Readiness of the LHCb experiment for first data

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On behalf of the LHCb collaboration
• Introduction

• Some results from experiment commissioning in the last year

• Present Activities

• Short term perspective (first beam in 2009)

• Conclusions
NP (?) in CP & b rare decays

Potential

Effective $\sigma_{bb}(14 \text{ TeV})$ in LHCb acceptance $\sim 230 \mu$b

$$\int_{0}^{\text{LHC year}} Ldt = 2 \text{ fb}^{-1}$$

- $270 \times 10^9 B_d$ per year
- $70 \times 10^9 B_s$ per year

All b–hadrons species produced

Challenges

- Multiplicity per rapidity unity $= 30$
- Background from high inelastic cross section of 80 mb
- Branching ratios for B–meson decays relevant for LHCb physics $O(10^{-3} - 10^{-9})$

Performance

**VELO:**

$$\sigma(IP) \sim \left| 14 + 35/p_T(\text{GeV}) \right| \mu\text{m}$$

$$\sigma(t) \sim \left| 40 - 100 \right| \text{fs}$$

**TRACKING**

- $c = 95\%$ when $p > 5 \text{ GeV}$ and $1.9 < \eta < 4.9$
- $\sigma(p)/p \sim 0.4\%$
- $\sigma(m|B_s \rightarrow \mu \mu|) \sim 20 \text{ MeV}$
- $\sigma(m|K^* \mu \mu|) \sim 15 \text{ MeV}$

**MUON, RICH**

- $c(K) \sim 88\%$ for 3% $\pi$ mis-id
- $c(\mu) \sim 95\%$ for 5% $\pi/K$ mis-id

**ECAL**

- $\sigma(E)/E \sim \left| 9.4/\sqrt{E(\text{GeV})} + 0.83 \right| \times 10^{-2}$
- $\sigma(m|B_s \rightarrow \phi \gamma|) \sim 90 \text{ MeV}$

**LEVEL–0 TRIGGER**

- $c(B_{ds} \rightarrow J/\psi X) \sim 90\%$
- $c(B_{ds} \rightarrow hh) \sim 50\%$
**LHCb trigger**

**Level-0 Hardware Trigger**

*high-pT m, e, g, hadron candidates*

<table>
<thead>
<tr>
<th>Trigger</th>
<th>had</th>
<th>μ</th>
<th>μμ</th>
<th>e⁺</th>
<th>γ</th>
<th>π⁰</th>
</tr>
</thead>
<tbody>
<tr>
<td>p_T &gt; (GeV)</td>
<td>3.5</td>
<td>1.3</td>
<td>Σ &gt; 1.5</td>
<td>2.6</td>
<td>2.3</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**High Level Trigger (C++ application)**

*Event Filter Farm with up to 1000 16-core nodes*

**HLT1**: Check L0 candidate with more complete info (tracking), add impact parameters and lifetime cuts

**HLT2**: Global event reconstruction + selections.

<table>
<thead>
<tr>
<th></th>
<th>ε(L0)</th>
<th>ε(HLT)</th>
<th>ε(total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadronic</td>
<td>50%</td>
<td>80%</td>
<td>40%</td>
</tr>
<tr>
<td>Electromagnetic</td>
<td>70%</td>
<td>60%</td>
<td>40%</td>
</tr>
<tr>
<td>Muon</td>
<td>90%</td>
<td>80%</td>
<td>70%</td>
</tr>
</tbody>
</table>

ε corrected for acceptance and selection

"software" approach provides increasing processing power "for free"
- **Nominal Muon trigger configuration:**

  Coincidence of $\geq 1$ hit for each muon station in projective geometry (from IP) $\sim 0$ Hz rate

- **Used Muon trigger config:**

  $\geq 1$ hit in station M3
  $\rightarrow$ 60 Hz rate
  $\geq 1$ hit in stations (M4 & M5)
  $\rightarrow$ 4 Hz rate

- **Calorimeter trigger:**

  ECAL & HCAL with high gain (MIP)
  $\rightarrow$ 10 Hz rate

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"Wrong" detector geometry, but still well visible in large sub-detectors (Muon, Calo, Outer Tracker)

**OR of Calorimeter and Muon triggers (in various combinations)**

$1.8 \times 10^6$ triggers acquired during Summer 2008

$\rightarrow$ Extensive commissioning of basic L0 building blocks
First muon Alignment with cosmics

