Parton Densities from DIS and Hadron Colliders to LHC

WG Summary

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7 sessions with 2 joint HF and 1 EW sessions

- HERA precision measurements and $F_L$
- asymmetries at Tevatron
- LHC: Z/W
- news from JLab
**HERA** Colliding-Beam Experiments: **H1 & ZEUS**

*Inclusive Measurement:*

\[
\sigma_{NC}(x,Q^2) , \sigma_{CC}(x,Q^2)
\]

\[
Q^2 = -q^2  \\
x = \frac{Q^2}{2p.q}
\]

HERA provides unique opportunity to study the proton.

**H1/ZEUS Kinematics**

6 orders of magnitude in \(Q^2\)

6 orders of magnitude in \(x\)
Precision measurement of $F_2$ with H1 detector

- H1 data from the year 2000 combined with published results using 1996/97 data

- significant achievement in the QCD PDF fit
- concept of parametrisation uncertainties introduced

Ringailė Plačakytė, DIS Florence, 23.04.2010
Measurement of $e^+p$ Scattering Cross Section at low $Q^2$

(F.D. Aaron et al. [H1 Collaboration], Eur. Phys. J. C63, 625 (2009) [ArXiv 0904.0929].)

- new combined measurement of $e^+p$ scattering cross section at $0.2 \leq Q^2 \leq 12\text{GeV}^2$ and $5 \times 10^{-6} \leq x \leq 0.02$
- measured accuracy is $\sim 1.7\%$ in the central region
- dipole models gives good description of the data

energy scale determination (SpaCal)
(band - uncertainty due to the scale difference between the data and the simulation)

Data included in:
- H1 QCD analysis (M. Klein)
- H1-ZEUS combination (S. Habib)
- $F_L$ extraction (J. Grebenyuk)
- QCD fits (V. Radescu)

Ringailė Plačakytė, DIS Florence, 23.04.2010
Combined Measurement and QCD Analysis of the Inclusive ep Scattering Cross Sections at HERA

H1 and ZEUS combined measurements: improved precision (down to 1%)

→ input to QCD fits

→ predictions for LHC

→ data used for $F_L$ determination

S. Habib

JHEP 1001:109, 2010
Combined HERA $F_L$ measurement

Longitudinal structure function $F_L$

$$\sigma_r(x, Q^2, y) = F_2(x, Q^2) - \frac{y^2}{Y_+} \cdot F_L(x, Q^2)$$

here $Y_+ = 1 + (1-y)^2$

- larger difference in $y \rightarrow$ increased sensitivity to $F_L$
- $Q^2 = xys$: different $y \rightarrow$ different $s \rightarrow$ different beam energies

**HERA:** $E_p = 920$ GeV, 460 GeV, 575 GeV
• ZEUS/H1 overlap region: $24 < Q^2 < 110 \text{ GeV}^2$

Measured reduced cross sections: $E_p = 460 \text{ GeV}$

ready for further data combination!
HERAPDF Fits including Low Energy Data

New accurate measurement in $Q^2 > 2.5 \text{ GeV}^2$ range, sensitive to $F_L$

Combined Low Energy Data Set of $E_p = 460, 575 \text{ GeV}$ with $Q^2 > 2.5 \text{ GeV}^2$

QCD Fit settings: same settings as for HERAPDF1.0

NLO DGLAP evolution equations, RT-VFNS

The $Q^2 > 5 \text{ GeV}^2$ cut brings large improvement in $\chi^2$

$818/806 \rightarrow 698/771$
- $Q^2$ cut doesn't change $F_L$ prediction

Low $Q^2$ range remains very interesting for further QCD tests

Investigation to HF model treatments: RT, ACOT, FFNS shows larger sensitivities than before:
Charged Current in $e^\pm p$ Scattering at HERA with Longitudinally Polarized Lepton Beams

K. Oliver/A. Raval

S. Shushkevich

H1: combined HERA data
ZEUS: 06-07 $e^\pm p$ data

$\frac{d^2\sigma(e^\pm p)}{dx dQ^2} = (1 + P) \times \frac{G_F^2 M_W^4}{2\pi(Q^2 + M_W^2)^2} \left[ \bar{u} + \bar{c} + (1 - y)^2 (d + s) \right]$
Neutral Current in $e^\pm p$ Scattering at HERA with Longitudinally Polarized Lepton Beams

H1: combined HERA data

V. Chekelian

ZEUS: measurement at high $x$

(HERA II + new reconstruction method)

New in this analysis:

1. HERA-II statistics (187 pb$^{-1}$), previous study (16.7 pb$^{-1}$)
2. Multi jet events (previous 0 + 1 jets)
3. New $x$-reconstruction method – leading to better resolution
4. Better understanding of the detector calibration

