Targetry Simulations

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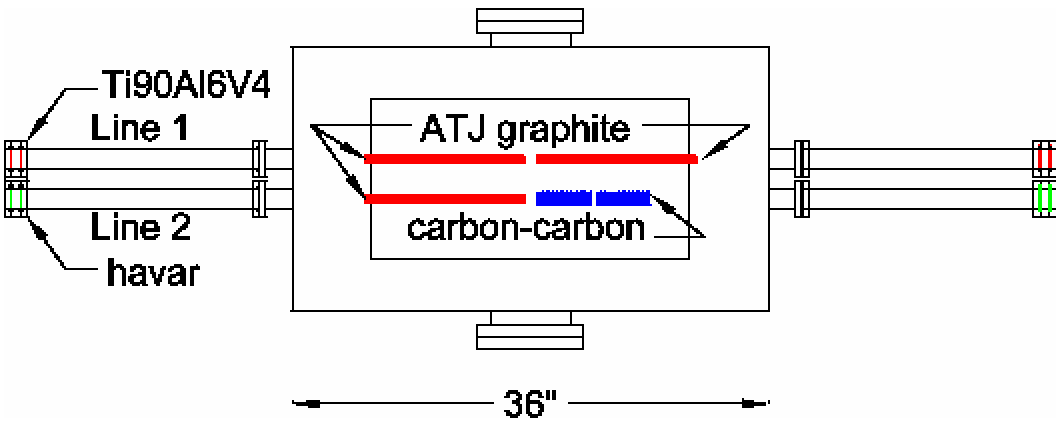
Simulation Topics

- Calculations of Energy Deposition in the Target:
  - Using MARS (H. Kirk, S. Kahn, N.Mokhov)
  - Using GEANT(S.Kahn)
  - Using MCNPX (H. Ludwick}
- Acoustic Analysis of E951 Experiment:
  - Simulation of Target and Windows with ANSYS (N. Simos)
- Dynamics of Mercury Jet in a Magnetic Field:
  - Simple Perturbation Calculations
  - More Sophisticated Calculations with HEIGHTS (A. Hassanein)
- Hydrodynamic Calculations for Mercury Nozzle.

