Preliminary notes on two-fermion group activities

Contact persons:

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I. Tomalin (A) Ian.Tomalin@cern.ch,
A. Olchevski (D) Alexander.Olchevski@cern.ch,
D. Bourilkov (L) Dimitri.Bourilkov@cern.ch,
M. Kobel (O) mkobel@physik.uni-bonn.de
Z. Was (Th) Z. Was@cern.ch

Abstract

This note contains a preliminary discussion of the issues which are to be addressed by the 2-fermion group. New input or criticism would be most welcome. It contains a list of experimental and theoretical observables for difermion events, and provides estimates of their theoretical uncertainties, together with the one requested by experiments. Comparisons are made of predictions from different packages.

To evolve into a chapter in future yellow book

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1 Introduction

It is probably fair to assume that the theoretical effort to describe difermion physics at LEP2 is now almost finished. The main goal of the difermion workshop should thus be to review our present knowledge of these theoretical predictions, collecting references from relevant papers and programs. It should estimate theoretical systematic errors for experimentally interesting quantities, etc. However, if important predictions are still missing, the present workshop should bring this to the attention of the theoretical community.

Our group will work closely with the LEP2 $f\bar{f}$ working group (coordinated by Pete Renton), which aims to develop the procedure for combining the results from the four LEP experiments. We should also interact with searches groups, for which Standard Model (SM) difermion processes are a source of background. It is natural that members of these working groups are best placed to formulate a list of practical observables for which theoretical predictions and their systematic errors are needed. They can also highlight cases where the theoretical issues need clarifying and estimate the relative urgency with which the different issues need to be addressed. Of course we should coordinate our efforts with other working groups of the workshop, in particular the 4-fermion as well as $\nu\bar{\nu}\gamma's$ working groups.

Two kinds of observables should be studied.

- Realistic observables which correspond more closely to the event selection cuts actually applied by experiments.

- Idealized theoretical quantities, such as the total cross sections or asymmetry with no cuts or very simple cuts. Such quantities are best suited for theoretically clear extraction of basic quantities such as particle masses or couplings. They also make it easier to average results from different experiments and allow a comparison with SM predictions from semi-analytical programs.

A list of such observables is given in **Section 2**. The list of realistic observables may be long and semi-repetitive . (e.g., Observables with cuts differing slightly by numerical value of some parameters – angles, energies etc.) However, this is necessary, as the discussion of theoretical systematic errors often depends on particular kinematical cuts applied. It may also contain observables which are known to have good theoretical predictions and reliably estimated theoretical errors. Later, we can decide on how to group and simplify the list according to e.g., convenience for discussion of theoretical errors. However, it is important that from the very beginning the list should be complete and describe exhaustively the event selections of the various experiments. Section 2 will also describe why some observables are better than others from an experimental point of view. It will also identify for which variables it is most urgent to have theoretical input, e.g., because experimental errors are small compared with theoretical ones, or where experimental cuts have to be modified to exclude phase space regions poorly known from theory. The list of idealized variables must use simple cuts, which make sense experimentally and can also be implemented in semi-analytical programs.

One of the most important tools to achieve the aim of this workshop is comparisons between different available theoretical calculations. Before making such comparisons, one need a clear understanding of definitions of quantities and tuning of input parameters. **Section 3** will therefore address the question of conventions and definitions in order to avoid such inconsistencies when using different programs. This chapter on definitions should also address the question of compatibility of LEP1 and LEP2 conventions and motivation of why they are chosen like that (gauge invariance, conventions of LEP1 published results, etc.). Eventually such section(s) could be part of general section of the whole report and could be taken over by the main editor.

In **Section 4**, we plan to describe the various theoretical programs and give the basic ideas behind them, together with the list of main publications and indication of where the present versions of these programs can be taken from.

Section 5 will contain numerical results and present theoretical studies of systematic errors for the individual (or for groups of) observables presented in Section 2. It should also assess theoretical errors on the difference between idealized and experimental observables, to determine how reliably experiments can correct their results to the idealized case. The aim will be, of course, not to list all the predictions for each case but to provide numerical benchmark and concentrate on the discussion of possible systematic errors. In this discussion the breakdown of errors and understanding of applicability of different components is important.

