# Simulation of 3d granular dissipative gas under different kinds of excitations & with different number of balls N

## Result 3: $V_z$ bin as a function of z, for different e= 0.7 to 0.9 and bi-parabolic excitation,

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**Abstract:**
*This group of papers publishes a series of simulations on the dynamics of N equal-size spheres* (D=1) *in a* 3d *rectangular cell* ($L_x$=20D, $L_y$=20D, $L_z$=60D) *excited along z in 0 gravity.*(N=100, 500, 1000, 1200, 2000, 3000, 4000, 4500). *Different Oz excitation kinds have been used (symmetric and non symmetric bi-parabolic, symmetric and non symmetric saw teeth, thermal wall). No rotation is included, dissipation is introduced via a restitution coefficient* $e= -V'_n/V_n$ *, where* $V'_n$ *and* $V_n$ *are the relative ball speed along normal to ball centres after and before collision.*

**Pacs # : 5.40 ; 45.70 ; 62.20 ; 83.70.Fn**

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Recently, much work has been done to simulate dissipative granular gas in 0g [1] which looks coherent with classic continuous theoretical approach [2]. However, experimental results obtained with rocket experiment (Mini-Texus 5, Maxus 5, Maxus 7) or Airbus A300-0G (Novespace) as well as satellite SJ-8 have found [3] some disagreement with these classical publications and understanding [4, 5]. Few other results [6,7] contradict the common statement [1,2] and/or is in agreement with our simulations [7].

The goal of theses simulations is to demonstrate that behaviour of granular dissipative gas is more complex (i) than what can think at first sight, (ii) that the role of boundary collisions can be observed directly on the ball dynamics and (iii) that the system can not be understood as a system controlled by a single temperature at a given positions.

## Figure symbols and abbreviations:

| | |
|---|---|
| e0.9: coefficient of restitution $e$ = 0:9 | N***: number of particles $N$ = *** |
| BP: bi-parabolic driving | ST: saw-tooth driving |
| Sym: symmetrical driving | Nsym: Non-symmetrical driving |

Protocol is given in appendix. Data are reported for a given physical quantity (n(z), pdf,…) as a function of the ball number in the cell and for a given restitution coefficient e and a given wall driving. Then e is varied. Then driving is varied. The data are divided in papers, which are divided into driving cases label A , B and subdivided into sections corresponding to different e (0.7,0.8, 0.9).

