Jet Flavour Tagging and Top Production at LHCb

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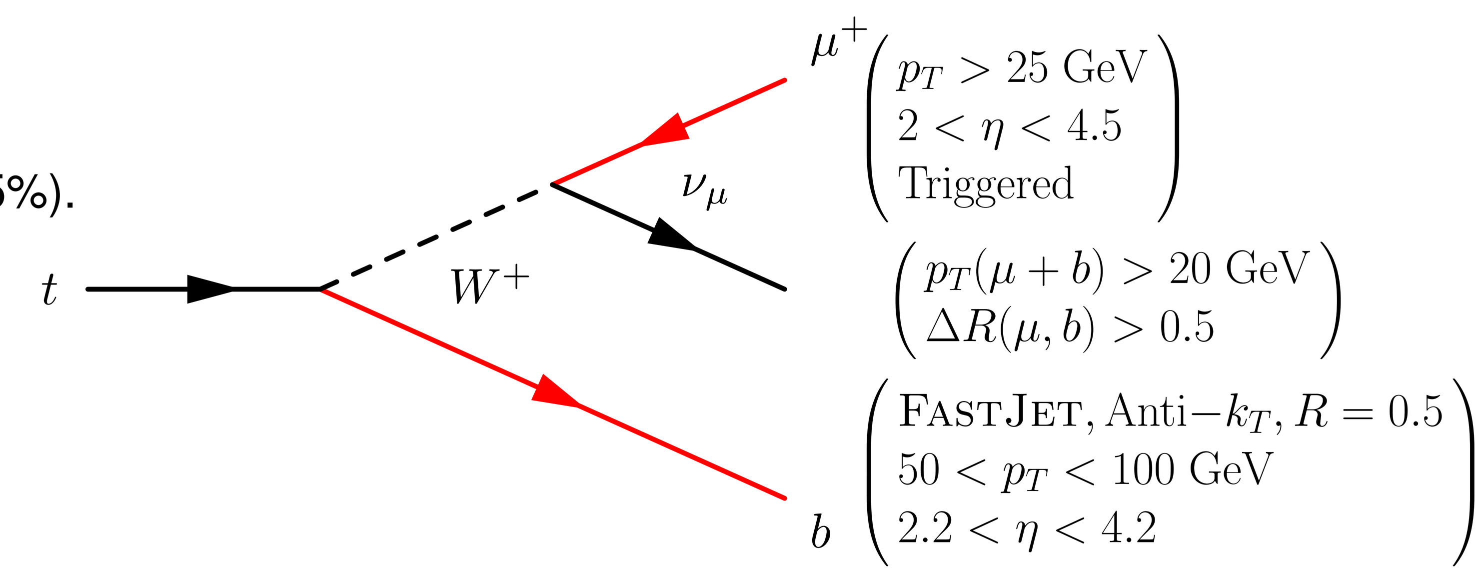
Forward Top Production

Phys. Rev. Lett. 115 112011 [3]

Introduction

- A promising method for BSM physics search. [1, 2]
- Run I – SM Top forward production: $t\bar{t}$ (75%), single-top (25%).
- Strategy:
  - Reconstruct $t \to Wb$ as μ + b-jet final state.
  - Subtract SM background: direct-Wb, $Z+b$, di-b-jet.
- This analysis made no distinguishment between single-top and $t\bar{t}$.



Key discriminants

- Charge asymmetry: $\to 0$ for $t\bar{t}$; > 0 for t, Wb

$$\mathcal{A}(Wb) \equiv \frac{\sigma(W^+b) - \sigma(W^-b)}{\sigma(W^+b) + \sigma(W^-b)}$$

- Muon isolation: $\to 1$ for W/Z; < 1 for QCD-jet

$p_T(\mu)/p_T(\mu\text{-jet})$

Jet Flavour Tagging

JINST 10 P06013 [4]

Aim: Identify jet from (b,c)-quark with secondary vertex (SV) using BDT.

