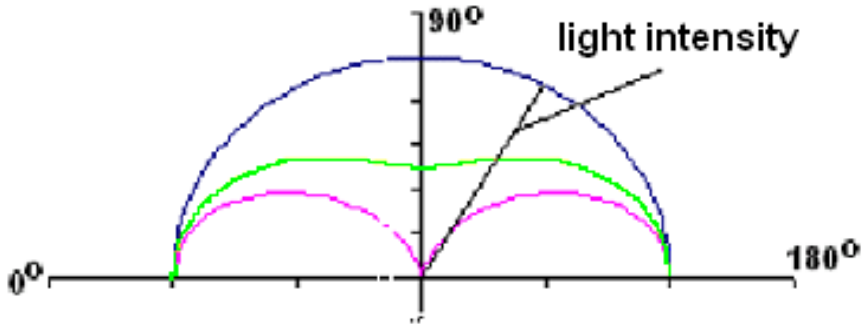
Light scattering

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



1st Graph: laser light incidents from 0^0 direction

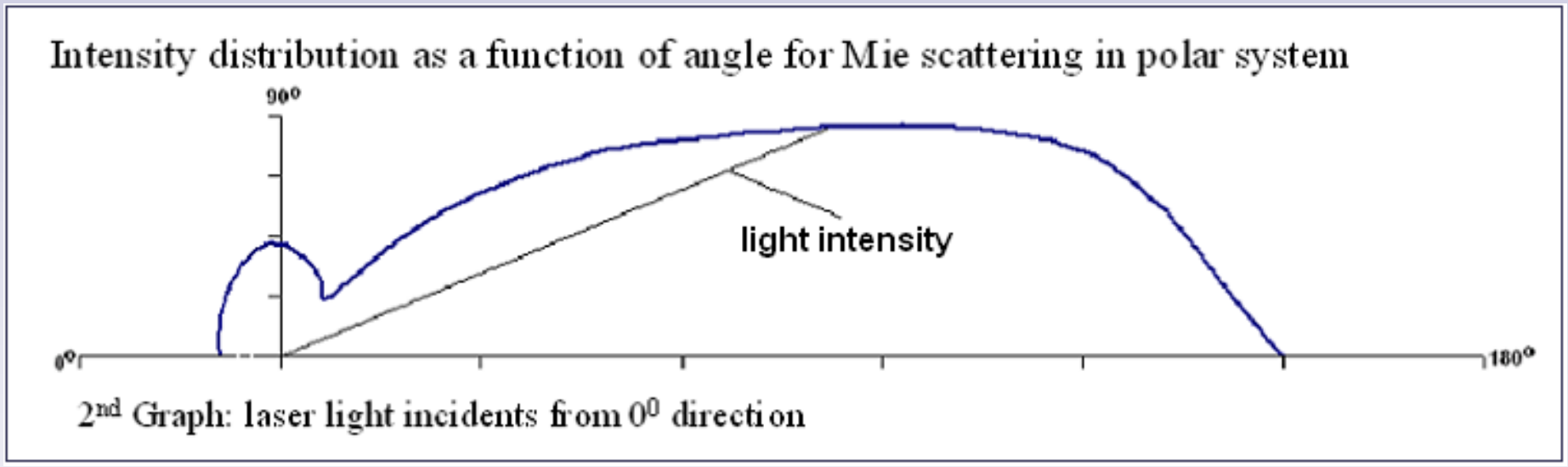
Intensity of scattered light

- in the plane of polarization
- in the plane of oscillations of electric vector of incident light
- for non-polarized radiation

light polarization plane is very important

Scattering on large molecules

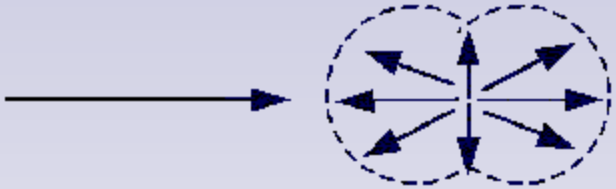
In case of scattering on large particles we use Mie theory



Both of these theories describe scattering on a singular molecule!

