Dynamics of translational and rotational movement of cigar-shaped particles in colloidal systems

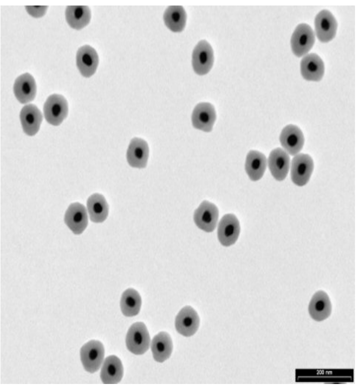
Magdalena Kordon
Alexander Schavkan

Supervisor: Christian Gutt
Co-supervisors: Birgit Fischer
Fabian Westermeier

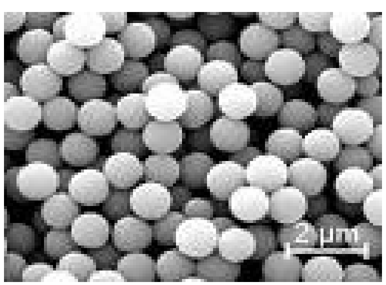
Plan of the presentation

1. What are colloids?
2. Sample preparation
3. Setup
4. Theory
5. Results
6. Conclusions
7. Outlook

What are colloids?

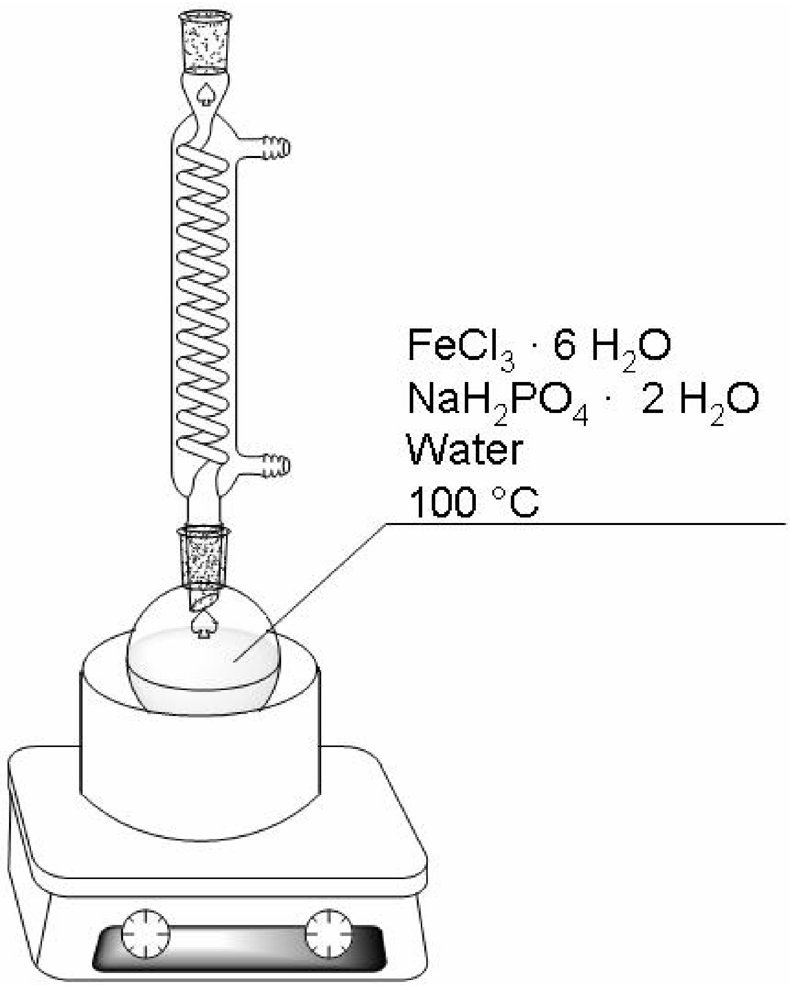


- small particles dispersed in a solution
- the particles of the dispersed substance are only suspended in the mixture, not dissolved like in a solution
- their size ranges from *nm* to *µm* scale
- the particles are small enough to maintain a homogenous appearance but on the other hand large enough to scatter light



The aim of measuring the light scattering in the colloidal systems is to investigate the structure and the dynamics of the systems and therefore understand the processes of phase behavior and glass transition better.

