Technical Note

The FACT Lidar Veto
FLV

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The FACT telescope as well as the MAGIC telescopes are sometimes affected by the LIDAR events. This is an old problem and the solutions have been discussed in the past and we decided that LIDAR events should be vetoed at the FACT camera trigger. This documentation is about our hardware implementation of the **F**ACT (MAGIC-)**L**idar **V**eto (**FLV**).

Contents

1 Introduction

1.1 Motivation

MAGIC operates a LIDAR that produces pulsed laser light that shoots (with an offset) to their FoV with few 100Hz. Details can be found in Christian Fruck's Diplomarbeit [1]. This light gets scattered in the atmosphere and is used (by MAGIC) to detect and correct for clouds. Unfortunately, this scattered pulsed laser light often triggers our telescope and therefore saturates our DAQ. The basic problem can be seen in Fig. 1.1. The FACT telescope as well as the MAGIC telescopes are sometimes affected by the LIDAR events. We decided that LIDAR

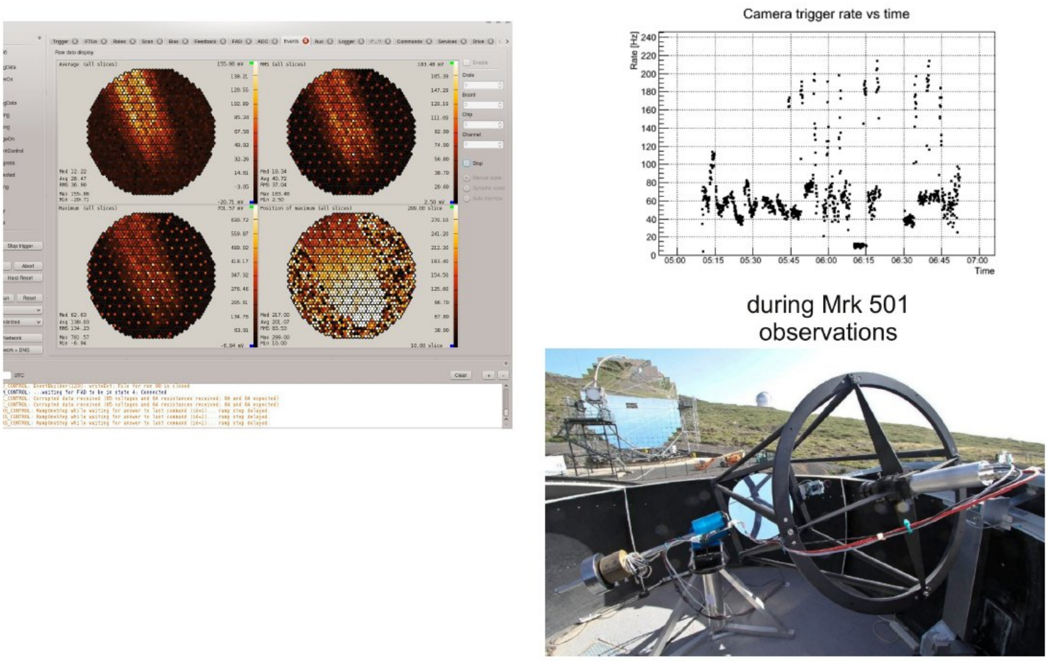

Figure 1.1: The MAGIC LIDAR affecting the FACT Telescope. On the top left image one can see a LIDAR event in our camera display. Top right shows the FACT camera rate during one night. The LIDAR shooting in regular intervals can be clearly seen. The bottom right image shows the LIDAR itself in the dome at the MAGIC counting house.

events should be vetoed at the FACT camera trigger.

1.2 The Idea

The MAGIC Lidar is triggered by a computer. The computer produces TTL pulses that are processed in a NIM module. From this module, the Lidar laser is fed. Our plan is to build a module ourselves, that will go in between the computer and the Lidar NIM module. Our module would fan-out our FACT-Veto and the regular Lidar trigger. From the NIM crate we have to go all the way to our container, through the cable canal (see Fig. 1.2). Then, with

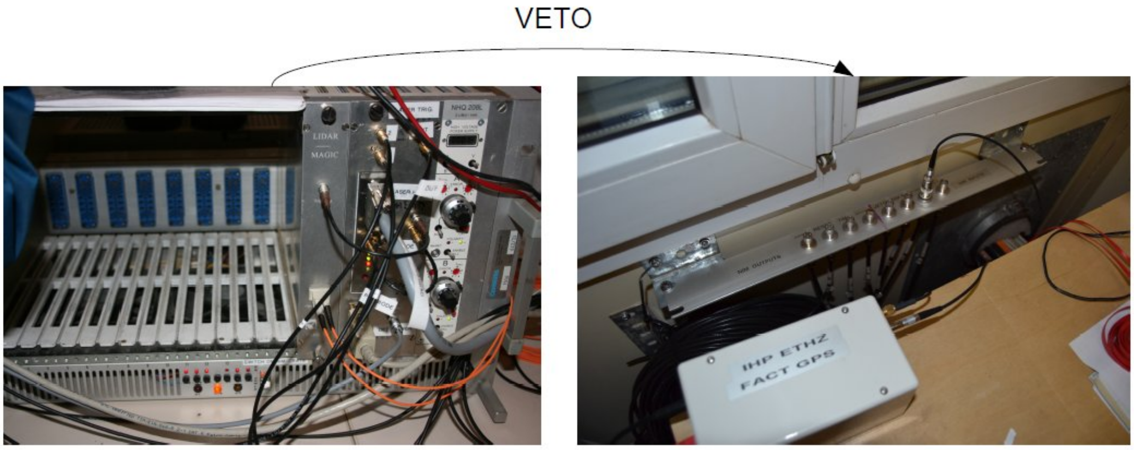

Figure 1.2: Left: inside the MAGIC Lidar tower. The NIM rack would be used in order to intercept the TTL trigger from the lidar computer and fan out a veto that goes all the way to the FTM trigger inputs in our container (right picture)

another module, we could produce a precise (delayed and adjusted width in time) veto signal and feed it into the VETO on the FTM inputs.

