

Anode Electronics Crosstalk on the ME 234/2 Chamber

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Introduction

An anode crosstalk probability higher than the allowed limit of 5% was observed at the US FAST sites using test #12 ("Connectivity test") performed on ME 234/2 chambers during the summer of 2002. A detailed study of the crosstalk was then performed at the Florida FAST site on the same type of chamber using an AFEB analog test channel with a digital oscilloscope, as well as the standard DAQ. The new results of the crosstalk from the test channel are consistent with the data obtained three years ago on the CMU AFEB test stand at Fermilab.

The reason for the observed high crosstalk probability was the use of an average value of 0.25 pF for the AFEB's internal test capacitance, instead of the nominal values measured for each AFEB board. This yields a lower than nominal AFEB threshold settings of 20 fC for some boards having internal capacitance less than 0.25 pF. Using the correct threshold calibration for each board reduced the anode crosstalk probability by more than a factor of 10, making it well below the allowed limit of 5%. Reliable grounding also reduced the crosstalk.

Additional measurements of the anode crosstalk were performed using cosmic rays. In two measurements, the even (odd) layers of the CSC were supplied with the maximum working high voltage of HV=3.8 kV. The crosstalk in the odd (even) layers was measured as a fraction of events having at least one hit in the given layer. The observed crosstalk was less than 1%. At the nominal working HV=3.6 kV, we therefore expect the anode crosstalk to be negligible.

I. Anode Electronics Crosstalk Definition

In a multi-channel system a crosstalk event is an event on any channel induced by its neighbors. There are two reasons for crosstalk events in a CSC. The first one is a chamber internal process, and the second reason is an electronics design and behavior on the chamber. Only the second reason for crosstalk is discussed in this paper.

The anode wires of the chamber are connected to the 16 channel Anode Front End Boards (AFEB) through a Protection Boards (PB). One PB collects signals from two anode planes – eight from each plane. Also each chamber plane has a test strip for injecting test charge into all channels of one plane at once. The biggest crosstalk is observed between the pair of planes joined with the Protection Boards.

The number of crosstalk events depends on the number of parasitic pulses that went over the AFEB threshold. The parasitic signal components are the following:

- Analog crosstalk charge. This portion is a part of a channel input signal spreaded to the neighbors. This portion is dependent on channel to channel isolation of the AFEB input networks.
- Digital crosstalk charge. Each fired discriminator generates output pulse and associated with the pulse a “digital noise”. Some part of this noise can feed back to the AFEB inputs. The value of this portion depends on the output pulse amplitude, AFEB design, quality of AFEB-ALCT connection, quality of AFEB and ALCT grounding.
- Amplifier pick-up noise. This portion depends on quality of AFEB grounding and shielding as well as the chamber grounding and shielding performance in the whole. Noise correlated with readout signals (fed back from readout electronics) is a direct fraction of crosstalk. Unrelated pick-up noise only increases the crosstalk probability.
- Amplifier input noise. This portion is a function of the AFEB input capacitance and increases the crosstalk probability.

II. Anode Electronics Grounding Influence

The grounding and shielding influence was tested in 1999 year on a ME234/2 chamber completely equipped with anode electronics (there was prototype version of electronics).

The noise spectrum was measured with a digital oscilloscope using the AFEB test channel connected to the chamber wire group. (There is a special test channel in the anode amplifier chip. For regular boards, this channel is disconnected and idle, but for the tests one standard channel was replaced with the test channel.)

The best noise performance was obtained when all chamber frame screws were properly tightened and all AFEBs were properly connected and fixed. The noise spectrum for “good” grounding presented at Figure 1.

Any loose screw at the chamber fixture as well as a poor AFEB ground contact leads to increasing the noise amplitude. Figure 2. Few loose ground connections may cause an unstable work of AFEBs and even AFEB oscillations.

Grounding and shielding effect

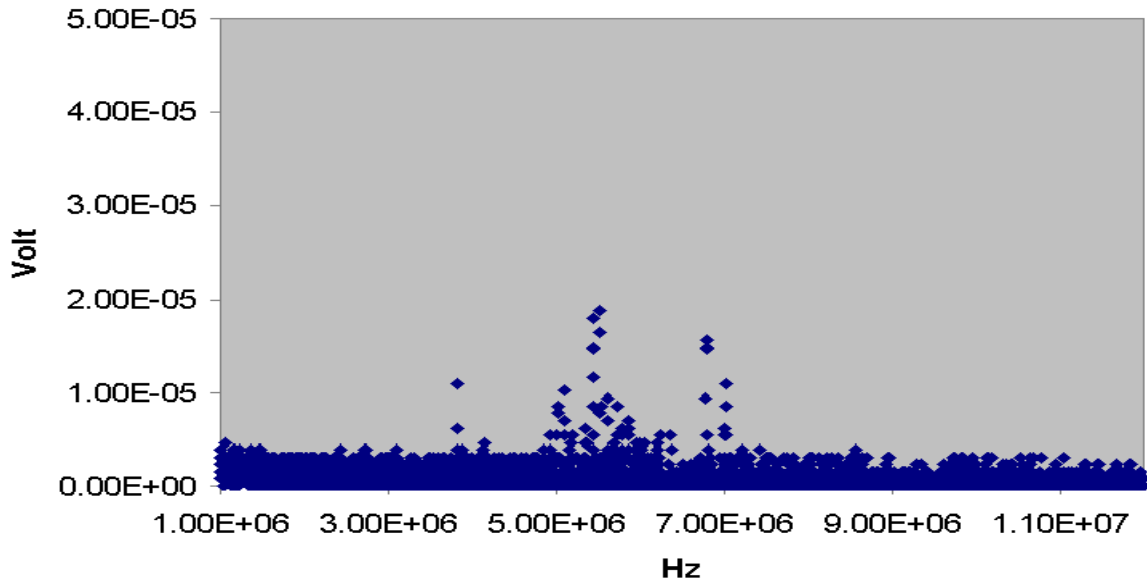


Figure 1. AFEB noise spectrum for "good" grounding.

