Physics with electroweak gauge bosons at LHCb

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on behalf of the LHCb Collaboration

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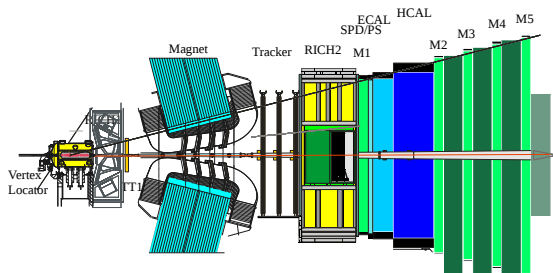
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Phenomonology 2012, Pittsburgh

Outline

LHCb

- 2010 dataset
  - 37.7 pb^{-1} $\sqrt{s} = 7$ TeV
- 2011 dataset
  - 1.0 fb^{-1} $\sqrt{s} = 7$ TeV
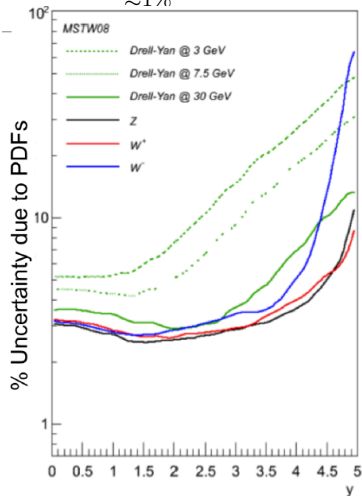- 2012 dataset
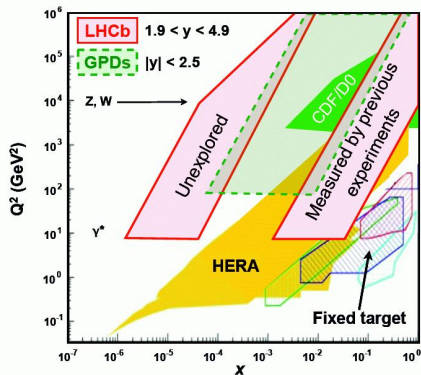 - 1.5 fb^{-1} $\sqrt{s} = 8$ TeV

- designed for B decays
- forward arm spectrometer
  - $1.9 \leq \eta \leq 2.5$ (common to GPD's)
  - $2.5 < \eta \leq 4.9$ (unique to LHCb)

- tracker, ECAL, HCAL, muon chambers (common to GPD's)
- Cherenkov detectors (unique to LHCb)
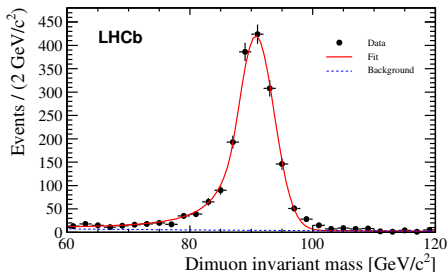- $p_T > 10$ GeV muon trigger

PDF Uncertainty

$$\sigma(x, Q^2) = \sum_{i,j} \int \underbrace{f_i(x_i, Q^2) f_j(x_j, Q^2)}_{\approx 1-8\%} \times \underbrace{\hat{\sigma}(x_i, x_j, Q^2)}_{\approx 1\%} \, \mathrm{d}x_i \, \mathrm{d}x_j$$

- new constraints on PDF's at low x and high Q

$Z \to \mu\mu$ Analysis (LHCb-PAPER-2012-008)

- trigger on single muon
  - $p_T^\mu > 10$ GeV
- reconstruct two muons
  - track quality
  - $p_T^\mu > 20$ GeV
  - $2.0 < \eta_\mu < 4.5$
  - $60 \le M_{\mu\mu} \le 120$

