Report on the activities of the LEP2 Monte Carlo Workshop[1]

0.1 Structure of the Workshop

The formal structure of the Workshop is as follows

Chairman

- R. Pittau (roberto.pittau@cern.ch)

Organising Committee

- A. Ballestrero (ballestrero@to.infn.it)
- P. Bambade (philip.bambade@cern.ch)
- P. de Jong (paul.de.jong@cern.ch)
- M. Dubinin (mikhail.dubinin@cern.ch)
- P. Giacomelli (paolo.giacomelli@cern.ch)
- M. Grunewald (martin.grunewald@cern.ch)
- S. Jadach (Stanislaw.Jadach@cern.ch)
- M. Kobel (mkobel@physik.uni-bonn.de)
- Y. Kurihara (yoshimasa.kurihara@kek.jp)
- G. Passarino (giampiero@to.infn.it)
- G. Schuler (gerhard.schuler@cern.ch)
- G. Taylor (gary.taylor@cern.ch)
- Z. Was (zbigniew.was@cern.ch)
- B. Webber (webber@hep.phy.cam.ac.uk).

The following working groups have been organised

1) <u>2 fermions</u>

   Contact persons:

   I. Tomalin (A) (at a later stage Marie-Noelle Minard), S. Olchevski (D), D. Bourilkov (L), M. Kobel (O), Z. Was (TH)

   Coordinators:

   Z. Was, M. Kobel

[1] Prepared by R. Pittau.

2) 4 fermions

Contact persons:

J.B. Hansen (A), R. Tanaka (A), H. Phillips (D), M. Gruenewald (L), M. Verzocchi (O), G. Passarino (TH)

Coordinators:

G. Passarino, M. Gruenewald

3) photonic final states

Contact persons:

G. Taylor (A), A. de Min (D), A. Favara (L), S. Arcelli (O), S. Jadach (TH)

Coordinators:

S. Jadach, G. Taylor

4) gamma-gamma for background studies

Contact persons:

A. Wright (A), K. Hultqvist (D), A. Favara (L), P. Giacomelli (O), G. Schuler(TH)

Coordinators:

G. Schuler, P. Giacomelli

5) QCD as a background for searches and WW systematics

Contact persons:

G. Dissertori (A), P. Bambade (D), P. de Jong (L), N. Watson (O), B. Webber (TH)

Coordinators:

B. Webber, P. Bambade

0.2 The early stage of the work

As a first step, the experimental contact persons and coordinators of each group have been asked to compile a list of *experimental questions and wishes*, including an inventory of observables with the required experimental precision tags. This step took a considerable amount of time, because it required several iterations among the 4 LEP collaborations and a lot of discussion. The main results can be summarised as follows

- A document was written by the 4f group, with a very precise list of questions and experimental needs.
- An analogous *shopping list* was compiled by the 2f group.

- A merging of the group *photonic final states* with the 2f group was decided, because the latter seemed to be a more natural environment for many processes relevant for searches, such as $e^+e^- \to \nu\bar{\nu} + n\gamma$.
- The QCD group focused on problems related to the estimate of the theoretical uncertainties in the production of jets with b-tagging - that is a potential background for Higgs searches - and on QCD modelling in general. Unofficially, but in practice, topics related to QCD soft phenomena (as Bose-Einstein and Color-Reconnection effects) have been moved to the parallel Workshop WW99.
- As for the $\gamma\gamma$ topics, it was noticed that processes involving 1 or 2 *t-channel* exchanged $\gamma' s$, leading to fermionic or high-hadronic mass ($>$ 40 GeV) final states, naturally belong to the 4f group. So that only the low-hadronic mass (<40 GeV) processes were left to the $\gamma\gamma$ group. Unfortunately, work started very late in such a *restricted* $\gamma\gamma$ group. Topics relevant to SUSY searches in very degenerate scenarios have been investigated basically only by DELPHI. However, there is hope to characterise the uncertainties in a useful way, although perhaps not strictly on the time-scale of the workshop.

All activities of the Workshop are documented and the results collected in the following web page:

`http://www.to.infn.it/ ~giampier/lep2.html`

where the proposals of the various groups can be found, together with the talks given at the plenary meetings of the Workshop.

0.3 General considerations

So far, a lot of effort has been devoted in the Workshop to study not only problems relevant for searches (QCD background to Higgs production, estimate of the theoretical uncertainty in $\nu\bar{\nu}\gamma$ final states, etc.) but also topics related to the final analysis of the LEP2 data.

The fact that soft QCD effects were moved elsewhere poses no problems of principle. But one has to be aware of the fact that no big improvement on low-mass single-W and low-mass $\gamma\gamma$ processes with hadrons in the final state is expected by the end of the Workshop.

On the other hand, significant progress is expected on the following issues:

- Single-W and $\gamma\gamma$ processes in the high-mass region.
- Reduction of the theoretical error on σ_{WW} from the present 3% to the required 0.5% accuracy.
- Better understanding of the pattern of the radiation in radiative 4-fermion processes.

- Better understanding of the QCD modelling for the jet production with and without b tagging.

- Better estimates of the theoretical errors on 2f (+ γ) observables.

At the very beginning, the deadline of the Workshop was put at the end of 1999, for searches related topics, and few months later for questions relevant to the final LEP2 analysis.

Given the present status of the Workshop, a realistic estimate of the needed time to close a successful Workshop, would suggest to unify the two deadlines.

A good solution could be to have a Yellow Report ready by the end of May/beginning of June 2000. In such a report both questions (analysis related and searches related topics) could be studied together. After all, the separation between the two subjects appeared very artificial in practice.

