Measurement of the forward-central $b\bar{b}$ production asymmetry

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Introduction

CDF and D0 collaborations results suggests that the top-quark forward-backward production asymmetry is much larger than the Standard Model (SM) predictions. Measuring the $b\bar{b}$ asymmetry production would provide constraint on the flavor structure of any model that attempts to explain the CDF and D0 results.

A measurement of the forward-central (FC) $b\bar{b}$ production asymmetry is presented based on the LHCb data collected in 2011 at $\sqrt{s} = 7$ TeV corresponding to an integrated luminosity of 1.0 fb^{-1} using selected events that have two identified b jets, one of which is flavor tagged by one muon with high momentum. The FC asymmetry is defined as

$$A_{FC}^{b\bar{b}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

where $\Delta y = |y_b| - |y_{\bar{b}}|$ is the rapidity difference between b and $\bar{b}$. No SM precise prediction is evaluated but there is a consensus that at low $M_{b\bar{b}}$ gluon fusion dominates resulting in $O(0.1\%)$ asymmetry[1]. For $M_{b\bar{b}} > 100$ GeV the expected asymmetry is about $O(1\%)$ where the gluon fusion which has no asymmetry is less dominant at high mass.

Event Selection

Jets are reconstructed using the anti-kt algorithm with a radius parameter $R = 0.5$ [2]. Their energy are corrected for out-acceptance particles, calorimeter response, noise and pile-up. After corrections, the jet energy resolution is about $\sigma = (15 - 20)\%$. Jets are b-tagged using a boosted decision tree (BDT-based) trigger algorithm which is based on displaced secondary vertices (SV).

A $b\bar{b}$ event is selected by requiring two back-to-back ($\Delta\phi > 2.5$) b-tagged jets with $p_T > 15$ GeV. The jets are associated to the same primary vertex (PV) and at least one of the jets is flavor-tagged as b or $\bar{b}$.

The rapidity resolution is about 0.1 and the dilution of $A_{FC}^{b\bar{b}}$ due to this resolution is found to be negligible.

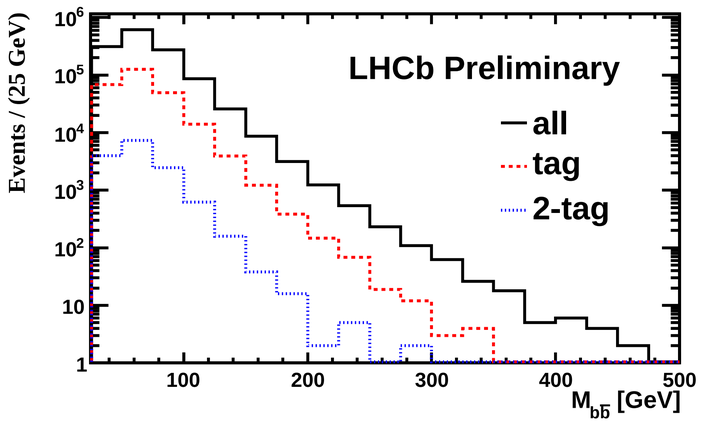

Figure 1: Di-jet $b\bar{b}$ mass ($M_{b\bar{b}}$) distribution obtained from the selected events. In total 1.3M $b\bar{b}$ events are selected. The (solid black) is for all events, (dashed red) for flavor-tagged events and (dotted blue) doubly-flavor-tagged events.

Flavor Tagging

To measure $A_{FC}^{b\bar{b}}$ with at least one b-jet, the most feasible way is muon tagging. The flavor tagging developed for this analysis only considers jets whose hardest displaced ($\chi^2_{IP} > 16$) track is identified as a muon. The charge of the muon is used to tag the b hadron from decay $b \to \mu\nu X$.

The tagging purity is estimated in a sample with one of the b quarks fully reconstructed using $B^+ \to J/\Psi K^+$ or $B^+ \to \bar{D}^0\pi^+$ decays.

Finally the lifetime of the b hadron is computed using the measured jet energy and the flight distance that includes a small correction factor determined from simulation.

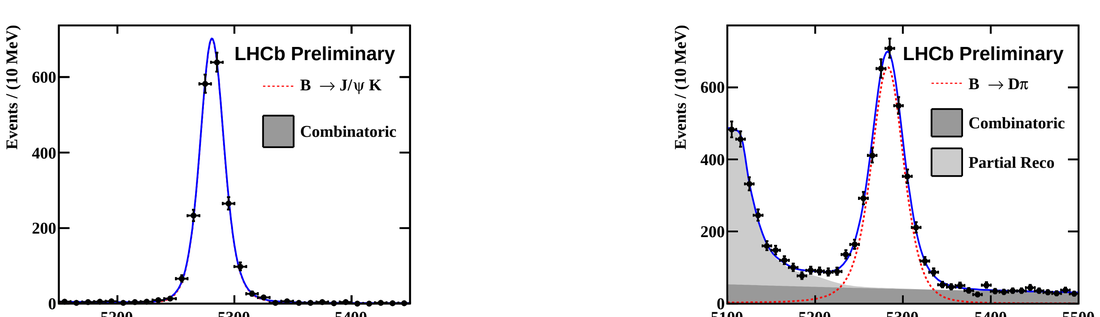

Figure 2: Distributed B candidates masses for (left) $B^+ \to J/\Psi K^+$ decays and $B^+ \to \bar{D}^0\pi^+$ decays used in the flavor-tagging study.

