Recent Study Results on Precision QCD and Electroweak Physics at the LHeC

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Selected new study results are presented in this talk [1] on the precision QCD and electroweak physics potential at a possible future Large Hadron electron Collider (LHeC). The results covered here are: proton parton density functions, for the first time a determination of the expected precision of the light quark couplings to the Z boson and results on charm, bottom and top production. The findings are based on certain scenarios for the lepton beam energy and obtainable luminosities that have recently been agreed on [2]. The results have been collected from several authors and were presented in full detail at a LHeC pre-meeting to this conference (slides available at [3]).

1 Scenarios

A future *ep* collider as envisaged with the LHeC would provide ample opportunities to continue and extend precision QCD and electroweak studies beyond what has been achieved at HERA. The physics potential depends crucially on the available lepton and proton beam energies, the luminosity and other parameters such as the polarisation. Recently several scenarios have been agreed upon which are listed in Fig. 1. These scenarios span a range of what is currently regarded as technically feasible options. The next sessions describe new physics studies that have been performed using some selected scenarios.

config.	E(e)	E(N)	N	$\int L(e^+)$	$\int L(e^-)$	|Pol|	$L/10^{32}$	P/MW	years	type
A	20	7	p	1	1	-	1	10	1	SPL
B	50	7	p	50	50	0.4	25	30	2	RR hiQ^2
C	50	7	p	1	1	0.4	1	30	1	RR lo x
D	100	7	p	5	10	0.9	2.5	40	2	LR
E	150	7	p	3	6	0.9	1.8	40	2	LR
F	50	3.5	D	1	1	--	0.5	30	1	eD
G	50	2.7	Pb	0.1	0.1	0.4	0.1	30	1	ePb
H	50	1	p	--	1	--	25	30	1	lowEp

Figure 1: LHeC scenarios wich have been recently agreed upon to be used for physics studies. The integrated luminosities are in fb^{-1}.

2 New studies of proton parton densities and electroweak physics

In this section new results are discussed that Claire Gwenlan has obtained and presented in the talk [4]. The findings are based on a combined NLO QCD and electroweak analysis using LHeC neutral current (NC) and charged current (CC) pseudodata as provided by Max Klein (which are available at [5]). For these data also the expected systematic errors have been estimated in detail, as Max reported in his talk [2]. For instance a 1% error in the hadronic energy scale in the calorimeter was assumed. In general the simulations show a demand for an exellent forward hadron calometry and calibration in order to allow precise inclusive ep measurements up to large values $x > 0.1$, where x denotes the Bjorken-x.

Fig. 2 show the expected errorbands for the proton valence quarks, sea quarks and the gluon density that Claire has obtained from a first NLO QCD fit to the new pseudodata (scenario D). A clear improvement is visible from the uncertainties at HERA (represented

