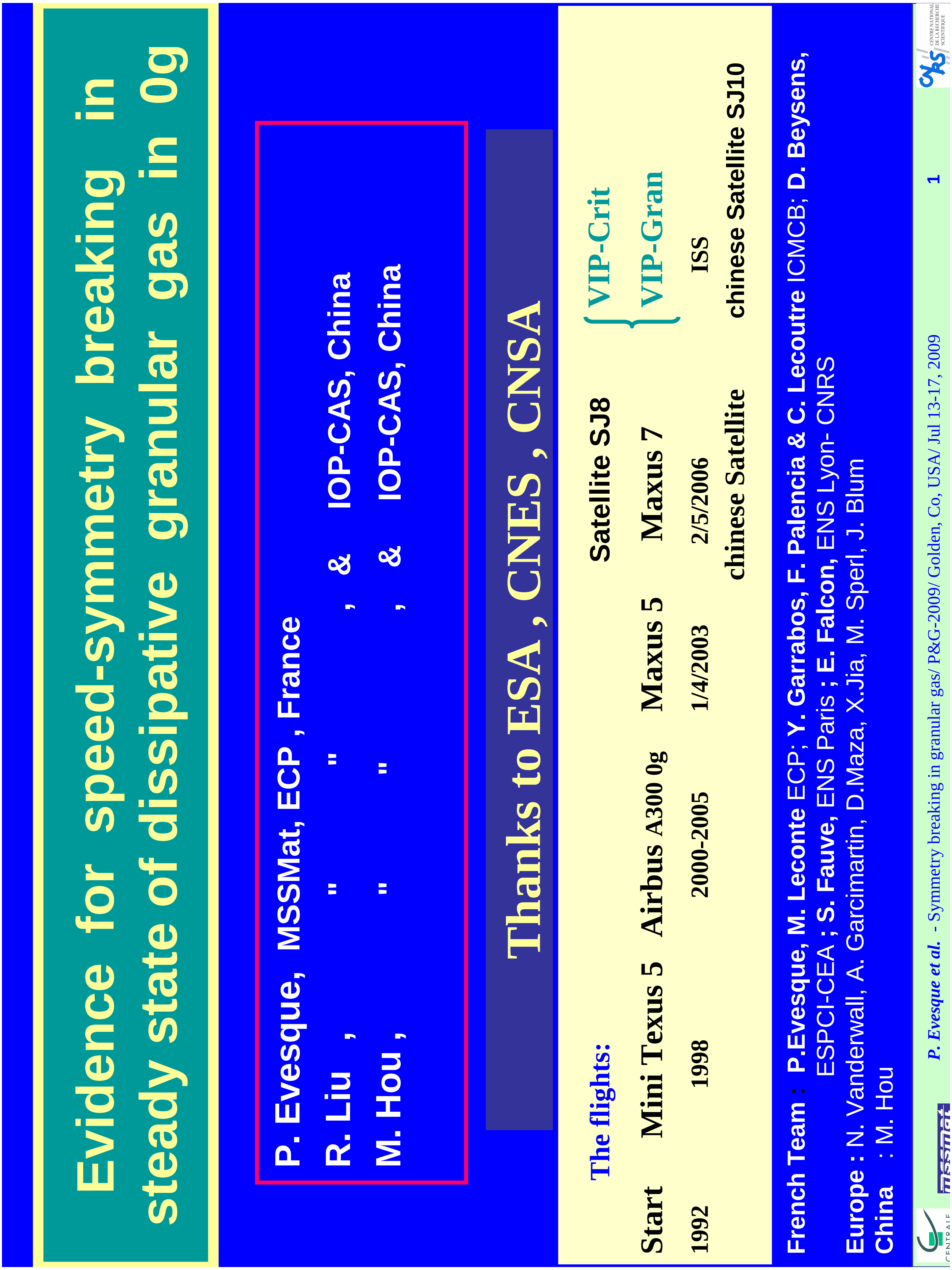
Evidence for speed-symmetry breaking in steady state of dissipative granular gas in 0g
P. Evesque, MSSMat, ECP , France
R. Liu , " " , & IOP-CAS, China
M. Hou , " " , & IOP-CAS, China
Thanks to ESA , CNES , CNSA
The flights:
Start Mini Texus 5 Airbus A300 0g Maxus 5 Satellite SJ8 Maxus 7 VIP-Crit VIP-Gran ISS
1992 1998 2000-2005 1/4/2003 2/5/2006
chinese Satellite chinese Satellite SJ10
French Team : P.Evesque, M. Leconte ECP; Y. Garrabos, F. Palencia & C. Lecoutre ICMCB; D. Beysens, ESPCI-CEA ; S. Fauve, ENS Paris ; E. Falcon, ENS Lyon- CNRS
Europe : N. Vanderwall, A. Garcimartin, D.Maza, X.Jia, M. Sperl, J. Blum
China : M. Hou
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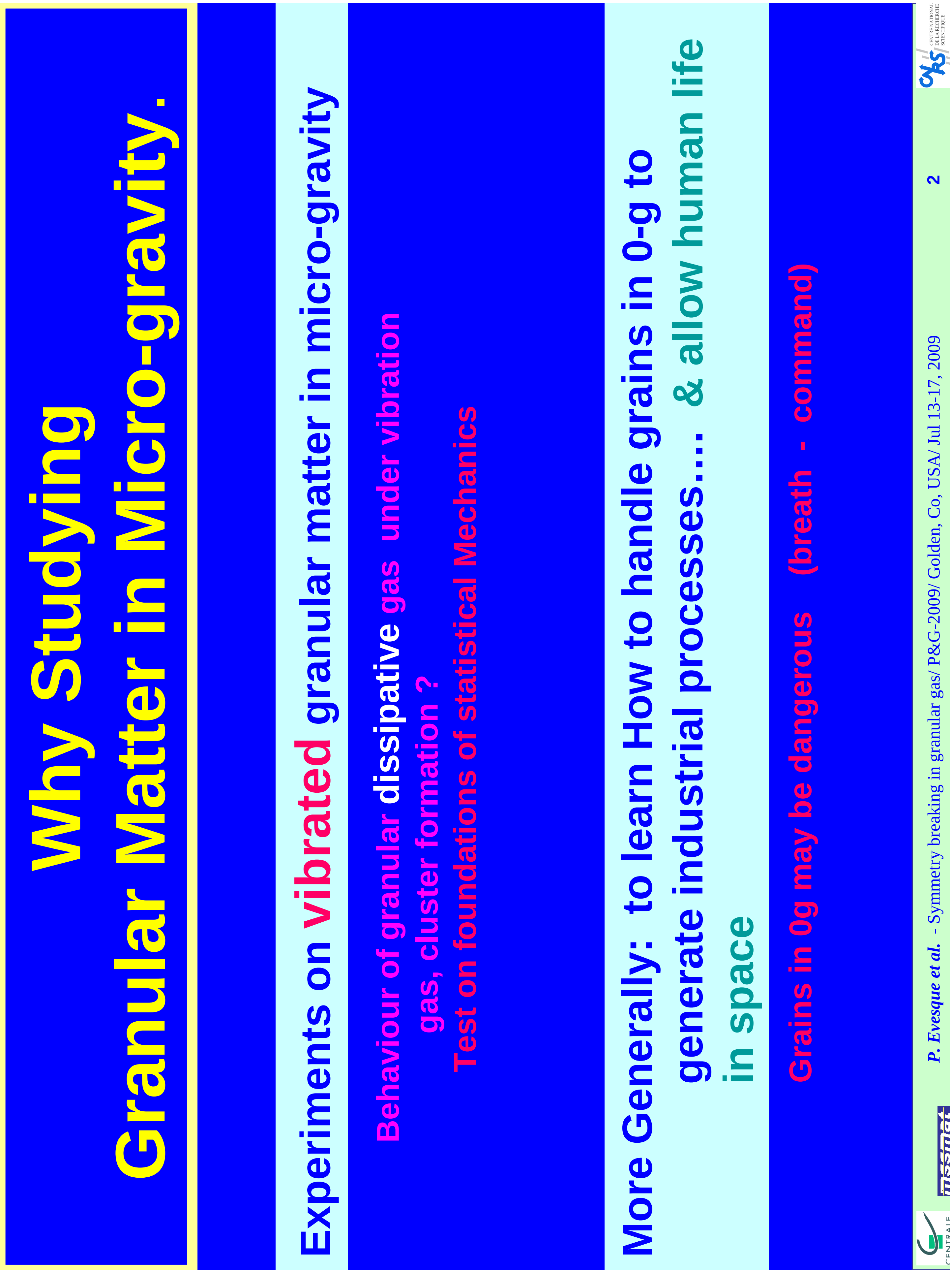
Why Studying
Granular Matter in Micro-gravity.
Experiments on vibrated granular matter in micro-gravity
Behaviour of granular dissipative gas under vibration
gas, cluster formation ?
Test on foundations of statistical Mechanics
More Generally: to learn How to handle grains in 0-g to
generate industrial processes…. & allow human life
in space
Grains in 0g may be dangerous (breath - command)
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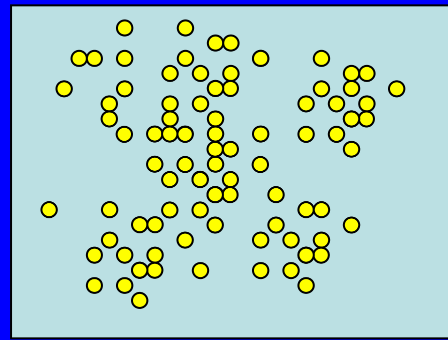
# Granular Gas: State of the art on simulations and theoretical predictions