- $\mathscr{L} = 37$ pb^{-1} (2010)
- backgrounds
  - heavy flavor background (data)
    - 3.5 ± 0.8 events
  - misidentified pions or kaons (data)
  - $Z \to \tau\tau$ background (MC)
    - 0.6 ± 0.1 events
  - WW (MC)
    - 0.2 ± 0.1 events
  - $t\bar{t}$ (MC)
    - 0.5 ± 0.2 events
- $N_{\text{bkg}} = 4.9 \pm 2.0$
- $N_{\text{tot}} = 1966$

$Z \to \mu\mu$ Cross Section Determination

$$\sigma(p_T^\mu > 20, 2.0 < \eta^\mu < 4.5, 60 < M_{\mu\mu} < 120) = \frac{(N_{\text{tot}} - N_{\text{bkg}})f_{\text{FSR}}}{\mathscr{L}\mathcal{A}\varepsilon}$$
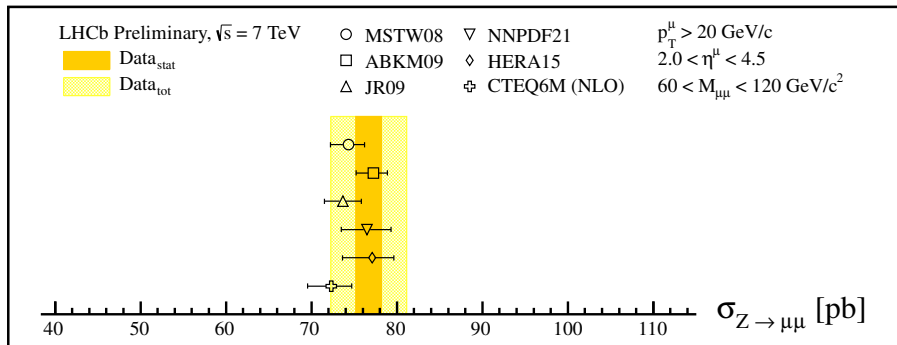
$$\varepsilon = \varepsilon_{\text{trg}}^\mu \varepsilon_{\text{trk}}^{\mu\ 2} \varepsilon_{\text{id}}^{\mu\ 2}$$

Systematic	$\Delta\sigma_{Z\to\mu\mu}$ [%]
Purity	± 0.1
ε	± 4.3
f_{FSR}	± 0.02
Total	± 4.3
Luminosity	± 3.5

- $\mathcal{A}$ defined as one
- tag-and-probe method
  - muon trigger ($\varepsilon_{\text{trg}}^\mu$)
  - muon tracking ($\varepsilon_{\text{trk}}^\mu$)
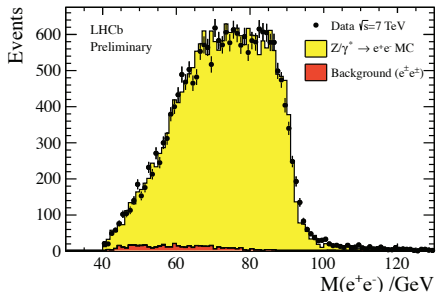 - muon id ($\varepsilon_{\text{id}}^\mu$)

$Z \to \mu\mu$ Cross Section Result

$$\sigma(p_T^\mu > 20, 2.0 < \eta^\mu < 4.5, 60 < M_{\mu\mu} < 120) = 76.7 \pm 1.7 \pm 3.3 \pm 2.7$$

$Z \to ee$ Analysis (LHCb-CONF-2012-011)

- trigger on single electron
  - $p_T^e > 15$ GeV
- reconstruct two electrons
  - track quality, calorimeter
  - $p_T^e > 20$ GeV
  - $2.0 < \eta_e < 4.5$
  - $40 \leq M_{ee}$

