

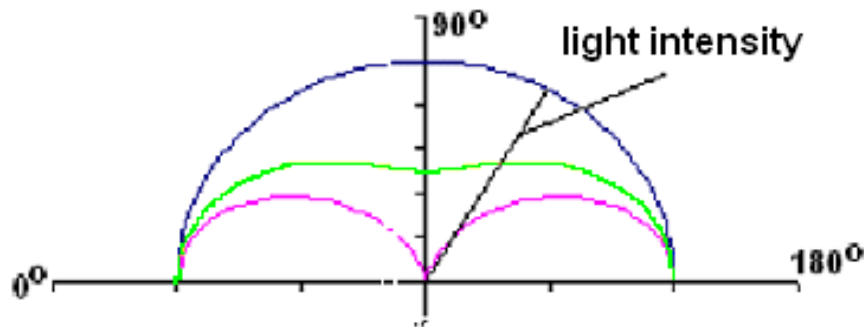
# Light scattering

Construct an optical device for measuring the concentration of non-soluble material in aqueous colloid systems. Use your device to measure the fat content in milk.

# Scattering on small molecules

In case of scattering on small particles we use Rayleigh theory

Intensity distribution as a function of angle for Rayleigh scattering in polar system



1<sup>st</sup> Graph: laser light incidents from 0° direction

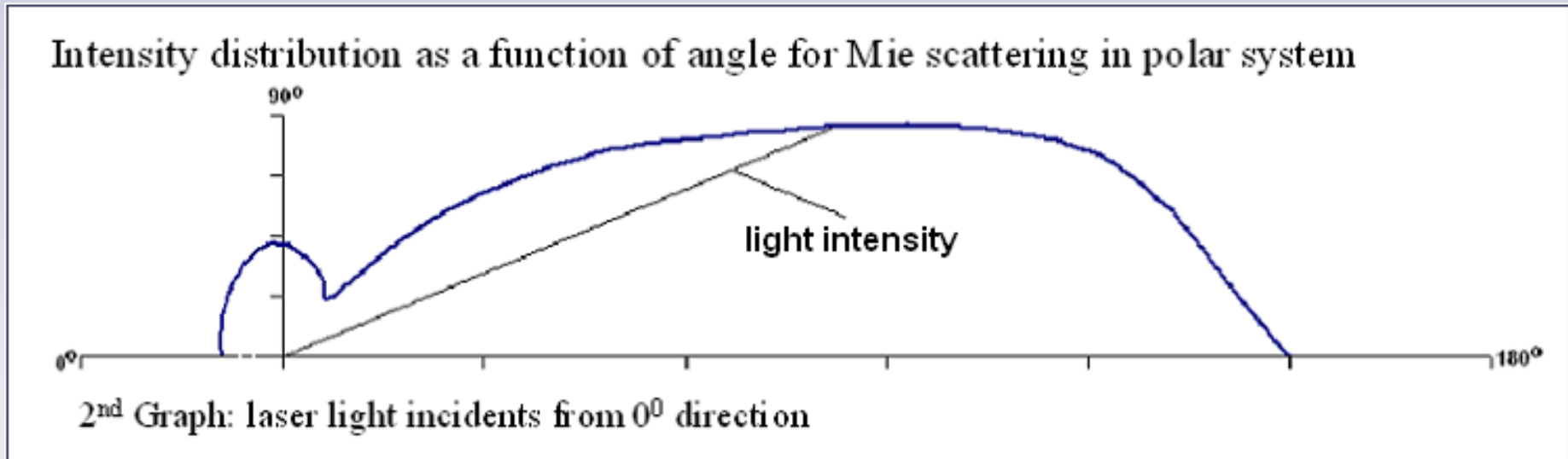
Intensity of scattered light

- Blue line** in the plane of polarization
- Green line** in the plane of oscillations of electric vector of incident light
- Magenta line** for non-polarized radiation

light polarization plane is very important

# Scattering on large molecules

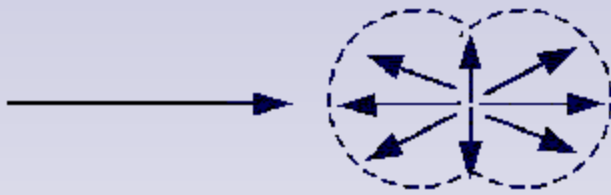
In case of scattering on large particles we use Mie theory



Both of these theories describe scattering on a singular molecule!

