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VELO Module Production – Pre-Assembly Hybrid Testing

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Abstract

This note describes in detail the procedures used in the reception, handling, testing and storage of Hybrids for the LHCb VELO detector modules.

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1. Introduction

This note describes in detail the procedures used in the reception, handling, testing and storage of Hybrids for the LHCb VELO detector modules. The procedures have been evolved over the last few years and this version was finalised for the Mid Term Review[1] of the production process after 12 production modules had been made and transported to CERN for installation.

The substrates are made in the departmental workshops and logged in the VELO production database [2]. Those passing the QA requirements on thickness and twist are sent to Stevenage Circuits to have the electrical circuits bonded to the two sides and cut to shape. The QA requirements on substrate twist were relaxed after the initial batches, since this property changed during the procedures at Stevenage Circuits. Upon return they are inspected and metrology measurements are made and logged. They are then sent to an outside company (Hawk Electronics) for the components to be soldered in place. The details of the quality assurance and reception procedures are given below.

A summary of the yields is given at the end of this note.

2. Reception Procedure from Stevenage

2.1. Visual Inspection

The circuits are visually inspected for surface quality and any delamination. Note that minor delamination can be corrected after the circuits are populated by the edge gluing step.

2.2. Metrology

The thickness of the hybrid is determined using a micrometer at each of the 16 chip sites.

The planarity of the hybrid is measured using the Smartscope. A plane is fitted to the measurements of three of the corners and the fourth corner deviation from the fitted plane was required to be positive and less than 400um initially. However this cut was abandoned in production and all parts which passed the visual inspection were sent for population as it was reasoned that the final non planarity could be affected by the attachment of components and bring it back towards flat. In addition the height of the hybrid was measured over the surface of the hybrid at points on a 1cm. grid on both the R and Phi sides.

2.3. Data Entry

Upon receipt from Stevenage a hybrid number is assigned and scratched onto an identification pad on one side, which is thereafter identified as the R side of the hybrid. The original substrate number is identified and the database is updated promoting the identified substrate to the newly allocated hybrid number, this was Stage 1 of the production process.

The thickness measurements at the 16 chips sites were all entered into the Stage 2 entry form, these were inserted into the module logfile and the average for the module was stored in the database.

The fourth corner deviation and Smartscope metrology data files were uploaded to the database as Stage 3.

They were then sent for population with components and updated to Stage 4 in the database.

3. Reception Procedure after population

3.1. Visual Inspection

Upon receipt after population with components a visual inspection is carried out. The purpose of the inspection is threefold:

1. To check periphery of hybrid for de-lamination or wrinkling.

2. To visually inspect the hybrid for Solder shorts/spills or damage with particular attention around bond pads 0-15.

3. To ensure that resistor R15 [3] has not been installed on either side of hybrid and remove if it has. (this was a mistake in the initial specification for the population an was corrected after the first batch of pre-production hybrids

3.2. Edge gluing and planarising of corners

This step was introduced part way into production when it was noticed that there was a slight tendency for delamination at the edges of the hybrids and particularly at the corners of the semicircular cut-out. Some hybrids were being rejected because of very slight delamination and it was decided to repair these. To remove the potential threat of delamination after construction all hybrids had 2011 epoxy applied by syringe to the front edges where the kapton circuit overhangs the substrate. In cases where there was visual evidence of existing delamination the adhesive was applied and the circuit was clamped in those areas during curing.

In some cases it was found that there was a raising of the kapton by up to 100um at the tips of the corners of the semicircular cut-out which could interfere with the attachment of the silicon. After the gluing and clamping step, if this was still evident, then the raised kapton was removed using a scalpel blade to planarise the area. Note that there is no copper in the circuit in this area and there was no danger of compromising the insulation to the substrate.

3.3. Data Entry

This is Stage 4A in module production [2]. This step simply informs the database that the hybrids have returned from population and allows for the visual inspection comments to be logged.

4. Electrical Testing

After the visual inspection described above, the hybrids are tested for functionality. At this point the Hybrids should be fully populated with connectors and resistors. The purpose of the electrical tests is to ensure the hybrids are suitable for population with the front end ASICS[4] and pitch adaptors [5]. All following tests are performed on both sides of the hybrid.

