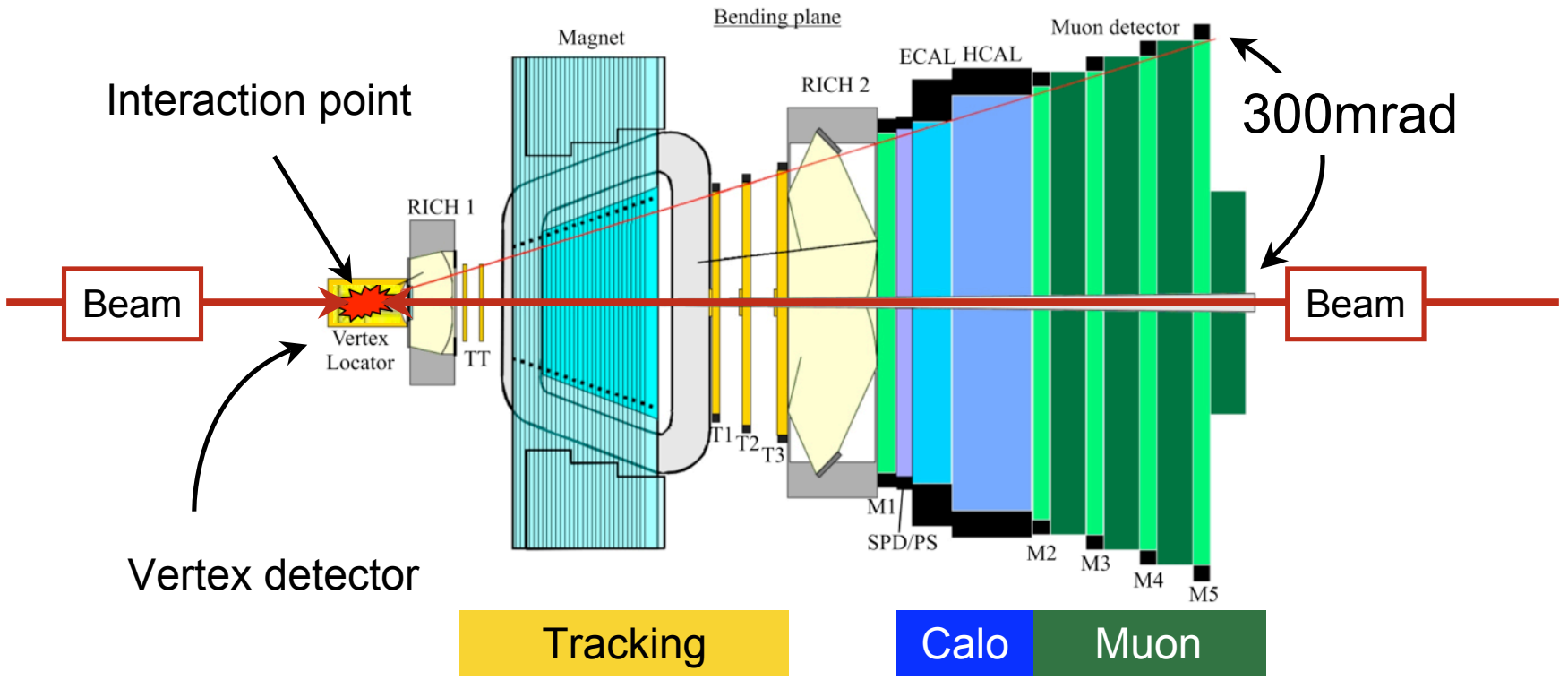
UNIVERSITY OF LIVERPOOL

Electroweak boson production in the forward region with **LHCb**

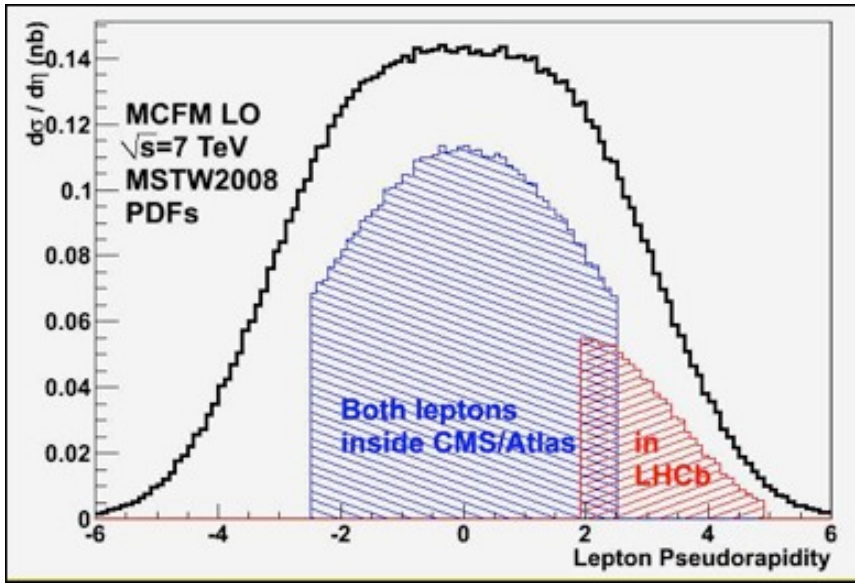
Tara Shears, for the LHCb collaboration

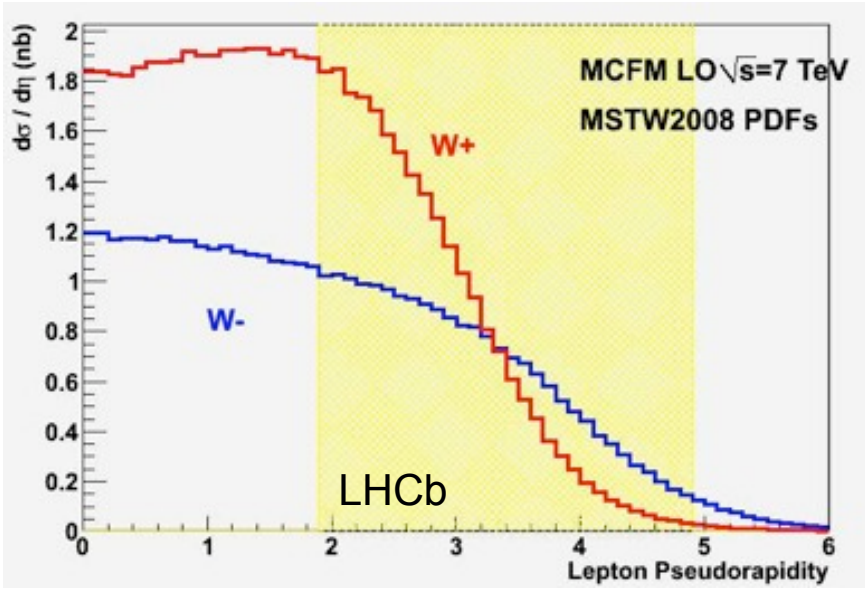
- Introduction
- W→μν, Z→μμ production measurements
- Z→ττ (eμ, μμ) production measurements
- Outlook
- Conclusions



Fully instrumented within $1.9 \leq \eta \leq 4.9$

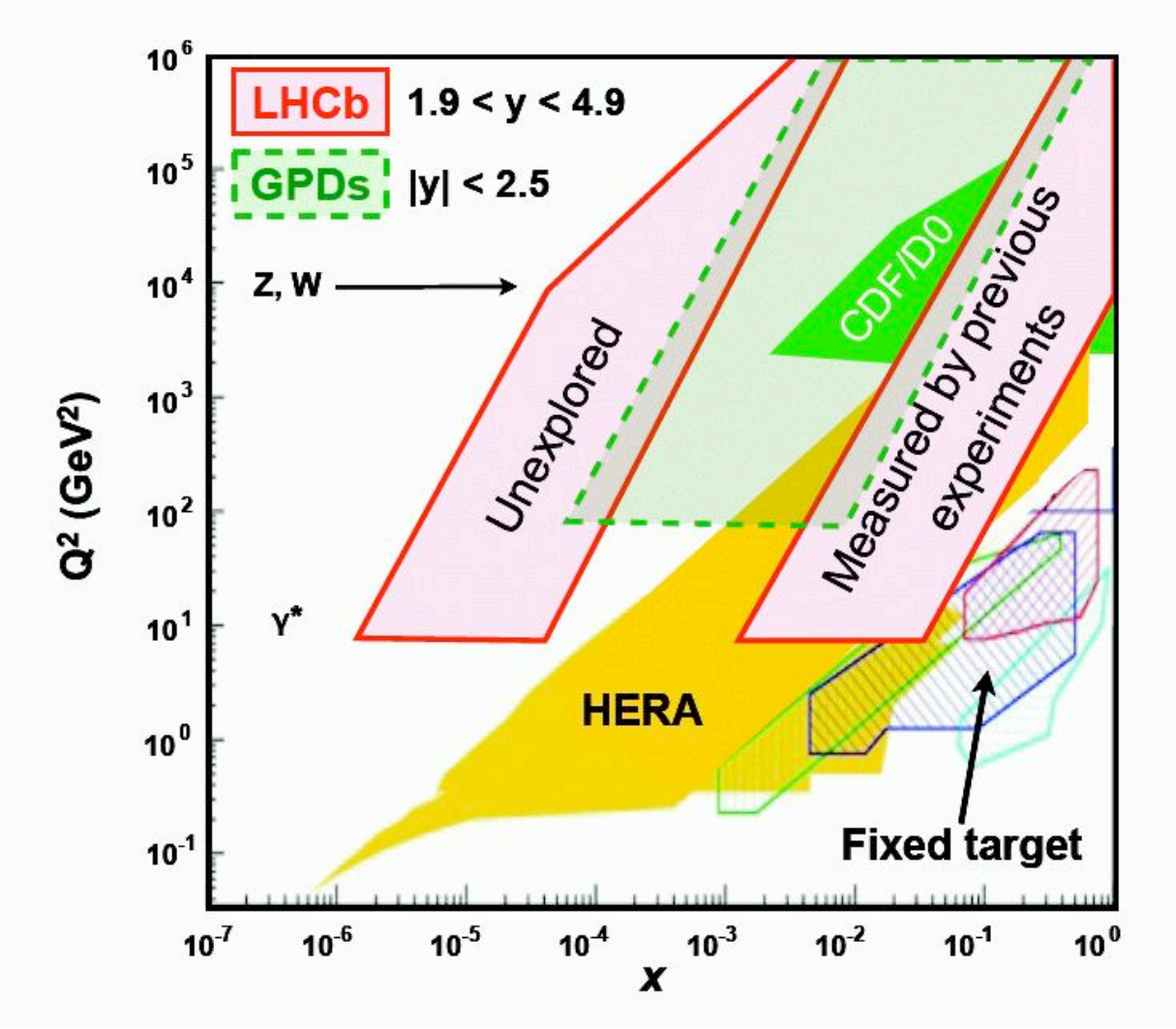
Trigger: $p_\mu > 3$ GeV, $pt_\mu > 0.5$ GeV, $m_{\mu\mu} > 2.5$ GeV