**1995-2005**

**Hypotheses**
- No Rotation or rotation (no matter)
- Boundary conditions (no matter)
- Restitution coefficient

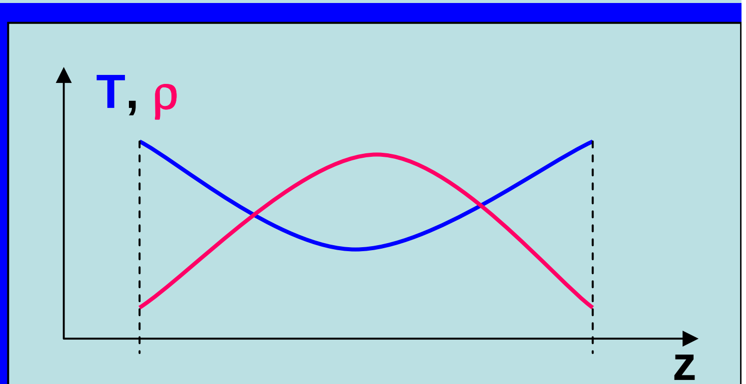


**Inhomogeneous collapse and clustering**

$T_1$, $T_2$, $\rho(z)$, $T(z)$, $f(v) \propto \exp[-(v^2/kT)^a]$

with **a** not far from 1

## Conclusion : Right parameters
- Effective temperature
- constant Pressure
- Kinetic theory works with thermal balance for dissipation

