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VELO Module Production - Module Electrical Tests

LHCb Technical Note

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Abstract

This note describes in detail the procedures used in the electrical testing of the hybrids at various stages in the production process using the NA60 DAQ and the LabVIEW program ModuleTesting.

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1. Introduction

Each LHCb hybrid is tested at different stages during production[1, 2]. This manual describes how to perform the electrical tests using the NA60 DAQ system and the LabVIEW program ModuleTesting.

There are five different tests used in the production process

- *Confirmation test*: a short test where the basic functionality of all chips is confirmed by configuring the chips and uses the scope to see that all chips return data when triggers are sent. No data are stored.
- *Noise test*: collection of data without any signals to characterize the noise levels of the chips. Data for each ADC (two chips) are stored for analysis.
- *Laser test*: a laser is fired on each strip to find dead or shorted channels.
- *IV scan*: the leakage current through the sensors as a function of the bias-voltage from 0 to 250 V, with a maximum of 105 μ A.
- *Charge collection test*: A scan of the signal height as a function of bias voltage to find the minimum bias voltage charge and determine where the charge collection efficiency plateau is. This will be the recommended initial bias voltage for operation (and for vac tank testing).

In the following documentation the three possible states of a hybrid are:

- *Bare*: chips are glued on the hybrid, and the back-end is bonded, including power supply bonds, address bonds and bonds for control signals and data.
- *FEB* (front-end bonded): the chips are bonded to the pitch adapter (PA), but the sensor is not glued on the hybrid.
- *SEB* (sensor end bonded): the sensors are glued on the hybrid, and the PA's are bonded to the sensors.

Noise tests are done for the hybrid in all stages: Bare, FEB and SEB. The laser test and the IV scan are done on the hybrid at the SEB stage. Before any noise test or laser scan it is recommended a confirmation test is performed.

2. Hardware

The following is a list of the hardware used during production for the testing of the hybrids. All the hardware was located in the LSDC[3] and some is shown in Figure 1.

- NA60 read-out system (repeater board, control board, ADCs)
- Video-camera
- PC with I/O Ethernet card, GPIB communication, video-camera control
- X-Y DC motors table, DC motor controller
- Hybrid placement jig
- LV power supplies (for hybrid, amplifier card and DAQ)
- Keithley source meter for HV sensor biasing and IV scan
- LeCroy oscilloscope
- DG535 digital delay pulse generator
- 1060nm laser driver and diode

The pulse generator provides a trigger signal to the DAQ and to the laser diode driver to produce short (~5 ns) light pulses. The two trigger signals are carefully synchronised so that the trigger to the DAQ is in time with the laser light pulse. A delay of the laser pulse relative to the trigger pulse that takes into account the pipeline depth and the cabling is found to be ~3 microseconds.

The video-camera is mounted on a two axis linear stage controlled by DC-motors. This in principle should enable the camera to cover the module. However the "travel" of the stages is not sufficient to span the whole module. Thus the equipment was modified so the camera can be shifted between two fixed positions, A and B.

Position A will cover the strips read-out by chips from 0 to 7, and position B will cover the strips of chips 8 to 15.

The laser light illuminates the detector via an optic fibre ending in a focusing lens to deliver a light beam-spot of about $7\mu\text{m}$ FWHM at focal distance. The lens is also mounted on the camera head, and it can be focused independently of the camera. The focus of the lens is tuned by shining visible light through the optic fibre onto a flat reflecting surface of the detector (metal pad).

When the detector is biased, the module must be covered up to remove the background light. A special cover-up box is used for this.

