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SUMMER SCHOOL STUDENT

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Final Report

Mu2e straw tube characterization with strodium source, and study of preamplifier-straw connections

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Introduction

Mu2e will search for a neutrino-less conversion of a muon into an electron, within the vicinity of a nucleus. It could discover the violation of Flavor Symmetry within the charged leptons. This process happens for fewer than 1 in 10^{12} muonic alluminium atoms. The muon go into transport solenoid and, if conversion occurs, the specific signature is an electron of 105 MeV. The conversion electron has an elic trajectory and the tracker, which is the first detector element, calculate the momentum of the particle. In Figure 1 the schematic view of the experiment is shown. My work concentrates on tracker's elements. Tracker resolution is about 180 keV and its elements need to be good to work in vacuum and in magnetic field.

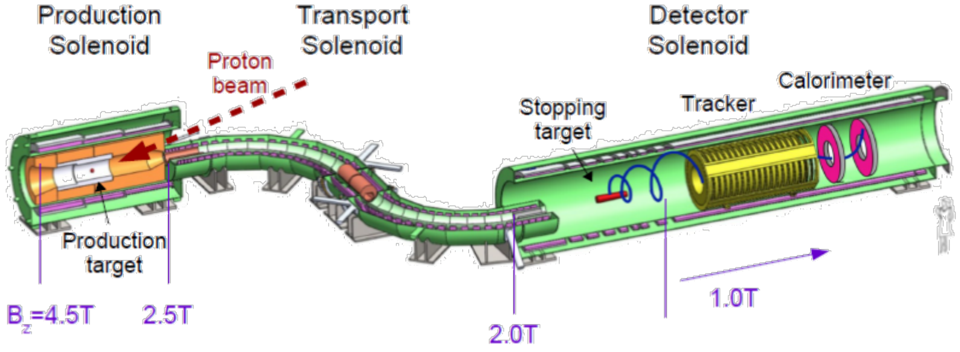


Figure 1: Scheme of the Mu2e experiment.

In the first chapter of this report we will give a look at Mu2e Tracker elements, with a particular view at straw tubes. In the second chapter we will talk about Data Taking with both shaper and no shaper channel and the relativ analysis. In the last chapter, we will show how many different type of connection we tried to connect preamplifiers to straws, and we will explain the importance of crosstalk. All the activities explained in Chapter 3 and 4 are made by me: data acquisition and analysys, preamplifiers assembling and crosstalk studies.

Chapter 1

Mu2e Tracker

1.1 Tracker Straw Tubes

Mu2e Tracker consists of gas drift tubes, or "straws". Tracker straw tubes of 5mm diameter are made by 15 μm mylar wall metalized and are from 0.5 to 1.2 m long. Anode wire is made of 25μm gold-plated tungsten and gas mixture used is made by Ar-CO2 80-20% at 1 atm. The tracker is composed by 18 station, one with 12 panels of 96 straw each, which covers 120°. The tracker detector needs to be highly segmented and with low mass, that could minimize multiple scattering. A schematic view of Mu2e Tracker station is shown in Figure 1.1, and a picture of one panel in Figure 1.2.

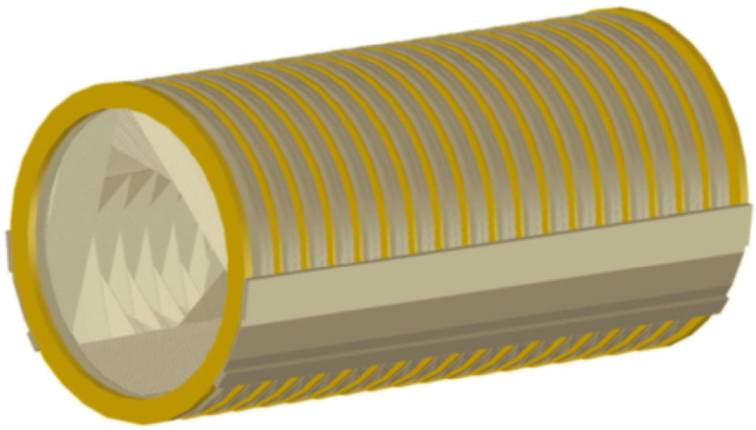


Figure 1.1: Schematic view of the Mu2e Tracker stations in the last configuration.

When the charged particle passes throught the straws, ionization occurs. The signal from ionization was collected by the anode wire. This is shown in Figure 1.3.

Figure 1.2: Picture of one panel of Mu2e Tracker, where it is possible to see the straw tubes and the readout electronics.

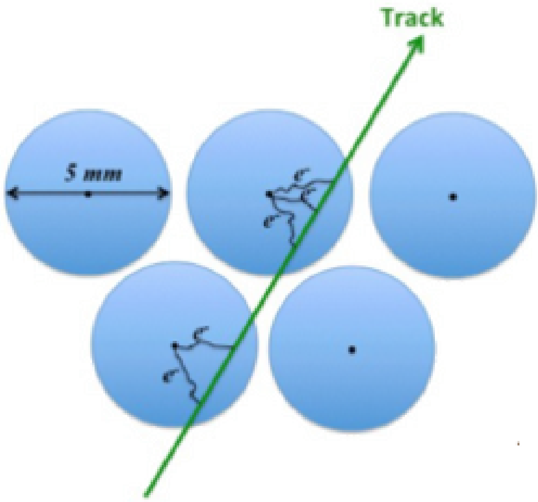


Figure 1.3: Ionization process of charge particle which passes trough the straw tubes of the tracker.

