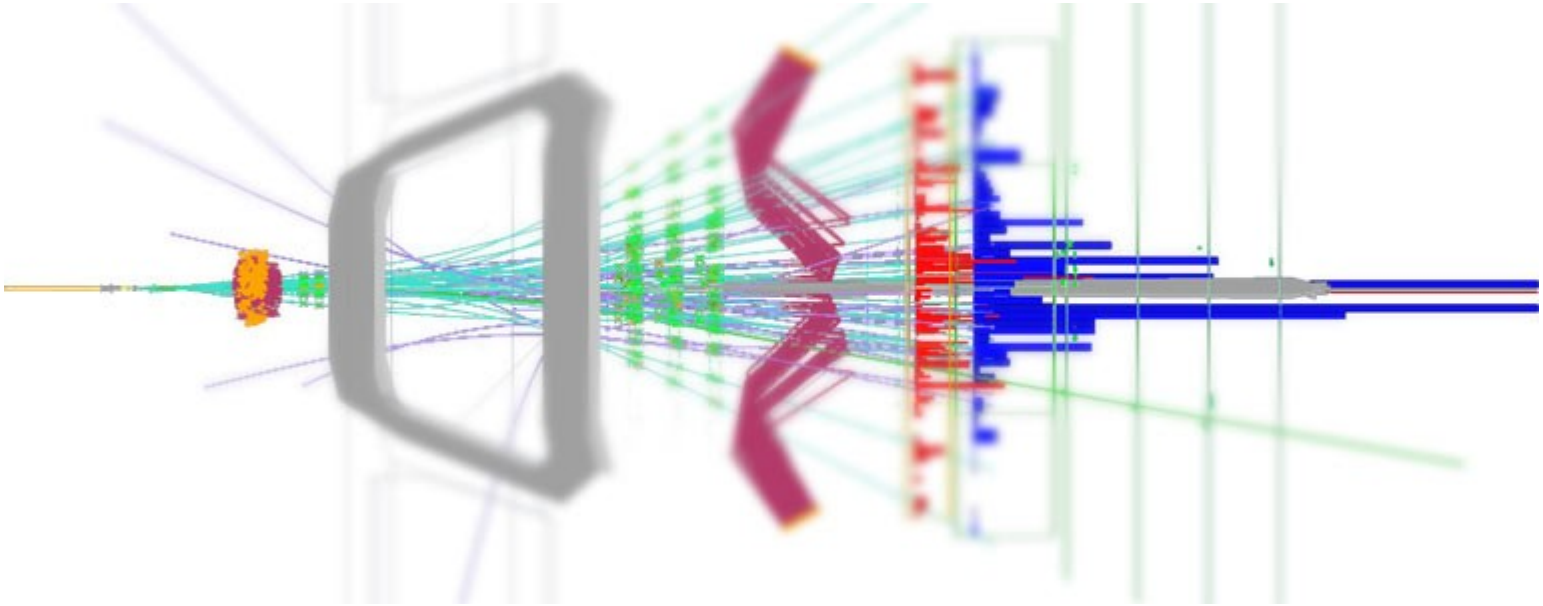
Measurements with electroweak bosons at LHCb

Katharina Müller
on behalf of the LHCb collaboration

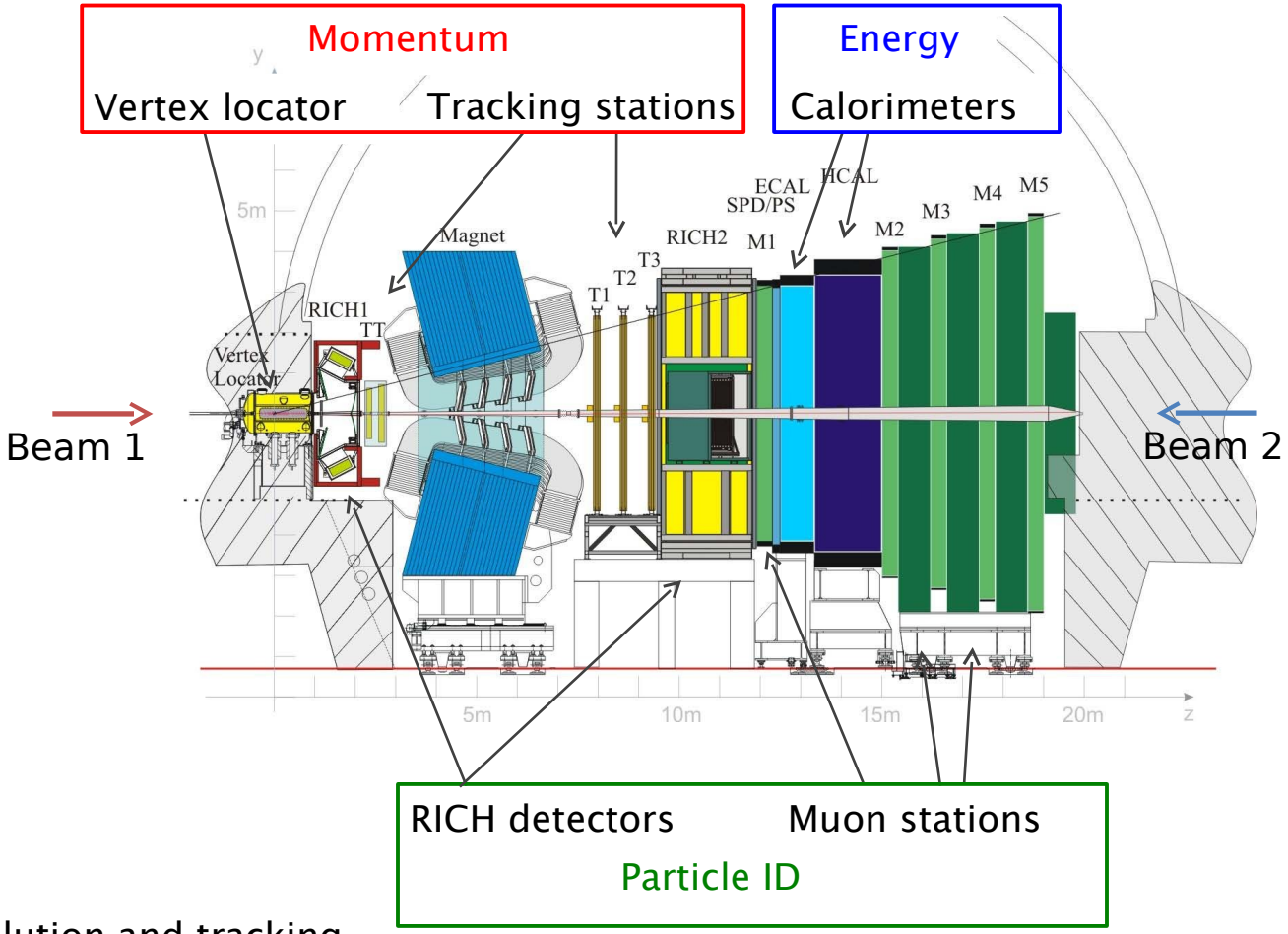


Introduction
Z→μμ, Z→ee, Z→ττ
W→μν
Low mass Drell-Yan γ*/Z→μμ
Z→μμ plus Jets
Conclusion

University of Zurich[UZH]
Physik Institut

LHCb detector

Forward spectrometer designed to search for new physics in B and D decays
Fully instrumented in the forward region ($2 < \eta < 5$)
Some detection: $-3.5 > \eta > -1.5$



- Excellent vertex resolution and tracking
- Particle identification
- Trigger: $p_\mu > 3$ GeV/c, $p_T^\mu > 0.5$ GeV/c, $M_{\mu\mu} > 2.5$ GeV/c^2

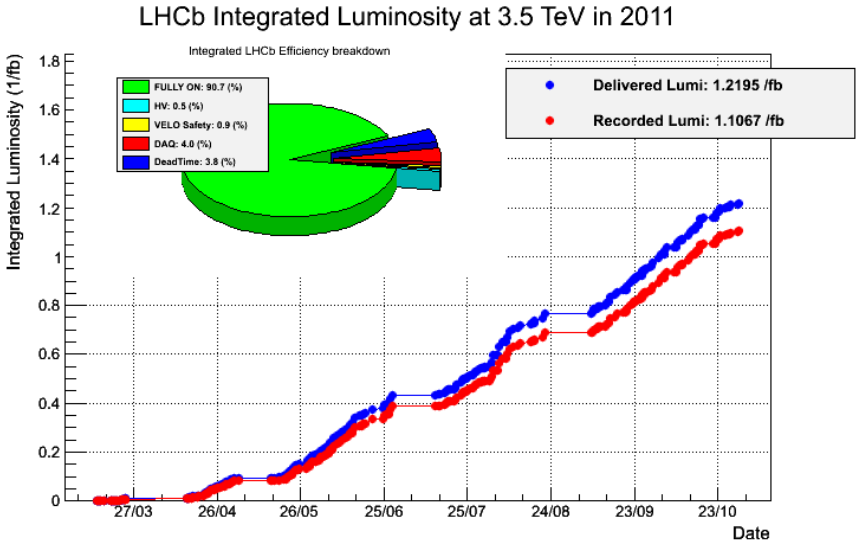
LHCb data taking

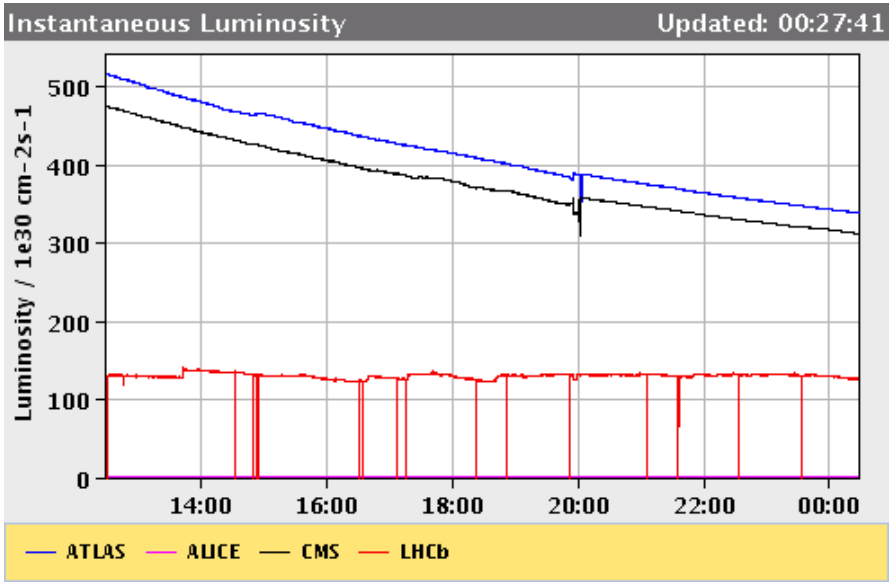
2010: 37pb^{-1} of data

2011: 1 fb^{-1} of data

>90% data taking efficiency

W/Z→μμ, low mass Drell-Yan: 2010 data
Z→ee, Z→ττ , Z plus Jet: 2011 data





LHCb: runs with luminosity levelling :

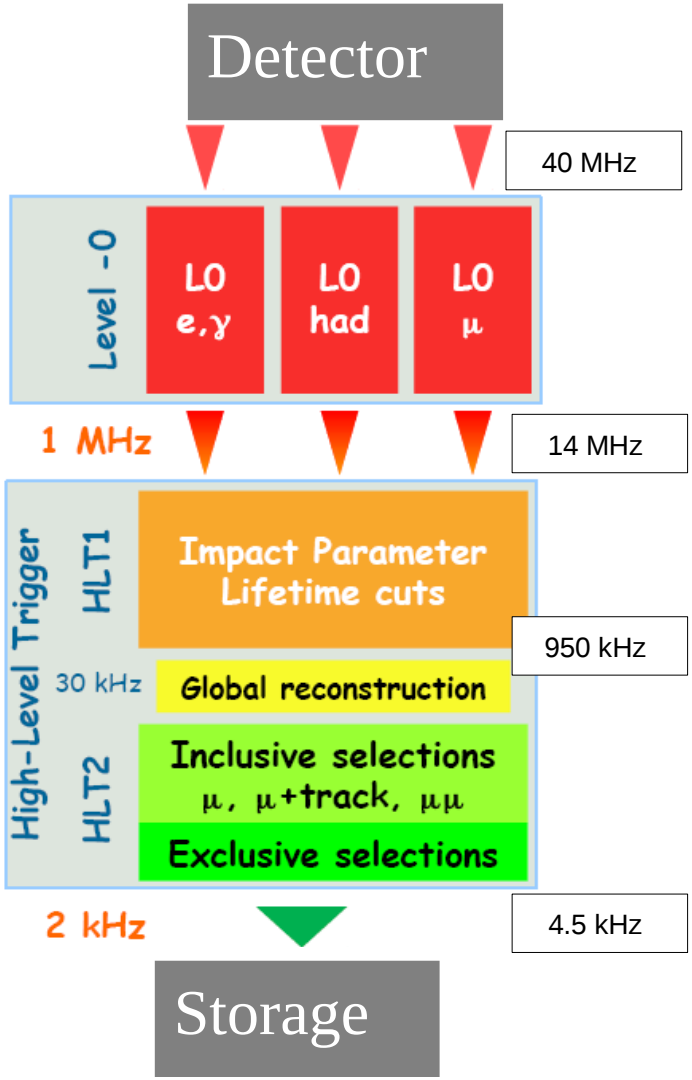
- Continuous adjust of beam overlap
- Low average number of interactions (1.5)
- Stable running conditions
- Roughly constant luminosity over a fill
- Thanks to LHC team for excellent work!

LHCb trigger

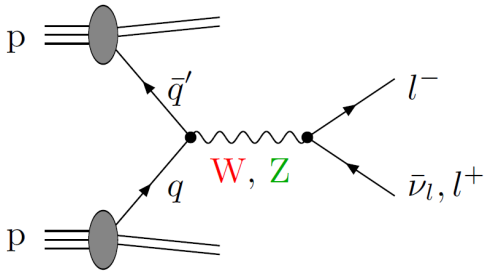
- Hardware trigger: L0 40→14 MHz
- Two software trigger stages

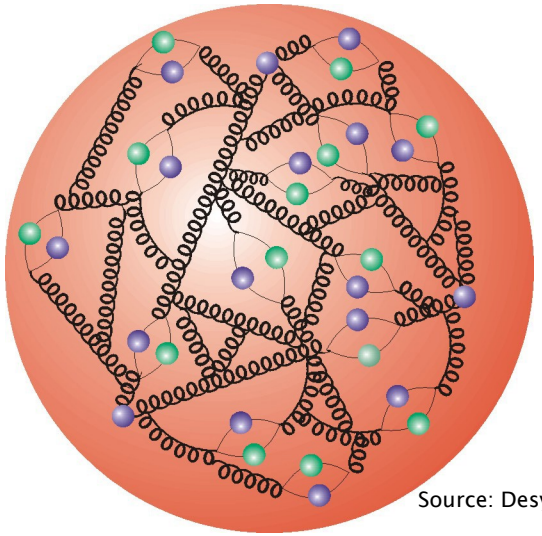
  14MHz →950 kHz

  950 →4.5 kHz
- Output rate 4.5 kHz (2 x design)
- Size per event: 60 kB



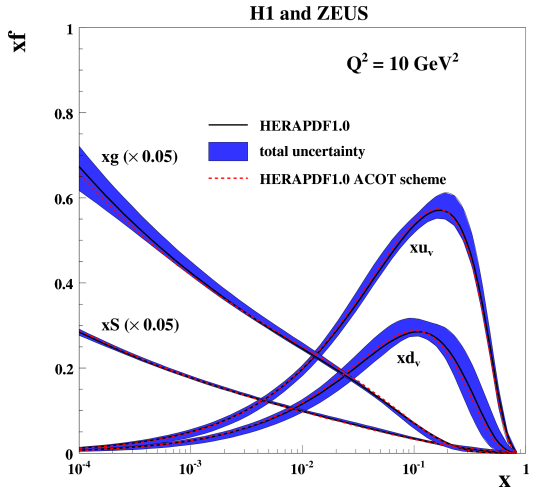
W and Z production at LHCb





Source: Desy, Hamburg

LHCb forward kinematics:
@ first order, collision of a sea and a valence quark
→ Asymmetry in production rate for W^+ and W^-
→ Sensitivity to structure of the proton:
parton distribution functions (PDF)



PDF : $f_q(x,Q^2)$
Probability, that proton contains a parton q with momentum fraction x
Q: invariant mass of parton interaction

JHEP 1001 (2010) 109
arXiv:0911.0884 [hep-ex]

Electroweak measurements at LHCb

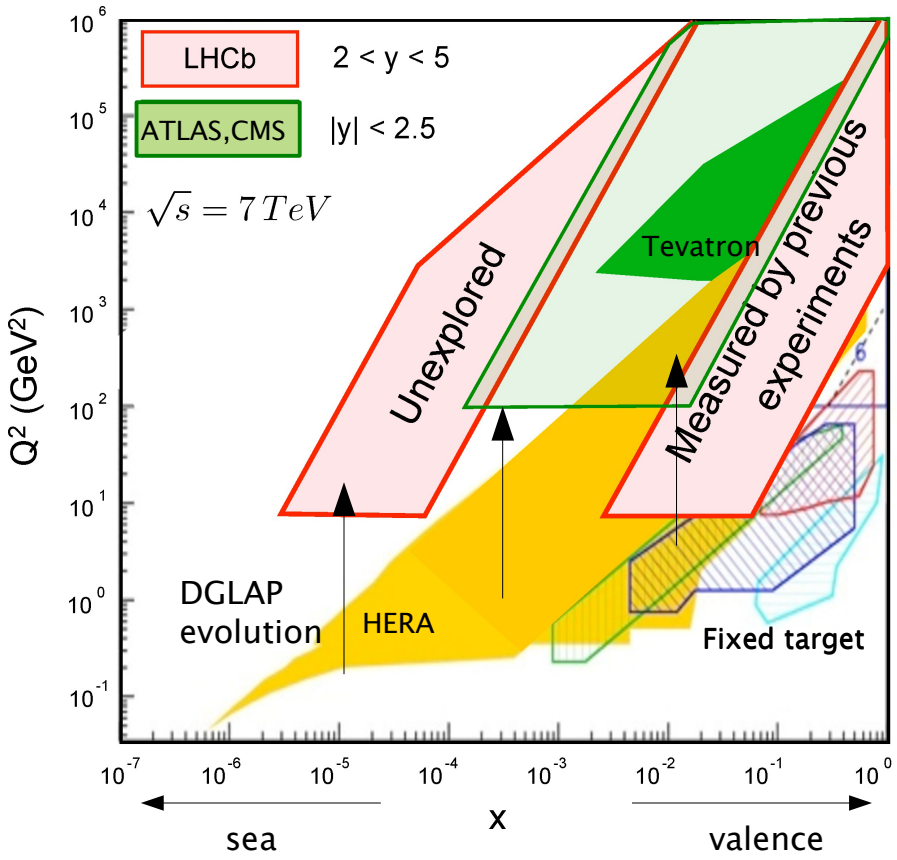
ATLAS & CMS:

- Collision between two partons with similar x
- PDF already measured or modest DGLAP extrapolation

LHCb

- Collision between parton at high and low x
- One parton well understood
- One parton unknown or large DGLAP evolved

Overlap region between ATLAS/CMS and LHCb between 2 and 2.5



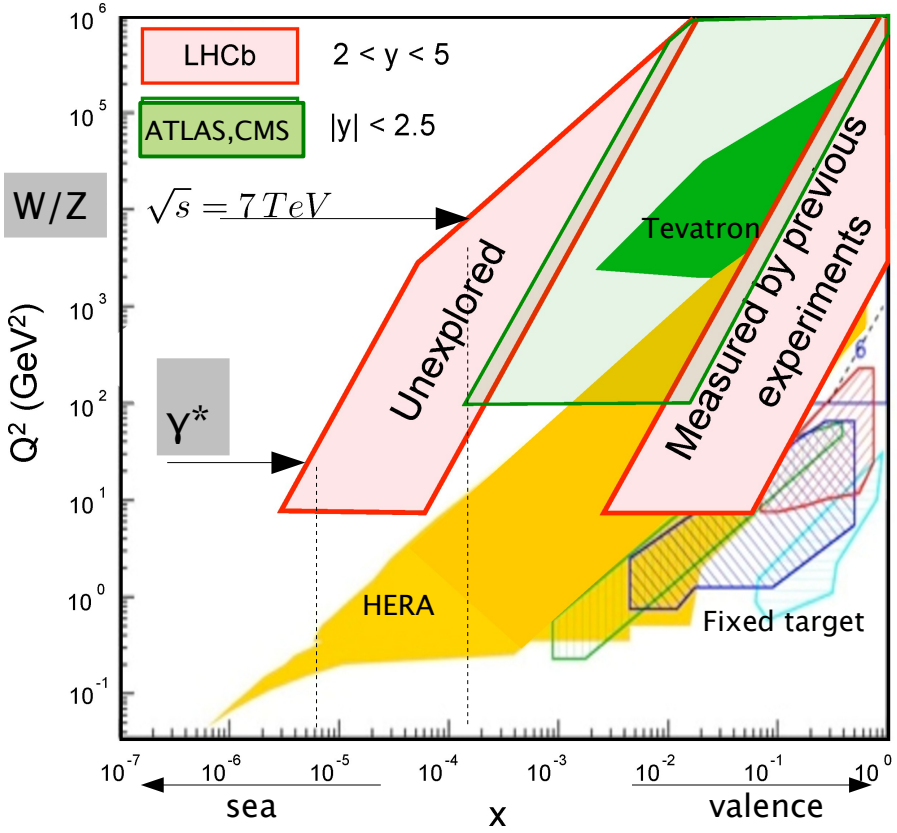
DGLAP evolution equations: evolution of PDFs in Q^2

Electroweak measurements at LHCb

- LHCb probes two distinct regions in x–Q^2
- $Q^2=M^2$, $x_{1,2}=(M/\sqrt{s})\, e^{\pm y}$
- Unique region at low x
- SM predictions known at NNLO order
- Important input for PDF fits

- Medium Q^2 (10'000 GeV^2):

  Z and W : $x = 1.7 \cdot 10^{-4}$
- Low Q^2 (25 GeV^2): Drell-Yan (γ^*): $x = 8 \cdot 10^{-6}$

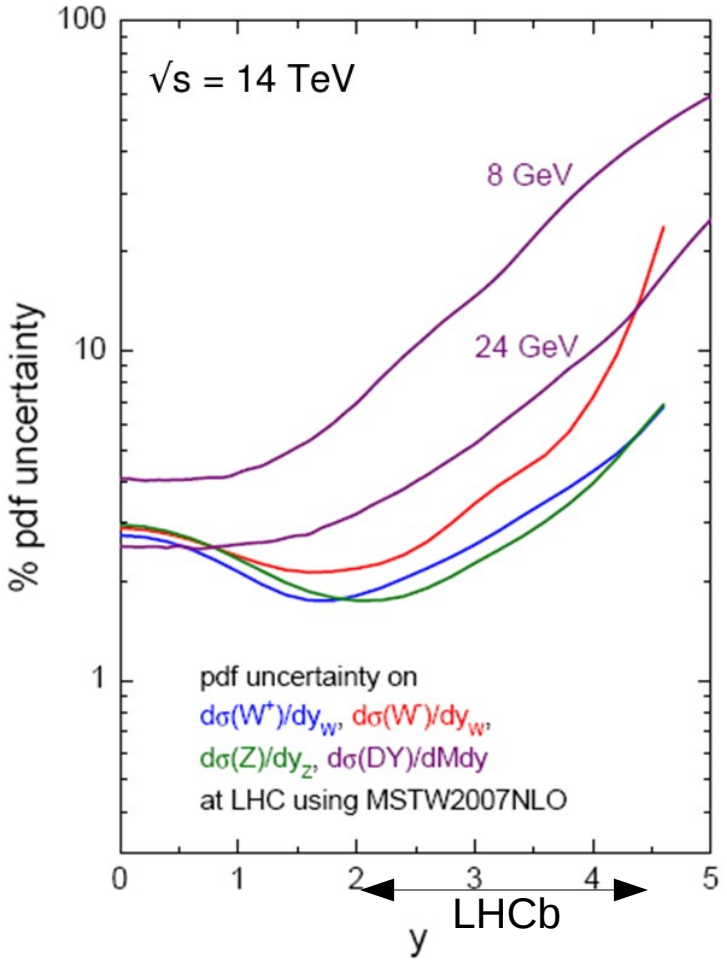


Theoretical uncertainties due to PDF

$$\underbrace{\sigma\left(x,Q^2\right)}_{\text{hadronic } x-\text{sec.}} = \sum_{a,b}\int_0^1 dx_1\,dx_2 \underbrace{f_a\left(x_1Q^2\right)f_b\left(x_2Q^2\right)}_{\text{PDFs } 2-8\%}\ \underbrace{\hat{\sigma}\left(x_1,x_2,Q^2\right)}_{\text{partonic } x-\text{sec.: NNLO } 1\%}$$