2 Preparatory Measurements

In order to find the correct specifications for the FACT Lidar Veto I was measuring some parameters during my nightshift on La Palma in January 2014.

2.1 Lidar Trigger and Delays

The Lidar is triggered by a TTL pulse from the lidar computer. This trigger goes to the laser and, after some time, the laser shoots. A schematic from Christians Diplomarbeit can be seen in Fig. 2.1. This delay happens because the laser needs some time to produce the inversion.

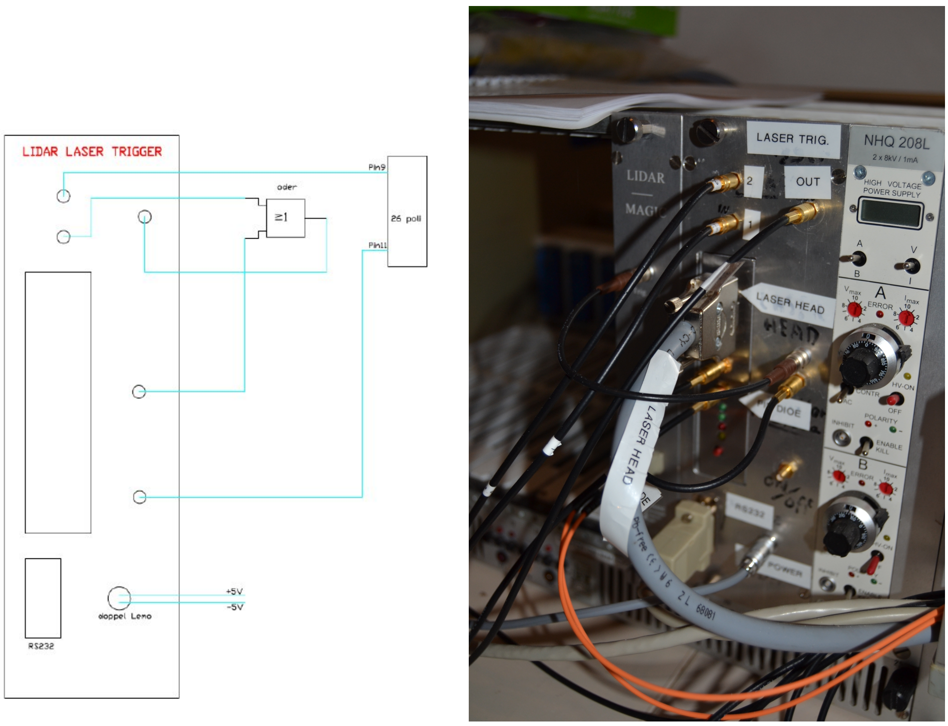

Figure 2.1: Left: The schematic of the NIM laser trigger module from Christian's Diploarbeit [1]. Right: the real NIM laser trigger module. The connectors are mainly SMB connectors.

This time is specified in the laser datasheet with $<$ 70mus. This value is not good enough for us, because it means that in the worst case we have to delay the veto quite a bit (the 100m cable from the Lidar to the Veto on the FAD in the camera give about 0.5mus « 70mus -> delay in order to avoid unneccessary deadtime). MAGIC uses a PIN-Diode, directly next to the laser, in order to flag their Lidar events as such and in order to start the Lidar FADC readout. This PIN-Diode I used to measure the delay between the Computer generated TTL trigger and the shot. Furthermore the TTL trigger signal itself was characterized. The results from this measurement can be seen in Fig. 2.2

