Charm-jet tagging at LHCb

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on behalf of the LHCb Collaboration

Higgs
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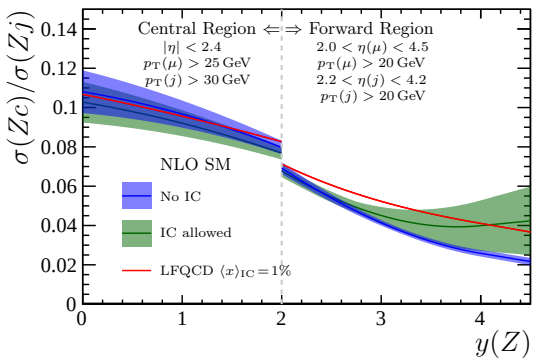
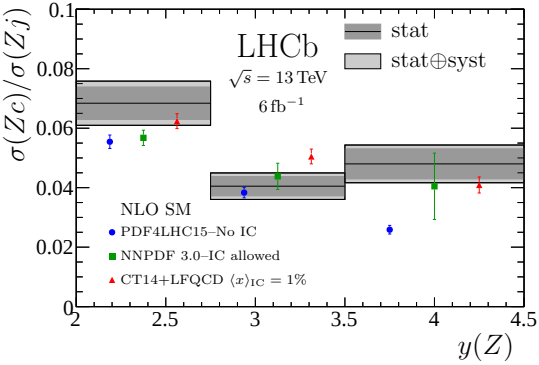
Motivation: Forward $Z + c$ production (arXiv:2109.08084)

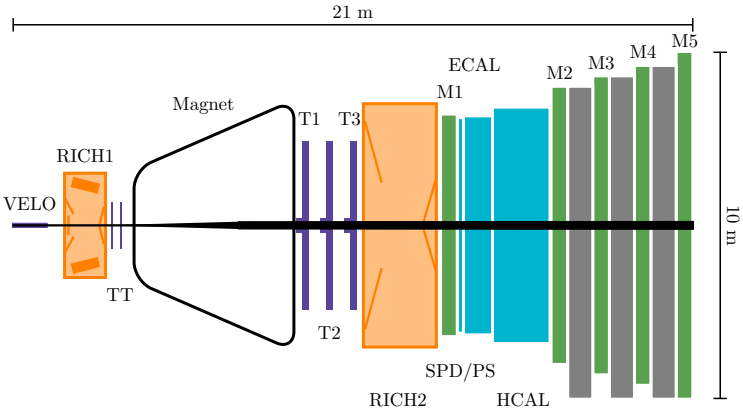




- Ideal probe of valence-like intrinsic charm (PRD **93**, no.7, 074008 (2016))
- Observe an enhancement at high $y(Z)$, consistent with IC
- b/c-jet tagging also used to search for $H \to c\bar{c}/b\bar{b}$:
  $y^b < 7y^b_{\text{SM}}$ and $y^c < 80y^c_{\text{SM}}$ (LHCb-CONF-2016-006)

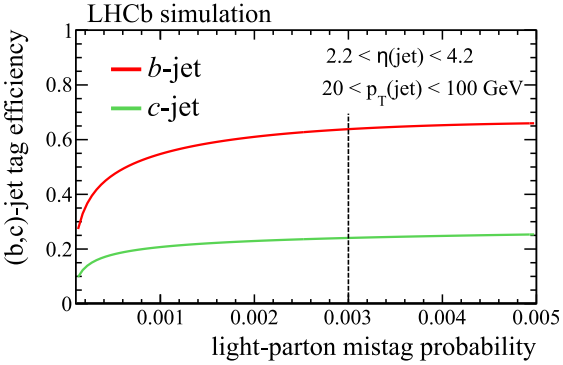
The LHCb detector (Int. J. Mod. Phys. A 30, 1530022 (2015))

- Forward spectrometer: $2 < \eta < 5$
- **tracking**, **calorimetry**, **RICH**, **muon** systems
- Excellent vertex resolution ($10 - 50$ μm in x and y)
- Track $\sigma(p)/p \sim 0.5 - 1.0\%$

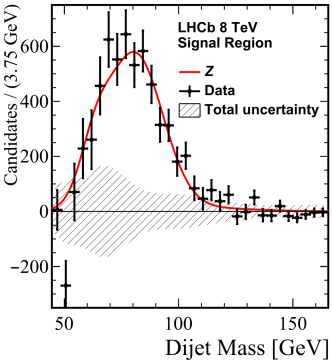


Optimized for heavy flavor physics → ideal for identifying heavy flavor jets

Heavy flavor jet tagging in Run 1 (JINST 10 P06013)



