Target Systematics

Greg Smith
JLab

- Basic Equations
- Properties
  - Cryogens
  - Hall C targets
- Boiling Data
- Theories
- Improvements
  - Related to boiling
  - Operational
- Web page

Basic Equations

$$c_p = \frac{\Delta Q}{m \Delta T}$$

$$\Delta T = \frac{dE/dx(MeV/g/cm^2)\ I_b(\mu A)}{c_p(J/gK)\ d_{raster}(cm)\ v_s(cm/s)}$$

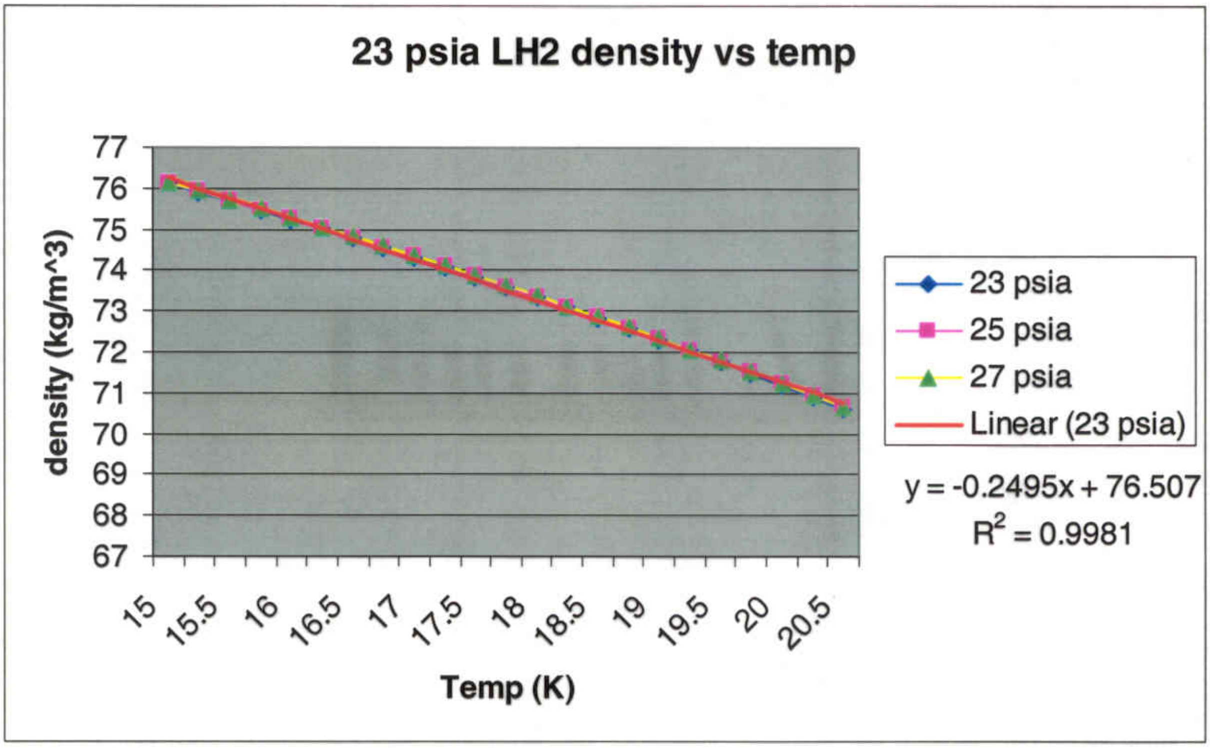
$$\Delta\rho/\rho \approx 1.5\%\Delta T$$

$$P_b(W) = I_b(\mu A)\ \rho(g/cm^3)\ t(cm)\ dE/dx(MeV/g/cm^2)$$

Where:	LH2 (19K,10 psig)	LD2 (22K, 10 psig)
ρ (g/cm^3)	0.0723	0.167
de/dx (MeV/g/cm^2)	4.7	2.3
C_p(J/gK)	8.8	6.8

