The LHCb Upgrade

Marina Artuso (Syracuse University) on behalf of the LHCb collaboration

- LHCb now
- Upgrade motivation
- New trigger and DAQ
- A two-stage plan for LHCb detector upgrade
- Conclusions
LHCb in 30 seconds (or less)

- LHCb is an experiment optimized to study beauty and charm decays at LHC, exploiting the high \( b\bar{b} \) and \( c\bar{c} \) production cross section, spatial correlation between \( b \) and \( \bar{b} \), and long \( b \) decay distance because of the high boost.

- A few important numbers:
  - Track acceptance \( 1.9<\eta<4.9 \)
  - \( \sigma_{bb} \approx 300 \mu b \) at 3.5+3.5 TeV [see Passaleva & Stone talks]
  - Nominal luminosity \( 2\times10^{32} \text{ cm}^2\text{s}^{-1} \)
LHCb now

See contributions by Borghi [01], Powell[01], Stone [01], Van Herwijnen [01], Blanks[04], McNulty[04], Passaleva[05], Mancinelli [06], Belyaev [06], Bediaga [06], Haines [06], Raven[06], Adinolfi [13]
We expect new physics to be seen at LHC (complementary information from ATLAS/CMS and LHCb), the next step is a characterization of new physics through virtual interference with W & Z in the b and c decays.

Thus we want a ≥ 10 increase in sensitivity through:
- Increase nominal luminosity
- Increase efficiency on b hadron trigger (× ≈ 2)

Planned in 2 phase matching LHC schedule: phase I (nominal $\mathcal{L}=1\times10^{33}\text{cm}^2\text{s}^{-1}$) and phase II (nominal $\mathcal{L}=2\times10^{33}\text{cm}^2\text{s}^{-1}$)

(Most of the talk focuses on phase I)
The high luminosity challenge

At $\mathcal{L}=2\times10^{32}$ cm$^2$s$^{-1}$ [nominal running conditions envisaged for the present detector] most crossings do not have an interaction and the mean number of interactions per crossing is 0.4.

- At $\mathcal{L}=10^{33}$ cm$^2$s$^{-1}$ [phase I] the mean number of interactions per crossing is $\approx 2.3$ & 15% of the crossings are empty
- At $\mathcal{L}=2\times10^{33}$ cm$^2$s$^{-1}$ [phase II] the mean number of interactions per crossing is $\approx 4.6$ and all the crossings have at least 1 interaction
The solution: software trigger

Concept:
we need to follow all the clues that will emerge in the next few years with a strategy flexible and highly selective ➔ software trigger exploiting detached vertex information early on

Implementation:
Read out the detectors at 40 MHz and use all the relevant information to suppress background (minimum bias, but also not so interesting beauty and charm signals)

Goals:
- 20 KHz on tape (now 2 KHz)
- $10^5$ reduction factor on minimum bias
- Trigger efficiency for interesting B hadronic decays 50%
Electronics & DAQ for 40 MHz readout

- Zero-suppressed readout
- Fast optical link used
- Readout boards common to all subdetectors

FE derandomizing buffer
Absorb statistical fluctuations in data

Throttling mechanism (tuneable pt thresholds) [phase 1]
LHCb detector evolution in Phase I

Vertex detector: new pixel system

Tracking system: new TT& IT, new electronics for OT

Hadron id: New photon detectors

Some electronics replacement for

Calorimeter

Muon detector
Upgrade schedule (matched to LHC)

- **phase I:** ≈2016 LHC shut-down
  - Novel pixel based vertex detector (VELOPIX)
  - New front end electronics
  - New trigger and data acquisition concept to achieve better efficiency for hadronic B decays
  - RICH photon detector replacement
  - New TT & IT tracking systems

- **phase II:**
  - New hadron ID system (torch) bases of precision time of flight
  - Better electromagnetic calorimeter segmentation
  - Change to tracking: IT & OT geometry
Challenges for the tracking system

occupancy

Radiation environment

- Dose after 100 fb\(^{-1}\)
- Tip of current VELO
- Danger of thermal runaway
- Si must be cooled down to \(-10^\circ\text{C}\)
The VELO PIXEL Detector System