## 1) Non-symmetric bi-parabolic excitation

### *1.1) with e= 0.7*

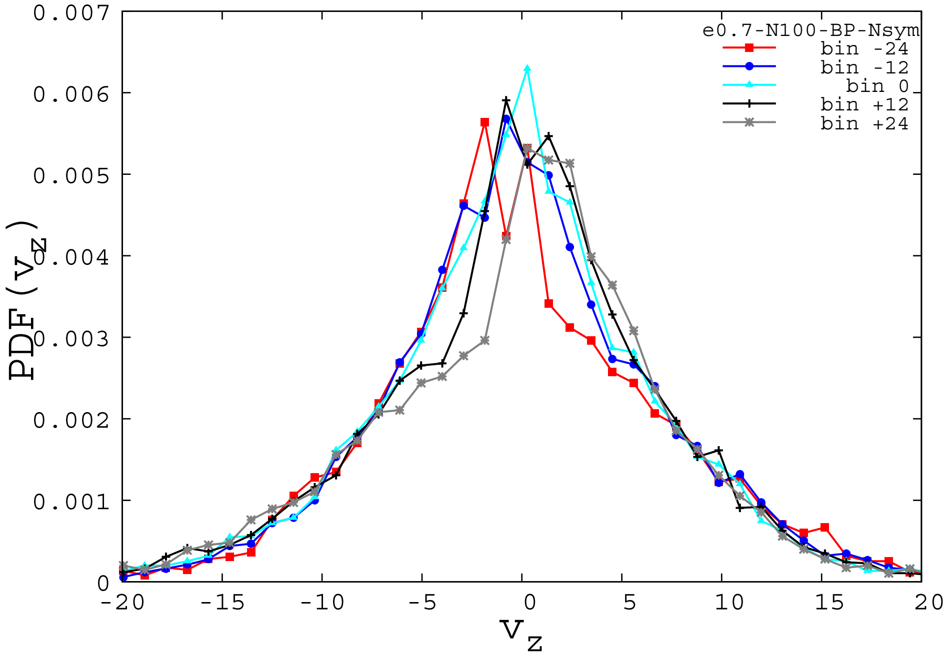



***Figure 1.1 - 1: Simulations of granular gas is 3d rectangular cell***

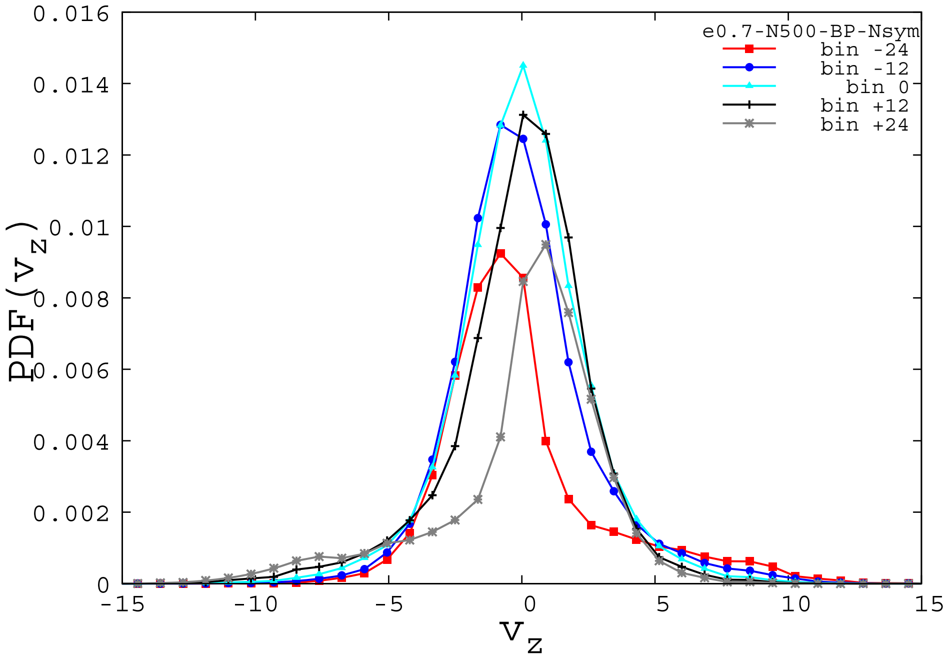



***Figure 1.1 - 2: Simulations of granular gas is 3d rectangular cell***

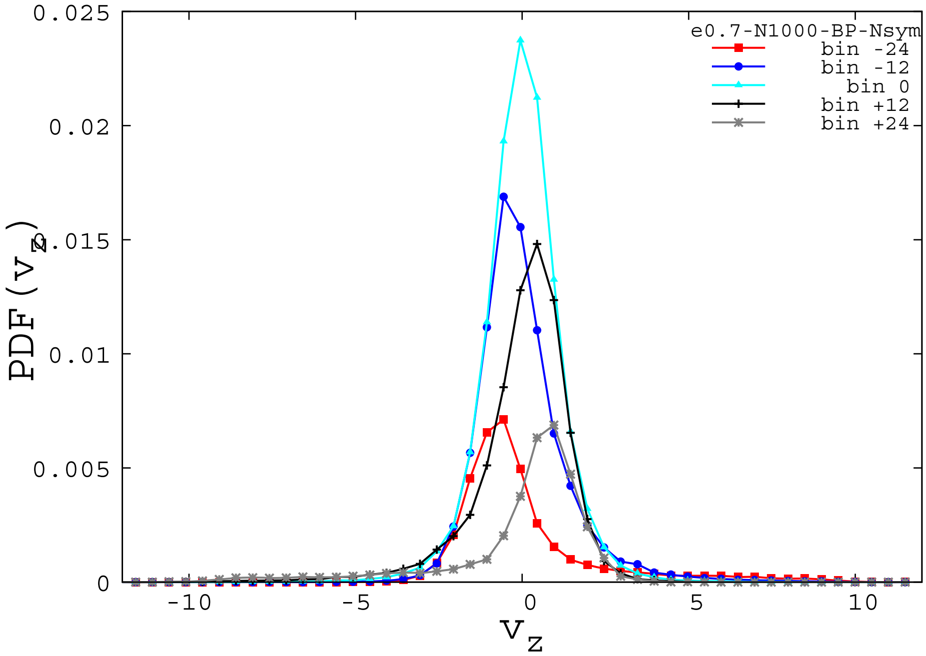



*Figure 1.1 - 3: Simulations of granular gas is 3d rectangular cell*

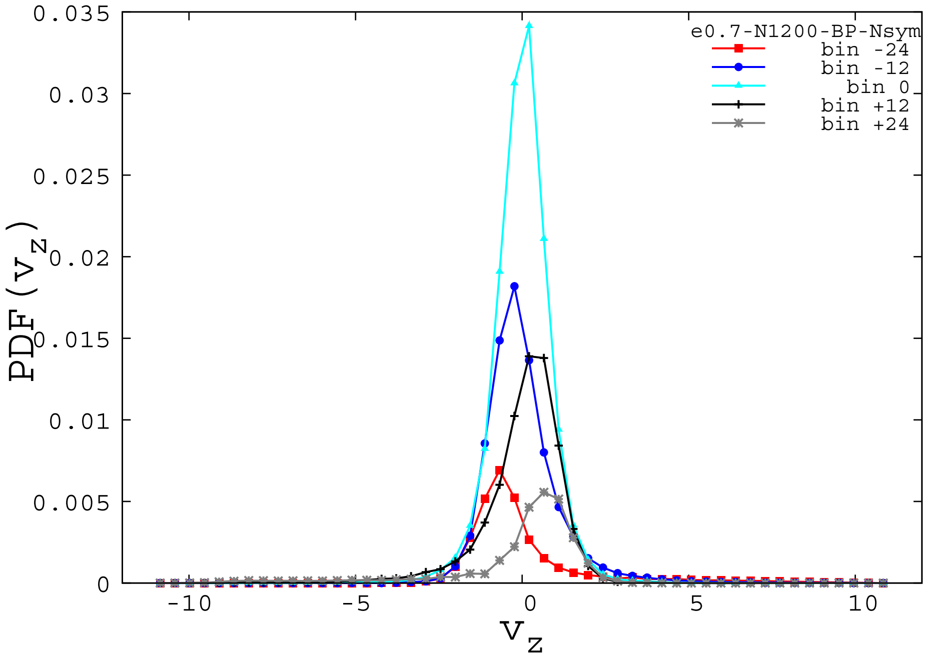



*Figure 1.1 - 4: Simulations of granular gas is 3d rectangular cell*

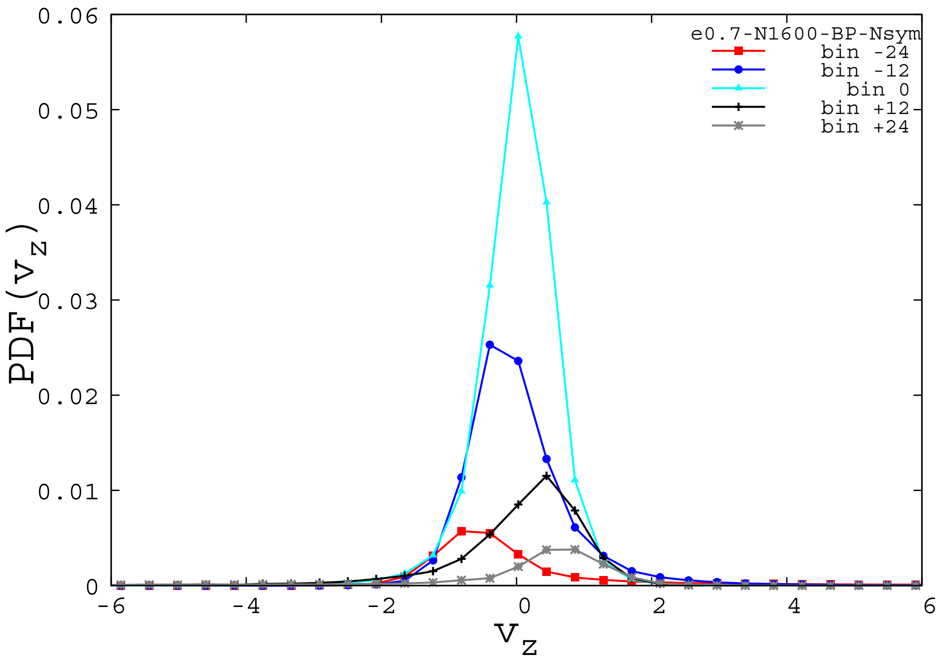



***Figure 1.1 - 5: Simulations of granular gas is 3d rectangular cell***

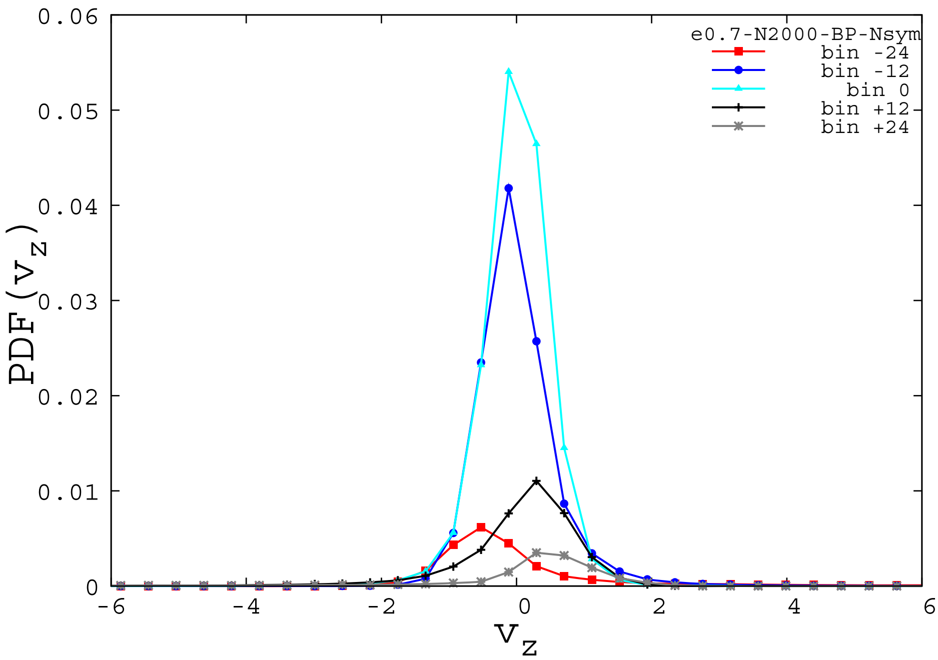



***Figure 1.1 - 6: Simulations of granular gas is 3d rectangular cell***

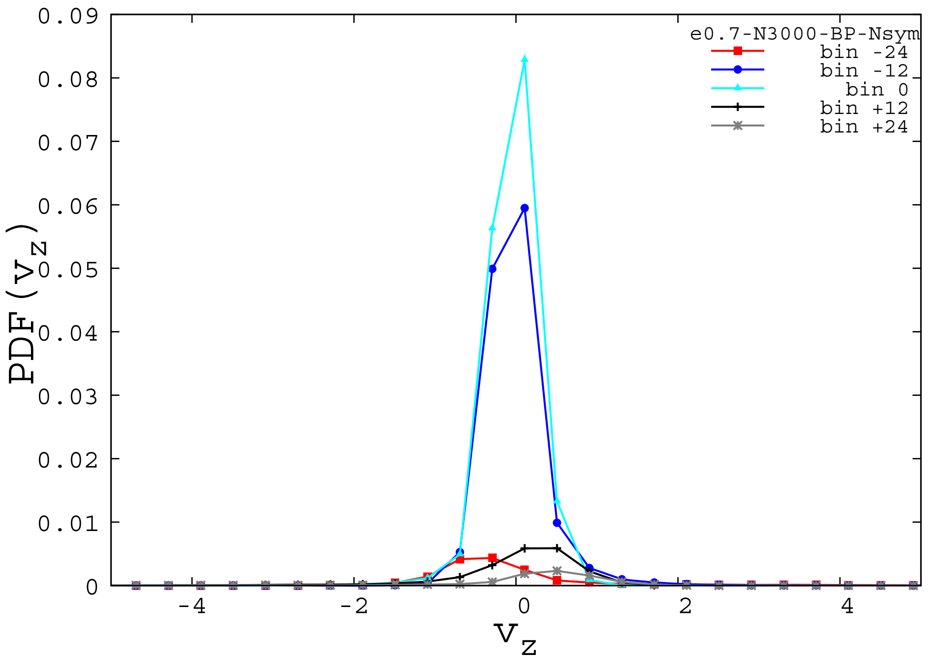



*Figure 1.1 - 7: Simulations of granular gas is 3d rectangular cell*

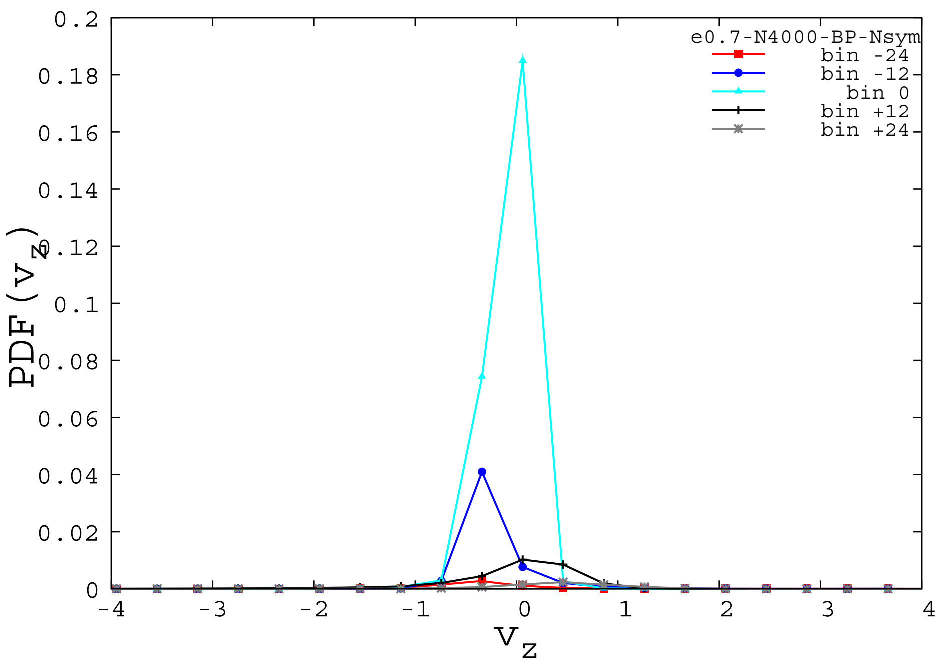



*Figure 1.1 - 8: Simulations of granular gas is 3d rectangular cell*

