W bosons in the CMS Experiment

in pp, pPb and PbPb collisions

Émilien Chapon
on behalf of the CMS experiment

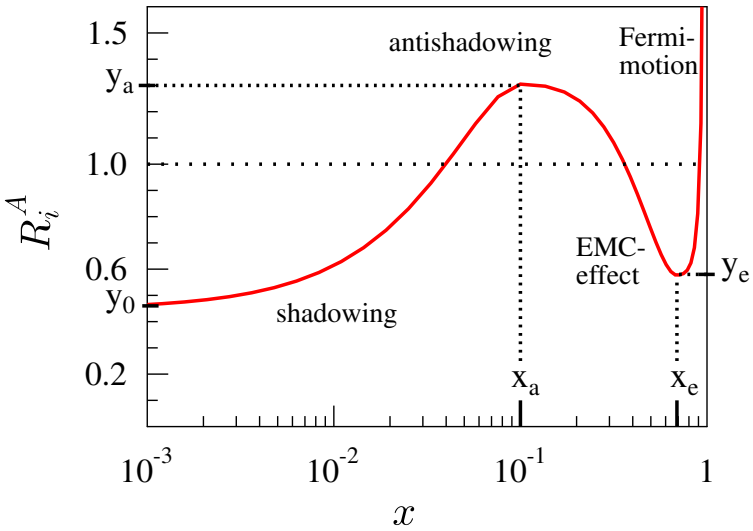
Laboratoire Leprince-Ringuet, École Polytechnique, Palaiseau

Hot Quarks 2014

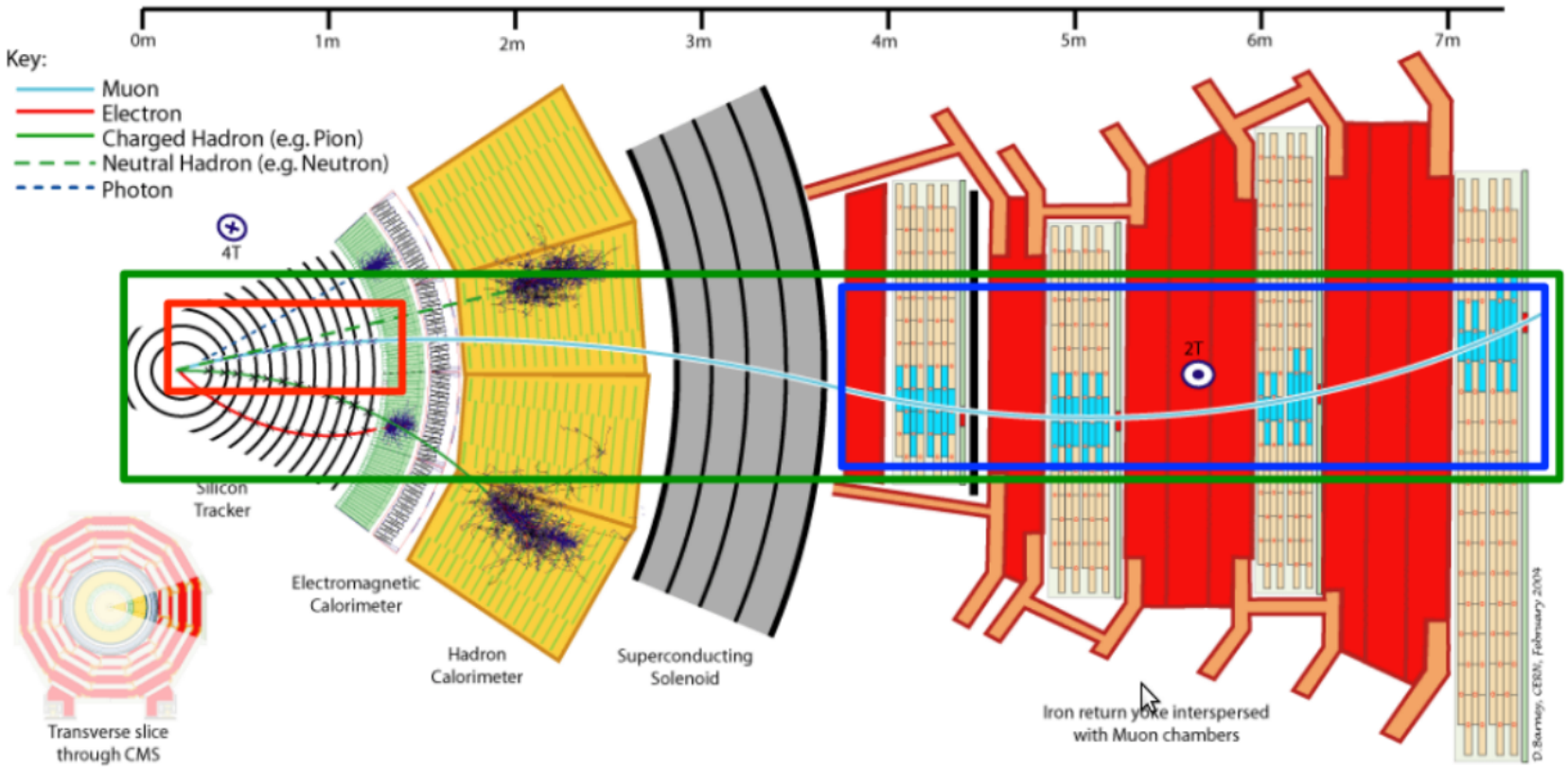
Motivation

- Electroweak bosons are produced and decay very early in the collision.
- They are not affected by the medium.
- Isospin effect for W (different between pp, pn and nn binary collisions).
- However they are sensitive to nuclear modifications of the parton distribution functions.
  - Good probes for nuclear effects in PDFs (shadowing / anti-shadowing).

