Jochen Stahn

TOF reflectometry at PSI:

from an optical bench set-up to a new instrument concept with a focus on small samples

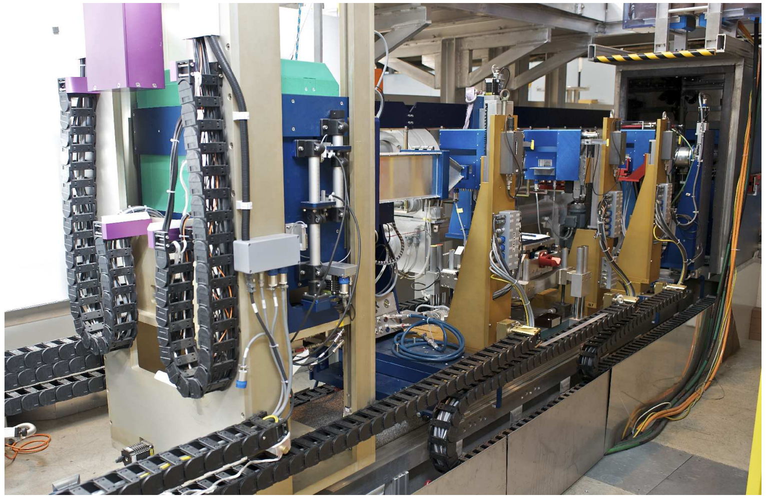
JCNS instrumentation workshop

04.–07. 10. 2011, Tutzing

pre-history

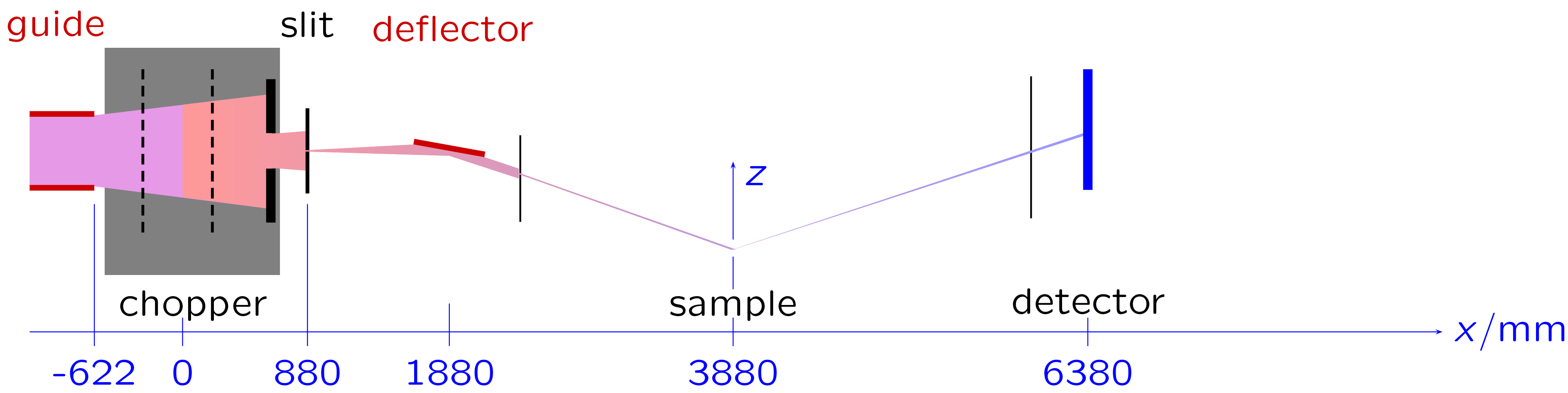
scientific case: liquid-air-interface

⇒ ∘ vertical scattering geometry
∘ (variable) inclination of the beam
∘ TOF operation (double-blind-chopper)

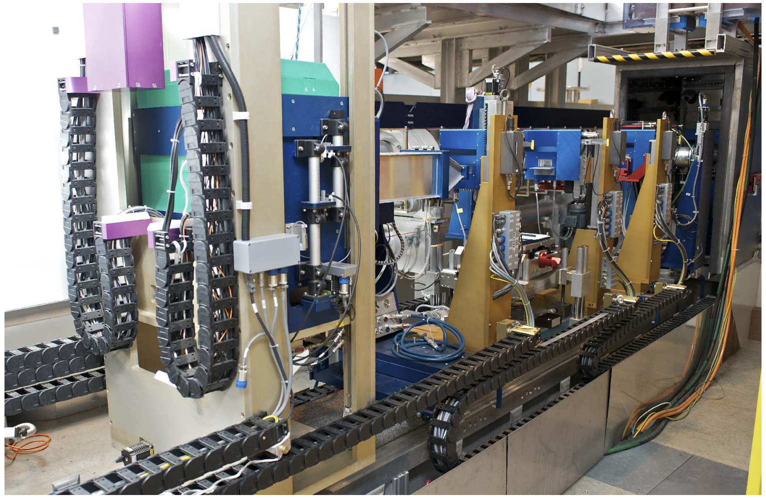


variable resolution

⇒ ∘ optical bench set-up
∘ high flexibility



the optical bench



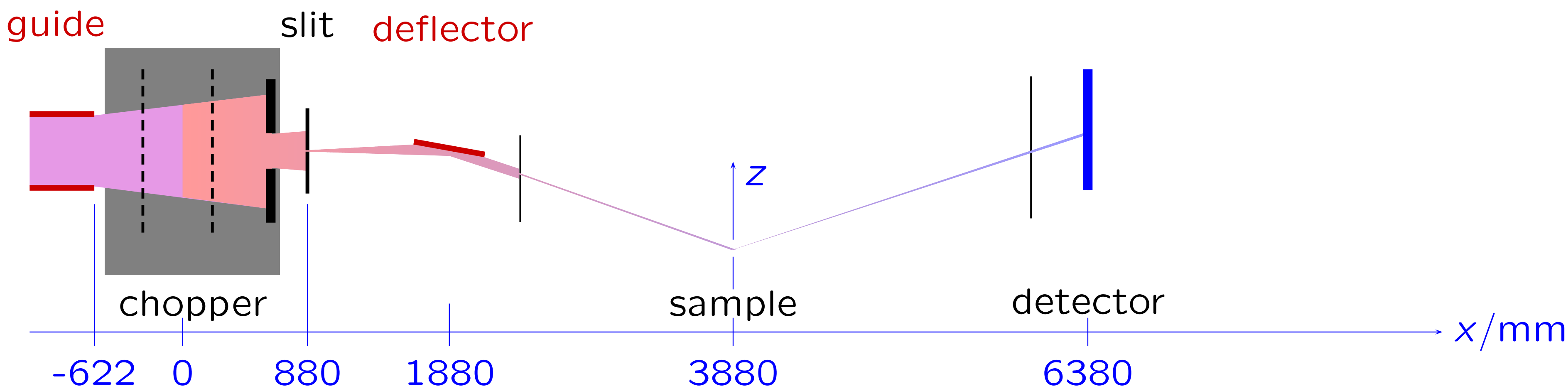
8 m granite block

maximum length chopper to detector = 10 m

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

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

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



options

trough

polarisation

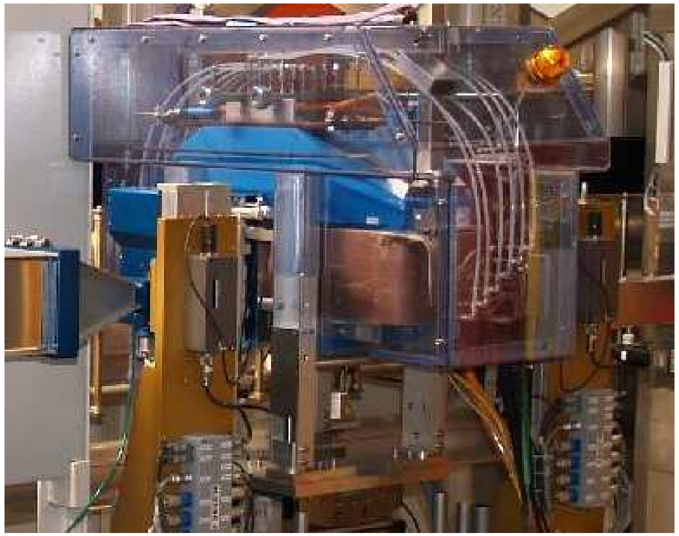
polarisation analysis

cryomagnet

(horizontal, 6 T)

1T electromagnet

large gap



actual usage of Amor

(Amor is the only reflectometer at SINQ)

liquid/air interfaces	$< 10\%$
liquid/solid interfaces	$< 30\%$
magnetic samples	$> 50\%$
non-magnetic solid samples	$> 10\%$

majority of the samples is $< 2\,\mathrm{cm}^2$
some are $< 5 \times 5\,\mathrm{mm}^2$

