

Spatially Resolved Neutron Reflectometry by Computed Tomography

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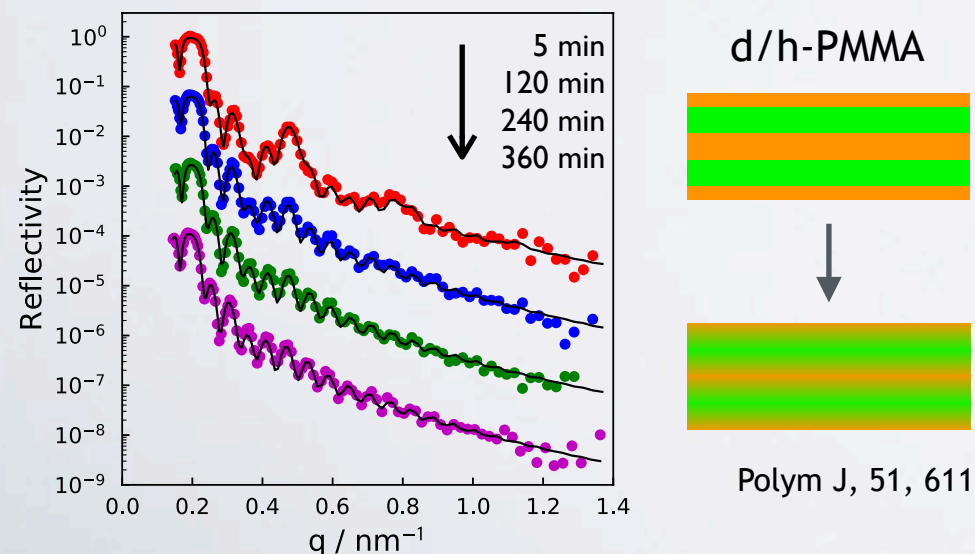
Who am I ?

- 2001 Dept of Polymer Chemistry, Kyoto Univ
- 2007 Advanced Biomedical Eng Unit, Kyoto Univ
- 2016 J-PARC, Japan Atomic Energy Agency (-present)
- 2018 IMSS, High Energy Accelerator Research Organization (cross-appointment) (-present)

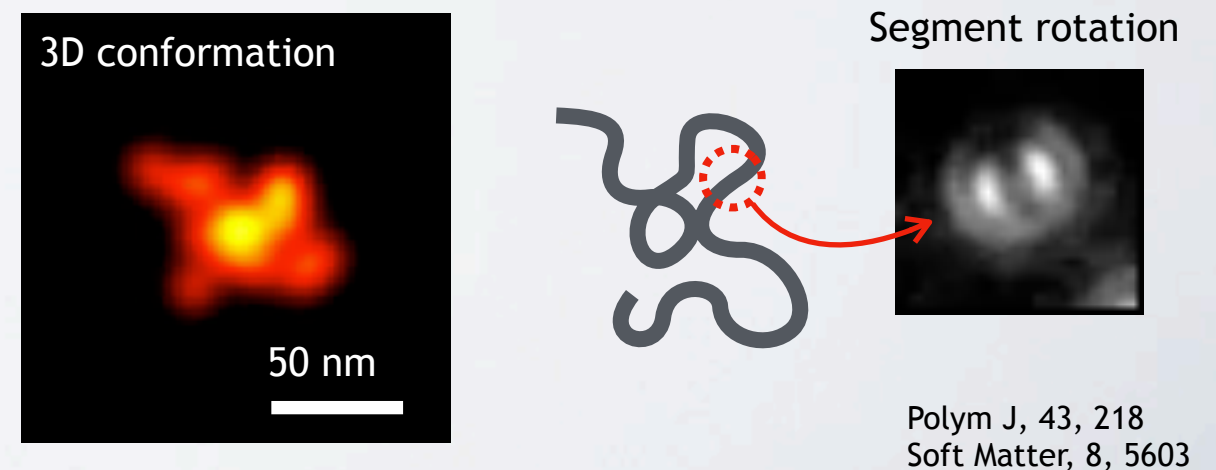
Research interests:

Structure and dynamics of polymer chains at surface/
interface/thin film using labeled samples

Chain diffusion in thin film probed by NR

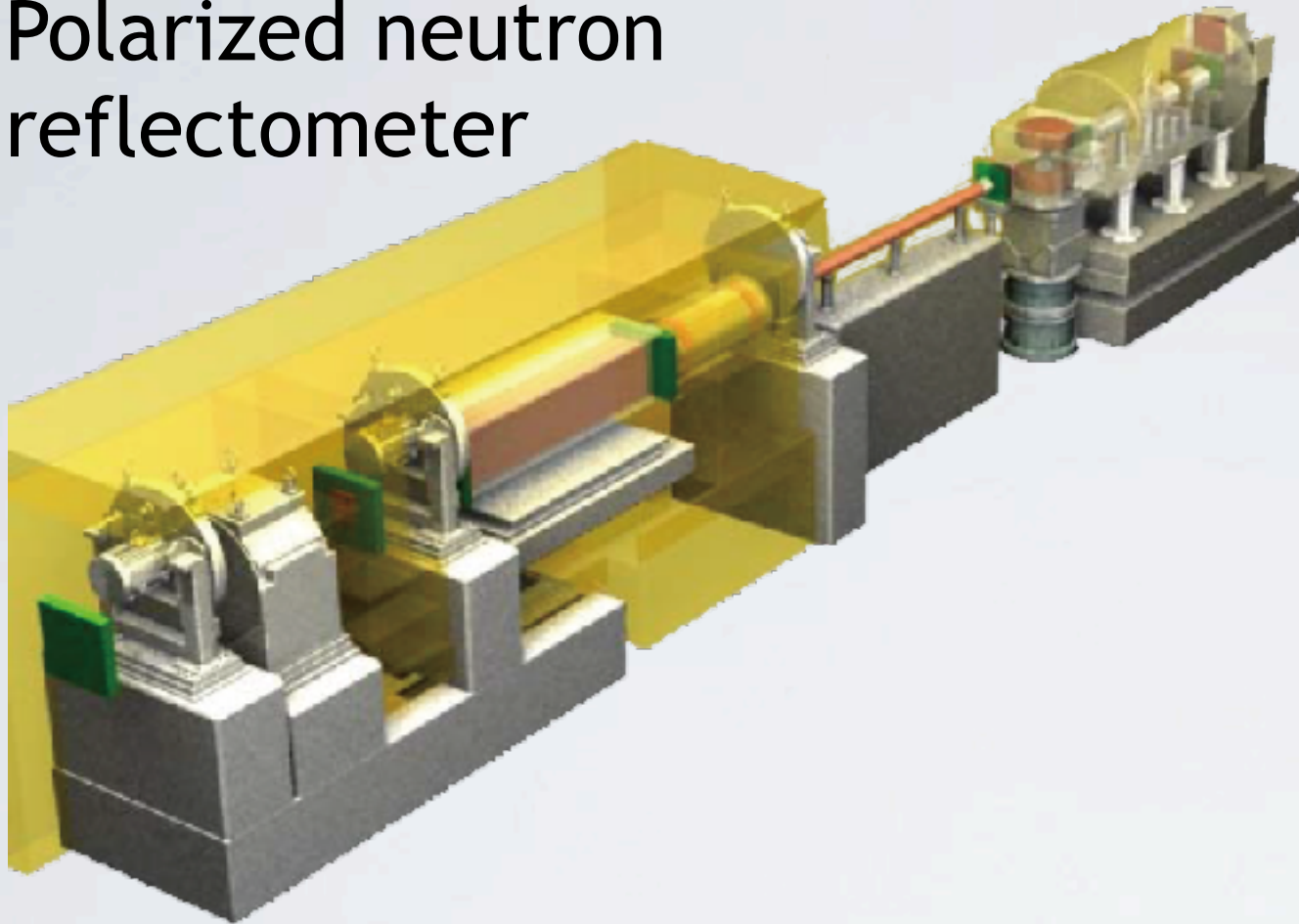


Conformation and dynamics of single chain

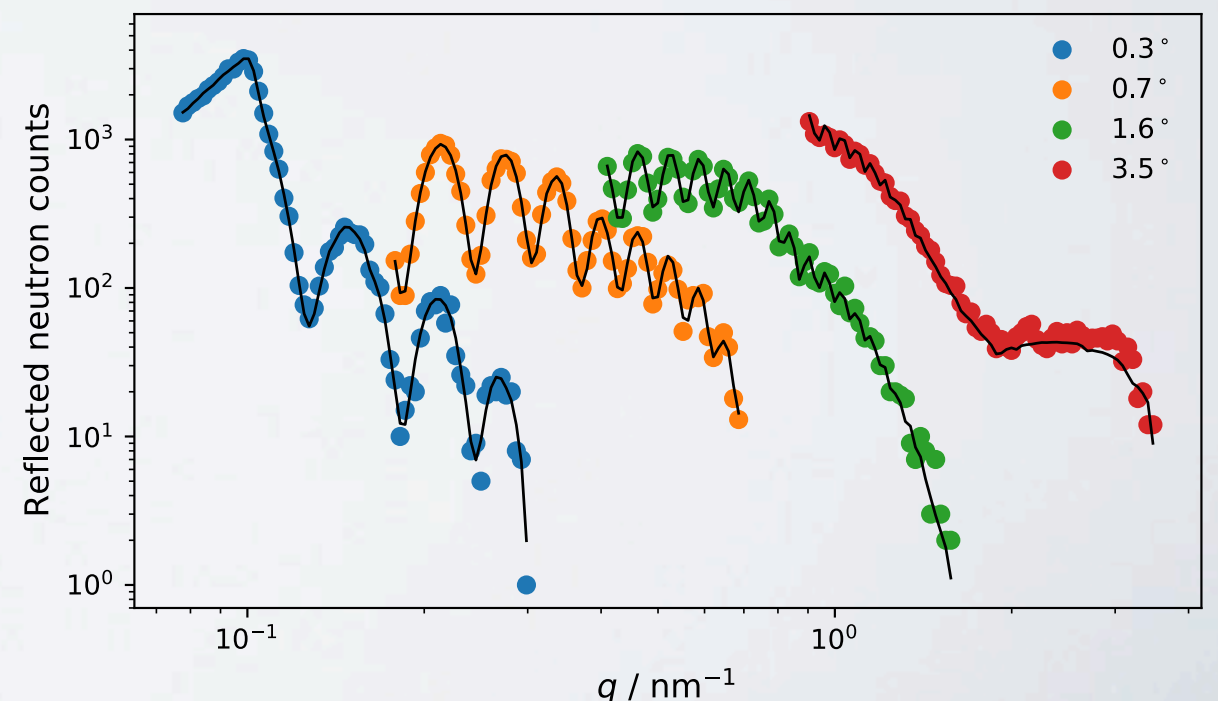
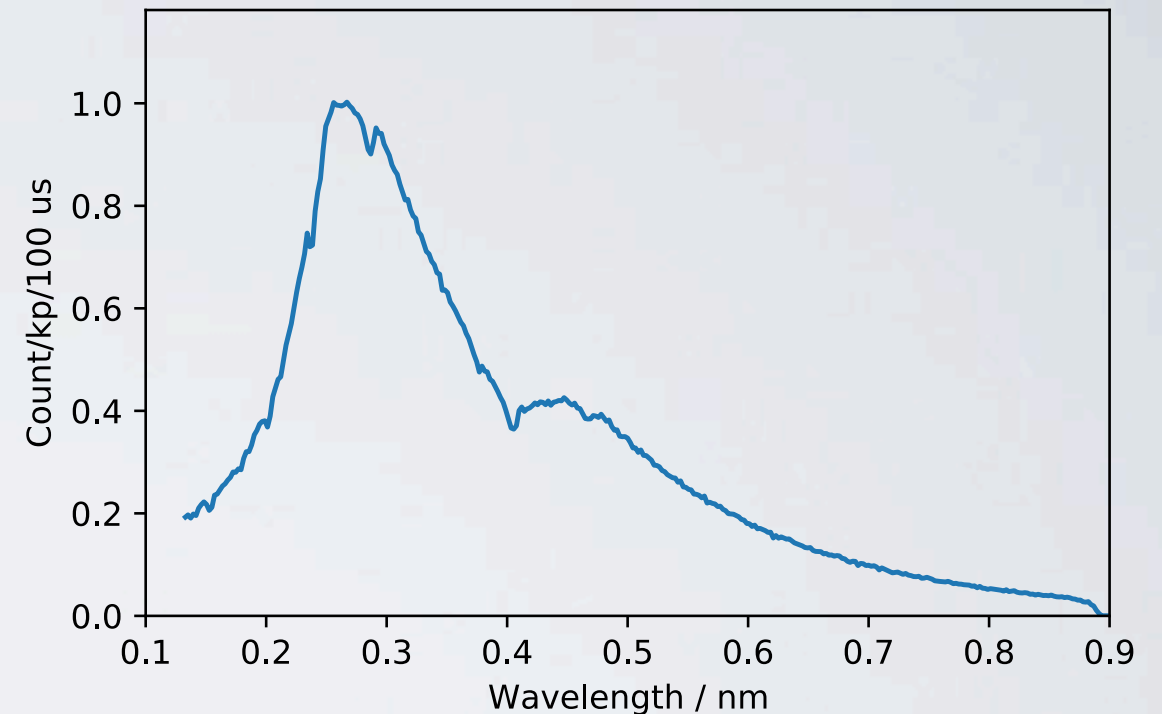