The tagging purity is measured in data using the doubly-tagged sample. The time integrated result obtained is $(70.7 \pm 0.4)\%$ which is used to scale the raw value of FC asymmetry by the mis-flavor-tag rate.

Tagging performance

Pseudo-lifetime distribution of tagged jets. The distribution from simulation contain no free parameters. We also present the observed and predicted time dependence of the tagging purity. The predicted value is not used in the measurement.

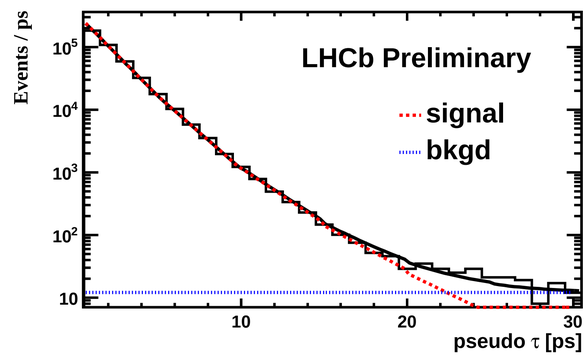

Figure 3: Observed (black solid) pseudo-lifetime distribution of flavor-tagged b jets. The signal shape (red dashed) is taken from simulation, while the background (blue dotted) is assumed to be uniform. The background is estimated to be $O(0.2\%)$.

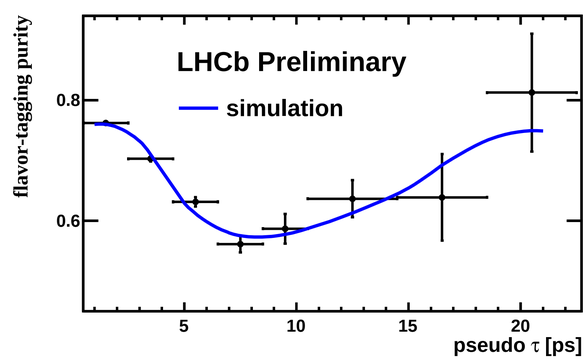

Figure 4: Observed time dependence of the tagging purity (black points). The (solid blue) curve is the predicted distribution obtained from simulation and has no free parameters.

Results

The bb forward central asymmetry is determined for all events and for those that have $M_{b\bar{b}} > 100$ MeV. The asymmetry is measured separately for the two polarities of the LHCb dipole magnet and the arithmetic mean is taken.

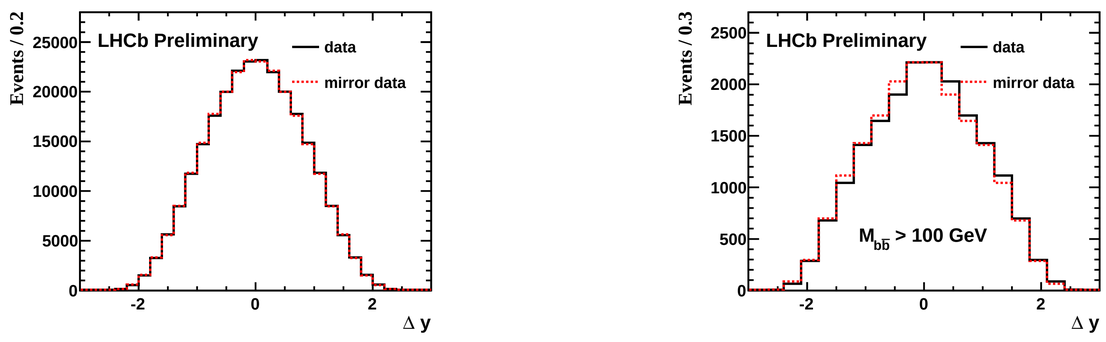

Figure 5: Observed Δy distributions for (left) all events and (right) just those with measured $M_{b\bar{b}} > 100$ GeV. The dashed distribution (mirror data) corresponds to $\Delta y \to -\Delta y$.

The measured and corrected values of the asymmetry by mis-flavor-tag rate is

$$A_{FC}^{b\bar{b}} = (0.5 \pm 0.5(stat) \pm 0.5(syst))\%,$$
$$A_{FC}^{b\bar{b}}(M_{b\bar{b}} > 100\mathrm{GeV}) = (4.3 \pm 1.7(stat) \pm 2.4(syst))\%$$

The systematic errors include the uncertainties on the flavor-tagging purity and a possible detector asymmetry.

Conclusion

The bb FC asymmetry has been measured using LHCb data collected in 2011 at $\sqrt{s} = 7$ TeV and corresponding to an integrated luminosity of 1.0fb^{-1}. No significant asymmetry is observed using the full mass range or using only di-jets events with measured $M_{b\bar{b}} > 100$ GeV, this results is consistent with SM estimates. The asymmetry in the high mass range is not corrected for the $b\bar{b}$ mass resolution. Ongoing studies to develop data-driven methods for these corrections.

Reference

The LHCb Collaboration.
Measurement of the forward-central $b\bar{b}$ production asymmetry.
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Measurement of jet production in $z^0/\gamma^* \to \mu^+\mu^-$ events at lhcb in $\sqrt{s} = 7$ tev pp collisions.
(LHCb-CONF-2012-016), Conference note, June 2012.

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