LHCb Measurements with Electroweak Bosons as Probes of the Proton Structure

Andreas Weiden (weiden@physik.uzh.ch), Katharina Müller (kmueller@physik.uzh.ch)
[LHCb Collaboration]
Group Ulrich Straumann, Nicola Serra

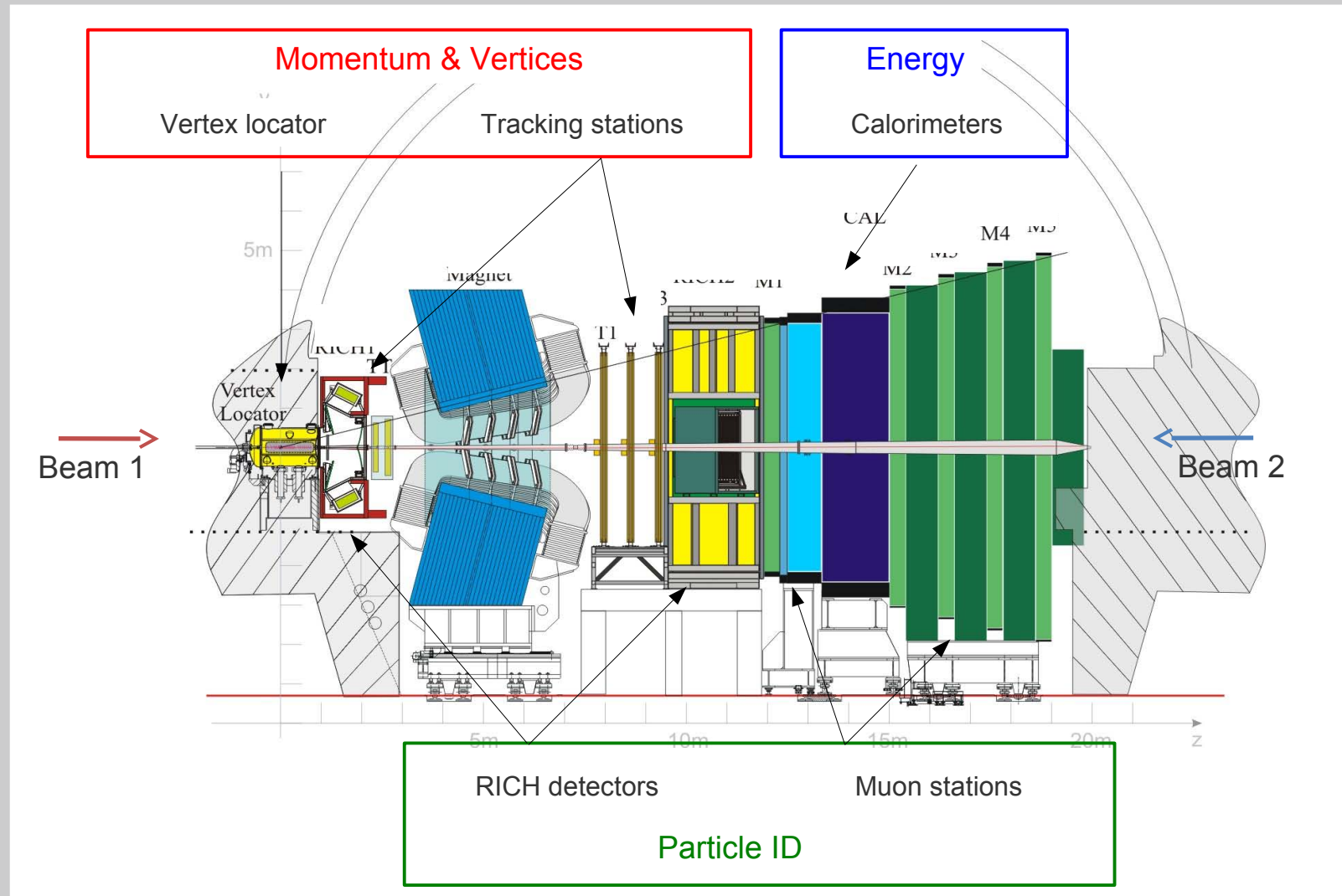## LHCb Detector at the Large Hadron Collider LHC

Fig1: LHCb detector [1].

