Measurement of electroweak boson production in PbPb collisions at 2.76 TeV with CMS

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Outlook
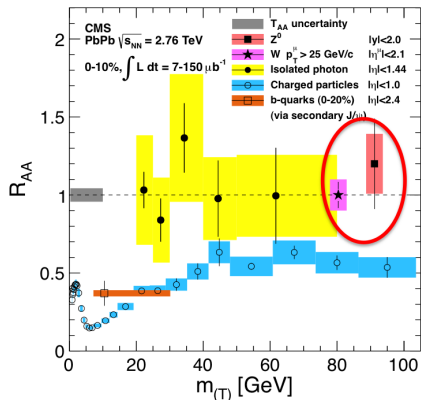
- ❶ Introduction

- ❷ CMS

- ❸ Results

  - 2010 PbPb data : $\int L dt \sim 7\ \mu\ b^{-1}$
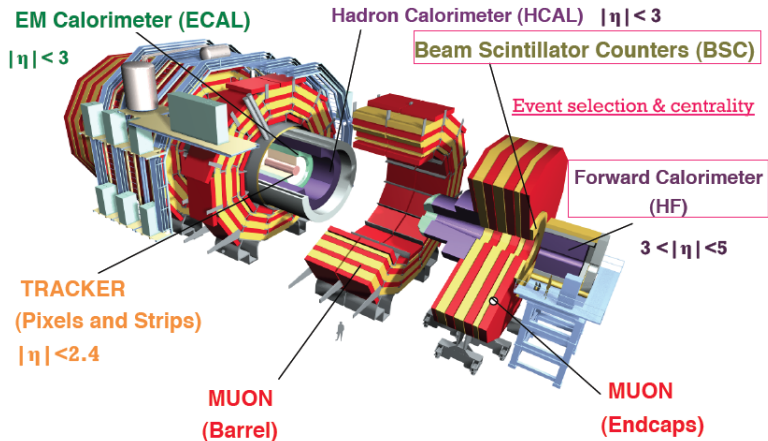
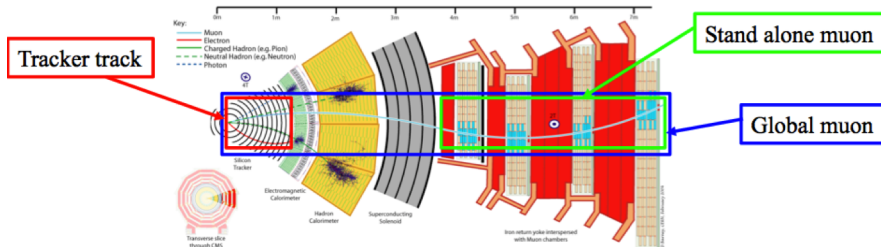 - $Z \to \mu^+\ \mu^-$ and $W^\pm \to \mu^\pm\ \nu$

- ❹ Conclusion

Motivation

- LHC allowed first observation and measurement of Z and W bosons in PbPb collisions
  - yields as a function of p_T, centrality and rapidity
  - measurement of W charge asymmetry

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

- They are studied through their leptonic decay $Z \rightarrow \mu^+ \mu^-$, $W^{\pm} \rightarrow \mu^{\pm} \nu$

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

Introduction
CMS
Electroweak bosons
Conclusion

CMS detector
Muon reconstruction

CMS Detector

Introduction
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CMS detector
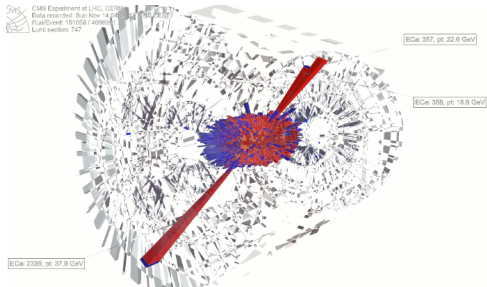Muon reconstruction

Muon reconstruction and performances

- Muon reconstruction requires information from tracker and muon system , tracks reconstructed in the tracker are matched to the tracks reconstruction in the muon system
- Adapted inner tracking for HI collisions
- Excellent high p_T resolution : 1-2%
- Good muon trigger performance

