Single bottom production and the heavy quark impact factor at NLO

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Why single bottom production?

Theoretical motivation:

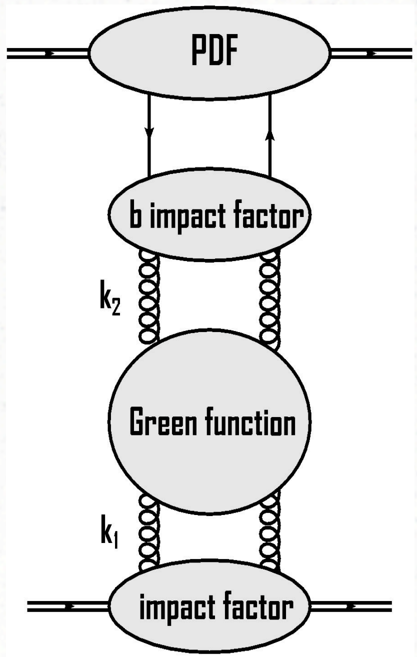
- Interesting for small-x physics
- Open questions of phenomenology

Experimental motivation:

- A tagged b-quark
- Large rapidity coverage

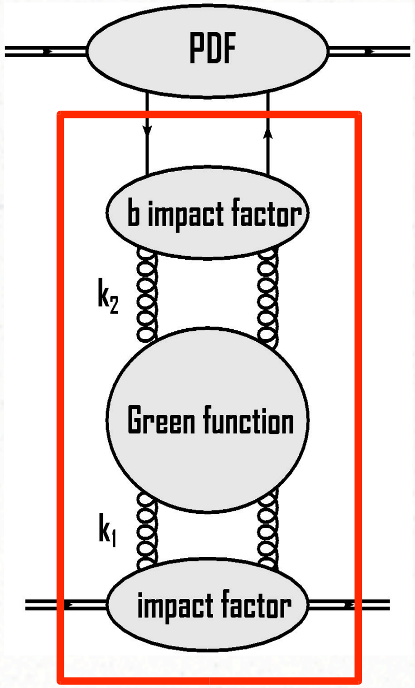
Framework

- Diagrams and cross sections



Framework

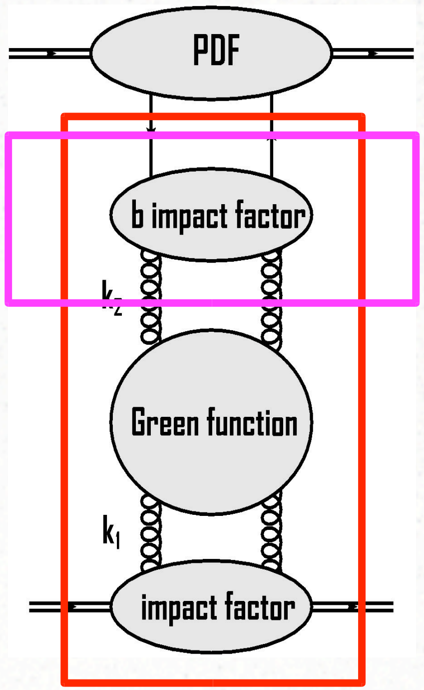
- Diagrams and cross sections



$$\frac{\mathrm{d}\sigma_{\mathsf{ab}}}{\mathrm{d}[\boldsymbol{k}_1]\,\mathrm{d}[\boldsymbol{k}_2]} = \int \frac{\mathrm{d}\omega}{2\pi i\omega} h_{\mathsf{a}}(\boldsymbol{k}_1)\mathcal{G}_\omega(\boldsymbol{k}_1,\boldsymbol{k}_2) \times \times h_{\mathsf{b}}(\boldsymbol{k}_2)\left(\frac{s}{s_0(\boldsymbol{k}_1,\boldsymbol{k}_2)}\right)^\omega$$

Framework

- Diagrams and cross sections



$$\frac{d\sigma_{ab}}{d[\boldsymbol{k}_1]\,d[\boldsymbol{k}_2]} = \int \frac{d\omega}{2\pi i\omega} h_a(\boldsymbol{k}_1)\mathcal{G}_\omega(\boldsymbol{k}_1,\boldsymbol{k}_2) \times \times h_b(\boldsymbol{k}_2)\left(\frac{s}{s_0(\boldsymbol{k}_1,\boldsymbol{k}_2)}\right)^{\omega}$$

