MANTA INSTRUMENTS
Better Nanoparticle Characterization

What does it take to accurately measure concentration of nanoparticles in colloids

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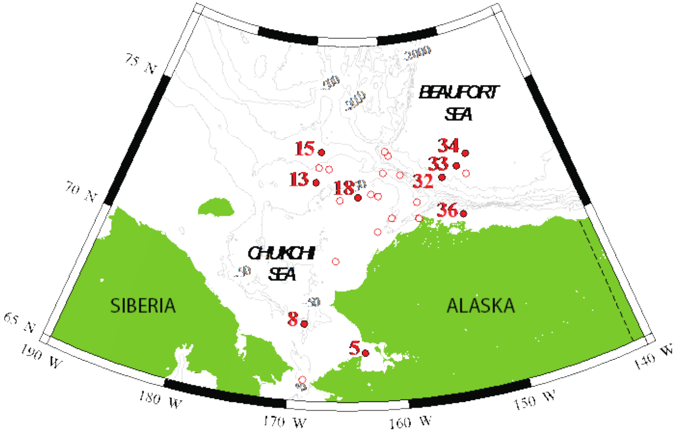
Counts

Volume

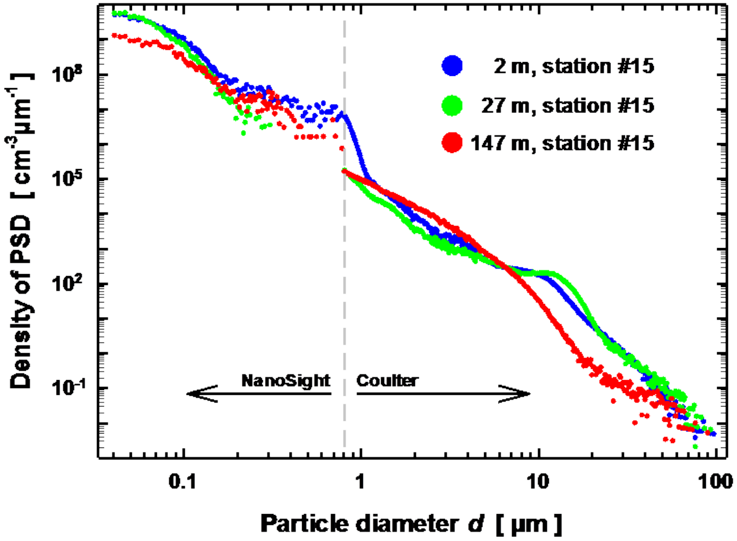
in chemistry typically mass [mg/mL] or volume [µL/mL] concentrations

Beginnings

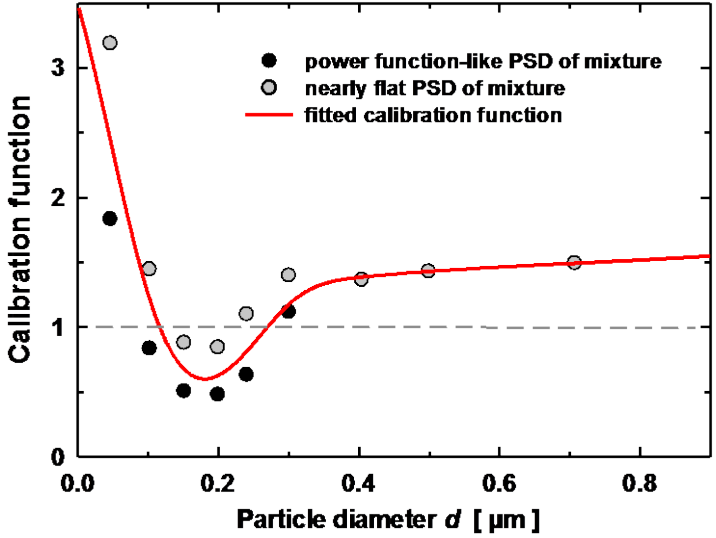
NASA sponsored ICESCAPE Project
two cruises on USCGC *Healy*
2010 - 2011



Results



J. J. Tatarkiewicz, R. A. Reynolds, and D. Stramski *Counting and sizing of colloidal particles in the Arctic Ocean* 2012 Ocean Sci Meeting A0412

