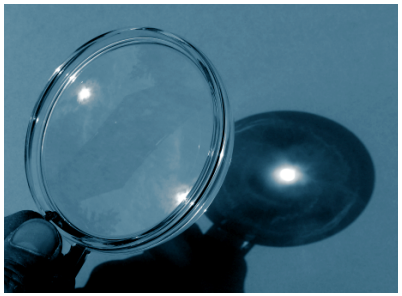
PAUL SCHERRER INSTITUT

Jochen Stahn Laboratory for Neutron Scattering
Uwe Filges Laboratory for Developments and Methods



focusing optical elements and guides for neutron reflectometry

experiences, projects and ideas

ESS Science Symposium
Surface and Interface Reconstruction: A Challenge for Neutron Reflectometry
24. - 26. 09. 2014, Bernried, Germany

people involved

experiments

Ursula Bengaard Hansen
Wolfgang Kreuzpaintner
Birgit Wiedemann
Anette Vickery
Sina Mayr

McStas simulations

Emanouela Rantsiou
Tobias Panzner
Panos Korelis
Uwe Filges

PSI infrastructure

Vincent Thominet
Sibylle Spielmann
Roman Bürge
Marcel Schild
Dieter Graf
Jan Krebs

ideas / discussions

Björgvin Hjörvarsson
Marité Cardenas
Beate Klösgen
Rob Dalgliesh
Frédéric Ott
Phil Bentley
Bob Cubitt
Peter Böni
Uwe Stuhr
. . .

inspiration

Selene

thanx!

focusing

- focusing
  - focusing Selene guide
    - experiences
      - projects
        - ideas
          - 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

⇒ conservation of states (neutrons)

other conservative optics: mirror, non-focusing reflectors

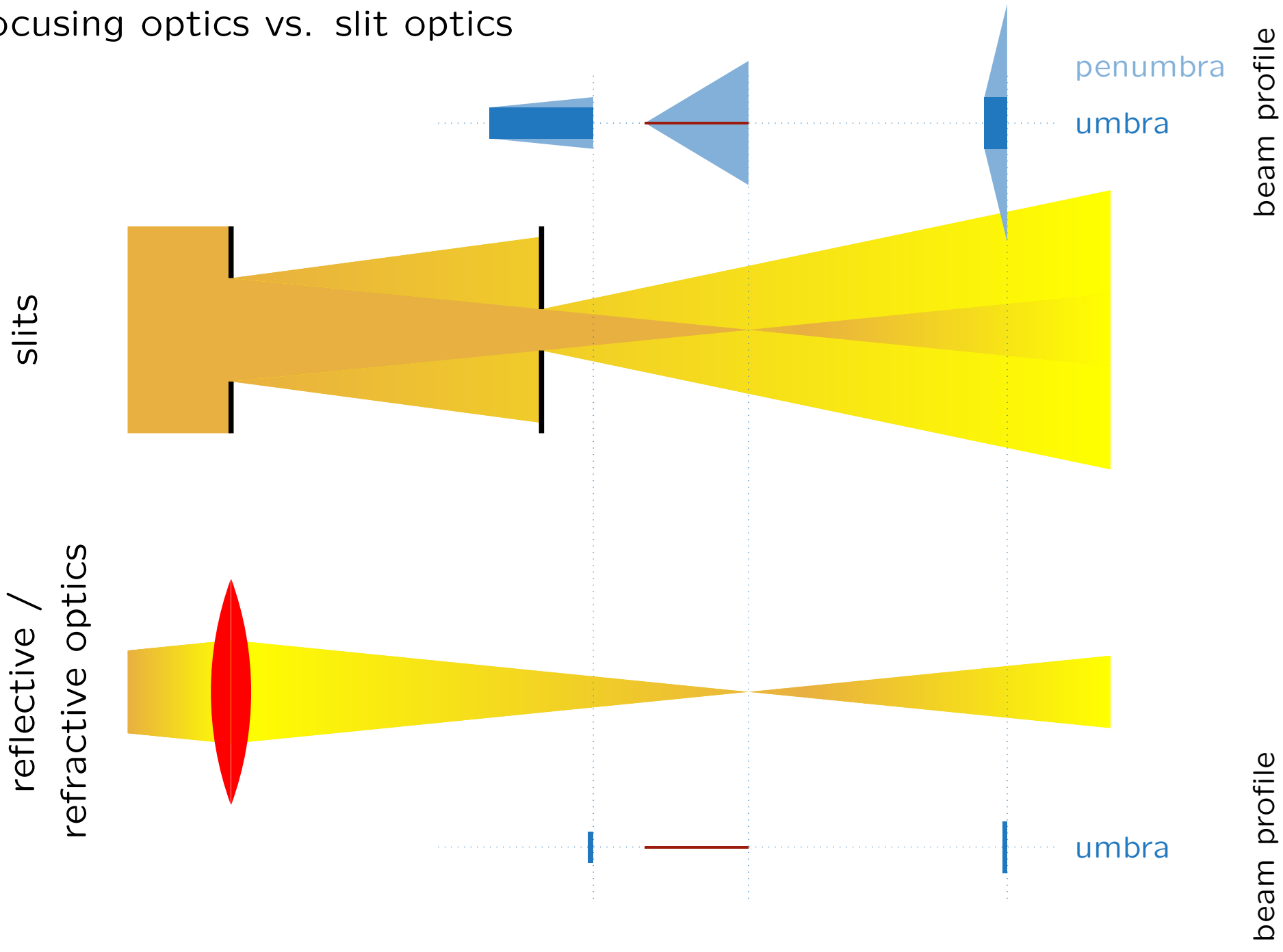
shading optics

reshapes the phase space by restricting it in space (slit)
or divergence (collimator)