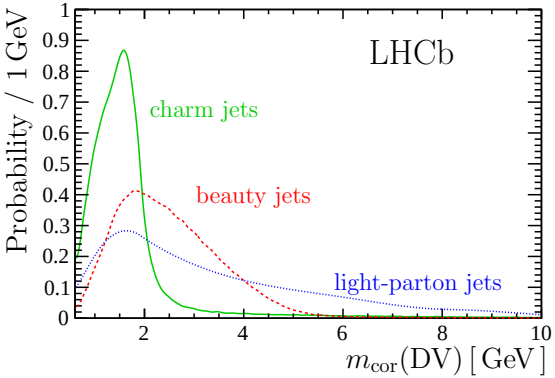
$Z \to b\bar{b}$ (Phys. Lett. B776 (2018) 430)



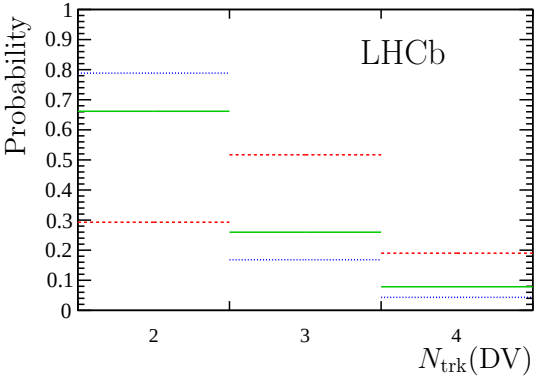
- Jets are identified using displaced secondary vertices and two BDTs: $BDT_{bc|udsg}$ and $BDT_{b|c}$
- b (c) jets tagged with 65% (25%) efficiency with 0.3% mistag probability
- Not optimizied for Run 2 + Can improve c-tagging performance with a dedicated algorithm.

Charm jet tagging with Displaced Vertices in Run 2

$m_{\text{cor}} \equiv \sqrt{m^2 + (p \sin\theta)^2} + p \sin\theta$

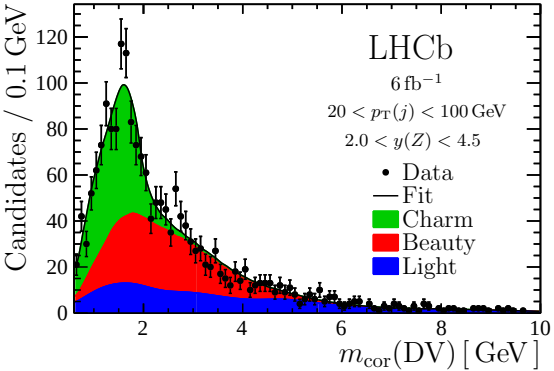


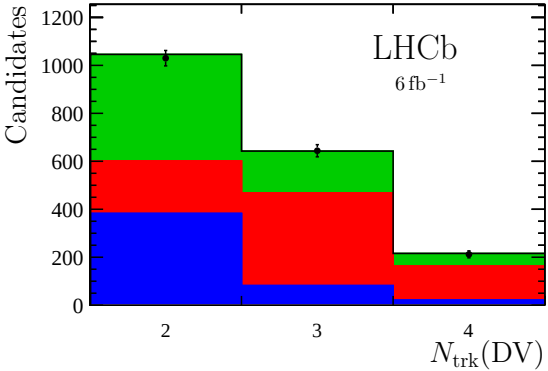
$N_{\text{trk}} \equiv$ number of tracks in DV



- "Tag" jets with a 2, 3, or 4-track displaced vertex (DV)
- Determine the composition of the tagged jets using a 2D fit to m_{cor} and N_{trk}

Tagging charm jets in $Z + c$

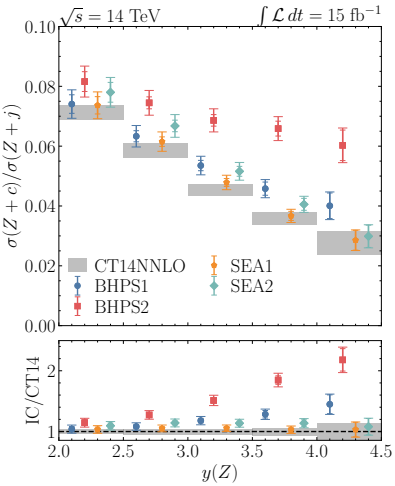




- Efficiency is measured using a tag-and-probe method with a dijet calibration sample
- Total c-jet yield determined using fully reconstructed $D^0 \to K^-\pi^+$ and $D^+ \to K^-\pi^+\pi^+$
- Efficiency is about 24% for $20 < p_{\mathrm{T}}(j) < 100\,\mathrm{GeV}$

