Z/W- Results @ LHCb

Yasmine Amhis
On behalf of the LHCb Collaboration
HCP Paris - 2011

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Outline

- LHCb Overview

-W & Z Production and PDF Sensitivity

- Preliminary Results

  $Z \rightarrow \mu\mu$

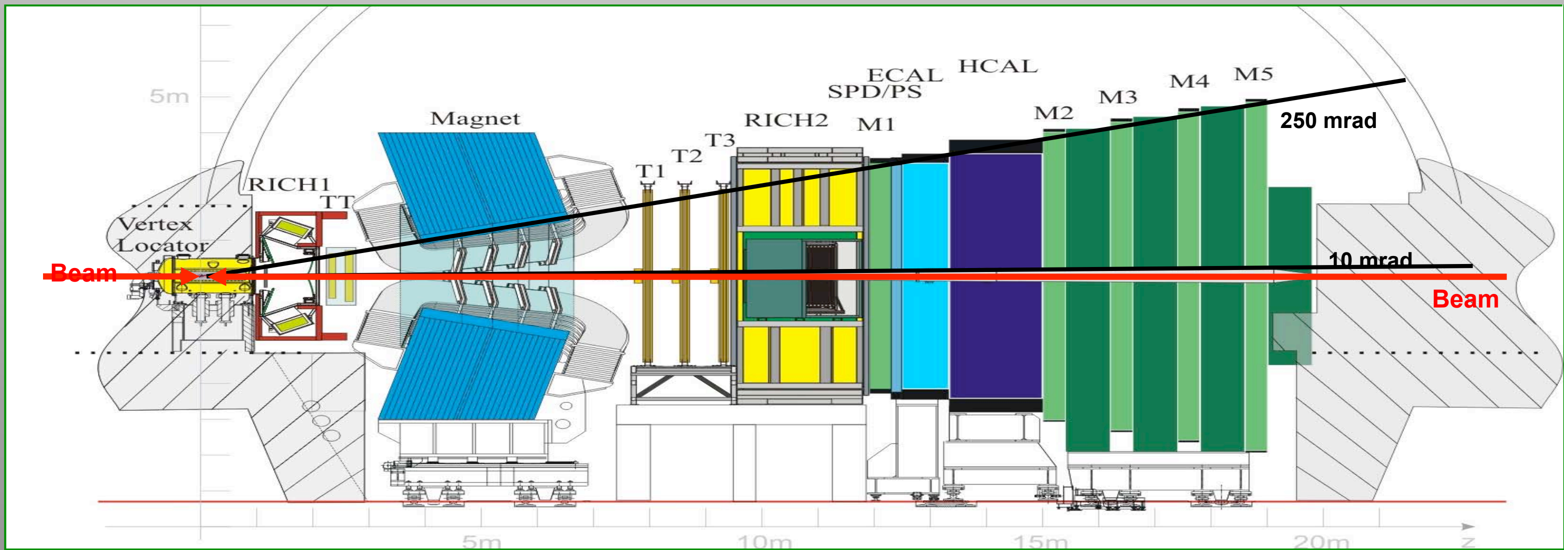
  $Z \rightarrow \tau\tau$

  $W \rightarrow \mu\nu_\mu$

- Summary and Outlook

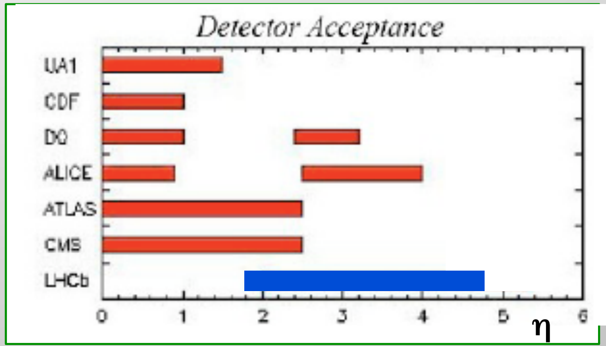
Looking forward

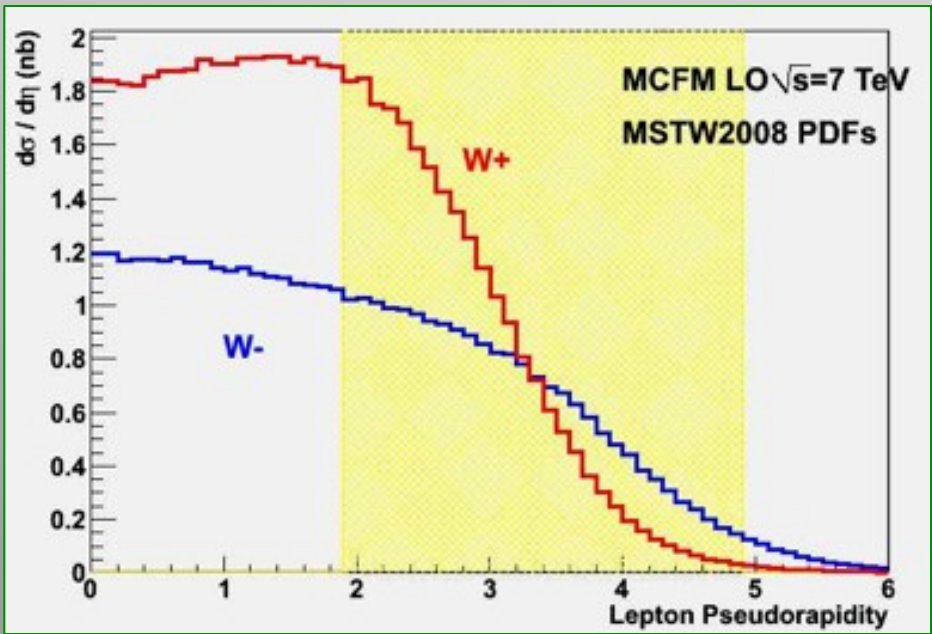
- Designed to look at CP violation and rare decays in beauty and charm hadrons @ LHC
- Fully instrumented within : $1.9 < \eta < 4.9$
- Muon reconstruction suited for EW : $P_t > 1$ GeV/c, $m_{\mu\mu} > 2.5$ GeV/c^2



