Monte Carlo simulations of ATLAS geometrical acceptance and estimation of systematic uncertainties from W and Z decaying into muons

Manuela Venturi

INFN, Università di Roma Tor Vergata, Italia

on behalf of the ATLAS collaboration

Signaling the arrival of the LHC era, ICTP, Trieste, 12.12.2008

Why W/Z cross section measurement ?

Drell Yan decays are clean processes with large cross sections and
$\Delta\sigma_{theory} \sim$ few %, and so useful for :

- detector understanding and calibration
- monitoring collider luminosity
- constraints on PDFs
  - LHC will explore the x range ($10^{-4} < x < 10^{-1}$) where gluons dominate

To reach high accuracy in cross section measurements...

$$\sigma_{q\bar{q}\to W(Z)} \cdot \mathrm{Br}_{W(Z)\to\ell\nu_\ell(\ell+\ell-)} = \frac{N^{\mathrm{obs}}_{W(Z)} - N^{\mathrm{bkg}}_{W(Z)}}{A_{W(Z)}\varepsilon_{W(Z)} \int \mathcal{L}(t)dt}$$

once we have statistics (10^8 Ws and 10^7 Zs /year expected for each leptonic channel) we need to constraint **luminosity** and **acceptance**.

Systematic uncertainty on acceptance IS theoretical uncertainty.

Outline

Acceptance is calculated through Monte Carlo simulations (Mc@Nlo at Next to Leading Order) **imposing kinematical cuts on outgoing leptons.**

- Systematic error is found to depend mainly on:
  - **PDF** error sets
    - Studied also PDF-induced correlation on acceptances
  - **Initial State Radiation** parameters

- Also analysed the impact of partonic intrinsic pT

Systematic errors

Start with default configuration, turn on and off each effect

separately and calculate the impact on acceptance for W and Z

Default configuration:

PDF = CTEQ 6.1M central value. sqrt(s)> 60 GeV for Z/gamma.

ISR on, UE on, Photos on, spin correlations on, rms intrinsic pT of

incoming partons = 0 GeV.

Standard cuts and parameters :

Muon and neutrino pT > 20 GeV, $|\eta|$< 2.5 only for charged leptons, NO

PREFILTER. Same masses and widths for all generators.

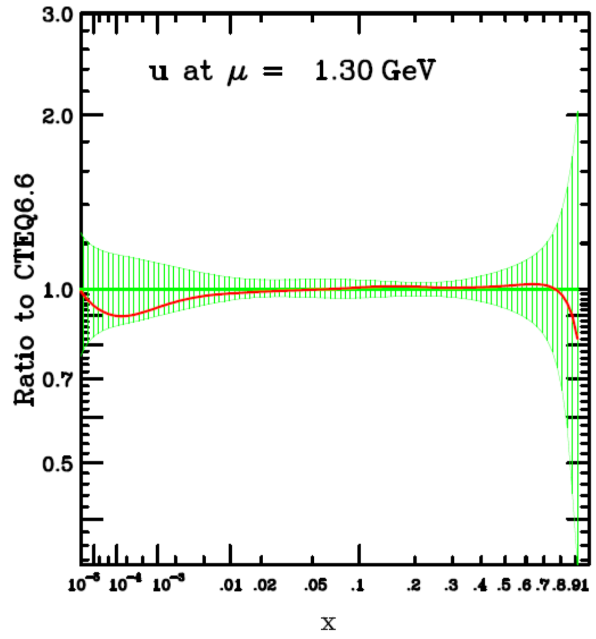
PDFs uncertainty

Uncertainty on PDFs is estimated with Mc@Nlo, comparing acceptances with different CTEQ error sets (40+1 sets for CTEQ 6 and 6.1, 44+1 sets for 6.6).

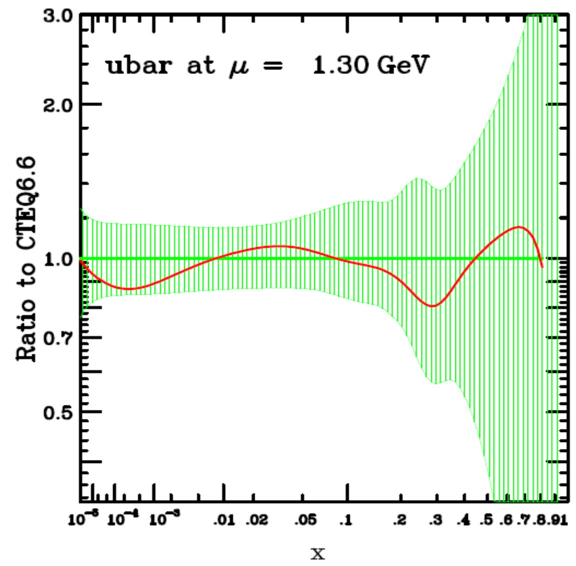
Tried to evaluate the impact of moving from CTEQ6(6.1) – default in ATLAS – to the newly released CTEQ 6.6.

