Sherpa Uncertainties Tutorial

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1 Introduction

In this tutorial we will discuss some of the uncertainties related to the simulation of multi-jet final states. We will use Higgs-boson plus jets production as an example.

This tutorial will show you how to quantify perturbative QCD uncertainties associated with the predictions from Sherpa for Higgs-boson plus multi-jet production with the Higgs decaying to a tau lepton pair (The actual type of decay is irrelevant here, because we focus on uncertainties in the production, not the decay process).

1.1 Uncertainty evaluations with Sherpa

To assess theory uncertainties in Sherpa, we will produce events with the MC@NLO technique, and with ME+PS merging at the NLO. The NLO merged simulation contains up to 2 jets computed with hard matrix elements, where the 0 and 1 jet process have NLO accuracy and the second jet is simulated at LO. We will vary renormalization and factorization scales as well as parton-shower parameters.

Change to the tutorial directory `tutorials/mc/higgs/sherpa`. In the first two runs, Sherpa will generate process-specific source code necessary for the computation of the tree-level matrix elements and for the NLO subtraction terms (Note that this is different from what you have experienced during the previous tutorial, because we are using a different matrix-element generator). You should execute the following commands

```
Sherpa
./makelibs -n
```

The individual cross sections have been pre-computed and the results are stored in the directory `Results`. You can launch Sherpa and it will start generating events immediately:

```
Sherpa
```

If you configured your VM to use more than one processor core, you may run Sherpa in MPI mode to speed up event generation. For example (using two processors)

```
mpirun -n 2 Sherpa -e50k
```

While Sherpa runs and generates events, have a look at the runcard. The most important part is the `(processes)` section:

```
(processes){
  Process 93 93 -> 25 93{NJET};
  Order (*,0,1); CKKW sqr(QCUT/E_CMS);
  NLO_QCD_Mode MC@NLO {LJET};
  Loop_Generator Internal;
  End process;
}(processes);
```

Note that we produce a stable Higgs boson with up to two additional "jets". This is because the tag NJET is defined as NJET:=2 in the (run) section. Such a tag can be used anywhere in the runcard, and its definition can also be changed on the command line.

Another tag is LJET, which is defined as LJET:=1,2. When it is used in the line

```
NLO_QCD_Mode MC@NLO {LJET};
```

it steers the implementation of NLO corrections to the hard processes. All processes with final state multiplicity 1 and 2 are then computed at NLO accuracy using the MC@NLO method.

All other options in the (processes) section are known from the other tutorials.

The (run) section contains several more settings, which are new.

- We use an effective operator approach to implement the Higgs-Gluon couplings using MODEL HEFT.
- The Higgs boson mass is set to 125 GeV.
- We allow variation of factorization, renormalization and resummation scales using the SCALE_VARIATIONS parameter. Details on the formalism employed and the available options for uncertainty variations can be found in [1].

The last point deserves some attention. Look at the precise specification of the scale:

```
# tags and settings for scale variations
SCALE_VARIATIONS 4,4 0.25,0.25; QSF:=1;
SCALES STRICT_METS{MU_F2}{MU_R2}{QSF*MU_Q2};
```

Firstly, the scale is defined using the ME+PS merging algorithm. This is indicated by the STRICT_METS setting (METS stands for Matrix Elements plus Truncated Showers). Secondly, the factorization and renormalization scales are varied by factors of two up and down using the tag SCALE_VARIATIONS 4,4 0.25,0.25. This is done on-the-fly in each run of the generator. Varying the resummation scale requires additional runs using the tag QSF.

Note that all scales in Sherpa have dimension GeV^2, hence setting QSF:=4, for example, means increasing the resummation scale by a factor two.

Now it is your turn! Generate the following event files:

- The central prediction and simultaneous variations of the renormalization and factorization, defined by the settings in the runcard.
- Variations of the resummation scale in the range $\sqrt{1/2}\ldots\sqrt{2}$.

Note that, because of the setting ANALYSIS_OUTPUT Analysis/NJET/QCUT/QSF/Sherpa; your yoda files will be put into a directory determined by the tags you specify, and it is not necessary to set file names on the command line.

Generate plots from the Sherpa output by using the plot script.

```
cd ~/tutorials/mc/higgs/
./plotit.sh -o MySherpaPlots sh shme shps
```

References

[1] E. Bothmann, M. Schönherr and S. Schumann, "Reweighting QCD matrix-element and parton-shower calculations," arXiv:1606.08753 [hep-ph].