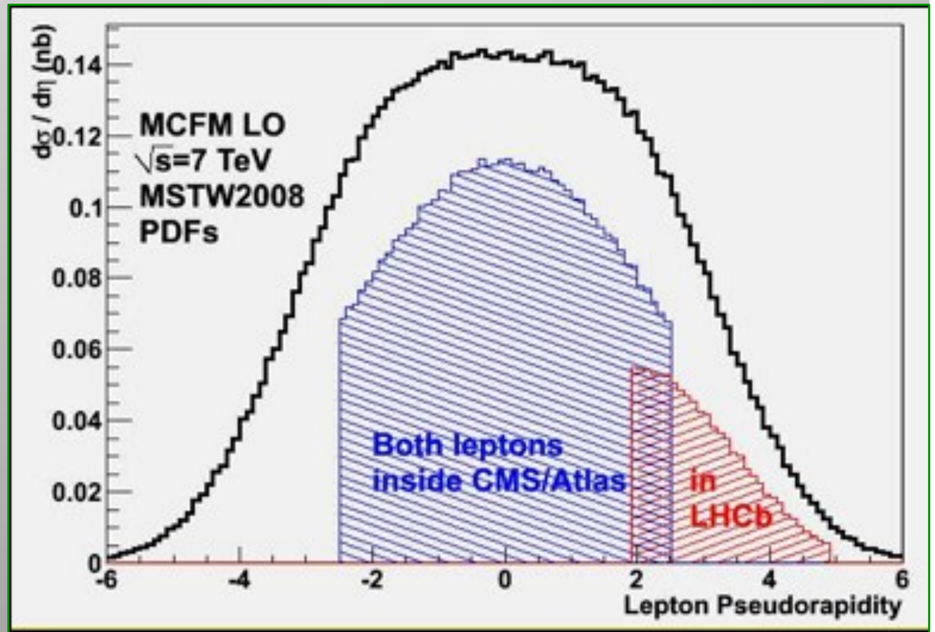
Looking forward

- **Complementary η range to ATLAS & CMS**
  - Overlap for cross check $1.9 < \eta < 2.5$
  - Unique to LHCb $2.5 < \eta < 4.9$





17%(16%) of $W^+(W^-)$ within LHCb

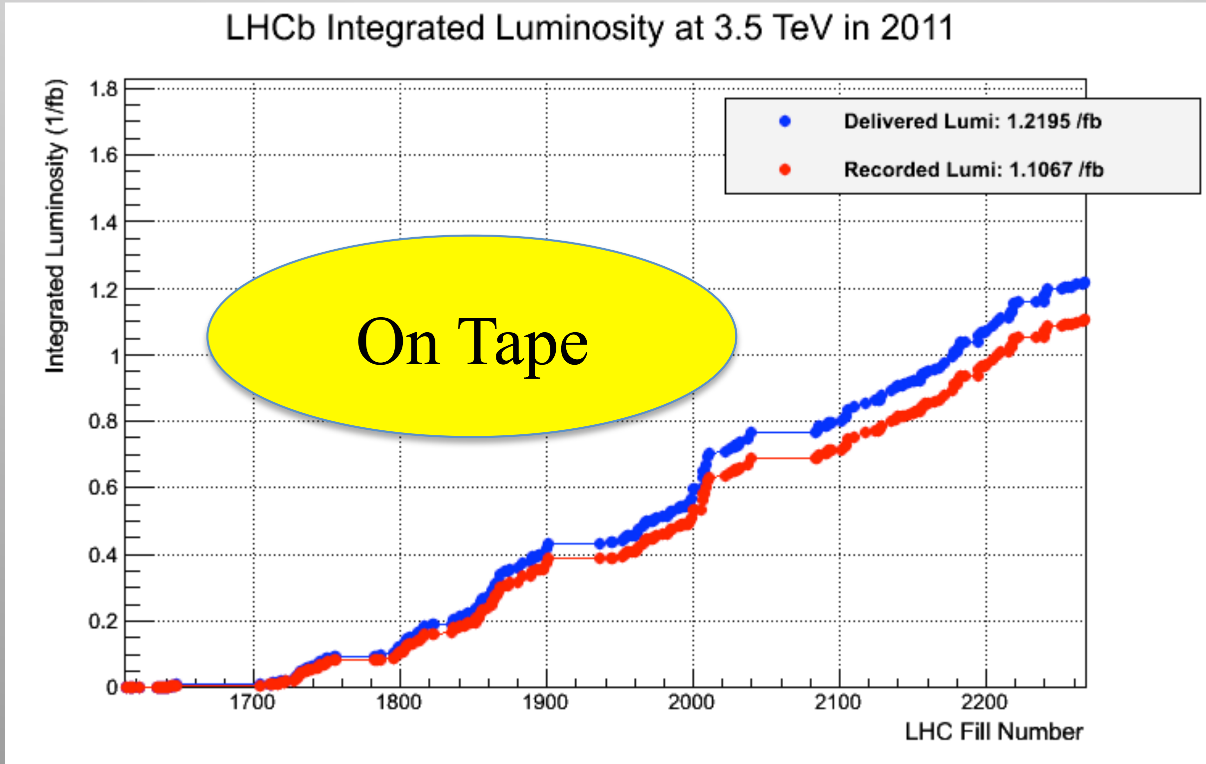


8% of Z within LHCb

Datasets

$\int L_{2010} = (37.1 \pm 1.3)\ pb^{-1}$ ($Z \rightarrow \mu\mu$, $Z \rightarrow \tau\tau$ and $W \rightarrow \mu\upsilon$ analyses)

$\int L_{2011} \sim 210\ pb^{-1}$ ($Z \rightarrow \tau\tau$ analysis)



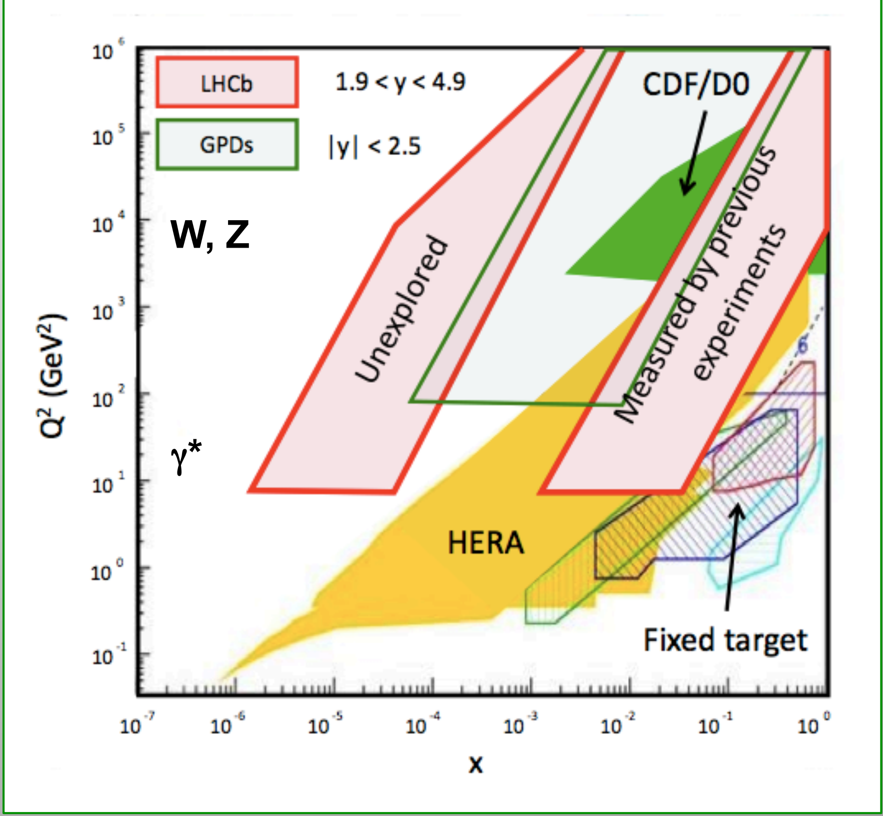
PDF @LHCb

-LHCb's forward acceptance provides very interesting possibilities for PDF studies

