Impact of LHC measurements on parton density functions

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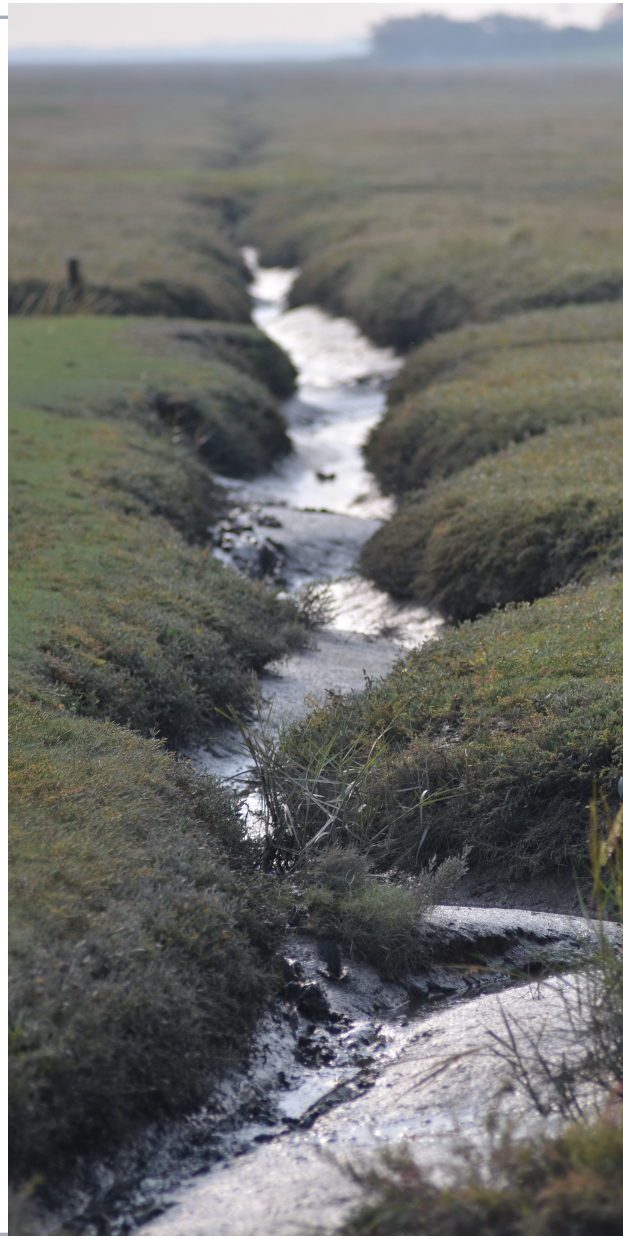
Outline

recent results on production of

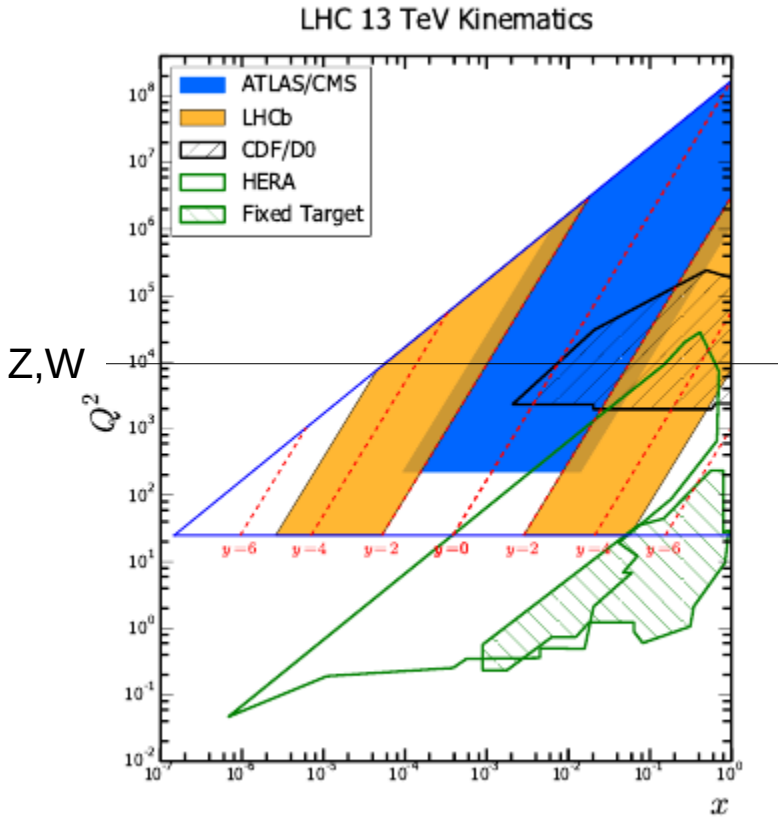
- jets
- isolated photons
- inclusive single vector bosons
- associated production of V-bosons
- central exclusive production



Kinematic region of LHC experiments

$$\underbrace{\sigma(x,Q^2)}_{hadronic\ x-sec.} = \sum_{a,b} \int_0^1 dx_1\, dx_2 \underbrace{f_a(x_1 Q^2) f_b(x_2 Q^2)}_{PDFs} \times \underbrace{\hat{\sigma}(x_1, x_2, Q^2)}_{partonic\ x-sec}$$

- x-section measurements and ratios sensitive to parton density functions (PDFs)
- measurements used to constrain PDFs → important for e.g. searches
- LHC, HERA, Tevatron and fixed target data: cover wide range in x-Q^2 plane



