# Drell-Yan Vector Boson Production with MCPWNLO

## 1 Introduction

This manual describes how to use this program to generate Drell-Yan events at hadron colliders 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/DRELLYAN, the file DYPP_INPUTS.h includes all the available user parameters for the main program DYPP.cxx. The parameters are:

bool MCNLO: Set to true if the MC@NLO method is to be used or false if the POWHEG method is to be used.
bool trunc: Set to true if truncated shower of at most one gluon is to be implemented for POWHEG method. Note that to interface with an angular ordered shower, this should be set to true.
int VBID: Particle ID for the vector boson required. Set to 23 for $Z$ boson production or 24 for $W$ boson production.
double cme: The hadron-hadron center of mass energy in GeV e.g. 1800/1960 for the Tevatron and 14000 for the LHC.
bool acc: Type of collider. Set to true if $p - p$ or false if $p - \bar{p}$.
double Mz: Pole mass of the $Z$ boson in GeV. double Mw: Pole mass of the $W$ boson in GeV.
bool zerowidth : Set to true if zero width approximation is to be used or false if Breit-Wigner resonance is to be used for boson mass.
double widthw: Width of the $W$ boson in GeV.
double widthz: Width of the $Z$ boson in GeV.
double halfwidth: Number of halfwidths either side of the resonance peak.
char* rscheme: Factorization scheme. Options are "MSbar" and "DIS".
char* PDFset: The PDFset to be used e.g. "cteq5m.LHgrid". Make sure this agrees with the factorization scheme set above.
int nevint: Number of events (typically $\approx 10^5$) to integrate over for cross-section calculation and determination of maximum weights.
int nevgen: Number of events (typically $\approx 10^5$) to generate.
int rseed: Initial seed for the random number generator.

# 3 Generating partonic events

After setting the parameters, open the `Makefile` and set `LHAPDFDIR` to your `LHAPDF` directory. Also set `HERWIGDIR` to the address of the `Herwig` folder in the directory `MCPWNLO`. To run `DYPP.cxx`, in the folder `DRELLYAN`, type the following commands :

```
make clean
make
```

This creates the executable `DYPP` and `run_dypp` (which is moved to `HERWIGDIR`). Next, type: `.\DYPP`
This runs the main program and generates the Les Houches file for interface with Herwig++. This file will be called `PWDYPP.dat` if running `POWHEG` and `MCDYPP.dat` if running `MC@NLO`. It contains 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 `DYAnalysis` in the `DRELLYAN` directory are some analysis files which analyze the events after interfacing the Les Houches file with Herwig++.
`MySimpleAnalysis.cc` contains the main program which provides histograms for the transverse momenta of the dilepton pair produced from the vector bosons, the rapidity and azimuthal distributions of the bosons, the masses of the bosons and the rapidity and azimuths of the leptons. Other histograms can be added by booking histograms in the `MySimpleAnalysis.icc` file and declaring them in the `MySimpleAnalysis.h`.
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 DYAnalysis directory. This recreates the library, MySimpleAnalysis.so.

# 6 Interfacing with Herwig++

Having generated the Les Houches file and set up the analysis handler, 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 DYPP.in. This contains Herwig++ user parameters which can be set depending on which process and NLO method you are running. The default set-up is for MC@NLO $W$ boson production at the 1800 GeV Tevatron. A selection of these are:

`set Reader2:FileName DYPP.dat`: This is the filename for the Les Houches file your generated file is converted into by the program DRELLYAN/run_dypp.cxx. Leave this as it is!
`set Reader2:EBeamA 900.0`: The beam energy in GeV of the hadron from the 'left'.
`set Reader2:EBeamB 900.0`: The beam energy in GeV of the hadron from the 'right'.
`set LesHouchesHandler:WeightOption NegUnitWeight`: The weight option for the events. This allows for negative weighted events.
`insert SimpleQCD:MatrixElements[0] MEqq2W2ff`: The hard process. Here it's set up for $W$ boson production.

Next are commands which should be uncommented if running POWHEG. If running
tt 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/Evolverr:HardVetoScaleSource 0`: This reads the maximum $p_T$ for the veto from SCALUP in the LEs Houches file. Set this to 1 for POWHEG.

Now open the file PDF.in and replace the line

```
setup MRST /usera/seyi/Herwig/Herwig++-2.3.0/PDF/mrst/2001/lo2002.dat
```

with the corresponding address on your system. This can be found by looking in your Herwig++ installation directory. Having set up the initialization file, run Herwig++ by typing the following commands:

```
Herwig++ init
.\run_dypp [eventfile] [number of events]
```

`Herwig++ init` only needs to be executed on the first run. An example of the run command is:

```
.\run_dypp /usera/seyi/MCPWNLO/DRELLYAN/MCDYPP.dat 10000
```

where you should replace the eventfile with the path to your Les Houches file.
At the end of the run, a topdraw file called `MG-MySimpleAnalysis.top` 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 MG-MySimpleAnalysis.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, *Simulations of QCD processes at High Energy Colliders* [**http://www.hep.phy.cam.ac.uk/theory/seyi/thesis/thesis.tar.gz**]. PhD thesis, University of Cambridge, 2008.