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Target Studies

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RAL

Progress

1. RMCS and FGES have been retired from the project.
2. Laboratory tests using projectiles will not truly replicate the thermal shock in the target.

So a new plan is needed

The New Plan

1. Pulsed ohmic-heating of wires replicates beam-induced shock.
2. In-Beam Tests at ISOLDE.
3. Calculate the shock. Goran Skoro and Chris Densham using LS-DYNA.
4. The VISAR can be made in Laser Division at RAL.
5. Calculate the pion yield, beam heating and activity. Stephen Brooks using MARS code.
6. Rob Edgecock will take over as the Work Package Manager.

7. Work on the TT2A Mercury Jet experiment continues – mainly the cryogenic system design and costing. (Mercury jet in 15 T solenoidal field with 24 GeV proton beam at CERN.)
8. Rob Edgecock and JRJB are writing a proposal to PPARC for funding to:
   - design, manufacture, install at CERN and commission the cryogenics.
   - MHD calculations of the behaviour of the mercury jet.
   - take part in the experiment at CERN and the analysis.
9. Pbar results.

Shock Heating of Wires

1. High frequency EM fields only penetrate the surface of conductors.

Skin depth for a plane surface

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$

This is the steady state situation.

For a transient we have a slightly different situation.

Transient Conditions

- Assume an electric field *E* is instantaneously applied across a conducting wire.
- Apply Maxwell's equations.
- This produces a diffusion equation:

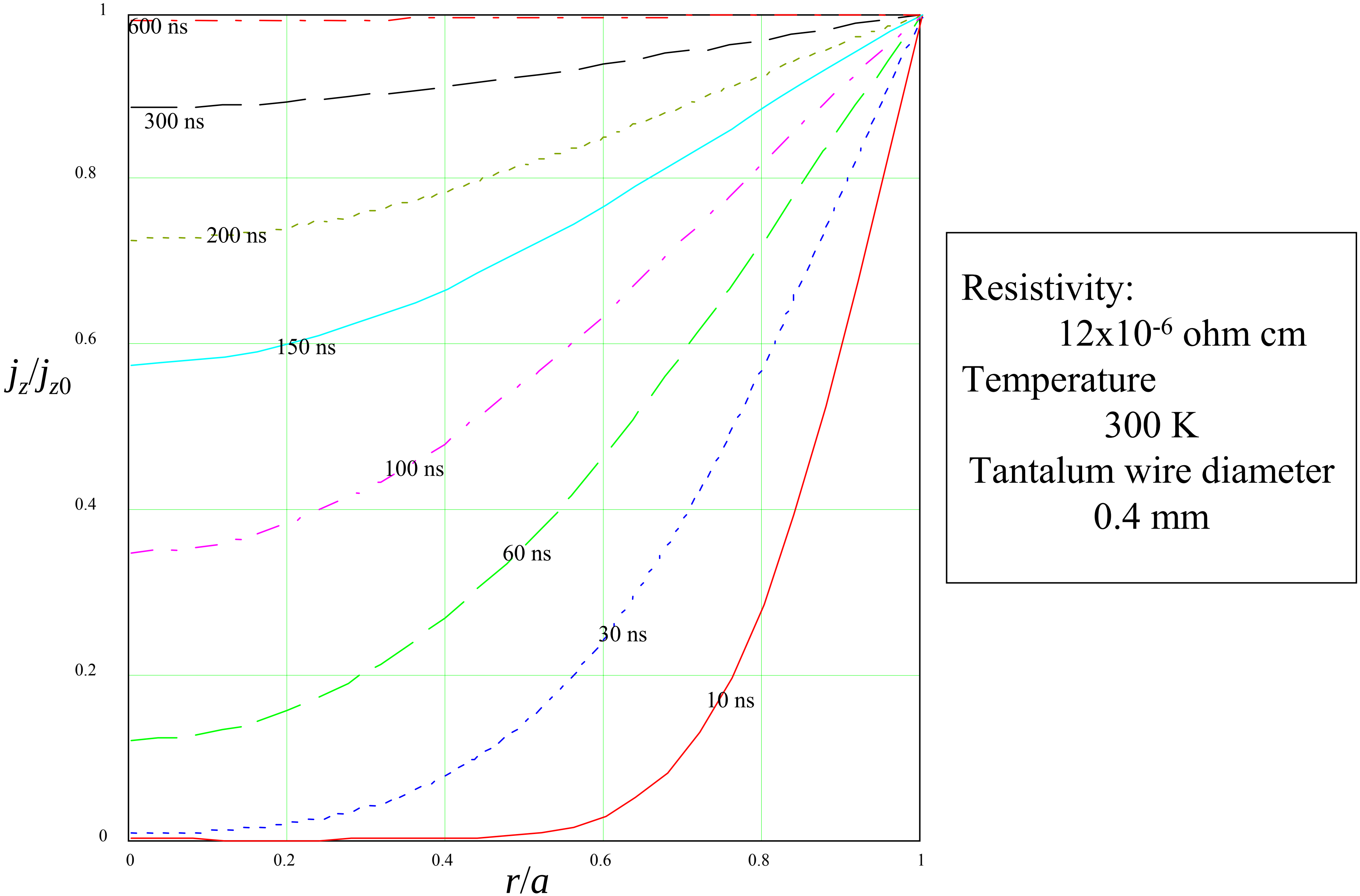
$$\frac{\partial \underline{j}}{\partial t} = \frac{1}{\mu_0 \sigma}\left(\frac{\partial^2 j_z}{\partial r^2} + \frac{1}{r}\frac{\partial j_z}{\partial r}\right)$$

