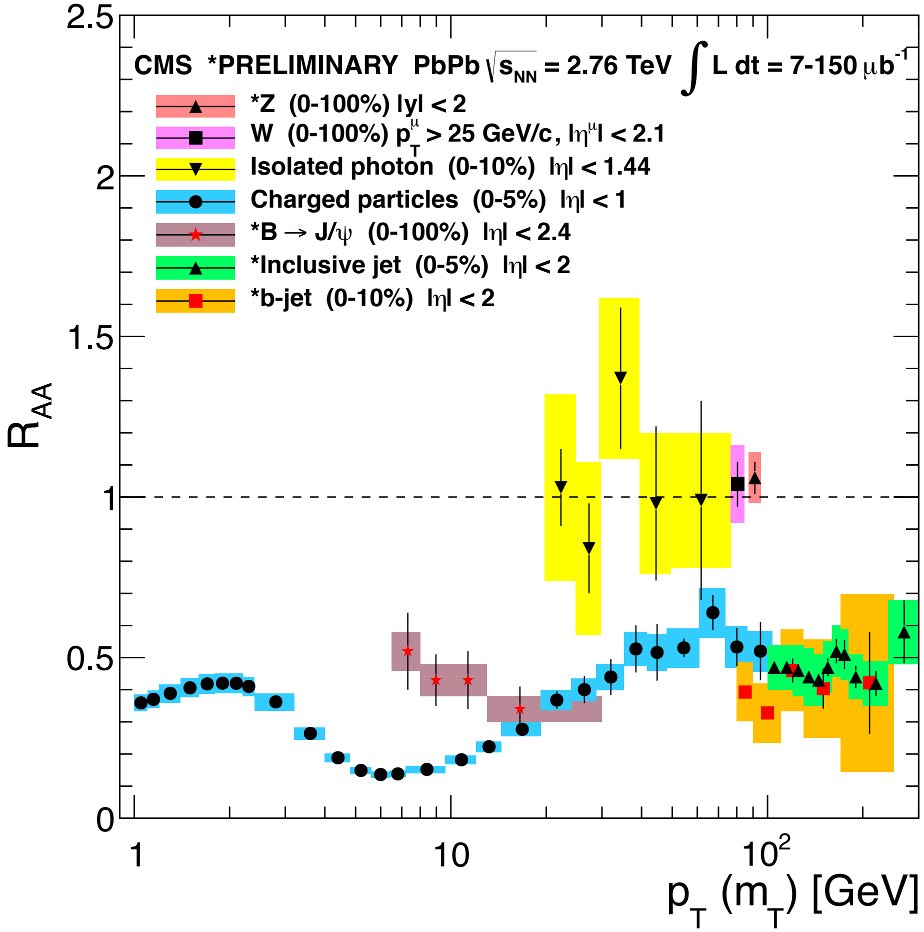
+

W production in pPb collision

$L = 34.6\ nb^{-1}$

Authors : Alice Florent (contact person), Emilien Chapon, François Arleo,
Raphael Granier de Cassagnac, LLR (France)
Begona de La Cruz, CIEMAT (Spain)
Ti Hien Doan, Shih-Yen Tseng, Chia-Ming Kuo, NCU (Taiwan)
Lamia Benhabib (CERN)

+ Z and W boson: medium blind



Z and W R_{AA}:

- Compatible with binary scaling (RAA=1)
- Large difference between electroweak bosons and QCD probes

- A R_{AA} compatible with 1 indicates that there are no strong nuclear effect but:
  - the effect might by symmetric
  - The error does not allow to see small initial cold effects

PLB 710 (2012) 256
PLB 715 (2012) 66
CMS PAS HIN-13-004

EPJC 72 (2012) 1945
JHEP 10 (2012) 087
PRC 84 (2011) 024906
CMS PAS HIN-12-003

+ Initial state observable

nPDF: probability density to find a parton with longitudinal momentum x at a resolution scale Q^2

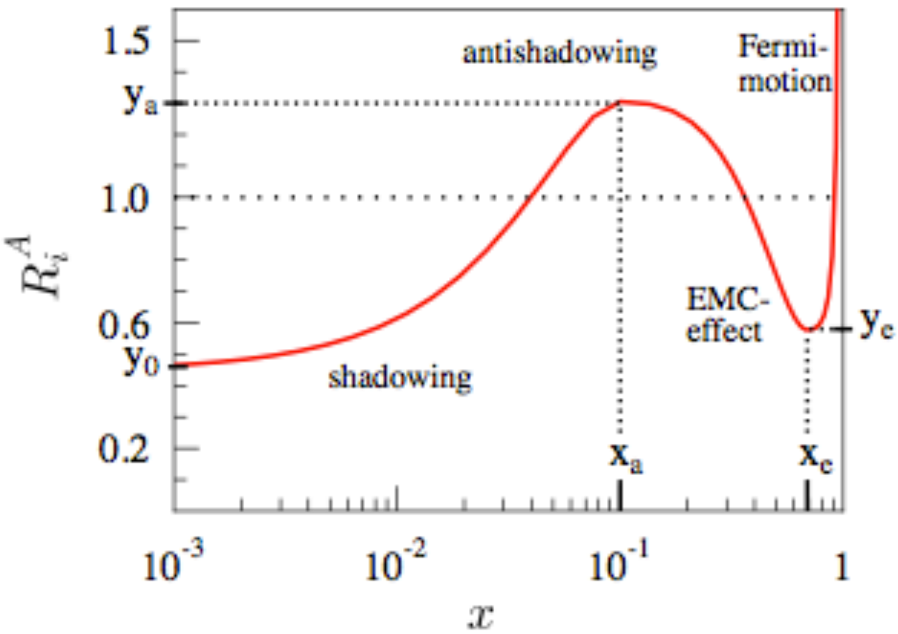
$$f^A = \frac{Z}{A} f^{\text{proton},A} + \frac{N}{A} f^{\text{neutron},A}$$

nPDF

Bound proton PDF

$$f^{\text{proton},A}(x,Q^2) \equiv R_f(x,Q^2) f^{\text{free proton}}(x,Q^2)$$

Nuclear modification factor



+ W in pPb: physics motivation

Aim: **probe the nPdf**

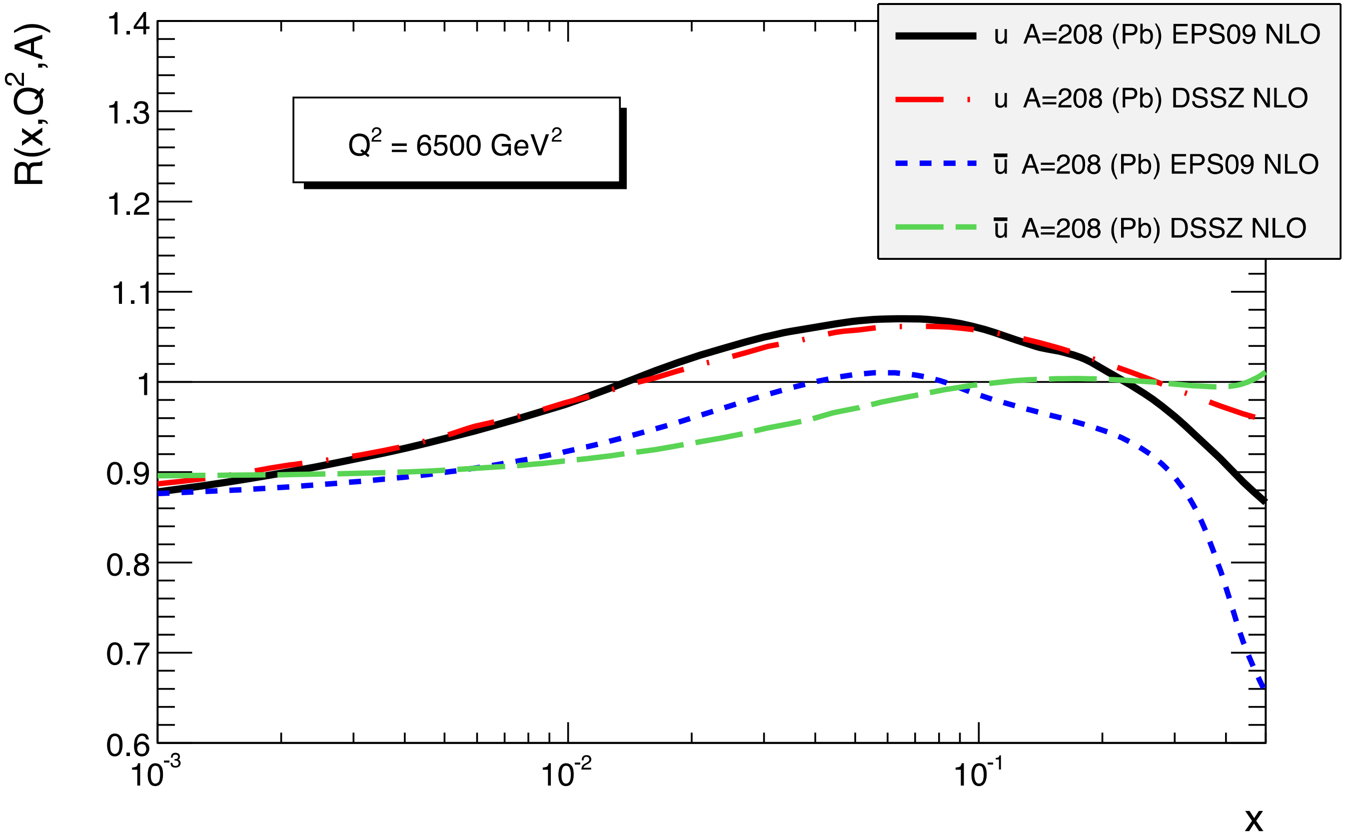
With: **the W boson in collisions pPb**
- The collision is asymmetric
- W boson is sensitive to quark flavor ⟶ **W+, W-**
- W boson are produced 10 times more than Z boson

How: **we propose 4 asymmetries results**
- charge asymmetry
- forward/backward W+
- forward/backward W-
- forward/backward W

Details:
-The first 3 are inspired by Salgado et al. JHEP03 (2011)071
- The last one is an asymmetry we proposed to replace A2 from their paper
- These 4 results are compared to two predicted PDFs set
    - CT10 (proton Pdf)
    - EPS09 (proton Pdf with nuclear effect)

+ W and nPDFs

- $Q^2 \sim 6500$ GeV^2 ($\sim m_W^2$)
- The asymmetries will probe
  - antiquarks in the nucleus at small x=[0.002;0.02] (shadowing region)
  - quarks at large x=[0.02;0.3] (anti-shadowing region)



+ Analysis strategy

- **Single lepton selection**
- **MET fitting**
- **Single lepton efficiency**
- **Scales Factors on single lepton Tag and Probe**
- **Cross section**
- **Asymmetry**

$$N^{\mathrm{corr}} = \frac{N^{\mathrm{raw}}}{\epsilon_{\mathrm{all}}^{\mathrm{MC},W} \times \mathrm{SF}}$$

+ Analysis strategy

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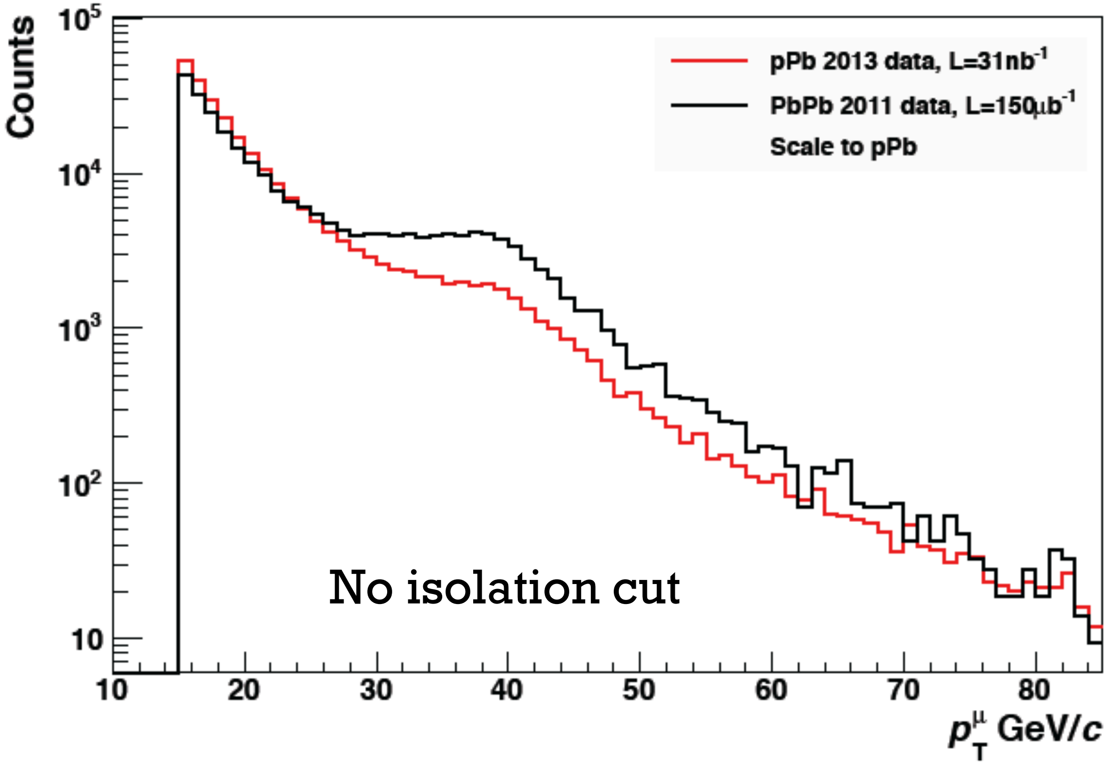
+ Single lepton selection

