JRA NEUTRON OPTICS

New spectrometer designs implementing advanced optical components

JRA presentation

General Assembly

Münich 2012

PARTICIPANTS

BNC	Budapest Neutron Center
DTU	Danmarks Tekniske Universitet
EPFL	Ecole Polytechnique Fédérale de Lausanne
HZB	Helmholtz Zentrum Berlin
ILL	Institut Laue Langevin
INFM	Istituto Nazionale per la Fisica della Materia
JCNS	Jülich Center for Neutron Scattering
LLB	Laboratoire Léon Brillouin
NPI	Nuclear Physics Institute
PSI	Paul Scherrer Institute
TUM	Technischen Universität München
UCPH	University Copenhagen - DTU

Hired people

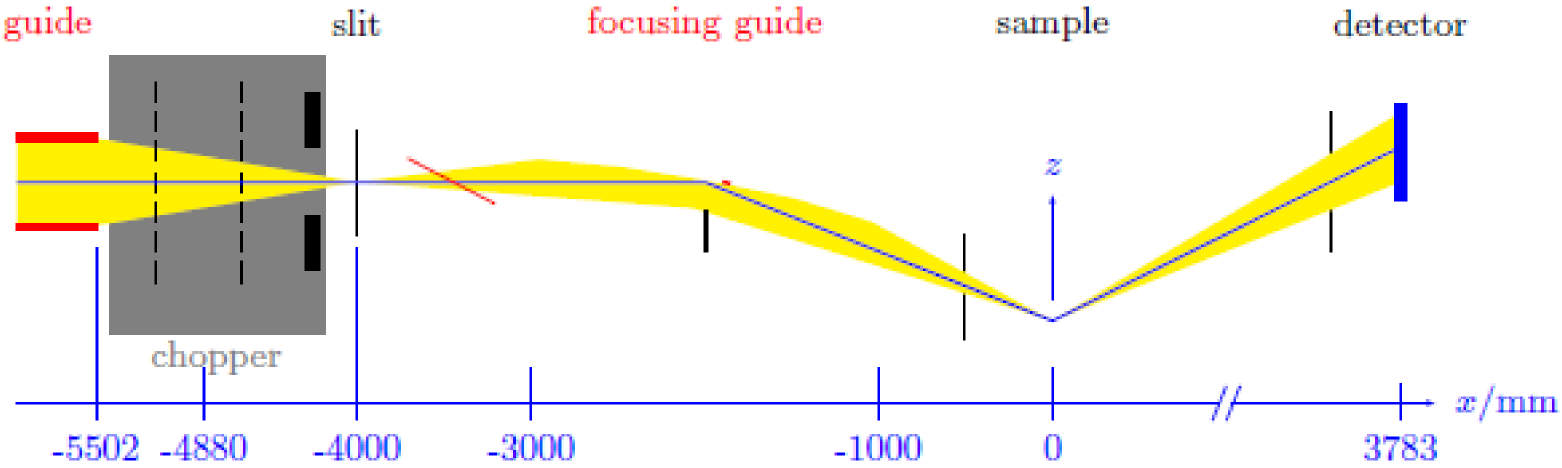
- PSI: J. Stahn
  - **Tobias Panzner**: Monte-Carlo simulations McSTAS
  - New component for elliptical and parabolic guides (tested)
  - Modeling of a modified REFOCUS concept: SELENE
- TUM: P. Böni
  - **Roxana Valicu**
    Work on adaptive optics
- HZB: T. Krist
  - **Jennifer Schultz**, PhD student
    Refraction by prisms
- INFM: F. Sacchetti
  - **Lorenzio Sani**
    Work on Fresnel Zone plates
- University Copenhagen: K. Lefman
  - **Jonas Okkels Birk**
    CAMEA project

