PDF uncertainties for ATLAS geometrical acceptance: comparing **CTEQ**, **MRST** and **Neural Network** results

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PDF4LHC, CERN, 29.05.2009

Cross section measurement and its uncertainties

The measurement of W/Z -> leptons cross sections will be one of the first goals of the ATLAS experiment

$$\sigma \equiv \sigma_{pp\rightarrow W/Z} \cdot \mathrm{Br}_{W/Z\rightarrow \ell\nu/\ell\ell} = \frac{N-B}{A \cdot \varepsilon \cdot \mathcal{L}}$$

geometrical acceptance

$$A = \frac{\text{Events inside kinematical cuts}}{\text{Total events}}$$

Cross section uncertainty:

$$\frac{\delta\sigma}{\sigma} = \frac{\delta N + \delta B}{N-B} + \frac{\delta A}{A} + \frac{\delta\mathcal{L}}{\mathcal{L}} + \frac{\delta\varepsilon}{\varepsilon}$$

statistical: $\frac{\delta N}{N} \sim \frac{1}{\sqrt{\mathcal{L}}}$

THEORETICAL

decrease with detector understanding

Estimated uncertainty sources for $Z \rightarrow \ell^+\ell^-$:

After the first fb^{-1}, $\delta\sigma$ will be dominated by acceptance uncertainty

$\int \mathcal{L}\,dt$	$\delta\sigma/\sigma$ (stat)	$\delta\sigma/\sigma$ (sys)	$\delta\sigma/\sigma$ (lum)
50 pb^{-1}	0.8 %	4.1 %	10 %
1 fb^{-1}	0.2 %	2.4 %	-

Monte Carlo simulations for acceptance calculations

We simulate samples of ~ 500k $Z/\gamma^* \to \mu^+\mu^-$ events at √s=14 TeV with **Mc@Nlo 3.3**, showered by Herwig 6.510, interfaced with LHAPDF, in stand alone mode

Starting from the *default configuration*, we change all the relevant parameters:

- **PDFs**:
  - **CTEQ // Neural Network // MRST**
- All the other effects **(intrinsic transverse momentum of partons ≠ 0, initial state radiation amount...)** are found to be **negligible wrt PDFs**

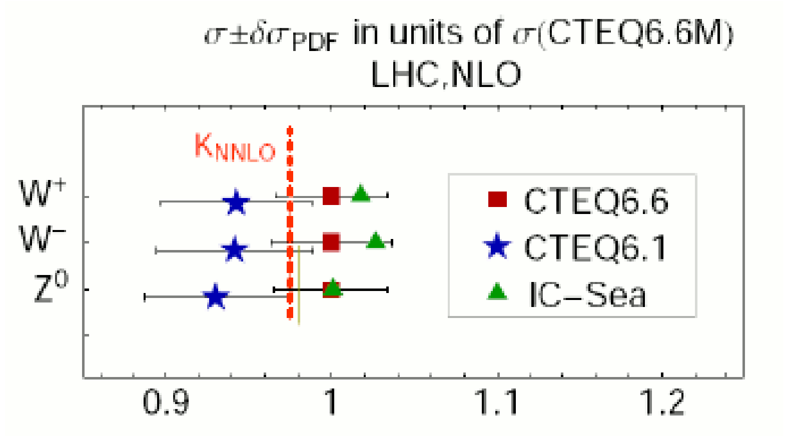
Acceptance is calculated imposing the following cuts on μ+ and μ-:

