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Event reweighting to account for DPA

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Abstract

This note reports about the way it is possible to reweight four-fermion (4-f) events in order to account for the $\mathrm{O}(\alpha)$ radiative corrections implemented in double pole approximation (DPA). The recommended choice for the DELPHI users is described and commented. This work is based on the new codes implementing DPA developed in the frame of the 2000 LEP2 Montecarlo workshop.

1 Introduction

One of the successes of the LEP2 MC workshop [1] has been the introduction of new codes, able to calculate O(α) correction to 4-f processes in the so-called Double-Pole Approximation (DPA), allowing a substantial improvement of the theoretical accuracy on total and differential cross-sections. This approach consists of an expansion of the 4-fermion matrix elements around the W poles, keeping only the first term. The number of contributing diagrams is thus enormously reduced, and it is possible to calculate the full radiative corrections for this subset only. This procedure has the big advantage of being gauge invariant, but is exact only at the resonances (i.e. for CC03 physics).

The codes which can be used for generating unweighted events and that include DPA are essentially two: RacoonWW [2] and YFSWW [3]. The features of these codes and a detailed comparison at distribution level which shows the necessity of taking into account these new calculation in a Montecarlo generation for precision measurements at LEP2 are described elsewhere [4]. Our aim, here, is to determine how to concile the generation of 4-f samples and WW samples with DPA in.

In what follows we will describe the possible solutions to this question and the choice made by DELPHI, providing practical ways to include the DPA through an event reweighting.

2 DPA and four-fermion

2.1 interfacing the two

By construction the DPA approach to radiative corrections is valid only for the signal, represented by the CC03 diagrams. The prediction of DPA calculations in regions of the phase space which are not WW-like are therefore expected to be wrong and, in general, not to be trusted. This means that it is not possible to simply use a DPA code for the whole 4-f physics generation. The best solution is to use then two generators, each of the two optimised for its own sector, and then match them.

The first indication on how the matching might be done comes from a decomposition of the new 4-f amplitude ($4f'$) as:

$$|4f'|^2 = |4f|^2 - |CC03|^2 + |CC03_{DPA}|^2 = |4f - CC03|^2 + Int. + |CC03_{DPA}|^2 \qquad (1)$$

where $|CC03|$ is the CC03 matrix element in the so-called Improved Born Approximation (IBA), i.e. already including radiative corrections like Initial State Radiation (ISR) and Coulomb corrections, whereas $Int.$ indicates the interference term between CC03 and the rest. A possible matching is therefore realised by using a pure 4-f generator for the $|4f - CC03|$ part and a DPA generator for $|CC03_{DPA}|$. In doing this one can either neglect the interference term or include it in the pure 4-f part in the generation. Both of these possibilities have undesired drawbacks; the first one introduces a systematic effect due to neglecting the interference, particularly evident for final states of the CC20 class which can lead to important systematic contributions; the second one implies that many events will result with negative weights in the generation because of the presence of the destructive interference term, which is rather awkward to be taken into account in the analyses.

An elegant way out to the problem of interfacing DPA with a full 4-f generation comes from the event reweighting. There are two ways of doing this:

- **4f reweighting:** consists in generating DPA CC03 events and reweighting them to account for the 4-f background contributions. This approach has the disadvantage of being totally inefficient (and therefore not precise) in certain regions of the phase space, particularly the non-CC03 like.

- **DPA reweighting:** consists in generating 4-f events and reweight them to account for the DPA correction in the CC03 part only. This is the approach chosen by DELPHI which will be explained with more details in the next subsections.

2.2 DPA event reweighting

The weight to be used to account for DPA in 4-f events can be evaluated as a ratio of matrix elements. Using the same notation of identity (1) the weight is written as:

$$w = \frac{|4f'|^2}{|4f|^2} = \frac{|4f|^2 - |CC03|^2 + |CC03_{DPA}|^2}{|4f|^2} = 1 - \frac{|CC03|^2}{|4f|^2}\left(1 - \frac{|CC03_{DPA}|^2}{|CC03|^2}\right) \quad (2)$$

In this reweighting procedure the interference term is included, although computed using CC03 as given by IBA. Relation (2) can be re-written in a more concise form as:

$$|4f'|^2 = |CC03|^2(1 + \delta_{4f} + \delta_{DPA}) \quad (3)$$

where:

$$\delta_{4f} = \frac{|4f|^2}{|CC03|^2} - 1 \; ; \quad \delta_{DPA} = \frac{|CC03_{DPA}|^2}{|CC03|^2} - 1 \quad (4)$$

This represents the so-called additive approach to the DPA reweighting. In this formulation the new 4-f matrix element results from the CC03 one with the addition of two corrections, one accounting for the presence of extra diagrams due to the 4-f background and the other for the radiative corrections.

