The charm production at LHeC and it's potential on probing the strange content of the proton.

Hamed Abdolmaleki

IPM

July 14, 2020

Outline

⊛ Motivation

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- Theoretical predictions for CC charm production at the LHeC

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DEUTSCHE BUNDESPOST
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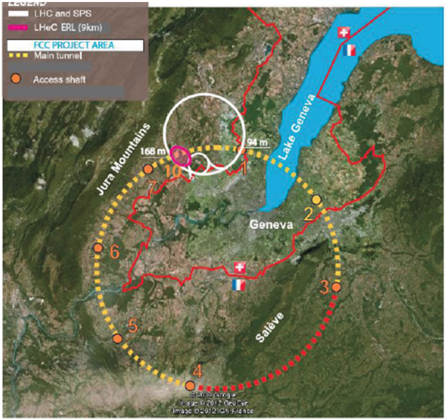
LHC and SPS
LHeC ERL (9km)
FCC PROJECT AREA
Main tunnel
Access shaft
Jura Mountains
Lake Geneva
168 m
94 m
Geneva
Salève
1
2
3
4
5
6
7
10

LHeC

※ The proposed LHeC facility would colide 60 *GeV* electron beam and 7 *TeV* proton beam.($\sqrt{s}$ = 1.3 *TeV*).

Theoritical prediction: elctroweak CC charm production, $\sqrt{s} = 1.3 TeV$, $100 < Q^2 < 10^4 GeV^2$, $0.0001 < x_{Bj} < 0.25$ and $0.0024 < y < 0.76$.

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Heavy-flavor schemes

FFNS A

a NLO FFNS with $n_f = 3$ at all scale, used with the ABMP16 or HERAPDF2.0 FF3A NLO PDF sets.

S. Alekhin, J. BlÃOEmlein, S. Moch, NLO PDFs from the ABMP16 fit. Eur. Phys. J. C 78(6), 477 (2018). arXiv:1803.07537 [hep-ph]

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FFNS B

a NLO FFNS with $n_f = 3$ for the PDFs and variable n_f for α_s , used with the HERAPDF2.0 FF3B NLO PDF set.

H. Abramowicz et al., Combination of measurements of inclusive deep inelastic e $\pm$ p scattering cross sections and QCD analysis of HERA data. Eur. Phys. J. C 75(12), 580 (2015). arXiv:1506.06042 [hep-ex]

Heavy-flavor schemes

FONLL-B

a VFNS used with the NNPDF3.1 NLO PDF set.

R.D. Ball et al., Parton distributions from highprecision collider data. Eur. Phys. J. C 77(10), 663 (2017). arXiv:1706.00428 [hep-ph]

The reduced cross section

$$\sigma^{\pm}_{\text{charm,CC}} = \frac{1}{2}\left(Y_+ F_2^{\pm} \mp Y_- x F_3^{\pm} - y^2 F_L^{\pm}\right), \; Y_{\pm} = 1 \pm (1-y)^2.$$

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In quark parton model at LO:

$$F_2^+ = xD + x\overline{U},$$
$$F_2^- = xU + x\overline{D},$$
$$F_L = 0,$$
$$xF_3^+ = xD - x\overline{U},$$
$$xF_3^- = xU - x\overline{D}.$$

In the phase-space corners $y \to 0$ and $y \to 1$:

$$xU = xu + xc,$$
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$$xD = xd + xs,$$
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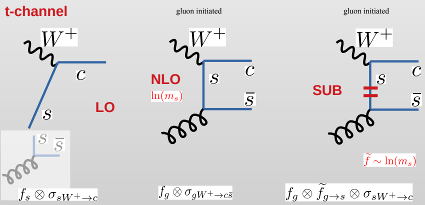
$$\begin{aligned} y \to 0: &\quad \sigma^{\pm}_{\text{charm,CC}} = F_2^{\pm} = xD(x\overline{D}) + x\overline{U}(xU), \\ y \to 1: &\quad \sigma^{\pm}_{\text{charm,CC}} = \frac{1}{2}(F_2^{\pm} \mp xF_3^{\pm}) = x\overline{U}(xU). \end{aligned}$$

F_2^c beyond leading-order

We sum the combination (NLO−SUB) to obtain the complete $\mathcal{O}(\alpha_S^1)$ correction; we find it useful to study these terms separately.



