Measurement of the Muon Charge Asymmetry in the pp→W(μν)+X Process

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Outline

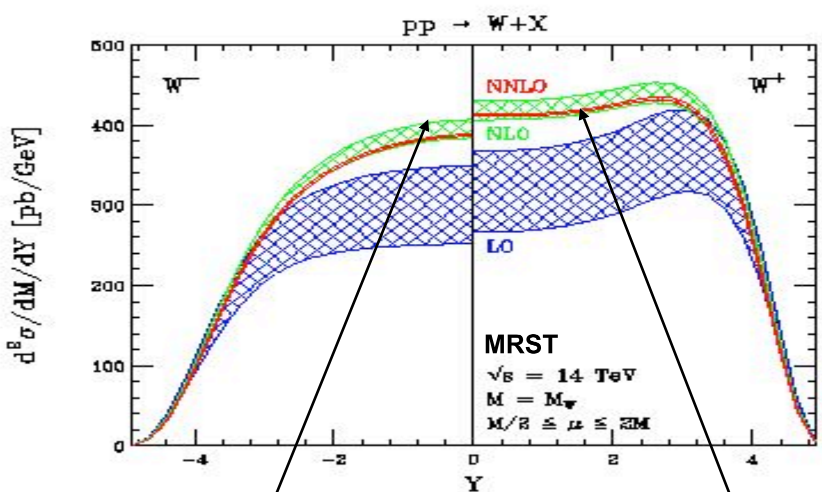
- ✦ Physics motivation
- ✦ Measurement of the Muon Charge Asymmetry

Approved by CMS, EWK-PAS-09-003

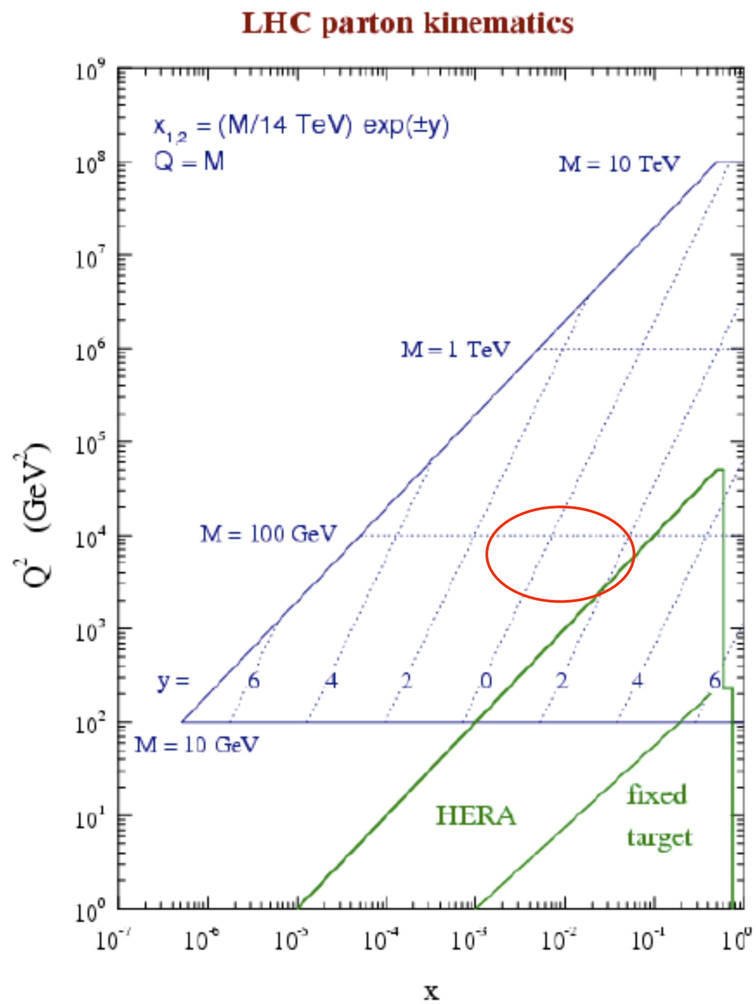
Probing the PDFs at LHC

$$\frac{d\,\sigma}{d\ \text{variable}}[pp \to X] \sim \sum_{ij} \left(f_{i/p}(x_1) f_{j/p}(x_2) + (i \leftrightarrow j)\right) \hat{\sigma}$$

- ✦ W/Z cross sections at LHC are at 10s-100s nb.
- ✦ LHC offers unique opportunity to probe Parton Distribution Functions (PDFs), kinematics, sea quarks, etc. $x \in 10^{-2} \sim 10^{-3}$ (central W/Zs)
- ✦ Test higher-order theoretical calculations with W/Z rapidity distributions.



