•GISANS-Advancing data reduction and analysis“ workshop (18 - 19.03. 2026, Grenoble

DWBA: kinematics, coherence & resolution issues

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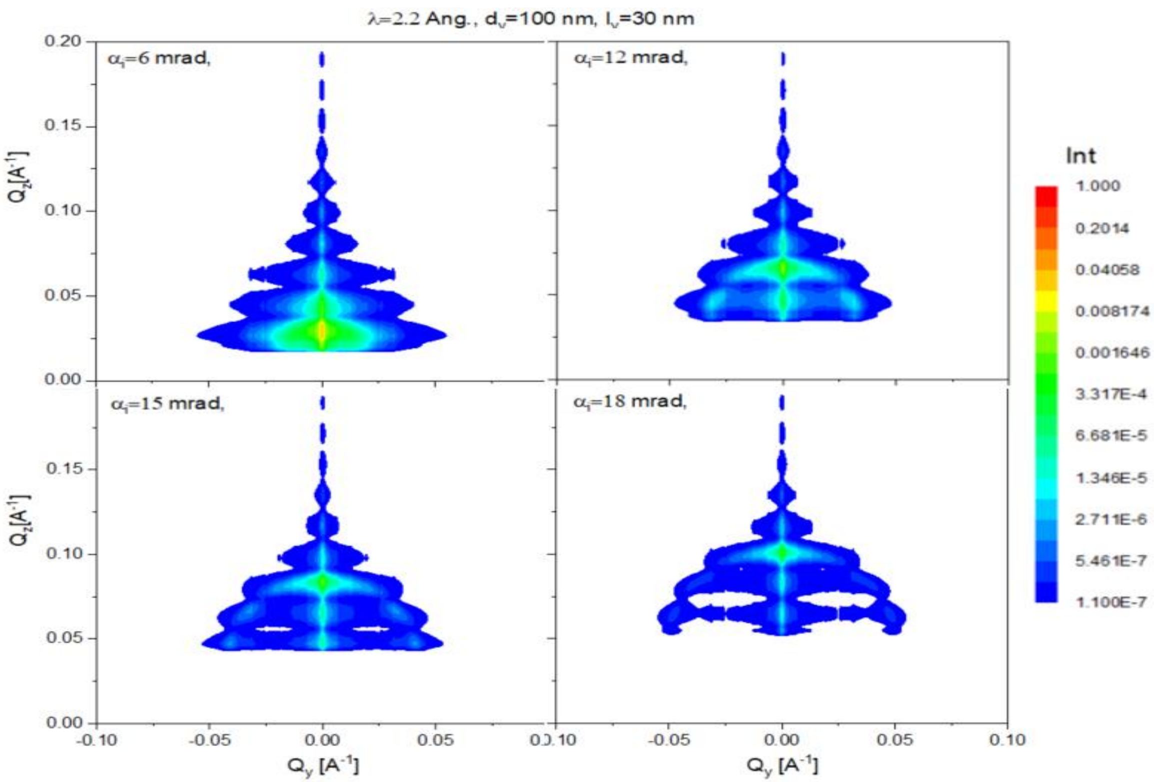


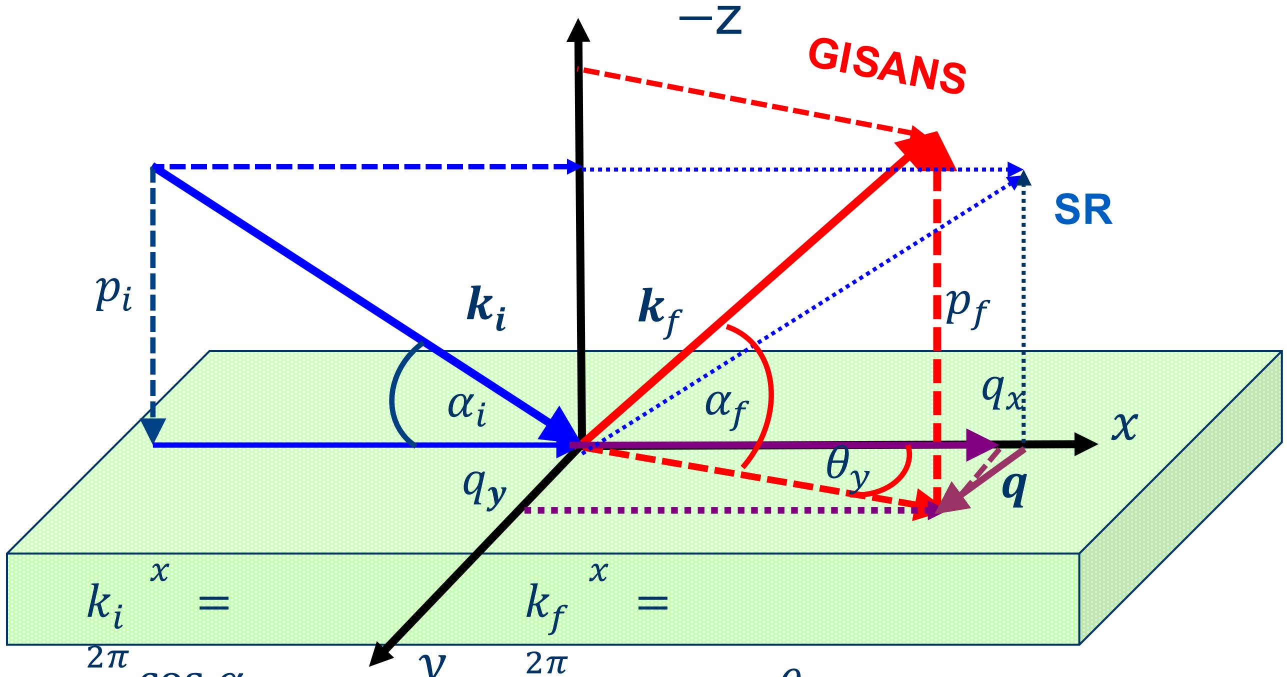
Subgects for <u>Grazing Incidence Crystallography</u>

