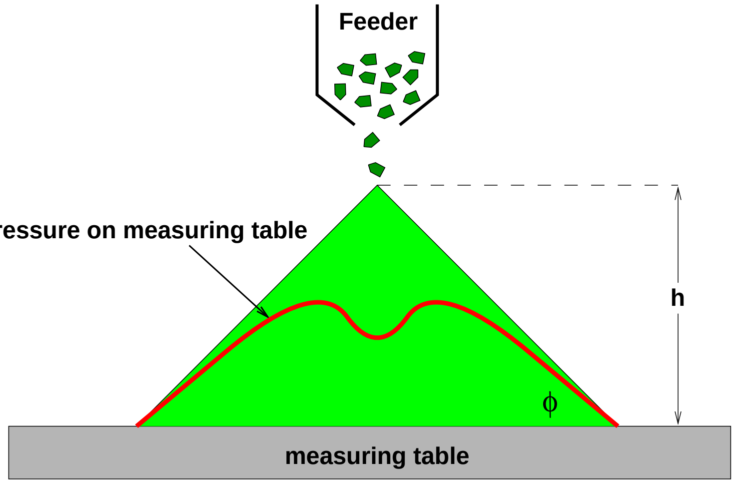
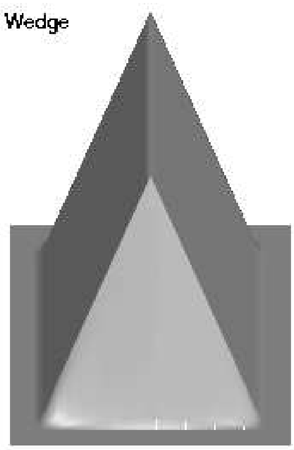
The Problem

The problem of finding the pressure distribution under a heap is not trivial and yields some counter-intuitive results. Influenced by different parameters the minimum of the pressure may appear at the center of the sandpile.



The dip under the heap is observed when a conical pile is built up from a point source. Wedges and conical piles built by a layer-wise construction do not show a dip, neither in experiments nor in simulatior

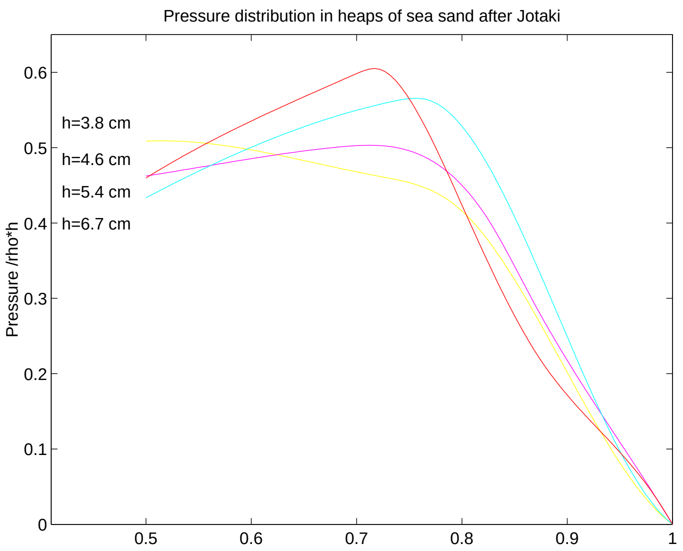


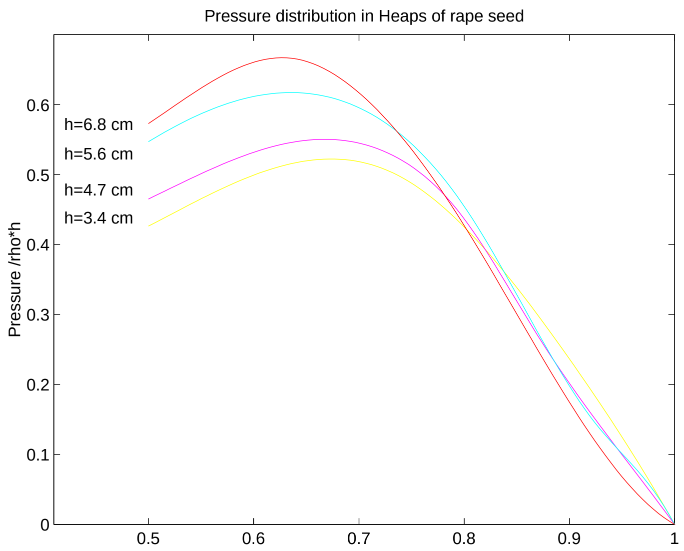
Experiments

Jotaki et al. performed experiments using

- rape seed
- sea sand
- 2 different kind of fertilizers

The size of the heaps ranged from 12 to 36 cm in diameter. The pressure gauge had a diameter of 2 cm.

