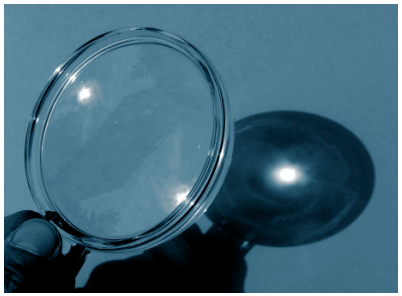
PAUL SCHERRER INSTITUT

Jochen Stahn Laboratory for Neutron Scattering



the focusing Selene neutron guide and related concepts

JCNS Workshop 2014, Trends and Perspectives in Neutron Scattering
From Spallation to Continuous Sources: a Positive Feedback on Neutron Instrumentation
20. - 23. 10. 2014, Tutzing, Germany

people involved

experiments

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Rob Dalgliesh
Frédéric Ott
Phil Bentley
Bob Cubitt
Peter Böni
Uwe Stuhr
. . .

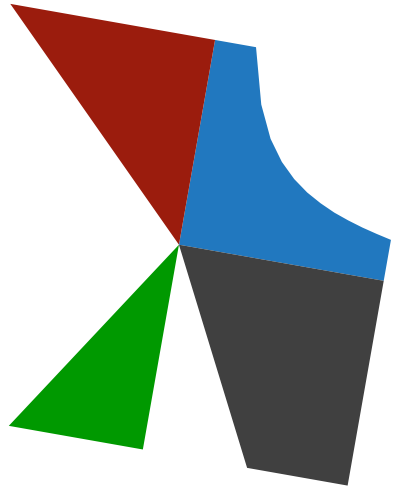
inspiration

Selene

thanx!

focusing

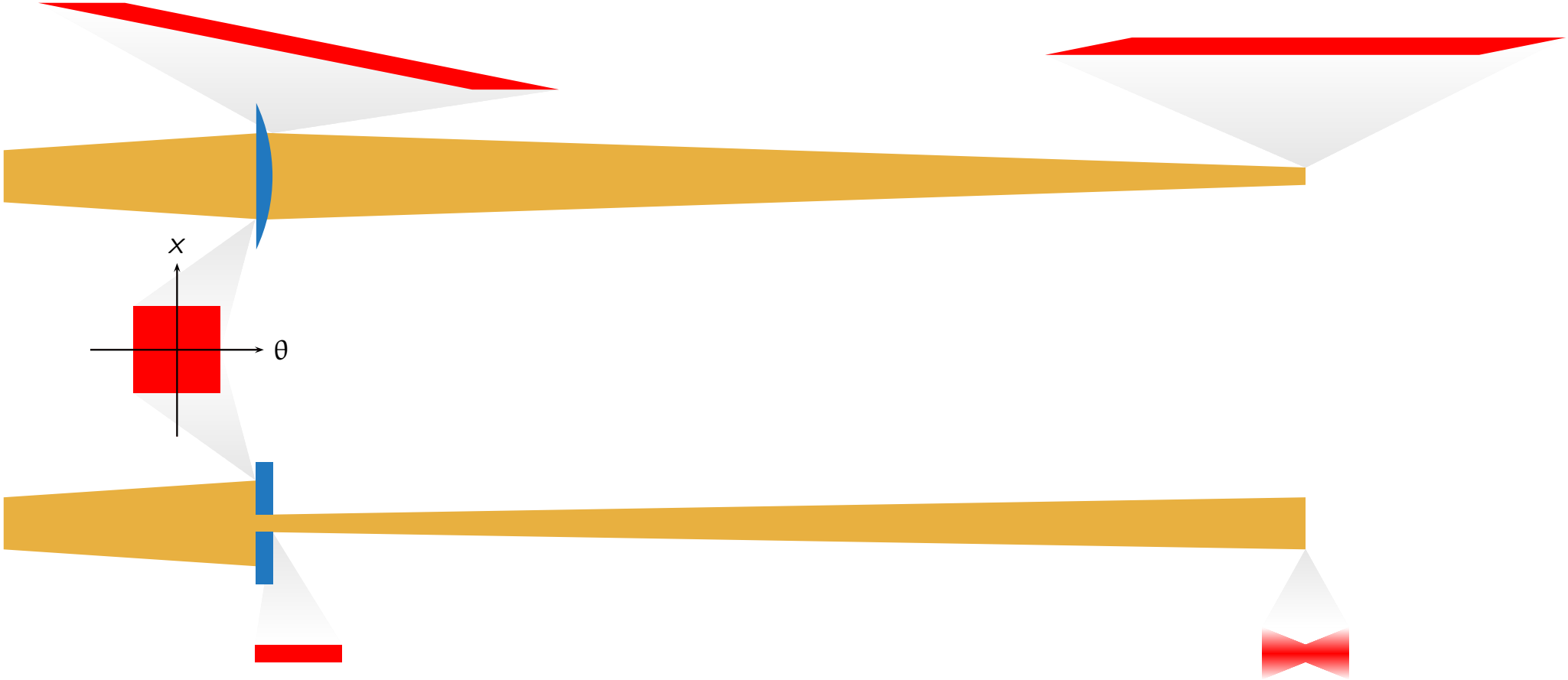
- **focusing**
  - **Selene guide**
    - **prototype**
      - **Estia**
        - **optics**
          - **discussion**



focusing: principles

focusing optics

reshapes the phase space of a n-beam (an ensemble of neutrons)
to a **small spatial extent** at a given position



shading optics

reshapes the phase space by restricting it in space (slit)

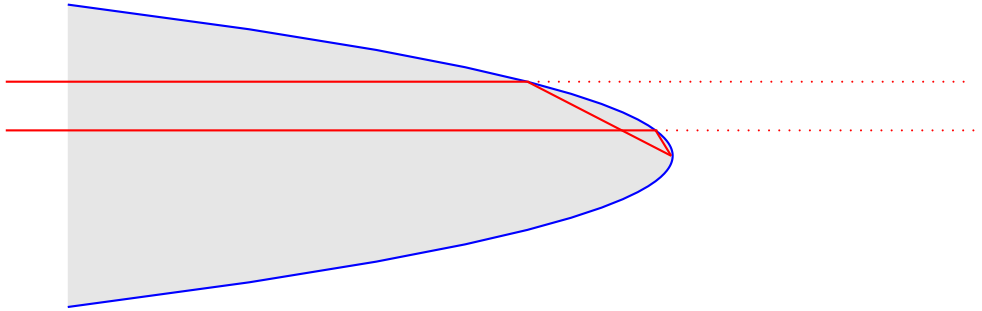
focusing: principles

focusing optics vs. shading optics

high costs (needs high precision)
lower transmission
convenient beam manipulation
real focusing
aberration

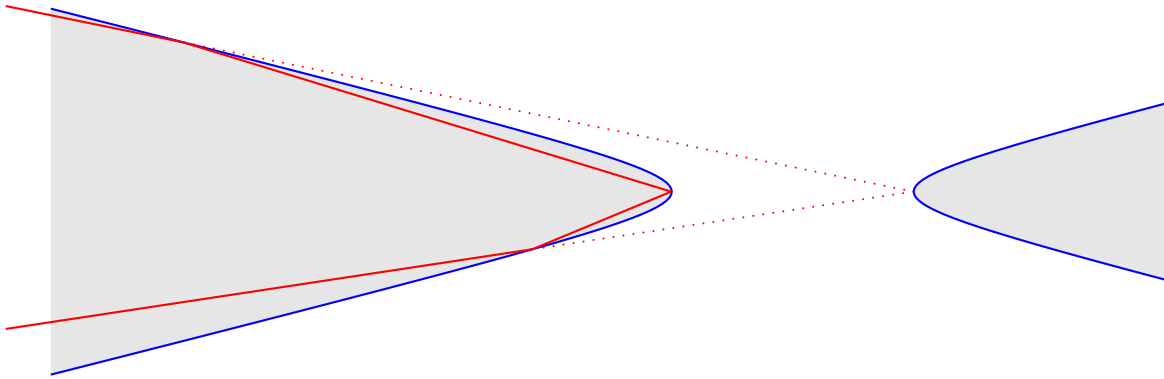
robust
flexible
high transmission
high background

focusing: basic reflector shapes



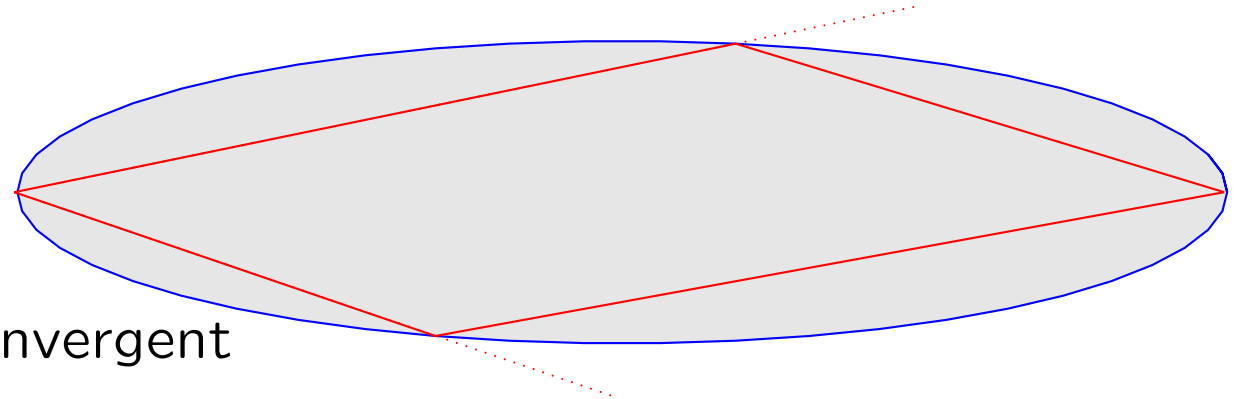
parabolic

parallel to convergent



hyperbolic

convergent to convergent



elliptic

divergent to convergent

focusing: full vs. half device

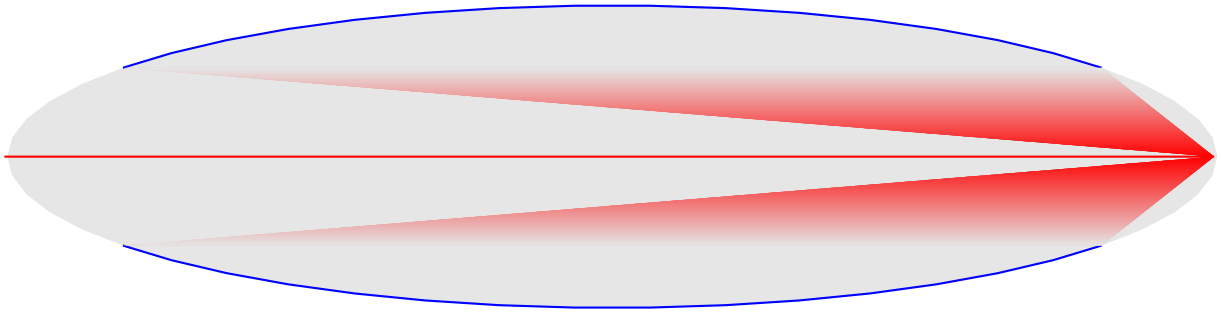
phase space homogeneity

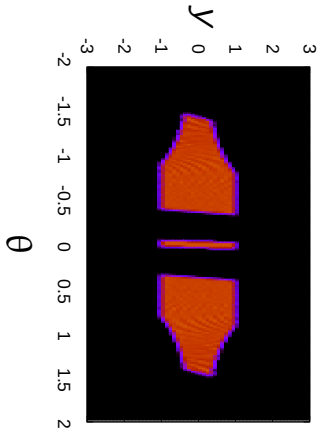
effective divergence

elliptic

2-sided

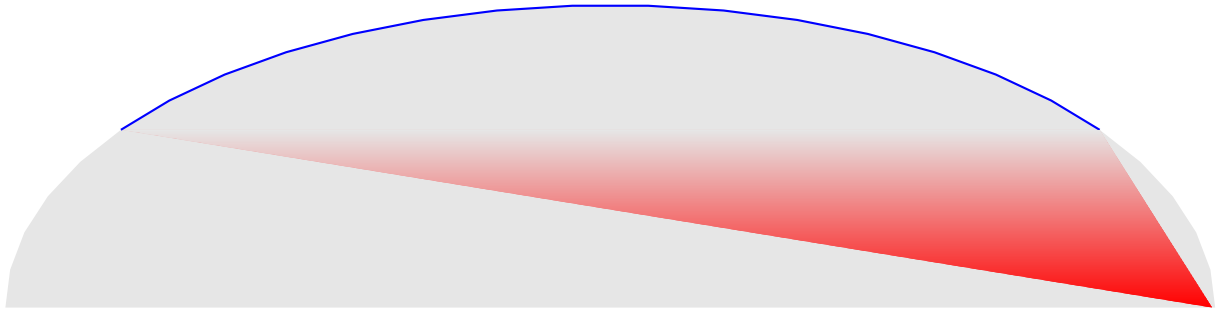
ideal case





elliptic

1-sided



focusing: ballistic ellipse vs. half device

early reflections suffer the most from coma aberration

⇒ multiple reflections

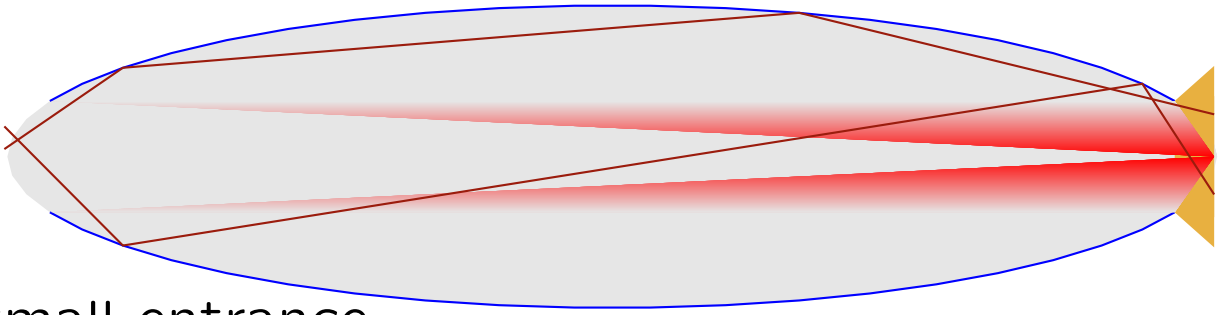
⇒ non-convergent beam behind guide exit

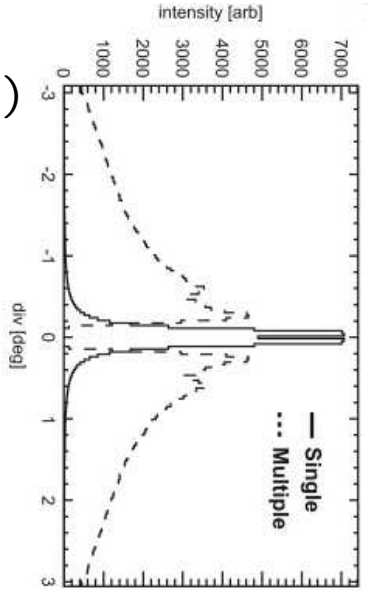
L. Cusssen *et al.*: NIM A **705**, 121 (2013)