In cylindrical coordinates, where *j* is the current density.

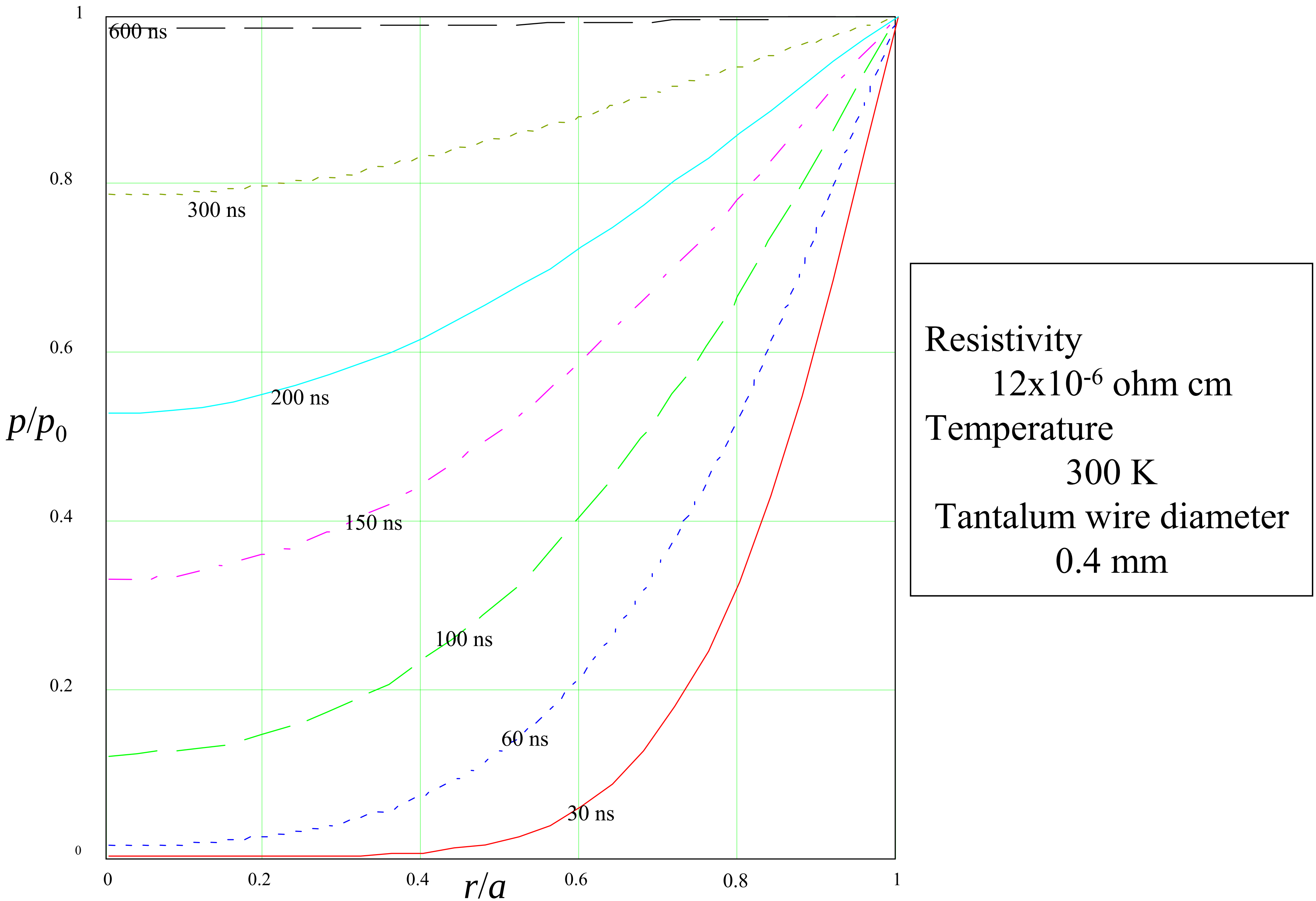
- The solution is:

$$j_z = j_{z0}\left[1 - \frac{2}{a}\sum_{n=1}^{\infty} e^{-\kappa \alpha_n{}^2 t}\frac{J_0(r\alpha_n)}{\alpha_n J_1(a\alpha_n)}\right]$$