⇒ *loss* of neutrons

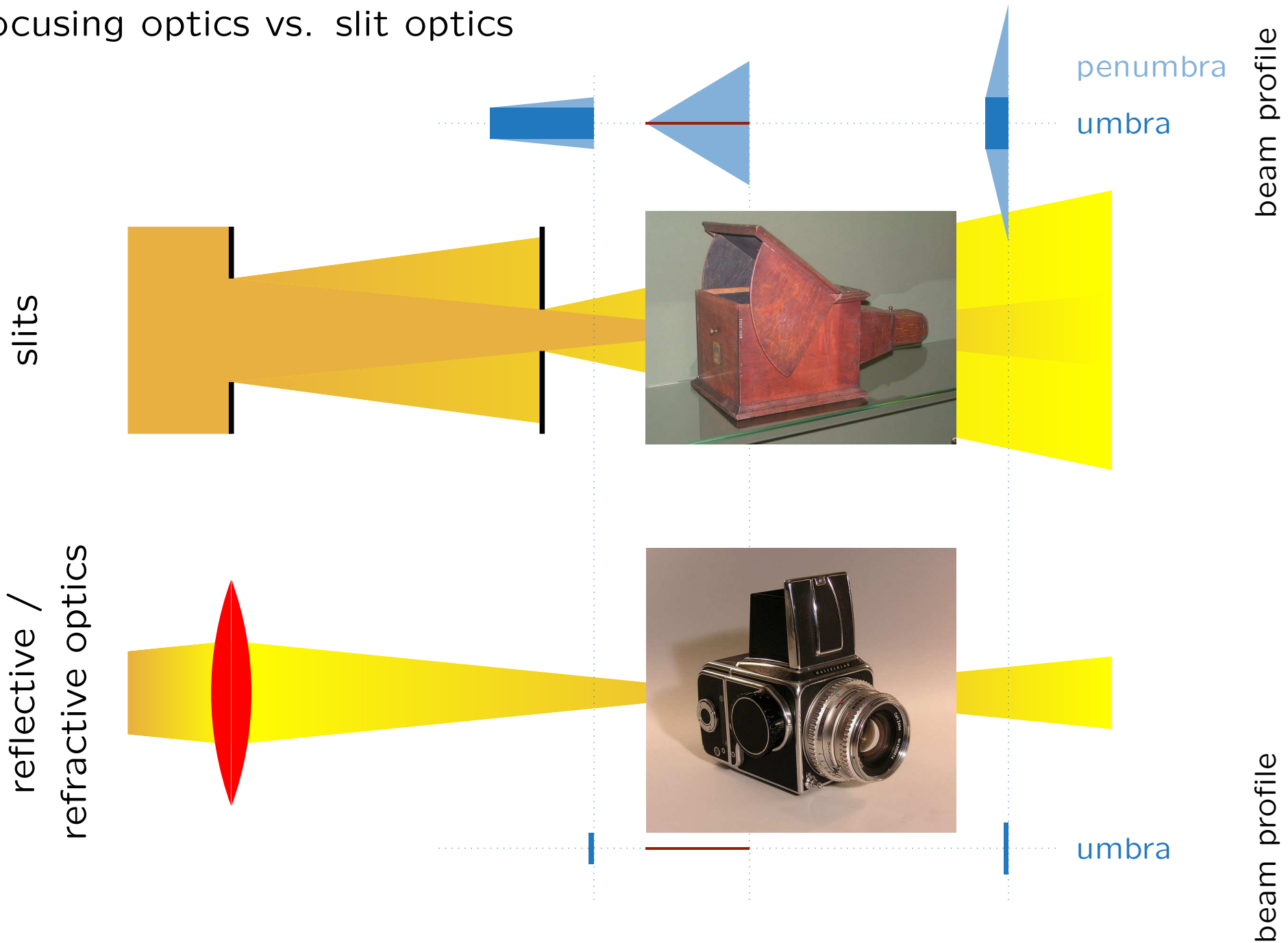
focusing: principles

focusing optics vs. slit optics



focusing: principles

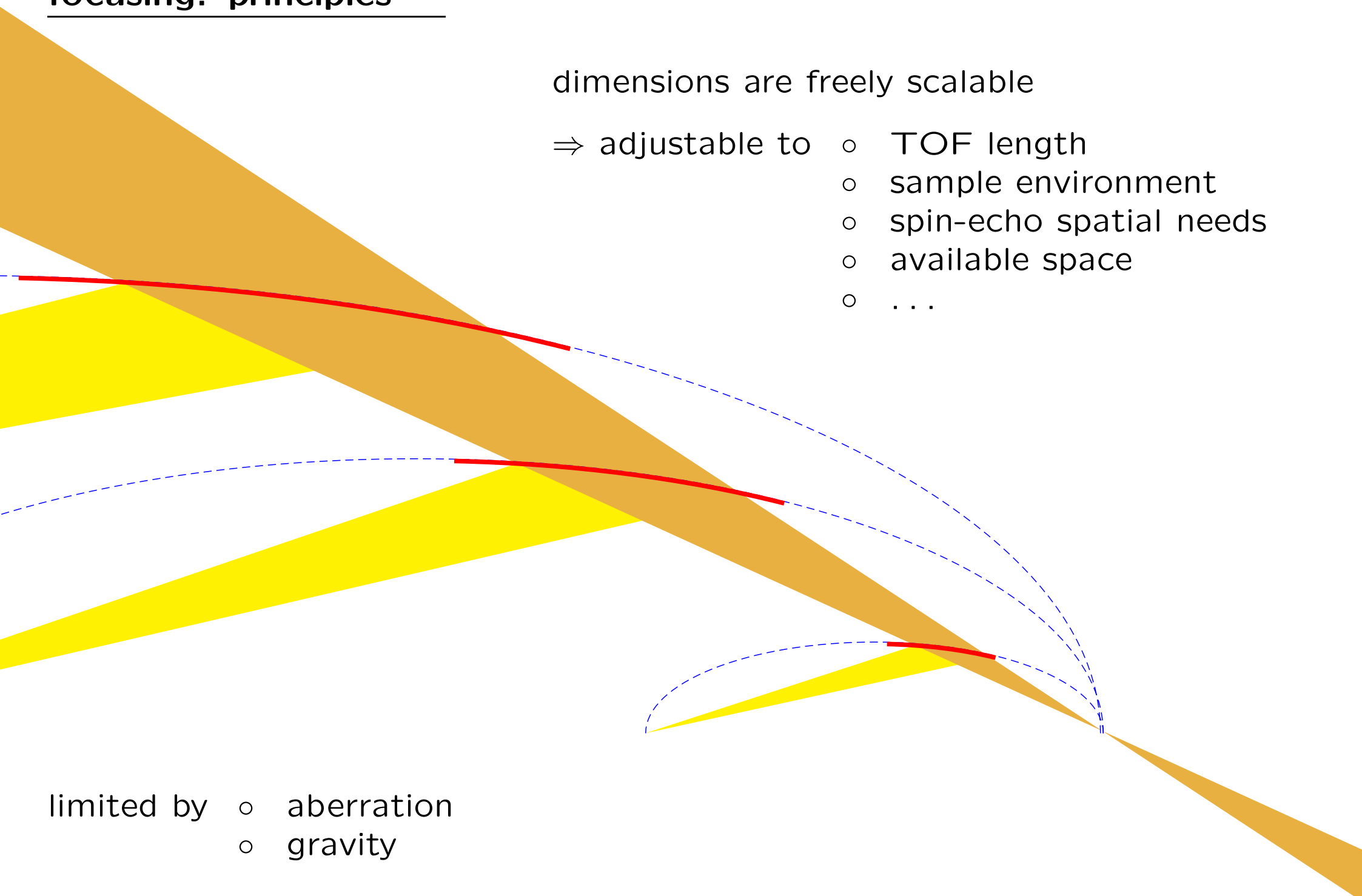
focusing optics vs. slit optics



focusing: principles

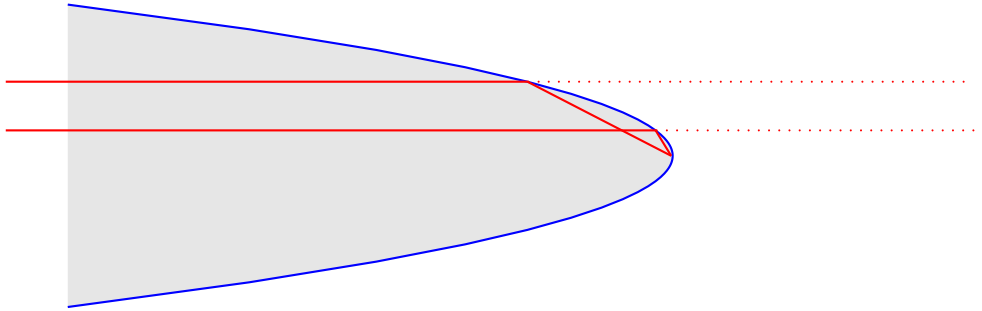
dimensions are freely scalable

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



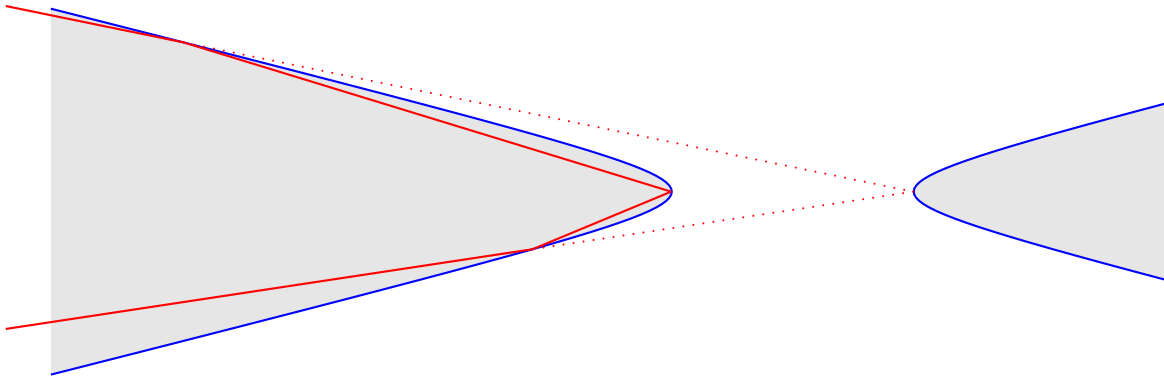
limited by
- aberration
- gravity

focusing: basic reflector shapes



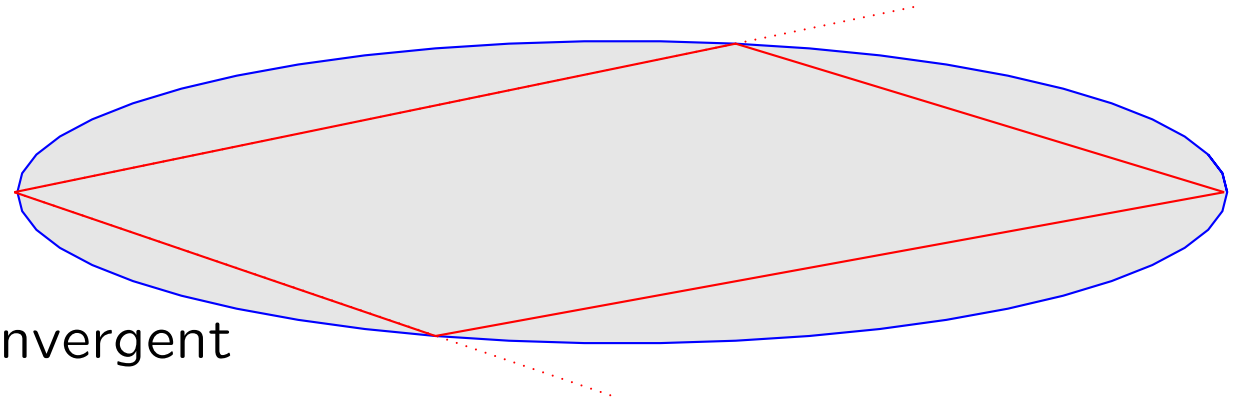
parabolic

parallel to convergent



hyperbolic

convergent to convergent



elliptic

divergent to convergent

focusing: full vs. half device

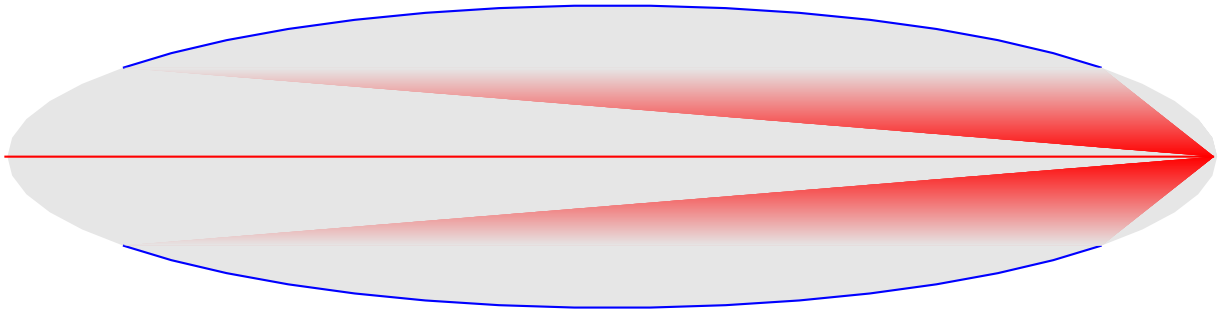
phase space homogeneity

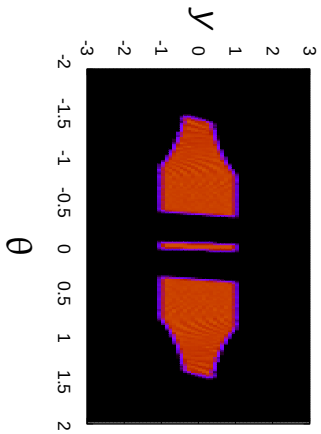
effective divergence

elliptic

2-sided

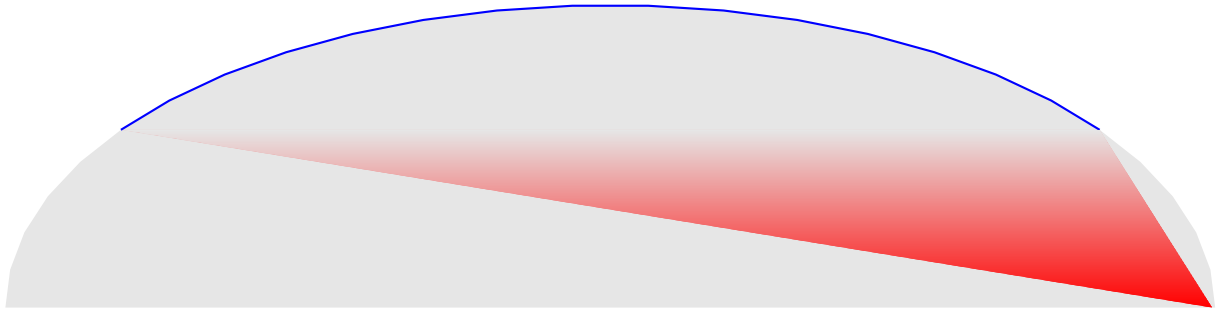
ideal case





elliptic

1-sided



focusing: ballistic ellipse vs. half device

early reflections suffer the most from coma aberration

⇒ multiple reflections

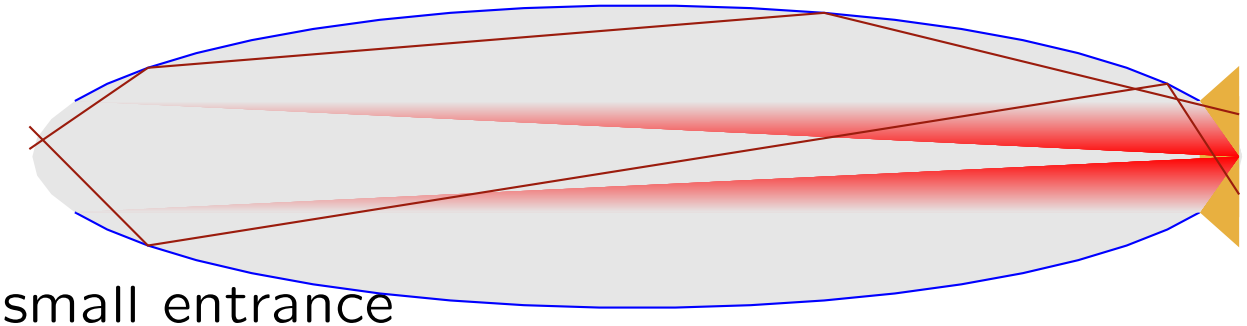
⇒ non-convergent beam behind guide exit

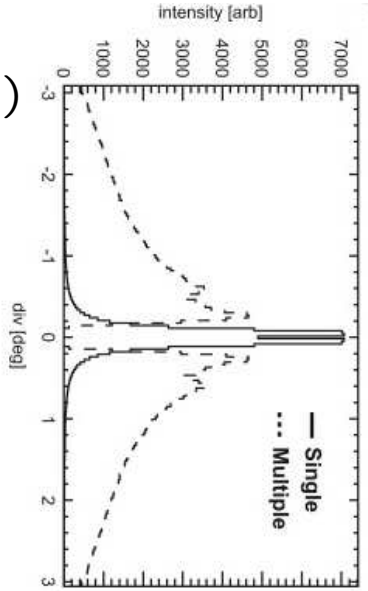
L. Cusssen *et al.*: NIM A **705**, 121 (2013)

