Calibration with data and expected performance and of LHCb Particle ID and Tracking

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On behalf of the LHCb collaboration

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Tracking detectors before the magnet

VELO is 88 silicon detectors with 8-42mm radius around the interaction point.

The Trigger tracker (TT) is four layers of silicon strip detectors covering 1.5 x 1.3m.
Tracking stations after the magnet

Outer tracker Straws extend to limit of the acceptance, the first layer is 2.6 x 2.2 m

Inner Tracker silicon strip detectors form a 120 x 40 cm cross around the beam pipe
Tracking performance

Typically pp collisions with reconstructable B events are quite busy

Reconstructed Trajectories and hits of a simulated event

- The VELO provides the precise vertex information
- The same track in the T stations provides the momentum
- TT improved the momentum measurement, finds tracks leaving the detector in the magnetic field and helps with Ks decays
- Acceptance is 250 (vertical) and 300 (horizontal) mrad

Efficiency
- For tracks crossing the whole detector and \( p > 10 \) GeV/c reconstruction efficiency \( \sim 94\% \)
- Rate of fake tracks (ghosts) is 9% but almost all have a low \( p_T \)
Expect to get around 20 to 40 microns track impact parameter resolution in the most probably $p_T$ region and a momentum resolution of 0.35%. Can be degraded by miss-alignment and uncertainties in the magnetic field. Alignment improved by using unbiased residuals on track measurements.
Calibrating LHCb’s Magnetic field

- VELO to T Station $\int B dl = 3.73$ Tm
- Both orientations (up and down) already mapped with Hall probes with a precision of 0.4%
- Improve the calibration by reconstructing decay masses

**Track types**
- Upstream track
- T track
- Long track
- Downstream track

**Magnetic field**

**Invariant Mass (MeV/c^2)**

- True $K_s \rightarrow \pi^+\pi^-$
- Reconstructed $K_s \rightarrow \pi^+\pi^-$
Two Ring Imaging Cherenkov Detectors (RICHes)
With a total of 3 radiator materials
Rings in the RICH detectors

View of a simulated event in RICH 1 HPD planes, rings around reconstructed tracks are found

Use three radiators to cover a wider momentum range.
Ring from a atmospheric muon

Rings in RICH 1 from an atmospheric muon
Taken Aug 26th
Taking the most likely particle combination gives the K/π separation.

Proton/Kaon separation from RICH detectors in $B_s \rightarrow D_s^-K^+$ events.
RICH PID calibration from data

- Use ability to select clean samples of particles with known decay decays from kinematics alone
  - Mass difference of $D^{*+}$ and $D^0$ allows clean sample of $K$ and $\pi$ tracks to be selected
  - Use $\Lambda$ and $K_s$ decays as sources of protons and pions
Particle ID effect on reconstructing B decays

Shows the improvement in the selection of $B^{\pm} \rightarrow D^{0}(K_{s}^{0}\pi^{+}\pi^{-})K^{\pm}$ decays when the particle identification of the bachelor hadron is included in the selection.
Calibrating the Muon particle ID

- Muons are identified by how straight the tracks are in the tracking and muon detectors
- Calibrate window sizes in the muon system
- Will collect samples of
  - unbiased muons $J/\psi \rightarrow \mu \mu$ $\sigma \sim 290 \mu b$
  - decaying particles $\Lambda \rightarrow p \pi$ $\sigma \sim 15 \text{mb}$
  - non-decaying $\Lambda \rightarrow p \pi$
- Use an inclusive $J/\psi \rightarrow \mu \mu$ selection with one triggered muon for signal muons for initial low luminosity calibration
- Use all $\Lambda$ from any triggers to make clean background samples

$J/\psi \rightarrow \mu \mu$ selection using tracking, calorimeter and 2nd layer of muon system only for one muon.

Record up to 240Hz output from this selection.
Electron Particle ID and energy correction

- Using the ECAL electrons can be identified by matching the associated track and ECAL cluster.
- Also the position of the cluster is compared to the track extrapolation.
- All of the information from calorimeters and RICHes are combined in an overall $-\Delta \log(\mathcal{L})$.

Bremsstrahlung correction is relatively easy as the radiation is all before or after the magnet.
Electron reconstruction and calibration

- Efficiency to identify electrons in \( B \rightarrow J/\psi(e^+e^-)K_s \) events is 95% with a 0.7% pion fake rate for tracks in the calorimeter acceptance.
- The majority of the backgrounds are at low \( p_T \) and can be removed.
- Even with the bremsstrahlung correction there is still a radiative tail.
- Use the \( J/\psi(e^+e^-) \) decays with a single tagged electron to calibrate the electron particle ID and bremsstrahlung correction.

\[ J/\psi \text{ reconstructed mass using all pairs of identified electrons in } B \rightarrow J/\psi(e^+e^-)K_s \text{ simulated events} \]
Efficiency for neutral pions is 40-60%.

Significant backgrounds from the hadronic environment.

Initial calibrations by correcting $\pi^0$ mass peak position.

LHCb will be the first hadron experiment to reconstruct $B$ decay with neutral hadrons.
Performance on B decays

- Proper time resolution for B decays is ~40 fs
- Mass resolutions:
  - \( B \rightarrow h^+h^- \) is 17 MeV/c^2,
  - \( B_s \rightarrow D_s \bar{s} K^\pm \) is 14 MeV/c^2,
  - \( B_d \rightarrow K^*\gamma \) is 64 MeV/c^2

In variant mass of \( \mu\mu KK \) \( B_s \rightarrow J/\psi(\mu\mu)\phi \) events width of 15 MeV/c^2
Conclusion

- LHCb is an optimised detector for B decays at the LHC
- Excellent tracking and particle identification mean we should have measurements of the B oscillations and asymmetries rather quickly
- We have the tools to trigger, reconstruct and calibrate the detector based on real data
- By this time next year all of the simulation based plots will have been replaced with measurements from data

- LHCb is also an excellent detector for other types of physics, for example all of the $J/\psi$ to $\mu^+\mu^-$ can be done with $Z$ to $\mu^+\mu^-$ decays