Parton Density Functions at the LHC: prospects for measurement from W and Z inclusive production

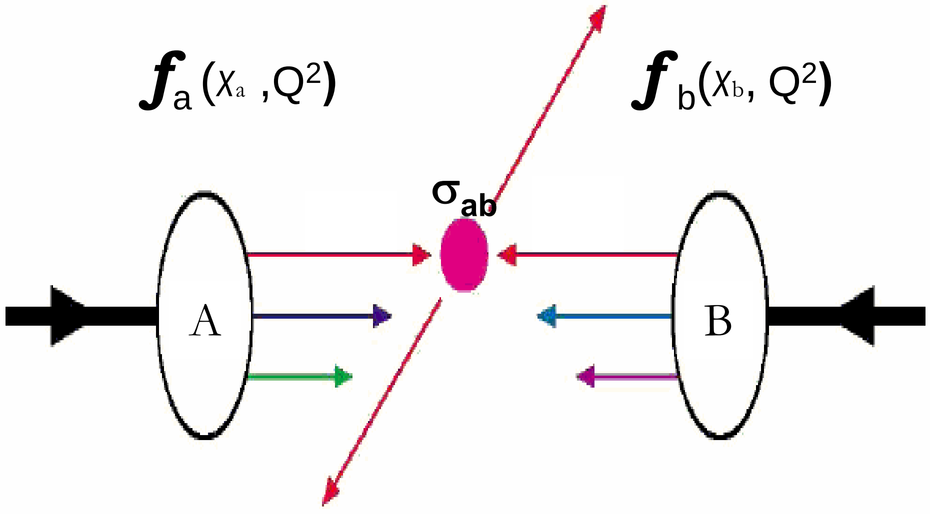
Sara Diglio

Summary

- Introduction to Parton Density Function
- Kinematic regime at LHC
- W and Z inclusive productions

1. Impact of PDFs uncertainties on Z and W measurements
2. How can the LHC contribute to provide input for the PDFs using W and Z?

Parton-Parton interactions



hadron collision

interaction between the partons which constitute the hadrons:
not well defined parton energy but energy distribution

At LHC pp collision

PDFs are parameterizations of the partonic content of the proton;
at Hadron Colliders cross-section calculation is a convolution of the cross-section at parton level and PDFs:

$$\sigma_X = \sum_{a,b} \int_0^1 dx_a dx_b f(x_a, flav_a, Q^2) f(x_b, flav_b, Q^2) \cdot \sigma_{ab \to X}(x_a, x_b, Q^2).$$

Sum over initial partonic states a,b

Parton Density Function

hard scattering cross-section

Parton density functions (PDFs)

$f_i(x,Q^2)$ $\begin{cases} i = u_v, d_v, g \text{ and sea} \\ x = p_{parton} / E_{beam} \\ Q^2 = \end{cases}$

- $i = u_v, d_v, g$ and sea
- $x = p_{parton} / E_{beam}$ **parton momentum fraction**
- Q^2 = **momentum transfer**

How are PDF's determined?

QCD predicts the scale dependence of $f_i(x,Q^2)$ through DGLAP evolution equations BUT does not accurately predict the x-dependence which has non perturbative origin

1. the x-dependence is parameterised at a fixed scale Q_0^2:
   - **valence quarks: $f \sim x^{\lambda} (1-x)^{\eta} P(x)$**
   - **sea/gluon: $f \sim x^{-\lambda} (1-x)^{\eta} P(x)$**

   different parameterisations and no.of free parameters used
2. $f_i(x,Q^2)$ is evolved from Q_0^2 to any other Q^2 by numerically solving the DGLAP equations to various orders (LO,NLO, NNLO)
3. the free parameters are determined by fit to data from experimental observables **(data from HERA experiments H1, ZEUS ,fixed target DIS experiments ,CDF, D0)**

Parton density functions (PDFs)

$f_i(x,Q^2)$
- $i = u_v, d_v$, g and sea
- $x = p_{parton} / E_{beam}$ **parton momentum fraction**
- Q^2 = **momentum transfer**

Three major groups provide semi regular updates to parton distributions when new data/theory become available:

1. **MRST**
2. **CTEQ**
3. **HERA collaboration H1, ZEUS**

PDF uncertainties:

Th: **perturbative calculations (i.e DGLAP approx., higher order truncation…)**

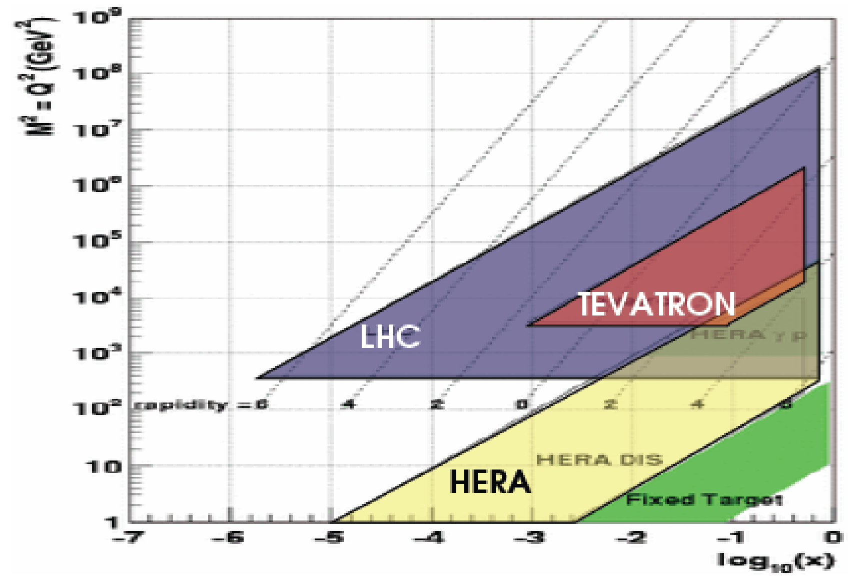
Th: **non-perturbative parameterisations (x-dependence)**

Exp: **statistical and systematic uncertainties on experimental data inputs**

Exp: **correlated systematic uncertainties on data points**

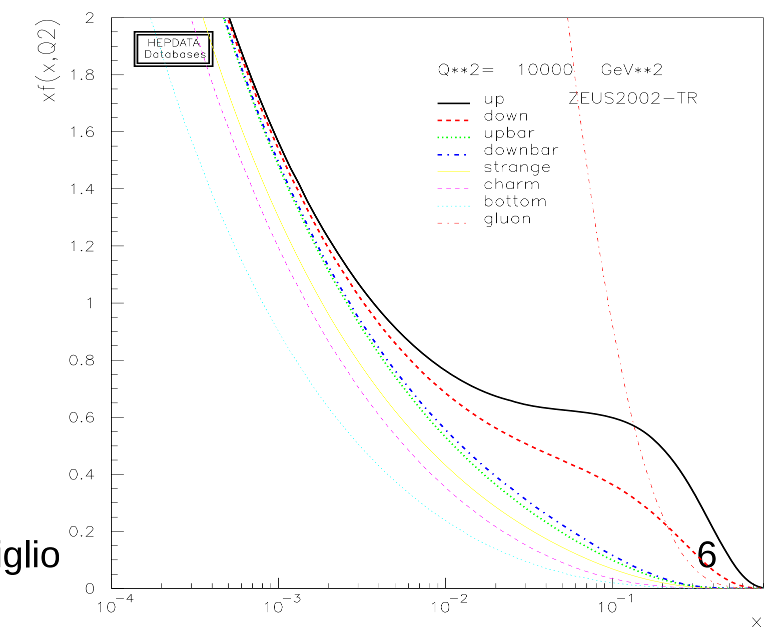
The LHC region

Kinematic regime for LHC much broader than currently explored



At the EW scale:

- cross section predictions for LHC are dominated by sea and/or gluon interactions at **low-x**
- at $Q^2 \sim M^2_{W/Z}$ the sea is driven by the **gluon** (via gluon splitting) which is far less precisely determined for all x values



low-x gluon uncertainty dominates

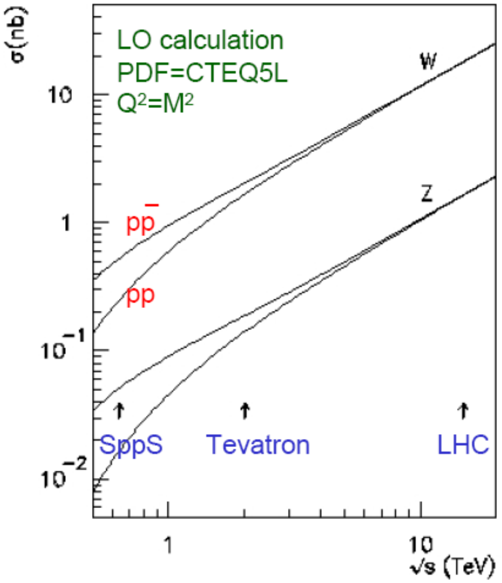
↓

We need an improvement in the knowledge of gluon PDF

W and Z cross sections

Z production: (main contributions) $\begin{cases} u\bar{u} \to Z \\ d\bar{d} \to Z \end{cases}$

W production: (main contributions) $\begin{cases} u\bar{d} \to W^+ \\ d\bar{u} \to W^- \end{cases}$



W/Z production have been considered as good standard candle processes with small theoretical uncertainty:

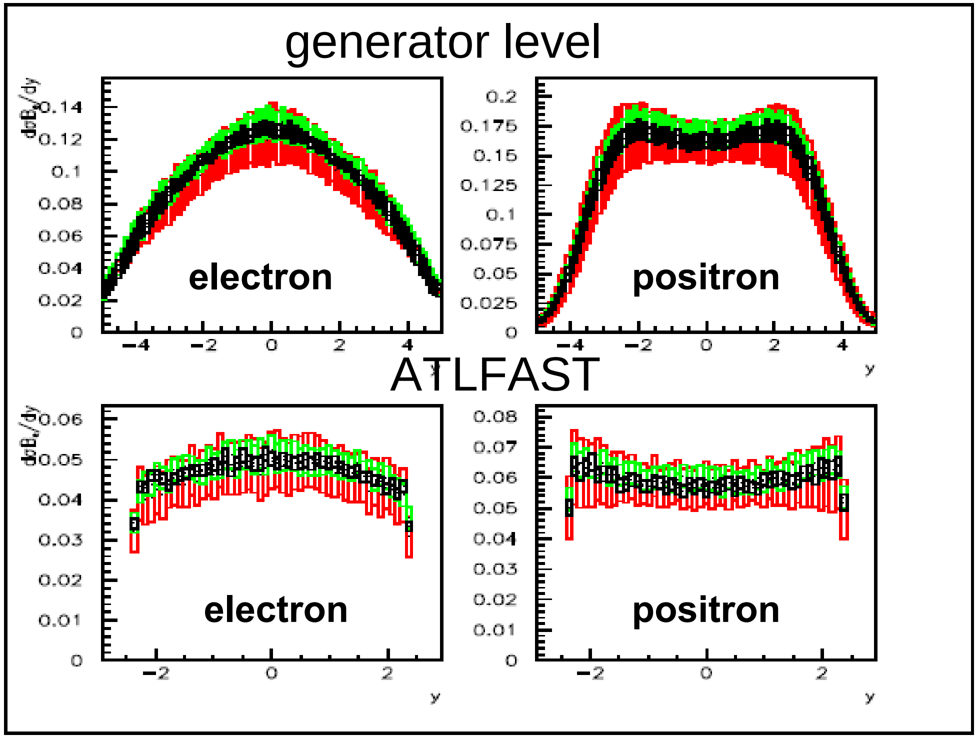
- **both experimental and theoretical errors are under control**

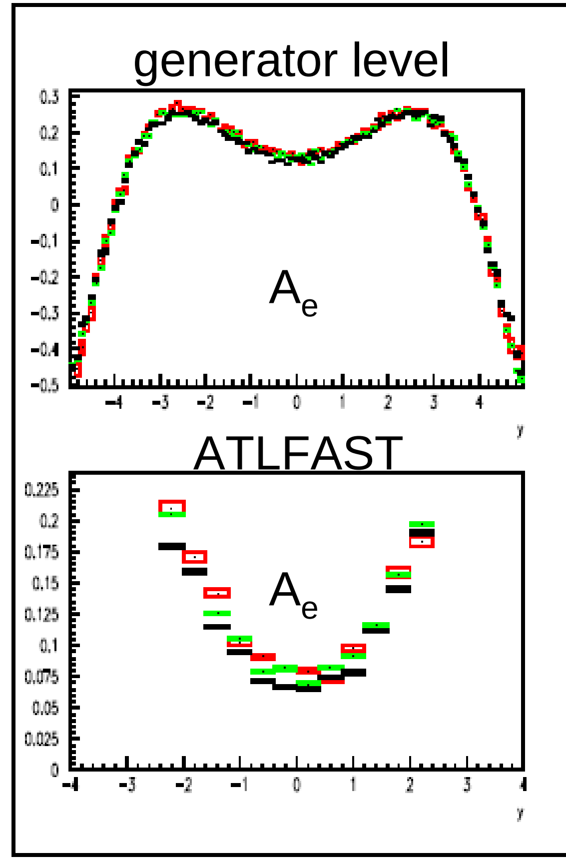
PDF Set	$\sigma(W^+).B(W^+ \to l^+\nu_l)$	$\sigma(W^-).B(W^- \to l^-\bar{\nu}_l)$	$\sigma(Z).B(Z \to l^+l^-)$
ZEUS-S no HERA	10.63 ± 1.73 nb	7.80 ± 1.18 nb	1.69 ± 0.23 nb
ZEUS-S	12.07 ± 0.41 nb	8.76 ± 0.30 nb	1.89 ± 0.06 nb
CTEQ6.1	11.66 ± 0.56 nb	8.58 ± 0.43 nb	1.92 ± 0.08 nb
MRST01	11.72 ± 0.23 nb	8.72 ± 0.16 nb	1.96 ± 0.03 nb

