LEP e^+e^- annihilation with MCPWNLO

1 Introduction

This manual describes how to generate e^+e^- annihilation events at LEP with NLO accuracy using the MC@NLO [1] and POWHEG [2] methods. More details on the use and application of the program and its interface with Herwig++ [3] can be found in [4, 5].

2 Setting the parameters

Within the directory MCPWNLO/EPEM, the files MCEPEM_INPUTS.h and PWEPEM_INPUTS.h include all the available user parameters for the main programs MCEPEM.cxx and PWEPEM.cxx for MC@NLO and POWHEG event generation respectively. The MCEPEM parameters are:

double cme: The center of mass energy in GeV e.g. 91.2 for LEP.
double Mz: Pole mass of the Z boson in GeV.
int nf: Number of parton flavours $(1-5)$.
bool massiveME : Set to true if a non-zero parton mass is to be used in the matrix element or false if all partons are to be considered massless.
double alphasmz : The value of α_S at the renormalization scale e.g. Mz for LEP.
bool boost: Set to true if masses should be boosted to true parton masses if massiveME above is set to false.
int it: Maximum number of iterations for the Newton-Raphson boost.
bool resolve: Set to true if the resolution cut on very soft emissions is to be implemented if massive is set to true. int nevint: Number of events (typically $\approx 10^5$) to integrate over for cross-section calculation and determination of maximum weights. Note that this is missing from PWEPEM_INPUTS.h.
int nevgen: Number of events to generate (typically $\approx 10^5$).
int rseed: Initial seed for the random number generator.

In PWEPEM_INPUTS.h, there are the following additional parameters:

double Lambda : The value of $\Lambda_{\rm QCD}$ for the running of α_S.
bool trunc: Set to true if the truncated shower is to be switched on.

3 Generating partonic events

After setting the parameters, open the Makefile and set HERWIGDIR to the address of the Herwig folder in the directory MCPWNLO. To run MCEPEM.cxx or PWEPEM.cxx, in the directory EPEM, type the following commands :

```
make clean
make
```

This creates the executables MCEPEM, PWEPEM and run_epem (which is moved to HERWIGDIR). Next, type:
.\MCEPEM
or
.\PWEPEM
depending on which NLO method is being applied. This runs the main program and generates the Les Houches file for interface with Herwig++. This file will be called PWEPEM.dat if running POWHEG and MCEPEM.dat if running MC@NLO containing unweighted events with absolute weights of 1.

4 POWHEG requirements

If running POWHEG, go to the folder PWInstallFiles in the main MCPWNLO directory. There you will find the following files:
PartnerFinder.cc PartnerFinder.h PartnerFinder.icc Replace the files of the same names in /Shower/Base folder of your Herwig++ installation directory. Then go back to the Shower folder (not in Base!) and type:

```
make
make install
```

This allows us to set the colour partner of the hardest emission correctly for POWHEG.

5 Analysis

In the folder LEPAnalysis in the EPEM directory are some analysis files which analyze the events after interfacing the Les Houches file with Herwig++.
The .cc files contain the main programs which provide histograms for various LEP event shapes. Open the Makefile and set HPDIR and THEPEGDIR to the folder where you installed Herwig++

and ThePEG. Compile the directory by typing the following commands

```
make
make install
```

in the LEPAnalysis directory. This recreates the .so libraries. You will need to do this every time to make a change in the analysis files.

6 Interfacing with Herwig++

Having generated the Les Houches file and set up the analysis handlers, the next step is to run Herwig++. It is assumed that both Herwig++ and ThePEG have already been installed on your system.

Now go to the directory MCPWNLO/Herwig and open the initialization file EPEM.in. This contains Herwig++ user parameters which can be set depending on which NLO method you are running. The default set-up is for MC@NLO. A selection of these are:

set Reader2:FileName EPEM.dat: This is the filename for the Les Houches file your generated file is converted into by the program EPEM/run_epem.cxx. Leave this as it is!
set Reader2:EBeamA 45.6: The beam energy in GeV of the electrons.
set Reader2:EBeamB 45.6: The beam energy in GeV of the positrons.
set LesHouchesHandler:WeightOption NegUnitWeight: The weight option for the events. This allows for negative weighted events.
insert SimpleEE:MatrixElements 0 MEee2gZ2qq: The hard process. Here it's set up for Z/gamma production and decay into $q\bar{q}$ pairs.

Next are commands which should be uncommented if running POWHEG. If running MC@NLO, comment these out.

set /Herwig/Shower/Evolver:HardVetoMode 0: The veto mode to be applied. For POWHEG, this should be set to 1.
set /Herwig/Shower/PartnerFinder:PHPartnerFinder 0: The partner finder option. This should be set to 1 for POWHEG.
set /Herwig/Shower/Evolver:HardVetoScaleSource 0: This reads the maximum p_T for the veto from SCALUP in the Les Houches file. Set this to 1 for POWHEG.

Next are some tuned parameters to reproduce LEP multiplicities and the best fit to LEP eventshapes for the POWHEG and MC@NLO methods.

`set /Herwig/Shower/AlphaQCD:AlphaMZ 0.118`: This sets the value of α_S at M_Z.
`set /Herwig/Shower/SudakovCommon:cutoffKinScale 2.45*GeV`: This sets the shower cut-off scale.

Having set up the initialization file, run Herwig++ by typing the following commands:

```
.\run_epem [eventfile] [number of events]
```

An example of the run command is:

```
.\run_epem /usera/seyi/MCPWNLO/EPEM/MCEPEM.dat 10000
```

where you should replace the eventfile with the path to your Les Houches file.
At the end of the run, `.top` files will be produced containing the histograms booked by the analysis handler. If you have topdraw installed, you can convert this to a postscript file by typing the command:

```
td -dPOSTSCRIPT *.top
```

7 Further Information

For further information about `MCPWNLO` contact: `seyi@hep.phy.cam.ac.uk`.

References

[1] S. Frixione and B. R. Webber, "Matching NLO QCD computations and parton shower simulations," *JHEP* **06** (2002) 029, `hep-ph/0204244`.

[2] P. Nason, "A new method for combining NLO QCD with shower Monte Carlo algorithms," *JHEP* **11** (2004) 040, `hep-ph/0409146`.

[3] M. Bahr *et al.*, "Herwig++ Physics and Manual," *Eur. Phys. J.* **C58** (2008) 639–707, `0803.0883`.

[4] O. Latunde-Dada, "Herwig++ Monte Carlo At Next-To-Leading Order for e+e- annihilation and lepton pair production," *JHEP* **11** (2007) 040, `0708.4390`.

[5] O. Latunde-Dada, S. Gieseke, and B. Webber, "A positive-weight next-to-leading-order Monte Carlo for e^+e^- annihilation to hadrons," *JHEP* **02** (2007) 051, `hep-ph/0612281`.