To calculate the B rest frame, the B momentum vector in the laboratory frame must point to the primary vertex. The B momentum vector in the laboratory frame is determined from the unit vector connecting the B decay point and the primary vertex. The module of this vector is equal to 
\[ \sqrt{\sum_{i} p_i^2} \]
where \( p_i \) are the momenta of the reconstructed final state particles.

**Motivation**

Lepton universality requires equal couplings between the gauge bosons and the three lepton families. No deviation of such behavior has yet been observed although some hints of lepton non-universality effects in \( B \rightarrow D^* \ell \nu \) and \( B \rightarrow K^* \ell \nu \) decays have been seen \([1]\). A large class of models that extend the Standard Model propose additional interactions involving enhanced couplings to the third family that would violate this principle. Semileptonic decays of b hadrons to \( \ell \) leptons provide a sensitive probe for these effects. The presence of additional charged Higgs bosons can have significant effect on the rate of \( B \rightarrow D^* \ell \nu \) \([2]\).

Ballar and Belle have recently reported updated measurements of the ratios \([3,4]\):

\[ \mathcal{R}(D^*) = \frac{B(B \rightarrow D^* \ell \nu)}{B(B \rightarrow D^\ell \nu)} \]

\[ \mathcal{R}(D) = \frac{B(B \rightarrow D \ell \nu)}{B(B \rightarrow D^\ell \nu)} \]

which show deviations from the Standard Model predictions as shown in the figure below.

Within the Standard Model, these ratios differ from unity mainly because of phase-space effects due to the difference in charged lepton masses. In this work we present the first measurement of \( \mathcal{R}(D^*) \) in hadron collisions at the LHC with data collected by LHCb in 2011 and 2012.

**The LHCb Detector**

The LHCb detector \([5]\) is a single-arm forward spectrometer covering the pseudo-rapidity range \( 2 < \eta < 5 \), designed for the study of b or c quarks. The detector includes a high-precision tracking system consisting of a silicon-strip vertex detector surrounding the pp interaction region, a 5,500 magnet. The tracking system provides a measurement of momentum, \( p \), of charged particles with a precision of up to 0.3\% in \( 3 < p < 100 \) GeV/c.

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**Trigger selection**

- no hardware trigger requirement of \( \mu p \) to preserve distinct kinematic distributions for the signal and normalization channels.
- one high \( p_T \) particle in the event independent of the \( D^* \mu \).
- software trigger: accept \( D^+ \rightarrow K^- \mu^+ \) with candidates satisfying \( p_T > 2 \) GeV/c.
- \( K^- \mu^+ \), \( p_T > 3 \) GeV/c at least one with \( p_T > 15 \) GeV/c.
- reconstructed mass consistent with the known \( D^0 \) mass.

**Offline Selection**

- well identified \( K^- \) and \( \mu^+ \) from \( D^0 \) decay.
- \( D^0 \) mass within 3 \( \sigma \) of measured value.
- \( D^0 \mu^+ \) form a vertex.
- \( \Delta m = m(D^{0 \text{rec}}) - m(D^{0}) \) within 2.5\% of the resolution.
- \( \mu \) well identified with \( 3 < p_T < 80 \) GeV/c forming a vertex with the \( D^0 \) and well separated from the primary vertex.
- \( D^0 \mu^+ \) should have invariant mass \( < 5280 \) MeV/c\(^2\) and their momentum vector must point to the primary vertex.
- \( MVA \) trained to select a sample coming from a b meson.

**Data Sample**

The data analysed in this work correspond to the integrated luminosity of 1.0 fb\(^{-1}\) and 2.0 fb\(^{-1}\) collected at proton-proton center-of-mass energies of 7 \( \mathrm{TeV} \) (2008) and 8 \( \mathrm{TeV} \) (2012) respectively. The signal channel \( B \rightarrow D^* \ell \nu \) with \( \ell \rightarrow \mu \) is used and the normalization channel \( B \rightarrow D \ell \nu \) produce identical visible states and are reconstructed by a common procedure.

**References**


5. LHCb collaboration, M. Gandelman, Miriam Gandelman on behalf of the LHCb Collaboration.