LHCb Report and Wishes

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xFitter Users Meeting, University of Oxford

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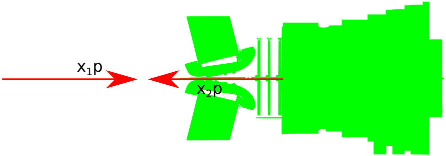
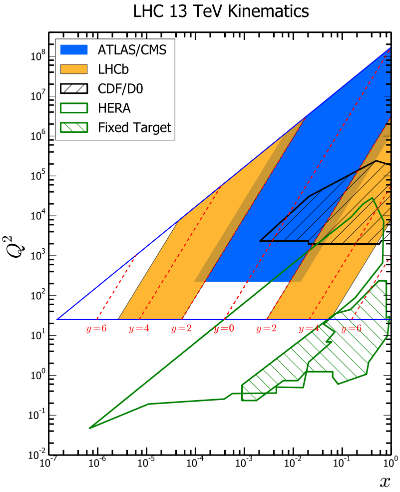
UNIVERSITY OF LIVERPOOL

outline

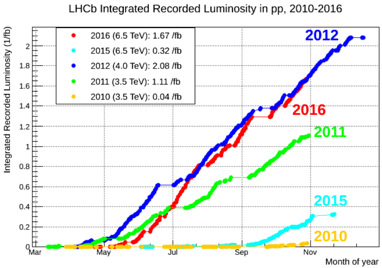
introduction

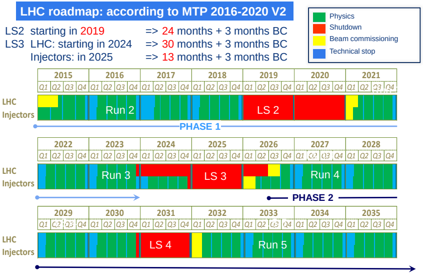




- LHCb's forward acceptance provides interesting possibilities to study Parton Distribution Functions
- two distinct large and small-x regions covered
- measurements of SM processes at LHCb can constrain the PDFs in this region

data



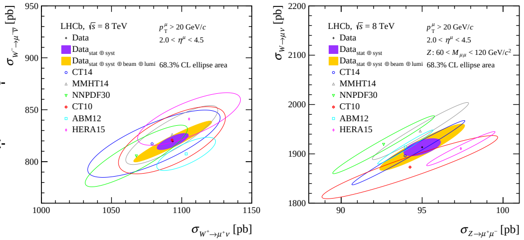


- collected 3 fb^{-1} of data in Run I at 7 and 8 TeV
- so far $\sim$ 2 fb^{-1} of Run II data at 13 TeV
- expect 5 fb^{-1} by end of Run II
- LHCb upgrade aims for 50 fb^{-1}

measurements

W/Z production measurements

- measurements of $W \to \ell\nu$ production made at 7 and 8 TeV
- measurements of $Z \to \ell\ell$ production at 7, 8 and 13 TeV

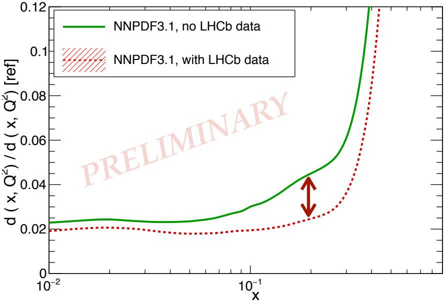


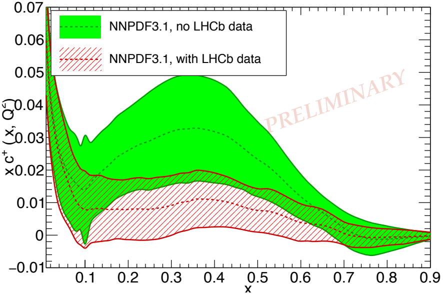
8 TeV muon systematics

Source	Uncertainty [%]		
	σ_{W+}	σ_{W-}	σ_Z
Statistical	0.19	0.23	0.27
Purity	0.28	0.21	0.21
Tracking	0.26	0.24	0.48
Identification	0.11	0.11	0.21
Trigger	0.14	0.13	0.05
GEC	0.40	0.41	0.34
Selection	0.24	0.23	—
Acceptance and FSR	0.16	0.14	0.13
Systematic	0.65	0.61	0.67
Beam energy	1.00	0.86	1.15
Luminosity	1.16	1.16	1.16
Total	1.67	1.59	1.79