Synthesis of the cigar-shaped particles



$FeCl_3 \cdot 6H_2O + NaH_2PO_4 \cdot 2H_2O$

↓ 100 °C, 2 days (observing the change of color from yellow to orange)

Hematite α-Fe_2O_3

↓ centrifugation, washing

α-Fe_2O_3 + PVP

↓ stirring for 24 h

α-Fe_2O_3 + PVP

↓ centrifugation, washing with ethanol

α-Fe_2O_3 + PVP + NH_3 + TEOS

↓ stirring for 24 h

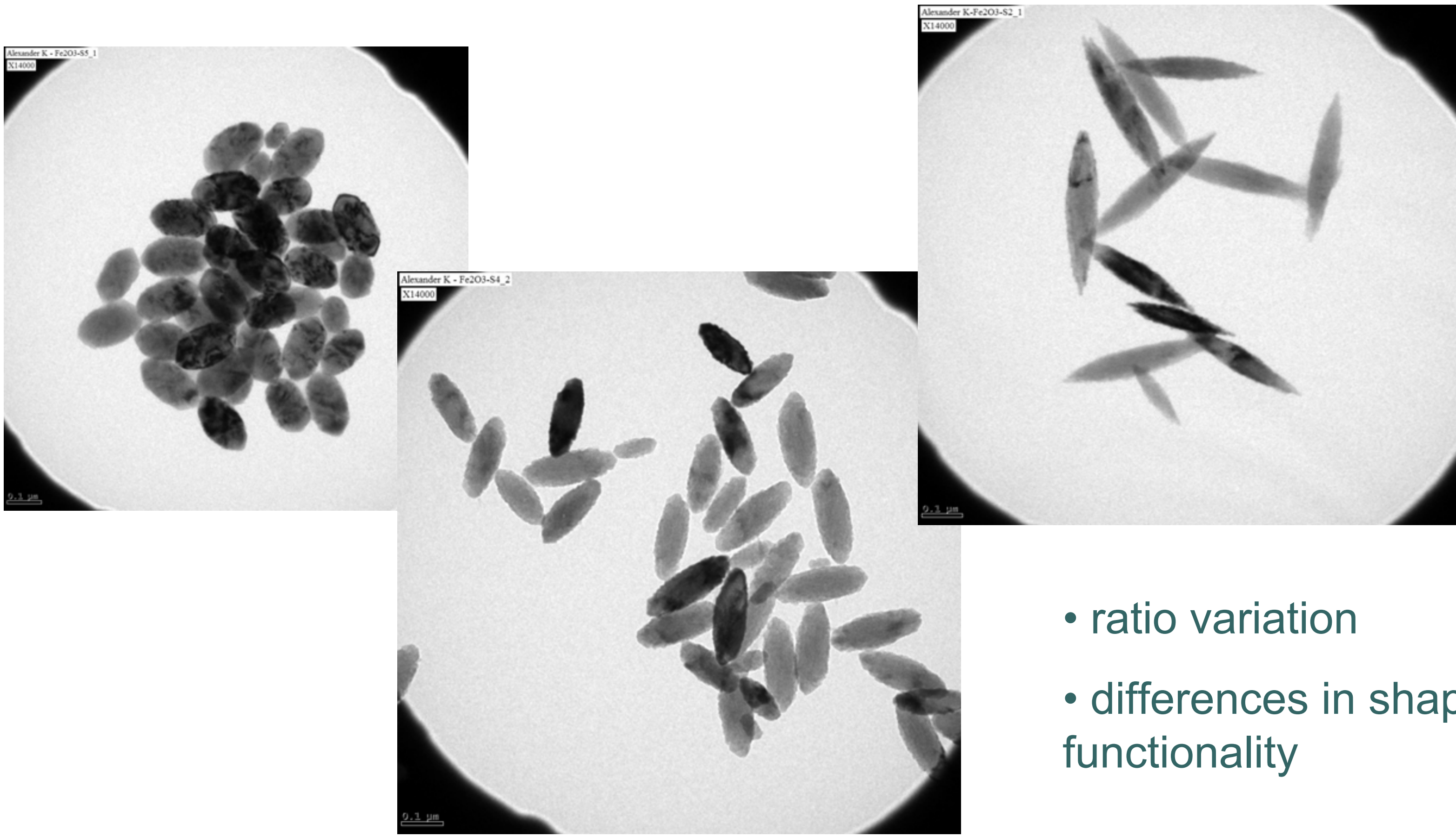
α-Fe_2O_3 + PVP + NH_3 + TEOS + TPM

↓ stirring for 24 h, removing ammonium hydroxide with the rotary evaporator, 2 x centrifugation, redispersion in ethanol