CTEQ6.6 versus CTEQ6 (6.1)

- 6.6 are in the General-Mass scheme, 6 (and 6.1) in the Zero-Mass scheme.
  - This leads to a reduction in *c*, *b* and *g* contributions at **low and medium *x***, and so to an increase in *u* and *d* quarks and antiquarks: <u>this is expected to have a big impact on W/Z production</u>!

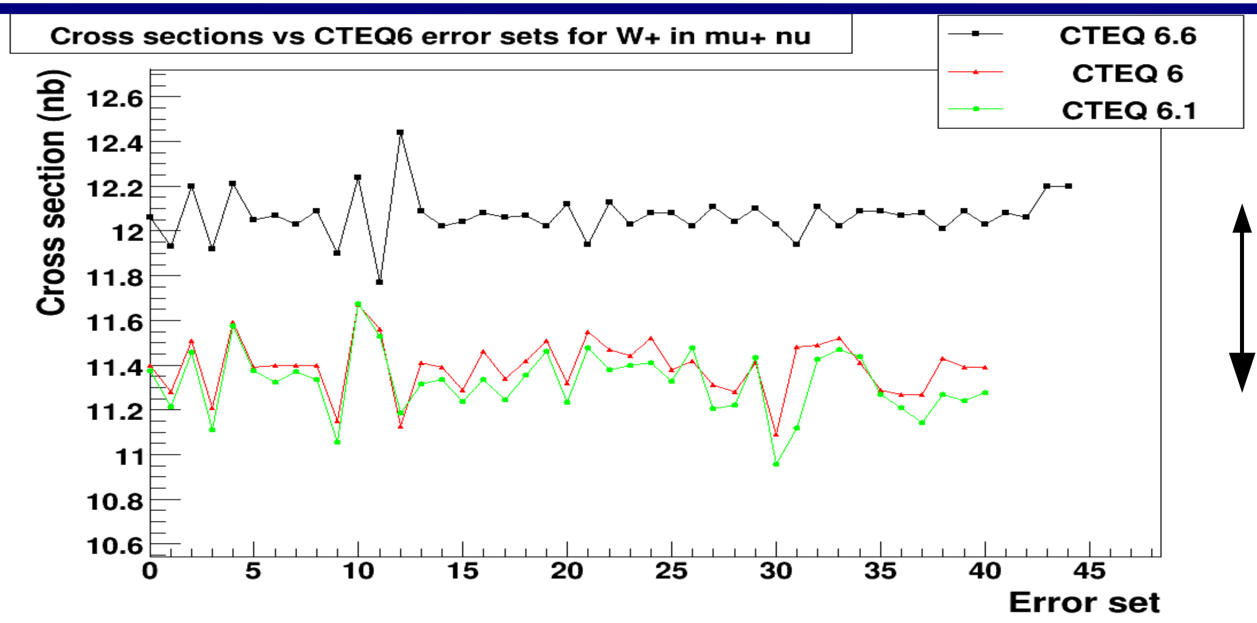


- In 6.6, sea can be asymmetric in strange and non-strange contributions: this provides **2 new degrees of freedom**, and consequently we have 44 error sets instead than 40.