elliptic

2-sided

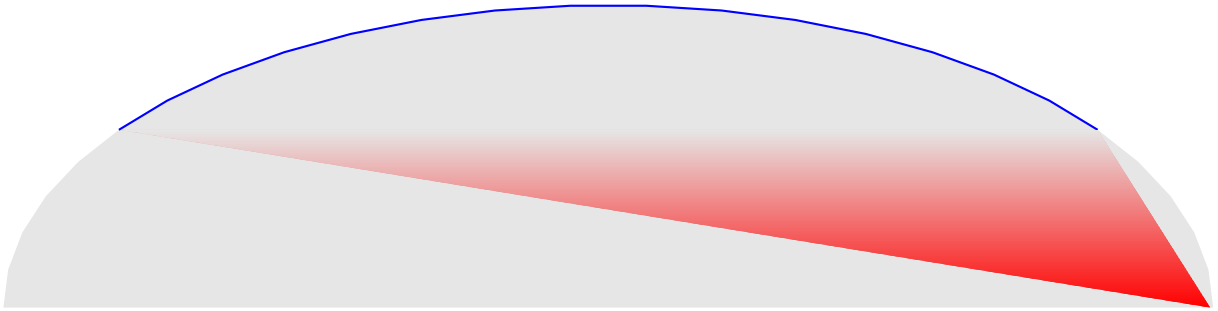
large source / small entrance



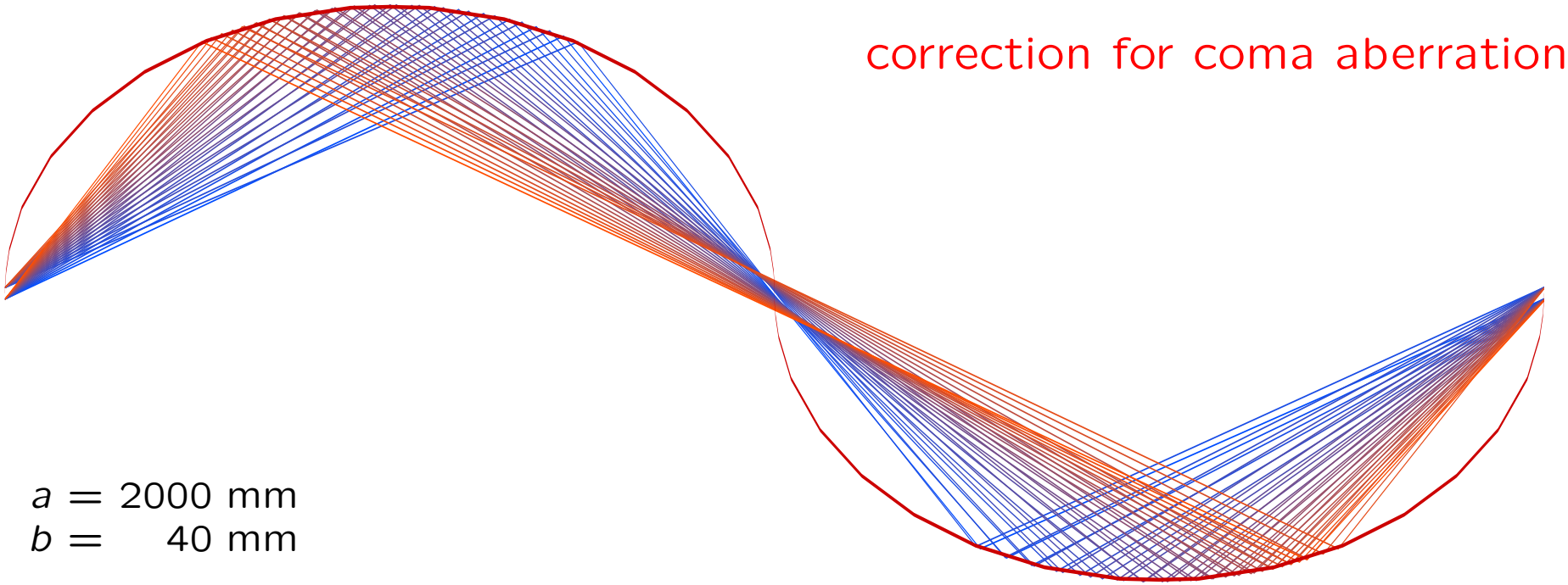


elliptic

1-sided

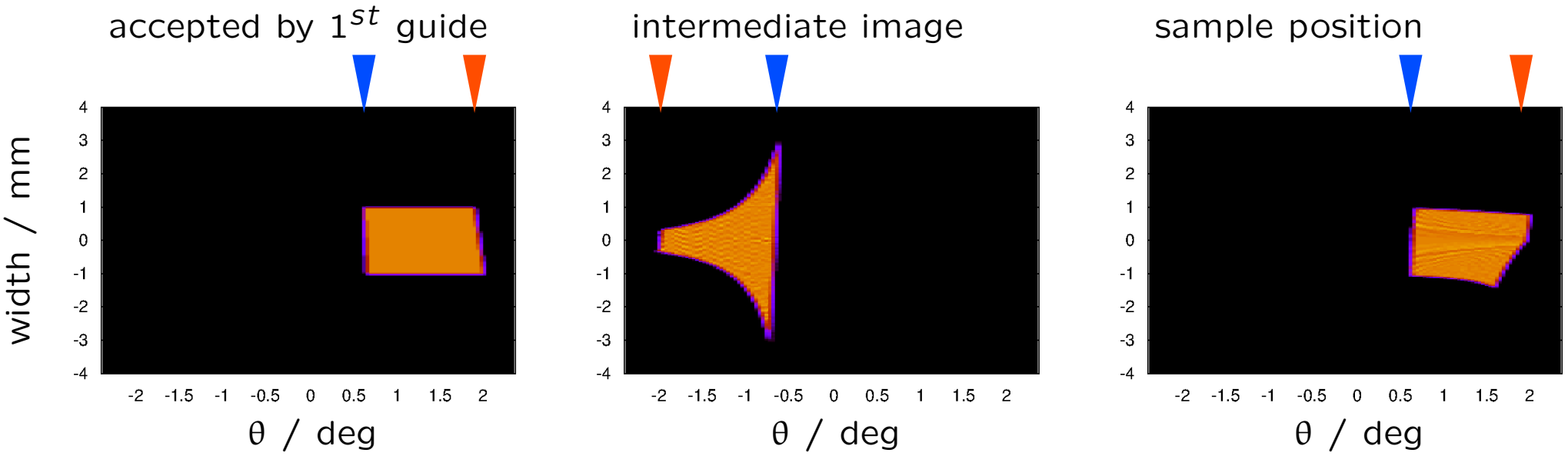


focusing: geometrical aberration



correction for coma aberration!

a = 2000 mm
b = 40 mm

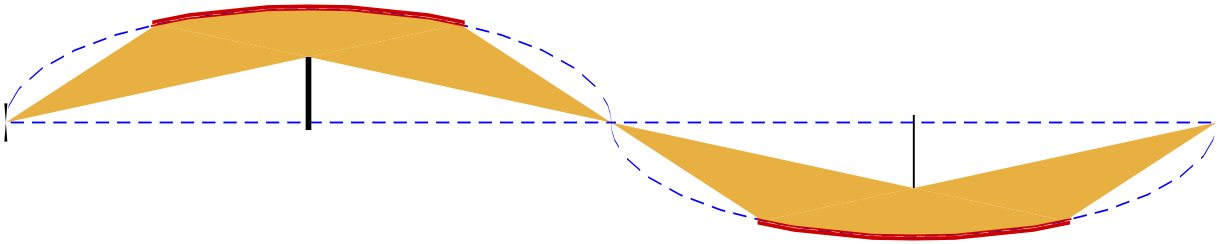


focusing: chromatic aberration

. . . due to gravity

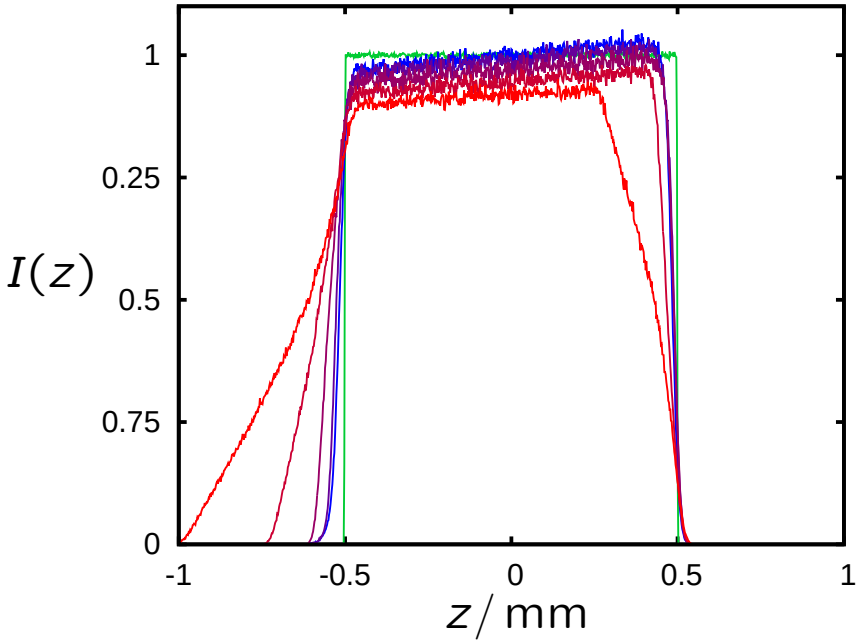
simulations (McStas) with (1 mm) tapered guides (40 m long, $b/a = 0.022$)

in agreement with analytic calculations



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

λ = 0 Å
3 Å
5 Å
7 Å
9 Å



focusing Selene guide

- focusing
  - focusing Selene guide
    - experiences
      - projects
        - ideas
          - discussion

