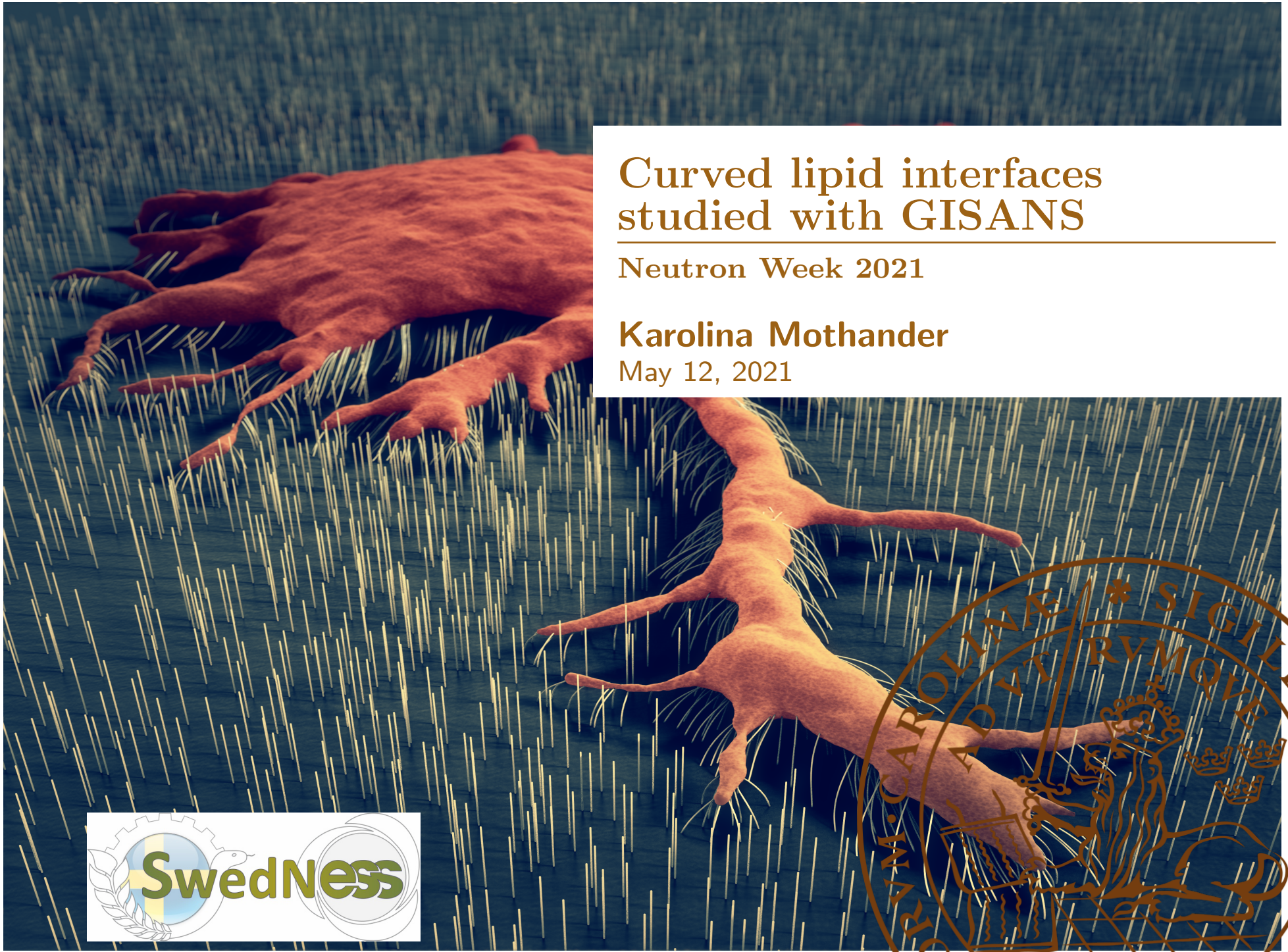


Curved lipid interfaces studied with GISANS

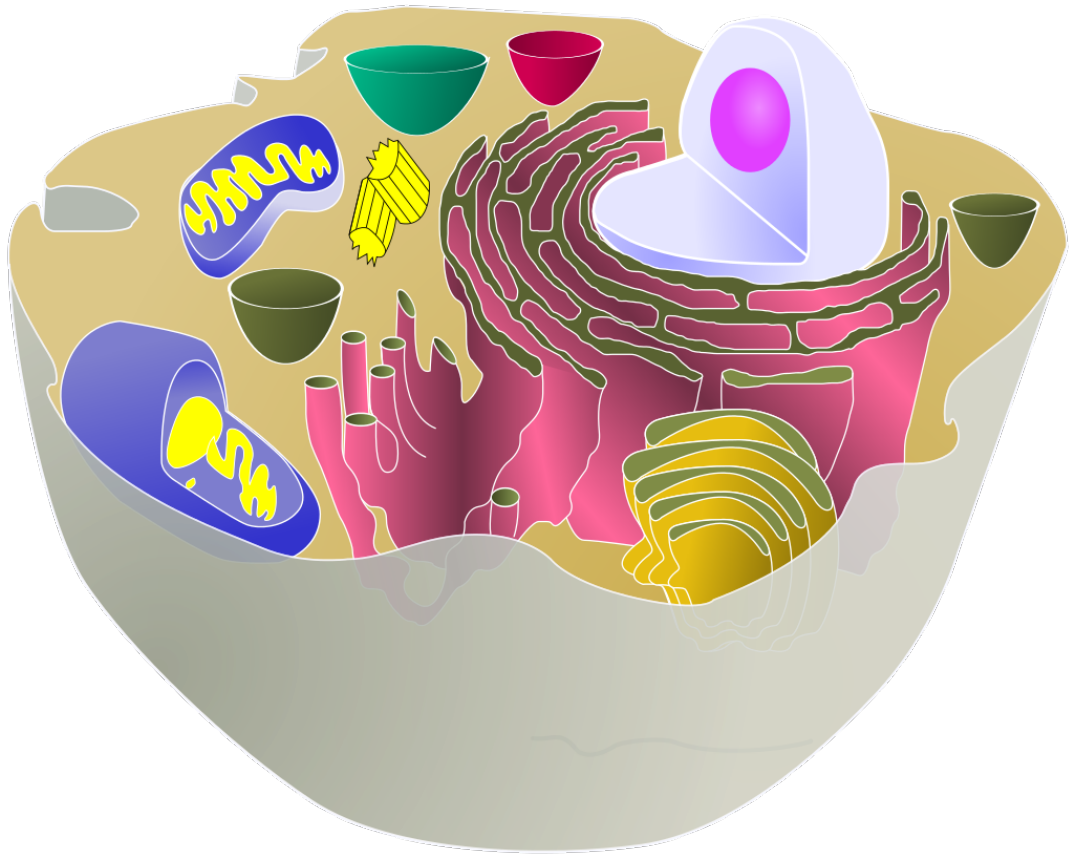
Neutron Week 2021

Karolina Mothander

May 12, 2021

Curved lipid bilayers

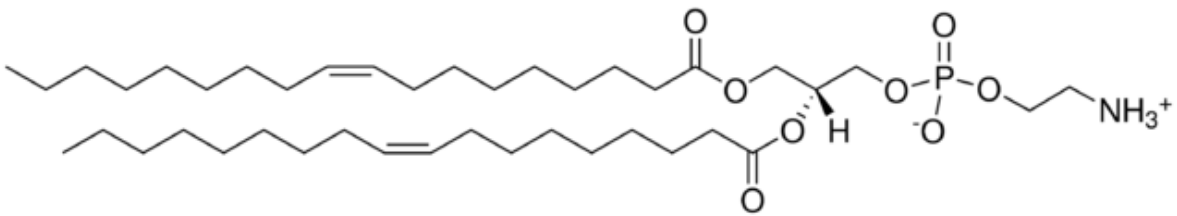
- Many curved lipid interfaces inside a cell
- Important for meiosis and mitosis
- Membrane proteins