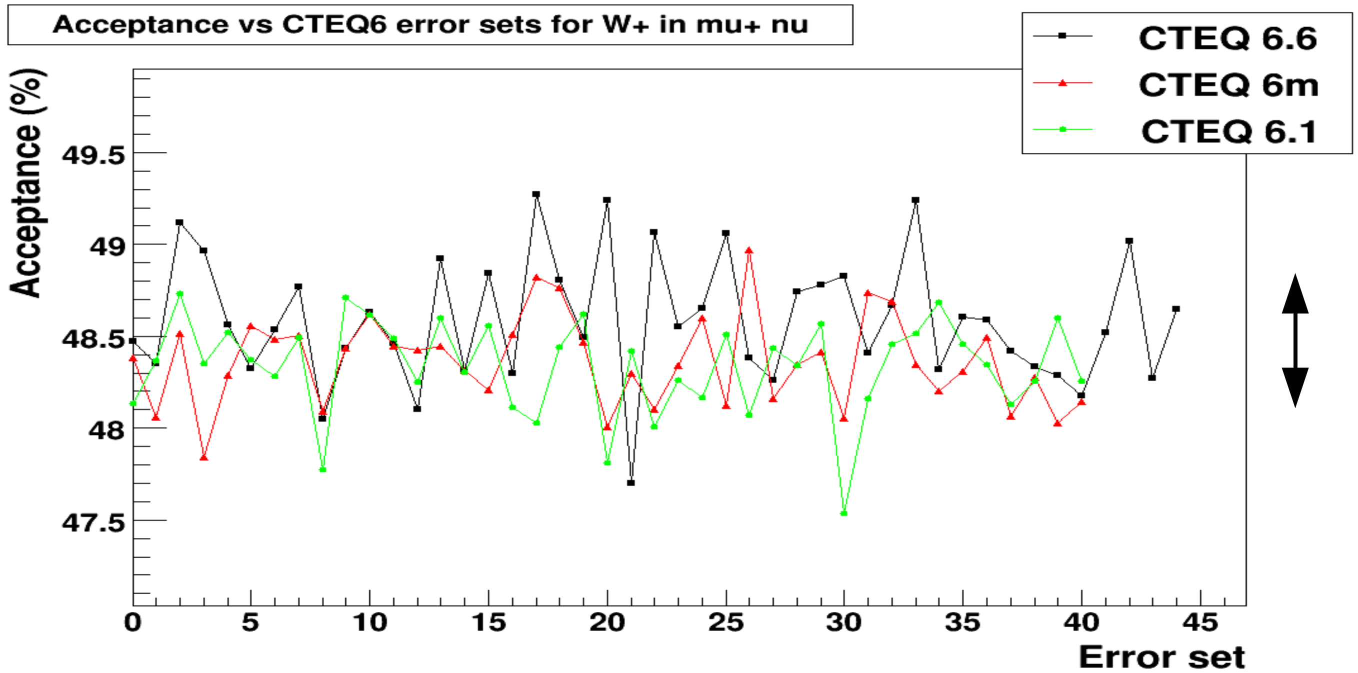


- New data included, especially HERA charm production.

$W^+ \rightarrow \mu^+ \nu_\mu$ cross section and acceptances



~ 5.5 % difference



~ 0.7 % difference

Hessian errors on acceptances

Errors associated with central value are calculated with CTEQ master formula:

$$\Delta X^{+}_{max} = \sqrt{\sum_{i=1}^{N}[max(X_i^{+} - X_0, X_i^{-} - X_0, 0)]^2}$$

$$\Delta X^{-}_{max} = \sqrt{\sum_{i=1}^{N}[max(X_0 - X_i^{+}, X_0 - X_i^{-}, 0)]^2}$$

Acceptance uncertainty grows for W⁺, decreases for W⁻ and Z, but remains > 3%

	$+\Delta A$	$-\Delta A$	$\max \frac{\delta A}{A} \times 100$
W^+ 6.1	1.772	0.787	3.682
W^+ 6	0.932	1.109	2.291
W^+ 6.6	2.059	1.111	4.248
W^- 6.1	1.178	1.486	3.078
W^- 6	2.453	0.425	5.102
W^- 6.6	0.888	1.708	3.493
Z 6.1	1.508	1.189	3.540
Z 6	0.386	2.792	6.471
Z 6.6	2.532	0.286	5.860

