

## Box calculations for homework2

Dear participants,

Thanks a lot for your efforts and the time you have devoted to the box simulations. In the following, please find a slightly different reformulation of homework #2, where some additional output information is requested, in order to allow us to perform a space-time Fourier analysis of the density oscillations.

**Vlasov mode: no collisions, only mean field,  $T = 0$ .**

In this mode we can check the dispersion relation for the mean field propagation of density fluctuations (zero sound). We consider a cubic box, of size  $L_k = 20$  fm, 1280 nucleons (640 neutrons, 640 protons) as in homework1. The simulation should be followed until  $t = 500$  fm/c, with a recommended step of  $\Delta t = 0.5$  or  $1.0$  fm/c. The way to introduce the Periodic BC can be found in the announcement of homework1.

### 1) Initialization

Consider symmetric nuclear matter at saturation density,  $\rho_0 = 0.16 \text{ fm}^{-3}$ .

Initialize with a standing wave impressed on the box, along the z direction for instance:  $\rho(z) = \rho_0 + a_p \sin(kz)$ . As suggested by D.Cozman, for MD type models, which employs a Gaussian wave packet (such as  $\exp[-(z-z_i)^2/\Delta x^2]$ ), the specified density distribution can be obtained by sampling the centroids of the wave packet according to the following distribution:

$$f(z_i) = \rho_0 + a_p \exp[(\Delta x^2 k^2)/4] \sin(kz_i).$$

The wave number  $k$  may take the values:  $k = n 2\pi/L_k$  ( $n=1, \dots, n_{\max} = L/(2dz)$ ). In the homework, we will test  $n=1$  and  $n=2$  and we take  $a_p = 0.2 \rho_0$ .

For the initial distribution in momentum space, the Fermi sphere has to be defined as a function of the local density.

### 2) Details of nuclear interaction

The same simplified force employed for the calculations of transport 2014 (Shanghai) should be considered:

- For non-relativistic transport codes:  
use a standard soft Skyrme parametrization (without momentum dependence) with the following parameters:  $a = -209.2$  MeV,  $b = 156.4$  MeV,  $\tau = 1.35$ ,  $M_n = M_p = 938$  MeV and a symmetry potential energy with linear density dependence  $S_{\text{pot}}^*(\rho/\rho_0)$ ,  $S_{\text{pot}} = 18$  MeV.

The total single-particle potential is then:

$$U_{\frac{n}{p}} = a \left( \frac{\rho}{\rho_0} \right) + b \left( \frac{\rho}{\rho_0} \right)^\tau \pm 2S_{pot} \frac{\rho}{\rho_0} \delta. \quad U_{\frac{n}{p}} = a \left( \frac{\rho}{\rho_0} \right) + b \left( \frac{\rho}{\rho_0} \right)^\tau \pm 2S_{pot} \frac{\rho}{\rho_0} \delta; \delta = \frac{\rho_n - \rho_p}{\rho}$$

(Properties of this parameterization: compressibility  $K_0=240$  MeV, saturation density  $\rho_0=0.16$  fm<sup>-3</sup>, binding energy at saturation density  $E_0=-16$  MeV, symmetry energy  $S(\rho_0)\sim 30.3$  MeV)

- For relativistic transport codes:  
use a nonlinear  $\sigma$ - $\omega$ - $\rho$  RMF parameterization “NL $\rho$ ” (see parameter set I in PRC65, 045201, by Liu B et al.)  
(Properties of this parameterization:  $K_0=240$  MeV,  $\rho_0=0.16$  fm<sup>-3</sup>,  $E_0=-16$  MeV,  $S(\rho_0)\sim 30.3$  MeV)
- Turn off the Coulomb interaction

### 3) Number of runs:

BUU-like: 100 test particles per nucleon, 10 runs  
MD: 200 runs

### 4) Output files :

**We need two output files, one is for the information of test particle which is generated from 1 run for BUU codes and 100 runs for MD codes (see case a) ), and another is a table of the density which are obtained from all 10 runs for BUU codes and 200 runs for MD codes (see case b) ).**

a) **(Test) particle files** (please name your file as “particle.\*”): 1 run for BUU codes and 100 runs for MD codes.

The following information should be given, for each (test) particle, **with a time step of  $\Delta t = 20$  fm/c: ID=0, charge (0 or 1), mass [GeV], (x,y,z) [fm], (px,py,pz) [GeV]** The variables “charge” and “ID” are *integer* variables, the others are *real*. (The variable ID, used previously to identify proj and target nucleons, is not needed in a box calculation. We keep it anyway, to have the structure of the files the same as before.)

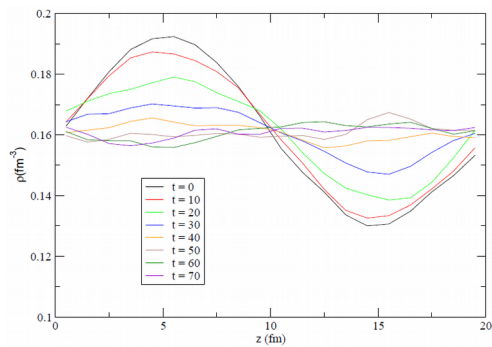
b) Please output **a table of the density** along z direction (averaged over all events and over the x-y plane). To do so, introduce a grid, of size dz, inside the box, we adopt  $dz = 1$  fm. The grid should be provided at each time step  $\Delta t=0.5$  or 1 fm/c.

(please name your file as “density.\*”)

From such a detailed output, it will be possible to perform a Fourier analysis of the density oscillations, in space and in time.

c) Figures:

If possible, please also generate the figures representing the density, averaged in the whole x-y plane, and averaged over all the events, as a function of z at the different time instants, in order to avoid misunderstandings, from our side, when analyzing your output files. Following is an example.



## 5) Reading program and uploading

a) Please provide a simple Fortran program to read your files, and check that this program indeed works. This sounds simple, but in Trento we had considerable difficulties. This may be caused by trivial things like a blank line between runs or a line with the time or impact parameter.

b) Compress your files using “gzip” or “bzip2”, otherwise we will have again problems to uncompress your files. The files will be very large!

d) We are very appreciated if you can finish the simulations **by Sep. 30, 2016**.

Many thanks for your efforts,  
and many greetings,

**the Box Simulation Organizing Committee**

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