Theoretical predictions

- Cross-sections known to NNLO to %-level
- PDF uncertainty dominates
  at large rapidities
  3% at y <2, 6-8% at y~5
- Low mass Drell-Yan: uncertainties much larger



Plot from Thorne et al. (arXiv:0808.1847)

Theoretical uncertainties due to PDF

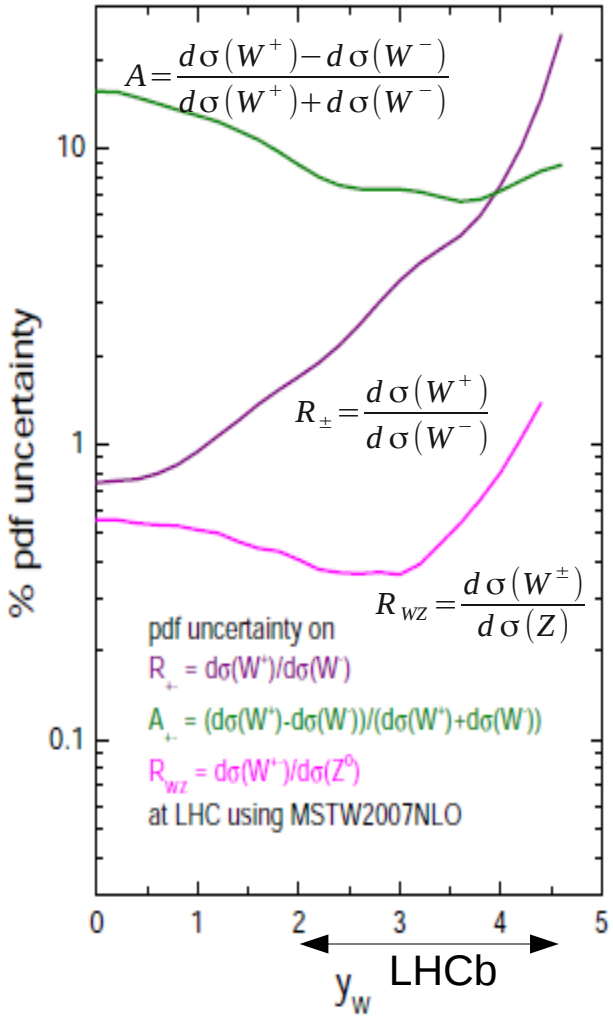
Cancel or highlight PDF uncertainties with ratios

- Many systematic uncertainties cancel
- Theoretical uncertainties partially cancel
- $A_W = (d\sigma(W^+) - d\sigma(W^-))/(d\sigma(W) + d\sigma(W^-))$

  tests valence quarks: difference between u_V and d_V
- $R_{+-} = d\sigma(W^+)/d\sigma(W^-)$

  tests valence quarks: u_V/d_V ratio
- $R_{WZ} = d\sigma(W^{+-})/d\sigma(Z)$

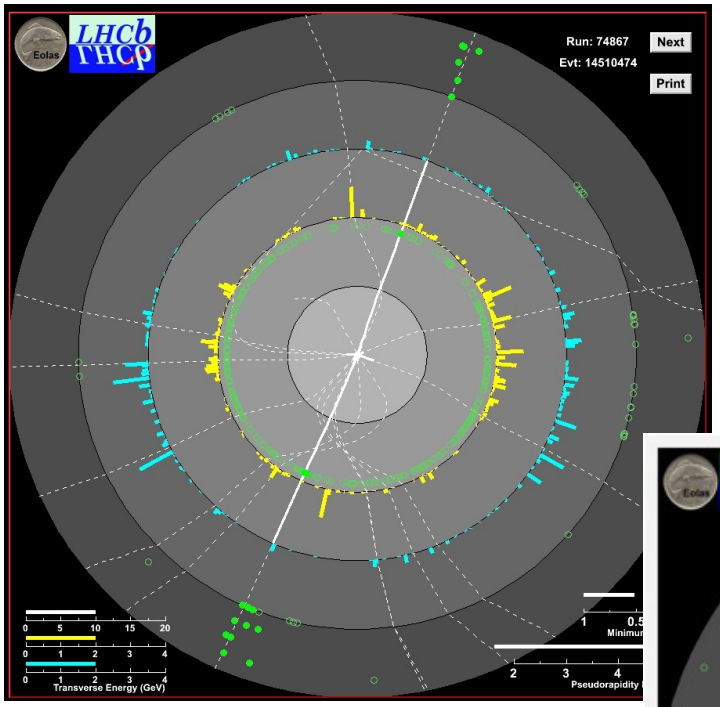
  almost insensitive to PDFs
  precise test of SM



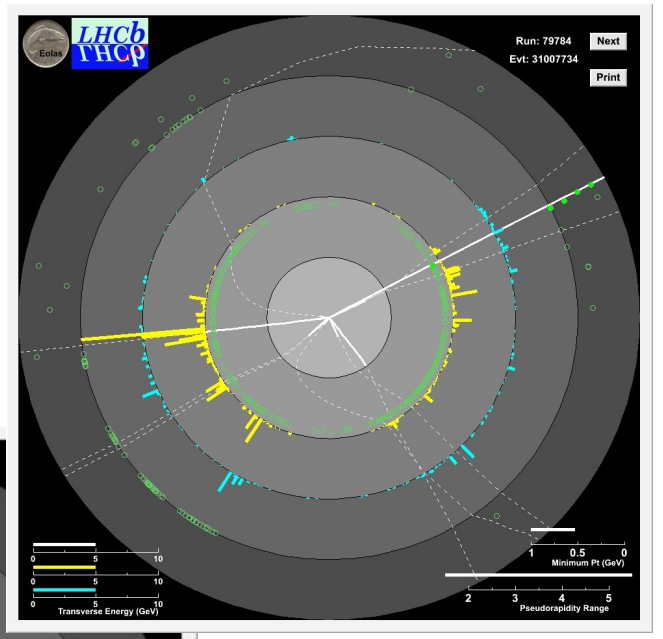
Plot from Thorne et al. (arXiv:0808.1847)

Z → μμ, Z→ee, Z→ττ

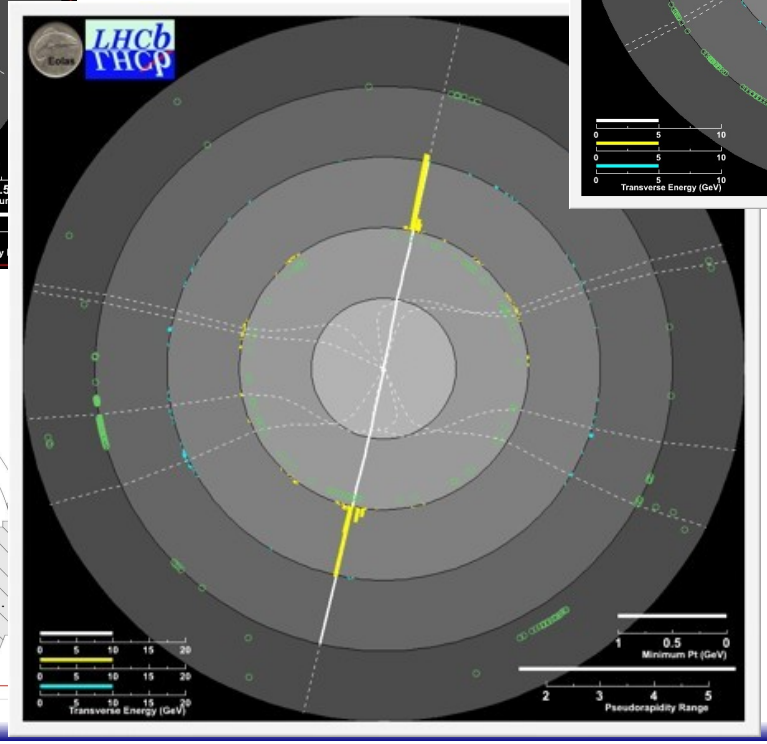
Z → μμ



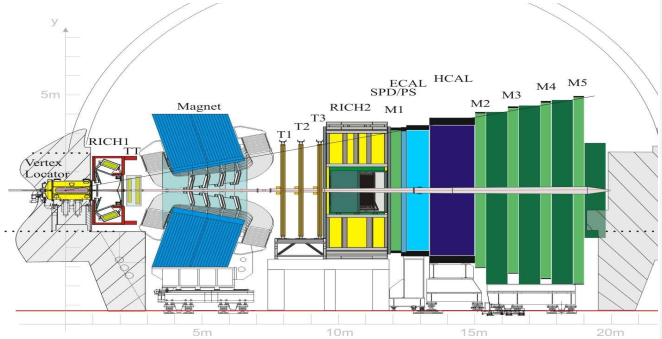
Z→ττ (→ eμ)



Z→ee



φ–z view (Radius=z)



Z → μμ selection

JHEP 2012, 6 (2012), 58

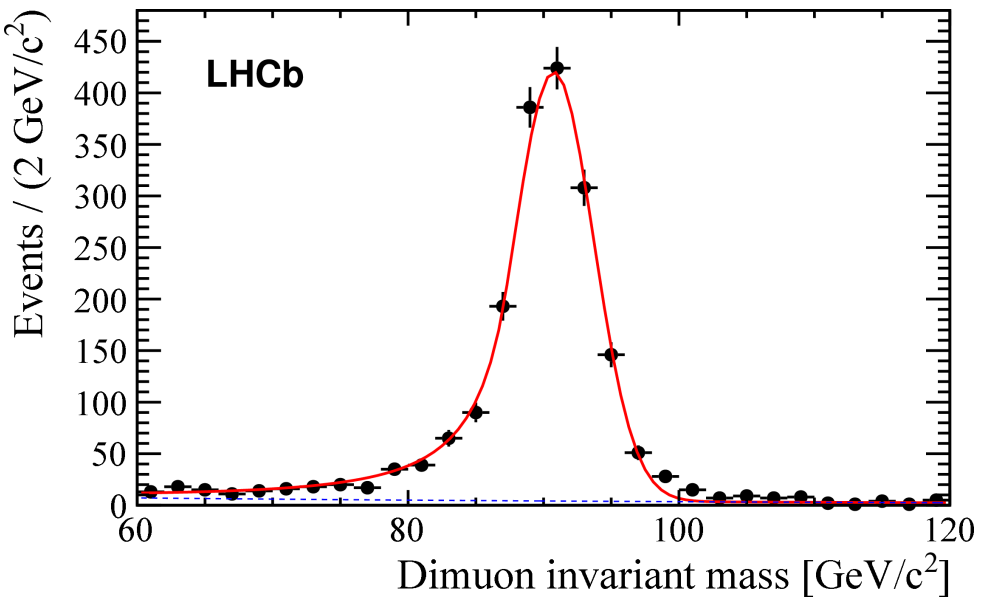
Data
- 2010 L = 37 pb^{-1}
- Trigger: single μ, p_T > 10 GeV/c

Two muons
- p_T> 20 GeV/c
- 2.0 < η_μ <4.5

Z selection
- 60 < M(μμ) < 120 GeV/c^2

Background: low
- Z→ττ (MC: 0.3‰)
- W-pair (MC: 0.1‰)
- Top-pair (MC: 0.3‰)
- QCD background (Data: 2‰)
  Semileptonic decays of heavy flavour or
  K/π misididentification
  Non isolated muons

Z mass peak



Candidates:	1966
Background:	4.8±1.0
Purity:	99.7%

Z → ee selection

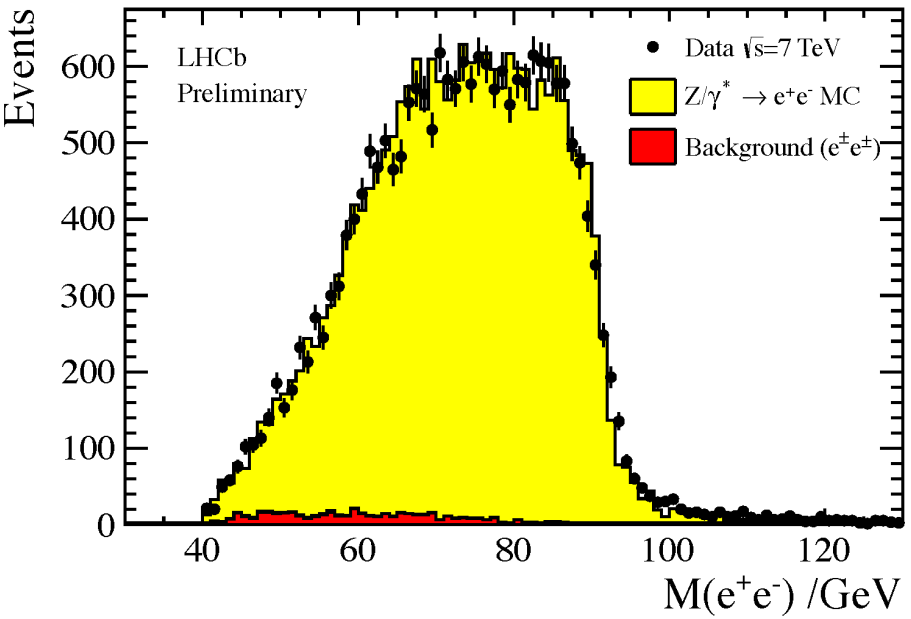
Data
- 2011 L = 1 fb^{-1}
- Trigger: single electron, p_T > 15 GeV/c

Two electrons
- p_T> 20 GeV/c
- 2.0 < η_μ <4.5
- Energy from momentum measurement
  Saturation in calorimeter
  Resolution worse, Bremsstrahlung

Z selection
- M(ee) > 40 GeV/c^2

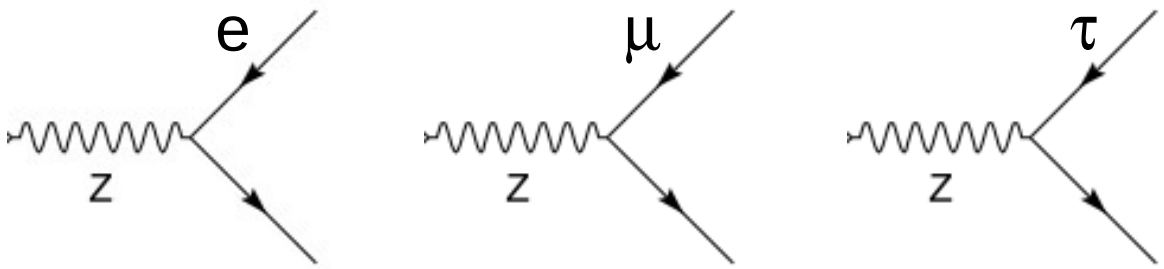
Background: low
- Z→ττ (MC, 0.1%)
- Top-pair (MC, <0.1%)
- QCD (Data, 2.2% same sign electrons)

Z mass peak



Candidates:	21535
Background:	473
Purity:	97.8%

Paper to be published within weeks



Electroweak tests using $Z \rightarrow \tau\tau$

- Lepton universality in Z decays, tested precisely by LEP
- → Sensitivity to new physics
- Other production mechanisms for $\tau\tau$ – Higgs?

Final states:

- $Z \rightarrow \tau_\mu \tau_\mu$
- $Z \rightarrow \tau_\mu \tau_e$, $\tau_e \tau_\mu$
- $Z \rightarrow \tau_\mu \tau_h$
- $Z \rightarrow \tau_e \tau_h$

Fiducial volume:
$p_T > 20$ GeV/c
$2.0 < \eta < 4.5$
$60 < M(\tau\tau) < 120$ GeV/c^2

2011 Data L 1 fb^{-1}
Single muon ($p_T > 10$ GeV/c) or single electron trigger ($p_T > 15$ GeV/c)

Z → ττ selection

arXiv:1210.6289

Muon/Electron
- 2<η <4.5, p_T> 20 (5) GeV/c

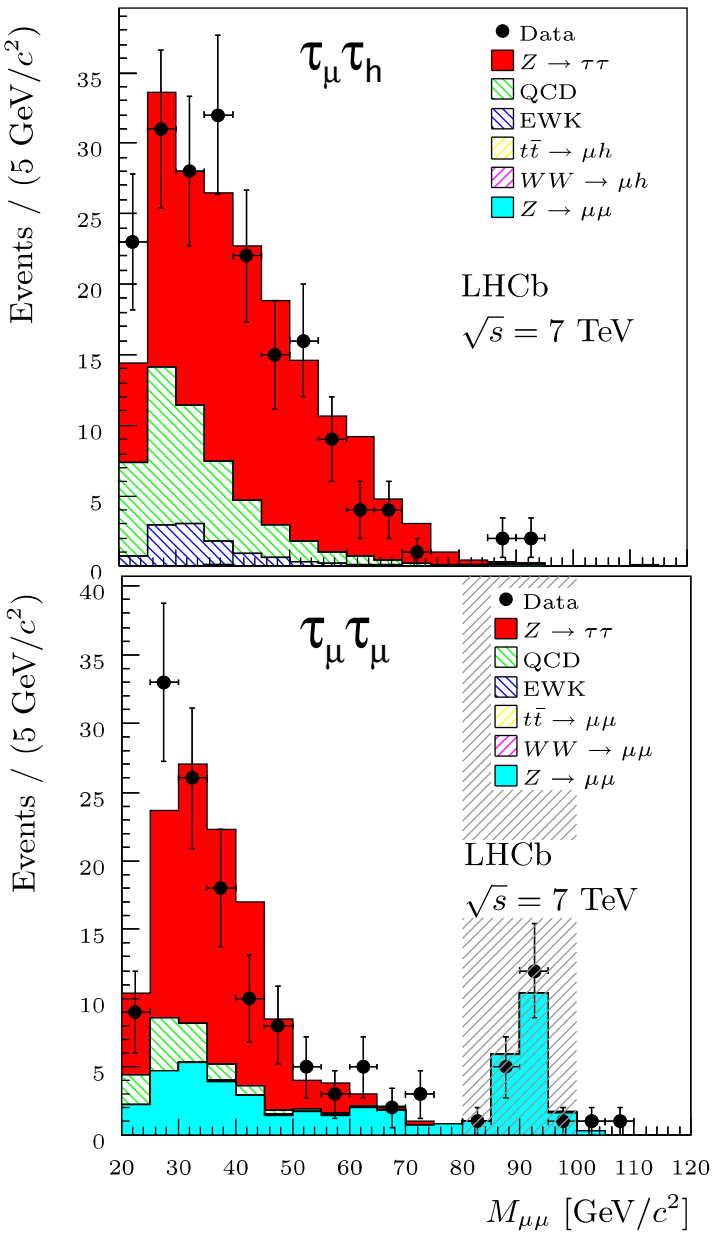
Hadron
- 1 prong
- 2.25<η <3.75, p_T> 5 GeV/c

Background
- Electroweak processes (WW, WZ, ZZ, top, Drell Yan)
- QCD

Selection
- back-to-back ΔΦ>2.7
- Isolated: I(pT)<2 (1) GeV ($\tau_\mu\tau_h$, $\tau_e\tau_h$)
- Lifetime: Impact parameter sign. >9 (0) ($\tau_\mu\tau_e$)
- Unbalanced p_T ($\tau_\mu\tau_\mu$ only)

Signal yield from template fit

	μμ	μe	eμ	μh	eh
Candidates	124	421	155	189	101
Purity [%]	66	69	63	72	65

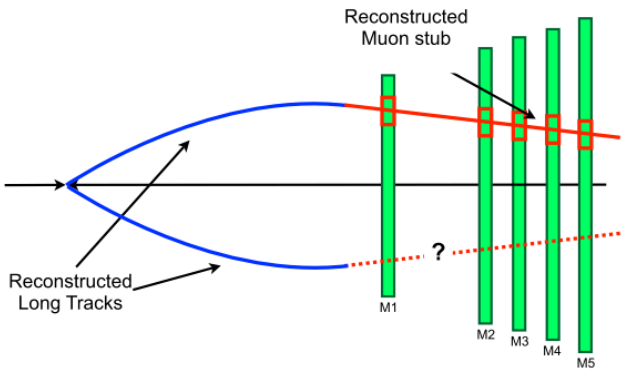


Efficiencies

$$\sigma = \frac{\rho N}{A L \epsilon} f_{FSR}$$

ρ: purity
A: acceptance
L: luminosity
ϵ: efficiency
N: candidates
f_{FSR}: final state radiation

Muon identification



Efficiencies mostly from data
tracking, identification and trigger: tag and probe in Z sample

Tag:
Well identified, triggered muon/electron

Probe:
Identification: fully reconstructed track
Tracking: muon-stub -TT hits
Trigger: identified muon/electron
Electron tracking from MC

Selection ($Z \to \tau\tau$) from MC
ϵ_{sel} = 0.14 (μμ), 0.52 (μe), 0.08 (eh)

Acceptance:
Result within fiducial range of measurement
$Z \to \mu\mu$: >0.99
$Z \to ee$: 0.4-0.6
$Z \to \tau\tau$: 0.15 (eμ)- 0.4 (μμ)

Typical efficiencies
Tracking: 90%
Muon identification: >99%
Electron identification: 95%
Muon Trigger: 88%
Electron Trigger: 85%

Corrected event-wise as function of η_μ
Checked for charge bias

Precision

Precision:	Z→ μμ	Z→ ee	Z→ ττ				
			μμ	μe	eμ	μh	eh
Statistical [%]	2.2	0.7	13.4	7.6	12.8	10.3	15.6
Luminosity[%]	3.5	3.5			3.5		
Systematic[%]	4.3	3.1	11.1	5.6	7.6	3.9	7.9
Luminosity	37pb	1fb			1fb		

Systematic uncertainties are statistical in nature → will reduce with more statistics

Dominant systematic uncertainties:
- Efficiencies 4.3%
- Purity 0.1%

- Z→ ττ : limited by statistics
- Z→ μμ : limited by efficiency uncertainty (statistical)
- Z→ ee : luminosity uncertainty

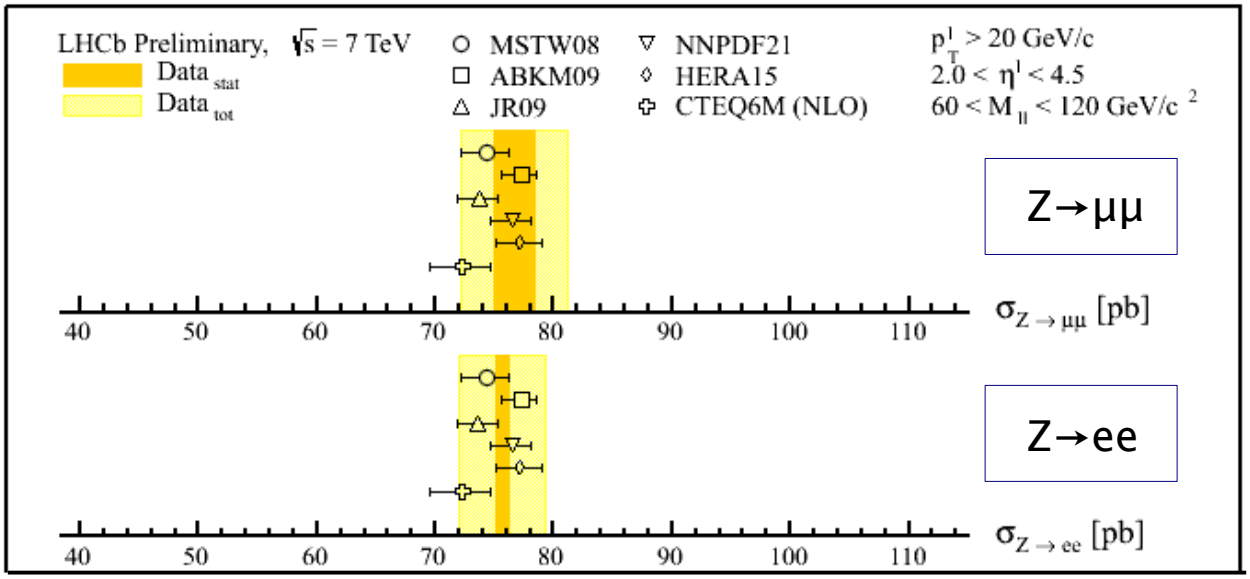
Predictions

Results compared to NNLO predictions (DYNNLO) with 6 recent PDF sets

- MSTW08: A. Martin, W. Stirling, R. Thorne and G. Watt
  arXiv:0901.0002
- ABKM09: S. Alekhin, J. Blumlein, S. Klein and S. Moch
  arXiv:0908.2766
- JR09: P. Jimenez-Delgado and E. Reya
  arXiv:0810.4274
- NNPDF: D. Ball et al.
  arXiv:1002.4407
- HERA15: H1 and ZEUS collaboration
  arXiv: 0911.0884
- CTEQ6M: P. M. Nadolsky et al. (NLO)
  arXiv:0802.0007