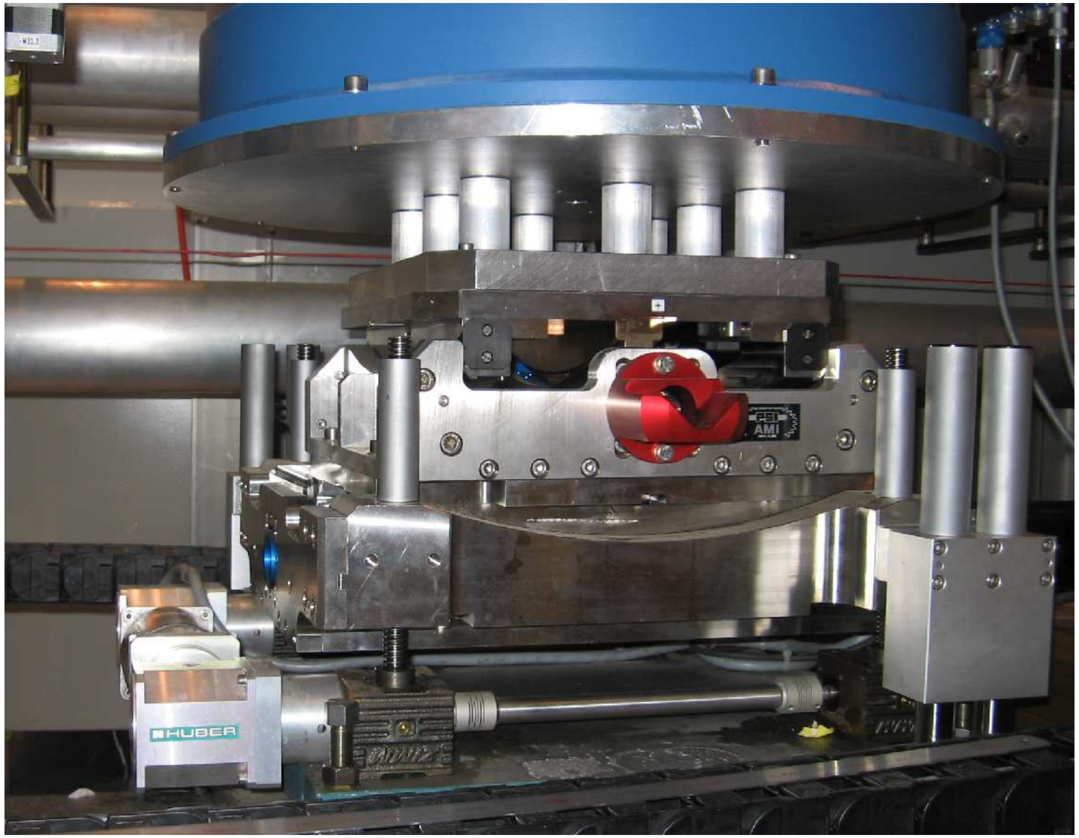
$\Rightarrow$ adaption of Amor for small magnetic samples

innovations:

non-magnetic sample table for 1t load

$\omega \in [\pm 4^\circ]$ for heavy set-up

$\omega \in [\pm 15^\circ]$ else



innovations:

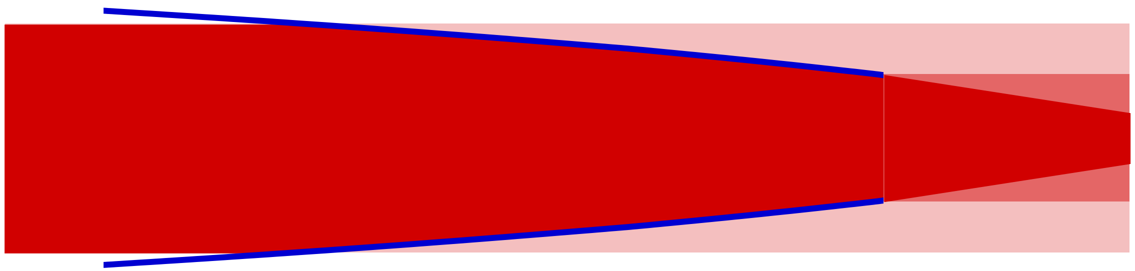
shielding of the detector and flight tube

$\Rightarrow$ background from sample(environment) only

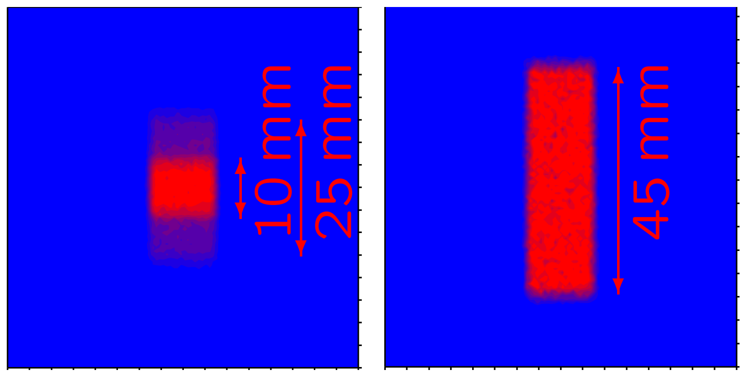
innovations:

focusing guide element for small samples
focusing in the sample plane

including the guide field



McStas simulation
of the beam spot:



with lens without lens

measured gain for samples of $< 10\,\mathrm{mm}$ width ≈ 3

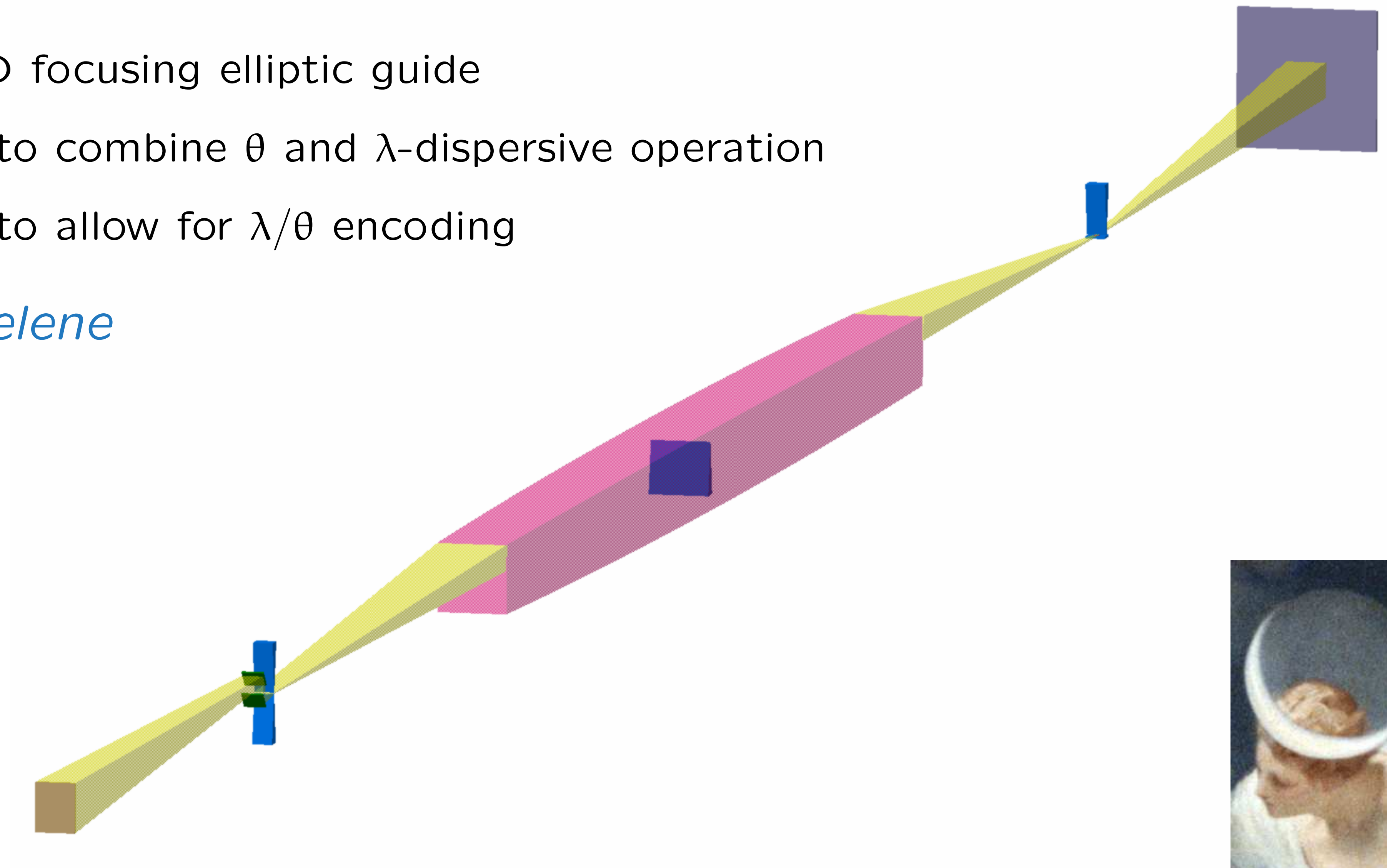
innovations:

2D focusing elliptic guide

– to combine θ and λ-dispersive operation

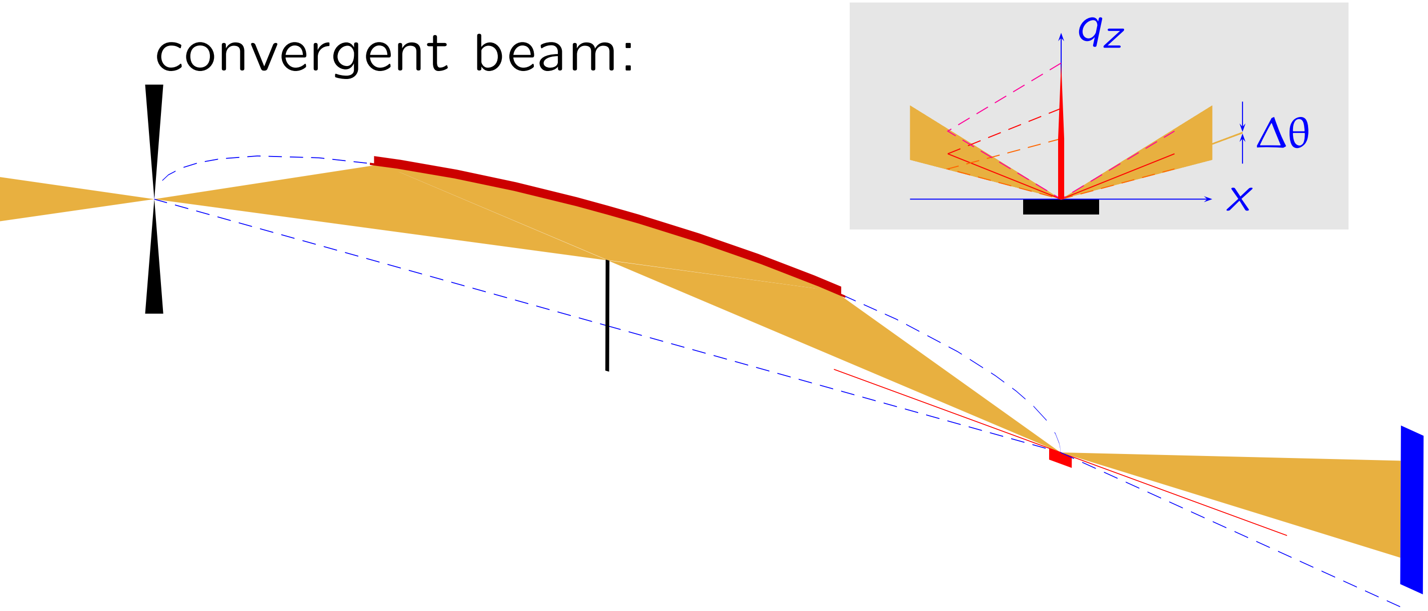
– to allow for λ/θ encoding

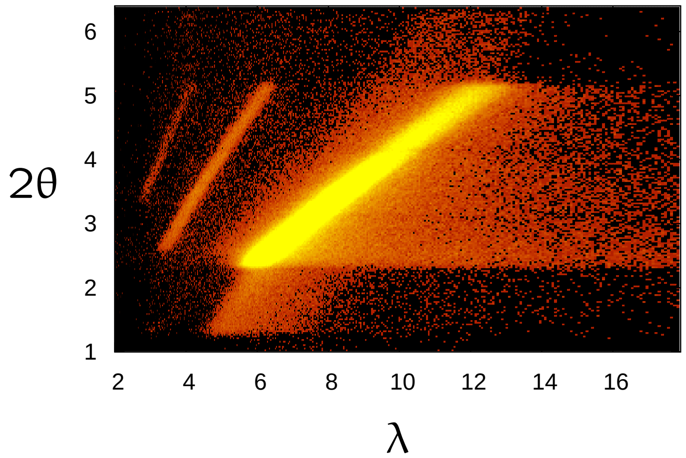
Selene



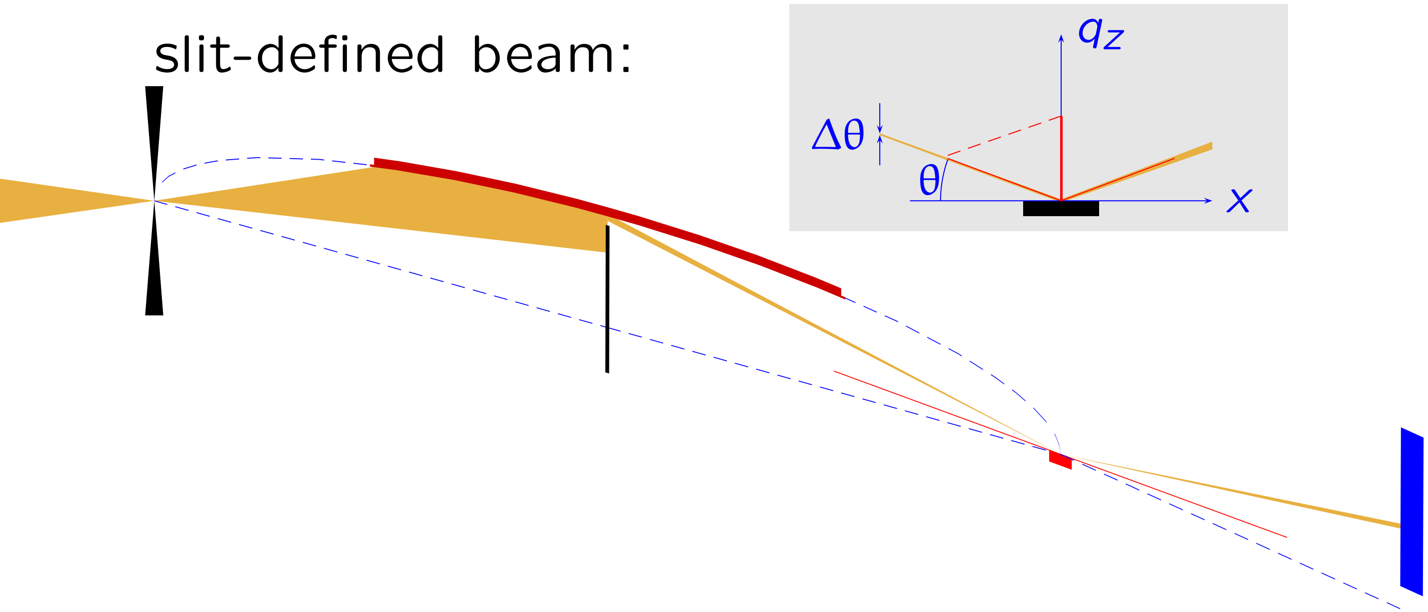
Selene: principle

convergent beam:

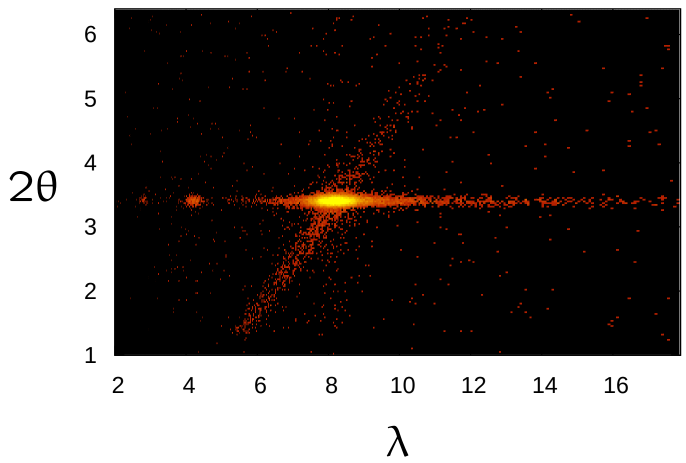




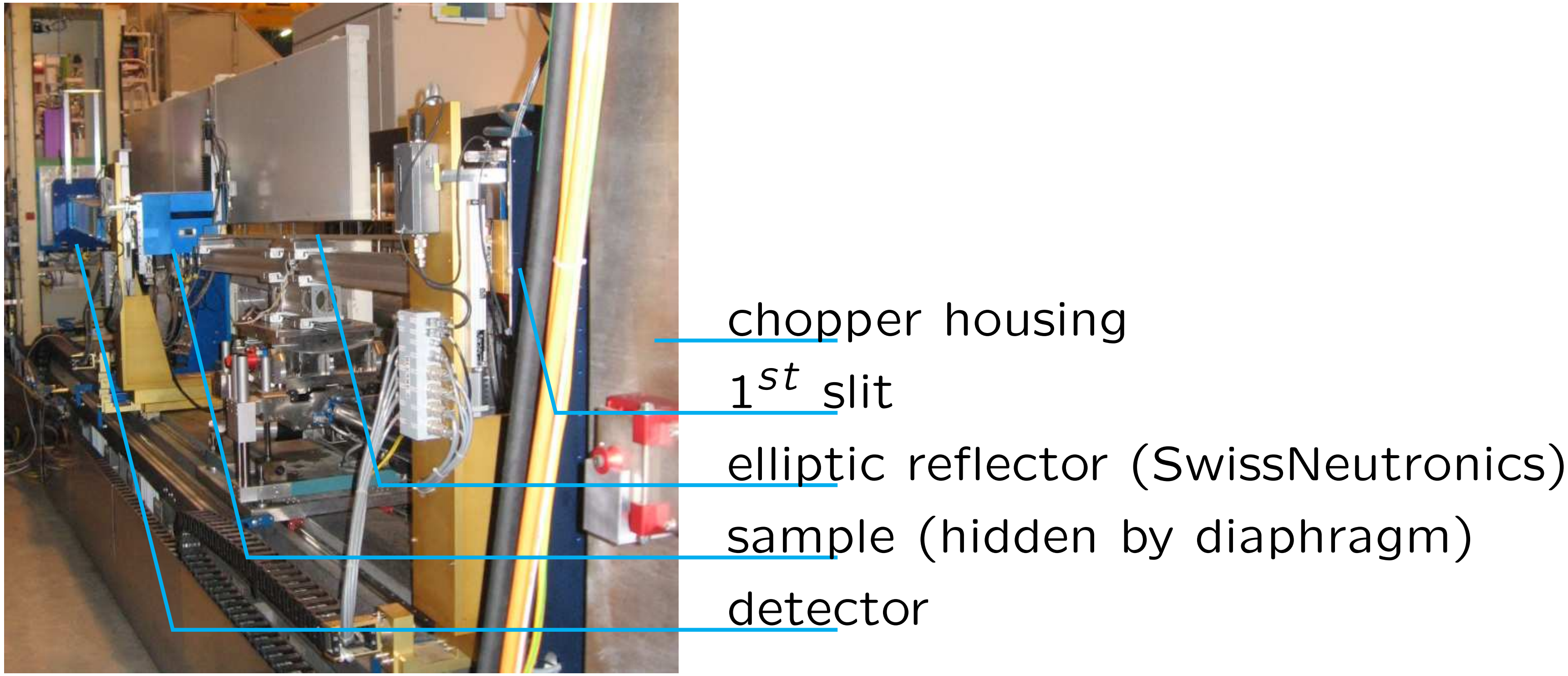
slit-defined beam:

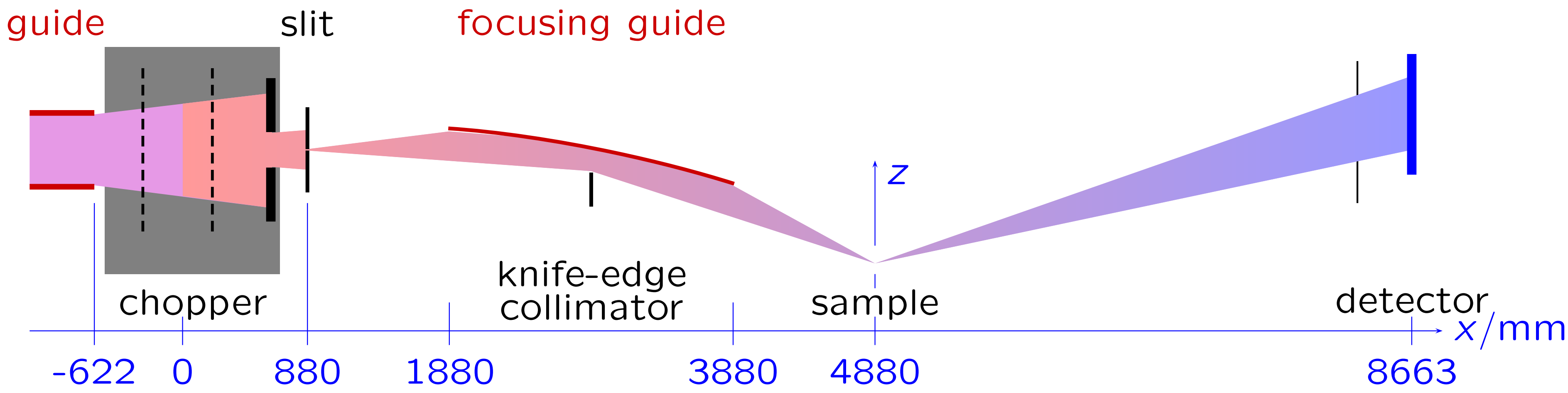


sample: Ni/Ti multilayer



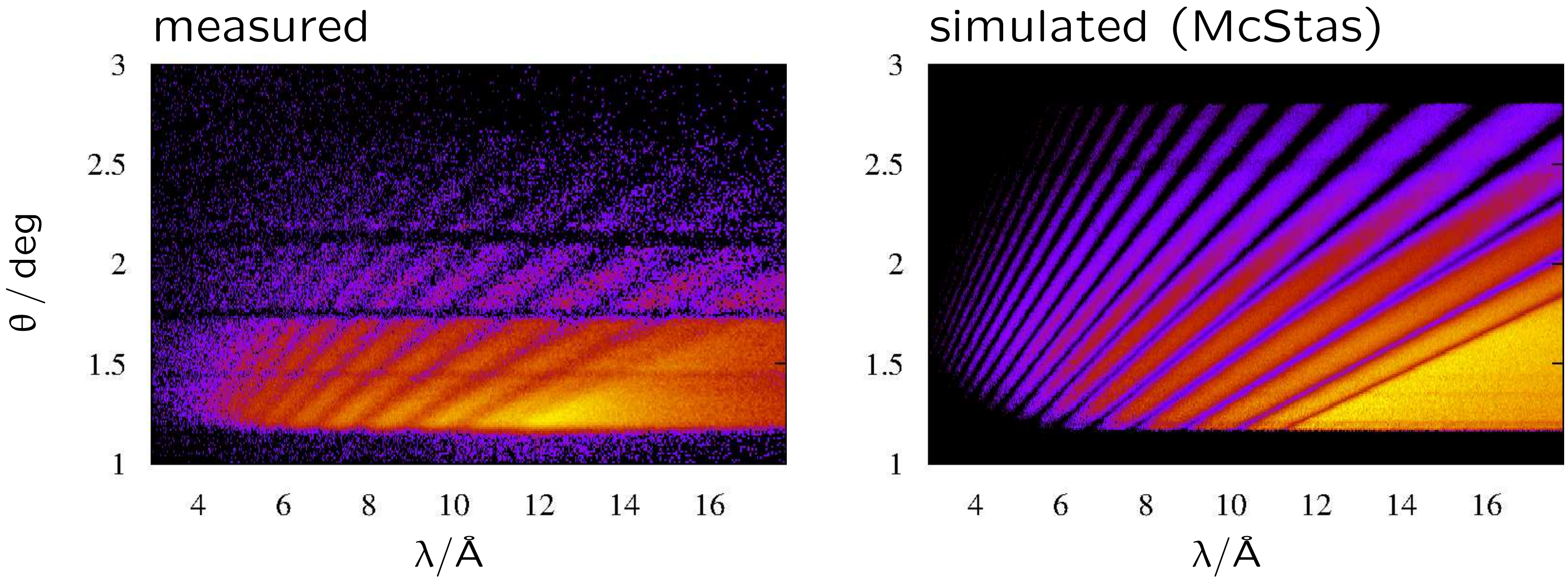
Selene: realisation

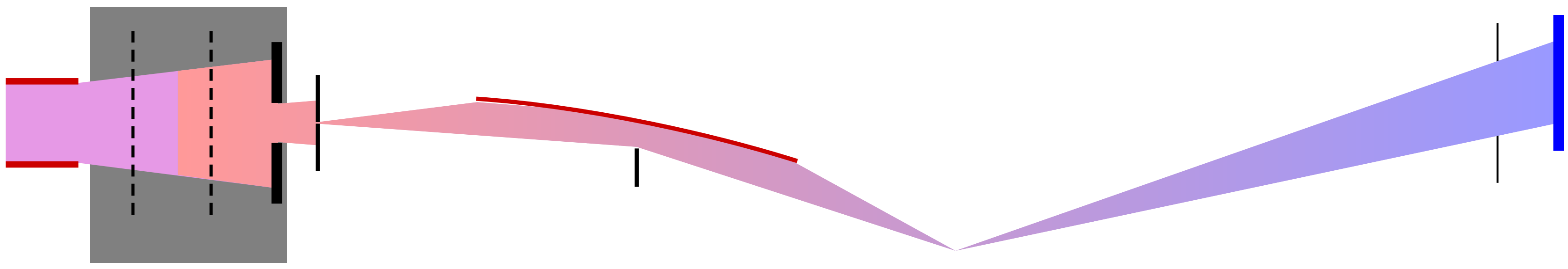




Selene

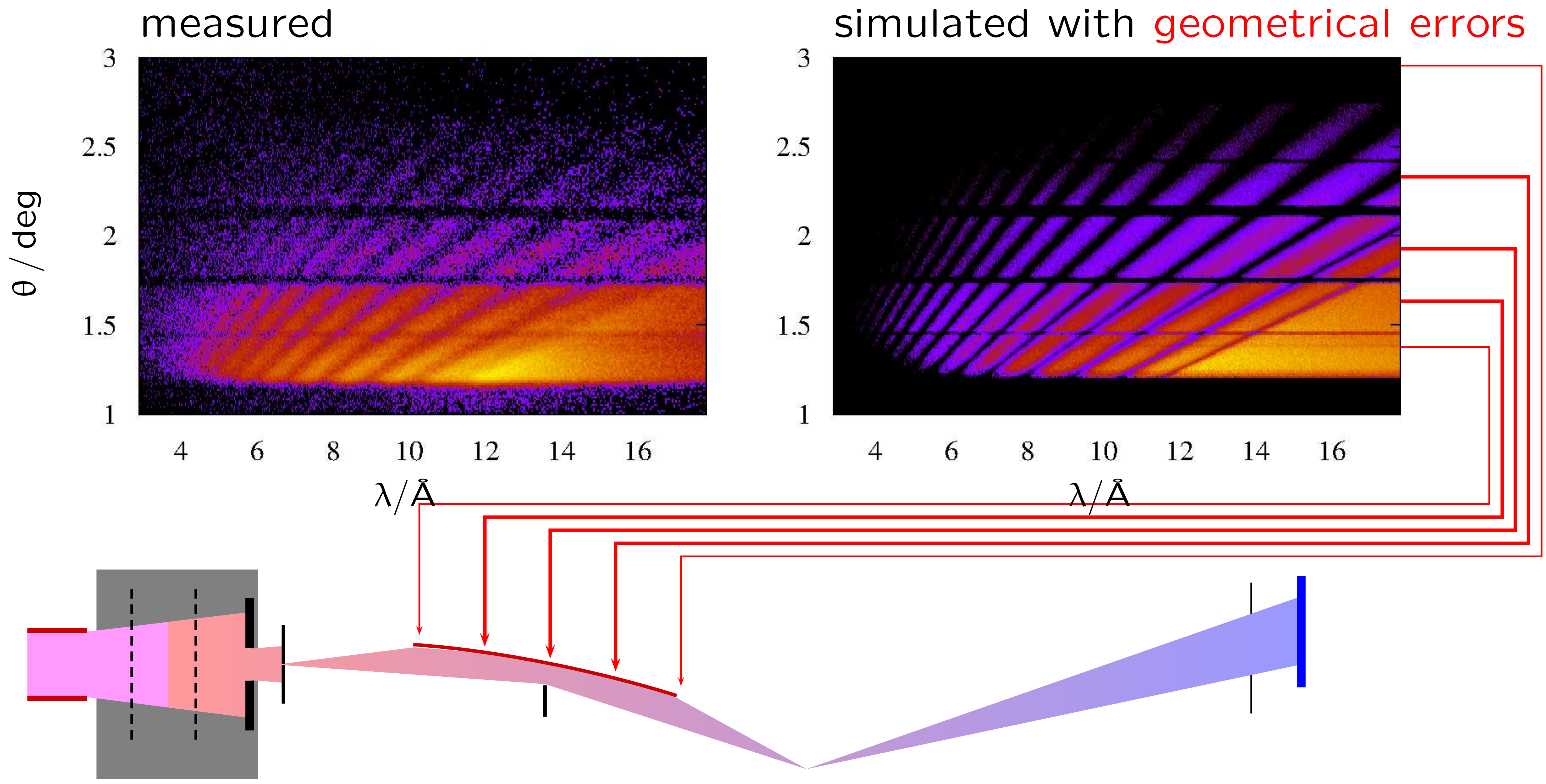
measurements: 1000 Å Ni film on glass, $9 \times 9\,\mathrm{mm}^2$