Jet production

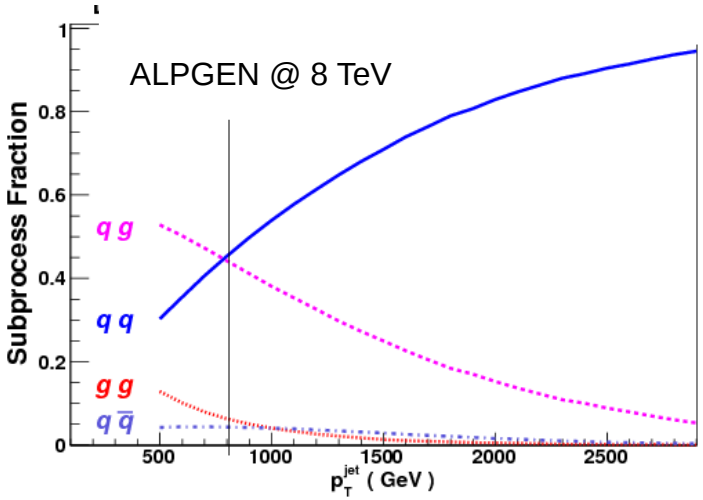
- p_T < 800 GeV, quark-gluon scattering

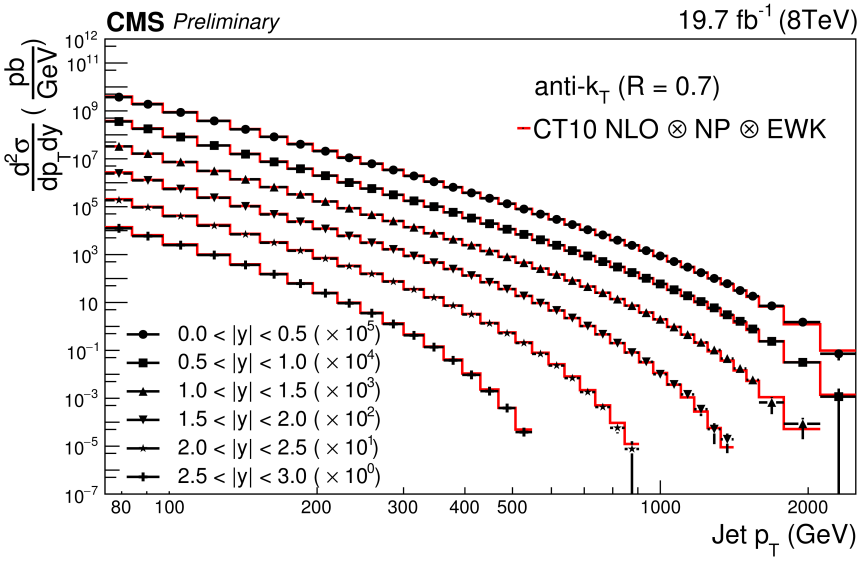
  → sensitivity to gluon

- p_T > 800 GeV: quark-quark scattering

  → sensitivity to quark

- LHC jet data provide constraints in high-x region and probe QCD at high scales





Inclusive jets @ 8 TeV

→ good agreement with NLO QCD over 12 orders of magnitude

2.76 TeV arXiv:15120612

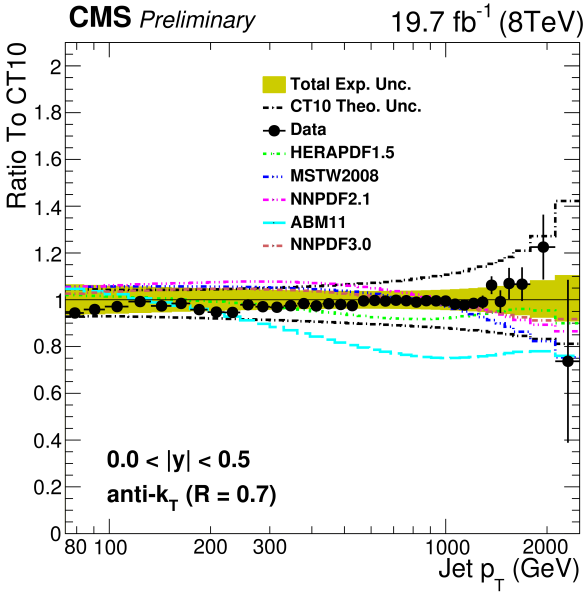
Inclusive jets @ 8 TeV

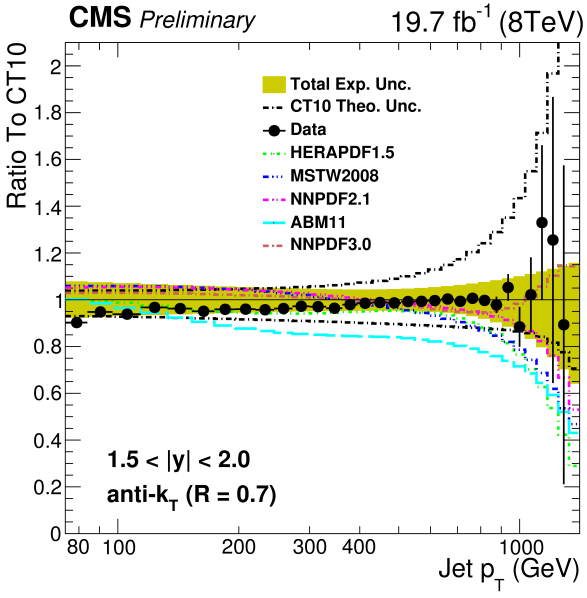
p_T(jet)>74 GeV

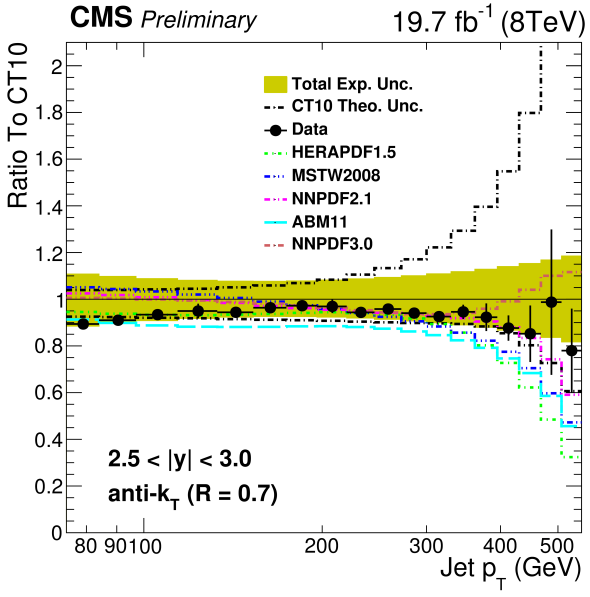
sensitive to α_s and PDF

uncertainties highly correlated

ratio to theory for different PDF sets → valuable input for PDFs







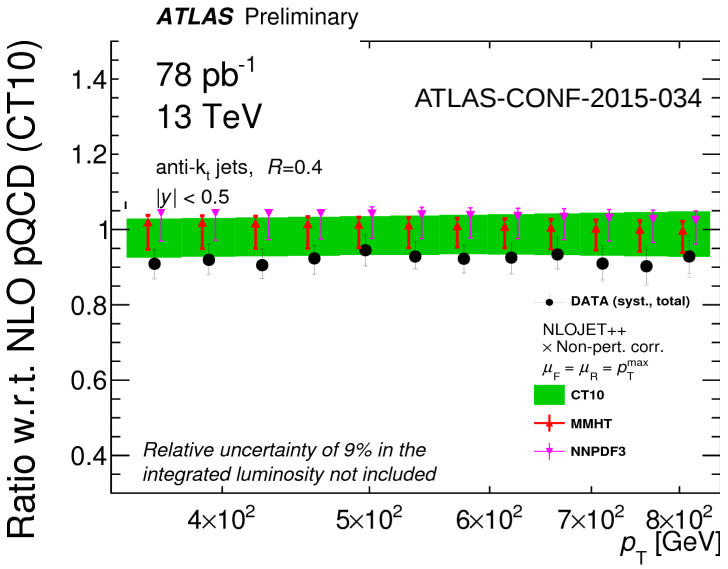
Inclusive jets at 13 TeV

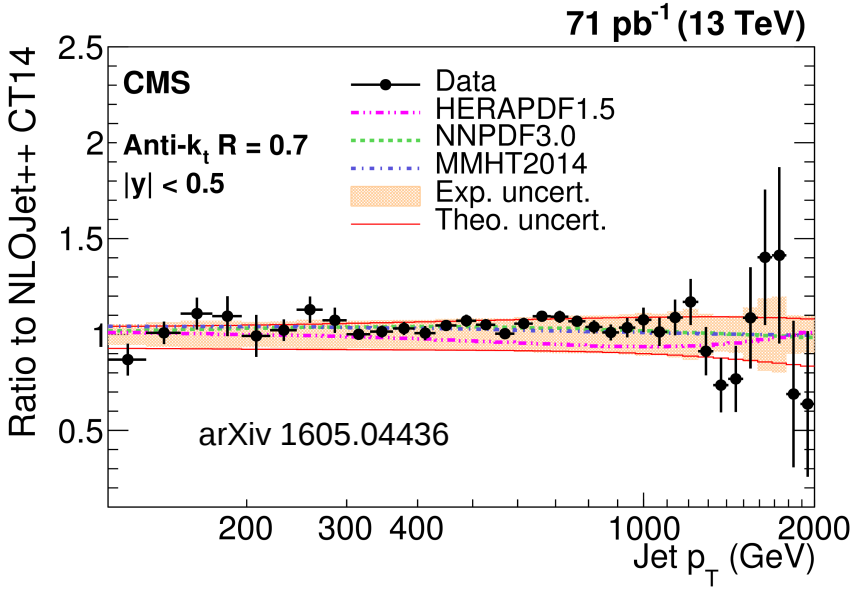
CMS: arXiv 1605.04436
ATLAS-CONF-2015-034

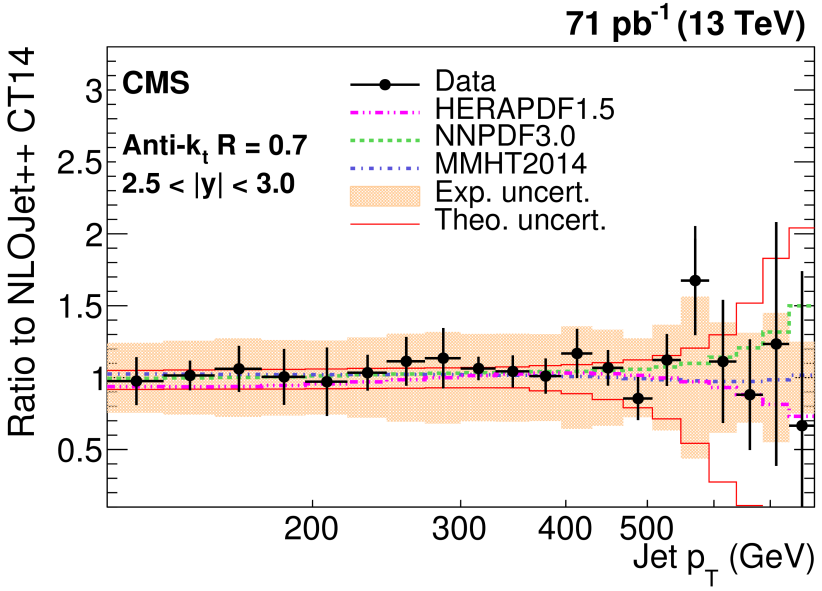
CMS: double differential x-sections with R=0.7 and 0.4
ATLAS: differential x-section with R=0.4

ratios over NLOJet++

- R=0.4 5-10% overestimation
  indication of soft effects?
- central: different PDF sets agree
- sensitivity in forward region at high p_T







Isolated photons @ 8 TeV

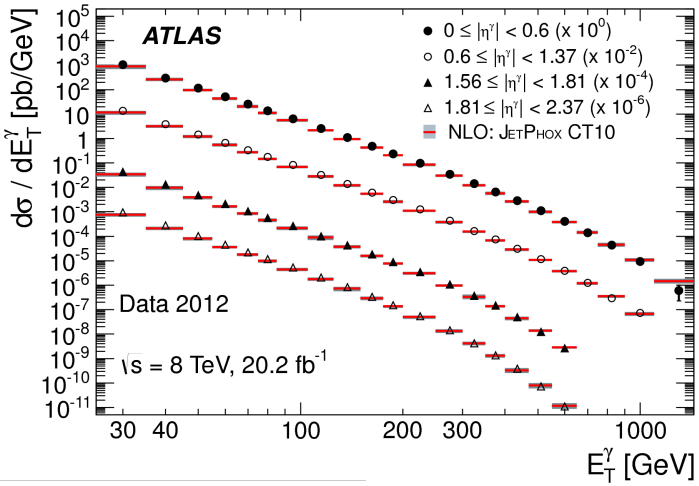
ATLAS:arXiv:1605.03495

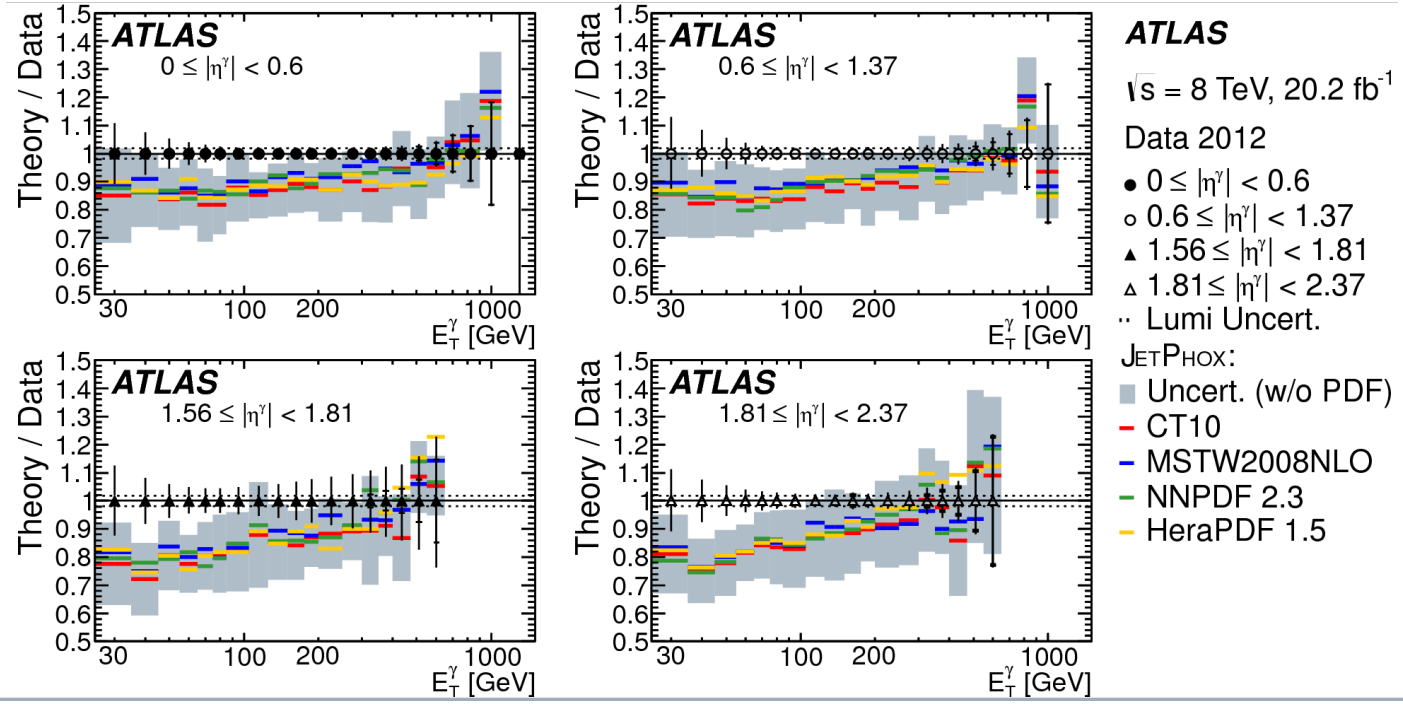
dominant production: q g → q γ

dominant systematic uncertainties:
energy scale, unknown admixture of fragmentation
background correlations

