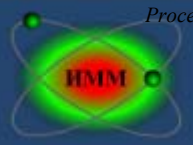


Numerical simulation of turbulent stage of Richtmyer-Meshkov instability with multi-shock interaction.

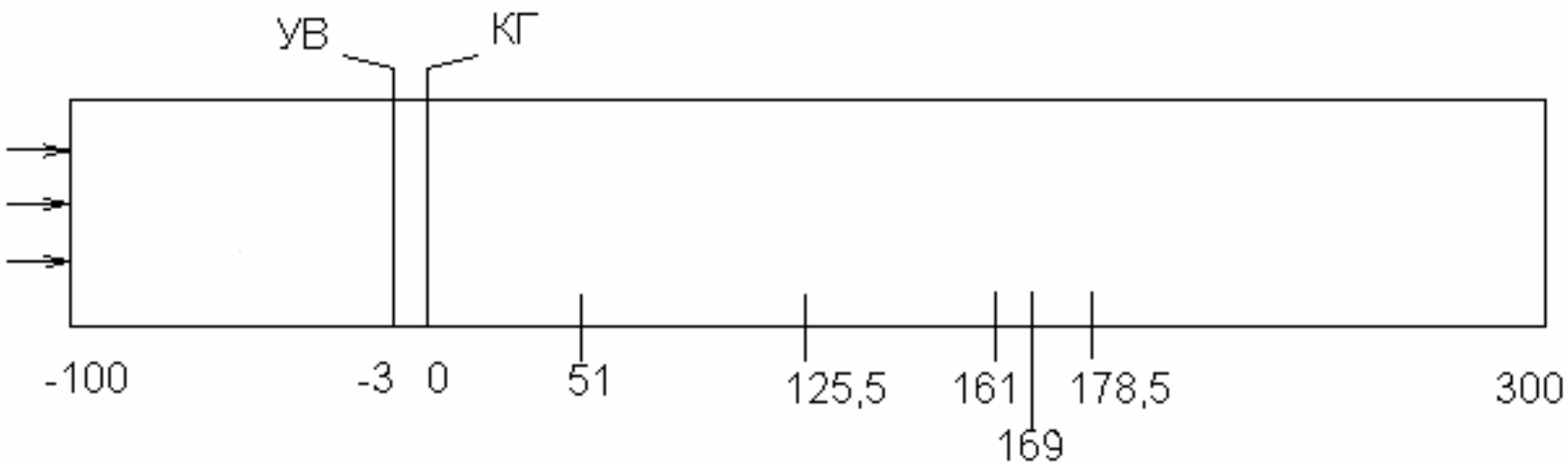
V.F.Tishkin, M.Ye.Ladonkina & N.V.Zmitrenko
(IMM RAS)

9th International Workshop on the Physics of Compressible Turbulent Mixing
Cambridge, UK
19-23 July 2004

Experimental [1] and numerical investigations of turbulent mixing

[1] F.Poggi, M.-H.Thorembey, G.Rodriguez. Velocity measurements in turbulent gaseous mixtures induced by Richtmyer-Meshkov instability.// Physics of Fluids, 1998, Vol.10, No.11, pp.2698-2700

Richtmyer-Meshkov instability development for SF6/Air (adiabatic exponents are 1,094 and 1,4)


УВ
КГ
-100
-3
0
51
125,5
161
169
178,5
300

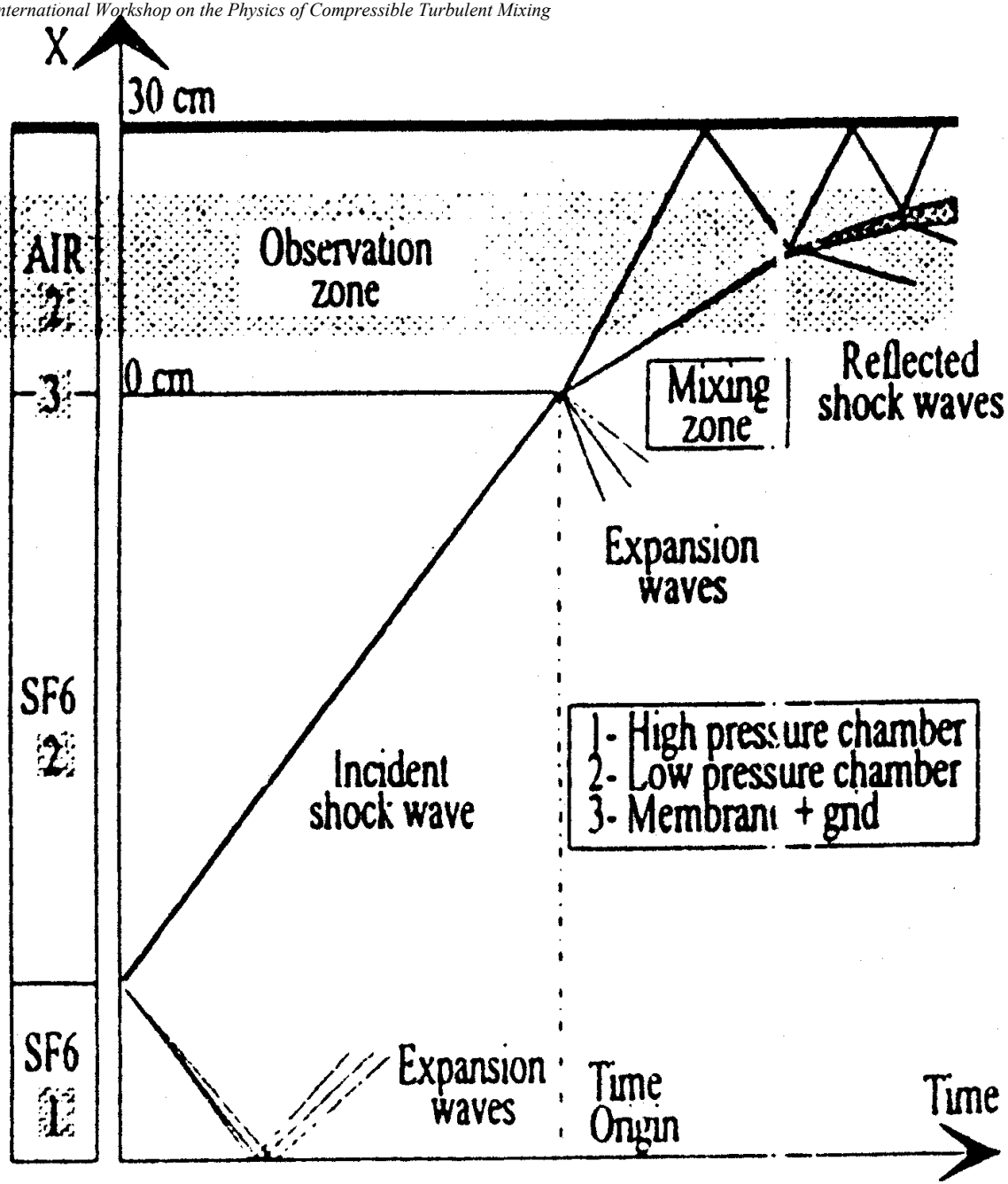
- Initial temperature 291^{O}K

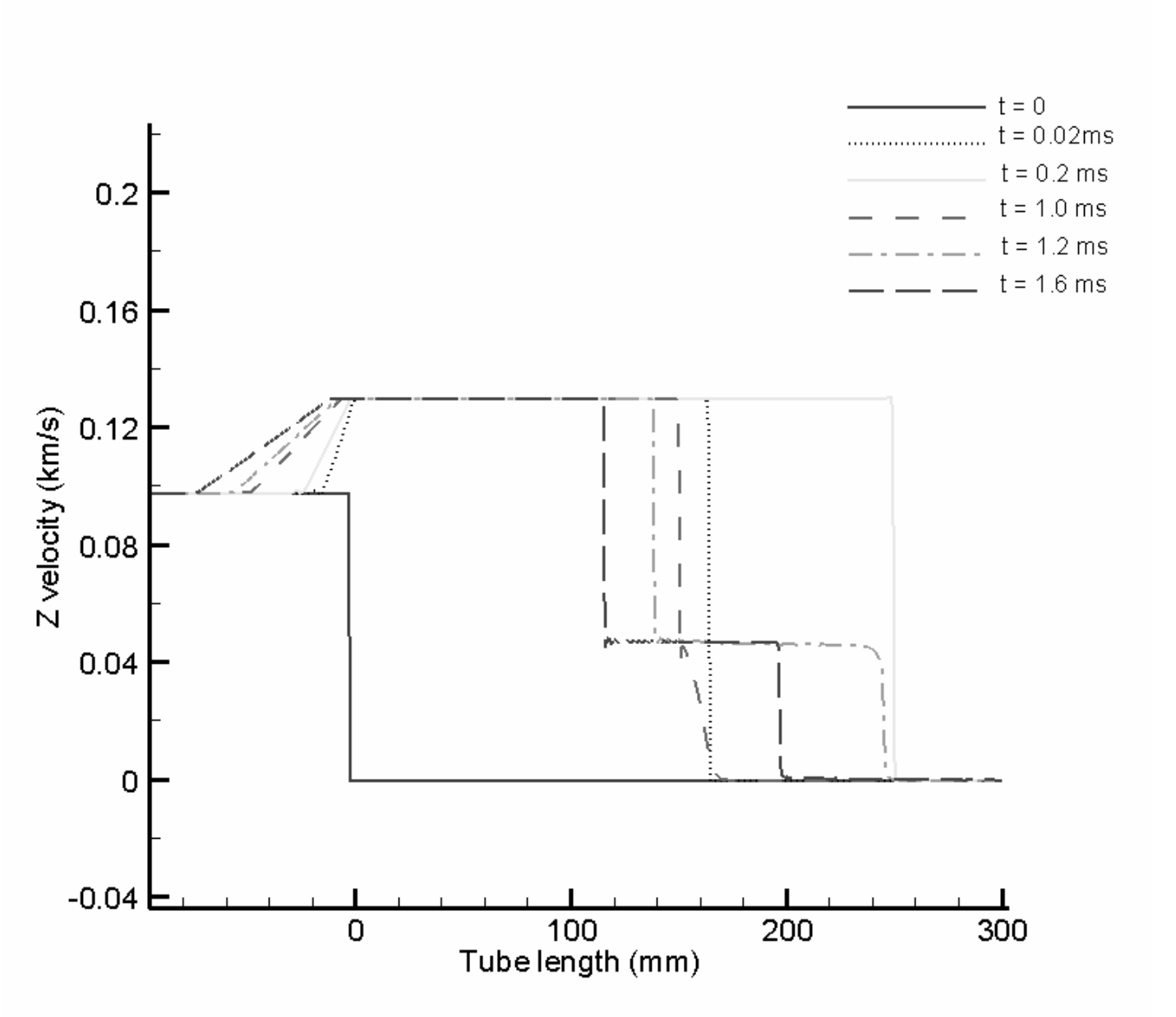
- Pressure in low-pressure camera 1Bar.
- Pressure after shock in SF_6 2,152 Bar.

- Density $1{,}209 \cdot 10^{-2}$ g/cm^3 ,
- Shock speed 195,2 м/s, flow speed after shock 97,76 m/s,
- Initial density SF_6 in low-pressure camera 6,037·10-3g/cm^3, air - 1,198·10-3 g/cm^3

- Shock speed in air 428,7 m/s
- Contact boundary speed 130,1 m/s.

