Next-to-Leading Order QCD Corrections to Inclusive Heavy-Flavor Production in Polarized Deep-Inelastic Scattering

Felix Hekhorn and Marco Stratmann

Institute for Theoretical Physics, University of Tübingen

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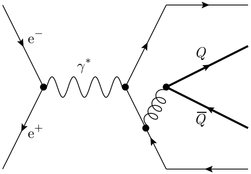
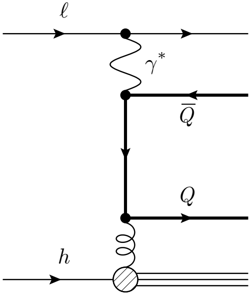
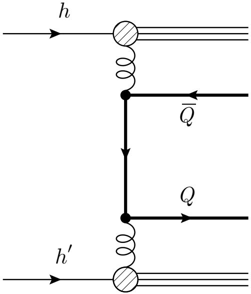
Outline

Introduction - Heavy Quarks

HQ are good

Introduction - Experimental Setups

<table>
<tr><td>e^--e^+-annihilation (SIA)</td><td>deep inelastic scattering (DIS)</td><td>Drell-Yan process (DY)</td></tr>
<tr><td>$\mathrm{e}^- + \mathrm{e}^+ \to \bar{Q} + X[Q]$</td><td>$\ell + h \to \ell' + \bar{Q} + X[Q]$</td><td>$h + h' \to \bar{Q} + X[Q]$</td></tr>
<tr><td>
</td><td>
</td><td>
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<tr><td>LEP, ILC</td><td>HERA, COMPASS, EIC</td><td>Tevatron, LHC</td></tr>
<tr><td>gluon</td><td>factorization</td><td>top, Higgs</td></tr>
</table>

Introduction - Structure Functions

cross section: $$\frac{d^2\sigma}{dxdy} = \frac{2\pi y\alpha^2}{Q^4} L^{\mu\nu} W_{\mu\nu} \tag{1}$$

hard. tensor: $$W_{\mu\nu} = \left(-g_{\mu\nu} + \frac{q_\mu q_\nu}{q^2}\right) F_1(x, Q^2) + \frac{P_\mu P_\nu}{P \cdot q} F_2(x, Q^2) + i\epsilon_{\mu\nu\alpha\beta} \frac{q^\alpha S^\beta}{P \cdot q} g_1(x, Q^2) \tag{2}$$

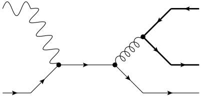
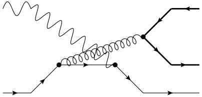
$$F_L(x, Q^2) = F_2(x, Q^2) - 2xF_1(x, Q^2) \tag{3}$$

unpol. xs: $$\frac{d^2\sigma}{dxdy} = \frac{2\pi\alpha^2}{xyQ^2} \left(Y_+ F_2(x, Q^2) - y^2 F_L(x, Q^2)\right) \tag{4}$$

pol. xs: $$\frac{d^2\Delta\sigma}{dxdy} = \frac{4\pi\alpha^2}{xyQ^2} Y_- \cdot 2xg_1(x, Q^2) \tag{5}$$