NNLO corrections small ~ few%
NNLO residual scale dependence < 1%



Lepton Charge Asymmetry

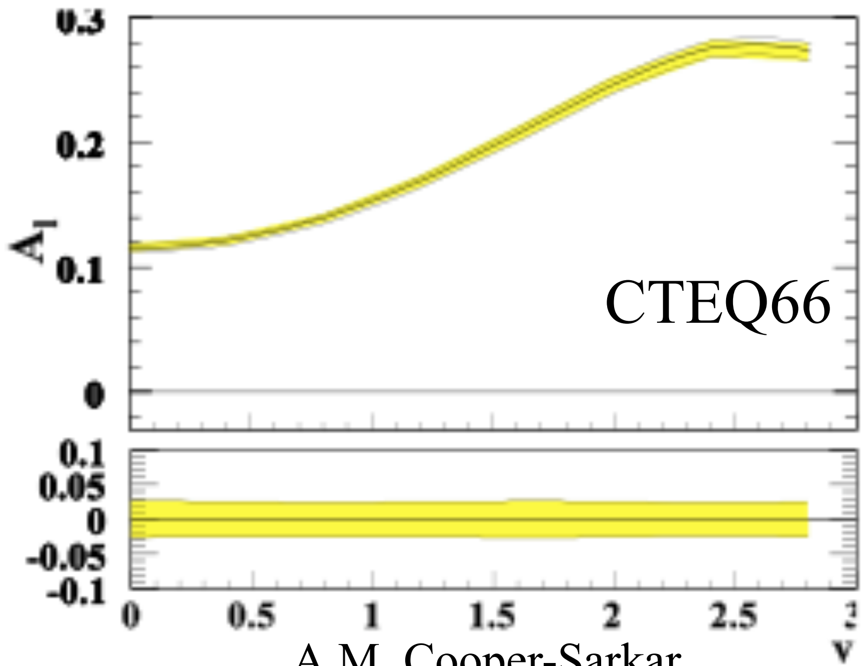
- W boson production can directly probe valence-sea quark ratio at LHC.

$$A_W \approx \frac{u\bar{d} - \bar{u}d}{u\bar{d} + \bar{u}d} \approx \frac{u_{val} - d_{val}}{u_{val} + d_{val} + 2\bar{q}}$$

- However, only the leptons can be accessible directly, ~3.5% theoretical precision (CTEQ66).

$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \rightarrow \mu^+\nu) - \frac{d\sigma}{d\eta}(W^- \rightarrow \mu^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \rightarrow \mu^+\nu) + \frac{d\sigma}{d\eta}(W^- \rightarrow \mu^-\nu)}.$$

- W V-A asymmetry dilutes the expected W asymmetry.
- Acceptance can differ from unity by about 10% when experimental cuts on lepton p^T or MET are applied.



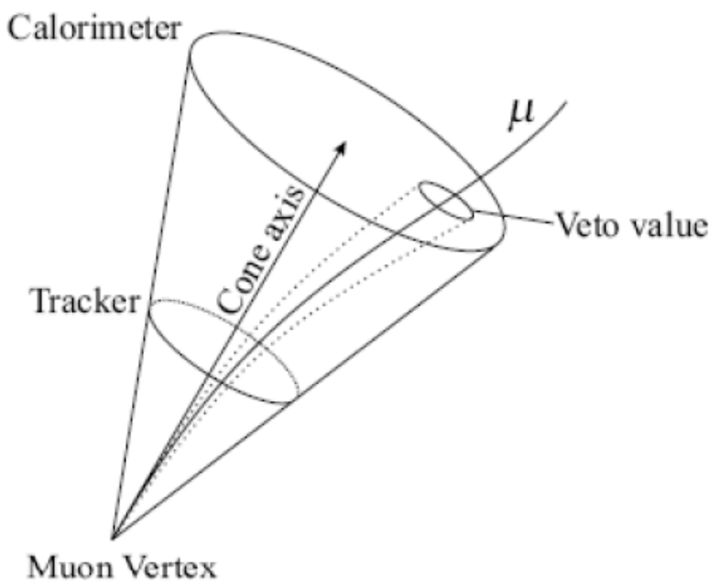
A.M. Cooper-Sarkar, PDF4LHC workshop (2009)