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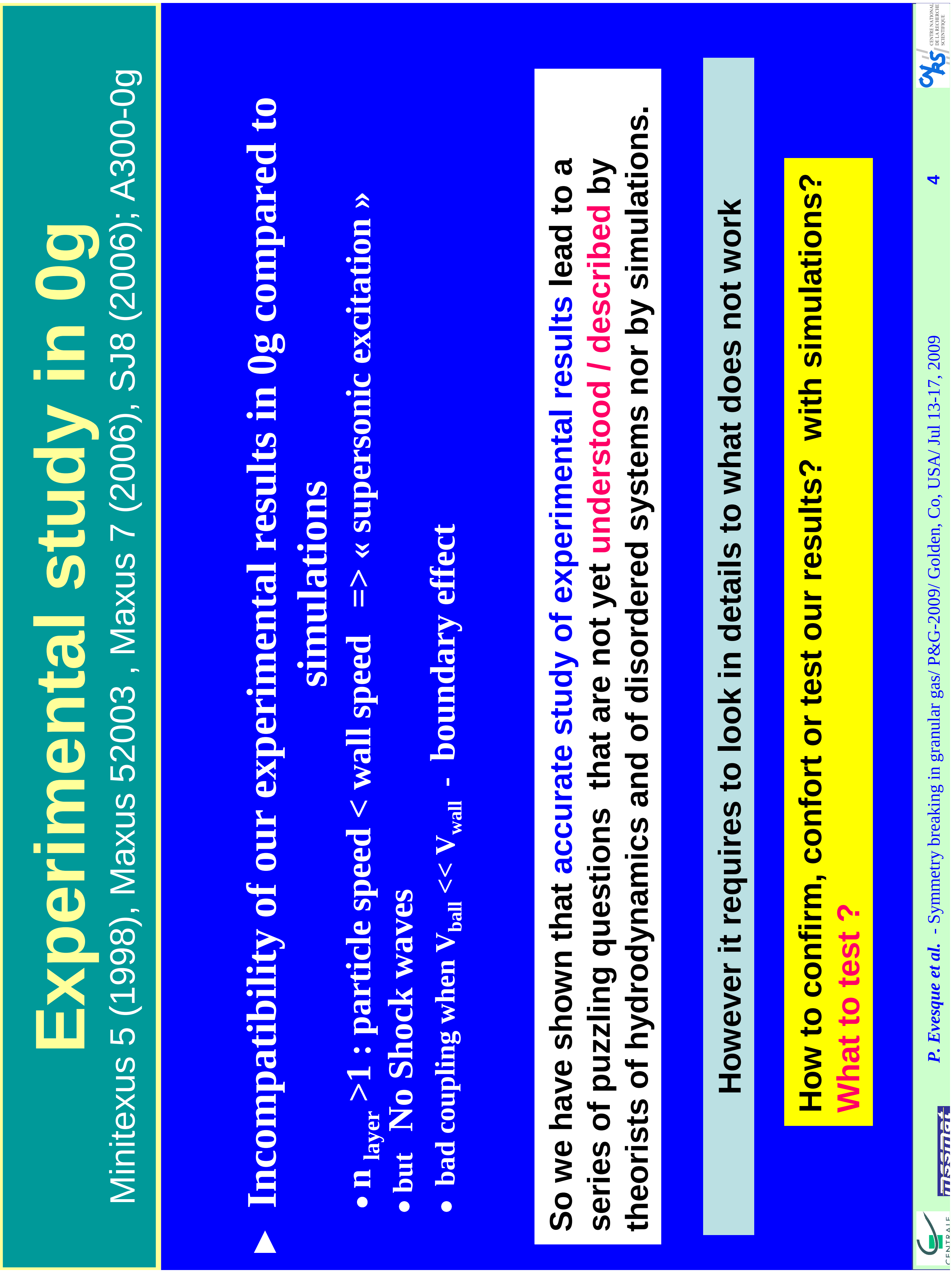
Experimental study in 0g
Minitexus 5 (1998), Maxus 52003 , Maxus 7 (2006), SJ8 (2006); A300-0g
Incompatibility of our experimental results in 0g compared to simulations
• n layer >1 : particle speed < wall speed => « supersonic excitation »
• but No Shock waves
• bad coupling when V ball << V wall - boundary effect
So we have shown that accurate study of experimental results lead to a series of puzzling questions that are not yet understood / described by theorists of hydrodynamics and of disordered systems nor by simulations.
However it requires to look in details to what does not work
How to confirm, confort or test our results? with simulations?
What to test ?
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# Simulation from others:
## averaging over whole cell

5.1 the pressure.

J. J. Brey et al [arXiv:0906.0747] find some stationary states with constant pressure, like that in classical gases. But they also observe wings in the velocity distribution. Their system is quite near elasticity ($e = 0.9 - 0.99$). For a strongly dissipative system, whether the constant pressure can be kept is still undiscussed. And it is difficult to calculate the pressure in the simulations if the local mean free path is too short. $\sum v_z^2$ does not give any information about the pressure if too many collisions there.

5.2 the stability of the cluster.

E. Khain and B. Meerson [Europhys. Lett., 65 (2), pp. 193-199 (2004)] discussed an oscillating phenomenon of the cluster in the center of the container. These results indicate that steady state sometimes is difficult to reach for large number of particles $N$.

Three states of the cluster, i.e. a static cluster(singular), a dynamical but steady cluster, and an oscillating cluster, may be found.

5.3 wings and double-peak structures in velocity distribution.

Morgado and Mucciolo [Physica A 311 (2002) 150-168] discussed the density and velocity distributions in a 2D system with their DSMC results. Wings are founded in the longitudinal velocity distributions.

J. F. Boudet et al [PRL 101, 254503 (2008)] observed a similar double-peak structure near the shock front of an obstacle, which indicates the area includes two kinds of particles, in a granular flow.

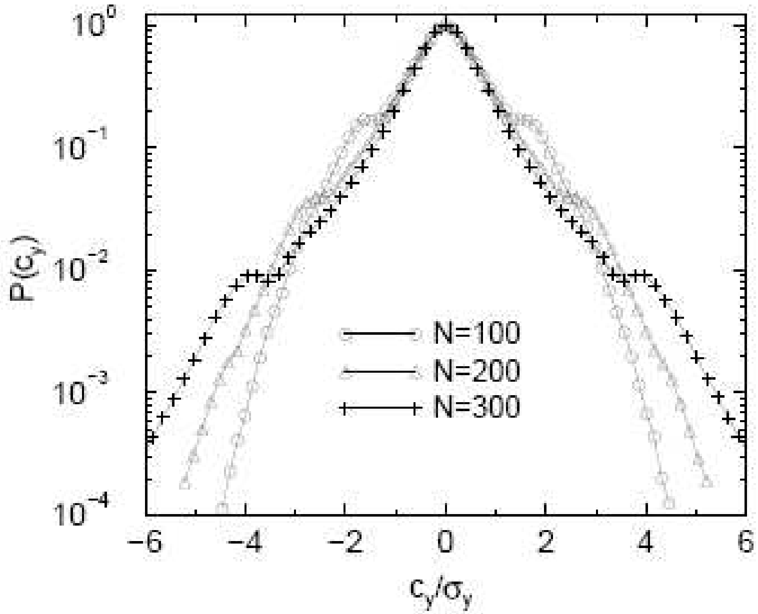


FIG. 3. The vertical (longitudinal) velocity distributions for the same parameters as in Fig. 2. The solid lines are only guides for the eyes.