-Take large-x from one proton and a small-x from the other

- Probe two distinct regions in (x, Q^2) space

-Can probe the low-x, high-Q^2 region inaccessible to other experiments



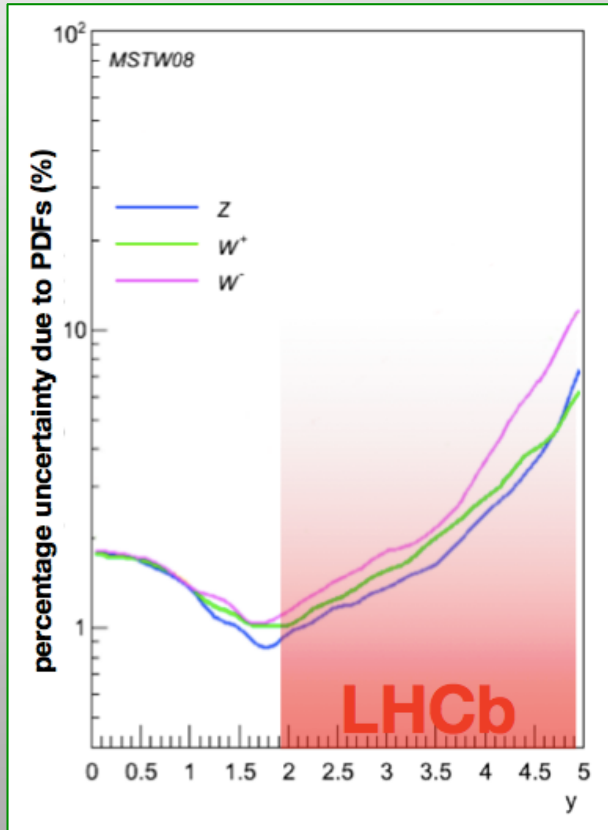
$$Q^2 = M^2 \ , \ x_{1,2} = \frac{M}{\sqrt{s}} \cdot e^{\pm y}$$

- Explore with W, Z (x of 10^{-4}, 10^{-1}) and low-mass Drell-Yan (x $>10^{-6}$)

W & Z Production and PDFs

- **Theoretical predictions**
  - Partonic cross-sections known @ NNLO to 1%
  - PDF uncertainty dominates @ large rapidities (1% @ y<2, 6-8% @ y~5)

$$\underbrace{\sigma(x,Q^2)}_{hadronic\ x-sec.} = \sum_{a,b} \int_0^1 dx_1 dx_2 \underbrace{f_a(x_1 Q^2) f_b(x_2 Q^2)}_{PDFs\ 2-8\%} \underbrace{\hat{\sigma}(x_1, x_2, Q^2)}_{partonic\ x-sec.:\ NNLO\ 1\%}$$



- **Experimental measurements**
  - Clean signature
  - Easily reconstructible final state
  - Low statistical and systematic errors

Cross-section measurements @ LHCb can constrain PDFs

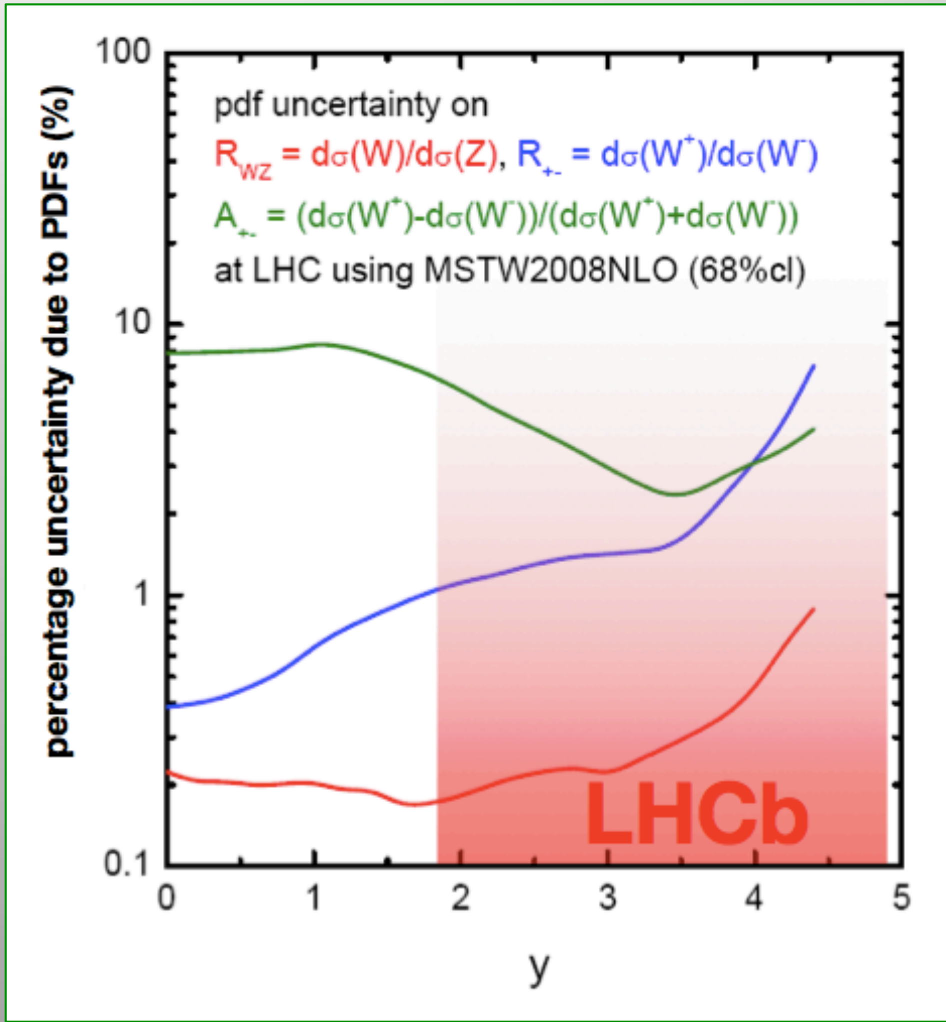
W & Z Production and PDFs

Cancel or highlight PDF uncertainties with ratios

$A_{+-} = (d\sigma_{W+} - d\sigma_{W-}) / (d\sigma_{W+} + d\sigma_{W-})$
→ Tests u_V and d_V difference

$R_{+-} = d\sigma_{W+} / d\sigma_{W-}$
→ Tests d_V/u_V ratio

$R_{WZ} = d\sigma_{W+-} / d\sigma_{Z}$
→Almost insensitive to PDFs
precise test of SM



$Z \rightarrow \mu\,\mu$

LHCb Preliminary
LHCb-CONF-2011-039

Trigger : Single muon trigger: $P_t > 10$ GeV/c

Reconstruction: 2 reconstructed muons

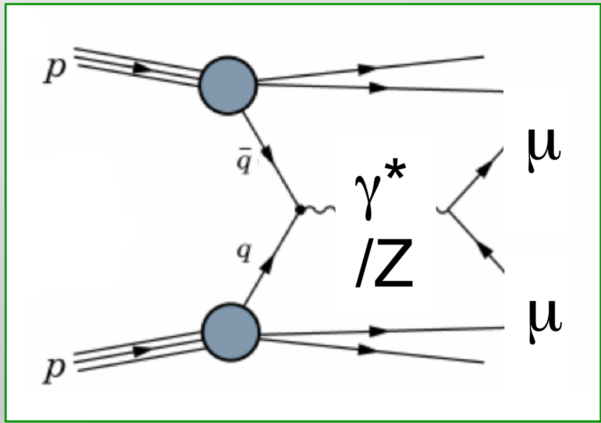
- $P_t > 20$ GeV/c
- $2.0 < \eta < 4.5$
- $60\ \text{GeV/c}^2 < m_{\mu\mu} < 120\ \text{GeV/c}^2$