- $\mathcal{L} = 945$ pb^{-1} (2011)
- backgrounds
  - generic QCD background (data)
    - 473 ± 22 events
  - $Z \to \tau\tau$ background (MC)
    - < 20 events
  - $t\bar{t}$ (MC)
    - < 20 events
- $N_{\text{bkg}} = 473 \pm 22$
- $N_{\text{tot}} = 21535$
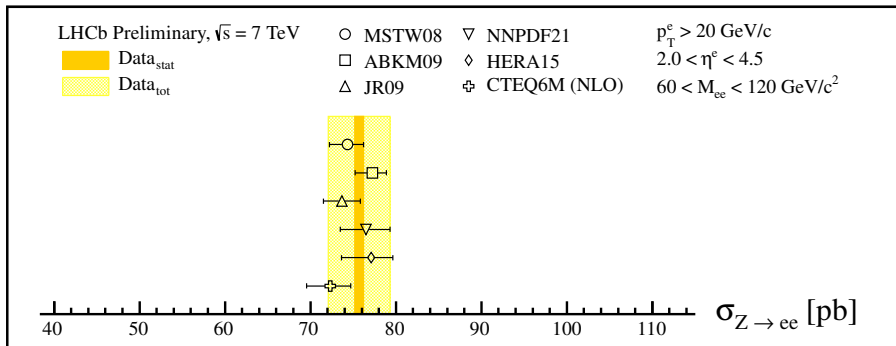
$Z \to ee$ Cross Section Determination

$$\varepsilon = \varepsilon_{\text{kin}} \varepsilon_{\text{trg}}^{e} \varepsilon_{\text{trk}}^{e}{}^{2} \varepsilon_{\text{id}}^{e}{}^{2}$$

- tag-and-probe
  - electron trigger ($\varepsilon_{\text{trg}}^{e}$)
  - electron identification ($\varepsilon_{\text{id}}^{e}$)
- Monte Carlo
  - kinematic (ε_{kin})
  - electron tracking ($\varepsilon_{\text{trk}}^{e}$)

Systematic	$\Delta\sigma_{Z \to ee}$ [%]
ε_{kin}	± 1.8
$\varepsilon_{\text{trg}}^{e}$	$0.4 - 14.0$
$\varepsilon_{\text{trk}}^{e}{}^{2}$	$1.6 - 1.7$
$\varepsilon_{\text{id}}^{e}{}^{2}$	$0.5 - 2.8$
f_{FSR}	± 0.1
Total	± 3.2
Luminosity	± 3.5

$Z \to ee$ Cross Section Result

$$\sigma(p_T^e > 20, 2.0 < \eta^e < 4.5, 60 < M_{ee} < 120) = 75.7 \pm 0.5 \pm 2.4 \pm 2.6$$

$Z \to \tau\tau$ Analysis (LHCb-CONF-2011-041)
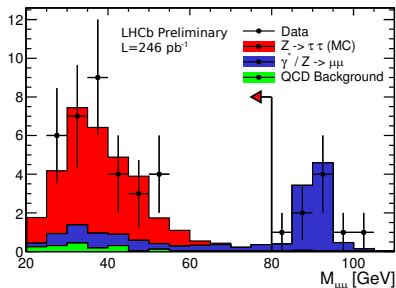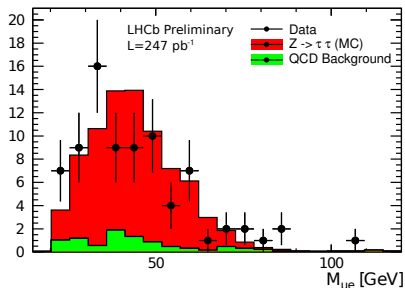
- two final states, $\tau_\mu\tau_\mu$ and $\tau_\mu\tau_e$
- trigger on single muon
  - $p_T^\mu > 10$ GeV
- reconstruct two particles
  - muon, electron identification
  - $p_T^\mu > 20$ GeV, $p_T^{\mu/e} > 5$ GeV
  - $2.0 < \eta_{\mu/e} < 4.5$
  - $M_{\mu\mu/e} \geq 20$ GeV
- event selection
  - isolated
  - back-to-back in transverse plane
  - impact parameter ($\tau_\mu\tau_\mu$ only)
  - p_T asymmetry ($\tau_\mu\tau_\mu$ only)