elliptic

2-sided

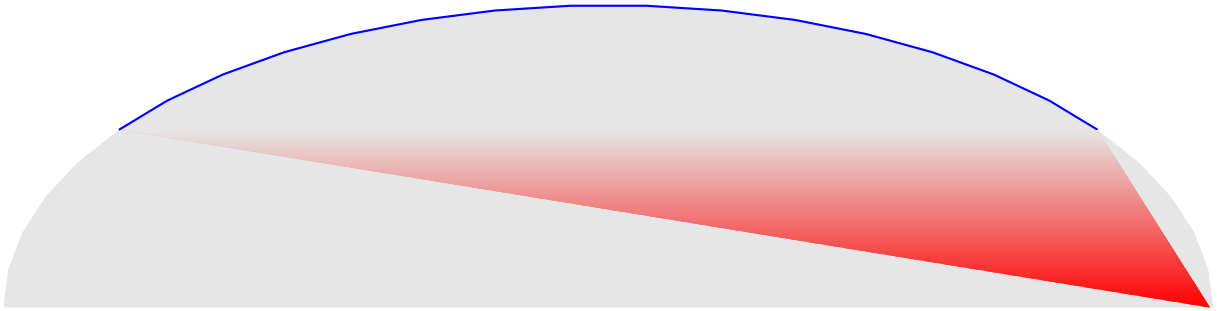
large source / small entrance



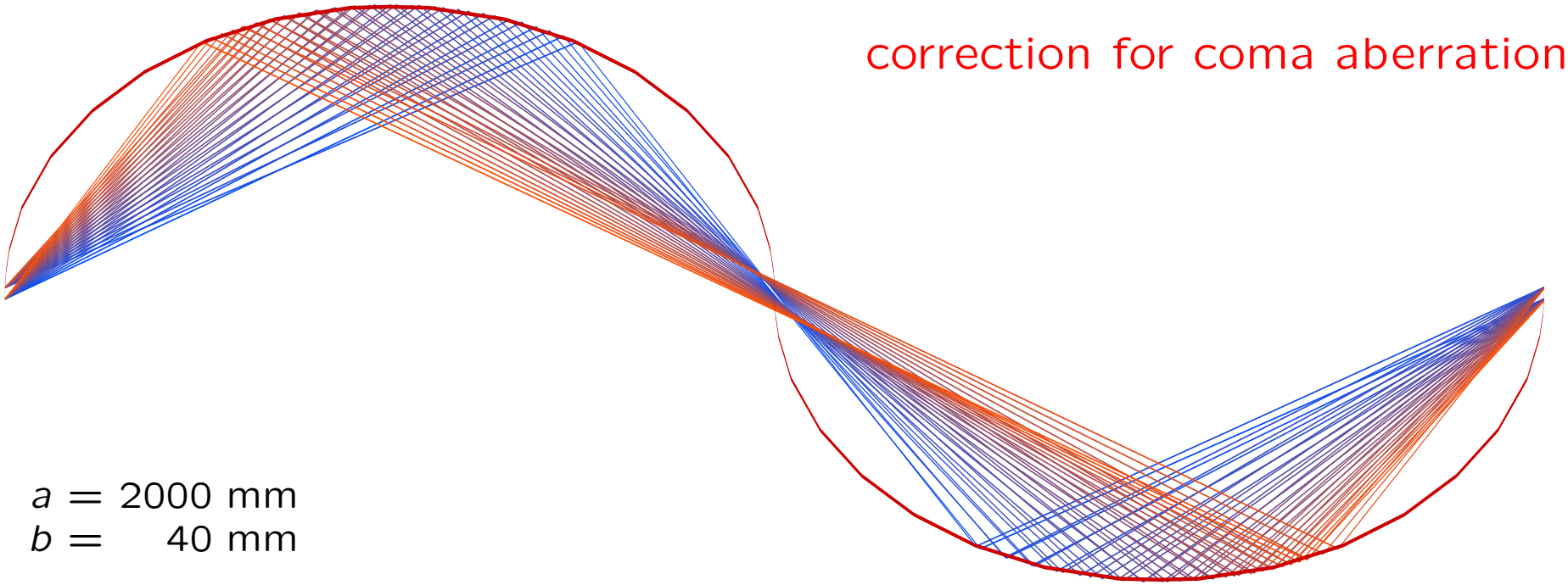


elliptic

1-sided

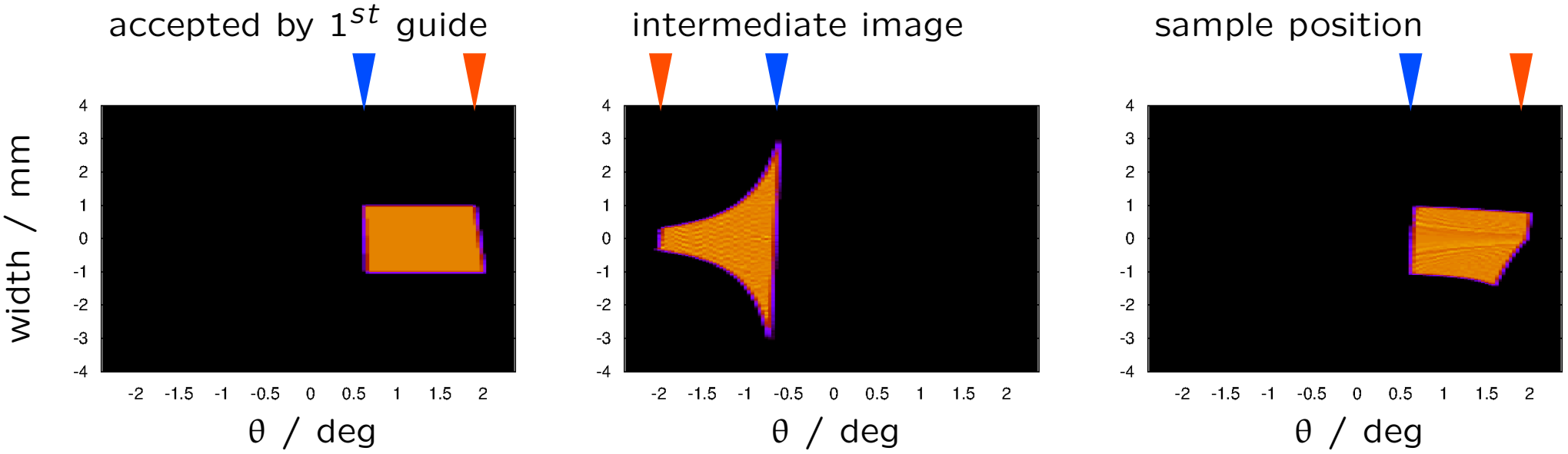


focusing: geometrical aberration



correction for coma aberration!

a = 2000 mm
b = 40 mm

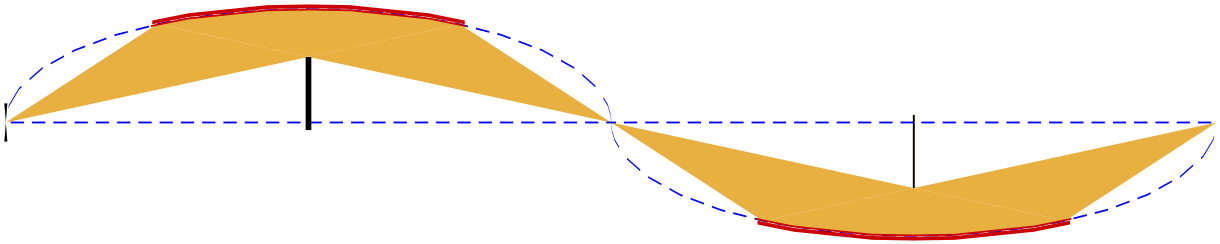


focusing: chromatic aberration

. . . due to gravity

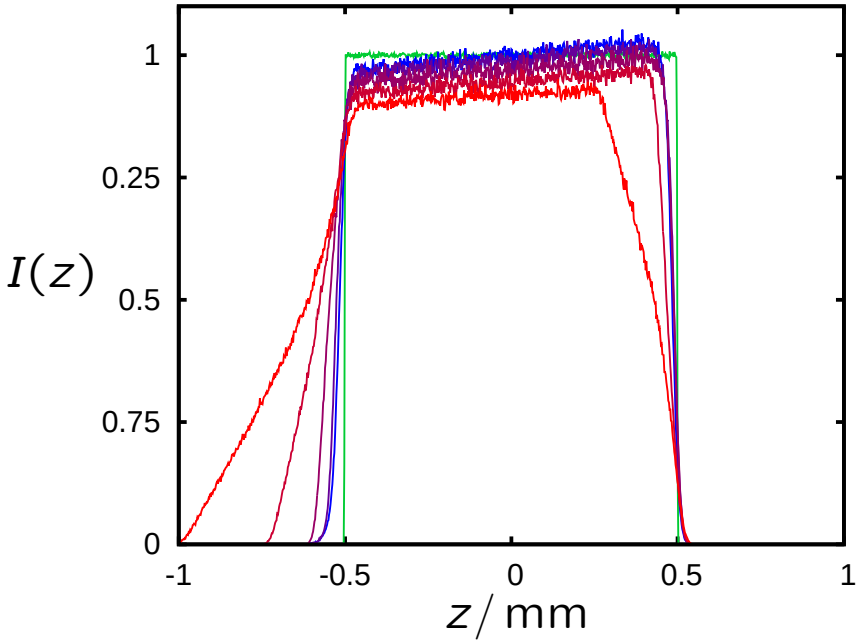
simulations (McStas) with (1 mm) tapered guides (40 m long, $b/a = 0.022$)

in agreement with analytic calculations



$I(z, \lambda)$ area normalised to 1

λ = 0 Å
3 Å
5 Å
7 Å
9 Å



Selene guide

- focusing
  - **Selene guide**
    - **prototype**
      - **Estia**
        - **optics**
          - **discussion**

