Top and W+b/c jets results at LHCb

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CERN

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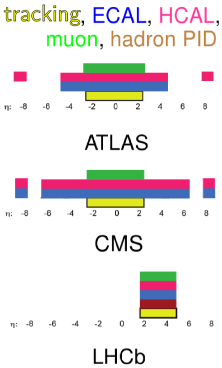
Implication Workshop

Introduction

- LHCb is fully instrumented in the forward region $2 < \eta < 5$
- Complementary to central detectors:
  - high/low-x partons involved.
  - Different production mechanism. (e.g. more q initiated $t\bar{t}$ production).
- Tracking in the forward region

$\rightarrow$ b,c jet tagging @ $2 < \eta < 5$



Outline

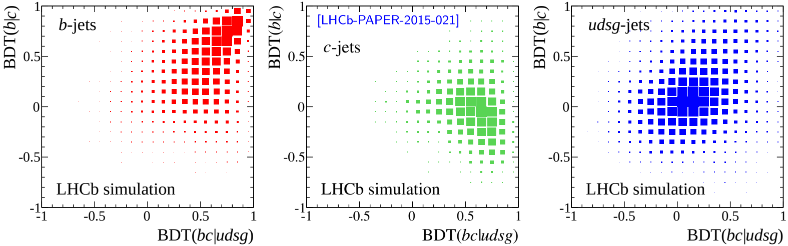
- Heavy-flavour jet tagging @ LHCb
- $W + b, c$jet production ratios @ $\sqrt{s} = 7, 8\ TeV$
- Top production in the forward region @ $\sqrt{s} = 7, 8\ TeV$
- Prospects for run II

Heavy-flavour jet tagging @ LHCb

b and c jet tagging @ LHCb
[JINST 10 P06013]

- ParticleFlow jets with anti-k_T (R=0.5).
- Inclusive 2-body vertexing merged in n-body vertices (SV):

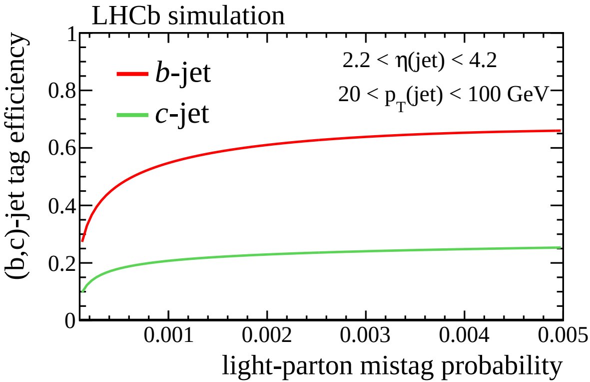
  $\rightarrow$ light jet mistag rate $< 1\%$, $\epsilon_b \sim 65\%$, $\epsilon_c \sim 25\%$.
- SV properties (displacement, kinematics, mulitplicity,...) and jet properties combined in two BDTs.
  - $BDT_{bc|udsg}$ optimised for heavy flavour versus light discrimination.
  - $BDT_{b|c}$ optimised for b versus c discrimination.



- Enrichement in a *b* or *c*-jets can be obtained from cuts on the BDT distributions.
- Flavour content of a given jet sample can be obtained from 2D fit of the BDT distributions.

b and c jet tagging @ LHCb
[JINST 10 P06013]

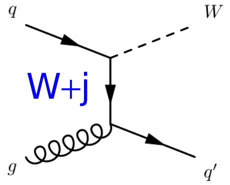
- Applying a cut on $BDT_{bc|udsg}$:

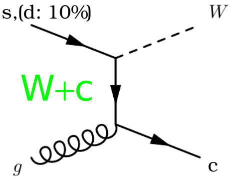


- Relative uncertainty of 10% of (b,c)-jet tagging efficiencies.
- Uncertainties on the mis-tag rate $\sim$ 30%.

W+(b,c)-jet production ratio @ $\sqrt{s} = 7, 8\,TeV$

Motivations



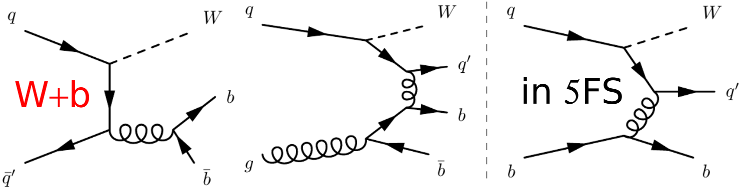


W+c

- LO production involve s-quark PDFs
- $Q \sim 100$ GeV and x down to 10^{-5}
- Existing constraints based on DIS with $Q \sim 1$ GeV and $x \sim \mathcal{O}(0.1)$.
- At higher Q, measurement in the central region at TeVatron and LHC.

W+b

- Main production process sensitive to probability of gluon splitting in $b\bar{b}$.
- LO production in 5FS from intrinsic b quark content of the proton.



Measurement of $W + (b, c)$-jet ratios and asymmetries.

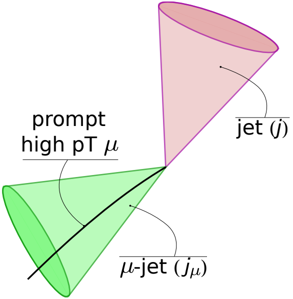
- $W \to \mu\nu$ final state.
- Jets tagged with the SV-tagger.