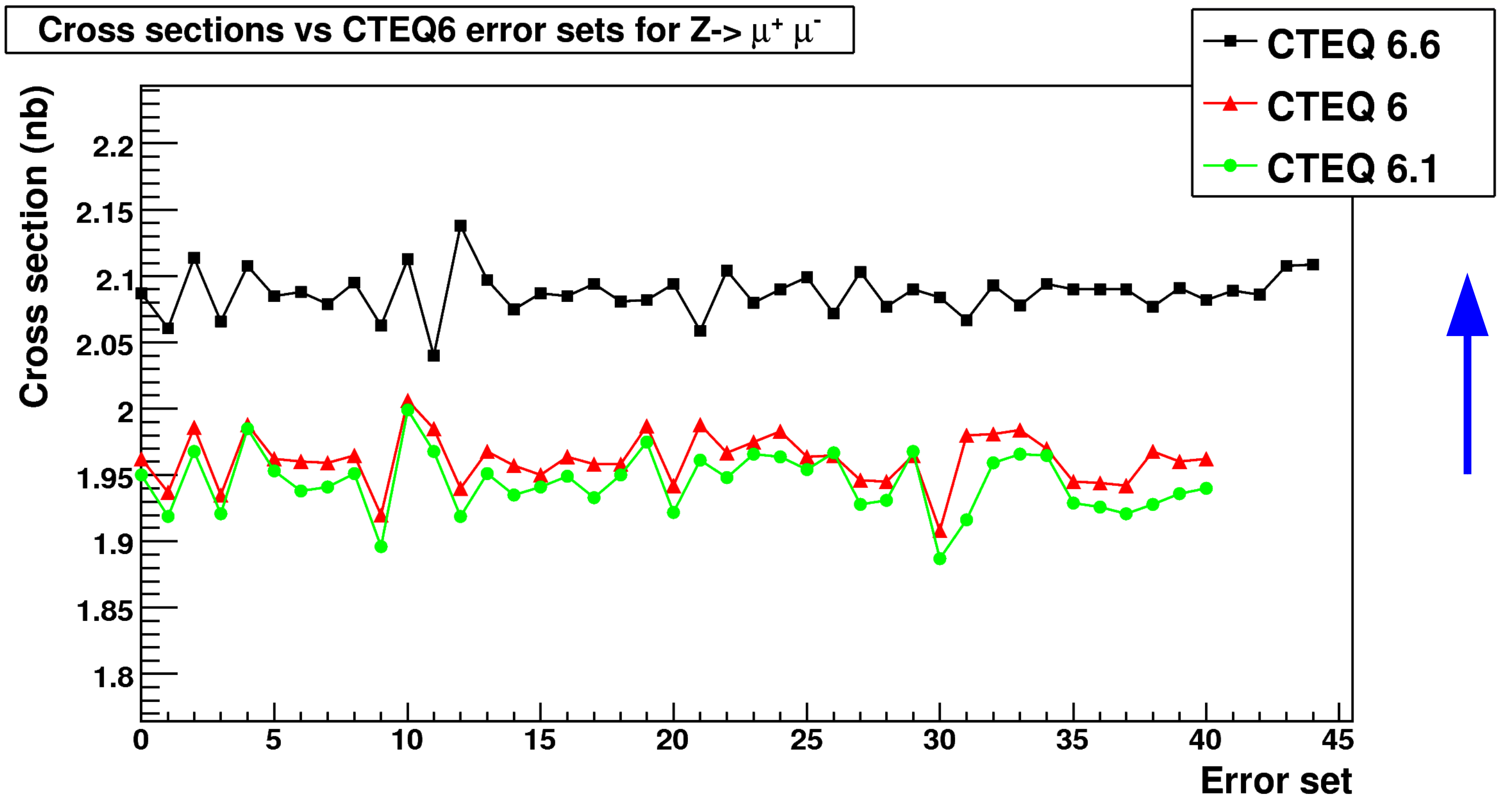
- p_T > 20 GeV to be separable from background
  - this threshold will be optimized as a function of √s and luminosity
- $|\eta|$ < 2.5 in order to make them triggerable

CTEQ6.6: inclusion of mass effects

CTEQ 6.6 analysis includes mass effects for heavy quarks (in the **General-Mass VFN** scheme). This causes the reduction of *c*, *b* e *g* contributions at **small and medium values of *x***, and a corresponding increase in *u* and *d* distributions:

➡ Big impact on W and Z production at the LHC: cross sections increase up to 6%.