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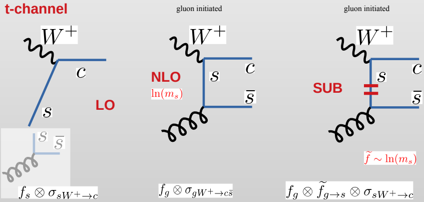
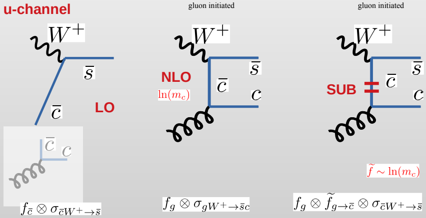
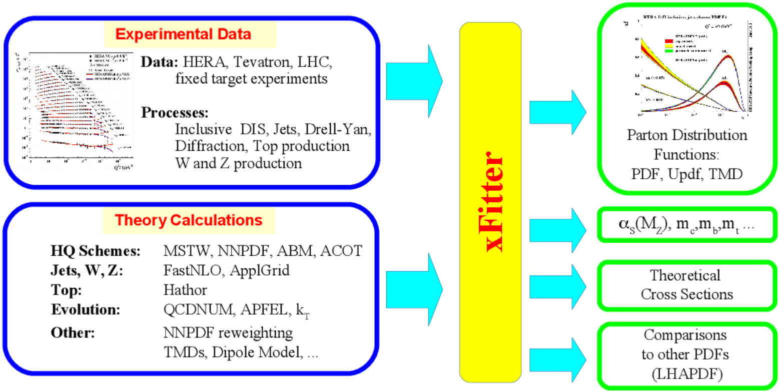


The NLO *t*-channel and *u*-channel terms are combined coherently at the amplitude level.



xFitter


Experimental Data
Data: HERA, Tevatron, LHC, fixed target experiments
Processes: Inclusive DIS, Jets, Drell-Yan, Diffraction, Top production W and Z production
Theory Calculations
HQ Schemes: MSTW, NNPDF, ABM, ACOT
Jets, W, Z: FastNLO, ApplGrid
Top: Hathor
Evolution: QCDNUM, APFEL, k_T
Other: NNPDF reweighting TMDs, Dipole Model, ...
xFitter
Parton Distribution Functions: PDF, Updf, TMD
$\alpha_S(M_Z)$, m_c,m_b,m_t ...
Theoretical Cross Sections
Comparisons to other PDFs (LHAPDF)

xFitter

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Alternative Methods: Profiling and Reweighting

The Profiling and Reweighting method are the alternative approaches to PDF studies.

The xFitter package allows these methods to be used to update any PDF that is available either as a probability distribution or as a PDF eigenvector set.

Reweighting

The Reweighting allows to update probability distribution based PDF (e.g. NNPDF PDF sets) to be updated with new data inputs.

Once PDF probability distributions are available as inputs, they can be updated to incorporate the new data.

$$\langle \mathcal{O}^{new}(PDF) \rangle = \frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} \omega_k \mathcal{O}(PDF_k)$$

The weights ω_k calculated according to:

$$\omega_k = \frac{(\chi_k^2)^{\frac{1}{2}(N_{data}-1)} exp^{-\frac{1}{2}\chi_k^2}}{\frac{1}{N_{rep}} \sum_{k=1}^{N_{rep}} (\chi_k^2)^{\frac{1}{2}(N_{data}-1)} exp^{-\frac{1}{2}\chi_k^2}}$$

The final χ^2 for all data points:

$$\chi^2(y, PDF_k) = \sum_{i,j=0}^{N_{data}} (y_i - y_i(PDF_k))\sigma_{ij}^{-1}(y_i - y_i(PDF_k))$$

Profiling

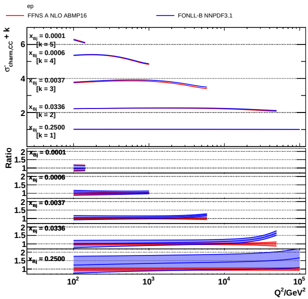
PDF profiling is a bit more universal, it compares data and MC predictions and based on the χ^2-minimization technique, it constraints the individual PDF eigenvector sets of the input PDFs taking into account also the data uncertainties.

