W and Z Studies at CMS

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On Behalf of CMS

- Inclusive W and Z boson cross section at $\sqrt{s} = 8$ TeV (NEW)

- Measurement of the charge asymmetry in inclusive W at $\sqrt{s} = 7$ TeV:
  - using electron decay
  - using muon decay

- Drell-Yan at $\sqrt{s} = 7$ TeV
  - Differential and double-differential cross section
  - Forward-backward asymmetry
  - Measurement of the weak mixing angle
W/Z studies

The main LHC goal: explore physics at the TeV energy scale via pp collision

Benefits of W and Z studies:

- Test for the Standard Model (sensitive to new physics)
- Precision measurements at TeV scale
- Unique test and contribution to the proton PDF
- Better understanding of background for Higgs and new physics search analyses
The Compact Muon Solenoid (CMS)

- The strongest magnet
- Tracking system:
  - silicon pixel
  - strip tracker
- ECAL:
  - \(~76000\) lead tungstate crystal
- Muon system:
  - DT
  - CSC
  - RPC

L1 level up to 100 kHz ➔ High Level Trigger to record \(~300\) Hz

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Precise measurement is any important test for Standard Model and contribution PDFs:

- We repeat analysis in similar way like it was done for 2010 data with low pile-up with \( \mathcal{L} = 36 \text{ pb}^{-1} \) (J. High Energy Phys. 10 (2011) 132)

- CMS requested special LHC conditions during luminosity ramp up period to achieve low pile-up events (~5) for good MET resolution at W:
  - LHC separate beams in transverse plane to reduce effective overlap
  - separation was periodically adjust to keep instantaneous \( \mathcal{L}_{\text{inst}} \sim 3\text{E32} - 6\text{E32 cm}^{-2}\text{s}^{-1} \)
  - Integrated \( \mathcal{L} = 18.8 \text{ pb}^{-1} \)
  - Special HLT menu with low thresholds:
    - 22 GeV for e and 15 GeV for \( \mu \)
  - minimal ID/Iso requirement to suppress background
W and Z boson cross section at $\sqrt{s} = 8$ TeV

Event Selection:

e-channel:
$E_T > 25$ GeV and $|\eta| < 2.5$, exclude $1.4442 < |\eta| < 1.566$ (barrel/forward transition)
$W \rightarrow e\nu$: Reject events with 2$^{nd}$ e with $E_T > 20$ GeV

$\mu$-channel:
$p_T > 25$ GeV and $|\eta| < 2.1$
$W \rightarrow \mu\nu$: Reject events with 2$^{nd}$ $\mu$ with $p_T > 10$ GeV

$Z \rightarrow ll$: $60$ GeV $< M_{ll} < 120$ GeV

The dominant source of systematic uncertainty:
- Experimental:
  - Luminosity (4.4%) for absolute cross sections
  - Lepton efficiency (1-3%)
  - Theoretical uncertainty in acceptance (2-3%)
- Theoretical:
  - PDFs
  - Higher order QCD corrections
  - Higher order electroweak corrections
W and Z boson cross section at $\sqrt{s} = 8$ TeV

Z Signal Extraction: cut and count

CMS Preliminary

Events / 10 GeV/c^2

M(e^+e^-) [GeV/c^2]

CMS Preliminary

Events / 10 GeV/c^2

M(\mu^+\mu^-) [GeV/c^2]
W extraction: fit MET distribution
- W: MC with recoil corrected to data
- QCD model: analytic function
- Other background: from MC with xsec fixed to W from theory
W and Z boson cross section at $\sqrt{s} = 8$ TeV

W, Z cross-section

- Good agreement with theoretical NNLO prediction
W and Z boson cross section at $\sqrt{s} = 8$ TeV

- Good agreement with theoretical NNLO prediction

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Charge asymmetry in inclusive $W \rightarrow \mu \nu$ (7 TeV)

Proton: 2u and 1d $\rightarrow W^+$ (u$d$) is easier to produce than $W^-$ (d$u$)

Asymmetry $A(\eta)$ is observed:

$$A(\eta) = \frac{d\sigma / d\eta(W^+)}{d\sigma / d\eta(W^+)} - \frac{d\sigma / d\eta(W^-)}{d\sigma / d\eta(W^-)}$$

Precise measurement will provide significant contribution to PDFs

Muon charge asymmetry for $p_T > 25$ GeV

- Data has flatter variation of the asymmetry in $\eta$ then predicted by MSTW2008NLO, CT10W and NNPDF2.1 (NLO)
- Will provide significant contribution to PDFs
Charge asymmetry in inclusive $W \rightarrow e\nu$ (7 TeV)

- Good agreement with NLO prediction except MSTW
- Background contribution increase with $\eta$
- Will provide significant contribution to PDFs

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Drell-Yan: $d\sigma/dM$ (7 TeV)

- $d\sigma/dM$ is calculated in the full phase space
- normalized to the cross section in the Z peak region ($60 < M < 120$ GeV) to reduce systematic uncertainties
- good agreement with NNLO theoretical prediction, computed with FEWZ using MSTW2008 PDFs
- NNLO correction is required to describe low dilepton invariant masses
Drell-Yan: dσ/dMdY (7 TeV)