- single arm spectrometer [1]– designed for precision measurements in decays of particles containing heavy quarks
- fully instrumented in the forward region (2 < η < 5)
- primary vertex resolution: σ_{xy} ~ 15μm, σ_z ~ 80μm
- momentum resolution: Δp/p = 0.5-1%
- particle identification: excellent K/π/p separation kaon ID
  eg. kaon identification ε = 90% with < 5% π mis-identification
- very flexible trigger → able to trigger on low momentum objects

Introduction
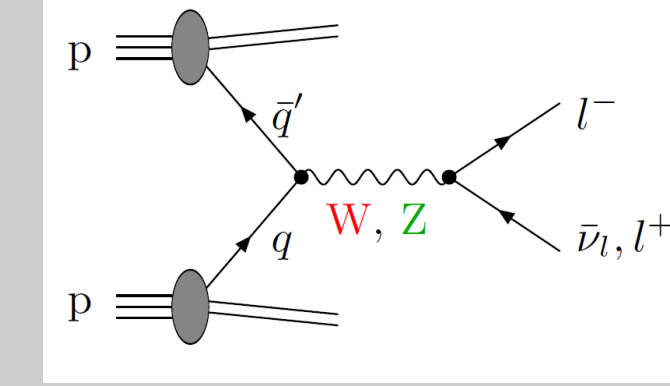
LHC: proton-proton collisions→ collisions between the partons in the protons

cross-section:

$$\sigma(x,Q^2) = \sum_{a,b} \int_0^1 dx_1 dx_2 f_a(x_1 Q^2) f_b(x_2 Q^2) \hat{\sigma}(x_1, x_2, Q^2)$$

parton density functions

sum over initial partonic states a,b   hard scattering cross-section

- partonic cross-section known at next-to-next-to leading order (NNLO) in perturbative QCD
- parton density functions (PDF), $f_q(x,Q^2)$, describe probability, that proton contains a parton q with momentum fraction x
- PDF need to be determined from global fits to experimental data
- input from HERA, CDF, fixed target and LHC experiments
- LHCb covers a unique area in phase space at first order: a collision between a sea and a valence quark
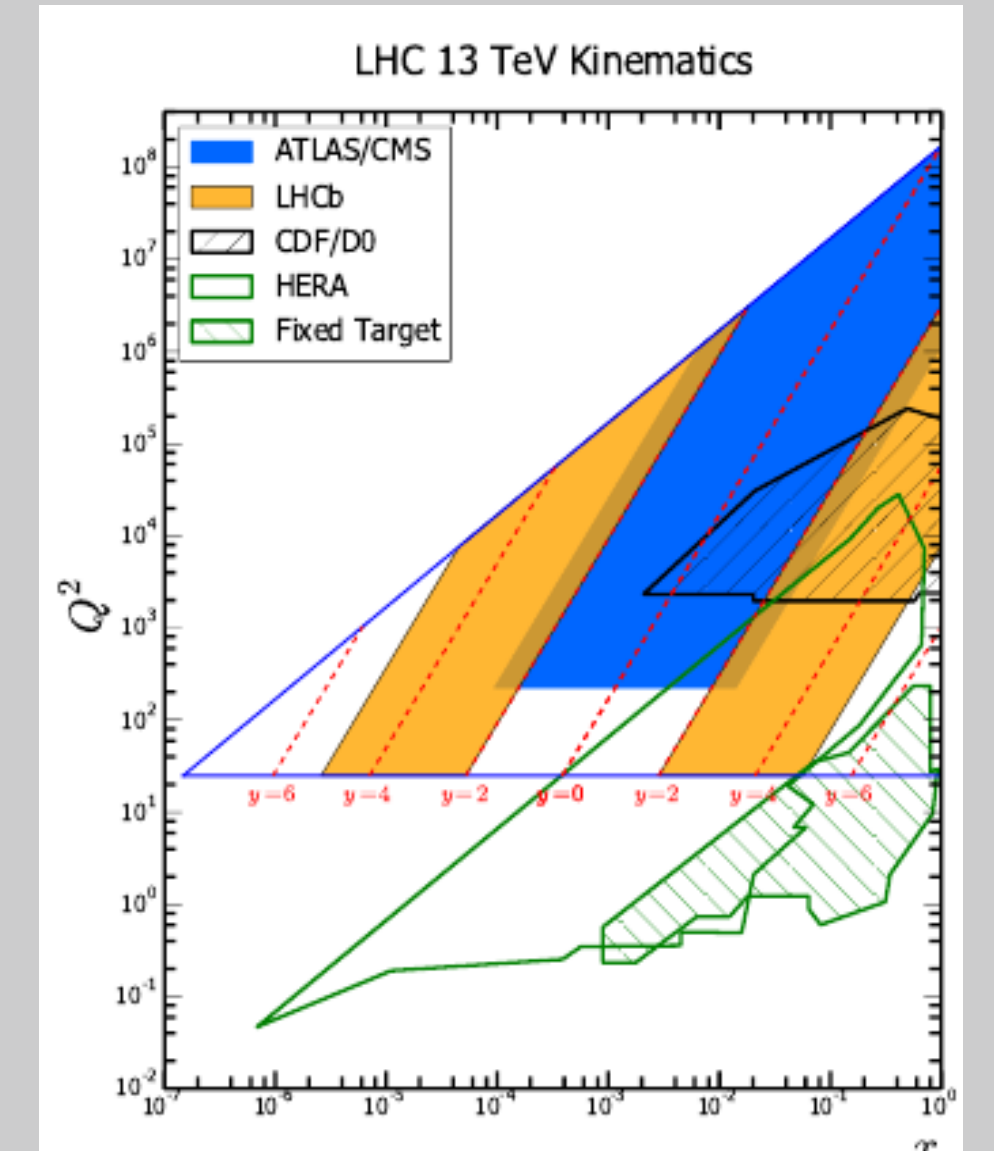- LHCb measurements are complementary to ATLAS and CMS

Fig2: kinematic plane Q^2-x.