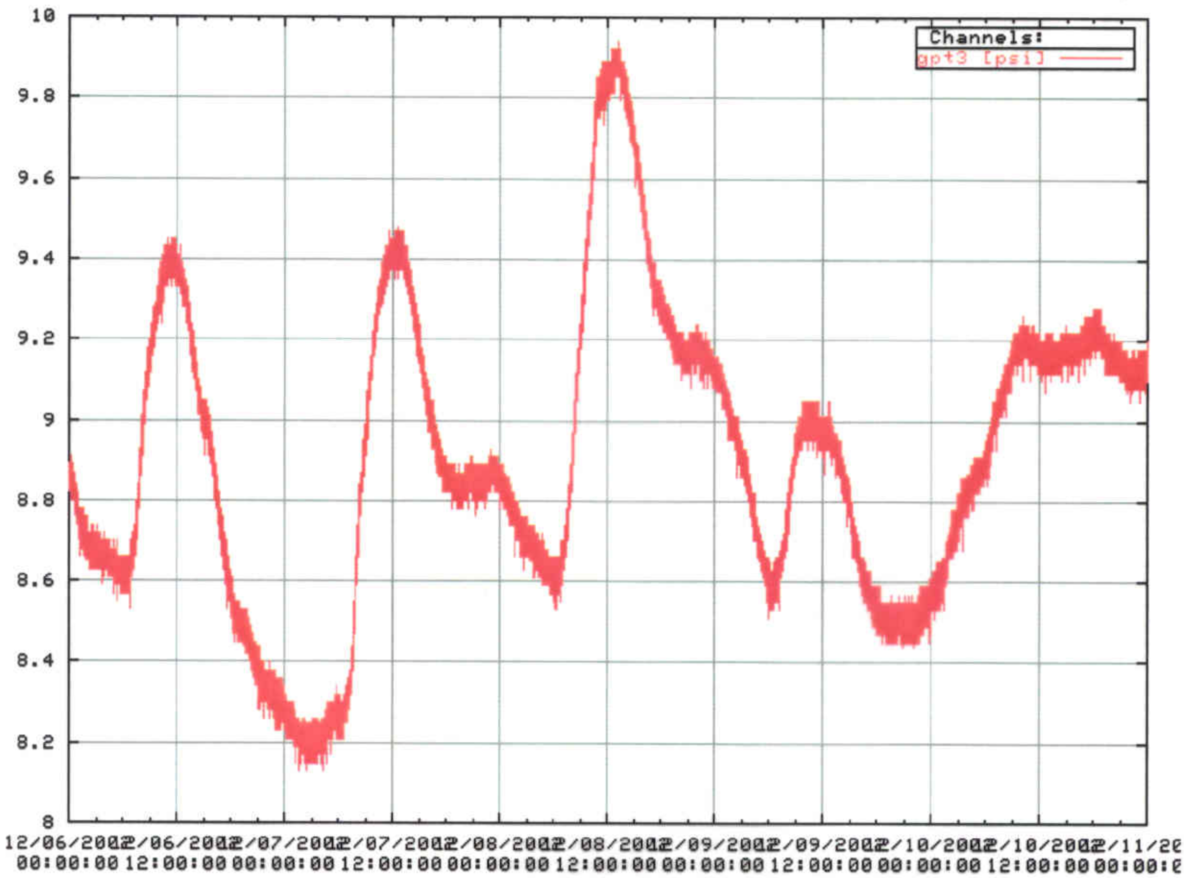
Diurnal ΔP

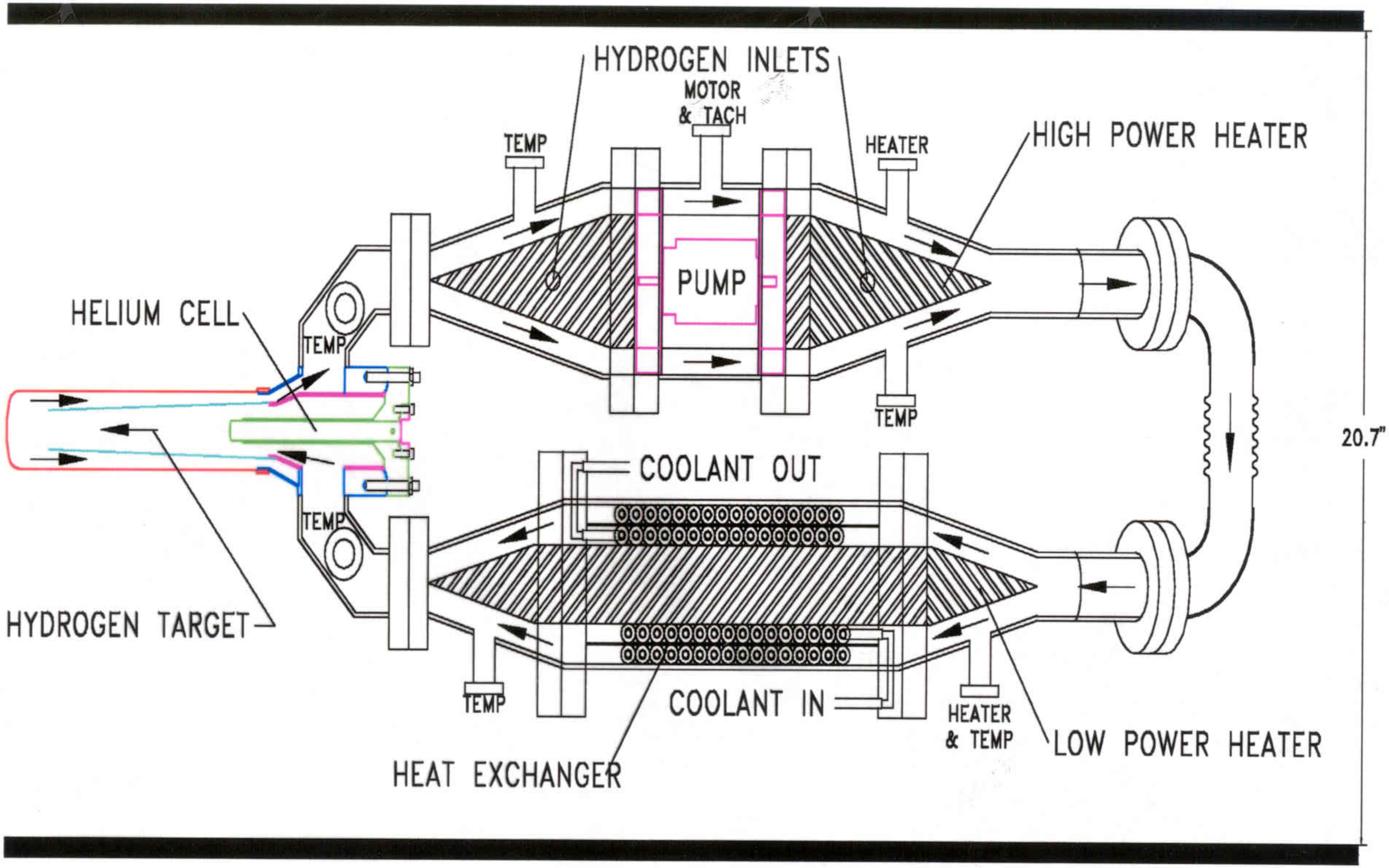
- Ballast tank outside, and $P \propto T$.
- Ex: ΔT=15C (5%) → ΔP=1 psi
- Systematic effect on target ρ negligible:



Archived ΔP

- 5 days in December, G0 tgt





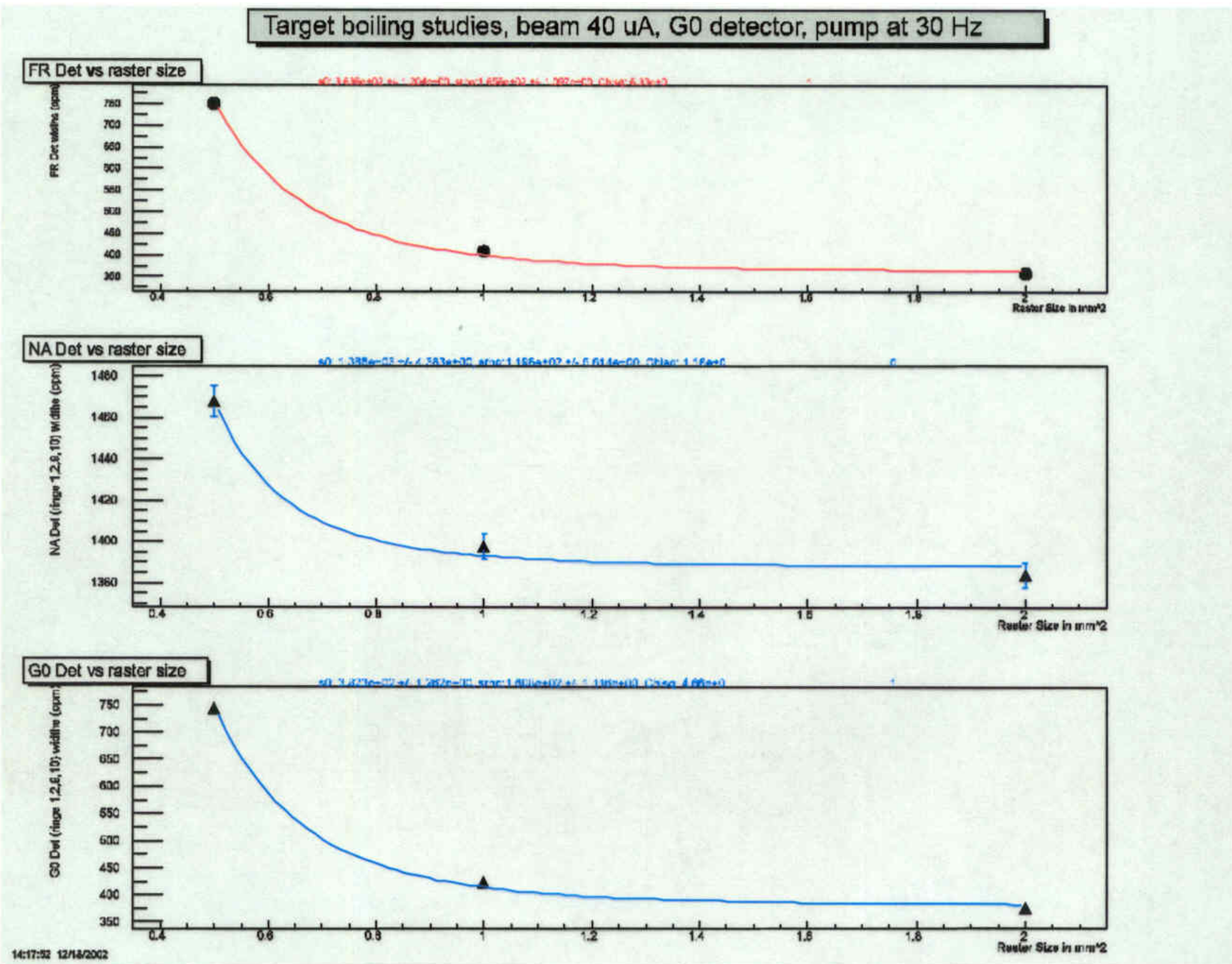
NOTE: The port positions for electrical and transducer feedthroughs may be rotated into other planes.