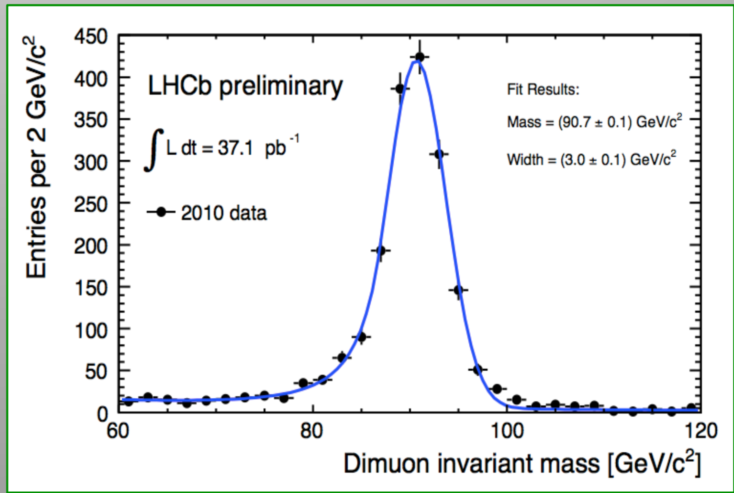
Backgrounds :

- $Z \rightarrow\!> \tau\tau = 0.61 \pm 0.04$ (MC)
- Heavy flavour $= 4.3 \pm 1.7$ (Data)
- π/K mis-ID $= 0 \pm 1$ (Data)

$\mathbf{N_{Candidates} = 1966 \pm 44}$

$\mathbf{N_{Background} = 4.9 \pm 2.0}$





Z → τ τ

Single muon trigger: $P_t > 10$ GeV/c

Both τ decay to muons

2 reconstructed isolated muons

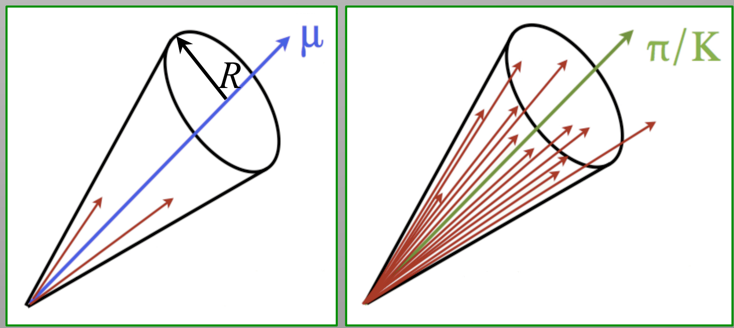
- $P_{t,1} > 20$ GeV/c, $P_{t,2} > 5$ GeV/c
- $2.0 < \eta < 4.5$
- $\Delta\varphi > 2.7$
- Cone P_t asymmetry (R=0.5) > 0.8

-Muon P_t asymmetry > 0.2
-Impact parameter significance > 4
-$m_{\mu\mu} < 80$ GeV/c^2

One τ decays to μ, one to e

1 reconstructed & isolated μ &e

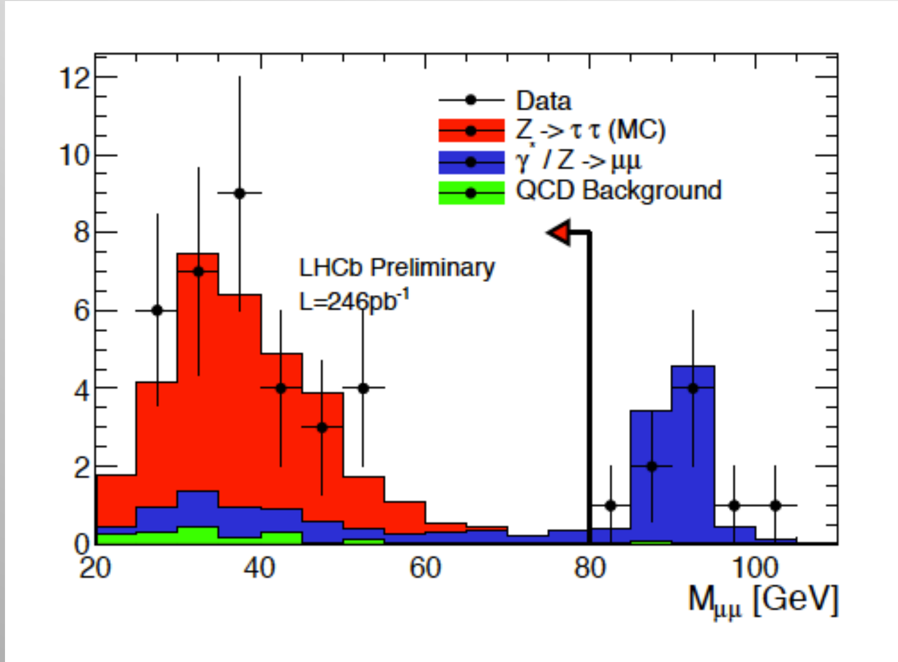
- $P_{t,\mu} > 20$ GeV/c, $P_{t,e} > 5$ GeV/c
- $2.0 < \eta < 4.5$
- $\Delta\varphi > 2.7$
- Cone P_t asymmetry (R=0.5) > 0.8

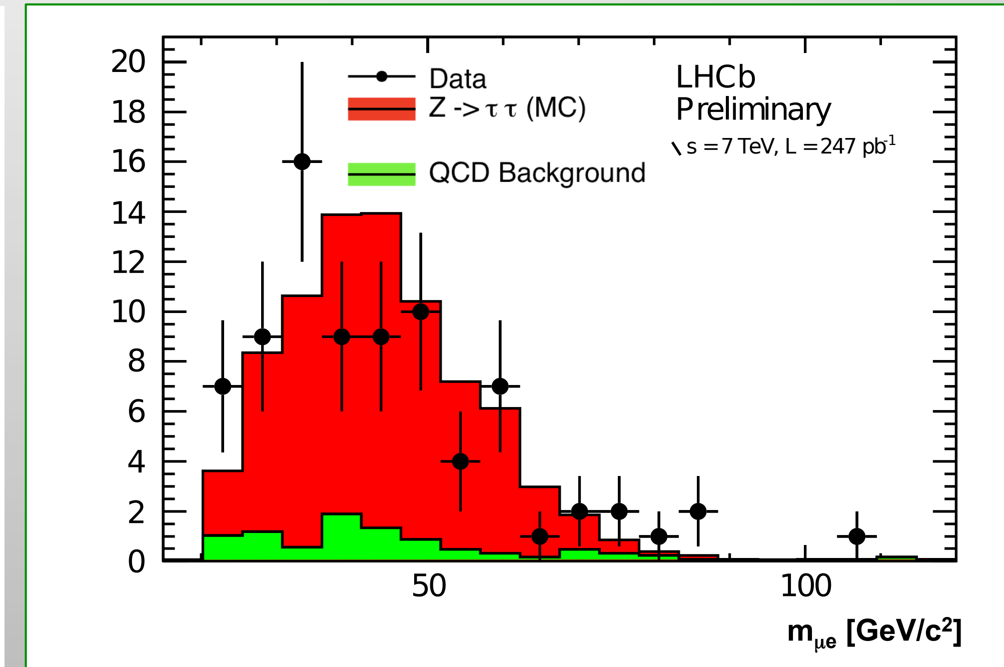


$$R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

$Z \rightarrow \tau\tau$

LHCb Preliminary
LHCb-CONF-2011-041





Backgrounds

EW = 5.5 ± 1.8 (Data)