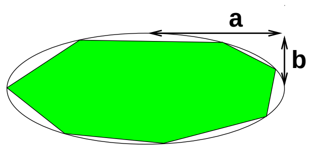




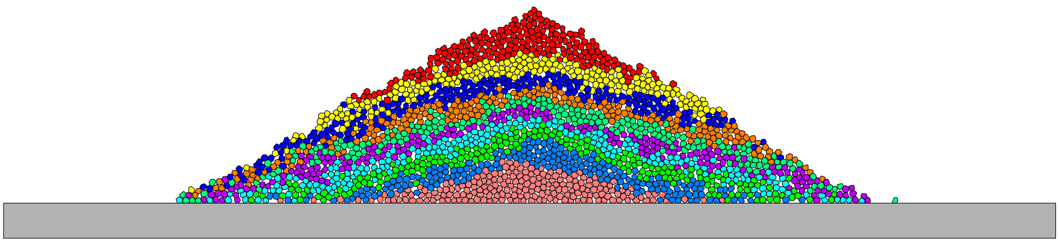
Material	Pressure Dip [%]	Angle of rep. [deg]	Particle size [mm]	Coeff. int. friction
GB 708	81	22.5	0.3-0.7	0.41
GB 733	60	22.7	0.044-0.088	0.27
Sea Sand	77	33.6	0.17-0.71	0.6
Rape Seed	87	24.9	1.4	0.40

Simulations

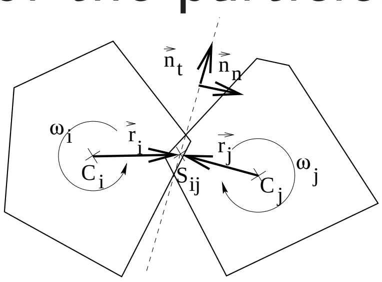
We use a two dimensional molecular-dynamics simulation. The particles are modelled as irregular heptagons.



By varying the size of a and b we simulate sand piles with a certain distribution of particle sizes. (polydispersive)



The forces acting between particles are calculated from the overlap of the particles.

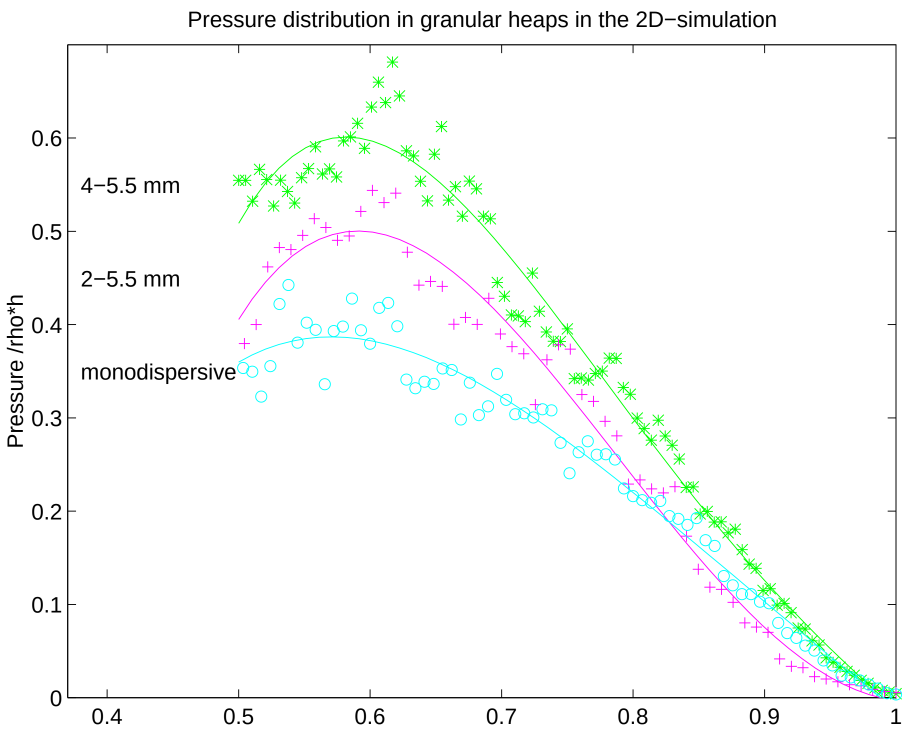


The advantage over hard-particle simulations is the possibility to incorporate static friction and therefore to simulate static configurations.