- precision luminosity
  - 1.2% in 2012 dataset
  - best achieved at a bunched beam hadron collider
- per-mille level precision on normalised distributions and ratios
- dominant uncertainty due to tracking efficiencies (Z) and purity (W)

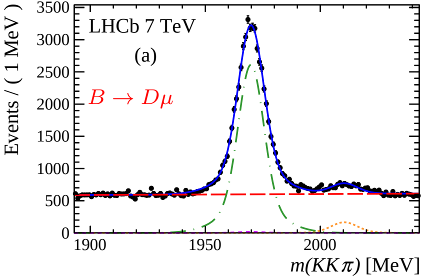
impact of W/Z measurements

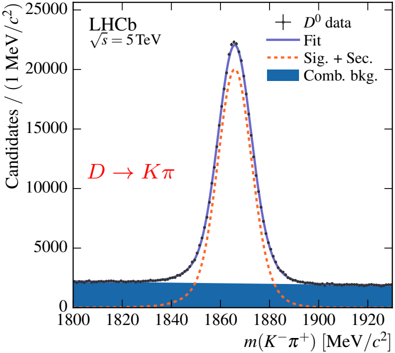




- preliminary plots of impact of LHCb data in NNPDF 3.1 (thank to Juan Rojo)
- factor of 2 decrease in uncertainty on down quark PDF at $x = 0.2$
- sensitivity to charm quark content of the proton at large-x
  - constraints on non-perturbative charm

beauty and charm production at LHCb

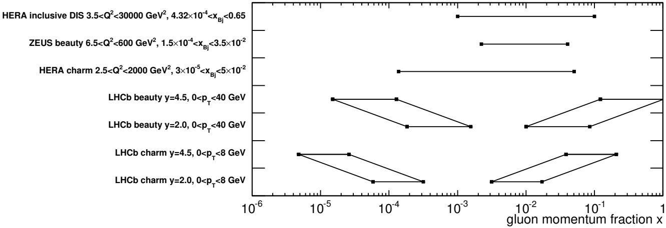




- LHCb is a dedicated heavy flavour experiment
- unique ability to identify exclusive B and D decays
  - good vertexing resolution, low mass triggers, particle identification
- beauty hadron production measured at 7 TeV using exclusive B decays and $B \to J/\psi X$ decays and at 7 and 13 TeV using semi-leptonic B decays
- charm production measured at 5, 7 and 13 TeV using exclusive charm decays

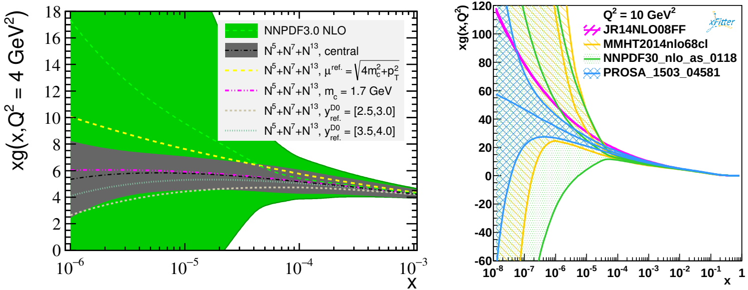
sensitivity to PDFs

[*Eur. Phys. J.*(2015)C75:p. 396]



