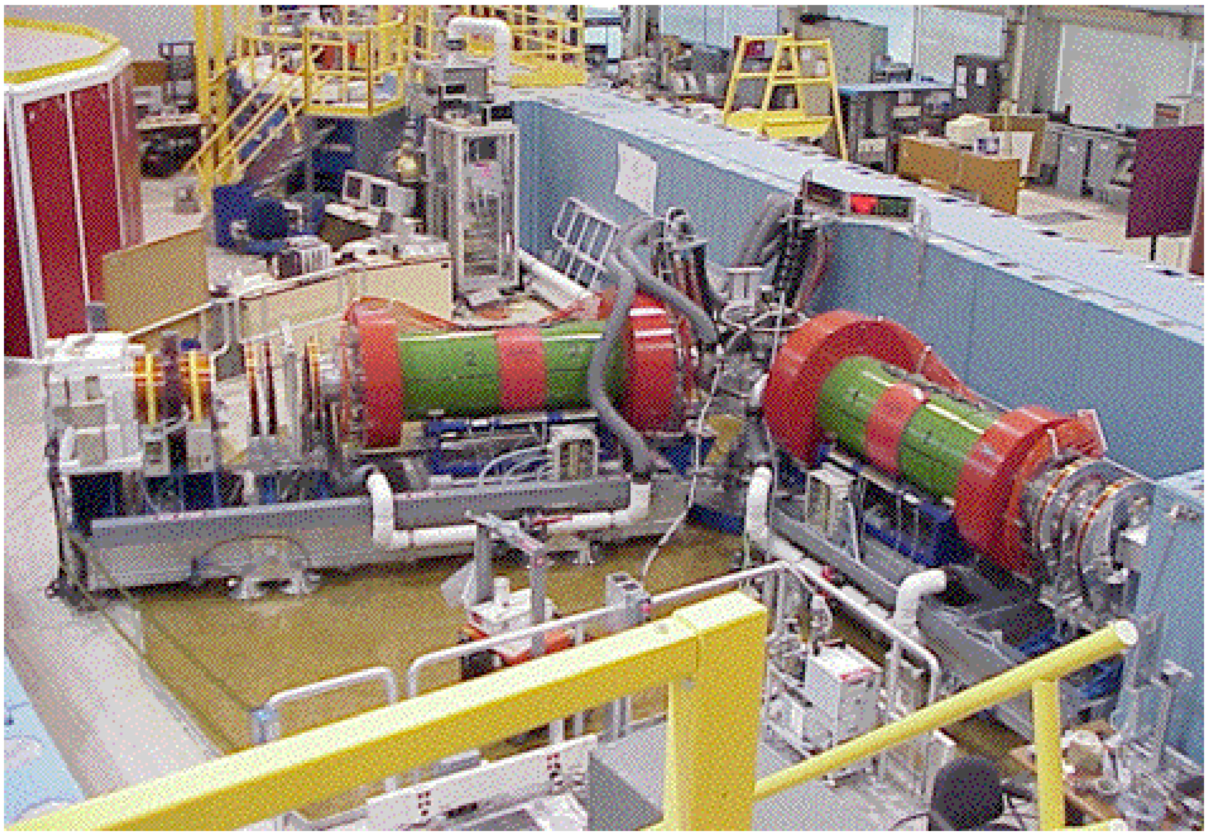
Neutron Spin Echo Spectroscopy (NSE)

2003 Summer School
NCNR, NIST
Gaithersburg, MD 20890

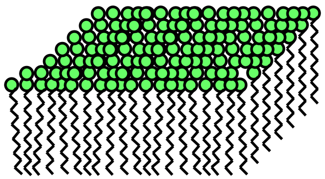


Group A

Alina Visinoiu
Erick Lawson
Gokhan Caliskan
Jose Rodriguez
Kapil Gupta
Martin Sulic
Mike Lewis
Tessema Xabiher

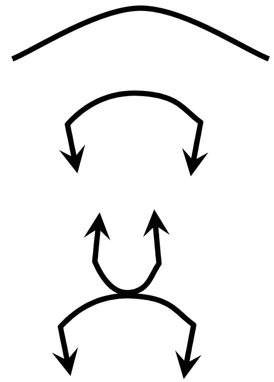
Why NSE?