Trigger & Event Selections

- A single muon trigger with p_T > 15 GeV.
- Exactly one muon candidate within full detector coverage($|\eta|$<2.4) per event
  - Associated silicon track hits >=12
  - Silicon track normalized $\chi^2 < 5$
  - Muon p_T > 10 GeV.
- Match muon candidate with trigger object.
- Muon p_T + Iso > 25 GeV, $Iso = \sum E_T$
- Isolation z < 0.05 (reduce QCD background)

$$z = 1 - \frac{p_T}{p_T + Iso}.$$

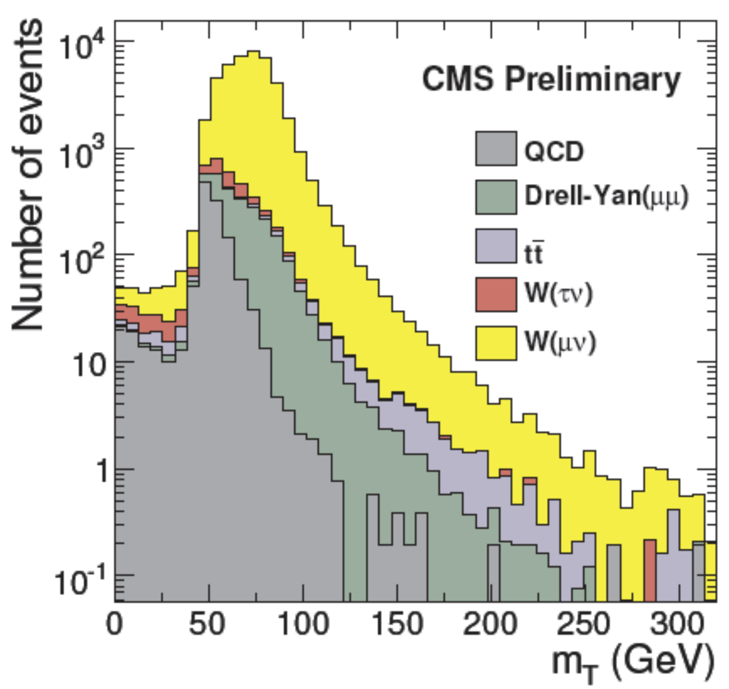
- MET > 20 GeV



Signal efficiency is 53.4% (μ^+) and 60.6%(μ^-) (normalized to generated signal events within $|\eta|$<2.1)

Expected Signal Yields

MC Type	Luminosity (pb^{-1})	$W^+ \to \mu^+\nu$ Events/pb	$W^+ \to \mu^+\nu$ Relative frac. (%)	$W^- \to \mu^-\nu$ Events/pb	$W^- \to \mu^-\nu$ Relative frac. (%)
$W \to \mu\nu$	133.1	2294.3±4.2	91.9±0.2	1623.2±3.5	89.8±0.2
$W \to \tau\nu$	91.8	43.1±0.7	1.70±0.03	32.9±0.6	1.80±0.03
$t\bar{t}$	75.4	9.9±0.4	0.40±0.02	10.1±0.4	0.61±0.02
Drell-Yan	666.8	89.4±0.4	3.60±0.02	81.6±0.4	4.50±0.02
QCD	51.6	60±1.0	2.40±0.04	60±1.0	3.30±0.06



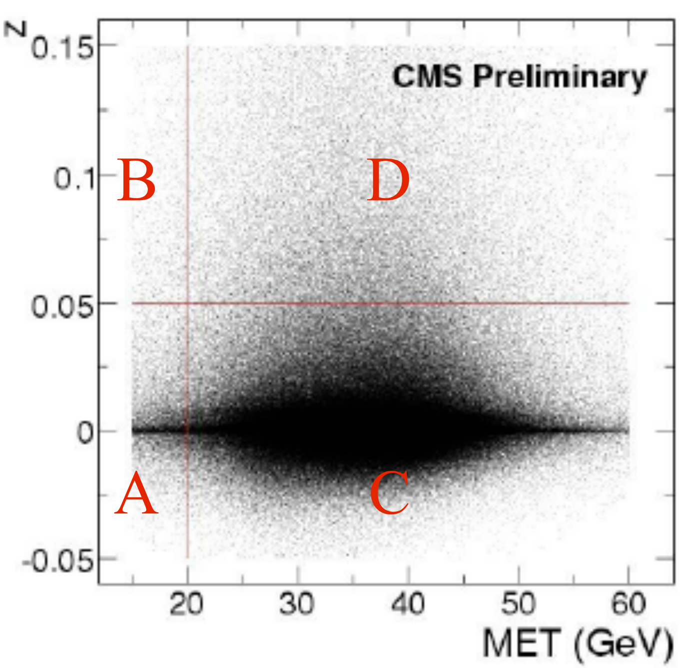
- Drell-Yan background dominates (~4%).
- QCD dijet background is at 2-3% level, large uncertainty in MC predictions.
- Overall S/B ~ 10. (Using LO cross sections)