Selene guide

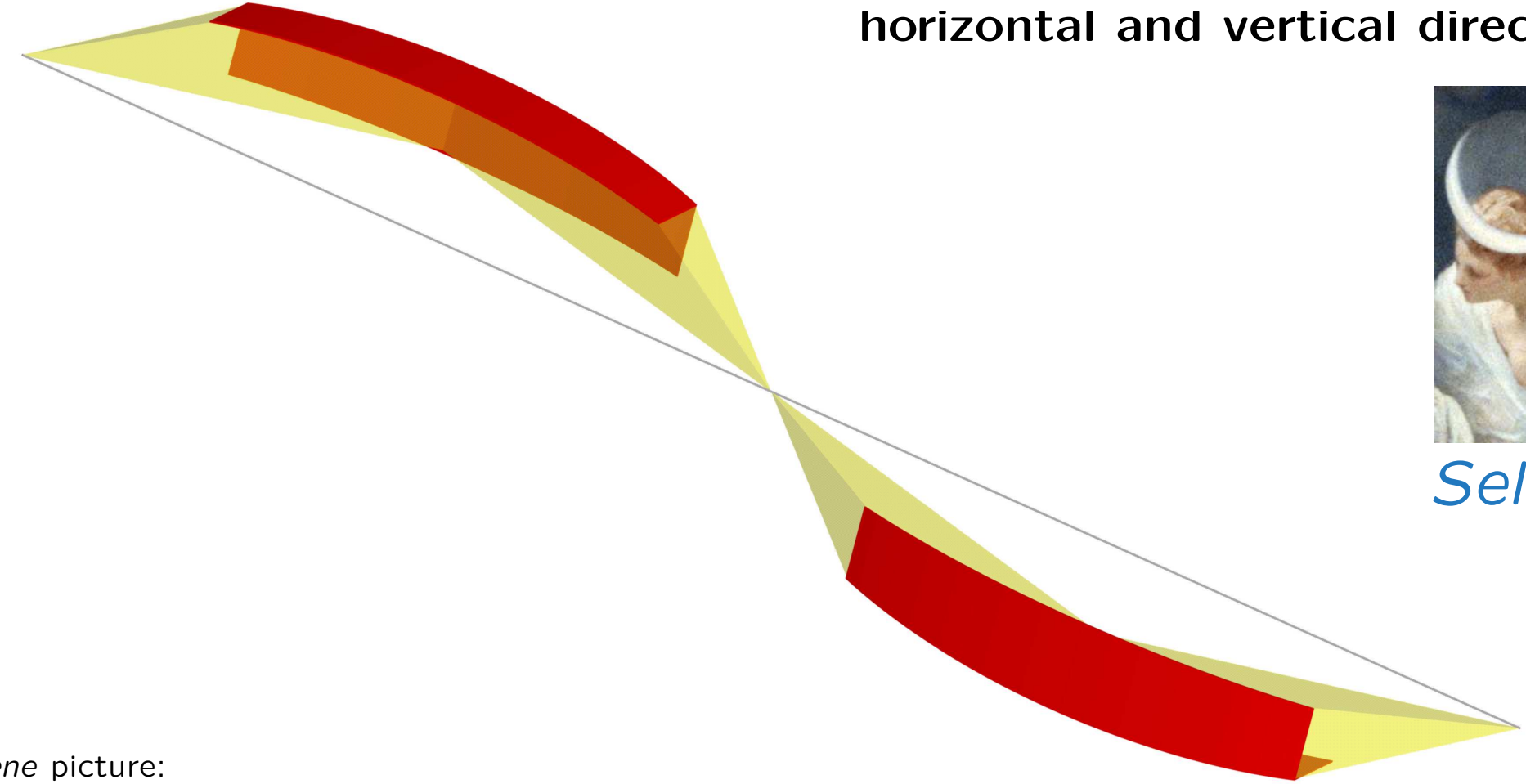
point-to-point focusing

with

2 subsequent elliptical reflectors

for

horizontal and vertical direction



Selene

Selene picture:
ceiling painting in the Ny Carlsberg Glyptotek, København

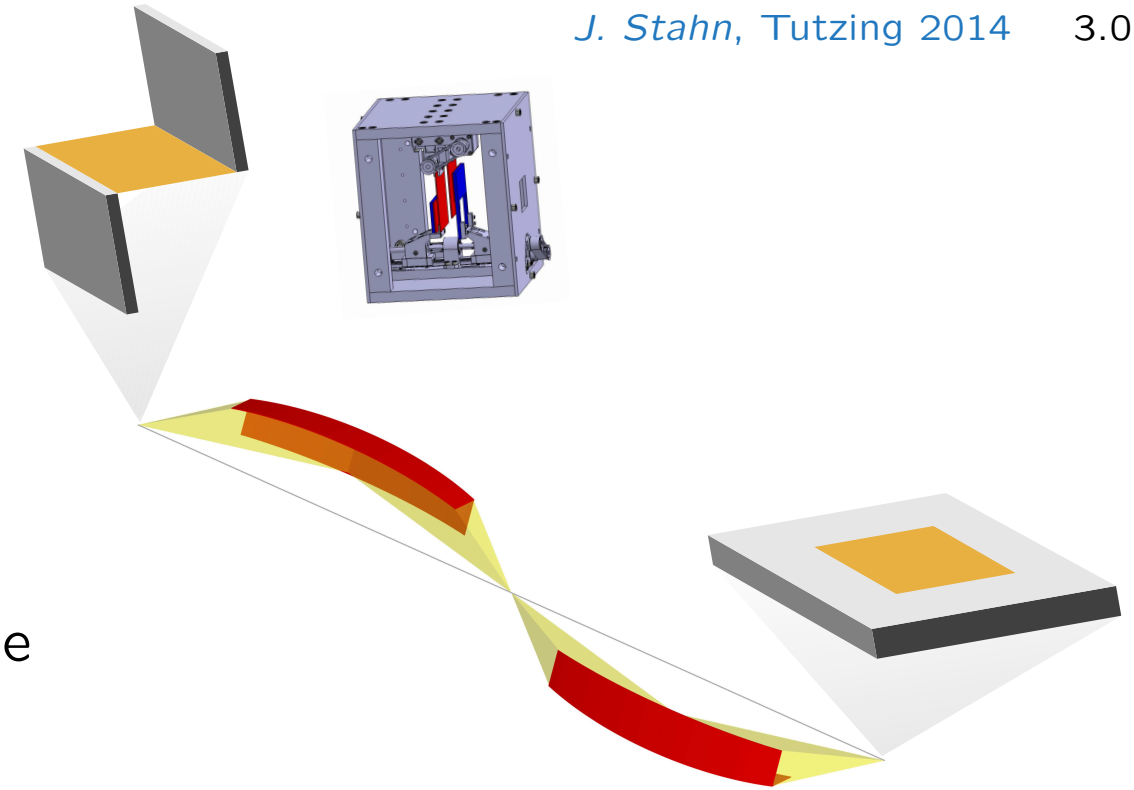
Selene guide

footprint definition

a luminous field diaphragm defines

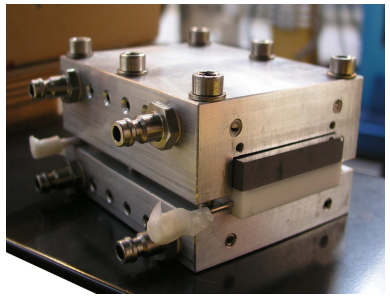
- shape
- size
- orientation

of the beam footprint on the sample

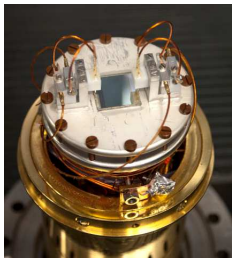


to

- avoid over-illumination



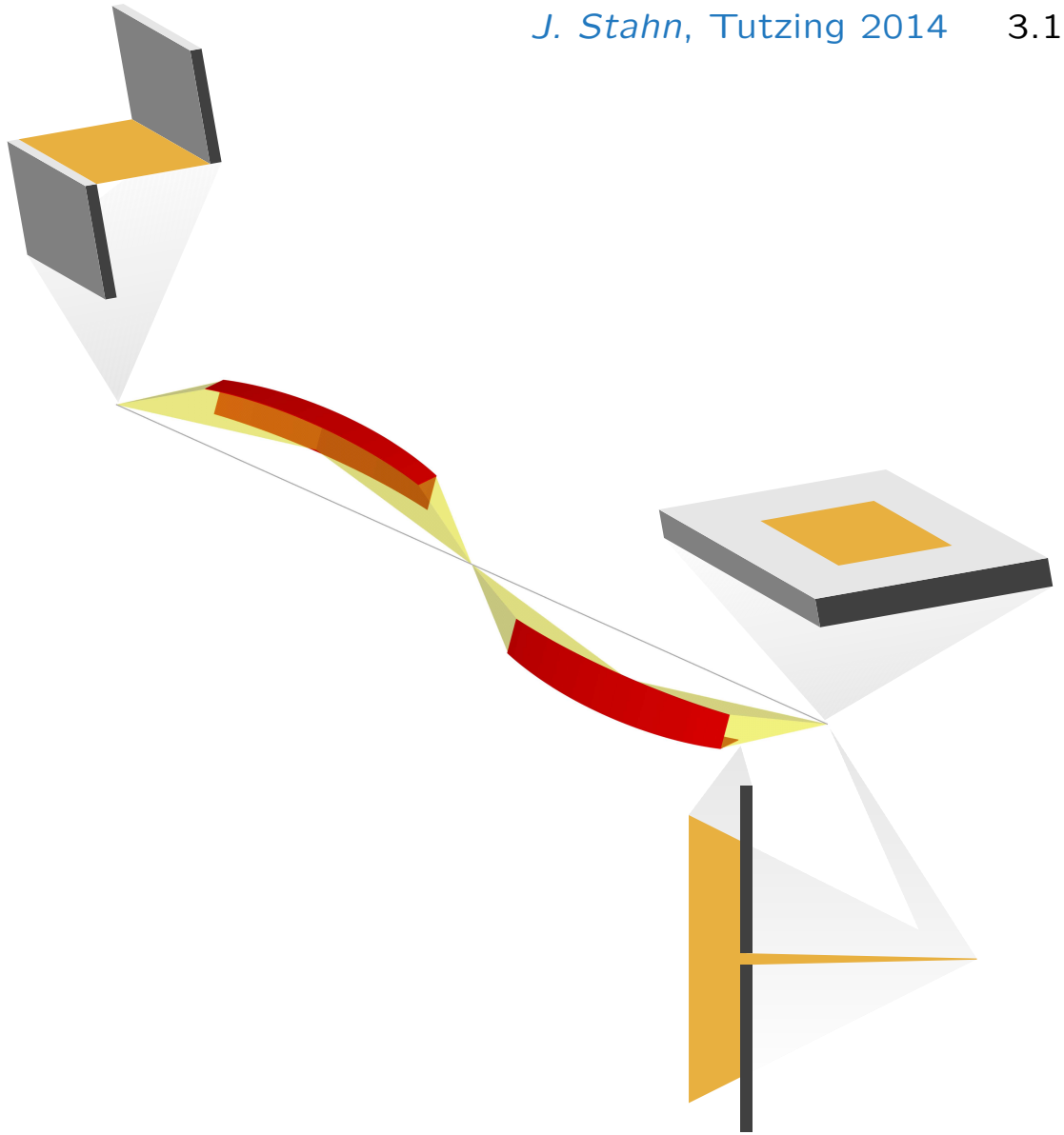
- avoid inhomogeneous field areas



- raster the sample

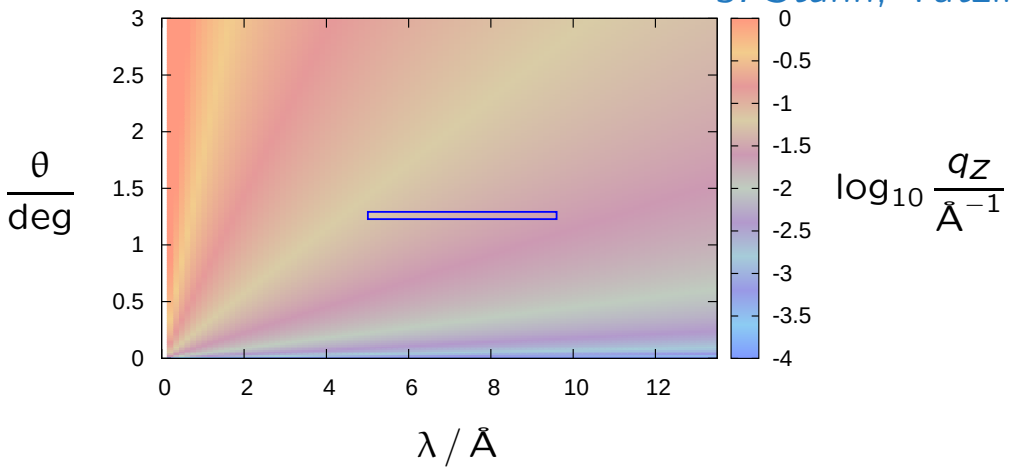
Selene guide

decoupling of spot-size and divergence



Selene guide

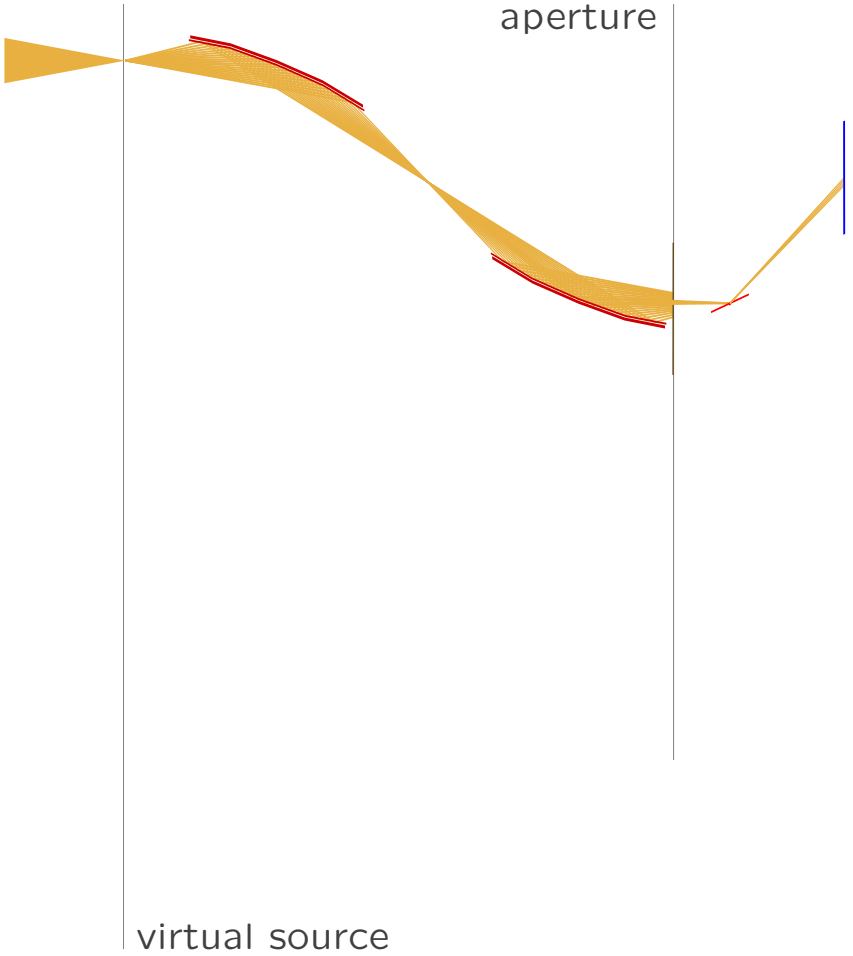
reflectometry: operation modes



almost conventional reflectivity

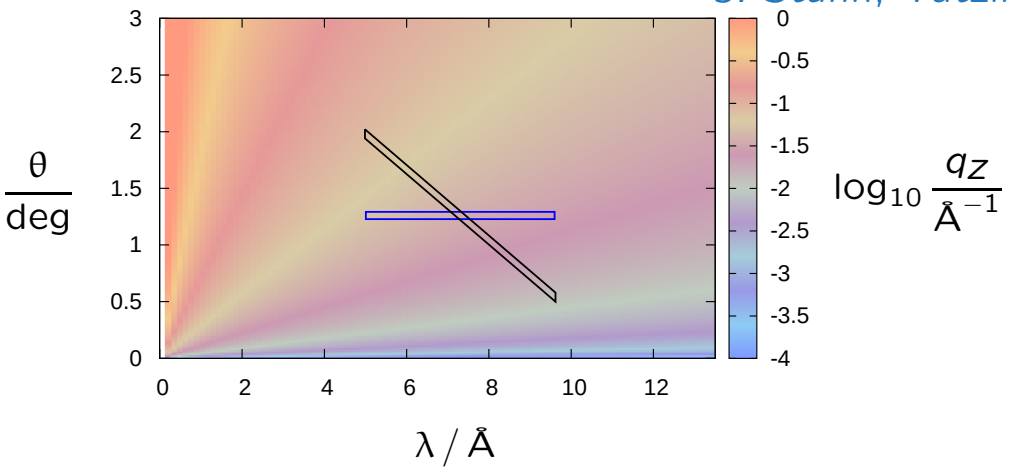
= TOF

- defined foot-print
- off-specular reflectivity