SV Tagger

Build SV with two or more unique tracks, and associate to jets with $\Delta R < 0.5$. Requirements of SV based on vertex fix, B^0 mass window, jet axis, and spatial primary vertex separation.

Corrected Mass

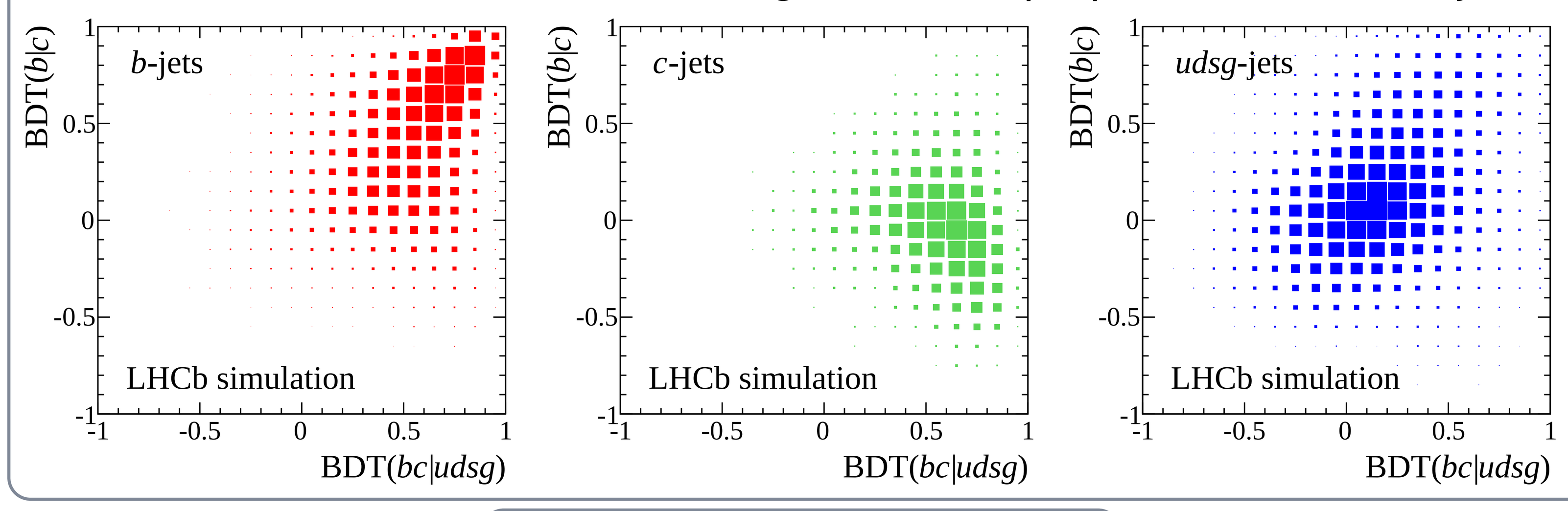
One of the prominent BDT input variable. It defines minimum mass that the long-lived hadron can have that is consistent with the direction of flight.

$$M_{\text{cor}}(\text{SV}) = \sqrt{M^2 + p^2 \sin^2\theta} + p \sin\theta$$

$\theta = \angle$(momentum, flight direction) of the SV.

Two-dimensional BDTs

Separation for (1) bc -vs- $udsg$ (light jet), (2) $beauty$ -vs- $charm$.
Total 10 variables are used for training, based on properties of SV and jet.