1. **Depth resolved lateral periodic structures;**
2. **Fourier imaging of surface element states;**
3. **Interlayer and inter-element magnetic coupling;**
4. **Magnetization reversal mechanisms;**
5. **Magnetization kinetics & signal propagation;**
6. **Skyrmion lattice in a planar chiral magnets;**
7. **Spin-ice systems, quantum states, etc;**
8. **2D Diffraction templates for bio-macromolecules**

<u>GISANS & GIWAS Advantage: coherence enhancement of scattering surface & depth sensitivity</u>

Scattering kinematics at grazing incidence $\alpha_i \sim \alpha_f \sim \theta_y \ll 1$

Elastic scattering: $k_f = k_i = \frac{2\pi}{\lambda}$ **@ ideally flat surface:** $q_x = q_y = 0$



$k_i^x = \frac{2\pi}{\lambda}\cos\alpha_i$ $k_f^x = \frac{2\pi}{\lambda}\cos\alpha_f \cos\theta_y$

$$p_i = \frac{2\pi}{\lambda}\sin\alpha_i \approx \frac{2\pi}{\lambda}\alpha_i$$

$$p_f = \frac{2\pi}{\lambda}\sin\alpha_f \approx \frac{2\pi}{\lambda}\alpha_f$$

$$q_z = p_i + p_f$$

$$q_y = \frac{2\pi}{\lambda}\sin\theta_y \approx \frac{2\pi}{\lambda}\theta_y$$

$$q_x = k_f^x - k_i^x \approx \frac{\pi}{\lambda}\left(\alpha_f^2 + \theta_y^2 - \alpha_i^2\right)$$

Coherent lengths

$$l_z^{coh} \sim 2\pi / \Delta q_z \sim \lambda / \alpha_{i,f} \sim 100\,\text{nm}$$

$$l_y^{coh} \sim \lambda / \Delta\theta_y \sim 1 - 100\,\text{nm};$$

$$l_x^{coh} \sim \lambda / (\alpha \Delta\alpha) \sim 100\,\mu\text{m}$$

$$l_x^{coh} >> l_z^{coh}, l_y^{coh}$$

If $q_x = q_y = 0$ then

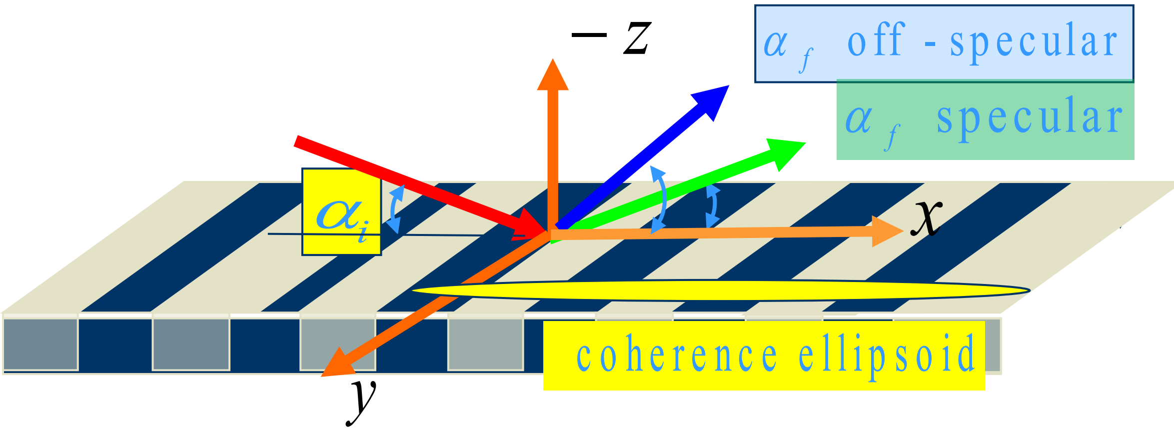
$\alpha_f^2 + \theta_y^2 = \alpha_i^2$ &