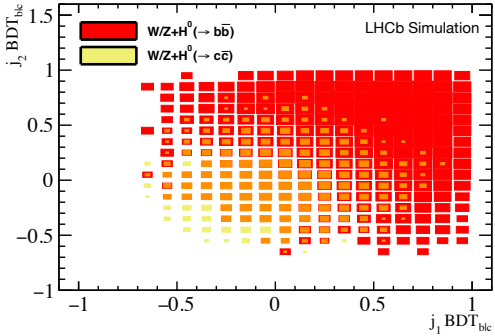
Outlook

PRD **93**, no.7, 074008 (2016)



LHCb is uniquely suited for studying charm jets

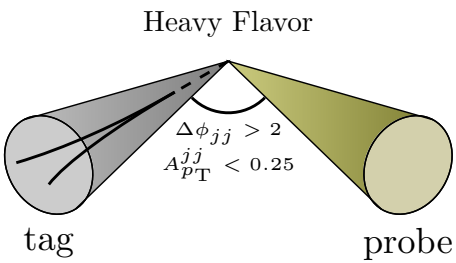
- Run 3: factor of ~ 3 increase in sensitivity to intrinsic charm in $Z + c$ production
- $V + H(\to c\bar{c})$ with $300\,\mathrm{fb}^{-1}$ at LHCb potentially sensitive to y_c as small as $\sim 2y_c^{\mathrm{SM}}$ (see Davide's talk)

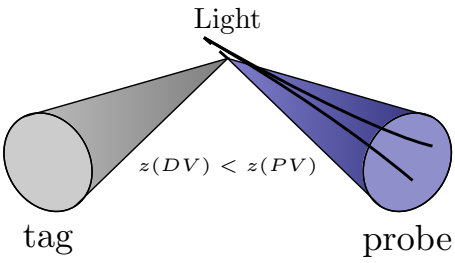


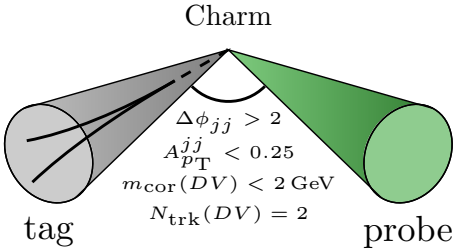
arXiv:1808.08865

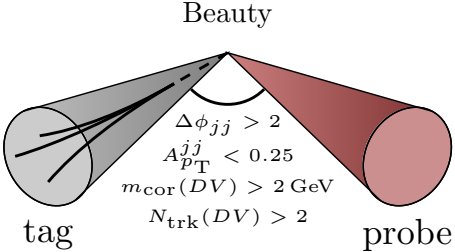
Thank You!

Tag-and-Probe



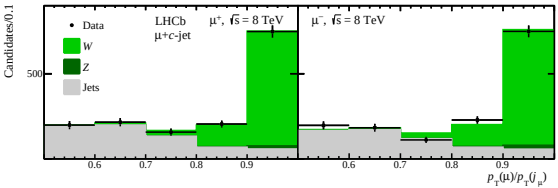




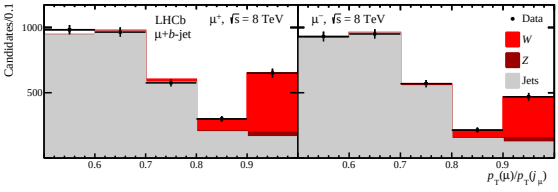


$W + (c, b)$ (PRD 92 (2015) 052001)

