Charge Asymmetry in beauty dijet production at the LHCb detector

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Overview

- Working towards a measurement of the charge asymmetry in beauty dijet production at LHCb, this is defined as:

$$A^{b\bar{b}} = \frac{N(\Delta\eta > 0) - N(\Delta\eta < 0)}{N(\Delta\eta > 0) + N(\Delta\eta < 0)}.$$

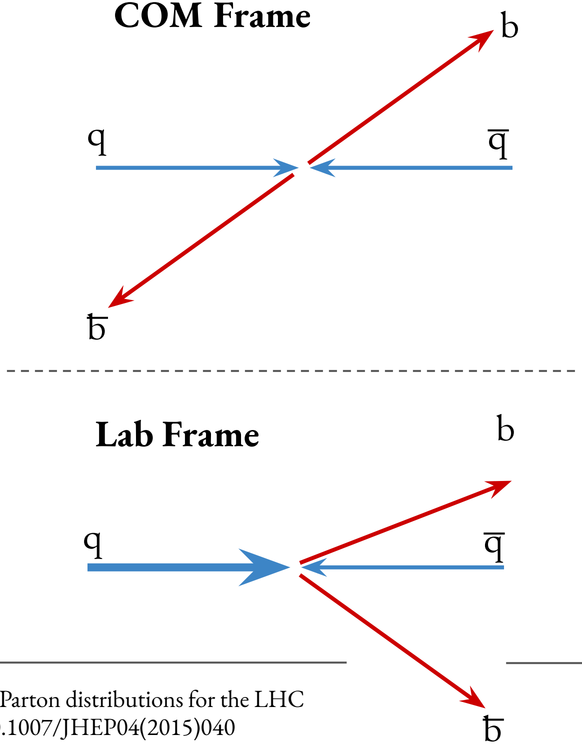
- $\Delta\eta = \eta_{\mathrm{b}} - \eta_{\bar{\mathrm{b}}}$ is difference in pseudorapidities of jets containing the b and $\bar{\mathrm{b}}$, N is the number of events
- Leading order (LO) contribution to the asymmetry from production via: $q\bar{q} \rightarrow Z \rightarrow b\bar{b}$
- Measurement will be provided in bins of the invariant mass of the dijet system

Motivation

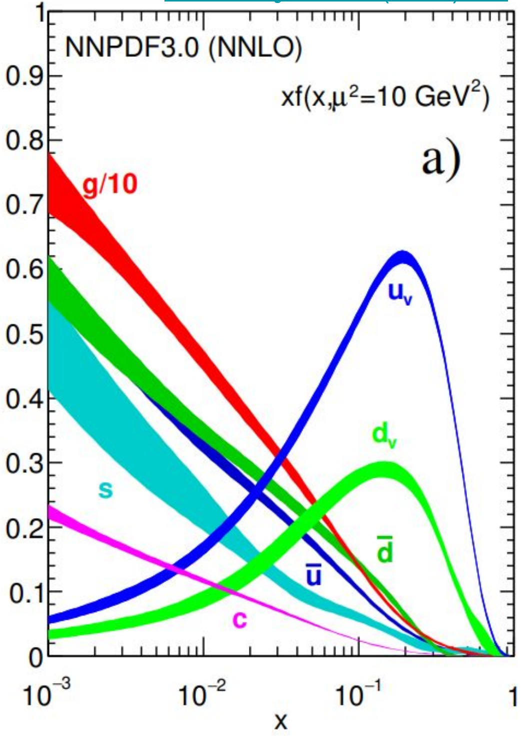
- New physics models can modify effective Zbb coupling, probed by asymmetry measurement
- Measurement at LEP showed a 2.8σ deviation from the SM
- Previous LHCb measurement in 2014: 1fb^{-1} , at 7 TeV, three dijet mass bins, statistically limited. Consistent with the SM but had larger uncertainties than LEP
- New measurement: 6fb^{-1}, at 13TeV, roughly 10× more $b\bar{b}$ events for asymmetry measurement

Why measure this at LHCb?

