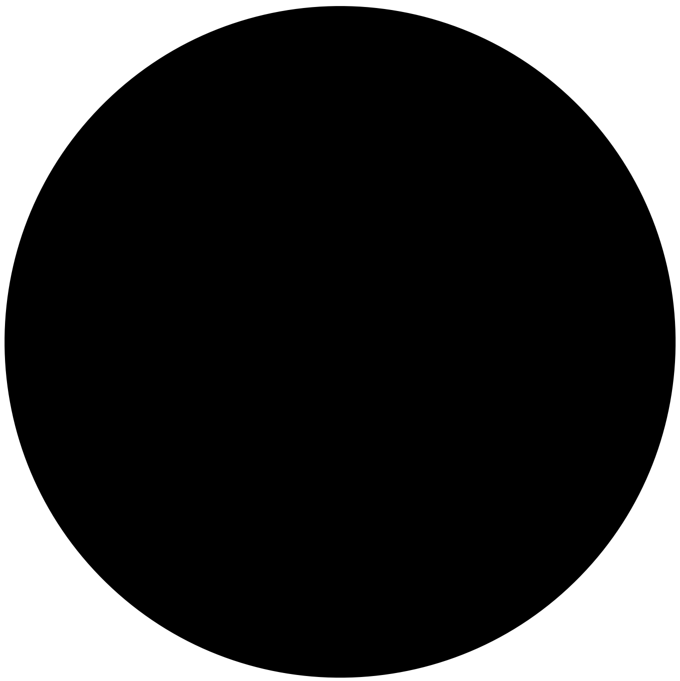
Quickly before we start.....

My 2ct. on Image Processing

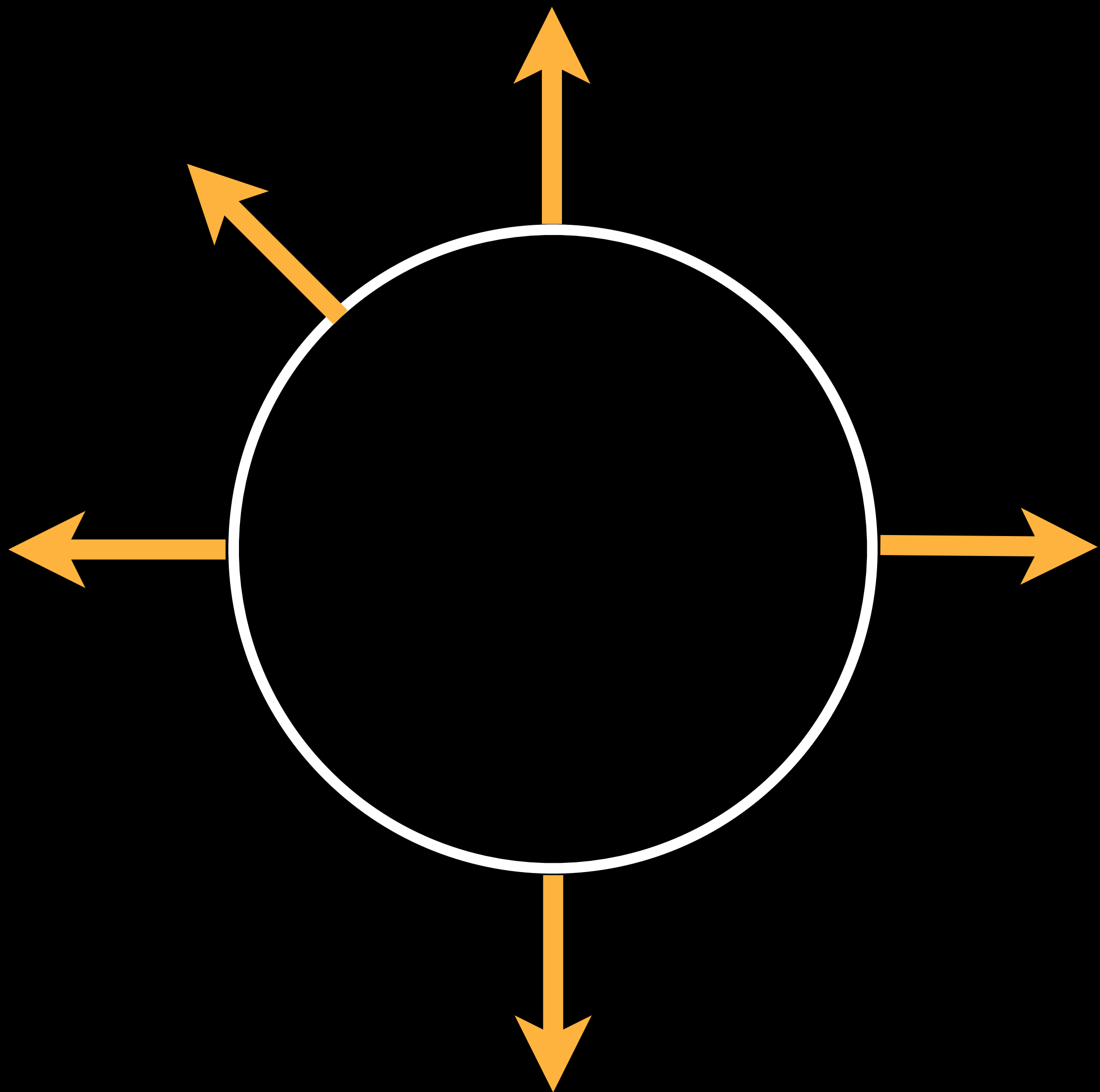
fast-hough-transformation for circles

(or: how to computationally fast turn a black circle into a white spot)



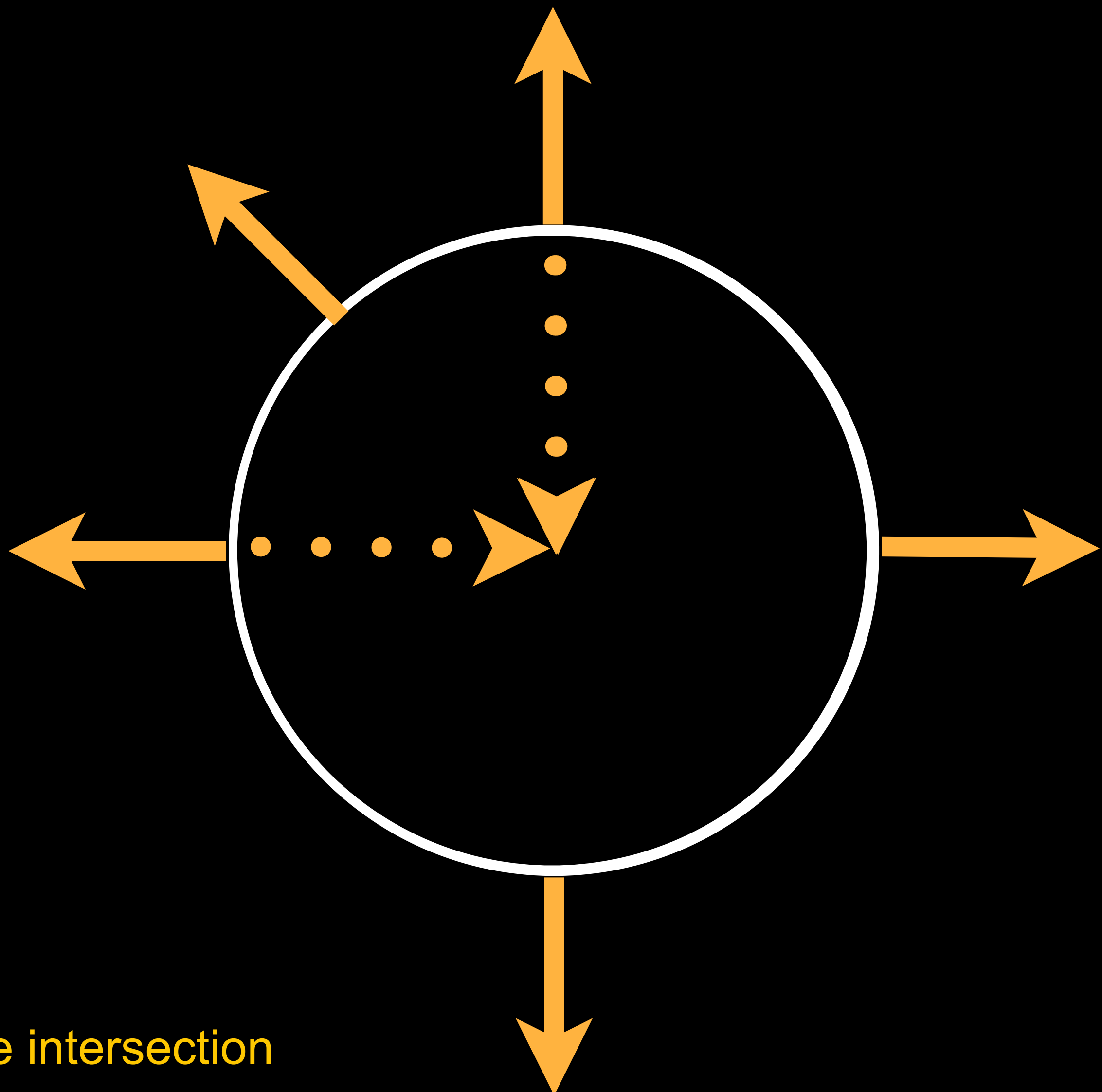
Compute brightness gradient

Gives you surface normals



If you know the radius already:

Walk for one radius length along oppisite direction and you're at the center



Otherwise: compute intersection

Mark the endpoints and you're

done

or just average the vectors

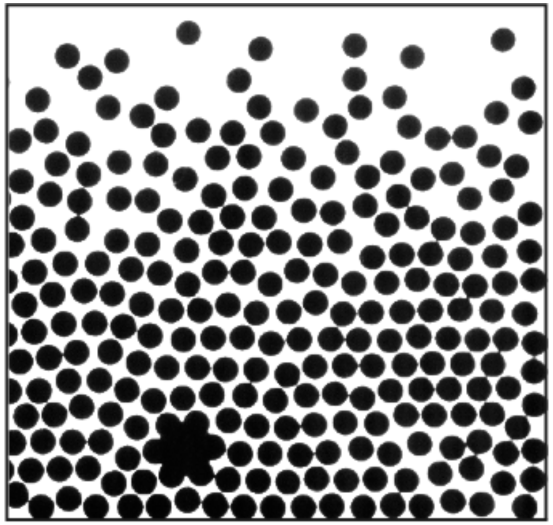
Computational effort:

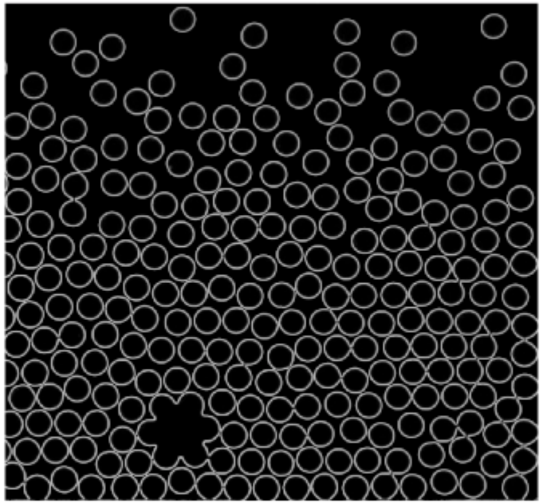
Compute gradient
Threshold surface normals
Multiply surface normals by radius
Average computed centers

Hundreds of Megapixel-Frames per Second on Desktop PC from 2010

Real World Example

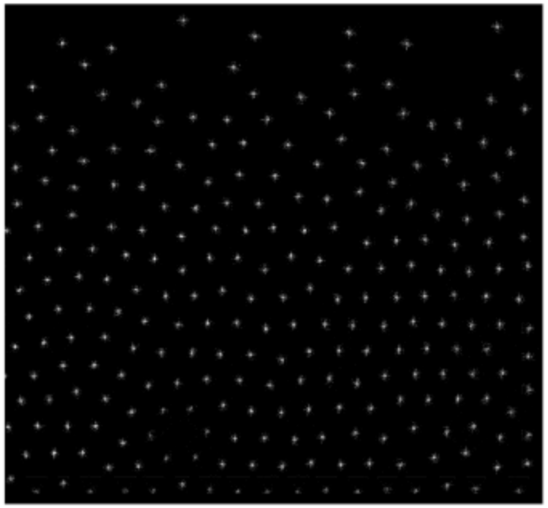
Camera Image

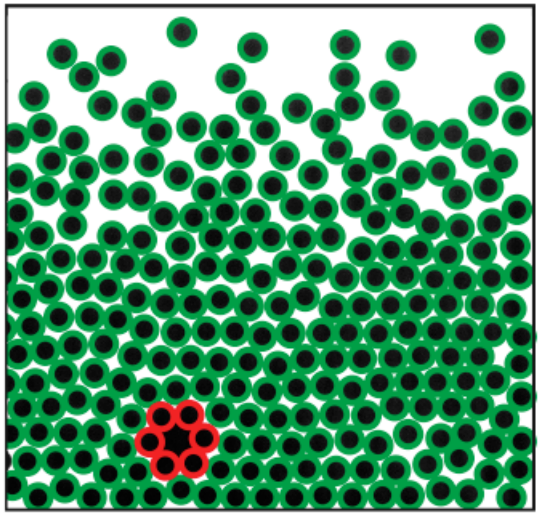




abs(Gradient)