$$m_T = \sqrt{2 \cdot p_T \cdot MET \cdot (1 - cos(\Delta\phi))}.$$

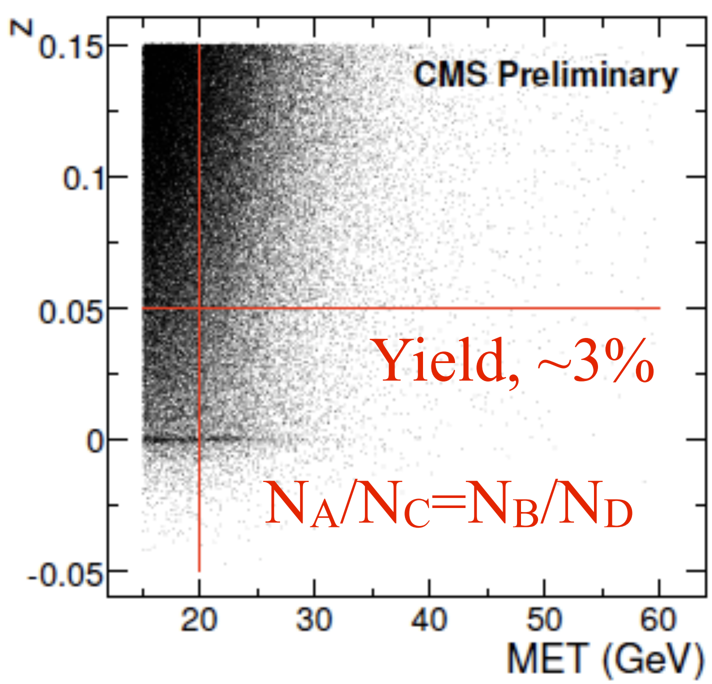
QCD Background Subtraction

- ✦ Relying on MC to estimate electro-weak background (Drell-Yan, W(τν), ttbar). (NLO, NNLO effects)
- ✦ Data-driven method to subtract the rest of the QCD background (reduce systematic error).

W(μν)