4.1. Termination Tests

This test checks for opens circuits and correct termination resistances on the hybrids prior to population with ASICS. To facilitate this test a dedicated board was designed called the CABSPY. This is connected to the hybrid under test, via the short kapton cables [6], see

Figure 1.

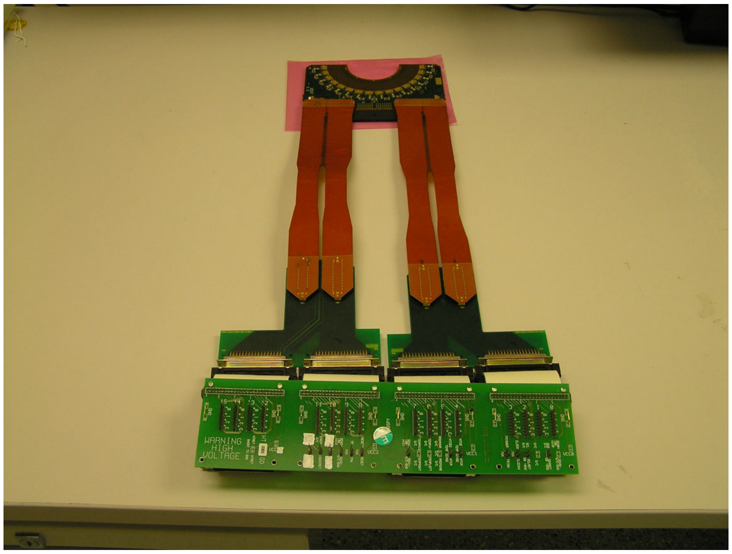

Figure 1: Photograph of hybrid connected to the CABSPY PCB.

The CABSPY PCB gives easy access to hybrid signal traces and allows quick measurements to be made with an ohmmeter between the test points for both the 'R' and 'Phi' sides, see Table 1.

N.B. Trace resistances add several ohms to resistor values.

	Test points	Value(ohms)	Typical Value(ohm)
1	SEN0+ and VCC0	100	102
2	SEN0- and GND	0	3.9
3	SDRARET and GND	47	50
4	SCLRET and GND	47	50
5	CLOCK and CLOCKN	100	102
6	TRIGGER and TRIGN	100	102
7	SEN1+ and VCC1	100	103
8	SEN1- and GND	0	3.9
9	RESETN and RESET	100	107
10	TP and TPN	100	108
11	PORRET and GND	o/c	O/C
12	SEN2+ and VCC2	100	103
13	SEN2- and GND	0	4.7

	Test points	Value(ohms)	Typical Value(ohm)
14	ENEDCRET to GND	47	49
15	SENSE3+ to VCC3	100	103
16	SENSE3- to GND	0	3.6
17	HT to Hybrid test points	9k4	9k6
18	HTRET and GND	0	1.8

Table 1: Nominal and expected terminations on the hybrid.

4.2. Temperature Sensor Tests

On the CABSPY PCB, connect the temperature readout box to header pins NTCB/NTCA and NTCB2/NTCA. This will readout the on-board sensors which should measure room temperature. Carefully touch each of the sensors with a gloved finger and confirm that the measured temperature changes.

4.3. Testing for Electrical Shorts

This test uses the CABTEST PCBs which are also used to test cables and is shown in Figure 2. On the CABTEST boards each of the traces on the hybrid is connected to an individual LED with an internal resistor which is then taken to a common ground point. Each of the lines is then individually contacted with an led and resistor on a flying lead from a power supply and the LED for that trace should light. If any other LED should light then this will indicate a short between traces. However, as there are terminating resistors and some commoned traces there are exceptions to this rule as noted below.