focusing: Selene guide

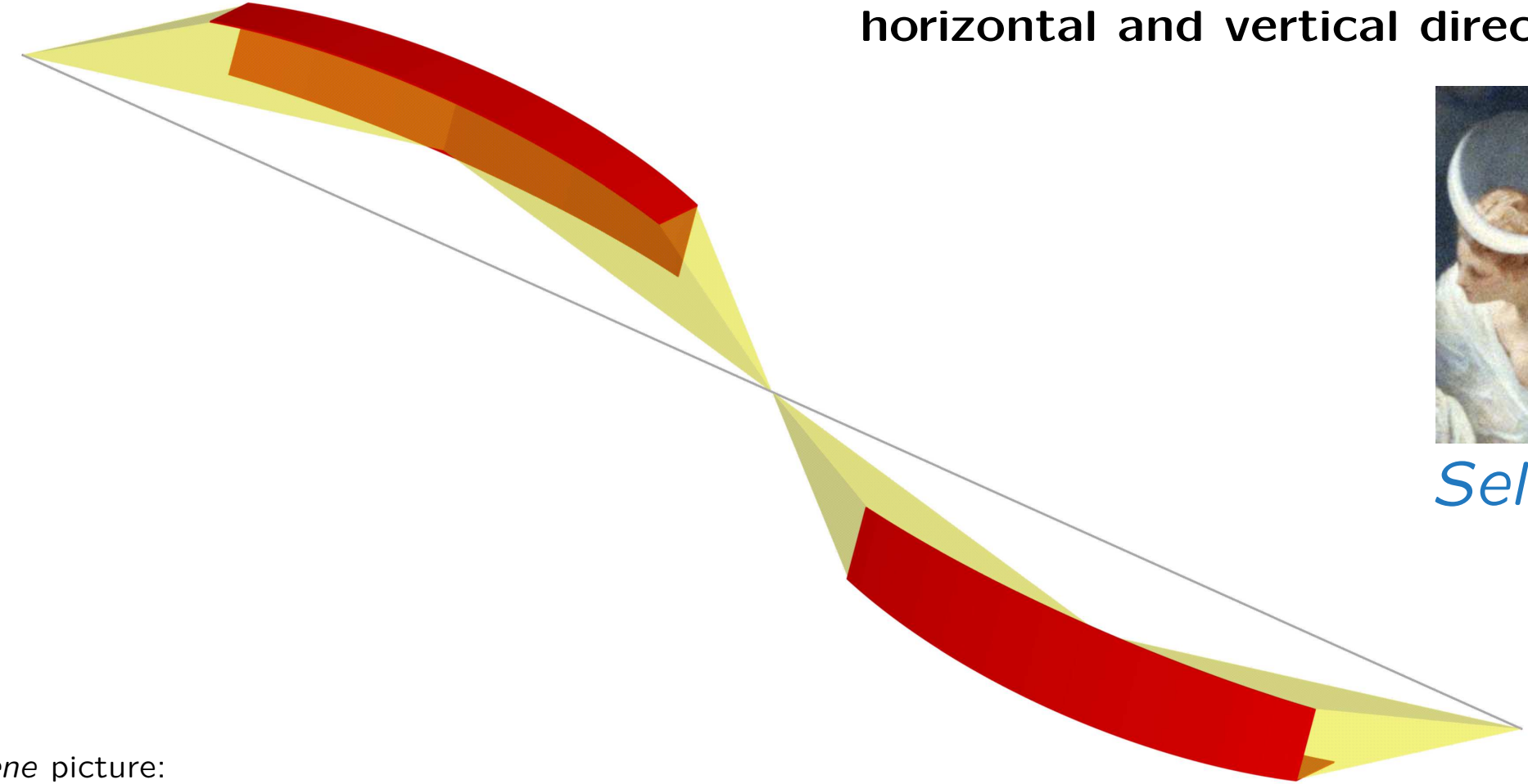
point-to-point focusing

with

2 subsequent elliptical reflectors

for

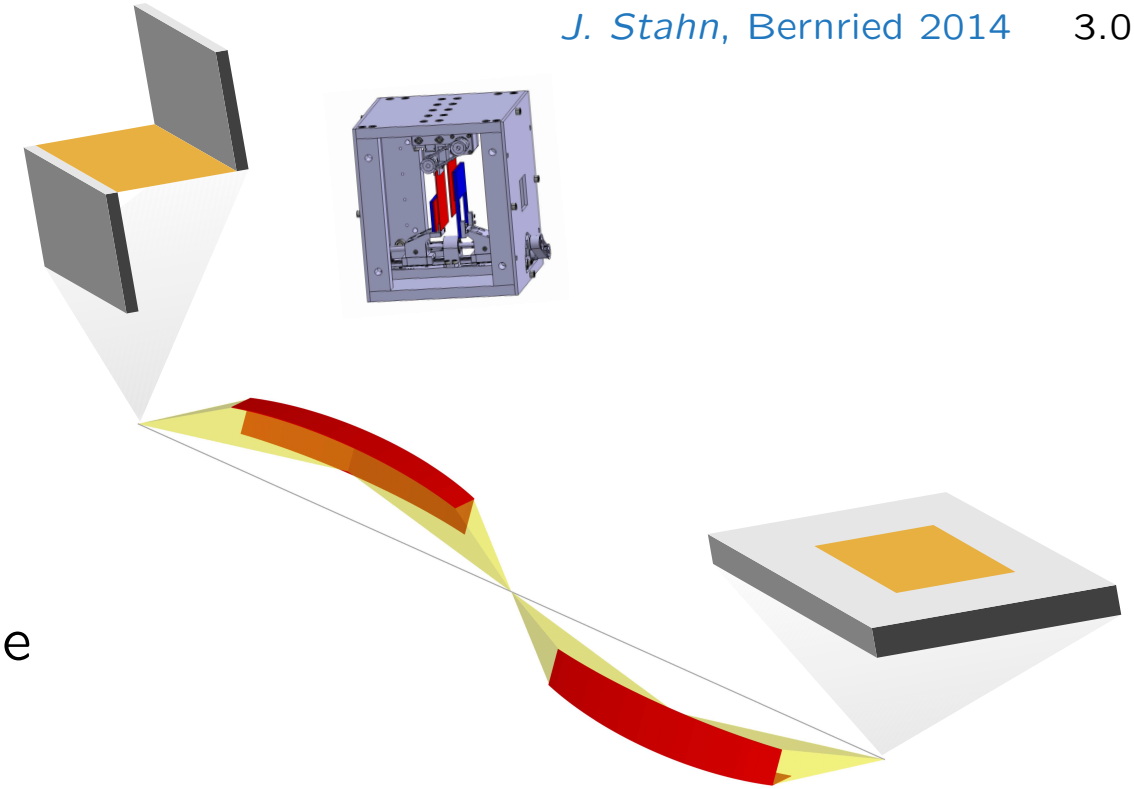
horizontal and vertical direction



Selene

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

focusing: Selene guide



footprint definition

a luminous field diaphragm

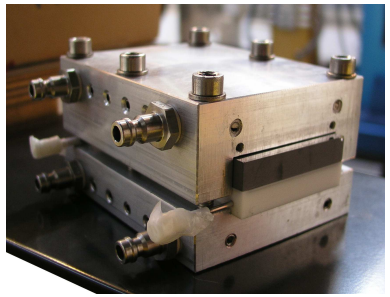
defines

- shape
- size
- orientation

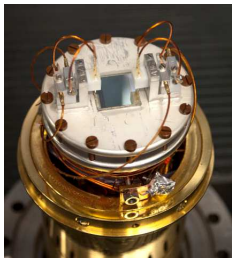
of the beam footprint on the sample

to

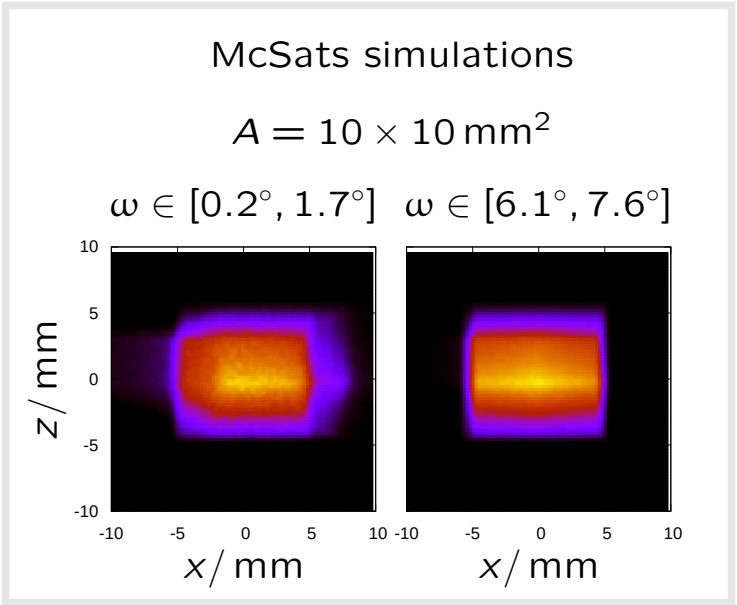
- avoid over-illumination



- avoid inhomogeneous field areas

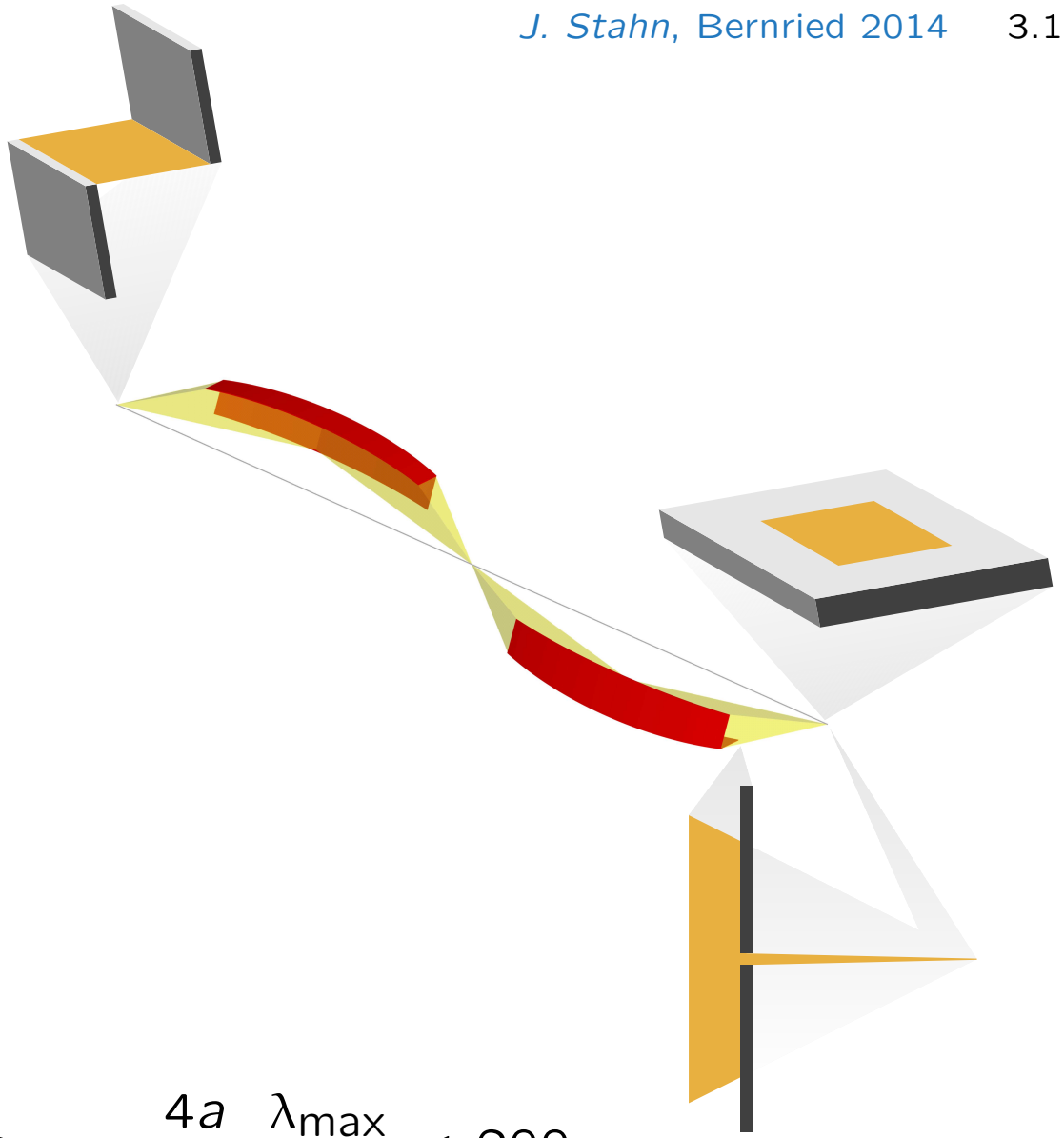


- raster the sample



focusing: Selene guide

decoupling of spot-size and divergence



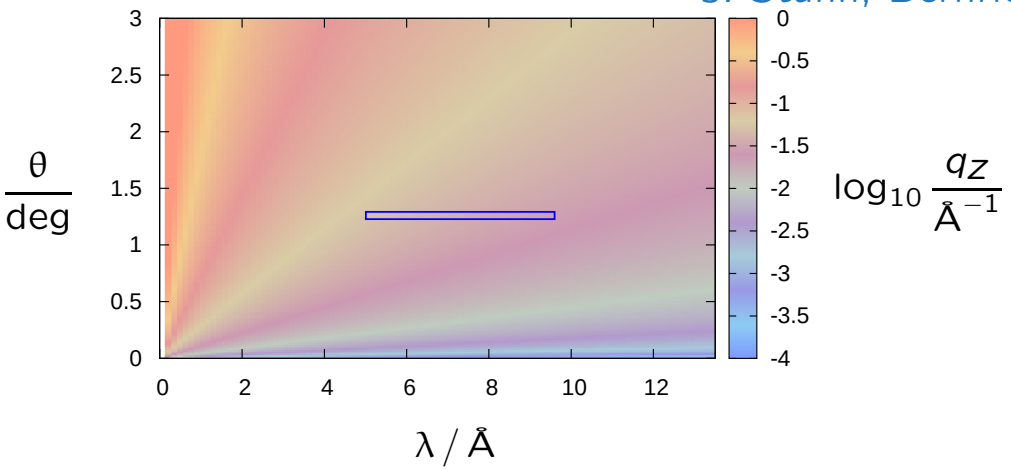
characteristic parameters

guide length vs. max. wavelength $\frac{4a}{\mathrm{m}} \cdot \frac{\lambda_{\mathrm{max}}}{\text{Å}} < 200$

divergence vs. min. wavelength $\frac{\Delta\theta}{\mathrm{deg}} \Big/ \frac{\lambda_{\mathrm{min}}}{\text{Å}} < 0.4$

focusing: Selene guide

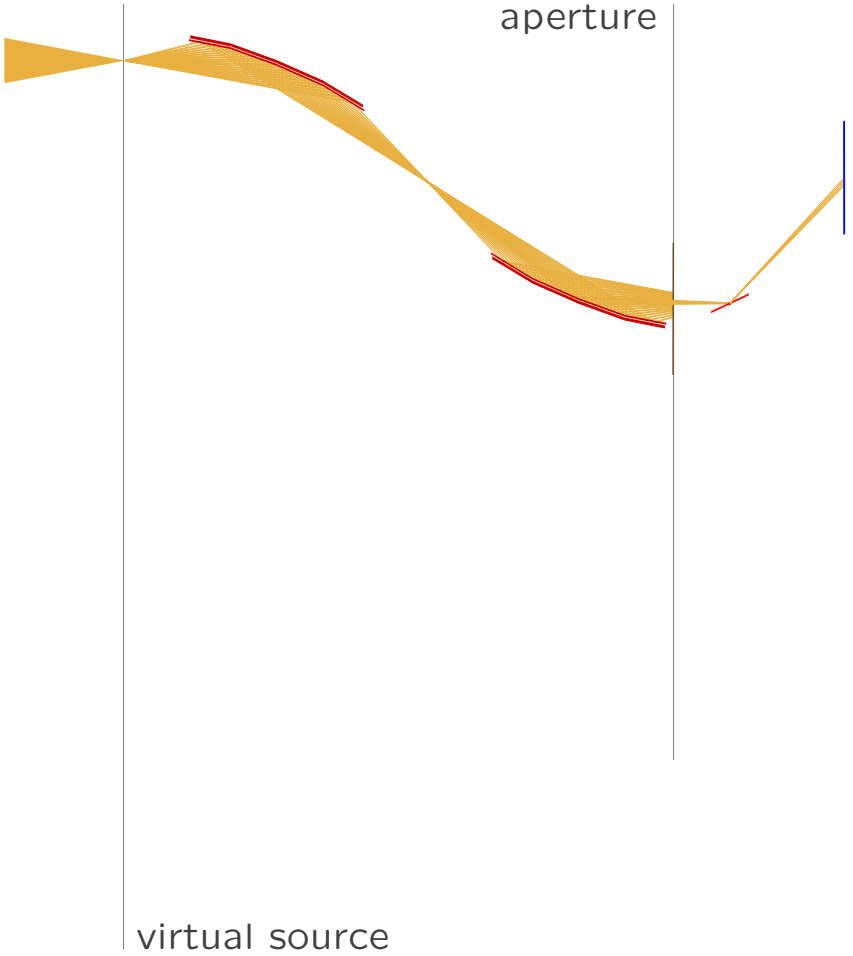
operation modes



almost conventional reflectivity

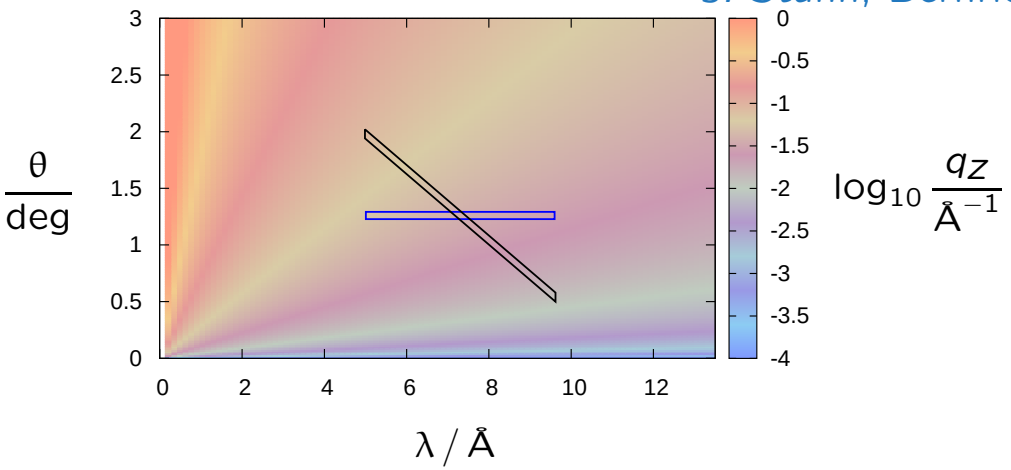
= TOF

- defined foot-print
- off-specular reflectivity



focusing: Selene guide

operation modes



almost conventional reflectivity

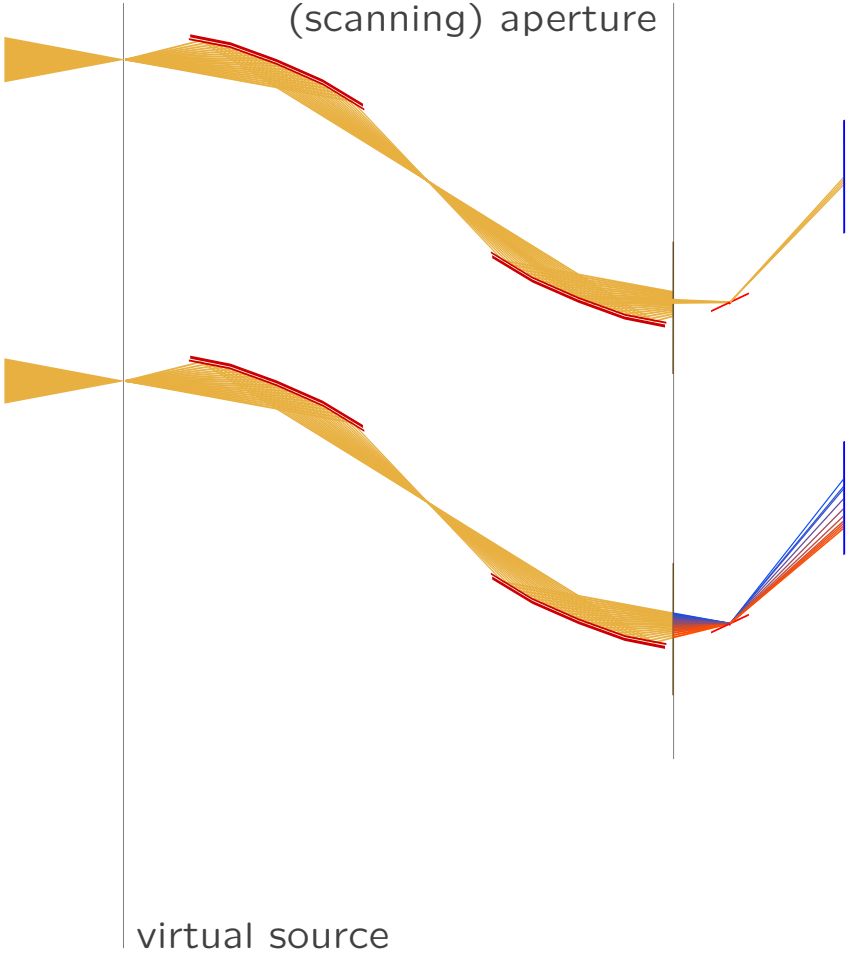
= TOF

- defined foot-print
- off-specular reflectivity

λ-θ-encoding

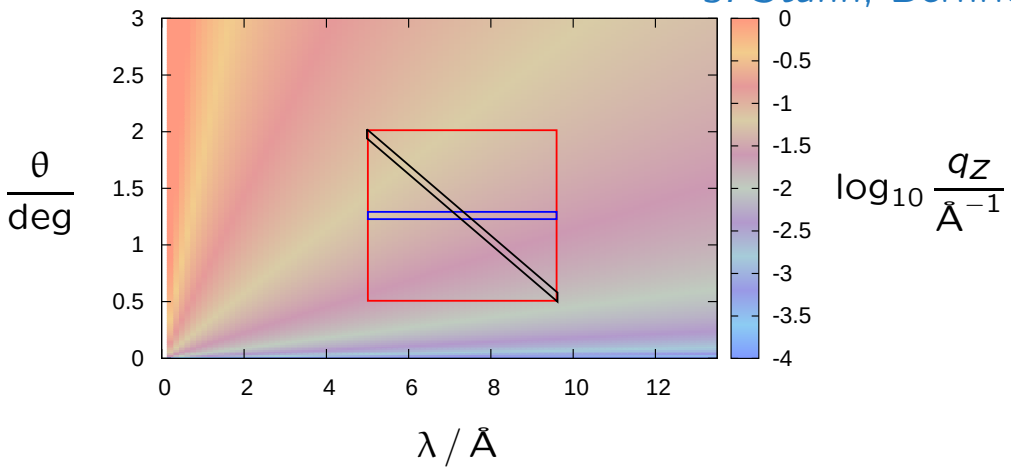
= TOF(θ)

