Single- sectsw

Another interesting process at LEP 2 is the so-called single- production, $e^+e^- \to e\nu$ which can be seen as a part of the CC20 process, $e^+e^- \to q\,(\mu\,\nu_\mu,\ \tau\,\nu_\tau)\,e\,\nu_e$, or as a part of the Mix56 process, $e^+e^- \to e^+\,e^-\,\nu_{e\ e}$. For a more detailed theoretical review we refer to swc and to bd. All processes in the CC20/Mix56 families are usually considered in two regimes, $|\cos\theta(e^-)| \geq c$ or SA and $|\cos\theta(e^-)| \leq c$ or LA. In the list of observables, the single production is defined by those events that satisfy $|\cos\theta(e^-)| \geq 0.997$ and therefore is a SA.

The LA cross-section has been computed by many authors and references can be found in EGWWP. It represents a contribution to the $e^+e^- \to$ total cross-section. From a theoretical point of view the evaluation of a LA cross-section is free of ambiguity, even in the approximation of massless fermions, as long as a gauge-preserving scheme is applied and $\theta(e^-)$ is not too small.

For SA instead, one cannot employ the massless approximation anymore. In other words, in addition to double-resonant -pair production with one decaying into $e\nu_e$, there are t-channel diagrams that give a sizeable contribution for small values of the polar scattering angle of the t-channel electron. Single- processes are sensitive to the breaking of $U(1)$ gauge invariance in the collinear limit, as described in Ref. BHF1 (see also Kurihara). The correct way of handling them is based on the so-called Fermion-Loop (FL)scheme BHF2, the gauge-invariant treatment of the finite-width effects of and bosons in LEP 2 processes. However, till very recently, the Fermion-Loop scheme was available only for the LA-regime. For $e^+e^- \to e^-_e f_{12}$, the $U(1)$ gauge invariance becomes essential in the region of phase space where the angle between the incoming and outgoing electrons is small, see the work of BHF1 and also an alternative formulations in fls-baur. In this limit the superficial $1/Q^4$ divergence of the propagator structure is reduced to $1/Q^2$ by $U(1)$ gauge invariance. In the presence of light fermion masses this gives raise to the familiar $\ln(/s)$ large logarithms. Furthermore, keeping a finite electron mass through the calculation is not enough. One of the main results of swc was to show that there are remaining subtleties in CC20, associated with the zero mass limit for the remaining fermions.

In tfl a generalization of the Fermion-Loop scheme (hereafter EFL) is introduced to account for external, non-conserved, currents. Another extension has been given in abm for the imaginary parts of Fermion-Loop contributions, which represents the minimal set for preserving gauge invariance.

The most recent numerical results produced for single- production are from the following codes groups: `CompHEP`, `GRC4F`, `NEXTCALIBUR`, `SWAP`, `WPHACT` and `WTO`.

In view of a requested, inclusive cross-section, accuracy of 2% we must include radiative corrections to the best of our knowledge, at least the bulk of any large effect. As we know, the correct scale of the couplings and their differentiation between s- and t-channel is connected to the real part of the corrections, so that the imaginary FL is not enough, we need a complete FL for single-, or EFL. Having all the parts, the tree-level couplings are replaced by running couplings at the appropriate momenta and the massive gauge-boson propagators are modified accordingly. The vertex coefficients, entering through the Yang–Mills vertex, contain the lowest order couplings as well as the one-loop fermionic vertex corrections.

Each calculation aimed to provide some estimate for single- production is, at least nominally, a tree level calculation. Among other things it will require the choice of some Input Parameter Set (IPS) and of certain relations among the parameters. Thus, different choices of the basic relations among the input parameters can lead to different results with deviations which, in some case, can be sizeable and should be included in the theoretical uncertainty. Here, more work is needed.

For instance, a possible choice is to fix the coupling constant g as $\mathrm{g}^2 = \frac{4\pi\alpha}{s^2}, \quad s^2 = \frac{\pi\alpha}{\sqrt{2}^2}, whereistheFermicouplingconstan$

$4\sqrt{2}^2, but, inbothcases, wemissthecorrectrunningofthecoupling.Adhocsolutionsshouldbeavoided, andtherunningofthepara$

Another important issue in dealing with single- production is connected with the inclusion of QED radiation. It is well known that universal, s-channel structure functions are not adequate enough to include the radiation since they generate an excess of ISR bremsstrahlung. In t-channel dominated processes the interference between incoming fermions becomes very small while the destructive interference between initial and final states becomes strong.

It is quite a known fact that, among the electroweak corrections, QED radiation gives the largest contribution and the needed precision requires a re-summation of the large logarithms. For annihilation processes, $e^+e^- \to f$, initial state radiation is a definable, gauge-invariant concept and we have general tools to deal with it; the structure function approach and also the parton-shower method. However, when we try to apply the algorithm to four-fermion processes that include non-annihilation channels we face a problem: it is still possible to include the large universal logarithms by making use of the standard tools but an appropriate choice of scale is mandatory. Such is the case in single-. The problem of the correct scale to be used in QED corrections has been tackled by two groups, `GRACE` and `SWAP` and additional results will be shown in esdscalegrace and in rcsw.

Signal definition in single-

The experimental requirements on single- are:

itemize

[–] CC20 – Mix56 calculations with some detector acceptance that are used for a) triple gauge coupling determination, b) standard model background to searches;

[–] the LEP EWWG cross-section definition that is used to combine the cross-section measurements from the four LEP experiments.