Hogyan befolyásolja a részecskék alakja a nyírt szemcsés anyagok sűrűségét?

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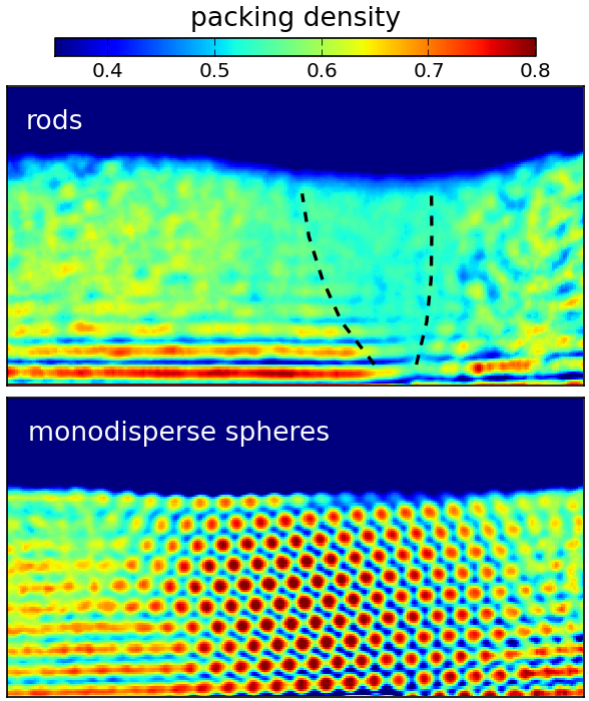

Soft Matter, accepted (2014)

Introduction – Deforming granular materials

- deformation of granular media: shear
  (jamming transition...)

Introduction – Deforming granular materials

- deformation of granular media: shear (jamming transition...)
- Reynolds dilatancy

www.abc.net.au

Introduction – Shear induced alignment

Log jam

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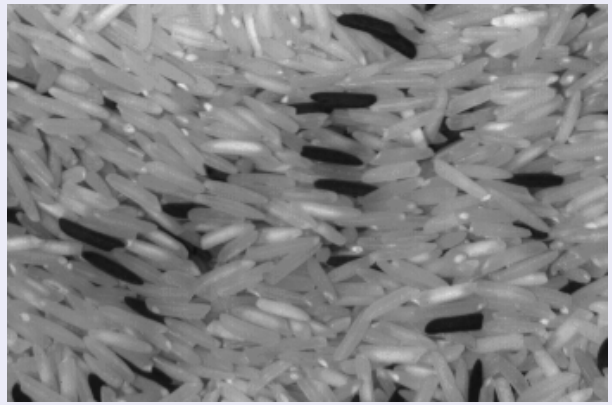
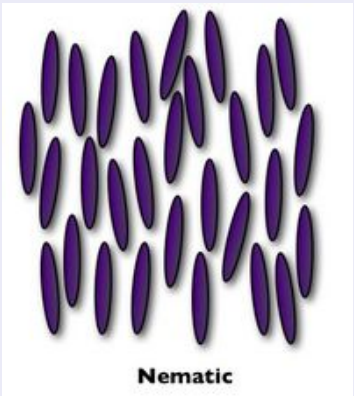
Rice



Liquid crystals



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Bacteria

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Introduction – Shear induced alignment

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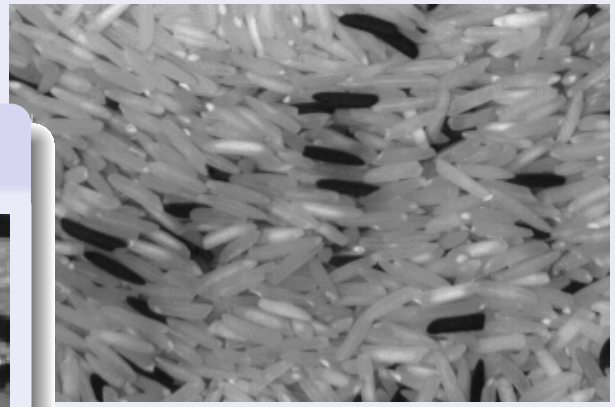
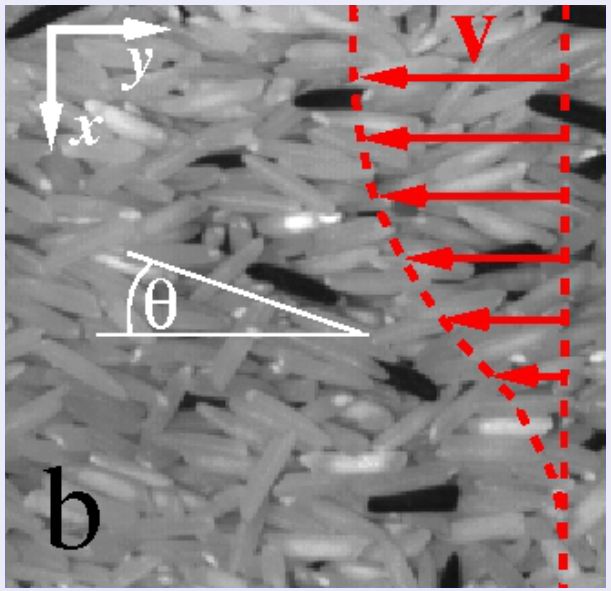
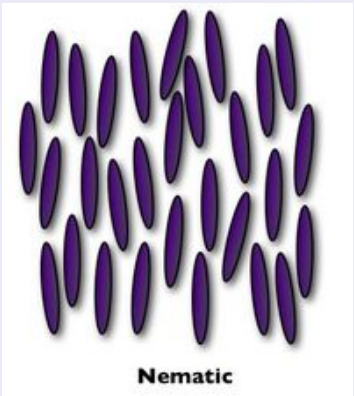
Rice