1) Isolated lepton

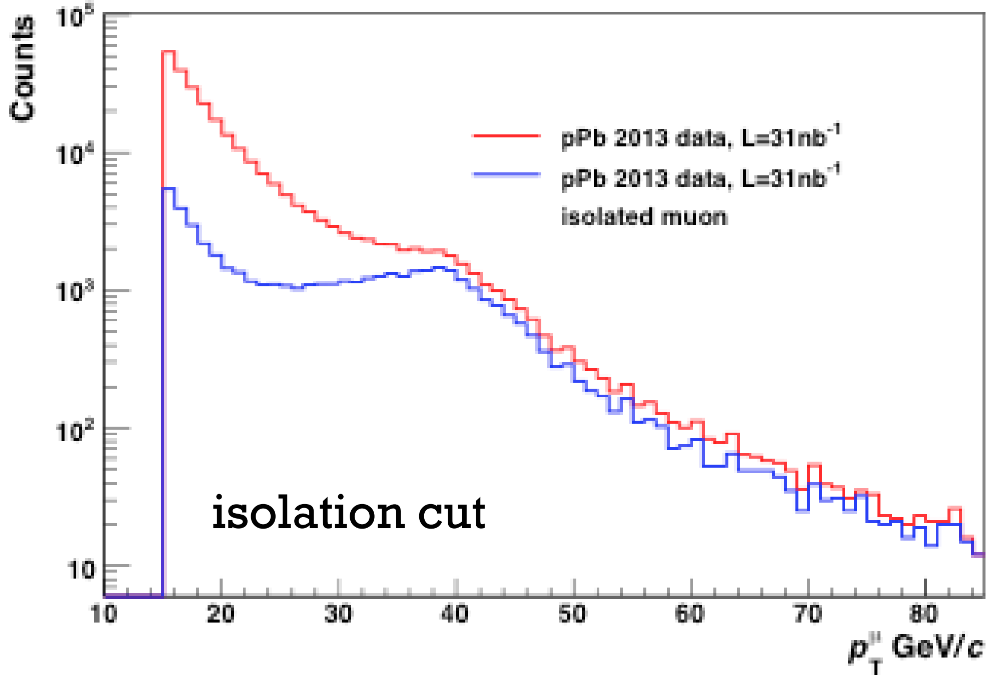
PbPb and pPb comparison



- Signal more visible in PbPb than in pPb
- Background suppression because of jet quenched?
- First use of isolation on lepton in Pb

+ Single lepton selection

1) Isolated lepton



- Sum over the Particle Flow candidates inside a cone $\Delta R = 0.3$

With $\Delta R = \sqrt{(\eta_{\mu} - \eta_{PF})^2 + (\Phi_{\mu} - \Phi_{PF})^2}$

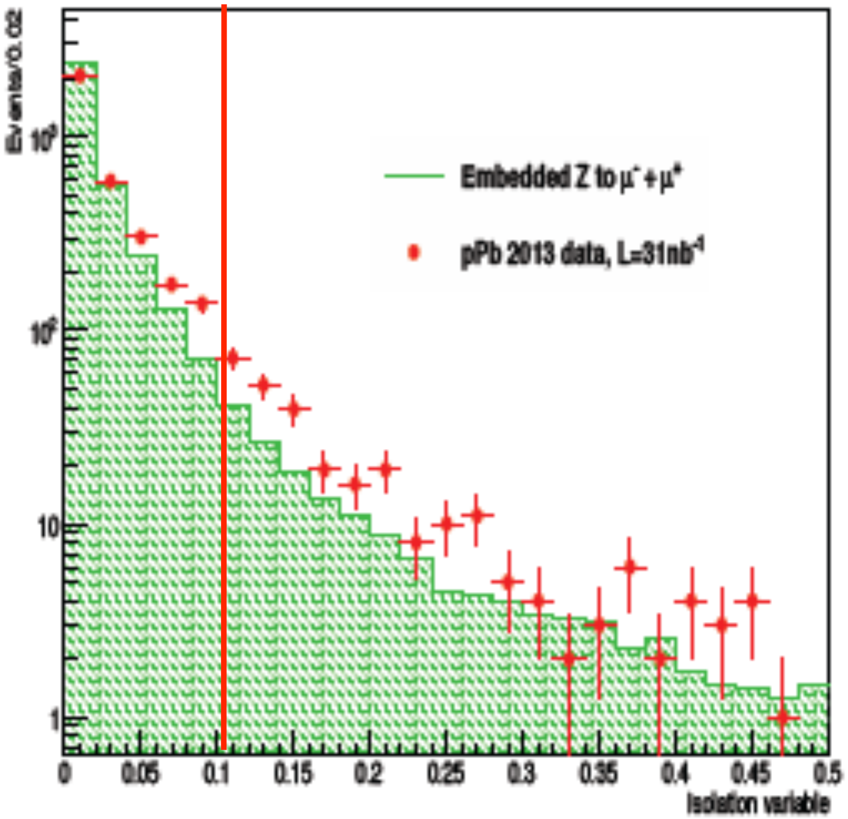
- A muon is considered as "isolated" if the sum inside the cone is lower than 10% of its p_T

+ Single lepton selection

1) Isolated lepton

- **Caveat**

Z events from data and MC



• MC does not reproduce data perfectly. Several % of difference around 0.1.
• The centrality weight ensures global multiplicity agreement but not local one. More details about multiplicity in back up.

• The difference between the isolation efficiency in data and MC will be corrected and controlled with Scale Factors based on TnP

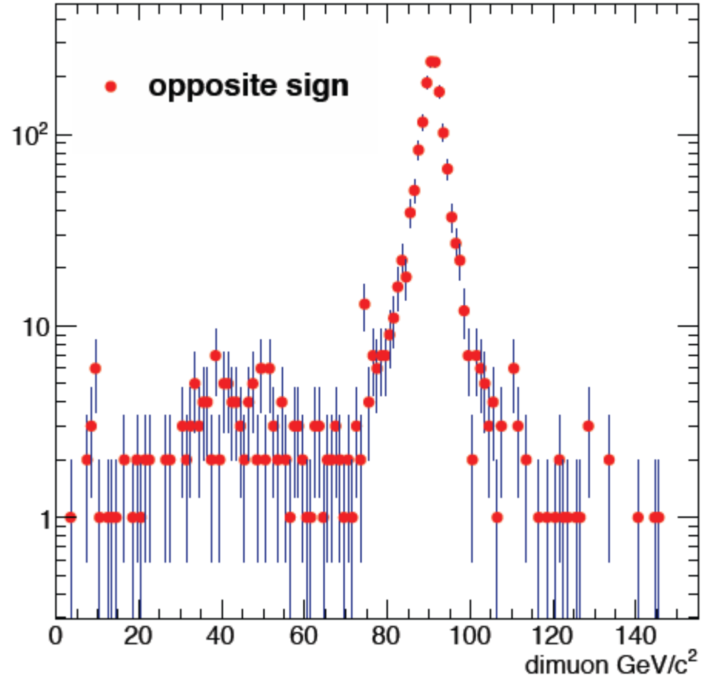
+ Single lepton selection

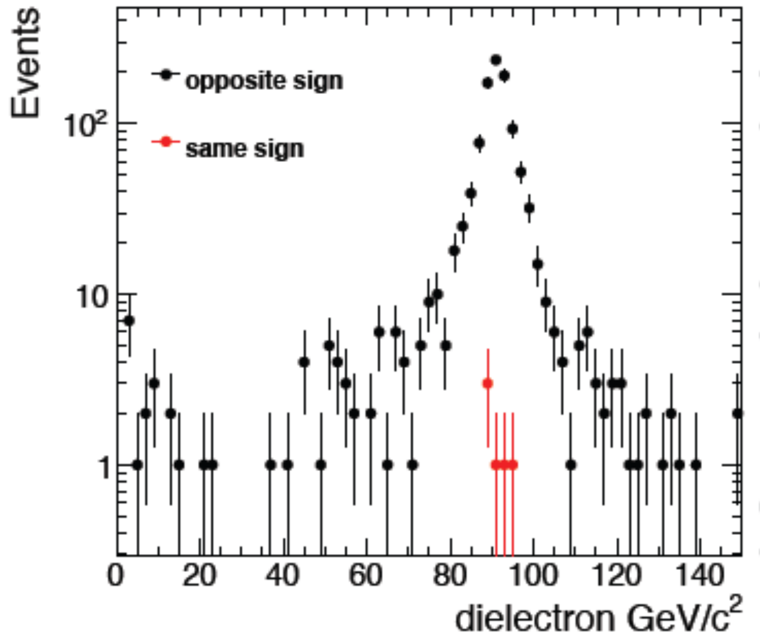
3) Z veto

High quality lepton = trigger+ selection cut + isolation

Muon:
Event with 2 high quality leptons, with l_1 >25 GeV and l_2 > 15 GeV are removed.
No invariant mass cut, since no same sign pair can be found in the mass spectra.

Electron:
Event with 2 high quality leptons, with l_1 >25 GeV and l_2 > 10 GeV are removed.
No invariant mass cut, since only 6 same sign pair.



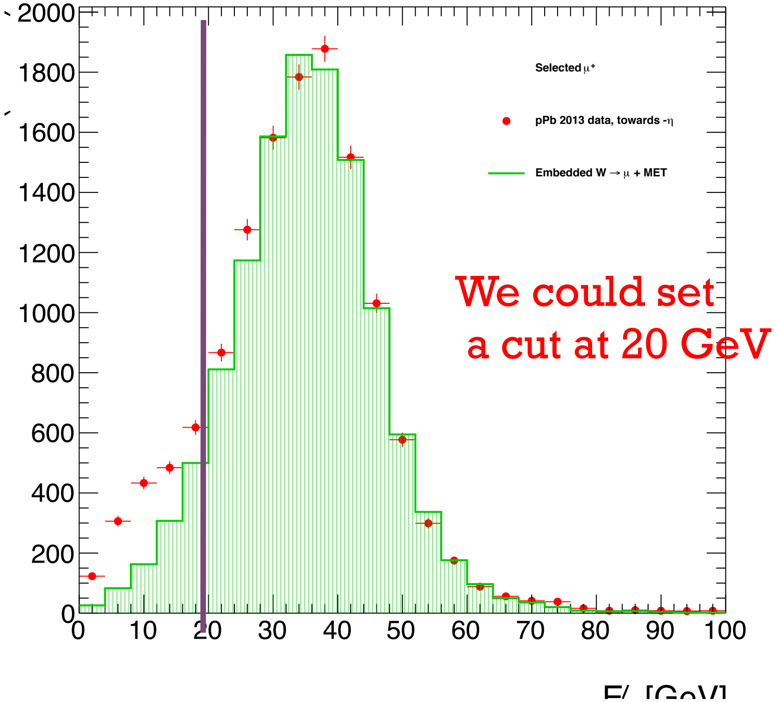


+ Indirect neutrino reconstruction

Unbalanced energy in the transverse plane

$$\begin{aligned}
\not{E}_{Tx} &= -\Sigma_{particles} \vec{E_{Tx}} = -\Sigma_{particles} E_{Tx} cos(\phi) \\
\not{E}_{Ty} &= -\Sigma_{particles} \vec{E_{Ty}} = -\Sigma_{particles} E_{Ty} sin(\phi) \\
\not{E}_{T} &= -\Sigma_{particles} \vec{E_{T}} = \sqrt{\not{E}_{Tx}^2 + \not{E}_{Ty}^2}
\end{aligned}$$

Particles = Particles Flow candidates: muon, electron, photon, charged hadrons and neutral hadrons



+ Indirect neutrino reconstruction

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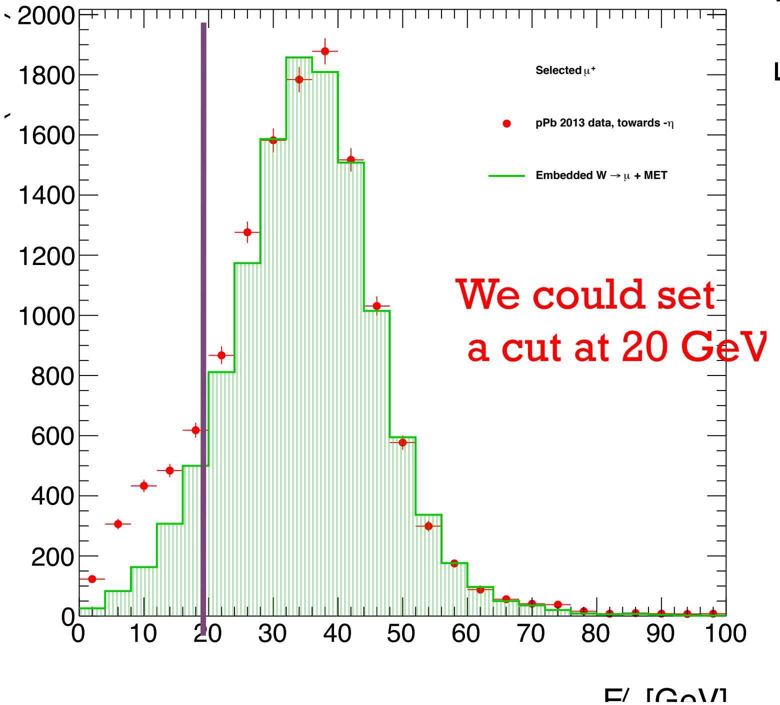
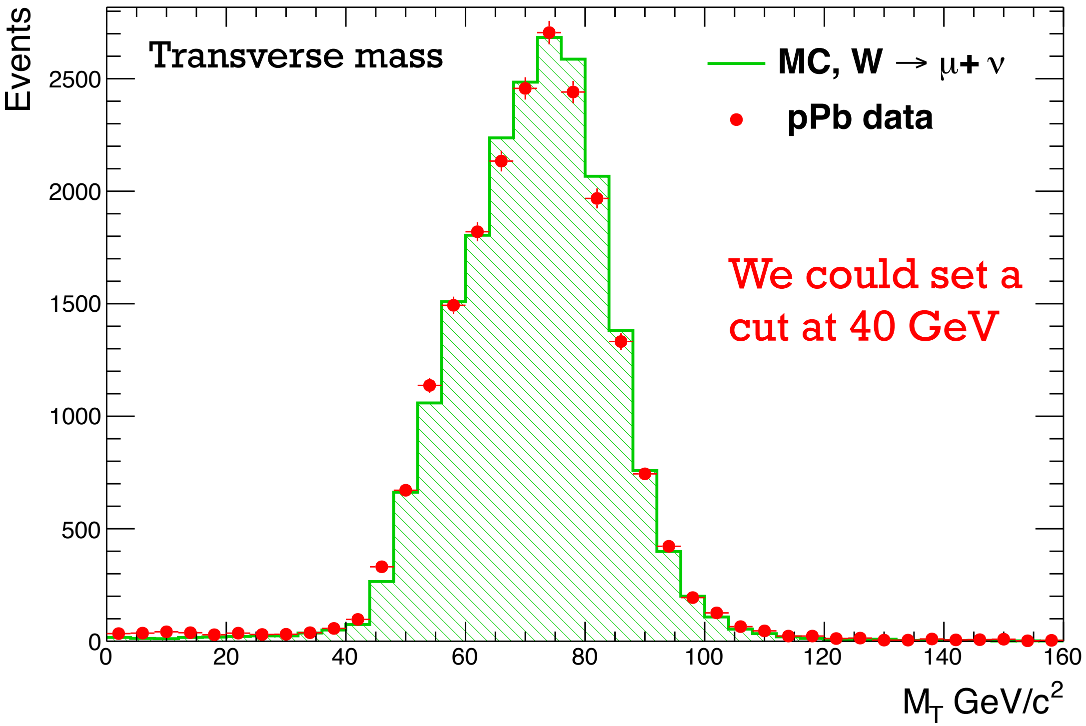
Particles = Particles Flow candidates: muon, electron, photon, charged hadrons and neutral hadrons