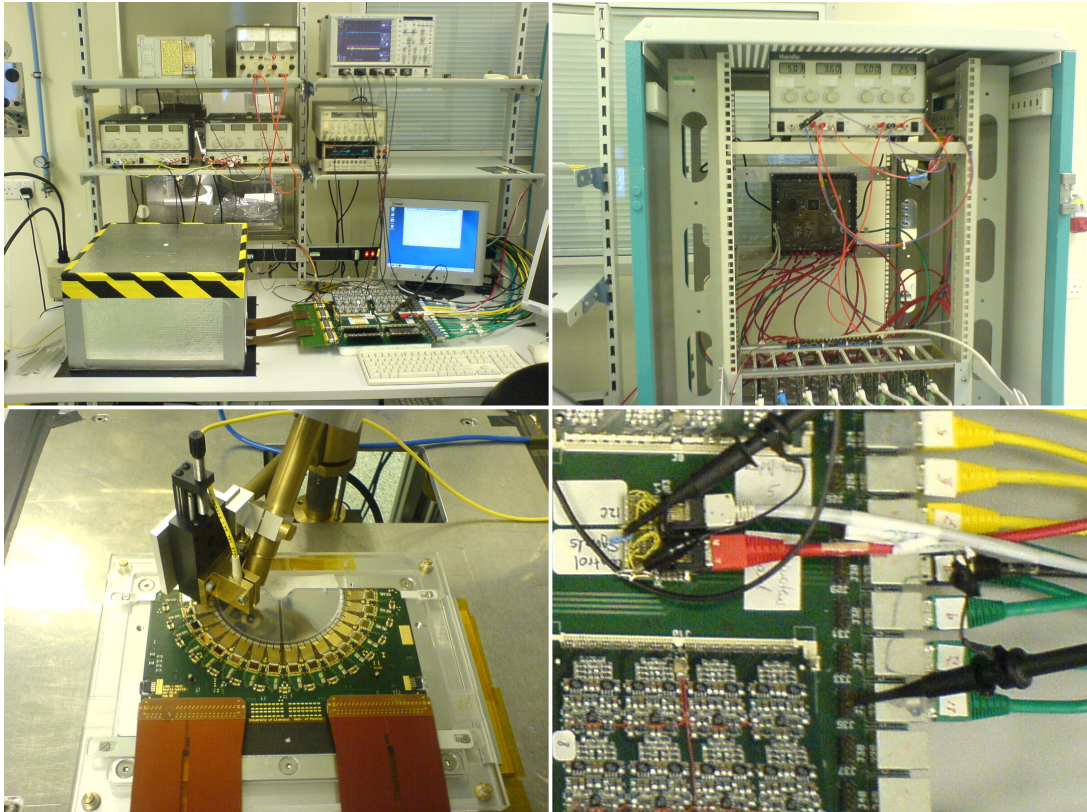


Figure 1: The electrical test stand with laser, power supplies, pulse generator and scope (top left). The DAQ with power supply (top right). The hybrid in its jig, and the camera and laser head mounted on a xy-table (bottom left). The amplifier board with probing pins (bottom right).

3. Electrical Testing

The following section contains the instructions for running the electrical testing procedures and is copy of the instructions utilized during production.

3.1. Starting up the programs

Linux-pc (DAQ):

- Log on as root with password: XXXXXXXX
- Enter **startx** to enter the graphical mode.

- Start LabVIEW by entering **labview** in a terminal window.
- From LabVIEW open the VI `/data/huse/Labview_Lasertest/ModuleTesting.vi`
- The data are stored in the directory `/data/DAQ/VELO_DATA/`. A short-cut to this directory is to enter DATA in a terminal window. In this directory each hybrid has a subdirectory structure: HybridN/R(Phi)/ with the subdirectories Bare/ FEB/ and Sensor/.

Note that on the Windows-pc:

- The camera software is located on the desktop.
- The IV scan software is located at `C:\IV\LabVIEW\IV_Scan.vi`

3.2. Power up the DAQ

There are three power supplies to power up the DAQ system and the module. Power them up with the main switch to the left on each of them. Labels are put on each power supply with nominal voltage levels. Make sure that these levels match the levels on the displays.

The two power supplies on the shelf above the hybrid table are for the amplifier boards (to the right) and to the hybrid (to the left). The power supply in the crate is for the ADC's. Make sure that the hybrid is not powered while connecting or disconnecting the cables.

First power up the hybrid and amplifier board, the hybrid is now powered but not clocked, and the current should be around 0.085 A. If the current is much higher than this, there might be a short between power and ground. Next power up the DAQ, the hybrid is now clocked, and with no chips configured the current should be around 0.660A.