Cartoon of Carbon Targets In Test Box

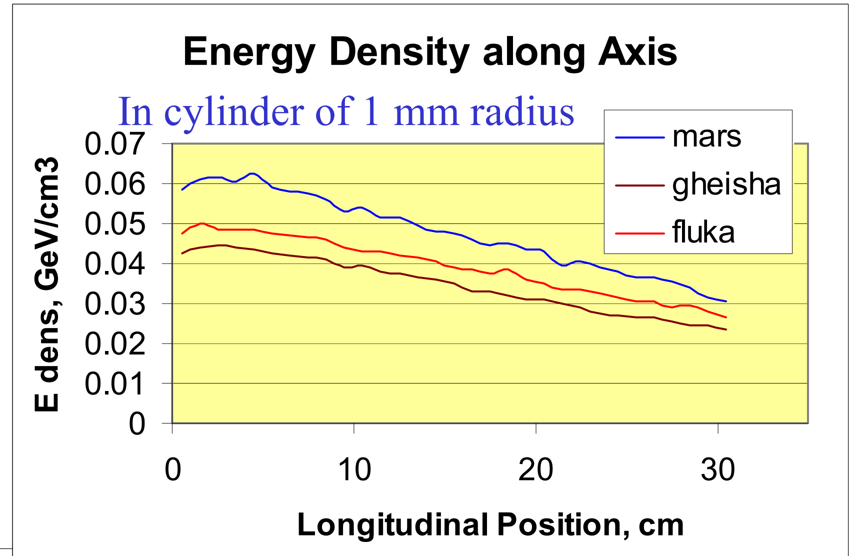


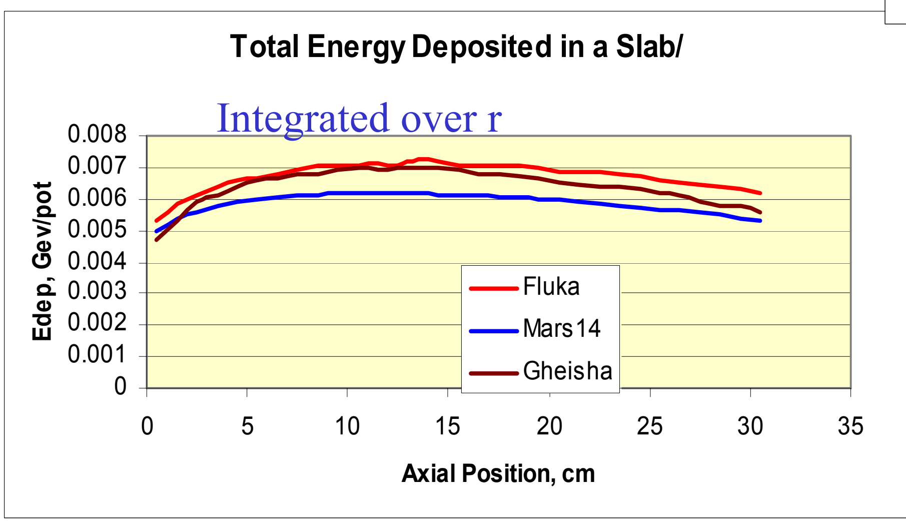
Material	Specific Density	Expansion Coefficient
ATJ-Graphite	1.72	??
Carbon-Carbon Compound	2.0	~0

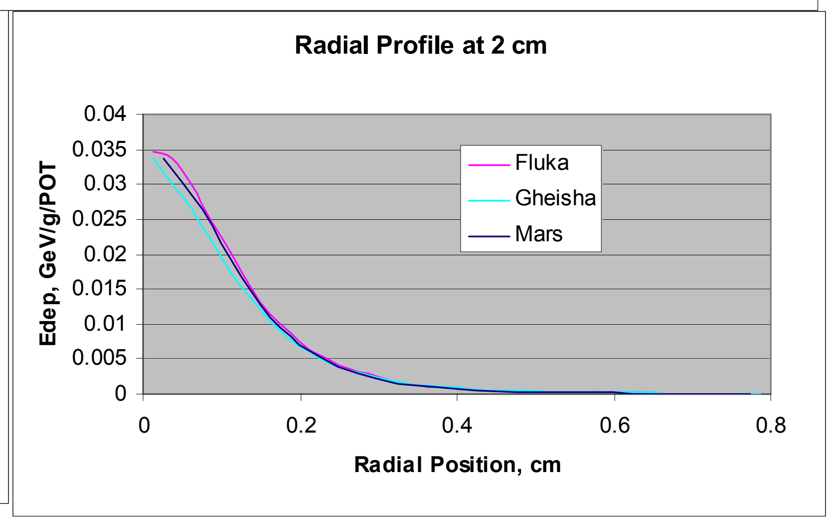
Energy Deposition in a Carbon Target

•Comparison of the calculation of the energy deposited between different programs:

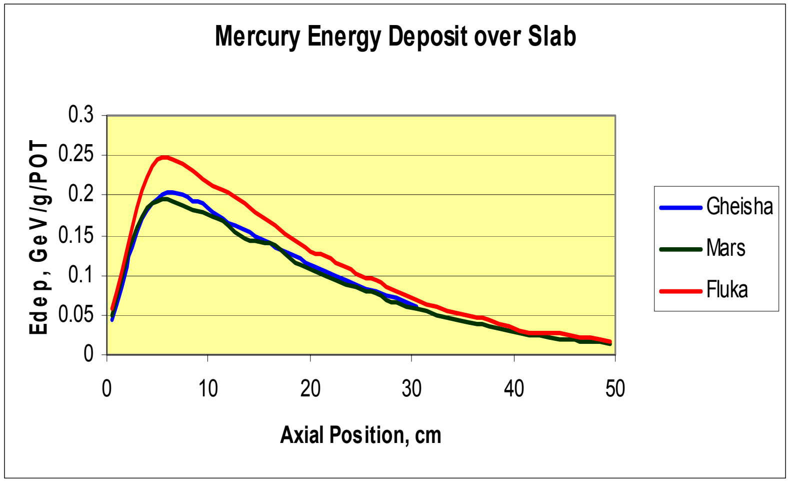
- •Geant with Fluka
- •Geant with Gheisha
- •Mars 14
- •MCMPX (not shown because agreement is not good)

