MU2E STRAW TUBE CHARACTERIZATION WITH STRODIUM SOURCE

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FINAL REVIEW

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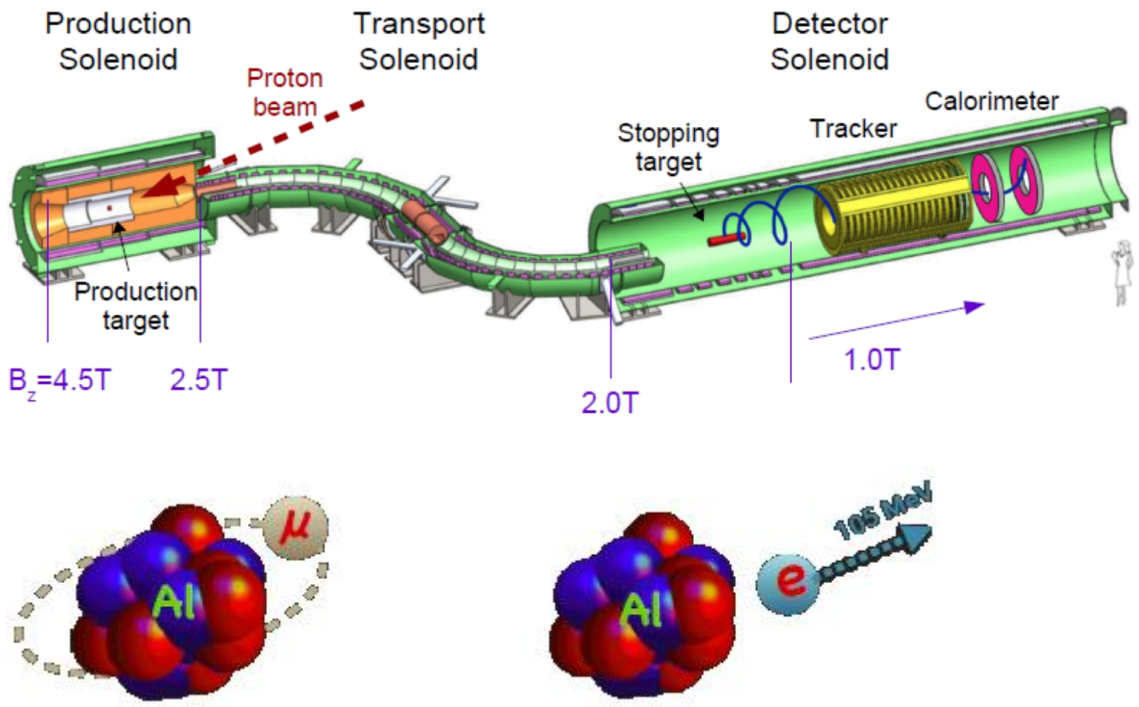
SUMMARY

- Introduction
  - First Look at Mu2e Experiment
  - Mu2e Straw Tracker
- Data Taking
  - Time Difference Resolution and Energy Spectrum
  - No-Shaper and Shaper Channel data
  - Comparison between ^{90}Sr and ^{55}Fe sources
- Preampifier/Straw Connection
  - Method and Alternatives
  - Application and Considerations
  - Crosstalk

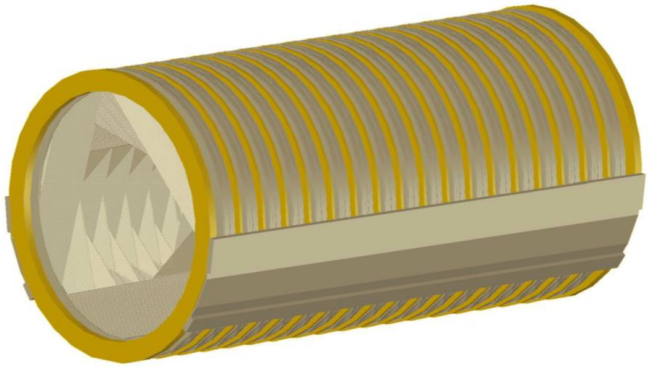
INTRODUCTION

MU2E EXPERIMENT



- Mu2e will search for signatures of Charged Lepton Flavor Violation
- The Mu2e Tracker is designed to efficiently detect conversion electron and reconstruct its trajectory
- Resolution about 180 keV - Specific signature: 105MeV electron
- Operation in vacuum and in magnetic field
- Must reject backgrounds from conventional processes

MU2E STRAW TRACKER



- Consists of gas drift tubes, or "straws"
- Low mass, minimize multiple scattering
- Highly segmented
- Lifetime ~10yrs
- Operation in vacuum
- 12 panels per station, 18 stations

