Albert-Ludwigs-Universität Freiburg

Direct W Asymmetry at the LHC

Kristin Lohwasser (Universität Freiburg)
James Ferrando, Cigdem Issever (University of Oxford)

UNI FREIBURG

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

Outline

- Technique to extract directly the W asymmetry has been successfully developed and applied at the TeVatron by A. Bodek et al.

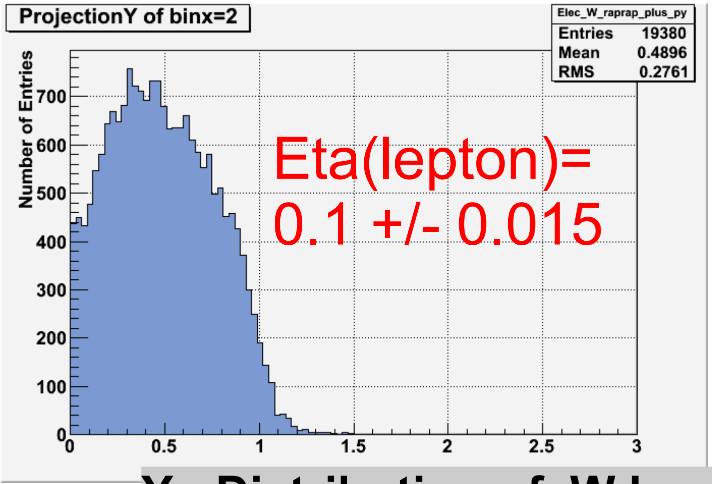
  CDF Collaboration, F. Abe *et al.*, *Measurement of the lepton charge asymmetry in W boson decays produced in $p\bar{p}$ collisions*, *Phys. Rev. Lett.* **81** (1998) 5754–5759, [hep-ex/9809001].

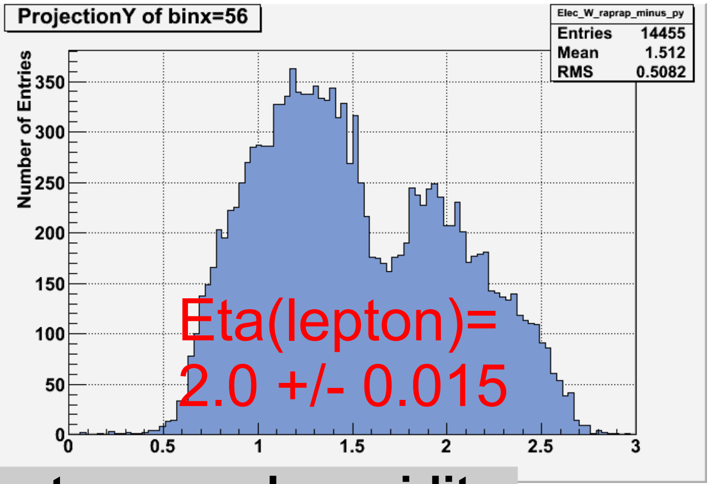
  CDF Collaboration, D. E. Acosta *et al.*, *Measurement of the forward-backward charge asymmetry from $W \to e\nu$ production in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV*, *Phys. Rev.* **D71** (2005) 051104, [hep-ex/0501023].

- This talk reports on a test of its applicibility of the method to the LHC:
  - Idee and Review of the method (at TeVatron and LHC)
  - Problems of the weighting procedure at the LHC
  - Modified reweighting procedure
  - Application and comparison with the lepton asymmetry
  - Outlook

Why both with the W?

- W Asymmetry due to differences in the PDFs (mainly u and d quarks)
- W decay preserves helicity, strong correlation between W and lepton direction → therefore one can also measure a lepton asymmetry
- One value of in lepton eta samples a wide range of W rapidities
- The lepton asymmetry is a convolution of the W asymmetry and the W decay