G0 $\Delta\rho/\rho$

Preliminary G0 tgt boiling results from S. Covrig

Result: @40μA, 30 Hz, 2x2 raster: $\Delta\rho$<40 ppm

Note: IA, deadtime not yet unfolded



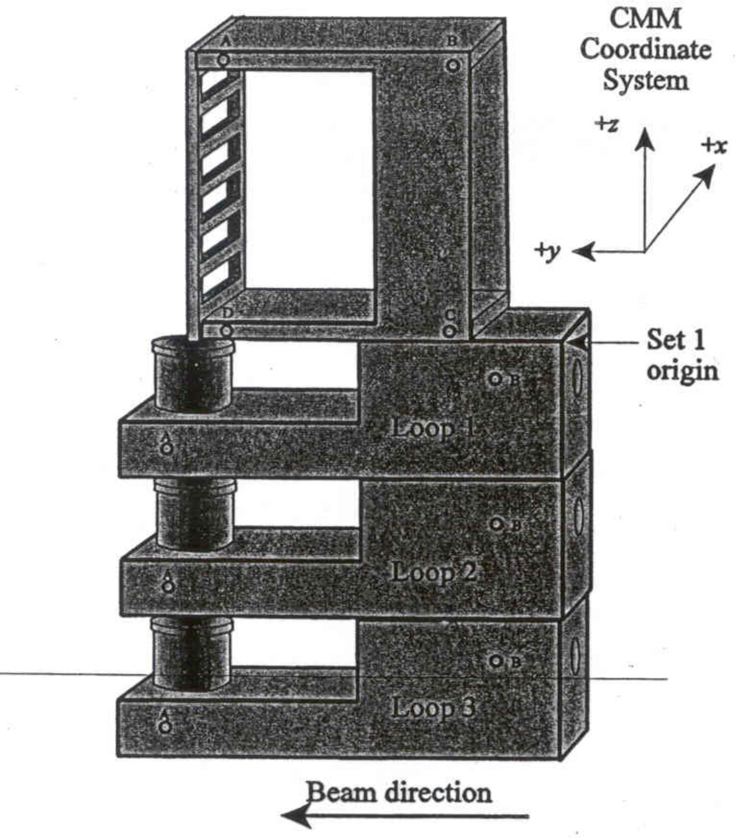


Figure 1 Target Stack

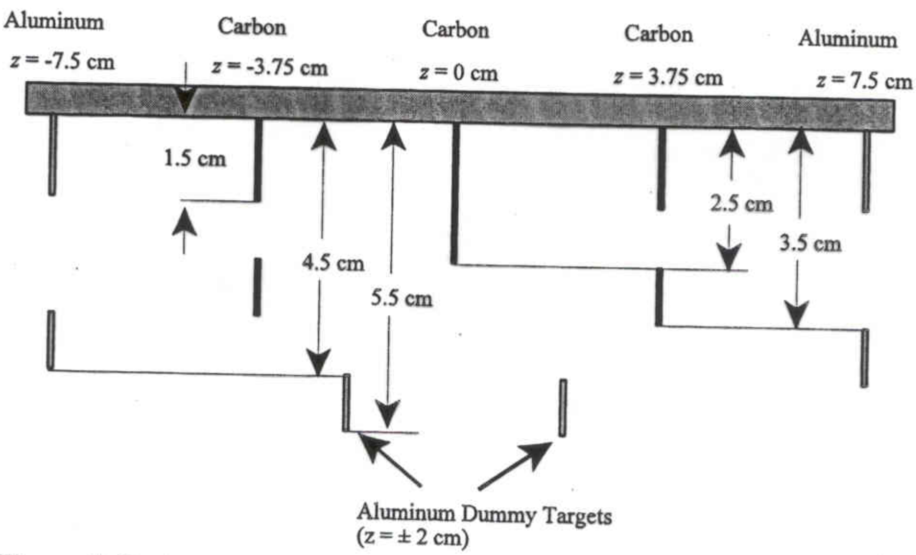
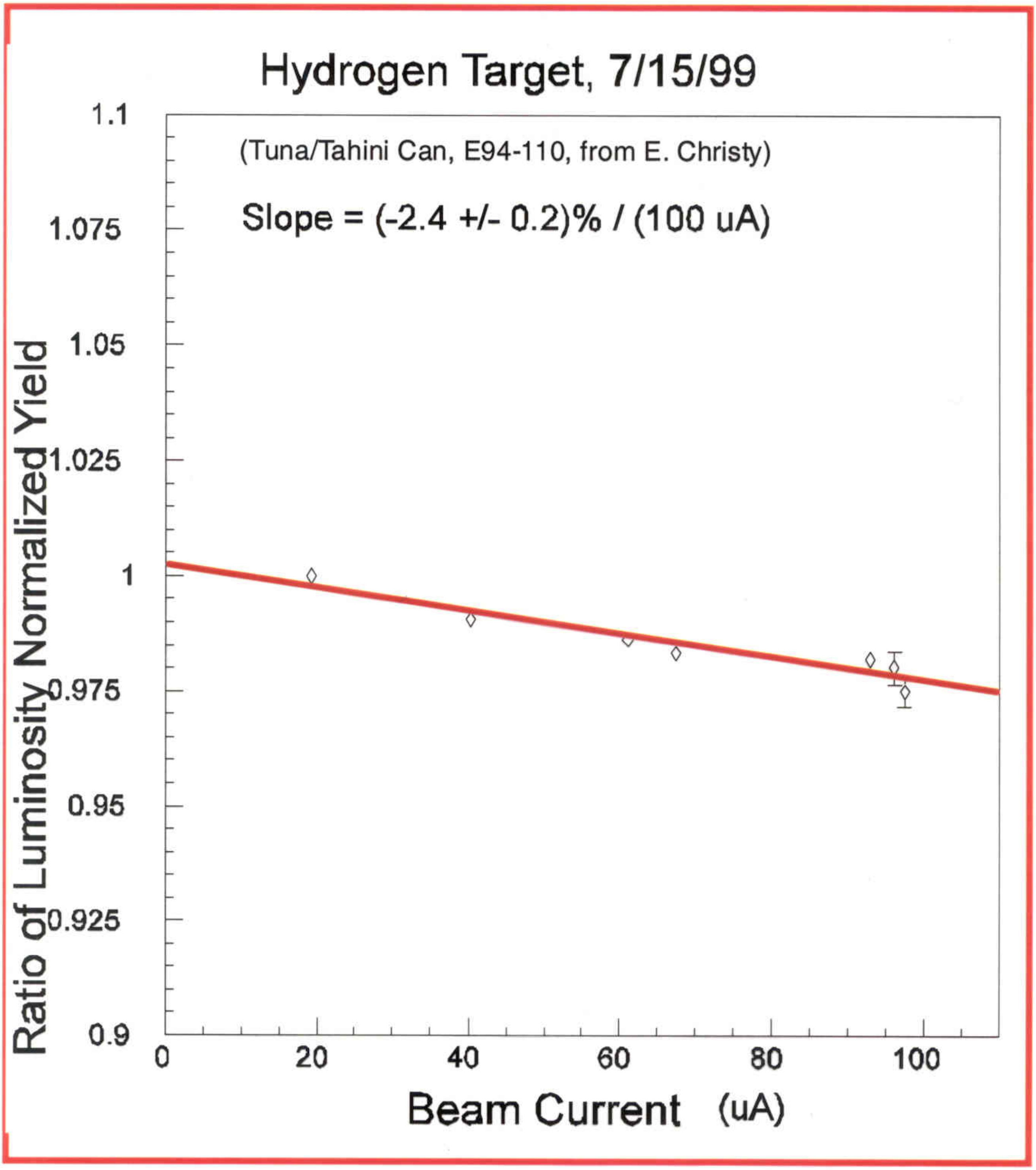
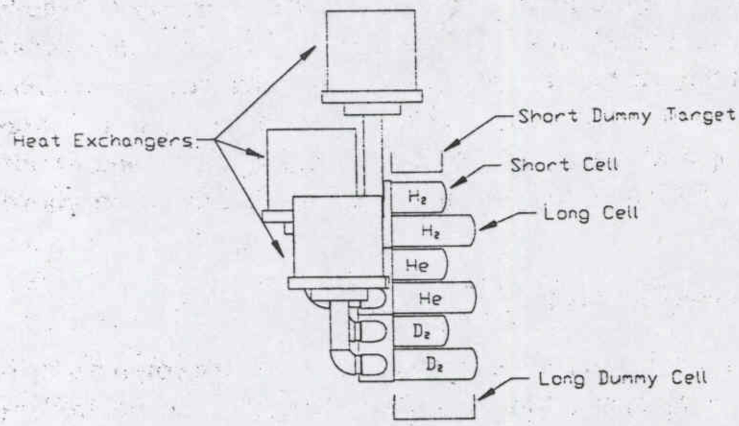