SHARAKU at MLF, J-PARC

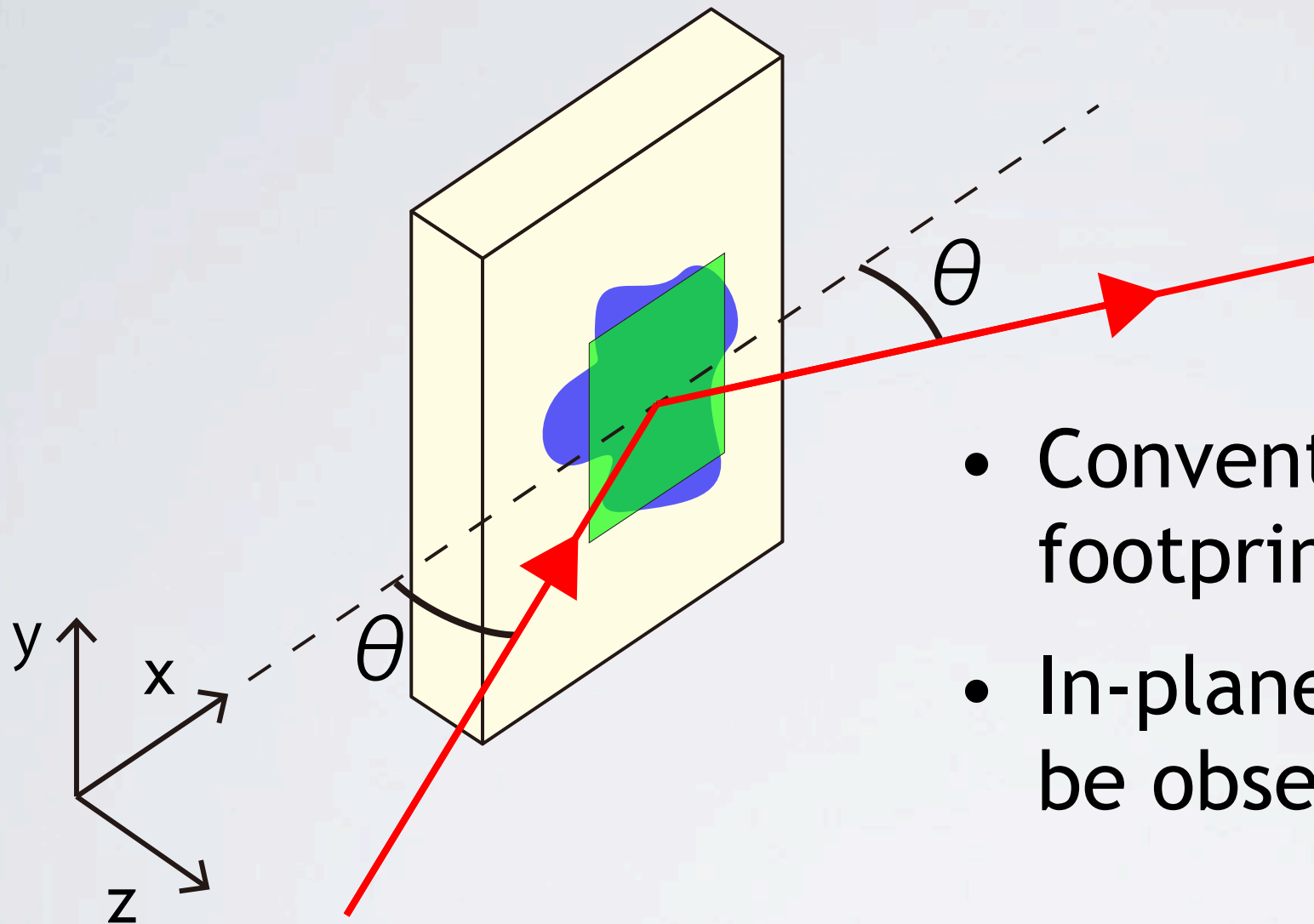
Polarized neutron reflectometer



- Vertical sample
- ^3He MWPC 2D detector
- Spin polarizer/analyzer/flippers
- 1T/4T/7T magnets with cryostat
- Liquid-solid cell
- Temperature/Humidity controller



Spatially Resolved Neutron Reflectometry

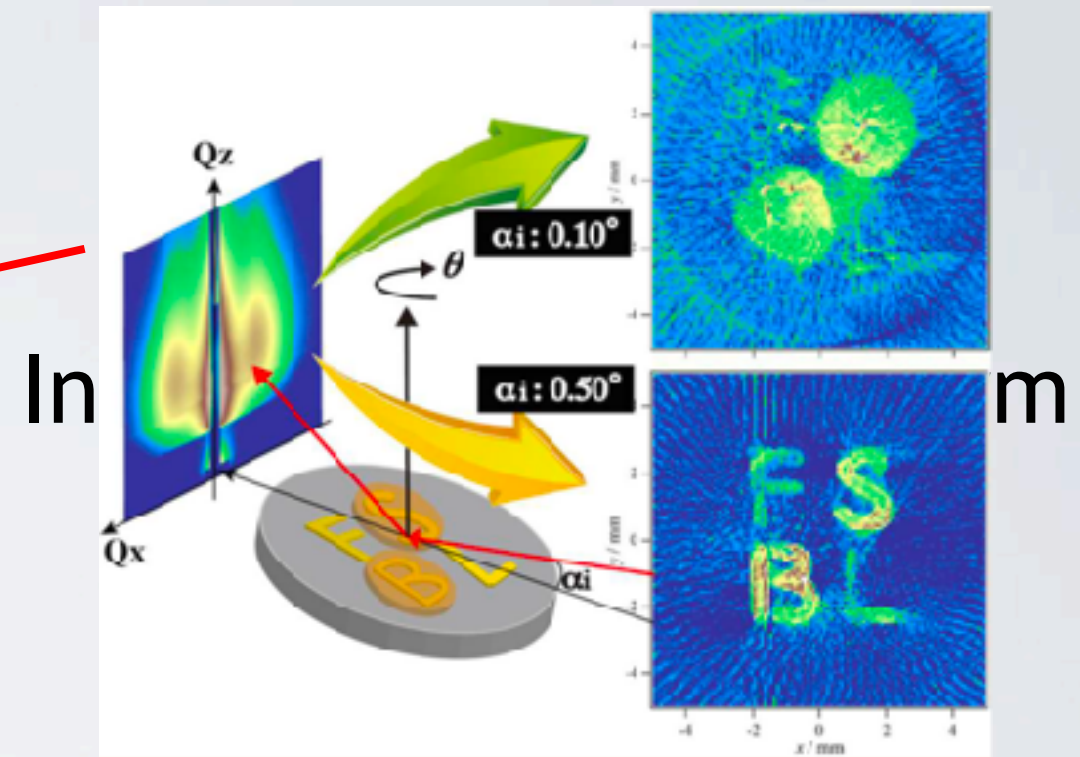
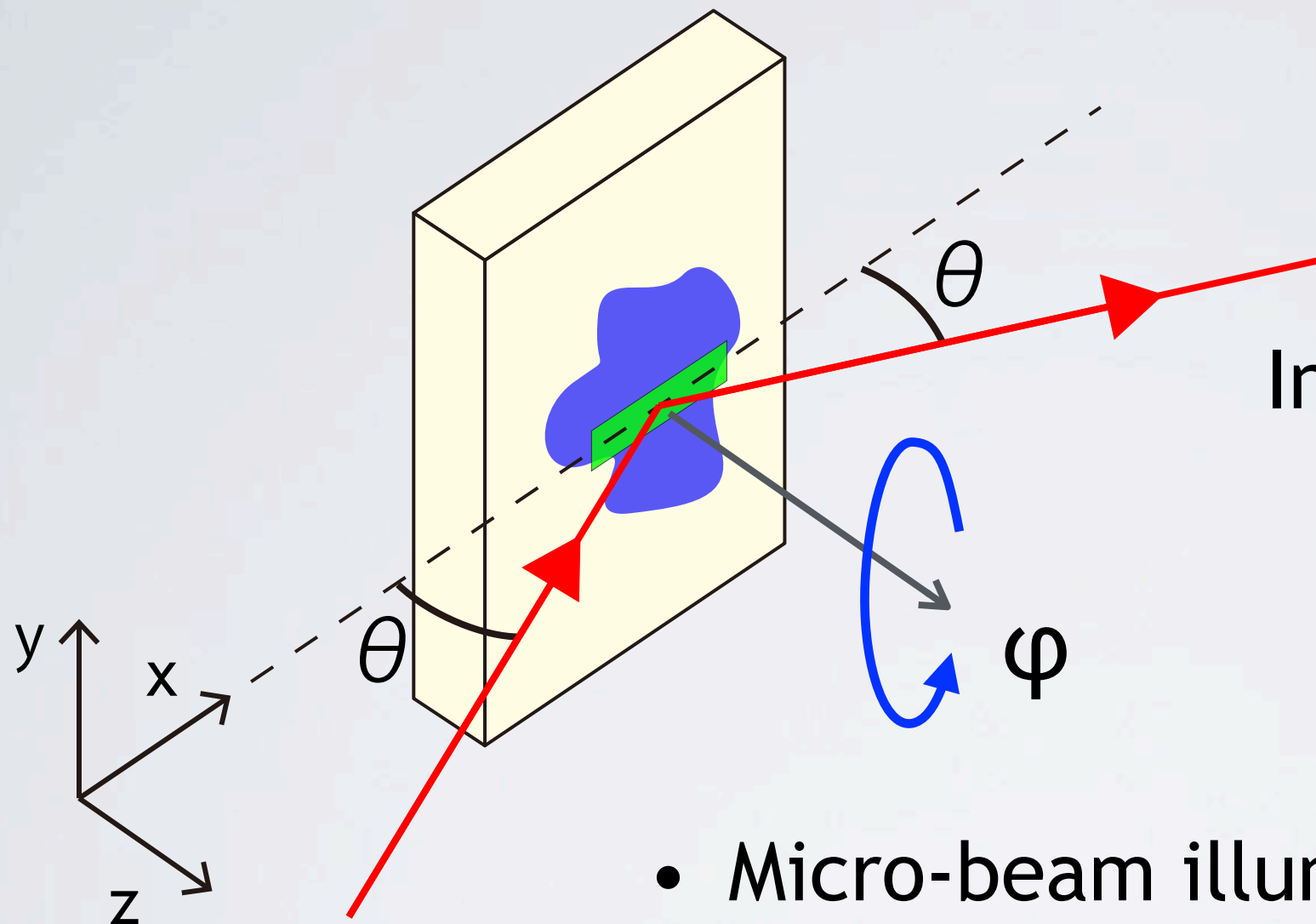


- Conventional NR illuminates a footprint as large as 1--10 cm².
- In-plane inhomogeneity cannot be observed



Fracture interface
of adhesion

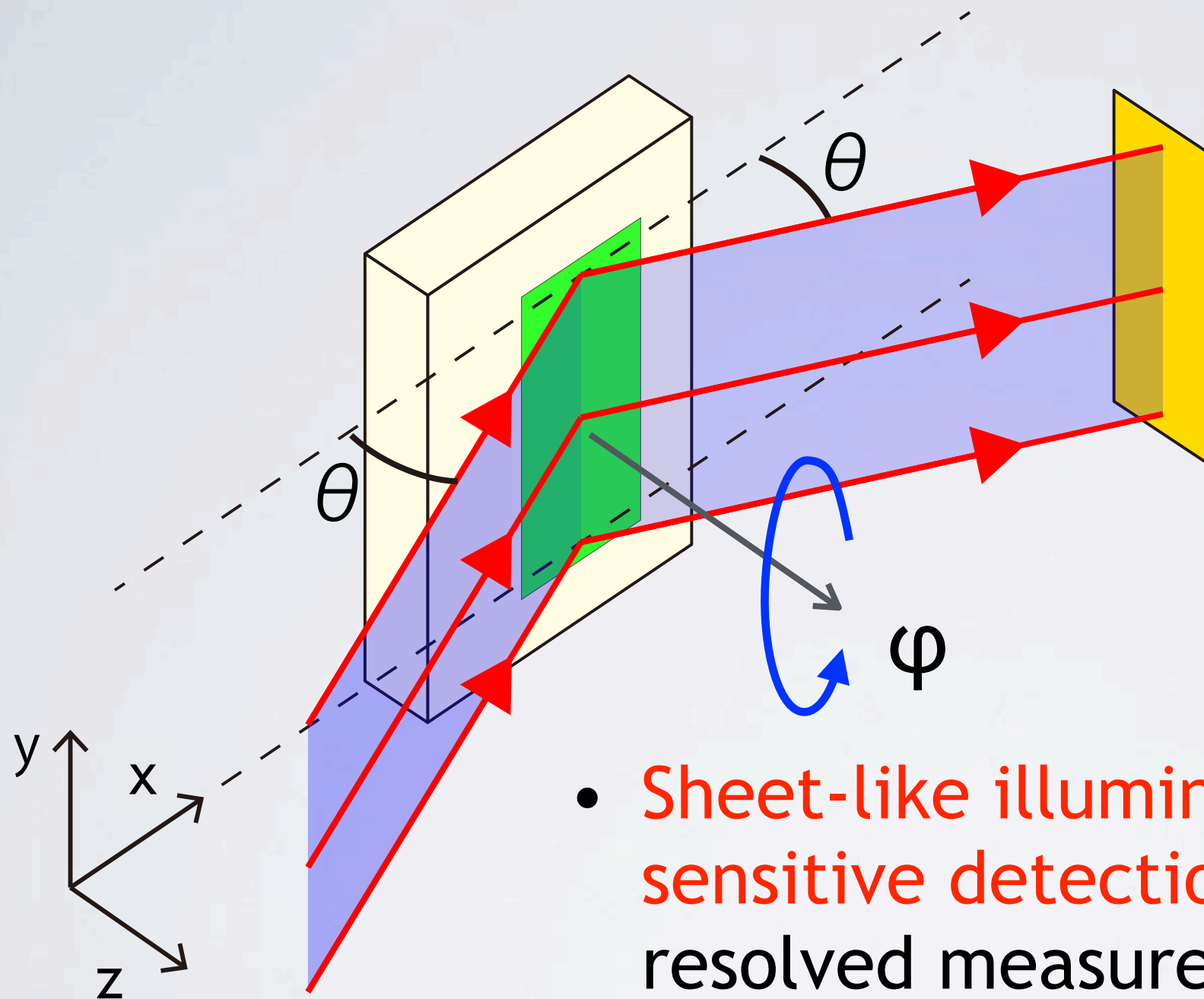
Spatially Resolved Neutron Reflectometry