- SF_6 and air are ideal gases


X
30 cm
AIR
2
Observation
zone
3
0 cm
Mixing
zone
Reflected
shock waves
Expansion
waves
SF6
2
1- High pressure chamber
2- Low pressure chamber
3- Membrane + gnd
Incident
shock wave
SF6
1
Expansion
waves
Time
Origin
Time


t = 0
t = 0.02ms
t = 0.2 ms
t = 1.0 ms
t = 1.2 ms
t = 1.6 ms
0.2
0.16
0.12
0.08
0.04
0
-0.04
Z velocity (km/s)
0
100
200
300
Tube length (mm)

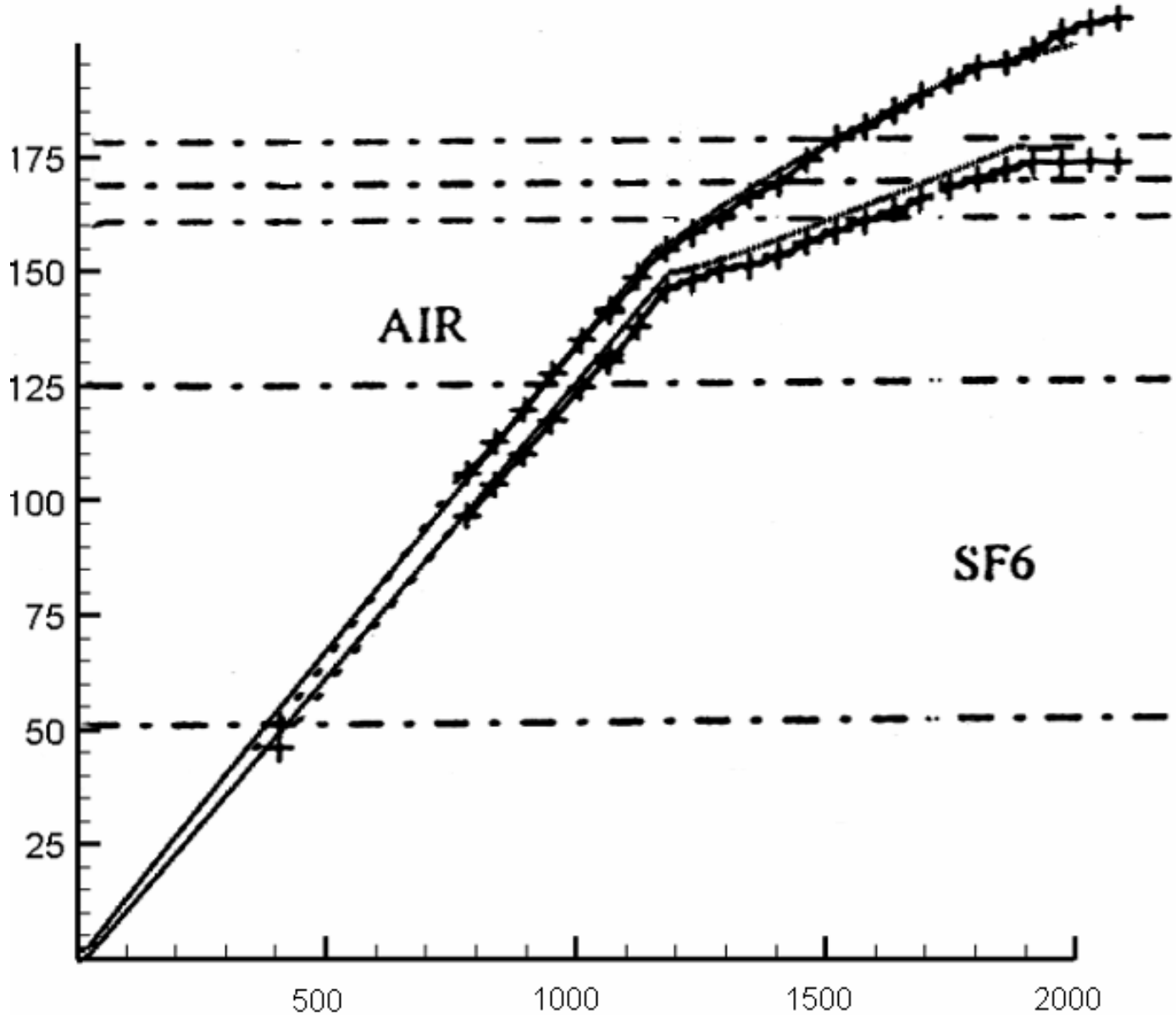
- On the basis of the calculations executed on grids with h=1 and 0,5mm it is possible to draw the following conclusions:

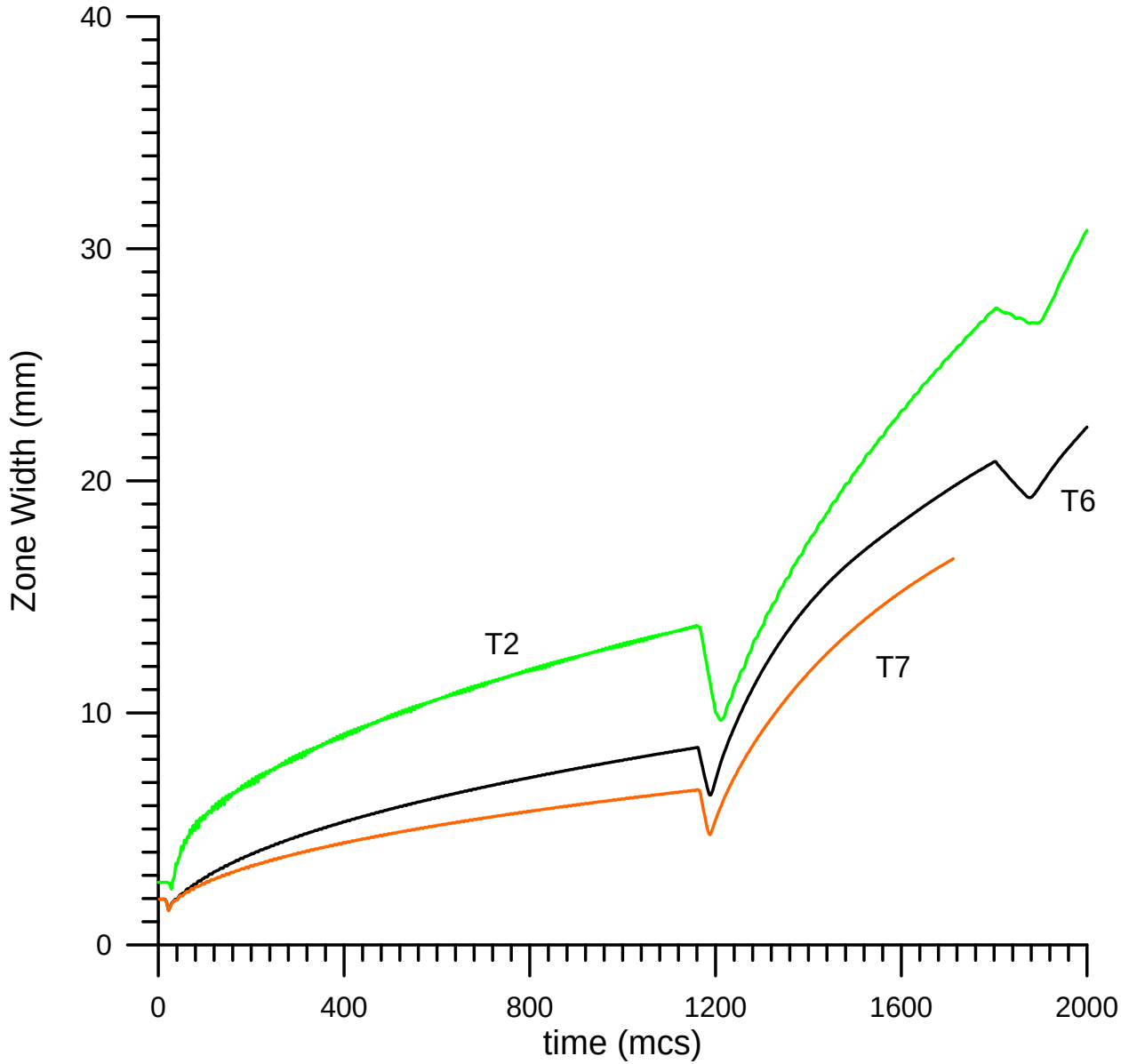
- For satisfactory reproduction of experimental data [1] it is enough to carry out calculations in area with the sizes $0 \le x \le 80$ мм, $0 \le y \le 80$ мм, $-100 \le z \le 300$ мм; Before arrival of a shock wave on contact border in a zone of the unit of gases there are no perturbations of numerical character.
- The sizes of cross-section section of a tube do not render appreciable influence on results of calculations.

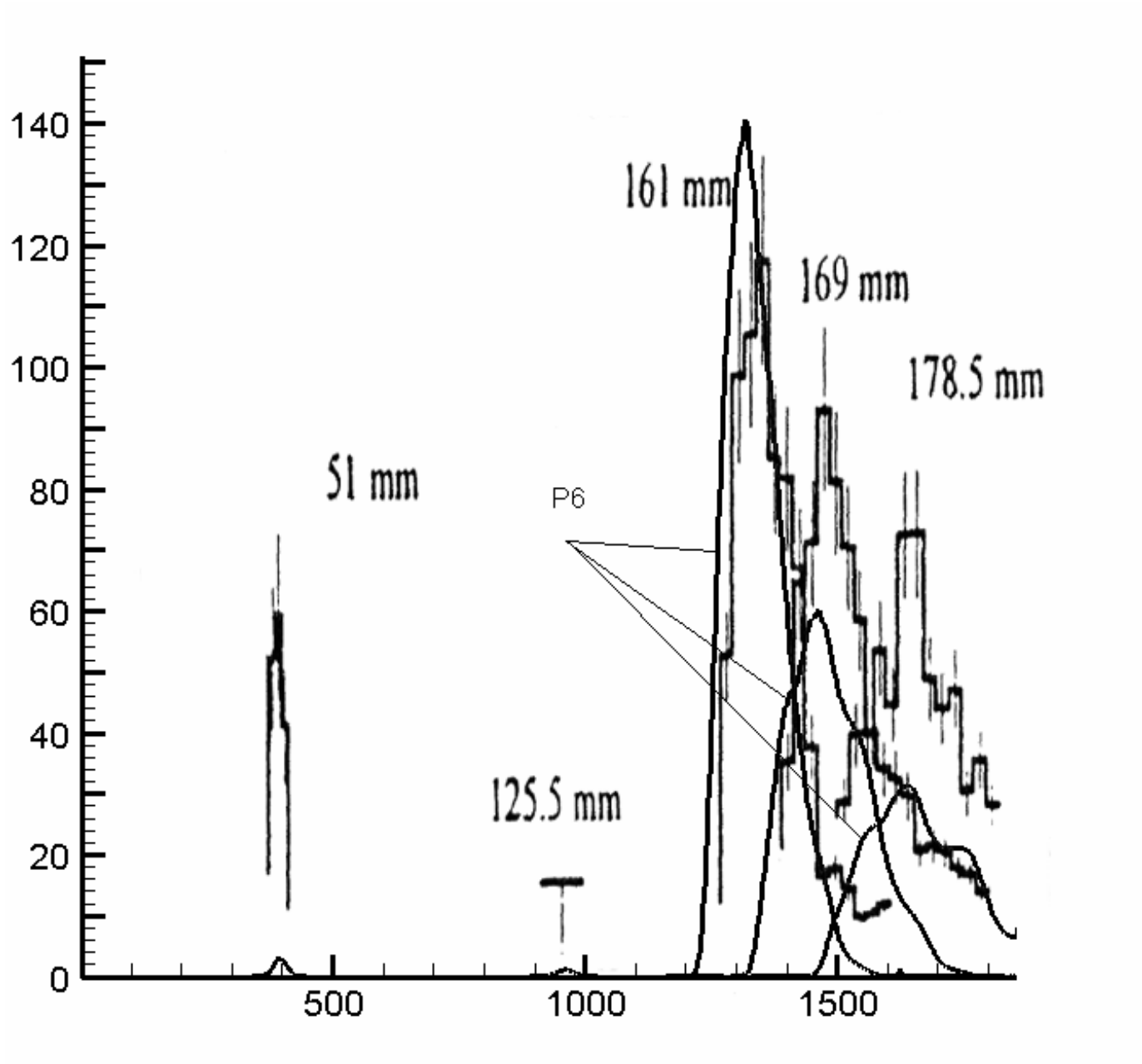
- The type of the task and size of initial perturbations of density noticeably affect results of calculations.