α-Fe2O3 + PVP + NH3 + TEOS + TPM + Dibutylphthalate

M. Ozaki, S. Kratohvil, E. Matijevic, Journal of Colloid and Interface Science, Vol. 102, No. 1, November 1984

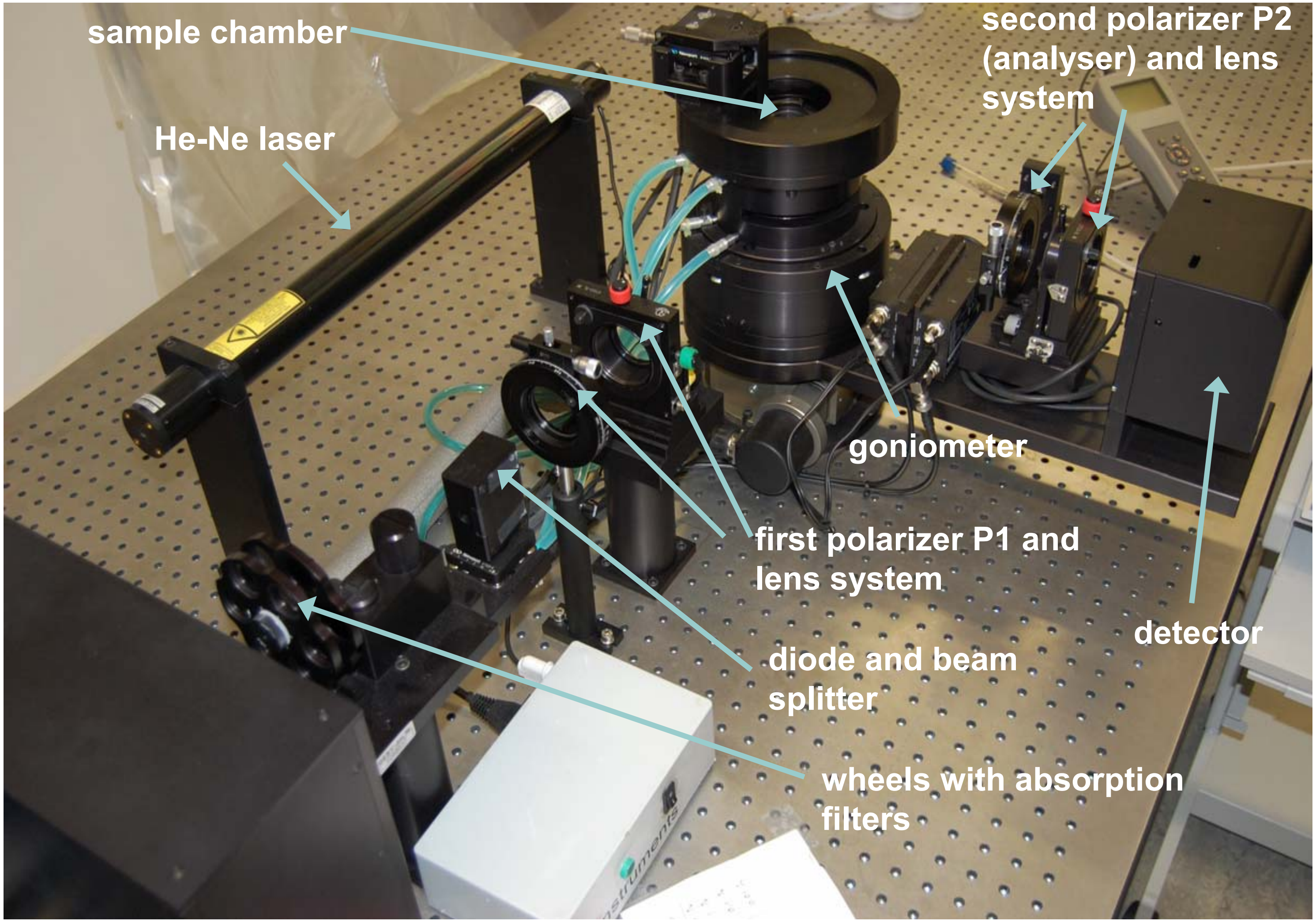
The difference between cigar-shaped particles with a silicium-dioxide layer and the ones without