Hough

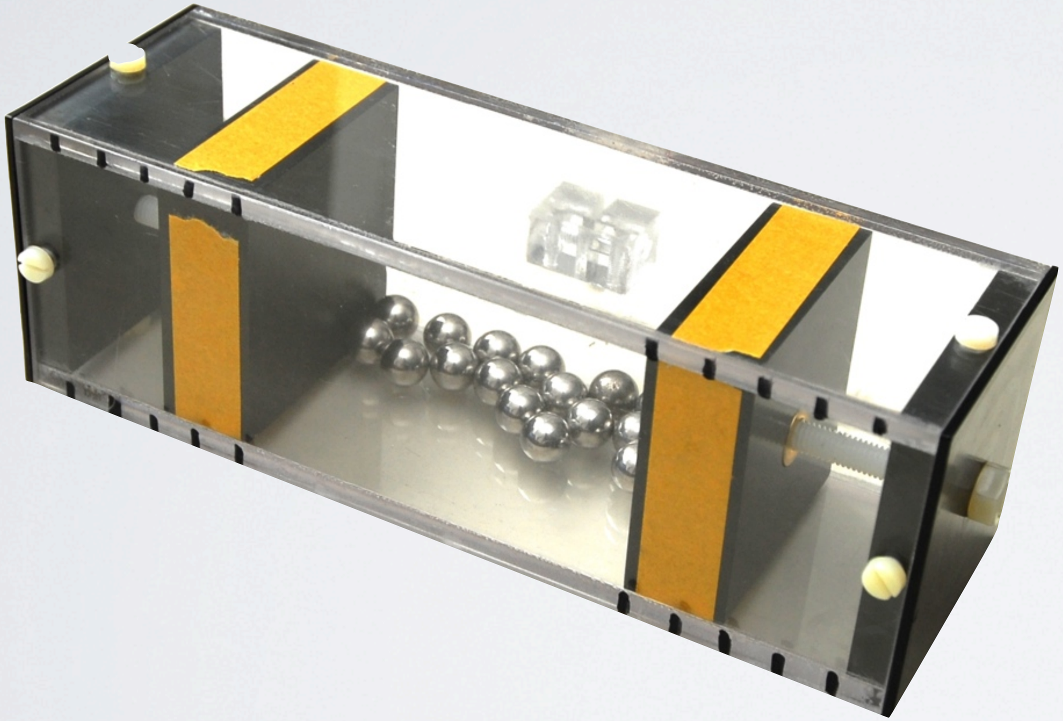




Identified Particles

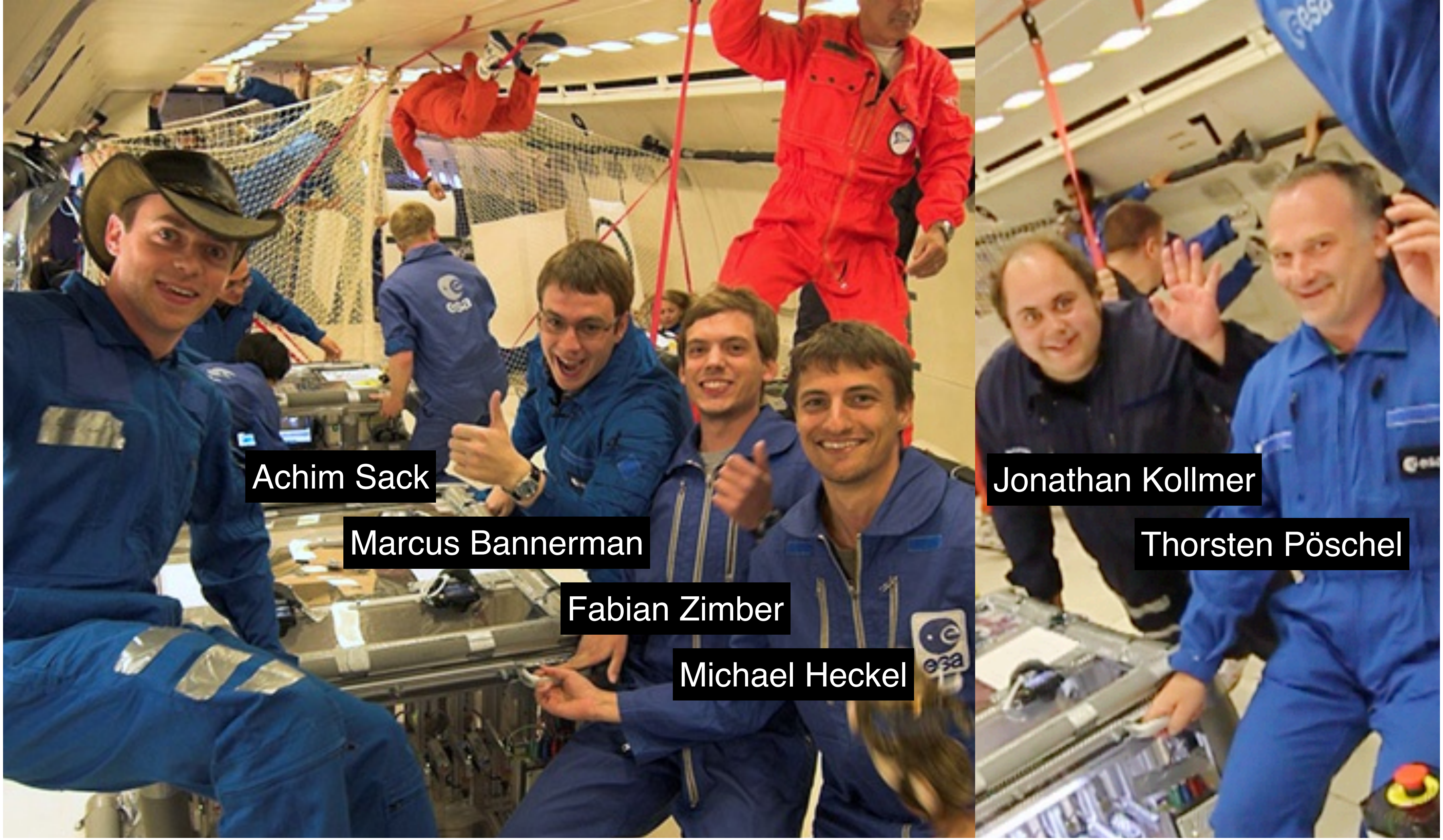
And now the real talk

Granular Dampers in Microgravity



M. N. Bannerman, **J. E. Kollmer**, A. Sack, M. Heckel, P. Mueller, and T. Pöschel

Photo: Novespace



FRIEDRICH-ALEXANDER
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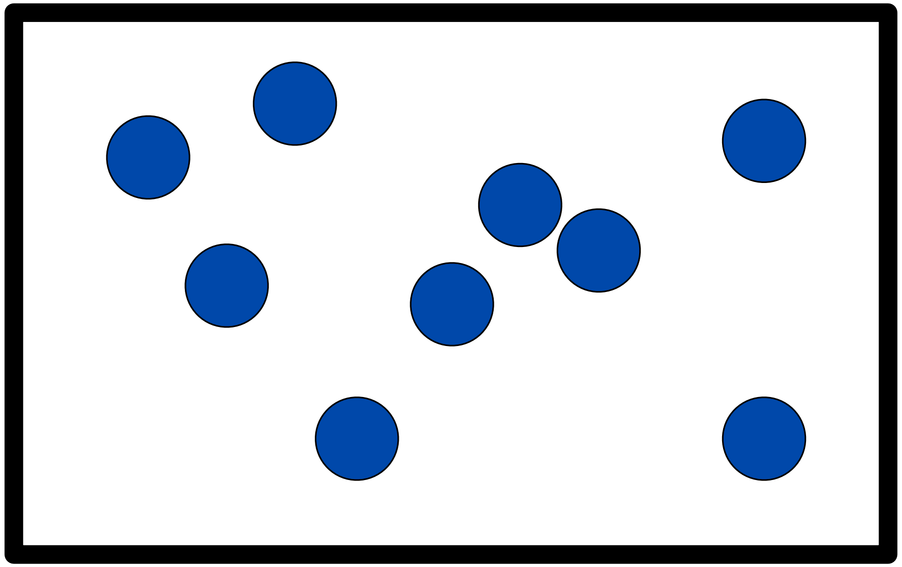
ERLANGEN-NÜRNBERG

MSS

Institute for
Multiscale Simulation of
Particulate Systems

Granular Dampers

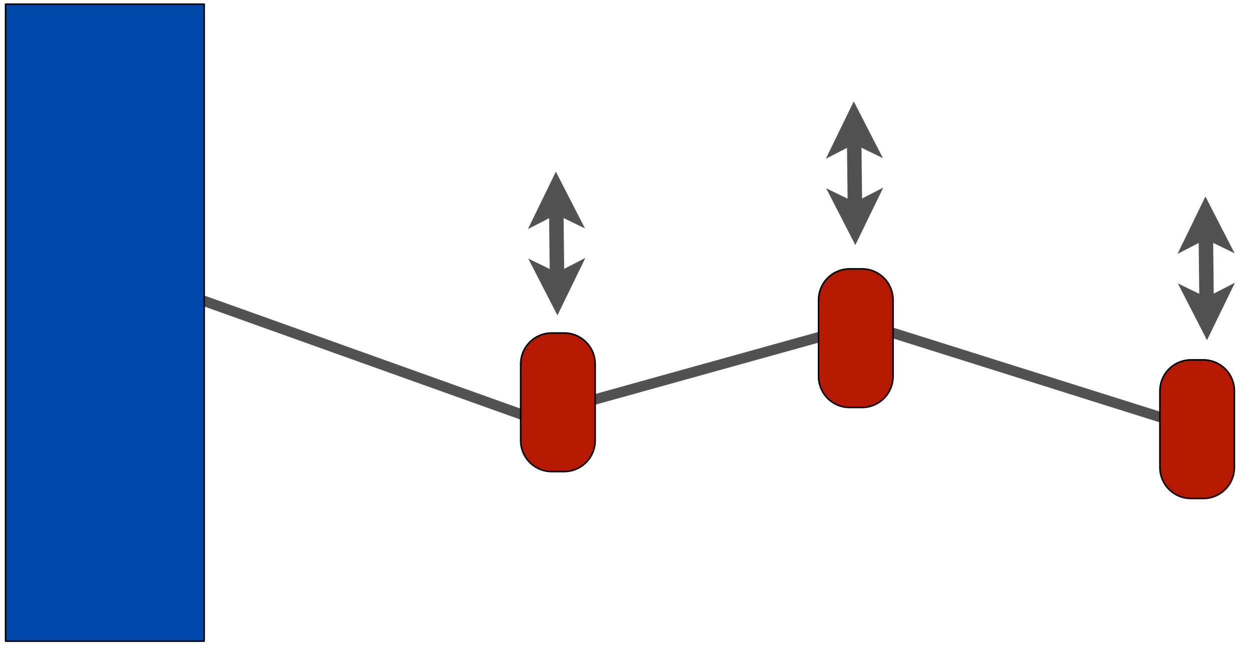


+ no anchor required
+ extremely simple
+ slow aging
+ weak dependence on temperature

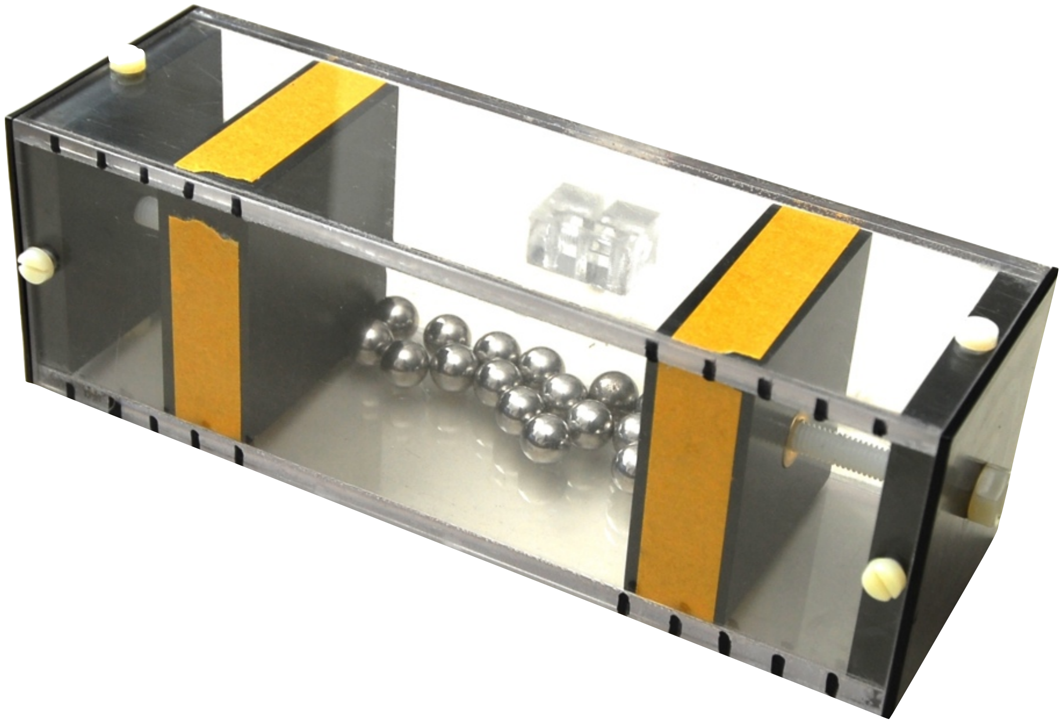
- lacks good model

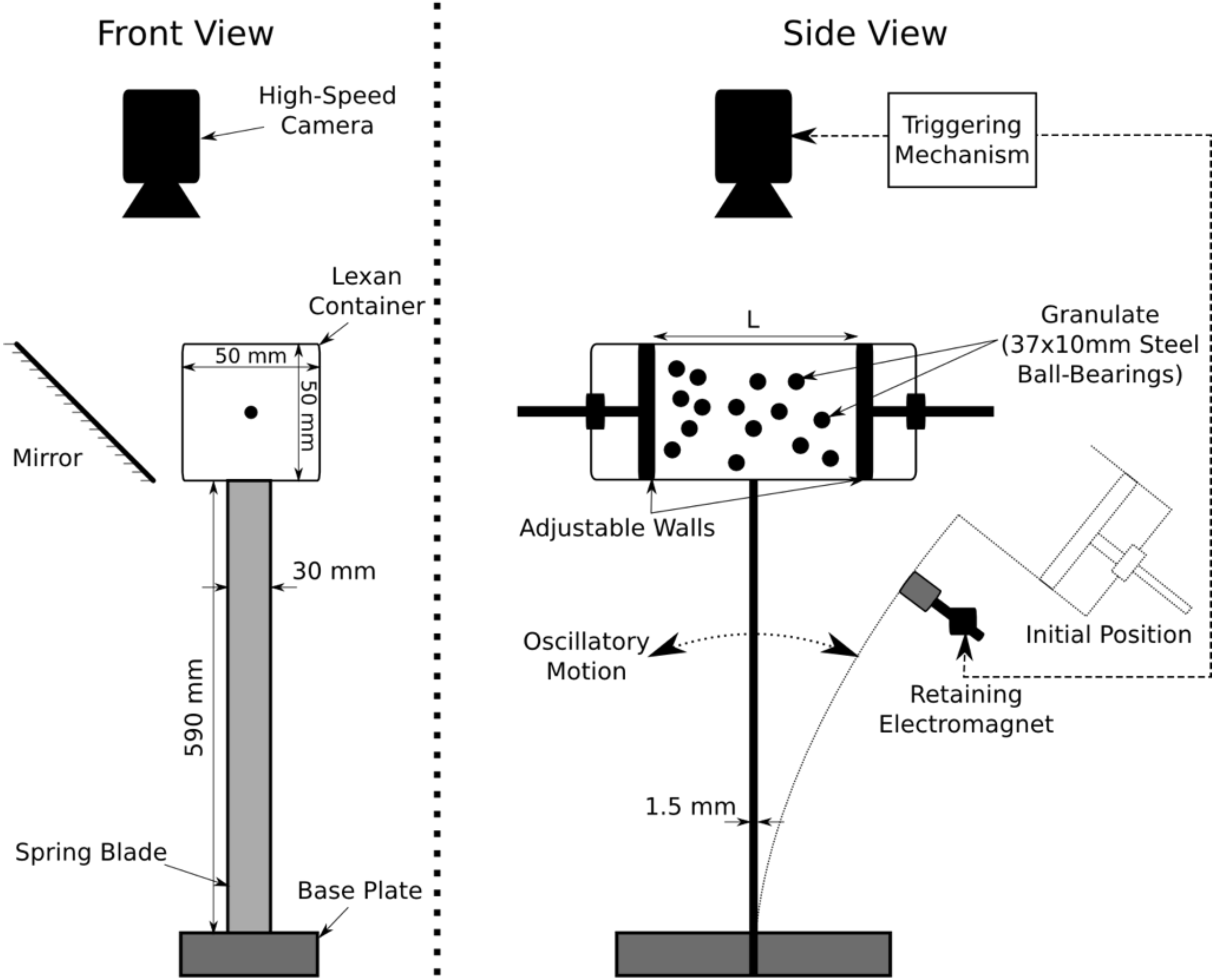
Granular Dampers are efficient when strong forcing: Dead-Blow Hammer