$\kappa = 1/\mu_0 \sigma$

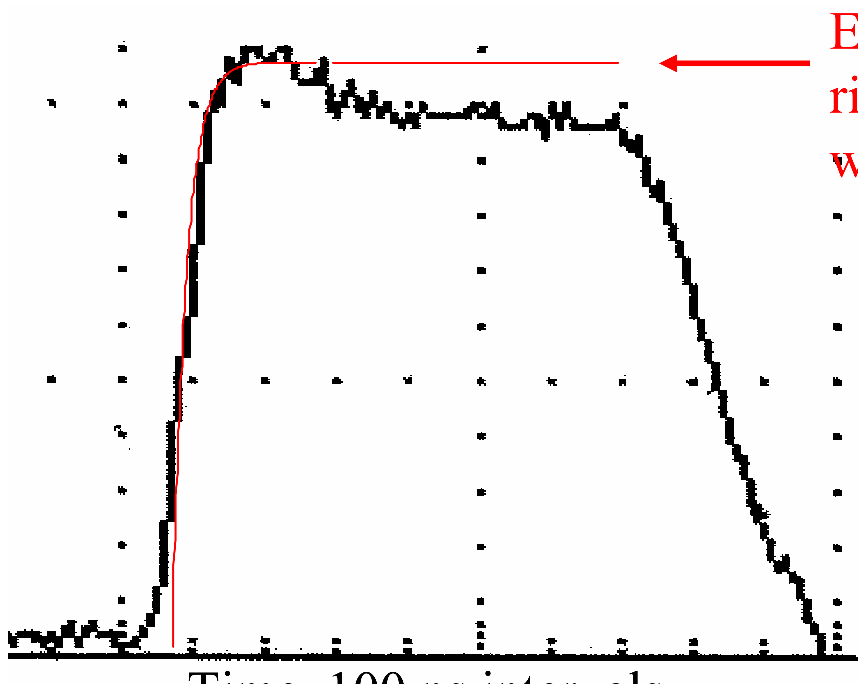


1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
jz/jz0
r/a
600 ns
300 ns
200 ns
150 ns
100 ns
60 ns
30 ns
10 ns
Resistivity:
12x10-6 ohm cm
Temperature
300 K
Tantalum wire diameter
0.4 mm


1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
p/p_0
r/a
600 ns
300 ns
200 ns
150 ns
100 ns
60 ns
30 ns
Resistivity
12x10^{-6} ohm cm
Temperature
300 K
Tantalum wire diameter
0.4 mm