QCD = 1.6 ± 1.3 (Data)

$N_{Candidates}$ = 33 ± 6

Backgrounds

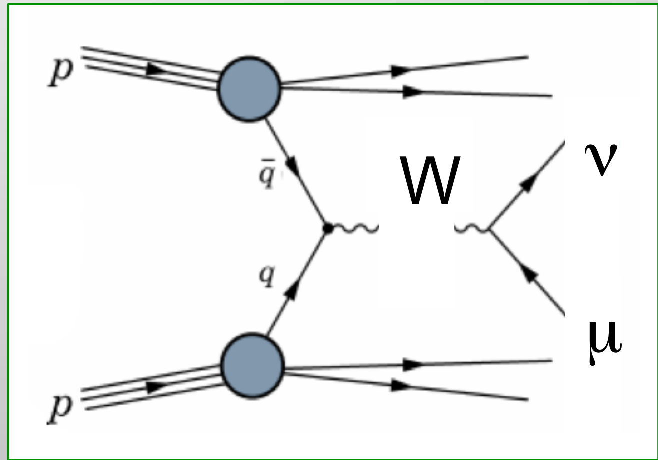
EW = 3.0 ± 1.2 (MC)

QCD = 9.5 ± 3.0 (Data)

$N_{Candidates}$ = 81± 9

$W \rightarrow \mu\, \nu_\mu$

Trigger : Single muon trigger: $P_t > 10$ GeV/c



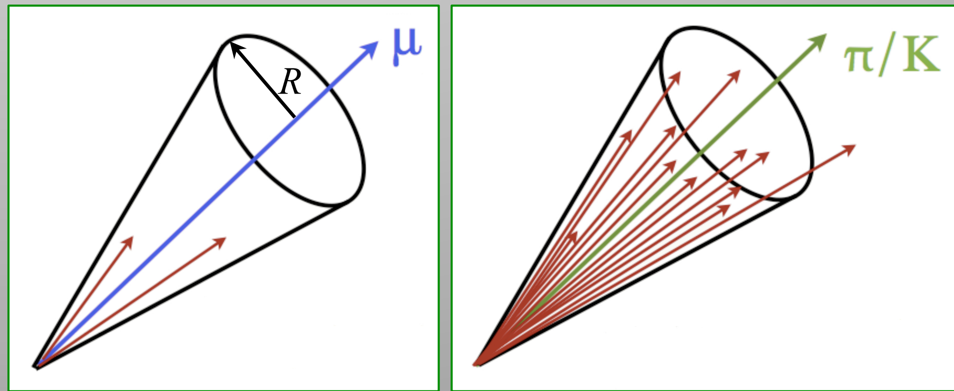
Reconstruction :

1 reconstructed & isolated muon

- $P_t > 20$ GeV/c
- $2.0 < \eta < 4.5$
- Cone P_t (R=0.5) < 2 GeV/c
- (charged & neutral information)

Backgrounds:

- $\gamma^*/Z \rightarrow \mu\mu$ (MC)
- $W \rightarrow \tau\nu$ and $Z \rightarrow \tau\tau$ (MC)
- K/π punchtrough (Data)
- K/π decay in flight (Data)
- Heavy flavour (Data)



$$R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

$W \rightarrow \mu\, \nu_\mu$

- Specific cuts implemented to reduce each background component

- $\gamma^*/Z \rightarrow \mu\mu$
  - No extra muons with $P_t > 5$ GeV/c

- $W \rightarrow \tau\nu$, $Z \rightarrow \tau\tau$ and Heavy flavour
  - Impact parameter < 40 mm

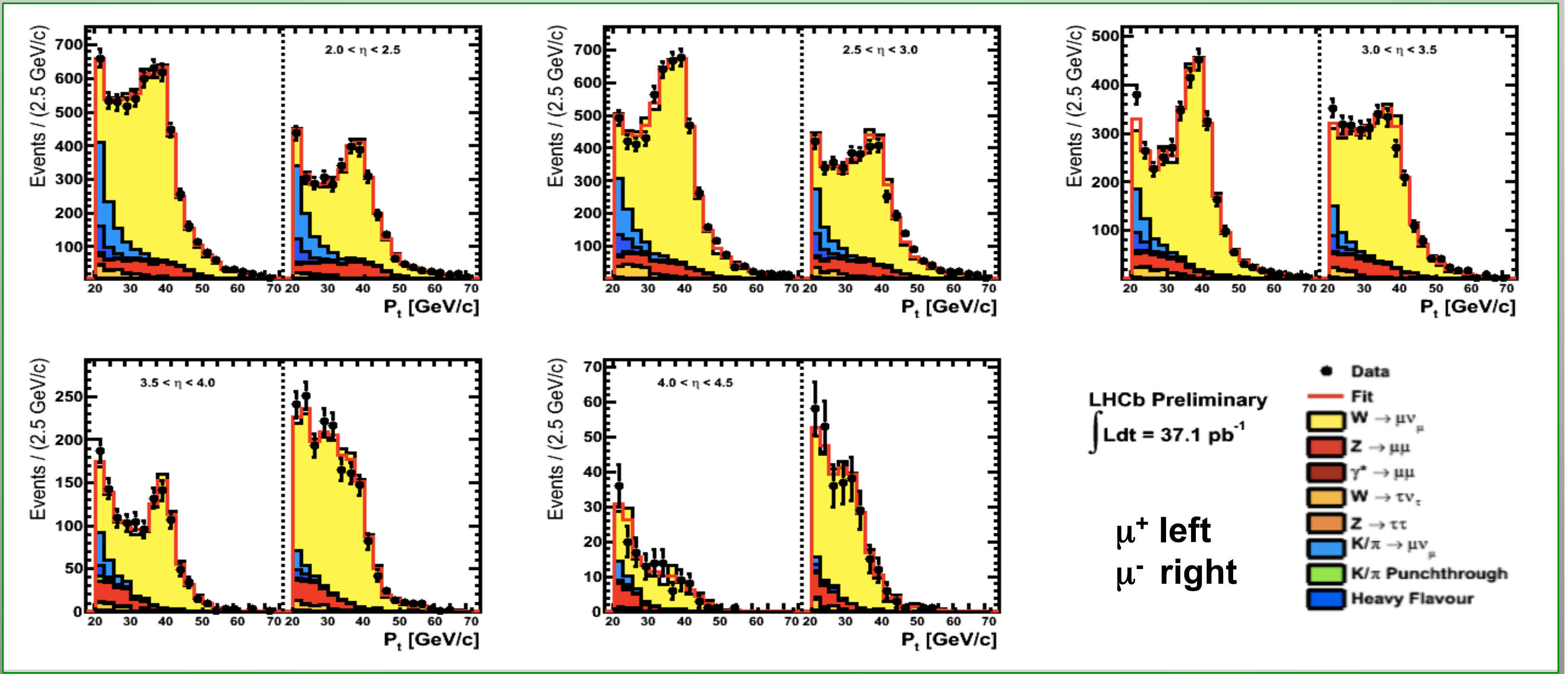
- K/π punchtrough
  - $E_{E+H} / P < 4\%$

- K/π decay in flight
  - Largest residual background besides $Z \rightarrow \mu\mu$ with one muon outside the acceptance.

