MuLan Kicker
New Installation

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1 Introduction and Description

Starting on August 16, 2005, we were in charge of rebuilding the MuLan Kicker, such that it should work reliably for the fall 2005 run, starting on September 12, 2005. With a constant help of Mike Barnes, we reach an acceptable situation on August 31, 2005.

This report is supposed to give a relatively deep overview of the work which was done around the kicker during this period. We are listing the requested minor tasks.

- The lower stack 315 V box had been removed during fall 2004 run. It was reinstalled on June 2005, just before using the kicker in DC mode for beam-tuning.
- The remote controller panel was missing in June 2005. No one could remember to have seen it since the MuLan run started. It was used by the MuLan group in the MuCap barrack for some beam-tuning measurements in mid November 2004. Rob and Françoise have made a new remote panel for the June 2005 run.
- The 2.5kΩ high-voltage resistors which were removed from the MV1 and MV2 cabinet in November 2004 have been found at the end of the June 2005 run.
- One of the MV2 white cable, which drives the lower MOSFETS stack was missing. A new cable was shipped by TRIUMF technician and installed in August.

Mike Barnes and Gary Wait have send to PSI in June 2005, the corrected MOSFETS, as well as the over-current protection circuit boards and their associated fiber-optic cable. A new TTL input distribution box was build at TRIUMF and shipped to PSI. It include the over-current trip system and monitor. Once the material was at PSI, the hardware work could start. The tasks were:

- Install all MOSFETS cards. There is 17 cards per stacks, two stacks per cabinet, and 4 cabinets. This give a total of 136 cards. In addition, there is two flat top cards per cabinets. A complete amount of 144 cards are needed to make the kicker working with each of its power supply and cabinets.
- Install and connect the 2 over-current protection circuit boards per cabinet, as well as there associated fiber-optic cables.
- Install and connect the new TTL distribution box.
- Make new inside tank copper braid connection, for the MV1 and MV2 deflector plates.
- Make new inside cabinet high-voltage connectors, for the MV1 and MV2 cabinets.

As soon as the hardware work was finished, the kicker tests had to be started. Essentially, we needed to

- Test that each and every MOSFETS cards is receiving power.
- Test each MOSFETS card timing and voltage grating.
- Run the kicker up to working frequency, with the deflector plates in air.

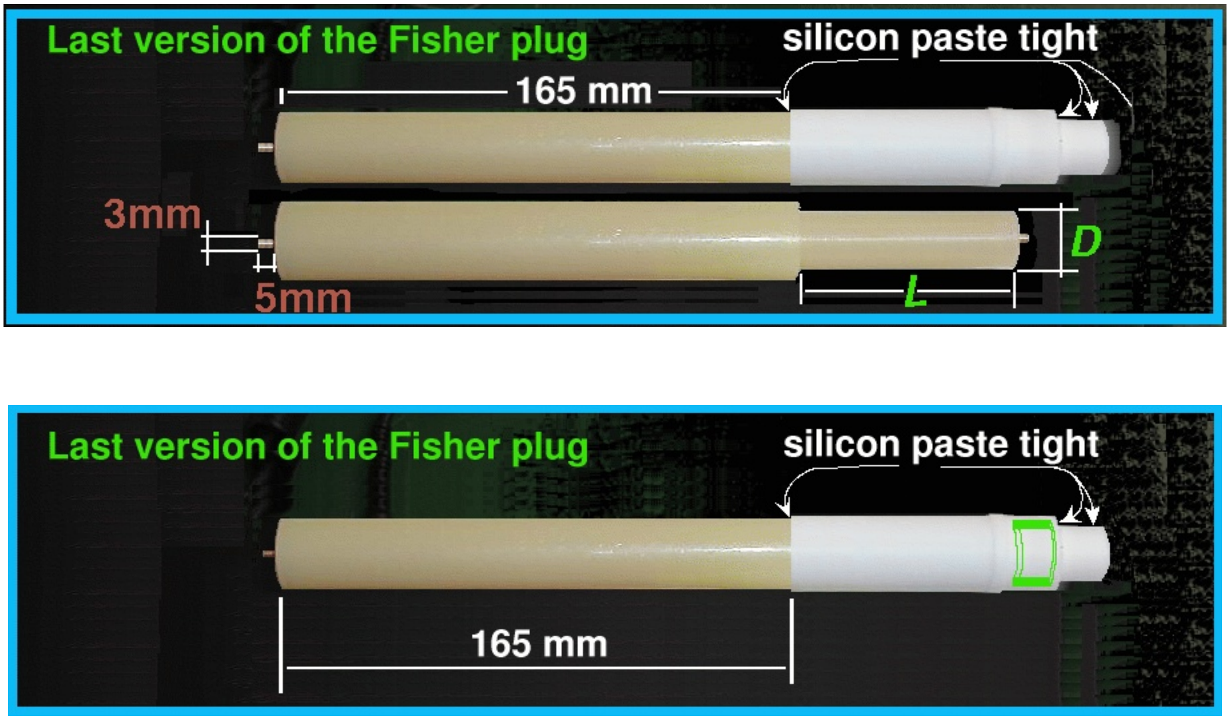

Figure 1: *Replacement of Fischer connector. The top figure was used for the workshop to build the connectors. The length $D = 15.7$ mm and $L = 63$ mm were measured on the previous connector. The bottom figure was used to build the final version.*

– Run the kicker up to working frequency, with the deflector plates in vacuum.