Such a longer time scale would really help the authors of the various codes to better understand the differences in the various implementations and would allow a more reliable estimate of the theoretical uncertainties.

0.4 Group activities and results

In the following, I briefly list, for each group and topic, the results achieved up to now and a projection of what can be achieved by the end of May.

4f group

Single-W production

Achieved tasks:

1) Technical agreement among codes.

2) Understanding of the correct scale to be inserted in the QED Structure Functions.

3) Preliminary comparisons among QED Parton shower, Structure Function approach and exact matrix element for radiative single-W production.

4) A discussion started about the correct running α_{EM} to be used in t-channel dominated processes.

What can be achieved by May:

1) A More accurate study of the pattern of the QED radiation in single-W production.

2) A reliable estimate of the theoretical uncertainties.

3) The problem of the scale for α_{EM} will be solved through the inclusion of the full set of fermion loop corrections and compared with equivalent approaches. The size of the corrections will be therefore explicitly computed.

4) The precision tags indicated in the 4f proposal, namely:

   – 2% for $e^+e^- \to e^-\ \bar{\nu}_e\ q\ \bar{q}'\ (\gamma)$
   – 5% for $e^+e^- \to e^-\ \bar{\nu}_e\ e^+\ \nu_e\ (\gamma)$
   – 5% for $e^+e^- \to e^-\ \bar{\nu}_e\ \mu^+\ \nu_\mu\ (\gamma)$

   will be probably achieved.

4f + 1 visible γ

Achieved tasks:

1) A first comparison took place among codes that contain the exact matrix element for 4f production + 1 visible γ. Discrepancies of the order of 15% appeared, but most of them are already understood.

2) Distributions have been compared, with reasonable agreement.

What can be achieved by May:

1) A technical agreement among codes.

2) A complete study of the interplay among QED Parton shower, Structure Function approach and exact matrix element, to allow a safe estimate of the theoretical uncertainties associated with QED radiation in 4f processes.

σ_{WW} and M_W

Achieved tasks:

1) Two codes can now implement the EW corrections in the so called Double Pole Approximation and comparisons started between them.

What can be achieved by May:

1) A technical agreement between the two codes.

2) The precision tag indicated in the 4f proposal, namely 0.5% on σ_{WW}, will be probably achieved.

3) A study of the shift in the invariant W mass distribution induced by the EW corrections, will allow a more precise determination of M_W.

σ_{ZZ}

Even if the Double Pole Approximation is not implemented anywhere at the moment to compute the EW correction to σ_{ZZ}, there is in principle such a technical possibility, but it is unclear whether or not this will be done. However, there is common consensus that it would be extremely important to specify at least a few percent theoretical error on this observable, by the end of the Workshop.

2f group

Difermion observables

Achieved tasks:

1) A quite complete list of difermion observables, both realistic and idealised has been compiled, including the required precision tags. Realistic observables are those that take into account all kind of selection cuts actually used by the experiments. Idealised observables are quantities such as the total cross section or asymmetry with no cuts or very simple cuts. Such quantities are best suited for theoretically clear extraction of basic quantities such as particles masses or couplings. They also make it easier to average results from different experiments and allow a comparison with Standard Model predictions for semi-analytical programs. The actual activity of comparison among codes just started.

What can be achieved by May:

1) To complete the comparisons among the difermion codes.
2) A reliable estimate of the theoretical uncertainty for each observable by comparing the different results and/or by varying the internal assumptions/parameters of the codes.

2f-4f interplay

Discussion started, but it is unclear at the moment whether activities will be pursued in that direction. Common feeling is that should this become a real matter of concern, theoretical investigations could be in principle carried out.

QCD group

Achieved tasks:

1) The lack of a massive NLO calculation induces uncertainties in the prediction of the 4-jet rates with b-tagging at LEP2. It was proposed to estimate such an uncertainty by varying the value of m_b in the Lowest Order massive calculations. This was found to be a reasonable estimate, by investigating the same procedure in 3-jet rates, where massive NLO calculations are available.

2) Comparisons started between Matrix Element calculations and Parton Shower predictions in 4-jet rates.

3) A new version of PYTHIA is available in which the quark mass effects are taken into account also in the Phase Space and a better agreement with the data is found.

4) A new version of HERWIG will be soon available, containing a full massless 4-parton Matrix Element option.

5) A new generator (APACIC++) is now on the market, containing tree-level matrix elements for n= 2,...,5 partons.

6) Distributions for event shape variables have been produced and compared at matrix element, parton and hadron levels.

7) Distributions for event shape variables have been compared among different generators.

What can be achieved by May:

1) A more coherent set of comparisons among the various codes.

2) A better understanding of the interplay between Matrix Element and Parton Shower approaches.

3) A reliable estimate of the QCD uncertainties in 4-jet production.

0.5 Concluding remarks

A lot of effort has been put by all people contributing to the Workshop in order to keep the activities going.

For most of the topics we now have a clear list of relevant experimental questions and a precise indication of the required theoretical accuracy.

Collecting such a list, took more than expected. Nevertheless, very important results are very likely to be achieved. To name one, a better theoretical prediction for σ_{WW}, that is, after all, one of the main LEP2 measurements.

In order to close a satisfactory Workshop, I propose the end of May / beginning of June 2000 as a deadline of the group activities. There is consensus among the representatives of the experimental groups that this delayed deadline will not affect their ability to prepare the appropriate MC samples for the analyses using the most up-to-date results, nor will it delay the combination of results among the four experiments, expected to take place prior to the July LEPC.

In the final Yellow Report of the LEP2 Monte Carlo Workshop, both analysis and searches related topics could be studied jointly.