Selene guide

reflectometry: operation modes



almost conventional reflectivity

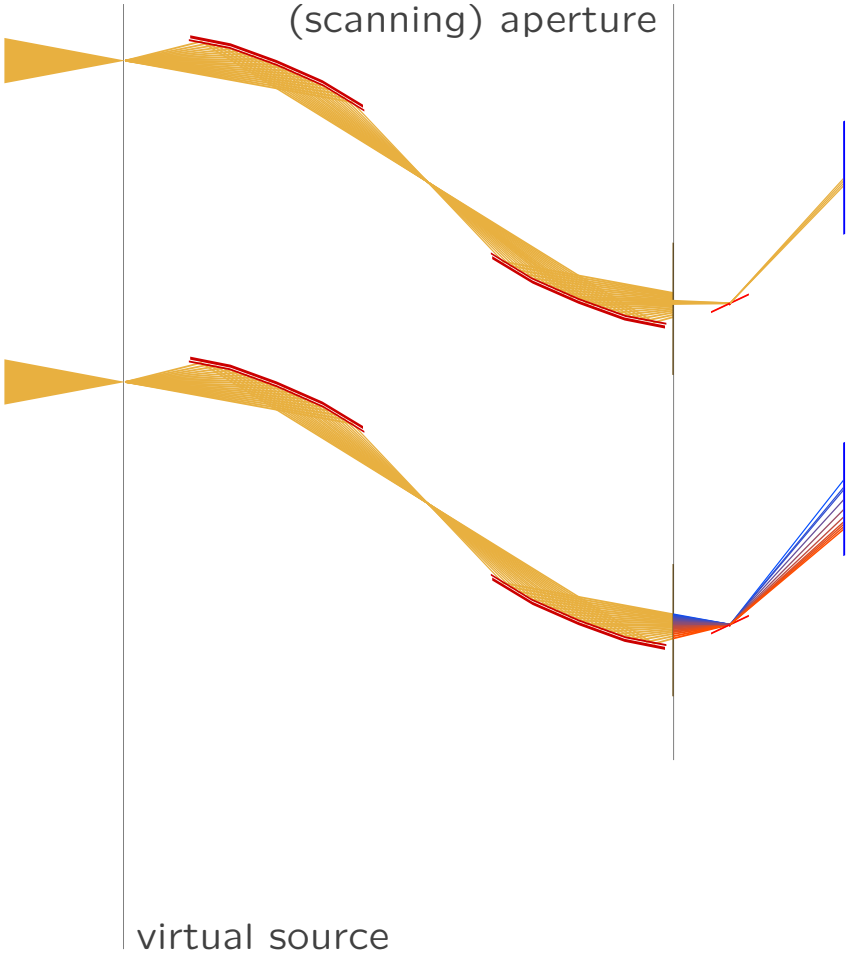
= TOF

- defined foot-print
- off-specular reflectivity

λ-θ-encoding

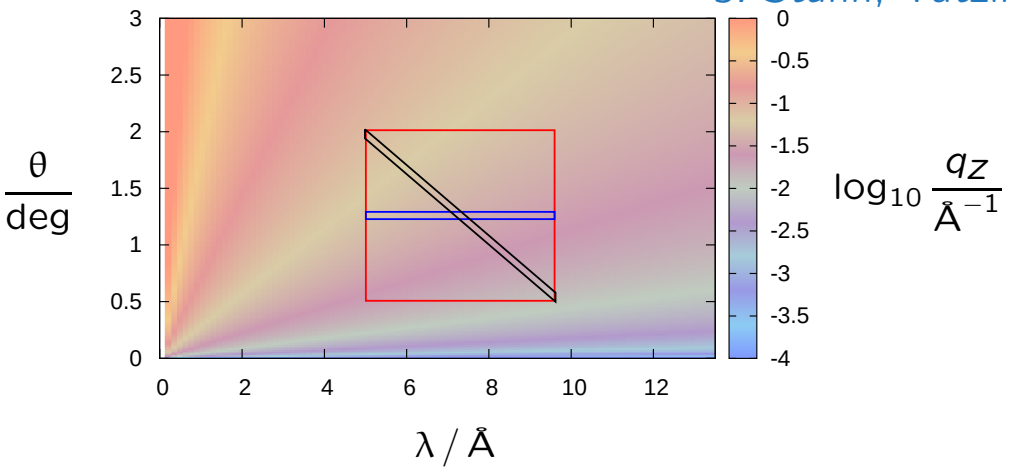
= TOF(θ)

- wider q_z-range
- constant $\Delta q/q$



Selene guide

reflectometry: operation modes



almost conventional reflectivity

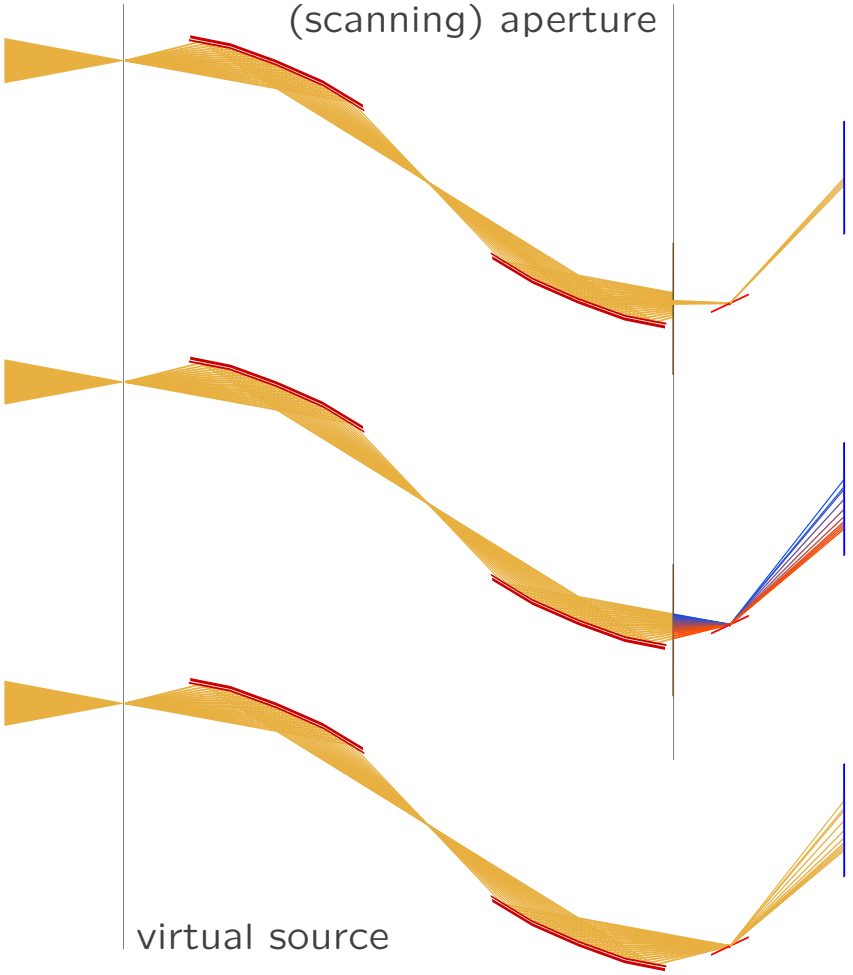
= TOF
- defined foot-print
- off-specular reflectivity

λ-θ-encoding

= TOF(θ)
- wider q_z-range
- constant $\Delta q/q$

high-intensity specular reflectivity

= TOF × θ-dispersive
- split-second t-resolution
- screening of parameter space



Selene guide

simple dependence's of parameters

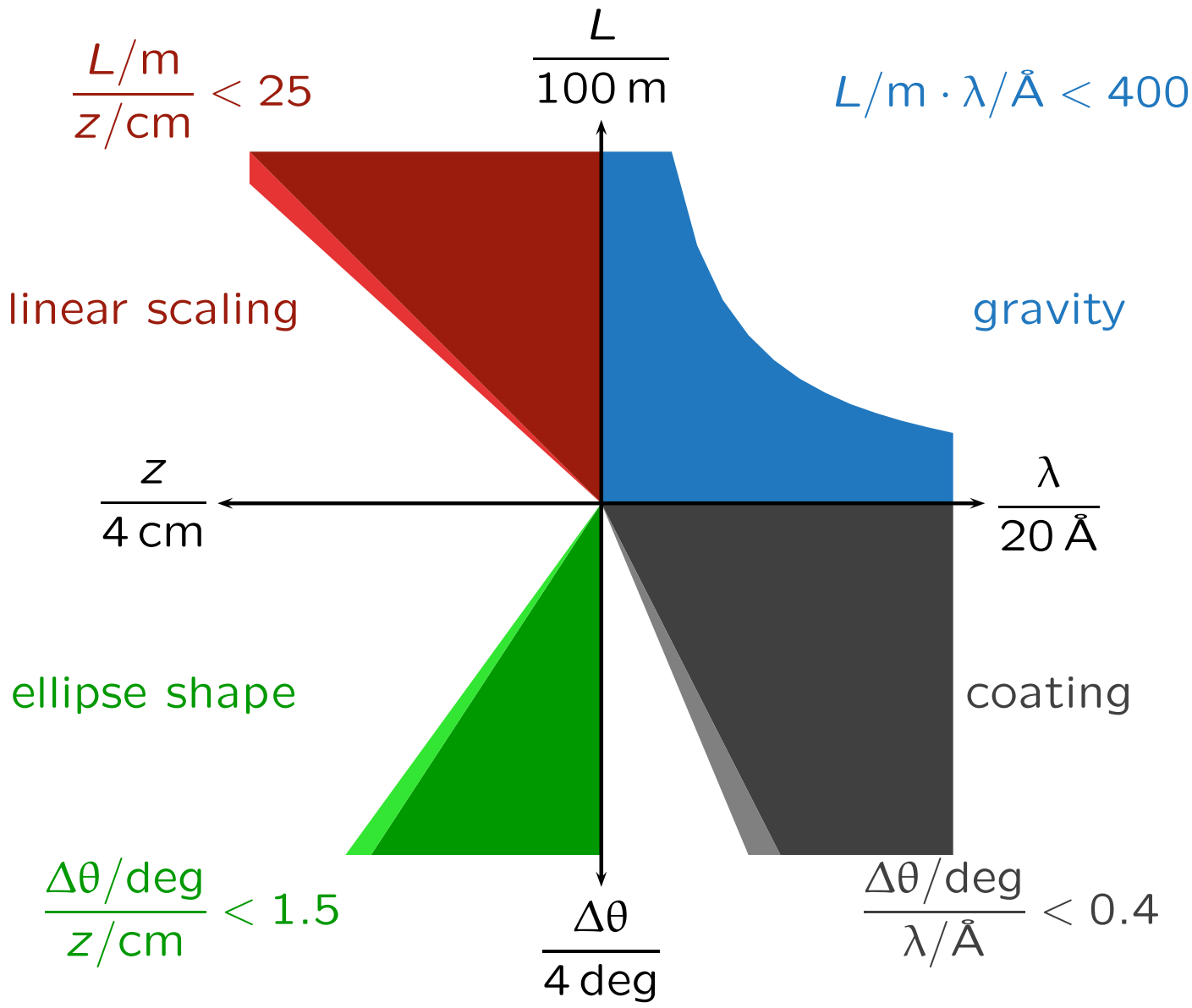
- $\Delta\theta$
- λ-range

constraints

- length L
- coating

and performance

- spot size
- transmission

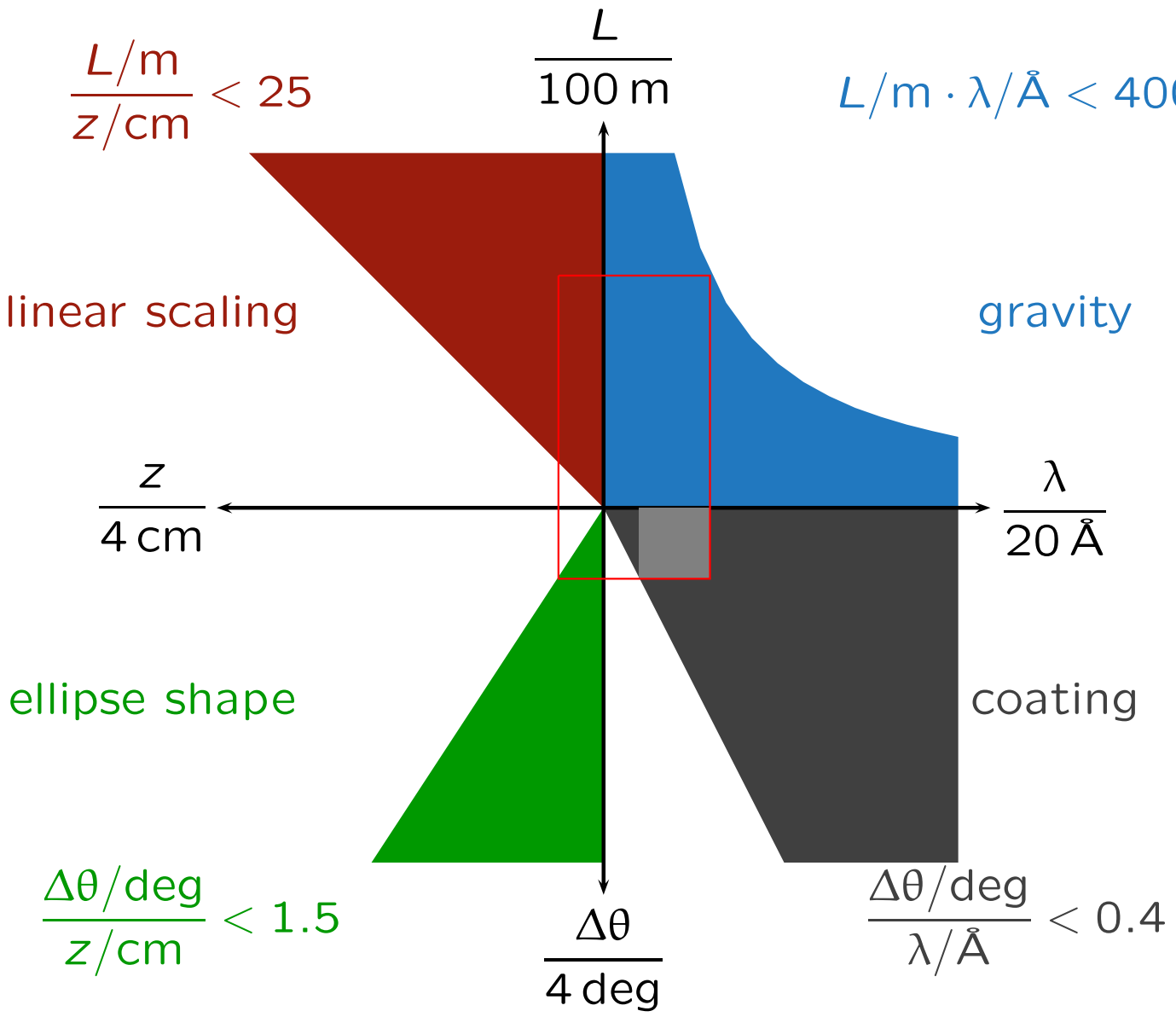


Selene guide

example: spectrometer (FOCUS for small samples)