Shear alignment



Liquid crystals



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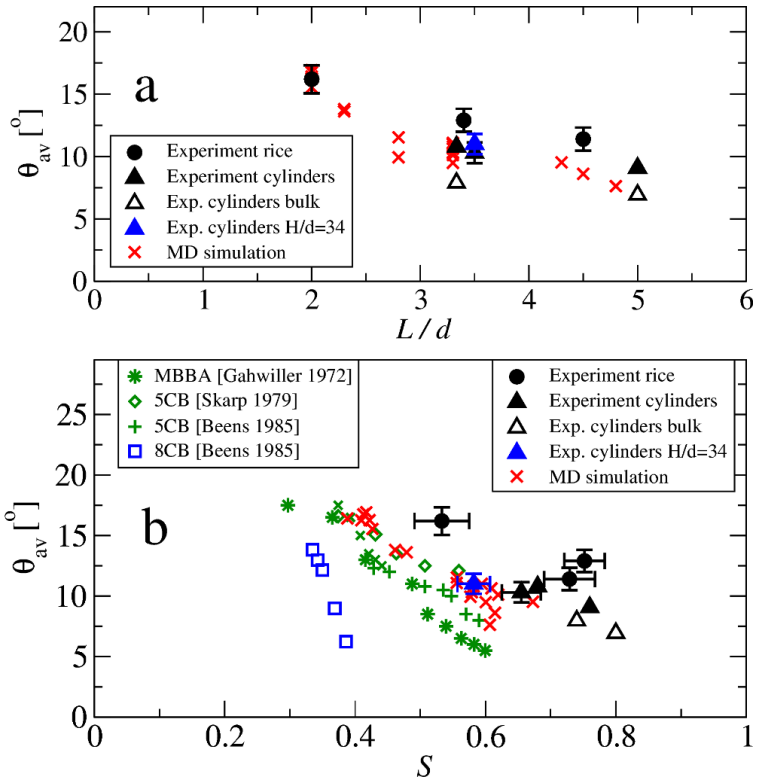
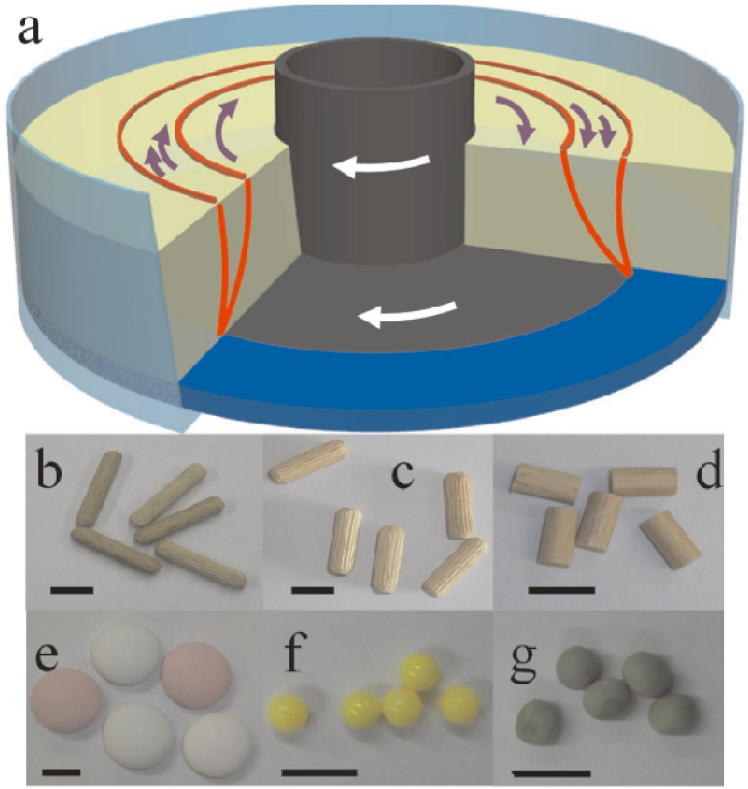
Introduction – Shear induced alignment



- average orientation extends small angle θ_{av} with streamlines
- θ_{av} is independent of shear rate over 3 decades in quasistatic regime, and decreases with L/d
- similarities with nematics

Börzsönyi, Szabó, Törös, Wegner, Török, Somfai, Bien, Stannarius: Phys. Rev. Lett. (2012)
Börzsönyi, Szabó, Wegner, Harth, Török, Somfai, Bien, Stannarius: Phys. Rev. E (2012)

Experimental setup



particles:

- wooden "pegs": $Q = L/d = 5,\ 3.3,\ 2$
- chocolate lentils: $h/d = 0.45$
- airsoft ammunition (monodisperse spheres)
- peas

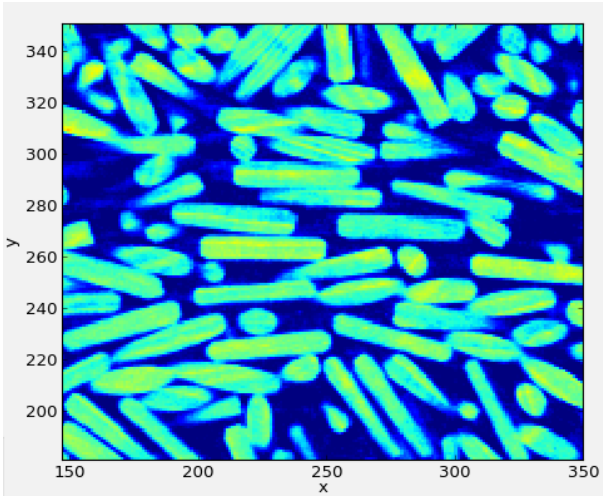
Experimental setup – x-ray CT

Inka Angio Lab, Univ. Magdeburg

Resolution:

- pixel spacing 0.5 mm or 0.68 mm
- (less than) $512 \times 512 \times 386$ pixels
- intensity values: x-ray absorption

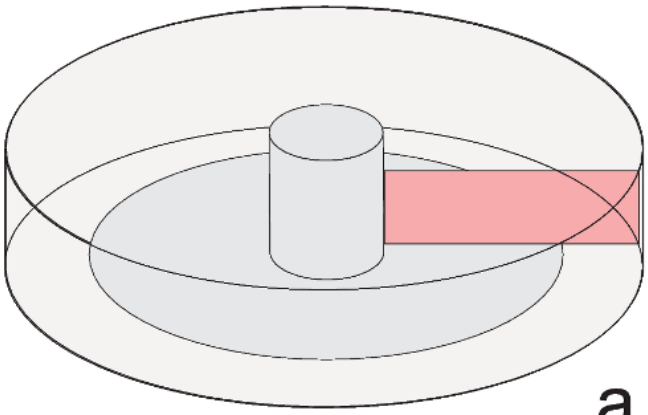
Experimental setup – 3d reconstruction



- thresholding
  Otsu's method
  - \+ CPU-cheap, high resolution 3d density
  - – no individual particle positions

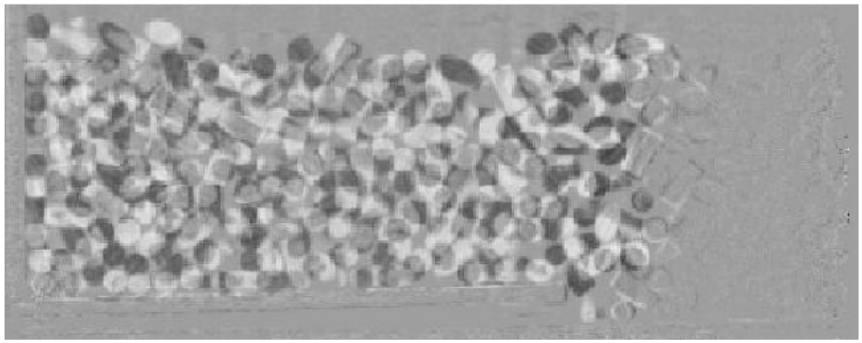
- particle detection
  "watershed" algorithm
  fine tuned for relatively low resolution detection of identical particles
  - \+ individual particle position and orientation data
  - – CPU-expensive, some particle loss (typical $< 1\%$)
    3d density reconstruction difficult

