Using Catani and Seymour's Dipole Method to Calculate NLO QCD Cross-Sections

William Link

UIUC Physics

April 29, 2008

Collaborators

- Scott Willenbrock
- Fabio Maltoni
- John Campbell
- Keith Ellis

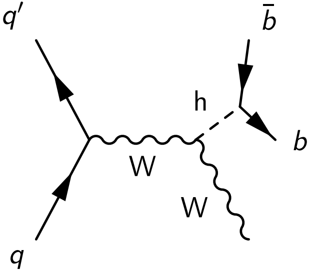
Outline

Calculating $pp\,(p\bar{p}) \rightarrow Wcj$ background at NLO

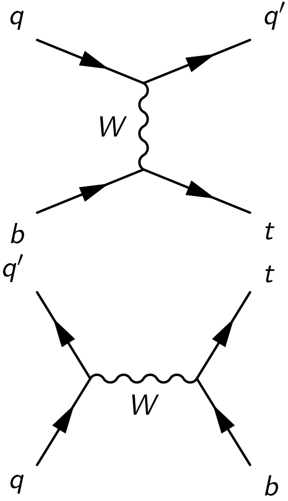
- Why Calculate Wcj?
    - Background to Higgs
    - Background to Single Top
- How to Calculate Wcj?
    - The Leading Order Calculation
    - Canceling Divergences in Monte Carlo
    - Difficulties in Implementing cancellation for Wcj

Important Signals

Higgs Production



Single Top

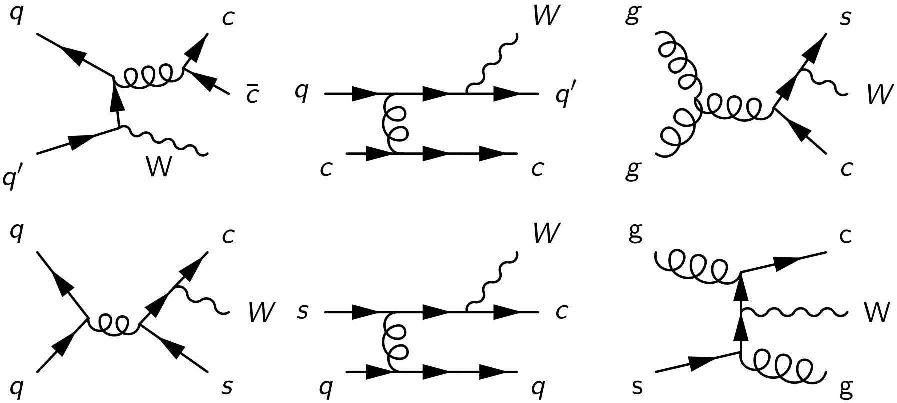


Both Higgs and Single Top have W and heavy-jet backgrounds.
Wbj already calculated at NLO

Tools Utilized

- MCFM, a Next-to-Leading-Order Monte Carlo code written by John Campbell and Keith Ellis
- MADGRAPH/MADEVENT, a Leading-Order code written by Tim Steltzer and Fabio Maltoni

Leading Order Feynman Diagrams



All of the leading order Feynman diagrams relevant to the *Wcj* calculation.

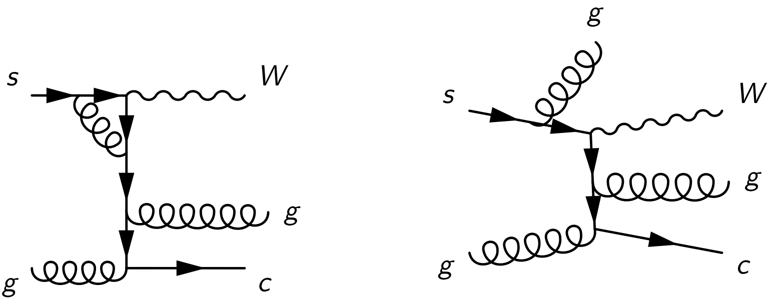
Leading-Order Result

$\mu = \mu_f = \mu_r$	Cross Section(pb)
$\frac{M_W}{2}$	25.56
M_W	18.31
$2M_W$	13.53

Calculated at $\sqrt{s} = 1.96\,TeV$, $p_t > 15$ GeV, $\eta < 2.0$ $R > 0.7$. CTEQ6L1 pdf, and $V_{cs} = V_{ud} = 0.974$, $V_{us} = V_{cd} = 0.227$.

Next-to-Leading-Order Divergences

At Next-to-Leading-Order various divergences crop up, but their sum is finite.



Unfortunately, this cancellation isn't convenient for Monte-Carlo integration.

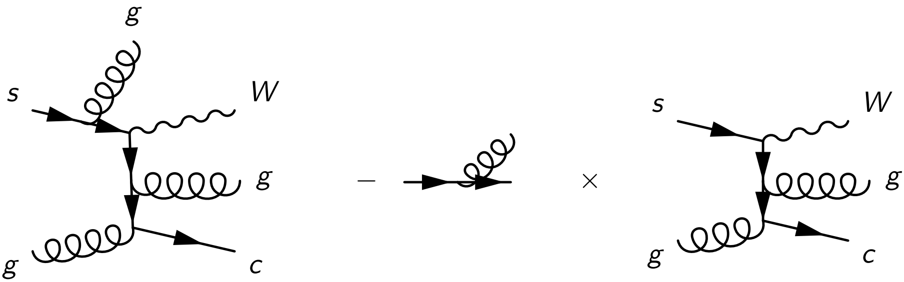
Implementing Divergence Cancellation in Monte-Carlo

Build Counter-terms

- Counter-terms have the same divergent behavior as the real matrix elements.
  - $d\sigma_{\text{real}} - d\sigma_{\text{counter}}$ is finite everywhere in phase space
- Counter-terms must be structured in such a way that the phase space factorizes and one final state particle can be integrated out.
  - $\sigma_{\text{virtual}} + \int d\sigma_{\text{counter}}$ is finite.

Structure of the Counter-terms

The structure of the counter-terms is easily understood by examining soft gluon emission.

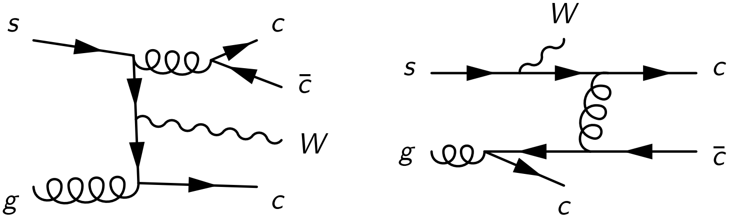


$$|\mathcal{M}|^2_{\text{real}} - \mathcal{D}^{ij,k}_{qq}\,|\mathcal{M}|^2_{\text{Lo}}$$

The $\mathcal{D}$ terms are known as dipoles.

Complications in Implementing Cancellation

For $Wc\bar{c}j$ processes, if the $c\bar{c}$ quarks end up collinear, the process is sensitive to the charm quark mass.



These processes interfere. Also, with the gluon in the initial state, we have to abandon dipole subtraction which is designed for massive quarks.

Conclusion

- We need to pursue *Wcj* and other QCD backgrounds at NLO
- MCFM with its implemented dipole subtraction provides a good avenue to pursue such calculations.