or g is low: Satellite Antenna

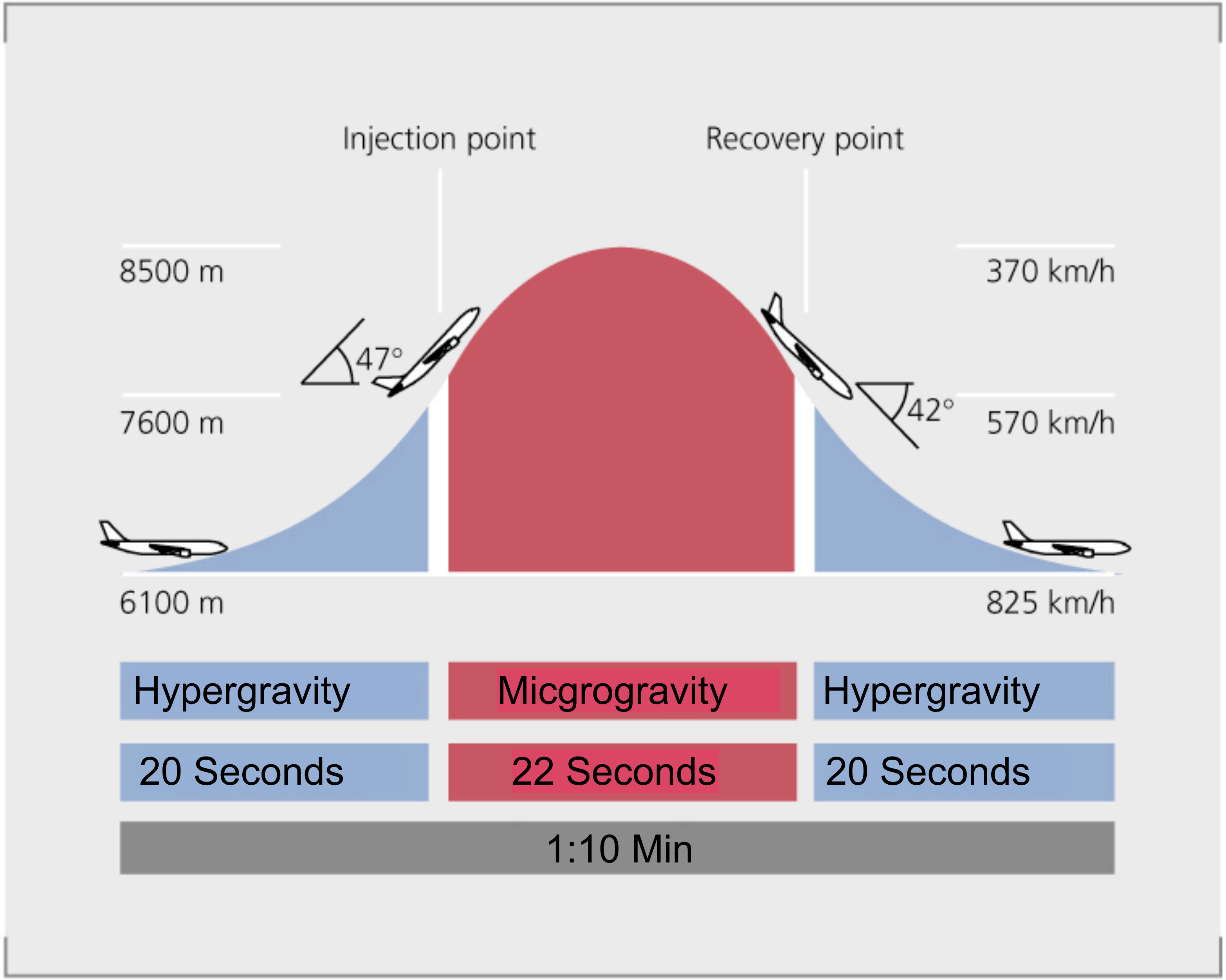


µg experiment




Front View
High-Speed Camera
Lexan Container
50 mm
50 mm
Mirror
30 mm
590 mm
Spring Blade
Base Plate
Side View
Triggering Mechanism
L
Granulate (37x10mm Steel Ball-Bearings)
Adjustable Walls
Oscillatory Motion
Initial Position
Retaining Electromagnet
1.5 mm