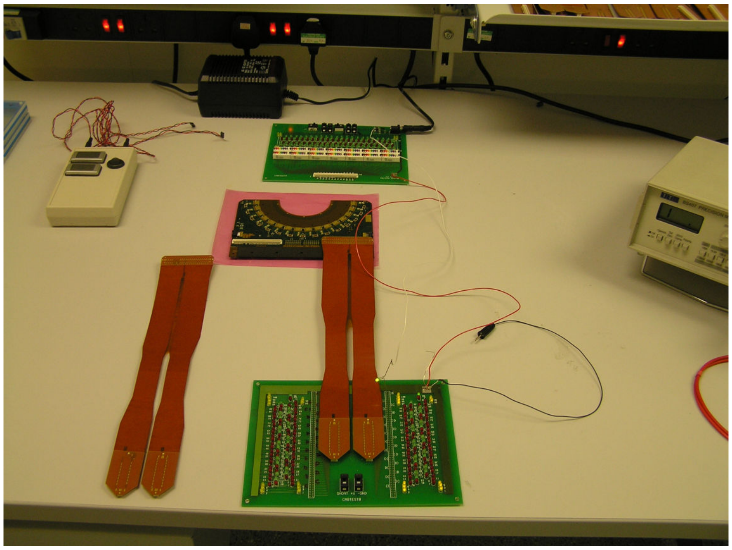

Figure 2: Photograph of the hybrid connected to the CABTESTB PCB

This test is in four sections corresponding to the four cables attached to the module. i.e.

‘R’ side LT cable.

‘R’ side HT cable.

‘Phi’ side LT cable.

‘Phi’ side HT cable.

The first step is to connect the Hybrid to the CABTESTB PCB using either an ‘HT’ or ‘LT’ cable. The power is applied on the AC-DC Adapter.

With the LED on a flying lead, connect to each of the test plated through holes on the CABTEST PCB and check the led illumination.

Confirm that all led positions tested are at normal brilliance. A dim led will indicate a fault, but note the following exclusions, where the locations will illuminate more than one led:-

4.3.1. High Voltage Ribbon, Left hand side:-

HT RETURN (87)	All Ground leds.
VCC3	led 10 on the right hand side.

4.3.2. High Voltage Ribbon, Right hand side:-

Vcc	led 15	Due to Sense2+
RESETN (99)	led 97	
RESET (97)	led 99	
GND	leds 13, 84	
TP (87)	led 85	
TPN (85)	led 87	
ENEDCRET (84)	leds 13, 84, Gnd leds dim.	
SENSE2- (13)	All Gnd leds dim, leds 12,13 dim.	
SENSE2+ (15)	All RHS Vcc leds dim.	
SENSE3+ (10)	All LHS Vcc leds dim	
SENSE3- (12)	All gnd leds dim, leds 13,12 dim.	

4.3.3. LT Ribbon, Left hand side:-

NTCB (99)	led 97 dim via temp sensor

NTCA (97)	led 99 dim via temp sensor
SENSE1- (92)	Gnd leds dim
SENSE1+ (90)	All LHS Vcc leds dim
Vcc1	led 90 dim.
Vcc1	leds 94, 96, 98, 100 on.
NTCB2 (85)	led 87 dim via temp sensor
NTCA2 (87)	led 85 dim via temp sensor

4.3.4. LT Ribbon, Right hand side:-

SENSE0+ (99)	All RHS Vcc leds
SENSE0- (97)	All Gnd led
TRIGGER (90)	led 92 via termination
TRIGGERN (92)	led 90 via termination
SDARET (85)	all Gnd leds dim and led 97 via termination.
CLOCKN (84)	led 82 via termination
CLOCK (82)	led 84 via termination
SCLRTN (12)	all Gnd leds dim and LED 97 via termination
VCC0	led 99 on (sense connected to vcc via 100R)
GND	ground leds and led 97.

4.4. Data Entry

This is Stage 5 in module production[7], a comment together with the outcome of the electrical testing is logged as one of four possible outcomes:

- PASS hybrid is accepted and moved on to next stage of production
- FIX Problem found that can be repaired. Problem logged and this step repeated.
- FAIL Hybrid is not acceptable
- SKIP This is for historic reasons and backward compatibility where pre-production hybrids were not tested.

5. Cleaning inspection and metrology

5.1. Cleaning

Spray both sides of the Hybrid with Prozone; scrub the board gently with a soft brush, paying particular attention to the area around and including bond pads 0-15.