In the literature, also the so-called multiplicative approach can be found, where:

$$|4f'|^2 = |CC03|^2(1 + \delta_{4f})(1 + \delta_{DPA}) = |4f|^2(1 + \delta_{DPA}) \quad (5)$$

The multiplicative approach is convenient for reweighting already generated 4-f events, for which it is impossible to recalculate δ_{4f}. The error of this approach, compared to the additive one, is of the order of $\delta_{4f}\delta_{DPA}$. Such error is negligibly small in the signal region, i.e. for CC03 where δ_{4f} is virtually zero. However, outside this region, the magnitude of the error cannot be predicted since δ_{DPA} can be arbitrarily wrong and δ_{4f} large. It is therefore dangerous to use such approach for 4-f analyses.

2.3 The DELPHI approach

The DELPHI approach to DPA reweighting makes use of the additive scheme described in the previous section. The advantage of writing the DPA weight w in terms of the identity (2), is that it can be conveniently decomposed as a product of terms depending only upon two ratios, namely $|CC03|^2/|4f|^2$ and $|CC03_{DPA}|^2/|CC03|^2$. The first term can be calculated event by event with an IBA 4-f generator given the matrix elements of subsets of diagrams, whereas the second can be determined from an output of YFSWW. The YFSWW generator, used as a rewighter, returns the value $|CC03_{DPA}|^2/|CC03_{K-C}|^2$, i.e. the DPA matrix element with respect to the CC03 one which already includes the Coulomb screening via the Khoze-Chapovski correction [5]. The desired ratio can be determined by multiplying this output by $|CC03_{K-C}|^2/|CC03|^2$, which gives a very small smearing to the weight distribution of the order of a few permill.

Figure 1 shows the distributions of these matrix element ratios for 670K 4-f charged current events generated with the WPHACT [8] generator. In the upper left-hand plot the CC03 weight is shown; the peak at zero is due to the non-CC03 part of the sample, basically composed by single W events. Interference effects introduce events with weight larger than 1. The DPA weight, relative to CC03 with Khoze-Chapovski, is shown in the upper right-hand figure for all 4-f events. The lower figure is the derived DPA weight to 4-f; the average value of the distribution gives the total cross-section reduction induced by DPA. The peak at 1 represents the contribution of the non-CC03 part for which $|CC03|^2/|4f|^2 \approx 0$

A question might arise about the conceptual correctness of the DPA weight calculation inside YFSWW, where the input number of photons from a 4-f event without real radiation from W is different from the one of events where such radiation is calculated. Anyway the YFSWW group has shown in [6] that the reweighting procedure of 4-f KoralW [7] events in the additive scheme correctly reproduces the main differential distributions of CC03 obtained with YFSWW alone, thus demonstrating the robustness of the approach.

It is important to note again that in (2) the $|CC03|$ matrix element is evaluated as given by IBA, and therefore already accounts for part of the radiation. In the ratio $|CC03|^2/|4f|^2$, the standard ISR factorises and therefore which radiator function is used for the generation of 4-f events is not a crucial issue. This is also true for the matrix elements ratio DPA/IBA, since it is calculated in YFSWW by using the same ISR implementation via the YFS exponentiation. However, in order to have a consistent 4-f+n-γ phase space coverage in all the parts of the DPA weight, it is convenient to use the same ISR implementation in both terms. This guarantees the use of the same kinematics used for the generation in the determination of the DPA/IBA ratio. This is the reason why in DELPHI it is preferred to use, where possible, the YFS exponentiation for ISR in the 4-f generation, realised by interfacing the KoralW implementation with the WPHACT 4-f generator.

Both the ratios of relation (2) needed for calculating the DPA event weight can now be directly determined from the information contained in the extra comment lines of the simulation banks. All relevant matrix elements and both ratios $|CC03_{DPA}|^2/|CC03_{K-C}|^2$, $|CC03_{K-C}|^2/|CC03|^2$ are now stored there, and can be retrieved by using the routine `WPHDST`, in `/afs/cern.ch/delphi/tasks/generators/wphact/wphdst.car`. An example on how to use it can be found in the subroutine `REAWPH`, contained in the same file. The decoding of the simulation banks and the calculation of the DPA weight is already implemented in the W physics common code and saved in the simulation block of the ntuple. The explanation of the common WW ntuple structure can be found in [9].