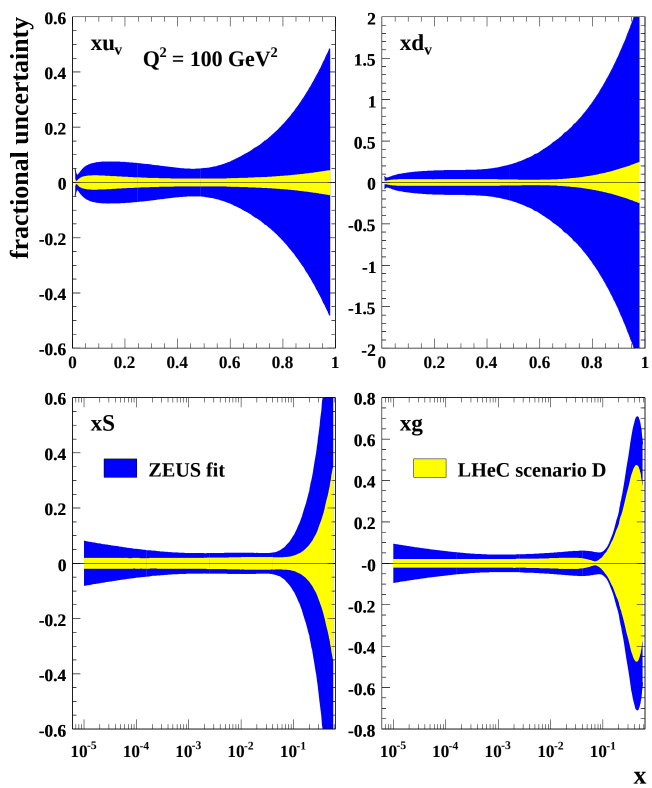

Figure 2: Expected uncertainty bands for the densities in the proton of valence quarks, sea quarks and the gluons. The projected band for LHeC, using scenario D, is compared to a recent fit to HERA data (labeled as ZEUS fit).

by *ZEUS fit*) to the LHeC, especially for the valence quarks. A main reason for this is the much larger rate of charged current events at LHeC compared to HERA, which helps especially for the flavour decomposition. Further studies are planned in order to investigate model and parameterisation uncertainties.

Fig. 2 shows the results for the expected error ellipses for the vector and axial couplings of u-type and d-type quarks to the Z-boson which Claire has obtained from a combined QCD+electroweak fit to the NC and CC pseudodata.

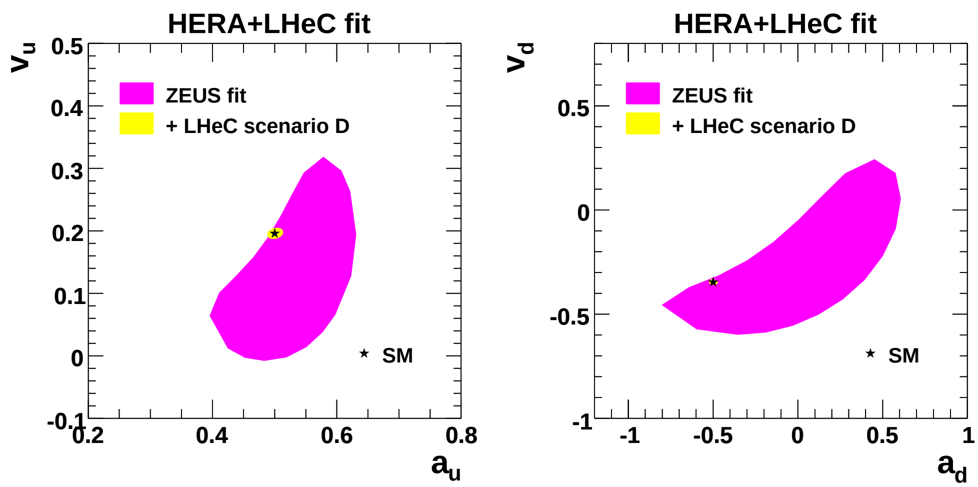

Figure 3: Error ellipses for the axial and vector couplings of u and d type quarks to the Z boson. The projected results for LHeC, using scenario D, are compared with a recent fit to HERA data (labeled as ZEUS fit).

This is the first ever such analysis performed for the LHeC project. Again the results show a dramatic improvement compared to the HERA findings which are represented by the *ZEUS fit*. Claire presented in her talk also results using different assumptions for luminosities, lepton beam polarisations and systematic errors. Furthermore she performed a study of the expected precision for determining the W-boson propagator mass.

3 Heavy flavour results

Max Klein presented in his talk [2] results on the possibility to observe at the LHec an intrinsic charm component in the proton which would be expected at $x > 0.2$. Figure 3 shows projections for LHeC on measurements of the structure function $F_2^{c\bar{c}}$ in bins of x as a function of the photon virtuality Q^2, assuming no intrinsic charm in the proton. The projection shows that precision measurements of $F_2^{c\bar{c}}$ are expected for x up to $x \sim 0.1$ but that at higher x the uncertainties are large. However, it remains to be checked what the precision at large x would be with much higher values of $F_2^{c\bar{c}}$ as expected in the intrinsic charm Ansatz.

