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concept for a
reflectometer for the ESS
with
focusing in sample
and scattering plane



Selene

Workshop on off-specular neutron scattering
09.–10. 01. 2012, Bruxelles, Belgium

outline

slit optics vs. focusing optics

small samples

- focusing with elliptic guides**
- coma aberration
 - operation modes

realisation

	add-on for Amor → experimental results
	2D prototype for BOA
	concept for the ESS

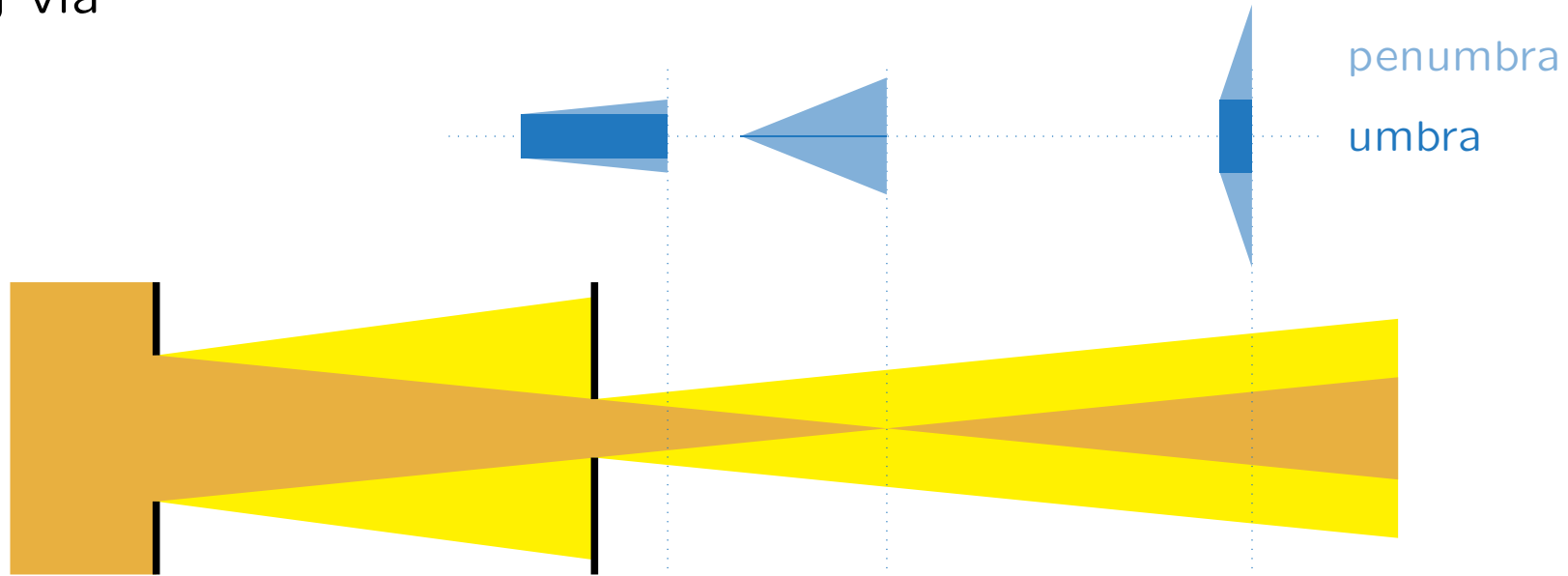
3D reflectometry		$R(q_z, q_x)$ (conventional)
		$R(q_z, y)$ (scan of the sample surface)
		parallel beam (for GISANS)
		spin-echo type add-ons / spatial constraints

slit vs. focusing optics

slit vs. focusing optics

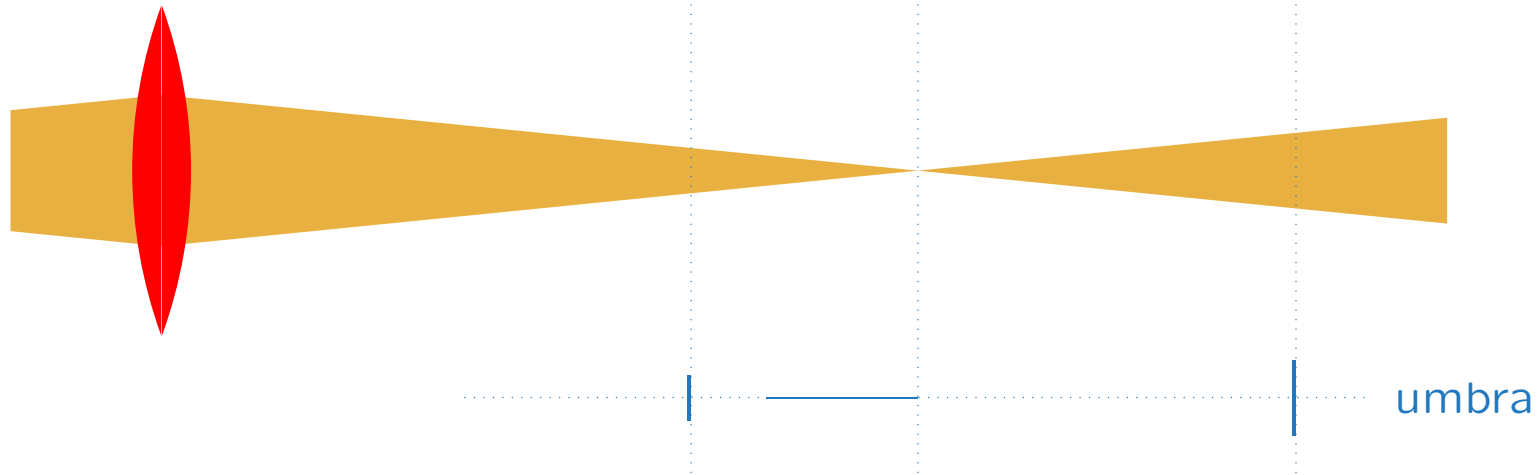
focusing via

slits



beam profile

reflective /
refractive optics

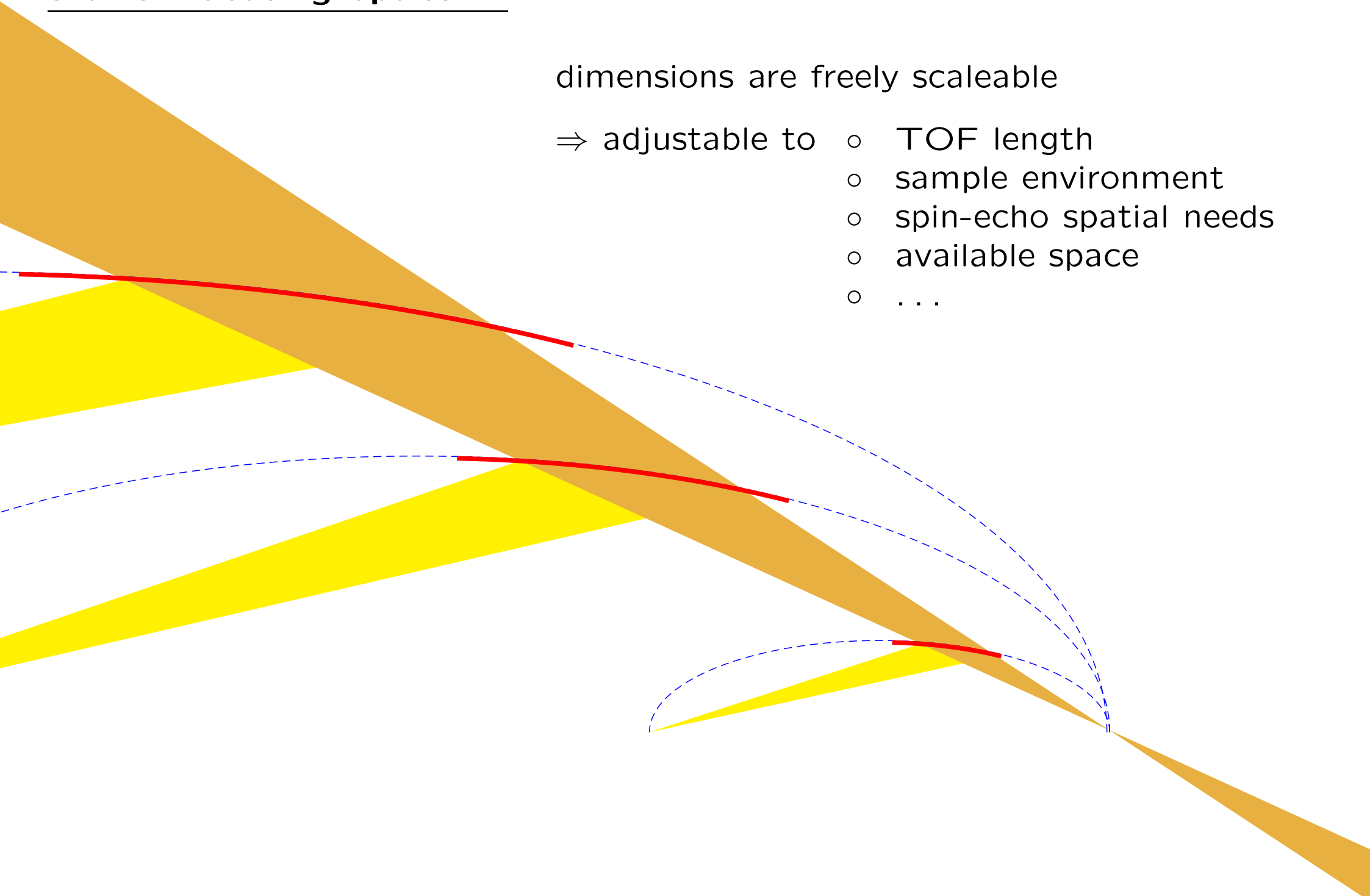


beam profile

slit vs. focusing optics

dimensions are freely scaleable

- ⇒ adjustable to
- TOF length
 - sample environment
 - spin-echo spatial needs
 - available space
 - ...

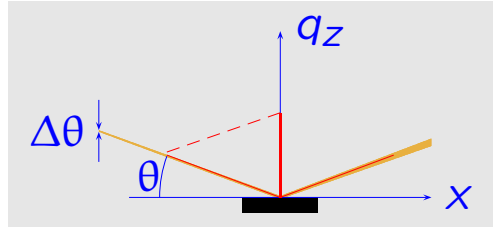


slit vs. focusing optics

focusing for high-flux specular reflectometry

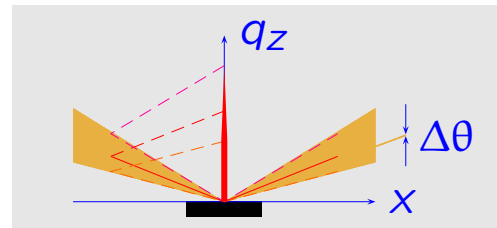
slit-defined beam:

- θ -dispersive, **or**
- λ -dispersive,
- resolution given by $\Delta\lambda$ and $\Delta\theta$



convergent beam:

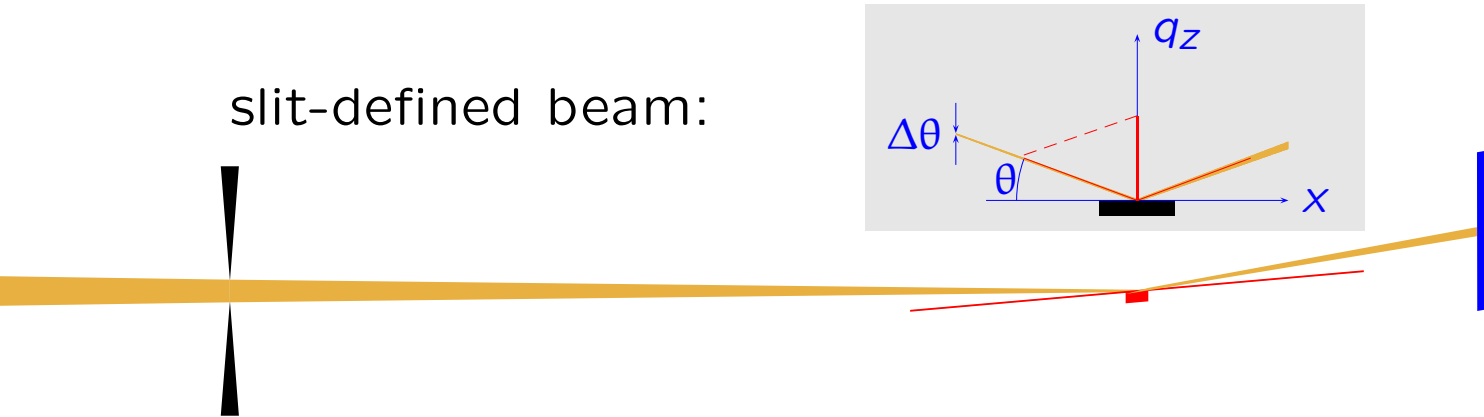
- θ -dispersive **and**
- λ -dispersive,
- resolution given by $\Delta\lambda$ and detector



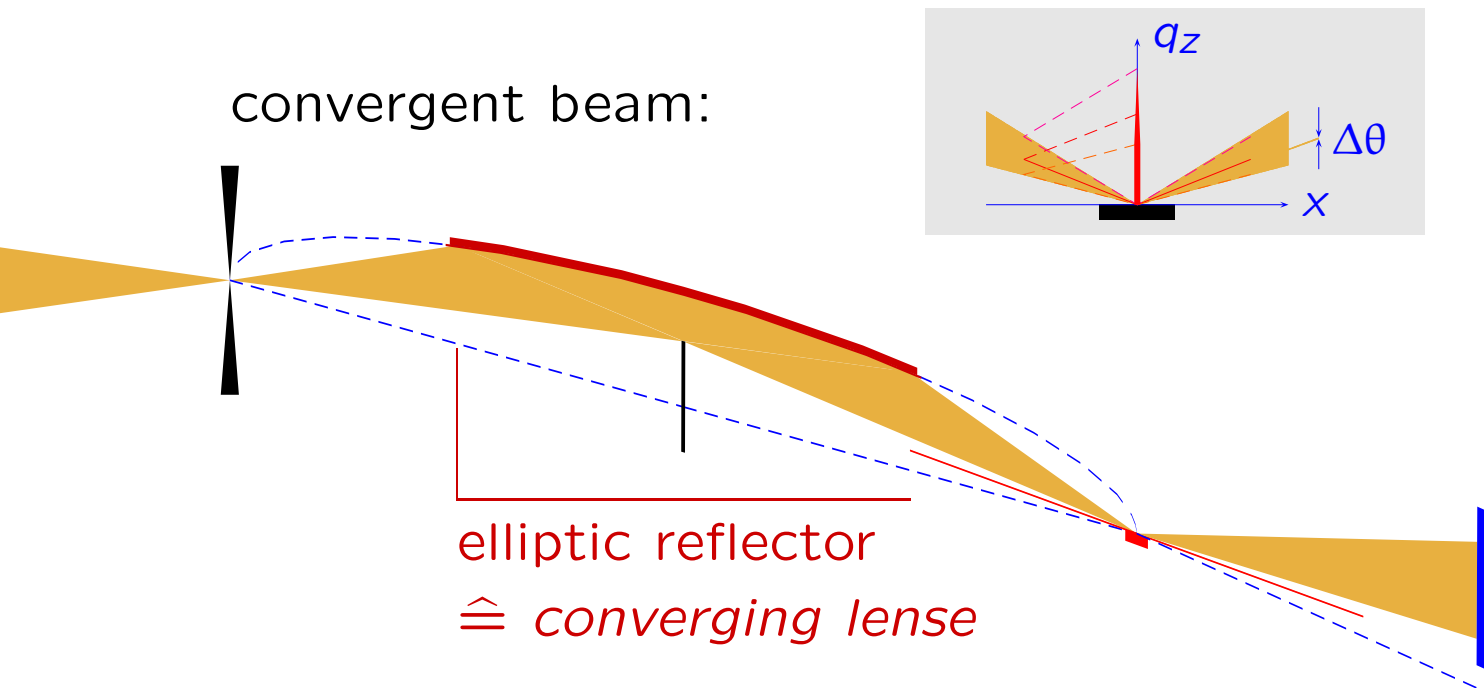
slit vs. focusing optics

focusing for high-flux specular reflectometry

slit-defined beam:



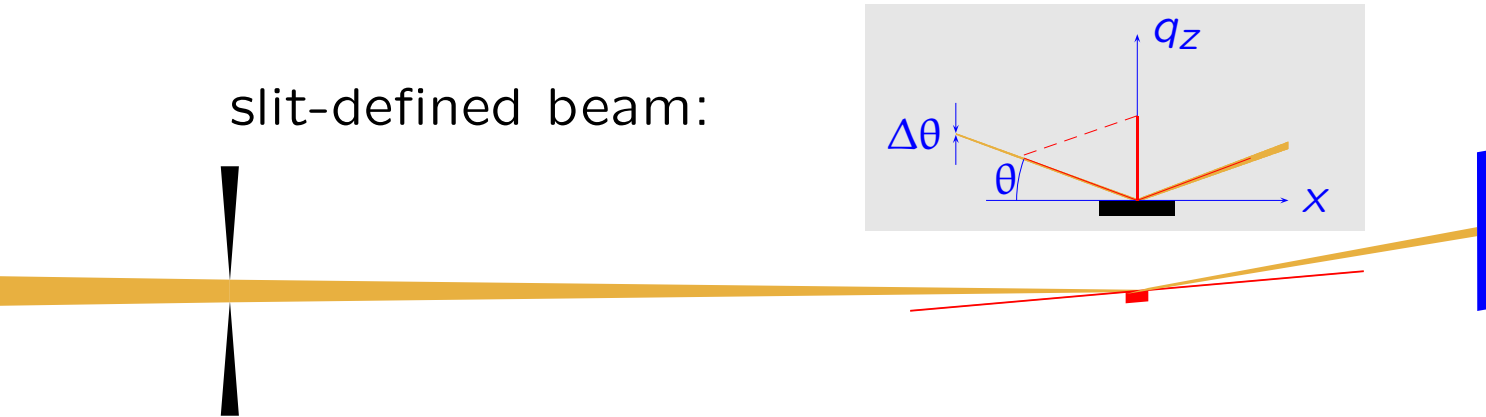
convergent beam:



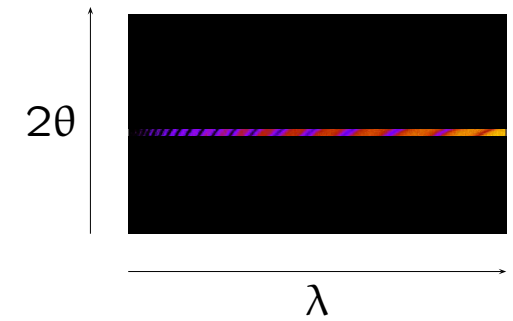
slit vs. focusing optics

focusing for high-flux specular reflectometry

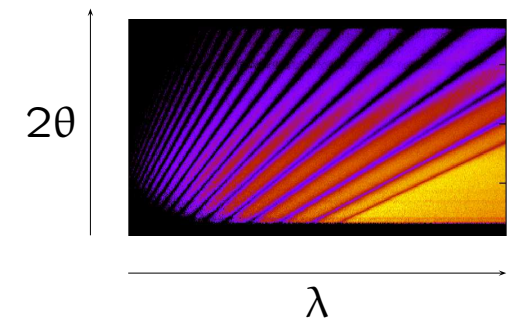
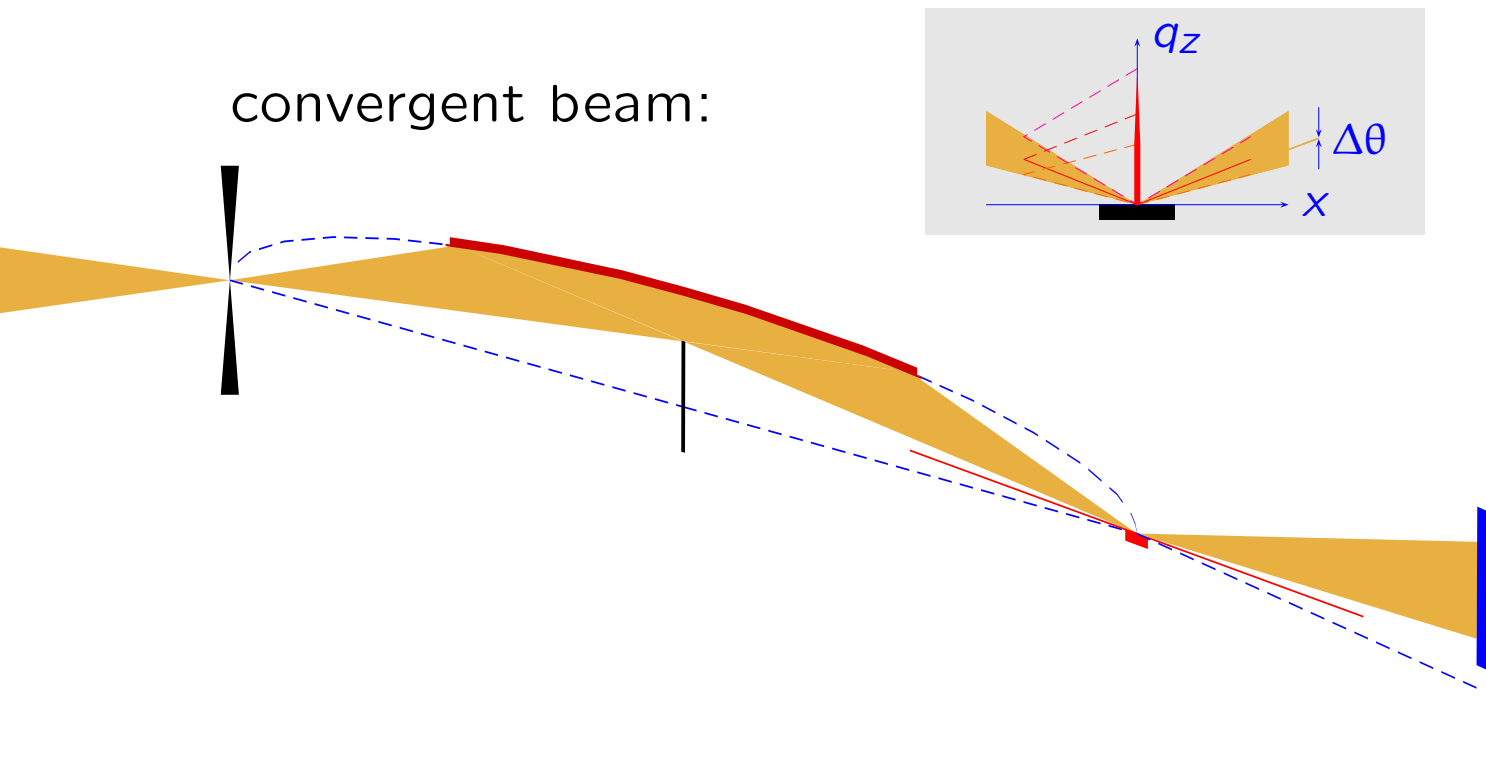
slit-defined beam:



TOF operation



convergent beam:



small samples

small samples

i.e. **samples smaller than the beam**

- e.g.
- PLD-grown samples
 - laterally structured films
 - functional devices
 - samples compatible with x-ray or magnetometry environments

projected height < 1 mm!

Ni/Ti multilayer on Si, $4 \times 3 \text{ mm}^2$

perovskite multilayer on STO, $5 \times 5 \text{ mm}^2$



small samples

i.e. **illumination of a defined area, only**

- e.g.
- inner region within a trough
 - inner region of a **solid-liquid cell**:
 - samples with electrical contacts
 - partially coated substrates
 - bent substrates



footprint < substrate typical dimensions: $10 \times 10 \text{ mm}^2$ to $20 \times 40 \text{ mm}^2$

i.e. **latteraly inhomogeneous samples**

- e.g.
- structured materials
 - samples with (large) domains

footprint $\ll$ substrate

typical dimensions: $0.1 \times 10 \text{ mm}^2$

⇒ scanning of sample area

focusing with elliptic guides

real focusing!

$\Rightarrow$ pre-image $\longrightarrow$ image

no fancy version of a ballistic guide!

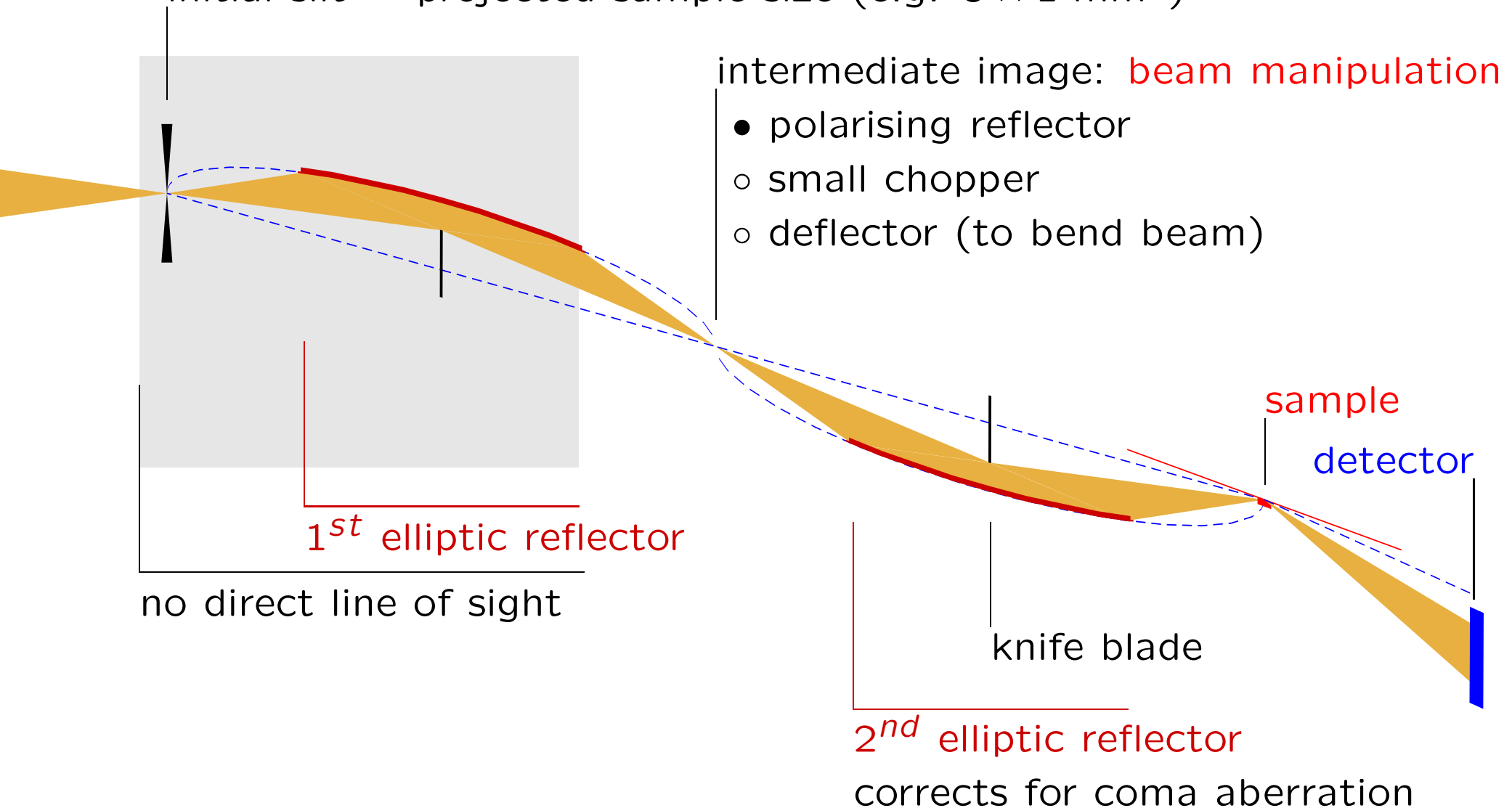
focusing with elliptic guides

generic instrument layout

cut in the scattering plane

stretched by 10 normal to incident beam

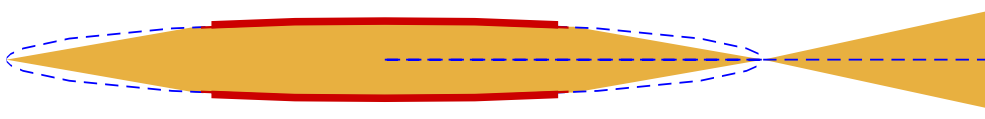
initial slit $\hat{=}$ projected sample size (e.g. $5 \times 1 \text{ mm}^2$)



focusing with elliptic guides

why only one branch of an ellipse?

- no structured $I(\theta, z)$

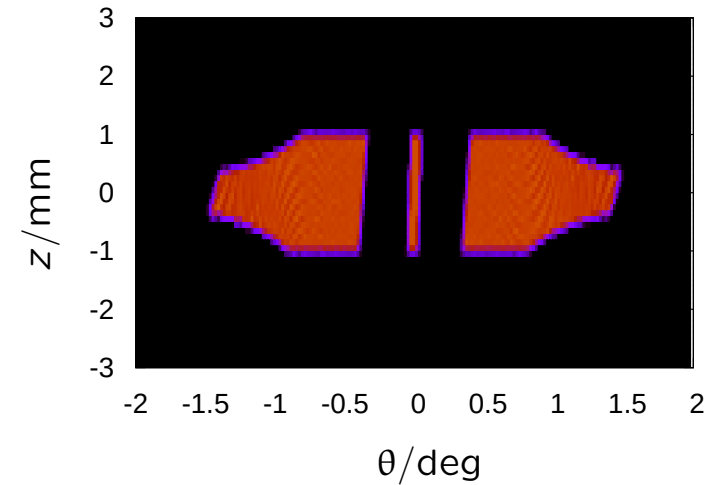


- one branch can cover $\Delta\theta$

why two subsequent elliptic guides?

- convenient beam manipulation
- guide dimensions not too large
- correction for coma aberration!