It is easy to imagine that nothing happened smoothly. However, its is important to state that the kicker is finally working at the time of writing this report.

2 Installation

The kicker is installed in the main experimental hall of PSI. It is connected to a major power supply. Its ground cable is connected to the PSI main ground.

While building and installing the various parts, questions and remarks were transmitted back and forth between M. Barnes, A. Gafarov, and PSI crew. To make the procedure more efficient, pictures were taken at major steps, and deposited on various web pages.

– The MOSFETS cards installation and the inside cabinet new connectors can be seen at *www.npl.uiuc.edu/ mulhauser/mulan/kicker/psi-aug-05/index.html*. At the time when pictures were taken, the MV2 lower stack white cable was still missing. Requested was send by A. Gafarov to correctly add the silicon paste inside the macor isolator, following Fig. 1.

– The over-current protection circuit boards and the inside tank new connector braid can be seen at *www.npl.uiuc.edu/ mulhauser/mulan/kicker/aug-19-2005/index.html*. Following the study of these pictures, M. Barnes requested that the length of wires attached to the over-current protection circuit board has to be reduced to minimal values. Some solder joint were also changed. Additionally, minimal distance of 10 mm was checked between the flat-top MOSFET card and the over-current protection circuit board.

– The installation of the fiber-optic cable was performed and can be seen at *www.npl.uiuc.edu/ mulhauser/mulan/kicker/aug-23-2005/index.html*. The box installation is shown in Fig. 2. In addition to the description, a reset button is located at the back of the box. It has to be pressed by the operator, to allow the kicker to function again after a trip.

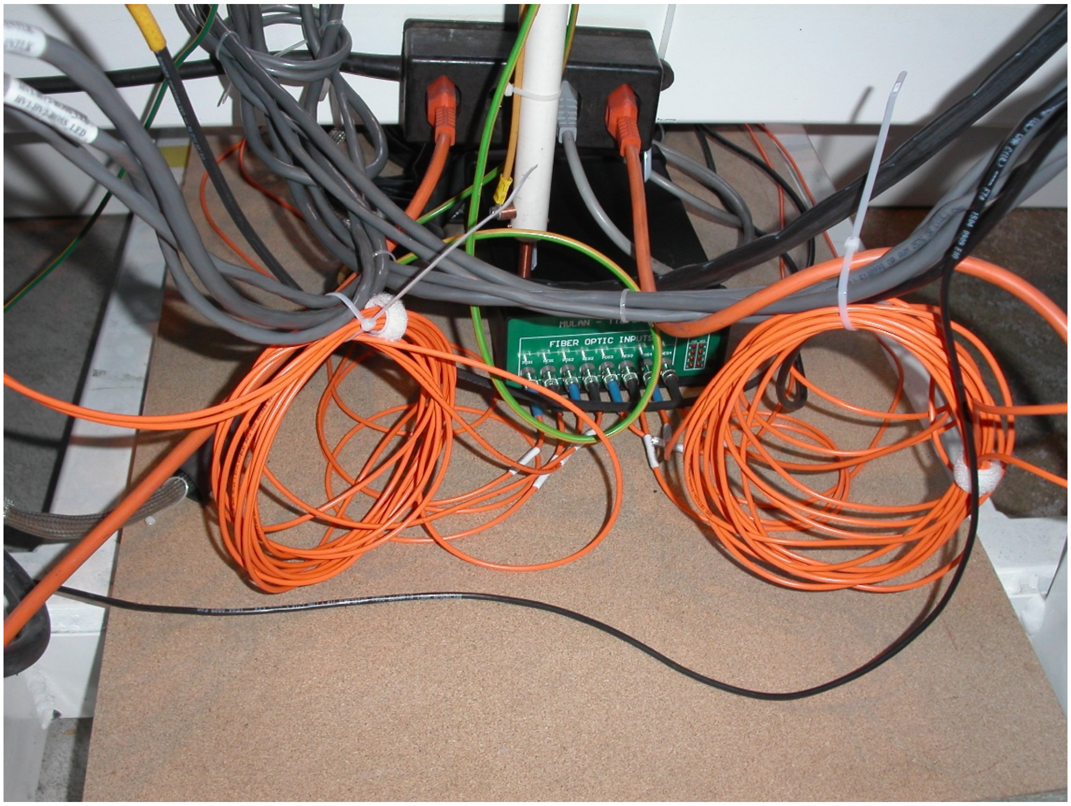

Figure 2: *This box replace the previous TTL distribution box. It is located at the center of the kicker, on the lower frame. The visible front view shows the possible over-current trip LEDs. The non-visible back view has the TTL input signal, the four TTL output signals, towards each cabinet, and the TRIP monitor TTL signal as well as optical out for relay purpose.*

Instructions are given in the document send by TRIUMF, which is attached to *elog:30* of fall 2005.

The correspondence between the LED light on the over-current protection box and the stack is given in Table 1.