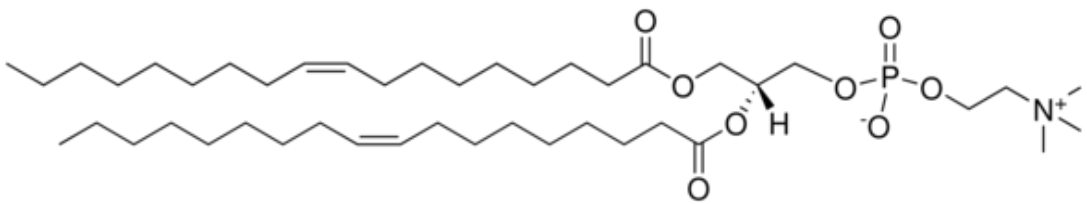
Wikimedia Commons

Model system

- Phospholipids
- Components of biological membranes
- 20 mol% DOPE in DOPC



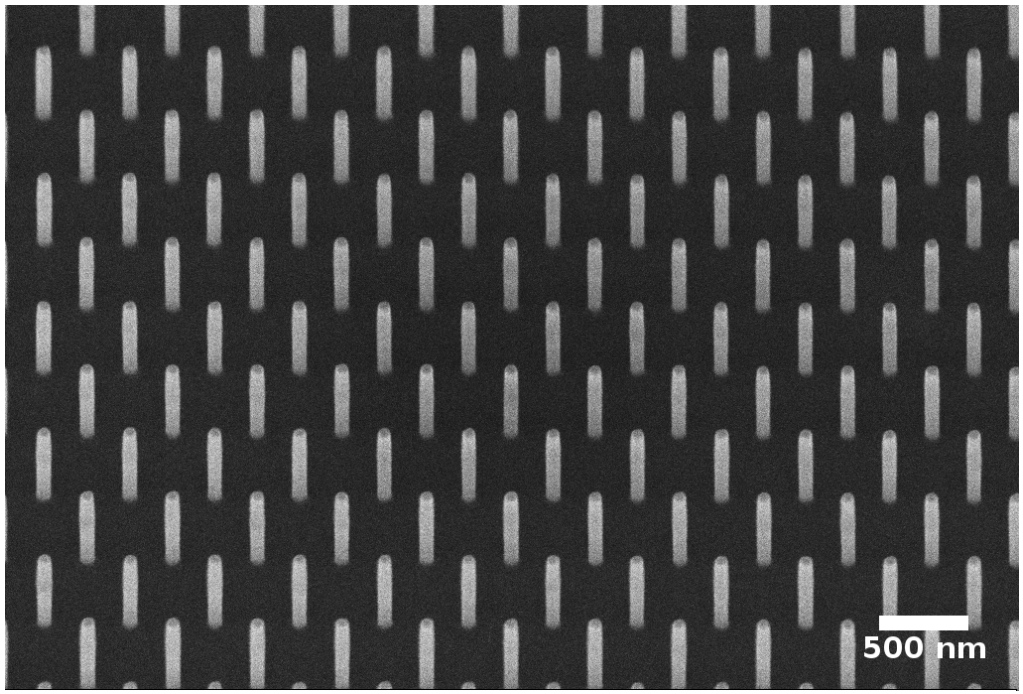
- DOPE, 1,2-dioleoyl-sn-glycero-3-phosphoethanolamine



- DOPC, 1,2-dioleoyl-sn-glycero-3-phosphocholine

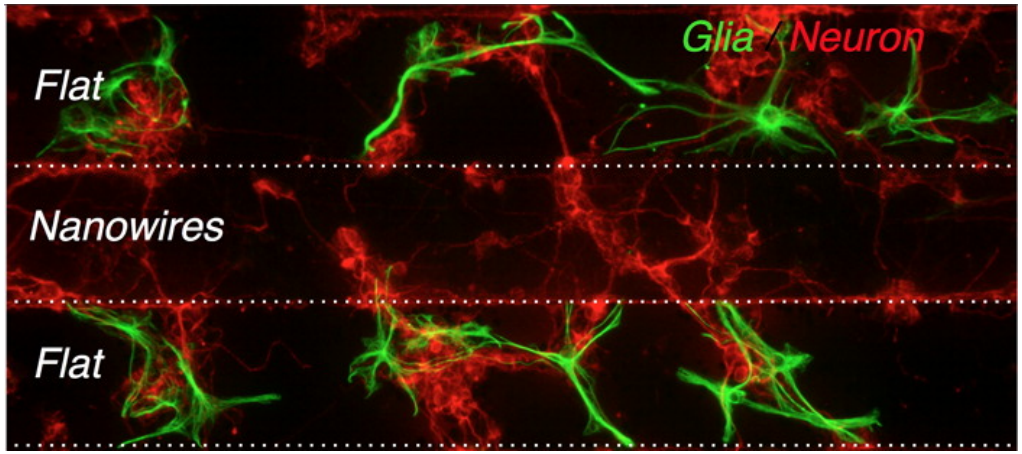
Nanowire supported lipid bilayer

- Semiconductor nanowires, i.e. silicon, gallium phosphide
  - Hexagonal pattern
  - Spaced 500 nm apart
  - 80 nm in diameter

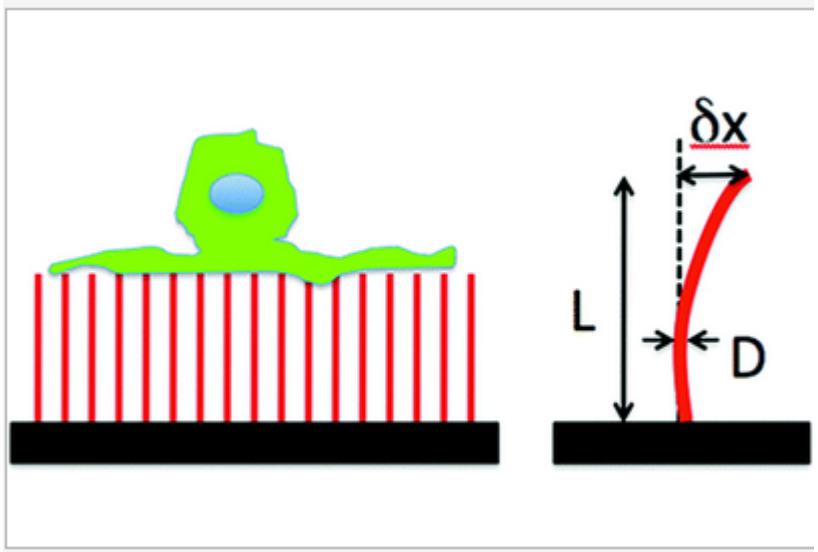


Nanowire supported lipid bilayer

- Semiconductor nanowires, i.e. silicon, gallium phosphide
- Increasingly used for cell interaction
  - Steering cell proliferation
  - Measure cellular force