$I(\theta, z)$ map

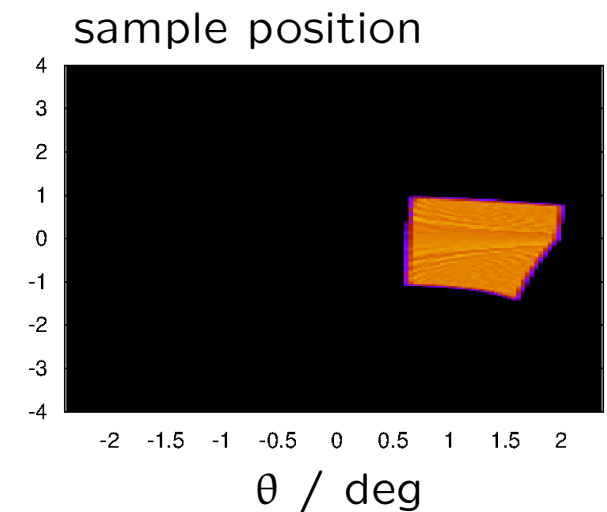
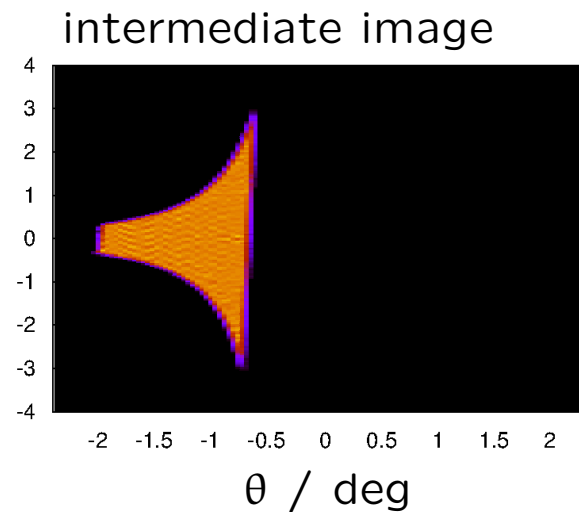
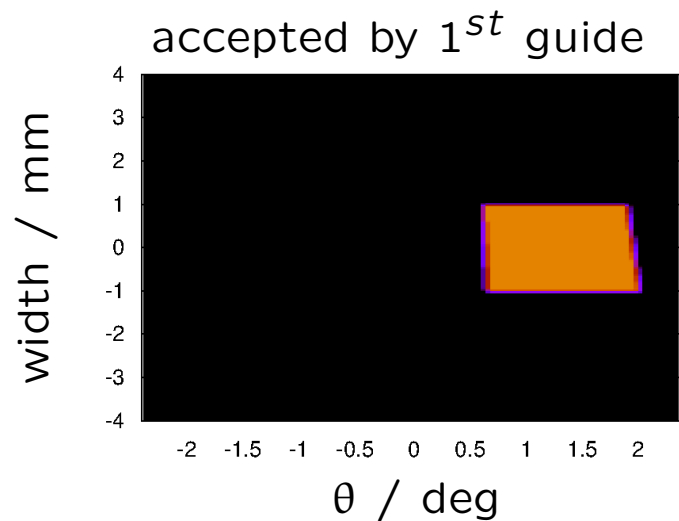
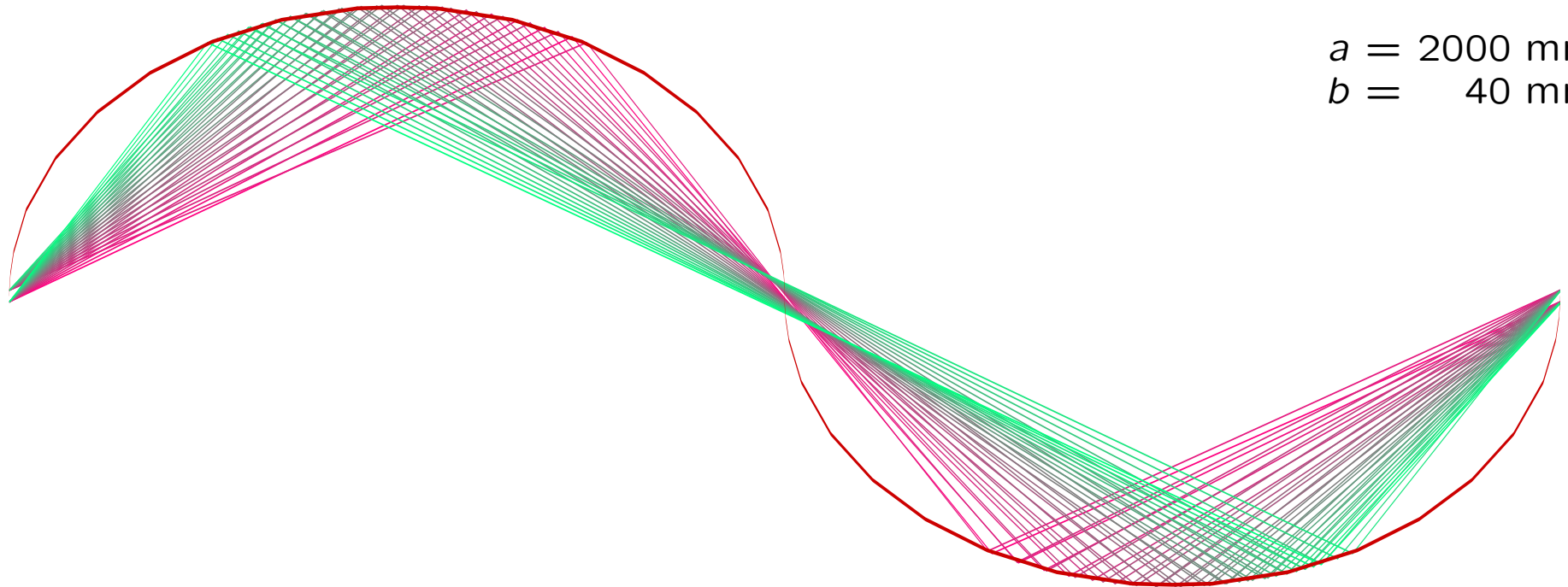


focusing with elliptic guides

coma aberration — and its correction

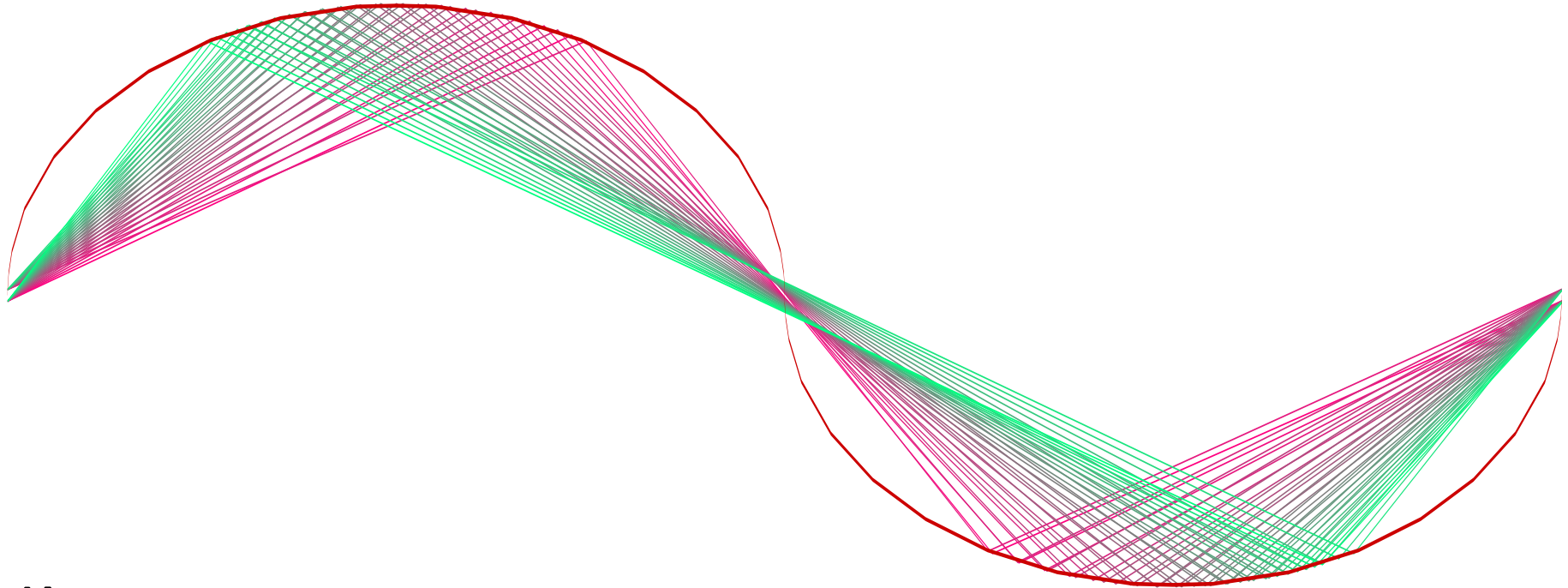
$$a = 2000 \text{ mm}$$

$$b = 40 \text{ mm}$$



focusing with elliptic guides

coma aberration — and its correction



limitations:

- finite length of the guides
- non-perfect coating

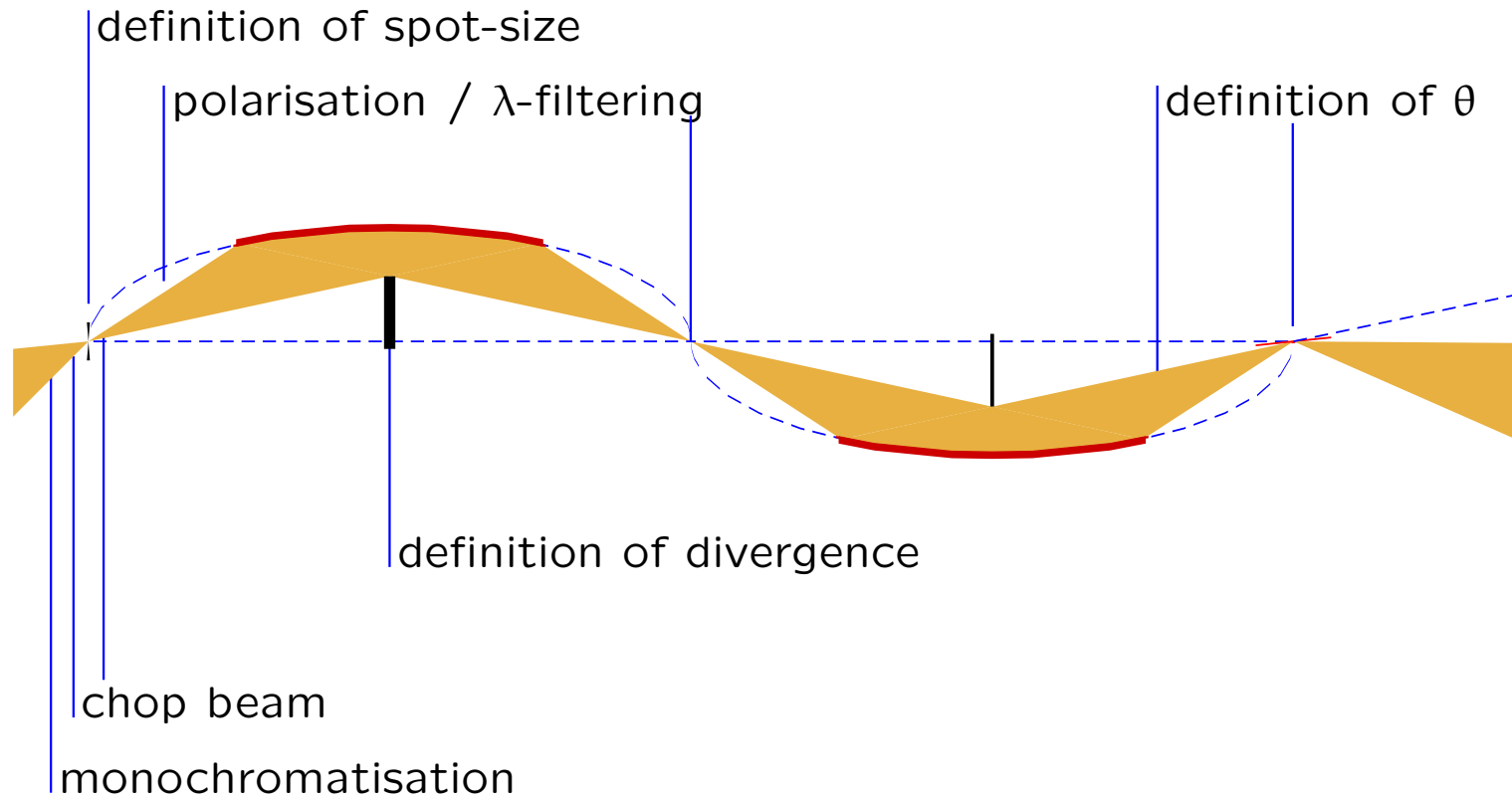
opportunities:

- use aberration to reduce beam spot or divergence at the sample

focusing with elliptic guides

operation modes for TOF:

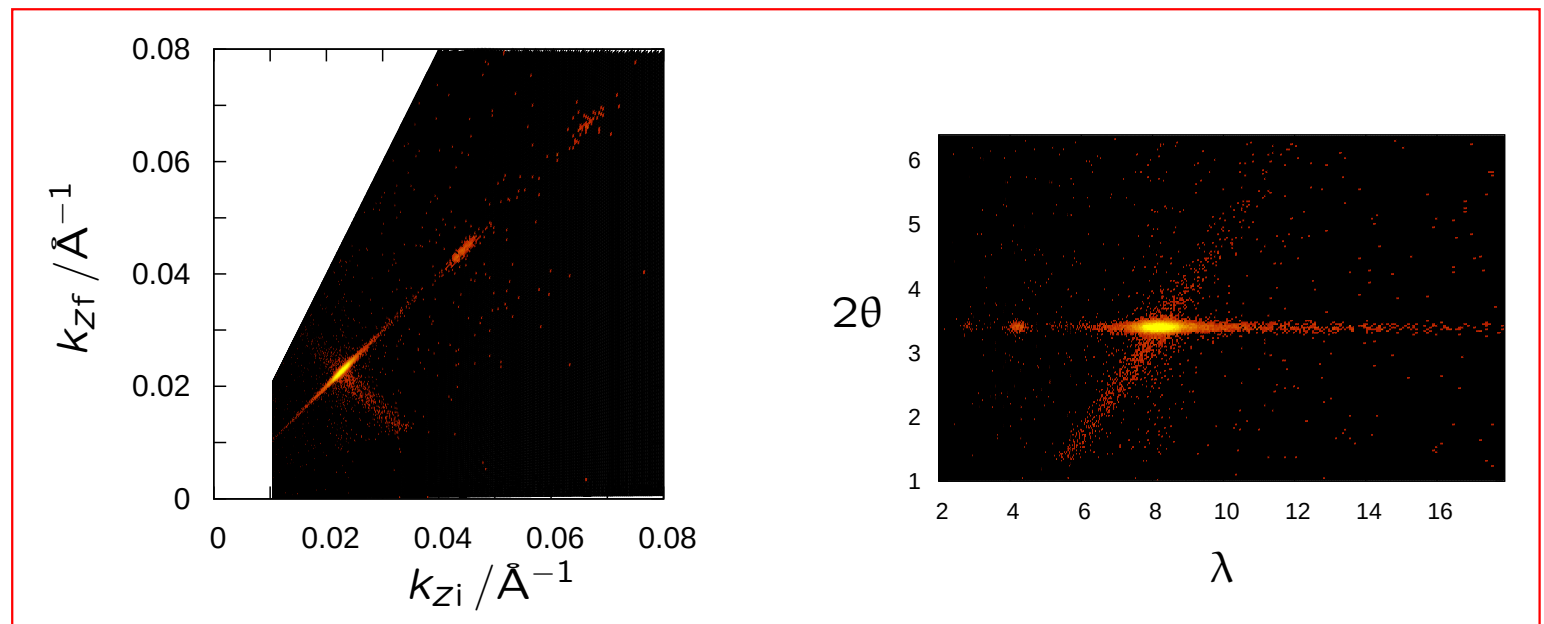
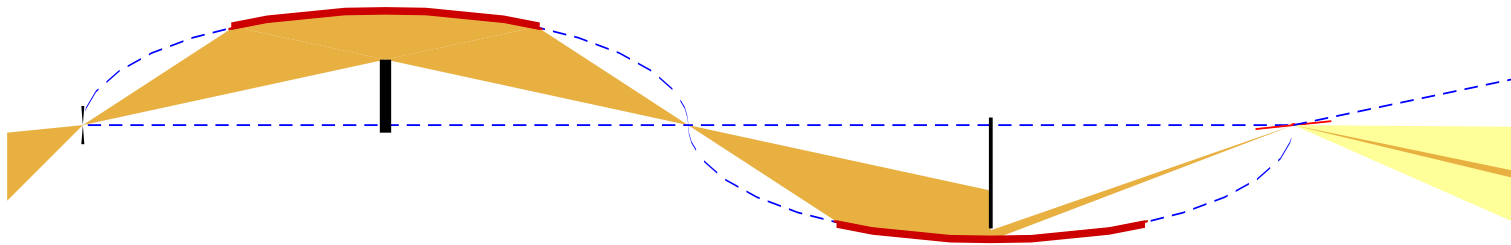
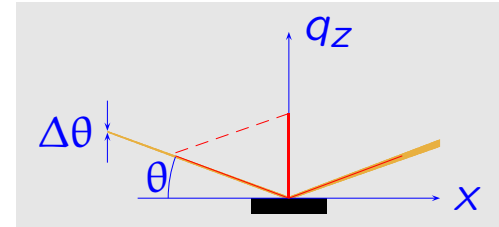
(non-TOF operation is also possible!)