$\theta_y = 0$

result in the Snell's law:

$\alpha_f = \pm\alpha_i$

Simplest example DWBA: Lateral diffraction from stripes



$$l_x^{coh} \sim \lambda/(\alpha\Delta\alpha) >> l_z^{coh}, l_y^{coh}$$

$$q_z \approx (2\pi/\lambda)(\alpha_f + \alpha_i)$$

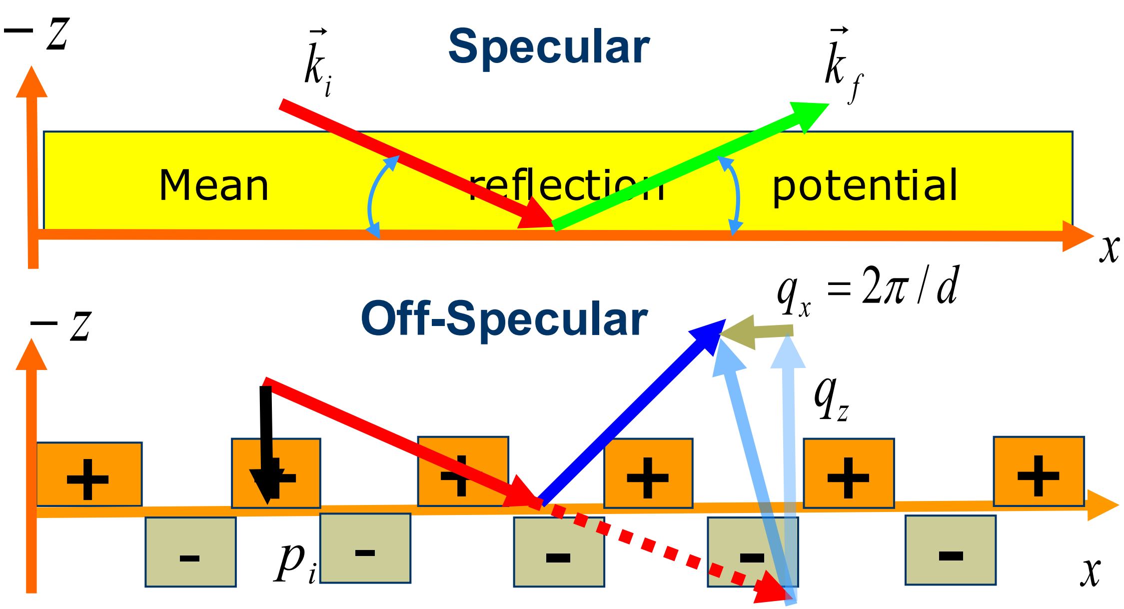
$$q_x \approx (\pi/\lambda)(\alpha_f^2 - \alpha_i^2)$$

$$l_z^{coh} \sim 2\pi/\Delta q_z = \lambda/\Delta\alpha$$

$$l_y^{coh} \sim 2\pi/\Delta q_y = \lambda/\Delta\theta$$

$$l_y^{coh} \sim l_z^{coh} \leq 100\ \text{nm}; \quad l_x^{coh} \geq 10\ \mu\text{m}$$