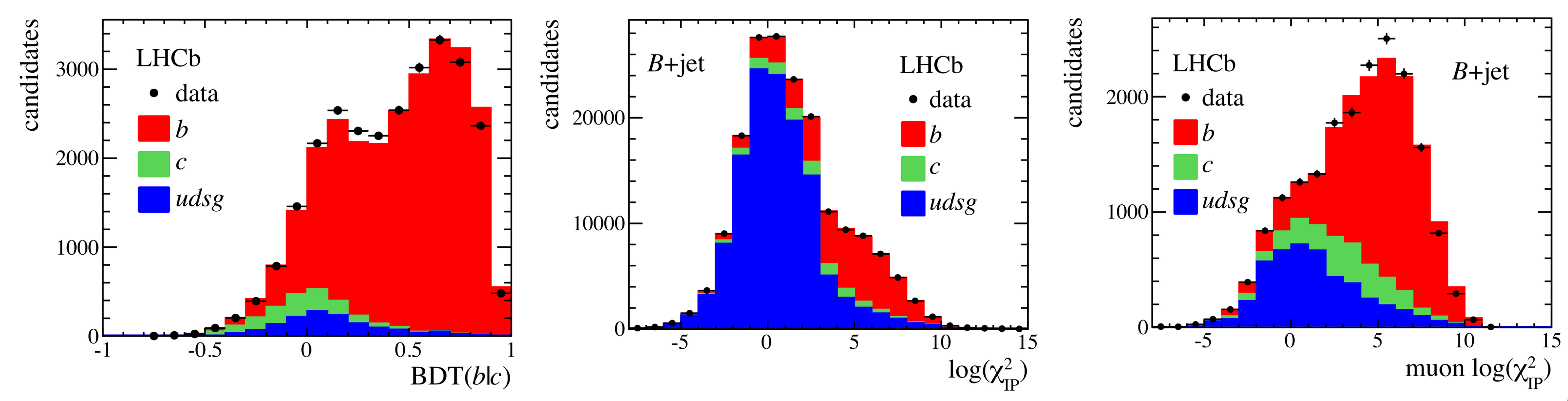
Tagging efficiency in data

$\varepsilon_{(b,c)\text{-tag}}$ = [#Tagged (b,c) jets] / [#Total (b,c) jets]

Fit BDTs in the SV-tagged subsample.

Method 1: Fit IP-χ^2 of $p_T^{\max}$(track).

Method 2: Fit IP-χ^2 of $p_T^{\max}$(muon).



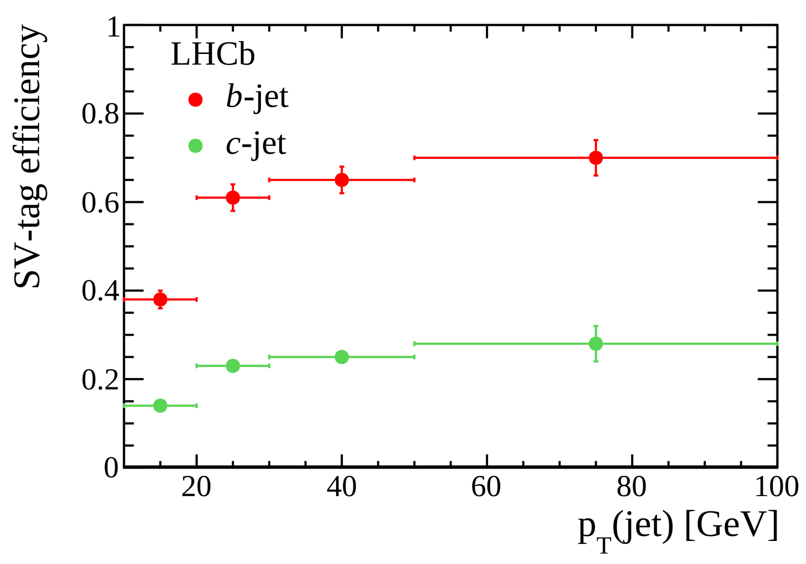
Results

$\langle \varepsilon_{(b,c)\text{-tag}} \rangle$ = 65%, 25%.
Mis-id by light jet: 0.3%.

Efficiencies measured in data are consistent with simulation.
($p_T(j) > 20$ GeV, $2.2 < \eta(j) < 4.2$)

Main systematic uncertainties:

- Large-IP light-jet (5%, 10-30%).
- hadron-as-muon prob. (5%, 20%).



