$W^{\pm}$ production asymmetry with ATLAS

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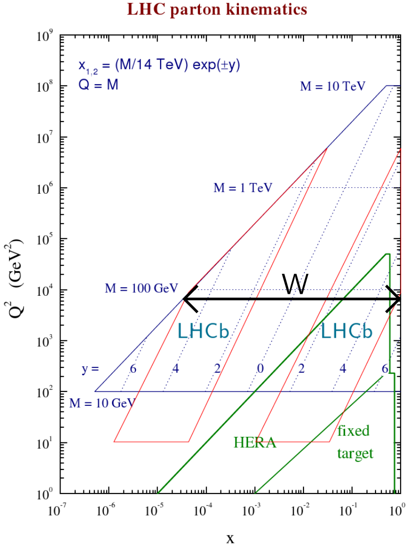
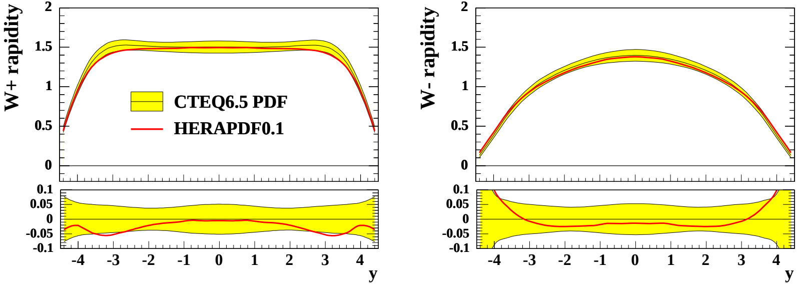
Outline

- Vector boson production is one of our strongest tools for constraining PDFs at the LHC
- Absolute cross-sections predicted with uncertainty of $\approx 5\%$
- Asymmetries and ratios offer best prospect of early measurement with potential to constrain the PDFS since many systematics cancel out
- This talk presents recent work within the ATLAS SM group on measurements of the W production cross section
- Also presented are some recent MC studies on W asymmetry measurements.



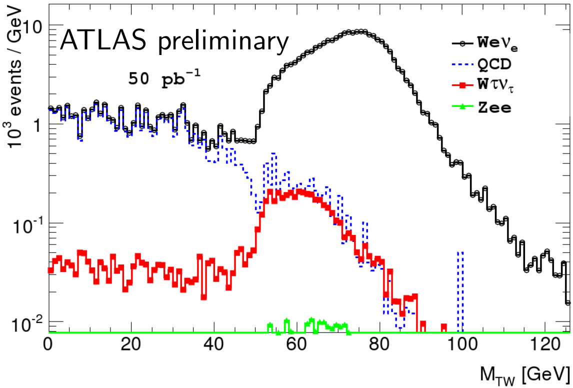
W Production at ATLAS/CMS

- Will explore a new range of parton kinematics
- Not only lower x than TeVatron, also lower x than HERA at central rapidity
- LHCb has potential to further extend measurement in x
- W production cross section in pp collisions very sensitive to PDFs ...



- Uncertainty obtained using different PDF sets on total cross section usually 5%
- Central values of different PDF sets can differ by $> 5\%$

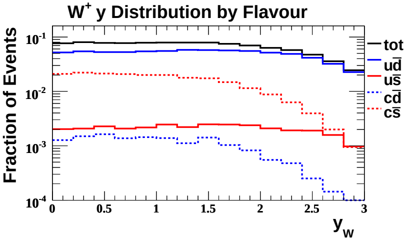
- Select events with:
  - $E_T^e > 25\,\mathrm{GeV}$
  - $|\eta^e| < 2.4$
  - $E_T^{miss} > 25\,\mathrm{GeV}$
  - $M_T > 40\,\mathrm{GeV}$
- Main experimental backgrounds expected:
  - QCD $(7 \pm 4\%)$
  - $W \rightarrow \tau\nu$ (2%)
  - $Z \rightarrow ee$ (0.2%)

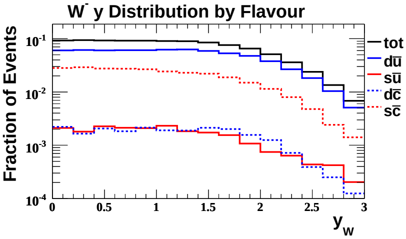


W production preliminary measurement studies performed for 14 TeV dataset from forthcoming ATLAS Standard Model group CSC note: ATL-COM-PHYS-2008-064