JHEP **0904** (2009) 065

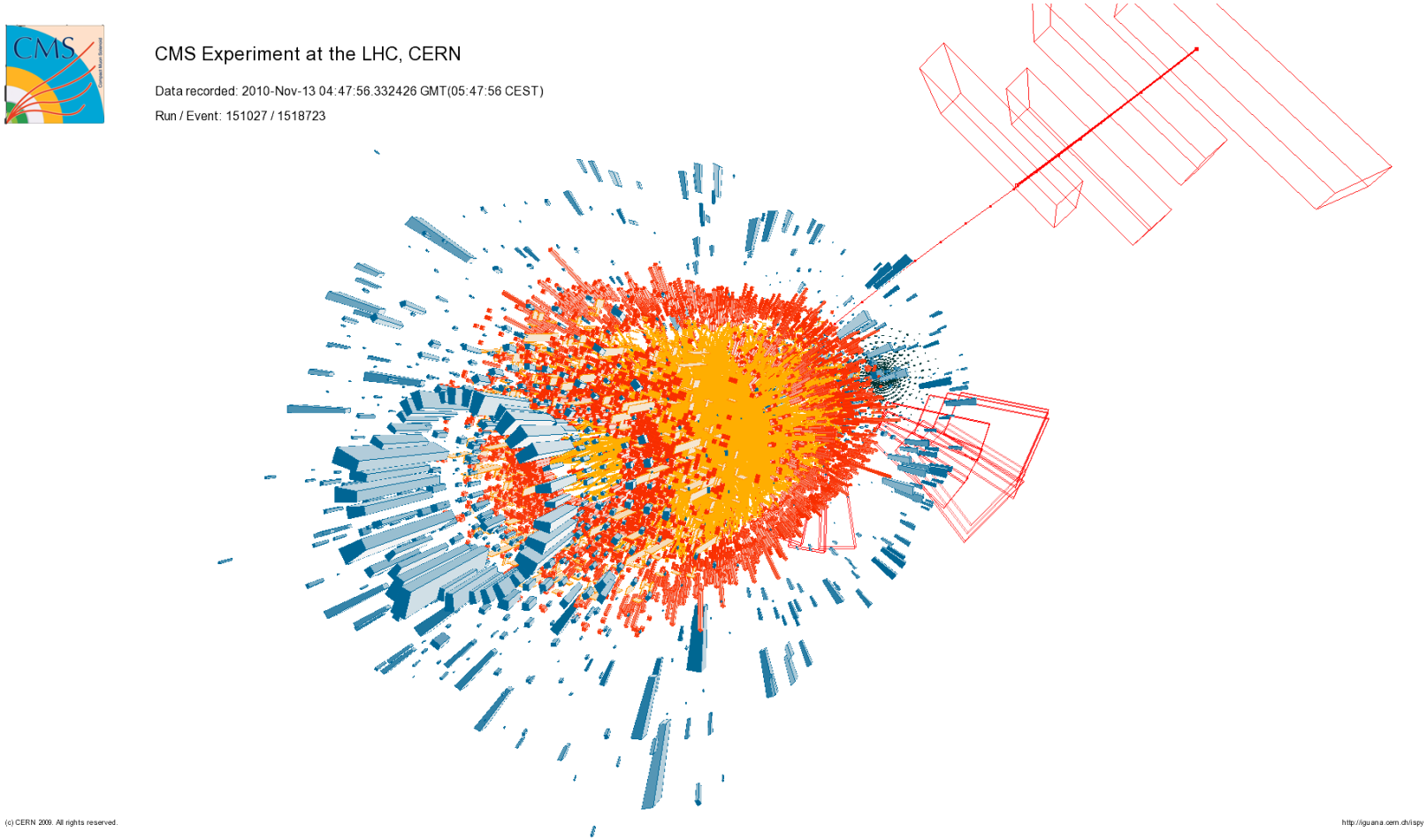


The CMS experiment



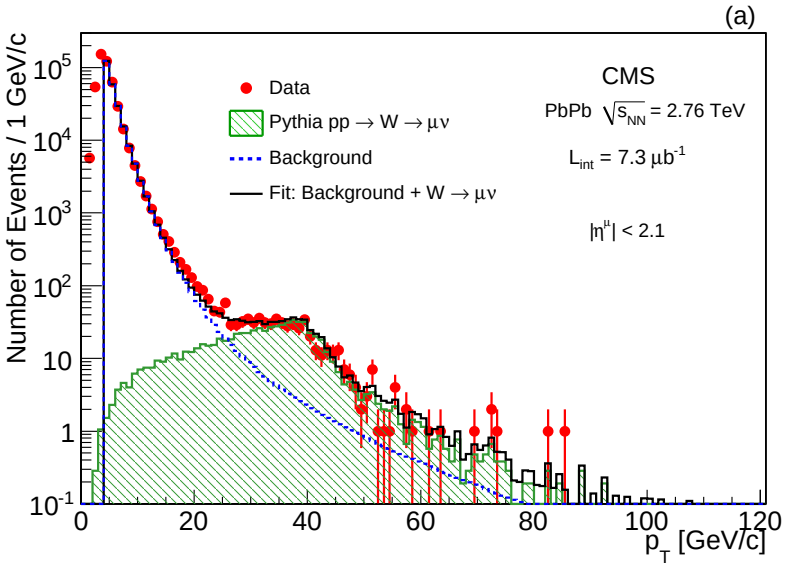
- Muon reconstruction: silicon tracker + muon sub-detectors
  - Tracker p_T resolution: 1-2% up to $p_T \sim 100\,\mathrm{GeV}/c$:
- Electron reconstruction: tracks associated with an ECAL cluster.
  - h/e discrimination: shower shape + fraction of energy in ECAL.

$W \rightarrow \mu\nu$: event display

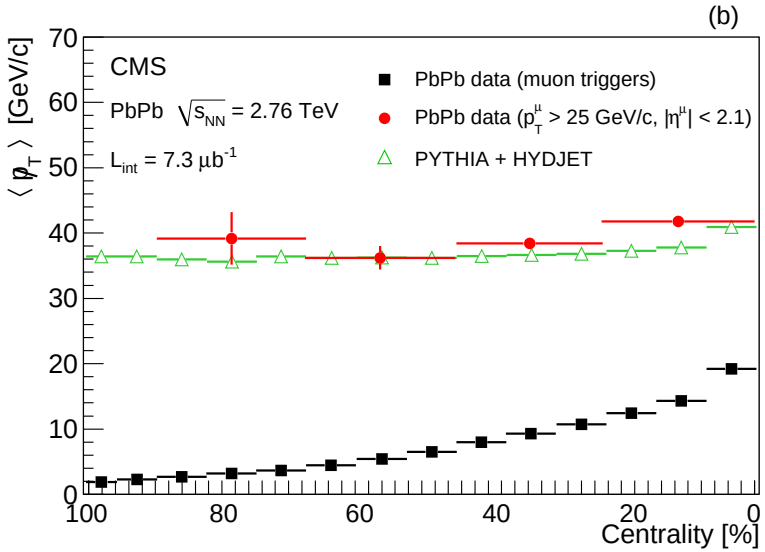


$W \to \mu\nu$: event kinematics

Phys. Lett. B **715** (2012) 66



- Signal visible in p_T spectrum of good quality muons.
- Background concentrated at low p_T.



