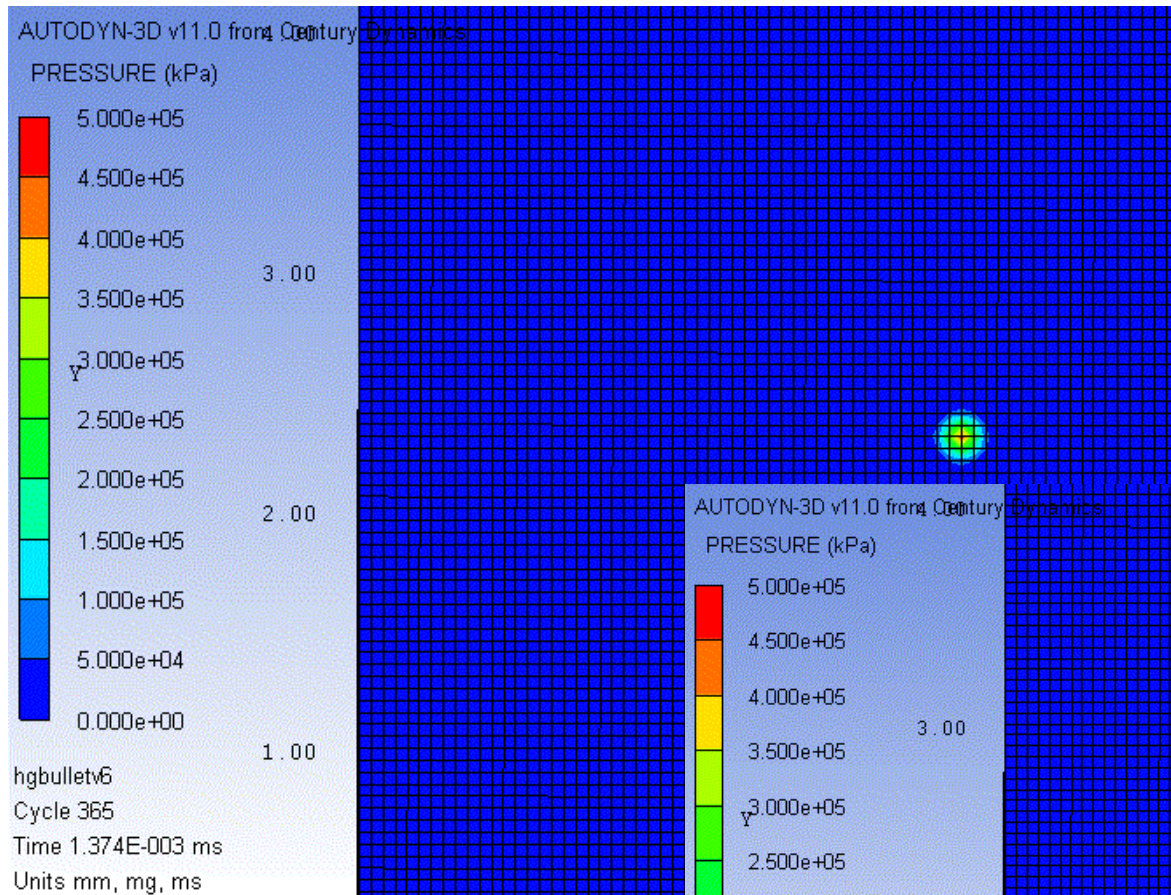
AUTODYN-3D v11.0 from Century Dynamics

Material Summary (hgbulletv6)

