Paul Scherrer Institut

Jochen Stahn, Uwe Filges, Tobias Panzner

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 $\longrightarrow$ 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)

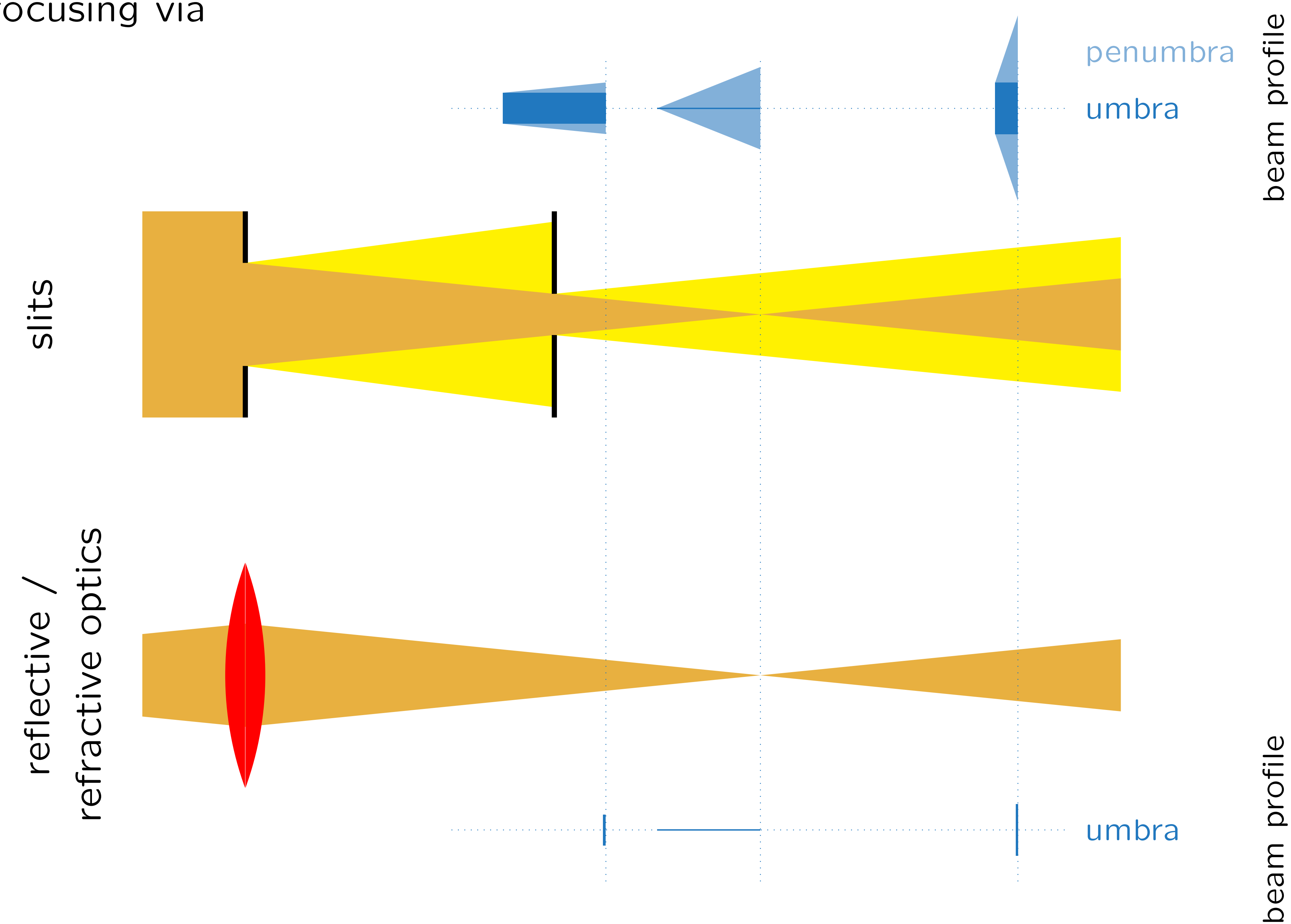
parallel beam (for GISANS)

spin-echo type add-ons / spatial constraints

slit vs. focusing optics

slit vs. focusing optics

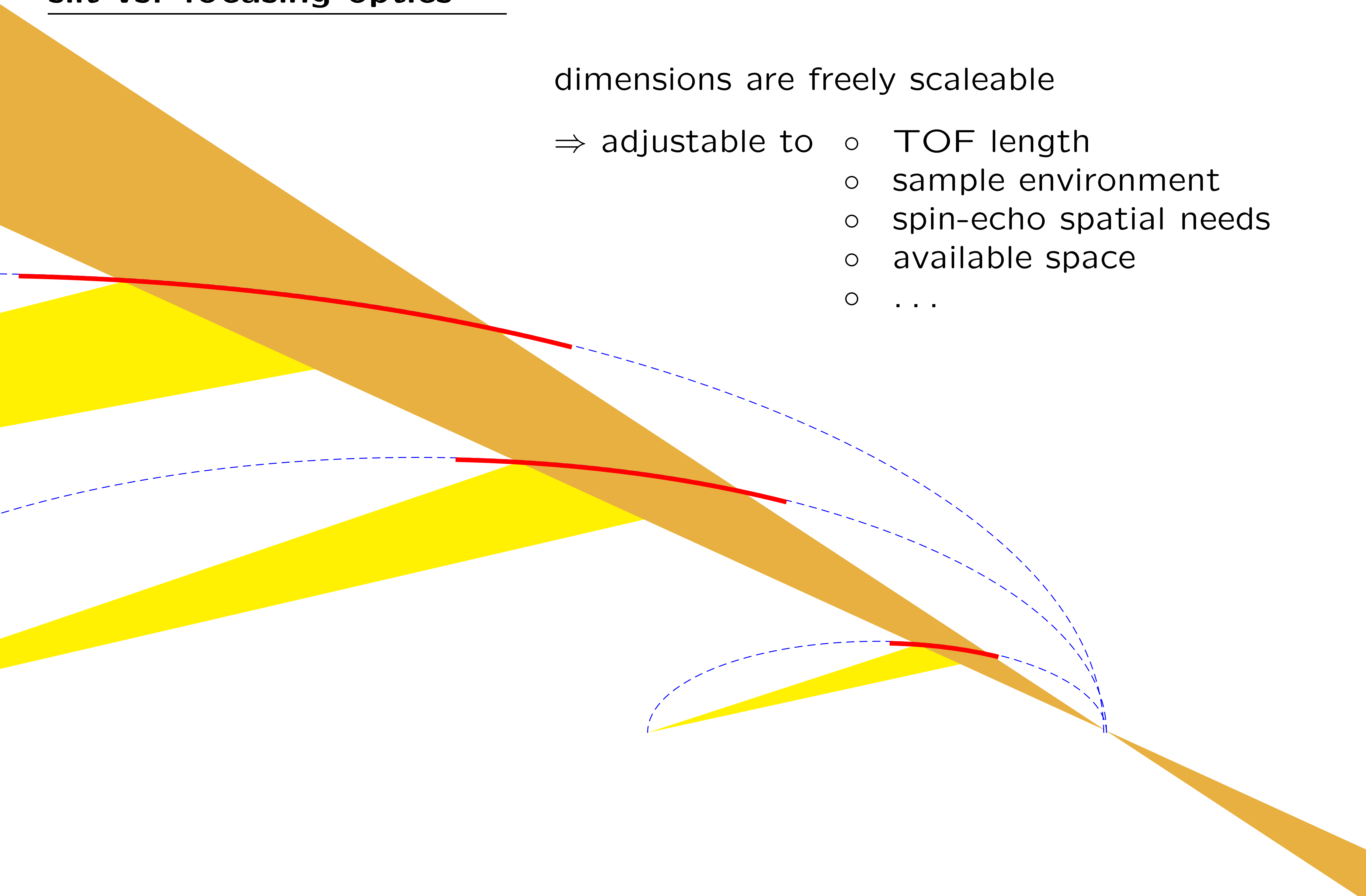
focusing via



slit vs. focusing optics

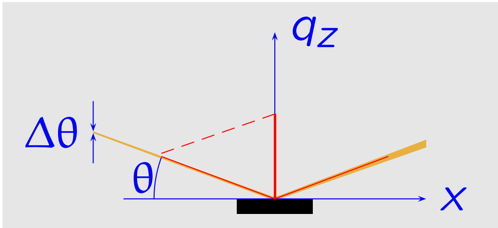
dimensions are freely scaleable

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



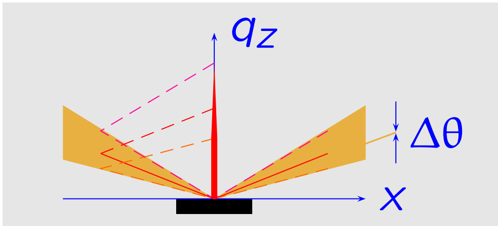
slit vs. focusing optics

focusing for high-flux specular reflectometry



slit-defined beam:

- ∘ θ-dispersive, **or**
- ∘ λ-dispersive,
- ∘ resolution given by Δλ and Δθ



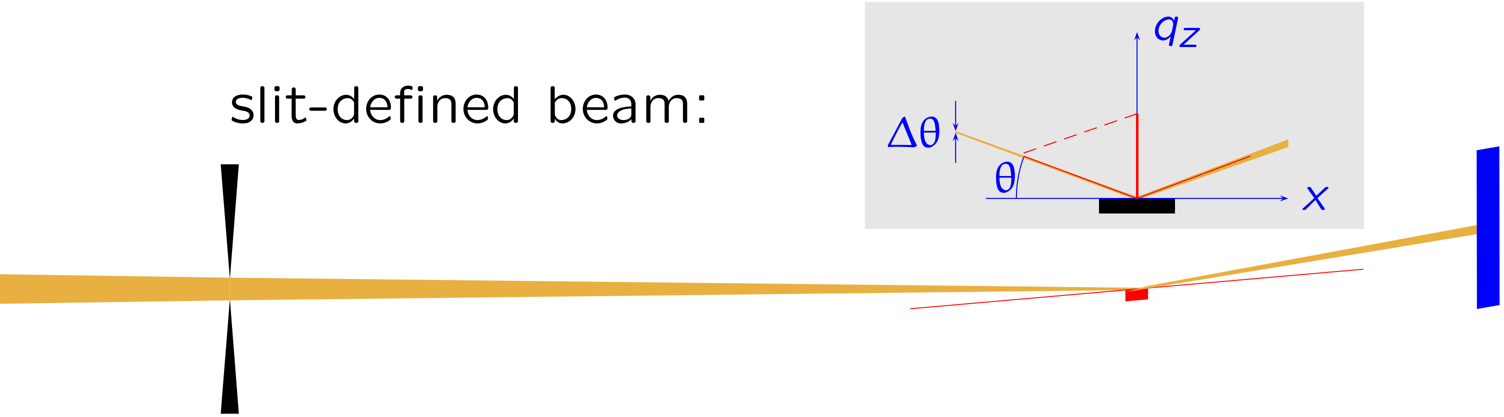
convergent beam:

- ∘ θ-dispersive **and**
- ∘ λ-dispersive,
- ∘ resolution given by Δλ and detector

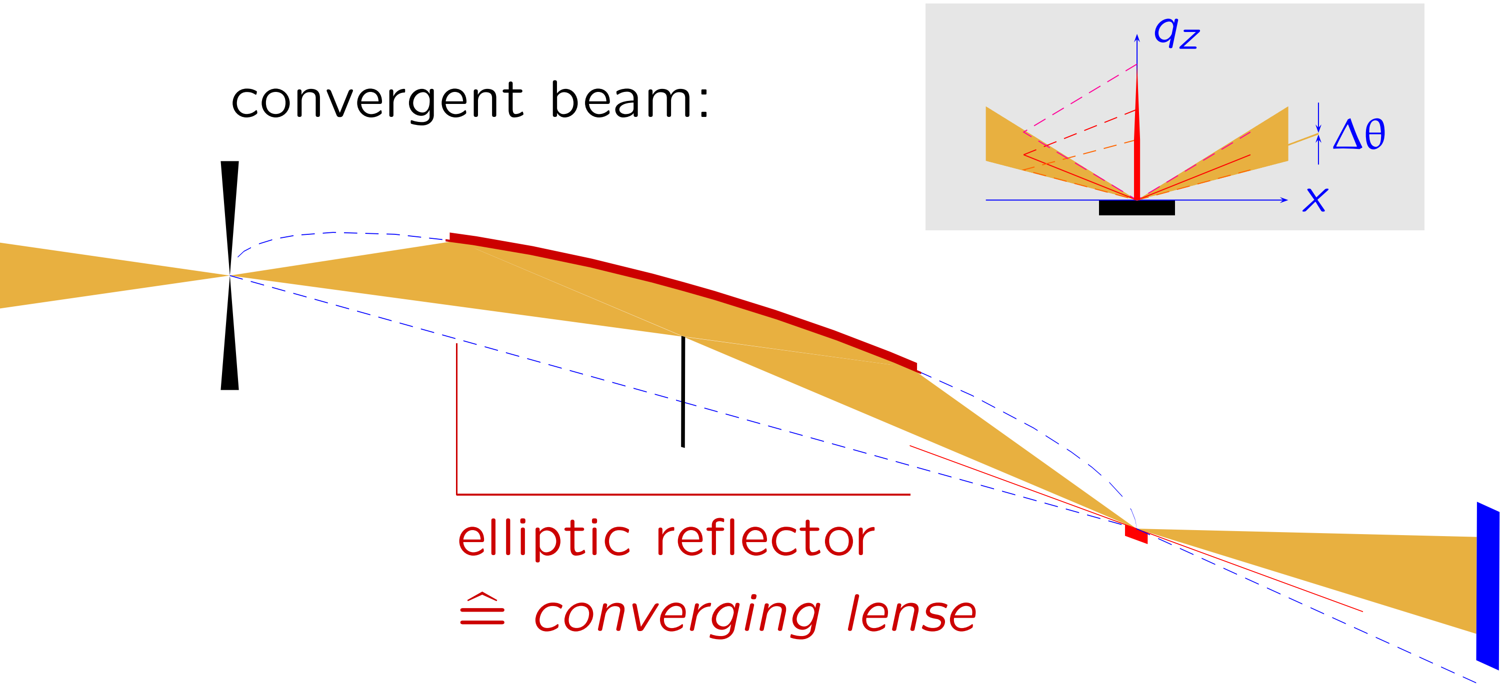
slit vs. focusing optics

focusing for high-flux specular reflectometry

slit-defined beam:



convergent beam:



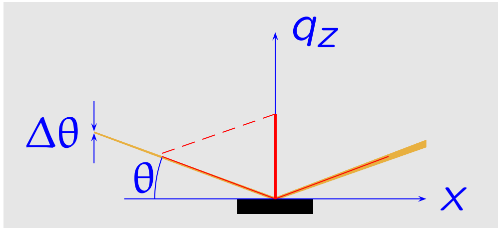
J. Stahn, et al. *N.I.M A* **634**, S12 (2011)

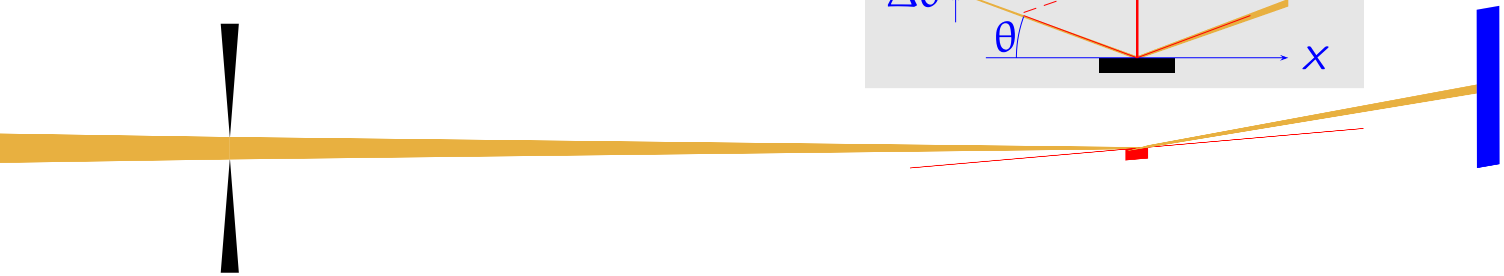
slit vs. focusing optics

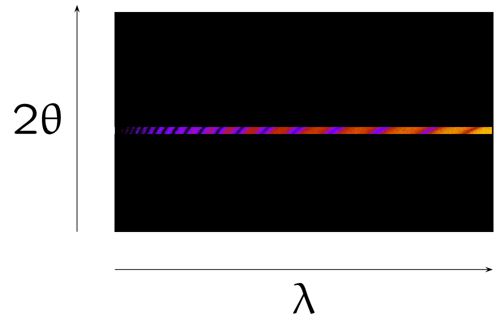
focusing for high-flux specular reflectometry

TOF operartion

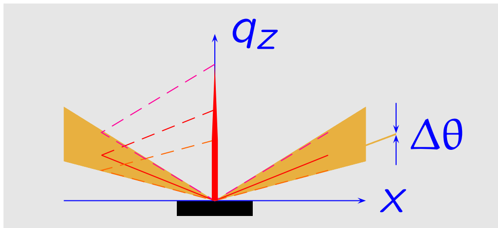
slit-defined beam:

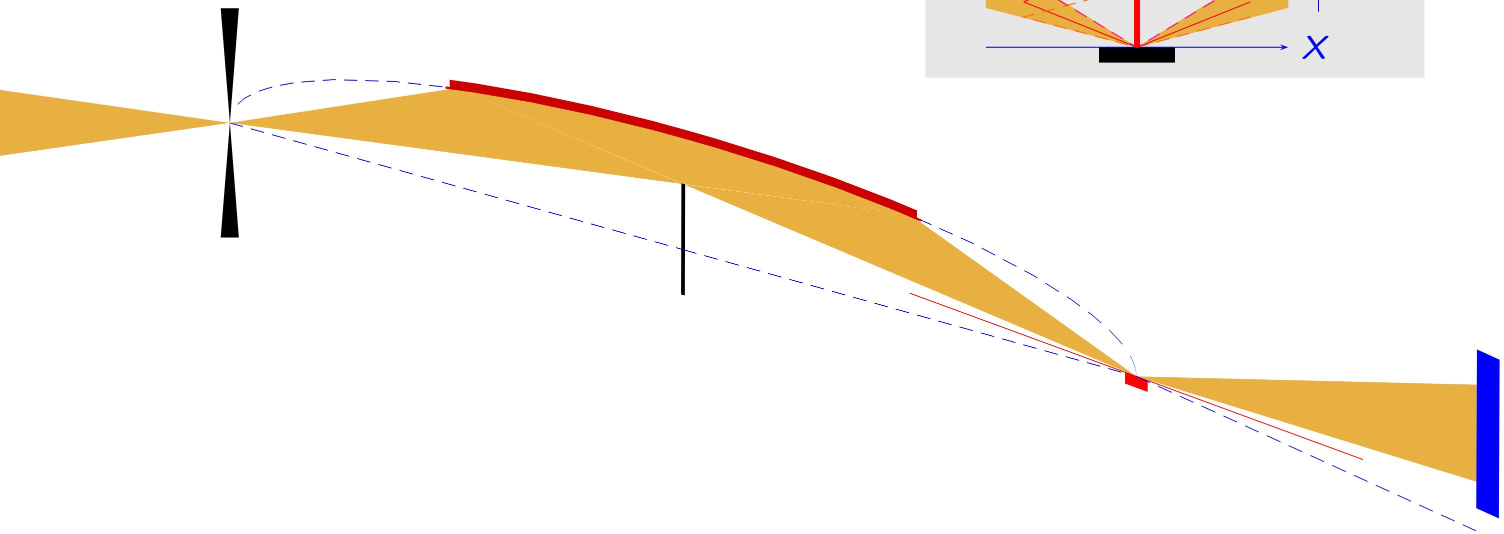


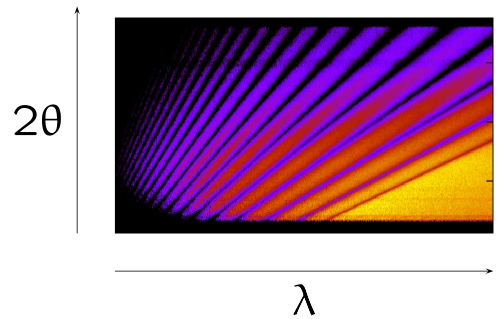




convergent beam:







small samples

small samples

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

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

projected height < 1 mm!

Ni/Ti multilayer on Si, 4×3 mm^2

perovskite multilayer on STO, 5×5 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: $0.1 \times 10\,\text{mm}^2$

$\Rightarrow$ scanning of sample area

focusing with elliptic guides

real focusing!

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

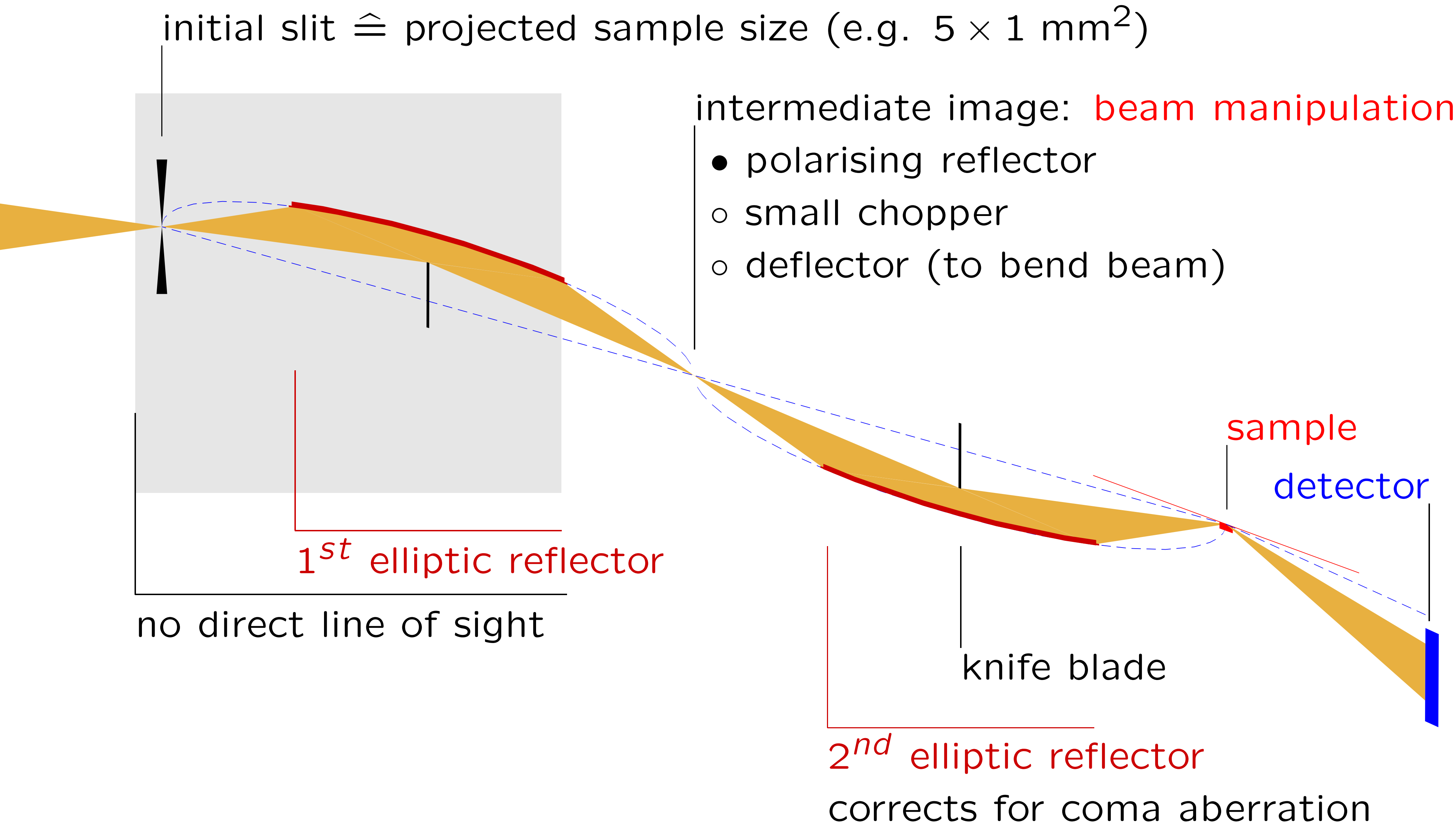
no fancy version of a ballistic guide!

focusing with elliptic guides

generic instrument layout

cut in the scattering plane

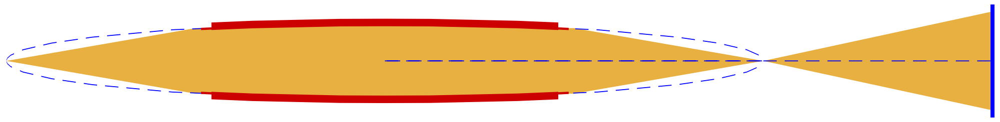
stretched by 10 normal to incident beam



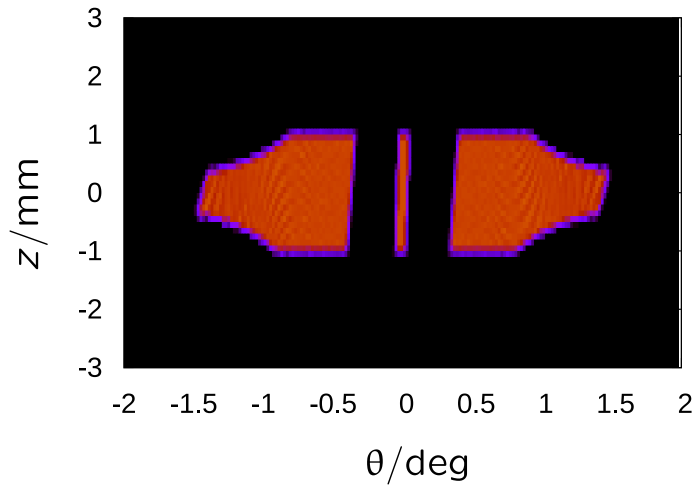
focusing with elliptic guides

why only one branch of an ellipse?

– no structured $I(\theta, z)$



$I(\theta, z)$ map



– one branch can cover $\Delta\theta$

why two subsequent elliptic guides?