$Z \to \tau\tau$ Cross Section Determination

- $\mathscr{L} = 247$ pb^{-1} (2010/2011)
- backgrounds
  - QCD (data)
  - $Z \to \mu\mu$ (data)
- $N_{\mathrm{bkg}}^{\tau_\mu \tau_e} = 12.4 \pm 2.7$
- $N_{\mathrm{tot}}^{\tau_\mu \tau_e} = 81$
- $N_{\mathrm{bkg}}^{\tau_\mu \tau_\mu} = 7.1 \pm 2.0$
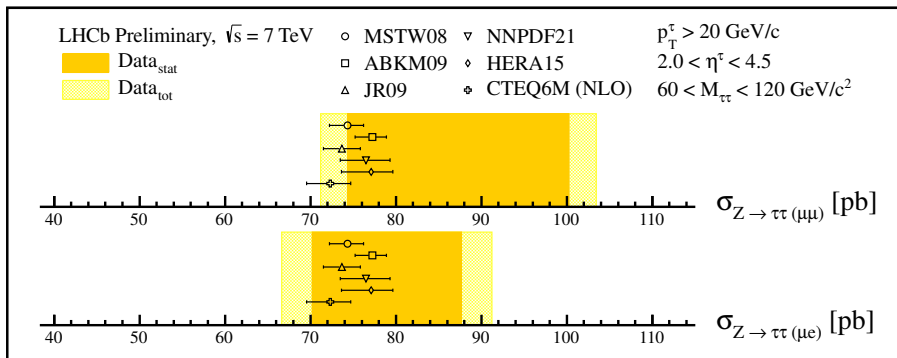- $N_{\mathrm{tot}}^{\tau_\mu \tau_\mu} = 33$

$$\varepsilon = \varepsilon_{\mathrm{sel}} \varepsilon_{\mathrm{trg}}^{\mu} \varepsilon_{\mathrm{trk}}^{\mu} \varepsilon_{\mathrm{trk}}^{\mu/e} \varepsilon_{\mathrm{id}}^{\mu} \varepsilon_{\mathrm{id}}^{\mu/e}$$

Systematic	$\Delta\sigma_{Z \to \tau_\mu \tau_e}$ [%]	$\Delta\sigma_{Z \to \tau_\mu \tau_\mu}$ [%]
$\varepsilon_{\mathrm{sel}}$	± 6.5	± 8.1
$\varepsilon_{\mathrm{trg}}^{\mu}$	± 1.3	± 1.3
$\varepsilon_{\mathrm{trk}}^{\mu}$	± 2.4	± 2.4
$\varepsilon_{\mathrm{id}}^{\mu}$	± 0.2	± 0.2
$\varepsilon_{\mathrm{trk}}^{e}$	± 3.8	
$\varepsilon_{\mathrm{id}}^{e}$	± 1.0	
Total	± 10.1	± 11.2
Luminosity	± 6.0	± 6.0

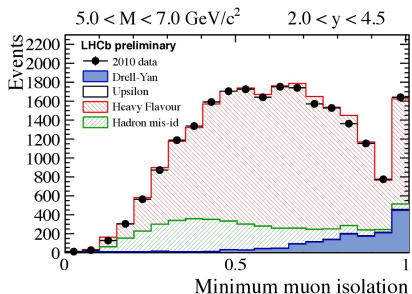# $Z \to \tau\tau$ Cross Section Result

$$\sigma_{\tau_\mu \tau_e}(p_T^\tau > 20, 2.0 < \eta^\tau < 4.5, 60 < M_{\tau\tau} < 120) = 79 \pm 9 \pm 8 \pm 4$$

$$\sigma_{\tau_\mu \tau_\mu}(p_T^\tau > 20, 2.0 < \eta^\tau < 4.5, 60 < M_{\tau\tau} < 120) = 89 \pm 15 \pm 10 \pm 5$$

$$\Gamma_{Z\to\tau\tau}/\Gamma_{Z\to\mu\mu} = 1.09 \pm 0.17$$

$\gamma^*/Z \to \mu\mu$ Analysis (LHCb-CONF-2012-013)