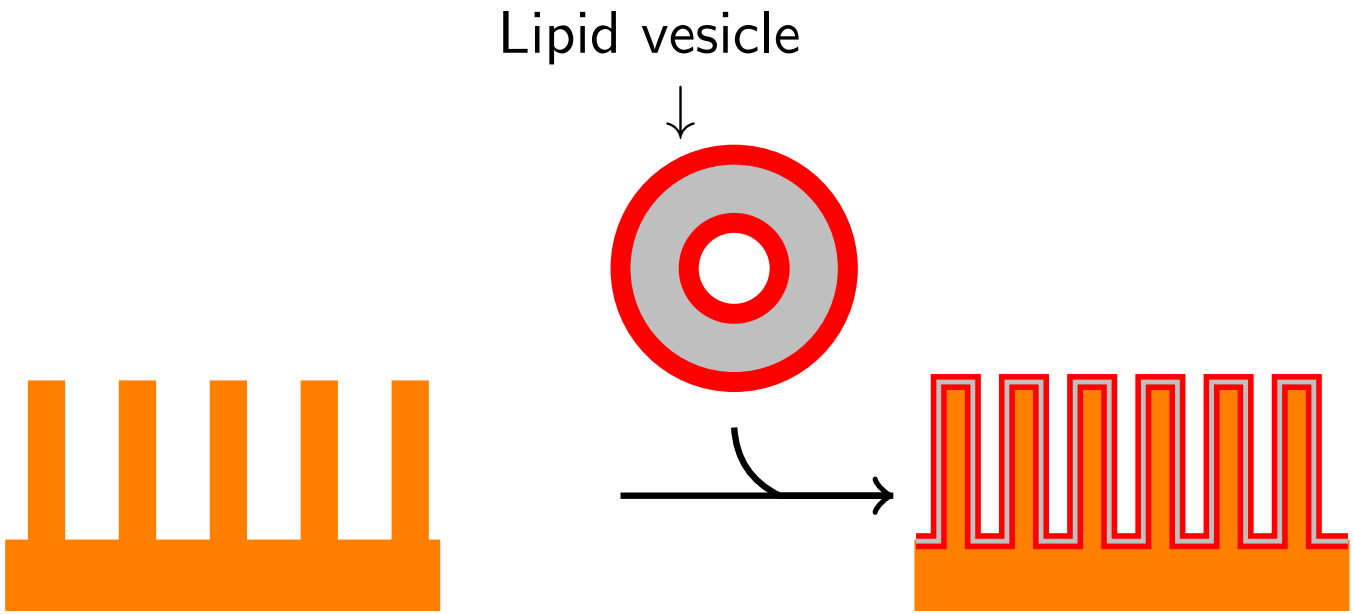


Piret *et.al*, ACS Appl. Mater. Interfaces 2015



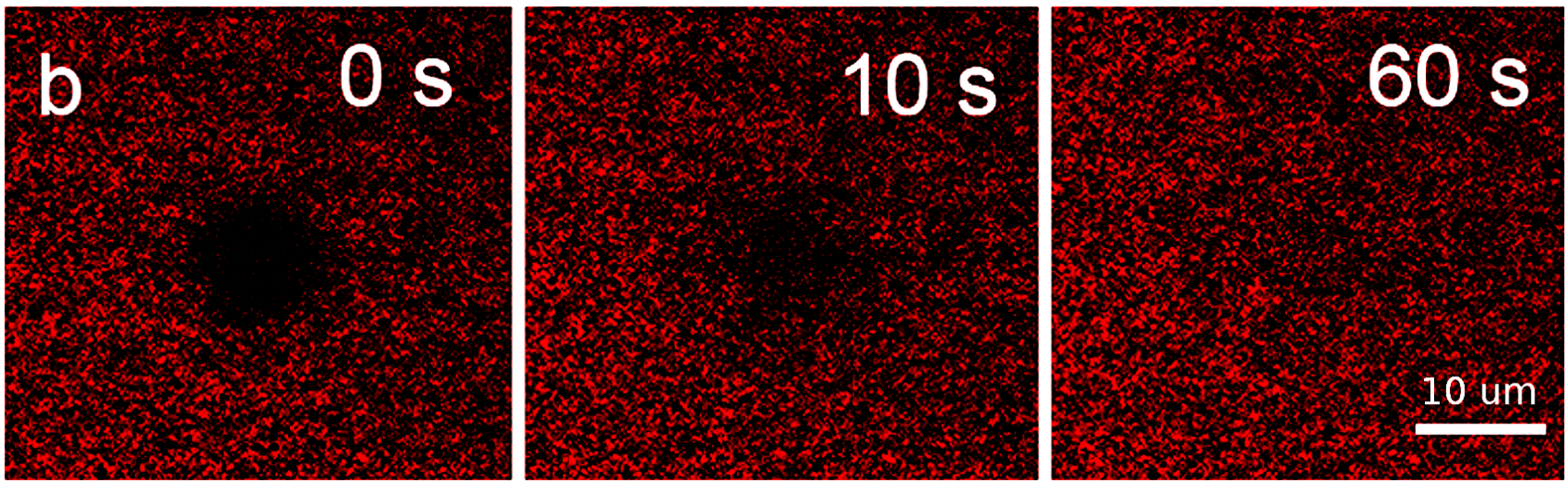
Hällström *et.al*, Nano Lett. 2010

Nanowire supported lipid bilayer – vesicle fusion



NOTE! Not to scale

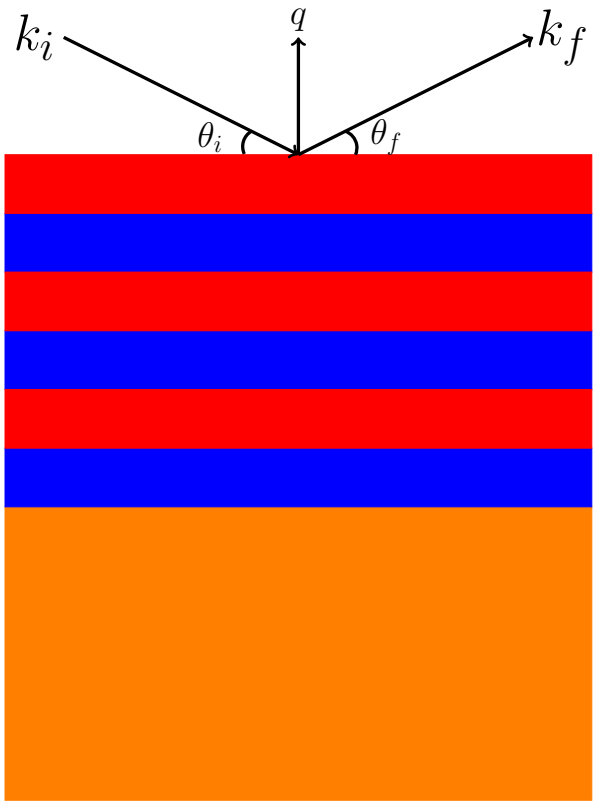
FRAP



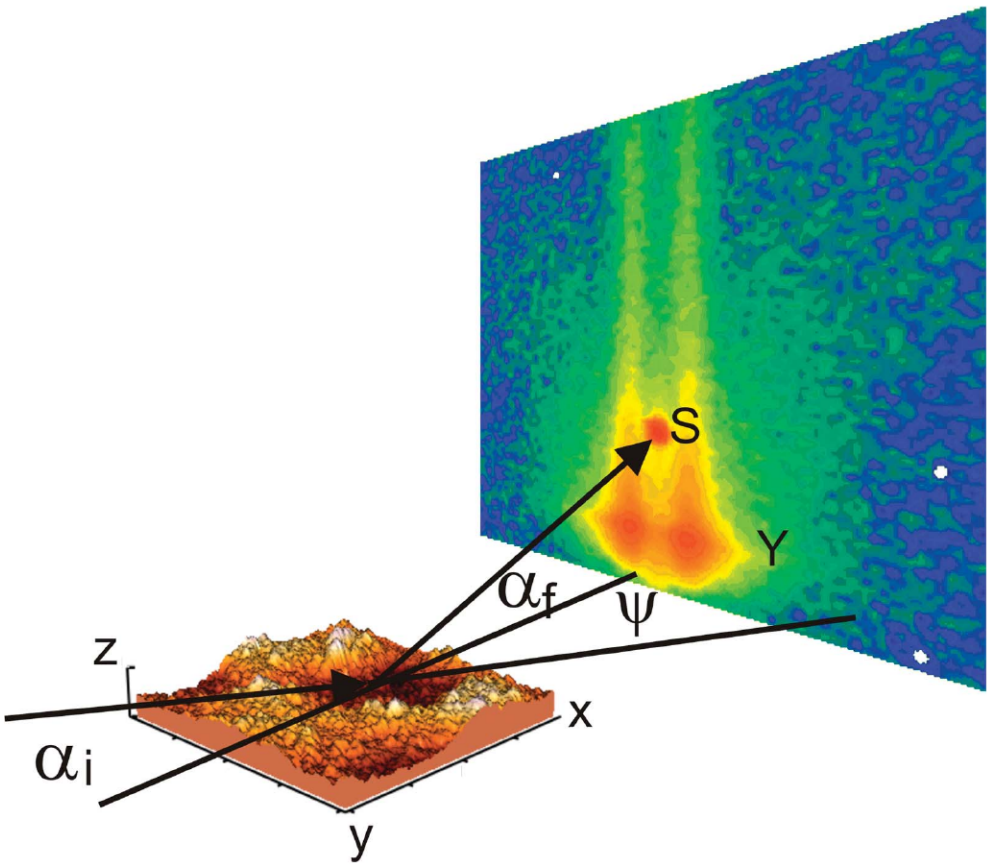
Dabkowska *et.al*, Nano Lett. 2014

Reflectometry

- Surface technique
- Interfaces
- Reflection mode
- Information perpendicular to the surface
  - In my case, information about the areas between the nanowires