PDF uncertainties at 68% CL
Theory uncertainty from scale variation (0.5,2)

Results



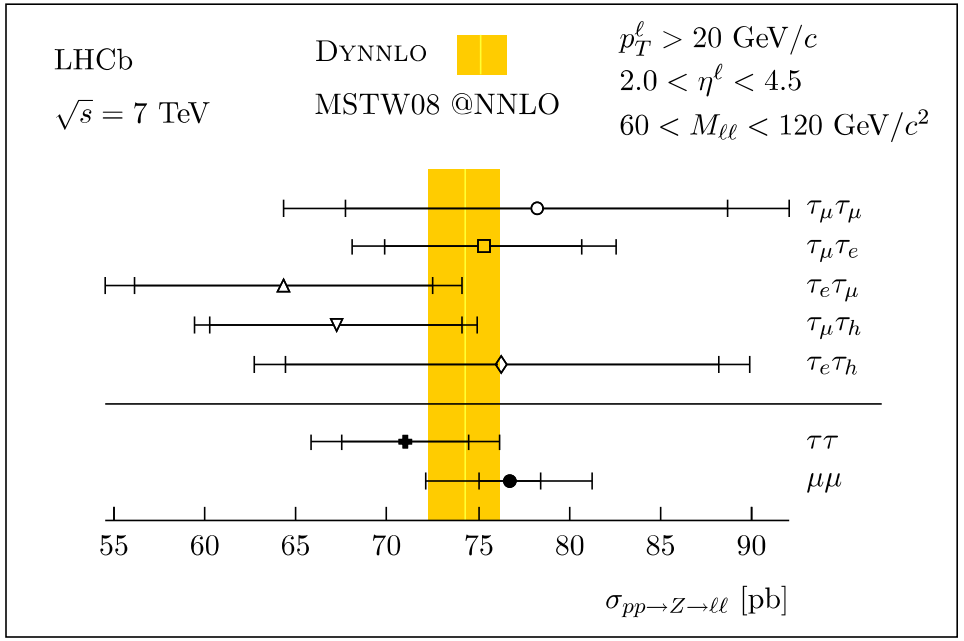
JHEP 2012, 6 (2012), 58

LHCb-CONF-2012-011

arXiV:1210.6289

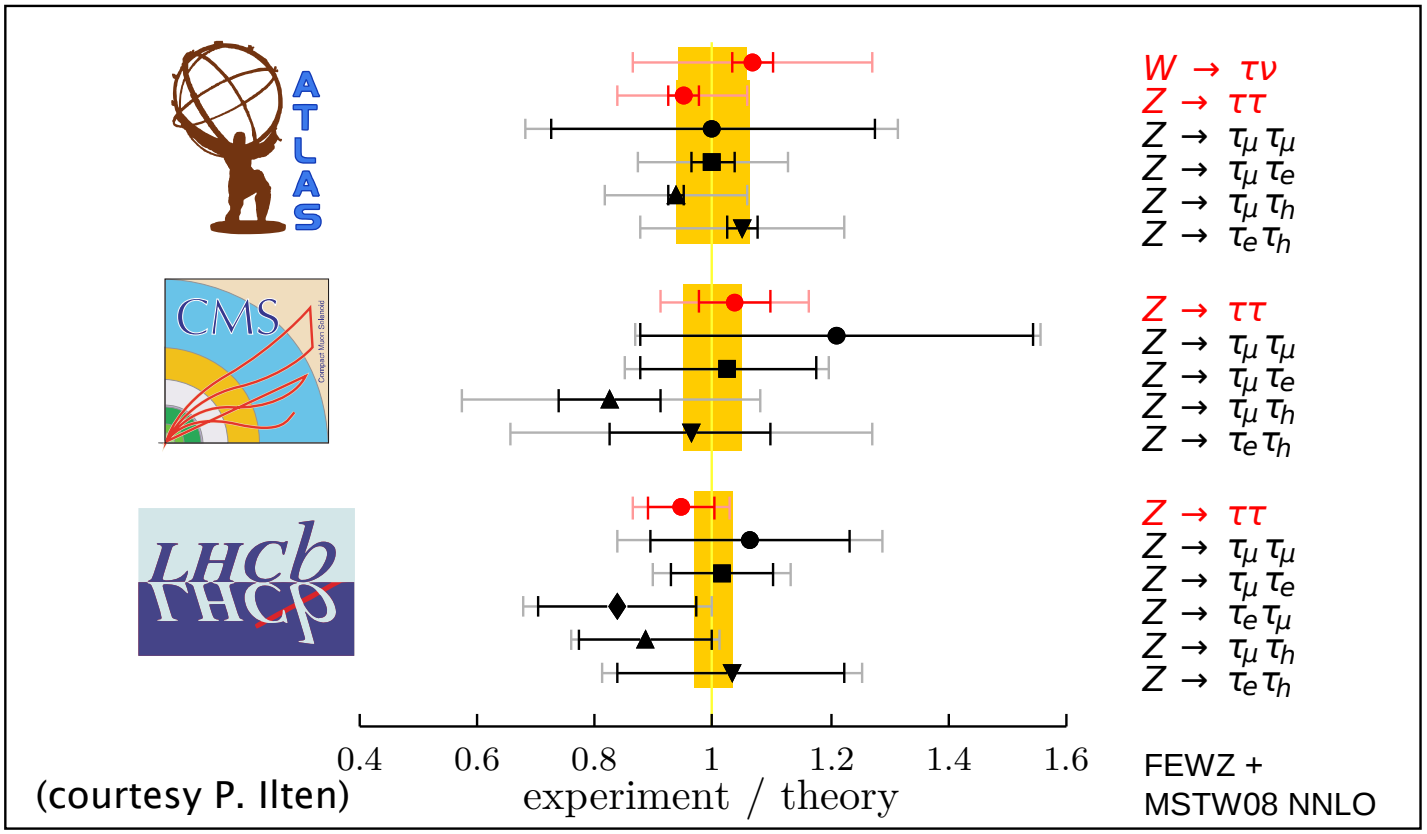
- Good agreement between channels
- Good agreement with NNLO

NNLO (DYNNLO) PDF uncertainties at 68% CL



τ- Results: Comparisons to theory

ATLAS: Phys. Rev. D84 (2011) 112006; ATLAS-CONF-2012-006. CMS: JHEP 08 (2011) 117;
LHCb: arXiV:1210.6289

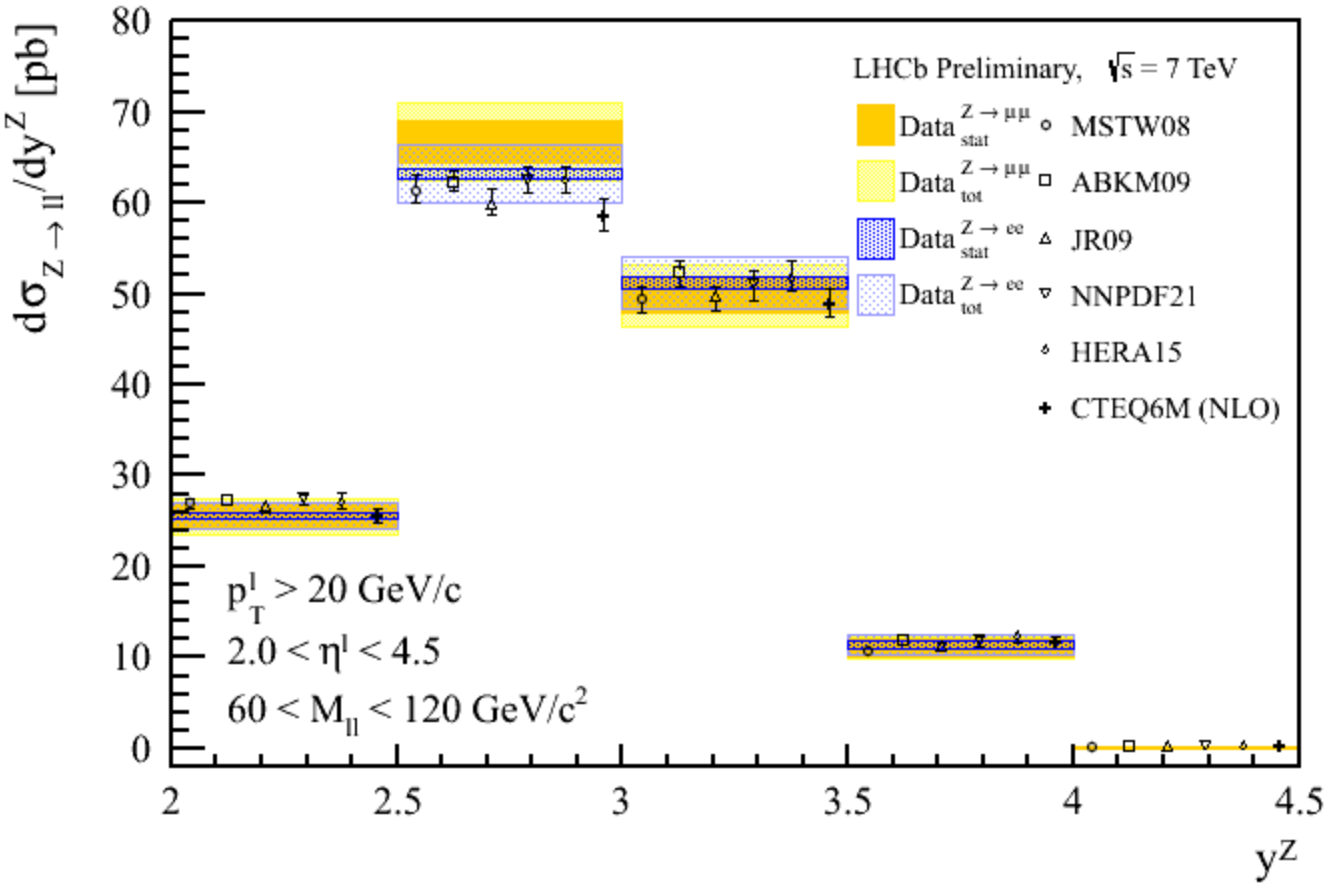


(courtesy P. Ilten)

Combined LHCb result is currently the most precise Z→ ττ measurement @ LHC

Results

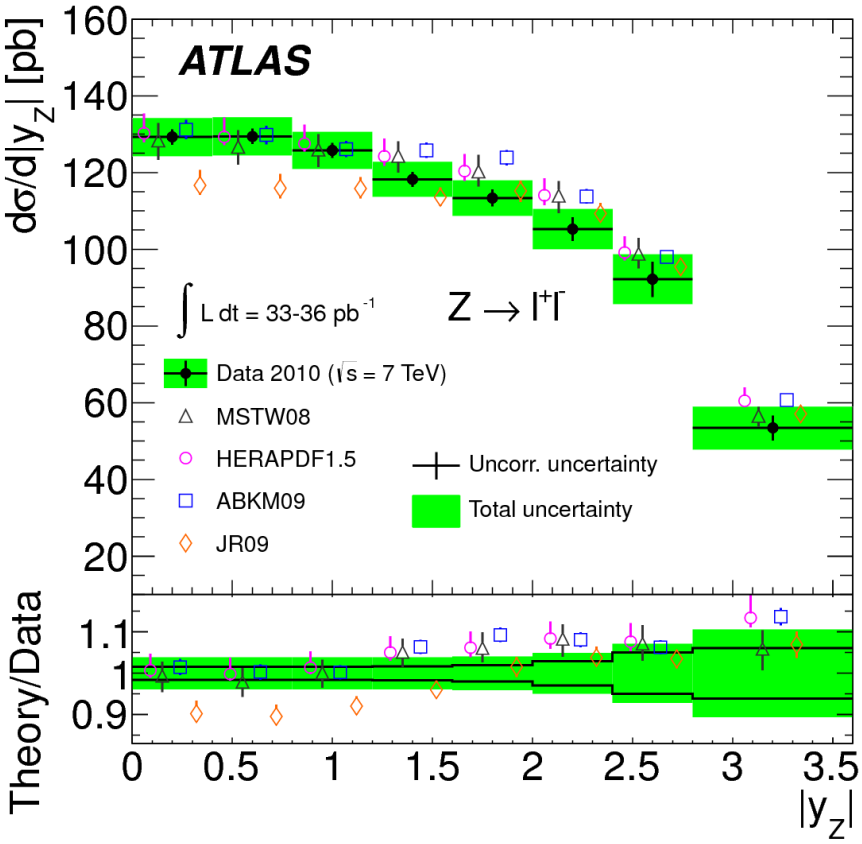
JHEP 2012, 6 (2012), 58
LHCb-CONF-2012-011



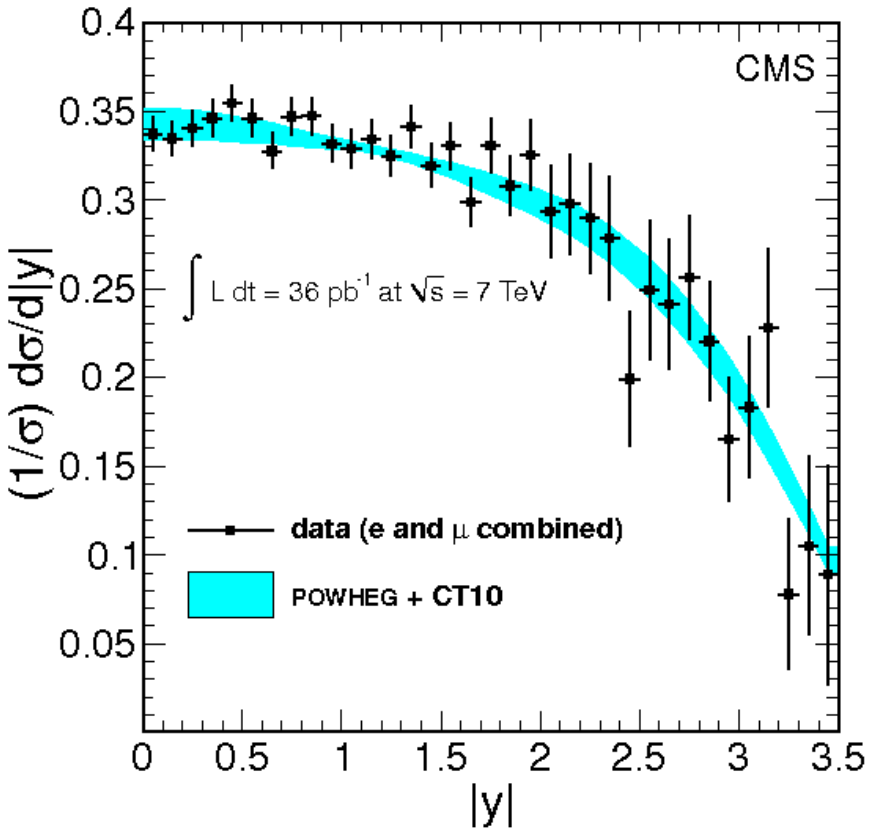
Z → μμ and Z→ ee in agreement with each other and with NNLO
Z→ ee publication will also contain φ* distribution

Z rapidity (ATLAS, CMS)

ATLAS
pT>20 GeV/c 66<M<116 GeV/c²
Electron, Muon, Electron (forward)
Phys. Rev. D85 (2012) 072004



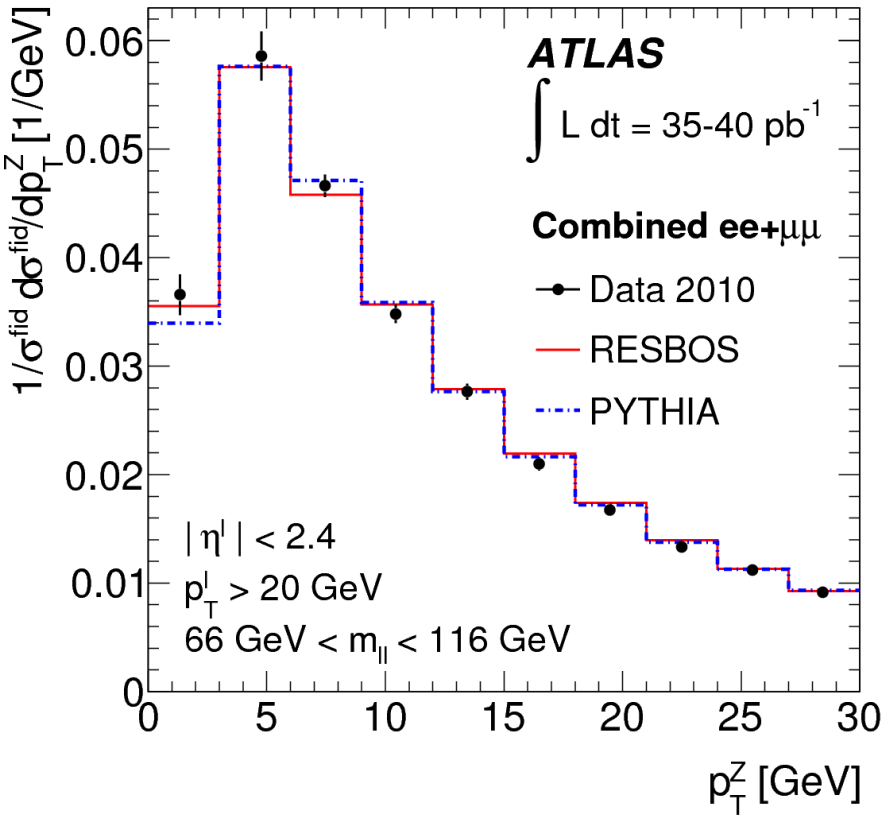
CMS
pT>20 GeV/c 60<M<120 GeV/c²
Electron, Muon, Electron (forward)
Phys. Rev. D85 (2012) 032002



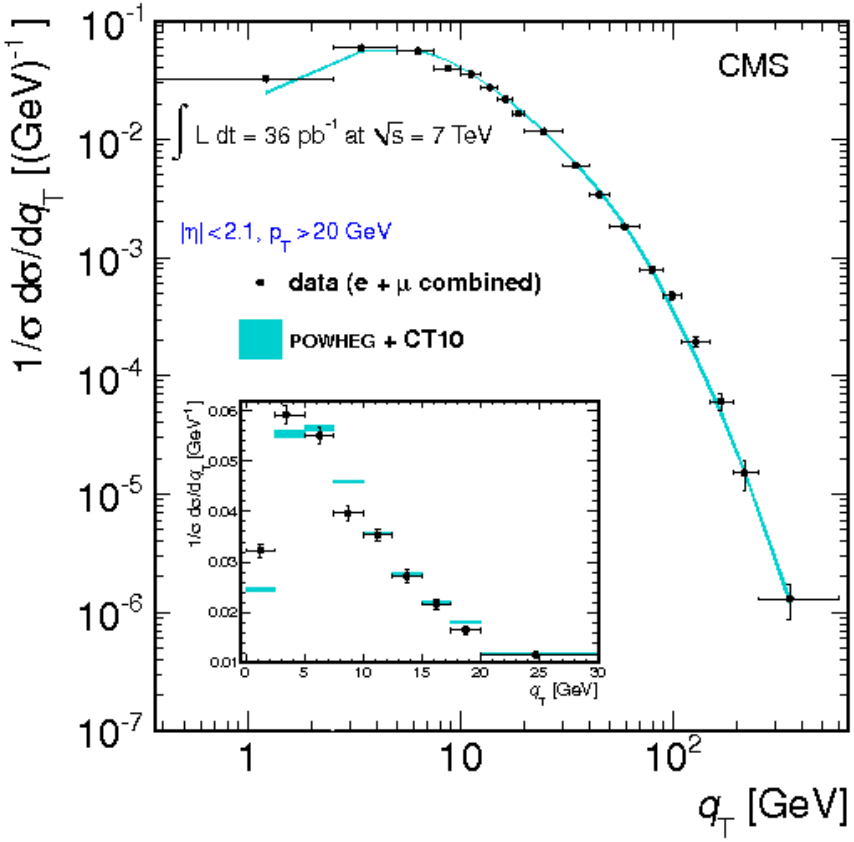
forward electron analysis: one electron forward, one electron central

Z transverse momentum (ATLAS, CMS)

ATLAS
66<M<116 GeV/c^2
Phys.Lett. B705 (2011) 415-434

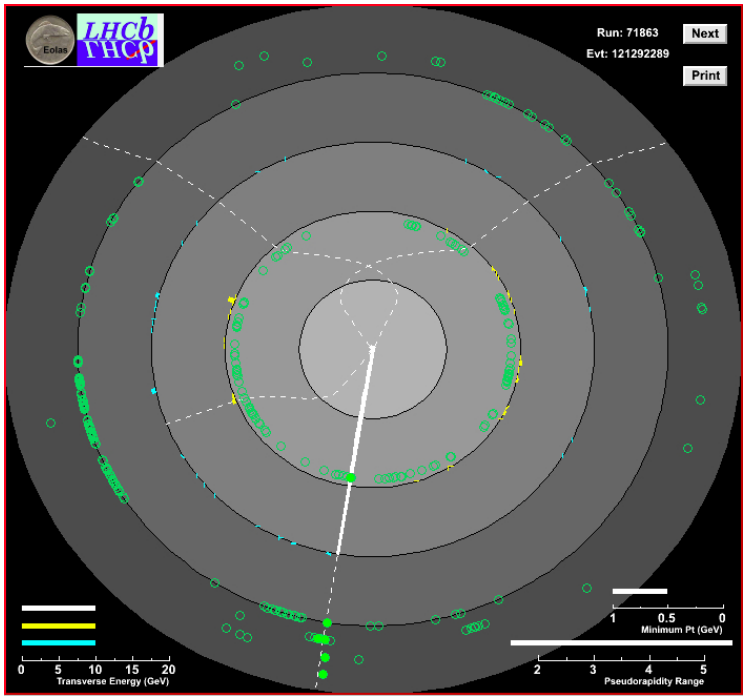


CMS
60<M<120 GeV/c^2
Phys.Rev. D 85 (2012) 032002



W analysis

W → μν



W selection: one (isolated) muon

W → μν selection

JHEP 2012, 6 (2012), 58

Data: 2010 L = 37 pb^{-1}
Single μ, p_T > 10 GeV/c

Muon: one muon
20<p_T < 70 GeV/c, 2.0 < η_μ < 4.5

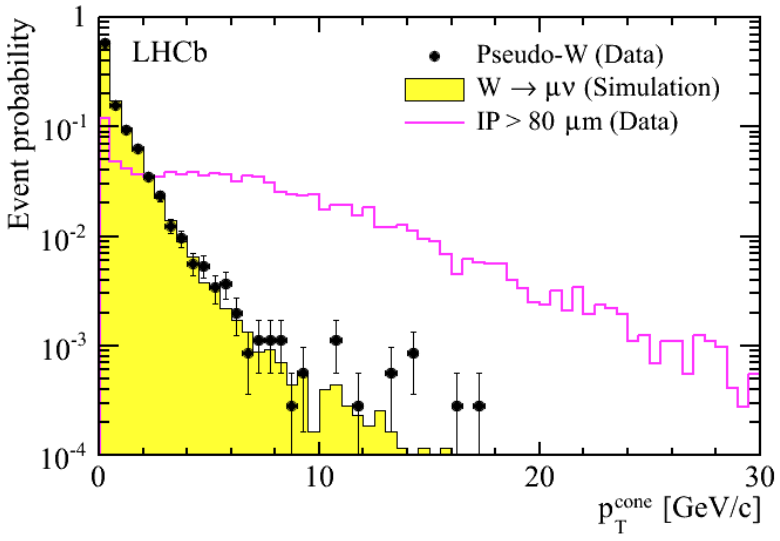
Isolation E_T^{cone}<2 GeV (Cone R<0.5 around muon)
p_T^{cone}<2 GeV/c

Cuts against background:
- from semileptonic decays of heavy flavour
  Impact parameter < 40 μm
- γ*/Z: No other muon with p_T>2GeV/c
- K/π punch through
  E(Calorimeter)/pc<0.04

Candidates: N_{W+} = 14660
N_{W-} = 11618

Main background:
Kaon, pion decay in flight
γ*/Z→μμ, one muon in acceptance

Muon isolation: p_T in cone



Signal: pseudo-W data
Z events with one muon removed

Backgrounds:
- semileptonic decays of heavy flavour
- kaon, pion misidentification