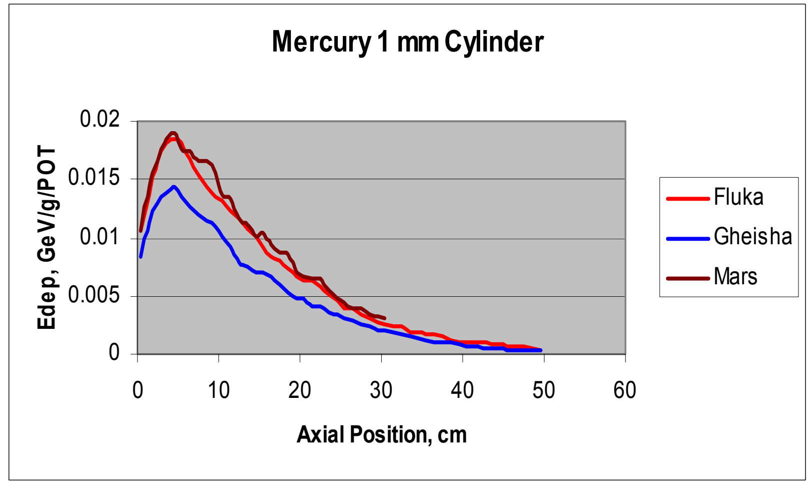






Energy Deposition in Mercury Target





Integrated over r

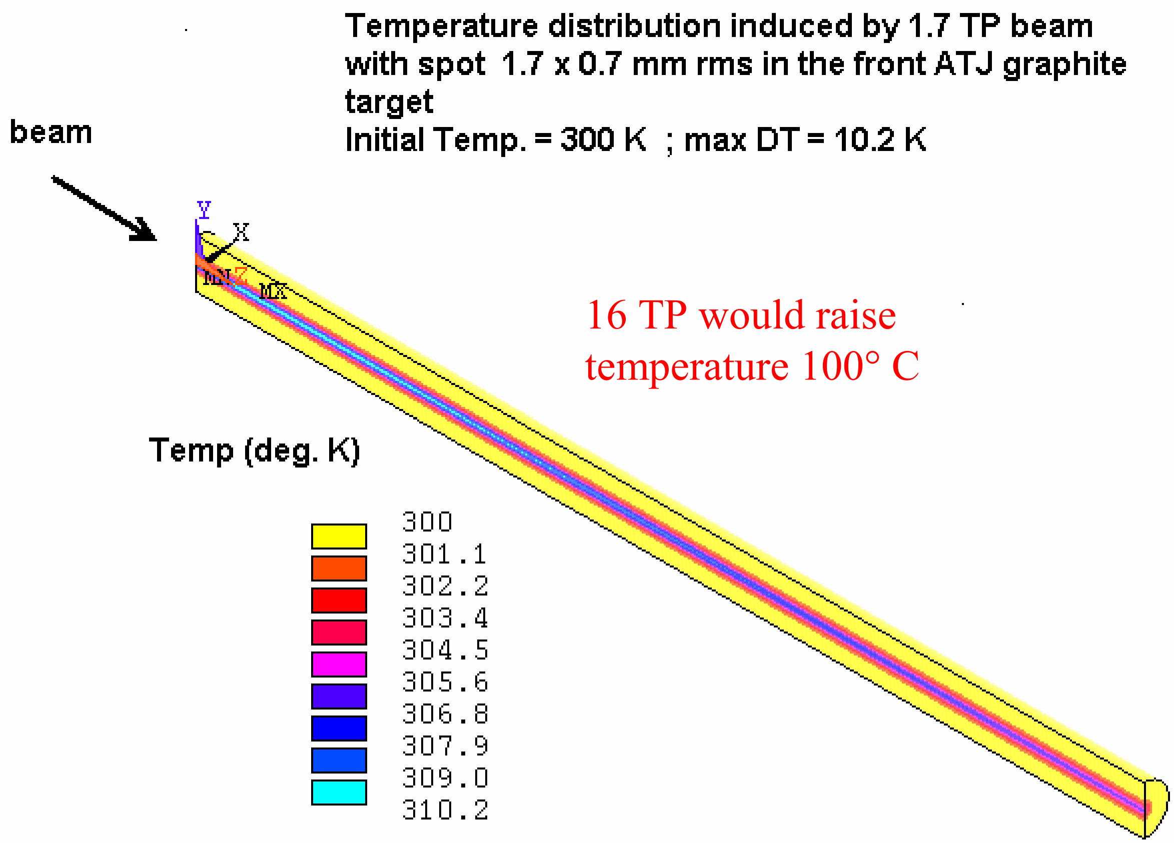
Peak Energy Deposited

E951 Parameters

Parameter	Desired	Achieved	Study II
Intensity	16 TP	4 TP	16 TP
Spot Size	0.5 mm × 0.5 mm	0.7 mm × 1.9 mm	1.5 mm × 1.5 mm
Single Pulse Length	100 ns	100 ns	100 ns
Beam Energy	24 GeV	24 GeV	14 GeV

- So far the AGS has not delivered a beam with sufficient energy density to destroy metal windows.
