Study of Parton Distribution Function at LHC

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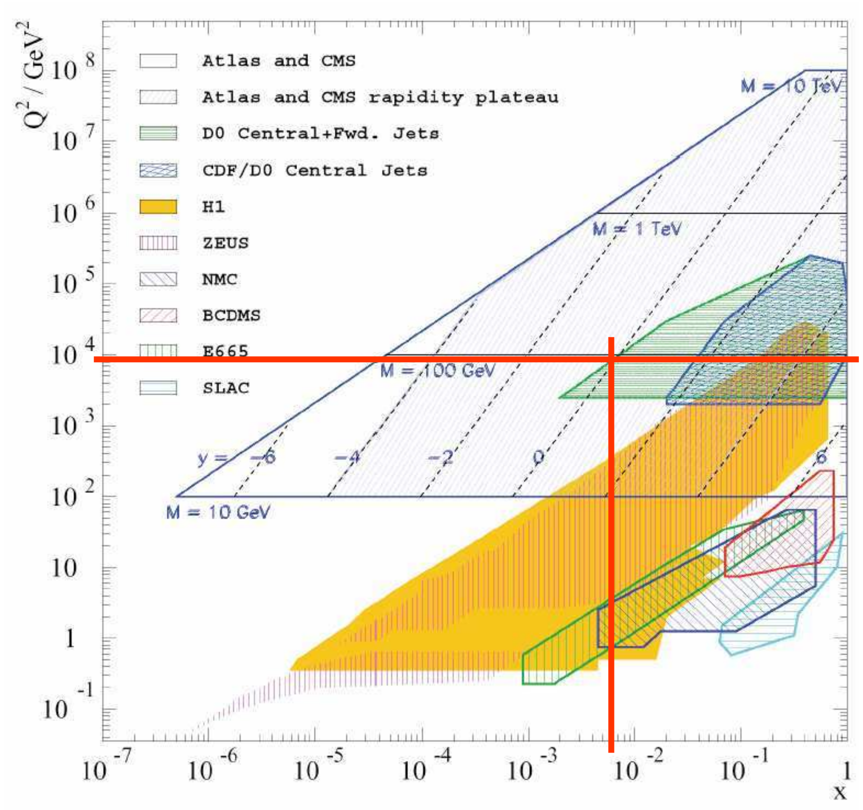
Outline

- List of the processes which are studied till now to know PDF.
- How the information of PDF is extracted from the experimental data.
- Some general trend of PDF uncertainties.
- How the asymmetry in W rapidity distribution can reduce the uncertainty of PDF.
- Possible sources of background.
- The required event selection criteria to eliminate the background.

Process/ Experiment	Leading order subprocess	Parton behaviour probed
DIS ($\boldsymbol{\mu N \to \mu X}$) $F_2^{\mu p}, F_2^{\mu d}, F_2^{\mu n}/F_2^{\mu p}$ (SLAC, BCDMS, NMC, E665)*	$\gamma^* q \to q$	Four structure functions $\to$ $u+\bar{u}$ $d+\bar{d}$ $\bar{u}+\bar{d}$ s (assumed $=\bar{s}$), but only $\int xg(x,Q_0^2)dx \simeq 0.35$ and $\int(\bar{d}-\bar{u})dx \simeq 0.1$
DIS ($\boldsymbol{\nu N \to \mu X}$) $F_2^{\nu N}, xF_3^{\nu N}$ (CCFR)*	$W^* q \to q'$	
DIS (small x) F_2^{ep} (H1, ZEUS)*	$\gamma^*(Z^*)q \to q$	λ $(x\bar{q} \sim x^{-\lambda_S},\ xg \sim x^{-\lambda_g})$
DIS ($\boldsymbol{F_L}$) NMC, HERA	$\gamma^* g \to q\bar{q}$	g
$\boldsymbol{\ell N \to c\bar{c}X}$ F_2^c (EMC; H1, ZEUS)*	$\gamma^* c \to c$	c $(x \gtrsim 0.01;\ x \lesssim 0.01)$
$\boldsymbol{\nu N \to \mu^+\mu^- X}$ (CCFR)*	$W^* s \to c$ $\hookrightarrow \mu^+$	$s \approx \frac{1}{4}(\bar{u}+\bar{d})$
$\boldsymbol{pN \to \gamma X}$ (WA70*, UA6, E706, ...)	$qg \to \gamma q$	g at $x \simeq 2p_T^\gamma/\sqrt{s} \to$ $x \approx 0.2 - 0.6$
$\boldsymbol{pN \to \mu^+\mu^- X}$ (E605, E772)*	$q\bar{q} \to \gamma^*$	$\bar{q} = ...(1-x)^{\eta_S}$
$\boldsymbol{pp, pn \to \mu^+\mu^- X}$ (E866, NA51)*	$u\bar{u}, d\bar{d} \to \gamma^*$ $u\bar{d}, d\bar{u} \to \gamma^*$	$\bar{u}-\bar{d}$ $(0.04 \lesssim x \lesssim 0.3)$
$\boldsymbol{ep, en \to e\pi X}$ (HERMES)	$\gamma^* q \to q$ with $q = u, d, \bar{u}, \bar{d}$	$\bar{u}-\bar{d}$ $(0.04 \lesssim x \lesssim 0.2)$
$\boldsymbol{p\bar{p} \to WX(ZX)}$ (UA1, UA2; CDF, D0)	$ud \to W$	u, d at $x \simeq M_W/\sqrt{s} \to$ $x \approx 0.13;\ 0.05$
$\boldsymbol{\to \ell^\pm}$ **asym** (CDF)*		slope of u/d at $x \approx 0.05 - 0.1$
$\boldsymbol{p\bar{p} \to t\bar{t}X}$ (CDF, D0)	$q\bar{q}, gg \to t\bar{t}$	q, g at $x \gtrsim 2m_t/\sqrt{s} \simeq 0.2$
$\boldsymbol{p\bar{p} \to}$**jet** $\boldsymbol{+ X}$ (CDF, D0)	$gg, qg, qq \to 2j$	q, g at $x \simeq 2E_T/\sqrt{s} \to$ $x \approx 0.05 - 0.5$



