Warsaw in LHCb experiment

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- Production of **130 + 1** modules of straw drift chambers for **Outer Tracker**
- Design, construction and tests of electronics boards for **Time and Fast Control (TFC)** part of **ONLINE** system:
  - Readout Supervisor
  - TFC Switch
  - TFC Throttle …
- Beam Phase and Intensity Monitor (BPIM) readout
- **LHCb upgrade**: 40 MHz readout
- **High Level Trigger (HLT2)**: selection for events of $B_s^0 \rightarrow J/\Psi(ee)\Phi$ decay (see Artur Ukleja talk)

Warsaw, 6.11.2009
LHCb Detector

VELO: Vertex Locator (around IP); TT, T1, T2, T3: Tracking stations
RICH 1-2: Ring Imaging Cherenkov (PID); M1–M5: Muon stations
ECAL, HCAL: Calorimeters

Crucial for B physics:
- polyvalent trigger (incl. hadrons)
- excellent particle ID
- excellent tracking/vertexing ($\sigma_m, \sigma_\tau$)
Straw Drift Tubes Modules

- Straw Tubes packed in double-layered modules

- Modules 64-cells wide
- Modules only ~0.37% $X_0$:
  - “light” panel
    (Rohacell core with carbon fiber skins)
  - “light” straws:
    2 strips of thin KAPTON foil:
    - 40 µm kapton XC
    - 25 µm kapton +12.5 µm Al

\[ r = v_d \Delta t \]
Outer Tracker

- 3 stations T1, T2, T3
- Each station: 4 planes of modules XUVX (3*4*2 = 24 points on track)
- Vertical B field ⇒ measurement of x
- $\theta_{u,v} = \pm 5^\circ$ enough to reduce combinatorics

For each plane modules of standard heights and widths
Geometry of IT requires special modules of OT around IT

- Module type “F”, F, S1U, S1L, S2U, S2L: 64 straws
- Module type “S1U”, S3U, S3L: 32 straws in layer

Short frames:
- Module type “S1U”
- Module type “S2U”
- Module type “S1L”
- Module type “S2L”
- Module type “S3L”
### Scope of production

<table>
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<th>Type</th>
<th>Quantity</th>
<th>Spare</th>
<th>Total</th>
</tr>
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<tr>
<td>F</td>
<td>168</td>
<td>17</td>
<td>185</td>
</tr>
<tr>
<td>S1U</td>
<td>24</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>S1L</td>
<td>24</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>S2U</td>
<td>12</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
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<td>S3U</td>
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<td>4</td>
<td>16</td>
</tr>
<tr>
<td>S3L</td>
<td>12</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>

Production division:
- Heidelberg: 60 F modules
- NIKHEF: 125 F modules
- Warsaw: all 124 S modules (96+28) + 6 + 1 (TRA-BOND glue)

309 modules ⇒ ~ 63 000 straws ⇒ ~ 190 000 soldering points
Steps of module production

**Straw preparation:**
- length, tongue, wire locators, end pieces

**Panel flatness adjusting on template**

**Adjustment of straws** on template, soldering tongues to PCB

**Gluing panel to straws** (wait one day for glue hardening)

**Wiring 64 straws**

**H.V. and wire tension tests**

**Gluing spacers, gas blocks, gas pipes in panel A**
(wait one day for glue hardening)

**Module assembly: gluing side walls and spacers** (panel B)
(wait one day for glue hardening)

**Soldering Faraday cage points, Gluing Al foil for F. cage**
(wait one day for glue hardening)

**Gas leak test**
- H.V. test in Ar/CO₂
- Fe⁵⁵ test

**Repair**
(wait one day for glue hardening)

**Packing and storage**
The crew
Straw preparation

1. Cut to proper length
2. Insert and crimp 2 wire locators
3. Cut grounding tongue
4. Crimp prolongation strip to the tongue
5. Insert end pieces

Substantial increase of production speed with crimping tool

Special tool designed by Frans Mul (Vr.Uni.)
Panel flatness adjusting

PHD with vacuum system assures flatness of panel during whole production process.

Panel Handling Device (PHD) designed in Heidelberg.