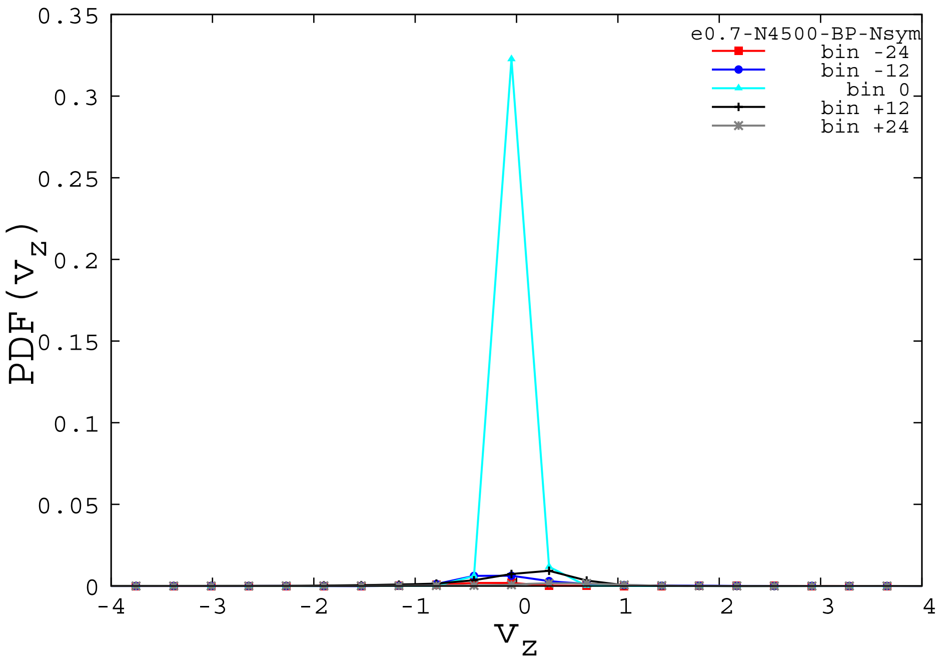



***Figure 1.1 - 9: Simulations of granular gas is 3d rectangular cell***

## *1.2) with e= 0.8*

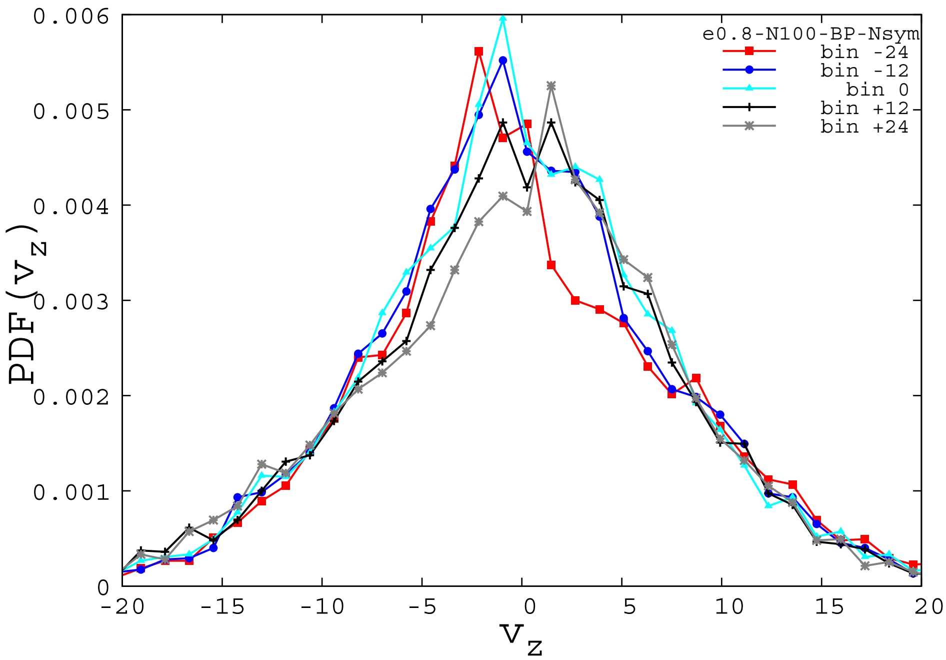



***Figure 1.2 - 1: Simulations of granular gas is 3d rectangular cell***

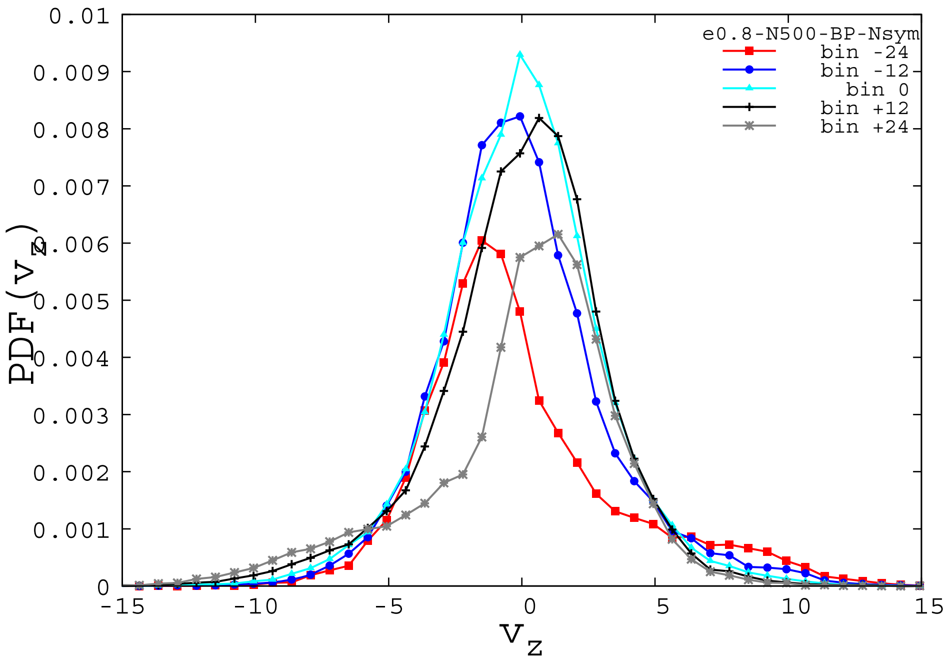



***Figure 1.2 - 2: Simulations of granular gas is 3d rectangular cell***

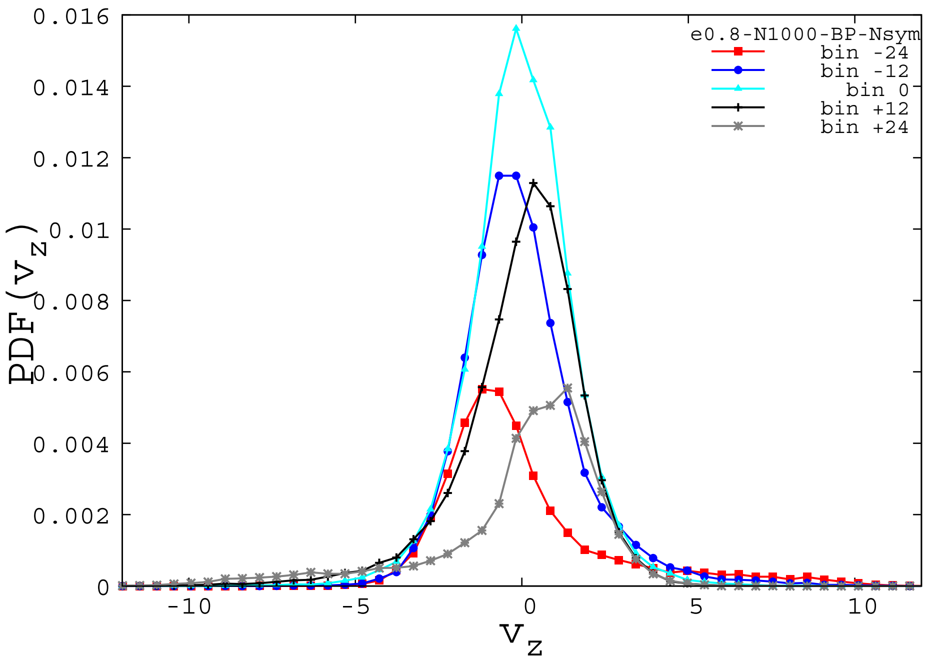



***Figure 1.2 - 3: Simulations of granular gas is 3d rectangular cell***

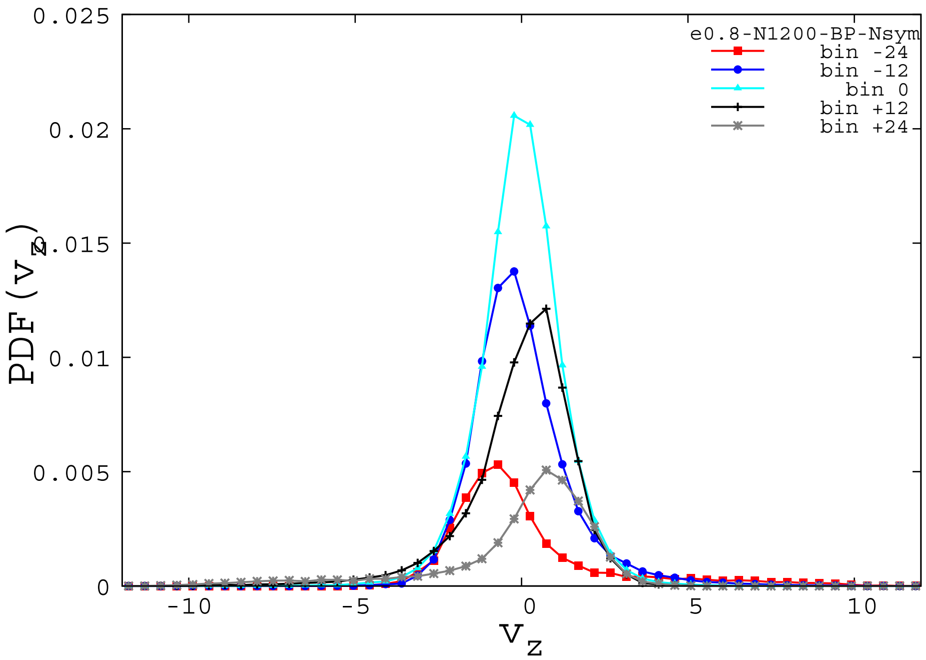



***Figure 1.2 - 4: Simulations of granular gas is 3d rectangular cell***

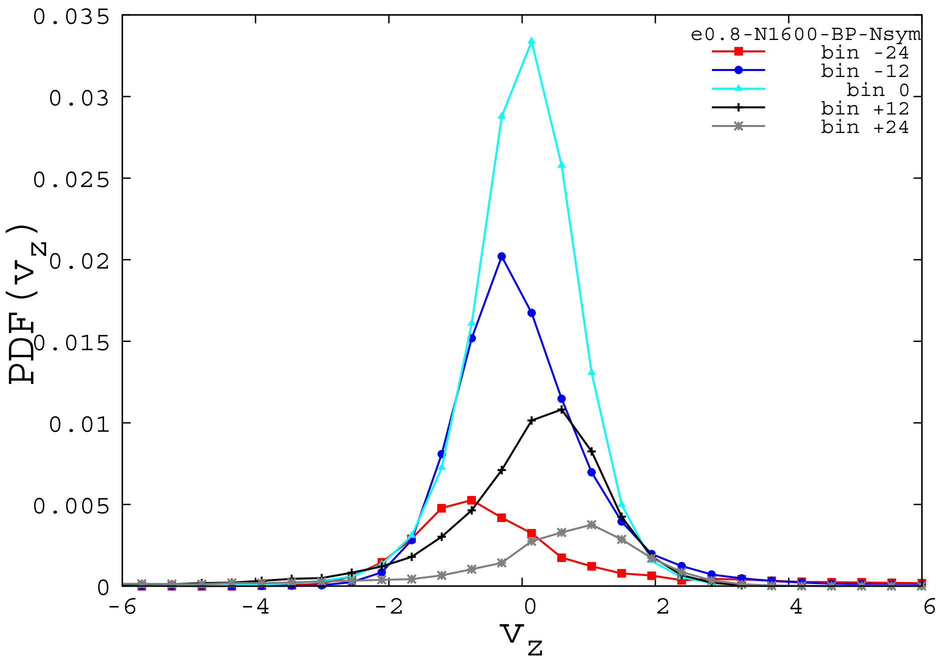



***Figure 1.2 - 5: Simulations of granular gas is 3d rectangular cell***

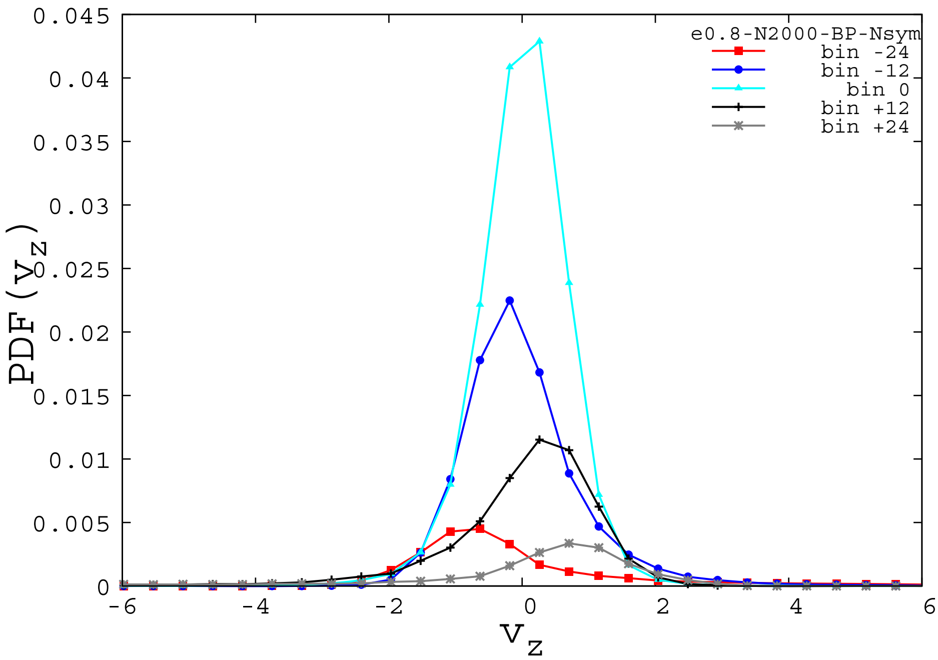



***Figure 1.2 - 6: Simulations of granular gas is 3d rectangular cell***

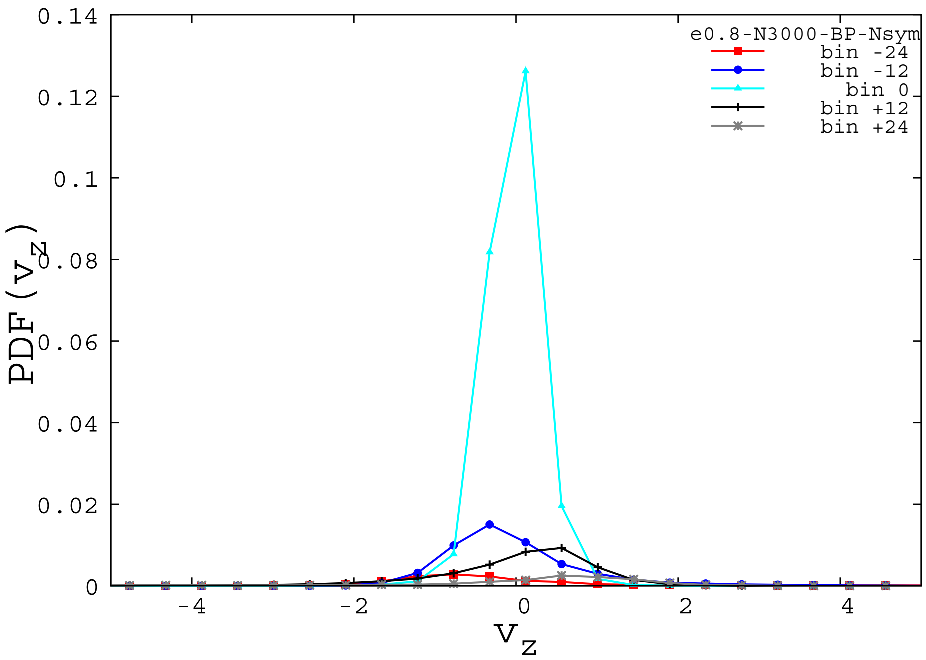



***Figure 1.2 - 7: Simulations of granular gas is 3d rectangular cell***

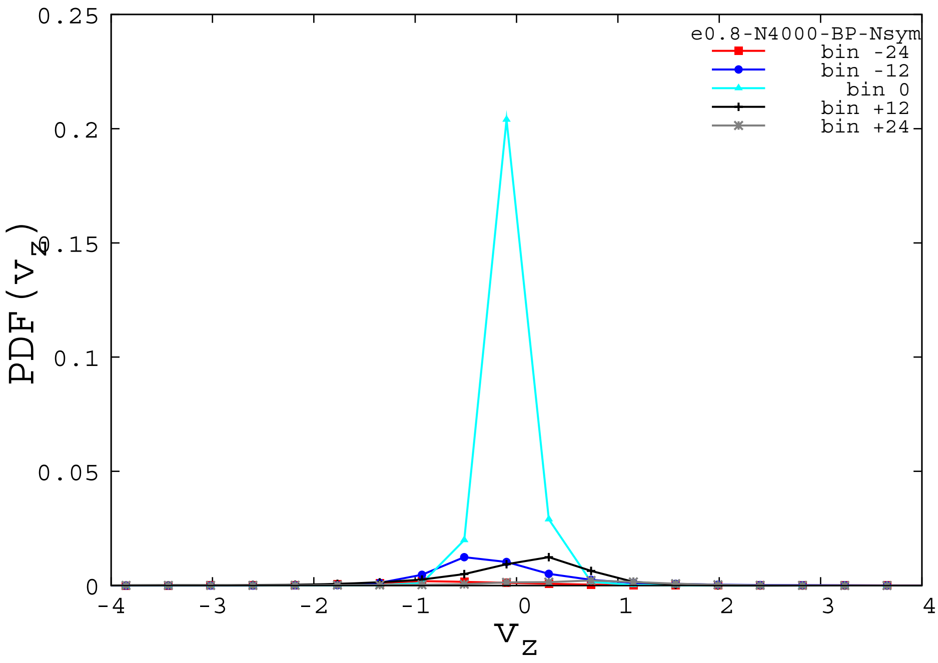