The procedure to prepare the kicker before turning it on was very well described by A. Gafarov in *elog:406* of fall 2004. Each step was carefully followed, using the pictures as references. Because the kicker had been used in DC mode previously, the current limitation of the 315 V power supply was set too low for our work. The current nob, on the lower left Step 3 figure, has to be set at **7.0** before being able to have 315 V for the four cabinets. I should add the Step 8 figure could mislead non professional users. Indeed, the picture was taken when the kicker was in a DC mode instead of an AC mode. Any

Table 1: *Input specifications of the over-current protection circuit box. Red LEDs are turned on in case of trip.*

Fiber Optical Cable End	Cabinet	Stack	LED name
Blue	HV1	Top	POS 1
Black	HV1	Bottom	NEG 1
Blue	HV2	Top	POS 2
Black	HV2	Bottom	NEG 2
Blue	MV1	Top	POS 3
Black	MV1	Bottom	NEG 3
Blue	MV2	Top	POS 4
Black	MV2	Bottom	NEG 4

potential user has to make sure that

1. The lower left red nob is set on **OFF**.
2. The middle switch is well set on **TRIGGER**.

Another slightly misleading information is the current readout on Step 11 figure. When running in AC mode, the current is much higher than 0.1 mA. As an exampled, at 20 kHz and 12.5 kV, we are reading around 60 mA.

3 Measurements

Before trying any high voltage measurements, it is necessary to clamp the back and front door micro-switch. This allows us to turn the 315 V power on the cabinets, while having access to the cabinet core. Care has to be taken when bypassing this interlock feature.

The high voltage AC probe was borrowed from PSI electronic division. We used the Tektronix P6015 probe, rated up to 20 kV. We attached its ground cable to a small extension cable (with two alligator clips), such that the length is long enough to move the probe from one end of a stack to the other, but not too long, otherwise it picks up noise. We attached this ground to the metal plate on the Fischer connector side of the cabinet.

Because not many of us are specialists, you will see pictures of one MOSFET card in Fig. 3. On the front side, you see well the ferrite, through which the 315 V cable goes as well as the copper shielding of the diode itself. Of particular interest is also a small resistor located in position C13. On the back side, one has a visible view of a long blue resistor. Some cards came back from TRIUMF with this resistor de-soldered. Also nicely visible are the drain (OUT +) and source (OUT -) pads.

Once the MOSFET cards are installed in the cabinet, the first measurement to perform is the check of the drain-source resistor, without any voltage around. You measure the drain-source resistor from the back side of the cabinet. In this position, the drain pads is on the right side of the card. One has to pay attention to the DVM orientation. Make sure that the positive (normally red) sensor is on the drain, whereas the negative (normally black) sensor is on the source. When the MOSFET is properly working, you should be reading **1.6 MΩ**. Non working cards will most likely show very low resistor values.

The next measurement to perform requires that the 315 V be turned on. We are checking that the yellow LED receives the proper voltage and are correctly turned on. The measurement takes place via the front cabinet door. At first, check that all yellow LEDs are ON. Then, care has to be taken because the big gray resistor is at 315 V. One measures, for each card, the DC voltage on both ends of the C13 resistors. Values around **16 V** should be obtain. Too low or too high values are signs of non properly working cards. Once those two measurements are successful, one should be able to proceed to turning on the high voltage.

Before turning the kicker on, it was important to follow M. Barnes advice about the testing procedure. We decided to test one cabinet at the time, to avoid major damages. As an example, here is the procedure to test HV1.

Figure 3: *Front and back sides of one MOSFET card. On the front side, one sees the ferrite, the copper shielding of the MOSFET and other electronic parts. Of particular interest is the small resistor located on position C13 (lower middle part). On the back side, one sees clearly the long blue resistor, as well as the drain (OUT +) and source (OUT -) pads.*

1. Remove upper and lower 2.5 kΩ resistors from cabinet MV1, so that power from HV1 HV DC supply does not charge 220nF capacitors in MV1.
2. Turn on 315 V power supply. Current drawn should be approximately 1.350 A.
3. Turn on HV1 HV DC supply at say 1 kV. Do NOT turn on HV2 HV DC supply. Check that there is NOT one or two bright red LEDs in HV1.
4. Pulse all cabinets at say 1 kHz with 1 μs width signal ON.
5. Turn HV1 DC supply up to say 3.4 kV.
6. Voltage grade HV1.
7. Turn off HV1 and 315 V power supplies.
8. Replace upper and lower 2.5 kΩ resistors in cabinet MV1.

However good is this procedure, we did some more careful test before grating each card in the cabinet. We first decided to test the entire cabinet in a DC mode. Instead of changing a lot in the kicker setup, there is an easy procedure that works for our test. With the 315 V on, one need a 50 Ω BNC terminator and also a DC TTL signal (> 3 V).

1. Set the HV polarity to positive. Turn the HV to 1 kV.
2. Check that NO red LEDs are visible.
3. Turn the HV to 2 kV@.
4. Remove the TTL input on the cabinet.
5. Plug the 50 Ω terminator.
6. The lower stack is now ON, thus NO red LED should be seen on the lower stack cards.
7. The upper stack is now OFF, thus red LED should be seen on each of the upper stack cards.
8. Remove the terminator and plug the DC TTL signal.
9. The LEDs on both stacks should not have changed, because no switch has occurred.
10. Remove the DC TTL signal and replug it again.
11. This time, the switch has occurred and the LEDs on both stacks should be the opposite.
12. The lower stack is now OFF, and thus red LED should be seen on each of the lower stack cards.
13. The upper stack is now ON, thus NO red LED should be seen on any of the upper stack card.
14. Remove the DC TTL signal and put back the real TTL signal.

