Z and W production in PbPb collisions at 2.76 TeV with CMS
Outline

- Introduction: motivation
- CMS and muon reconstruction
  - Z results (L_{int} = 150 \, \mu b^{-1})
    - PAS-HIN-12-008 (new)
  - W results (L_{int} = 7.3 \, \mu b^{-1})
- Conclusion
Motivation

- LHC allowed the first observation and measurement of $Z$ and $W$ bosons in PbPb collisions

- $Z$ and $W$ yields are predicted to be unaffected by the strongly interacting medium produced in PbPb collisions

- Precise measurement of $Z$ and $W$ production in heavy ion collisions may help to constrain nuclear PDFs

- Calibration of the detectors: validate efficiency and energy scale of lepton reconstruction

- For now, both $Z$ and $W$ are studied through their leptonic decay channels: $Z \rightarrow \mu^+\mu^-$, $W^\pm \rightarrow \mu^\pm\nu$
CMS detector

3.8 T Magnet

ECAL $|\eta| < 3$

HCAL $|\eta| < 3$

Beam Scintillator Counters (BSC)

Forward Hadron Calorimeters (HF) $\sim 3 < |\eta| < 5$

Muon Barrel

Silicon Tracker Strips and pixels

Drift Tubes (DT)

Resistive Plate Chambers (RPC)

Cathode Strip Chambers (CSC)

Muon Endcaps
Muon reconstruction requires information from the tracker and muon systems, tracks reconstructed in the tracker are matched to tracks reconstructed in the muon system.

- Used inner tracking modified for HI collisions
- Excellent high-\(p_T\) resolution: 1-2%
- Good muon trigger performance
$Z \rightarrow \mu^+ \mu^-$
Z boson

- Data sample Pb+Pb collisions at $\sqrt{s} = 2.76$ TeV:
  - 2010: $L_{\text{int}} = 7.2$ µb$^{-1}$
  - 2011: $L_{\text{int}} = 150$ µb$^{-1}$

- 7616 candidates
- 39 candidates no same charge pairs

New

- CMS-PAS-HIN-12-008
- PRL 106 (2011) 212301

39 candidates

616 candidates

no same charge pairs
\( \frac{dN}{dy} T_{AA} \) vs. \( N_{\text{part}} \)

- \( \frac{dN}{T_{AA}} = d\sigma_{pp} R_{AA} \)

- \( T_{AA} \): nuclear overlap function estimated with a Glauber model calculation

- \( Z \) production scales with \( T_{AA} \)

- Assuming from POWHEG
  \( d\sigma_{pp}/dy = 59.6 \text{ pb} \) in \( |y| < 2 \)

\( R_{AA} = 0.95 \pm 0.03 \pm 0.13 \)
Normalized Z yield vs. $p_T$ and rapidity

- 8 rapidity bins and 7 $p_T$ bins (more bins than 2010 data)
- Both $dN/dy$ and $d^2N/dydp_T$ are in good agreement with POWHEG

CMS-PAS-HIN-12-008
Experimental signature: a high $p_T$ muon recoiling against an (undetected) neutrino in transverse plane
Muon $p_T$ spectrum

- Good quality muons reconstructed offline in $|\eta| < 2.1$
- Veto on Z candidates

Bump in the region $p_T > 25$ GeV/c where $W$ decay products are expected

For the analysis we require $p_T > 25$ GeV/c
Missing $p_T$

$$p_T = - \sum \bar{p}_T$$ of all charged tracks with $p_T > 3$ GeV/c

After high $p_T$ muon selection, almost no dependence vs. centrality

Before selection

$\langle p_T \rangle > 20$ GeV /c used in the analysis
W transverse mass $m_T$

- Transverse mass $m_T = \sqrt{2p_T^\mu \eta_T (1 - \cos \phi)} \quad \phi = \phi(\mu) - \phi(p_T)$
- Sharp Jacobian peak at $m_T = m_W$
- pp data at 2.76 TeV analyzed with the same procedure

- Compatible W signals in PbPb and pp
- Residual contamination from $Z \rightarrow \mu^+\mu^-$ and $W \rightarrow \tau \nu$ subtracted (2%); QCD (<1%)

Selected events:

<table>
<thead>
<tr>
<th></th>
<th>PbPb</th>
<th>pp</th>
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<tbody>
<tr>
<td>$W^+$</td>
<td>275</td>
<td>301</td>
</tr>
<tr>
<td>$W^-$</td>
<td>264</td>
<td>165</td>
</tr>
</tbody>
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$W^\pm \rightarrow \mu^{\pm} \nu$

- Different yields expected for
  - $W^+ \rightarrow \mu^+ \nu$
  - $W^- \rightarrow \mu^- \nu$

- $W$ are mostly produced via the fusion of a valence quark and a sea antiquark ($u\bar{d} \rightarrow W^+$ and $d\bar{u} \rightarrow W^-$)

- More $W^-$ (less $W^+$) in PbPb than in pp:
  - → strong isospin effect expected
  - (small when considering $W^+ + W^-$)
$W^\pm \rightarrow \mu^\pm \nu$ in pp

- More $W^+$ than $W^-$ in pp due to the isospin effect

CMS
$\sqrt{s}=2.76$ TeV
$L_{\text{int}} (pp) = 231$ nb$^{-1}$

$N_W/\Delta \eta / T_{AA}$ [pb]

$p_T^\mu > 25$ GeV/c
$|\eta^\mu| < 2.1$

- More $W^+$ than $W^-$ in pp due to the isospin effect

$W^+$
- $W^-$

pp

PbPb

W+ 301
W- 165

Within uncertainties, no dependence of \( W \) production vs. centrality observed in \( \text{PbPb} \) collisions.
Within uncertainties, no dependence of W production vs. centrality observed in PbPb collisions. Individual $R_{AA}$ for $W^+$ and $W^-$ reflect the different u & d quark content in Pb and proton → isospin effect.
Different $\mu^\pm$ distributions vs. $\eta$

- $W$ are boosted in the valence quark direction (away from midrapidity)

- Spin conservation
  - $\mu^+$ ($\mu^-$) are boosted back to (away from) midrapidity
  - Asymmetric $\mu^+$ and $\mu^-$ distributions varying with pseudorapidity
    - Different acceptances for $W^+$ and $W^-$
Muon charge asymmetry:

\[
\frac{N(W^+) - N(W^-)}{N(W^+) + N(W^-)}
\]

- **pp**: $W^+$ production higher than $W^-$
- **PbPb**: Predominance of $W^-$ production for large muon rapidities

Experimental values compatible with theoretical predictions:
- MCFM calculation (@NLO) + nucleon PDF (MSTW08) (pp data)
- + [nuclear PDF (EPS09)] (PbPb data)
Conclusion

- Within uncertainties, no modification of $W$ and $Z$ production is observed with respect to theoretical NLO pQCD $p-p$ cross sections scaled by elementary nucleon-nucleon collisions.

- Confirm Glauber model validity in nucleus-nucleus collisions.

- $W^+$ and $W^-$ yields in $PbPb$ collisions exhibit an isospin effect as expected, enhancement for $W^-$ production and reduction of $W^+$ with respect to that measured in $pp$ collisions at same $\sqrt{s}$.

- Muon charge asymmetry evaluated in $PbPb$ and $pp$ collisions. In agreement with NLO pQCD calculation.