Doing the Test

The ISIS Extraction Kicker Pulsed Power Supply



Rise time: ~100 ns

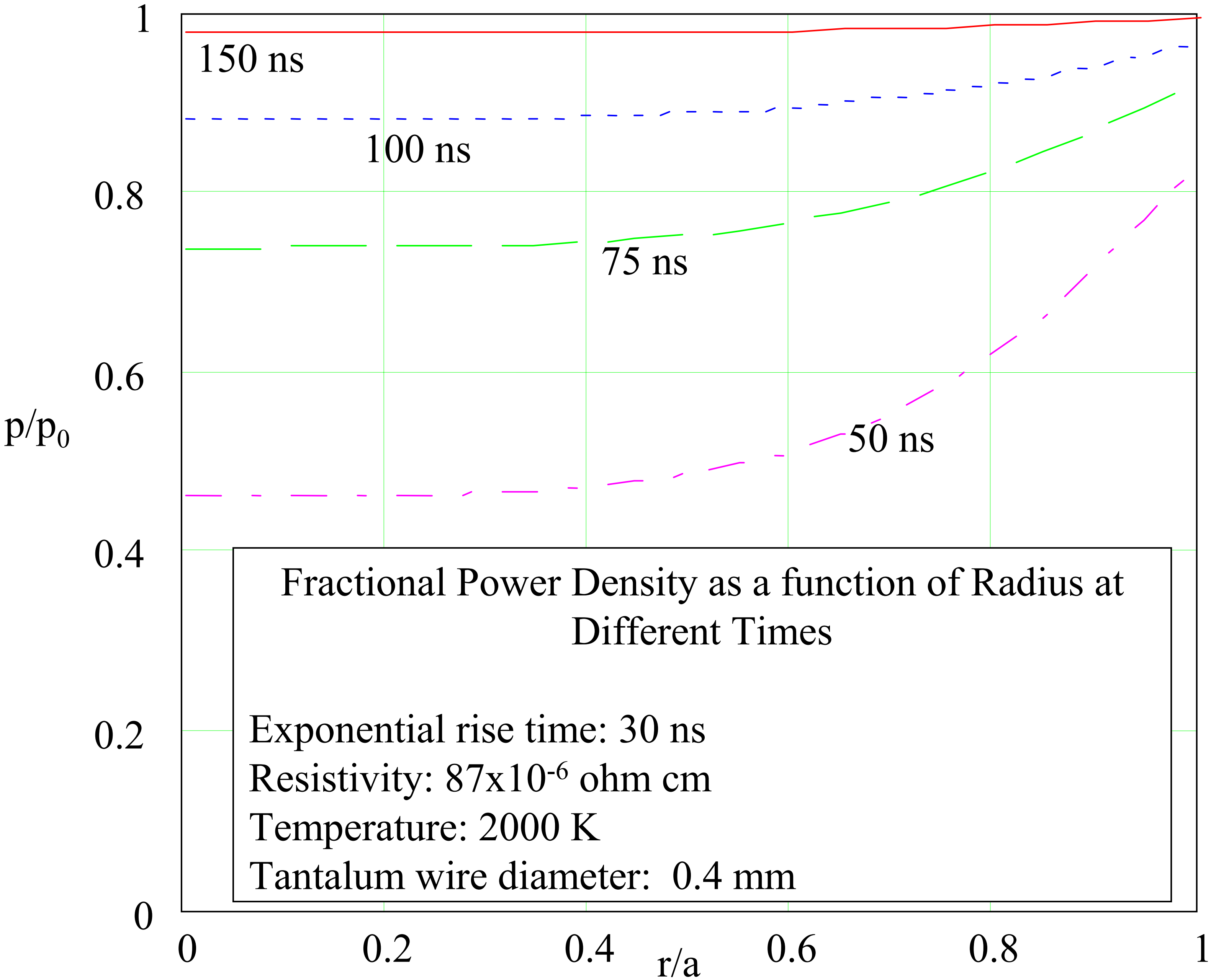
Flat Top: ~300 ns

Voltage peak: ~40 kV

Current Peak: ~8 kV

Repetition rate up to 50 Hz.

There is a spare available for use.



1
0.8
0.6
0.4
0.2
0
p/p0
0
0.2
0.4
0.6
0.8
1
r/a
150 ns
100 ns
75 ns
50 ns
Fractional Power Density as a function of Radius at Different Times
Exponential rise time: 30 ns
Resistivity: 87x10-6 ohm cm
Temperature: 2000 K
Tantalum wire diameter: 0.4 mm

The Velocity of the Shock Wave

- Shock travels at the Speed of Sound.

$$s = \sqrt{\frac{E}{\rho}} = 3.3\ \mu\text{m ns}^{-1}$$

- It takes 60 ns for the shock wave to cross to the centre of the wire.
- Can only use small diameter wires of up to ~0.4 mm.
- "Choose a better material"

Different Materials

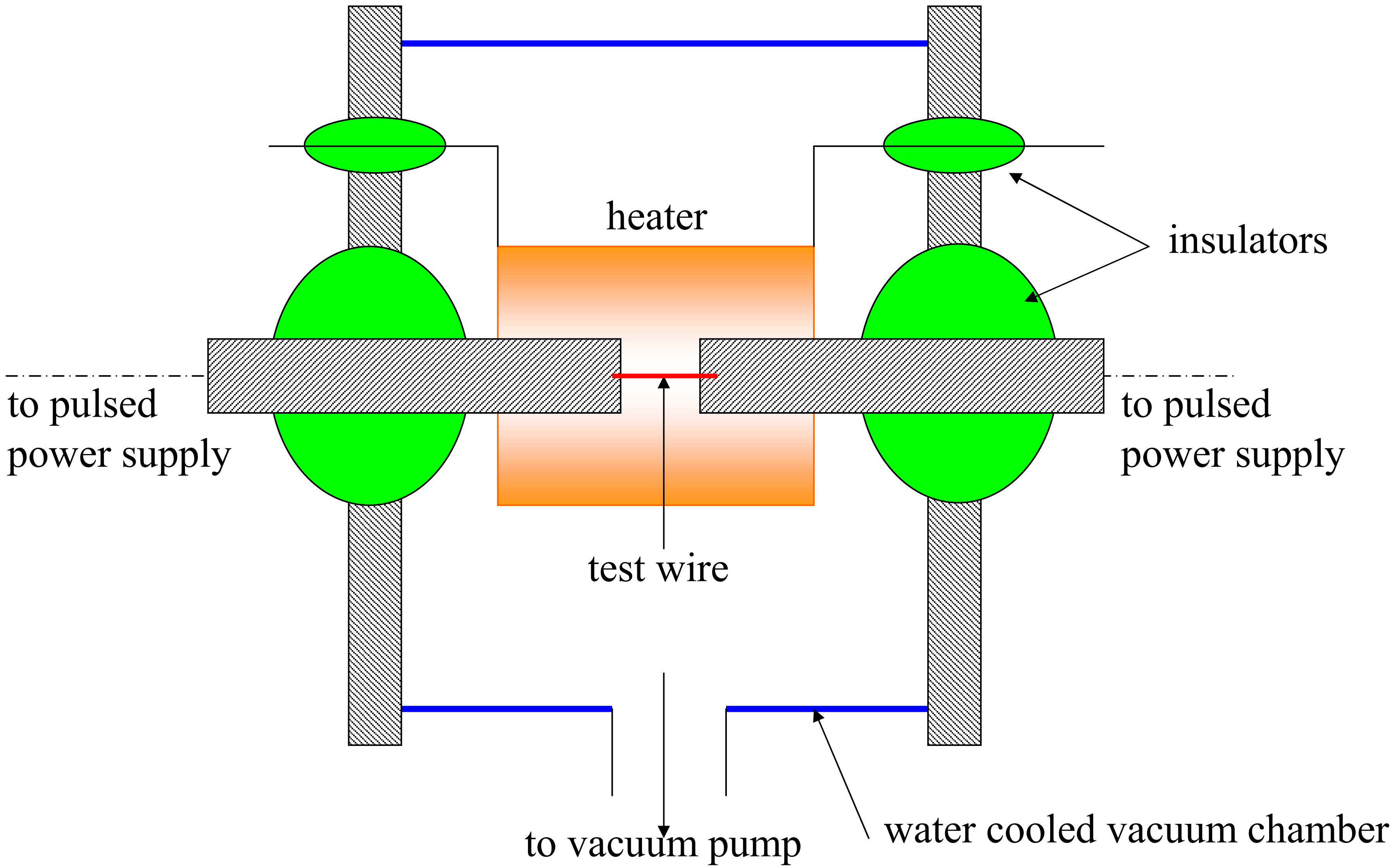
- Graphite has an electrical resistivity [1] at room temperature of 1356 μohm cm would be very suitable.