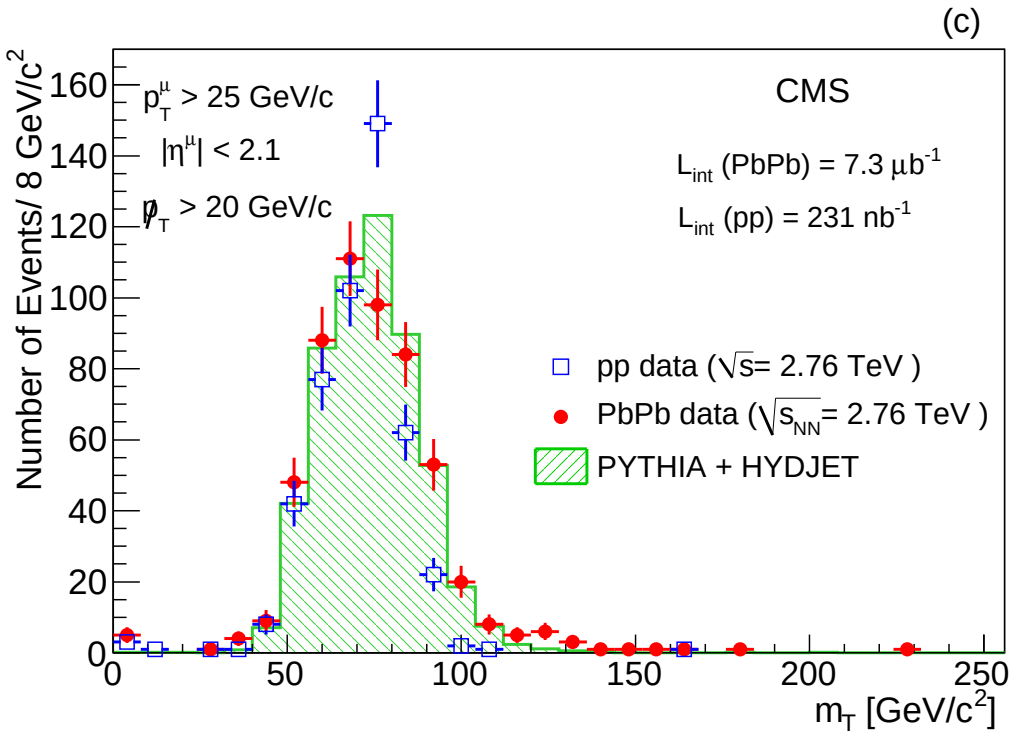
- Missing momentum from tracks.
- Signal: no dependence of $\not{p}_T$ with centrality.
- Balanced energy in background events.

$W \to \mu\nu$: transverse mass

Phys. Lett. B **715** (2012) 66

Selection of events

One good quality muon ($|\eta^\mu| < 2.1$, $p_T^\mu > 25\,\mathrm{GeV}/c$) and significant momentum imbalance ($\not{p}_T > 20\,\mathrm{GeV}/c$).



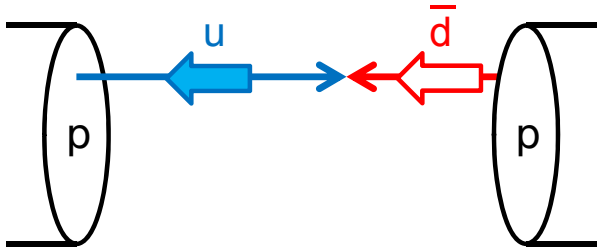
$$m_T = \sqrt{2 p_T^\mu \not{p}_T (1 - \cos\phi)}$$

- Almost background-free sample.
- Good agreement between PbPb data and simulation.
- Consistent shapes between pp and PbPb data.
  - Sightly worse resolution in PbPb.

W production

Leading order

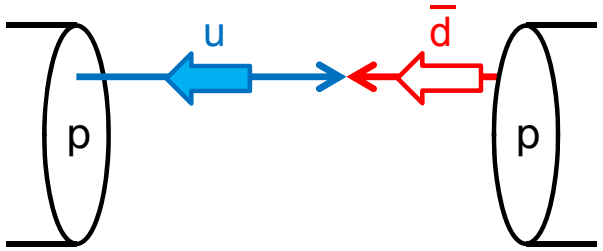
$$u\bar{d} \to W^+, \quad d\bar{u} \to W^-$$



W production

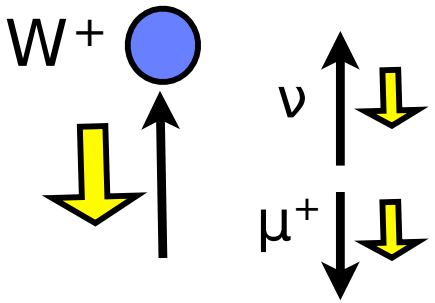
Leading order

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



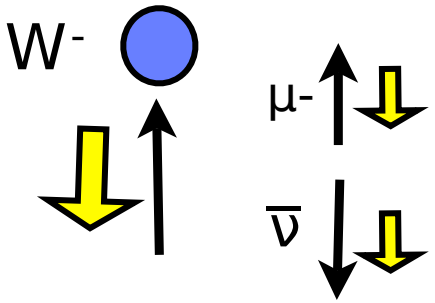
Yields

- Expect 2× more W^+ than W^- in pp.
- Expect more W^- than W^+ in PbPb.



Rapidity

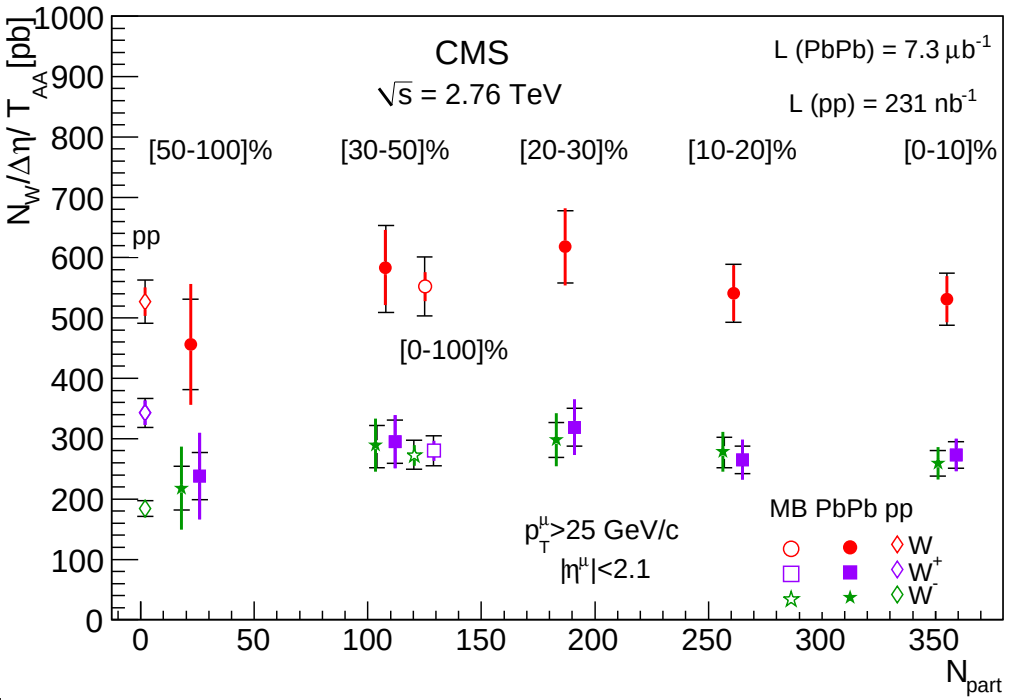
- W boosted towards the valence quark.
- Spin conservation + parity violation: μ^+ (μ^-) boosted back to (away from) midrapidity.
  - $\Rightarrow$ different rapidity distributions between μ^+ and μ^-.