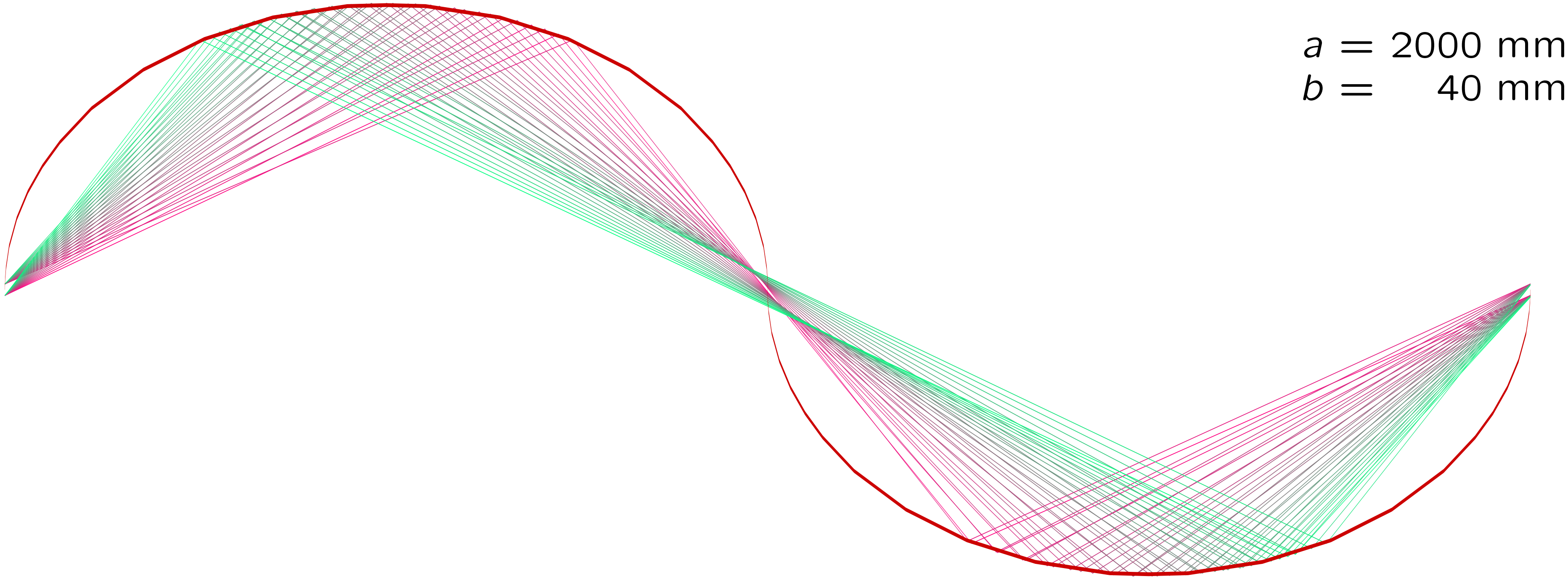
– convenent beam manipulation

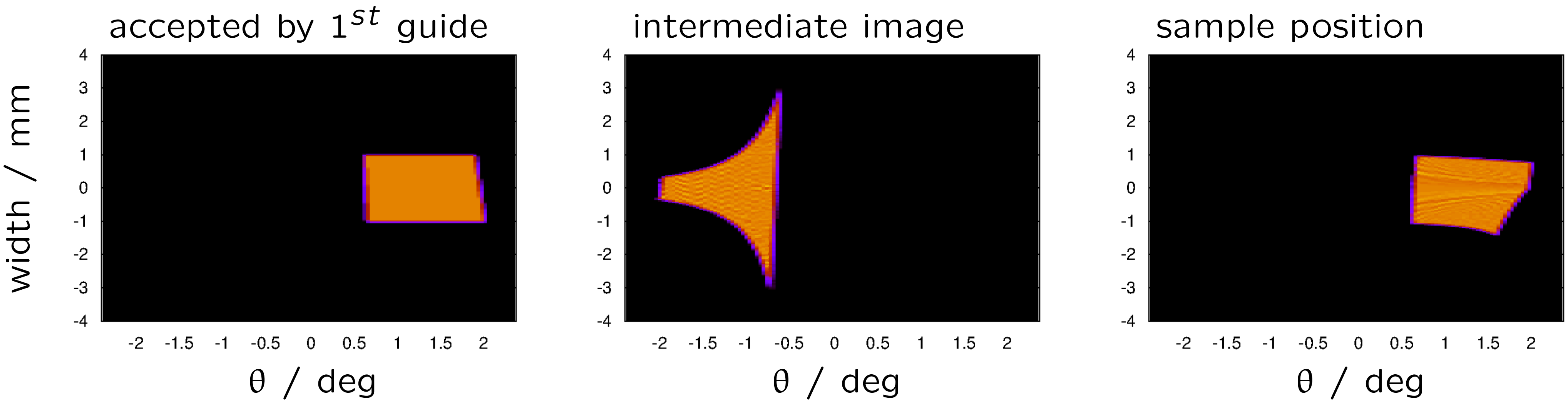
– guide dimensions not too large

→ correction for coma aberration!

focusing with elliptic guides

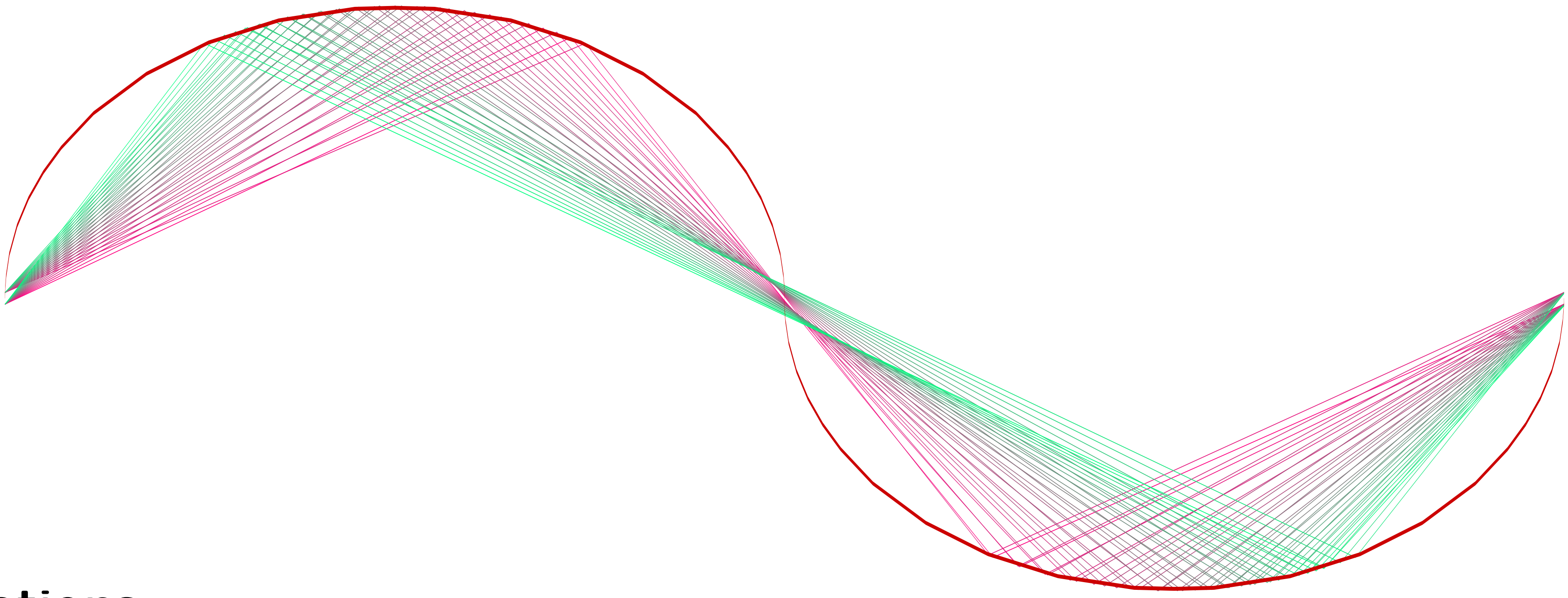
coma aberration — and its correction





focusing with elliptic guides

coma aberration — and its correction



limitations:

– finite length of the guides

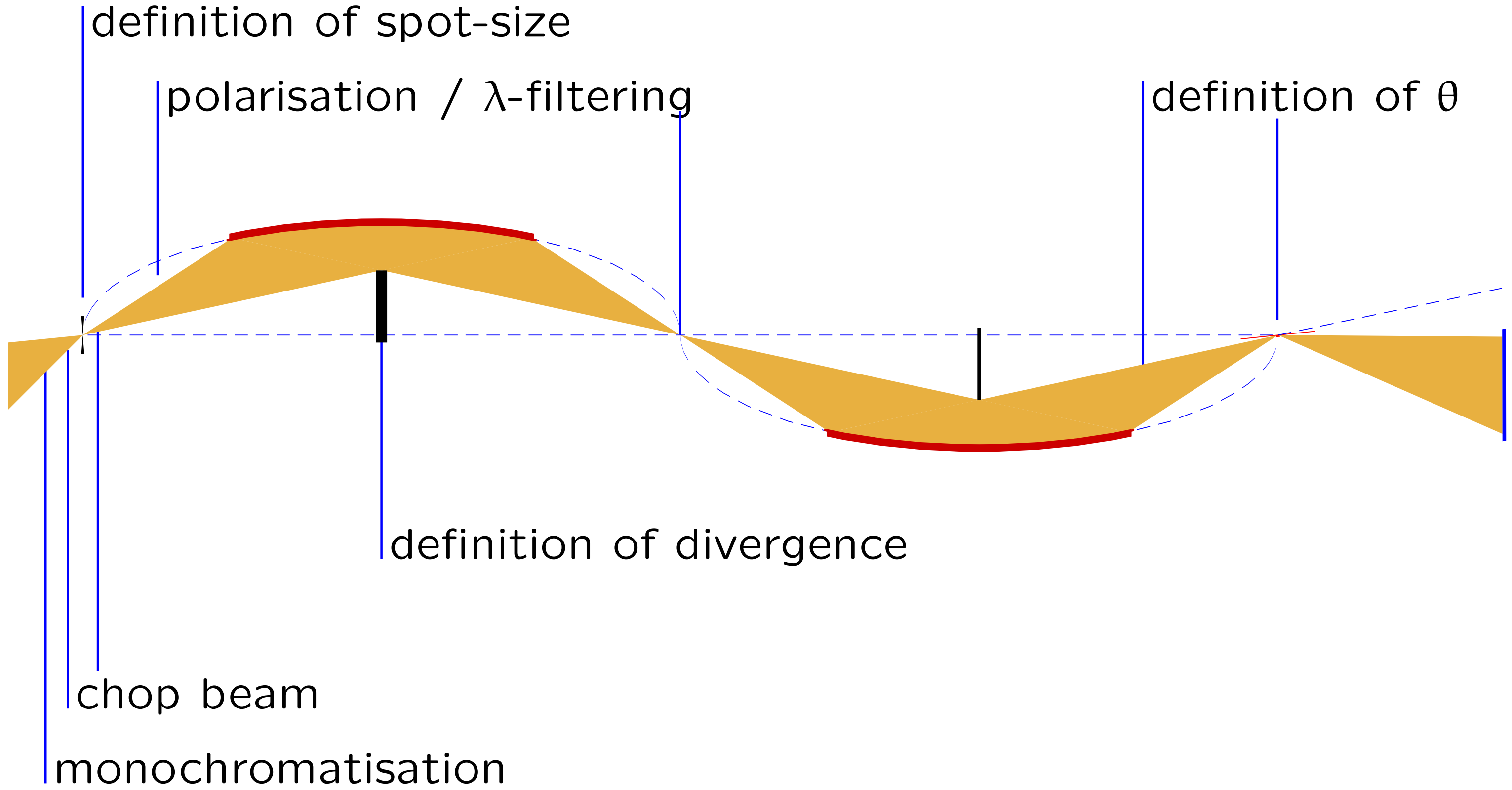
– non-perfect coating

oportunities:

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

focusing with elliptic guides

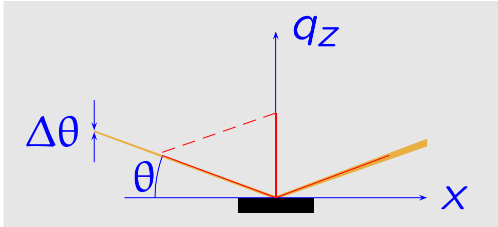
operation modes for TOF: (non-TOF operation is also possible!)