***Figure 1.2 - 8: Simulations of granular gas is 3d rectangular cell***

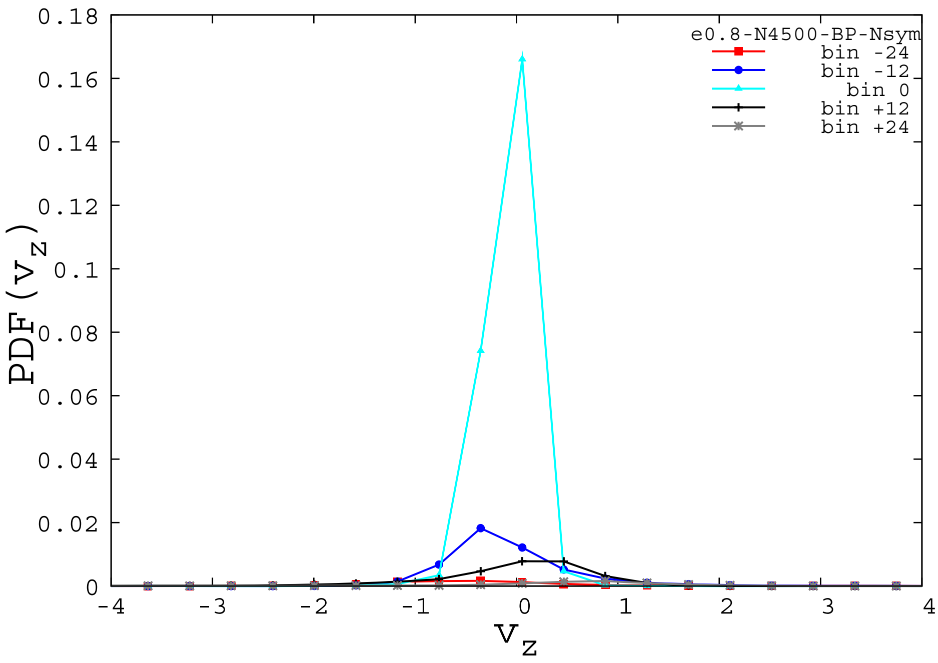



***Figure 1.2 - 9: Simulations of granular gas is 3d rectangular cell***

## 1.3) with e= 0.9

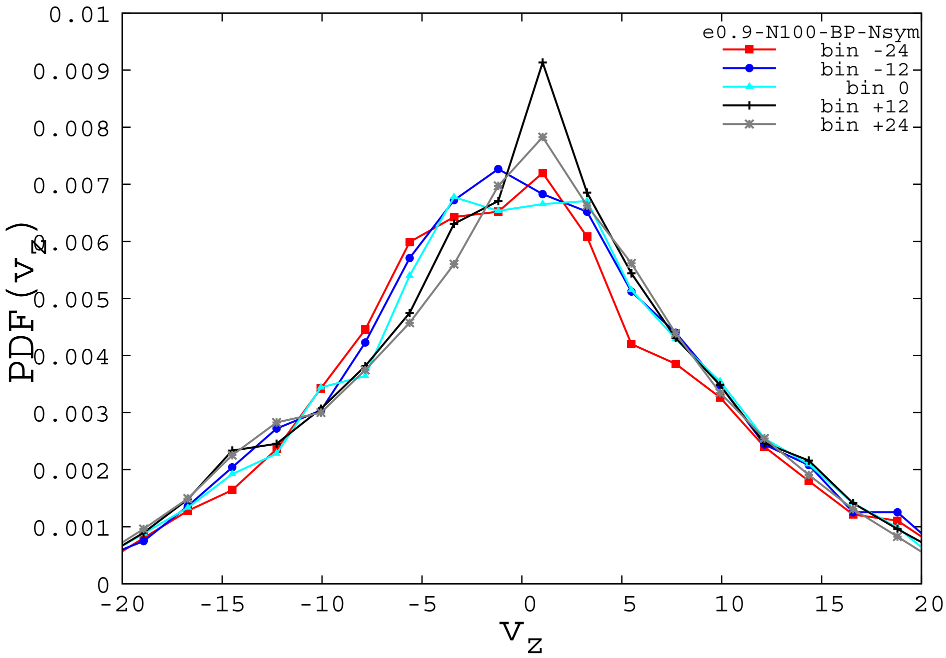



**Figure 1.3 - 1: Simulations of granular gas is 3d rectangular cell**

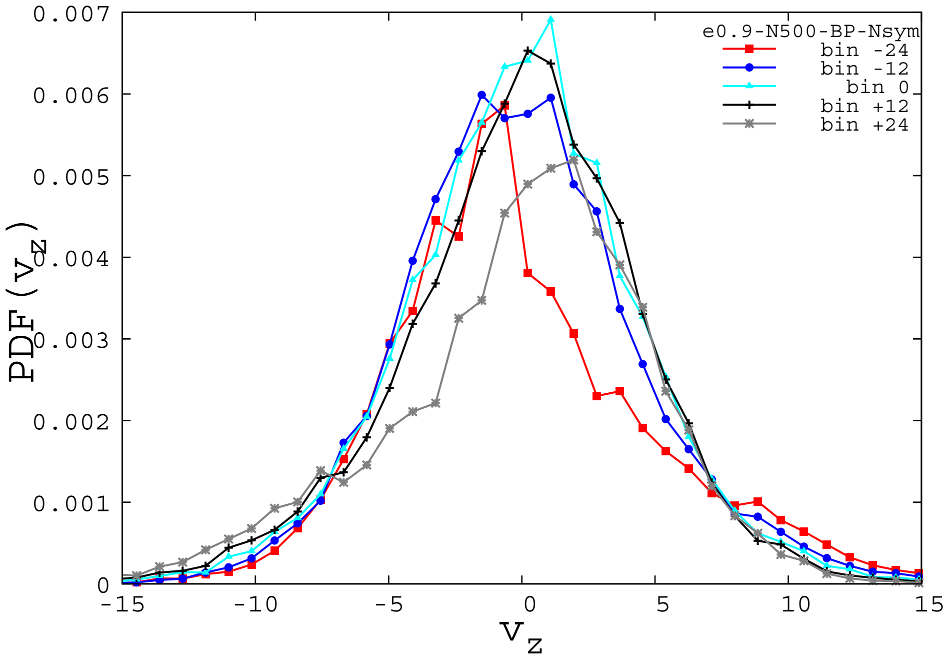



**Figure 1.3 - 2: Simulations of granular gas is 3d rectangular cell**

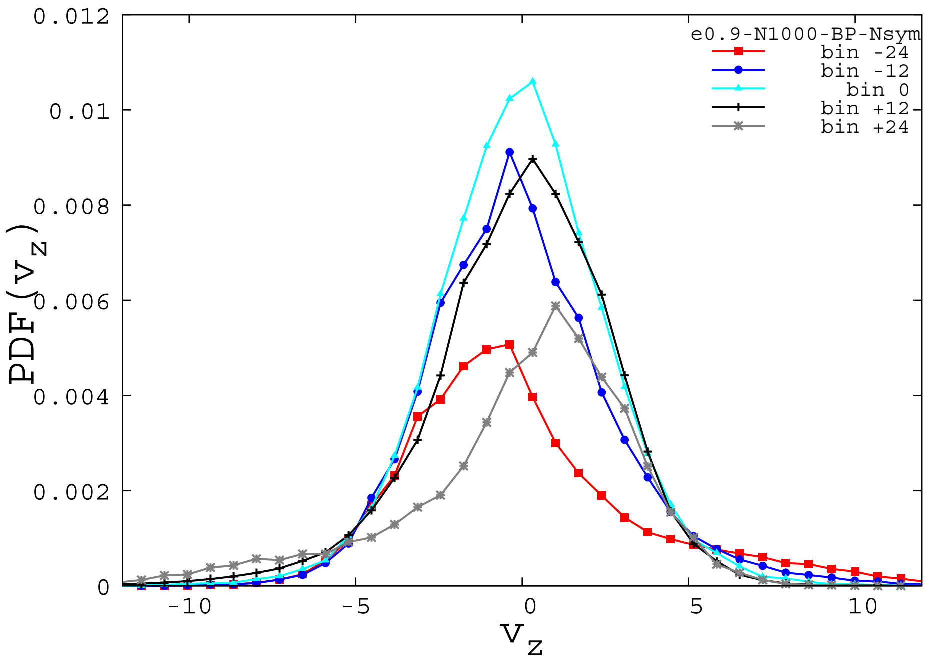



*Figure 1.3 - 3: Simulations of granular gas is 3d rectangular cell*

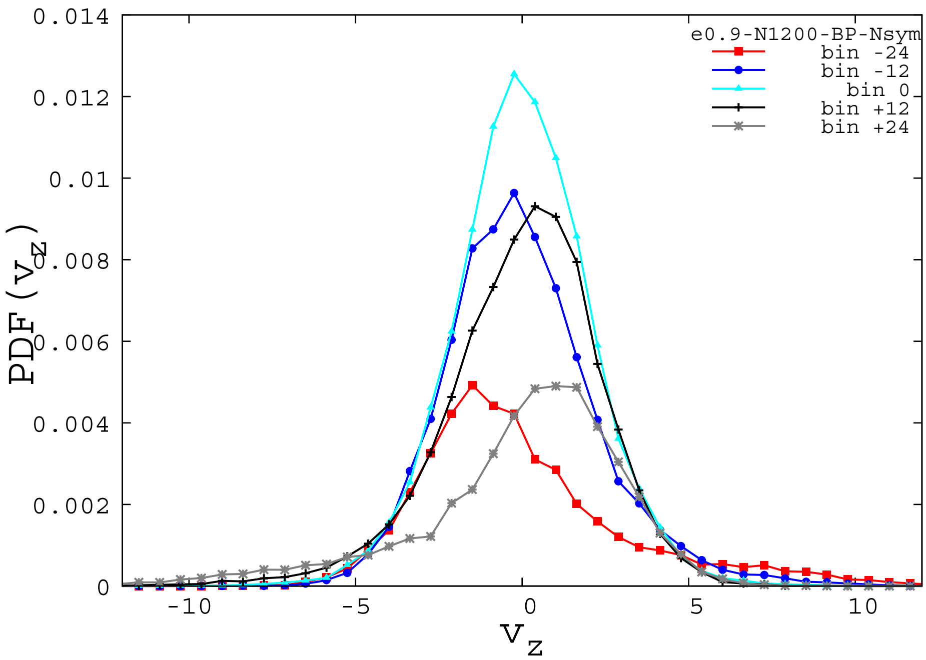



*Figure 1.3 - 4: Simulations of granular gas is 3d rectangular cell*

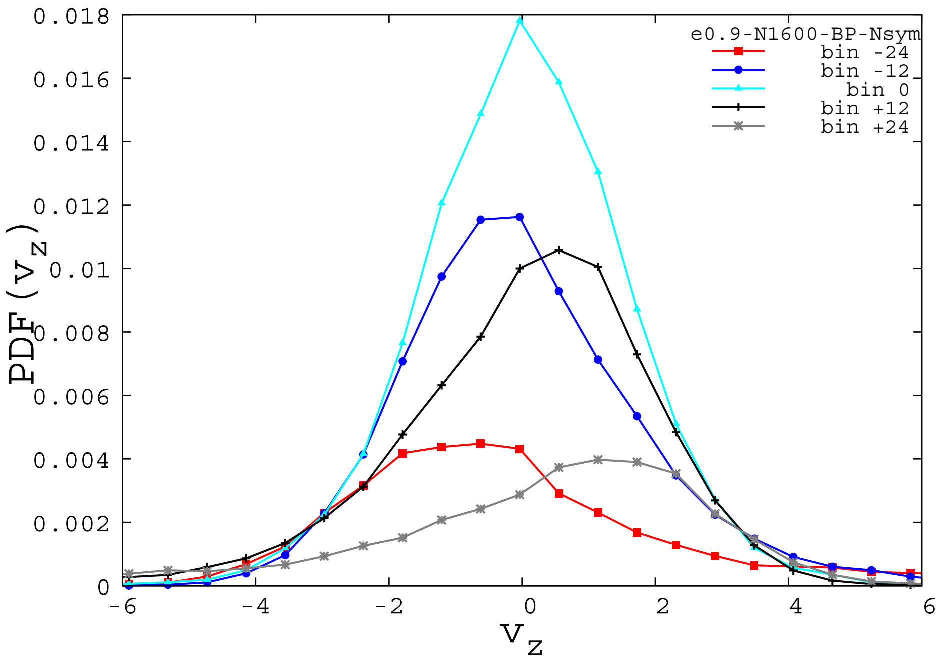



**Figure 1.3 - 5: Simulations of granular gas is 3d rectangular cell**

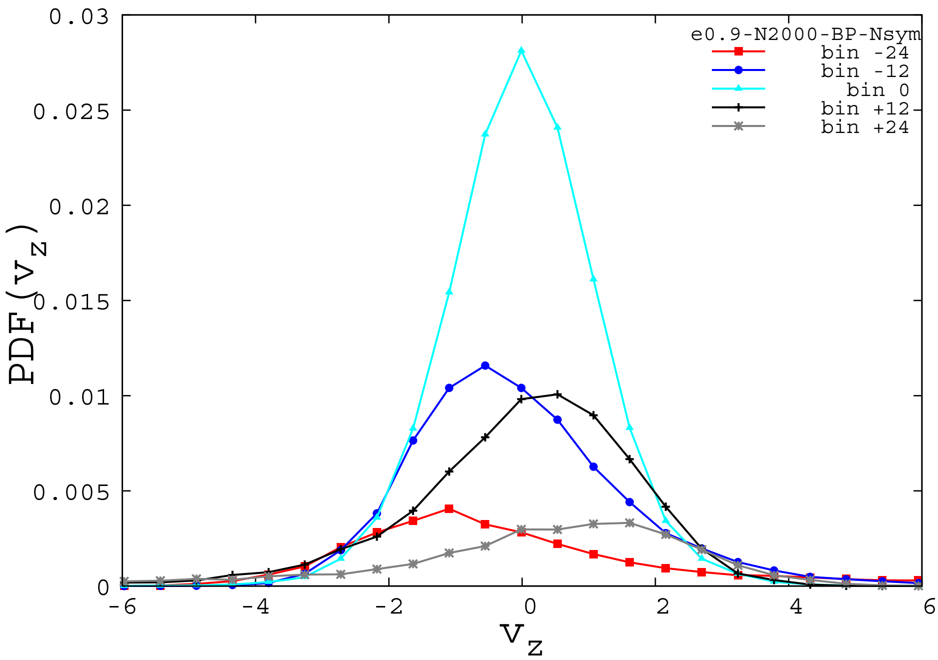



**Figure 1.3 - 6: Simulations of granular gas is 3d rectangular cell**

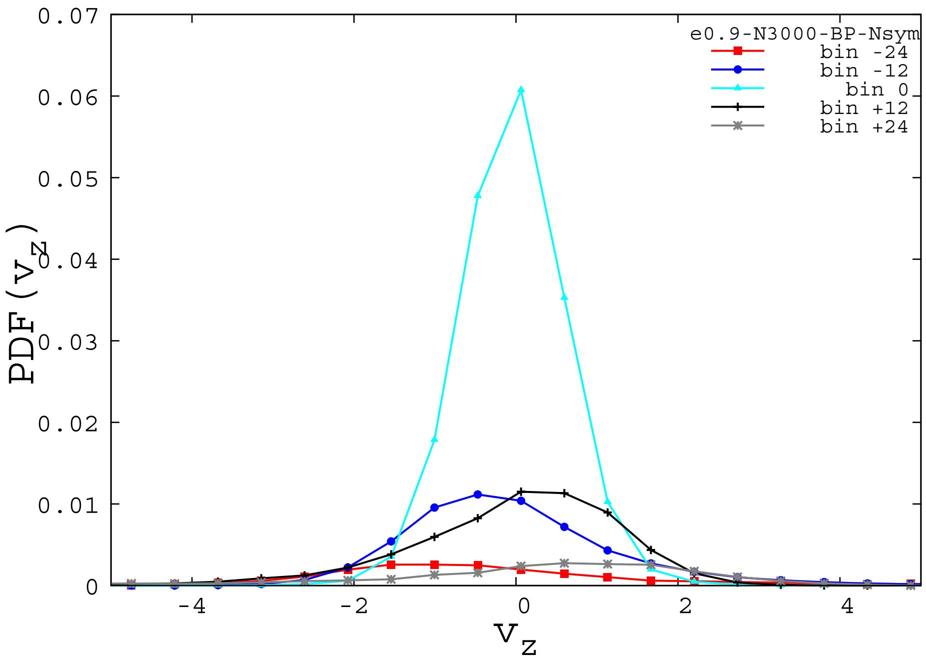