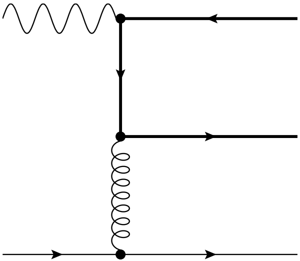
$$Y_\pm = 1 \pm (1 - y)^2 \tag{6}$$

Computation Review

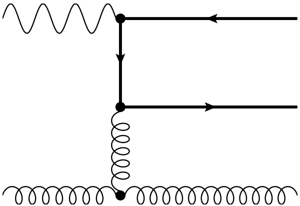
- use factorisation theorem: $s \to \xi S_h$ + PDF
- $g(k_1) + \gamma^*(q) \to \bar{Q}(p_2) + Q(p_1)$
- three massive particles: $2 \cdot m^2 > 0$, $q^2 = -Q^2 < 0$
- compute 2-to-3-phase space: e.g. $dPS_3 \sim dt_1\, ds_4\, d\theta_1\, d\theta_2$
- compute diagrams:  + 
- $\Rightarrow 2xg_1(x) \sim e_u^2 \cdot \xi \Delta u(\xi) \otimes d_{P,q}^{(1)}(\chi, \chi')$
- $d_{P,q}^{(1)}(\chi,\chi') = c_1(\chi,\chi')\ln(\chi) + c_2(\chi,\chi')\,\mathrm{Li}_2\left(\frac{1+\chi'}{1+\chi}\right) + \ldots$ ✓
- $\frac{m^2}{s} = \frac{\chi}{(1+\chi)^2}$ and $\frac{m^2}{s+Q^2} = \frac{m^2}{s'} = \frac{\chi'}{(1+\chi')^2}$ and $\frac{m^2}{Q^2} = \frac{\chi_q}{(1-\chi_q)^2}$

Computation Review - Collinear Poles

collinear poles appear in, e.g.,



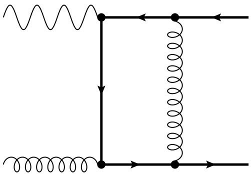
or



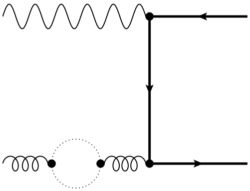
- remove by mass factorization $\rightarrow \overline{\mathrm{MS}}_m$
- $\Rightarrow 2xg_1(x) \sim e_H^2 \cdot \xi \Delta g(\xi) \otimes \ln(\mu_F^2/m^2) \bar{c}_{P,g}^{F,(1)}(\chi, \chi_q)$
- $\bar{c}_{P,g}^{F,(1)}(\chi, \chi_q) = c_1(\chi, \chi_q) \ln(\chi) + c_2(\chi, \chi_q) \,\mathrm{Li}_2\left(\frac{1-\chi_q}{1+\chi}\right) + \ldots$ (✓for $Q^2 \gg m^2$)

Computation Review - UV,IR and Virtual Poles

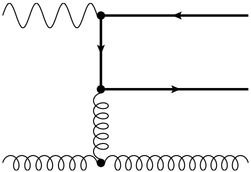
virtual diagrams are, e.g.,



or



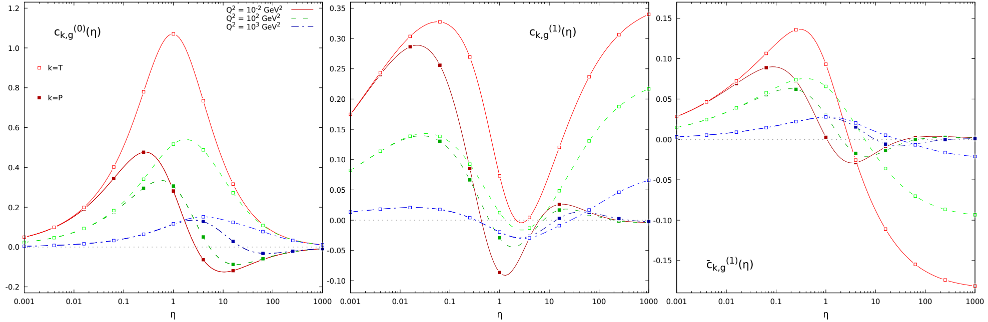
soft poles appear in the limit of a soft gluon $k_2 \to 0$, e.g.,



soft + virtual + renormalization + factorization is finite!