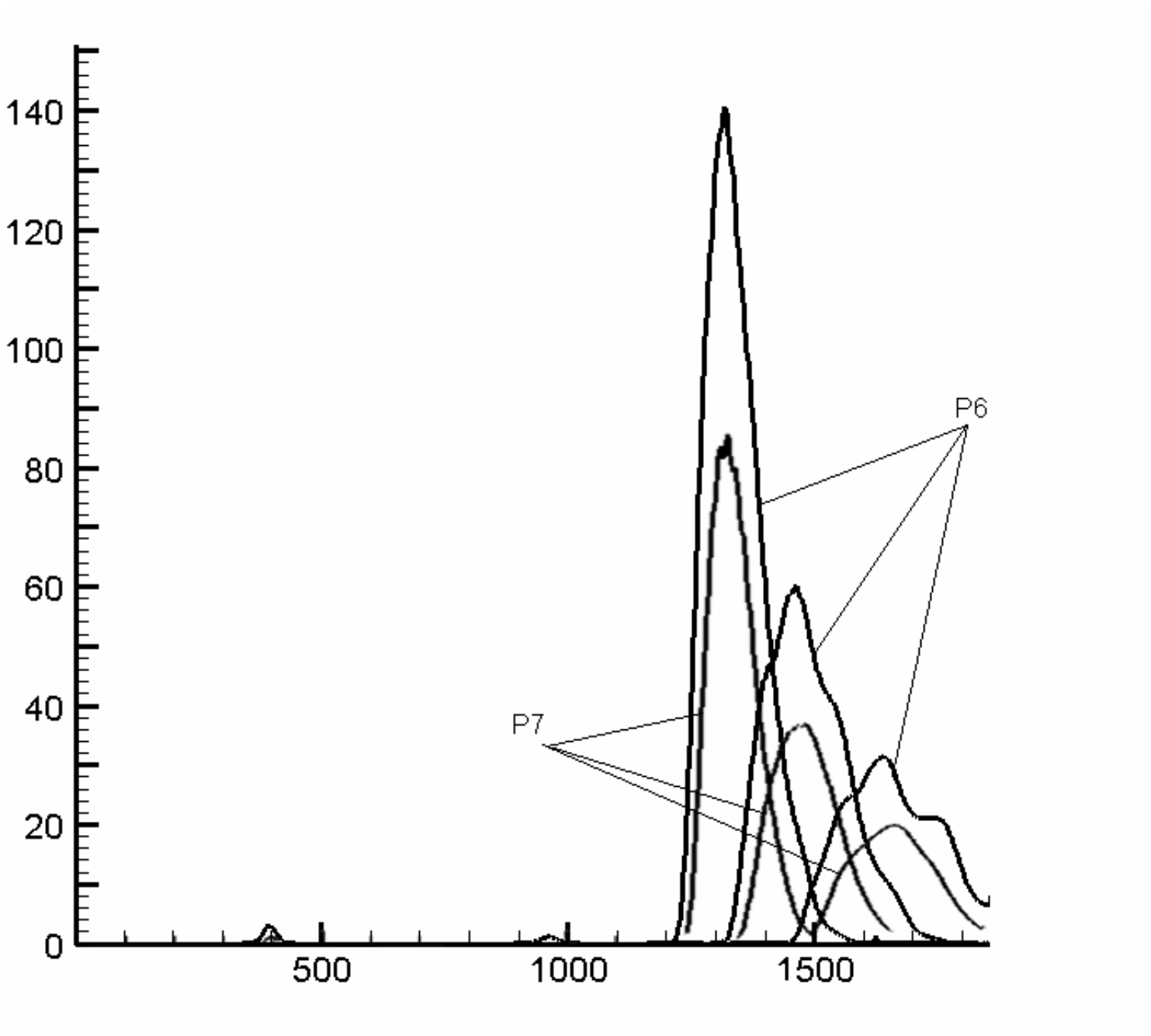
- For the further calculations we shall reduce a step of a grid (h=0.333 mm) and we shall keep a level of initial perturbations in a transitive layer (20 % of a variation of density with the additional requirement $0 \le C \le 1$).

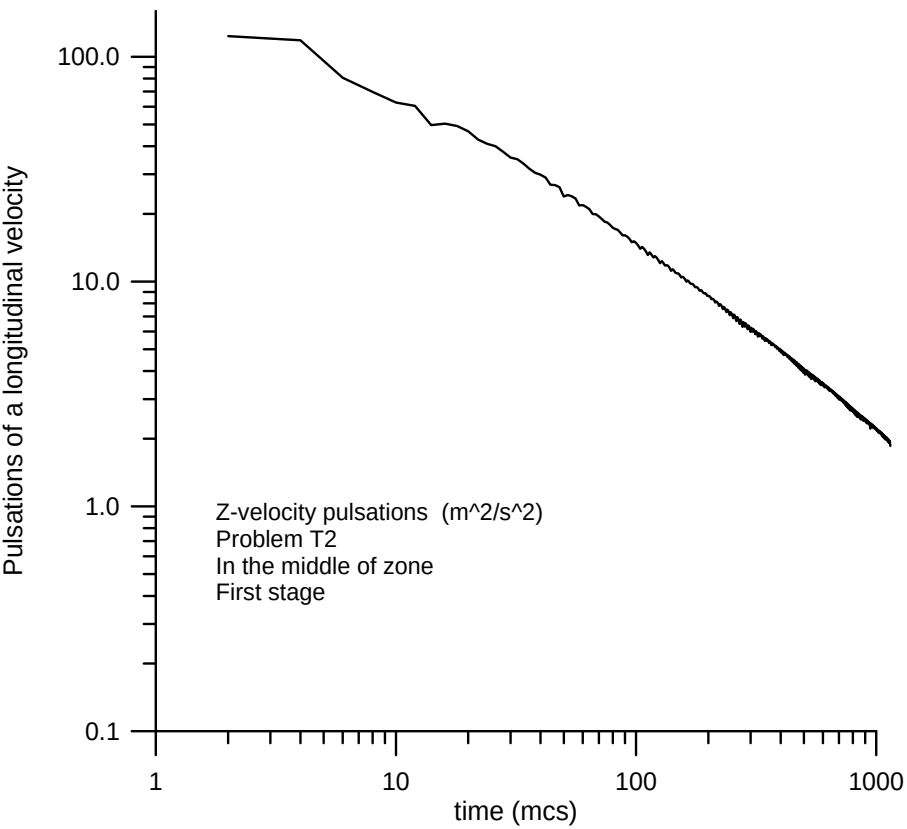
- These calculations can be lead for section of a tube 4x4 sm that will allow to reduce the general number of accounting cells twice.

