Pocket manual for PHSD

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1 General description

The Parton-Hadron-String Dynamics is a dynamical approach for strongly interacting systems. The description of both partonic and hadronic phases are included in the code as well as their transition, it also includes the QGP phase in terms of strongly interacting quasi-particles and its further hadronization and decay. Therefore, a full time evolution of heavy-ion collisions at microscopic level is encoded in the PHSD approach.

2 installation

The recommended compiler to run PHSD is the Intel Fortran Compiler, free for personal use and available for Linux distros.A registration will be needed to obtain full access to the compiler, for a personal serial number should be provided after that. For the installation you can either run the *install.sh* script for a command line interface or run the *install_GUI.sh* for a graphical user interface, both scripts are integrated in the installation folder of Intel.

After unzipping the compressed source, inside the installation folder of PHSD there should be a makefile already included, the compilation is initiated by the *make* command. Once installed, there should be an executable file named phsd, executing this file will initialise the simulation.

3 Input file

To specify the initial parameters for collisions one has to use the input file (inputPHSD) inside the PHSD directory. An example 100 Min.Bias Au+Au events at 11 GeV is given in the following table:

197,	MASSTA: target mass
79,	MSTAPR: protons in target
197,	MASSPR: projectile mass
79,	MSPRPR: protons in projectile
62.623,	ELAB lab energy per nucleon
0,	BMIN: minimal impact parameter in fm
14,	BMAX: maximal impact parameter in fm
0.5,	DeltaB: impact parameter step in fm
1,	NUM: optimized number of parallel ensambles
1000,	ISUBS: number of subsequent runs
99997,	ISEED: ANY uneven INTEGER number
1,	IGLUE: =1 with partonic QGP phase; =0 (HSD mode)
50.45,	FINALT: final time of calculation in fm/c
10,	ILOW: output level (default=10)
0,	Idilept: =0 no dileptons; =1 electron pair; =2 muon pair
0,	ICQ: =0 free rho's, =1 dropping mass, =2 broadening, =3 drop.+broad.
0,	IHARD: =1 with charm and bottom; =0 - without
1,	IBweight_MC: =0 constant step; =1 by Monte-Carlo ISUBS times in $[Bmin, Bmax]$
0,	IUSER: =1 for general users; = 0 for PHSD team

The parameters MASSTA, MSTAPR,MASSPR and MSPRPR establish the species of the particles colliding by counting separately the number nucleons. The parameter that describes the center of mass energy is given by ELAB, which is this case represents the "bombarding" kinetic energy per nucleon in the laboratory frame. As PHSD uses a fixed target setting, the relation between ELAB and s_{NN} is given by:

$$s_{NN} = 2 \times m_N \times (ELAB + 2m_N) \tag{1}$$

where $m_N = 0.938\ GeV$

The next table shows the relation between $\sqrt{s_{NN}}$ and $ELAB$ for some of the energies in the range planned to run at NICA.

ELAB (GeV)	$\sqrt{s_{NN}}$ (GeV)
6.65	4
11.45	5
17.31	6
24.24	7
32.23	8
41.30	9
51.42	10
62.62	11

The parameters BMIN and BMAX give a range for the impact parameter as $b \in [BMIN, BMAX]$. The impact parameter can be chosen either by Monte Carlo following the minimum bias probability distribution by marking 1 in the IBweight_MC parameter, or by a Δb step (in fm) by marking 0 in the same parameter and choosing the step width in the DeltaB parameter.

PHSD has de option to perform a certain number of parallel events NUM for each subsequent run ISUB for which Monte Carlo chooses randomly one value for the impact parameter. With this setting we can reduce the time of the simulation to process and reduce the statistical error at the same time.

PHSD is a complex code, therefore the computational time for general tasks as particle multiplicities, spectra and pseudorapidity distributions should be "optimized". In order to do that, a parametrization of the maximum propagation time t_max as a function of the center of mass energy $\sqrt{s}$ is performed by

$$t_{max} = 35 + \frac{170}{\sqrt{s}[GeV]}[fm/c] \tag{2}$$

The value obtained should be marked in the parameter FINALT.

4 Output files

After running the *phsd* executable, an output file called *phsd.dat* will be created which is organized as:

Output file *phsd.dat* **- all particles**

N	ISUB	IRUN	b	IBweight_MC							
N_P	$\psi(2)$	$\varepsilon(2)$	$\psi(3)$	$\varepsilon(3)$		$\psi(4)$	$\varepsilon(4)$	$\psi(5)$	$\varepsilon(5)$		
ID	Q	P_x	P_y	P_z	P_0	ID(J,5)/IPI(5,J)		$[X$	Y	Z	$T]$
...	...	...	...	...	...	...		...	...	...	...

Here, the first two lines are the header that characterize each event, and the third line lists the observables of each generated particle.

For the header I listed the meaning of each quantity in the first two lines:

- N represents the total number of particles per event
- $ISUB$ and $IRUN$ show the subsequent run and the current parallel event.
- b is the current impact parameter in fm
- N_p is the number of participants per event.
- $\psi(i)$ and $\epsilon(i)$ are respectively the out-of-plane angle and the eccentricity of the i^{th} harmonic.

For the list of particles:

- ID is the particles identification in PDG notation
- Q is the electric charge
- P_x, P_y, P_z ans P_0 are the 4-momentum coordinates of the particle
- $ID(J,5)/IPI(5,J)$ shows the story of the particle creation; either particle mother or the type of interaction involved in the creation.
- $[X\ Y\ Z\ T]$ are the coordinates of the freeze-out.

Once obtained this file, one has to convert the output to a "*.root*" file in order to perform the analysis in the ROOT framework. For this task, one has to run the macro ConvertToRoot.C as follows:

root - q - b [path to this macro]/ConvertToRoot.C\(\"[name of input file]\" ,\"[name of output file]\",[number of events],[print flag]\)

For more information look at the commented instructions inside the macro.

5 Analysis

Once you obtain the .root file, a quick look at the distribution of the variables described in the output file can be seen. Looking at the distribution of N, the maximum number of particles per event can be estimated by sight, these quantity will be useful for the analysis made with the macro "*loop.C*", for some of the variables are described as arrays, borrowing the memory of N objects inside. Looking at the "*loop.C*" macro, the variables id[n], q[n], e[n], px[n], py[n], pz[n], code1[n] and code2[n] should be edited to save the memory of the maximum number of particles [n] per event, in order to avoid a segmentation break.

The later macro draws the distribution of the angle of deflection (θ) and pseudorapidity (η) distribution for specific ensemble of particles and for charged pions separately. Feel free to edit it to obtain different analyses at generator level.

References

[1] W. Cassing and E.L Bratkovskaya, *Parton-hadron dynamics: An off-shell transport approach for relativistic energies*, Phys. Rev. C 78 (2008) 034919, arXiv:0808.0022 [hep-ph]; *Parton-Hadron-String Dynamics: an off-shell transport approach for relativistic energies*, Nucl. Phys. A 831 (2009) 215-242, arXiv:0907.5331 [nucl-th].

[2] Intel compiler web page https://software.intel.com/content/www/us/en/develop/tools/parallel-studio-xe/choose-download/student-linux.html

[3] My github repository https://github.com/dchezz/PHSD