Ogawa et al, Langmuir, 33, 4675

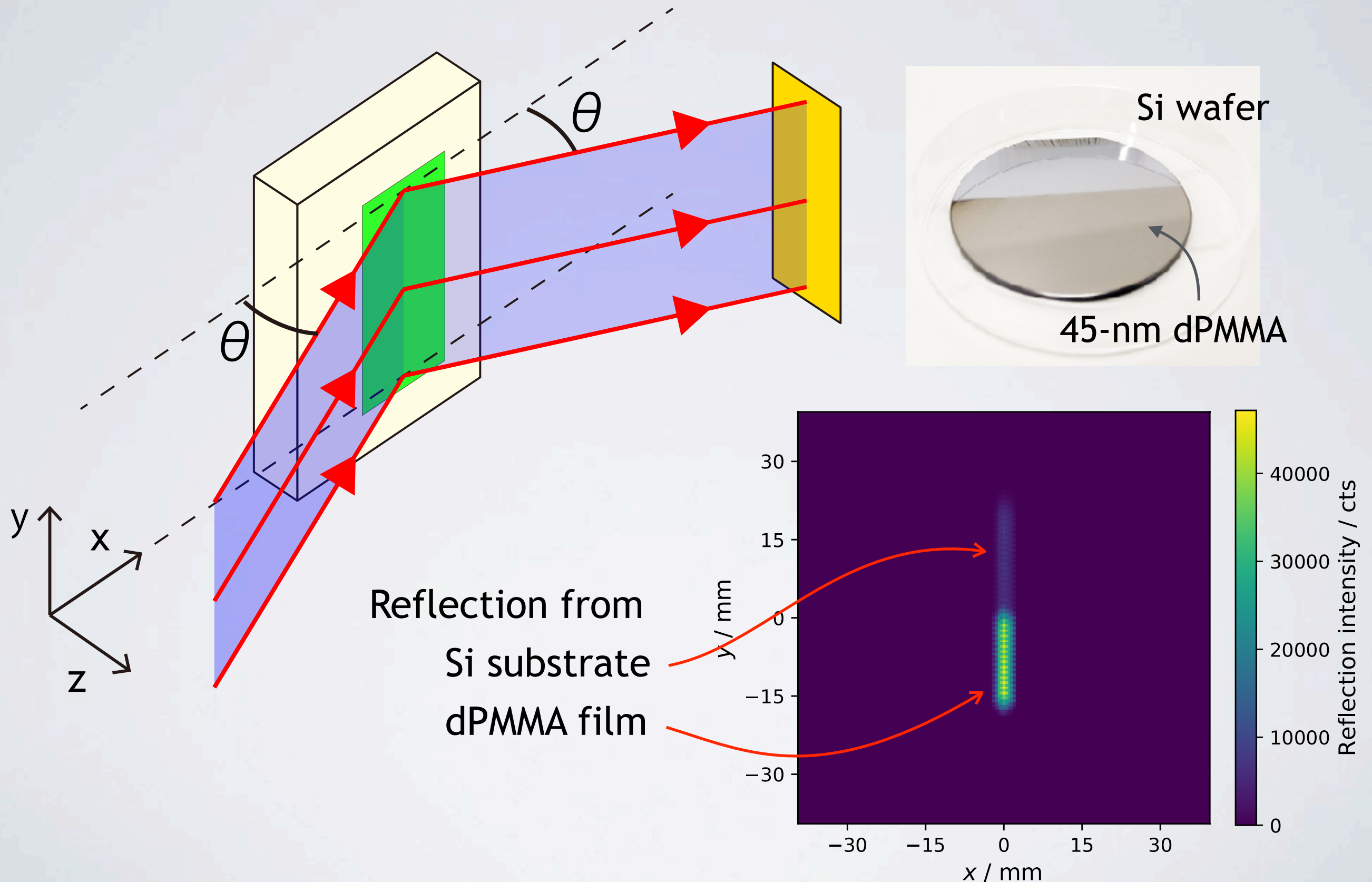
- Micro-beam illumination provides y-resolution
- Sample rotation and tomographic reconstruction provides x-resolution

Spatially Resolved Neutron Reflectometry

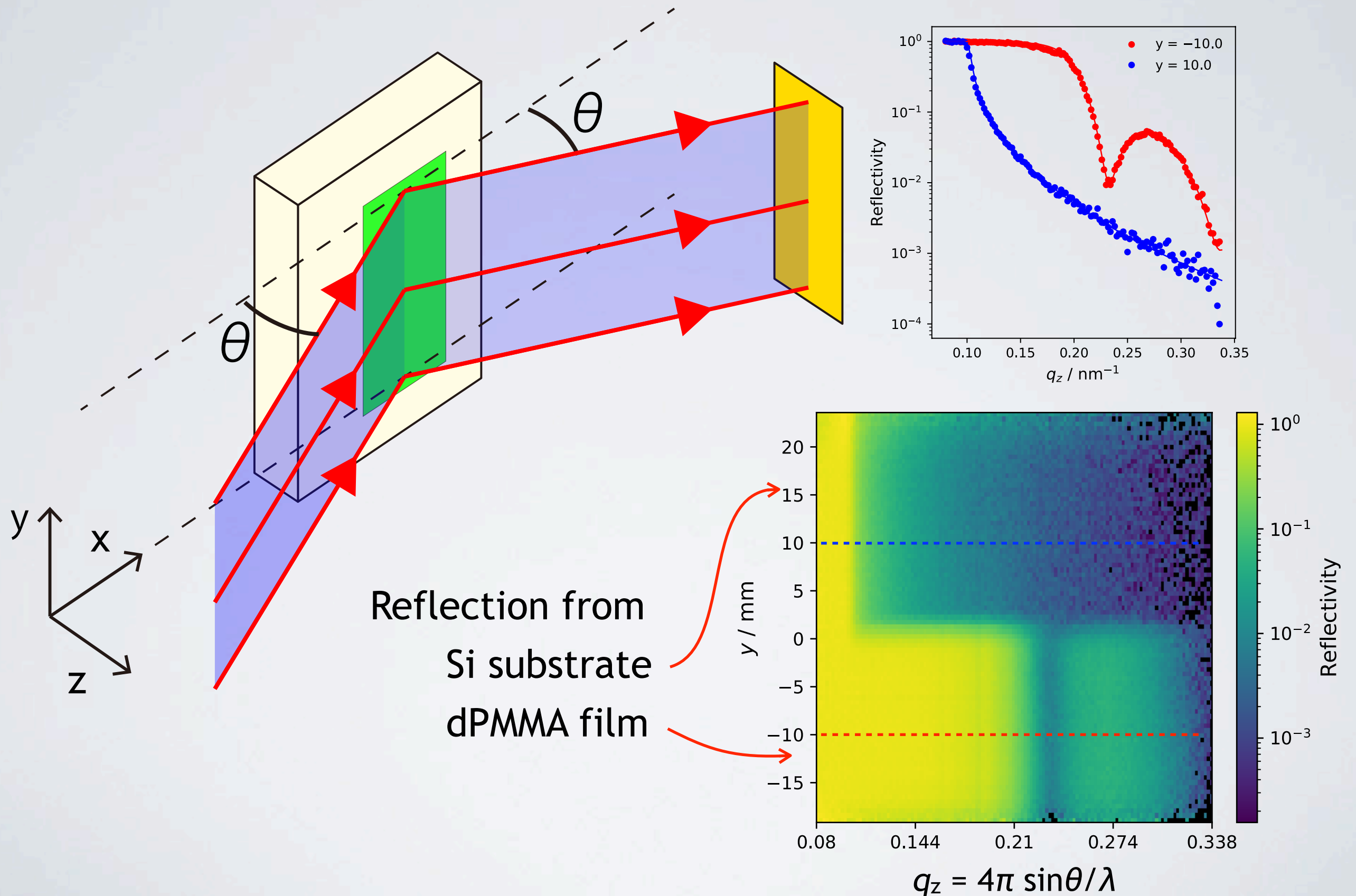


- Sheet-like illumination and position-sensitive detection for direct spatially resolved measurement in y -direction
- Sample rotation and tomographic reconstruction provides x -resolution

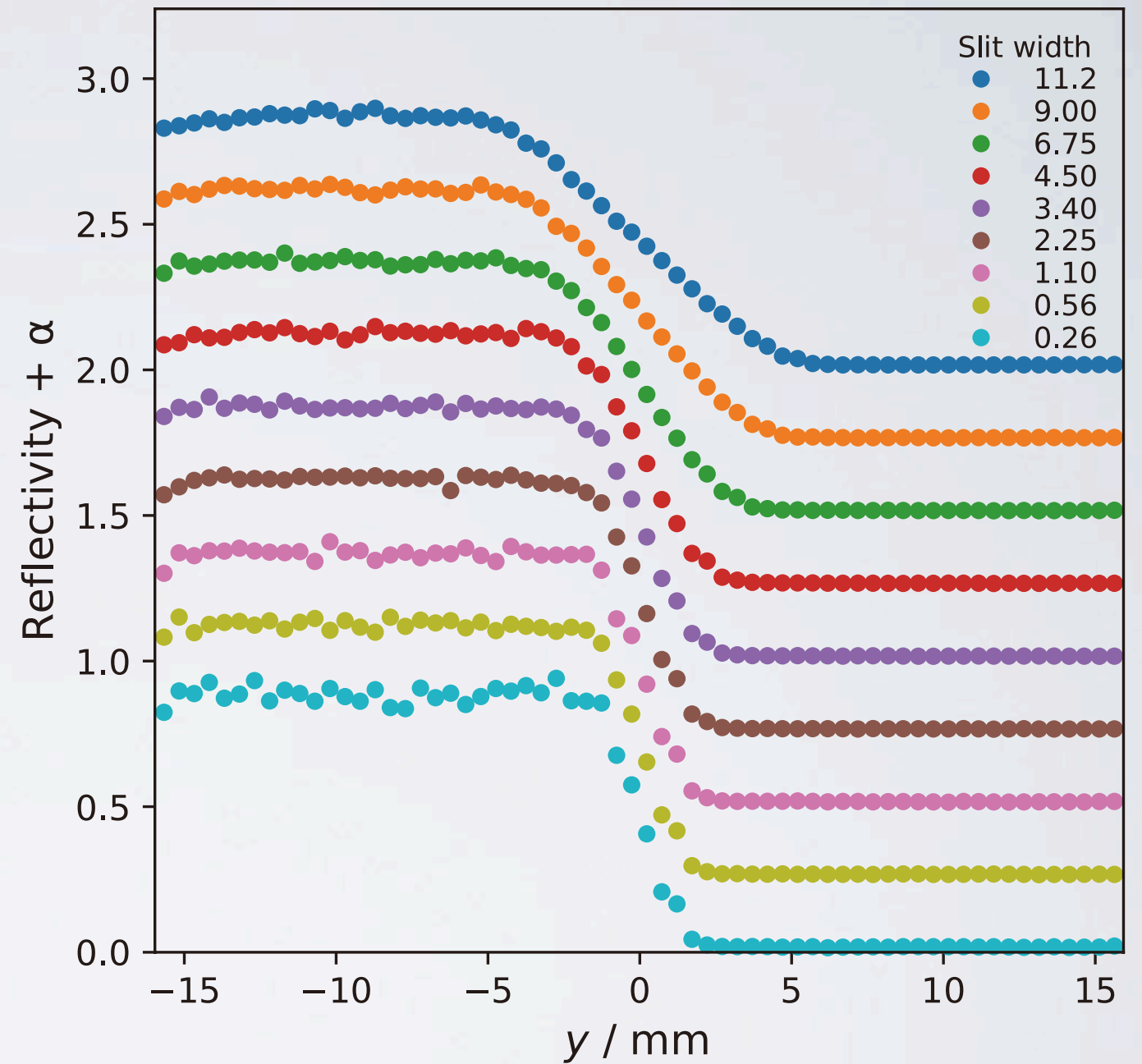
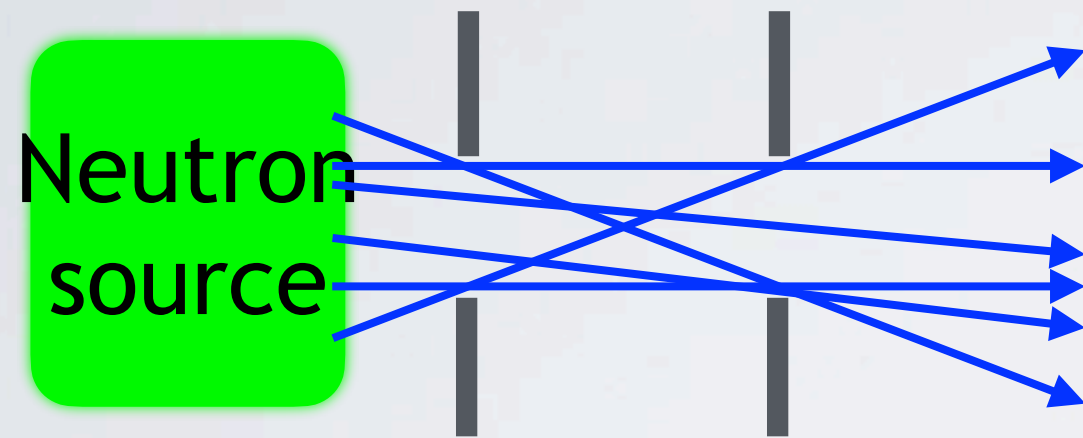
Spatially Resolved Neutron Reflectometry