At this point, you know that your cabinet is safe to operate and that you should be able to increase the high voltage without enormous surprise. The next step is to use the HV probe to see the shape of the signal seen at the braid which connects the stack and the new connectors. Turn HV off as well as 315 V power. Once the probe is well attached, turn the 315 V on. Turn the HV to 350 V and look at the probe on the scope (1 MΩ impedance, the probe gives a factor 1000 less than what is measured). You should trigger the scope with a copy of your TTL signal. You will see the shape of the signal. If it looks correct, you can ramp the HV to higher voltage, up to 3.4 kV. Figure 4 shows such a result. One important result is that the probe measure approximatively 3.3 V, thus the correct HV. The second result is the rise and fall time which are measure there. One obtains around 50 ns for both. It is important to notice that these risetime varies with the voltage. At low voltage, such as 350 V, the risetime was measured at 72 ns. Above 3.4 kV, the risetime will still decrease. However, we did not measure with the probe at higher voltage.

The grating measurement are performed on each of the 17 cards of a stack. All cabinet polarity was set to positive for each measurement. The TTL signal is 1 μs long and has a 1 kHz frequency. The cabinet voltage is 3.4 kV. One uses the HV probe.

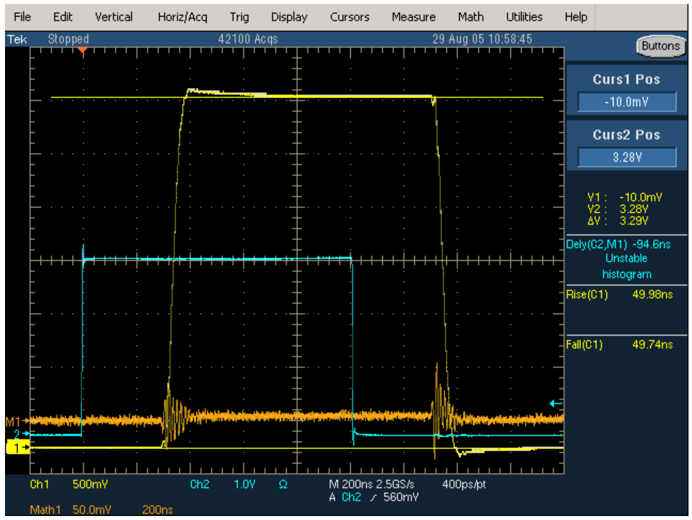

Figure 4: *Example of the probe measurement attached to the braid in the HV1 cabinet. The trigger is given by signal 2 (blue) which is the TTL input. The signal #1 (yellow) is our probe (discard M1 signal). The HV was set at 3.4 kV.*

1. Measure the drain signal. Save it as reference signal.
2. Measure the source signal. Have the scope performing a math subtraction between ref and signal.
3. Look at the math signal. Save the file.

A graph for each card in all four cabinets has been saved. One could find them at *www.npl.uiuc.edu/ mulhauser/mulan/kicker.html*, following the grating link for each cabinet.

For non specialist, it may be important to explain what one sees on those graphs and what one should pay attention to. Figures 5– 8 represent some typical cases. The first two figures, Figs. 5 and

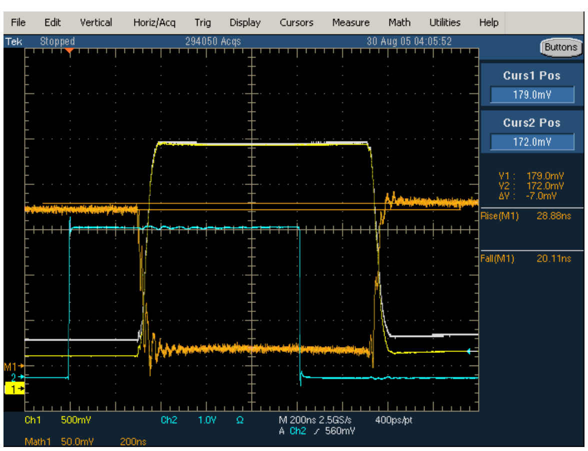

Figure 5: *Grating measurement for card #15 in the upper stack of the HV2 cabinet. The white signal is the drain measurement, saved as reference signal. The yellow signal (#1) is the source measurement. The M1 signal, in orange, is the subtraction of the previous ones. For upper stack, one measures the height of M1 signal (∼160 mV) and one pays attention at the possible spike (barely visible, ∼7 mV) at the start of the fall time.*