8% of Z within LHCb acceptance

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

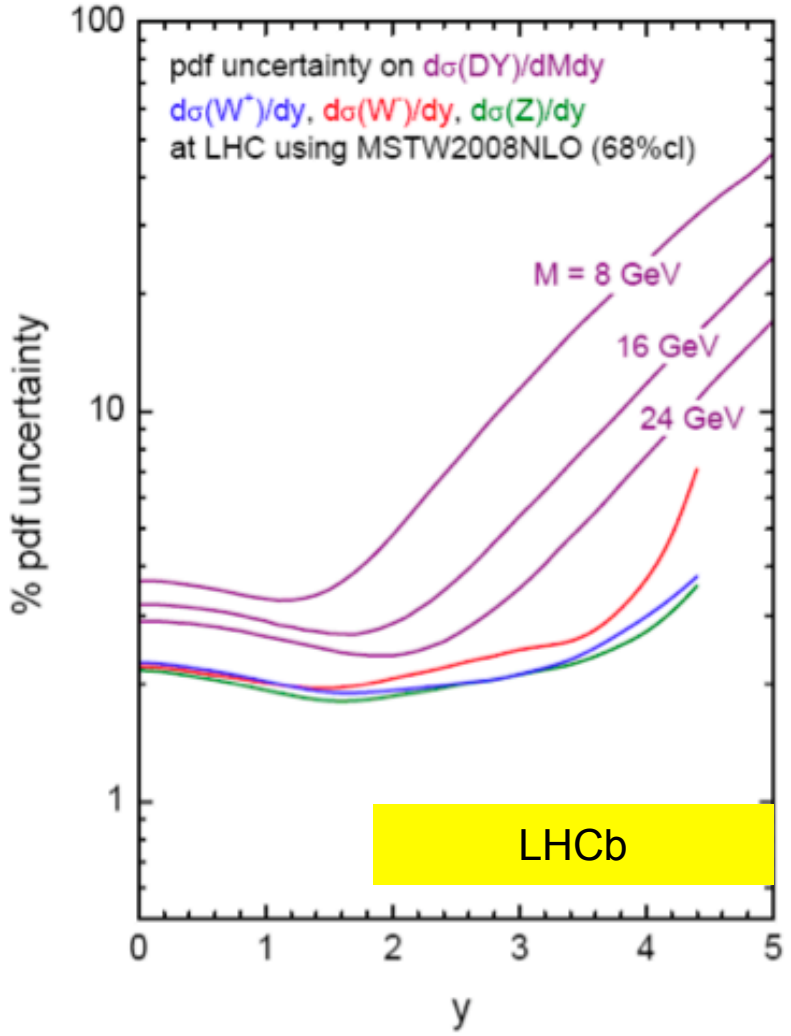


X, Q^2 explored by previous experimental data

Cross-sections known to NNLO
PDF uncertainty dominates.

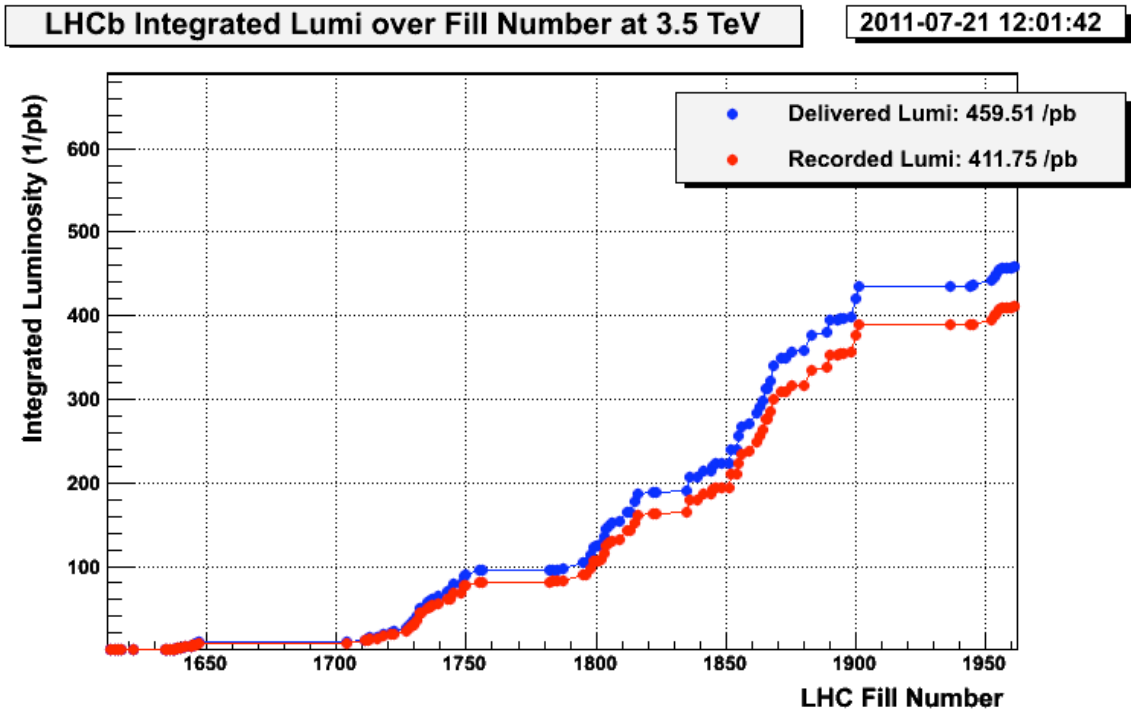
W,Z: Known to ~2% at y ~1.5-2, 6-8% at y~5

Forward measurements can test SM, and provide data to constrain partons.



2010:
37.7 pb^{-1} data recorded

2011:
410 pb^{-1} recorded so far
(210 pb^{-1} analysed here)



Definition of measured cross-sections:

$$\sigma(Z \to \mu\mu : 2 < \eta_\mu < 4.5, P_{T\mu} > 20GeV, 60 < M_{\mu\mu} < 120GeV)$$

(as function of Z rapidity, Z P_T)

$$\sigma(W \to \mu\nu : 2 < \eta_\mu < 4.5, P_{T\mu} > 20GeV)$$

(as function of muon pseudorapidity)

Trigger:

Single μ, p_T > 10 GeV

Muon:

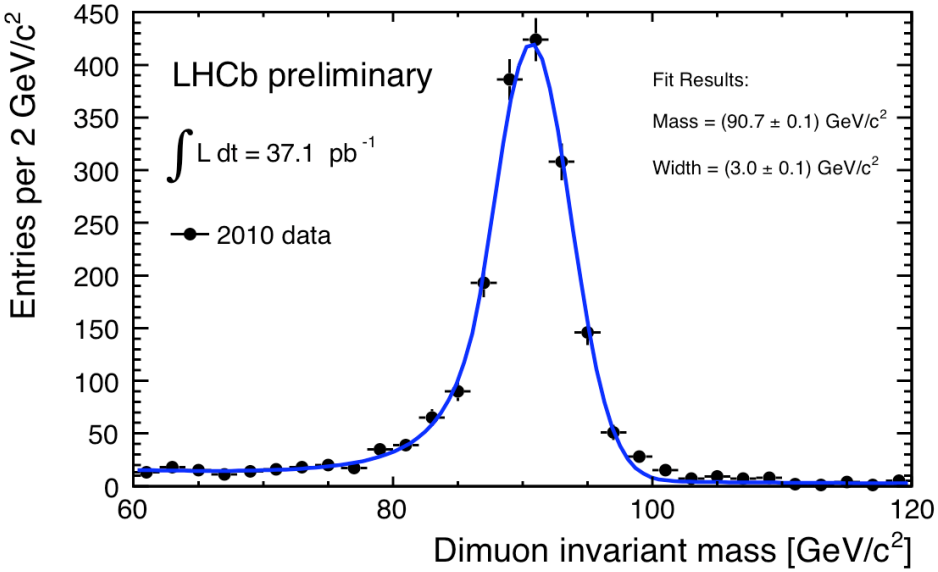
Good track quality

p_T> 20 GeV

2.0 < η < 4.5

Z:

60 < M(μμ) < 120 GeV



1966 candidates

Backgrounds:

Z→ττ 0.6 ± 0.2

Heavy flavour: 4.3 ± 3

Mis-id: 1 ± 1

Trigger:

Single μ, p_T > 10 GeV

Muon:

Good track quality
p_T > 20 GeV
2.0 < η < 4.5
Unbiased impact parameter < 40 μm
$\Sigma(p_T + E(\gamma))$ in $R=\sqrt{(\Delta\eta^2+\Delta\phi^2)}=0.5$ cone around μ < 2 GeV
E/p < 0.04
No other μ with P_T > 5 GeV