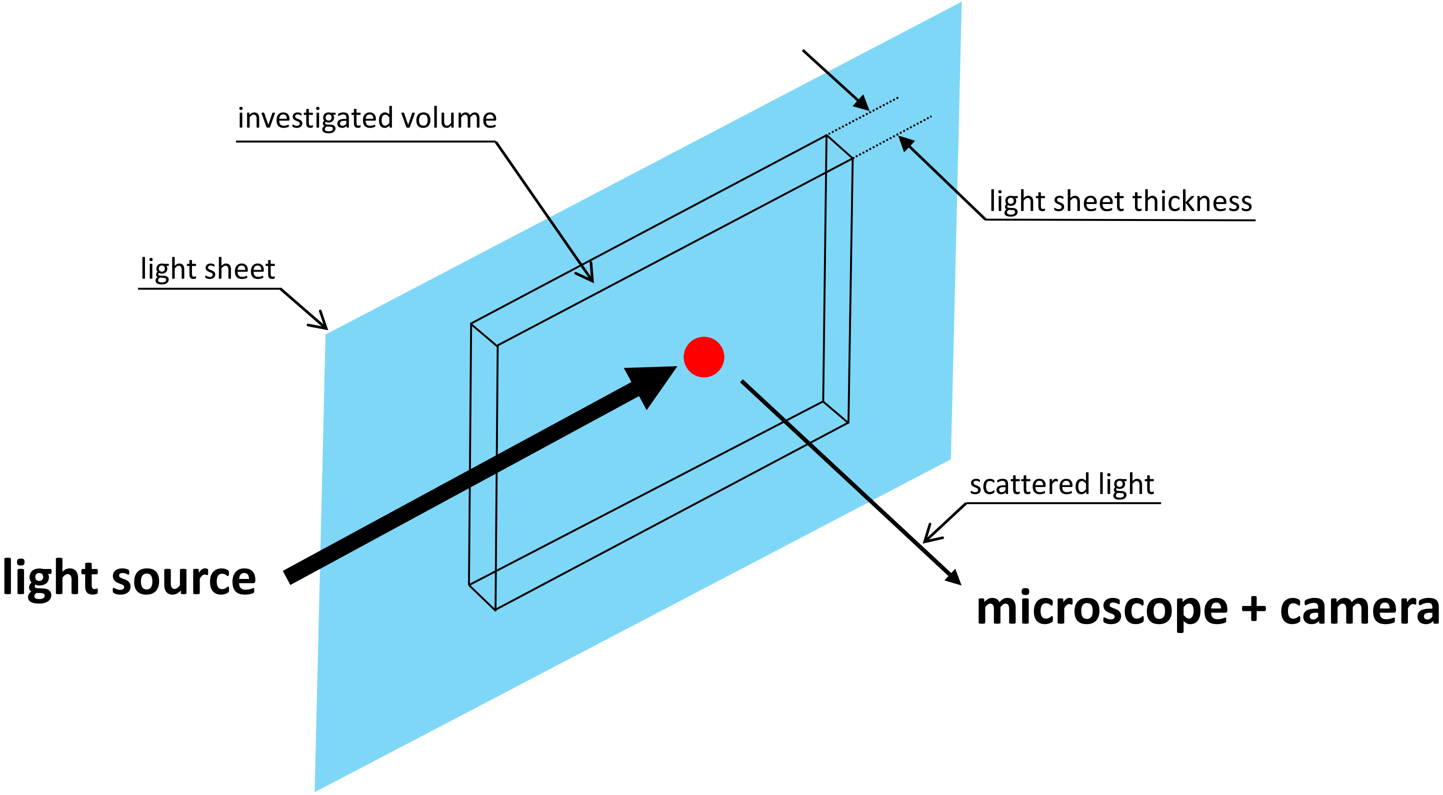


This is a very strange function...