- LHCb beauty and charm data sensitive to very low gluon PDF ($\sim 5x10^-6$)
- charm production in ultra-high-energy cosmic rays source of background to prompt neutrino flux
- overlap in kinematics between cosmic rays and LHC
- particularly interesting for astrophysics

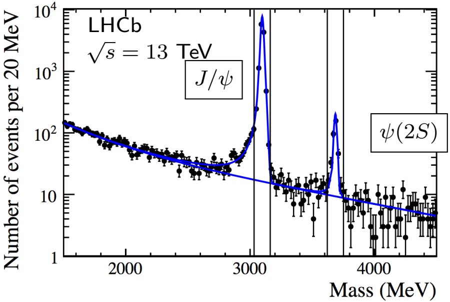
impact of beauty and charm production

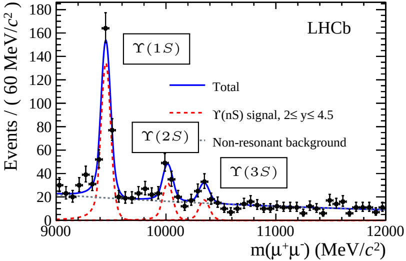


- potential of the LHCb data to constrain the low-x gluon has been studied by two groups [*Phys. Rev. Lett.*(2017)118:p. 072001], [`1611.03815 [hep-ph]`]
- normalised cross-sections provide best constraints
  - less sensitive to higher order effects
- inclusion of 5, 7 and 13 TeV LHCb charm data in NNPDF framework results in factor of 10 decrease in gluon PDF uncertainties at low-x
- PROSA collaboration include both B and D data using xFitter framework - also see significant reductions

central exclusive production at LHCb

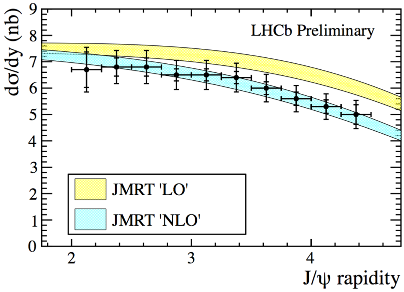
- exchange of neutral, colourless particles - protons remain intact
- experimental signature - events with just two muon tracks in the final state

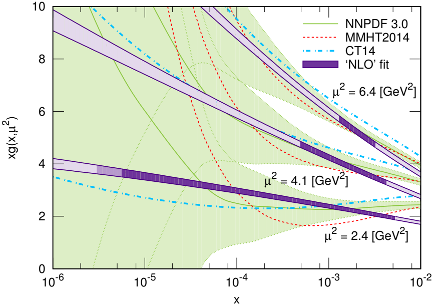




- LHCb is ideal environment to perform measurements
  - relatively low number of pile-up collisions
  - backward VELO coverage can be exploited to identify rapidity gap
- forward region constrains gluon PDF at x down to $\sim 3x10^{-6}$
- addition of HERSCHEL detector in Run II increases measurement precision

impact of exclusive J/ψ measurements

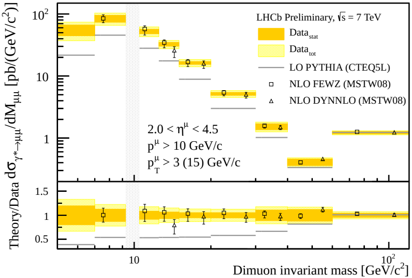




- exclusive J/ψ production cross-section $\propto (xg(x,\bar{Q}^2))^2$
- JMRT analysis updated to include most recent LHCb data [*J. Phys.*(2017)G44:03LT01]
- significant reduction in low-x gluon PDF when including central exclusive production measurements from LHCb
- however, 'NLO' gluon PDF obtained from exclusive data not directly comparable to $\overline{\text{MS}}$ PDFs of NLO global PDF sets
  - work ongoing in this direction

