The LHCb commissioning

Moriond QCD and
High Energy Interactions

La Thuile,
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on behalf of the LHCb group
Outline

- The LHCb detector
- LHCb commissioning
  - Commissioning with Cosmics
  - Commissioning with Beam
- F.E.S.T.
- Conclusions
The LHCb detector (I)

Single-arm forward spectrometer, dedicated to B-physics:

- \( L = 2 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1} \rightarrow 10^{12} \text{ bb/year} \)
- Acceptance 10-250 mrad (V) / 10-300 mrad (H) \( \rightarrow 1.6 < \eta < 4.9 \)
- Useful \( \sigma_{bb}(14 \text{ TeV}) \) for LHCb is 230 \( \mu \text{b} \)
The LHCb detector (II)
LHCb trigger

- Level-0 hardware trigger: 40MHz → 1MHz
  - Search for high-$p_T$ $e$, $\gamma$, $\mu$, hadron candidates
  - Pile-up veto

- High-Level Trigger (sw): 1MHz → 2kHz
  - HLT1: 1MHz → 30kHz
    - full detector information
    - confirm L0 objects
    - impact parameter cuts (optional)
  - HLT2: 30kHz → 2kHz
    - inclusive and exclusive selections using full event information

- Event size: 36 kB
LHCb vertex locator

- 2 retractable detector halves:
  - 5 (30) mm from beam when closed (open)
- 21 stations per half with an R and φ sensor
- 2 Pile-Up stations per half (trigger)
- Operates in secondary vacuum
- 300μm foil separates detector from beam vacuum
- 2 phase CO₂ cooling system
Run the detector as a whole:
- Bring all components (sub-detectors and service systems) to operational state
- Define, implement and validate tools and procedures
- Organise the activities to reach the ready state in time

Detector calibration:
- Test pulses and radioactive sources
- Cosmic rays
- LHC injection tests

Experiment Control System:
- Operating the whole detector from one console
- Tools for diagnostics, alarms and monitoring
- Shifters training

Make it efficient:
- cold start < 10min, warm start < 1min
Goals achieved in 2008

- Detector readout at 100 kHz (final target = 1 MHz in 2009)
- Data storage at 2 kHz
- Detector operated with a unified control software:
  - PVSS SCADA to control hw and sw processes
  - Finite State Machine
    - states and commands
    - sub-detector configuration
    - trigger/event-building configuration
    - timing/fast control configuration
    - storage
    - monitoring
- All data acquisition boards successfully operated
- Data successfully transmitted and stored

March 15, 2009
Commissioning with Cosmics (I)

- Challenging because of the detector geometry: horizontal cosmics are rare (<1Hz)!
- Still $1.1 \times 10^6$ triggers recorded!
- Special ECAL/HCAL and MUON triggers:
  - low thresholds to see MIP
  - coincidence between 2 MUON stations
  - no vertex constraints
- Commissioning of the trigger (same logic as for real data used)
- Coarse time alignment
Commissioning with Cosmics (II)

MUON Chambers

Time alignment

Backward tracks are skewed

Forward tracks are aligned
Commissioning withCosmics (III)

Triggering by CALO & MUON

😊 reconstruction in the Outer Tracker
😊 low chances for the Inner Tracker (small)
😊 impossible for the Trigger Tracker (far) and the Vertex Locator (small and far)
LHC sector tests
- beam2 dumped on the injection line beam stopper (TED).
- TED: 4m tungsten, copper, aluminum, graphite rod in a 1m diameter iron casing
- 340m downstream LHCb
- 8 mrad horizontally and 12 mrad vertically from LHCb beam axis
- very high flux: (10 particles/cm²) in the center of shower

Time alignment

Space alignment

August, 22th- 24th
Vertex Locator, Calorimeters, Muon

September, 5th- 6th
Vertex Locator, Inner Tracker, Outer Trackers, Calorimeters, Muon
First TED tracks

August, 22\textsuperscript{th} - 24\textsuperscript{th}

Vertex Locator, R and $\phi$ measurements
TED data: VELO space alignment

Alignment:
- 5 μm for X(Y) translation
- 200 μrad for Z rotation
- σ = (3.2±0.4) μm

Resolution:
- 85%-90% clusters are one strip clusters
- Resolution evaluated integrating the results of all sensors
TED data: TT space alignment

Extrapolation of Vertex Locator tracks to TT:

- Resolution expected: 300 μm
- Hit residuals observed: 500 μm
- Offsets: 150-300 μm

Residual for TT/TTa/TTaULayer

σ=500μm

Entries: 5070
χ²/ndf: 92.67/96
p0: 24.16 ± 3.56
p1: -0.147 ± 0.064
p2: 0.4762 ± 0.0727
p3: 9.741 ± 0.337
TED data: time alignment

expected BX
First Beam: LHC media day

10.9. 2008 10:37:08 -50ns

MUON, CALO and RICH systems

☐ Circulating beam1: right direction for LHCb
☐ Readout of consecutive triggers
☐ Clean events
☐ Splash events (hitting on collimator)
☐ Only for ½ an hour....

10.9. 2008 11:25:26 -50ns

Tracking system

10th September 2008

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Shutdown activities

- General maintenance.
- Improvements and repairs.
- Installation of full-size readout network for a 1 MHz readout.
- Installing 350 farm computing nodes → total = 550 (bought later to get more). Infrastructure available for 2000 nodes.
- Commissioning 1 MHz readout.
- Installation of last Muon Station (M1).
- Full Experiment System Test.
Full Experiment System Test

Everything but the real detector!

Exercise:
- run control
- data stream, event building and HLT
- dynamic farm node balancing,...
- data monitoring
- data quality tools
- run database, conditions database
- data storage (to tape and sending to the GRID)

All this @ nominal rate!

1.9 kHz achieved steadily (limited by MC injector)
Conclusions

☐ LHCb was ready for beam in 2008

☐ Cosmics data have been very useful for initial commissioning

☐ Beam-induced events allowed some fine tuning

☐ Shutdown activities progressing well

☐ We will be *more ready* for Physics in 2009!