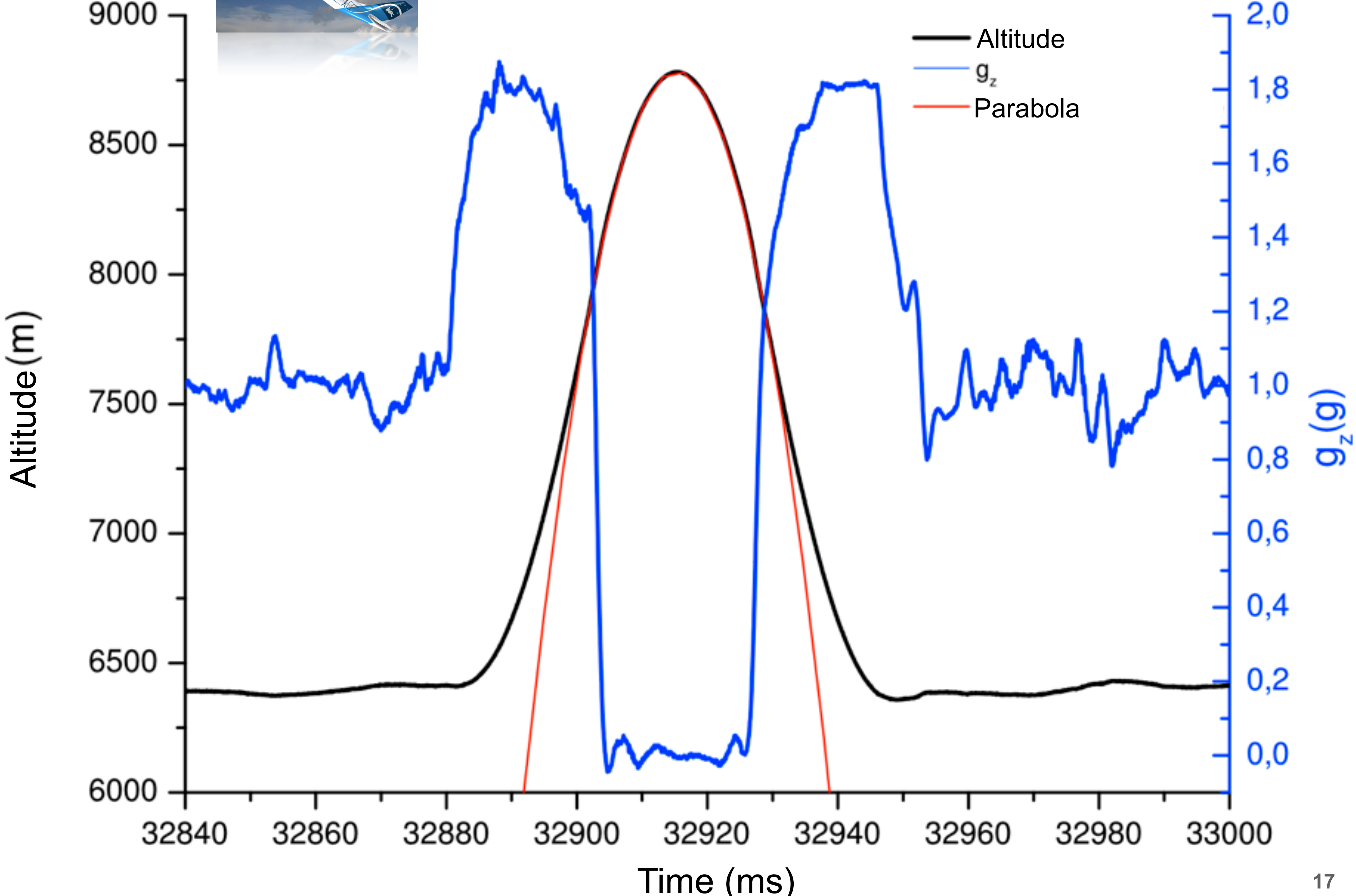
Parabolic Flight Maneuver



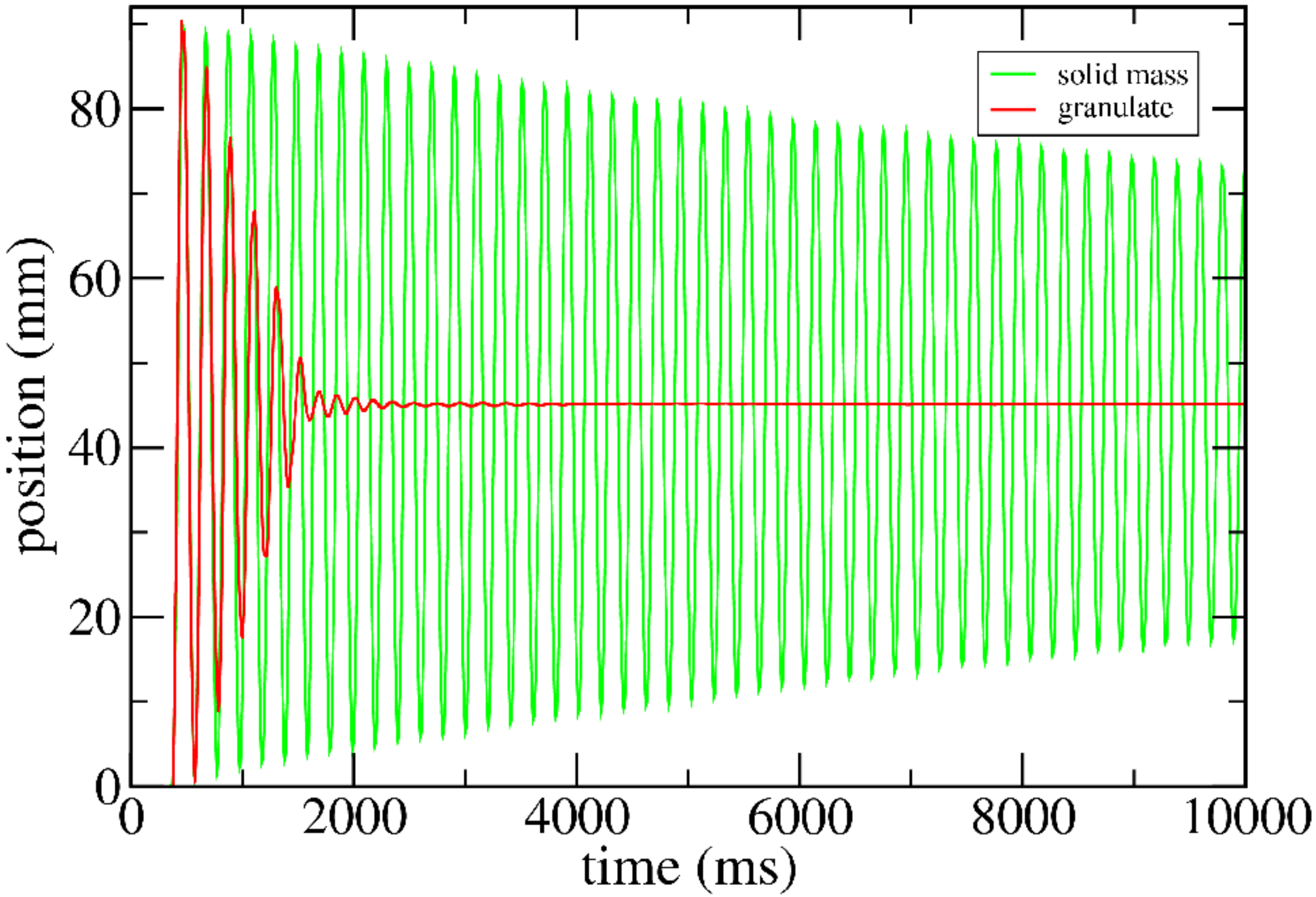
Source: DLR

Mit freundlicher Genehmigung durch Kpt. Gilles Le Barzic

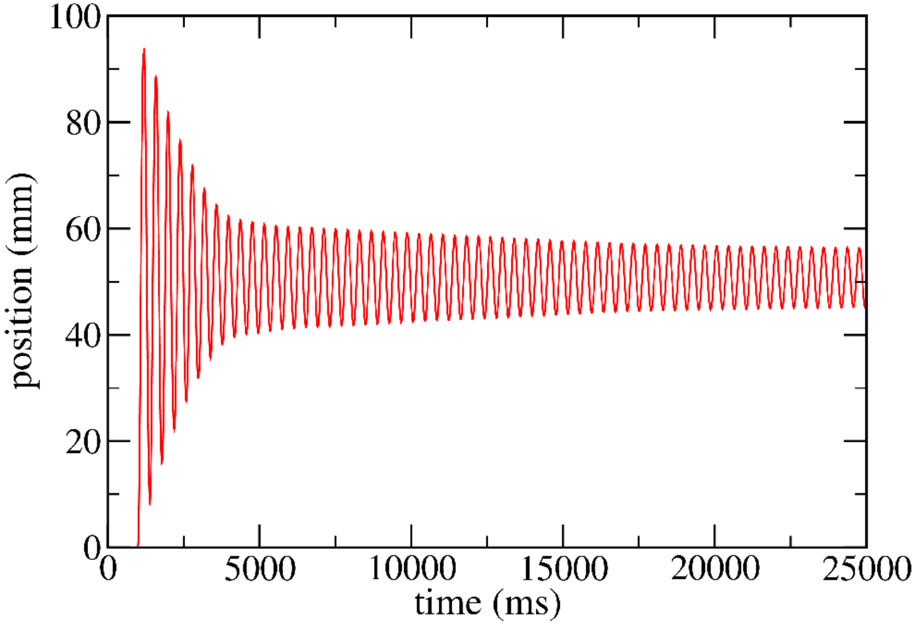
Microgravity



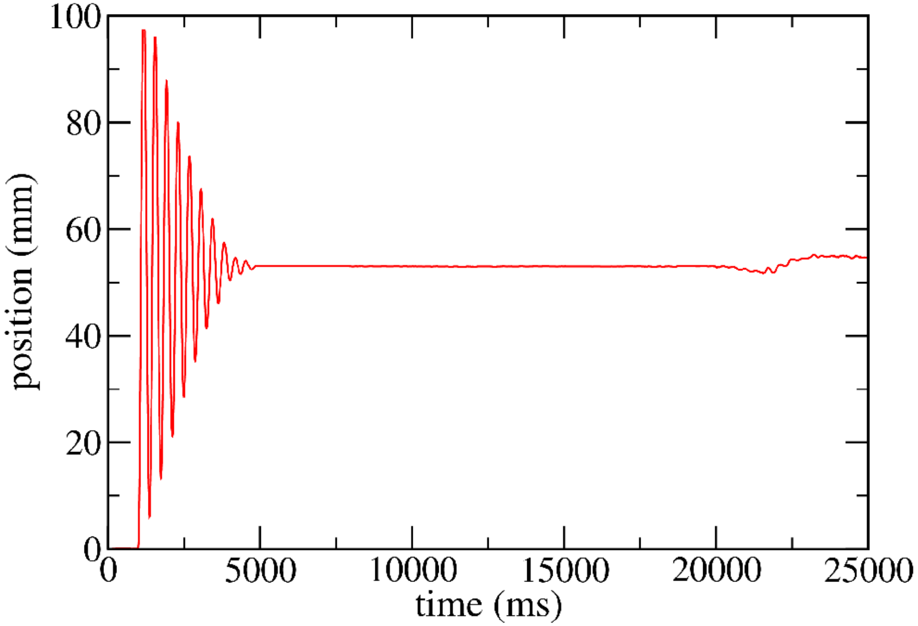
comparision granulate/solid mass



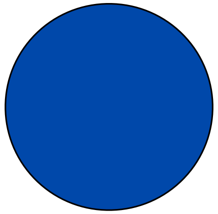
normal gravity (1g)



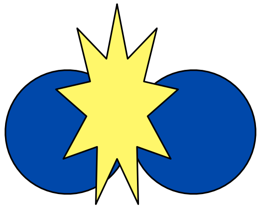
micro gravity (μg)



Simulation



Hard Spheres

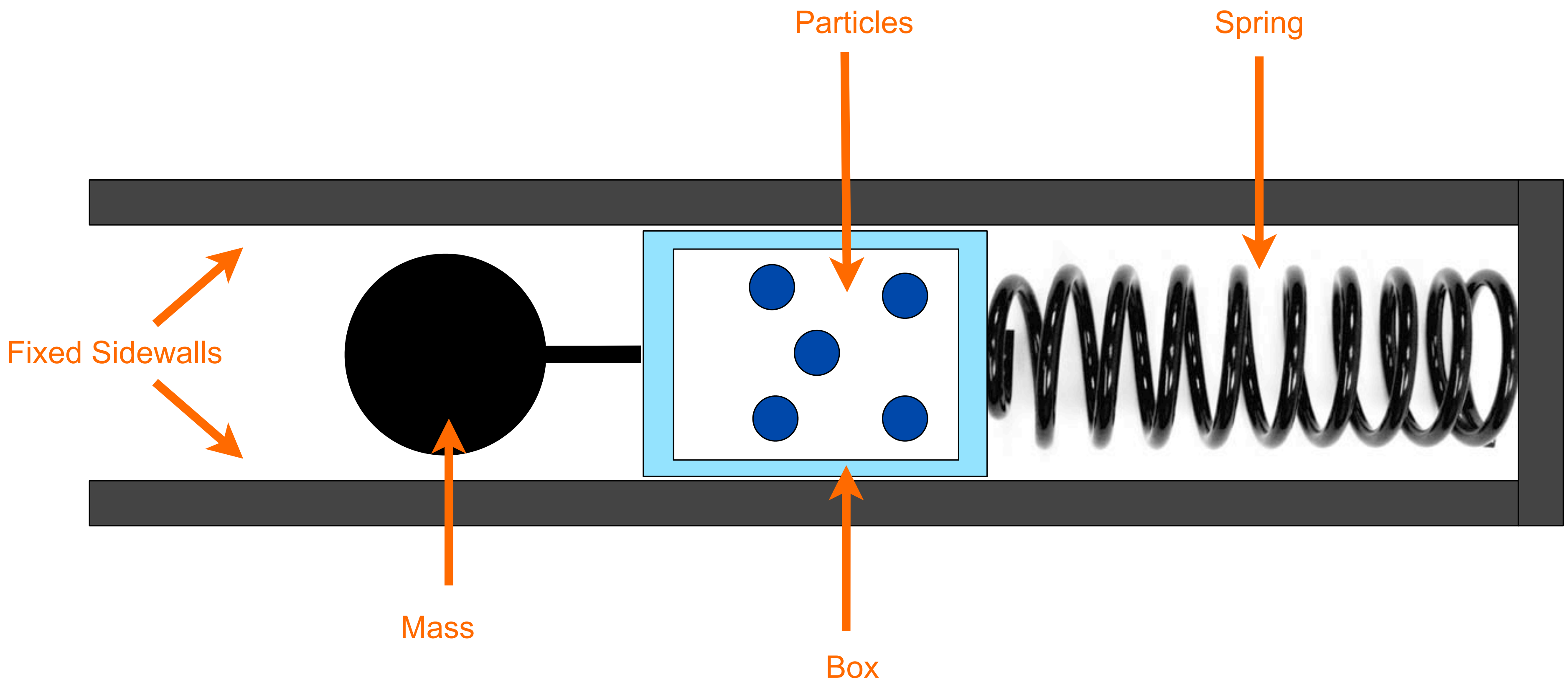


Inelastic Collisions

No Rotation

No Gravity

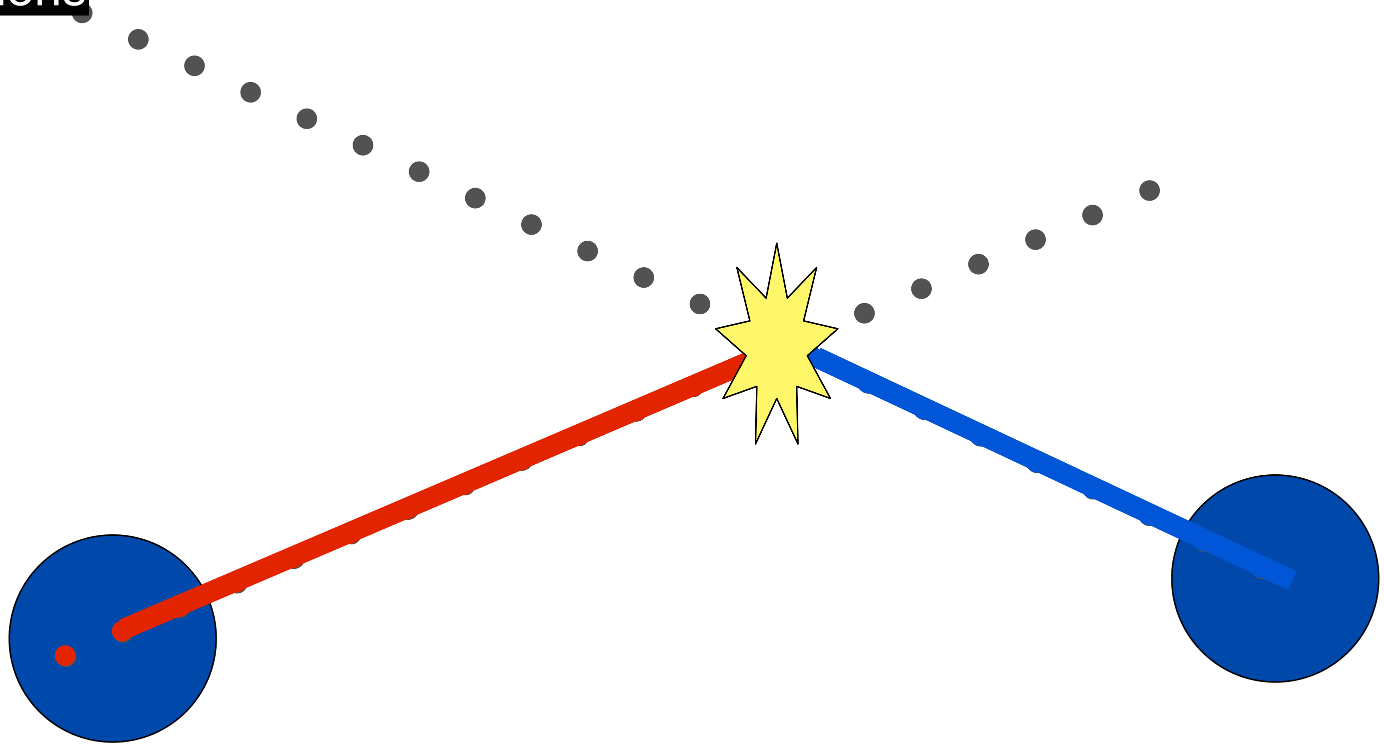
Model



Model

Event Driven Molecular Dynamics (DEM)

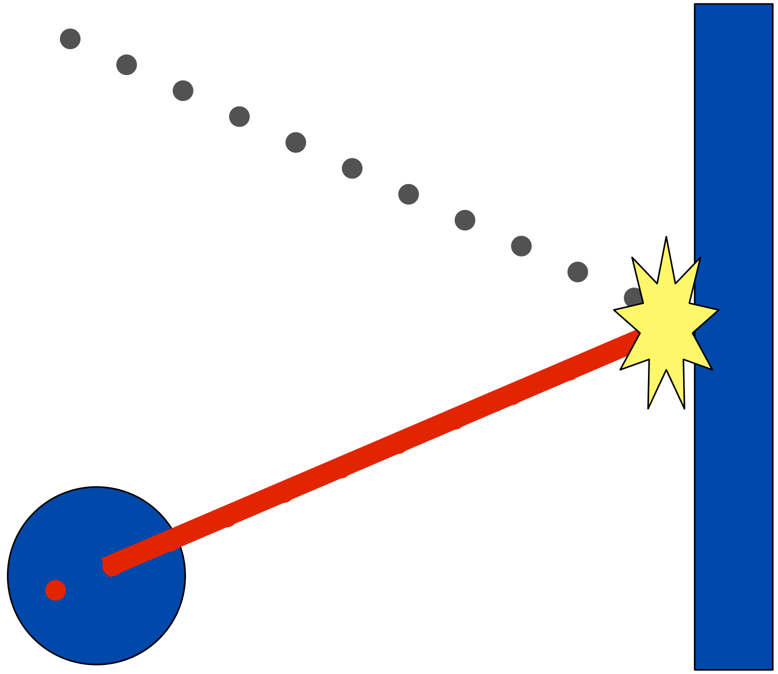
Particle-Particle Collisions



1. Calculate Intersection of Trajectories
2. Advance Time to Moment of Impact
3. Execute Collision
4. Calculate new Trajectories
5. Repeat