Over the measurable rapidity range, $|y| < 2.5$, x values remain in the range, $5 \times 10^{-4} < x < 5 \times 10^{-2}$.

Thus the scattering happens between the sea quarks.

All the hadron-hadron cross sections are dependent of the PDFs.

QCD factorization theorem for short distance inclusive processes:

$$d\sigma_X = \sum_{ij} \int dx_1 dx_2 f_i(x_1,\mu^2) f_j(x_2,\mu^2) d\hat{\sigma}_{ij\to X}$$

where X = W, Z, quarks, jets, Higgs.

The Processes must have well measured final states.

The NLO corrections to σ are known

Provide an important cross-check on the PDFs.

Parametrization of PDFs:

$$
\begin{aligned}
xu_v &= A_u x^{\eta_1}(1-x)^{\eta_2}(1+\epsilon_u\sqrt{x}+\gamma_u x)\\
xd_v &= A_d x^{\eta_3}(1-x)^{\eta_4}(1+\epsilon_d\sqrt{x}+\gamma_d x)\\
xS &= A_S x^{-\lambda_S}(1-x)^{\eta_S}(1+\epsilon_S\sqrt{x}+\gamma_S x)\\
xg &= A_g x^{-\lambda_g}(1-x)^{\eta_g}(1+\epsilon_g\sqrt{x}+\gamma_g x).
\end{aligned}
$$

$\eta_{1,3}$, $\lambda_{s,g}$ control the low-x shape

$\eta_{2,4}$, $\eta_{s,g}$ control high-x shape

ϵs and γs control middle-x shape

To ensure rise at low-x and $xg(x) \to 0$ as $x \to 1$.

QCD fits:

Parametrize a set of PDFs at a "starting scale" Q_0^2

Q_0^2: not too high, to keep as much data as possible (mainly DIS)
not too low, to be on perturbative domain.

Typical value of $Q_0^2 \sim 4GeV^2$

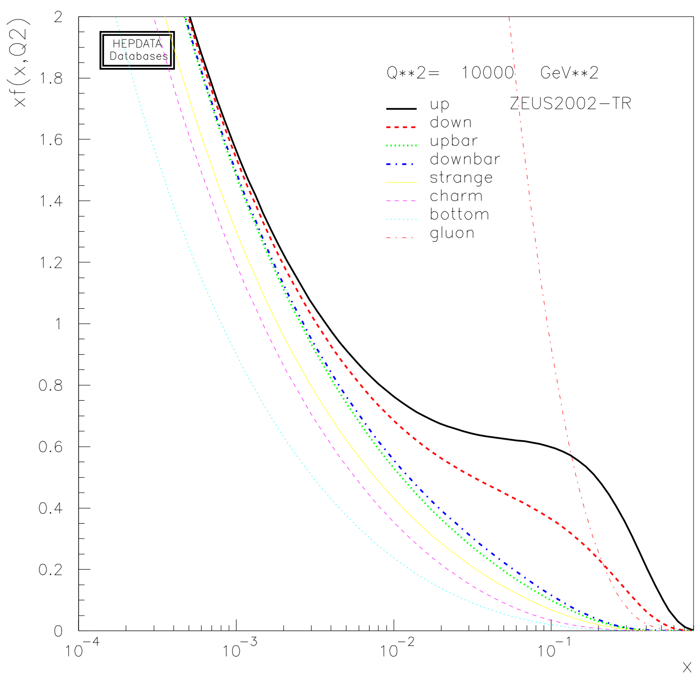
DGLAP equations give $f(x, Q^2)$ at any Q^2, once $f(x, Q_0^2)$ is known.