$W \to \mu\nu$: nuclear modification factor

Phys. Lett. B **715** (2012) 66

$$
\begin{aligned}
R_{AA}(W) &= 1.04 \pm 0.07 \pm 0.12 \\
R_{AA}(W^+) &= 0.82 \pm 0.07 \pm 0.09 \\
R_{AA}(W^-) &= 1.46 \pm 0.14 \pm 0.16
\end{aligned}
$$

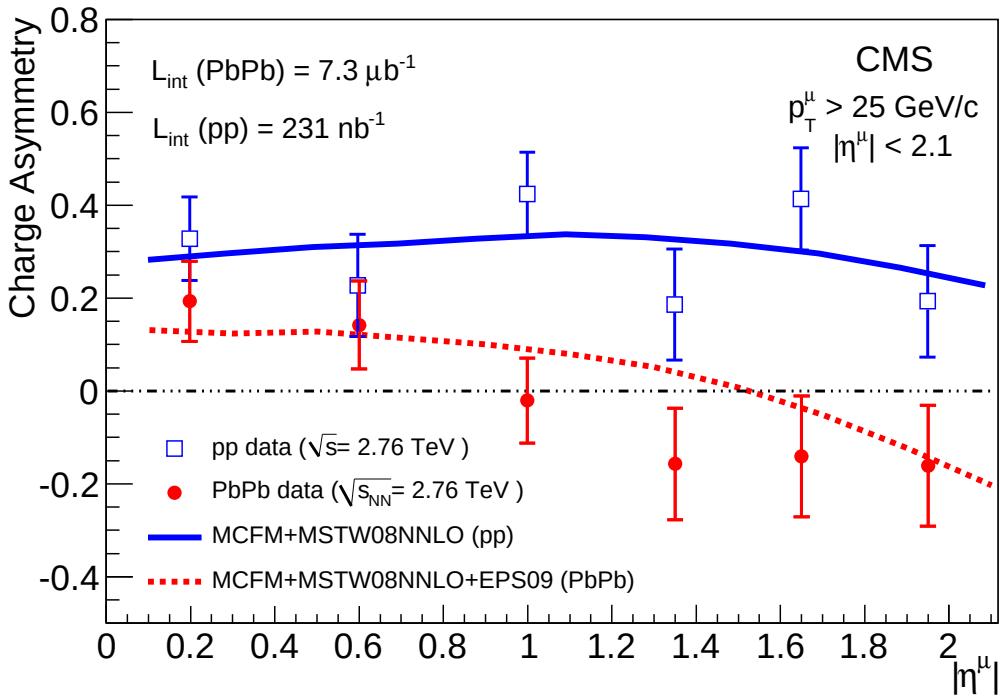


- No centrality dependence.
- Expect ~ 2 times more W^+ than W^- in pp (isospin).
- More balanced production in PbPb (mixture of protons and neutrons).

$W \to \mu\nu$: charge asymmetry

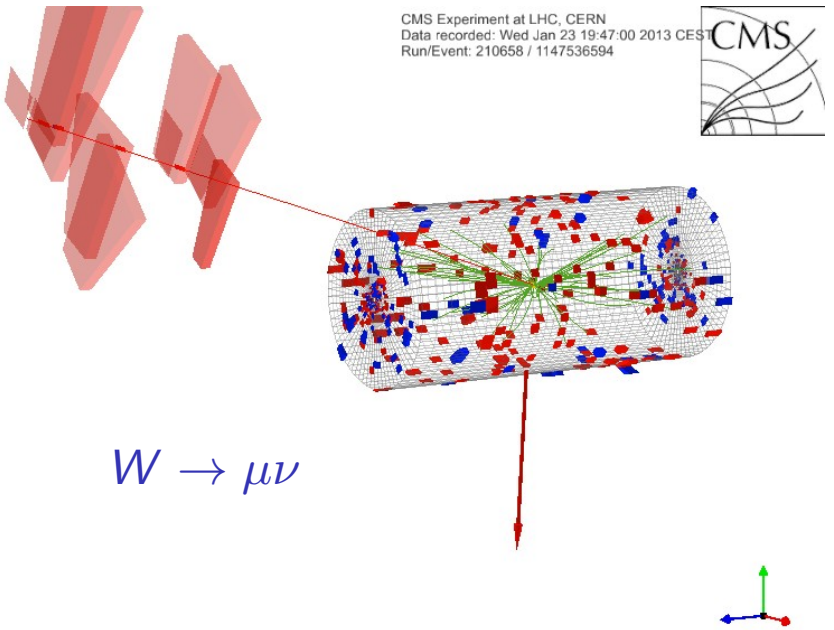
Phys. Lett. B **715** (2012) 66

$$\text{Charge asymmetry} = \frac{dN(W^+) - dN(W^-)}{dN(W^+) + dN(W^-)}$$

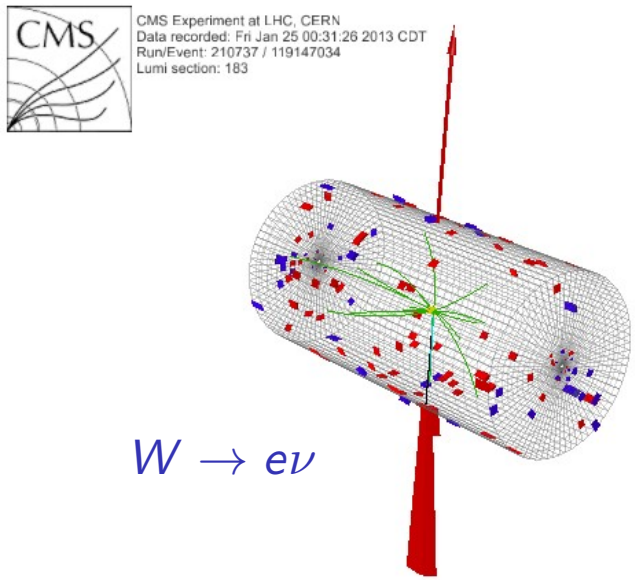


- pp: small dependence on η, asymmetry $\sim 1/3$.
- PbPb: asymmetry closer to 0, larger dependence with η.

