The Carleton EUDET Telescope: Modification Details

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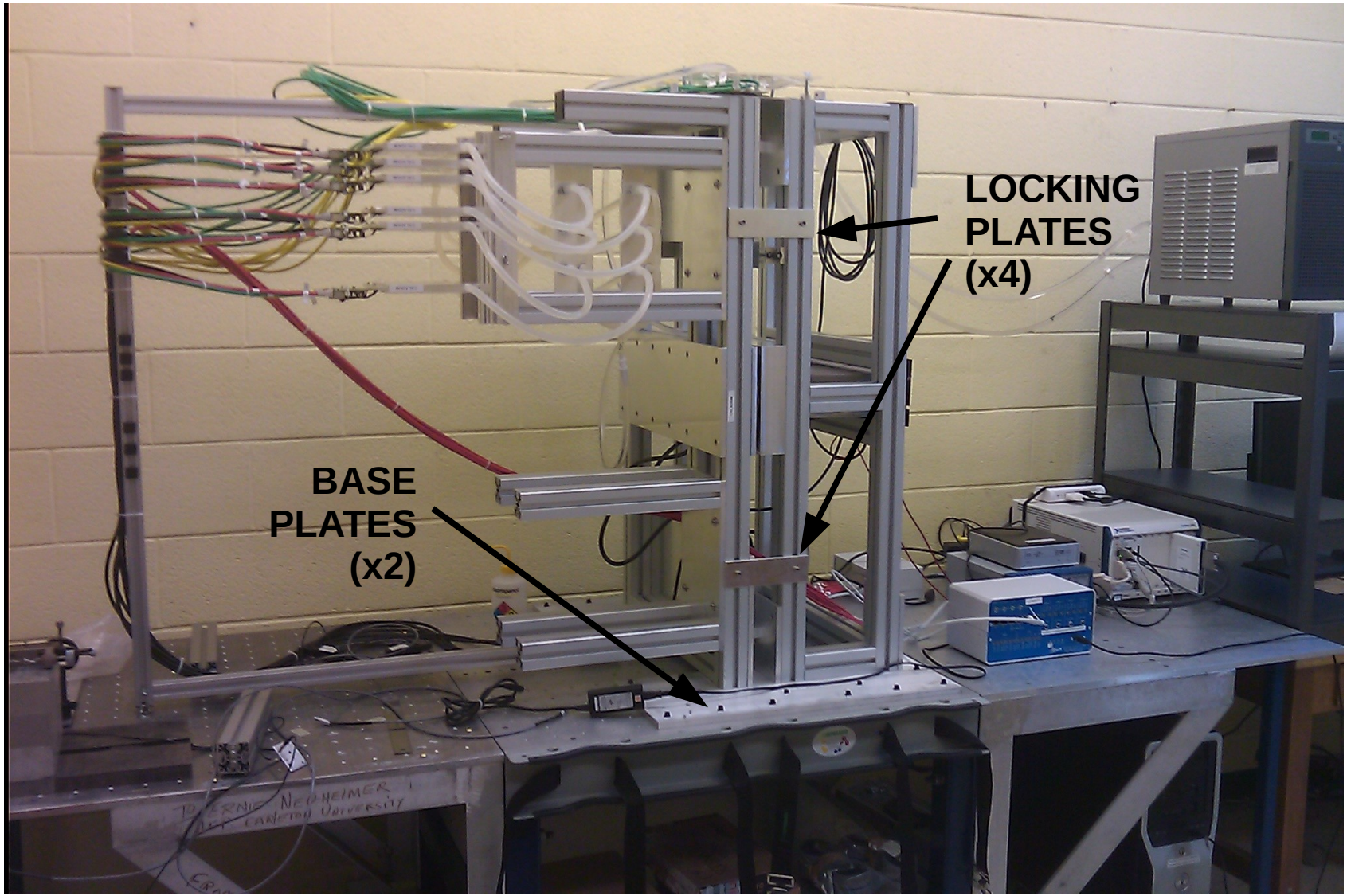
Required for Cosmic Ray Studies