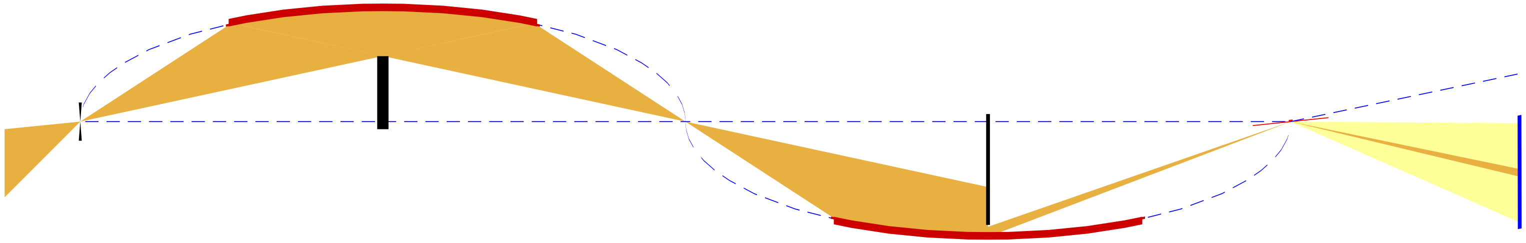


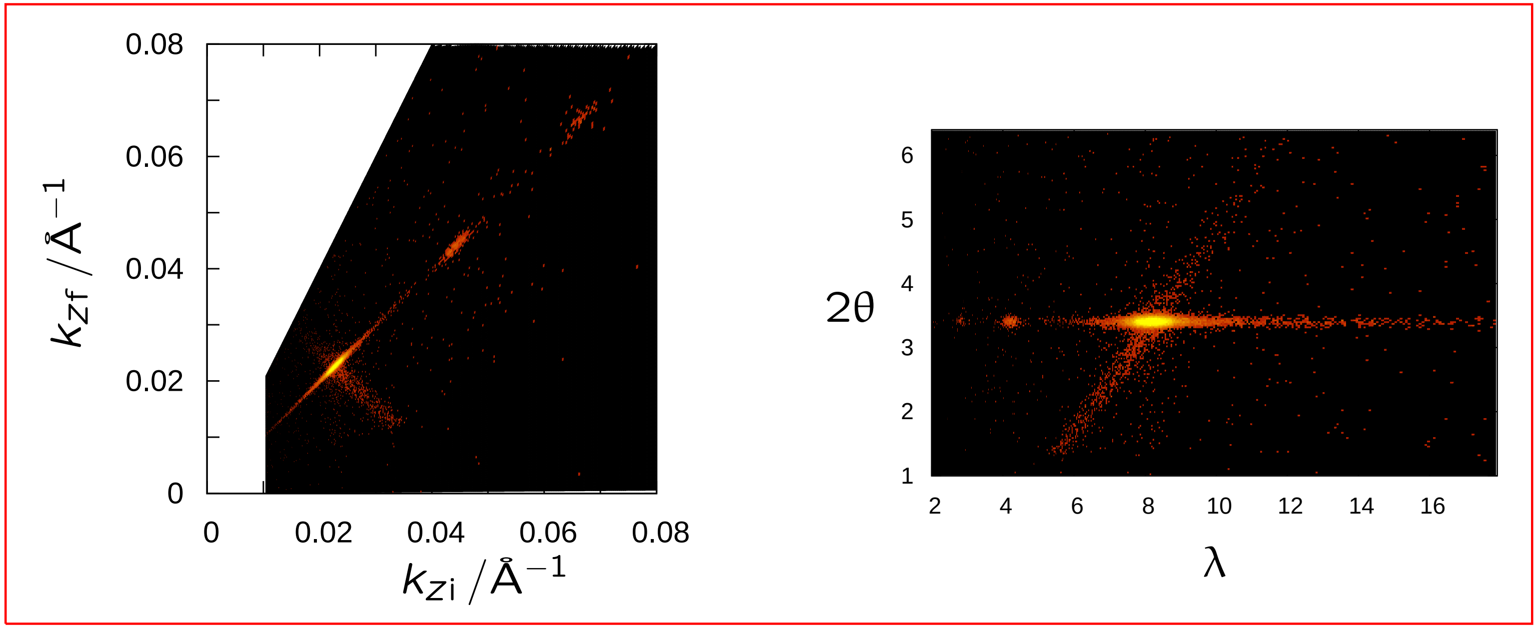
focusing with elliptic guides

mode: almost conventional

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





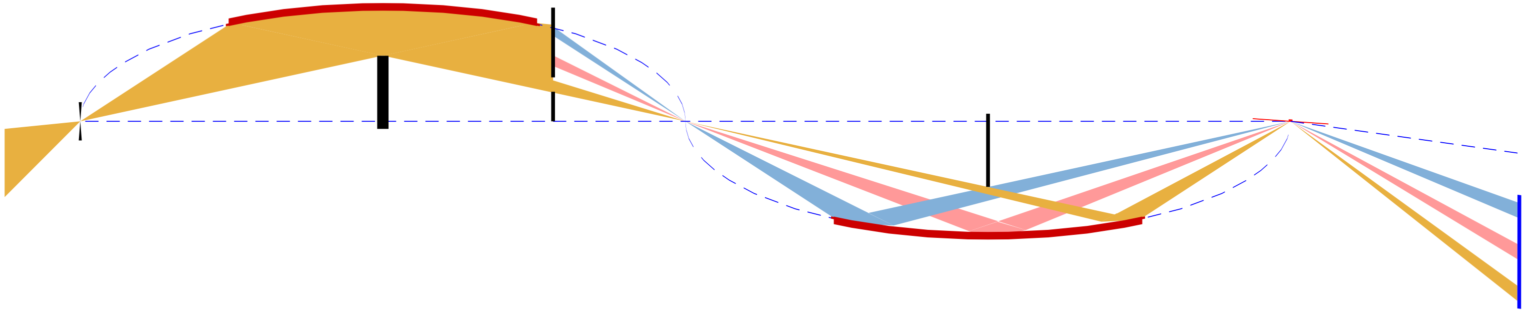


focusing with elliptic guides

mode: wide *q*-range

– vary θ with fixed sample position

– shift diaphragm (chopper) between pulses

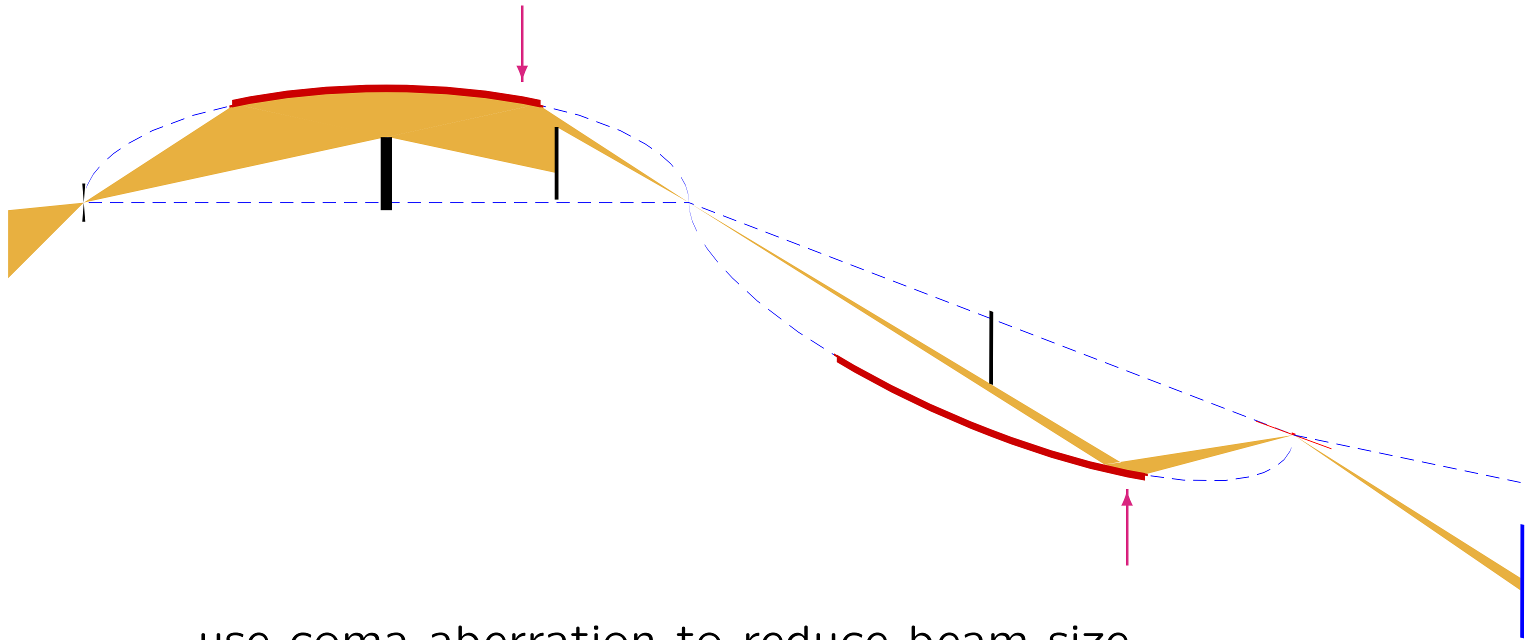


– suited for liquid surfaces

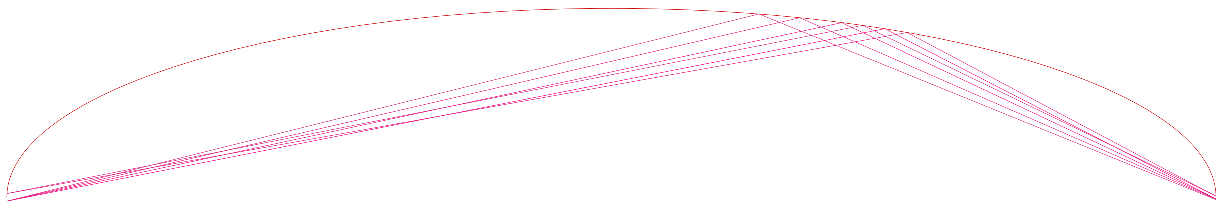
focusing with elliptic guides

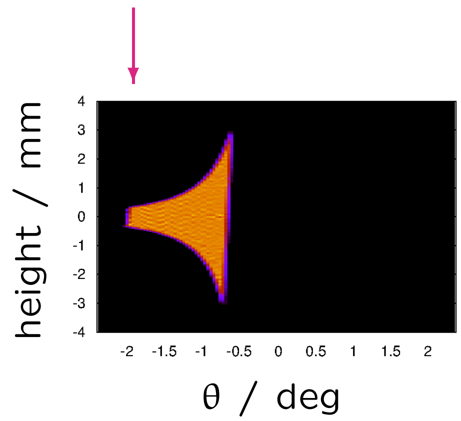
mode: small spot size

– uses focusing due to coma aberration
– scanning mode possible



use coma aberration to reduce beam size





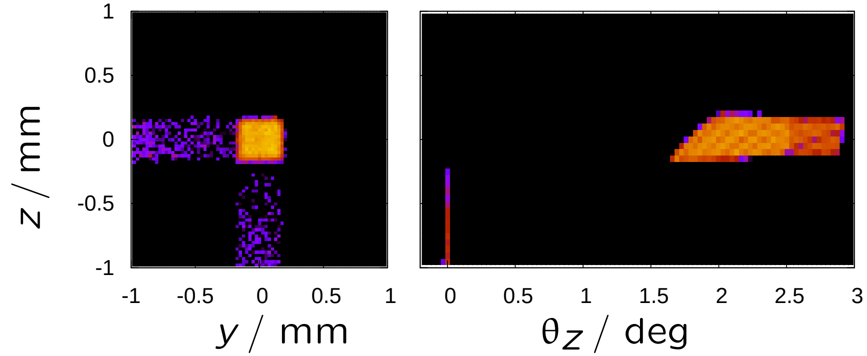
focusing with elliptic guides

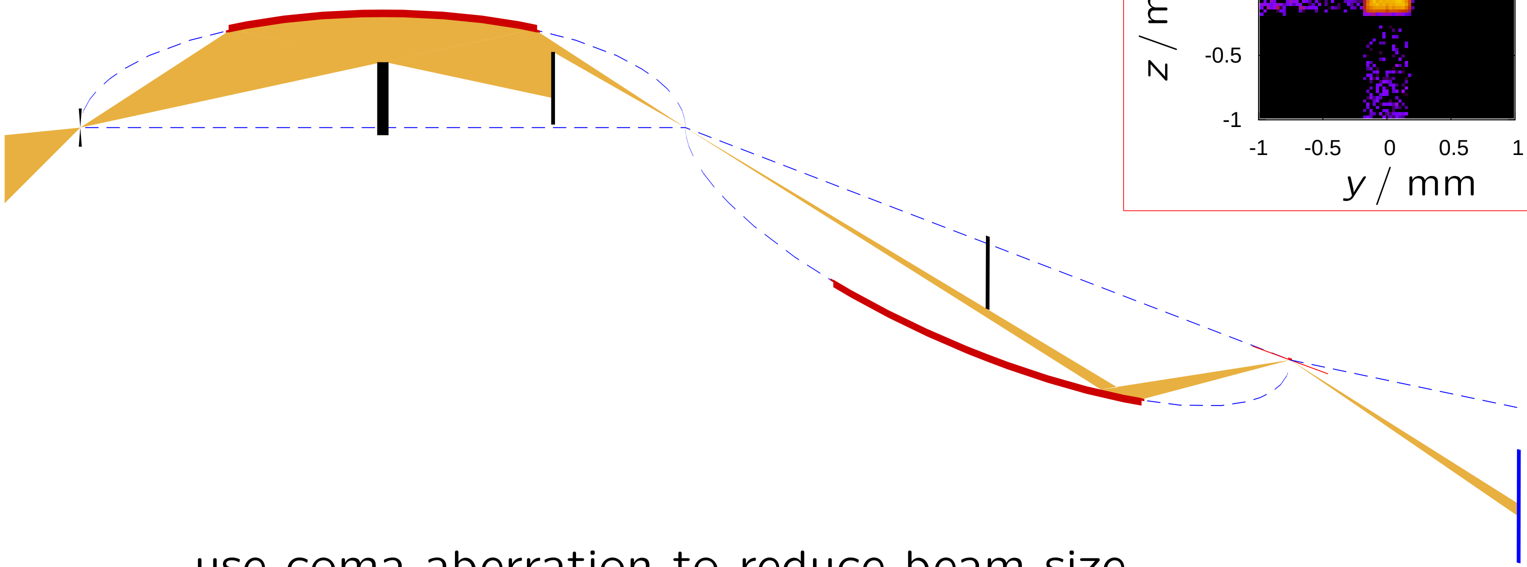
mode: small spot size

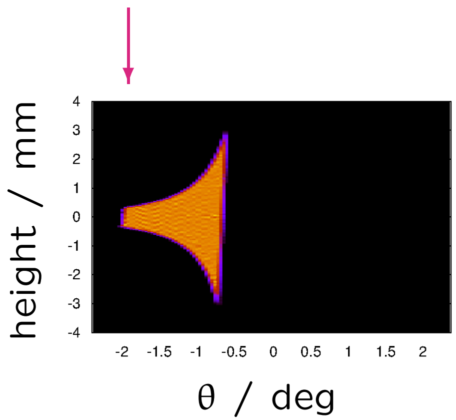
- uses focusing due to coma aberration
- scanning mode possible

$I(y,z)$ and $I(z,\theta_z)$ at the sample

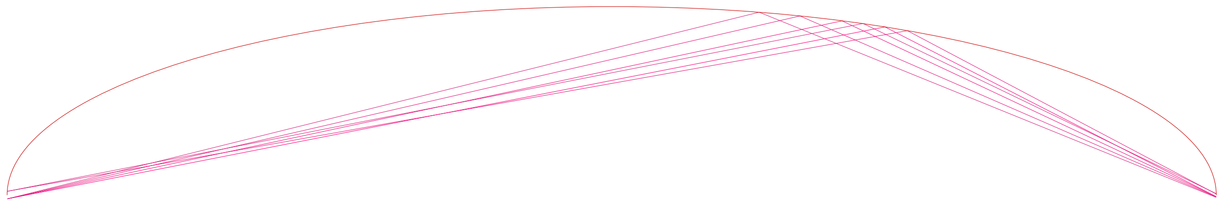
for a $1 \times 1\,\mathrm{mm}^2$ entrance slit







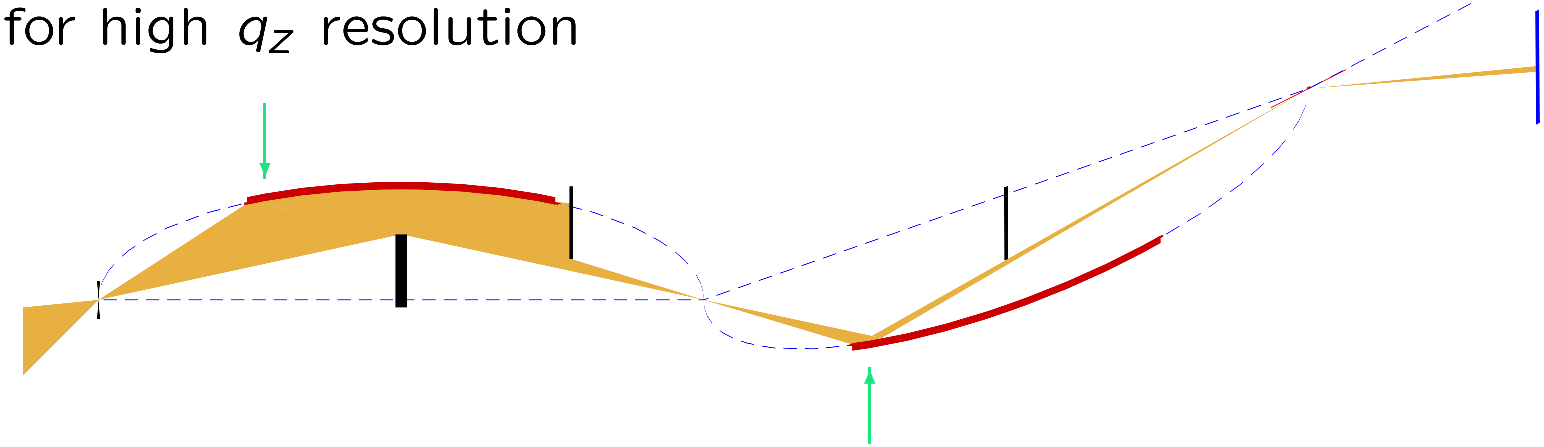
use coma aberration to reduce beam size



focusing with elliptic guides

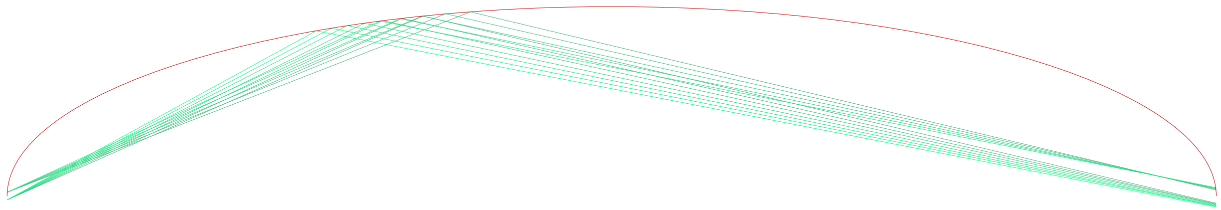
mode: low-divergent beam

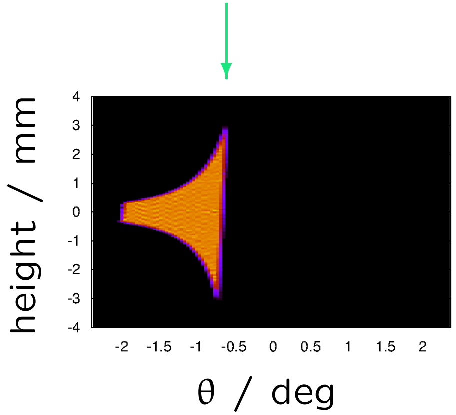
– uses defocusing due to coma aberration
– corresponds to the use of Montel optics used at synchrotrons
– for high q_z resolution