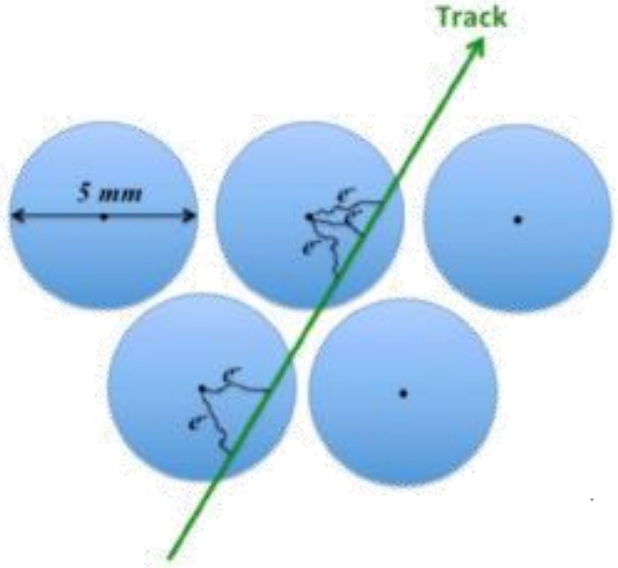
120° panel of 96 straws each

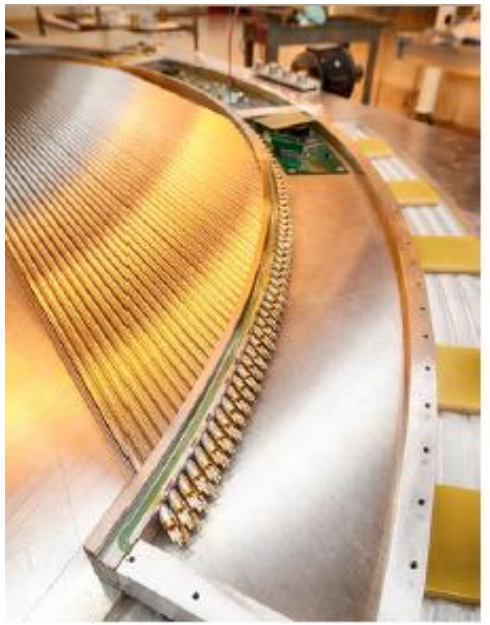
5mm diameter, 0.5-1.2m long

15μm mylar wall, metalized

25μm gold-plated tungsten wire

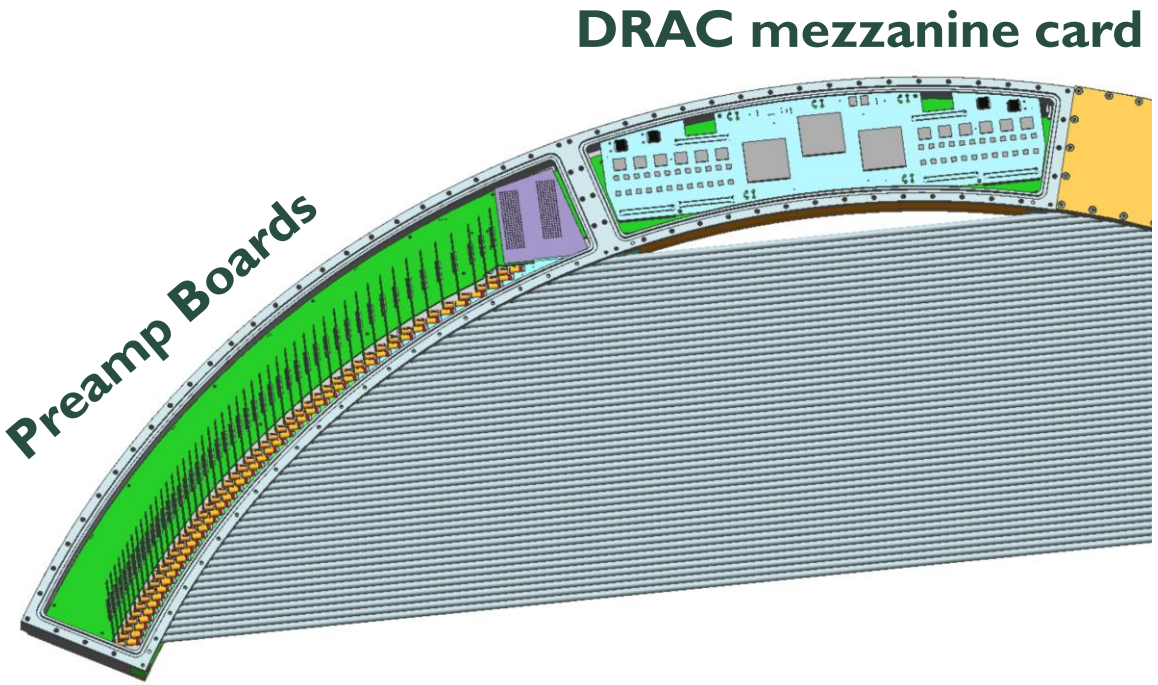
Gas mixture Ar:CO_2 80%-20%





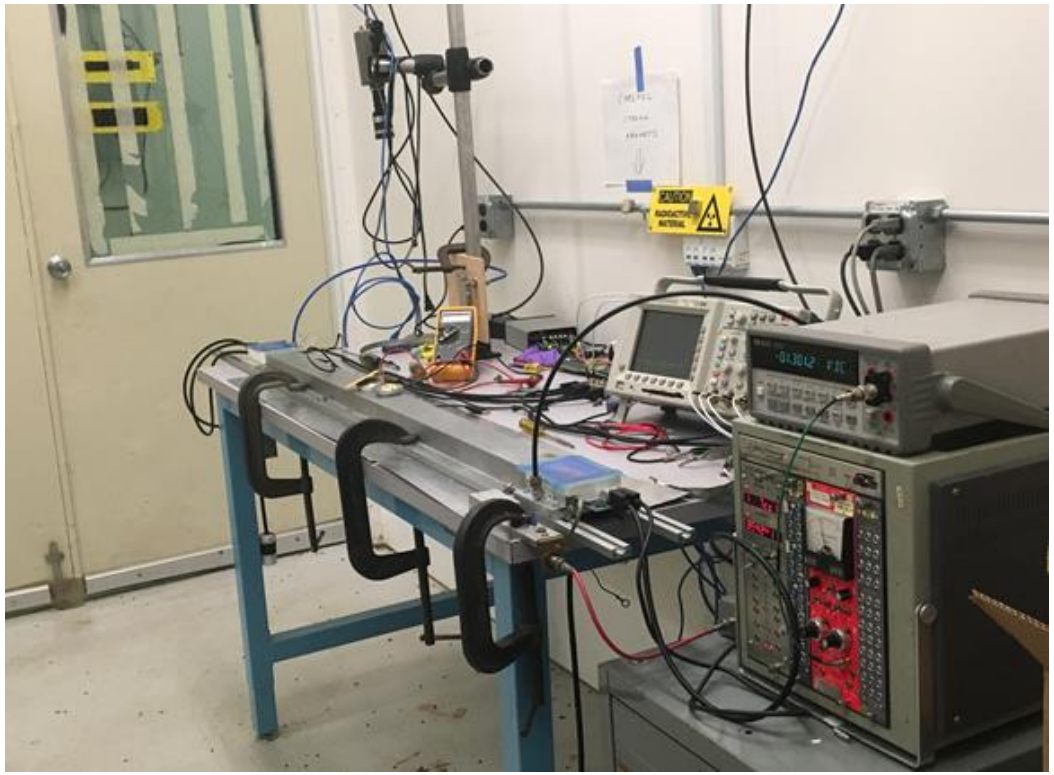
TRACKER FRONT-END ELECTRONICS

- Front-End Electronics
  - Readout of straw signals on both sides
  - Signal shaping and processing
  - Digitization and DataTrasmission
- Measurements
  - TDC measurement of drift time
  - Straw readout from both ends allows time-difference measurement
  - ADC for dE/dx measurement to identify highly-ionizing proton hits



DATA TAKING

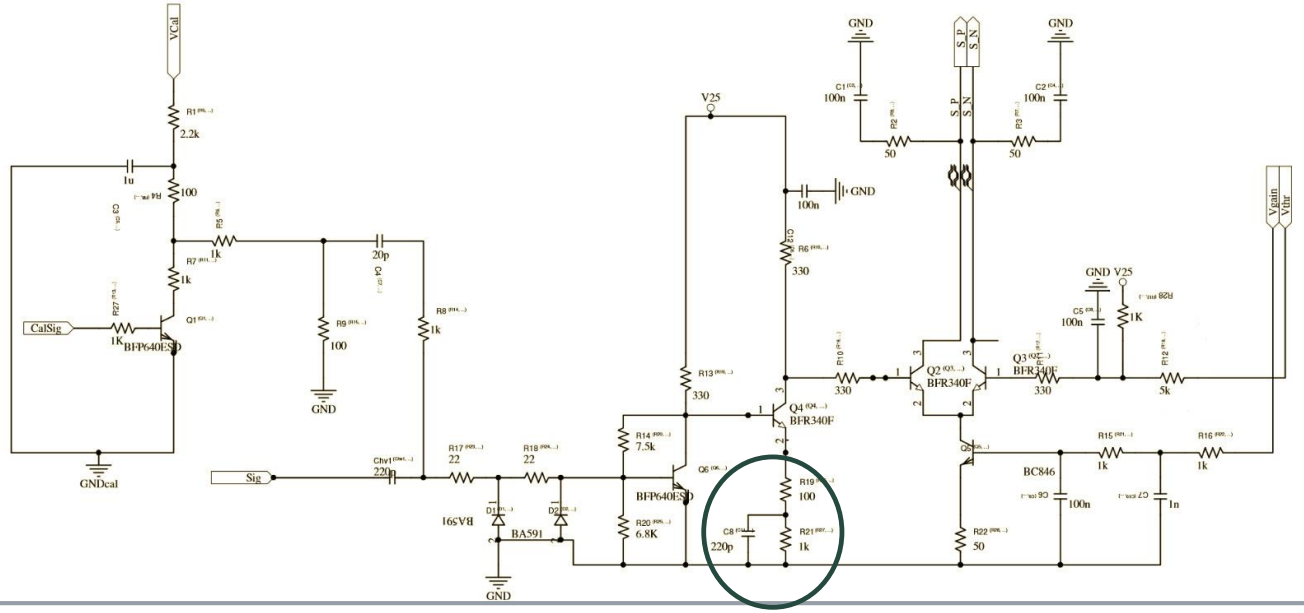
SETUP SUMMARY



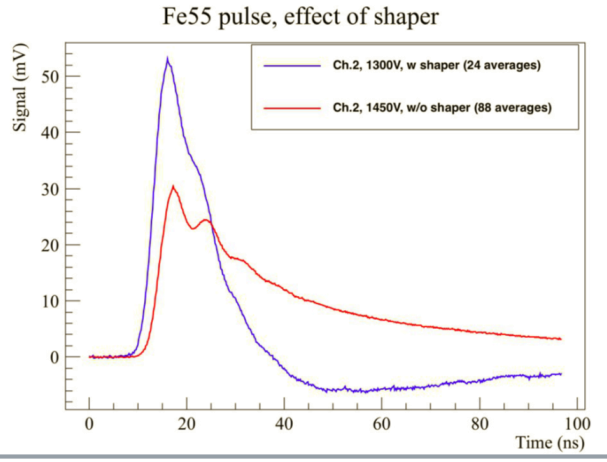
Straw Test Setup with custom electronics

- Straws inside an aluminum cover, to reduce electromagnetic interference
- ^{90}Sr Source put at the center of the straw
- DRAC mezzanine card is only used for control
- Signal from the scope
- Gas Mixture Ar-CO_2 80%-20%
- Data acquisition with Rpi, long term measurements

Because we read from the scope, and we have access to the analog signal from the straws, we can directly observe the effect of the Shaper.