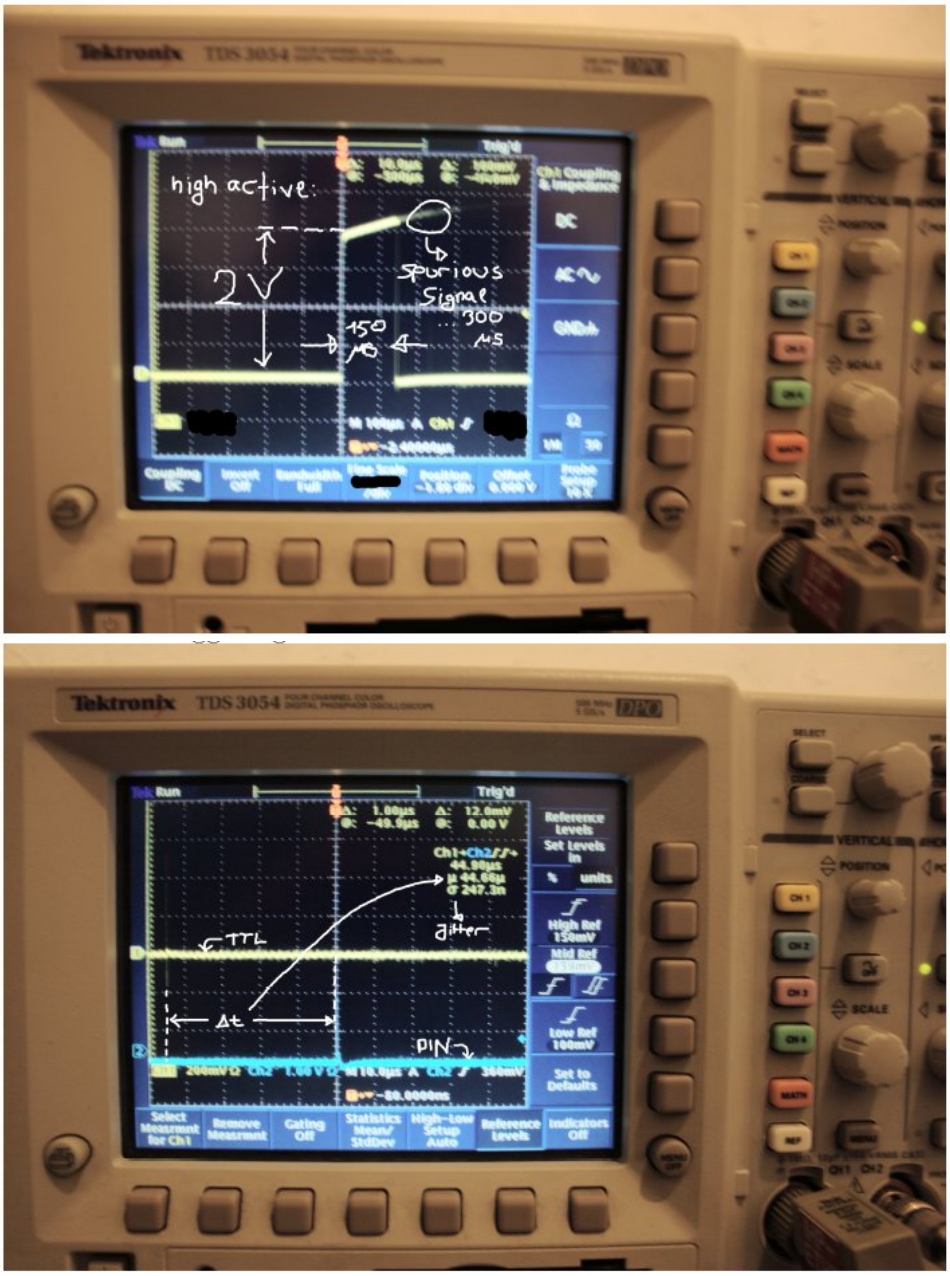

Figure 2.2: Prepatory measurements. Top: TTL trigger characterization. Bottom: Delay and jitter measurement.

The TTL channel can be seen and was directly measured with one probe. The second channel is the signal directly from the PIN-Diode that Christian Fruck also uses as a reference for triggering the readout on the FADC. The delay was measured with the TEK-Oszi-built-in delay measuremet function. The results are:

- active high TTL trigger
- TTL trigger has 2V Amplitude
- TTL trigger is 150mus long, with spurious pulses up to 300mus
- 44.6mus delay from TTL trigger to laser shot
- Jitter on this delay: 0.25mus
- all other delays (measurement cable length) are small ($<$50ns) compared to this and can be neglected.

2.2 Cable Length

The total distance from the NIM crate in the Lidar tower was measured with a 50m measuring tape and two persons. The path is indicated in Fig. 2.3. The result is that we need (64 ± 10)m cable inbetween the two modules.

Figure 2.3: The path from the NIM crate to the FTM trigger in board in the FACT container.

3 Hardware

Hanspeter and Lubomir produced, after fixing the specifications, the following FACT Lidar Veto. It consists of one NIM module to be placed at the Lidar side, one long cable that transmits signals and power, and one module to go in the FACT container.

3.1 NIM Module: FLV01

Figure 3.1: The FLV01 module

The NIM Module "FLV01" has to be placed in the NIM rack inbetween the computer and the laser trigger module. It produces two triggers out of one. The first is fed via two independent differential lines to the FACT container. The second is given back to the Laser trigger module. A picture of it can be seen in Fig. 3.1 An annotated schematic of the module can be seen in Fig. 3.2. It consists of a power supply, a signal splitter into: first a two way differential,

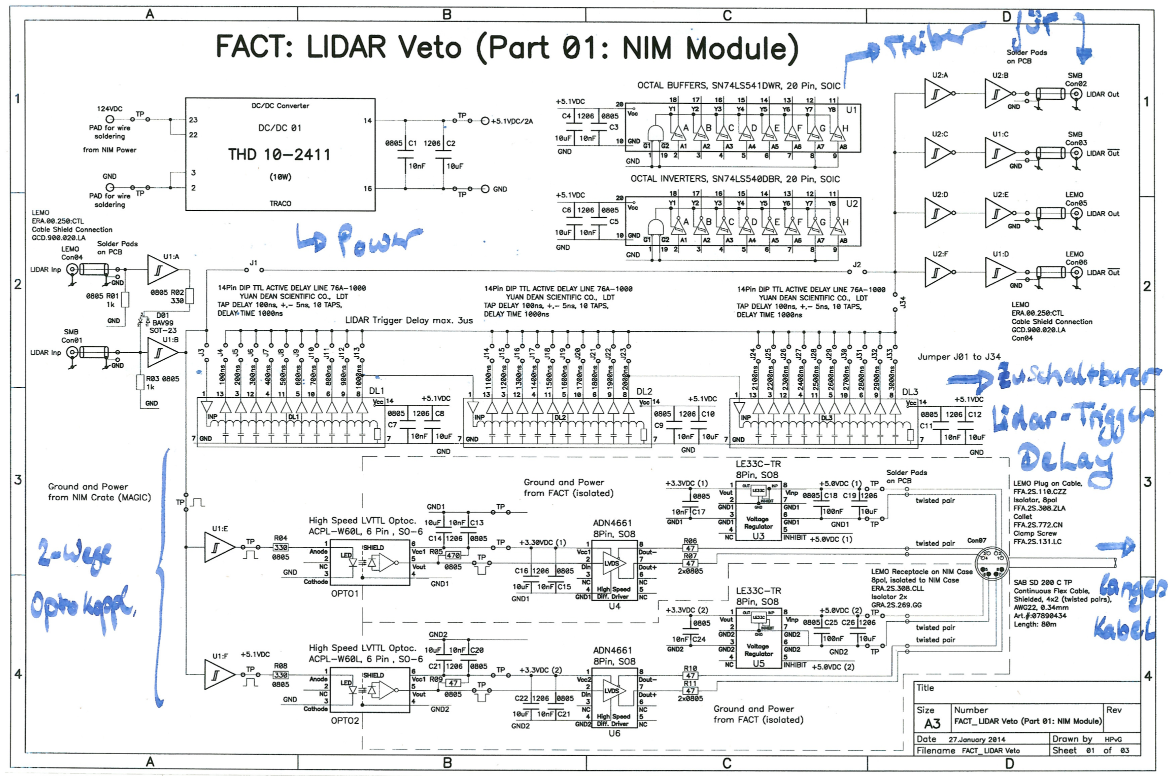

Figure 3.2: The FLV01 module

opto-coupled signal transmission line, and second a switchable (with jumpers) analog delayline to the MAGIC Lidar TTL out. The module needs the TTL trigger signal from the computer and will produce two out of it: The MAGIC Lidar module gets one and also (through the long cable) the FACT Lidar Veto module 02 in the container.