– parallel beam e.g. for GISANS

use coma aberration to reduce divergence

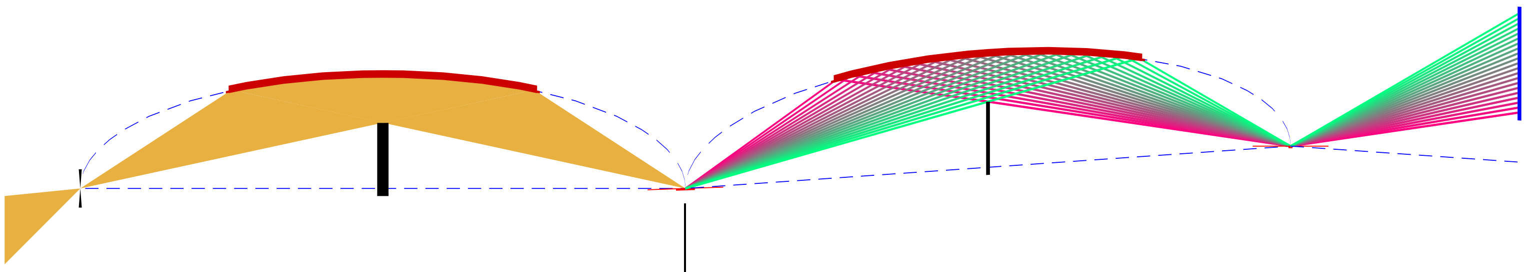




focusing with elliptic guides

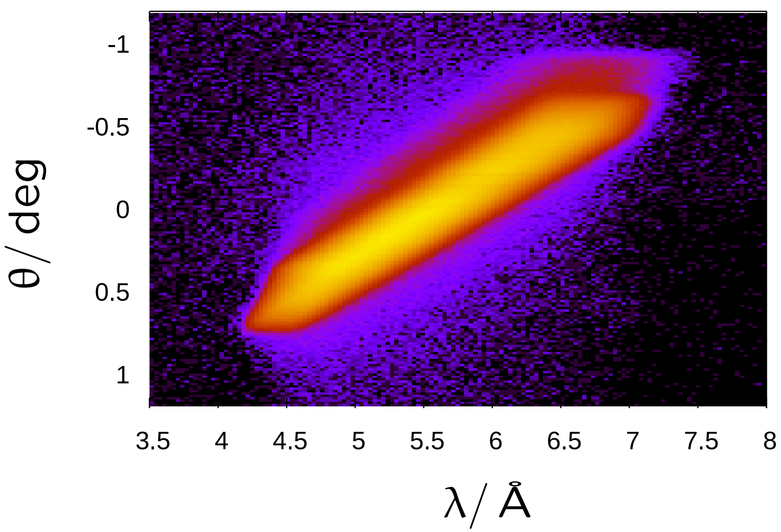
mode: angle/energy encoding

– 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

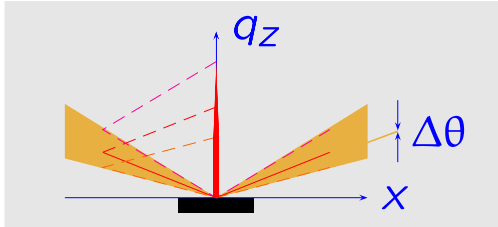
$I(\lambda, \theta)$ after ml monochromator

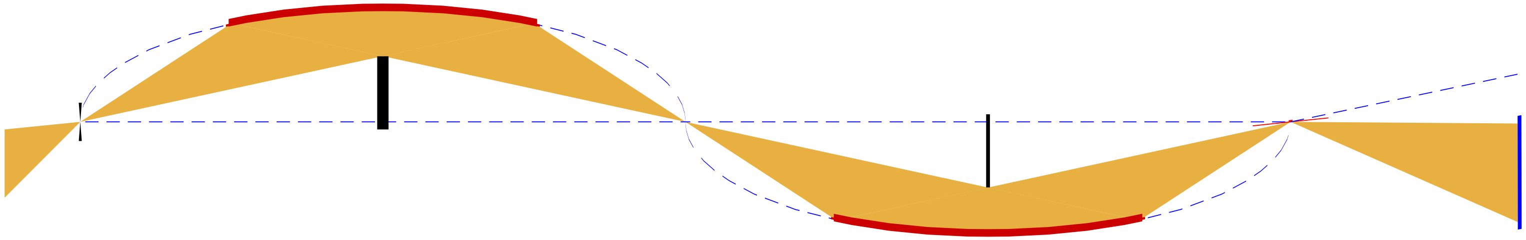


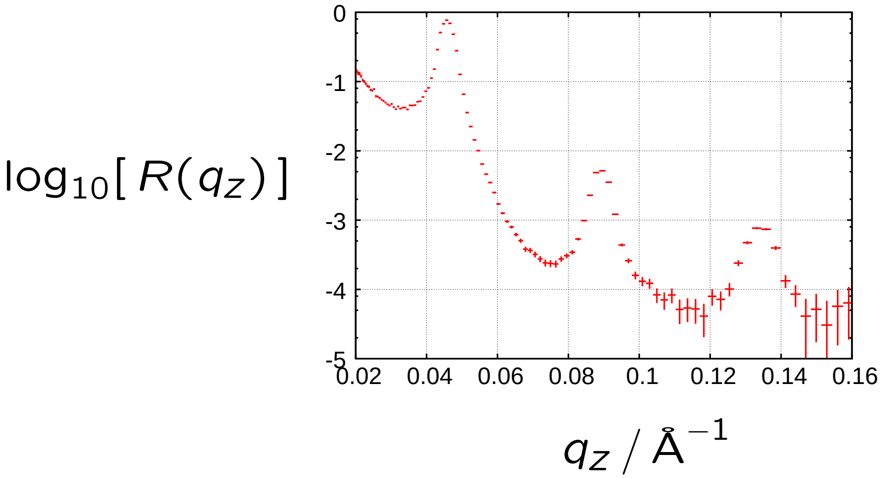
focusing with elliptic guides

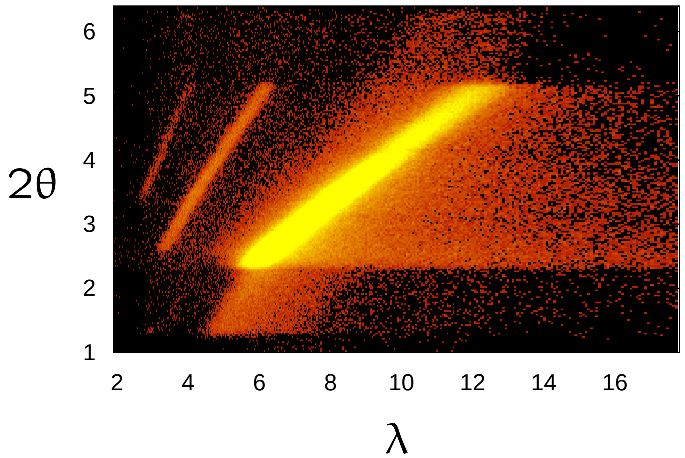
mode: high-intensity specular reflectivity