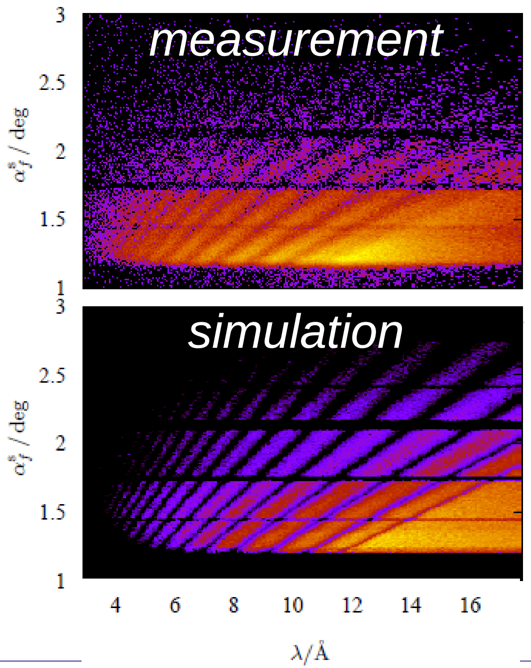
Working plan

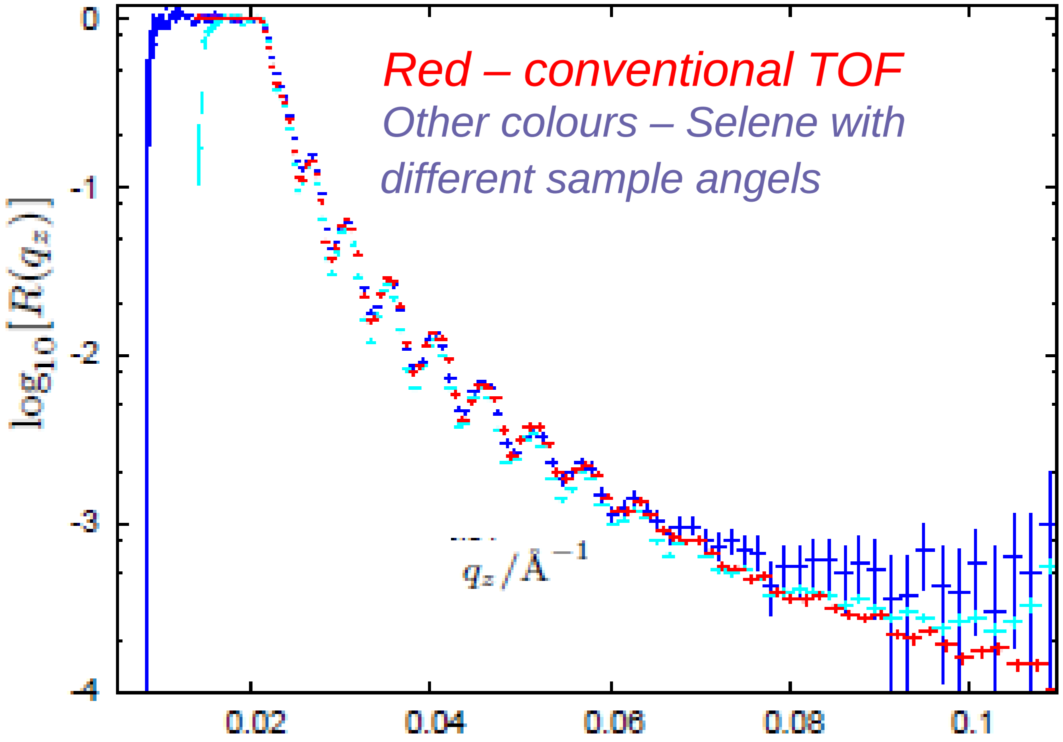
- Task 2: High flux reflectometry and energy analysis
- Task 3: Advanced Focusing Techniques
- Task 4: Monte-Carlo simulations of complex optics

Task 2: High flux reflectometry and energy analysis

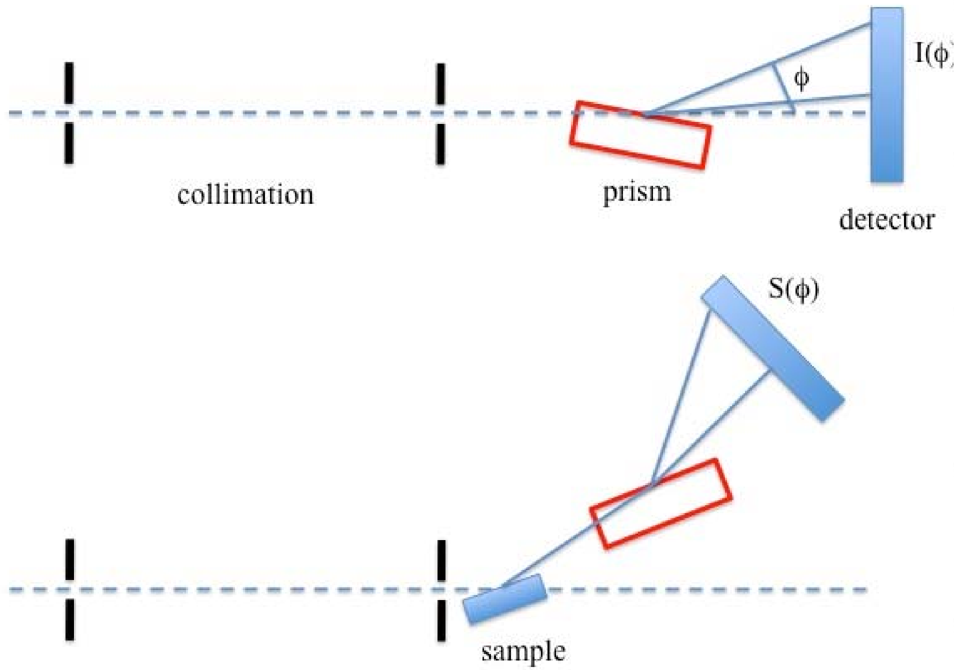
SELENE (J. Stahn, T. Panzner, PSI)