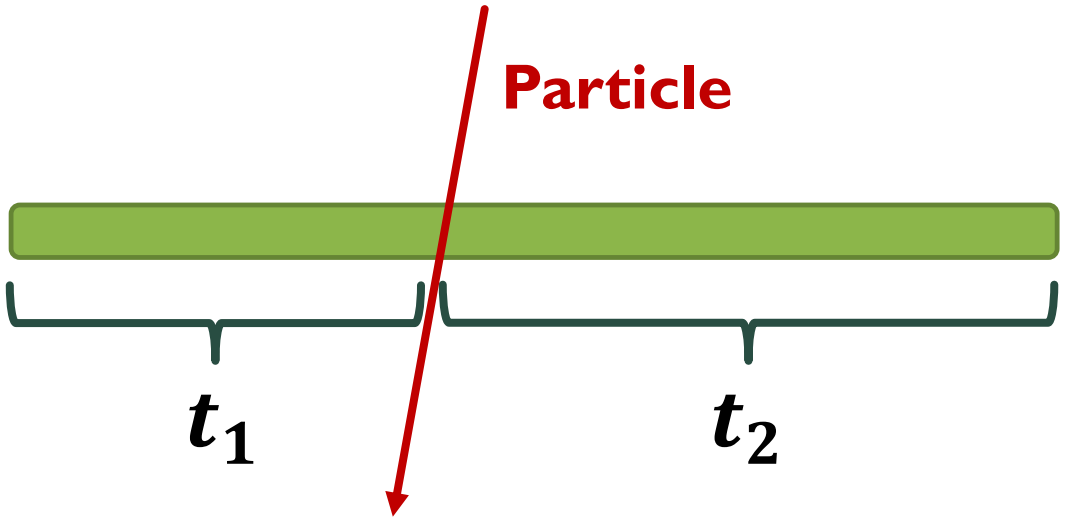


The Shaper is a capacitor on emitter of the 2nd stage
It serves as high pass filter, boosts higher frequencies, removing long tail from ion motion.



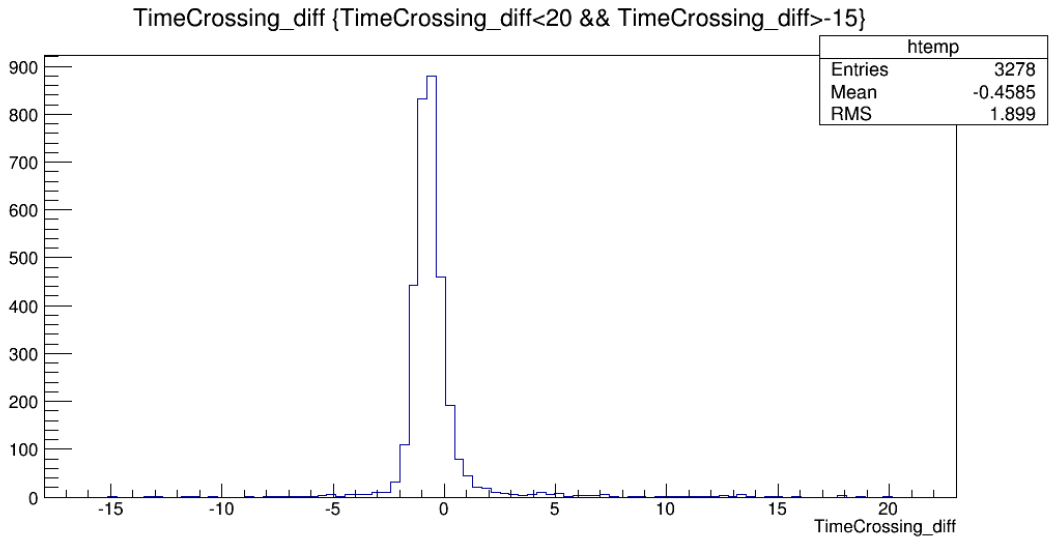
SHAPER AND NO-SHAPER CHANNELS

TIME DIFFERENCE DISTRIBUTION



$$\Delta t = t_1 - t_2$$

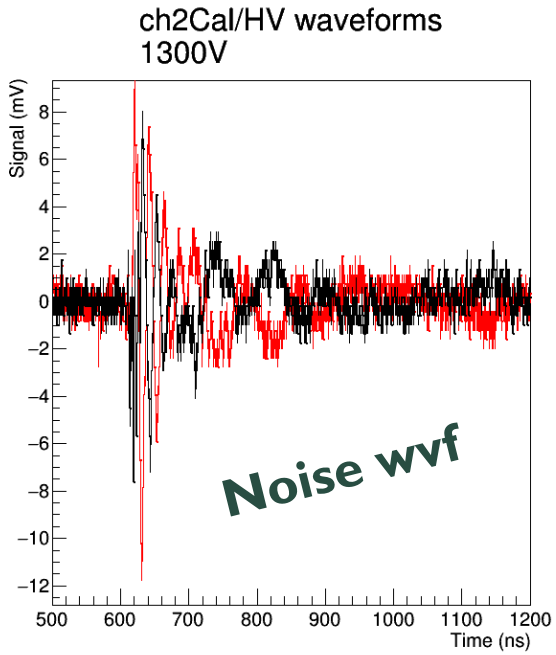
Plot by Shaper data – 1375V

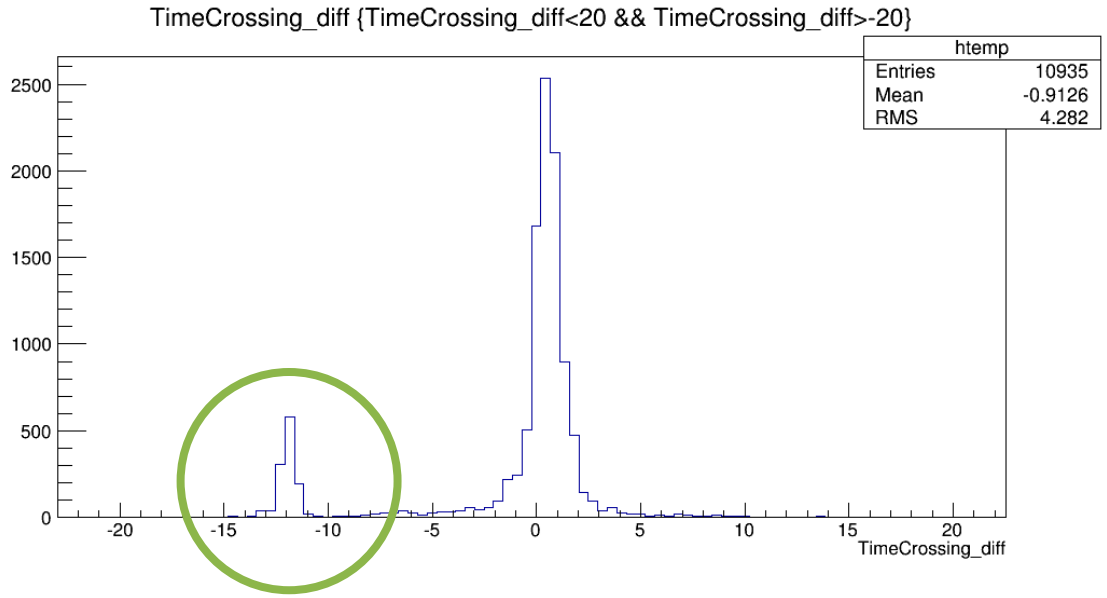


TIME DIFFERENCE DISTRIBUTION – NOISE CUT

The second Peak around -12 ns is made by noise. If we look at wvf in that Peak there are only noise wvf (shown in Figure).