focusing with elliptic guides

mode: almost conventional

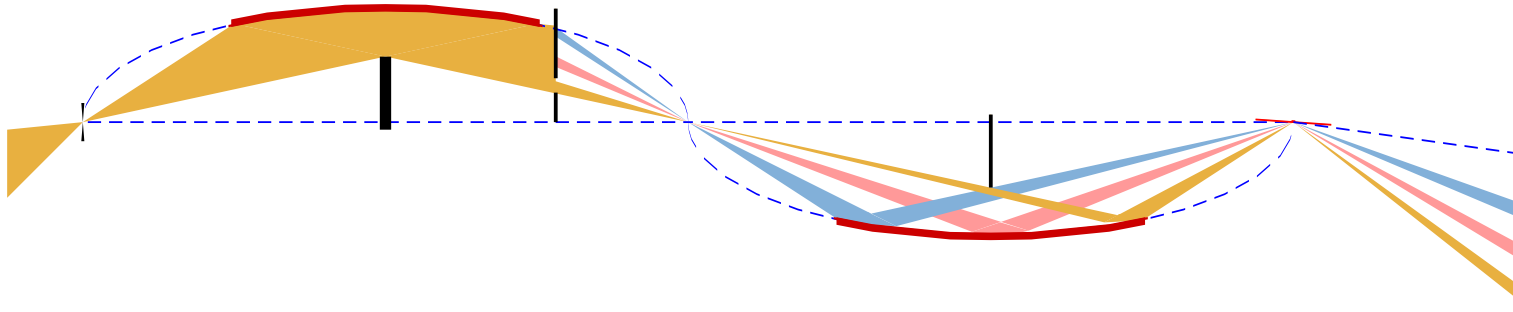
- beam is still convergent
- off-specular measurements are feasible



focusing with elliptic guides

mode: wide q -range

- vary θ with fixed sample position
- shift diaphragm (chopper) between pulses



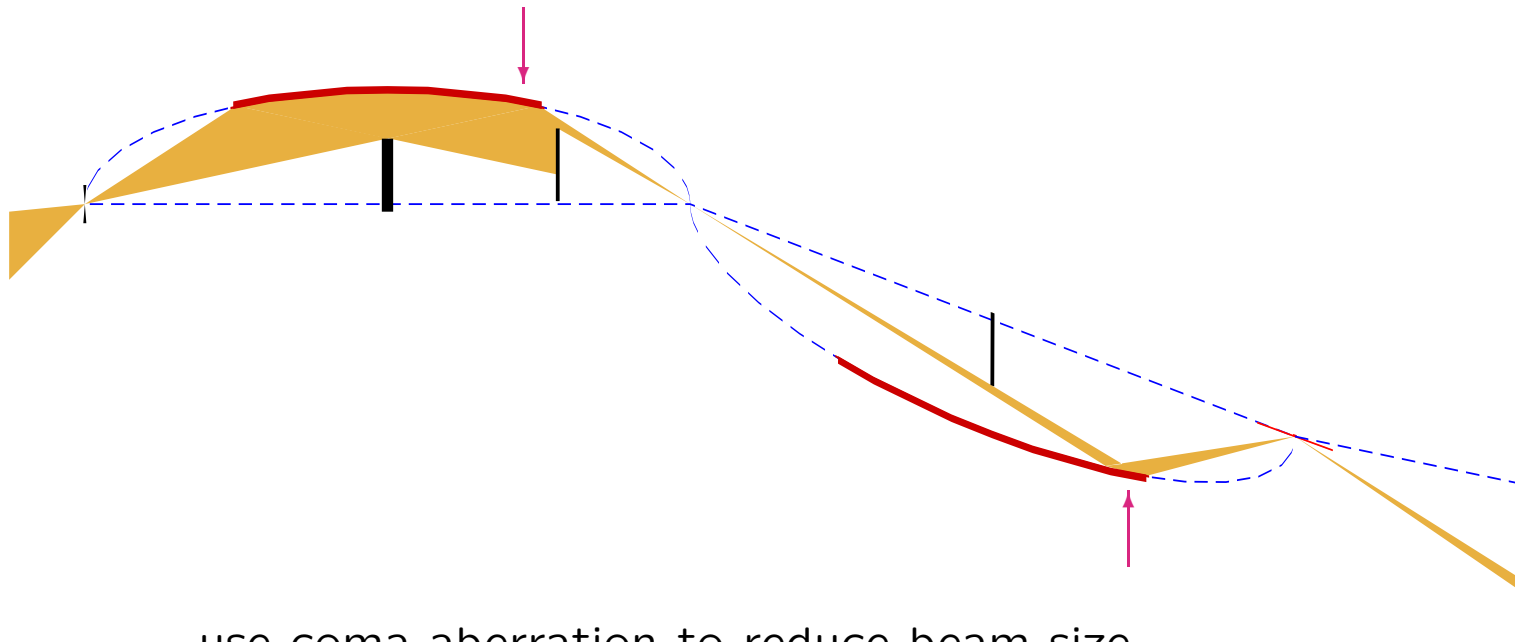
- suited for liquid surfaces



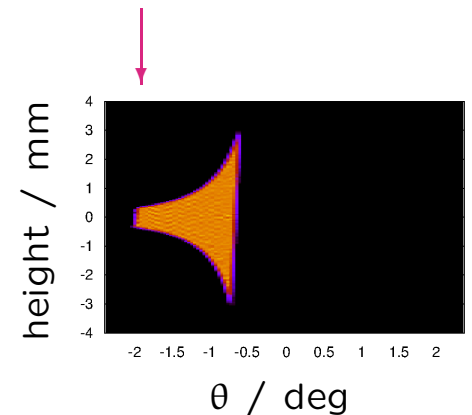
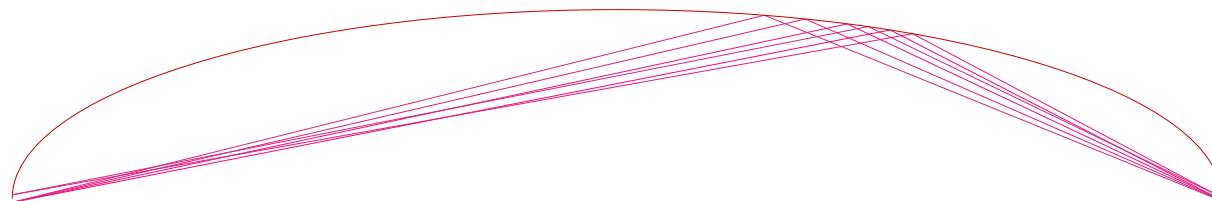
focusing with elliptic guides

mode: small spot size

- uses focusing due to coma aberration
- scanning mode possible



use coma aberration to reduce beam size



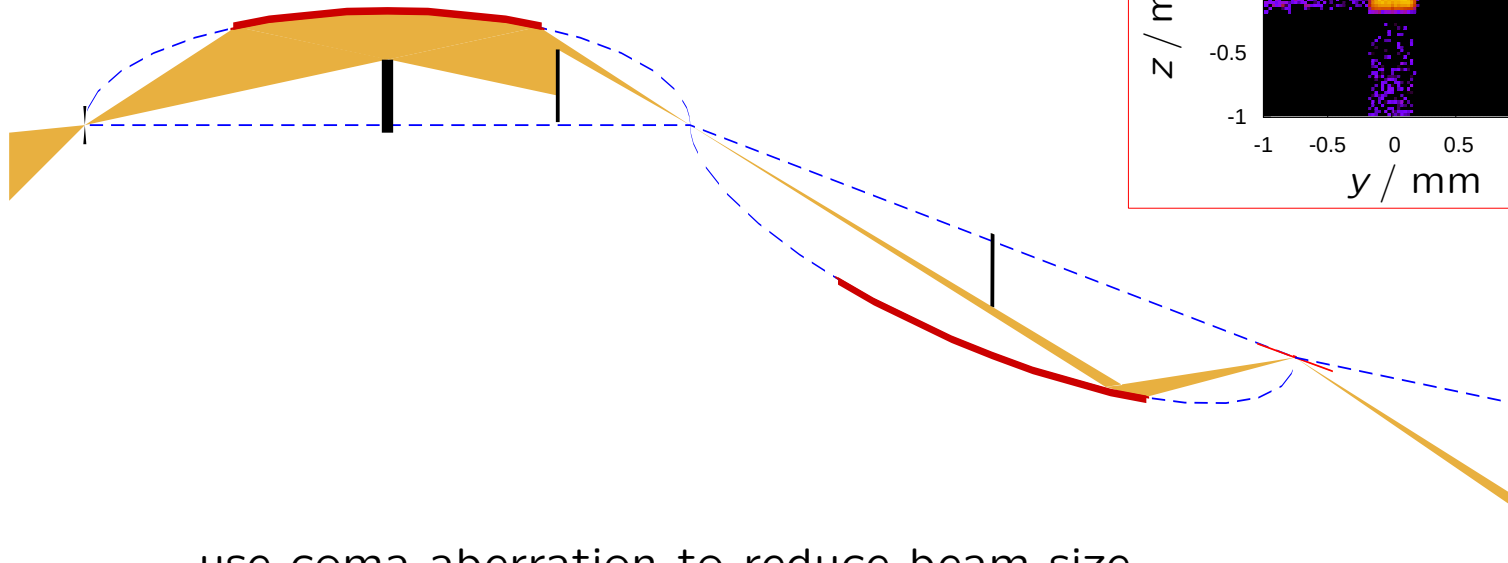
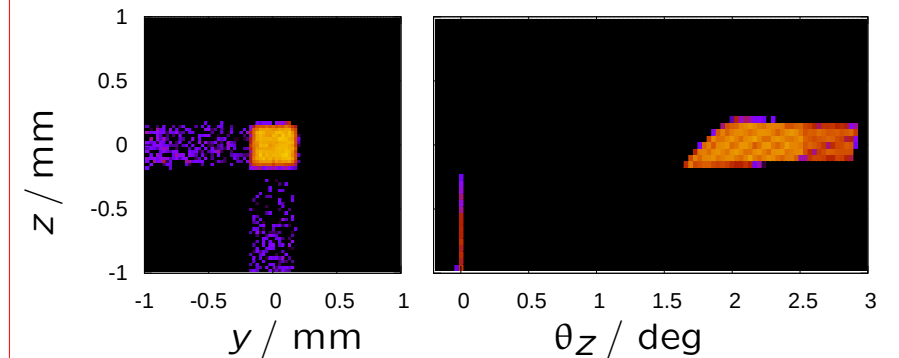
focusing with elliptic guides

mode: small spot size

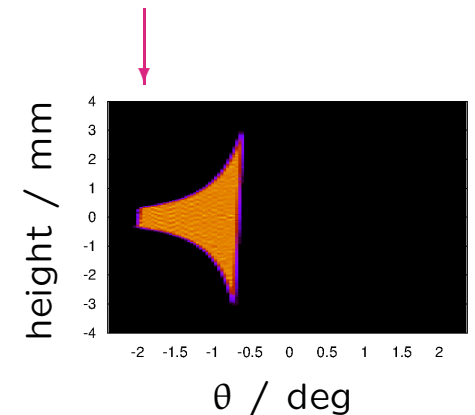
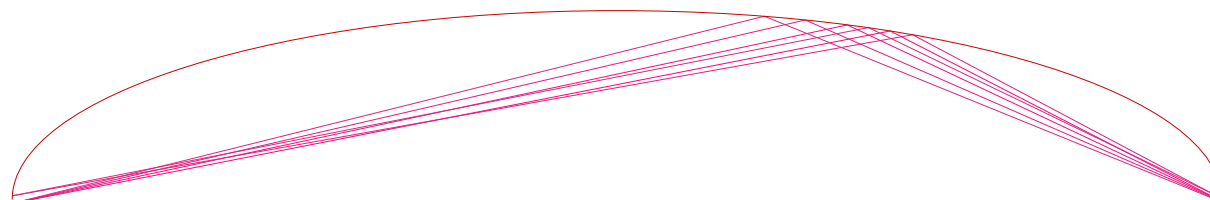
- uses focusing due to coma aberration
- scanning mode possible



$I(y, z)$ and $I(z, \theta_z)$ at the sample
for a $1 \times 1 \text{ mm}^2$ entrance slit



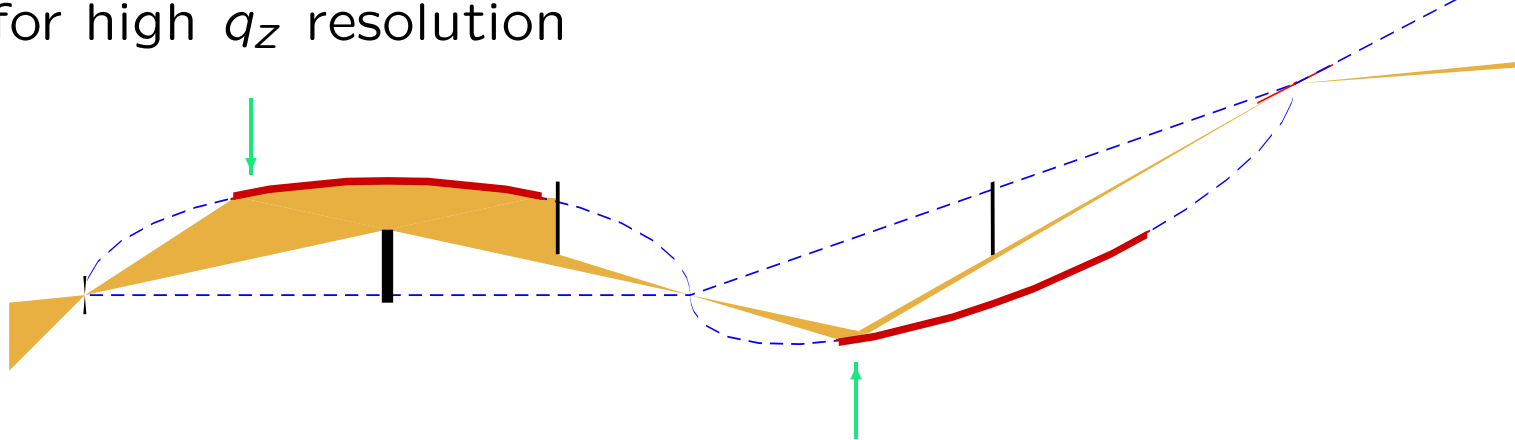
use coma aberration to reduce beam size



focusing with elliptic guides

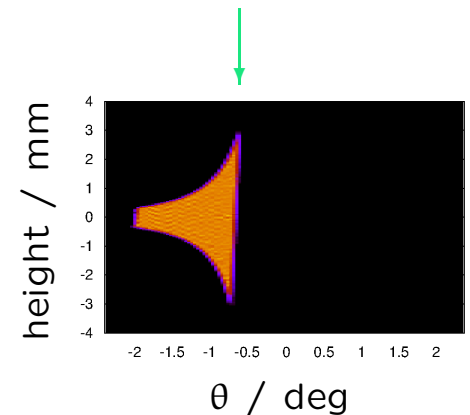
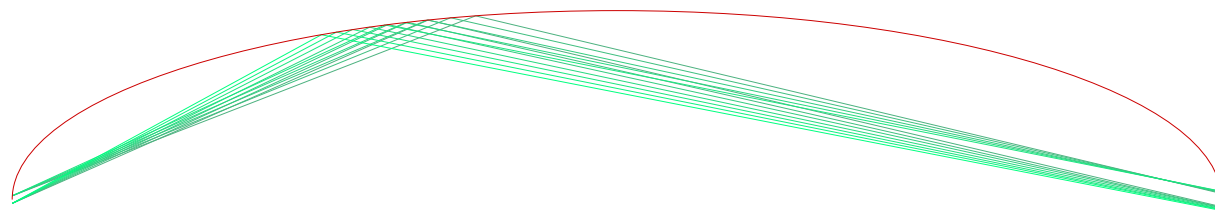
mode: low-divergent beam