- Wash the hybrid using de-ionised water under a tap, then blow dry using Nitrogen taking care to remove any liquid remaining under the connectors and SMD components.

5.2. Visual Inspection

Using a microscope, carefully check each bond pad 0-15. Generally inspect the Hybrid for soldered joints, track damage etc. In particular inspect for

- Over etching on bond pads
- Solder on or near bond pads.
- Surface mount capacitors close to the bond pads skewed or installed such that could cause damage to the bond head
- If any flux contamination is evident or any other debris is found then re-clean and repeat the inspection

5.3. Metrology

The hybrid metrology described in section 2.2 was repeated to obtain the fourth corner deviation from a plane and the metrology data files.

5.4. Data Entry

The comments from the visual inspection were logged to the hybrid logfile via the database web interface as Stage 6 in module production

The metrology information was logged as Stage 7, and a full review of all the data was carried out by the production manager in the subsequent authorisation step where a decision to proceed with the placement of ASICs and pitch adaptors was recorded in the database.

6. Summary of Results

In this section we review the fail and pass rates for the hybrid visual and electrical tests. The complete set of hybrids is tabulated inTable 2. There were 87 hybrids in total. One, H74 which was particularly flat, was used for mechanical tests. Of the remaining 86, 7 were rejected on return from Stevenage due to twist or lamination. After population 5 were failed on visual inspection and a further 5 failed the electrical tests. Approximately equal numbers of hybrids fail in visual and electrical tests i.e. about 6% each, with an 8% loss before population and subsequent production problems losses of 16% the total useful yield was 64%.

Table 2: Summary of hybrid pass / fail for production. Columns are **electrical** testing, **overall** (electrical+visual) and the **final** yield through to the end of production

Hybrid	Date	Final	Overall	Electrical	Comments
51	27.04.06	Fail	Fail	Pass	Chip 8 (Phi side) severe solder smearing - unable to bond
52	24.03.06	Fail	Fail	Pass	Hybrid twisted.
53	27.04.06	Pass	Pass	Pass	
54	27.04.06	Pass	Pass	Pass	
55	28.03.06	Pass	Pass	Pass	
56	07.06.06	Pass	Pass	Pass	
57	03.04.06	Pass	Pass	Pass	
58	14.07.06	Fail	Fail		Hybrid very twisted.
59	17.02.06	Pass	Pass	Pass	
60	26.04.06	Pass	Pass	Pass	
61	07.06.06	Fail	Pass	Pass	
62	15.06.06	Fail	Pass	Pass	
63	03.04.06	Fail	Pass	Pass	(200 μm sensors)
64	13.06.06	Pass	Pass	Pass	
65	25.05.06	Fail	Pass	Pass	
66	13.04.06	Fail	Pass	Pass	(Conductive glue spillage)
67	25.05.06	Pass	Pass	Pass	
68	07.06.06	Pass	Pass	Pass	
69	26.05.06	Pass	Pass	Pass	
70	22.06.06	Pass	Pass	Pass	
71	30.05.06	Pass	Pass	Pass	
72	13.06.06	Fail	Pass	Pass	Temperature Sensor Phi Side, NTCB2 not working.

Hybrid	Date	Final	Overall	Electrical	Comments
73	25.06.06	Pass	Pass	Pass	
74	22.03.06				Allocated for mechanical tests
75	05.06.06	Fail	Pass	Pass	Electrical tests ok, Marks on gold pads.
76	18.08.06	Fail	Fail		Hybrid discoloured/not populated
77	18.08.06	Fail	Pass	Pass	
78	08.06.06	Pass	Pass	Pass	'R' side, SEN1+ to Vcc1 measures 79R, usual value is >100R
79	23.06.06	Pass	Pass	Pass	
80	23.06.06	Fail	Pass	Pass	Surface ripple
81	22.06.06	Fail	Fail	Fail	Chip 8 (Phi side) severe solder smearing - unable to bond
82	21.06.06	Pass	Pass	Pass	
83	04.07.06	Pass	Pass	Pass	
84	30.05.06	Pass	Pass	Pass	
85	30.05.06	Pass	Pass	Pass	
86	02.06.06	Fail	Fail		Not populated
87	05.07.06	Pass	Pass	Pass	
88	06.07.06	Pass	Pass	Pass	HT Connector 180degree out (R Side)
89	05.07.06	Pass	Pass	Pass	
90	04.07.06	Fail	Pass	Pass	Excess infill glue
91	03.07.06	Fail	Fail	Pass	Twisted, used for mechanical
92	03.07.07	Fail	Fail		Very Twisted, used for mechanical
93	03.07.06	Pass	Pass	Pass	
94	17.08.06	Pass	Pass	Pass	Short to ground on 3, repaired.
95	18.08.06	Pass	Pass	Pass	
96	15.08.06	Pass	Pass	Pass	