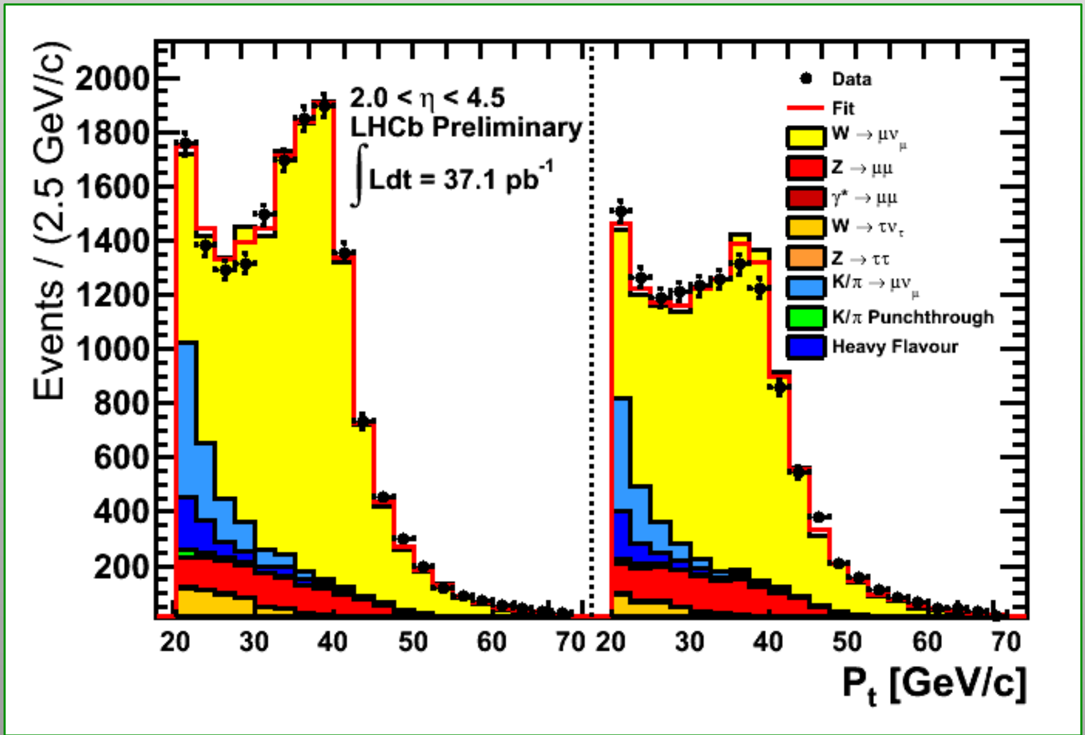
$W \rightarrow \mu\, \nu_\mu$

LHCb Preliminary
LHCb-CONF-2011-039

- Fit positive and negative muon P_t spectra in data to expected shapes for signal and backgrounds in 5 η bins



$W \rightarrow \mu \, \nu_\mu$



$N^{+}_{Candidates}$ = 15608 ± 125

$N^{-}_{Candidates}$ = 12301 ± 111

$Purity^{+}$ ~ 80%

$Purity^{-}$ ~ 78%

Efficiencies

The cross-section for boson production can be expressed as

$$\sigma = \frac{N_{Candidates} - N_{Background}}{A \cdot \varepsilon_{Trigger} \cdot \varepsilon_{Tracking} \cdot \varepsilon_{ID} \cdot \varepsilon_{Selection} \cdot \int L}$$

Measurements performed in the forward region ($2.0<\eta<4.5$) for leptons with $P_t>20$ GeV/c → A = 1 (except for Z→ττ, obtained from MC)
Efficiencies determined from data and cross checked with simulation

Selection efficiency

- Z→μμ selection criteria define the measurement kinematic region
- Z→ττ: determined from MC
- W→μν: measured from Z→μμ data with 1 muon masked

Efficiencies

Efficiencies determined with a Tag&Probe method in Z→μμ samples

Trigger

Tag: triggered muon

Probe: offline identified muon

Tracking (electron from MC)

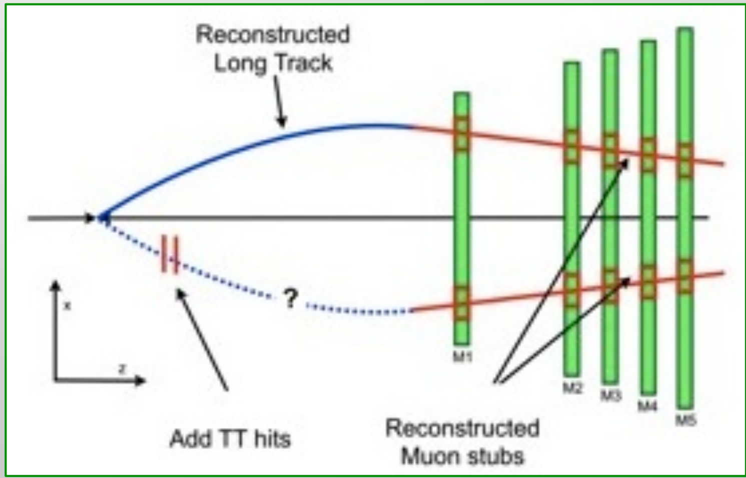
Tag: identified muon track

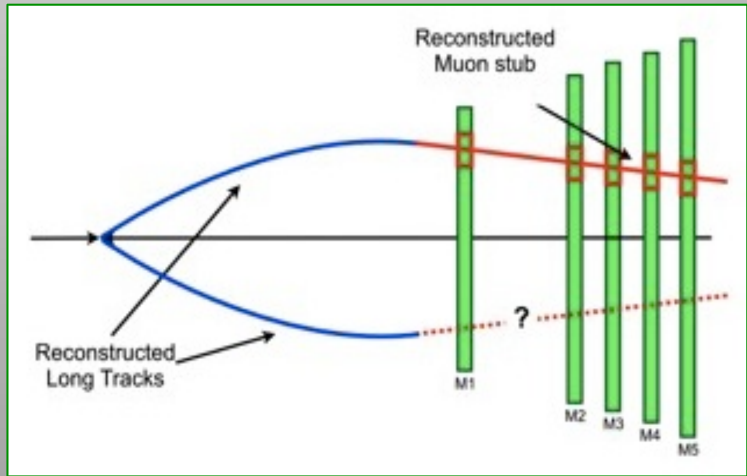
Probe: trajectory from muon stub and minimal tracking information