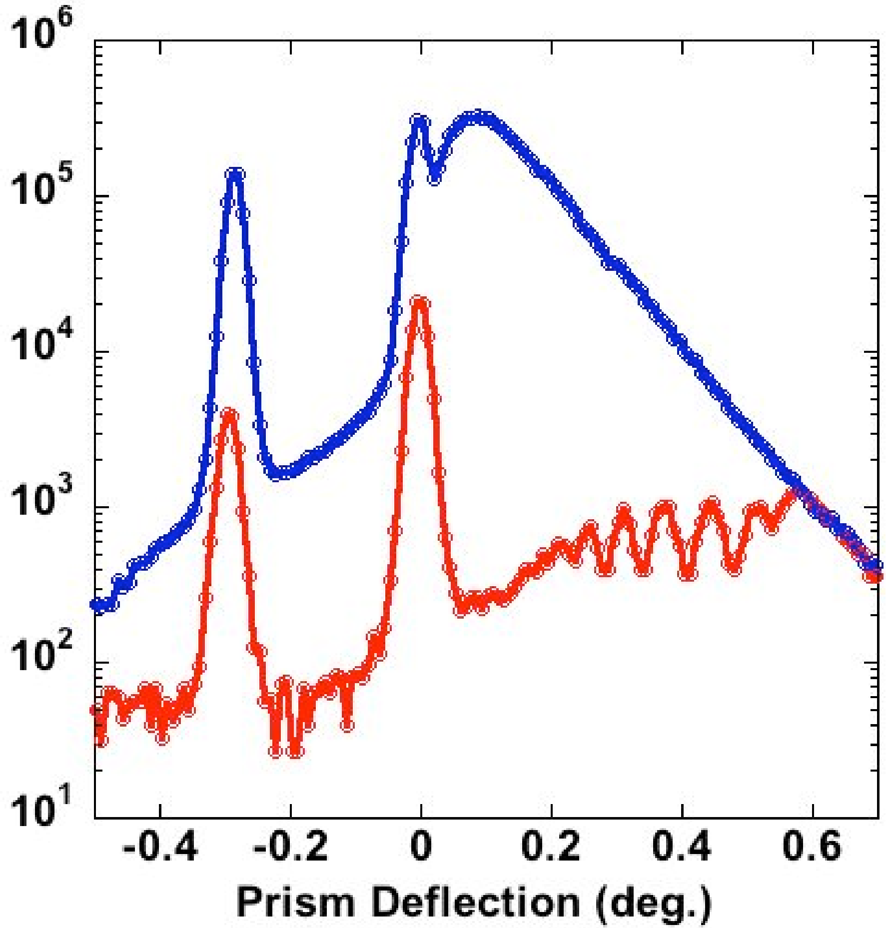






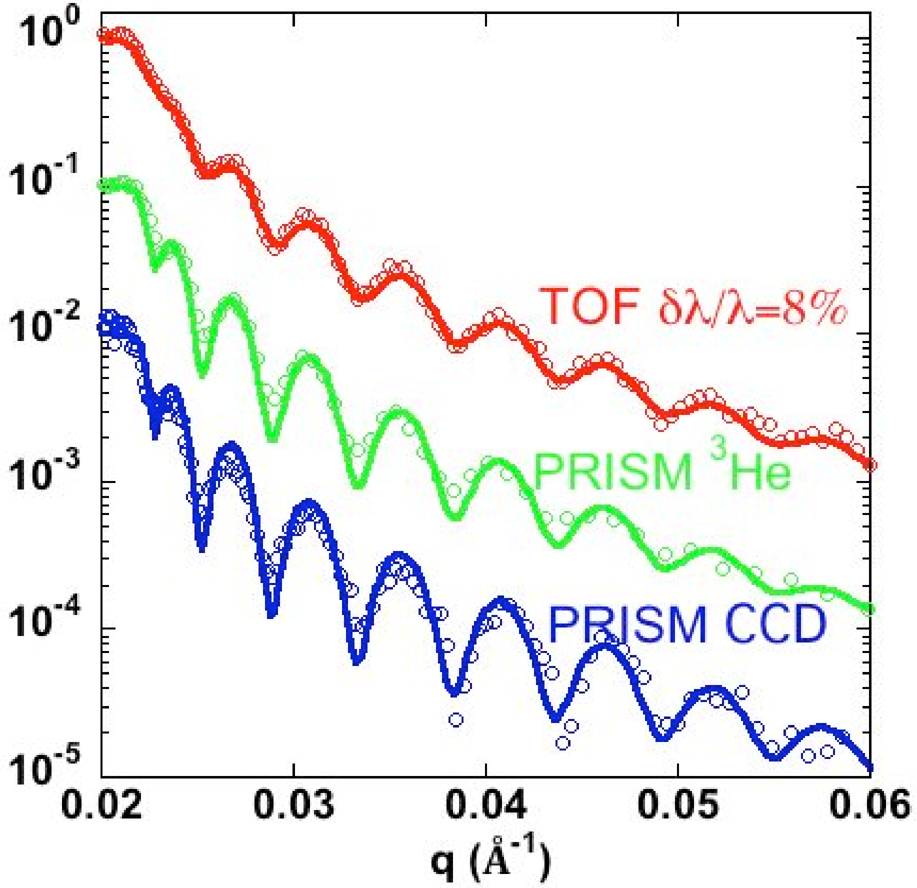
SYSTEM USING A SINGLE PRISM (R. Cubitt, ILL)