Hybrid	Date	Final	Overall	Electrical	Comments
97	26.07.06	Pass	Pass	Pass	Phi side HT connector 180 degree out. Filed off location lugs - nowok.
98	14.07.06	Fail	Fail		Too twisted
99	17.08.06	Pass	Pass	Pass	
100	14.07.06	Fail	Fail		Twisted
101	20.07.06	Pass	Pass	Pass	
102	20.07.06	Fail	Pass	Pass	
103	21.07.06	Fail	Pass	Pass	
104	20.07.06	Pass	Pass	Pass	
105	17.08.06	Pass	Pass	Pass	
106	17.08.06	Pass	Pass	Pass	
107	06.11.06	Pass	Pass	Pass	
108	22.09.06	Fail	Fail		Bad lamination
109	07.11.06	Fail	Pass	Pass	
110		Fail	Fail	Fail	PCB Thickness.
111	06.11.06	Fail	Fail	Pass	
112	05.12.06	Pass	Pass	Pass	
113	05.12.06	Pass	Pass	Pass	
114	05.12.06	Pass	Pass	Pass	
115	27.11.06	Pass	Pass	Pass	
116	27.11.06	Pass	Pass	Pass	
117	10.01.07	Pass	Pass	Pass	Short to ground on Phi side, on ANA7-2N, repaired. Was fittedwith100pin plugs instead of sockets.
118	22.01.07	Pass	Pass.	Pass.	Was fitted with 100pin plugs instead of sockets.
119	27.11.06	Pass	Pass	Pass	

Hybrid	Date	Final	Overall	Electrical	Comments
120	24.11.06	Pass	Pass	Pass	
121	24.11.06	Pass	Pass	Pass	
122	22.02.07	Pass	Pass	Pass	Was fitted with 100pin plugs instead of sockets.
123	22.02.07	Fail	Fail	Fail	PCB Thickness. Was fitted with 100pin plugs instead of sockets.
125	06.12.06	Pass	Pass	Pass	
126	19.01.07	Pass	Pass	Pass	Short ANA2-ON to ANA2-0 (Phi side)
127	07.12.06	Pass	Pass	Pass	
128	07.12.06	Fail	Fail	Pass	
129	15.02.07	Pass	Pass	Pass	
130	19.02.07	Pass	Pass	Pass	Temperature sensor NTCB2/NTCA ocated next to chip 0, 'R' side reading low.
131	21.02.07	Fail	Fail	Fail	Short to ground on Vcc0 (Phi side)
132	22.02.07	Pass	Pass	Pass	
133	22.01.07	Fail	Fail	Fail	PCB Thickness
134	23.02.07	Pass	Pass	Pass	
135	07.12.06	Pass	Pass	Pass	
136	27.02.07	Pass	Pass	Pass	
137	28.02.07	Pass	Pass	Pass	
138	23.01.07	Fail	Pass	Pass	

The data are also presented graphically. Figure 3 shows the fractions of hybrids passing as a function of the sequential production number after the electrical and visual inspections and also after the full production .

Figure 4 shows the same data as total numbers of hybrids that passed these two categories as a function of the sequential production number.