The profiling is performed using a χ^2 function which includes both the experimental uncertainties and the theoretical uncertainties arising from PDF variations:

$$\chi^2(b_{exp}, b_{th}) = \sum_{i=1}^{N_data} \frac{(\sigma_i^{exp} + \sum_\alpha \Gamma_{i\alpha}^{exp} b_{\alpha,exp} - \sigma_i^{th} - \sum_\beta \Gamma_{i\beta}^{th} b_{\beta,th})^2}{\Delta_i^2} + \sum_\alpha b_{\alpha,exp} + \sum_\beta b_{\beta,exp}$$

Theoretical prediction comparison

Comparison of theoretical predictions in the FFNS A and FONLL-B schemes.



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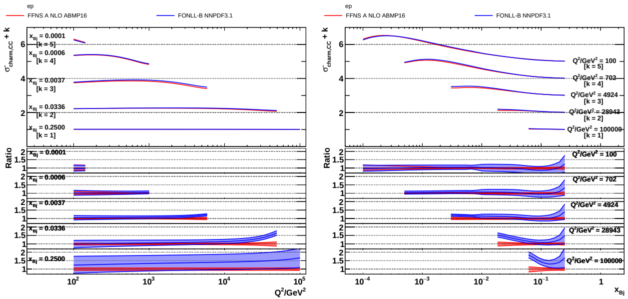

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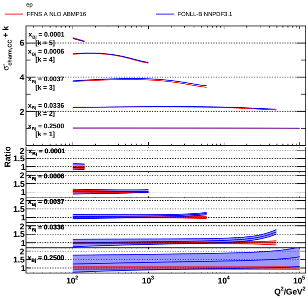

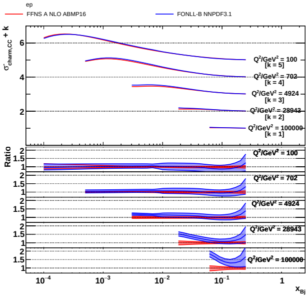

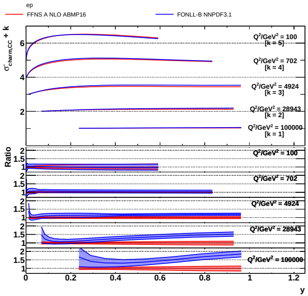

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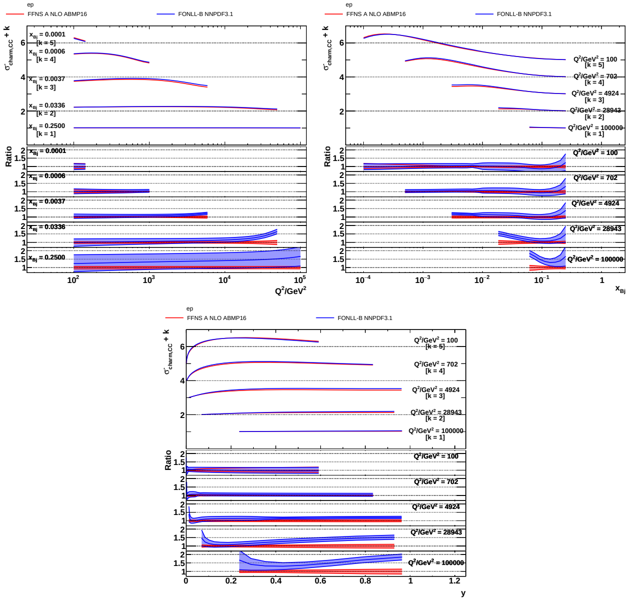
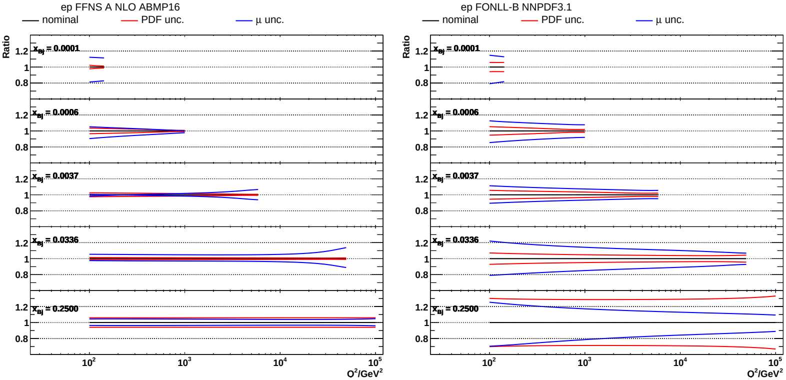