$L < 65\,\mathrm{m}$

$\lambda \in [2, 6]\,\text{Å}$

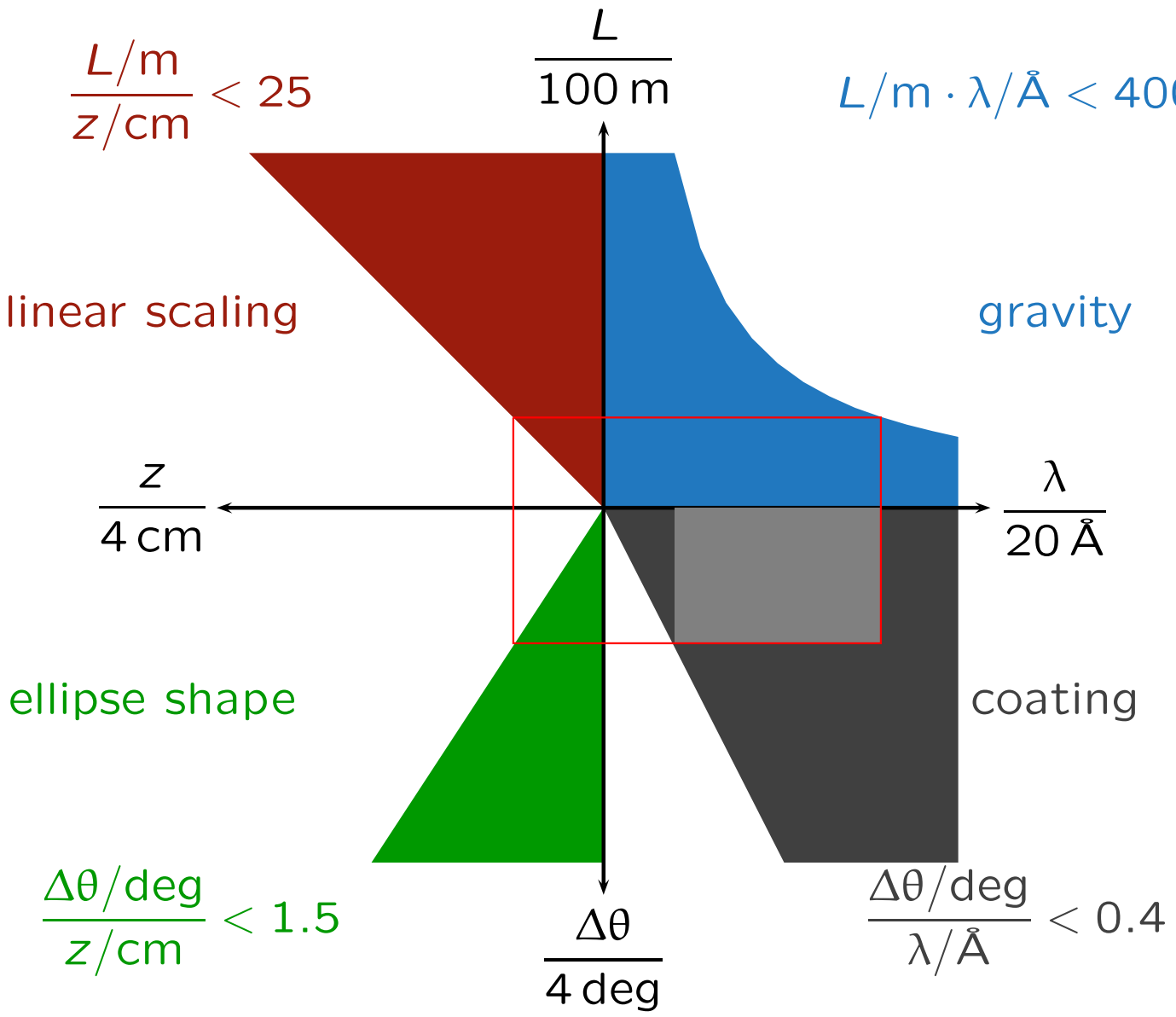


Selene guide

example: *Estia* (TOF reflectometer project)

$L = 24\,\mathrm{m}$

$\lambda \in [4, 10]\,\text{Å}$

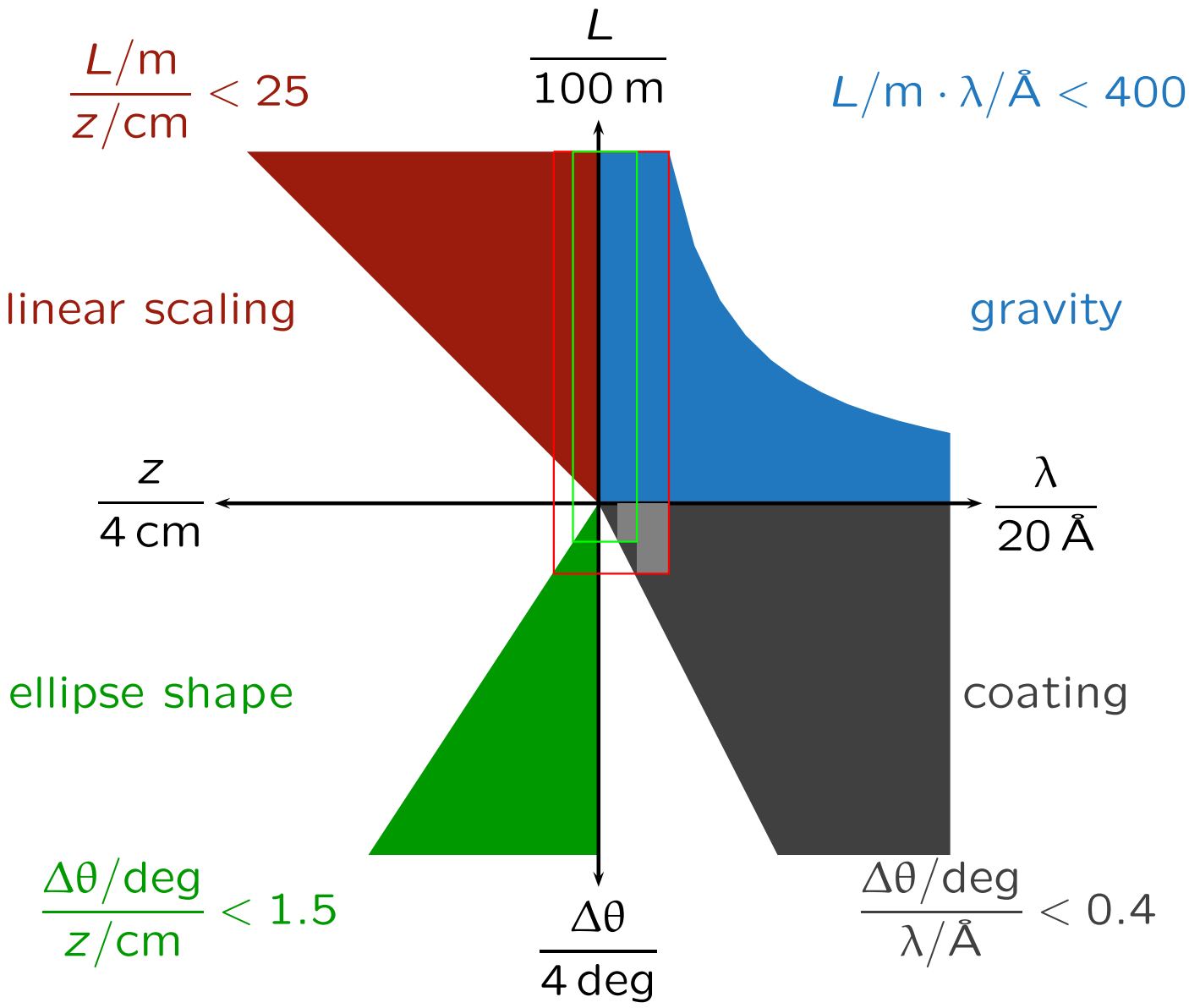


Selene guide

example: Werner's thermal/cold guide

$L = 100\,\mathrm{m}$

$\lambda \in [1, 4]\,\text{Å}$

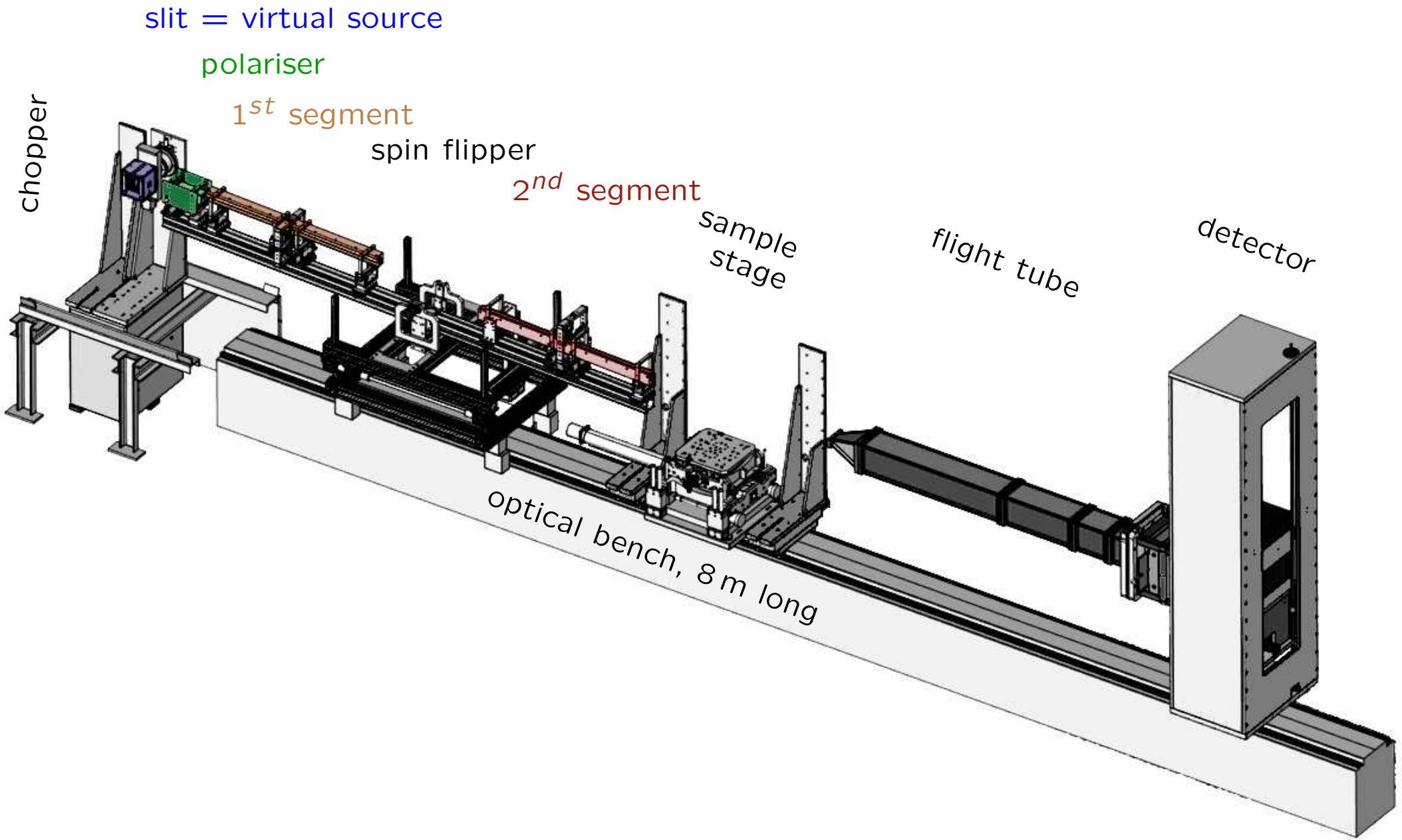


Selene prototype

- focusing
  - Selene guide
    - prototype
      - Estia
        - optics
          - discussion

Selene prototype

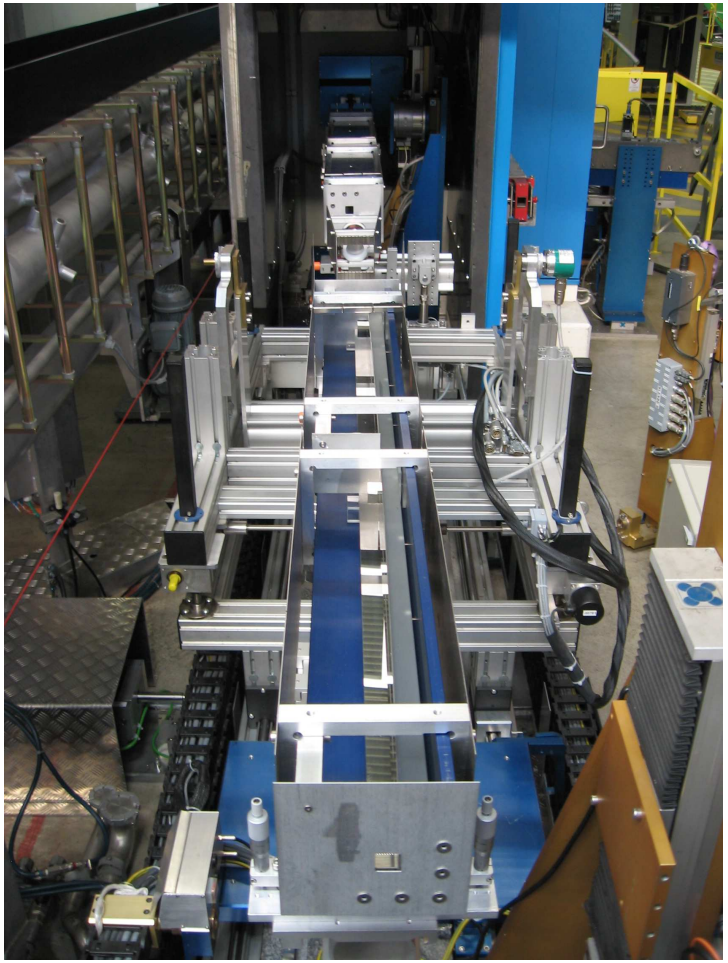
prototype guide on Amor@PSI

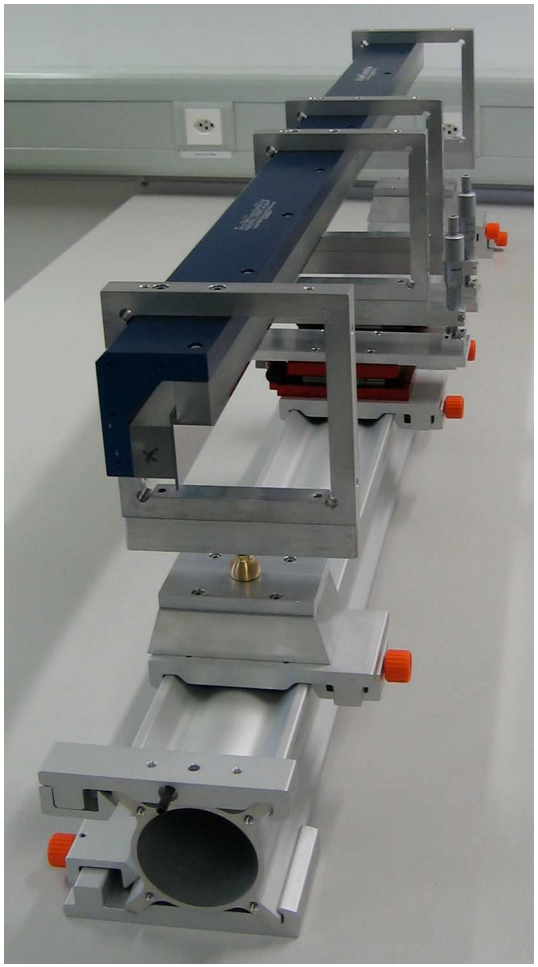


Selene prototype

prototype guide on Amor@PSI

- total length $= 4\,\mathrm{m}$
- max spot size $\approx 2 \times 2\,\mathrm{mm}^2$
- divergence $1.8^\circ \times 1.8^\circ$