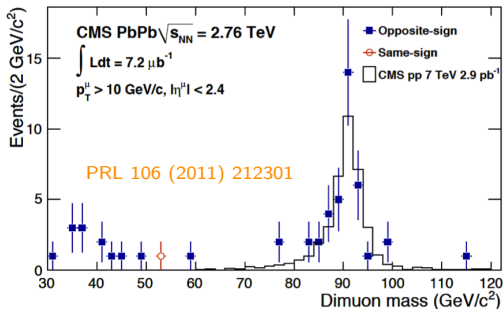# $Z \rightarrow \mu^+ \ \mu^-$ and $Z \rightarrow e^+ \ e^-$
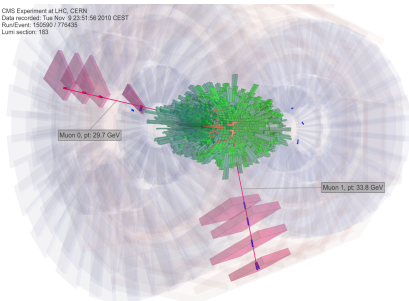
$Z \to \mu^+ \mu^-$

- 39 Z candidates counted in a di-muon invariant mass window $[60,120 \text{ GeV}/c^2]$
- No background just with loose quality cuts, only one same-sign event in $[30,120 \text{ GeV}/c^2]$
- Z mass resolution comparable to p-p

Normalized Z yield vs. N_{part}

- Z production scales with T_{AB}, i.e. with the number of NN collisions

- Comparison to different theoretical predictions
  - POWHEG: no effect
  - Paukkunen: shadowing + isospin
  - Neufeld: isospin + energy loss

- Uncertainties: 16% statistical, 14% systematic

PRL 106 (2011) 212301
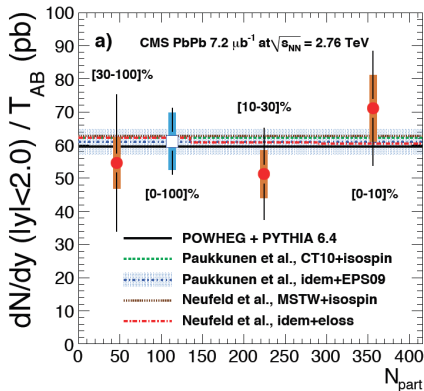
- Assuming from POWHEG $\frac{d\sigma_{pp}}{dy} = 59.6$ pb in $|y| < 2$
  - $\mapsto R_{AA} = \frac{dN_{AA}}{T_{AB} d\sigma_{pp}} = 1.00 \pm 0.16 \pm 0.14$ (MinBias)

Normalized Z yield vs. p_T and Rapidity

- 3 rapidity bins and 3 p_T bins
- $\frac{dN^z}{dy}$ is in a good agreement with different theoretical and MC predictions within statistical error bars and uncertainties
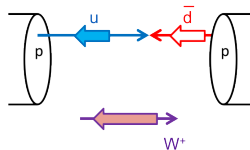 - NLO calculation agrees with Z measurement in CMS

PRL 106 (2011) 212301
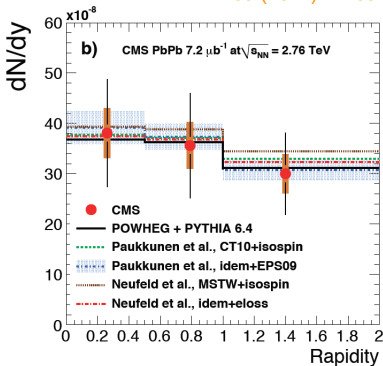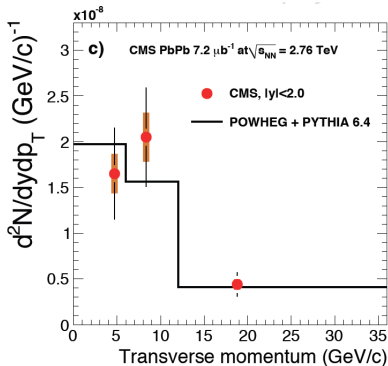
$W \to \mu^{\pm}\nu$

- $q\bar{q} \to W$ - $u\bar{d} \to W^{+}$ - $d\bar{u} \to W^{-}$

- W mostly produced via the fusion of a valence quark and a see antiquark
  - More W^{+} (less W^{-}) in pp than in PbPb
    $\mapsto$ strong isospin effect
    (small when considering $W^{+} + W^{-}$)
  - W are boosted in the valence quark direction
    (away from midrapidity)