1.2 Front-End Electronics

The function of Front-End Electronics is readout the signal from both side of the straws and do the signal shaping and processing. There are two component of Front-End Electronis: the preamplifier board and the DRAC mezzanine card. The function of preamplifiers is, of course, to amplify the signal come from the straws; the DRAC has the function to digitize and transmits data to the acquisition system. A schematic view of the Front-End Electronis is shown in Figure 1.4. This FEC allows us to do some different measurements:

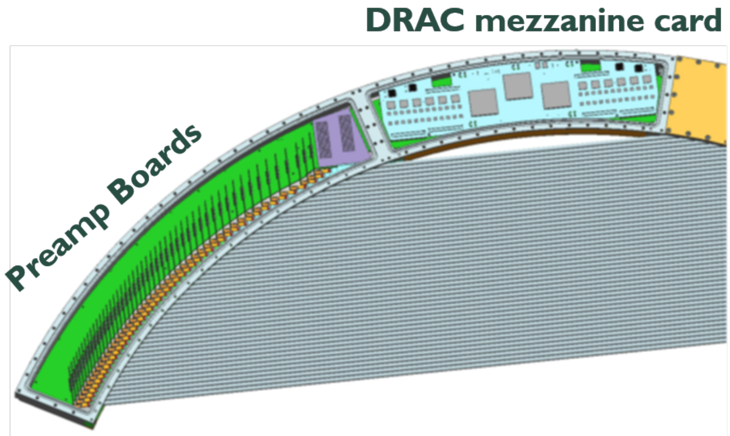


Figure 1.4: Front-End electronics on the panel. On the left side there is the preamp board, on the right there is the DRAC card.

- TDC measurements on drift time;
- Time difference measurements from the readout on both side of the straws;
- ADC for dE/dx measurement to identify highly-ionizing proton hits.

In this work the DRAC card will not be used, because I did measurements trough the waveforms acquired by the oscilloscope.

Chapter 2

Data Taking

2.1 Setup for taking data

I have took data with ^{90}Sr source to consider the Time Crossing resolution of the tracker straw tube. These results will be compared with the other taken with ^{55}Fe source by my supervisor in the last months. I took data at different high voltages and different conditions to compare different time resolutions. We are looking at data with Shaper and with no-Shaper channels: we will analyze the cuts that we need to do on data to clean data set from noise and we will look at the results in comparison with ^{55}Fe ones. In Figure 2.1, the setup of my measurements is shown. In that picture, we can see that the straw tube is inside an aluminium cover, that halps to reduce electromagnetic interferences. The Sr source is putted at the center of the straw, signals were acquired from the scope with a Rpi, these measurements take a very long time. The DRAC mezzanine card is used only for control, and not for digitization and readout, and gas mixture is Ar-CO_2 in percentage 80%-20%. The cathode is at ground, while we change the voltage only on the anode wire.

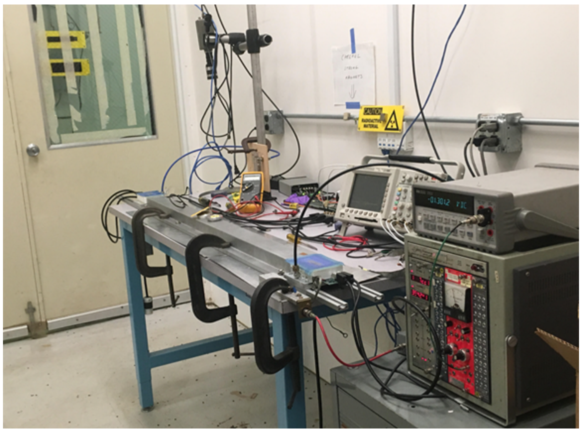


Figure 2.1: Setup in Lab 3 for taking data with Sr source.

2.2 Shaper and no-Shaper

Before looking at data, we need to explain how differences there are between Shape and No-Shape signals. The shaper serves a HighPass filter, it is a capacitor on the emitter of 2nd stage, as it is evidenced in Figure 2.2. This remore long tails

