<u>Muon Capture Experiment</u>

Scott Headley

I spent the summer of 2003 working for Professor Peter Kammel on the Muon Capture (MuCap[1]) experiment at the Paul Scherrer Institute[2] (PSI) in Switzerland. The MuCap experiment is designed to precisely measure the muon capture by the proton. I was hired to work on the electronics for a cylindrical wire chamber detector being built for the experiment. For the MuCap experiment it is necessary to have clean electronics with low pick up and noise because noise can be confused with an actual signal that is useful as data. The specifications for the chamber that I was working on are as follows:

Active length (mm)	800
Diameter of the anode wire plane (mm)	640
Distance anode-cathode (mm)	4
Distance between two anode wires (mm)	2.0
Thickness of the inner wall (mm)	0.45
Thickness of the outer wall (mm)	0.20
No. of anode wires	1024
No. of cathode strips (Inner cylinder)	316
No. of cathode strips (Outer cylinder)	324
Width of the cathode strips (mm)	4.44
Chamber thickness (mg/cm^2)	147
Operating voltage (V)	2950

Starting in Illinois, I made the cables that connect the anode discriminator cards with the receiver boards in the compressor and use the new LVDS fast logic standard. LVDS uses low voltage to drive large currents long distances. The compressors take the signal and assign a time to the location that the signal was detected, which is then used in the data acquisition. Making the cables involved cutting cable to a length of 4 meters, putting the 40 pin connectors on the 40 wires contained in the cables, using braided metal shielding to create a ground for the cables with shrinking tube and grounding rings and finally testing the cables to make sure there were no shorts or open wires.

First at PSI, I made the intermediate amplifier boards (Image 1) for the anode side of the detector. To do this I took the cut circuit boards and soldered on all the connectors necessary for the pre-amplifier boards to be connected and for the cables to connect to the compressors, then I soldered surface mount resistors and sockets to complete the cards. Then I took the already made pre-amplifier boards and put thermal tape on the IC chips on the cards and put a copper shield on them. The shield is for grounding purposes and also to create a heat sink through the thermal tape for the IC chips, which get very hot when voltage is put on them. Then I took bolts to go between the two pre-amplifier bards

[1] www.npl.uiuc.edu/exp/mucapture/
[2] www.psi.ch

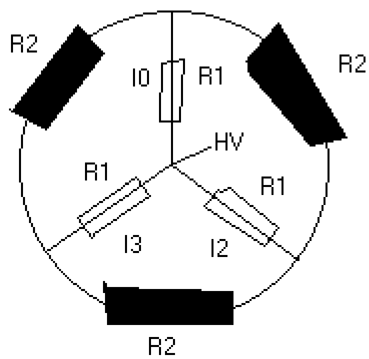
on each intermediate board and cut them to the required length. The bolts create a common ground for the two pre-amplifier cards and also provide support between them. Then to create grounding points that can be connected to ground for the entire detector, I cut and drilled holed in copper sheets and mounted them to the pre-amplifier boards. Another ground was also required, so I took a heavy copper wire and crimped grounding rings on the ends and mounted those also on the pre-amplifier boards.

In the MuCap experiment the incident muon beam is detected with plastic scintillators. I assisted Bernhard Lauss in making a scintillator detector. I took the light guide that Bernhard had cut and polished the cut edge to make it flat and polished, using different grains of sand paper. The grains I used were: 240μm, 40μm, and 20μm. I started with the largest grain and then moved on down to the smallest. After the sand paper I used Alumina Polished Suspension with grains of 3.0μm, and 0.3μm. When I finished with the light guide I did the same to the cut edges of the scintillator. Afterwards we glued the light guide to the scintillator using UV sensitive glue. Then, I covered the light guide and scintillator with aluminum foil, black paper and black electrical tape to ensure that no light would escape. After that we glued the light guide and scintillator to a phototube. Then we checked the detector under high voltage for light leaks.