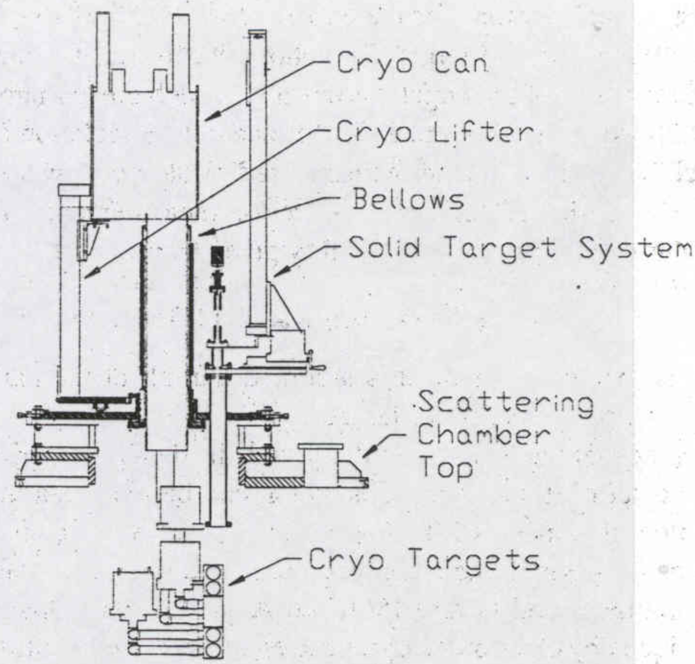
Figure 1 Optics target configuration

4cm Tuna Can Boiling

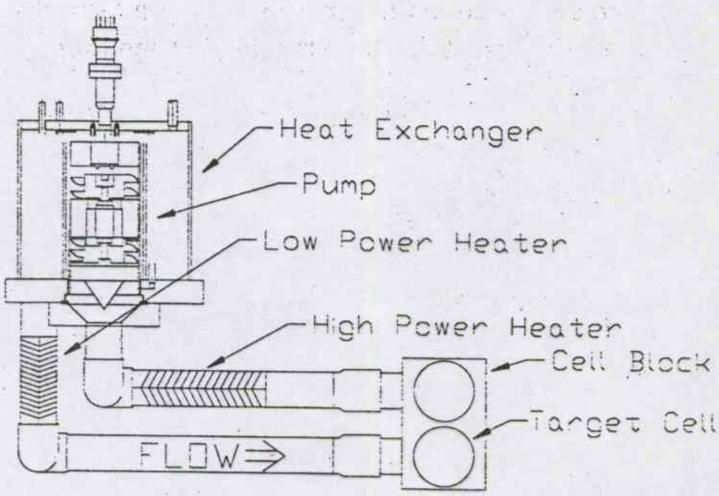




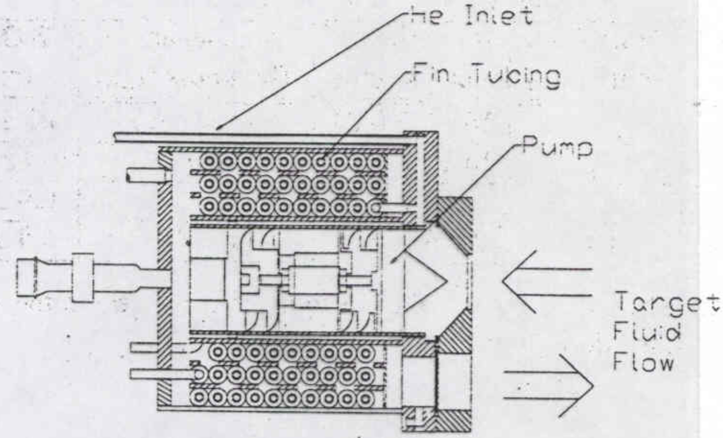
Heat Exchangers
Short Dummy Target
Short Cell
Long Cell
H_2
H_2
He
He
D_2
D_2
Long Dummy Cell



Cryo Can
Cryo Lifter
Bellows
Solid Target System
Scattering Chamber Top
Cryo Targets