DWBA for diffraction from stripes



reference potential:

$$U_0(z) = \langle U(x,z) \rangle_x$$

$$\psi(z) = te^{ipz} + re^{-ipz}$$

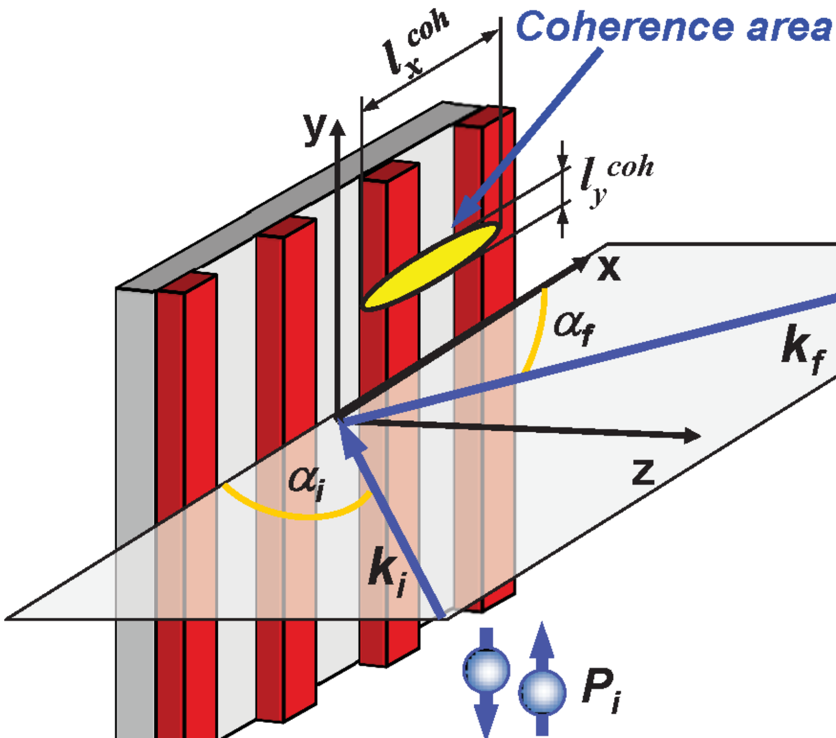
$$p = \sqrt{p_0^2 - p_c^2}$$

perturbation:

$$\Delta U(x,z) = U(x,z) - U_0(z)$$

$$\text{Constrain}: \langle \Delta U(x,z) \rangle = 0$$

Kinematics with stripes perpendicular to reflection plane



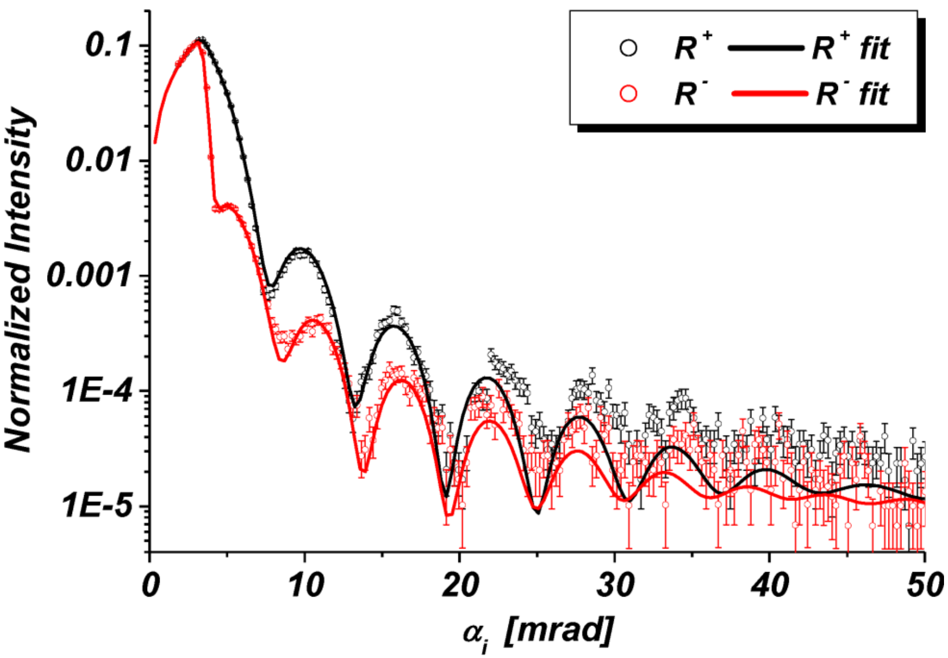
$$q_x = n2\pi / a,\ \ n = 0,1,2...$$

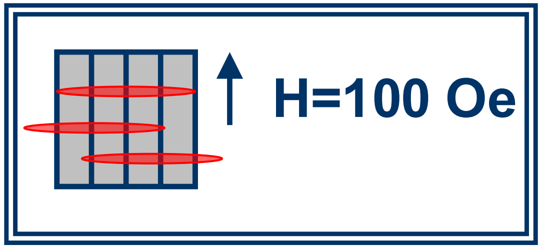
$$\alpha_f^2 - \alpha_i^2 = 2n(\lambda / a)$$