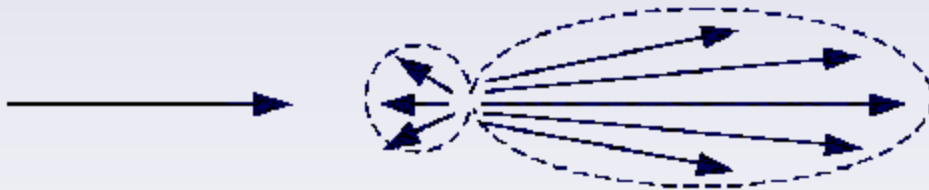
# Comparison

$$R \ll 1/10 \lambda$$



Rayleigh law  $I \sim \frac{1}{\lambda^4}$

$$R \geq 1/10 \lambda$$



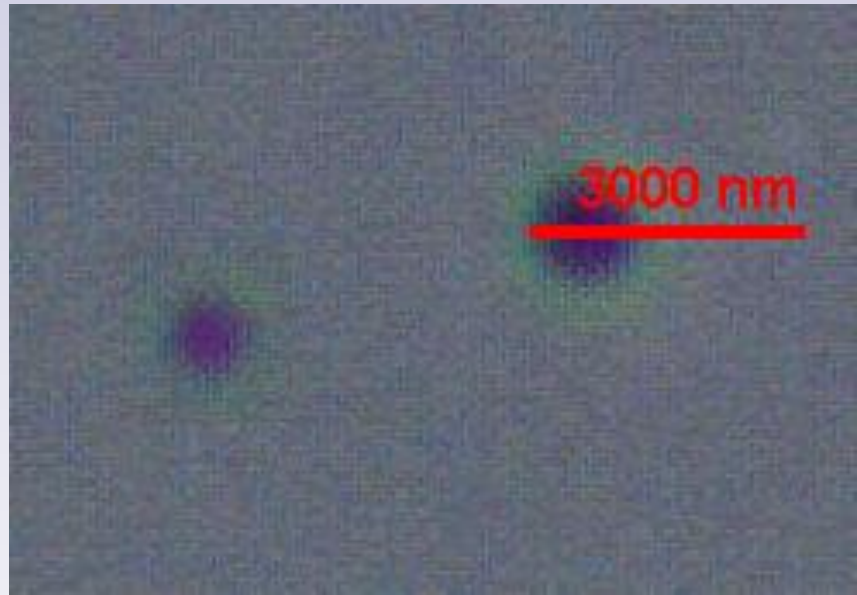
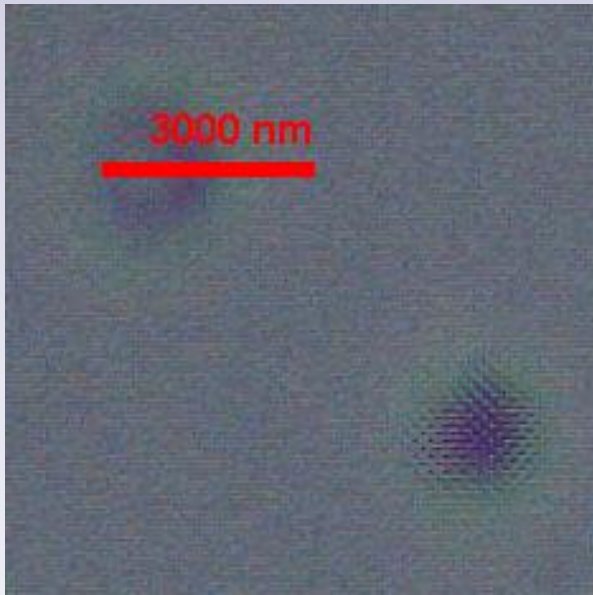
Mie theory  $I \sim \frac{1}{\lambda}$

# Our experiments

- 1) Measurement of light intensity as a function of concentration for determined angle ( $90^0$ )
- 2) Spectral analysis of light beam passing through the solution
- 3) Measurement of light intensity as a function of angle in various fat to proteine concentration ratios

# Extra testings

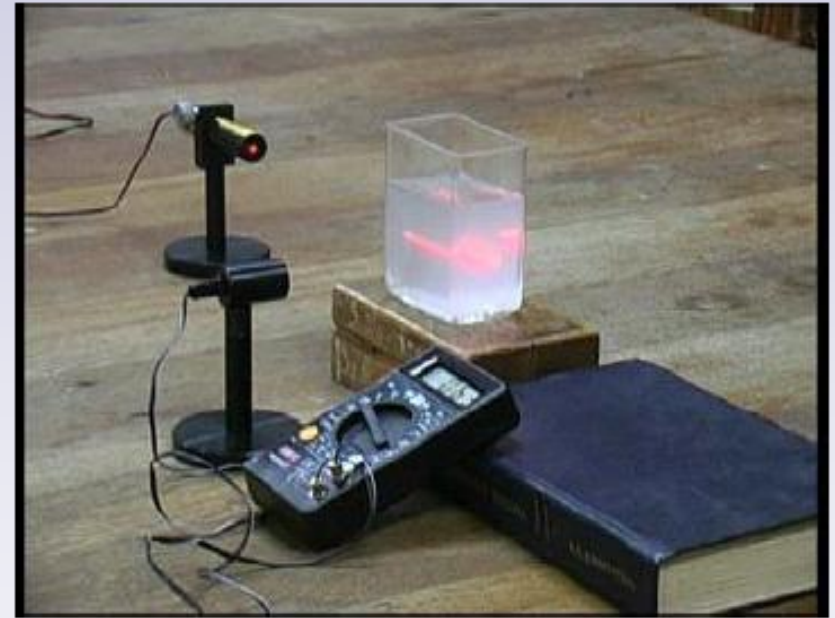
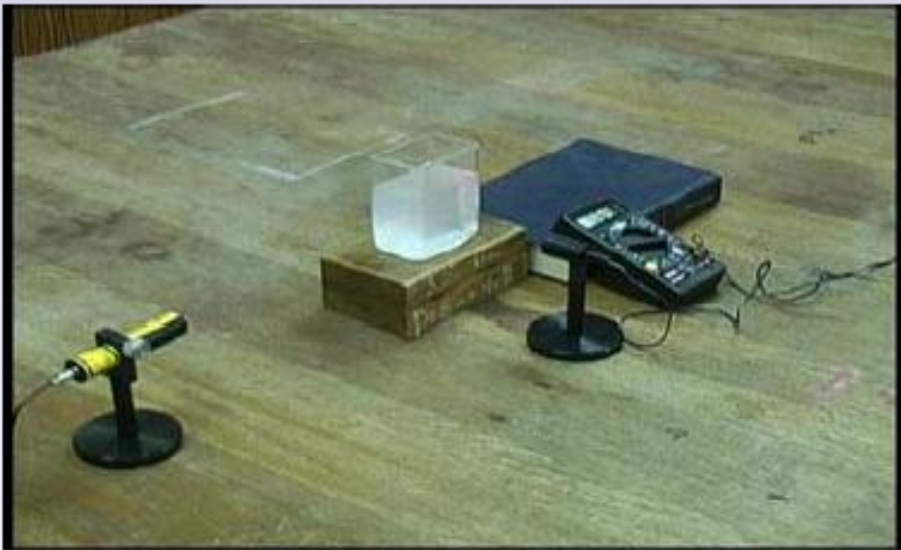
## Microscopic milk photograph