25< E_T <1500 GeV: measurement over 10 orders of

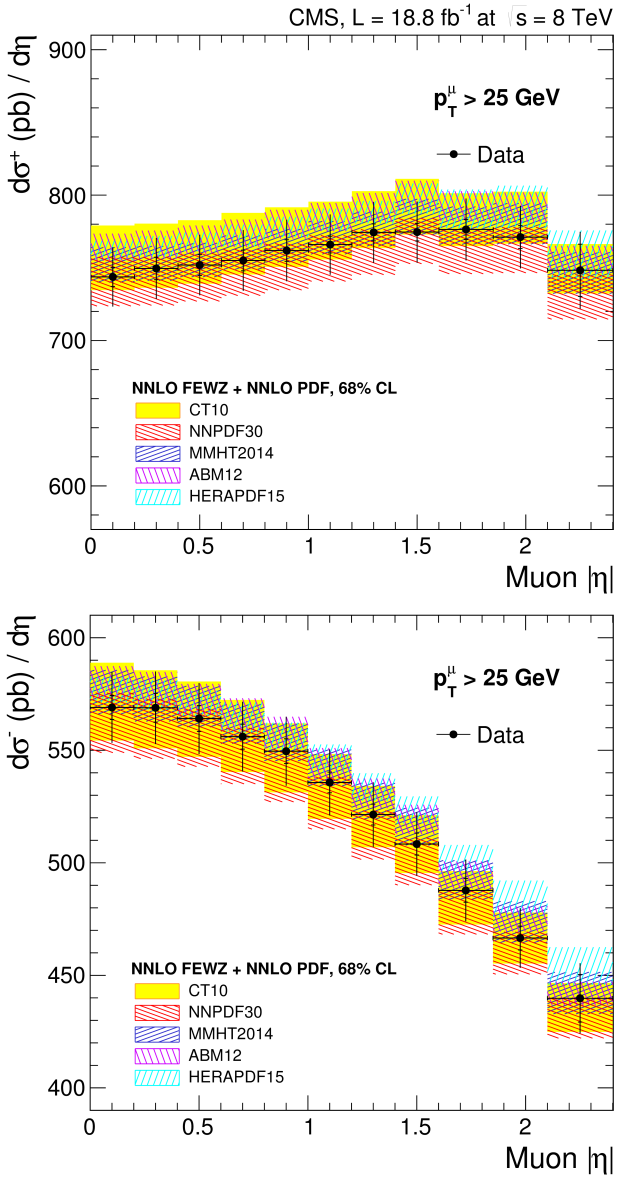
JetPhox: too low in normalisation

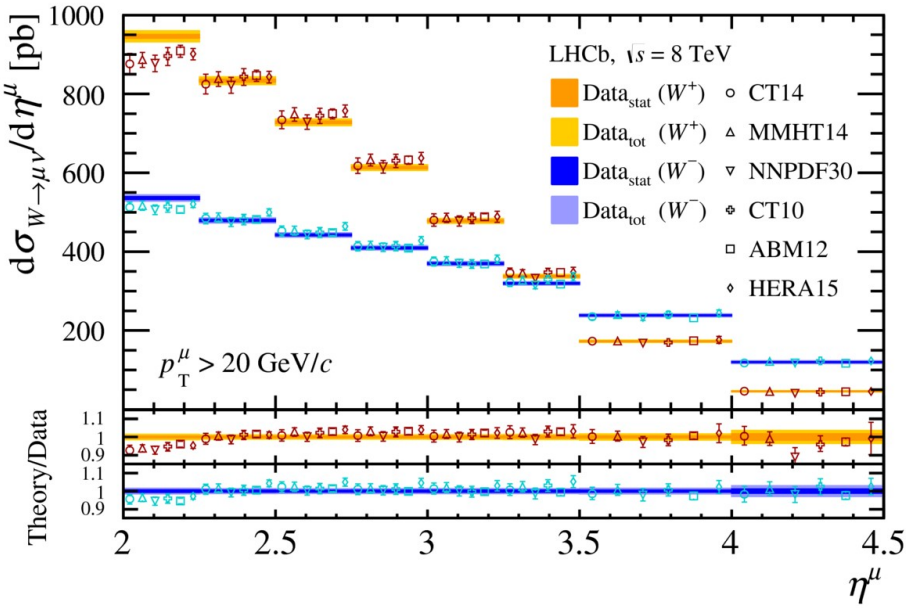




W @ 8 TeV: inclusive cross sections

LHCb JHEP 01 (2016) 155
CMS: arXiv:1603.01803





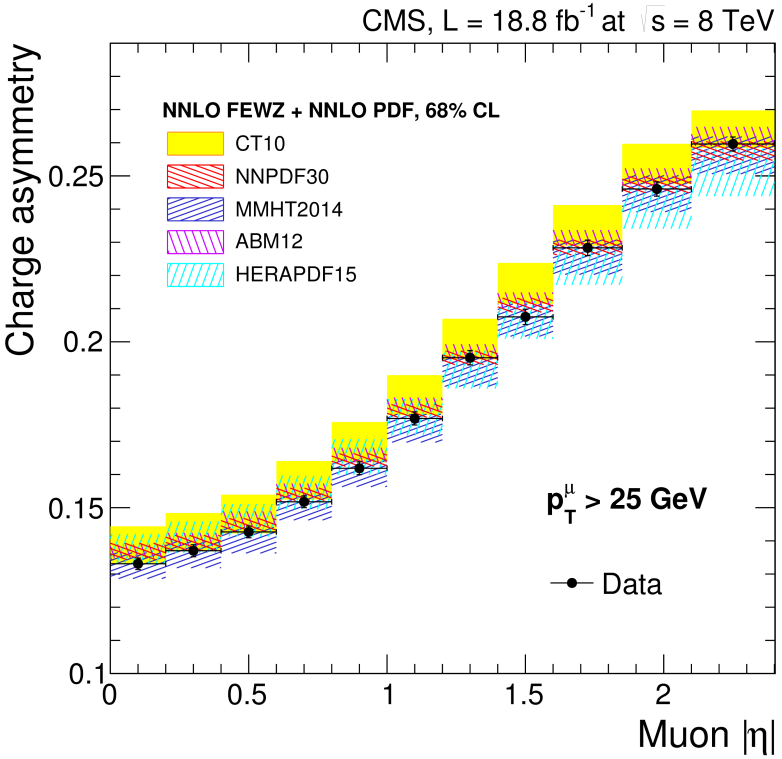
forward: overall good description

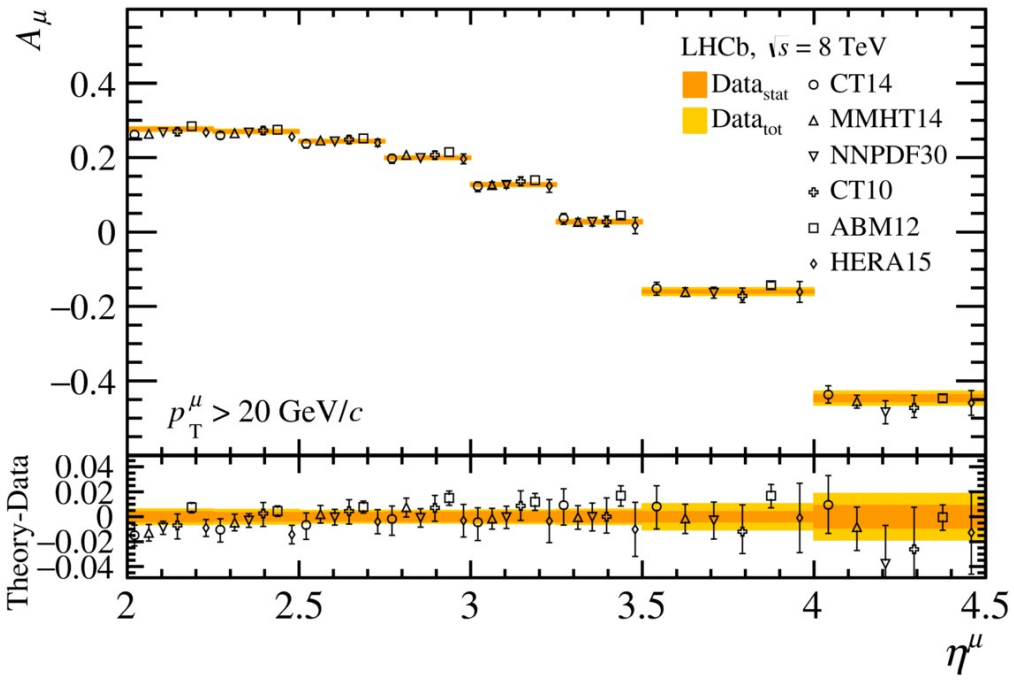
central: CT10, ABM12, HERA1.5 tend to be higher
NNPDF3.0 lower than the data

luminosity uncertainty: 2.6% (CMS), 1.6% (LHCb)
other systematic uncertainties sub%-level

W @ 8 TeV: lepton charge asymmetry

LHCb:JHEP 01 (2016) 155
CMS:arXiv:1603.01803





lepton charge asymmetry: $$A_\mu(\eta_i) = \frac{\sigma_{W^+\to\mu^+\nu}(\eta_i) - \sigma_{W^-\to\mu^-\overline{\nu}}(\eta_i)}{\sigma_{W^+\to\mu^+\nu}(\eta_i) + \sigma_{W^-\to\mu^-\overline{\nu}}(\eta_i)}$$

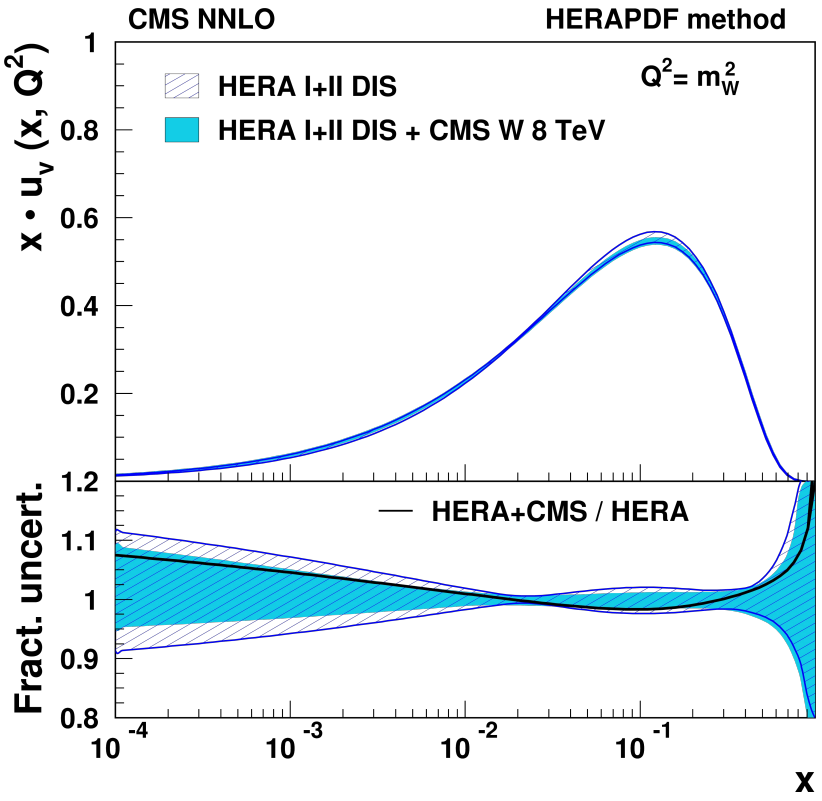
high experimental precision – uncertainties at sub-% level