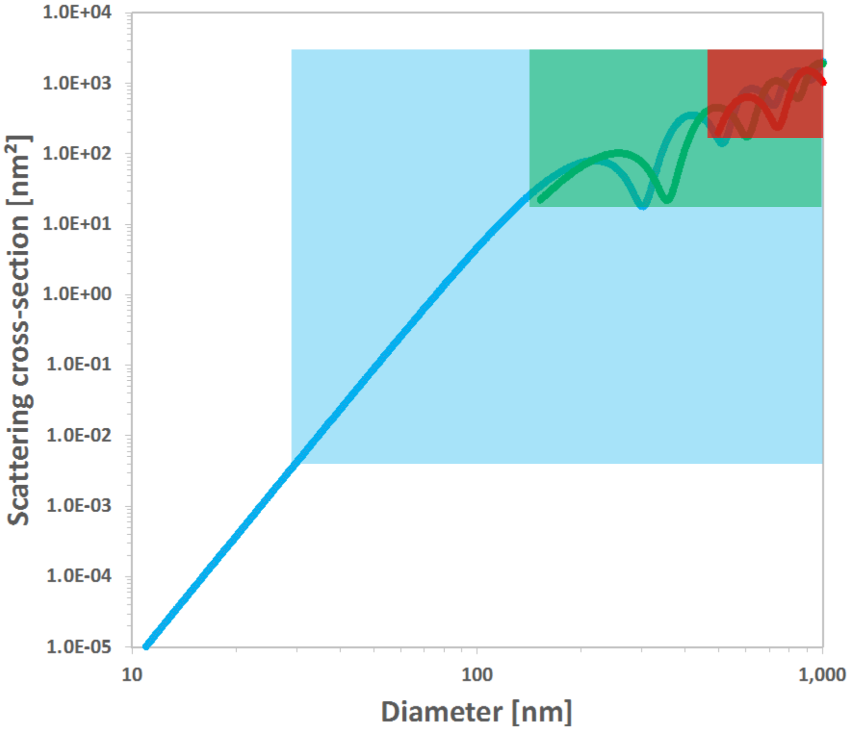
2nd generation NTA

- **M**ultispectral **A**dvanced **N**anoparticle **T**racking **A**nalysis
- NSF grant for MRI #1126870, 2012-2014
- MANTA Instruments, Inc. founded in 2014
- US patents granted up to now:
    - 9541490, 9645070, 9857283, 9909972

Visualization



MANTA



Mie calculations for 445 nm, 520 nm and 635 nm polarized laser beams scattering on PSL in water (n=1.337), objective NA=0.28, 80°÷100° integration

Sizes

- Mean Squared Distance MSD (2D, N frames track, n frames lag*):

$$MSD(n) = \frac{1}{N-n} \sum_{i=1}^{N-n} (x_{i+n} - x_i)^2 + (y_{i+n} - y_i)^2$$

- Diffusion coefficient D (least-squares fit of MSD as a function of n):

$$MSD(n) = (4 \cdot \Delta t \cdot D) \cdot n$$

- Hence hydrodynamic diameter:

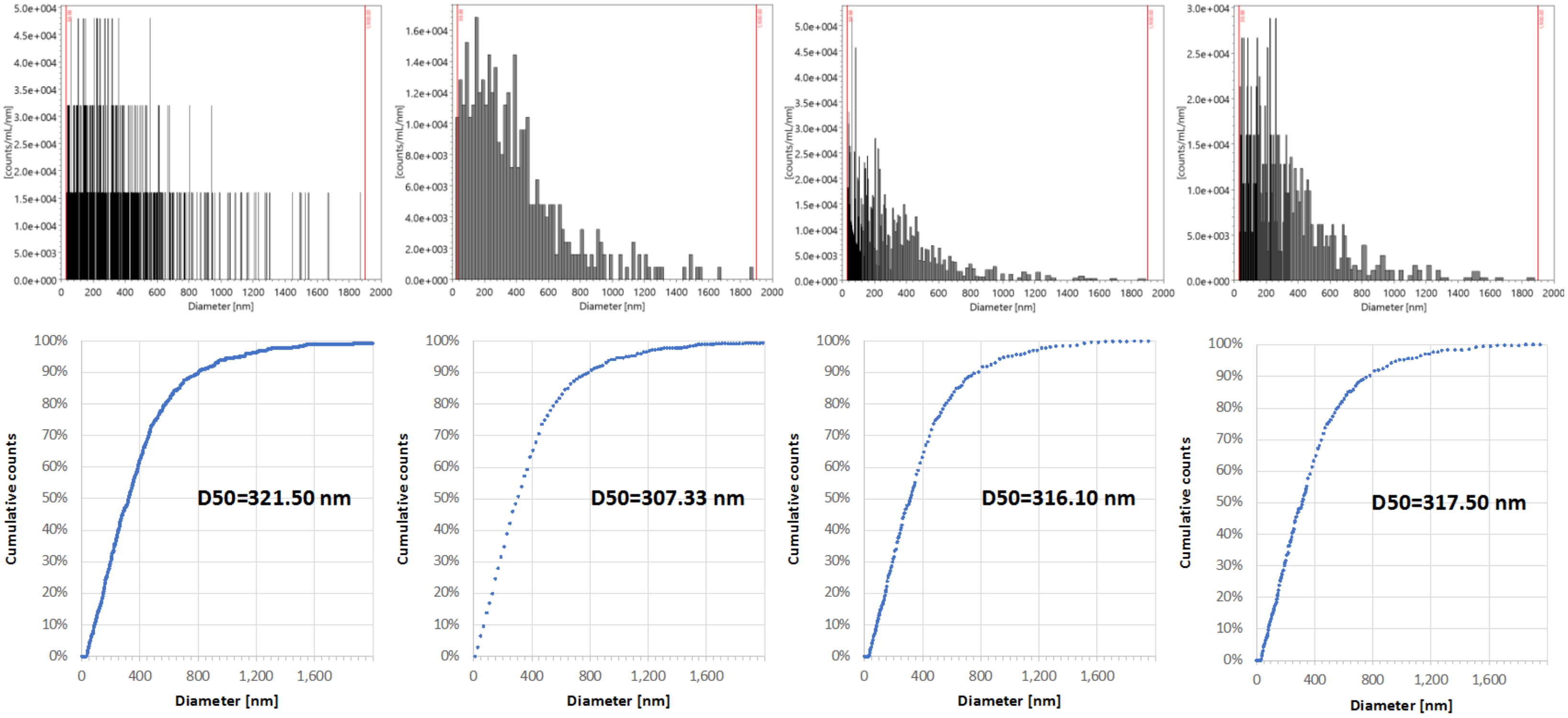
$$d_h = \frac{k_B T}{3 \pi \eta D}$$

* *ergodicity: assembly average ≡ time average*

Statistics

- Cramér-Rao statistics decides length of each track used for optimal MSD fitting
  - X. Michalet and A.J. Berglund *Optimal diffusion coefficient estimation in SPT*, Phys Rev **E85**, 061916 (2012)
- Binning diameters with different schemes (like equal or logarithmic widths) into density of particle-size distribution (PSD) with **variable investigated volume** *(explained later)*
- Statistical parameters of PSD (average size, standard deviation)

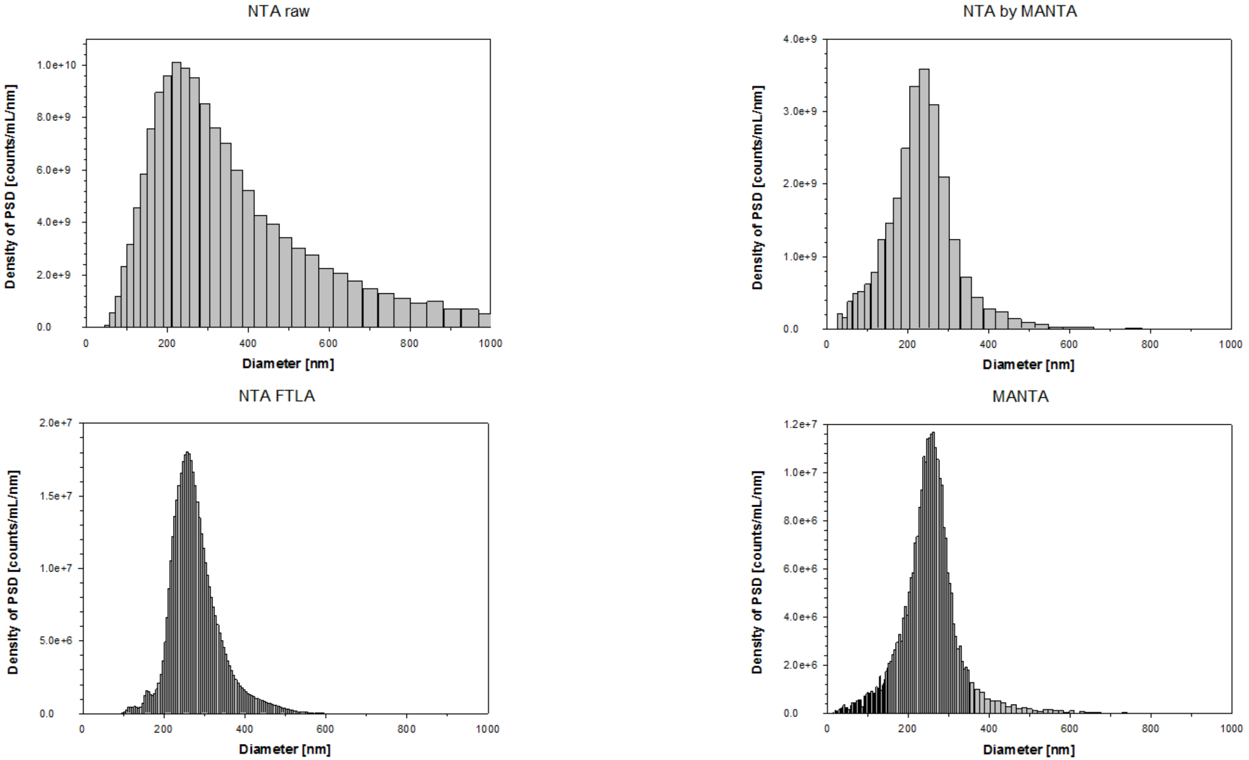
Mode, D50?