Selene

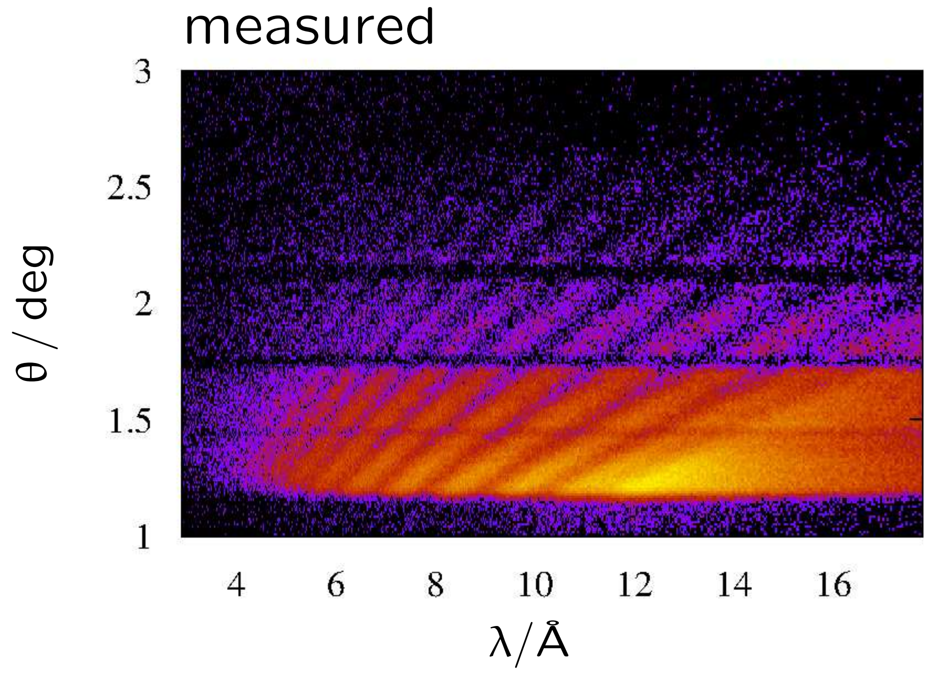
measurements: 1000 Å Ni film on glass, $9 \times 9\,\mathrm{mm}^2$

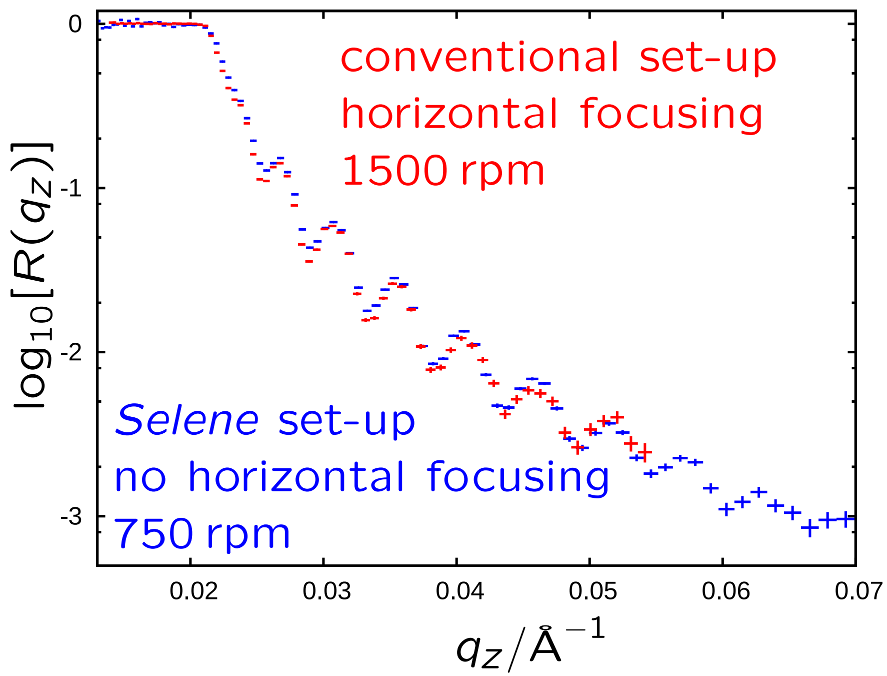


4 guide elements à 500 mm

Selene

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

Selene

focusing in the sample plane

+ counting time reduced by 60%

focusing in the scattering plane

+ counting time reduced by 90%

± off-specular & incoherent scattering set limits

− high-precision guide and careful alignment needed

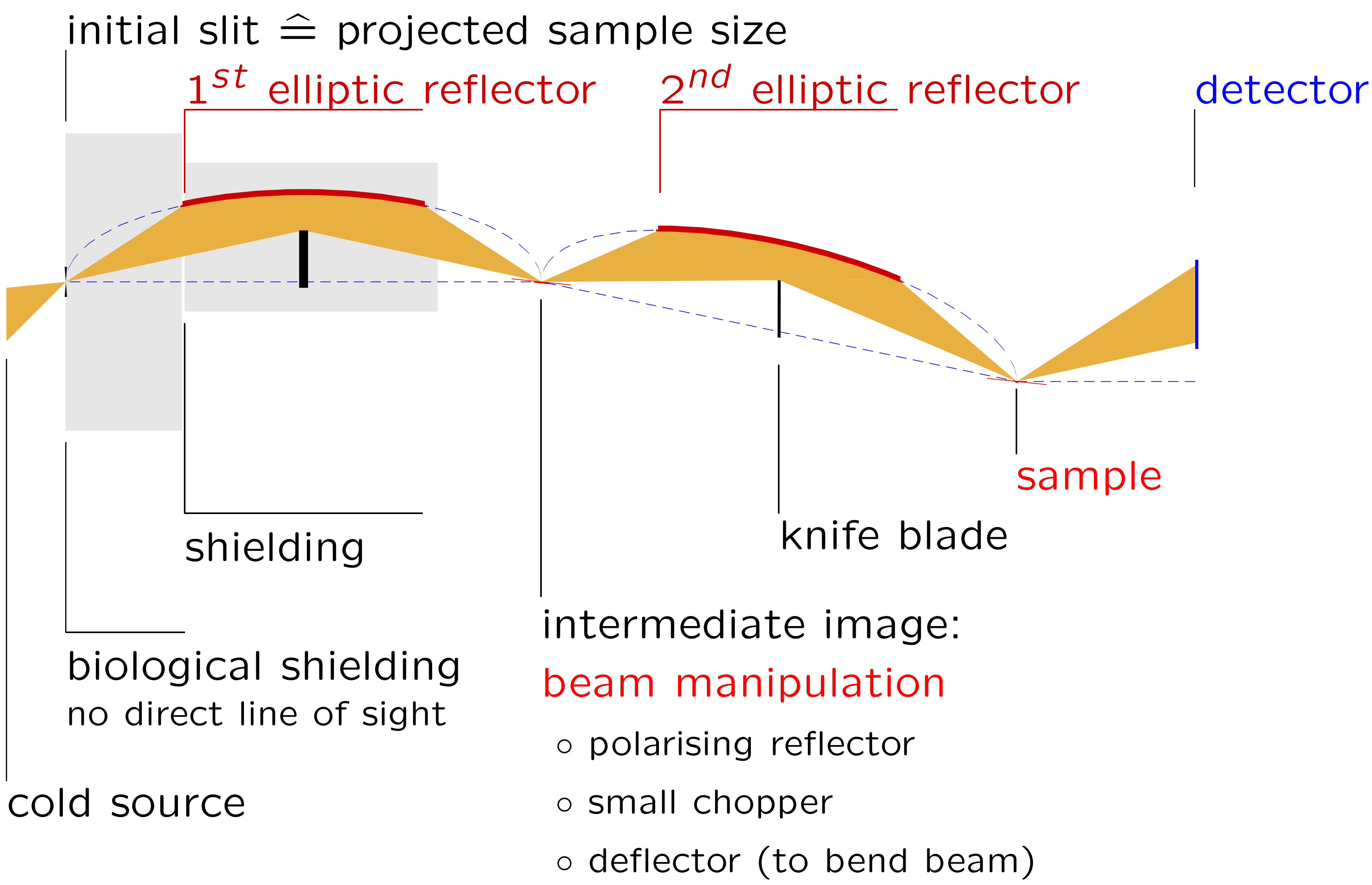
→ improvements under development

− coma aberration

→ correction possible

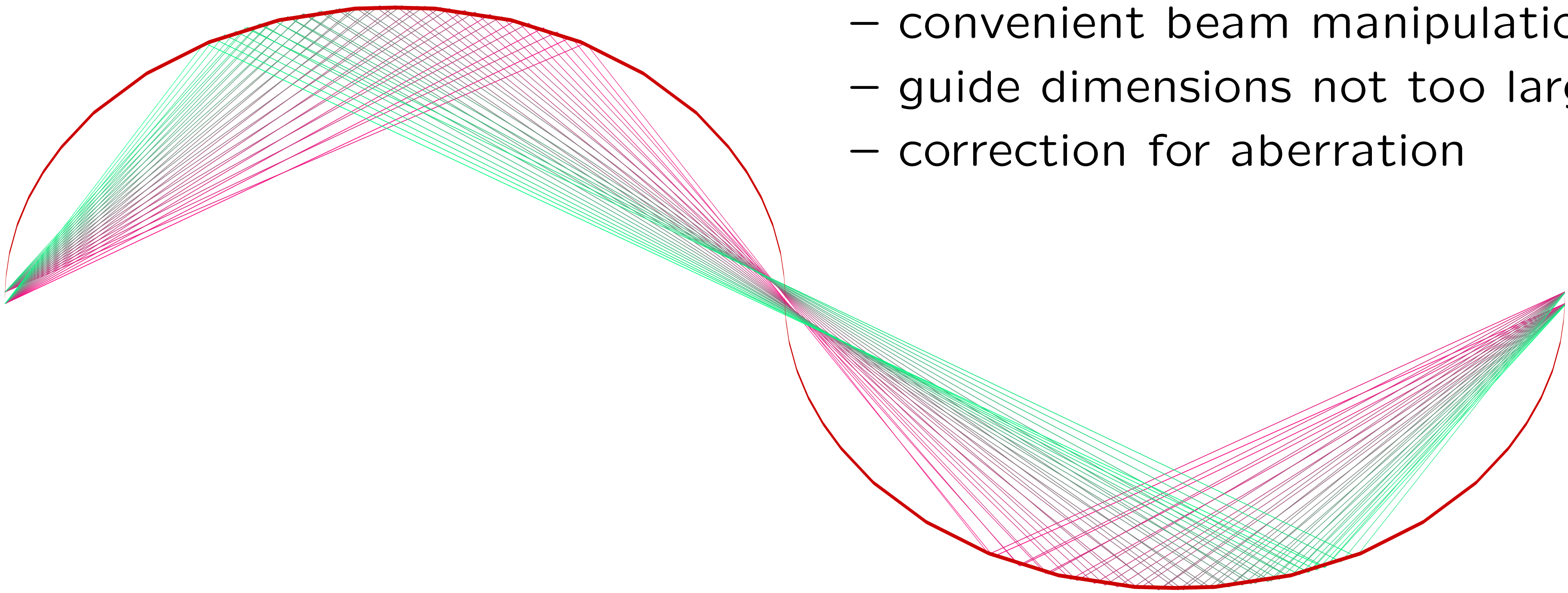
Selene as an instrument concept (TOF)