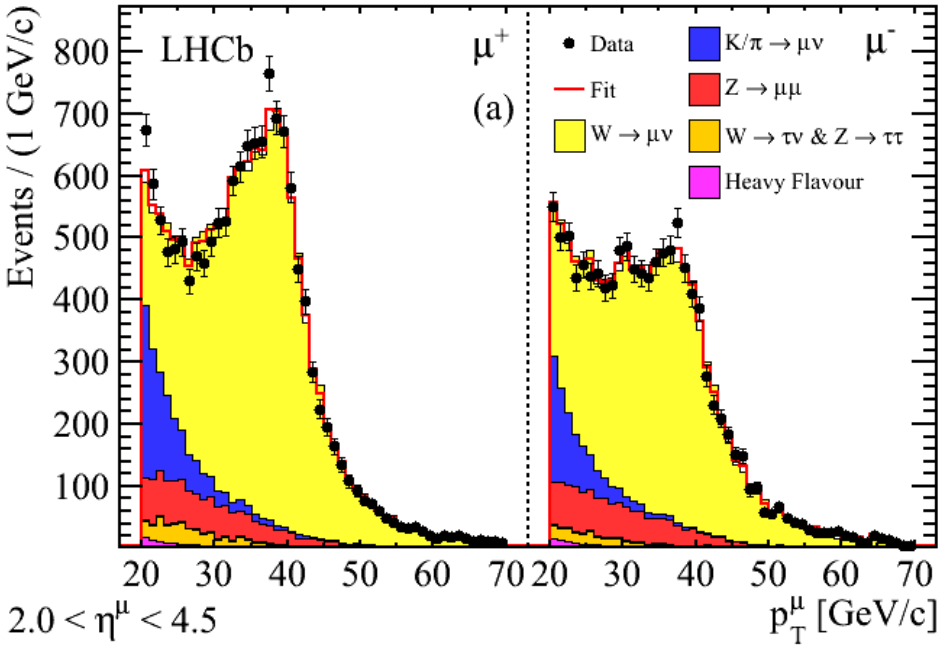
From data: muons with
impact parameter > 80 μm

W purity

JHEP 2012, 6 (2012), 58

Purity: fit to positively and negatively charged muon p_T distribution

	Shape
W →μν	Simulation
K/π decay in flight	Data
γ*/Z→μμ	Simulation
W→τν , Z→ττ	Simulation
Heavy Flavour	Data



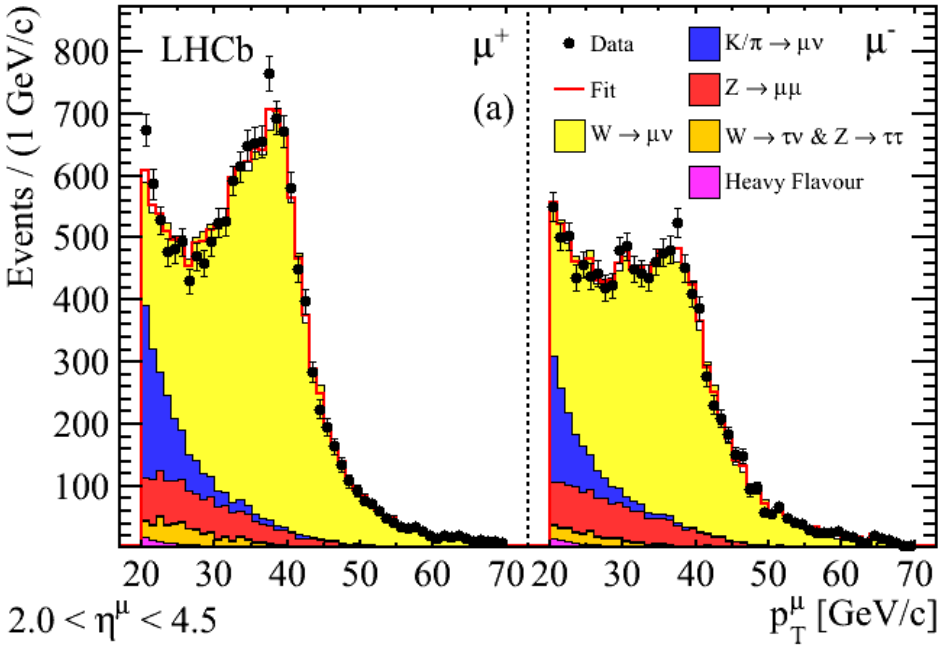
W purity

JHEP 2012, 6 (2012), 58

Purity: fit to positively and negatively charged muon p_T distribution

	Shape	Norm.
W →μν	Simulation	Fit
K/π decay in flight	Data	Fit
γ*/Z→μμ	Simulation	Fixed
W→τν , Z→ττ	Simulation	Fixed
Heavy Flavour	Data	Fixed

Normalisation
- Signal and decay in flight: fitted
- Others : fixed from data



	W+	W−
Purity	78.8%	78.4%

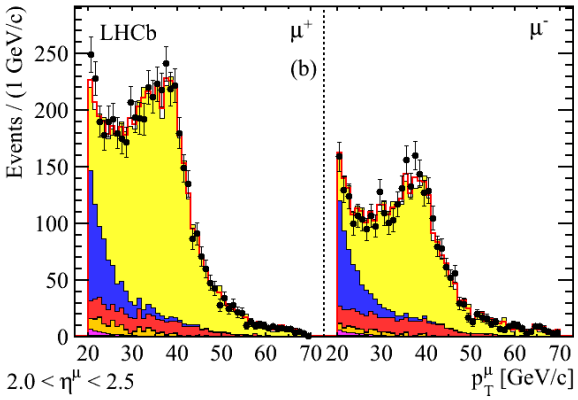
W purity

JHEP 2012, 6 (2012), 58

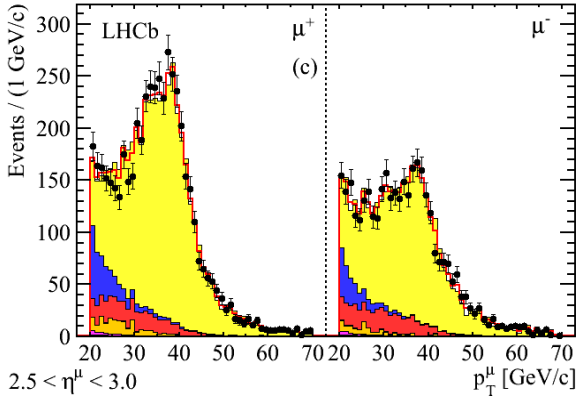
Purity: fit to positively and negatively charged muon p_T distribution in 5 η bins

(15 free parameters: 10 signal, 5 background)

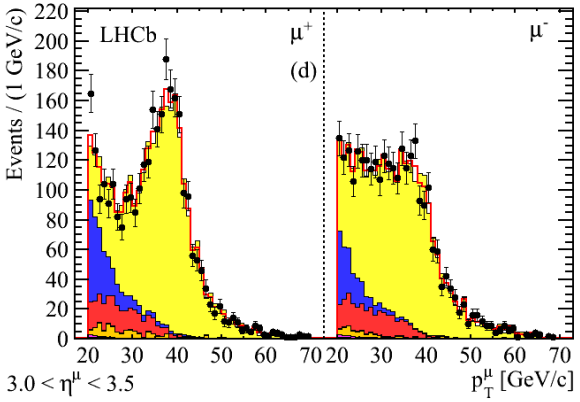
$2.0<\eta^{\mu}<2.5$



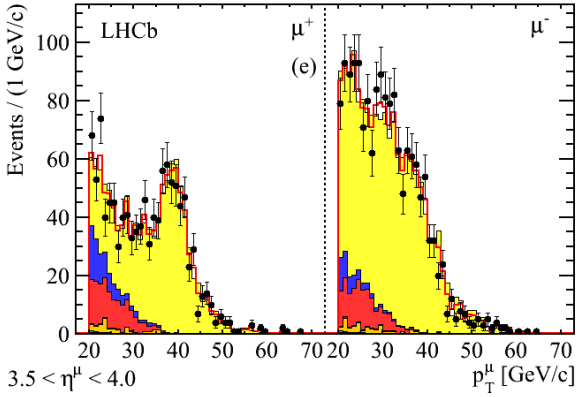
$2.5<\eta^{\mu}<3.0$



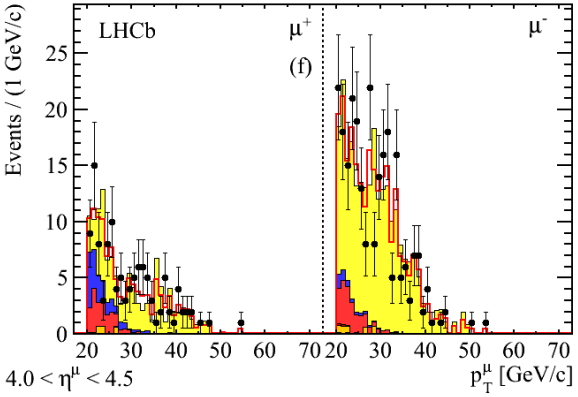
$3.0<\eta^{\mu}<3.5$



$3.5<\eta^{\mu}<4.0$



$4.0<\eta^{\mu}<4.5$



arXiv: 1204.1620

Additional selection efficiency

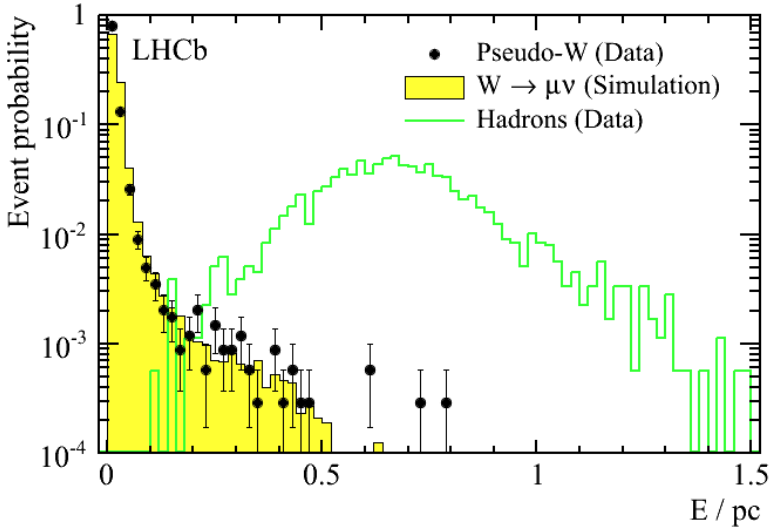
JHEP 2012, 6 (2012), 58

$$\sigma = \frac{\rho N}{A L \epsilon} f_{FSR}$$

W selection: (E/p), IP, P_T^{max}, E_T^{cone}
from pseudo-W events: ϵ_{sel} = 0.3–0.7

Acceptance: $p_T > 20$ GeV, $2<\eta<4.5$
$W \rightarrow \mu\nu$: >0.99

Energy in calorimeters



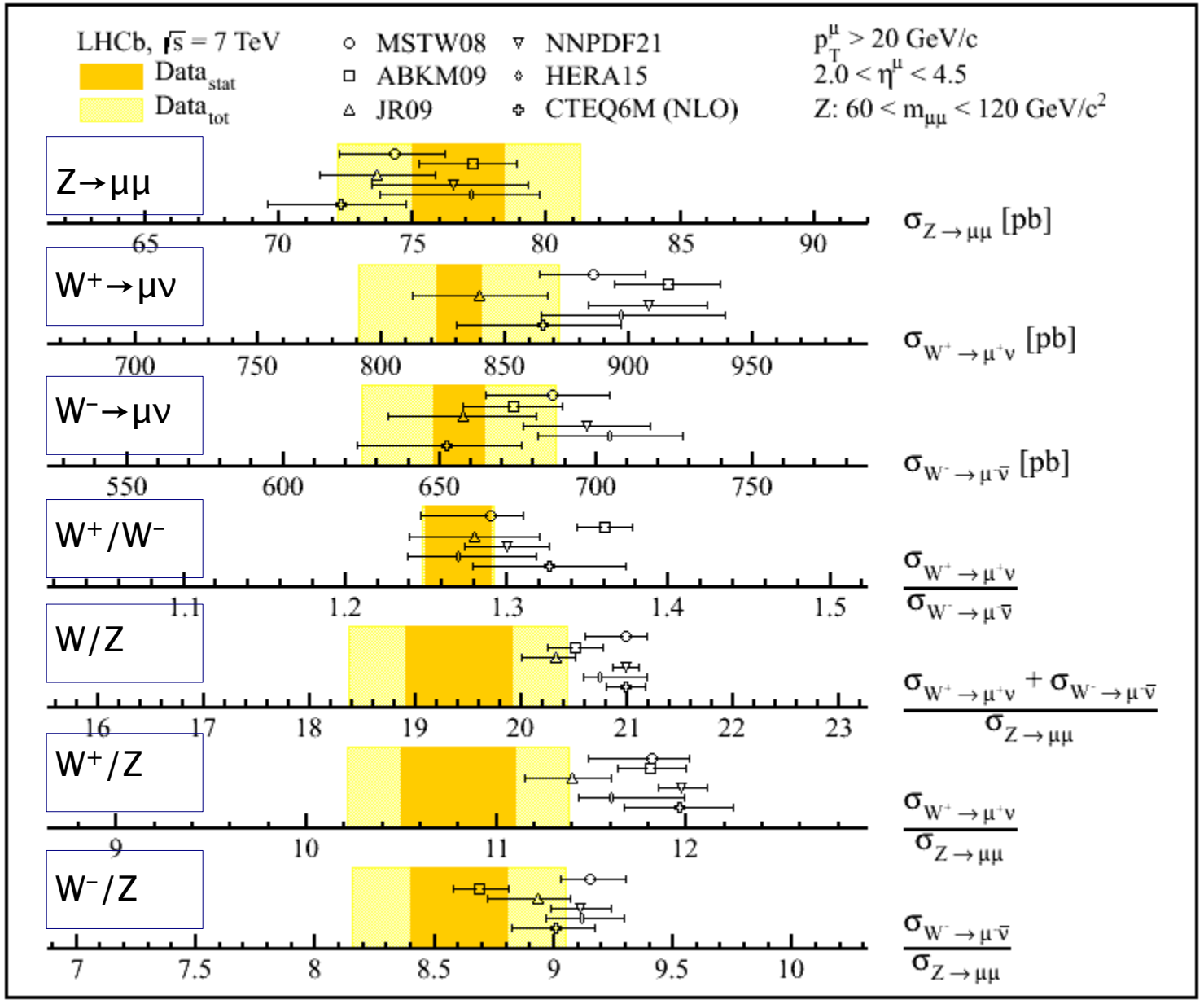
Signal: pseudo-W data
Background:
hadrons from randomly triggered events

Systematic uncertainties:

Source	W^+(%)	W^-(%)
Purity	1.2	0.9
Template shapes	0.9	1.0
Efficiency (trigger, tracking, muon id	2.2	2.0
Selection Efficiency	1.8	1.7
Total	3.2	2.9
Luminosity	3.5	3.5

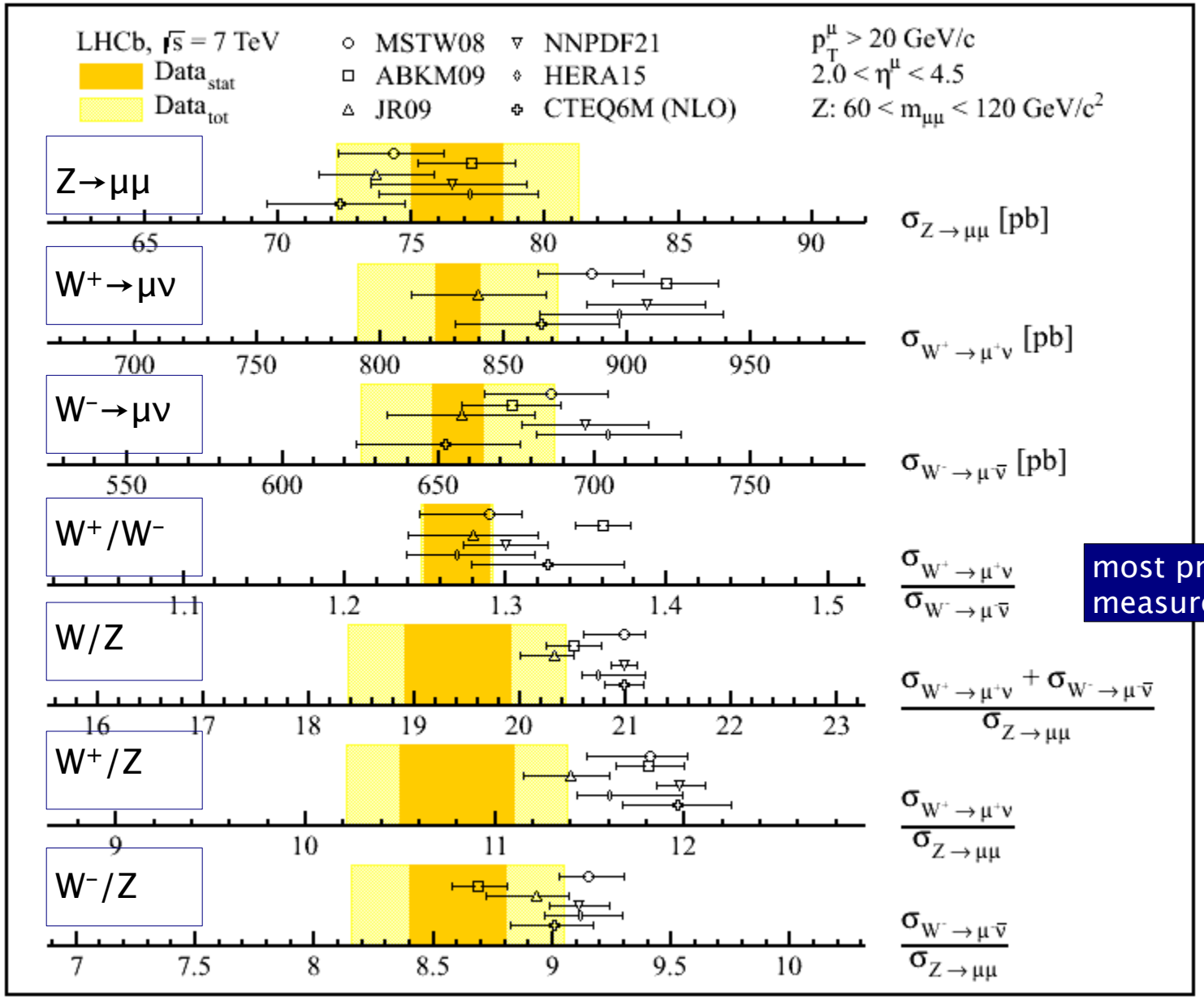
Cross sections and ratios

JHEP 2012, 6 (2012), 58



Cross sections and ratios

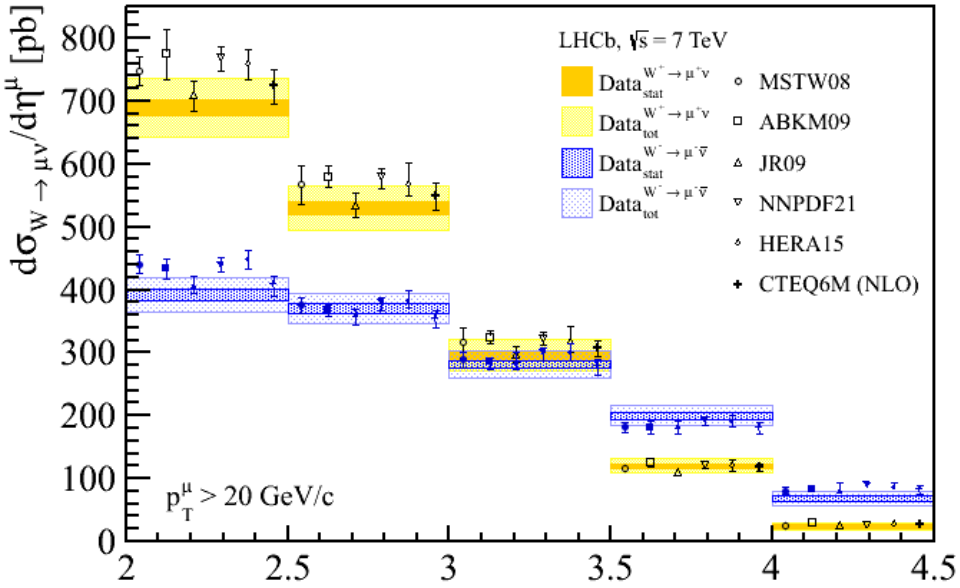
JHEP 2012, 6 (2012), 58

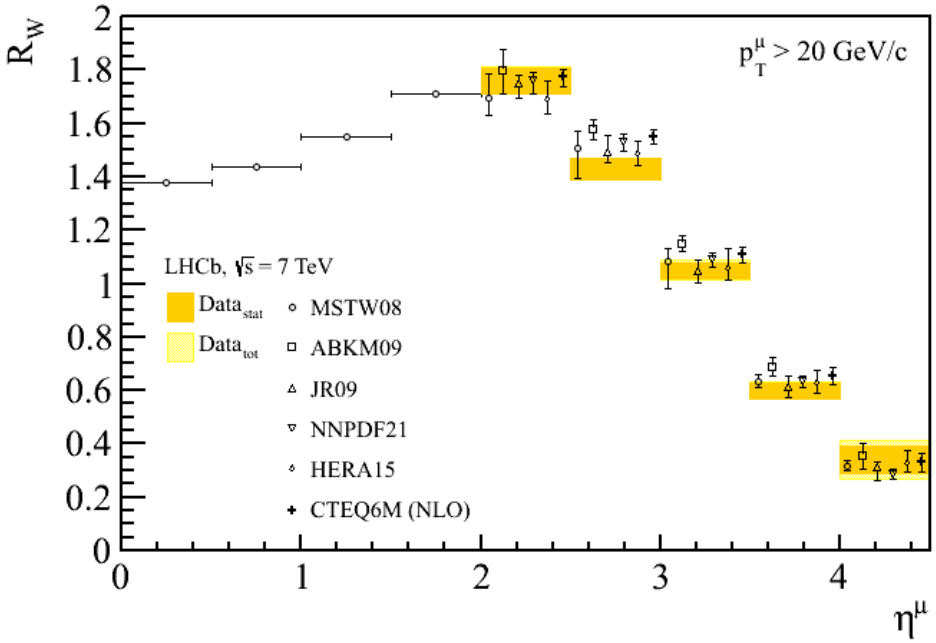


most precise measurement: 1.7%

Differential W cross section and W ratio

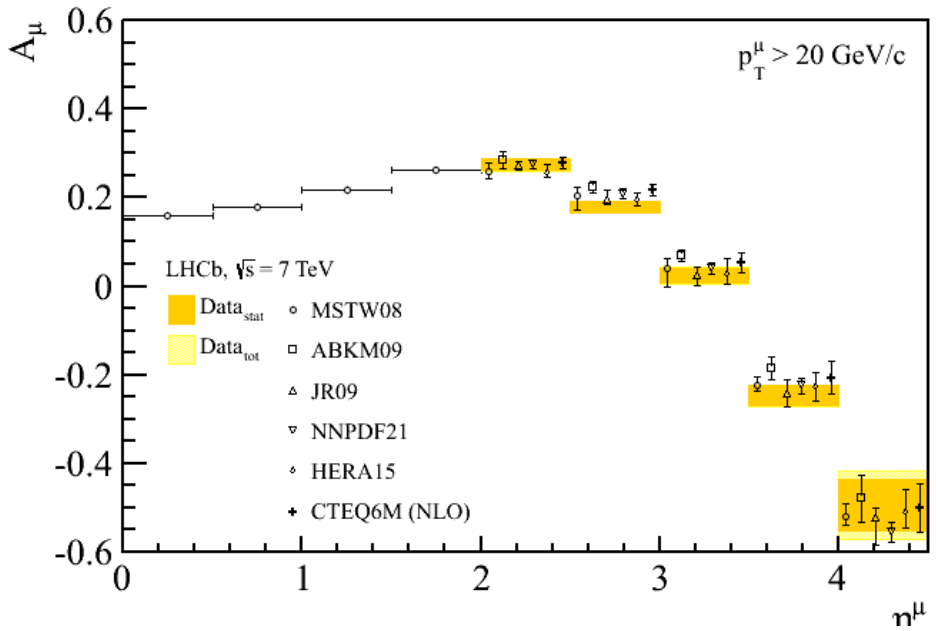
JHEP 2012, 6 (2012), 58





Lepton charge asymmetry

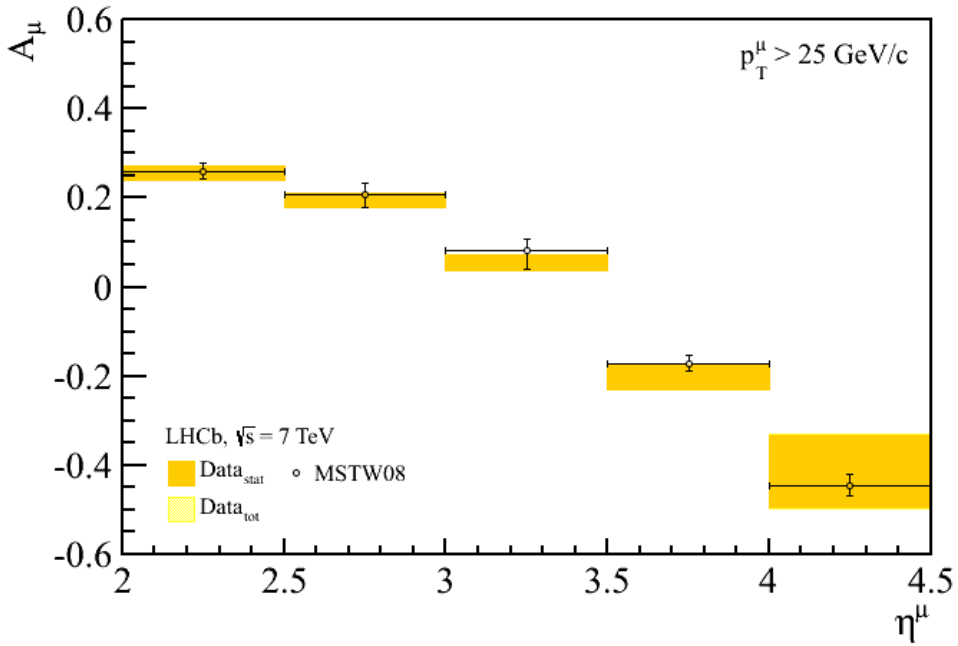
JHEP 2012, 6 (2012), 58

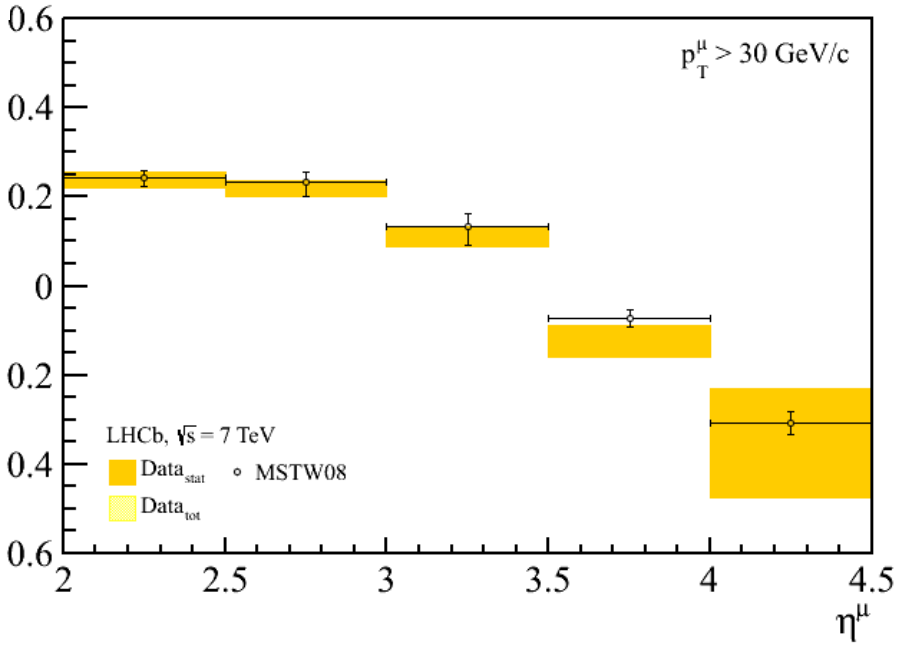


W lepton charge asymmetry for different p_T thresholds

sensitive to valence quark difference at high x

$$A_\mu = \frac{\sigma(W^+ \to \mu^+ \nu_\mu) - \sigma(W^- \to \mu^- \bar{\nu}_\mu)}{\sigma(W^+ \to \mu^+ \nu_\mu) + \sigma(W^- \to \mu^- \bar{\nu}_\mu)}$$

