Oliver Dekkers

ESR

Education Background

05/10 Diplom in Physics
RWTH Aachen University
Title of thesis: *Eine Subtraktionsmethode für massive Quarks in der NNLO QCD*
Supervisor: Prof. W. Bernreuther

Present status

Since 06/10 PhD student at the Institute for Theoretical Particle Physics and Cosmology
RWTH Aachen University
Topic: *Heavy quark-antiquark production in high-energy electron-positron collisions at NNLO QCD*
Supervisor: Prof. W. Bernreuther

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LHCPhenoNet

05/11	Recruitment as ESR
	WP4: Technological Innovations
02/12 - 05/12	Secondment to ETH Zürich
	Supervisor: Prof. A. Gehrmann-de Ridder

Motivation

The exploration of heavy quark production, in particular $t\bar{t}$ and or single top production, is a central issue at high energy colliders

- By studying the top quark in detail, one hopes to gain insight into the origin of particle masses and the mechanism of electroweak symmetry breaking
- Important background to a number of new physics searches, including (non-SM) Higgs boson(s) and SUSY particles.
- New heavy resonances R may exist that decay into heavy quark pairs $R \to Q\bar{Q}X$, $Q = t, b$. Investigation of the properties of R also requires predictions of distributions.
- ...

NNLO predictions for heavy quark pair production cross sections are desirable.

- Development of calculational methods/techniques for higher order QCD computations

Tasks:

- Development of subtraction algorithm for handling IR singularities at NNLO
  ($\to$ Antenna Subtraction)
  - Analytic calculations using state-of-the-art techniques and knowledge about special functions in mathematical physics
  - Extensive use of computer algebra (`Mathematica, Maple, form,...`)
- Development of fast numerical code for calculating production cross sections and distributions

NNLO Subtraction Terms

Consider

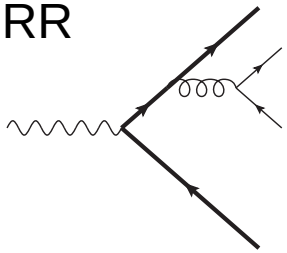
$$S \to Q\bar{Q} + X \quad \text{at NNLO QCD}$$

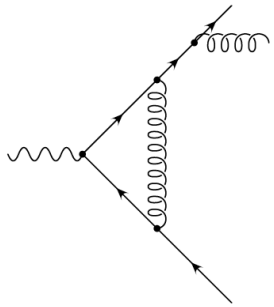
with uncolored initial state S, e.g. $e^+e^- \to \gamma^*, Z \to Q\bar{Q}X$ or $H \to Q\bar{Q}X$.

Generic structure of NNLO cross section with subtraction terms:

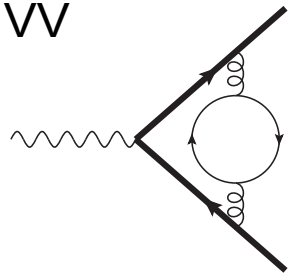
$$\begin{aligned} d\sigma_{\text{NNLO}} = & \int_{d\Phi_4} \left(d\sigma^{RR}_{\text{NNLO}} - d\sigma^{S}_{\text{NNLO}} \right) \\ & + \int_{d\Phi_3} \left(d\sigma^{RV}_{\text{NNLO}} - d\sigma^{V,S}_{\text{NNLO}} \right) \\ & + \int_{d\Phi_2} d\sigma^{VV}_{\text{NNLO}} + \int_{d\Phi_4} d\sigma^{S}_{\text{NNLO}} + \int_{d\Phi_3} d\sigma^{V,S}_{\text{NNLO}} \end{aligned}$$