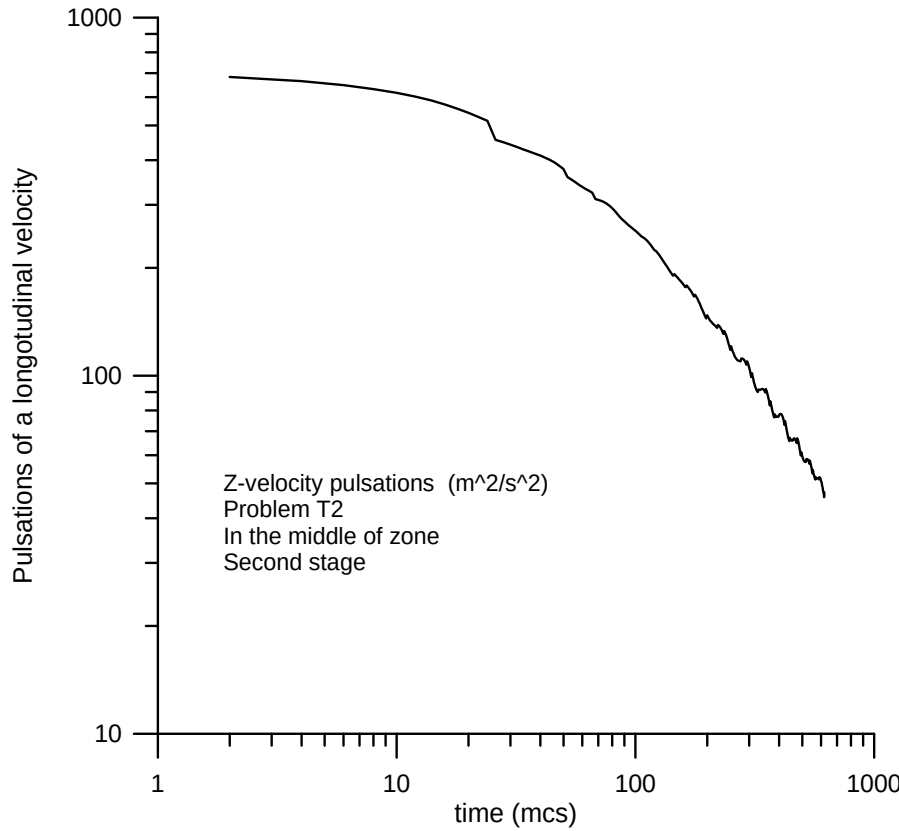

175
150
125
100
75
50
25
AIR
SF6
500
1000
1500
2000

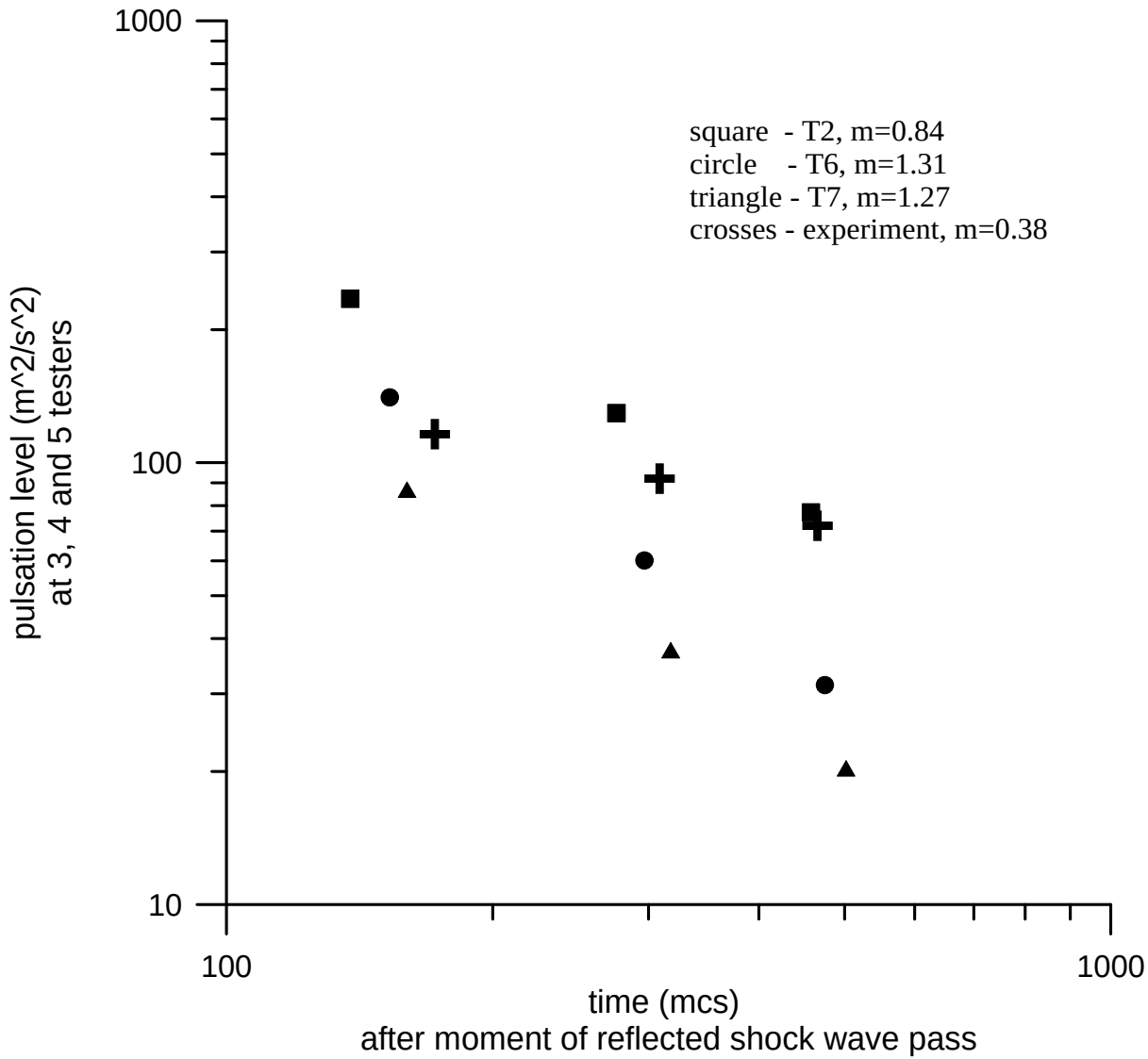

40
30
20
10
0
Zone Width (mm)
0
400
800
1200
1600
2000
time (mcs)
T2
T6
T7


140
120
100
80
60
40
20
0
500
1000
1500
161 mm
169 mm
178.5 mm
51 mm
P6
125.5 mm


140
120
100
80
60
40
20
0
500
1000
1500
P6
P7


100.0
10.0
1.0
0.1
Pulsations of a longitudinal velocity
Z-velocity pulsations (m^2/s^2)
Problem T2
In the middle of zone
First stage
1
10
100
1000
time (mcs)


1000
100
10
Pulsations of a longotudinal velocity
Z-velocity pulsations (m^2/s^2)
Problem T2
In the middle of zone
Second stage
1
10
100
1000
time (mcs)

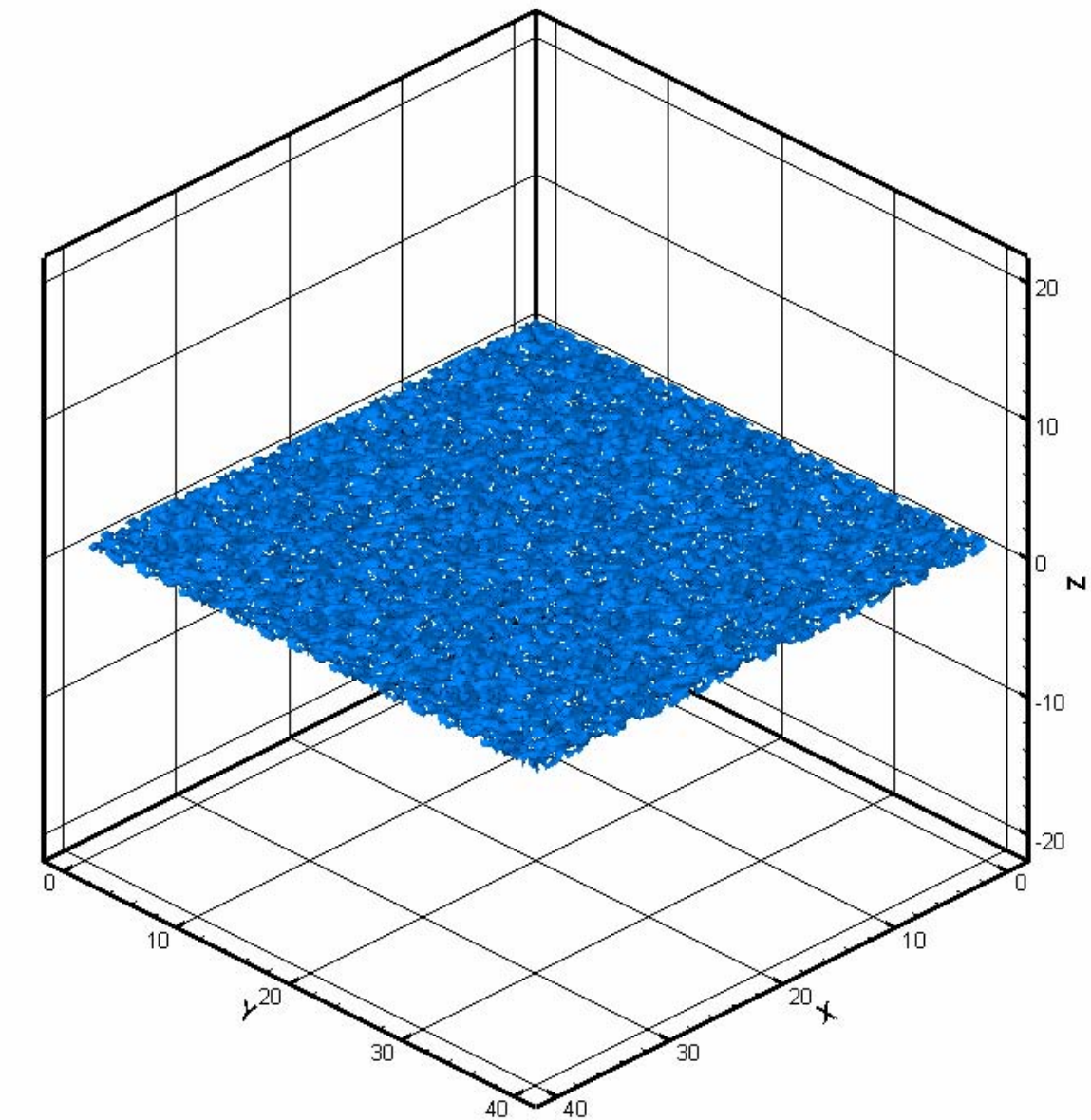

1000
100
10
100
1000
square - T2, m=0.84
circle - T6, m=1.31
triangle - T7, m=1.27
crosses - experiment, m=0.38
pulsation level (m^2/s^2)
at 3, 4 and 5 testers
time (mcs)
after moment of reflected shock wave pass

- Pulsation in mixing zone $W_p(t)$ may be approximate by expression

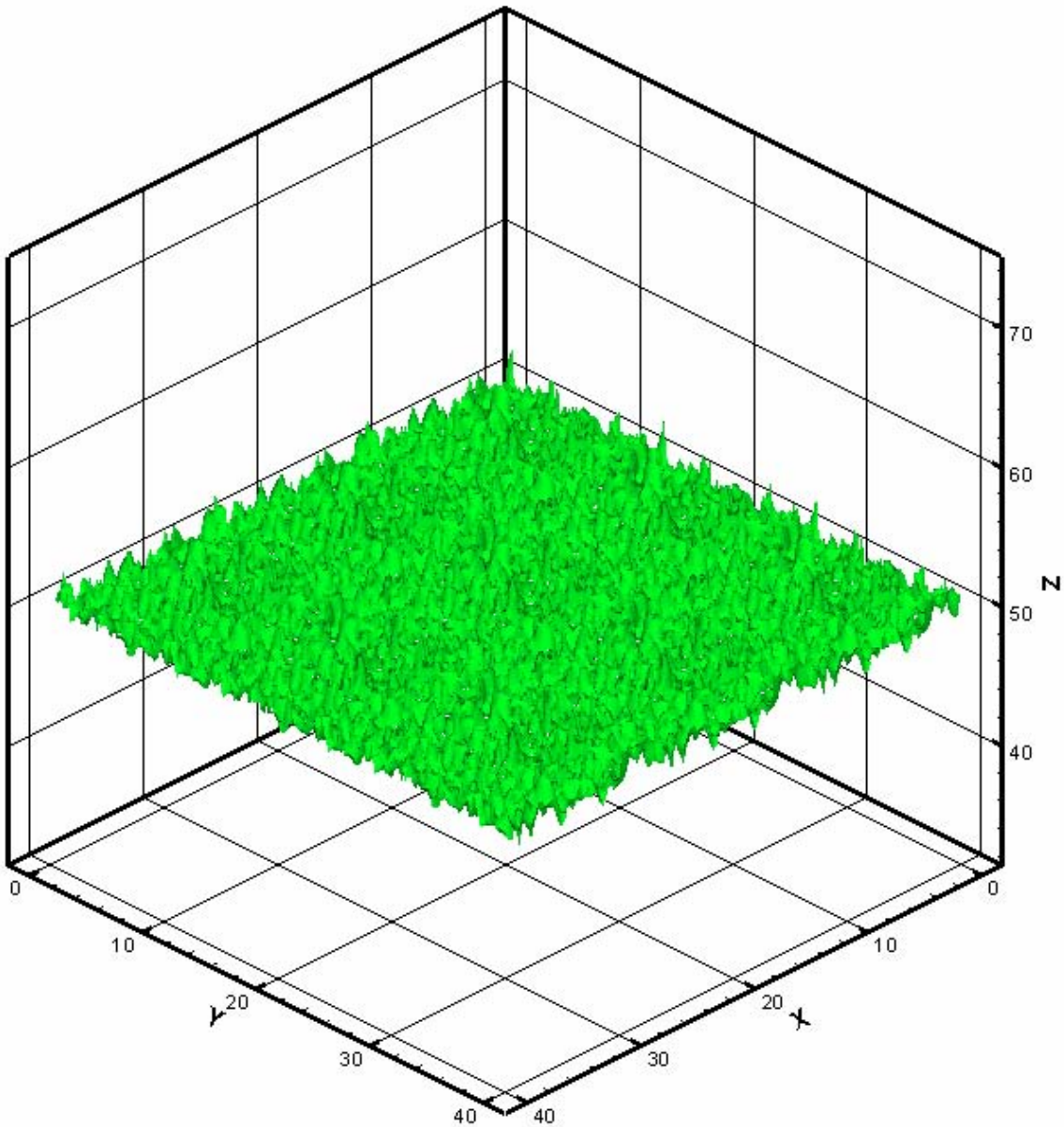
  $W_p(t)=B(t-t^*)^{-m}$,

  $Wp\sim(dL/dt)^2\sim(L/t)^2\sim(t-t^*)^{(2k-2)}$, $m=2-2k$.