- uses defocusing due to coma aberration
- corresponds to the use of Montel optics used at synchrotrons
- for high q_z resolution



- parallel beam e.g. for GISANS

use coma aberration to reduce divergence

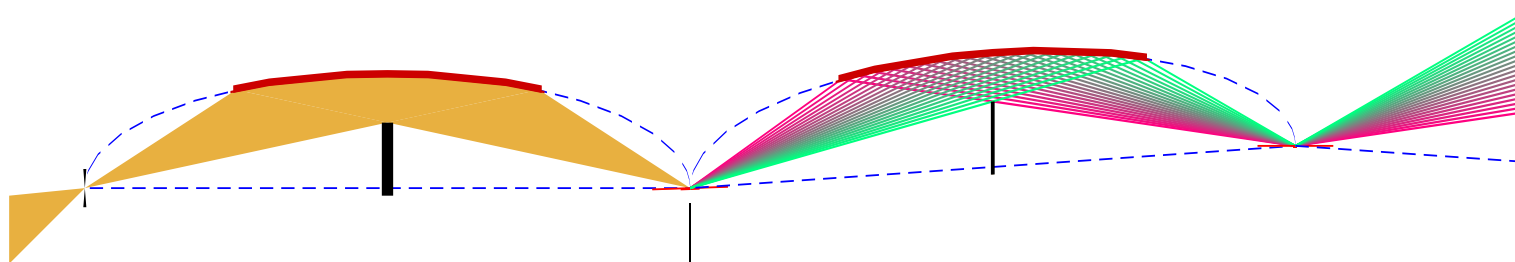


focusing with elliptic guides

mode: angle/energy encoding

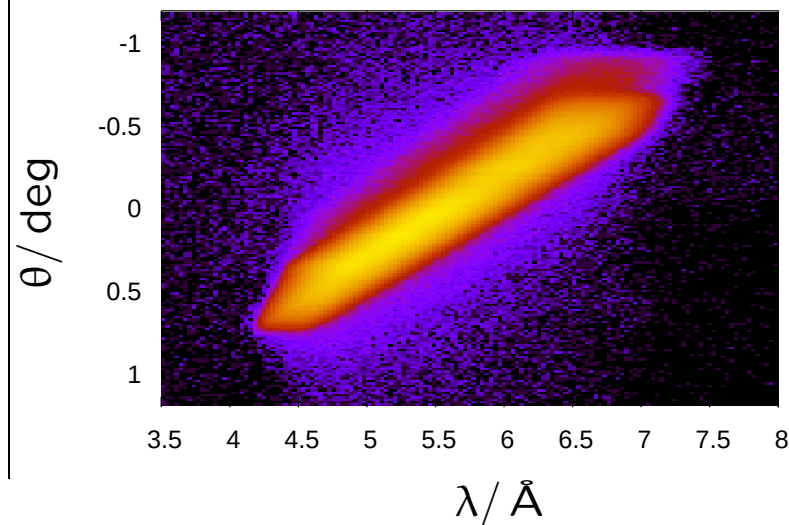


- use a ml-monochromator at the intermediate image
- spectral analysis of the beam: λ / θ encoding



- large λ on small θ
 $\Rightarrow$ wide q_z -range

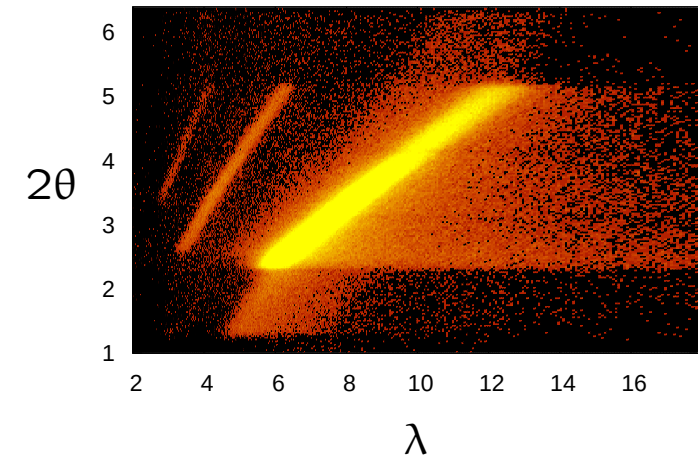
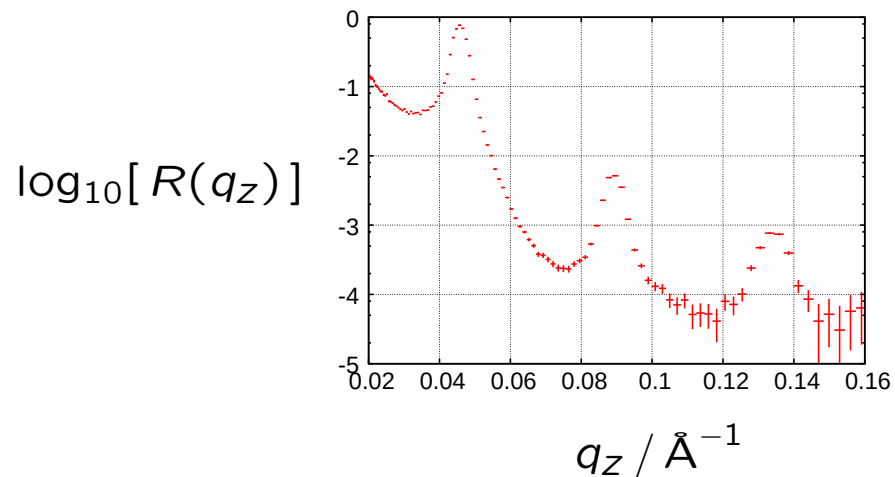
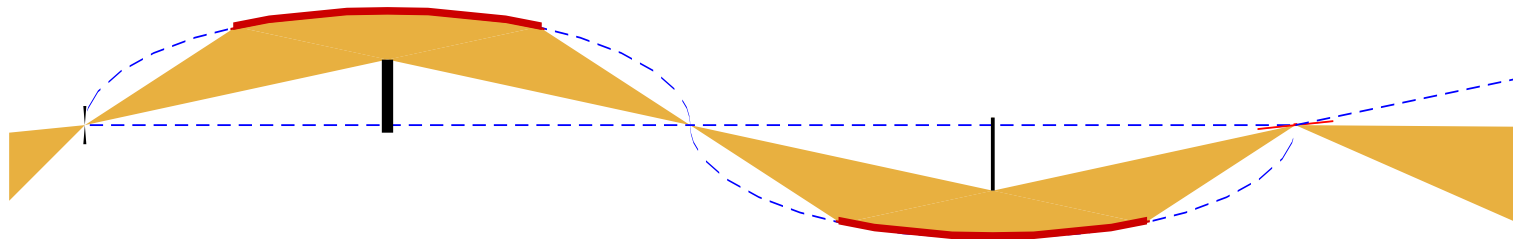
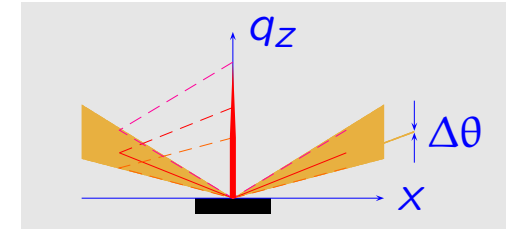
$I(\lambda, \theta)$ after ml monochromator



focusing with elliptic guides

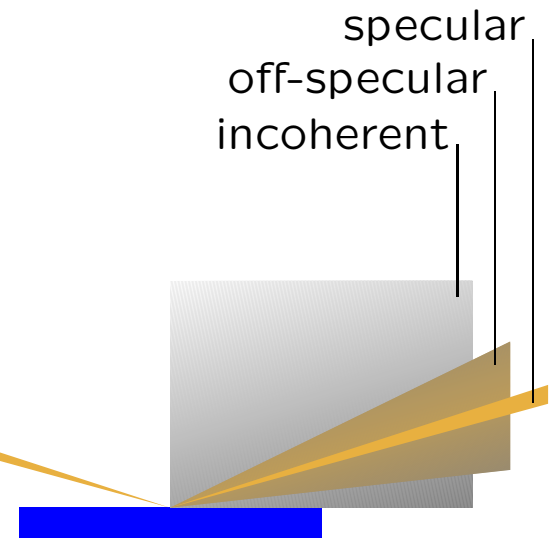
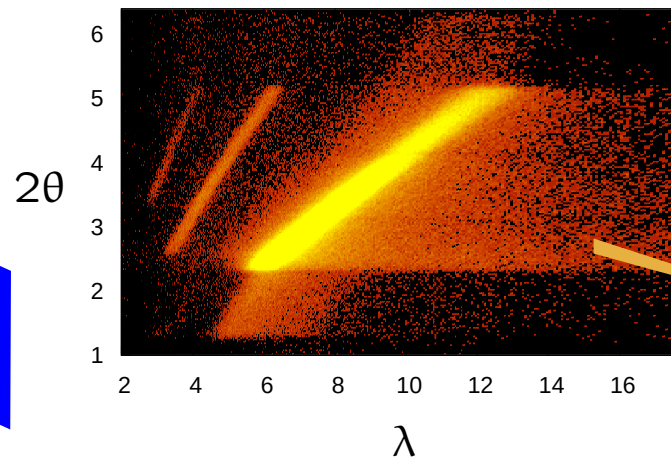
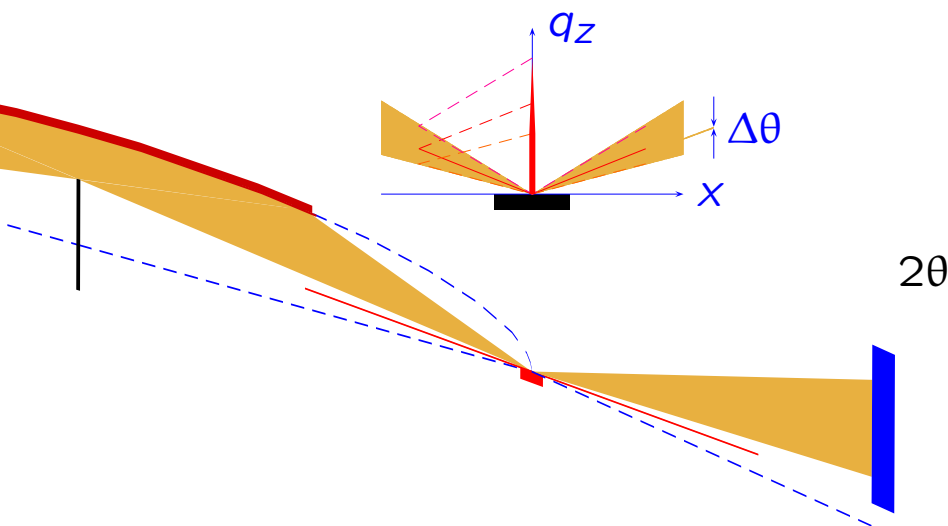
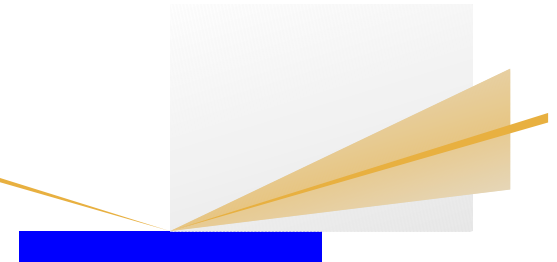
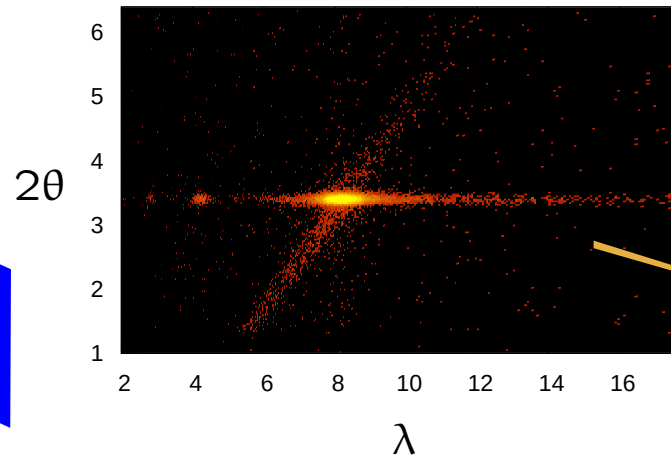
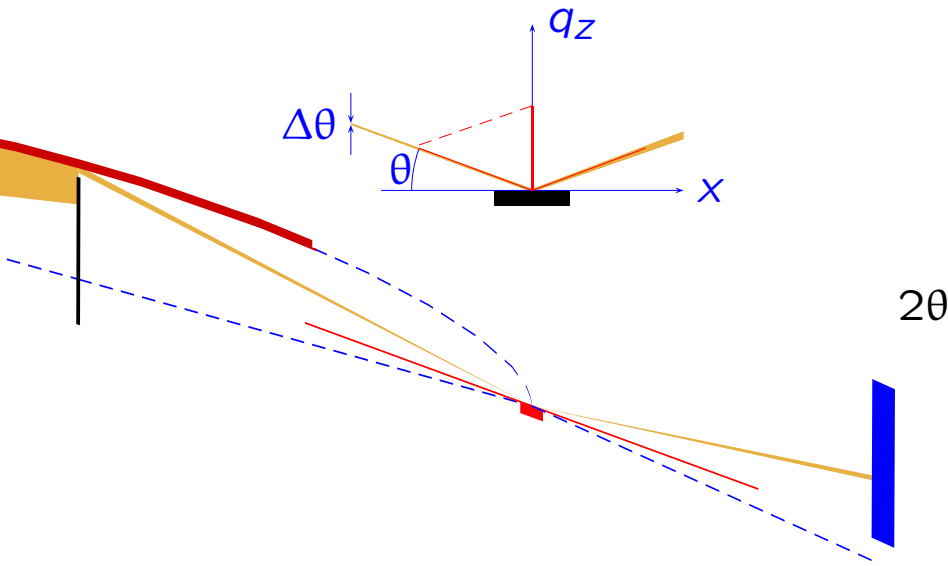
mode: high-intensity specular reflectivity