Fiducial volume

$$p_T(\mu) > 20\ GeV,\ 2.0 < \eta_\mu < 4.5$$
$$p_T(j) > 20\ GeV,\ 2.2 < \eta_j < 4.2$$
$$\Delta R(\mu, j) > 0.5$$
$$p_T(\mu + j) > 20\ GeV$$

Selection:

- Prompt μ selection as in [JHEP12(2014)079].
- Events with 2 μ vetoed or classified as Z+jet.
- "j" is the highest-p_T jet.
- μ candidate used in the jet reconstruction.
- ν missed $\to$ p_T-unbalance.
- $p_T(j_\mu + j) > 20$ GeV .
- **Isolation defined as $\mathbf{p_T}(\mu)/\mathbf{p_T}(\mathbf{j}_\mu)$.**
- **Selection $\equiv$ fiducial volume**[a]



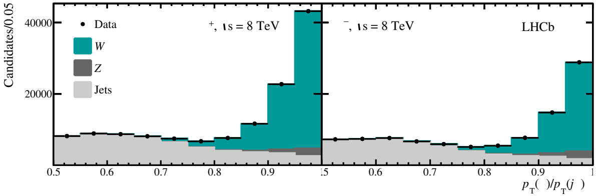
[a] For W+jet, $p_T(j_\mu + j) > 20\ GeV \equiv p_T(\mu + j) > 20 GeV$ to $\sim 1\%$

Yields

Fit of the isolation in μ+jet sample

[PRD92 (2015) 052001]

- μ_W+jet yields obtained from fit of the μ isolation

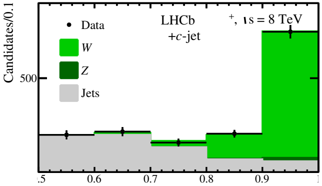


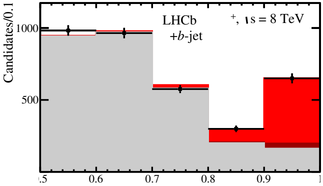
Shape from MC, cor. with Z data

Yields from $Z[\mu\mu]$+jet

Shape from data

- Yields of μ_W+(b,c)jet from 2D BDT fit of SV-tagged sample and isolation fit

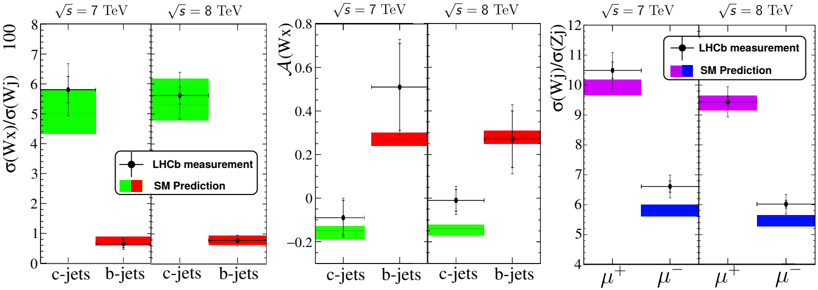




- μ+(b,c)tag corrected for SV tagging efficiencies.
- W+jet and W+(b,c)jet yields corrected for backgrounds from $Z \to \tau\tau$ and top.

$W + (b, c)$-jet ratios and asymmetries results [PRD92 (2015) 052001]

- $\mathcal{A}(Wq) = \frac{\sigma(W^+q)-\sigma(W^-q)}{\sigma(W^+q)+\sigma(W^-q)}$.
- Main uncertainties from heavy flavour fraction determination (5-10%), tagging efficiency (10%), isolation fit (4-10%), and for $W + b$ the Top background (13%)
- Predictions @NLO: MCFM[PRD62(00)114012] and CT10 PDF set,[PRD82(10)074024].

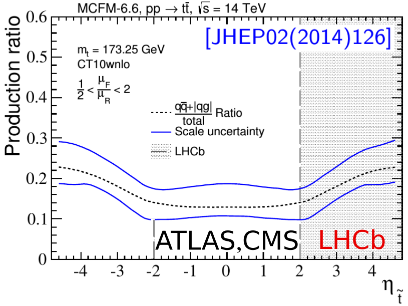


- $|\mathcal{A}(Wc)|$ is 2σ lower than predictions using CT10 PDFs.
- Could point to asymmetric $(s,\bar{s})$ PDFs.
- Data do not support large contribution from intrinsic b-quark in the proton:

$\rightarrow$ Insufficient precision to rule out extra contribution at the $\mathcal{O}(10\%)$ level.

Top production
in the forward region @$\sqrt{s} = 7, 8\,TeV$

Top quark production in *pp* collisions

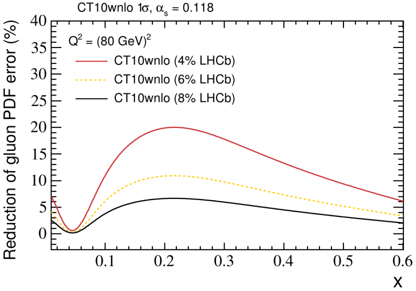


Motivation for studies in the forward region:

- test for the differential predictions.
- reduced g-initiated production.
- enhanced $t\bar{t}$ charge asymmetry

Large uncertainty on the high-x gluon PDFs:

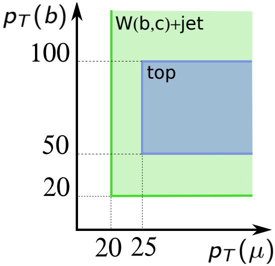
- ATLAS/CMS $t\bar{t}$ measurements constraint the high-x gluon PDF [JHEP07(2013)167]
- $t\bar{t}$ production in the forward region involve higher-x / lower-x gluon, [JHEP02(2014)126].



Selection and strategy

- Combined measurement of the single-t and $t\bar{t}$ production in the $\mu + b$ channel.
- $t\bar{t}$ accounts for 3/4 of the top production.