ASIC IS AN ARRAY OF 256X256 SQUARE PIXELS (55 mm X 55 mm)
Velopix Sensor Choices

- 3 options being pursued:
  - Planar silicon n-in-p 150 mm thick (started studies of 150 mm thick p-in-n USC/CNM)
  - 3D silicon under investigation (Glasgow/CNM)
  - Diamond pCVD: advantages no thermal runaway, produced 1.43x1.43 cm² 750 mm thick sensors.
    - metallized with a large pad & measured collection distance using Sr⁹⁰ source
    - 1 sensor metallized with strips, test beam underway
    - Will produce pixel devices in the fall

preliminary
The VELOPIX ASIC

- Starting point TIMEPIX (imaging ASIC developed by the MEDIPIX collaboration)
- Studied in the test beam gave excellent spatial resolution (≈5 mm at 8°) still including 2.3 mm track prediction error. Red curve is with non-linear charge weighting correction.
- VELOPIX will be derived from TIMEPIX2 development (faster analog front end, simultaneous TOT & time of arrival measurement, faster output data rates)

Unique to VELOPIX: clustering of the sparsified information, data formatting and buffering, additional multi-Gbit output links for 40 MHz readout
Photon detector candidate MaPMT R7600 from Hamamatsu

Performance studies under way (pulse shape, timing)

New 40 MHz readout under development
A new hadron ID device: the TORCH

Modular design:

1 cm quartz at $z \approx 9.5$ m

Marina Artuso ICHEP 2010 7/24/10
Performance goals and requirements

Requirement: time resolution per photon
50 ps, not unreasonable, see work by P. Krizan Pos (PD07)021
Calorimeter & Muon system

- Currently trigger processor read out at 40 MHz
- Modifications to electronics needed:
  - Upgraded FE boards to read out all the detector information at 40 MHz
## Conclusion

- LHCb has a well developed plan and timeline for a staged upgrade (first step in \( \approx 2016 \))
- The upgrade strategy is SLHC independent
- We are poised for a long and exciting physics program

![New Collaborators are Welcome!]

### Upgraded Sensitivities (50 fb\(^{-1}\))

<table>
<thead>
<tr>
<th>Observable</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPV((B_s \to \phi\phi))</td>
<td>0.024</td>
</tr>
<tr>
<td>CPV((B_d \to \phi K_s))</td>
<td>0.027-0.064</td>
</tr>
<tr>
<td>CPV((B_s \to J/\psi\phi)) (2(\beta_s))</td>
<td>0.004</td>
</tr>
<tr>
<td>CPV((B_d \to J/\psi K_s)) (2(\beta))</td>
<td>0.004-0.014</td>
</tr>
<tr>
<td>CPV((B \to D K)) ((\gamma))</td>
<td>&lt;1.4(^{\circ})</td>
</tr>
<tr>
<td>CPV((B_s \to D_s K)) ((\gamma))</td>
<td>1.4-2.8(^{\circ})</td>
</tr>
<tr>
<td>(\varepsilon)((B_s \to \mu^+\mu^-))</td>
<td>(\sim 15%) of SM</td>
</tr>
<tr>
<td>(A_{FB}(B \to K^*\mu^+\mu^-))</td>
<td>Zero to (\pm 0.1) GeV(^2)</td>
</tr>
<tr>
<td>(\sigma(\sin 2\psi)(B_s \to \phi\gamma))</td>
<td>0.03</td>
</tr>
<tr>
<td>Charm mixing (x^{\text{12}})</td>
<td>(3 \times 10^{-5})</td>
</tr>
<tr>
<td>Charm mixing (y')</td>
<td>(4 \times 10^{-4})</td>
</tr>
<tr>
<td>Charm CP (y_{CP})</td>
<td>(2 \times 10^{-4})</td>
</tr>
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