*Figure 1.3 - 7: Simulations of granular gas is 3d rectangular cell*

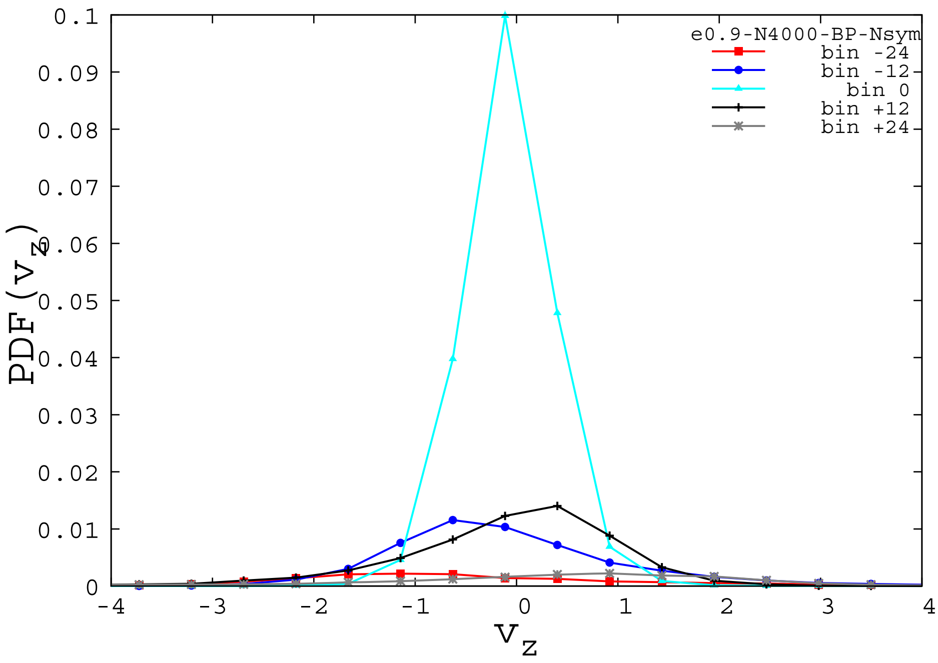



*Figure 1.3 - 8: Simulations of granular gas is 3d rectangular cell*

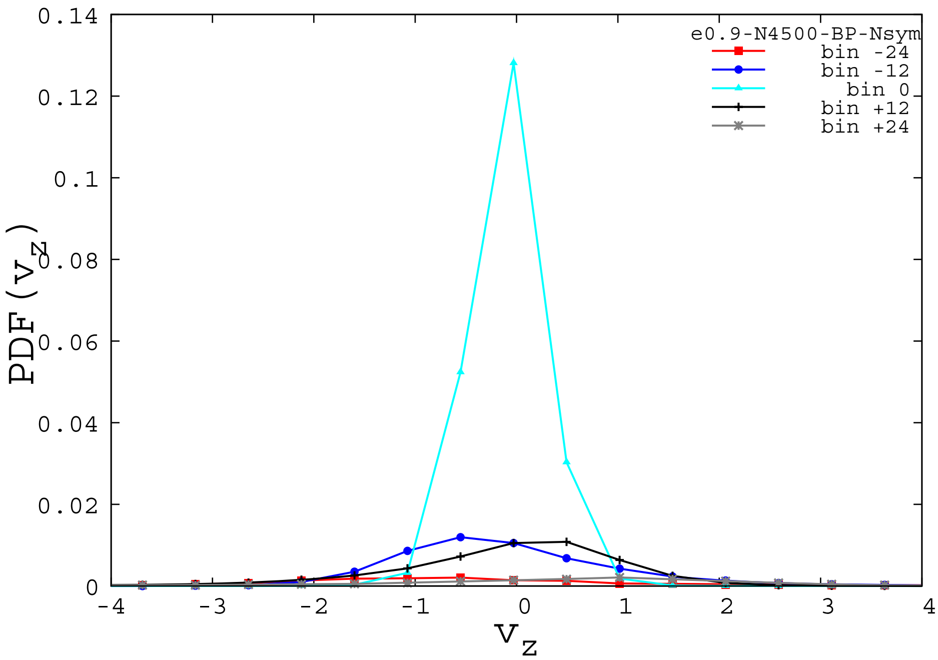



***Figure 1.3 - 9: Simulations of granular gas is 3d rectangular cell***

## 2) Symmetric bi-parabolic excitation

### *2.1) with e= 0.7*

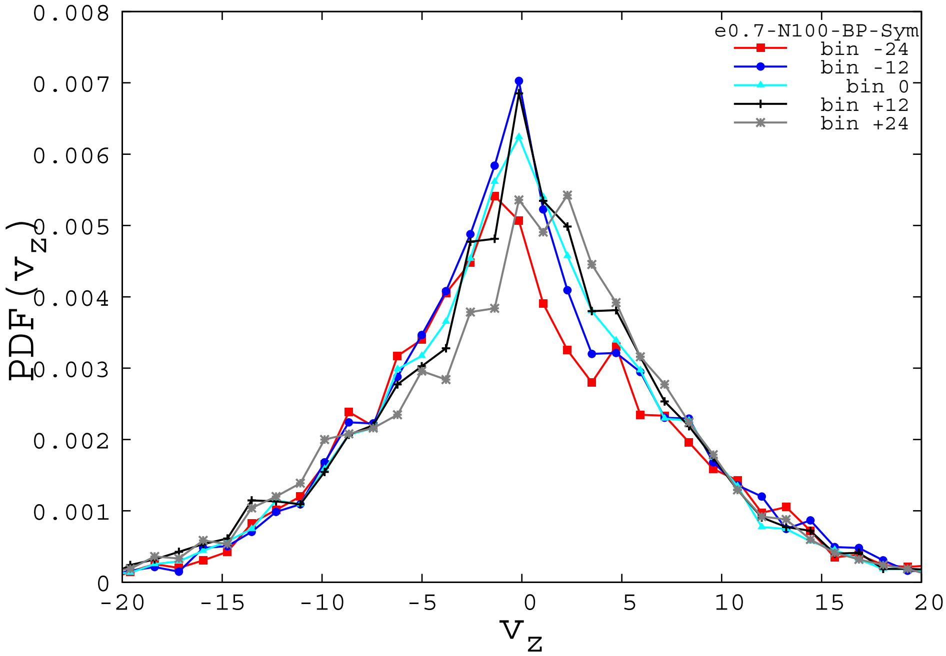



***Figure 2.1 - 1: Simulations of granular gas is 3d rectangular cell***

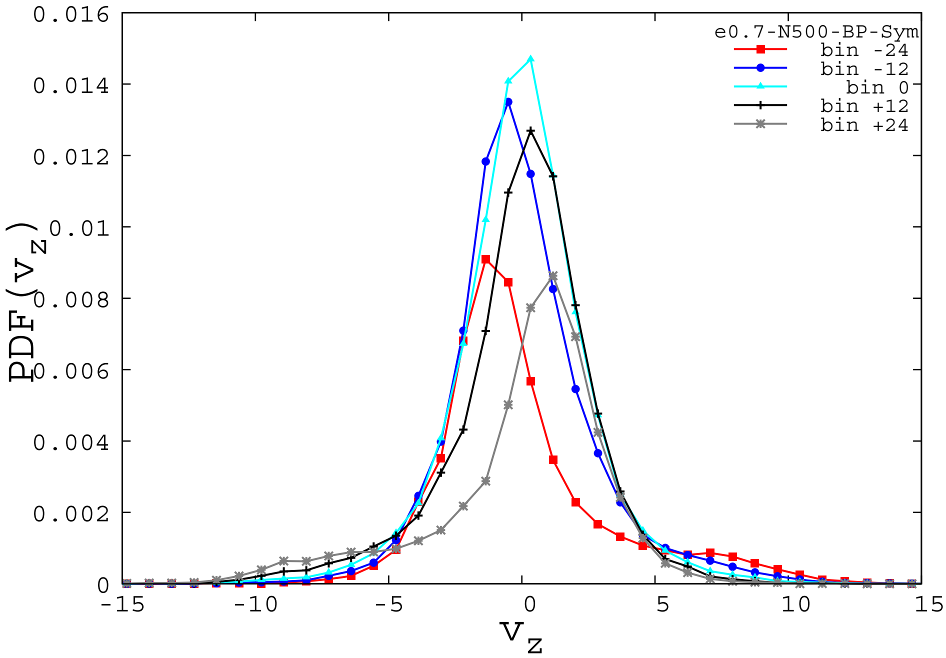



***Figure 2.1 - 2: Simulations of granular gas is 3d rectangular cell***

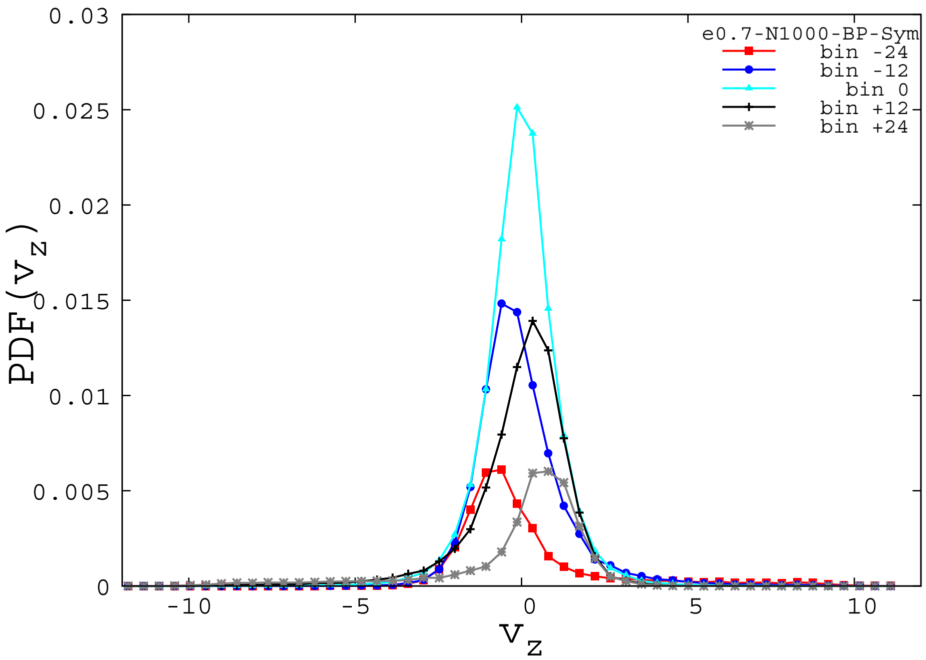



*Figure 2.1 - 3: Simulations of granular gas is 3d rectangular cell*

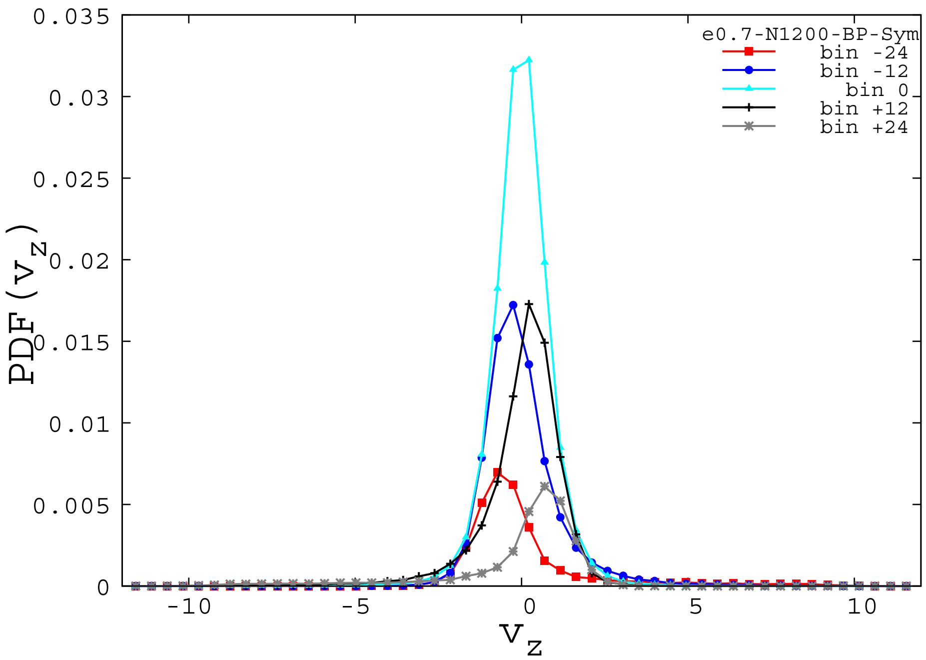



*Figure 2.1 - 4: Simulations of granular gas is 3d rectangular cell*

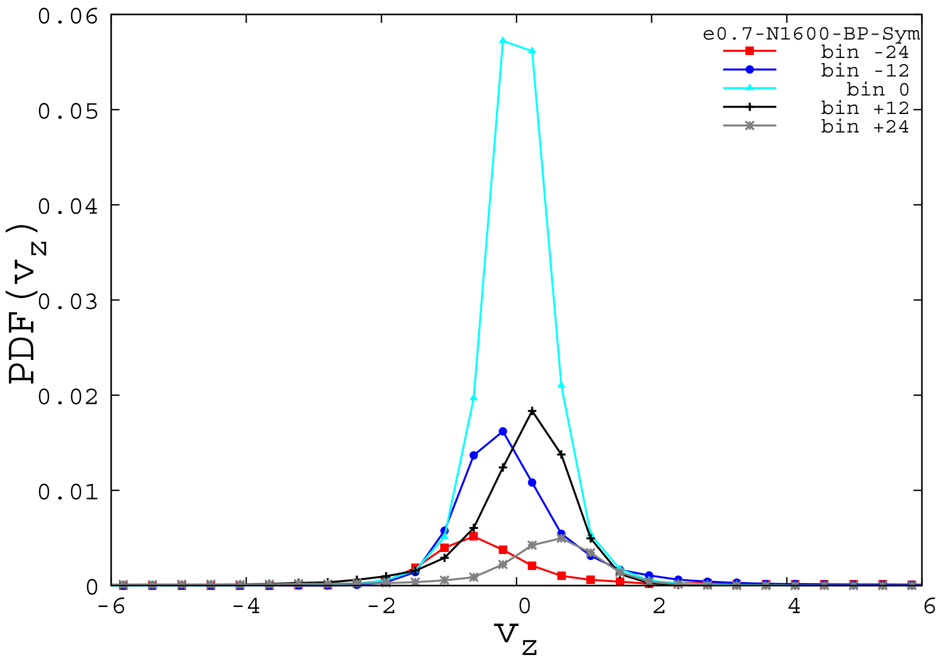



***Figure 2.1 - 5: Simulations of granular gas is 3d rectangular cell***

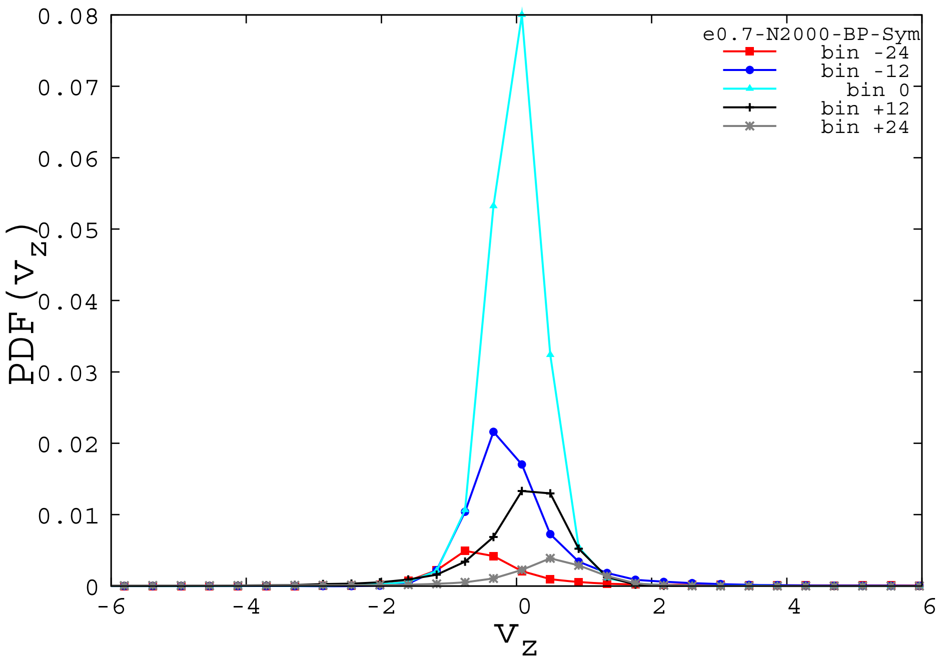



