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

Felix Hekhorn

Institute for Theoretical Physics, University of Tübingen

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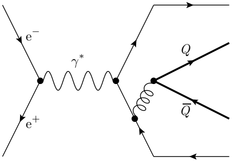
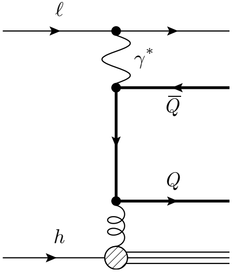
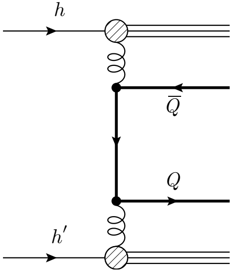
Outline

Introduction - Heavy Quarks

HQ are good

Introduction - Experimental Setups

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

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

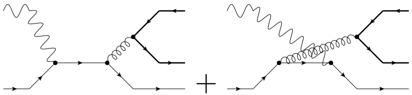
$$F_L(x, Q^2) = F_2(x, Q^2) - 2xF_1(x, Q^2) \tag{3}$$

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

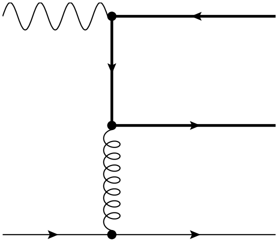
$$Y_\pm = 1 \pm (1 - y)^2 \tag{6}$$

Computation Review

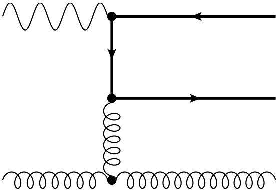
- use factorisation theorem: $s \to \xi S_h$ + PDF
- $g(k_1) + \gamma^*(q) \to \overline{Q}(p_2) + Q(p_1)$
- three massive particles: $2 \cdot m^2 > 0, q^2 = -Q^2 < 0$
- compute 2-to-3-phase space: e.g. $dPS_3 \sim dt_1 ds_4 d\theta_1 d\theta_2$
- compute diagrams: 
- $\Rightarrow 2xg_1(x) \sim e_u^2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



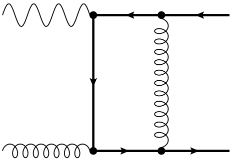
or



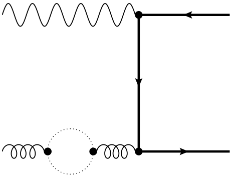
- remove by mass factorization $\to \overline{\text{MS}}_m$
- $\Rightarrow 2xg_1(x) \sim e_H^2 \cdot \xi\Delta g(\xi) \otimes \ln(\mu_F^2/m^2)\bar{c}_{P,g}^{F,(1)}(\chi,\chi_q)$
- $\bar{c}_{P,g}^{F,(1)}(\chi,\chi_q) = c_1(\chi,\chi_q)\ln(\chi) + c_2(\chi,\chi_q)\,\mathrm{Li}_2\left(\frac{1-\chi_q}{1+\chi}\right)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

Computation Review - Virtual and Soft Poles

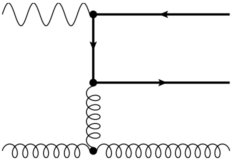
virtual diagrams are, e.g.,



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

cg, cq, dq

Hadronic Results

ALL g1

Outlook

- inclusive distributions: $\frac{dg_1}{dp_T}$, $\frac{dg_1}{dy}$
- correlated distributions: $\frac{dg_1}{dM^2_{Q\bar{Q}}}$, $\frac{dg_1}{d\phi}$
- 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: $\frac{dg_1^{NC}}{dp_T}$, $\frac{dg_1^{NC}}{dM^2_{Q\bar{Q}}}$