**2d case (W. Morgado & Eduardo R. Mucciolo) Sawtooth exc. (2002 ) (= 2008)**

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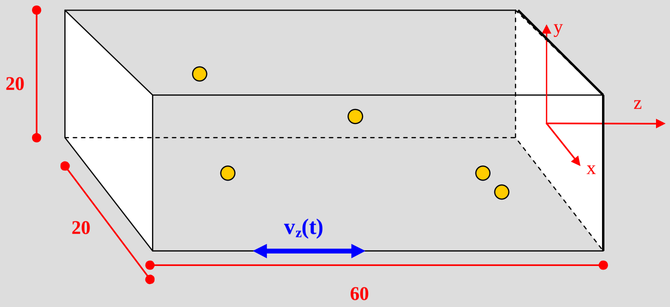
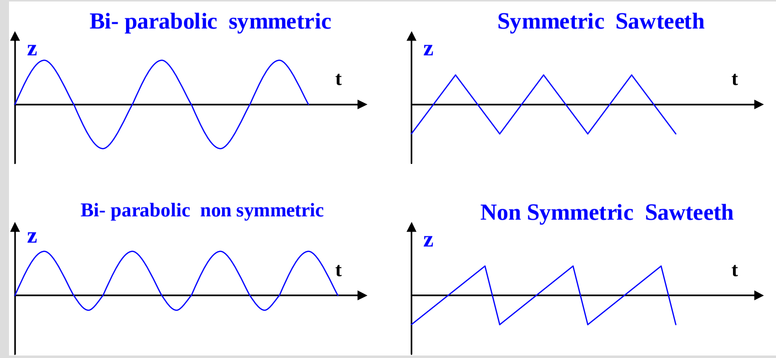
# Simulations:




**Cell: 20d*20d* 60d**

## Wall Motion kinds




**+ Thermal wall**

## Parameters:

**e = 0. 7 , 0. 8 and 0. 9**

**N = 100 , 500 , 1200, 1600, 2000, 3000, 4000, 4500**

## Measurements:

n(z)

PDF $V_z$ at different z , PDF of $V_x$,at different z

$<V_z>$ , $\Sigma V_z$=flow ; < V+>, <V->, $F^+$ et $F^-$

$p=\Sigma V^2_z$ , $p^+ =\Sigma V^2_z{}^+$ , $p^- =\Sigma mV^2_z{}^-$ ,

$T= \Sigma mV^2_z/\Sigma m$ ; $T^- =\Sigma mV^2_z{}^-/\Sigma m$ ; $T^+=\Sigma mV^2_z{}^+ /\Sigma m$