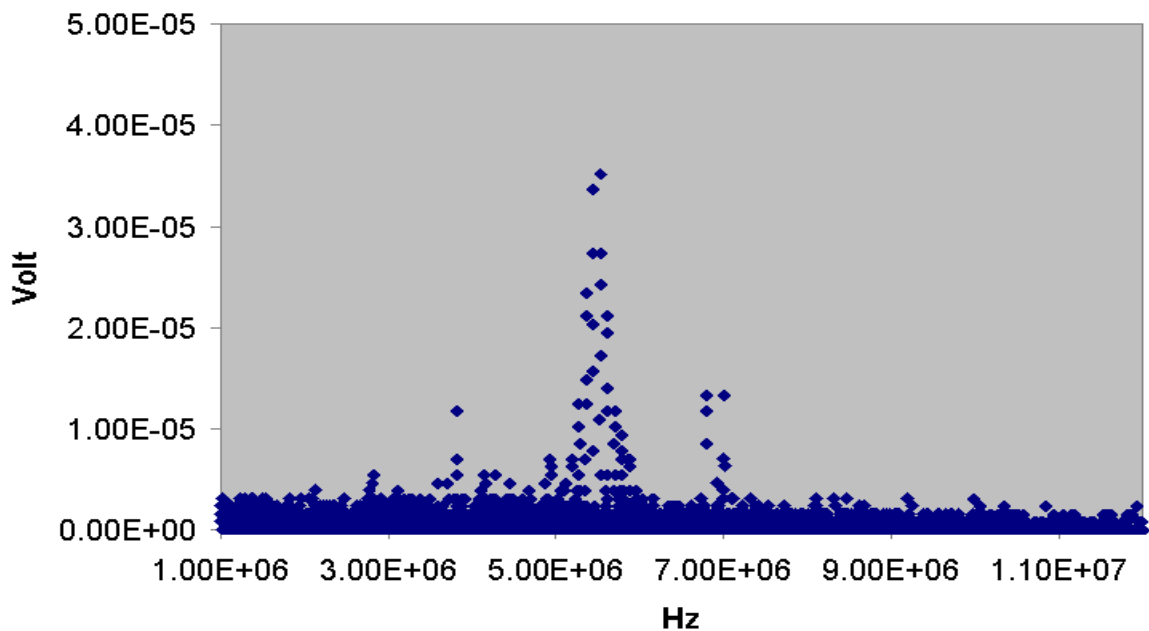


Figure 2. AFEB noise spectrum for "poor" grounding.

Proper grounding of the anode front-end electronics reduces by a factor of two the noise level and, as a result, the crosstalk probability.

III. AFEB Crosstalk Studied on the Bench

(Early measurement, November 1999)

Crosstalk vs. number of fired channels

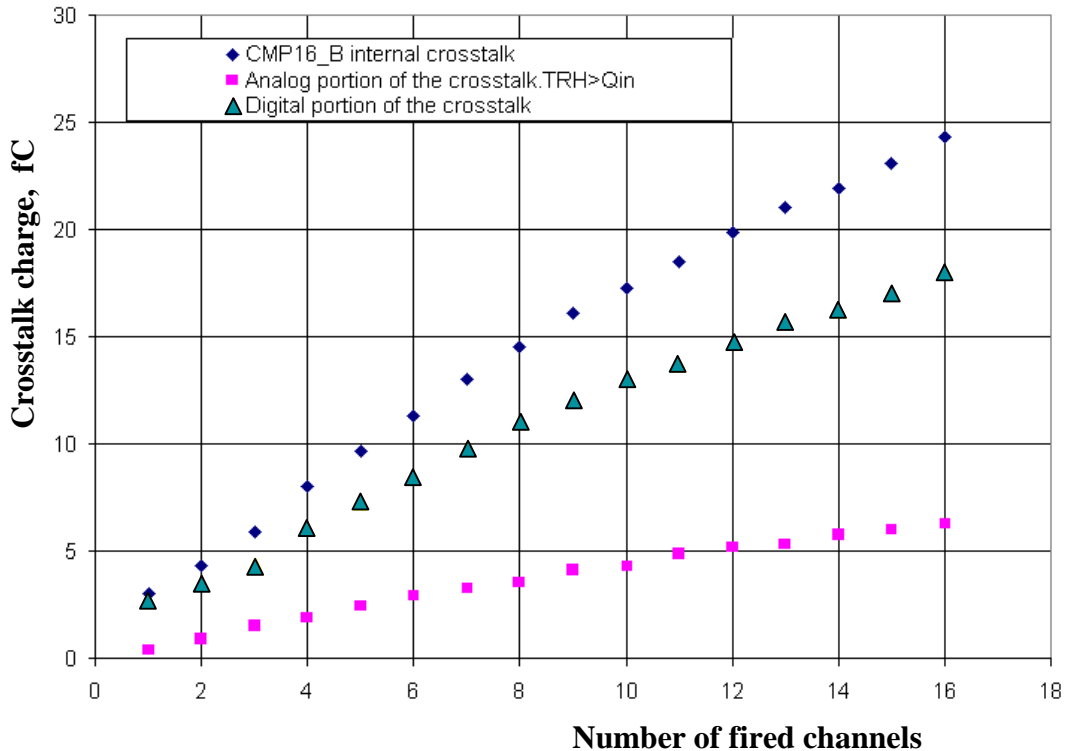


Figure 3. AFEB crosstalk measured on the bench.

Test conditions:

All channel inputs connected to ground through 220 pF capacitors.

The crosstalk amplitude is measured with an oscilloscope on one AFEB test channel.

The input charge for all channels is set to 100 fC.

There are two portion of crosstalk charge:

- analog portion
- digital portion

To study the analog portion of the crosstalk, the threshold of the board was set to its maximum value of 1.2 V.

Results of these measurements are presented on figure 3.

The analog crosstalk is proportional to the number of connected channels (total injected charge). The analog crosstalk ~ 0.5 fC/channel @ 100 fC. This is about 0.5% of the injected charge.

The digital crosstalk is proportional to the number of fired channels.

The digital crosstalk is ~ 1.1 fC/channel.

The analog and digital crosstalk values did not depend on the position of the fired channel.

IV. Crosstalk on the ME234/2 Chambers

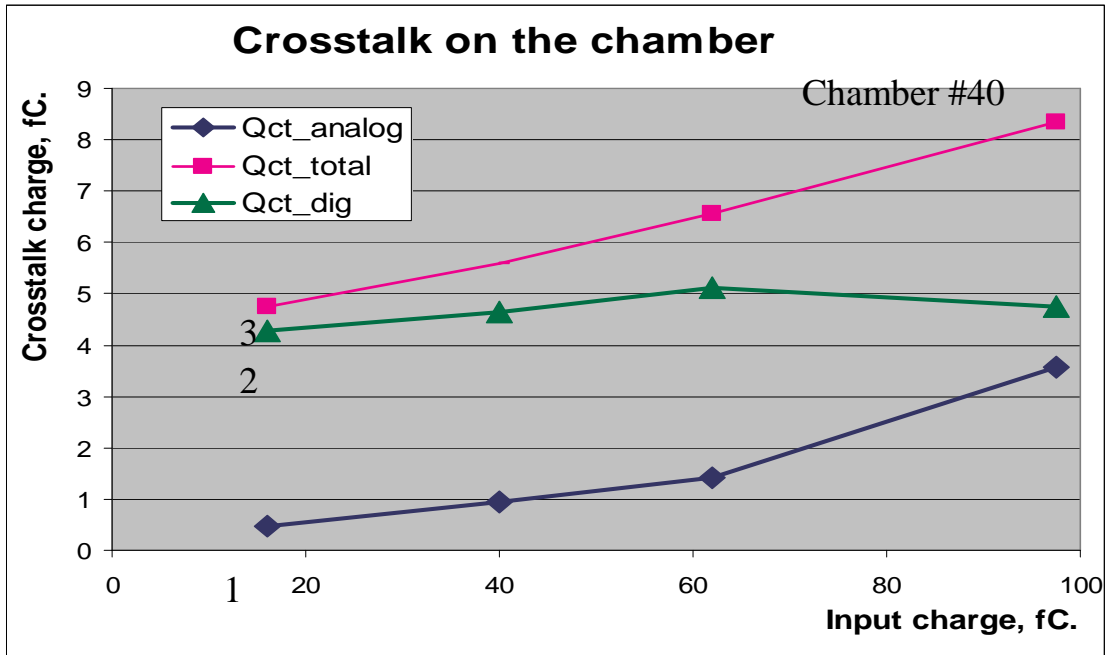


Figure 4. AFEB crosstalk measured on the chamber.