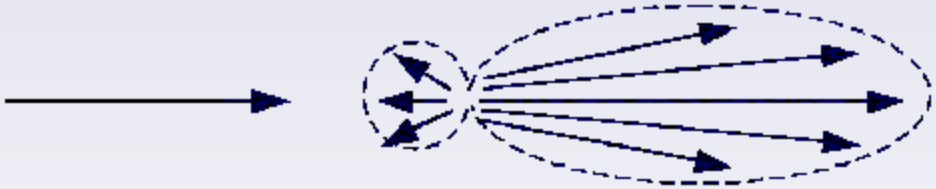
Comparison

$R << 1/10\ \lambda$



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

$R \geq 1/10\ \lambda$



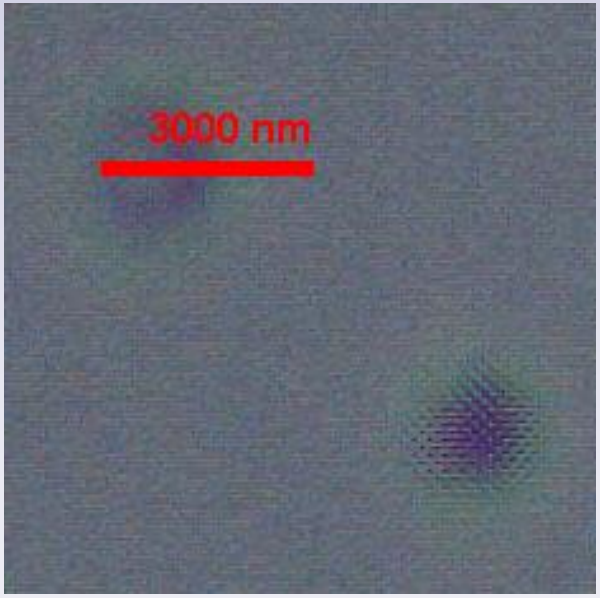
Mie theory $I \sim \frac{1}{\lambda}$

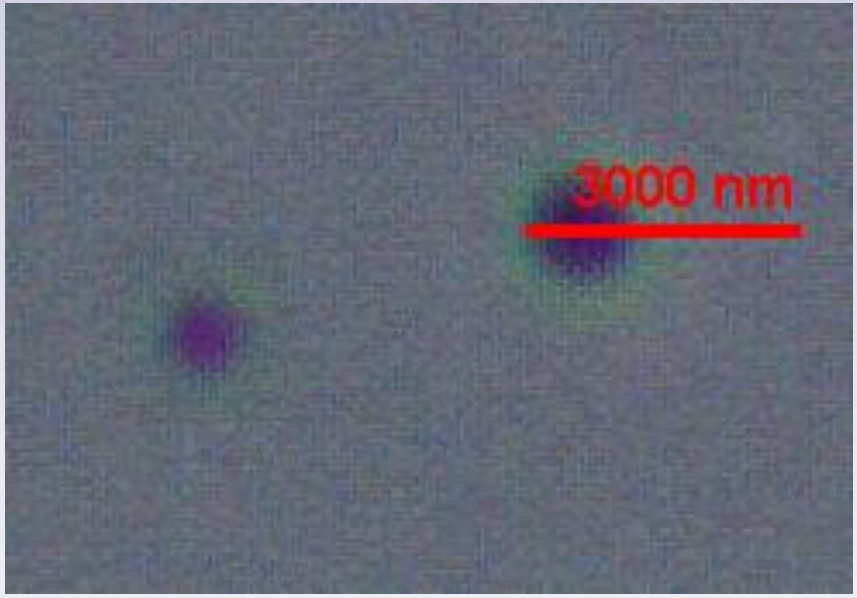
Our experiments

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

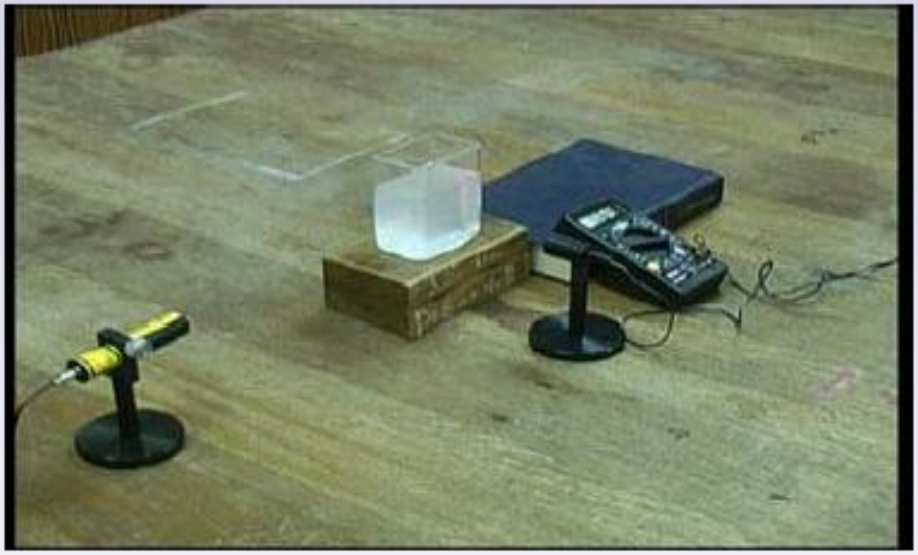


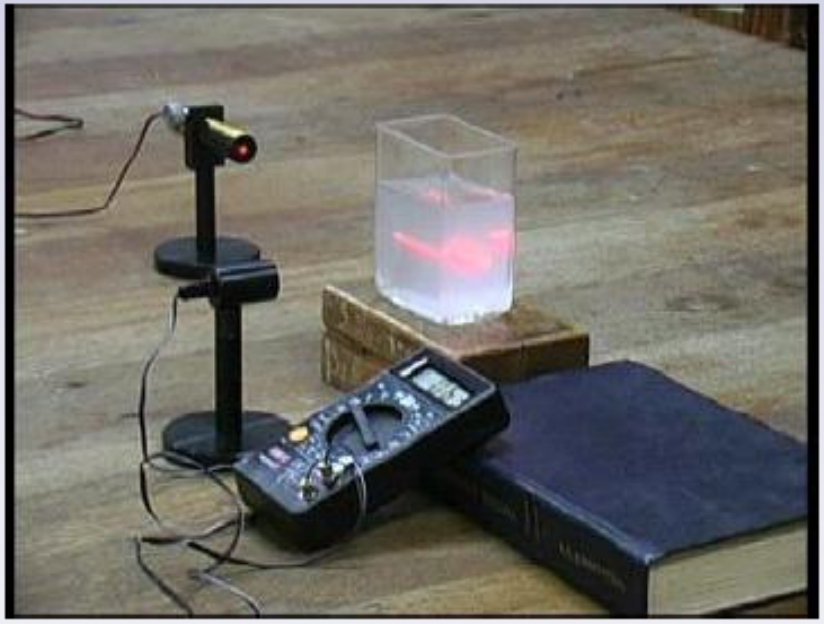


made in the University of Warsaw, Faculty of Biology

1st experiment

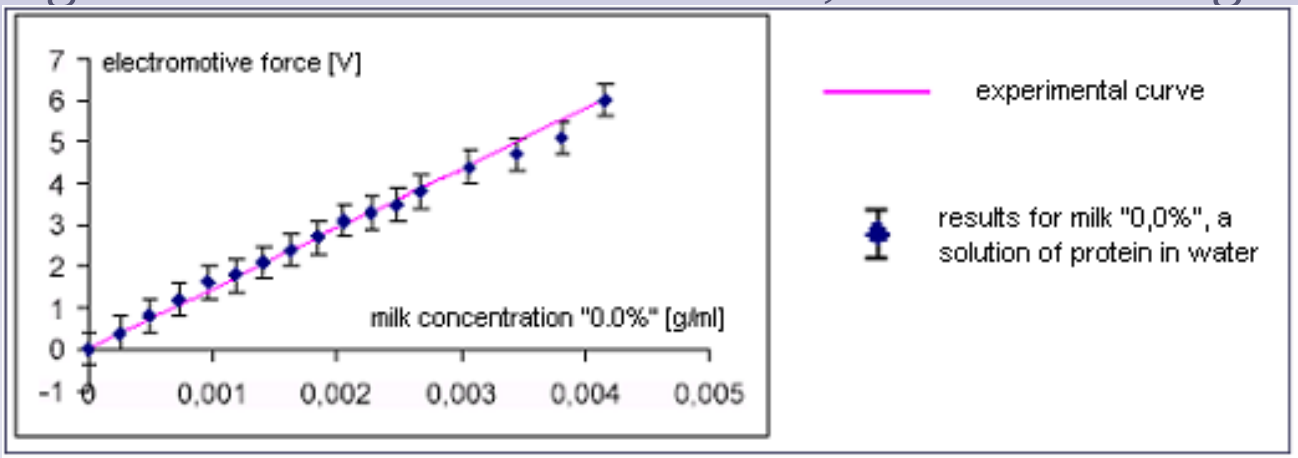
Our measuring device consists of: laser, rectangular vessel and photoelectric diode connected to voltmeter