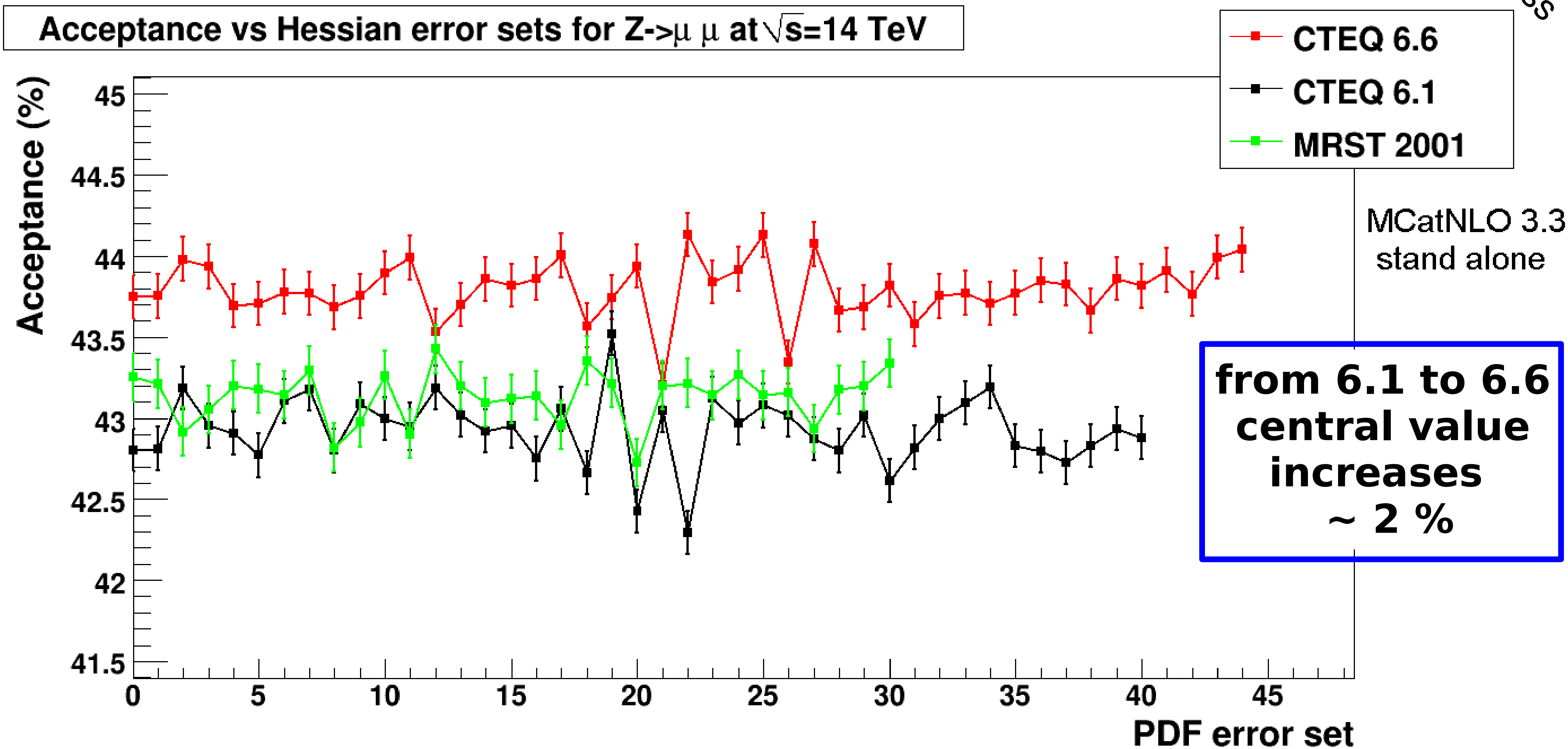
central values increase as expected

What happens to acceptance?