Next with Genna Petrov, I made a bronze shield for the inside of the chamber. To do this we used a 240μm thick bronze mesh soldered to a 200μm thick bronze foil. Using the density and a set amount of each the foil and the mesh we determined that the mesh is over half air and therefore so the electron scattering is much less than that of the bronze foil. So the mesh is much better for the inside of the chamber, but the foil is used for the ends where support is necessary and it is better for soldering the ground lines of the amplifier boards. Also, at the ends the scattering becomes unimportant so it does not matter that the foil is there. After measuring the chamber and deciding where it was necessary to have foil and where to have mesh, we soldered the mesh to the foil. We made a 85 centimeter by 200 centimeter rectangle of the foil which can be rolled into a cylinder of the exact diameter of the inside of the wire chamber. We then soldered the foil to opposite ends of the mesh adding about 25 centimeters to the anode side of the shield and 10 centimeters to the cathode side of the shield creating a final rectangle of 120 centimeters by 200 centimeters. The inner circumference of the chamber is 193.2 centimeters so the 200-centimeter length provides some overlap for added support when the rectangle is rolled and soldered into a cylinder.

Because the high voltage cards (Image 2) made for the anode end of the chamber were too wide it was necessary to cut them, but in that process a waterproof seal on the cards was damaged and the cards began drawing an unacceptable amount of current, between 30 and 60 nanoamperes, because of the humidity that was getting into the components. We needed to dry the cards before testing and putting on another waterproof seal so several methods were used. One was to put the cards in a sealed bag of nitrogen gas. Another was to leave them over night in a pre-clean room with very low humidity. The last was to put them in an oven over night. I tested the cards with Steven Clayton after they were dried. To test them we slowly ramped the voltage applied to the cards up to 3 kilovolts. If the voltage was applied to quickly the cards would spark and then they were destroyed. When the cards were brought up to positive 3 kilovolts, we then waited and watched to see what the current drawn by the cards was. After time, the cards dried by each method would only draw a current between 0 and 2 nanoamperes, a much more acceptable level. Then we applied the new waterproof seal and mounted the high voltage cards onto the chamber. After they were all mounted it is necessary to check what current the combination of the chamber and all 32 high voltage cards were drawing. This was still in the process and being slowly ramped up to higher voltages when I had to leave PSI.

A current leak in the chamber (Image 3) was found through observation of the chamber's behavior when under high voltage. In order to determine if it is possible to locate the leak I was given a Kirchoff problem to solve. Through measurements, we found I1=I2=60nA and I0=30nA and R1=10MΩ, R2=300MΩ



I2*R1 = I0/2*(R1+R2) but R1 is insignificant here so I2*R1 = I0/2*R2
Then I2/I0 = R2/(2*R1), then I2/I0 = 15 from the resistance values. But our measurements showed I2/I0 = 2. So our simple model of a single current leak cannot work. This calculation suggested that the chamber was leaking current from multiple points and the simple model we used is ineffective.

I worked several shifts on data taking runs of the experiment. During these shifts I was responsible to make sure that the data acquisition program continued to run properly and also to monitor the Slow Control for the experiment to make sure that everything was running properly. Below is a copy of the data acquisition computer screen that I was to monitor and make sure that everything was close to what is shown here. (Figure 1)

With Genna Petrov, on the cathode side of the chamber it was necessary to add a resistor to the already made pre-amplifier cards to change the threshold level. I also took bronze sheets and cut them to the appropriate size and drilled holes for them to be mounted on the pre-amplifier cards. The bronze sheets were for grounding and to create a heat sink with the thermal tape for the IC chips similarly to what I did for the anode side. Once all the cards were modifies and mounted on the chamber we looked at the noise from the cards and tried to find the grounding points that minimized the noise. When we found the best points and all the grounds were attached, we again checked for noise and if there were any other points for grounding that would further reduce the noise but the configuration that we had found seemed to be the best. (Image 4)