Collimations 0.5mm / 1.6m apart
PRISM set 0.742m after the sample
^{3}He detector (6m from the sample) / resolution 2.4mm FWHM
CCD camera / 5.1m from sample / resolution 0.2 mm / efficiency 10%
Sample Ni/glass (50 x 140mm^2)

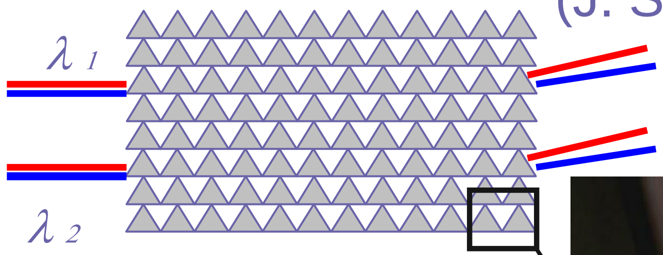
Measurement on a thick Ni layer



- *Very efficient for high resolution experiments (gains x30 – x90)*
  - *Kinetic measurements*
  - *Small samples*
- *Limitation: high resolution detector required (δx~0.2mm)*
- *Results to appear in EuroPhysicsLetters*

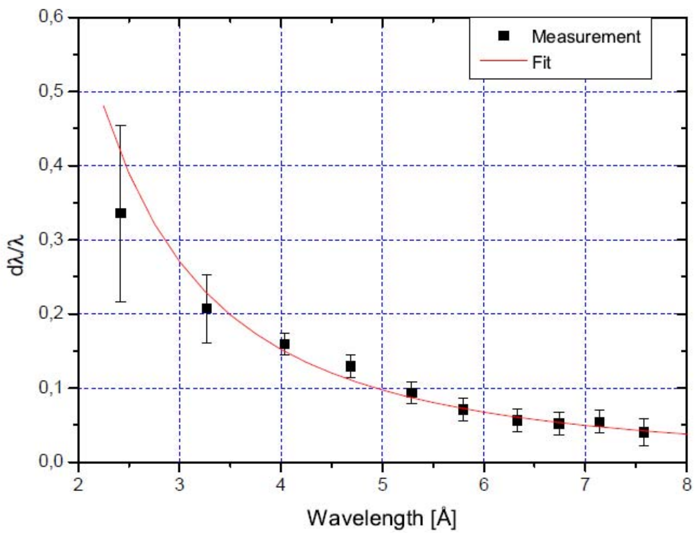
Energy analysis by Si prisms

(J. Schulz, Th. Krist, HZB; F. Ott, LLB)