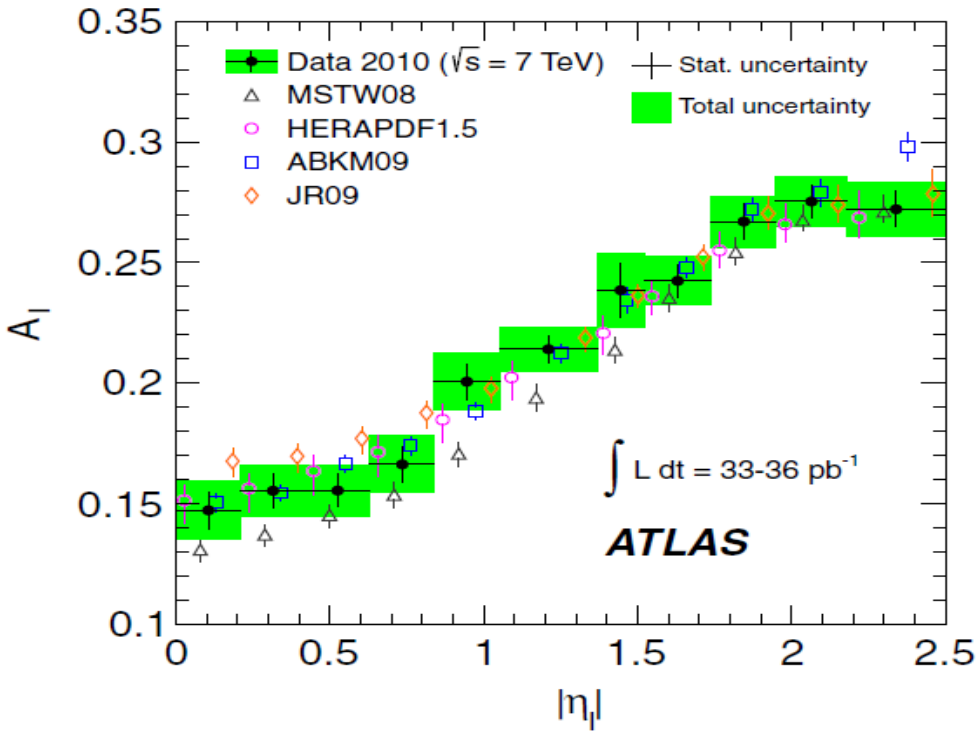


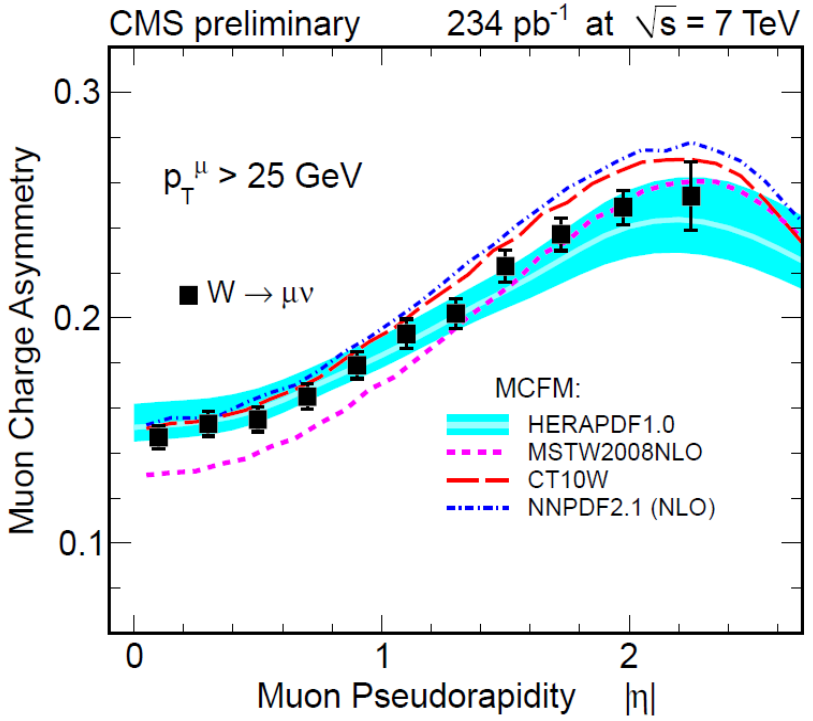


Lepton charge asymmetry: ATLAS, CMS

ATLAS
p_T>20 GeV/c $|\eta_l|$< 2.4
Etmiss> 25 GeV , M_T>40 GeV/c^2
combine: muon, electron channel
Phys. ReV D85 (2012) 072004

CMS
p_T>25 GeV/c $|\eta_\mu|$< 2.4
systematics limited
(momentum scale,efficiency, model)
CMS-PAS-EWK-11-005

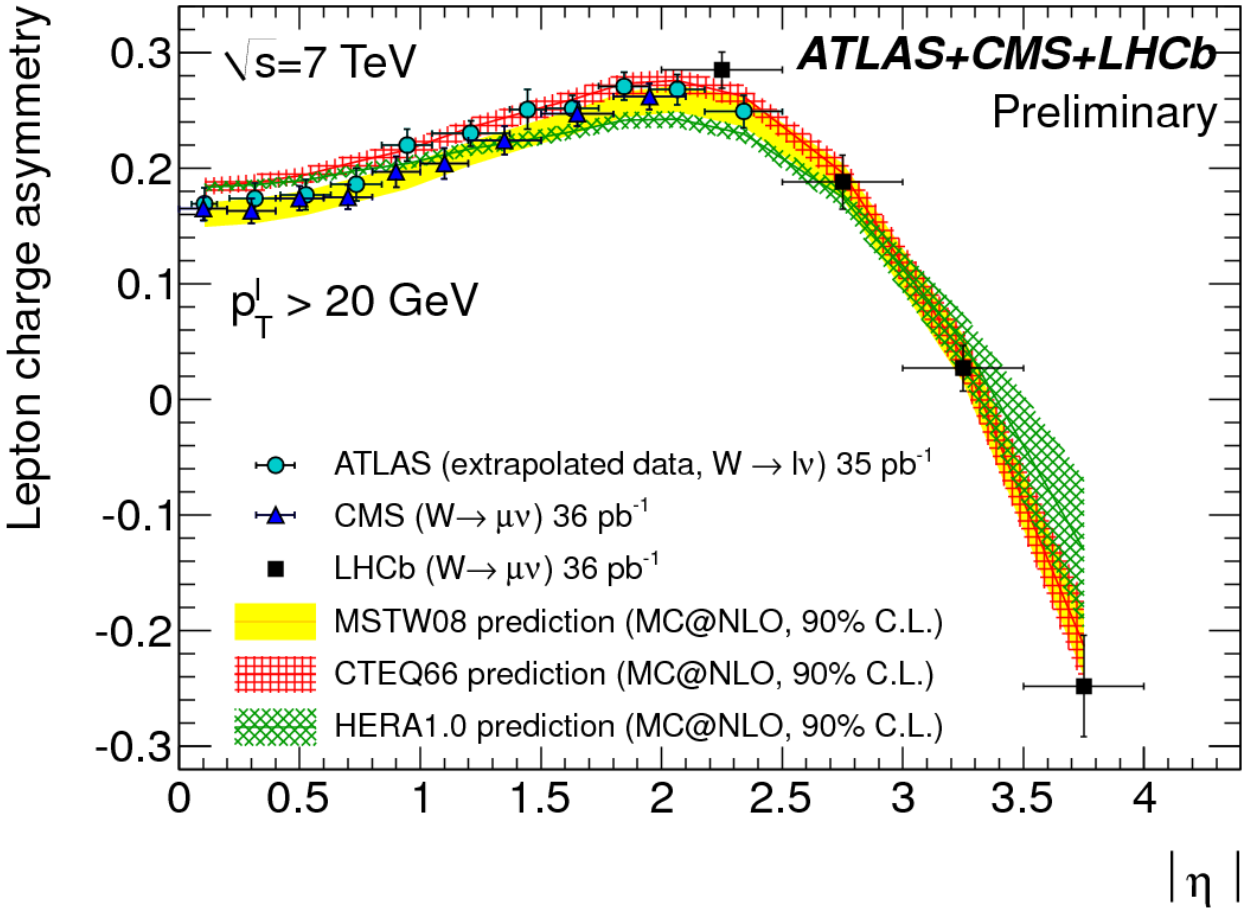




Disagreement with MSTW2008NLO at low |η|, more pronounced at higher p_T
(subsequently improved)

Lepton charge asymmetry: outlook

Combined plot with all three experiments
(very early preliminary analyses)



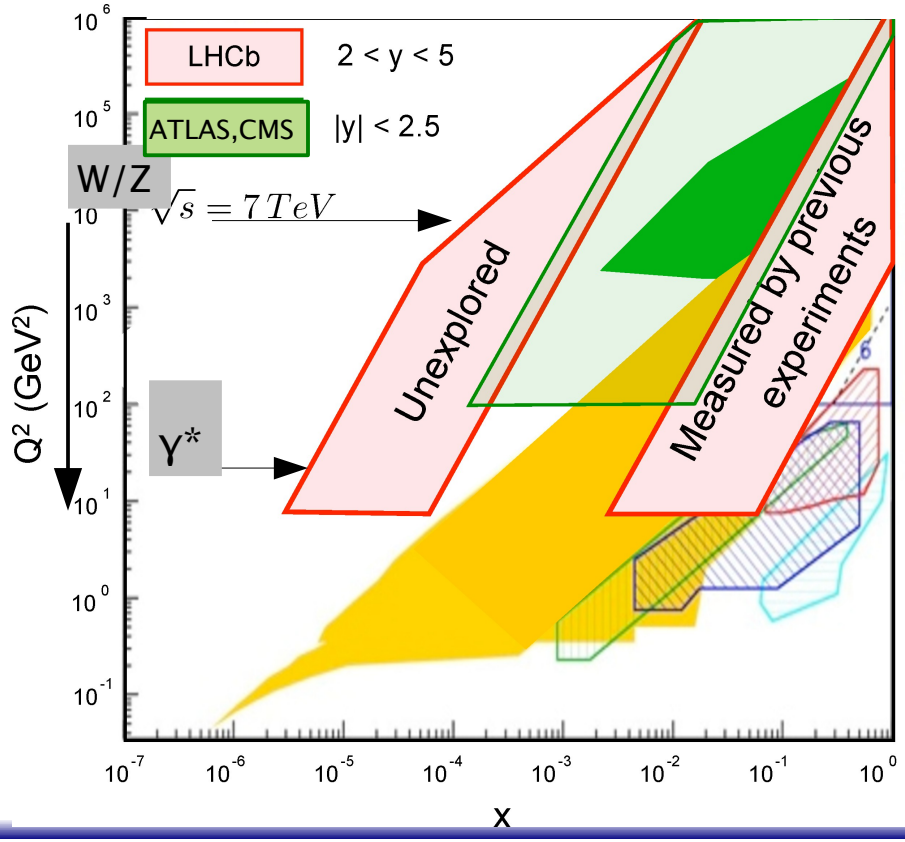
Low mass Drell-Yan

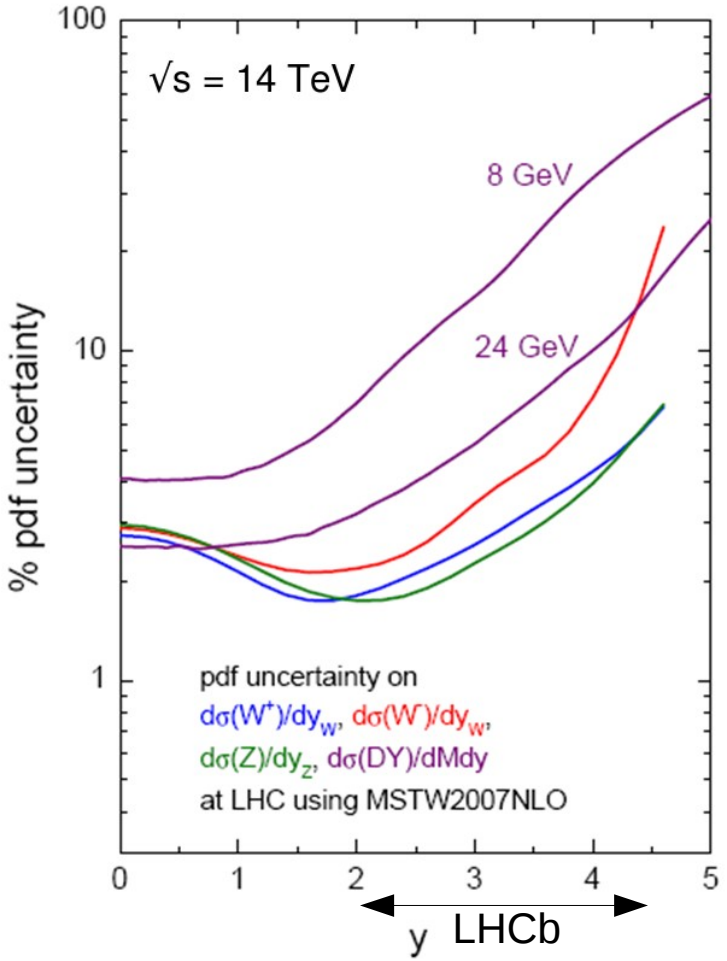
- W/Z measurements probe

  Q^2 =10'000 GeV^2, x= 1.7·10^{-4}

- Low mass Drell-Yan (γ*)

  Q^2 =25 GeV^2, x= 8·10^{-6}



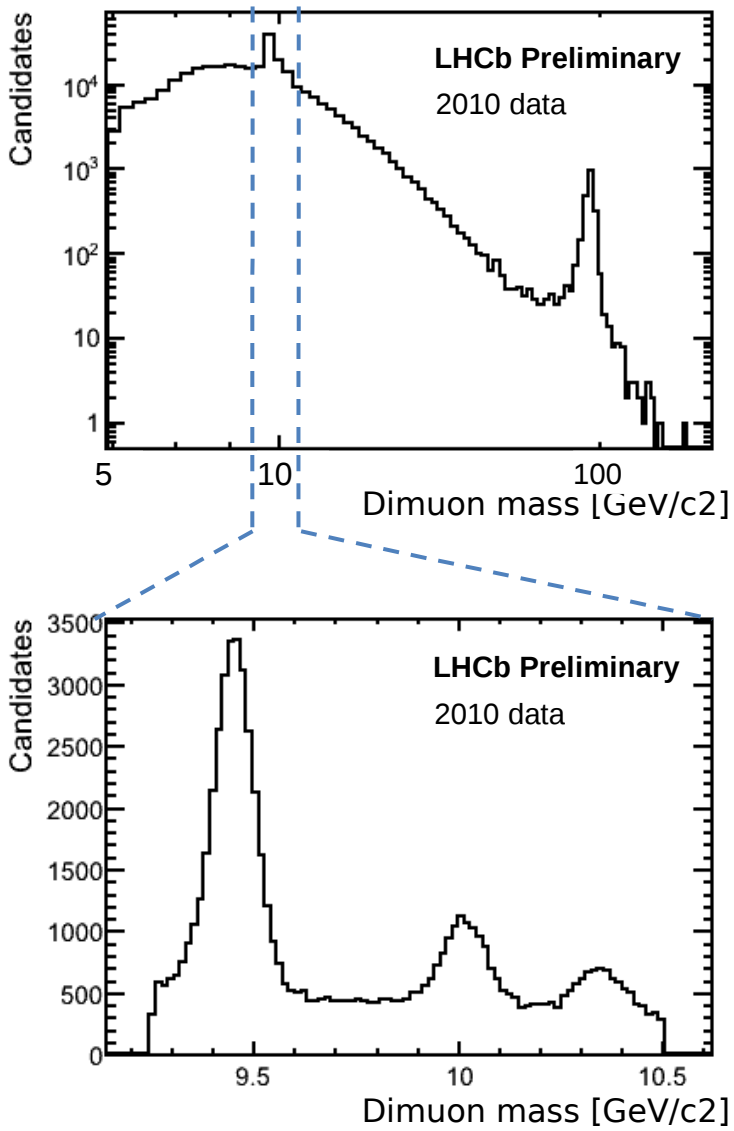


γ*→μμ selection

Data
- 2010 L = 37.1 pb^{-1}
- Trigger: dimuon, p_T > 2.5 GeV/c

Muon
- two identified muons
- p_T> 3 GeV/c
- p_T>15 for $M_{\mu\mu}$ >40 GeV/c^2
- p> 10 GeV/c
- 2.0 < η_μ 4.5

Mass selection
- 5 < $M_{\mu\mu}$ < 120 GeV/c^2



Purity

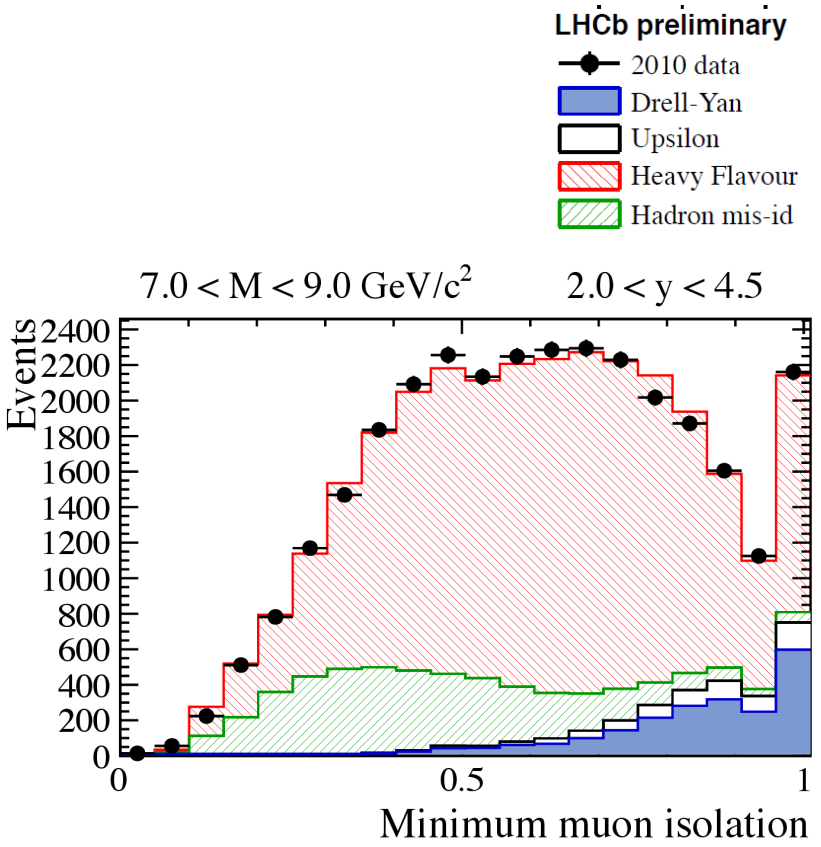
Background
- Semileptonic decays of heavy flavour events
- K/π misidentification
- Radiative tail of Upsilon (M<10 GeV/c^2)

Background large at low masses

Signal extraction
- Template fit to minimum muon isolation
- Muon isolation: $p_T(\mu)/p_T(\mu\text{–Jet})$
- Fit for 9 mass bins
- Fit for 5 η bins (two mass ranges)

Templates
- Signal: simulation
- Background: data

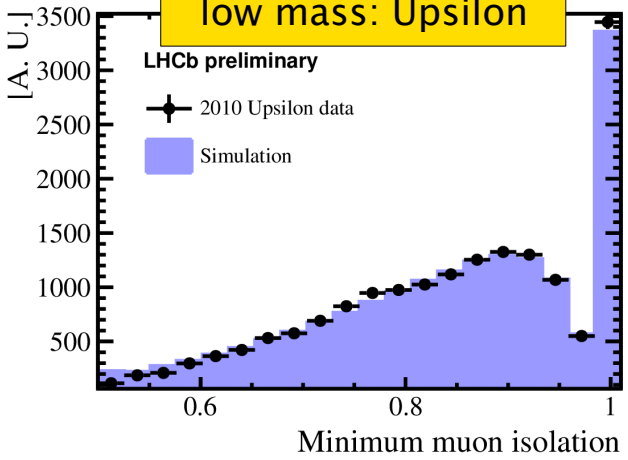
Efficiencies
- From data (similar to W/Z)