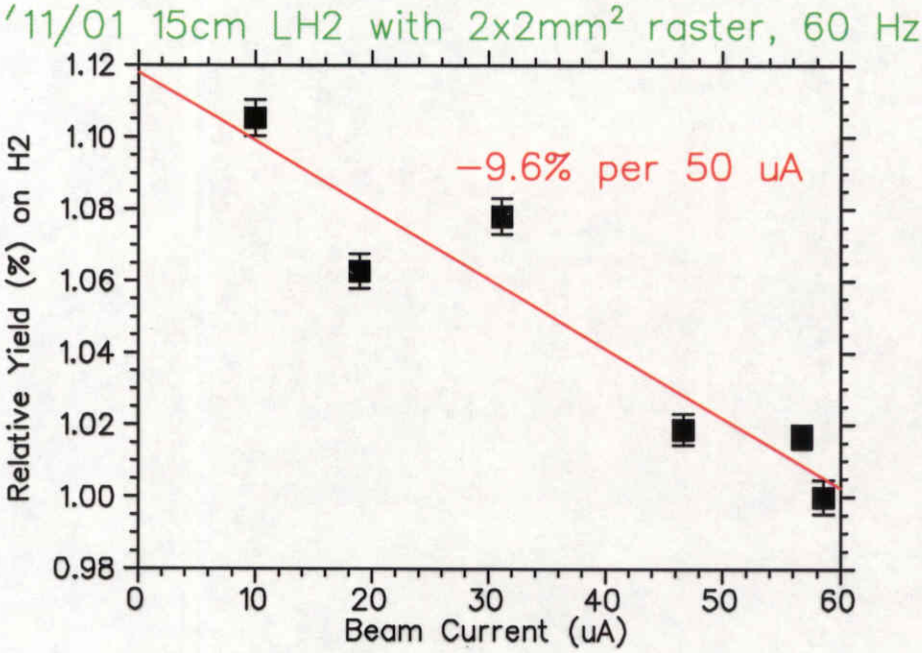


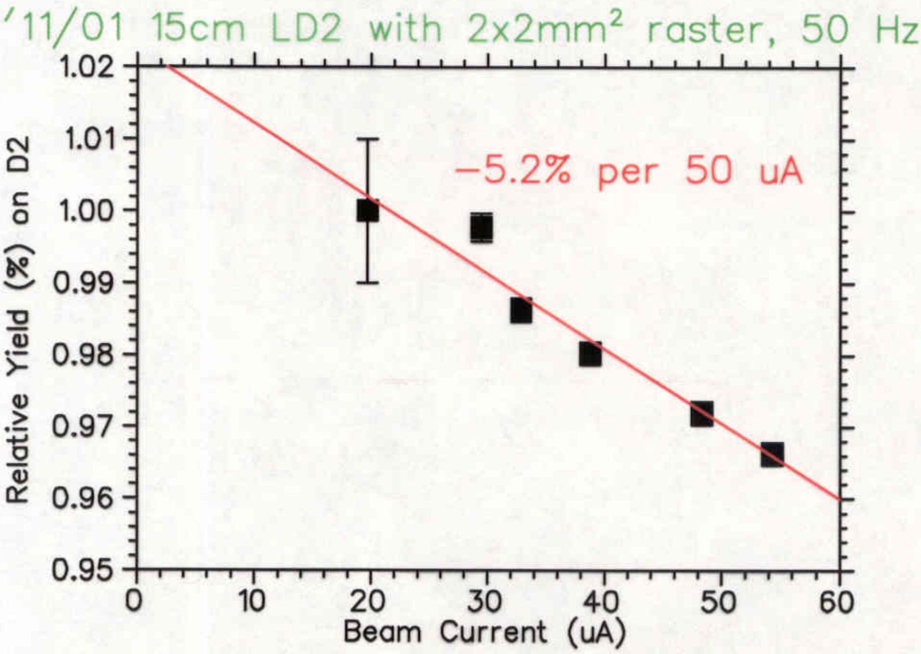
Heat Exchanger
Pump
Low Power Heater
High Power Heater
Cell Block
Target Cell
FLOW



He Inlet
Fin Tubing
Pump
Target Fluid Flow

Hall C new small cells





Thesis, D. Meekins

beam by multiply scattering the electrons to form a wider spot on the target.

To estimate the effect of localized boiling in the target, data were taken on the 15 cm deuterium cell for various currents and raster pattern sizes. The data were and events with suitable electron particle identification and tracking parameters were selected. By examining fluctuations in the yield normalized to beam current, estimates can be made of the magnitude of the effect of localized boiling in the target. A summary of these data is shown in Figure 3.16. As can be inferred from the figure, the density fluctuations present, for a raster amplitude of ± 1 mm and for beam currents less than 50 μA, are less than 0.5% [60]. A more recent study of the effects of localized boiling found a $\sim$ 0.04% /mm/μA drop in target density [61]. This would result in a $\sim$ 1.5% decrease in the target density for a 50 μA beam with a raster size of ± 1 mm. Because this is a small effect and the fact that the electron beam multiple scatters after impinging on the bremsstrahlung radiator (making this an even smaller effect), no correction for localized boiling is made in the analysis.

(old, formed beer cans)

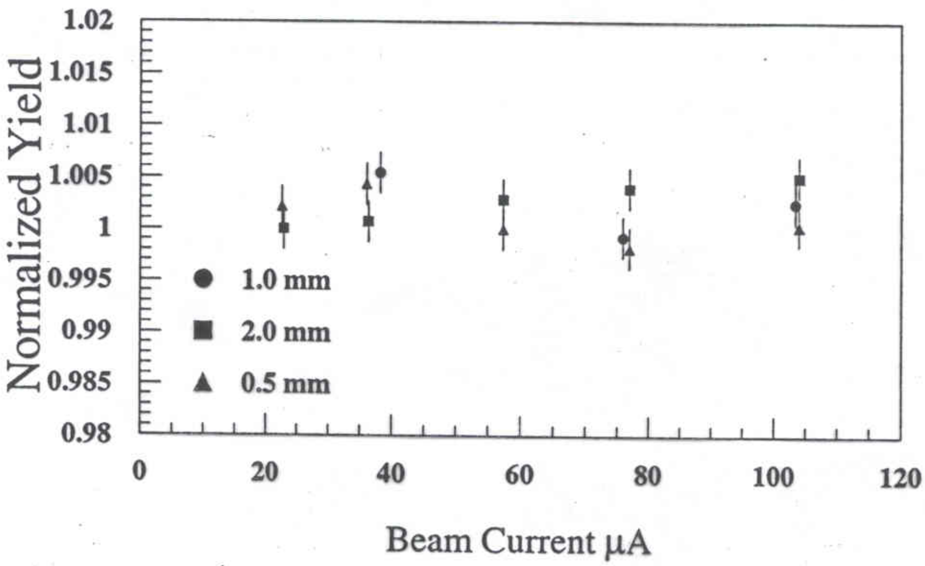
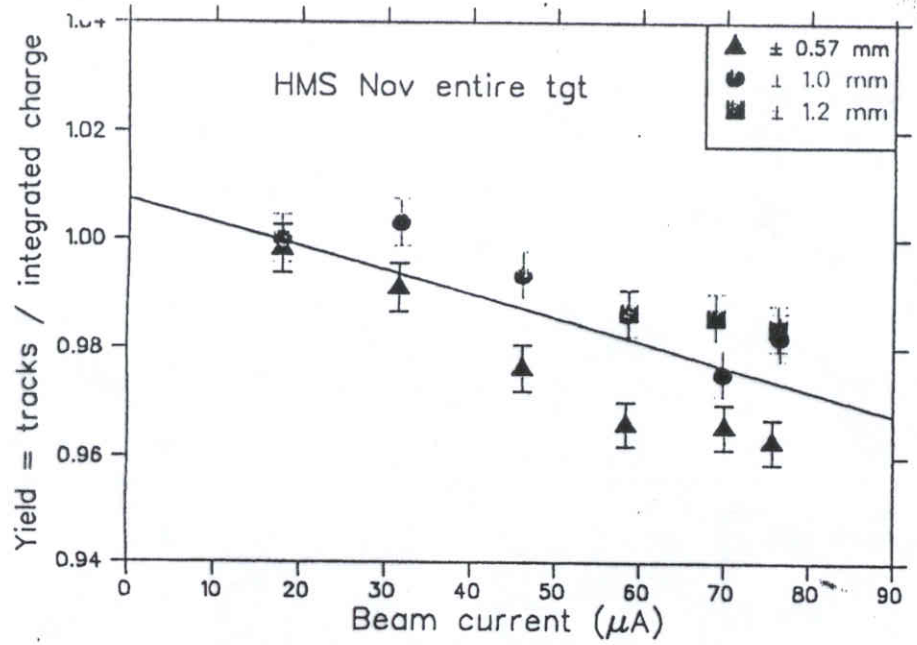
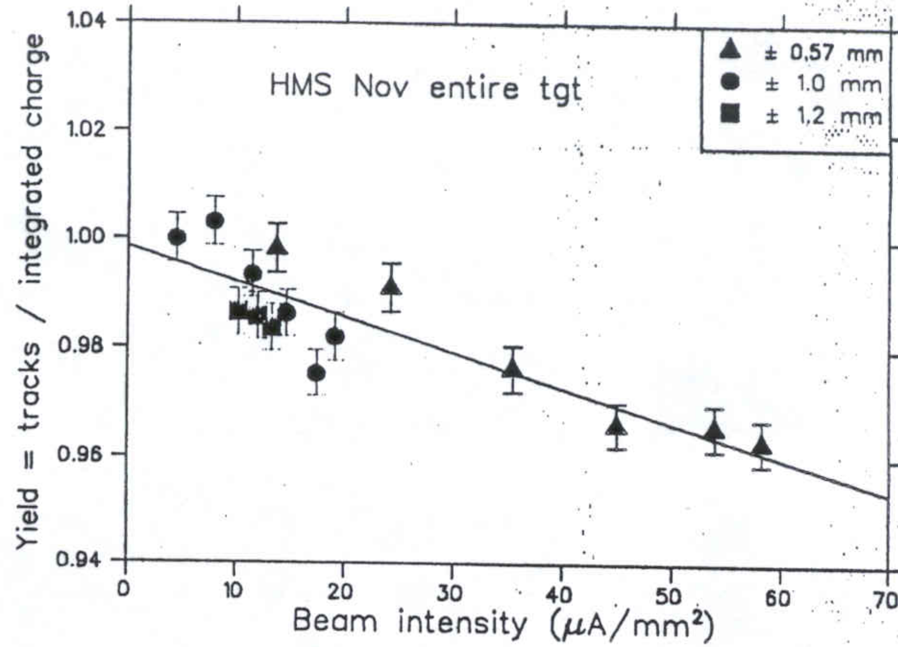
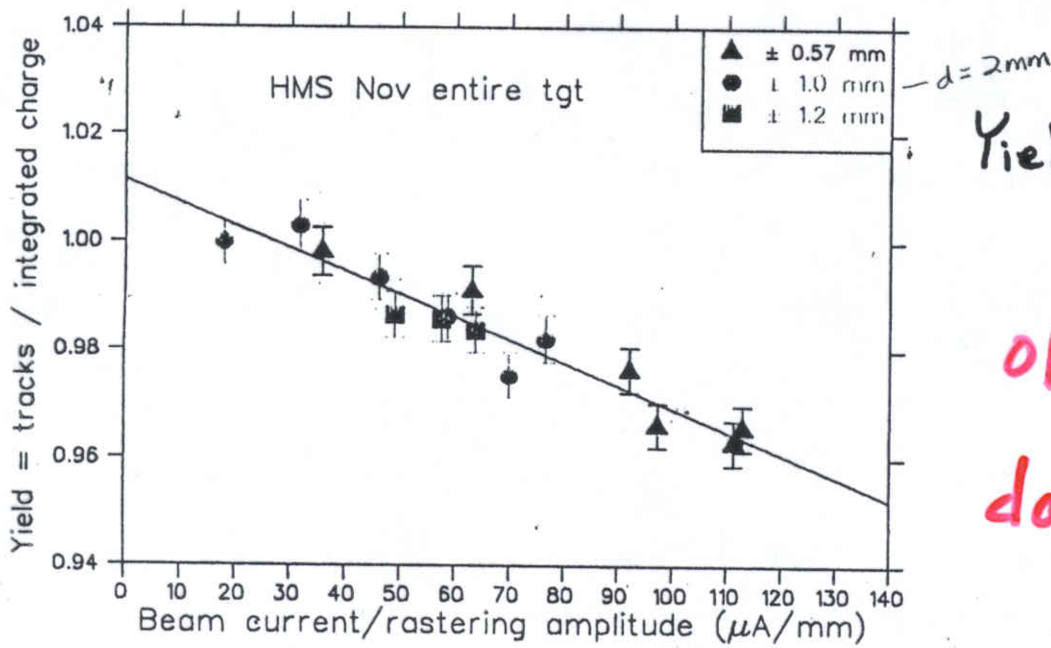