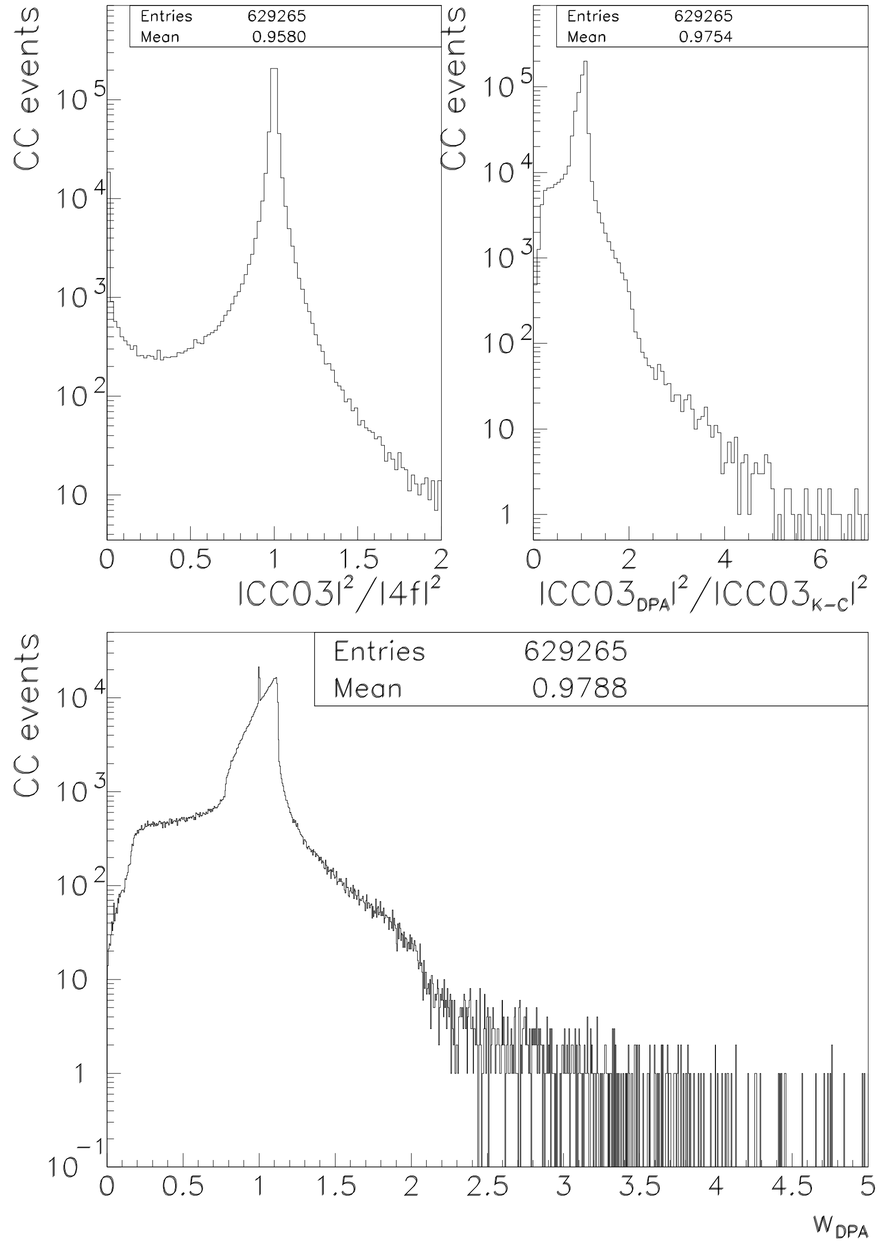

Figure 1: Distributions of the CC03 relative weights (upper left), the DPA to CC03 with K-C relative weight (upper right) and the global DPA weight (lower) from WPHACT 4-f simulated samples.

3 Conclusions

In this note we briefly reported about the ways in which it is possible to account for the most recent calculations of O(α) EW radiative corrections in a coherent 4-f event generation. Advantages and disadvantages of the different approaches have been illustrated and the DELPHI choice, summarised in relation (2), presented. This work is also intended as a reference for the DELPHI users.

References

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