Updates on the data analysis of cold-neutron reflectometry measurements

2021-10-12 Pan Pacific Meeting

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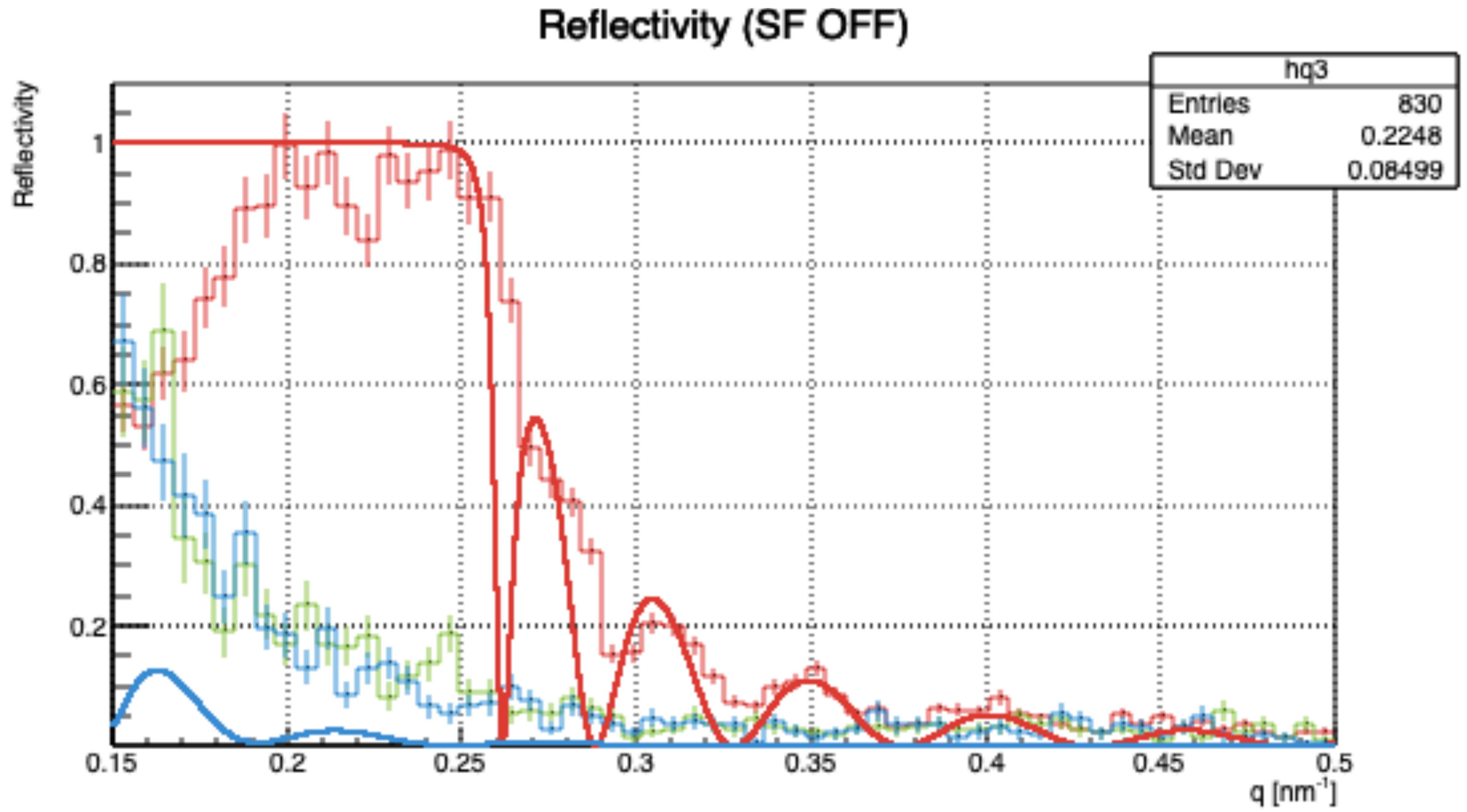
Background

- We performed cold-neutron reflectometry measurement of Fe foils at J-PARC
- Last update: the reflectivity was obtained as a function of *q* for each measurement condition
    - Low reflectivity at q < 0.2 nm^{-1}: because of not full beam polarization
- **This presentation:** the fit model was constructed based on the results of beam polarization measurement with the upstream magnetic super-mirror that was used to polarize the beam