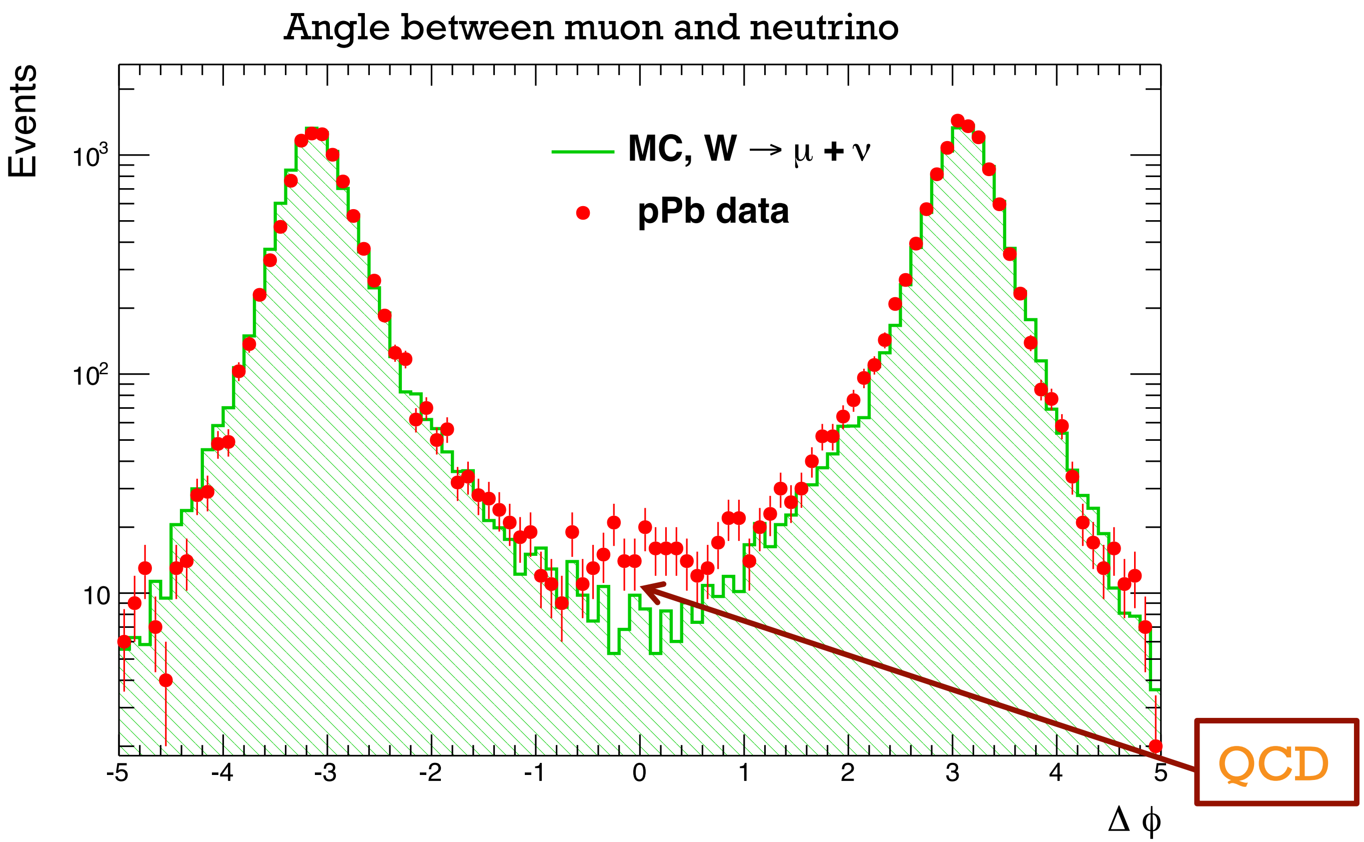




+ Extracting the W yields with cuts?

From the MET and mT cuts, we get a sample with only 3-6% background left:

- QCD with heavy quarks inside jets decaying into $\mu + \nu$
- Z ➔ $\mu^+ + \mu^-$ with one of the two muons passing the analysis cut and the other outside the acceptance
- W ➔ $\tau + \nu$ ➔ $\mu + \nu$



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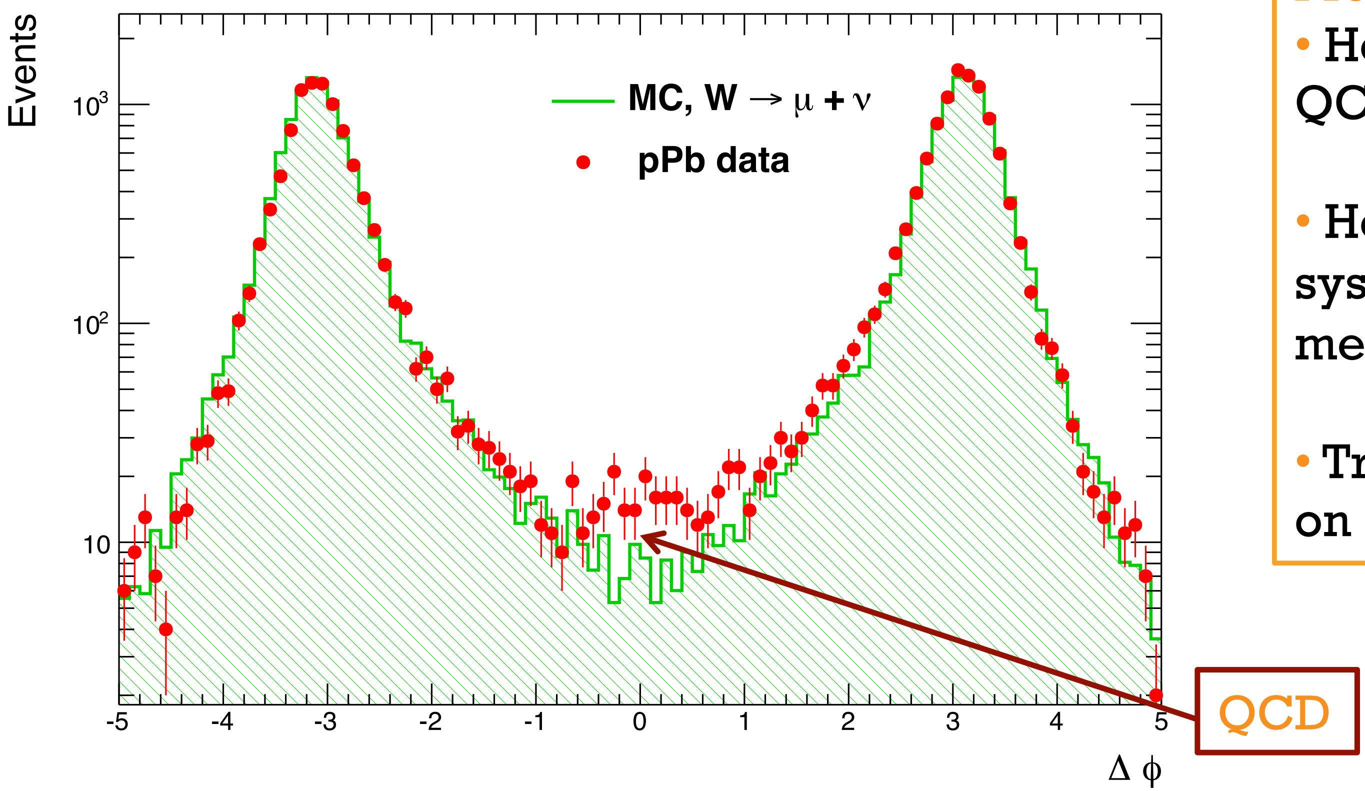
- W ➔ τ + ν ➔ μ + ν

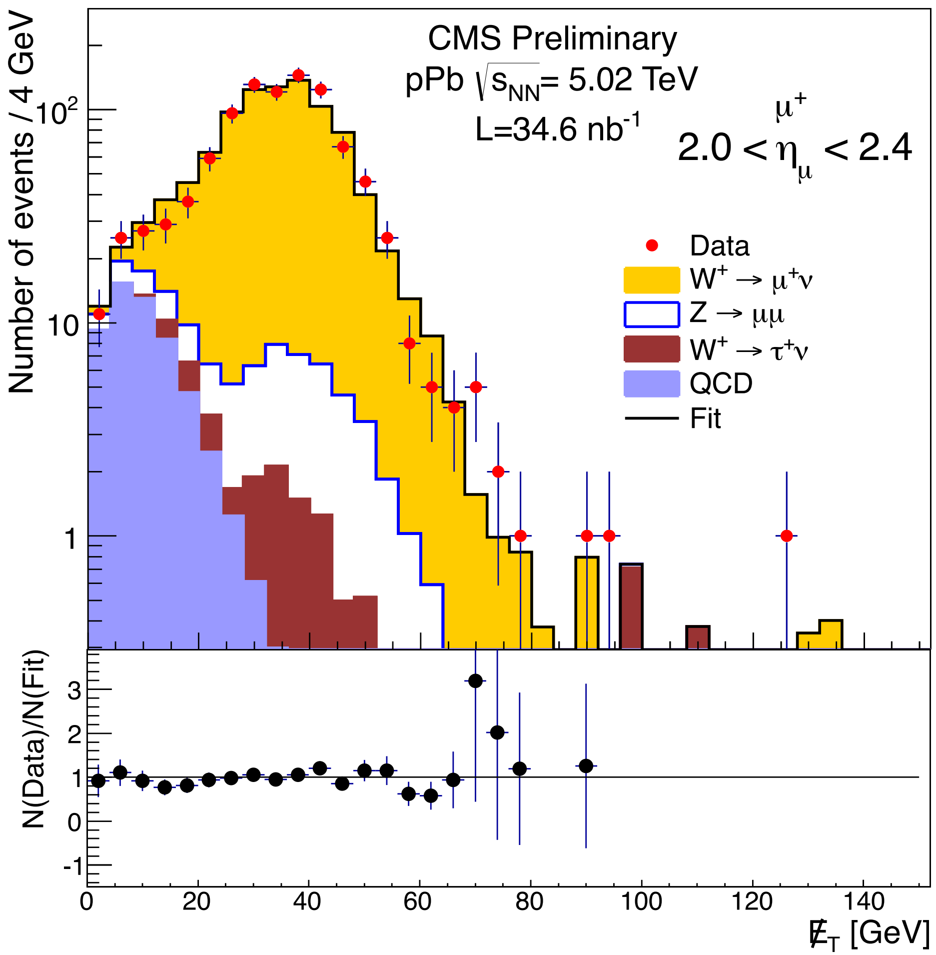
Angle between muon and neutrino

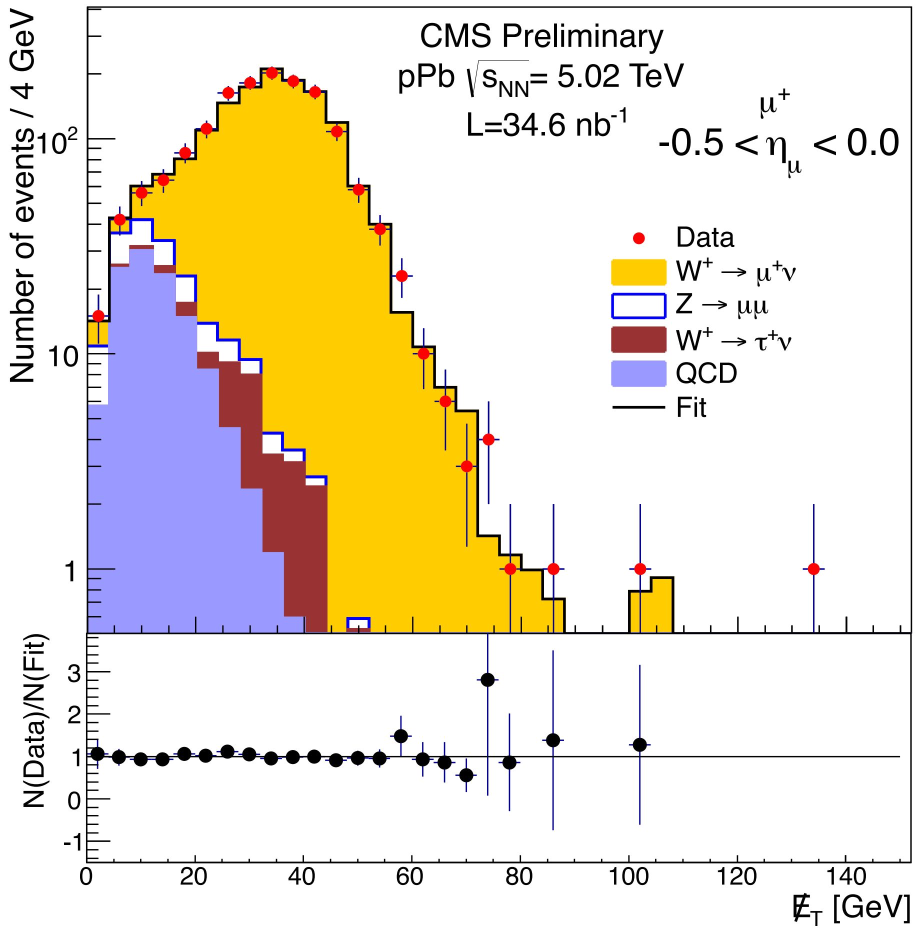


Problems:

- How to estimate the QCD contamination ?
- How to establish a systematic on this method?
- Tree cuts that depends on the MET resolution…

+ MET templates

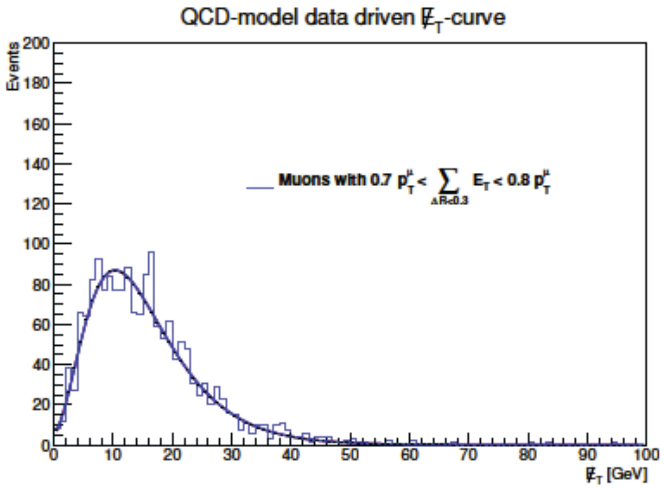


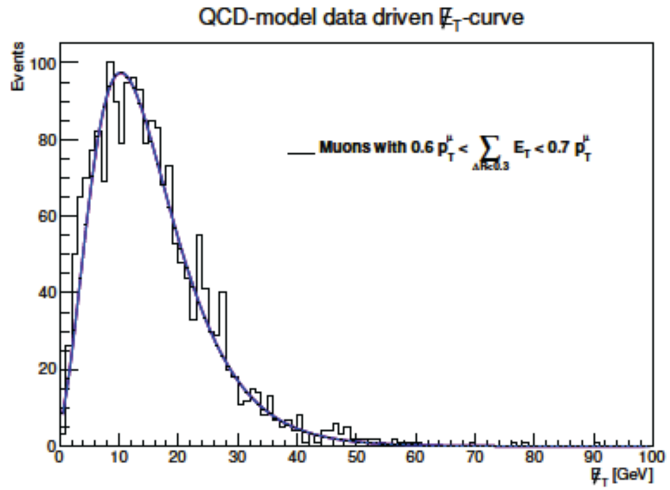


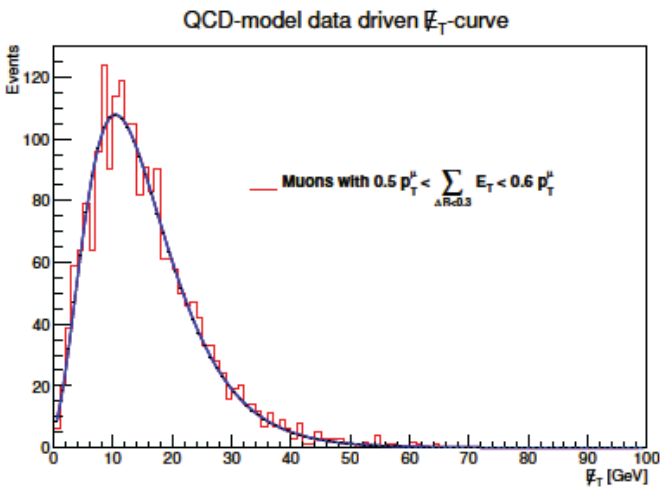
+ MET fitting

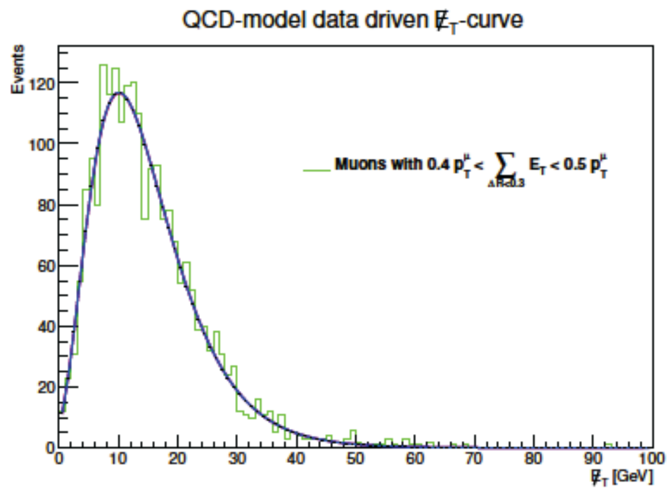
Muon QCD

- Low QCD contamination and low non-isolated muons
- 4 sets of (β , α X_0) on only one η bin [-2.4,2.4]









+ MET fitting

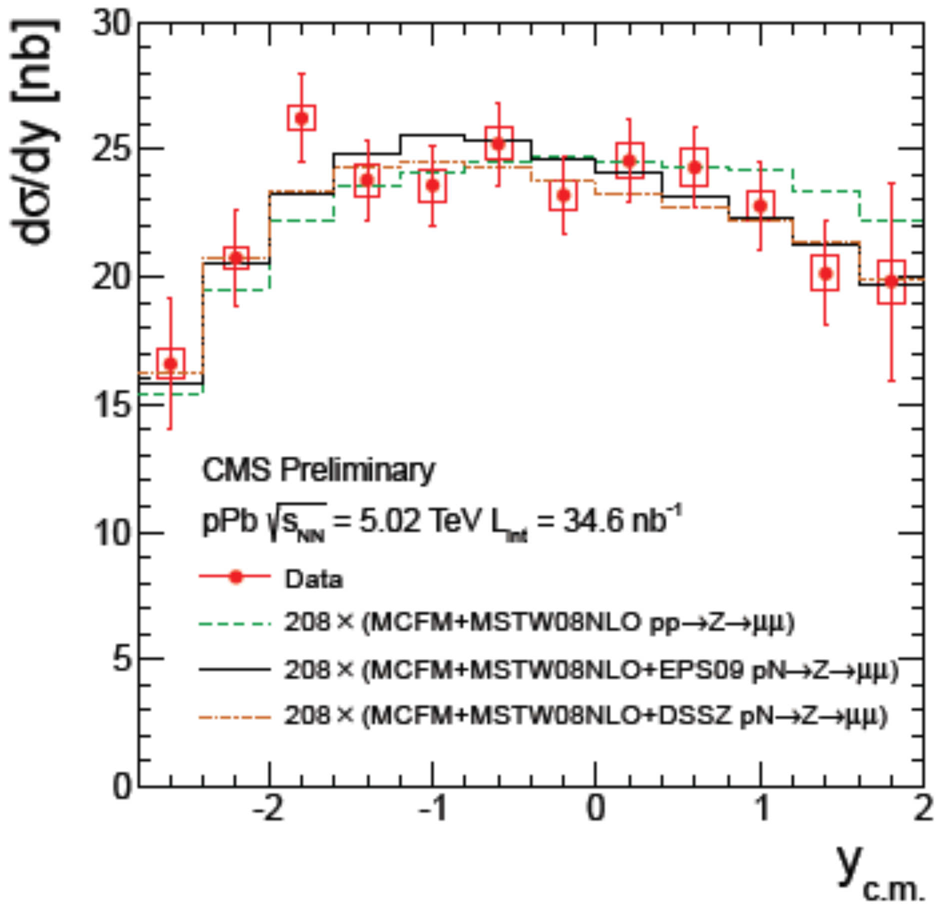
4) Systematic

QCD systematic:

- From 0.3 to 2 % with muon channel
- From 0.8 to 3.8 % with electron channel

Electroweak systematic:

- The W signal over background (Z and W τ) is fixed to the theoretical cross sections in pp collisions (k1 and k2)
- We need to take into account the effects on nPDFs not taken into account in k1 and k2
- Looking at Z analysis results we set a limit at 20% (conservative): between 1-3%.

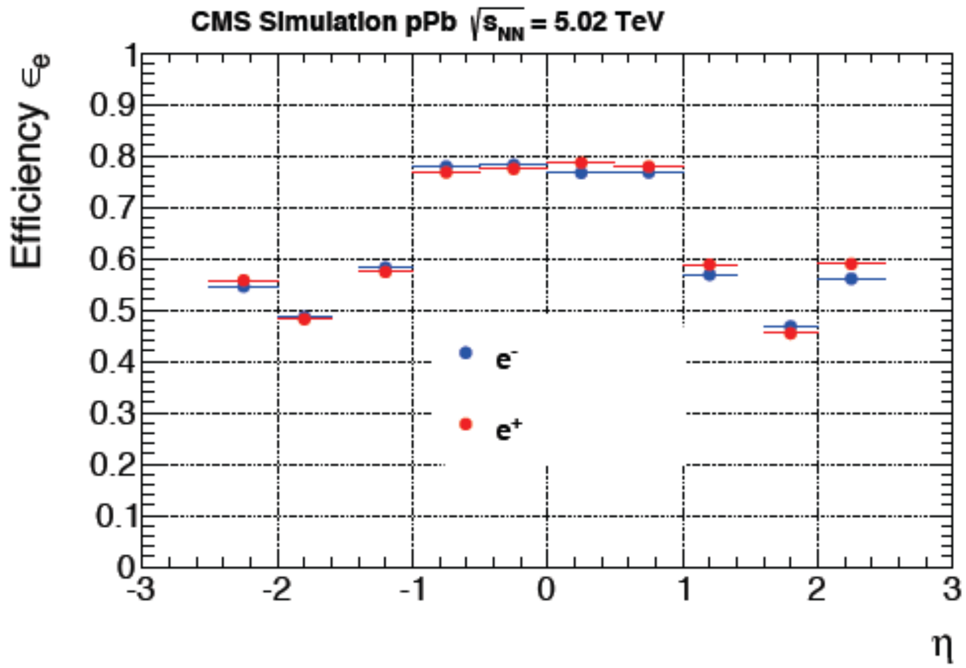


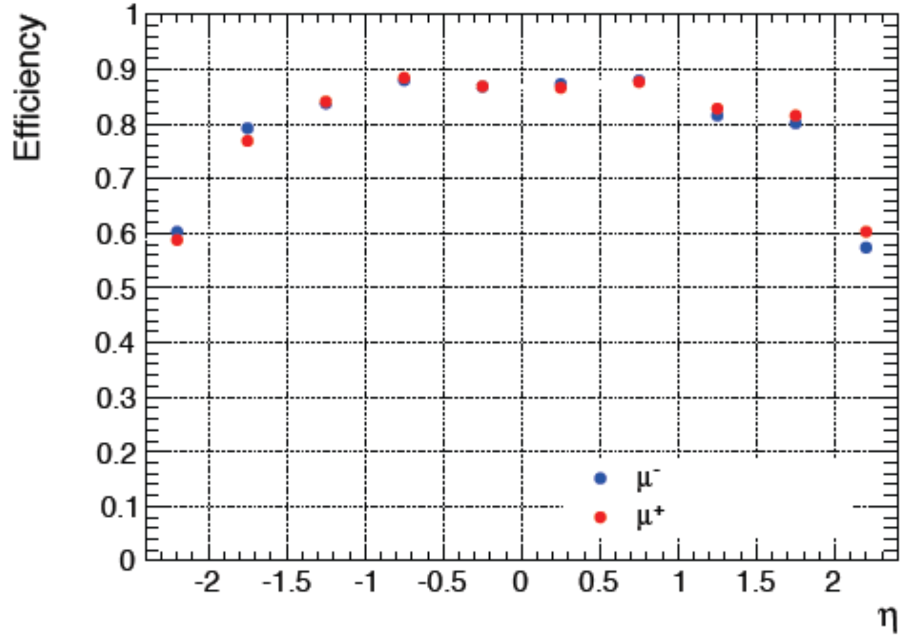
+ Analysis strategy

- Single lepton selection
- MET fitting
- **Single lepton efficiency**
- Scales Factors on single lepton Tag and Probe
- Cross section
- Asymmetry

$$N^{\mathrm{corr}} = \frac{N^{\mathrm{raw}}}{\epsilon_{\mathrm{all}}^{\mathrm{MC},W} \times \mathrm{SF}}$$

+ Single lepton efficiency





+ Analysis strategy

- **Single lepton selection**
- **MET fitting**
- **Single lepton efficiency**
- **Scales Factors on single lepton Tag and Probe**
- **Cross section**
- **Asymmetry**

$$N^{\mathrm{corr}} = \frac{N^{\mathrm{raw}}}{\epsilon_{\mathrm{all}}^{\mathrm{MC},W} \times \mathrm{SF}}$$

