1 Description of data

2 PDFs

3 $\alpha_s$ studies
Description of data
Data simulated by Max Klein, full description available: http://hep.ph.liv.ac.uk/~mklein/lhecdata/

<table>
<thead>
<tr>
<th>$E_e$/GeV</th>
<th>$E_p$/TeV</th>
<th>e Charge</th>
<th>e Polarisation</th>
<th>Luminosity/fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1</td>
<td>-1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>60</td>
<td>7</td>
<td>+1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>60</td>
<td>7</td>
<td>-1</td>
<td>0.8</td>
<td>300</td>
</tr>
<tr>
<td>60</td>
<td>7</td>
<td>-1</td>
<td>-0.8</td>
<td>1000</td>
</tr>
</tbody>
</table>

All datasets include neutral current (NC) and charged current (CC) interactions. Also testing data with 1/10 luminosity → constraints on PDFs after just one year of running. This data does not include low energy set.
Data simulated by Max Klein, full description available: 
http://hep.ph.liv.ac.uk/~mklein/fccdata/

<table>
<thead>
<tr>
<th>$E_e$/GeV</th>
<th>$E_p$/TeV</th>
<th>e Charge</th>
<th>e Polarisation</th>
<th>Luminosity/fb$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>7</td>
<td>-1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
<td>+1</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
<td>-1</td>
<td>0.8</td>
<td>300</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
<td>-1</td>
<td>-0.8</td>
<td>1000</td>
</tr>
</tbody>
</table>

All datasets include neutral current (NC) and charged current (CC) interactions.
**LHeC data to** $x = 10^{-6}$

**FCC data to** $x = 10^{-7}$

**LHeC higher concentration at high-x.**
Data provided to LO in pQCD - what we’re really interested in is error.

Provided data shifted to HERA PDF theory line (error retained as a percentage).

Data then perturbed randomly (gaussian dist.).
HERAPDF parameterisation ansatz used:

\[ xq_i(x) = A_i x^{B_i} (1 - x)^{C_i} P_i^{(n)}(x) \]

Primed gluon terms removed from fit.
PDFs
PDF results compared to status today.

Valence quark ratios at full and 10% luminosity.
PDF results compared to status today.

Sea ratios at full and 10% luminosity.
PDF results compared to status today.

Gluon linear distributions.

Gavin Pownall - gavin.pownall@cern.ch
PDF results compared to status today.

Gluon log-x distributions.
Direct comparison

Valence distributions at low $x$.
Direct comparison

Valence distributions at high $x$. 

$q^2 = 1.9 \text{ GeV}^2$

- LHeC
- FCC
Direct comparison

$\bar{u}$ and $\bar{d}$ distributions at low $x$. 

\[ Q^2 = 1.9 \text{ GeV}^2 \]

LHeC

FCC
Direct comparison

Gluon and strange distributions at low $x$.

Gavin Pownall - gavin.pownall@cern.ch
Does HERA make a difference any more?

LHeC with and without HERA DIS data.

Gavin Pownall - gavin.pownall@cern.ch
Does HERA make a difference any more?

FCC with and without HERA DIS data.
Sea and gluon: LHeC performs better at high-x, FCC at low-x.

- Both data sets have the same luminosity.
- When FCC probes lower x (higher COM), it is balanced by a loss at high-x.

Valence: LHeC performs better at all x.

- Same argument as above.
- Valence quarks dominated by high-x.

HERA DIS data makes minimal difference.

Most LHeC constraining power comes from first 10% of data.

- Study dominated by systematics.
Relaxing constraints

\[ xu_v = A_{u_v} x^{B_{u_v}} (1 - x)^{C_{u_v}} \]
\[ xd_v = A_{d_v} x^{B_{d_v}} (1 - x)^{C_{d_v}} \]
\[ x\bar{u} = A_{\bar{u}} x^{B_{\bar{u}}} (1 - x)^{C_{\bar{u}}} (1 + D_{\bar{u}} x) \]
\[ x\bar{d} = A_{\bar{d}} x^{B_{\bar{d}}} (1 - x)^{C_{\bar{d}}} \]
\[ xg = A_g x^{B_g} (1 - x)^{C_g} \]
\[ x\bar{s} = A_{\bar{s}} x^{B_{\bar{s}}} (1 - x)^{C_{\bar{s}}} \]

With constraints:

\[ A_{\bar{u}} = A_{\bar{d}} \]
\[ B_{\bar{s}} = B_{\bar{d}} = B_{\bar{u}} \]

which ensure \( \bar{u} = \bar{d} \) as \( x \to 0 \).

\( A_g \) (momentum sum rule)
\( A_{u_v}, A_{d_v} \) (number sum rule)

\[ f_s = (s + \bar{s})/(\bar{u} + \bar{d}) = 0.4 \]
Relaxing sea constraints

Free parameters $A_{\bar{u}}, B_{\bar{u}}, B_{\bar{d}}, B_{\bar{s}}, f_s$.

$\bar{d}$ and $\bar{u}$; strange quark.
Preliminary results.
HL-LHC plots: Lucian Harland-Lang, HL-LHC workshop, CERN, June 2018
Preliminary results.
HL-LHC plots: Lucian Harland-Lang, HL-LHC workshop, CERN, June 2018
Low-x resummation

Still a work in progress...

Credit: Francesco Giuli (University of Oxford)
\( \alpha_s \) studies
\( \alpha_s \) scan

**LHeC precision: 0.2%**

**FCC precision: 0.5%**
What if HERA is added?
What if HERA is added?
Backups
Data provided to LO in pQCD - what we’re really interested in is error.
- Data provided to LO in pQCD - what we’re really interested in is error.
- Provided data shifted to HERA PDF theory line (error retained as a percentage).
Data provided to LO in pQCD - what we’re really interested in is error.

Provided data shifted to HERA PDF theory line (error retained as a percentage).

Data then perturbed randomly (gaussian dist.).
Difference made by perturbing data points...

Very little.

Gavin Pownall - gavin.pownall@cern.ch

Proton PDFs at the LHeC and FCC-eh
Gluon constraints

\[ x_g(x) = A_g x^{B_g} (1 - x)^{C_g} - A'_g x^{B'_g} (1 - x)^{C'_g} \]

Add extra parameter \( D_g \)...
Relaxing sea quarks

Free parameters $A_{\bar{u}}, B_{\bar{u}}, B_{\bar{d}}, B_{\bar{s}}, f_s$.

$\bar{u}$ better constrained by LHeC even with relaxed parameters. $\bar{d}$ similar constraining power as previous HERA fit.
Free parameters $A_{\bar{u}}, B_{\bar{u}}, B_{\bar{d}}, B_{\bar{s}}, f_s$.

Freeing all at once may be too brutal - more work to be done.