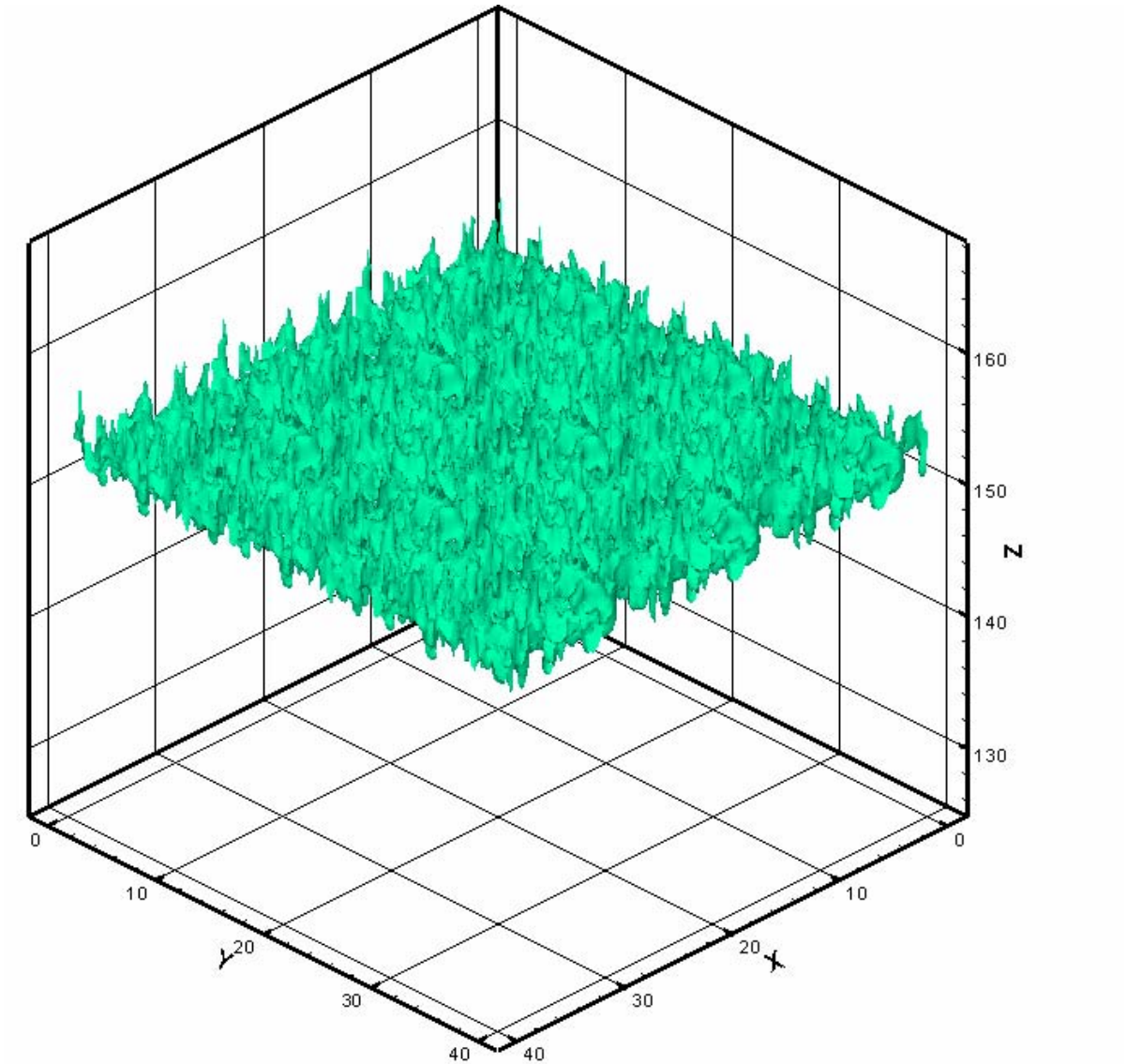
t = 0.