- ratio variation
- differences in shape and functionality

TEM images of cigar-shaped particles (Hematite α-Fe_2O_3)

Setup used for DLS measurements



Static and Dynamic Light Scattering

Static:

- single values of intensity for each scattering angle – no possibility to observe any kind of movement

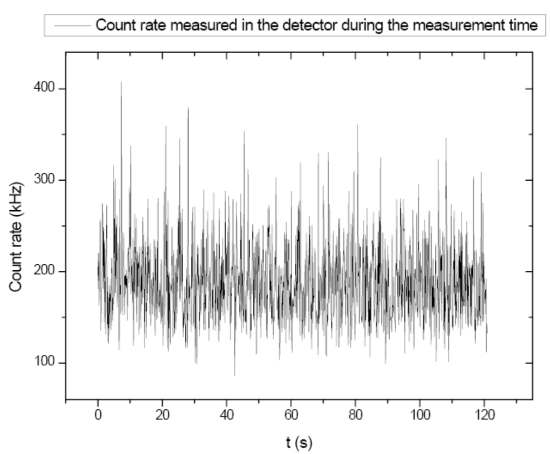
Dynamic:

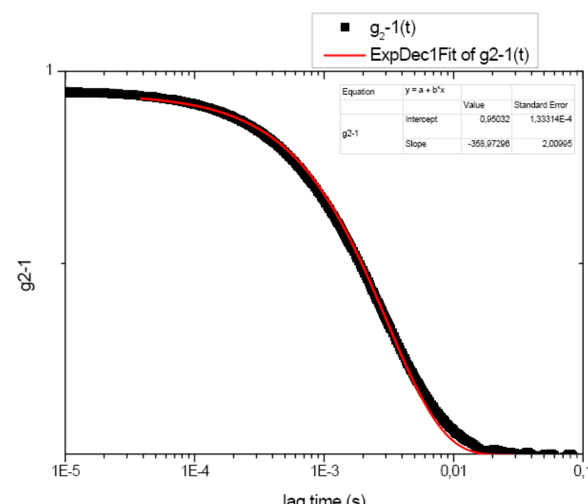
- intensity measured in certain periods of time for each scattering angle – time dependent results
- calculation of autocorrelation function
- different values of intensity depending on time represent different positions

B. J. Berne, R. Pecora, *Dynamic Light Scattering. With applications to chemistry, biology and physics,* Dover Publications. Inc. Mineola. N.Y. 11501

Autocorrelation Function

- Measurement of correlation with autocorrelation function: $\langle I(0)I(\tau)\rangle = \lim_{T\to\infty}\frac{1}{T}\int_0^T dt I(t)I(t+\tau)$
- or normalized: $g^{(2)}(\tau) = \langle I(t)I(t+\tau)\rangle \,/\, \langle I\rangle^2$
- The time correlation function of a nonperiodic property decays from $\langle I^2\rangle$ to $\langle I\rangle^2$ in the course of time
- The intensity autocorrelation function measures the dynamic scattering function

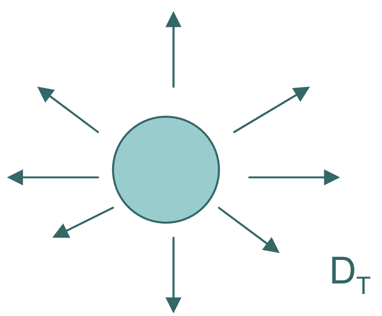




Round vs. Cigar-shaped

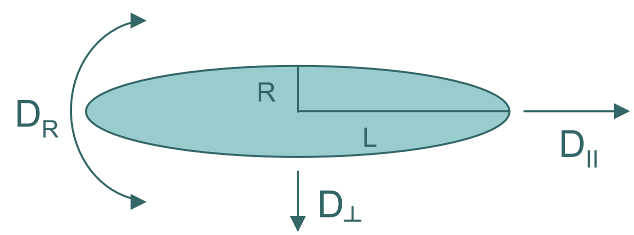
- Rotation and translation are characterised in different time scales; the former is faster than the latter.

