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VELO Module Production - Pitch Adaptor Testing

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Abstract

This note describes in detail the procedures used in the reception, handling, testing and storage of Pitch Adaptors (PA) 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 Pitch Adaptors (PA) 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 of the production process after 12 production modules had been made and transported to CERN for installation. The final section (Section 7) summarizes all the data from the testing process.

The pitch adaptors allow for the tight bonding pad layout on the ASICs to be matched to the wider silicon strip pad layout on the sensors, as it would not be possible to bond the ASICs directly to the sensors. See Figure 1. Each pitch adaptor has 512 channels and due to the layout 4 different types (R1,R2,R3,R4) are required for the 2048 R sensor channels and a different 4 (P1,P2,P3,P4) are required for the 2048 Phi sensor channels.[1, 2]

The PAs were fabricated at CERN where they were visually inspected. In order to ensure that no sensor's channels were "lost" it was decided to use only pitch adaptors that were electrically perfect i.e. had no breaks or shorts. This required further testing at Liverpool and was a vital part of the quality assurance process.[3]

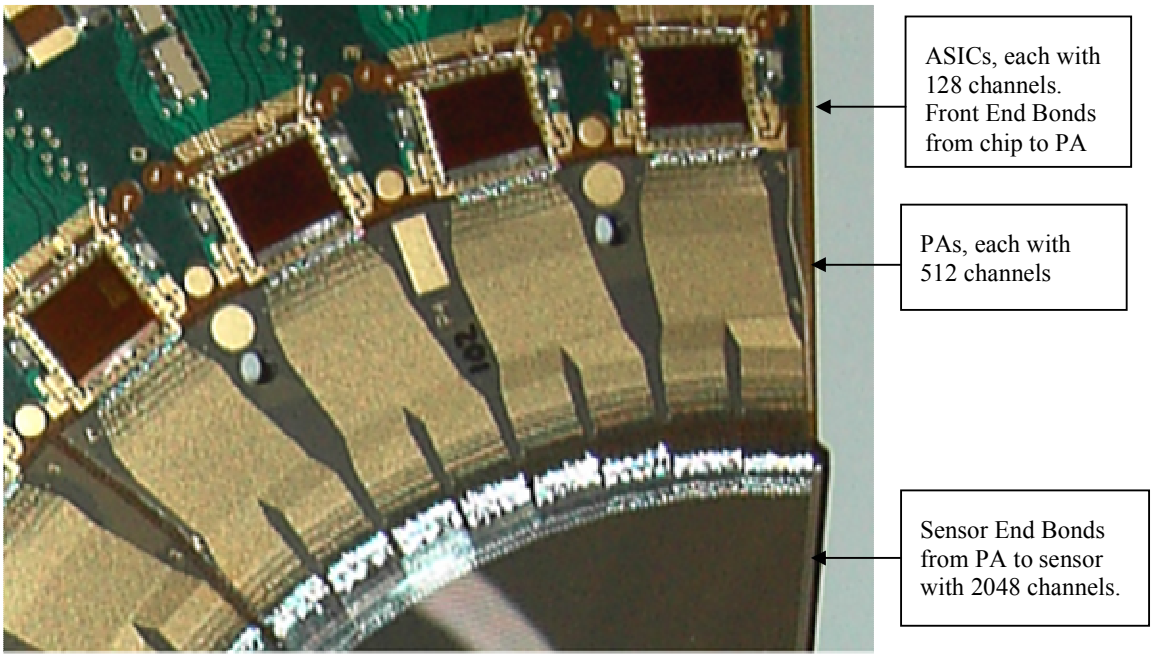
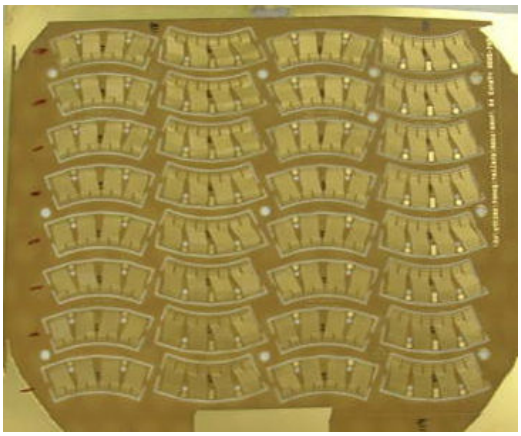


Figure 1: Photograph of a hybrid with the ASICS, sensors and pitch adaptors shown.