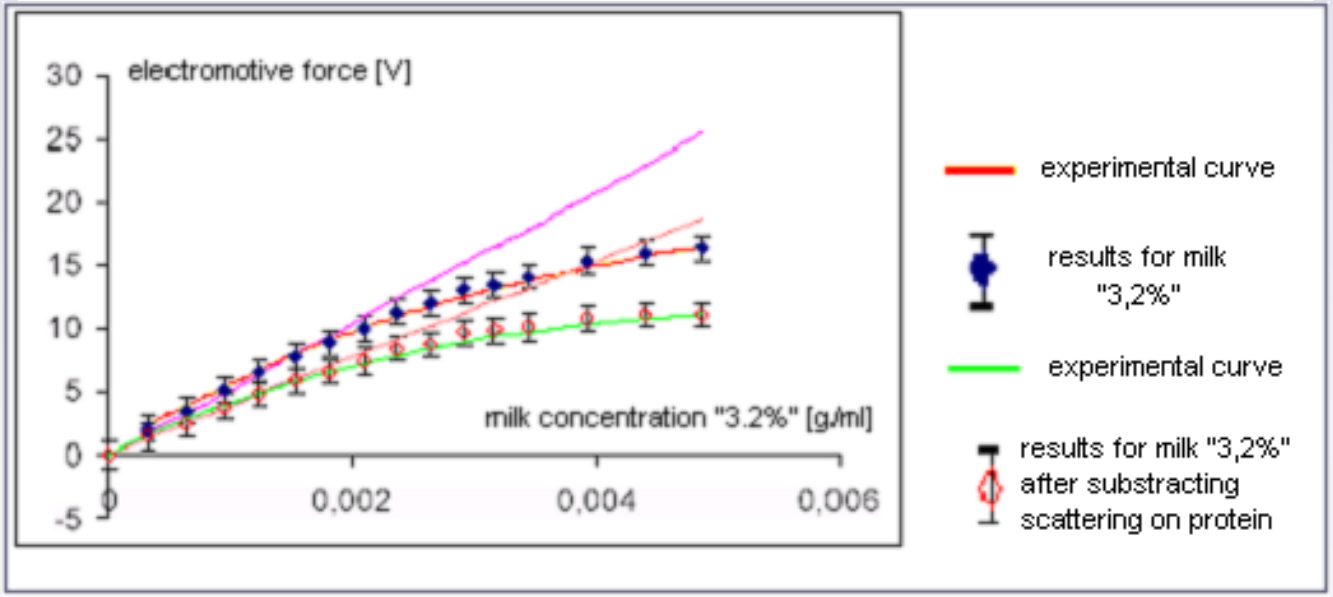




Results of 1st experiment

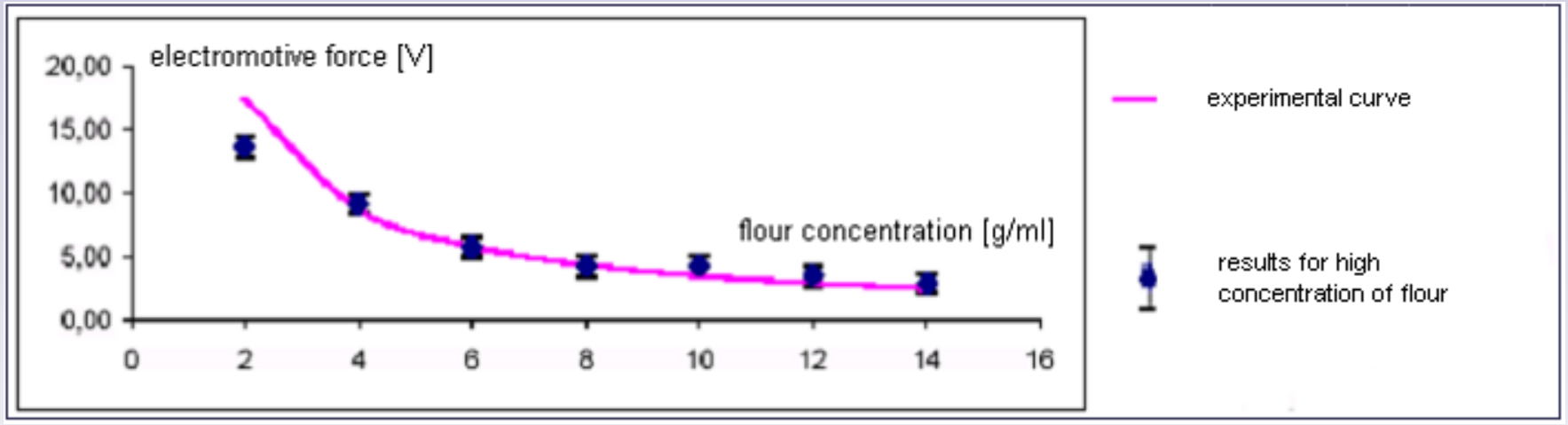
Scattered light intensity distributions as a function of concentration;
Light source – from 0^0 direction; diode at an angle: 90^0





Conclusions from 1st 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:

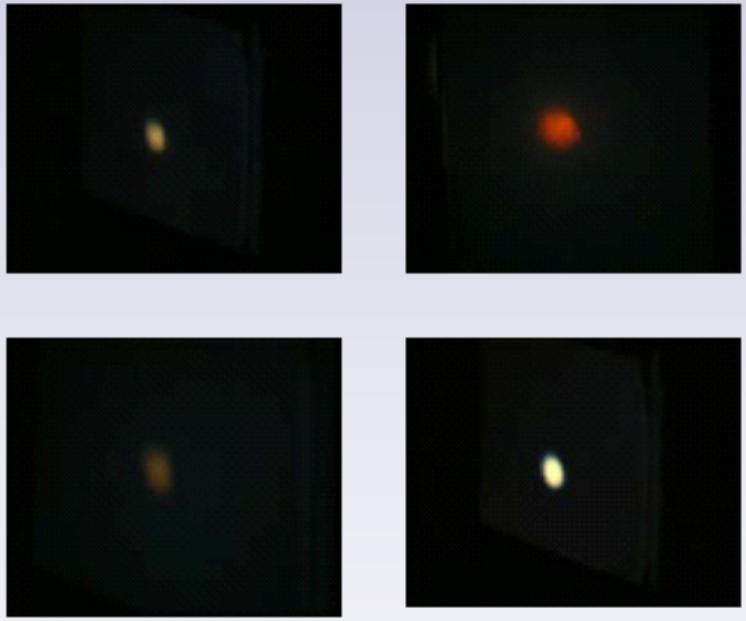


In bigger concentrations intensity becomes a non-linear function of concentration!