Z production

measurements for √s=7, 8 and 13 TeV [2,3,4,5] with Z decaying into two muons or two electrons

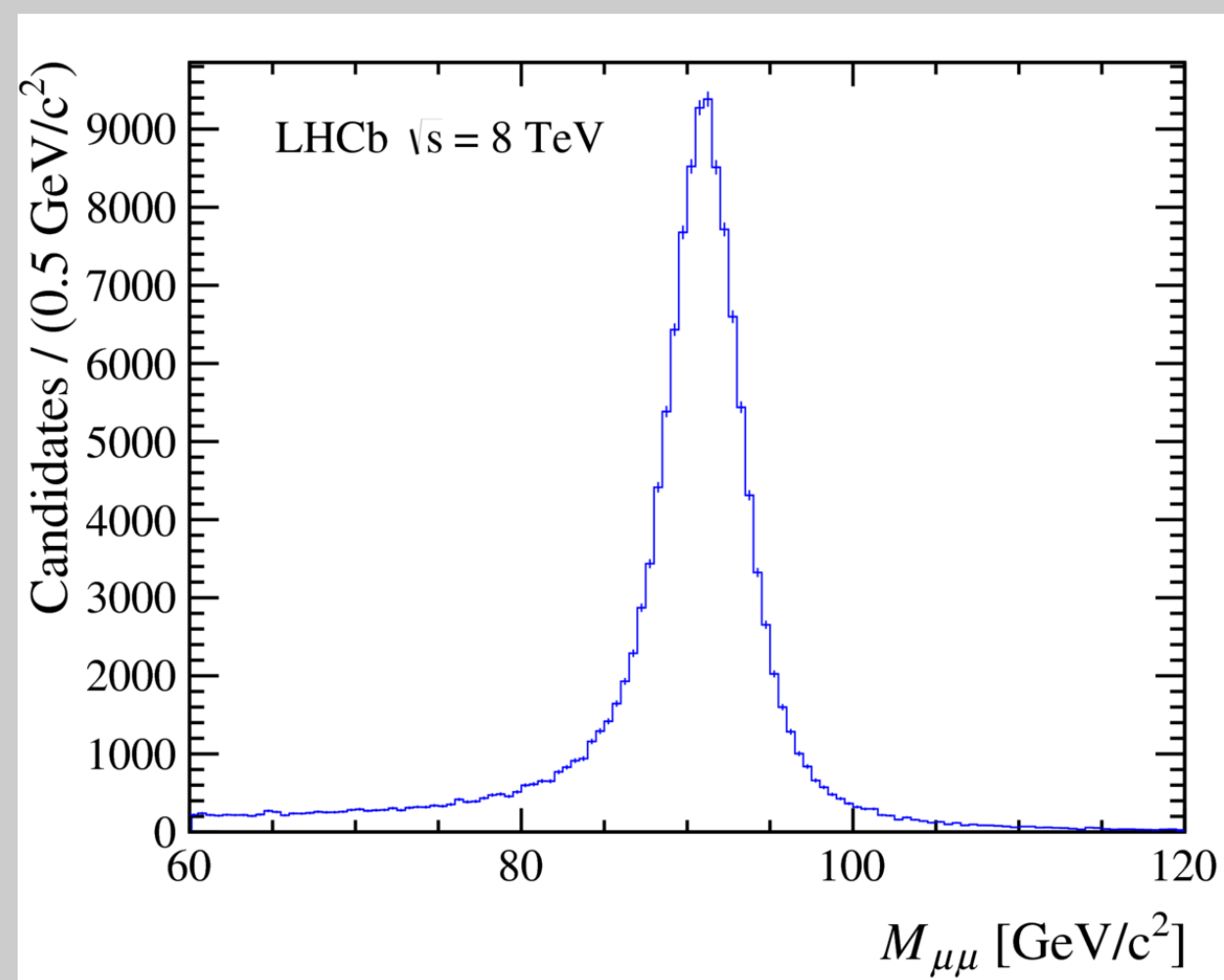fiducial volume:
leptons: p_T> 20 GeV, 2 < η <4.5
mass: 60 < M_{ll}< 120 GeV²

very low background contribution: purity> 99.7%

Fig3: di-muon invariant mass distribution [4].