- Tightened fiducial region to enhance top contribution.
  - $p_T(\mu) > 25$ GeV.
  - $50 < p_T(b) < 100$ GeV
- Reduces the uncertainty associated to QCD jets.
- Improves $S/\sqrt{B}$ at large $p_T(\mu + b)$.
- Identical selection to $W + (b, c)$ otherwise.



- $p_T(\mu + b)$ provides discrimination between top and $W + b$-jets.
- $\mathcal{A}(Wb) \sim 1/3$ while $\mathcal{A}(top) \sim 0.1$, mainly from single-$t$.

- Look for an excess of $\mu + b$ events and deviation of $\mathcal{A}$ as function of $p_T(\mu + b)$.
- **Needs good control on W + b-jets predictions.**

SM predictions

- NLO predictions from MCFM [JPG42(2015)1,015005] in the 4FS and CT10 PDF set [PRD82(2010)074024].
- NLO PowhegBox [JHEP01(2012)137] showered with Pythia8 [CPC178(2008)852-867] (for consistency check)
- Prediction uncertainties from PDFs, α_s and scale.
- Integration uncertainties and from $m_{c,b,t}$ negligible.
- α_s and PDF uncertainties are found to be close to 100% correlated between bins.
- Detector response folded to the prediction:
  - Main contribution from μ efficiencies, b-jet p_T migration, (b,c)-tagging efficiencies.
- $\sigma(Wb)/\sigma(Wj)$ theory uncertainties partially cancel in the ratio.
- In the most significant bin of $p_T(\mu + b)$:

$$\text{rel. error}[\sigma(Wb)/\sigma(Wj)] \sim \frac{1}{3}\ \text{rel. error}[\sigma(Wb)]$$

Measure W+jets yields to fix the scale of W + b-jets from data

In situ constraint from W+jet

Isolation fit

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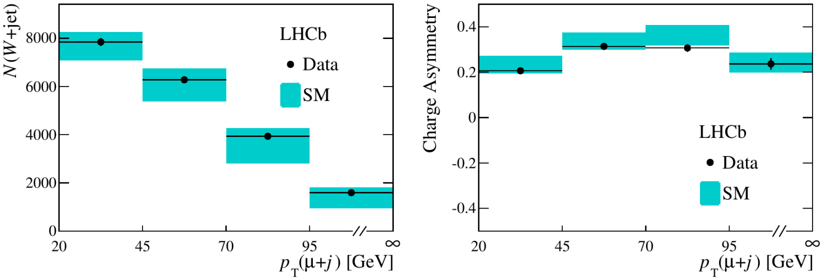
- Same procedure than for the previous measurement.
- The isolation fit is performed in 4 $p_T(\mu + j)$ bins $[20; 45; 70; 95; \infty]$.



- W+jet data consistent with NLO predictions at the 1σ level.
- Slightly lower $\mathcal{A}$, consistent with slightly higher $\sigma(W^- j)/\sigma(Zj)$.
- **Low uncertainty allows to fix the scale of $\mathbf{W(c,b)}$ from $\mathbf{W(c,b)/Wj}$ predictions.**

$\rightarrow$ Validated on **Wc** sample, yields in agreements with the NLO predictions.

$W + b$-tag yields and asymmetry

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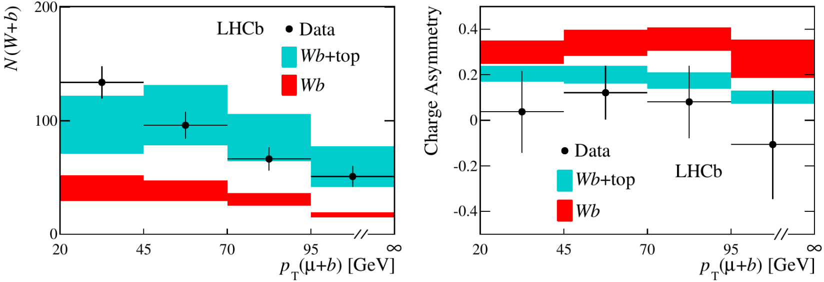

- Discrepancy between data and *Wb* predictions.
- Good agreement with $Wb + top$ predictions.

- Binned likelihood fit of $N(top)$ and $\mathcal{A}(top)$.
- Systematic uncertainties treated as Gaussian constraints.
- $N(top)$ and $\mathcal{A}(top)$ shapes are fixed. The total yields is allowed to vary.
- Profile likelihood to compare $Wb + top$ and Wb hypotheses

5.4σ observation of top production in the forward region.

Cross section measurements

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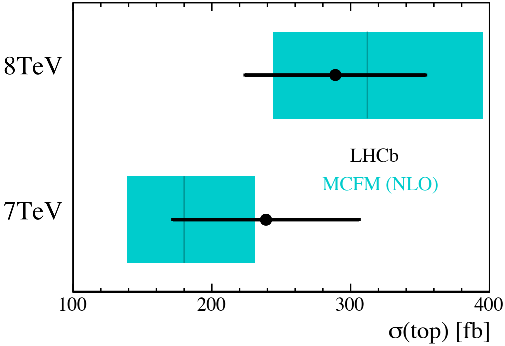
- The observed excess above Wb prediction is used to measure $\sigma(t\bar{t}+t+\bar{t})$.

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

- b-tagging, jet energy scale and isolation fit related uncertainties dominates the systematics uncertainties.

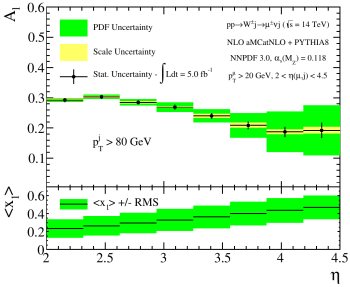


Cross sections at $\sqrt{s} = 7, 8$ TeVare consistant with NLO SM predictions.