Spatially Resolved Neutron Reflectometry

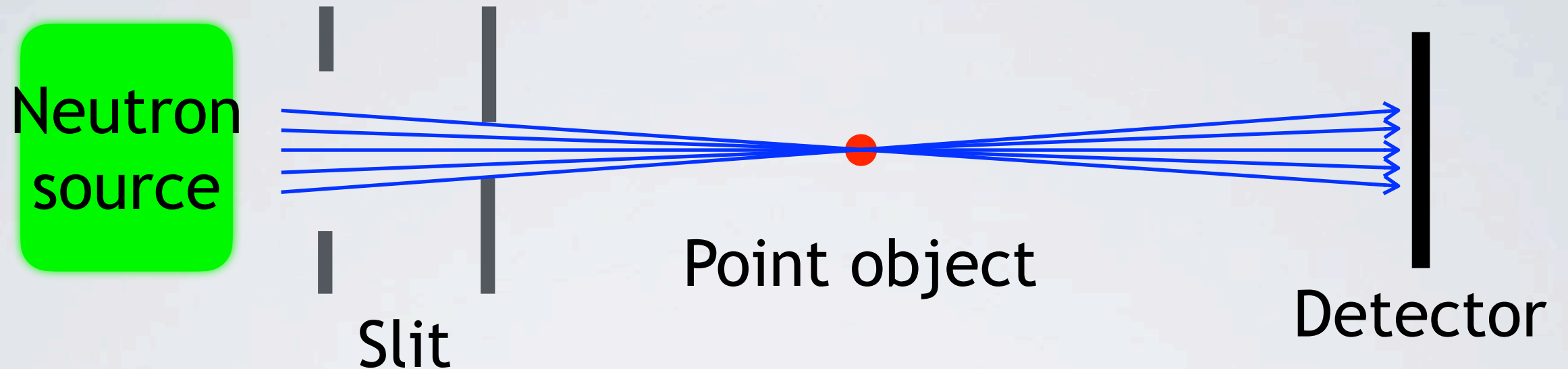


Spatial Resolution



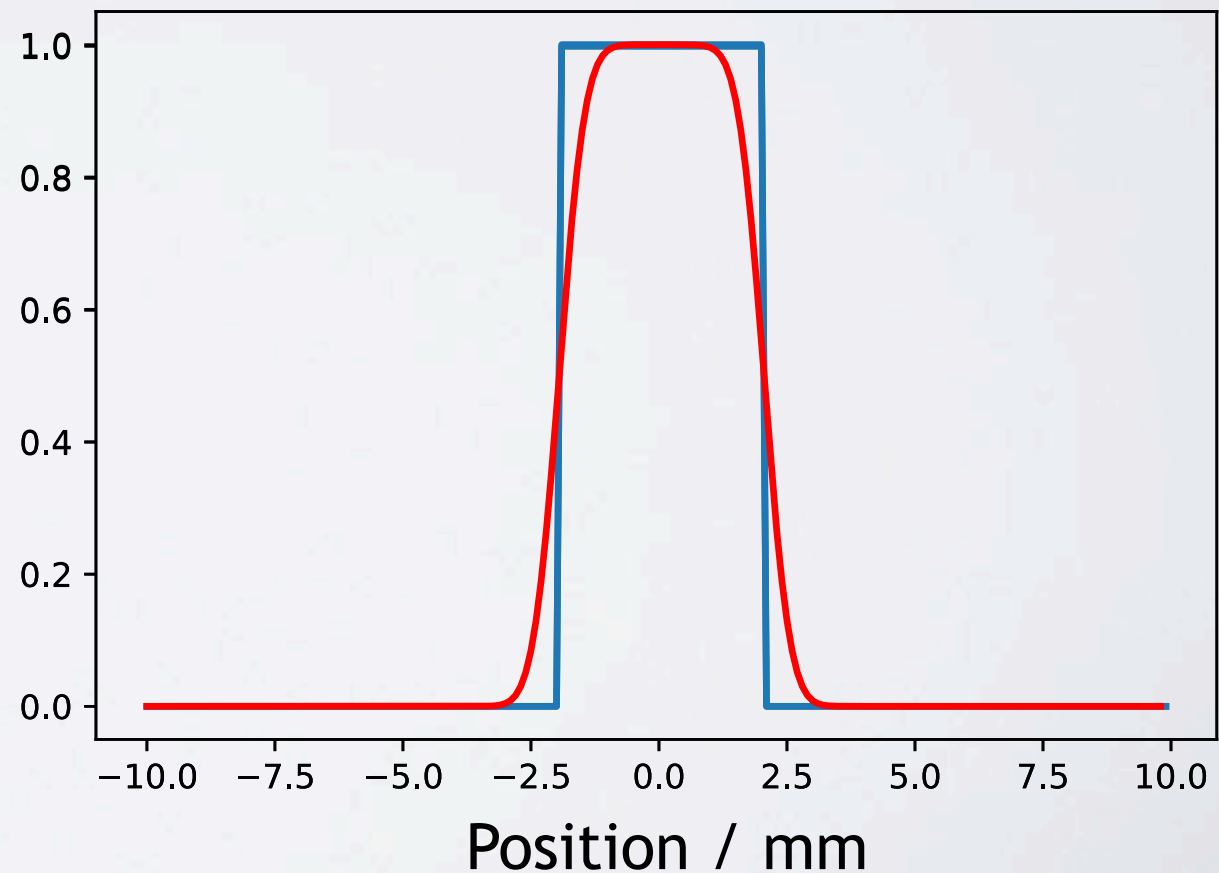
The spatial resolution is dependent on the slit width.

Spatial Resolution

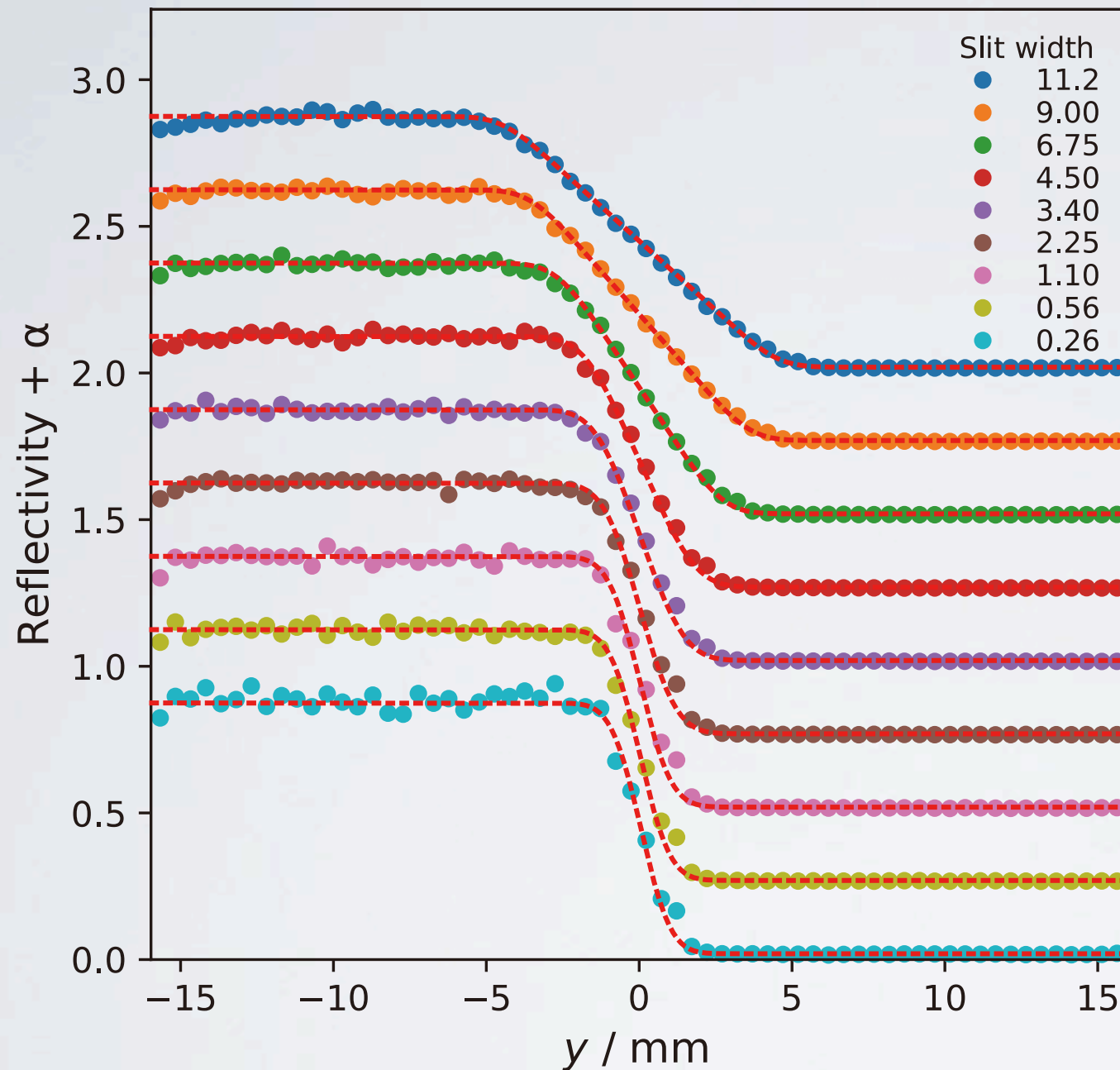


A point object is observed as a broadened spot with a finite size.

PSF is a convolution of a rectangular and Gaussian functions.



Spatial Resolution



Resolution: 1.0 mm
(determined by the
resolution of 2D detector)

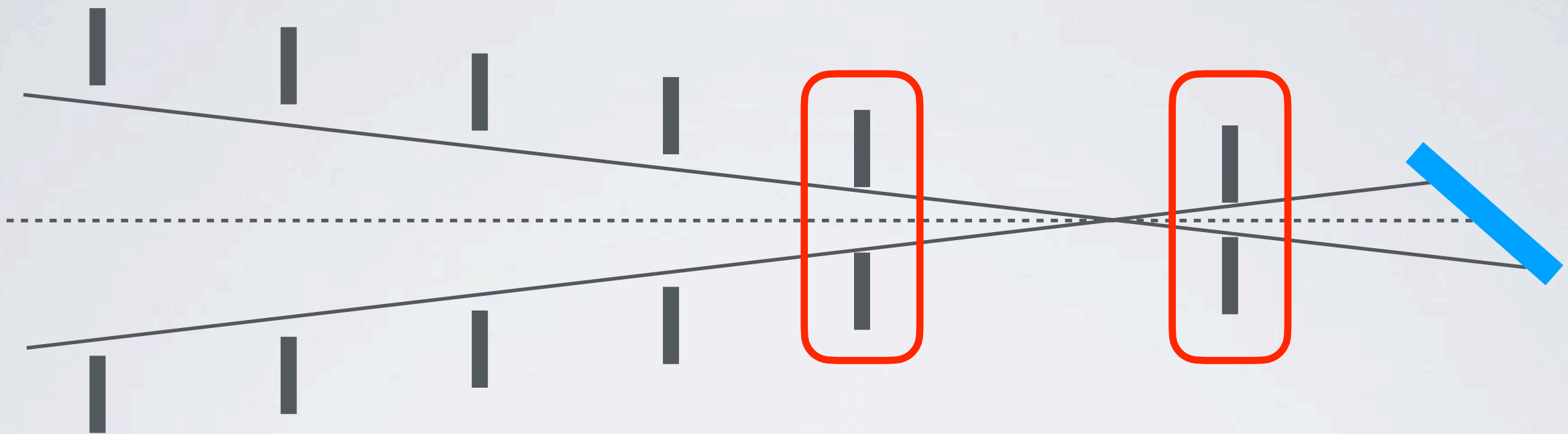


Resolution: 0.6 mm
at the sample plane

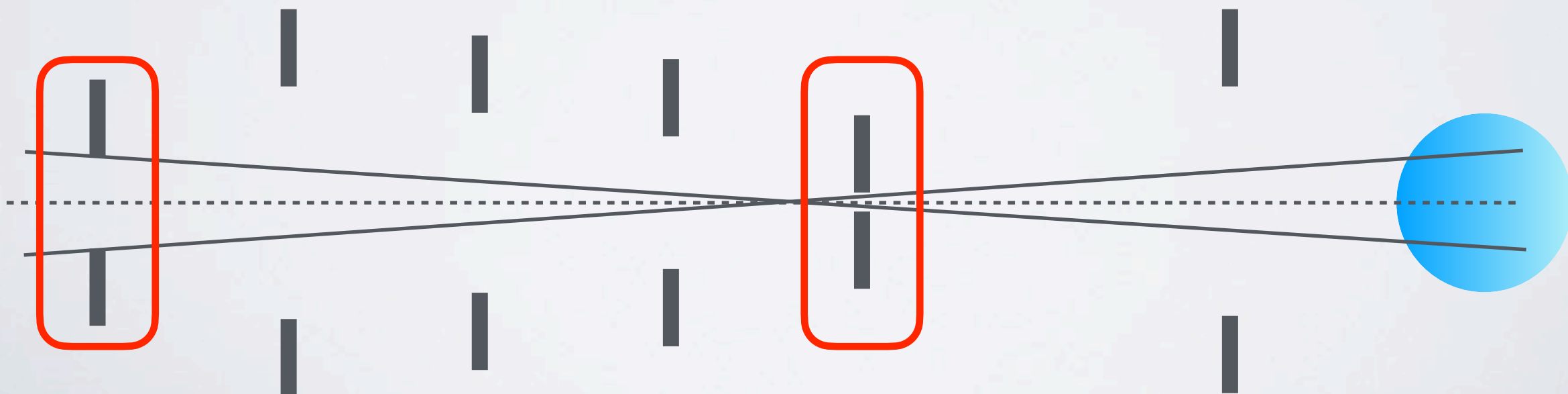
The calculated curves agree with the experimental
cross-section profile.