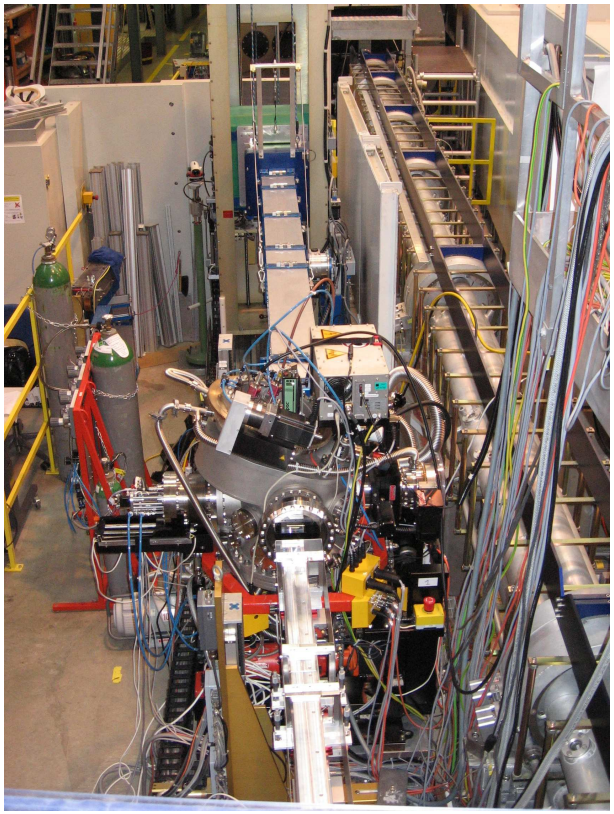


Selene prototype

example:
quasi in-situ reflectometry during sample growth

sample: Si/Cu(50 nm)/Fe(0 . . . 20 layers)

by B. Wiedemann, S. Mayr, W. Kreuzpaintner, TU Munich

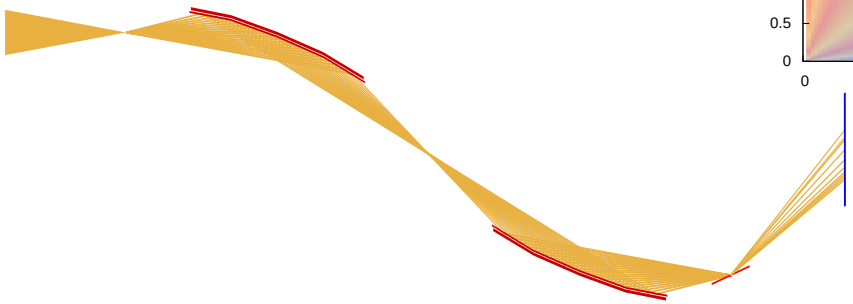


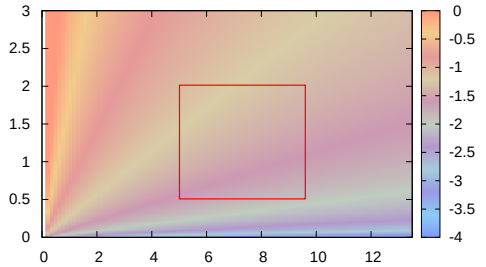
Selene prototype

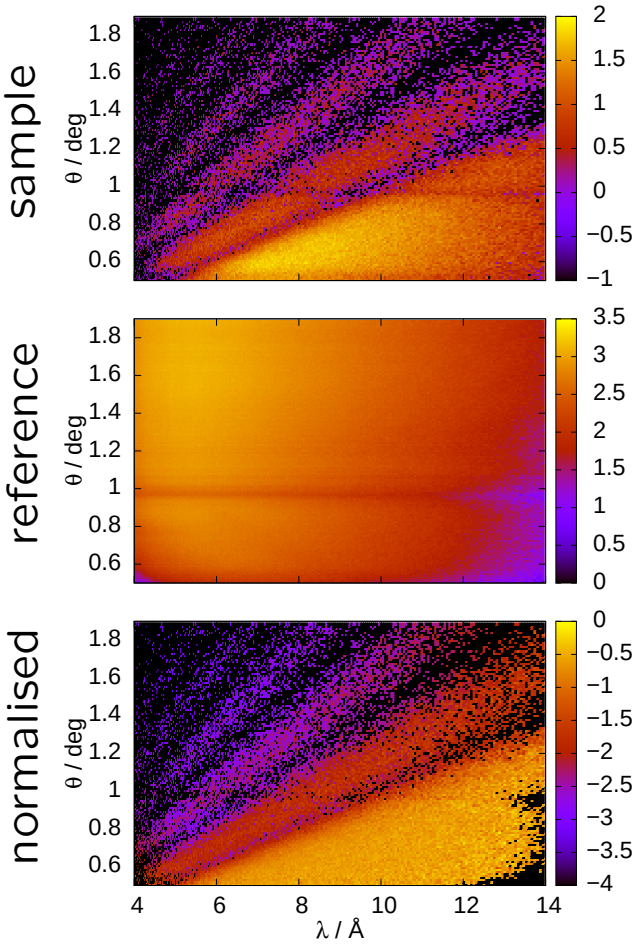
example:

quasi in-situ reflectometry during sample growth

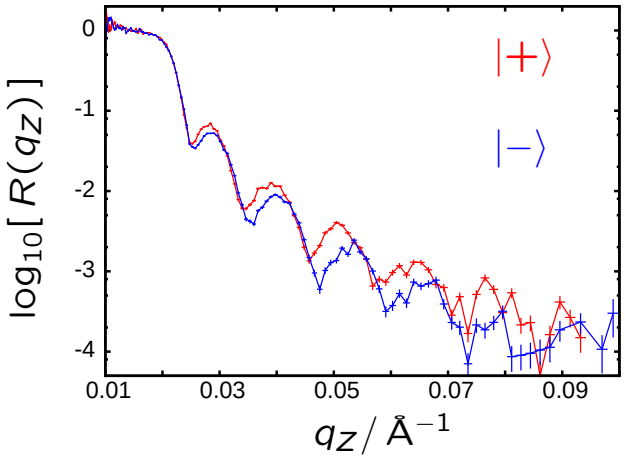
high-intensity specular reflectometry







sample	Si /Cu /Fe (6 monolayers)
instrument	Amor
size	2×20 mm^2
time / spin	10 min



estia

- focusing
  - Selene guide
    - prototype
      - **Estia**
        - optics
          - discussion

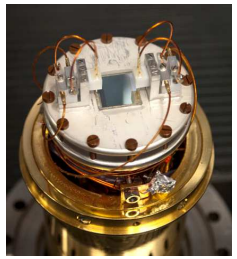
Estia

Estia ***a polarised focusing reflectometer for small samples***

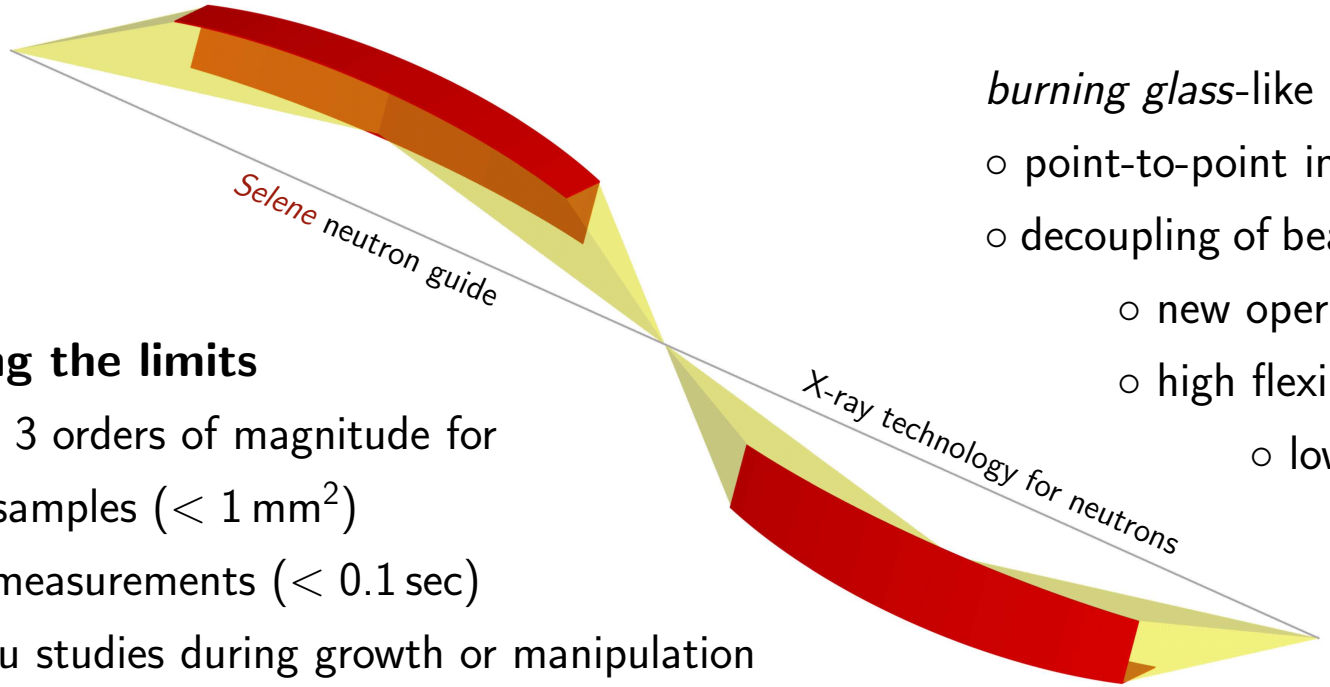
Paul Scherrer Institut
Switzerland
Jochen Stahn

University of Copenhagen
Denmark
Marité Cardenas

for the investigation of the
chemical and magnetic depth-profile near surfaces
and of lateral correlations and structures

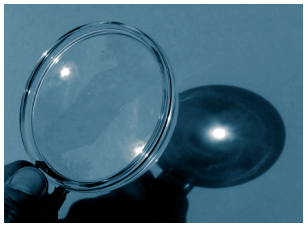


functional devices:	*spin-valves, spintronics*
diffusion processes:	*Li batteries, corrosion protection*
multifunctional materials:	*interface-coupled electric and magnetic properties*
towards *real* materials:	*raster-scanning of bent, faceted or multi-domain surfaces*



burning glass-like **neutron guide**

- point-to-point imaging
- decoupling of beam size and divergence
  - new operation modes
  - high flexibility
    - low background



pushing the limits

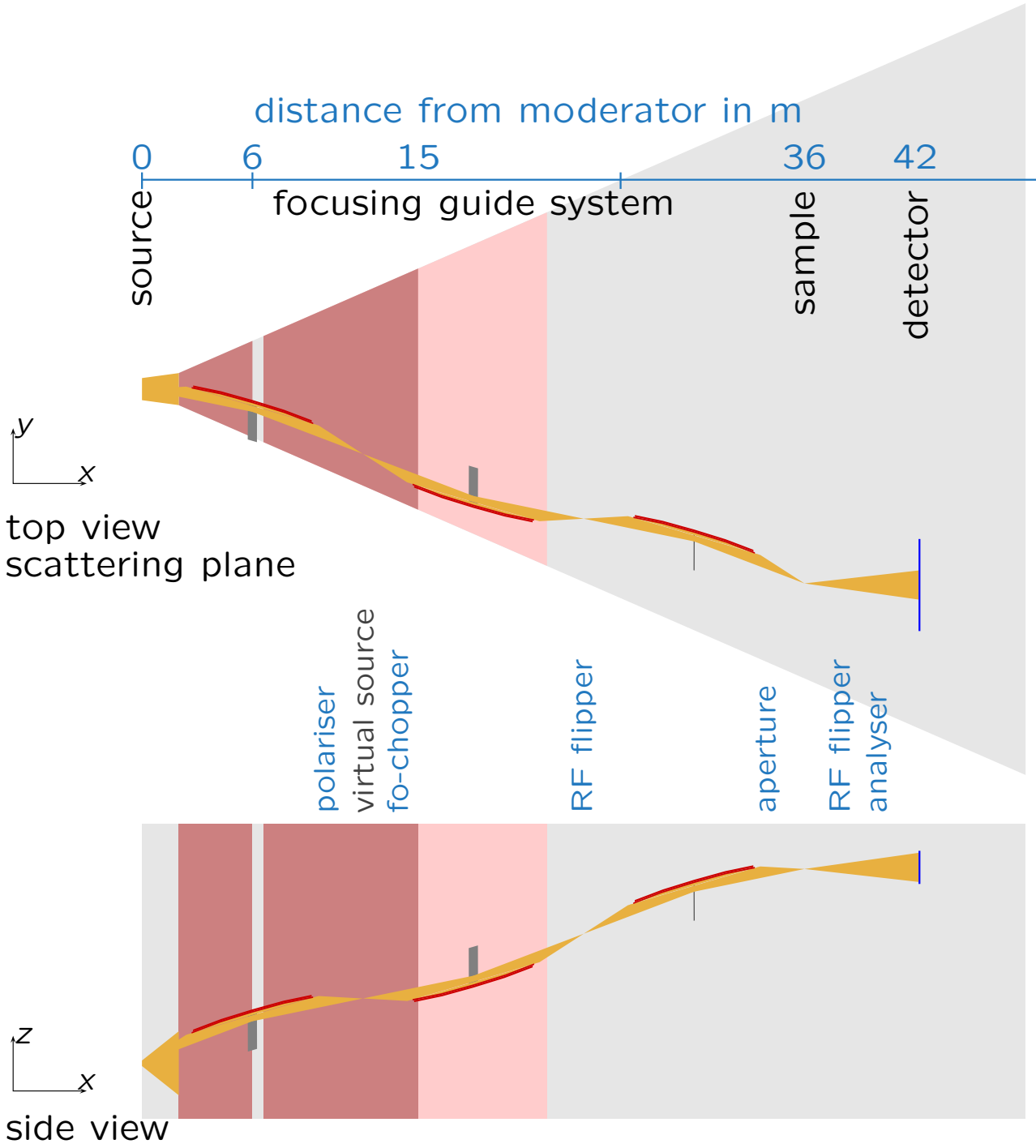
by 2 to 3 orders of magnitude for

- tiny samples ($< 1\,\mathrm{mm}^2$)
- fast measurements ($< 0.1\,\mathrm{sec}$)
- in-situ studies during growth or manipulation

Estia

TOF reflectometer
for the ESS

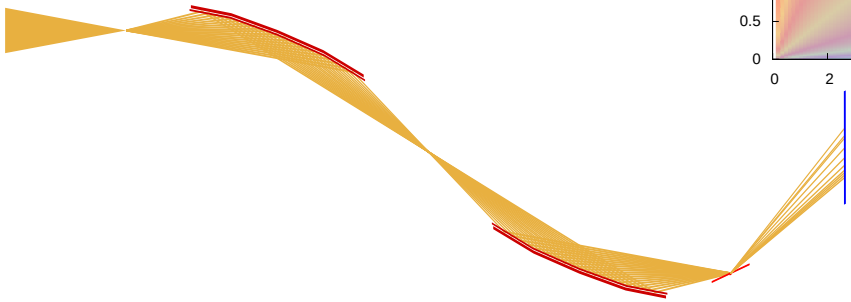
- horizontal scattering plane
- sample size $< 10 \times 50\,\mathrm{mm}^2$
- divergence $1.5^\circ \times 1.5^\circ$
- $\lambda \in [4, 10]\,\text{Å}$
- *feeder* + *Selene* guide
- low background
- stopping fast neutrons / γ