+ Scales Factors on single lepton Tag and Probe

- To correct the MC efficiency from eventual bias we use the Tag and Probe method on Z events
- We define 3 sub-efficiency $\varepsilon_{\text{Reco}}$, $\varepsilon_{\text{Id+Iso}}$, $\varepsilon_{\text{trig}}$
- SF are define for each η bin

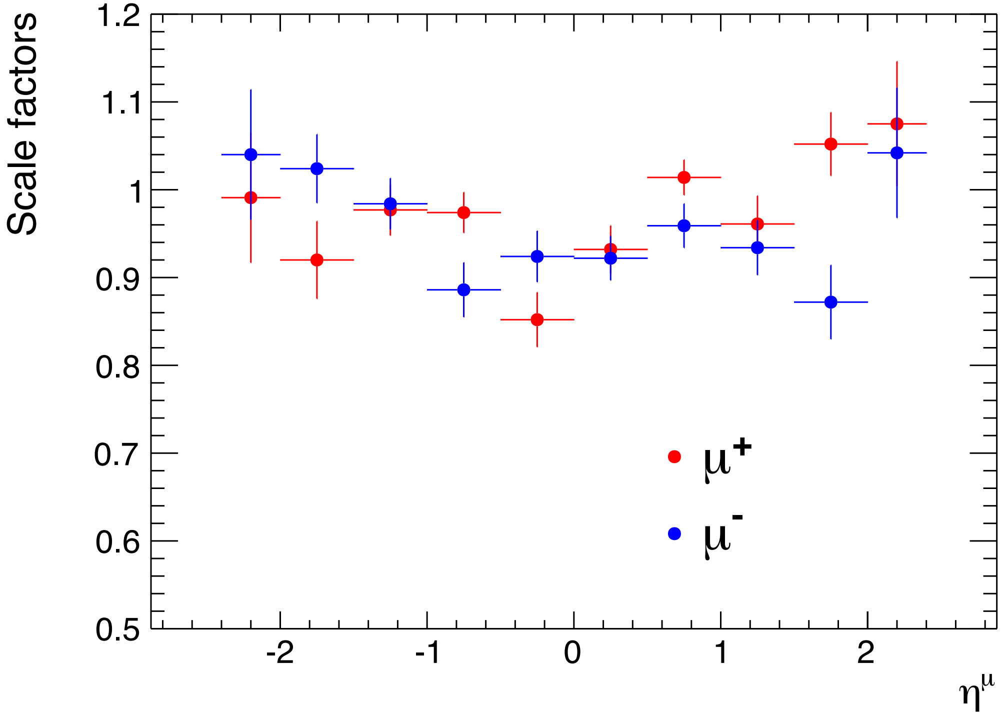
$$SF(\eta) = \frac{(\varepsilon_{\text{Reco}} * \varepsilon_{\text{Id+Iso}} * \varepsilon_{\text{trig}})_{\text{Data}}}{(\varepsilon_{\text{Reco}} * \varepsilon_{\text{Id+Iso}} * \varepsilon_{\text{trig}})_{\text{MC}}}$$

+ Scales Factors on single lepton Tag and Probe

3) Muon SF

• The TnP measurements are dominated by the limited data statistics. The main systematic is then the sum of the tree TnP data errors: around 3%.

• In addition the difference between the Efficiency true and the product of the three MC TnP, is taken as systematic (MC closure test). At maximum 0.9%.



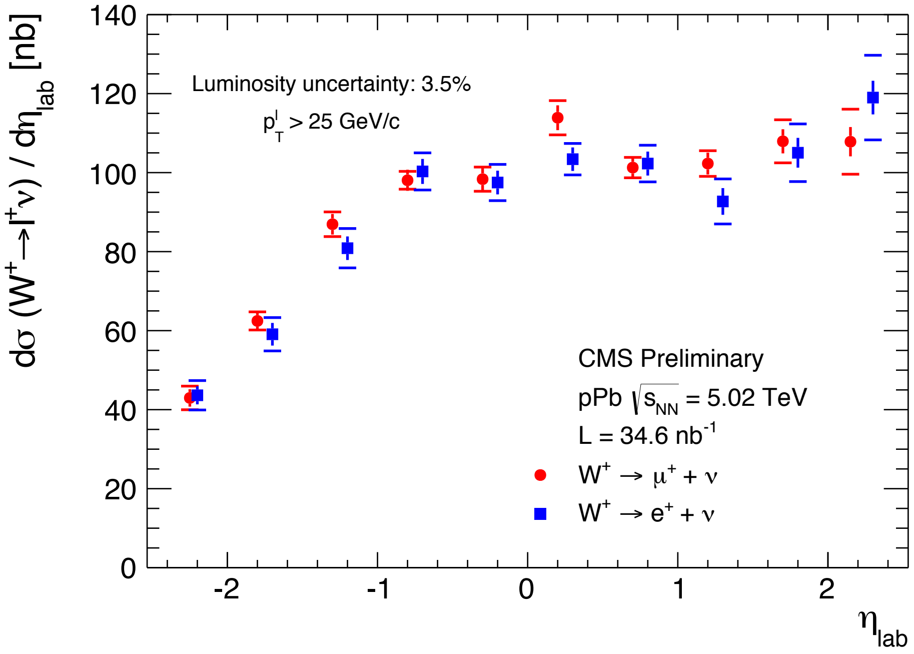
+ Analysis strategy

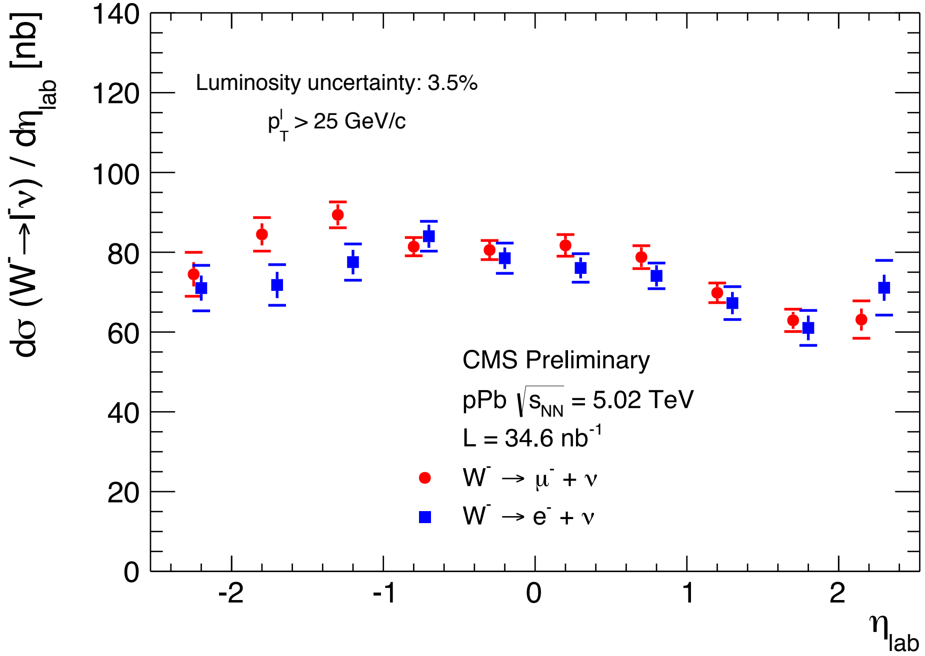
- Single lepton selection
- MET fitting
- Single lepton efficiency
- Scales Factors on single lepton Tag and Probe
- **Cross section**
- Asymmetry

$$N^{\text{corr}} = \frac{N^{\text{raw}}}{\epsilon_{\text{all}}^{\text{MC},W} \times \text{SF}}$$

+Cross section

HIN-13-007

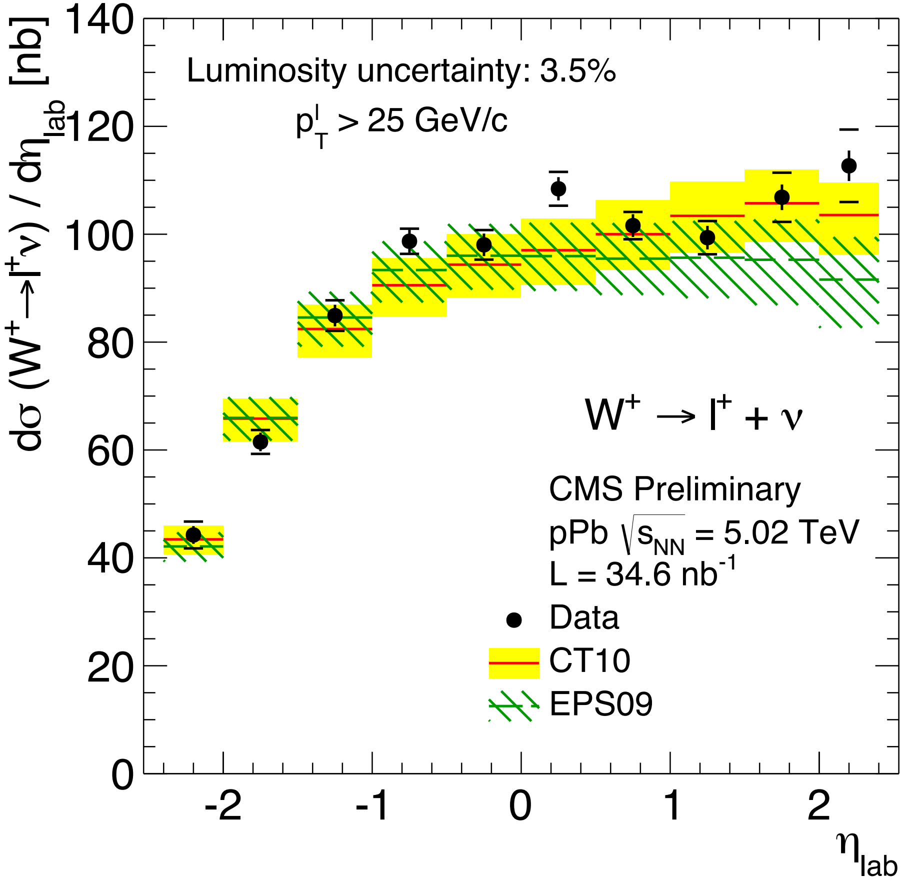


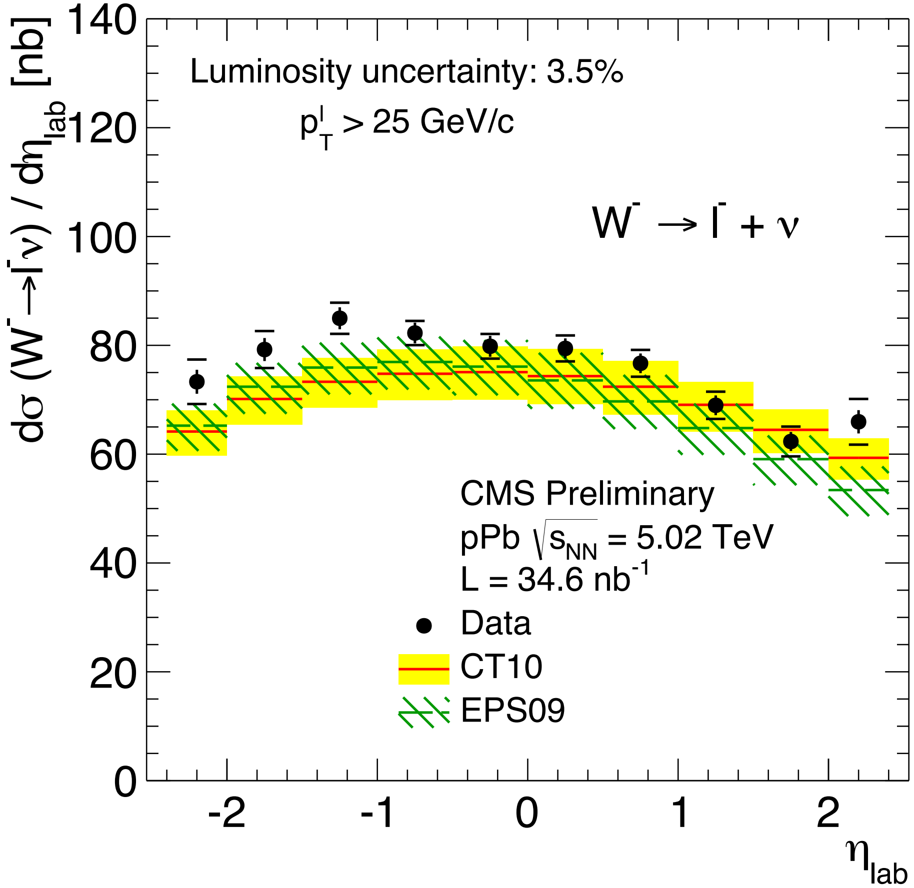


- Cross section tables are provided in the PAS
- W+ are found mainly in the proton region fragmentation because of u valence quark coming from boosted proton

+ Cross section

HIN-13-007





- Results are combined according to the standard blue method
- There are no correlations bin to bin
- The two PDFs set have been provided by C.Salgados and H.