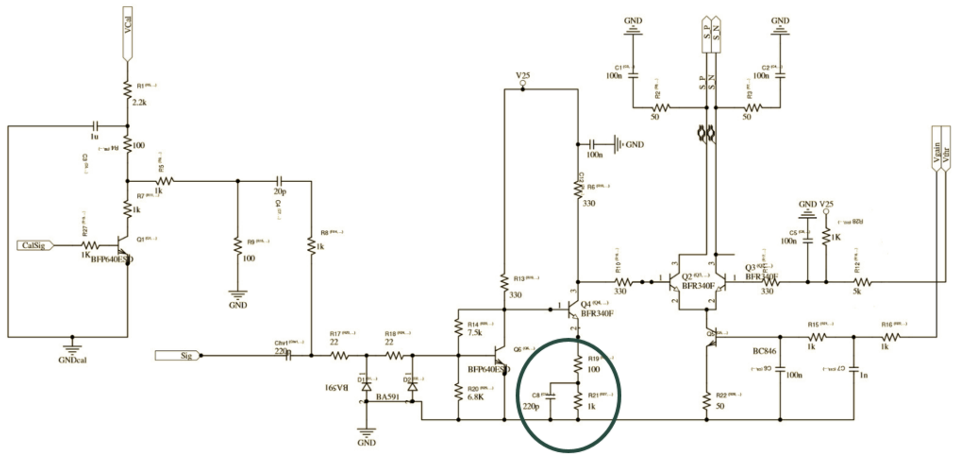


Figure 2.2: Electric circuit on the preamplifier. In the green circle the shaper capacitor is evidenced.

from the ion motion. To acquire the entire waveform we use No-Shape signal, that has a very long tails, as we can se from the Figure in 2.3. To get a better view of actual signal we want to remove that capacitor/shaper, and No-Shaper signals have a very long tail because the entire signal was acquired.

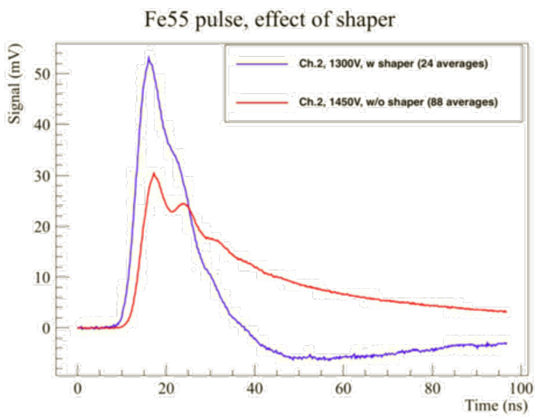


Figure 2.3: Difference between waveform acquired with shaper (blue) and another one acquired without shaper (red). In the shaper one it is possible to see that the long tail of the ion motion is not present.

2.3 Looking at data

Before look at data with Shaper and No-Shaper signal, we go through the different variables that will be object of our analysys.

2.3.1 Time Crossing Difference

Time Crossing difference is the first variable that we are looking at: the differences between CAL and HV outputs help us very much to clean the data from noise signals. Due to the fact that the source is putted at the centre of the straw, this difference should be equal to 0. In fact, referring to the Figure 2.4, as we can see two times t_1 and t_2 should be equal, such as $\Delta T \sim 0$. In Figure 2.5, it

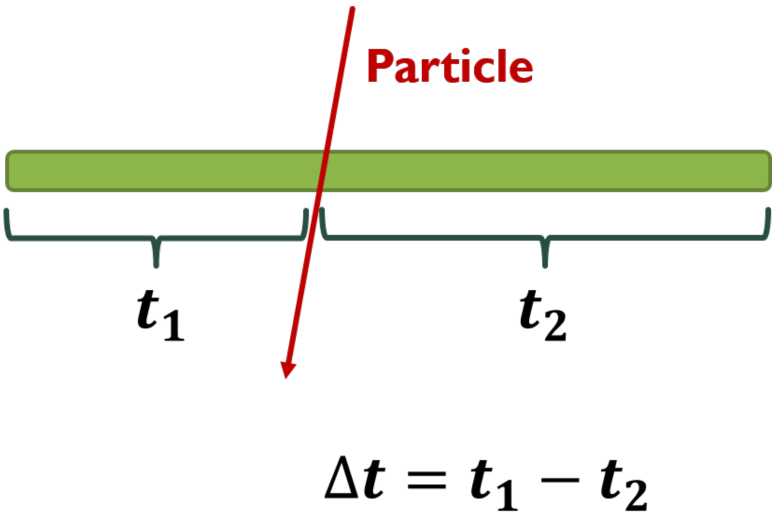


Figure 2.4:

is shown how a Time Crossing Difference distribution should be after cleaning procedure. The distribution in 2.5 regards data with No-Shaper channel at 1375 V on the anode wire. The cleaning procedure regards all the eventually peaks far from 0. When there are peaks at unexpected values of differences, we looket at waveforms that give us difference in these peaks. When these waveforms show that there are noise signals, we can cut these from our analysys. This happened, for example, in No-Shaper data at 1300V. Referring to the Figure 2.6 (a), we can see two peaks, one big peak around 0 ns and another one aroind -12 ns. This second peak is related to noise signals. After looked at the waveforms related to events in this peak, we cut this value of time crossing difference out from the analysys. An example of noise waveform is shown in Figure 2.6 (b).