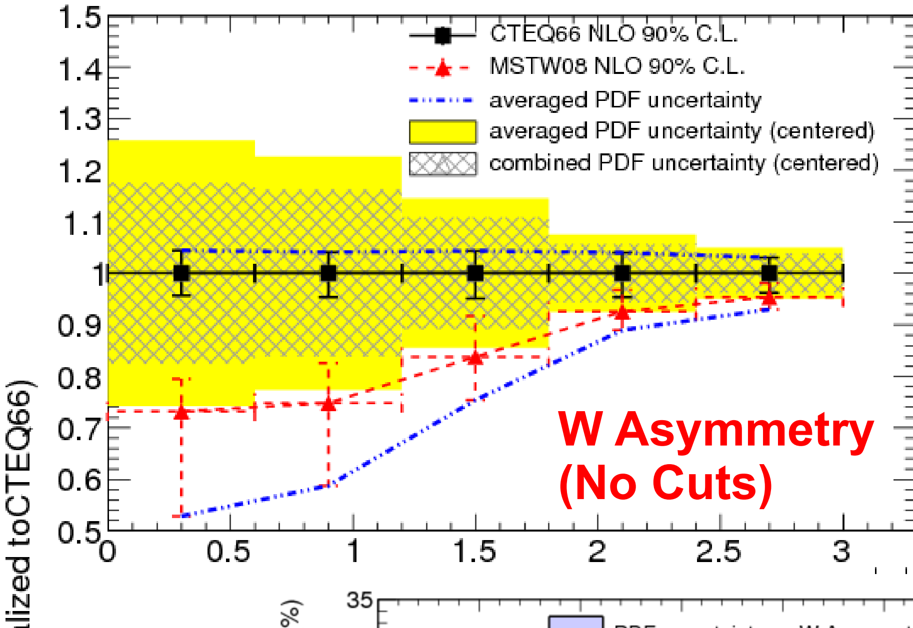


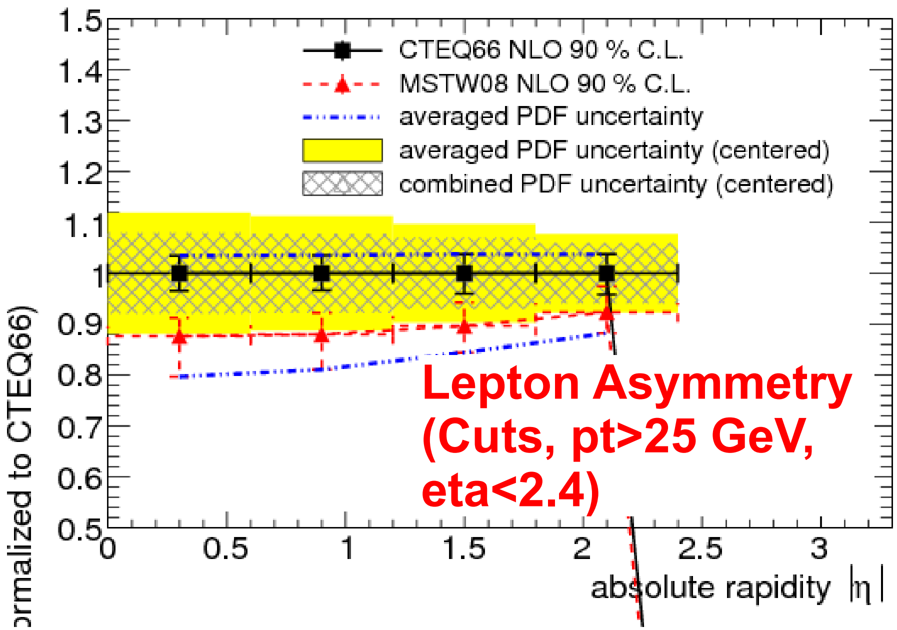


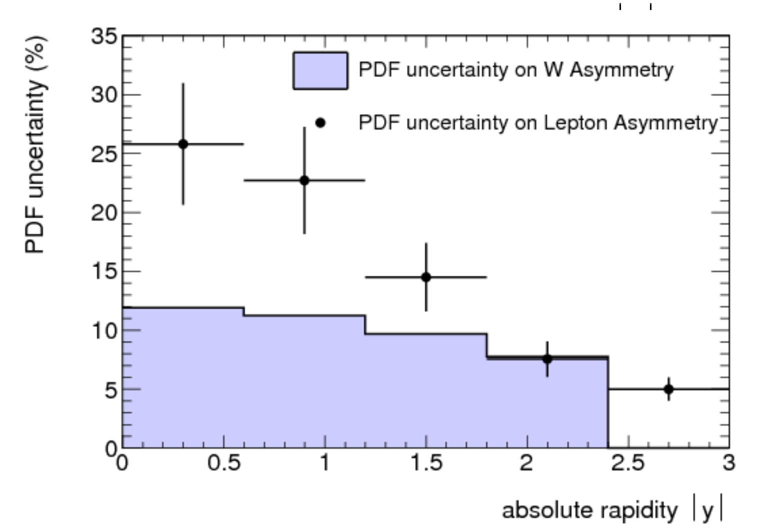
Y - Distribution of W bosons in bins of lepton pseudo-rapidity

Theoretical uncertainty

- PDF errors on W Asymmetry *larger* than lepton asymmetry

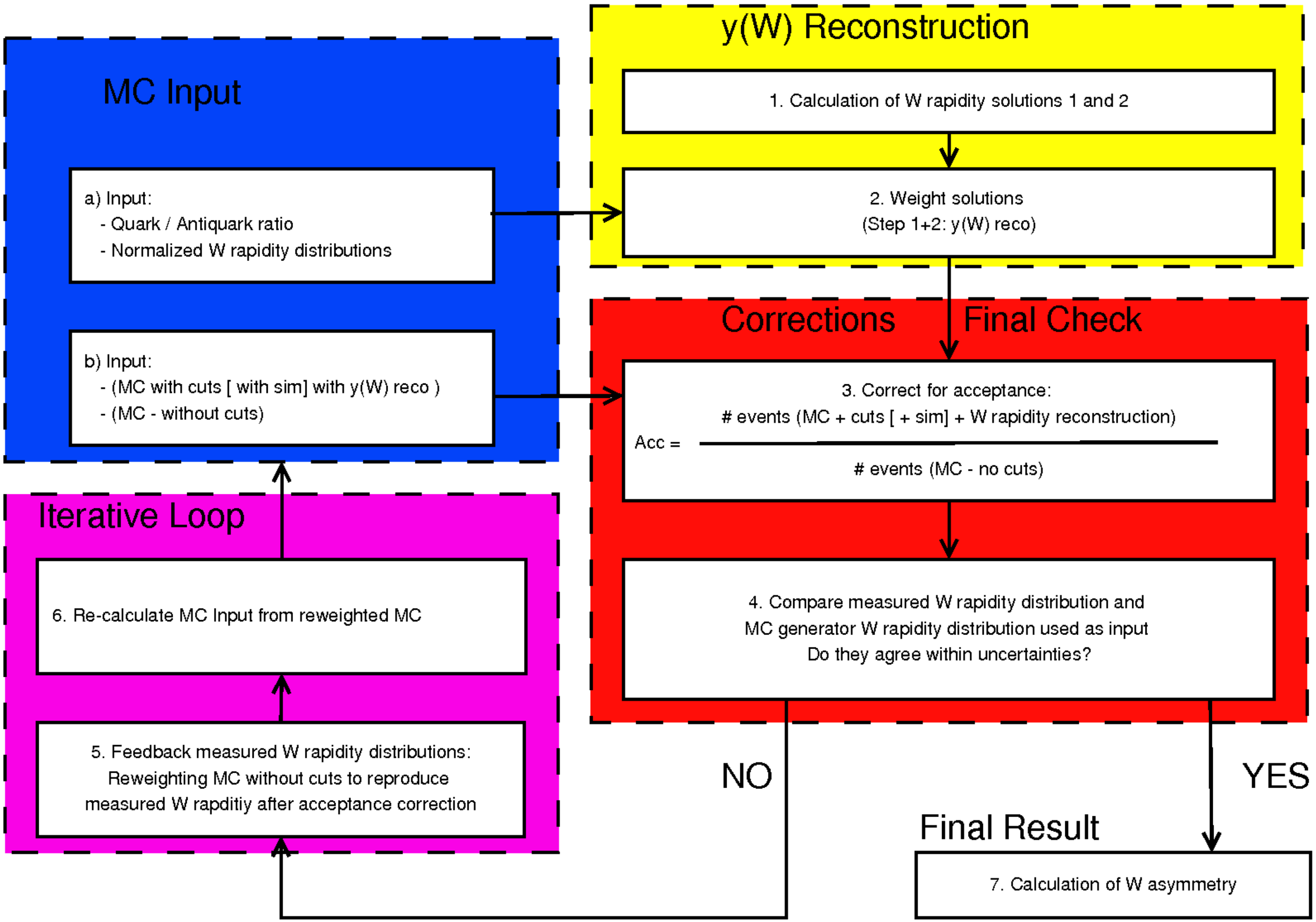






Direct Comparison:
Almost a factor 2 difference

Flow of the method



MC input

- In the weighting procedure, MC input is used to resolve ambiguities between the two solutions for y(W) obtained in the reconstruction step
- The MC input is for a data measurement is:
  Generator + Detector simuation + reconstruction
- Here, only Generator level particles are studied
- Used are Pythia 8 with CTEQ66 and MSTW08 (if not specifically mentioned, it is MSTW08) with ~ 10 mio events.
- For NLO tests, Herwig++ was used (will be mentioned where applicable)

Reconstruction

- Take the W mass to be its nominal value = 80.398 GeV
- Reconstruct electron 4-vector and pT of neutrino (Missing ET)
- Calculate Pz momentum of neutrino

$$p_z^\nu = +\frac{ap_z^e}{c} \pm \sqrt{\left(\frac{ap_z^e}{c}\right)^2 + \frac{(a^2-b)}{c}}$$

with

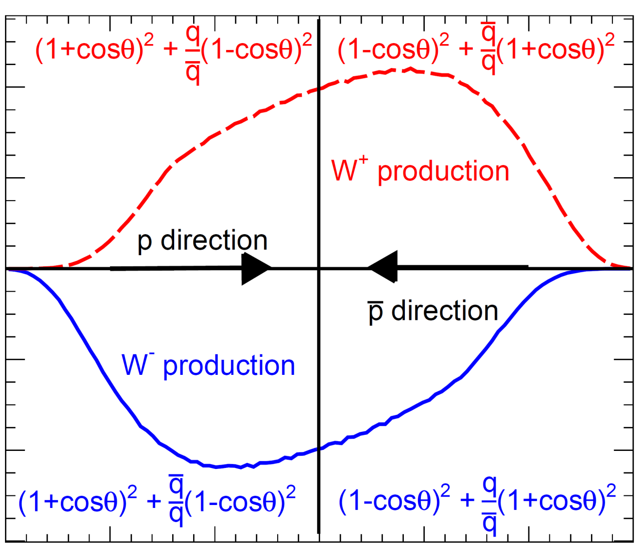
$$\begin{aligned} a &= \frac{1}{2}M_W^2 + p_x^e p_x^\nu + p_y^e p_y^\nu \\ b &= E_e^2(p_{x,\nu}^2 + p_{y,\nu}^2) \\ c &= E_e^2 - p_{z,e}^2. \end{aligned}$$

