Paul Scherrer Institut

Swiss-Danish instrumentation work packages

WP 2

high-intensity specular reflectometry

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concept, design and first results:

convergent-beam reflectometry using a focusing elliptic guide

IKON-1

First In-Kind Contributions Meeting for Neutron Science for the ESS
8. 9. 2011, Lund, Sweden

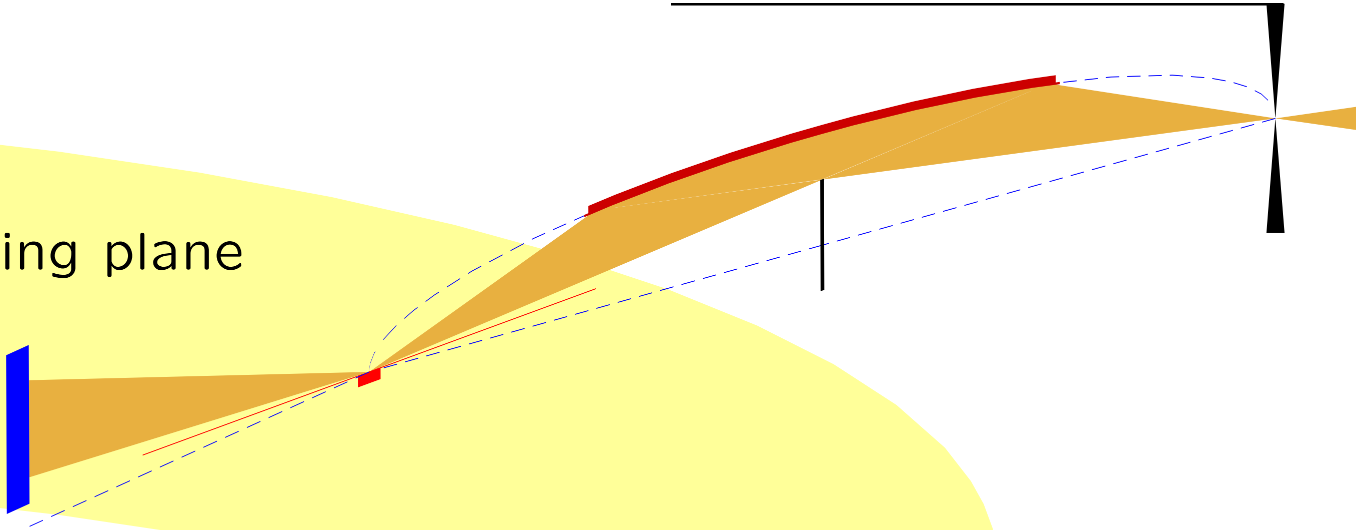
outline

principle:

○ focusing in the scattering plane

○ aberration

● instrument lay-out

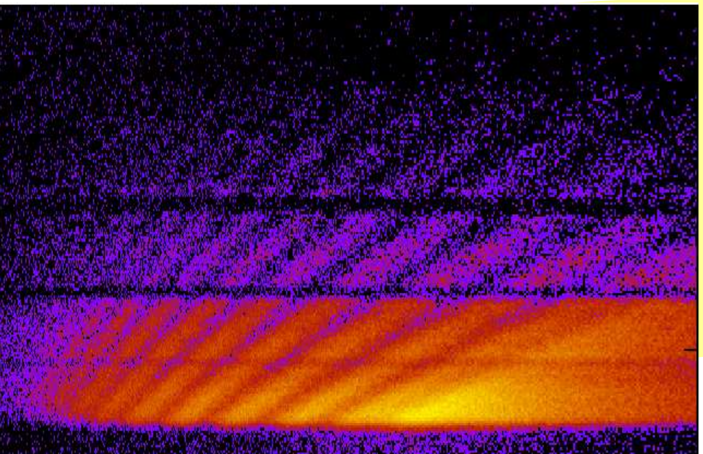


operation modes:

○ λ - θ encoding

● TOF

○ conventional



experience so far:

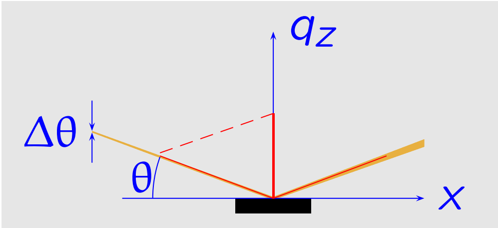
● TOF

○ guide quality

○ λ - θ encoding

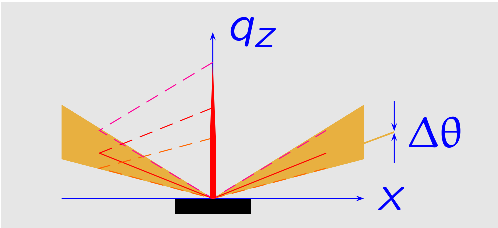
focusing in the scattering plane

slit-defined beam:



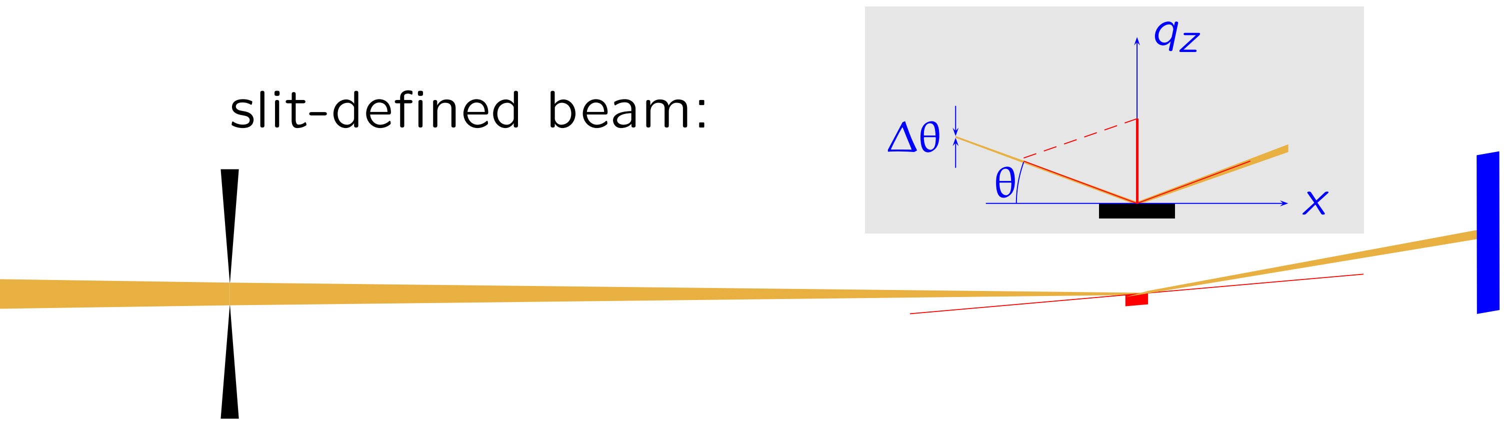
- ω-dispersive, **or**
- λ-dispersive,
- resolution given by $\Delta\lambda$ and $\Delta\omega$

convergent beam:

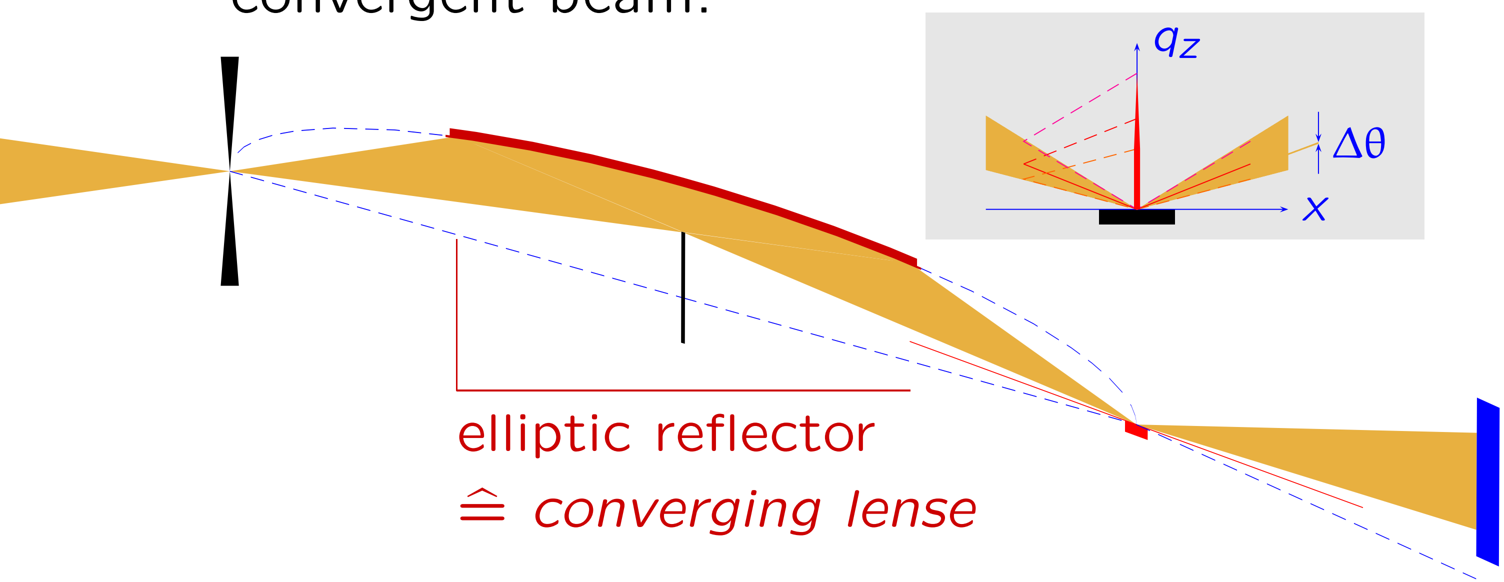


- ω-dispersive **and**
- λ-dispersive,
- resolution given by $\Delta\lambda$ and detector

slit-defined beam:



convergent beam:

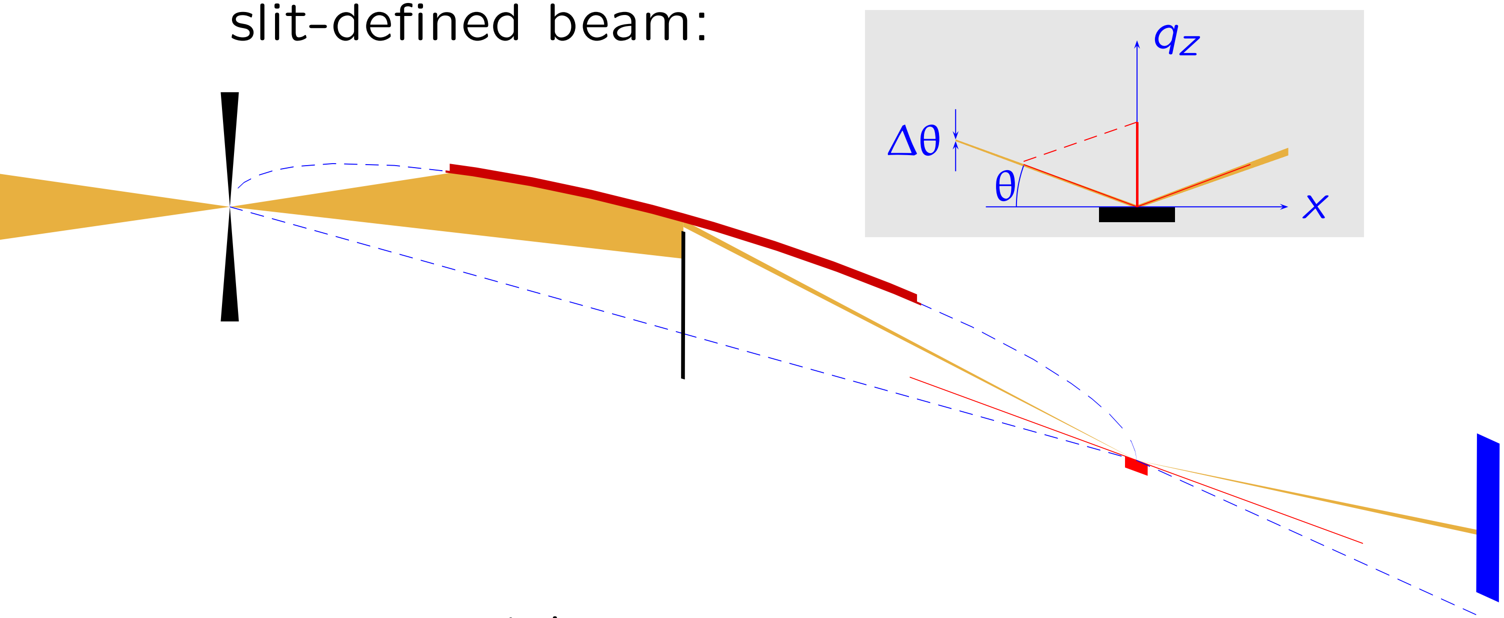


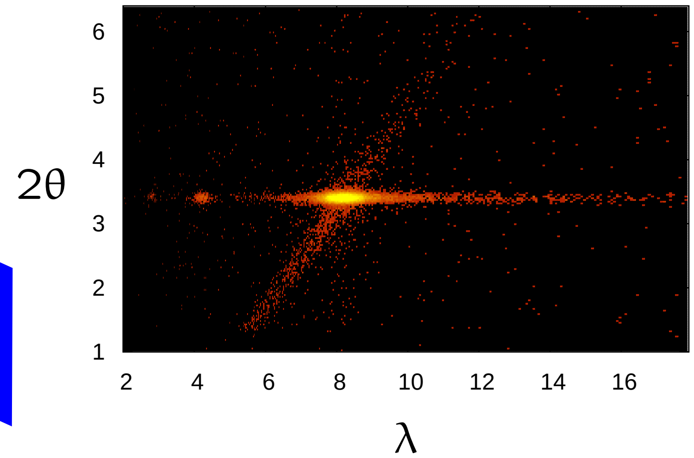
J. Stahn, et al. *N.I.M A* **634**, S12 (2011)

focusing in the scattering plane

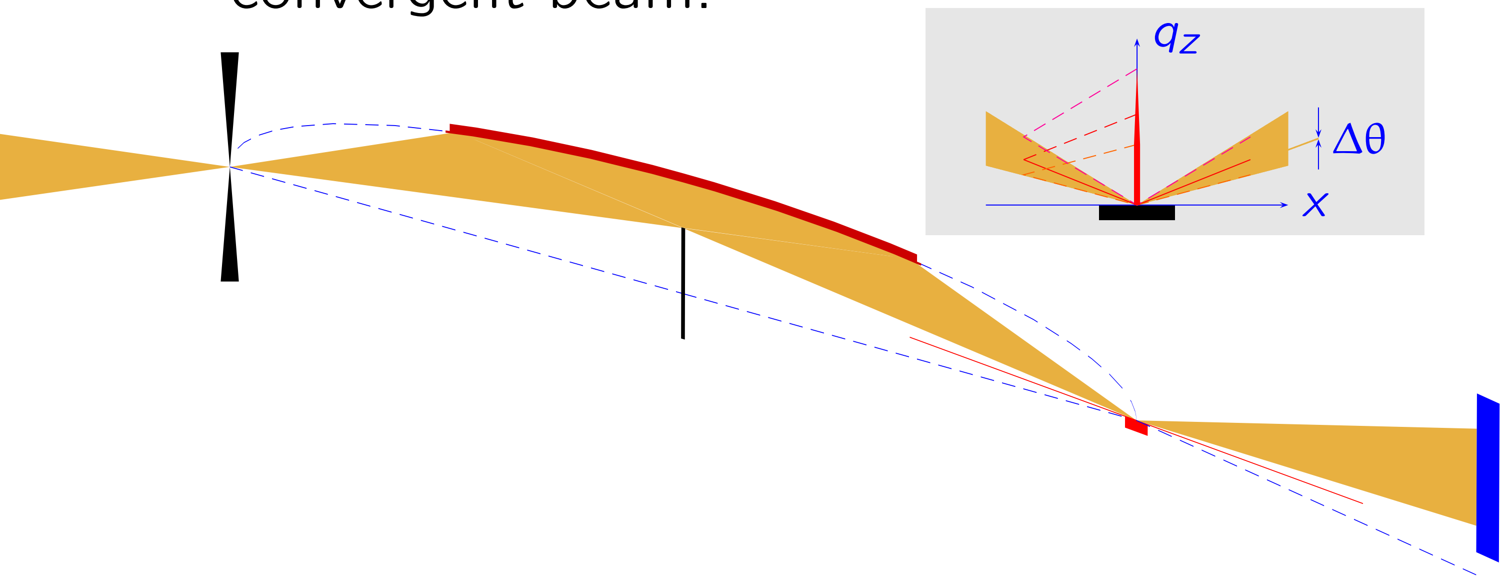
TOF operartion

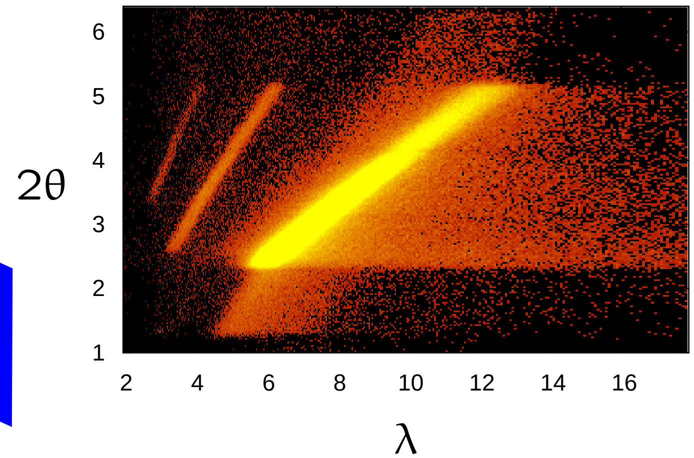
slit-defined beam:





convergent beam:

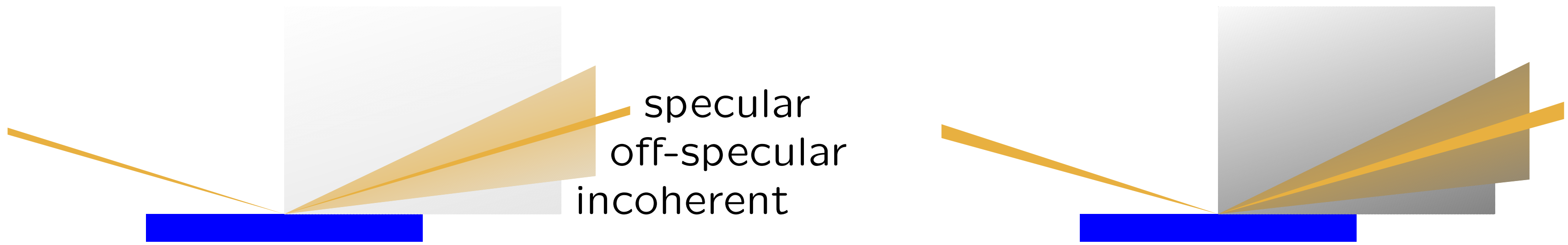




discussion:

− Δq_z varies with θ (finite detector resolution)

− off-specular and incoherent scattering cause background

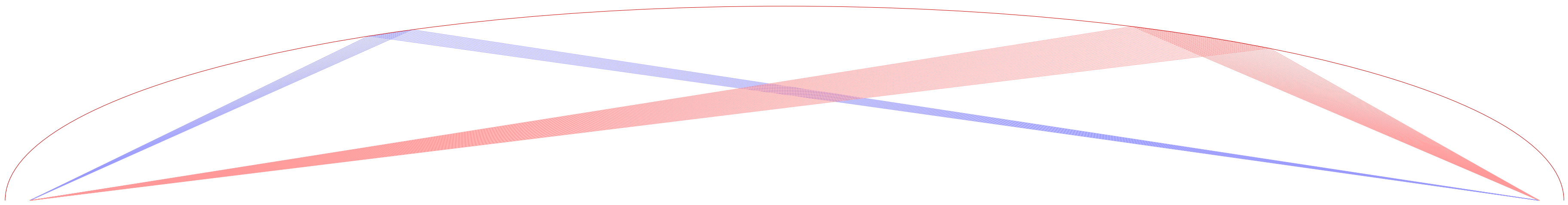


+ flux gain > 10

+ fast screening of parameter space $(T, \mathbf{H}, \mathbf{E}, \ldots)$

still possible for high background (*finger print*) point source at focal point:

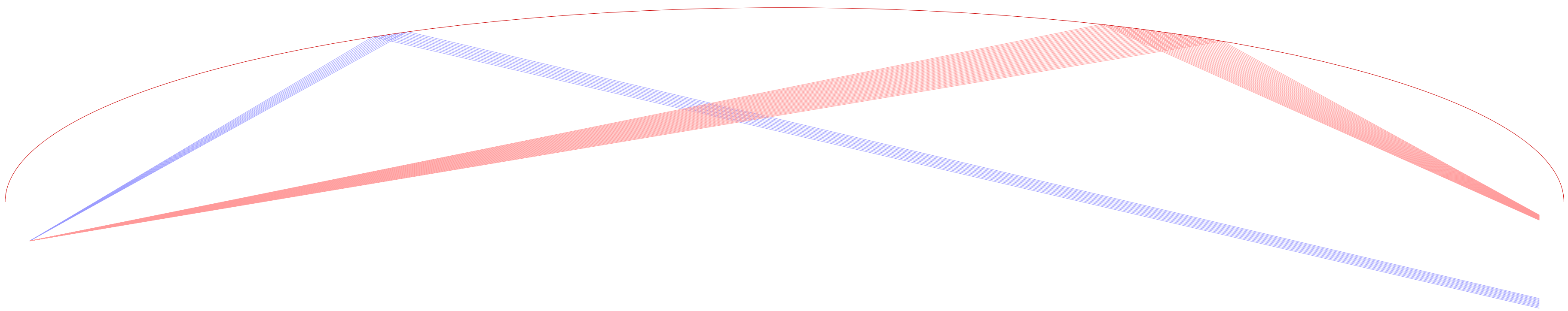
∘ intensity is a function of θ



point source off focal point:

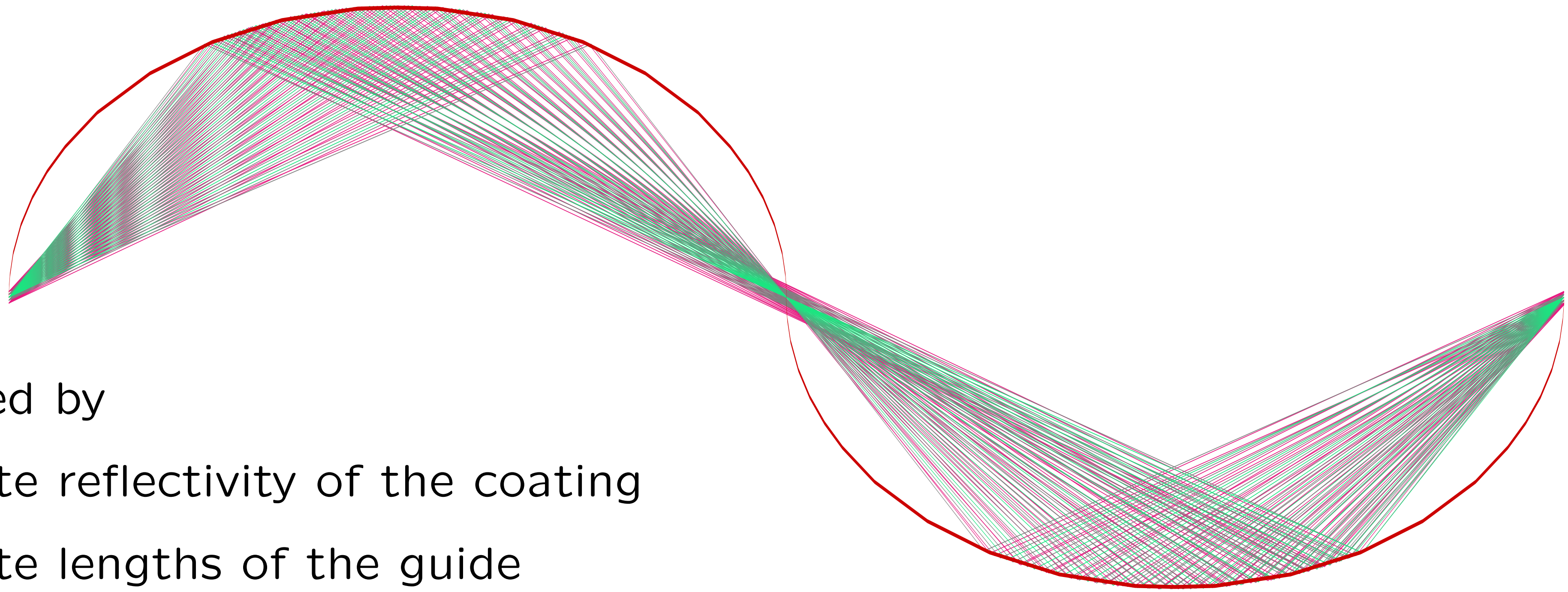
∘ coma effect: image is blurred

∘ defocusing / focusing in the early / late part of the ellipse



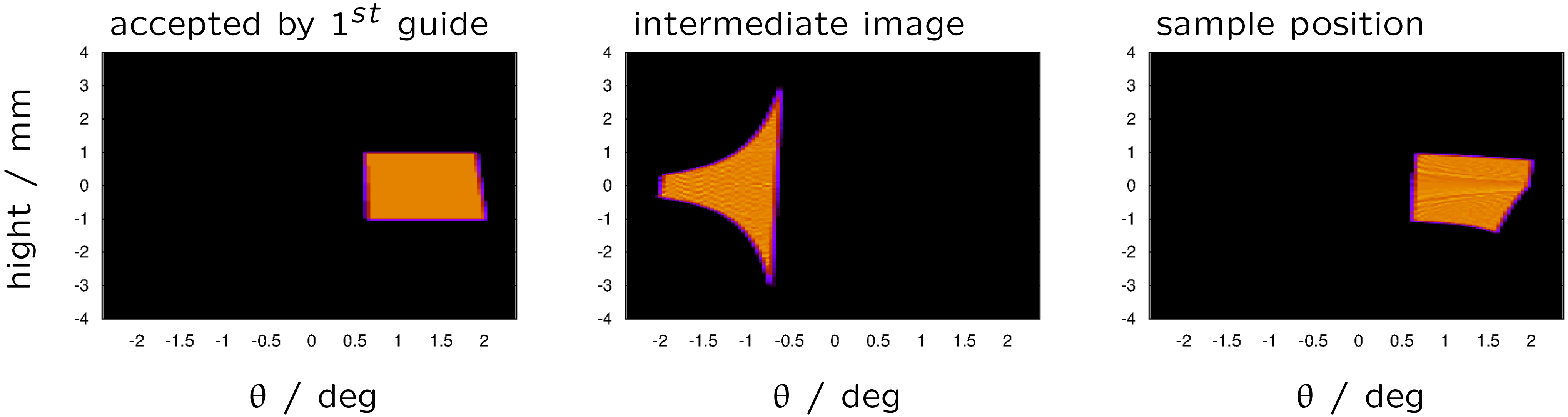
aberration of elliptic guides

correction for coma aberration:



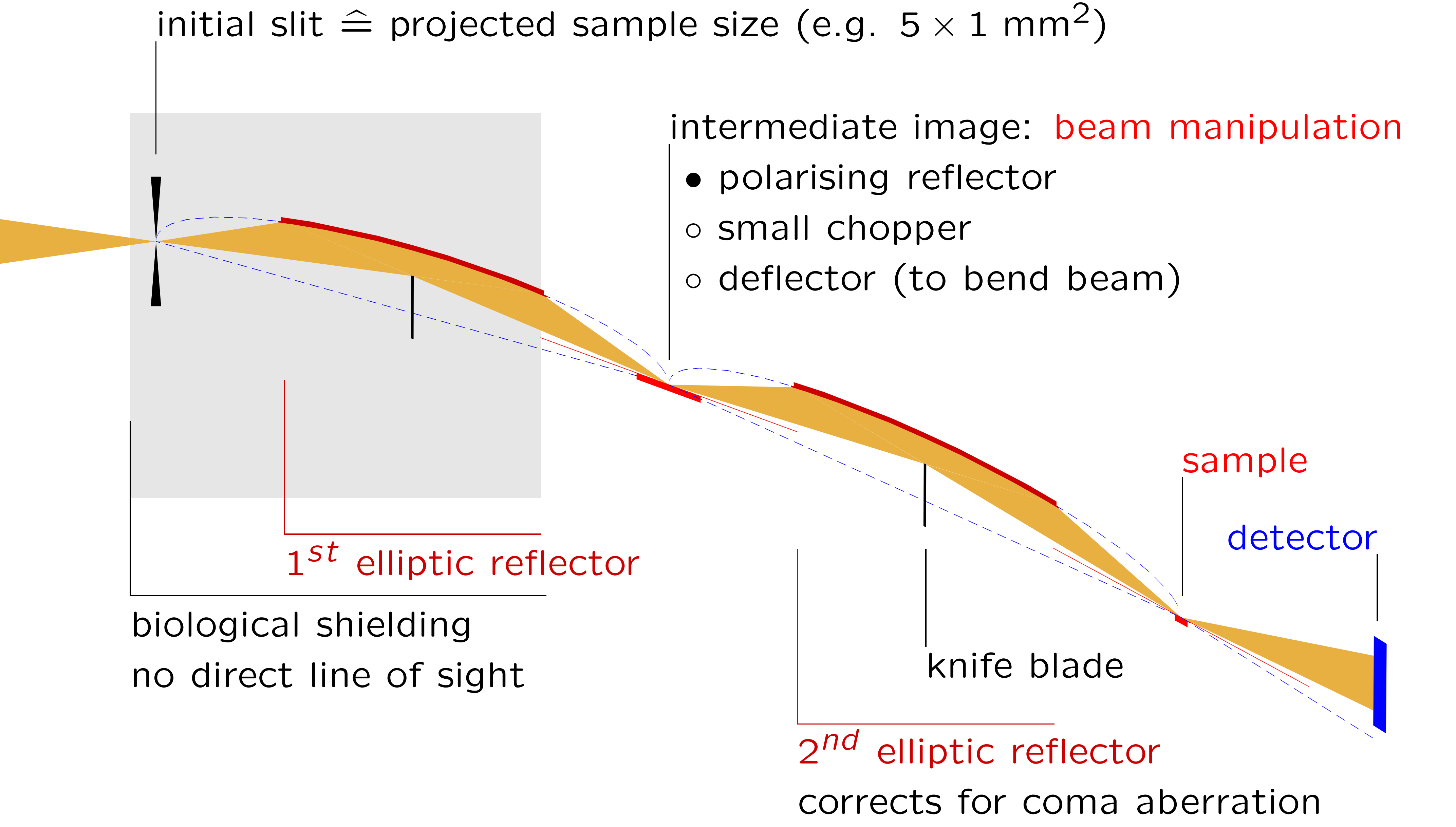
limited by

- finite reflectivity of the coating
- finite lengths of the guide



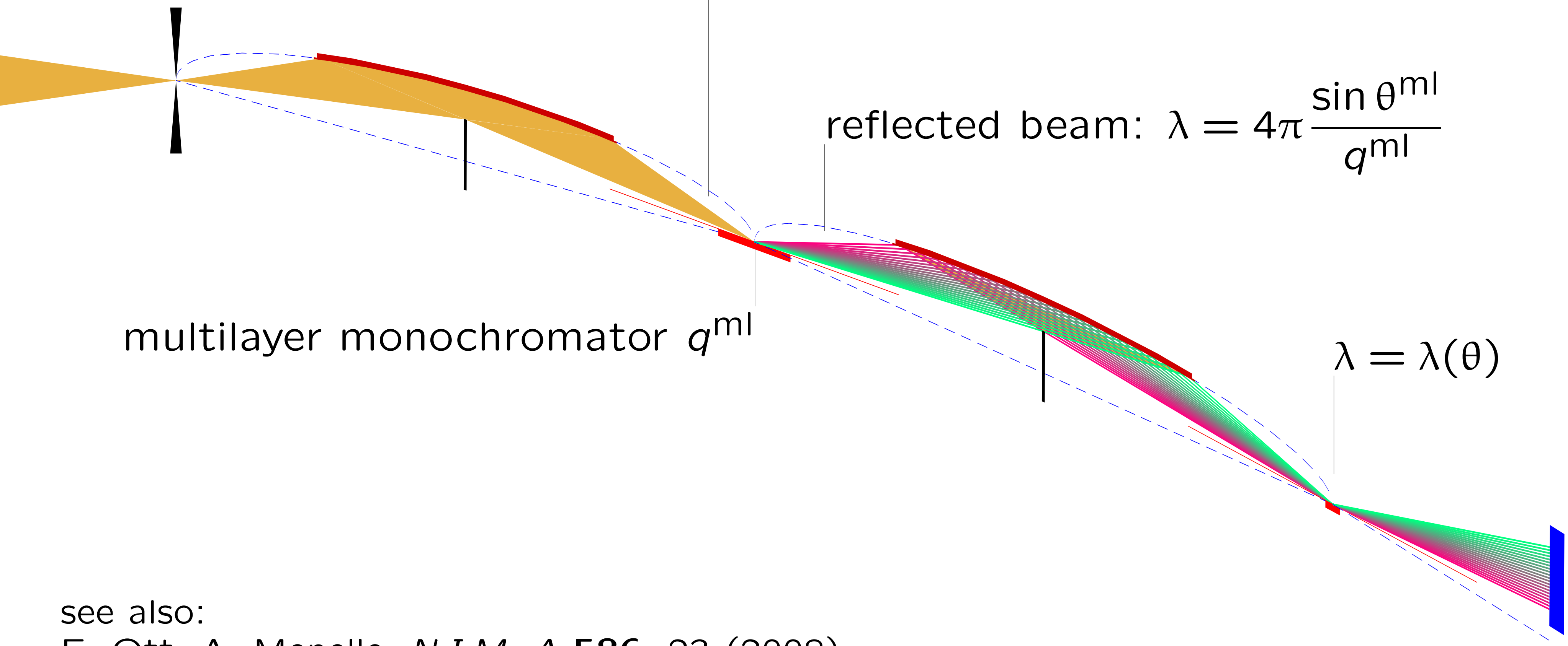
cut in the scattering plane

stretched by 10 normal to incident beam



- λ - θ encryprion

for each 2θ one q_z is probed



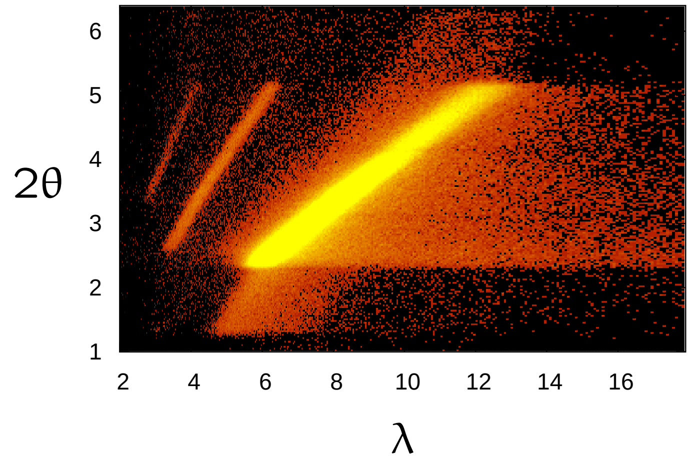
see also:

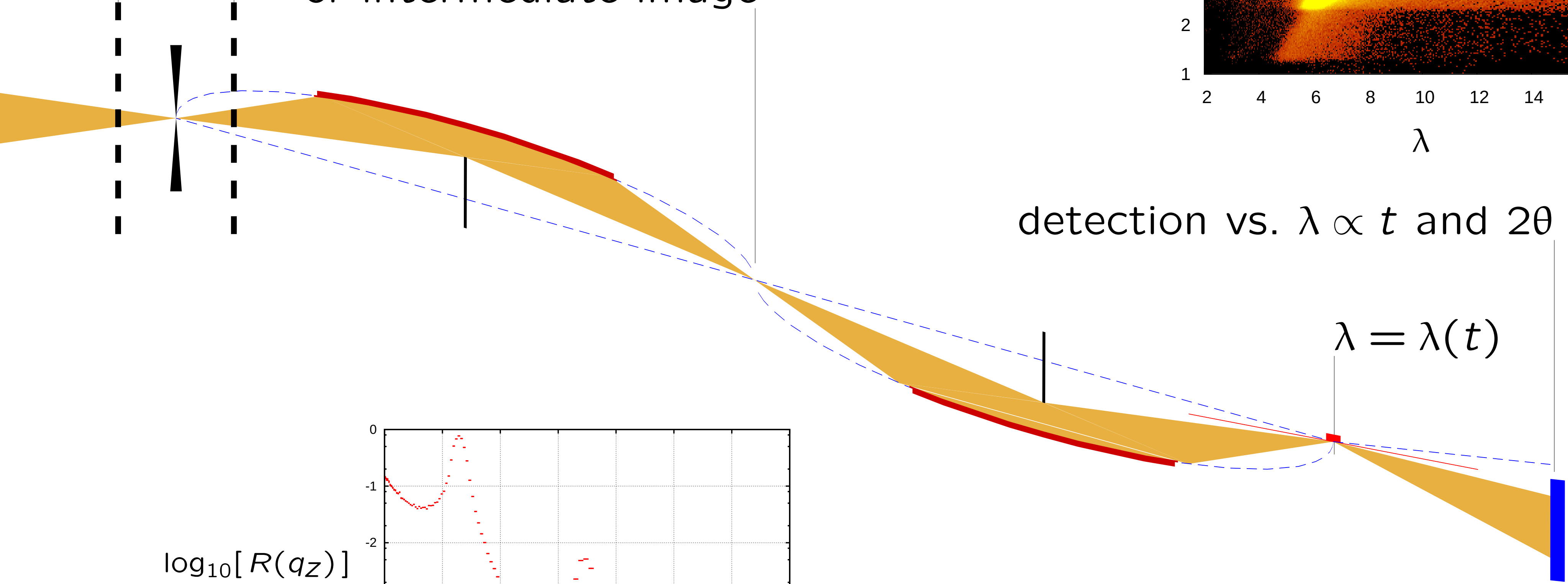
F. Ott, A. Menelle, *N.I.M. A* **586**, 23 (2008)

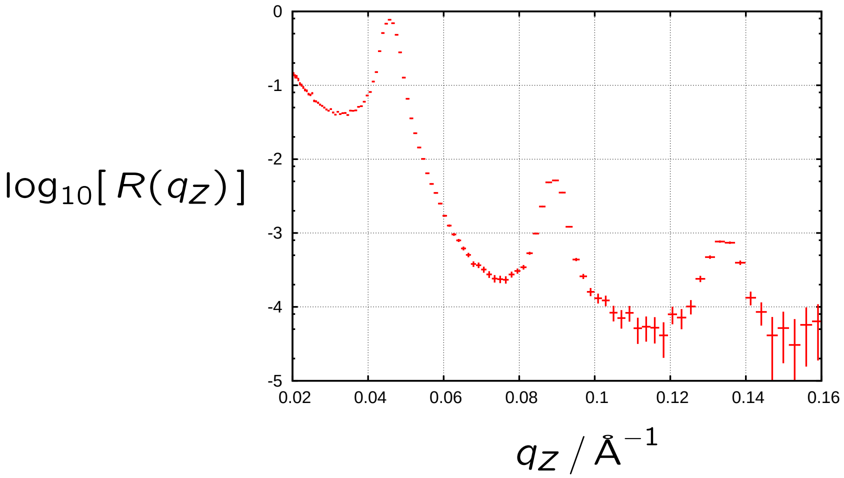
F. Ott, A. Menelle, *Euro. Phys. J.* **167**, 93 (2009)