Flavour Tagging

μ + jet

μ + b

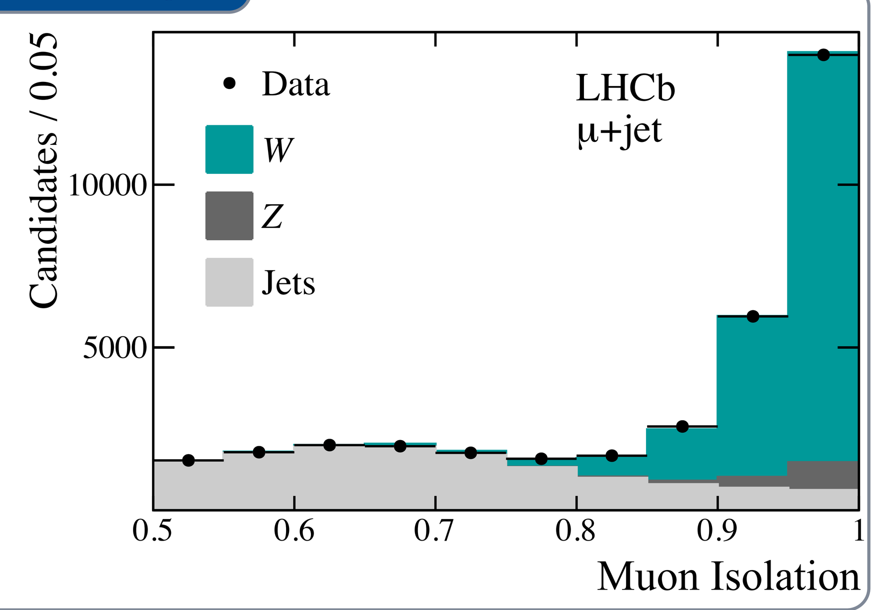
Analysis

Control: W+jet

Inclusive W+jet is very pure, obtained by fitting against Z+jet (data-driven), and di-jets from μ+jet candidates.

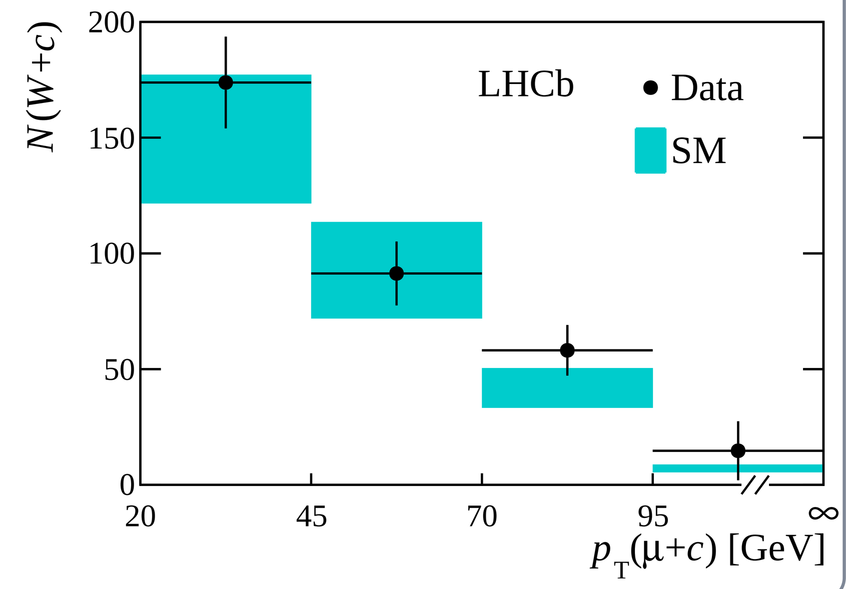
It's used for:

- Detector response.
- Predict direct Wb yield.



Control: $W+c$

- Validate flavour tagging and analysis procedure.
- No contribution from SM di-bosons or top.
- Good agreement with SM prediction.