- Spin conservation
  - $\mapsto \mu^{+}$ (μ^{-}) are boosted
    back to (away from) midrapidity
  - $\mapsto$ Asymmetric μ^{+} and μ^{-} distributions,
    varying with pseudorapidity
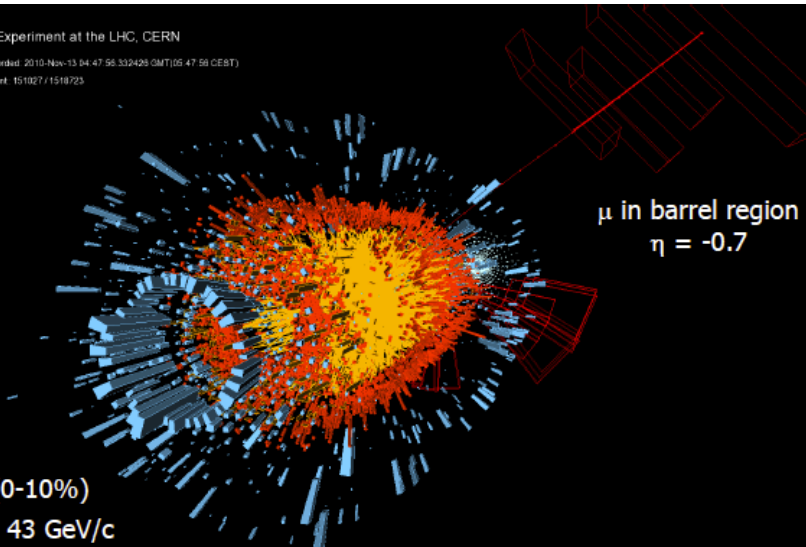 - $\mapsto$ different acceptances for W^{+} and W^{-}
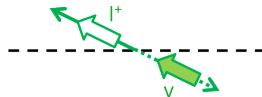
$W \to \mu^{\pm}\nu$

Muon p_T spectrum

- Trigger and selection cuts on $\mu^\pm$
  - Single muon triggers $p_T \geq$ 2-3 GeV/c
  - Number of hits in the tracker > 10
  - Compatibility with primary vertex (< 0.3 mm)
  - $\chi^2/\text{ndf} < 10$

- Veto on Z candidates

(a)

Data
Pythia pp → W → μν
Background
Fit: Background + W → μν

CMS
PbPb $\sqrt{s_{NN}}$ = 2.76 TeV
L_{int} = 7.3 μb^{-1}
|η$^\mu$| < 2.1
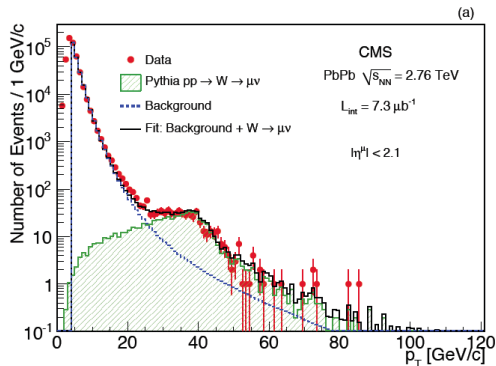
- PYTHIA simulation : $W\pm \to \mu^\pm\nu$ in pp collisions at $\sqrt{s} = 2.76$ TeV
- Bump in the region $p_T^\mu > 30$ GeV/c where W decay product are expected
- At high p_T muons from W dominate
- For the analysis we require $\underline{p_T^\mu > 25 \text{ GeV/c}}$

Missing p_T
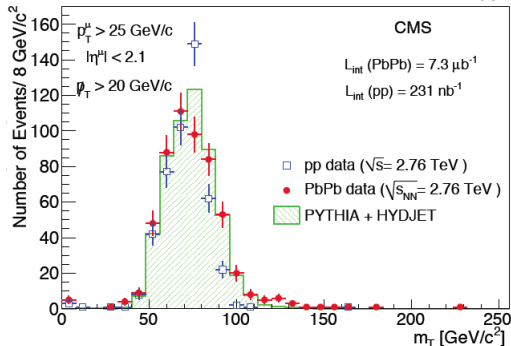
- $\not{p}_T = -\Sigma p_T$ of all tracker tracks with $p_T > p_T^{thresh}$, $p_T^{thresh} = 3$ GeV/c
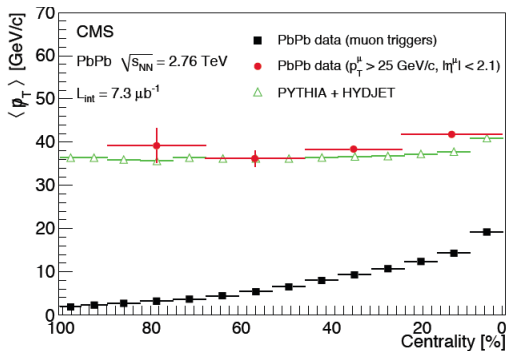
- Selecting a high p_T muon $\mapsto < \not{p}_T > \sim 40$ GeV/c, and almost no dependence vs. centrality
- Good agreement between MC (W $\to \mu^{\pm} \nu$ signal embedded in HYDJET PbPb) and PbPb Data for missing p_T calculation