- Expected systematic precision of measurement $\frac{\Delta\sigma}{\sigma} \approx 5\%$ $(50\,\mathrm{pb}^{-1}) \rightarrow 2.5\%(1\,\mathrm{fb}^{-1})$
- Expected 10% early luminosity uncertainty not included
- Theoretical contributions to measurement uncertainty:
  - ISR (2%)
  - input PDFs (0.9%)
  - Intrinsic k_T of partons (0.4%)
  - FSR (0.3%)
  - Underlying event (0.2%)

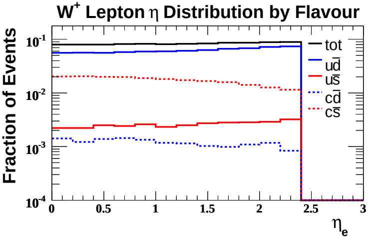
Early measurement of cross section with 10% luminosity uncertainty at LHC cannot constrain the PDFs

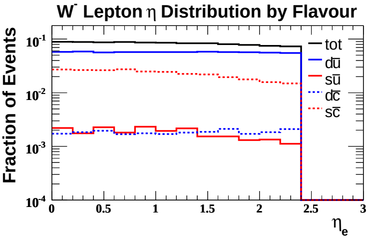




- Different PDFs also affect the shape of the W rapidity distribution
- The difference in shapes is still visible in the decay-lepton η distribution
- W^+ and W^- shapes and production rates different $\rightarrow$ exploit asymmetries to constrain PDFs

Rapidity Distributions





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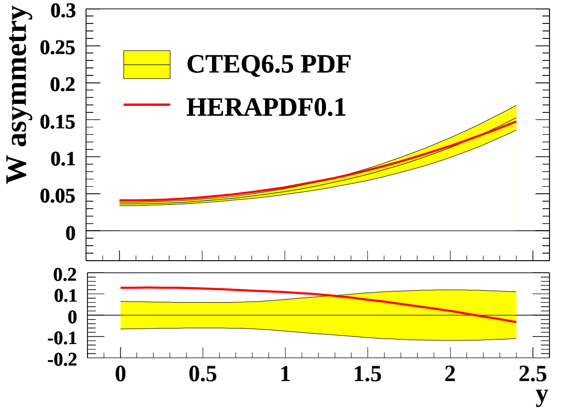
Two measurable $W^{\pm}$ asymmetries to be discussed :

- W boson production asymmetry as a function of y_W
- Charged-lepton asymmetry as a function of η_l

Both have been measured in $p\bar{p}$ at TeVatron



Definition

$$A = \frac{\mathrm{d}\sigma/\mathrm{d}y_{W+} - \mathrm{d}\sigma/\mathrm{d}y_{W-}}{\mathrm{d}\sigma/\mathrm{d}y_{W+} + \mathrm{d}\sigma/\mathrm{d}y_{W-}}$$

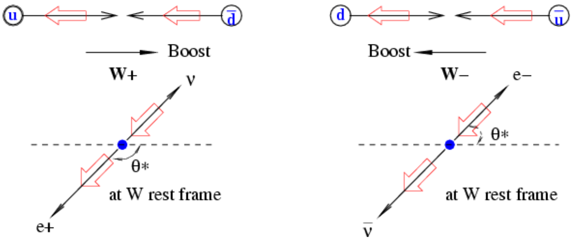
- Asymmetry because e.g. u quarks mainly at higher x than d $\rightarrow$ W^+ boosted forwards more than W^-

Definition

$$A = \frac{d\sigma/d\eta_{e^+} - d\sigma/d\eta_{e^-}}{d\sigma/d\eta_{e^+} + d\sigma/d\eta_{e^-}}$$

Charged lepton asymmetry:

- Directly measurable
- Asymmetry of W production itself washed out by V-A decay
- V-A decay very well understood theoretically