Results

Surprisingly, we find the fluctuations in pressure suppressed in small systems due to polydispersity. The size of the pressure dip is comparable to the pressure dip found experimentally. The angle of repose seems to increase with the polydispersity of the system.

Angle of rep. [deg]	Particle size $a \times b$ [mm]	Heap height [cm]	Particle tot.
23	4×5	14	2600
24	$4 \times$ 4-5.5	17	4000
28	2-5.5 $\times$ 2-5.5	8	2000



Building a pile

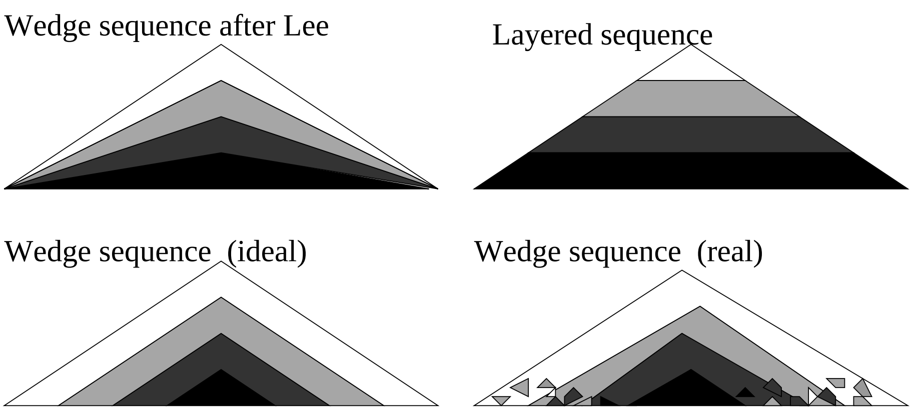
One has to build the pile from a point source, but even then the existence of the dip depends on the height of the feeder above the pile. It seems that the formation of arches inside the pile is responsible for the formation of a dip.

For small heights one gets dips but has large avalanches. This may disturb the formation of arches.

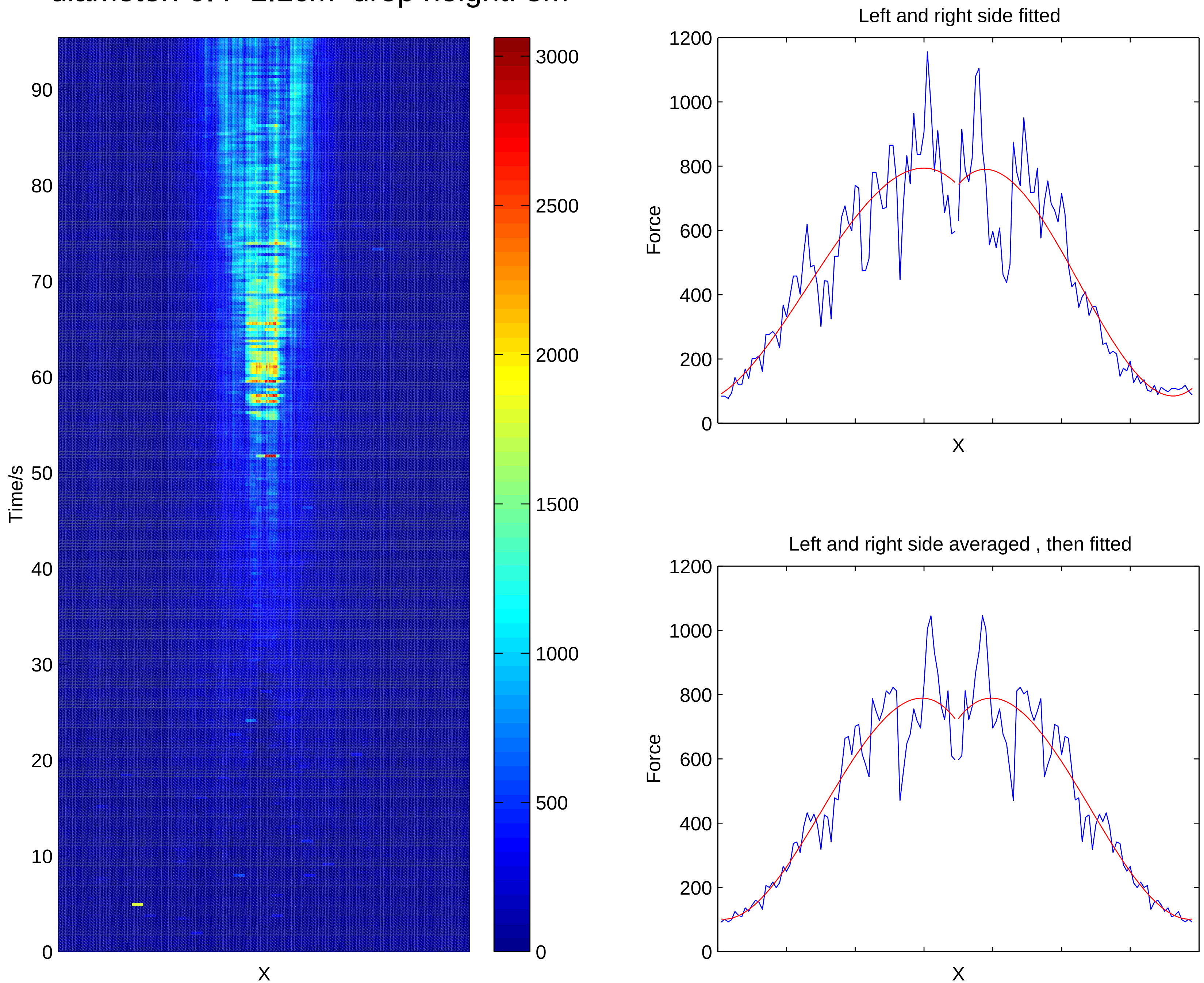
For medium heights the dips can be seen clearly.