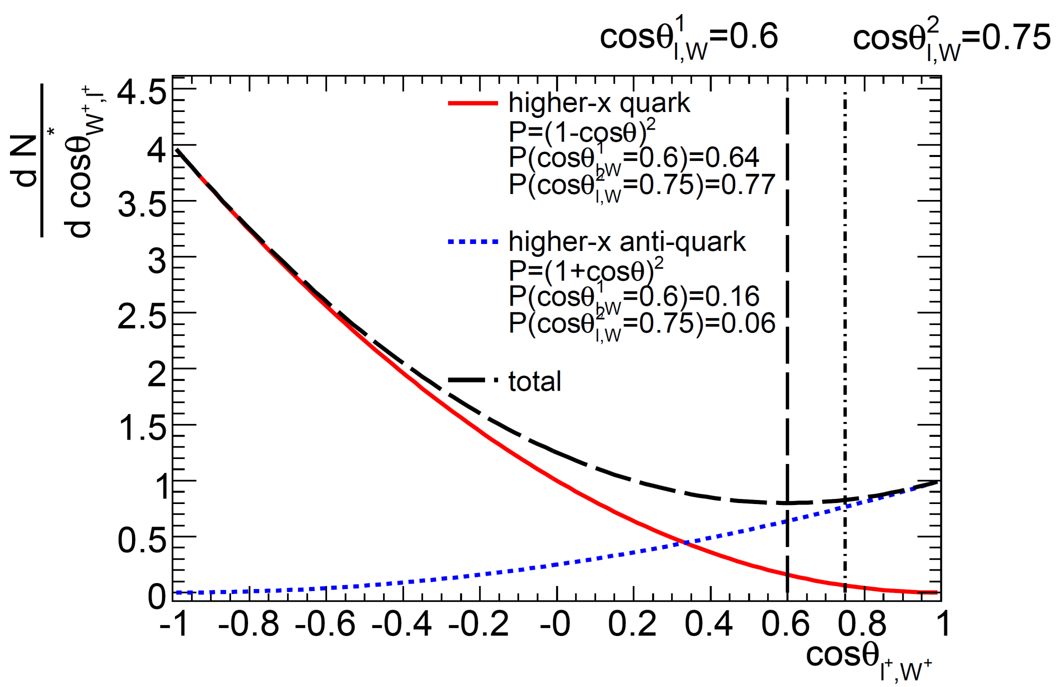
- Using the 4-momenta of electron and neutrino, reconstruct the W rapidity
- This yields a two-fold ambiguity, that is resolved by a **weighting procedure**

Reconstruction II

- Weight the two solutions according to their probabilities using:
- Expected cross section dσ/dy(w)
- Expected decay angle distribution cosΘ(w,l) and sea-valence quark ratio (here shown for TeVatron!)

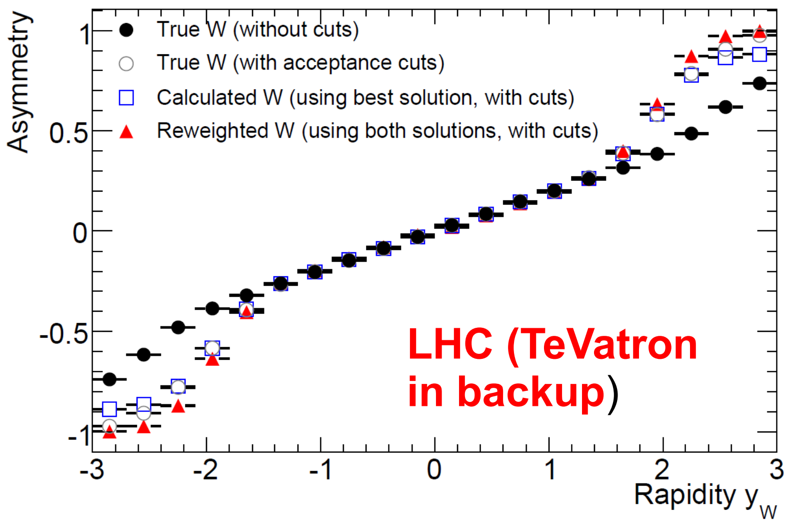
Depending on the helicity of the incoming higher-x parton (e.g.quark = -1), the cosΘ(w,l) follows a distribution. that can be used to weight events

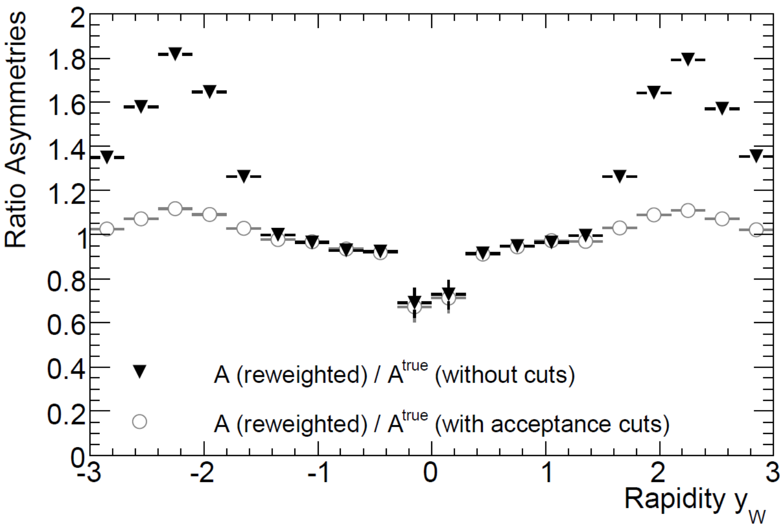




Acceptance Corrections

- Weighting works well, but is not perfect
- Even on truth particle level, an acceptance correction to go from the reweighted y(W) to the true y(W) needs to be applied
- The acceptance corrections also includes a correction for kinematic cuts
- For a data measurement this includes also simulation!



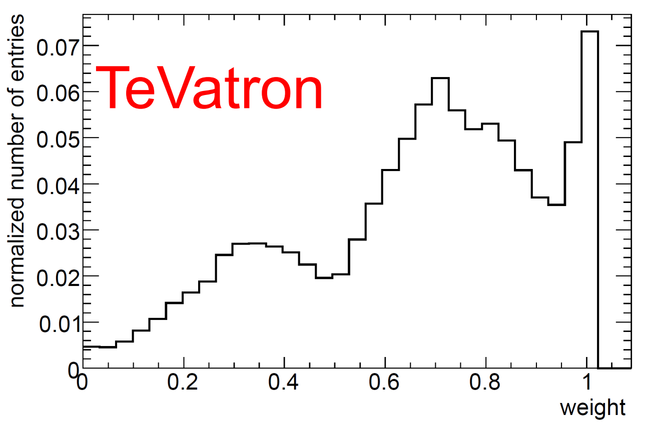


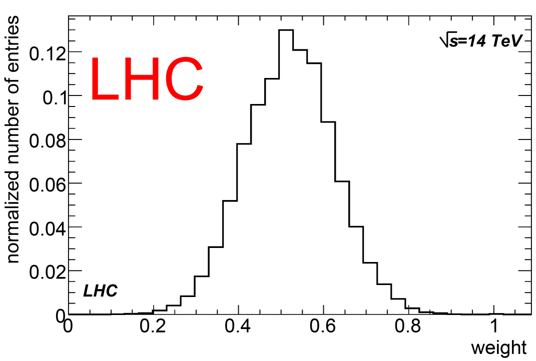
Iterative Feedback Loop

- Iterate to become independent of input
- Compare experimentally determined y(W) distributions and MC input y(W)
  Input MC y(W) distributions should been the yW distributions we intended measure.
  Therefore, the MC input distributions are compared to the measured distributions after the weighting procedure and after the acceptance corrections.
  If they disagree, the procedure needs to be iterated.
- Reweight input MC to reproduce experimentally determined yW distributions
- Recalculation of weighting tables
- Iterate the measurement until convergence betwee (reweighted) MC input and measured data