2. Reception Procedure

This section records the reception procedure.

2.1. Handling



Pitch Adaptors arrive in sheets shown in Figure 2.

There are 8 different types.

4 Radial sensor PAs (R1, R2, R3, R4)

4 Phi sensor PAs (P1, P2, P3, P4)

Figure 2: Photograph of a PA sheet

[Time: 1 hour/sheet]

1) Open the carton. Avoid touching the metal tracks by hand: handle by the sheet edges or use a clean vacuum pen. Check the contents against the delivery note. Notify QA manager if not complete. Proceed only if there is no discrepancy.

2) Write the sheet number, using the marker pen labelled "pitch adaptors only", on each pitch adaptor in the space before its type number, to create a label e.g. 12P3 for Sheet 12, phi-type pitch adaptor, Type 3. A "sheet" comprises four r-type pitch adaptors R1, R2, R3, and R4 and four phi-type pitch adaptors P1, P2, P3, and P4. When thirty-two pitch adaptors are delivered on the same physical sheet, those in the top, left corner are numbered sheet 21 (for example); those in the top, right corner are numbered sheet 22; those in the bottom, left corner are numbered sheet 23; and those in the bottom, right corner are numbered sheet 24.

3) Store the sheets of pitch adaptors, between the protective sheets with which they were delivered, in the small Nitrogen cabinet near to the door of Room G16 until just before they are to be measured.

4) Using the designated curved-blade scissors, cut the two small retaining tabs on each pitch adaptor, leaving some of the tab attached to the pitch adaptor. The tabs are then completely removed by making a second cut. Care should be taken to make clean cuts to avoid leaving strands as shown in Figure 3.

5) Check that the alignment marks at each end of the pitch adaptor have not been trimmed away, either completely or partially.

6) Check that both alignment holes are free from swarf. If not, clear them using a 2mm drill. Then clean the pitch adaptor with isopropyl alcohol and dry it with Nitrogen.

7) Store each pitch adaptor in the input tray next to Probe Station 1 in Room G16. About eight pitch adaptors are stored here to be available for probing – one of each type. The number is kept small so that the pitch adaptors are held flat and under Nitrogen for as long as possible.

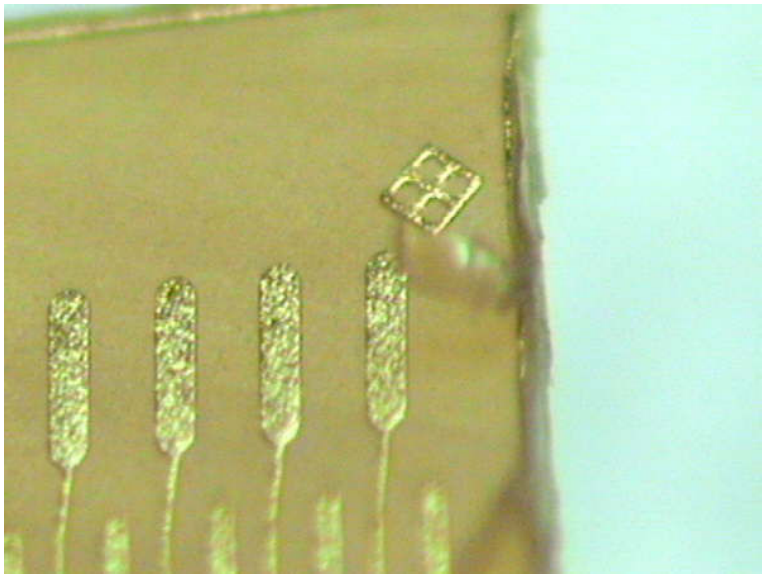


Figure 3: Careful cutting of the pitch adaptors is necessary in order to avoid leaving conductive strands that can short the wire bonding.