W production

measurements for √s=7 and 8 TeV
with W → μν or W → eν [4,6]
charge of the lepton defines the charge of the W

selection: isolated lepton with p_T> 20 GeV, 2<η<4.5

signal yield from a fit to lepton p_T distribution
backgrounds: misidentified leptons (QCD), W→τν or Z decays (Electroweak), heavy flavour decays
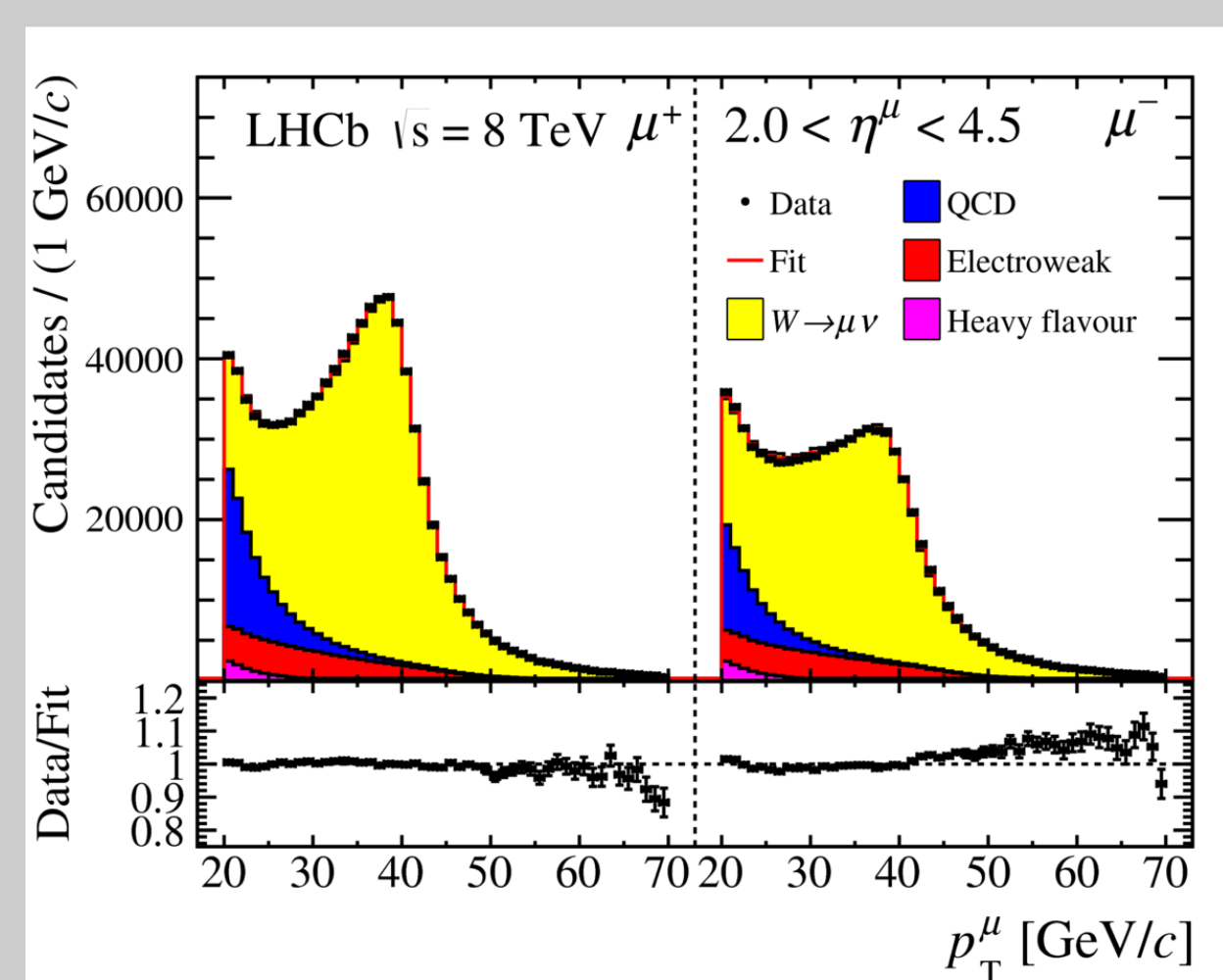

Fig4: muon transverse momentum distribution [4].