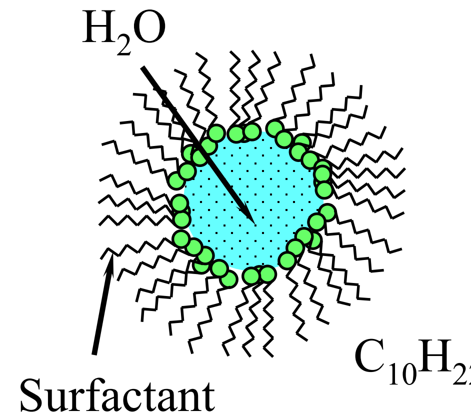
Surfactant film

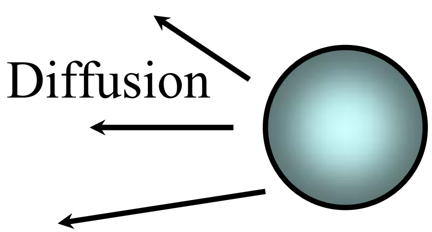


Goals:

- Spontaneous curvature
- Bending elasticity
- Saddle splay elasticity



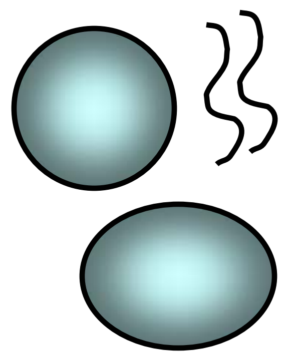




Diffusion:

- NMR
- Dynamic light scattering

(*t* scale > 100 ns)



Shape fluctuations are in very short time and length scales!

Spontaneous curvature, bending elasticity, saddle splay elasticity

↓

shape fluctuations

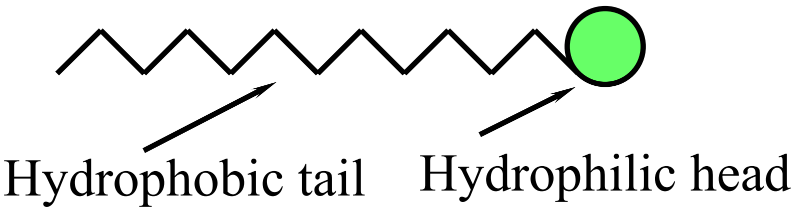
↓

NSE

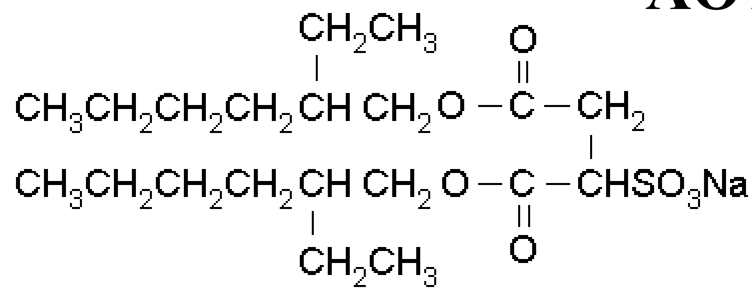
(*t* scale ~ 1 - 10 ns)

Experimental

Surfactant molecule



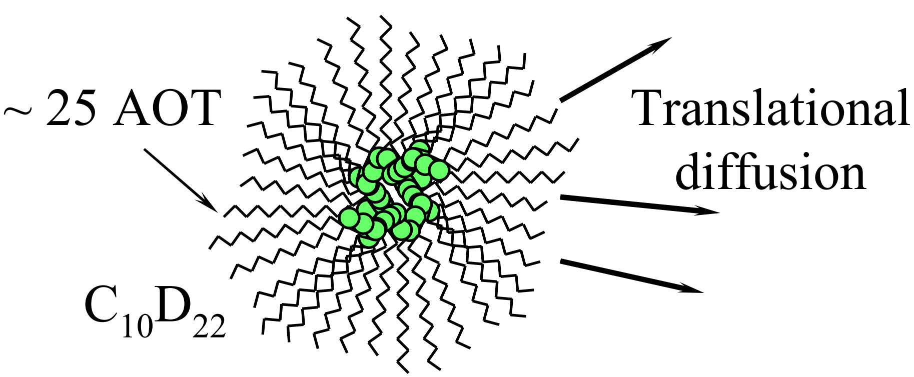
AOT



Experiment I

Diffusion of AOT micelles in $C_{10}D_{22}$
(5.4 % vol. fraction)

