Quality assurance tests of the LHCb VELO Modules

F. Marinho on behalf of the LHCb VELO group
Outline

LHCb intro
VELO Module
Production & reception
Measurements
Summary
• Lifetime and Impact Parameter of b-hadrons
  Decay Length resolution: 220-330μm
  Impact Parameter ~ 20μm (P_T > 10 GeV/c)
• Vertex Locator (VELO) designed to make precise measurements of tracks close to the interaction region
- Two halves each with 21 modules (retractile)
- 8mm close to the beam during operation
- Primary vertices resolution 42 $\mu$m x 10 $\mu$m (beam direction and xy plane)

Expected vacuum $< 10^{-5}$ mbar
VELO Cooling System
Low mass
Biphase CO2 @ 15bar

For more details see Ann Van Lysbeten’s talk
LHCb VELO Modules

2 silicon sensors (R/Φ measuring)
- $n^+\text{-on-}n$ (300 μm)
- 2048 strips/sensor
- Pitch varies 37-100 μm
- Fluences < $1.3 \times 10^{14} n_{eq}/cm^2$

Hybrid
- Kapton circuit encapsulating substrate to allow heat removal

Thermal Pirolytic Graphite
- Electronics support
  pitch adaptors, beetles, thermistors, ...
- Mechanical support

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Module Production

- TPG/CF core
- Double sided
- Populated
- Pitch adaptors
- Chips
- Bonding
- Sensors
- More bonding

Components tested separately or/and during module production
• Reception and Visual inspection to check integrity
• Uncover any possible weakness introduced in components
• Modules operated in vacuum and thermally stressed
  temperature between 30.0°C/-30.0°C, pressure levels ~10^{-5}/10^{-6} mbar
Sensor Testing

Radial Strips
40µm spacing

Capacitance residuals

Small four fold symmetry
(repeating pattern) on
capacitance of R-sensor strips
Sensor Testing

Thickness versus production number

Average curvature
Pitch Adaptor Testing

Average PA strip capacitance

Breaks (flat along length)

Probability of breaks and shorts. Shorts at correct capacitance (modelled)
Visual Inspection

- Pitch adaptors
- Kapton damage
- ~ 450,000 bond wires inspected
- Silicon marks, Lifted bonds, Pitch adaptor faults, Kaptons connectors, Burnt preamp bonds, Debris

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Leakage Current

Ratio of currents before and after testing (300V).

~6% increase

Aim: Evaluate the behaviour of current levels on the sensors during burn-in procedure.
- Overall picture of IV curves
- Higher leakage current than usual
- Significant increasing of current on the silicon
- Any other unexpected behaviour
- Pretty small leakage current for most modules ($I < 20 \mu A$)
- Small percentage changes after burn-in ($\Delta I/I < 30\%$)
- Temperature dependence verified
- Just a small number of unexpected cases
Signal/Noise estimate

Signal
- Used header test beam calibration

Noise analysis
- Pedestal subtraction ~ 1000 events
- Common mode suppression

<table>
<thead>
<tr>
<th>Side</th>
<th>R side</th>
<th>Φ side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>20.39±0.03±2.86</td>
<td>22.45±0.06±3.15</td>
</tr>
<tr>
<td>Value</td>
<td>20.44±0.03±2.86</td>
<td>22.37±0.06±3.15</td>
</tr>
</tbody>
</table>

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Bad Channels

- Confirm already known bad channels and look for any new ones after burn-in
- Combination of VI and electrical data analysis
- Analysis criteria:
  Cuts on raw and common mode suppressed noise.
  Raw and CMS noise of each channel compared to average values per link.
- Good, noisy, dead, shorted

<table>
<thead>
<tr>
<th></th>
<th>Bad/Total (%)</th>
<th>Agreement (%)</th>
<th>Shorted (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R sensors</td>
<td>0.7%</td>
<td>76%</td>
<td>13%</td>
</tr>
<tr>
<td>Φ sensors</td>
<td>0.5%</td>
<td>83%</td>
<td>15%</td>
</tr>
</tbody>
</table>

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Vacuum Studies

• Safe operation with low pressure conditions
• Above 0.1 mbar. (Breakdown risk with ~ 400-500V)
• VELO interlock $10^{-3}$ mbar
• No breakdown observed on sensors

See Gwenaelle’s Lefeuvre studies dedicated to Vacuum Studies

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Velo Commissioning

All modules already mounted

Commissioning going on in the pit
Detector halves to go down soon

- metrology of detector halves
- detector positioning system
- cooling system
- Electronic boards/cables
Quality Assurance

- Hybrid Electrical Test
- Hybrid Cleaning/Visual Inspection
- Hybrid Metrology
- PA/Chip Attachment
- Visual Inspection
- Back-end Wirebond
- Electrical Test
- Laser Test
- Sensor Wirebonding
- Sensor IV
- Sensor-Sensor Metrology
- Sensor Attachment
- Electrical Test
- Front-end Wirebond
- Visual Inspection
- Pedestal Attachment
- Module Metrology
- Cable Attachment
- Module Metrology
- Vacuum Test
- Assemble onto VELO half
- Visual Inspection
- Module Burn-in
- Visual Inspection
- Ship to CERN
- Pack/Visual Inspection
- Thermflow Cooling
- Electrical Test
- Vacuum Test
- VELO Metrology
- Vacuum Test
- Install in Pit

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Summary

- The LHCb VELO modules and components tested exhaustively.
- A total of 6 visual inspections, 6 metrologies, 7 electrical tests and 4 vacuum tests along the production, reception and assembly of the VELO.
- Modules performance as good as expected.
- Commissioning of full VELO in a quite advanced status.
- Studies on many other aspects undergoing (Upgrade and replacements).

LHCb preparation in good shape
Looking forward to data taking in 2008.
Special Thanks

• To P. Collins, T. Bowcock, C. Parkes, M. Artuso and VELO colleagues
• Vertex 2007 Organisation
• Stephan technical issues at last minute