Cargese '12 MadGraph Tutorial Instructions

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In this tutorial, we will learn how to run `MadGraph/MadEvent`, and make simple plots using the simulated events. **NOTE:** This tutorial is of the `"Hello, world"` type: It assumes zero prior experience with MadGraph. Students with prior experience should not waste their time on it. A couple of suggestions for such students are:

- Go to `http://www.phys.ufl.edu/~matchev/mc4bsm6/` where you will find instructions for a self-directed tutorial at a more advanced level, including: coding a new physics model using `FeynRules` or `LanHEP`, simulating events in that model with `MadGraph/MadEvent` or `CalcHEP`, and hadronizing/showering with `Pythia`. Installation instructions for all programs are also included.
- Or, hit the beach.

OK, now for the tutorial. In a terminal window, enter the MG directory you created when you installed MG: for me

```
cd MadGraph5_v1_4_8_2
```

Launch MadGraph:

```
./bin mg5
```

You will see the MG command prompt: `mg5>`. MG is waiting for our commands. First, let's see the notation for SM particles:

```
mg5> display particles
```

Now, let's "generate" our favorite process: Z production in pp collisions, followed by, for example, $Z \to \mu^+\mu^-$:

```
mg5> generate p p > z > mu+ mu-
```

MadGraph has just constructed all tree-level diagrams (including all relevant partonic initial states), and constructed a piece of code containing the symbolic (analytic) expression for the $|\bar{\mathcal{M}}|^2$ of this process. Now, we need to output this code in a way useful for an event generator. We'll use MadEvent to generate events; for this, we simply do

```
mg5> output TEST1
```

where `TEST1` is the name given to a folder where everything related to this event generation run will be placed.

In a separate window, enter the newly created folder `TEST1` and open `index.html`. Click on "Process Information" and inspect the Feynman diagrams constructed by MadGraph.

Now, it's time to generate events. To do this, MadGraph needs to know a couple of things we have not yet specified:

- Numerical values of all parameters, such as masses of the Z, μ and other particles, Z couplings, etc. In a separate window, enter `TEST1/Cards`, and open `param_card.dat`. Inspect it.
- How many events to generate; What's the energy of the colliding protons; Shich set of parton distribution functions to use and how to choose renormalization and factorization scales; What cuts to impose on the final-state particles to model detector acceptance etc. All this information is in `TEST1/Cards/run_card.dat` Open it and inspect it. What is the energy of the colliding beams? Let's change it to 4 TeV to match this year's LHC run. What is the maximum rapidity of the muons? Why do you think the muons of higher rapidity should not be included?

OK, finally, let's go:

```
mg5>launch
```

A (local) html file will open automatically. What is the cross section of our process? Now, click on "LHE". This opens `TEST1/Events/run_01` which contains the event records we generated.

Create a new folder somewhere outside the MadGraph folder, and place the two Mathematica notebooks, `MadEvent analysis.nb` and `Example1`, in there. Open both and run `MadEvent analysis.nb`. Adjust the top line of `Example1` to refer to your current directory. Copy the file `unweighted_events.lhe.gz` from `TEST1/Events/run_01` into your current directory, and unzip it. Now, run `Example1`, making sure you understand what each command does/means.

Done? Here are a couple of simple exercises to test your new skills:

1. Repeat the exercises above for the same final state, but without insisting that there is an intermediate on-shell Z: just $pp \to \mu^+\mu^-$. Explain the differences in the invariant mass and rapidity distributions between this case and the case of on-shell Z.

2. Now, simulate 10000 events with W boson production, followed by a leptonic decay: $pp \to W^- \to \mu^-\bar{\nu}_\mu$. Plot the distributions of events in (a) muon p_T and (b) transverse mass. Compare to theoretical expectations as discussed in the lectures.