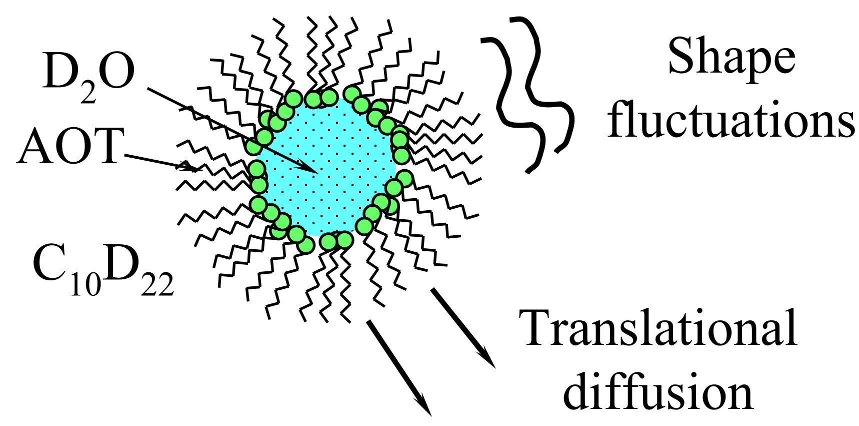
Inverse spherical micelle



Experiment II

Shape fluctuations in
$AOT/D_2O/C_{10}D_{22}$ microemulsion
(5.4/4.6/90 % vol. fraction)