W bosons in pPb collisions



$W \to \mu\nu$

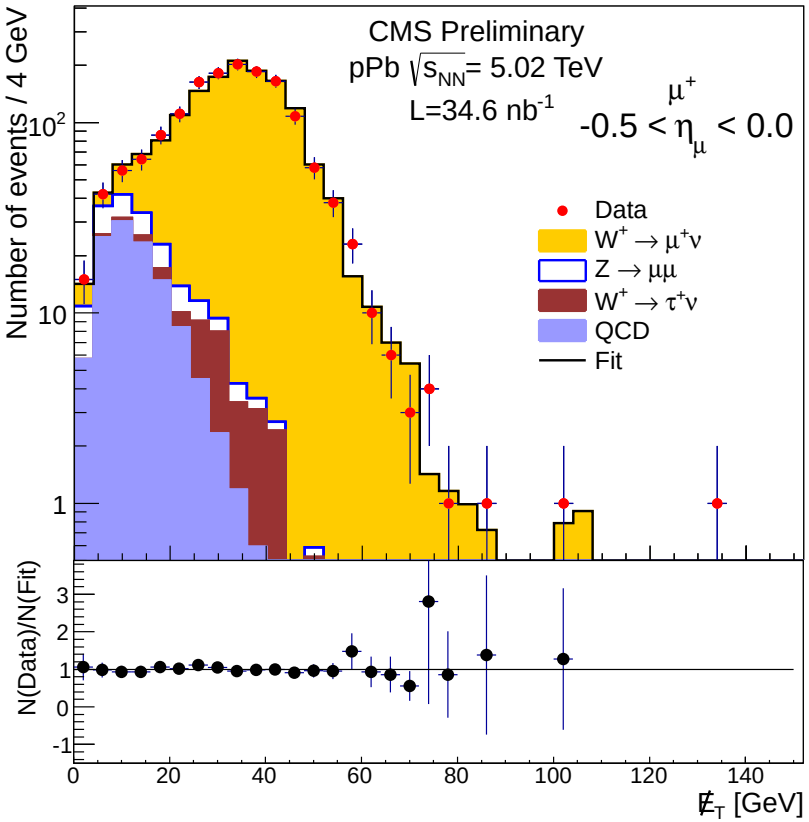


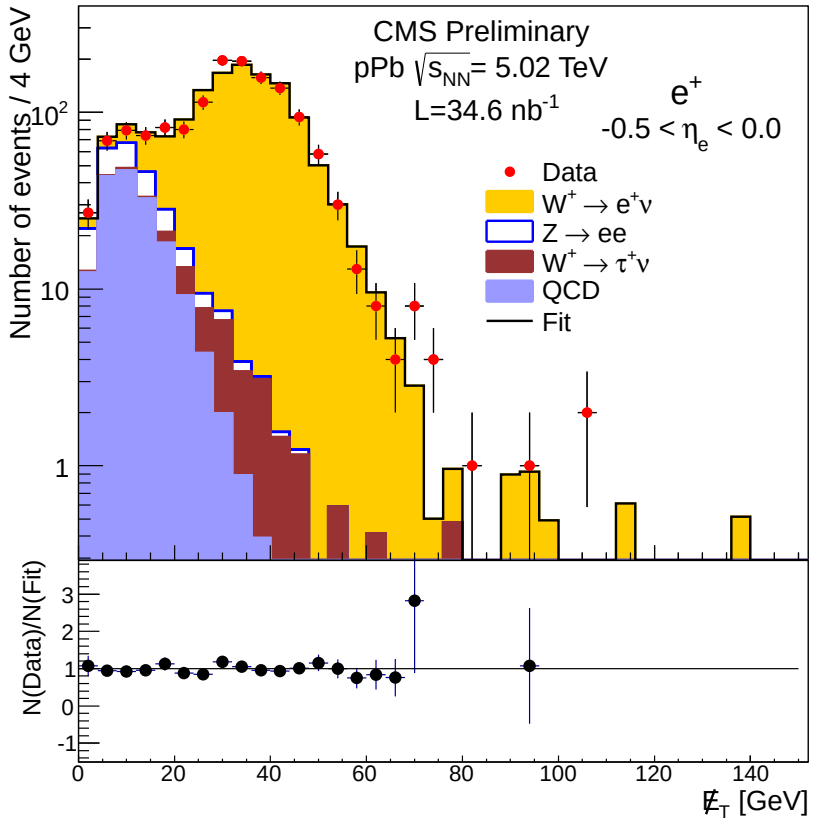
$W \to e\nu$

- Asymmetric collisions: new observables (e.g. forward / backward asymmetries)
  - Better sensibility to nPDF
- higher cross section as compared to PbPb, because of $\sqrt{s_{NN}}$ ($\sqrt{s_{NN}} = 2.76\,\text{TeV}$ in PbPb $\to$ $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ in pPb)