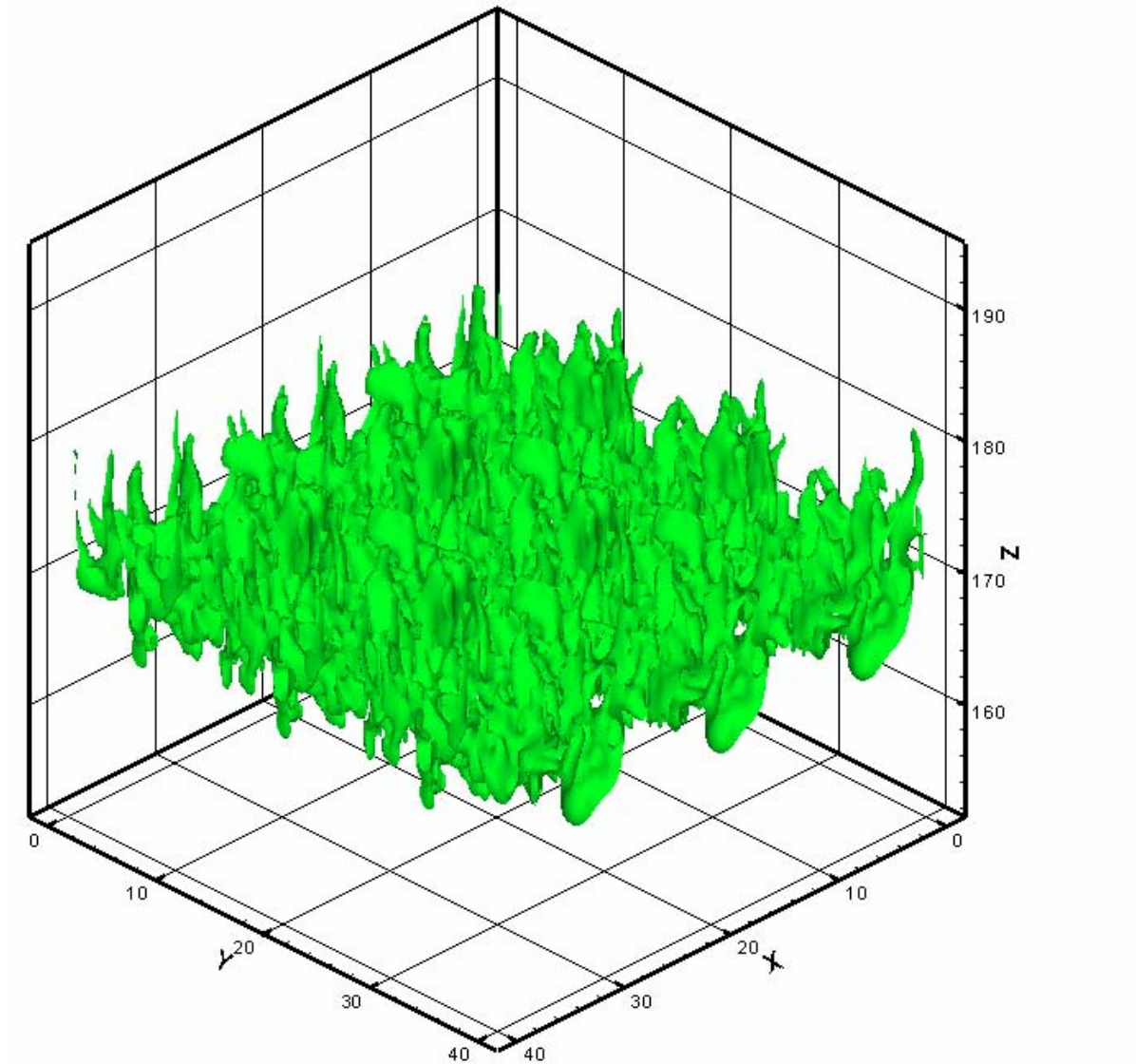
t = 400 mks



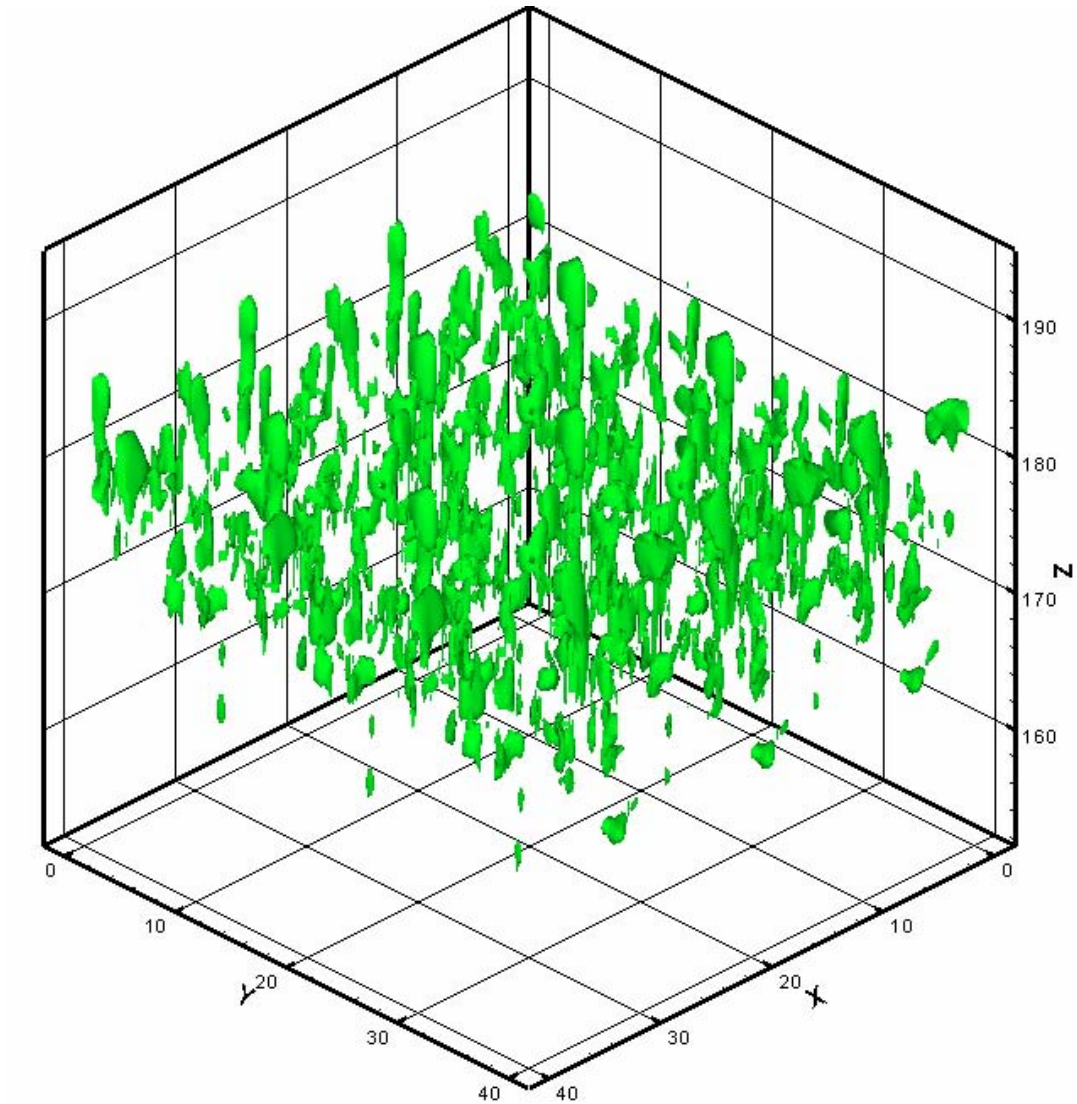
t = 1200 mks



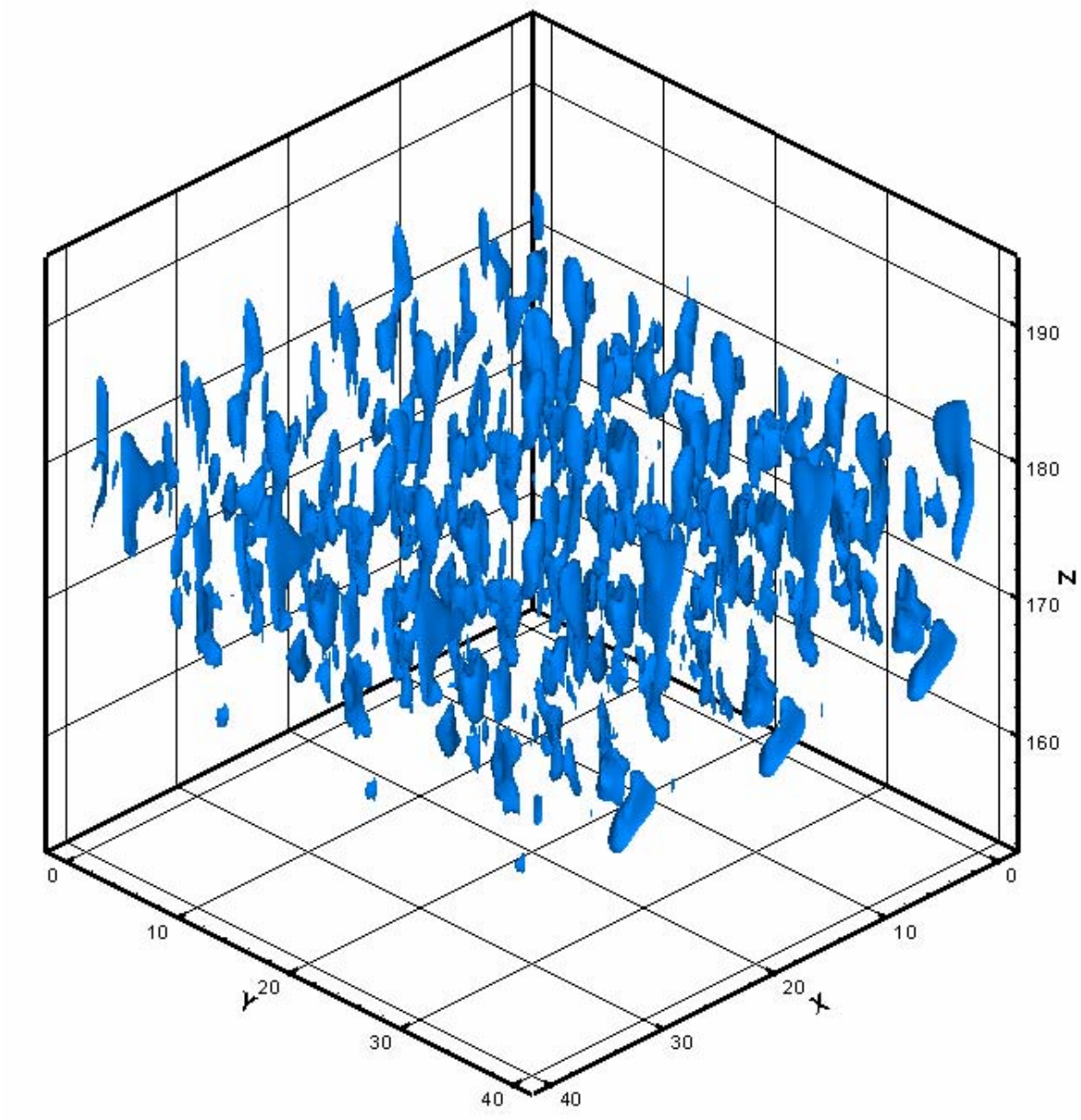
t = 1600mks



Iso-Surface |rotV|, t=1600 mks

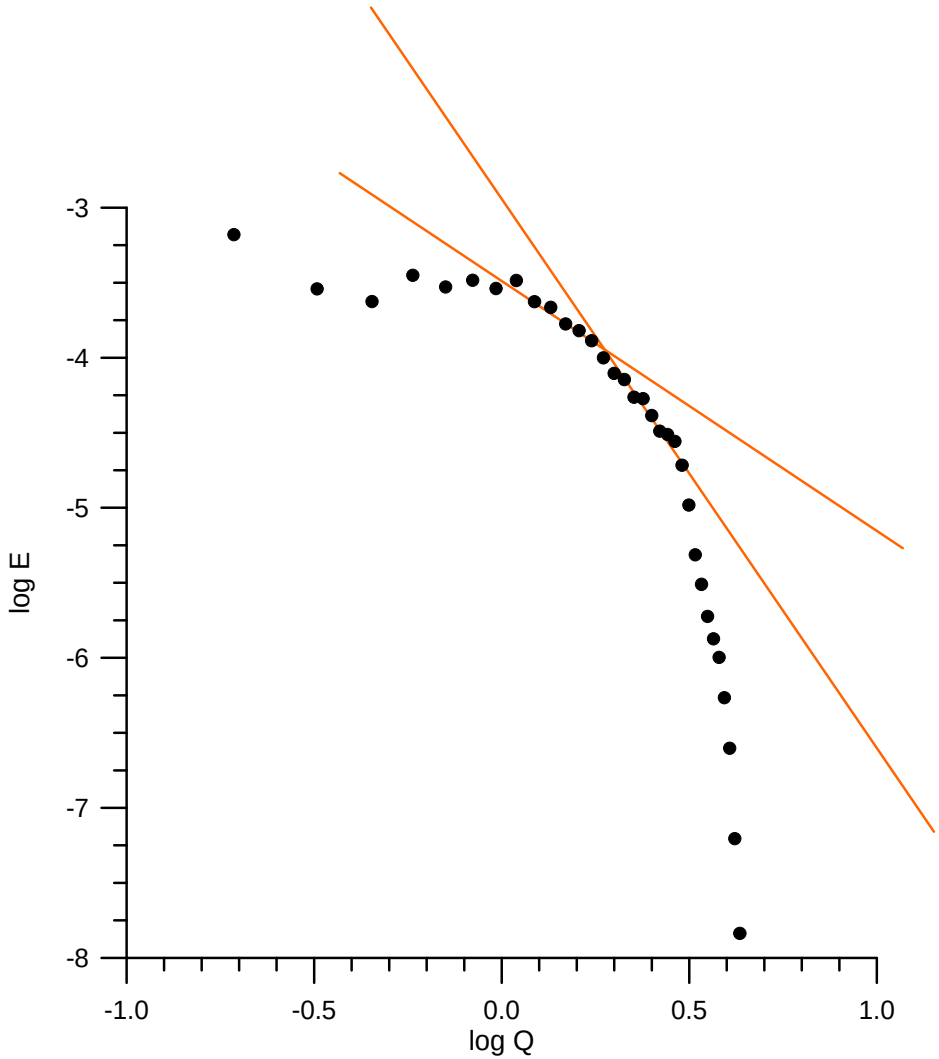


Iso-Surface Ekin, t=1600 mks



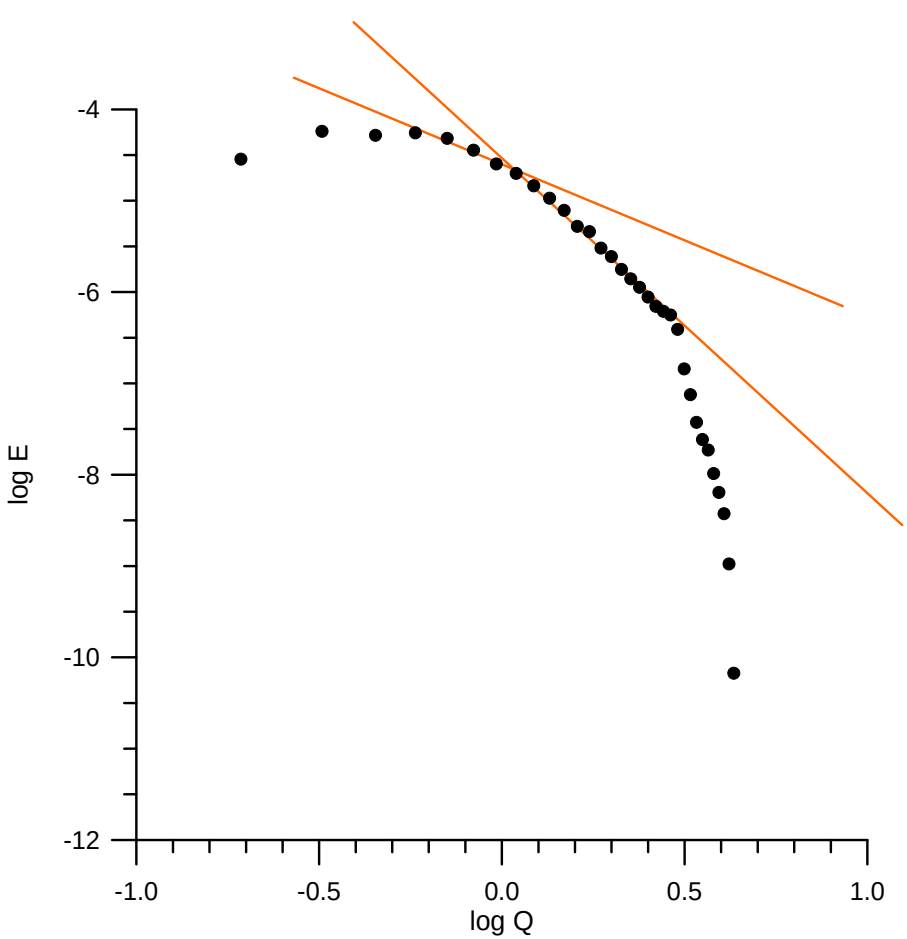
t=1200mks

T6



t=1600mks

T6



T7

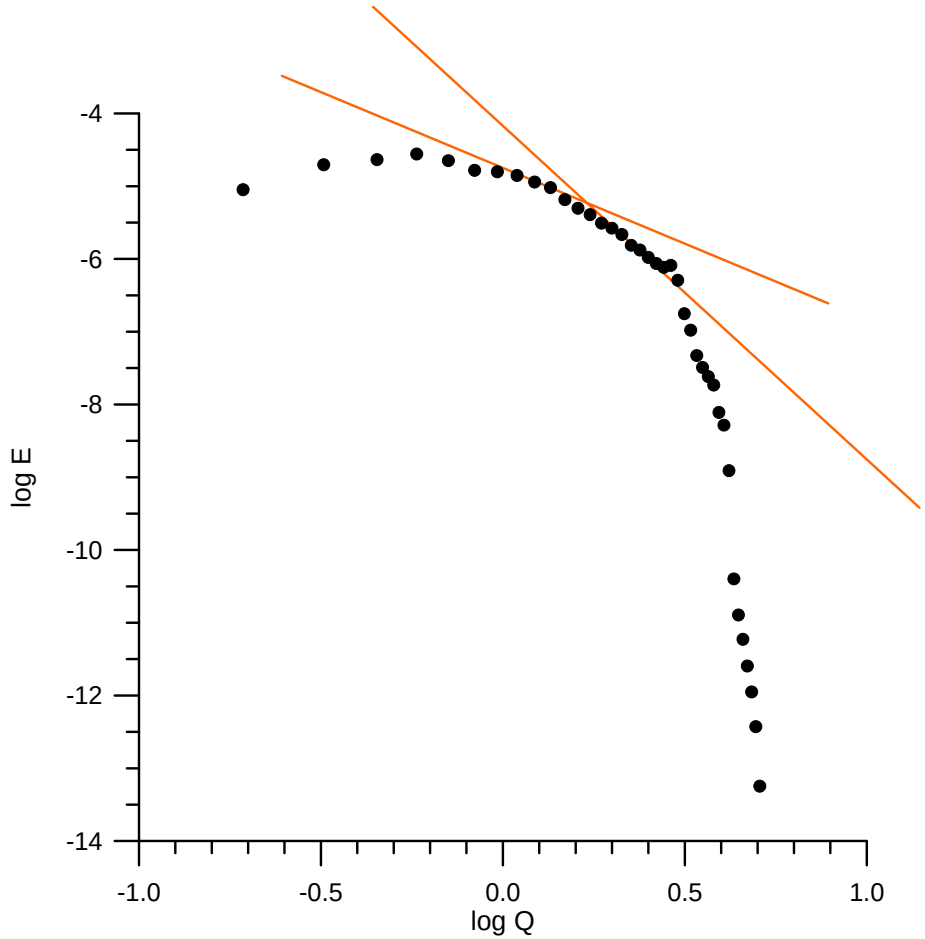
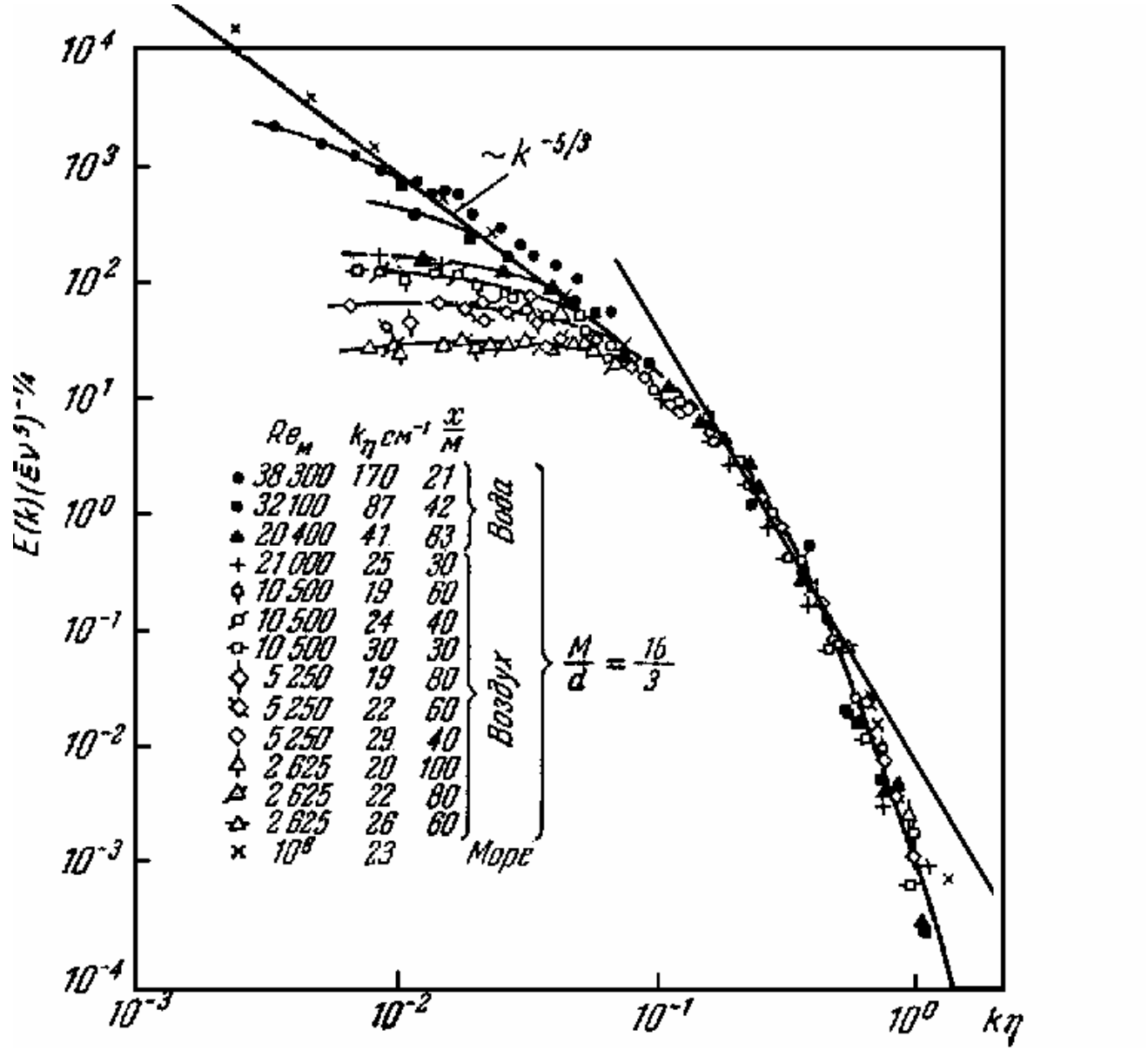
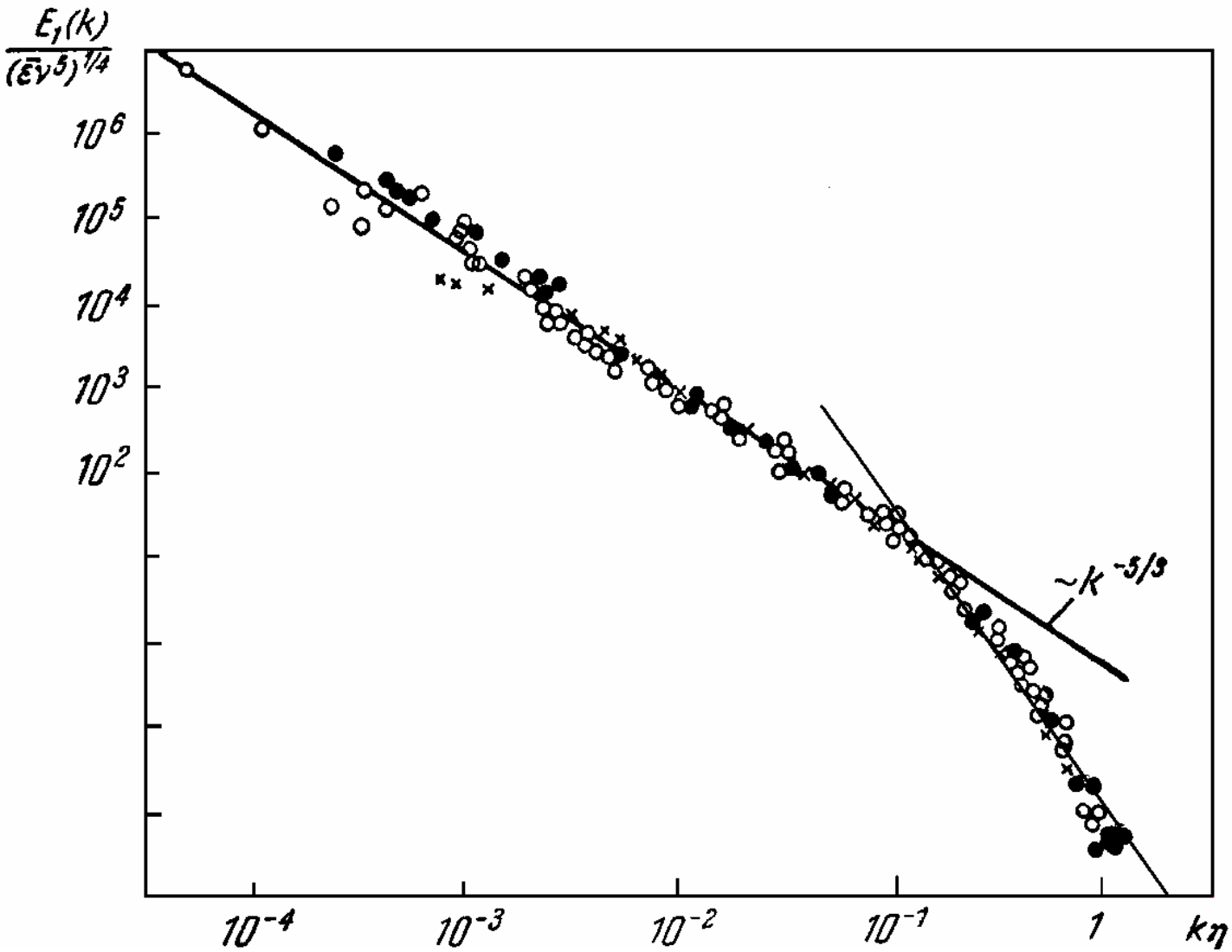