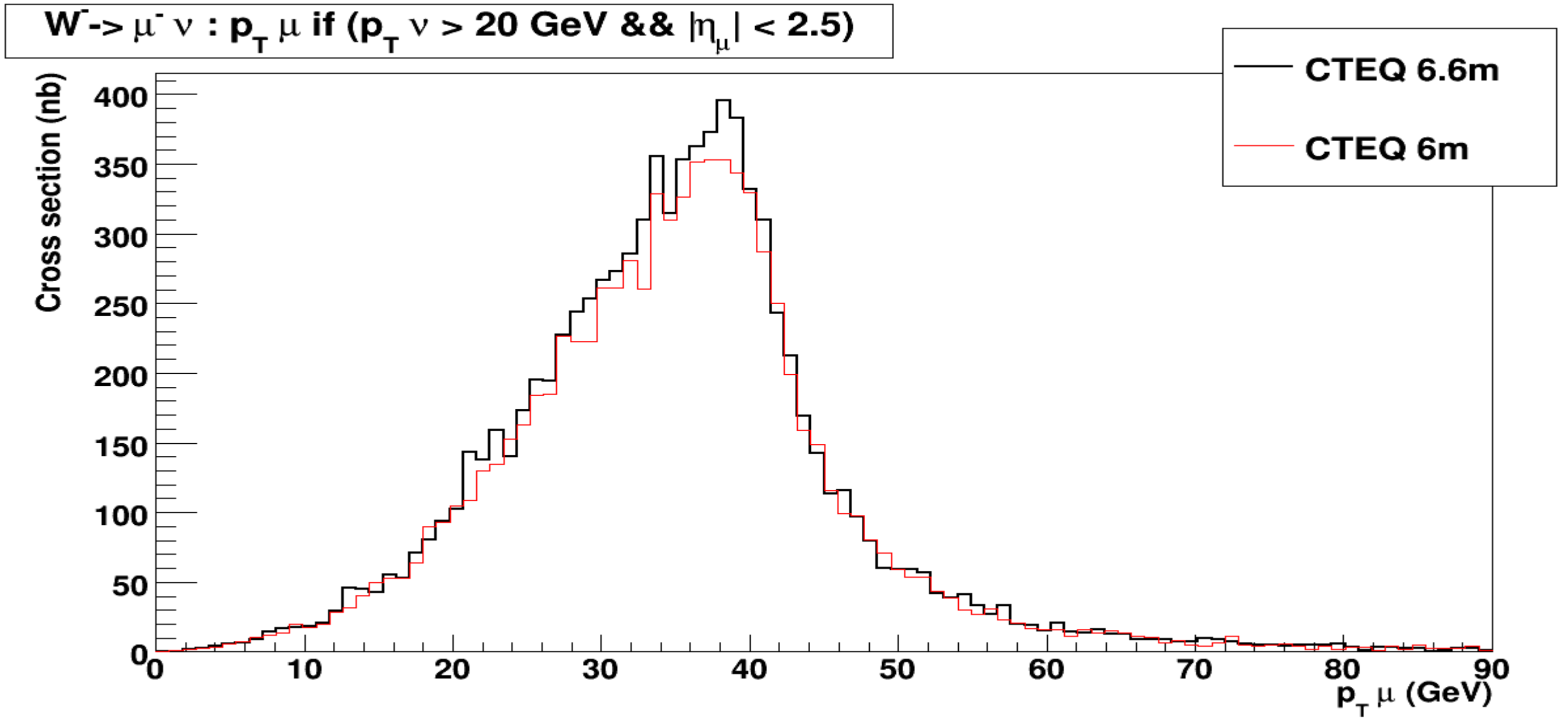
+

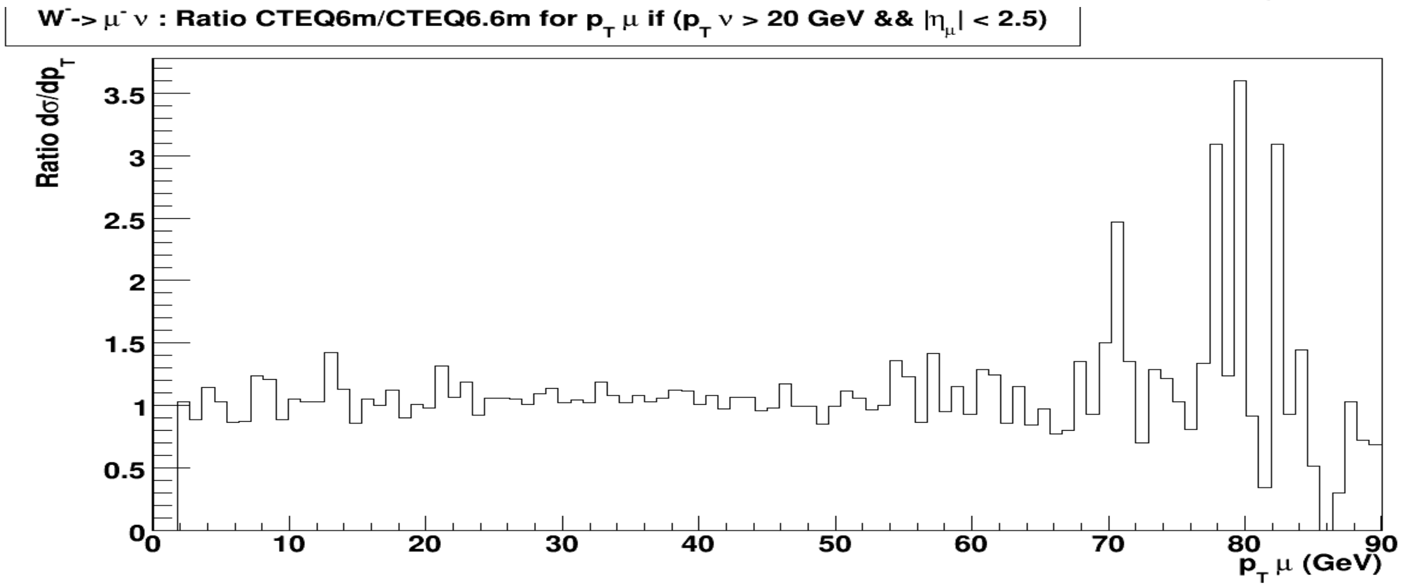
-

-

very asymmetric errors!

pT of the muon coming from W⁻ decay:





As expected, shapes do not change moving from CTEQ6 to 6.6.

PDF-induced correlation on acceptance

Following **hep-ph 0802.0007** (Nadolsky et al.), we study correlation between PDF degrees of freedom for W and Z acceptances.

For any two variables depending on PDFs: $X(\overrightarrow{a}),\ Y(\overrightarrow{a})$

we can investigate correlation drawing an **ellipse** in the rescaled δX - δY plane:

$$\begin{cases} X - X_0 = \Delta X \cos\theta \\ (Y - Y_0)\cdot \frac{\Delta X}{\Delta Y} = \Delta X \cos(\theta + \varphi) \end{cases}$$

where we calculate ΔX ignoring Hessian asimmetry:

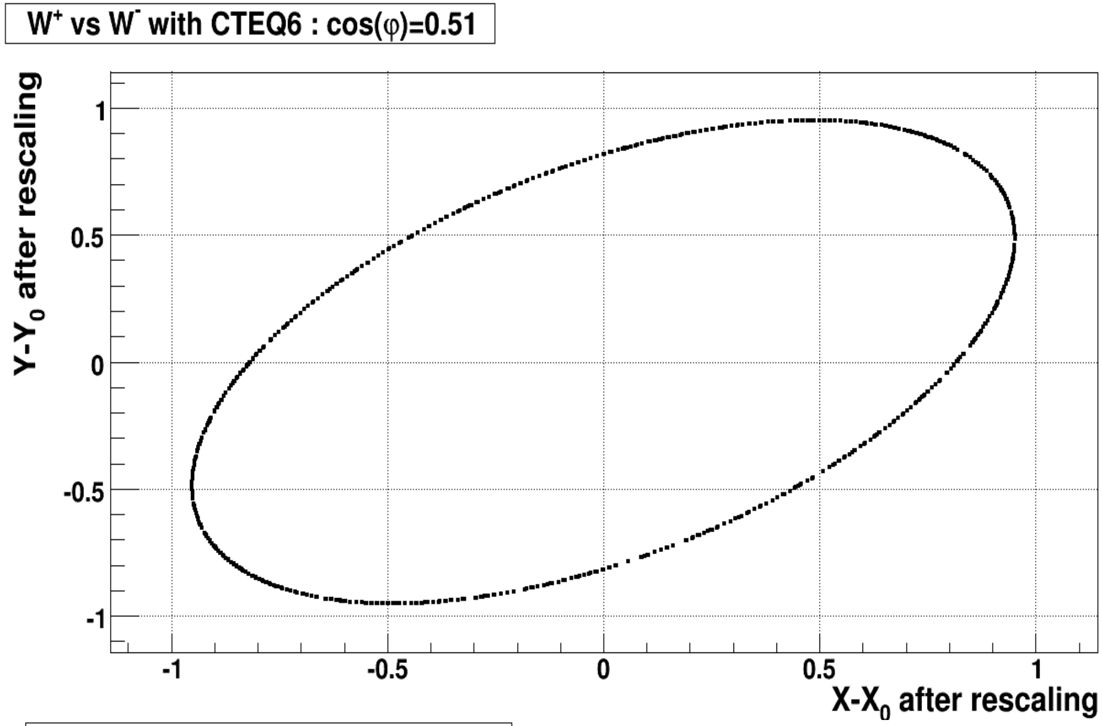
$$\Delta X = \left|\overrightarrow{\nabla} X\right| = \frac{1}{2}\sqrt{\sum_{i=1}^{N}\left(X_i^{(+)} - X_i^{(-)}\right)^2}$$

***cosφ* characterizes the amount of correlation between *X* and *Y* :**

$$cos\varphi = \frac{\overrightarrow{\nabla} X \cdot \overrightarrow{\nabla} Y}{\Delta X \Delta Y} = \frac{1}{4\Delta X \Delta Y}\sum_{i=1}^{N}\left(X_i^{(+)} - X_i^{(-)}\right)\left(Y_i^{(+)} - Y_i^{(-)}\right)$$

The more *cosφ* is close to 1, the more the curve is an ellipse: so if we constrain X, we're constraining Y at the same time