made in the University of Warsaw, Faculty of Biology

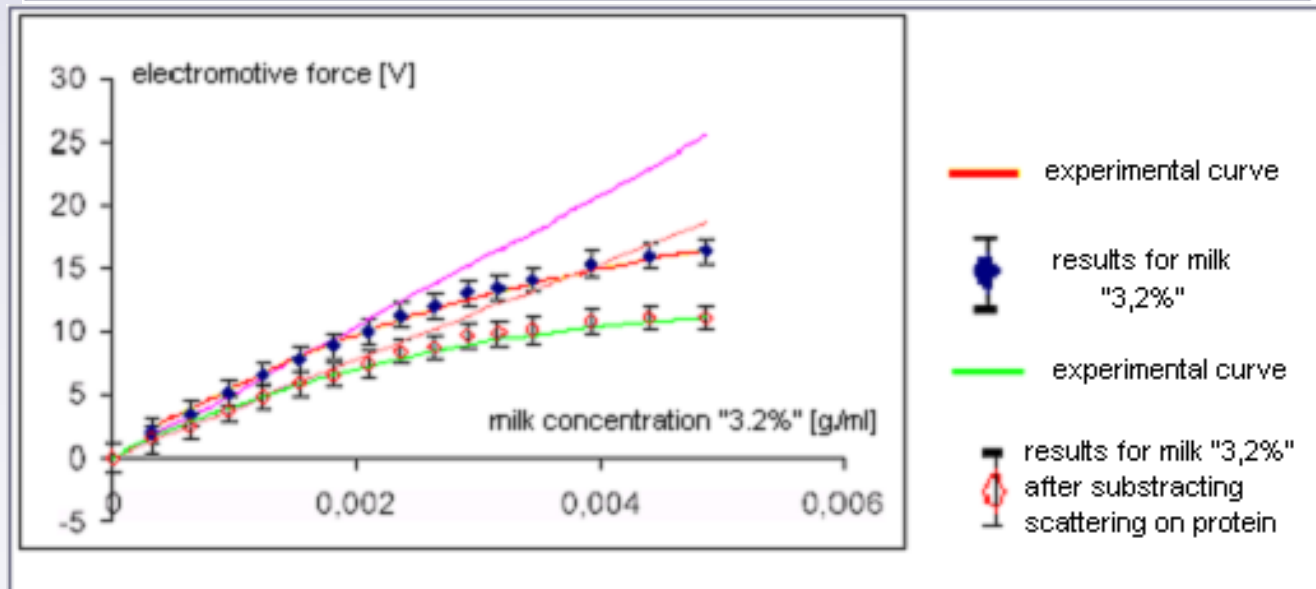
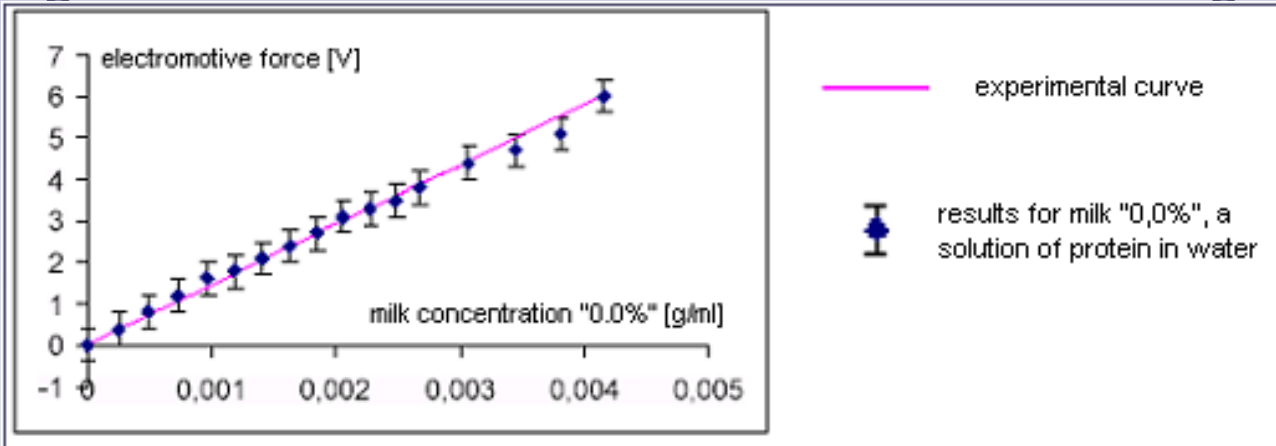
# 1<sup>st</sup> experiment

Our measuring device consists of: laser, rectangular vessel and photoelectric diode connected to voltmeter



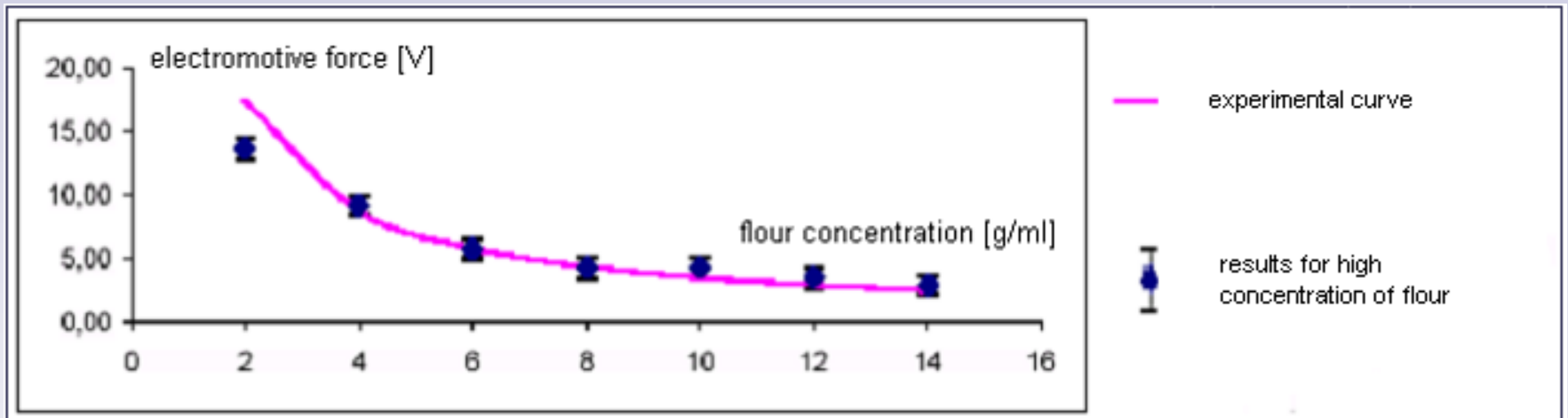
# Results of 1<sup>st</sup> experiment

Scattered light intensity distributions as a function of concentration;  
Light source – from  $0^{\circ}$  direction; diode at an angle:  $90^{\circ}$



# Conclusions from 1<sup>st</sup> experiment

In case of small concentrations intensity is a linear function. There is no double scattering, light absorption is insignificant. In case of bigger concentration:



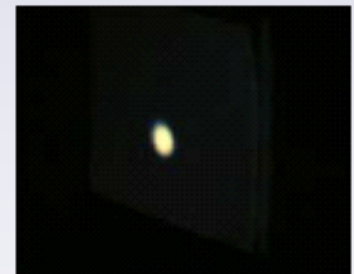
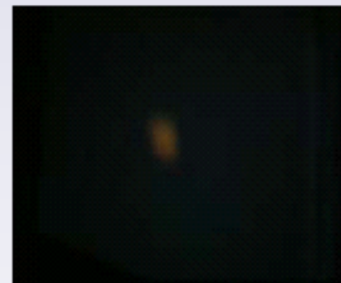
In bigger concentrations intensity becomes a non-linear function of concentration!