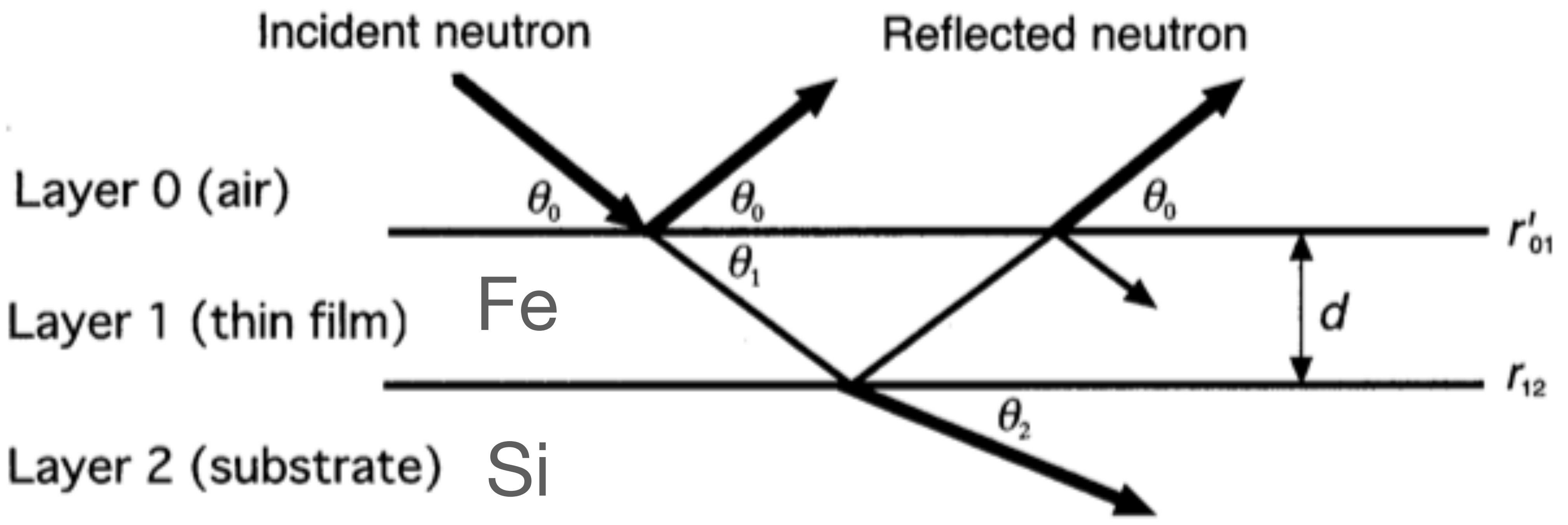


Neutron reflectivity measurement

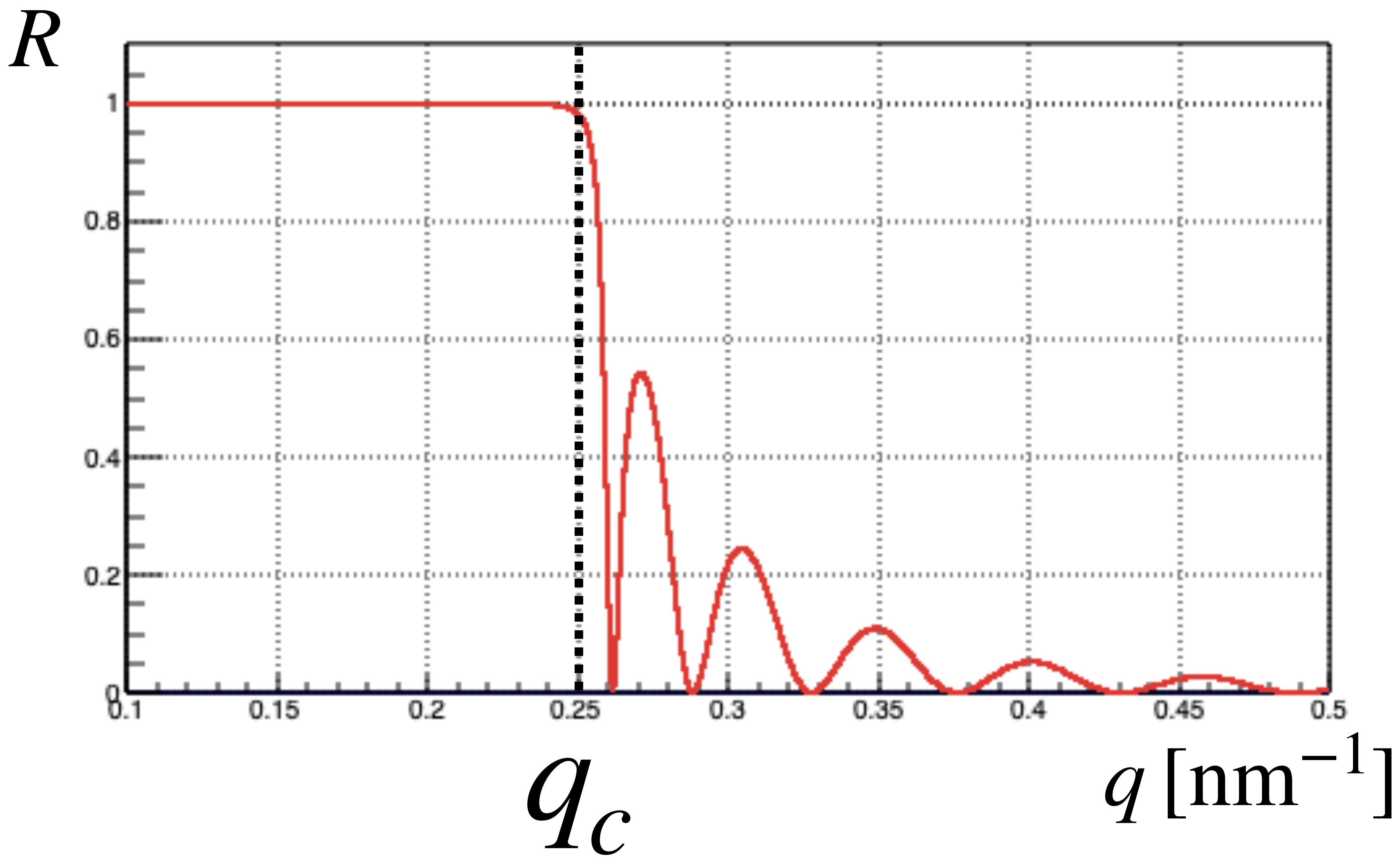
- Cold neutrons (wavelength $0.2 \sim 1\,\mathrm{nm}$) are applied to a sample while changing the magnetic field applied to the sample, and the reflectivity is measured.

- From the graph of q(momentum transfer $q = \dfrac{4\pi \sin \theta_0}{\lambda}$) vs R(reflectivity), the cutoff q_c can be determined.

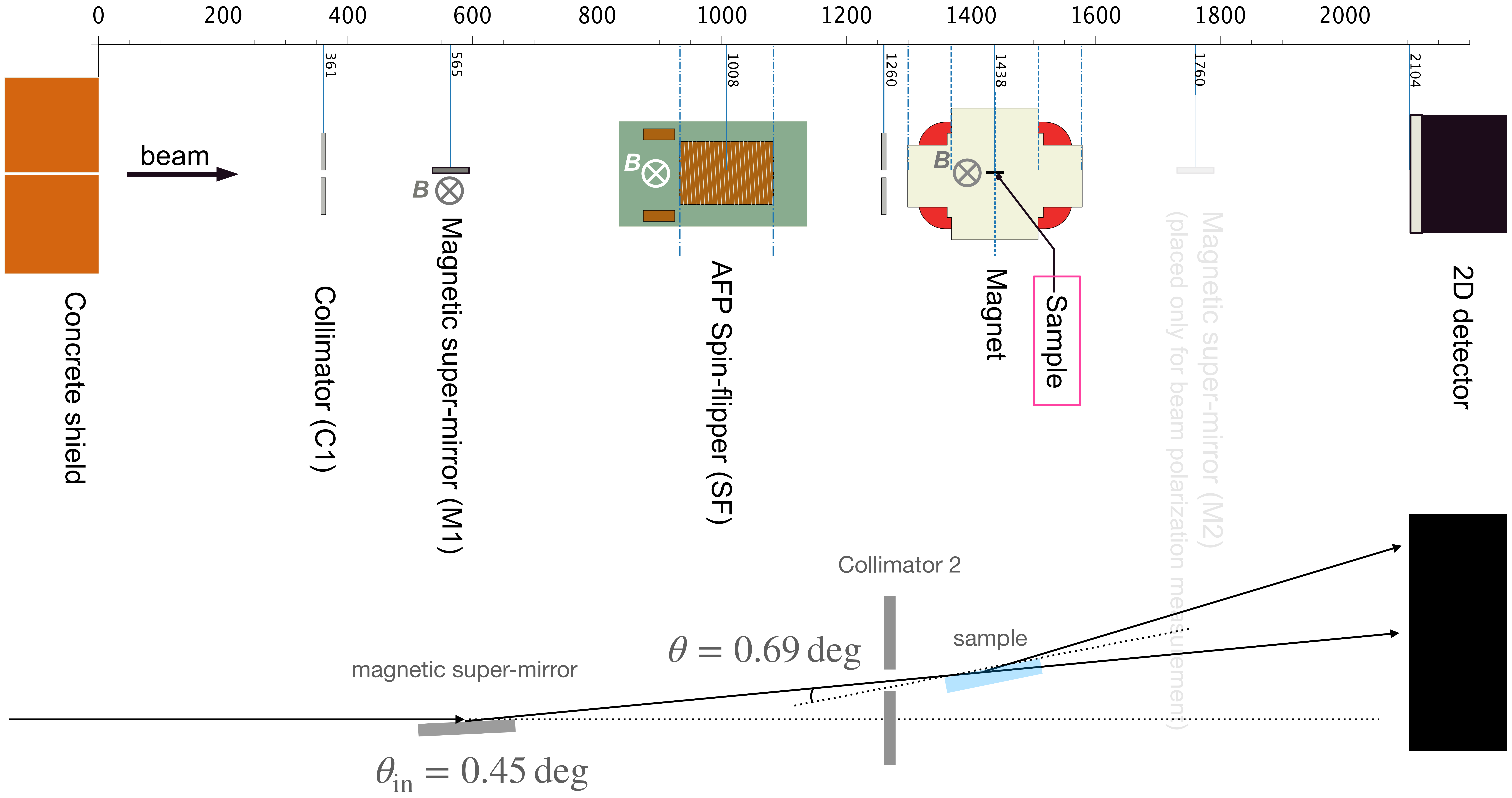
- From the cutoff q_c , the magnetic potential felt by the neutron can be determined.