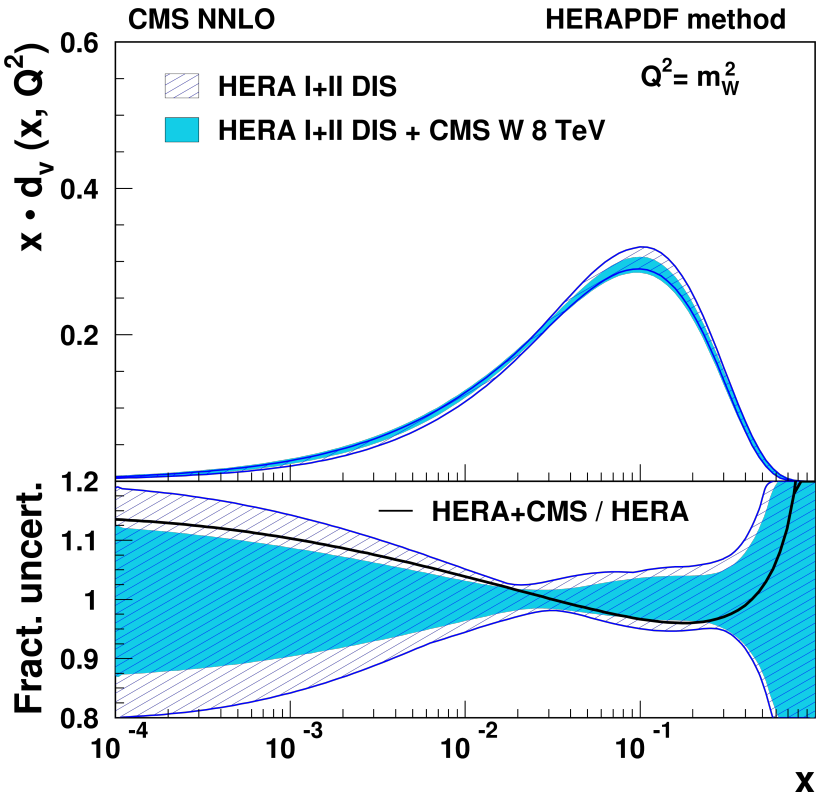
agreement with different PDF sets within 1-2%

asymmetry constrains u/d PDF ratio

Impact of 8 TeV CMS data on PDF

CMS:arXiv:1603.01803





HERAFitter @ NNLO using the lepton charge asymmetry
heavy quark contribution: general mass variable flavor number scheme
$Q^2 \geq Q^2_{min} = 3.5\ GeV^2$

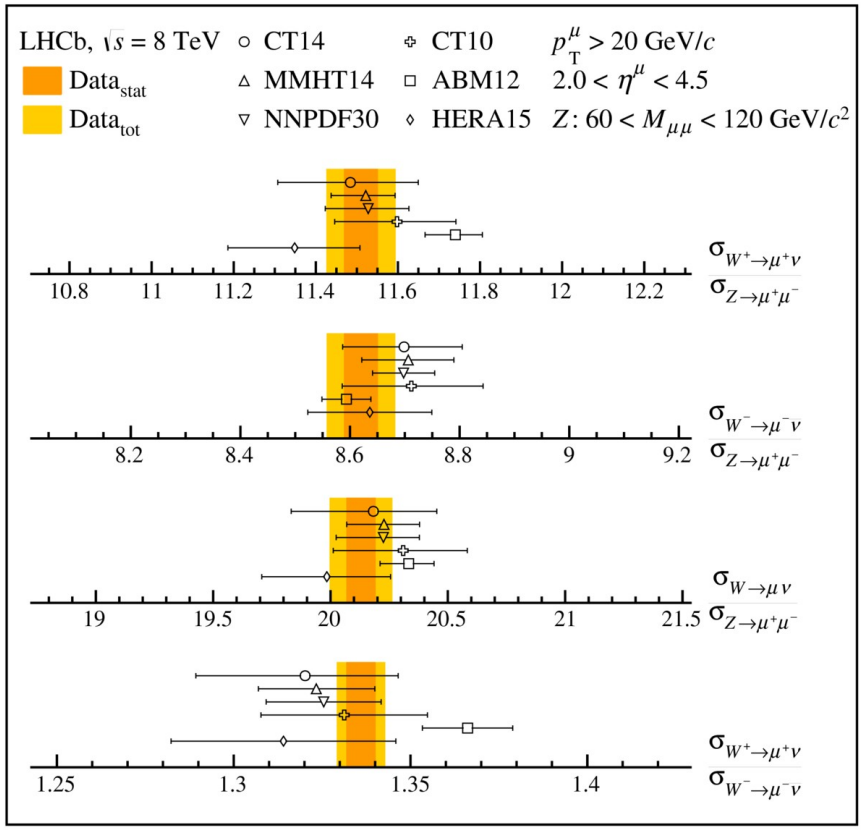
→ changes in shapes and reduction of the uncertainties of the valence quark distribution

W, Z – ratios

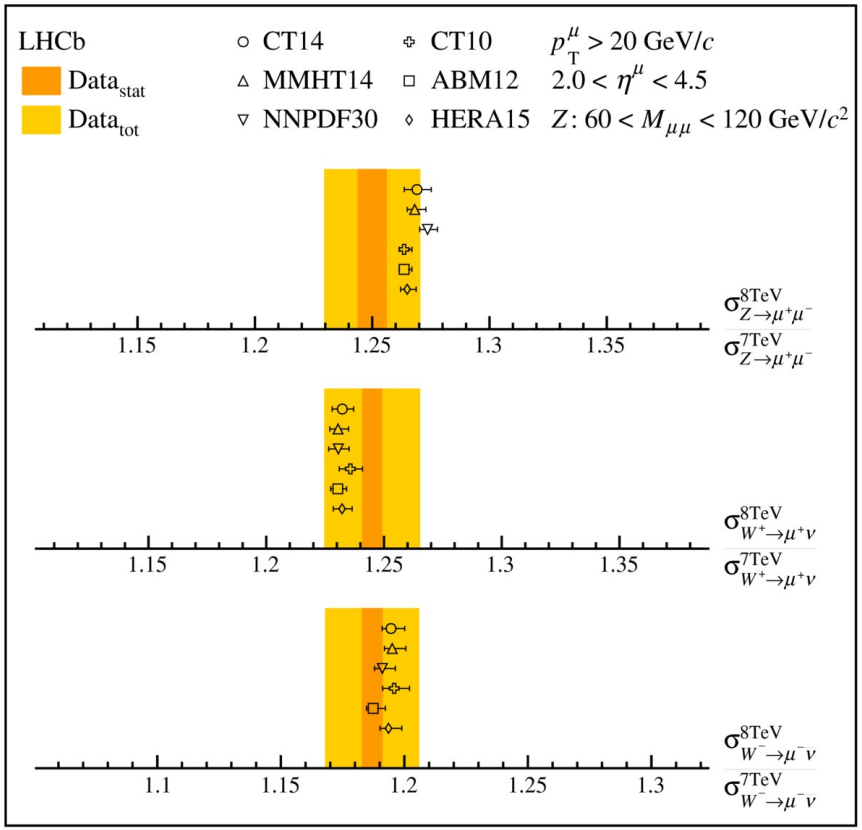
LHCb: JHEP 01 (2016) 155

- ratio W/Z or W^+/W^- : sensitive test of predictions
- ratio at different cm energies: PDF uncertainties very much reduced