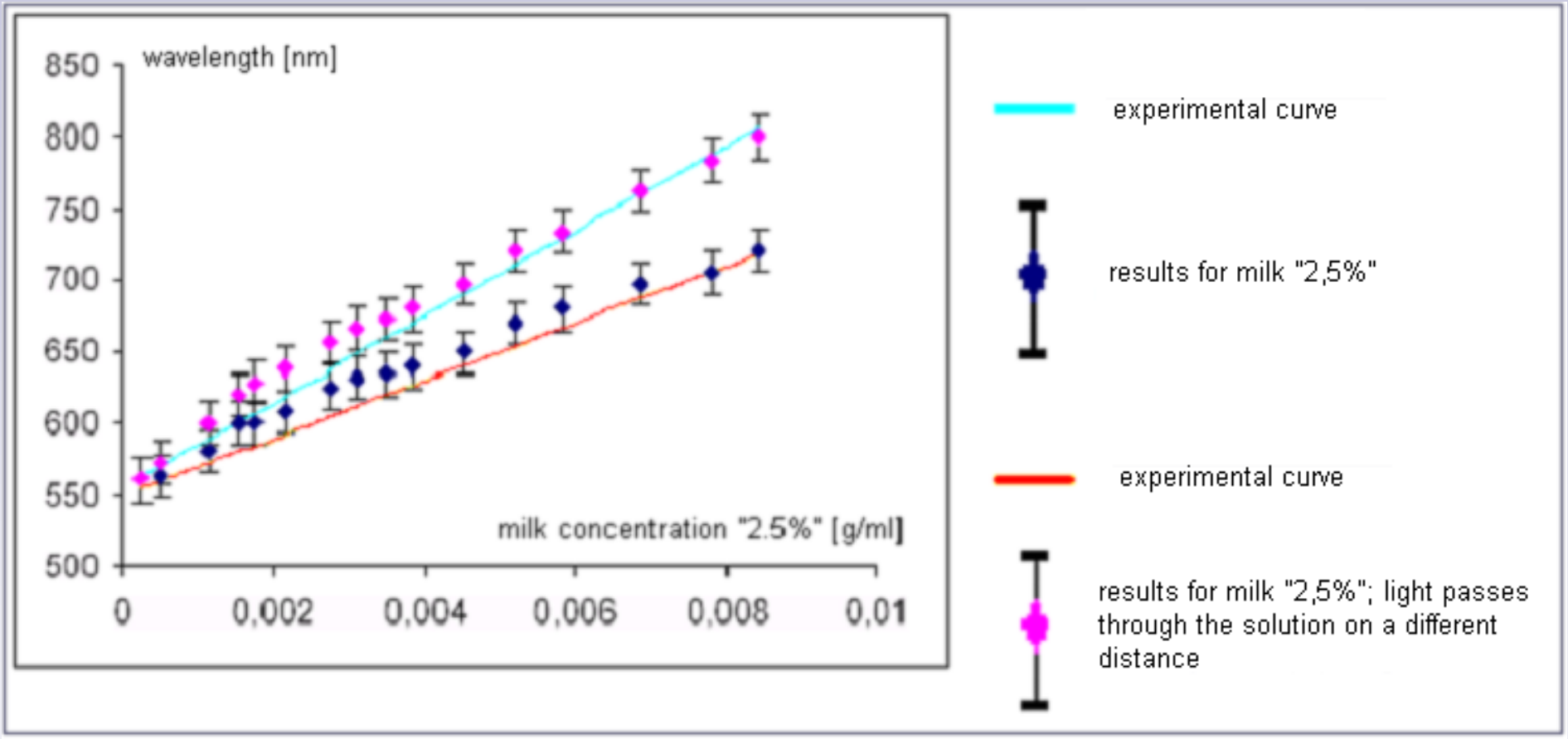
2nd experiment

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

Colours that we obtained on the screen



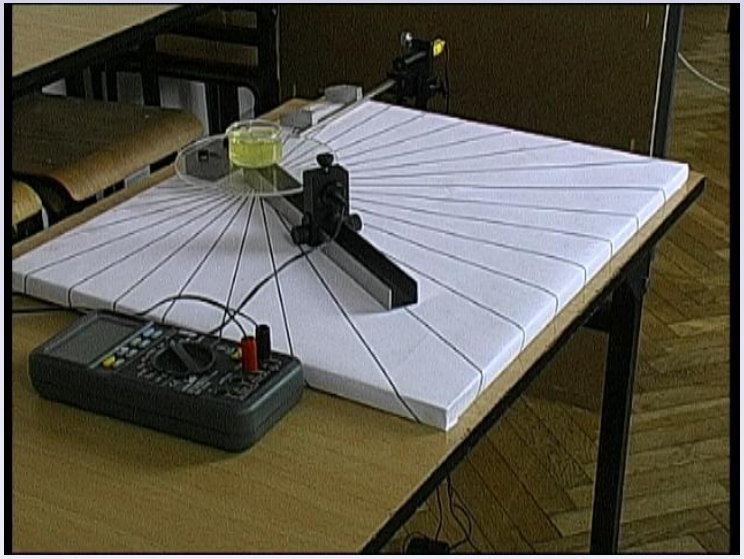
Results of 2nd experiment

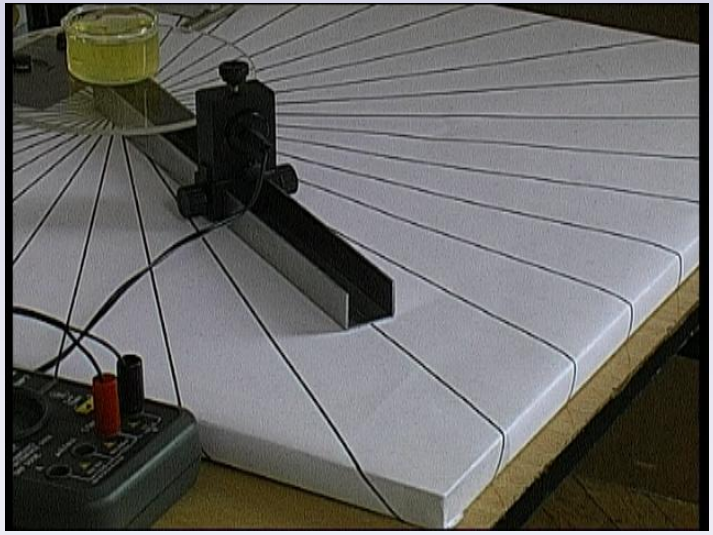


The wavelength of absorbed light increases with concentration increase. This is characteristic for Mie-type scattering

3rd experiment

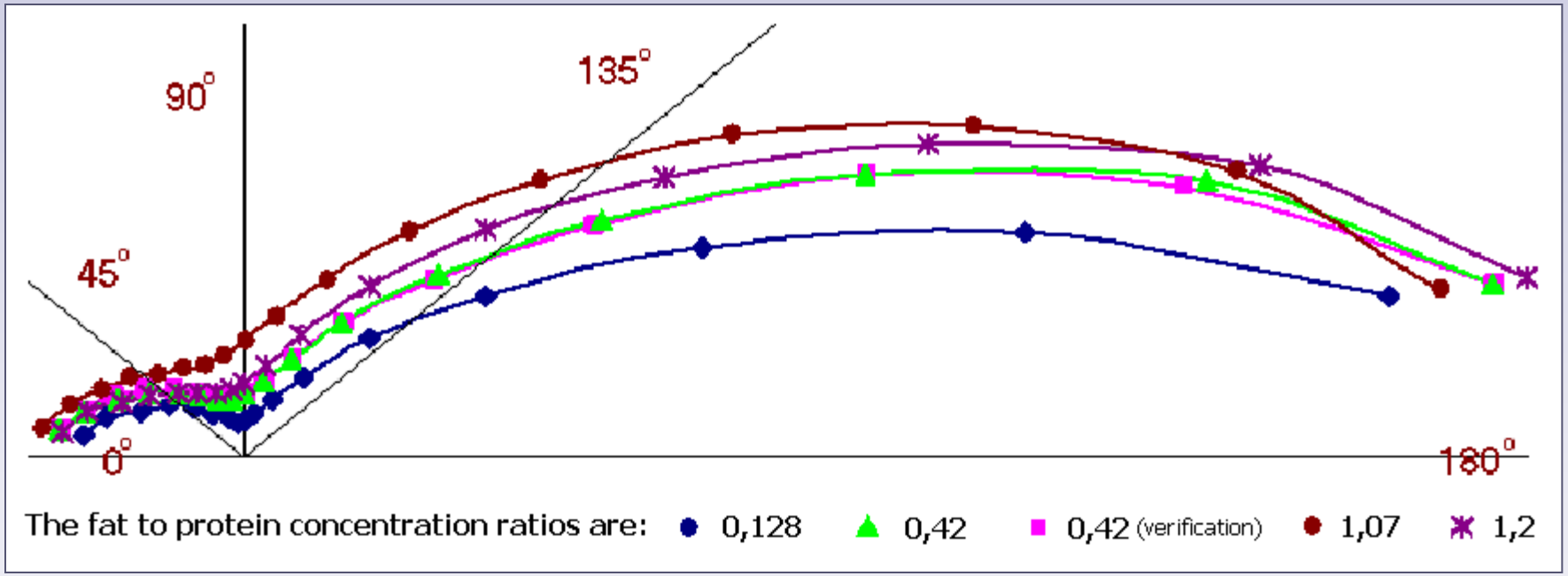
Our measuring device consists of: laser, cylidnrical vessel, photoelectric diode attached to a mobile arm and connected to a voltmeter





Results of 3rd experiment

Scattered light intesity distribution as a function of angle in various fat to proteine concentration ratios



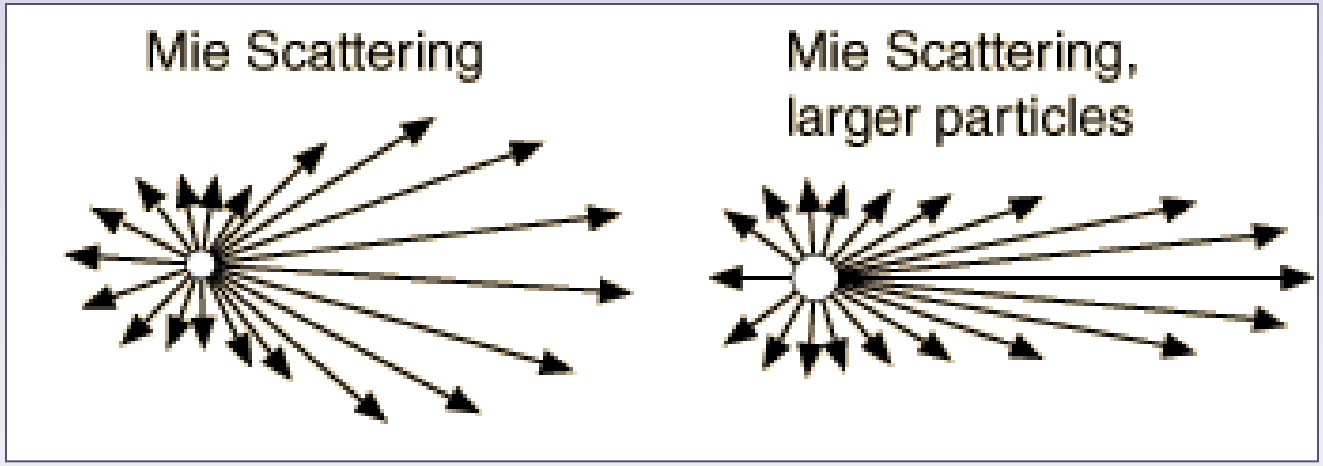
We have obtained these ratios by mixing „0,0%” and „3,2%” milk.