Inverse microemulsion droplet

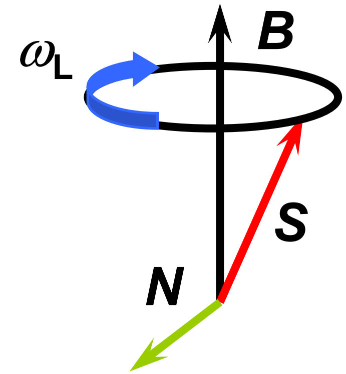


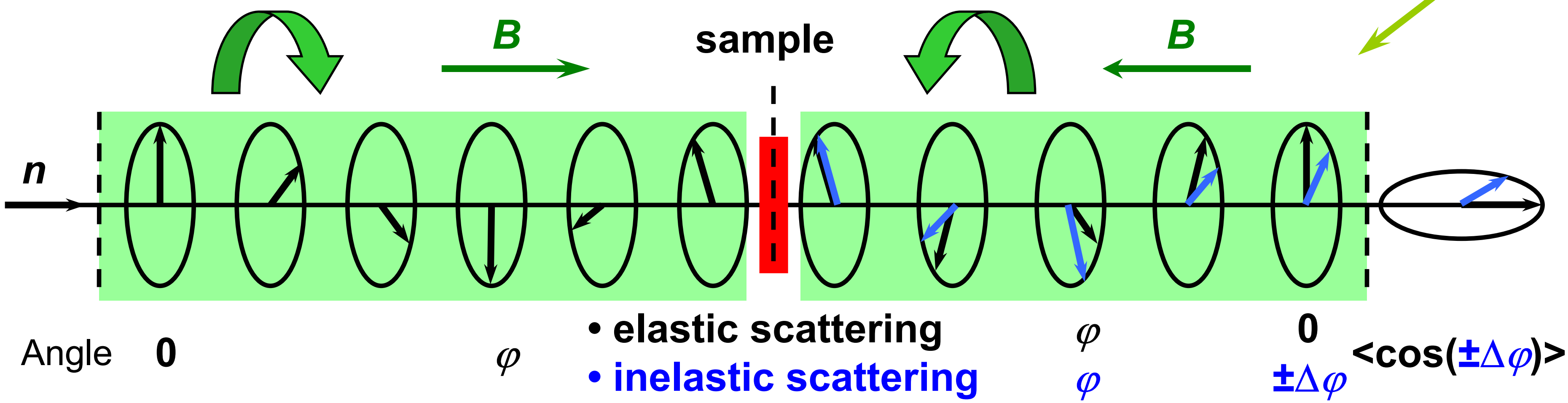
Principle of NSE

Neutrons posses spin and magnetic moment. They precess in magnetic fields with the Larmor frequency that depends on the strength of the magnetic field only. (g =1.83×10^{8} $s^{-1}T^{-1}$)

$$N = S \times B$$

$$\omega_L = gB$$





$$\varphi = gB\frac{L}{v} \qquad \Delta\varphi = gBL\left(\frac{1}{v} - \frac{1}{v'}\right) = \frac{gBL\Delta v}{v^2}$$

$$\frac{\Delta v}{v} \approx 10^{-5} \;!$$

$$\langle P \rangle = \left\langle \int_{-\infty}^{\infty} S(\mathbf{Q},\omega)\cos(\omega t)\,d\omega \right\rangle = I(Q,t)$$