2.2. Data Entry

[Time: 20 mins/sheet]

1) Login. Select "**Add new**" under "**Pitch adaptor**".

2) Enter the sheet number under "**Sheet Number**".

3) Enter special conditions, if any, under "**Sheet Comment**" e.g. "Sheet has adhesive backing."

4) For each pitch adaptor that passed visual inspection at CERN: no action.

5) For each pitch adaptor that failed visual inspection at CERN: set "**Status**" to "**FAIL**". Leave "**Action**" as "**Visual**". Add the comment "**Failed by CERN**".

6) When data for all eight pitch adaptors on the sheet have been entered, click "**Add new pitch adaptors**".

7) Logout if finished, or repeat for next sheet.

3. Electrical Testing

3.1. Initial Tests

[Time: 2 hours/PA]

For each pitch adaptor, perform capacitance measurements as follows:

1) Remove the pitch adaptor from the input tray using a vacuum pen. Ensure that the lid of the tray is closed afterwards. Locate the pitch adaptor on the two pins on the carrier in Probe Station 1:

keeping the long groove in the carrier to the right; keeping the long edge of the pitch adaptor to the right; and keeping the track side of the pitch adaptor uppermost.

2) Place the transparent jig on top of the pitch adaptor with its holes aligned with the pins.

3) While keeping downward pressure on the jig, turn on the vacuum by pushing the hose connector at the back right of the probe station towards the stage.

Figure 4: Photograph of pitch adaptor on its testing jig.

4) Remove the jig. Listen to ensure that the vacuum is not leaking. The pitch adaptor should be securely attached (see Figure 4)

5) Clean the top surface of the pitch adaptor by blowing with dry Nitrogen, being careful that the gun does not touch the pitch adaptor.

6) If the LabVIEW programme is not running (from a previous test), then start Galaxy; start LabVIEW; open “prober_V1.5”; run programme; load configuration “pitch adaptor config”.

7) “Load new device”. When prompted, enter the pitch adaptor label preceded by “PA” and followed by “C2” e.g. “PA12P3C2”, where C2 refers to carrier type 2.

8) Follow the instruction on the screen, using the on-screen controls to align the probe needle. The first alignment mark is the centre of the small cross within a square at the front right of the pitch adaptor. Zero the coordinate system on the first alignment mark. The second alignment mark is the centre of the similar cross at the back right of the pitch adaptor. Record the “radius”, which will be the separation of the alignment marks. Strip 1 is near to the second alignment mark.

9) If this is the first measurement performed during the day, then the capacitance meter should be calibrated: Select “Local” on the Wayne Kerr 6440A capacitance meter; “CALIBRATE”; “Self

Calibration"; remove the four colour-coded BNC leads from the front of the capacitance meter"; "Start"; when complete, replace the leads in the same positions by matching the colours on the leads to the colours on the sockets; choose "O/C Trim"; ensure that the probe needle is just clear of the pitch adaptor; "All freq"; when complete, hit "MEASURE".

10) The probe station wiring should be as shown on the "PA testing" diagram, shown in Figure 5.