Heavy quark impact factor

Momentum space

- Single heavy quark production matrix element at NLO

$$F_{\mathsf{q}}(z_1, \boldsymbol{k}_1, \boldsymbol{k}_2) = F_{\mathsf{q}}^{m=0}(z_1, \boldsymbol{k}_1, \boldsymbol{k}_2) + \Delta F_{\mathsf{q}}(z_1, \boldsymbol{k}_1, \boldsymbol{k}_2)$$

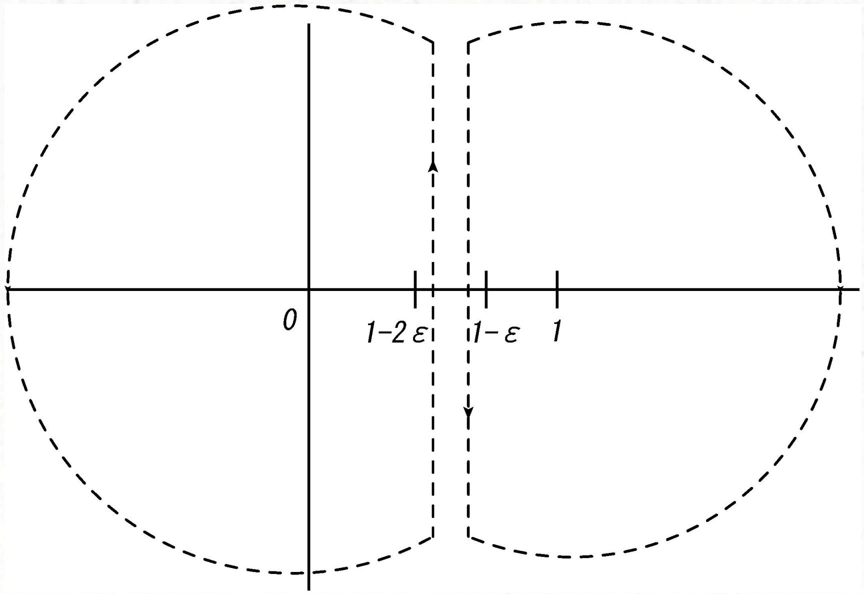
$$\begin{aligned} \Delta F_{\mathsf{q}}(\boldsymbol{k}_2) &= \Delta F_{\mathsf{q},\mathrm{real}}(\boldsymbol{k}_2) + \Delta F_{\mathsf{q},\mathrm{virt}}(\boldsymbol{k}_2) \\ &= A_\varepsilon \left[\frac{\Gamma(-\varepsilon)}{2(1+2\varepsilon)} \frac{(m^2)^\varepsilon}{\boldsymbol{k}_2^2} + \frac{\Gamma(1-\varepsilon)}{2} \left\{ \int_0^1 \int_0^1 \mathrm{d}z_1\, \mathrm{d}x \left(\frac{1-z_1}{z_1} + \frac{1+\varepsilon}{2} z_1 \right) \times \right.\right. \\ &\quad \times \left[\frac{1}{\left[x(1-x)\boldsymbol{k}_2^2 + m^2 z_1^2\right]^{1-\varepsilon}} - \frac{1}{\left[x(1-x)\boldsymbol{k}_2^2\right]^{1-\varepsilon}} \right] + \\ &\quad \left.\left. + \frac{2m^2}{\boldsymbol{k}_2^2} \int_0^1 \int_0^1 \frac{z_1(1-z_1)\, \mathrm{d}z_1\, \mathrm{d}x}{\left[x(1-x)\boldsymbol{k}_2^2 + m^2 z_1^2\right]^{1-\varepsilon}} \right\} \right] \end{aligned}$$