Conditions: Fired 8 channels (one connected plane)

To get the analog portion of the crosstalk, the AFEB threshold is set to its maximum value (1.2 V).

The crosstalk amplitude is measured with an oscilloscope on the AFEB test channel, connected to the anode wire group. Two samples of oscillogram with the crosstalk signal are presented at the Figures 5 and 6. The accuracy of this measurement is about 20%. The results of these measurements are illustrated at the Figure 4.

Curve 1. The analog crosstalk is proportional to the total charge injected into the board.

Curve 2. The digital crosstalk is proportional to the number of the firing channels.

In our case, the number of firing channels was 8 and the digital portion of the crosstalk is practically constant.

Curve 3. Total measured crosstalk charge.

The overlapping results for 8 fired channels from Figure 1 are used for comparison with the “on chamber” crosstalk measurement.

	Bench test	Chamber test
Number of fired channels	8	8
Injected charge per channel	100 fC	98 fC
Analog crosstalk	~3.8 fC	~3.8 fC
Digital crosstalk	11 fC	5 fC

Summary: AFEB crosstalk on the chamber is about the same level as on the bench.

Samples of oscillogram

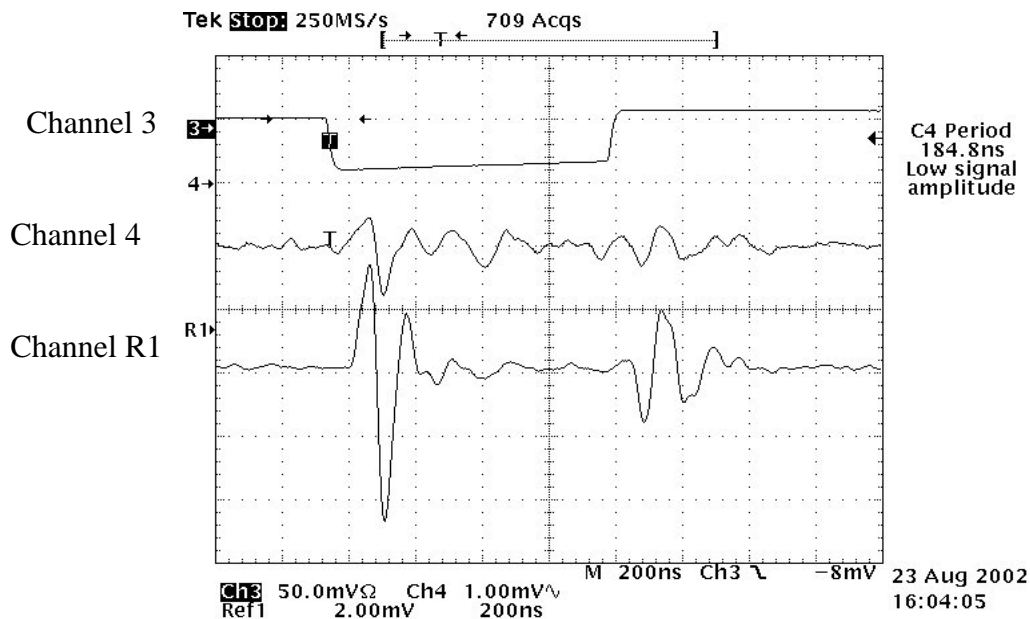


Figure 5. AFEB analog crosstalk waveform.

Fired 8 channels with an amplitude of 16 fC. Channel 3 shows test pulse.

AFEB threshold set to maximum, AFEB's discriminators blocked.

Channel 4 shows the analog portion of the crosstalk $\sim +0.4 \text{ mV} \Leftrightarrow 0.47 \text{ fC}$

Trace R1 is a reference trace.

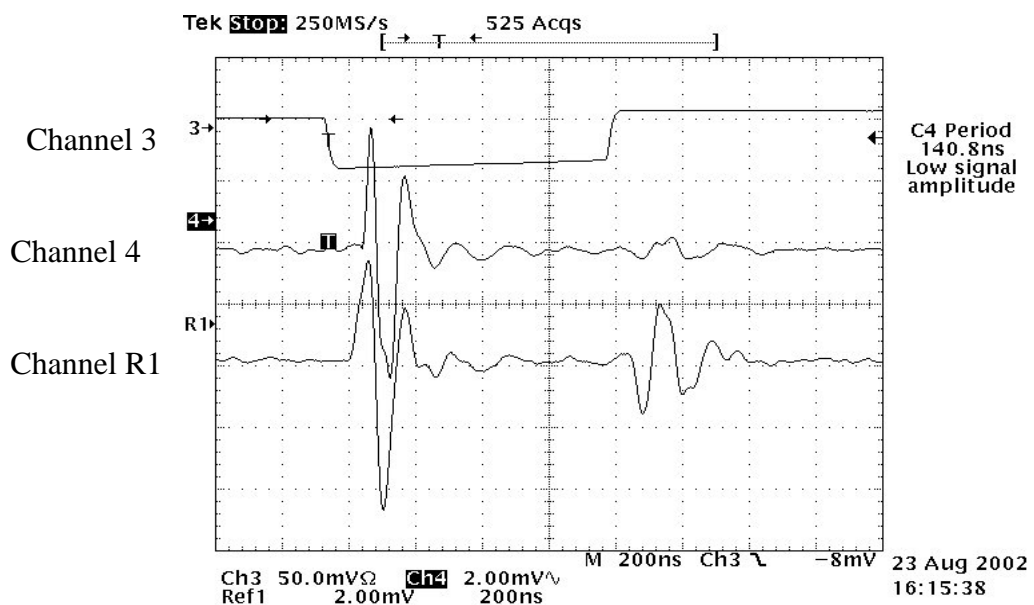


Figure 6. AFEB total (analog+digital) crosstalk waveform.

Fired 8 channels with amplitude of 16 fC. Channel 3 shows test pulse.

AFEB threshold set to $\sim 10 \text{ fC}$, AFEB's discriminators enabled.

Channel 4 shows total crosstalk $\sim +4.0 \text{ mV} \Leftrightarrow 4.7 \text{ fC}$.

Trace R1 is a reference trace.