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



focusing: Selene guide

operation modes



almost conventional reflectivity

= TOF

- defined foot-print
- off-specular reflectivity

λ-θ-encoding

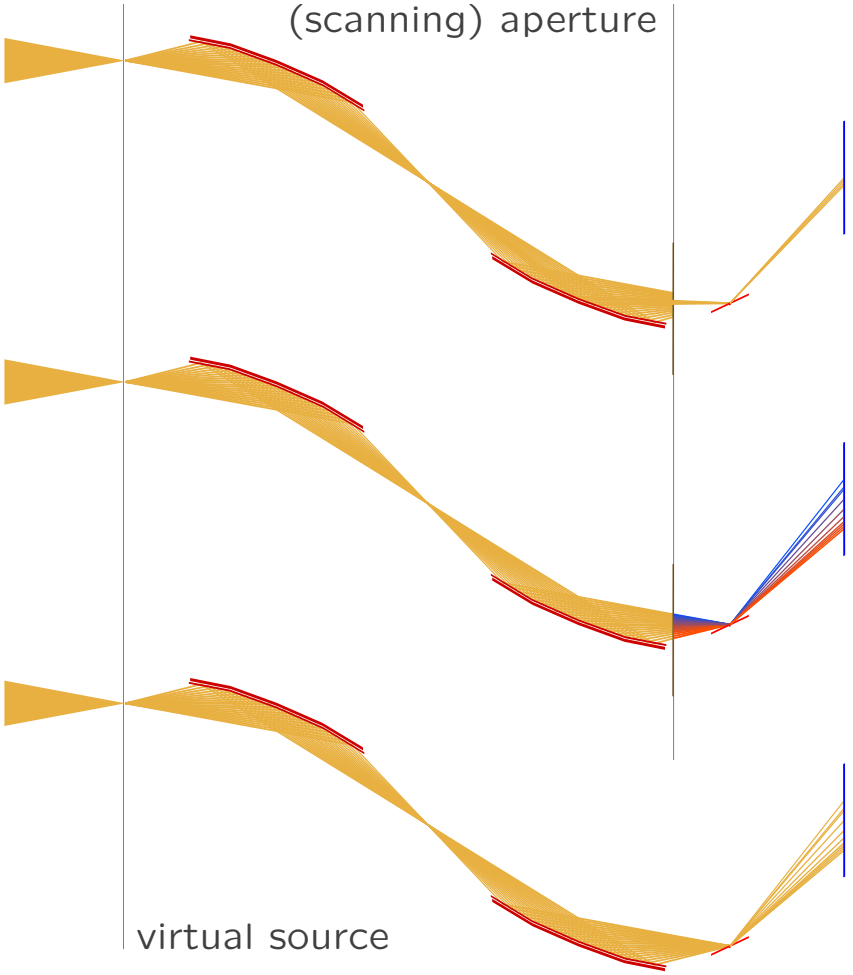
= TOF(θ)

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

high-intensity specular reflectivity

= TOF × θ-dispersive

- split-second t-resolution
- screening of parameter space

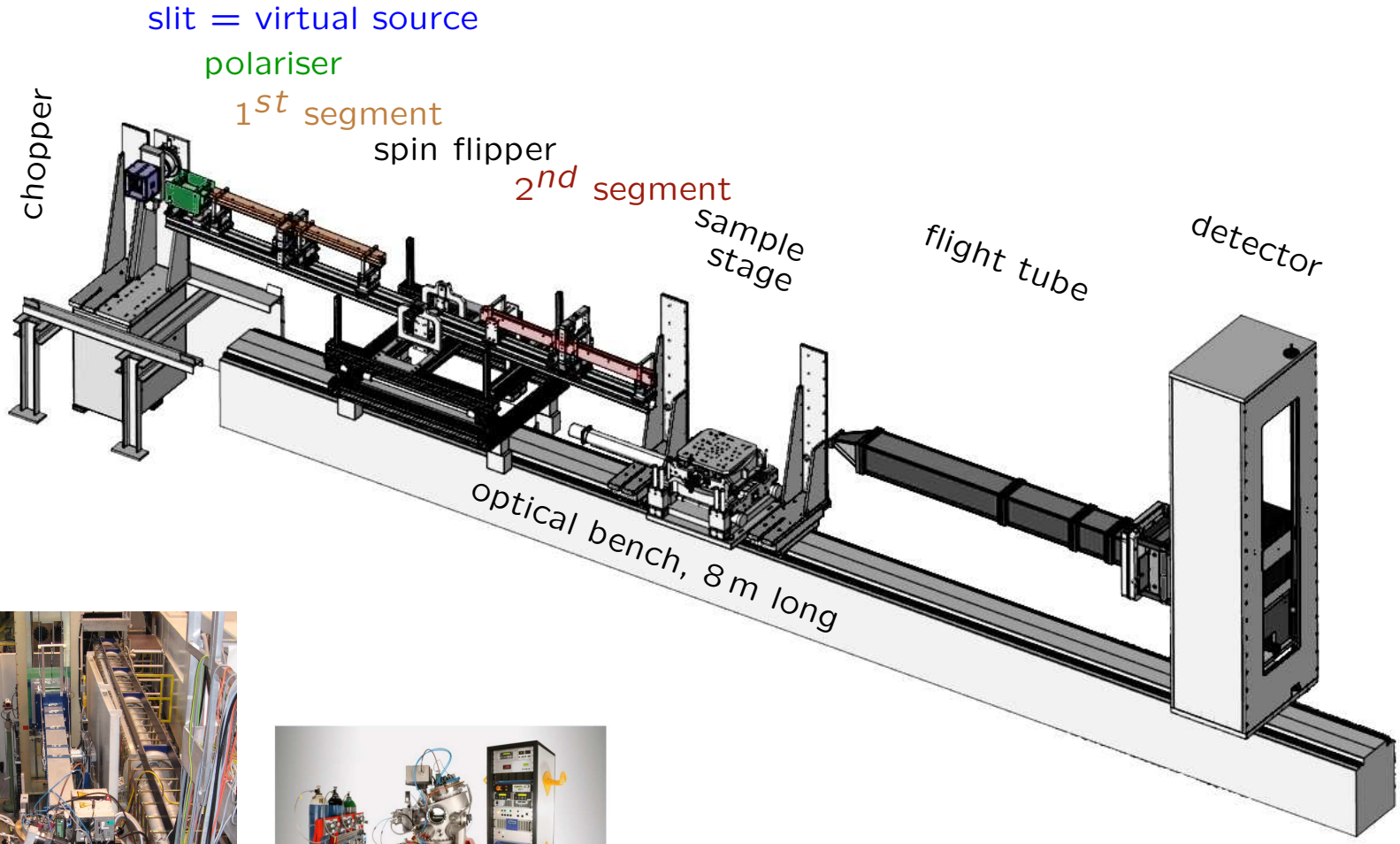


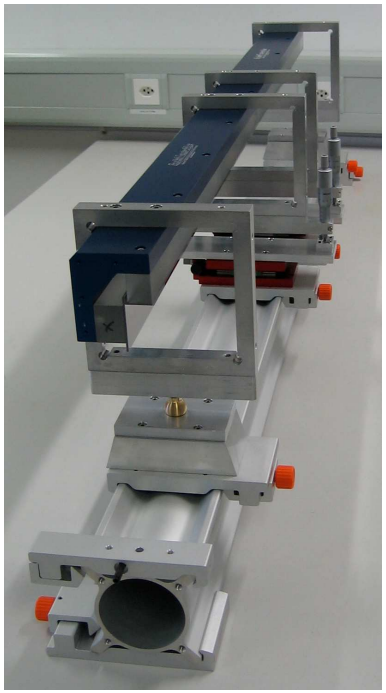
experiences

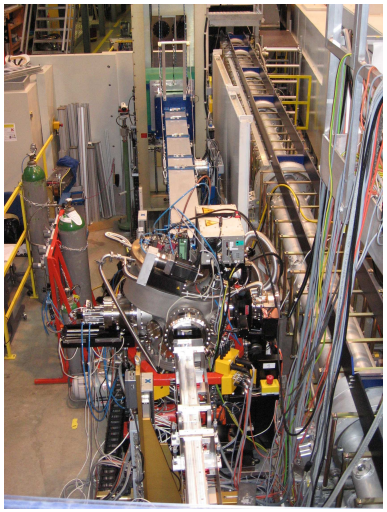
- focusing
  - focusing Selene guide
    - experiences
      - projects
        - ideas
          - discussion

experiences: Selene guide

prototype guide on Amor@PSI







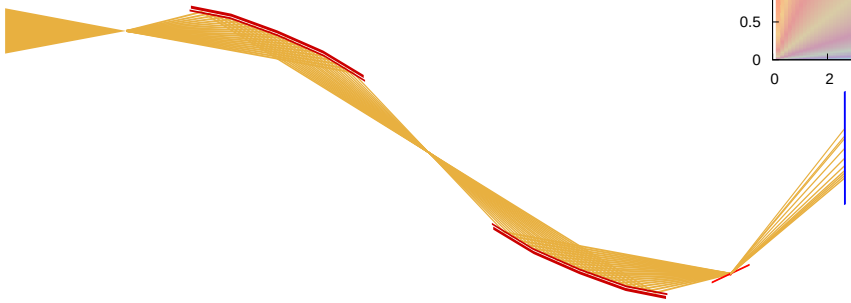
in-situ sputtering & n-reflectometry

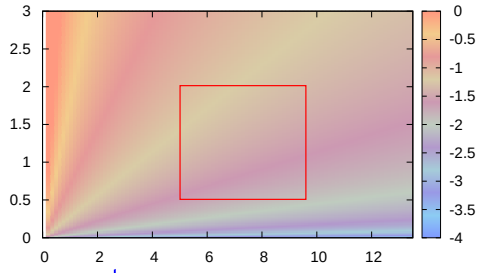
B. Wiedemann, TU Munich

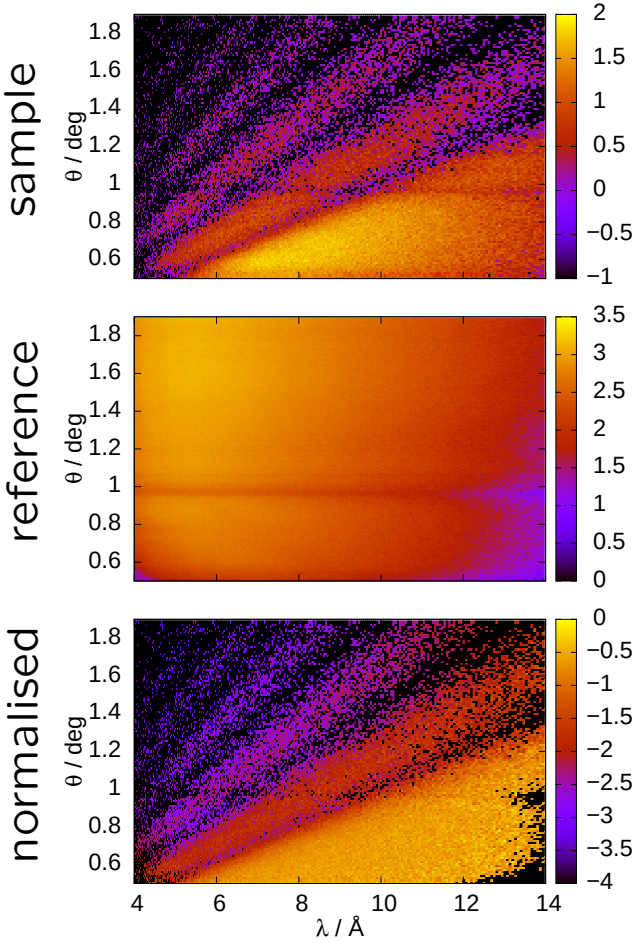
experiences: Selene guide

prototype guide on Amor@PSI

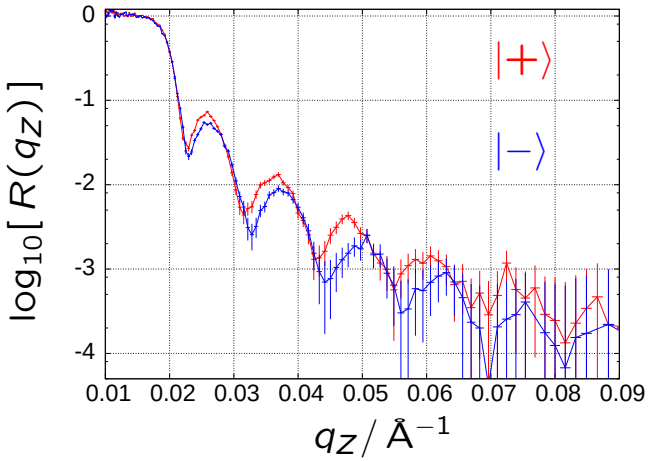
high-intensity specular reflectometry







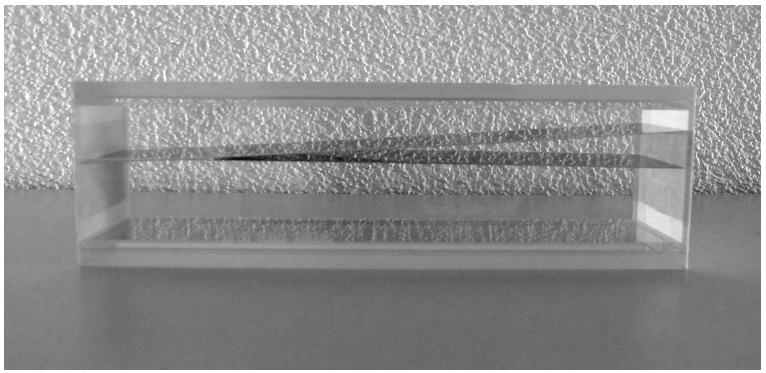
sample	Si /Cu /Fe (6 monolayers)
instrument	Amor
size	2×20 mm^2
time / spin	10 min