W/Z or W^+/W^-

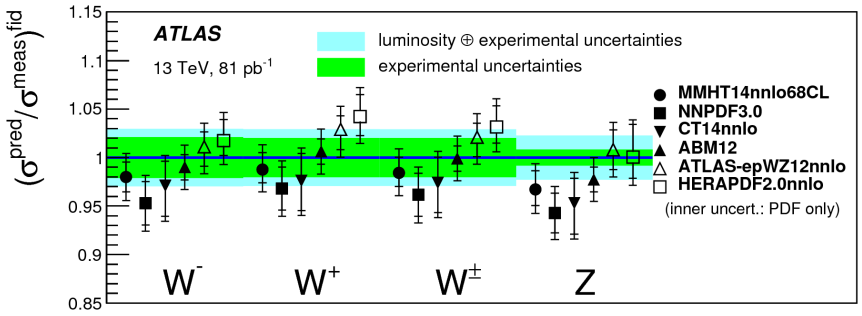


ratio 7/8 TeV

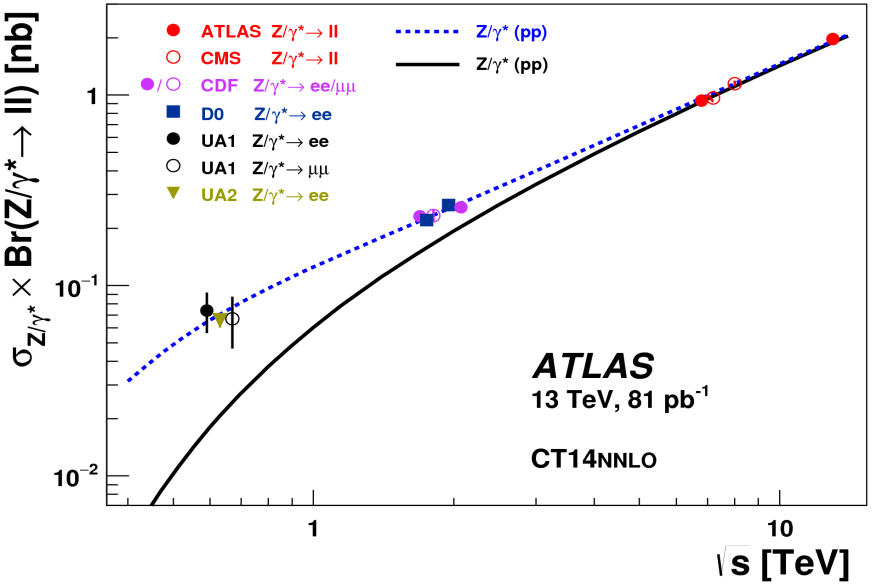


W, Z @ 13 TeV

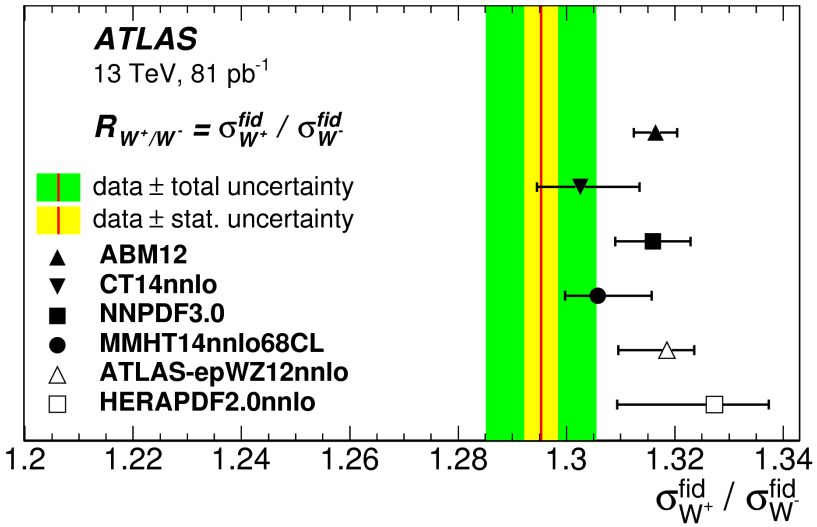
ATLAS: arXiv:1603.09222

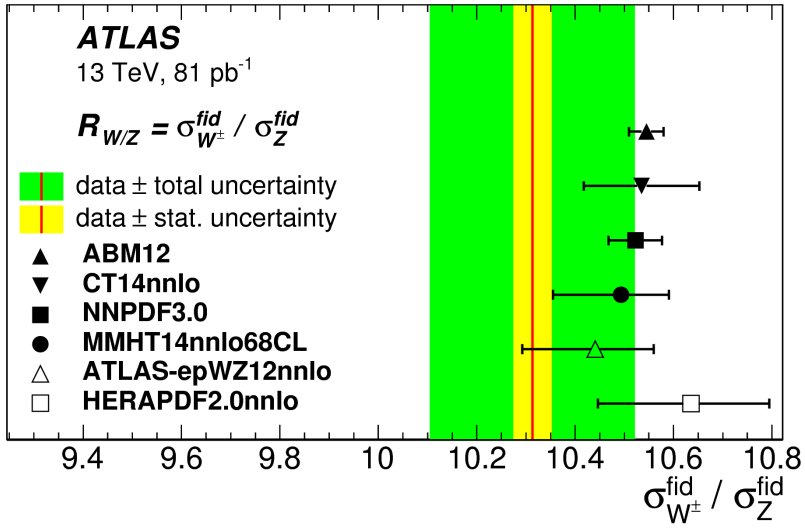


good agreement with predictions
luminosity uncertainty 2.1%
systematic uncertainties 2%(W), 1%(Z)



W+/W- ratio: uncertainty 0.8%

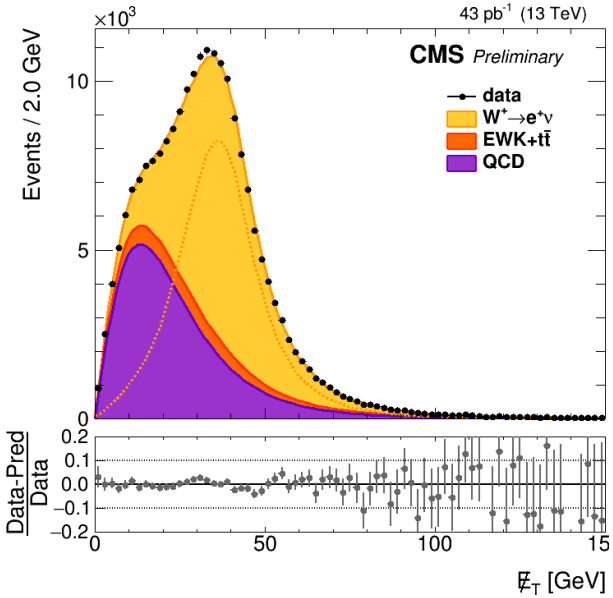




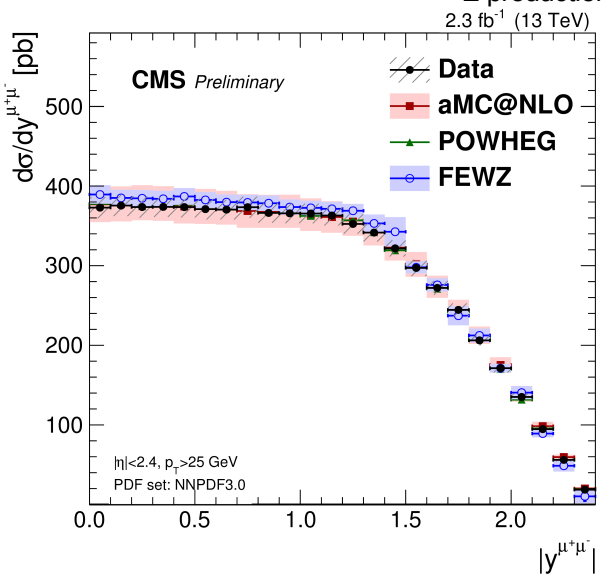
Z,W @13 TeV

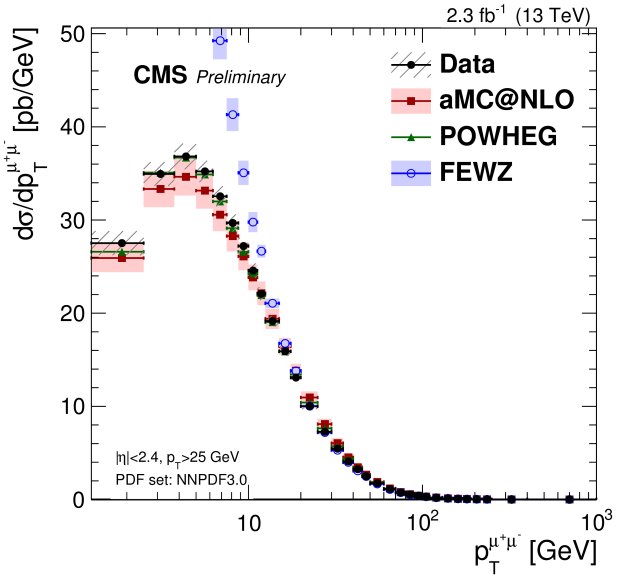
CMS-PAS-SMP-15-004
CMS PAS SMP-15-011

CMS-PAS-SMP-15-004

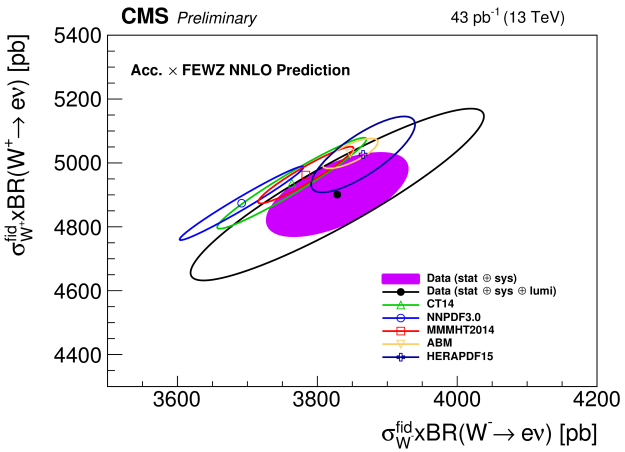


Z production: CMS-PAS-SMP-15-011





CMS-PAS-SMP-15-004



luminosity uncertainty 4.8 (W), 2.7% (Z)

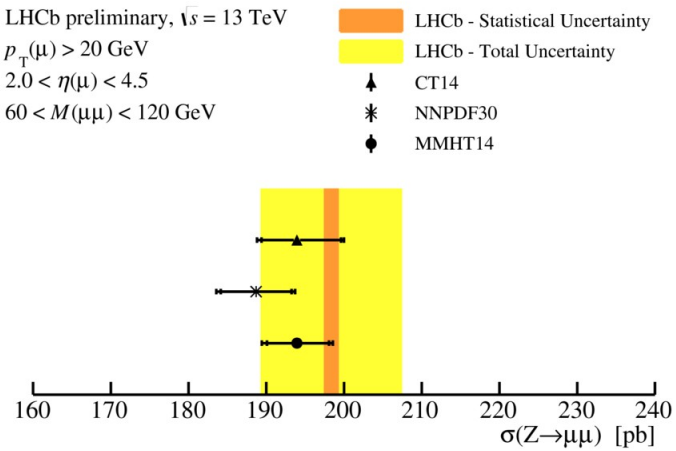
Z: inclusive and differential results

→ detector description well understood
→ x-sections well described by predictions

Z @ 13 TeV - forward

LHCb-CONF-2016-002

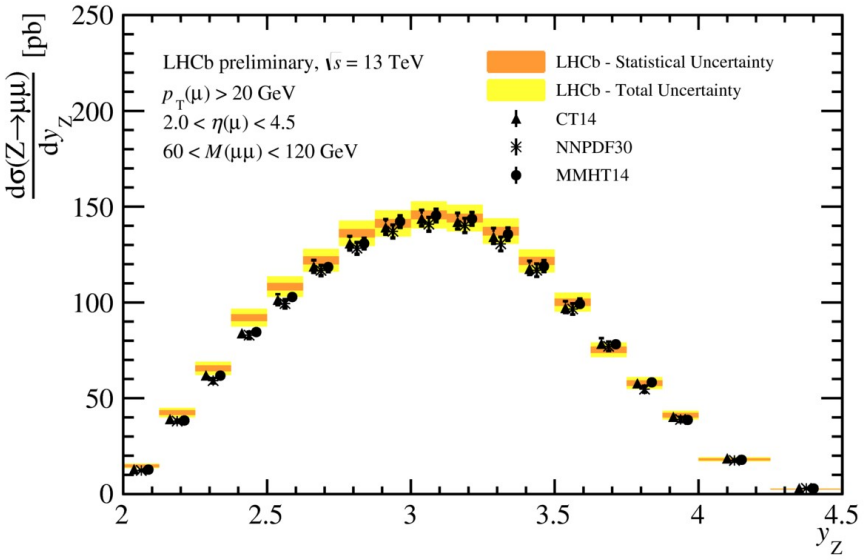
fiducial volume:
$2.0<\eta<4.5$, $p_T>20$ GeV
$60 < M(\mu\mu) < 120$ GeV