- Sound velocity ~same as for Ta.

- The rod could be 2 mm diameter and the average current in the rod would reach 94% of its long term value in only 100 ns.

- Need more current for the same energy dissipation as Tantalum.

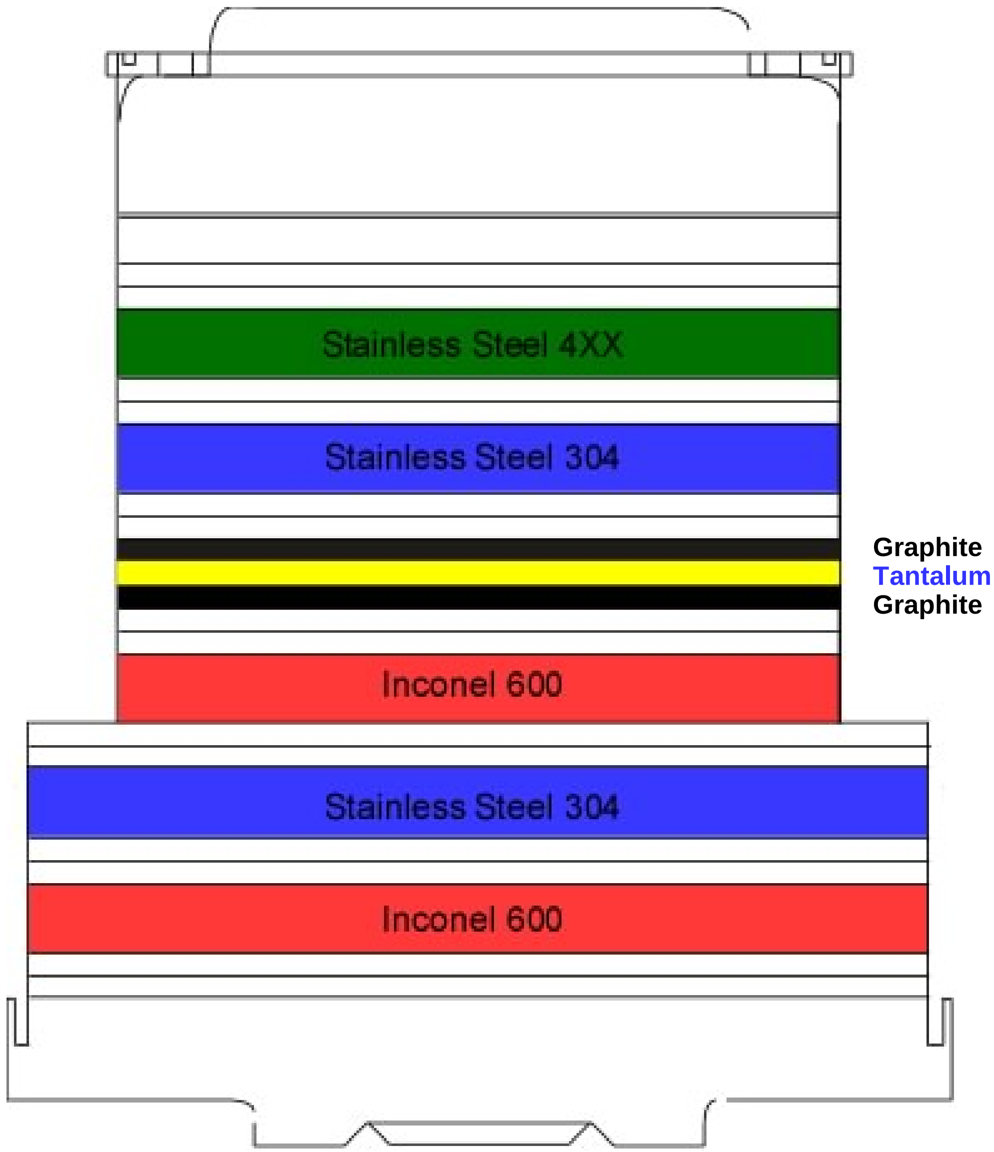
[1] Values for carbon are taken from "Goodfellow Cambridge Ltd". Graphite has very variable properties depending on the grade etc.