Efficiency 45%-80%
Estimated using Z data
η dependent

N_{W+} = 15 608
N_{W-} = 12 301

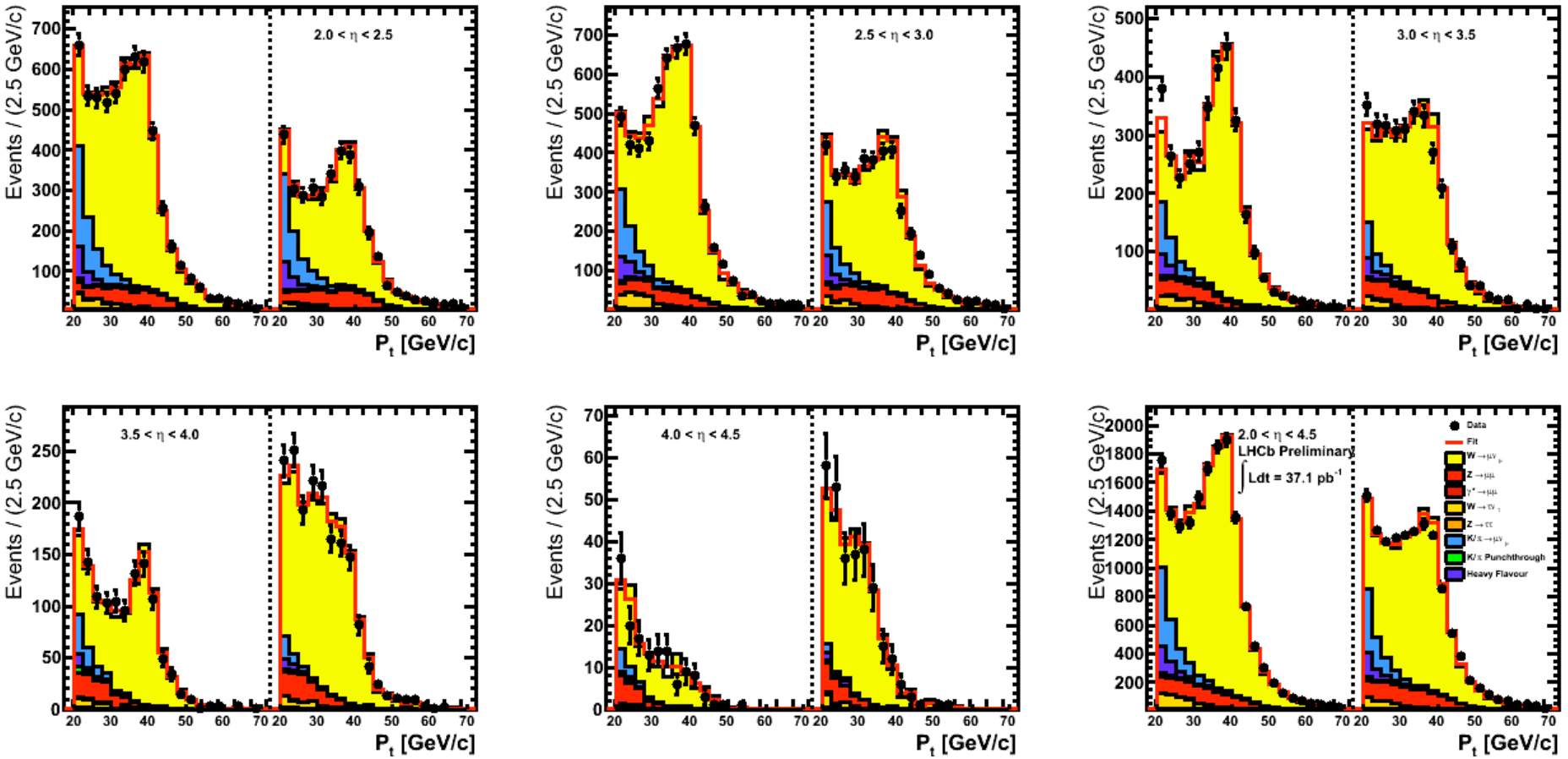
Background sources:

- $Z \rightarrow \mu\mu$ (1 μ in acceptance)
- $\gamma^* \rightarrow \mu\mu$
- $Z \rightarrow \tau\tau$
- $W \rightarrow \tau\nu$
- Punch-through
- Heavy flavour
- Decay in flight

Data
Simulation
Data + simulation

Fit muon p_T spectrum in data to expected shapes for signal and background, extract N_{bkg+}, N_{bkg-}

μ+ μ-


2.0 < η < 2.5
2.5 < η < 3.0
3.0 < η < 3.5
3.5 < η < 4.0
4.0 < η < 4.5
2.0 < η < 4.5
LHCb Preliminary
∫Ldt = 37.1 pb⁻¹
Data
Fit
Heavy Flavour
Events / (2.5 GeV/c)
P_t [GeV/c]

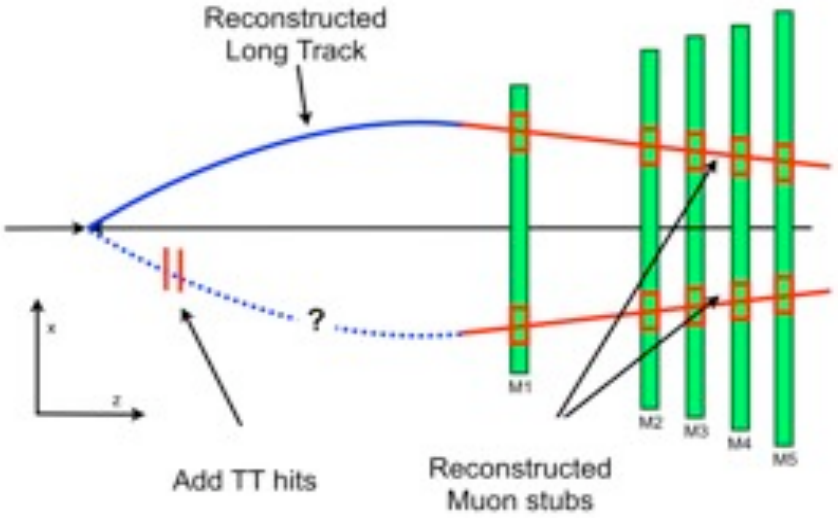
$$\varepsilon_Z = A_Z \varepsilon_Z^{track} \varepsilon_Z^{muon} \varepsilon_Z^{trig} \varepsilon_Z^{selection}$$

$$\varepsilon_W = A_W \varepsilon_W^{track} \varepsilon_W^{muon} \varepsilon_W^{trig} \varepsilon_W^{selection}$$

A_W (A_Z) from MC, consistent with 1.0.

$$\varepsilon_Z = A_Z \varepsilon_Z^{track} \varepsilon_Z^{muon} \varepsilon_Z^{trig} \varepsilon_Z^{selection}$$

$$\varepsilon_W = A_W \varepsilon_W^{track} \varepsilon_W^{muon} \varepsilon_W^{trig} \varepsilon_W^{selection}$$



Determine from data (Z events)

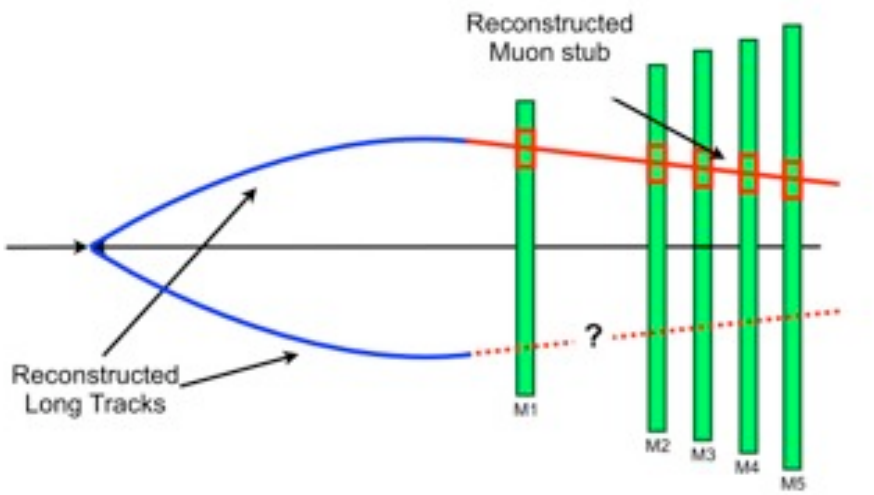
Tag: 1 identified muon

Probe: 1 muon stub + TT hit

Bin efficiencies in lepton η, calculate for each event.
ε(W+,W-) ~ 79%
ε(Z) ~ 81.5%

$$\varepsilon_Z = A_Z \varepsilon_Z^{track} \varepsilon_Z^{muon} \varepsilon_Z^{trig} \varepsilon_Z^{selection}$$

$$\varepsilon_W = A_W \varepsilon_W^{track} \varepsilon_W^{muon} \varepsilon_W^{trig} \varepsilon_W^{selection}$$



Determine from data (Z events)

Tag: 1 identified muon

Probe: 1 track

Bin efficiencies in lepton η, calculate for each event.
ε(W+,W-) ~ 99%
ε(Z) ~ 98%

$$\varepsilon_Z = A_Z \varepsilon_Z^{track} \varepsilon_Z^{muon} \varepsilon_Z^{trig} \varepsilon_Z^{selection}$$

$$\varepsilon_W = A_W \varepsilon_W^{track} \varepsilon_W^{muon} \varepsilon_W^{trig} \varepsilon_W^{selection}$$

Determine from data (Z events)