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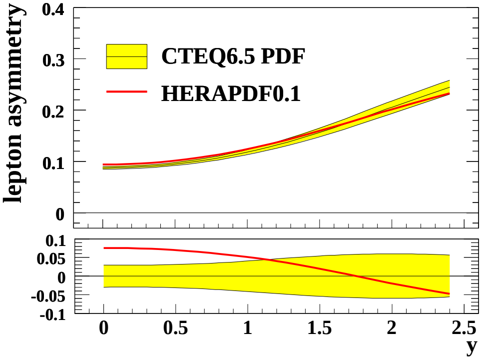
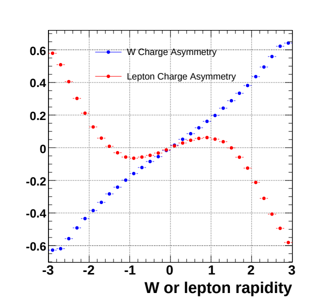
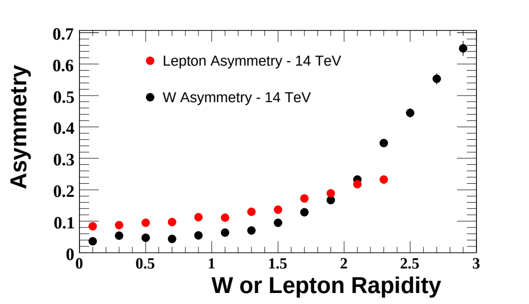


TeVatron



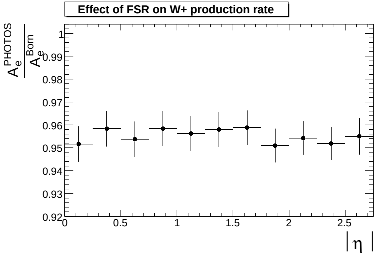
LHC

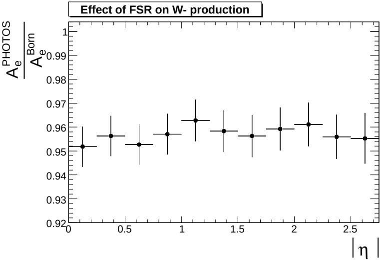


- TeVatron asymmetries antisymmetric about 0, LHC symmetric.
- LHCb can measure $1.9 < |\eta_l| < 4.9$ region - good overlap

Presentation here of some studies with HERWIG and PYTHIA MC on prospects for $W \rightarrow e\nu$ measurement

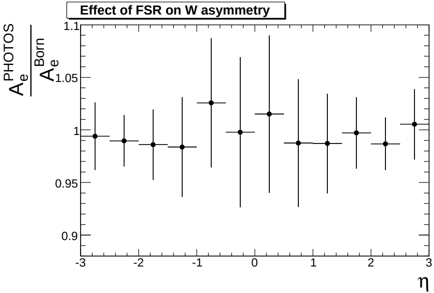
- Effect of FSR on measured W asymmetry
- Is the expected understanding of QCD background at ATLAS sufficient?





Study comparing HERWIG with and without FSR (PHOTOS):

- FSR reduces cross section for $W^{\pm}$, $P_T^l > 10\,\mathrm{GeV}$ by $\approx 1.5\%$ ($P_T^l > 25\,\mathrm{GeV}$ $\approx 5\%$)
- No significant effect on Asymmetry from FSR



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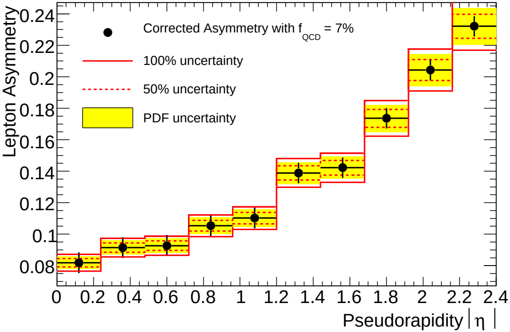
Importance of QCD uncertainty