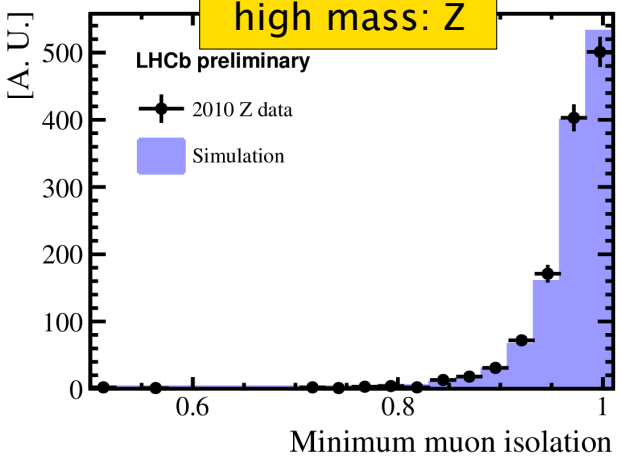
Purity-Templates

Signal template:
Compare data and MC

low mass: Upsilon



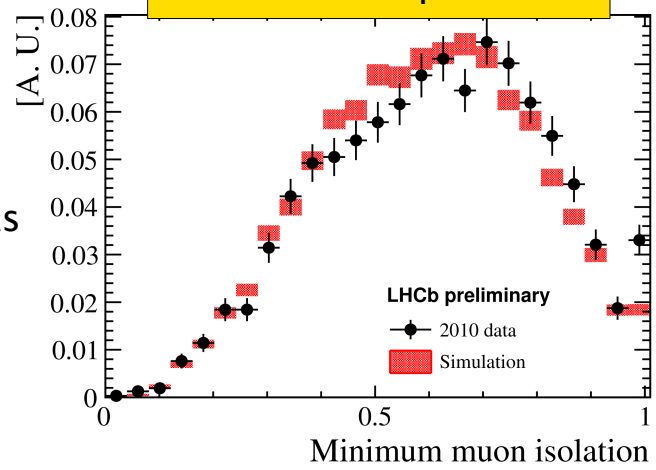
high mass: Z



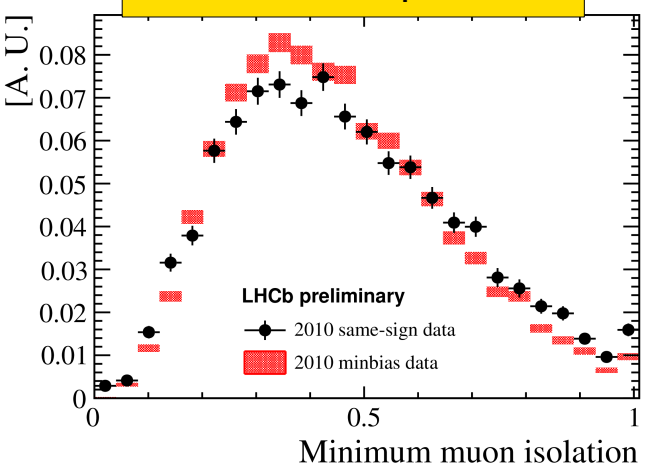
Background templates:
1) Heavy Flavour
- data: IP cut
- simulation

2) Kaon-Pion mis-id
- data: minimum bias
- data: same sign

BG:HF template

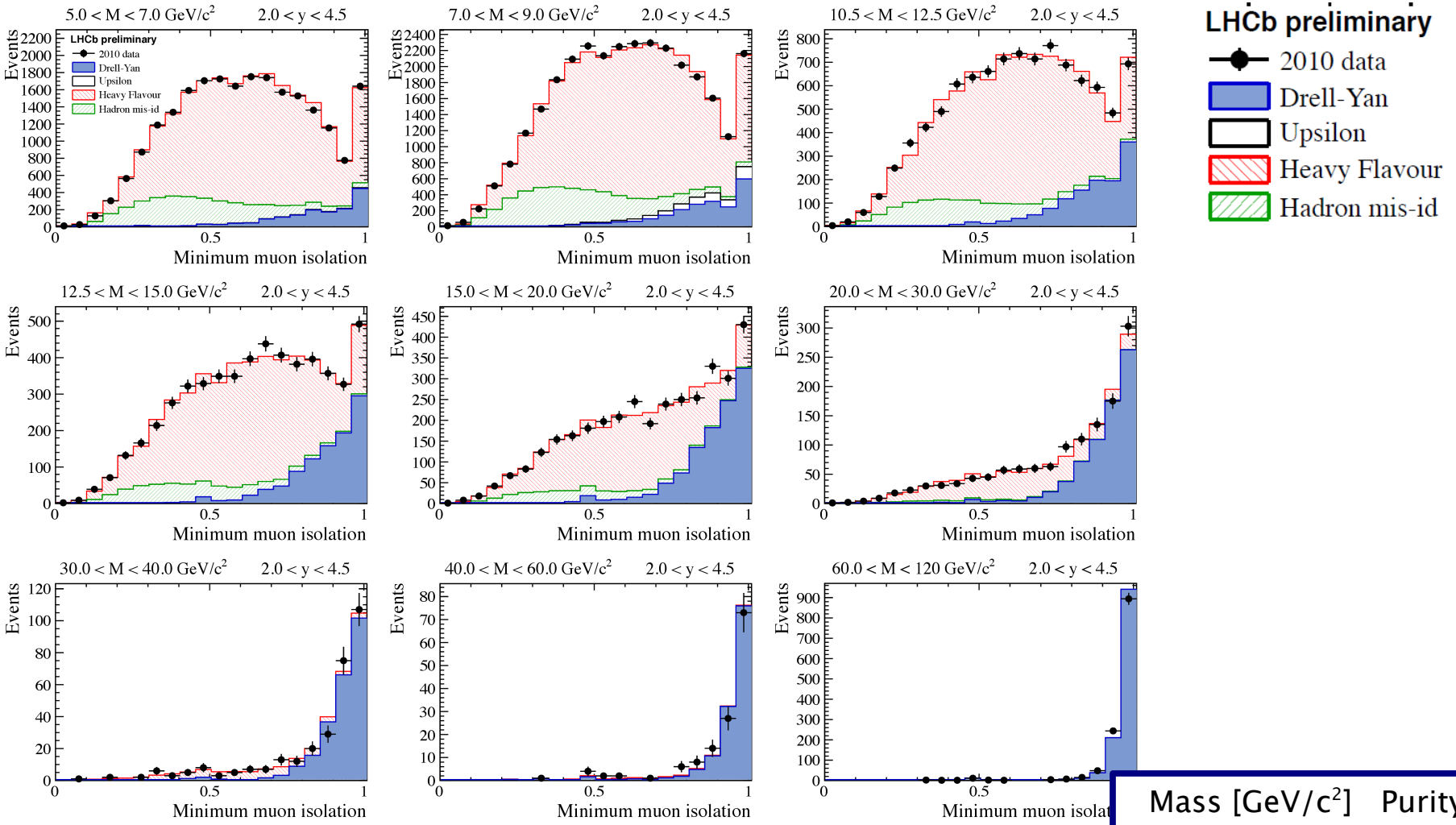


Mid-id template



Systematic uncertainties due to templates:
Background: Difference in fitted signal fraction when using different background templates
Signal: distort signal template

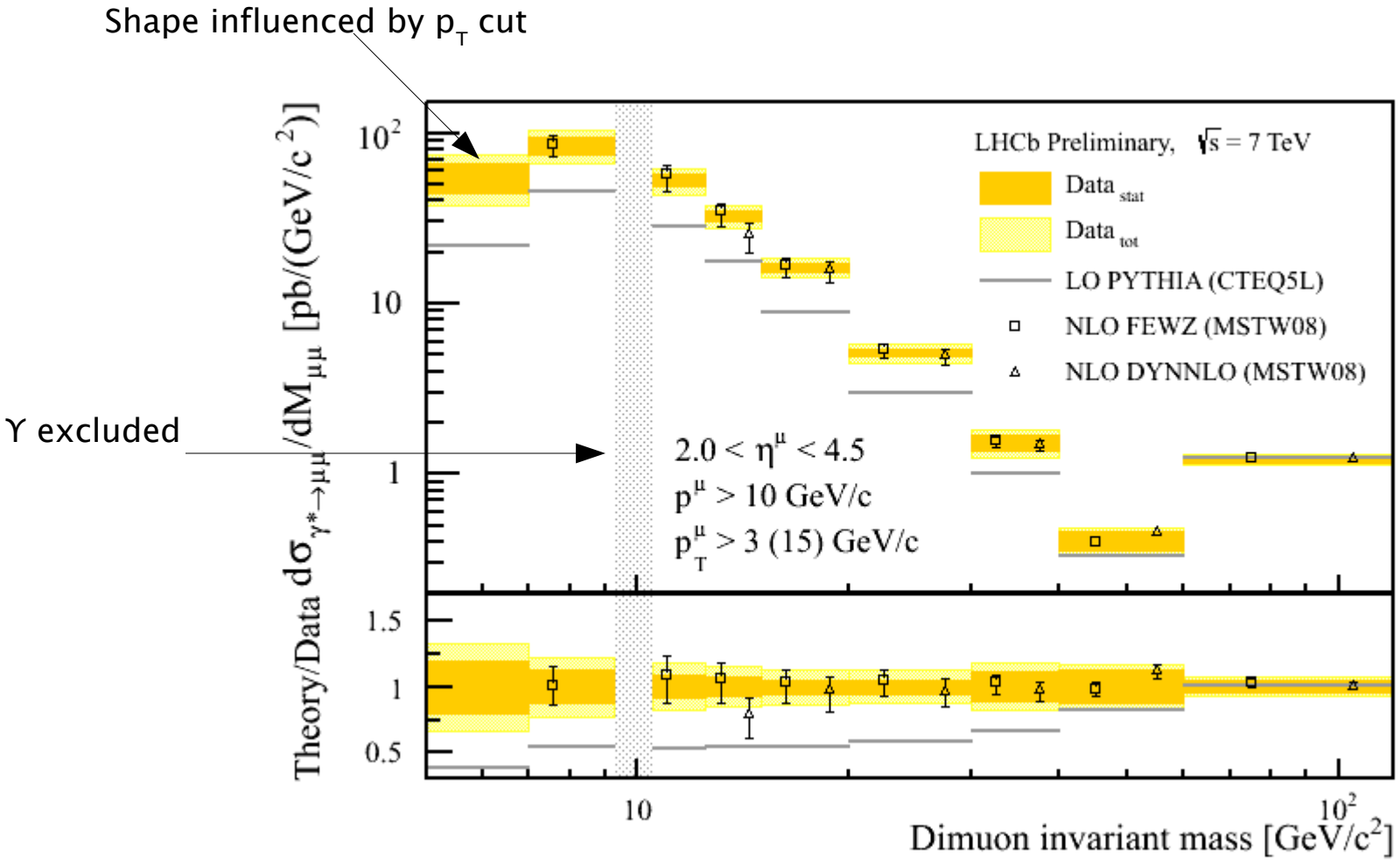
Purity



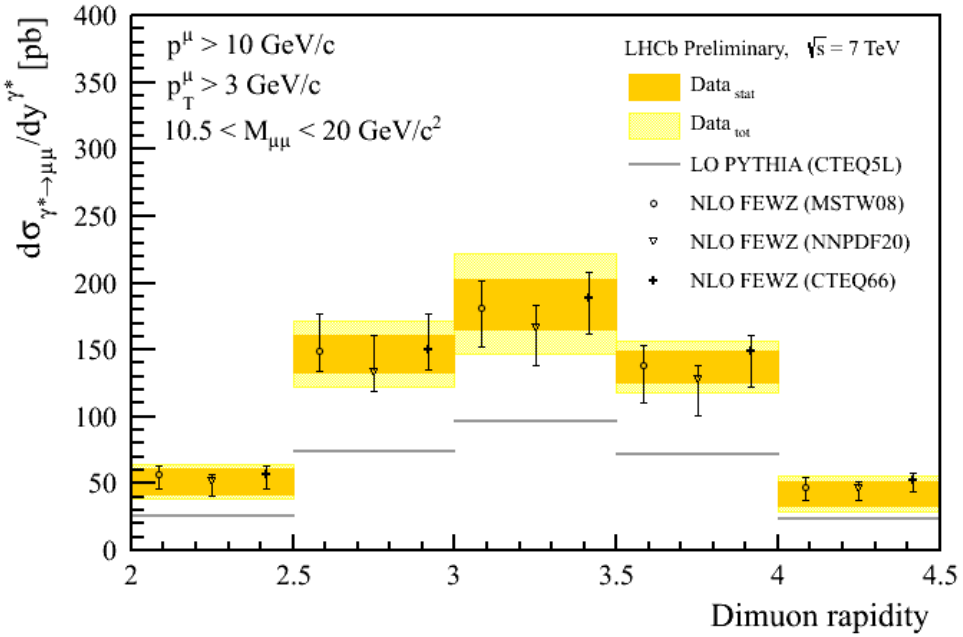
Systematic uncertainties

- At low masses: shapes used for template fit 24%
- Efficiencies

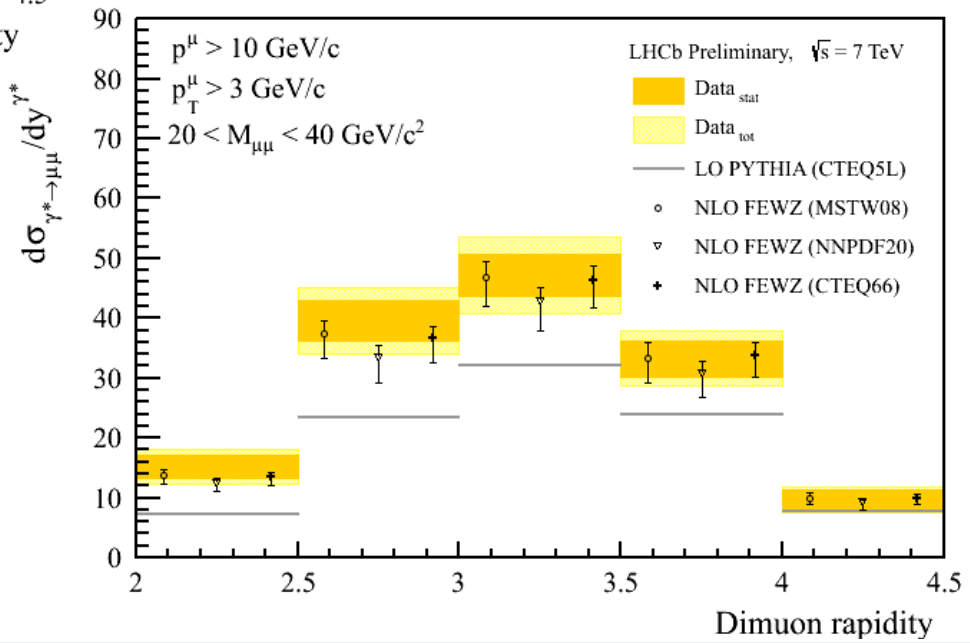
Mass [GeV/c²]	Purity [%]
5–7.5	6.8
7.5–9	9.0
12.5–15	20.4
20–30	54.9
40–60	91.4



Compared to NLO predictions (FEWZ and DYNNLO) and PYTHIA
FEWZ predictions above 7 GeV/c^2, DYNNLO above 12.5 GeV/c^2



Differential in dimuon rapidity



Compared to NLO predictions (FEWZ) and PYTHIA

ATLAS and CMS Results

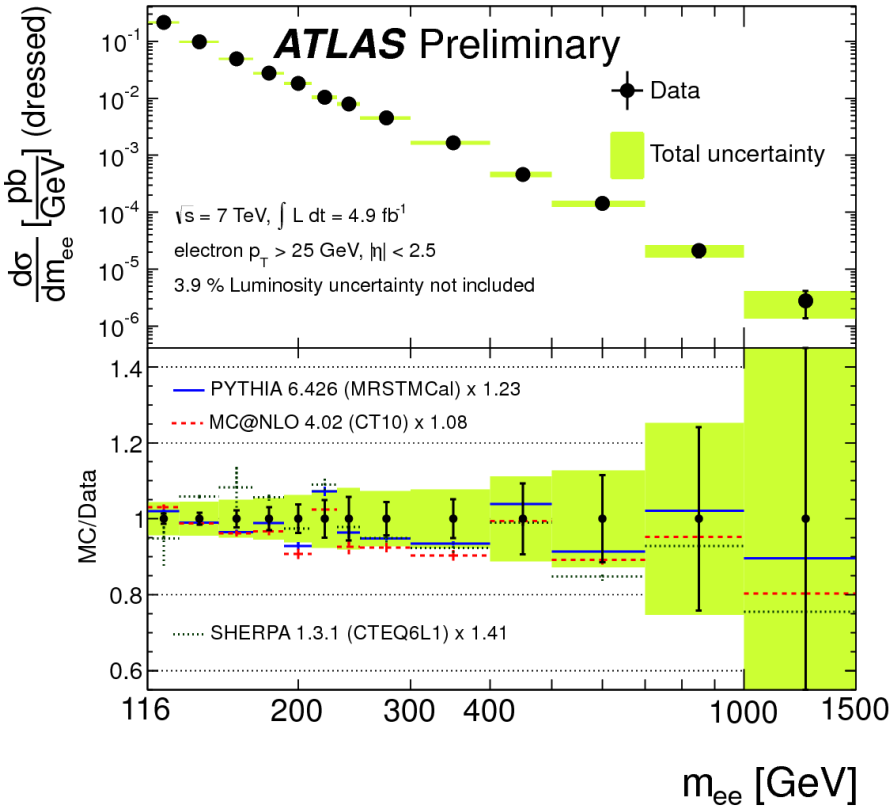
ATLAS: electron 116-1500 GeV/c2
Electron p_T>25 GeV/c^2,$|\eta_e|$<2.47

Backgrounds W plus jets, di-jets from data
ATLAS-CONF-2012-159

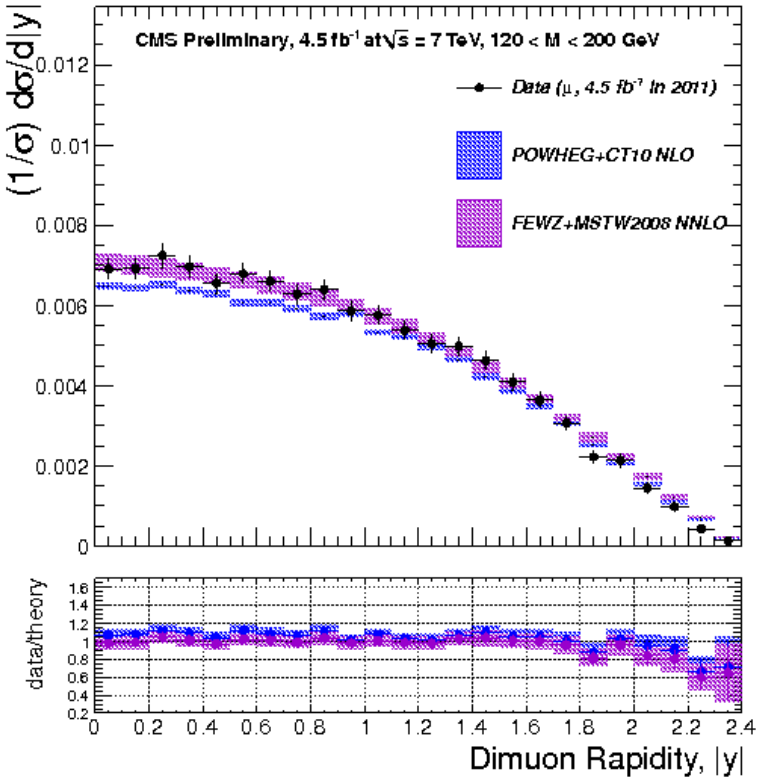
CMS: muon and electron 15-1500 GeV/c2
Muon p_T>14.9 GeV/c^2,$|\eta_\mu|$<2.4

Electron p_T>20,10 GeV/c^2,$|\eta_e|$<2.5

Backgrounds: QCD, τ, top and di-boson pairs
CMS-PAS-EWK-11-007

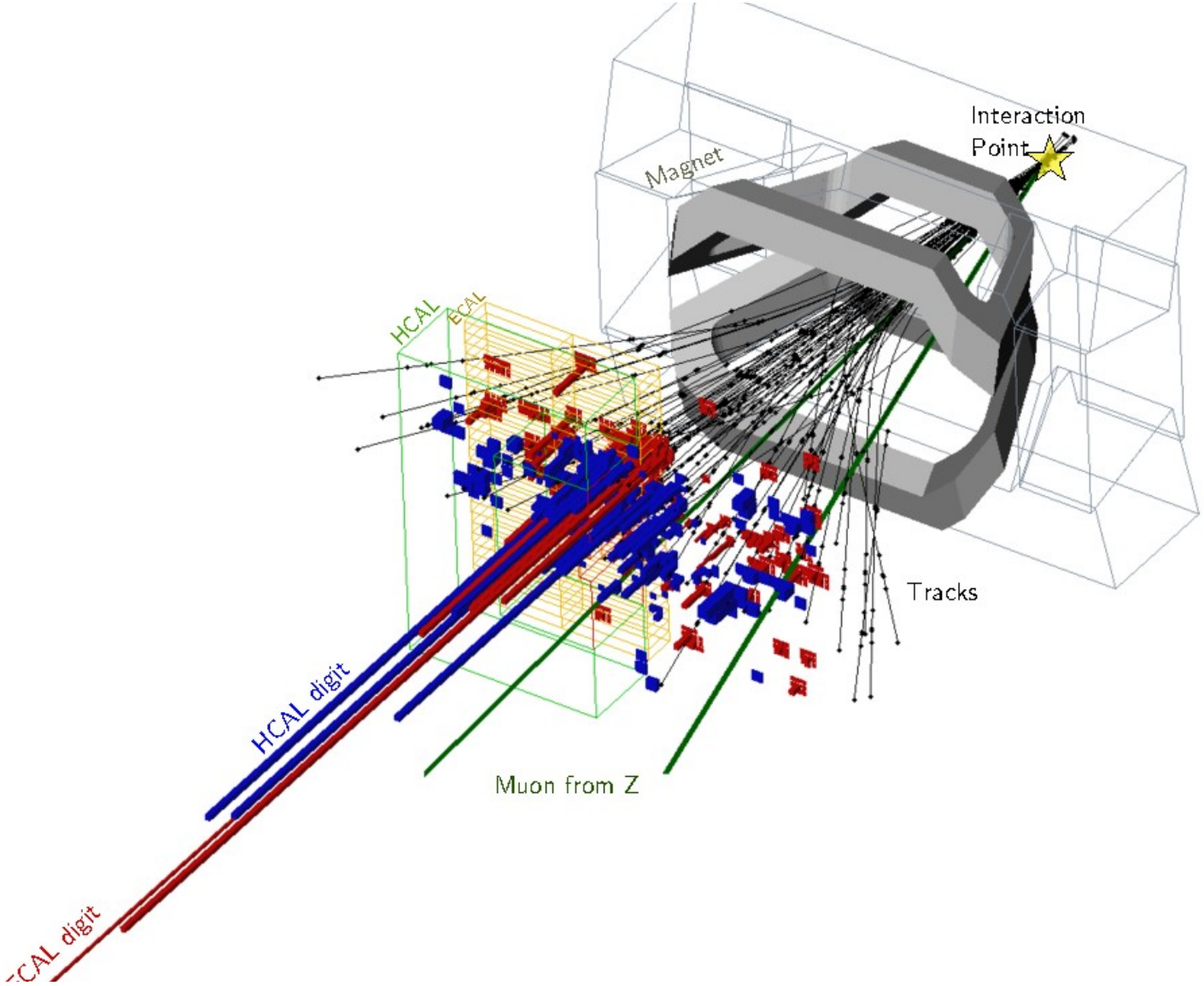


Good agreement with MC and NNLO predictions



central rapidity: NNLO needed

Z plus jet analysis



Selection

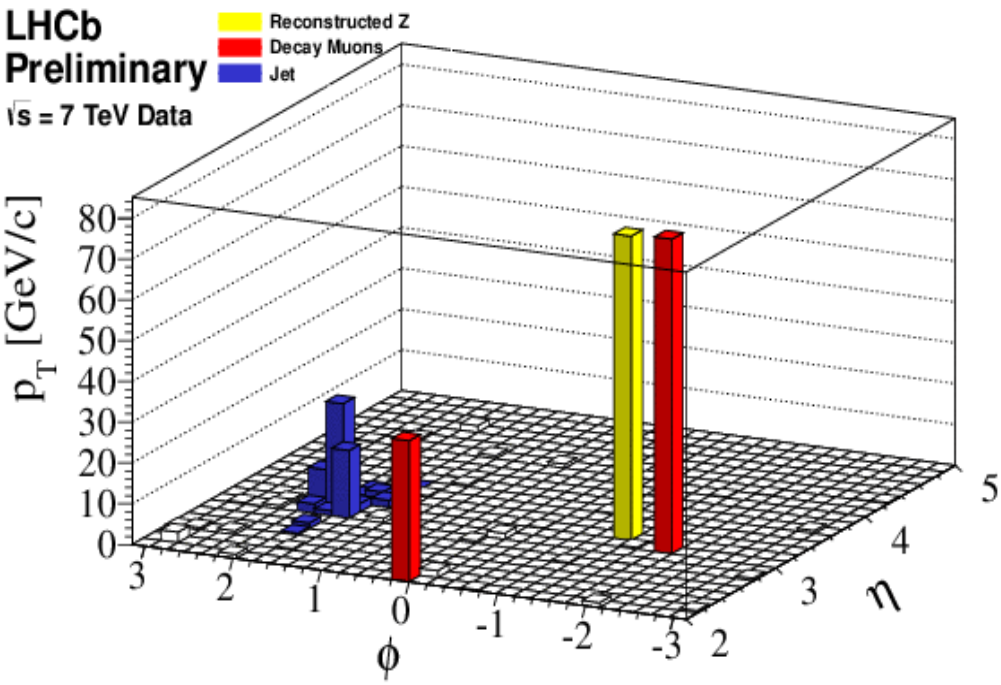
Test QCD in a new region

Background for searches @ LHC

Data
- 2011 L = 1 fb^{-1}
- Z→μμ selection
- 60 < M(μμ) < 120 GeV/c^2

Jet reconstruction
- Anti-k_T algorithm (R=0.5)
- Energy flow objects: tracks, photons, neutral hadrons, V0
- Energy mainly from tracks
- Measurement on hadron level