$$\alpha_f \approx \pm\sqrt{\alpha_i^2 \pm 2n \lambda/a}$$

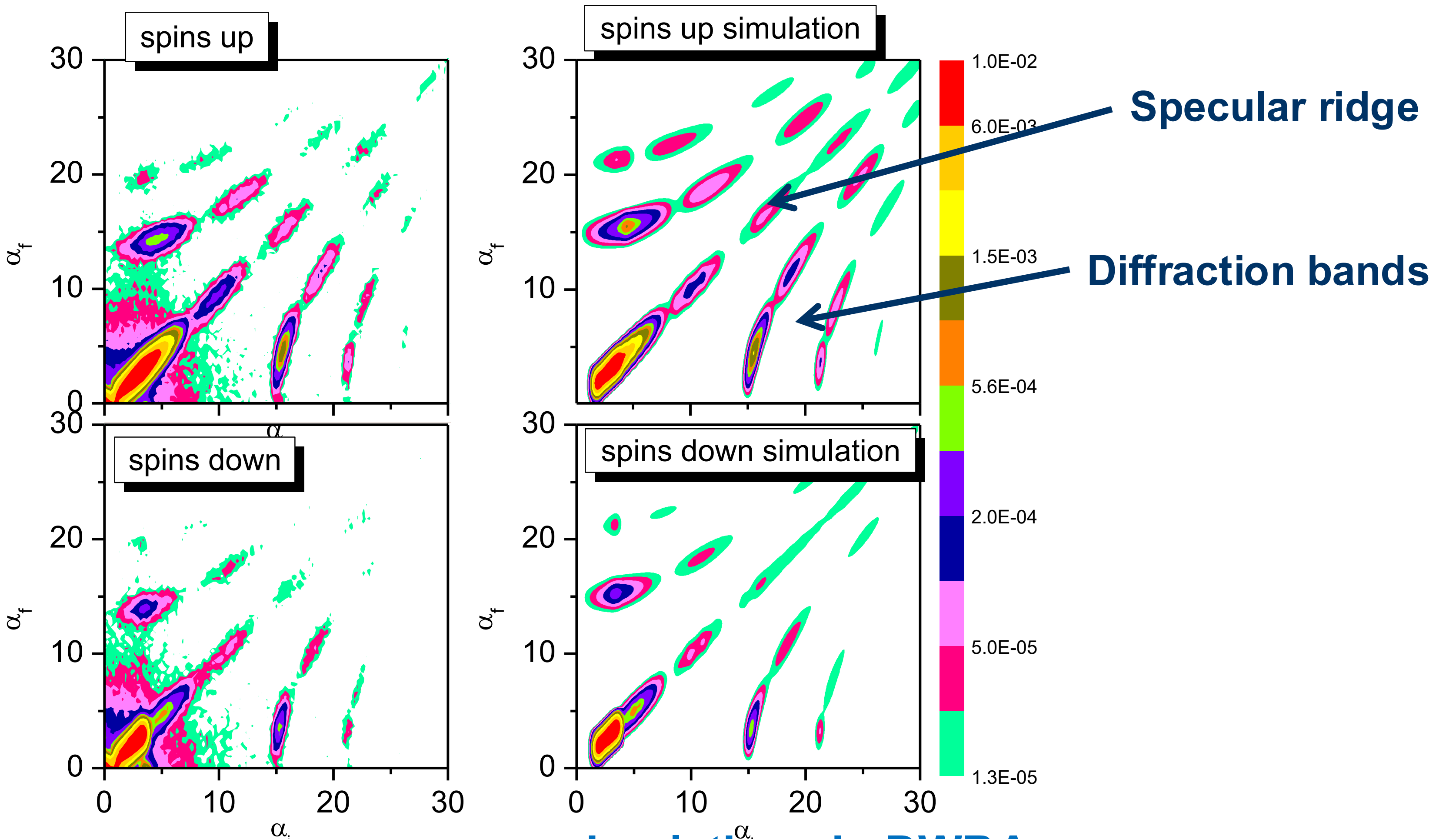
$$\alpha_i \approx \pm\sqrt{\alpha_f^2 \pm 2n \lambda/a}$$

$n = 0,\ \alpha_f = \alpha_i$ specular reflection from mean optical potential averaged over coherence ellipsoid