Study this variable helps us to decide the best cut to apply to our data: this cut will be called ***Noise cut***



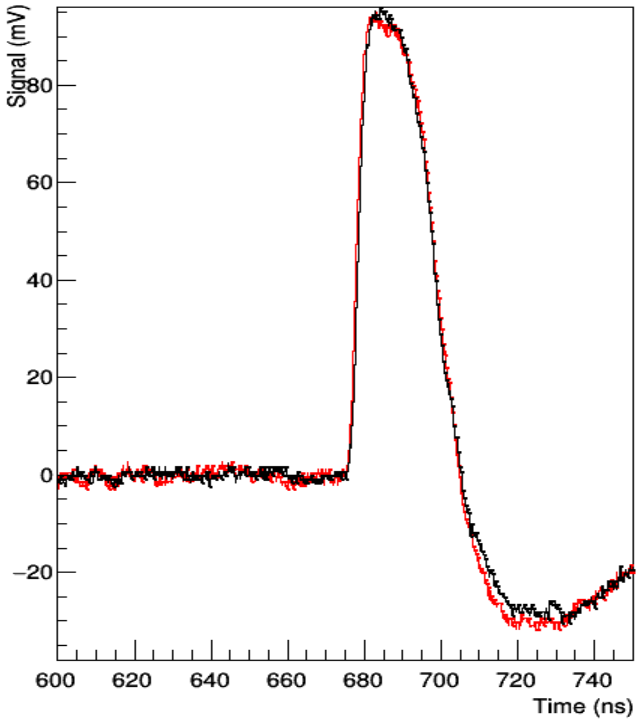


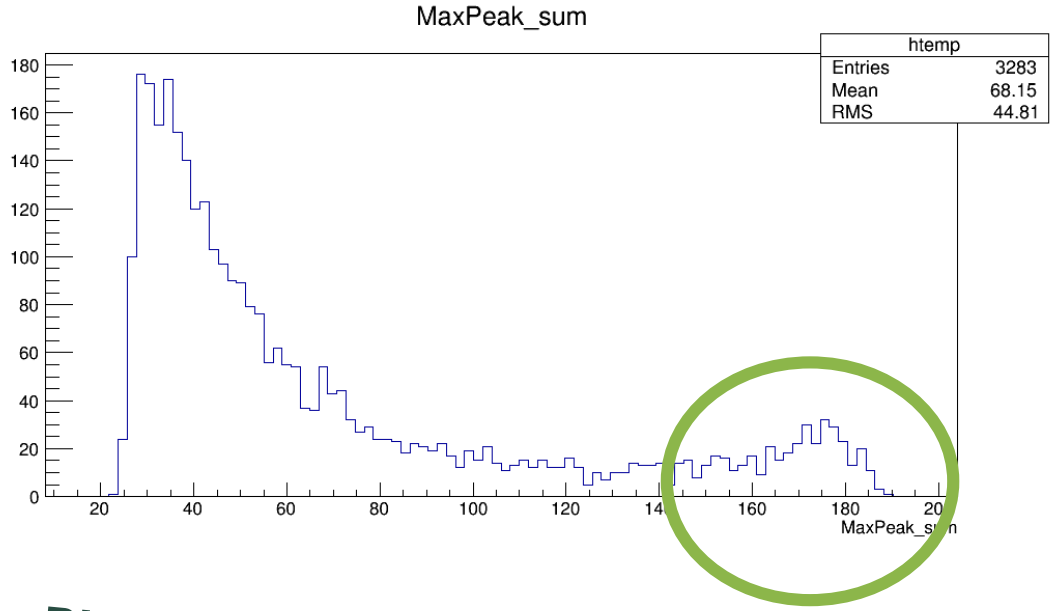
Plot by No-Shaper data – 1300V

MAX PEAK SUM DISTRIBUTION – SATURATION CUT

- Sometimes can happen that the sum of the two peak of Cal and HV channels is too large. This is due to the saturation of the preamplifier.

- To avoid this signal, we consider only waveforms with MaxPeak sum < 150 mV. This cut will be called ***Saturation cut***