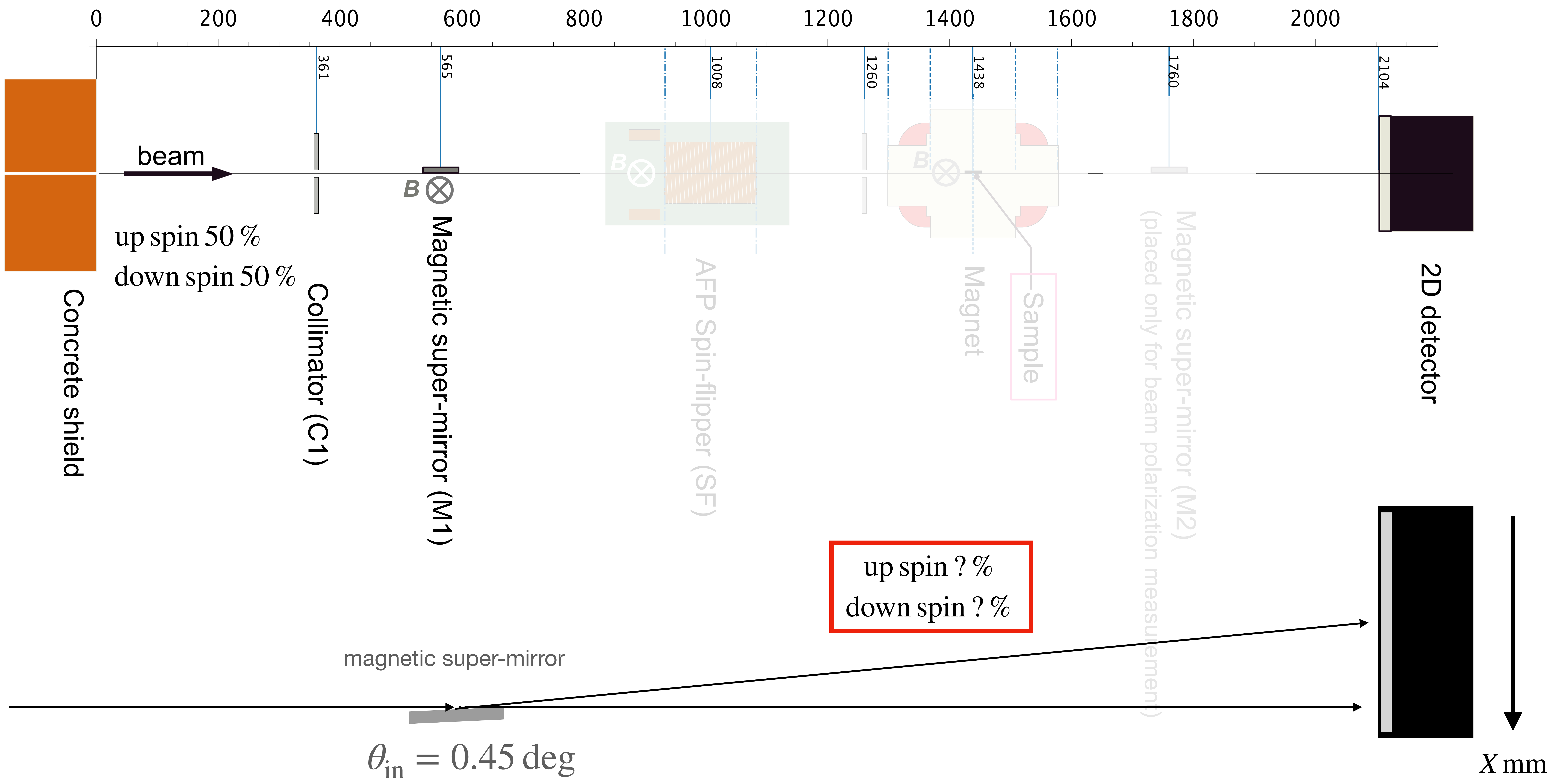
Journal of the Neutron Science Society of Japan "Ripples" Vol.18, No.4, 2008 Principle of neutron reflectometry Naoya Torikai and Masayasu Taketa



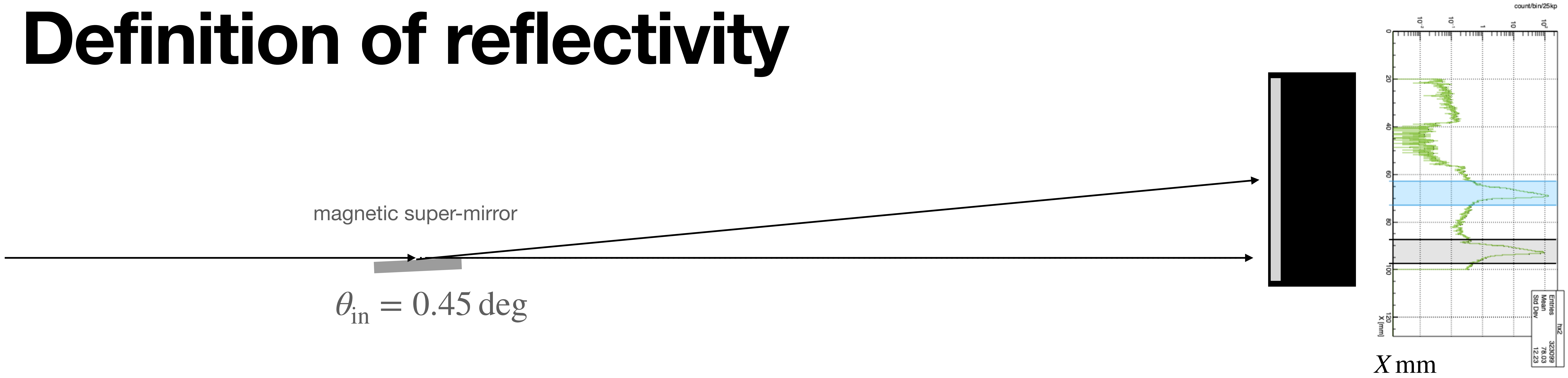
Neutron Reflectometer Setup (J-PARC BL05)