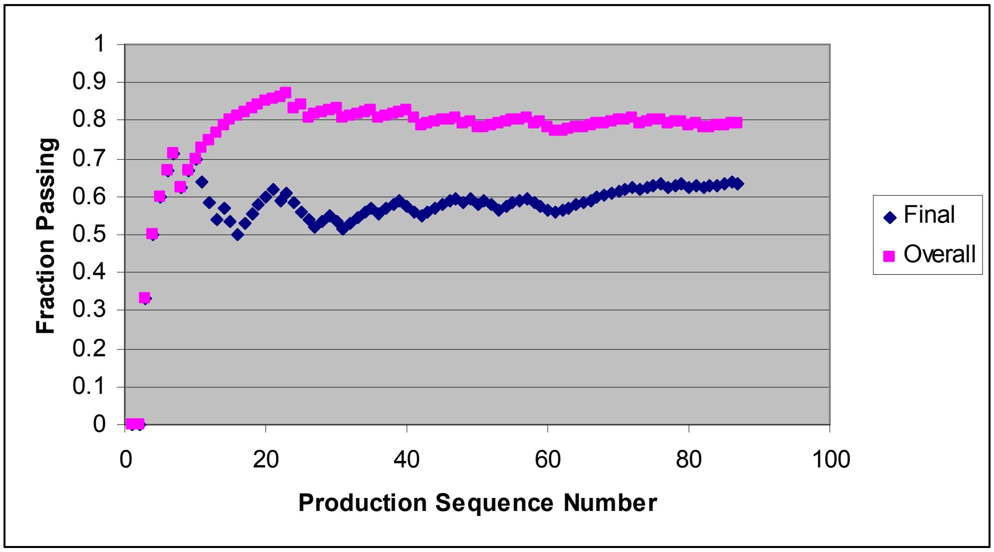

Figure 3: The fraction of hybrids passing **overall** (electrical+visual) inspections as a function of hybrid sequence. Also shown is the **final** overall yield.

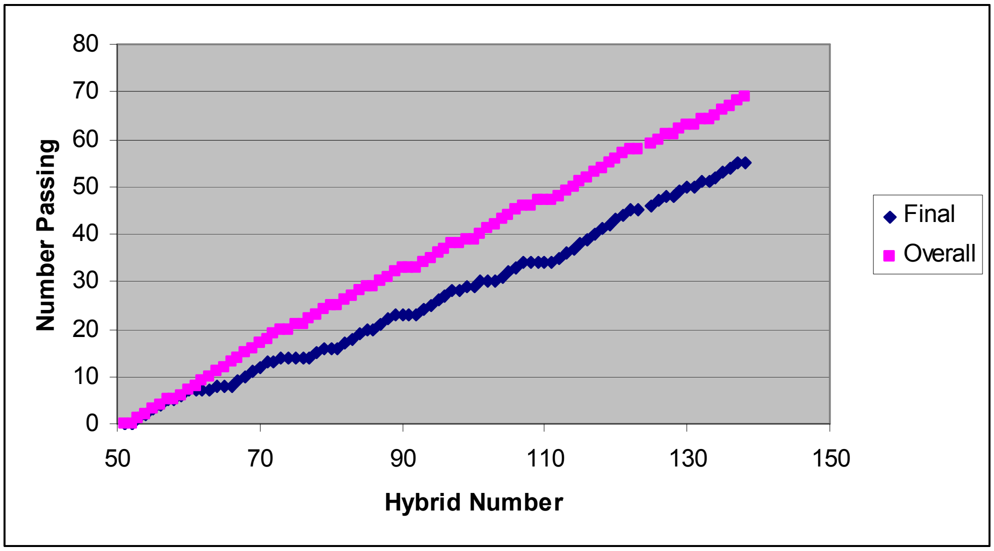

Figure 4: The number of hybrids passing the **overall** (electrical +visual) inspections (pink) as a function of sequential production number. The **final** number at the end of production is shown in (blue).

7. References

1. *LHCb VELO Module Production - Mid Term Review*, http://hep.ph.liv.ac.uk/lhcb/html/mtr_home.html

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6. *Short Kaptons for LHCb VELO Module*, http://hep.ph.liv.ac.uk/lhcb/html/cable-6.html

7. *Summary of stages in module production*, http://hep.ph.liv.ac.uk/lhcb/html/summary.html