***Figure 2.1 - 6: Simulations of granular gas is 3d rectangular cell***

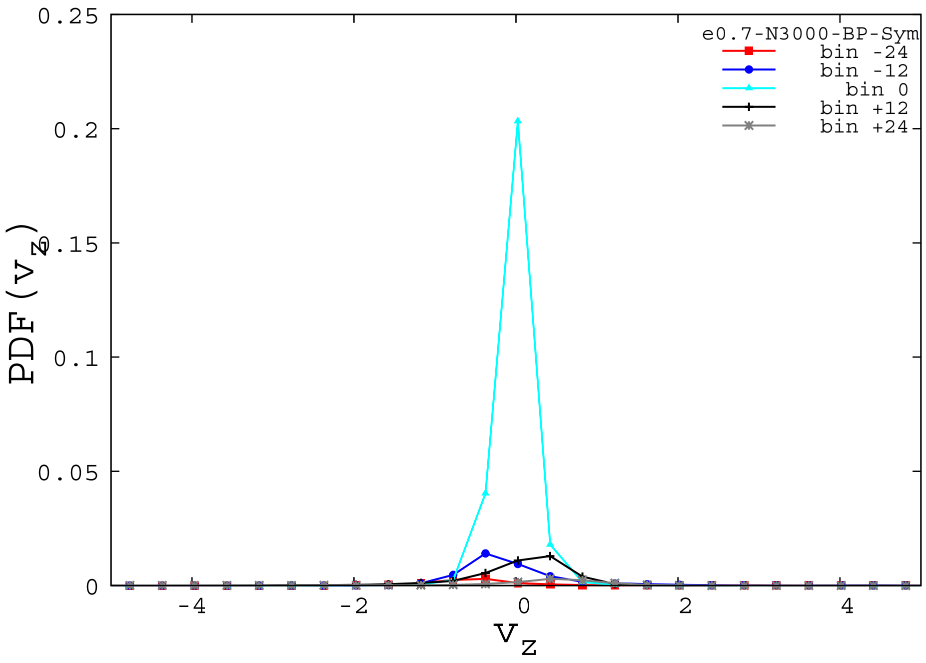



**Figure 2.1 - 7: Simulations of granular gas is 3d rectangular cell**

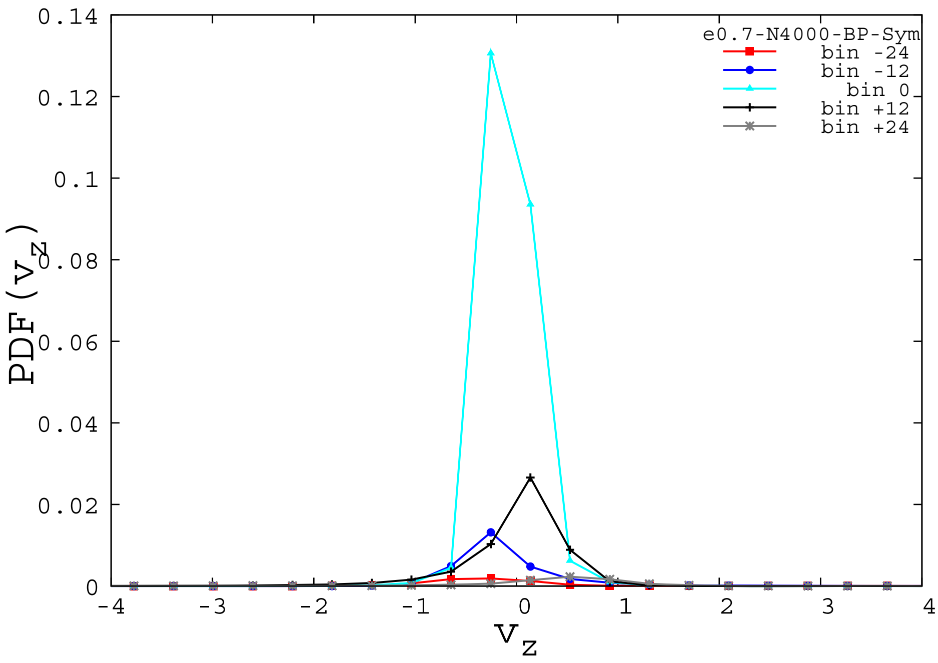



**Figure 2.1 - 8: Simulations of granular gas is 3d rectangular cell**

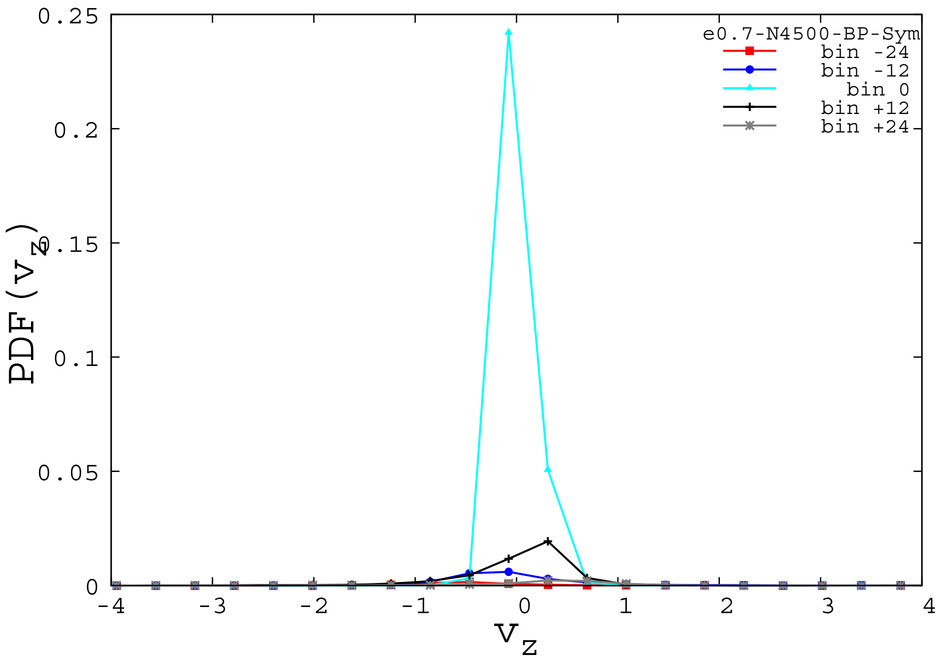



***Figure 2.1 - 9: Simulations of granular gas is 3d rectangular cell***

## *2.2) with e= 0.8*

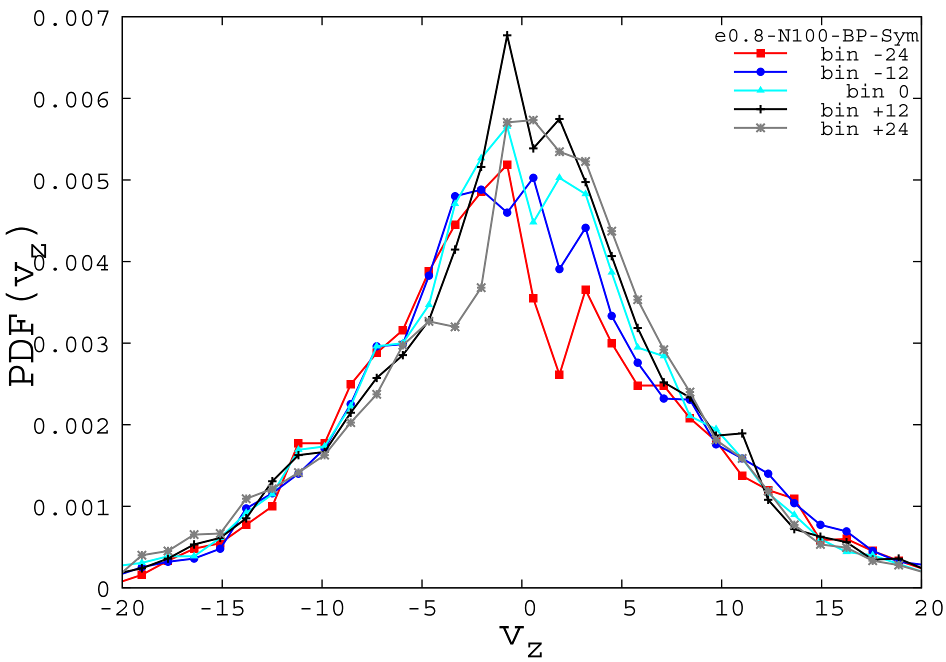



***Figure 2.2 - 1: Simulations of granular gas is 3d rectangular cell***

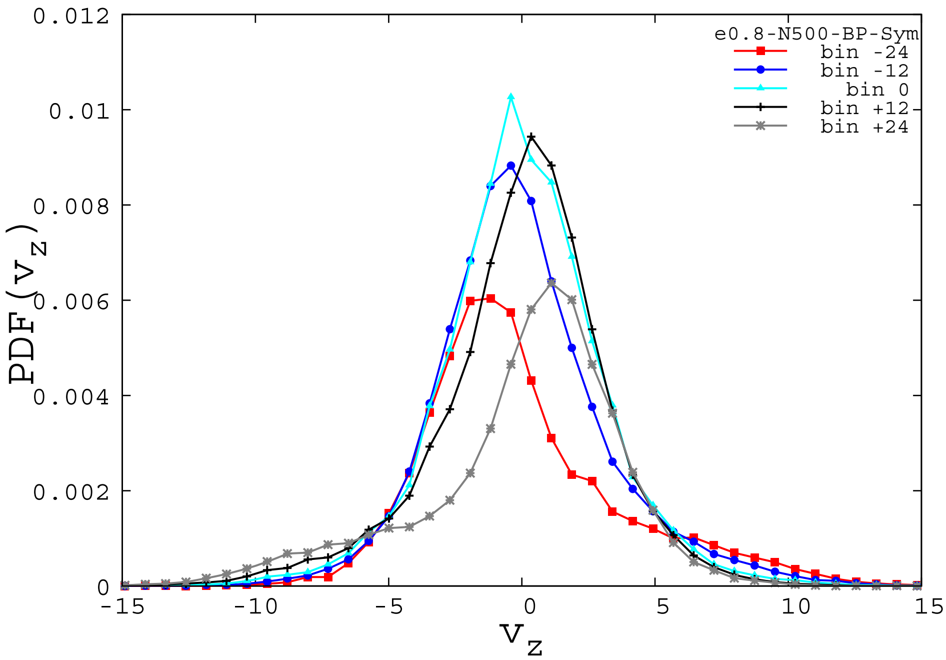



***Figure 2.2 - 2: Simulations of granular gas is 3d rectangular cell***

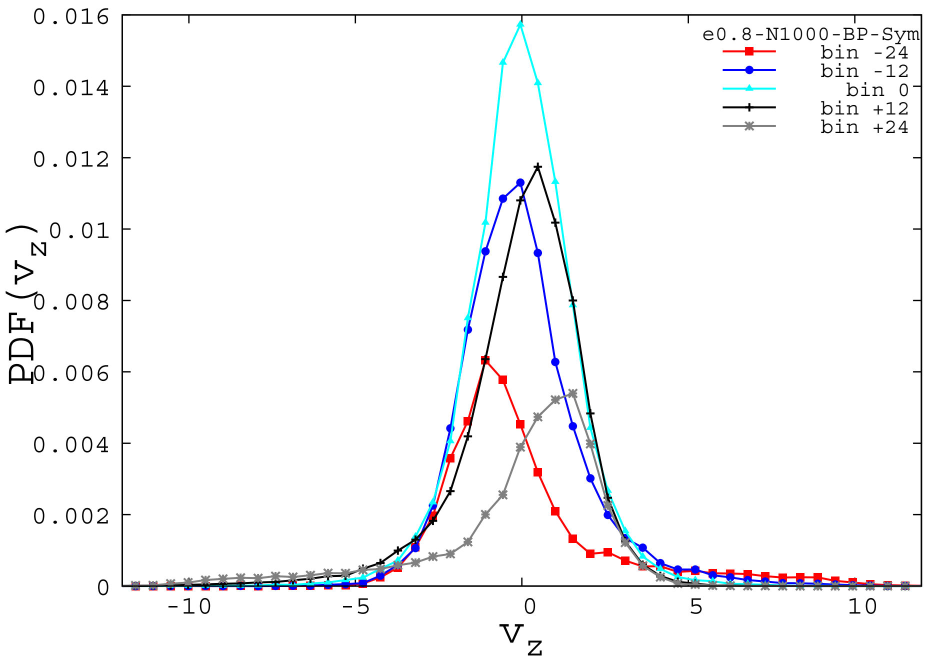



***Figure 2.2 - 3: Simulations of granular gas is 3d rectangular cell***

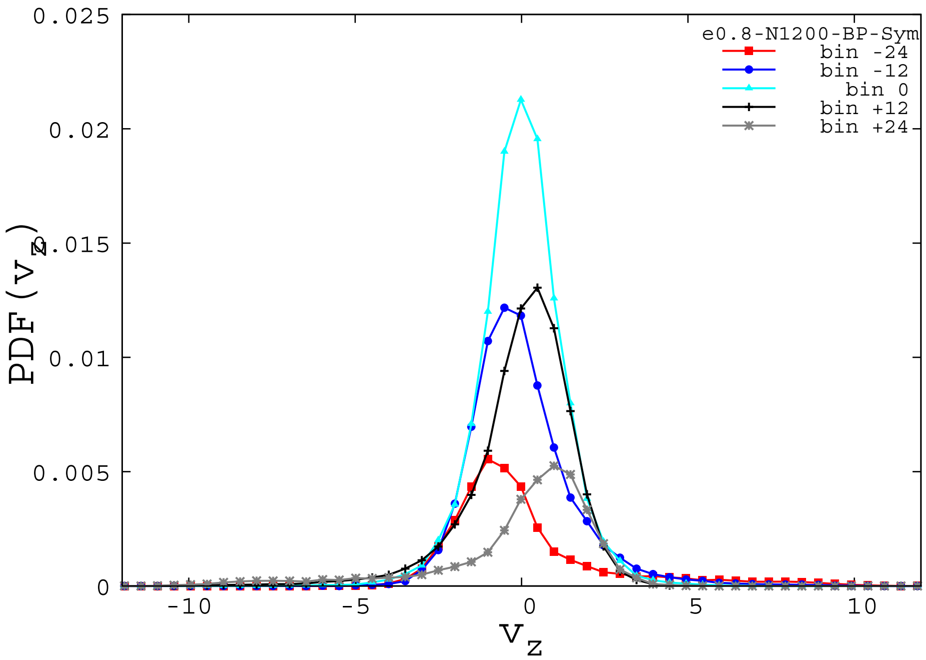



***Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell***

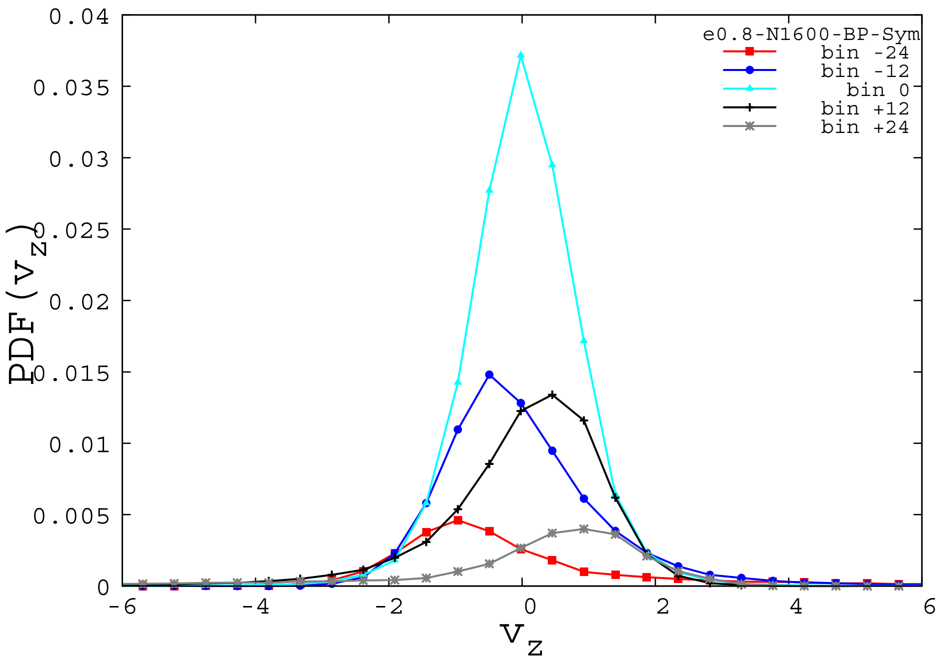
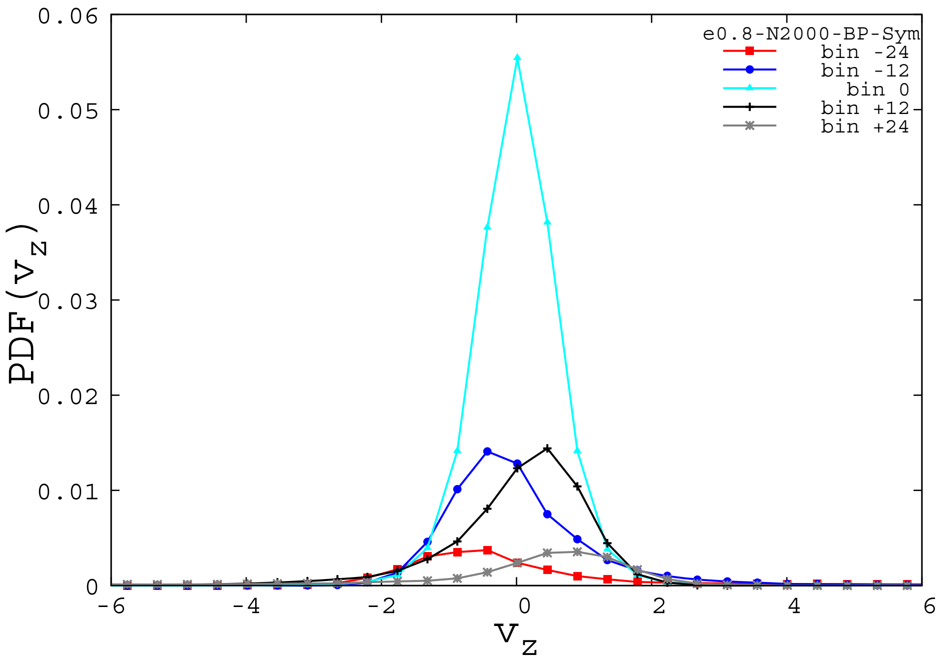