Expected outcome:

reduced PDF uncertainty at high $x$

PDFs uncertainties

1/σ uncertainty to CTEQ6D

$Q^2 = 648$ GeV$^2$

$0.5 < x < 0.9$

$\sigma = \frac{1}{\sigma}$

$X \in [0.5, 0.9]$

$Y_+ = \frac{Y_+ \times (\tilde{\sigma}_{NC} - \tilde{\sigma}_{NC})}{2Y_-}$
Combined Electroweak and QCD Fit to NC and CC Data

- primary constraint of PDFs
- also sensitive to light quark couplings to Z
- additional sensitivity in polarised e data $v_q$ by $F_2^{\gamma Z}$

$\chi^2$/dof=1183.8/(1244-14)=0.96

⇒ Weak couplings $v_q$: much improved as expected

→ For final precision, need the combined H1+ZEUS data
Asymmetries at CDF and D0

- D0 muon charge asymmetry
- CDF W asymmetry in the e channel
- Comparison of D0 and CDF lepton asymmetries

D0 muon charge asymmetry (new in 2009)
A different channel than previous W→ev measurements

20 GeV < PT(μ) < 35 GeV

PT(μ) > 20 GeV

PT(μ) > 35 GeV
CDF W asymmetry in the e channel

New technique as documented in: A. Bodek, Y. Chung, E. Halkiadakis, B. Han, K. McFarland, Phys. Rev. D 77, 111301(R) (2009).

Systematics $<1.5\%$ for $|y_W| > 2.0$

Compare to CTEQ6.1M (NLO) and MRST2006 (NNLO) PDFs and their uncertainties

Experimental precision is much better than the theoretical error band!
Comparison of D0 and CDF lepton asymmetries

- CDF have measured the electron asymmetry from the same data sample as their W asymmetry
- Compare with D0 muon and electron data:

**Tentative conclusions:**

- The CDF W asymmetry agrees well with theoretical predictions
- D0 and CDF lepton asymmetries disagree with theoretical predictions for binned lepton $p_t$, but seem to agree with each other!
Electroweak bosons at LHCb

- LHCb has unique access to a previously unexplored region of \((x,Q^2)\)
  - unique pseudo-rapidity coverage \(1.9 < \ll 4.9\)
  - low momentum trigger

- LHCb expects 1fb\(^{-1}\) in 2010/11.

Estimated yields =>

| channel           | #selected events in 2010/11 | purity |
|-------------------|-----------------------------|--------|
| \(W^+/^- \rightarrow \mu^- \nu_{\mu}\) | \(2.81 \times 10^6\)       | 0.94   |
| \(Z \rightarrow \mu^+ \mu^-\)          | \(6.73 \times 10^5\)       | 0.99   |
| \(\gamma^* \rightarrow \mu^+ \mu^-\)  | \(5.93 \times 10^5\)       | 0.95   |

- These measurements can provide a useful input to PDF constraining procedures in the low \(x\) region very quickly.
PDF sensitivity studies using electroweak process at LHCb

- potential for LHCb to constraint PDFs using rapidity distribution for Z, W\(^\pm\) and Drell-Yan production

A fitting procedure of the rapidity distribution has been developed

  • **Hessian method (MSTW, CTEQ)**
    possible to extract from the rapidity distribution the contribution from each eigenvector

  • **NNPDF method**
    a re-weight operation of the Montecarlo replicas has been performed

**Improvement on PDF:**

- about 10% with small amount of data (0.1 fb\(^{-1}\))

- up to 50-60% with 1 fb\(^{-1}\) gluon and sea distribution with low mass Drell-Yan
Measurement of the shape of Z rapidity distribution at LHC

- provides constraints on PDF's
- directly compared to similar measurements at Tevatron

**Sensitivity for 10 TeV (100 pb\(^{-1}\))**

Assuming no forward/backward structure in pp collisions, we can fold over the \(Y_Z\) distribution to reduce uncertainties.

Positive variation of CTEQ6.5(13)

Insufficient statistics for a 10 pb\(^{-1}\) measurement, although signal is visible.
The APPLgrid project

- Eur Phys J C66 (2010) 503
- Completely open source project
- Allows user generation of weight grids for both
  - Jet production (NLOjet)
  - Electroweak boson production (MCFM)
- Allowing simple input of any user defined PDF set
- Arbitrary variation of renormalisation and factorisation scales and the centre-of-mass energy.
- Built in interface to read fastNLO grids - adds additional APPLgrid functionality

- Typical differential cross section convolution around 50 ms
- Typically precision better than 0.05% - can be controlled by the user
New Measurements of the EMC Effect in Very Light Nuclei and at Large $x$

New data from E03-103 provide new precise data on EMC effect in light nuclei.

- Fit slope between $x=0.35-0.7$ as another measure of the magnitude of the EMC effect.

Density scaled by $(A-1)/A$ to remove contribution from struck nucleon.
Data show smooth behavior as density increases… except for $^9\text{Be}$

Results suggest that EMC effect depends on *local* nuclear environment rather than “average” properties.

N* Transition Form Factors with CLAS at Jefferson Lab

- New accurate measurements on $Q^2$ dependence of transition form factors of low lying excited states of the nucleon.