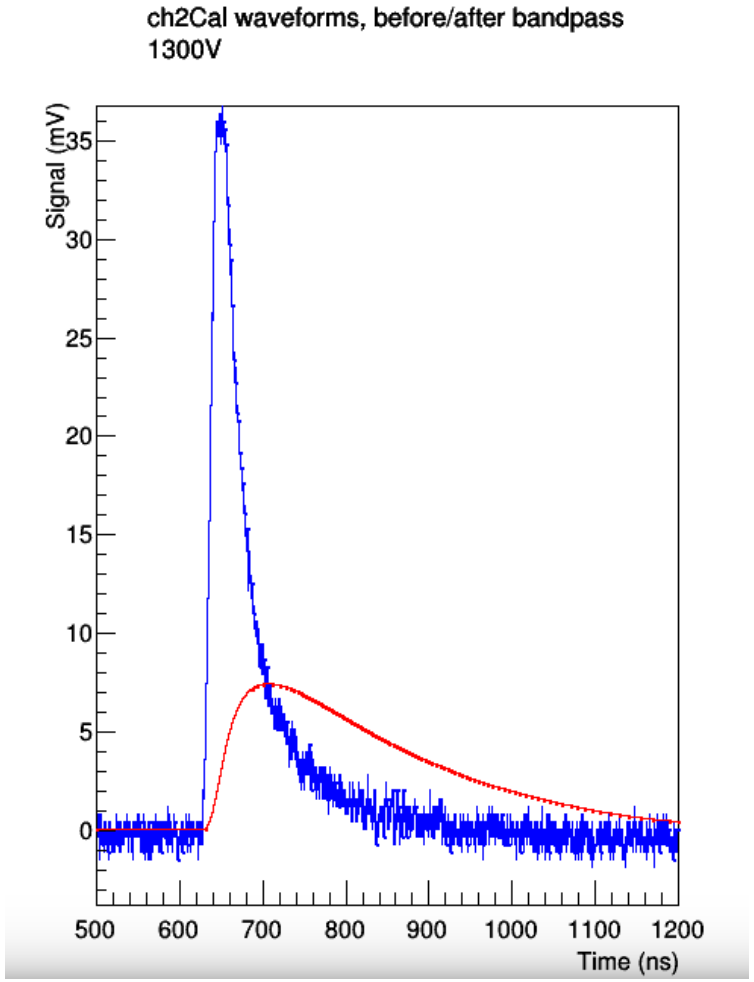




Plot by Shaper data – 1375V

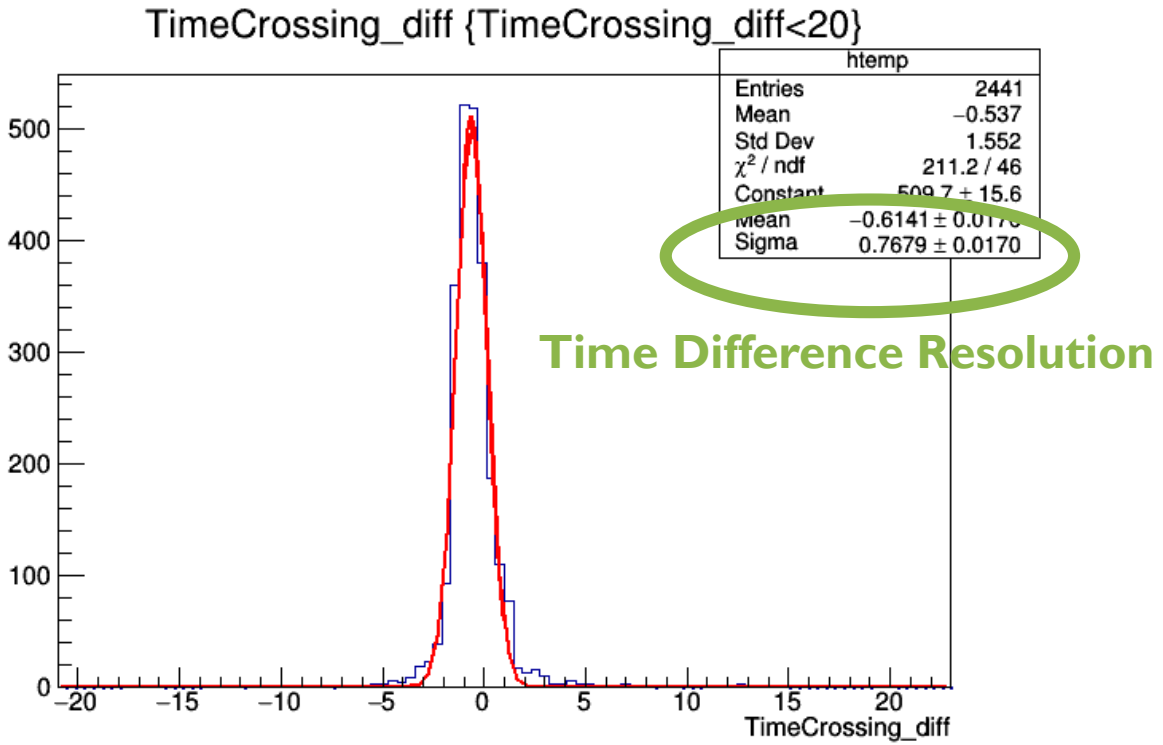
LOW PASS FREQUENCY DEPENDENCE

- Time resolution was studied as a function of bandwidth (BW), limiting it in software
- In Figure the same waveform before (BLUE) and after (RED) BW limitation are shown
- With higher BW we retain more of the fast rising edge, so we expect more amplitude and better time resolution



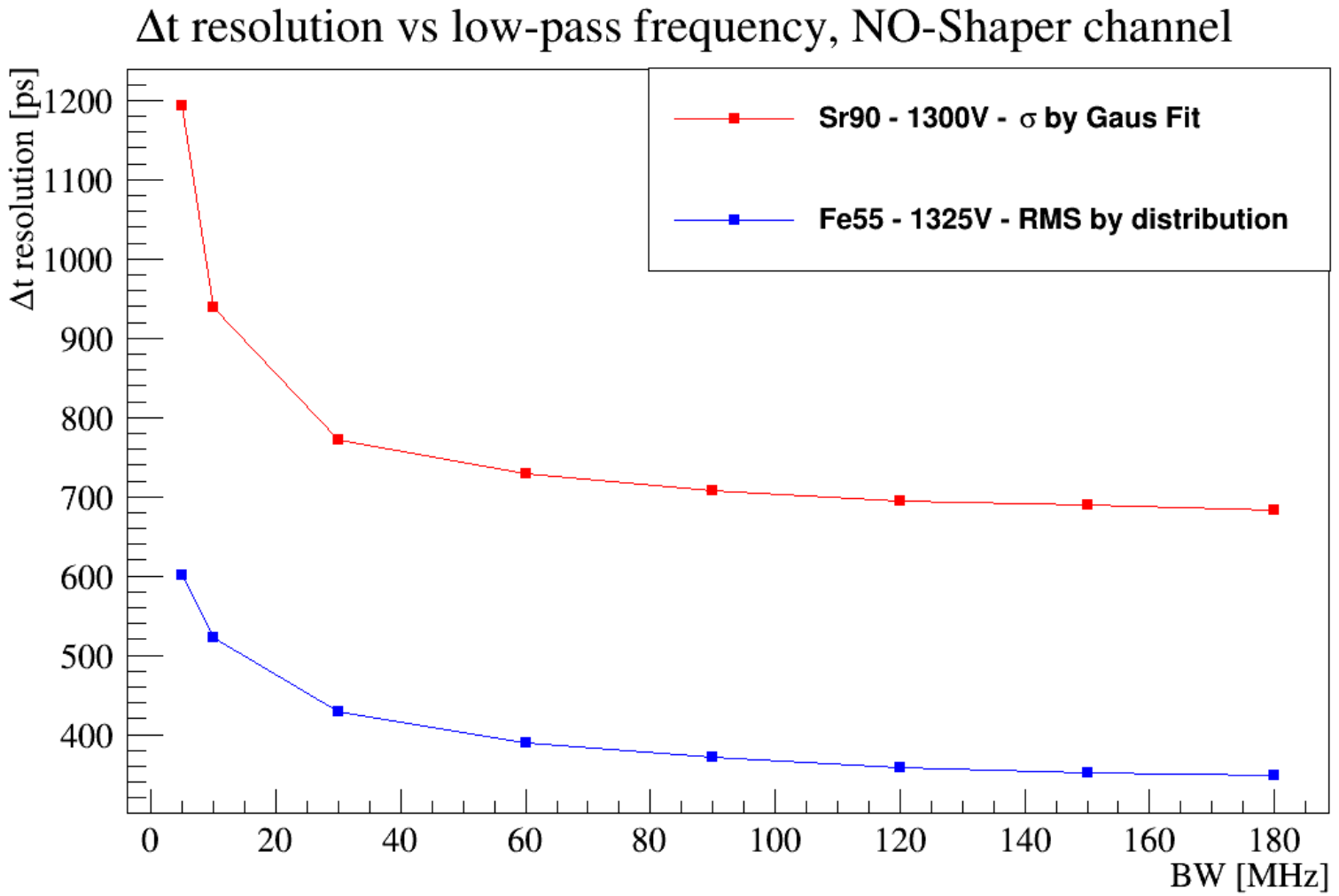
TIME DIFFERENCE RESOLUTION

- I compared different voltages data with ^{90}Sr Source with data with ^{55}Fe Source, both with Shaper and No-Shaper channel
- For each voltage, I considered Time Differences distribution at different Low Pass Frequencies
  - For each frequency I did a fit on the distribution with gauss function and extract sigma value from the fit parameters
- On the right is shown an example of Time Crossing differences distribution at 1450V with Low Pass Frequency = 5 MHz and Shaper channel



NO SHAPER DATA

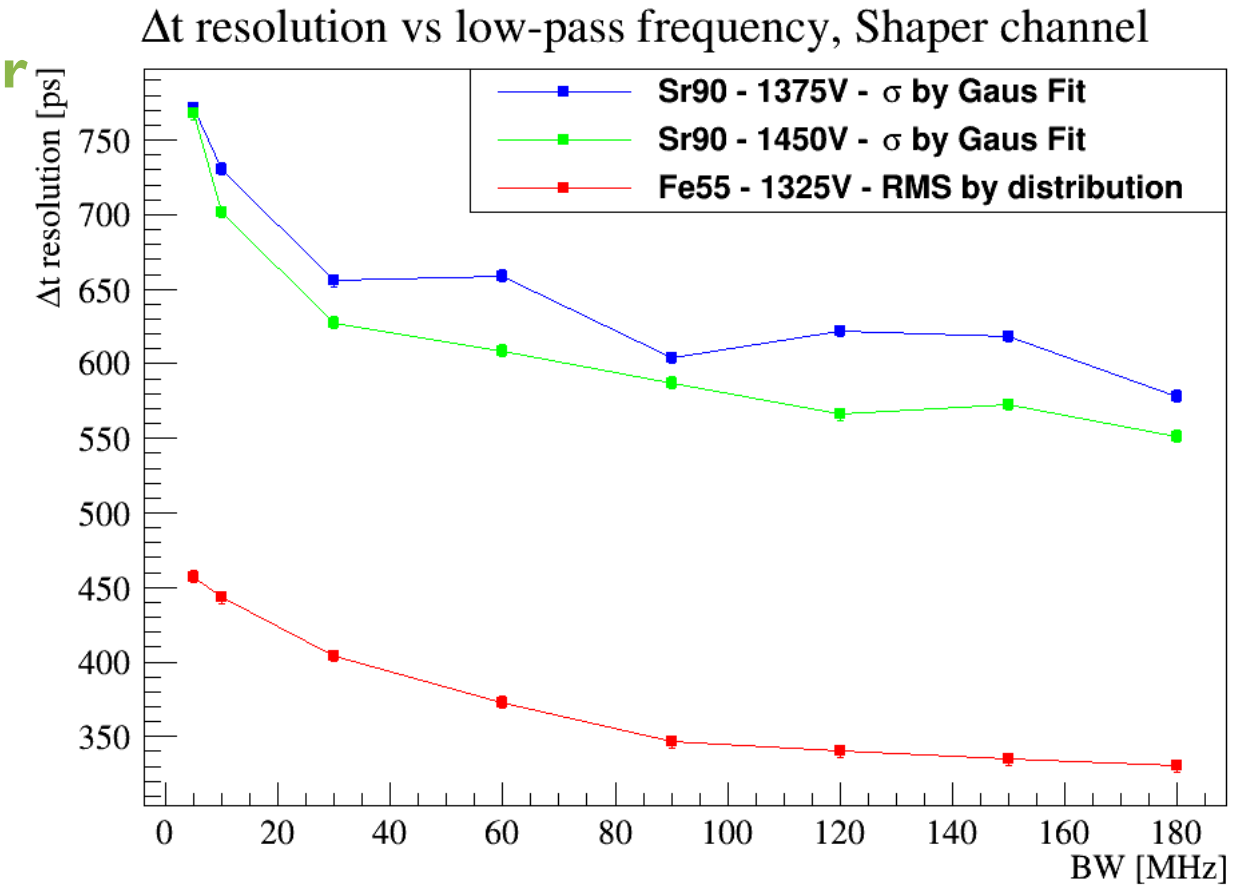
- No Shaper data
- Anode HV = 1300V
- Gas Mixture Ar-CO_2 80%-20%
- ***Noise cut***