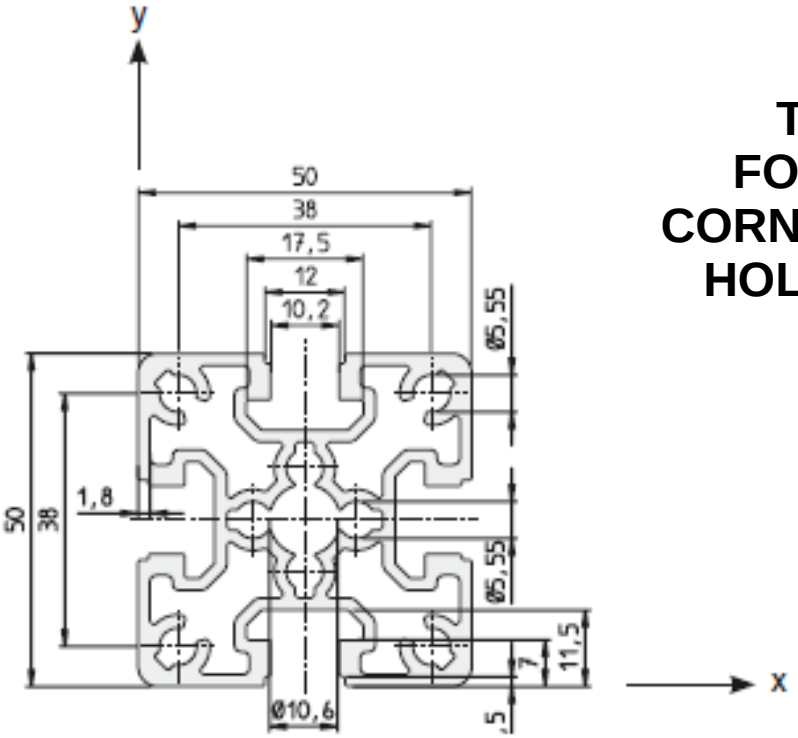
- Cosmic ray muons have a roughly $\cos^2\theta$ angular distribution, therefore a vertical configuration is needed for max. flux (which is still *very* low)
- The following were required:
  - A pair of base plates were machined to mount the telescope to an optics table (required the telescope extrusion ends to be tapped with threads)
  - Detector planes were mounted as close as possible and 15x25mm scintillators were used to maximize the solid acceptance angle through all six planes
  - Two extra locking plates were machined and attached to prevent the frame from moving

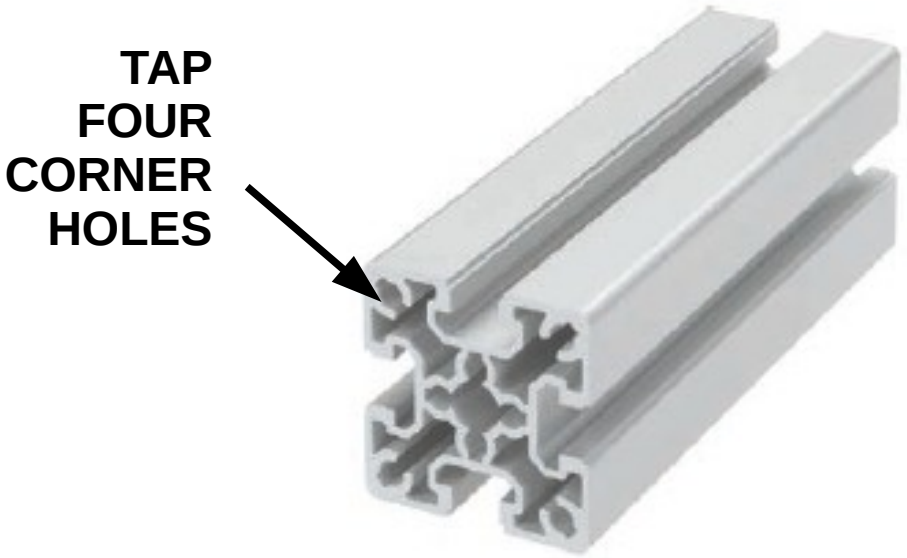
Vertical Orientation



Extrusion Tapping

- 6 extrusion ends with 4 holes each were tapped for M6.0 x 1.00 x 30mm screws
- Extrusion: Rose+Krieger model F-50x50-L (in Structural Profiles catalogue)