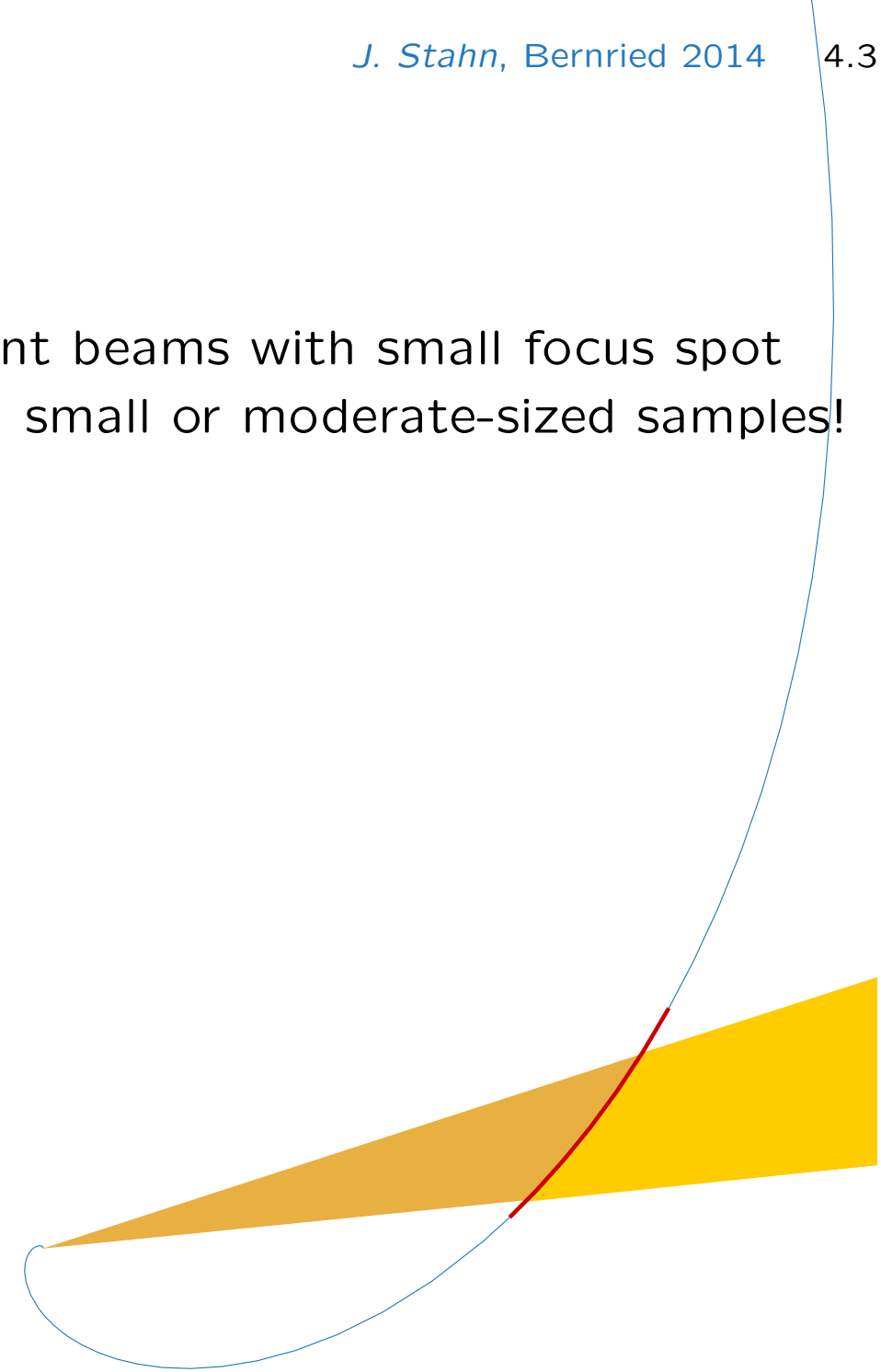


experiences: logarithmic spiral

polariser, frame-overlap mirror

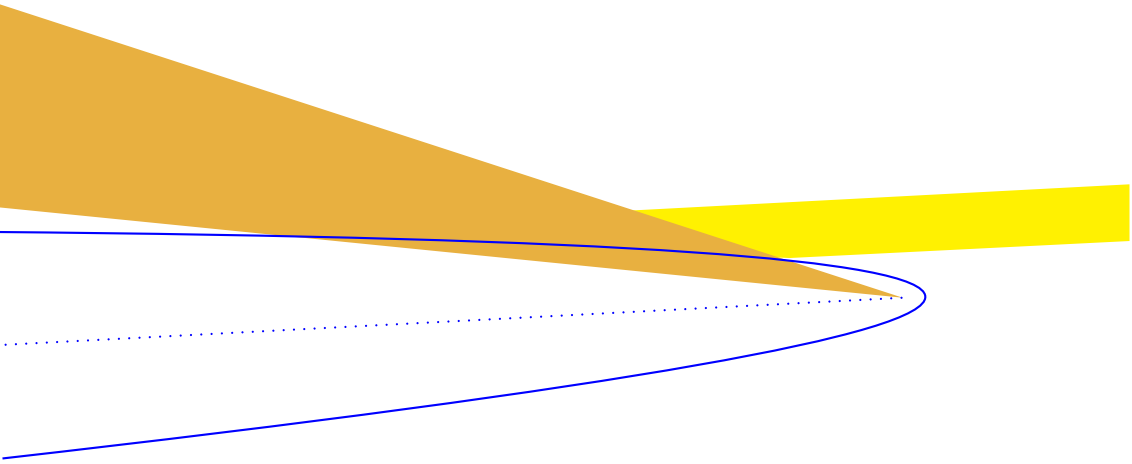
can be applied to all convergent / divergent beams with small focus spot
e.g. as analyser for any beam reflected on small or moderate-sized samples!





experiences: adaptive optics

condenser: parabolic deflector to generate a parallel beam



parabola axis ⇒ beam direction

focal length ⇒ beam width

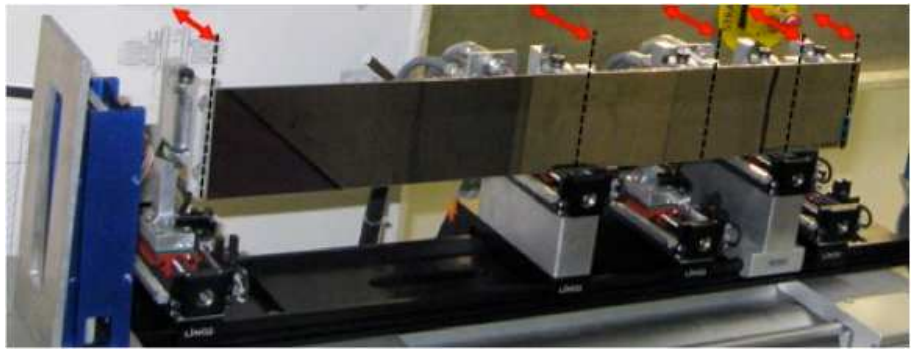
beam width & spot size ⇒ divergence

no collimator needed

tunable

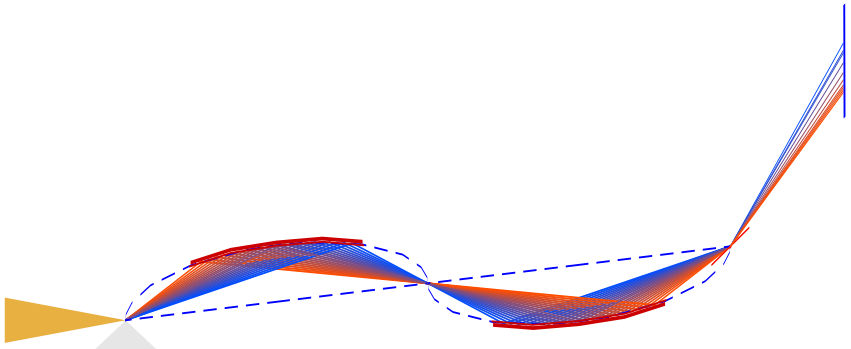
adaptive parabola (convex)
focal spot with 170 µm reached

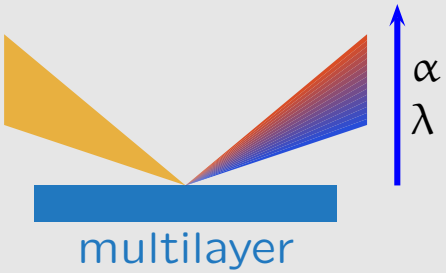
(PSI, early version)

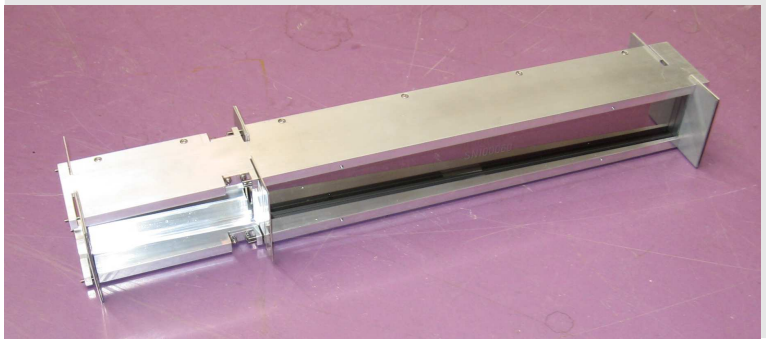


experiences: spectral analysis

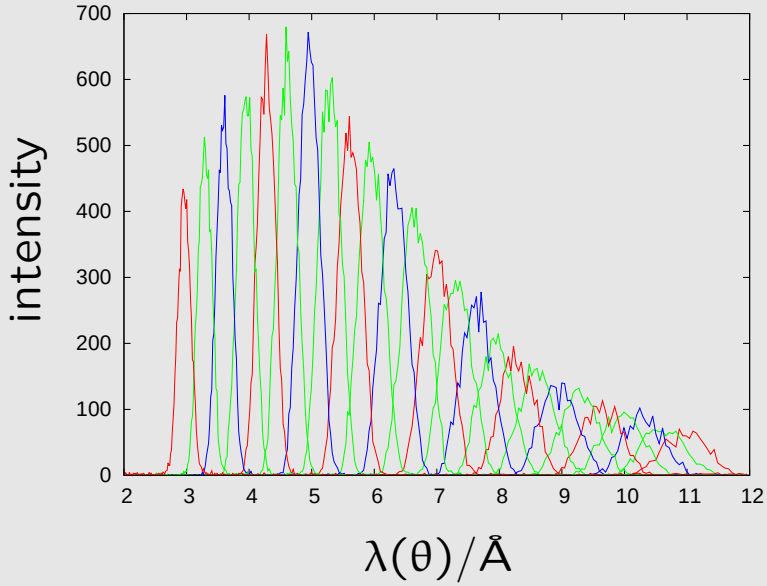
using a multilayer monochromator



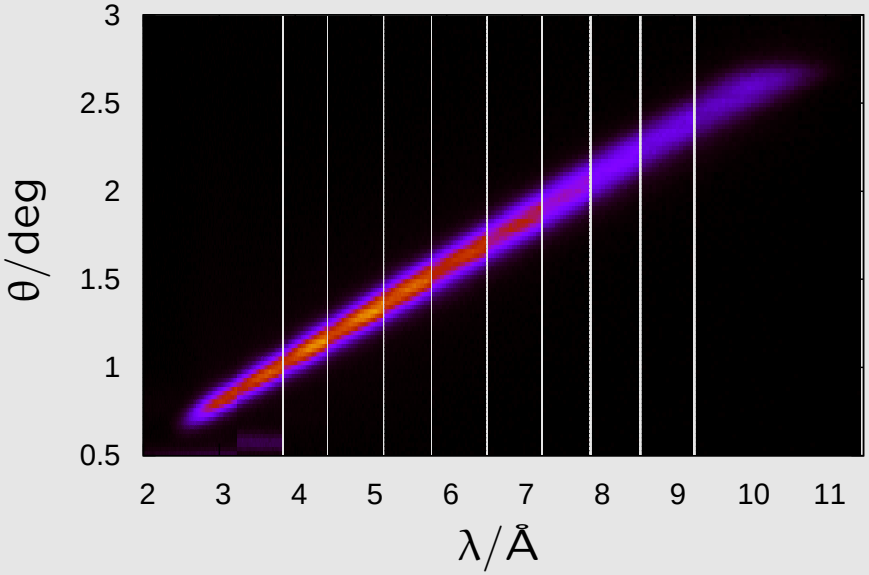




double ML monochromator



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



projects

- focusing
  - focusing Selene guide
    - experiences
      - projects
        - ideas
          - discussion

projects: Estia

- ESS
  - long pulse ($\approx 30\,\mathrm{ms}$)
  - high brilliance
  - small moderator ($30 \times 120\,\mathrm{mm}^2$)
  - operational in 2020
- reflectometers
  - Freia
    - liquid surfaces
    - wide simultaneous q_z-range
  - *Estia*
    - vertical scattering plane
    - small (magnetic) samples
  - ???
    - GISANS