SHAPER DATA – 1375 V & 1450 V

TWO DIFFERENT VOLTAGES FOR ^{90}Sr

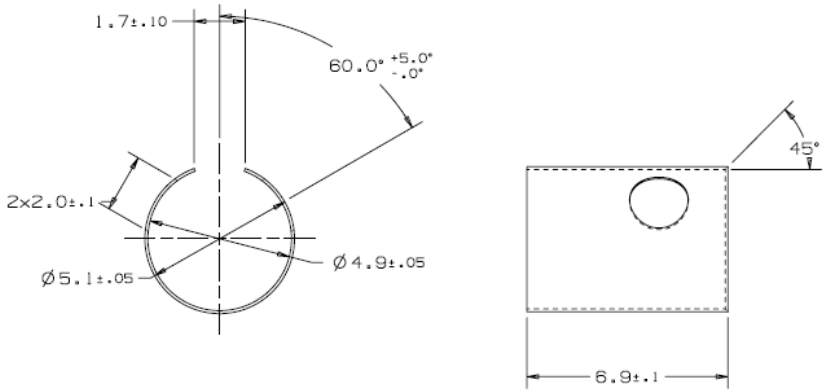
- Anode HV = 1375V (*blue points*), with ***Noise*** and ***Saturation cuts***
- Anode HV = 1450V (*green points*), with ***Noise*** and ***Saturation cuts***
- On the right Time Crossing Resolution is shown in comparison with distribution from ^{55}Fe (*red points*)
- Previous calibrations suggest 600 ps translate to <7 cm resolution on the position along the straw



PREAMPLIFIER/STRAW CONNECTION

PREAMPLIFIER/STRAW CONNECTION

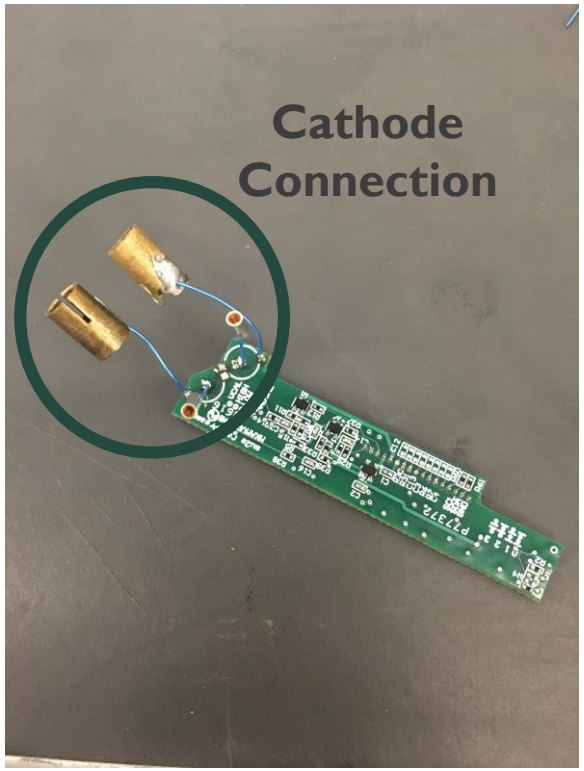
- In current design the anode connection is made with a wire and the cathode is connected through a sliding "sleeve" part.
- Sleeve design:
  - Holes allow control with minimal access
  - Slot allows expansion and restoring force ensures good connection
  - Slot and holes allow gas flow through straws
- The connection design and method was tested on a 3D-printed mockup

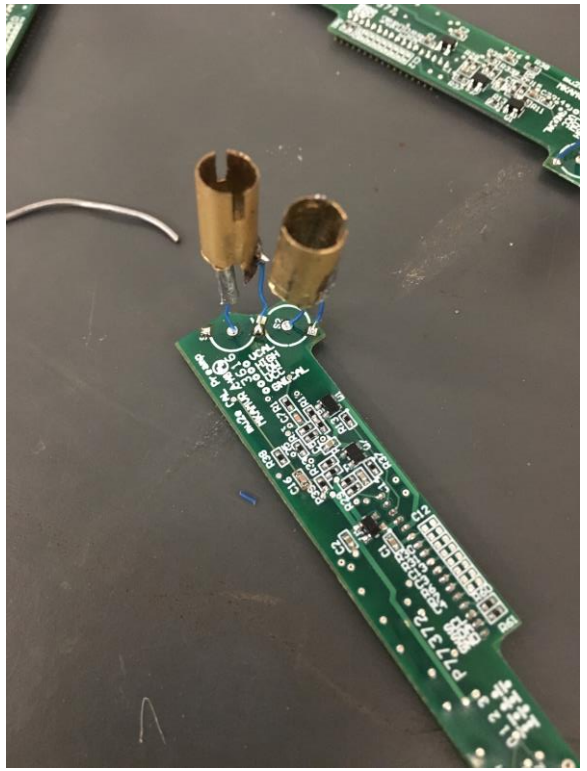


APPLICATION AND CONSIDERATIONS

- This setup reproduces preamp/straw distances as in the actual system. Connection procedure:
  - 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
- Average Time per connection:
  - 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