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



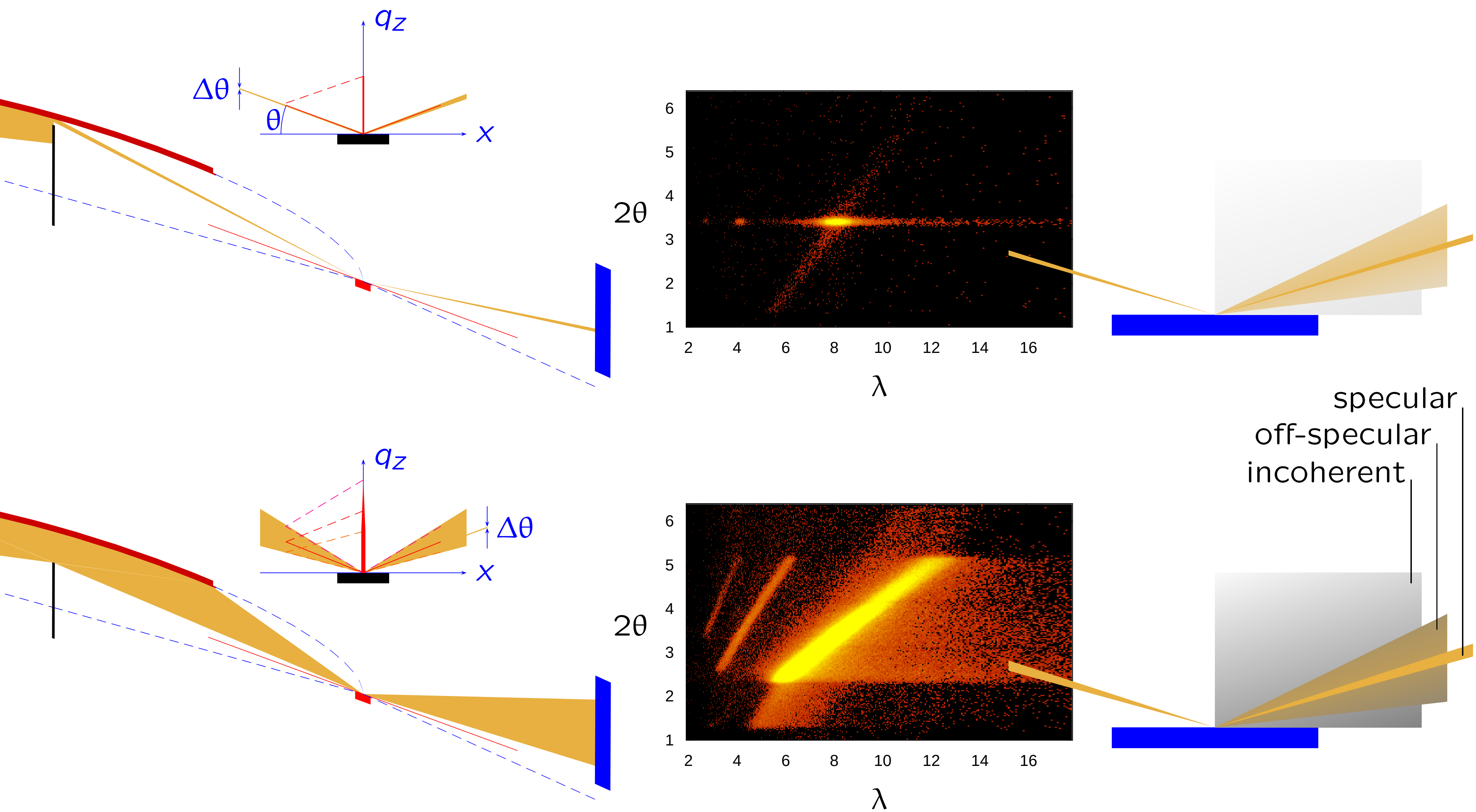






focusing with elliptic guides

high-intensity specular reflectivity vs. allmost conventional



realisation

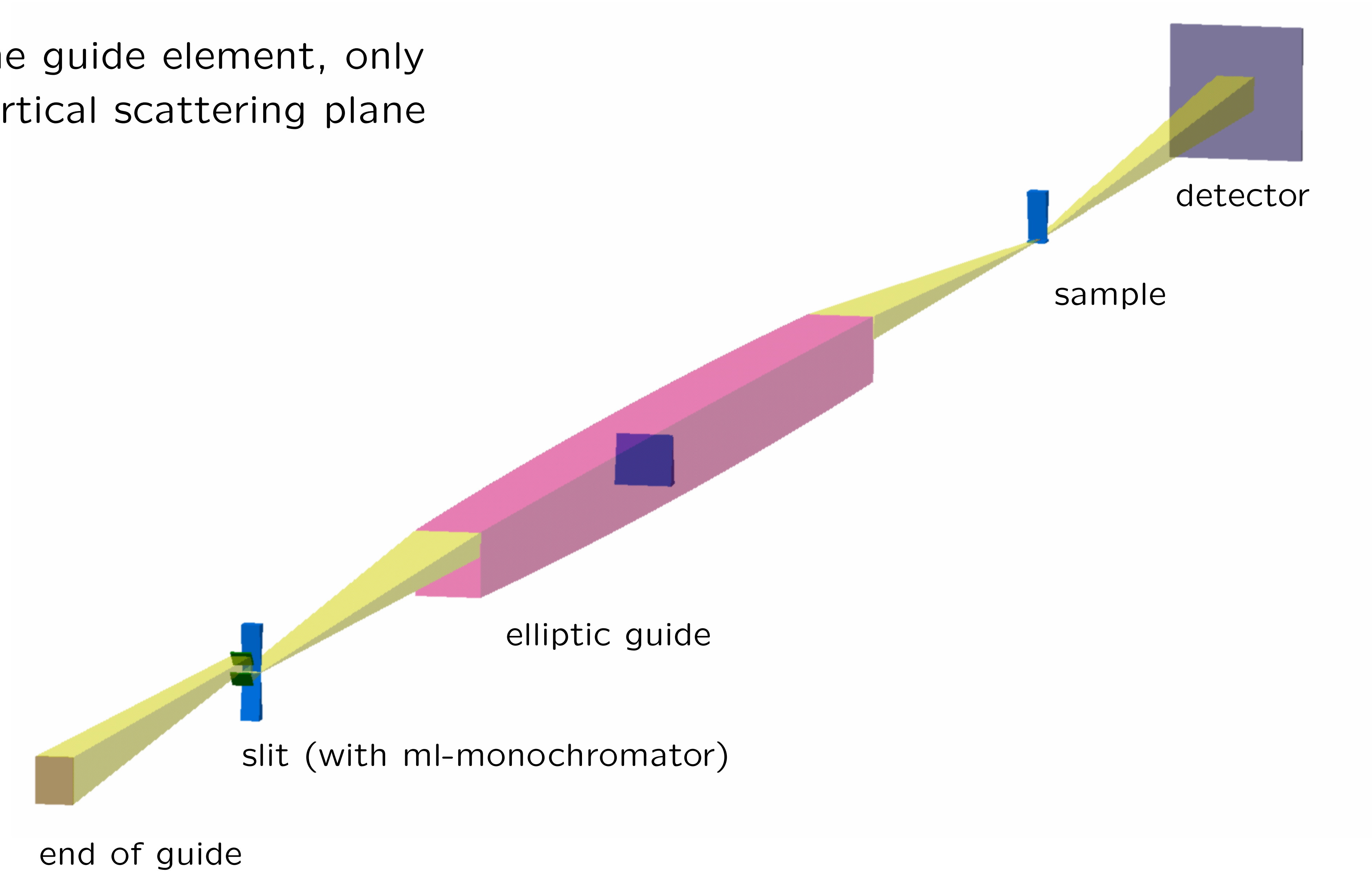
add-on for Amor

prototype on BOA

concept for the ESS

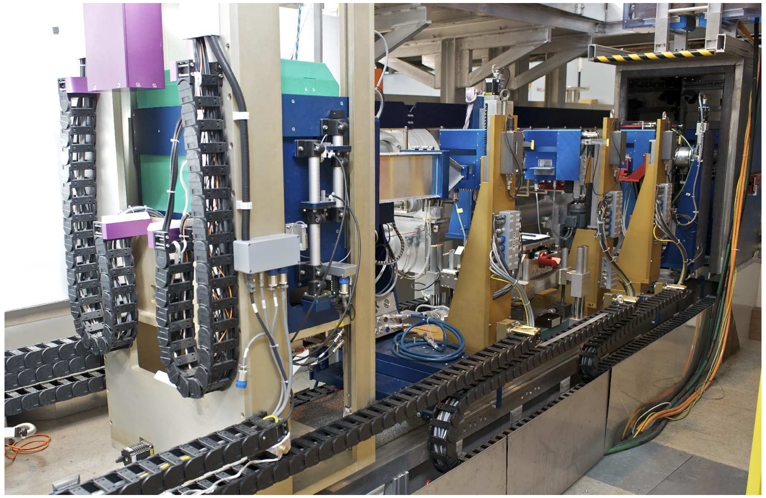
realisation: add-on for Amor

one guide element, only
vertical scattering plane



realisation: add-on for Amor

Amor, conventional TOF set-up



8 m granite block

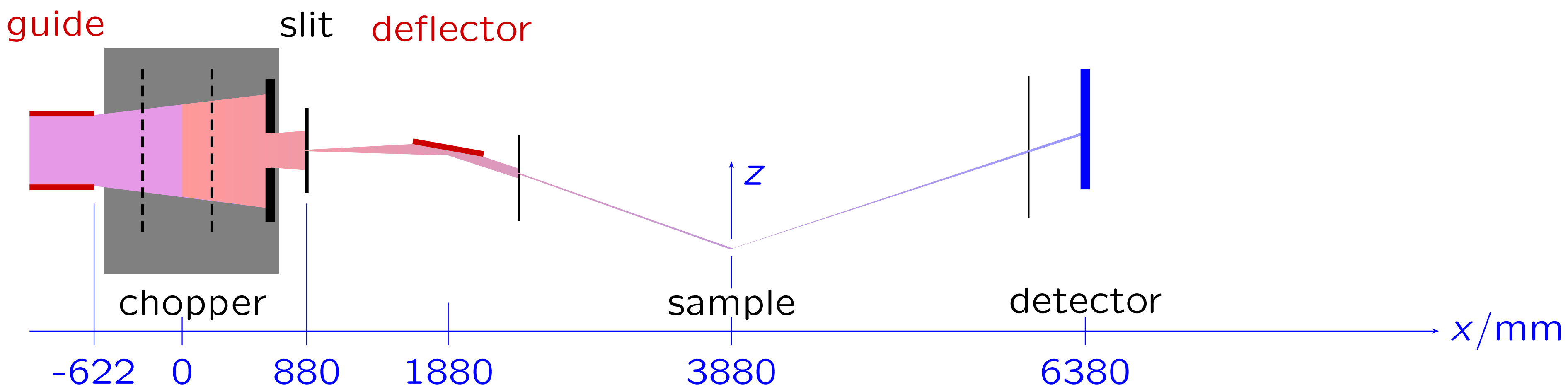
maximum length chopper to detector = 10 m

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

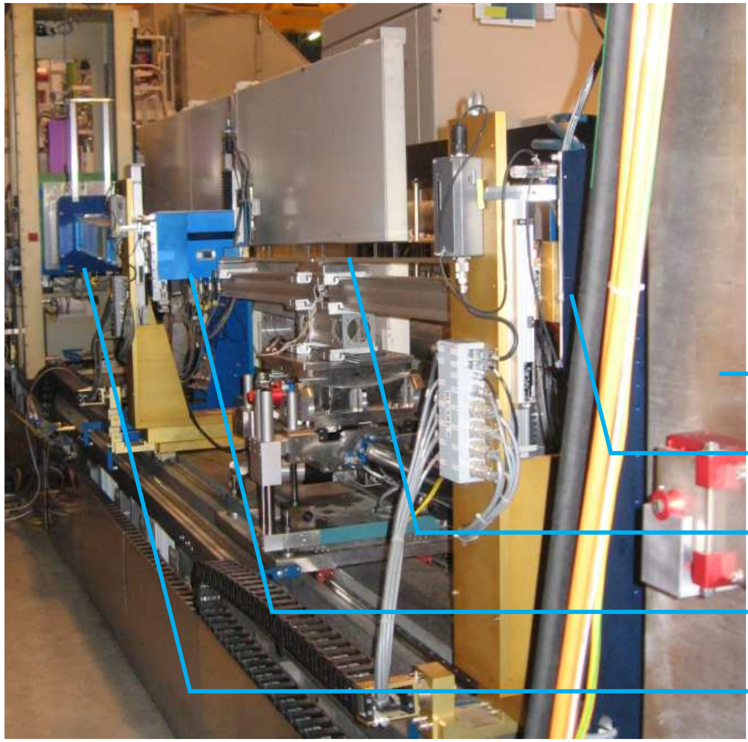
$\lambda \in [2\,\text{Å}, 18\,\text{Å}]$