- Different production modes to those at LEP, important to add further information
- For symmetric proton-proton collision asymmetry would cancel at zero pseudorapidity, need to look in forward region to measure asymmetry



10.1007/JHEP04(2015)040

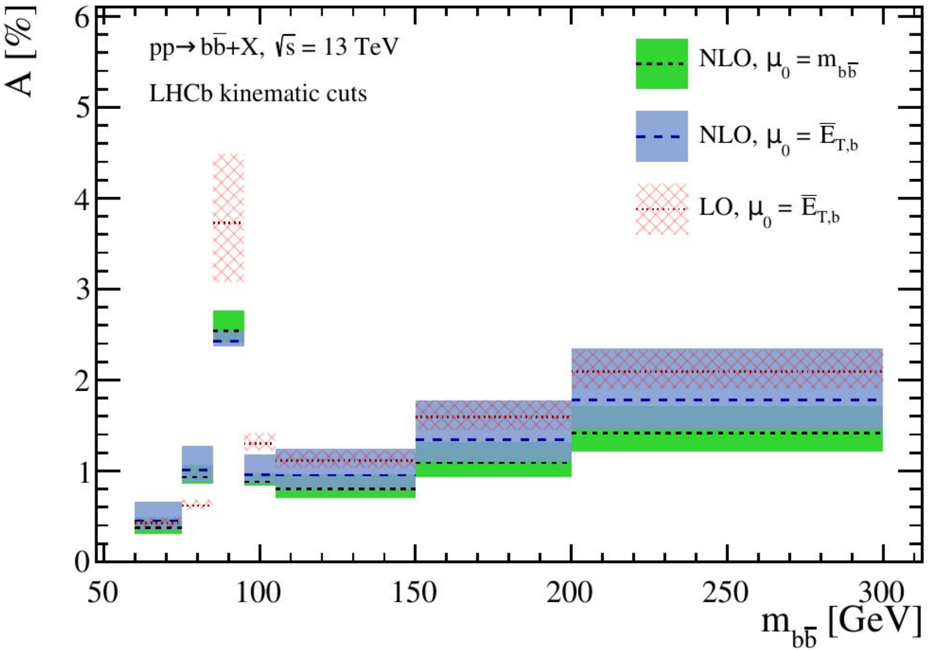


Plot: The NNPDF collaboration., Ball, R.D., Bertone, V. et al. Parton distributions for the LHC run II. J. High Energ. Phys. 2015, 40 (2015). https://doi.org/10.1007/JHEP04(2015)040

Theoretical Predictions

- Asymmetry peaks at the Z-pole due to Z→bb production being the LO source
- Current predictions include up to next-to-LO (NLO) contributions these are include QCD contributions
- Fine mass binning around the Z-pole will allow resolution of structure

10.1007/JHEP03(2019)166



Plot: Gauld, R., Haisch, U. & Pecjak, B.D. Asymmetric heavy-quark hadroproduction at LHCb: predictions and applications. *J. High Energ. Phys.* 2019, 166 (2019). https://doi.org/10.1007/JHEP03(2019)166

Analysis strategy

Selection

Jets are tagged by presence of secondary vertex, kinematic cuts are applied to ensure good quality and within fiducial region

Flavour

We apply some flavour tagging BDTs to differentiate between beauty, charm and light dijets

Charge

We apply a charge tagging procedure to identify the jets as b or b-bar

Fits

We use simulated dijet events of different flavours to fit the data sample. This allows us to calculate the purity of bb events.