Partonic Results - Gluon Channel

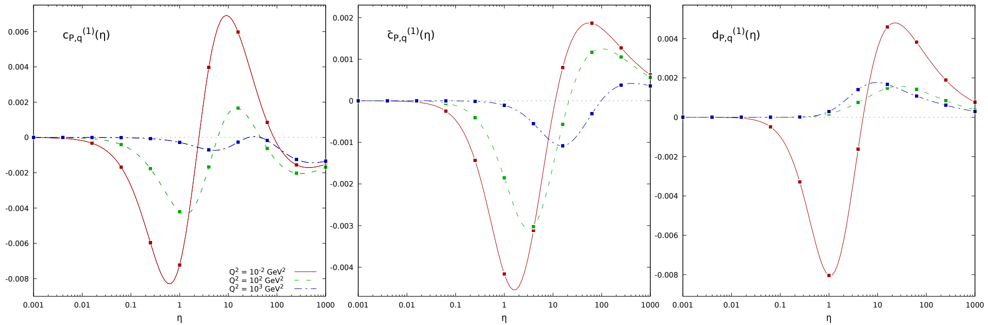
$$2xg_1(x) \sim \xi\Delta g(\xi) \otimes \left(c^{(0)}_{P,g} + 4\pi\alpha_s \left[c^{(1)}_{P,g} + \ln\left(\frac{\mu^2}{m^2}\right) \bar{c}^{(1)}_{P,g} \right] \right) \tag{7}$$



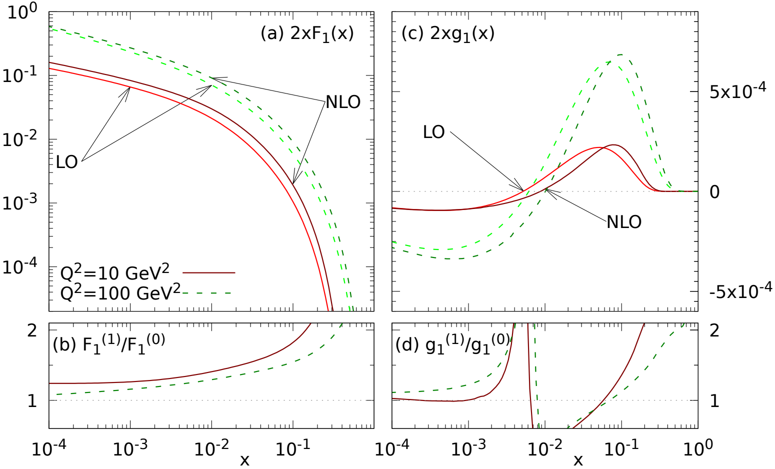
$$\eta = \frac{s - 4m^2}{4m^2}, \qquad m = m_b = 4.75\,\text{GeV}$$

Partonic Results - Light Quark Channel

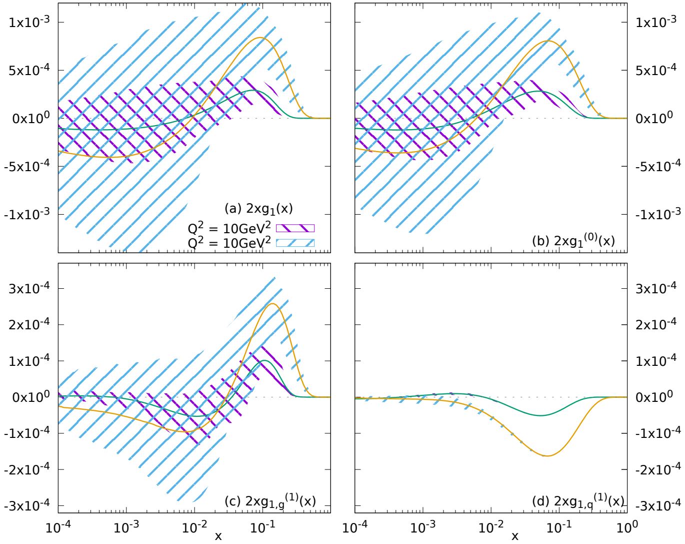
$$2xg_1(x) \sim \sum_{q\in\{u,d,s\}} \xi\Delta q(\xi) \otimes \left(e_H^2 \left[c_{P,q}^{(1)} + \ln\left(\frac{\mu^2}{m^2}\right) \bar{c}_{P,q}^{(1)} \right] + e_q^2 d_{P,q}^{(1)} \right) \tag{8}$$



