Flavoured jet algorithms

This summer I was working under the supervision of Gavin Salam and Fabrizio Caola as part of the UROP programme at the Rudolf Peierls Centre for Theoretical Physics. The internship was focused on algorithms for clustering particles observed at colliders, called jet algorithms.

It is extremely difficult to compare predictions of modern theoretical physics with experimental data collected at high energy particle colliders, like the Fermilab Tevatron or the LHC at CERN. We can approximate collisions of particles at the so-called *parton* (quark and gluon) level, but it is still beyond the reach of particle theory to predict the exact configurations of particles observed at detectors[1]. It has, however, been well established that *jets* (collimated sprays of particles) predicted on the parton level agree with the observations to an acceptable extent. This highlights the importance of defining jet algorithms (ways of clustering nearby particles into jets by recombining their properties[2]) in a way that allows to reconcile theoretical predictions with experimental observations.

While a very wide spectrum of effective jet algorithms has been produced over the last decades, it is difficult to make one that would produce jets with well-defined flavour (flavour is a property of elementary particles, just like charge or spin). Looking into this problem was the topic of my internship.

A working[3] solution was produced by *G. Salam et al.* already in 2006. Since then, there has been considerable progress (due to, among others, Fabrizio Caola) in understanding the consequences of the choice of a jet algorithm on the properties of jets that we obtain. It has become clear that it would be desirable to produce a jet flavour algorithm that would retain the main properties of the ones in current use (called generalised-k_t sequential recombination algorithms).

During my internship, we defined one such algorithm - the *Flavour Neutralising Algorithm* - and tested its performance in simple events. Its advantage lies in the modification of only the ways of recombining flavours in generalised-k_t algorithms (rather than their distance measures, as was done by *G. Salam et al.*

[1] The parton model works only at large energies, due to *asymptotic freedom*. The stable particles we observe at detectors are created by (among other processes) a process called *hadronization* where asymptotic freedom no longer applies, and it is not yet fully understood.
[2] A recent development by *J. Thaler et al.* provides a beautiful geometric definition of jet algorithms as nearest approximations of N-particle events as M-particle events (M < N) by defining an appropriate (machine learning-inspired) metric on the space of particle collider events.
[3] Satisfying the most important constraints of *Infrared* (IR) and *Colinear Safety*.

in 2006), thus, by construction, keeping all other properties unchanged. My personal contributions lied mostly in discussions of the caveats of modifying distance measures and coding the first draft of the Flavour Neutralising Algorithm using *Fastjet* libraries in a general form that can be applied to any other jet algorithm defined in *Fastjet*, as well as running first infrared safety tests using that code. I also learned the basics of cross section calculations using Feynman rules and programmed a basic (linear order) simulation of the production of a W boson and a Higgs boson decaying into a bottom quark-antiquark pair in a hadronic collision.

It has been an amazing experience to get to learn from the best experts in the fields presented above. Although my internship had to be conducted online, I have gained not only factual knowledge, but also witnessed ways of tackling problems in systematic and incredibly effective ways. Designing jet algorithms is more of a craft than anything else, and thus learning from the best craftsmen is of special importance. I am especially grateful for the college grant, because it let me fully focus on this internship, thus letting me contribute in ways significant enough to extend beyond a summer project to co-authoring a paper on this idea.

Radosław Grabarczyk