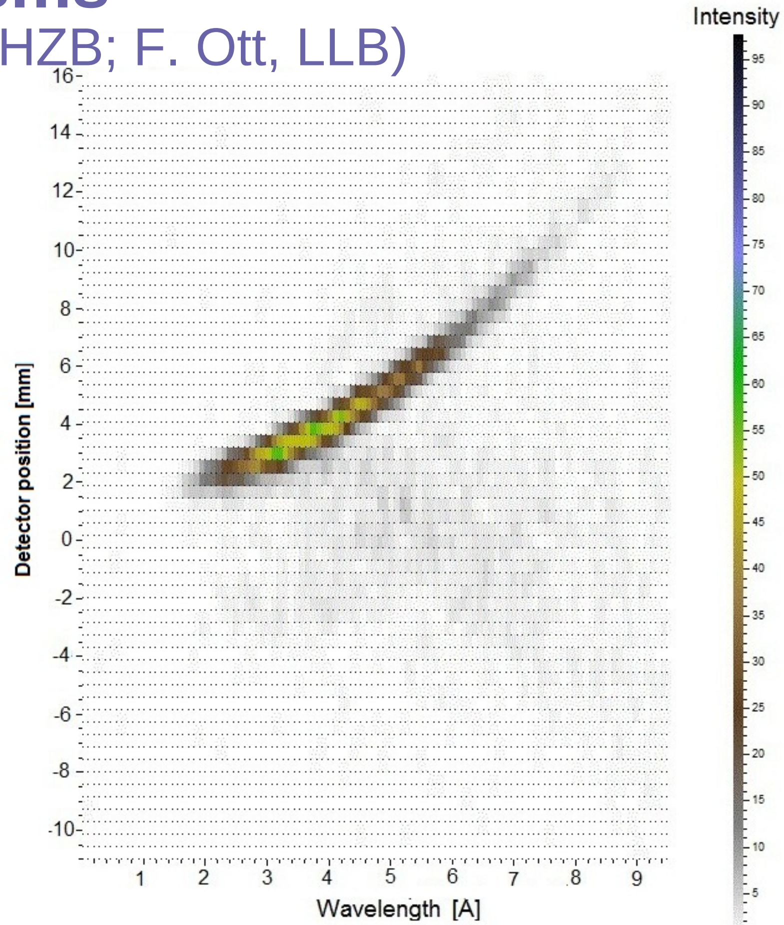


Energy analyzer

Silicon prisms with a height of 0.25mm



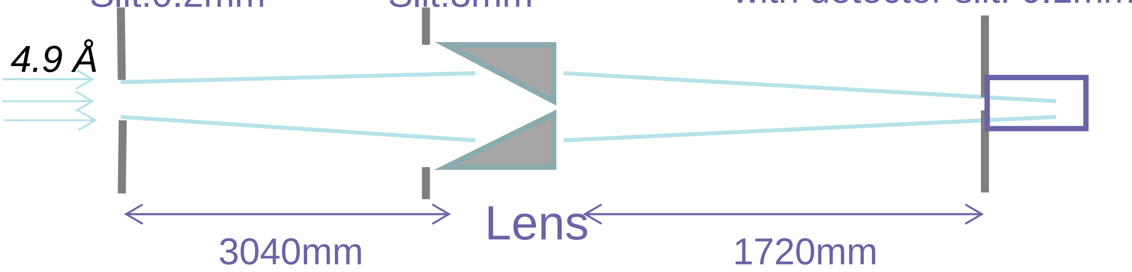
Measured wavelength resolution of the Si energy analyzer



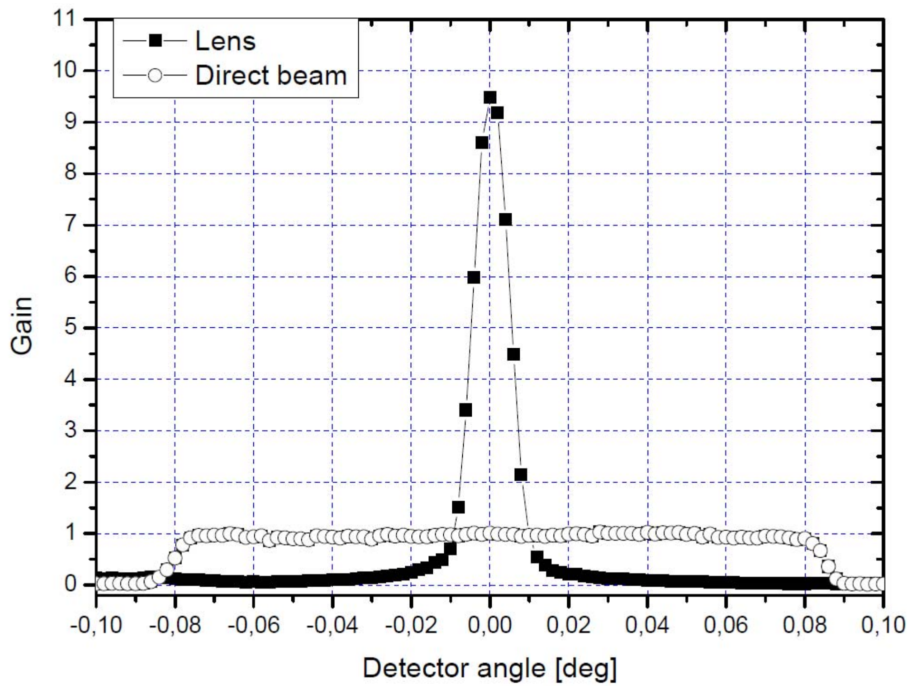
Measurement of the refraction 2m behind the energy analyzer at the EROS reflectometer at LLB

Imaging a small slit with a Si prism lens

(J. Schulz, Th. Krist, HZB)



Measurement of the imaging by a 3.25mm high Si prism lens at HZB at 4.9Å.



