First running scenarios including alignment and calibration

Gloria Corti
for the LHCb collaboration

Outline

- Global commissioning

- LHC startup scenario from the LHCb point of view
  - 450 GeV protons
  - 7 TeV protons

- First steps with beam
  - Time and space alignment
  - Systems and particle ID calibration

- Physics with first data

- Conclusions
Commissioning plans

- **Commissioning without beam in 2006-2007**
  - Commission each detector
    - can be done in parallel
  - Commission the global control and safety
  - Test the DAQ
  - Test the electronics calibration procedure
  - Check the scalability of the system, improve when needed

- **Commissioning with beam and collisions in 2007 and early 2008**
  - LHCb is a forward detector, only limited use of cosmics for some sub-detectors before installation
  - Beam gas in LHCb interaction region and halo from collimator system can give useful tracks for time and position alignment
    - Studies at 7 TeV ongoing, at 450 GeV starting

First CRack installed
3 in total

Muons from collimators without and with shield in tunnel
(Nominal LHC)
LHCb running scenario with 450 GeV protons

- **LHCb running condition in 2007**
  - LHC Beam operation with collisions at 450 GeV in Nov/Dec 2007
  - LHCb displaced interaction point requires shift of 4 out of 43 bunches or 24 out of 156 bunches to have collisions
  - Start with experimental dipole magnet off
  - L @ IP8 ~ 10^{27} cm^{-2} s^{-1} with
    - 40 Hz inelastic rate
    - up to 10^6 s of data

- **LHCb running program in 2007**
  - Full detector operation with beam
  - Establish running procedures
  - Time alignment
  - Space alignment with magnet OFF and ON
  - Commission VELO movement to his “stable beam” position of 5 mm distance from the beam
    - Beam stability and envelope studies with open VELO tracking

Display of test beam event (open VELO tracking)
LHCb running scenario with 7 GeV protons

- **LHCb running condition in 2008**
  - LHC commissioning for 7 TeV physics followed by operation period in 2008 from late spring/early summer
  - From collisions with 4/43 bunches to 25 ns bunch spacing
  - L @ IP8 from $4 \times 10^{27}$ cm$^{-2}$ s$^{-1}$ with 4/43 bunches to $1.2 \times 10^{32}$ cm$^{-2}$ s$^{-1}$ with 25 ns operation

- **LHCb running program in 2008**
  - Complete energy, momentum and particle ID calibrations
  - Complete trigger commissioning
  - Prepare for stable running operation
  - First physics results with collected data
  - Integrated luminosity of 0.5 fb$^{-1}$
First steps with beam: Time alignment

- Time alignment of whole detector in 2007 starting with circulating beam and continuing with collisions
  - Single interactions per bunch and no spill-over with 450 GeV proton beams

- Use Hadron Calorimeter trigger as interaction trigger
  - Commissioned without beam with LED
  - Collect all events

- Read all detectors together
  - Reasonable initial delays set during hardware commissioning
  - Readout of multi bunch crossing to set delays of various sub-detectors optimizing signal while minimizing amount of spill-over

- Muon system time alignment essential for L0-μ trigger commissioning
  - Electronics channels synchronized at the level of few ns with pulse system without beam
  - TDC histograms per logical channel filled in electronics
  - Studies in progress to use stand-alone tracking in Muon system
  - Investigating possibility to use MIP in Hadron Calorimeter to do Muon system independent timing
First steps with beam: Space alignment

- Start aligning the tracking detectors
  - Hardware surveyed to different precisions as needed
    - typically 0.3-0.5 mm level (VELO box 0.3mm)
  - Internally align the sub-detectors independently from each other using global minimization method
    - Millepede from V. Blobel
  - Relatively align each tracker sub-detector
  - Use clean tracks sample

- Magnet OFF data to separate magnetic field effects from geometrical ones
  - Use energy from calorimeter
The VELO alignment

- **VELO is the most critical system**
- **Very good mechanical accuracy**
  - Sensor on a same module measured to be positioned with \( \sim 10 \, \mu m \) accuracy
  - Module positioned within a box with \( \sim 20 \, \mu m \) accuracy
- **It is a moving detector**
  - Position reproducibility of \( 10 \, \mu m \)
  - Internal alignment monitoring / updating online vs. offline

- Implementation and misalignment studies well advanced
- Proven to work in Alignment Challenge and Detector Commissioning test beam in August using a 3 modules setup
  - Full system test from raw data to software
The VELO alignment

- **VELO is the most critical system**
- **Very good mechanical accuracy**
  - Sensor on a same module measured to be positioned with $\sim 10 \, \mu m$ accuracy
  - Module positioned within a box with $\sim 20 \, \mu m$ accuracy
- **It is a moving detector**
  - Position reproducibility of 10 $\mu m$
  - Internal alignment monitoring / updating online vs. offline

- Implementation and misalignment studies well advanced
- Proven to work in Alignment Challenge and Detector Commissioning test beam in August using a 3 modules setup
  - Full system test from raw data to software
Align the other detectors to the tracking system

- RICH is the most sensitive
  - Tracking component in Cherenkov angle resolution
- Calorimeters and Muon system positioned with ~ 1 mm precision
  - Calorimeter position resolution 1.5 mm in inner cells ($B \rightarrow K^*\gamma$)
  - Use electrons and hadrons for calorimeters and muons candidates for Muon system

Relative position of modules in both X and Y within ± 0.5 mm

Closing the two halves precision ~ 1mm
First steps with beam: momentum calibration

- Momentum resolution sensitive to both B-field inhomogeneities and misalignment
- Final map for both polarities measured in 2005
  - B known with < 0.03% uncertainty
    - affect momentum resolution < 10%
  - Regularly flip polarity during data taking
    - B-field reproducible within measurement accuracy