future measurements

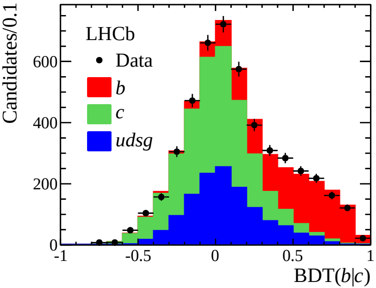
Drell-Yan production

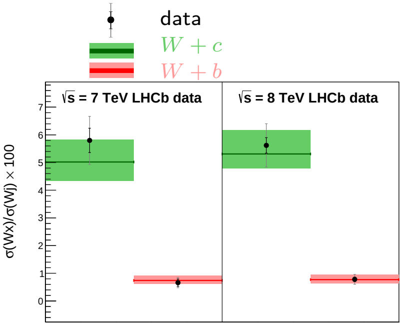


- large range of (x, Q^2) phase space can be covered by measurements of low-mass Drell-Yan $(\gamma^* \to \mu\mu)$
  - further constraints at low-x ($\sim 10^{-4}$)
- preliminary analysis performed with 2010 dataset (37 pb^{-1})
- measurement is ongoing and plan is to release results with Run I and Run II data in the near future

W+b and c jets

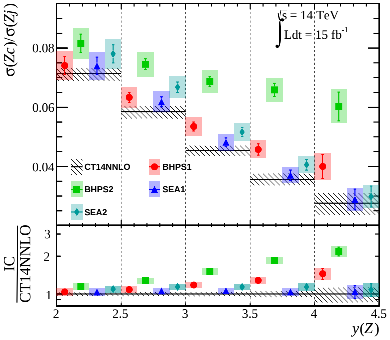
[*Phys. Rev.*(2015)D92:p. 052001]

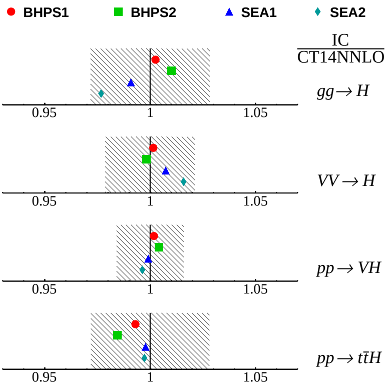




- LHCb demonstrated potential to perform b and c tagging of jets in Run I
- measurements of W production in association with c-jets sensitive to strange content of the proton
- measurements of $W + c$ in Run-I based on $\sim 2,000$ events
- larger statistics available in Run-II - more precise measurements

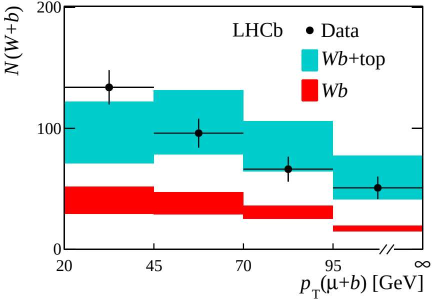
[*Phys. Rev.*(2016)D93:p. 074008]

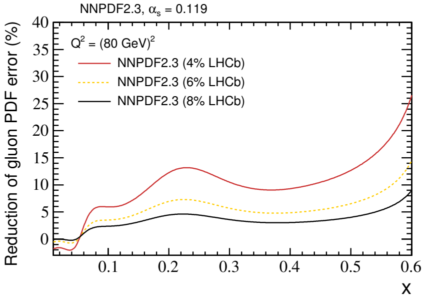




- c-tagging can also be exploited to measure $Z + c$ production at LHCb in Run-II (and Run-III)
- sensitive to intrinsic charm content of proton
- per-cent level effects on Higgs production cross-sections