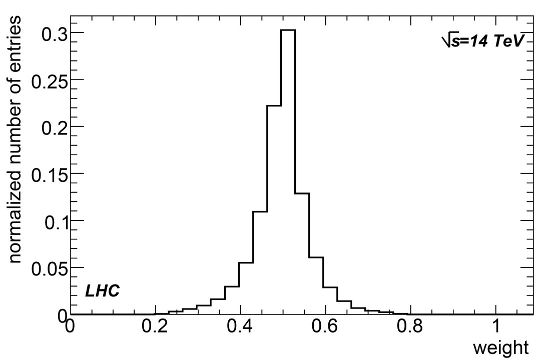
Problems at the LHC

- At the LHC the weighting procedure breaks down
- The the cross section for W production are much flatter and expand over a much larger range of y(W) compared to the TeVatron.
- Ratios of leading qbar versus leading q production come closer to 1, the cosΘ distribution cannot help to distinguish two solutions anymore.
- The weights in the reconstruction are mostly around 0.5 while peaking at 1 at the TeVatron.

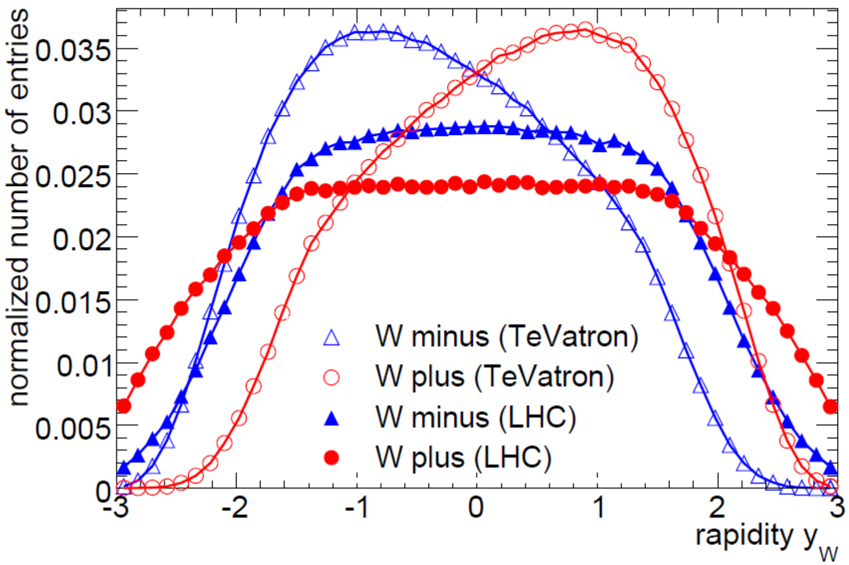




a) Weight given to the right solution for W^-

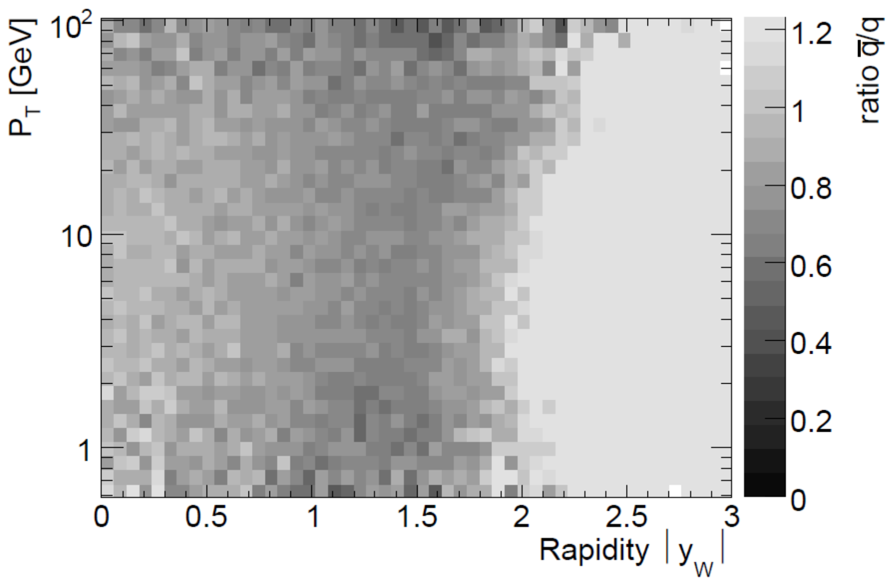


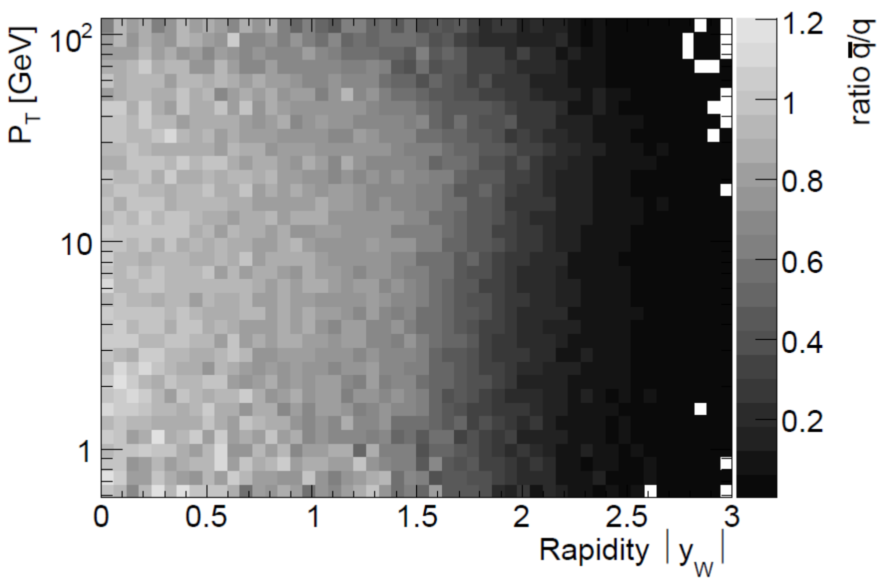
b) Weight given to the right solution for W^+



a) Normalised $y_{W^\pm}$ distributions

Figure 3.9: Problems of the weighting procedure at the LHC: a) The normalised $y_{W^\pm}$ distributions are flatter at the LHC (full markers) compared to the TeVatron (open markers). The ratios $\bar{q}/q$ used in the weighting procedure at the LHC are shown for W^- in b) and for W^+ in c). For both charges, the ratio is considerable larger than 0.25, which is the maximal value of this ratio at the TeVatron.