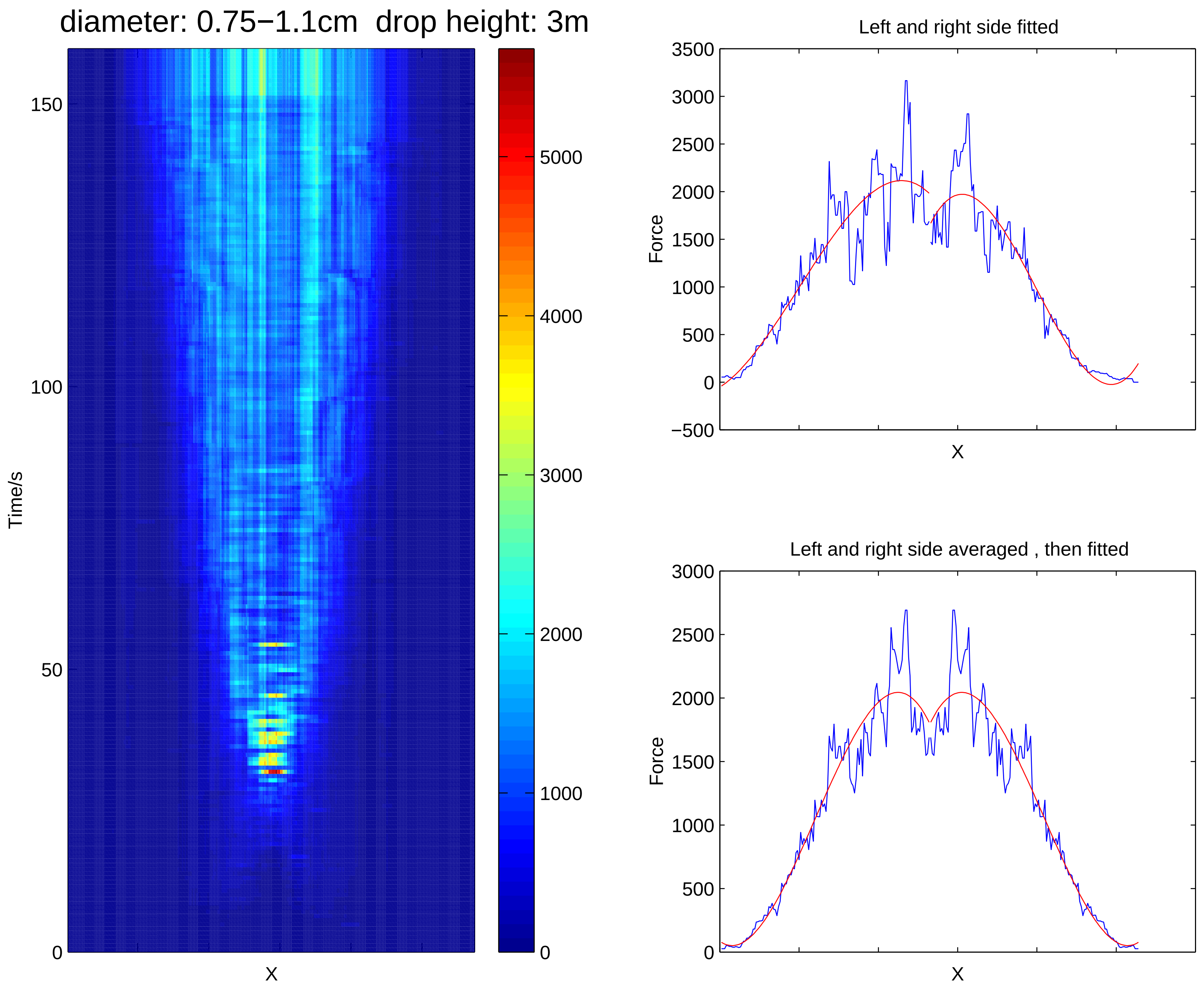
Building the pile from large heights we observe strong fluctuations in the pressure.