***Figure 2.2 - 5: Simulations of granular gas is 3d rectangular cell***

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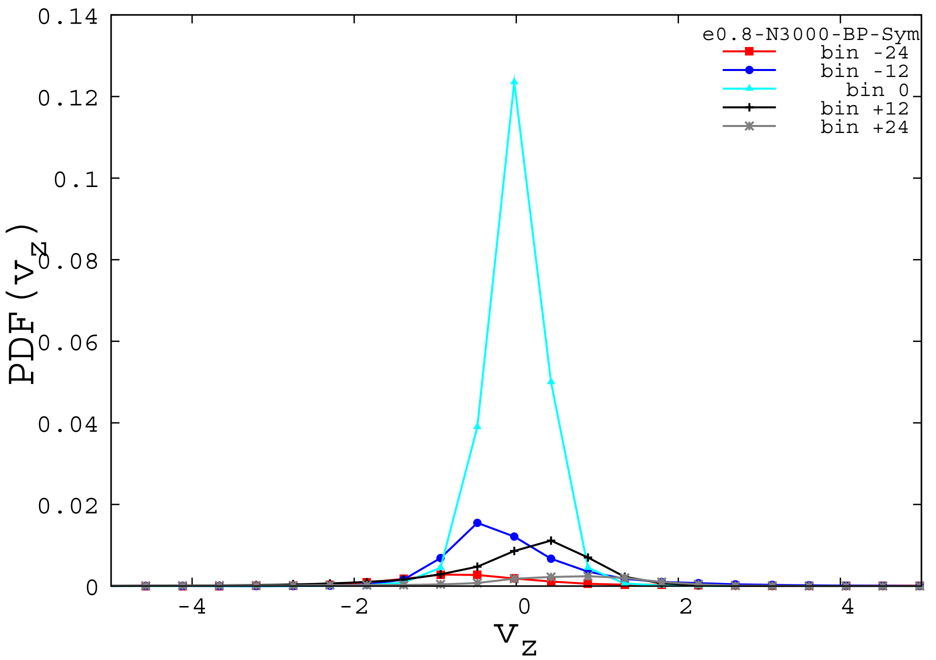



