NLO Dipole Subtraction

J. Archibald

Institute for Particle Physics Phenomenology
Durham University

MCnet Meeting January 2009

Outline

NLO Cross Sections

The next-to-leading order cross section for a process with *m* final state partons is

$$\sigma = \sigma_{LO} + \sigma_{NLO} \,,$$

where

$$\sigma_{NLO} = \int_m \mathrm{d}\sigma_V + \int_{m+1} \mathrm{d}\sigma_R \,.$$

Subtraction Term

A subtraction term is introduced to cancel divergencies:

$$\sigma_{NLO} \;=\; \int_m \left[\mathrm{d}\sigma_V + \int_1 \mathrm{d}\sigma_A \right] + \int_{m+1} \left[\mathrm{d}\sigma_R - \mathrm{d}\sigma_A \right] .$$

The subtraction term takes the form:

$$d\sigma_A = N_{in} \sum_{\{m+1\}} d\phi_{m+1}(p_1, \ldots, p_{m+1}; Q) \frac{1}{S_{\{m+1\}}} \cdot \sum_{i,j} \sum_{k \neq i,j} D_{ij,k}(p_1, \ldots, p_{m+1}) F_J^{(m)}(p_1, \ldots, \tilde{p}_{ij}, \tilde{p}_k, \ldots, p_{m+1}) .$$

Nagy Phase Space Cuts

Introduce phase space cuts to dipole terms:

$$
\begin{aligned}
{D'}_{ij,k} &= D_{ij,k}\,\Theta(\alpha - y_{ij,k}) \\
{D'}_{ij}^{a} &= D_{ij}^{a}\,\Theta(\alpha - 1 + x_{ij,a}) \\
{D'}_{k}^{ai} &= D_{k}^{ai}\,\Theta(\alpha - u_i) \\
{D'}^{ai,b} &= D^{ai,b}\,\Theta(\alpha - \tilde{v}_i)
\end{aligned}
$$

Nagy arXiv:hep-ph/0307268

Nagy Phase Space Cuts

Adjust integrated dipole subtraction terms to include dependence on cut-off α:

$$\begin{aligned}
\mathbf{I}(p_1, \ldots, p_m; \alpha; \epsilon) &= -\frac{\alpha_s}{2\pi} \frac{1}{\Gamma(1-\epsilon)} \sum_I \frac{1}{\mathbf{T}_I^2} \nu_I(\alpha, \epsilon) \\
&+ \sum_{I \neq J} \mathbf{T}_I . \mathbf{T}_J \left(\frac{4\pi\mu^2}{2 p_I p_J} \right)^{\epsilon} \\
\nu_i(\alpha, \epsilon) &= \mathbf{T}_i^2 \left(\frac{1}{\epsilon^2} - \frac{\pi^2}{3} \right) + \gamma_i \frac{1}{\epsilon} \\
&+ \gamma_i + K_i(\alpha) + \vartheta(\epsilon) \\
K_i(\alpha) &= K_i - \mathbf{T}_i^2 \ln^2 \alpha + \gamma_i (\alpha - 1 - \ln \alpha)
\end{aligned}$$

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NLO Event Generation

We want to constrain real emission to lie within jets.
The constrained NLO cross section can be written as

$$\sigma_{NLO,constr.} = \int_N \left[\mathrm{d}\sigma_V + \int_0^\alpha \mathrm{d}\sigma_A \right] + \int_N \int_0^J [\mathrm{d}\sigma_R - \mathrm{d}\sigma_A] + \int_N \int_\alpha^J \mathrm{d}\sigma_A \,.$$

Jet Definition

The jet measure reads

$$Q_{ij}^2 = 2(p_i \cdot p_j) \min\left\{\frac{1}{C_{i,j}}, \frac{1}{C_{j,i}}\right\},$$

where, in the massless case,

$$\frac{1}{C_{i,j}} = \min_k \begin{cases} \frac{1-z_i(1-y_{ijk})}{z_i(1-y_{ijk})} & \text{if } j = g \\ 1 & \text{else} \end{cases} .$$

Optimised value for α_{cut} for $Q_{ij}^2 < J$ is

$$\alpha_{opt} = J/Q^2 .$$

Status

Current status:

- implementing ee $\longrightarrow$ qq processes as a test case

Future plans:

- EW corrections