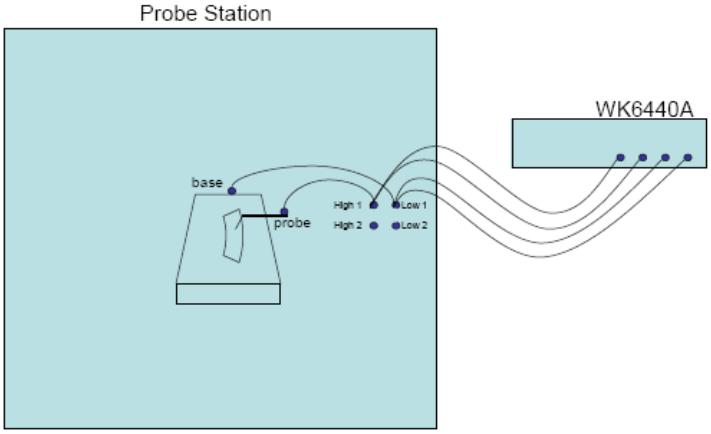


Figure 5: Wiring Diagram for Pitch Adaptor Testing

11) The front panel of the 6440A capacitance meter should show:

a) 8.00 Vac 10.000 kHz
b) Bias OFF External
c) Range Auto
d) Speed Med ALC off
e) Series
f) And 'C' and 'R' should be highlighted.

12) Enter "1" as the starting strip number and enter "512" as the finishing strip number. Select "perform scan".

13) When the scan is complete, save the data to the local disc.

3.2. Evaluation

[Time: 1 minute/PA]

All 512 points on the capacitance plot from the previous test should be distributed around a straight line at about 0.55 pF. Two or more adjacent measurements significantly above this line denote shorts: they will be about 50% above the line if there are two shorted strips. Measurements below this line usually denote bad lifts, but they could represent broken strips.

For help in analysing the plot: choose "Analyse Capacitance" under "pitch adaptor"; "Browse" to locate the data file and then click "Analyse". This provides a graphical representation of the data with possible shorts and breaks colour coded in red (See Figure 6) and a list of all potential problem strips including those with a bad lift flag.

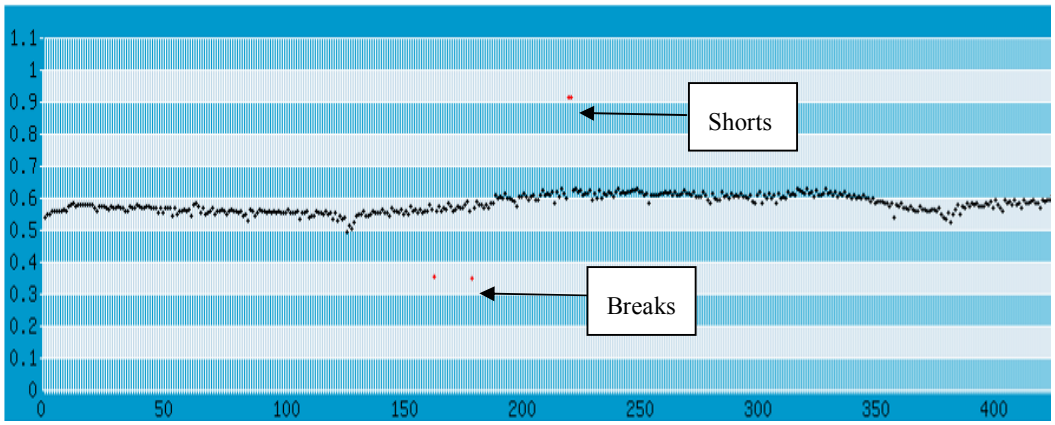


Figure 6: Capacitance data for a pitch adaptor showing both breaks and shorts.

3.3. Re-measurements

[Time: 30mins/PA]

1) Re-measure channels with a high resistance and channels having a capacitance different from the expected value: position the cursor on the suspect point in the capacitance graph to obtain the channel number; enter this channel number as the starting strip number; enter 0 as the finishing strip number; select "perform scan".

2) Almost all (95%) of strips will give a correct capacitance when remeasured. If the capacitance is not correct after the first remeasure, it should be remeasured once more. At the time of writing, no strip has failed to give a satisfactory capacitance after two remeasures. If this were to happen, start to measure the strip again using the option "adjust touchdown before each scan", and manually note the capacitance displayed on the front of the capacitance meter when the probe needle is in good contact with the strip.