DYNAMO Sim Package

Particle-Wall Collisions



Conservation of Momentum

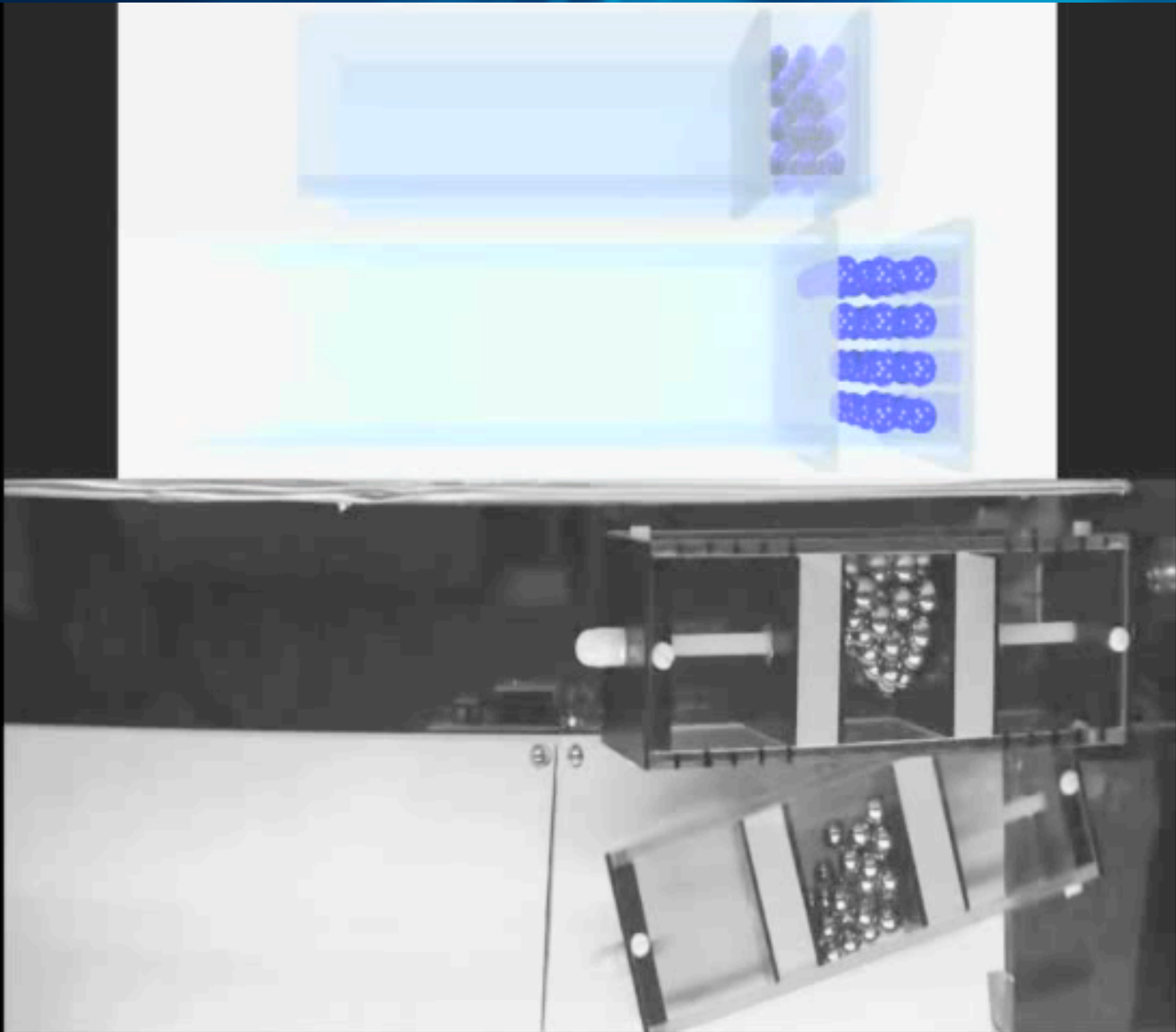
Constant Inelasticity

Parameters

Particle Diameter	10	from experiment
Particle Mass	4.04 g	from experiment
Number of Particles	37	from experiment
Initial Amplitude	107.5 mm	from experiment
Unloaded Frequency	1.23 s^{-1}	from material parameters
Container Mass	434 g	from experiment
Particle-Particle Inelasticity	0.75	fit
Particle-Wall Inelasticity	0.76	fit