- Integrals over *x* and *z* - <u>finite</u>

Some technical aspects

- Sum of residua – picture

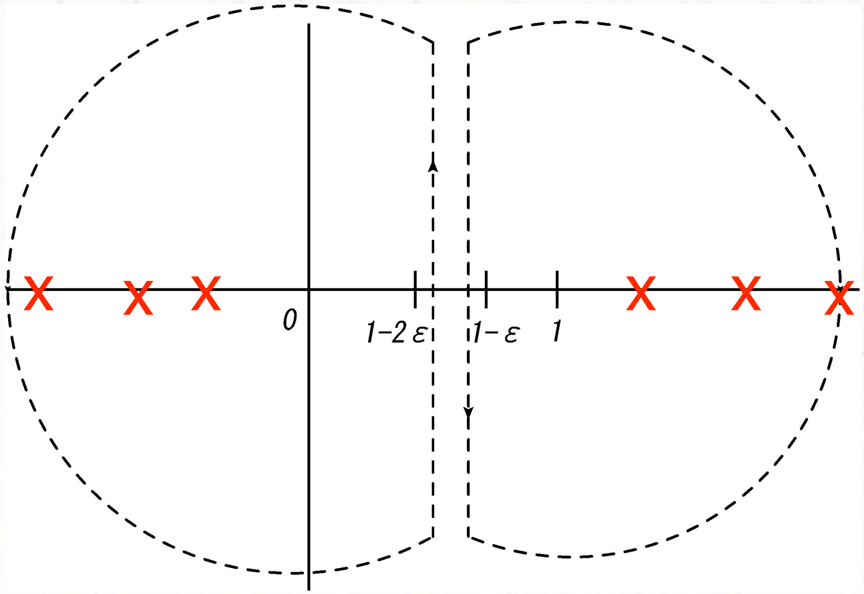
$$\Delta F_{\mathsf{q}}(\boldsymbol{k}_2) = \frac{1}{m^2} \int_{1-2\varepsilon<Re\gamma<1-\varepsilon} \frac{\mathrm{d}\gamma}{2\pi i} \left(\frac{\boldsymbol{k}_2^2}{m^2}\right)^{-\gamma-\varepsilon} \Delta\tilde{F}_{\mathsf{q}}(\gamma, \epsilon)$$



Some technical aspects

- Sum of residua – picture

$$\Delta F_{\mathsf{q}}(\boldsymbol{k}_2) = \frac{1}{m^2}\int_{1-2\varepsilon<Re\gamma<1-\varepsilon} \frac{\mathrm{d}\gamma}{2\pi i}\left(\frac{\boldsymbol{k}_2^2}{m^2}\right)^{-\gamma-\varepsilon} \Delta\tilde{F}_{\mathsf{q}}(\gamma,\epsilon)$$



Some technical aspects

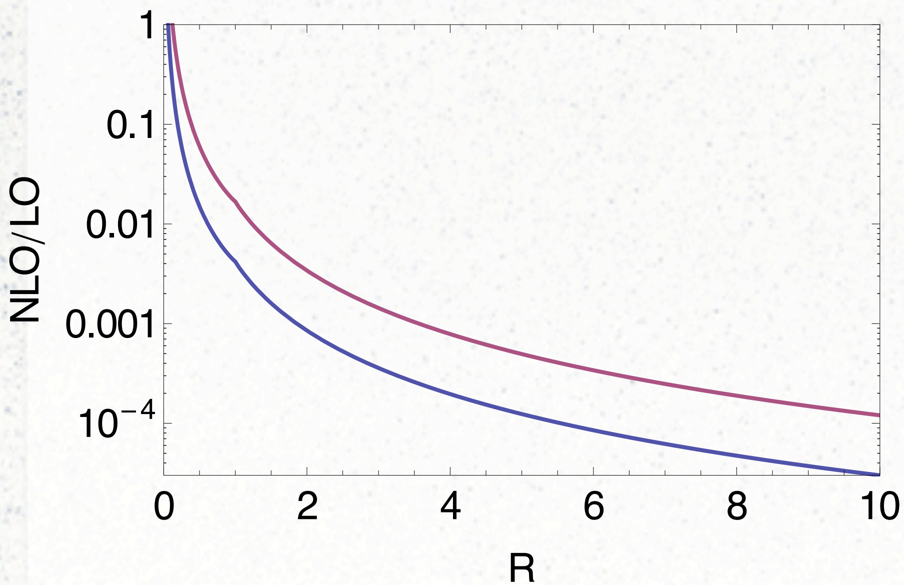
- Sum of residua
- $R = \boldsymbol{k}_2^2/m^2$

