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 $bb$ and $cc$ 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 $2 \times 10^{32}$ cm$^2$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]
Upgrade goals

- 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 (x≈2)

- Planned in 2 phase matching LHC schedule: phase I (nominal $L=1 \times 10^{33} \text{cm}^2\text{s}^{-1}$) and phase II (nominal $L=2 \times 10^{33} \text{cm}^2\text{s}^{-1}$)

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

At $L=2 \times 10^{32} \text{ cm}^2 \text{s}^{-1}$ [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 $L=10^{33} \text{ cm}^2 \text{s}^{-1}$ [phase I] the mean number of interactions per crossing is $\approx 2.3$ & 15% of the crossings are empty
- At $L=2 \times 10^{33} \text{ cm}^2 \text{s}^{-1}$ [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 I]
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
- **Muon detector**
- **Calorimeter**
- **Some electronics replacement for**

Diagram showing the layout and components of the LHCb 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$^{-1}$

radius (cm)

TID (MRad)

Particle occupancy per event (simulation)

Curves fitted to Ar$^{1.5}$

Luminosity (cm$^2$ s$^{-1}$)

- Current
- 5.10$^{32}$
- 10.10$^{32}$
- 20.10$^{32}$ Upgrade

A

0.98
1.46
2.46
4.80

Radius (cm)

n$_{eq}$ cm$^{-2}$ x 10$^{16}$

500
50
5

Danger of thermal runaway
Si must be cooled down to -10°C
The VELO PIXEL Detector System

ASIC IS AN ARRAY OF 256X256 SQUARE PIXELS (55 \( \mu \text{m} \times 55 \ \mu \text{m} \) )
Velopix Sensor Choices

- 3 options being pursued:
  - Planar silicon n-in-p 150 μm thick
    (started studies of 150 μm thick p-in-n USC/CNM)
  - 3D silicon under investigation
    (Glasgow/CNM)
  - Diamond pCVD: advantages no thermal runaway, produced 1.43x1.43 cm² 750 μm 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
The VELOPIX ASIC

- Starting point TIMEPIX (imaging ASIC developed by the MEDIPIX collaboration)
- Studied in the test beam gave excellent spatial resolution (≈5 μm at 8°) still including 2.3 μm 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
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 ≈2016)
- The upgrade strategy is SLHc independent
- We are poised for a long and exciting physics program

NEW COLLABORATORS ARE WELCOME!