Results – individual particle motion

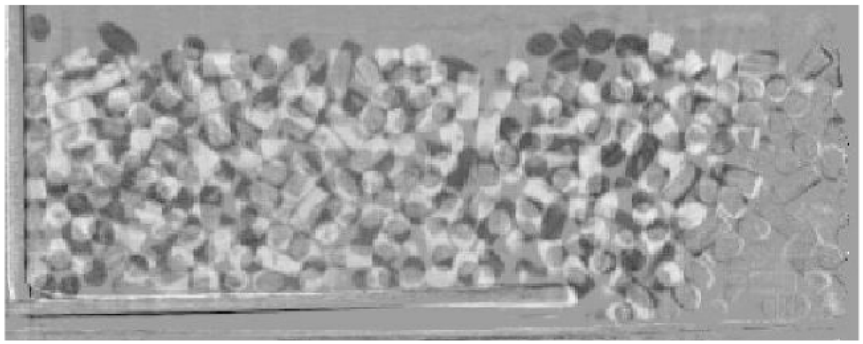


a

b



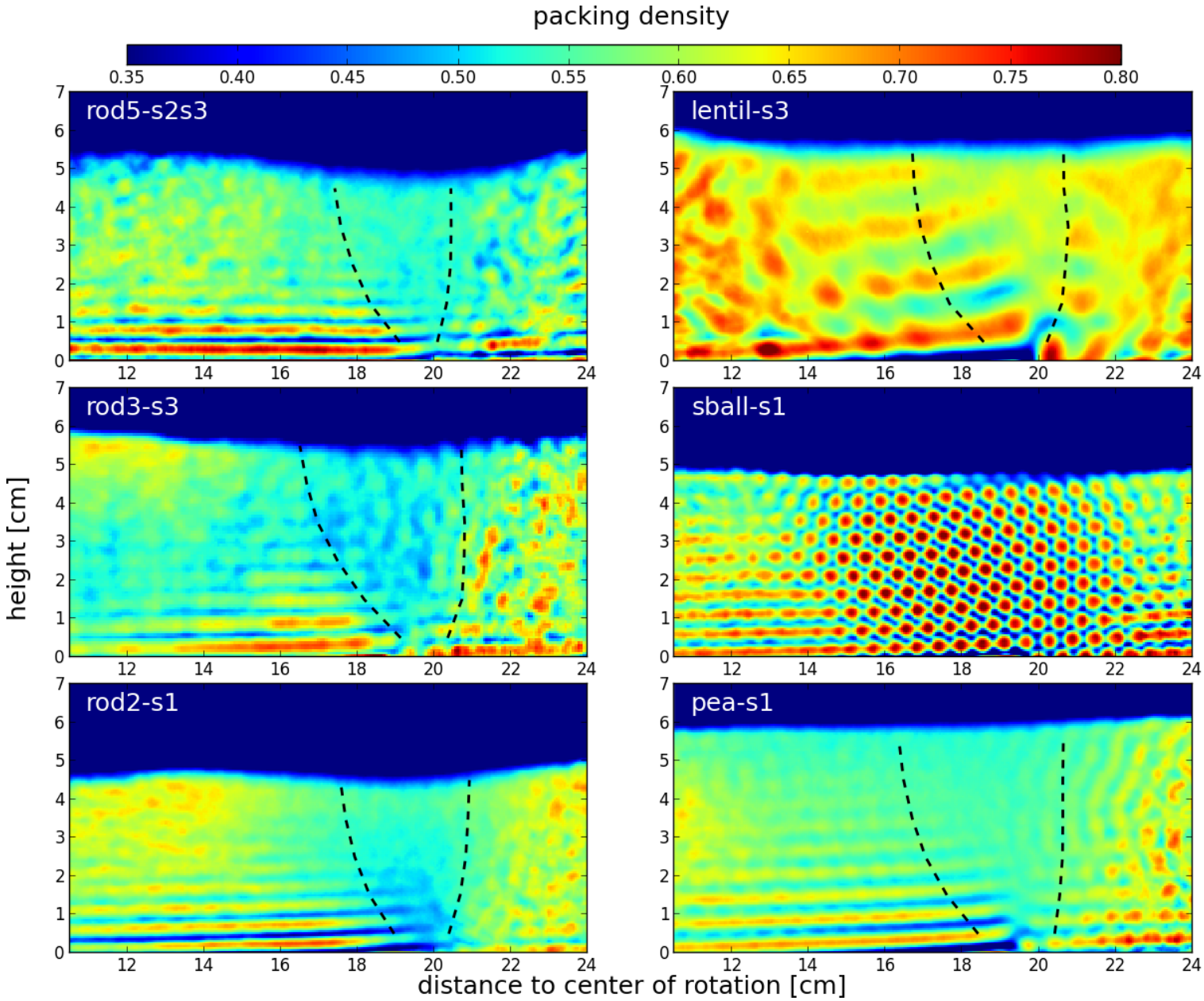
c (2° rotation)



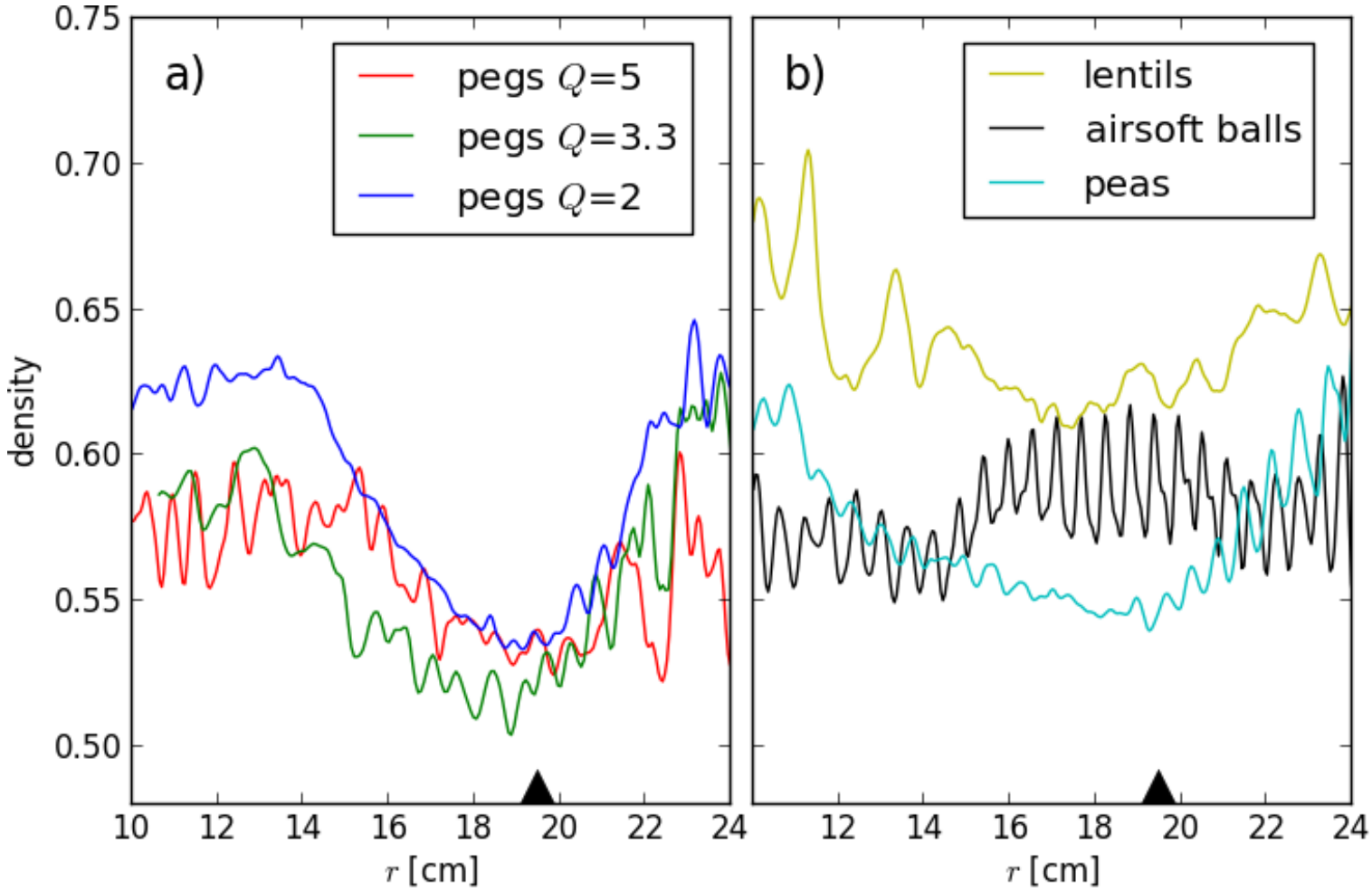
d (160° rotation)