3) Save the data to the local disc when all re-measurements have been completed.

3.4. Data Entry

1) Login. Select "**Update**" under "**Pitch adaptor**".

2) Select "**Update**" under "**Sheet-nn**", where **nn** is the sheet number, the first two or three characters of the label.

3) For each pitch adaptor: Set "**Status**" to "**PASS**" if there are no broken or shorted strips, to "**FAIL**" if there are broken or shorted strips; and to "**TEST**" if you have abandoned remeasuring before scanning all suspect strips – remeasuring may be continued later.

4) Set "**Action**" to "**Capacitance**".

5) Enter comment, starting with the fiducial separation, e.g. "**41.470mm One pair of shorted strips**". The fiducial separation is the "radius" value which was recorded after positioning on the second alignment mark.

6) "**Browse**" to upload the capacitance measurement data.

7) When data for all pitch adaptors have been entered: Select "**Change pitch adaptors**".

4. Storage

4.1. After Testing

[Time: 3mins/PA]

Place the pitch adaptor in the next slot in the output tray, or, if it has failed, in one of the boxes marked "Single pair of broken strips", "Broken strips", "Shorts", or "Visual rejects" as appropriate.

4.2. Send for Attachment

When a set of eight good pitch adaptors has been measured, clean each pitch adaptor by blowing both sides with dry Nitrogen, stack the pitch adaptors between sheets of sensor separator paper, and seal the set of eight pitch adaptors in a plastic bag while flushing the bag with Nitrogen.

Label the bag with the batch number and store in the small Nitrogen cabinet.

Individual pitch adaptors are needed when a pitch adaptor needs to be replaced on a module, for example if it has been damaged by glue, so each set of pitch adaptors is not stored as a batch until the next set is ready: this ensures that a single pitch adaptor of the required type is always available.

4.3. Data Entry

[Time: 1min/PA]

1) Login. Select "**Send**" under "**Pitch adaptor**".

2) Click on one of each type of pitch adaptor to create a batch. A tick mark appears. If you make a mistake, click again to deselect.

3) Select "Mark pitch adaptors SENT".

5. After gluing to hybrid

5.1. Data Entry

[Time: 1mins/PA]

When hybrids are returned, enter into the database which pitch adaptors are bonded to which hybrids.

1) Login. Select "**Update**" under "**Module**".

2) Under the column headed "**Pitch adaptors**" for the relevant hybrid, select "**Add Pitch Adaptors**" and tick against the labels of the four pitch adaptors attached to this hybrid. The programme enforces that p-type pitch adaptors are entered for a p-type hybrid and that r-type pitch adaptors are entered for an r-type hybrid.

6. Pitch Adaptor Problem Solving

1) **Problem**: Scanning a pitch adapter results in large amounts of bad lifts.

   (A bad lift is indicated by a resistance that is over around 900kOhm. In the .txt file in which the scan data is saved, a bad lift has the number 3 in the lift column. A number 2 indicates that the lift is good. Number 0 indicates that there was no scan of this strip.)

   Solution 1: Check that the needle is touching the contact. Sometimes the needle will have moved over the course of the scan, so it will need to be re-positioned. This can be done by physically moving the needle.

   Solution 2: The needle may be dirty or may have been bent out of shape. To clean the needle, take a tissue that has been dampened with isopropyl alcohol and wipe the needle towards the tip.

   If cleaning the needle doesn't help, try another one, as the tip may have been damaged in some way.

   Note: To remove the needle, pull it with a pair of pliers.

2) **Problem**: When the "go to position" button is clicked, a warning appears that says the "LIMIT" has been exceeded. This sometimes makes the LabVIEW programme crash.

   Solution: This problem occurs if the needle is greater than 2mm above the surface of the pitch adapter when the "go to position" button is clicked.

   Before telling the needle to "go to position", always drop the needle by 1 mm first. This is done by clicking on the purple arrow that points up.