Prospects for Run II and LHCb Upgrade

VB + jets

- Z+jet [JHEP 01(2014)33], Z+b-jet [JHEP 01(2015)064], Z+D [JHEP 04(2014)91] performed at 7 TeV → **to be updated.**
- At $\sqrt{s} = 13$ TeV, W+(b,c,ℓ)jet **cross sections increases** by a factor $\sim 2 - 2.5$.
- A **larger fraction of visible events** in LHCb acceptance.
- 7,8 TeV $\mathcal{A}$ measurements are dominated by statistical error.
- Part of the systematic uncertainties are of statistical nature and methods could be improved.
- **Differential measurements** becomes accessible.
- The impact of W+jet differential cross-section and asymmetry measurements on large-x d-quark PDF studied in [arXiv:1505.01399].
- Enhanced sensitivity for high-p_T jet and high-η lepton.
- Up to $\sim 35\%$ improvement of the d-quark PDF uncert. at $x = 0.7$ for a 1% systematic uncert. measurement with run II dataset.



Top production

[LHCb-PUB-2013-009]

$d\sigma$(fb)	8 TeV			14 TeV		
lb	504	$\pm$	94	4366	$\pm$	663
lbj	198	$\pm$	35	2335	$\pm$	323
lbb	65	$\pm$	12	870	$\pm$	116
$lbbj$	26	$\pm$	4	487	$\pm$	76
l^+l^-	79	$\pm$	15	635	$\pm$	109
l^+l^-b	39	$\pm$	8	417	$\pm$	79

- Cross-sections and acceptance increased at run II

  $\sim$ 20$\times$RunI yields.

- $\sim$ 5% stat. uncertainty at RunII on μb

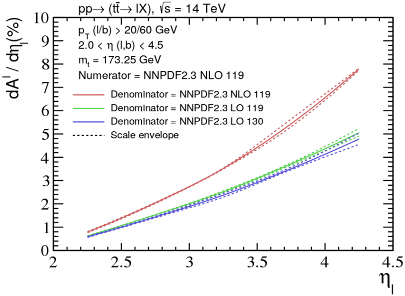
- Work needed on the systematic uncertainties: b-jet tagging, isolation fit, discrimination w.r.t $W + b$.
- Separation between $t\bar{t}$ and single-t using the various final states.
- Differential cross-section.
- Investigate overlap region with ATLAS-CMS

  common particle level / pseudo top definitions to be studied

$t\bar{t}$ charged asymmetry

- Originally proposed in [PRL(2011)107].
- Further work in [LHCb-PUB-2013-009] and [PRD91(2015)054029]
- Considering ℓb : $A_\ell = \frac{N(\mu^+ b) - N(\mu^- b)}{N(\mu^+ b) + N(\mu^- b)}$.
- Lower fraction of $gg \to t\bar{t}$:

  $\to$ less dilution of the asymmetry.
- In $q\bar{q} \to t\bar{t}$:
  - high-x and low-x needed to end in LHCb.
  - high-x parton from the valence q.
    $\to$ less dilution from unknown q direction.



- Background asymmetry need to be well under control.
- A^l_{SM} out of reach with Run I (and probably II) dataset ($5 - 10\%$ statistical uncertainty).
- With upgrade statistics ($50\ fb^{-1}$) with $A^l_{SM} = (1.4 - 2.0)$ expect 0.3% statistical error.

Outlook

- Developed efficient (b, c)-jet tagging method with low light-jet mistag rate.
- $W + (b, c)$-jets production ratios and $\mathcal{A}$ in good agreement with NLO predictions.
- Observed top production in the forward region.
- Combined $t\bar{t}$ and single-t cross sections at $\sqrt{s} = 7, 8$ TeV in good agreement with NLO predictions.

- **LHCb starting its Top physics program, more to come with RunII**

BACKUP

Sytematic uncertainties

For significance evaluation and cross section measurement

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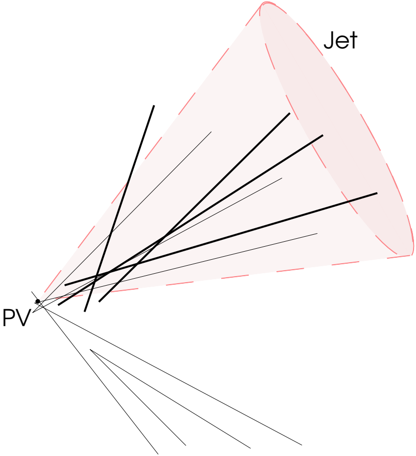
source	uncertainty
GEC	2%
$p_{\mathrm{T}}(\mu)/p_{\mathrm{T}}(j_\mu)$ templates	5%
jet reconstruction	2%
SV-tag BDT templates	5%
b-tag efficiency	10%
trigger & μ selection	2%†
jet energy	5%†
$W \to \tau \to \mu$	1%†
luminosity	1–2%†
Total	14%
Theory	10%

Secondary vertex tagger

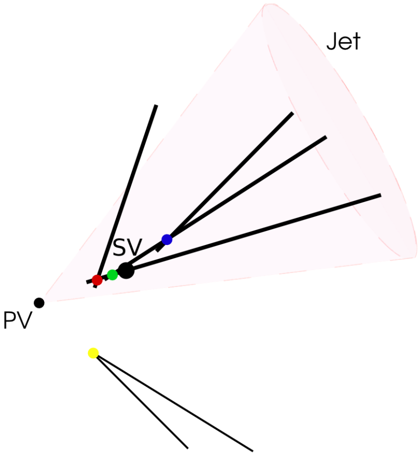
Inclusive vertexing

- Tracks consistent with B,D decays
  - Displaced: $\chi^2_{IP} > 16$
  - High p_T: $p_T > 0.5\ GeV$



Secondary vertex tagger

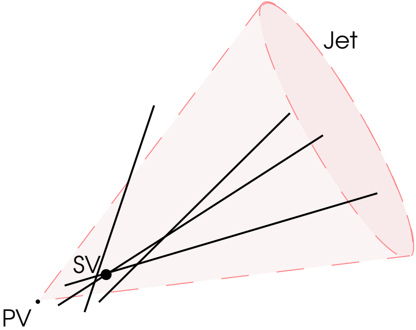
- Tracks consistent with B,D decays
- Inclusive 2-body vertexing
  - $DOCA < 0.2\ mm$, $\chi^2_{vertex} < 10$.
  - $0.4 < m_{vertex} < m_B$.
  - $\Delta R(PV - SV, j) < 0.5$.