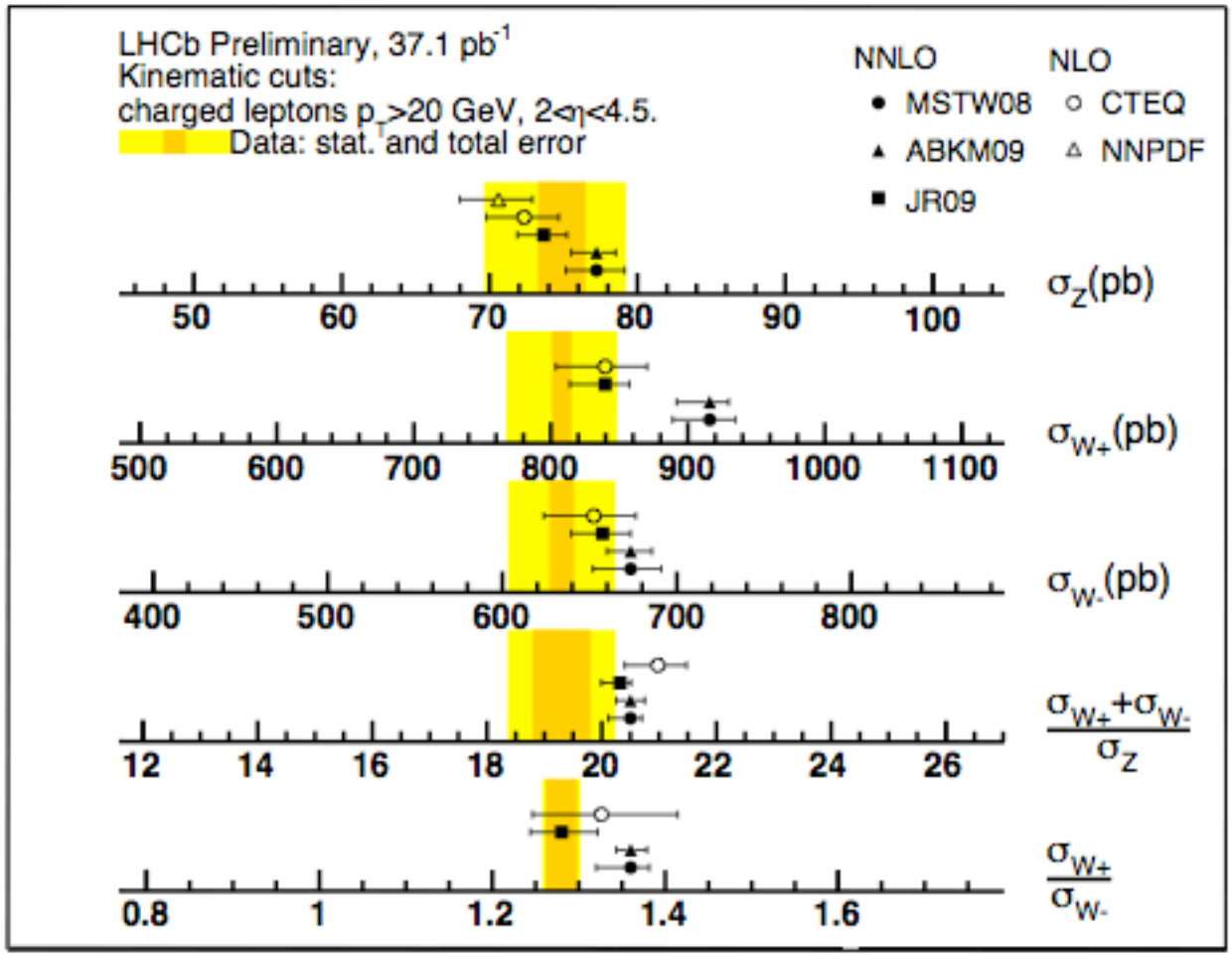
Tag: 1 identified muon having fired the single muon trigger

Probe: 1 identified muon

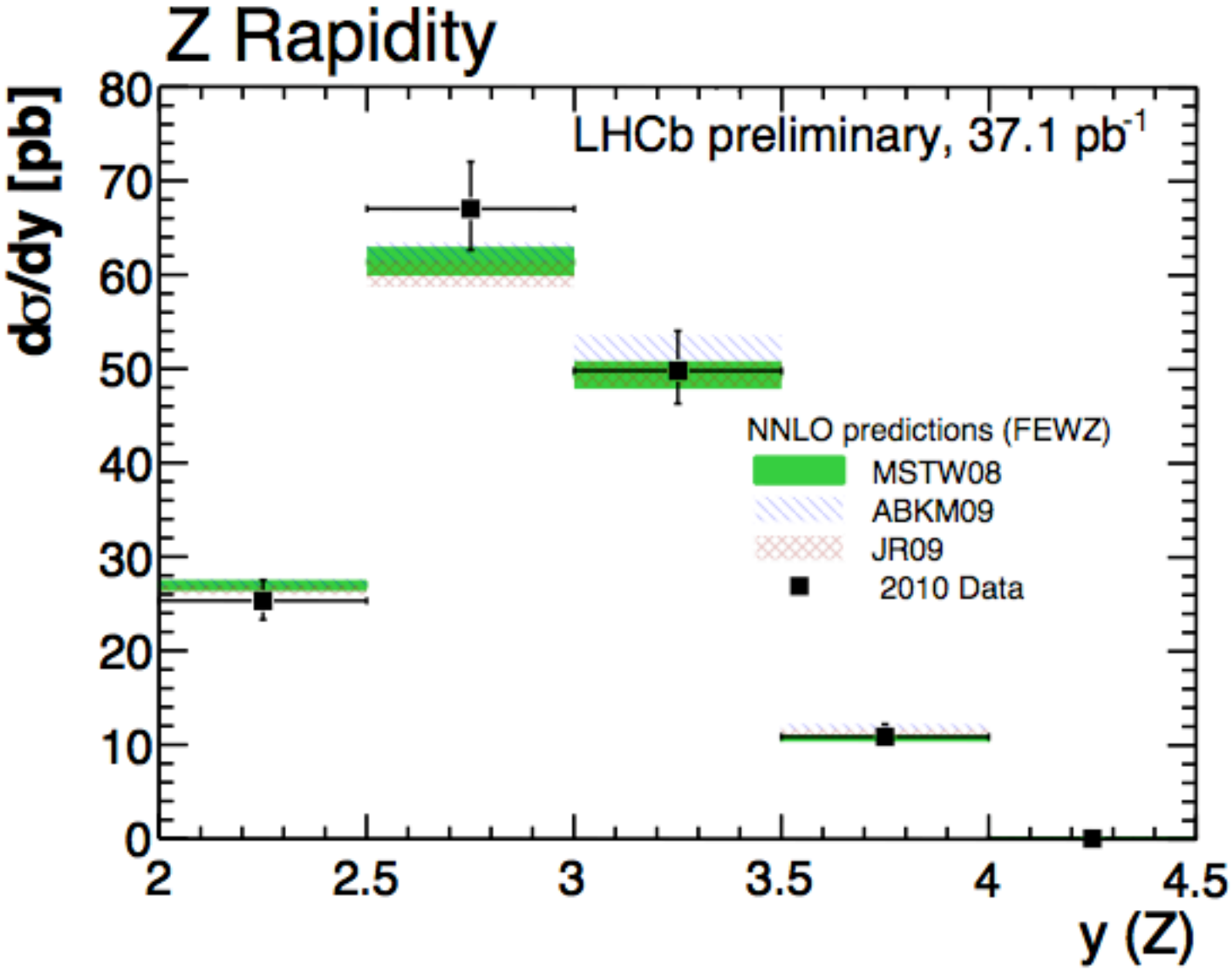
+ Hit multiplicity threshold: estimate from data.

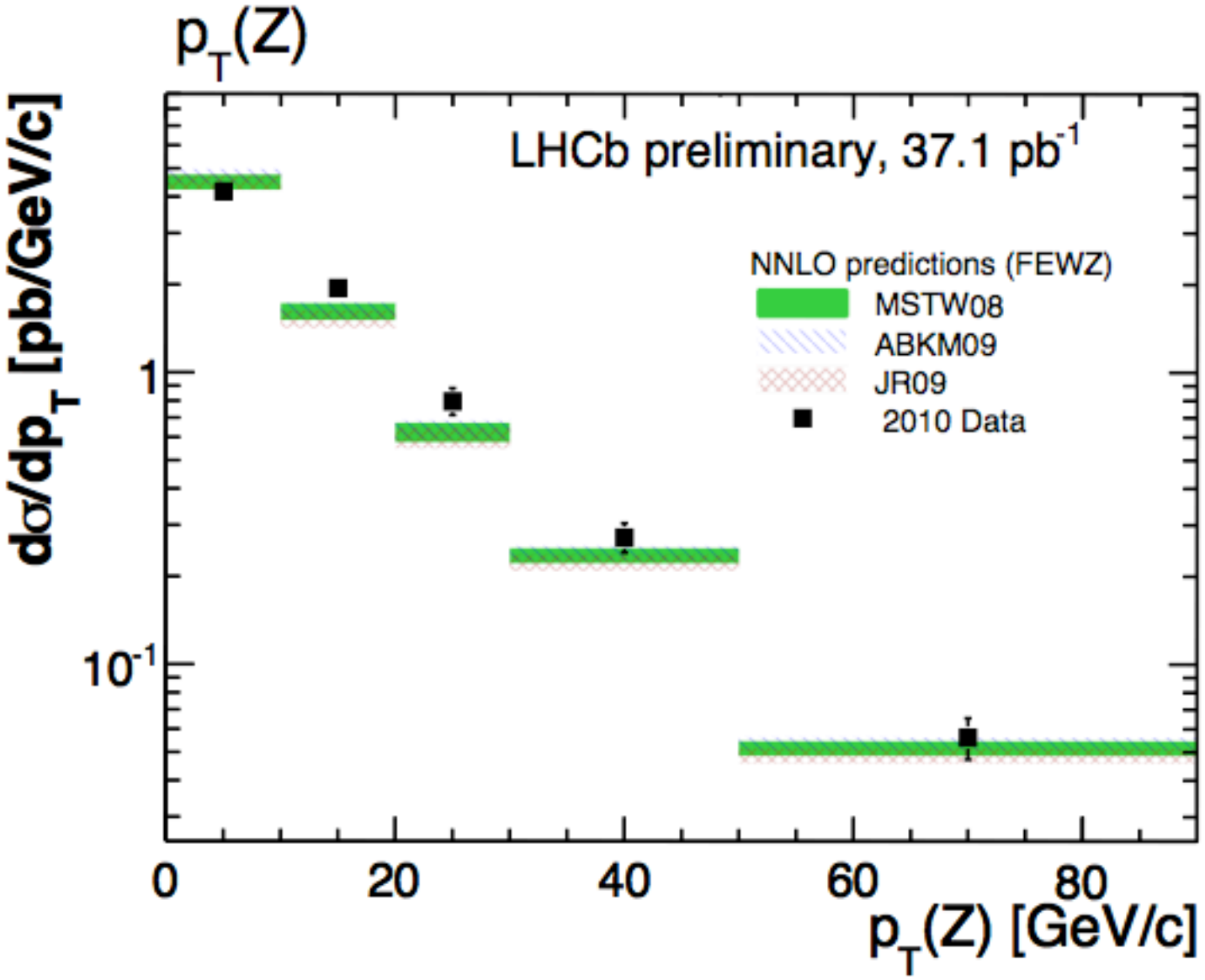
Bin efficiencies in lepton η, calculate for each event.
ε(W+,W-) ~ 80%
ε(Z) ~ 95%
ε(mult) ~ 95%