3.3. The ModuleTesting program

The LabVIEW vi (virtual instrument) ModuleTesting is started by pressing the arrow symbol in the toolbar, or by choosing run from the file-menu. The front panel is shown in Figure 2. It should be stopped by pressing the STOP button on the front-panel, not with the stop button in the toolbar.

Choose one of the functions from the roll-down menu, and press START. The functions include Noise test, Laser scan (complete and partial), Config hybrid, Trigger and Add hybrid.

The other controls and displays on the front panel are:

- Module side (R/Phi). Set this to match the module side you are working on.
- Hybrid number. This gives a list of all the hybrids in the directory structure. Choose the hybrid you are working on.
- Hybrid status (Bare/FEB/Sensor). This indicates the status of the hybrid, and determines where the data are stored. For the initial bare hybrid test, after the back-end bonding of the chips, choose Bare. After the front-end bonding to the PA has been done, choose FEB. And when the sensors have been bonded, choose Sensor.
- All ADC/Single ADC switch. Some tests can be done on all ADC's or on single ADC's only by choosing the desired setting with this switch.
- ADC number. If you choose to do a test on a single ADC, choose the ADC number with this control.
- Position A/B. The camera can be set to two different positions to scan all chips. If you choose to do a partial laser scan, and choose All ADC's, it means all ADC's in position A or B according to this setting.
- A message box at the bottom of the front panel will give instructions to the user, and the OK and Cancel buttons allows for interaction with the user.