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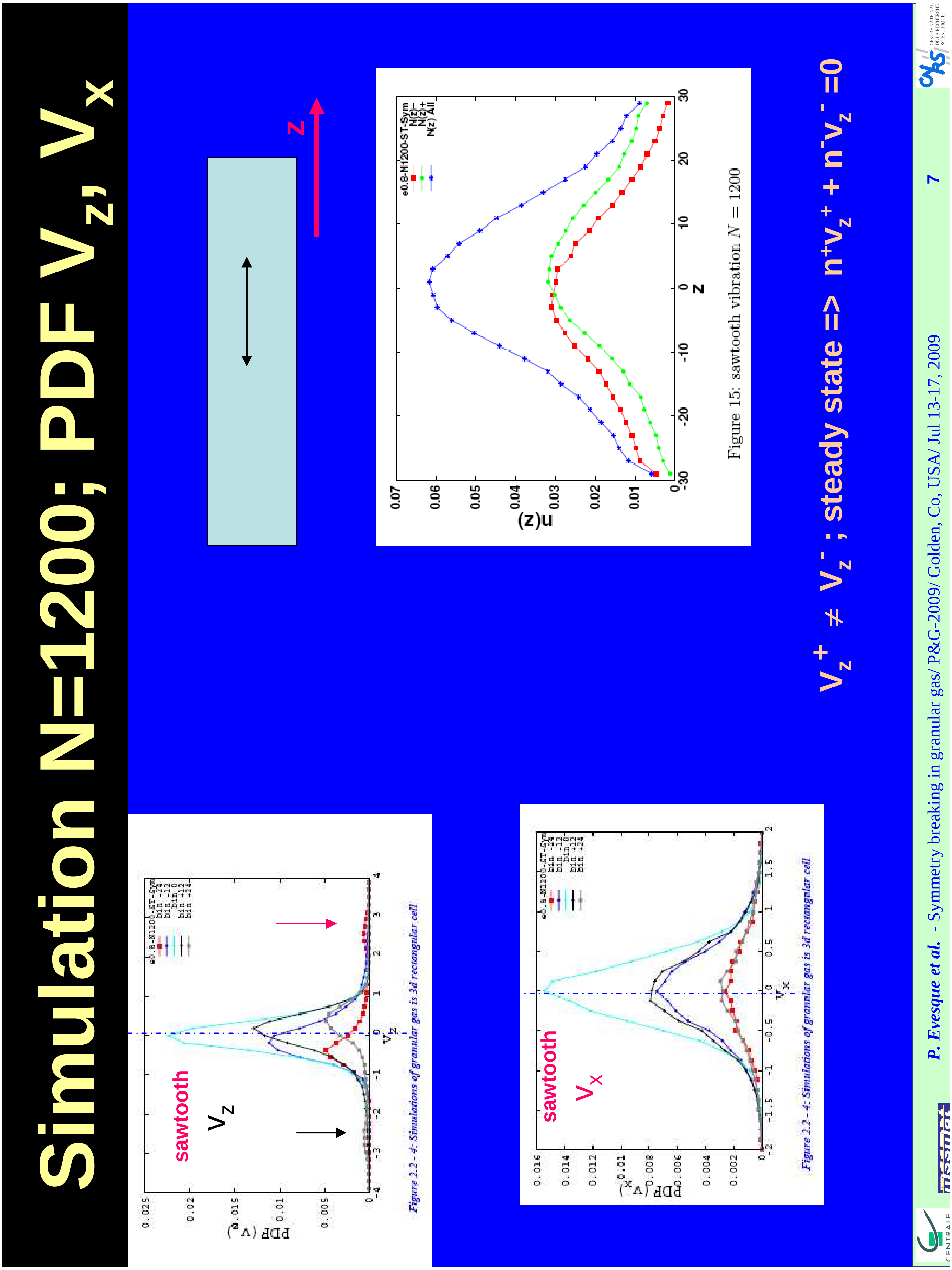
Simulation N=1200; PDF $V_z$, $V_x$
sawtooth
$V_z$
Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell
sawtooth
$V_x$
Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell
z
Figure 15: sawtooth vibration N = 1200
n(z)
e0.8-N1200-ST-Sym
N(z)-
N(z)+
N(z) All
$V_z^+ \neq V_z^-$ ; steady state => $n^+v_z^+ + n^-v_z^- = 0$
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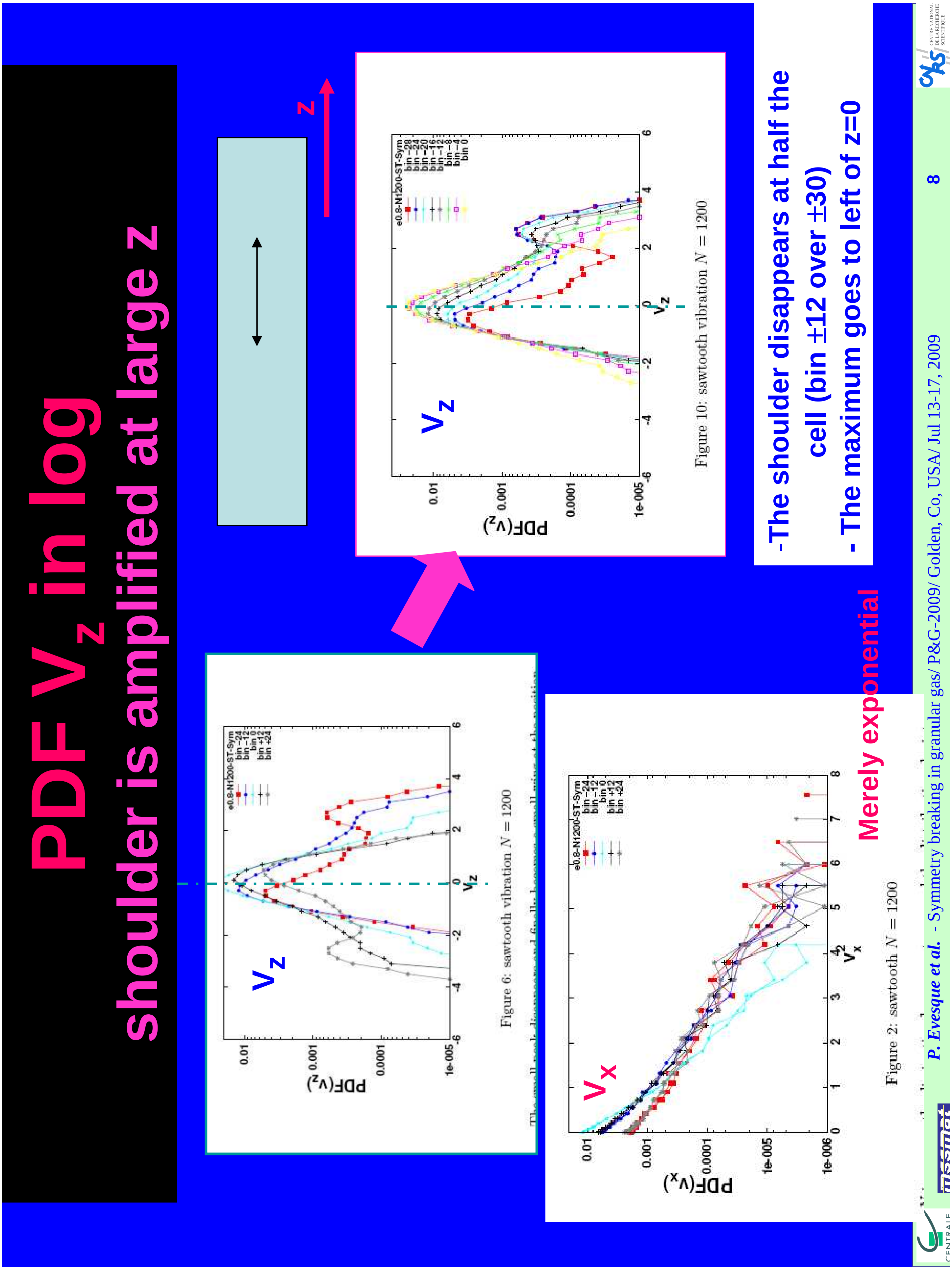
PDF $V_z$ in log
shoulder is amplified at large z
z
$V_z$
e0.8-N1200-ST-Sym
bin -24
bin -12
bin 0
bin +12
bin +24
PDF($v_z$)
Figure 6: sawtooth vibration N = 1200
$V_z$
e0.8-N1200-ST-Sym
bin -28
bin -24
bin -20
bin -16
bin -12
bin -8
bin -4
bin 0
PDF($v_z$)
Figure 10: sawtooth vibration N = 1200
$V_x$
PDF($v_x$)
Figure 2: sawtooth N = 1200
Merely exponential
-The shoulder disappears at half the cell (bin ±12 over ±30)
- The maximum goes to left of z=0
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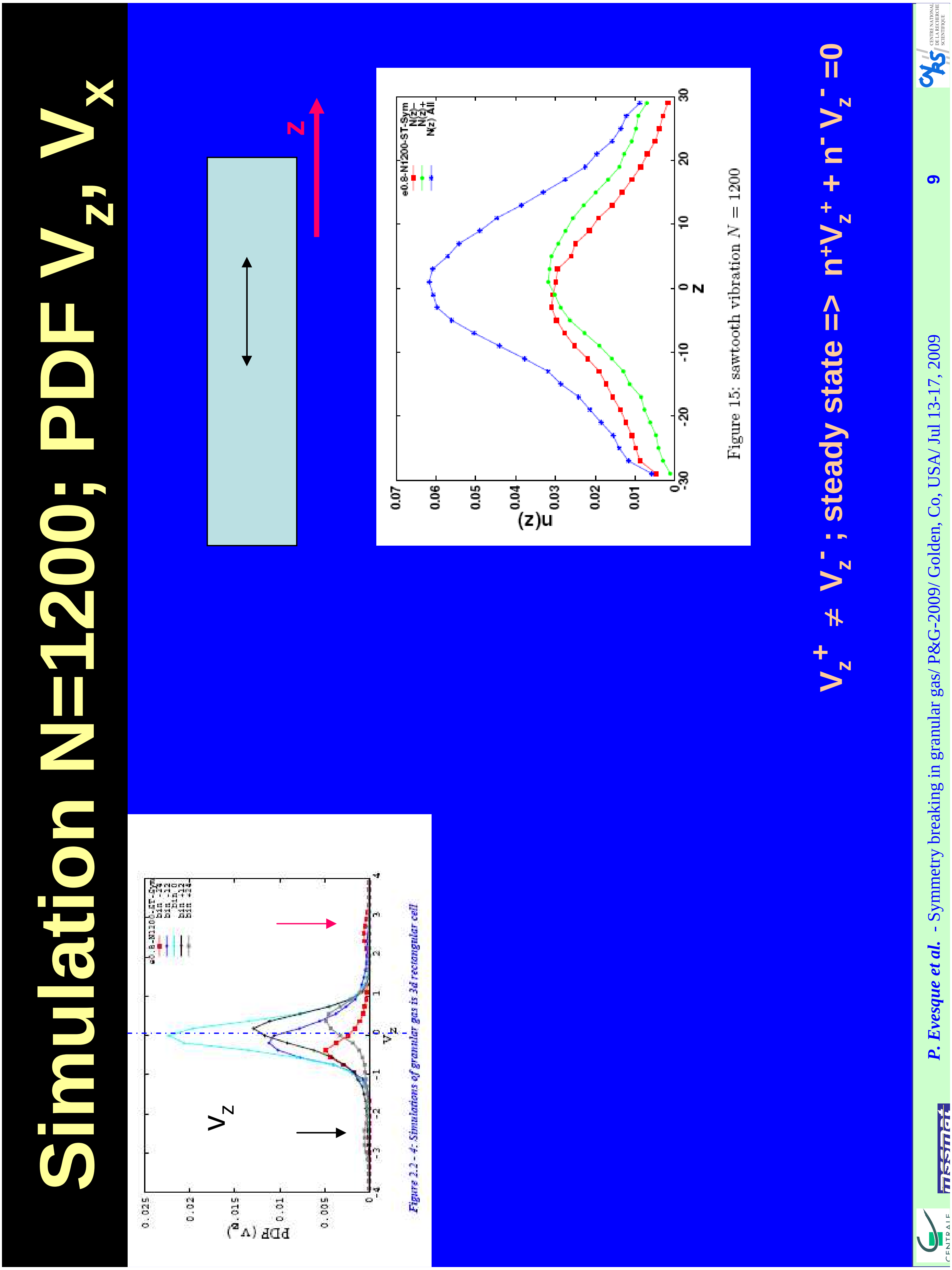