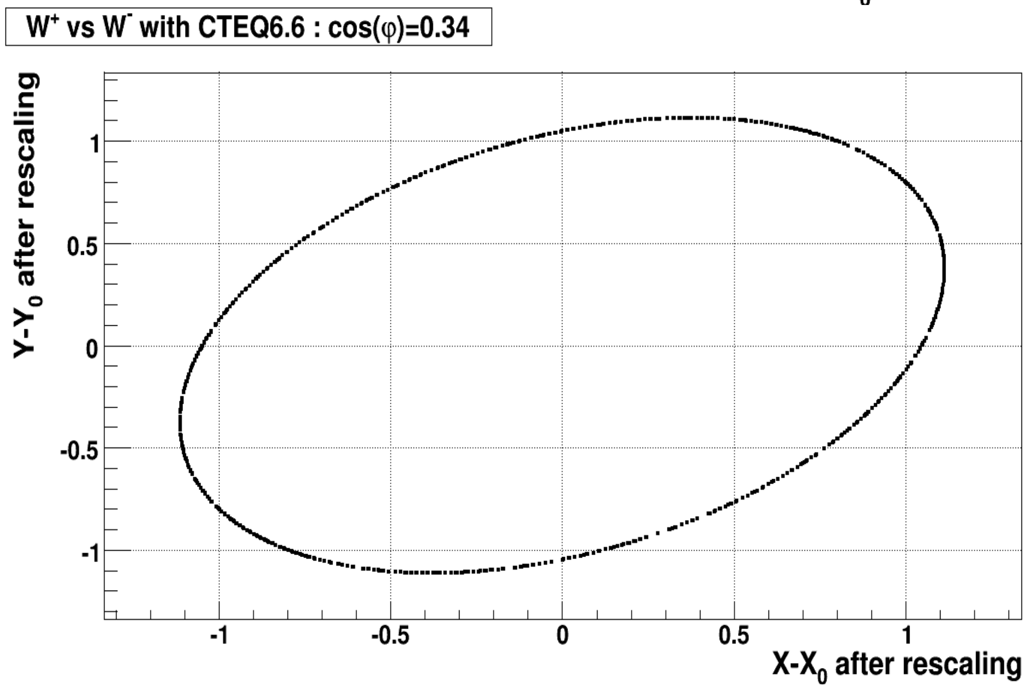
CTEQ 6 and 6.6 : W+ vs W-



X = acceptance for W-

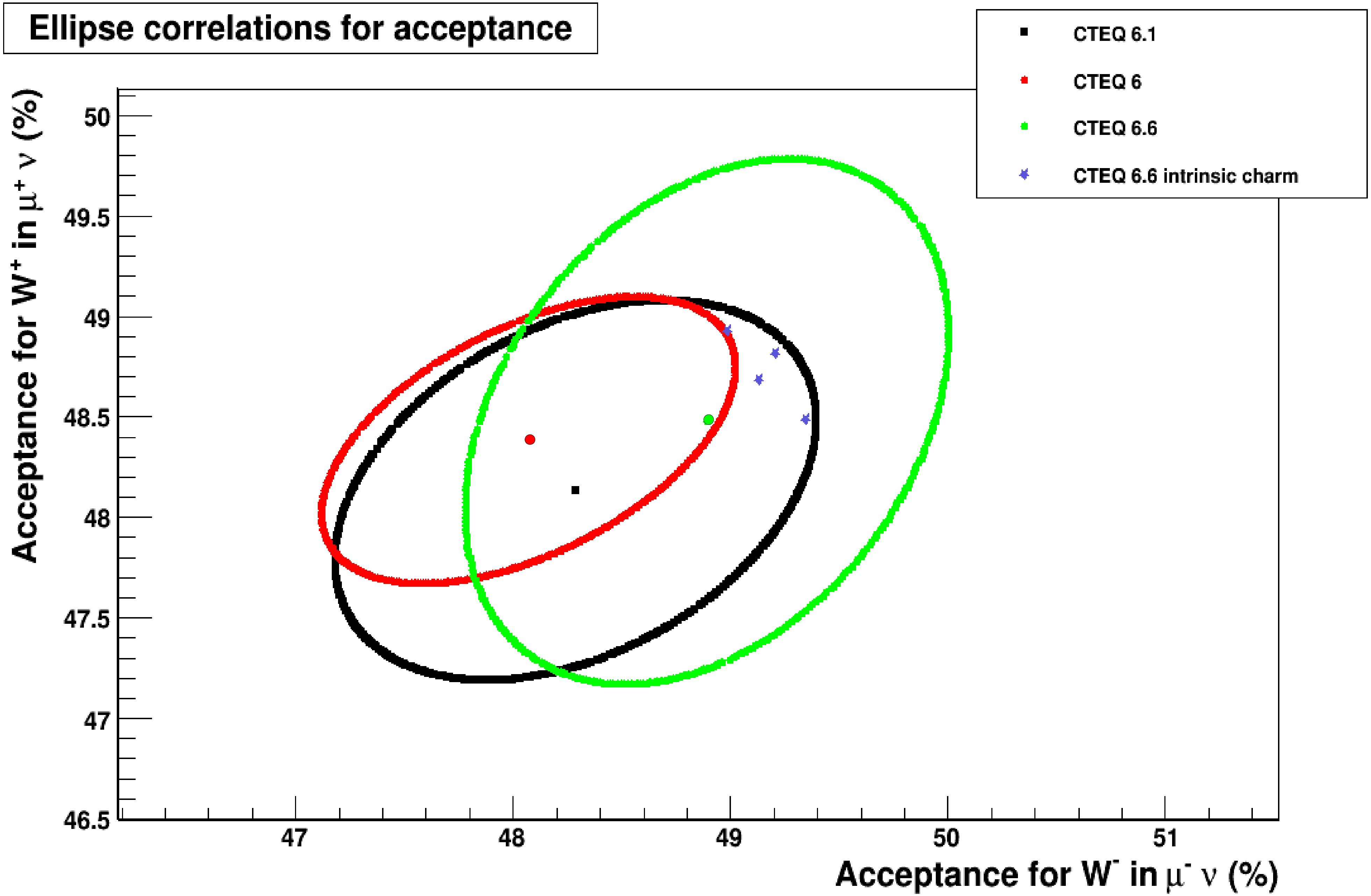
Y = acceptance for W+

CTEQ 6: cos(φ) = 0.51
medium correlation



CTEQ 6.6: cos(φ)=0.34
low correlation

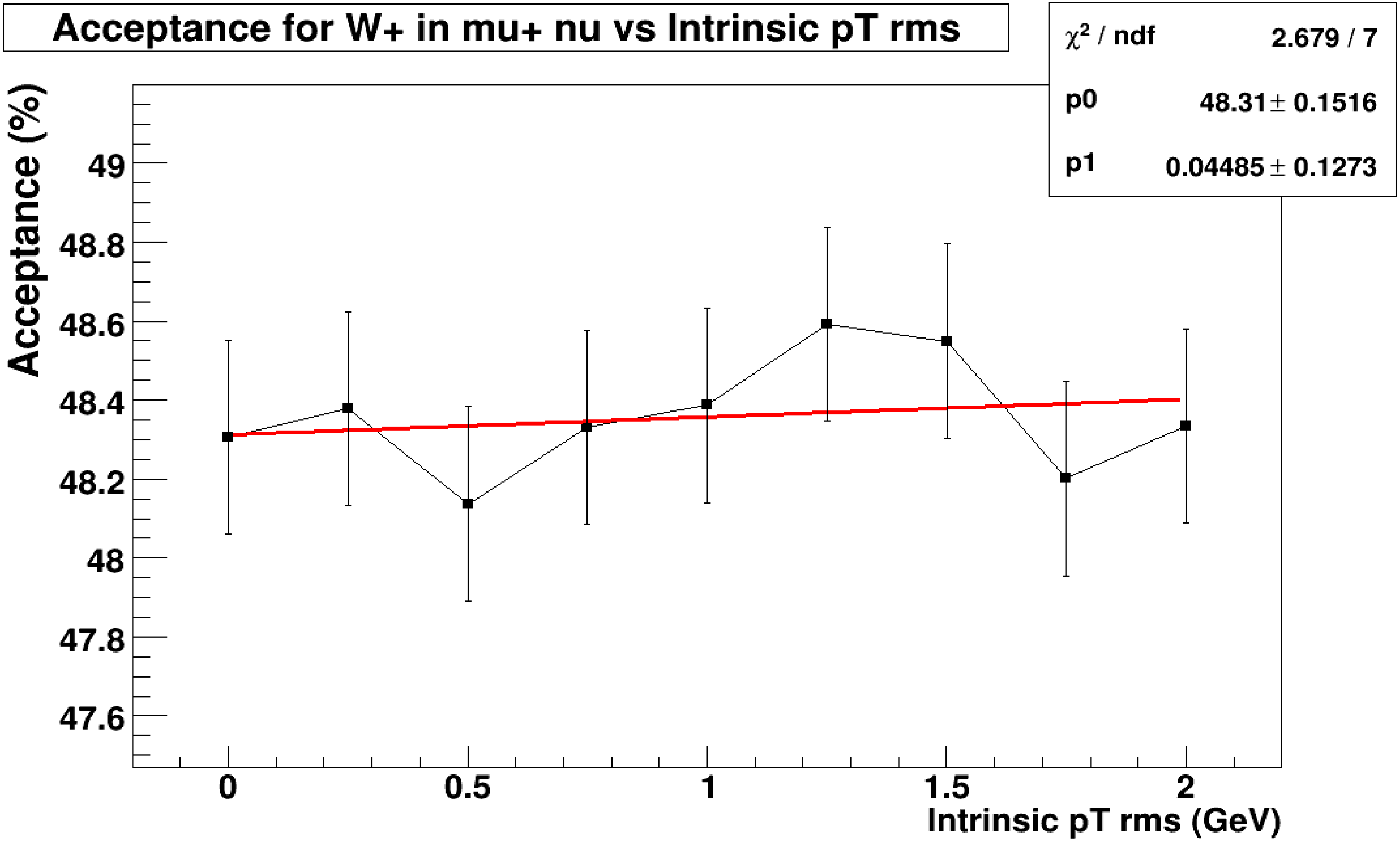
Without rescaling, we can see how much ellipses are overlapped:



Partonic intrinsic pT

After having assessed that slope is compatible with zero, we calculate

error on default value from a constant fit

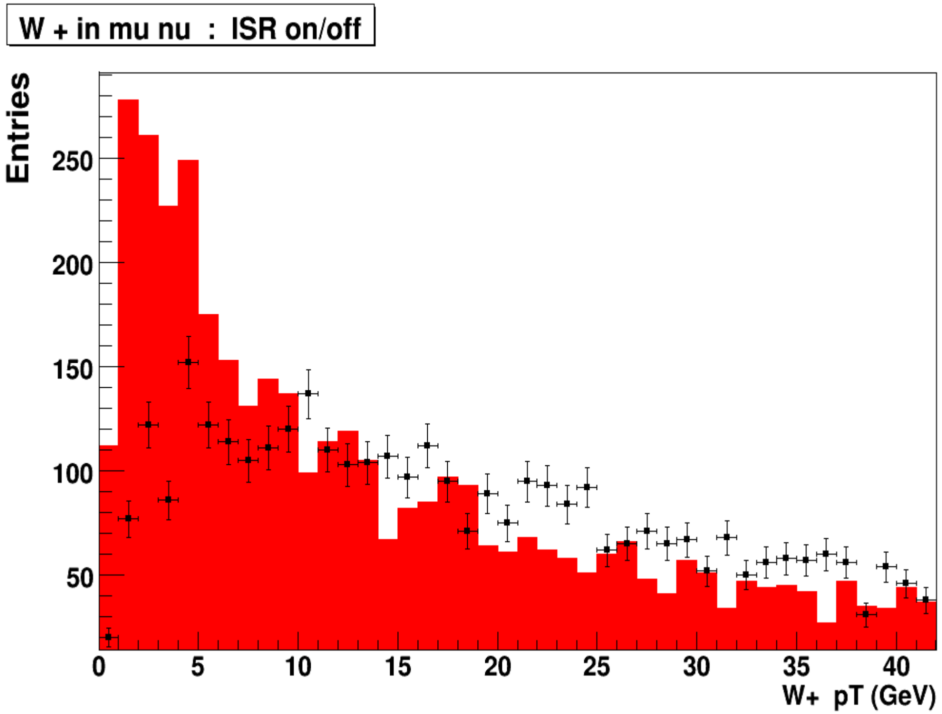


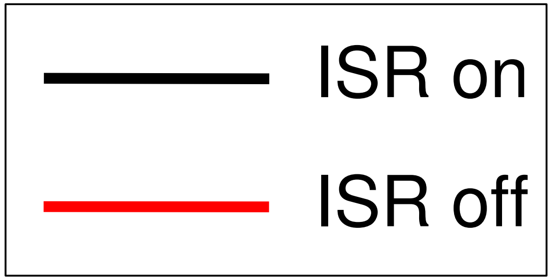
Impact of Initial State Radiation

Beside PDFs uncertainty, turning off ISR causes the most important change in acceptance (up to 6% for W^+).