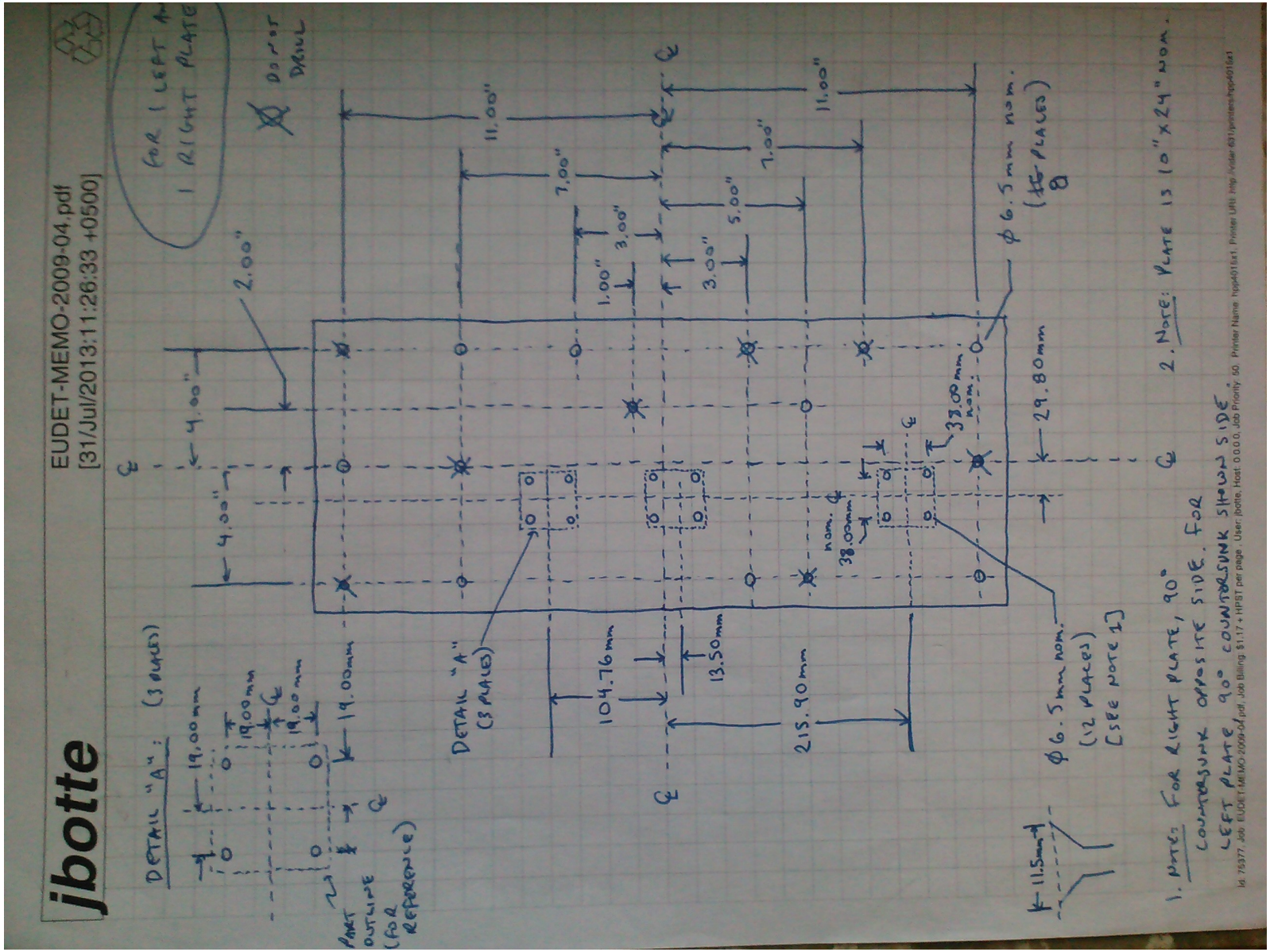




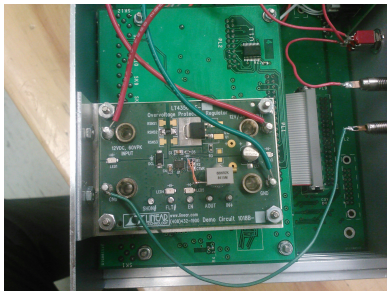
Base Plate Overview

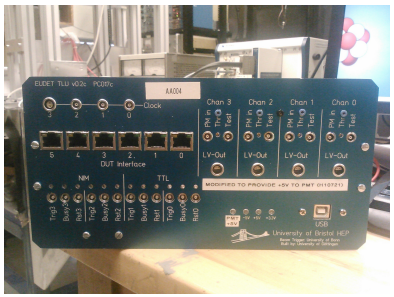
- Two aluminum plates, 24” x 10” x 1/2”
- Mated telescope (metric) to optics table with grid of holes w. 2” spacing
- Flat head M6.0 screws used to mount telescope to plates (provided a flush mounting for plate bottom to table)
- Used cap head screws (Imperial) to mount plates with attached telescope to old optics table

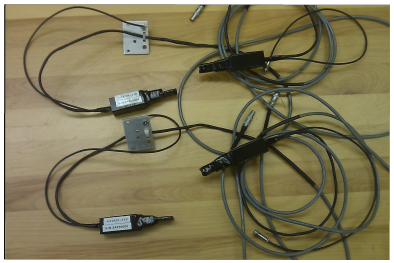
Base Plate Design

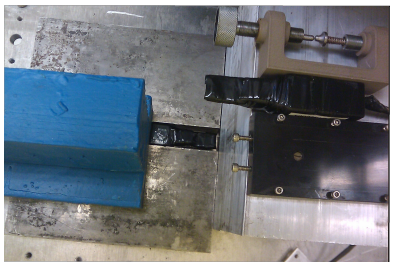


TLU Modifications









- PMT Power Supply: Modified to step +3.3V to +5V instead of +15V for Hamamatsu model H10721-110
- Added PMT Power overvoltage/current protection circuit (LT4356-3 using DC1018B-C circuit) after report of destroyed PMTs on Aconite (root cause unknown)
- Aconite issue also prompted us to add an external PSU input for PMT Power: internal/external switchable
- PMT Control Voltage: 0.0V to +2.0V (vs. 0.0V to +1.0V) – internal switch selectable
- Added support in EUDAQ to allow the control voltages to be set independently for each PMT (and for +1.0V vs. +2.0V max. operation) rather than all set to 0.8V
- Added gain and offset error compensation for control voltage DACs (provided spreadsheet to calculate)
- Added support to ramp up control voltages to prevent triggering of overcurrent protection circuit (not yet folded into latest EUDAQ)
- Added external monitoring pins to allow the thresholds of the four individual discriminators in the TLU to be measured without having to remove the unit’s cover
- Added straps to secure TLU power brick cable to TLU power input connector (could be pulled out)