Particle ID

Tag: identified lepton

Probe: reconstructed track





Efficiencies flat in φ, P_t, and #PV

No evidence for charge bias

Correction vs η

Systematics

- Background error large for W because of uncertainty on shapes
- Efficiency uncertainties dominated by limited statistics

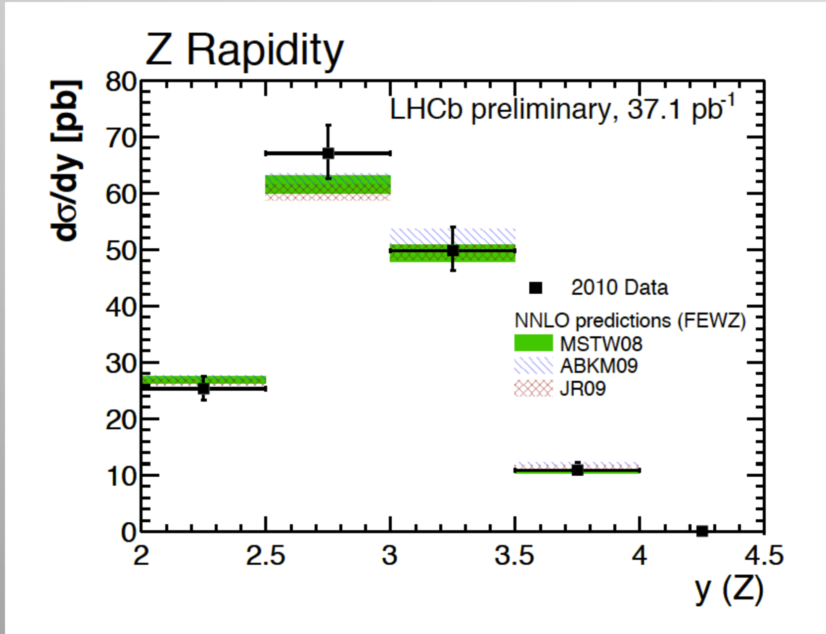
Source	$Z \to \mu\mu$	$Z \to \tau\tau(\mu\mu)$	$Z \to \tau\tau(\mu e)$	$W^+ \to \mu^+ \nu_\mu$	$W^- \to \mu^- \nu_\mu$
Background	0.4	7	5	1.6	1.6
Shape (Fit)	-	-	-	1.9	1.7
Efficiency	5.1	9	8	2.5	2.3
Acceptance	-	2	5	-	-
FSR	0.3	0.2	0.2	0.2	0.2
Systematic	5.1	11	10	3.5	3.2
Luminosity	3.5	5.1		3.5	
Statistical	2.1	17	12	0.9	1.1

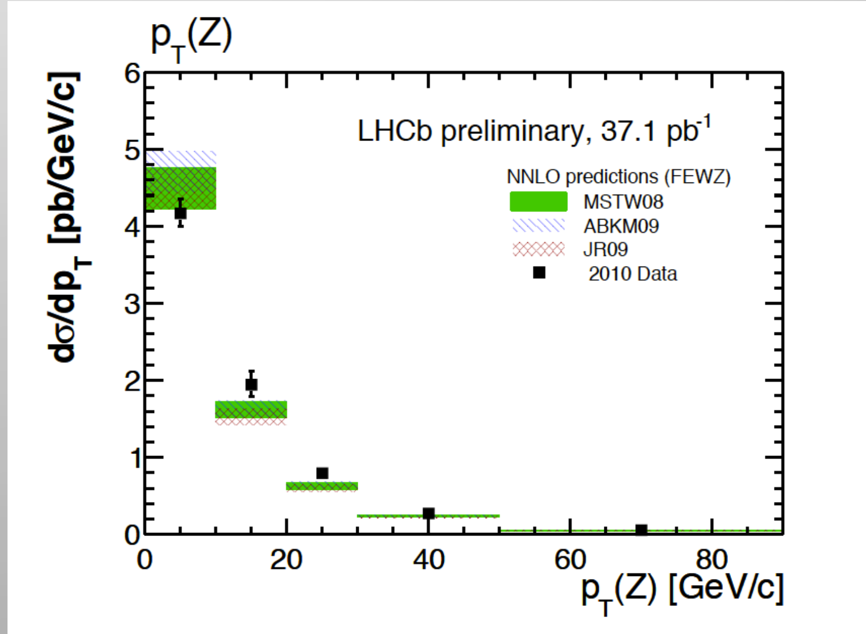
Relative errors are quoted

Z Cross-Section

LHCb Preliminary
LHCb-CONF-2011-039(041)

Kinematic range: $2.0 < \eta_\mu < 4.5$, $P_{t,\mu} > 20$ GeV/c and $60 < m_{\mu\mu} < 120$ GeV/c^2





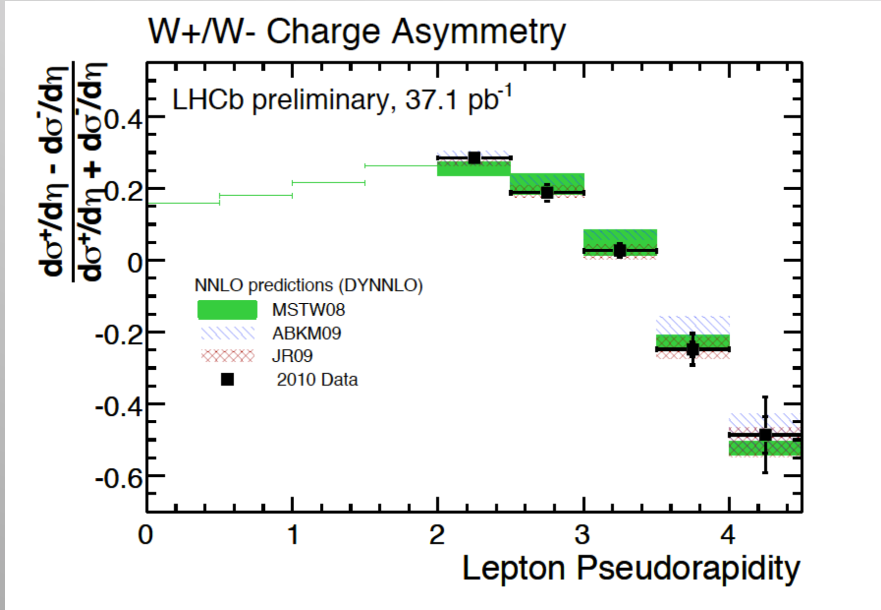
$\sigma_{Z\to\mu\mu} = 74.9 \pm 1.6_{stat} \pm 3.8_{syst} \pm 2.6_{lumi}$ [pb]