- Creeping motion outside shear zone

Results – packing density in the stationary state

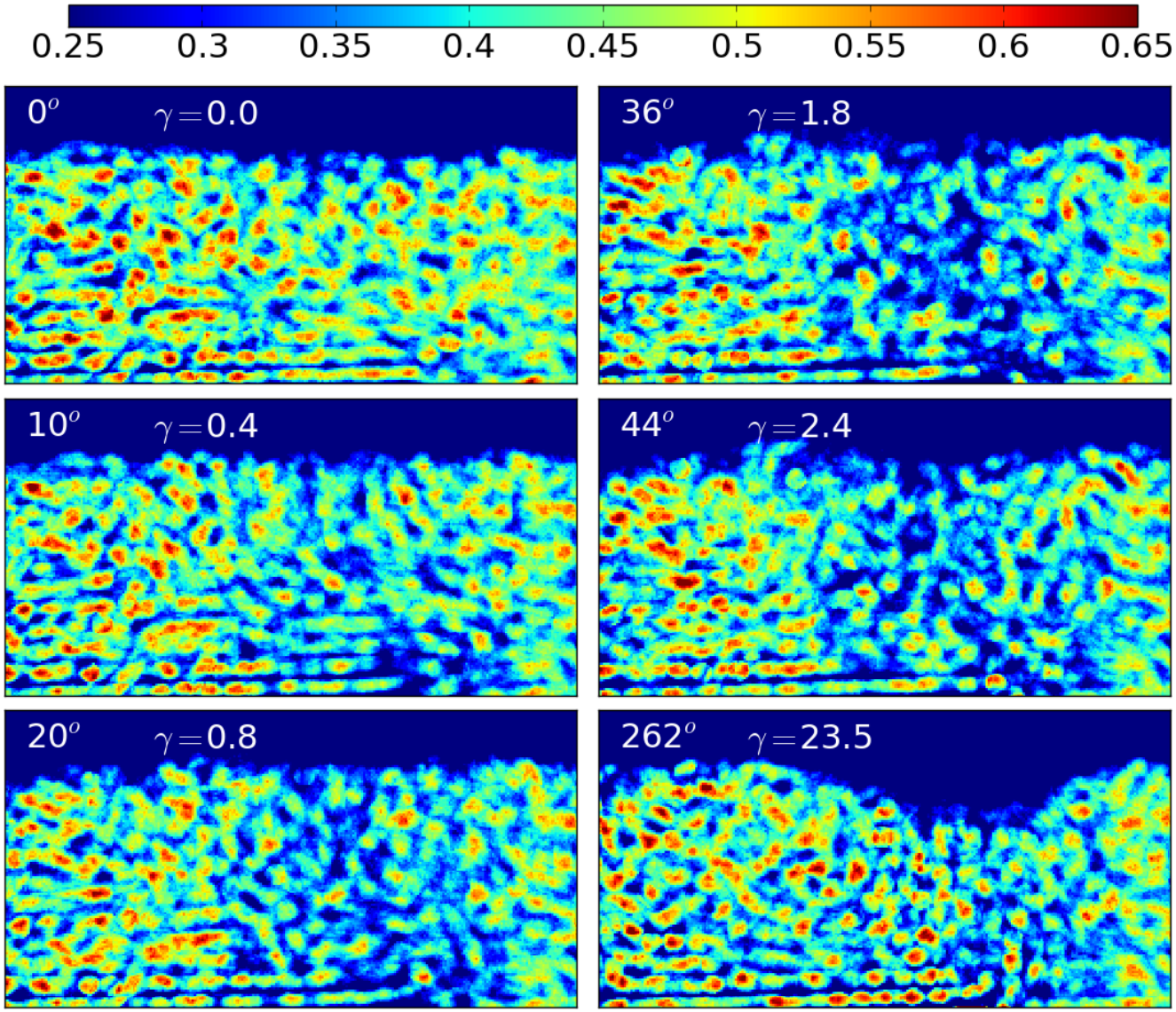


Results – packing density in the stationary state

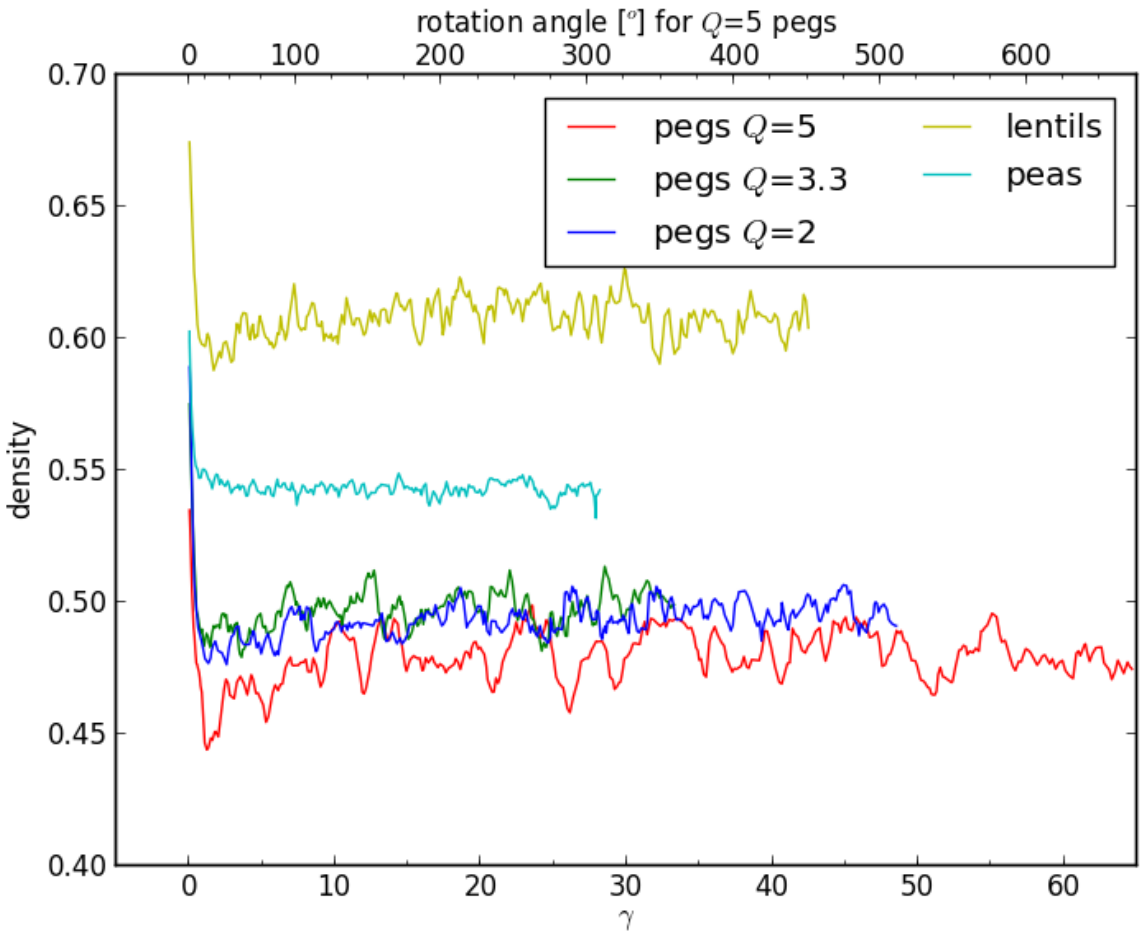


- Density is smaller in shear zone than in neighboring regions except: monodisperse spheres

Results – time evolution (rods $Q = 5$)