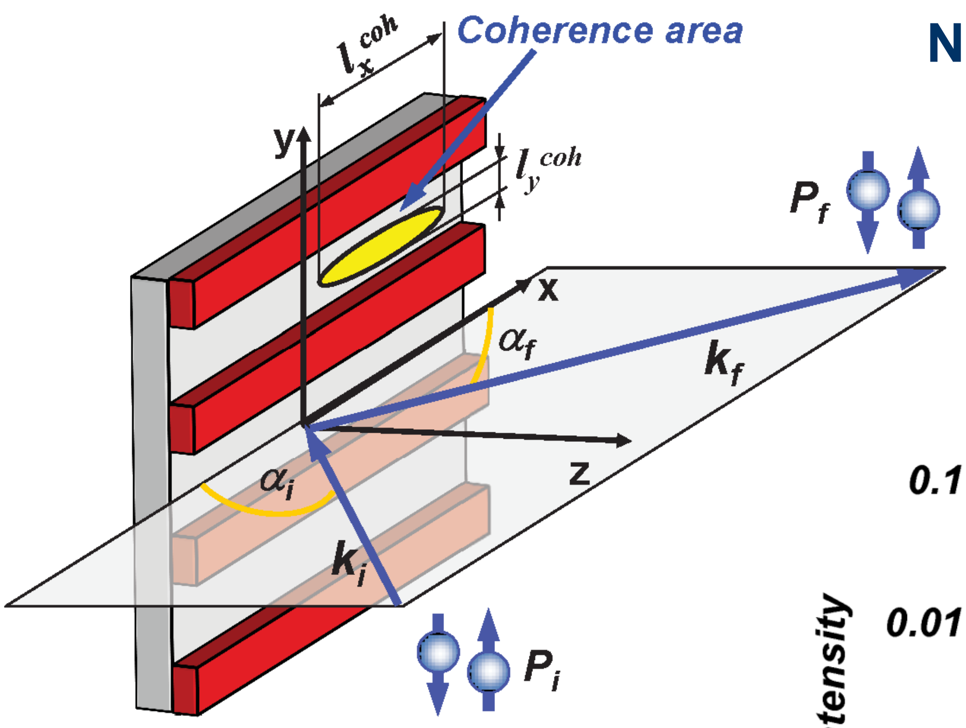
OS Bragg Diffraction OSBD



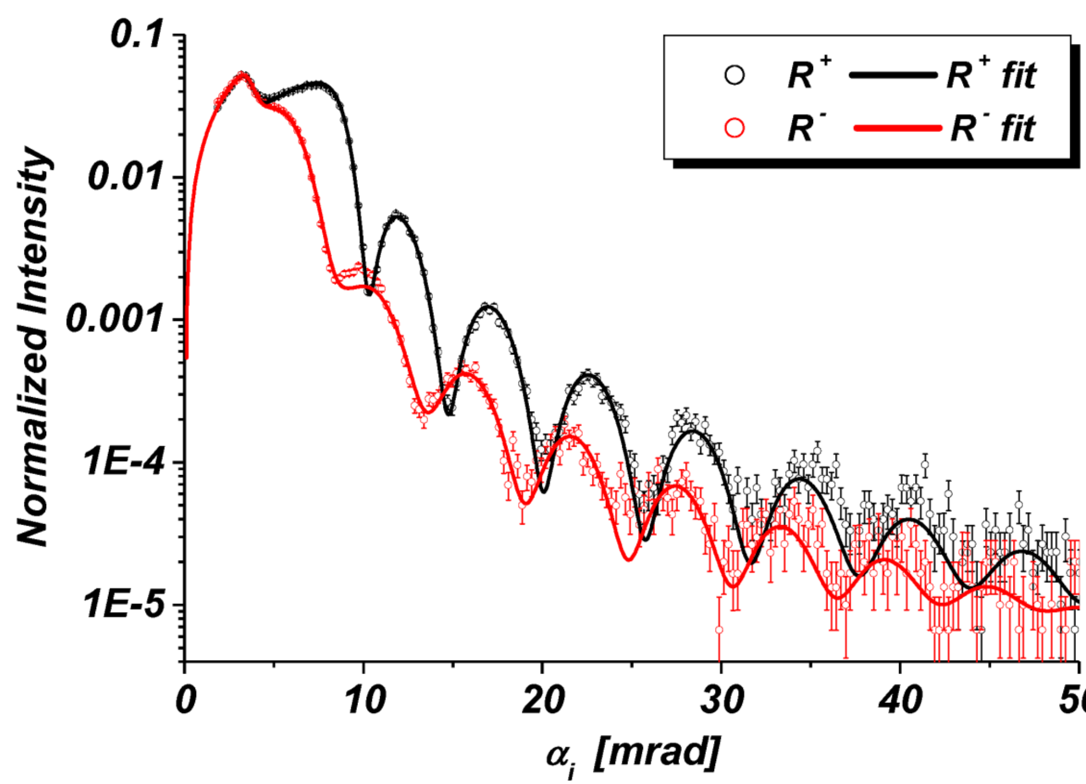
Experiment, SADAM

simulations in DWBA

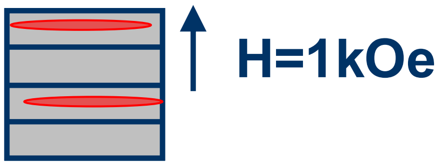
Kinematics with stripes parallel to reflection plane