narrow equal bins *wide equal bins* *logarithmic bins* *variable bins*

Processing

240 nm PSL in water



Counts

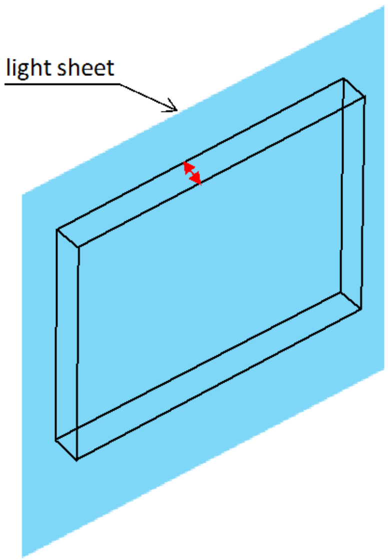
- 25 (*or more*) short videos (*300 frames each*) recorded*
- Track and count particles detected on 1st frame of each video
- Mixing sample between videos to get different aliquots (magnetic stirrer)
  - external fluidics for magnetic materials and low concentration samples – do **not** use sample flow during recording
- Proper PSD binning (*bin widths*) for polydispersity

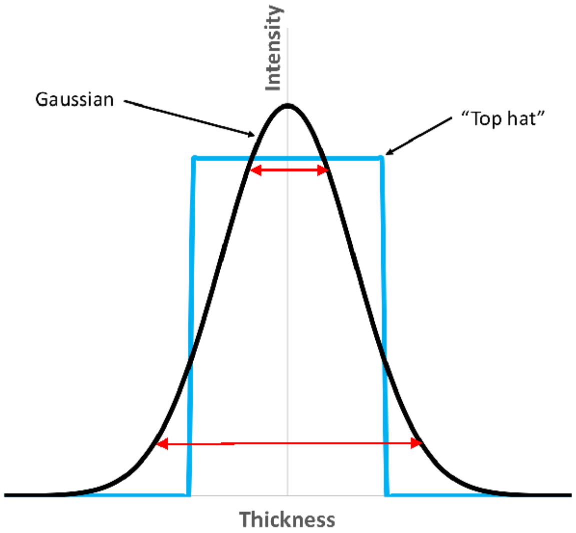
* *typically between 100 and 150 particles tracked per video*

Thickness

$$C = \frac{N}{V}\left[\frac{counts}{mL}\right]$$

$$V_0 \approx 2.5\, nL$$





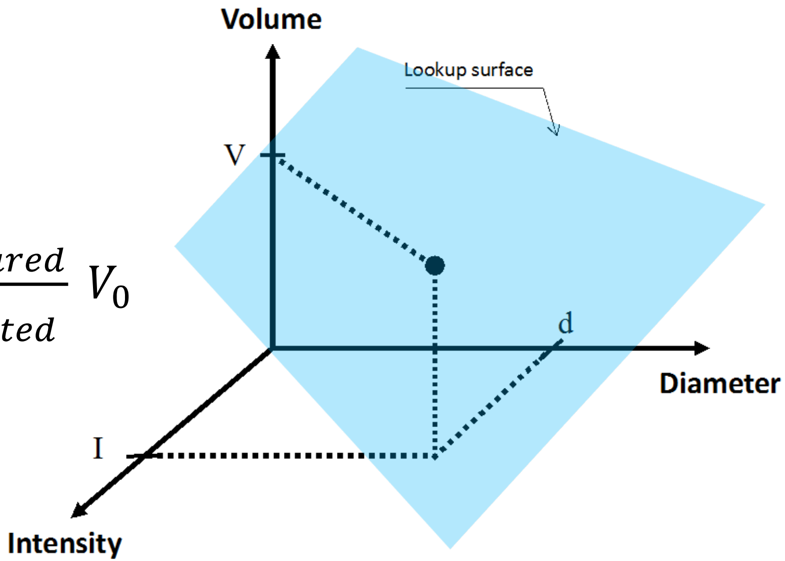
Volume

How to calibrate volume:

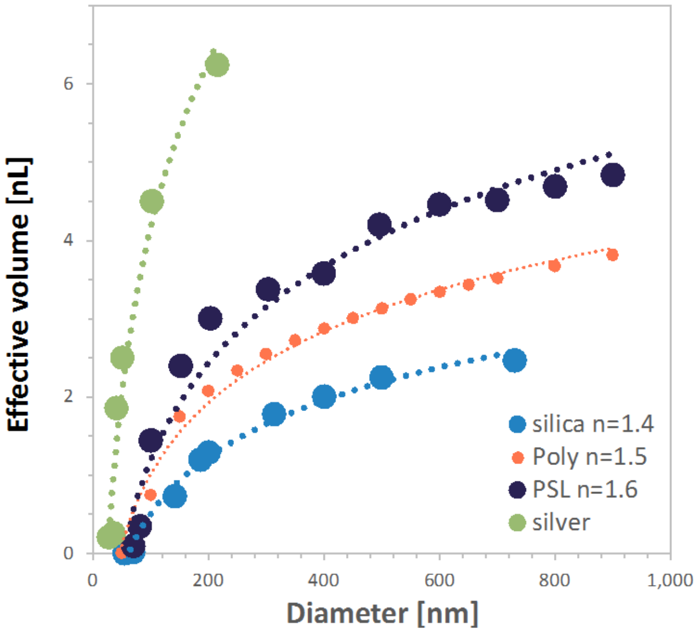
- Measure concentrations for standards of different sizes and made out of different materials (various RIs)
- Determine effective volumes

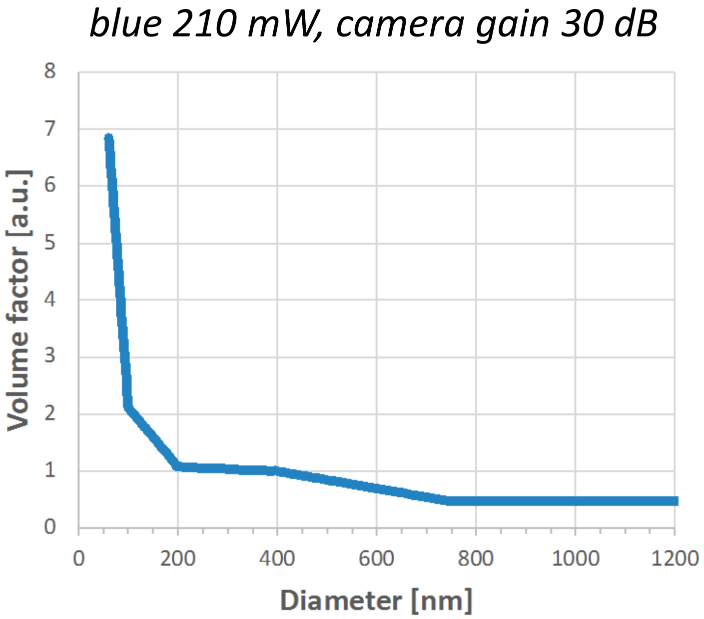
$$V = \frac{N_{measured}}{N_{expected}} V_0$$

- Create look-up surface of volume
- Extrapolate by using intensity of individual tracks and applying Mie scattering cross-section formula