Results: Cross-sections

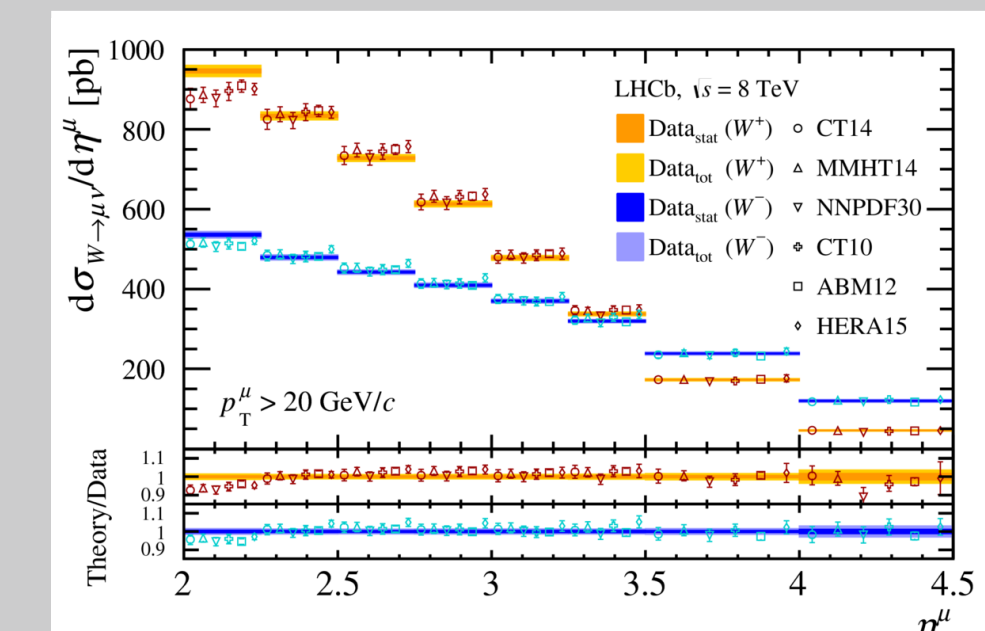compared to NNLO predictions with six different PDF parametrizations

Fig5: W production cross section vs pseudorapidity η [4].

definitions:

- pseudorapidity η
  η=-ln tan(θ/2)
- rapidity y
  y=ln[(E-p_z)/(E+p_z)]

dominant uncertainties:

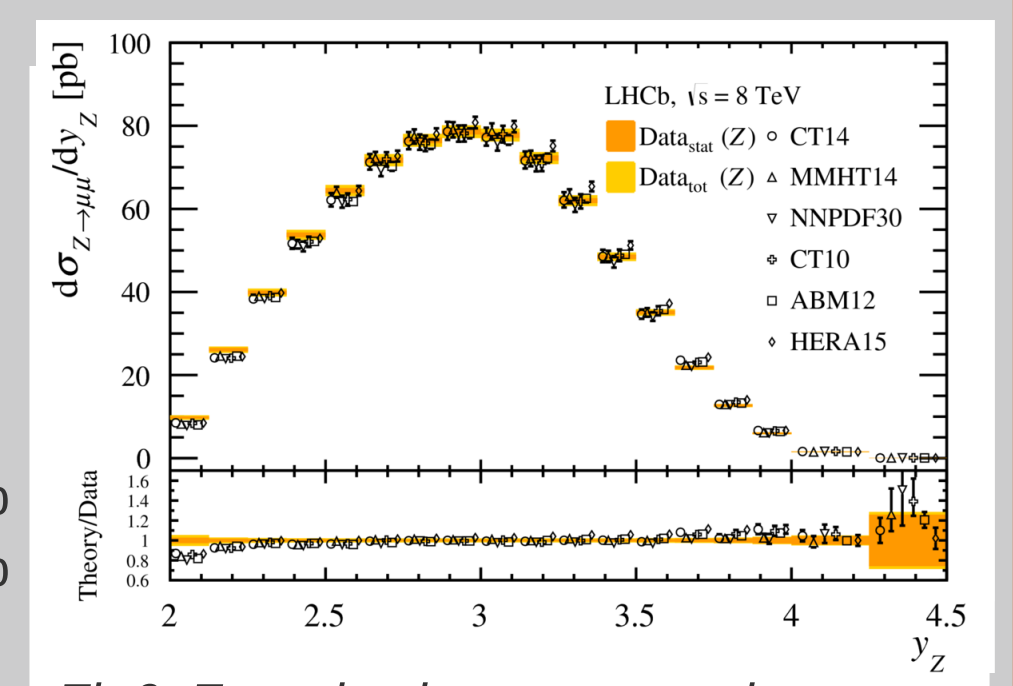|	
luminosity:	1.16%
beam energy:	1-1.15%
statistical:	0.2-0.3%
purity :	0.2-0.25%
tracking eff.:	0.25-0.5%

Fig6: Z production cross section vs rapidity y[4] .