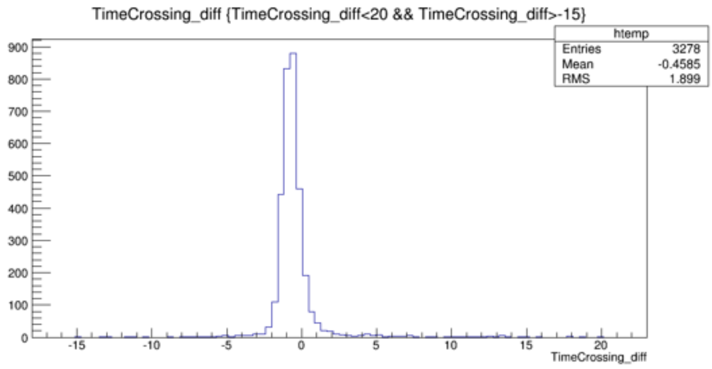
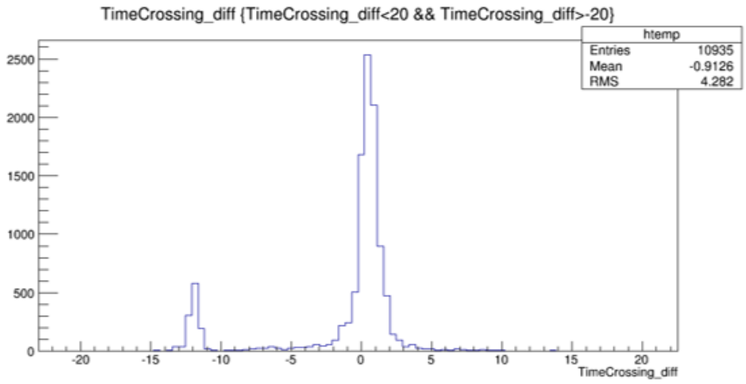
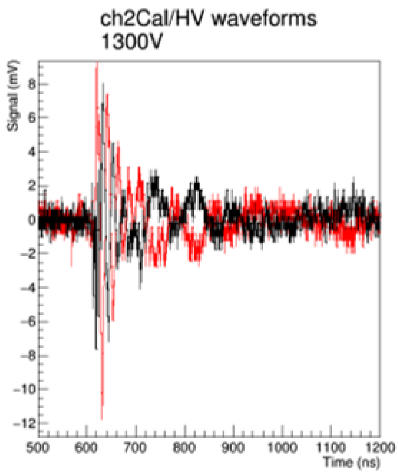


Figure 2.5: Time Crossing Difference distribution for Shaper data at 1375V. This distribution is considered after the cleaning procedure.



(a) Time Crossing Difference distribution for No-Shaper data at 1300V.

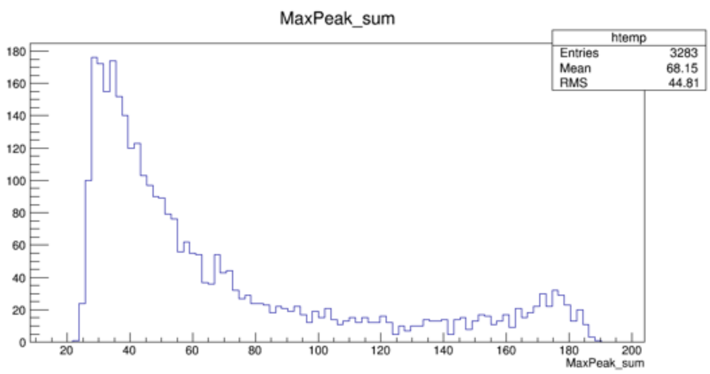


(b) Noise waveform.

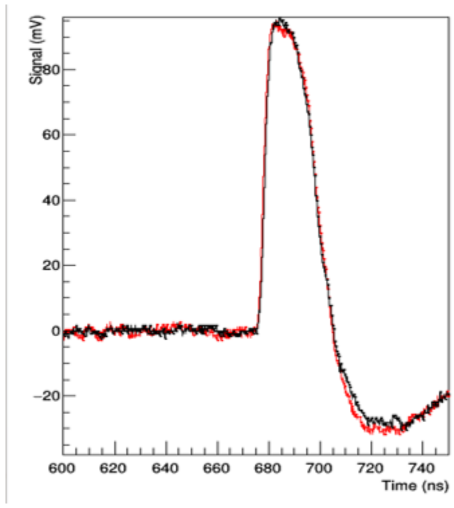
Figure 2.6:

2.3.2 Max Peak Sum Distribution

The Sum of the two Max Peaks of our waveforms CAL and HV is much important for energy distribution. Sometimes can happens that this sum is too large, and this is related to the saturation of the preamplifier. In fact, each preamplifier has its range, which is related to the fact that it cuts off the events due to the protons. Referrign to the Figure 2.7 (a), the energy distribution is shown. Around 170 mV another peak is presented. This peak is related to saturated events, so we decided to cut off events with sum bigger that 150 mV. In Figure 2.7 (b), an event with sum bigger than 150 mV is shown. This explain how is not very important the fact that the two signals waveforms are not saturated, but is important the sum of thesse two.



(a) Max Peak Sum distribution for events for Shaper data at 1375V.



(b) Signal waveform.