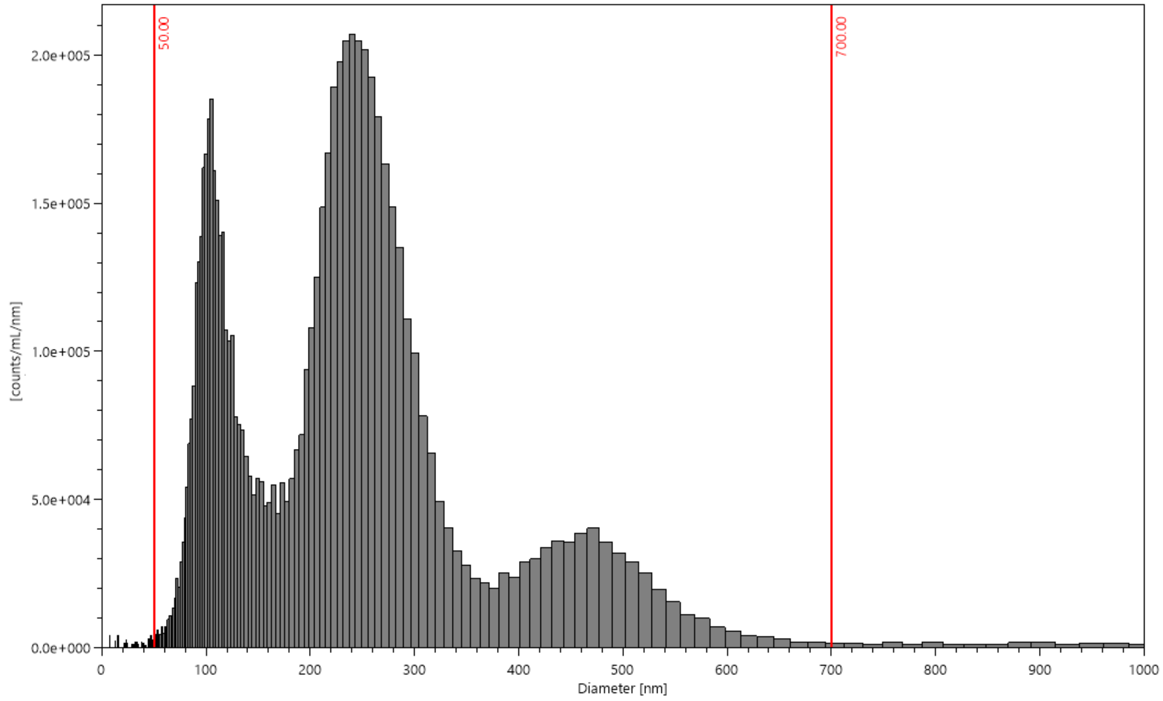
Simplified method





Histogram

Density of PSD



$$\delta_i = \sum_m \frac{1}{b_i \cdot V_m}$$

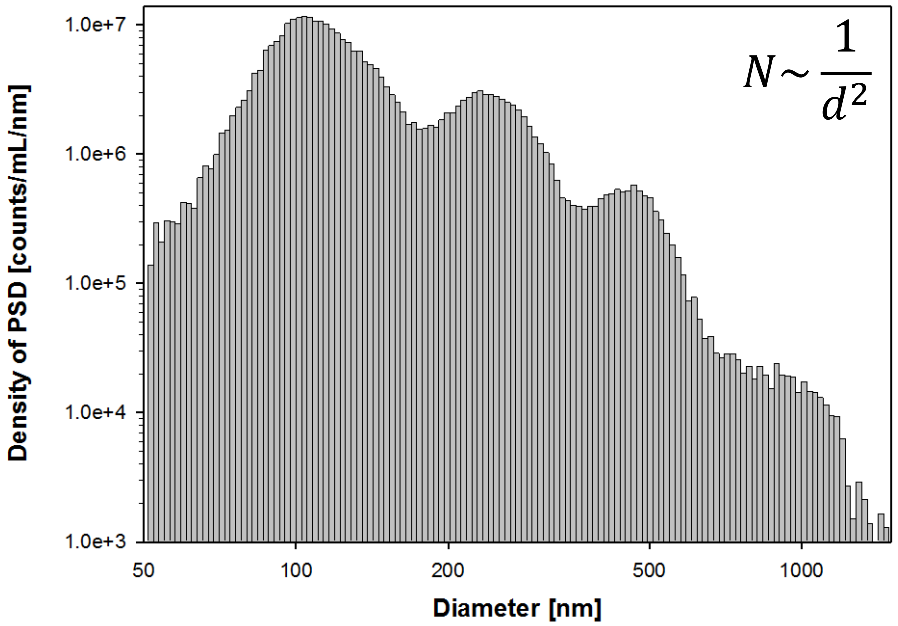
$$C_{kl} = \sum_{i=k}^{l} \delta_i \cdot b_i = \sum_{i=k}^{l} \sum_m \frac{1}{V_m}$$

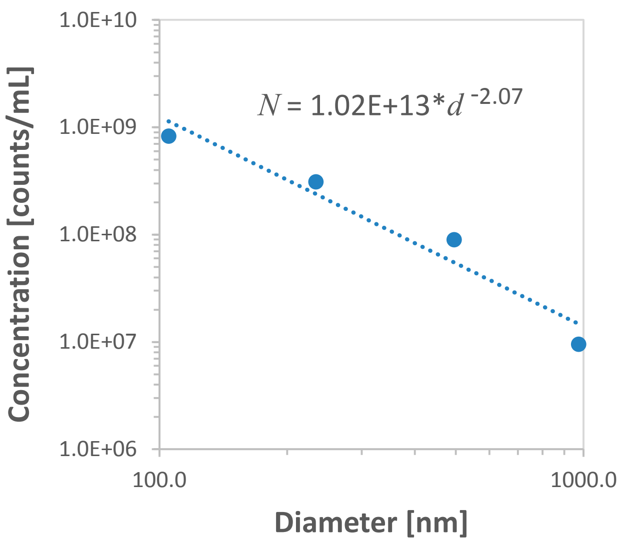
Concentration from 50 nm to 700 nm = area of density of PSD histogram