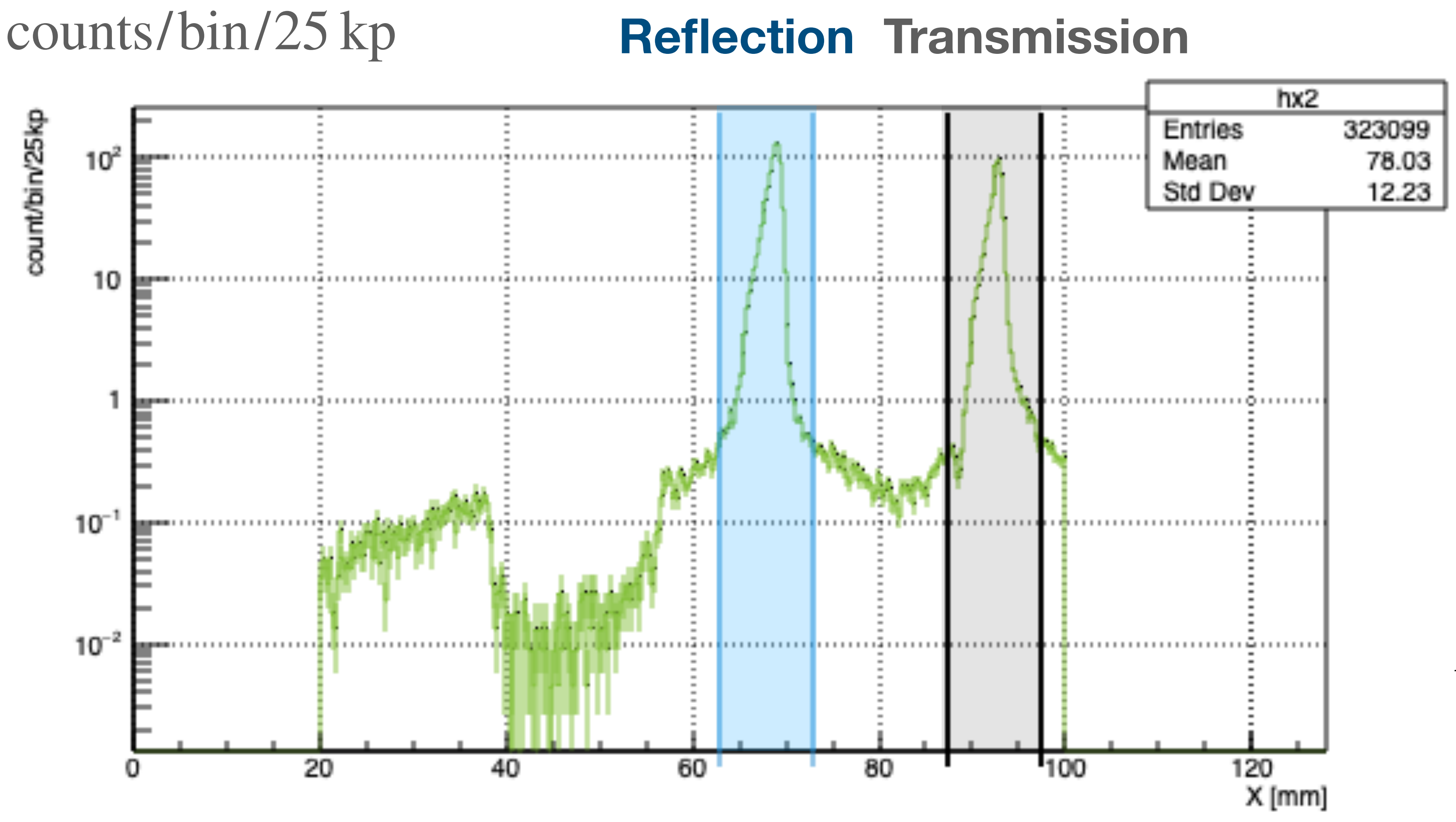


Magnetic super-mirror reflectivity measurement Setup (J-PARC BL05)



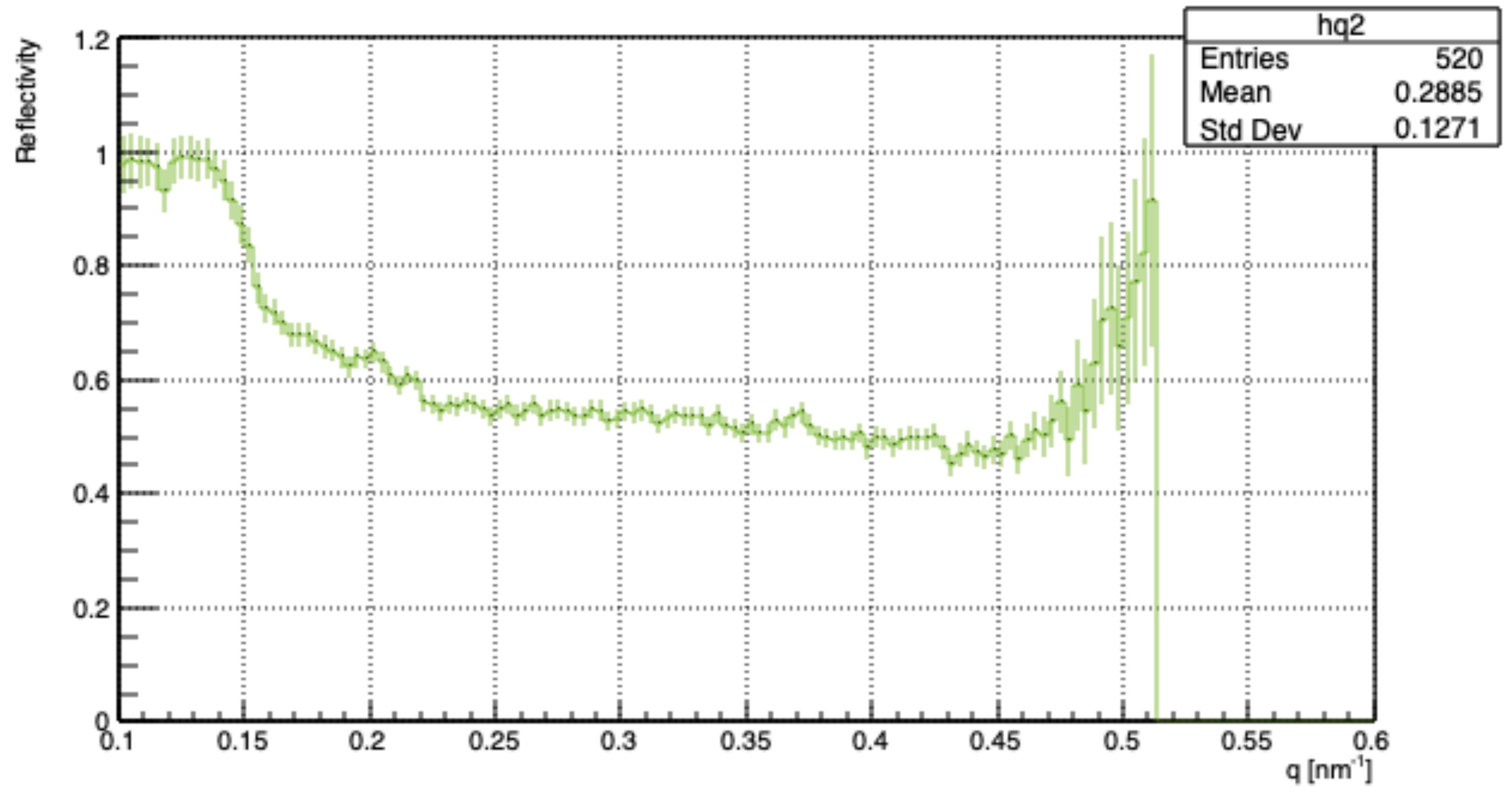
Definition of reflectivity





detection position X mm vs reflectance R

$$R = \frac{\text{Reflection}}{\text{Reflection} + \text{Transmission}}$$



momentum transfer$q$ [nm^{-1}] vs reflection R

Extract beam polarization from the M1 reflectivity

parameter $(0.11 < q_c < 0.15), (1 < m_2 < 10), (\text{Fix } W = 2.5 \times 10^{-3}), (\text{Fix } \alpha = 0.28), (\text{Fix } m = 5.2), (\text{Fix } R_0 = 1)$