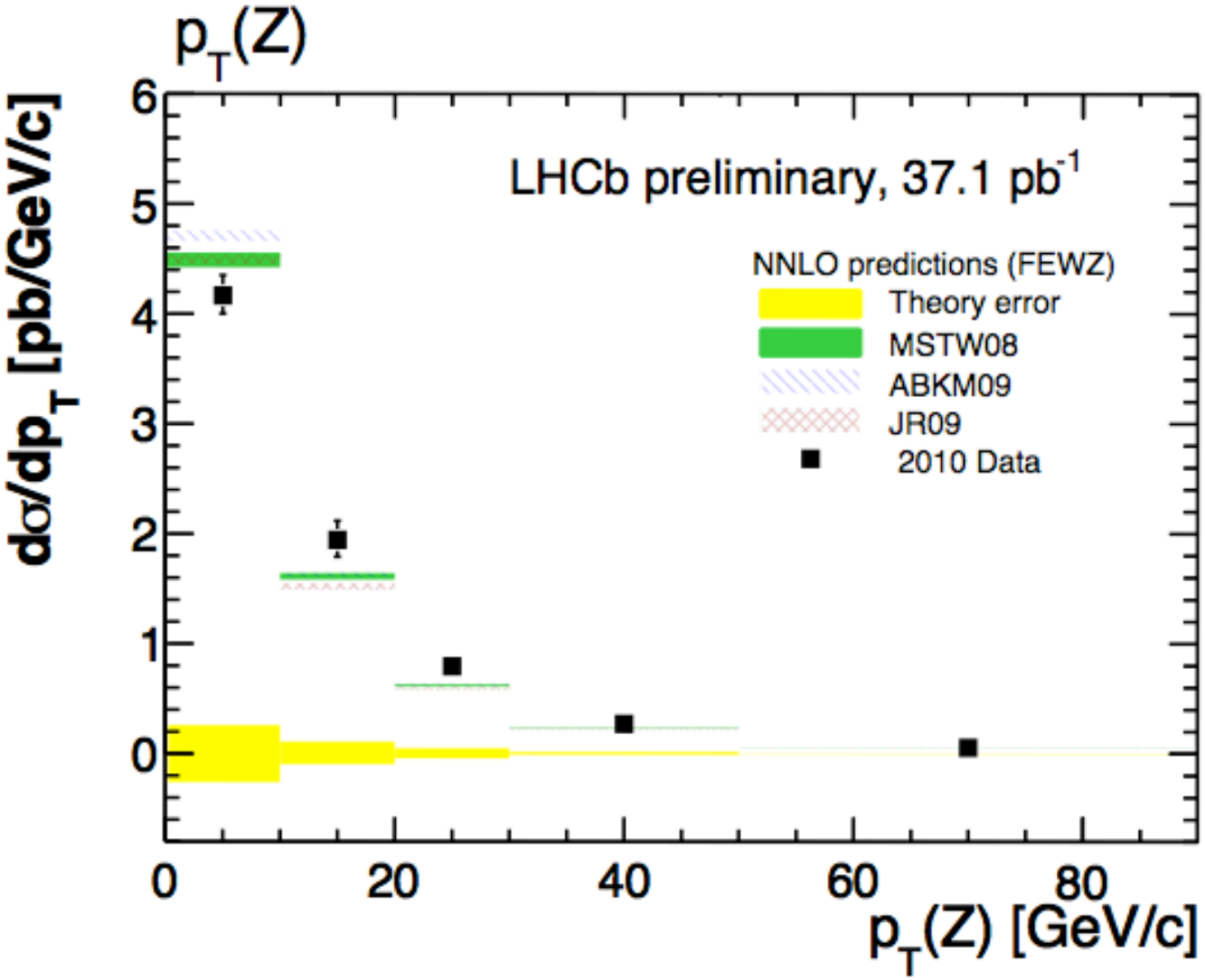
	Δσ(W+) [%]	Δσ(W-) [%]	Δσ(Z) [%]
Background	± 1.6	± 1.6	± 0.4
Shape (fit)	± 1.9	± 1.7	n/a
Efficiency	± 2.0	± 1.8	± 5.1
FSR correction	± 0.2	± 0.2	± 0.3
Sys. error	± 3.5	± 3.2	± 5.1
Luminosity	± 3.5	± 3.5	± 3.5
Stat. error	± 0.9	± 1.1	± 2.1

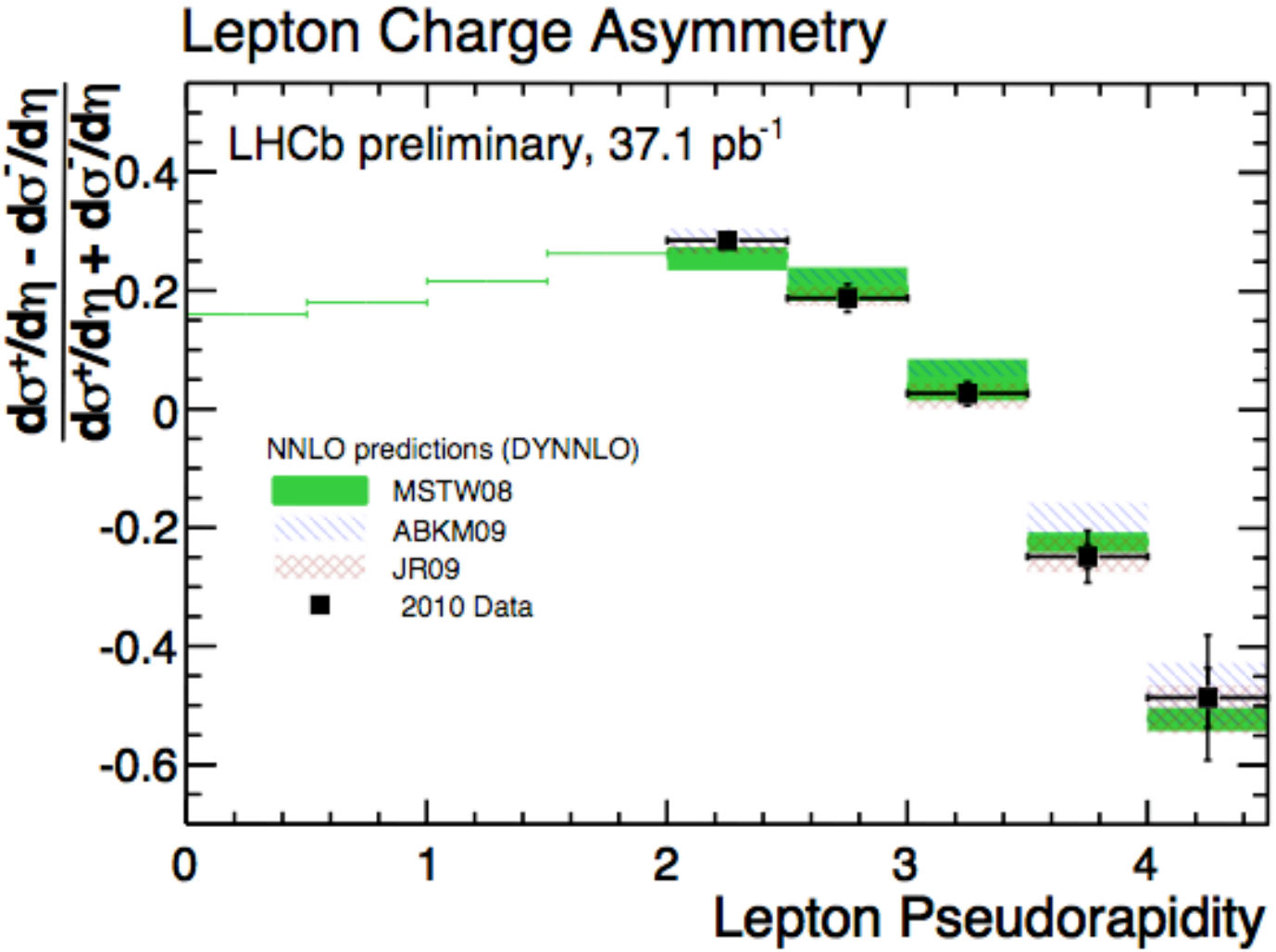


(FSR corrected, using HORACE)


Z Rapidity
LHCb preliminary, 37.1 pb-1
dσ/dy [pb]
y (Z)
NNLO predictions (FEWZ)
MSTW08
ABKM09
JR09
2010 Data
0
10
20
30
40
50
60
70
80
2
2.5
3
3.5
4
4.5


p_T(Z)
LHCb preliminary, 37.1 pb^-1
NNLO predictions (FEWZ)
MSTW08
ABKM09
JR09
2010 Data
dσ/dp_T [pb/GeV/c]
1
10^-1
0
20
40
60
80
p_T(Z) [GeV/c]


p_T(Z)
LHCb preliminary, 37.1 pb^-1
NNLO predictions (FEWZ)
Theory error
MSTW08
ABKM09
JR09
2010 Data
dσ/dp_T [pb/GeV/c]
p_T(Z) [GeV/c]
0
1
2
3
4
5
6
0
20
40
60
80



(also W+/W- differential spectrum in backups)

Definition of measured cross-section:

$$\sigma(Z \to \tau\tau : 2 < \eta_\tau < 4.5, P_{T\tau} > 20GeV, 60 < M_{\tau\tau} < 120GeV)$$