V. AFEB Connectivity (Test #12)

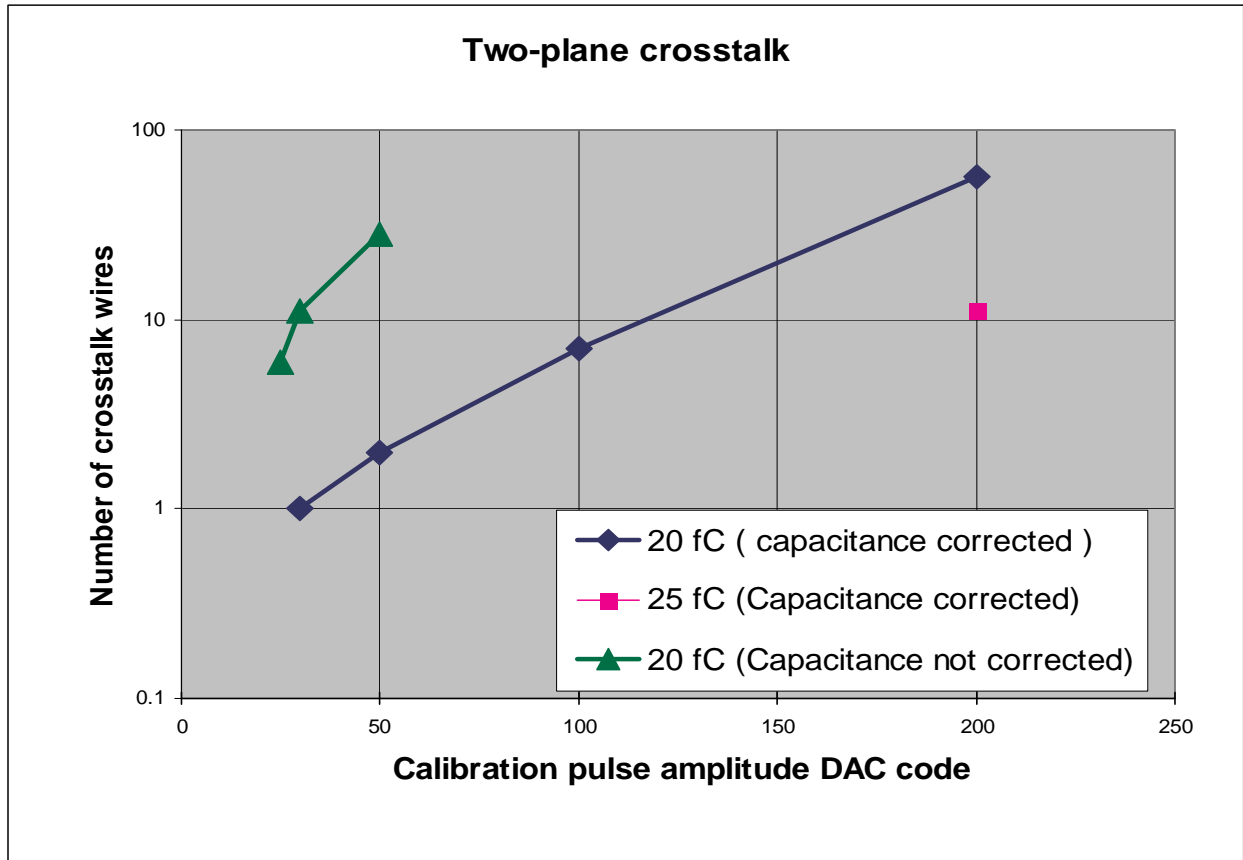


Figure 7. Two-plane crosstalk test result.

The standard procedure for testing crosstalk is the FAST site connectivity test #12. The test procedure is described in the “Assembly and Test Instruction”. Complete text of the instruction is located at: <http://www.phys.ufl.edu/cms/emu/fast/fast-site-test.shtml>. For this test the ALCT generated test pulses are applied to the test strip of each layer in turn. The amplitude of the test pulse fixed to provide 60 fC of injected charge. The signals should be seen on all wire groups of fired layer. Any events on others wire groups are the crosstalk events. If a wire group has the number of crosstalk events equal or more than 5%, this wire group is called a “crosstalk wire”. Two samples of a typical crosstalk event display presented on Figures 8 and 9.

For this test the AFEB thresholds are set to 20 fC using the “on chamber” threshold calibration. Currently for this calibration an average value for the test capacitance of 0.25 pF is used. However, due to technological process variation, this capacitance value may vary by up to +/-20%. As a result, the thresholds may be set with an error up to +/- 20%. This effect leads to extra crosstalk. See Figure 8.

To avoid this effect, it is better to use the measured value of the test capacitance. After the capacitance value was corrected, the number of crosstalk events dropped by a factor of 10. See Figure 9. The plot of crosstalk wires for “standard” and “corrected” procedures versus of input charge is presented on Figure 7.

Two-Plane Crosstalk display

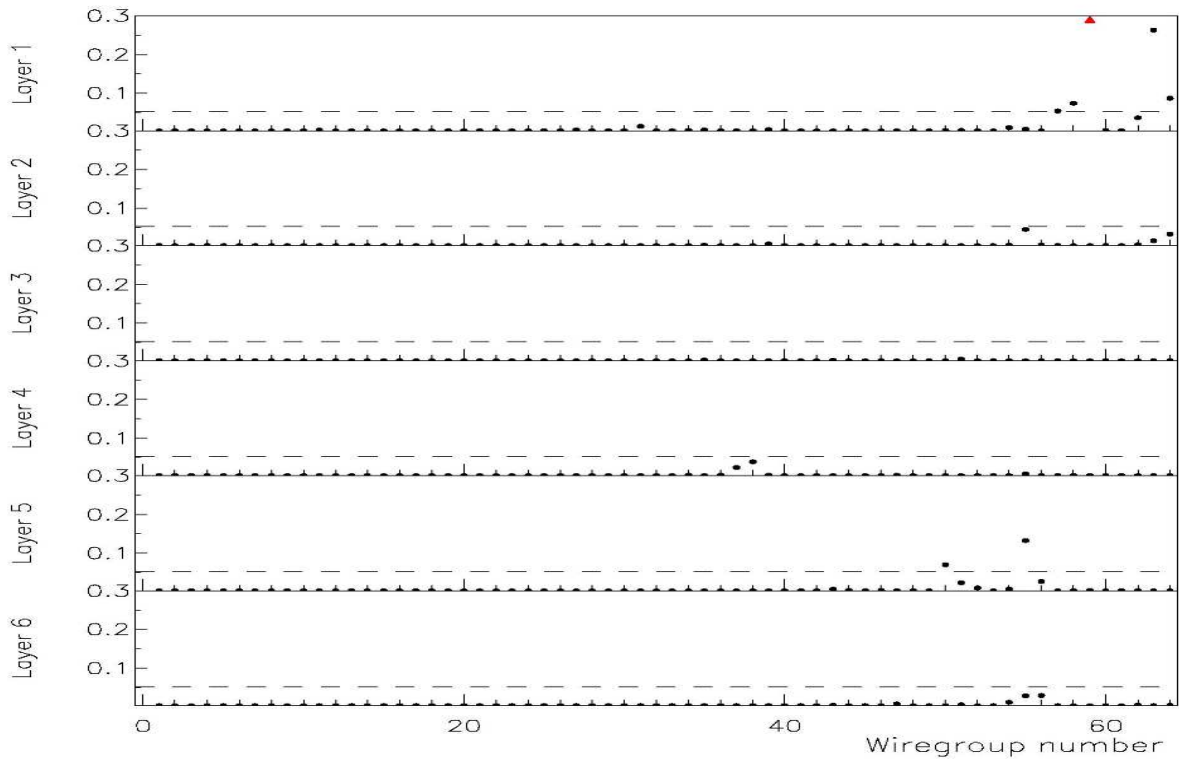


Figure 8. Un-corrected test capacitances (standard procedure).