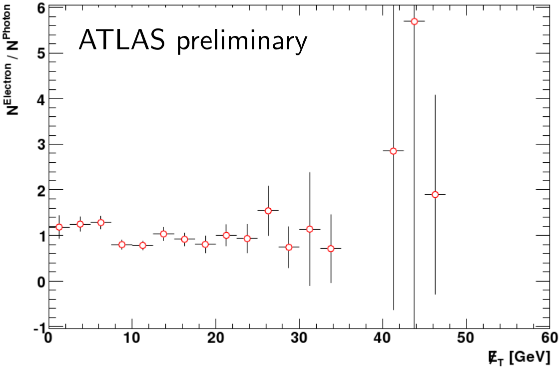
- Uncertainties of order 5% on prediction (from PDF uncertainties)
- Expected uncertainty of $\mathcal{O}(50)\%$ on QCD bkg ($7 \pm 4\%$), gives similar uncertainties on measurement
- Priority at ATLAS: accurate QCD bkg. determination using data-driven techniques



Example Method For Determining QCD Background to $W \longrightarrow e\nu$

- Principle: Measure shape and normalisation of jet background prior to E_T^{miss} cut.
- Requirement: A pure jet background sample with appropriate M_T and jet multiplicity distributions
- Usage: Use sub-sample to evaluate E_T^{miss} cut rejection and determine uncertainty
- Implementation: Apply similar selection to $W \longrightarrow e\nu$ except use a single γ trigger and select γ candidates rather than e candidates

(This method used to determine background in $W \longrightarrow e\nu$ cross section discussed earlier)



Method succeeds in describing the QCD background well

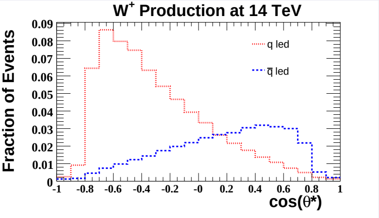
Method for measuring direct W-asymmetry presented by Bodek et al. in arχiv:0711.2859[hep-ph]

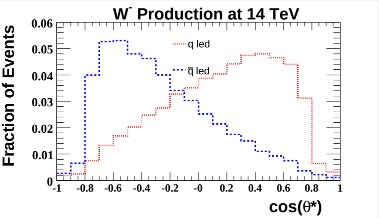
- Use Mass constraint $M_W^2 = (E_l + E_\nu)^2 - (P_l + P_\nu)^2$ to find two possible solutions for neutrino momentum
- Use both solutions, each with a weight proportional to probability from V-A decay and differential cross-section

This method has also been used by CDF (CDF Note 8942)

Showing here a comparison of the environment at LHC compared to TeVatron for this measurement

LHC





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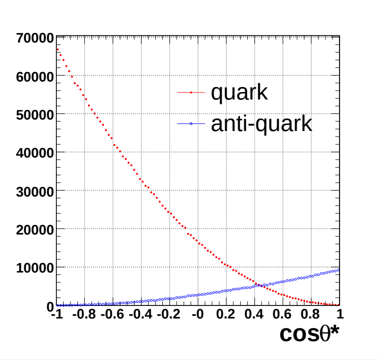
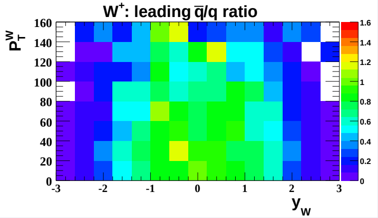
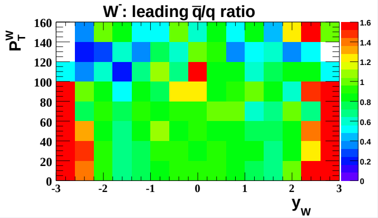


- $\cos\theta^*$ dist. much flatter at LHC

LHC





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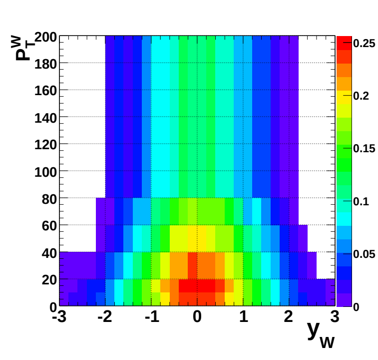

$\bar{q}/q$ much closer to 1 over large phase space

Summary

- W production asymmetries very promising for putting an early constraint on PDFs at LHC with ATLAS
- For charged lepton asymmetry:
  - FSR effects negligible
  - Expected understanding of QCD backgrounds is sufficient to allow constraint on PDF
- For full W production asymmetry:
  - distributions used to extract event by event weights at CDF seem much flatter
  - Investigating whether this presents a problem for the method
  - Potential disadvantage is dependence on input PDFs