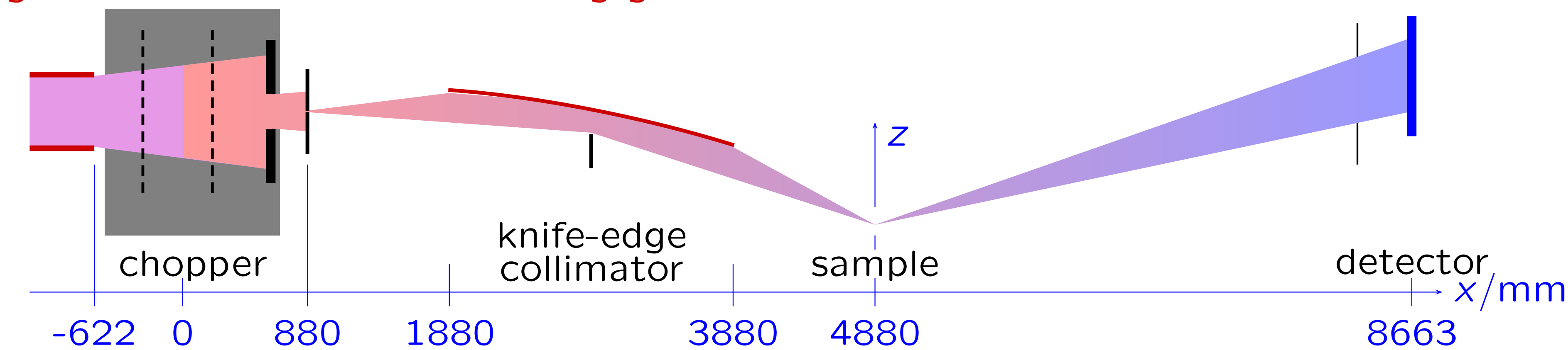
vertical scattering plane

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



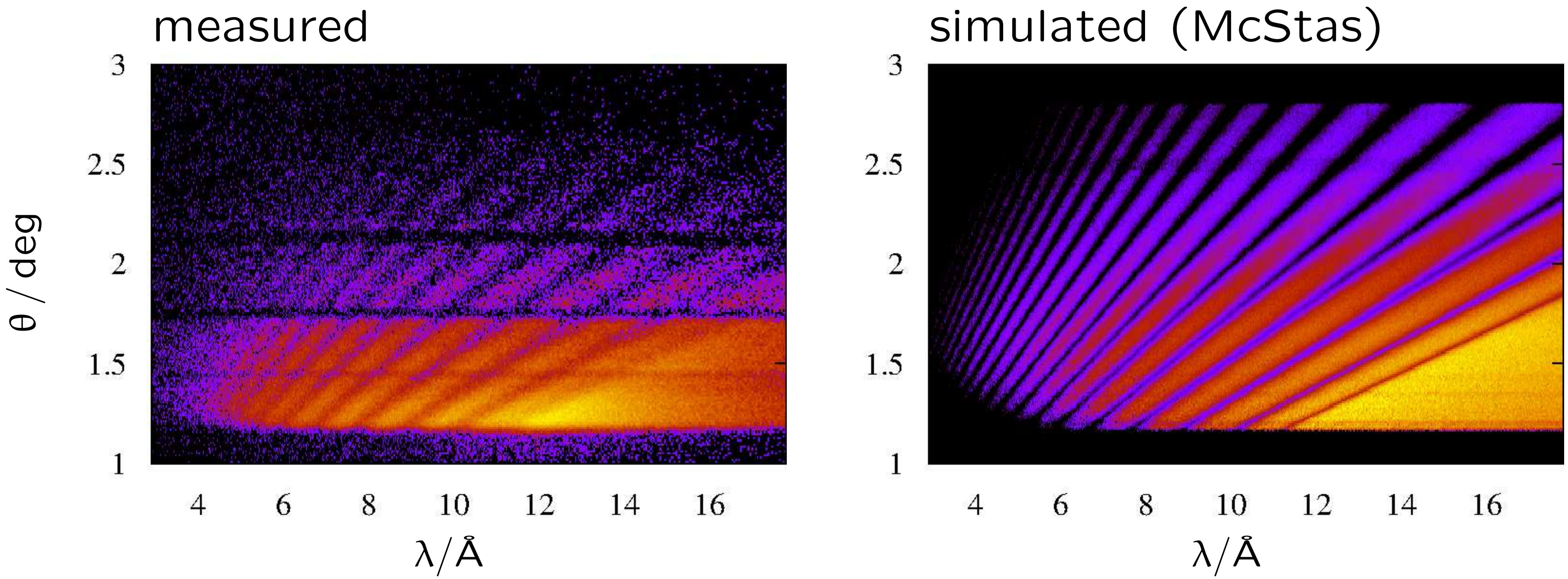
realisation: add-on for Amor

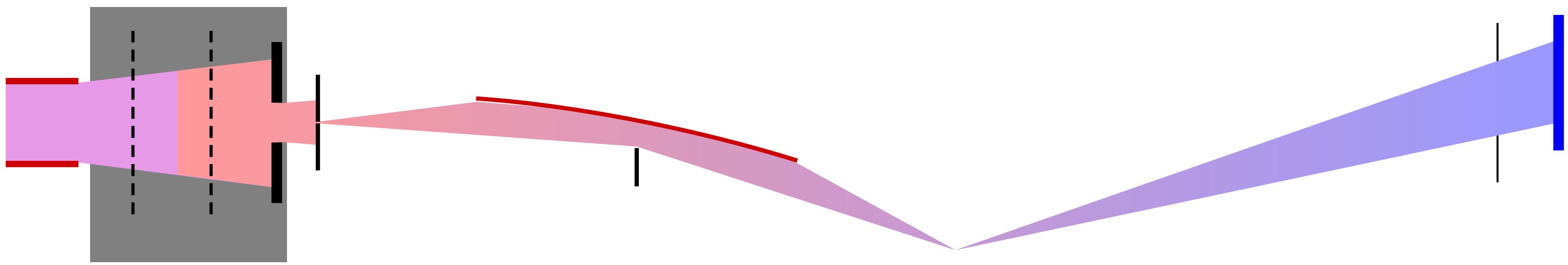




realisation: add-on for Amor

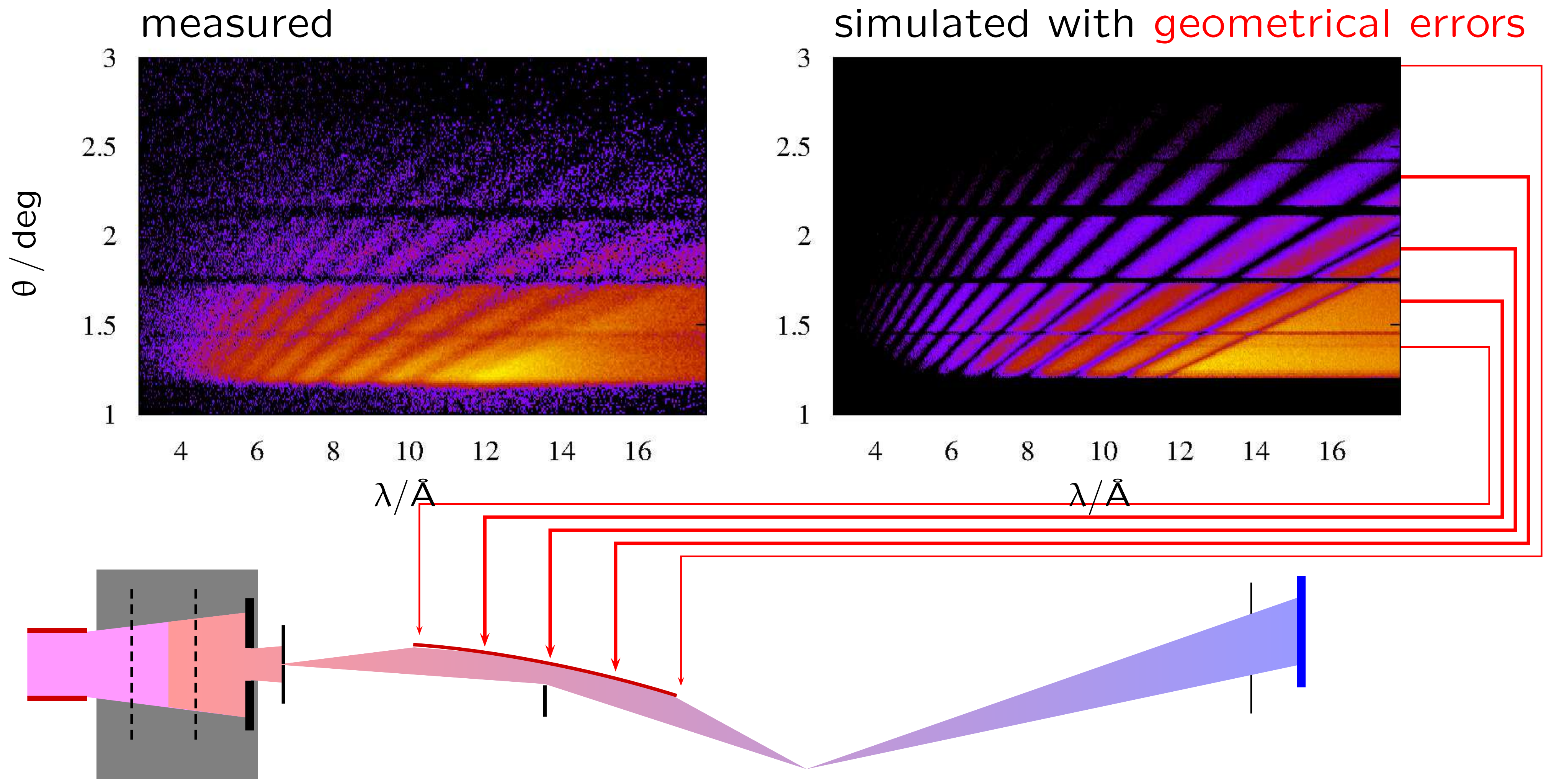
measurements: 1000 Å Ni film on glass, $9 \times 9\,\text{mm}^2$





realisation: add-on for Amor

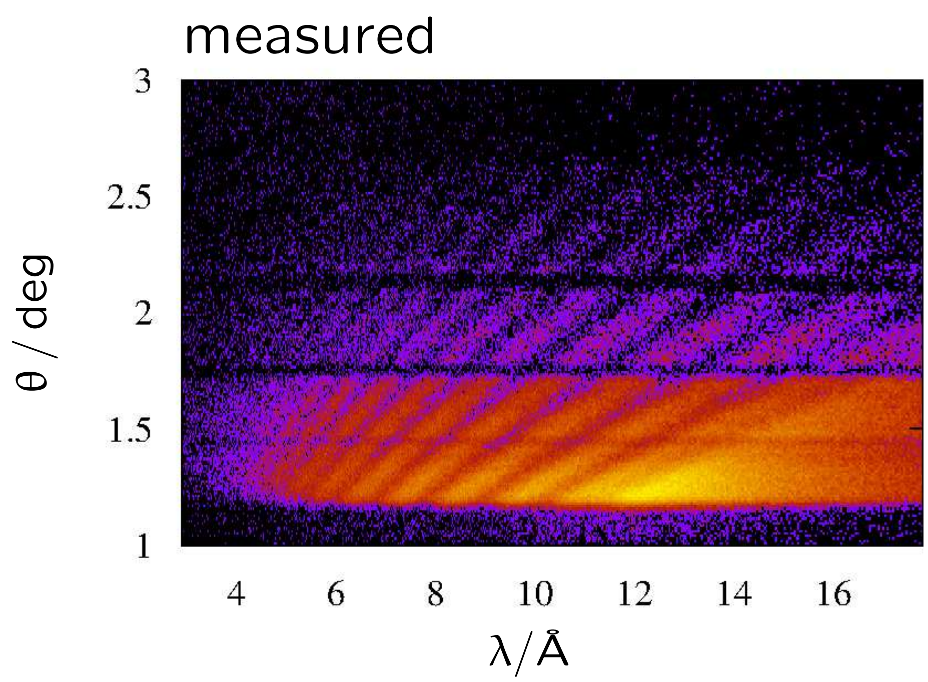
measurements: 1000 Å Ni film on glass, $9 \times 9\,\text{mm}^2$

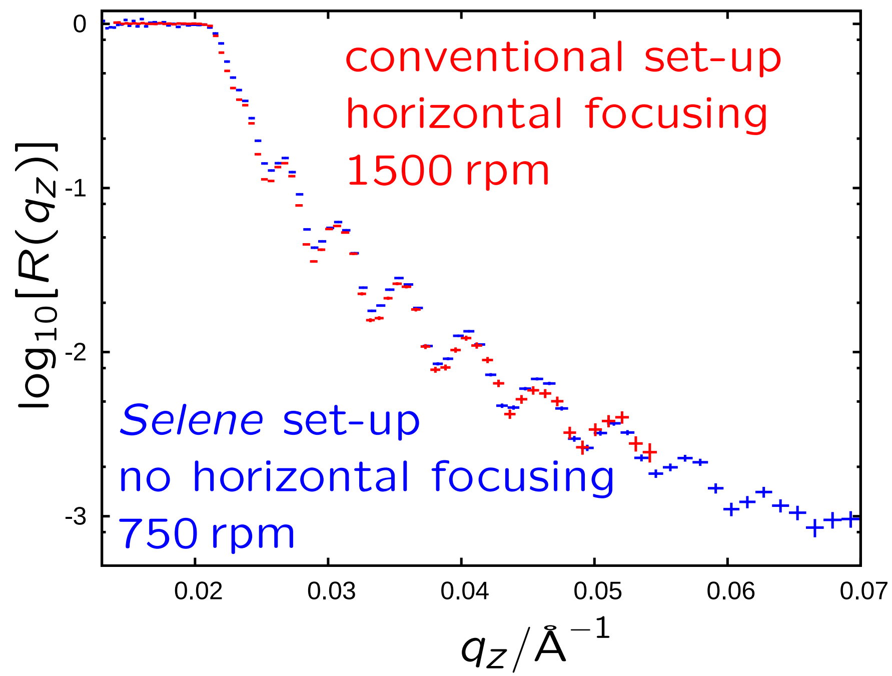


4 guide elements à 500 mm

realisation: add-on for Amor

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





measurement time:

conventional	5 h
Selene	45 min
gain-factor	6.7

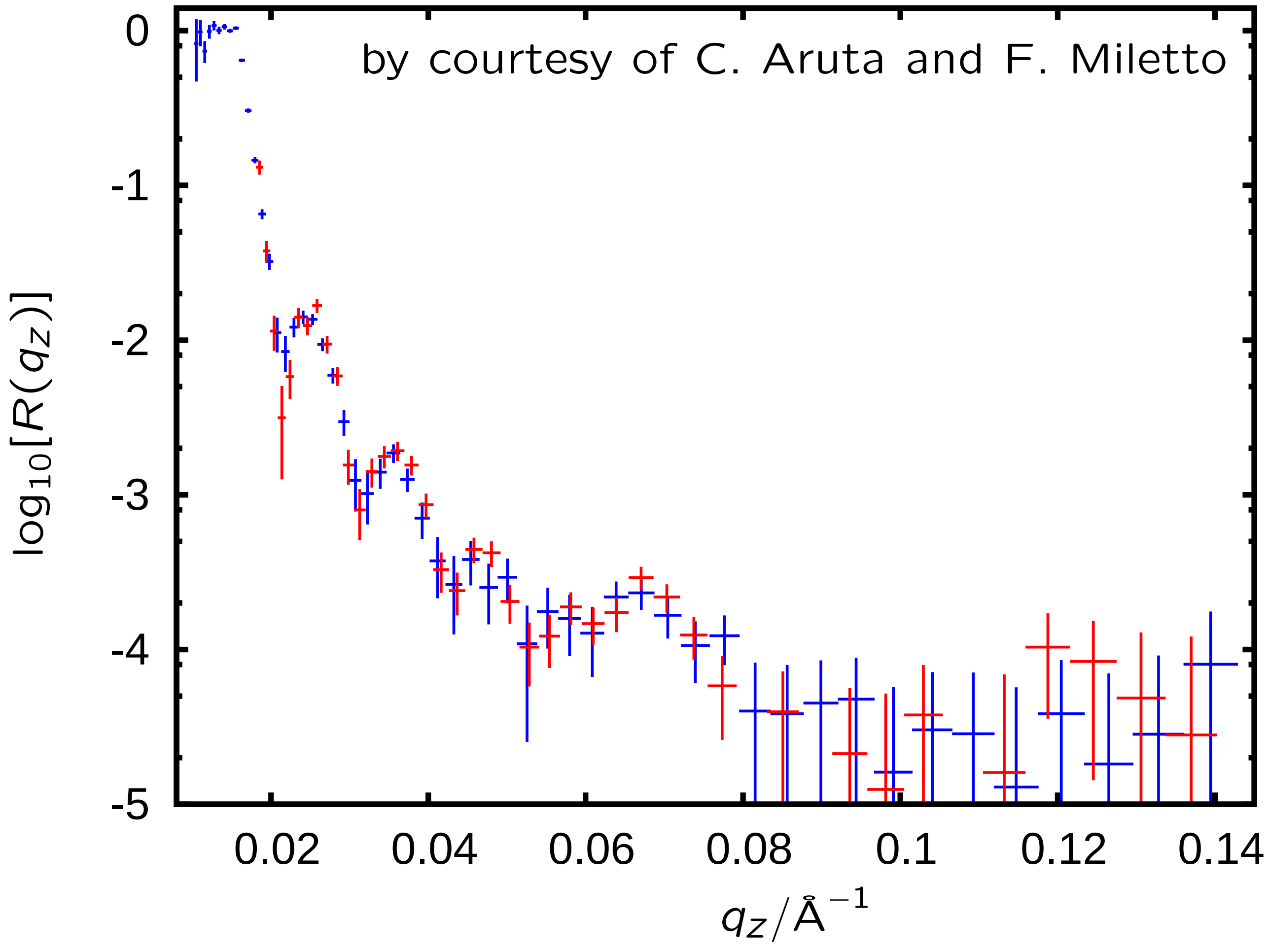
realisation: add-on for Amor

$[La_{2/3}Sr_{1/3}MnO_3 / SrTiO_3]_4 / NGO$ $4 \times 5\,mm^2$

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

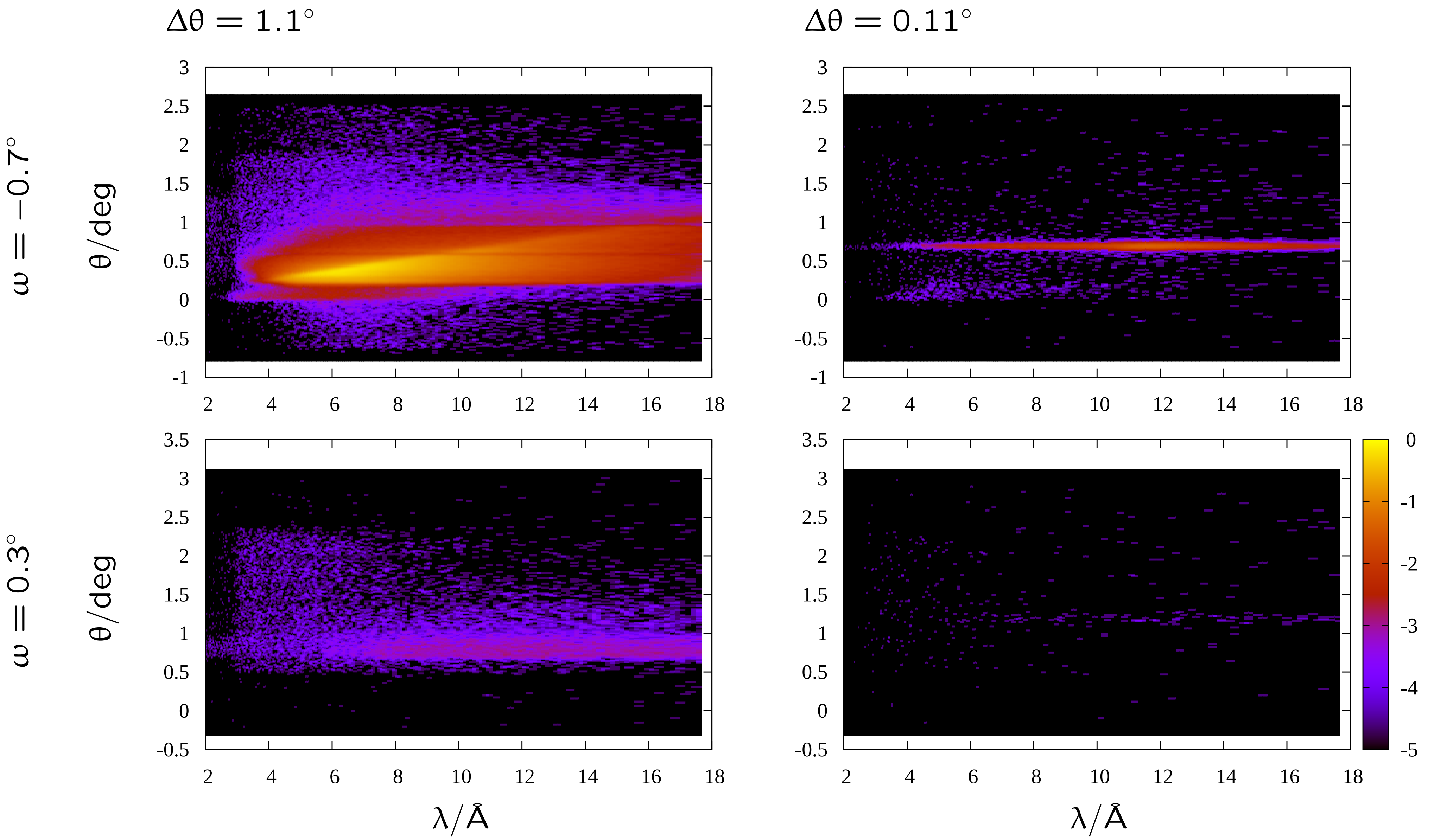
– measurement time:

conventional	6.5 h
Selene	45 min
gain-factor	8.3



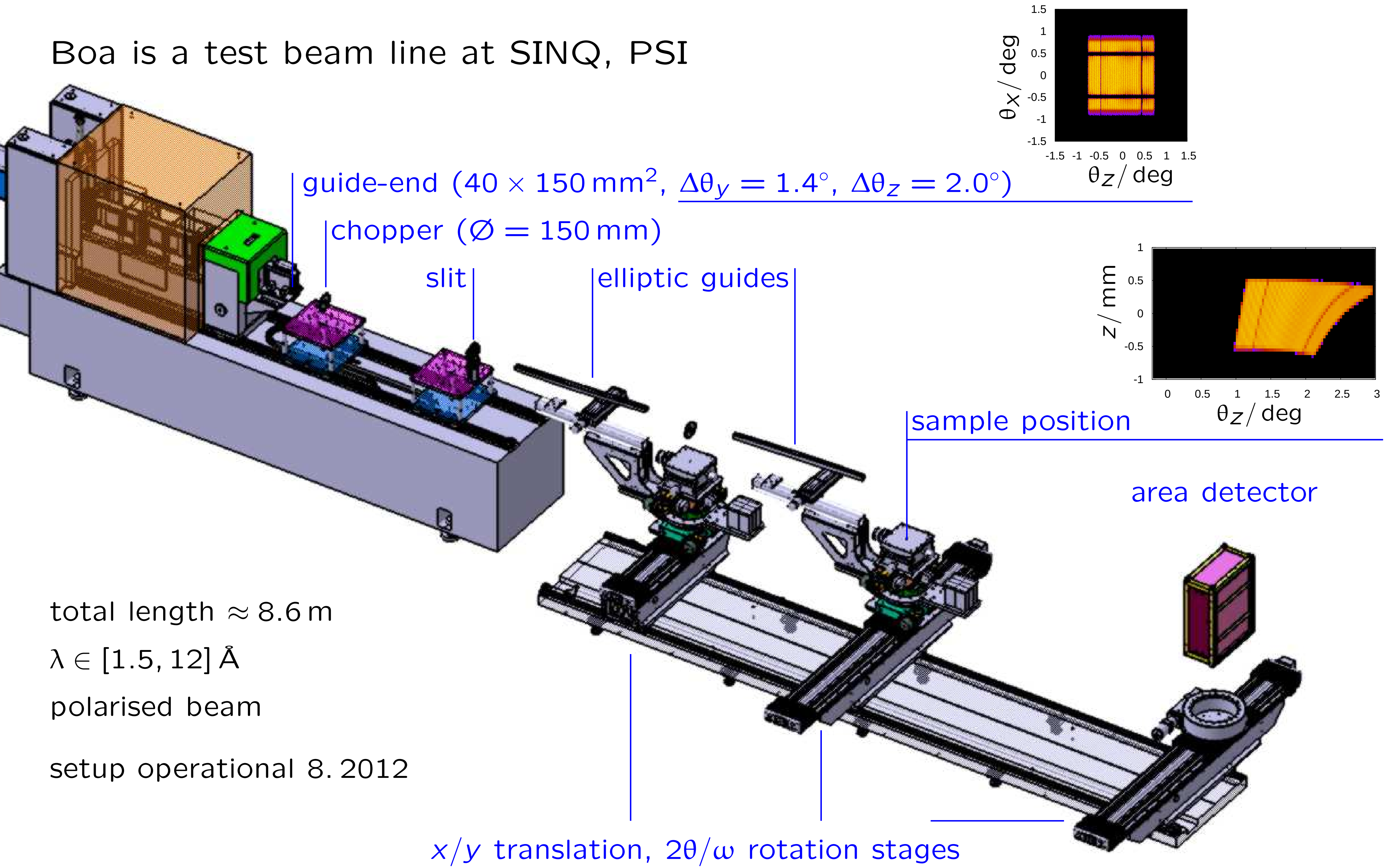
realisation: add-on for Amor

$\log_{10}[I(\lambda, \theta)]$ 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 $\approx 8.6\,\mathrm{m}$

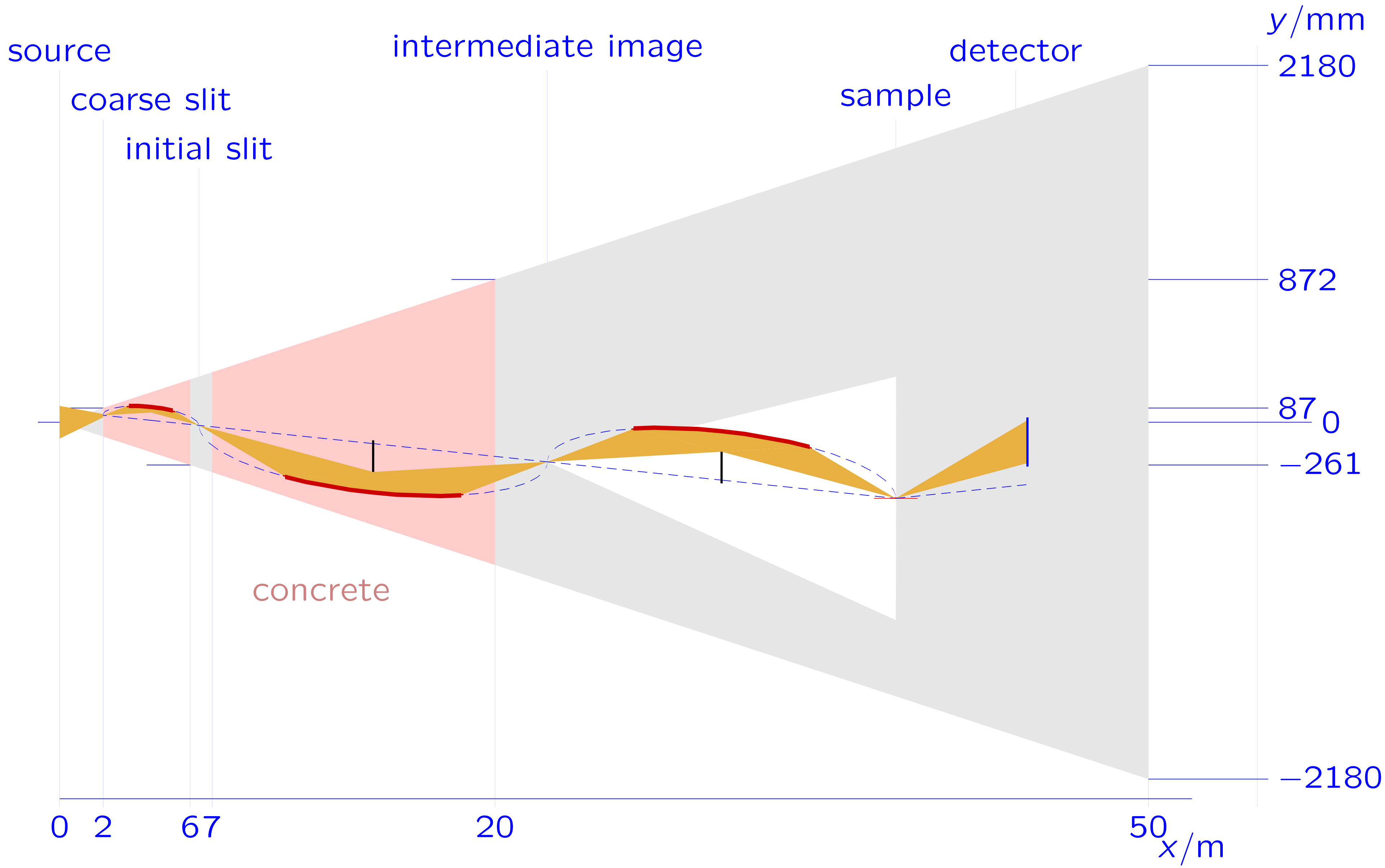
$\lambda \in [1.5, 12]\,\text{Å}$

polarised beam

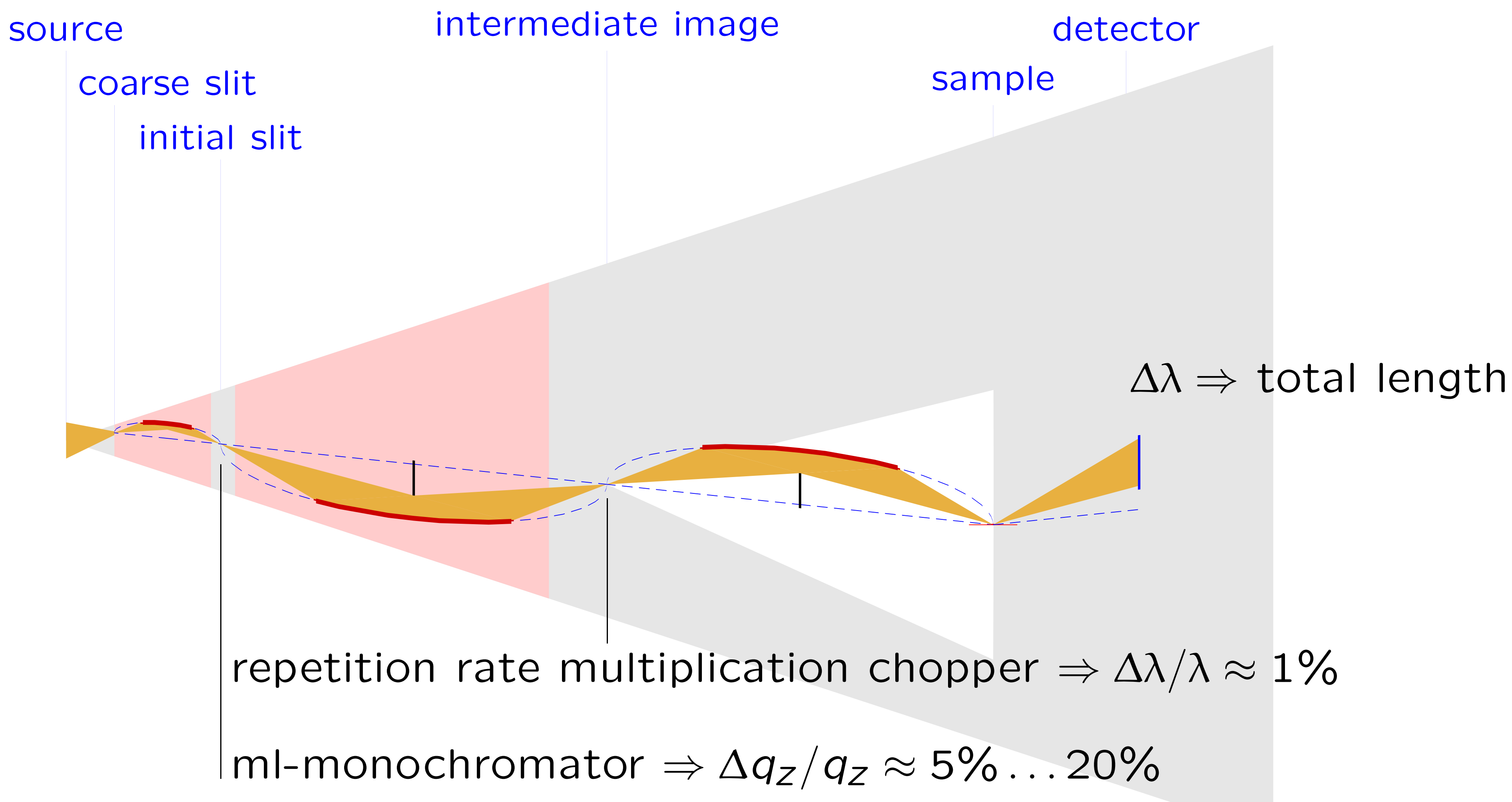
setup operational 8. 2012

realisation: concept for the ESS

schematic lay-out of the reflectometer for tiny samples



realisation: concept for the ESS



$\Delta\theta, \lambda -$ range $\Rightarrow q_z -$ range

final remarks

critical points

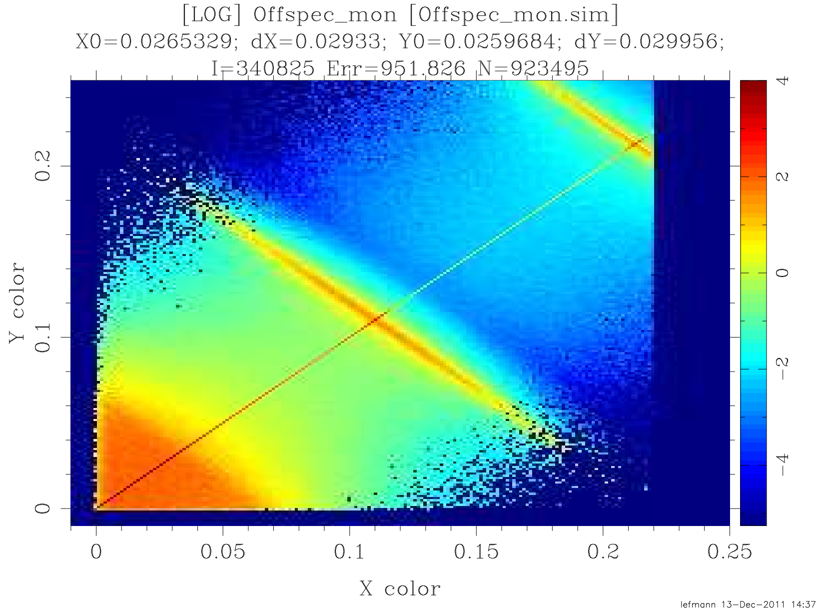
thanks

Selene

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 Uwe Filges	McStas simulations, experiments, BOA
Dieter Graf	conctruction
Marcel Schild	electronics
SwissNeutronics	elliptic guide development
Marité Cardenas Anette Vickery	experiments
Hanna Wacklin Bob Cubitt Peter Böni Uwe Stuhr Frederic Ott Thomas Krist	discussions

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