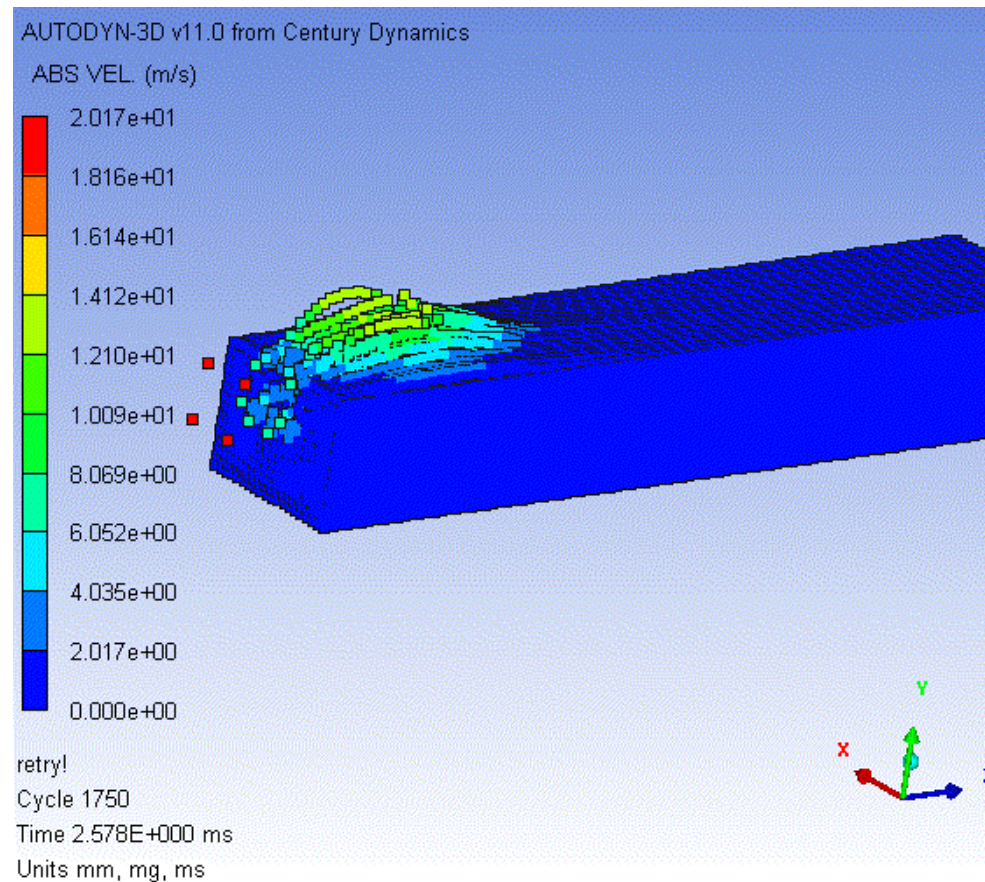
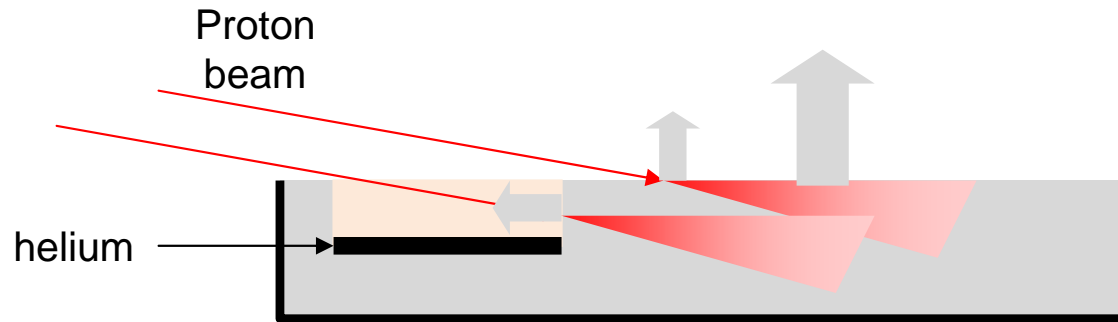


Damage as a result of high speed impact of a mercury droplet

Change in contact area and surface pressure during impact (1mm diameter)