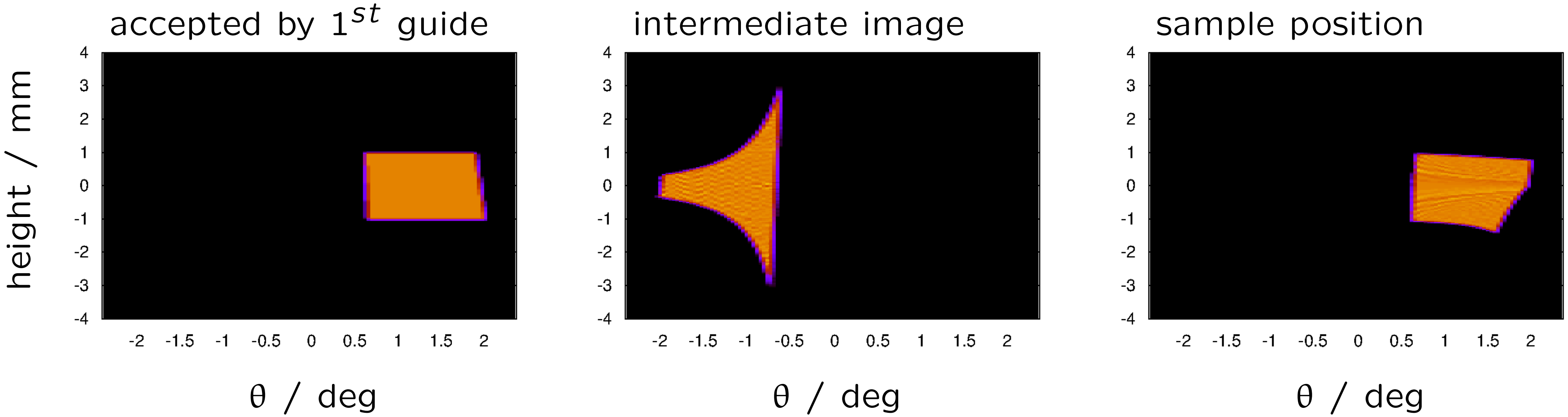
cut in the scattering plane
stretched by 10 normal to incident beam



why 2 ellipses?

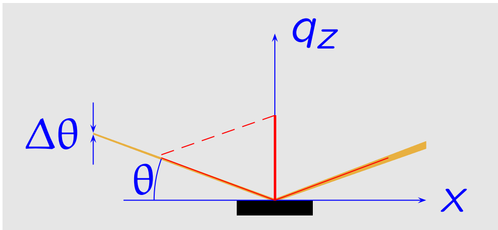
– convenient beam manipulation
– guide dimensions not too large
– correction for aberration

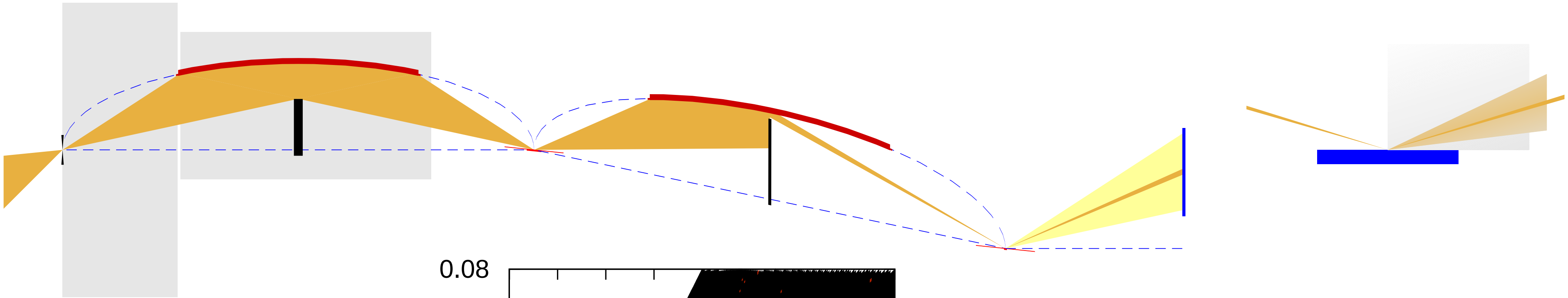


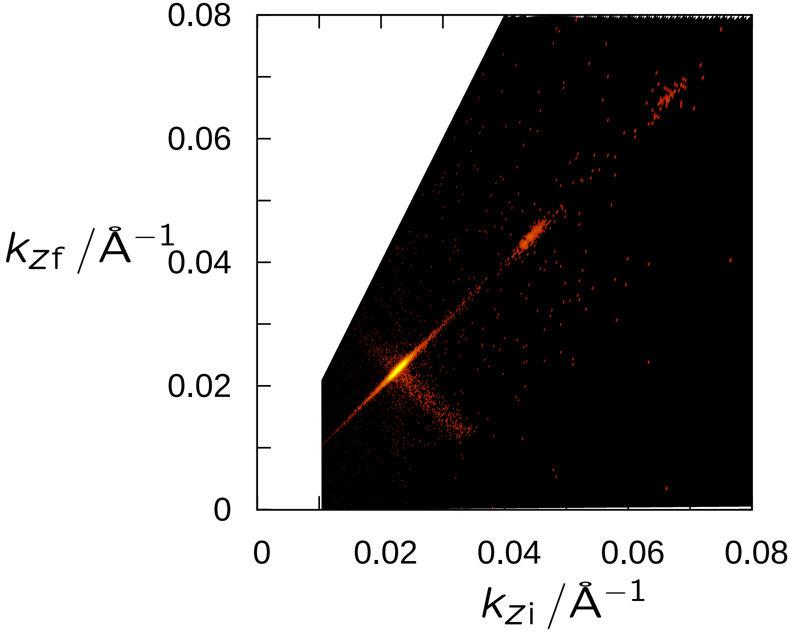


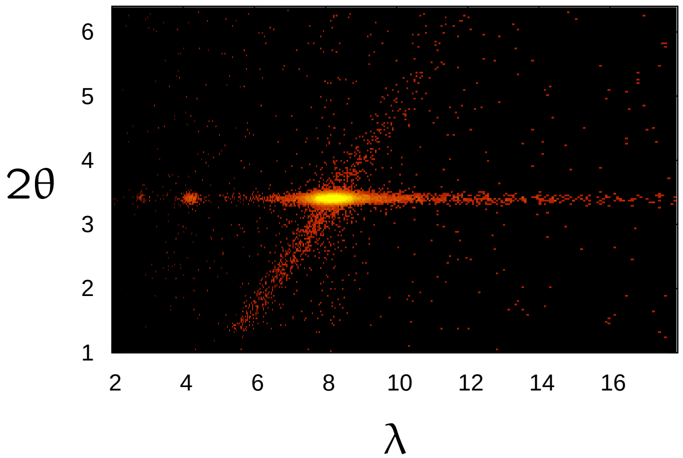
mode: almost conventional

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



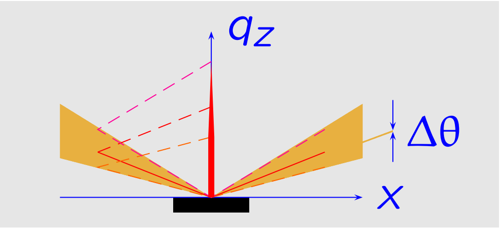


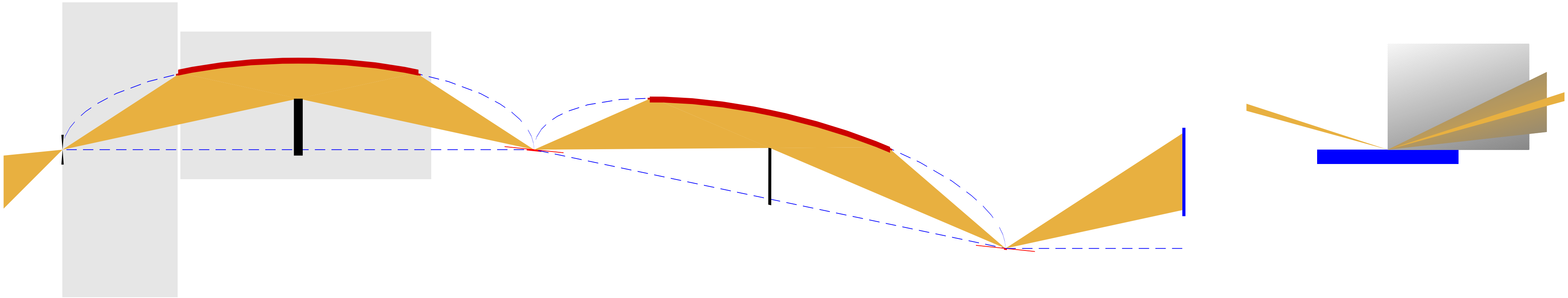


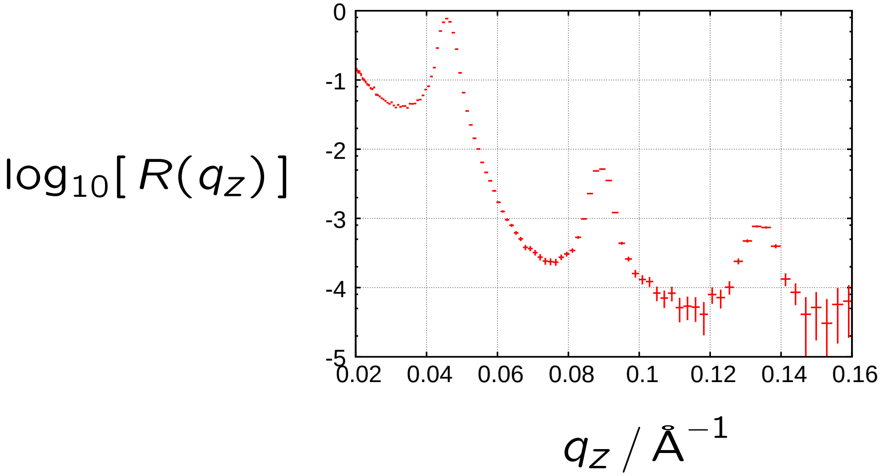


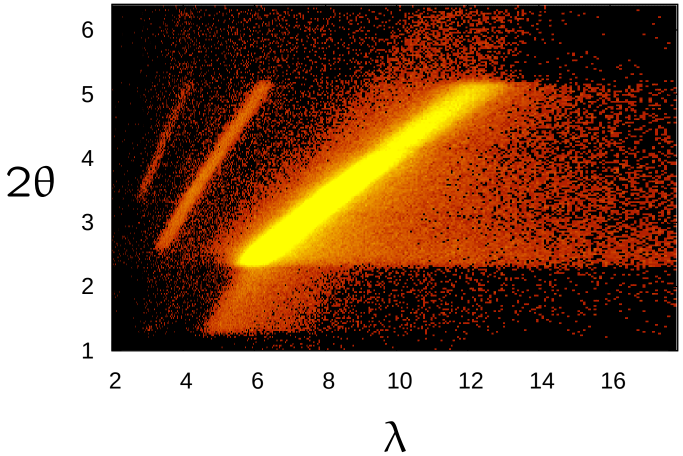
mode: high-intensity specular reflectivity