CMS Preliminary, 4.5 fb⁻¹ at \( \sqrt{s} = 7 \) TeV, 20 < M < 30 GeV

\[ \text{Data (i), 4.5 fb}^{-1} \text{ in 2011} \]

POWHEG+CT10 NLO

FEWZ+MSTW2008 NNLO

✓ dσ/dMdY is measured for muons only within detector acceptance and normalized to the Z peak region with |Y| < 2.4 to reduce systematic

✓ 6 bins at M from 20 to 1500 GeV

✓ very important measurement for test and contribution to PDFs

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Drell-Yan: forward-backward asymmetry (7 TeV)

Interference $\gamma^*$ and $Z$ boson

$\Rightarrow$ forward-backward asymmetry $A_{FB}$

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

✓ unfolded, combined (ee and $\mu\mu$)
and Born level $A_{FB}$ is measured
with acceptance cuts:
$p_T > 20$ GeV, $|\eta| < 2.4$, $M(ll) > 40$ GeV

✓ test of Standard Model:
$A_{FB}$ is in agreement with Standard
Model prediction within uncertainties
Drell-Yan: weak mixing angle (7 TeV)

✓ $\sin^2 \theta_w$ is measured at $\sqrt{s} = 7$ TeV with 1% precision like at all hadronic experiments: CDF and D0 (Tevatron), H1 (HERA)

✓ dominant processes: $u\bar{u}$ and $d\bar{d} \rightarrow \gamma^*/Z \rightarrow \mu\mu$

✓ use unbinned extended maximum-likelihood, simultaneous fit data of di-muon rapidity, di-muon invariant mass and di-muon decay angle

$$\sin^2 \theta_w = 0.2287 \pm 0.0020\text{(stat.)} \pm 0.0025\text{(syst.)}$$

as expected in Standard Model
Conclusion

- First results at $\sqrt{s} = 8$ TeV are presented: W and Z inclusive cross section
- W, Z and Drell-Yan are studied very detailed at $\sqrt{s} = 7$ TeV:
  - Precise test of Standard Model
  - Sensitive to New Physics
  - Significant contribution to PDFs
- Looking forward for more 8 TeV results … and 14 TeV

The most recent public results always could be found at 
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP
BACK UP
LHC Luminosity

2010

2011

2012

✓ Good start up from 2010 to 2012
✓ In 2012 before ICHEP2012 CMS recored more data then in 2010&2011
⇒ Much more data coming soon
⇒ Very exiting time

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W and Z boson cross section at $\sqrt{s} = 8$ TeV

$W/Z$ ratio

CMS Preliminary

18.7 pb$^{-1}$ at $\sqrt{s} = 8$ TeV

NNLO, FEWZ+MSTW2008 prediction [with MSTW2008 68% CL uncertainty]

$W \rightarrow e\nu$, $Z \rightarrow ee$
$10.99 \pm 0.16_{\text{stat}} \pm 0.39_{\text{syst}}$

$W \rightarrow \mu\nu$, $Z \rightarrow \mu\mu$
$10.44 \pm 0.14_{\text{stat}} \pm 0.29_{\text{syst}}$

$W \rightarrow l\nu$, $Z \rightarrow ll$ (combined)
$10.65 \pm 0.11_{\text{stat}} \pm 0.23_{\text{syst}}$

$R_{W/Z} = [\sigma \times BR_{W}] / [\sigma \times BR_{Z}]$

$W^+ \rightarrow e^+\nu$, $W^- \rightarrow e^-\bar{\nu}$
$1.44 \pm 0.01_{\text{stat}} \pm 0.05_{\text{syst}}$

$W^+ \rightarrow \mu^+\nu$, $W^- \rightarrow \mu^-\bar{\nu}$
$1.38 \pm 0.01_{\text{stat}} \pm 0.03_{\text{syst}}$

$W^+ \rightarrow l^+\nu$, $W^- \rightarrow l^-\bar{\nu}$ (combined)
$1.39 \pm 0.01_{\text{stat}} \pm 0.02_{\text{syst}}$

$R_{W+/W^-} = [\sigma \times BR_{W^+}] / [\sigma \times BR_{W^-}]$
Drell-Yan: $d\sigma/dM$

4.5 fb$^{-1}$ at $\sqrt{s} = 7$ TeV

CMS Preliminary

- data
- $\gamma^*Z \rightarrow \mu\mu$
- $\gamma^*Z \rightarrow t\bar{t}$
- EWK
- $t\bar{t}$
- QCD

entries per bin

$10^8$

$10^7$

$10^6$

$10^5$

$10^4$

$10^3$

$10^2$

$10$

$1$

$0.5$

$0.1$

$15$ $30$ $60$ $120$ $240$ $600$ $1500$

M($\mu\mu$) [GeV]

$15$ $30$ $45$ $60$ $120$ $200$ $320$ $600$ $1500$

M(ee) [GeV]
Drell-Yan: $d\sigma/dM \, dy$

- at low $M$ dominates QCD BG
- at high $M$ dominates ttbar BG

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