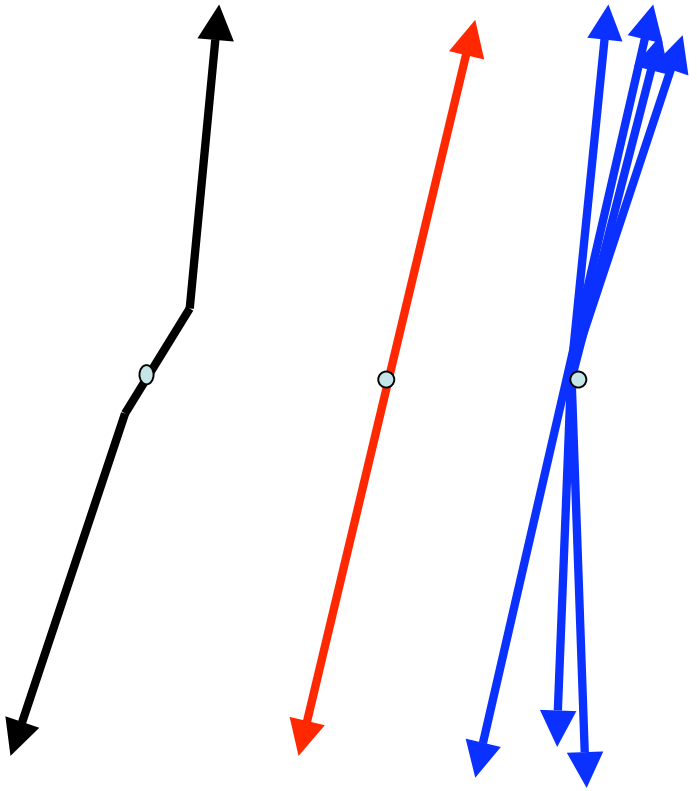
Final states considered: eμ, μμ

μ: $2 < \eta_\mu < 4.5$
$E/p < 0.2$

e: $2 < \eta_e < 4.5$
$E_{ECAL}/p > 0.1$, $E_{HCAL}/p < 0.05$
$E_{PRS} > 0.05$ GeV

Distinguish from backgrounds by Isolation

$$I = \min\left(\frac{p_{\mu,e} - \sum p_{track}}{p_{\mu,e} + \sum p_{track}}\right)$$



EWK, QCD

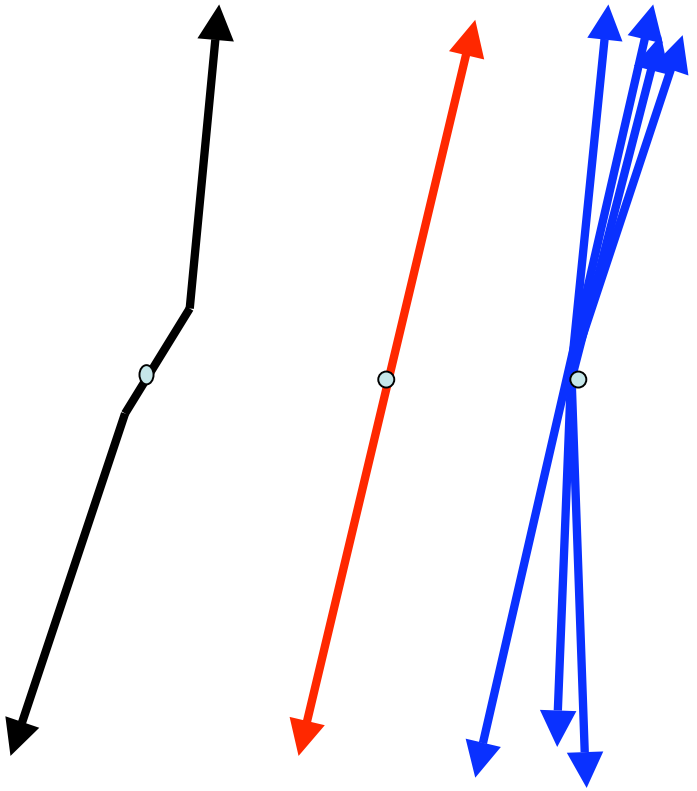
Final states considered: eμ, μμ

μ: $2 < \eta_\mu < 4.5$
$E/p < 0.2$

e: $2 < \eta_e < 4.5$
$E_{ECAL}/p > 0.1$, $E_{HCAL}/p < 0.05$
$E_{PRS} > 0.05$ GeV

Distinguish from backgrounds by
Impact parameter sum
$\Delta\phi$
P_T asymmetry

$$A_{PT} = \left(\frac{P_T^{\mu 1} - P_T^{\mu 2}}{P_T^{\mu 1} + P_T^{\mu 2}} \right)$$



EWK, QCD

Trigger:

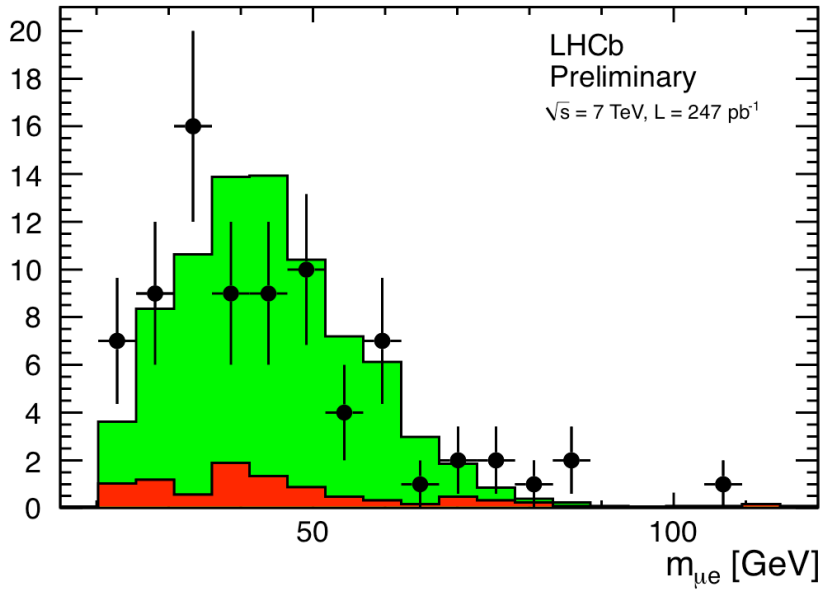
Single μ, p_T > 10 GeV

Muon: P_T^{μ} > 20 GeV

Electron: P_T^{e} > 5 GeV

Z: Δφ (eμ) > 2.7 radians

Isolation *I* > 0.8.



81 candidates

Backgrounds:

QCD: 9.5 ± 3

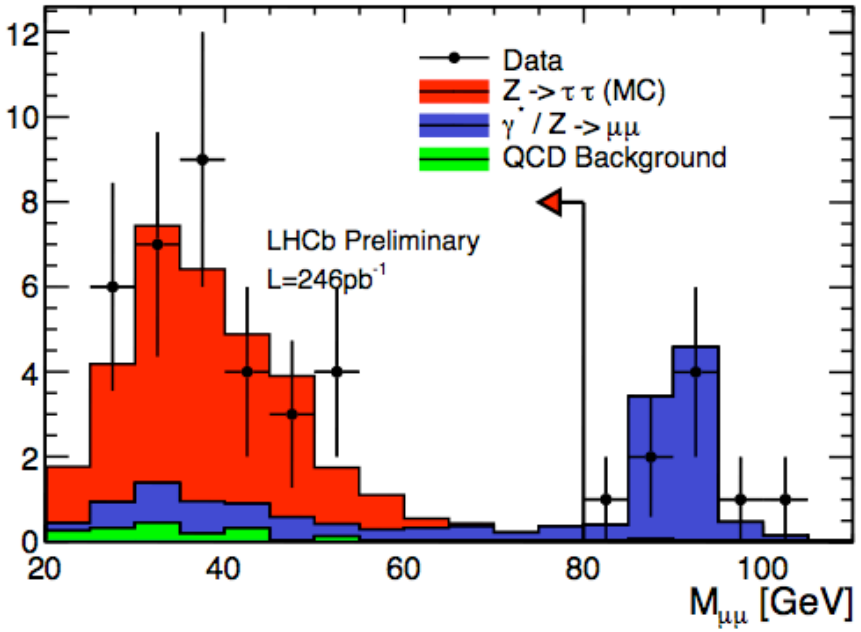
EWK: 3 ± 1.2

Trigger:

Single μ, p_T > 10 GeV

Muon: $P_T^{\mu 1}$ > 20 GeV,
$P_T^{\mu 2}$ > 5 GeV.

Z : I > 0.8
$\Delta\phi(\mu\mu)$ > 2.7 radians
IP_{sum} significance > 4
A_{PT} > 0.2



33 candidates
Backgrounds:
QCD: 1.6 ± 1.3
EWK: 5.5 ± 1.8

$$\varepsilon = A\ \varepsilon_{\mu}^{track}\varepsilon_{e}^{track}\varepsilon^{muon}\varepsilon^{electron}\varepsilon^{trig}\varepsilon^{selection}$$

A (MC)