Figure 1

MIDAS experiment "muCap"			Fri Aug 1 23:15:09 2003 Refr:10		
Stop Pause ODB CNAF Messages ELog Alarms Programs History Config Help					
Run #1876	Running	Alarms: On	Restart: Yes	Data dir: /data	
Start: Fri Aug 1 23:14:28 2003			Running time: 0h00m41s		
Equipment	**FE Node**	**Events**	**Event rate[/s]**	**Data rate[kB/s]**	**Analyzed**
Crate 1	Crate 1@psfe90	634	18.3	1044.8	0.0%
Crate 2	(inactive)	12233	0.0	0.0	0.0%
Crate 3	Crate 3@psfe92	654	18.0	2293.1	0.0%
Crate 4	(inactive)	0	0.0	0.0	0.0%
HV	(inactive)	5	0.0	0.0	0.0%
Beamline	(inactive)	10614	0.0	0.1	0.0%
EBuilder	**Node**	**Tot. Events**	**Tot. Rate[/s]**	**Tot. Data[kB/s]**	**Analyzed**
Chan. Settings	pc3608	662	15.4	2893.9	0.0%
Channel		**Active**	**Events**	**MB written**	**GB total**
0 run01876.mid		Yes	663	119.527	613.559
Lazy Destination		**Progress**	**File Name**	**Speed [kb/s]**	**Total**
archivftp.psi.ch		2 %	archivftp.psi.ch	0.0	2.1 %
23:14:30 [Logger] Run #1876 started					
Logger [pc3608]		EBuilder [pc3608]		Crate 1 [psfe90]	
Crate 3 [psfe92]		mhttpd [pc3608]		Lazy_archivftp [pc3608]	