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



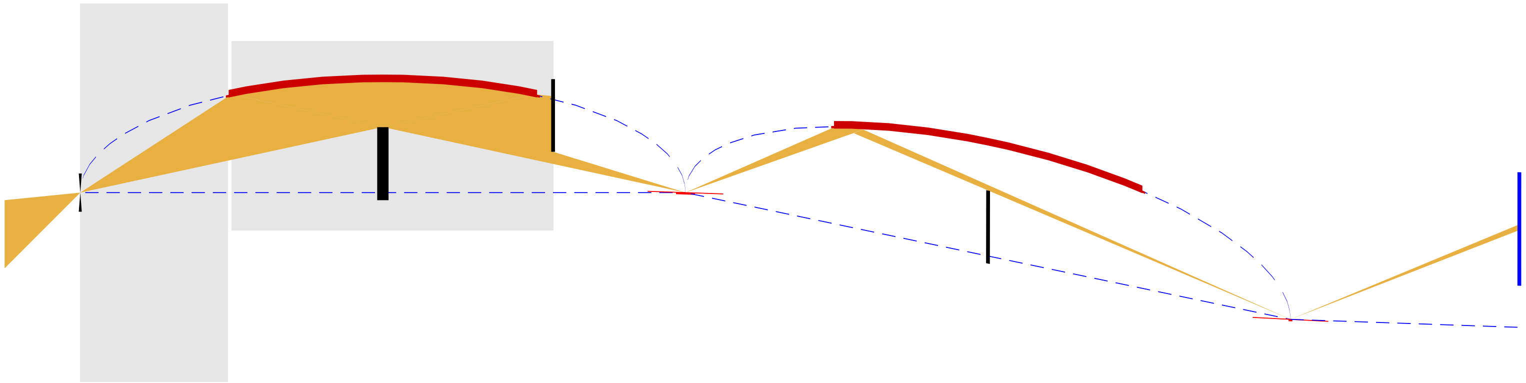




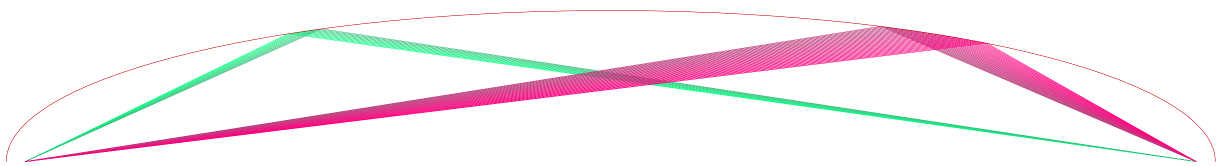


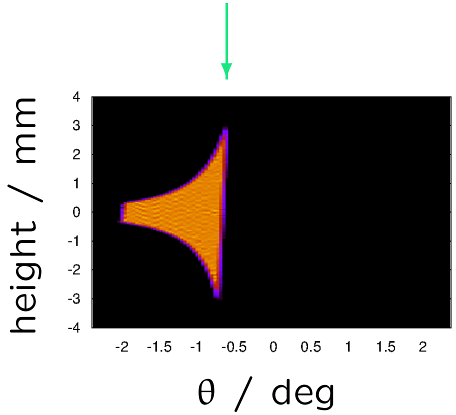
mode: low-divergent beam

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



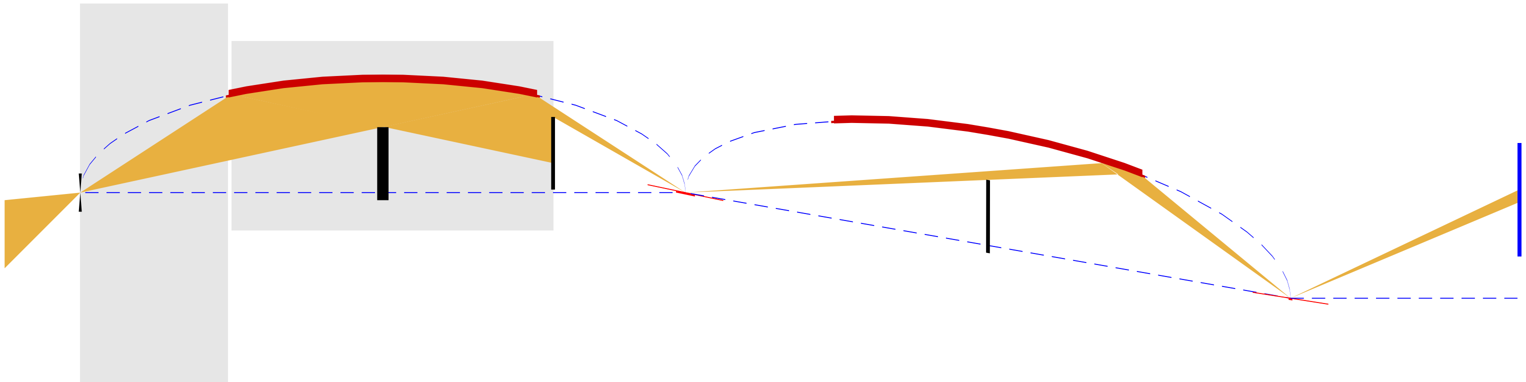
point source at focal point: intensity is a function of θ



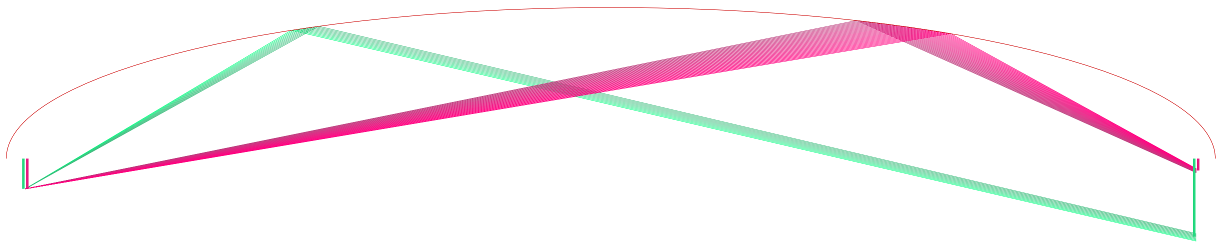


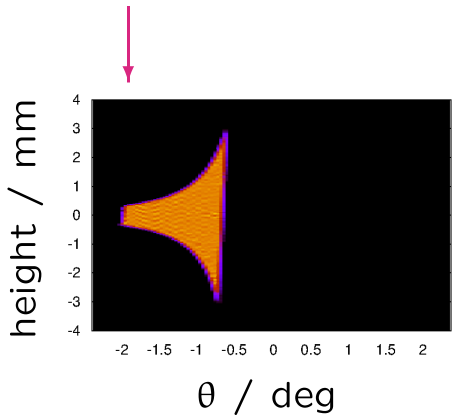
mode: small spot size

- uses the focusing due to coma aberration
- scanning mode possible



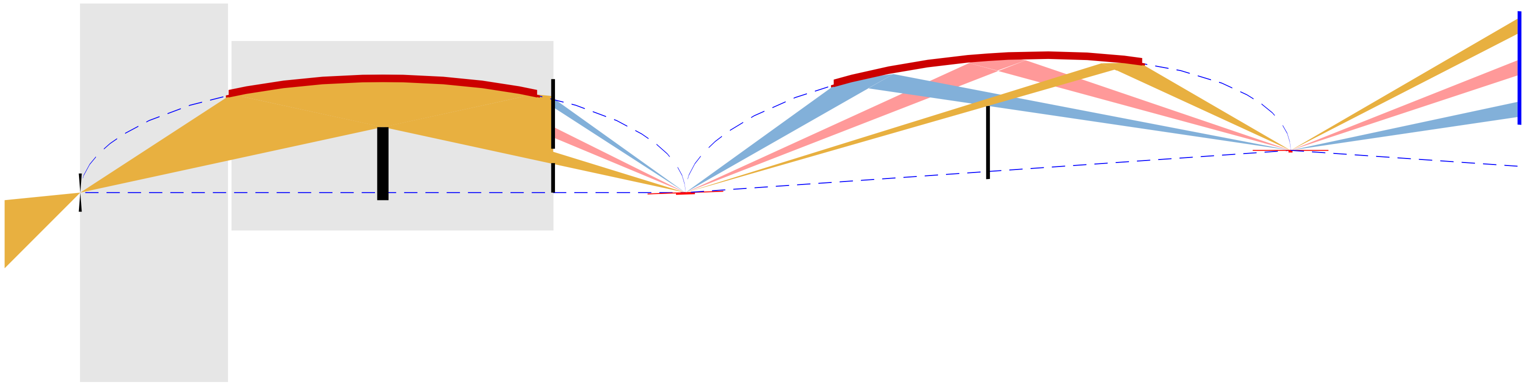
point source off focal point: image is a function of θ





mode: wide q-range

- shift diaphragm (chopper) between pulses
- vary θ with fixed sample position
- suited for liquid surfaces