Results: Cross-section ratios

very sensitive probe as many systematic and theoretical uncertainties cancel
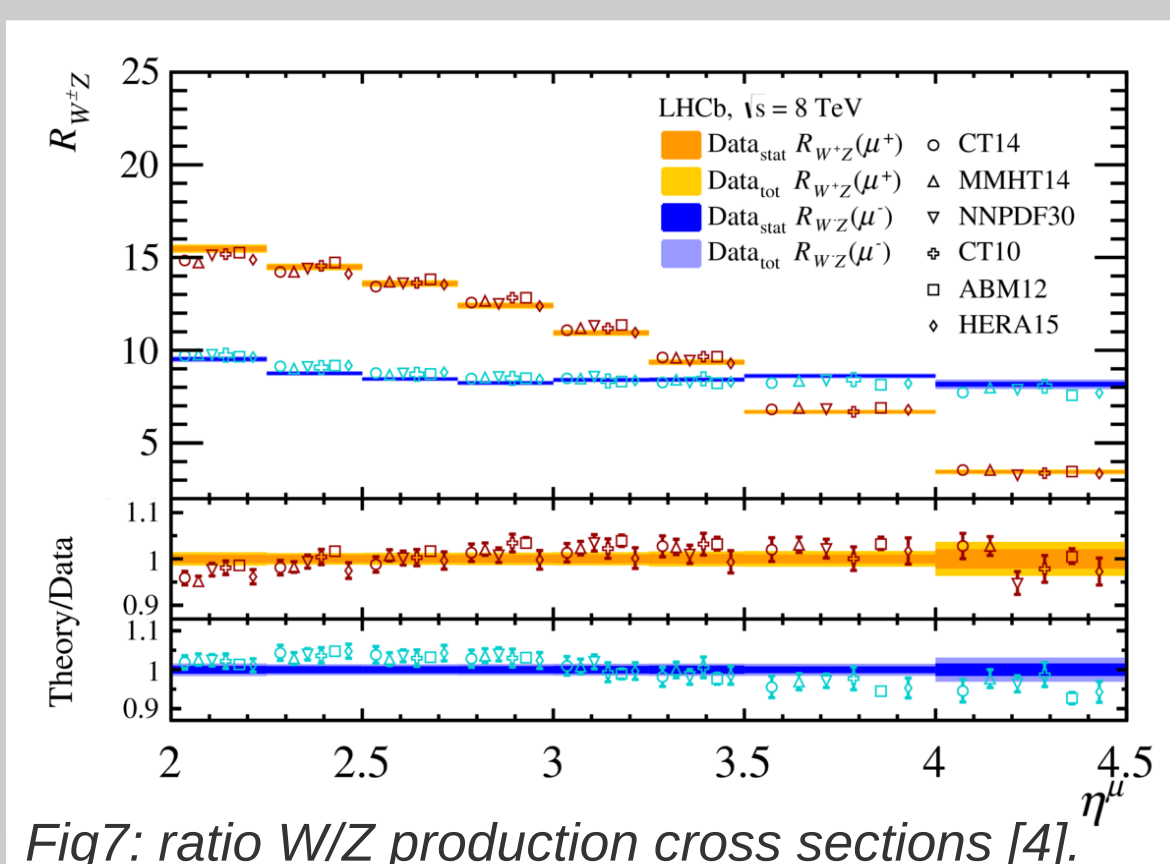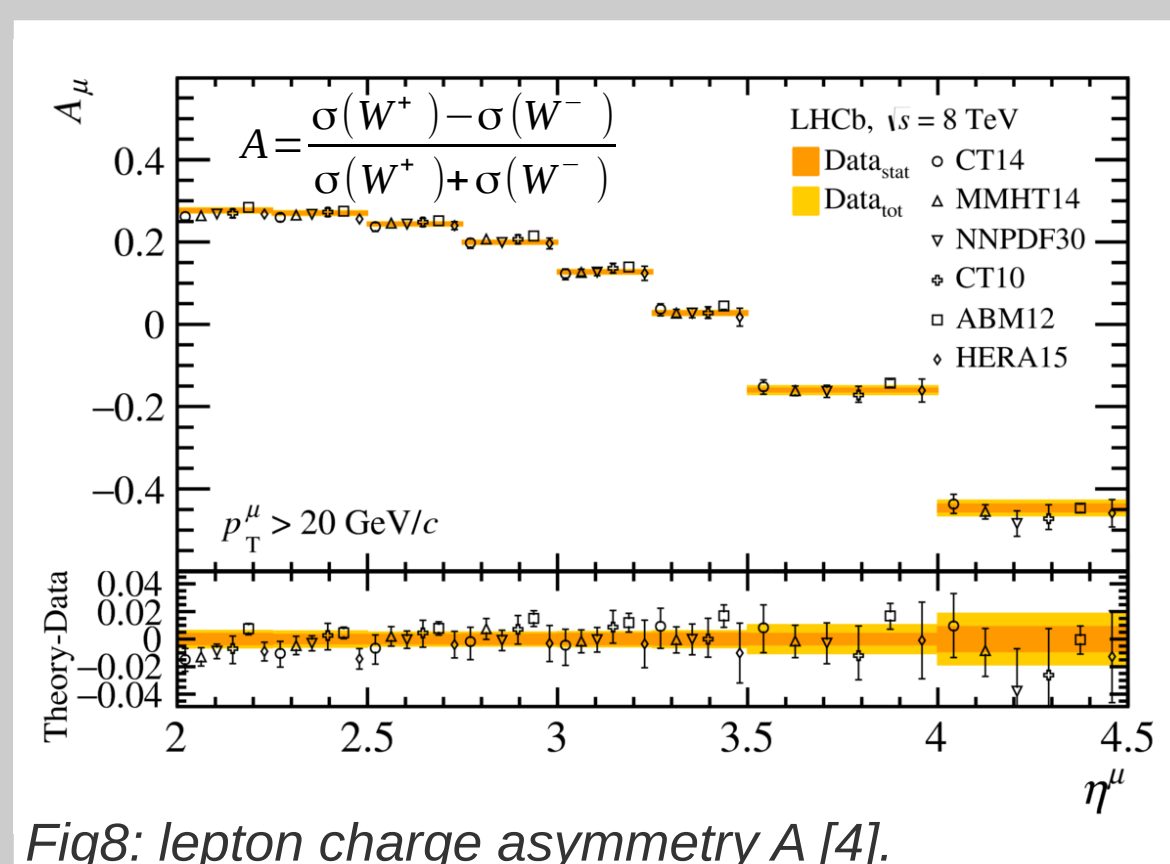