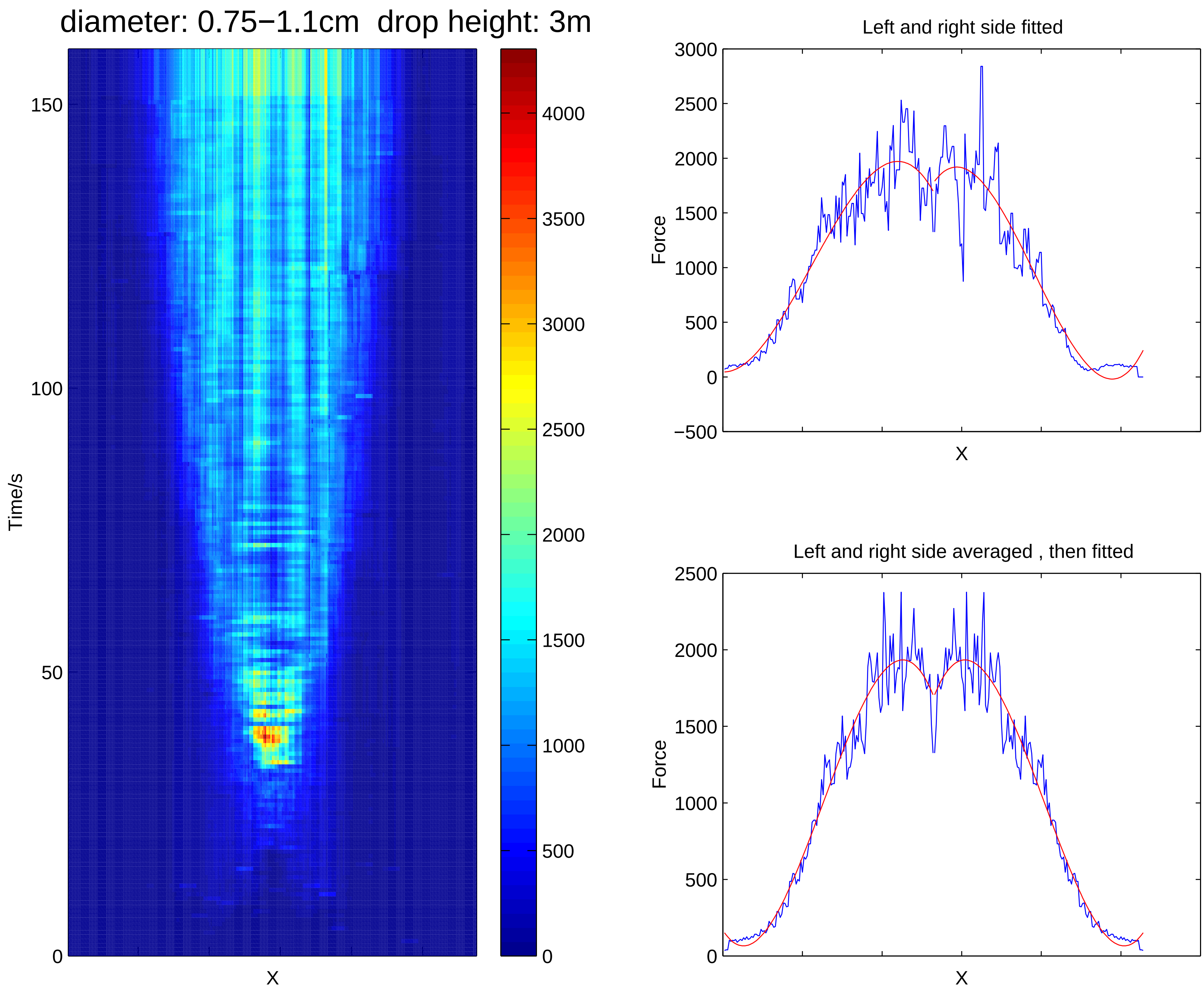
These observations suggest the existence of an optimal energy of particle impact.