Concentration

- Integrate density of PSD (*counts/mL/nm*) across sizes of interest, for example from 50 to 700 nm, to get concentration (*counts/mL*)
- Instruments are calibrated for optics scaling (*nm/pix*) and for laser(s) power (*mW*) (*manufacturing variability of active elements*)
- For unknown materials, extrapolate investigated volumes by using Mie scattering cross-sections of known test materials
- Use measured data with statistically significant number of counts, do **not** use fitted distributions (*PSD is **not** an invariant*)

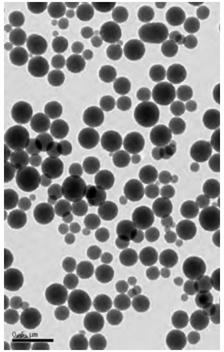
NIST exploratory mix

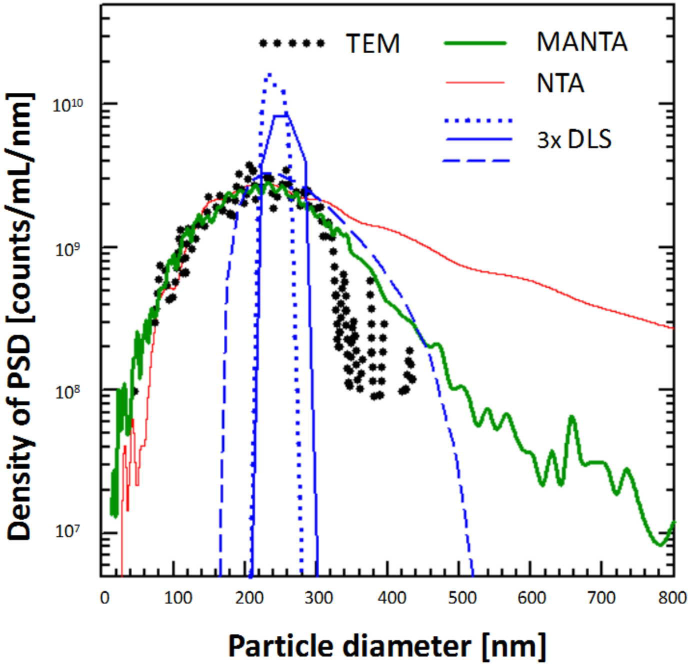




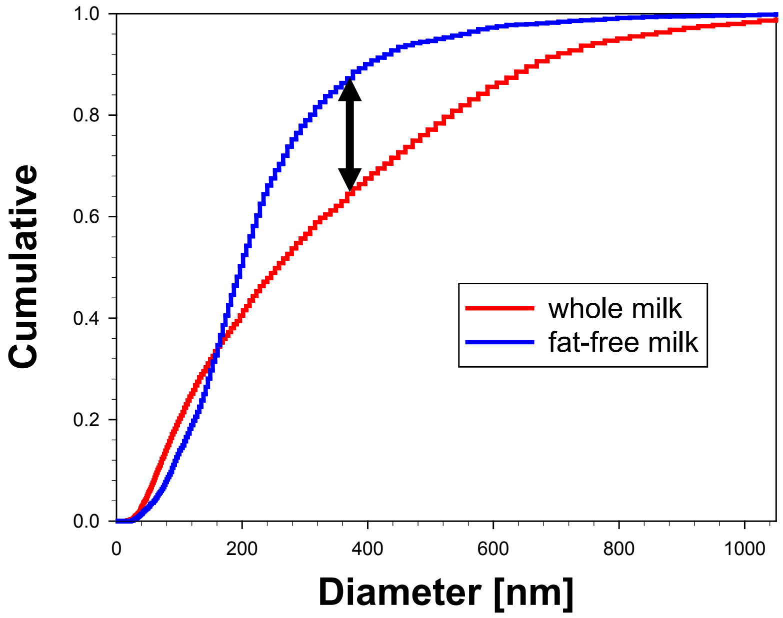
TEM, DLS & NTA vs. MANTA

α-lactalbumin nanoparticles made as per Arroyo-Maya et al. J Dairy Sci **95**, 6204 (2012)





Comparing PSDs



d_{av}=256 nm, SD=145 nm, CV=0.57

d_{av}=163 nm, SD=68 nm, CV=0.42

see Anscombe's quartet of descriptive statistics

Non-parametric tests like Kolmogorov-Smirnov statistics:

$D_{A,B}$	*alpha*	$D_{A,B,\alpha}$	*Reject?*
0.2335	0.05	0.0338	**yes**

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Thank you

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