LHCb Muon System

Alessia Satta
on behalf of LHCb Muon System:
CAGLIARI, CERN, LNF, FERRARA, FIRENZE, PNPI, ROMAI, ROMAII
13/09/05
LHCB physics

- A beauty dedicated LHC experiment:
  - CP violations: measurements of $\alpha \beta \gamma$
  - Unique access to Bs: measurements of $\Delta m$ and $\Delta \Gamma$ and mixing angle
  - Rare decays
  - Unique access to all beauty hadrons ex. $\Lambda_b, B_c$
- Indirect search for new physics, complementary to direct observation possible in Atlas or CMS
LHCb: a dedicated b experiment

Beauty production peaks in forward-backward directions: a fixed target like detector layout
Muons in LHCb: usage

- **Trigger:**
  - Muons are ~ 200 KHz out of the 1MHz first level trigger rate
  - Inclusive muon selections fill 75% of stored data

- **Offline**
  - Decay channels mu:
    - $\text{Bs} \rightarrow \text{J/Ψ φ}$
    - $\text{Bs} \rightarrow \text{J/Ψ η}$
    - $\text{Bs} \rightarrow \mu\mu$ ($\text{Bd} \rightarrow \mu\mu + \text{D0} \rightarrow \mu\mu$)
    - $\text{B} \rightarrow \text{K*} \mu\mu$
    - ....
  - tagging
Muon system design

Design driven by first level (hardware) trigger (L0)
- A rejection factor of mb of ~1/100
- Medium Pt > 1GeV/c
  - Good momentum resolution is required
  - No B field in the detector
  - a station in front of the calorimeter
- Trigger requires 5 hits out of 5 inside BX
  - high efficiency in 25ns
Optimized granularity ~ MCS contribution to $\sigma(1/P_T)$

- High correlation angle momentum
  - Better granularity at high $\eta$

- 4 concentric regions
  - Channel linear dimensions double from an inner to an outer region
  - 20 different channels sizes
    - min 6.3x31 mm
    - max 250x 310 mm
Adopted technology

- Multi Wire Proportional chambers with 4 ORed gas gaps (2 gaps in M1 to reduce $X_0$) → high efficiency
  - + GEM chambers 1% area (*see next talk*)
- 1 Front End per 2 gaps (1 in M1) → rate capability and robustness

5 mm gas gap
2 mm wire pitch
Ar /CO$_2$ /CF$_4$ = 40/ 55/ 5
Layout

- Large variation in channel **dimensions** and **occupancy** in the 5x4 regions + **technology** and **cost constraints** → the desired layout is obtained by
  - Chambers with cathode, wire, combined readout
  - Pads and strips
  - Strips reduce from 55k → 26k trigger channels

- To minimize **capacitance** and **deadtime**, pads smaller than required by granularity are connected to a FE → 120k ORed FE channels
MWPC performance

Efficiency

- 2.0mm pitch, cathode readout
- 25ns time window
- 20ns time window
- 15ns time window

- 2.0mm pitch, wire readout
- 25ns time window
- 20ns time window
- 15ns time window

- Time resolution RMS < 4 ns
- XTalk ~ 10%
Rates

- Large radiation dose in the inner regions of station M1 and M2
  - Rate = 80(M1R2), 35(M1R3,M2R1), < 15 (rest) kHz/cm²
  - Integrated Q = 0.9(M1R1), 0.5(M2R1), < 0.3 (rest) C/cm²
  - 10 years of running + safety factor 2 (M1) 3(M2-M5) $L=2\times10^{32}$

- 5 years of running of M1R2 (> 8 per M2R1 and > 10 for the rest) have been tested and chamber performance is ok, wire ok - some etching on cathode and panel due to CF4 → CF4 content ↓ 5%
MWPC construction

- 1368 chambers → automatic tools

Ferrara wiring machine

CERN soldering machine

Many measurements tools exist: panel planarity, wire tension, wire pitch
Status of production