# 2<sup>nd</sup> experiment

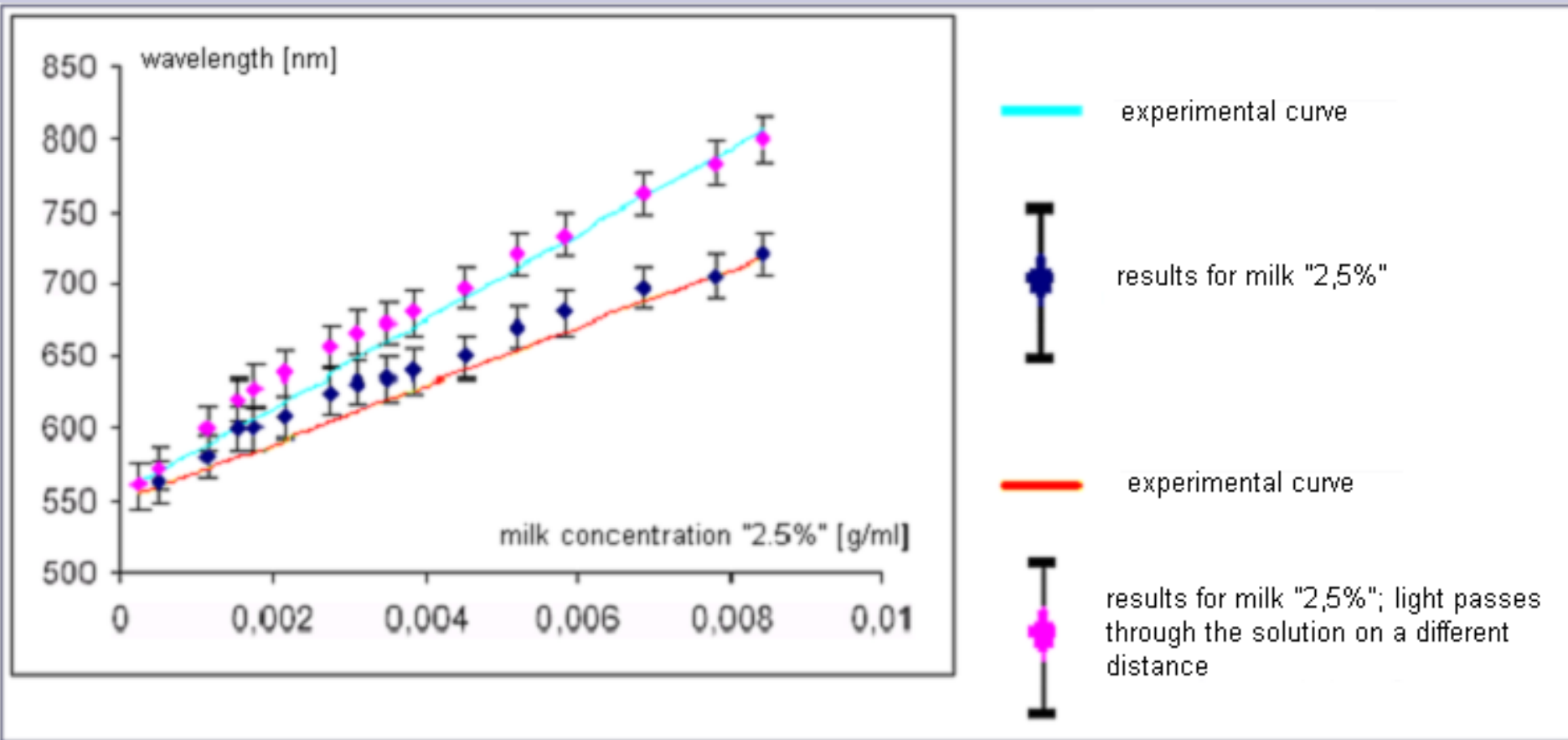
Our measuring device consists of: polychromatic light source, optical system, rectangular vessel and screen



Colours that we obtained on the screen



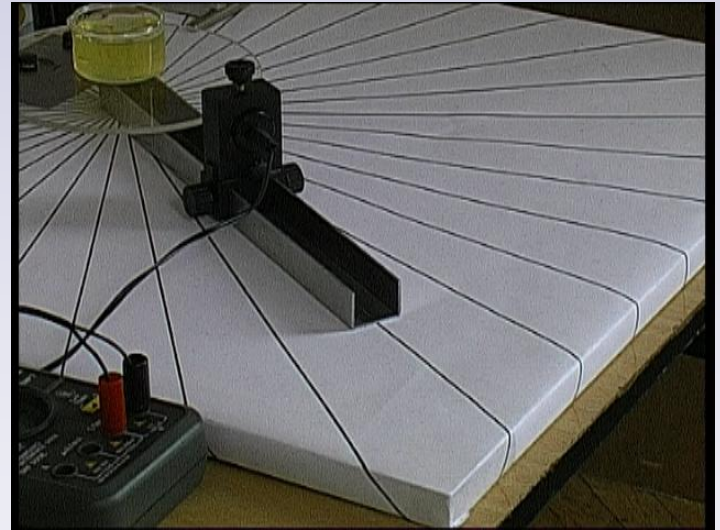
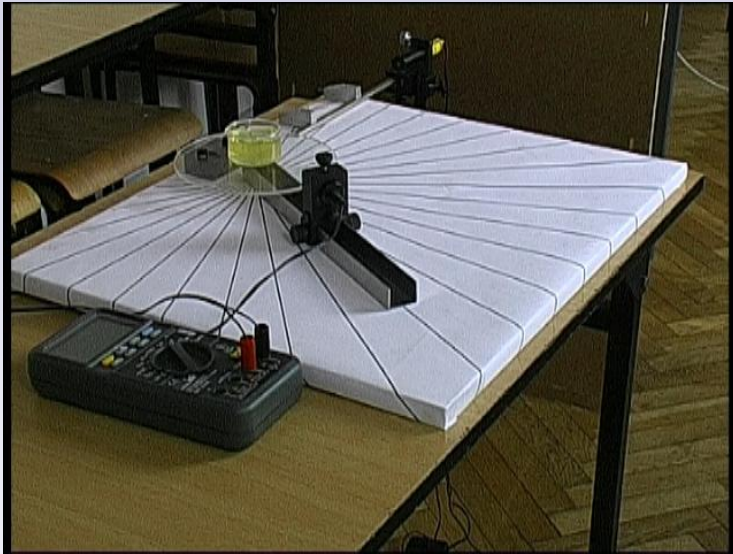
# Results of 2<sup>nd</sup> experiment