- TOF mode

for each 2θ a $R(q_z)$ curve is measured

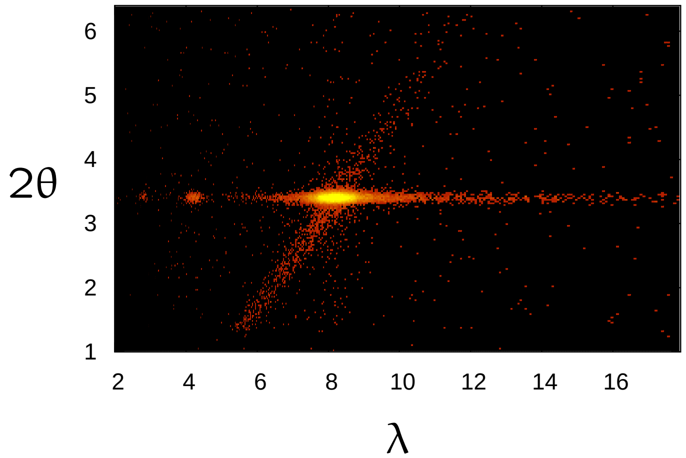


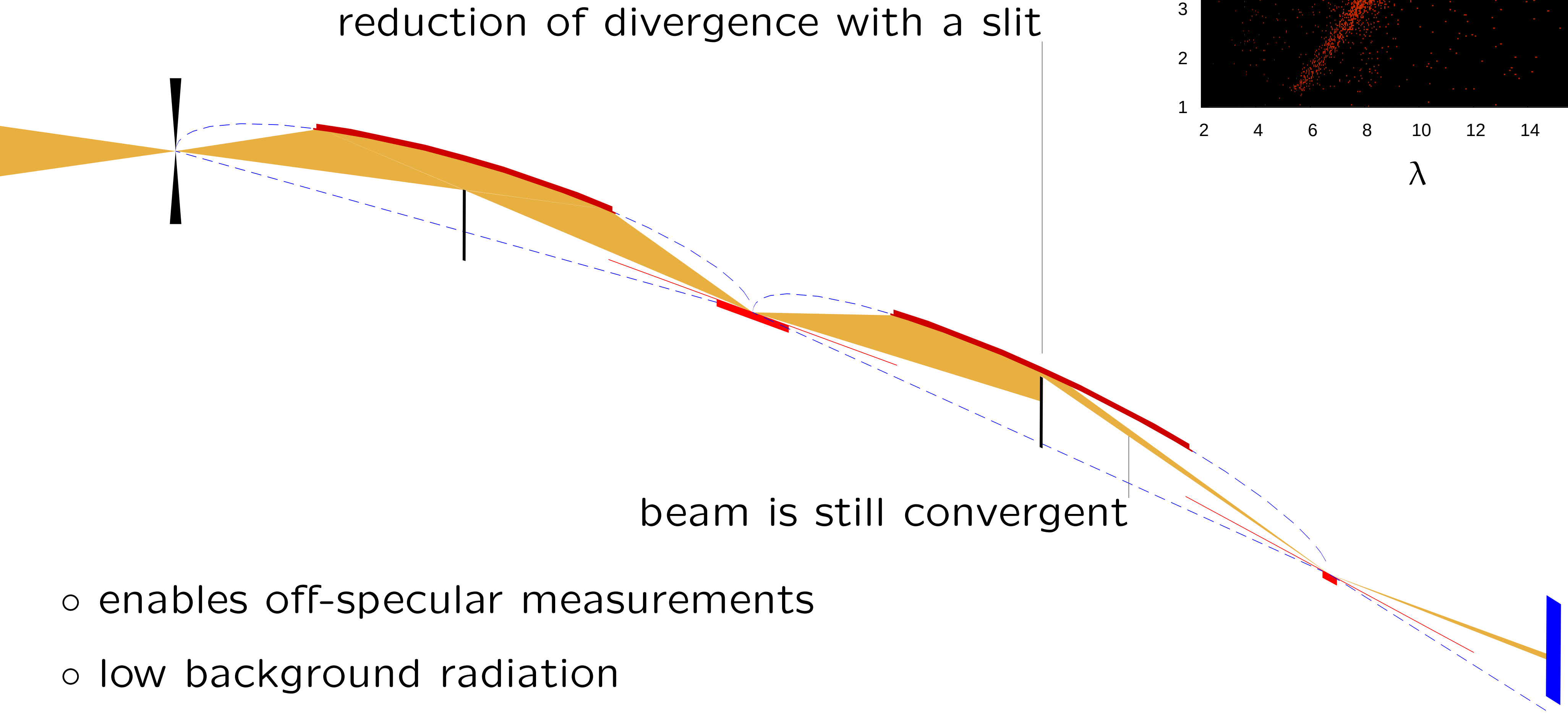




operation modes

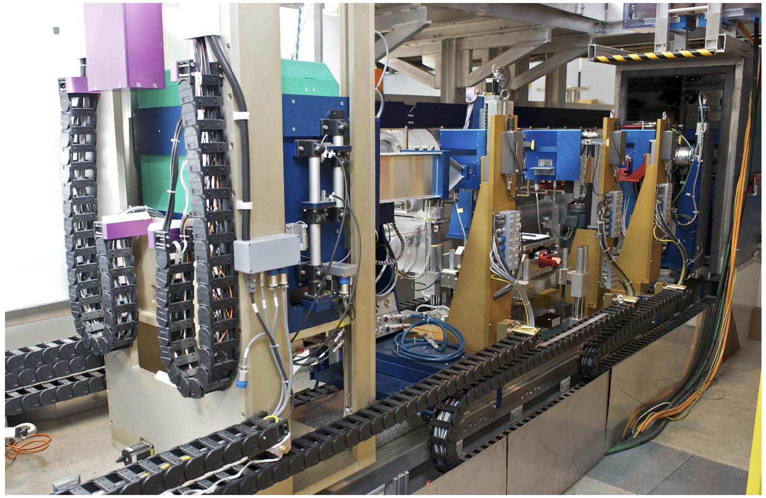
- conventional (*allmost* slit-defined)



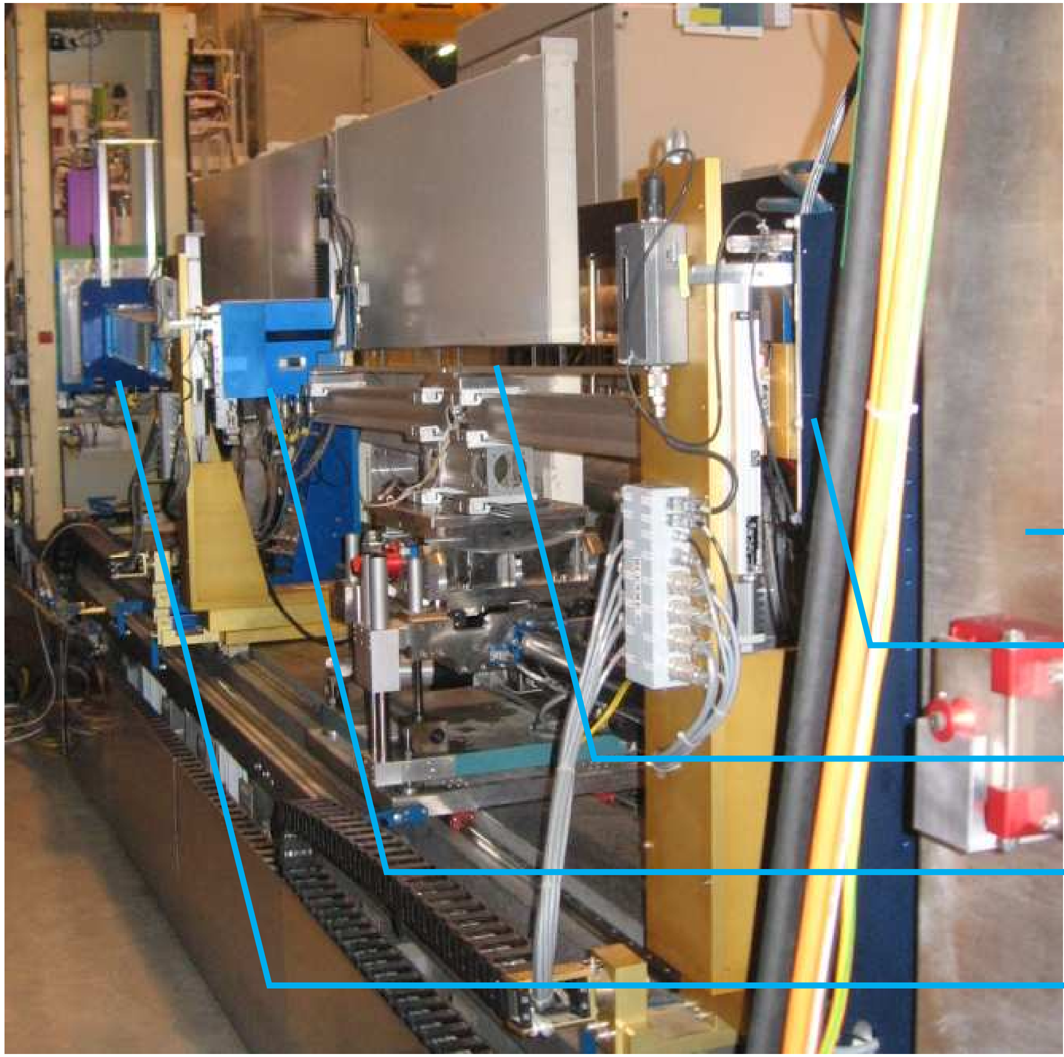


- ◦ enables off-specular measurements
- ◦ low background radiation
- ◦ compatibel with all beam manipulations

○ vertical reflectometer on an optical bench



○ set-up with *Selene* reflector:



choper housing

1^{st} slit

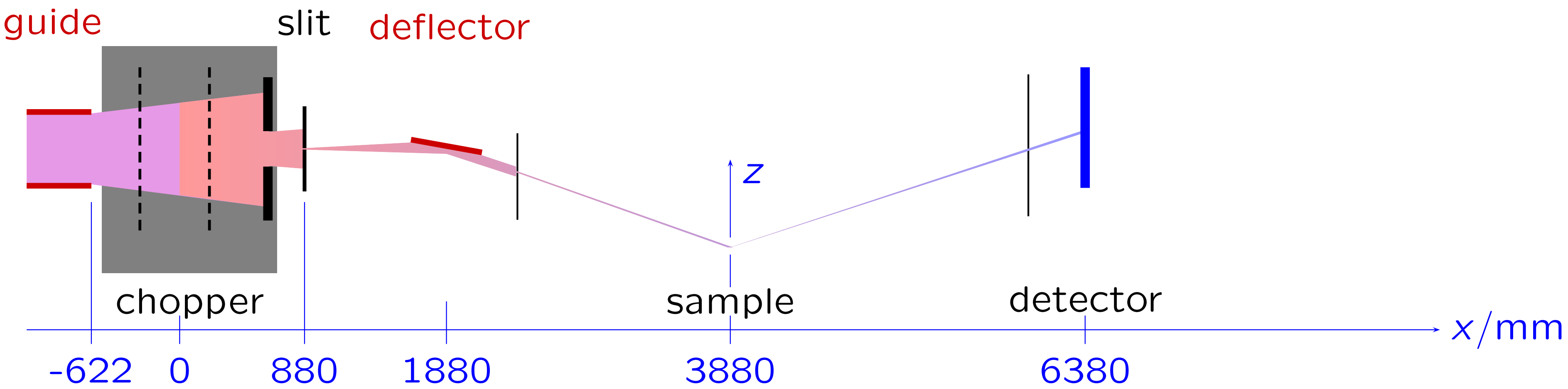
elliptic reflector (SwissNeutronics)

sample (hidden by diaphragm)