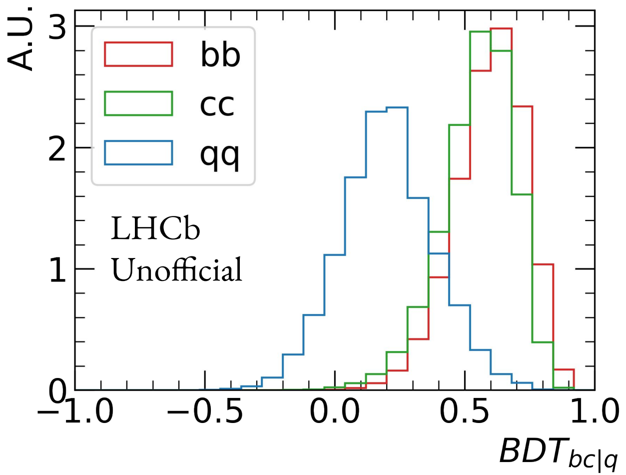
Corrections

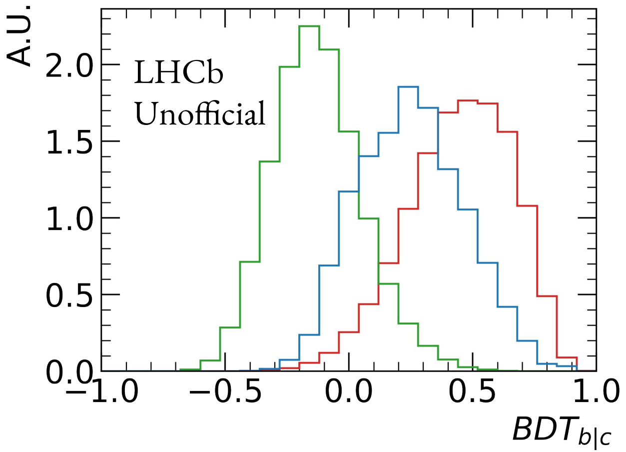
We correct for detector effects and errors caused by misidentifying the charge of the jets.

Measurement!
(currently blinded)

Selection of jets

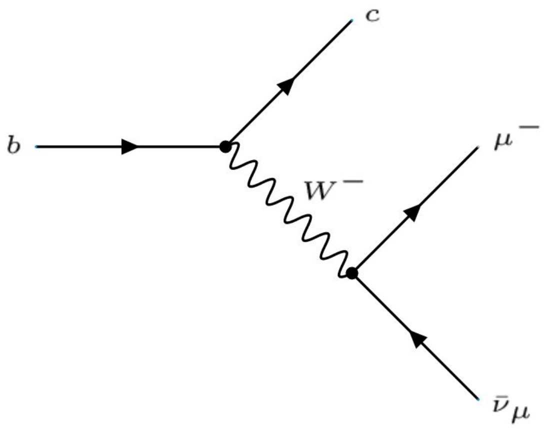
- Data events are selected using the criteria that there are two jets with high transverse momentum and both contain a secondary vertex
- Offline cuts are applied to ensure that the jets are of high quality and within the fiducial region of the detector
- Using information about the jets and the secondary vertices, BDTs are applied to tag the flavour of the jets
- Plots here show these BDT scores in simulated dijet events used in the analysis





Charge tagging (qTAG)

- Charge of jets needed to determine whether the b or $\bar{b}$ jet has greater pseudorapidity
- Tag charge of b-jets by searching for muons from $b \to \mu X$ decays
- Find the highest p_T, displaced track in the jet, and if this track is identified as a muon then the jet is qTAG
- Only require that one jet in the event is tagged, as the charge of the other jet can also be inferred from this.
- Bonus of method is that it preferentially selects beauty jets as the efficiency of having a high momentum muon in charm jets is lower