Schematic diagram of the test chamber and heater oven.

Pbar Target Tests

Pbar target assembly presently in use



Tantalum target test summary (1)

Pat Hurh

- Goal was to create enough target damage to reduce pbar/π^- yield
  - Started with a proton intensity of 1.0E11 and a spot size of σ = 0.50 mm. Maximum energy deposition was attained with a proton intensity of 6.5E12 and a spot size of σ = 0.15 mm
    - Target rotation was stopped so that beam pulses were accumulated in the same area
  - After accumulating 100 beam pulses, energy deposition was increased by a factor of 2 and process repeated
    - Target rotated 10° between data points

Tantalum target test summary (2)

Pat Hurh, FNAL

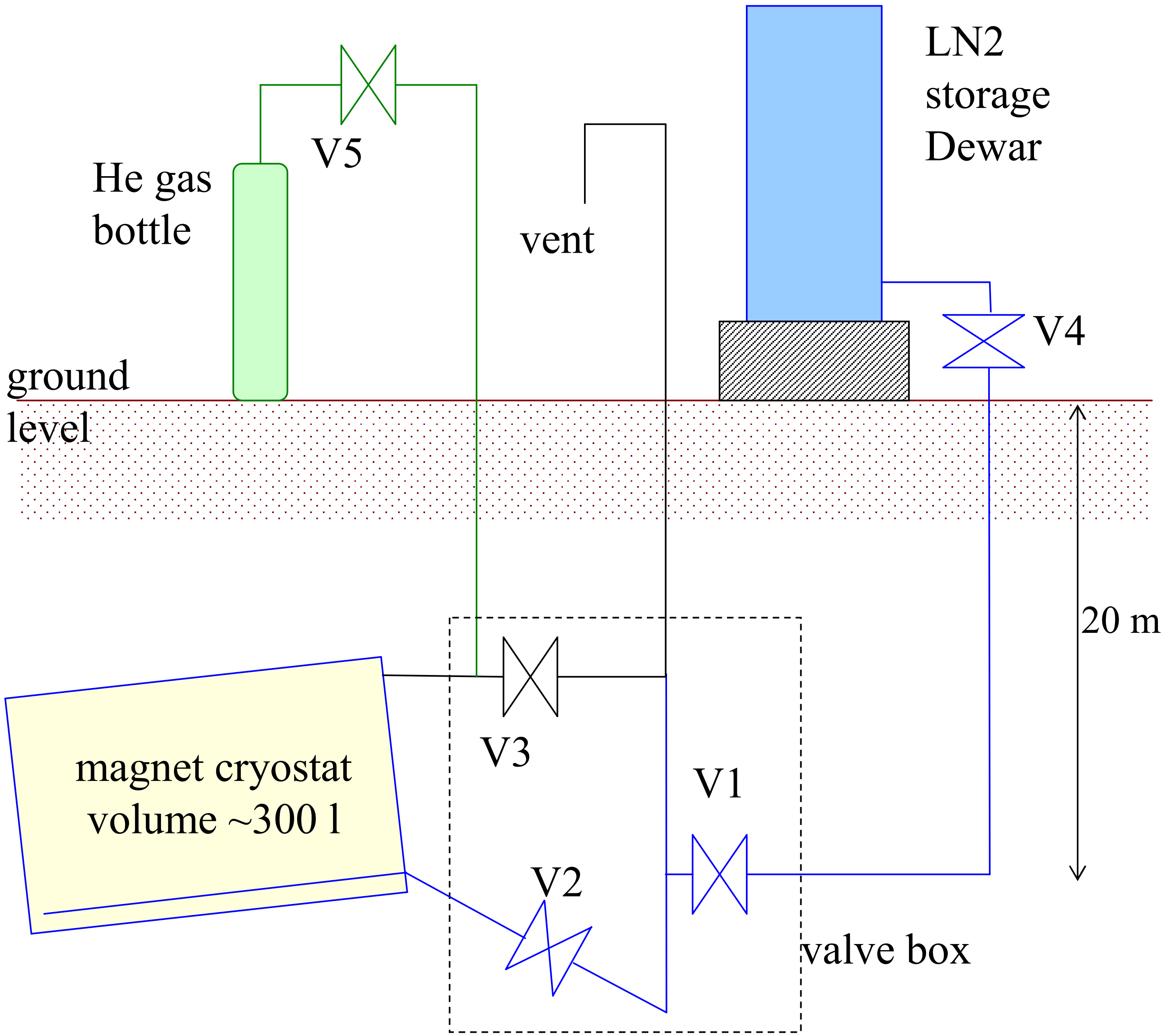
- Goal was to create enough target damage to reduce pbar/π^- yield
  - Target did not show appreciable pbar/π^- yield reduction up to maximum energy deposition
    - 1,100 pulses with proton intensities of 5.8-6.5E12
    - Energy deposition estimated at 2,300 J/g (38,300 J/cc)
  - Tantalum target had 8% lower pbar/ π^- yield as compared with nickel (model predicted a few percent higher)