Simulation N=1200; PDF Vz, Vx
Vz
PDF (vz)
vz
Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell
z
e0.8-N1200-ST-Sym
N(z)-
N(z)+
N(z) All
n(z)
z
Figure 15: sawtooth vibration N = 1200
Vz+ ≠ Vz- ; steady state => n+Vz+ + n-Vz- =0
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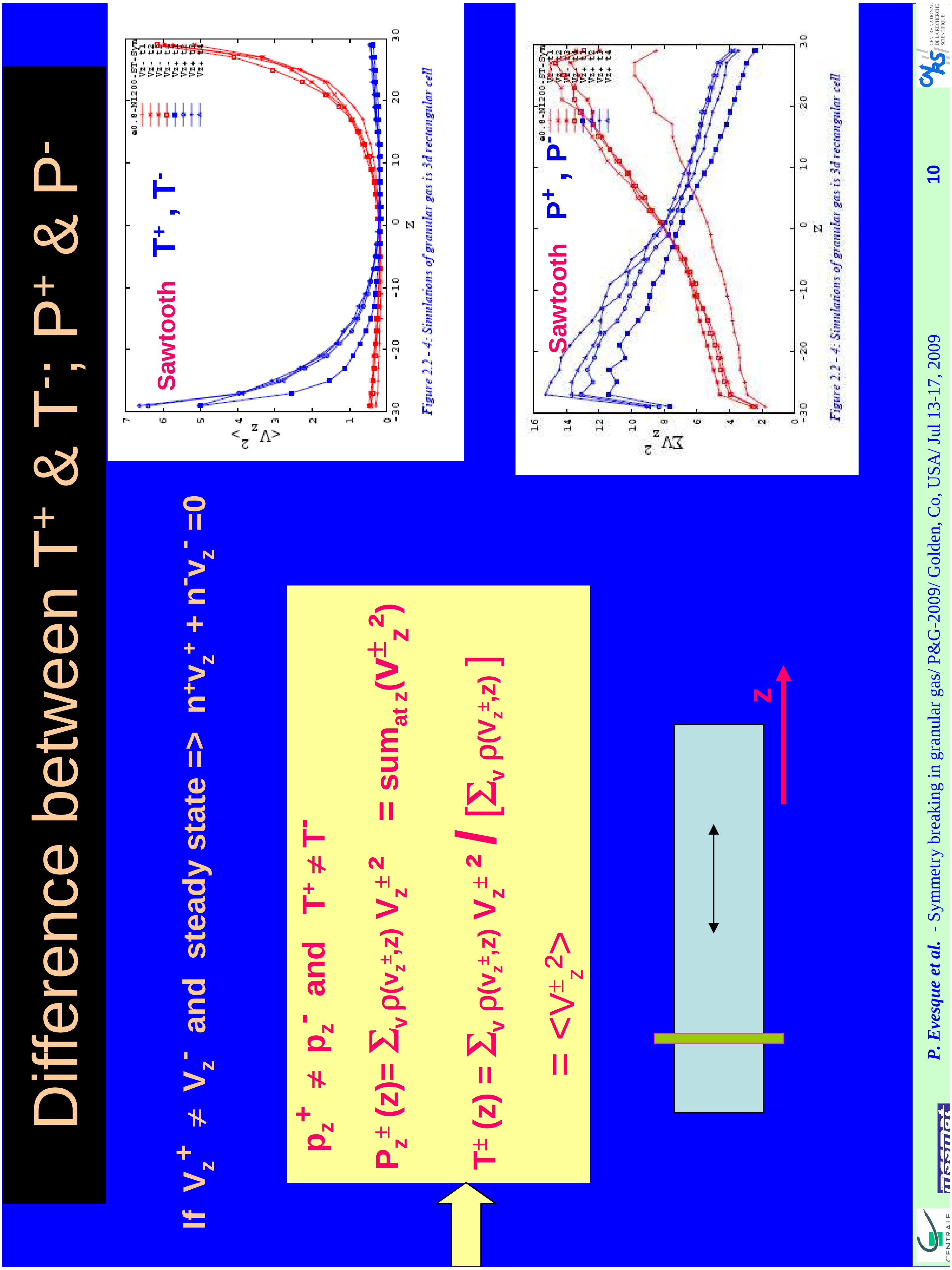
Difference between T+ & T-; P+ & P-
If Vz+ ≠ Vz- and steady state => n+vz+ + n-vz- =0
pz+ ≠ pz- and T+ ≠ T-
Pz± (z)= Σv ρ(vz±,z) Vz± 2 = sumat z(V±z 2)
T± (z) = Σv ρ(vz±,z) Vz± 2 / [Σv ρ(vz±,z) ]
= <V±z 2>
z
Sawtooth T+ , T-
Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell
Sawtooth P+ , P-
Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell
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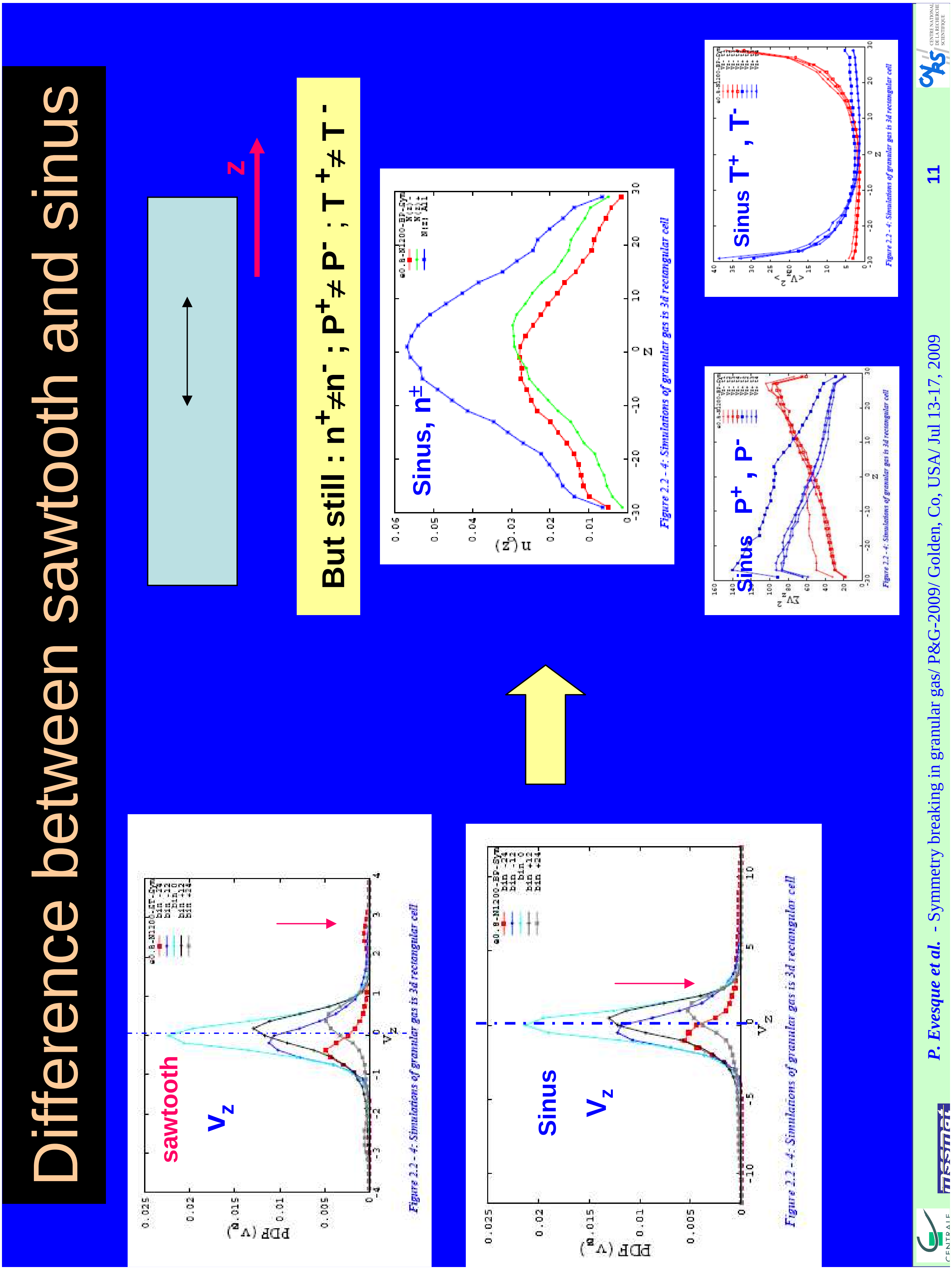