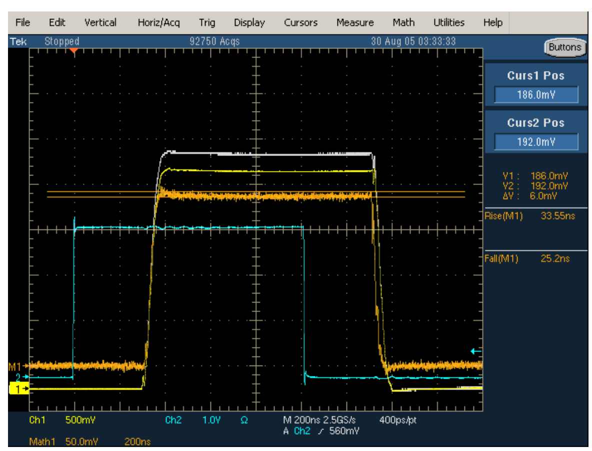

Figure 6: *Grating measurement for card #15 in the lower stack of the HV2 cabinet. Explanation of signal is given in Fig. 5. For lower stack, one measures the height of M1 signal (∼186 mV) and one pays attention at the possible spike (barely visible, ∼6 mV) at the end of upper part of the signal, before it falls back.*

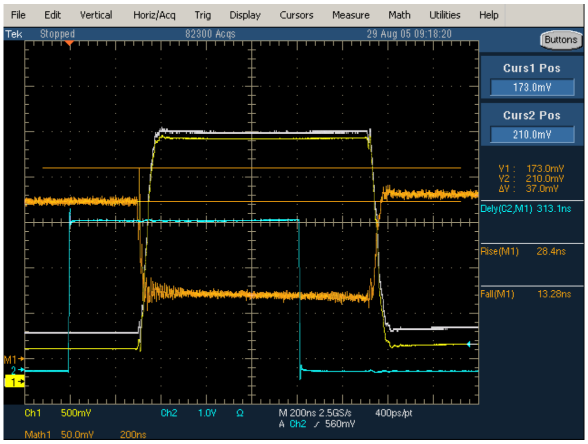

Figure 7: *Grating measurement for card #15 in the upper stack of the HV1 cabinet. Explanation of signal is given in Fig. 5. This card shows a much more pronounced spike (∼30 mV).*

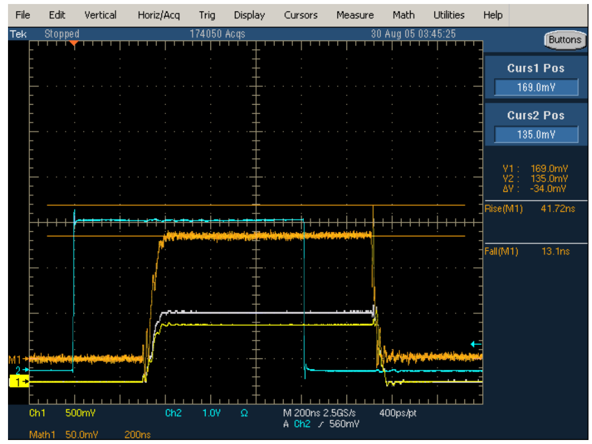

Figure 8: *Grating measurement for card #05 in the lower stack of the HV2 cabinet. Explanation of signal is given in Fig. 5. This card shows a much more pronounced spike (∼30 mV).*

6, are showing perfect cases for upper and lower stack measurements. The height of the source–drain measurement is in the 160–180 mV range. The timing of the card switch is fine and does not show any special spike. The horizontal cursors are showing the amplitude of the switch for each card. If this is small, the card is working perfectly well.

The next two figures, Figs. 7 and 8 are similar examples where the timing is not as good as what we would like to have. The spike is pronounced, ∼30 mV, but still acceptable. When we measured other cards with bigger variations, we suspected the fiber optic cable and the card itself. The first reparation is to turn the HV off, reseated the fiber optic cable in the card correctly, and turn the HV on. A new measurement is performed. In most of the case, this was sufficient to reduce the spike to appropriate levels.

4 Results

Because this report is supposed to help us find as many solutions as possible, I am listing the card numbers and their location in each of the cabinets in Table 2. In addition to those cards, there is seven cards not correctly tested at TRIUMF, with the serial numbers: #43, 60, 71, 94, 108, 122, and 163. It is important to notice that the content of Table 2 correspond to the card situation after we finished the test on August 29–31, 2005.

We studied each cabinet at the time, starting with HV1. When we turned the 315 V on for the first time, we noticed that card #50 did not have the yellow LED. It was replaced by card #171. In reality, also the fiber optic of this card position, namely DN17, was replaced. The second card to fail was card #46, which was replaced by card #175. In fact this card was having the blue resistor (see Fig. 3) de-soldered. This card was used in the HV1 cabinet for the early test with the broken join, at voltage up to 3.4 kV. Therefore, M. Barnes was hesitating to use it. It may very well be that the new solder joint which was made will solve the problem and that the card could be used properly. When performing DC tests, we found that card #30 was not turning on properly. Once on, its red LED was always on. It was replaced by card #187.

Cabinet MV1 was checked just after. Card #32 (position DN12) was also having a broken blue resistor joint. It was re-soldered and used. Up to now, no problems were found with it.

We continued with cabinet HV2. Due to some timing problems in card position DN17 (card #117), we exchange it with the card in position DN03 (card #11), where the time switch is less a problem.