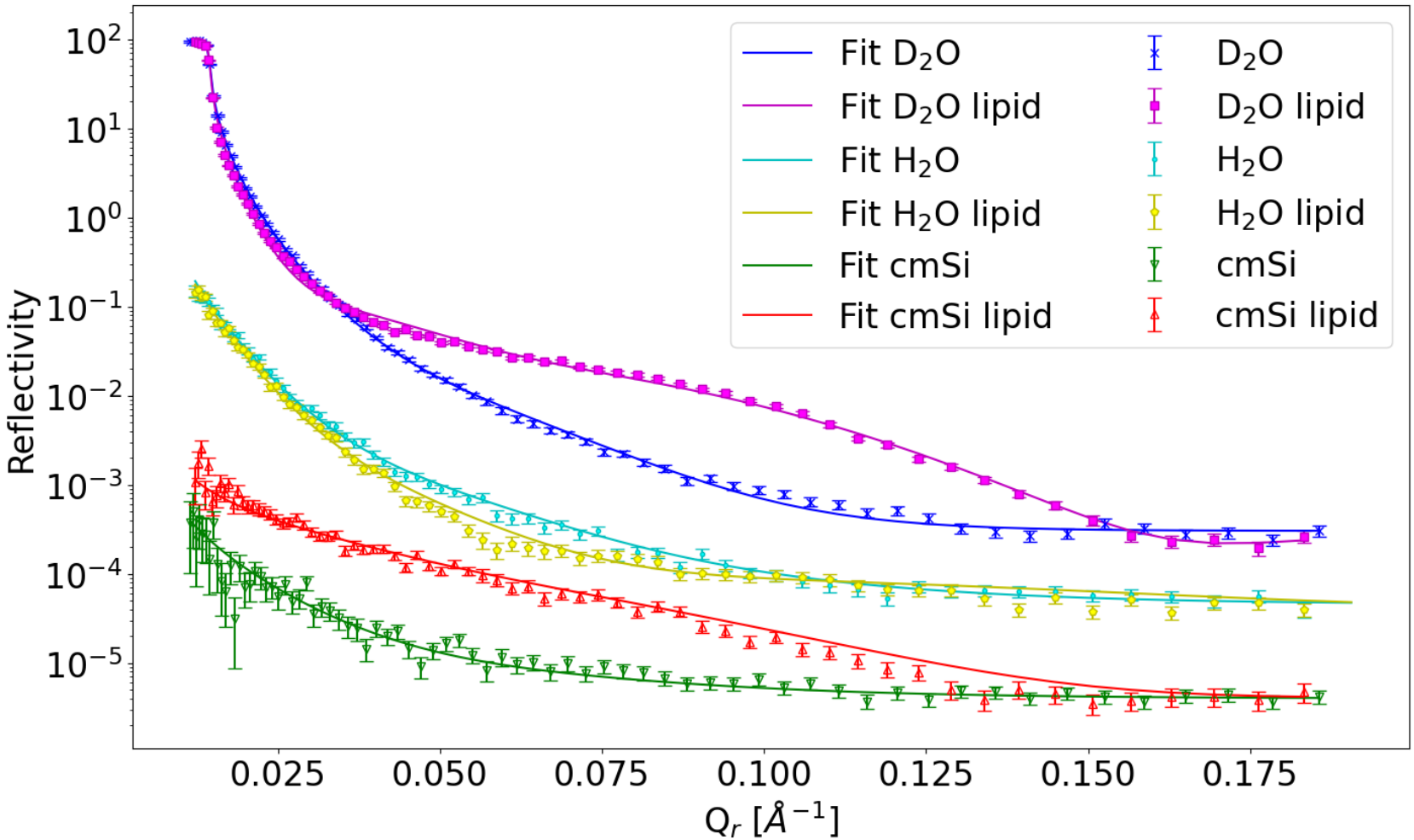
Grazing Incidence SANS



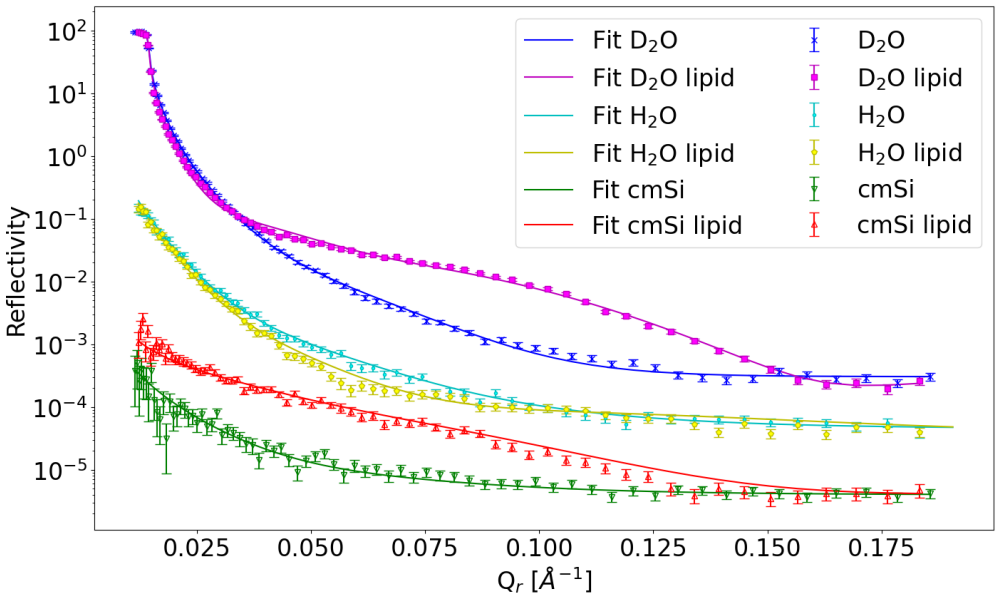
Müller-Buschbaum, Polym J. 2013

- Surface technique
- Lateral structure in the sample
  - In my case, the structure of the nanowires
- Incidence angle less than 1°
- Combining SANS set up and reflectometry
- New technique, first data published 1999