Figure 3.16: Data from the high power test of the 15 cm deuterium cell.

A chemical analysis of the hydrogen and deuterium target gases was performed by Lawrence Livermore National Laboratory (LLNL). For a detailed description of the collection of samples and results of the test, see Reference [62]. The purity of the hydrogen gas was found to be 99.8% where the largest contaminations were nitrogen and oxygen. These gases should freeze at 19 K and plate to the surfaces in the heat exchanger. Therefore it is assumed that the contamination in target cell is negligible and no correction in density



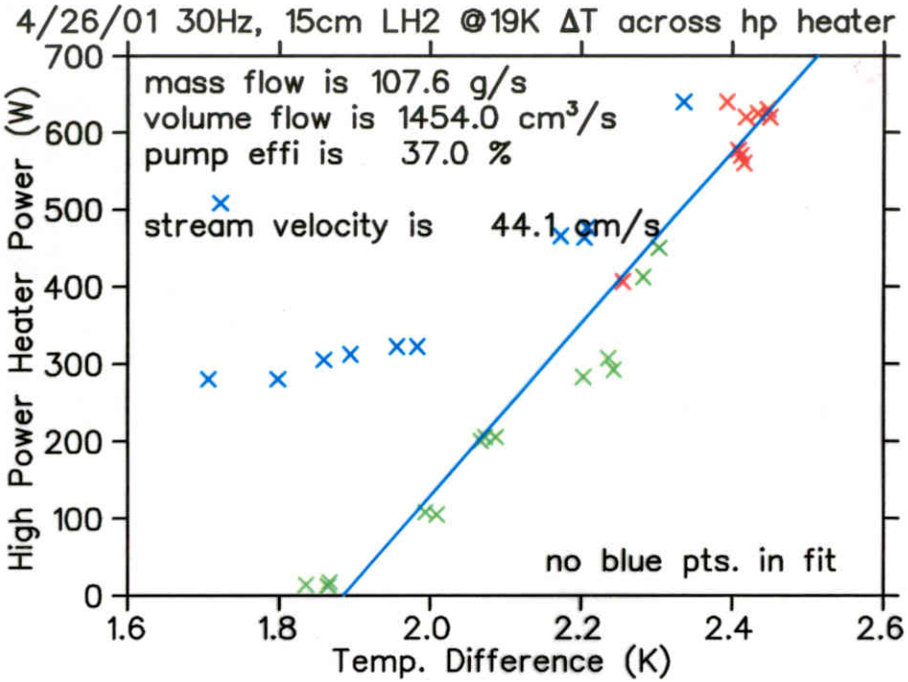


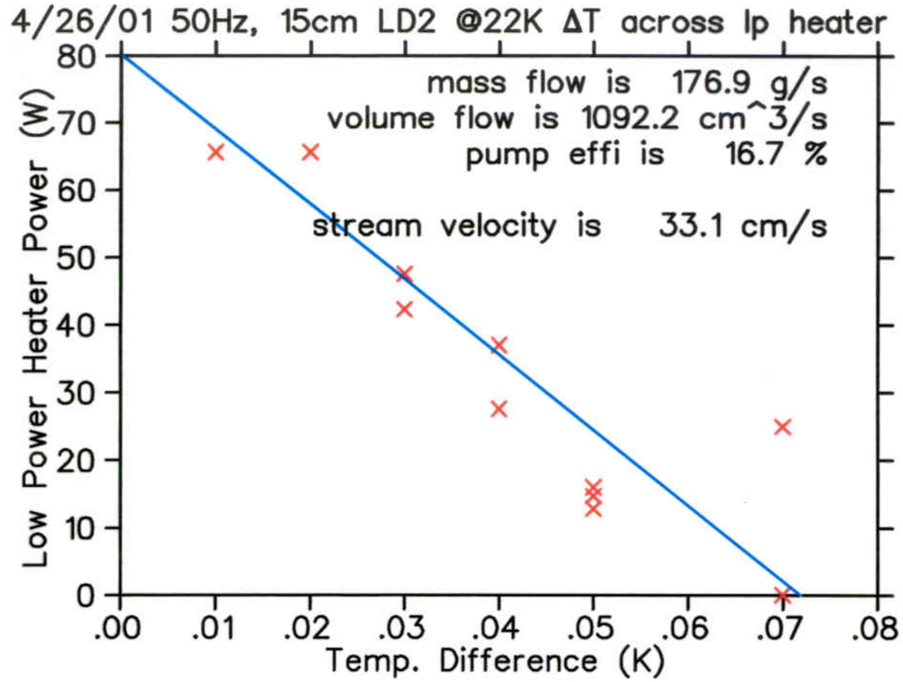


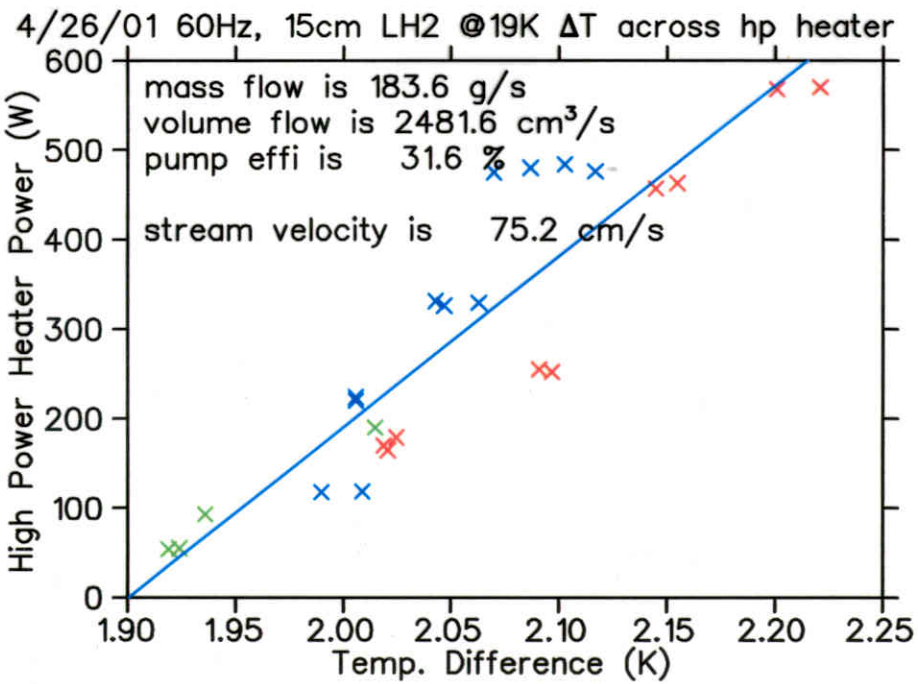
$$\text{Yield} \propto \frac{\text{beam current}}{(\text{rastering amplitude})^{0/1/2}}$$

old (formed) 4cm beer can

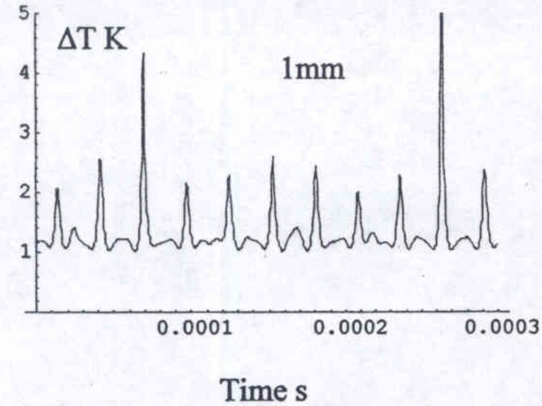
data from K. Gustaffson

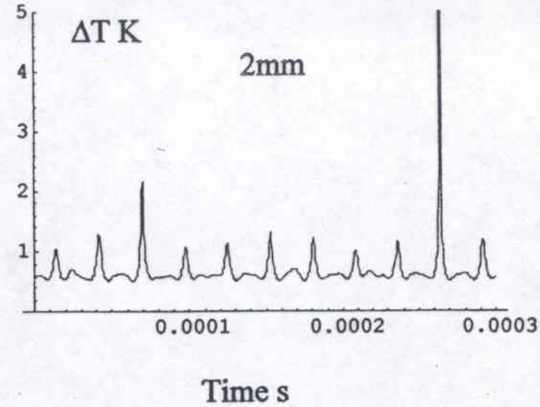

4/26/01 30Hz, 15cm LH2 @19K ΔT across hp heater
mass flow is 107.6 g/s
volume flow is 1454.0 cm³/s
pump effi is 37.0 %
stream velocity is 44.1 cm/s
no blue pts. in fit
High Power Heater Power (W)
Temp. Difference (K)
0
100
200
300
400
500
600
700
1.6
1.8
2.0
2.2
2.4
2.6


4/26/01 50Hz, 15cm LD2 @22K ΔT across lp heater
mass flow is 176.9 g/s
volume flow is 1092.2 cm^3/s
pump effi is 16.7 %