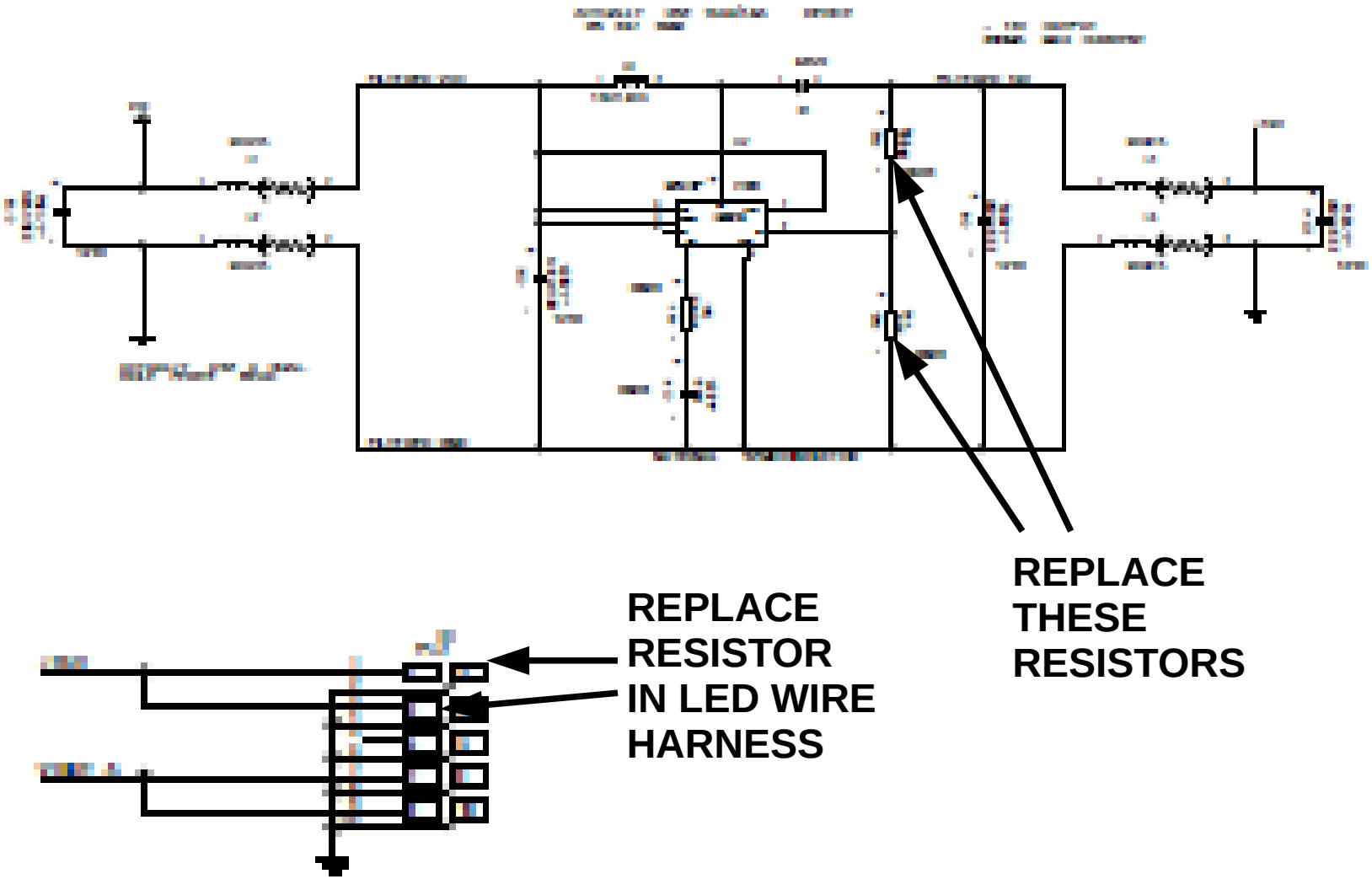
Existing TLU: New PMTs

- The TLU was designed for Hamamatsu model H5773 PMTs; however, they were no longer available
- Hamamatsu has a roughly equivalent unit: model H10721-110; however, it requires +5V instead of +15V for power and a +0.5V to +1.1V control voltage range instead of +0.25V to +0.9V.
- Decision was made to modify the TLU rather than build a separate PMT controller and power supply

Power Supply Mod. Instructions

- TI WebBench for LM3224 was used to validate design changes to change output from +15V to +5.0V
- Replace R2 (300KΩ) with 3.01KΩ and R3 (27KΩ) with 1.02KΩ (1% tolerance) – smaller values were recommended by simulations for stability at +5.0V
- Current setting resistor in wire harness for “power on” LED indicator needed to be replaced to maintain similar intensity: 1.2KΩ replaced with 390Ω
- We made a hard change, however a 3PDT could have been used to allow for backward compatibility with H5773 PMTs, but we thought it presented too great a risk for blowing up H10721 PMTs! Thus, Caladium TLU has a +5.0V only output for powering PMTs.