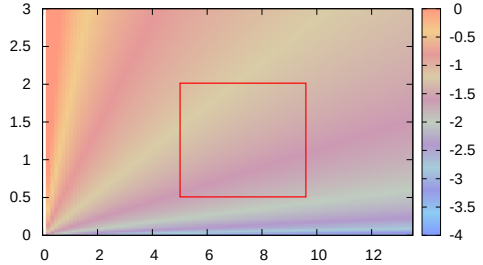


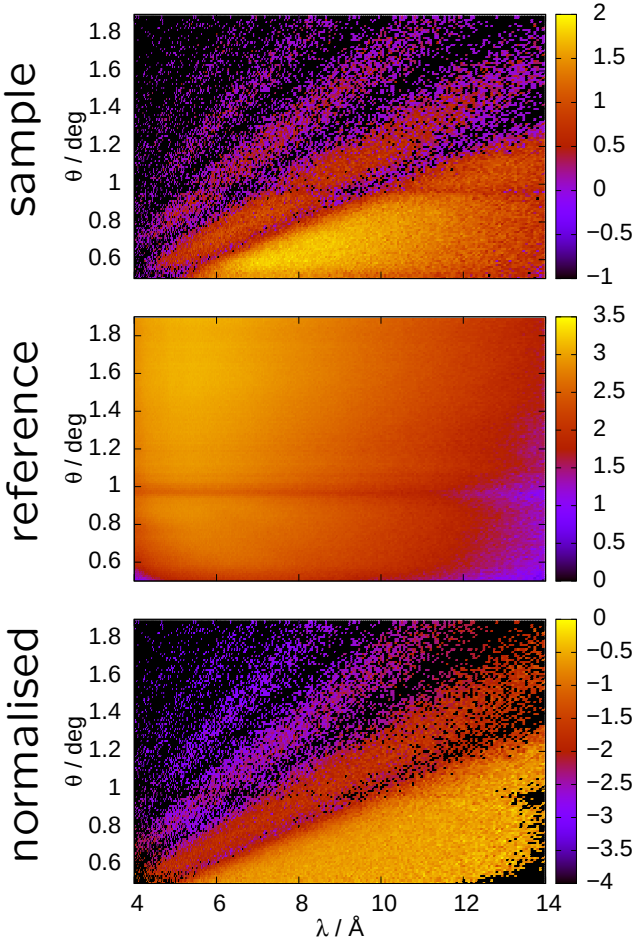
Estia

comparison to prototype

high-intensity specular reflectometry

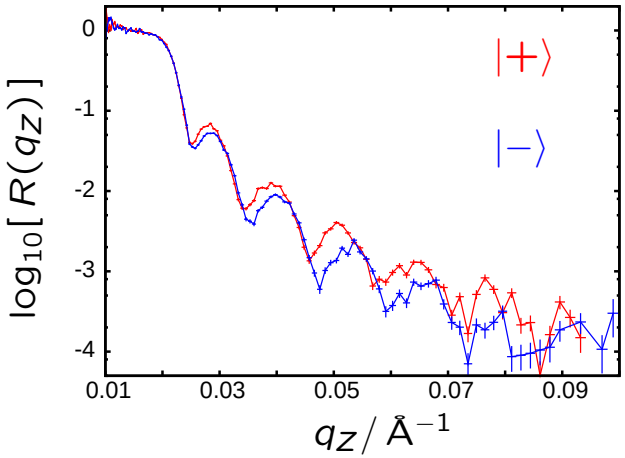






sample	Si /Cu /Fe (6 monolayers)	
instrument	Amor	*Estia*
size	2×20 mm^2	10×20 mm^2
time / spin	10 min	0.1 s

gain-factor: 10000



due to:

- brilliance of sources
- Amor guide (20%)
- sample size

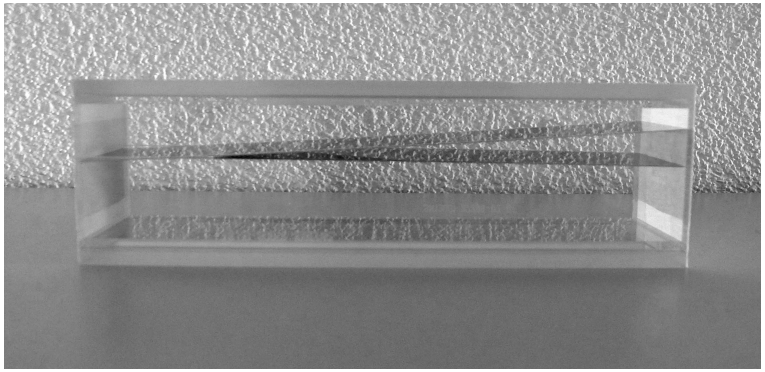
optics

- focusing
  - Selene guide
    - prototype
      - Estia
        - optics
          - discussion

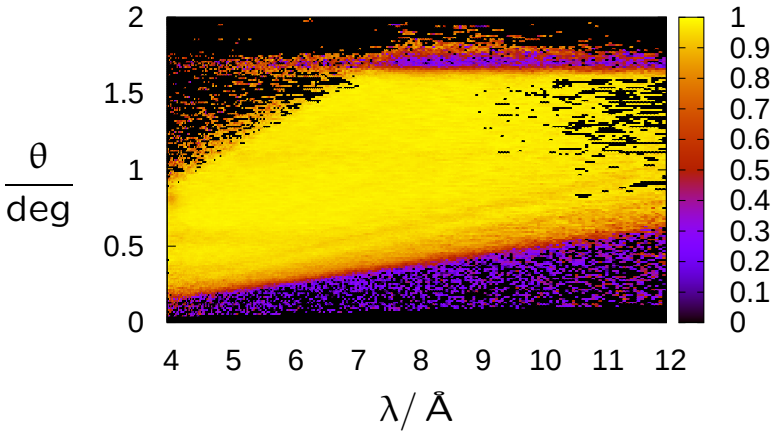
optics: logarithmic spiral

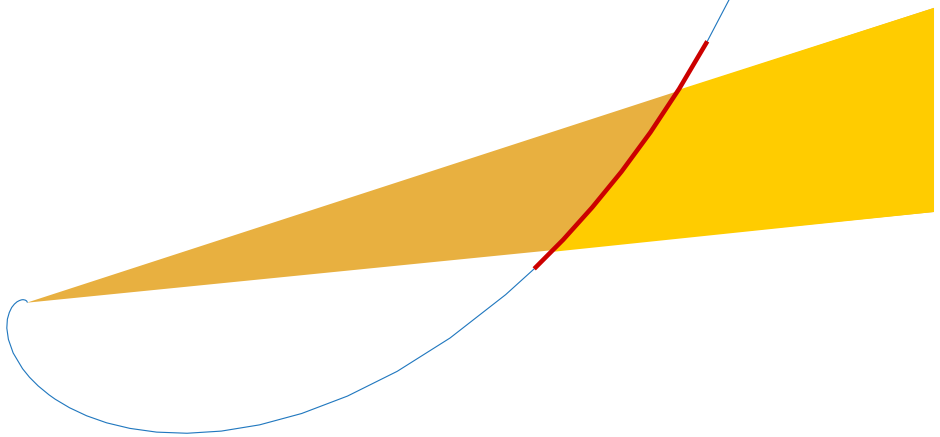
polariser, frame-overlap mirror

can be applied to all convergent / divergent beams with small focus spot
e.g. as analyser for any beam reflected on small or moderate-sized samples!



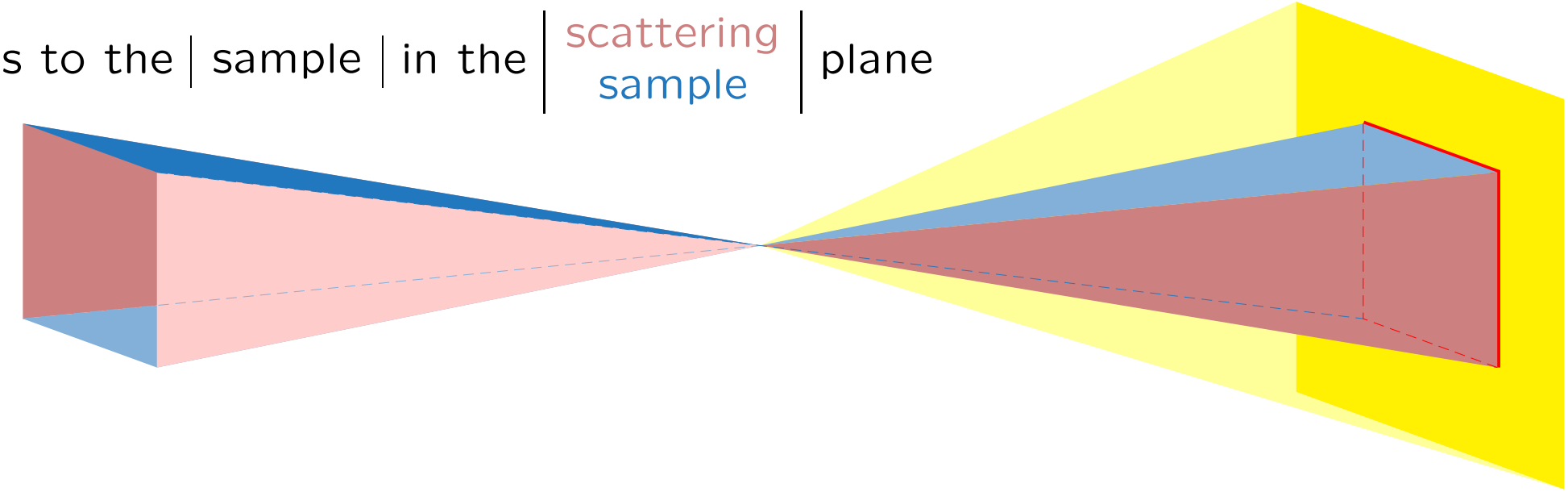
polarisation efficiency measured
with a Fe/Si supermirror



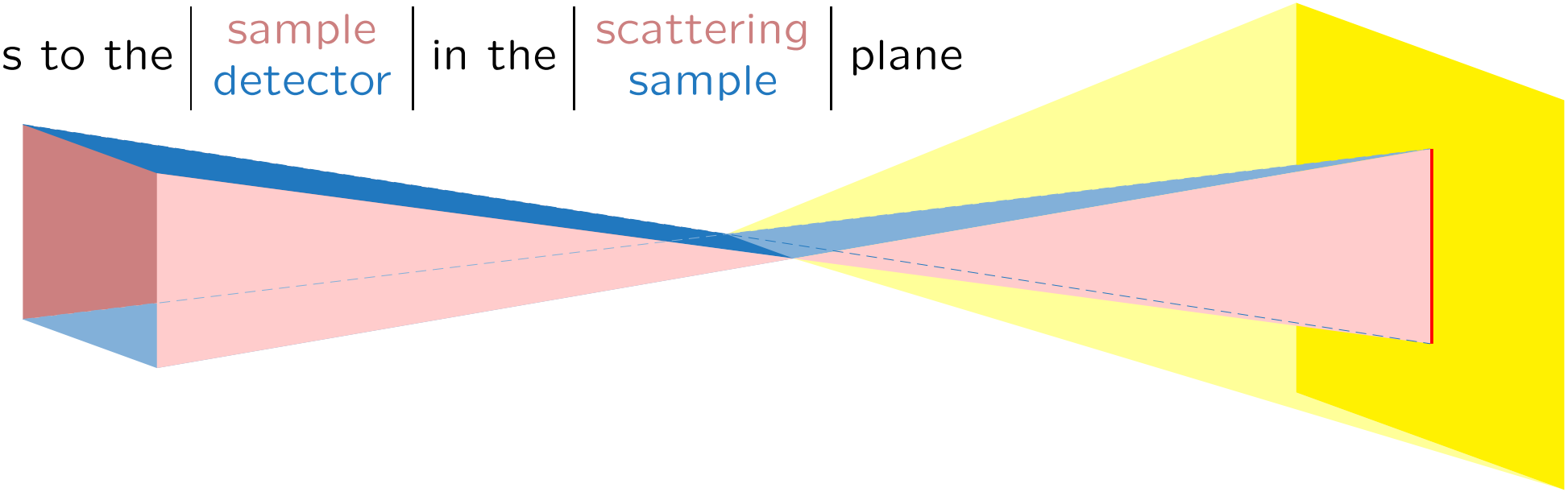


optics: astigmatic focusing

focus to the | sample | in the | scattering sample | plane



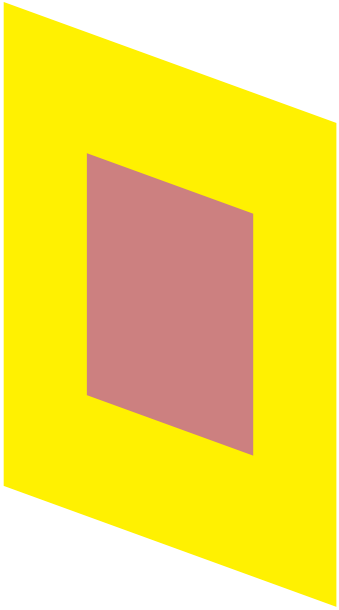
focus to the | sample detector | in the | scattering sample | plane