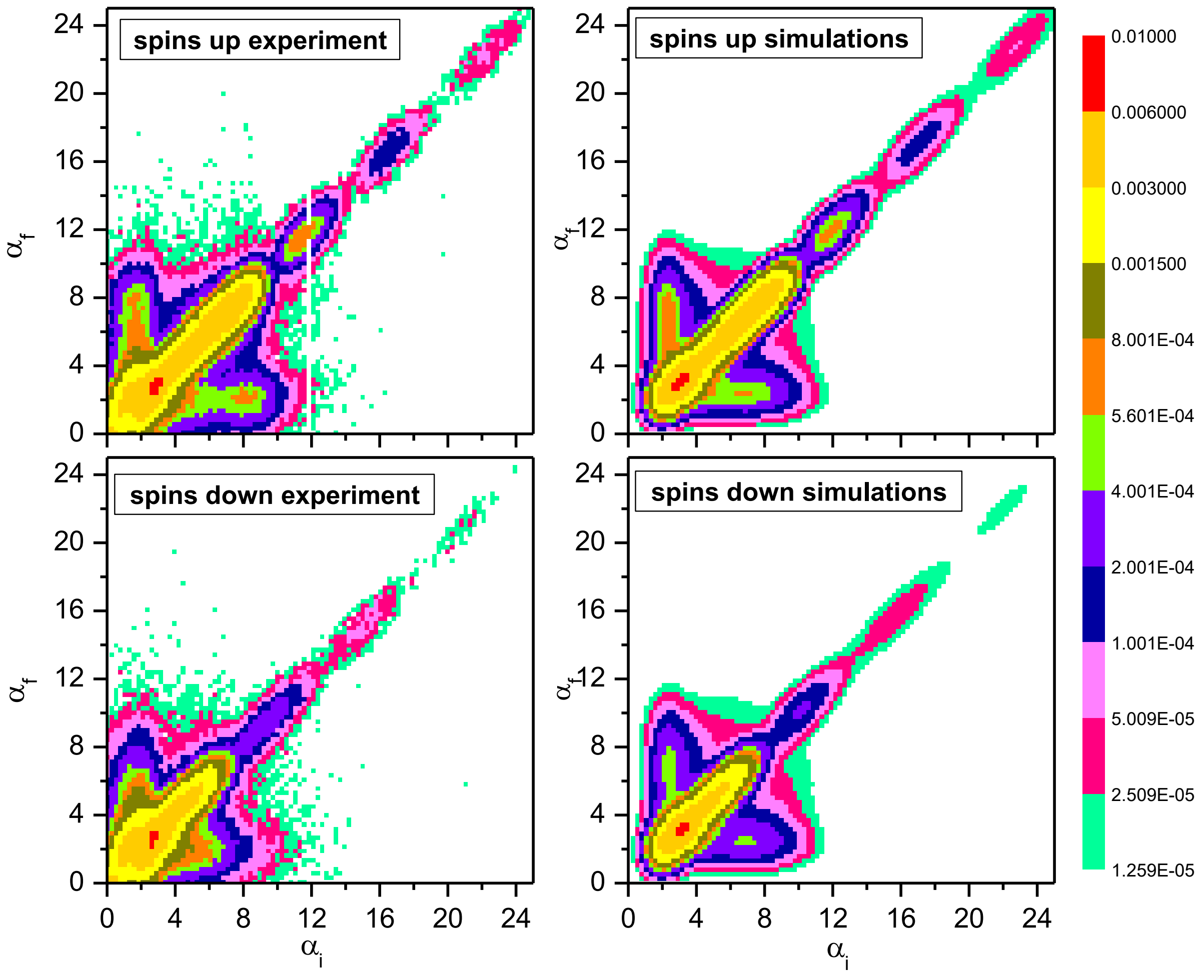
No Bragg diffraction is possible



Reflectivity is incoherent sum of reflection coefficients from stripes and inter-stripe regions



OSS from heterogeneous inter-stripe field



experiment

simulations

Strong inhomogeneous magnetic field between stripes is generated by their rough edges