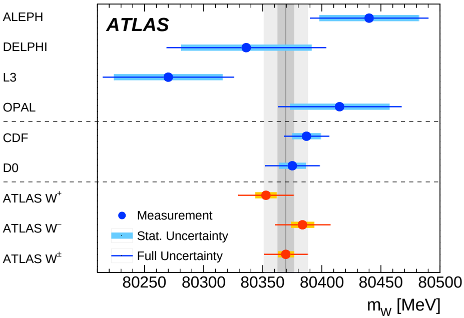
top production

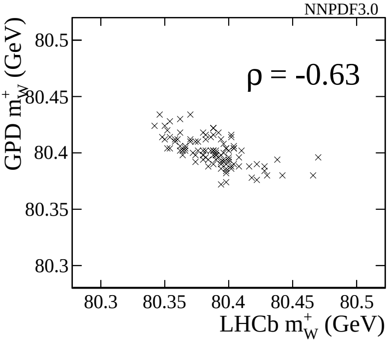




- top production at LHCb acts as a sensitive probe of high-x gluon PDF [*JHEP*(2014)02:p. 126]
- low integrated luminosity, low acceptance limits statistical sensitivity
- first observation made in μb final state in Run-I [*Phys. Rev. Lett.*(2015)115:p. 112001]
  - measurement also made in μbb final state
- increase in centre-of-mass energy gives ∼10 increase in μeb final state
  - highest purity final state, highest precision
- measurement already underway with Run II data

W mass measurements



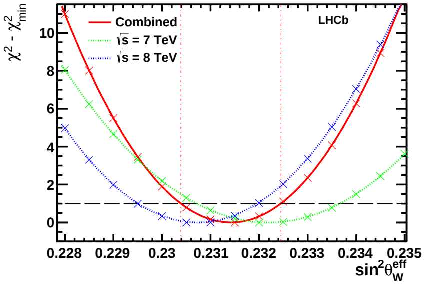


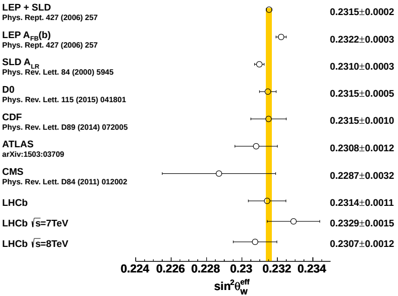
- precision measurement of the W mass from ATLAS [1701.07240 [hep-ex]]
  - p_T^ℓ fit dominates combination (86%)
  - PDF uncertainty significant contribution to final uncertainty
- LHCb can perform measurement in p_T^ℓ mode (no missing energy for m_T)
- PDF uncertainties on measurements in the central and forward regions are anticorrelated
- LHCb can contribute to overall measurement [*Eur. Phys. J.*(2015)C75:p. 601]

$\sin^2\theta_W^{\text{eff.}}$

[*JHEP*(2015)09:p. 049]

- enhanced A_{FB} at large rapidities gives LHCb most sensitivity to $\sin^2\theta_W^{\text{eff.}}$ at the LHC





- most precise measurement at the LHC
  - statistically limited
- largest systematic uncertainty due to PDFs
- further constraints on PDFs ahead of Run II will give more precise result

conclusions and outlook

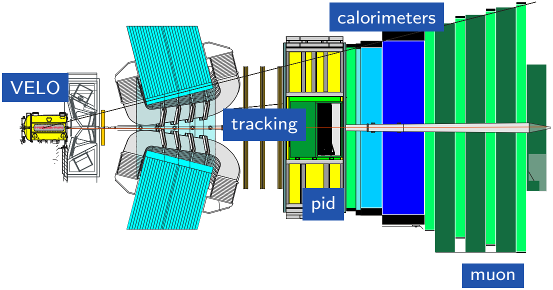
- measurements made so far by LHCb have had a significant impact on PDFs at high and low x
- plenty of plans to make further measurements with data from Run-II (and Upgrade)
- more precise PDFs will also improve precision of measurements of m_W and $\sin^2\theta_W$
- while we have no extensive experience of using xFitter within the collaboration so far, would be very happy to change that in the coming years
  - offers an excellent tool to study the potential of our data

backup

LHCb

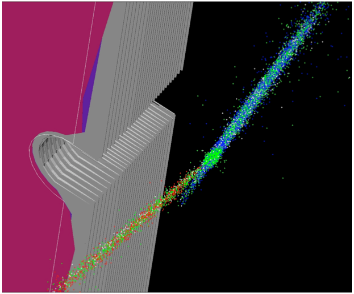
[*JINST* (2008)3:S08005]