The author of this talk presented several Monte Carlo simulation studies (for details see the talk [6]) focusing on charm, beauty and top production at the LHeC. Results on charm and beauty production in DIS, as represented by the structure functions $F_2^{c\bar{c}}$ and $F_2^{b\bar{b}}$, have been obtained using RAPGAP. The projections (not shown here) indicate a high potential

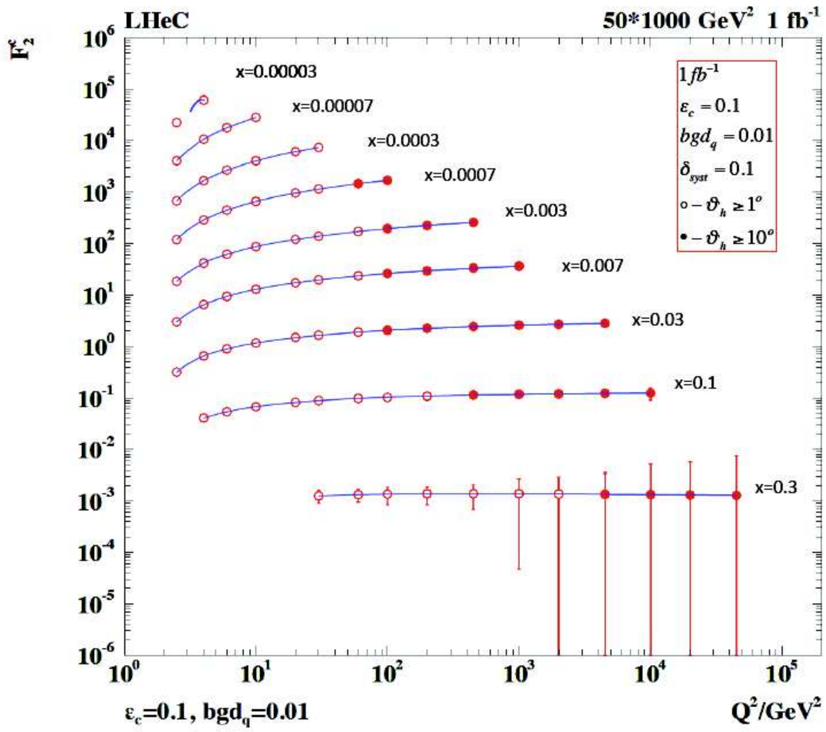

Figure 4: Projection of the proton structure function $F_2^{c\bar{c}}$ at the LHeC.

to perform measurements down to low $x < 10^{-4}$ at reasonably large $Q^2 \geq 50$ GeV^2 which should be helpful for the determination of the gluon density in the proton.

A summary plot of the total expected cross sections for several processes as a function of the lepton beam energy is shown in Fig. 5. The simulations are based on using the programmes RAPGAP for DIS, PYTHIA for photoproduction and LEPTO for charged current interactions. For comparison the respective simulated cross sections at HERA (27.5 GeV electrons or positrons on 920 GeV protons) are plotted as open symbols. The results indicate that LHeC will be a factory for heavy flavour production which will be in turn very useful for the further decomposition of the proton structure, for precision QCD studies and for studies of the top quark.