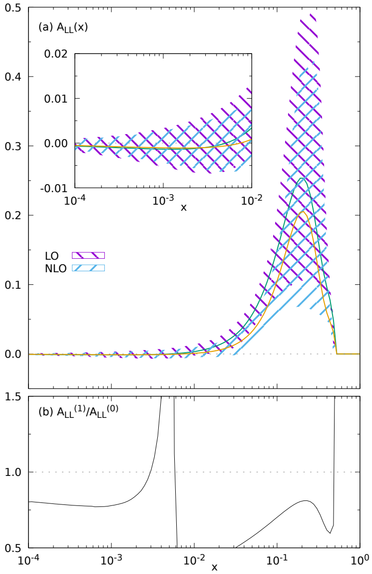
unpolarized ∼ MSTW2008 ⇔ polarized ∼ DSSV2014



Hadronic Results - PDF Uncertainties DSSV (I)

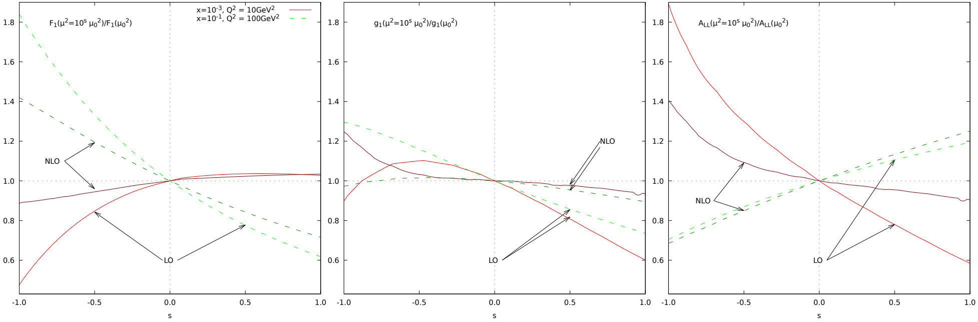


Hadronic Results - PDF Uncertainties DSSV (II)

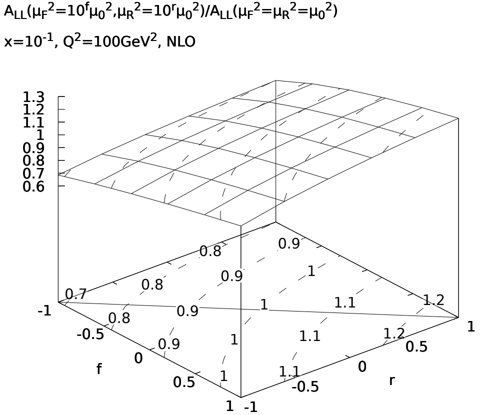


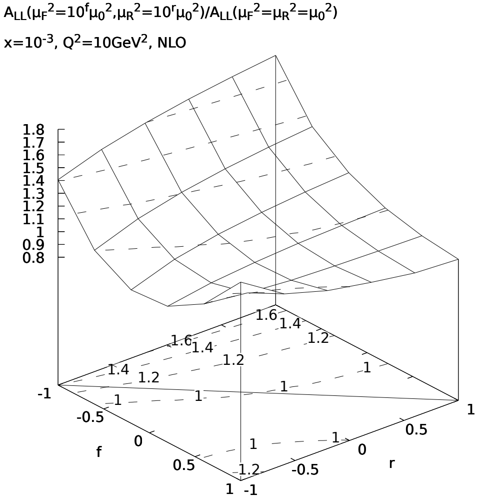
Hadronic Results - Scale Uncertainties (I)

$$\mu_0^2 = 4m^2 + Q^2$$



Hadronic Results - Scale Uncertainties (II)





Outlook

- inclusive distributions: $\frac{dg_1}{dp_{T,\bar{Q}}}, \frac{dg_1}{dy_{\bar{Q}}}$
- correlated distributions: $\frac{dg_1}{dM^2_{Q\bar{Q}}}, \frac{dg_1}{d\phi_{Q\bar{Q}}}$
- full neutral current (NC) contributions: $F_3^{Z\gamma}, g_4^{Z\gamma}, g_5^{Z\gamma}$ and F_2^Z, F_L^Z, g_1^Z
- distributions of full NC structure functions: $\frac{dg_1^{NC}}{dp_{T,\bar{Q}}}, \frac{dg_1^{NC}}{dM^2_{Q\bar{Q}}}$