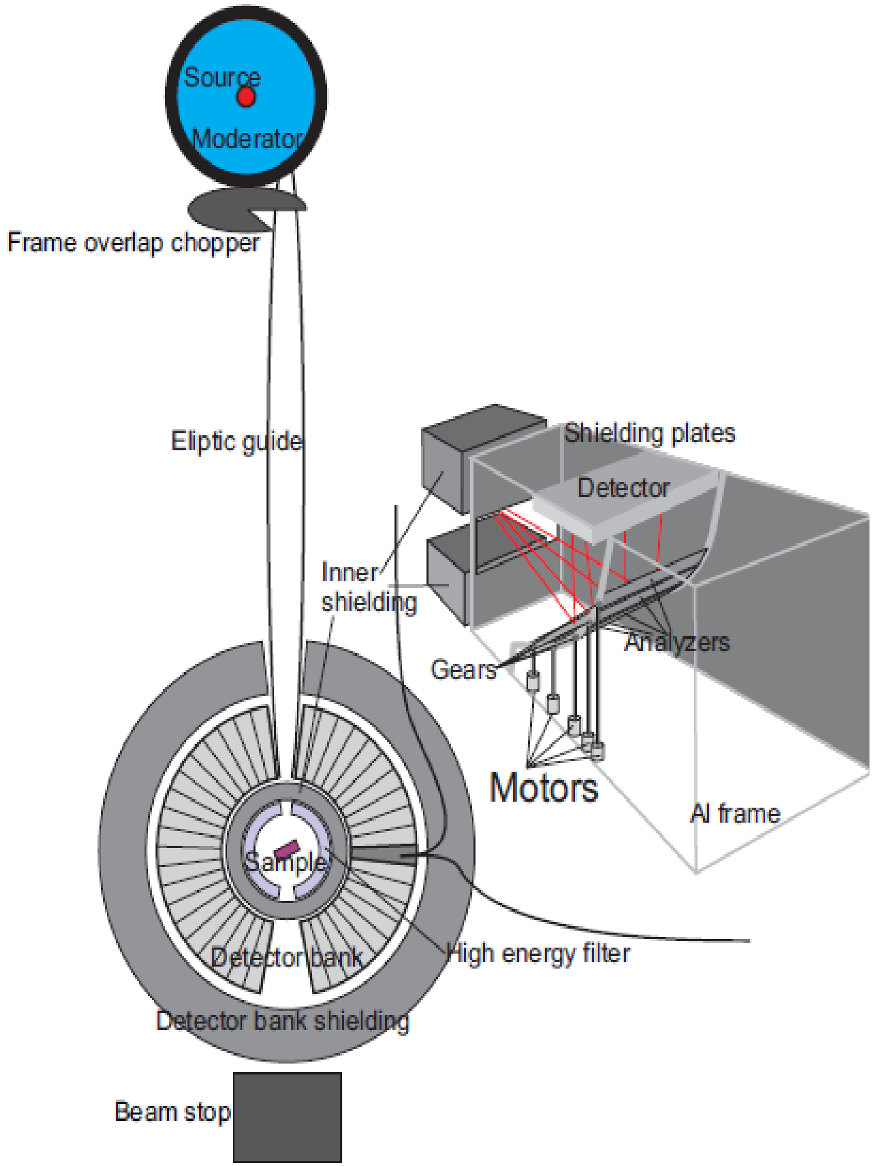
<u>Experimental results:</u>

- FWHM: 0.35mm
- Transmission: 83%
- Gain: Max. 9.7
  FWHM 7.9

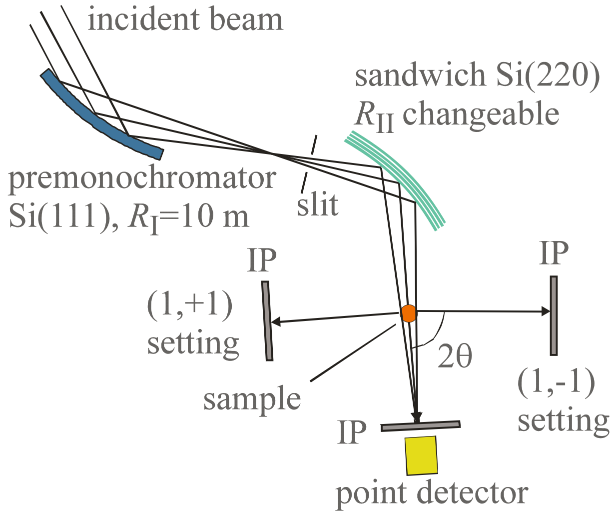
Task 2: Crystal Optics

Energy analysis using crystal optics : CAMEA Project
(Univ. Copenhagen - EPFL, Jonas Birk, K. Lefman, H. Ronnow)

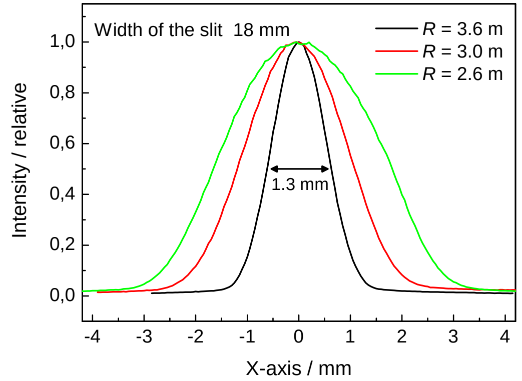
- Initial task aim switched from TAS to TOF
- NO is supporting MC simulations / Feasibility study for implementation on cold TOF at ESS



„Micro“-beam preparation – NPI REZ



Schematic layout of the diffractometer permitting experiments in two or three axis mode for Si(220) sandwich in focusing diffraction geometry.