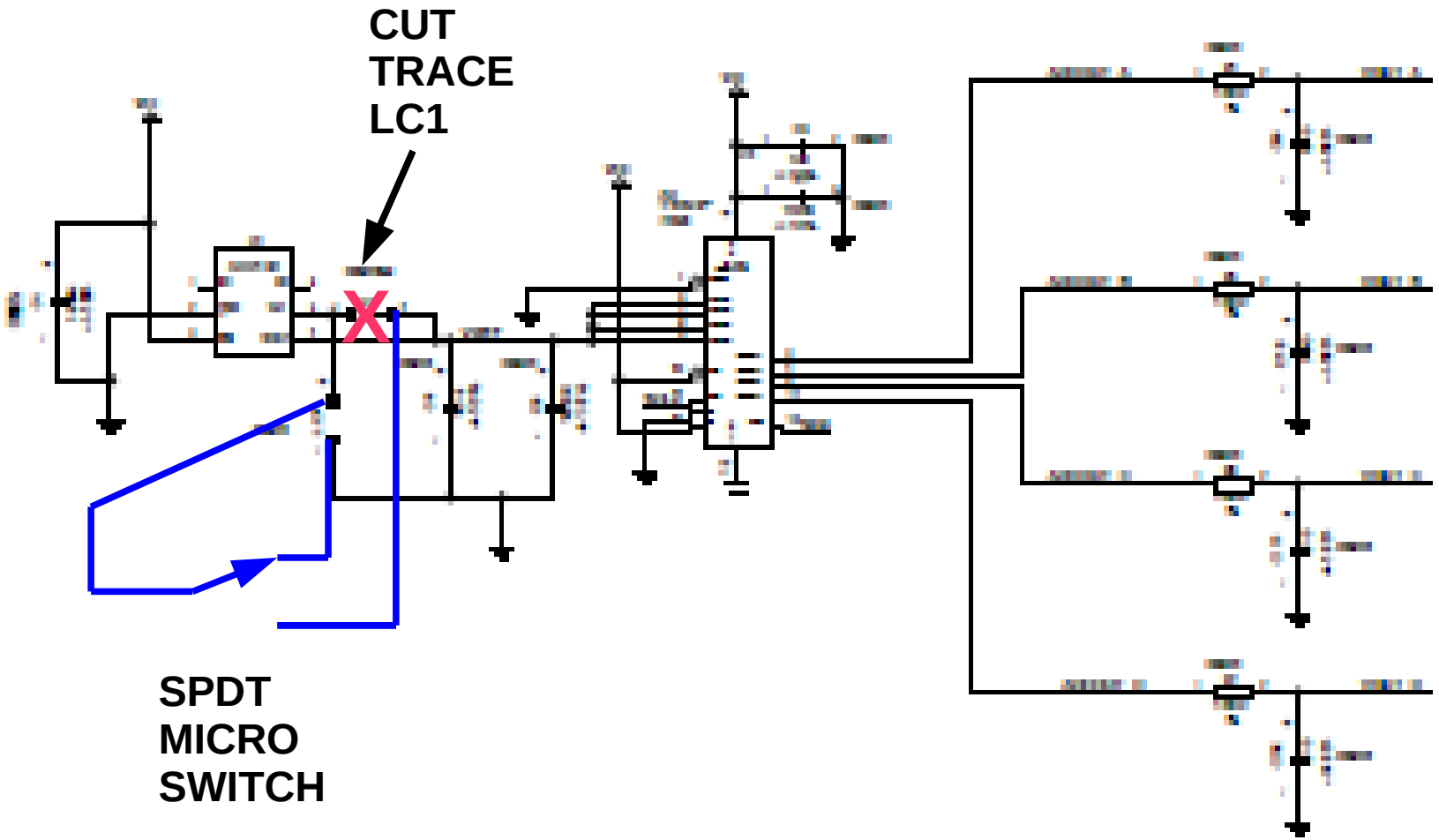
Power Supply Schematic



PMT Control Mod. Instructions

- Needed control voltage to PMTs to go above the +1.0V available on the unmodified TLU (to +1.1V)
- Control circuit is I^2C programmable DAC with 4 independent channels. An ADR130 supplies voltage reference to the DAC. Unmodified TLU sets the ADR130 output to +0.5V, but ADR130 supports a +1.0V output (DAC is configured with a 2x amplifier on its output)
- Cut PCB trace labelled LC1, strap pads labelled LC0 to select the +1.0V output option on the ADR130
- We used an SPDT switch to allow the reference voltage to be selected (as the 0 to +2.0V range required software changes before it could be used, but we needed to do testing before the software could be implemented)