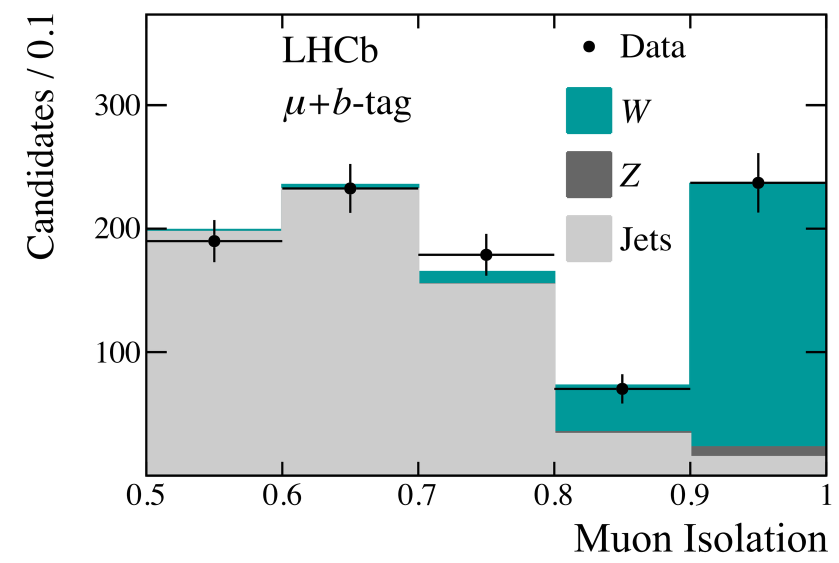


Backgrounds: $Z+b$, di-b-jet, direct Wb

$Z+b$, di-b-jet are accounted for in the fitting.

Direct Wb yield predicted via scaled inclusive W+jet from data, which has smaller uncertainty relative to theory prediction.

$$N(Wb) = N(Wj) \cdot \varepsilon_{b\text{-tag}} \cdot \left.\frac{\sigma(Wb)}{\sigma(Wj)}\right|_{\text{MCFM}}$$



Control: $W+b$ study

Phys. Rev. D 92 052001 [5]

Study cross-section ratio $[\sigma(Wb) + \sigma(\text{top})]/\sigma(Wj)$ in larger fiducial region ($p_T(\mu) > 20$ GeV, $p_T(j) > 20$ GeV), more dominated by direct Wb production.

[%] ± stats. ± syst.	7 TeV	8 TeV
With top	$1.17 \pm 0.13 \pm 0.18$	$1.29 \pm 0.08 \pm 0.19$
Without top	$0.66 \pm 0.13 \pm 0.13$	$0.78 \pm 0.08 \pm 0.16$

In agreement with SM prediction.