Jet selection
- p_T(jet)> 10 GeV/c
- 2.0 < η_μ <4.5
- ΔR(μ,jet)>0.4
- Jet identification



p_T(jet) = 75 GeV/c
p_T(μ+)= 35 GeV/c
p_T(μ−) = 77 GeV/c
M(μμ) = 97 GeV/c^2

Selection

Data

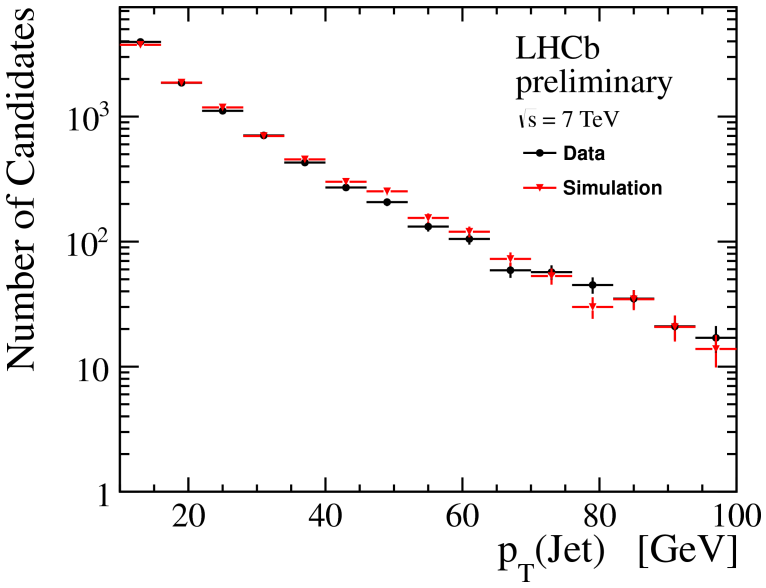
- 2011 L = 1 fb^{-1}
- Z→μμ selection
- 60 < M(μμ) < 120 GeV/c^2

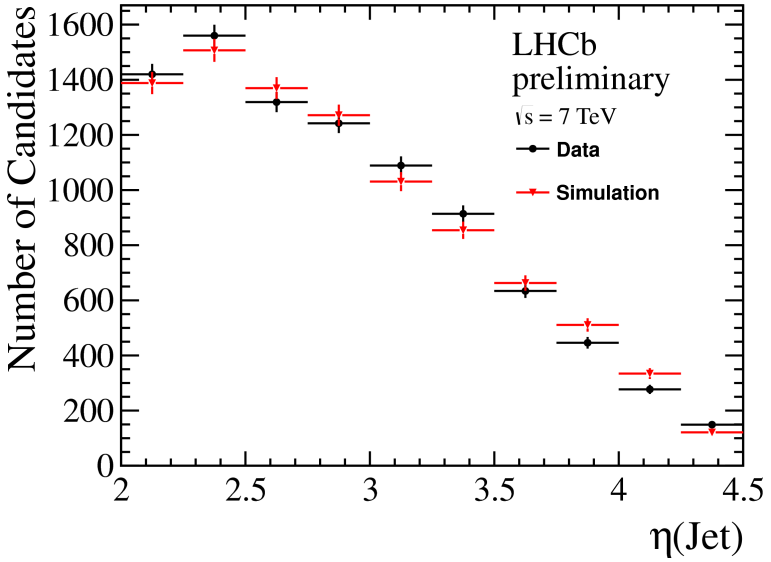
Jet reconstruction

- Anti-k_T algorithm (R=0.5)
- Energy flow objects:
  tracks, photons, neutral hadrons, V^0
- Energy mainly from tracks
- Measurement on hadron level

Jet selection

- p_T(jet)> 10 GeV/c
- 2.0 < η_μ <4.5
- ΔR(μ,jet)>0.4
- Jet identification





No efficiency correction in these plots
Good agreement between data and simulation on detector level

→ LHCb has the potential for good jet measurements

→ Simulation describes the data well

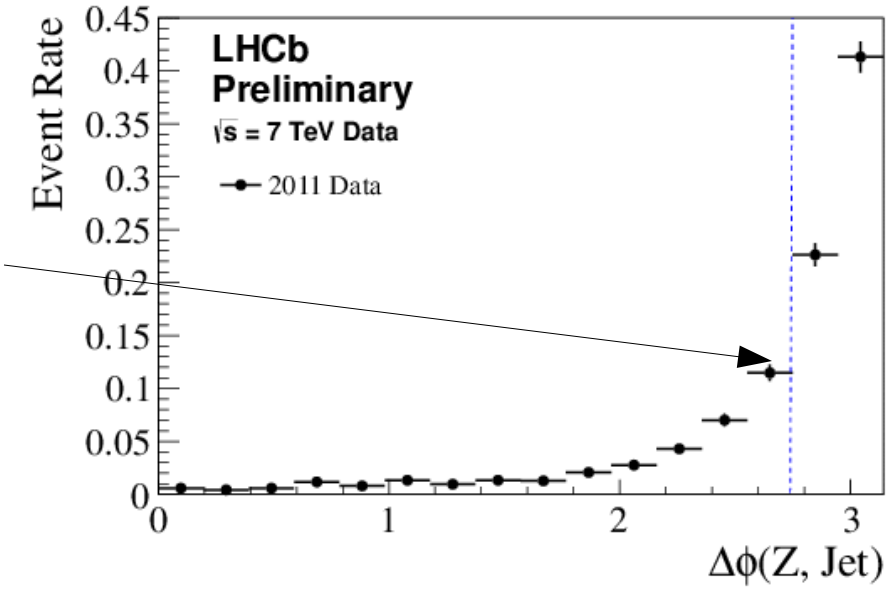
Jet energy scale

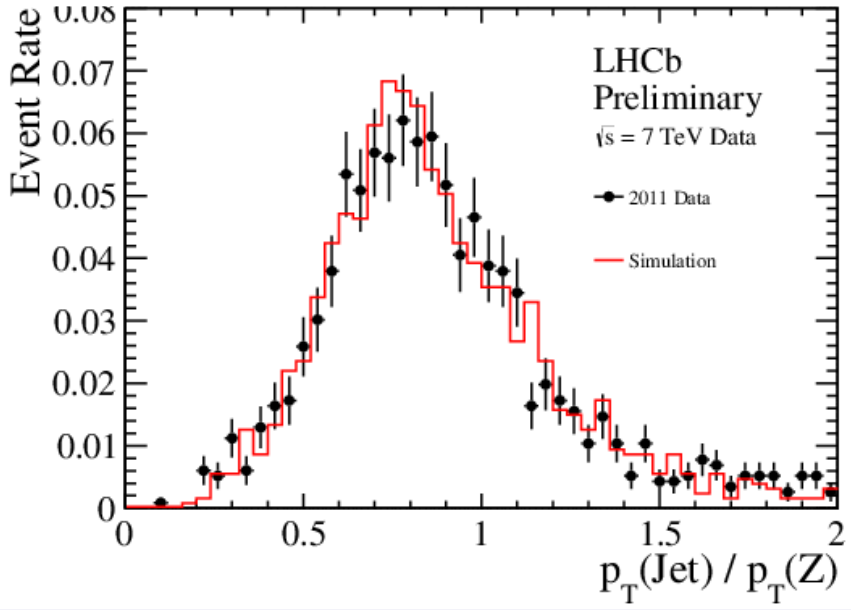
Jet energy scale and resolution

- Jet energy correction from simulation
- Cross check energy scale with data
- From events with Z and jet back-to back
  Expect balance between jet and Z p_T
- p_T(Jet)/p_T(Z) compare data with simulation
  - → Good agreement observed
  - → Energy scale: known with 3% precision
  - → Energy resolution: compare width in simulation and data
  - → Energy resolution 17% @ p_T(Jet)=30 GeV/c

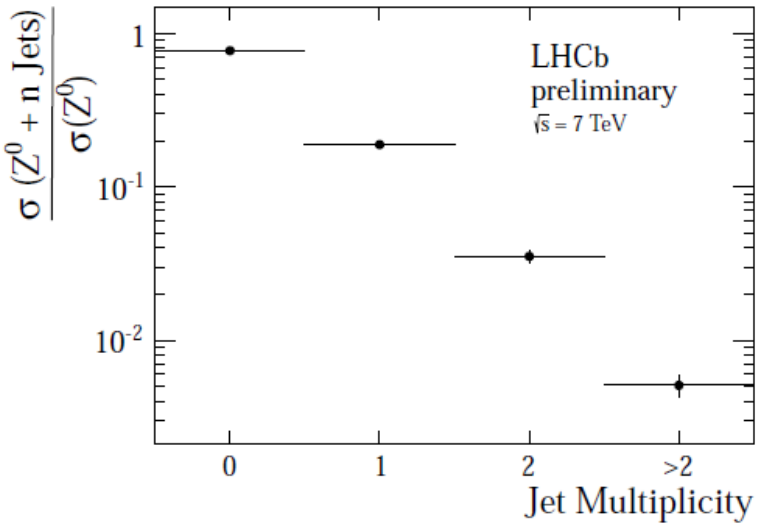
Systematic uncertainties

- Energy scale dominant





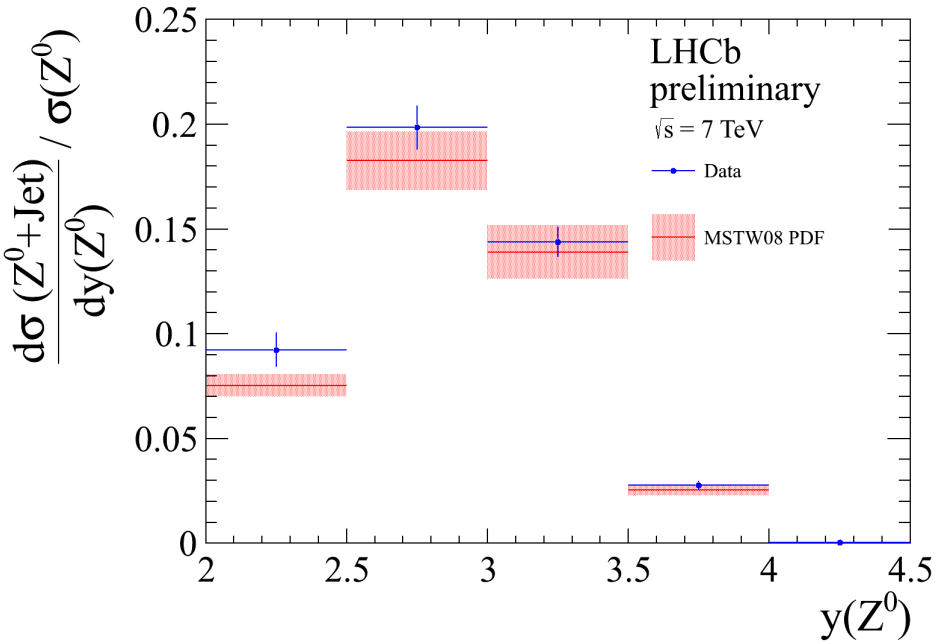
Z plus jets - results



Fraction of events with at least one jet:

LHCb preliminary:
0.229 ±0.006(stat) ±0.009(syst))

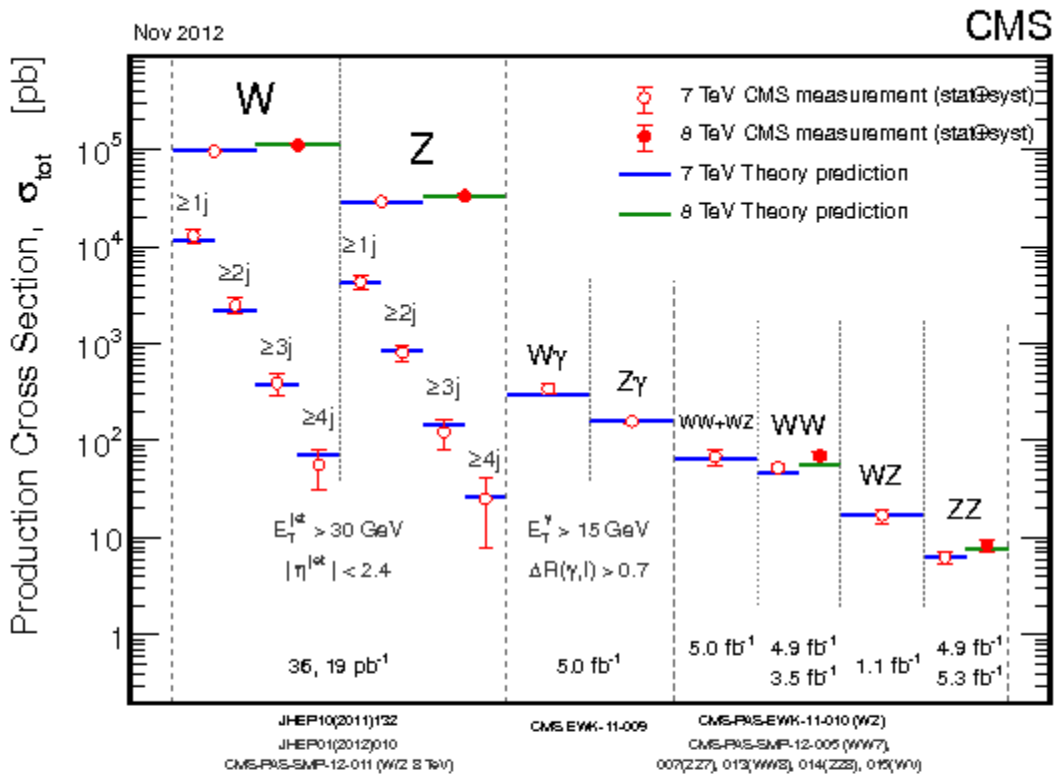
NLO: FEWZ with MSTW08 (parton level)
$0.212\ ^{+0.006}_{-0.009}$ (PDF) ±0.016 (scale)



ATLAS and CMS

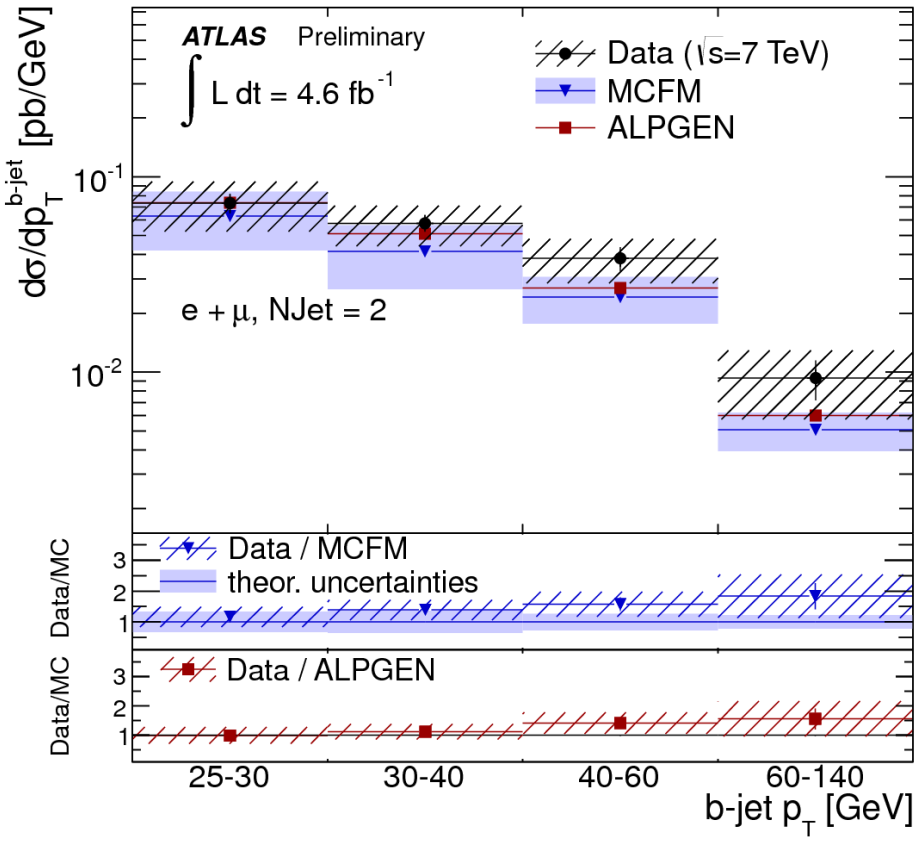
Boson plus jet(s) important background for searches
Production rate high →
- cross sections and observables as function of # jets
- angular correlations
- event shapes
- W/Z plus b jets
- W plus charm

But: high pileup
→ correct JES
CMS: 3% for p_T^{Jet}>30 GeV/c



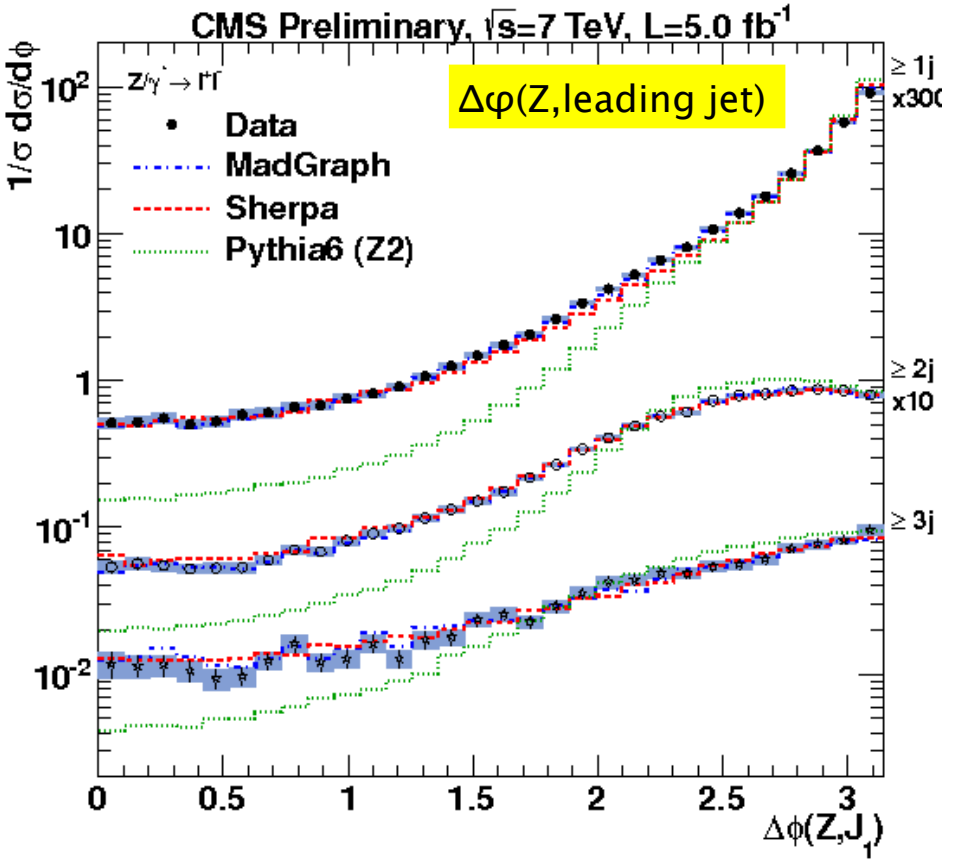
ATLAS and CMS

ATLAS: W plus b-jet
Lepton: p_T> 25 GeV/c, |η|<2.5
p_T^{miss}>25 GeV/c, m_T>60 GeV/c^2
Jet: p_T>25 GeV/c, |η|<2.1



Single top contribution subtracted
ATLAS-CONF-2012-156

CMS: Z plus jet
Leptons: p_T> 20 GeV/c, |η|<2.4
71<M_{ll}<121 GeV/c^2
Jet: p_T>50 GeV/c, |η|<2.5



PYTHIA is unable to describe non back-to-back configuration
CMS EWK11021

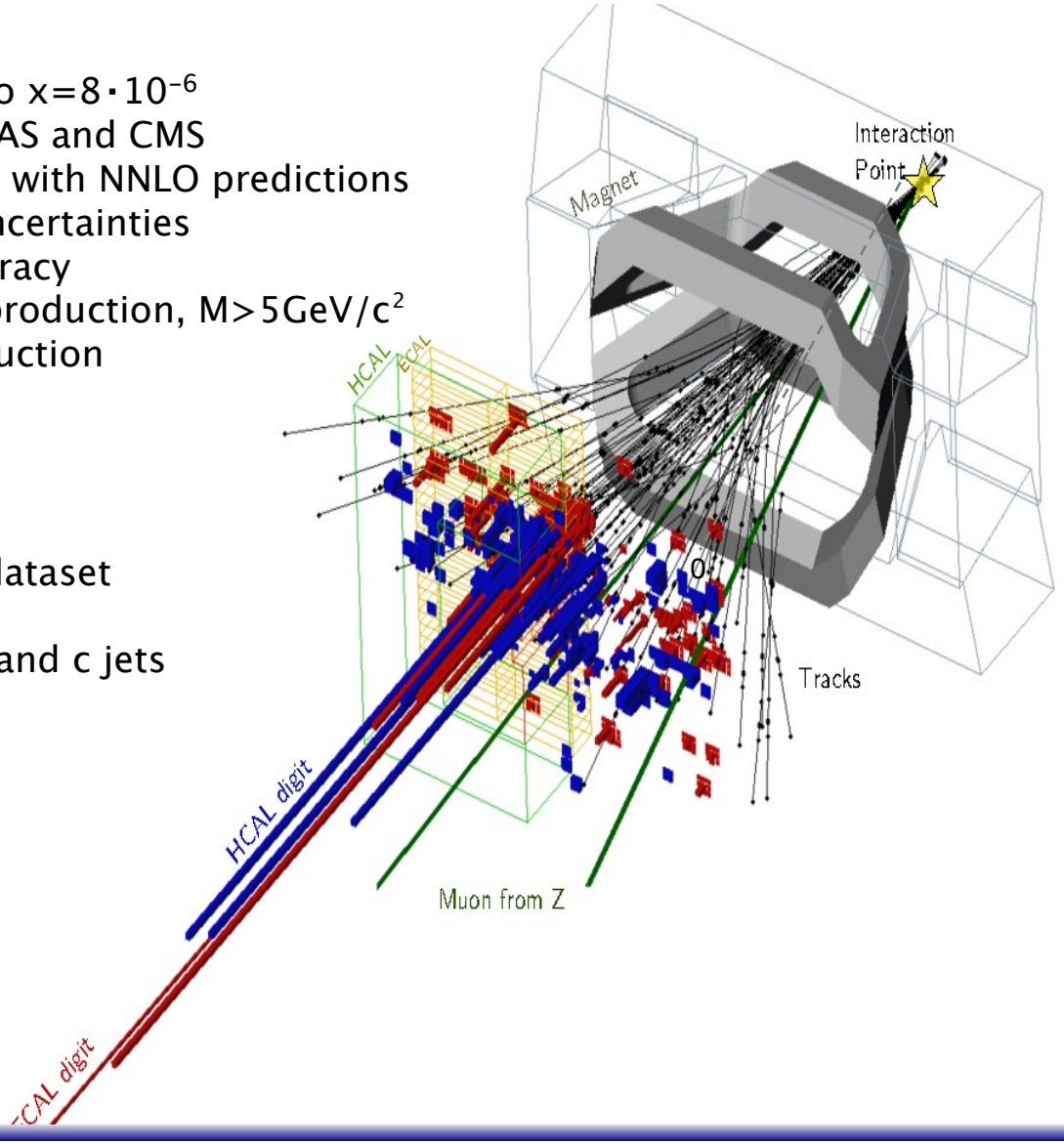
Summary & Outlook

Summary

- LHCb: unique kinematic range down to $x=8\cdot10^{-6}$
- Measurements complementary to ATLAS and CMS
- W/Z production at LHCb in agreement with NNLO predictions
- Precision comparable to theoretical uncertainties
- Ratio W+/W- cross section: 1.7% accuracy
- Measurement of low mass Drell-Yan production, $M>5\text{GeV}/c^2$
- First measurements of Z plus jet production

Outlook

- Precision will improve with full 2011 dataset
- 2012: 8 TeV running, new kinematics
- W, Z production in association with b and c jets