Conclusions from 3rd experiment

» Both fat and protein scatter light asymmetrically.

» Fat hoverer generates larger diffrences in angular distribution of scattered light.

» That is due to the larger size of fat droplets in milk compared with protein aggregations' size.



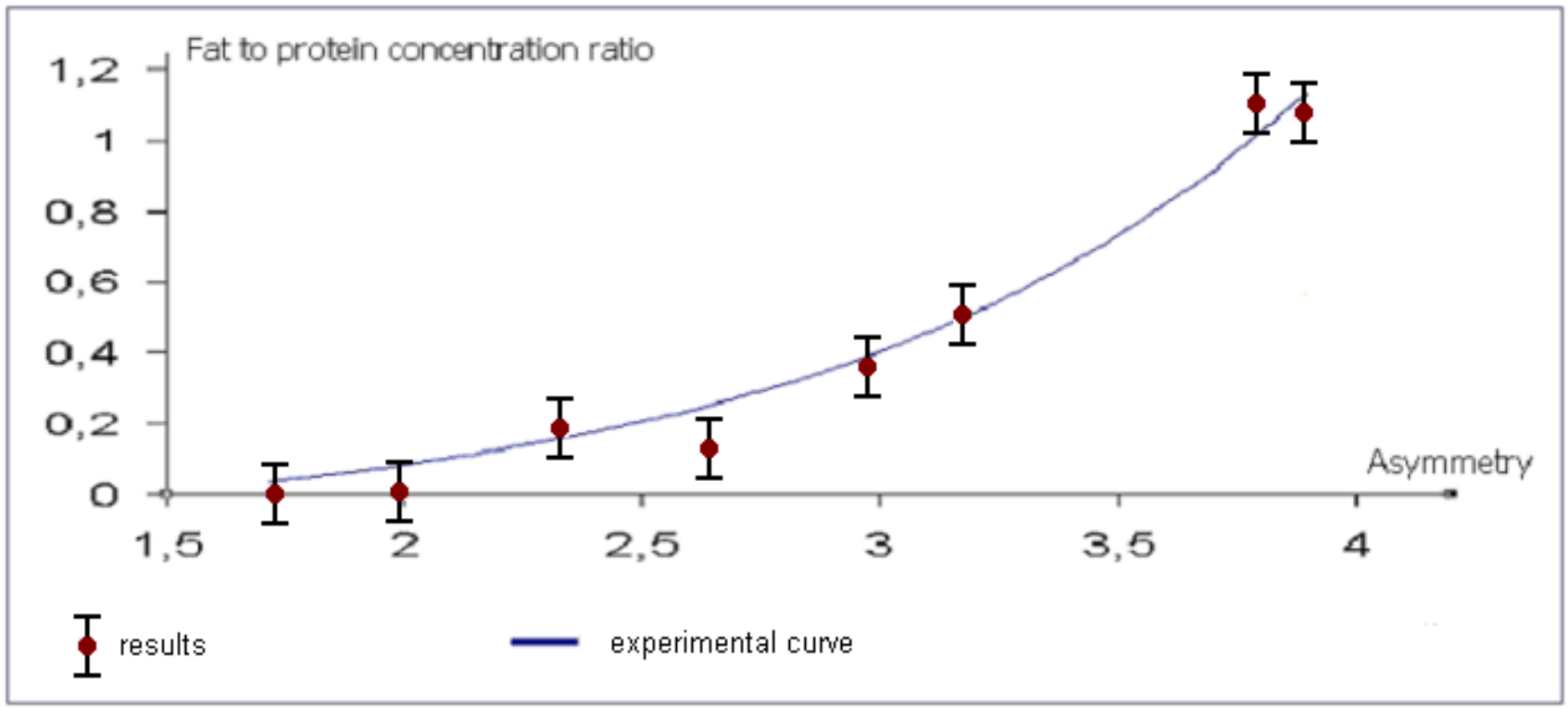
» A dependence between fat and protein concentration ratios and the distribution of scattered light has to exist.

Conclusions from 3rd experiment

» The intensity of scattered light measured at angles close to 0^0 and 180^0 is different

» We introduced a parameter "**asymmetry**" - the ratio between intensity at 0^0 and 180^0

» We have plotted the solution's asymmetry against the fat to protein concentration ratio



The dependence seems to be expotential

Determining scattering constants

- In small concentrations the dependance 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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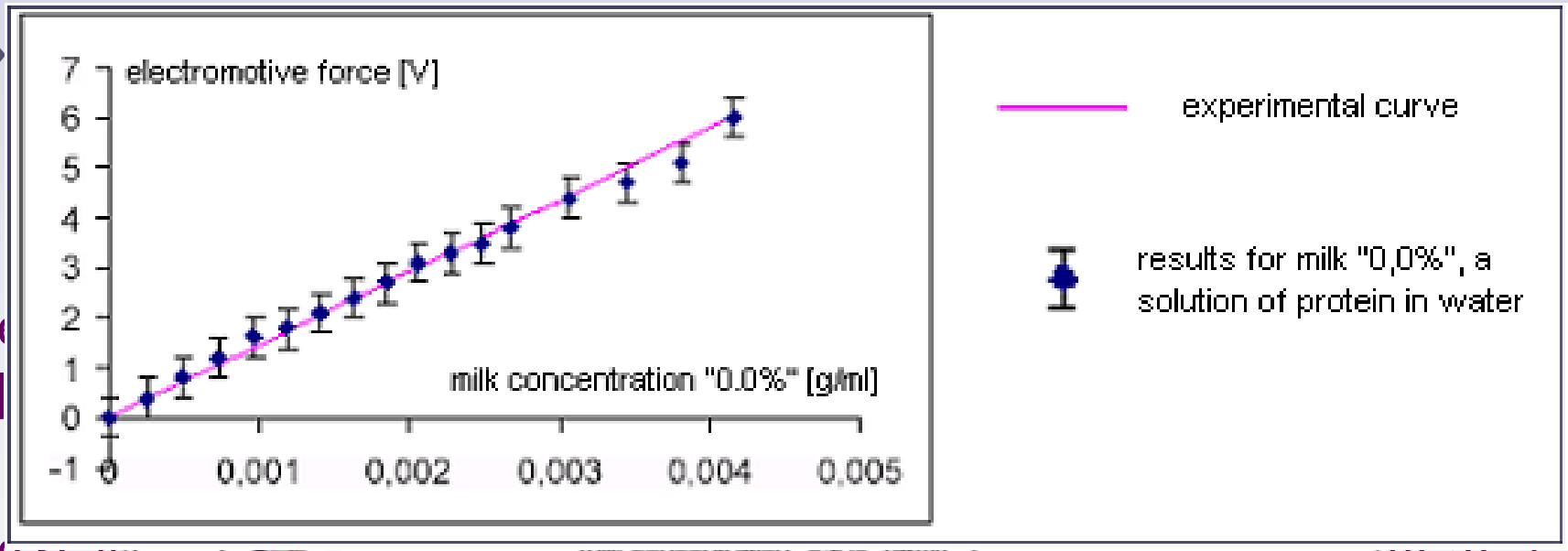