The contributions to this section will be the responsibility of the individual authors of the various packages used in making predictions of difermion production. We should ensure that all such packages are considered, not only those already used by experimentalists, but also all other which are officially released.

The ideal item in this section would be just extended citation to published papers (preprints or completed entries in this book) of the form which may look like the following one: "Observables (*list of labels from Section 2*) have theoretical systematic uncertainties of xx% as shown inx [**?**]. These uncertainties are estimated with the help of the program [**?**], by varying the following assumptions/parameters .... Simmilarily on the basis of that calculations we expect that in the following cases: (*another list of labels from Section 2*) systematic errors for predictions should not exceed the tag of xx %. Finally in the following cases: (*again another list of labels from Section 2*) the predictions and their systematic errors can be calculated accordingly to scenario explained above, but we can not guess the numerical size of the outcome with enough certaintity.

We can not expect the ideal situation in case of all observables. We will need to adopt our approach, stimulate effort etc., accordingly to experimental importance of the particular observable, available theoretical results and manpower. In the cases where the theory error is unknown or possibly big, we will try to find other alternative observables with reliable/small errors.

Section 6 will provide numerical comparisons of predictions from different theory packages, comparisons for the observables listed in Section 2 .These comparisons will check the robustness of the error estimates provided in Section 5. Eventual traps or potential misunderstandings due to different conventions will be presented here.

Finally, **Section 7** will summarize the effort. In some cases we may find predictions to be insufficiently precise. In such cases stimulation for the future efforts can be generated.

2 Observables

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2F

Let us complete the list of observables first. From the preliminary discussion we find that at least the two classes of observables are to be discussed: those corresponding to realistic experimental cuts and those of an idealized nature. Furthermore, each of these may apply to either

1. 2 fermion final states
2. 2 fermion + visible photons (esp radiative return).

As it was pointed out, the first item should be discussed in close contact with the LEP2 ffbar subgroup of the LEP electroweak working group. It should help to facilitate the averaging procedure of the results of the four LEP experiments, and assess the theoretical and MC modeling errors for each experiment as well as their correlation in the average. It might even help to clearly define a benchmark 2-fermion "signal" for the averaging procedure in terms of s' definition, $\cos\theta$ definition, QED I/F interference, and pair radiation correction.

The 2f+photon final state (i.e. high pt photons) , mainly consisting of radiative return events, is essential to be understood for searches for excited leptons , decaying to gamma-ℓ and anomalous ZZ-γ and γZ-γ couplings. Here the theory predictions , semianalytical programs and MC generators agree worst with the data, especially for electrons. An improvement of these predictions and an assessment of remaining errors is crucial for obtaining valid limits (or discoveries) of new physics.

Precise realistic observables together with the required precision for each of the above categories are currently set up by the experimentalists.

In the definition of cuts we need to adress the question of possible contamiation of one process by another one. Often experimental cuts are specifically designed to elliminate such contaminations, but in practice some remnant contaminations may still stay. As simple example we can imagine the τ-predictions (case of the $\tau \to \mu$ decay) which can provide non-negligible contribution for the observable designed eg. for the measurement of μ-pair with ISR photons. As prediction for such τ-channel can be easily calculated we may expect the question on its size and related uncertainty.

More complicated is the case of 2-f versus 4-f definition, i.e. how to set the limit defining which pair radiation is a radiative correction to the 2f signal, and should be included in the measurement and the efficiency determination, and which is background, to be subtracted. To understand this interplay between 2-f and 4-f processes three groups have to work closely together: Our group, the LEP2 ffbar subgroup of the LEP electroweak working group and the 4-fermion subgroup of this MC workshop. Theoretically little effort has yet gone in this problem at LEP2, and there is urgent need for theorists to talk to experimentalists and vice versa, in order to define the work that has to be done (e.g. common exponentiation of pairs and photons, options to apply a cut on the pair mass) The outcome might even have some impact on LEP1 results, although there the effect is very much suppressed.

We may expect other simmilar situations, due e.g. of particle misidentiffications which we may need to include in our scheme of predictions and their systematic errors.

Our list of observables is yet too preliminary to be shown on May 27.

3 Conventions and translation guidelines

4 Semianalytical and Monte Carlo tools used

5 Theoretical uncertainties of observables

6 Tests and comparisons

7 Summary – what will remain to be done by th community later ...