Figure 2.7:

2.3.3 Low Pass Frequency Dependance

I have studied Time Crossing resolution as a function of the Bandpass. This cut is applied on software, not changing the preamplifier. Each preamplifier has its own rage of frequencies, I've just moved higher limit of this range. With the increasing of LowPass frequencies we expect that signals appear more clean, as the effect of bandpass. In Figure 2.8 the same waveform before (BLUE) and after (RED) BW limitation is shown. With higher BW we retain more of the fast rising edge, so we expect more amplitude and better time resolution. After it will be shown the Time resolution as a function of the Bandpass.

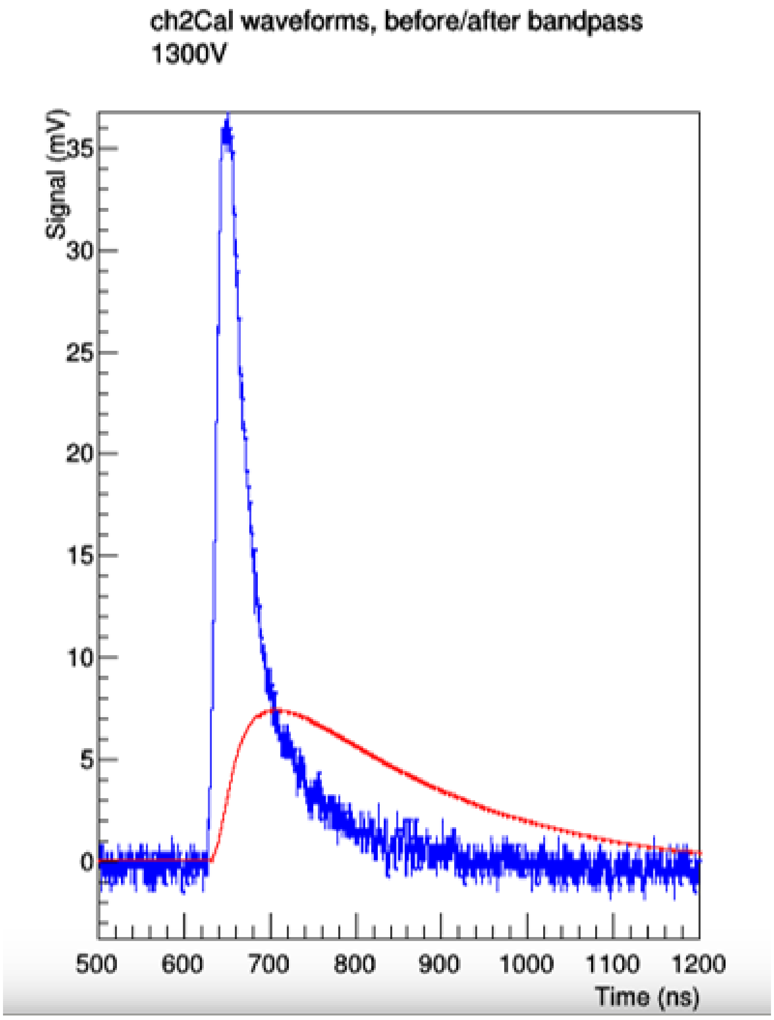


Figure 2.8:

2.4 Time Difference Resolution

To study Time Difference Resolution, I compared different results obtained by me with ^{90}Sr source, with results from ^{55}Fe obtained by my supervisor. We used for both sources both Shaper and No-Shaper channels. For each voltage, I considered Time Difference distribution at different Low Pass frequencies, from 5 MHz to 180 MHz. For each frequency I did a gaussian fit on the distribution and extract the sigma value from fit parameters. In Figure 2.9 an example of Time Crossing differences distribution at 1450V with Low Pass Frequency = 5 MHz and Shaper channel is shown. I repeated this procedure for all voltages and frequencies.

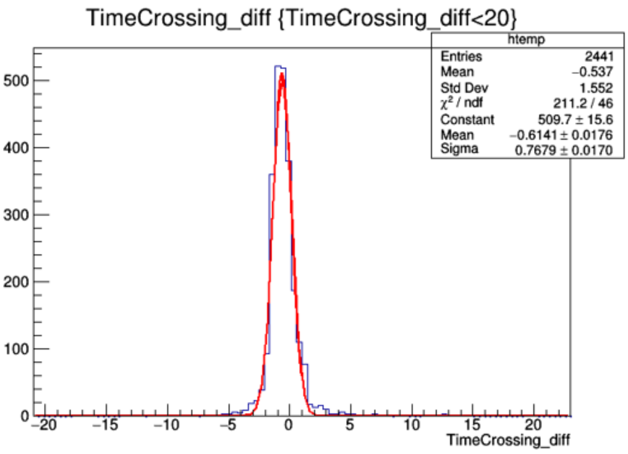


Figure 2.9: Example of the gaussian fit on the time crossing difference distribution.