- Sphere (parameter R)
- Only translational movement can be observed
- Spherical particles do not alter the polarization of the scattered radiation



$$\Gamma = D_0 q^2$$

- Ellipsoid (parameters R and L)
- Both translational and rotational movements affect the results of our experiment
- Assymetric cigar-shaped particles change the polarization of the scattered radiation

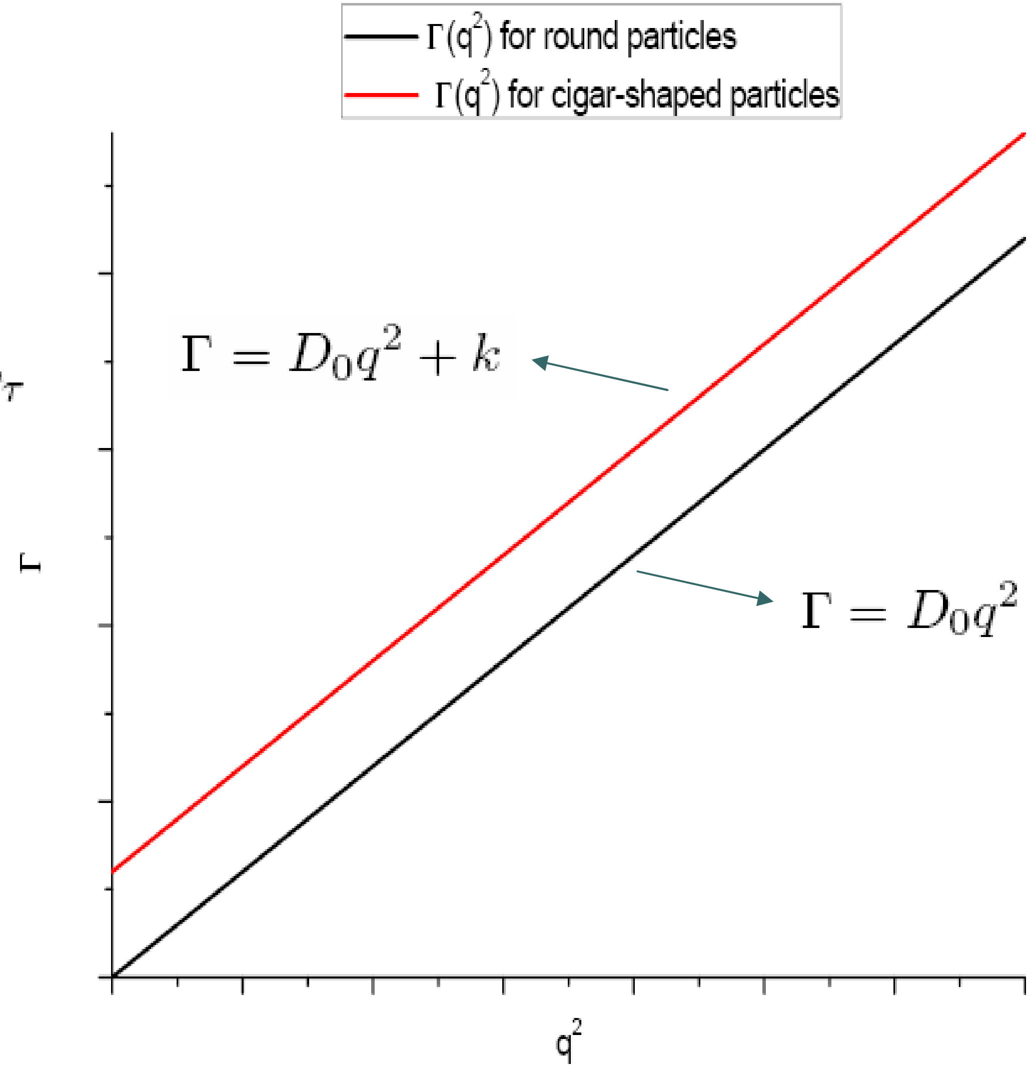


$$\Gamma = D_0 q^2 + k$$

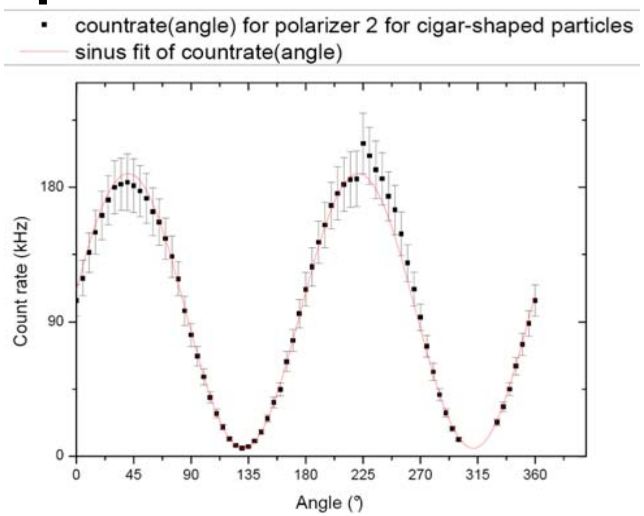
$$g^{(2)}(\tau) - 1 = A e^{-2\Gamma\tau}$$

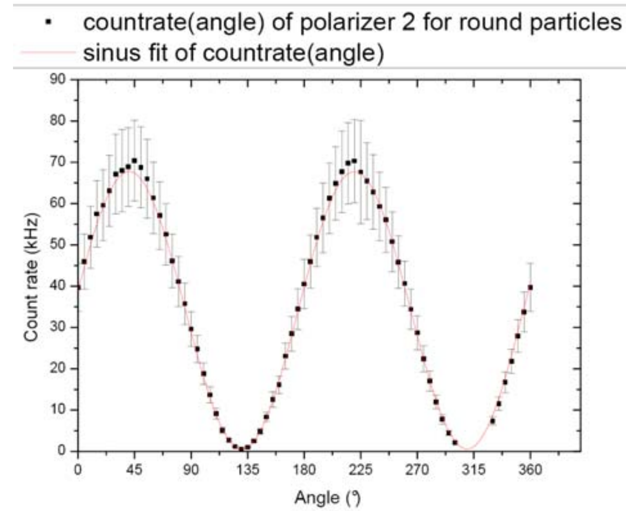
Expected $\Gamma(q^2)$ dependance

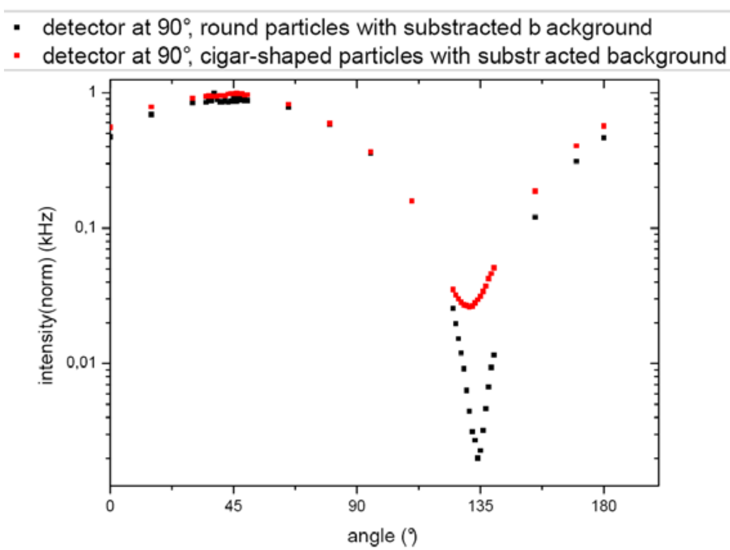
$$g^{(2)}(\tau) - 1 = Ae^{-2\Gamma\tau}$$