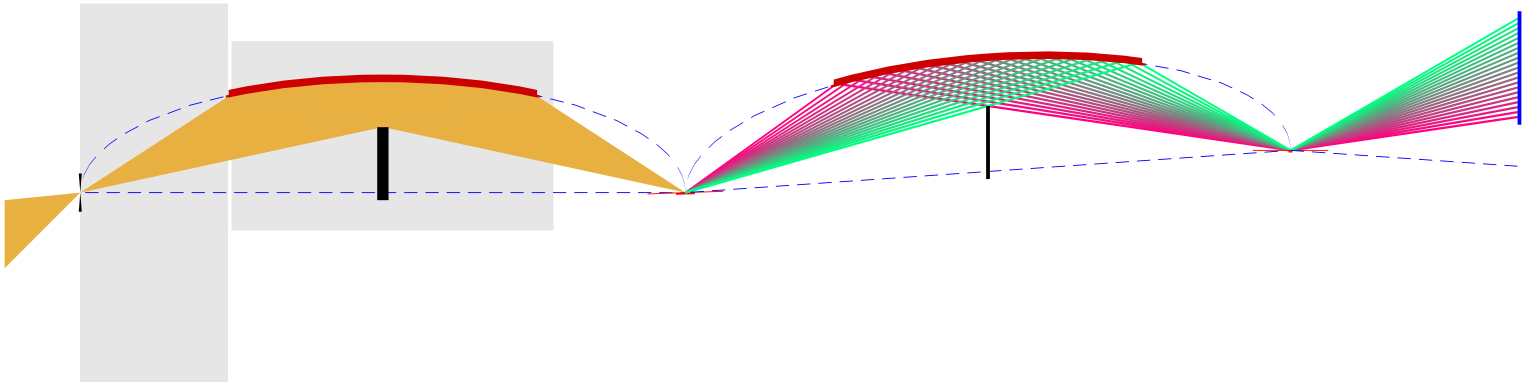


e.g. $\lambda = 2\,\text{Å} \ldots 8\,\text{Å}$

θ	$q_z/\text{Å}^{-1}$
$0.5°$	$0.014 \ldots 0.055$
$1.5°$	$0.042 \ldots 0.165$
$2.5°$	$0.070 \ldots 0.275$

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



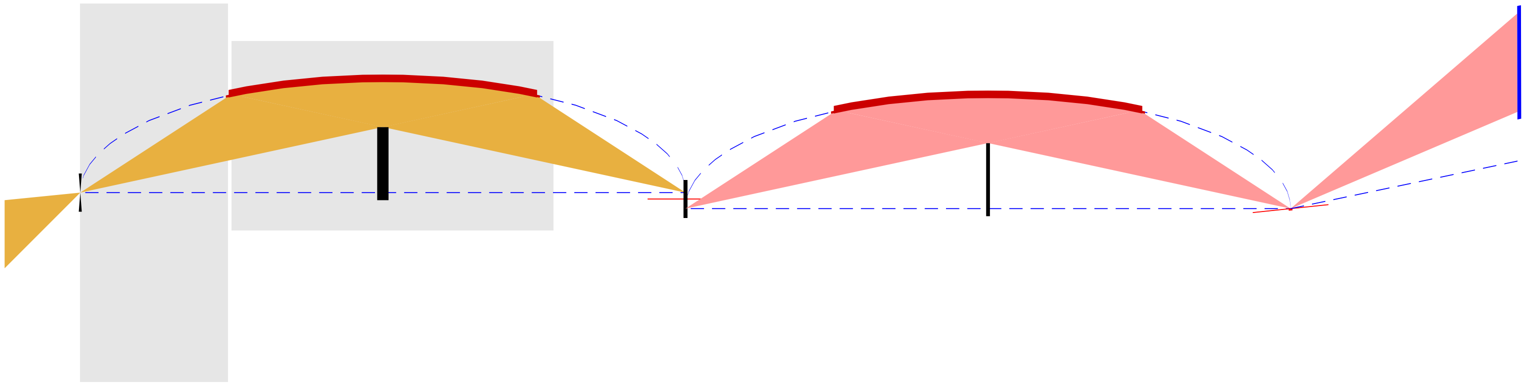
e.g. $\lambda = 2\,\text{Å} \ldots 8\,\text{Å}$
$\theta = 0.5^\circ \ldots 2.5^\circ$
$\Rightarrow q_z = 0.014\,\text{Å}^{-1} \ldots 0.275\text{Å}^{-1}$

mode: high q_z-resolution

– double PG-monochromator at the intermediate image

– high resolution for $\Delta\lambda/\lambda$, i.e. specular reflectivity

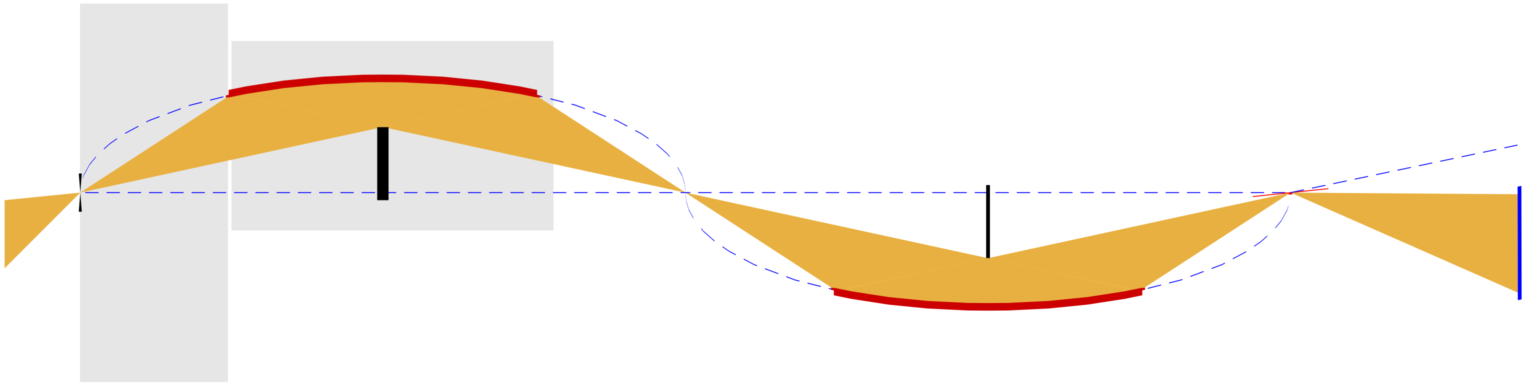
– moderate resolution for q_x



– convergent beam is used to recover losses due to the combination of TOF and monochromator

mode: pure TOF

– free choice where to put the choppers



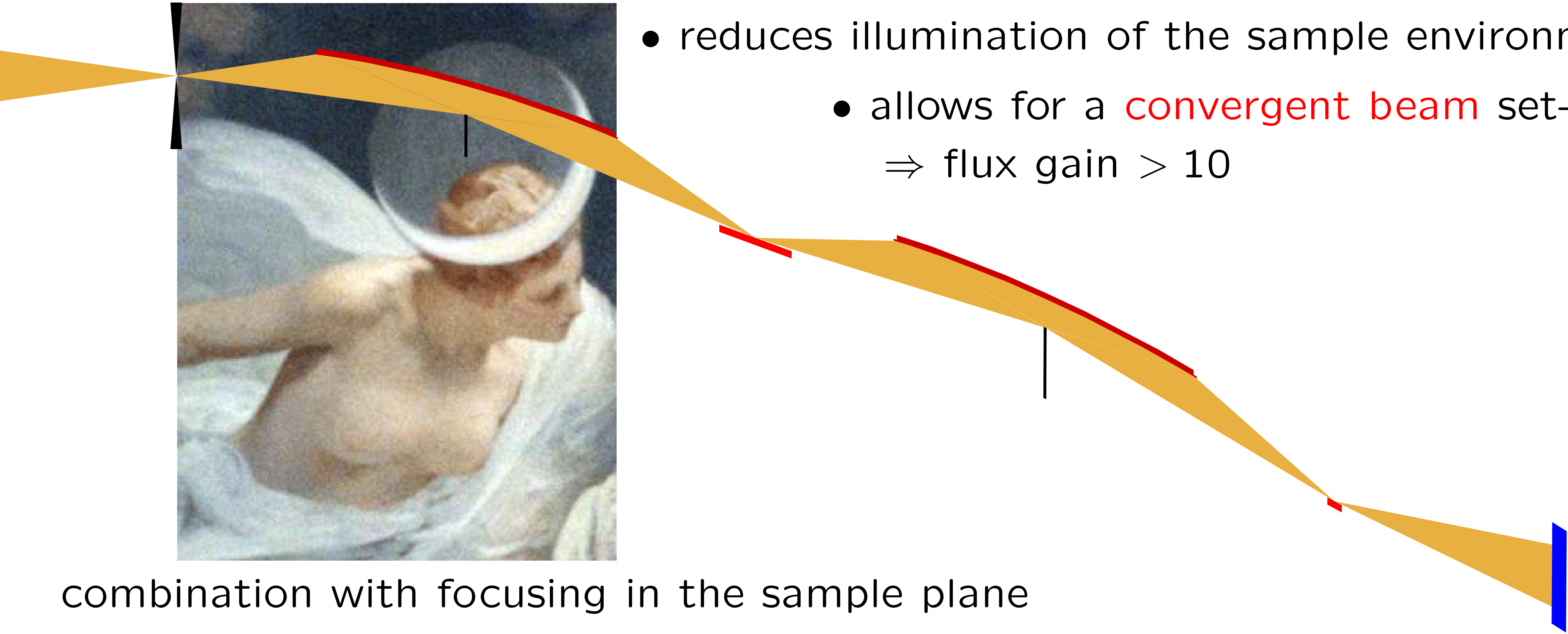
e.g. chopper behind 1^{st} slit at $x = 2\,\mathrm{m}$

$\Rightarrow \Delta\lambda/\lambda = \text{const.} = 5\%$

Selene is a guide concept...

- 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

                  ⇒ flux gain > 10



combination with focusing in the sample plane

- beam spot of the order of $0.1 \times 1\ \mathrm{mm}^2$ reachable
- flux gain > 100 for high-intensity specular reflectometry

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

- 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