We finished with cabinet MV2. When performing the small C13 resistor DC voltage test, we found out that card #93 was having around 18 V (instead of 15–17 V). We removed the card and replaced it by card #176. Also due to some timing problem, card #166 (position DN11) was first exchange with the flat-top circuit card #88. However, this did not solve the problem in DN11. Therefore, we switch card from DN11 and DN10 and solved the timing problem.

Table 2: *Card serial numbers relative to stacks and cabinets. The vertical numbering matches the geographical location of the cards. The topmost card is UP–01 and the lowest card is DN–01. The last two raws correspond to the cards used for the flat-top circuit on both stacks.*

HV1 Cabinet		HV2 Cabinet		MV1 Cabinet		MV2 Cabinet	
Location	Card #	Location	Card #	Location	Card #	Location	Card #
UP01	69	UP01	147	UP01	100	UP01	85
UP02	66	UP02	149	UP02	103	UP02	105
UP03	73	UP03	34	UP03	150	UP03	111
UP04	80	UP04	42	UP04	159	UP04	157
UP05	138	UP05	54	UP05	24	UP05	164
UP06	143	UP06	72	UP06	59	UP06	03
UP07	22	UP07	76	UP07	99	UP07	58
UP08	35	UP08	119	UP08	114	UP08	97
UP09	62	UP09	121	UP09	154	UP09	104
UP10	68	UP10	156	UP10	162	UP10	141
UP11	82	UP11	18	UP11	08	UP11	25
UP12	84	UP12	21	UP12	29	UP12	56
UP13	127	UP13	63	UP13	57	UP13	81
UP14	137	UP14	67	UP14	61	UP14	92
UP15	161	UP15	83	UP15	96	UP15	123
UP16	06	UP16	86	UP16	106	UP16	131
UP17	187	UP17	102	UP17	124	UP17	16
DN17	171	DN17	11	DN17	145	DN17	17
DN16	53	DN16	129	DN16	165	DN16	75
DN15	01	DN15	139	DN15	05	DN15	77
DN14	14	DN14	112	DN14	13	DN14	176
DN13	31	DN13	126	DN13	26	DN13	140
DN12	33	DN12	07	DN12	32	DN12	148
DN11	55	DN11	15	DN11	41	DN11	10
DN10	110	DN10	40	DN10	65	DN10	88
DN09	132	DN09	47	DN09	180	DN09	28
DN08	158	DN08	107	DN08	87	DN08	51
DN07	02	DN07	109	DN07	116	DN07	91
DN06	23	DN06	118	DN06	151	DN06	130
DN05	175	DN05	134	DN05	152	DN05	135
DN04	64	DN04	144	DN04	155	DN04	160
DN03	79	DN03	117	DN03	04	DN03	45
DN02	95	DN02	20	DN02	19	DN02	128
DN01	133	DN01	48	DN01	27	DN01	153
UP18	146	UP18	186	UP18	38	UP18	70
DN18	136	DN18	168	DN18	49	DN18	166

On August 29, 2005, I found that card #78 (MV1, DN09 position) was missing both its LEDs. It was taken out, measured to be dead, and replaced by card #180. At this moment, we don't have any spare card.

Another important information is the "conclusions" from fall 2004 dead MOSFETS. Once the full stack killing process was finished, we end up having single dead card. The first time it was located in HV2 cabinet, position UP07 and DN02, DN04, DN08, and DN11. Then we had DN01 in the same cabinet, followed by HV1 cabinet UP01. Finally, we had HV2 DN11 and DN17. Thus we exchange the HV2 fiber optic cable for position DN11 and DN17.

We reach now the moment of giving a list of the timing we found during our grating measurement. As already mentioned, each graphs can be found on the web page. However, a table with all results may be of some interest and is given in Table 3. For each cards, one give the lower and higher amplitude

Table 3: *Grating timing for each card. For each card, one gives the lower and higher voltage of the drain–source measurement, to see the presence and amplitude of spike.*