Fig7: ratio W/Z production cross sections [4].

Fig8: lepton charge asymmetry A [4].

even better: ratios for different centre-of-mass energies: here scale uncertainties cancel but some sensitivity to PDFs remain
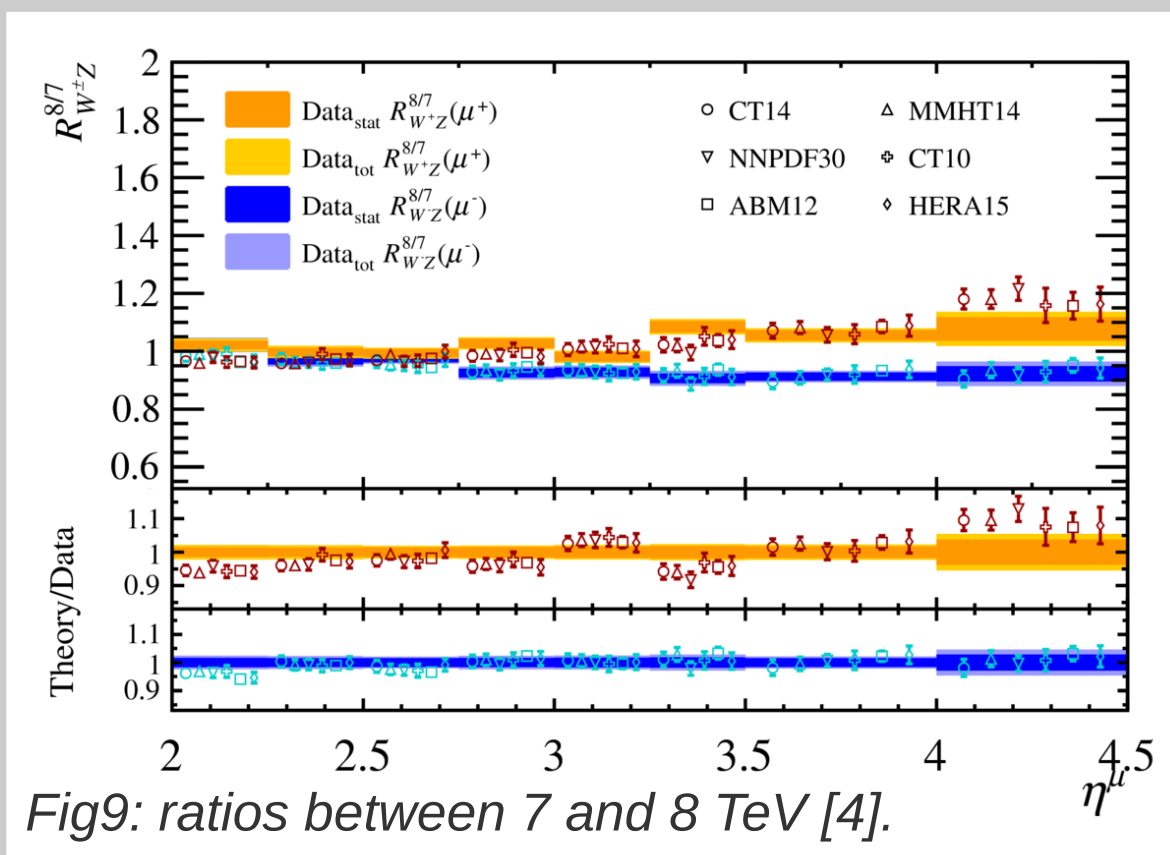

Fig9: ratios between 7 and 8 TeV [4].