Beam profiles measured by means of IP situated at the distance of 60 cm from the Si(220) crystal for three radii of curvature and for two widths of the incident premonochromatized beam and 1 slab in the sandwich.

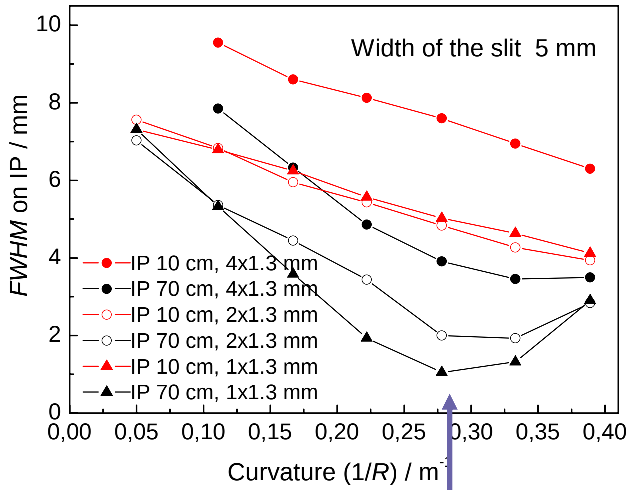
Fixed premonochromator take-off angle: λ=0.162 nm.

Si(222) monochromator, sandwich of the thickness of: 1x1.3 mm, 2x1.3 mm or 4x1.3 mm; radius of curvature is changeable.

Sample and detector positions: 50 cm and 75 cm from the Si(222) crystal, respectively.

IP position: 45 cm from the sample.

Width of the incident beam inpinging on the Si(220) sandwich: 5 mm and 18 mm.

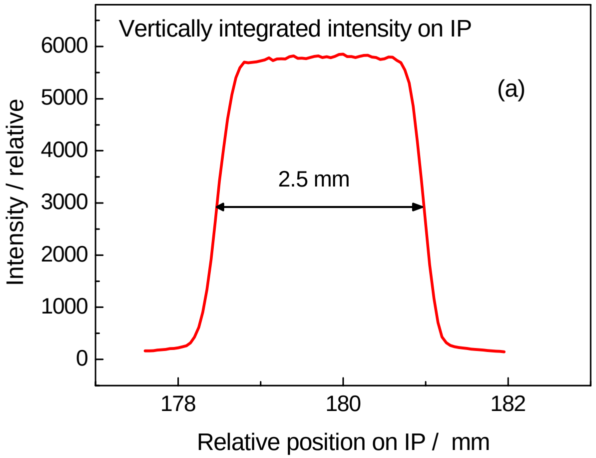


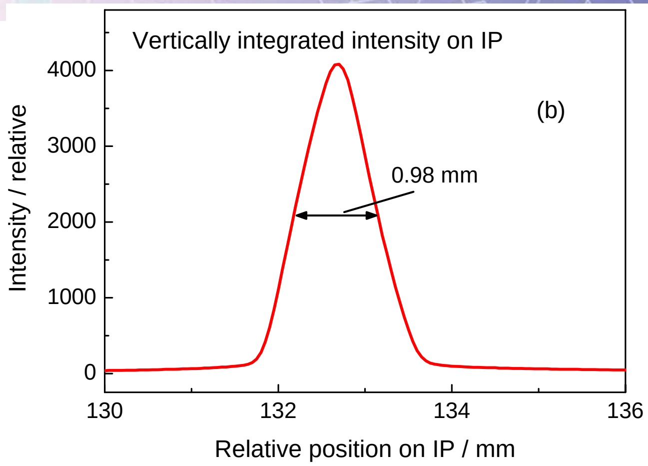
***FWHM* of the beam diffracted by the bent sandwich as a function of curvature for 5 mm slit. FWHM was measured at the distance of 10 cm or 70 cm from the Si(220) sandwich.**

The divergence of the focused beam made by one slab in the sandwich for the curvature of 0.28 m^{-1} is about $7x10^{-3}$ rad.