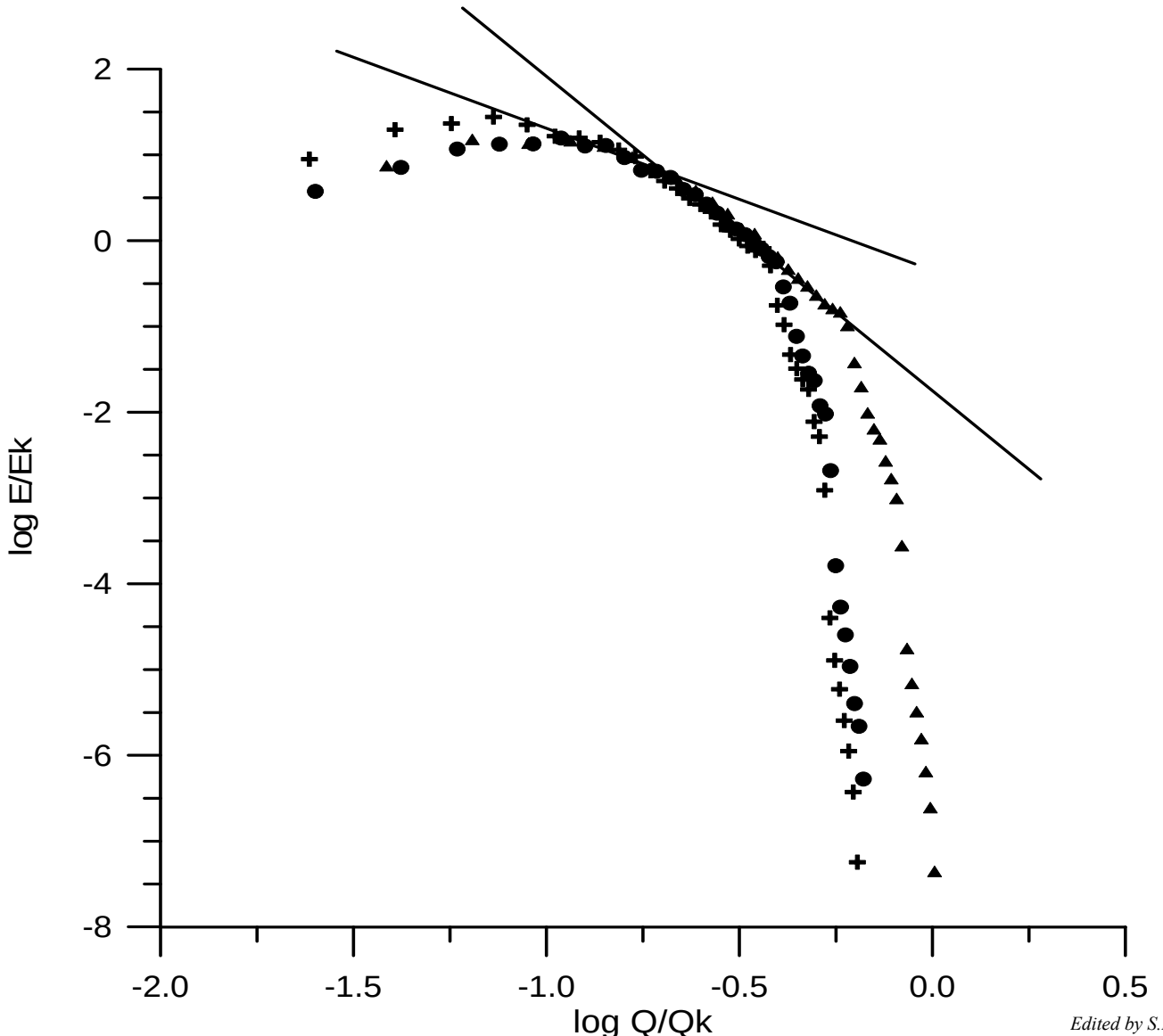


Figure from A.S.Monin and A.M.Jaglom monograph. Experimental value of spectral density. Line have inclination –5/3 and –11/3.




$E_1(k)$
$(\bar{\varepsilon}\nu^5)^{1/4}$
10^6
10^5
10^4
10^3
10^2
$\sim k^{-5/3}$
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
$k\eta$

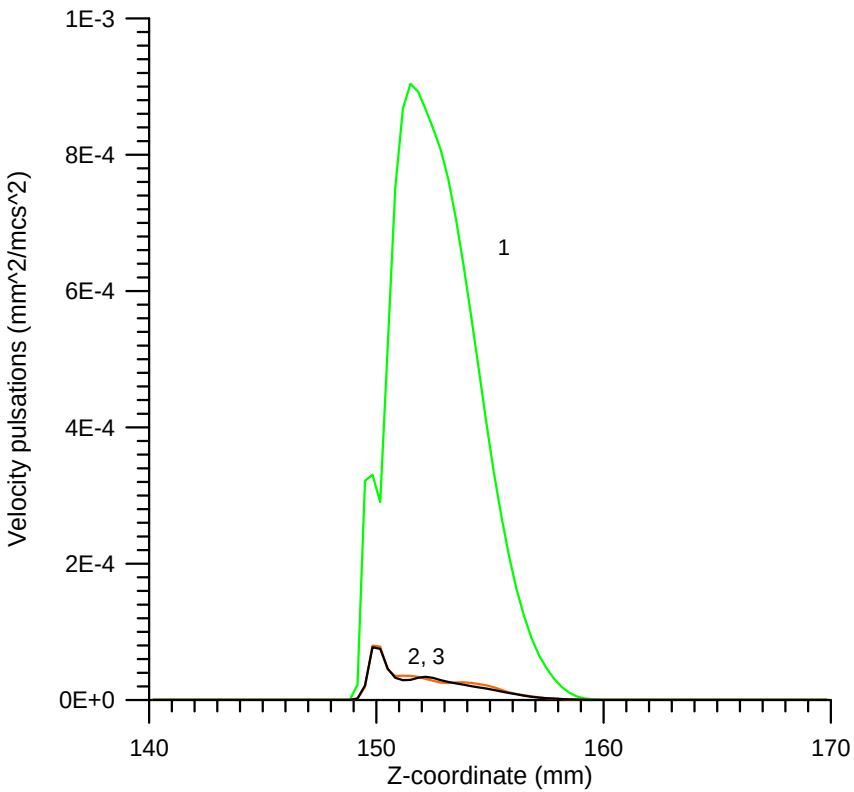
Orthonormalized spectral density of kinetic energy in tasks T2 (circles), T6 (triangles) и T7 (crosses). Line have inclination –5/3 and –11/3.