Summary of data analysis

Experiment I

AOT micelles in $C_{10}D_{22}$

$$\frac{I(Q,t)}{I(Q,0)} = \exp\left[-D_{eff}Q^2 t\right]$$

Experiment II

AOT/D_2O/$C_{10}D_{22}$ microemulsion

$$\frac{I(Q,t)}{I(Q,0)} = \exp\left[-D_{eff}(Q)Q^2 t\right]$$

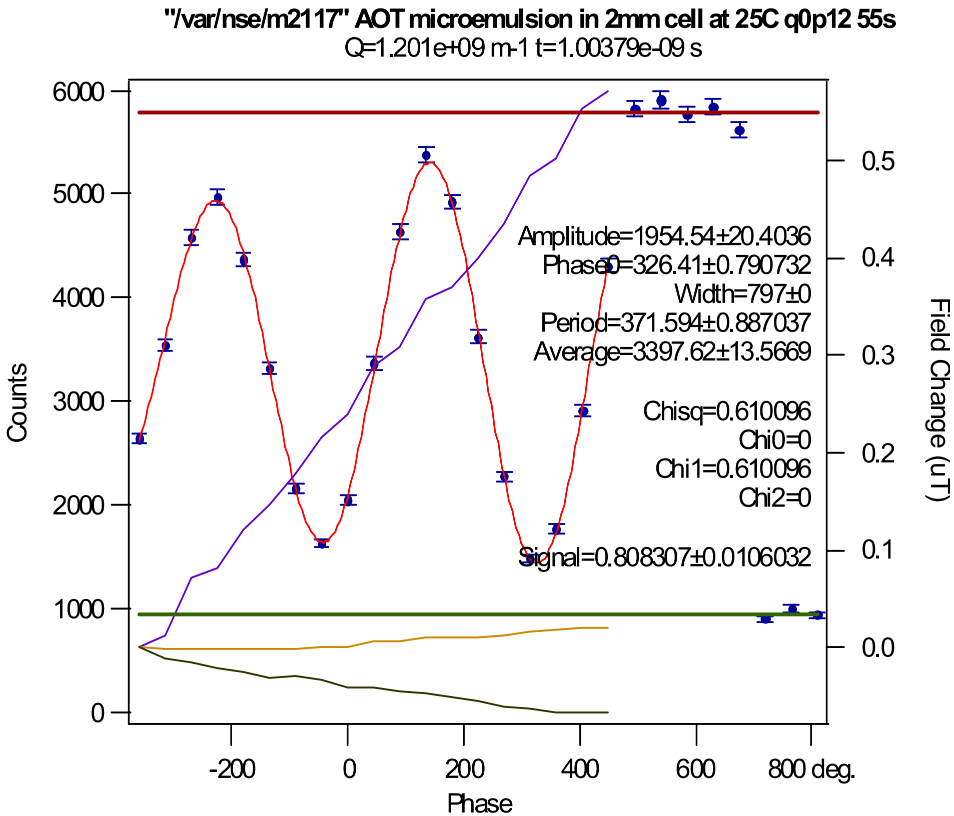
$$D_{eff}(Q) = D_{tr} + D_{def}(Q)$$

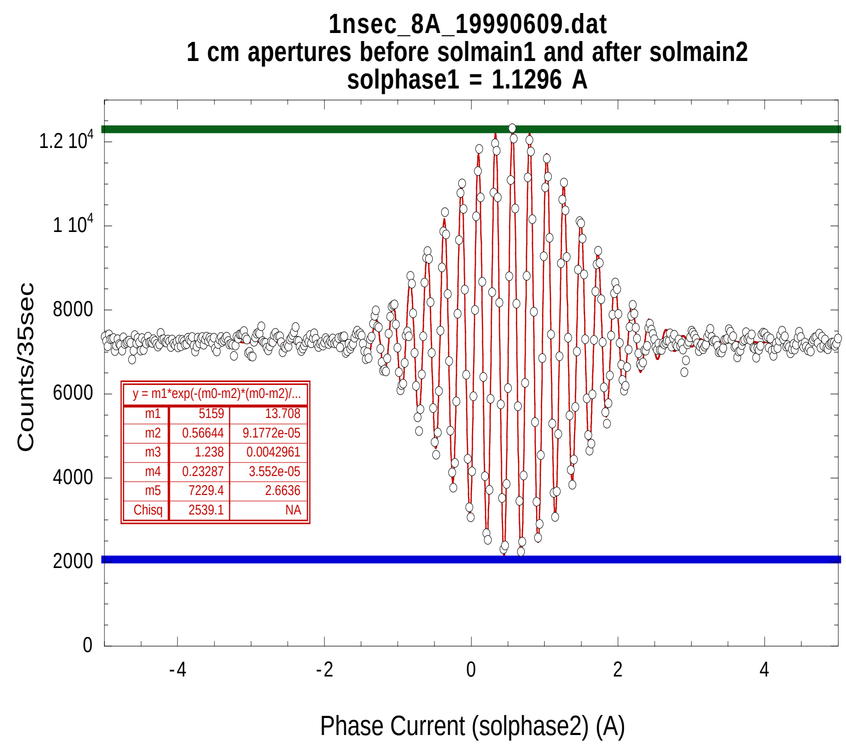
Goal:

- **Calculate the bending modulus of elasticity**
- **Calculate the frequency of deformation**

Echo Point determination

Echo Point:- Phase current where the magnetic field integral in the two magnets are balanced.