$5.0 < M < 7.0$ GeV/c^2 $\quad$ $2.0 < y < 4.5$

- dimuon trigger
  - $p_T^\mu > 2.5$ GeV
- reconstruct two muons
  - track quality
  - $p_T^\mu > 3$, $p^\mu > 10$ GeV
  - for $M_{\mu\mu} > 40$, $p_T^\mu > 15$
  - $2.0 < \eta_\mu < 4.5$
  - $5 \leq M_{\mu\mu} \leq 120$

- $\mathscr{L} = 37$ pb^{-1} (2010)
- event selection
  - muon isolation
- backgrounds
  - heavy flavour (data)
    - require large impact parameter
  - hadron mis-id (data)
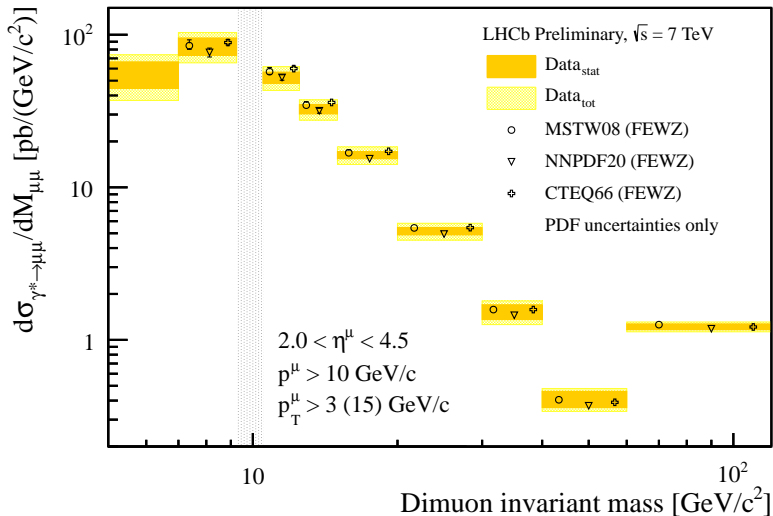   - taken from minimum bias sample
  - upsilon (MC)

$\gamma^*/Z \to \mu\mu$ Cross Section Determination

$$\varepsilon = \varepsilon_{\text{trg}}^{\mu}\varepsilon_{\text{trk}}^{\mu\ 2}\varepsilon_{\text{id}}^{\mu\ 2}$$

- $\mathcal{A}$ defined as one
- tag-and-probe method
  - muon trigger ($\varepsilon_{\text{trg}}^{\mu}$)
  - muon tracking ($\varepsilon_{\text{trk}}^{\mu}$)
 - muon id ($\varepsilon_{\text{id}}^{\mu}$)

Systematic	$\Delta\sigma_{\gamma^*/Z \to \mu\mu}$ [%]
$\varepsilon_{\text{trg}}^{\mu\ 2}$	$1.7 - 4.3$
$\varepsilon_{\text{trk}}^{\mu\ 2}$	$4 - 10$
$\varepsilon_{\text{id}}^{\mu\ 2}$	± 1.4
HF template	$1 - 24$
mis-id template	$1 - 4$
signal template	$1 - 8$
Luminosity	± 3.5

$\gamma^*/Z \to \mu\mu$ Cross Section Result

$W \to \mu\nu_\mu$ (LHCb-PAPER-2012-008)