QCD

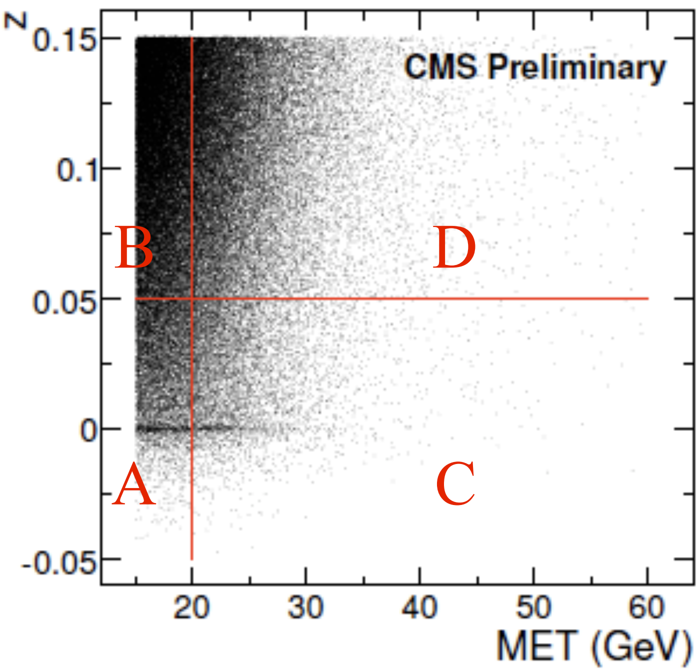


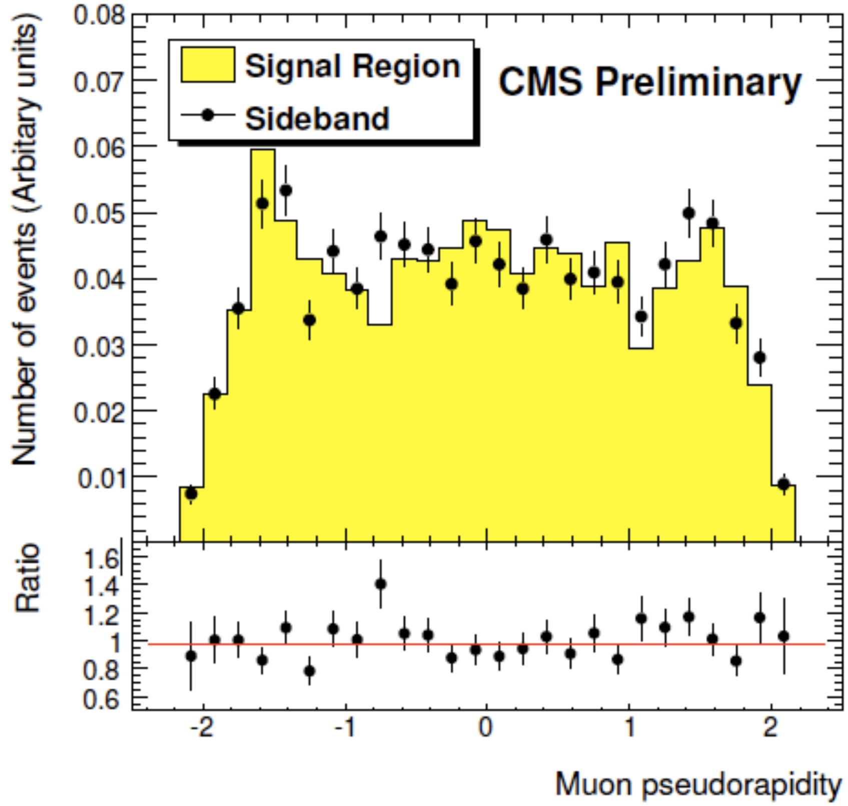
$$z = 1 - \frac{p_T}{p_T + Iso}.$$

~1% systematic uncertainty on signal yield (3% QCD background)

Rapidity Shape of QCD Background

- Use sideband (A) to predict rapidity distribution of QCD background in signal region (C).
- Checked over MC: agreement is within sample statistics.





Charge Asymmetry at 100 pb^{-1}

✦ Theoretically preferred charge asymmetry,

$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) - \frac{d\sigma}{d\eta}(W^- \to \mu^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) + \frac{d\sigma}{d\eta}(W^- \to \mu^-\nu)}.$$

✦ Relate experimental observable, number of events, to above asymmetry: experimental inefficiencies, acceptances, etc.

$$A(\eta) = \frac{\frac{dN^+}{d\eta} - \frac{dN^-}{d\eta} \cdot \frac{\epsilon^+_{HLT} \cdot \epsilon^+_{offline} \cdot \epsilon^+_{acceptance}}{\epsilon^-_{HLT} \cdot \epsilon^-_{offline} \cdot \epsilon^-_{acceptance}}}{\frac{dN^+}{d\eta} + \frac{dN^-}{d\eta} \cdot \frac{\epsilon^+_{HLT} \cdot \epsilon^+_{offline} \cdot \epsilon^+_{acceptance}}{\epsilon^-_{HLT} \cdot \epsilon^-_{offline} \cdot \epsilon^-_{acceptance}}}$$

✦ Symmetric detector: trigger/offline efficiency ratios are 1. Acceptance differs from unity.

$$A(\eta)_{obs} = \frac{\frac{dN^+}{d\eta} - \frac{dN^-}{d\eta}}{\frac{dN^+}{d\eta} + \frac{dN^-}{d\eta}} = \frac{d\sigma^+/d\eta - \left(\frac{\epsilon^-_{acceptance}}{\epsilon^+_{acceptance}}\right) \cdot d\sigma^-/d\eta}{d\sigma^+/d\eta + \left(\frac{\epsilon^-_{acceptance}}{\epsilon^+_{acceptance}}\right) \cdot d\sigma^-/d\eta}.$$

Experimental observable

Theoretical prediction

Charge Asymmetry at 100 pb^{-1}

- Statistical errors: 0.004-0.006.
- Systematic error is dominated by the error on the offline and trigger efficiency ratio between μ^+ and μ^-.
  (assumed to be determined at 1.3% level with 100 pb^{-1} of integrated luminosity)
- Could provide constraints to different PDF models.