***Figure 2.2 - 7: Simulations of granular gas is 3d rectangular cell***

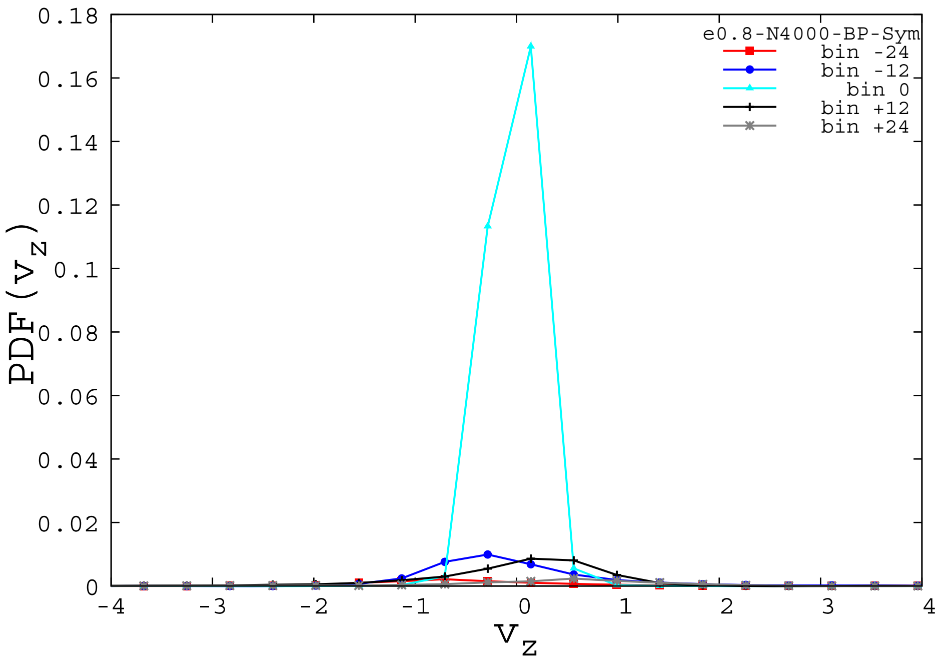



***Figure 2.2 - 8: Simulations of granular gas is 3d rectangular cell***

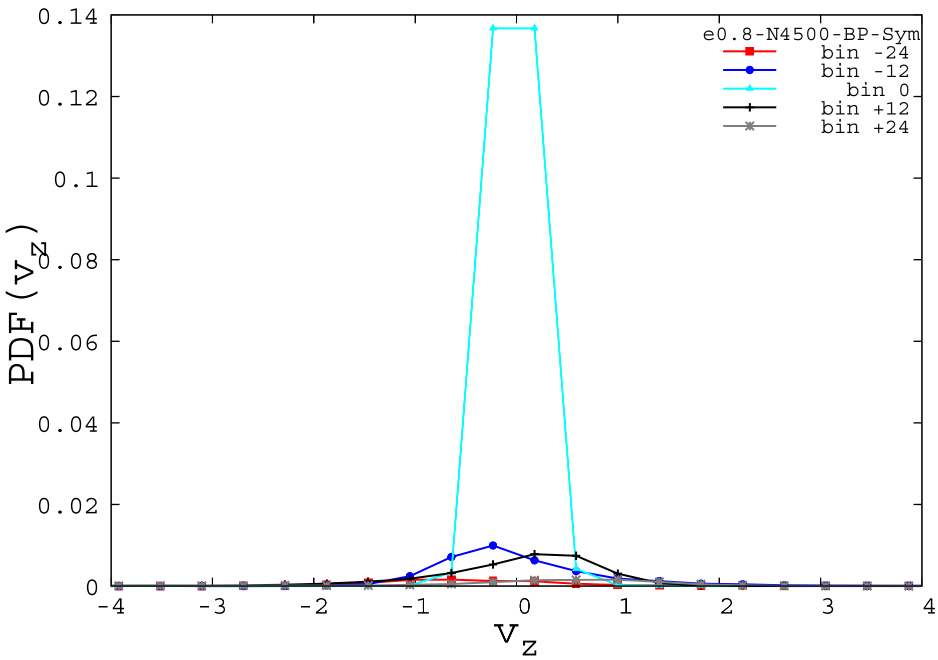



***Figure 2.2 - 9: Simulations of granular gas is 3d rectangular cell***

## *2.3) with e= 0.9*

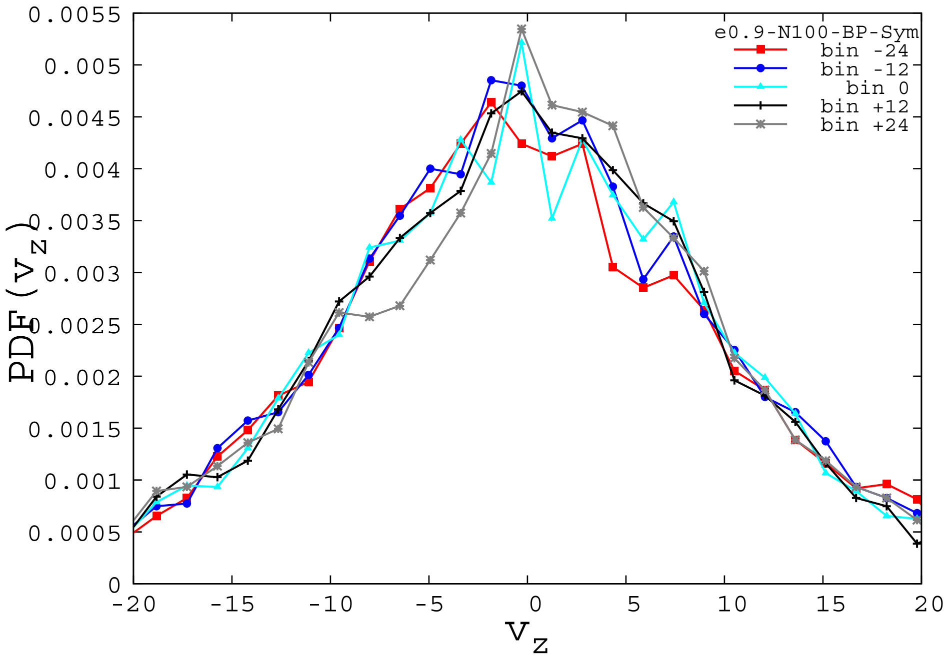



***Figure 2.3 - 1: Simulations of granular gas is 3d rectangular cell***

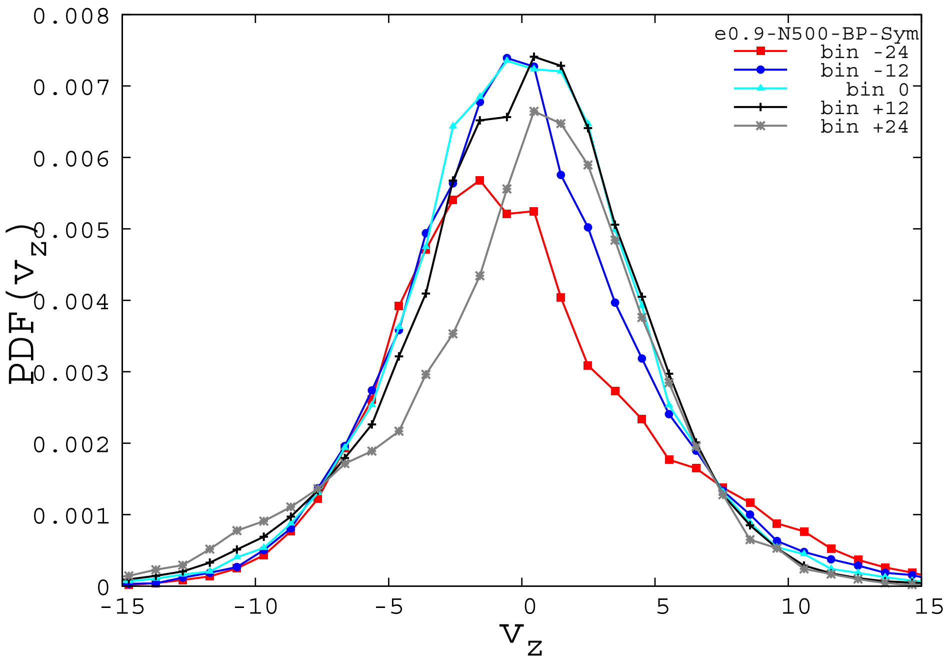



***Figure 2.3 - 2: Simulations of granular gas is 3d rectangular cell***

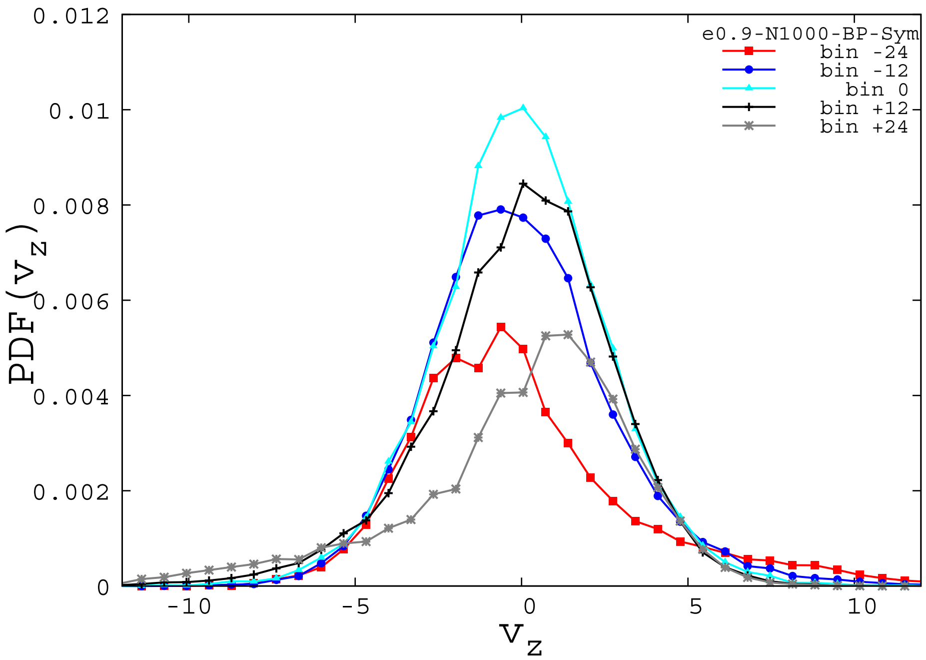



*Figure 2.3 - 3: Simulations of granular gas is 3d rectangular cell*

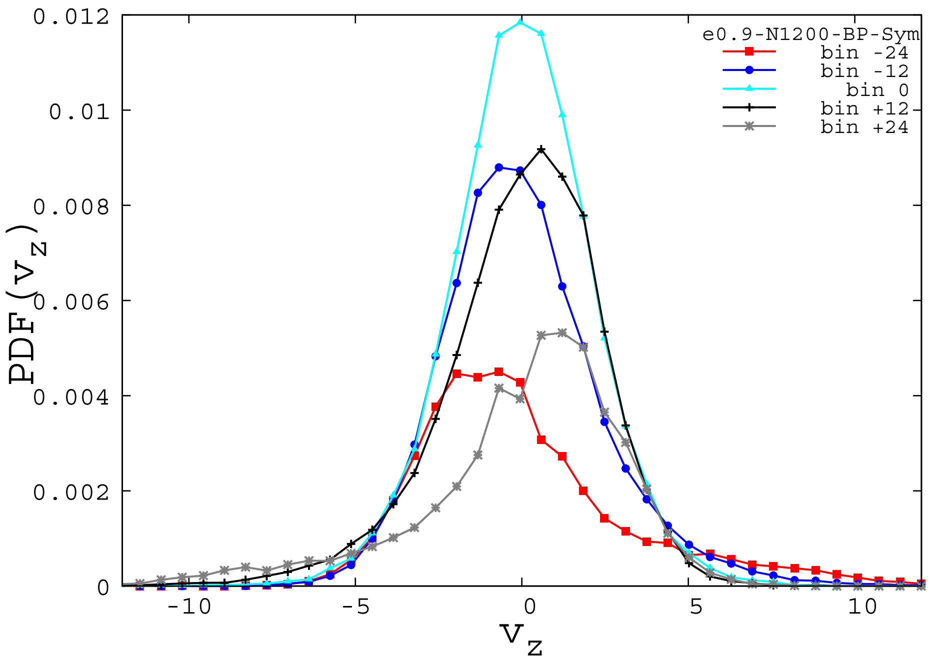



*Figure 2.3 - 4: Simulations of granular gas is 3d rectangular cell*

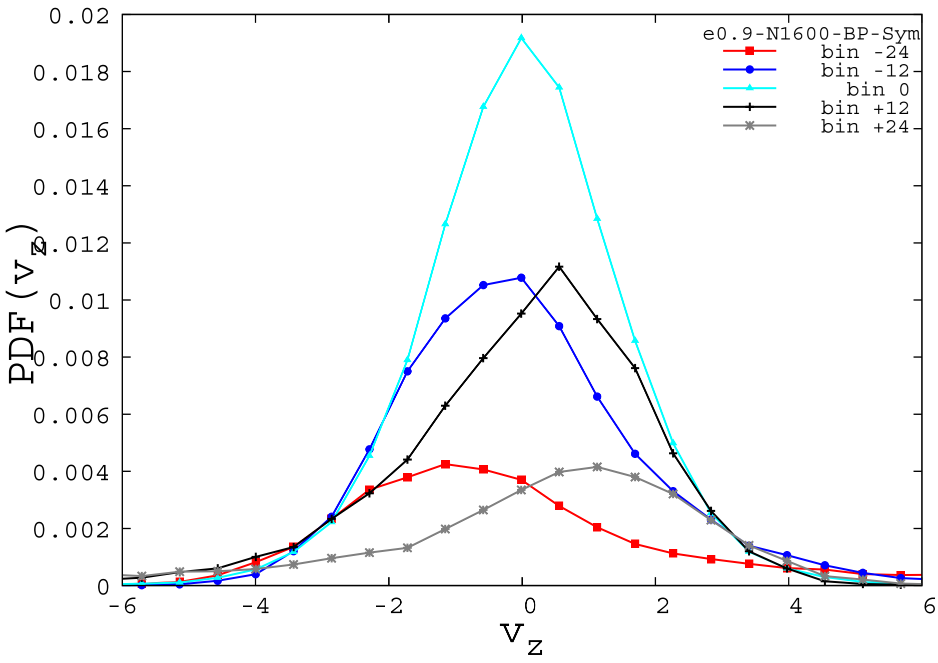



***Figure 2.3 - 5: Simulations of granular gas is 3d rectangular cell***

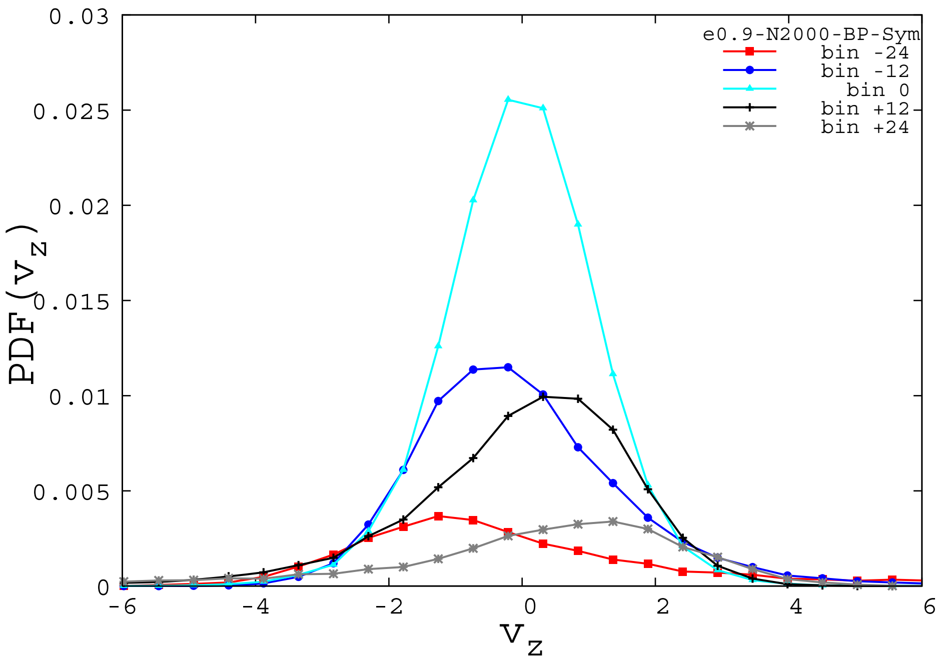



***Figure 2.3 - 6: Simulations of granular gas is 3d rectangular cell***

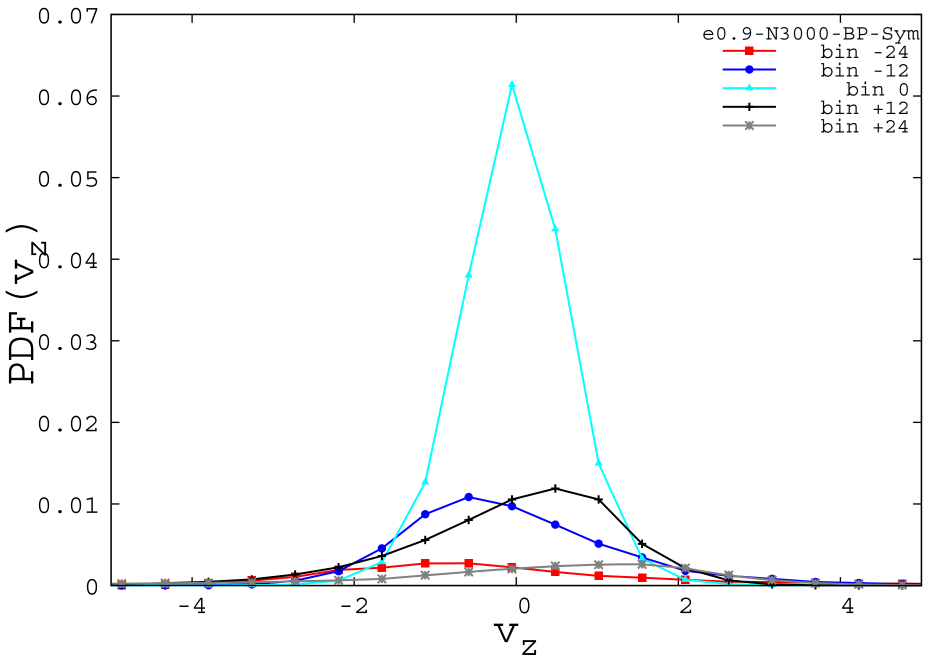



*Figure 2.3 - 7: Simulations of granular gas is 3d rectangular cell*

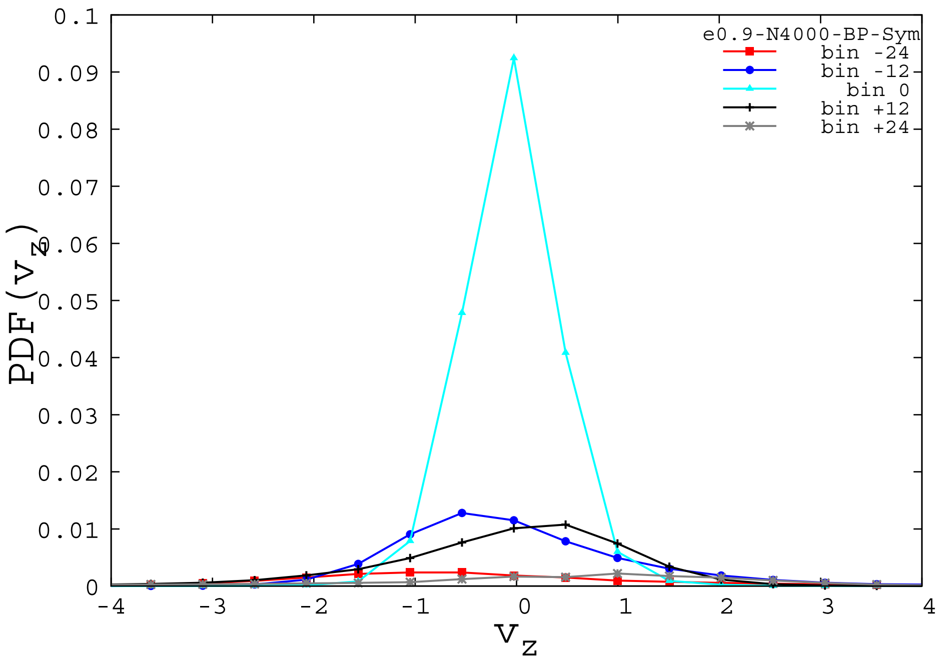



*Figure 2.3 - 8: Simulations of granular gas is 3d rectangular cell*

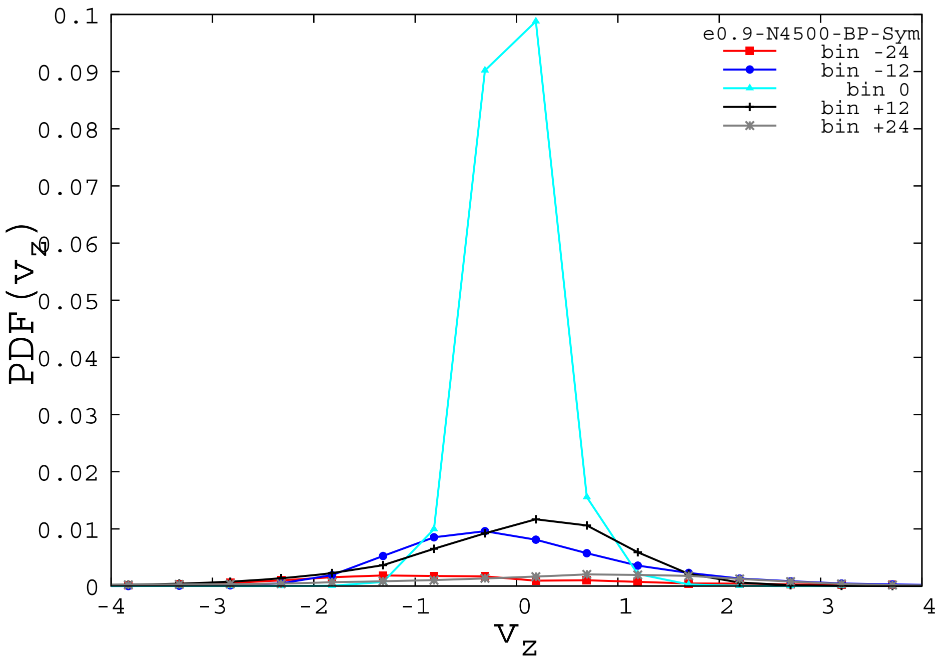
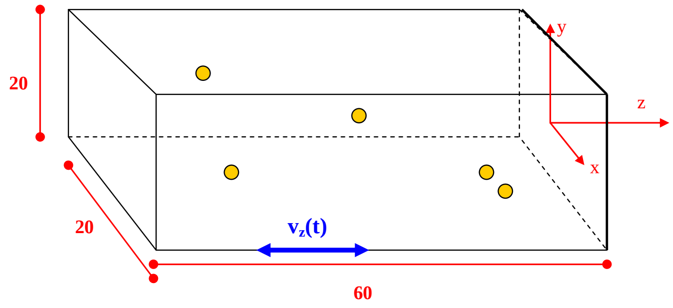


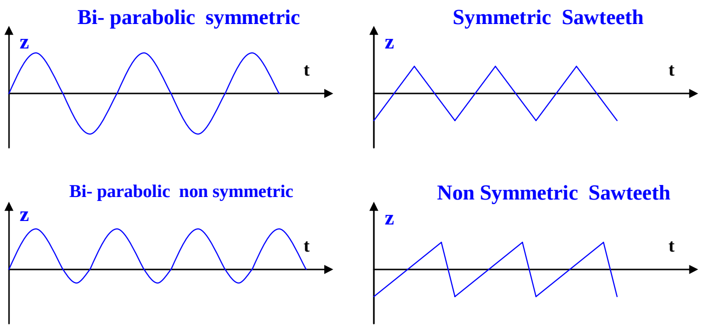

***Figure 2.3 - 9: Simulations of granular gas is 3d rectangular cell***

## Appendix : Simulation technique

A program of molecular dynamics working in C has been used to simulate the dynamics of a colliding gas of equal spheres with dissipation, with equal mass m. Ball-ball collision is treated using inelastic restitution coefficient $e=v_f/v_i$ (=0.9,0.8 or 0.7), excluding rotation effects and rotation parameters. Ball diameter D is the space unit (D=1). Rectangular box is used with dimension (x,y,z) = (20*20*60). Oz is along vibration; Transverse directions are Ox and Oy, no transverse motion of the box is imposed.




*(a)The shape of the container*




(b) Different excitation types of the vertical walls

We study 3d dynamics of N spheres (N=100, 500, 1200, 2000, 3000, 4000, 4500) with different excitation (symmetric and non symmetric bi-parabola and sawteeth drivings, thermal excitation ($\exp(-v^2/kt)$). In thermal excitation, balls which collide with moving wall get a random distribution according to the thermal noise. In bi-parabolic driving, the wall speed is assumed continuous and acceleration $+\Gamma_1$ is applied during $T_1$, then changes to $-\Gamma_2$ during $T_2$ and conversely; so a period $T=T_1+T_2$, and the continuity condition leads to $\Gamma_1 T_1=\Gamma_2 T_2$. This excitation is quite similar to a symmetric sinus wave when $\Gamma_1= \Gamma_1$.

The program finds ball-ball and ball-wall collisions and the snapshots of ball positions and speeds are recorded every (N/10) collisions; The program stops after 100*N collisions and contains 1000* snapshots of 3d- cell and balls. Steady state is obtained after some time. The cell is cut into 59 bins perpendicular to vibration direction, and the different local quantities are averaged over two consecutive bins.

Dynamics is studied in displaying different parameters such as the **p**robability **d**istribution **f**unctions (**pdf**) of the speed coordinates $V_z$, and $V_x$ (along and perpendicular to excitation respectively) at different position z, the density distribution n(z) , the speed distribution $V_z(z)$ as a function of the position z, the mean speed $\langle V_z\rangle=\Sigma_{particles} m V_z/(\Sigma_{particles} m)$, which is also the mean flow, the mean temperature kT/m = $\Sigma_{particles} V^2_z/(\Sigma_{particles})$ and the mean pressure $P_z= \Sigma_{particles} m V^2_z$. Only normal restitution coefficient e is introduced to take account of dissipation; No rotation and friction is included.

We also separate the particles into two sets at a given instant, *i.e.* those ones which move towards $z^+$ (positive $V_z$ ), and those ones which move towards $z^-$ (negative $V_z$ ) and we plot the same quantities with respect to these directions, i.e. the density distribution $n^{(\pm)}(z)$ , the speed distribution $V_z(z)$ as a function of the position z, the mean speed $\langle V^{(\pm)}_z\rangle=\Sigma_{particles} m V^{(\pm)}_z/(\Sigma_{particles} m)$, which is also the mean flow in + or - z, the mean temperature kT/m = $\Sigma_{particles}(V^{(\pm)}_z)^2/(\Sigma_{particles})$ and the mean pressure $P_z= \Sigma_{particles} m (V^{(\pm)}_z)^2$ , on graphs.

### Figure symbols and abbreviations:

| | | |
|---|---|---|
| e0.9: coefficient of restitution $e$ = 0:9 | N***: number of particles $N$ = *** | BP: bi-parabolic driving |
| ST: saw-tooth driving | Sym: symmetrical driving | Nsym: Non-symmetrical driving |

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