A new scheme for the LHC

- Independent of the goodness of the weighting in the reconstruction, acceptance corrections are needed
- So the new scheme would be:

  1) calculate 2 y(W) solutions, fill with weight 0.5 by default (no kinematic weights)

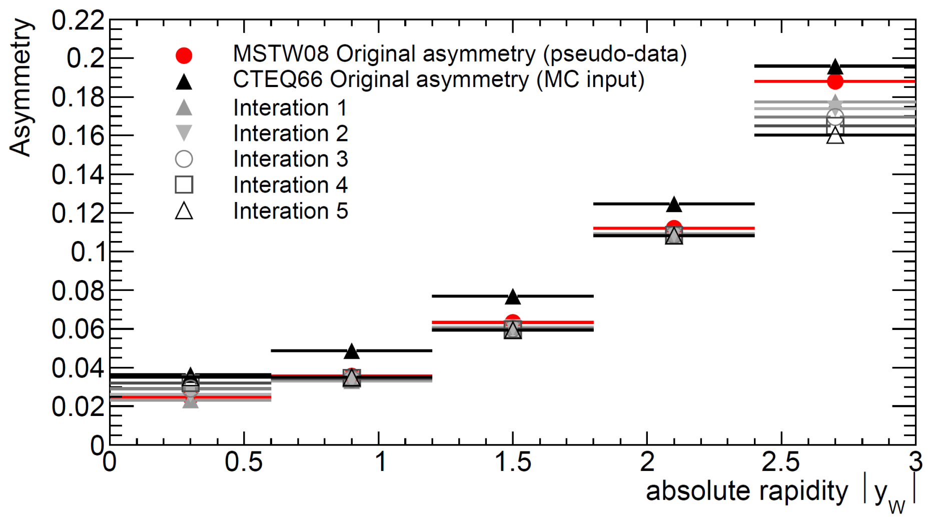
  2) apply acceptance corrections

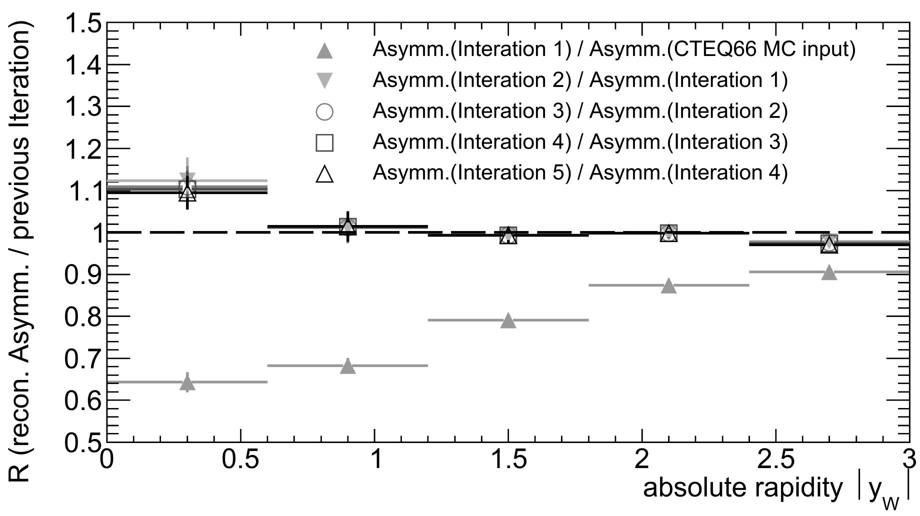
  3) do iterative loop
- If the additional systematic error from the acceptance corrections is small enough, then the W asymmetry is better than the lepton asymmetry (because PDF error on W is larger than PDF error on lepton)

Results (different PDFs)

Albert-Ludwigs-Universität Freiburg

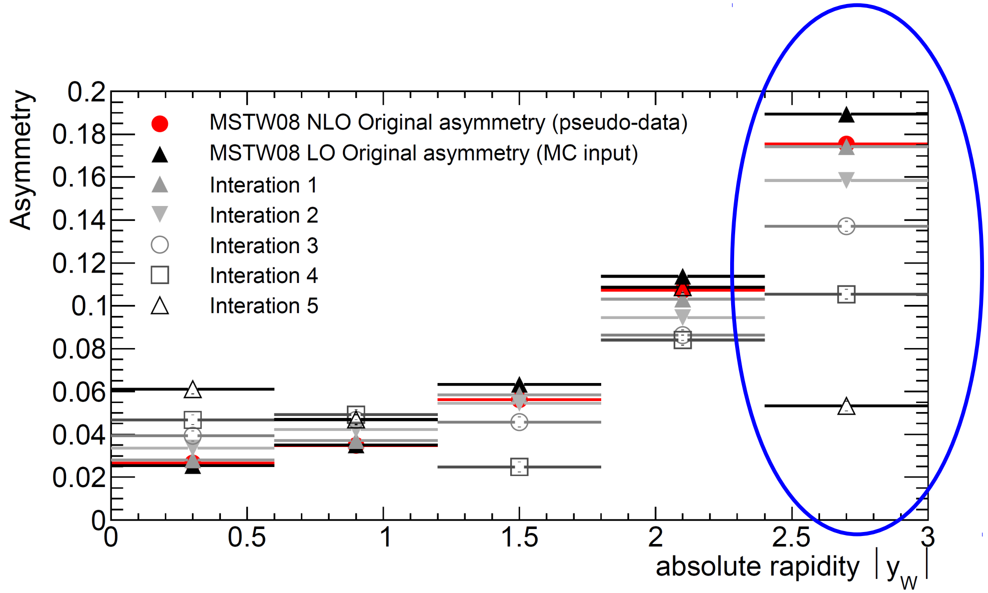
- Reconstruction of MSTW08 Asymmetry „data“ (8 mio. events) using CTEQ66 MC input (75 mio. events)
- It works and converges after the first iteration
- But there is some enhancement of statistical fluctuations

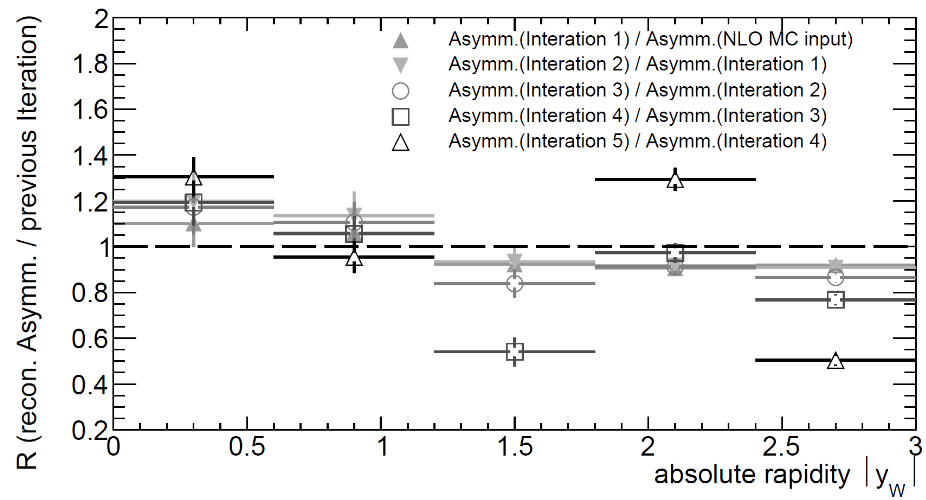




Results (different orders)