Selection

CMS-HIN-13-007

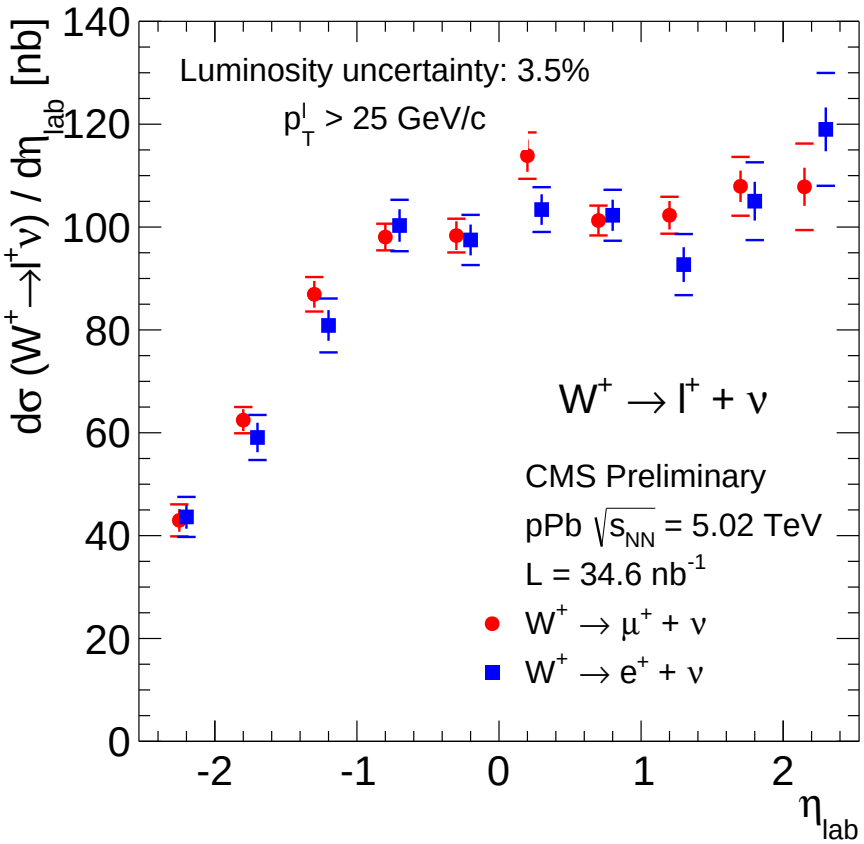


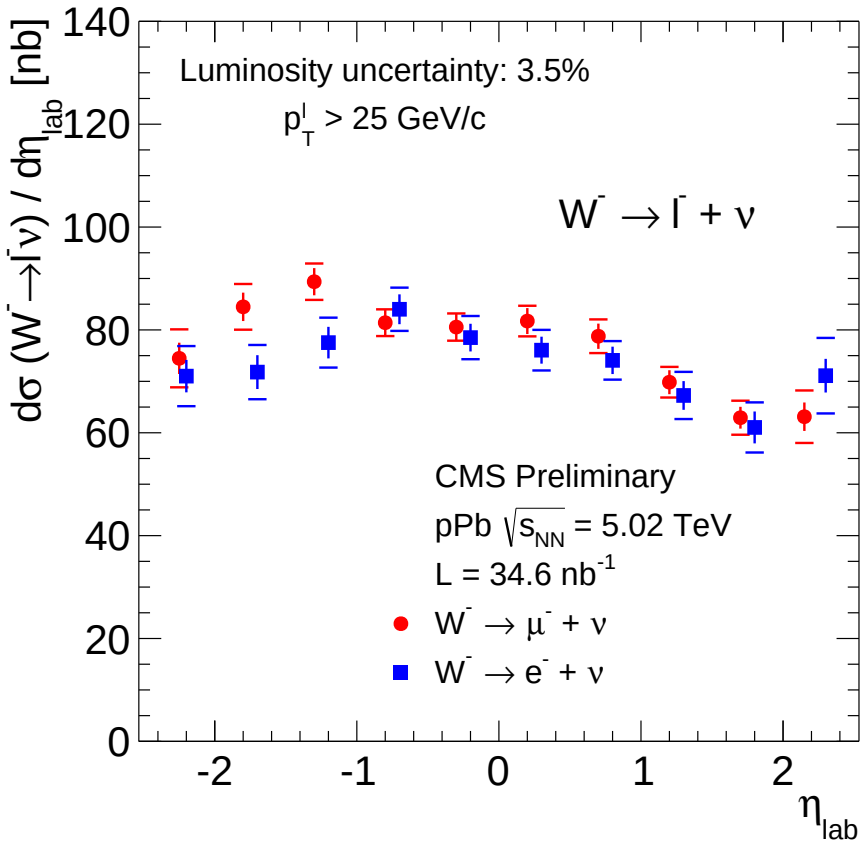


- Electron and muon channels.
- $p_T > 25\,\text{GeV}$, $|\eta^\mu| < 2.4$, $|\eta^e| < 2.5$, no $\not{E}_T$ cut.
- Requiring isolated lepton (to reject the HF and jet backgrounds)