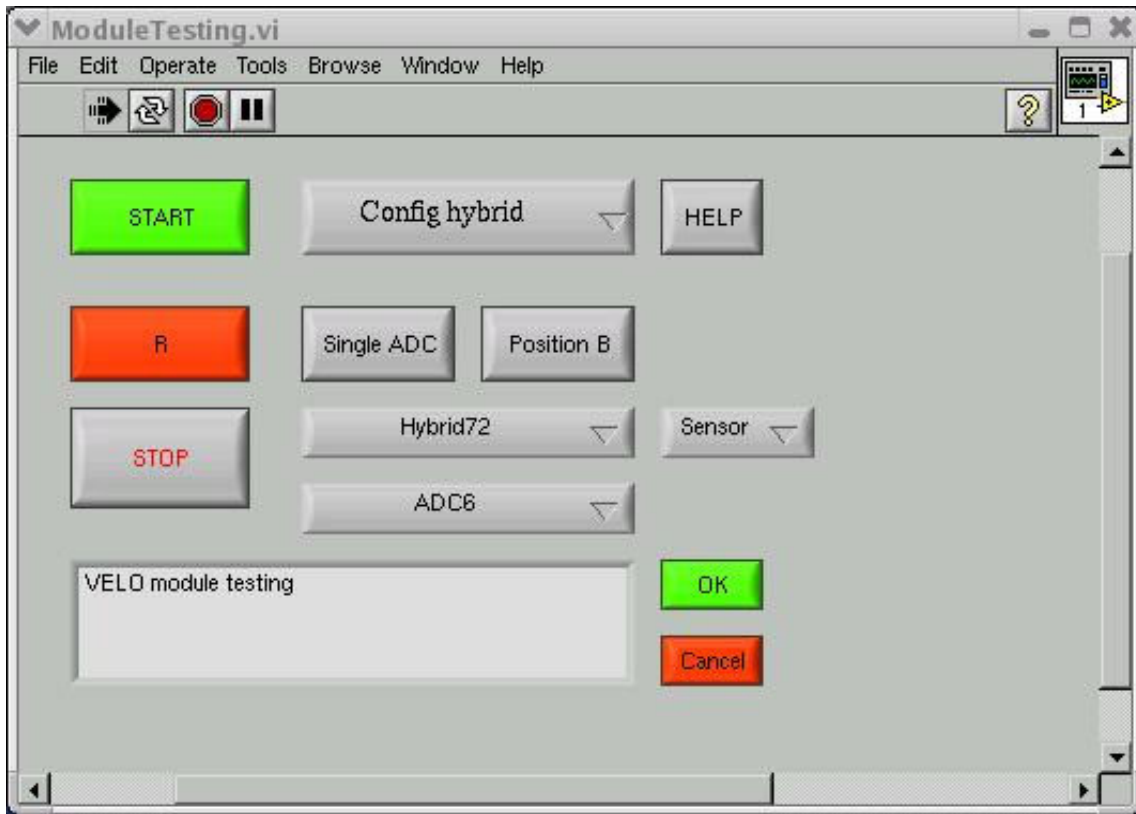


Figure 2: The ModuleTesting front panel.

3.4. Adding a hybrid (Add Hybrid)

A new hybrid must be added to the directory structure in order to save data. The Add hybrid function will create the directory structure for a new hybrid. Choose Add hybrid from the menu and press START. A new window appears where you can enter the hybrid number. Press ADD to add the hybrid to the list, or press cancel. The hybrid should now appear on the hybrid list.

3.5. Confirmation test (Config hybrid)

This function allows you to configure the chips on the hybrid, and check the basic functionality of the chips. Choose "Config hybrid" from the menu and press START. A new window appears.

Choose the correct module side (R/Phi). By clicking on individual chips, or ADC's, you choose which chips to enable. Press the CONFIGURE button to configure the chips. The button will remain blue until the chips are configured, and the array of 16 indicators at the bottom should turn green if all the chips are responding.

Press the TRIGGER button to send trigger bursts to the chips. Repeated triggers are sent until you press the button again. Use the scope to probe the chips, and verify that all chips respond by sending out data. For a bare hybrid the data consists of a header followed by analogue data from each channel. For each trigger signal, 14 time samples are read out from the chips. The header should be about 300 mV peak-to-peak. Some variations in amplitude and offset are normal.

3.6. Noise test

When the basic functionality of the chips is confirmed, a noise test can be done. Choose “Noise test” from the menu and press START. Set the correct hybrid number and module side. To test the whole side, choose All ADC’s, or choose Single ADC and the ADC number.

A data file for each ADC will be stored in /data/DAQ/VELO_DATA/HybridNN/R(Phi)/Bare(FEB/Sensor). Check that all files are there before running the analysis. They should be around 20MB in size. A description of how to analyse the data is given in [4] and in [5].

Running the analysis program will automatically put the results and graphical displays in the database. Log on to the data base, and go to update module. Click on the link to all chips for the r- or phi-side to display the chip data. In the top row you can click on the noise link to display the graphics for all chips.

3.7. Laser test, complete

A user guide for the analysis of the laser data is found online [6].

The “Laser test, complete” will scan the whole side (R or Phi) of a module. The range of the laser/camera movement is not sufficient to cover all strips, so the camera must be moved from position A to B during the scan.

- Mount the hybrid on the jig, position it and connect the cables.
- Connect the optic fibre to the (visible) light source. Make sure the laser is off.
- Move the camera to position A.
- Power up the DAQ.
- Set correct hybrid number and side (R/Phi), and hybrid status to Sensor.
- Choose “Laser test, complete” from the menu and press START.

Measure reference points

To calculate the positions of each strip, two reference points on the sensor must be measured for each camera position. You can also choose to read the positions from file if the hybrid has not been moved since the last measurement. Before the measurements you can choose to home the camera axis, which will reset the position of the stages (this is recommended).

The camera is driven to the approximate position of the first fiducial, and a joystick panel opens. Use the joystick to find the fiducial, and put the light spot in the centre of the four spots of the fiducial. Press the STOP button in the joystick panel. The camera is driven to the second fiducial. Repeat the search procedure here. Press the STOP button in the joystick panel when the light spot is centred on the fiducial.

The laser scan

You will be instructed to:

- Cover up the module (with the box).
- Connect the optic fibre to the laser and power up the laser.
- Bias the sensor to the depletion voltage plus 10 V (look up the depletion voltage in the database).