Backward tracks

Forward tracks

Alignment corrections loaded to be aligned on forward tracks

Hit raw time (ns)

No analysis, no TOF corrections

σ ~11 ns

M2

M3

M4

M5

A. Lai – Readiness of the LHCb experiment for first data
After data analysis of events from cosmics

<table>
<thead>
<tr>
<th>station and region</th>
<th>time res</th>
</tr>
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<tbody>
<tr>
<td>M2 R2</td>
<td>5.9 ± 1.6</td>
</tr>
<tr>
<td>M3 R2</td>
<td>6.5 ± 1.3</td>
</tr>
<tr>
<td>M4 R2</td>
<td>6.5 ± 1.4</td>
</tr>
<tr>
<td>M5 R2</td>
<td>5.8 ± 1.6</td>
</tr>
<tr>
<td>M2 R3</td>
<td>5.2 ± 0.5</td>
</tr>
<tr>
<td>M3 R3</td>
<td>5.0 ± 0.5</td>
</tr>
<tr>
<td>M4 R3</td>
<td>6.5 ± 0.4</td>
</tr>
<tr>
<td>M5 R3</td>
<td>6.5 ± 0.4</td>
</tr>
<tr>
<td>M2 R4</td>
<td>5.0 ± 0.1</td>
</tr>
<tr>
<td>M3 R4</td>
<td>4.9 ± 0.1</td>
</tr>
<tr>
<td>M4 R4</td>
<td>5.1 ± 0.1</td>
</tr>
<tr>
<td>M5 R4</td>
<td>5.6 ± 0.1</td>
</tr>
</tbody>
</table>

Cleaning of tracks (tracks with only 4 hits)

Detailed TOF correction

Average on smaller detector areas (not enough statistics on single channels)

Expectations from lab measurements

Low stat

- 5.3
- 5.7
- 6.0
Muon detector Efficiency

<table>
<thead>
<tr>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>M5</th>
</tr>
</thead>
<tbody>
<tr>
<td>(84.8±0.1)%</td>
<td>(87.0±0.1)%</td>
<td>(89.8±0.1)%</td>
<td>(89.4±0.1)%</td>
</tr>
</tbody>
</table>

Not corrected for projectivity

$\varepsilon$ as a function of the track angle
Commissioning (2008)

Particle blasts... the more messy the better...

What done during months with cosmics could be (better) done in a few hours or days with beam

→ Only a few opportunities: TED injection tests (August/September 08)
   First LHC beam circulation (10 September 08)
Beam 2 dump on injection line
beam stopper (TED)
340m before LHCb along beam 2
8 mrad H and
12 mrad V from LHCb beam axis

Particles coming from behind the detector and not centered
Centre of shower in upper right quadrant
High flux, centre of blast ~10 particles/cm² (x20 than nominal !)
Vertex Locator ~0.1 particles/cm²
Trigger by Scintillator Pad Detector (SPD) multiplicity. Readout of consecutive triggers centered on the triggered event (Time Alignment Events)

2 usable LHC injection tests:

August 22\textsuperscript{nd}, 5x10\textsuperscript{9} p per shot (every 48s)
- Muon, Calo, VELO
- 700 tracks in VELO

September 5\textsuperscript{th} and 6\textsuperscript{th}, lower flux 2x10\textsuperscript{9} p per shot
- Muon, Calo, VELO, IT, TT
- 700 tracks in VELO

Useful tests to verify space and time alignment within single sub-detectors and among sub-detectors
First opportunity of “good” statistics in small area detectors (VeLo, TT)
VeLo reconstructed tracks, August 22, 2008

Muons ~70 candidates per shot

VeLo tracks extrapolated to TT
TED runs and Alignments: highlights from space domain

**VELO alignment:**
Module alignment precision is about 3.4 μm for X and Y translation and 200 μrad for Z rotation.

- Expected uncertainty in VELO–TT extrapolation: 300μm
- Hit residuals observed in TT: 500μm
- Offsets: 150–300μm
1st circulating beams (no collisions yet)
Beam 1 in the right direction:
Looking for halo and splash events

**Important testbench for:**

- Alignments
- Experiment operation (smooth and quick on/off of the system)

**Exciting yet too short**

- Very good response of Control and DAQ Systems
- Use of "physics" Muon trigger (4-fold coincidences)
Beam 1 on RICH2

One event in RICH2 during the beam1 on collimator runs on September 10th.