Reflectometry at ISIS, UK

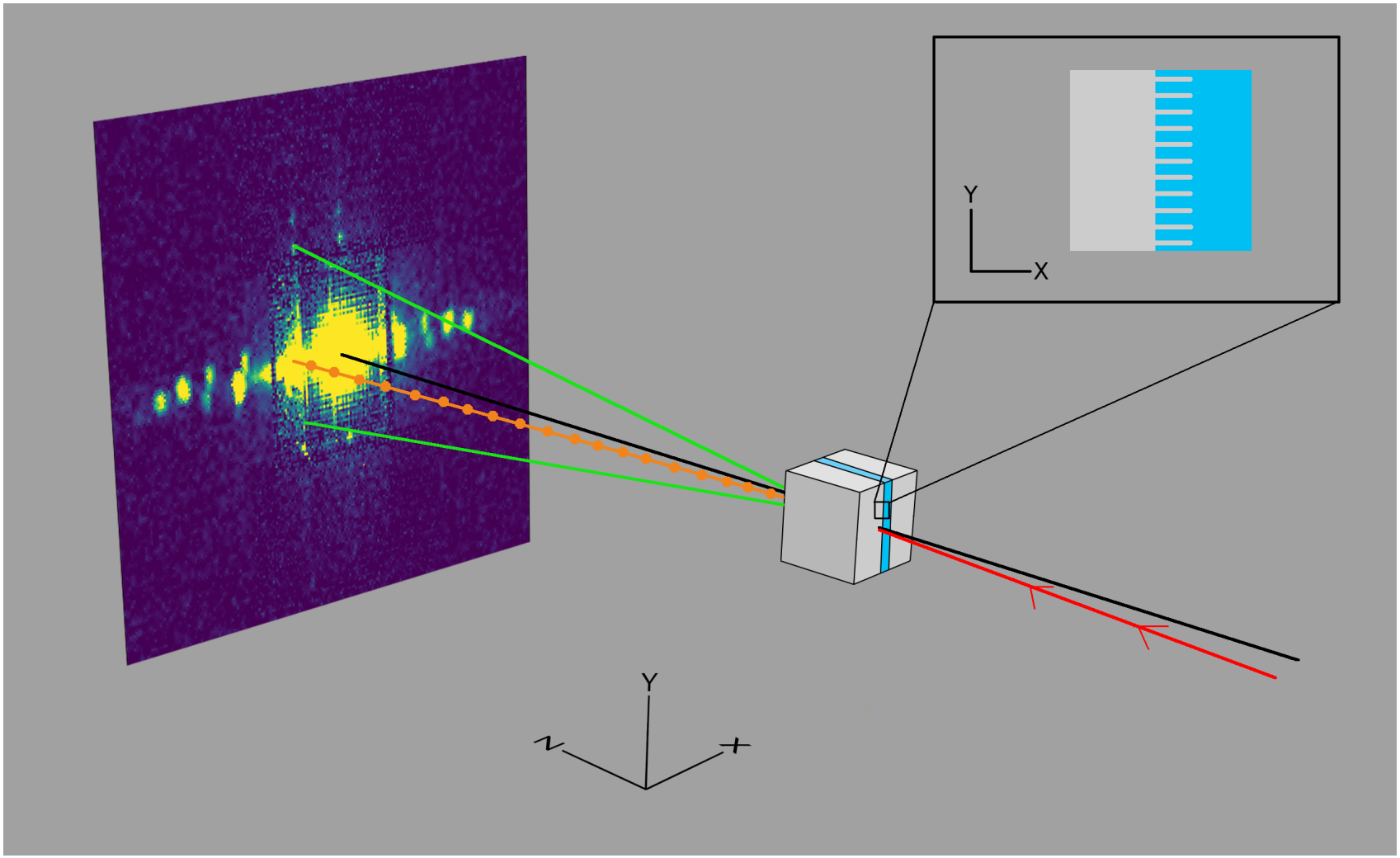


Reflectometry at ISIS, UK



- Rough substrate with inclusion of solvent
- 37 Å thick bilayer
- Nanowires fitted as a thick Si layer with 97.4% solvent

GISANS at NIST Center for Neutron Research

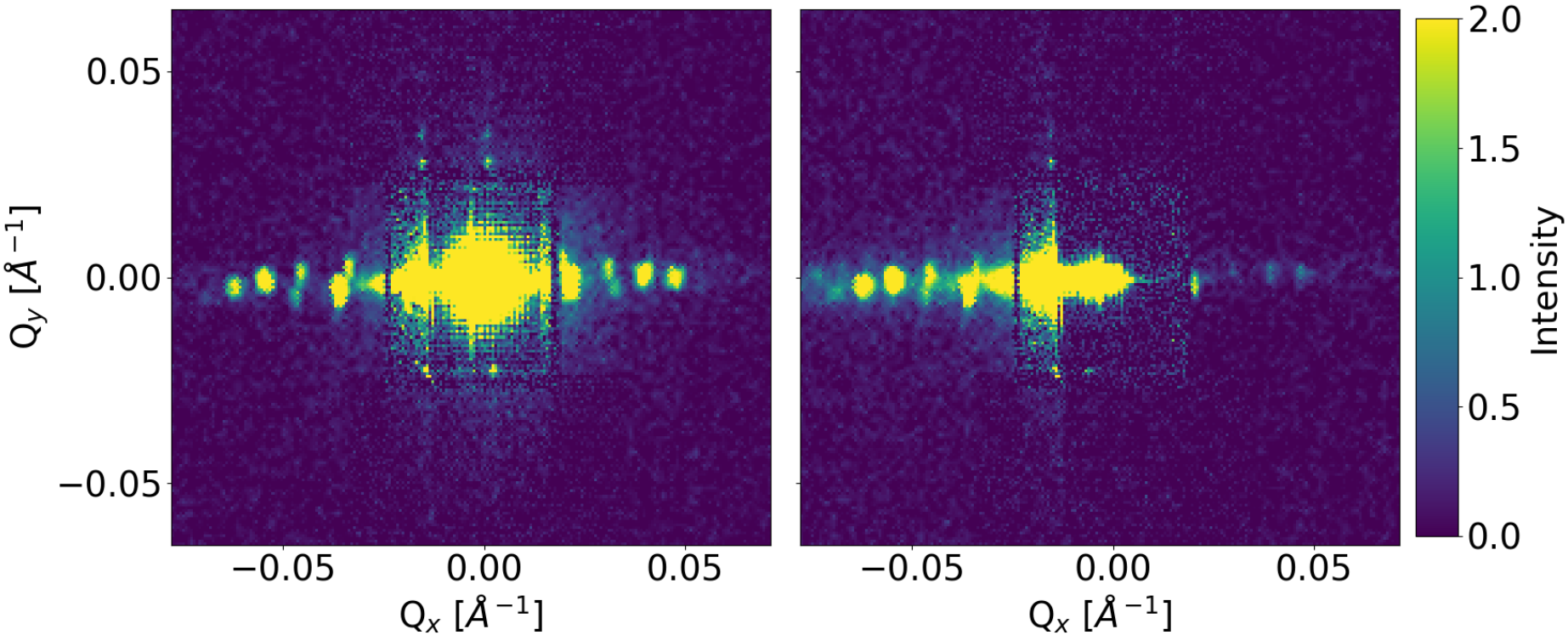


GISANS at NIST Center for Neutron Research

D_2O contrast

Bare nanowires

Lipid covered nanowires



Data analysis

- Developed a new and simplified analysis method
- Scattering pattern can be described by