Work in progress

Comparison between CTEQ and MRST acceptance:

errors are statistical



from 6.1 to 6.6 central value increases ~ 2 %

CTEQ 6.1	CTEQ 6.6	MRST 2001
$A_{0}{}^{+\Delta A}_{-\Delta A} = 42.80^{+1.34}_{-0.68}$	$A_{0}{}^{+\Delta A}_{-\Delta A} = 43.75^{+0.93}_{-0.77}$	$A_{0}{}^{+\Delta A}_{-\Delta A} = 43.25^{+0.22}_{-1.05}$

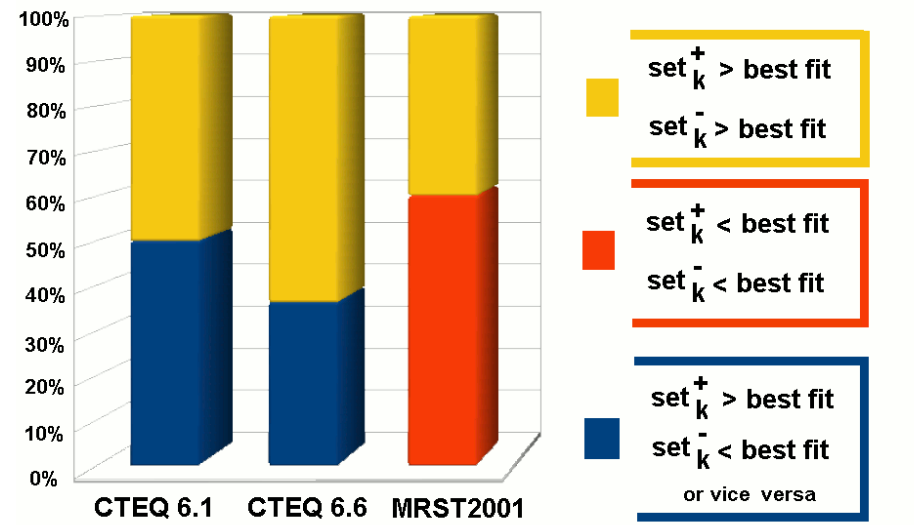
Error asymmetry

Hessian uncertainties are calculated via the asymmetric formula:

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

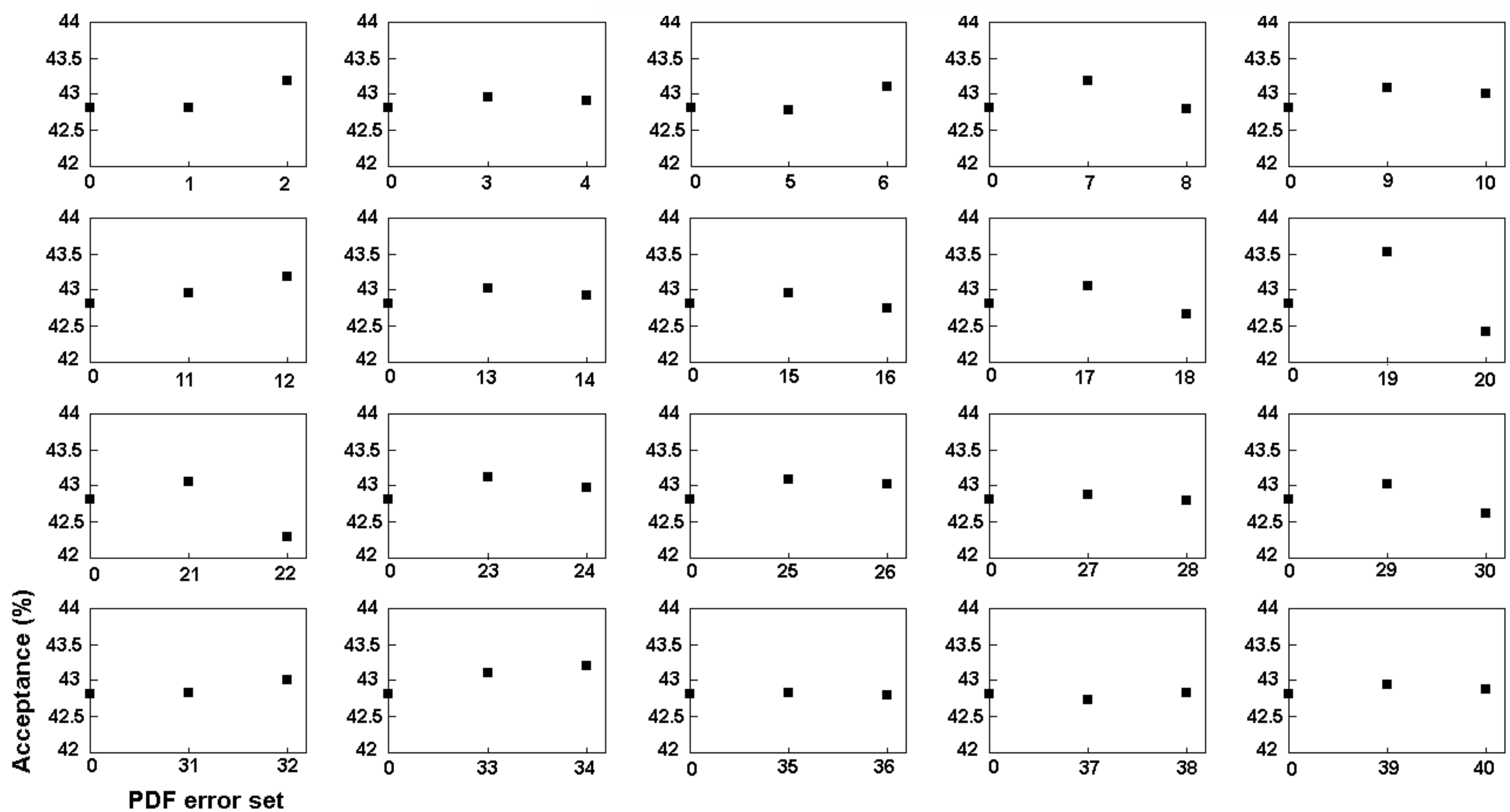
$$\Delta X^{-}_{max} = \sqrt{\sum_{i=1}^{N}[max(X_0 - X_i^{+}, X_0 - X_i^{-}, 0)]^2}$$

since we do NOT find symmetry for acceptance!



Example: **CTEQ 6.1**:

- **10 times** the two values along the k_{th} eigenvector are **bigger** than the best fit
- **10 times** they're **symmetrical**
- **0 times** they're **smaller**