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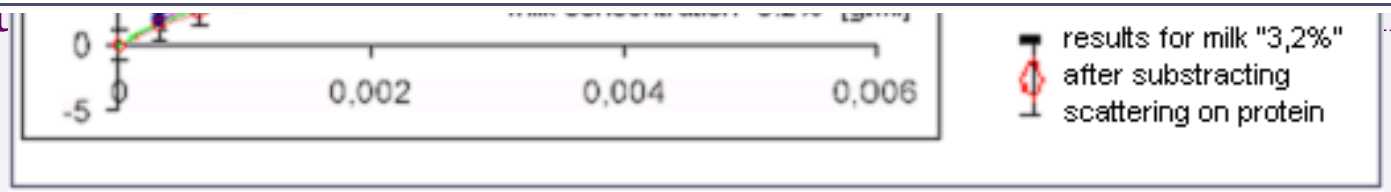

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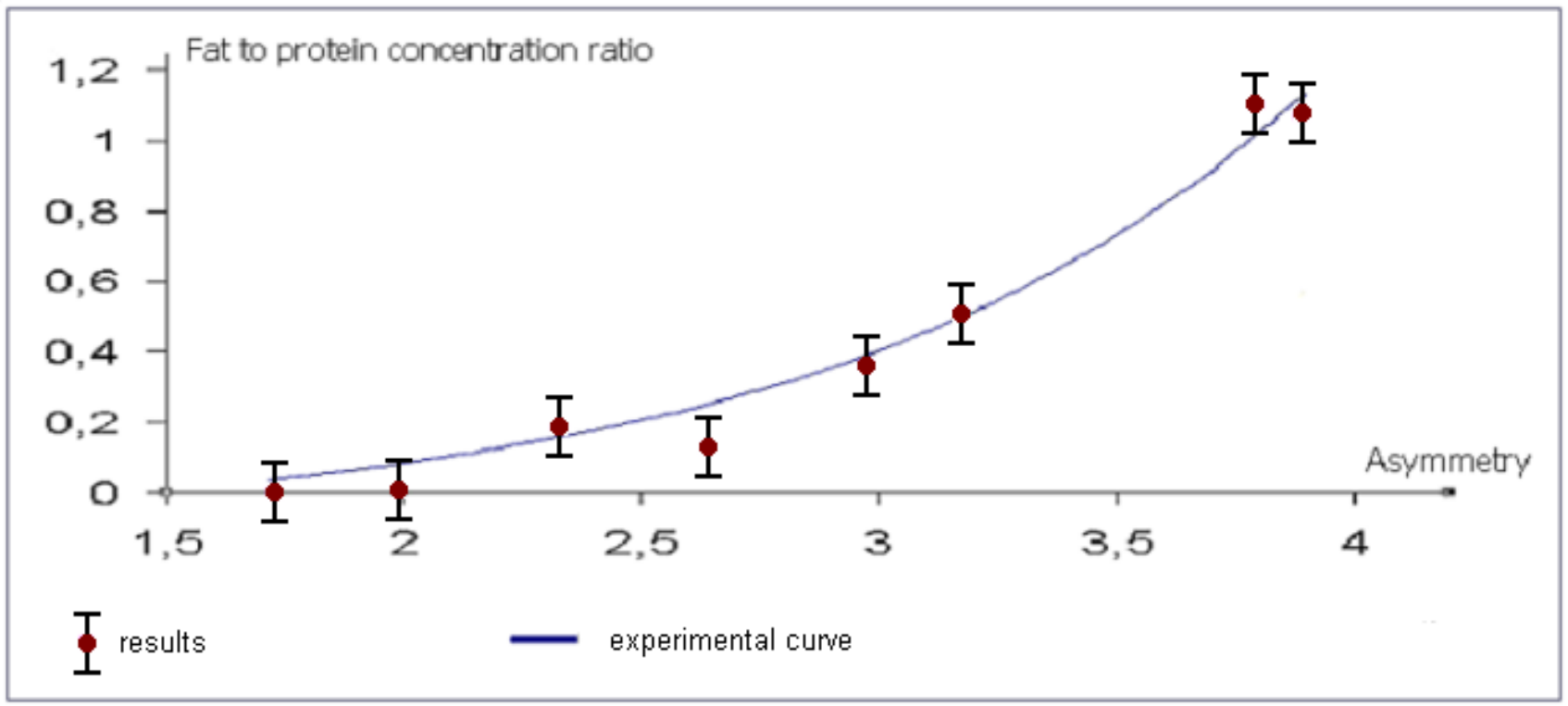
Measuring the fat content in milk