2.4.1 No-Shaper data

Now we can look at Time Resolution for Sr source in comparison with Fe one. In Figure 2.10 the comparison for No-Shaper channel is shown. After cleaning procedure from noise, I have studied time resolution for different Low Pass frequency. I moved LowPass frequency between 5 to 180 MHz looking at how the time resolution changes. The resolution is considered the sigma of the gaus function that we used to fit the Time Crossing differences distribution. In Figure 2.10 the distributions of time resolution from data obtained with ^{90}Sr source considering sigma of the gaus fit function, in comparison with values obtained with ^{55}Fe source considering RMS of the distribution of time differences. The reason because Sr resolution is worse is because Sr is a source of electron (our object of study), and Fe is a source of photon. The two different processes from electron and photon are the reasons for the different resolution. The photon deposits its entire energy and the related signal is very clear. The electron occurs some ionization in its path, so the signal is less clean because of the ionization clusters.

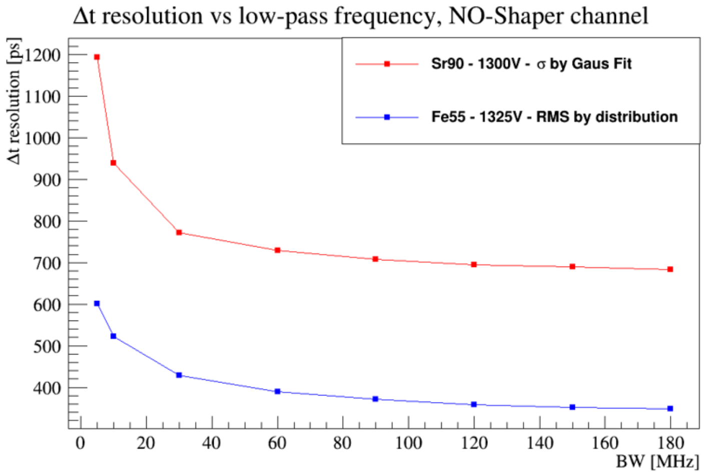


Figure 2.10:

2.4.2 Shaper data

In the same way as before we studied resolution for Shaper data. In Figure 2.11 the comparison between the two different sources is shown. The blue points are related to data at 1375 V on the aode wire, while the green points are related to data at 1450 V on the anode. For both the data sets it has been necessary the "Saturation cut", in addition to the cleaning procedure from noise. Data from Sr source are shown in comparison with Fe data (red points). Also in this shaper configuration, the behaviors of the curves respect what is expected from No-Shaper configuration.

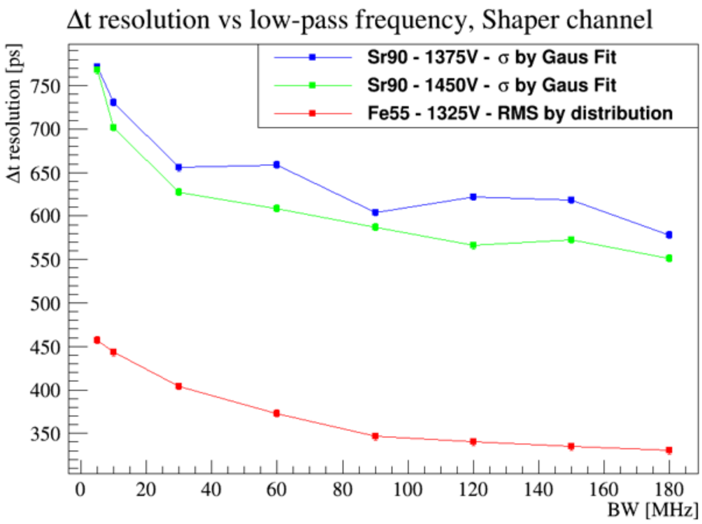


Figure 2.11:

Chapter 3

Assembling of Tracker's preamplifier and Crosstalk

3.1 Preamplifier Assembling

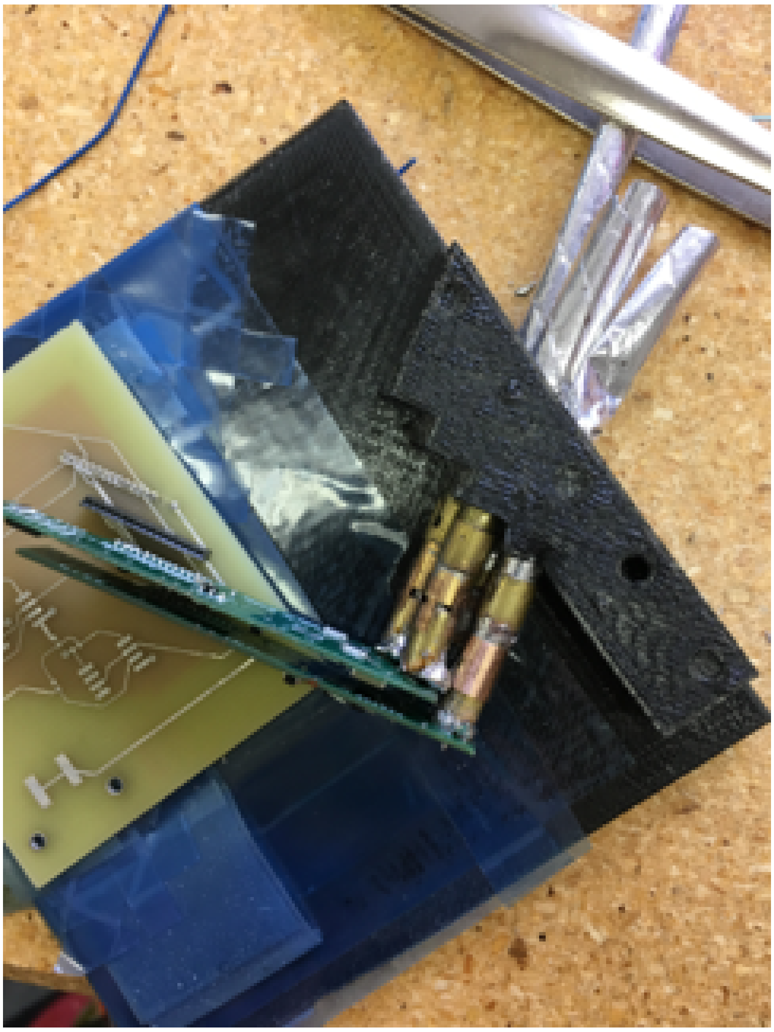
I study the preamplifier commection with straw on the mock-up that reproduces the distances between preamp and straws. The hard part is cathode connection. In current design the anode connection is made with a wire and the cathode is connected through a sliding "sleeve" part. The sleeve's design is very important for some reasons:

- Holes allow control with minimal access;
- Slot allows expansion and restoring force ensures good connection;
- Slot and holes allow gas flow through straws;

The connection design and method was tested on a 3D-printed mockup. In Figure 3.1 it is possible to see the sleeves that I used for cathode connection and the mockup used for the tests. It is also important to extimate how much time it's necessary to do the connections. The setup that I used (Figure 3.2) reproduces preamp/straw distances as in the actual system. The connection procedure is the following:

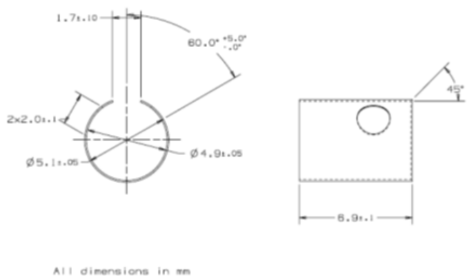
- At first I made anode connection;
- Then I mount preamp on the electronics;
- After I slide the cathode connection between cathode on the straw and ground on the preamp.

And the average Time per connection is:



(a) 3-D printed Mockup used for my tests.

(b) Slice used for cathode connection.



(c)

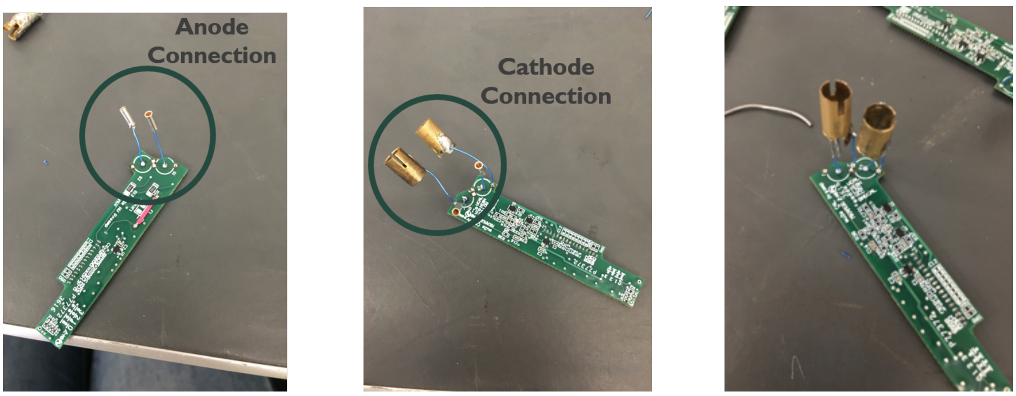
Figure 3.1:

- About 35s to make the anode connection and mounting preamp on the electronics;
- About 20s to make the cathode connection.

Connection is tested each time to ensure that connections are successful.

Figure 3.2: Mounted preamplifiers on the 3D mockup.