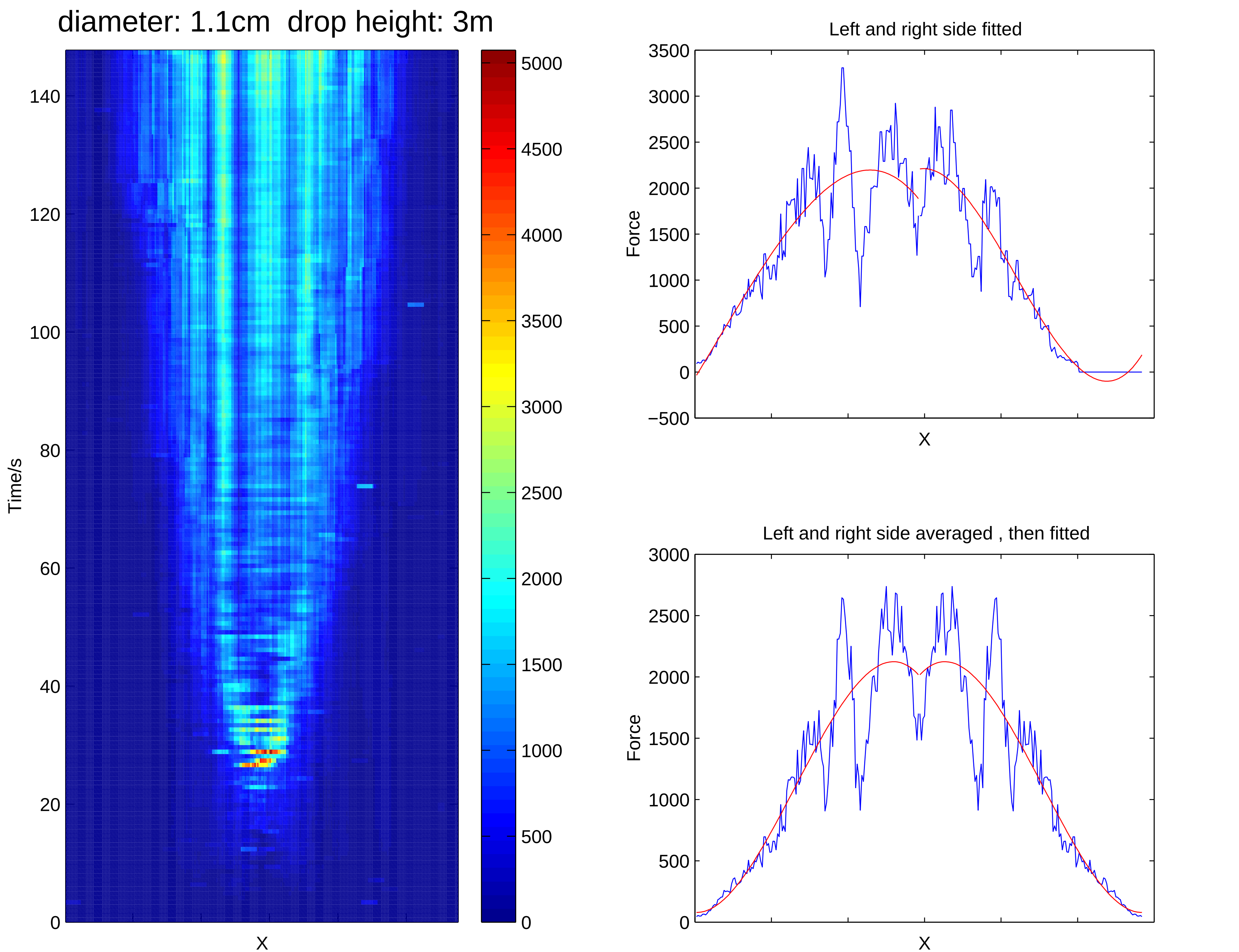
diameter: 0.4−1.1cm drop height: 3m



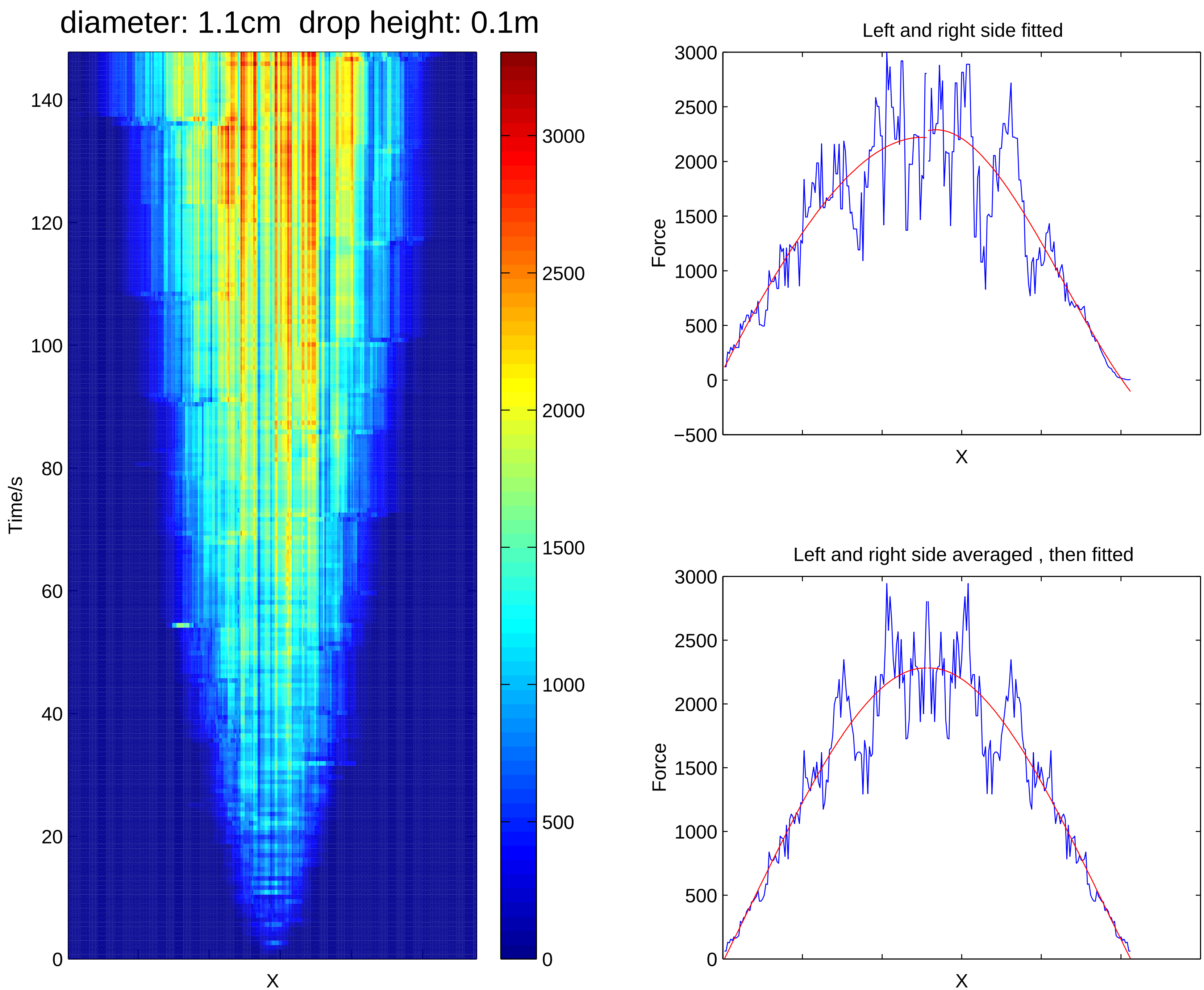

diameter: 0.75−1.1cm drop height: 3m
Time/s
150
100
50
0
X
5000
4000
3000
2000
1000
0
Left and right side fitted
Force
3500
3000
2500
2000
1500
1000
500
0
−500
X
Left and right side averaged , then fitted
Force
3000
2500
2000
1500
1000
500
0
X