RR





VV



Subtraction terms: $d\sigma^{S}_{\text{NNLO}}$, $d\sigma^{V,S}_{\text{NNLO}}$

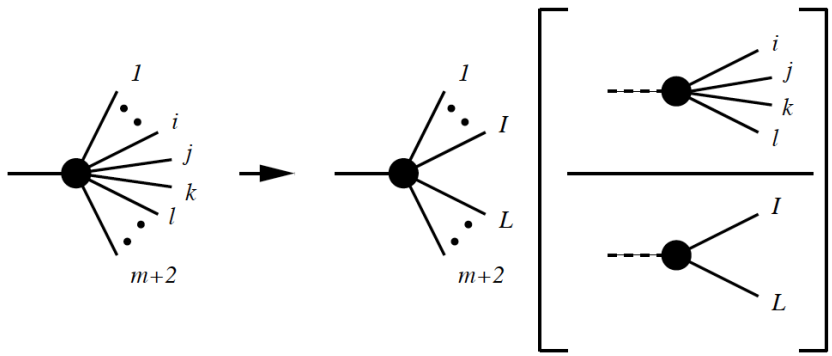
- Approximate the double-real (real-virtual) matrix element in all singular regions
- Integration over a factorised form of the phase space makes IR poles explicit
- Each line is free of infrared poles and integration over the phase space can be carried out numerically in 4 dimensions.

A Short Glance at Antenna Subtraction at NNLO

[Campbell, Cullen, Glover, Kosover, Gehrmann-De Ridder, Gehrmann,...]

Main building blocks: Antenna Functions.

- Normalised physical colour-ordered matrix elements squared with two hard particles (radiators) and unresolved radiation emitted between them.



For final-final colour-connected configurations: $X^0_{ijkl} \propto \left|M^0_{1\to4}(i,j,k,l)\right|^2$

$$d\sigma^S_{\mathrm{NNLO}} \propto X^0_{ijkl} \left|M^0_m(\ldots,I,L,\ldots)\right|^2 d\Phi_m(\ldots,p_L,p_K,\ldots;q)\, d\Phi_4(p_i,p_j,p_k,p_l;p_L+p_K)$$

Integrated antenna functions

$$\mathcal{X}^0_{ijkl} \propto \int d\Phi_4 \left|M^0_{1\to4}(i,j,k,l)\right|^2$$

- Analytic calculation using state-of-the-art techniques and knowledge about special functions in mathematical physics

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Milestones and Deliverables

... or steps towards antenna subtraction at NNLO QCD with massive quarks

- Construction of (integrated) subtraction terms for $S \to Q\bar{Q}q\bar{q}, Q\bar{Q}gg$ accomplished
  - in collaboration with W. Bernreuther and C. Bogner
  - analytic results for integrated massive final-final double-real antenna functions in terms of HPLs

- Integrated massive (flavour-violating) initial-final antenna functions
  - in collaboration with G. Abelof and A. Gehrmann-de Ridder (ETH Zürich).
  - main outcome of my LHCPhenoNet secondment to ETH Zürich

Next steps:

- (Integrated) massive real-virtual antenna functions
  - work in progress with W. Bernreuther and C. Bogner
- apply method to $H \to b\bar{b}$, $e^+e^- \to Q\bar{Q}$ and $pp(p\bar{p}) \to t\bar{t}$ at NNLO QCD
- Development of fast numerical code for calculating production cross sections and distributions

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Overview of Training

Network training events

- LHCPhenoNet School of Analytic Computing in Theoretical High-Energy Physics (Atrani, Italy, Oct. 2011).
- LHCPhenoNet Winter School (Ascona, Switzerland, Jan. 2012).
- LHCPhenoNet School on Integration, Summation and Special Functions in Quantum Field Theory (Linz, Austria, July 2012).

Education and Outreach

- Help supervise bachelor students
- Teaching assistant for undergraduate courses in theoretical physics

Publications and Presentations

- W. Bernreuther, C. Bogner, O. Dekkers, *The real radiation antenna function for* $S \to Q\bar{Q}q\bar{q}$ *at NNLO QCD*, *JHEP* 1106 (2011) 063, [arXiv:1105.0530].
- *The real radiation antenna function for* $S \to Q\bar{Q}q\bar{q}$ *at NNLO QCD*, talk given at 15^{th} Meeting of SFB/TR9 Computational Particle Physics, DESY Zeuthen, May 2011.
- *Double real radiation antenna functions for heavy quark pair production*, talk given at LHCPhenoNet Annual Meeting, Durham, March 2012.

Publication in preparation

- *Integrated massive (flavour-violating) initial-final antenna functions,* in collaboration with G. Abelof and A. Gehrmann-de Ridder (ETH Zürich).