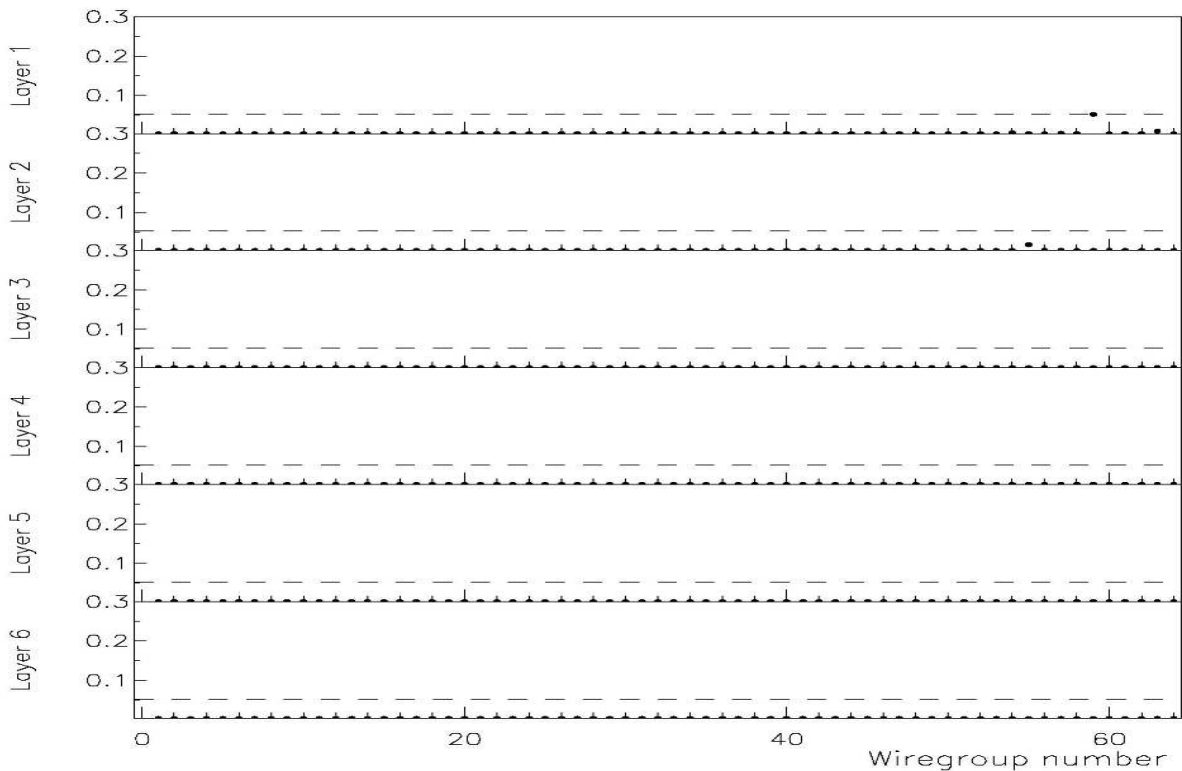


Figure 9. Corrected test capacitances (recommended procedure).

VI. Crosstalk Measured by Using Cosmic Rays

To estimate crosstalk with cosmic rays, the following procedure is proposed by N. Terentiev.

The idea is to apply HV only to the every other plane of the CSC and trigger the stand DAQ with the cosmic ray trigger. The HV powered plane will present the cosmic ray profile, but the planes without HV will show only crosstalk events. As soon as the maximum crosstalk is between the pair of anode board connected together with the Protection Boards, we can divide channel by channel the crosstalk event number per the registered events number at corresponding plane. The result is a “relative crosstalk profile”. The ratio of total crosstalk events to the total events number of the corresponding plan is an “average crosstalk” .

The first time HV was applied to the even planes. To have a visible crosstalk behavior the maximum working HV of 3.8 KV was applied. The test results presented at Figure 10. Then the test was repeated with HV applied to the odd planes. The test results presented at the Figure 11. The typical event without crosstalk is presented on the display picture - Figure 12 , and with crosstalk event – Figure 13.

Test results:

The measured cathode charge for normal events (no crosstalk) is about 1,000-2,000 ADC counts, but for crosstalk events, the measured cathode charge is about 10,000 ADC counts. The main cause of crosstalk is a hit with a large ionization charge.

The number of crosstalk events increase from narrow side to wide side of chamber. The wide side has a bigger detector capacitance.

The lagesst channels of “even-odd” crosstalk are 1, 9, 17, 25, 33, 41, 49, 57

The largest channel of “odd-even” crosstalk are 8, 16, 24, 32, 40, 48, 56, 64

The reason of this behavior is not clear yet.

The average crosstalk value correlates with the chamber gas gain. The maximum gas gain was in layers 1, 5 and 6. The maximum crosstalk was from plane 1 to plane 2 and between plane 5 and 6. Plane 3 and plane 4, with the minimum gas gain, have the minimum crosstalk.

Even-Odd Plane Crosstalk

Measurement conditions:

HV = 3800 V on planes 2, 4, 6 – cosmic ray particles

HV = 0 V on planes 1, 3, 5 – crosstalk events

Histograms of ALCT Wire Occupancy.

Relative Crosstalk Profile.