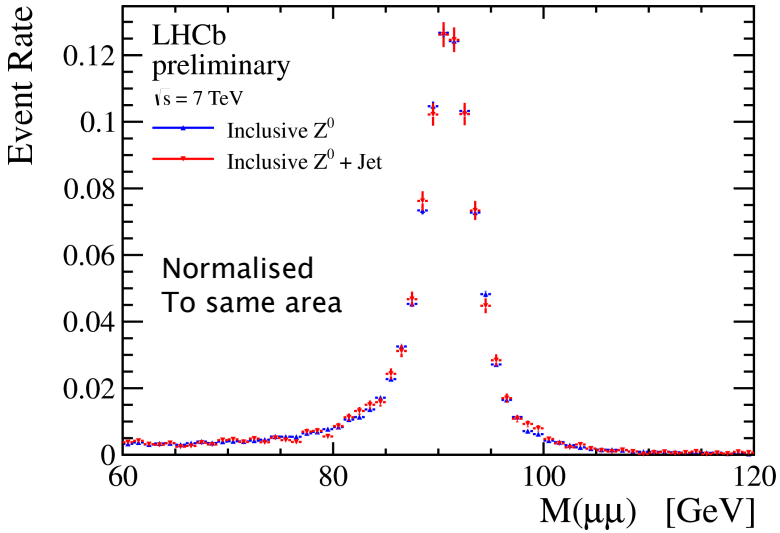
Backup

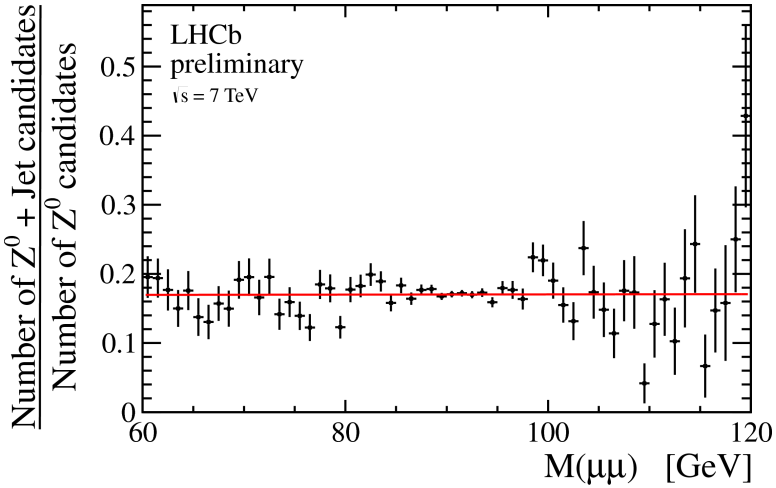
Backgrounds

- Similar to Z→μμ analysis

Efficiencies

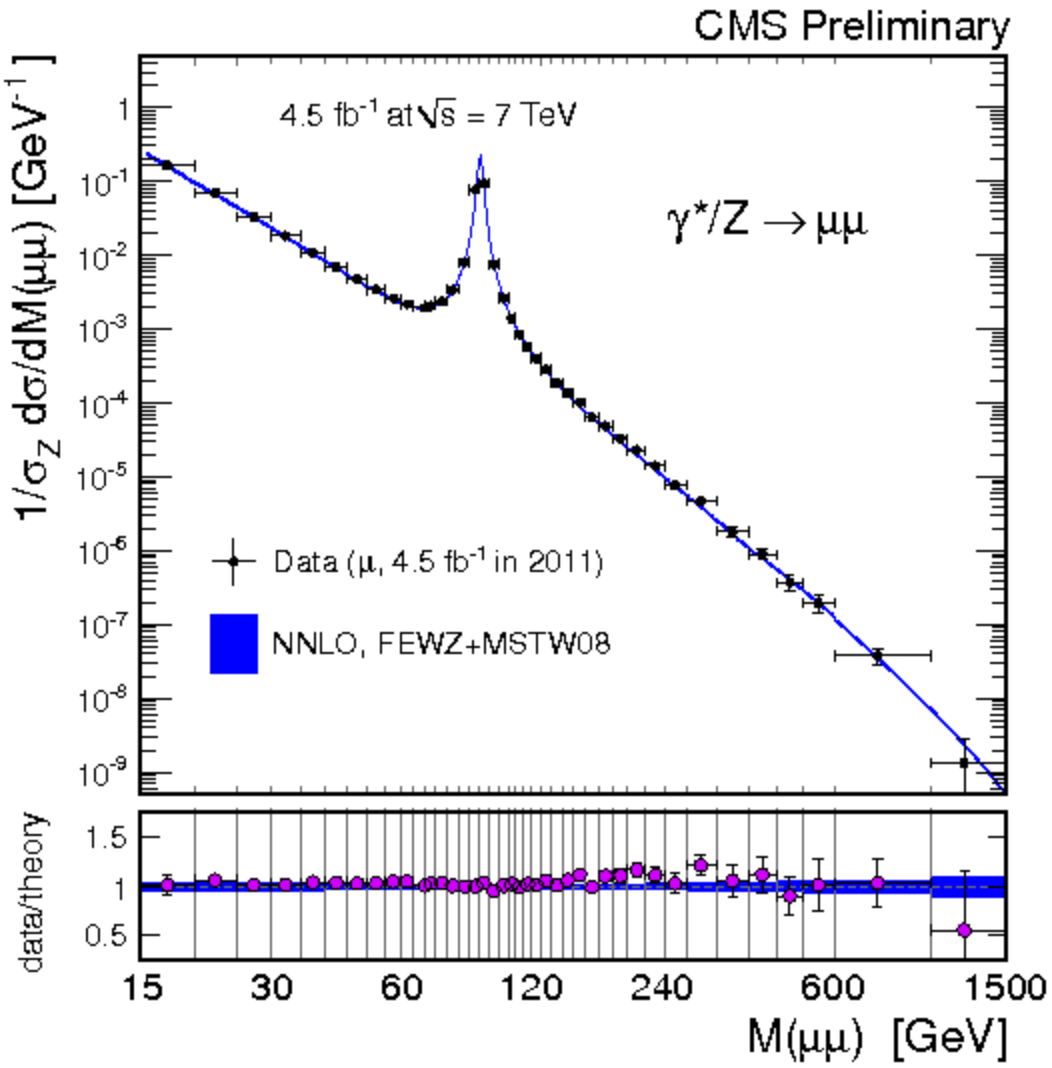
- Studied as a function of track multiplicity
- Jet finding efficiency: from simulation, reweighted to measured jet multiplicity





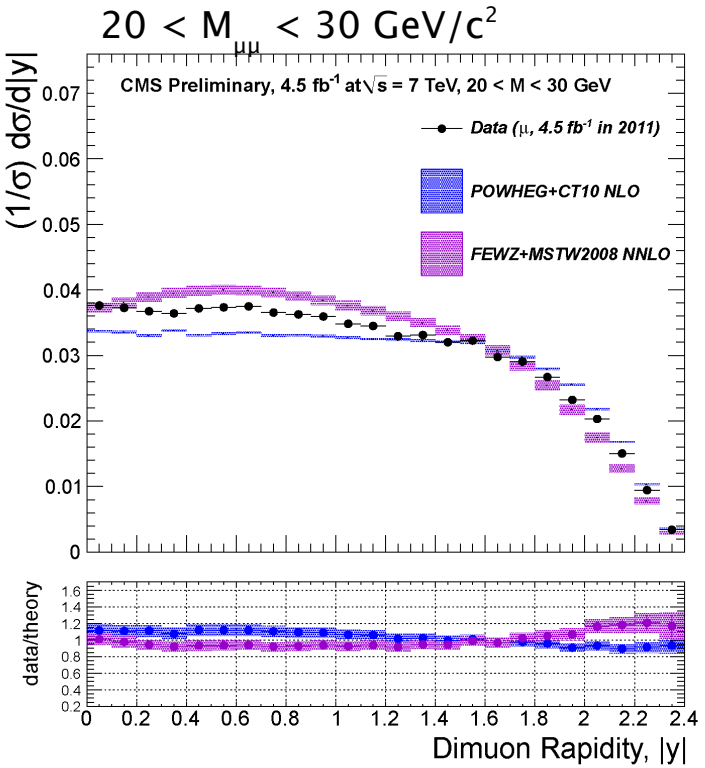
No evidence for enhanced background contribution

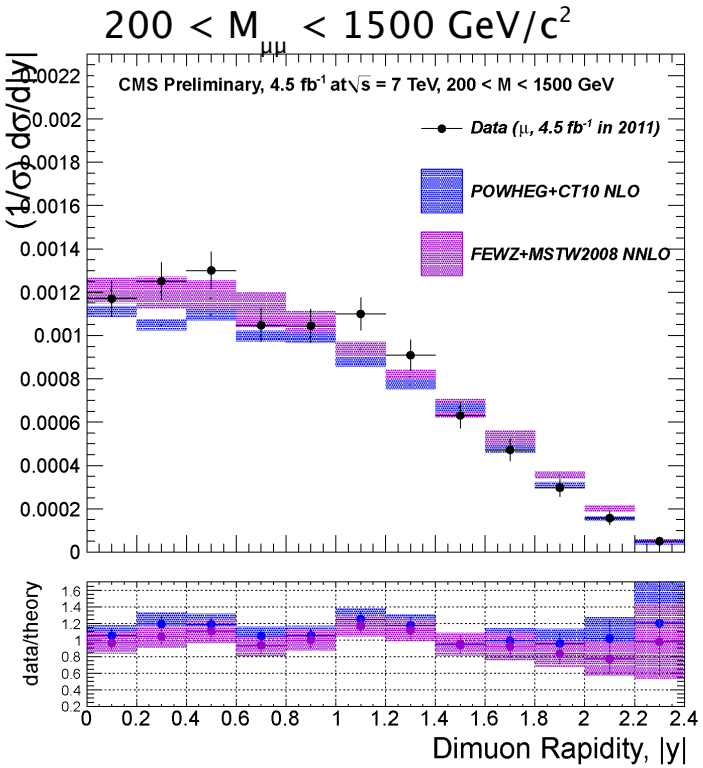
CMS: muon and electron 15-1500 GeV/c^2
Muon p_T>14.9 GeV/c^2,$|\eta_\mu|$<2.4
Electron p_T>20,10 GeV/c^2,$|\eta_e|$<2.5
Backgrounds:
QCD, τ, top and diboson pairs
CMS-PAS-EWK-11-007



Good agreement between the two channels and with NNLO and MC predictions

Differential cross section: 6 mass bins

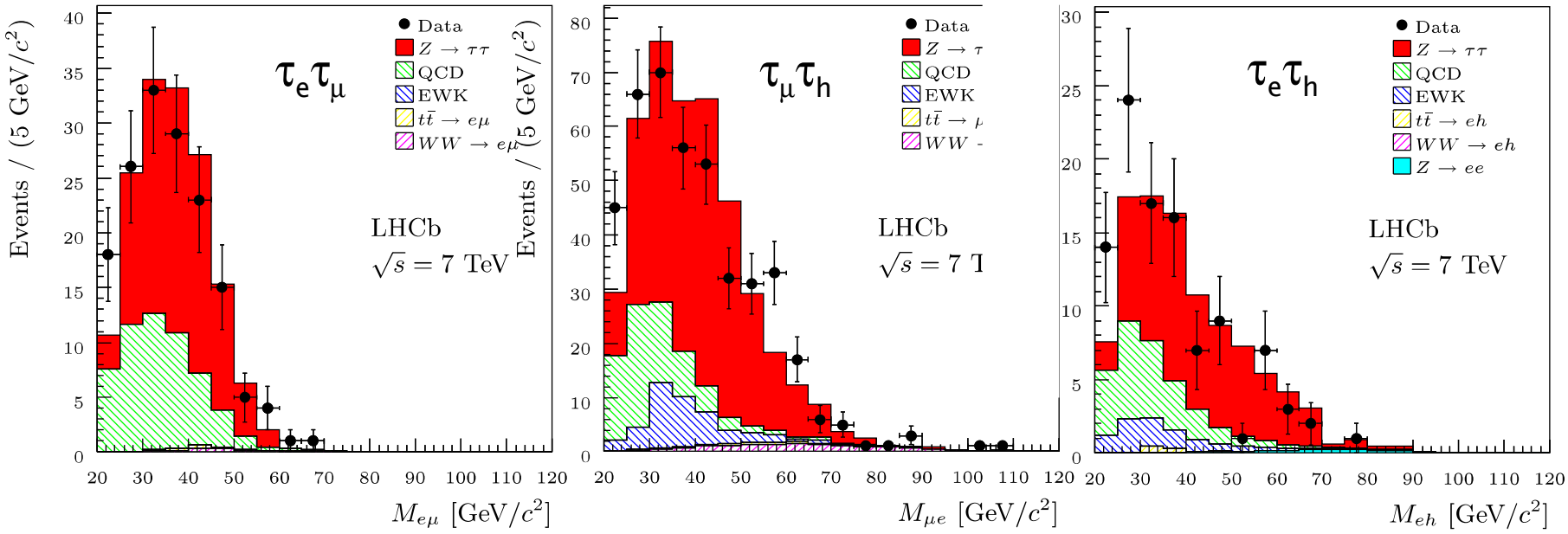




- low masses NNLO important in the central region
- high masses: statistical limited, good agreement with FEWZ

Z → ττ selection

arXiV:1210.6289

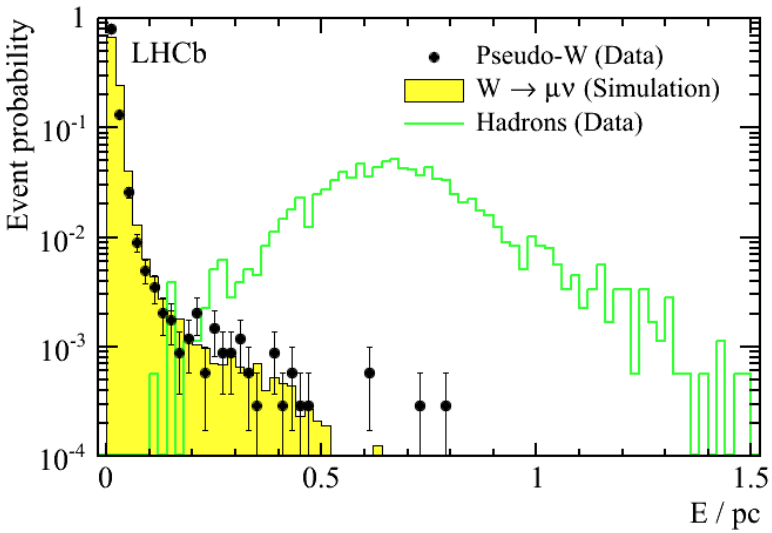


	μμ	μe	eμ	μh	eh
Candidates	124	421	155	189	101
Purity [%]	66	69	63	72	65

W → μν selection

JHEP 2012, 6 (2012), 58

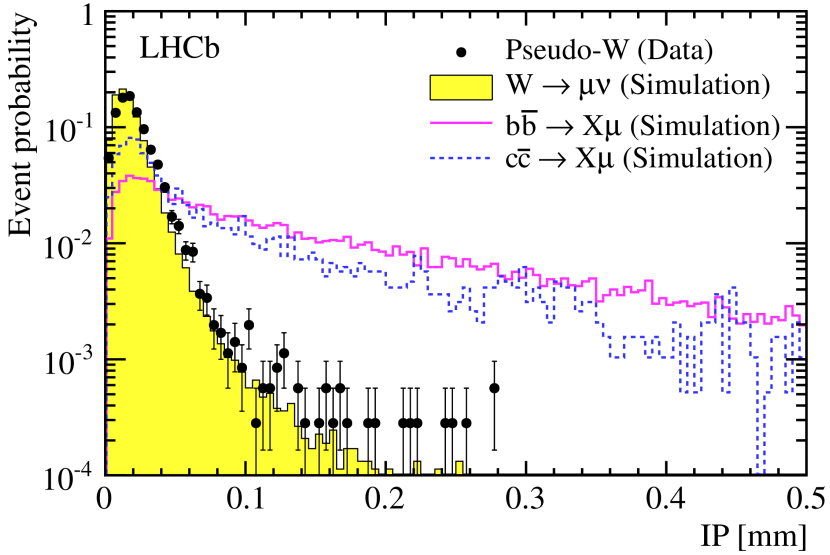
Energy in calorimeters



Signal: pseudo-W data

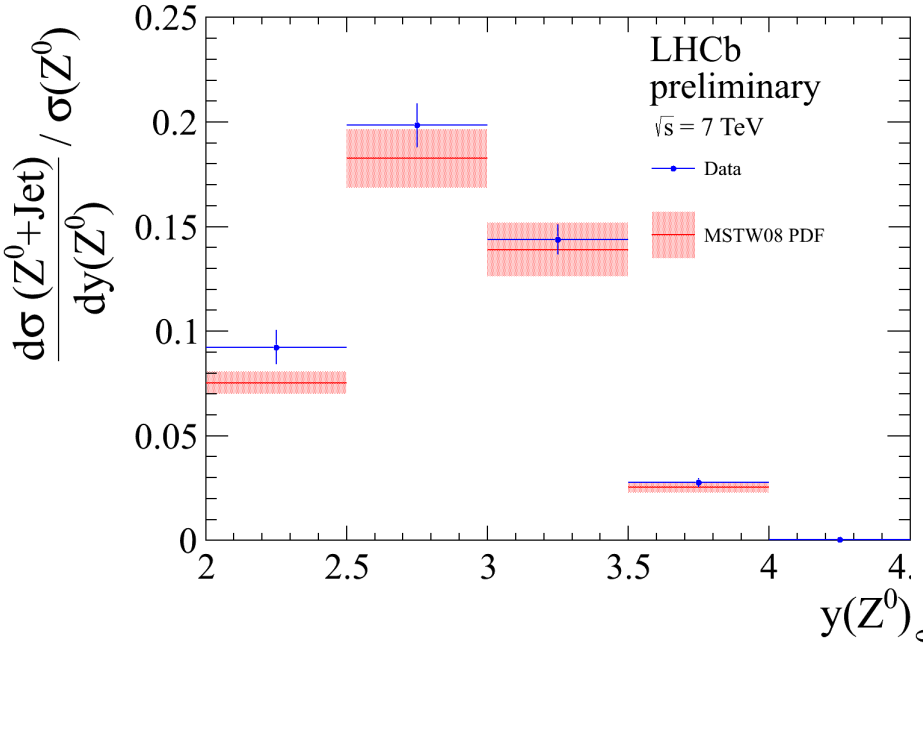
Background:
hadrons from randomly triggered events

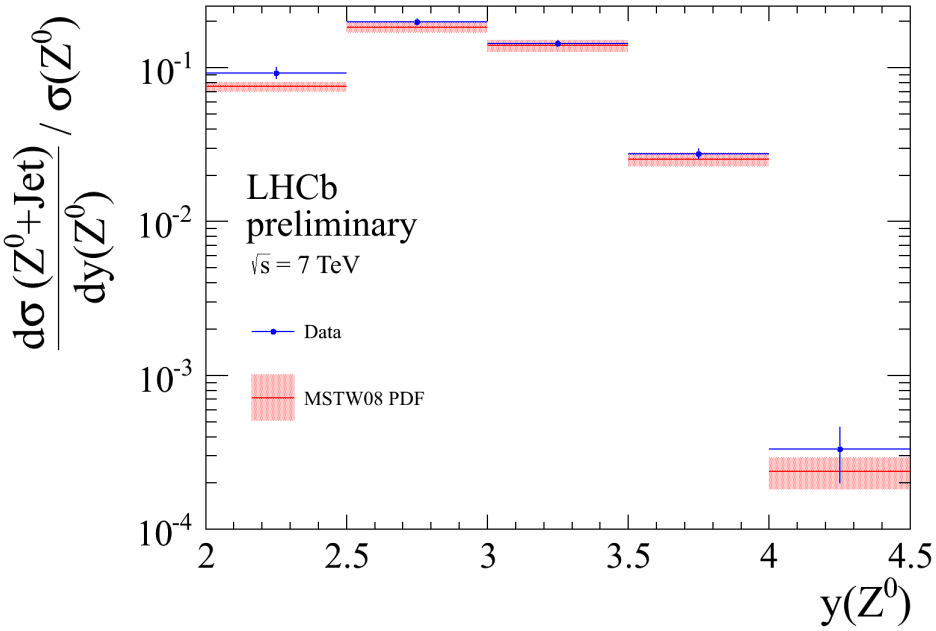
Muon impact parameter distribution



Signal: pseudo-W data

Background: semileptonic decays of hadrons containing b or c quarks from simulation

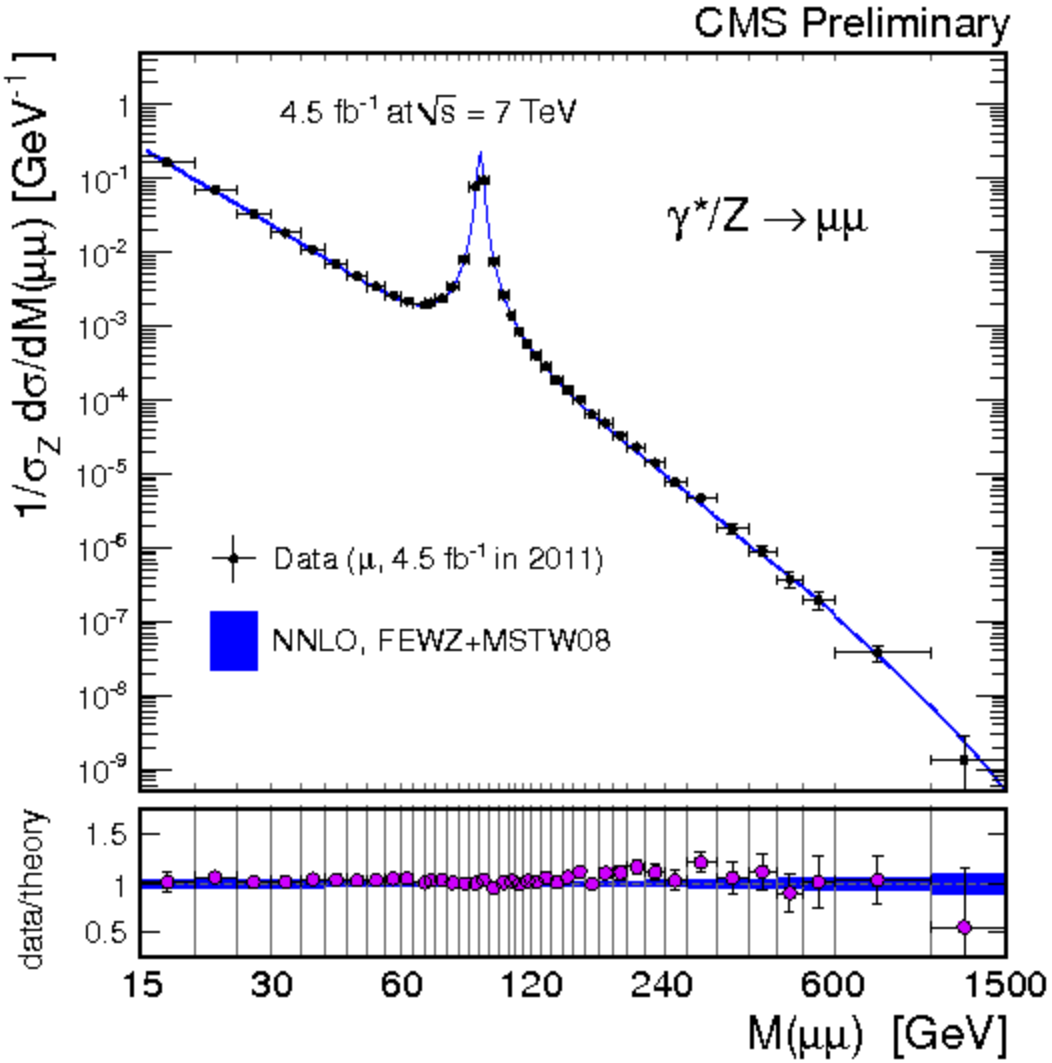




Result on hadron level
Migrations small <4%

CMS Results

CMS: muon and electron 15-1500 GeV/c^2
Muon p_T>14.9 GeV/c^2,$|\eta_\mu|$<2.4
Electron p_T>20,10 GeV/c^2,$|\eta_e|$<2.5
Backgrounds:
QCD, τ, top and diboson pairs
CMS-PAS-EWK-11-007



Good agreement between the two channels and with NNLO and MC predictions

W charge asymmetry

W rapidity cannot be measured
W lepton charge asymmetry for different p_T thresholds

$$A_\mu = \frac{\sigma(W^+ \to \mu^+ \nu_\mu) - \sigma(W^- \to \mu^- \bar{\nu}_\mu)}{\sigma(W^+ \to \mu^+ \nu_\mu) + \sigma(W^- \to \mu^- \bar{\nu}_\mu)}$$