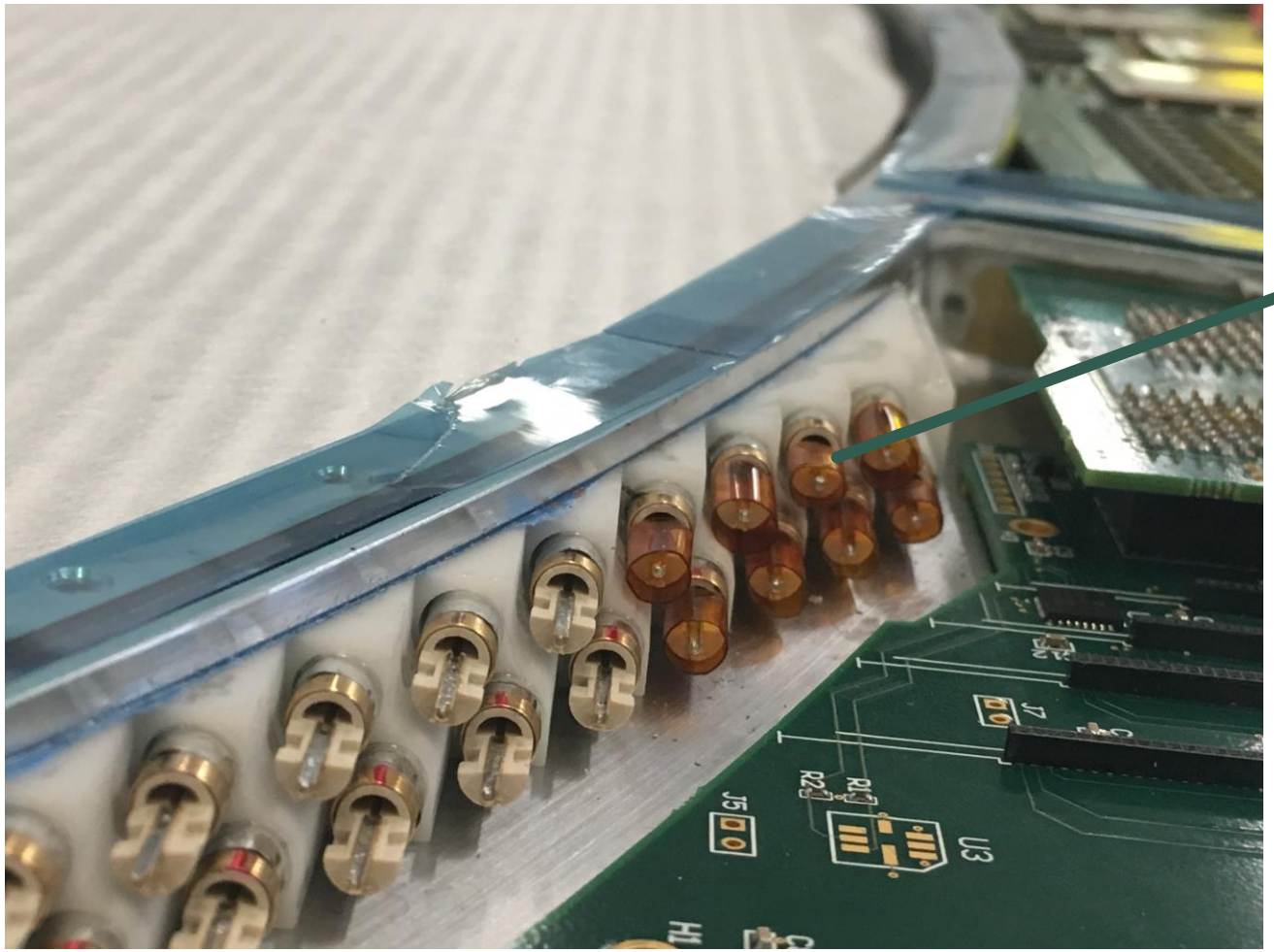
PREAMPLIFIER ASSEMBLING



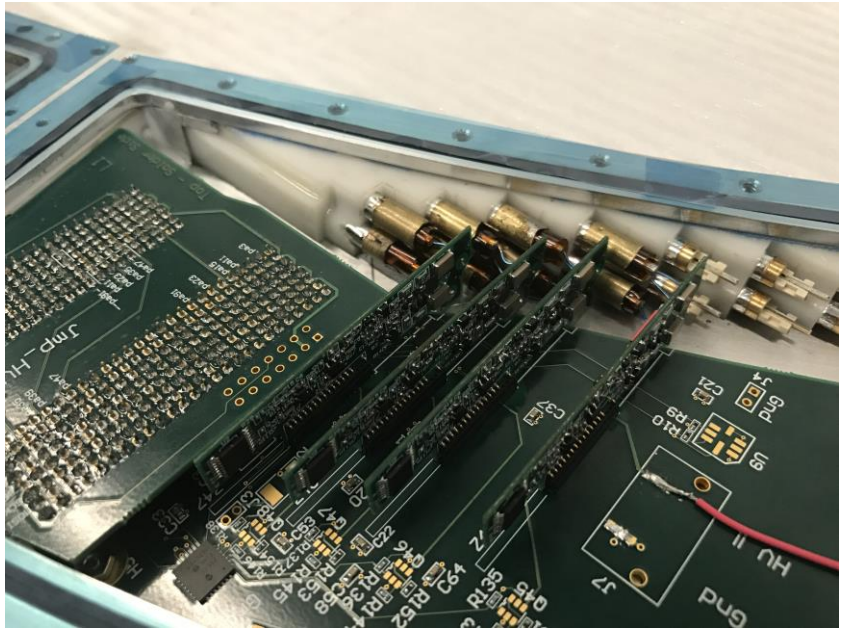


Ad hoc cathode connection for panel prototype, as straw end pieces are not available yet.

PREAMPLIFIER ASSEMBLING ON PANEL PROTOTYPE



Kapton coverage: this foil covers each anode connection between straw tube and preamplifier connector

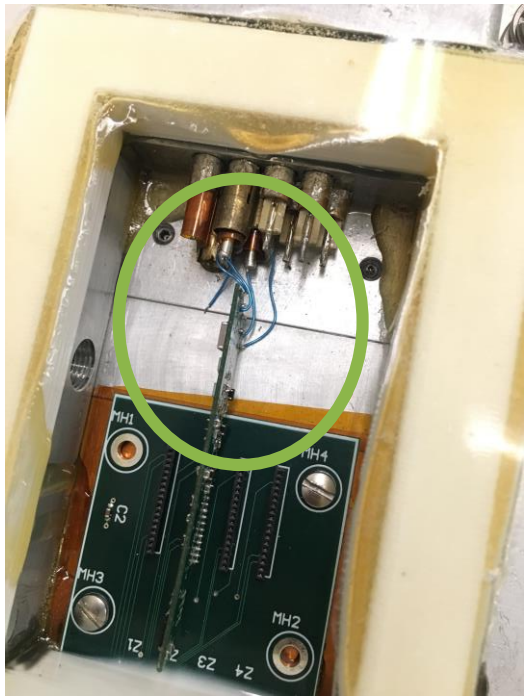


CROSSTALK DATA WITH ^{55}FE SOURCE

What is "Crosstalk"?

- 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 1490V with ^{55}Fe source with all channels, triggering on one channel and seeing crosstalk on the other one
- We compare two different connection of the preamplifiers to the straw tube. First connection is with only wire and cathode slice on straw, second one is with cathode shielding on the preamp.