Secondary vertex tagger

Inclusive vertexing

- Tracks consistent with B,D decays
- Inclusive 2-body vertexing
- Merge into n-body
  - based on shared tracks
  - $p_T > 2$ GeV, $\chi^2_{d_{PV,SV}} > 5\sigma$.
  - $d_{PV,SV}/p < 1.5$ mm/GeV.
  - max 1 track with $\Delta R(tr, j) > 0.5$.



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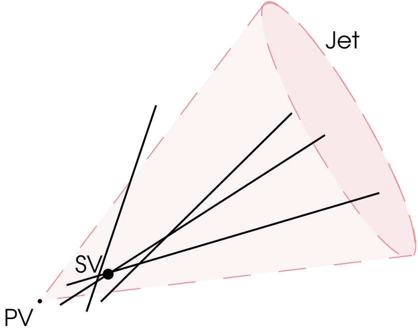
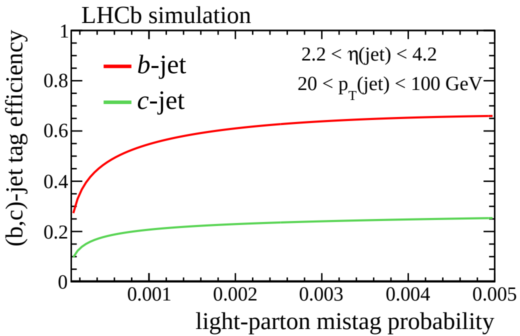


- **mistag rate well below 1% for b tag efficiency $\sim 65\%$, c tag efficiency $\sim 25\%$.**

Performances in simulation

further discrimination with $BDT_{bc\ vs\ udsg}$ cut

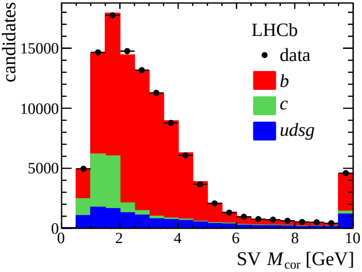


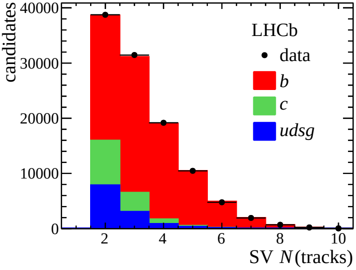
- Flavour content can be obtained by fitting the 2D BDT distributions but when needed they can be used to cut.

Alternative Tagged yields

Systematics for BDT shapes modeling

- Alternative fit using SV based only variables
  - N_{trk} for b-jet discrimination.
  - $M_{cor}(SV)$ for c-jet discrimination.
- 2D fit in each (p_T,η) bins, for each sample.
- Difference with 2D BDT fits used as BDT shapes modeling uncertainties.
- $1-2\%$ uncertainty on the flavour fraction.

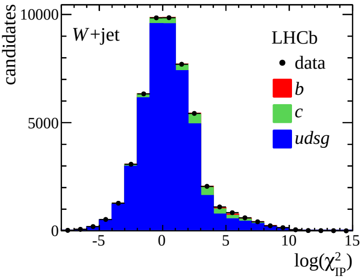




Untagged yields

χ^2_{IP} calibration on W+jet sample

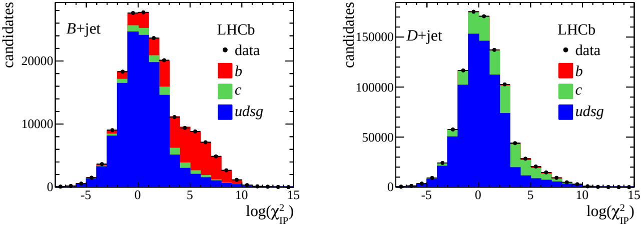
- Fit of the χ^2_{IP} of the highest p_T track or μ in the jet.
- Calibration of the χ^2_{IP} from the W+jet sample (light jet dominated)
  - 95% in MC.
  - $\sigma_{\chi^2_{IP}}$ 10% worse in data.
  - Take the correction as universal
  - s component source of uncertainties



Untagged yields

Fitting the χ^2_{IP} of the highest-p_T track of the probe jet.

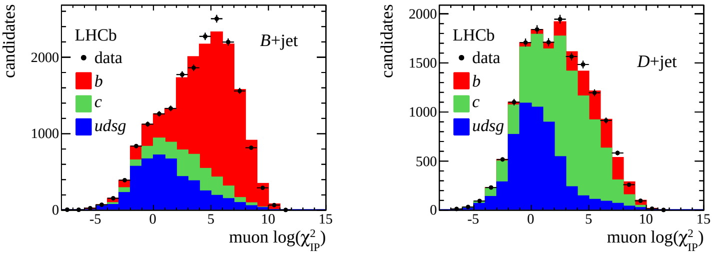
- Requires $p_T(trk)/p_T(j) > 0.1$ and has low fake probability.
- Pros: Inclusive jet sample (covers 95% of the jets).
- Cons: dominated by light parton jets $\rightarrow$ large uncertainties $(10-30\%)$ on the c jets contribution.