The program will now scan the laser over all the strips, and read out data to be stored in the directory /data/DAQ/VELO_DATA/HybridN/Phi(R)/Sensor/. One file for each strip is created with the name laser_test_adc0_pos1_strip1.bin and so on. In this case the file name says that ADC0 is being read out while the laser fires at ADC1 strip 1. (On the phi-side, the ADC being scanned is always the same as the ADC being read out, while on the r-side it is necessary to scan the laser over one ADC while reading out another ADC to check for shorts between strips of different ADC’s.)

A new window appears with the current strip position of the laser, a status LED and a STOP-button. If data is successfully collected, the status LED should be green. If you need to stop the scan before it is completed, always use this STOP-button (not the stop button in the ModuleTesting front panel).

When the scan is completed for camera position A:

- Ramp down the bias voltage to zero, and turn off the voltage source.
- Turn off the laser, and connect the optic fibre to the light source.
- Remove the cover box from the module.
- Move the camera to position B.

New reference points for position B must be measured, so the procedure described above is repeated. You will be instructed to:

- Cover up the module (with the box).
- Connect the optic fibre to the laser and power up the laser.
- Bias the sensor to the depletion voltage plus 10 V (look up the depletion voltage in the database).

The laser scan continues in position B. After completion:

- Ramp down the bias voltage to zero, and turn off the voltage source.
- Turn off the laser, and connect the optic fibre to the light source.
- Remove the cover box from the module.

This completes the laser scan of this side of the module. Repeat the procedure with the other side.

The scan order of the sensor for the Phi side:

- Position A (~40 min):
 1. ADC0, laser position ADC0
 2. ADC1, laser position ADC1
 3. ADC2, laser position ADC2
 4. ADC3, laser position ADC3
- Position B (~40 min):
 1. ADC4, laser position ADC4
 2. ADC5, laser position ADC5
 3. ADC6, laser position ADC6
 4. ADC7, laser position ADC7

The scan order of the sensor for the R-side:

- Position A (~30 min):
 5. ADC0, laser position ADC0
 6. ADC1, laser position ADC1
 7. ADC0, laser position ADC1
- Position B (~90 min):
 8. ADC2, laser position ADC2
 9. ADC3, laser position ADC3
 10. ADC2, laser position ADC3
 11. ADC4, laser position ADC4
 12. ADC5, laser position ADC5
 13. ADC4, laser position ADC5
 14. ADC6, laser position ADC6
 15. ADC7, laser position ADC7
 16. ADC6, laser position ADC7

3.8. Laser test, partial

The “Laser test, partial” option allows you to scan single ADC’s, or all ADC’s for one camera position (A or B). It also allows you to scan the laser over an ADC region, while reading out a different ADC. Use “Laser scan, partial” if you for some reason needs to retake some data after the complete scan.

- Mount the hybrid on the jig, position it and connect the cables.
- Connect the optic fibre to the (visible) light source. Make sure the laser is off.
- Move the camera to the position you need to scan, position A or B.
- Power up the DAQ.
- Set correct hybrid number and side (R/Phi), and hybrid status to Sensor.
- Choose All ADC’s if you want to scan all ADC’s of a given camera position, and choose which position to scan, A or B. Choose Single ADC if you want to scan a single ADC.
- Choose “Laser test, partial” from the menu and press START.

If you chose single ADC, you are now asked to choose which ADC to read out, and which ADC to scan with the laser. For the phi-side, position A covers ADC0-ADC3, while position B covers ADC4-ADC7. For the r-side, position A covers ADC0-ADC1, while position B covers ADC2-ADC7.

The reference points of the sensor are measured as described under “Laser test, complete”. If you have measured the reference points previously, and the hybrid and camera have not moved, press Cancel to read the coordinates from file.

You will be instructed to:

- Cover up the module (with the box).
- Connect the optic fibre to the laser and power up the laser.
- Bias the sensor to the depletion voltage plus 10 V (look up the depletion voltage in the database).

The program will now drive the laser over the strips of the ADC’s you chose, and a window showing the current strip number, strip status and a STOP button will appear. If you need to stop the program during the scan, use this STOP button and not the STOP button in the ModuleTesting front panel.