3.1.1 Connectors

The connectors are the following (there is secondary and primary. The primary input has always higher priority than the secondary)

- MAGIC Lidar Trigger TTL: main Out, main Out-Inverted, sec Out, sec Out-Inverted. These are outputs to which the MAGIC Lidar module must be connected.
- Inp: main in, sec in. These are the inputs to which the Lidar TTL coputer trigger must be connected.

- MAGIC <=> FACT Power & Lidar Veto Signal: Here the long cable to the FACT container must be connected to. The NIM modules TTL outputs are galvanically (opto-couplers) separated from the transmission line to the FACT container. Therefore we also deliver power from the container to the FLV01 via the long cable.

3.1.2 LEDs

Following LED show the status of the FLV01 module:

- +5V: shows if the voltage from the NIM rack is delivered.
- LVO: shows if the Lidar TTL trigger gets processed.

3.1.3 Jumpers

There is a row of jumpers on the FLV01 that can be used to enable the delay line to the TTL output, in case the Laser would shoot too fast (to be vetoed). Luckily after the measurement of $\sim$ 44mus delay we probably do not need this delay anymore, but for completeness I want to document it here. The Jumpers J4 - J33 can be set (only one at a time!) in order to get 0.1mus delay on the Laser side per jumper (total of 3mus possible). The jumpers are marked in Fig. 3.3, please have a look at the extensive schematics in case you want to use them (in the trac-svn).

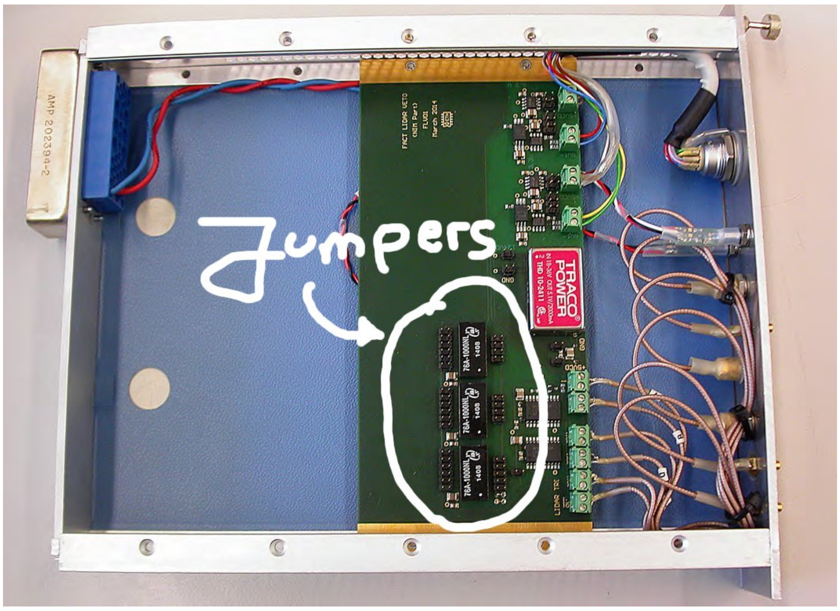

Figure 3.3: The FLV01 jumpers

3.1.4 Special Remarks

There exist three versions of the FLV01: #1, #2, #3. We plan on shipping only one and to keep the other two for possible testing purposes. The module FLV01#3 has a shortcut at the side of the jumpers (J2), in order to circumvent the delay line completely and permanently. If one wants to use the delay line on this module one first has to remove this short.

3.2 Cable

The long cable is 80m long in order to have some spare meters if the measurement maximum of 74m was too tight. The cable transmits power and signals according to Fig. 3.4 There exist

FACT_LIDAR_Veto_Kabel_Signal&Low Voltage.xls 06/25/2014

FACT_LIDAR_Veto_Cable					**HPvG**	**Mo, 05. Mai 2014**
Cable Signal & Low Voltage 2x						
Cable Length: 85m						
Con07 :			Cable01:			Con08 :
LEMO Plug on Cable (8 Pol)			Cable: Schleppkettenleitung			LEMO Plug on Cable (8 Pol)
Type FFA.2S.110.CZZ			Type: SD 200 C TP			Type FFA.2S.110.CZZ
Isolator, 8 Pol			Company: SAB Bröckskes			Isolator, 8 Pol
Type FFA.2S.308.ZLA			Art.-Nr. 07890434			Type FFA.2S.308.ZLA
Collet: Type FFA.2S.772.CN			4 x 2 x 0.34 mm² (AWG22)			Collet: Type FFA.2S.772.CN
Clamp Screw: Type FFA.2S.131.LC						Clamp Screw: Type FFA.2S.131.LC
Pin #	Function	Signal Name	Wire #	Wire Color	Signal Name	Pin #
1	FACT LIDAR Veto Trg(1)	+5VDC(1)	1	weiss / white	+5VDC(1)	1
2	FACT LIDAR Veto Trg(1)	Return (+5VDC(1)) GND1	2	braun / brown	Return (+5VDC(1)) GND1	2
3	FACT LIDAR Veto Trg(1)	LIDAR VETO -Trg(1)	3	grün / green	LIDAR VETO -Trg(1)	3
4	FACT LIDAR Veto Trg(1)	LIDAR VETO +Trg(1)	4	gelb / yellow	LIDAR VETO +Trg(1)	4
5	FACT LIDAR Veto Trg(2)	+5VDC(2)	5	grau / grey	+5VDC(2)	5
6	FACT LIDAR Veto Trg(2)	Return (+5VDC(2)) GND2	6	rosa / pink	Return (+5VDC(2)) GND2	6
7	FACT LIDAR Veto Trg(2)	LIDAR VETO -Trg(2)	7	blau / blue	LIDAR VETO -Trg(2)	7
8	FACT LIDAR Veto Trg(2)	LIDAR VETO +Trg(2)	8	rot / red	LIDAR VETO +Trg(2)	8

Figure 3.4: The cable specifications and an image of the two cables

two cables of the same type, one is marked with a red ribbon.