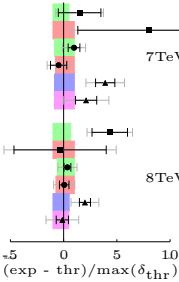
Probes $s/\bar{s}$ PDFs via $gs \to Wc$



Probes $b/\bar{b}$ PDFs via $qb \to Wbq'$



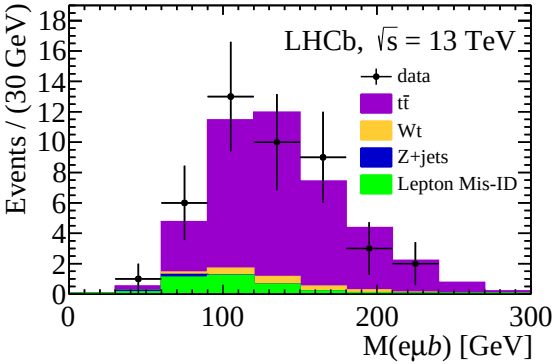
Wc, Wb, W^-j, W^+j



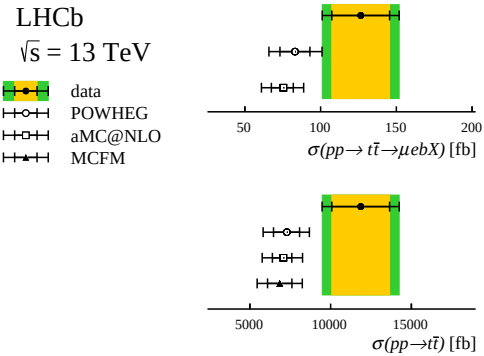
$-0.09 \pm 0.08 \pm 0.04$	$\mathcal{A}(Wc)$
$0.51 \pm 0.20 \pm 0.09$	$\mathcal{A}(Wb)$
$5.80 \pm 0.44 \pm 0.75$	$\sigma(Wc)/\sigma(Wj) \times 10^2$
$0.66 \pm 0.13 \pm 0.13$	$\sigma(Wb)/\sigma(Wj) \times 10^2$
$6.61 \pm 0.19 \pm 0.33$	$\sigma(W^-j)/\sigma(Zj)$
$10.49 \pm 0.28 \pm 0.53$	$\sigma(W^+j)/\sigma(Zj)$
$-0.01 \pm 0.05 \pm 0.04$	$\mathcal{A}(Wc)$
$0.27 \pm 0.13 \pm 0.09$	$\mathcal{A}(Wb)$
$5.62 \pm 0.28 \pm 0.73$	$\sigma(Wc)/\sigma(Wj) \times 10^2$
$0.78 \pm 0.08 \pm 0.16$	$\sigma(Wb)/\sigma(Wj) \times 10^2$
$6.02 \pm 0.13 \pm 0.30$	$\sigma(W^-j)/\sigma(Zj)$
$9.44 \pm 0.19 \pm 0.47$	$\sigma(W^+j)/\sigma(Zj)$

$\sim 2\sigma$ tension in $\mathcal{A}(Wc)$ could point to an asymmetry between s and $\bar{s}$ PDFs

$t\bar{t}$ at 13 TeV (JHEP 08 (2018) 174)

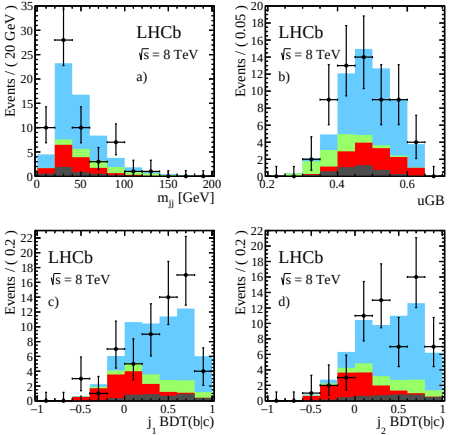


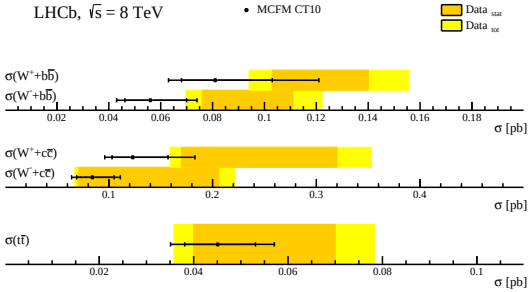
- Measured in the $\mu + e + b$ final state
- Probes the gluon PDF at high-x



- Syst. and stat. uncertainties are similar
- Syst. uncertainties dominated by b-tagging efficiency

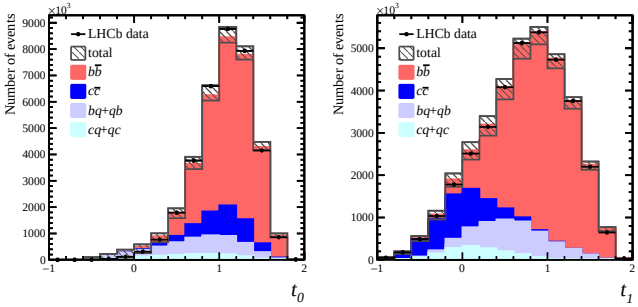
$t\bar{t}$, $W + c\bar{c}$, and $W + b\bar{b}$ (Phys. Lett. B767 (2017) 110)

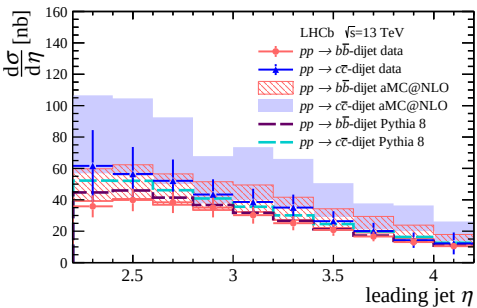




First ever measurement of $W + c\bar{c}$ cross-section

$c\bar{c}$ and $b\bar{b}$ at 13 TeV (JHEP 02 (2021) 023)





- Yields determined using template fits to jet tagging BDT outputs:

$$t_0 = BDT_{bc|udsg}(j_0) + BDT_{bc|udsg}(j_1)$$
$$t_1 = BDT_{b|c}(j_0) + BDT_{b|c}(j_1)$$

- Theoretical uncertainties dominated by scale uncertainties