Spatially Resolved Neutron Reflectometry

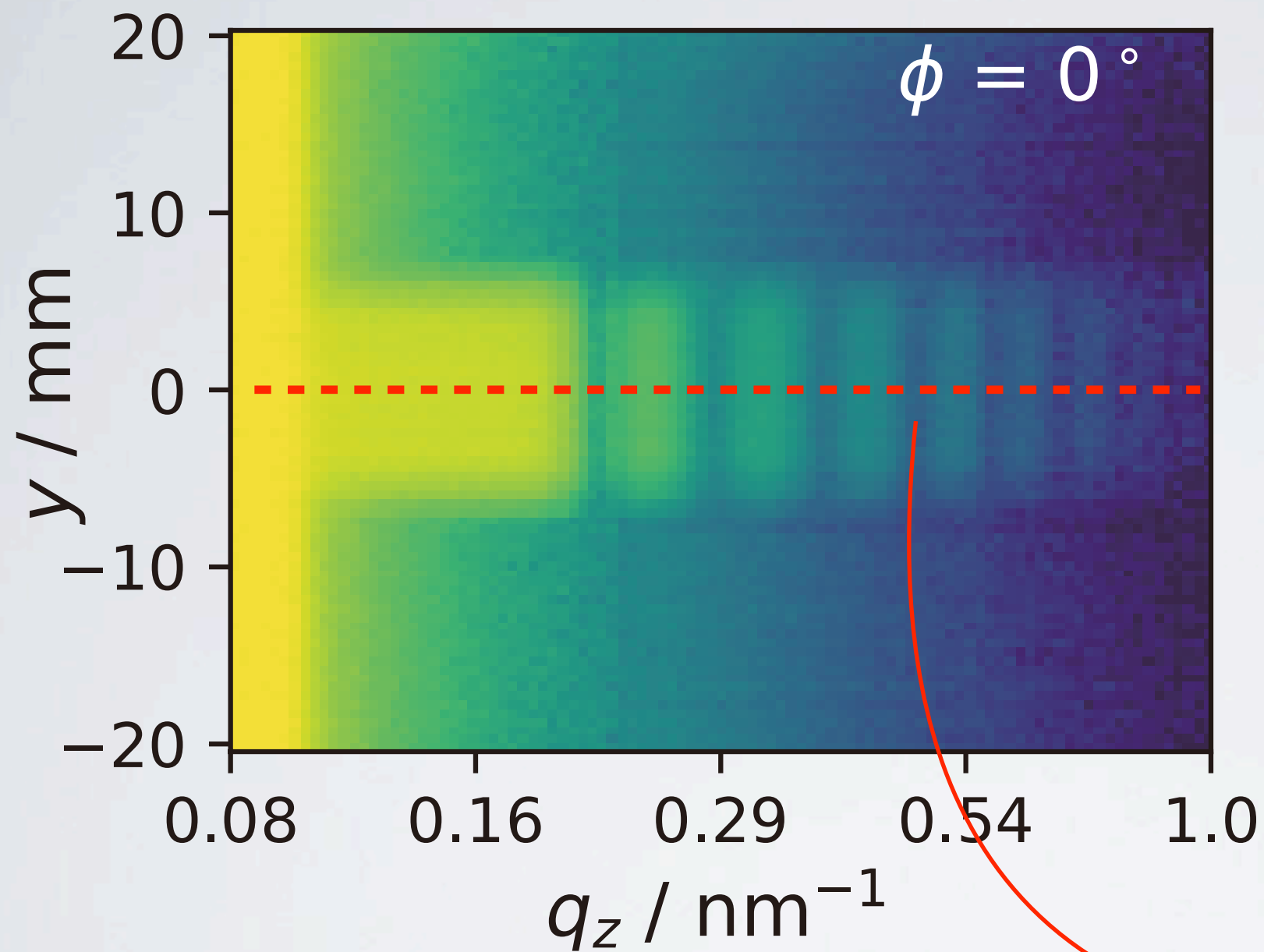
Top view



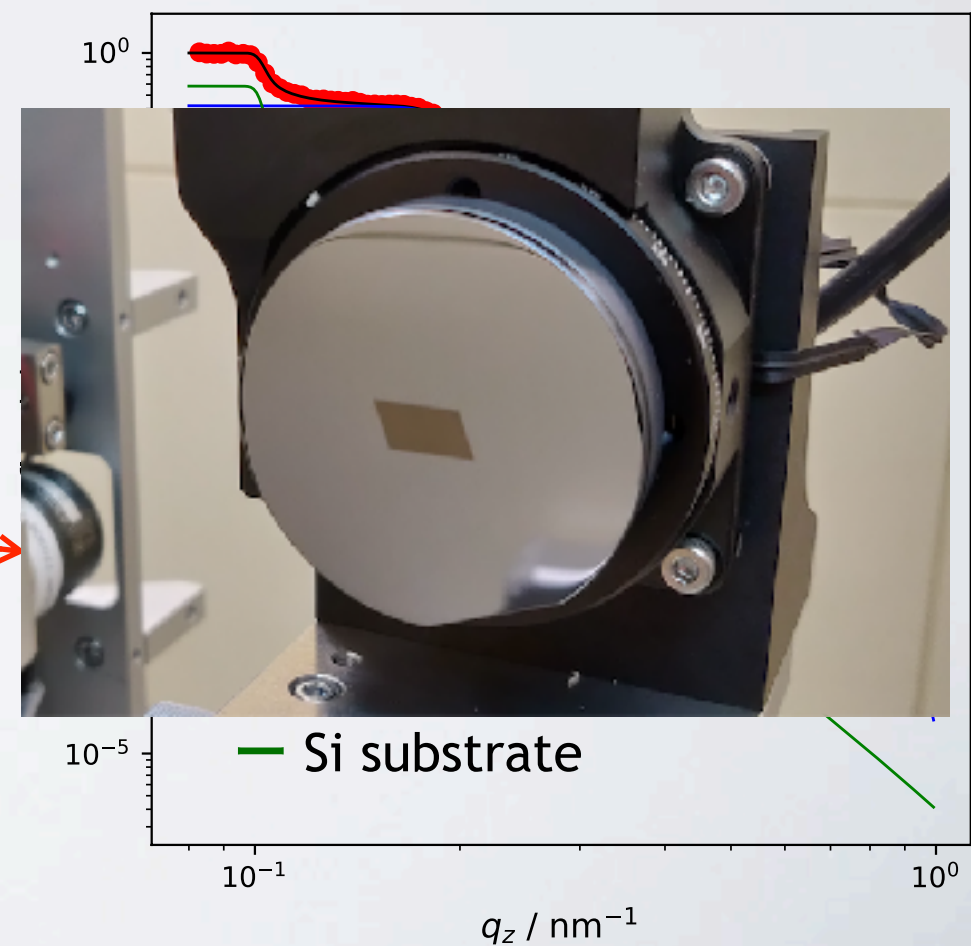
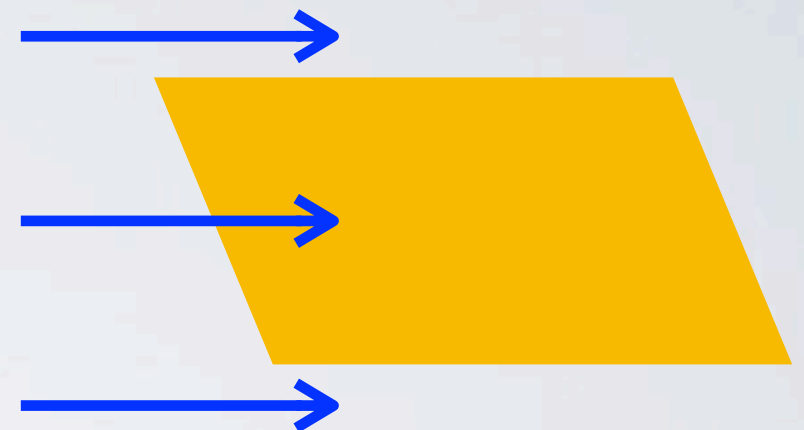
Side view



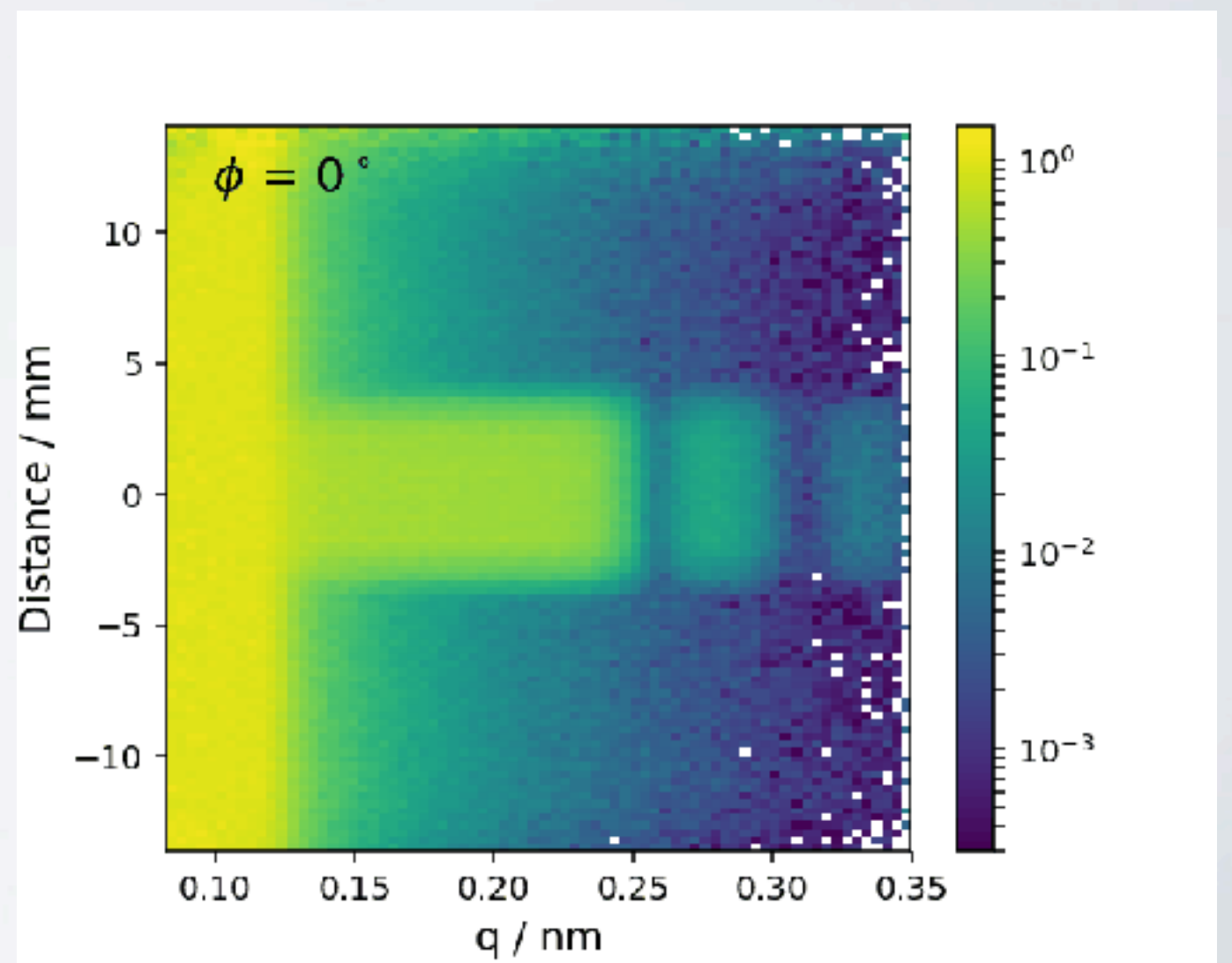
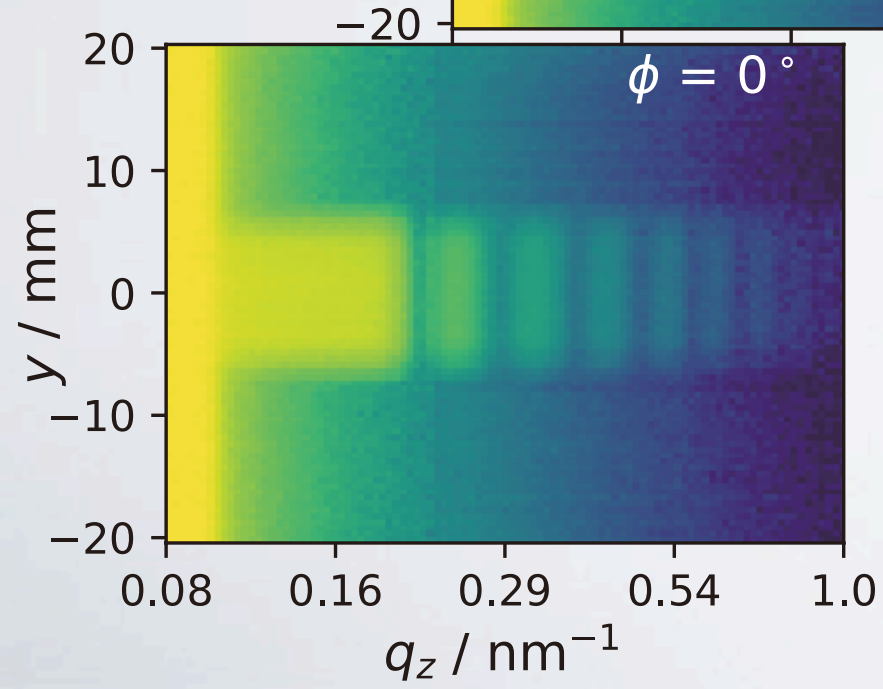
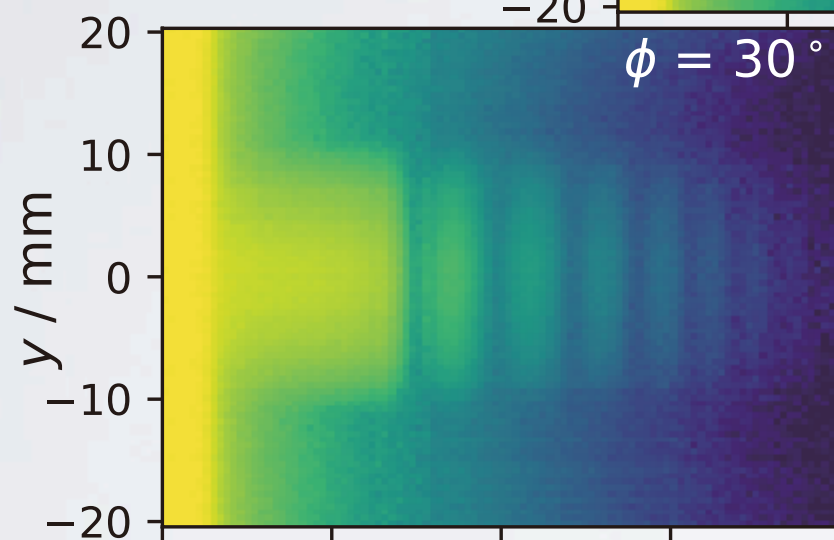
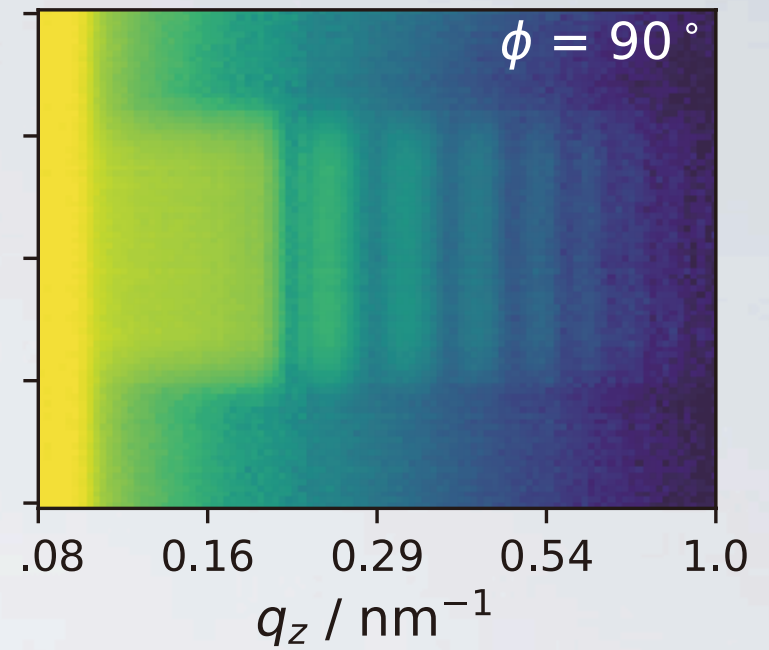
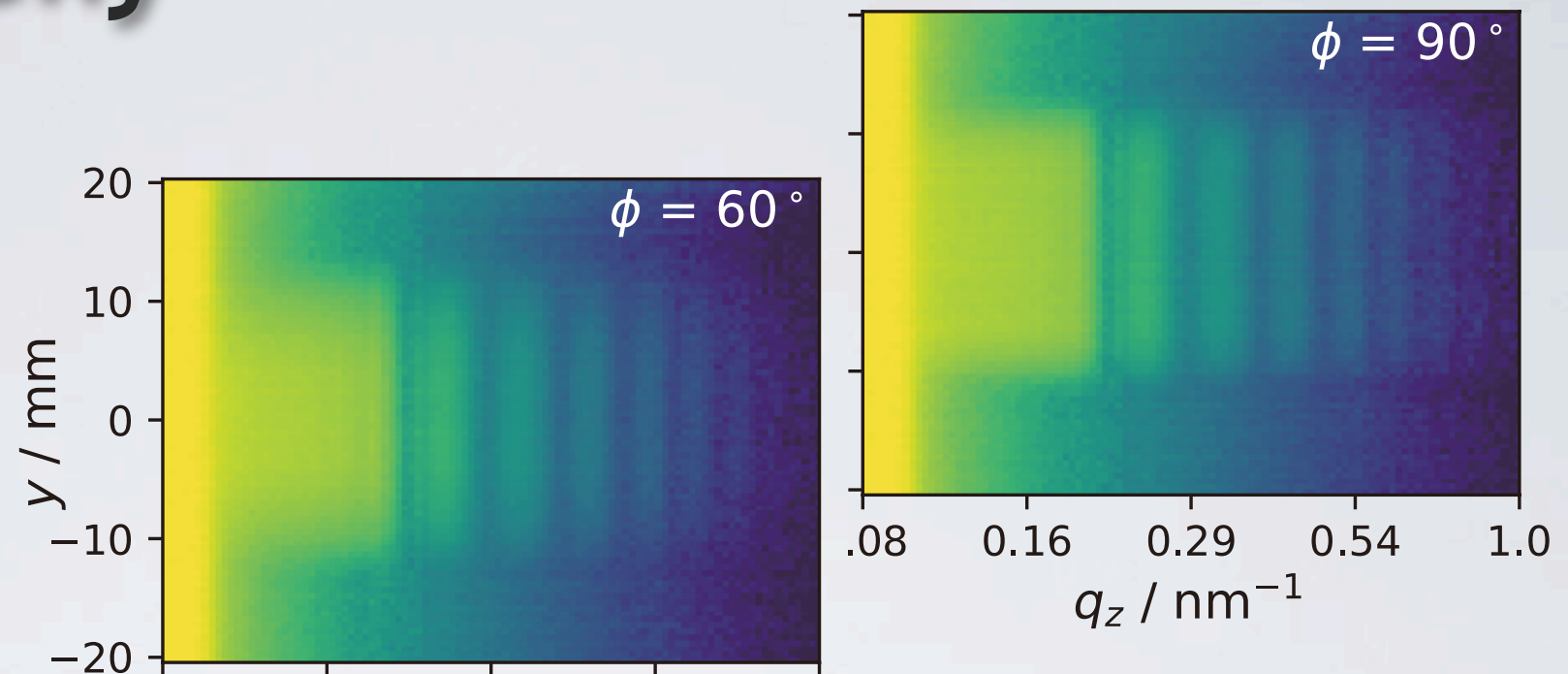
NR Tomography