Cross section

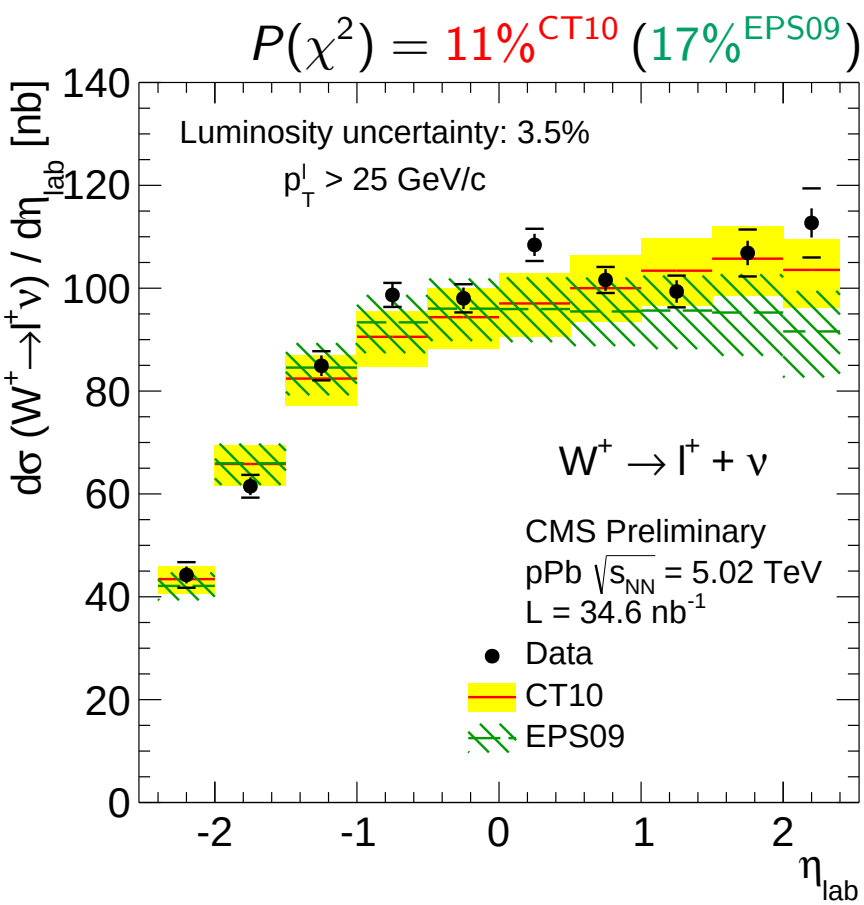
CMS-HIN-13-007

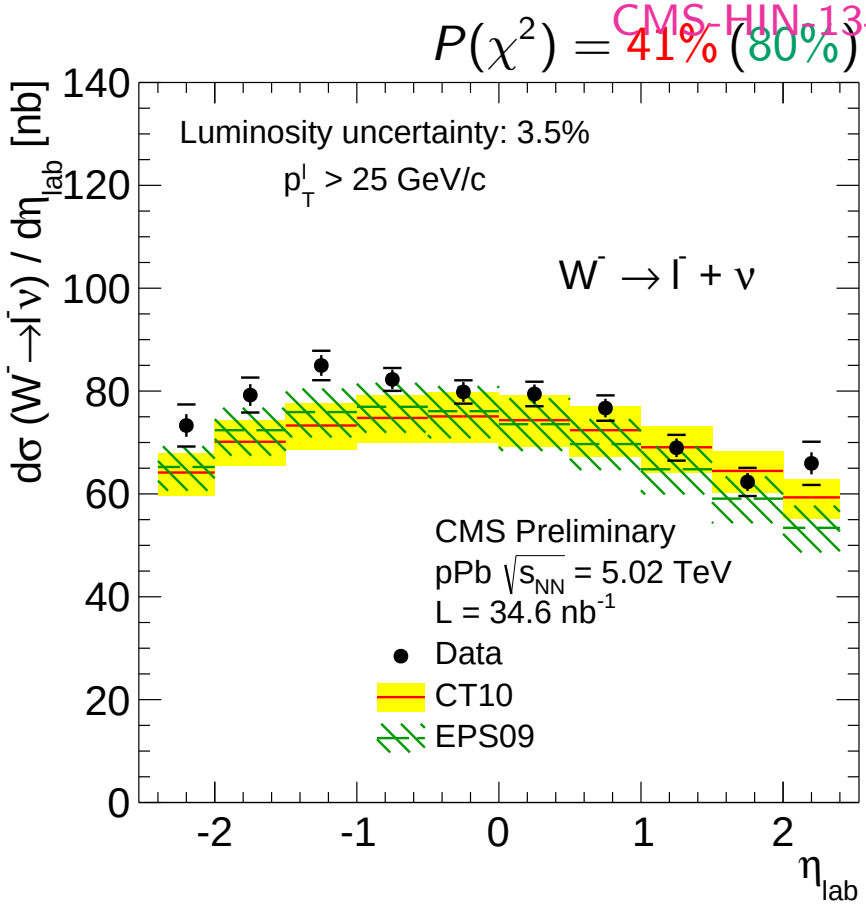




- Good agreement between the electron and muon channels.
- Combine the two channels for a better precision.

Cross section



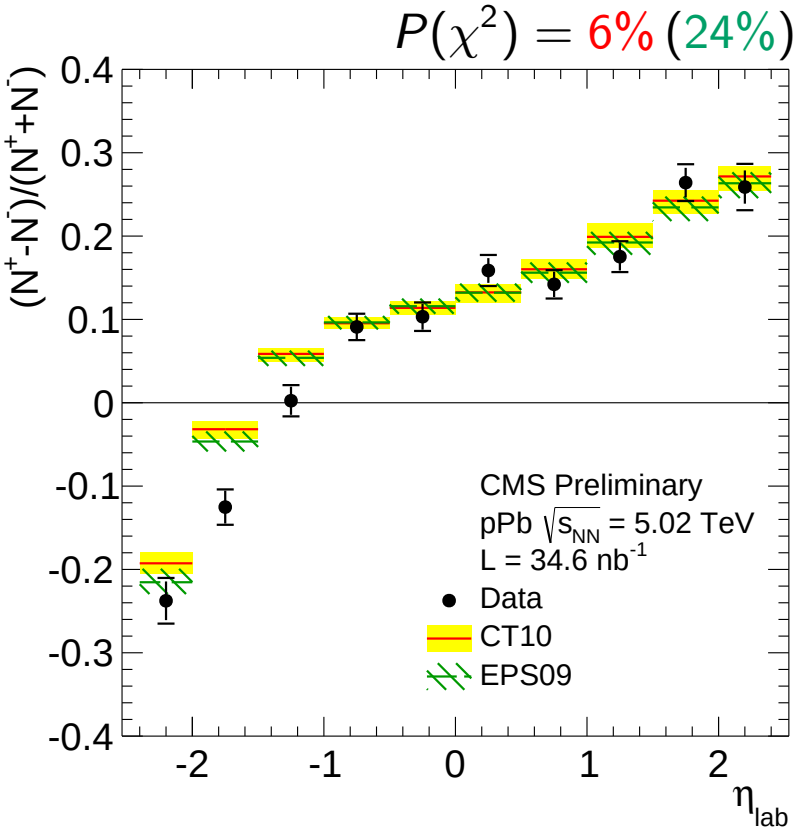


- NLO theory predictions with or without nuclear effects from EPS09[1].
- Good agreement with prediction.
- Poor discrimination between CT10 and CT10+EPS09: build asymmetries.