3.3 Box Two

The “FLV02” box for the FACT container looks as in Fig. 3.5. It produces a Veto signal

Figure 3.5: The box that goes in the FACT container “FLV02”

out of the transmitted signal from the FLV01. The veto signal is adjustable, more about that in the subsection on the potentiometers. The box itself consists of an inverse copy of the optocouplers in the FLV01. The FLV02 has two in dependent lines (as the FLV01), each with two channels. On both lines one can adjust the extra delay and the time width of the veto signal via two potentiometers, two on each line, in total four. The delay and the variable time width is realized with CMOS Dual Monostable Multivibrators., as can be seen in the annotated schematics abuot the FLV02 in Fig. 3.6. After the section where the veto signal is produced, there comes a section that produces regular NIM pulses in order to feed them to the FTM input plugboard. Furthermore there is power supplys on the FLV02, as it also poweres, via the 80m cable, the FLV01.

3.3.1 Connections

The following connectors can be attached:

- Lidar Veto Out: 1, 1-Inverted, 2, 2-Inverted, 3, 3-Inverted, 4, 4-Inverted. These are the outputs for the FTM plugboard. The inverted outs are for completeness and should not be connected to the FTM.
- Power: self explanatory
- Veto inhibit (on the backside): 1, 2. These connectors inhibit (switch off) the Veto if they are pulled to ground (negative logic as indicated). Every one inhibit disables two channels, either 1 & 2 or 3 & 4.
- Power & Lidar Veto Signal (on the backside): Here the long cable from the FLV01 in the MAGIC countinghouse has to be plugged in.

3.3.2 LEDs

Following LED show the status of the FLV02 module:

- +5V: shows if the voltage from the NIM rack is delivered.
- LVO (left/right): shows if the Lidar trigger gets processed.

3.3.3 Adjusting the Veto with potentiometers

The veto is adjustable. It's width and delay with respect to the initial trigger can be changed. The specifications were: Delay from 10mus - 100mus, width from 50mus - 150mus. The delay has to be introduced because the trigger arrives much faster the FACT container than the Laser shoots. The Laser has a measured delay of about 44mus and therefore, in order to prevent unneccessary deadtime, the delay has to be set to $\sim$ 40mus. The width is a more tricky thing. A light pulse travels forwards and gets scattered off up to 22km distant air molecules and dust within 150mus. This is about the effective range of the MAGIC Lidar and we hope that our problems with its light beam also stop at 22km. Two potentiometers can adjust the width and delay on each of the two independent lines. They are marked in Fig. 3.7. It was first thought it could be possible to adjust the potis from outside, but the holes in the box lid are too small and therefore one has to open the lid in order to do so. Furthermore, the settings can only be measured with a full FLV01 - Cable -FLV02 setup with pulse generator and oscilloscope. Therefore Hanspeter and I set the potis in our lab on all channels to: 40mus delay, 150mus width. This would introduce 300Hz x 150e-6s $\sim$ 4.5% deadtime, assuming the Lidar fires with 300Hz.

3.3.4 Special Remarks

The person to commission the thing must especially test the veto width and delay in many configurations of the lidar beam in the camera (from below, edge on, top part, bottom part, etc...).

It is atm. not forseen to use the Veto inhibit connector. Instead we will probably rely on a switchable power supply for the FLV02.