- ~ 45% of the chambers have been produced
- Chamber tests on 100% of production
  - gas tightness
  - HV
  - gain uniformity

Gas gap gain uniformity

Production status

* Ratios $\text{Avr}/\text{Avr}^*$ for double gaps (1+2)&(3+4)
Electronic chain

- On detector boards:
  - **CARIOCA**: Custom front end chip (ASD+BLR) unipolar, peaking time 10 ns, deadtime ~60ns (120k channels)
  - **DIALOG**: Custom chip OR FE’s to achieve the required granularity, introduce the delays per FE

- Off detector boards:
  - **SYNC**: a custom chip with TDC to allow the synchronization of the apparatus
L0 muon trigger

Completely hardware and fully synchronous

- Track search in M1-M5
  - Seed in M3
  - Hits in M4 and M5 define a $\mu$ track ($20 \lambda_I$)
  - M2 and M3 hits predict M1 hit position
  - M1 and M2 hits define $\mu$ direction after magnet

- B-kick to calculate $P_T$
  ($P_T$ kick $\sim 1.2$ GeV/c)
L0 Muon performance

- $P_T$ resolution $\sim 20\%$
- High efficiency
- Very robust against high background level in the detector

<table>
<thead>
<tr>
<th>100 kHz output rate</th>
<th>efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal condition</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td>82%</td>
</tr>
<tr>
<td>+ safety factors</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td>76%</td>
</tr>
</tbody>
</table>

Safety factor 2 in M1 and 3 in M2-M5

$B \to \mu X$

$B \to J/\Psi \phi$
HLT muon streams

Lifetime unbiased **dimuon stream (600Hz)**

- High rate dimuon trigger will provide invaluable **calibration** tool
- Distinctive mass peaks: $J/\Psi$, $\Upsilon$, $Z$
  - can be used to fix mass scale
- Sample selected **independent of lifetime** dominated by prompt $J/\Psi \rightarrow$ allow study of IP and proper time res. in data
- Overlap with other triggers will allow proper time acceptance to be studied

---

**True $J/\Psi$ rate ~ 130 Hz**

$\rightarrow 10^9$ events / year!
**HLT muon streams**

<table>
<thead>
<tr>
<th>Inclusive single muon (900Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- providing <strong>unbiased selection</strong> of ‘other B’ in event, invaluable for studying biases in exclusive trigger selection</td>
</tr>
<tr>
<td>- useful for <strong>‘data-mining’</strong></td>
</tr>
<tr>
<td>- <strong>Straightforward &amp; robust trigger;</strong> a reassuring lifeboat for early operation</td>
</tr>
<tr>
<td>- High beauty purity: 550 Hz of true $b \rightarrow \mu$ events in the 900 Hz</td>
</tr>
<tr>
<td>- $\sim 10^9$ perfectly tagged B decays / year !</td>
</tr>
<tr>
<td>- Add $\sim 10%$ of effective statistics with respect to exclusive selection</td>
</tr>
<tr>
<td>- Useful to <strong>recover decay modes</strong> difficult to trigger exclusively (e.g. $B_s \rightarrow Ks Ks$)</td>
</tr>
</tbody>
</table>
Offline performance

- $B_s \rightarrow J/\Psi \phi + B_s \rightarrow J/\Psi \eta$
  - Mixing angle of $B_s$: $\sigma \sim 0.05$ (1y)
  - $\Delta \Gamma/\Gamma: \sigma \sim 0.03$ (1y)
- $B_s \rightarrow \mu \mu$: $\sim 1/7$ (1/5) of the effective tagging power is due to muons in $B_s$ ($B_d$)

$\Delta m_s = 25 \text{ ps}^{-1}$
Conclusions

- The designed detector has
  - Good time resolution, high efficiency, robustness, high rate capability, aging resistance

- Construction well advanced