The wavelength of absorbed light increases with concentration increase. This is characteristic for Mie-type scattering

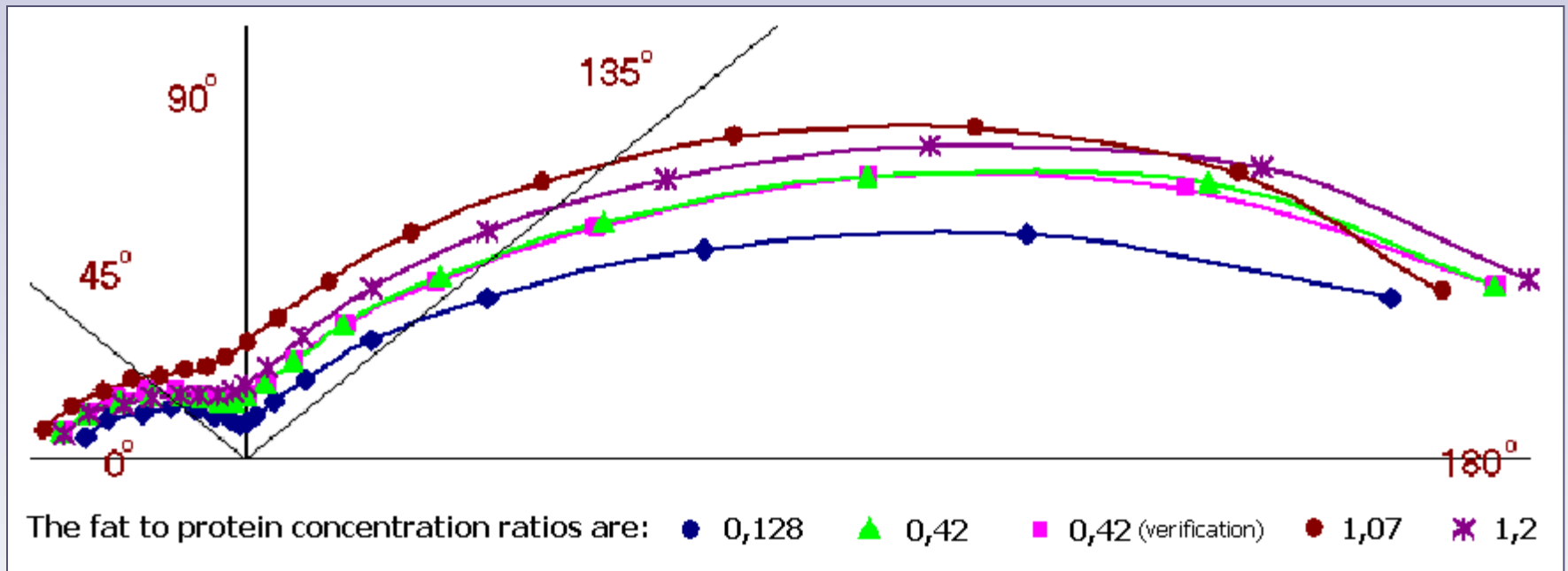
# 3<sup>rd</sup> experiment

Our measuring device consists of: laser, cylindrical vessel, photoelectric diode attached to a mobile arm and connected to a voltmeter



# Results of 3<sup>rd</sup> experiment

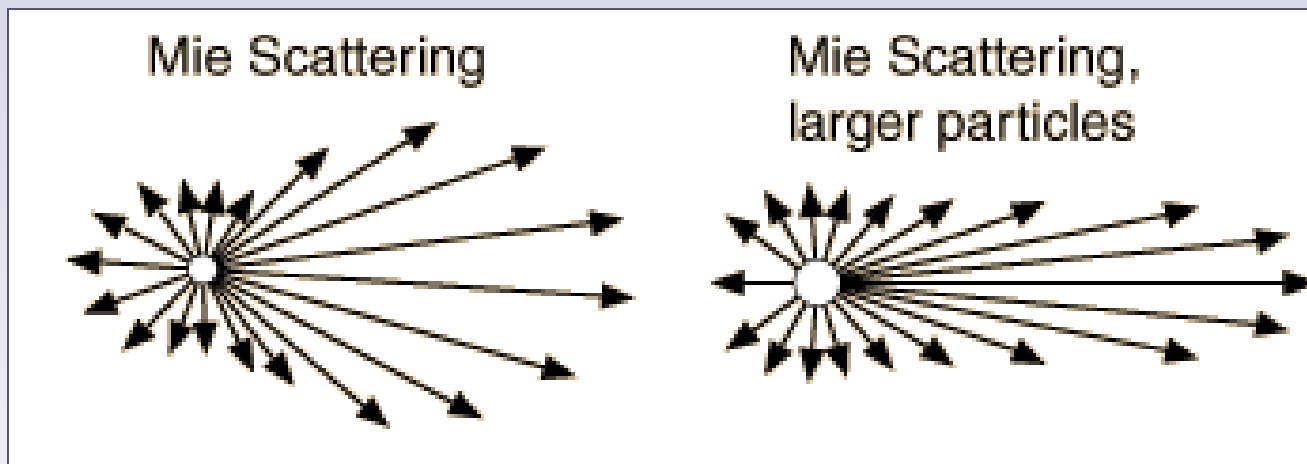
Scattered light intensity distribution as a function of angle in various fat to protein concentration ratios



We have obtained these ratios by mixing „0,0%” and „3,2%” milk.