When the scan is completed, you are instructed to:

- Ramp down the bias voltage to zero, and turn off the voltage source.
- Turn off the laser, and connect the optic fibre to the light source.
- Remove the cover box from the module.

3.9. Collecting data with the client-server programs

- Open two terminal windows and go to the directory /data/DAQ/VELO_DAQ/... by entering DAQ.
- In the first terminal window you run the server program:
 1. **rmmod sld**
 2. **source load0** to run ADC0-ADC3 or **source load1** to run ADC4-ADC7.
 3. **readout/server /dev/sld0 -m0x1** (-m0x2, -m0x4, -m0x8) to run ADC0 (ADC1, ADC2, ADC3). To run ADC4-ADC7 change to **/dev/sld1**.
- In the second terminal you run the client program:
 1. **readout/client /dev/sld0 -t tag -o output_directory** (use /dev/sld1 for ADC4-ADC7).
 2. The *tag* gives the files the name structure *tagnnnnnnn.bin*, where *nnnnnnnn* indicates a unique time stamp. For the noise test of a bare hybrid, use the tag *adcN_noise_*.

3. The *output_directory* is the directory where the files are written.
- Configure the chips you want to run, and send a trigger burst. This will create a file for each trigger burst you send.
 - Kill the server by pressing Ctrl-C in the server terminal window.

3.10. IV scan

The IV scans are done for the hybrids before and after bonding. Mount the hybrid on the jig and connect the cables to the amplifier board. Cover up the module with the box. Do not power up the hybrid. Make sure the Keithley source meter is turned on.

On the window machine start up the labview program IV_scan located under C:\IV\Labview\. It will open with the correct default values. Start the program by pressing the arrow. You will be prompted for the file name to store the data. The format is Hyb71P_2349-10A_unbonded.txt for the phi side of hybrid 71 with sensor number 2349-10A. Save it in C:\IV\Data.

The program will scan from 0 to 250V in 10V steps. The resting time is 30 seconds. At the end the voltage is ramped gradually down, and the output of the Keithley is turned off.

When both sides are measured, the data must be uploaded to the database.

4. Summary

In the production of LHCb Velo modules, 45 modules have been completed. Each of these modules has been electrically tested at three different stages:

1. After bonding the back end of the chips to the hybrid (BEB).
2. After bonding the front end of the chips to the pitch adapter (FEB)
3. After bonding the sensor to the pitch adapter (Sensor)

In addition, 36 modules have been terminated at different stages in the production, and 5 modules have been stopped before they were completed, but could be continued. The electrical tests look at the basic functionality of the chips as well as the noise characteristic. Information about bad channels could also be extracted from the noise data, however these statistics are summarised in the “Laser test and noise analysis document” [1].

Out of the 98 module sides (R- and Phi-side) which have been tested at all three stages from the 45 completed production modules and the 5 stopped modules:

- 80 module sides did not fail any electrical test.
- 15 module sides failed electrical test at the BEB stage. These were repaired and re-tested.
- 4 module sides failed electrical at the FEB stage. These was repaired and re-tested.
- 1 module side failed the electrical test at both the BEB stage and FEB stage.

Out of the 36 terminated modules:

- One module was terminated after electrical tests at the BEB stage as it could not be repaired.

- Two modules were terminated after electrical tests at the Sensor stage. These modules had problems with the sensors on the Phi-side (p-spray problems).

The electrical tests are a vital part of the module production. The failure rate during the production was 18%, however most of the hybrids which failed the electrical test were repaired successfully. Only three hybrids were terminated after failing the electrical tests.

5. References

1. Patel, G.D., *LHCb VELO module production database*. <http://hep.ph.liv.ac.uk/lhcb/html/database.html>, 2006.
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5. *VELO Module Noise Analysis Software*, <http://hep.ph.liv.ac.uk/~rinnert/noiseanalysis.html#top>
6. *VELO Module Laser Test Software*, <http://hep.ph.liv.ac.uk/~rinnert/lasertest.html#top>