optics: astigmatic focusing

focus to the | sample | in the | scattering sample | plane

| specular / off-specular | intensity distributed over the detector



focus to the | sample detector | in the | scattering sample | plane

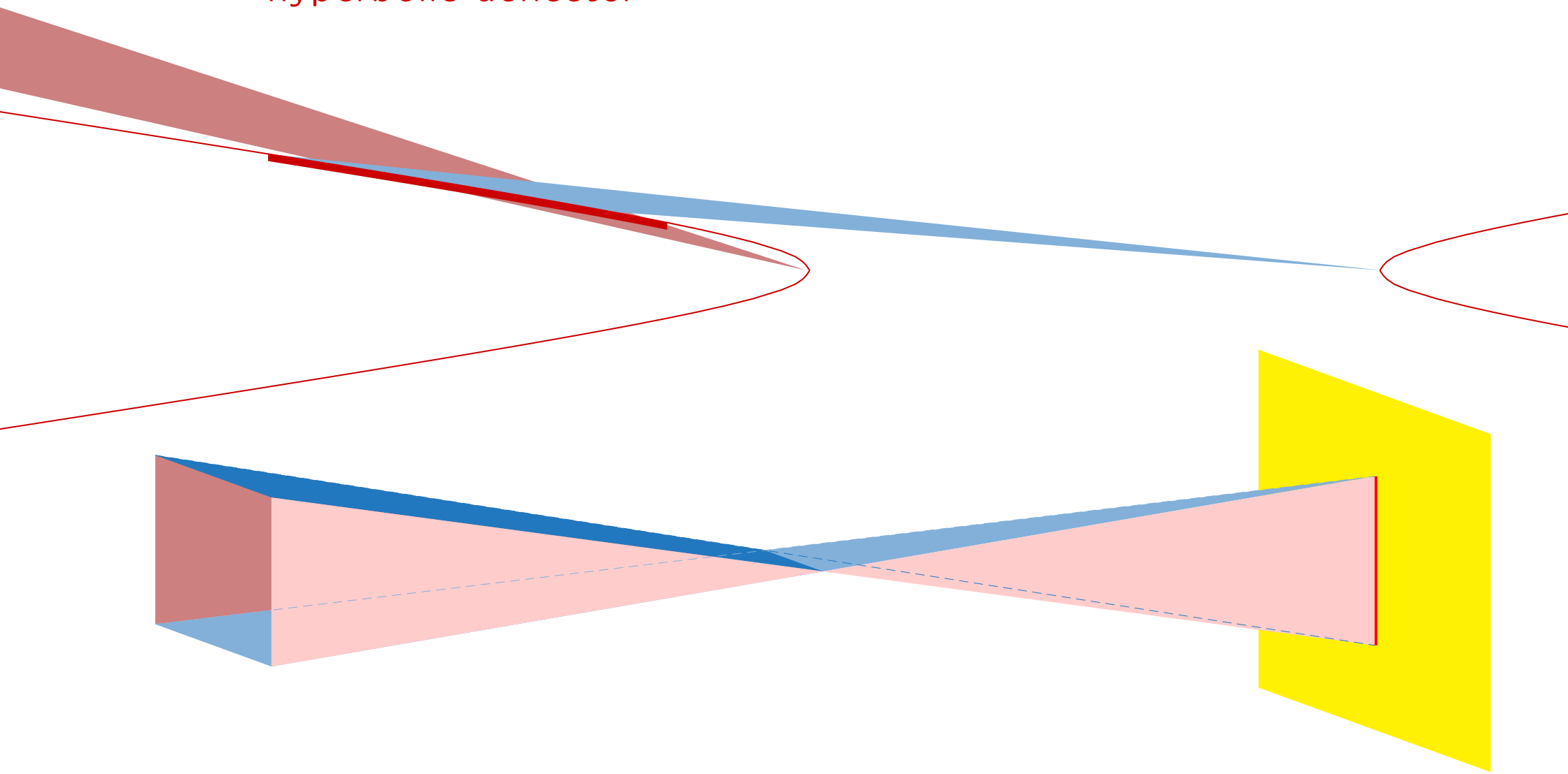
| specular / off-specular | intensity | concentrated along a line / distributed over the detector |

$\Rightarrow$ strongly reduced background under specular signal

optics: astigmatic focusing

focusing to the detector by shifting the focal point:

hyperbolic deflector

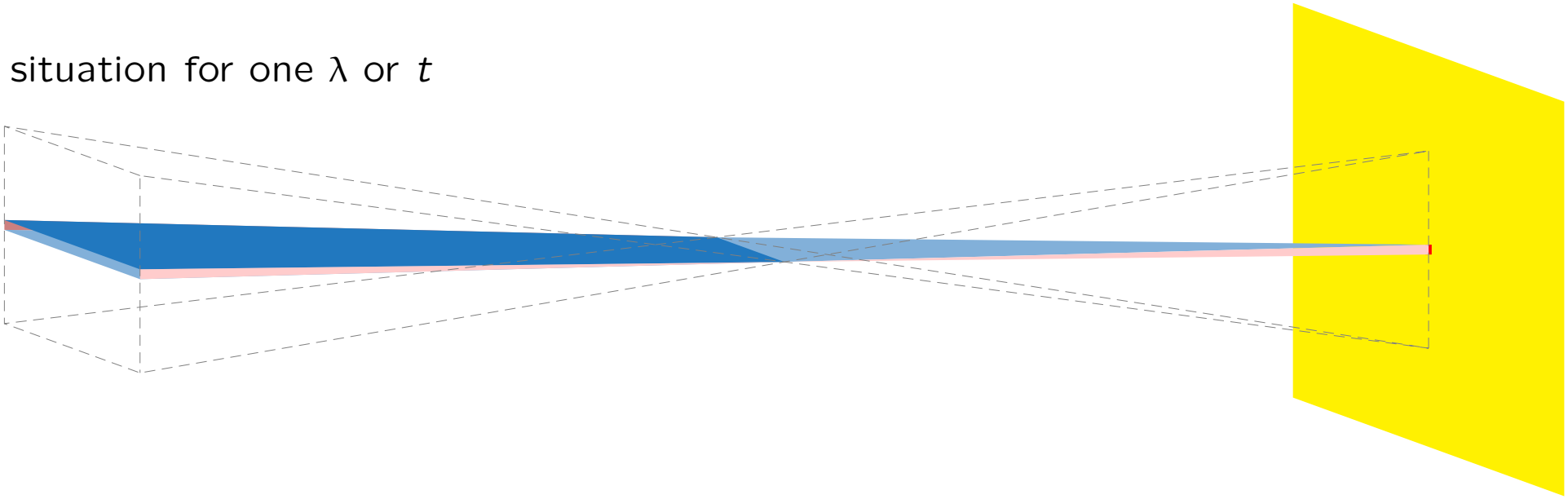


optics: astigmatic focusing

in combination with TOF and

a chopper / scanning aperture / dispersive monochromator

situation for one λ or t

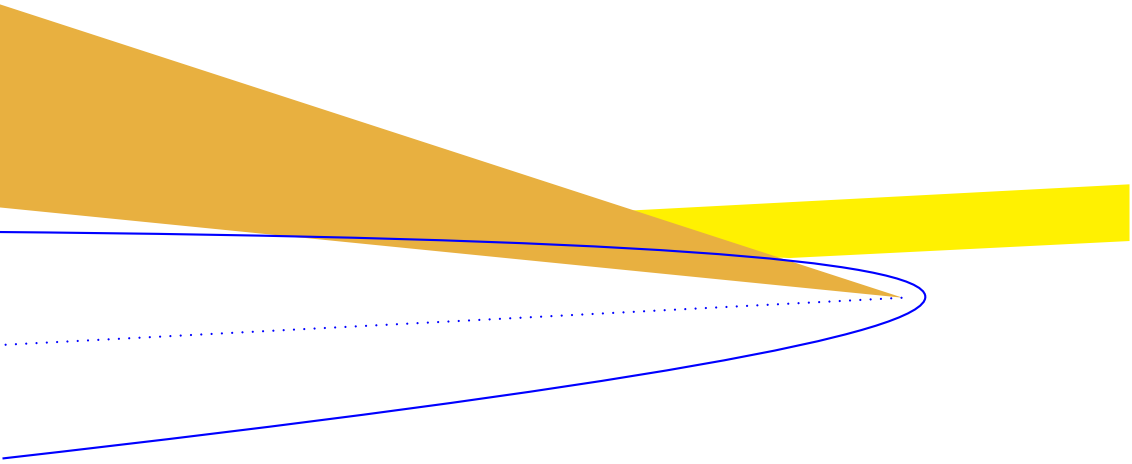


specular intensity concentrated on a small spot

$\Rightarrow$ focusing GISANS configuration

optics: adaptive optics

condenser: parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

focal length ⇒ beam width

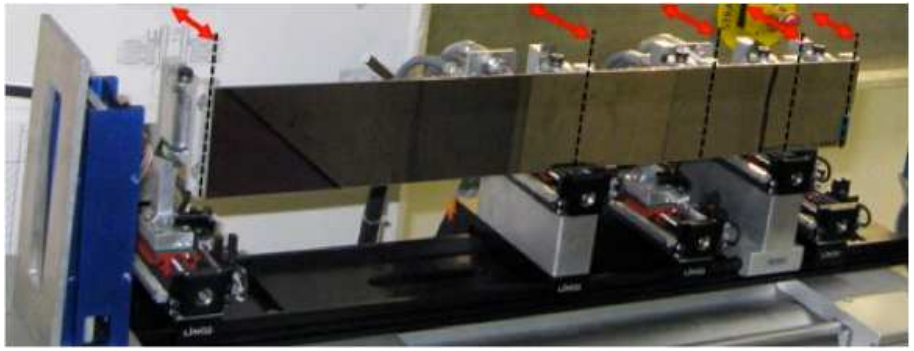
beam width & spot size ⇒ divergence

no collimator needed

tunable

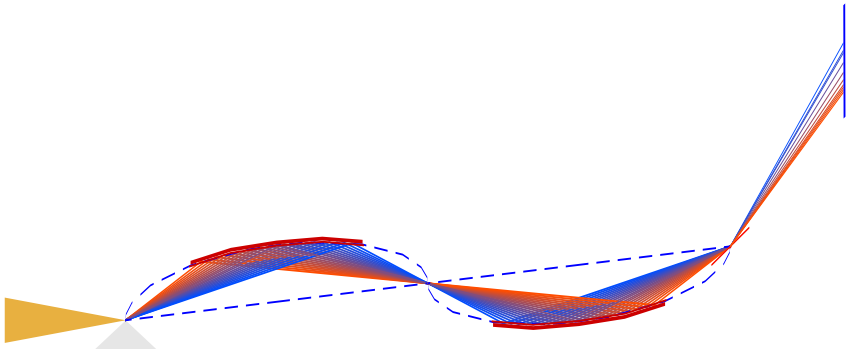
adaptive parabola (convex)
focal spot with 170 µm reached

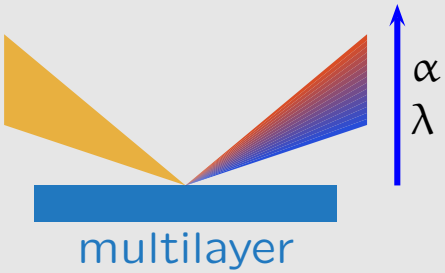
(PSI, early version)

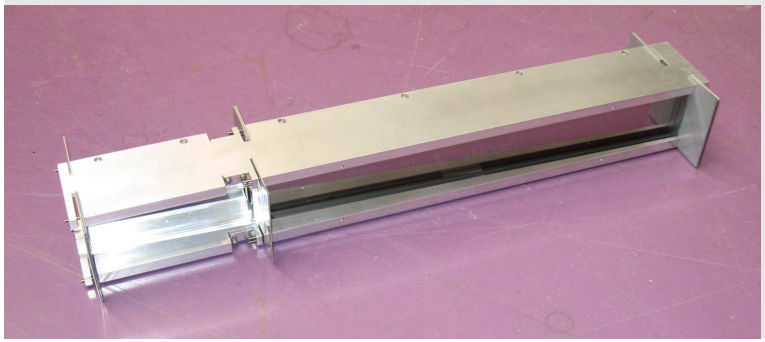


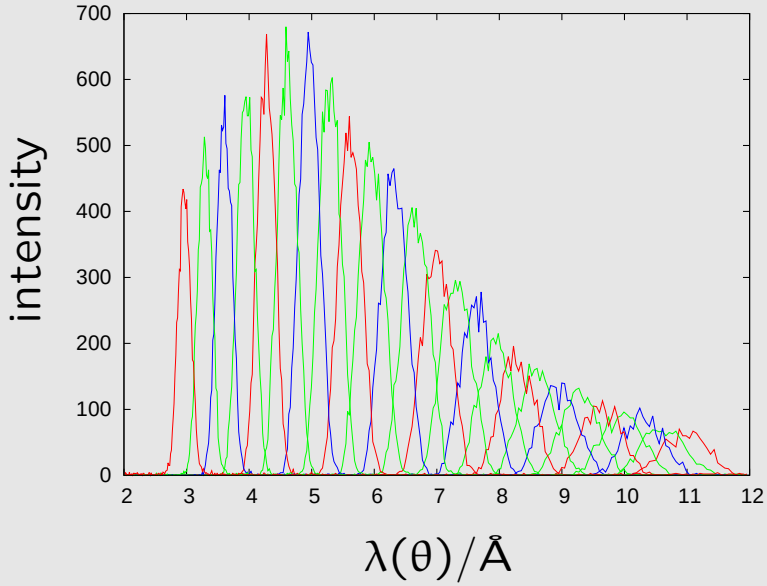
optics: spectral analysis

using a multilayer monochromator

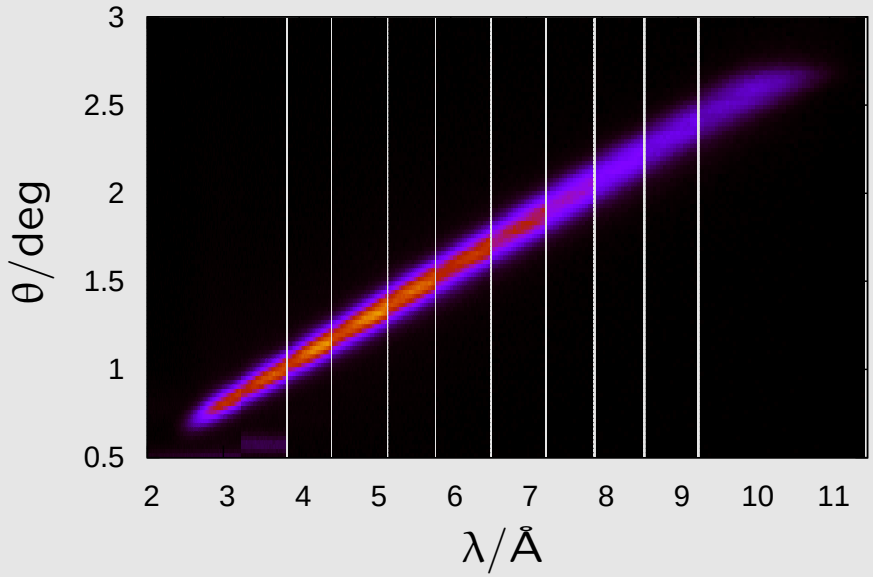








$I(\lambda, \theta)$ measured on Amor



double ML monochromator

discussion

- focusing
  - Selene guide
    - prototype
      - Estia
        - optics
          - **discussion**

discussion

focusing results in . . .

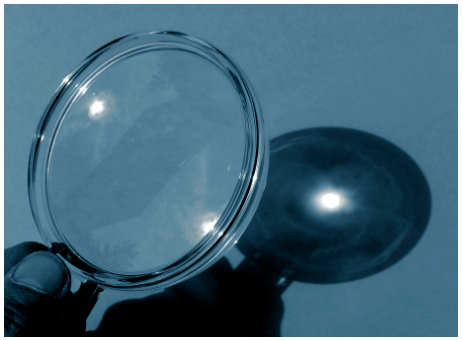
. . . no gain in brilliance

. . . a defined footprint

. . . a clean beam

homogeneous

uni-modal angular or spatial distribution



non-perfect optics

$\Rightarrow$ reduction of resolution / transmission

works best for small samples

weak aberration