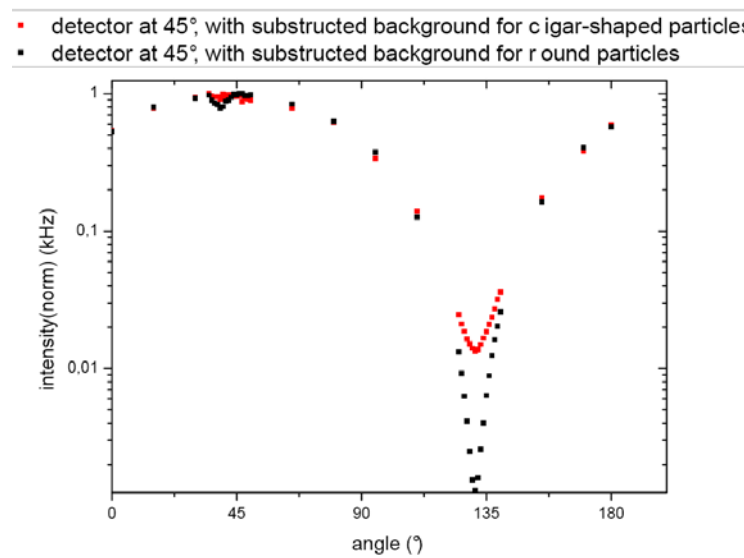


Comparison between round and cigar-shaped particles

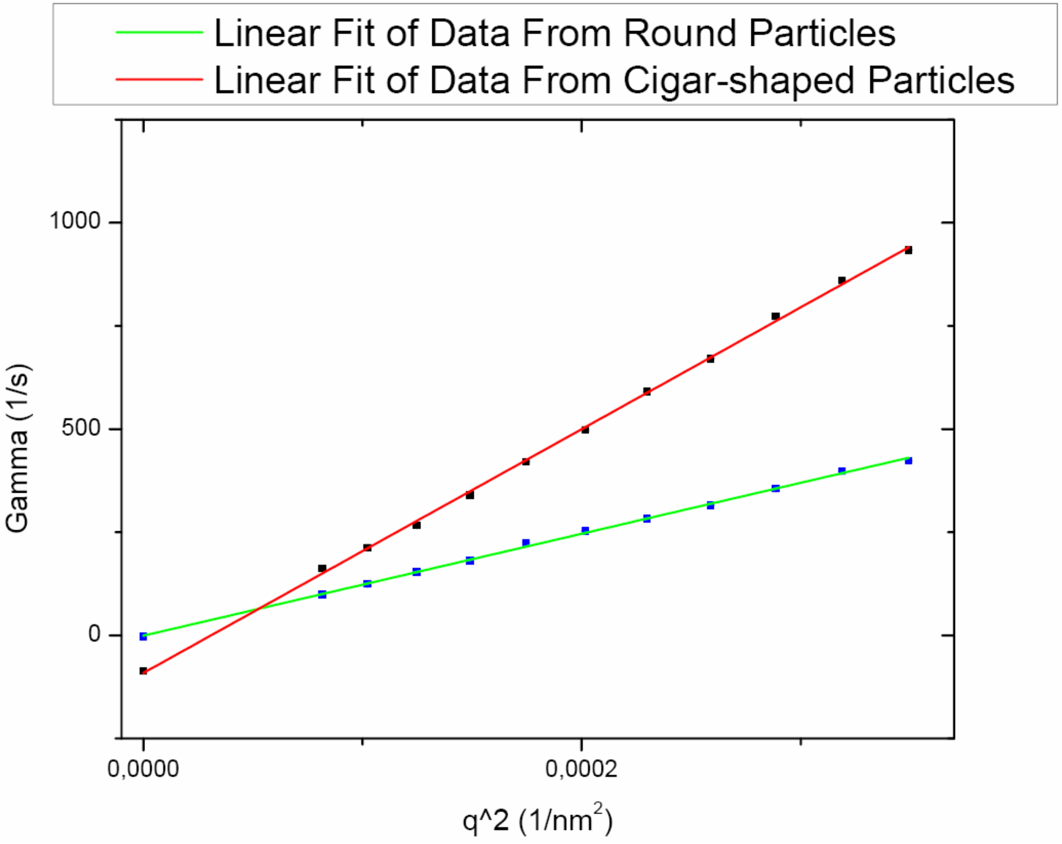








Interception of Γ(q^2) curve with y-axis



- Γ calculated from exponential decay of the autocorrelation function:

$$g^{(2)}(\tau) - 1 = Ae^{-2\Gamma\tau}$$

- Plot Γ(q^2) with $q = \frac{4\pi n}{\lambda} \cdot sin(\theta/2)$

Conclusions

- DLS measurements confirmed the presence of both translation and rotation when considering Brownian motion
- This method let us find parameters describing the shape, the size and the diffusion of the particles
- So far we managed to see the basic differences between the round and cigar-shaped particles

