EmiT Proton Paddle Cooling Requirements

The following report concerns cooling of the proton detector segments. Two sets of cooling tests were performed. The first featured the fractured (repaired w/ epoxy) berylia rod used during the first run. The second was conducted with a copper piece of the same dimensions in place of the damaged berylia rod. The second of the two tests is described below. It is worth mentioning, however, that considering the difficulty estimating the effect of the fracture on the thermal characteristics of the berylia, the two tests are consistent.

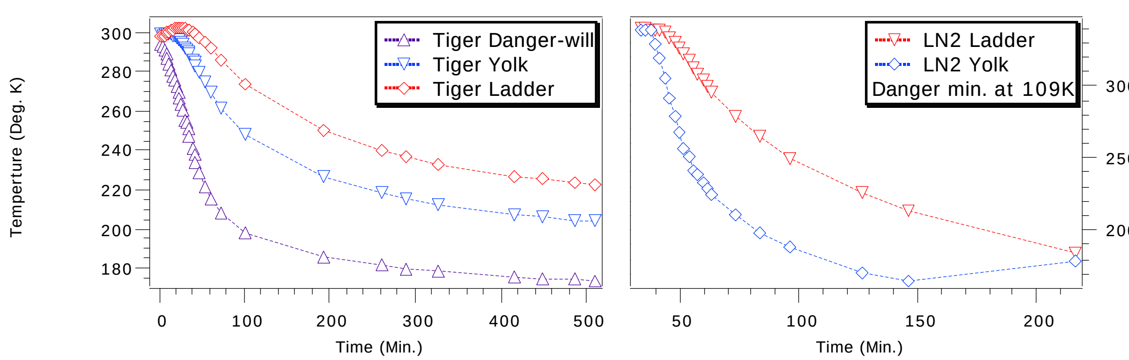
Heat Loads

Pre-amp power was measured to be 2.3 Watts with nine pre-amps installed, with sixteen channels running the total power consumption would be approximately 4 Watts. We can assume this is all dissipated into the body of the Quansit Hut as heat. (The new pre-amps will operate at six volts, thus reducing the power and heat dissipated by a factor of two). The other heat sources, radiative and conductive can be simply modeled using the geometry of the paddle. The major unknown is the 'Danger Will' flange or it's replacement. Estimated heat loads for the various structural components are shown in Table 1. Quoted errors are based on simple error propagation and reasonable guesses for the errors in temperature, component dimensions, etc. . (Anybody interested should see the Mathematica notebook used to describe the proton paddle). The total errors are quoted only to indicate confidence in the calculations. It would still be reasonable to assume an additional factor of two in any design decisions.

Radiative (Paddle surface at 150°K)	4.4 ± 2 Watts
Glass Support Rods (ΔT = 176°K)	0.62 ± 0.05
Teflon Support Rods (ΔT = 176°K)	0.2 ± 0.02
Stainless Steel Tube (HV side)	0.3 ± 0.03
Signal Cables	1.7 ± 0.1 $\times 10^{-4}$
Pre-amp Power	2-4
Danger-Will Flange	?
Grand Total	**7.5 ± 2 Watts**

Table 1.

To test the accuracy of these calculations, temperature measurements were made at three points on the cooling assembly during cool-down. A thermocouple was clamped into the 'Danger Will', and AD590s (Solid state temperature dependent current sources)



were attached to both the yolk (Labeled A) and the end of the cooling ladder (B). Three complete cool down temperature profiles were recorded (Data is shown in plots 1 and 2). The three profiles show cooling with the Cryo-Tiger[â] and the pre-amp power on, cooling with the Cryo-Tiger[â] and the pre-amp power off and Cooling with liquid nitrogen with the pre-amp power on. The minimum temperature achieved was determined by fitting an exponential to the data shown. The results are summarized in table two.

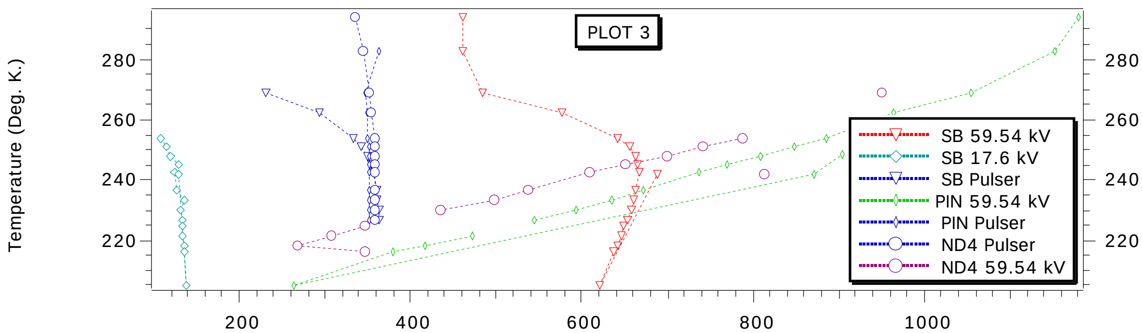
	Danger-Will (Degrees K)	Support Point (Calculated)	Yolk	Ladder
Tiger + Preamp	173.95	182.2	201.2	219.59
Tiger	157.25	160.2	166.7	177.7
Nitrogen	109.0	121.1	173.3	180.5

Table 2.