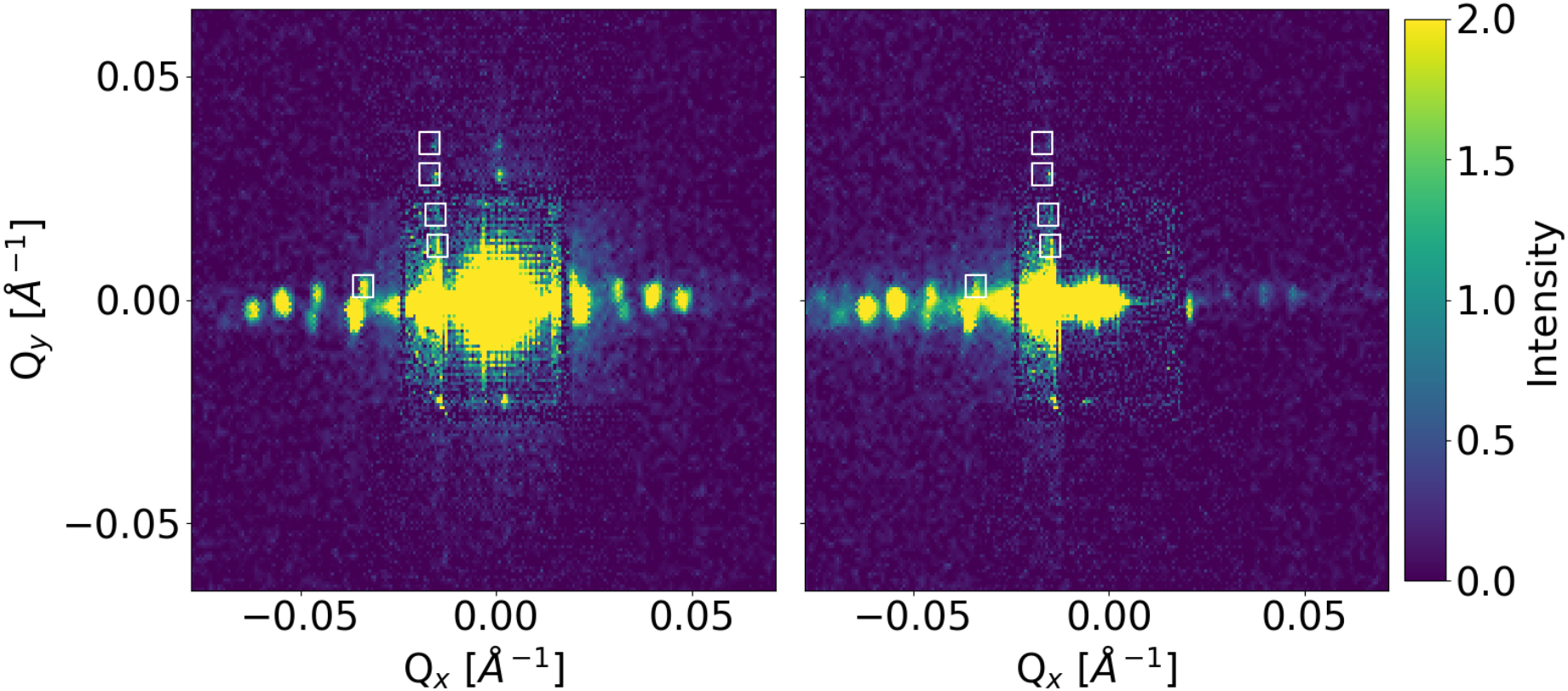
$$\frac{d\Sigma}{d\Omega} = S(Q) \cdot F^2(Q) + background$$

  - Structure factor = nanowire array
  - Form factor = Nanowires, approximated to a cylinder
- Ratios of form factors