Template used as reference plane to obtain flat surface within ± 0.1 mm.
Adjustment of straws on template

Wide PCB side

Soldering tongues to wide PCB pads for proper grounding

Narrow PCB side

Straws sucked to template grooves with vacuum system
Gluing panel to straws

Glue:
50% Araldite AY 103 + 50% (vol.) colloidal silica

Panel with glue placed on straws in template and left for one night.
Wiring 64 straws on panel

Low table for wiring

Vacuum used to suck wires through straws

Wire: tungsten gold plated 25 micron diameter

Wire stretched to 70 G
H.V. and wire tension tests

2 wire locators ⇒ 3 magnet positions
Gluing spacers and gas blocks (panel A)

Aluminium spacer

Plastic spacer (beam side)

Gas block
Module assembly (1)

- Two panels placed on top of each other
- Lowered to the proper positions

Beam side (plastic spacer)

Outer side (Al spacer, FTB with connectors)
Module assembly (2)

Side walls

Add additional line of glue next to the straw to cover the Al side strip edge on panel

Side walls gluing

Pressed with a pneumatic system
Module assembly (3)

Assembled module is left for one night for glue hardening.
Module finishing

- Soldering strips of Faraday cage
- Gluing Al foil (beam side) for Faraday cage
- Gluing gas pipes
Quality Assurance during production:
- wire tension
- dark current

Quality Assurance after production:
- gas tightness, dark current
- $^{55}\text{Fe}$ uniform gain test
- detector response to $^{90}\text{Sr}$ $\beta$-source.

Full scan (every cm$^2$) of all OT modules at NIKHEF

$\sim 0.1\%$ of "bad" channels
Test Beam Results

r - t relation:

efficiency profile:

Drift time (ns)

Efficiency, $\varepsilon$

$\varepsilon_{predicted}$, $\lambda=0.3$
$\varepsilon_{smeared}$, $\sigma_{tr}=200\mu m$

Test beam 2005
Good efficiency and resolution for $HV > 1520$ V

$\varepsilon \approx 98 \%$

$\sigma \approx 200 \, \mu$m

corresponds to gain $> 50,000$
Tracking Performance

Outer Tracker station

Long tracks:
- ~38 measurements per track
- Efficiency >95% (p>12 Gev)
- Ghost rate <7% (p>12 GeV)

in b\ b events: \(<n_{ch,\text{reconstructed}} > \approx 72\)
OT Installation (1)

- Bridge
- C- Frames
- Modules
- Distribution of LV, HV, ECS/TFC, etc.
- Distribution of cooling and gas
- 9+9 Detector Modules
- 2 × 2 × 9 Front-End Electronics Boxes
OT Installation (2)

Straw tubes modules

FE Boxes

OT C-frames

survey targets (photogrammetry)
LHCb Experiment Status

Outer Tracker

Installation and commissioning completed
Data taking with cosmics

Cosmics event

Magnet

OT

Calo

Muon

Cosmics event
Some Events…

Clean event

Splashy event
(not all tracks reconstructed...)
LHCb ONLINE system

Three components:
- **Time and Fast Control (TFC)**
- **Data Acquisition (DAQ)**
- **Experiment Control System (ECS)**
LHCb TFC system
Readout Supervisor

The heart of the TFC system is the Readout Supervisor

- Distributes **the LHC clock** to the entire FE electronics and the trigger systems.
- Distributes **the L0 trigger decision** to the L0 FE electronics.
- Generates and time-in **all types of self-triggers** (random triggers, calibrations, etc.).
- **Controls the trigger rate** by taking into account the status of the different components in the system in order to prevent buffer overflows and to enable/disable the triggers at appropriate times during resets, etc.
- Generates and time-in **resets** (counters- and electronics-) and the other asynchronous commands.
- Records **detector status information** and information related to timing, triggering and fast control in **a special data block** and transmits them to the event building.
- Incorporates an **ECS interface** for configuring, controlling and monitoring the Readout Supervisor.
A TFC switch allows a dynamic partitioning of the LHCb detector to support independent and concurrent sub-detector activities such as commissioning, calibration and testing.
Throttle Switch and throttle „OR”

The optical throttle network is used to transmit trigger inhibit from the asynchronous parts of the readout system to RS in case of congestion of data path. It incorporates a Throttle Switch to allow partitioning of the readout system and modules which perform locally an OR of the throttle signals of each subsystem.
Beam Phase and Intensity Monitor

- **Global clock stability:**
  - LHCb: 14 km of fibre between SR4 and PA8 at a depth of ~1m
  - Estimated max. diurnal drift 200 ps
  - Estimated max. seasonal drift 8ns
- **Local beam monitoring:**
  - Measure bunch phase bunch-by-bunch
  - Bunch intensity bunch-by-bunch
- **Beam pick-ups are installed on both beams**
Beam Phase and Intensity Monitor readout

Test results

Measured intensity of SPS beam (three groups of 72 bunches)

Measured time intervals between bunches: mean = 25.05 ns, r.m.s. = 54 ps
The end