- Cross checks with mass resolution
  - $K_s$, $J/\Psi$, $Y$, $D \rightarrow K\pi$, $Z^0$
First steps with beam: energy calibration

- Energy calibration in ECAL with successive and alternative methods under study
  - Cosmic before installation has provided ~ 10% calibration
  - Studies with energy flow method show ~ few % calibration
  - Calibration with iterative procedure on resolved $\pi^0$ demonstrated at the level of 1% with sufficient statistic
    - Special calibration run $O(10\ \text{min})$ at normal luminosity for all areas of calorimeter
  - Start with 2007 data and complete early in 2008
First steps with beam: trigger

- **L0**
  - Hardware trigger based on high $E_T/P_T$ particles ($\mu$, e, h, $\pi^0$, $\gamma$)
  - Start L0 commissioning in 2007, 1MHz L0 output rate calibrated in 2008

- **HLT**
  - Software trigger based on high $E_T/P_T$ particles & high impact parameter particles & displaced vertices & B-mass ...
    - several trigger streams to refine L0, inclusive and exclusive selections
  - Start HLT commissioning in 2007 with tuning of online tracking, complete commissioning early 2008 to output rate of 2 kHz
    - $\sim$ 100 nodes in 2007 out of 1800 nodes for full system (as estimated with Real Time Trigger Challenge last year)
  - Built in redundancy allows for quick cross checks

For LHCb trigger see E. Rodrigues presentation
First steps with beam: particle ID

- RICH particle ID calibrated first via “basic” measurements with data then with D* events
  - Maps of pixel to photo-cathode position with light patterns on HPD planes to correct distortions due to fringe magnetic field
    - also for relative alignment
  - Saturated tracks without field provide functional calibration for basic Cherenkov angle resolution
  - Saturated tracks with field provide recalculation of refractive index
    - available from test beam
  - Different components to be aligned to each other and to Tracking system

\[ \Delta \theta = a \cos(\phi_{ch}) + b \sin(\phi_{ch}) \]

Mirror alignment with data

For each mirror combination
Preparing for physics with first data

- Demonstrated that $K/\pi$ Particle ID with $D^{*} \rightarrow D^{0} (K\pi)\pi$ events provide a Monte Carlo independent way to calibrate and study the performance of the RICH detector
  - ”Golden” kinematics – easy to suppress the background in order to obtain a clean sample
  - Inclusive HLT (~300 Hz) provides $D^{*}$ unbiased sample
  - See R. Muresan presentation for details

- Use $B^{+}/B^{0}$ control channels for tagging tuning
  - See H. Ruiz presentation for details

\[
\begin{array}{c|c|c|c|c|c|c|c|c|c}
0 & 0.14 & 0.145 & 0.15 & 0.155 \\
0 & 100 & 200 & 300 & 400 & 500 & 600 & 700 & 800
\end{array}
\]
LHCb physics program with very first data includes:

- **J/ψ** production studies
  - e.g. prompt vs. B → J/ψ cross section
    - \( \sigma(\text{J/ψ prompt}) = 0.313 \text{ mb} \)
    - \( \sigma(\text{J/ψ from B}) = 11 \text{ μb} \)
  - Unbiased sample in HLT inclusive dimuon stream
    - \( \sim 2.5 \times 10^8 \text{ J/ψ with 0.5 fb}^{-1} \)
    - LHCb will measure \( 2.0 < |\eta| < 5.3 \)
    - ATLAS/CMS will measure \( |\eta| < 2.5 \)
    - ALICE will measure \( |\eta| < 0.9 \) and \( 2.5 < |\eta| < 4 \)
  - Preliminary generator studies show
    - \( \sigma(\text{J/ψ prompt}) \sim 3 \text{ times lower with NRQCD models turned on in Pythia} \)
  - Even rough measurements will be interesting
LHCb physics program with very first data includes:

- $\sin(2\beta)$ with $B^0 \rightarrow J/\psi K_S$
  - As a proof of principle of CPV measurements
  - LHCb sensitivity is $\sigma_{\text{stat}}(\sin2\beta) \sim 0.04$ with 0.5 fb$^{-1}$

- $\phi_S$ and $\Delta\Gamma_S$ from $B_S \rightarrow J/\psi \phi$
  - Sensitivity (at $\Delta m_S = 17.5$ ps$^{-1}$) with 2 fb$^{-1}$
    - $\sigma_{\text{stat}}(\sin \phi_S) = 0.023$
    - $\sigma_{\text{stat}}(\Delta\Gamma_S/\Gamma_S) \sim 0.011$
  - LHCb will set limit or measure NP enhancement with first data

- $B_S \rightarrow \mu\mu$
  - BR $\sim 3.5 \times 10^{-9}$ in SM, can be strongly enhanced in SUSY
  - Current limit from Tevatron CDF+D0 with 1 fb$^{-1}$ is $\sim 7 \times 10^{-8}$ at 90% CL
    - Expected limit with 8 fb$^{-1}$ is $\sim 2 \times 10^{-8}$ at 90% CL
  - Very recent studies show LHCb can set exclusion limit at $1 \times 10^{-8}$ with $< 0.2$ fb$^{-1}$
Conclusions

- Commissioning strategy being prepared in details
- Strategy for calibrations, alignments, triggers and analysis tuning in view of current LHC startup schedule being devised
- Hardware commissioning in 2007 without beam
- Take advantage of machine engineering run in 2007 and commissioning period at 7 TeV in 2008 to be in stable physics operation at end of 2008
- Very interesting measurements already with the very first 0.5 fb⁻¹ in 2008