Towards the legacy of HERA

Combining H1 and ZEUS data

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DESY

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High energy landscape 1990 - 2010

0.21 TeV, ~ 0.9 fb⁻¹/exp.

0.32 TeV, ~ 0.5 fb⁻¹/exp.

1.96 TeV, ~ 4 fb⁻¹/exp.

- $500 \text{ fb}^{-1}/\text{exp.}$
- $10^9$ events/\exp.
- $10^{10}$ simulated events
- $2 \times 10^9$ € total investment
Publications

185 papers so far
Current activities and plans

• Finishing analyses and publishing:
  – 1\textsuperscript{st} round: Statistically limited or flagship analyses in each individual experiment; e.g. searches
  – 2\textsuperscript{nd} round: Systematically limited analyses in each individual experiment; e.g. inclusive measurements
  – 3\textsuperscript{rd} round: Joint H1-ZEUS analyses; e.g. QCD fits

• Grand Reprocessing of all data
• Long-term compact data format
• Freeze author lists in 2009
• Plans extend through 2014
Manpower situation

surveys done by collaborations in 2007/2008
Getting the most out

• Searches etc…:
  – maximize sensitivity/statistics
  – finish as quickly as possible
• Proton structure and QCD dynamics
  – maximize precision;

⇒ combine H1 & ZEUS statistics
⇒ cross calibrate the detectors
⇒ eventually make the data publicly accessible
Joint analysis groups

- Structure functions
- Diffraction
- Charm
- Jets

- Isolated leptons and missing $E_T$
- Multi-leptons
- Leptoquarks and contact interactions
Isolated leptons and missing $E_T$

- once a hot topic
  - excess observed by H1 (not seen by ZEUS)
- Full HERA-II data
  - in excellent agreement with SM

$e, \mu + P_T^{\text{miss}}$ events at HERA I+II ($e^\pm p$, 0.97 fb$^{-1}$)

- H1+ZEUS Data (prelim.)
- All SM
- Signal

$N_{\text{Data}} = 87$
$N_{\text{SM}} = 92.7 \pm 11.2$
Structure function $F_2$
Combination benefit
CC cross sections

Flavor separation:

\[ \sigma_{CC}(e^+ p) \propto x \left[ (1 - y^2)D + \bar{U} \right] \]

\[ \sigma_{CC}(e^- p) \propto x \left[ U + (1 - y^2)\bar{D} \right] \]
PDF fits to combined HERA-I data

Q^2 = 10 GeV^2

H1 and ZEUS Combined PDF Fit

Q^2 = 10 GeV^2

HERAPDF0.1 (prel.)
exp. uncert.
model uncert.
x^u_x
x^d_x
x^g_x (x 0.05)
x^S_x (x 0.05)

10/28/08 Tobias Haas: Legacy of HERA
Predictions from HERA combinations
W production at LHC

• Note:
  – HERA-I only
  – publication is imminent
  – work on HERA-II data is going on
Jet production Tevatron

- HERA PDFs agree with global fits to Tevatron high-$p_T$ jets
Summary

- HERA data are unique and will remain so for a long time
- Collaboration of H1 and ZEUS has been very beneficial
- Current DESY plans for funding extend through 2014
- Eventually the data should be publicly available for an indefinite period
First Workshop organized in DESY (January 26-28, 2009)

- http://indico.cern.ch/conferenceDisplay.py?confId=42722

Exploratory, but with clear agenda/objectives

- Define the editorial procedure for a document (blue print) for data preservation and long term analysis in HEP.

A second workshop mid-2009 (SLAC)
Backups
Combining the data for precision

- Use full knowledge of detectors and systematics:
  - fit the experiments to each other:

\[
\chi^2(M^{i,\text{true}}, \Delta \alpha_j) = \sum_i \left[ \frac{M^{i,\text{true}} - \left( M^i + \sum_j \frac{\partial M^i}{\partial \alpha_j} \Delta \alpha_j \right)}{\sigma_i^2} \right]^2 + \sum_j \frac{\Delta \alpha_j^2}{\sigma_{\alpha_j}^2}
\]

- $M^i$: measured central values
- $\sigma_i$: statistical and uncorrelated systematic errors
- $\sigma_{\alpha_j}$: correlated systematic uncertainty
- $\frac{\partial M^i}{\partial \alpha_j}$: sensitivity of the data to systematic source $j$
- $M^{i,\text{true}}$: fitted H1-ZEUS cross section
- $\frac{\partial M^i}{\partial \alpha_j} \Delta \alpha_j$: fitted shift of data $i$ due to systematic source $j$
- $\Delta \alpha_j = 0$ coincides with standard average
Multi-leptons

- Currently only electron channel combined
- Muons and taus still to come

Multi-electrons, HERA I+II ($e^+p$, 0.94 fb$^{-1}$)

H1+ZEUS (common phase space)

- Data (prelim.)
- SM
- SM Signal

Events vs. $\Sigma P_T$ [GeV]
\( \alpha_S \) from jets

- \( \alpha_S \) fit on HERA-I jet data
- Theory uncertainties are a problem
Diffraction

- Key to understand exclusive central production at LHC
A HERA highlight

Electroweak unification

Maximal parity violation