Towards an Electroweak Parton Shower

Jo Reimer

Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

The Large Hadron Collider (LHC) is taking data since 2009 and is expected to continue until roughly 2040 in its high-luminosity phase. At the core of the high-energy physics programme of the LHC are analyses with known Standard Model (SM) particles which require very precise predictions. The predictions are not only a critical prerequisite to explore the validity of the SM, like in the currently ongoing precision studies of the Higgs boson, but are also crucial in predicting background for new-physics searches. In that respect, electroweak (EW) corrections play a very important role. In the high-TeV regime, where new-physics phenomena are potentially expected to appear and which is starting to be experimentally probed, EW corrections are typically dominated by large logarithms induced by soft and/or collinear exchange or emission of EW gauge bosons, often leading to corrections of several 10%. The leading effects are of soft origin and known as Sudakov logarithms. Therefore searches for new physics require predictions that include higher-order EW corrections in order to make any reliable statement about the presence or absence of new physics. However, next-to-leading-order (NLO) EW predictions typically leave out contributions from the real radiation of massive EW bosons (W, Z or Higgs bosons), which are considered as background and estimated via leading-order (LO) predictions. EW corrections are typically of the order of few percent for total cross sections at intermediate energies, but grow in size at high energies, in particular in differential distributions. Even the corresponding EW two-loop corrections can reach the size of $5 - 20\%$ in the high-energy tails, but are often ignored in predictions. In the TeV range it is, thus, mandatory to include and control EW corrections beyond NLO accuracy. For processes that are sufficiently inclusive in the initial and final states, the large mass-singular EW corrections would be completely cancelled by their counterparts from the contributions induced by real emission, including massive-particle radiation initiated by EW interactions. Since the necessary level of inclusiveness can never be reached in realistic scattering experiments, the cancellation of mass-singular EW corrections will always be incomplete. This calls for a proper inclusion of all virtual and real-emission effects, not only at NLO but also taking into account at least the leading effects beyond NLO. This is already true for upcoming LHC physics and even more so for the physics at any future high-energy collider. The impact of multiple emissions via EW cascades on physical observables depends a lot on the details of the considered process and the experimental setup. However, the large mass-singular corrections are of universal origin, so that the EW cascade can be simulated by a Parton Shower (PS) of all participating EW particles. The construction and subsequent analysis of such an EW PS is the goal of my thesis.

In this talk, after a motivation of the necessity of including PSs generally in theoretical predictions, the need for considering electroweak splittings is indicated. Next, the main ingredients of a PS, i.e. splitting functions and the Sudakov form factor, are introduced. The probabilistic interpretation of these is a key element. Thereafter, a simple algorithm for the construction of a generic Parton Shower will be sketched, while problems and difficulties of it will be explained. This includes the so-called veto algorithm, which will then be covered. Throughout the talk, difficulties in the realization of a full electroweak shower will be highlighted. Moreover, different orderings of emissions in a PS will be explained, and the PS approach will be compared generally to fixed-order calculations.