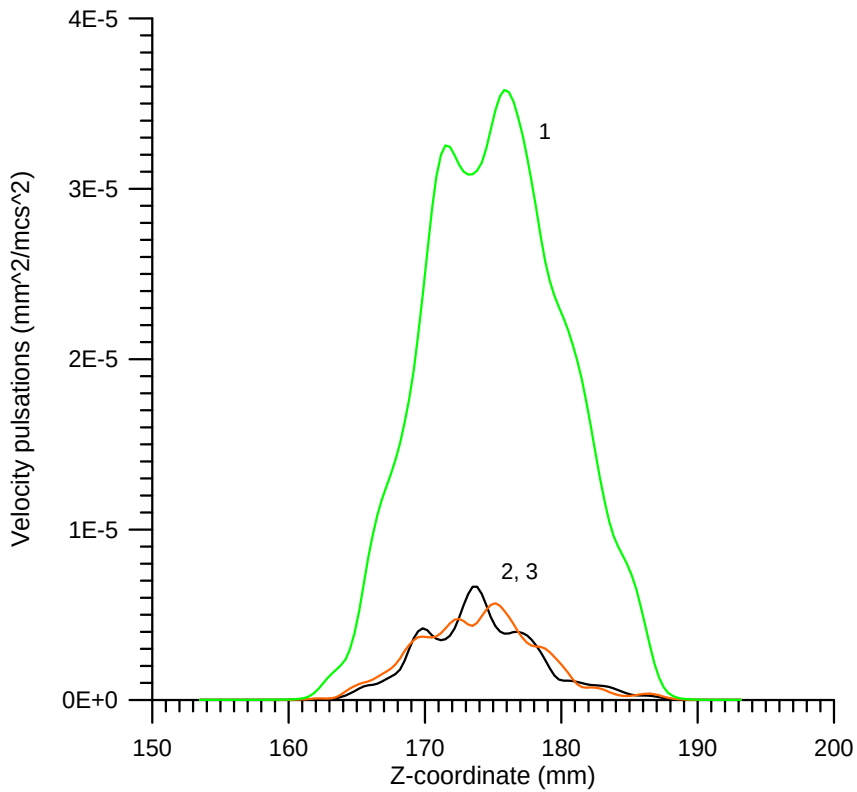
T6

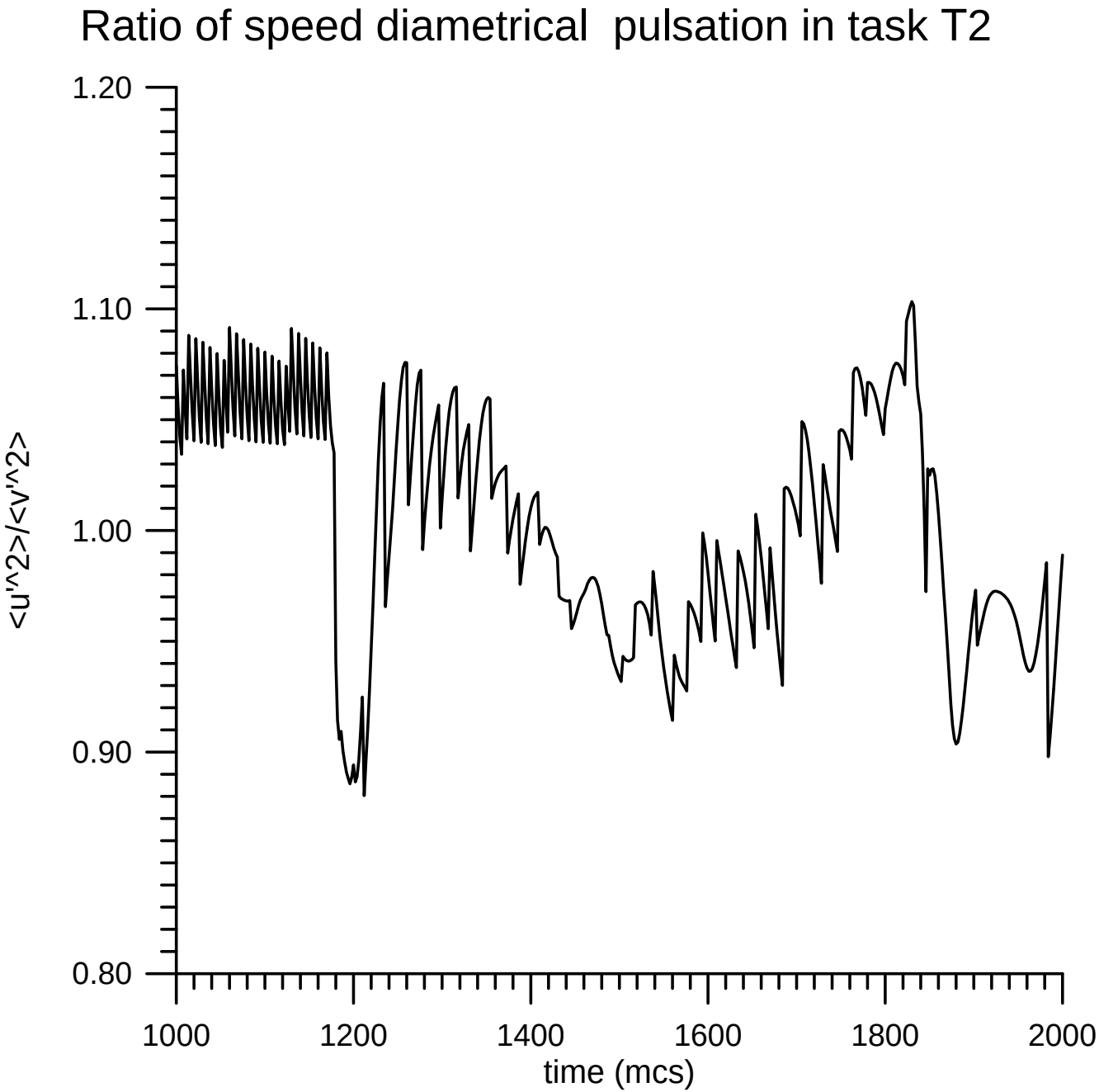
<w'^2> -(curve 1), <v'^2> -(curve 2) <u'^2>- (curve 3)

t=1200mks

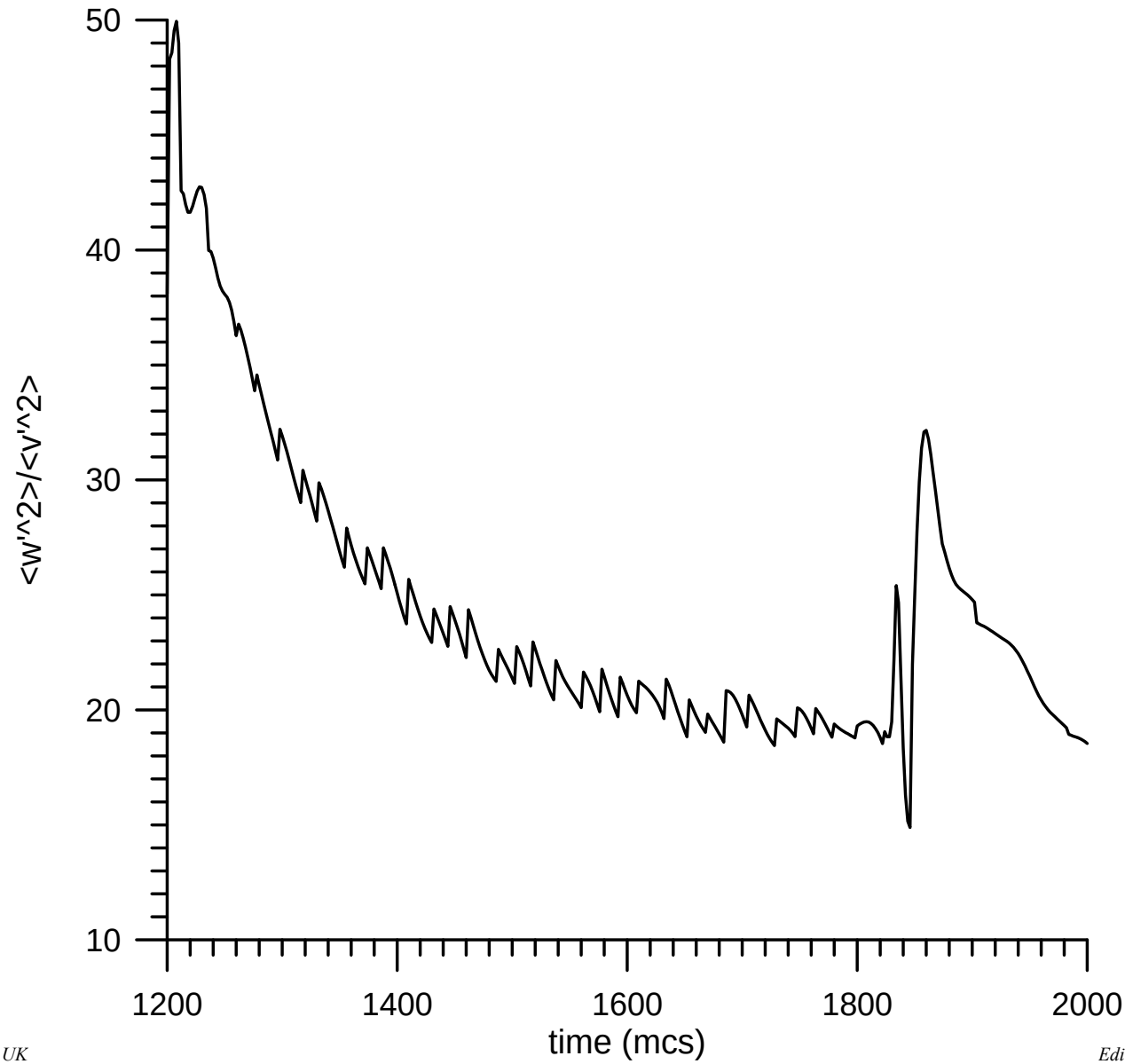


t=1600mks




Ratio of speed diametrical pulsation in task T2
1.20
1.10
1.00
0.90
0.80
<u'^2>/<v'^2>
1000
1200
1400
1600
1800
2000
time (mcs)

Ratio of speed longitudinal pulsation <w′2> to diametrical pulsation <v′2> in task T2



Conclusion

- Simulation of Richtmyer-Meshkov instability were fulfilled (parallel version of the NUT code) at a set of the condensed grids. (h=1.0, 0.5 and 1/3mm).
- Dependence of mixing zone and velosity pulsations are obtain.
- The main characteristics of a mixing zone width growth with time and level of pulsation are established in a connection with the forms and amplitudes of the initial perturbations.
- The spectral analysis of the turbulent kinetic energy shows,that we observe inertial interval ($E \sim q^{-5/3}$) and dissipative interval ($E \sim q^{-11/3}$)