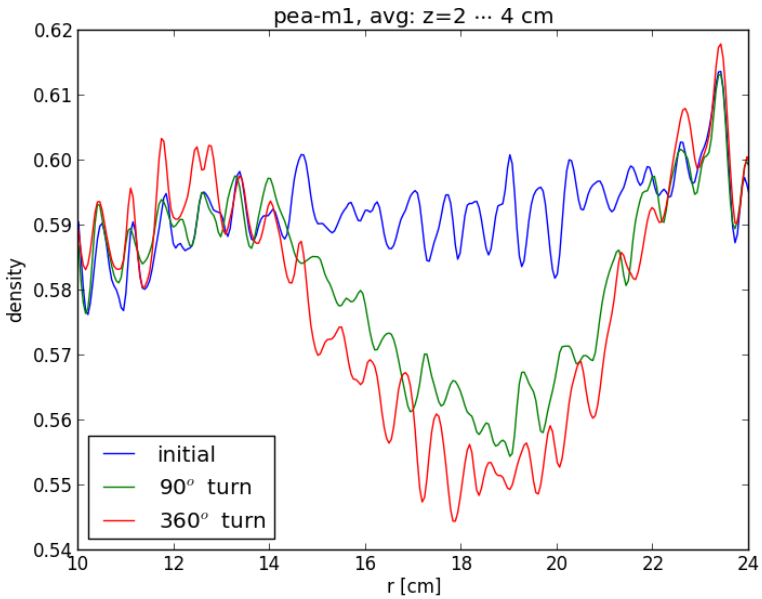


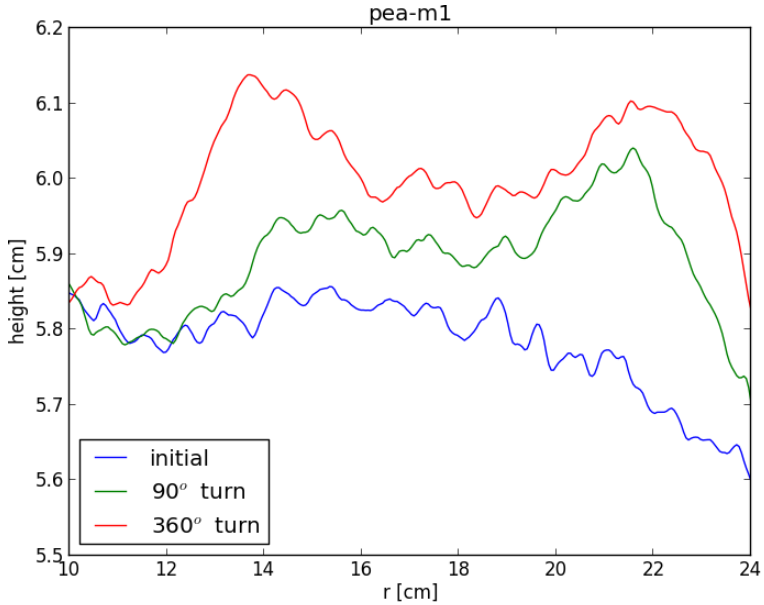
Results – time evolution – density

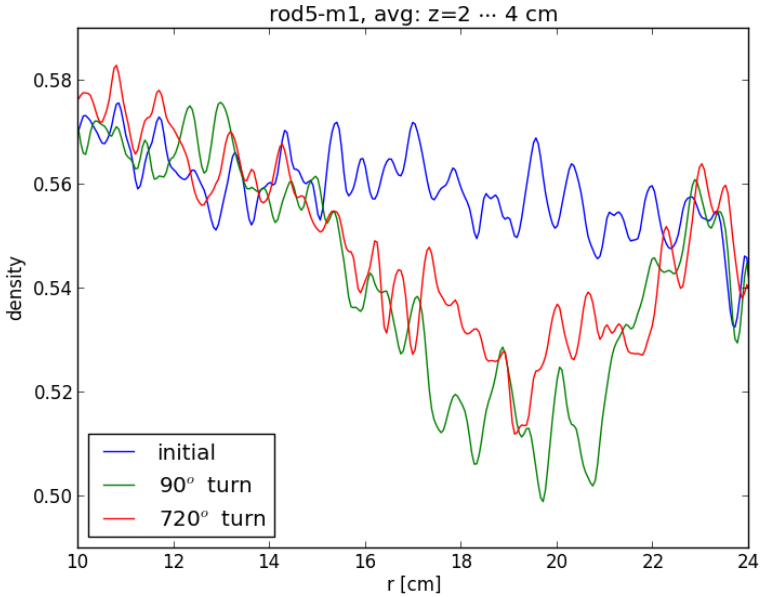


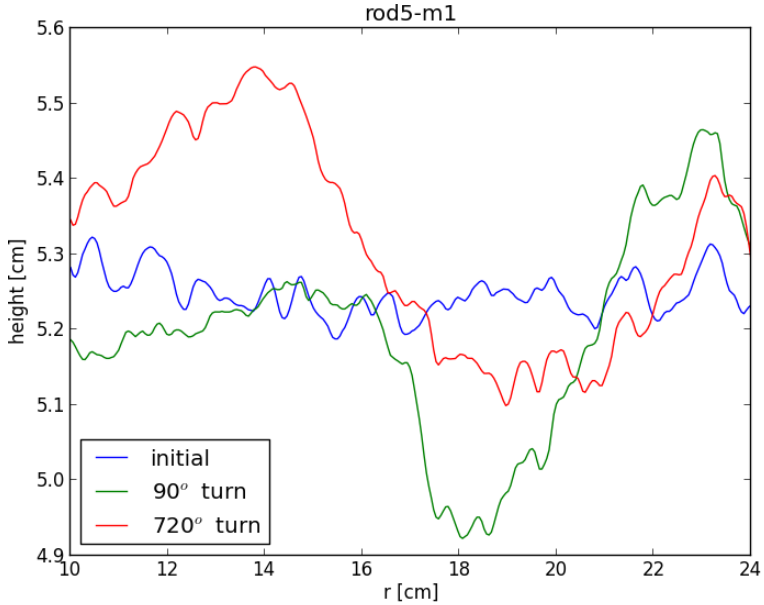
- all shapes: initial density drop (Reynolds dilatancy)
- non-spherical: subsequent density increase (shear alignment)