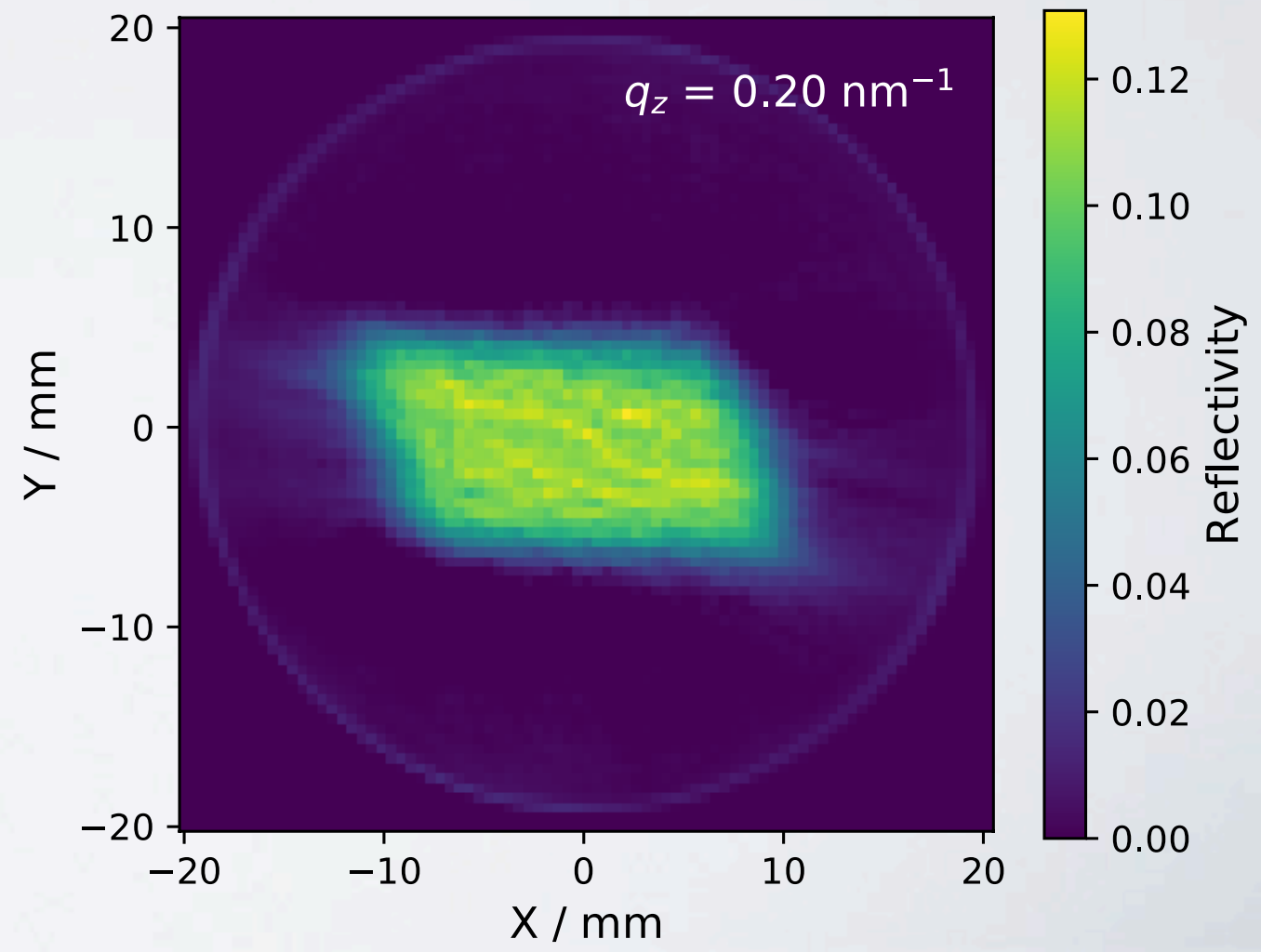
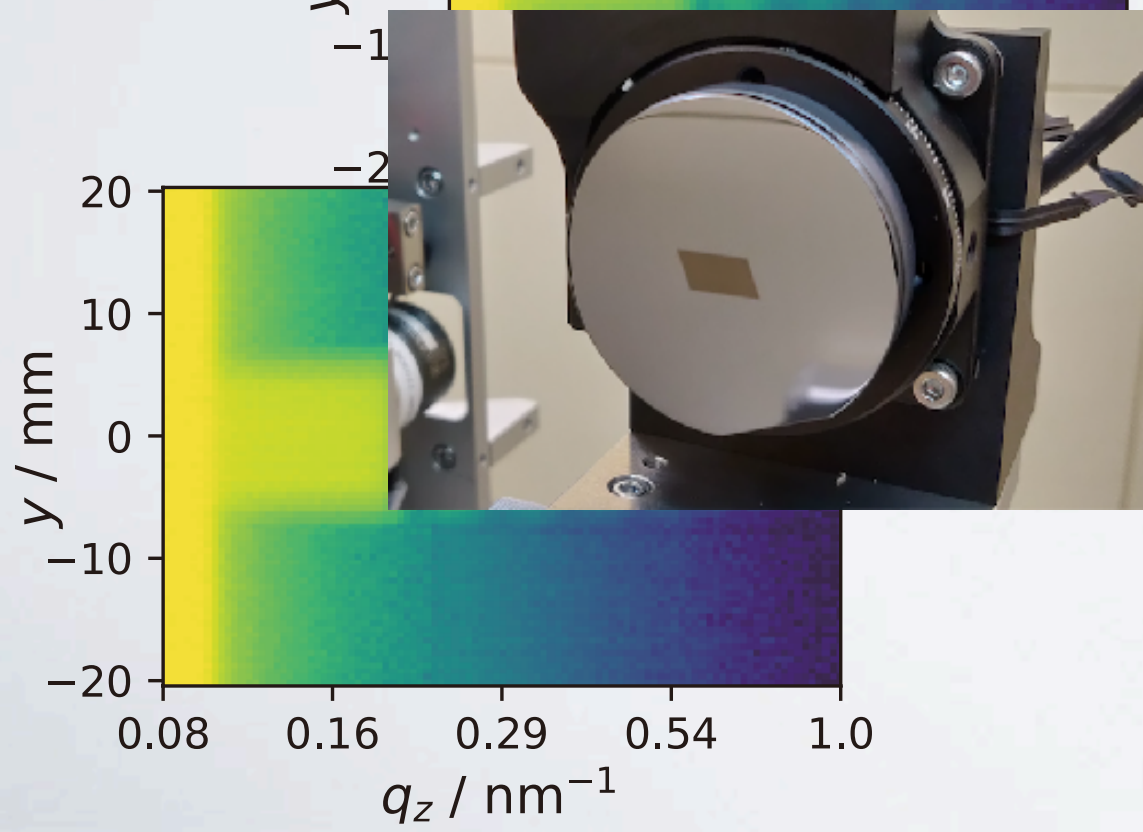
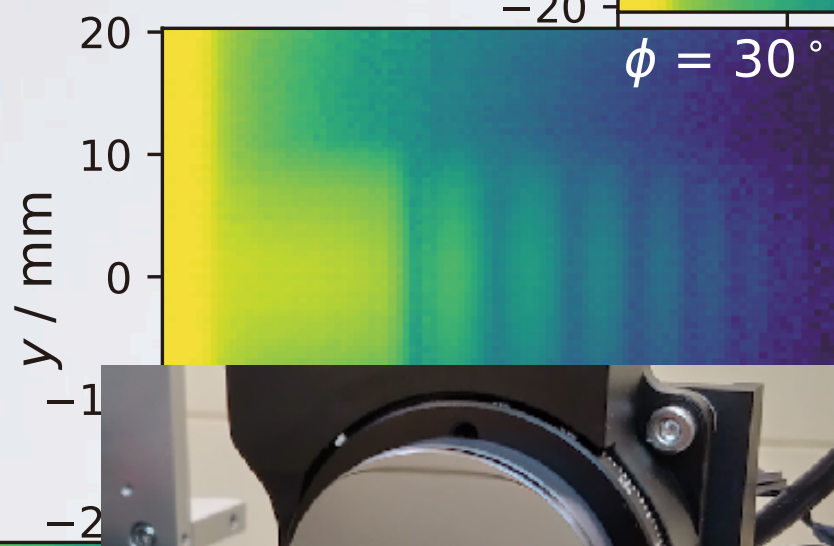
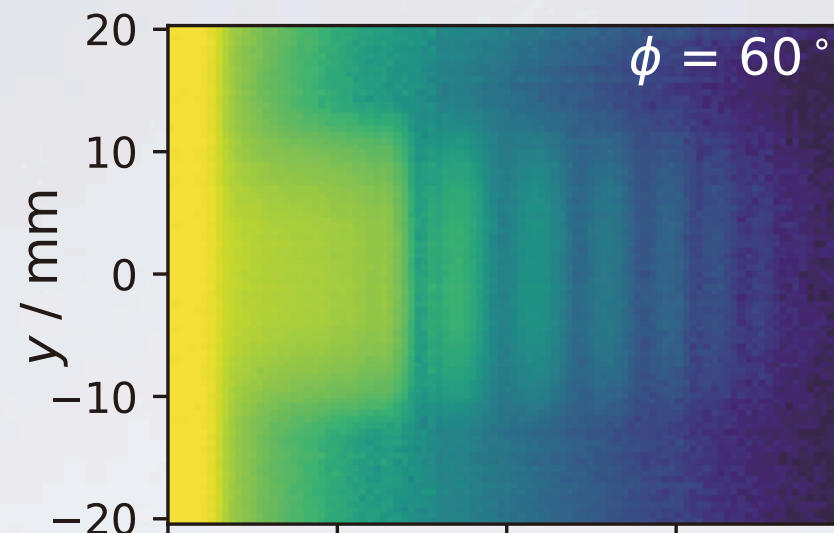
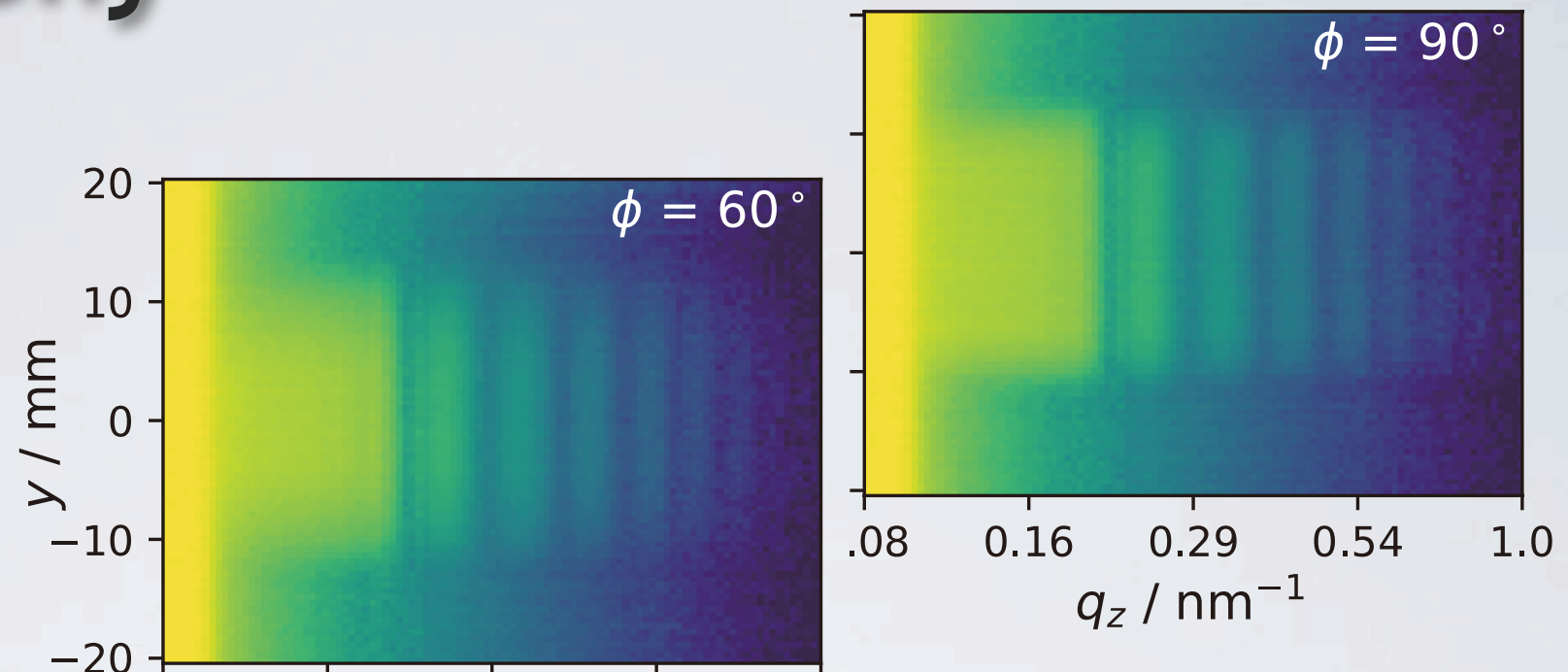
60-nm dPMMA