VIDEO

Simulation

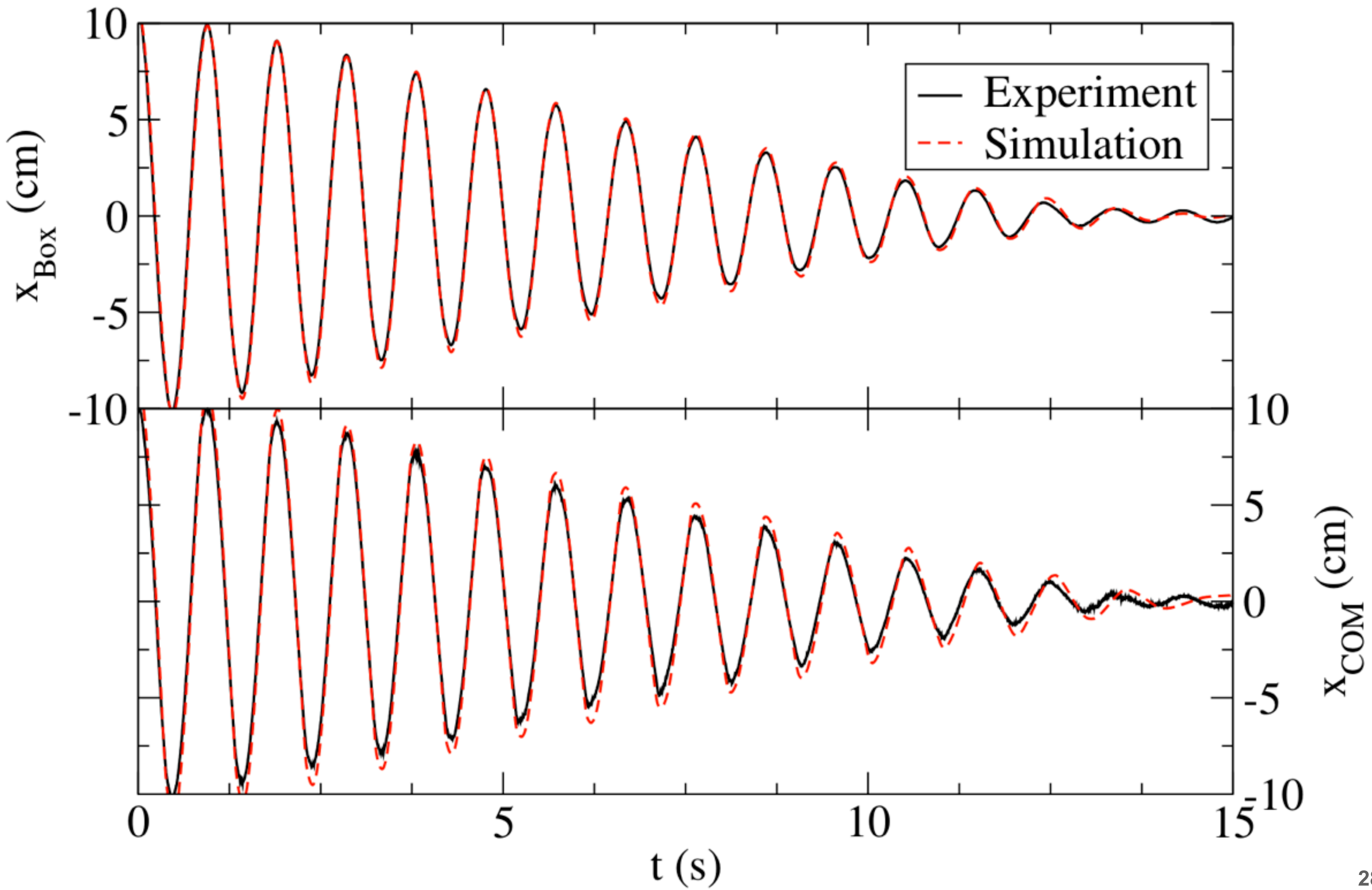


Experiment

Validation

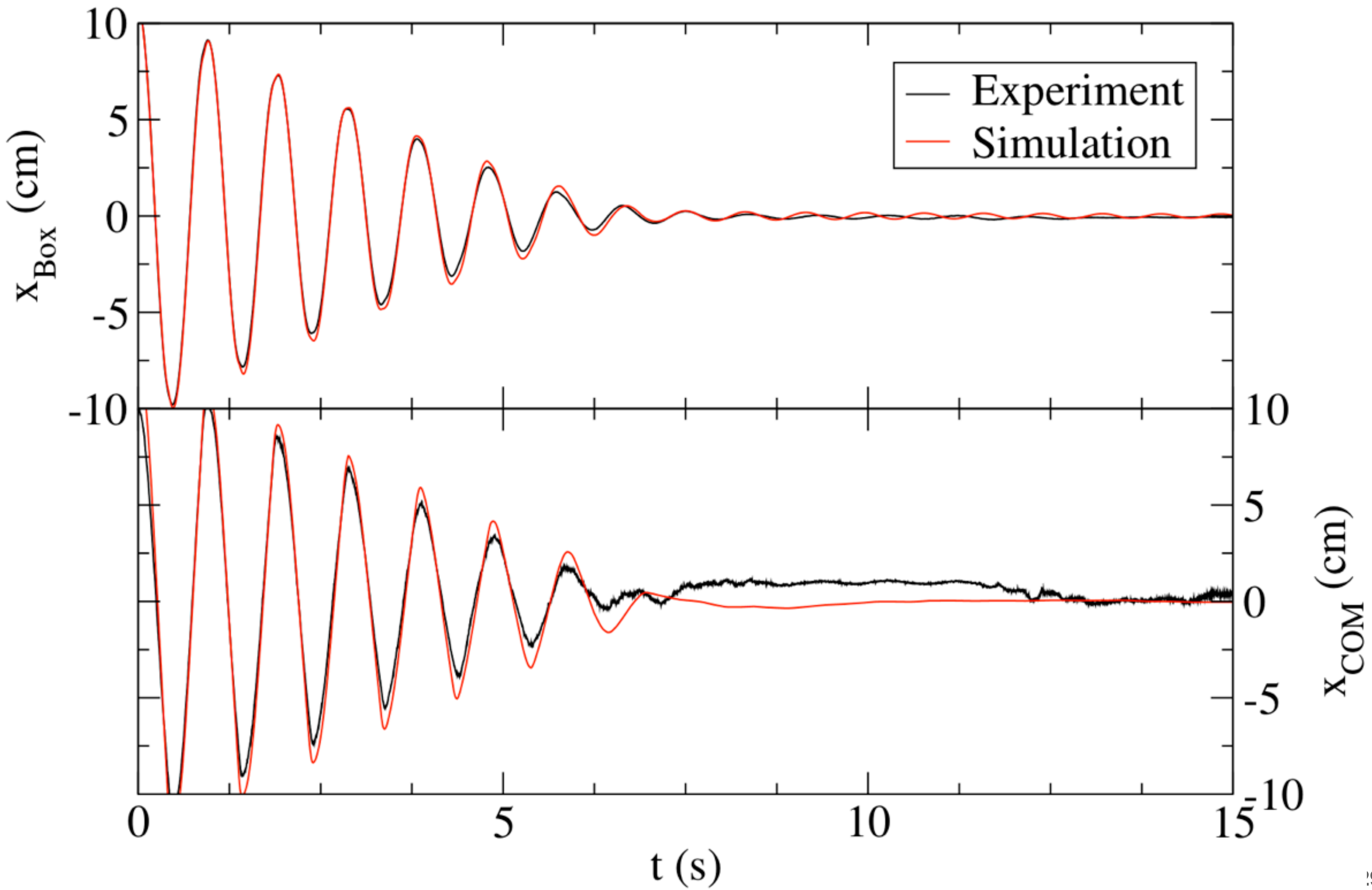
Dynamics of the 40mm Box with Beads

fit



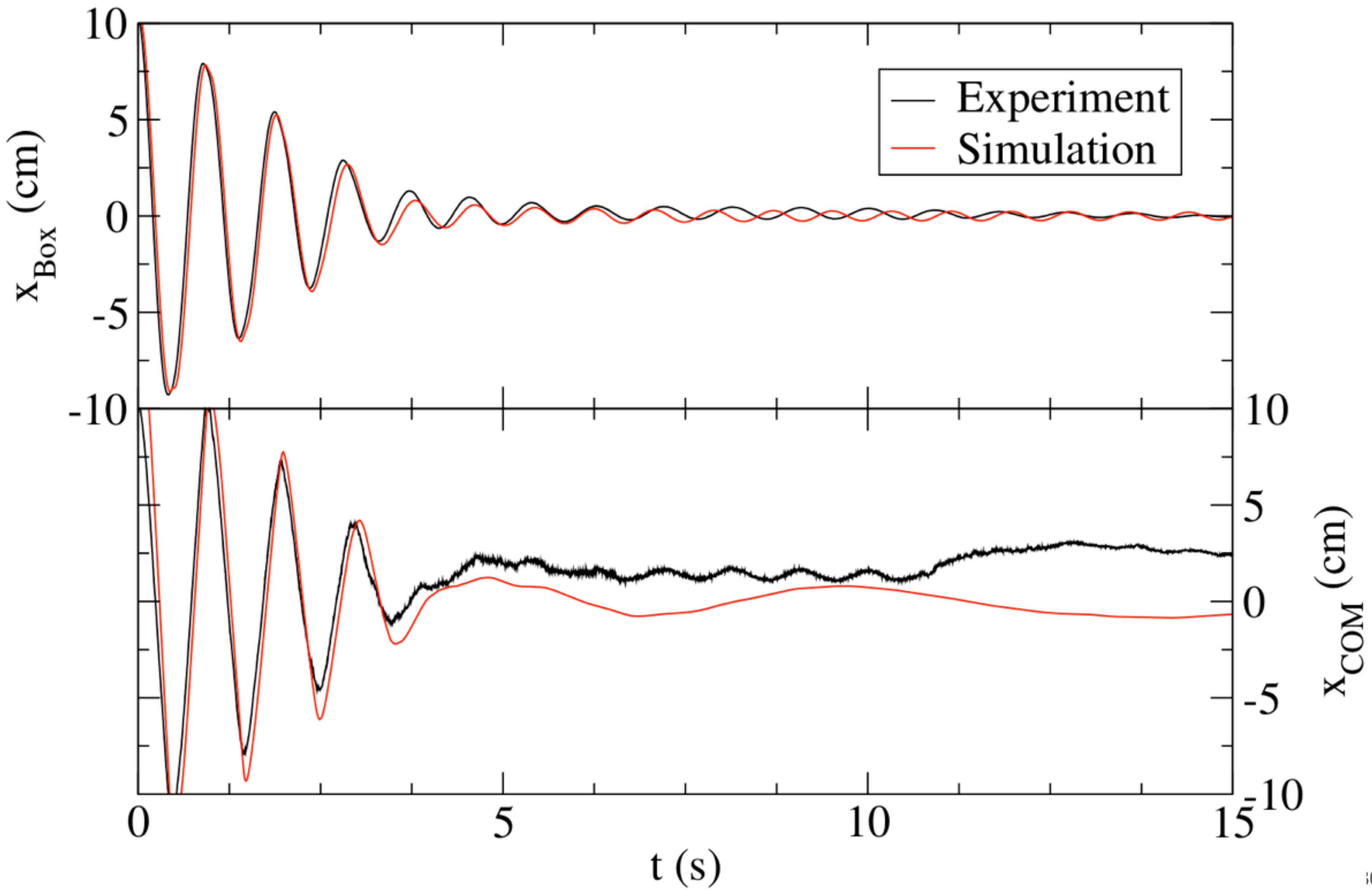
Dynamics of the 65mm Box with Beads

no fit

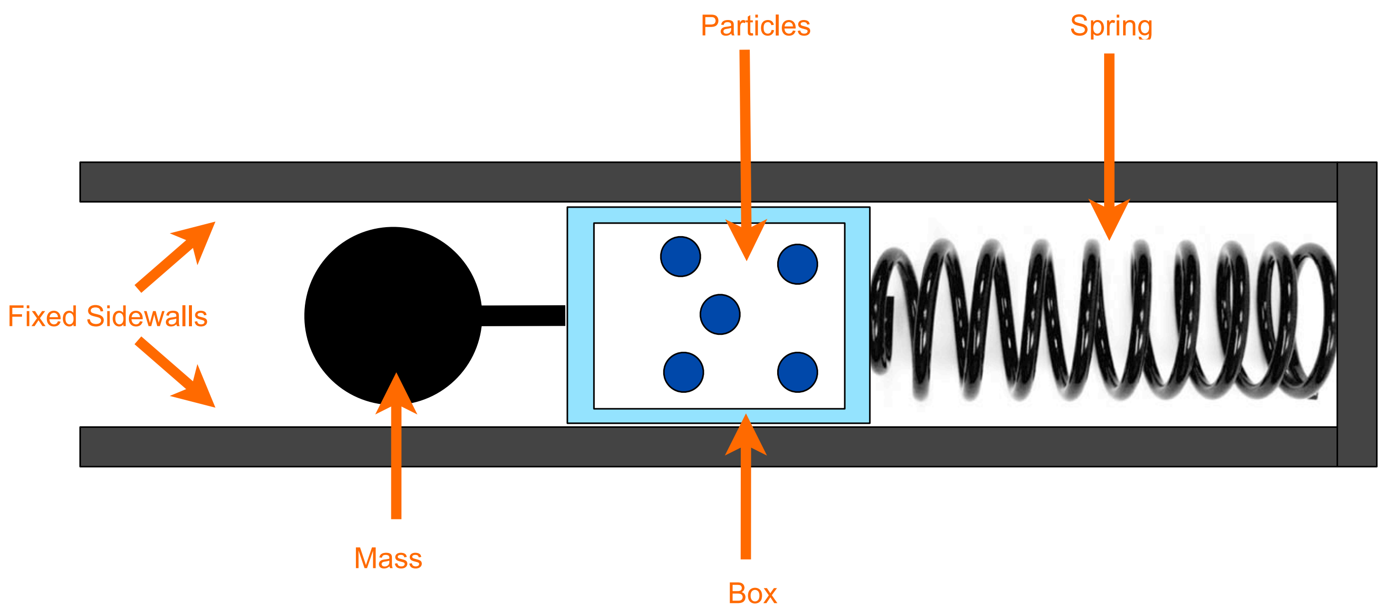


Dynamics of the 104mm Box with Beads

no fit



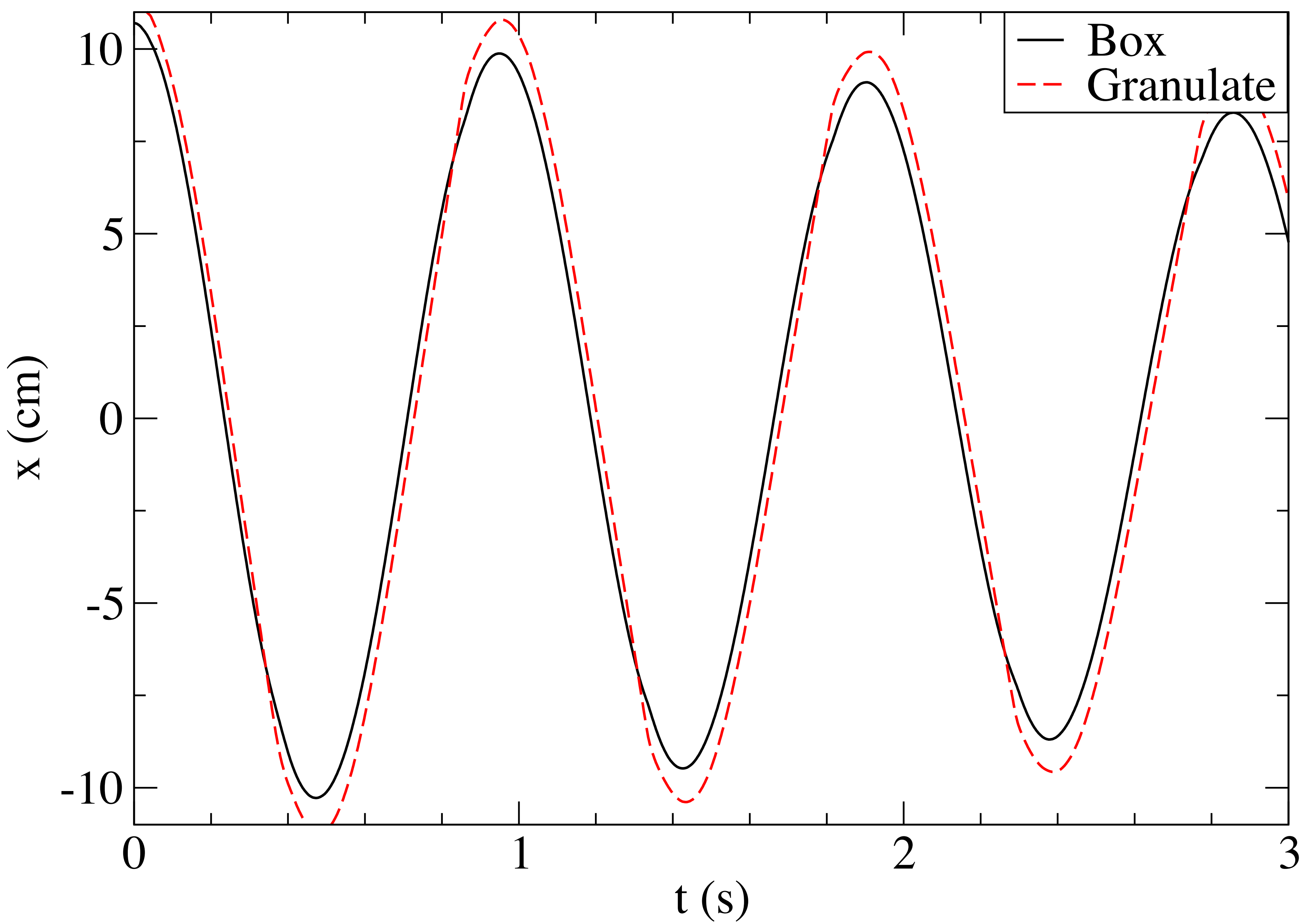
model



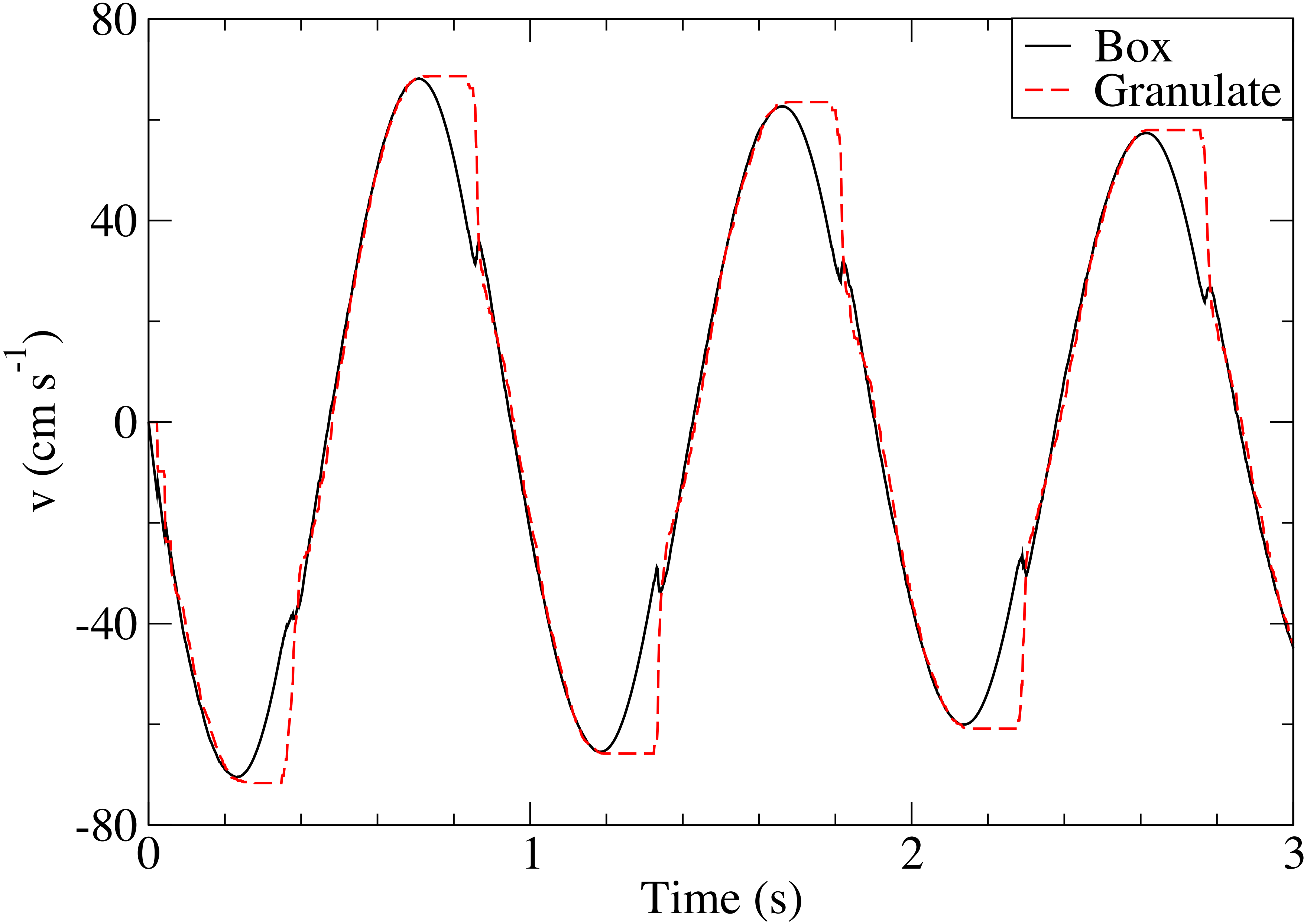
valid in µg

Optimization

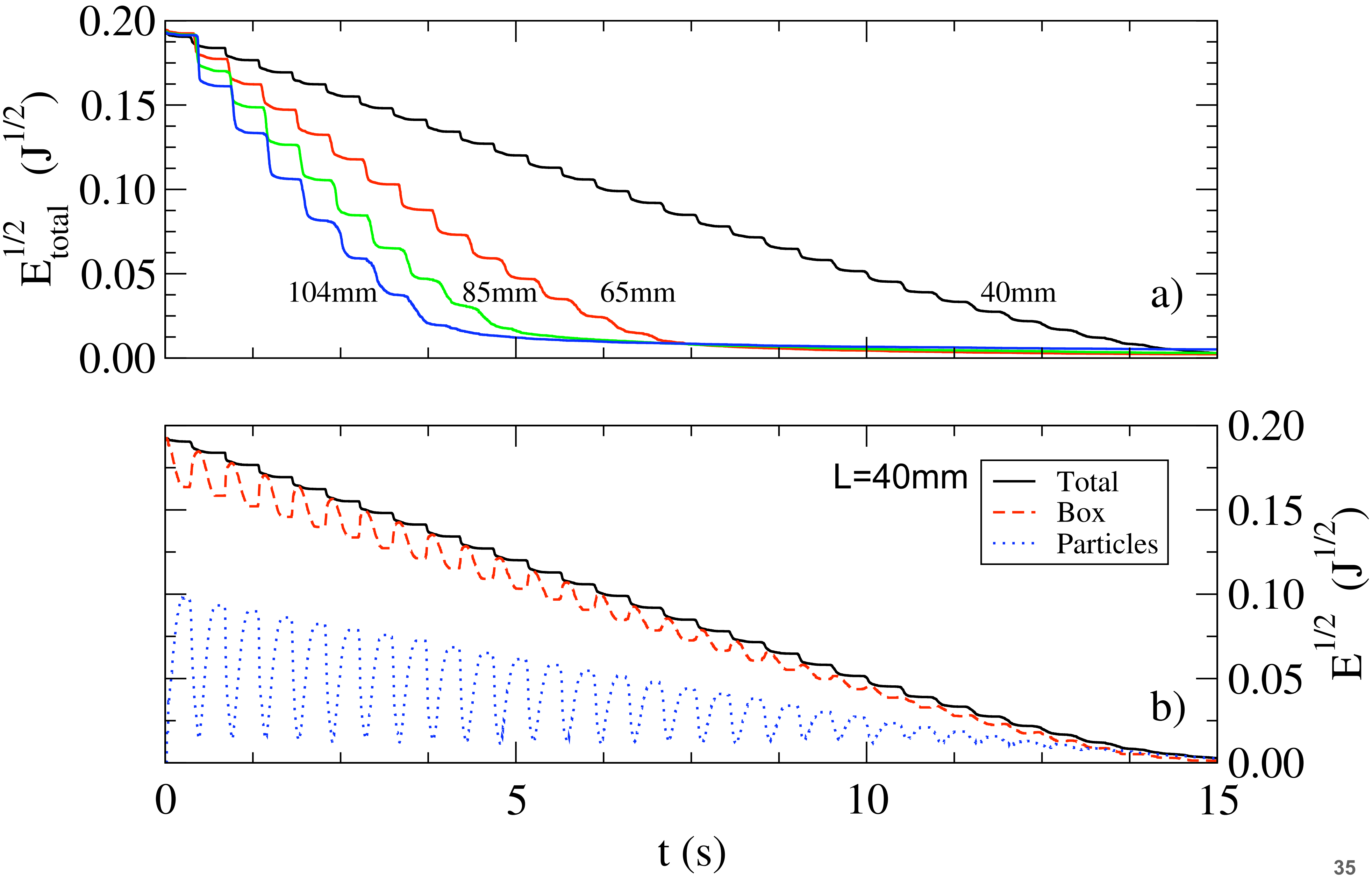
Phase Shift in Position (40mm Box)