# Conclusions from 3<sup>rd</sup> experiment

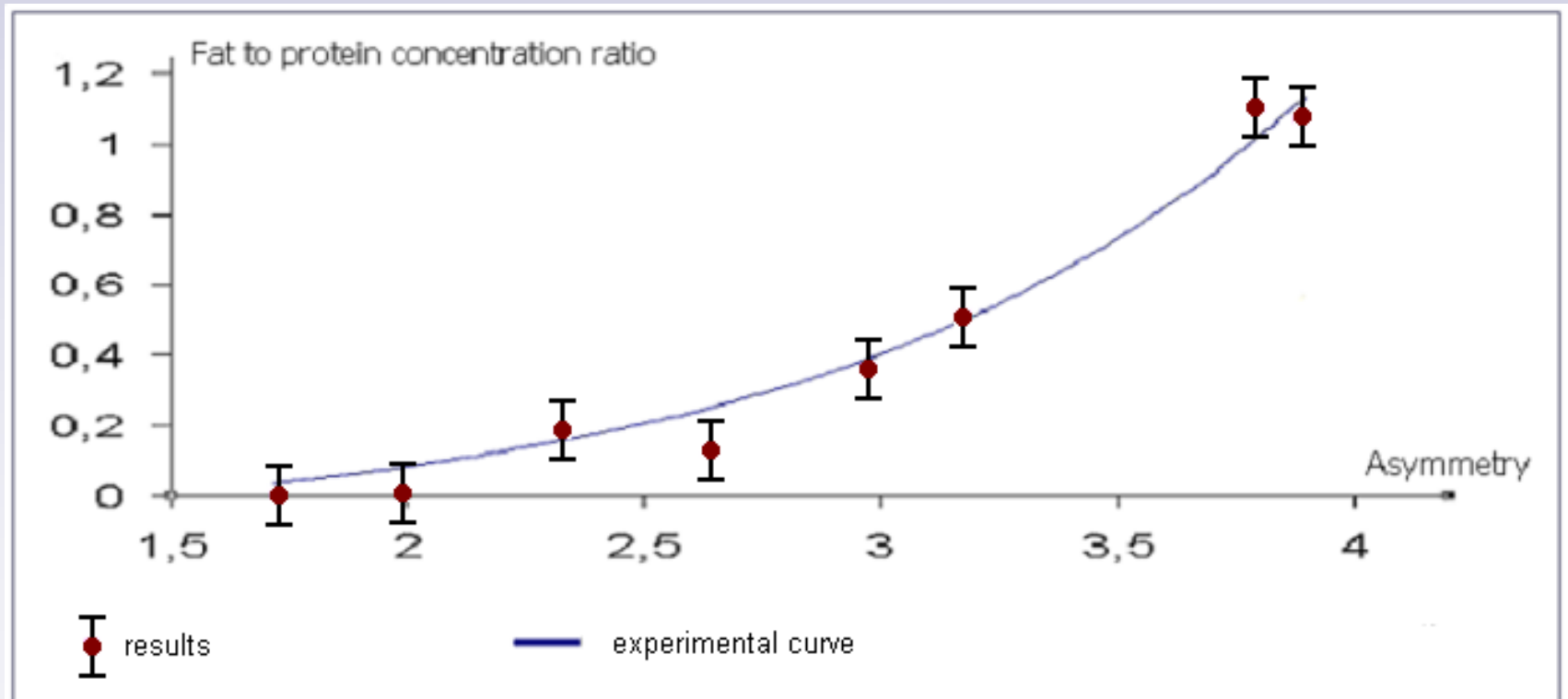
- » Both fat and protein scatter light asymmetrically.
- » Fat however generates larger differences in angular distribution of scattered light.
- » That is due to the larger size of fat droplets in milk compared with protein aggregations' size.



- » A dependence between fat and protein concentration ratios and the distribution of scattered light has to exist.

# Conclusions from 3<sup>rd</sup> experiment

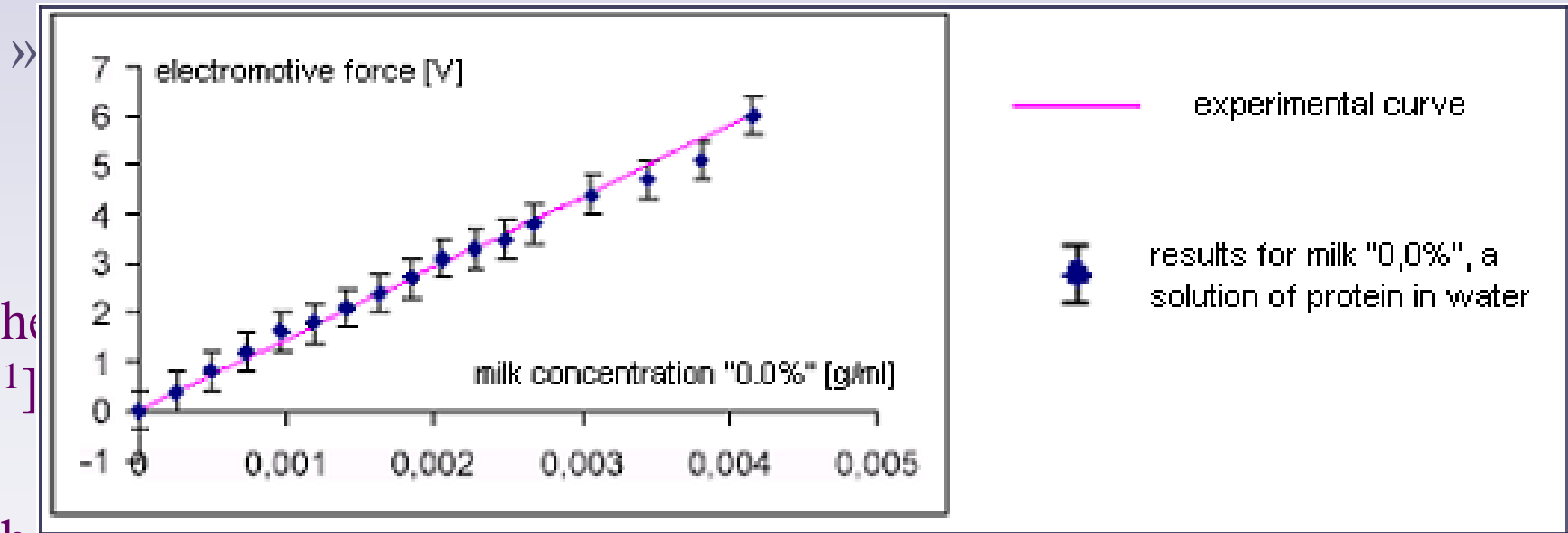
- » The intensity of scattered light measured at angles close to  $0^\circ$  and  $180^\circ$  is different
- » We introduced a parameter “**asymmetry**” - the ratio between intensity at  $0^\circ$  and  $180^\circ$
- » We have plotted the solution’s asymmetry against the fat to protein concentration ratio