- The sudden deposit of energy causes an acoustic shock wave.
- The target is instrumented with strain gauges to detect acoustic wave signal.
- The observed acoustic wave intensity is consistent with the expected energy density from the observed spot size and beam intensity

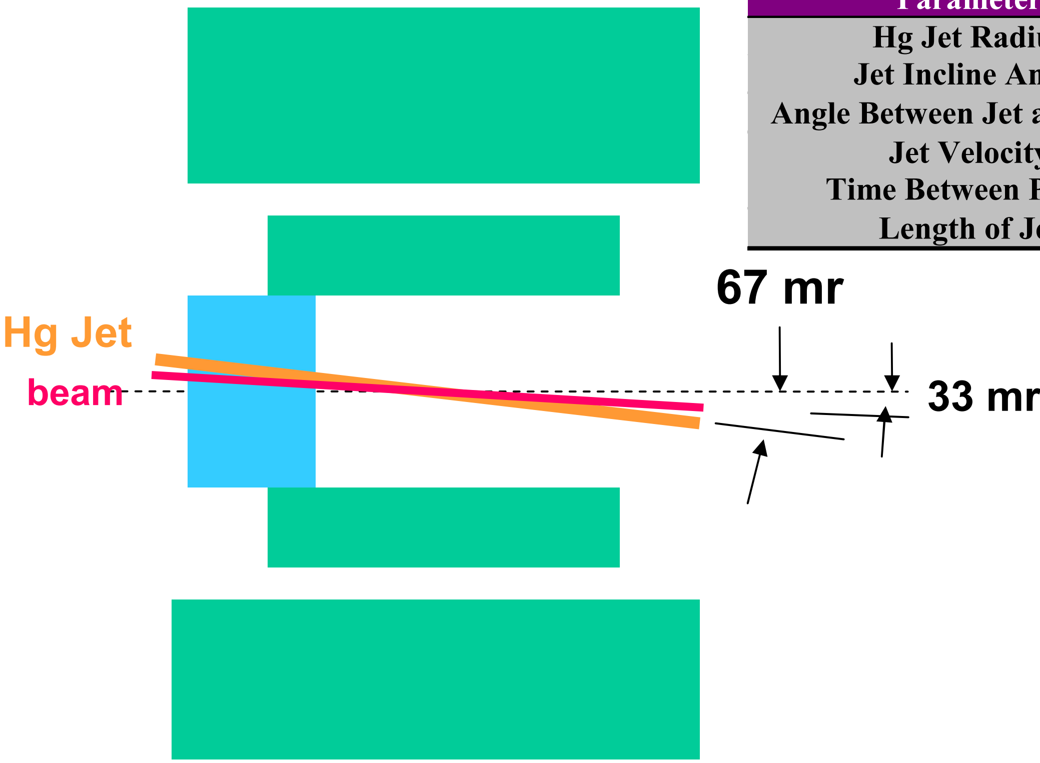
Temperature Profile in FRONT ATJ Graphite induced by 1.7 TP and beam spot 1.7 x 0.7 mm rms