Results – time evolution – density and height profile

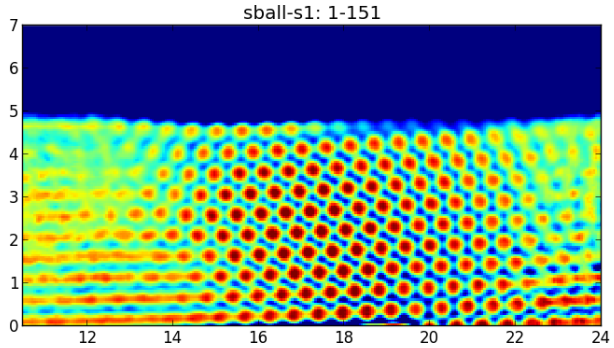








Results – crystallisation of monodisperse spheres



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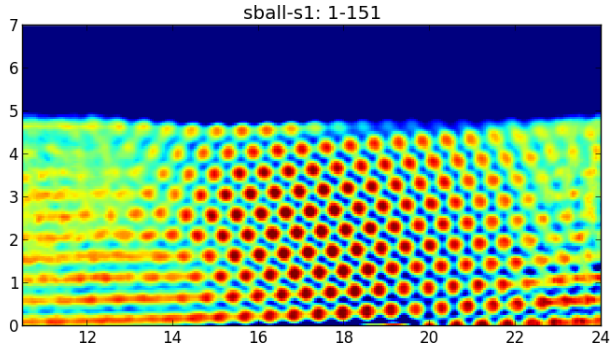
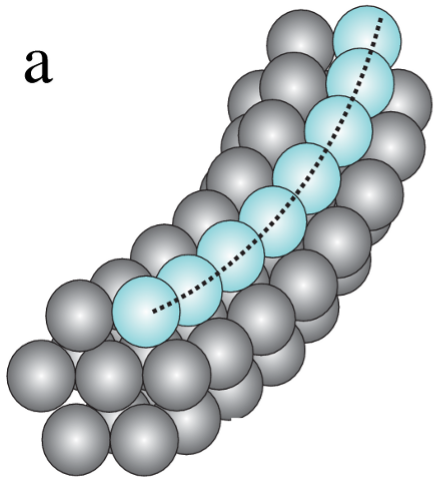
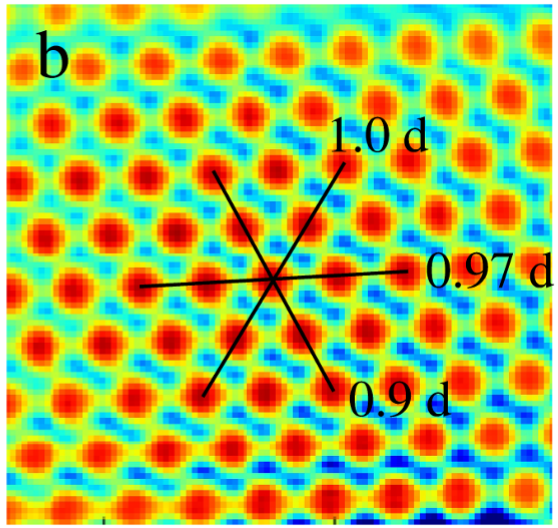


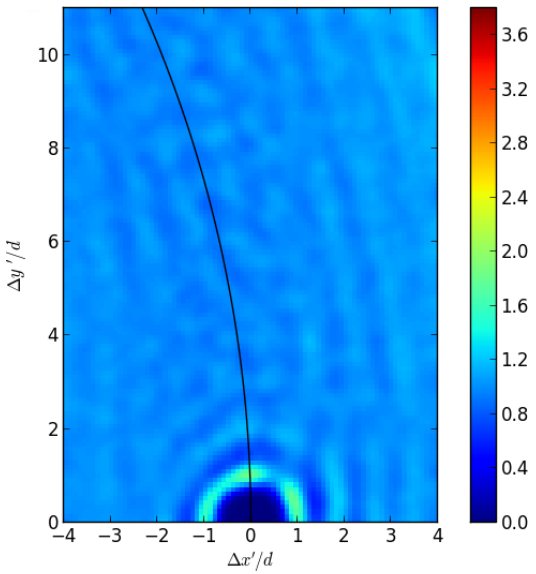




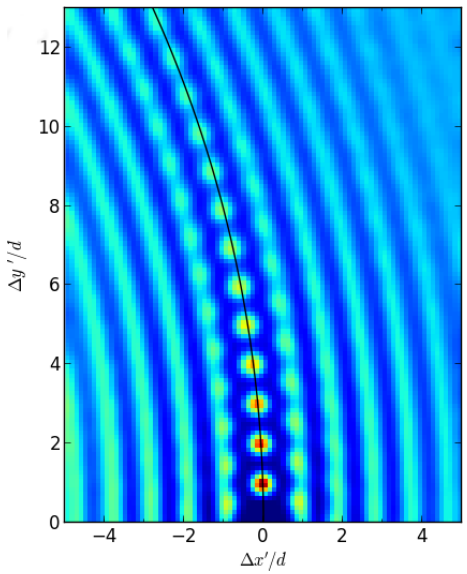
- chains of particles along streamlines
- hexagonal arrangement of the chains
- sides $\approx d$ in direction of velocity gradient
  sides $< d$ (slight interpenetration) in direction of no velocity gradient

Results – pair distribution functions

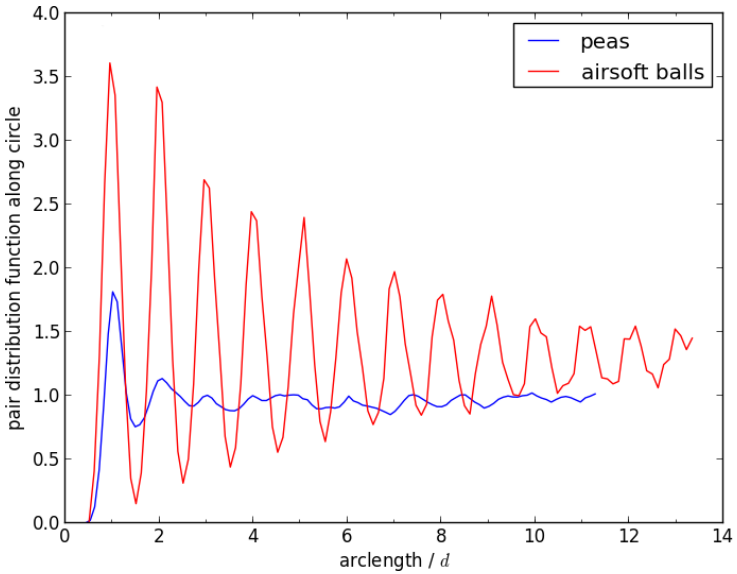
peas



airsoft balls



cut along streamlines



- peas: *(nearly spherical, slightly polydisperse)*
  quickly decaying pair distribution function
- airsoft balls: *(monodisperse spheres)*
  slowly decaying oscillation
  converging to value > 1: long range order

Conclusions

- density evolution in shear zone:
  - initial drop – Reynolds dilatancy
  - nonspherical shapes: subsequent partial rebound – shear induced alignment
- height profile evolution:
  - initial elevation above shear zone + heaps on both sides
  - nonspherical shapes: collapse above shear zone
- positional ordering:
  - monodisperse spheres:
    chains of particles along streamlines
    hexagonal arrangement of the chains
    long range order visible in pair distribution function
  - even few % polydispersity prevents ordering