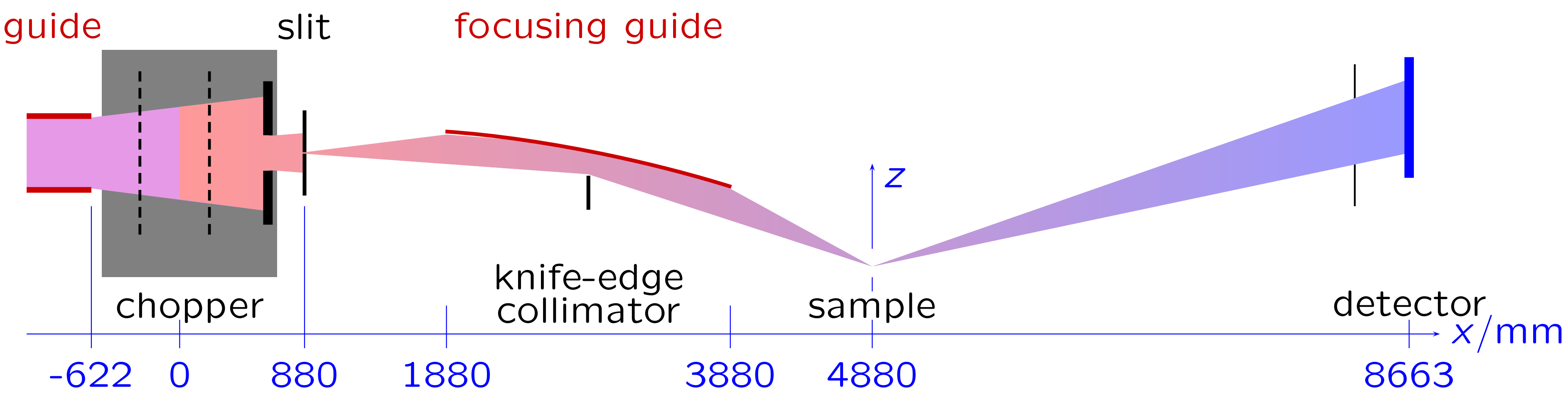
detector

TOF mode:

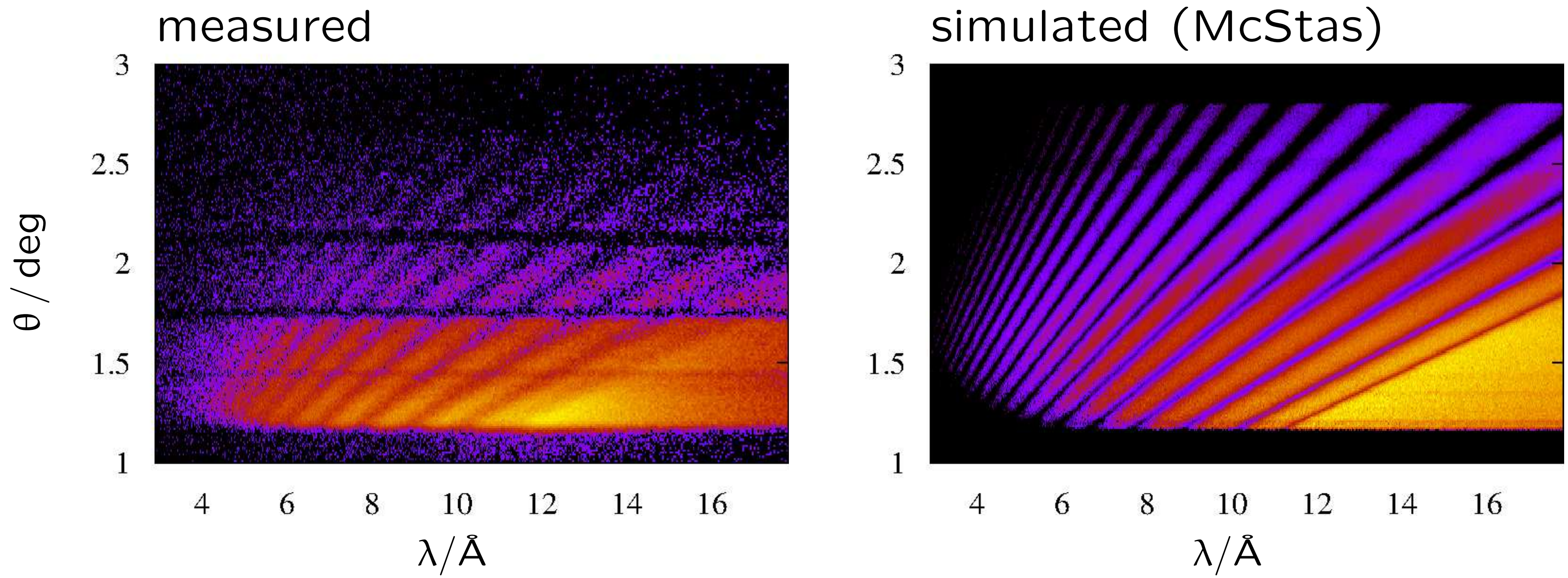
conventional set-up

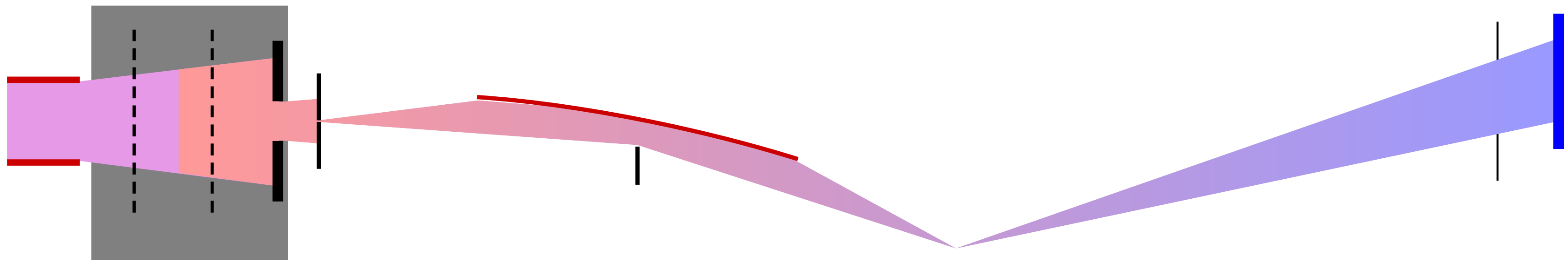


Selne set-up

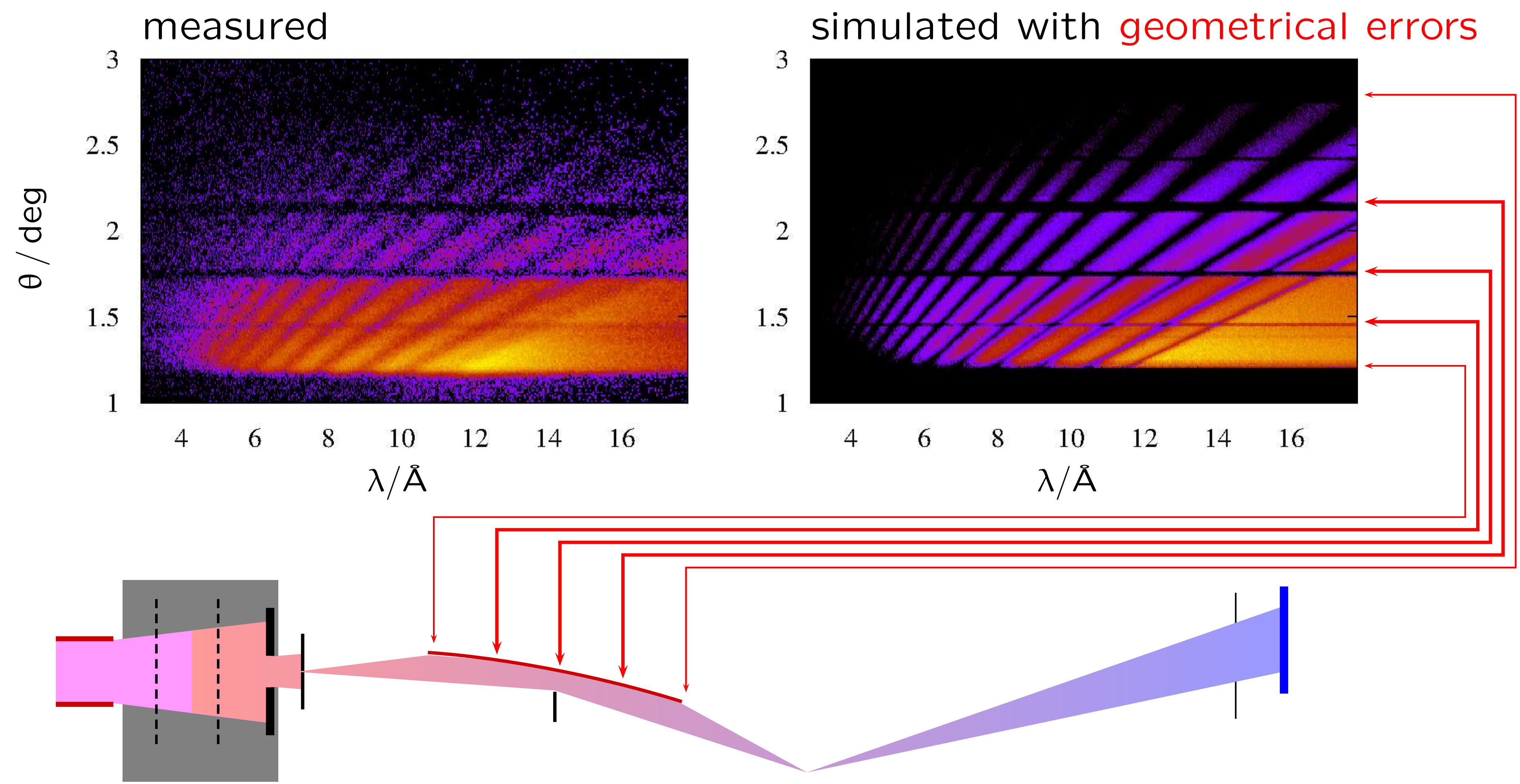


TOF mode sample: 1000 Å Ni on glass



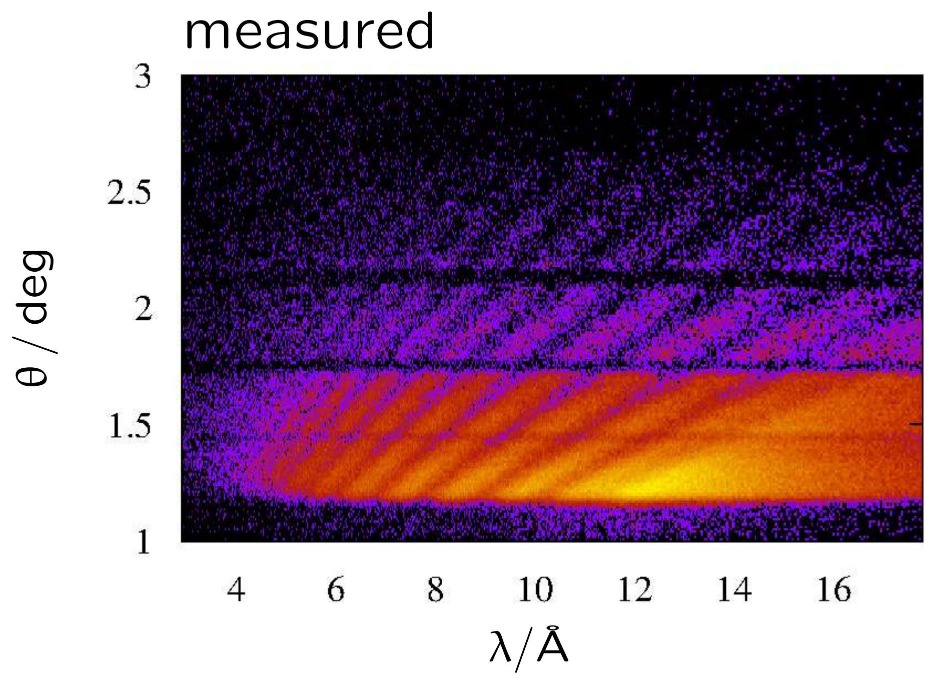


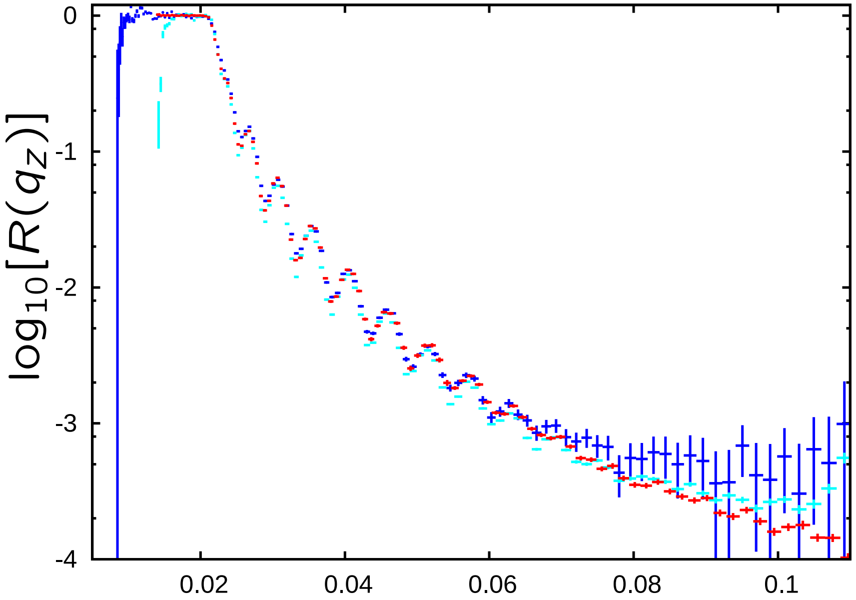
TOF mode   sample: 1000 Å Ni on glass

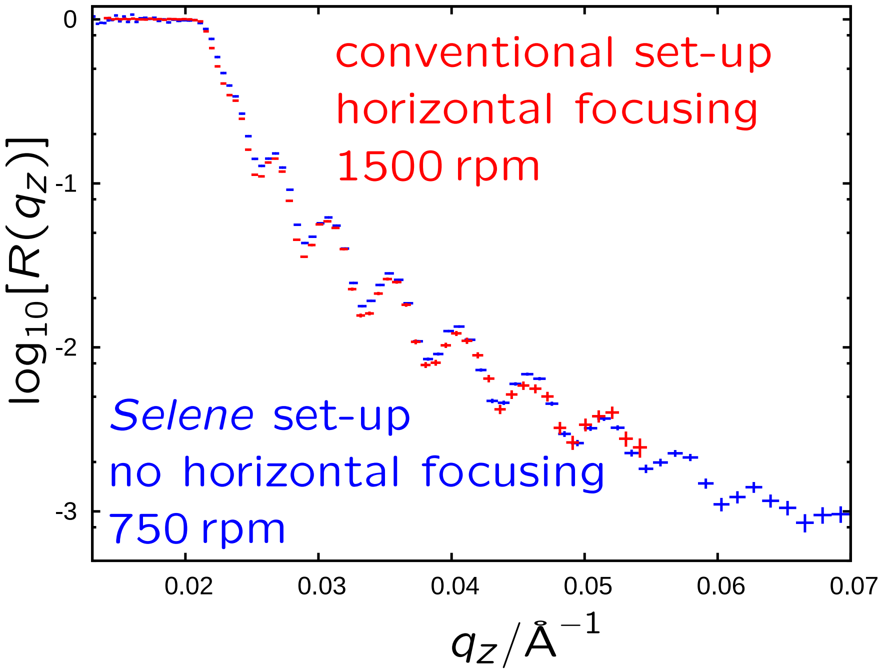


4 guide elements à 500 mm

TOF mode   sample: 1000 Å Ni on glass





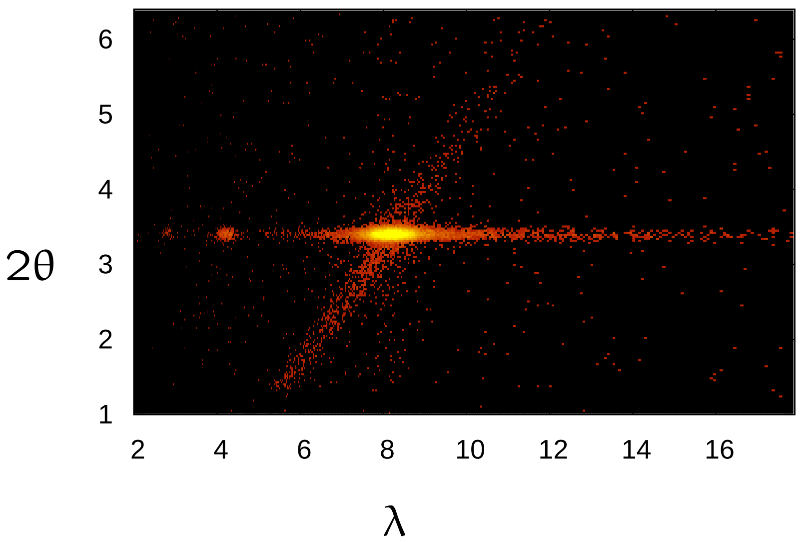


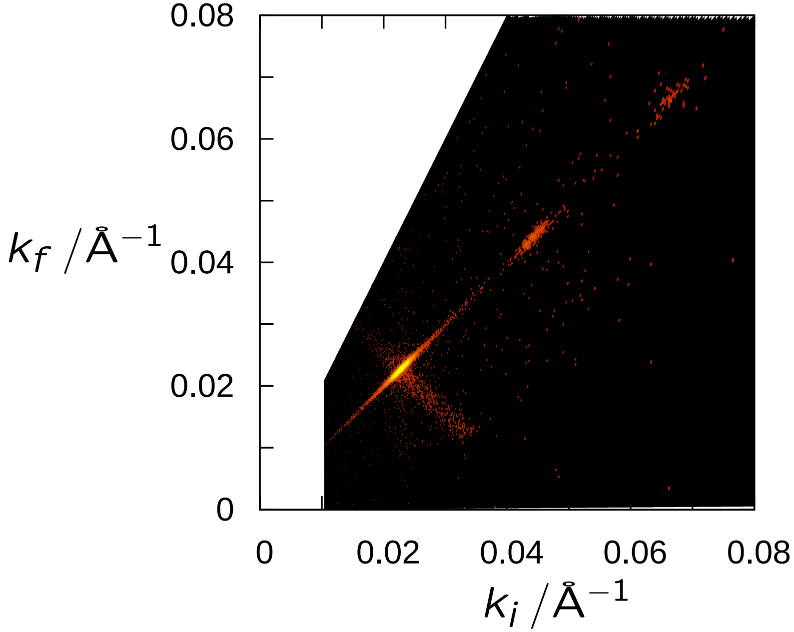
measurement time:

conventional	5 h
Selene	45 min
gain-factor	6.7

experiments on Amor

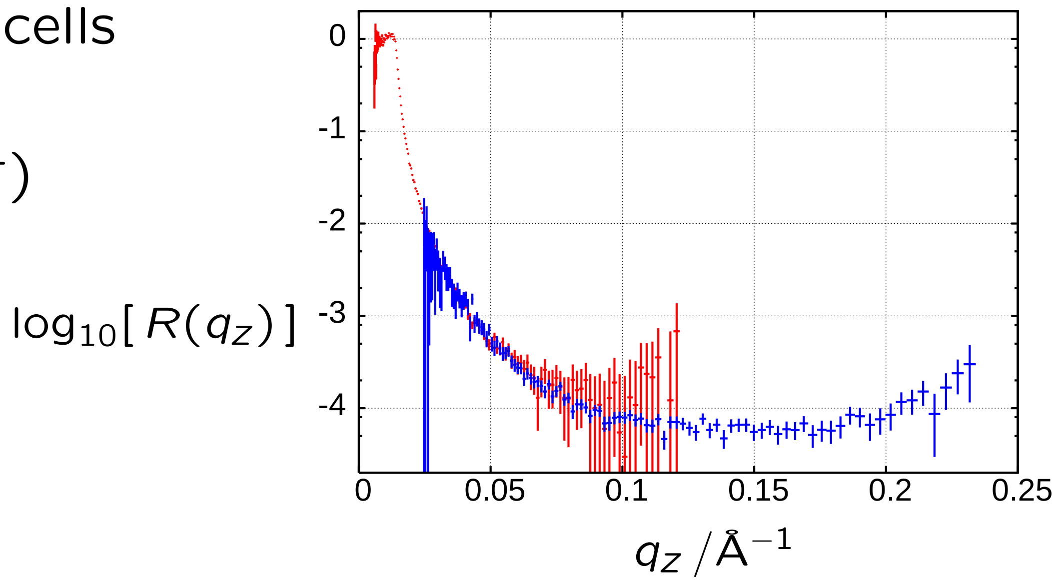
- off-specular scattering can be measured by reducing the divergence:





- measurements with solid/liquid cells have not been successfull: background was too high ($\approx 10^{-4}$) for unclear reasons

D_2O / Si



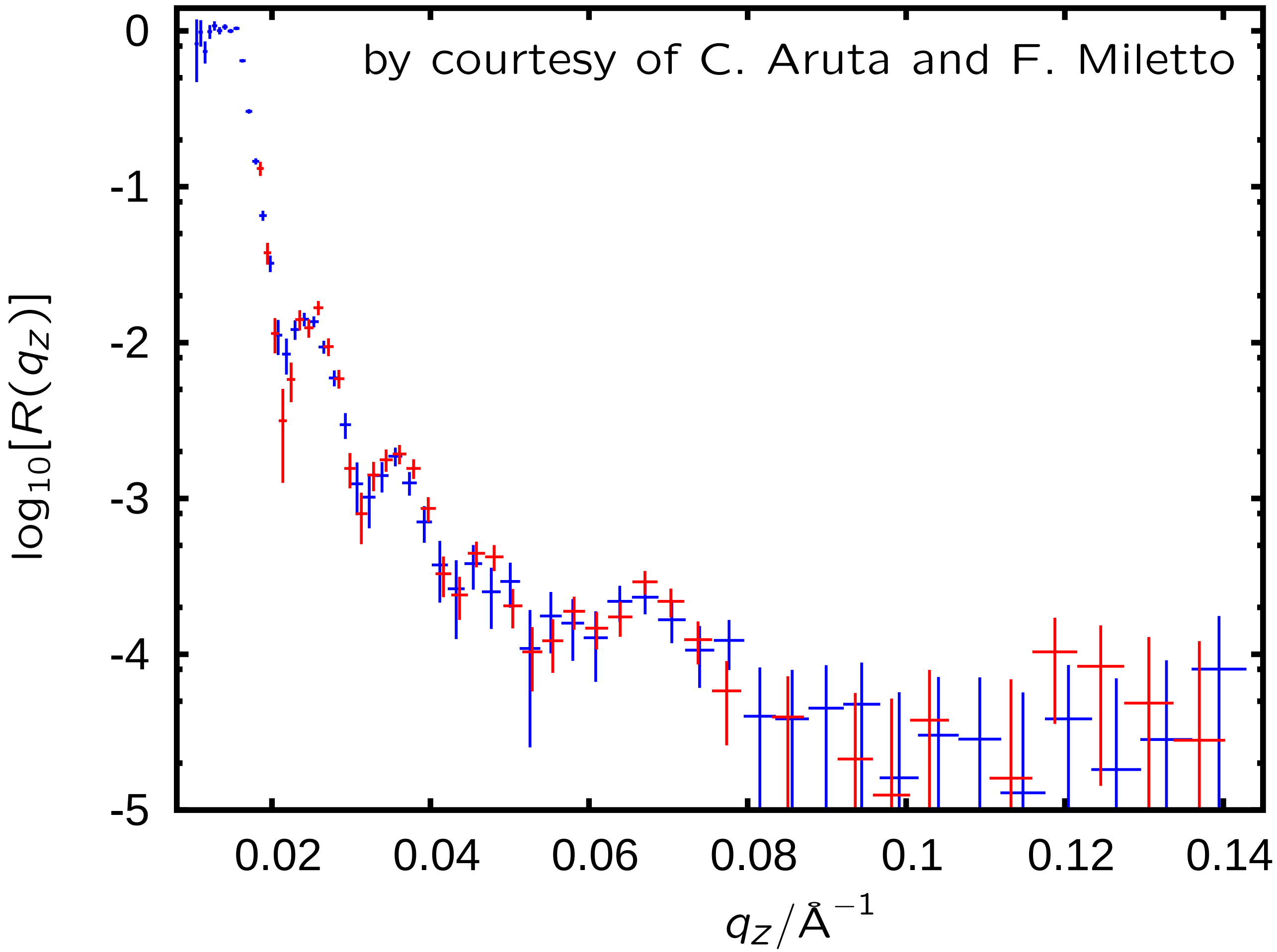
TOF mode

sample: $[\mathrm{La}_{2/3}\mathrm{Sr}_{1/3}\mathrm{MnO}_3 \,/\, \mathrm{SrTiO}_3]_4 \,/\, \mathrm{NGO}$
sample-size: $4 \times 5\ \mathrm{mm}^2$

no focusing in sample plane
TOF mode, $\lambda \in [2 \ldots 18\ \text{Å}]$

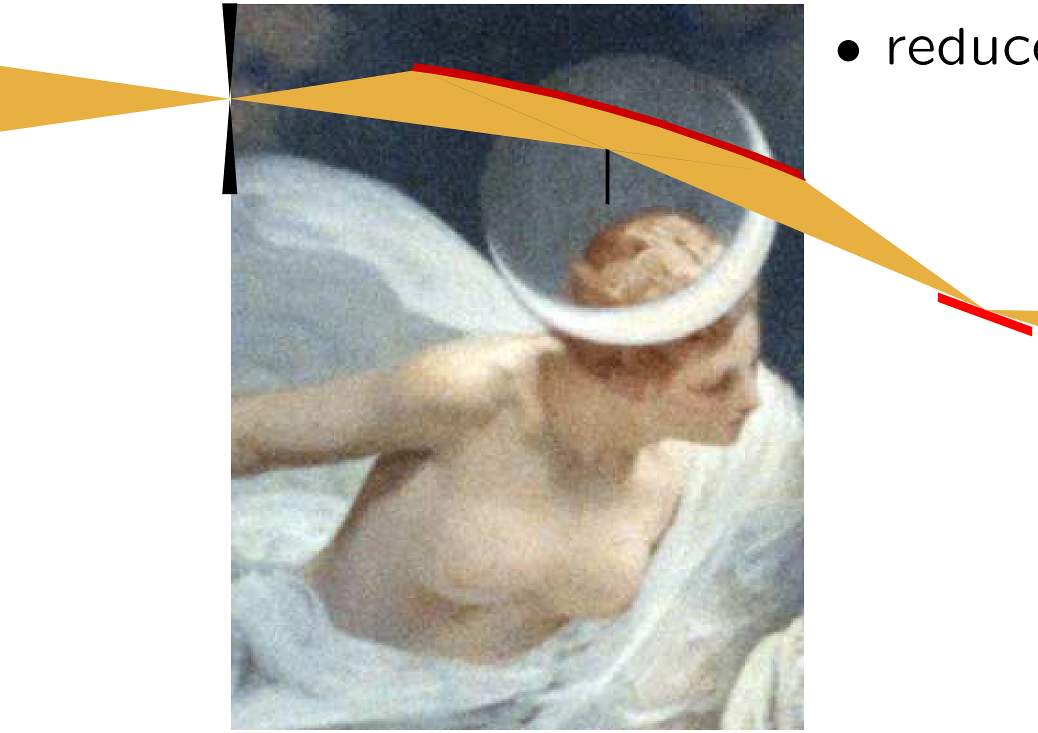
measurement time:

conventional	6.5 h
Selene	45 min
gain-factor	8.3



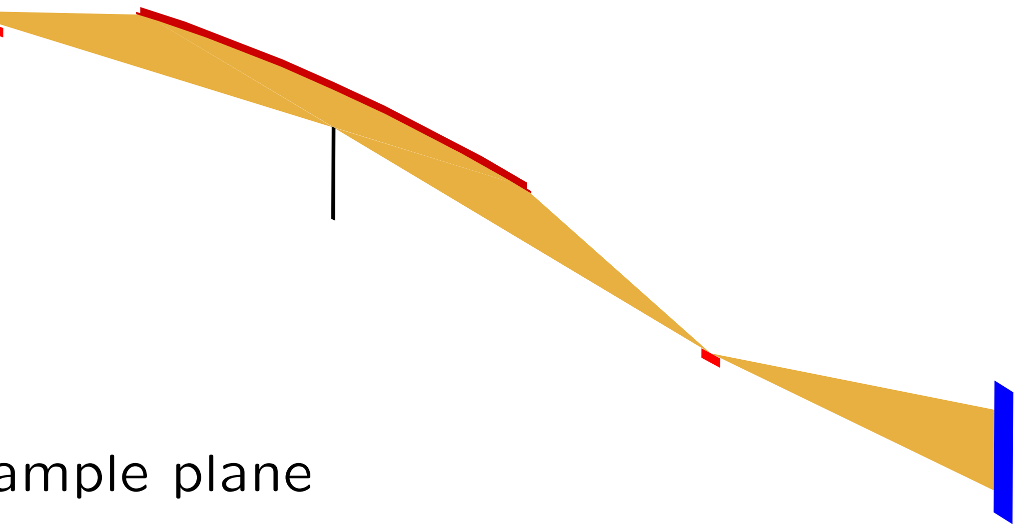
Selene is a guide concept which

- prevents direct line of sight
- reduces radiation in the guide
- allows for convenient beam manipulation



- reduces illumination of the sample environment
- allows for a convergent beam set-up

$\Rightarrow$ flux gain > 10



combination with focusing in the sample plane

- beam spot of the order of $2 \times 0.5\ \mathrm{mm}^2$ within reach
- flux gain > 100 for high-intensity specular reflectometry

Reflectometer(s) with

defined by ESS

sample plane	horizontal	vertical
resolution	$\Delta q_z / q_z \in [1\%, 10\%]$	
q_z-range	$[-0.5\,\text{Å}^{-1}, 0.5\,\text{Å}^{-1}]$ (2 to 3 settings)	$[0\,\text{Å}^{-1}, 0.5\,\text{Å}^{-1}]$
sample size	$10 \times 10\,\text{mm}^2$	$< 5 \times 5\,\text{mm}^2$
options	full polarisation, GISANS	
	troughs	cryomagnets

- focusing in the sample plane, and
- a convergent beam in the scattering plane

pro: allows for high-intensity specular reflectometry (gain-factor > 10)
can be operated as a conventional reflectometer
convenient beam manipulation
low background along the guide and at the sample

con: low flexibility