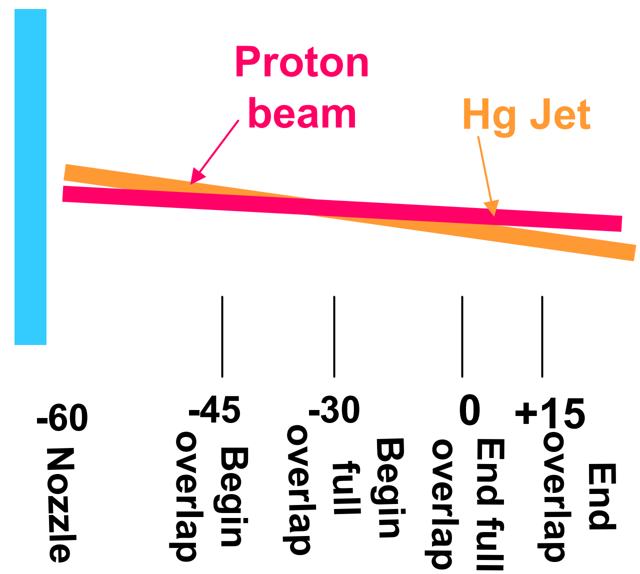
16 TP would raise temperature 100° C

Targeting Schematic

Parameter	Symbol	Current Study
Hg Jet Radius	R_{Hg}	0.5 cm
Jet Incline Angle	θ_{jet}	67 mrad
Angle Between Jet and Beam	$\theta_{crossing}$	33 mrad
Jet Velocity	V_{jet}	30 m/sec
Time Between Pulses	Δt	20 ms
Length of Jet	L_{jet}	60 cm



Obviously Not to Scale



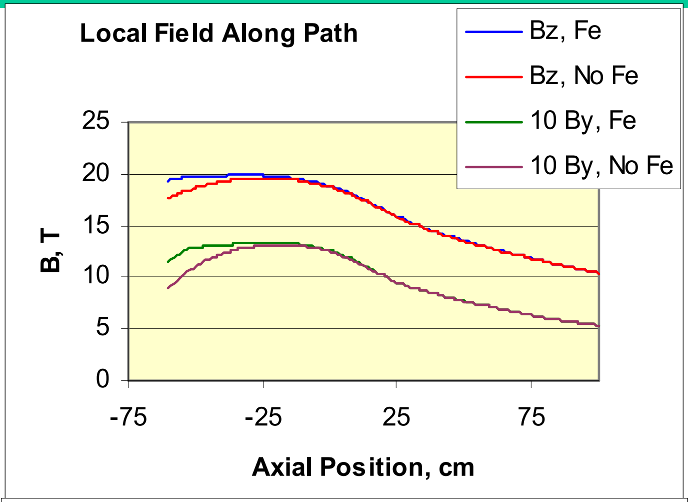
Parameter	Symbol	Value
Conductivity	κ, Ω cm	10^4
Density	ρ, gm/cm^3	13.4
Surface Tension	$T_{surface}$, n/m	0.456