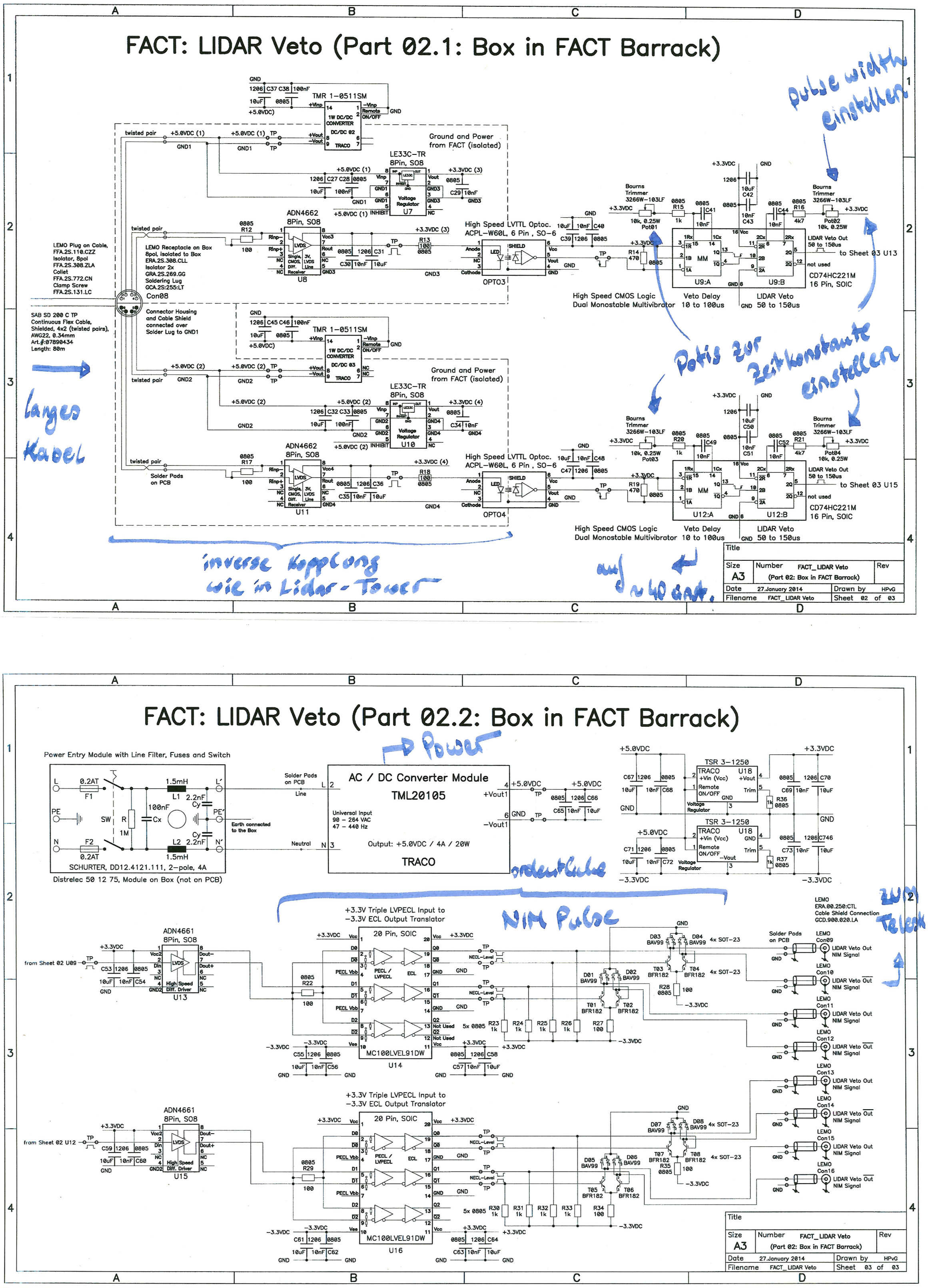

Figure 3.6: The annotated schematics of the FLV02. Some last changes were made, in order to accomodate the “Veto inhibit”. Please find the final schematics in the fact-trac.

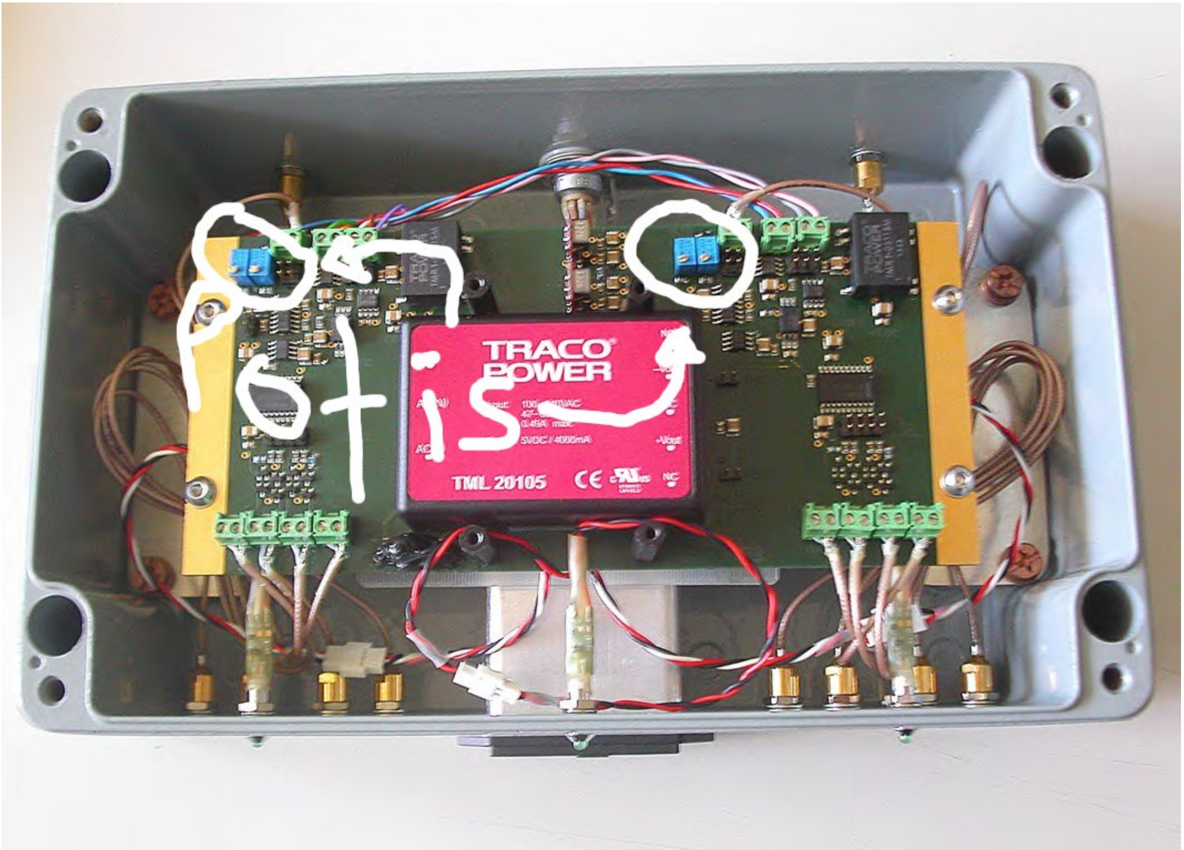

Figure 3.7: The potentiometers to adjust the delay and the width of the veto signal on each individual line.

4 Lab Tests

This section coveres the conducted lab tests. All tests were performed on a full setup (Fig. 4.1) with: one HP 33120A Pulse generator, one LeCroy Waverunner LT264M 350MHz 1GS/s DSO, one active probe to measure the signals on our FTM, one sector of the FACT camera, 2 Agilent N5770A Powersupplys (50V for the Camera, 80V for the GAPDs, not used), one computer on the ethernet, the full FLV system (FLV01, Cable, FLV02), and 40m lemo cable inbetween the FLV02 Veto out and the FTM veto input. The FTM is triggered at 12ms interval pedestals and about 5kHz (not quite to prevent synchronous problems) veto signals with 100mus width so that we expect about 50%deadtime.

4.1 Function test

The first test was to test if the system worked at all. On Fig. 4.2 one can see a screenshot from the LeCroy scope while operation. Channel one shows the signals from the pulse generator. Channel 2 shows the signals after the U42 chip (input stage) on the FTM. Channel 3 shows the signal after the FLV02. This shows that every stage is working as expected. in the same Figure one sees that the FTM trigger rate is reduced by the correct fraction of veto time. Result: No problems found, everything worked as expected.

4.2 Test set: Connectos et al.

Test of all connectors, cables, and signals. The list of performed checks can be found in Fig. 4.3. All tests were successful. The specifications are met.