PDFs uncertainties and scale variation

The PDF and scale uncertainties in the FFNS A and FONLL-B schemes.



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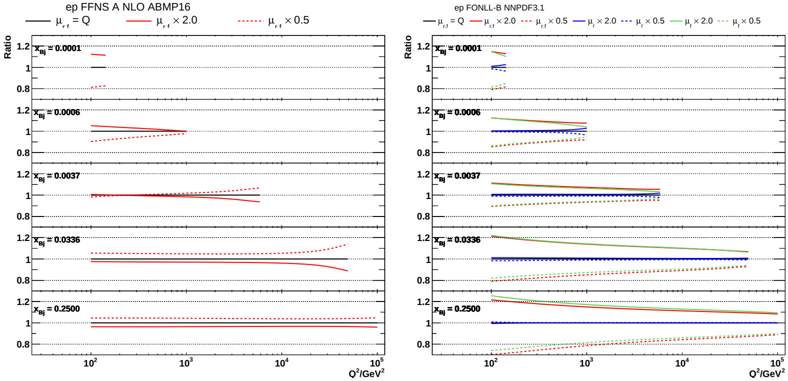
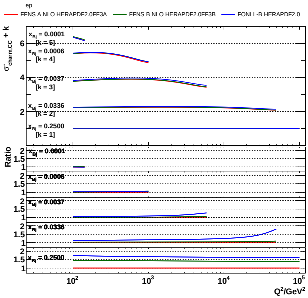
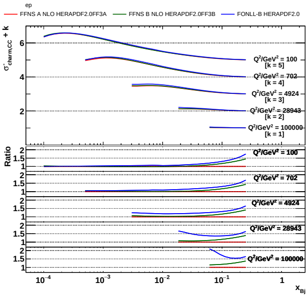
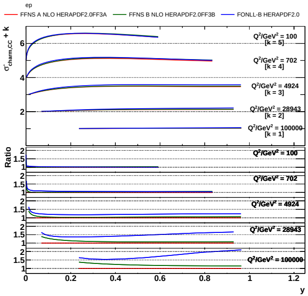


PDFs uncertainties and scale variation

The theoretical predictions for CC charm production at the LHeC using by HERAPDF2.







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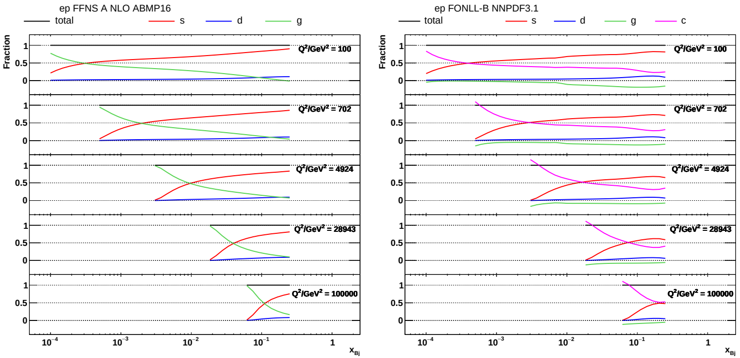