HV1 Cabinet		HV2 Cabinet		MV1 Cabinet		MV2 Cabinet	
Location	Low–High [mV]	Location	Low–High [mV]	Location	Low–High [mV]	Location	Low–High [mV]
UP01	223–245	UP01	220–230	UP01	223–231	UP01	223–236
UP02	211–232	UP02	211–225	UP02	211–229	UP02	210–215
UP03	204–239	UP03	204–220	UP03	201–208	UP03	203–214
UP04	192–212	UP04	192–211	UP04	191–196	UP04	193–201
UP05	183–195	UP05	184–198	UP05	183–188	UP05	184–199
UP06	178–190	UP06	179–189	UP06	179–184	UP06	180–185
UP07	172–180	UP07	171–185	UP07	172–177	UP07	172–184
UP08	172–185	UP08	172–177	UP08	171–178	UP08	172–183
UP09	166–188	UP09	165–175	UP09	166–171	UP09	165–177
UP10	166–183	UP10	168–173	UP10	169–172	UP10	167–181
UP11	166–189	UP11	163–168	UP11	165–170	UP11	165–176
UP12	166–187	UP12	168–176	UP12	168–173	UP12	167–184
UP13	166–190	UP13	166–183	UP13	165–171	UP13	167–182
UP14	170–194	UP14	172–181	UP14	172–176	UP14	169–182
UP15	173–210	UP15	172–179	UP15	172–186	UP15	172–183
UP16	179–205	UP16	177–182	UP16	179–186	UP16	182–188
UP17	185–216	UP17	186–192	UP17	186–193	UP17	184–193
DN17	246–268	DN17	169–189	DN17	205–211	DN17	173–189
DN16	150–156	DN16	200–211	DN16	172–177	DN16	169–186
DN15	203–211	DN15	186–192	DN15	187–191	DN15	157–162
DN14	201–206	DN14	151–168	DN14	146–150	DN14	190–194
DN13	174–196	DN13	131–168	DN13	146–151	DN13	154–166
DN12	201–205	DN12	136–143	DN12	172–179	DN12	150–161
DN11	187–194	DN11	185–207	DN11	135–140	DN11	151–166
DN10	186–194	DN10	150–169	DN10	235–241	DN10	169–185
DN09	184–191	DN09	190–197	DN09	157–161	DN09	142–149
DN08	181–186	DN08	139–145	DN08	145–152	DN08	161–168
DN07	179–192	DN07	125–134	DN07	161–169	DN07	180–185
DN06	185–191	DN06	180–190	DN06	191–198	DN06	142–146
DN05	173–197	DN05	135–169	DN05	134–142	DN05	130–134
DN04	195–201	DN04	169–192	DN04	176–182	DN04	166–171
DN03	173–179	DN03	137–150	DN03	151–160	DN03	164–181
DN02	207–226	DN02	193–215	DN02	204–209	DN02	203–221
DN01	207–227	DN01	189–208	DN01	208–222	DN01	196–218

of the spike, taken when the card is switching. It is important to notice that there is some variation in the total amplitude of each card. This problem is not totally real, because the measured value was depending a lot on the position of the HV probe. Many measurements were sometimes necessary to obtain a meaningful result. M. Barnes was not really happy about it, but could not find a better solution. Therefore, the full amplitude is only approximative.

Once the grating measurements were successful, the cabinet was tested to allow us to ramp it up to maximal voltage. Measurements of the HV probe on the braid as well as the capacitive pick-up for each deflector plate were done at 1 kHz, 5 μs width, 3.4 kV, with a BNC cable of 9.5 ns length. Results for MV2 cabinet is given in Fig. 9. One can measure a signal (yellow) of 3.4 V and a corresponding capacitive pick-up of 28 mV. It is important to notice the magenta signal in channel #3. This is the TRIP monitor signal, coming from the distribution box. It should be on (positive TTL) when everything is normal inside the cabinet. If a trip occurs, this signal will disappear until someone press the reset button on the box. The width of this signal is around 70 ns at full voltage, whereas only

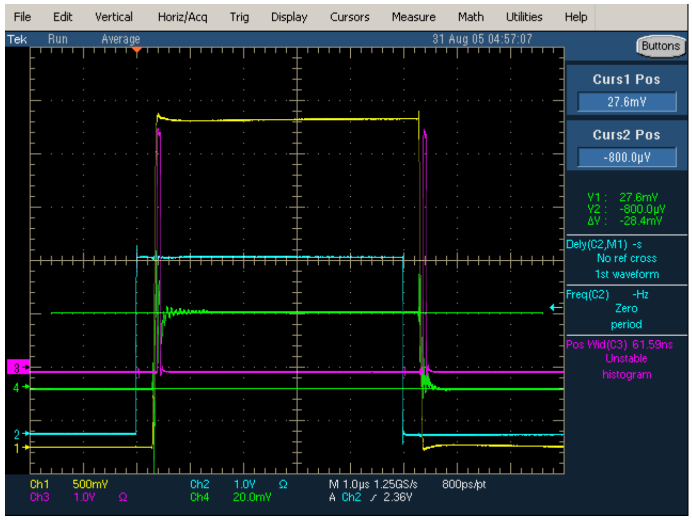

Figure 9: *Signal #2 (blue) is the TTL input and is triggering the scope. Signal #1 (yellow) is the HV probe on the braid. Signal #3 (magenta) is the TRIP monitor output of the distribution box. Signal #4 (green) is the capacitive pickup signal from the inside of the beampipe.*

60 ns at low voltage. It is also important to know that the height and noise of the capacitive pick-up signal varies with the length of the cable.

Once such a measurement was performed, we removed the HV probe from the cabinet and increased the HV up to 12.5 kV. Table 4 represents the results we obtained at various positive voltages. The time width is the value of the TRIP monitor one.

To see the effect of the capacitive pick-up cable length, it is interesting to compare Fig. 10 left and right. The amplitude decreases and the noise increases, as can be expected. It is clear that we will need longer cable during the run period, thus we will have noisier and smaller signals.

The same measurements were performed at higher frequencies, up to 20 kHz. Graphic results are presented in
www.npl.uiuc.edu/ mulhauser/mulan/kicker/capa-pickup/index.html, as function of the cabinet.

Finally, I installed all four capacitive pick-up signals with 16 ns length cable on the scope, while triggering on the TRIP monitor. Such a result is given in Fig. 11. At full voltage, negative polarity on HV1 and positive on HV2 and 20 kHz, with 5 μs width on, we measure 1.359 A at the 315 V power supply and 58 mA at both HV power supplies. Table 5 present on overview of the results for each voltage.