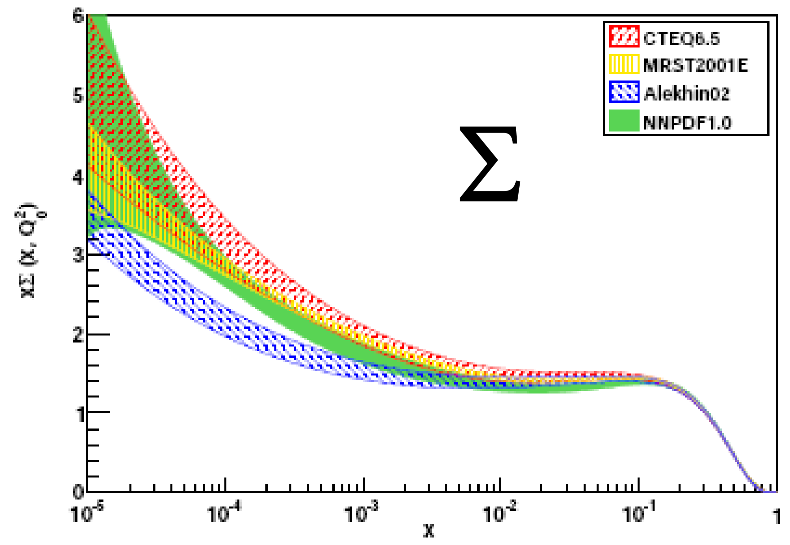


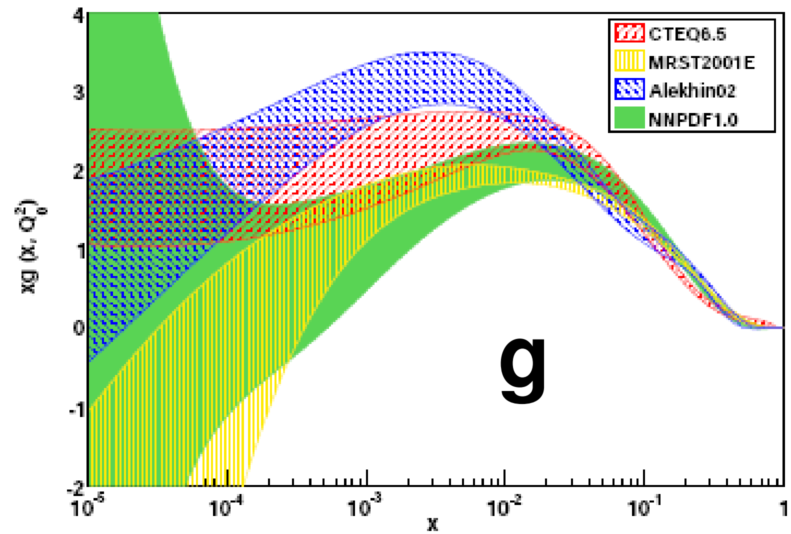
Advantages

- No biassing *a priori* parametrization
- Resulting PDF sets follow a Gaussian distribution, and so can be easily interpreted in a statistical way, needing no ad hoc tolerance criterion

Present limitations

- NNPDFs are in the **Zero-Mass** scheme, at NLO
- **Strange** distribution proportional to light sea (disfavoured by recent data)





Ball et al., arXiv:hep-ph/0808.1231

Acceptance estimation:

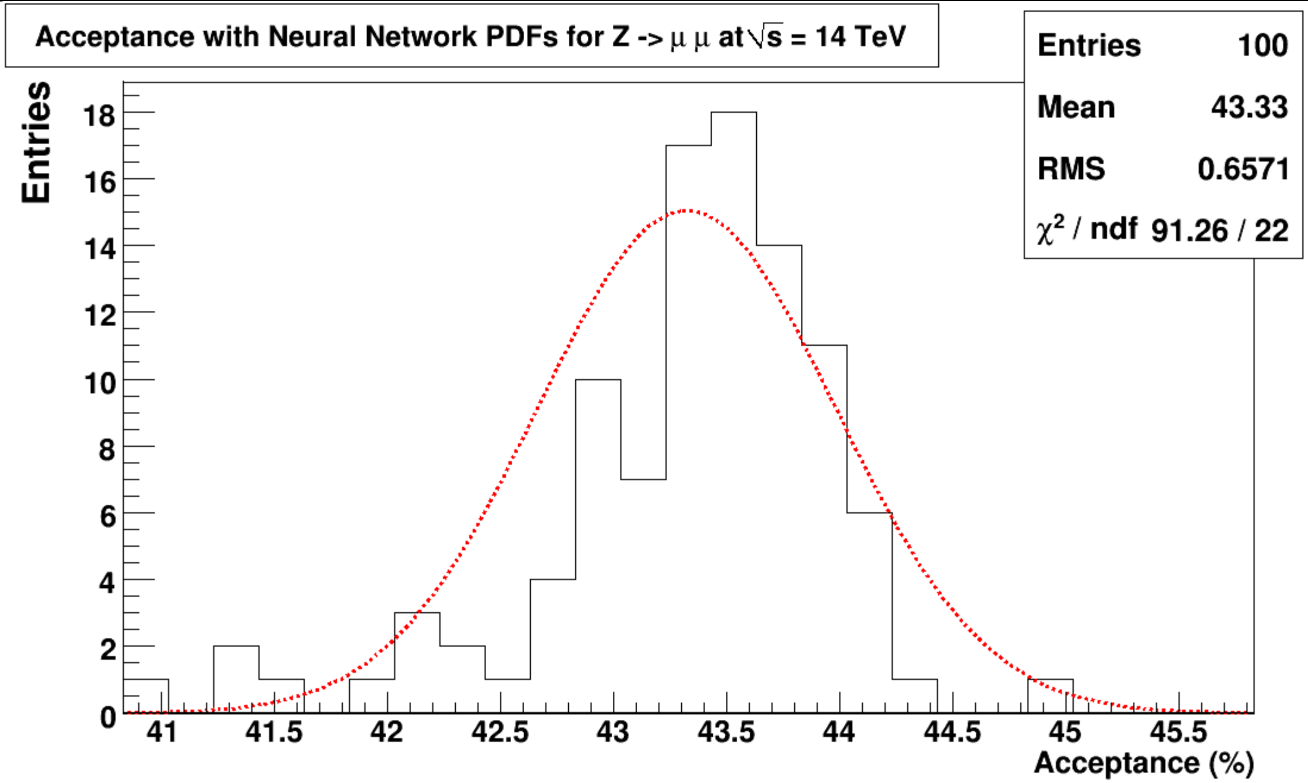
- We simulate events with the restricted set of 100 replicas
- **Uncertainties in principle are difficult to compare**