$$\frac{F^2_{lipid}(Q)}{F^2_{NW}(Q)}$$

Data analysis

Bragg peaks, ratio of intensities



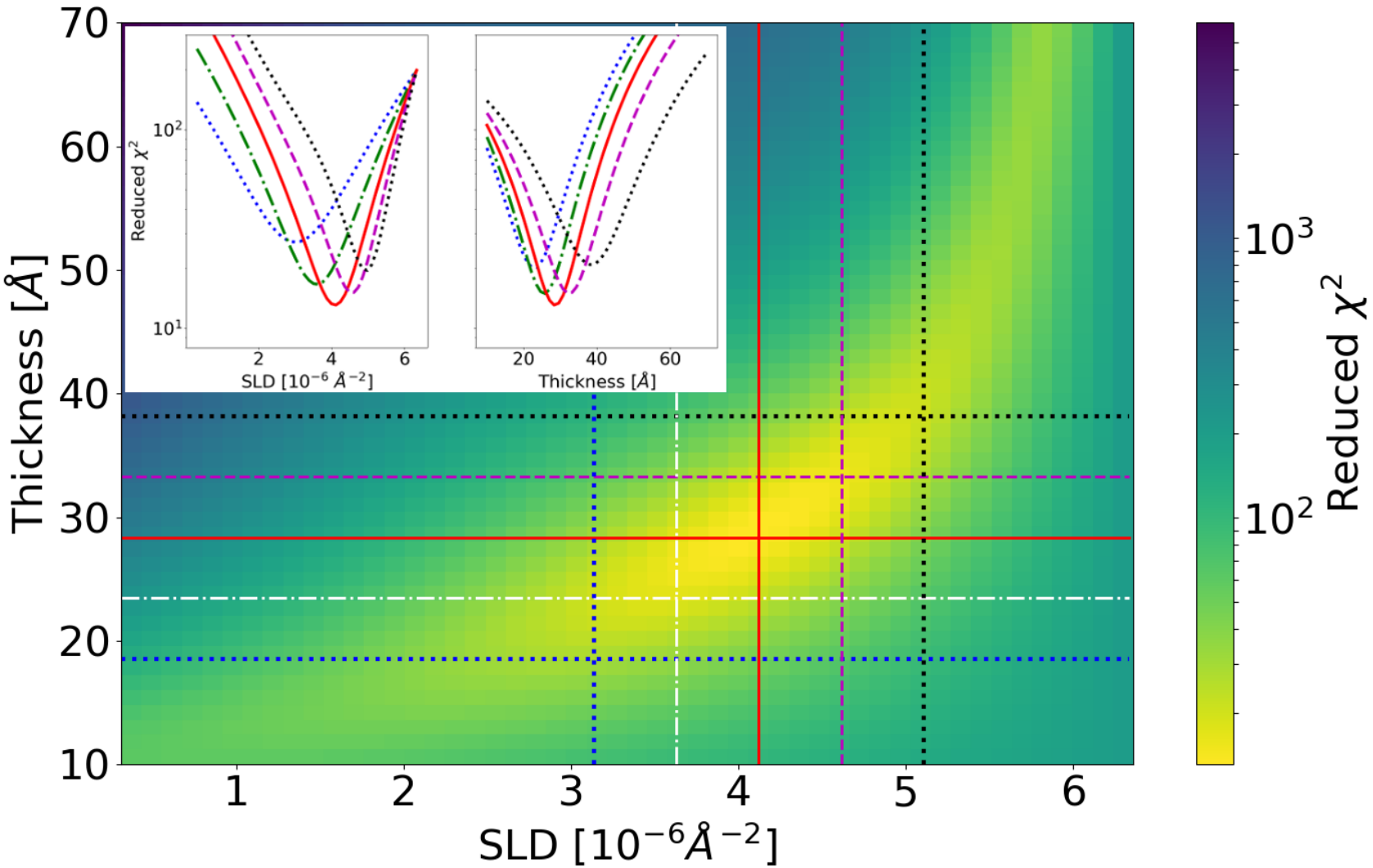
Data analysis

- Scattering pattern can be described by

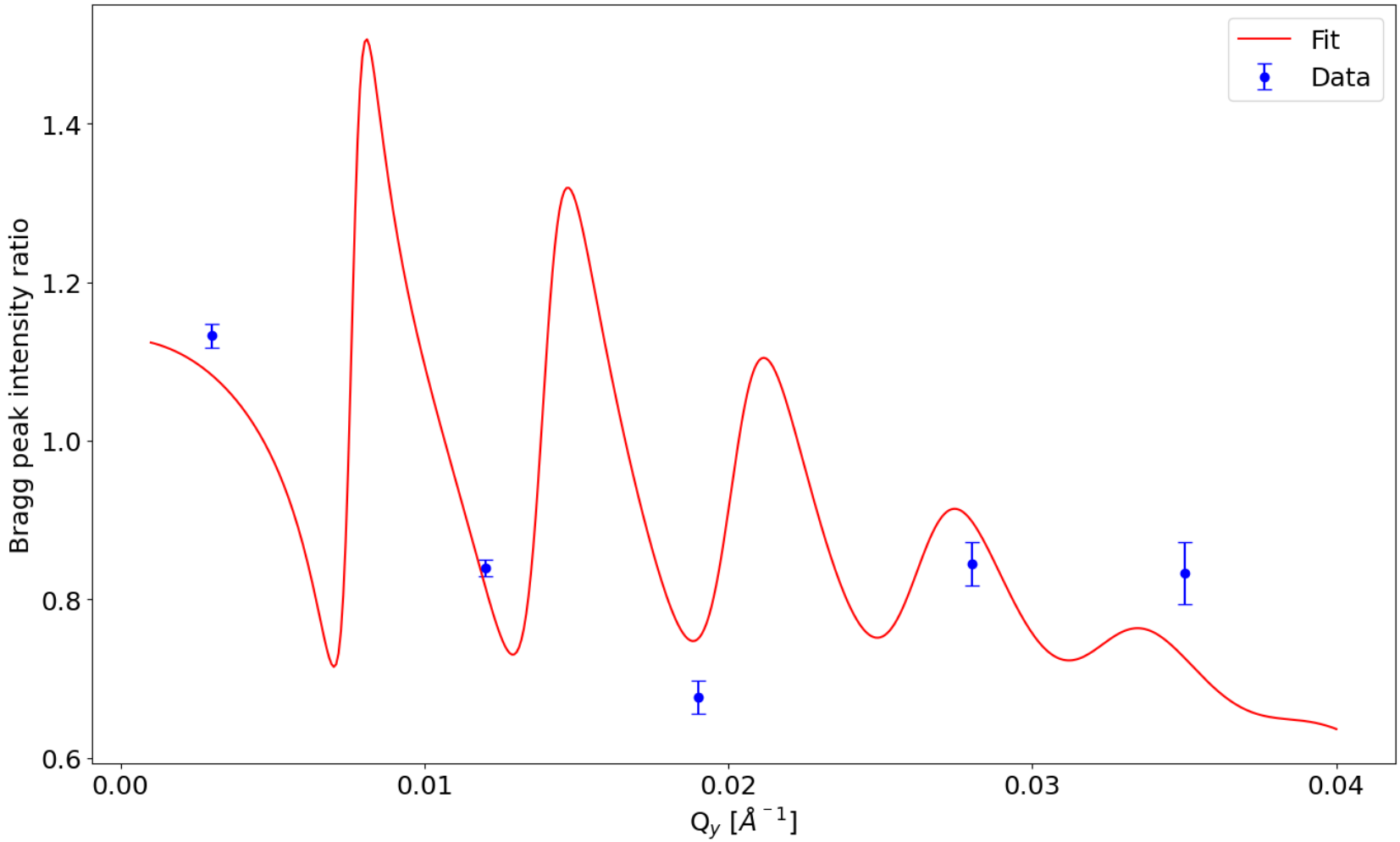
$$\frac{d\Sigma}{d\Omega} = S(Q) \cdot F^2(Q) + background$$

  - Structure factor = nanowire array
  - Form factor = Nanowires, approximated to a cylinder
- Ratios of simulated form factors is compared to Bragg peak intensity ratios
  - Cylinder with one shell representing an oxide
  - Cylinder with two shells representing an oxide and a lipid bilayer
- Best fit determined with a reduced χ^2 test

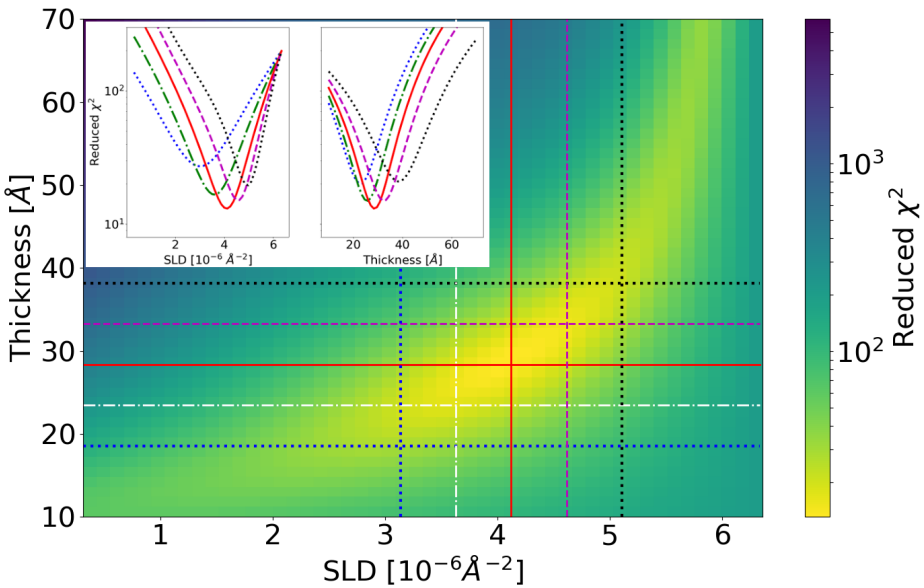
Data fit


Thickness [Å]
SLD [$10^{-6}Å^{-2}$]
Reduced χ^2
10^3
10^2
Reduced χ^2
10^2
10^1
SLD [10^{-6} Å^{-2}]
Thickness [Å]

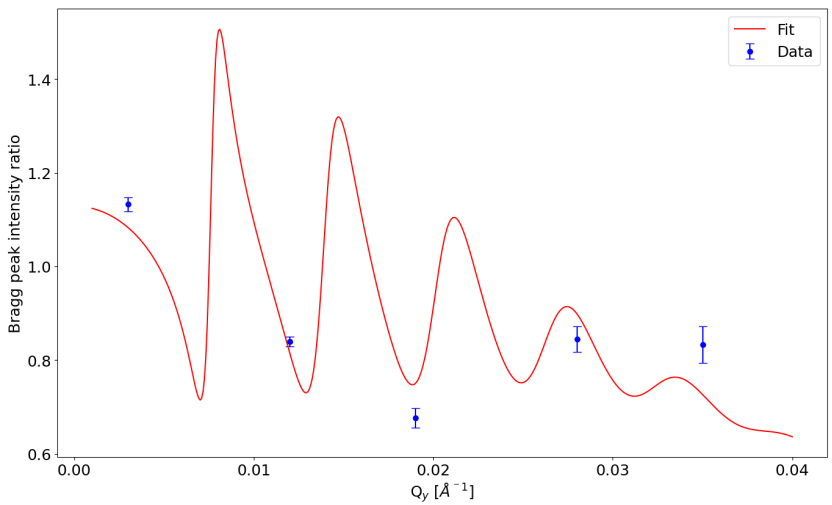
Data fit


Fit
Data
Bragg peak intensity ratio
1.4
1.2
1.0
0.8
0.6
0.00
0.01
0.02
0.03
0.04
Q_y [$Å^{-1}$]