Outlook

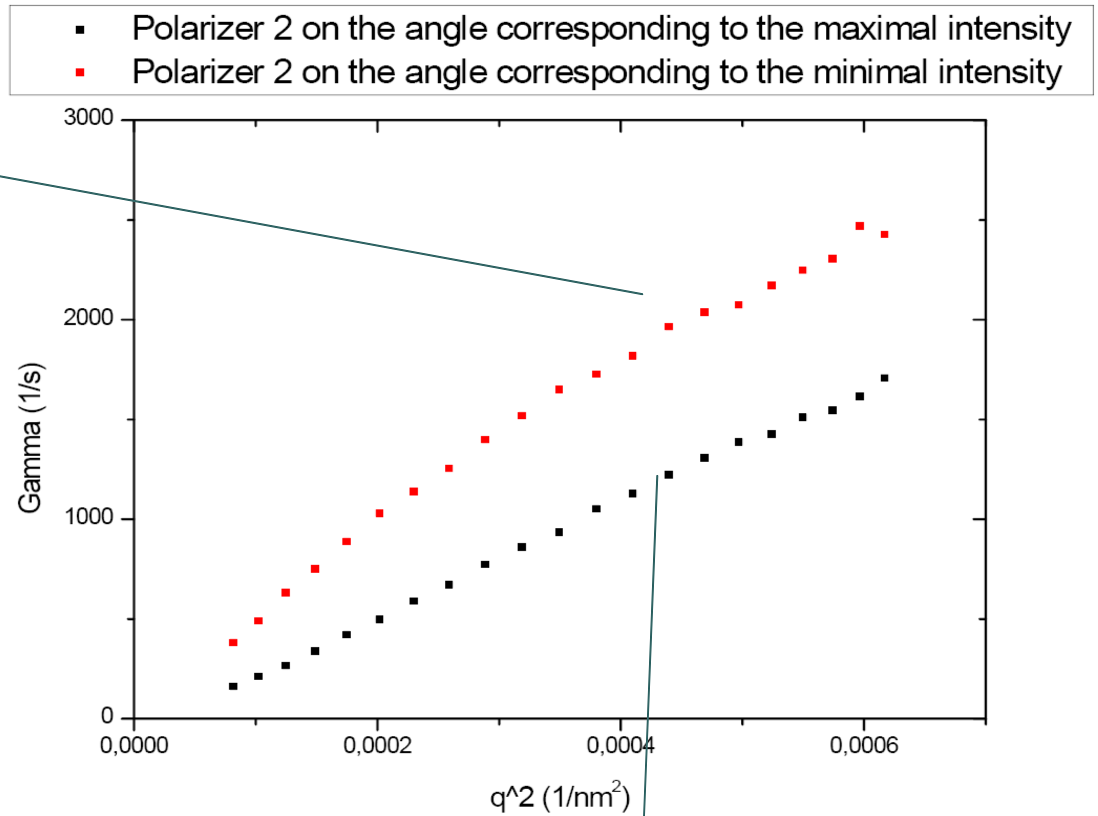
$$g_E(Q,t) = e^{(-Q^2(C(QL)\Delta D+\overline{D})t)} \cdot (S_0(QL) + S_2(QL)e^{-6D_r t} + ...)$$

$$S_{2l}(QL) = \frac{4l+1}{2} \cdot \frac{\left(\int_{-1}^{1} P_{2l}(x)_0(\frac{QLx}{2})dx\right)^2}{\int_{-1}^{1} j_0^2(\frac{QLx}{2})dx}$$

$$C(QL)_{t\to 0} = \frac{1}{2P(Q)} \int_{-1}^{1} j_0^2(\frac{QLx}{2})(x^2 - \frac{1}{3})dx$$

$$\overline{D} = \frac{1}{3}(2D_\perp + D_\|)$$

$$\Delta D = D_\| - D_\perp$$



$$D_T = \begin{pmatrix} D_\perp & & \\ & D_\perp & \\ & & D_\| \end{pmatrix}$$

Thank you for your attention.