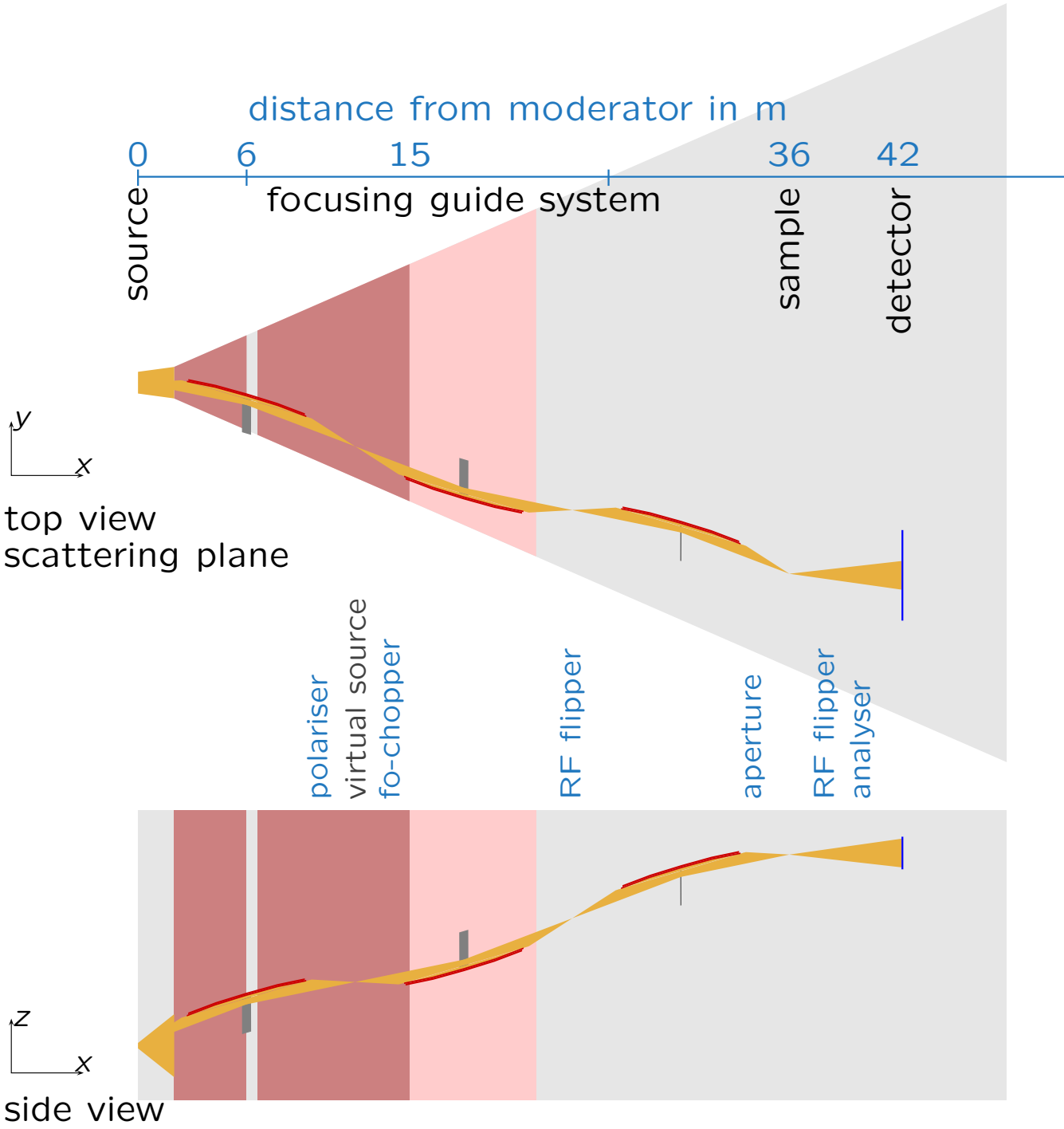
projects: Estia

TOF reflectometer
for the ESS

horizontal scattering plane

sample size $< 10 \times 50\,\mathrm{mm}^2$

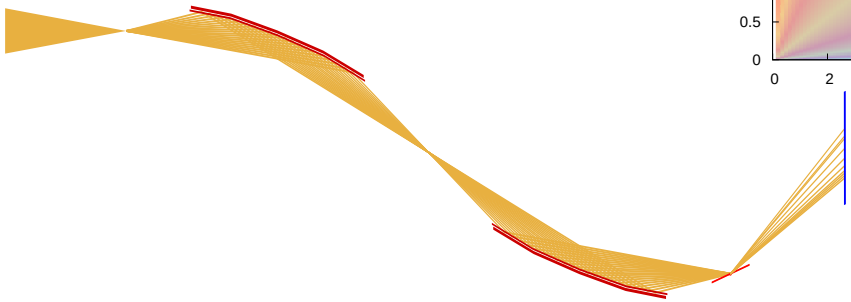
feeder + *Selene* guide

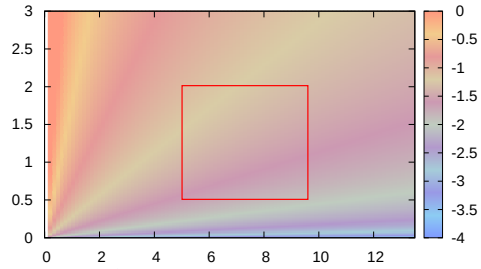


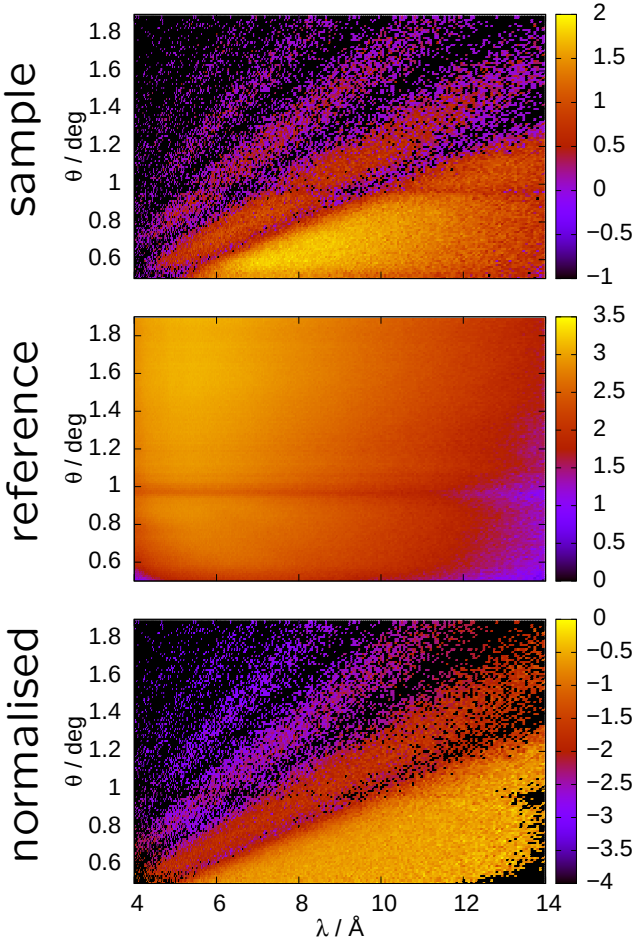
projects: Estia

comparison to prototype

high-intensity specular reflectometry

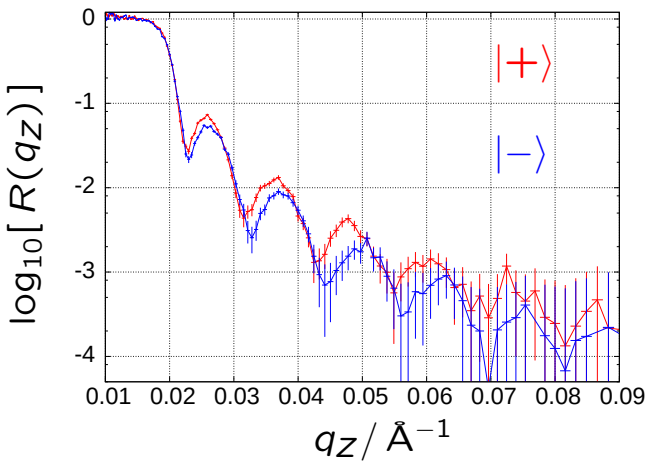






sample	Si /Cu /Fe (6 monolayers)	
instrument	Amor	Estia
size	2×20 mm^2	10×20 mm^2
time / spin	10 min	0.2 s

gain-factor: 3000



reasons:

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

projects: SINQ upgrade

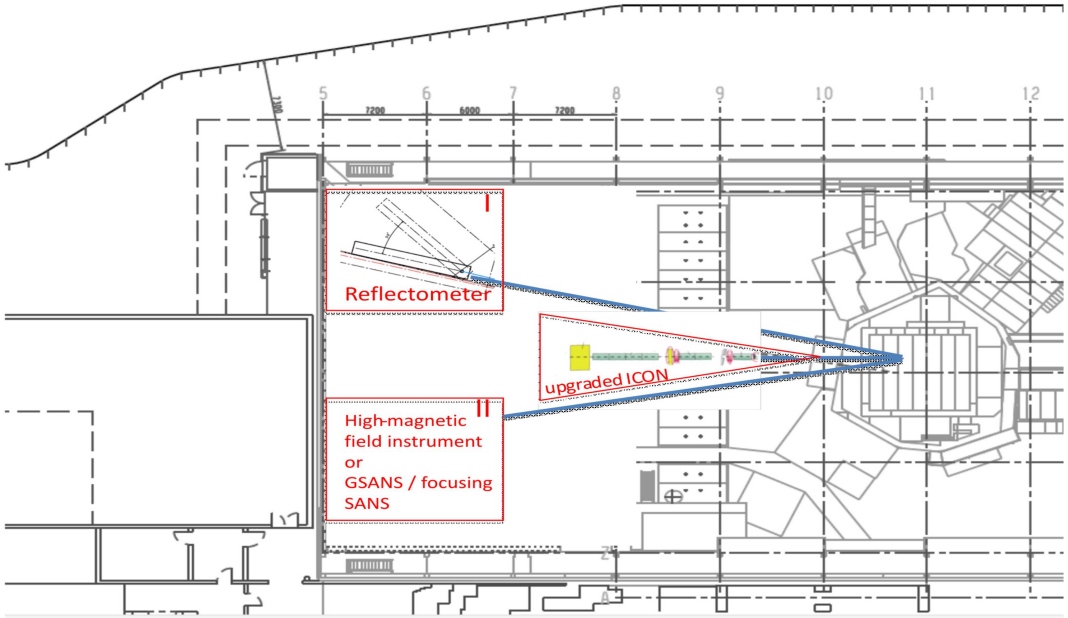
Selene guide for Amor

eventually at an other beam port

⇒ horizontal and vertical scattering plane possible

⇒ TOF and monochromatic mode

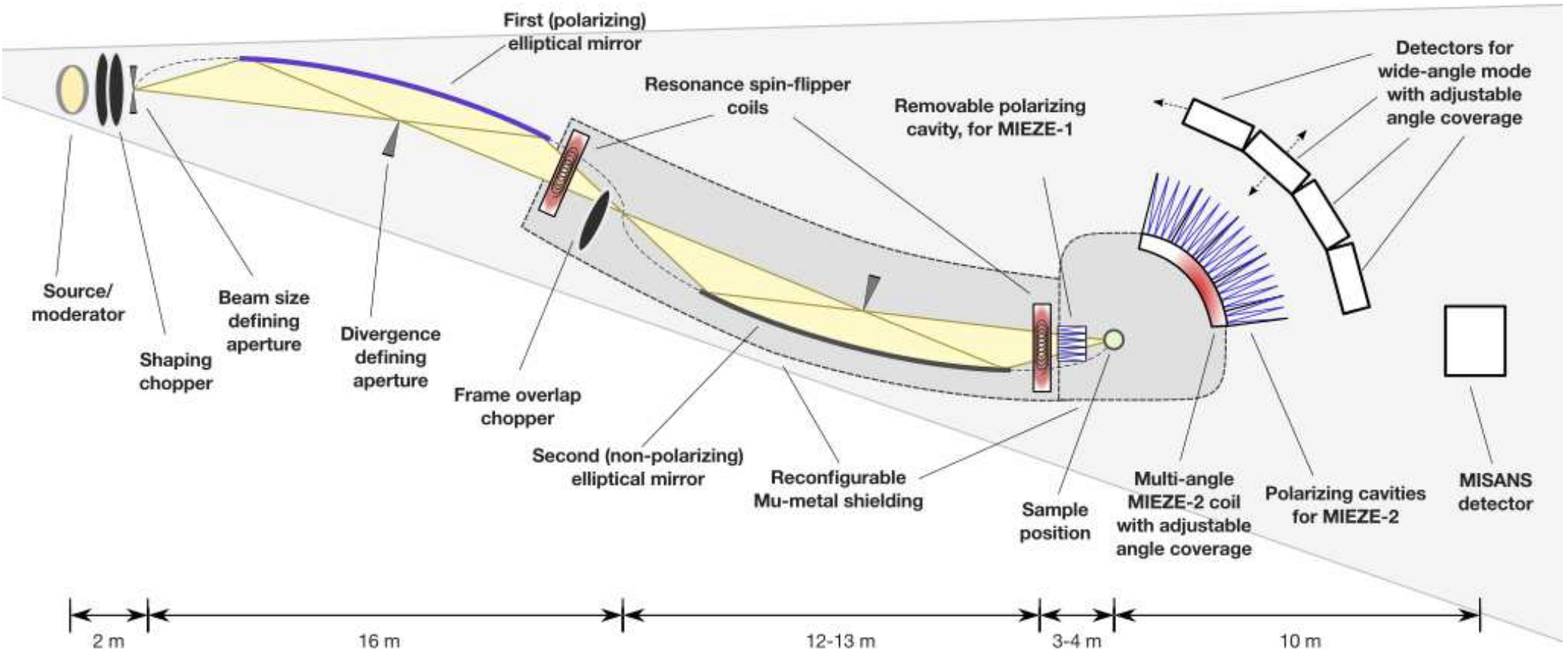
(the project is in an early stage)