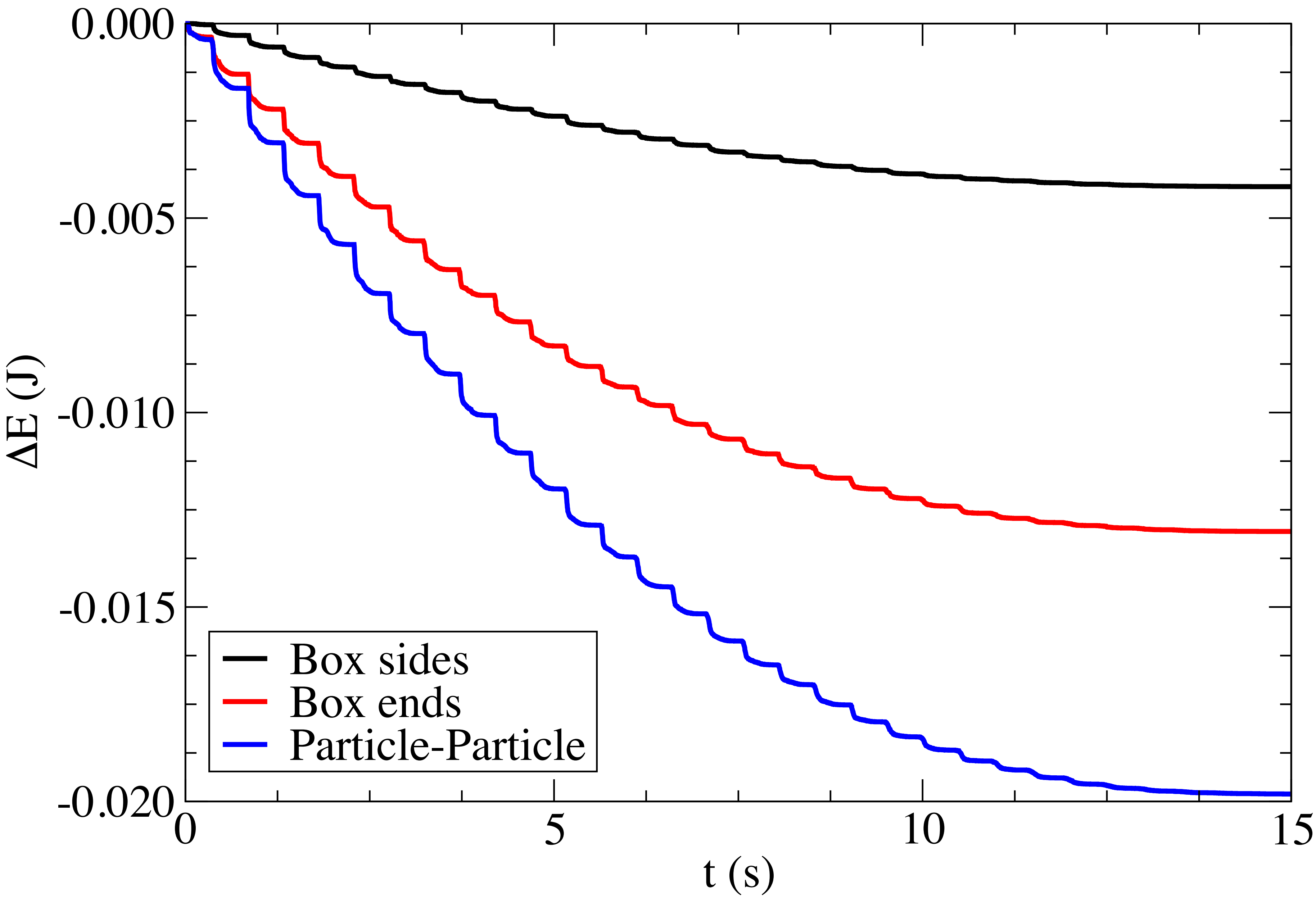
Phase Shift in Velocity (40mm Box)



Energy Loss


0.20
0.15
0.10
0.05
0.00
$E^{1/2}_{total}$ $(J^{1/2})$
104mm
85mm
65mm
40mm
a)
L=40mm
Total
Box
Particles
b)
0
5
10
15
t (s)

Energy Loss (40mm Box)



Coeffitient of Restitution

Relative Velocity

Particle Masses

$$\Delta E = \frac{m_1 m_2}{2(m_1 + m_2)} (1 - \epsilon^2) \left(\hat{r}_{12} \cdot [\vec{v}_1 - \vec{v}_2]\right)^2$$

Energy Loss

Coeffitient of Restitution

Simple Analytical Model for Optimisation

Particle Cluster as Single Mass

Harmonic Box Motion

Mass of Box

$$L_{opt} = \pi \Delta_0 \sqrt{\frac{M}{M + Nm}} + \sigma_{layer}$$

Optimal Box Length

Initial Amplitude

Number of Particles

Mass of One Particle

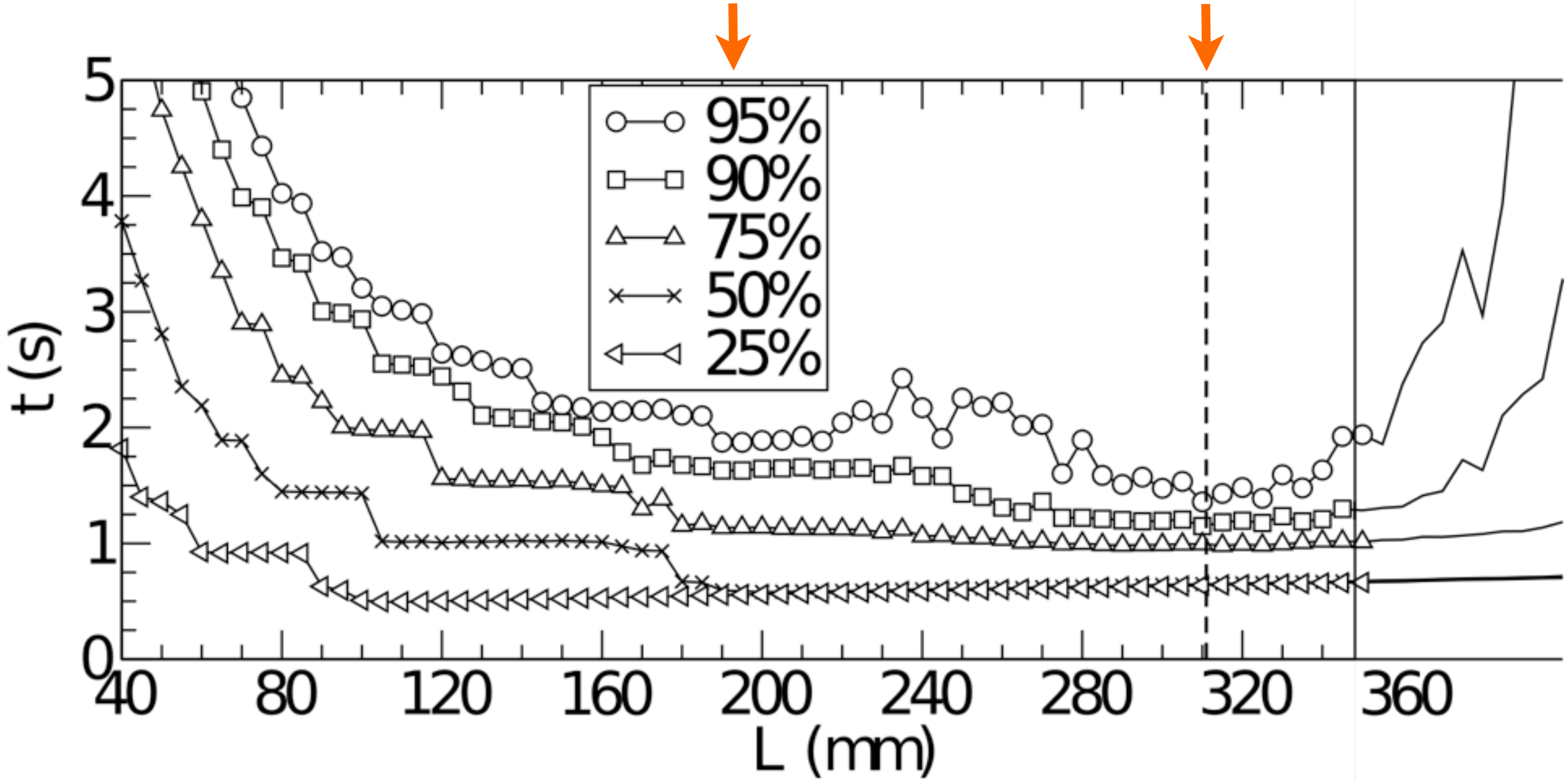
Size of Particle Cluster

independent of frequency!

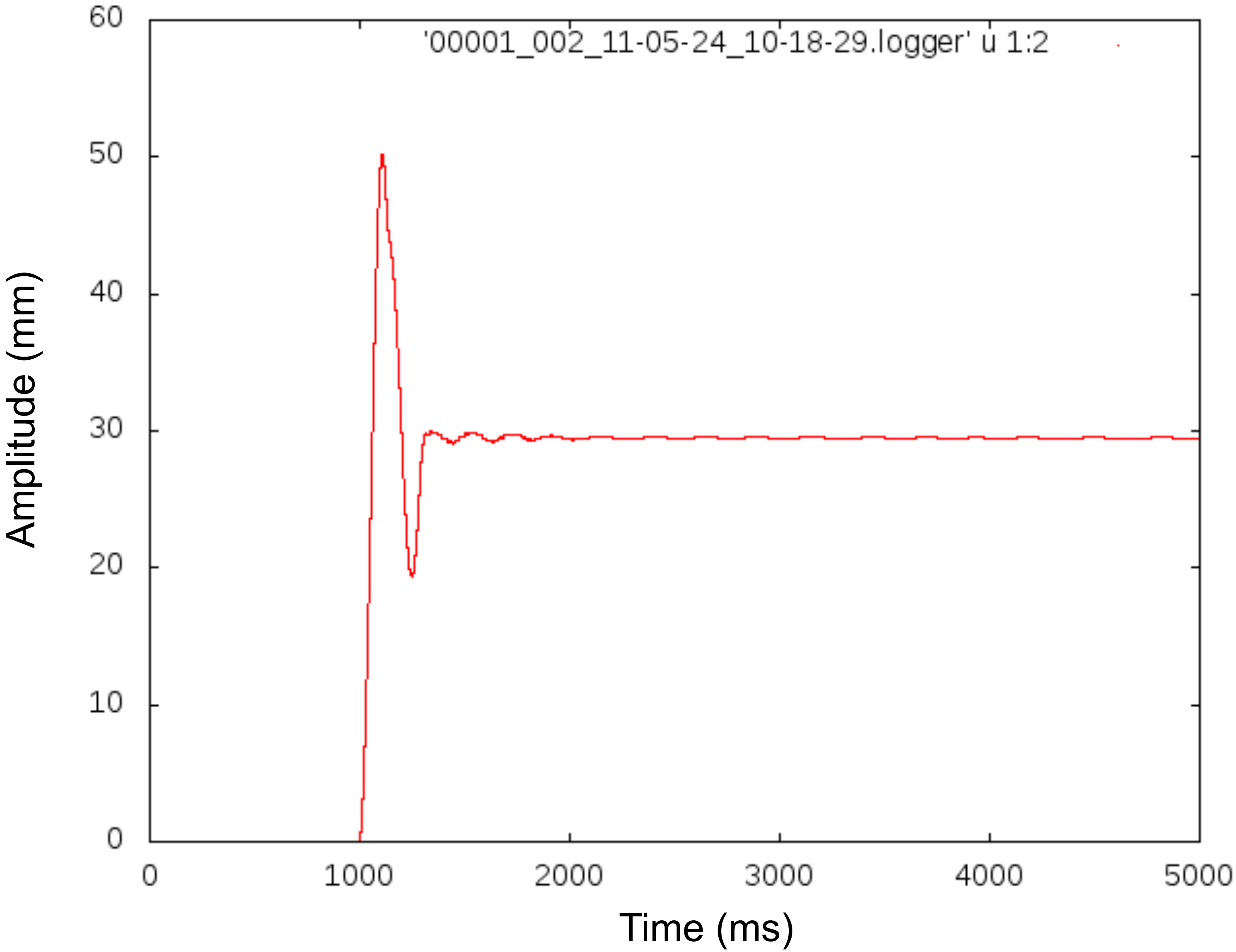
Test

ammount of initial energy dissipated

predicted optimal box length



Real Test


'00001_002_11-05-24_10-18-29.logger' u 1:2
Amplitude (mm)
Time (ms)
0
10
20
30
40
50
60
0
1000
2000
3000
4000
5000

Phenomenological Model

linear decay in amplitude reminds of friction-damped oscillator:

position

$$M_{tot}\,\ddot{x} = -k\,x - \mu\,M_{tot}\,\mathrm{sgn}\left(\dot{x}\right)$$

total mass

constant friction force

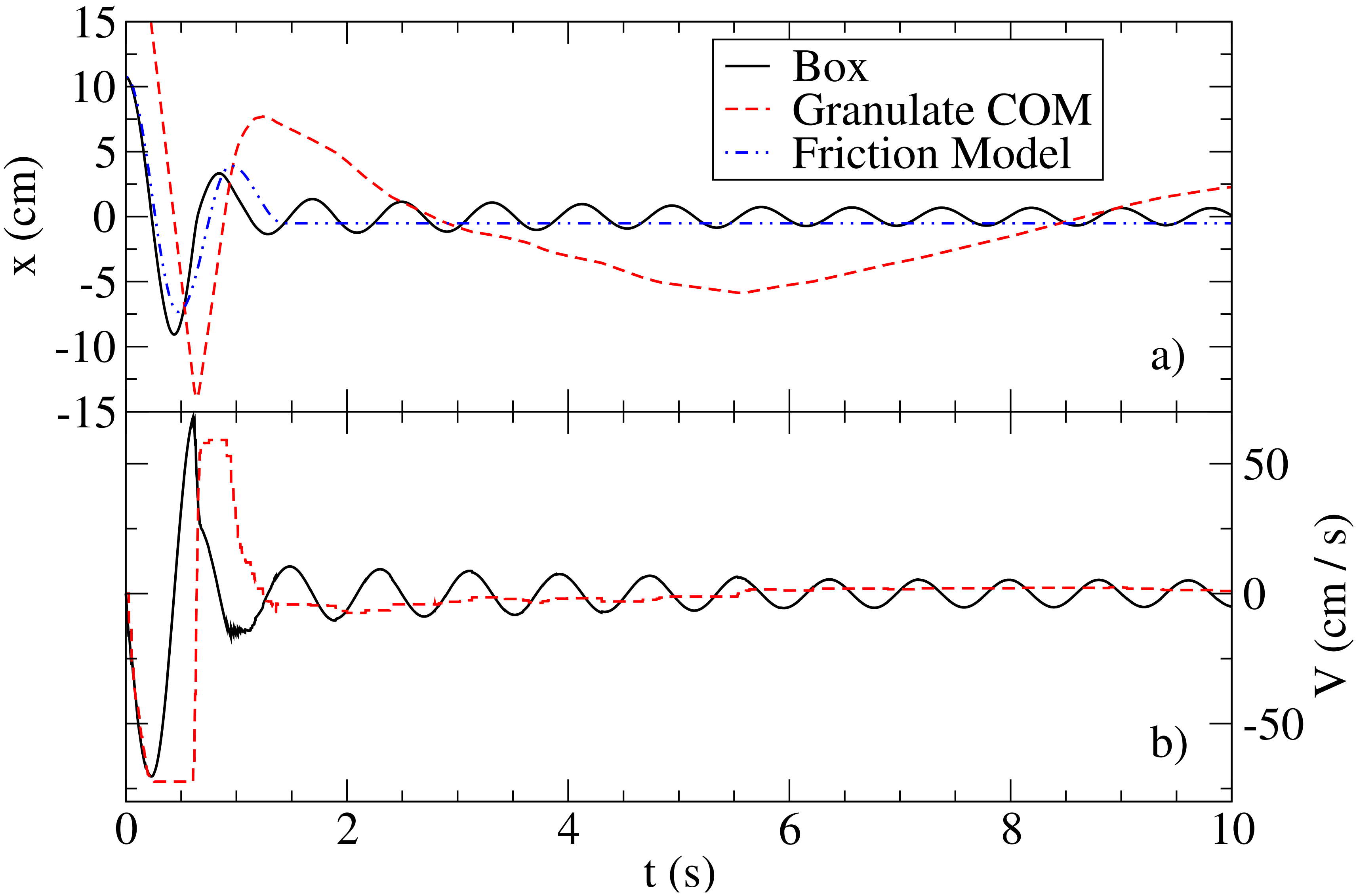
- assumes constant damping

+ characterize damper through effective frictional force

absolute oscillator displacement for nth peak

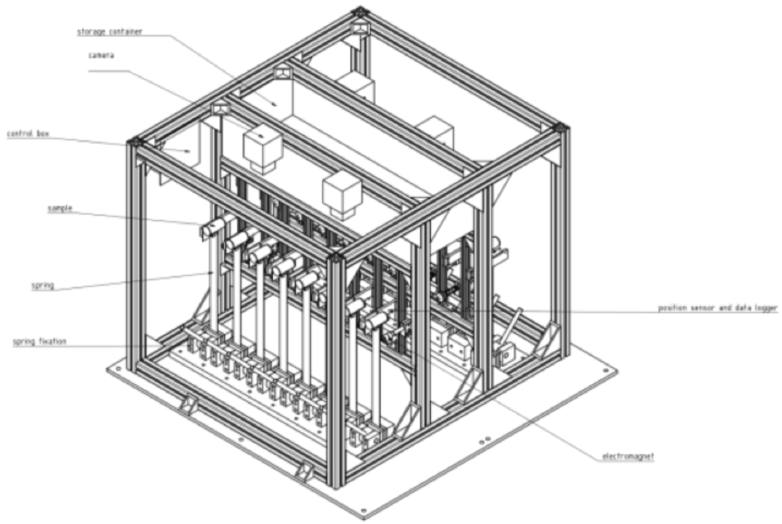
$$\mu \, M_{tot} = \frac{k \, (\Delta_0 - |x_n|)}{2\,n + 1 - (-1)^{2\,n}}$$

index of amplitude peak


15
10
5
0
-5
-10
-15
x (cm)
Box
Granulate COM
Friction Model
a)
50
0
-50
V (cm / s)
b)
0
2
4
6
8
10
t (s)

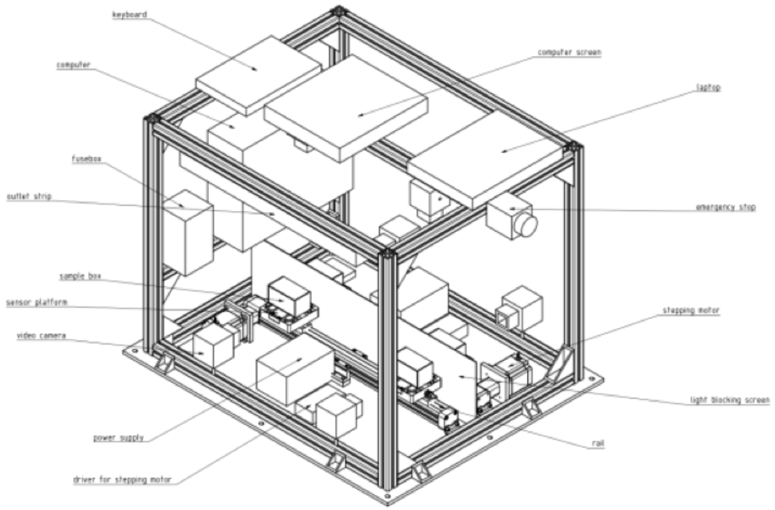
Outlook

More Experiments



16 springs simultaniously

measures decay times

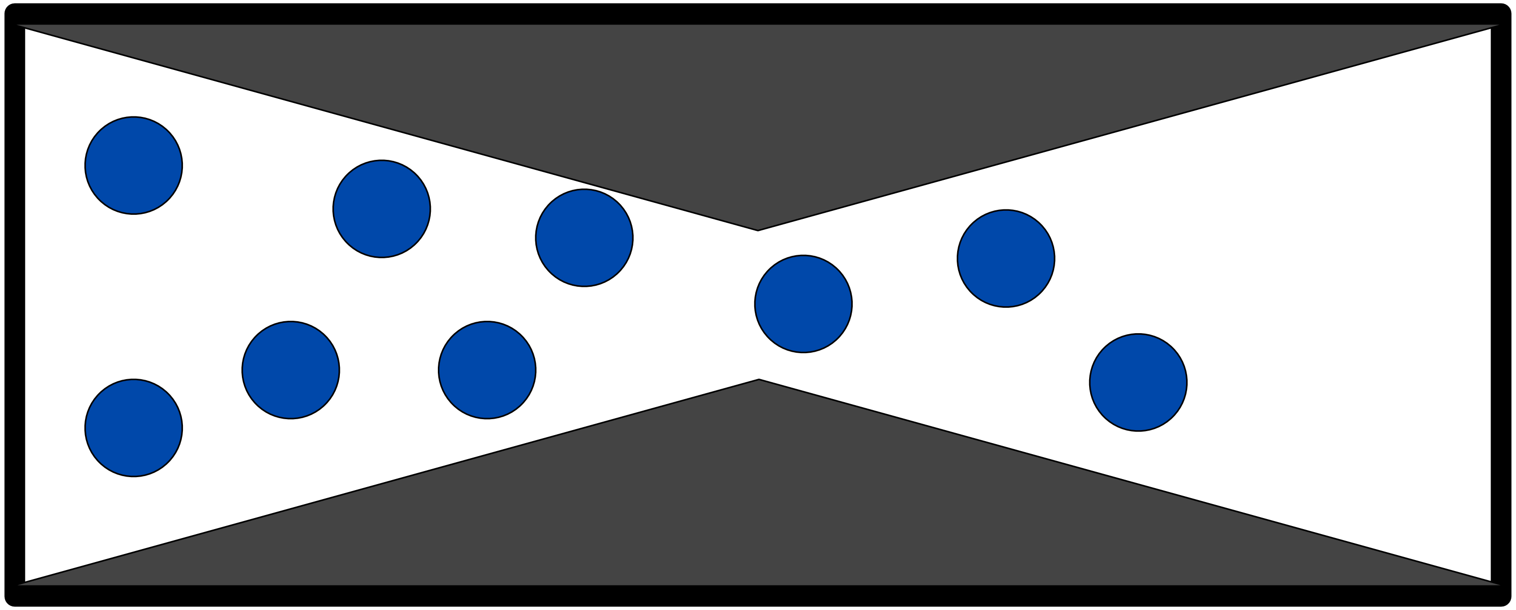


forced shaking

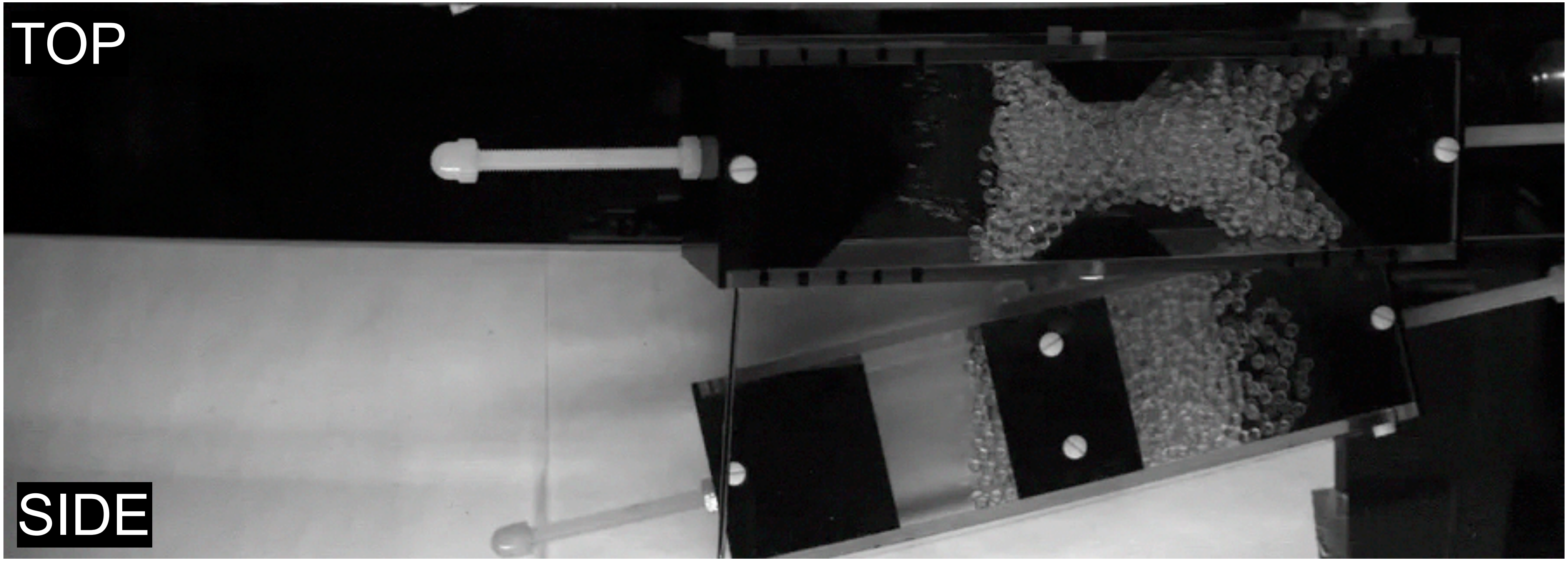
measures force needed to drive system on a given trajectory

Outlook: Forced Shaking

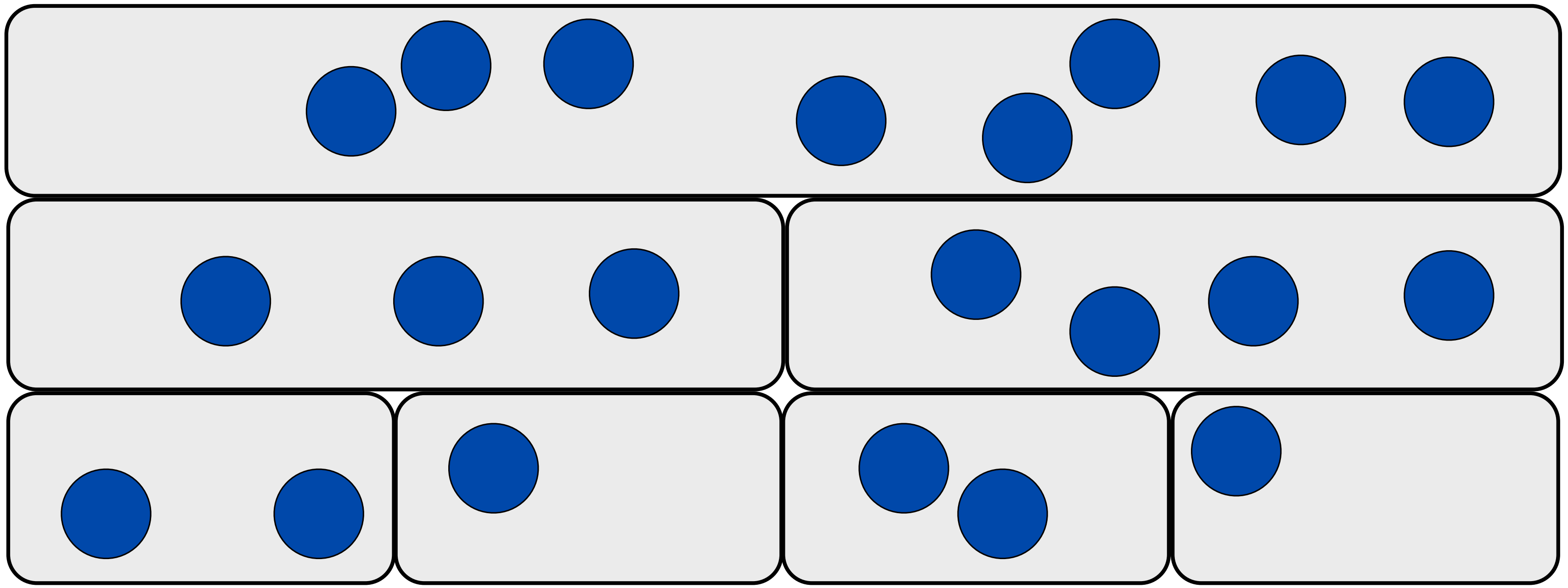
Outlook: Different Geometry



Outlook: Different Geometry



Outlook: Self Damping Materials



Extra Slide: Electrostatics

Conclusions

- controlled experiments on granular dampers in µg
- simple hard sphere model & EDMD compare well to exp.
- no frequency dependence
- prediction for optimal length
- linear decay in amplitude like in friction damping

Further reading: “Movers and shakers: Granular damping in microgravity” (Accepted, PRE 2011)

Thanks

Friedrich-Alexander-Universität Erlangen-Nürnberg

Cluster of Excellence ENGINEERING OF ADVANCED MATERIALS — Hierarchical Structure Formation for Functional Devices

Physikalisches Institut UNIVERSITÄT BAYREUTH

Hochschule Karlsruhe Technik und Wirtschaft — UNIVERSITY OF APPLIED SCIENCES

FOR 608 — DFG Forschergruppe 608 Nonlinear Dynamics of Complex Continua

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