Instructions for Charybdis++ v.0.1 pre-release

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Charybdis++ is a new black hole event generator, based on Charybdis2 [1], designed to simulate the production on back holes in high energy hadronic collisions according to the ADD model [2]. This generator Is used to calculate the total and differential cross-sections of black hole production with and without Yoshino-Rychkov improved cross-section and relaxation phase calculations [3]. Future versions of the generator will also simulate the evaporation phase. This version was released for testing purposes only. Documentation fully presenting the generator will be published once the implementation is complete.

- ## *Charybdis++ installation and usage*

The program is ready to use directly from the distribution. No installation is necessary. If you make any alteration to the source-code simply use the *makefile* script to recompile the generator.

Important: In order to use this generator you need to first install the LHAPDF library (follow the instructions here) and to download one of the PDF sets available here.

- ## *Terminal interface:*

The user interface of Charybdis++ is done through input and output files. When calling the program from the terminal you will need to use a series of commands to tell the program the pathways to those files:

`-i` <filepath>: Indicates the pathway to the input file. This is the only mandatory command.

`-o` <filepath>: Indicates the pathway to which the cout stream will be redirected (instead of printed in the terminal).

`--log` <filepath>: Indicates the pathway to which the clog stream will be redirected (instead of printed in the terminal).

`--err` <filepath>: Indicates the pathway to which the cerr stream will be redirected (instead of printed in the terminal).

`--lhevent` <filepath>: Indicates the pathway for the Les Houches [4] output file (if not used the program will create a file called *LH_output.xml* in the program folder).

`--eventhist` <filepath>: Indicates the pathway for the event history output file (if not used the program will create a file called *Event_history.xml* in the program folder).

`--model`: Creates a model input file called *input.init* in the program folder with all the switches necessary to run the program. You should then edit the parameters within the file as you like before running the program.

`--help`: Displays instructions concerning Charybdis++ commands on the terminal (basically the instructions written above).

As an example, if you wanted to run the generator using the file input.init as input and the file output.xml to store the Les Houches event file (while leaving the event history file in its default pathway) you would use this command on the terminal:

➔ **`$ ./Charybdis -i input.init --lhevent output.xml`**

- ***Input file:***

Charybdis++ is largely controlled by the variables and switches defined in its input file. In order to use the program you will need to either alter the *input.init* file present in this distribution or create one using the **`--model`** command. We will now present you with the list of variables present in the input file that you can use to control the generator:

- **`IDbmup[0], IDbmup[1]`**: Particle IDs for both beams (2212 for proton). Warning: These variables only controls the ID printed on the output files, It is up the user to make sure the PDF used corresponds to that ID.
- **`Ebmup[0], Ebmup[1]`**: Beam energies.
- **`minBHmass`**: Minimum mass allowed for black hole production.
- **`maxBHmass`**: Maximum mass allowed for black hole production (typically the sum of the beam energies).
- **`PDFname[0], PDFname[1]`**: Name of the groups of PDFs used (see here). Note: We included two variables to account for the possibility of possible future studies about collisions between two particles of different types. However, since currently the main interest lies in proton-proton collisions, the generator is not (yet) optimized for handling two different PDFs.
- **`PDFSup[0], PDFSup[1]`**: Set of PDFs used. LHAPDF uses 0 for the central value of each PDF so this would be the typical value of these variables.
- **`PDFnum[0], PDFnum[1]`**: PDFs numbers within each set. As before, the central value is 0.
- **`NumMaxEvents`**: Number of unweighted events to generate.
- **`mc_samplesize`**: Sample size for the Monte Carlo generator. Early testing revealed that a 10^5 sample size corresponds to an error margin $< 3\%$ with neglectable computing time.
- **`randseed`**: Seed for the random number generator. Since all randomness is used in the Monte Carlo generators there should be no statistical difference (assuming a sufficient sample size) in the output dependent on the seed. the variable was kept only so it was possible to fully reproduce results. The random number generator used was developed by Agner Fog and is available here.
- **`TotalDim`**: Total number of dimensions (4+n).
- **`PlanckMass`**: (4+n)dimensional Planck mass.
- **`planckmassdef`**: Switch controlling the convention used for the (4+n)dimensional Planck mass. 1: Giddings-Thomas [5]; 2: Dimopoulos-Landsberg [6]; 3: Particle Data Group [7]. Option 4 calls a function in the *charybdis_user.cpp* file that may be edited to use a new convention.
- **`enhanceXsec`**: Switch controlling the improved cross-section calculation used. 0: No improved calculation (the cross-section will simply be the black disc with the Schwarzschild radius r_S); 1: Yoshino-Rychkov's form factors [3]; 3: user defined function (editable in the *charybdis_user.cpp* file).
- **`MJlostGraviton`**: Boolean switch controling weather or not to simulate the loss of mass and angular momentum through gravitational waves during the relaxation phase. Warning: Since calculating the cross-section only requires the final black hole mass after this process, the current version does not account for the loss mass in the Les Houches file (which causes the initial and final energy of the system to be inconsistent). Future versions will create two "graviton-like" particles in the output file to account for this loss.

- **useminBHmass**: When used in conjunction with **MJlostGraviton** rejects the events that have a mass inferior to **minBHmass** after relaxation, effectively reducing the cross-section.
- **GTscale**: Switch controlling the energy scale used to call the PDFs. 0: Use the partonic center of mass energy ($\sqrt{\hat{s}}$); 1: Use the Giddings-Thomas convention ($1/r_S$).

Note: The model input file also contains a series of variables intended for the full implementation of Charybdis++. Although the current implementation does not use these, the program will not run if you simply delete them from the file.

• *Output files*

The output files contain a list of all input parameters and standard header for the Les Houches files [4]:

```
<init> IDbmup[0] IDbmup[1] Ebmup[0] Ebmup[1] PDFGup[0]
PDFGup[1] PDFSup[0] PDFSup[1] IDwtup Nprup
xsecup xerrup xmaxup Lprup </init>
```

• *Differential cross-section*

The generator is also capable of computing the differential cross-section $d\sigma/dM$ of the event production. This functionality is accessed through the function **generator.diffXsectionBin(num_bin,samplesize,output)** present in the *charybdis_main.cpp* file. This creates a file with the name given in **output**, containing **num_bin** differential bins for the cross section computed using a **samplesize** sample for the Monte Carlo generator of each bin. If you do not require the differential cross-section, you can simply remove this function from *charybdis_main.cpp*.

• *References*

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