   Note: The distance that the purple arrow causes the PA to move can be altered by changing the slide in the bottom-right corner of the control panel (the one with the purple arrow on).

   Normally it is set to 495 microns, so two clicks of the purple arrow should bring the needle to around 1 mm from the surface of the PA.

3) **Problem**: The Wayne Kerr Capacitance meter stopped making measurements.

   Solution: Turn it off. Leave it about 20 seconds. Turn it back on again. If that doesn't sort it out, try recalibrating it using the instructions on the sheet above it. If the computer doesn't seem to be able to "read" the measured capacitance, the channel that the Wayne Kerr is operating on may have changed. This can be changed in the Wayne Kerr's settings.

4) **Problem**: A short has been detected and the operator wants to locate it.

   Solution: Tell the LabVIEW programme to scan the shorted channel. When the scan is complete, the needle will retreat to 2mm above the PA, above the shorted channel. The position of the PA can be then be controlled using the galaxy program (the program that you open before the LabVIEW program). There are controls of the x, y and z axes and a speed control of the z axis through the user interface. Using these allow the operator to manually move the PA so that they can visually observe the surface. The joystick can also be used to move in x-y.

   Note: Shorts are not usually obvious. In most cases a short is very dark, making it invisible.

5) **Problem**: Regardless of whether the exact location of the short has been confirmed or not, the operator wishes to try and remove it.

Solution 1: If the Short appears to be a large black area that stands out from the rest of the surface of the PA, it is likely to be loose metallic dust of some description. These can sometimes be blown off the surface using the dry Nitrogen gun.

If that fails to remove it, touching the microscope needle on to the dust may move it, of even pick it up. This can loosen the dust, so try the dry Nitrogen gun again.

If this also fails, try scratching it off as described in solution 2 below.

Solution 2: If the short is a very obvious connection, such as a small path of gold connecting two strips, the most effective way of removing it is to scratch it off using a probe needle taped to a screwdriver, or similar device. Using the microscope, place the tip of this needle in the gap between the strips and put a small amount of pressure on the tip. Then drag it along the surface several times until the short is removed.

Note: Do NOT push the needle along the track, as this tends to "dig-up" bits of pitch adaptor, causing it damage and sometimes producing debris that can be difficult to remove.

Solution 3: If the operator can not locate the short on the strip it is still possible to remove it. Using the needle taped to the screwdriver, a small scratch can be drawn along the length of the track between the shorted strips. The most efficient way to do this is to make a scratch until the track turns a corner, and then use the microscope needle, to measure the capacitance. If the strips are still shorted, move on to the next section and repeat the process.

Note: To make the Wayne Kerr capacitance meter make continuous readings, thus allowing the operator to measure the capacitance of a strip once they have attempted a repair, press the "local" button on the Wayne Kerr, then the sng/rep button.

To measure the capacitance of a strip, manually touch the probe needle down on a strip using the Galaxy programme.

6) **Problem**: The LabVIEW programme is working very slowly (i.e. buttons appear to stick, it doesn't respond.)

Solution: There's no substitute for closing everything and starting again. If you do close the programmes down, it's important to open the Galaxy programme before the LabVIEW programme. When the LabVIEW programme is re-opened, it will ask if you want your previous data to be displayed. If you do want it (i.e. you just did a scan and the programme crashed before you saved it) choose "yes". The data will not appear until you try another scan, so if you want to see them, just tell the programme to scan a single channel, and all the data should appear.

7) **Problem**: The operator has some partially scanned data and wants to complete it.

Solution: Whereas you can load the data and then choose the "align device" option, this often caused LabVIEW to crash. A more reliable method is to choose "load new device" as if you where starting a new scan, and before choosing "perform scan", choose the "load data" option, and choose the data set you want to complete.