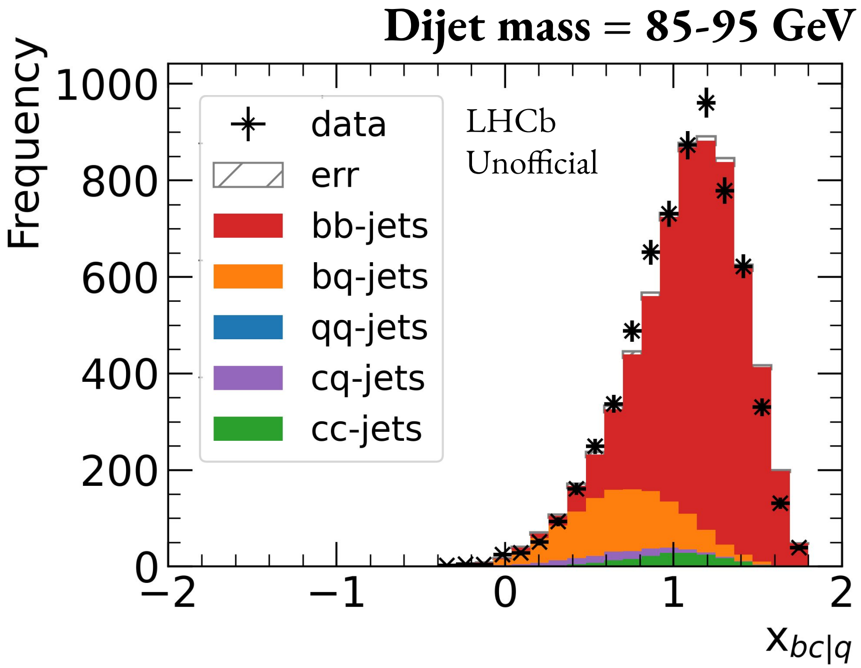


Dijet Flavour	qTAG efficiency (ε)
bb	10.74 ± 0.05%
cc	3.34 ± 0.03%

measured in simulation

Template fits

- Data sample of bb-dijets will include contamination from cc- and qq-dijets, as well as mixed flavour dijets (bq, cq)
- To measure the purity and account for these contaminations, a template fit is carried out using simulated dijet events
- A 2D-fit is performed with two observables constructed from the flavour BDT scores of the jets in the event:
  - $x_{bc|q} = BDT_{bc|q}(j_0) + BDT_{bc|q}(j_1)$
  - $x_{b|c} = BDT_{b|c}(j_0) + BDT_{b|c}(j_1)$



Number of data events	Purity of fit	Number of bb dijets
6,560	79.6 ± 1.6%	5,200 ± 100

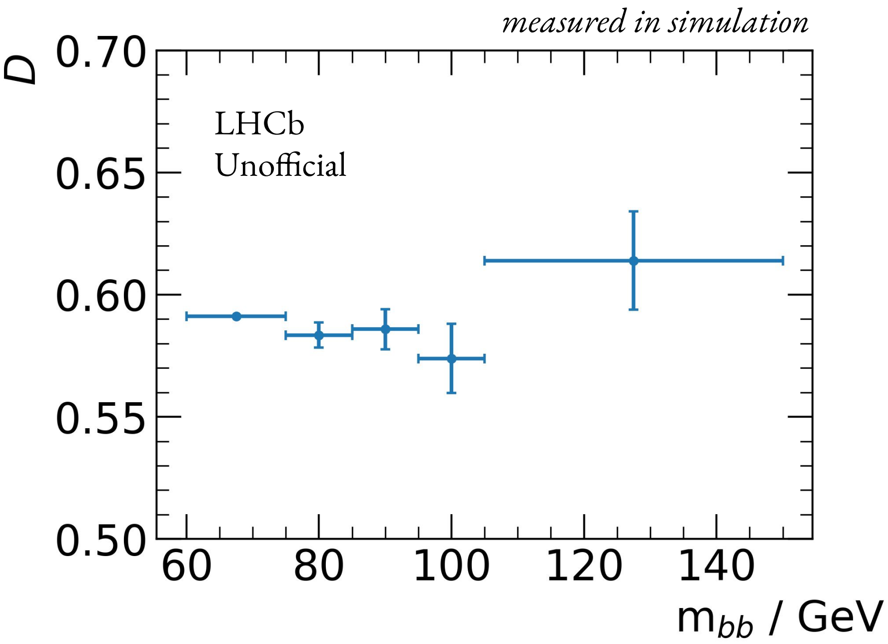
Small subsample of full run 2 dataset

Estimated statistical precision

Dijet mass / GeV	Estimated total yield	Estimated stat. uncertainty on asymmetry
60-75	1.5×10^6	± 0.16%
75-85	4.5×10^5	± 0.3%
85-95	2.0×10^5	± 0.4%
95-105	1.0×10^5	± 0.6%
105-150	1.0×10^5	± 0.6%

Systematic studies

- We are currently in the process of studying our systematic effects, the three main sources are:
    - Jet energy scale and resolution - affects measurement of m_{bb}
    - Dilution factor - used to correct the asymmetry from mistagging the charge of jets
    - Modelling of selection efficiencies and asymmetries