4.3 Long test

A long test was performed for 2 days straight without break. The full testbench setup was run at the ETH basement with the following parts: FLV01#001, cable with red ribbon, FLV02#002. The FTM triggered always with reduced rate also after 2 days. When decreasing the frequency of the pulse generator, the rate always went up to normal again. Result: System stable over long time.

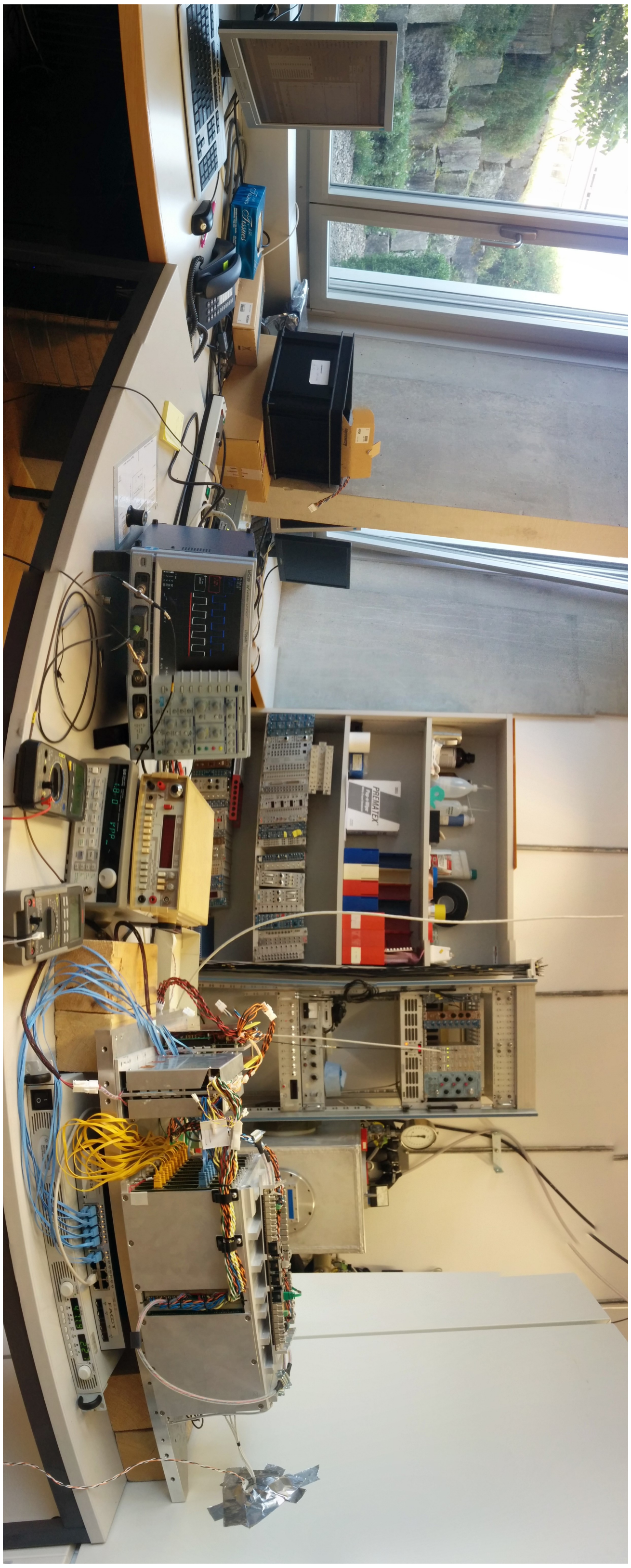

Figure 4.1: The FACT Lidar Veto (FLV) Testbench

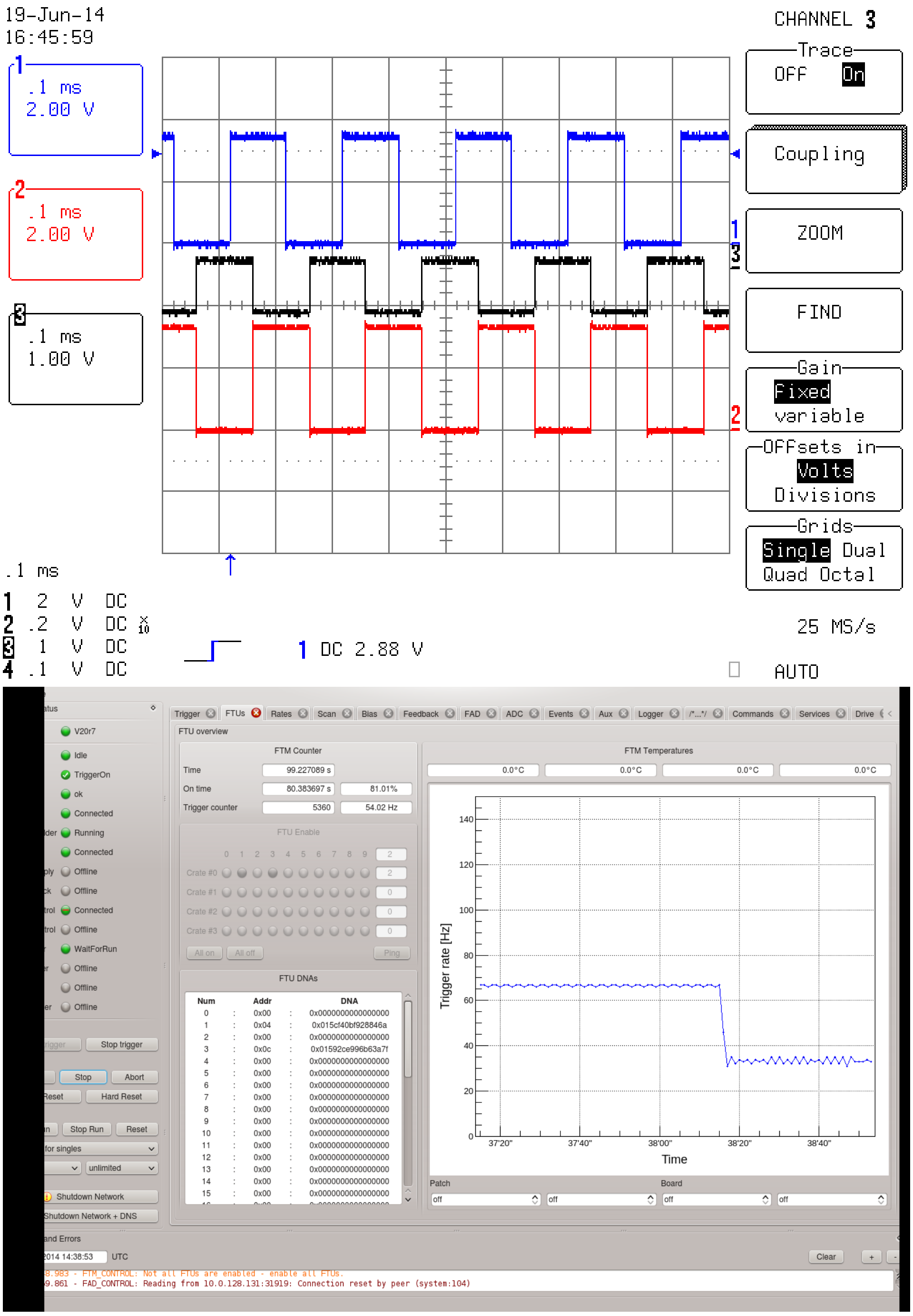

Figure 4.2: Top: The signals from the pulse generator, after the FLV02 and on the FTM. Everything gets transmitted fine, no problem. Below: FTM trigger rate drops by the correct veto time fraction.