- optimised to study $\mathcal{CP}$ Violation in B and D decays at the LHC
- fully instrumented between $2.0 \leq \eta \leq 5.0$
- excellent tracking, PID and vertexing capabilities (muon id efficiency ~98%)



precision luminosity at LHCb

[*JINST* (2014)9:P12005]



Distribution of vertices overlaid on detector display. z-axis is scaled by 1:100 compared to transverse dimensions to see the beam angle.
Beam 1 - Beam 2, Beam 1 - Gas, Beam 2 - Gas.

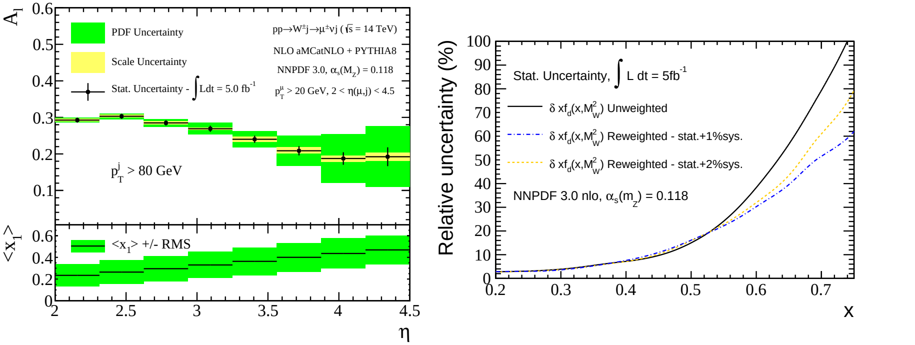
- luminosity measured at LHCb using two methods: Van der Meer Scan (VDM) and Beam-Gas Imaging (BGI)
- beams scanned across each order in VDM scan to trace beam profile
- in BGI method neon injected in beam-pipe to reconstruct beams using collision vertices

- BGI and VDM methods combined to achieve precision of 1.7% in 2011 and 1.2% in 2012
- "the most precise luminosity measurement achieved so far at a bunched-beam hadron collider"

W mass - PDF uncertainties

PDFs	Experiments	δ_{PDF} (MeV)	α
PDF4LHC(2-sets)	2×GPD	10.5	$(0.26, 0.74, 0, 0)$
PDF4LHC(2-sets)	2×GPD + LHCb	7.7	$(0.30, 0.45, 0.21, 0.04)$
PDF4LHC(3-sets)	2×GPD	16.9	$(0.50, 0.50, 0, 0)$
PDF4LHC(3-sets)	2×GPD + LHCb	12.7	$(0.43, 0.41, 0.11, 0.04)$
NNPDF30	2×GPD	5.2	$(0.50, 0.50, 0, 0)$
NNPDF30	2×GPD + LHCb	3.6	$(0.35, 0.47, 0.16, 0.02)$
MMHT2014	2×GPD	9.2	$(0.45, 0.55, 0, 0)$
MMHT2014	2×GPD + LHCb	4.6	$(0.39, 0.14, 0.46, 0)$
CT10	2×GPD	11.6	$(0.33, 0.67, 0, 0)$
CT10	2×GPD + LHCb	6.3	$(0.38, 0.20, 0.40, 0.03)$

Wj



- forward W production in association with high p_{T} jets sensitive to large-x PDFs
- differential charge asymmetry versus muon η is experimentally and theoretically clean
  - pdf uncertainties dominant
- LHCb measurements at a precision of 1% would reduce uncertainties on d-quark PDFs by 35% at high-x
- also improvements in the gluon and u quark PDFs