- energy- and angle-dispersive $\Rightarrow$ gain > 10
- for fast scanning ($T, \mathbf{H}, \mathbf{E} \dots$)
- or if off-specular scattering is no *problem*



focusing with elliptic guides

high-intensity specular reflectivity vs. almost conventional

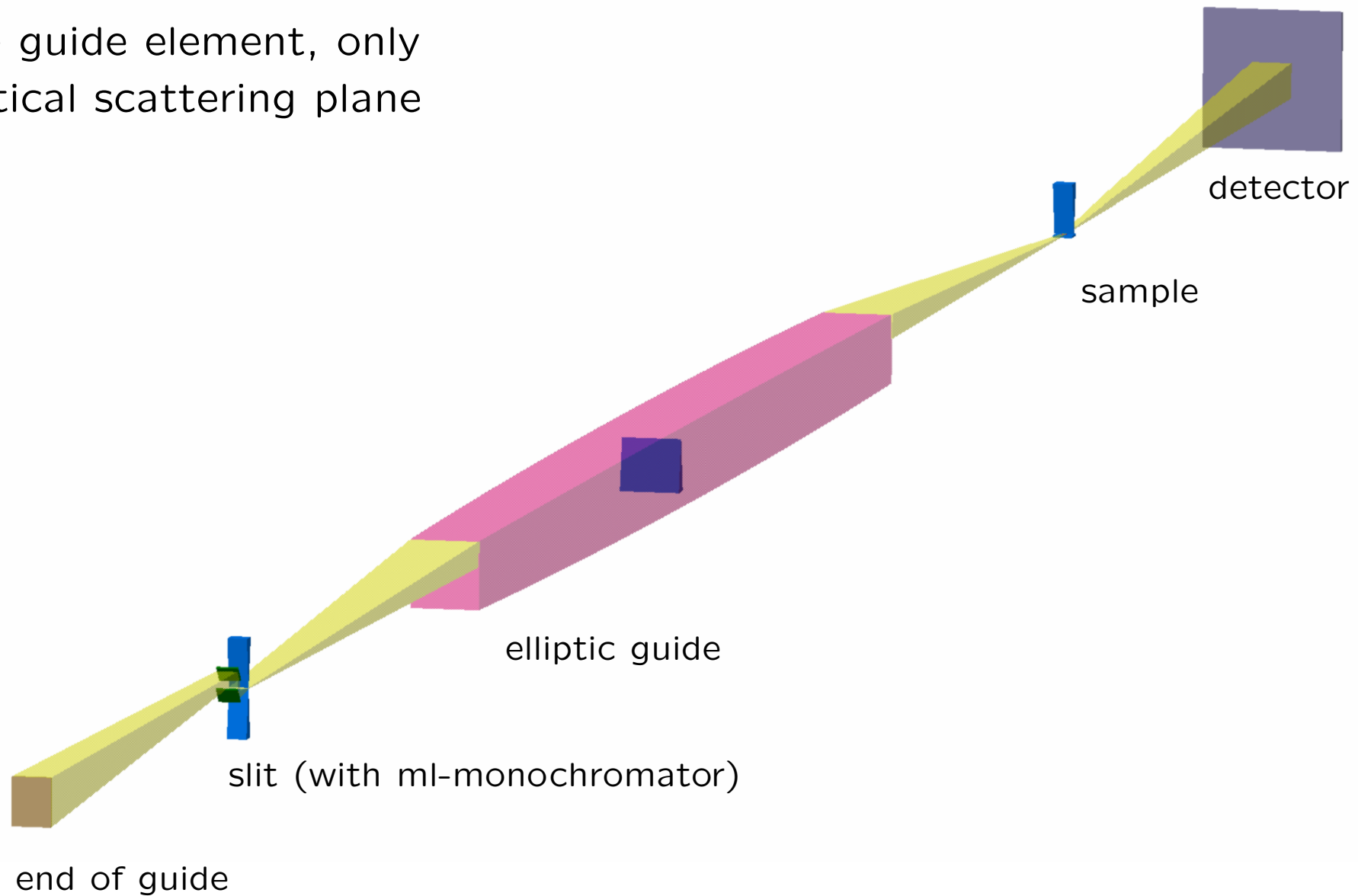


realisation

add-on for Amor
prototype on BOA
concept for the ESS

realisation: add-on for Amor

one guide element, only
vertical scattering plane



realisation: add-on for Amor

Amor, conventional TOF set-up

8 m granite block

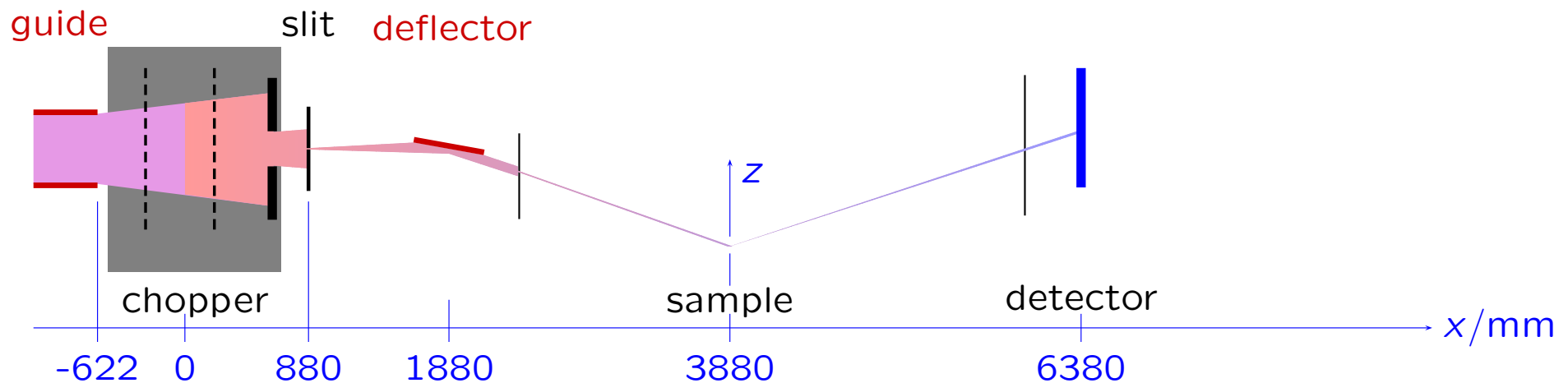
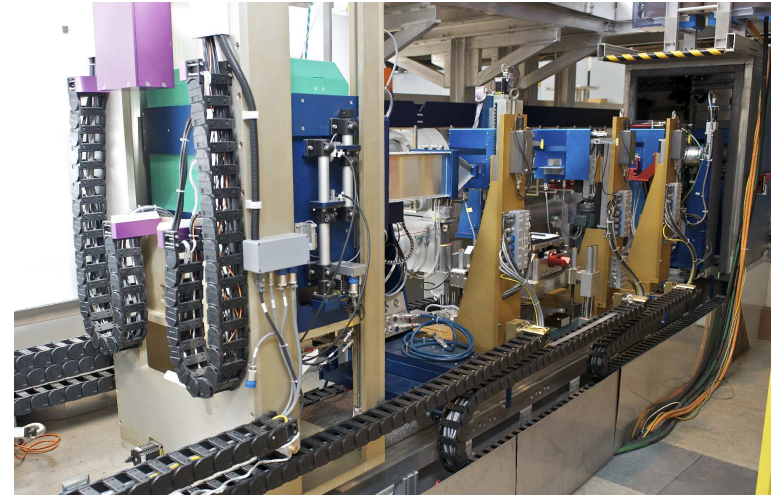
maximum length chopper to detector = 10 m

$2\theta \in [-3^\circ, 12^\circ]$

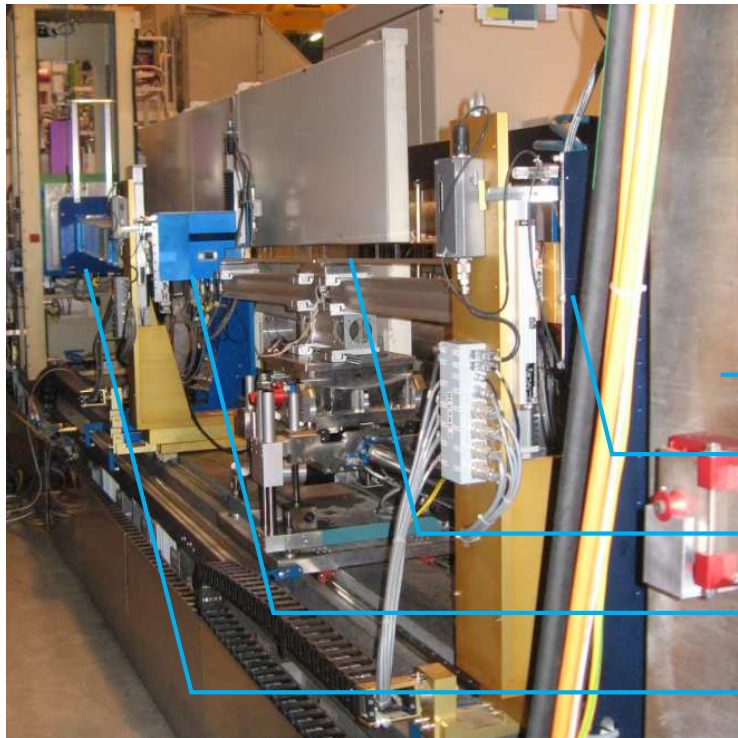
$\lambda \in [2 \text{ \AA}, 18 \text{ \AA}]$

vertical scattering plane

detectors: ^3He single and area ($180 \times 180 \text{ mm}^2$)



realisation: add-on for Amor



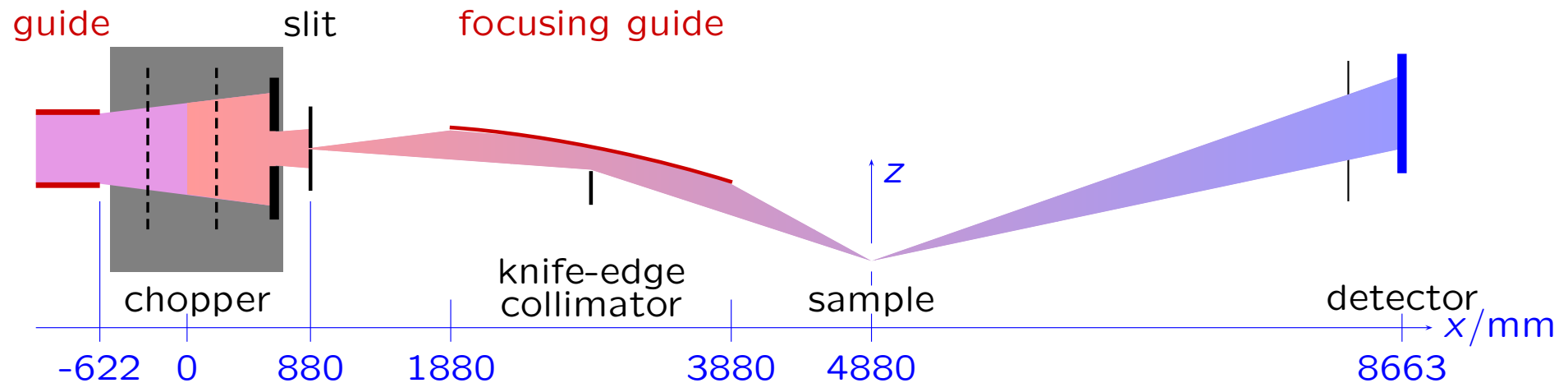
chopper housing

1st slit

elliptic reflector (SwissNeutronics)

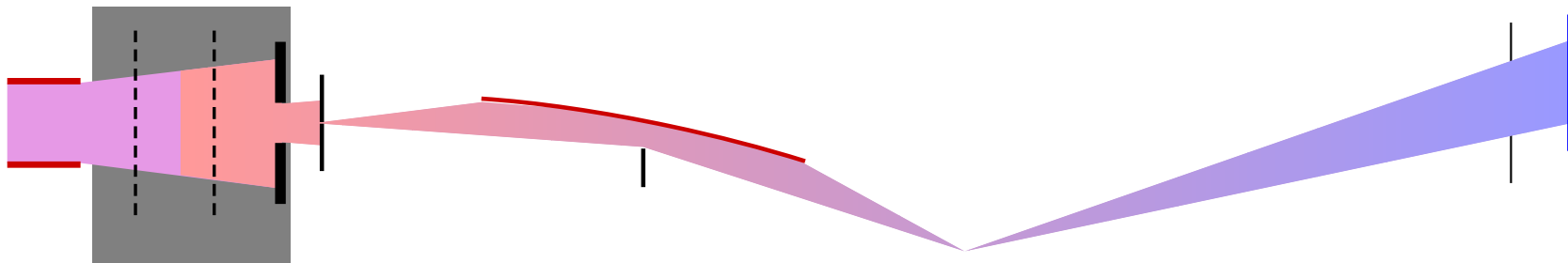
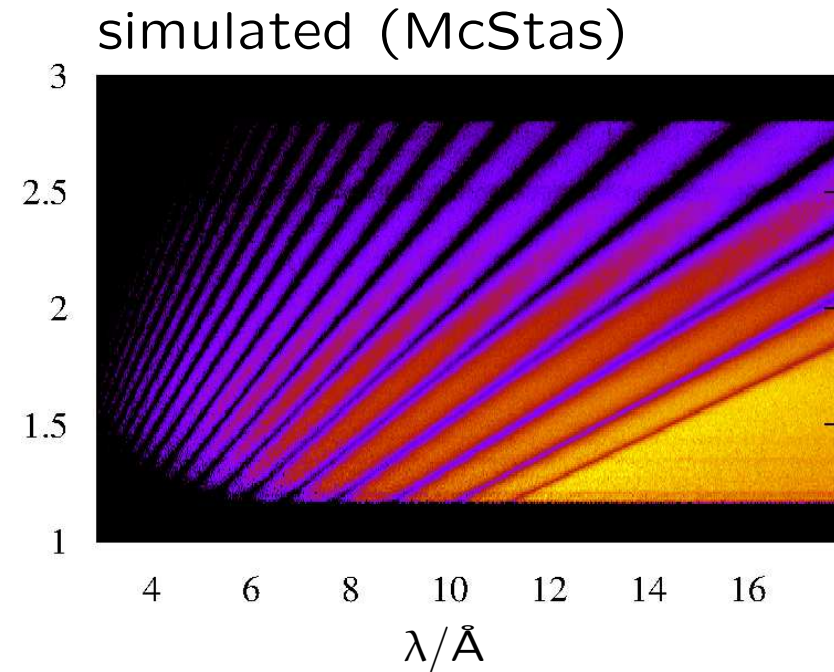
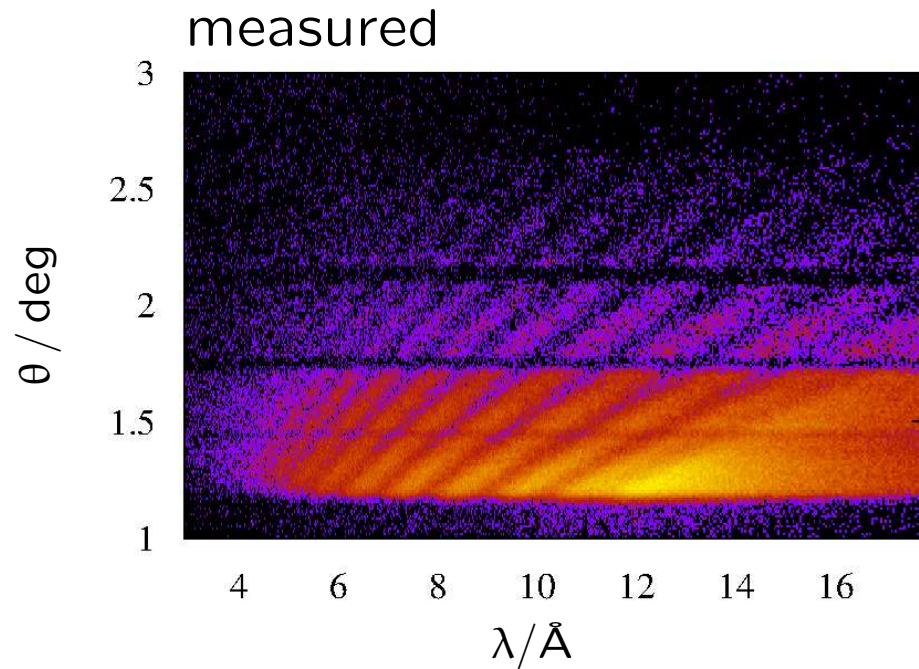
sample (hidden by diaphragm)