- trigger on single muon
  - $p_T^\mu > 10$ GeV
- reconstruct one muon
  - track quality
  - $p_T^\mu > 20$ GeV
  - $2.0 < \eta_\mu < 4.5$
- event selection
  - no other muons with $p_T > 5$ GeV
  - impact parameter
  - track isolation
  - calorimeter isolation
- $N_{\text{tot}}^{W^+} = 14660$
- $N_{\text{tot}}^{W^-} = 11618$
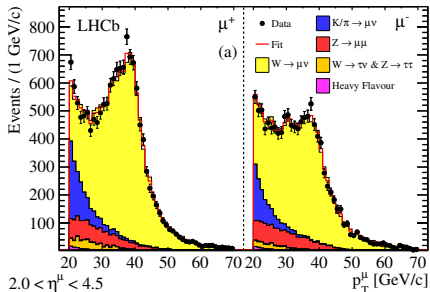
- $\mathscr{L} = 37$ pb^{-1} (2010)
- backgrounds
  - π/K decay (data)
  - $Z \to \mu\mu$ (MC)
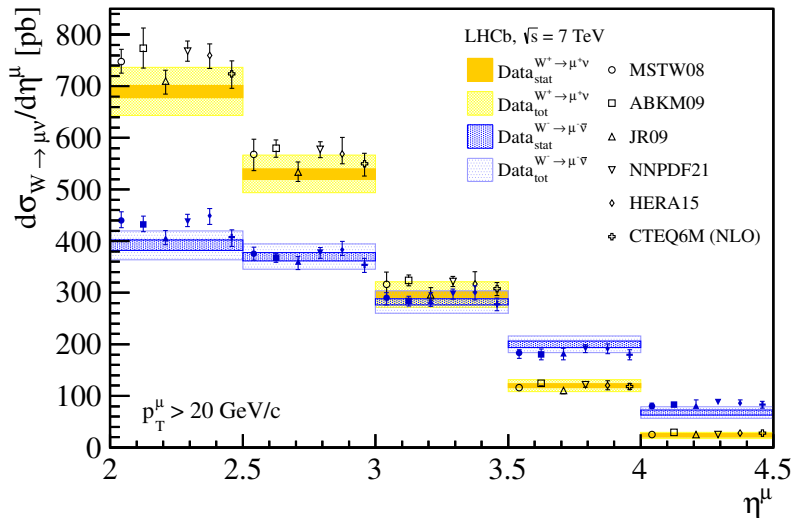 - $W \to \tau\nu_\tau$, $Z \to \tau\tau$ (MC)
  - heavy flavor (data)

$W \to \mu\nu_\mu$ Cross Section Determination

$$\varepsilon = \varepsilon_{\mathrm{sel}} \underbrace{\varepsilon^\mu_{\mathrm{trg}} \varepsilon^\mu_{\mathrm{trk}} \varepsilon^\mu_{\mathrm{id}}}_{\varepsilon_{\mathrm{rec}}}$$

- reconstruction efficiency ($\varepsilon_{\mathrm{rec}}$) same as $Z \to \mu\mu$

- event selection ($\varepsilon_{\mathrm{sel}}$)
  - from $Z \to \mu\mu$ data
  - single muon masked

Systematic	$\Delta\sigma_{W^+ \to \mu^+\nu}$ [%]	$\Delta\sigma_{W^+ \to \mu^+\nu}$ [%]
Purity	± 1.2	± 0.9
Shape	± 0.9	± 1.0
$\varepsilon_{\mathrm{rec}}$	± 2.2	± 2.0
$\varepsilon_{\mathrm{sel}}$	± 1.8	± 1.7
f_{FSR}	± 0.01	± 0.02
Total	± 3.2	± 2.9
Luminosity	± 3.5	± 3.5

$W \to \mu\nu_\mu$ Cross Section Result

Conclusion

- full set of W/Z measurements performed in forward region
- measurements in good agreement with NNLO theory
- upcoming updates with full 2011 data set for all analyses
- additional hadronic channels added to $z \to \tau\tau$ analysis
- W and Z plus jets analysis in progress
- looking forward to 2012 data!