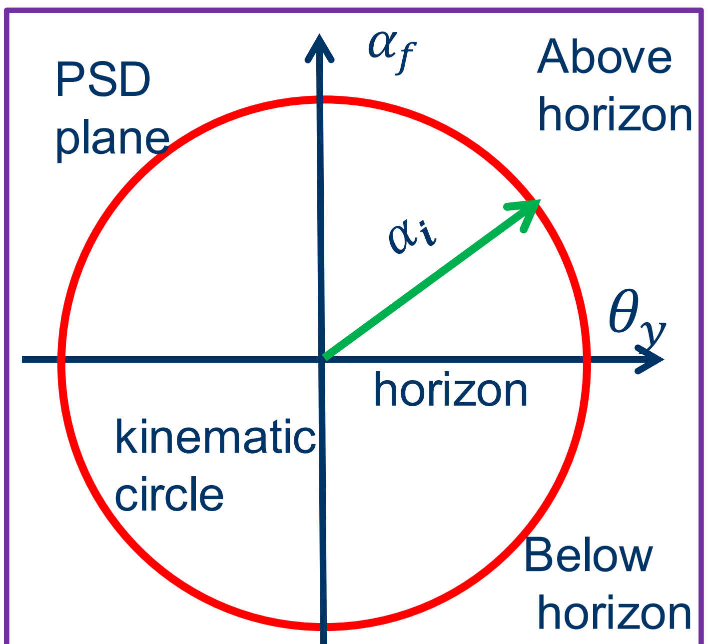
GISANS kinematic ring
(periodic set of nanowires)

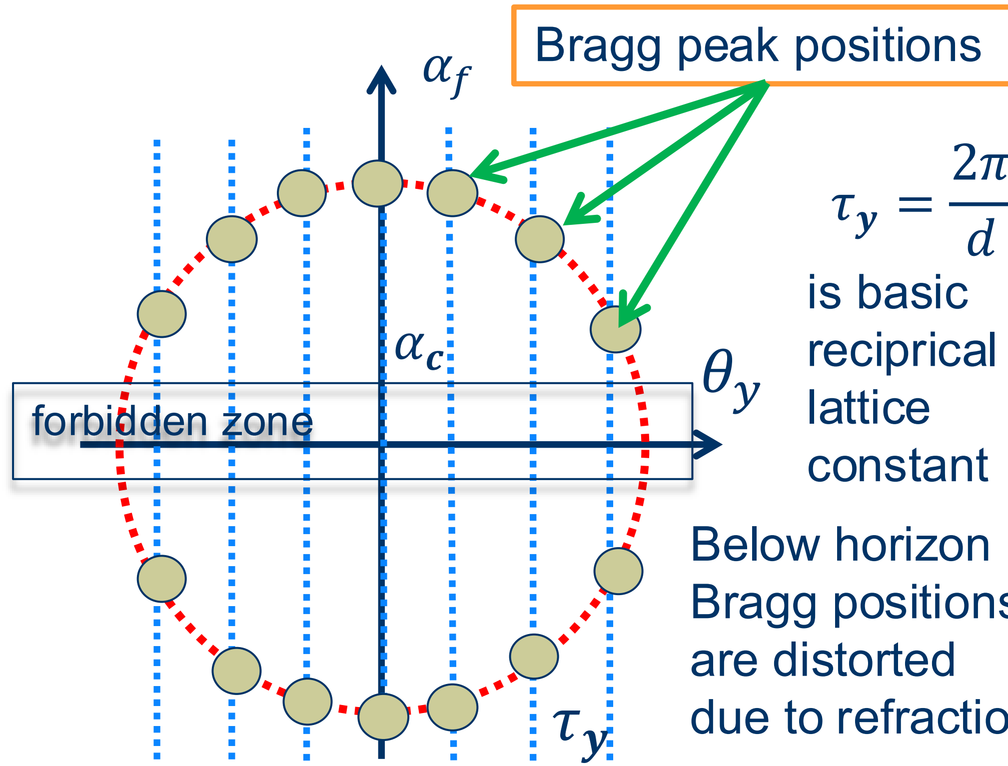
If $q_x = 0$, but $q_y \neq 0$ then

scattering angles α_f & θ_y must obey the equation:

$$\alpha_f^2 + \theta_y^2 = \alpha_i^2$$

for the circle of radius α_i





$$\tau_y = \frac{2\pi}{d}$$

is basic reciprical lattice constant

Below horizon Bragg positions are distorted due to refraction

-3, -2, -1, 0, 1, 2, 3

Orders of Bragg diffraction,
Specular reflection of 0-th order

Intensities of different orders are regulated by form- and structure factors. Bragg "rods" may be broadened and/or superimposed onto diffuse scattering modulated by transvers film structure