PDFs uncertainty dominant contribution. Most PDFs groups quote uncertainties <~5%

Impact of PDFs uncertainties on distributions

Monte Carlo W production and decay into lepton channel





Generation using CTEQ6.1M , ZEUS-S, MRST2001 PDFs

At y=0 the total uncertainty is

~ ±6% from ZEUS-S

~ ±4% from MRST01

~ ±8% from CTEQ6.1

Lepton asymmetry : $A_l = (l^+ - l^-)/(l^+ + l^-)$

In the *Ratios* there is a partial cancellation of the experimental PDF uncertainties: A_l ratio is ~1%

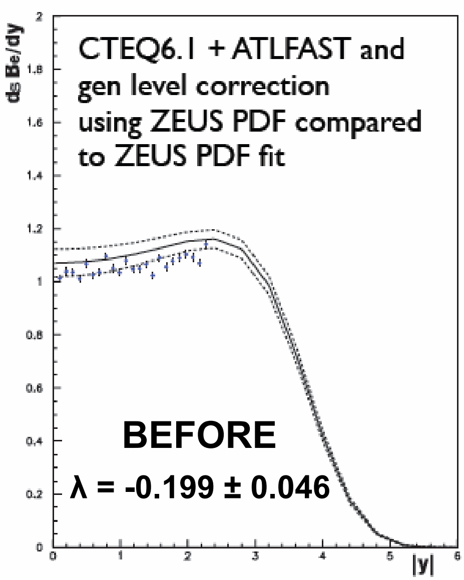
PDFs constraining potential

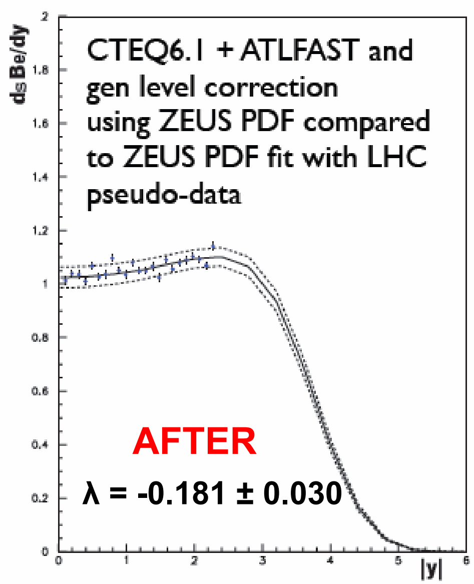
How much can we reduce the PDF errors when LHC is up and running?

GLUON

Simulate real experimental conditions: simulated W Rapidity pseudo data included in the global ZEUS PDF fit

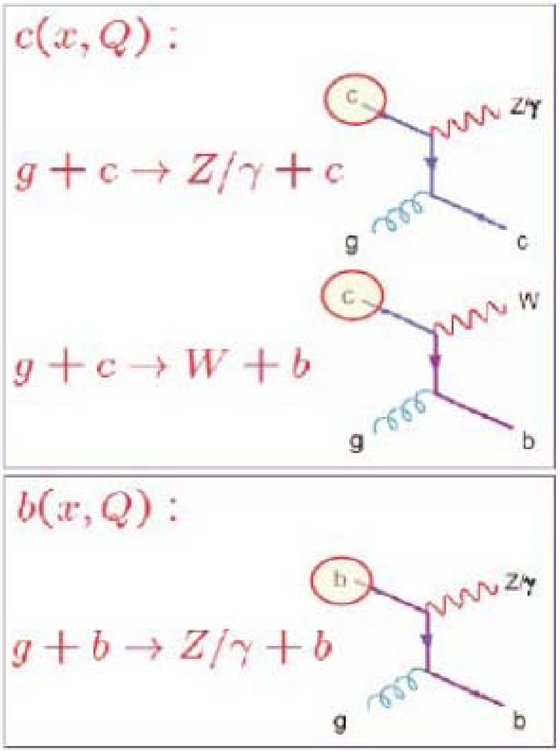
Central value of ZEUS-PDF prediction shifts and uncertainty is reduced: low-x gluon shape parameter λ, $xg(x) \sim x^{-\lambda}$





HEAVY QUARKS

Measurement of the Q-quark PDF (Q=s,c,b)
→ Process sensitive to Q content of the proton



Conclusions

- At LHC we are dominated by gluon/sea interaction at low-x: regions never accessed before will be covered
- Since HERA data largely improved our knowledge of PDFs, we expect that also LHC will improve this knowledge

- Current PDFs uncertainties on W/Z:
  - cross sections: <~ 5%
  - rapidity spectra: <~ 8%
  - Ratio and asymmetries: <~ 1%

- Many studies are ongoing to understand how LHC can improve the precision in the PDFs determination