Difference between sawtooth and sinus
z
But still : $n^+ \neq n^-$ ; $P^+ \neq P^-$ ; $T^+ \neq T^-$
Sinus, $n^\pm$
Sinus $P^+$, $P^-$
Sinus $T^+$, $T^-$
sawtooth
$v_z$
Sinus
$v_z$
Figure 2.2 - 4: Simulations of granular gas is 3d rectangular cell
P. Evesque et al. - Symmetry breaking in granular gas/ P&G-2009/ Golden, Co, USA/ Jul 13-17, 2009
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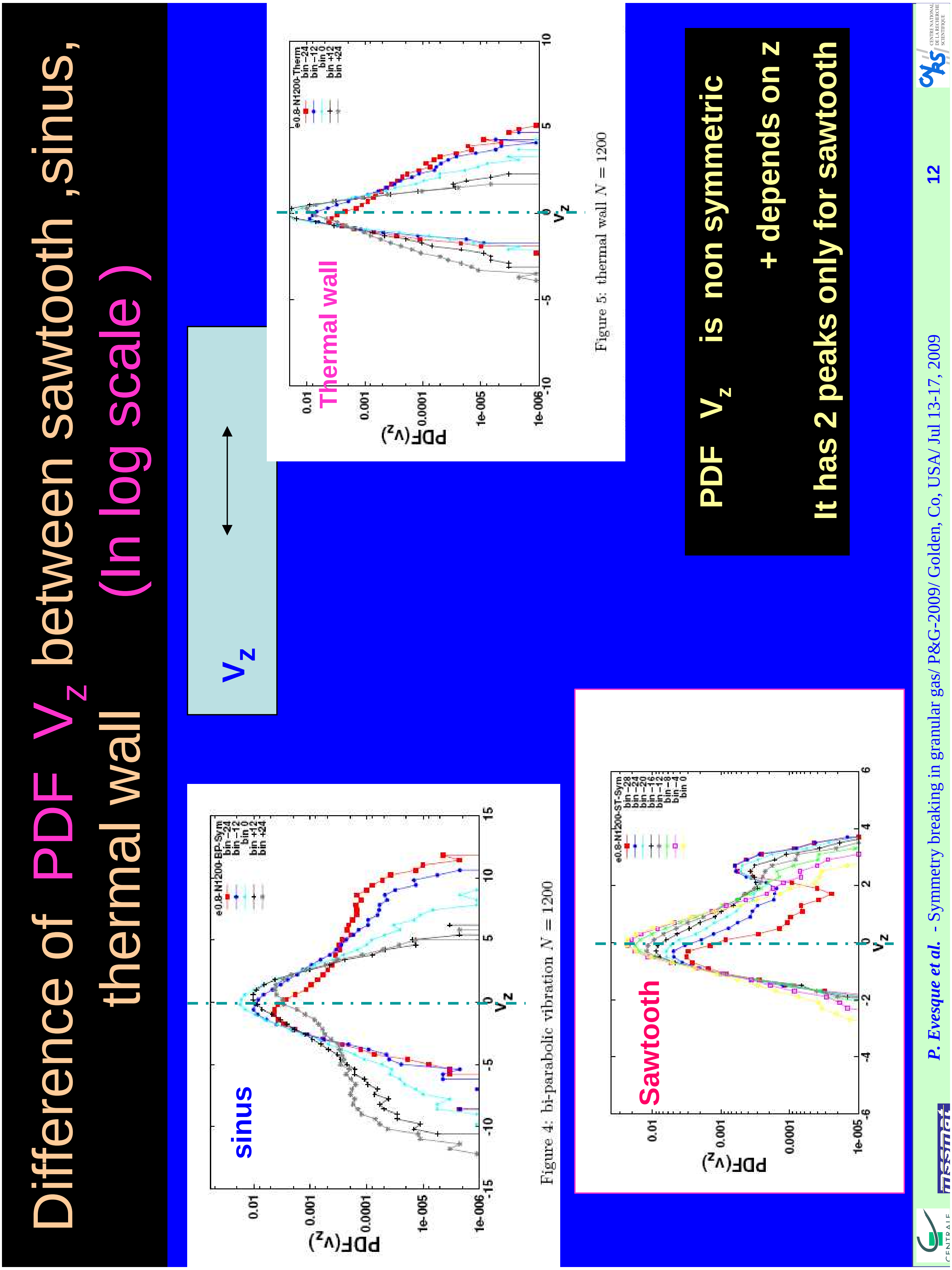
Difference of PDF V z between sawtooth ,sinus, thermal wall
(In log scale )
V z
sinus
PDF(v z)
Figure 4: bi-parabolic vibration N = 1200
Thermal wall
PDF(v z)
Figure 5: thermal wall N = 1200
Sawtooth
PDF(v z)
PDF V z is non symmetric
+ depends on z
It has 2 peaks only for sawtooth
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# Interpretation / Conclusion:

**Impact with moving boundary => $V_+ >> V_-$ on –L & $V_+ << V_-$ at +L**

**Steady state** => $\Sigma \rho_+ v_+ = \Sigma \rho_- v_-$ => $\rho_+/\rho_- = v_-/v_+$

This makes the **speed-symmetry breaking** at ±L, that **propagates** with **decrease** to 0 at z=0

## Characteristics:

- **2 different temperatures $T_\pm$ in any given position (z) for $V_{+z}$ and $V_{-z}$.**
  **since $kT_\pm/m = \langle\rho_\pm V_\pm{}^2\rangle / \langle\rho_\pm\rangle \propto |V_\pm{}^2|$**
- **2 different pressures $P_\pm$ in any given (z) since $P_\pm = \langle\rho_\pm V_\pm{}^2\rangle \propto |V_\pm|$**

**►This seems to be coherent with what we observed experimentally and not coherent/described in other simulations and theoretical description (P=cst)**

## Generalisation

- **This may happen very often for any flow with local jump and/or hydrodynamic discontinuities.**
- **i.e. Leidenfrost effect**

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# Conclusion:

**Complex non linear systems need large amount of data for analysis (non mean field)**

**And correct analysis**

**Number of curves studied: 6 000 (3e *8N* 5 boundaries* 4t *12 plots(v, $v^2$,..)**

***Poudres & Grains* 17 (2009) (550 pages)**

## Generalisation

- **This may happen very often for any flow with local jump and/or hydrodynamic discontinuities.**
- **i.e. Leidenfrost effect**

**This work uses concepts from our previous works:**

- boundary = thermostat or velostat
- Problem of diffusive or/propagative Boltzmann equation
- True effect of fast boundary

**physical idea: $V_+ \neq V_-$**

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