fit function

when $q < q_c$

$$y = R_0$$

when$q_c < q < q_{c,\mathrm{Ni}}$

$$R_{\mathrm{up}} = R_0$$

$$R_{\mathrm{down}} = \frac{R_0}{[1 + m_2(q - q_c)]^4}$$

$$R = \frac{1}{2}R_{\mathrm{up}} + \frac{1}{2}R_{\mathrm{down}}$$

when $q > q_{c,\mathrm{Ni}}$

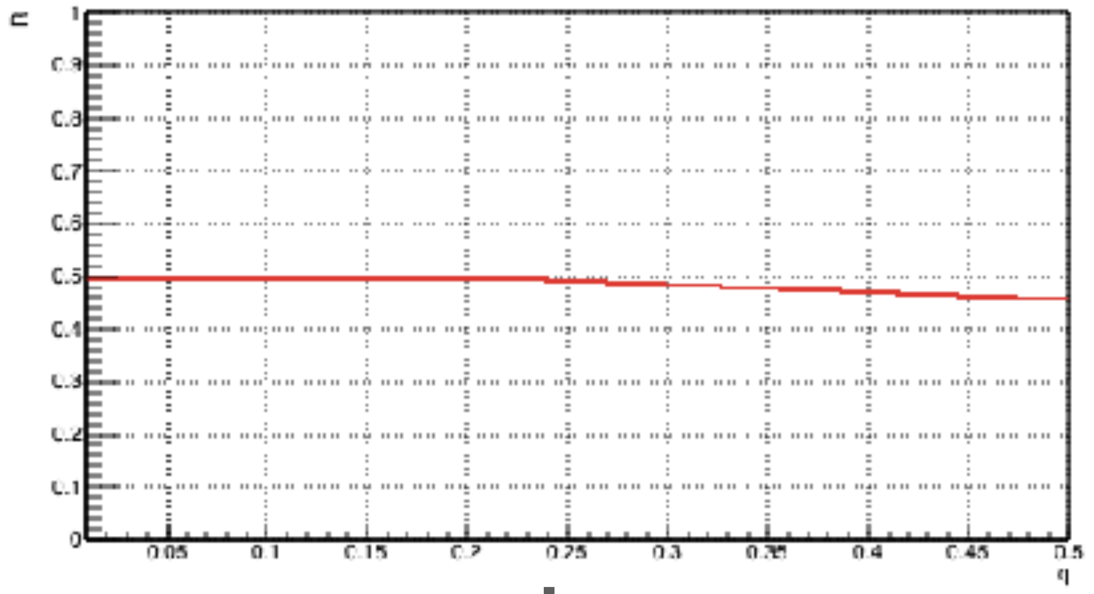
$$R_{\mathrm{up}} = \frac{1}{2}R_0(1 - \tanh((q - mq_c)/W))(1 - \alpha(q - q_c))$$

$$R_{\mathrm{down}} = \frac{R_0}{[1 + m_2(q - q_c)]^4}$$

$$R = \frac{1}{2}R_{\mathrm{up}} + \frac{1}{2}R_{\mathrm{down}}$$

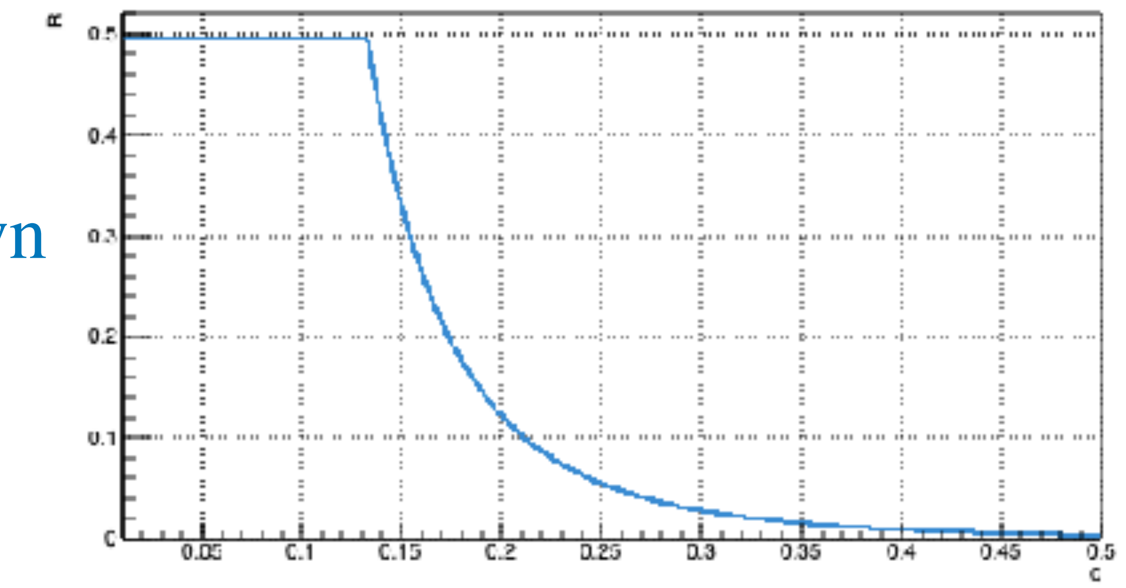
By fitting with the above equation for q vs R, determine q_c, m_2 and model the polarization