W transverse mass m_T

- We calculate the W transverse mass $m_T = \sqrt{2 p_T^\mu \not{p}_T (1 - cos\phi)}$ where $\phi = \phi(\mu)$ - $\phi(\not{p}_T)$

- Sharp Jacobean peak at $m_T = m_W$, smeared by detector resolution

- pp data at $\sqrt{s} = 2.76$ TeV analyzed with the same procedure

- Better m_T resolution in pp than in PbPb
- Residual contamination ($Z \to \mu^+\mu^-$, $W \to \tau\nu$) subtracted (2%); QCD (<1%) included in systematic uncertainty for both pp and PbPb

Centrality dependance
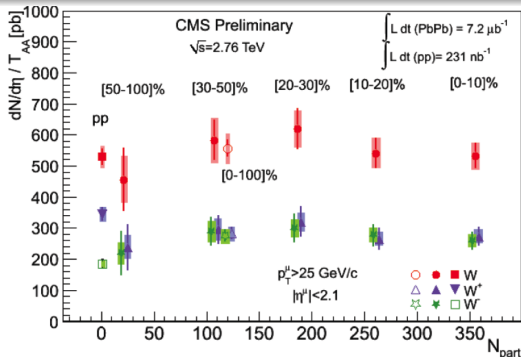
- Significant change in W^+ and W^- cross sections between pp and PbPb systems → isospin effect
  - PbPb(W^+) reduced with respect to $\sigma_{pp}(W^+)$ $R_{AA}(W^+) = 0.82 \pm 0.07 \pm 0.09$
  - PbPb(W^-) enhanced with respect to $\sigma_{pp}(W^-)$ $R_{AA}(W^-) = 1.46 \pm 0.14 \pm 0.16$
- No dependence on centrality within uncertainties
- Once summed W^+ and W^- consistent with pp

$R_{AA} = \frac{dN}{T_{AA}\sigma_{pp}} = 1.04 \pm 0.07 \pm 0.12$

Muon charge asymmetry

- Muon charge asymmetry : $\frac{dN(W^+) - dN(W^-)}{dN(W^+) + dN(W^-)}$
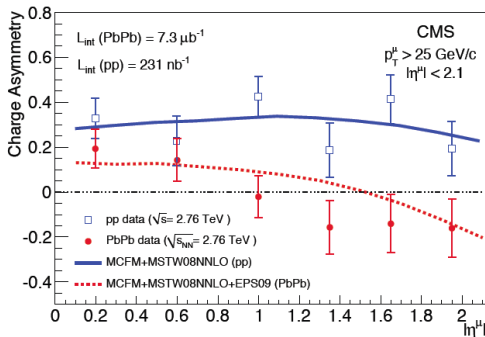
- PbPb: Predominance of W^- production for large muon rapidities
- pp: W^+ production higher than W^-
- Symmetry measured values compatible with theoretical predictions
  (MCFM + CTEQ6.6 + EPS09 (nuclear PDFs))

Conclusion

- Within uncertainties no modification is observed with respect to theoretical NLO pQCD p-p cross sections scaled by elementary nucleon-nucleon collisions

- Confirm the validity of Glauber scaling in nucleus-nucleus collisions

- For the Z boson, expected shadowing (10-20%), Isospin effect (3%) and energy loss (3%) cannot be confirmed or excluded, one need more statistics

- Individual W^+ and W^- yields in PbPb interactions exhibit an isospin effect, 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 interacting systems. In agreement with expectations from NLO pQCD calculations

- Z and W detailed and precise studies may help to constrain PDFs

Back-up

$Z \rightarrow \mu^+ \mu^-$ and $Z \rightarrow e^+ e^-$ with 2011 data

On going analysis on $Z \rightarrow \mu^+ \mu^-$, $Z \rightarrow e^+ e^-$ with 2011 PbPb data