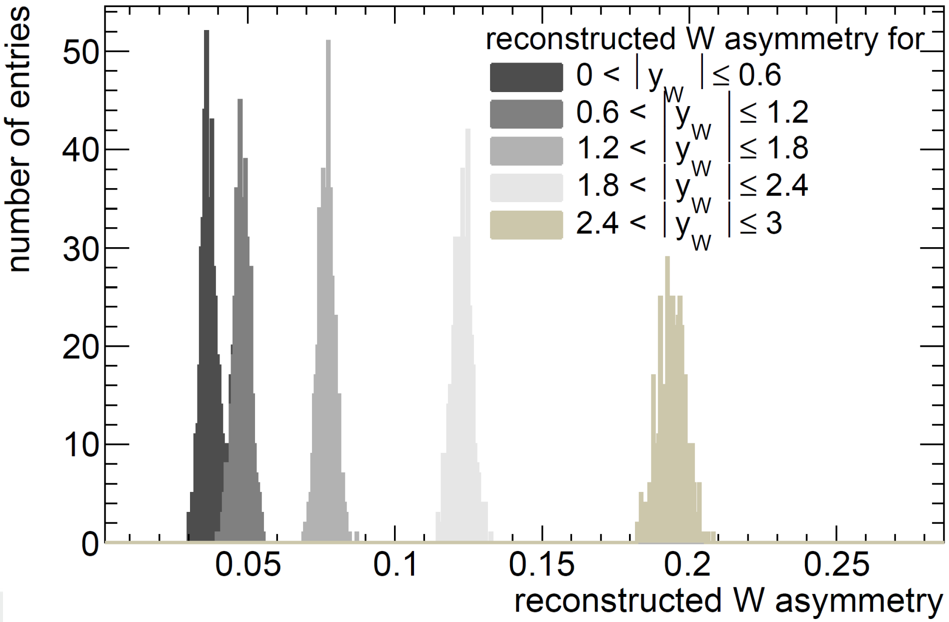
- Reconstruction of Herwig ++ MSTW08 Asymmetry NLO „data“ (1 mio. events) using Pythia MSTW08 MC LO input (8 mio. events)
- It works and converges after the first iteration
- More statistical fluctuations





Statistical errors

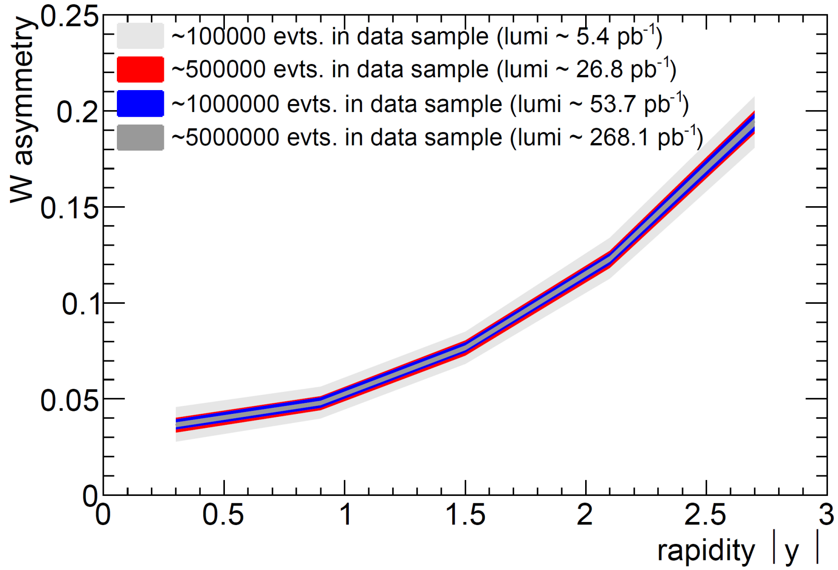
- Use same method as Bodek et al.: MC toy experiments
- High Stat MC input sample (CTEQ66)
- N~450 statistically independent input 'data' sample (of various lumis)
- Use RMS spread of reconstructed asymmetries for statistical error

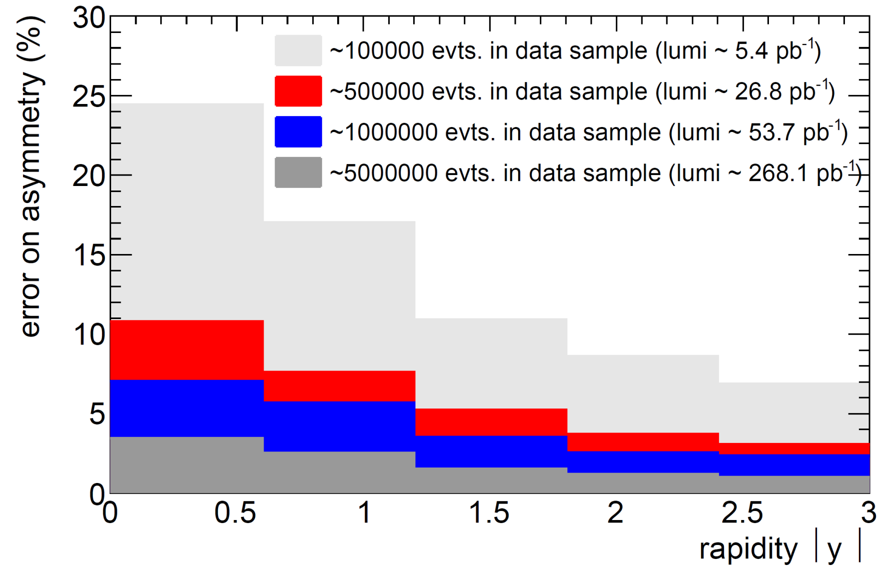


Example outcome of toy MC for N(data) = 1 mio. events

Statistical errors II

- Investigate as function of integrated luminosity
- The statistical error on the reconstructed asymmetry
  is larger than the statistical (poissonian) error on the asymmetry