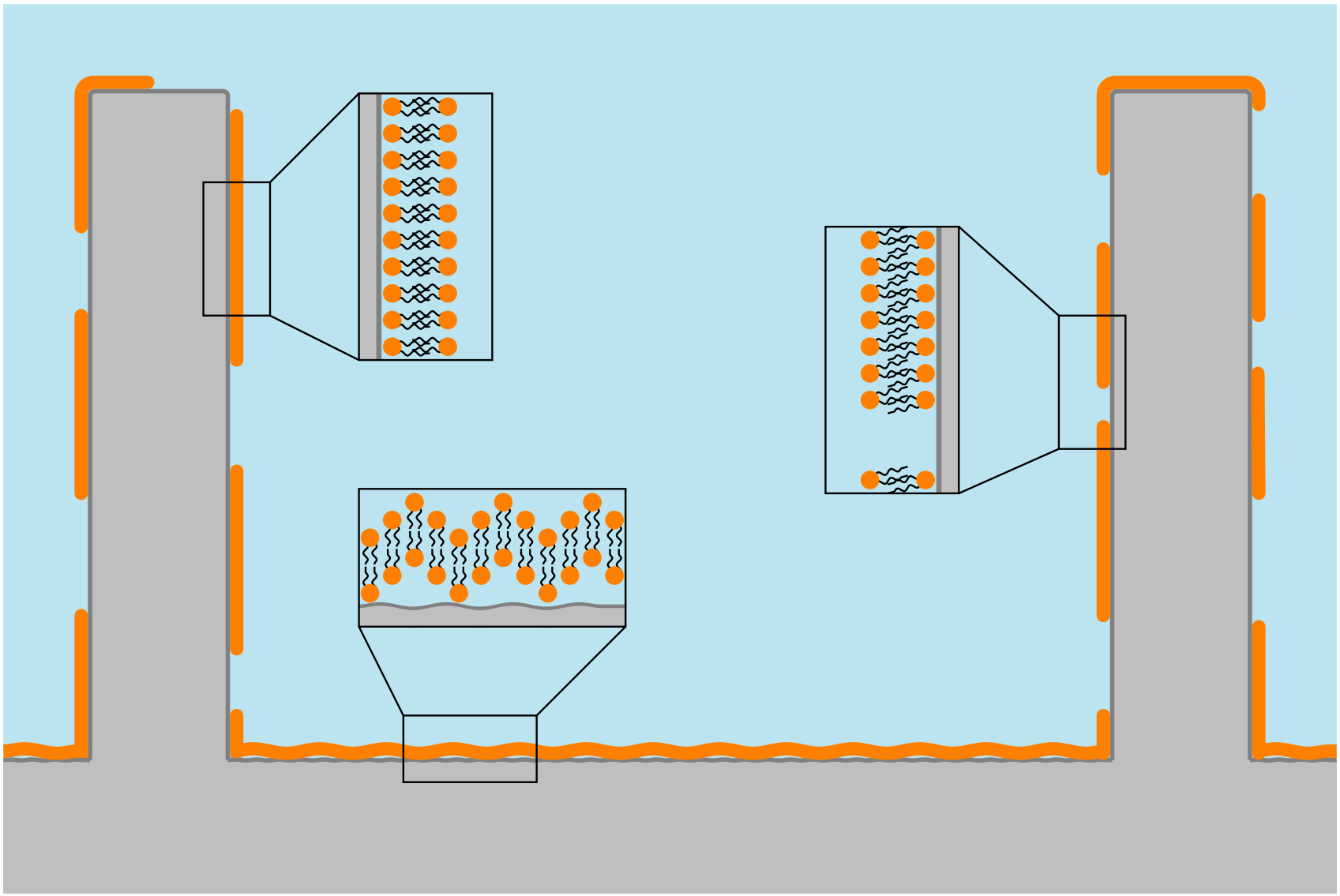
Data fit



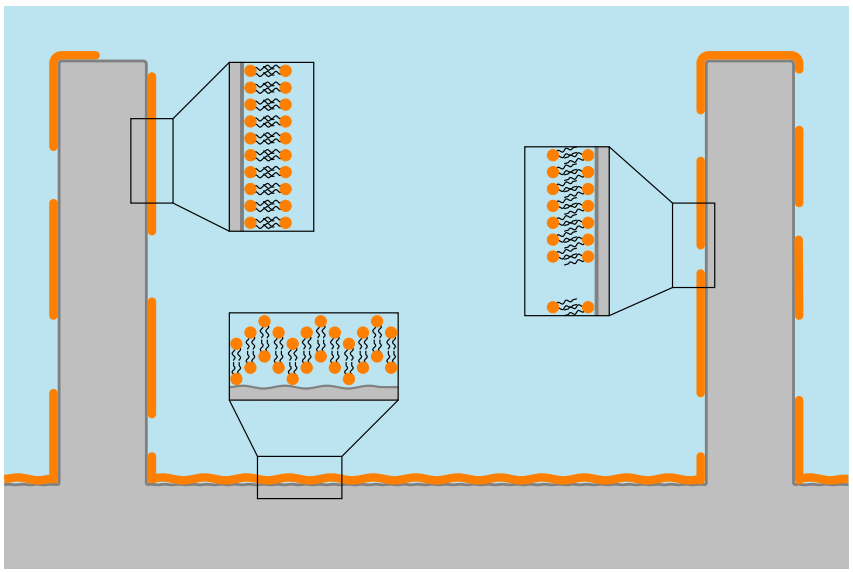
- 28 Å thick bilayer
- SLD of 4.1×10^{-6} Å^{-2}, 63% solvent



Interpretation

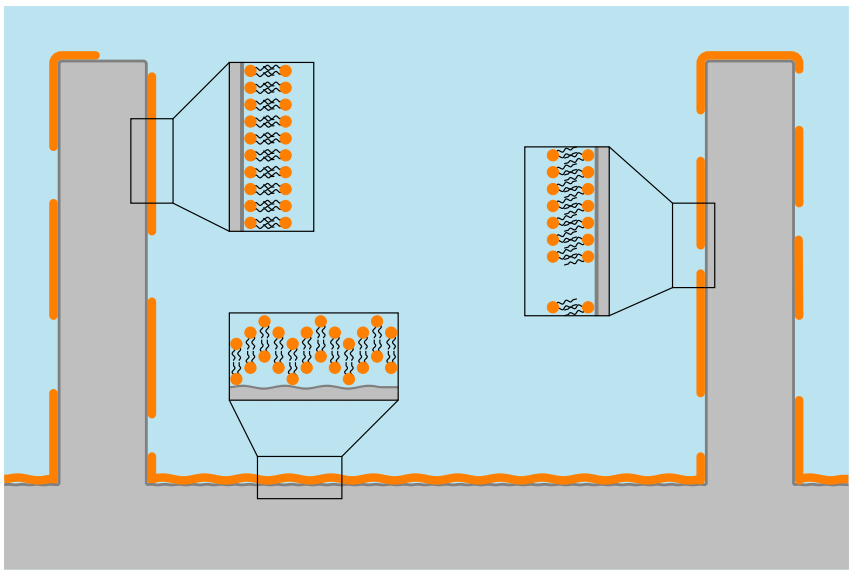


Interpretation



- NR = flat areas between nanowires
  - Total bilayer thickness = 37 Å
  - About 30% solvent
- GISANS = structure of nanowires
  - Bilayer thickness = 28 Å
  - About 63% solvent
- NR, fitted as two lipid leaflets
- GISANS, fitted as a slab

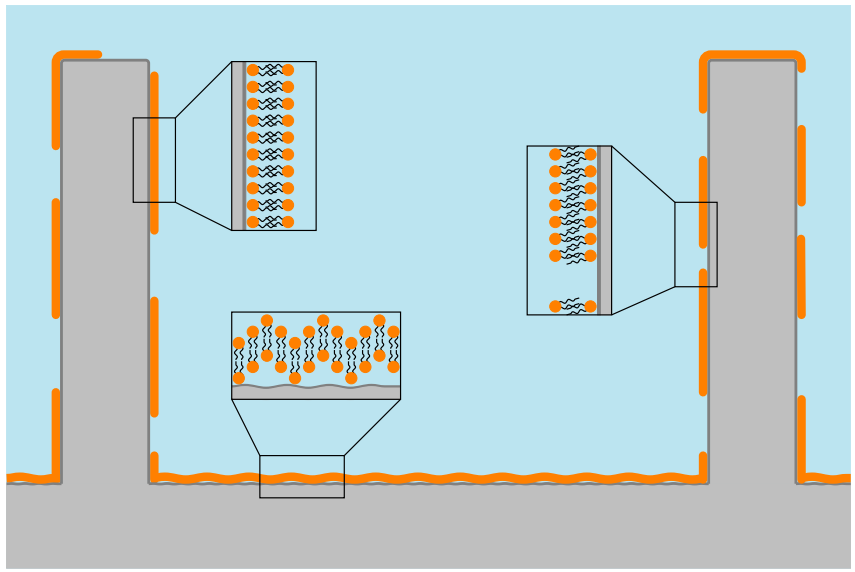
Interpretation



- Patchy lipid bilayer on the nanowires
- Lipid tails can be interpenetrating or be tilted
- Bilayer may be wavy
  - From NR fit, rough bilayer and potential intermixing of head and tails
- Similar thickness of lipid bilayer on nanowires and between

Conclusions

- Developed a new, simplified method for analysis of GISANS data
- Can find a lipid layer of about 30 Å with a large inclusion of solvent
- Use of Bragg peaks gives direct information about the lipid layer on the nanowires



Acknowledgments

Tommy Nylander
Adrian Rennie
Christelle Prinz

Paul Butler, NCNR, NIST
Nina-Juliane Steinke, ISIS
Jos Cooper, ISIS


Thank you for your attention!