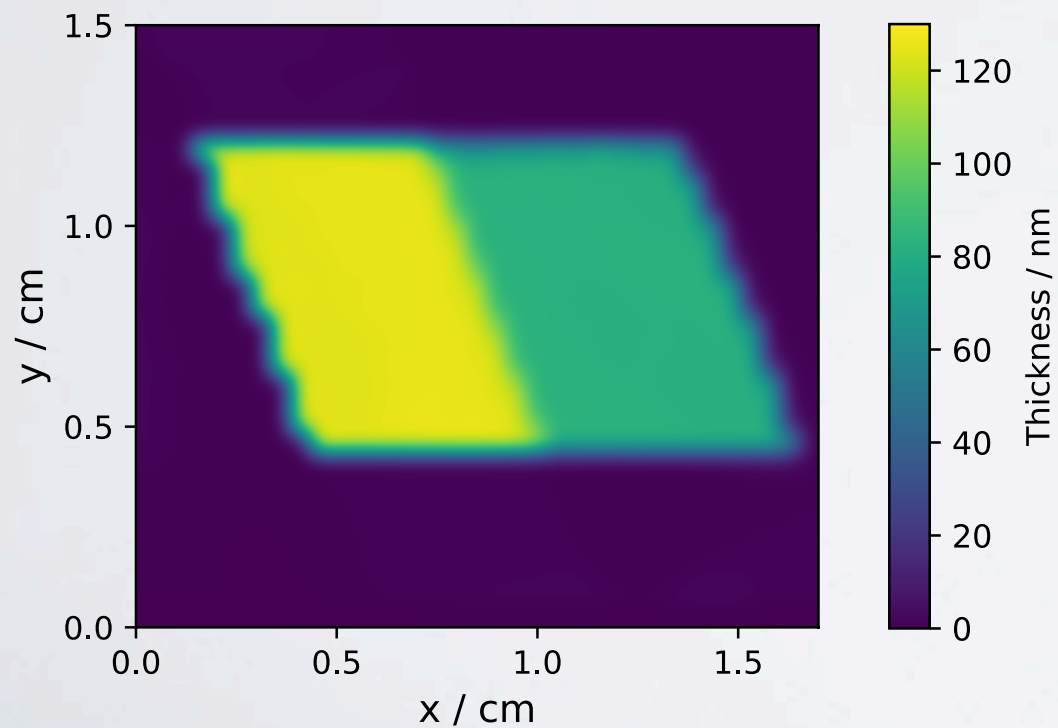
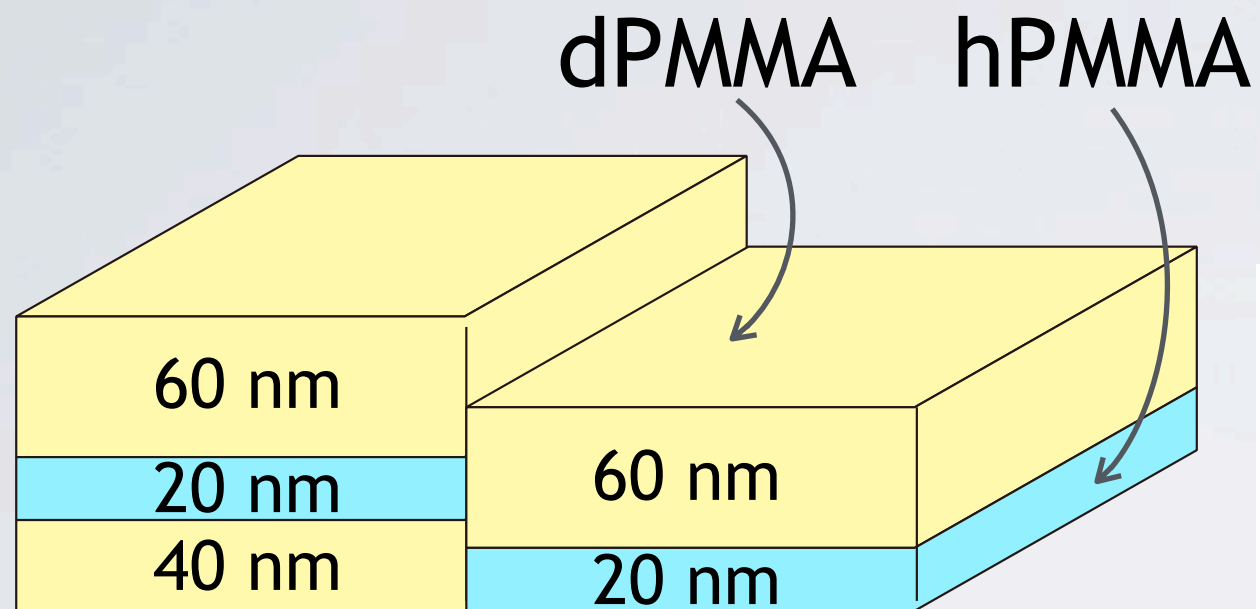
NR Tomography