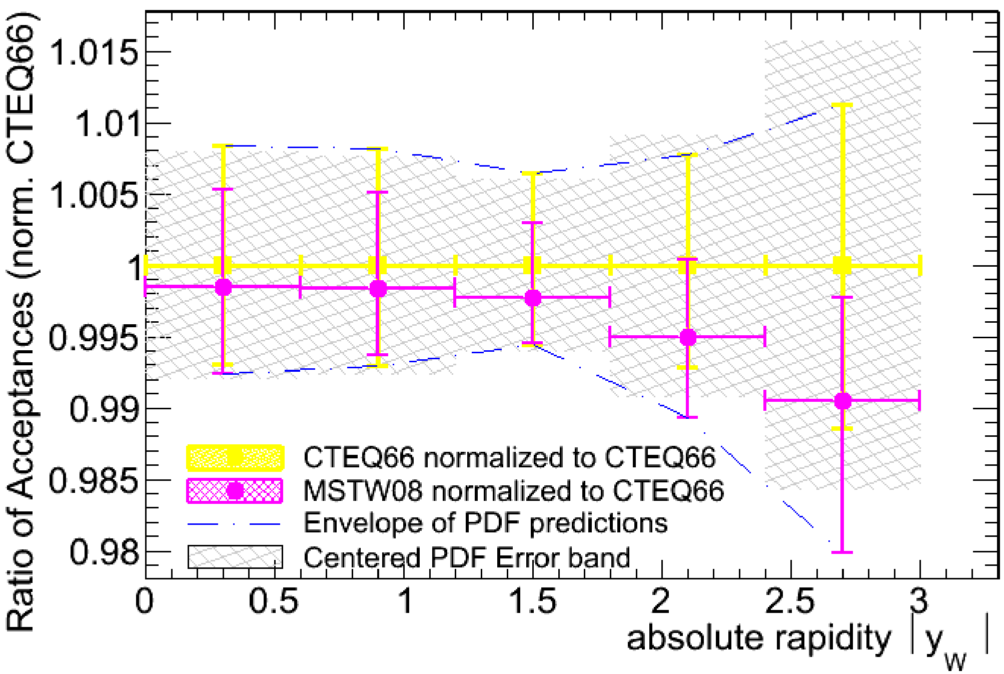


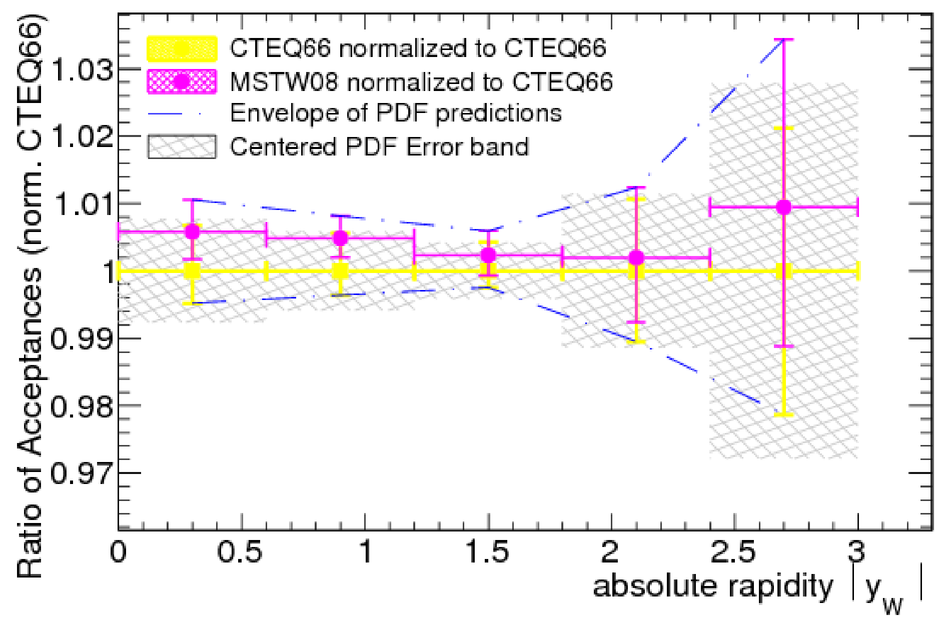


Note: This error includes all problems from reconstruction procedure itself
It is a factor of ~ 1.0-1.5 larger than pure statistical errors (N events)

Acceptance corrections

- PDF errors on acceptance corrections





Plus: maximal 2% error on acceptance

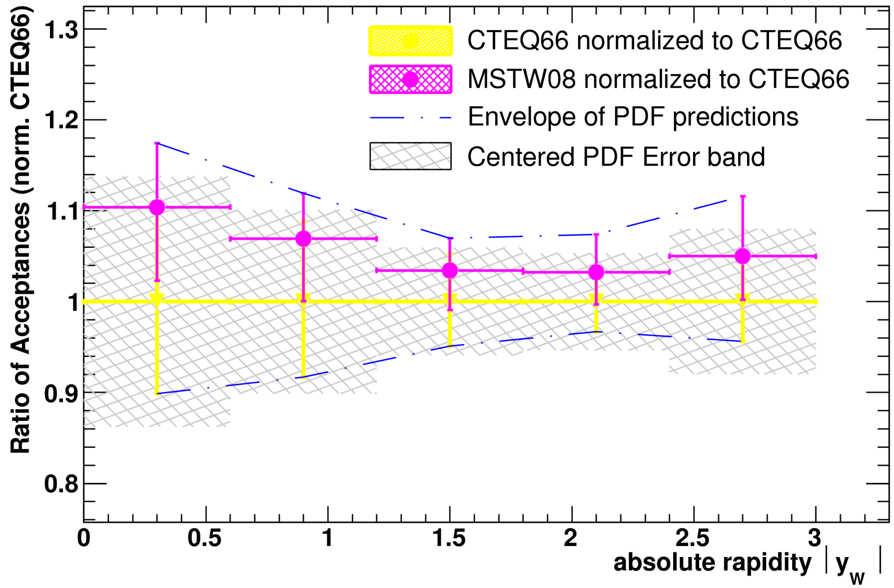
Minus: maximal 3.5% error

This is true for all pT bins !!!

Error due to Acceptance

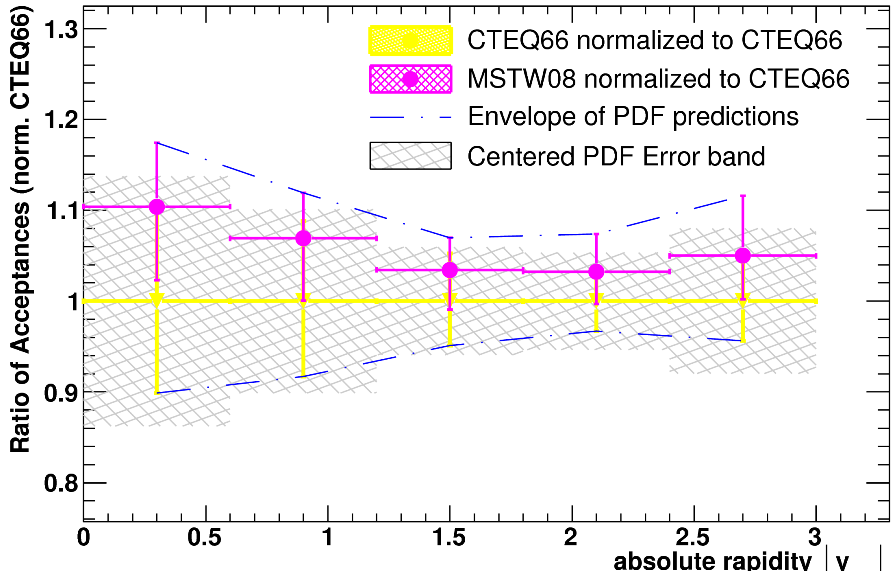
UNI FREIBURG

- Calculate the Acceptance correction for each PDF error set
- Apply acceptance correction to CTEQ66 central value of yw reconstructed
- Deviation of thus reconstructed asymmetries from CTEQ66 central value nominal asymmetry (wo cuts) is the PDF error due to acceptance.
- This procedure fully deals with correlations between the + and - errors



Error due to Acceptance

- Calculate the Acceptance correction for each PDF error set
- Apply acceptance correction to CTEQ66 central value of yw reconstructed
- Deviation of thus reconstructed asymmetries from CTEQ66 central value nominal asymmetry (wo cuts) is the PDF error due to acceptance.
- This procedure fully deals with correlations between the + and - errors