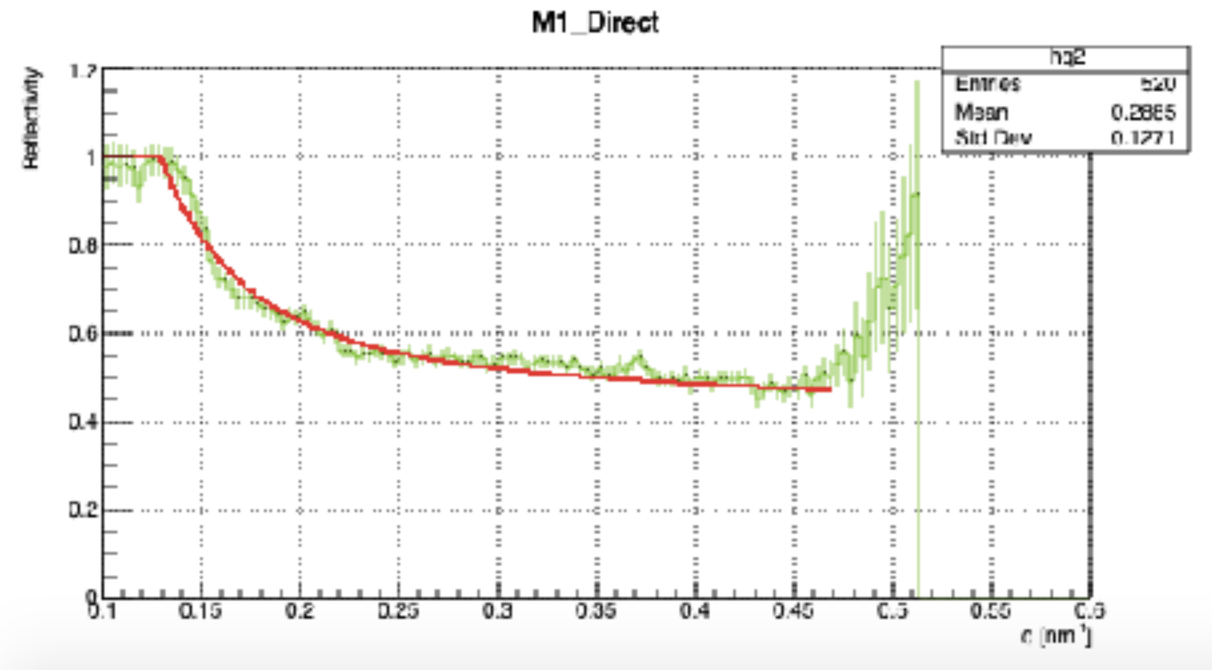
$\frac{1}{2}R_{\mathrm{up}}$



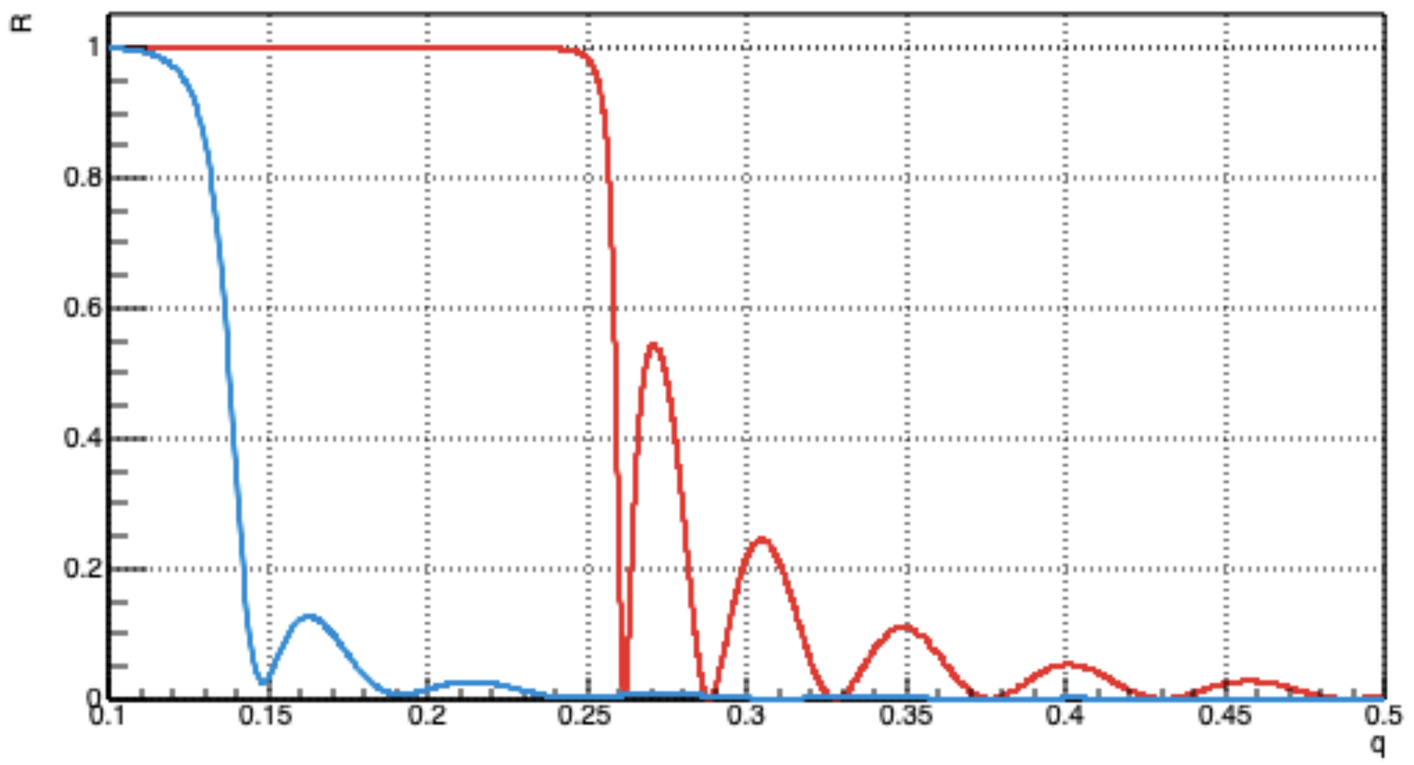
+

$\frac{1}{2}R_{\mathrm{down}}$



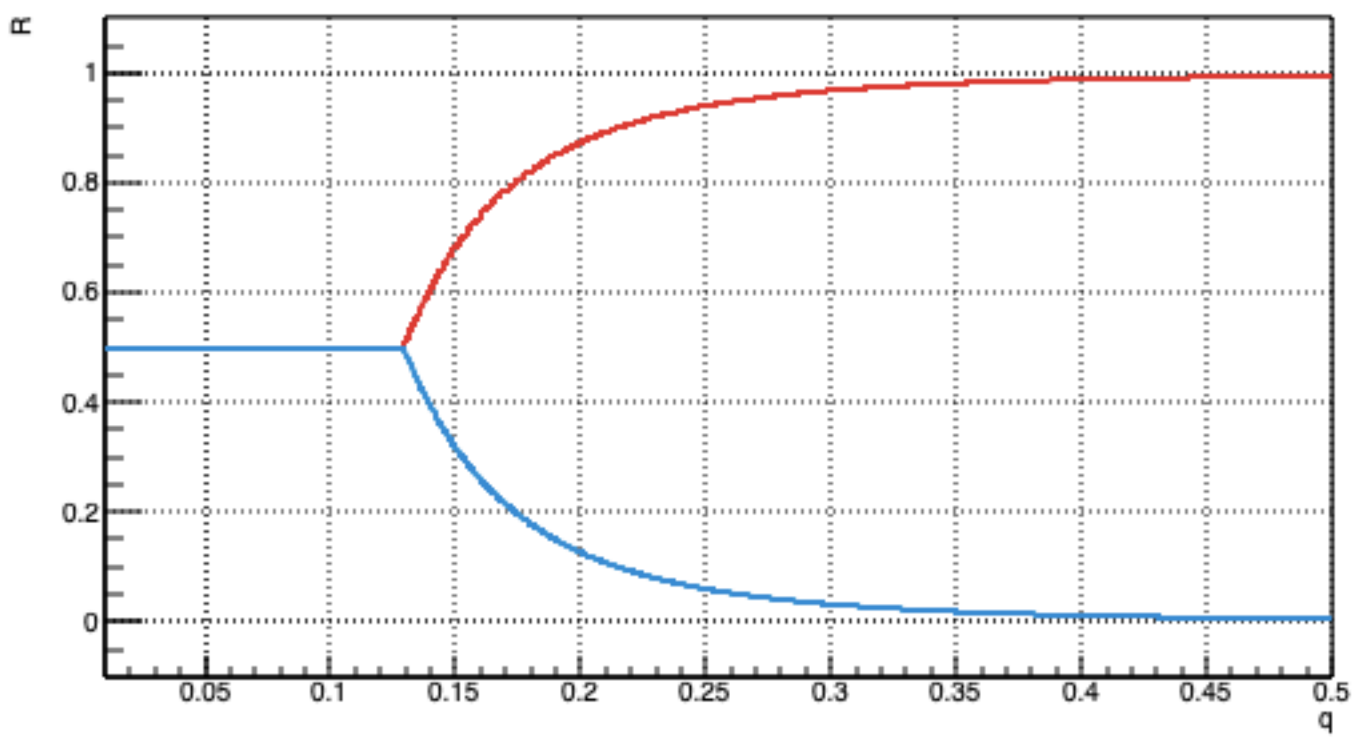


Create a reflectivity model with beam polarization taken into account



$R_{\mathrm{up,s}}$

$R_{\mathrm{down,s}}$

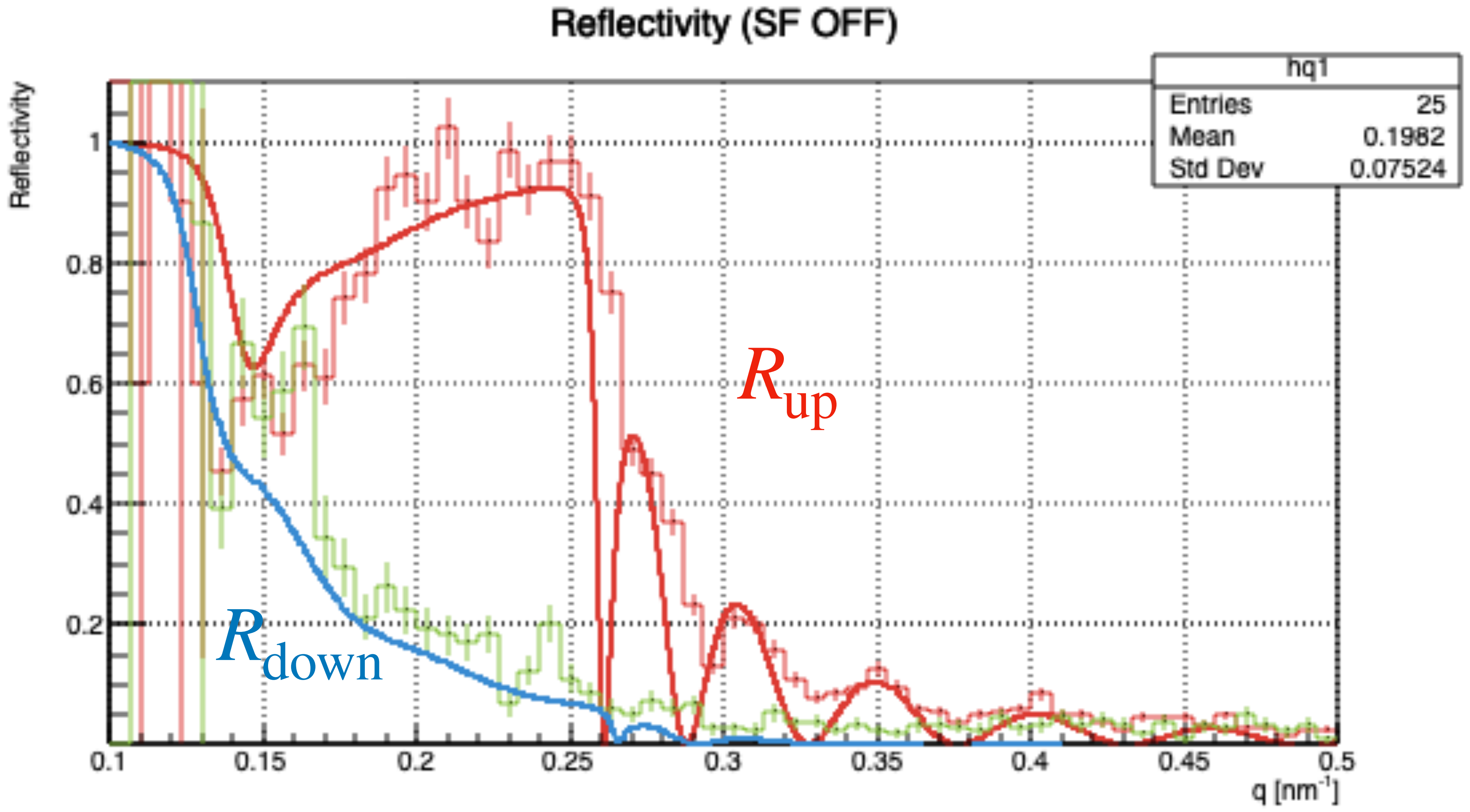


$$\frac{N_{\mathrm{up}}}{N_{\mathrm{up}} + N_{\mathrm{down}})} = 1 - \frac{1}{2} R_{\mathrm{down}}$$

$$\frac{N_{\mathrm{down}}}{(N_{\mathrm{up}} + N_{\mathrm{down}})} = \frac{1}{2} R_{\mathrm{down}}$$

Theoretical reflectivity of neutrons

Modeled polarization (percentage of up, down of incident beam)



Fitted experimental results with a model of reflectivity considering polarization to determine the potential experienced by the neutron