The dependence seems to be exponential

# Determining scattering constants

- » In small concentrations the dependence between concentration and scattering intensity is linear
- » Fat and protein have different proportionality coefficients
- » Determining the coefficient for protein is easy:



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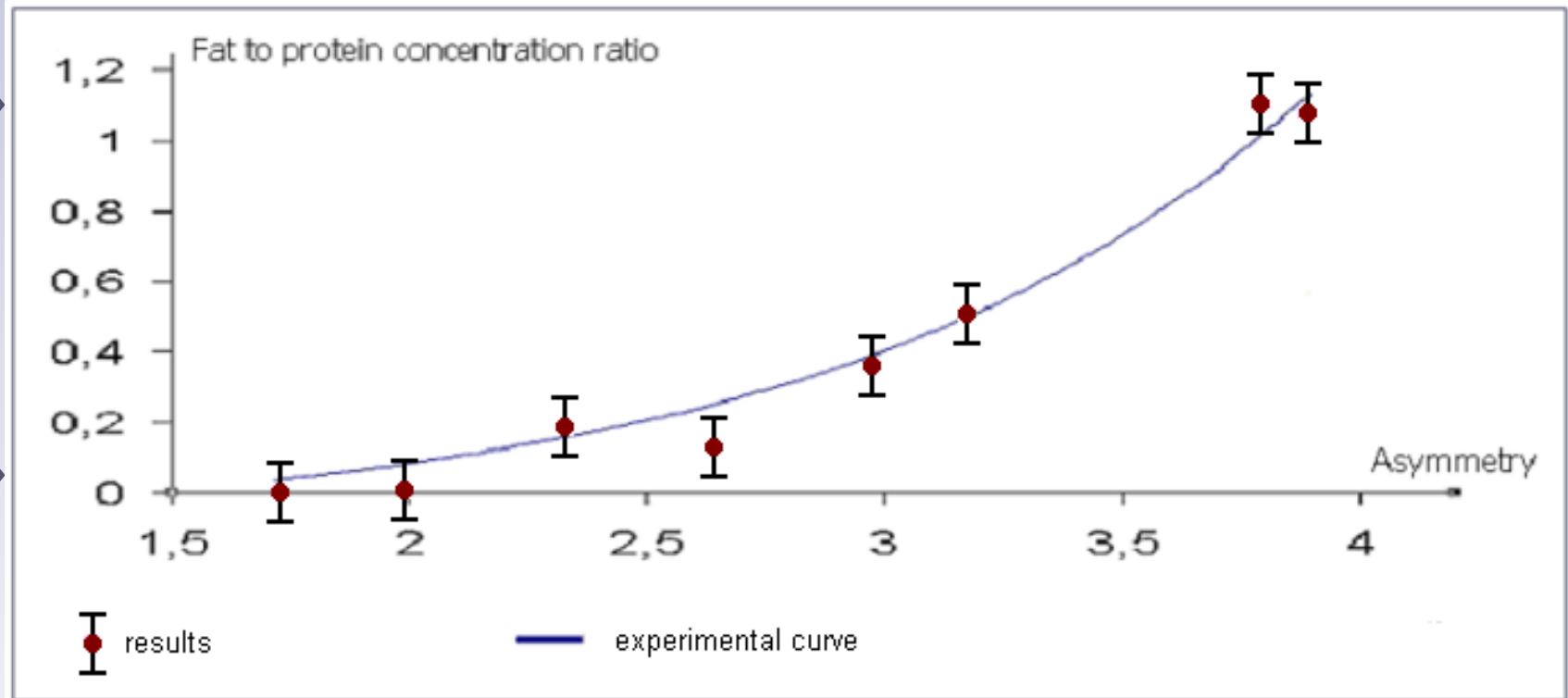
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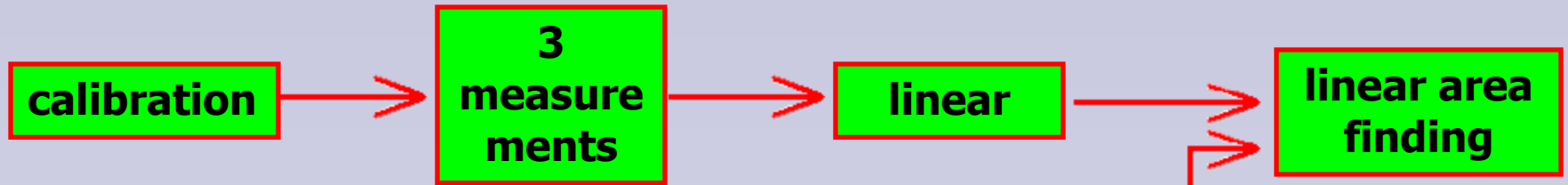
# Measuring the fat content in milk

» Because milk is a bidispersive colloid, we have to consider both scattering on



» The  $k_1$  and  $k_2$  constants are uniform for a given measuring device and can be obtained by measuring „0,0%” milk and „3,2%” milk.