References

[1] http://indico.cern.ch/getFile.py/access?contribId=59&sessionId=0&resId=0&materialId=slides&confId=53294

[2] http://indico.cern.ch/getFile.py/access?contribId=0&sessionId=0&resId=1&materialId=slides&confId=55684

[3] http://indico.cern.ch/conferenceOtherViews.py?view=standard\&confId=55684

[4] http://indico.cern.ch/getFile.py/access?contribId=1&sessionId=0&resId=2&materialId=slides&confId=55684

[5] http://hep.ph.liv.ac.uk/~mklein/simdis09/lhecsim.Dmp.CC

[6] http://indico.cern.ch/getFile.py/access?contribId=2&sessionId=0&resId=0&materialId=slides&confId=55684

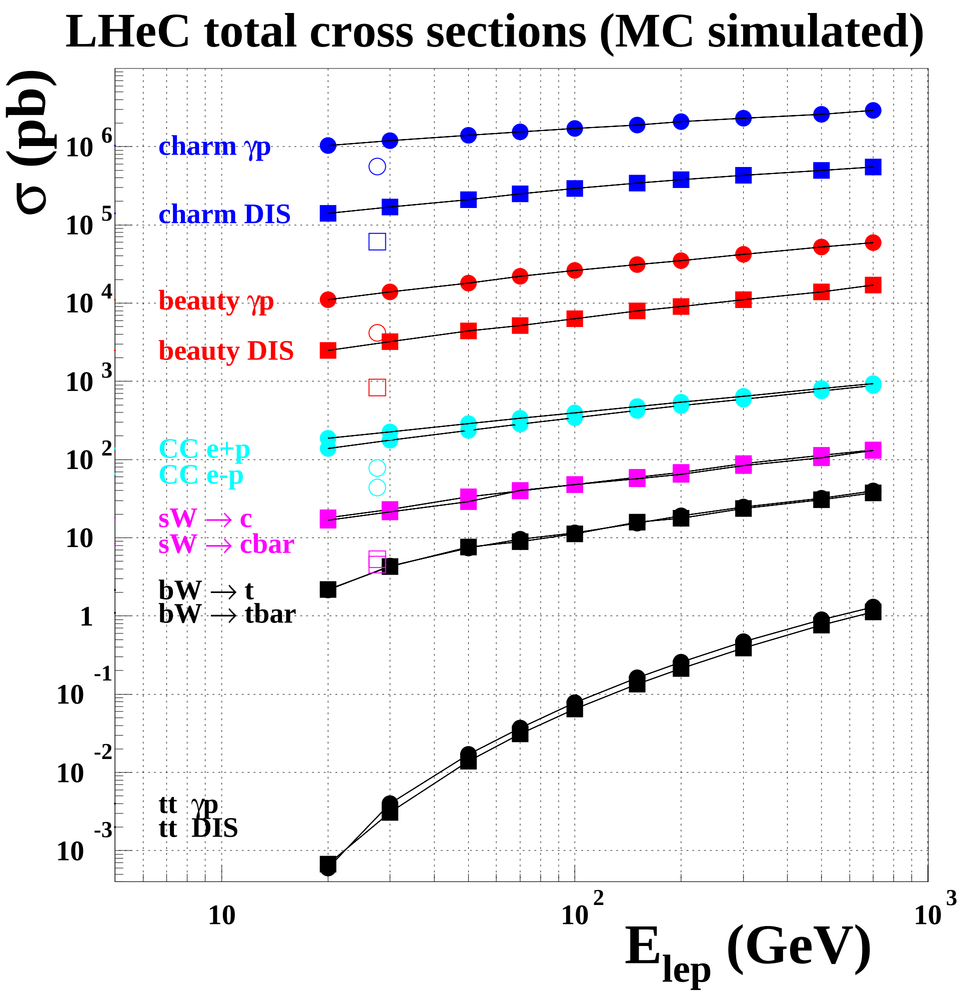

Figure 5: Total Monte Carlo simulated cross sections for various processes involving charm, beauty and top production at the LHeC. The results are shown as a function of the lepton beam energy assuming a fixed proton beam energy of 7 TeV. For comparison the respective cross sections at HERA (27.5 GeV electrons or positrons on 920 GeV protons) are indicated as open symbols. The Monte Carlo programmes used for this study are RAPGAP for DIS, PYTHIA for photoproduction and LEPTO for charged current interactions.