Fitting Results

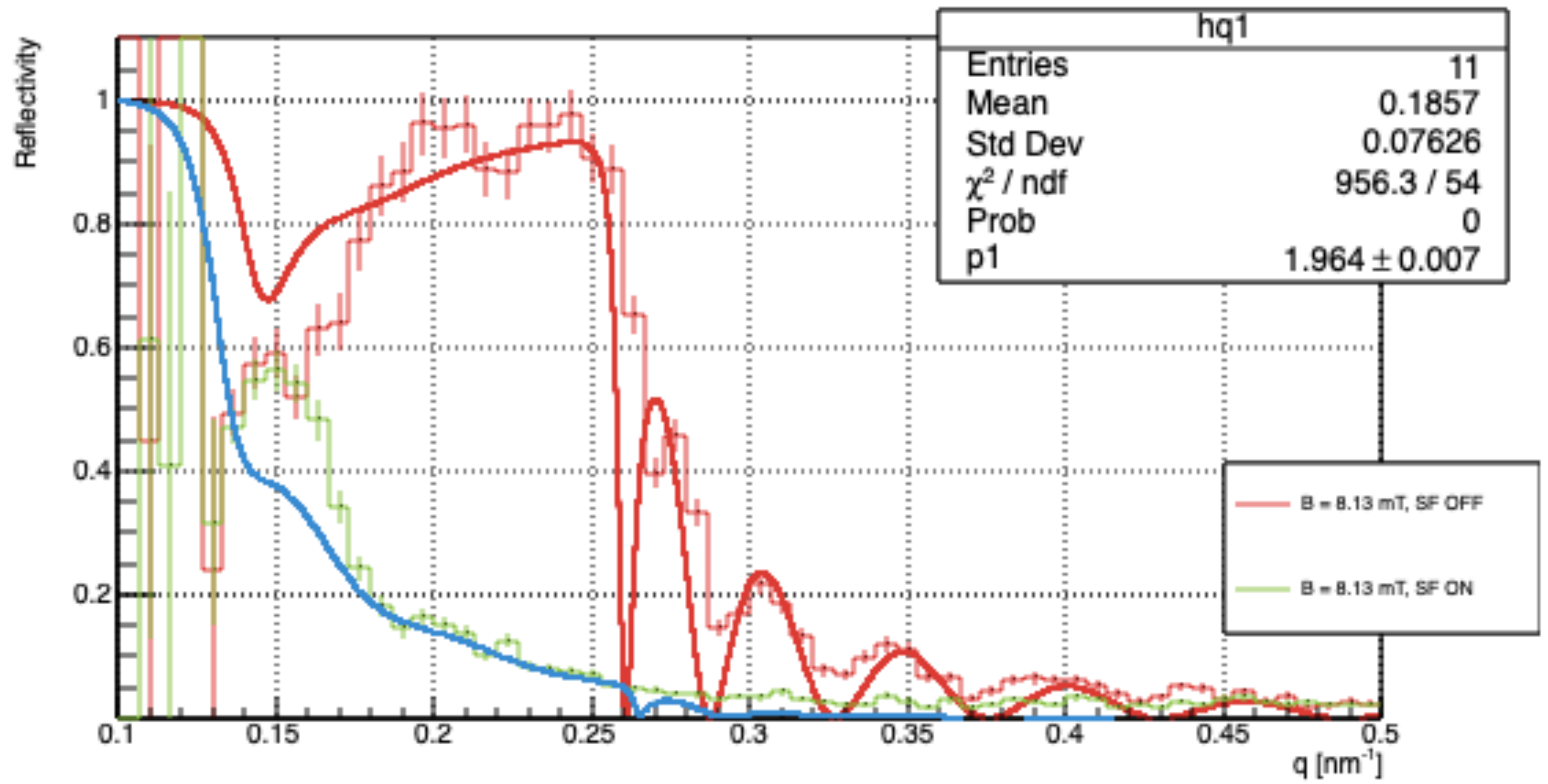
$$V_{\text{experience}} = V_{Fe} \pm \mu_n B$$

- Fermi potential of iron, fixed thickness of iron thin film, fitted with the value of saturation magnetization.

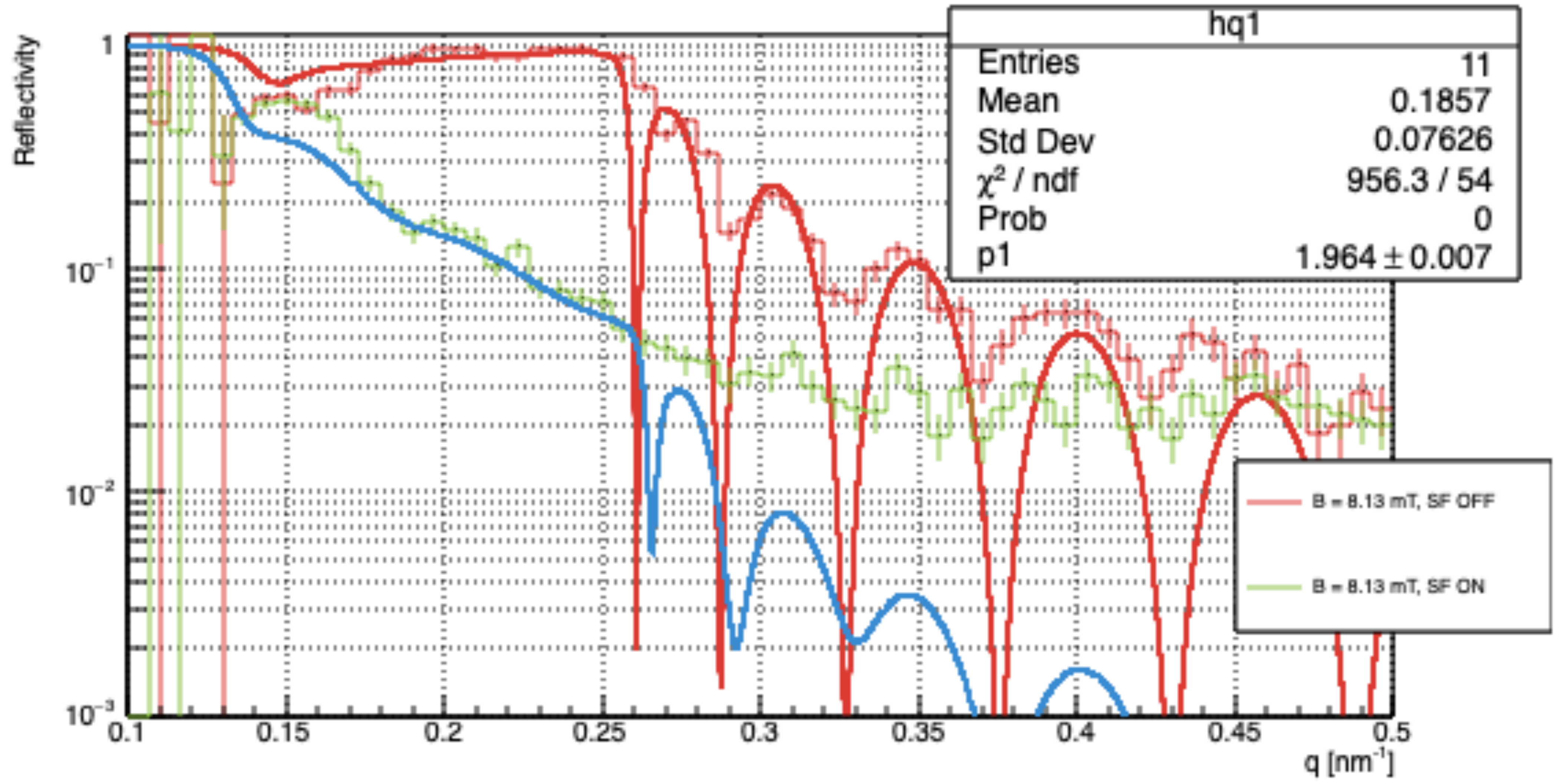
- Details are under analysis

R_up	VALUE	ERROR
thickness d(m)	9E-08	fixed
B(mT)	1.96410E+00	7.17197E-03
V_Fe	2.0906E+02	fixed

R_down	VALUE	ERROR
thickness d(m)	9E-08	fixed
B(mT)	2.18437E+00	1.73296E-02
V_Fe	2.0906E+02	fixed



q vs R_{up}, R_{down}



q vs R_{up}, R_{down} (log scale)

Conclusions

- Cold neutron reflectivity measurements were analyzed by considering the beam polarization.
- As a result of the analysis, we were able to determine the potentials of spin-up and spin-down neutrons.