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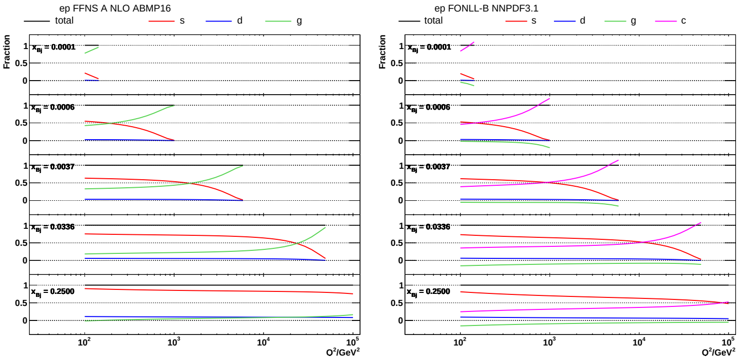

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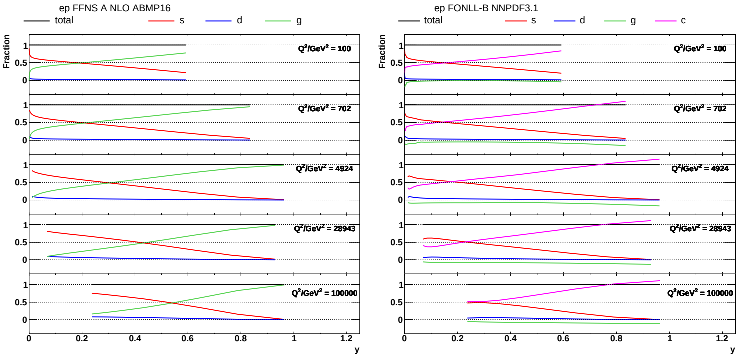
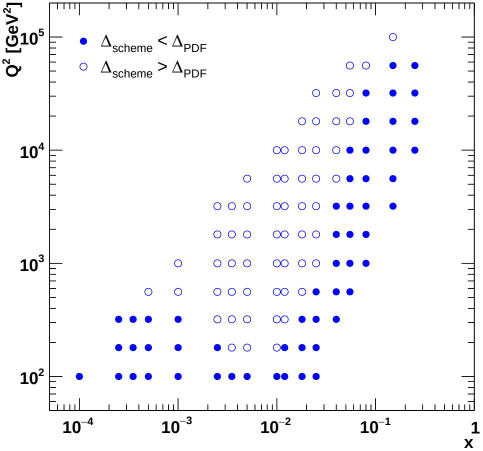


PDF constraint from CC pseudodata

The full ($\Delta_{\rm scheme} < \Delta_{\rm PDF}, \Delta_{\rm scheme} > \Delta_{\rm PDF}$) and restricted ($\Delta_{\rm scheme} < \Delta_{\rm PDF}$) sets of data points whicPDF profiling.



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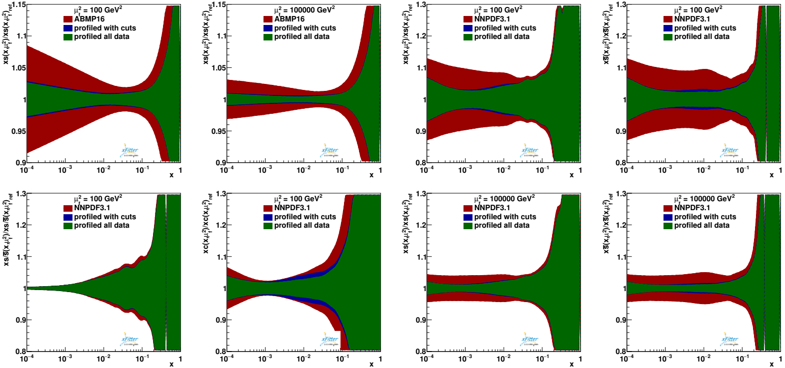

Summarize

* Our ability to characterize and constrain SM processes can indirectly impact beyond-standard-model (BSM) signatures.
* Unfortunately, at present the strange PDF has a comparably large uncertainty.
* The CC DIS charm production involves a flavor-changing $W^{\pm}$ boson, multiple quark masses enter the calculation.
* For a precise determination of $s/\bar{s}$ ratio, both $e^{-}p$ and $e^{+}p$ data will be needed.
* we find that CC DIS charm production at the LHeC can provide strong constraints on the strange PDF which are complementary to the current data sets.