+ Analysis strategy

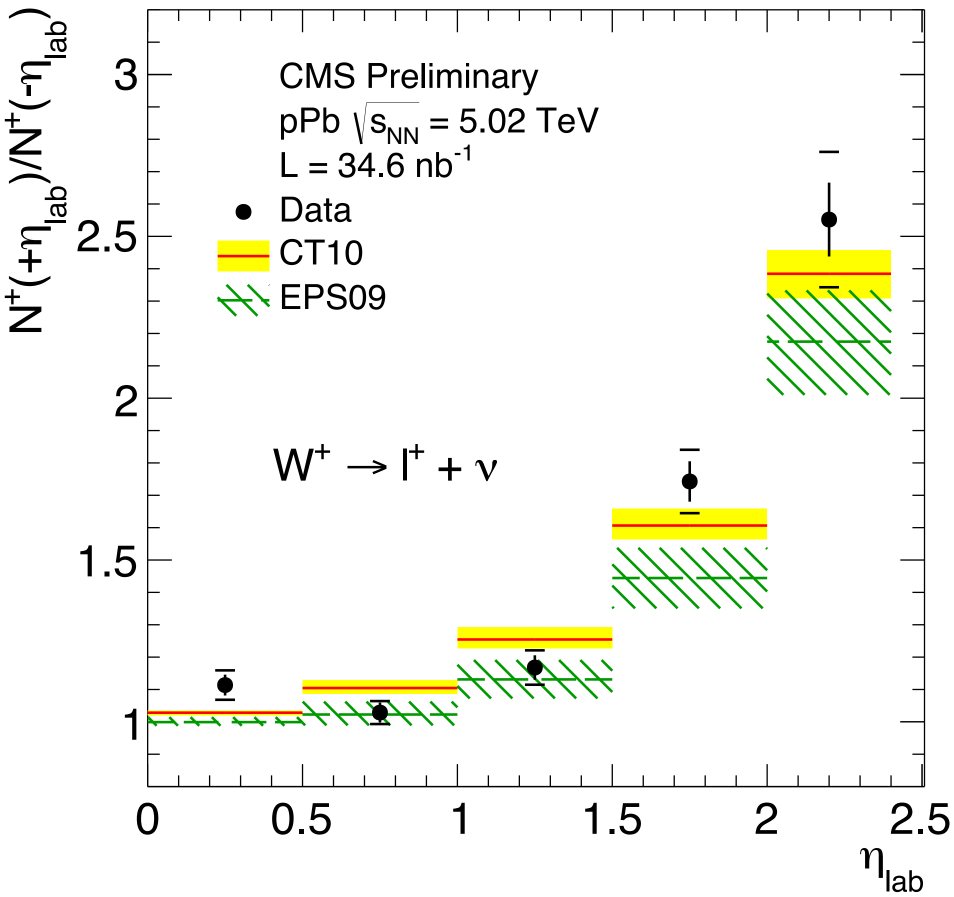
- Single lepton selection
- MET fitting
- Single lepton efficiency
- Scales Factors on single lepton Tag and Probe
- Cross section
- **Asymmetry : N^{corr} / L**

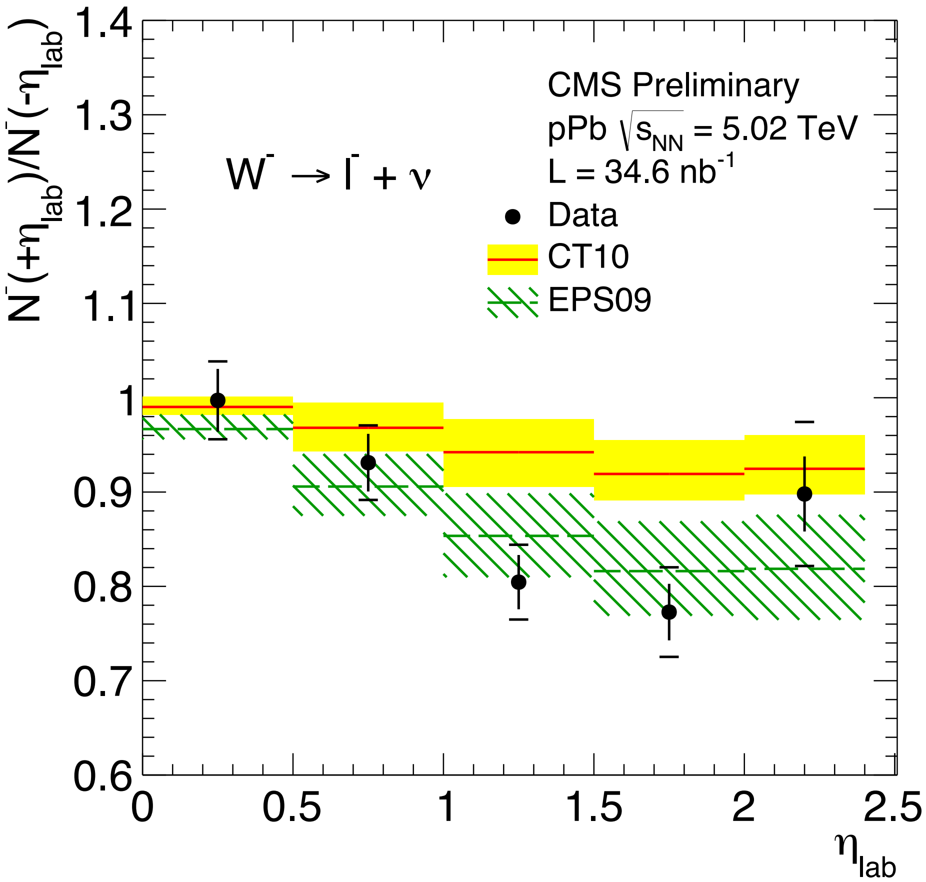
$$N^{\mathrm{corr}} = \frac{N^{\mathrm{raw}}}{\epsilon_{\mathrm{all}}^{\mathrm{MC},W} \times \mathrm{SF}}$$

+ Asymmetry

1) Forward/Backward W+ and W-

HIN-13-007



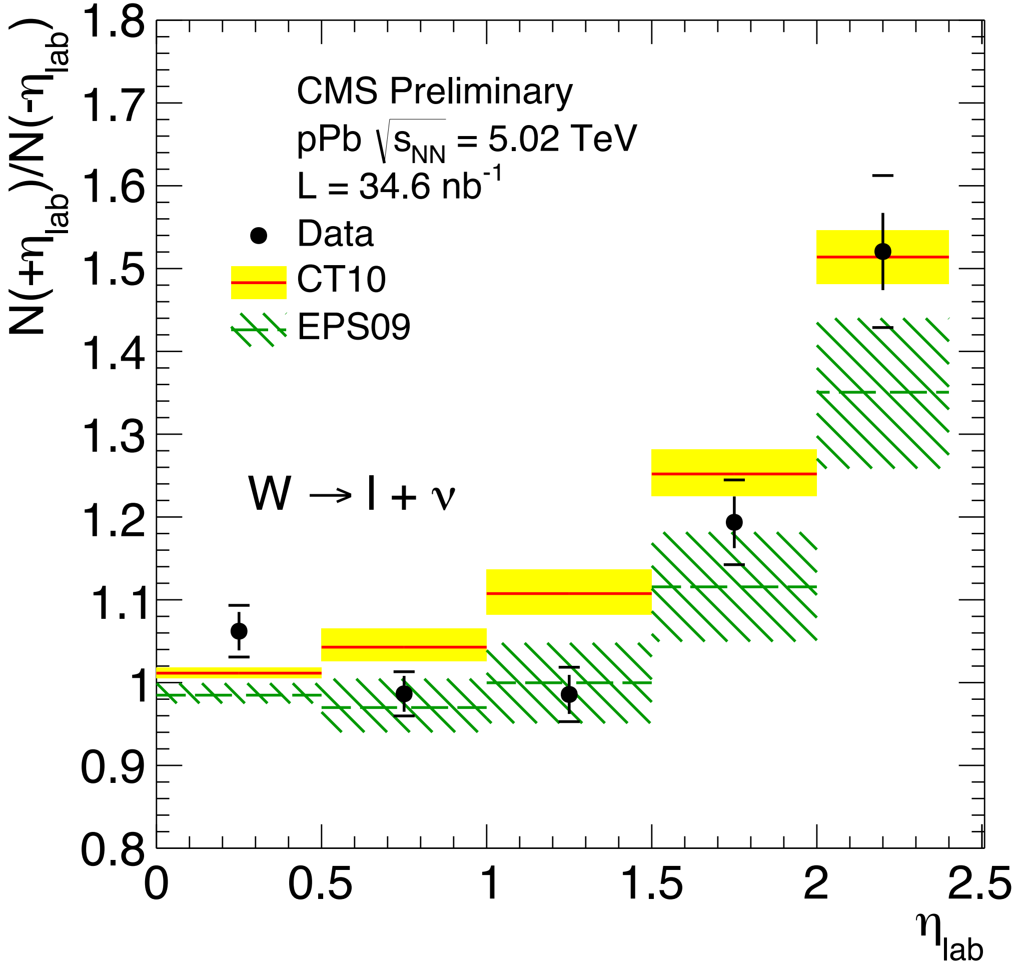


At High rapidity we probe the valence quark at high X (proton) compare to the sea quark at low X (lead)

+ Asymmetry

2) Forward/backward W

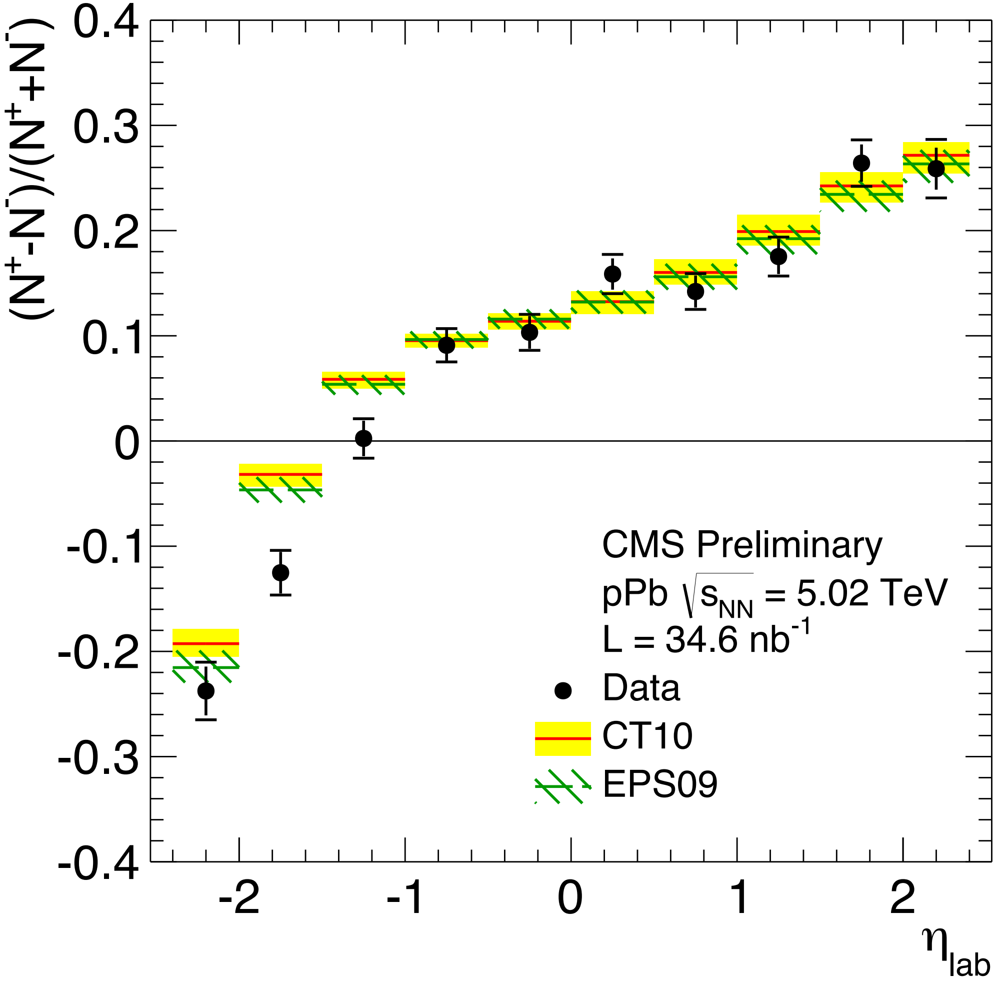
HIN-13-007



+ Asymmetry

HIN-13-007

1) Charge asymmetry

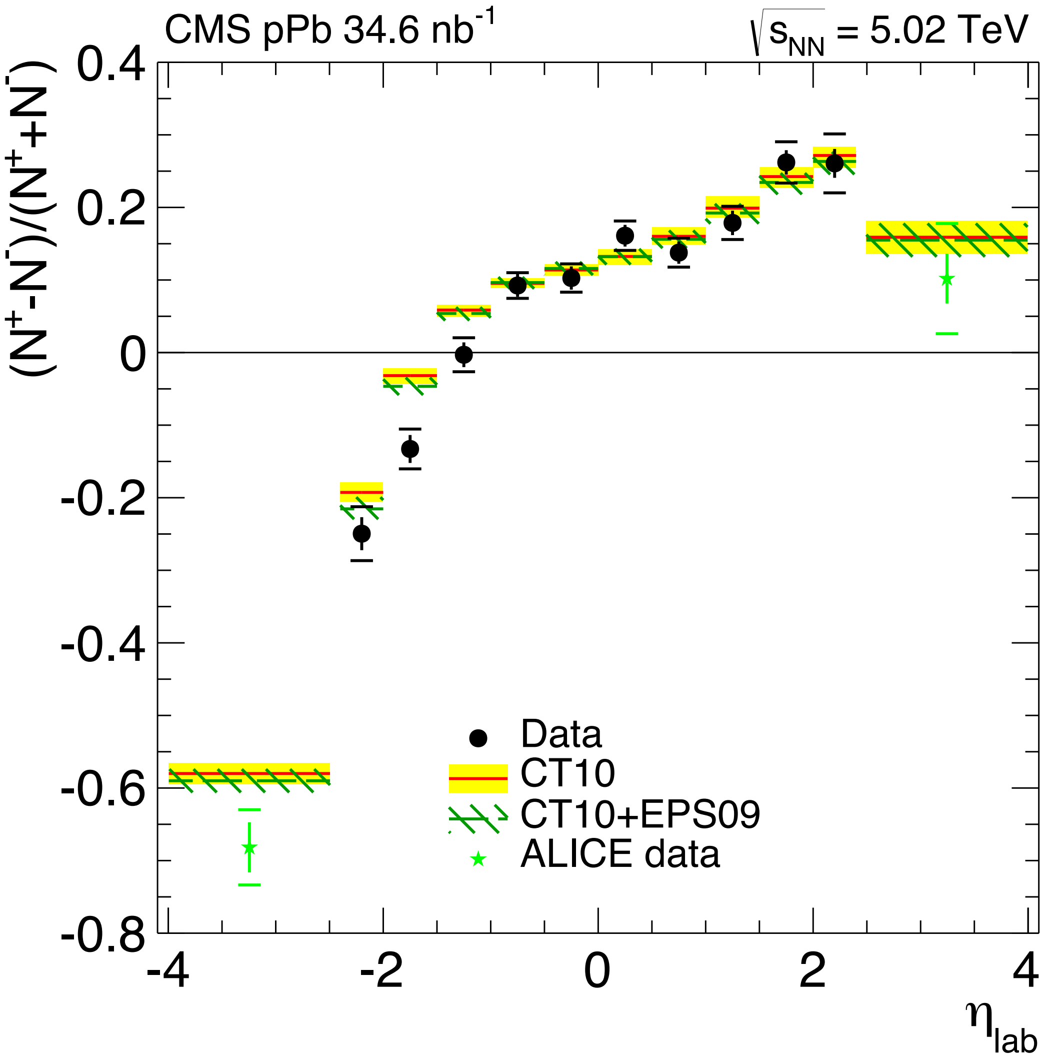


$$\frac{N(\mu^+) - N(\mu^-)}{N(\mu^+) + N(\mu^-)}$$

- Isospin effect: difference between the W- and W+ because of their sensitivity to quarks contents.