Impose sum and counting rules

The general trend of PDF uncertainties is:

- *The u quark is better known than the d quark.*
- *The valence quarks are much better known than the gluon at high-x.*
- *The sea and the gluon are well known at low-x.*
- *The sea and the gluon are poorly konown at high-x, but the valence quarks are more important in this region.*

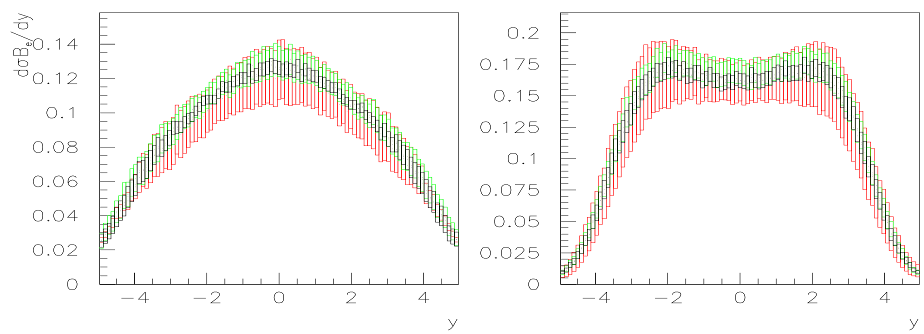
At the LHC we will have dominantly sea-sea parton interactions at low-x.



PDF distributions at $Q^2 = 10,000$ GeV^2.

At $Q^2 \sim {M_z}^2$ the sea is driven by the gluon, which is less precisely known

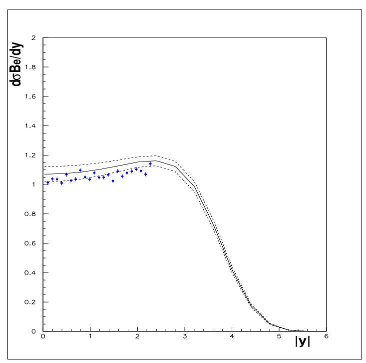
e^-, e^+ rapidity spectra for the lepton from the W decay at the generator level.

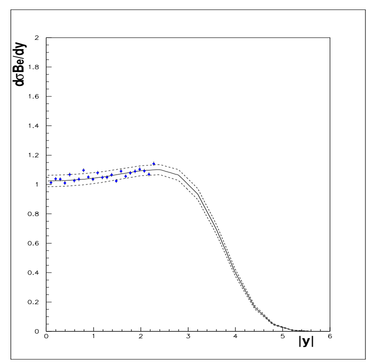


using CTEQ6.1 ZEUS-S MRST2001 PDF sets with full uncertainties.

Study of the effect of including LHC W rapidity distributions in global PDF fits:

- *Generate data with CTEQ6.1 PDF, pass through the detector simulation and then include this pseudo-data in the global ZEUS PDF fit. Central value of the prediction shifts and uncertainty at central rapidity is reduced from* 6% *to* 4.5%*.*





Improvement in the lox-x gluon shape parameter λ_g, $xg(x) \sim x^{-\lambda_g}$

$\lambda_g = 0.199 \pm 0.046$, before the input of the LHC pseudo-data,

$\lambda_g = 0.181 \pm 0.030$, after the input.

Background studies:

W is identified in the decay channel $W \to e\nu_e$

Several processes can be misidentified as $W \to e\nu_e$

1. $W \to \tau\nu_\tau$, with τ decaying to the electron channel
2. $Z \to \tau^+\tau^-$, at least one τ decaying to the electron channel
3. $Z \to e^+e^-$ with one electron identified

We apply the event selection criteria designed to eliminate the background.

The event selection criteria are:

- Pseudorapidity, $|y| < 2.4$, to avoid bias at the edge of the measurable rapidity range
- $p_{te} > 25GeV$, high p_t is necessary for electron triggering
- Missing $E_t > 25GeV$, the ν_e in a signal event will have a correspondingly large missing E_t
- No reconstructed jets in the event with $p_t > 30GeV$, to discriminate against QCD background