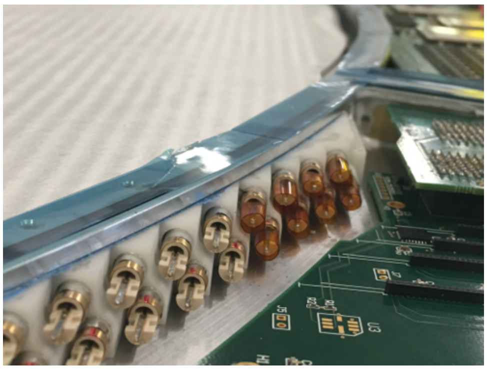
In addition to that I assempled some preamplifiers for the board that Mu2e Tracker group now is testing in Lab 3. The connections that I made and the complete preamplifier are in Figre 3.3. On the board it is not possible to connect



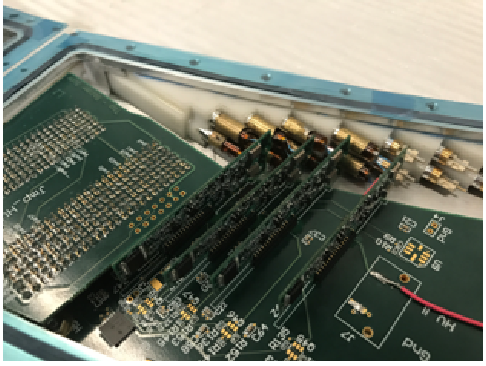
(a) Anode connection. (b) Cathode connection. (c) Complete preamplifier.

Figure 3.3:

the cathode through the slice because on the straw there isn't cathode tube. Before closing the panel I put on the anode connection some kapton foils, this helps because reduce discharges between HV and ground. This is very important because when the panel is closed it is full of gas, so it is very difficult to be sure that there are no leaks. In the Figure 3.4 it is possible to see a picture when the kapton foil is on the straw (Fig. 3.4 (a)) and another picture when there is the board complete with the preamplifiers (Fig. 3.4 (b)). All these connections were made by me.



(a) Straw tubes with kapton foils.



(b) Complete board with connection between straws and preamplifiers.

Figure 3.4:

3.2 Crosstalk data

To study Crosstalk for our data, we should give a first look at what crosstalk is. Large signal on a channel can induce some small signal on neighboring channels. The signal on the victim channel is called Crosstalk. I want to estimate the crosstalk using two different ways to connect the preamplifier cathode to the straw cathode and taking data at the same voltage. To do that, we take data at 1490 V with ^{55}Fe source with all HV and CAL channels, with the same setup that we explained in Chapter 3, triggering on one channel and seeing crosstalk on the other one. We compare two different connection of the preamplifiers to the straw tube, called *shielding* and *noshielding*, and shown in Figure 3.5. No-shielding connection is with only wire and cathode slice on straw, shielding one is with cathode shielding on the preamp.

(a) Shielding configuration.

(b) No-Shielding configuration.

Figure 3.5:

I considered some different intervals for Max Peak values of each waveform. After that I made the averaging of these waveforms to understand which is the percentage of crosstalk in comparison with signal. Averaging waveforms we reduce noise signal and we can look only at crosstalk, the averaged Signal and Crosstalk waveforms is shown in Figure 3.6.

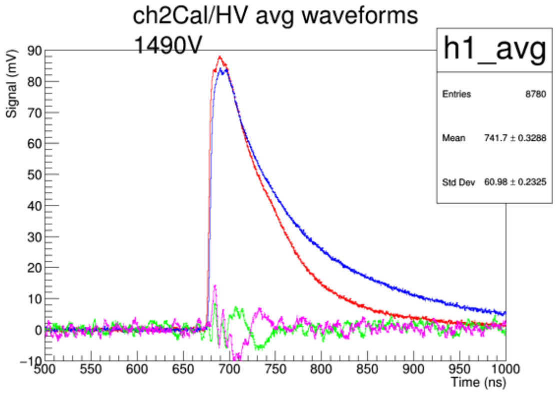


Figure 3.6: Crosstalk and signal waveforms.

For each interval I considered the Max Peak value of Crosstalk averaged waveform as a function of Max Peak of the signal. Its behavior is shown in Figure 3.7. In this plot we compare two different shield configuration: at this point, we can clearly say that crosstalk is clearly reduced with shielding configuration. This is very important for avoiding threshold crossings in neighbouring straws after proton hit. In addition, crosstalk over the connections is a small part of the total: it can come from cable, straws and preamp.

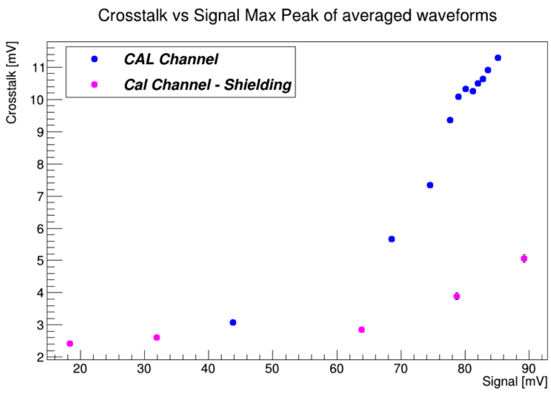


Figure 3.7: Crosstalk waveform peak as a function of Signal waveform peak.

Conclusions

In this work I have studied the behavior of straw tube of Mu2e Tracker system. I compare my results on Time Resolution with Sr source with results about Fe source with which my supervisor worked in the last months. After that I helped the group in the assempling of the preamplifiers that they used to test the board in Lab 3. After that I studied some conditions about connection that can help to reduce crosstalk, and I and my supervisor agreed about the fact that shielding connection clearly reduces the crosstalk.