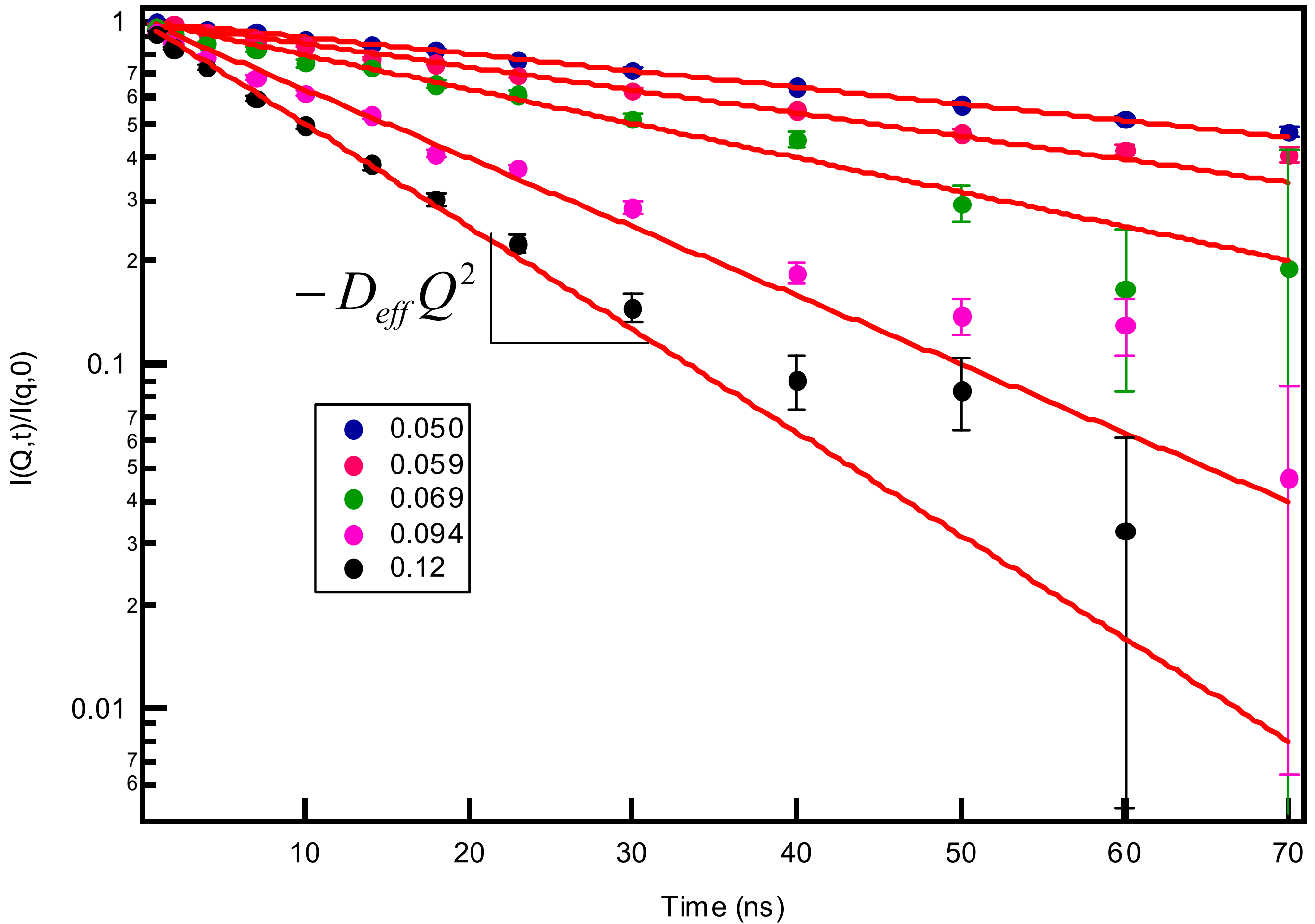


- Measured echo point for 13 fourier time points at three Q values (.05,.085,.12)

Results

$$\left(\frac{I(Q,t)}{I(Q,0)}\right) = \exp(-D_{eff}Q^2 t)$$

- Faster decay at high Q



Results

- Stokes-Einstein Relationship:

$$D = (1-\varphi)k_B T/6\pi\eta R_{h,}$$

$R_{micelle}$=1.6nm
$R_{emulsion}$= 3.4nm

Values are in good agreement with the SANS Data.