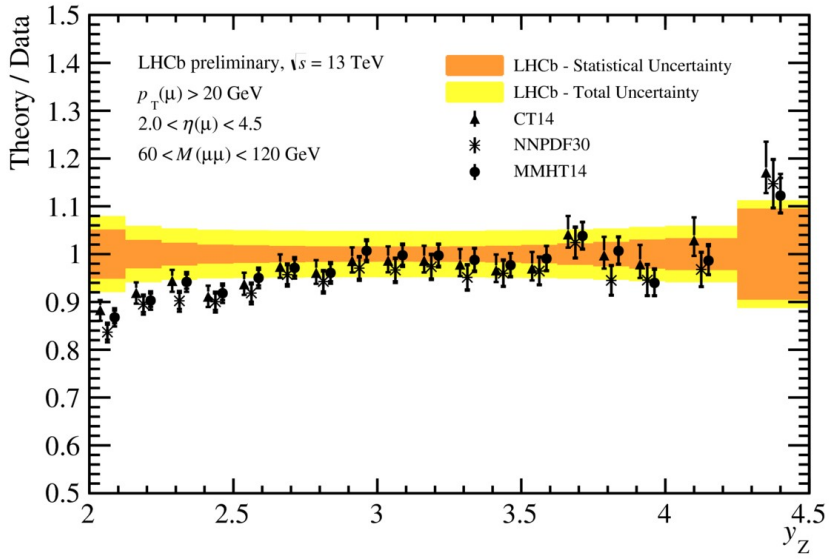


luminosity uncertainty: 3.9%

sensitivity to PDFs with more statistics
note: high rapidities are sensitive
to low and high x (close to one)

p_T and φ^* distributions also available

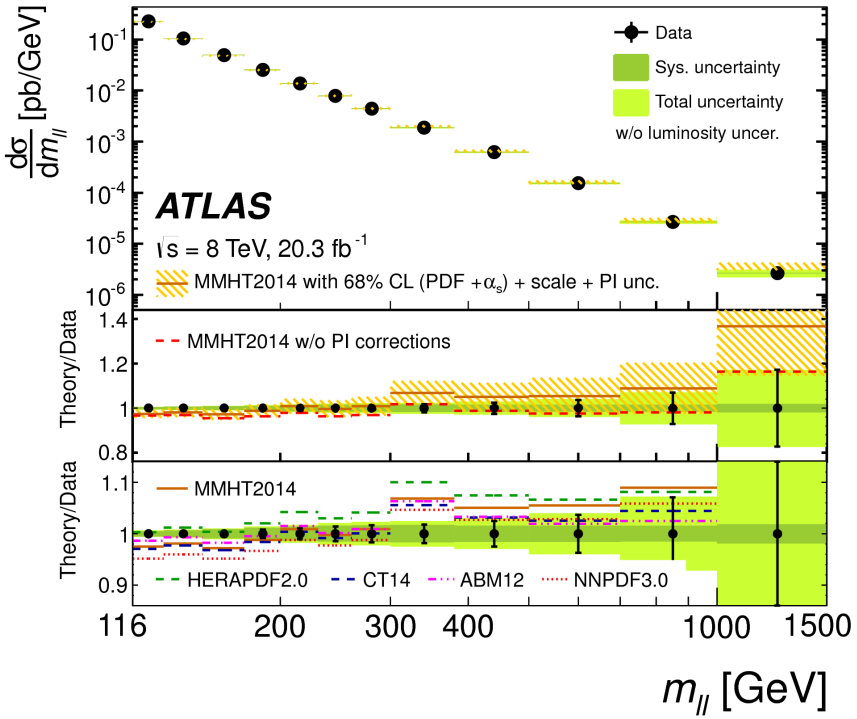




High mass Drell-Yan production @ 8 TeV

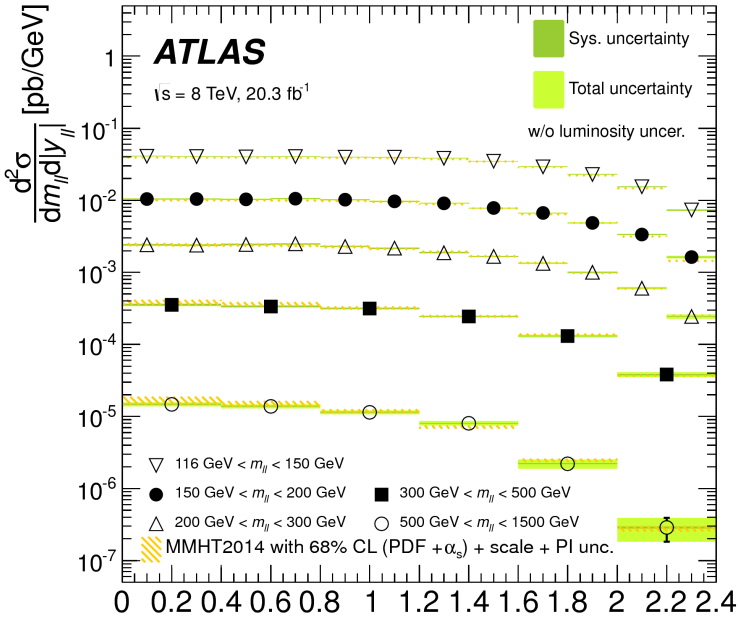
ATLAS arXiv:1606.01736

Drell-Yan lepton pair production: $Z/\gamma^* \rightarrow \ell\ell$
for $116 < M_{\ell\ell} < 1500$ GeV

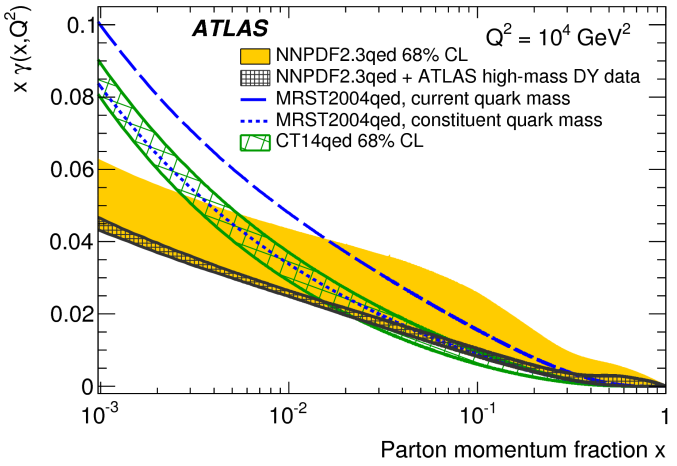


→ photon induced (PI) processes up to 15%
with large uncertainty of 60-90%
sensitivity to photon PDF via $\gamma\gamma \rightarrow \ell\ell$

→ predictions using various PDF sets generally agree
largest differences at low masses
→ sensitivity to PDFs



→ significant reduction of PDF uncertainty



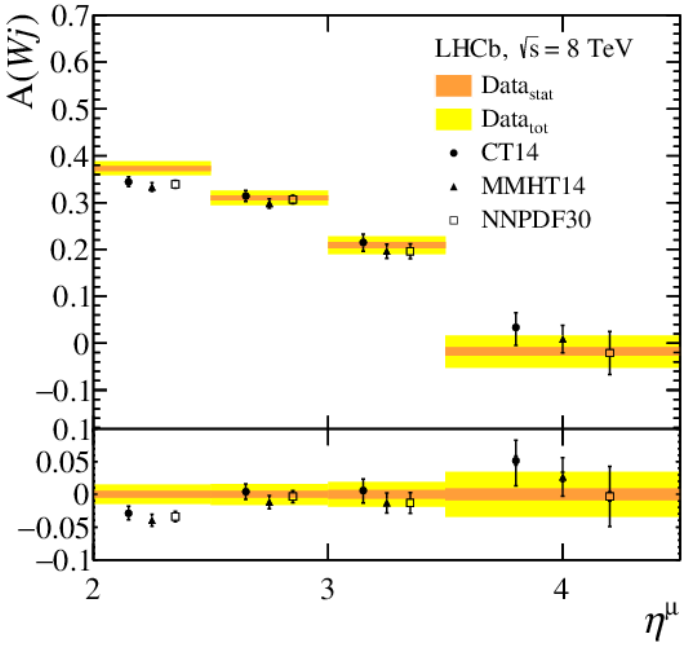
W, Z plus jet @ 8 TeV - forward

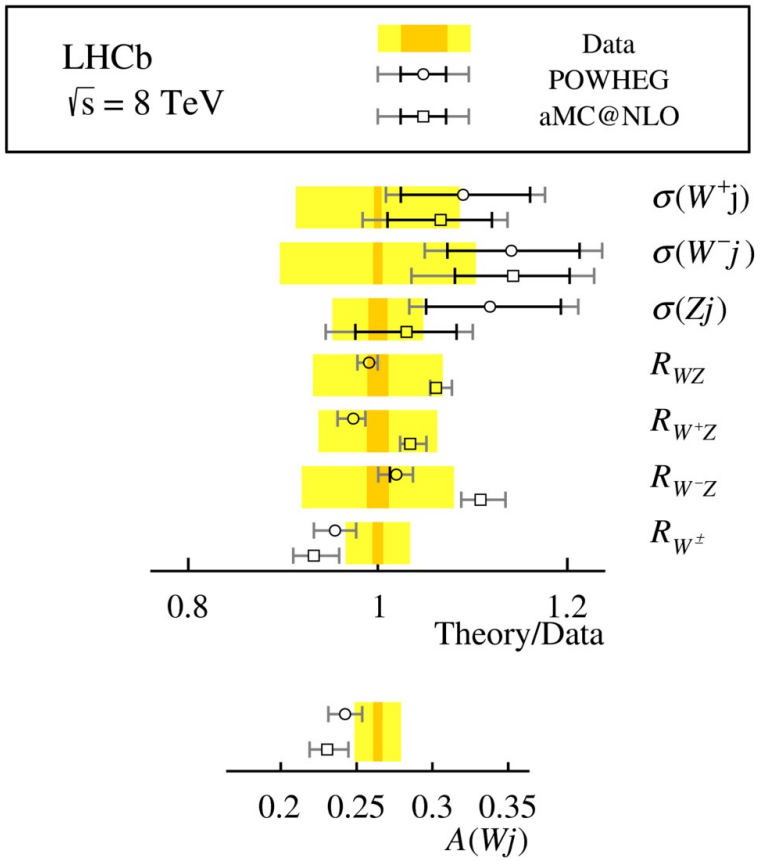
arXiv:1605.00951

agreement with NLO (+PS)

many differential distributions available
general good description by predictions

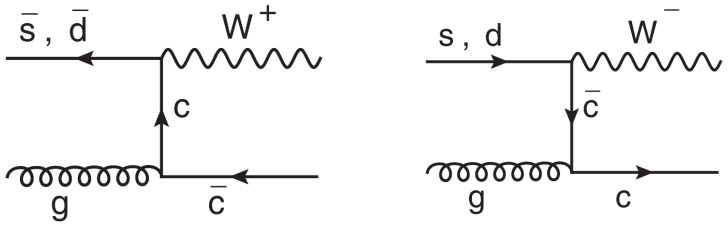
W + jet: lepton charge asymmetry
→ some sensitivity to PDFs