stream velocity is 33.1 cm/s
Low Power Heater Power (W)
Temp. Difference (K)
0
10
20
30
40
50
60
70
80
.00
.01
.02
.03
.04
.05
.06
.07
.08

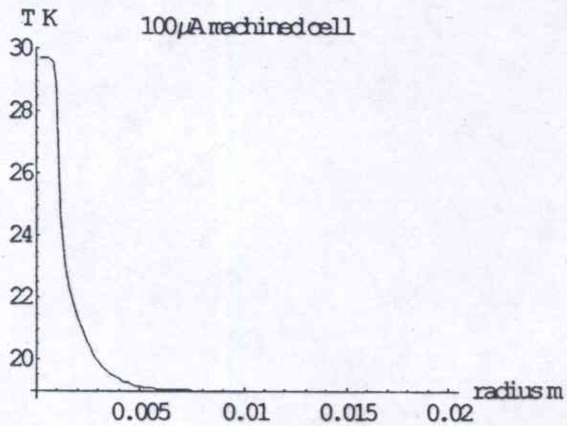

4/26/01 60Hz, 15cm LH2 @19K ΔT across hp heater
mass flow is 183.6 g/s
volume flow is 2481.6 cm³/s
pump effi is 31.6 %
stream velocity is 75.2 cm/s
High Power Heater Power (W)
Temp. Difference (K)
0
100
200
300
400
500
600
1.90
1.95
2.00
2.05
2.10
2.15
2.20
2.25

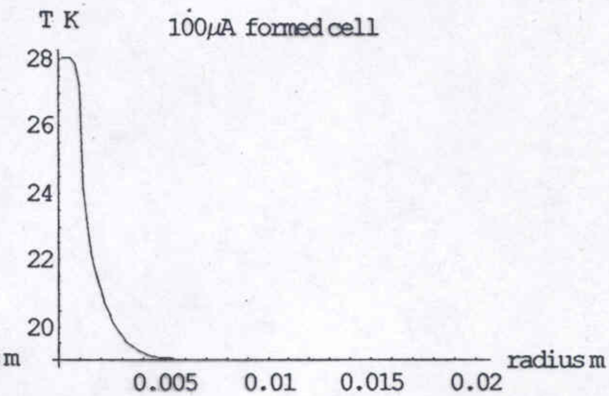
M. Seely
boiling
report
11/02



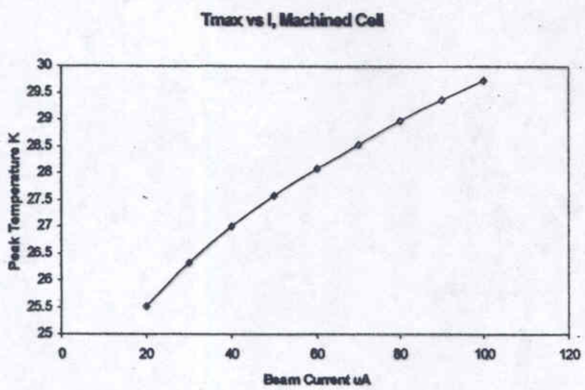


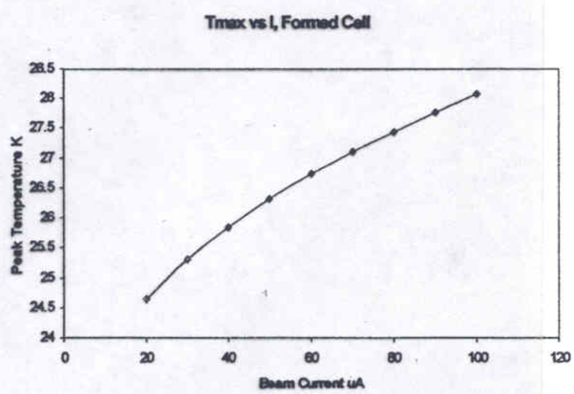
The 100 kHz frequency response of the triangle wave raster causes the beam to dwell near the corners of the raster pattern, corresponding to the spikes in the above plots. When both x and y rasters reach a turning point simultaneously a particularly large temperature spike is produced. These events are brief and infrequent and would not significantly affect the average density. The time averaged temperature rise is 1.3K for the 1mm raster and 0.67K for the 2mm raster, corresponding to density changes of 2.0% and 1.0% respectively. However, the temperature rise estimated here is the total temperature rise that a volume element would experience as the raster spot passes through it. The average temperature rise "seen" by the beam would be half of this amount.