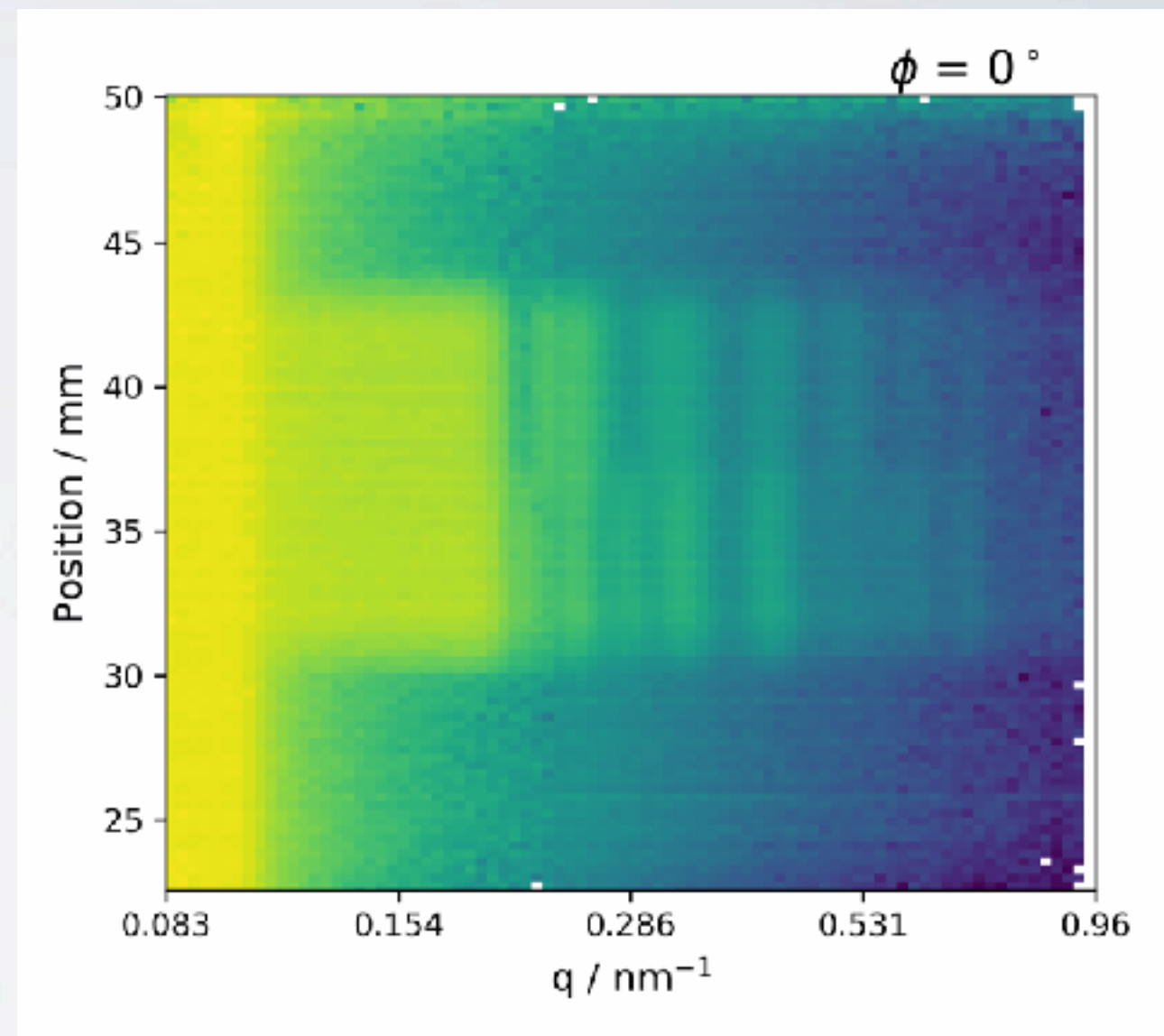
NR Tomography



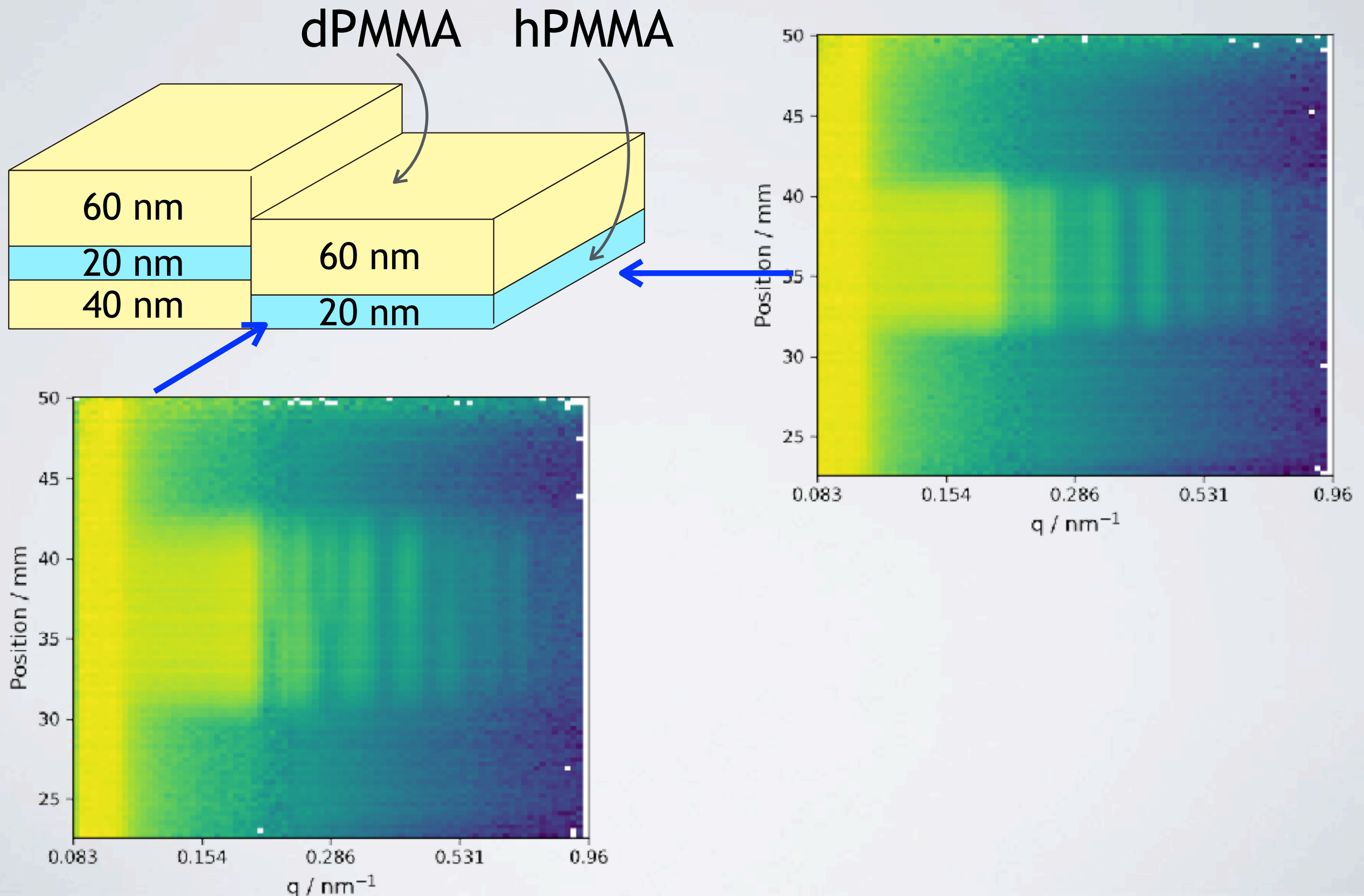
In-plane Structure Analysis



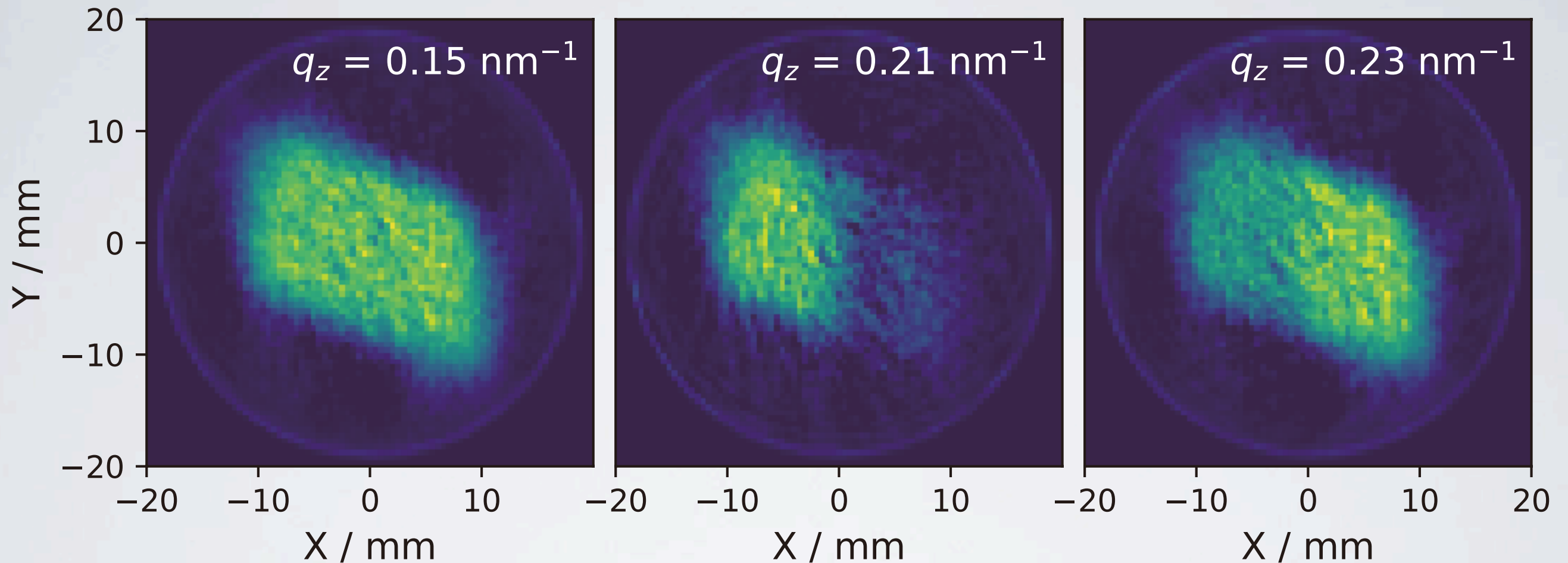
Ellipsometer image



In-plane Structure Analysis

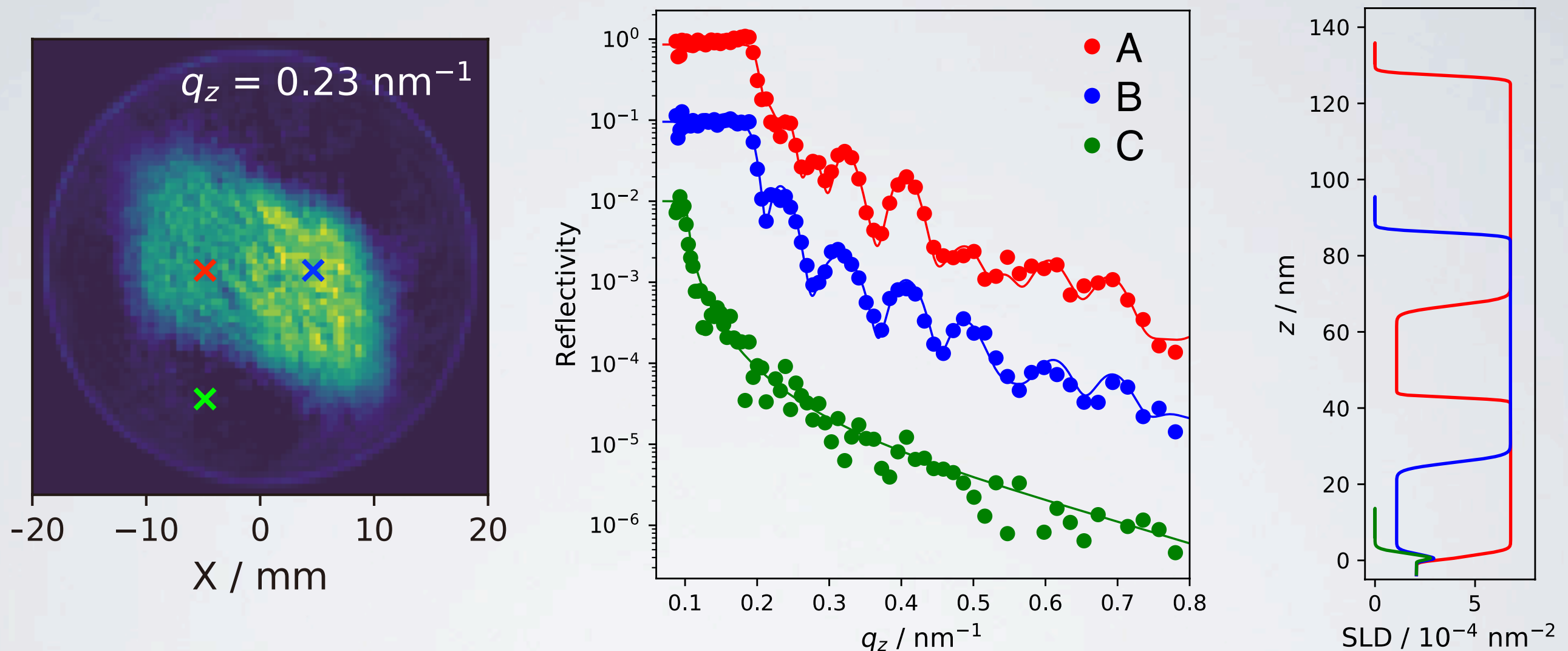


In-plane Structure Analysis



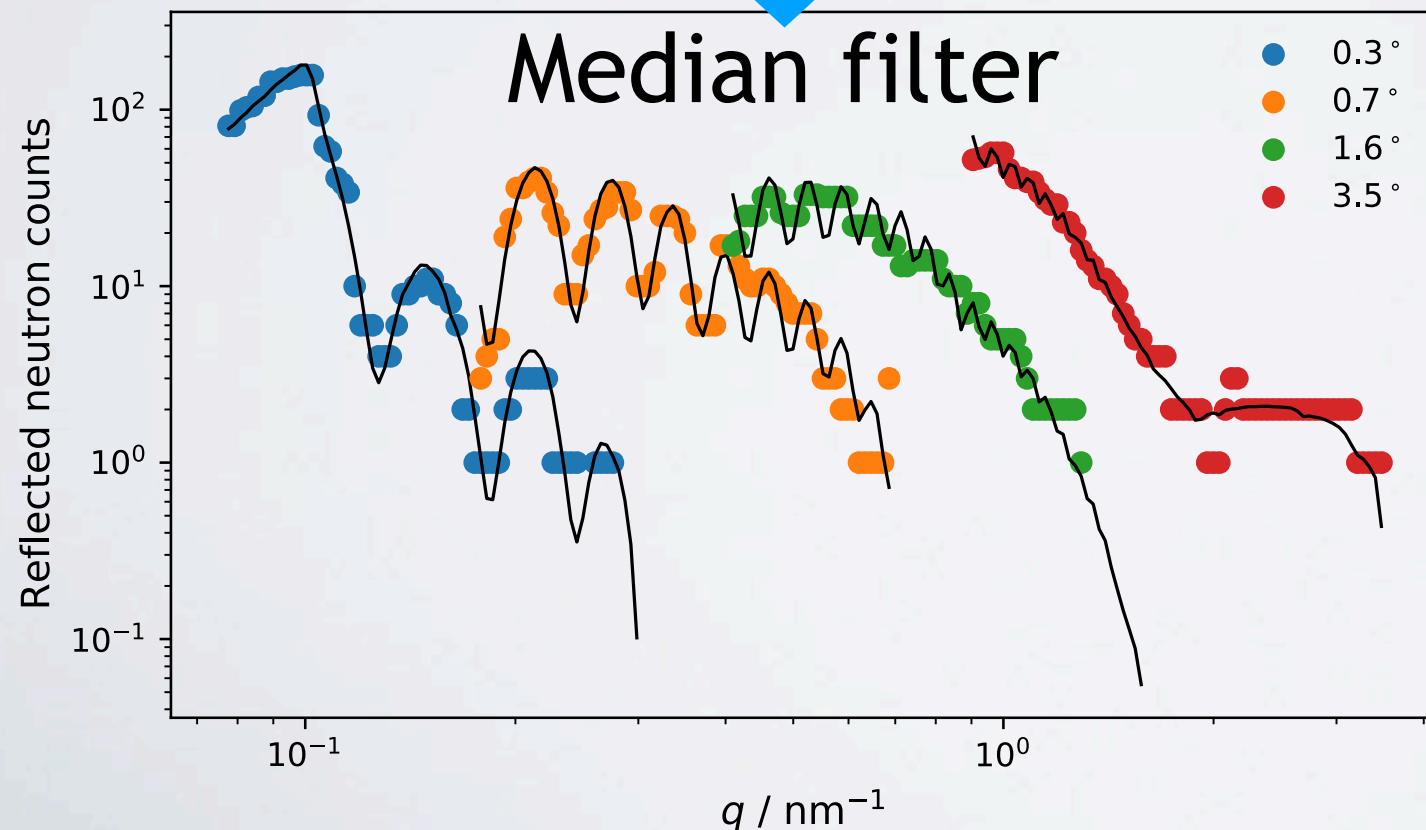
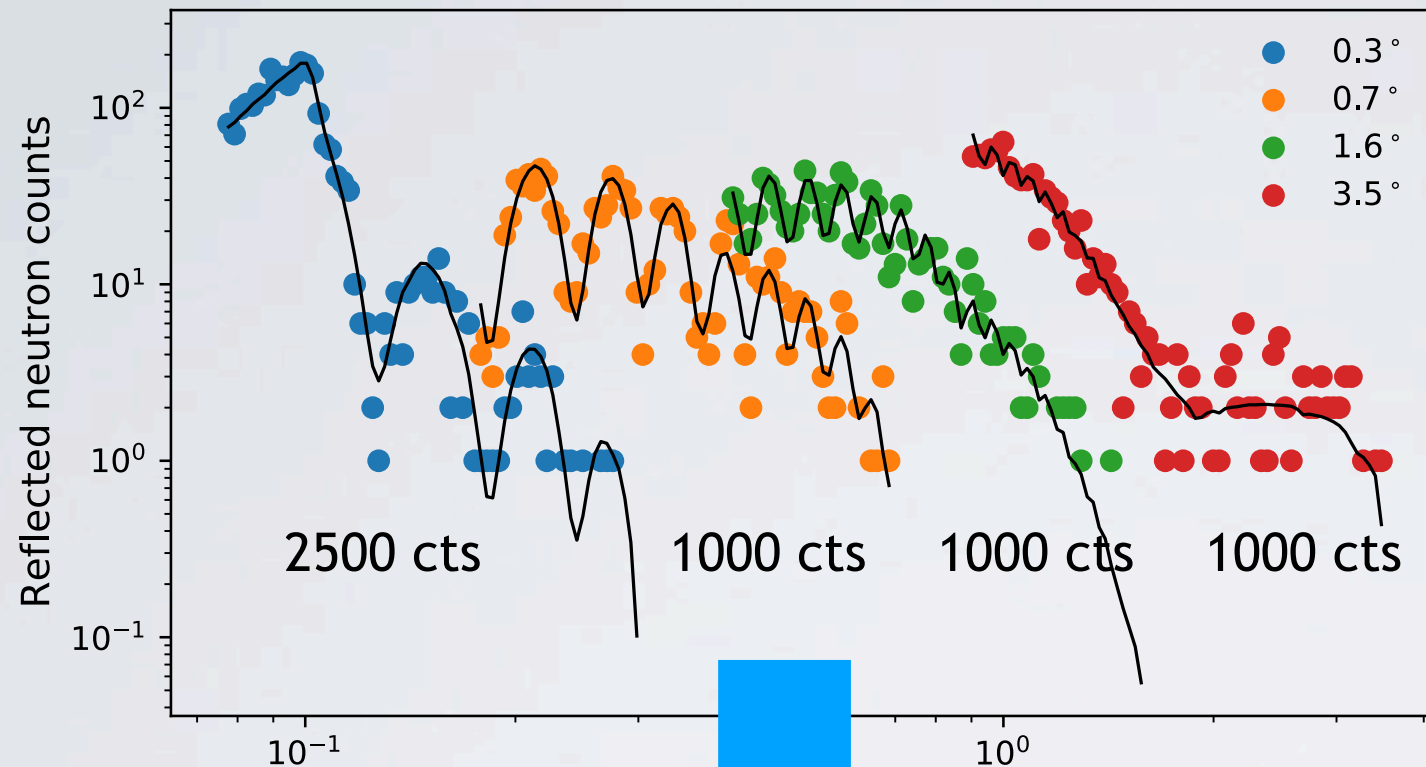
In-plane morphology is visualized in the CT images.
The image contrast is dependent on q_z .

In-plane Structure Analysis



Local NR profiles at a single pixel ($0.28 \times 0.28 \text{ mm}^2$) can be analyzed to obtain the SLD distribution in the depth direction.

Starving for neutrons!!



Spatially resolved experiments are starving for signal intensity.

The beam source with a higher intensity or signal filter for the noise reduction is necessary for the practical application.

Summary

Spatially resolved NR technique has been developed by a sheet-like neutron beam and a two-dimensional detector.

The computed tomographic reconstruction enables the visualization of a two-dimensional lateral structure of the interface.

The spatial resolution is 0.6 mm. The depth profile of SLD is available for a local area of $< 1 \text{ mm}^2$.

Acknowledgement

Prof. Hiroki Ogawa, Kyoto Univ.