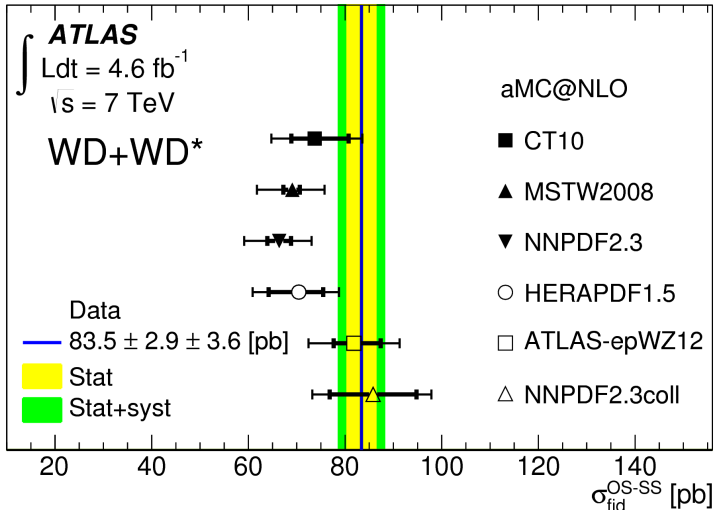


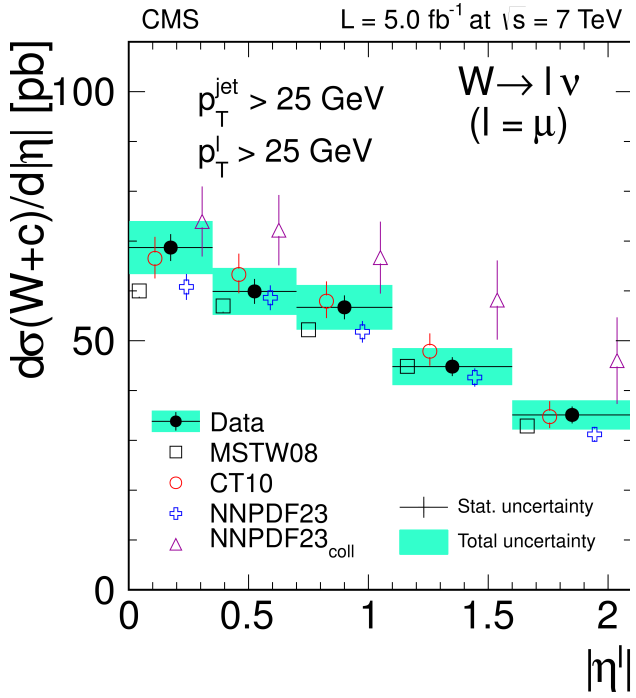
W plus charm

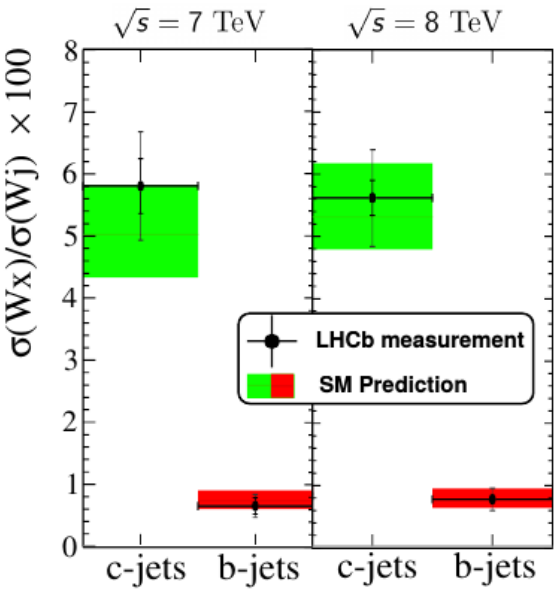
CMS: JHEP02 (2014) 013
ATLAS: JHEP05(2014)068
LHCb: PRD 92 (2015) 052001

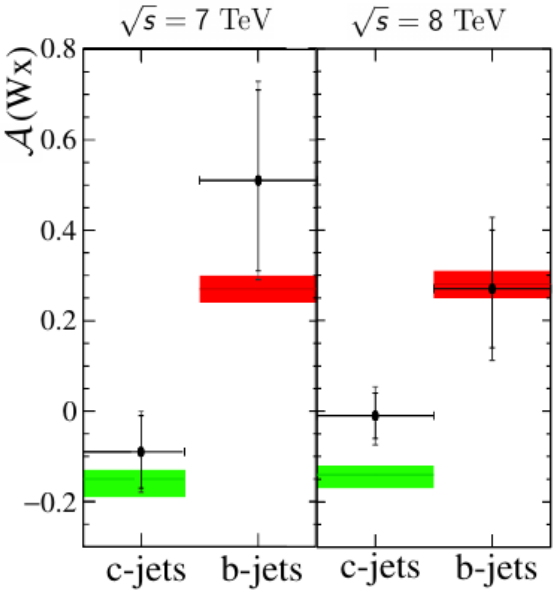


sg → W + c dominant
dg → W process is Cabibbo suppressed
→ σ(W + c-jet) sensitive to strange-quark



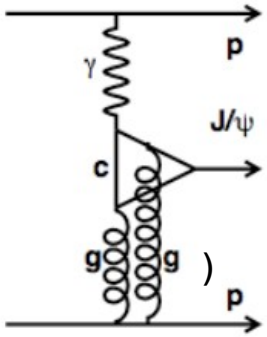






Central exclusive production

J. Phys. G: Nucl. Part. Phys. 41 (2014) 055002



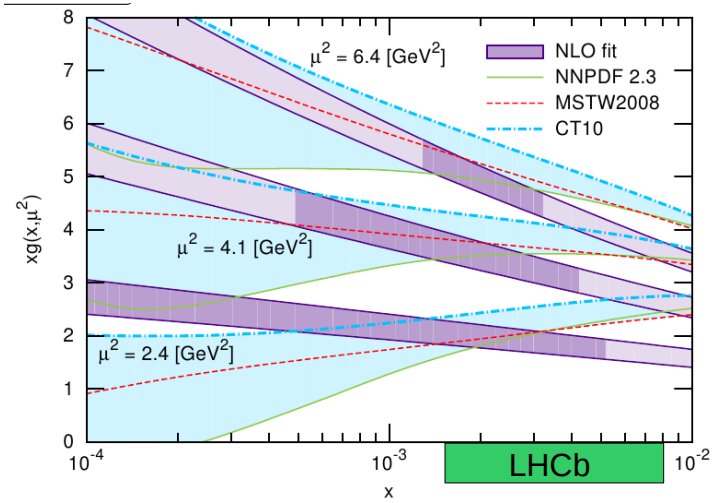
γ-pomeron fusion eg J/Ψ, Ψ(2S)

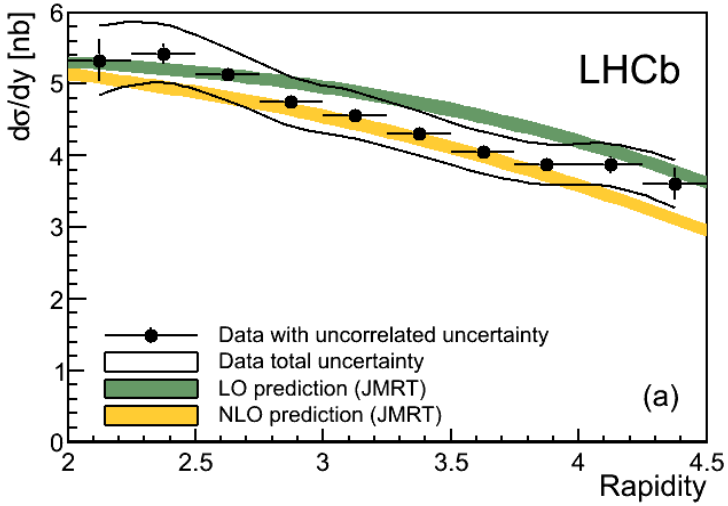
Exchange of neutral, colourless particles - protons remain intact

→ sensitivity to gluon distribution at low Bjorken-x ($5 \cdot 10^{-6}$)

NLO gluon resulting from a fit using LHCb exclusive J/Ψ production compared to the global fits (arXiv: 1307.7099)

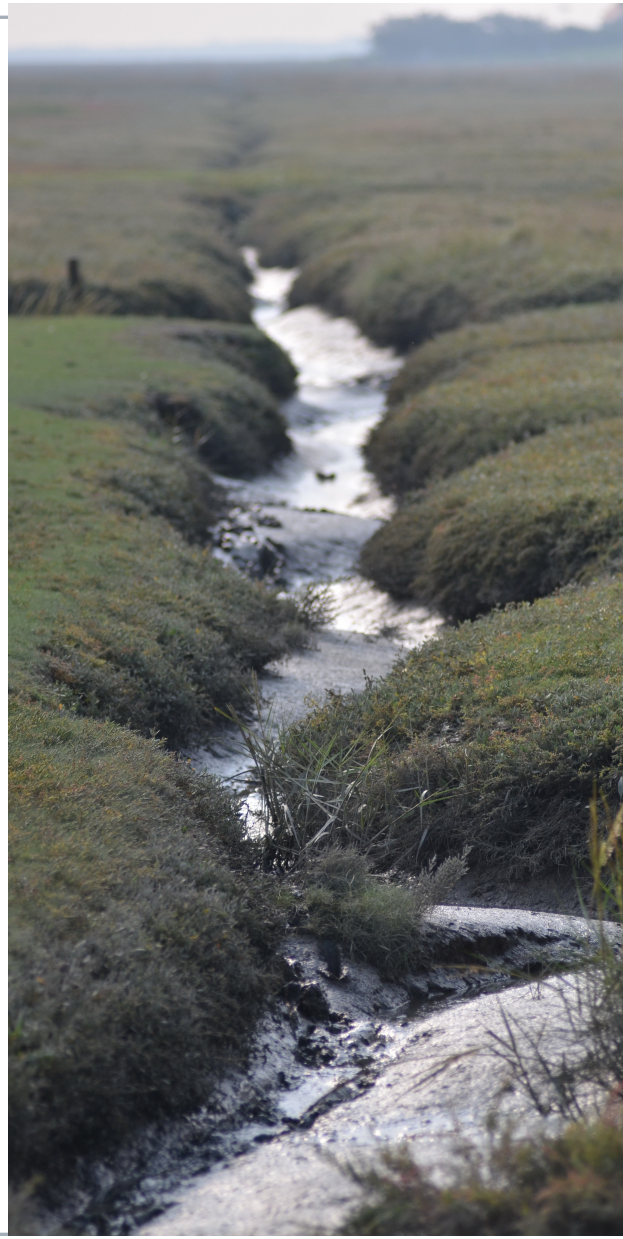
→ gluon PDF may rise faster than predicted by global PDFs