» 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

calibration → 3 measure ments → linear → linear area finding

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

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

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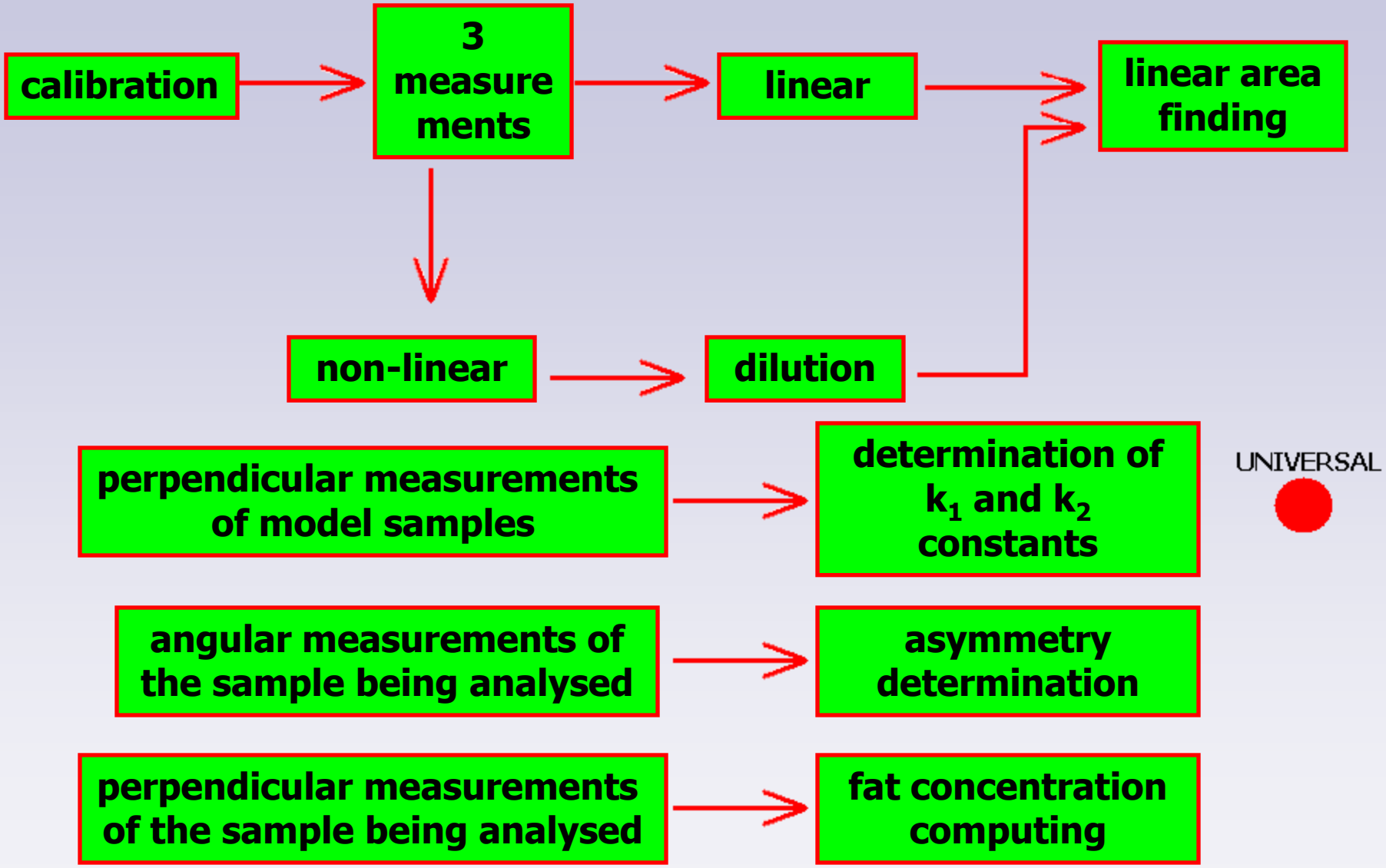
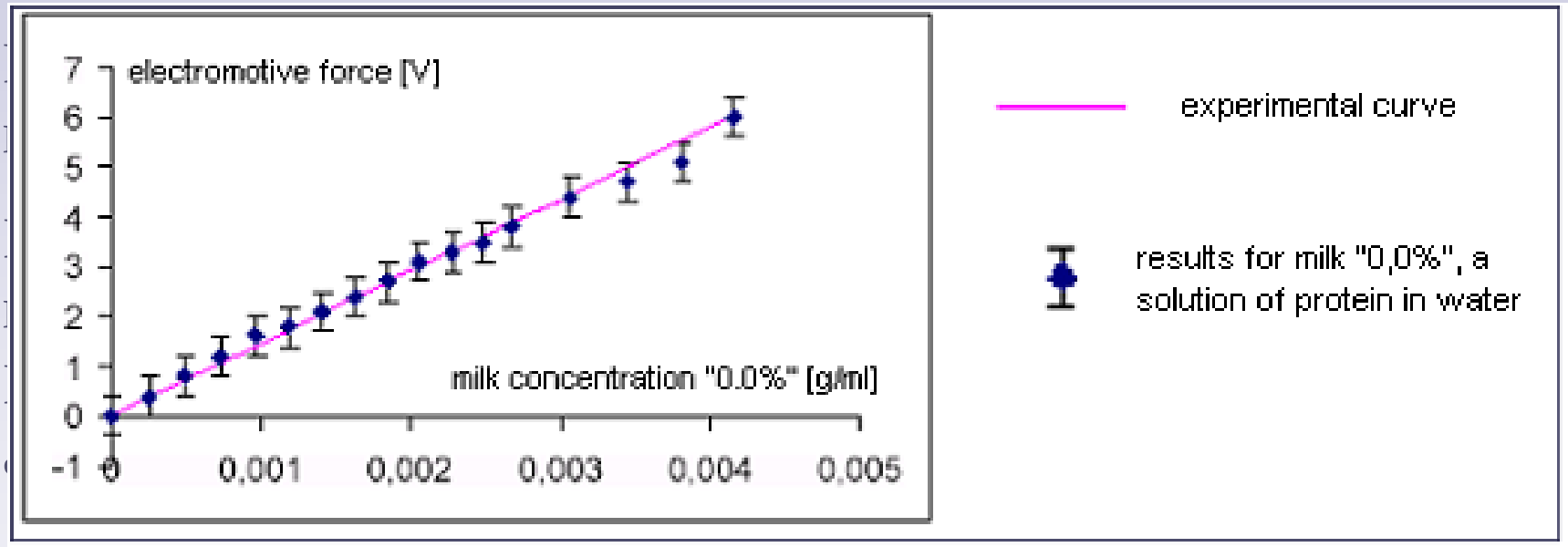
perpendicular measurements of the sample being analysed → fat concentration computing

Measuring the fat content in milk



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