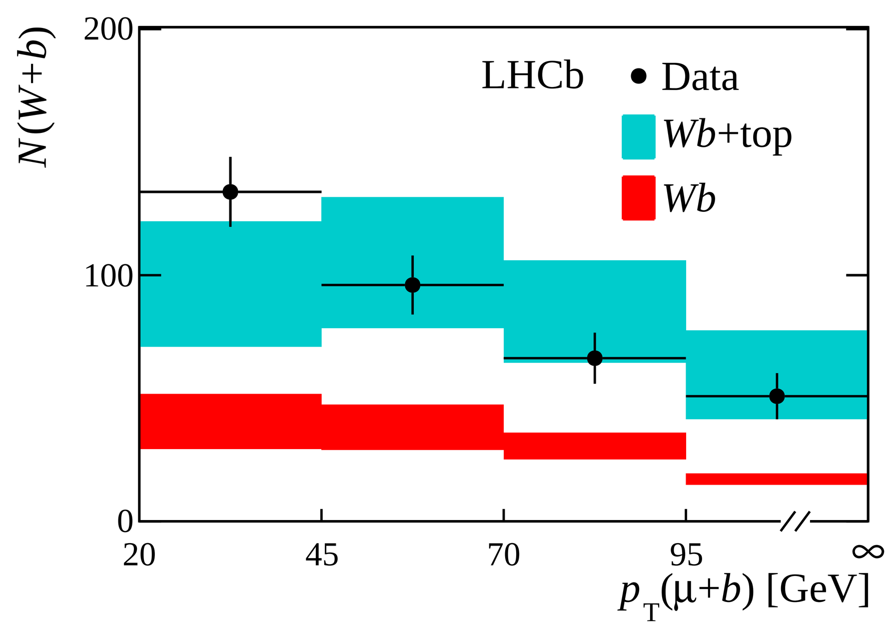
Results

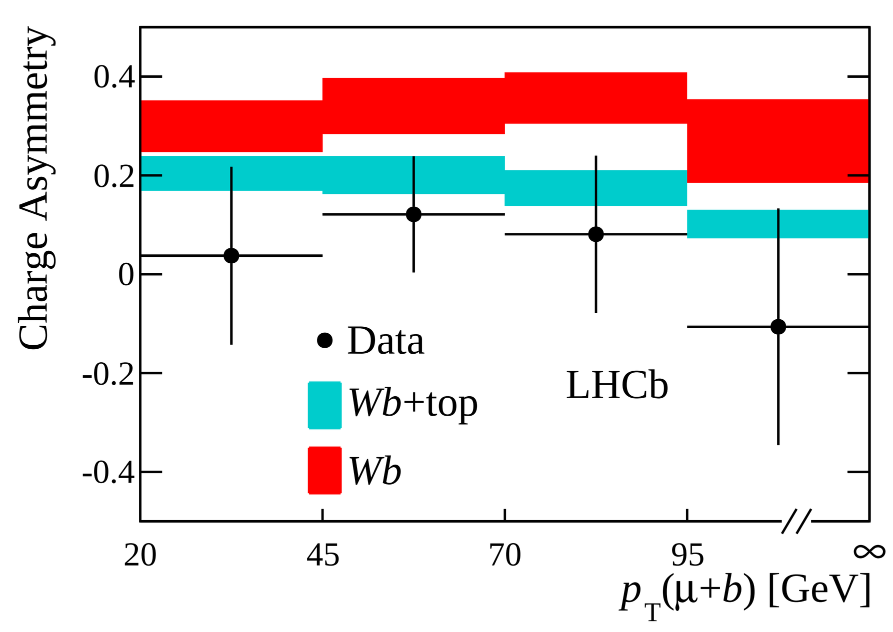
Distribution of yield N and charge asymmetry $\mathcal{A}(Wb)$ are consistent with SM prediction. Significance of 5.4σ for signal hypothesis with top, to null hypothesis without top (binned profile likelihood test).

Top production cross-section is consistent with SM prediction:

$$\sigma(\text{top})\ [7\text{ TeV}] = 239 \pm 53\ (\text{stat}) \pm 33\ (\text{syst}) \pm 24\ (\text{theory})\ [\text{fb}]$$
$$\sigma(\text{top})\ [8\text{ TeV}] = 289 \pm 43\ (\text{stat}) \pm 40\ (\text{syst}) \pm 29\ (\text{theory})\ [\text{fb}]$$

Fiducial region: $p_T(\mu) > 25$ GeV, $2.0 < \eta(\mu) < 4.5$,
$50 < p_T(b\text{-jet}) < 100$ GeV, $2.2 < \eta(b\text{-jet}) < 4.2$, $p_T(\mu + b\text{-jet}) > 20$ GeV





Main systematic uncertainties: $\varepsilon_{b\text{-tag}}$ (10%), BDT template (5%), Muon isolation template (5%), Jet energy (5%)

[1] Alexander L. Kagan et al. "Probing New Top Physics at the LHCb Experiment". Phys. Rev. Lett. 107.8 (2011), p. 082003.
[2] Rhorry Gauld. "Leptonic top quark asymmetry predictions at LHCb". Phys. Rev. D 91.5 (2015), p. 054029.
[3] The LHCb collaboration. "First Observation of Top Quark Production in the Forward Region". Phys. Rev. Lett. 115.11 (2015), p. 112001.
[4] The LHCb collaboration. "Identification of beauty and charm quark jets at LHCb". JINST 10.06 (2015), P06013–P06013.
[5] The LHCb collaboration. "Study of W boson production in association with beauty and charm". Phys. Rev. D 92.5 (2015), p. 052001.

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