Conclusions

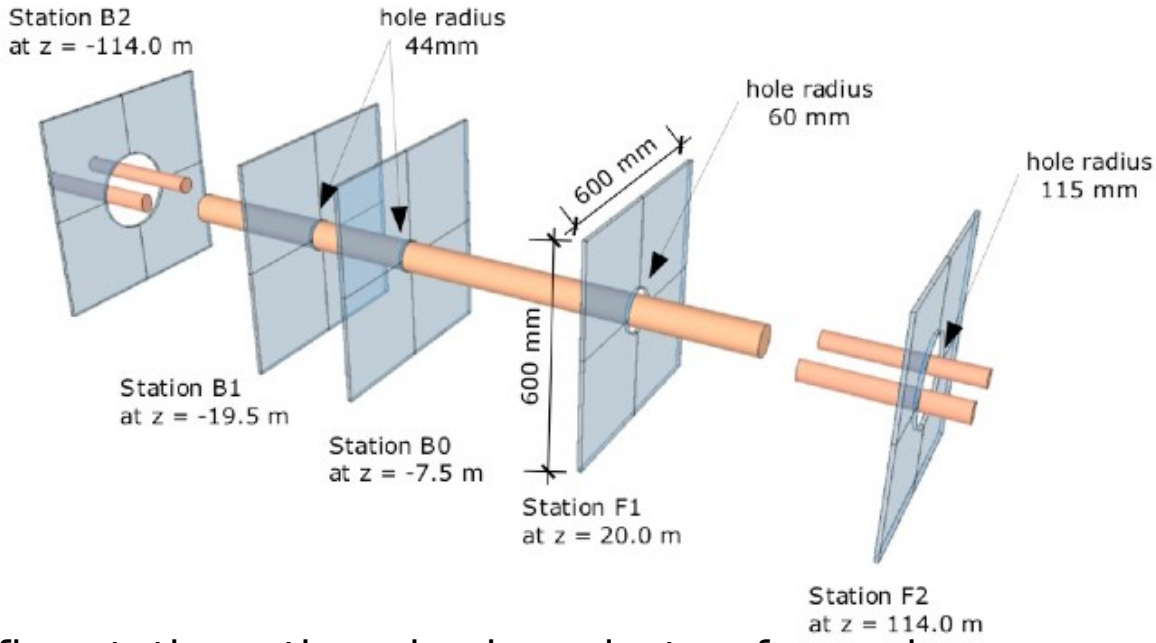
- LHC high-precision QCD measurements at 7 and 8 TeV being complemented by the first results at 13 TeV
- large variety of results with sensitivity to PDF
  in different kinematic regions
  different final states → different systematic uncertainties
  many different cm energies
- some Run I results still being completed
- new Run II results in the pipeline:
  jets, W&Z bosons
  central exclusive production
  ...



Backup

HERSCHEL

HeRSCheL: High Rapidity Shower Counters for LHCb



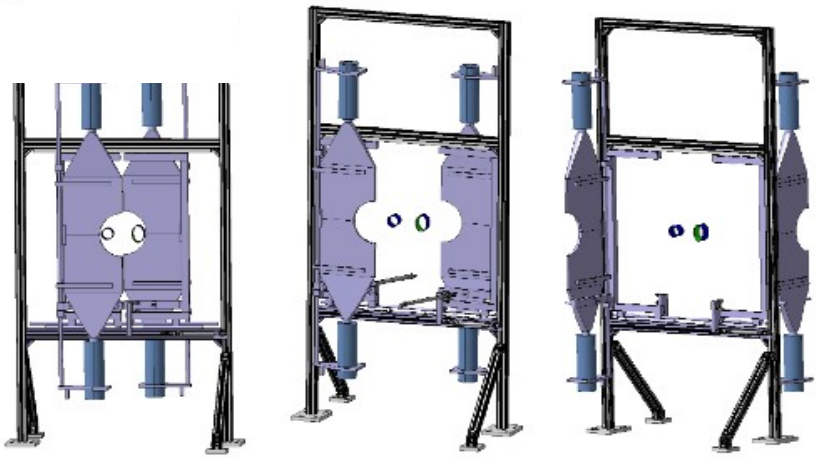
five stations: three backwards, two forward

detectors: four plastic scintillator plates,

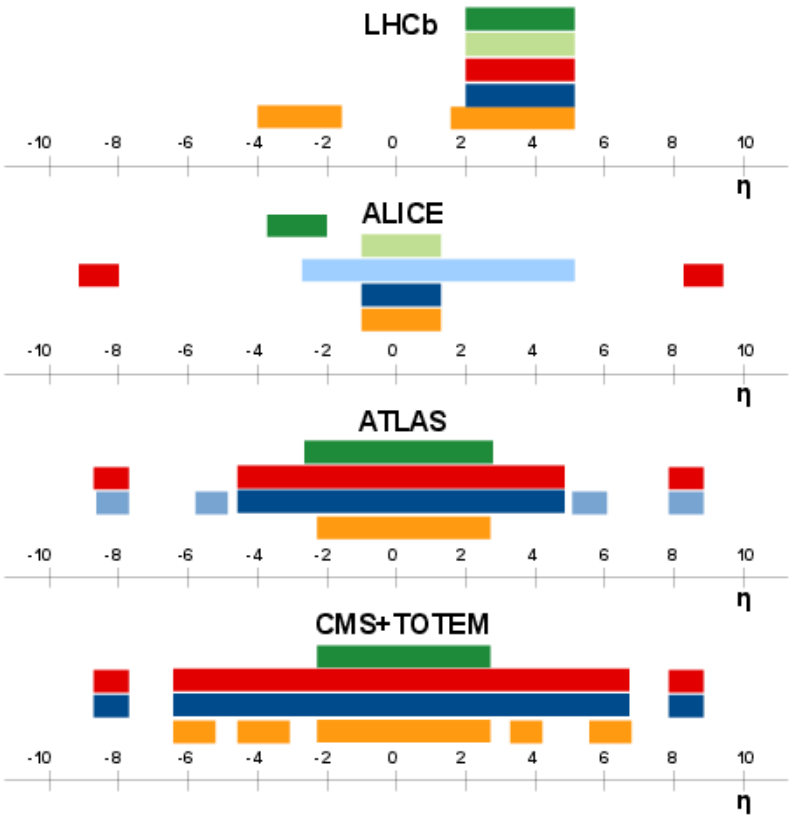
20 mm thick - retractable

→ improvements in triggering and

background rejection for CEP events



Coverage of LHC detectors



- ATLAS and CMS:
  precision tracking and muon identification in central region
- ATLAS and CMS:
  forward calorimetry - measurements of electrons and jets for $|\eta| < 5$
- ALICE focus on heavy ion physics
  very high multiplicity events
- LHCb:
  coverage for $\eta > 2$ – excellent tracking and particle identification
  low p_T, low mass triggers
  → complementary measurements

Central exclusive production

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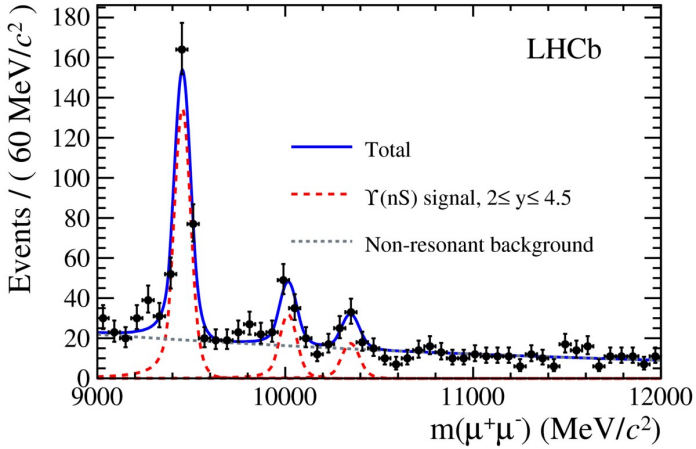
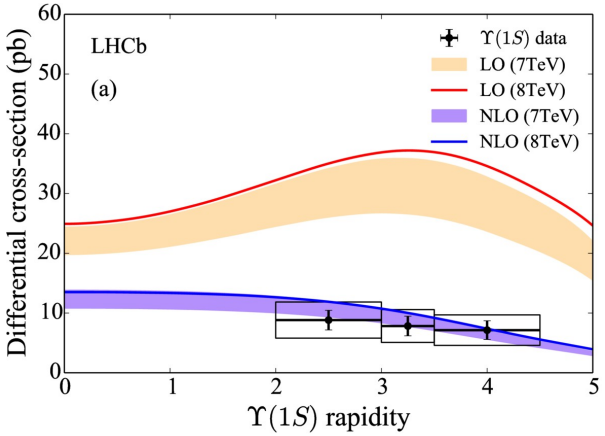
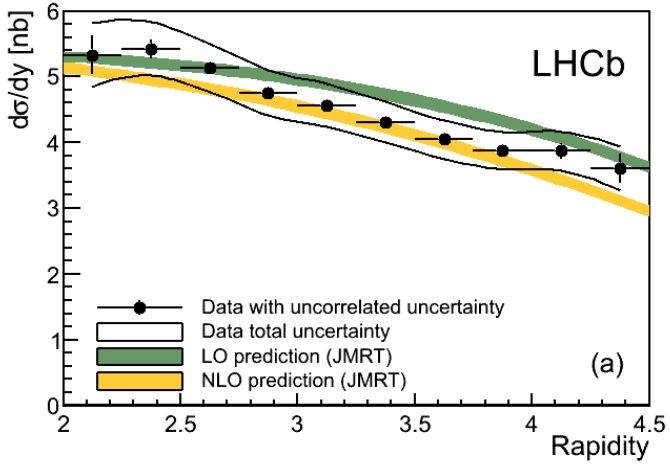
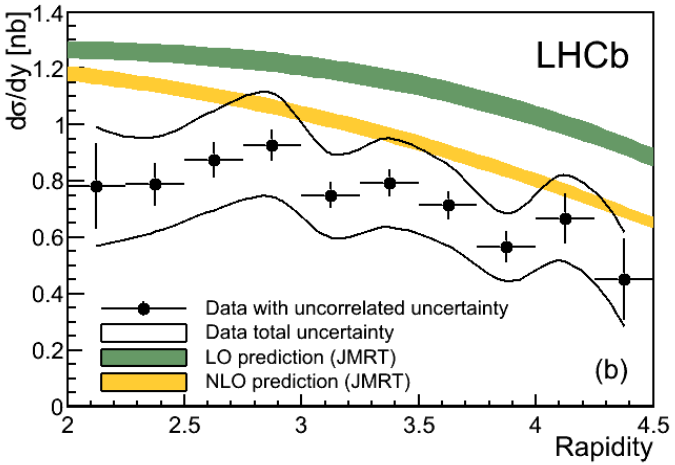


J/ψ



ψ(2S)





Run II: better sensitivity due to new detectors
→ better control of the inelastic background