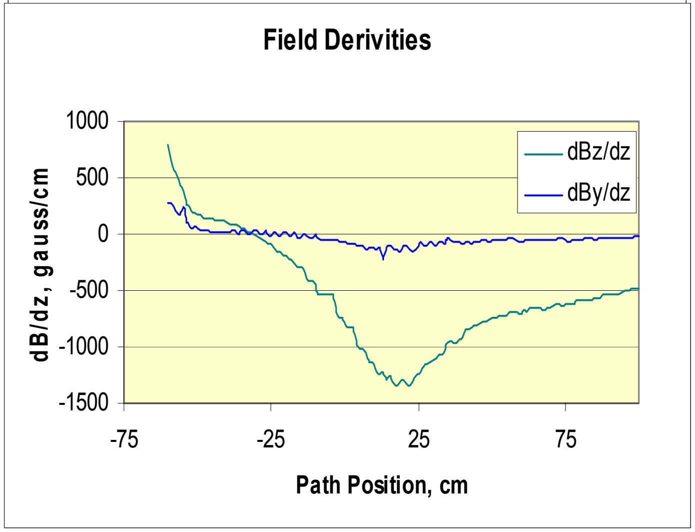
List of Forces, Pressures, Distortions, Deflections

- Induced azimuthal Eddy current.
- Radial forces: $J_{Eddy} \times B_z$
  - Hydrostatic Pressure
- Axial force
  - Contribution from Hydrostatic Pressure
  - Contribution from dB_z/dz
- Transverse forces and deflections
- Shear forces
- Transverse elliptical distortion

Magnetic Field in Local Coordinates

- Figure show B_z and B_y in the local coordinate system of the Hg jet.
  - Local system is inclined 67 mrad to solenoid axis.
  - Field shown with and w/o iron pole present:
    - Pole keeps field reasonably uniform over targeting region.
    - Pole is Vanadium Permadur Steel.
    - There is a 2T difference due to pole.
- Field Derivitives dB_z/dz and dB_y/dz in local coordinate frame.





Axial Forces

Equation for axial force on jet in the field:

Force Density

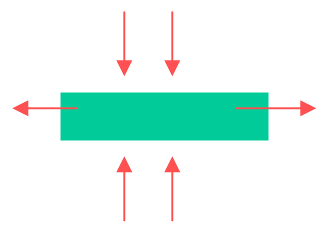
$$f_z = -\frac{r^2}{4} v\kappa \left(\frac{dB_z}{dz}\right)^2 - \left(\frac{r_o^2 - r^2}{4}\right) v\kappa \frac{d}{dz}\left(B_z \frac{dB_z}{dz}\right) - \frac{r v \kappa}{2} B_y \frac{dB_z}{dz} \sin\phi$$

Direct term

From $j_\phi B_r$

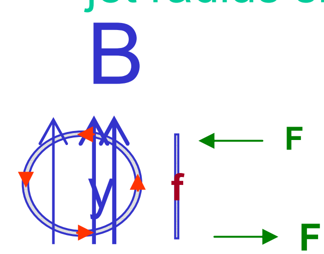
Hydrostatic term

From $j_\phi B_z$ transferred to axial direction since Hg is liquid



Shear term

Can be reduced by keeping incline angle small and by jet radius small



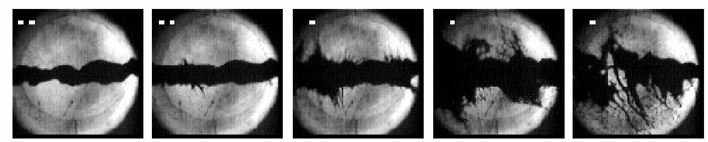
Design Considerations for Hg Jet

- Most of the disruption to Hg jet occurs upon entering and exiting the magnetic field.
  - Injecting Hg jet from nozzle inside the coil avoids disruption of jet on entrance to field.
- Nozzle made of High permeability steel causes field to be reasonably perpendicular in its vicinity.
  - This minimizes field derivitives over region where jet intersects proton beam.
    - This minimizes forces on jet in this region.
    - Retardation of Hg by the field is less than 1 m/s.

Future Directions

- Study Hydrodynamics of Hg Jet to improve nozzle design for a more laminer Hg jet.
- Perform experiments on Hg jet in high magnetic field.
  - This will provide feedback to the calculations.

1-cm-diameter Hg jet in 2e12 protons at $t = 0, 0.75, 2, 7, 18$ ms.



Grenoble Tests

No Field

13 Tesla

1 cm diam. jet, $v = 4.6$ m/s, $B = 0$ T; $v = 4.0$ m/s, $B = 13$ T: