I. INTRODUCTION

Analyses by the CDF [11] and D0 [2] collaborations suggest that the top forward-backward asymmetry is much larger than predicted by the Standard Model (SM). This asymmetry, which essentially measures the extent to which the top in $t\bar{t}$ production has a preference to be aligned with the initial state quark (rather than antiquark) is only a few percent within the SM, yet has been measured to be $\mathcal{O}(10\%)$ in inclusive $t\bar{t}$ samples, and even $\mathcal{O}(40\%)$ at high $m_{t\bar{t}}$. The latest results from CDF further demonstrate that the large asymmetry manifests itself at the $3\sigma$ level in both the semi- and fully-leptonic $t\bar{t}$ decay channels, making naive systematic/statistical effects a less likely explanation for the effect. While recent results from D0 [2] disagree somewhat with those of CDF in several areas (most importantly in the behavior of $A_{FB}$ at large invariant mass), and the LHC has yet to observe evidence for any similar new-physics effects [8], this asymmetry remains one of the most compelling experimental anomalies.

Indeed, as the top asymmetry continues to resist a more conventional explanation, many models of new-physics have been put forth to explain the anomaly [4,5], see Ref. [6] for a review. These models typically introduce new heavy intermediate particles to generate the top asymmetry via interference with the SM, and differ principally in (1) whether they are $s$, $t$, or $u$-channel, (2) in the spin/color of the new degrees of freedom, and (3) in their couplings to the first and third generation quarks. While it is true that many of these models seem to be in tension with other measurements (especially the $t\bar{t}$ differential cross section and searches for same-sign tops at the LHC [7]), such considerations can be subtle [8,9] and various models may still be able to reproduce the $t\bar{t}$ asymmetry while maintaining consistency with other measured properties of the top. Thus, to make progress in understanding the origin of the top asymmetry it is helpful to keep an open mind toward new models and subject them to further experimental scrutiny. Many analyses have already been proposed with this aim, including an LHC measurement of the top-quark forward-central asymmetry [10], studies making use of the polarization/spin-correlation in the $t\bar{t}$ system [11], and more specialized analysis designed to look for the signatures of particular models [12].

Since the flavor structure of the various models differs widely, it is important to measure similar asymmetries for other quarks. To wit, if the asymmetry in $t\bar{t}$ is indeed due to the effects of new physics, then one must ask if these only apply to the top-sector, or if they affect the entire third generation of fermions. Models of $t/u$-channel physics, for example, tend to affect only the right-handed top (or, in some cases, the entire up-type sector), using a flavor off-diagonal interaction to couple it to a first generation $u$ or $d$. In contrast, the simplest axigluon models couple new-physics with opposite signs to the left and right handed tops, and so necessarily include new couplings to the bottom sector.

It has been pointed out recently [4,13] that the data sets at the Tevatron are large enough to allow interesting measurements of the forward-backward asymmetries of both bottom and charm quarks in the same kinematic regime in which the top asymmetry is observed by CDF. This can be done with a dijet sample, using the charge asymmetries of muons embedded in high-$p_T$ jets. The muon charge asymmetry is correlated with the charge asymmetries of the main sources of muons, namely $c$ and $b$ quark decays. The forward-backward asymmetry prior to heavy-flavor tagging is dominated [13] by a combination of the $cc$ and $bb$ asymmetry, and separating bottom
from charm can be done using heavy-flavor tagging and kinematics. This analysis could help discern the different signatures of the various classes of models, especially when used in concert with some of the other tools referenced above.

In the current paper we consider a similar measurement at the LHC. We will limit ourselves to the bottom quark asymmetry. This is because the dilution of the asymmetries from symmetric backgrounds is much larger at the LHC than at the Tevatron, making charm asymmetries extremely difficult to detect.

Clearly, in contrast to the Tevatron and its beams of opposite charge, one cannot as simply measure a forward-backward asymmetry at a parity-symmetric collider like the LHC, whose beams are both of protons. But one can instead make use of the fact that in quark-antiquark collisions in a proton-proton machine, the motion of the parton center-of-mass frame relative to the lab frame is correlated with the direction of the incoming quark. Thus one may define a “forward-central” asymmetry, looking at whether one may define a "forward-central" asymmetry, looking at whether the parent parton center-of-mass frame relative to the lab frame is correlated with the direction of the incoming quark. Thus one may define a “forward-central” asymmetry, looking at whether the parent

As in [13], following [13], we will use the charge of a muon embedded in a jet to determine whether the parent of the jet is more likely to be a $b$ or a $\bar{b}$. The muon also provides us with an object for triggering. We will also use $b$ tagging and kinematic cuts to reduce backgrounds. As we will see, the measurement is difficult, although potentially feasible. For an underlying asymmetry of the size needed to explain the CDF $t\bar{t}$ anomaly, we are only able to obtain an observable asymmetry of order 2% or less, which is several times smaller than the corresponding forward-backward asymmetry at the Tevatron, yet we expect such an asymmetry to be visible above the 2$\sigma$ level in 10 fb$^{-1}$. We note that an asymmetry of the size expected in the Standard Model should be unobservable for the foreseeable future. The Tevatron data set may well be an easier place to make the measurement. However, we have certainly not exhausted all the options for improving the signal-to-background ratio at the LHC, and we feel our result should be viewed as encouraging, though in need of improvement by more sophisticated means.

This paper is structured as follows. In Sec. II we define the forward-central asymmetry carefully. Later, in Sec. III we will describe a set of cuts designed to optimize the discriminating power of this quantity in the kinematic region relevant for the top asymmetry. We emphasize that the signal region lies precariously close to the trigger thresholds, and some consideration of trigger strategy must be made in the near future if one is to ensure that the data relevant for this measurement is actually recorded. Introducing a signal comparable to that observed at the Tevatron (using a conservative axigluon toy model) we will show that a 7 TeV LHC can resolve an asymmetry in $b$-quark production at more than 2$\sigma$ in 10 fb$^{-1}$. While this level of statistical significance is not sufficient to claim the discovery of new phenomena, it would provide helpful model-building input, allowing ATLAS and CMS data to restrict the set of models which have been put forward to explain the $t\bar{t}$ anomaly. We comment on various experimentally relevant issues and the prospects for an LHCb measurement of the asymmetry in Sec. IV. We conclude in Sec. V.

II. OBSERVABLE

There are two natural forward-backward asymmetries to consider at a proton-antiproton machine, as applied to $bb$ production. The first is to define forward and backward in the lab frame

$$A_{FB}^{bb,lab} = \frac{N(qy > 0) - N(qy < 0)}{N(qy > 0) + N(qy < 0)},$$

where $q = 1 \ (-1)$ for the $b$ ($\bar{b}$) that generates the jet containing the observed muon, and $y$ is its rapidity.

Here $y \rightarrow +\infty \ (-\infty)$ is the direction of motion of the proton (antiproton). But the event-by-event boost of the hard-scattering system tends to wash out this variable, so it is better to consider forward and backward defined in the hard-scattering rest frame

$$A_{FB}^{bb} = \frac{N(q\Delta y > 0) - N(q\Delta y < 0)}{N(q\Delta y > 0) + N(q\Delta y < 0)},$$

where $\Delta y$ is the signed rapidity difference between the $b$ and the $\bar{b}$ (i.e., the rapidity difference between the two jets signed by the muon charge.)

At a proton-proton machine such as the LHC, symmetric under $y \rightarrow -y$, these forward-backward asymmetries will necessarily be zero. Instead we must turn to a forward-central asymmetry, which we define as:

$$A_{FC}^{bb} = \frac{N(q\Delta|y| > 0) - N(q\Delta|y| < 0)}{N(q\Delta|y| > 0) + N(q\Delta|y| < 0)},$$

where now $\Delta|y| = |y(b)| - |y(\bar{b})|$ is defined as the rapidity difference between the rapidity of the $b$ and the $\bar{b}$.

1 With an asymmetry comparable to that seen in $t\bar{t}$ samples, the observed raw asymmetry prior to heavy-flavor tagging would be of order 2–3% at the Tevatron [13]. But at the LHC it would be a factor of 10 smaller, presumably too low for beating systematic errors. Only with heavy-flavor tagging can the observed asymmetries at the LHC reach the percent level and above, but tagging removes most of the charm sample, leaving sensitivity only to $bb$ physics.

2 One could construct a similar analysis employing pseudo-rapidity ($\eta$) instead of rapidity($y$). As we are considering objects for which $m \ll p_T$, the results obtained would be largely the same.

3 We note that a differential distribution of the asymmetry, e.g. $dA_{FC}^{bb}/d\Delta|y|$ or $dA_{FB}^{bb}/dy_{jj}$ (see Eq. 2) may provide an even more powerful discriminant, although for simplicity we will not consider these here.
**JETS:** We require at least two jets with \(|y(j)| < 2.4\), and further demand \(p_T(j_1) > 150\) GeV and \(p_T(j_2) > 100\) GeV.

**Selection cuts**
- **Muon:** There must be a \(\mu\) close to \(j_1\) or \(j_2\) satisfying \(\Delta R(j, \mu) < 1\), \(p_T(\mu) > 25\) GeV, and \(|y(\mu)| < 2.4\).
- **Flavor tag:** Finally, we require that the jet without the nearby muon is \(b\)-tagged.

**Forward cut:** \(|\frac{y(j_1) + y(j_2)}{2}| > 0.5\)

**Mass cut:** \(m(j_1 + j_2) > 450\) GeV

| \(\nu\nu\rightarrow q\bar{q}g\) initiated scattering process in a **pp** system, the direction of the boost of the hard-scattering system along the beam direction will tend to reflect the direction of the initial state quark. This effect is illustrated in Fig. 3.

It is instructive to consider the behavior of Eqs. 2 and 3 under various reflection symmetries to determine their susceptibility to shifts from experimental errors. The forward-backward asymmetry measured at the Tevatron, for instance, flips sign \((A_{FB}^b \rightarrow -A_{FB}^b)\) if either \(y \rightarrow -y\) or \(q \rightarrow -q\). This tells us if there were no asymmetry to begin with, one would not be induced via a distortion in the efficiency to measure one charge over the other as long as both sides of the detector saw the same distortion. That is, the only way to find a spuriously non-zero value in \(A_{FB}^b\) would be to introduce a distortion in the charge efficiencies which was not invariant under \(y \rightarrow -y\). The situation at the LHC is more subtle as \(A_{FB}^b\) under \(y \rightarrow -y\), but one still has \(A_{FB}^b \rightarrow -A_{FB}^b\) under \(q \rightarrow -q\), which tells us that to the extent the detection efficiencies for muons and antimuons are equal, at any given rapidity, it is still the case that no asymmetry can be generated if none exists. We therefore emphasize that while every effort should be made to correct for detector and trigger effects to obtain a reliable measurement, the forward-central asymmetry of Eq. 3 is fairly robust against systematic shifts from rapidity-dependent efficiencies.

Of course, the asymmetry (or limit on an asymmetry) observed in data must be converted into an asymmetry (or limit) in the underlying **q\bar{q} → b\bar{b}** process. This translation will require careful modeling of the muon efficiency as a function of \(y\). But this last is also true for the Tevatron measurement, which involves an integral over \(y\), so there too one must account for the \(y\)-dependent detection efficiencies.

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**TABLE I. Cuts used to select events and to increase the signal size.** We denote the \(i\)-th hardest jet as \(j_i\). The effect of the cuts can be seen in Table II.

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**FIG. 1.** The fractional \(p_T\) carried by a muon produced from the hadrons of a \(b\)-jet with \(p_T > 150\) GeV where we have distinguished right-sign muons (\(b/\bar{b} \leftrightarrow \mu^-/\mu^+\)) from wrong-sign muons (\(b/\bar{b} \leftrightarrow \mu^+/\mu^-\)).

**III. LHC ANALYSIS**

As in [10][1], our strategy is to consider dijet events in which one of the two leading jets has an embedded muon, and to use the muon’s charge as an approximate surrogate for the charge of the parent \(b\) quark [14]. The resulting forward-central asymmetry in charged non-isolated muons is diluted by many effects, to be discussed below, but its value does correlate with the forward-central asymmetry in **q\bar{q} → b\bar{b}** events we wish to measure.

Let us first define our event sample. We will assume that a trigger exists that can easily accommodate a single non-isolated muon of 25 GeV within an event with at least one jet of 150 GeV and \(H_T\) of at least 250 GeV[4]. We will see this accords with the requirements of the measurement. Significantly higher thresholds might put the measurement out of reach. Within this sample we demand the jets be di-jet-like[4] and veto events with an isolated lepton.

To put ourselves in the same mass region as is probed by the measurements of the **tt** asymmetry, we will focus on dijet events where the hardest jet’s \(p_T\) is greater than 150 GeV and the second hardest’s is greater than 100 GeV. As we will later demand a muon in one jet and a

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4 We note that the cross section for events passing this particular trigger stream is roughly 1 nb at a 7 TeV LHC, and so could be easily accommodated in \(\mathcal{L} \sim 10^{33}\) cm\(^{-2}\) s\(^{-1}\) running.

5 Events that differ strongly from dijet structure — for instance, those in which the two leading jets are not fairly back-to-back or have MET that does not point roughly in the direction of one of the leading jets — should be vetoed. However these vetoes should be loose and chosen with some care to avoid making theoretical calculations of backgrounds unstable.
FIG. 2. The transverse decay length of the secondary vertex which gives rise to the muon. Here we have required $b$-jets with $p_T > 150$ GeV and $p_T(\mu) > 25$ GeV.

b-tag on the other, we require that both jets lie within $|y| < 2.4$ so they are within the tracking system. Later we will see that an additional cut requiring $m_{jj} > 450$ GeV will help us to further increase the signal to background ratio, although it will not help increase the statistical significance of the results.

The charge of the muon does not provide a fully reliable measure of the initiating quark’s charge, due to a combination of effects. The largest of these, at least when the muon carries a low fraction of the jet’s $p_T$, comes from the decay of a $b$-quark into a $c$, whose subsequent decay produces a wrong-signed muon. Another cause of wrong signed events is from neutral $B$-meson oscillations which switch constituent $b$’s to $\bar{b}$’s, and vice versa. To reduce the concentration of wrong-signed events, it is helpful, for jets with $p_T$ of order 150 GeV, to take the muon inside the jet to have $p_T$ above 25 GeV. This is illustrated in Fig. 1 where we show the relative fraction of the jet $p_T$ carried by the muon for $b$-jets with $p_T > 150$ GeV. As emphasized above, we are assuming here that 25 GeV is compatible with an available trigger pathway. This assumption appears to be correct at current luminosities but may not necessarily remain so throughout the 2011-2012 run.

Only a fraction of the selected events will contain a $b\bar{b}$ final state, with other contributions from $c\bar{c}$ pairs, gluons that split to heavy flavor, and events with a single $b$ or $c$. We significantly reduce the unwanted contributions by demanding that among the two hardest jets, the jet that does not contain the muon is $b$-tagged. This is our “initial selection”. Already, as we will see, there is sensitivity to an asymmetry comparable to that seen in the $t\bar{t}$ system. But the initial sample is not very pure, and the observed asymmetry would be very small, less than one percent. To increase the size of the observed asymmetry, with limited effect on the sensitivity, we impose additional cuts.

In our initial selection sample, the symmetric process $gg \rightarrow b\bar{b}$ dominates over the process we hope to probe: $qq \rightarrow b\bar{b}$. We can attempt to mitigate this dilution by using the fact that, at fixed $H_T$, the partonic center-of-mass frame in $gg$ events tends to be at lower $|y|$ than in $qq$ events. We define the average rapidity of the dijet system to be

$$y_{jj} = \frac{y(j_1) + y(j_2)}{2}$$

(4)

and apply a cut $|y_{jj}| > y_{\text{min}} = 0.5$ requiring that the system be relatively forward. The effects of such a cut can be seen in Fig. 3 where we show how such a cut increases the relative contribution of ‘right-orientation’ $qq \rightarrow b\bar{b}$ events — ones where the quark is moving in the same center-of-mass direction as the lab-frame $b\bar{b}$ system — while decreasing both the symmetric ($gg \rightarrow b\bar{b}$) and ‘wrong-orientation’ $qq \rightarrow b\bar{b}$ (where the anti-quark moves in the same direction as the scattering system) backgrounds. For the sake of simplicity we will only employ a sharp cut on $|y_{jj}|$, but a more powerful analysis could make use of a continuous discriminant to achieve a higher significance.

Furthermore, as we wish to measure the extent to which any new physics giving rise to the top asymmetry might be affecting the bottom sector, the best place to look for it is probably in the same kinematic region where the top anomaly is observed by CDF, namely at $t\bar{t}$ invariant mass above 450 GeV. We will therefore focus on events with a similar requirement that $m_{jj} > 450$ GeV. (Recent results from D0 might lead one to rethink this step, but in any case, as we will see, this cut is useful but not essential.) This also reduces backgrounds more than signal.

Our cuts are summarized in Table I. To quantify our results we introduce an asymmetric $b\bar{b}$ signal that is comparable, in the appropriate invariant-mass range, to that seen in $t\bar{t}$ at the Tevatron. We do this in a way that we believe is conservative. In particular, we use a toy model similar to the minimal two site axigluon model described in Ref. [4]. We choose the axigluon mass to be $M_{G'} = 1041$ GeV and the width to be $\Gamma(G') = 200$ GeV; we set its vector-like coupling to zero, and set its axial coupling equal in strength to the QCD coupling. Using these parameters we find a rest-frame parton-level asymmetry in acceptable agreement with that observed in the

$^6$ Tagging the jet containing the muon would not assist, since the relatively hard non-isolated muon is already indicative of a $b$ jet. However, see the discussion section below.

$^7$ The sign of the coupling of the axial gluon to the first generation is opposite to that of the coupling to the third generation.
of the center-of-mass as measured in the laboratory, while for the \( \bar{q}q \) state the anti-quark moves in the direction of the antitag.

Our background shift in our results. The other processes which constitute this to be subdominant compared to the new-physics effects.

Our parton-level \( gg \) analysis tools: we use these generators are used with their default PDF distributions: CTEQ [17] 6L1 and 5L, respectively. Our calculations ignore the next to leading-order asymmetry in b-production present in the SM, although we expect this to be subdominant compared to the new-physics effects we consider, and would at most yield a small linear shift in our results. The other processes which contribute to the non-tag rate. However, the rate for this process, before accounting for the efficiency of a c to fake a b, is roughly twice the rate for \( gg \to bb \) (again, before tagging efficiencies). Finally, the raw rate for processes yielding a muon in one jet but no c/b-hadrons in the other is usually ten to twenty times the rate for \( gg \to bb \) production, but once one applies the 0.3% efficiency for light QCD to fake a b-jet, this process makes the smallest contribution of those considered.

Now, since many of our jets are at high \( p_T \) and high \( y \), this may be a low estimate on the light QCD mistag rate.

The rate is so small that our result is not very sensitive to the mistag rate, which could be as large as a few percent without having a qualitative impact on our conclusions.

Our results showing the behavior of \( A_{bb}^{b\bar{b}} \), as various cuts are imposed are presented in Table [11]. Beginning with the initial selection cuts we first apply a cut on \( y_{jj} \) which increases the observed asymmetry by \( \sim 50\% \), and next apply a cut on \( m_{jj} \) to increase the observed asymmetry by another \( \sim 80\% \). While both of these cuts have a minimal impact on the statistical significance of the measured asymmetry, the increase in its absolute size is

8 From Ref. [13] we estimate that the asymmetry in b production at the Tevatron is \( \mathcal{O}(6\%) \) at high energies, to be compared to the \( \mathcal{O}(30\%) \) one might expect from new-physics effects.

9 The backgrounds for our study, aside from the symmetric \( gg \to bb \) process which we generate with Madgraph, include process with light-jets, processes with charm jets, gluon-splitting processes (e.g. \( g \to bb \)) and flavor-excitation processes (\( bx \to bx \)).

10 More precisely, we scan inside a jet for a b- or c-containing hadron, and tag with the above efficiencies if one is found.
comforting as it reduces the impact of systematic errors. A sensitivity of more than 2σ is possible with about 10 fb⁻¹ at 7 TeV.

### IV. DISCUSSION

Let us first make a brief theoretical comment before turning to the more serious experimental issues. In presenting the estimates of the previous section we have aimed to remain relatively conservative. Our toy model yields a somewhat small asymmetry compared to the CDF results, and if new physics is indeed present it may generate larger effects than we considered and would therefore manifest itself sooner. We have not accounted properly for K factors, but they tend to be larger than 1 for QCD di-jet processes. Accounting for them is unlikely to change the signal-to-background ratio very much though the statistical significance we found may slightly improve (though admittedly the improvement is likely to be cancelled by experimental inefficiencies.) We have no reason to expect unusually large K factors given that we have not introduced restrictive cuts on phase space. Also we should emphasize that a change in the relative rates of the different contributing processes will not induce a new source of asymmetry.

We believe that dominant sources of theoretical uncertainty affecting the analysis we propose are probably the uncertainties on (a) the values of the NLO K-factors, which will affect all of the production rates, (b) the gluon, c, and b PDFs, which are important in the backgrounds, and (c) the process of gluon splitting to c and b within a jet, which is also important for the backgrounds. The uncertainty on the Standard Model prediction for A_{FC}^{b\bar{b}} is likely unimportant. We further note that there are a number of data-driven handles that might be useful for determining backgrounds, including observables such as (a) the probability for a jet to contain two b-tags or multiple muons (both same- and opposite-sign), (b) the embedded muon p_T and k_T spectra (where k_T is measured with respect to the jet axis), and (c) tracking/vertexing information on b/c hadrons within jets.

A serious concern that we cannot address here involves the trigger. It is not clear to us that the cuts required for the analysis are compatible with the triggers that will be used in accumulating 10 fb⁻¹ of data. Again, the ingredients of the analysis are simple: a dijet event with the leading (sub-leading) jet carrying 150 (100) GeV of p_T, one of the two jets containing a muon with 25 GeV of p_T and the other b-tagged. A non-isolated-muon-plus-H_T trigger might be a suitable pathway, perhaps supplemented at higher trigger levels by requiring at least one of the two jets to contain displaced tracks. Requiring the muon track in particular to be slightly displaced is another possibility, but comes at the high cost of reduced statistics and possible challenges for trigger-acceptance determination. We must leave these important details to our experimental colleagues.

There is potentially additional room for the experiments to improve upon the analysis we have presented. The most obvious step would be to include electronic decays in addition to the muons used here, but since electrons come with a higher trigger threshold it is not clear this would add much sensitivity. Another potential source of improvement could come from using the displacement distance of displaced vertices to reduce the dilution of the underlying asymmetry from neutral meson oscillations. If the ATLAS or CMS vertexing systems could with sufficiently high efficiency measure the displacement of the secondary vertex which produces the mu, this would allow separation of samples in which the B meson has had time to oscillate (i.e. samples with a large displacement) from samples in which the decay time is short compared to the oscillation period. These samples would have different dilution factors and could be weighted differently to improve sensitivity. While we have not investigated such advanced techniques in our analysis, we present in Fig. 2 a comparison of the transverse decay length for different sources of the muon, illustrating this effect.

Finally, we comment that while our analysis was designed with one of the LHC’s all-purpose detectors in mind (i.e. ATLAS and CMS), it is worthwhile to consider the reach of LHCb as we are interested in a precision measurement of b-jets in the forward region. The main distinguishing feature of LHCb is its precision tracker and vertexing system, which allows for a precise reconstruction of hadron level decays. If this could be used to probe the decays of the b-hadrons then it could allow for a substantial reduction in the wrong-sign μ backgrounds and may open up other channels for use in signing the

\[ \sigma_{q\bar{q} \rightarrow b\bar{b}} \]  
\[ \sigma_{g\rightarrow b\bar{b}} \]  
\[ \sigma_{g\rightarrow c\bar{c}} \]  

\[ \sigma_{\text{total}} \]

| Selection | $y_{jj} > 1/2$ | $m_{jj} > 450$ |
|-----------|----------------|----------------|
| $\sigma_{q\bar{q} \rightarrow b\bar{b}}$ (pb) | 1.1 | 0.9 | 0.3 |
| $\sigma_{g\rightarrow b\bar{b}}$ (pb) | 0.3 | 0.1 | 0.0 |
| $\sigma_{g\rightarrow c\bar{c}}$ (pb) | 7.1 | 4.0 | 0.9 |
| other background | 10.0 | 5.7 | 1.6 |
| $\sigma_{\text{total}}$ (pb) | 18.6 | 10.7 | 2.7 |
| $A_{FC}^{b\bar{b}}$ (%) | 2.5 | 2.8 | 2.6 |
| significance ($\sigma$) | |