[1] Predictions from H. Paukkunen and C. A. Salgado, JHEP **1103** (2011) 071

Charge asymmetry $(N^+ - N^-)/(N^+ + N^-)$

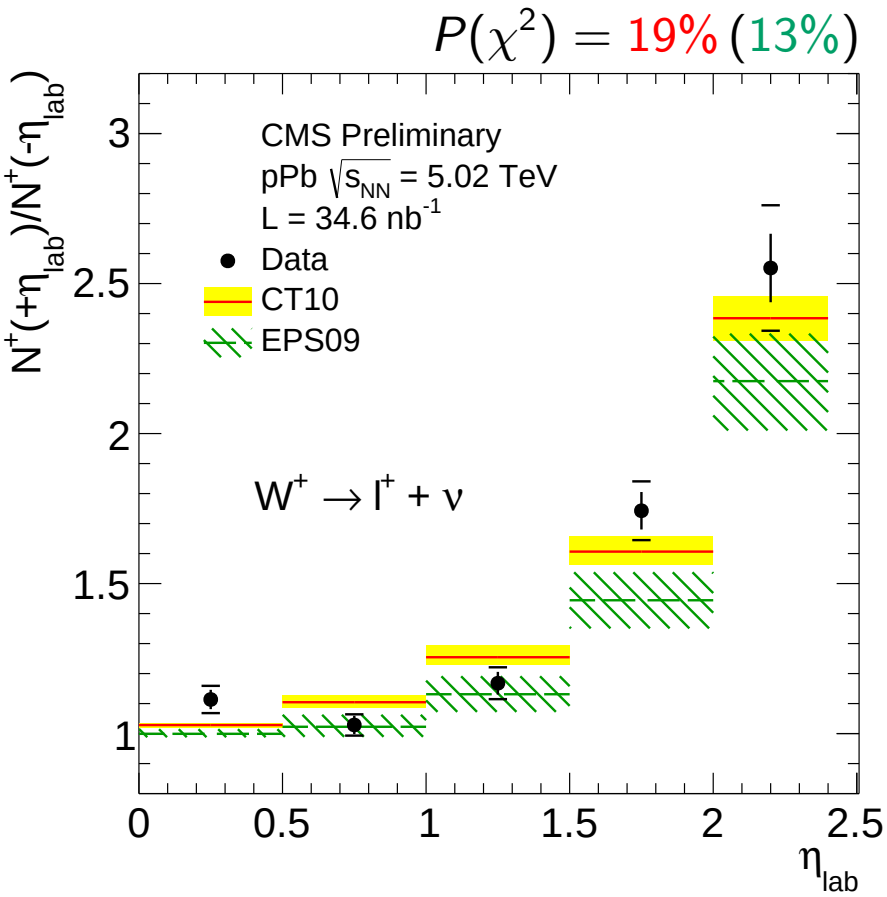
CMS-HIN-13-007

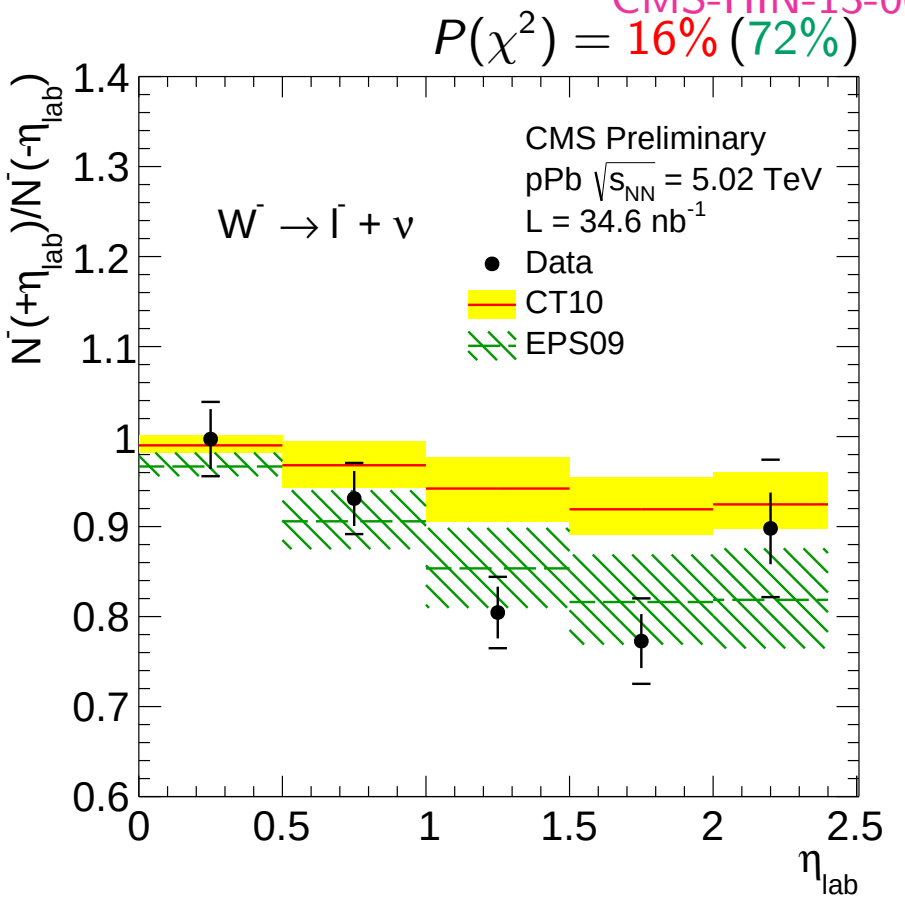


- Deviation at large negative η: different u vs. d quark modification?

Forward-backward asymmetry $N^{\pm}(+\eta_{\text{lab}})/N^{\pm}(-\eta_{\text{lab}})$

CMS-HIN-13-007

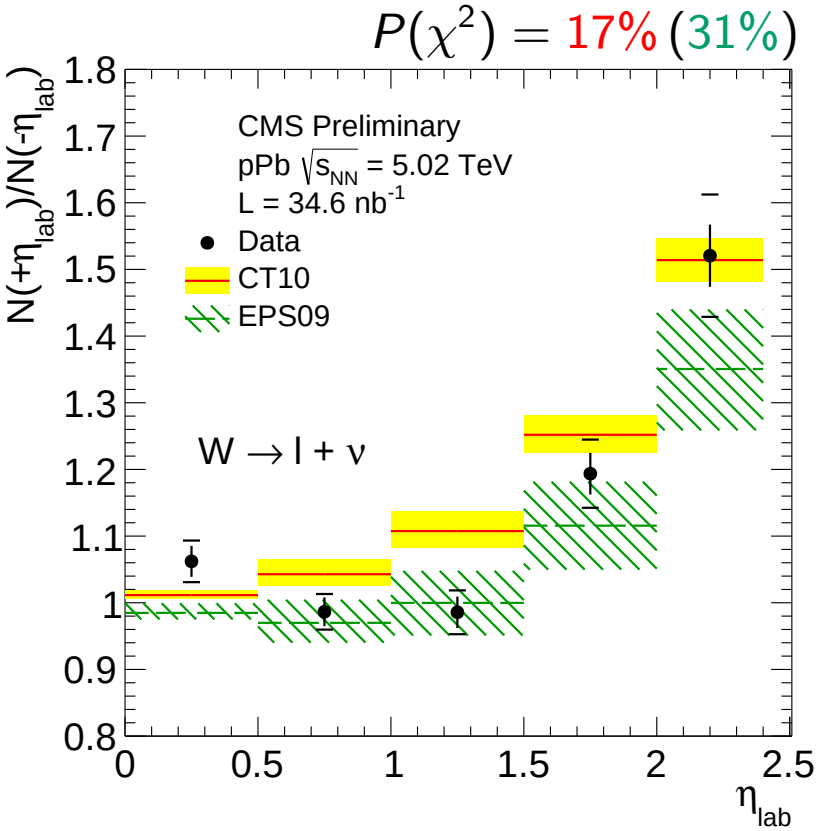




- F/B asymmetries are more sensitive to nuclear modifications.
- Negative leptons favor EPS09.
- Unclear conclusion for positive leptons.

Forward-backward asymmetry $N(+\eta_{\text{lab}})/N(-\eta_{\text{lab}})$

CMS-HIN-13-007



- Disfavoring the absence of nuclear modifications of PDFs.

Conclusion

W in pp and PbPb

- The difference between pp and PbPb is dominated by isospin.
- $R_{AA}(W)$ compatible with 1.

W in pPb

- Sensitivity to nuclear modifications of the PDFs.
- Hints of nuclear effects in the data.
- Some tension between data and theory in the charge asymmetry (different u and d PDF modifications?).