In both cases, the threshold for film boiling is exceeded.





The peak temperature was calculated as a function of beam current for each cell type. For the machined cell the transition to film boiling is expected at ~35μA while for the formed cell the transition is expected at ~60μA. The difference between the two cells is almost entirely due to the difference in power deposited by the beam (due to the difference in wall thickness). If this calculation is repeated using h_c for the 4cm cells the results obtained are almost identical with those shown above. As noted earlier, the convection

Boiling Results

- Bulk boiling due to low v_s is the main problem
- Predictions agree with data
- 15 cm target not good at present…
- Bedposts not predicted to be a problem

	HC 4cm LH2	HC 15cm LH2	HC 15cm LD2	HC tuna LH2	G0 LH2
v_s (cm/s)	225	60	< 60		700
dT at 100 uA (K)	1.1	4.3	2.8		0.4
I_b to boil (uA)	261.4	69.7	106.4	0.0	813.2
Measured (100 uA)		19%	10%	2%	
M. Seely predicted:					
- bulk	1%	16%			
- windows	3%	3%			
- total	4%	19%			

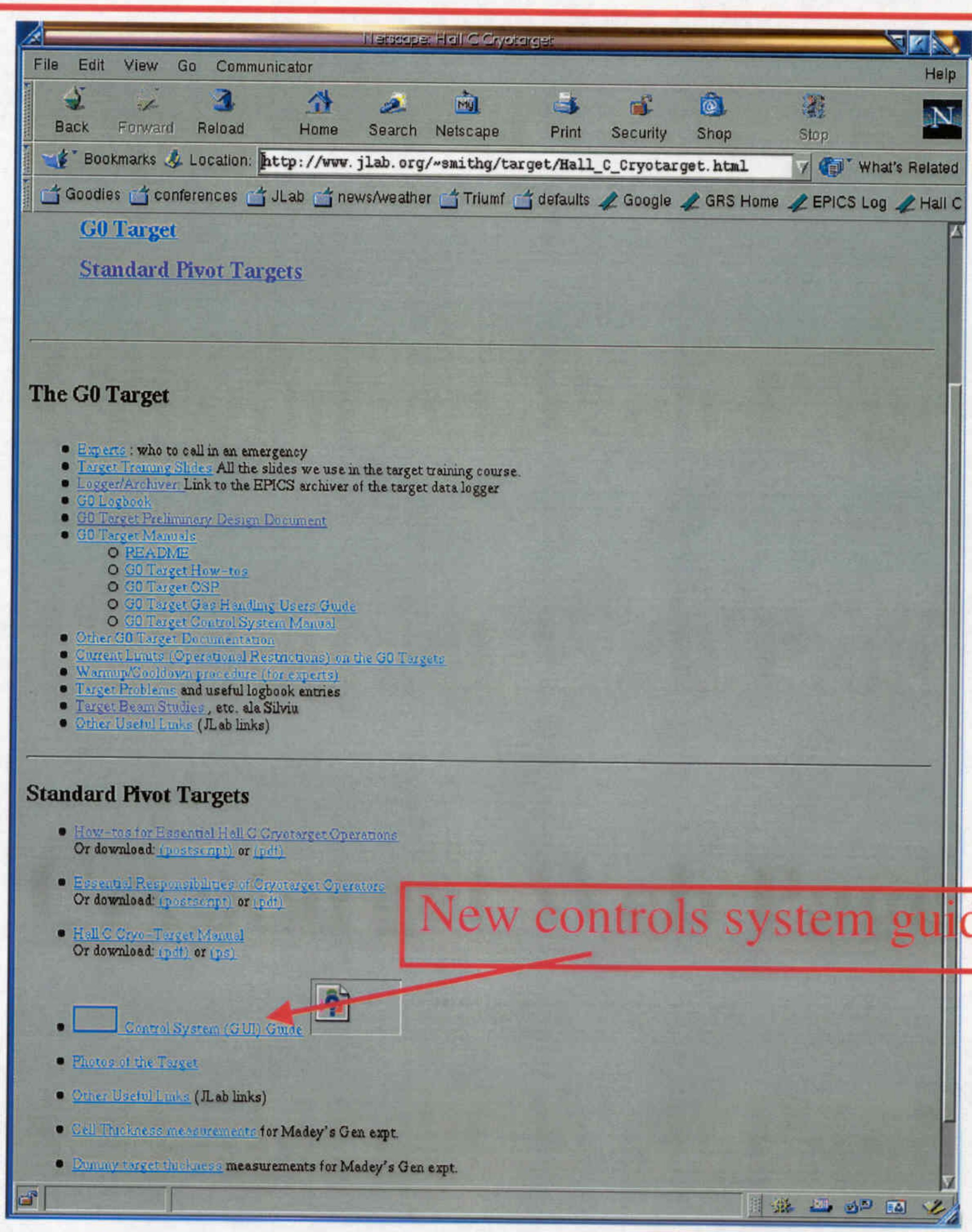
Coming Improvements (re boiling)

- Thinner windows
  - Over ~5mm Φ
  - Optimized alloy
- LPH removed √
  - Lowers impedance, improves v_s
- Fan changes
  - DC motor ala G0?
  - Impeller design
- EEL LH2 test facility (summer 03?)
- PID $f(I_b, T)$ → more stable T √
- Uniform (triangular) raster √
- Lumis?

Other Improvements

- Electronics behind green wall √
- Relief piping shortened √
- New He panels, compressor √
- Recabling/labelling √
- Single axis lifter, beefier gear boxes & couplings
- New IOC & MEDM controls √
- Mounting better → alignment √
- Permanent survey scopes √
- Check & solenoid valves changed to prevent P<1 atm √
- Documentation

Cryotarget Web Page



Some Definitions

Volume Flow:

V_{vol}=(pump displacement/cycle) f ε

V_{vol}~(144 cc/cycle) (60 Hz) (30%) ~ 2.6 l/s

Mass flow $\dot{m}$(g/s)=V_{vol}(cc/s) ρ(g/cm^3)~180 g/s

Stream velocity v_s=V_{vol}(cc/s)/A_{flow}(cm^2)~60 cm/s

$$\text{Turbulence } R = \frac{\dot{m}(g/s)\ D(cm)}{A(cm^2)\ \mu(g/cm\text{-}s)}$$

where D=pipe id, μ=dyn. vis.=1.3x10^{-3}g/cm-s,

So R~25000

$\Delta\rho/\rho \approx$ 1.5% ΔT

$$c_p = \frac{\Delta Q}{m \Delta T}$$

P_b(W)=I_b(μA) ρ(g/cm^3) t(cm) dE/dx(MeV/g/cm^2)