- The charge asymmetry is supposed to be independent of the nuclear modifications of partons densities, excepted if R(u)≠R(d)

+ Bonus: ALICE +CMS points



https://indico.cern.ch/event/219436/session/2/contribution/252/material/poster/0.pdf

Back up

+ MET fitting

4) Systematic

QCD:

- Change function: asymmetric lognormal, 4 parameters
- Ideally we would need an other set of data… Production of toy experiment

1) Production of a data sample where the QCD varies according to the asymmetric lognormal

$$f(x) = C/\sqrt{2\pi\sigma_L\sigma_R}\exp(-0.5((\log(x)-x_0)/\sigma_L)^2) \quad \text{if} \log(x) < x_0$$
$$f(x) = C/\sqrt{2\pi\sigma_L\sigma_R}\exp(-0.5((\log(x)-x_0)/\sigma_R)^2) \quad \text{if} \log(x) > x_0$$

2) The rest of the pseudo data: W + Z + W τ id estimated by subtracting the obtained QCD to the selected data.

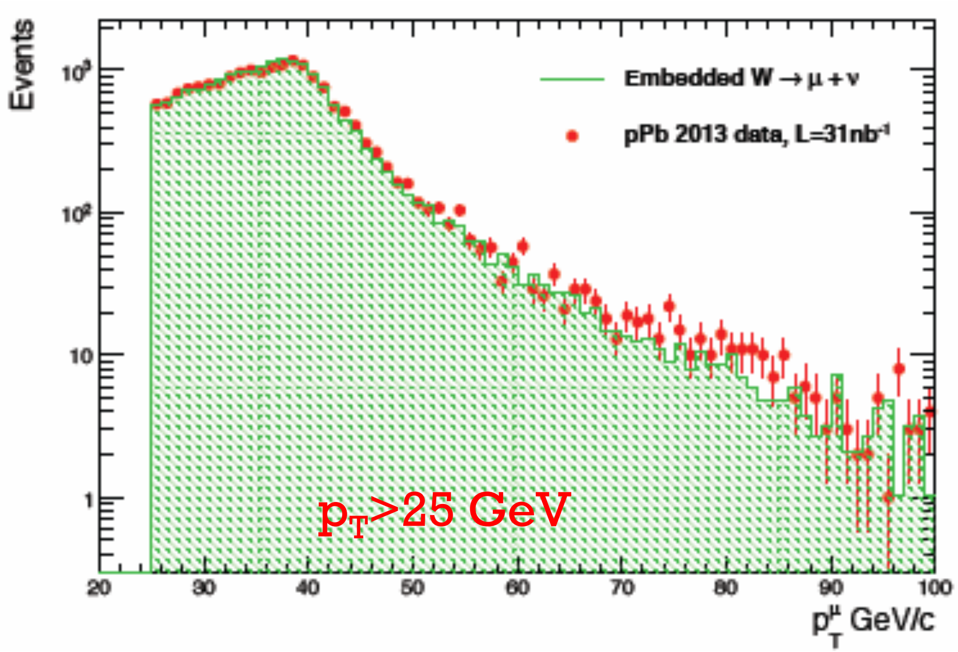
3) 1000 pseudo experiment per lepton charge and η bin

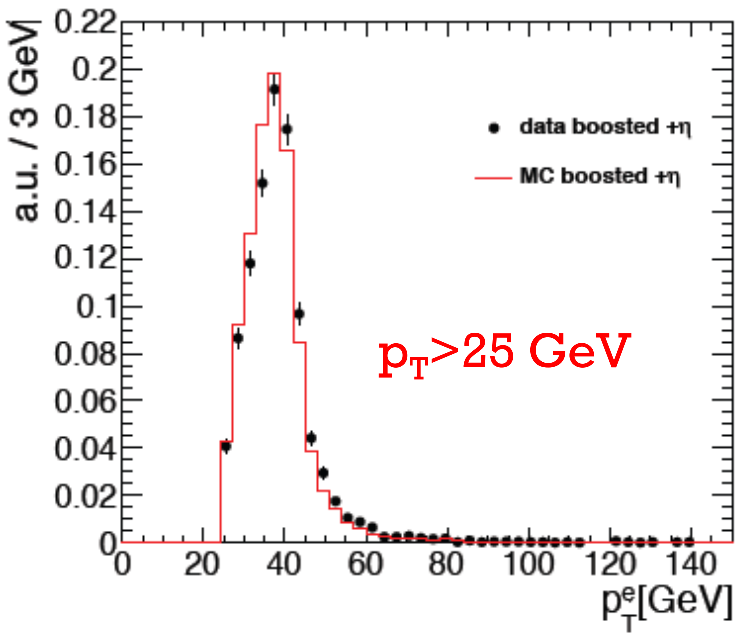
4) Each pseudo data set is fitted with the analysis function

5) The yields difference is taken as systematic coming from QCD modeling

+ Single lepton selection

2) High p_T lepton





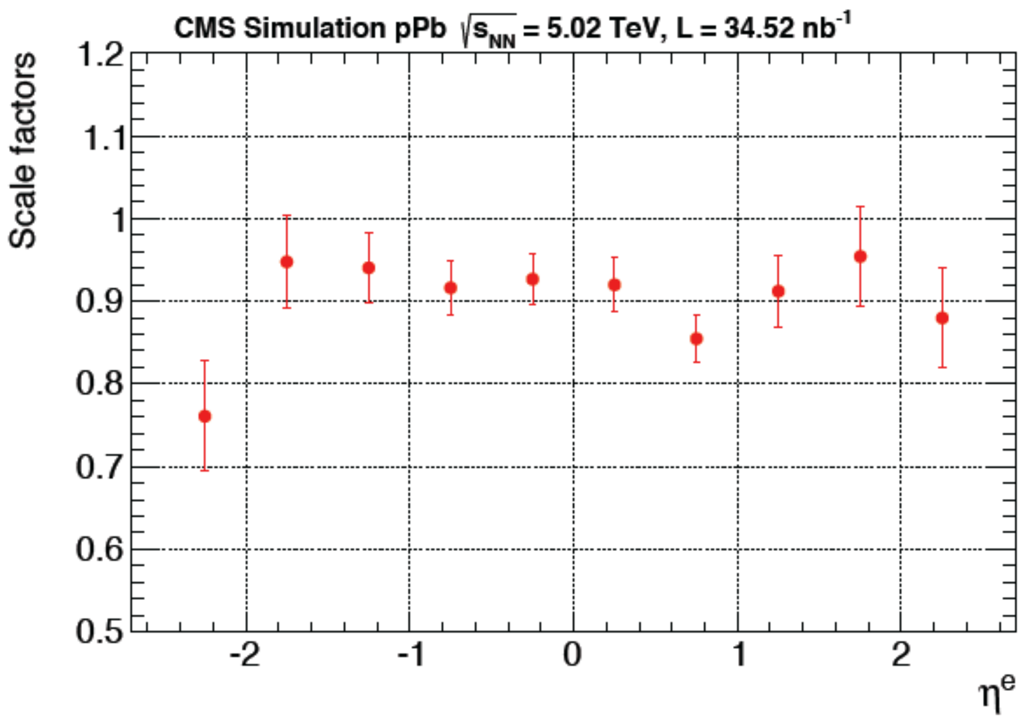
+ Scales Factors on single lepton Tag and Probe

3) Electron total SF

- The TnP measurements are dominated by the limited data statistics. The main systematic is then the sum of the tree TnP data errors

- In addition the difference between counting method and fit is taken as systematic

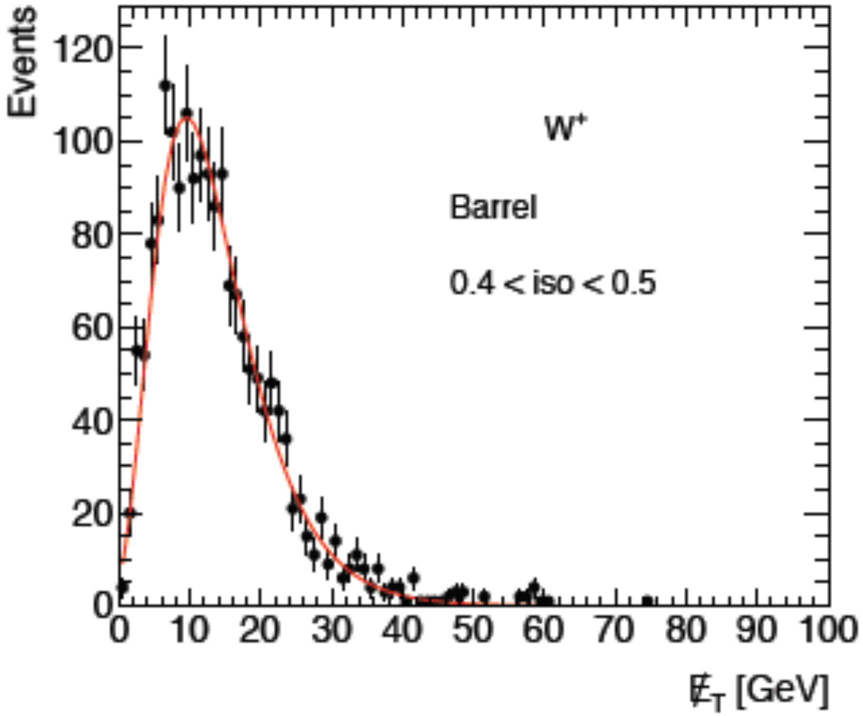
- For charge asymmetry theses contributions will cancel since they are the same for both charge in a given η bin

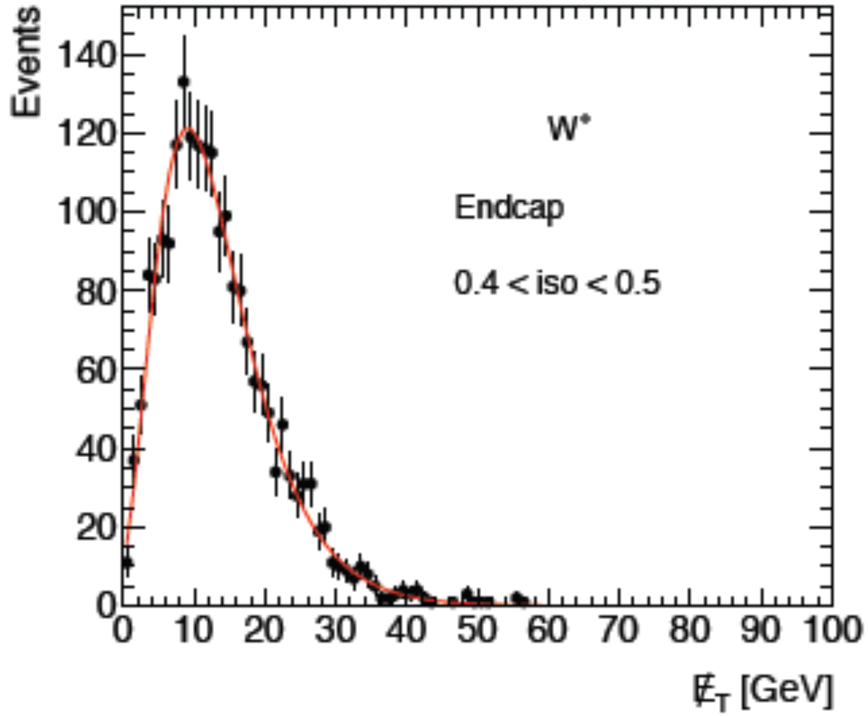


+ MET fitting

2) Electron QCD

- Large QCD contamination in end caps
- 4 sets of (β , α X_0) for barrel region and 4 others for the end caps region
- We also looked per charge