ε^{trig} (data): tag-and-probe Z→μμ

$\varepsilon^{track}_{\mu}$ (data): tag-and-probe Z→μμ

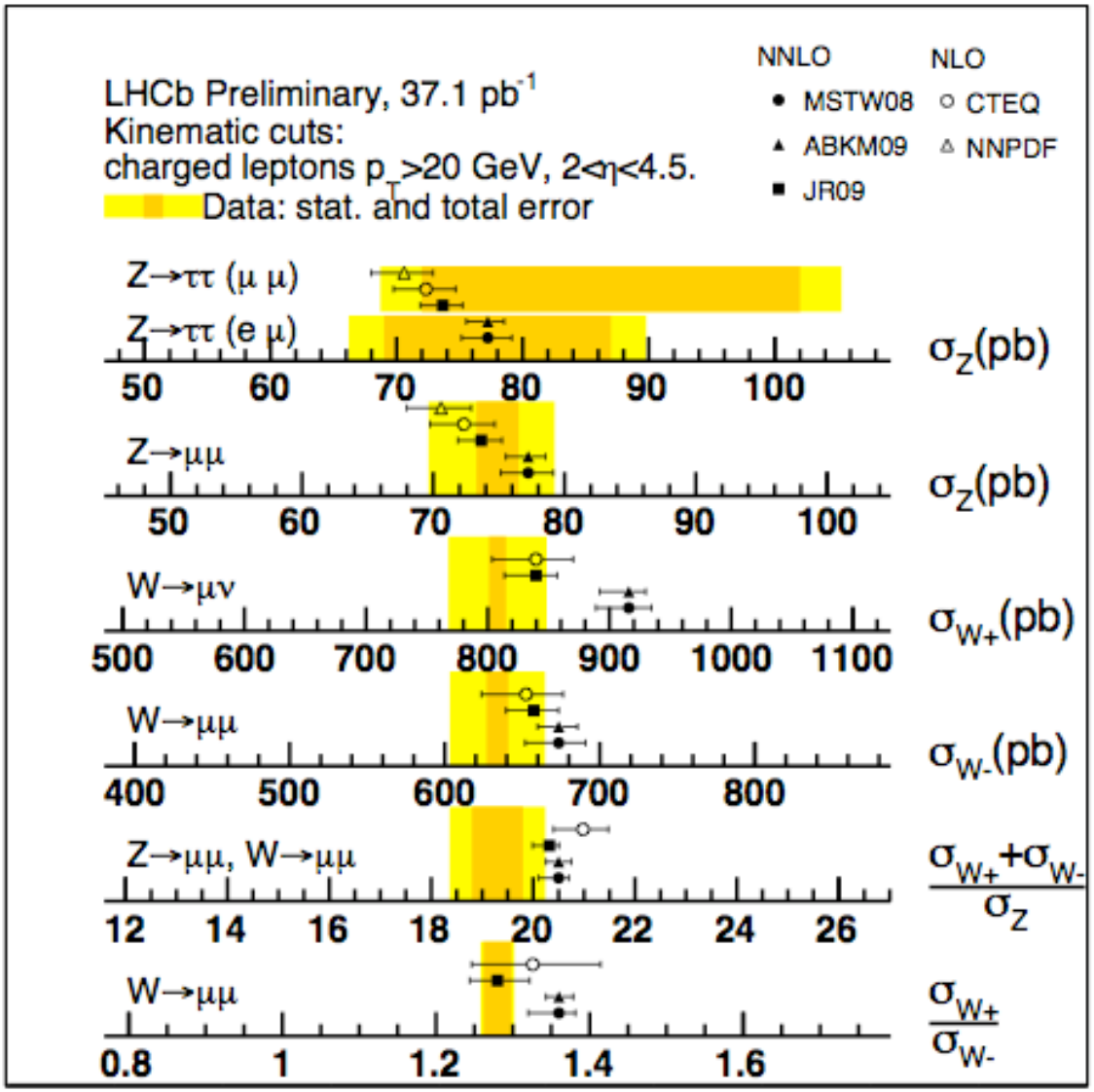
ε^{track}_{e} (MC) scaled to $\varepsilon^{track}_{\mu}$

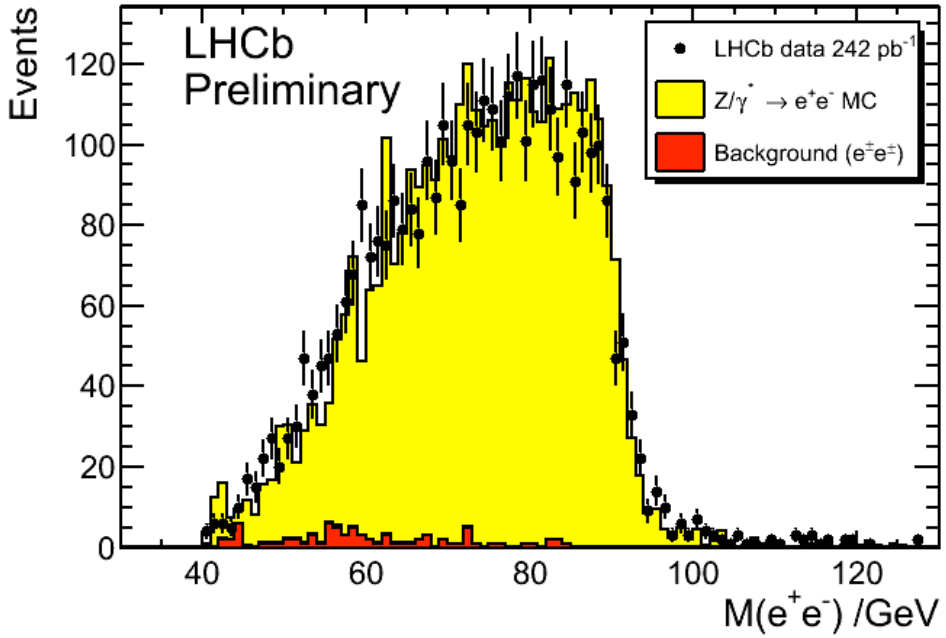
ε^{μ} (data): tag-and-probe Z→μμ

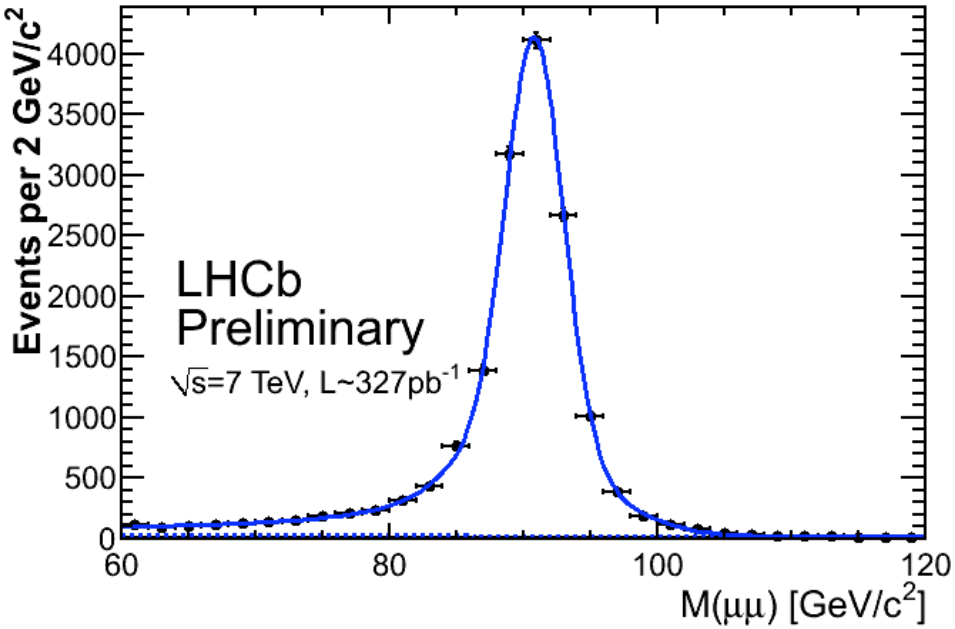
ε^{e} (data): tag-and-probe Z→ee

ε^{sel} (MC): systematic from MC/data comparison in Z→μμ events.

	$\Delta\sigma(e\mu)$ [%]	$\Delta\sigma(\mu\mu)$ [%]
Background	± 5	± 7
Efficiency	± 8	± 9
Acceptance	± 5	± 2
Sys. error	± 10	± 11
Luminosity	± 3.5	± 3.5
Stat. error	± 12	± 17


LHCb Preliminary, 37.1 pb-1
Kinematic cuts:
charged leptons pT>20 GeV, 2<η<4.5.
Data: stat. and total error
NNLO
MSTW08
ABKM09
JR09
NLO
CTEQ
NNPDF
Z→ττ (μ μ)
Z→ττ (e μ)
σZ(pb)
Z→μμ
σZ(pb)
W→μν
σW+(pb)
W→μμ
σW-(pb)
Z→μμ, W→μμ
σW+ + σW- / σZ
W→μμ
σW+ / σW-


LHCb
Preliminary
LHCb data 242 pb-1
Z/γ* → e+e- MC
Background (e±e±)
Events
M(e+e-) /GeV


LHCb
Preliminary
√s=7 TeV, L~327pb-1
Events per 2 GeV/c2
M(μμ) [GeV/c2]

Measurements of W, Z production in the forward region presented

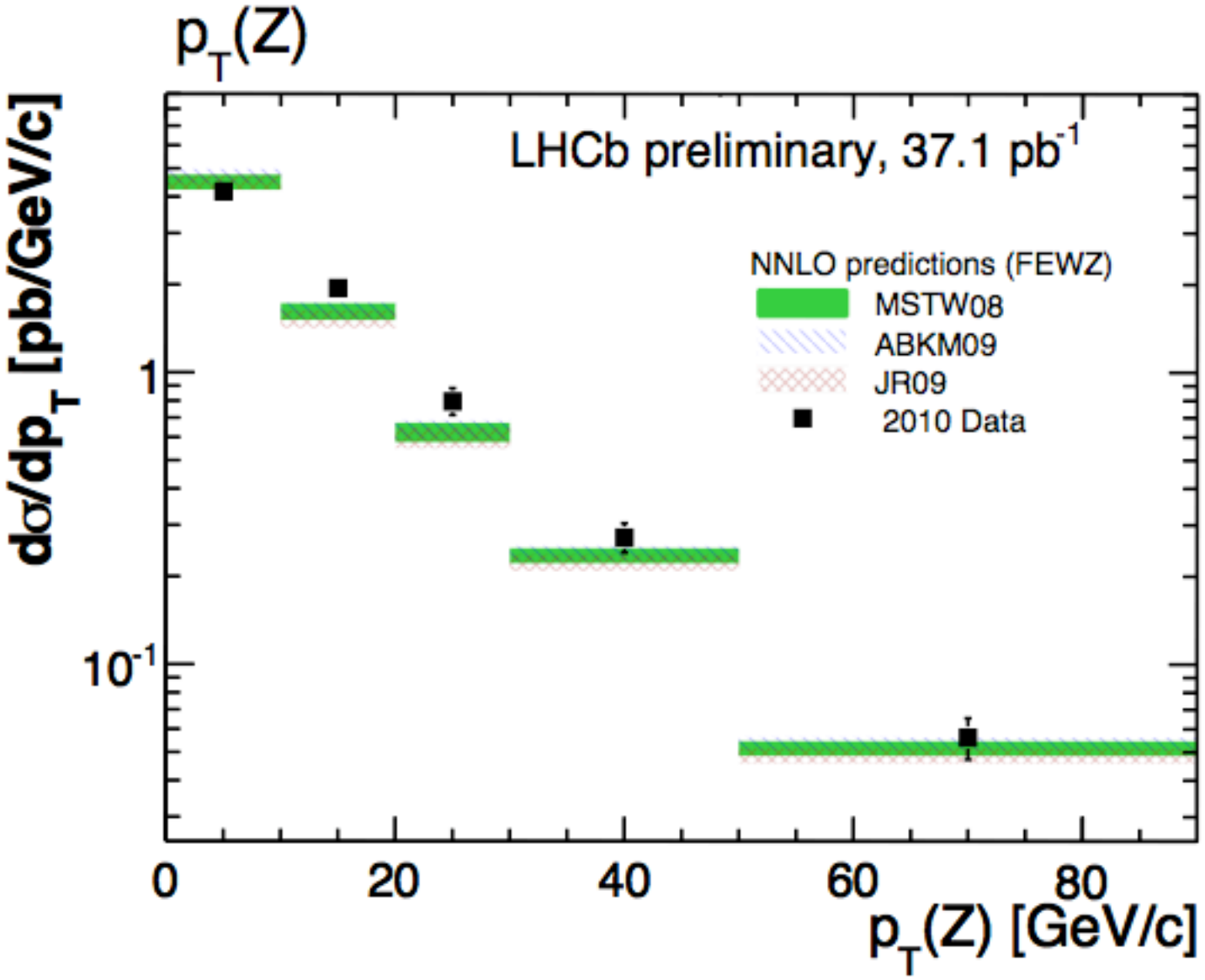
W→μν, Z→μμ:

- In agreement with NNLO predictions
- Data-driven method, precision will improve with 2011 data

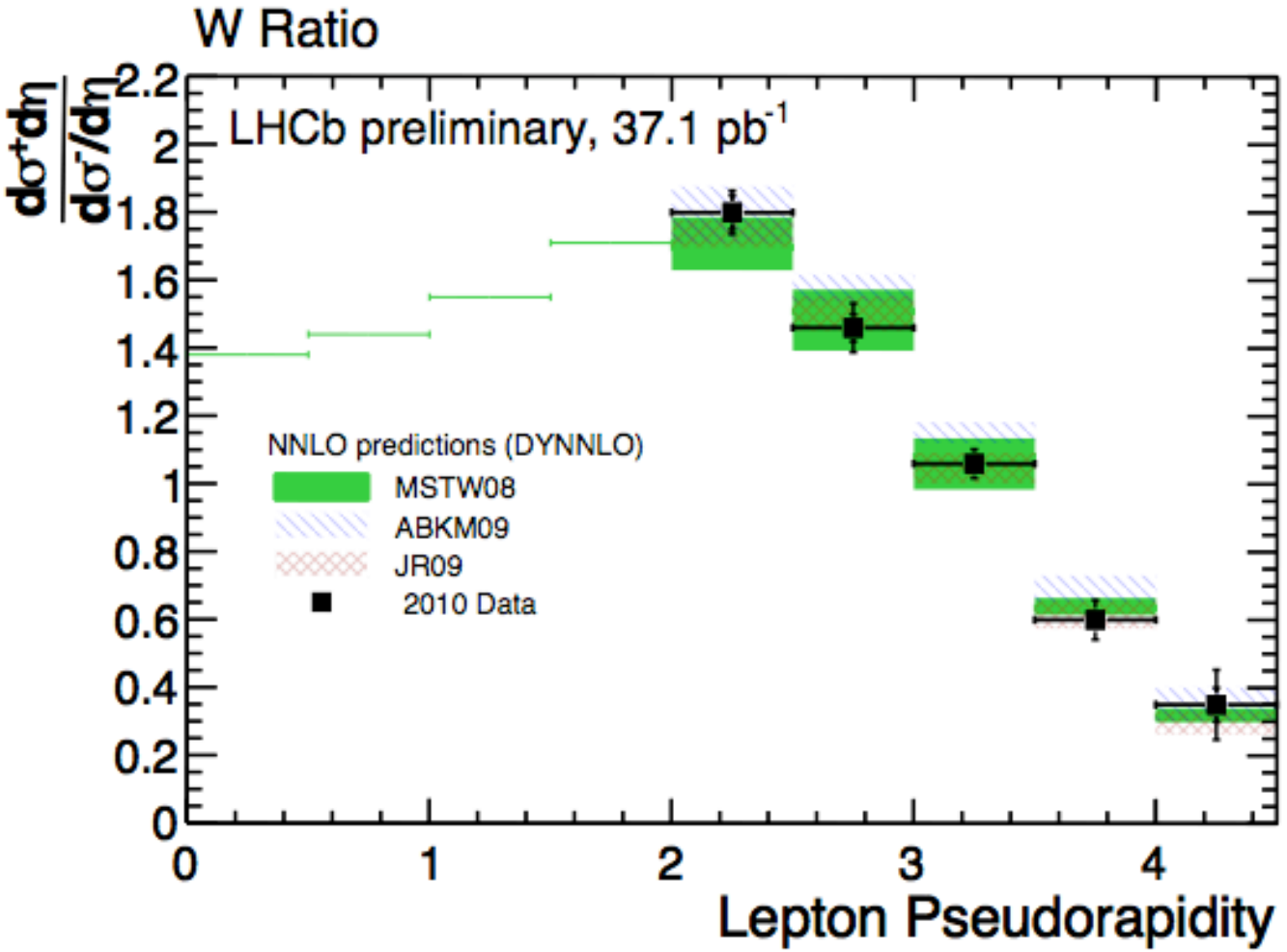
Z→ττ:

- First LHCb measurements presented
- Production in agreement with NNLO predictions.

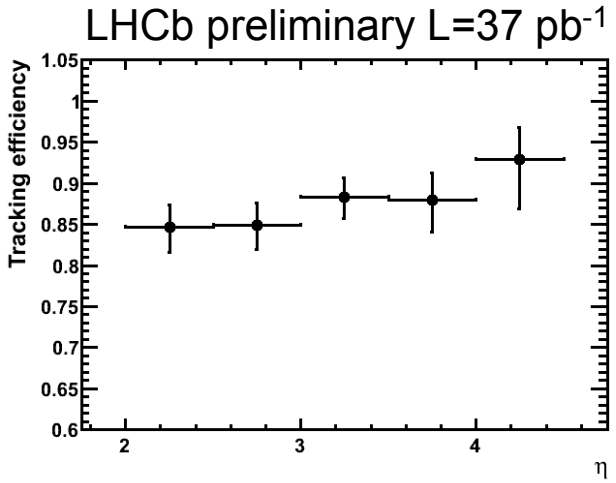
Backups

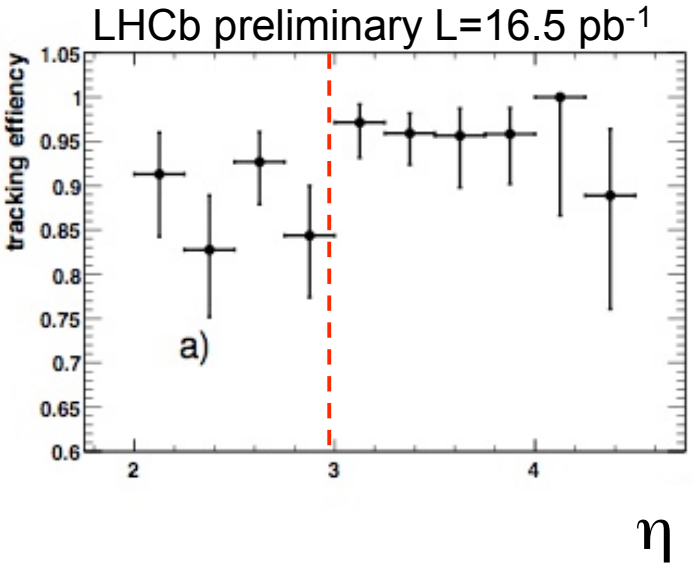

$p_T(Z)$
LHCb preliminary, 37.1 pb^{-1}
NNLO predictions (FEWZ)
MSTW08
ABKM09
JR09
2010 Data
$d\sigma/dp_T$ [pb/GeV/c]
1
10^{-1}
0
20
40
60
80
$p_T(Z)$ [GeV/c]

Backups


W Ratio
LHCb preliminary, 37.1 pb-1
dσ+/dη
dσ-/dη
NNLO predictions (DYNNLO)
MSTW08
ABKM09
JR09
2010 Data
Lepton Pseudorapidity
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
0
1
2
3
4

Backups


LHCb preliminary L=37 pb-1
Tracking efficiency
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
2
3
4
η


LHCb preliminary L=16.5 pb-1
tracking effiency
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
a)
2
3
4
η

Backups

	$e\mu$		$\mu\mu$	
	2010 data	2011 data	2010 data	2011 data
Number of events	10	71	4	29
Estimated background	1.9 ± 0.5	10.6 ± 2.7	1.1 ± 0.3	6.1 ± 2.0
$\epsilon_{trigger}$	0.73 ± 0.01	0.78 ± 0.01	0.81 ± 0.01	0.86 ± 0.01
ϵ^{μ}_{track}	0.84 ± 0.02		0.84 ± 0.02	
ϵ^{e}_{track}	0.80 ± 0.03		-	-
ϵ^{μ}_{id}	0.991 ± 0.002		0.991 ± 0.002	
ϵ^{e}_{id}	0.962 ± 0.01		-	-
ϵ_{sel}	0.46 ± 0.03		0.172 ± 0.014	
ϵ	0.215 ± 0.017	0.230 ± 0.019	0.097 ± 0.009	0.103 ± 0.010
Acceptance	0.249 ± 0.012		0.386 ± 0.009	
Luminosity (pb^{-1})	37.5 ± 1.3	210.4 ± 8.4	37.5 ± 1.3	208.9 ± 7.3
Branching Ratio	0.062		0.030	
FSR Correction	0.7 ± 0.1			
Cross-section (pb)	$79 \pm 9 \pm 8 \pm 3$		$89 \pm 15 \pm 10 \pm 3$	