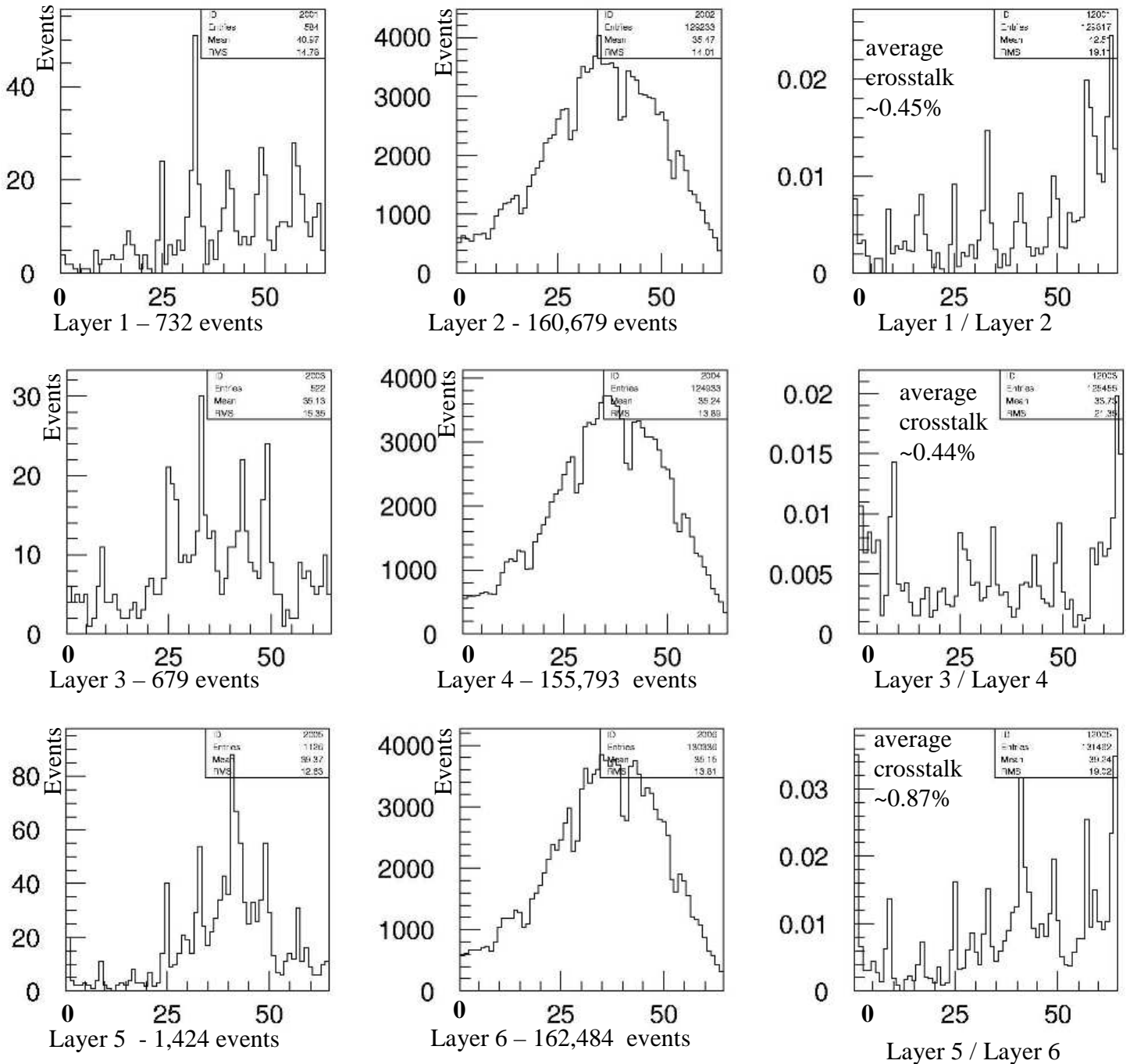


Figure 10. Even-Odd plane crosstalk

Largest channels
1, 9, 17, 25, 33, 41, 49, 57.

Maximum average crosstalk is from plane 6 to plane 5 ~0.87%

Odd-Even Plane Crosstalk

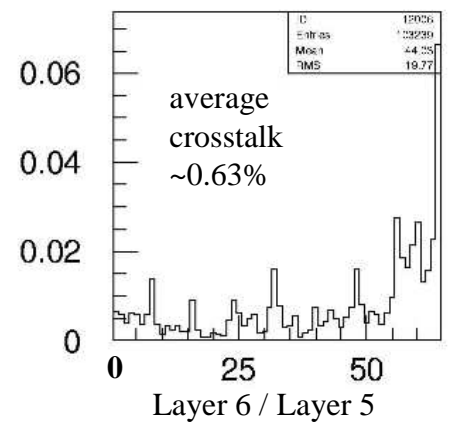
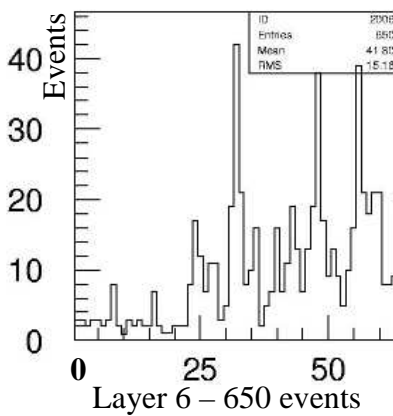
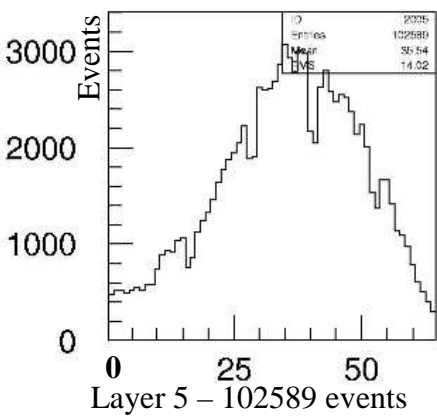
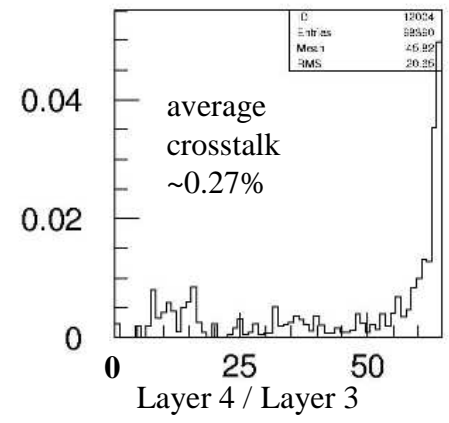
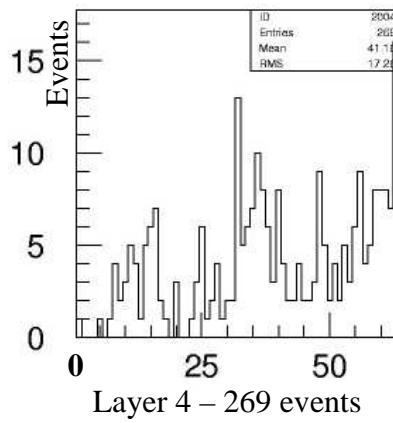
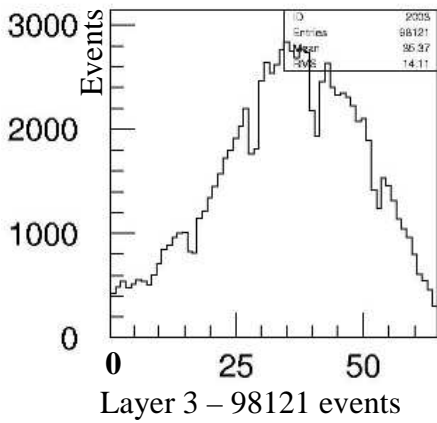
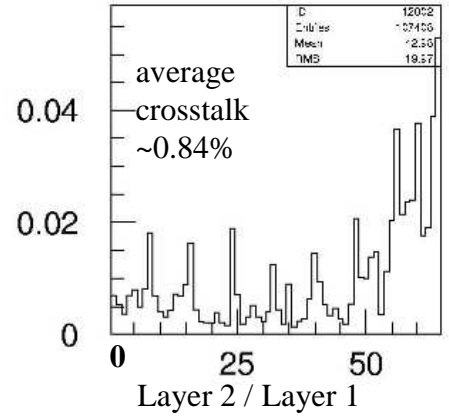
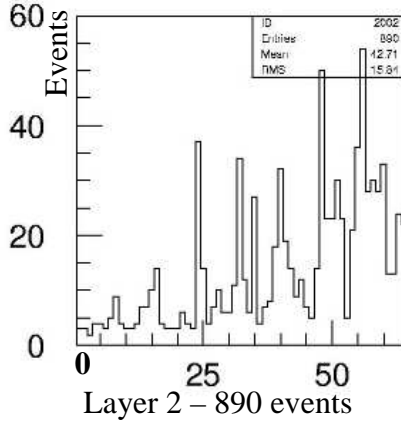
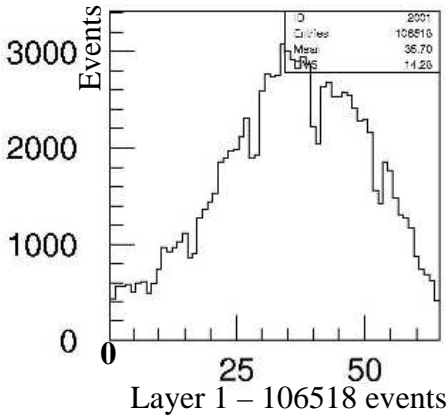
Measurement conditions:

HV = 3800 V on planes 1, 3, 5 – cosmic ray particles.

HV = 0 V on planes 2, 4, 6 – crosstalk events.

Histograms of ALCT Wire Occupancy.

Relative Crosstalk Profile.



Largest channels

8, 16, 24, 32, 40, 48, 56, 64.

Figure 11. Odd-Even plane crosstalk.

Maximum average crosstalk is from plane 1 to plane 2 and equals ~0.84% .

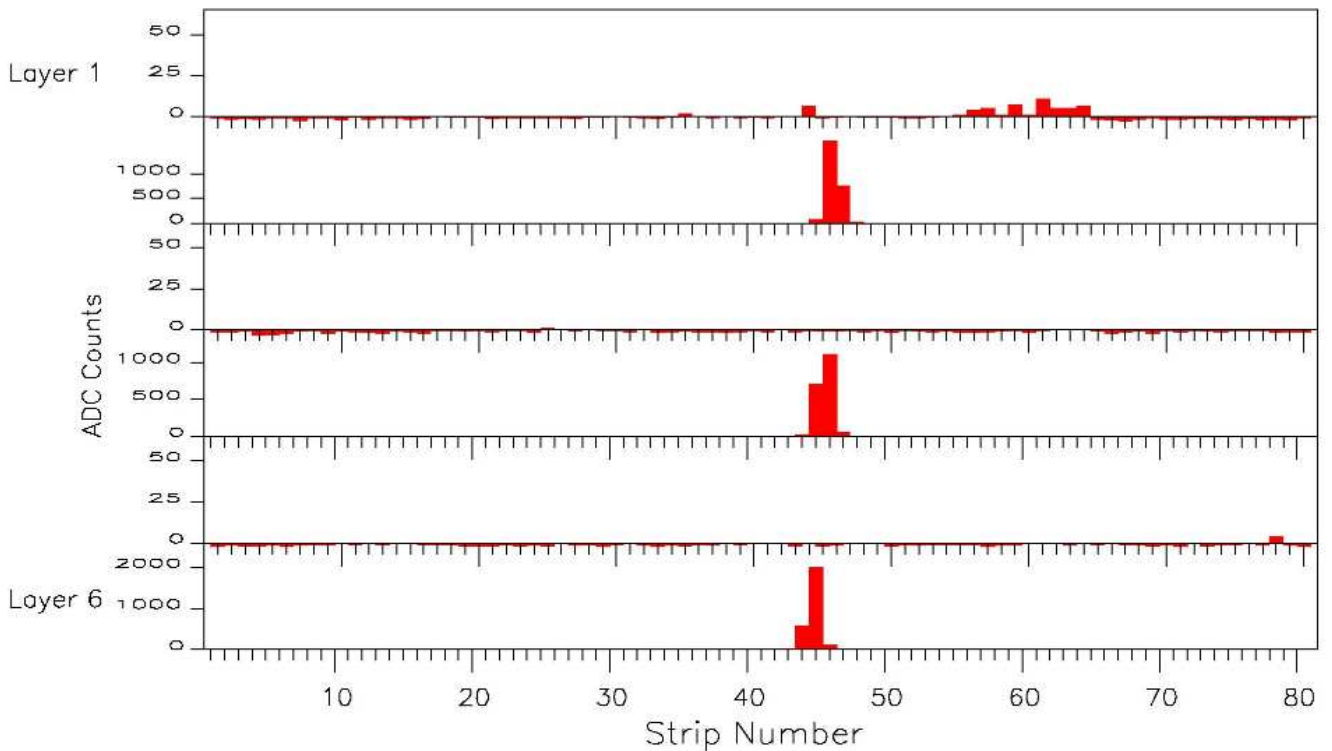
Typical “normal” event

Measurement conditions:

HV is 3.8 kV on planes 2,4,6 and 0 V on planes 1,3,5.

RUN 1465 EVENT 17247

STRIPS



WIRES

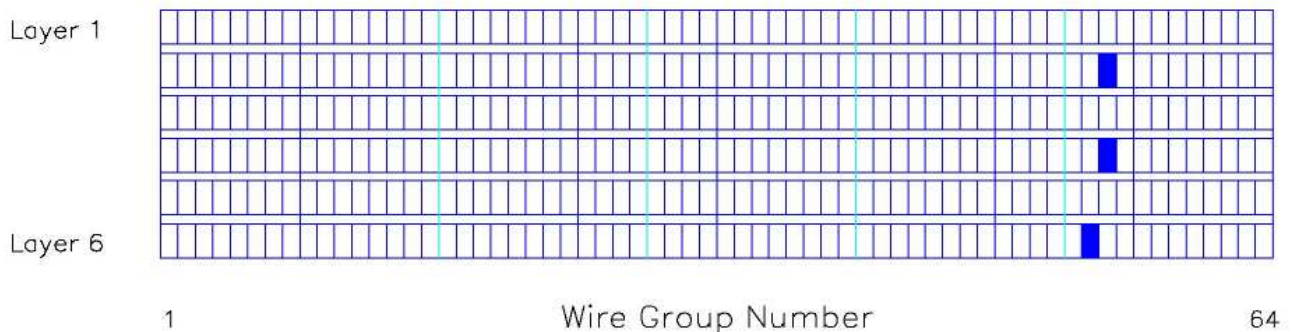


Figure 12. Event Display for a “normal” event.