TT2A Mercury Jet Test

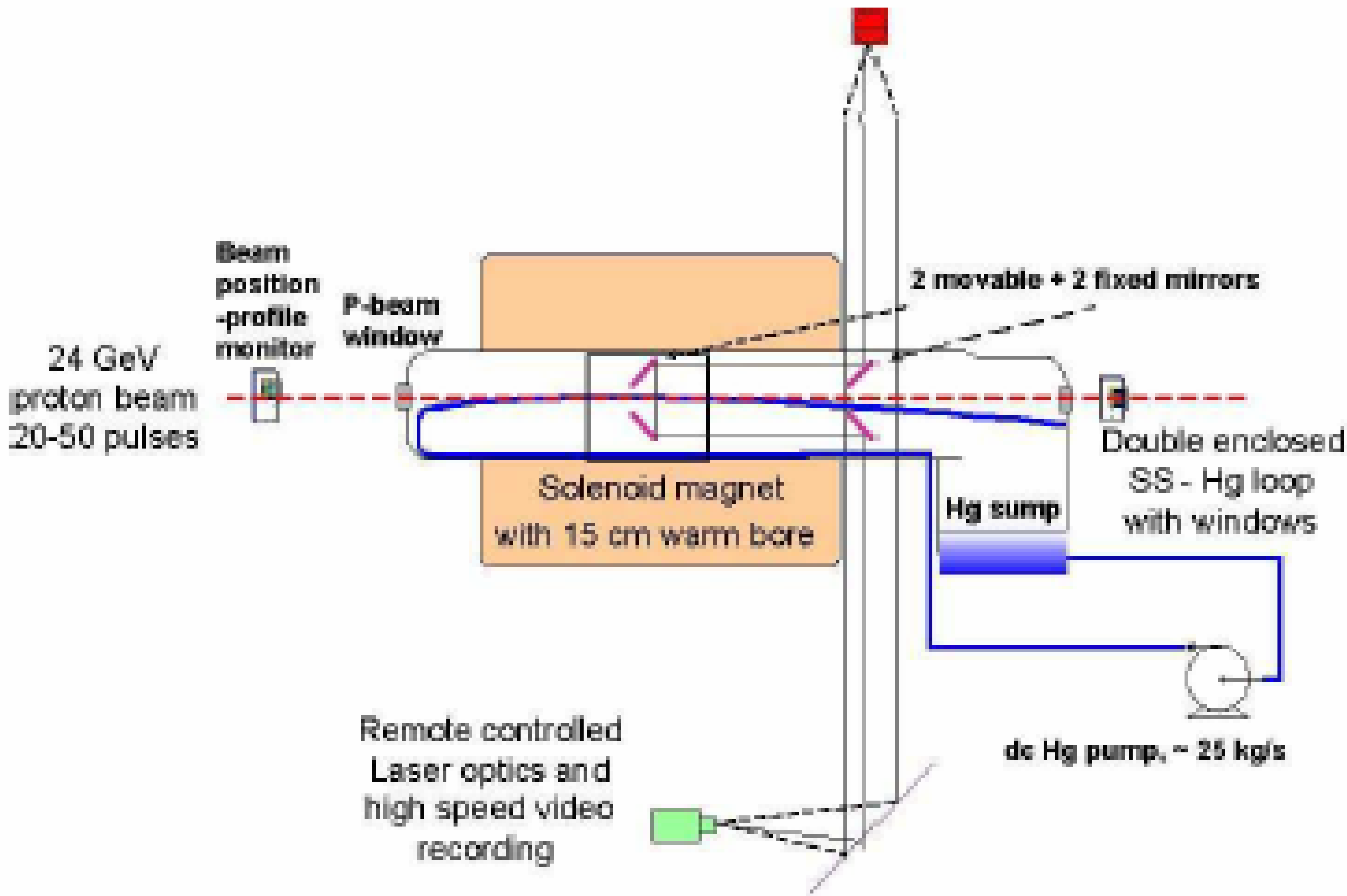
Cryogenic System

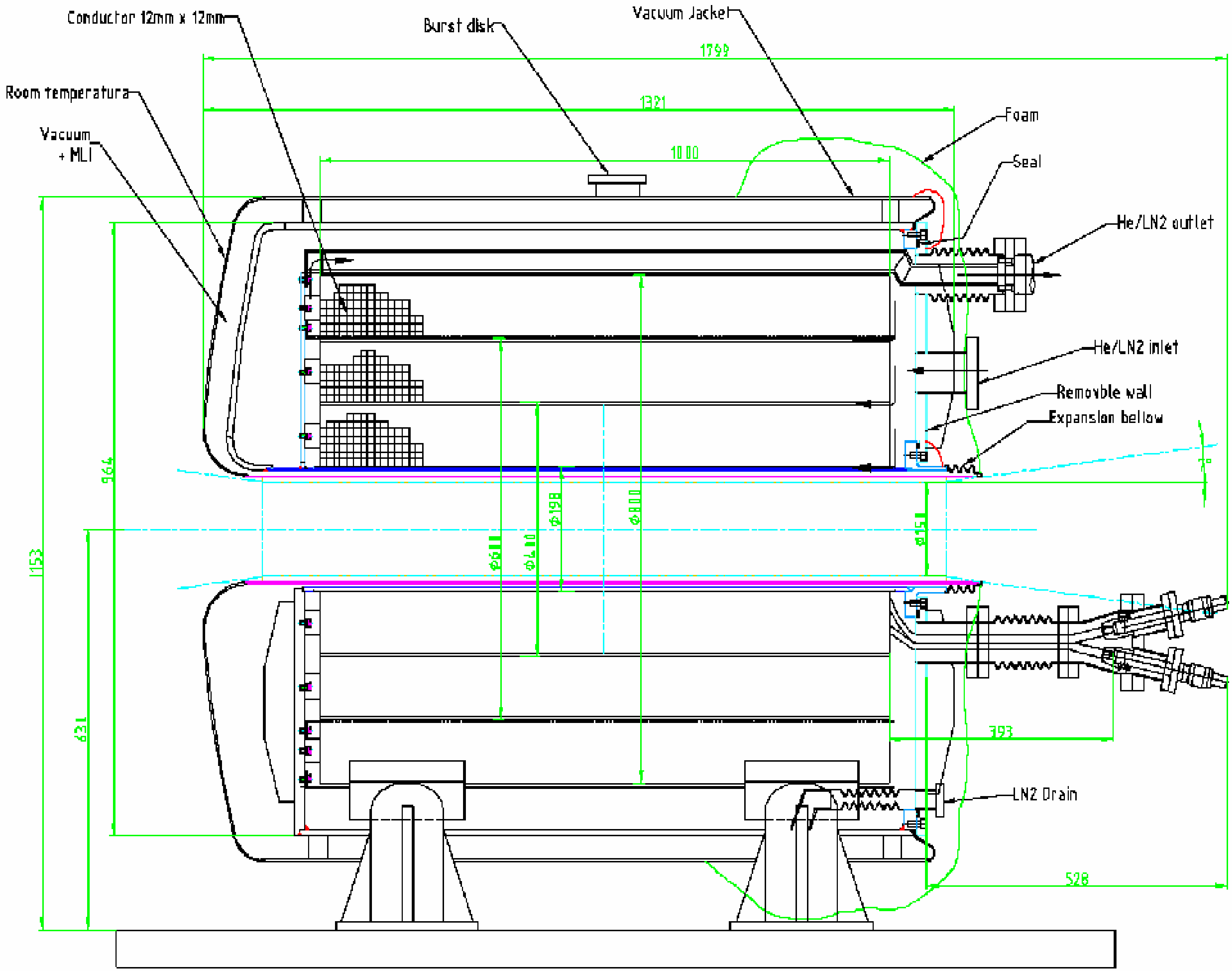
1. RAL are costing the cryogenic system for the mercury jet test.

2. Rob Edgecock and JRJB are writing a proposal to PPARC for funding to:
   - design, manufacture, install at CERN and commission the cryogenics.
   - MHD calculations of the behaviour of the mercury jet
   - take part in the experiment at CERN and the analysis



Insulated transfer lines, each 70 m long.


24 GeV
proton beam
20-50 pulses
Beam
position
-profile
monitor
P-beam
window
2 movable + 2 fixed mirrors
Double enclosed
SS - Hg loop
with windows
Solenoid magnet
with 15 cm warm bore
Hg sump
dc Hg pump, ~ 25 kg/s
Remote controlled
Laser optics and
high speed video
recording



Conductor 12mm x 12mm
Burst disk
Vacuum Jacket
Room temperatura
Vacuum
+ MLI
1799
1321
1000
Foam
Seal
He/LN2 outlet
He/LN2 inlet
Removble wall
Expansion bellow
964
1153
ϕ611
ϕ410
ϕ198
ϕ800
ϕ151
631
393
LN2 Drain
528