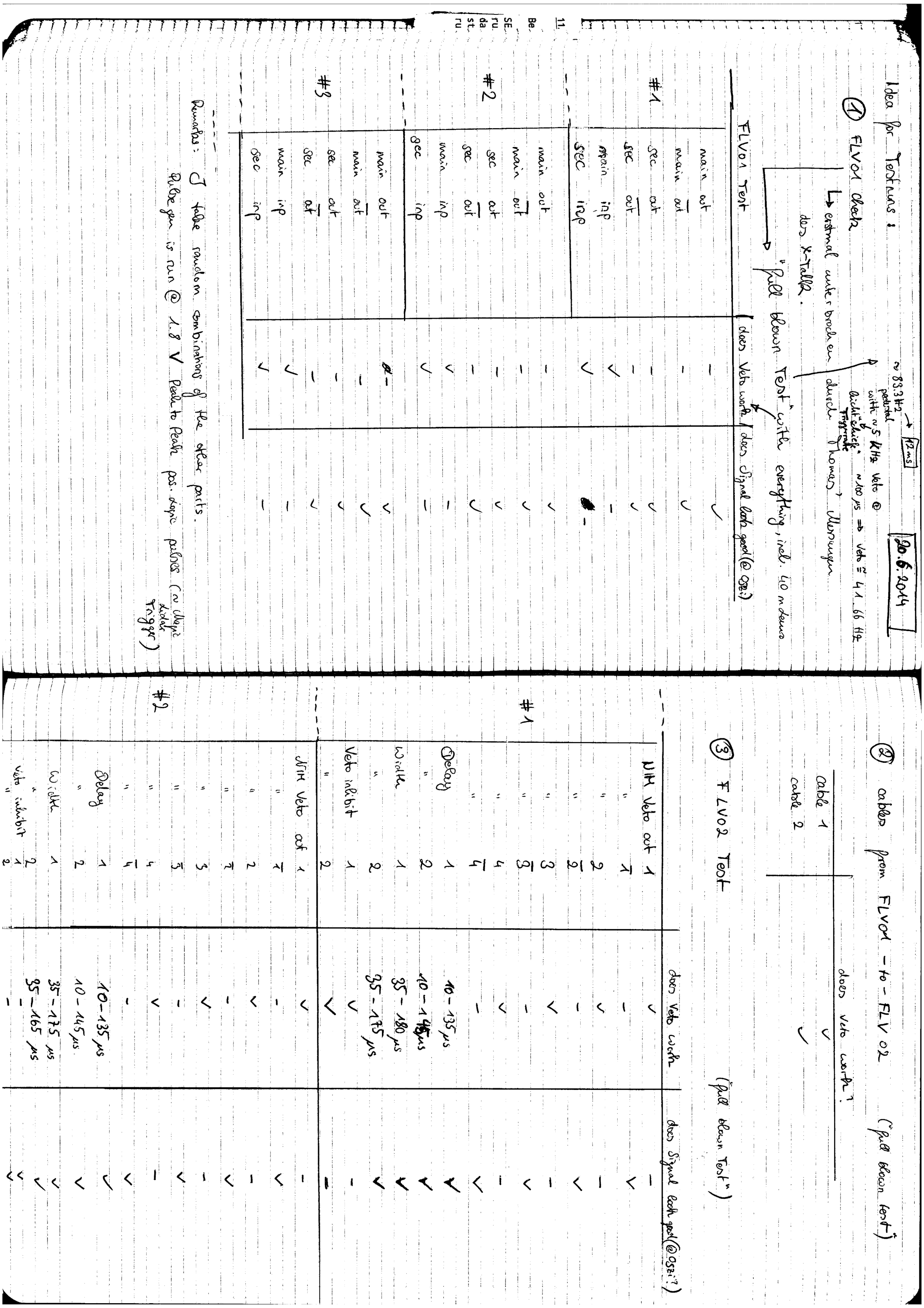

Figure 4.3: The check of all connectors, signals, switches, and potentiometers.

5 Attachments

The external schematics are stored in the svn on La Palma, together with this document:

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svn co https://www.fact-project.org/svn/firmware/FactLidarVeto FactLidarVeto
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Bibliography

[1] Fruck, C. A new lidar system for the magic telescopes and site search instrumentation for cta. *Diplomarbeit, TU Munich* (2011). URL https://magicold.mpp.mpg.de/publications/theses/CFruck_diploma.pdf.