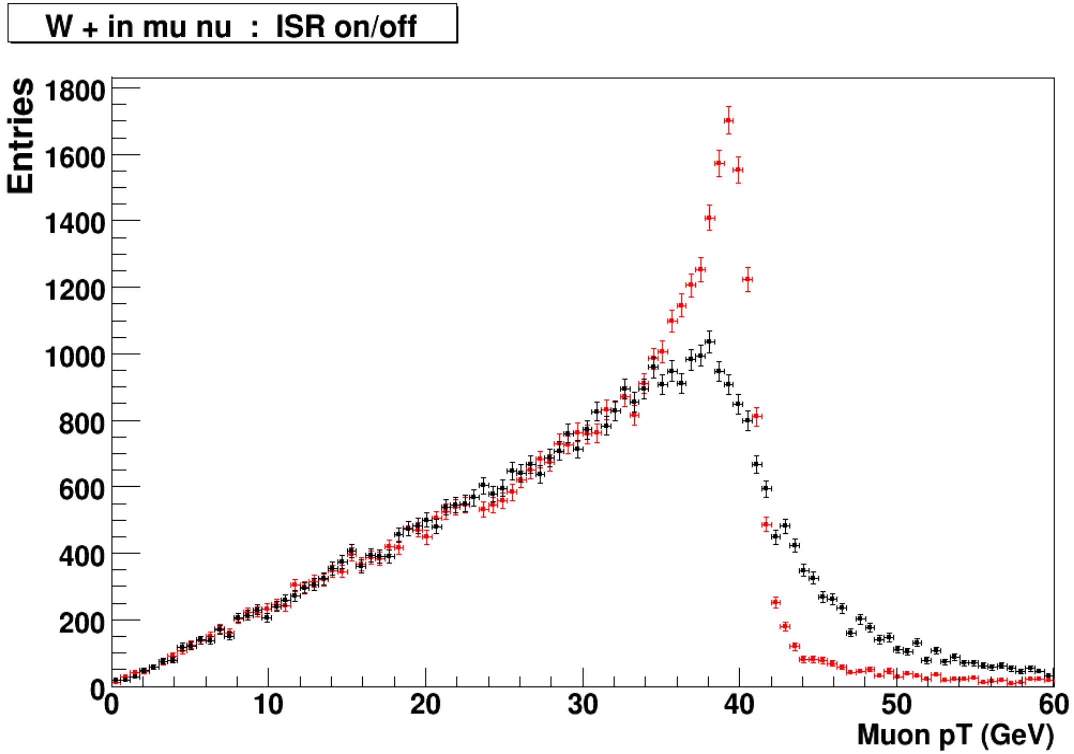
- Next slide: analysis of the impact of ISR on some interesting distributions (W and muon pTs) to see where this discrepancy arises from.

To do: quantify ISR impact varying theoretical parameters (scale of factorization, Matrix Element corrections for LO, scale of α_s, etc.).





W pT distribution is highly smoothed by presence of ISR, so we don't have anymore a sharp peak around ~ 3 GeV



As a consequence, also muon pT is well peaked when we turn ISR off (Jacobian peak)

Summary results for Mc@Nlo

	$W^+ \to \mu^+\nu_\mu$	$W^- \to \mu^-\overline{\nu}_\mu$	$Z \to \mu^+\mu^-$
Acceptance [%] (default setting)	48.306 ± 0.458	48.281 ± 0.465	42.623 ± 0.424
Photos *off* (Tool for EW corrections)	0.15 ± 1.34	0.19 ± 1.36	0.33 ± 1.41
ISR *off*	6.40 ± 1.37	4.50 ± 1.38	1.70 ± 1.41
Intrinsic $\mathrm{P}_t = 1$ GeV	0.17 ± 1.34	-0.27 ± 1.36	-0.36 ± 1.41
Spin correlation *off*	0.25 ± 1.34	-0.43 ± 1.09	0.59 ± 1.15

memo: default configuration: ISR on, UE on, Photos on, spin corr. on, intrinsic. pT= 0 GeV.

Errors are calculated as $\delta A = \frac{A - A_d}{A_d} \times 100$ with A_d = default

Conclusions

- Geometrical acceptances with different Monte Carlo generators have been studied, with focus on study of systematic errors. They are an important contribution to the overall systematic uncertainty of the cross sections.

⇒ Ultimately (≈ fb^{-1}) main error on σ : acceptance uncertainty

- Biggest effects are:
  - **PDFs uncertainty (up to 3.7 %)**
  - **ISR uncertainty ((6÷4) % for W, 1.7 % for Z)**.
- All other effects analysed are negligible.
  - Switch on/off ISR it is too 'crude', it appears more realistic to vary the switches regulating the amount and the strength of the radiation.