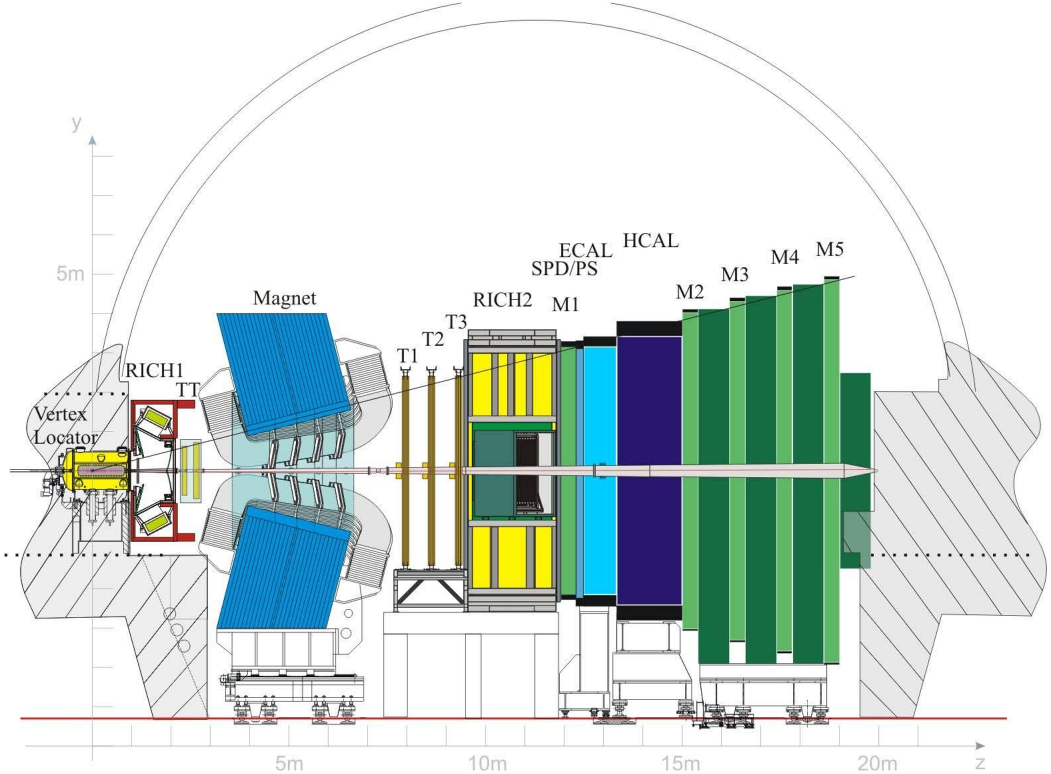
Conclusions

- A measurement of the charge asymmetry in beauty dijet production is an important test of the Standard Model and could help to constrain new physics models
- LHCb is well-placed to measure this asymmetry, results can be compared with tension seen at LEP
- Current status of the analysis has been presented, work is ongoing with the main area left to work on the systematics
- Analysis should lead to a result with much lower uncertainties than previous LHCb measurement and with much finer binning, meaning a better probe of the physics

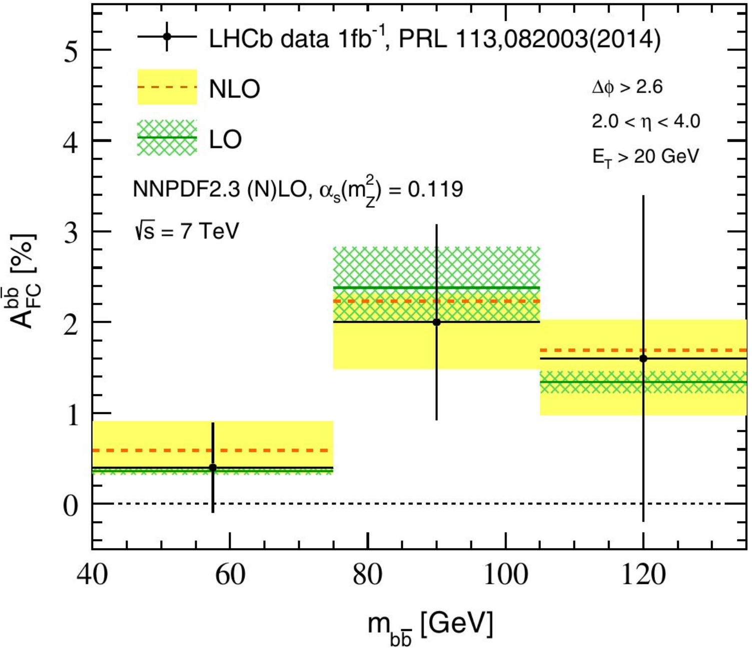
Thank you for listening!