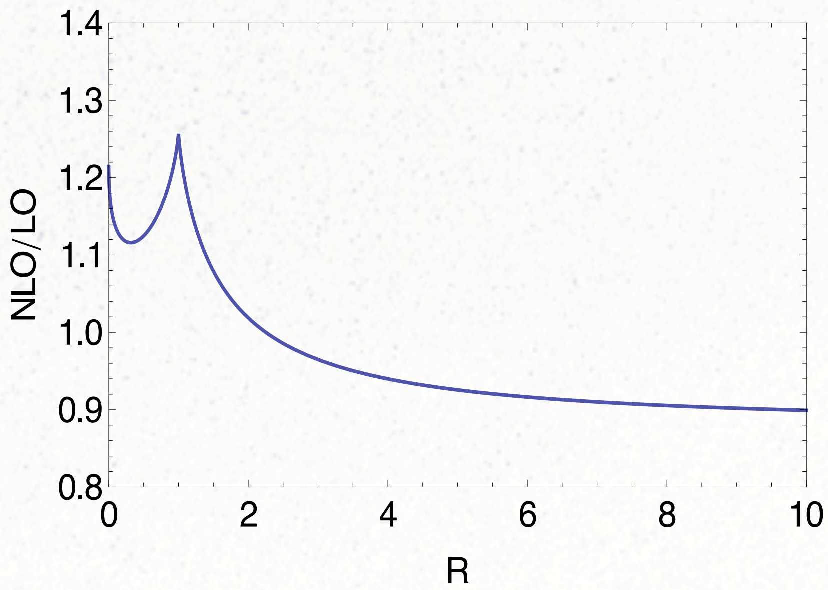
- point: $1-2\epsilon$
  contrib1 $= -\frac{1}{\epsilon^2} + \frac{1}{2\epsilon} + \frac{1}{2}\left(3 + \log(R) + \log(R)^2\right)$
- point: $\frac{1}{2}-2\epsilon$
  contrib2 $= -\frac{3}{8}\pi^2\sqrt{R}$
- point: $-\epsilon$
  contrib3 $= \frac{R}{4\mathrm{ep}} + \frac{7R}{12}$
- point: -2ϵ
  contrib4 $= \frac{1}{4}(R - R\log(R)) - \frac{R}{4\epsilon}$

$$\sum_{n=1}^{n=\infty} \text{contrib5(n)} = -1 - \frac{5R}{6} + \frac{3\pi^2\sqrt{R}}{8} + \frac{R^{3/2}\text{csch}^{-1}\left(\frac{2}{\sqrt{R}}\right)}{2\sqrt{R+4}} - 2\text{csch}^{-1}\left(\frac{2}{\sqrt{R}}\right)^2 + \frac{3\sqrt{R}\text{csch}^{-1}\left(\frac{2}{\sqrt{R}}\right)}{\sqrt{R+4}} + \frac{4\text{csch}^{-1}\left(\frac{2}{\sqrt{R}}\right)}{\sqrt{R}\sqrt{R+4}} - \frac{3}{4}\sqrt{R}\log(R)\text{csch}^{-1}\left(\frac{2}{\sqrt{R}}\right) + \frac{3}{2}\sqrt{R}\log\left(\sqrt{R+4}-2\right)\text{csch}^{-1}\left(\frac{2}{\sqrt{R}}\right) - 3\sqrt{R}\text{Li}_2\left(\frac{2}{\sqrt{R}+\sqrt{R+4}}\right) + \frac{3\sqrt{R}}{4}\text{Li}_2\left(\frac{2}{R+\sqrt{R+4}\sqrt{R}+2}\right)$$

Impact factor results

- 2 masses of the heavy quark: 5 and 10 GeV
- Ratio





Summary and Outlook

- Numerical results for heavy quark impact factor at NLO obtained

Next steps:

- Running coupling
- Convolution with the gluon Green function and heavy quark PDFs
- Cross section for single bottom at large rapidities