There is no crosstalk.

The measured cathode charge in planes 2, 4 and 6 is about 1000-2000 ADC counts.

Let's assume this value as an average charge for normal event.

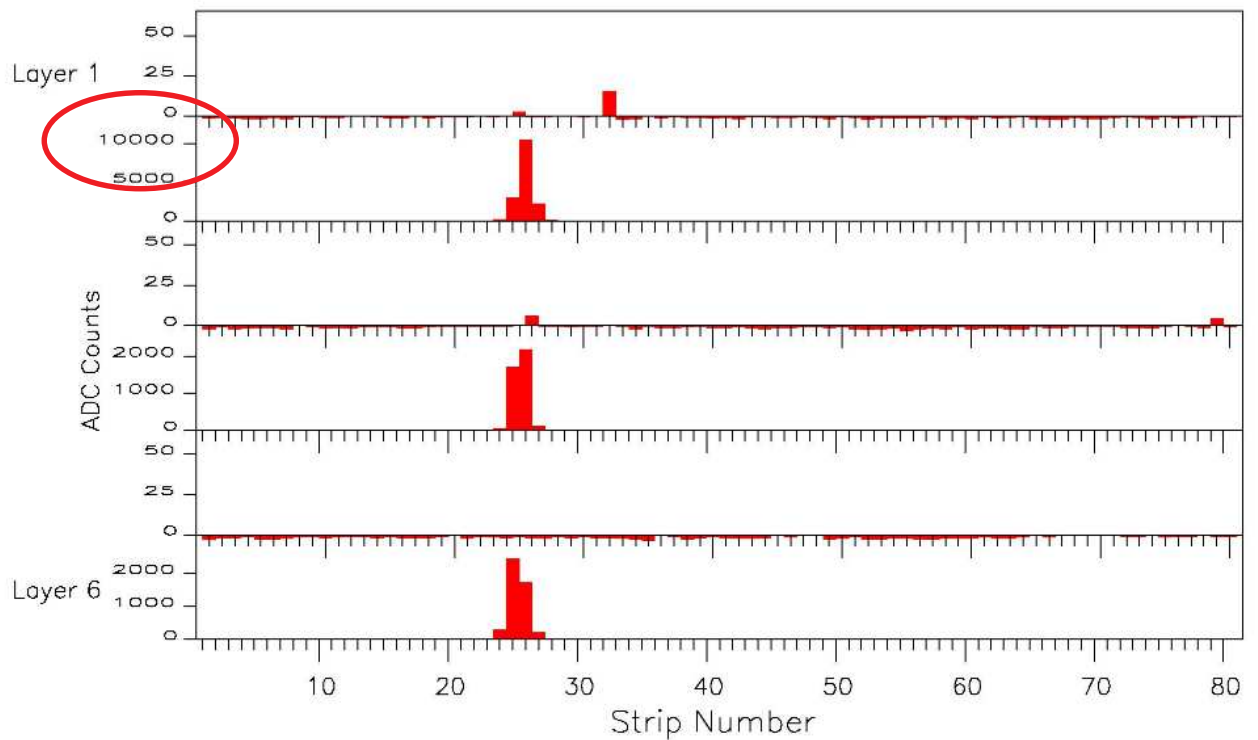
Typical “crosstalk” event

Measurement conditions:

HV is 3.8 kV on planes 2,4,6 and 0 V on planes 1,3,5.

RUN 1465 EVENT 3963

STRIPS



WIRES

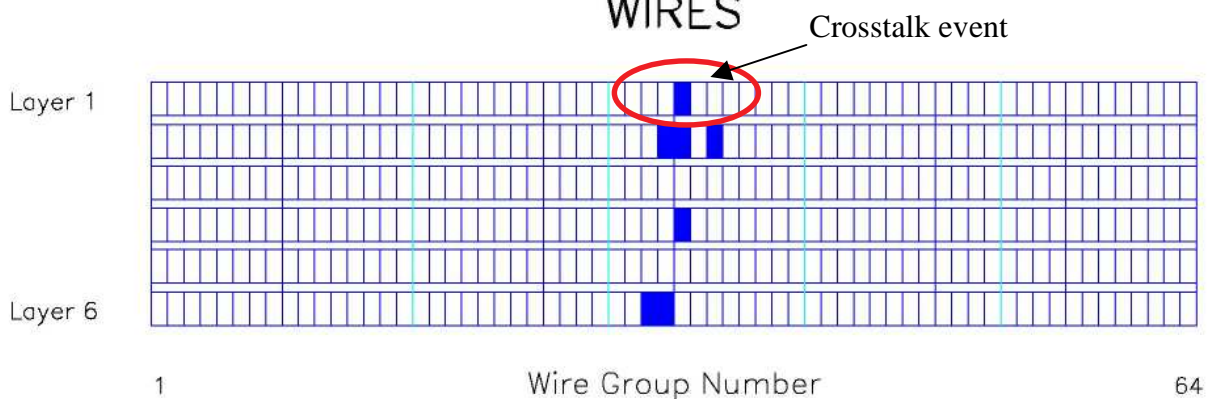


Figure13. Event Display of a “crosstalk” event.

There is a crosstalk event from plane 2 to plane 1.

The measured cathode charge in plane 2 is about 10000 ADC counts (10 times more than average).

VI. Summary of Crosstalk Test Results

1. The AFEB crosstalk has two components an analog portion and a digital portion.
The analog portion is proportional to the injected charge.
The digital portion is proportional to the number of fired channels.
The “on bench” measurements (performed in November 1999) and the new “on chamber” measurements are in a good agreement. The analog crosstalk value is ~0.5% of the injected charge. The portion of the digital crosstalk from one fired channel is 1.2 fC for the “on bench “ measurements and 0.6 fC for the “on chamber” measurements.
2. The crosstalk value and the pickup noise depend on the grounding and shielding performance. For good grounding and shielding, the estimated crosstalk charge for the FAST site connectivity test (8 fired channels) is about 9 fC (with an accuracy of 30%). The minimum allowed threshold of AFEB to pass this test is 16 fC (crosstalk charge plus noise).
3. The 20 fC AFEB threshold on the chamber is very close to the minimum allowed level. The accurate setting of the AFEB thresholds by using of the calibrated internal test capacitance values allows us to minimize crosstalk probability.
4. The crosstalk measured with cosmic muons at the maximum working HV=3.8 kV and with the anode threshold of 20 fC is less than 1%. The main cause of crosstalk is a hit with a large ionization charge. At the nominal working HV=3.6 kV we expect the anode crosstalk to be negligible.
5. The FAST site connectivity test #12 with the AFEB threshold setting of 20 fC is a good test of the chamber input grounding and shielding performance.