This data can be used in combination with a simple model of the cooling assembly to determine the total heat load on the paddle, the results are **5.43**, **1.60**, and **7.94** Watts for rows 1-3 respectively. The data from cooling with liquid nitrogen should match the calculated heat load in Table 1. (Surface and Yolk temperatures are in the correct range). It is clear that the measured values and the calculated values are consistent.

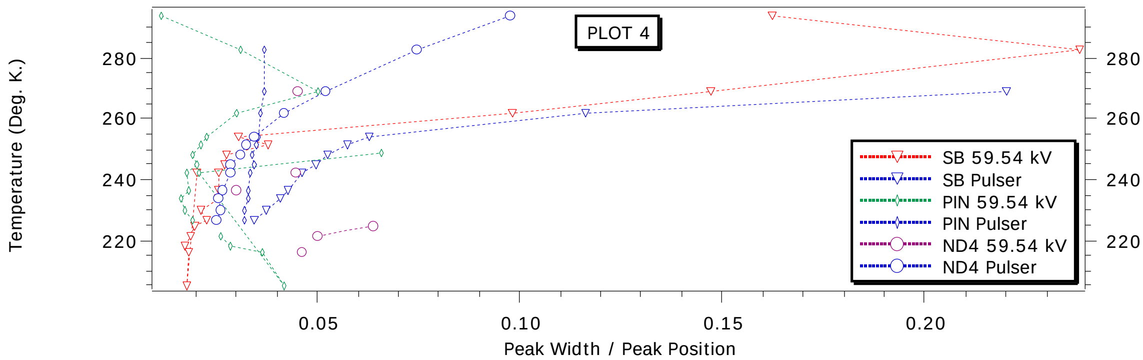
Resolution

To determine the relationship between temperature and energy resolution of the system, a thermocouple was attached to the Mother Board at a point approximately midway between a surface barrier and two PIN diode detectors. The peak position and peak width of an ^{241}Am source and of a pulser were measured during cooldown. The minimum board temperature reached was approximately 210 Kelvin. These data for the surface barrier detector and for two PIN diode detectors are shown in plots 3 and 4.



Plot 3

Initially the gain of the surface barrier channel is seen to increases as the temperature is lowered. This is easily explained by noting that surface barrier detectors have a high leakage current at room temperature. All detectors are in series with a one giga-ohm resistor, and hence the surface barrier detector is not fully biased until the temperature and hence leakage current are lowered. Unexpectedly the gain of all three detector channels decreases steadily as the temperature falls. Knoll was unable to provide insight as to the cause of this interesting and unexpected behavior.



Plot 4 shows the resolution as a function of temperature. The curves for the pulser and for the detector are not independent as there is noise from both the pulser and detector at the pre-amp input. In addition, because the gain changes over time the actual peak position shifts during the run. This broadens the peak and decreases the measured resolution. This effect is probably only important for the first few (Warmer) data points. Clearly a very reasonable resolution of approximately 3% is reached by the time the board reached a temperature of 250 °K. It is important to note that the temperature of the detector itself is likely to be warmer particularly in the case of the Surface barrier detector. The detector mounting was note particularly thermally conductive. Further increases in resolution may be expected by improvements in the behavior of the electronics with decreasing temperature (See pulser peaks), however the pulser for ND0 shows no improvement, so it is unclear how larger an effect this is.

Conclusions

The total cooling power needed in on the order of 8 Watts per channel, however a safe margin would be to assume around 16 Watts per channel. While the Cryo-Tigerâ system can only marginally fulfill this requirement, it does have other advantages such as being low vibration, it's small size and it's simplicity of operation. All other systems fulfill this requirement easily.

The surface barrier detectors reach their maximum resolution at a relatively high temperature (> 250 °K) but slight improvements may still be obtained by reducing the electronic noise. Although it is not required that the detectors be kept extremely cold, reaching even modest temperatures is difficult because the thermal resistance of the cooling assembly is very high. Unless significant changes can be made which seems doubtful as we are tightly constrained by the geometry of the paddle, the 'Danger Will' must be brought down to near liquid nitrogen temperatures (One small improvement is that the berylia rod will be bonded directly to the copper cooling rod, this will not decrease the thermal resistance significantly however).

I would love to discuss the interpretation of these tests with anybody who is interested.