projects: Selene guide for spin-echo

MIEZE (NRSE) compatibility with *Selene* guide under investigation

all trajectories have the same length



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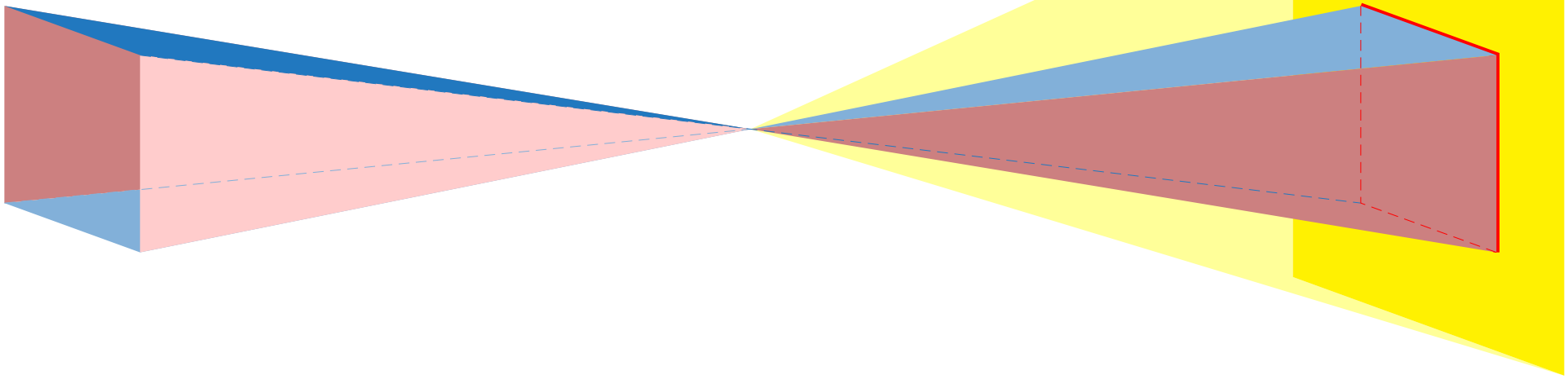
ideas

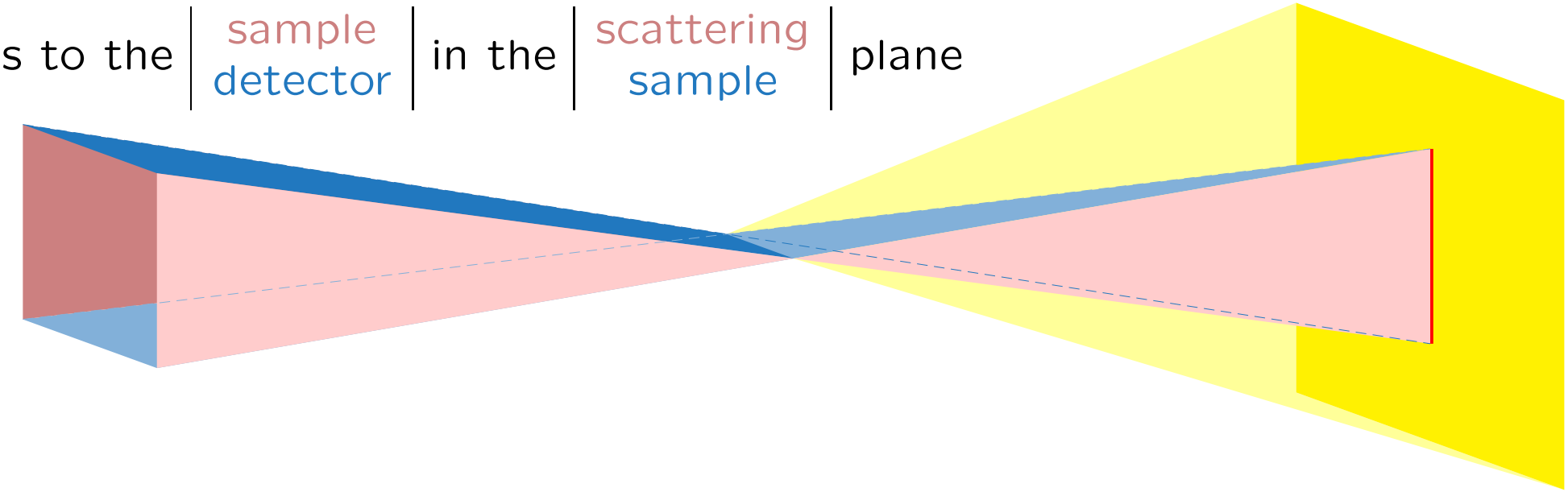
- focusing
  - focusing Selene guide
    - experiences
      - projects
        - **ideas**
          - **discussion**

ideas: astigmatic focusing

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



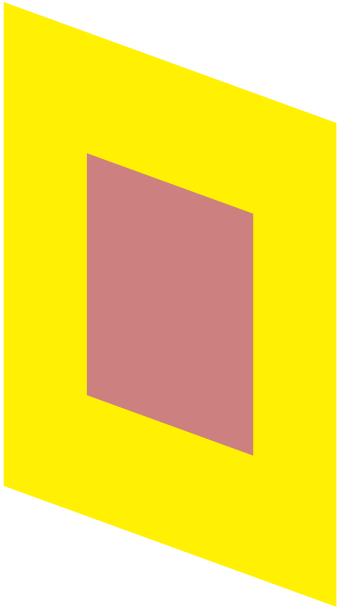
focus to the | sample detector | in the | scattering sample | plane



ideas: 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

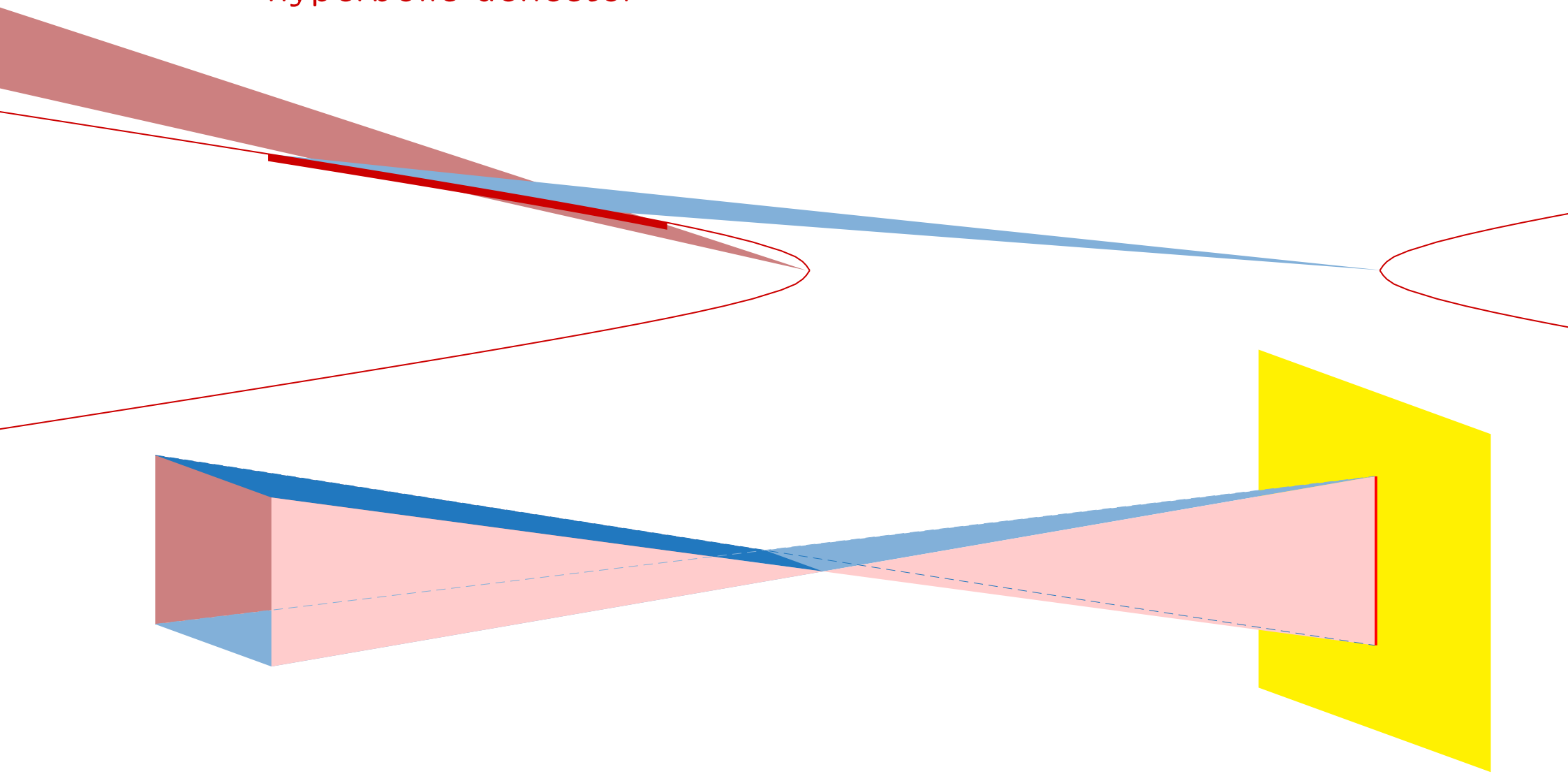
| specular / off-specular | intensity | concentrated along a line / distributed over the detector |

$\Rightarrow$ strongly reduced background under specular signal

ideas: astigmatic focusing

focusing to the detector by shifting the focal point:

hyperbolic deflector

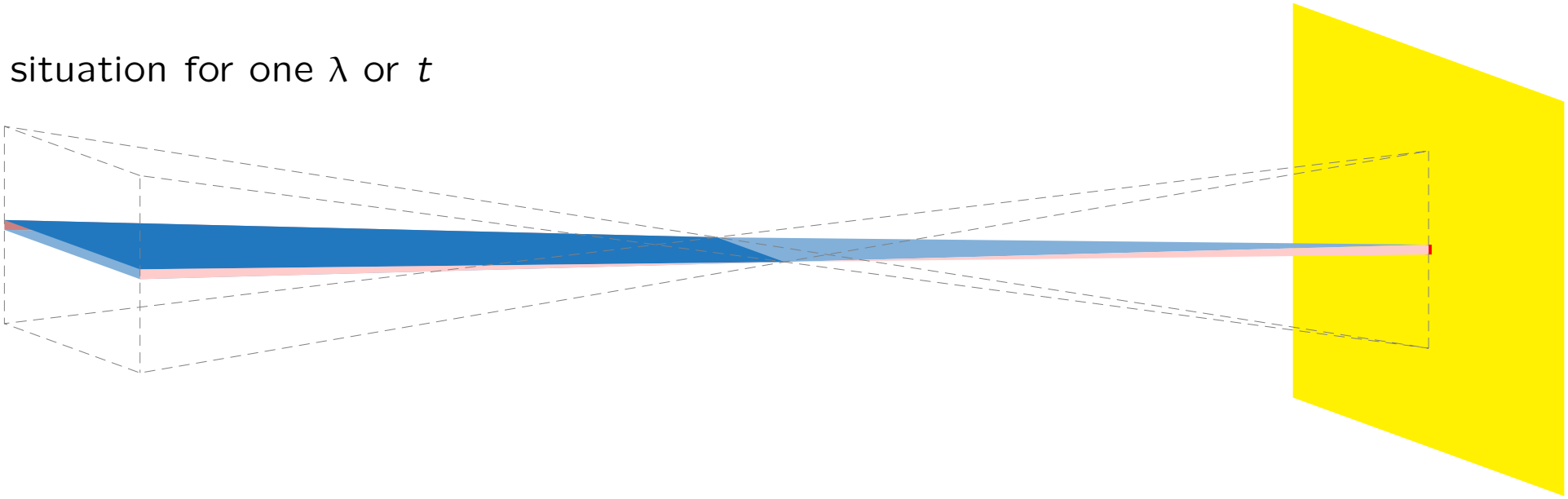


ideas: astigmatic focusing

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

discussion

- focusing
  - focusing Selene guide
    - experiences
      - projects
        - ideas
          - **discussion**

discussion

focusing results in . . .

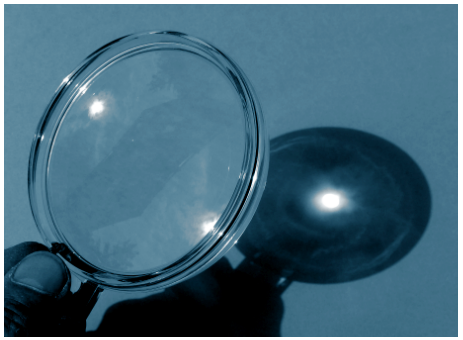
. . . no gain in brilliance

. . . 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