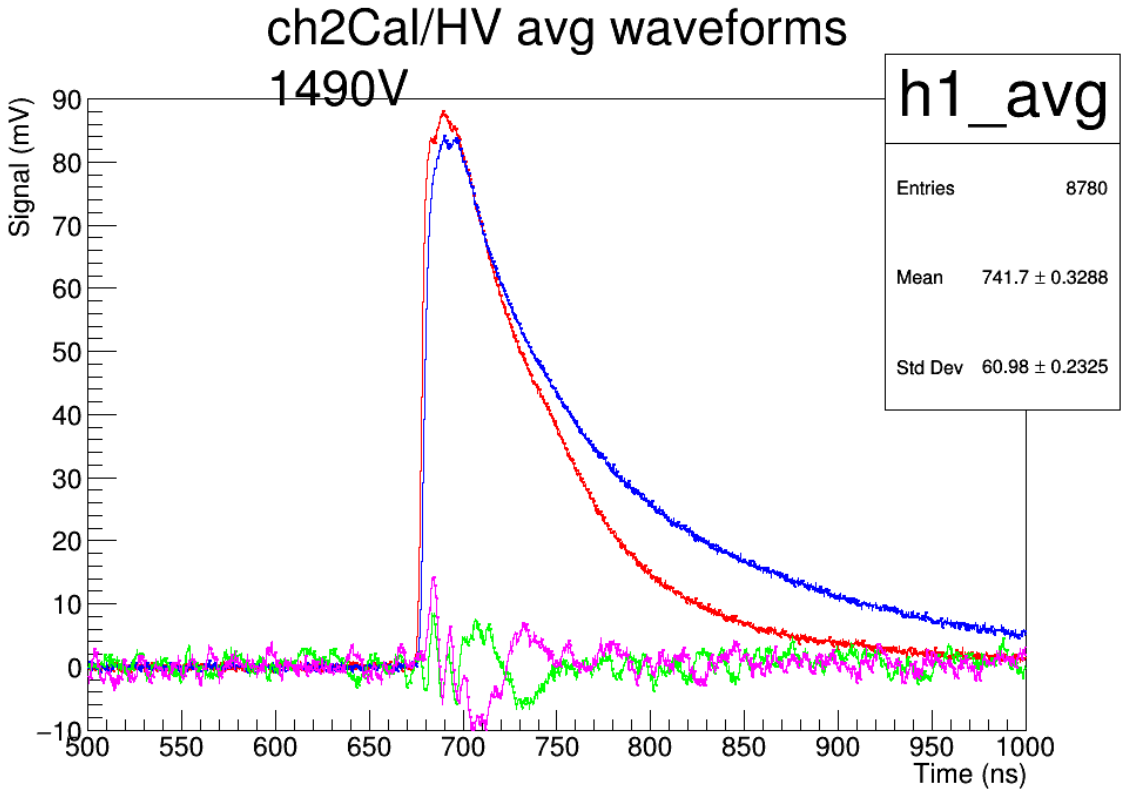
SHIELDING

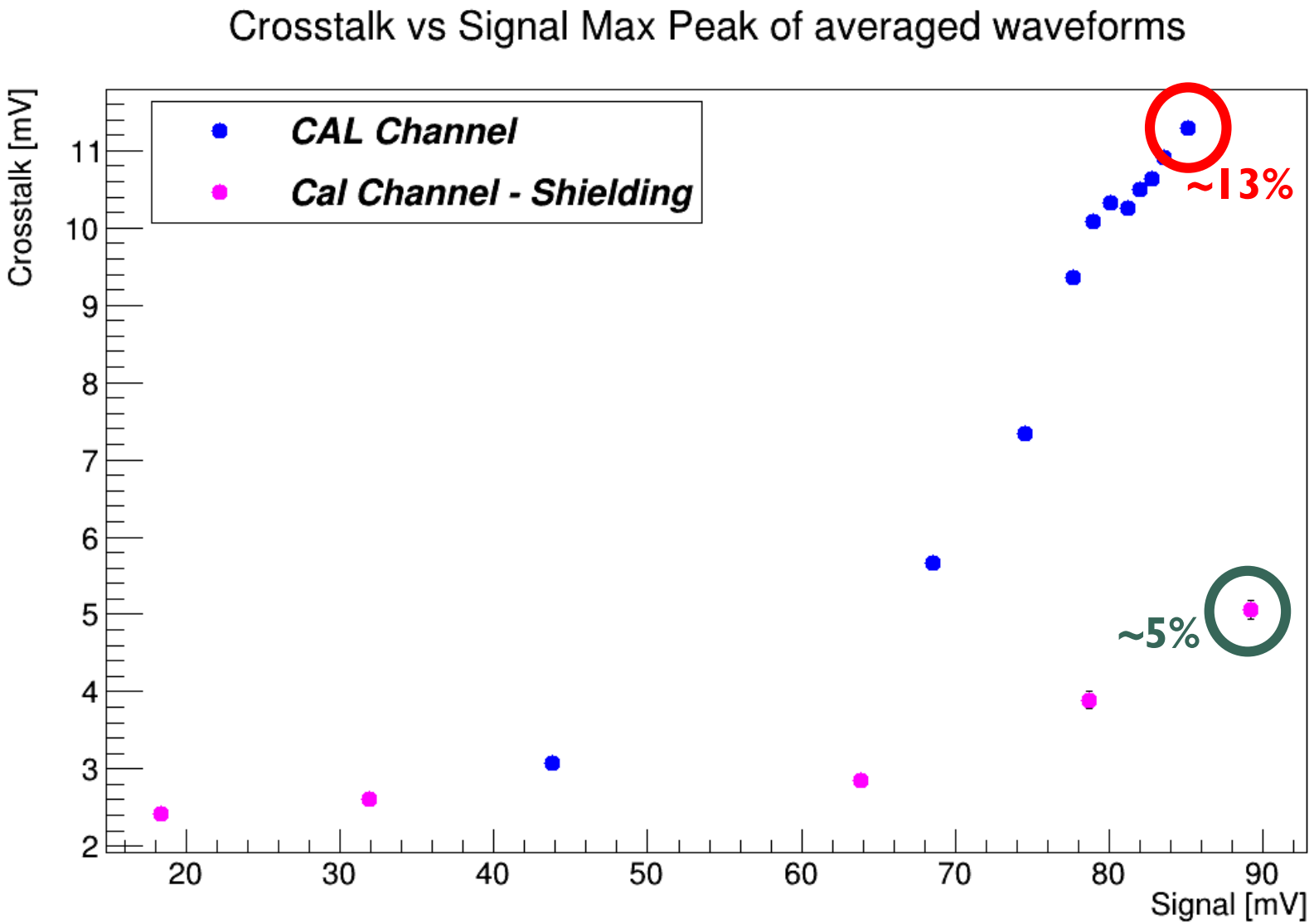


NO-SHIELDING

CROSSTALK DATA

- I considered some different intervals for Max Peak values of each waveform
- After that I made the averaging of these wvf to understand which is the percentage of crosstalk in comparison with signal. Averaging wvf we reduce noise signal and we can look only at crosstalk.
- For each interval I considered the Max Peak value of Crosstalk as a function of Max Peak of the signal.



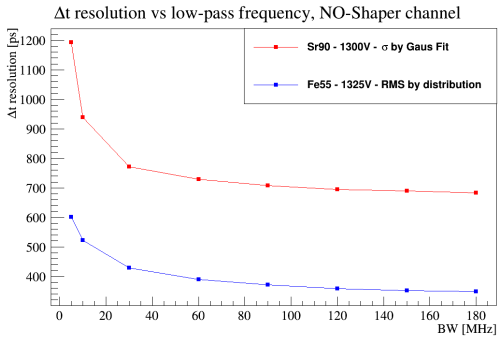


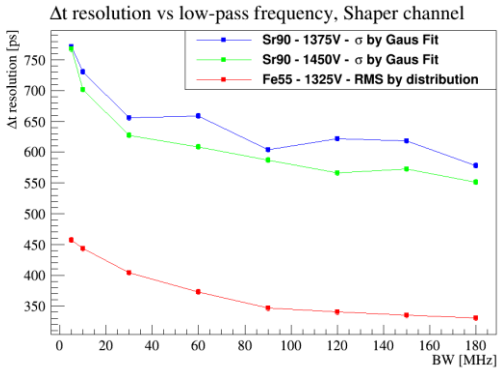
CROSSTALK: SHIELDING-NOSHIELDING COMPARISON

- Crosstalk clearly reduced with shielding
- Very important for avoiding threshold crossings in neighbouring straws after proton hit
- Crosstalk over the connections is a small part of the total: it can come from cable, straws and preamp

CONCLUSIONS

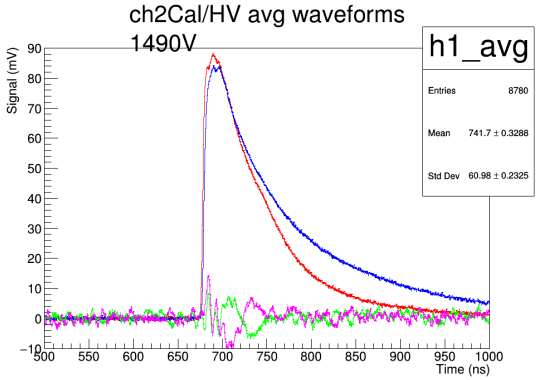
- Time Difference Resolution for Shaper and No-Shaper Data as a function of BW for ^{90}Sr source in comparison with data from ^{55}Fe





- Study about connection of preamplifiers

- Crosstalk study with Shielding and No-Shielding



THANKS FOR YOUR ATTENTION!