Consider helium bubbles in beam dump to reduce splash velocity



Mercury beam dump design from NUFACT Feasibility Study

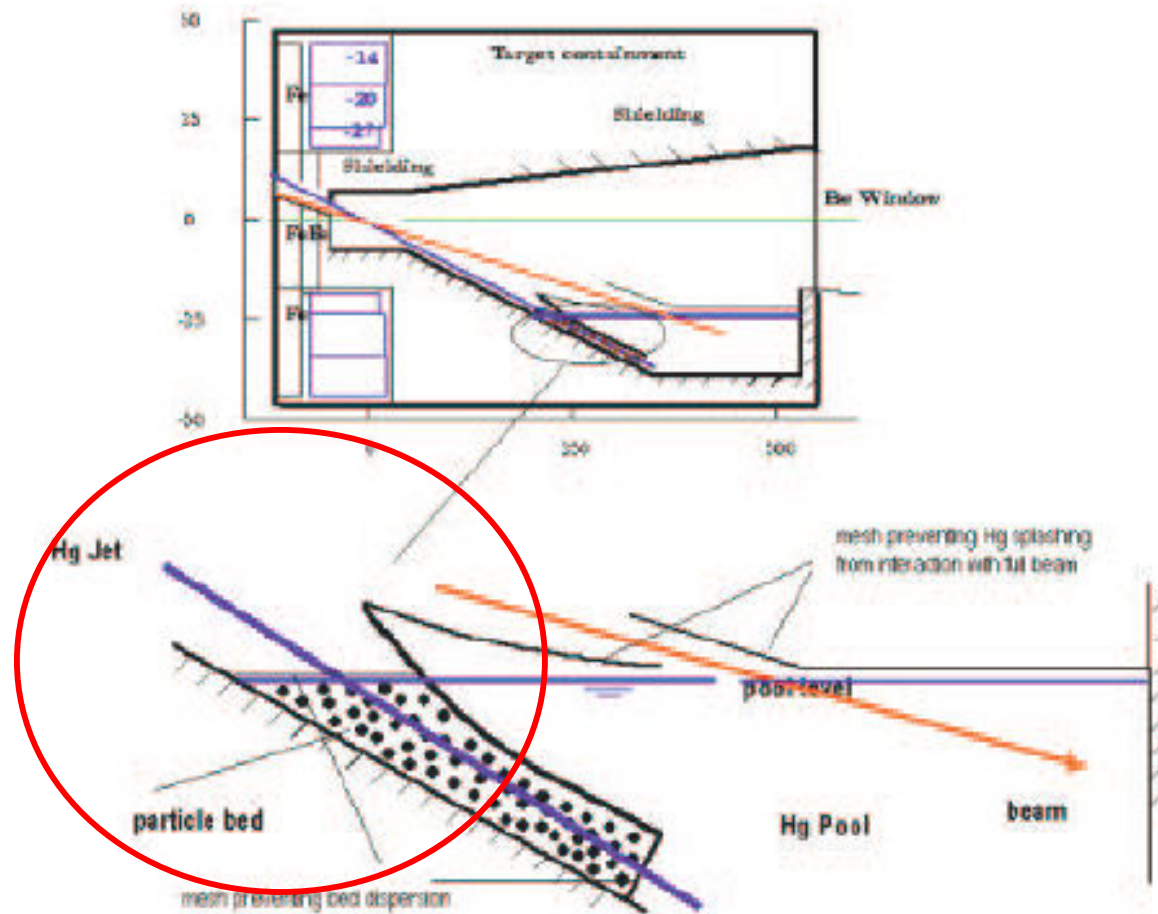
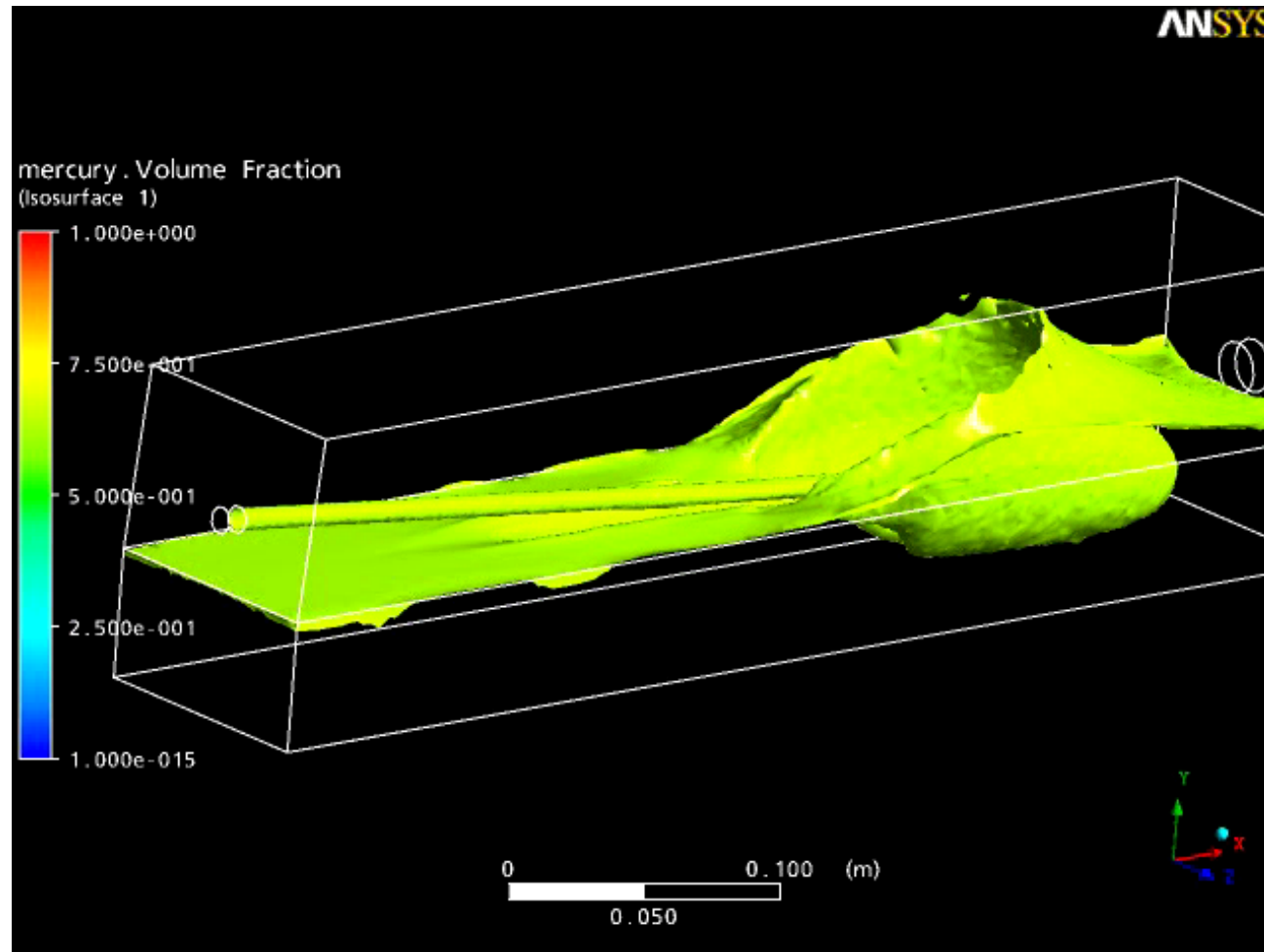


Figure 3.36: Schematic of the mercury pool that serves as the proton beam absorber.



Agitation of mercury pool surface due to impinging mercury jet

2 phase CFX model
mercury jet velocity = 20m/s
Angle of attack = 5.7°
mercury pool surface area = 0.05m²



Summary

Simulations indicate that mercury splashes with a maximum velocity of 75m/s will result when a pulse from the undisrupted 24GeV beam is absorbed by the mercury beam dump.

A 3mm diameter mercury droplet impacting a stainless steel plate at 75m/s is predicted to cause significant damage. Ti-6Al-4V is predicted to be more resistant to damage due to higher ultimate strength and shear strength.

Significant agitation of the mercury surface also results from the entry of the mercury jet.