Untagged yields

Fitting the χ^2_{IP} of the highest-μ of the probe jet.

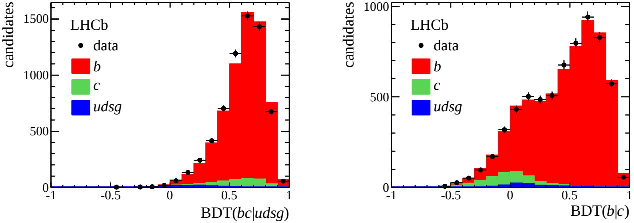
- Adds muon identification to the previous sample
- Pros: Large heavy flavour contribution
- Cons: lower statistics ($\mathcal{O}(10\%)$) and only acounts from semi-leptonic decays.



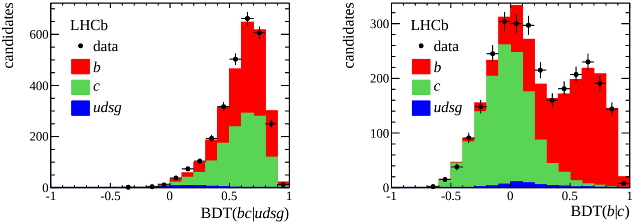
Tagged yields from 2D BDT fit

From probe jet with a high-p_T μ

- In B+jet sample



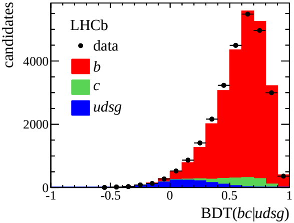
- In D+jet sample

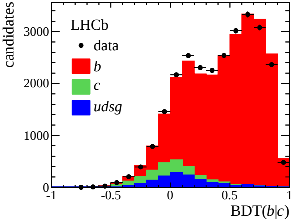


Tagged yields from 2D BDT fit

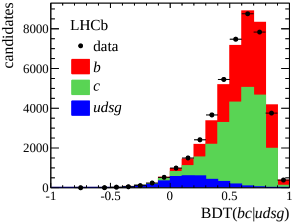
From probe jet with a high-p_T track

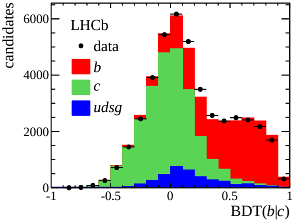
- In B+jet sample





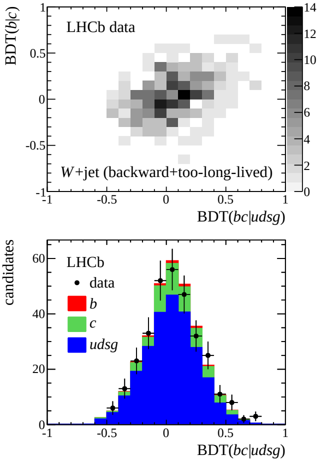
- In D+jet sample





Light jet misidentification

- prompt seen as displaced → studied through "backward" SV.
- decays of long-lived strange hadrons and interaction with material → studied through SV with $FD/p > 1.5\ mm/GeV$.
- Studied in W+jet sample to mitigate the same effect from (b,c)-jets.



Systematic uncertainties on the $(b, c)-$jet yields

source	b jets	c jets
BDT templates*	$\approx 2\%$	$\approx 2\%$
light-parton-jet large IP component*	$\approx 5\%$	$\approx 10-30\%$
IP resolution	–	–
hadron-as-muon probability (muon-jet subsample only)	5%	20%
out-of-jet (b, c)-hadron decay	–	–
gluon splitting	1%	1%
number of pp interactions per event	–	–

In particular, in the determination of $(b, c)-$jet yields in the efficiency denominator:

- $5-30\%$ from the variation of the large-IP component of light parton jets use in the fit of the χ^2_{IP} .
- $5-20\%$ from altering the hadron misID to match the fraction of μ in prompt jet in simulation wrt. data.

W+jet event selection

- Highest p_T jet and highest p_T, prompt μ from same PV.

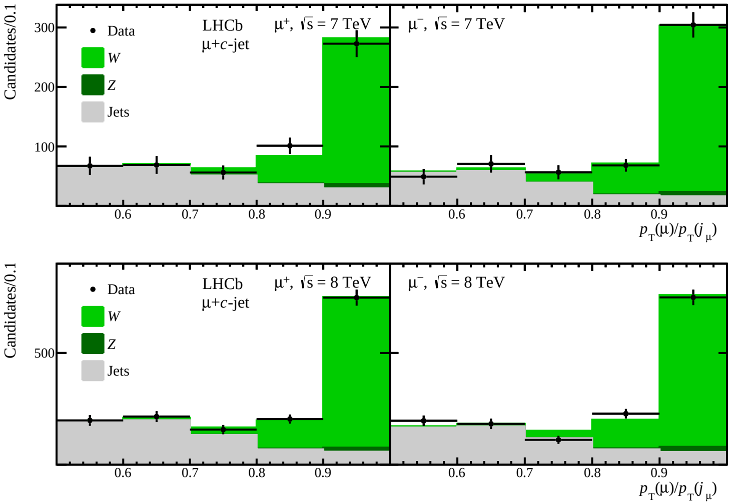
μ	**W** $+$ **jet**	**Z** $+$ **jet**
trigger	no OS μ	$60 < M_{\mu\mu} < 120$ GeV
$IP < 0.04$ mm, good track	$p_T(j_\mu + j) > 20$ GeV	
$(E_{ECAL} + E_{HCAL})/p < 4\%$		

- $p_T(j_\mu + j) > 20$ $GeV \equiv p_T(\mu + j) > 20 GeV$ (for Wj to about 1%)
- Isolation defined by $p_T(\mu)/p_T(j_\mu)$, were j_μ is the jet clustered with the μ.