Conclusions & Outlook

- measurements with electroweak bosons at LHCb probe the structure of the proton in a unique kinematic range
- precise results provide important input for fits of the parton density functions
- analysis of Drell-Yan production which probes lower masses and lower momentum fractions x are ongoing
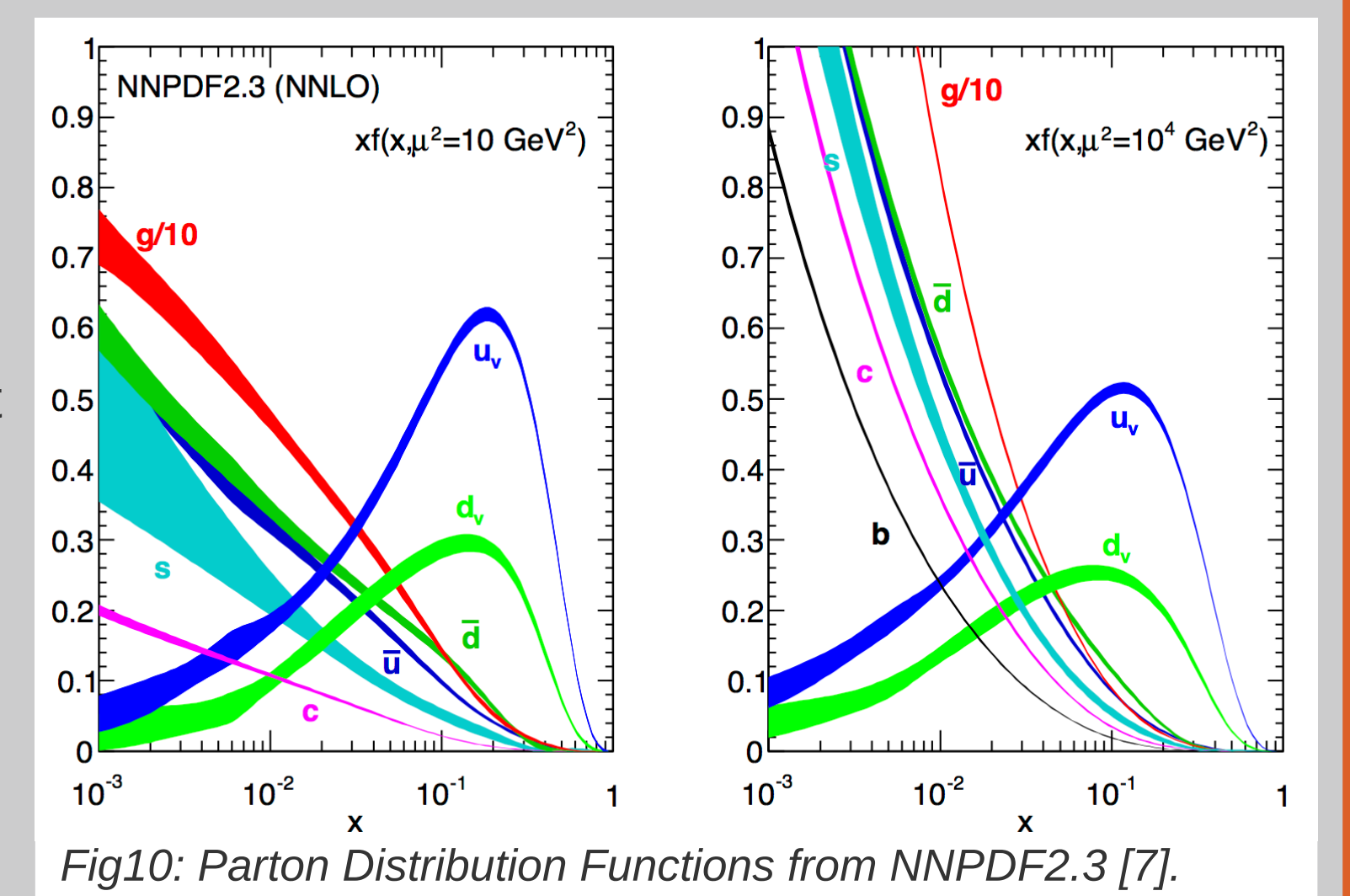

Fig10: Parton Distribution Functions from NNPDF2.3 [7].

References

[1] LHCb collaboration, *The LHCb detector at the LHC*, JINST 3 (2008) S08005
[2] LHCb collaboration, *Measurement of the forward Z boson cross-section in pp collisions at √s = 7 TeV*, JHEP 08 (2015) 039
[3] LHCb collaboration, *Measurement of forward Z→e+e− production at √s=8 TeV*, JHEP 05 (2015) 109
[4] LHCb collaboration, *Measurement of forward W and Z boson production in pp collisions at √s=8TeV*, JHEP 01 (2016) 155
[5] LHCb collaboration, *Measurement of the forward Z boson production cross-section in pp collisions at √s=13 TeV*, JHEP 09 (2016) 136
[6] LHCb collaboration, *Measurement of the forward W boson production cross-section in pp collisions at √s = 7 TeV*, JHEP 12 (2014) 079
[7] NNPDF collaboration, *Parton distributions for the LHC Run II*, JHEP 04 (2015) 040