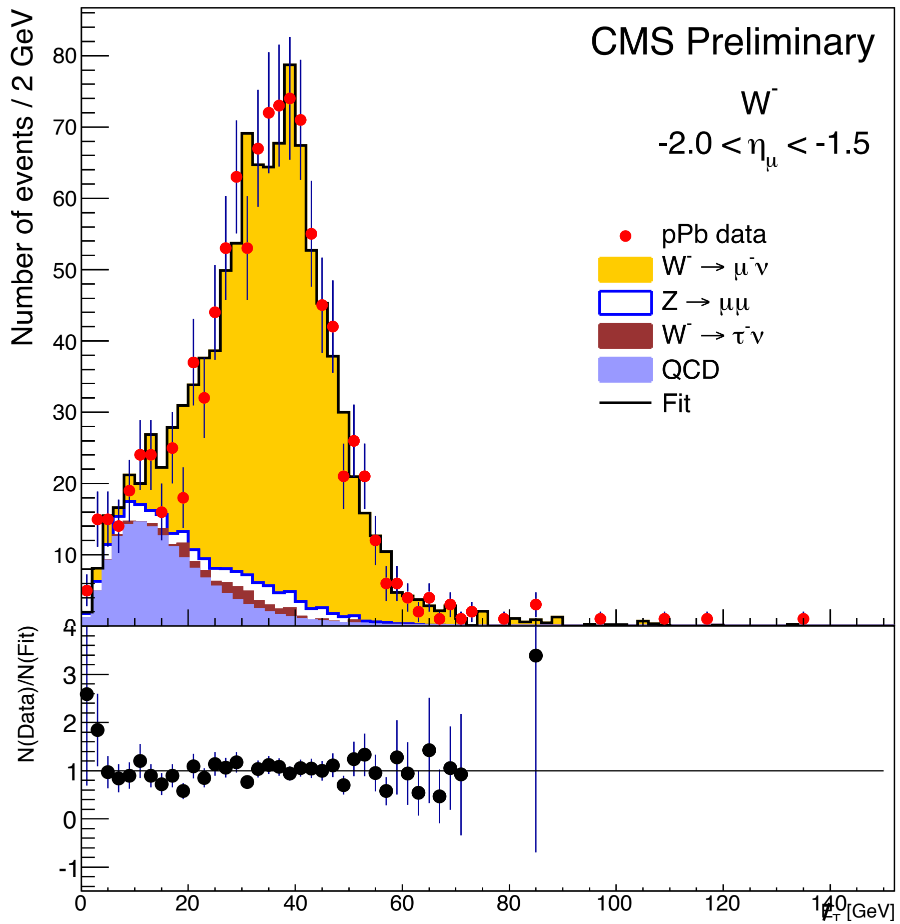


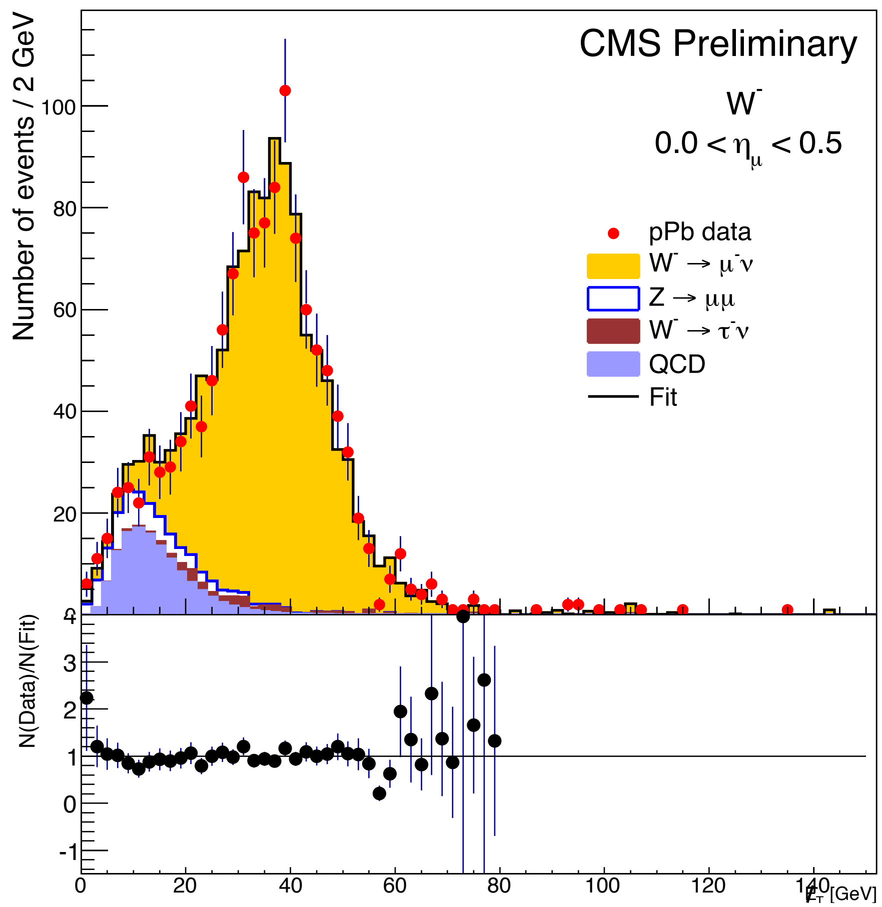


+ MET fitting

3) Templates

Muon

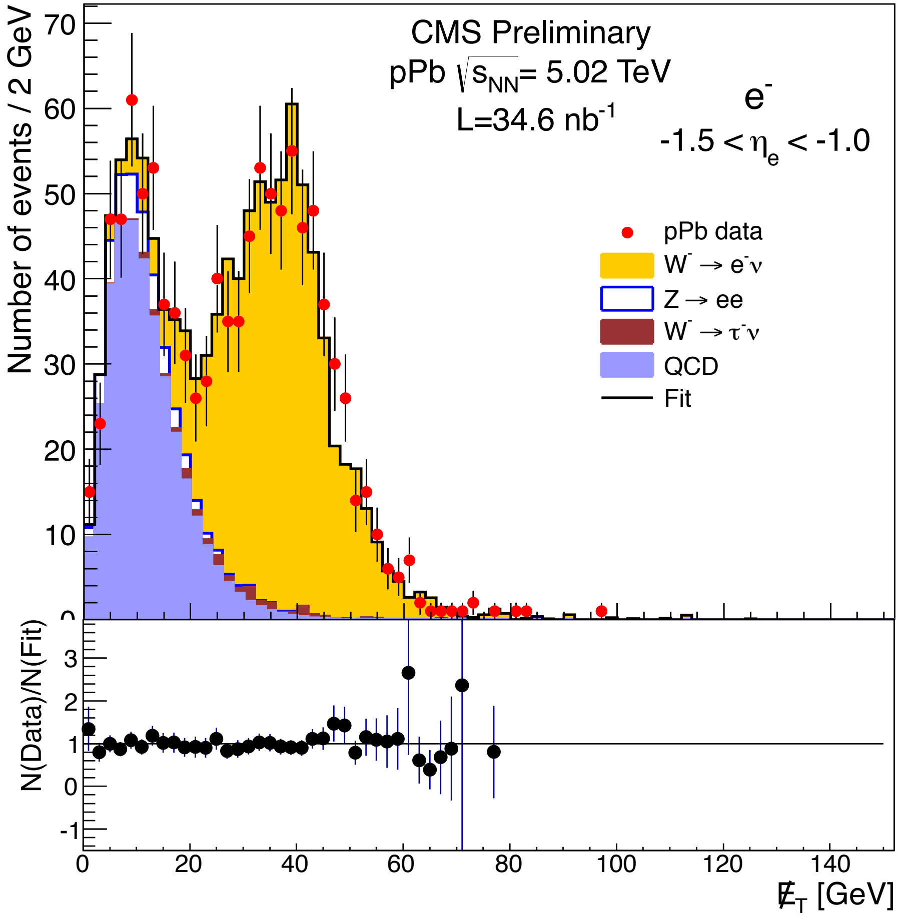


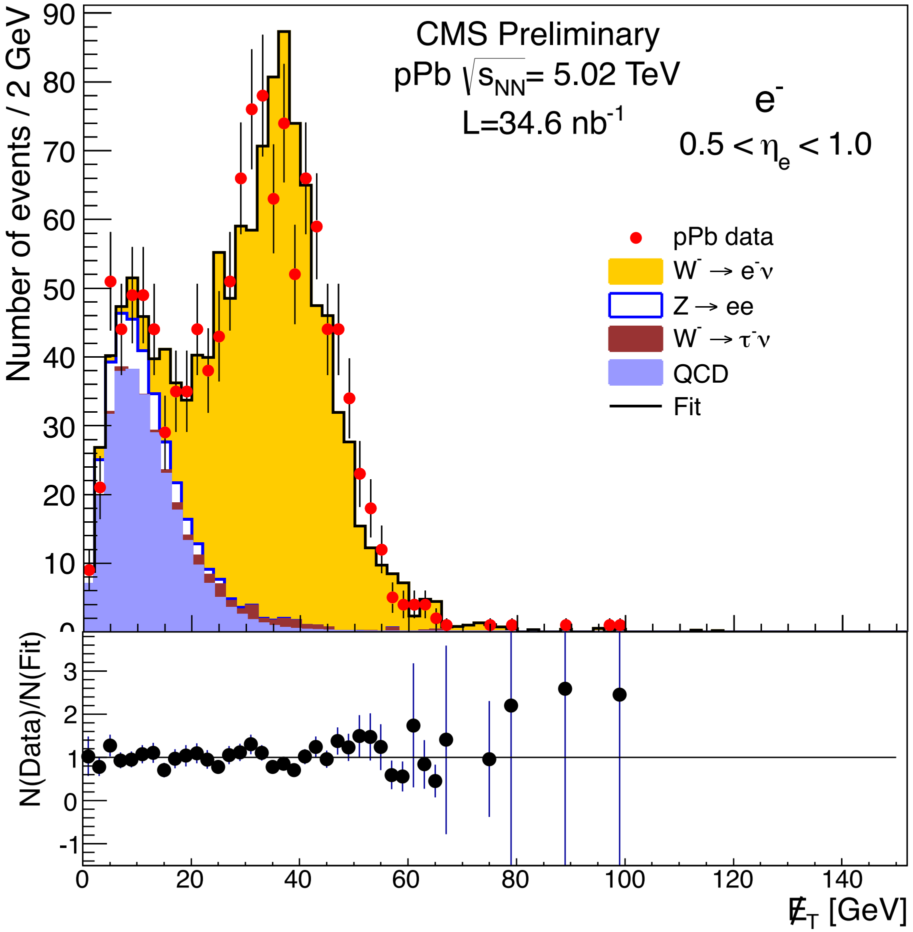


+ MET fitting

3) Templates

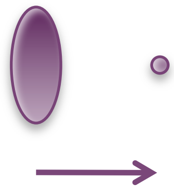
Electron



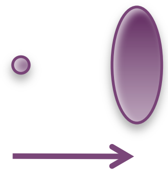


+ Data taking condition

- **One Pbp run**: lead going toward + η at $L_{int} = 20.7\ nb^{-1}$
  - [210 498] to [211 256]



- **One pPb run**: proton going toward + η at $L_{int} = 14\ nb^{-1}$
  - [211 313] to [211 631]



- For the W analysis the results need to be in the same boost configuration
  - Second run is flipped in η (the one with less statistic)

+ MET fitting

1) W, Z and W_τ

- **Shape:**
  - These two embedded simulation are passed over the analysis cut and the selected lepton fill MET histograms: T_{W}, T_{Z} and $T_{W\tau}$
- **Normalization:**
  - Correction for acceptance and efficiency
    - $Acc\_W_l * Eff\_W_l$ = N_selected/N-generated : $A_W * \varepsilon_W$
    - Acc_Z *Eff_Z(mimicking W) = N_selected/N-generated : $A_Z * \varepsilon_Z$, $A_{W\tau} * \varepsilon_{W\tau}$
  - The W is normalized to the W theoretical cross section σ_W
  - The Z and W_τ contamination are normalized to the W signal
    - The ratio of the theoretical Z and W cross sections $\mathbf{K_1} = \sigma_Z / \sigma_W$
    - The W_τ branching ratio $\mathbf{K_2}$

$$N(\not{E}_T) = \{\sigma_W \times [\mathcal{A}_W \cdot \epsilon_W \cdot \mathcal{T}_W(\not{E}_T) + K1 \cdot \mathcal{A}_Z \cdot \epsilon_Z \cdot \mathcal{T}_Z(\not{E}_T) + K2 \cdot \mathcal{A}_{W\tau} \cdot \epsilon_{W\tau} \cdot \mathcal{T}_{W\tau}(\not{E}_T) + \mathcal{F}_{QCD}(\not{E}_T)]\} \times \mathcal{L}$$

+ MET fitting

2) QCD

- The function used to fit the MET has 3 parameters: β , α and X_0

$$F(x) = (x+X_0)^{\alpha} \exp(\beta \sqrt{(x+X_0)})$$

- β will be fixed thanks to data driven method. α and X0 let free but cross checked with values from data driven method.

- These 3 parameters are extracted from data:
  - The shape of MET for events having non isolated lepton is fitted with this function
  - 4 different area of no isolation are chosen: [0.4,0.5], [0.5,0.6], [0.6,0.7] and [0.7,0.8], each one giving one (β , α X_0) set
  - The 4 (β , α X_0) set are plotted versus the isolation and the fit extrapolation is taken as β_s , α_s, X_{0s} in the signal region (iso<0.1)

$$N(\not{E}_T) = \{\sigma_W \times [\mathcal{A}_W \cdot \epsilon_W \cdot \mathcal{T}_W(\not{E}_T) + K1 \cdot \mathcal{A}_Z \cdot \epsilon_Z \cdot \mathcal{T}_Z(\not{E}_T) + K2 \cdot \mathcal{A}_{W\tau} \cdot \epsilon_{W\tau} \cdot \mathcal{T}_{W\tau}(\not{E}_T) + \mathcal{F}_{QCD}(\not{E}_T)]\} \times \mathcal{L}$$