Getting the Wc and Wb components

Wc yields extraction

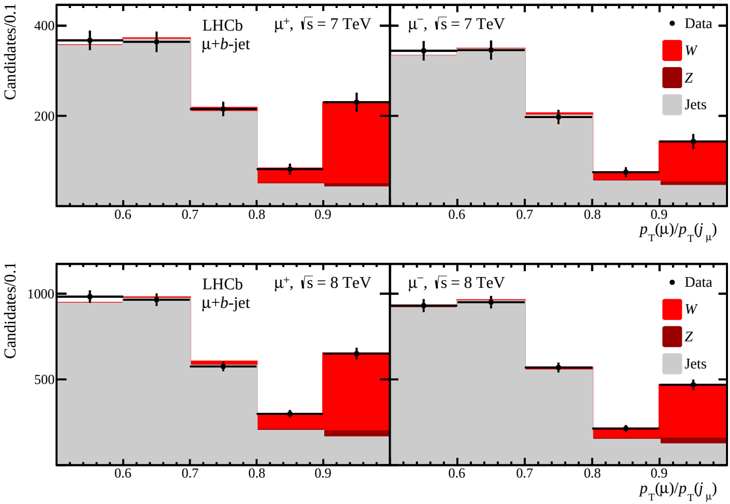
- Isolation templates using the same method than for Wj.
- $Z[\mu(\mu)]c$ from $Z[\mu\mu]c$ in data, extracted with 2D BDT fit.



Getting the Wc and Wb components

Wb yields extraction

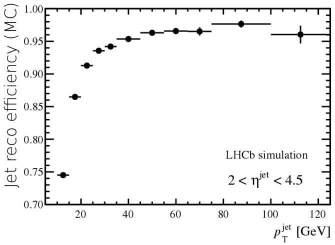
- Isolation templates using the same method than for Wj.
- $Z[\mu(\mu)]b$ from $Z[\mu\mu]b$ in data, extracted with 2D BDT fit.

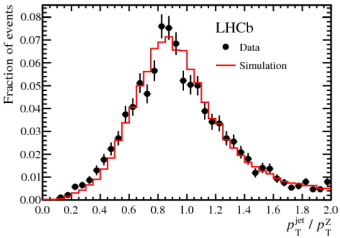


Jets @ LHCb

- ParticleFlow approach:
  - Charge particles from tracking.
  - Neutrals from calorimetry.
- Anti-k_T with $R = 0.5$.
- Jet Energy Scale:
  - corrections from MC (factor 0.9 to 1.1)
  - Validated on data, JES data vs. MC difference $< 5\%$
- Jet Energy Resolution:
  - $\sim 15 - 20\%$ for $p_T \in [10, 100 \text{ GeV}]$
  - Same ball-park than GPD for low-p_T.
  - Studied in $Z + jet$ and b-enriched dataset.

Z+jet @ 7TeV [JHEP01 (2014) 033]

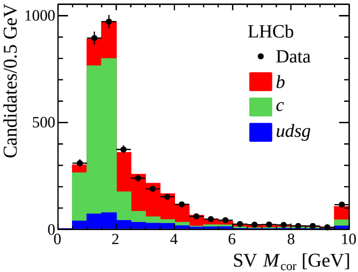


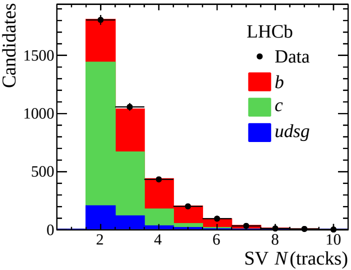


Getting the Wc and Wb components

Consistency check

- Alternative fit with M_{cor}, N_{trk} on events with $BDT(bc|udsg) > 0.2$.
- Yields in 5% agreement with nominal fit.
- misidentification probability fo W+light $\sim 0.3\%$ which agrees with simulation.





Systematic uncertainties

[PRD92 (2015) 052001]

- μ+(b,c)tag corrected for SV tagging efficiencies.
- W+jet and W+(b,c)jet yields corrected for backgrounds from $Z \to \tau\tau$ and top.
- **Charge asymmetry**: $\mathcal{A}(Wq) = \frac{\sigma(W^+q)-\sigma(W^-q)}{\sigma(W^+q)+\sigma(W^-q)}$.
  - Obtained from $\mu + (b, c)$ yields in $p_T(\mu)/p_T(j_\mu) > 0.9$.
  - Most backgrounds are charge symmetric (only introduce dilution)$\to \mathcal{A} \sim \frac{\mathcal{A}_{raw}}{purity}$

Source	$\frac{\sigma(Wb)}{\sigma(Wj)}$	$\frac{\sigma(Wc)}{\sigma(Wj)}$	$\frac{\sigma(Wj)}{\sigma(Zj)}$	$\mathcal{A}(Wb)$	$\mathcal{A}(Wc)$
Muon trigger and selection	–	–	2%	–	–
GEC	1%	1%	1%	–	–
Jet reconstruction	2%	2%	–	–	–
Jet energy	2%	2%	1%	0.02	0.02
(b, c)-tag efficiency	10%	10%		–	–
SV-tag BDT templates	5%	5%		0.02	0.02
$p_{\mathrm{T}}(\mu)/p_{\mathrm{T}}(j_\mu)$ templates	10%	5%	4%	0.08	0.03
Top quark	13%	–	–	0.02	
$Z \to \tau\tau$	–	3%	–	–	–
Other electroweak	–	–	–	–	–
$W \to \tau \to \mu$	–	–	1%	–	–
Total	20%	13%	5%	0.09	0.04