PMT Control Schematic



Overvoltage/current PMT Protection

- Fear over loss of Aconite PMTs (no root cause known) prompted addition of a protection circuit to Caladium TLU
- The LT4356-3 Surge Stopper with Fault Latchoff chip was selected as providing the necessary features and the DC1018B-C evaluation board (with +12V, 3A protection) was purchased and modified for +5V, 50mA protection
- Found at FNAL test beam: turning on all four PMTs at once caused the overcurrent circuit to trigger even though it was set to *six times* the published worst case maximum current for the four PMTs due to inrush to their internal high voltage converter circuits (it is fine after powering up)
- Configurable control voltage ramping code was written on the spot for EUDAQ (note: has not been folded into trunk due to uncertainties from churn in code base)

PMT Protection Circuit Instructions

- Start with commercial DC1018B-C evaluation board (datasheet and schematics easily found online)
- Replace LED current limiting resistors R10, R12, and R14 with 1.6KΩ (maintain intensity moving from +12V to +5V)
- Replace current sensing resistor RSNS2 with 1Ω, 1% resistor with 1206 or 1210 package (2.5mW max. current)
- Replace voltage threshold resistor R1 with a 16.2KΩ, 1% (1/8W or better) in series with a 2KΩ multi-turn potentiometer glued to board (adjustment needed to compensate for chip variability and resistor tolerance)
- Replace D4 with 6.2V (10% tol. or better) zener diode
- Insert modified DC1018B-C in wire harness between PMT power supply and front panel PMT LEMO connectors

PMT Gain Control Options

- In main branch of EUDAQ since last year. All four PMT control voltages are now individually controllable. Whether the TLU has been modified for allow for 0V to +2.0V Vcntl range for H10721 PMTs (e.g.) can also be specified.
- Options for TLUControl.exe command-line program: -pv/--pmtvcntl, -p1/--pmtvcntl1, -p2/--pmtvcntl2, -p3/--pmtvcntl3, -p4/--pmtvcntl4, -pm/--pmtvcntlmod (*see User's Manual* for descriptions of these options).
- In EUDAQ configuration file: PMTVcntl1, PMTVcntl2, PMTVcntl3, PMTVcntl4, PMTVcntlMod (these do the same things as their counterparts in TLUControl.exe. Note 800mV will be used if a PMTVcntl# is not specified).
- New EUDAQ config options: PMTID1 to PMTID4: strings are stored verbatim in BORE (i.e. for PMT serial numbers).

Calibrating the TLU's PMT Control

- In main branch of EUDAQ since last year, but there is no place to document this sort of thing (not a secret, but who the heck reads TLUProducer.cxx?), so here it is here...
- Eight EUDAQ config file options: PMTGainError1 to PMTGainError4 and PMTOffsetError1 to PMTOffsetError4
- Used to correct for reasonably significant gain and offset errors in the TLU's AD5316 DAC chip that is used to generate the four independent PMT Vcntl signals
- A LibreOffice spreadsheet is tucked away in the EUDAQ source code: "etc/tools/TLU_Vcntl_Calibration.ods" that contains detailed instructions on the procedure and calculates the values to plug in for the config file options
- Generally a one-time procedure (36 measurements)

PMT Control Sequencing/Ramping

- After adding the overvoltage/current protection, turning on two PMTs at once was fine, but four would trip the overcurrent protection circuit (we found this out two days before a Fermilab test beam!). The protection circuit was set to trip six times the expected maximum current for four PMTs, so there must be a large initial inrush.
- Huge code churn in trunk at the time, so it has never been added... will do soon since Caladium is visiting SLAC.
- In EUDAQ config file: PMTDelayStart (seconds between initializing PMTs), PMTInitialStep (set to turn on PMT's HV converter), PMTStepCount (number of ramp steps), PMTStepInterval (time between steps, in ms).
- Where/how to I let people know this has been added to the main trunk of EUDAQ???