7. Test Results

The pitch adaptors were manufactured at CERN and some were rejected upon visual inspection at CERN and not shipped to Liverpool. The database contains information on 640 pitch adaptors that were designated as pre-production. The final production pitch-adaptors number 1376, of these about 30% were rejected at manufacture. For the remainder which were received in Liverpool, every strip (512 per pitch adaptor) had to be tested to ensure that no strips were shorted together and that all strips had continuity (no breaks).

This was done by probing every strip and measuring the capacitance with high precision. A break would show up with a low capacitance measurement and shorting would show up with high capacitance measurement. There is substantial variation of the average capacitance of the PAs as a function of batch number (Figure 7) – this is directly attributable to differences in etching during production. The plot below (Figure 8) shows the measured average capacitance per strip separately for the eight types of R and Phi pitch adaptors tested.

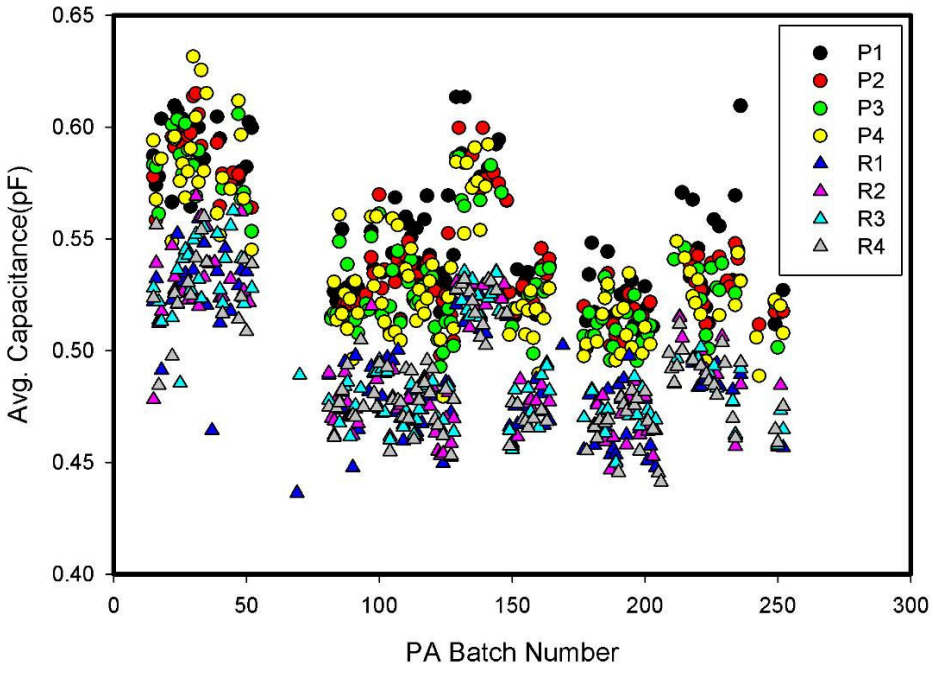


Figure 7: Average capacitance of the pitch adaptors as a function of PA batch number.