detector



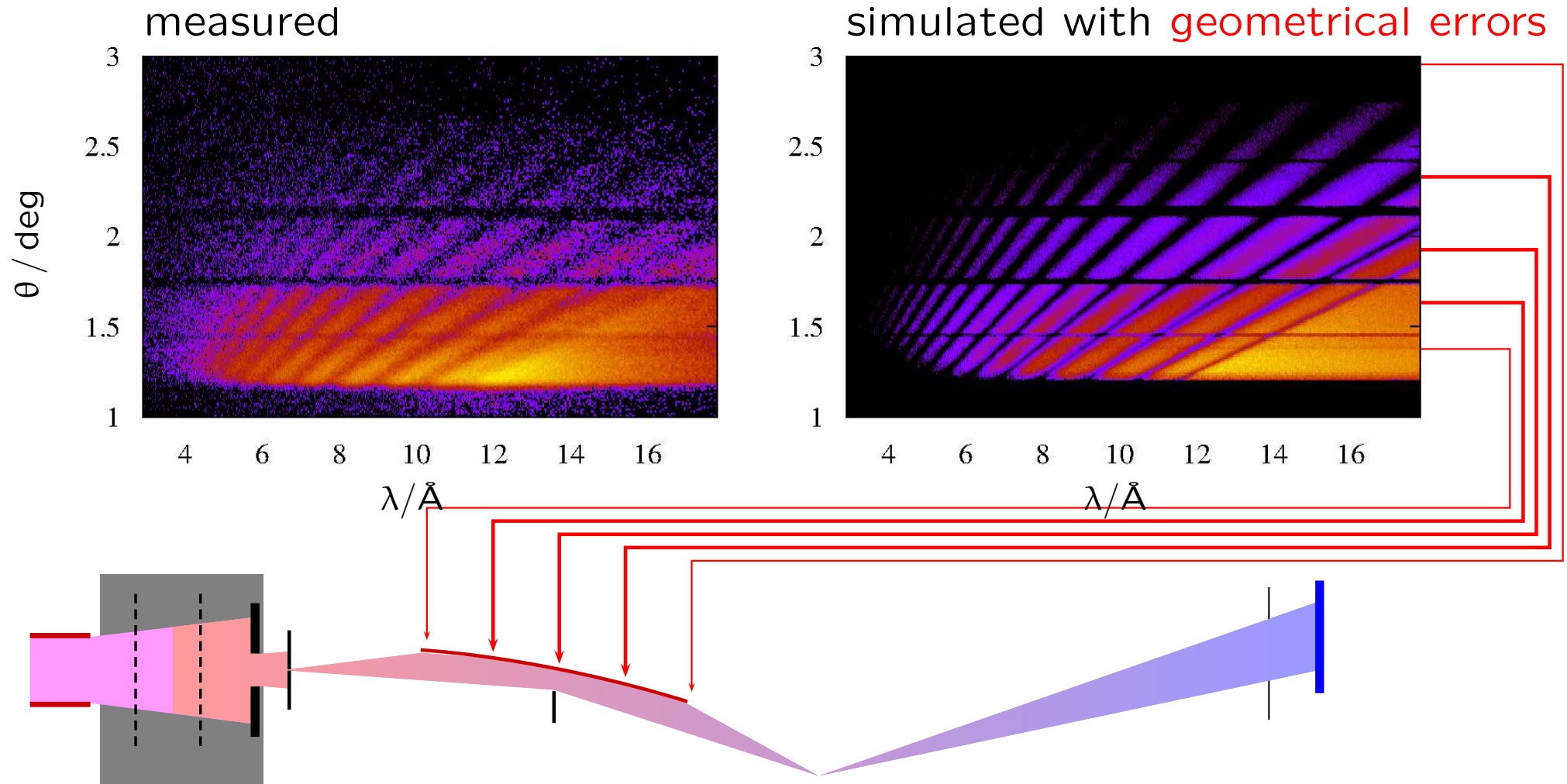
realisation: add-on for Amor

measurements: 1000 Å Ni film on glass, $9 \times 9 \text{ mm}^2$



realisation: add-on for Amor

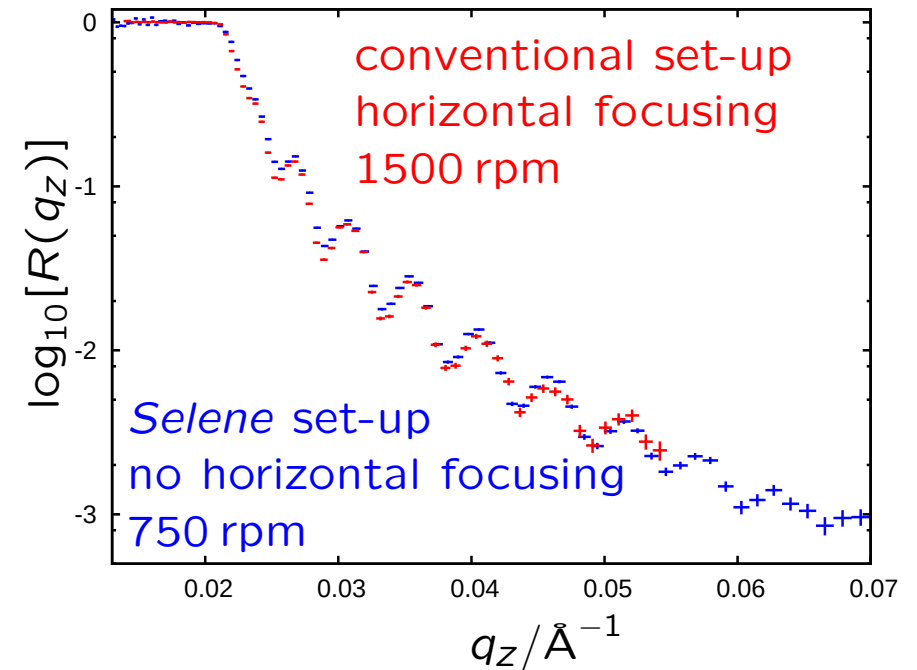
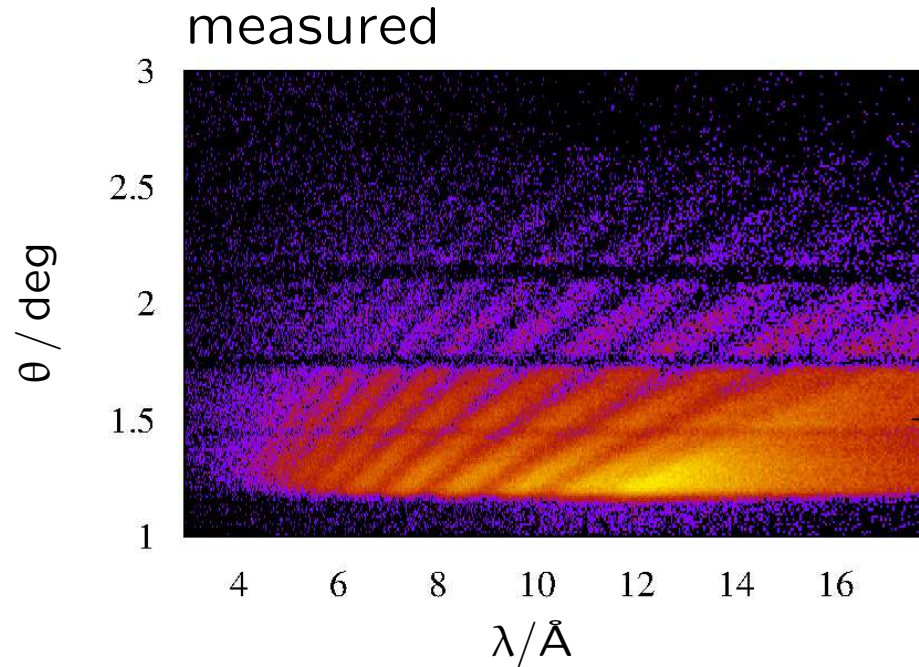
measurements: 1000 Å Ni film on glass, $9 \times 9 \text{ mm}^2$



4 guide elements à 500 mm

realisation: add-on for Amor

measurements: 1000 Å Ni film on glass, $9 \times 9 \text{ mm}^2$



measurement time:

conventional	5 h
Selene	45 min

gain-factor 6.7

realisation: add-on for Amor

$[\text{La}_{2/3}\text{Sr}_{1/3}\text{MnO}_3 / \text{SrTiO}_3]_4 / \text{NGO}$

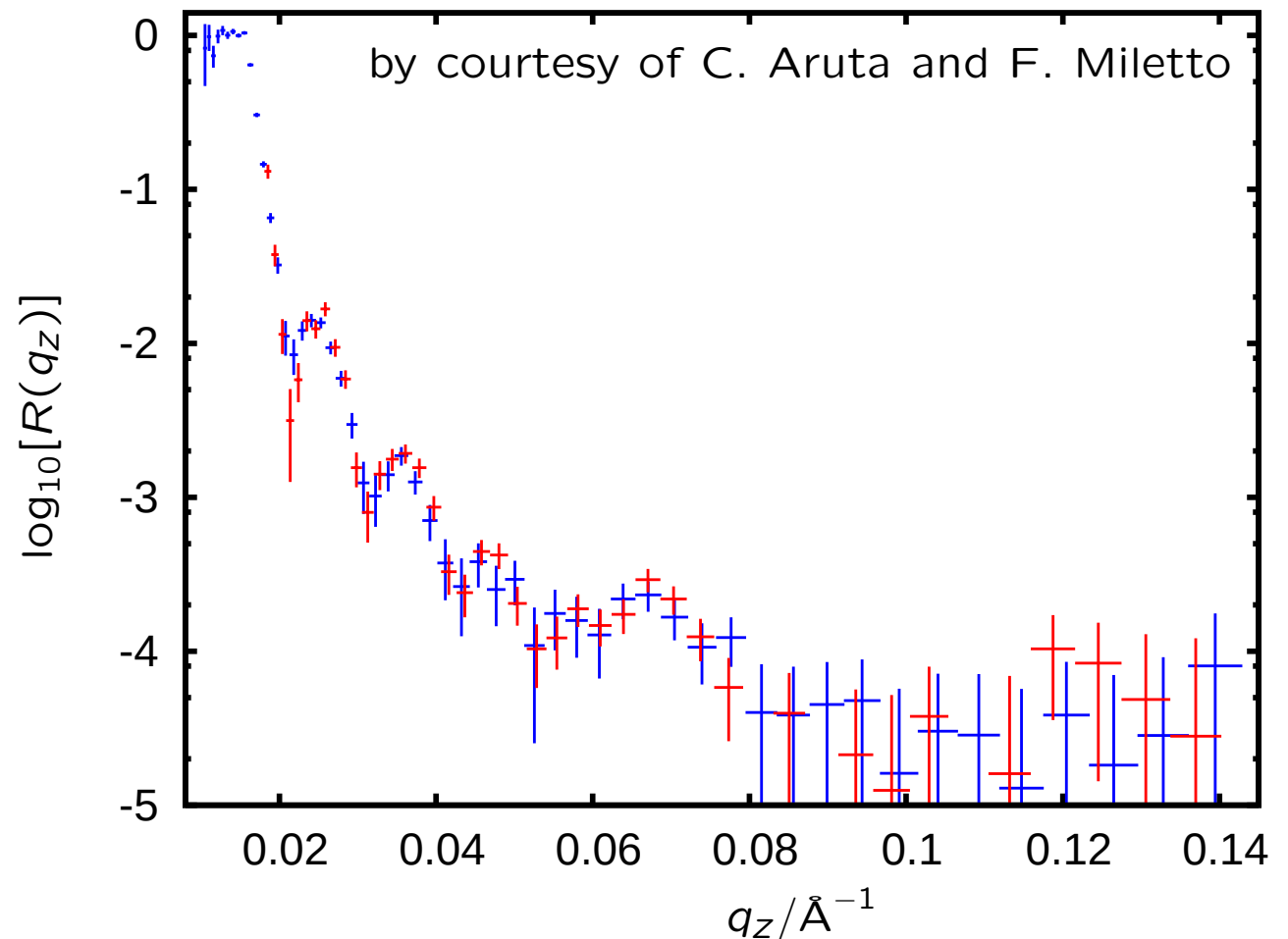
$4 \times 5 \text{ mm}^2$

- no focusing in sample plane
- TOF mode, $\lambda \in [2 \dots 18 \text{ \AA}]$
- measurement time:

conventional 6.5 h

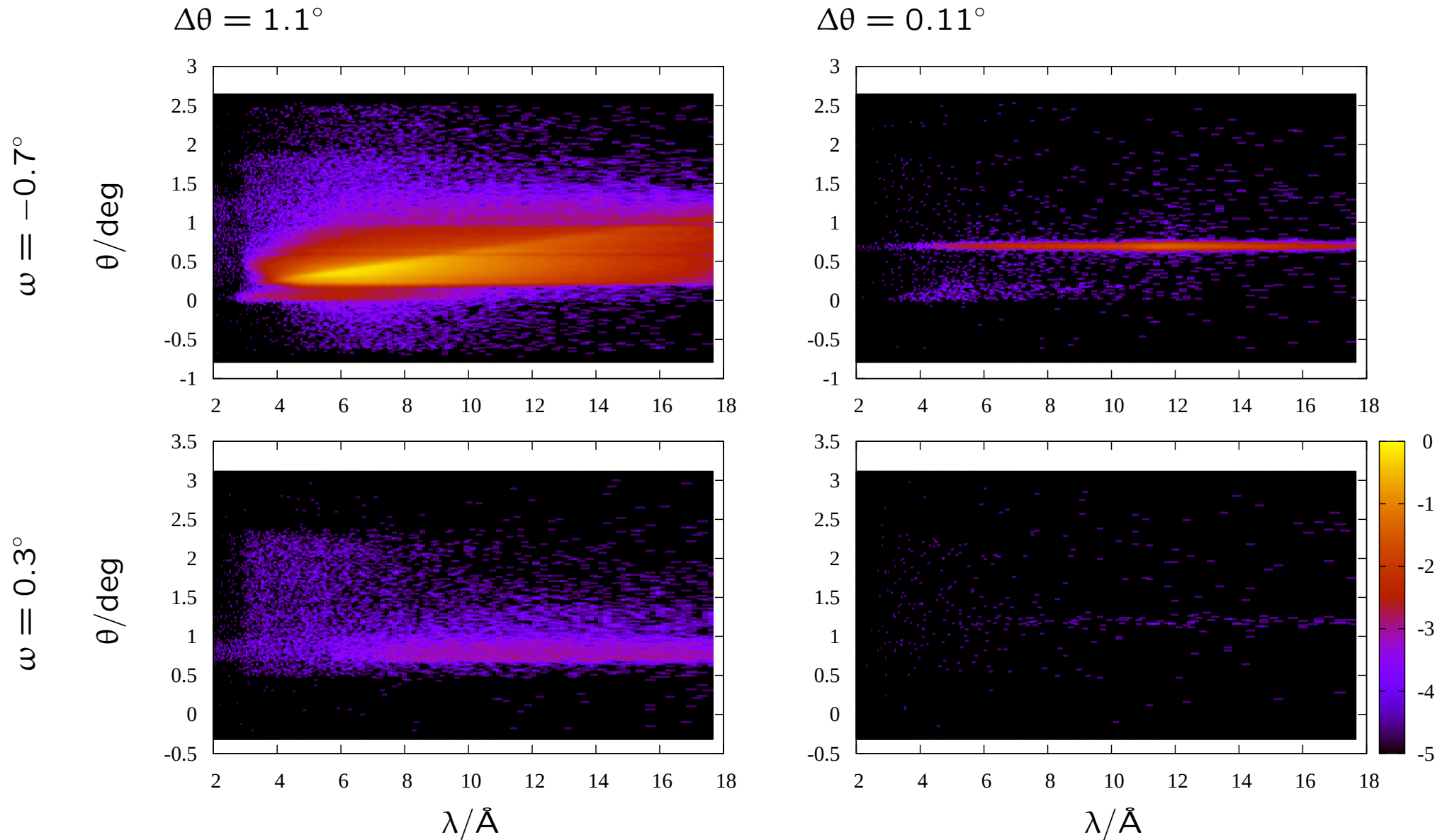
Selene 45 min

gain-factor 8.3



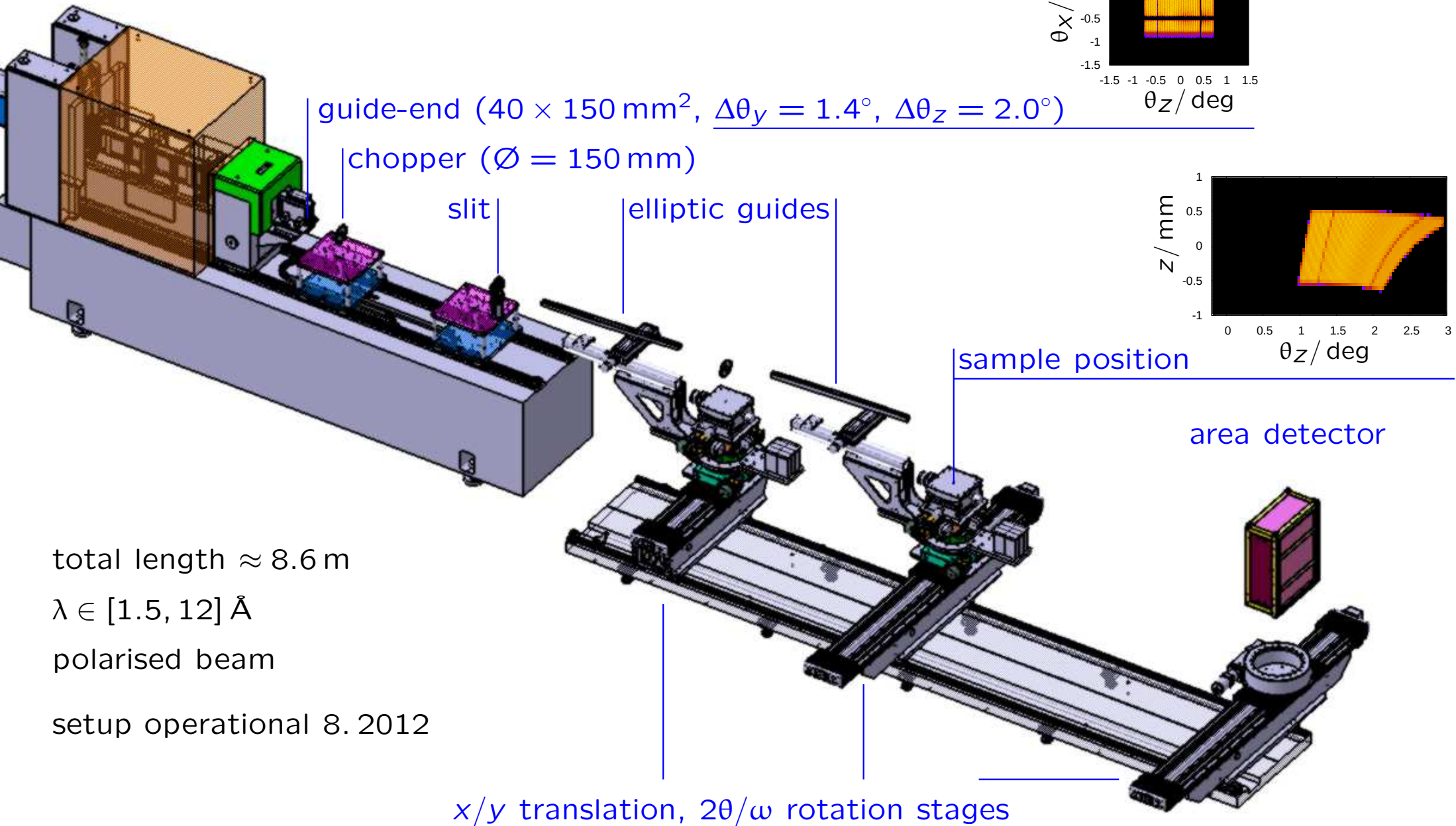
realisation: add-on for Amor

$\log_{10}[I(\lambda, \theta)]$ maps taken with the liquid/solid interface cell with Si vs. D_2O .



realisation: prototype on BOA

Boa is a test beam line at SINQ, PSI



total length $\approx 8.6 \text{ m}$

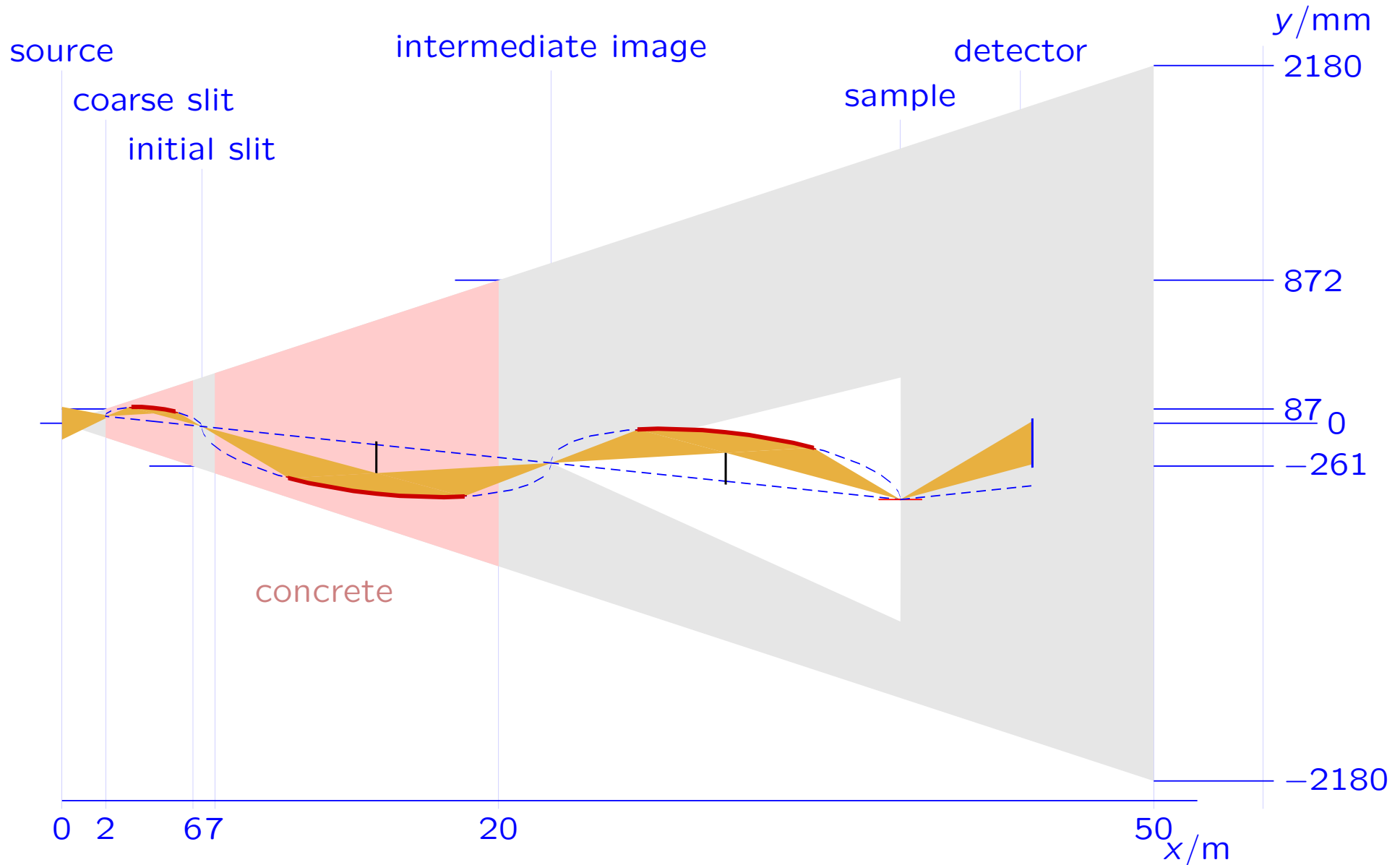
$\lambda \in [1.5, 12] \text{ \AA}$

polarised beam

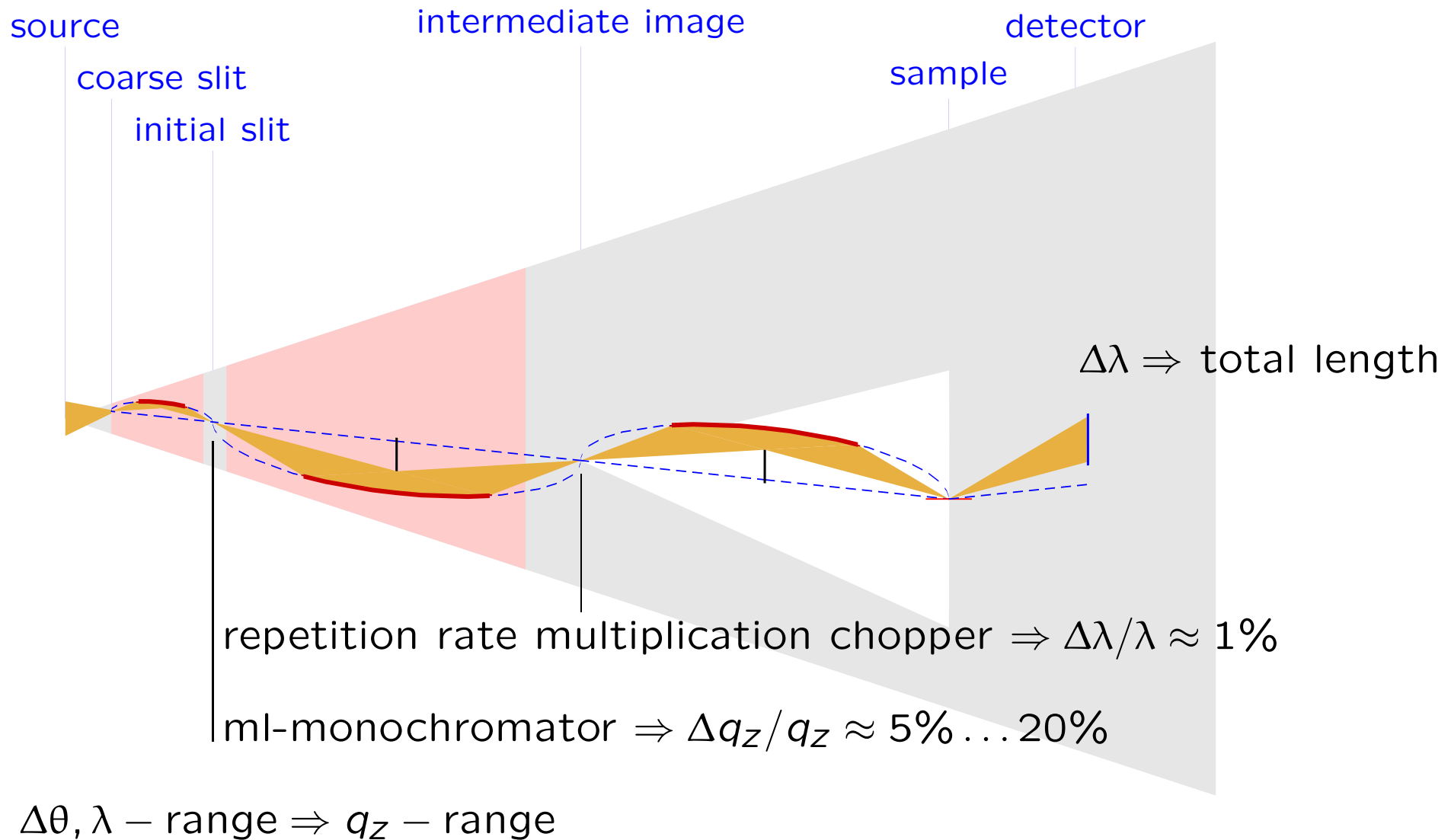
setup operational 8. 2012

realisation: concept for the ESS

schematic lay-out of the reflectometer for tiny samples



realisation: concept for the ESS



final remarks

critical points

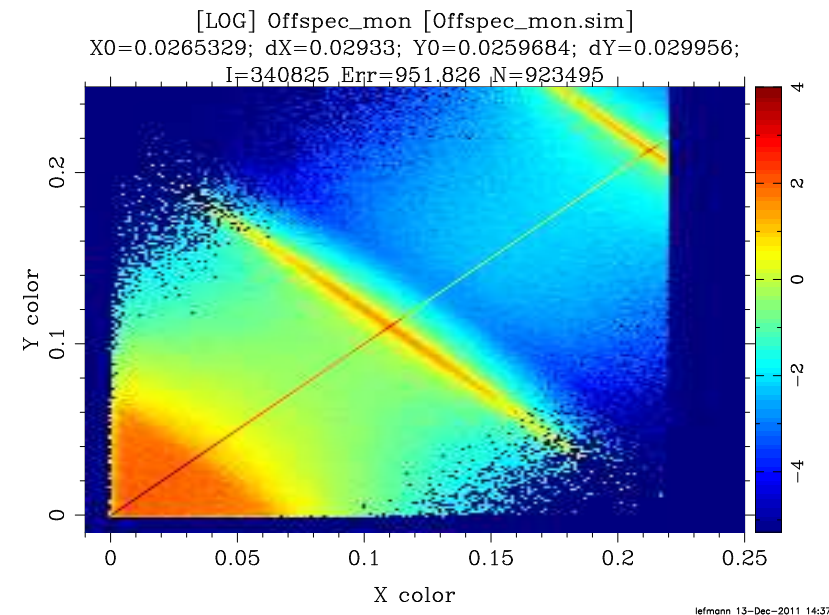
thanks

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critical points

- accuracy of guides
 - how to assemble the 0.5 m units without errors
- alignment of guides
- scattering at focal points
 - from diaphragms / choppers
 - off-specular form mirrors

first simulation with off-specular
scattering with McStas
(K. Leffman, 12. 2011)



- influence of gravity
 - will be simulated within the next months

thanks to

Tobias Panzner McStas simulations, experiments, BOA
Uwe Filges

Dieter Graf conctruction

Marcel Schild electronics

SwissNeutronics elliptic guide development

Marité Cardenas experiments
Anette Vickery

Hanna Wacklin discussions
Bob Cubitt
Peter Böni
Uwe Stuhr
Frederic Ott
Thomas Krist

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