Table 4: *Capacitive pick-up amplitude as function of cabinet high voltage. All measurements were done with 9.5 ns long cable and a positive high voltage on each plate. The third column for each cabinet correspond to the width of the TRIP monitor signal (magenta channel in Fig. 9).*

HV1 Cabinet			HV2 Cabinet			MV1 Cabinet			MV2 Cabinet		
HV [kV]	Pick-up [mV]	Width [ns]	HV [kV]	Pick-up [mV]	Width [ns]	HV [kV]	Pick-up [mV]	Width [ns]	HV [kV]	Pick-up [mV]	Width [ns]
3.4	30	62	3.4	26	43	3.4	22	45	3.4	28.4	61
5	46.6		6.25	48		6	38		6	50.8	
7	64.8										
9	84.4		9	69		9	56.4		9	76.8	
10	93.6		10	77							
11	102.8		11	84		11	69		11	94	
12	112		12	92		12	75				
12.5	116.4	70	12.5	96	75	12.5	78.4	73	12.5	107	72

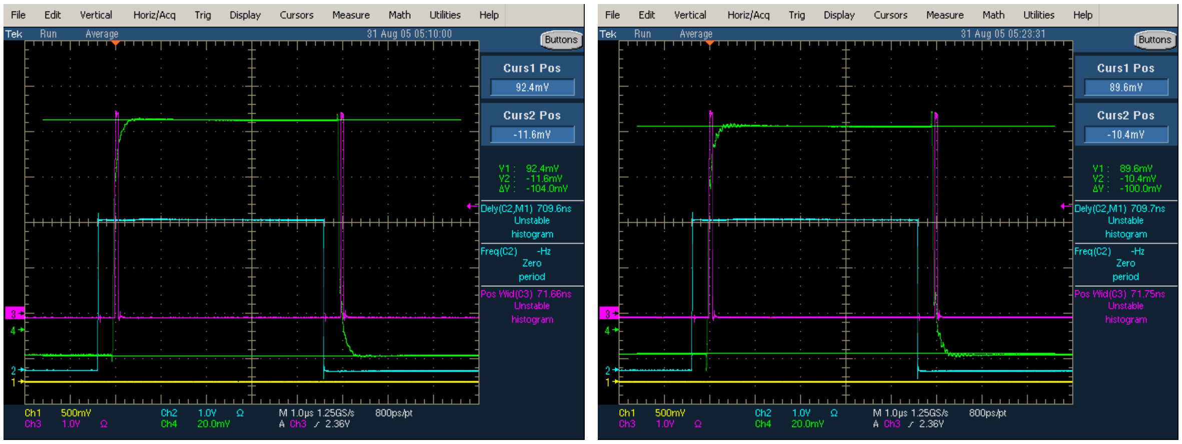

Figure 10: *Influence of the capacitive pick-up cable length. One measure MV2 cabinet at 12.5 kV, at 20 kHz, with a cable length of 9.5 ns (left) and 16 ns (right).*

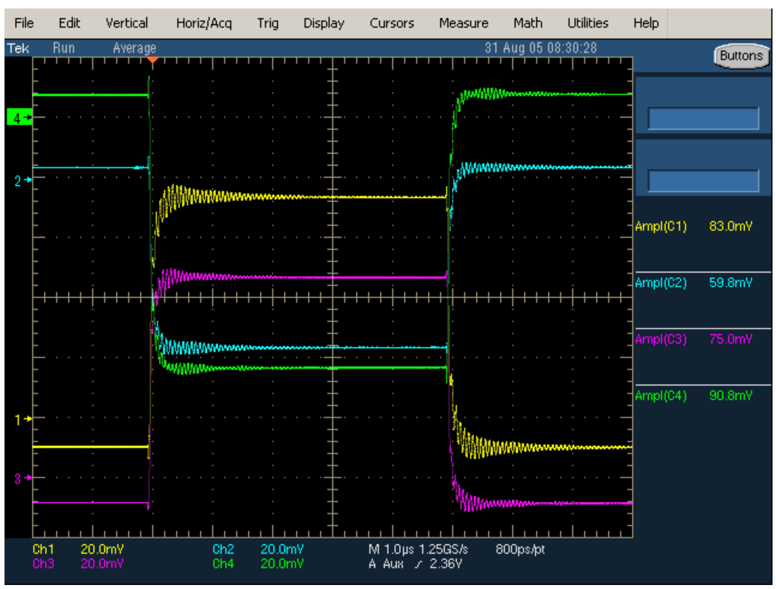

Figure 11: *All four capacitive pick-up signal on scope. High voltage at 12.5 kV (positive on HV2 and negative on HV1), 5 µs width on, 20 kHz frequency, 16 ns length cables. Channel #1 is upstream top, #2 bottom, whereas channel #3 is downstream top and #4 bottom.*

Table 5: *Amplitude of the capacitive pick-up signal for each signal with the 16 ns long cable (1 MΩ input impedance). Units are mV.*

Channel	Location	3.4 kV	6 kV	9 kV	12.5 kV
#1	Upstream Top	22.2	39.4	59.4	82.6
#2	Upstream Bottom	16.4	28.8	43.2	60
#3	Downstream Top	20.4	36.1	54	75
#4	Downstream Bottom	24.7	44	65.4	90.8