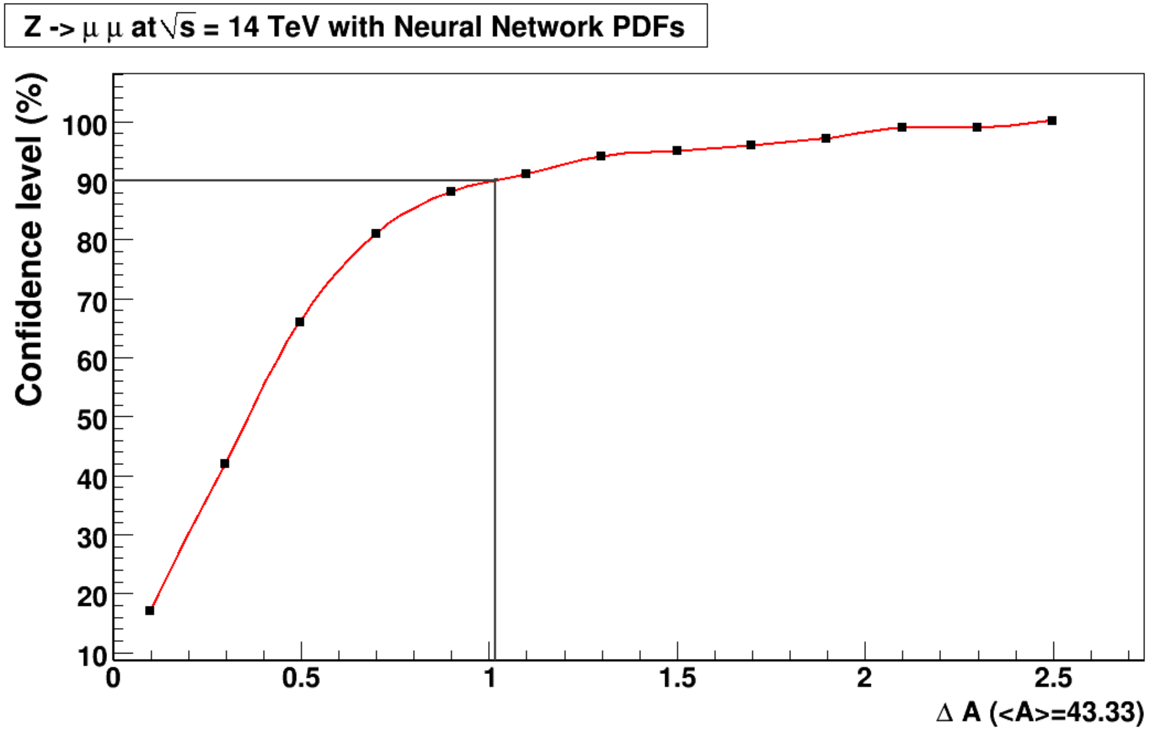
Preliminary results with NNPDFs

Gaussian fit:

χ^2 /ndf $\approx$ 91/22

A ± σ(A) = 43.33 ± 0.66





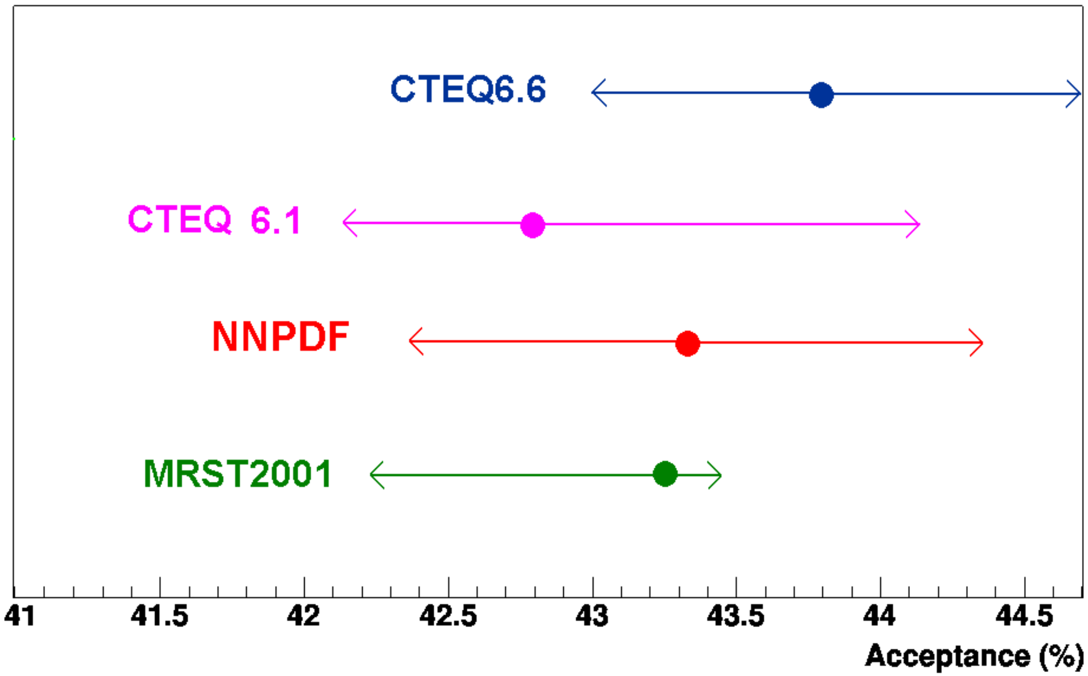
We can compare directly the 90% NN confidence level with that resulting (approximatively) from CTEQ tolerance criterion:

$$\chi^2_{\text{global}} \leq T^2 = 100$$

and MRST T^2 = 50

NNPDFs vs standard PDF sets

Work in progress



- All the sets used are at NLO
  - CTEQ 6.1 do not include mass effects
- Central values of standard PDF sets are **inside the NN allowed range** (90% CL)
- Uncertainties are of the **same order** but NN ones have the advantage to be symmetric

	A_0	$+\Delta A$	$-\Delta A$	$\left(\max \frac{\delta A}{A}\right) \times 100$
CTEQ 6.1	42.80	1.34	0.68	3.12
CTEQ 6.6	43.75	0.93	0.77	2.12
MRST 2001	43.25	0.22	1.05	2.43
Neural Network	**43.33**	**1.0**		**2.3**

Conclusions

- PDFs are the most important source of uncertainty for acceptance calculations (up to ~ 3%), hence for cross section measurements

- Different PDF sets (CTEQ 6.1 – 6.6, MRST2001, Neural Network PDFs) give comparable results
  - NNPDFs are not biassed by:
    - a priori parametrization
    - ad hoc tolerance criterion

- Thus they look very promising for future ATLAS studies