Photon blast, occupancy as high as 140k hits, out of roughly 200k pixels in the active area.

RICH1 stayed off during these runs (too close to the beam pipe).

Timing inside 25 ns window
First beam: Calo & Muon

10.9.2008 10:41:20 +50ns

5 consecutive time slots acquired per trigger
Tracks in the Outer Tracker

10.9. 2008 11:32:26 +50ns

5 consecutive time slots acquired per trigger
Back-end tests
FEST (Full Experiment System Test)

Raw-Monte Carlo events injected into the DAQ chain as if coming from the readout boards (@2kHz “preselected events that will pass the HLT”)

What we test:
- Run control (the “injector” emulates a sub-detector);
- Data stream;
- Dynamic farm node balancing;
- Data monitoring;
- Data storage
- Interaction with the GRID

1.9kHz achieved steadily (limited by MC injector)

AIM: get prepared to receive, process and analyze 7 million events in the first hour of collisions

Online and offline data monitoring and processing
2009 Shutdown activities

Main activities until next July:

- **M1 installation and commissioning**
- HPD replacement (RICH)
- HV and readout boards modification (ECAL)
- Fixing of defective channels (MUON)

Control System optimization
FEST weeks

Installation of full-size readout network for a 1 MHz readout
(add 350 nodes to the 200 presently in place)
Commissioning 1 MHz readout from April onwards

Reduce HLT output rate to 2 KHz

Debug, continue to debug and, when finished, start debugging again

Still (always) a lot of work...
What we can expect/hope today:

TED runs (August)
450 Gev runs (September)

Preliminary phase
(~like planned one year before…)

October and beyond

450 GeV → 2 TeV  Setting-up run
2 TeV → 4 TeV, 5 pb\(^{-1}\) overall  Technical run
4 TeV 50 ns, 0.5(3) fb\(^{-1}\) overall  Physics run
**LHCb plans 2009/10**

**Set-up and Technical phases:** ramping from 450 GeV to 4 TeV

68 colliding bunch pairs out of 156

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9 x 10^{10} p/bunch, β^* = 3m \( \Rightarrow \) \( L \sim 2.3 \times 10^{31} \) (target L)

Few weeks @ 2.3 \( \times 10^{31} \), \( \varepsilon_{op} = 20\% \) \( \Rightarrow \) 5 pb\(^{-1}\)

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**Up to 2 TeV (6–7 weeks ?):**

1. Refine time and space alignment reaching nominal conditions.

2. VELO open, no LHCb B-field
   (With LHCb B-field at nominal, VELO may only be closed with \( \geq 2 \) TeV/beam)

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\( \geq 2 \) TeV/beam (6–7 weeks ?):

1. Operation of LHCb magnets
2. Closing of VELO
50ns bunch scheme: 1173 colliding bunch pairs out of 1333, 4(5?) TeV/beam

\[ 9 \times 10^{10} \text{p/bunch, } \beta^* = 10m \Rightarrow \mathcal{L} = \sim 1.3 \times 10^{32} \]

200 days @ 1.3 x 10^{32}, \( \varepsilon_{\text{op}} = 20/30\% \Rightarrow \sim 0.3(5) \text{ fb}^{-1} \)

Nominal LHCb year should provide 2 fb^{-1} @ 7 TeV

...but significant measurements @ 0.3 fb^{-1} and lower energy are possible

\[ B_s \rightarrow J/\psi(\mu^+\mu^-) \phi \]
\[ B_s \rightarrow \mu^+\mu^- \]
\[ A_{FB} \text{ in } B_d \rightarrow K^*\mu^+\mu^- \]

2\( \beta_s \) measurement competing or better than Tevatron result

BR limit approaches SM value

Statistics ~4 times better than present B-factories

Trigger strategy is adapted to favor inclusive selections of key channels for the first measurements
**Conclusion**

*LHCb is eager to receive the first collisions (we need them!) to conclude commissioning and tune calibrations towards nominal conditions.*

The experiment is well advanced in preparing the reception of the first collisions at moderate luminosity as soon as the LHC will be able to deliver significant physics (DAQ, HLT and analysis).

*Our (reachable!) target is collecting and quickly exploiting 0.3 fb⁻¹ of physics in the first “year” of run.*
THANK YOU!