Image 1

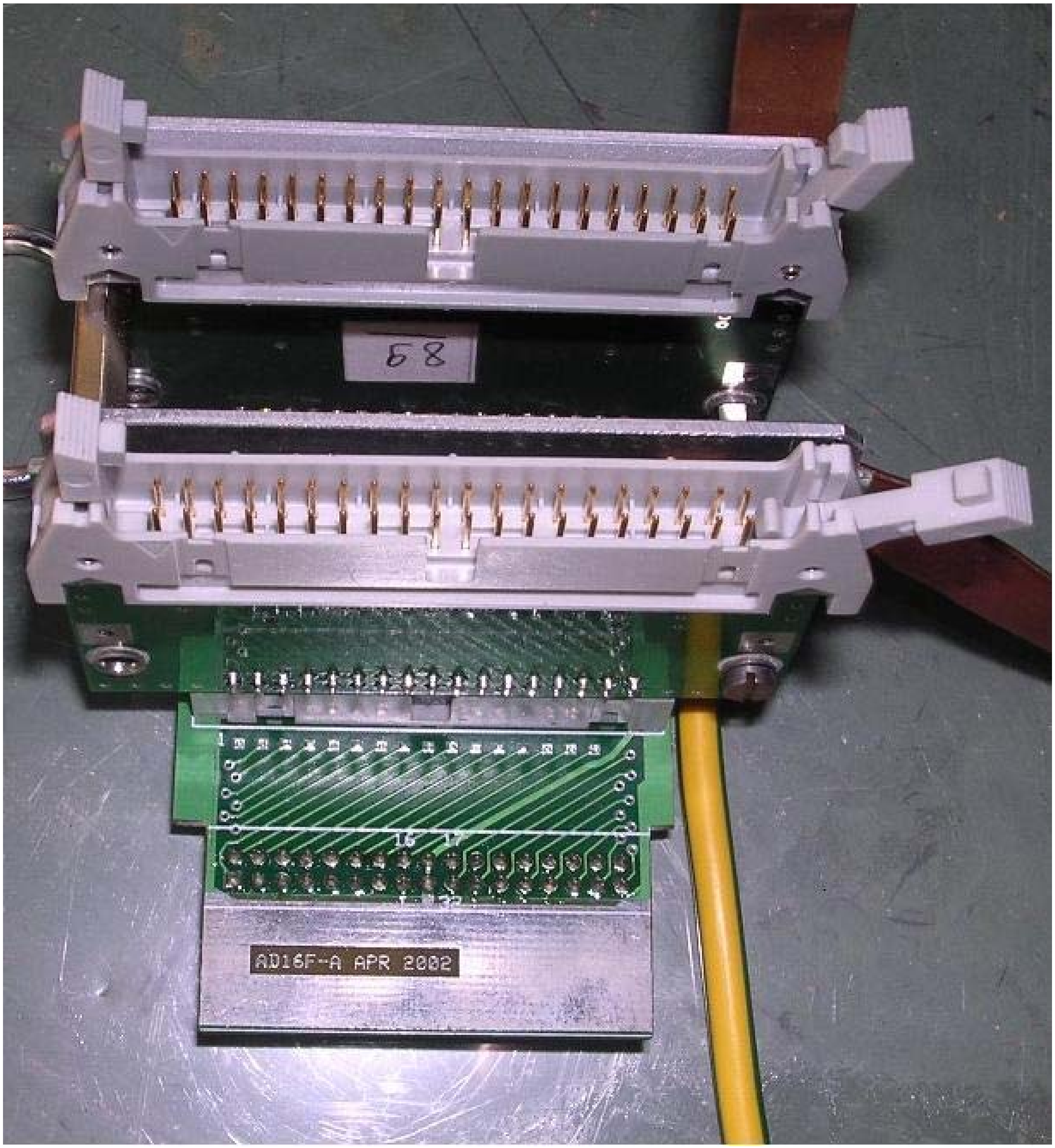


Image 2

Image 3

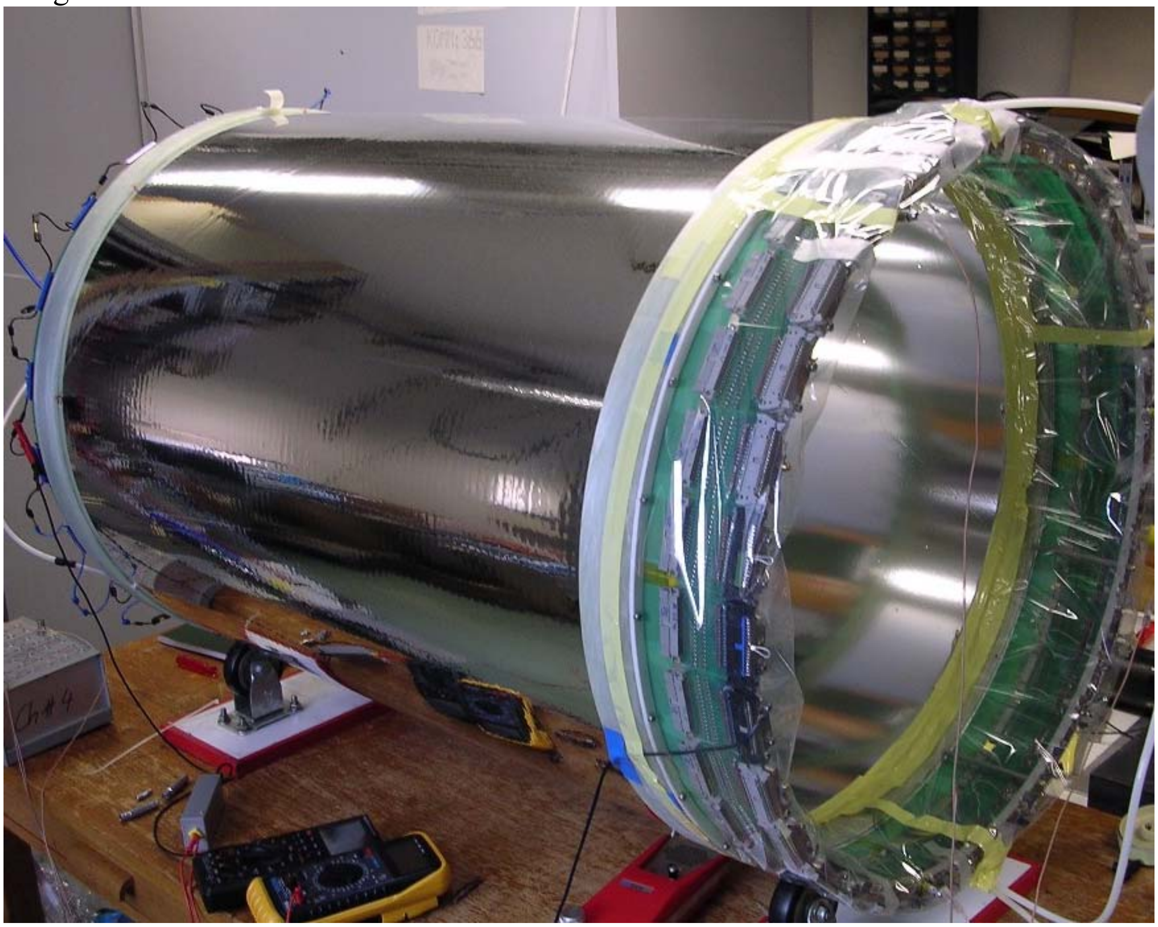


Image 4