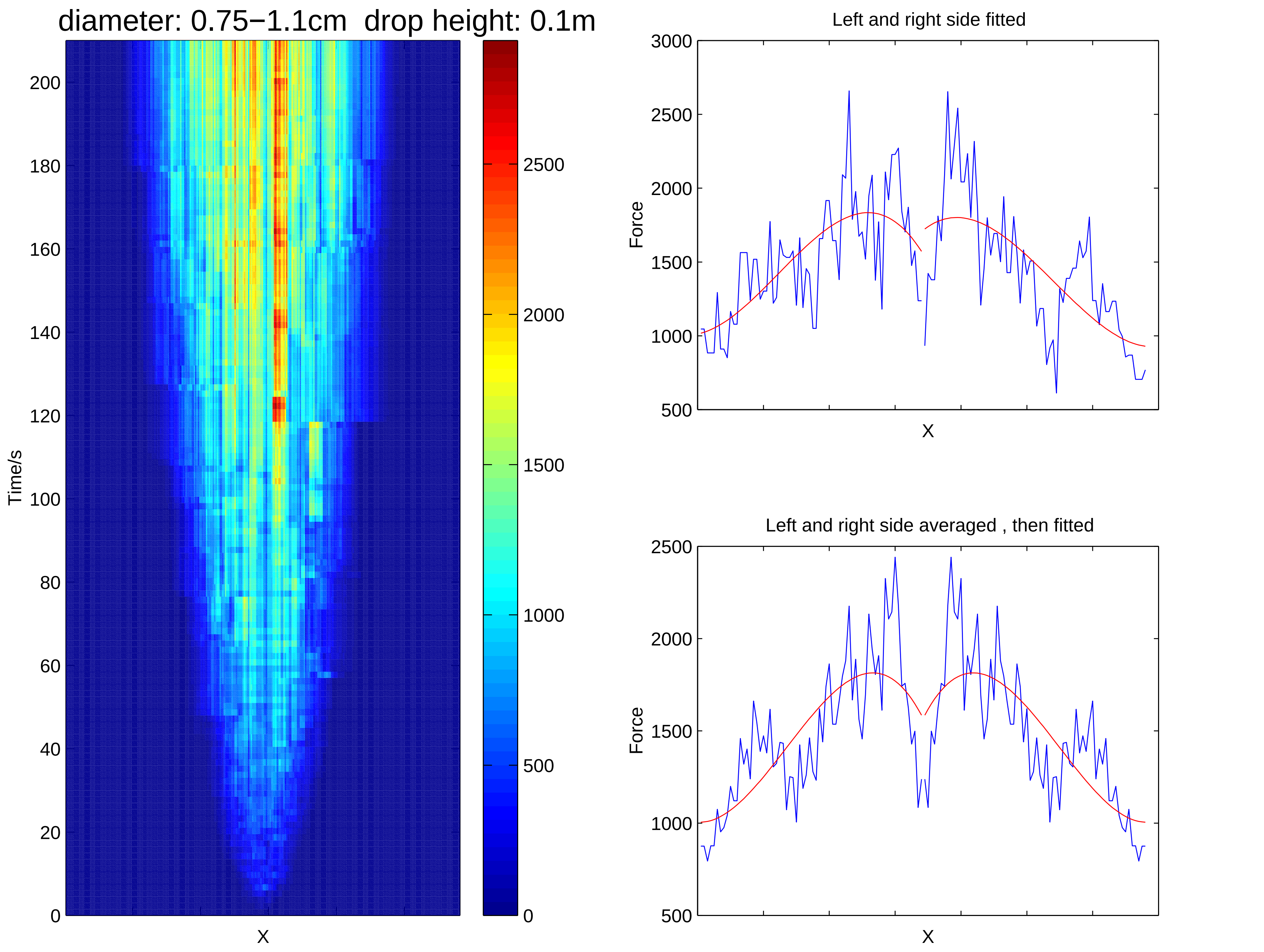


diameter: 0.75−1.1cm drop height: 3m
Time/s
150
100
50
0
X
4000
3500
3000
2500
2000
1500
1000
500
0
Left and right side fitted
Force
3000
2500
2000
1500
1000
500
0
−500
X
Left and right side averaged , then fitted
Force
2500
2000
1500
1000
500
0
X



diameter: 1.1cm drop height: 3m
Time/s
X
0
20
40
60
80
100
120
140
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Left and right side fitted
Force
3500
3000
2500
2000
1500
1000
500
0
−500
X
Left and right side averaged , then fitted
Force
3000
2500
2000
1500
1000
500
0
X


diameter: 1.1cm drop height: 0.1m
Time/s
0
20
40
60
80
100
120
140
X
0
500
1000
1500
2000
2500
3000
Left and right side fitted
Force
−500
0
500
1000
1500
2000
2500
3000
X
Left and right side averaged , then fitted
Force
0
500
1000
1500
2000
2500
3000
X


diameter: 0.75−1.1cm drop height: 0.1m
Time/s
X
0
20
40
60
80
100
120
140
160
180
200
0
500
1000
1500
2000
2500
Left and right side fitted
Force
X
500
1000
1500
2000
2500
3000
Left and right side averaged , then fitted
Force
X
500
1000
1500
2000
2500