# Measuring the fat content in milk



$$I = c_1 k_1 + c_2 k_2 \Rightarrow I = c_2 \left( \frac{c_1}{c_2} k_1 + k_2 \right) \Rightarrow$$

$$\Rightarrow \begin{cases} \frac{c_1}{c_2} = 0,025e^a - 0,1 \\ c_2 = \frac{I}{(0,025e^a - 0,1)k_1 + k_2} \end{cases}$$

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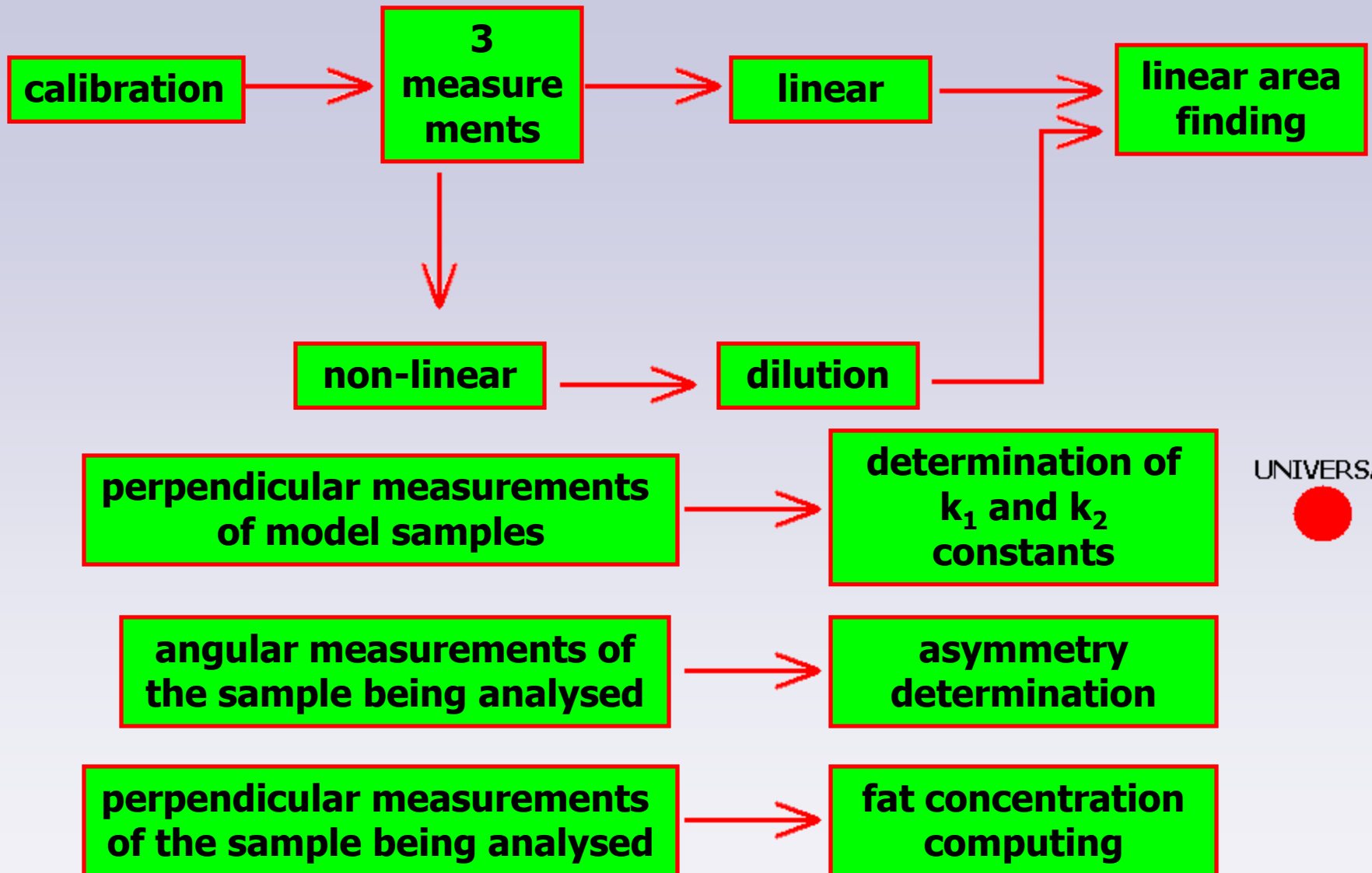
on

fat concentration  
computing

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# Measuring the fat content in milk

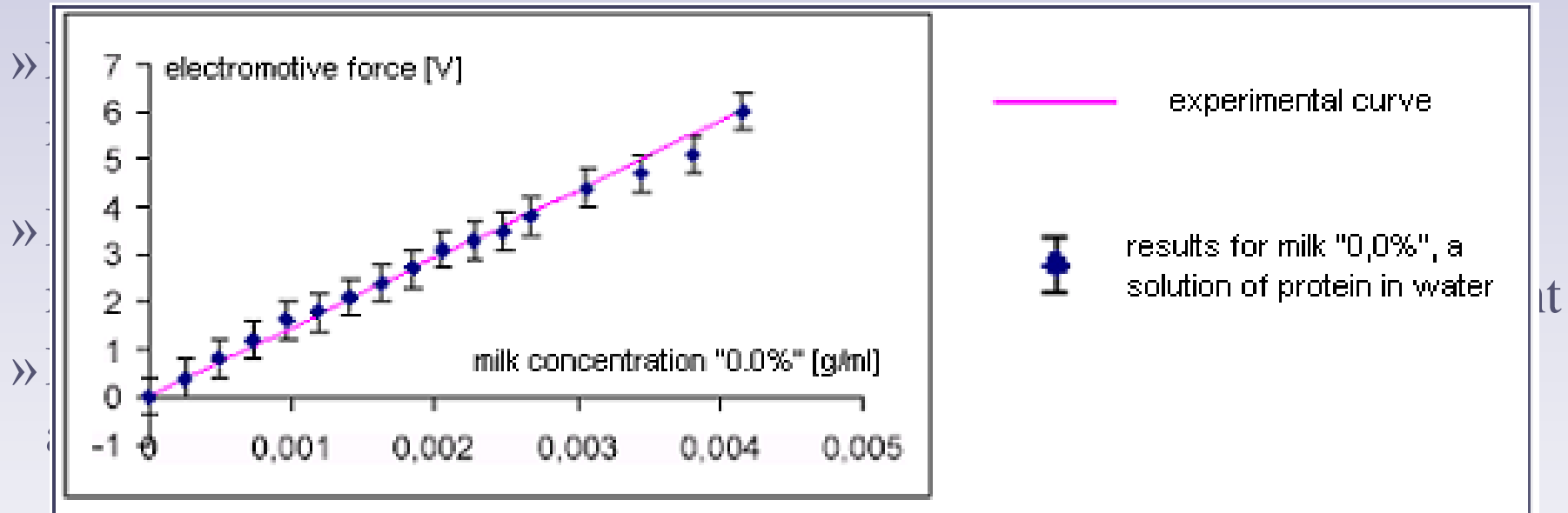


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# Measuring concentration in other solutions

» The presented method can be used to measure concentrations of colloids other than milk



Thus our method is suitable for any kind of monodispersive or bidispersive colloid with different particle size and employs the same machinery.

**THE END**