Experimental error

- Calculate experimental error by conducting 500 pseudoexperiments, where the momenta of electron and neutron are smeared with 1% (5%) Gaussian resolution
- Calculated W asymmetry and compare to original asymmetry
- Were needed (because there are unphysical solutions), scale the neutrino pT down (in very small steps)
- Use pull and spread as experimental error

y_W or η_l	$\sigma_{\text{stat}}(W)$	$\sigma_{\text{acc}}(W)$	$\sigma_{\text{det}}(W)$	$\sigma_{\text{th}}^{\text{meas}}(W)$	$\sigma_{\text{tot}}^{\text{meas}}(W)$	$\sigma_{\text{stat}}(l)$	$\sigma_{\text{det}}(l)$	$\sigma_{\text{tot}}^{\text{meas}}(l)$
0 - 0.6	3.47	10.1	9.61	10.7	14.4	1.49	4.04	4.3
0.6 - 1.2	2.52	8.31	6.51	8.68	10.9	1.24	2.64	2.92
1.2 - 1.8	1.54	4.9	0.699	5.13	5.18	0.921	1.46	1.73
1.8 - 2.4	1.19	3.3	1.77	3.51	3.93	0.695	0.925	1.16
2.4 - 3	1.02	4.38	3.96	4.5	5.99	-	-	-

Total errors

- Errors in comparison:

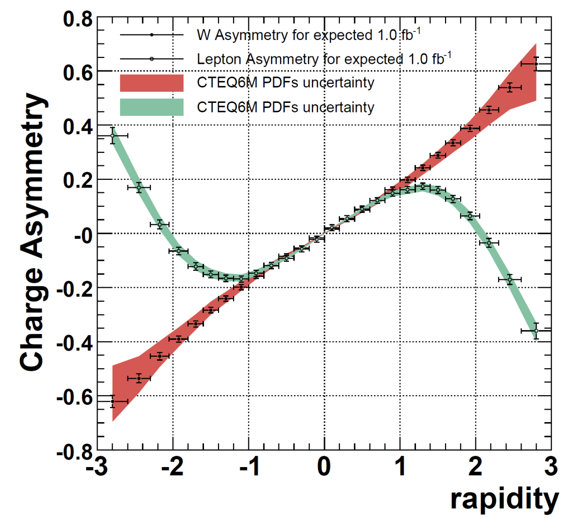
y_W or η_l	$\sigma_{stat}(W)$	$\sigma_{acc}(W)$	$\sigma_{det}(W)$	$\sigma_{th}^{meas}(W)$	$\sigma_{tot}^{meas}(W)$	$\sigma_{stat}(l)$	$\sigma_{det}(l)$	$\sigma_{tot}^{meas}(l)$
0 - 0.6	3.47	10.1	9.61	10.7	14.4	1.49	4.04	4.3
0.6 - 1.2	2.52	8.31	6.51	8.68	10.9	1.24	2.64	2.92
1.2 - 1.8	1.54	4.9	0.699	5.13	5.18	0.921	1.46	1.73
1.8 - 2.4	1.19	3.3	1.77	3.51	3.93	0.695	0.925	1.16
2.4 - 3	1.02	4.38	3.96	4.5	5.99	-	-	-

- Comparison to PDF uncertainties:

y_W or η_l	$\sigma_{PDF}(W)$	$\mathcal{R}(W)$ $\sigma_{PDF}/\sigma_{th}^{meas}$	$\mathcal{R}(W)$ $\sigma_{PDF}/\sigma_{tot}^{meas}$	$\sigma_{PDF}(l)$	$\mathcal{R}(l)$ $\sigma_{PDF}/\sigma_{th}^{meas}$	$\mathcal{R}(l)$ $\sigma_{PDF}/\sigma_{tot}^{meas}$	$\mathcal{R}(W/l)$ $\sigma_{PDF}/\sigma_{th}^{meas}$	$\mathcal{R}(W/l)$ $\sigma_{PDF}/\sigma_{tot}^{meas}$
0 - 0.6	24.5	2.29	1.7	11.9	8	2.77	0.287	0.616
0.6 - 1.2	20.7	2.39	1.91	11.2	9.07	3.85	0.263	0.496
1.2 - 1.8	15.1	2.95	2.92	9.69	10.5	5.6	0.281	0.521
1.8 - 2.4	11.7	3.32	2.97	7.75	11.1	6.7	0.298	0.443
2.4 - 3	8.39	1.87	1.4	-	-	-	-	-

Conclusions

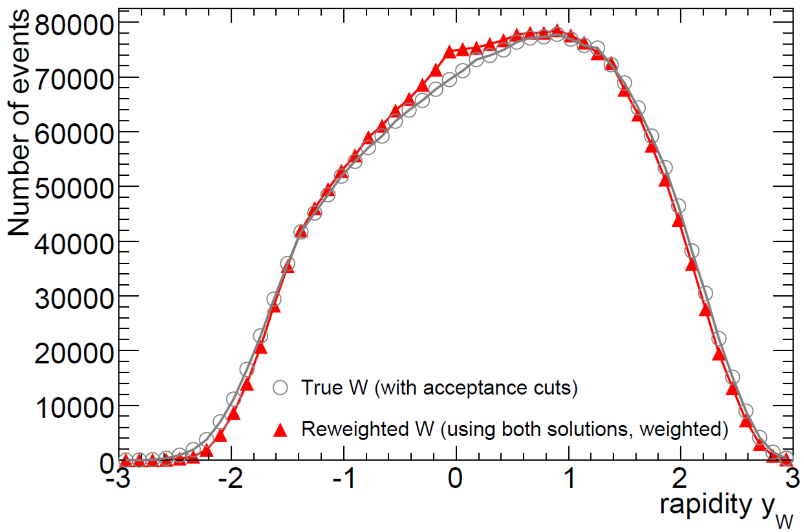
- W asymmetry reconstruction is less suited for LHC conditions
- Proposed modification of the scheme and proved that it works
- Error on reconstructed W asymmetry is smaller than the current PDF uncertainty, therefore measurement could constrain PDFs
- However, error on lepton asymmetry even much smaller compared to PDF error, so that a measurement of the lepton asymmetry seems more favourable (if there a no other strong reasons, why one would prefer the W asymmetry)

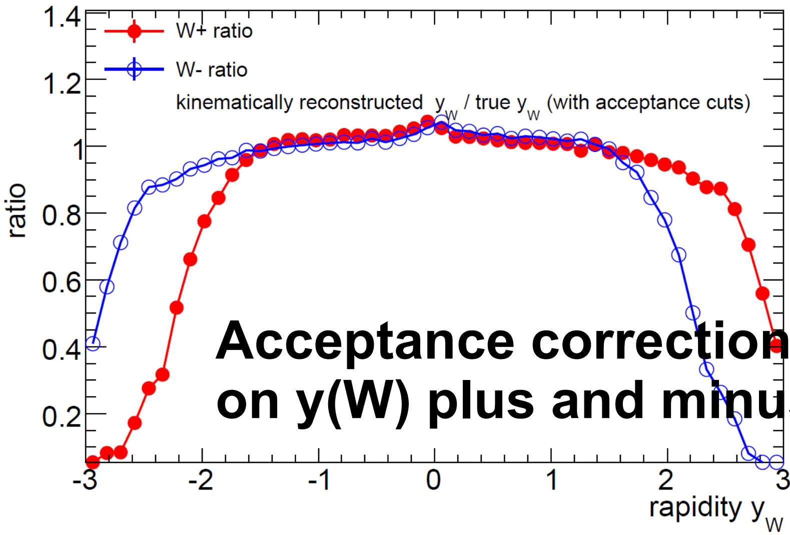


- Method has however a clear advantage at the TeVatron

Acceptance Corrections at the TeVatron

- Weighting works well, but is not perfect
- Even on truth particle level, an acceptance correction to go from the reweighted y(W) to the true y(W) needs to be applied
- The acceptance corrections also includes a correction for kinematic cuts
- For a data measurement this includes also simulation!





Acceptance correction on y(W) plus and minus