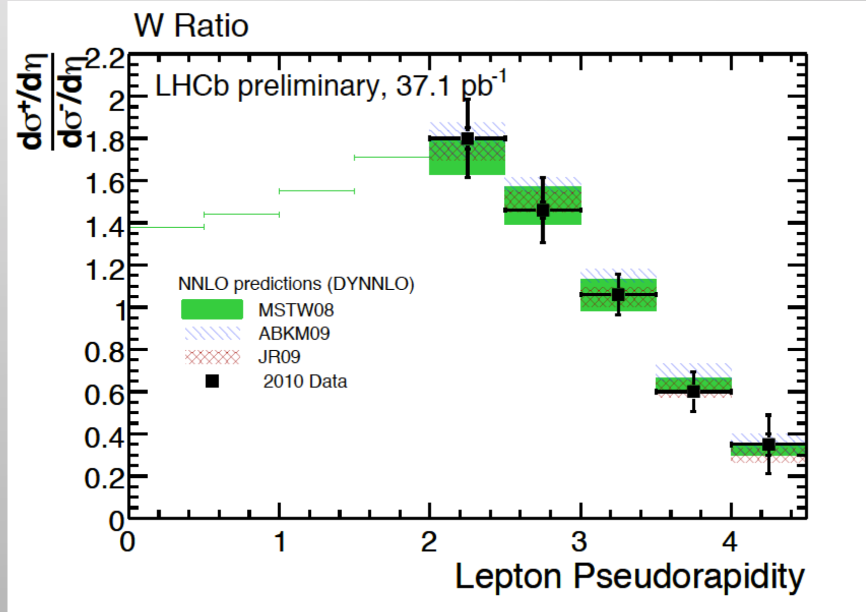
$\sigma_{Z\to\tau\tau} = 82 \pm 8_{stat} \pm 7_{syst} \pm 4_{lumi}$ [pb]

$\Gamma(Z\to\tau\tau) / \Gamma(Z\to\mu\mu) = 1.09 \pm 0.17$

W Cross-Section

LHCb Preliminary
LHCb-CONF-2011-039





$\sigma_+ = (808 \pm 7_{stat} \pm 28_{syst} \pm 28_{lumi})$ pb

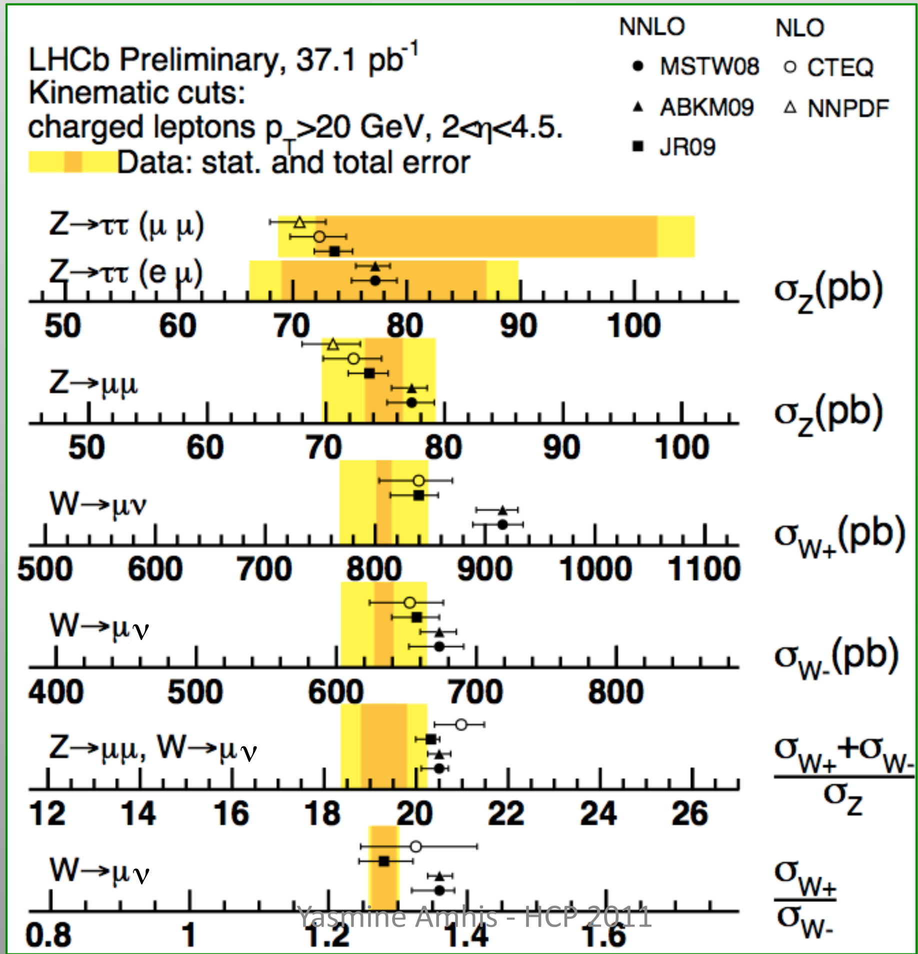
$\sigma_- = (634 \pm 7_{stat} \pm 21_{syst} \pm 22_{lumi})$ pb

$\sigma_+ / \sigma_- = 1.28 \pm 0.02_{stat} \pm 0.01_{syst}$

Comparisons

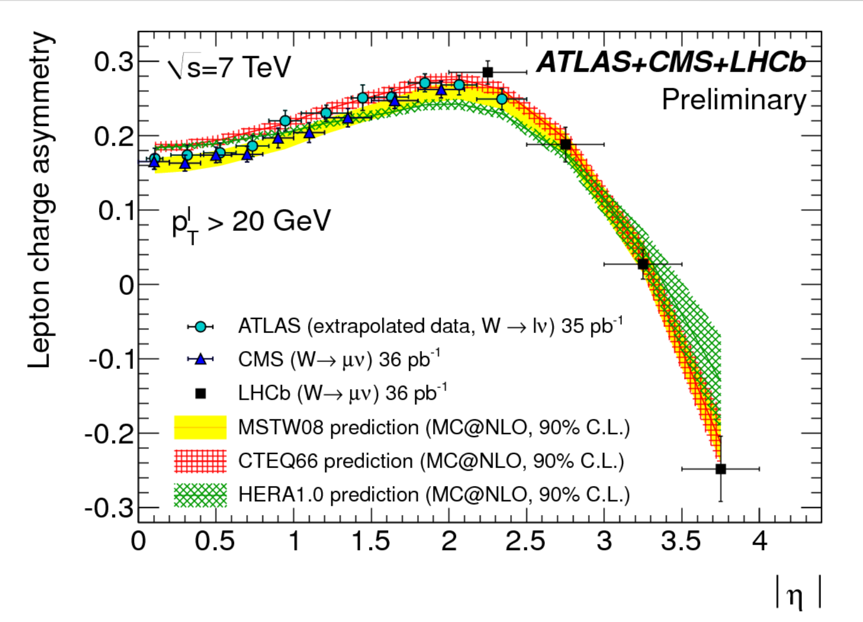
LHCb Preliminary
LHCb-CONF-2011-039(041)

- All W and Z observations are consistent with NNLO predictions



Improvements on PDFs

Central and forward measurements of the W charge asymmetry will reduce the PDF uncertainty in both the large and small x regions



Summary and Outlook

- Cross-sections and ratios of W and Z measured @ 7TeV in the kinematic range $2.0 < \eta < 4.5$ and $P_t > 20$ GeV/c
- All observations consistent with the current NNLO predictions
- Collected 1.1 fb^{-1} in 2011
  → improved efficiency and background knowledge
- Probe PDFs in previously unexplored regions
- Distinguish different PDF models