Backups

LHCb Detector



Previous LHCb Measurement



- Taken from a theory paper published after the first measurement
- Shows good agreement between theoretical predictions with the SM and the measurement
- Large uncertainties on measurement and theoretical values here

Gauld, R., Haisch, U., Pecjak, B.D. and Re, E., 2015. Beauty-quark and charm-quark pair production asymmetries at LHCb. Physical Review D, 92(3), p.034007

qTAG Performance

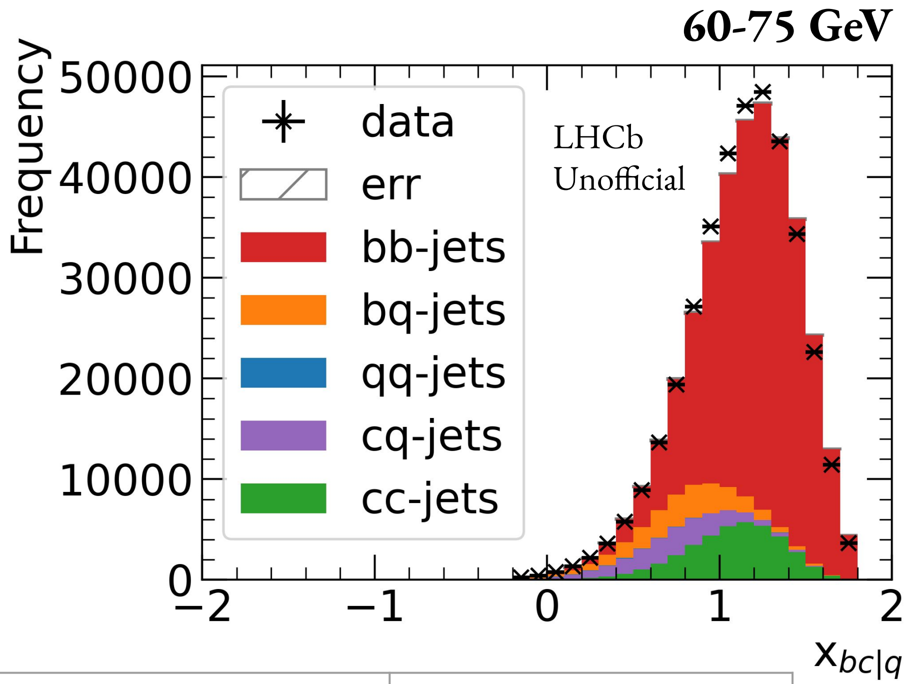
- Measure qTAG efficiency as the fraction of events that contain one tagged jet
- In data events where both jets are tagged can be used to extract the rate of mistags
- Efficiencies (ε) for simulated samples in the table.
- Mistag rate (r_{mis}) can be calculated in data by looking at the number of events tagged with the same sign
- Unoptimised results in data are:

$$\varepsilon = 12.78 \pm 0.03\% \;, \qquad r_{mis} = 26.4 \pm 1.1\%$$

MC Sample	Efficiency (ε)
bb	10.74 ± 0.05%
cc	3.34 ± 0.03%
qq	0.22 ± 0.01%
bq	7.29 ± 0.05%
cq	1.97 ± 0.03%

Fit without qTAG

- See much larger contributions from background events with no qTAG



	Number of data events	Purity of fit	Number of bb dijets
Before qTAG	371,951	77.3 ± 0.3%	287,500 ± 1,100
After qTAG	47,499	88.4 ± 1.0%	42,000 ± 500