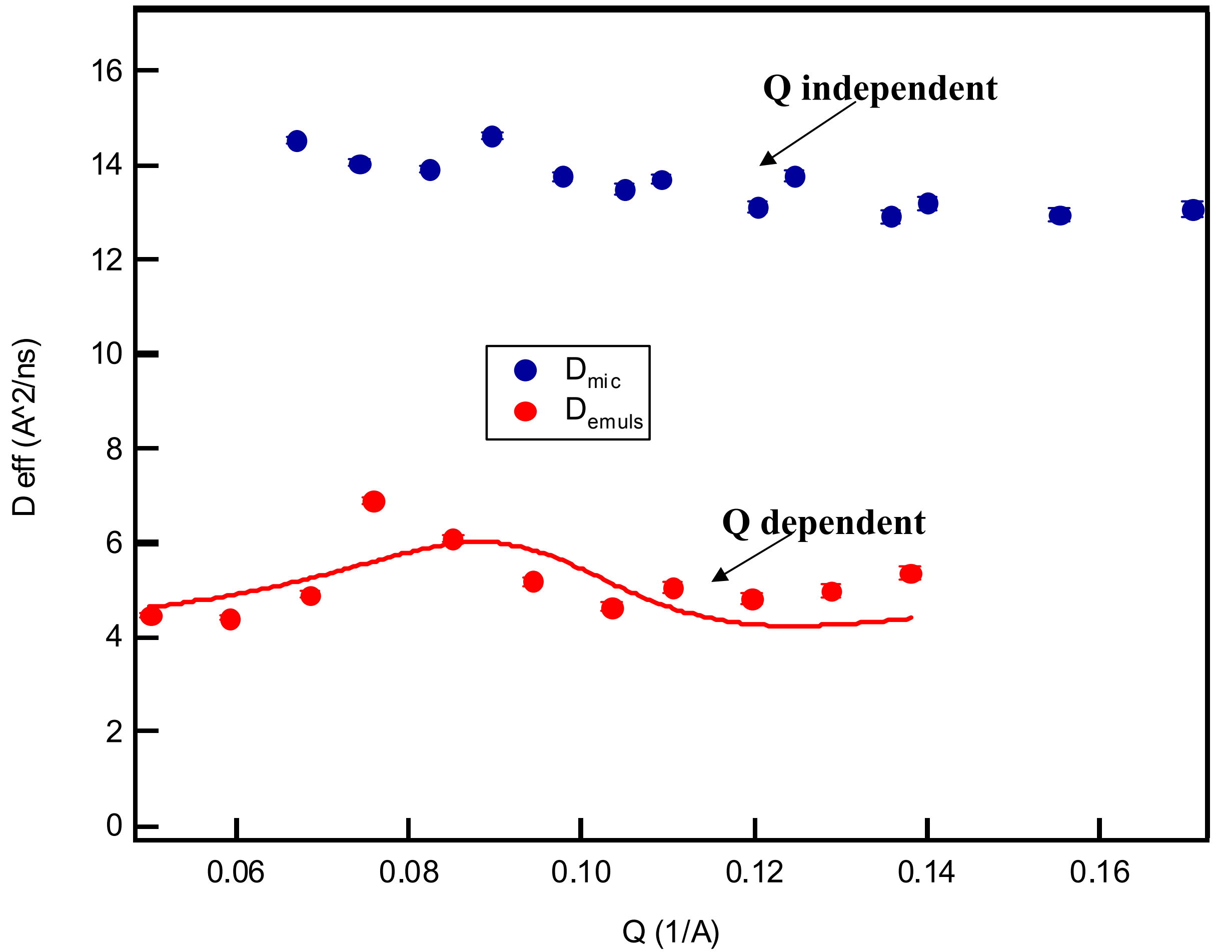
Results

- Fitting model

$$D_{eff}(Q) = D_{tr} + \frac{5\lambda_2 f_2(QR_0)\langle |a_2|^2 \rangle}{Q^2\left[4\pi[j_0(QR_0)]^2 + 5 f_2(QR_0)\langle |a_2|^2 \rangle\right]}$$

$$f_2(QR_0) = 5[4 j_2(QR_0) - QR_0 j_3(QR_0)]^2$$

Damping frequency (λ_2) (Hz)	1.45e+7
Amplitude (a_2)	.0406
Mean radius (A^0)	34
D_{trans} (A^2/ns)	4.24



- Bending modulus

$$k = \frac{1}{48}\left[\frac{k_B T}{\pi p^2} + \lambda_2 \eta R_0^3 \frac{23\eta' + 32\eta}{3\eta}\right]$$

λ_2- damping frequency
$<|a|^2>$ - amplitude of deformation
p^2- size polydispersity, measured by SANS

$k = .1 k_B \mathrm{T}$

- Fluctuations are thermal in origin

Summary

- Energy resolution is very high (10^{-5}meV)
- Measures the Intermediate scattering function(I(Q,t))
- Provides information on the Brownian dynamics of the particle
- Very small shape fluctuations can be characterized

Acknowledgements

- NIST/NCNR staff
- NSF