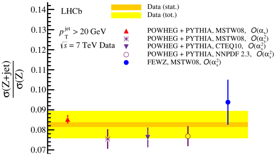
SM predictions

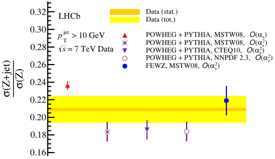
- NLO prediction from MCFM[JPG(2015)42] with 4FS and CT10 PDF set,[PRD(2010)82].
- NLO PowhegBox[JHEP(2012)1201] showered with Pythia8[CPC(2008)178:852-867] (for consistency check)
- Prediction uncertainties from PDFs, α_s and scale.
  - Uncertainties from integration negligible wrt. other uncertainties.
  - PDF uncertainties using asymmetric Hessian approach.
  - scale uncertainties using 7-point scale method.
  - α_s uncertainties using envelope of $\alpha_s(M(Z)) \in [0.117, 0.118, 0.119]$.
  - Uncertainties from $m_{c,b,t}$ found to be negligible.
- α_s and PDF uncertainties are found to be close to 100% correlated between bins.

Z+jet production in *pp* at $\sqrt{s} = 7$ *TeV*

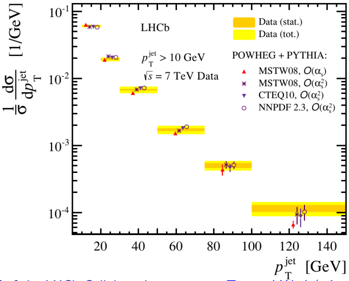
Result

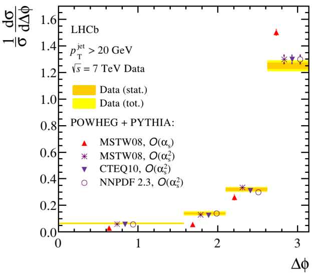
- Predictions from POWHEG+PYTHIA at $O(\alpha_s)$ and $O(\alpha_s^2)$ with different PDF sets.
- Predictions from FEWZ at $O(\alpha_s^2)$ not corrected for hadronisation and underlying event.





- Not corrected for FSR
- Shapes in good agreement with NLO





Central forward $b\bar{b}$ asymmetry $A_{FC}^{b\bar{b}}$

Motivation

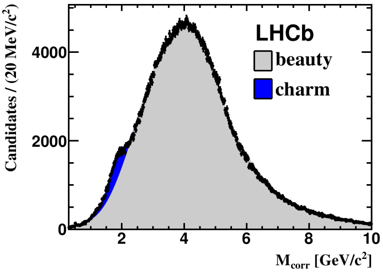
- Depending on new physics flavour structure, asymmetry could shows up in the bottom sector.

[arXiv:1108.3301,Kahawala et al.]

- At LHC access to the forward central asymmetry.
- Expected to be $O(1\%)$ from QCD with an extra $O(1\%)$ in the Z mass region.

PRL 113 (2014) 082003

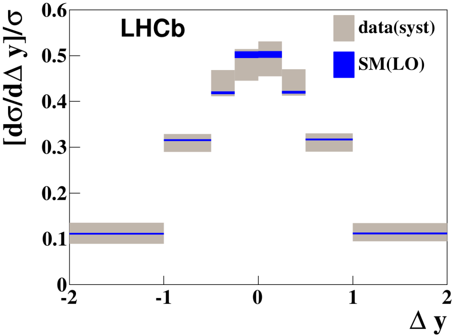
- Analysis performed with 1 fb^{-1}
- Pairs of b-jets with $\Delta\phi(bb) > 2.6$ *rad*.
- One of the b-jets charge is tagged with a muon.
- Purity of the charge tagging $70.3 \pm 0.3\%$



Central forward $b\bar{b}$ asymmetry $A_{FC}^{b\bar{b}}$

Result with 1 fb^{-1}

PRL 113 (2014) 082003



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

$\Delta y = |y_b| - |y_{\bar{b}}|$

In different m_{bb} bins:

- $A_{FC}^{b\bar{b}}(40, 75) = 0.4 \pm 0.4 \pm 0.3$ %
- $A_{FC}^{b\bar{b}}(75, 105) = 2.0 \pm 0.9 \pm 0.6$ %
- $A_{FC}^{b\bar{b}}(> 105) = 1.6 \pm 1.7 \pm 0.6$ %

- No deviation from expectation with available statistics.
- Still 2 fb^{-1} of the Run I data to be analysed.
- More efficient b-tagging available now.

PHYSICAL REVIEW D **86,** 034021 (2012)

Next-to-leading order QCD predictions for $W + 1$ jet and $W + 2$ jet production with at least one b jet at the 7 TeV LHC

TABLE V. Inclusive event cross sections (in pb) for different PDF sets including PDF + α_s uncertainties at 68% C.L., determined according to the PDF4LHC NLO prescription [22] (with $\mu_R = \mu_F = \mu_0$).

	W^+b incl.		$W^+(bb)$ incl.	W^-b incl.		$W^-(bb)$ incl.
	4FNS	5FNS	4FNS	4FNS	5FNS	4FNS
NNPDF2.1 [19]	44.1	59.2 ± 1.7	11.4 ± 0.3	27.6	36.2 ± 1.0	7.1 ± 0.2
CTEQ6.6 [18,20]	42.6	56.7 ± 2.1	10.9 ± 0.3	26.3	34.8 ± 1.3	6.8 ± 0.2
MSTW2008 [21]	44.2	59.8 ± 1.7	11.5 ± 0.3	28.6	37.9 ± 1.0	7.4 ± 0.2