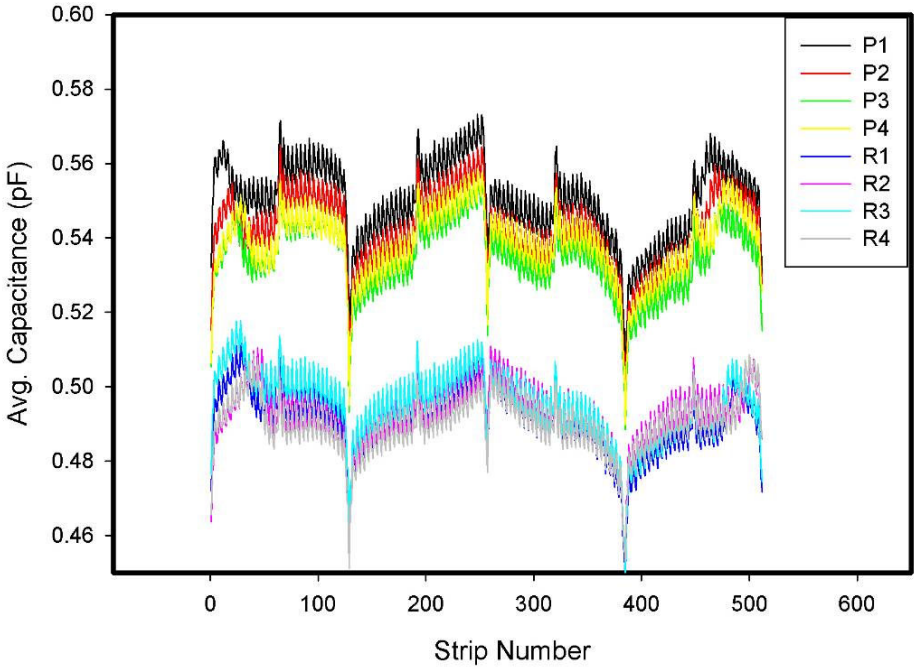


Figure 8: Average capacitance per strip for each of the different pitch adaptor types. The R pitch adaptors have a lower capacitance than the P types. This largely reflects the approximately 10% difference in the lengths of the PA types.

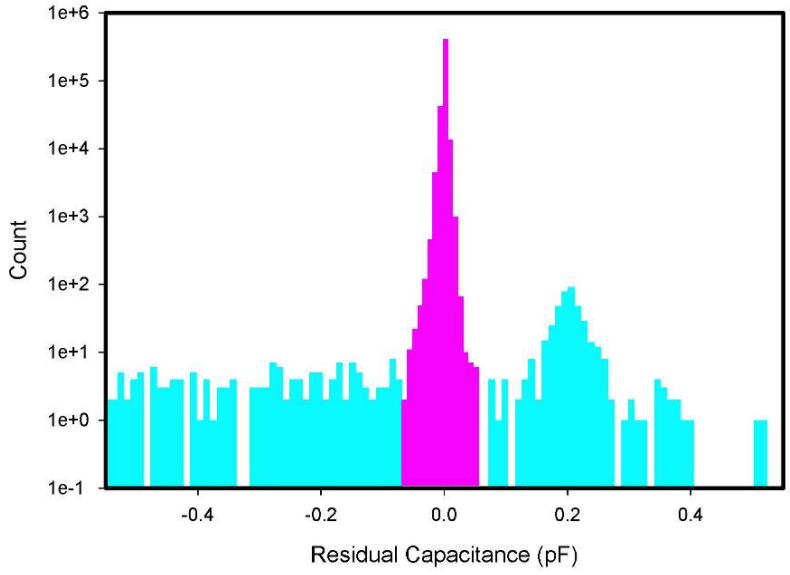


Figure 9: Distribution of residual capacitance from nominal for all strips on the good pitch adaptors (pink) superimposed on that for those labeled as having at least one bad strip (cyan). The distribution of shorts (capacitance less than 0) is uniform showing an even probability of the strip breaking along its length. A peak corresponding to shorts is seen at 0.2pF.

Overall the mean strip capacitance of R pitch adaptors was 0.49pF and 0.55pF for the Phi, both with a standard deviation of 0.03pF. Strips with a measured capacitance that was significantly above or below the expected value (0.07pF away - see Figure 9), were flagged as shorts or breaks

11.4% of pitch adaptors tested had shorted strips and 4.1% had strips with breaks. A total of 14% of all pitch adaptors tested were rejected by the electrical testing. Total number of strips tested was >500000, of the strips tested 0.1% were shorted and 0.03% had breaks.

8. References

1. P.R.Turner, *Silicon Sensor Design and Geometry.* CERN/EDMS. **401568 v.4**

2. *PA-06 Pitch adaptors*, http://hep.ph.liv.ac.uk/lhcb/html/pa-6.html

3. Patel, G.D.*, et al.*, *VELO Module Production - Quality and Process Control.* LHCb Internal Note, 2007(088).