TABLE II. The rates of various contributing processes, the forward-central asymmetry and and the statistical significance after selection, rapidity and invariant mass cuts (the cuts are presented in Table I). We denote by $q\bar{q} \rightarrow b\bar{b}$ the ‘right-orientation’ $q\bar{q}$ initial state, and by $q\bar{q} \rightarrow b\bar{b}$ the ‘wrong-orientation’ state. Our ‘other background’ contribution includes processes of flavor excitation and gluon splitting, as well as fake b’s from charm and light flavor. The results account for a tagging efficiency of 50%/10%/0.3% for b/c/light-flavor jets. The significance is measured as $1/\sqrt{N}$ assuming $\mathcal{L} = 10$ fb⁻¹.
b. However, such a measurement would be challenging as the rates for \( \bar{b}b \) production become quite small once both \( b \)s lie in the forward region. At parton level we find the \( \bar{b}b \) rate to be \( \sim 0.5 \) pb, yielding an asymmetry of \( \sim 3\% \) when requiring only \( p_T(b/\bar{b}) > 150 \) GeV and \( 2 < y(b/\bar{b}) < 5 \) (the rapidity range for LHCb), with the rate dropping precipitously as cuts on \( m_{jj} \) are further applied. Further challenges may also come from employing LHCb to study high-\( p_T \) jets that we require, as the detector was primarily designed to study softer objects in a relatively clean environment.

The situation changes somewhat at a 14 TeV LHC, where the parton level rate for \( \bar{b}b \) production subject to the above cuts rises to 12 pb, yielding an asymmetry of \( \sim 5\% \) before accounting for other sources of background (i.e., gluon splitting, flavor excitation, and \( b \)-fakes). Here LHCb might be able to measure the asymmetry in \( b \)-production, although to properly evaluate its potential one would need to perform a more detailed study of its capabilities than we would feel comfortable making. We therefore feel that although it appears that such a measurement would be quite difficult, a more detailed study of LHCb’s reach in this channel is probably warranted.

\section{Conclusions}

The CDF and D0 collaborations have both observed an anomalously large asymmetry in \( tt \) production. While some discrepancies between the two experiments remain to be resolved, the evidence for a large asymmetry seems robust, and if the excess is due to SM effects they must be quite subtle. Many beyond the SM explanations have been put forward to explain the asymmetry, offering various treatments of the many potential quark couplings to new-physics. Previously, Refs. \[4\]\[13\] proposed that Tevatron data at CDF and D0 could be used to probe these interactions for bottom and charm quarks. Here we have argued that, through a forward-central asymmetry, the CMS and ATLAS experiments at the LHC are sensitive in the immediate future to whether new-physics interactions generating the asymmetry in \( tt \) production also affect the bottom quark.

Our results indicate that, with around 17 fb\(^{-1}\) of 7 TeV LHC data, the general purpose LHC detectors can probe such new interactions with a sensitivity greater than 2\( \sigma \). While less sensitive than a Tevatron search with the same amount of data, and while insufficient to discover new physics, such a measurement would still provide useful model-building guidance. However, whether this is feasible depends crucially upon whether the selection cuts required for the measurement are compatible with the trigger menu for the corresponding integrated luminosity. Given the importance of determining whether there are unexpected asymmetries affecting bottom quark production, we hope that the ATLAS and CMS experiments will investigate this issue carefully, and consider adjusting trigger thresholds if adjustments are indeed necessary.

\section*{Acknowledgments}

We would like to thank Gustaaf Brooijmans, Valerie Halyo, David E. Kaplan, Sal Rappoccio, Matt Schwartz, and Sheldon Stone for helpful discussions. D. Kahawala is supported by the General Sir John Monash Award. D. Krohn is supported by a Simons postdoctoral fellowship and by an LHC-TI travel grant. M.J.S. is supported by NSF grant PHY-0904069 and by DOE grant DE-FG02-96ER40959.

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