Comparison of neutron intensities

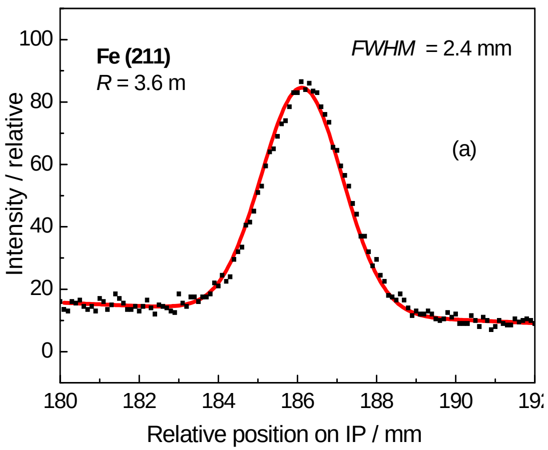
Beam profiles and neutron currents

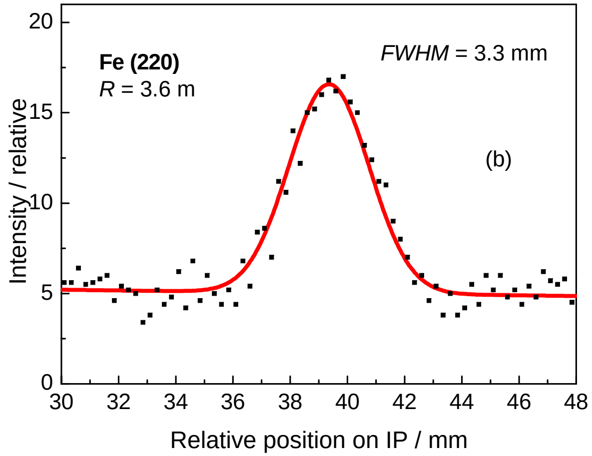




Relative comparison of neutron intensities: (a) - intensity passing through a 2 mm slit measured by IP before the Si(220) crystal, (b) - intensity of the focused beam measured by IP at 70 cm behind the Si(220) crystal when using a 5 mm slit before the Si(220) crystal.

Powder diffraction tests



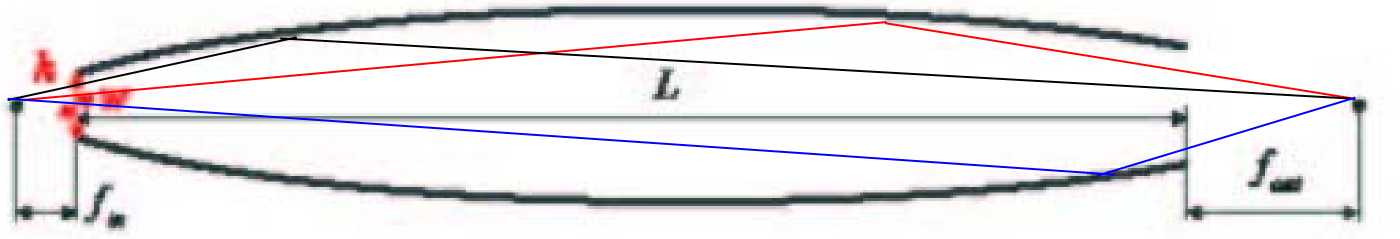


Diffraction profiles related to α-Fe(211) - (a) and α-Fe(220) - (b) reflections obtained by diffraction on a polycrystalline pin of the diameter of $\phi = 2$ mm.

Inspection of the profiles reveals that the diffracted beam from the α-Fe pin has a very low divergence $\Delta(2\theta_S)$ of about 1×10^{-3} rad for 211 reflection and 3×10^{-3} rad for 220 reflection and provide an excellent resolution in the vicinity of $2\theta_S = 90^o$.

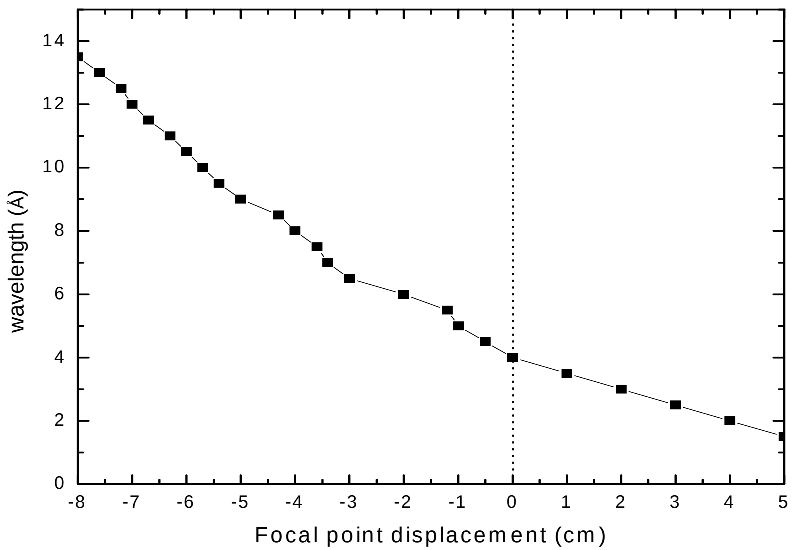
Task 3:
Advanced Focusing Techniques

THEORY

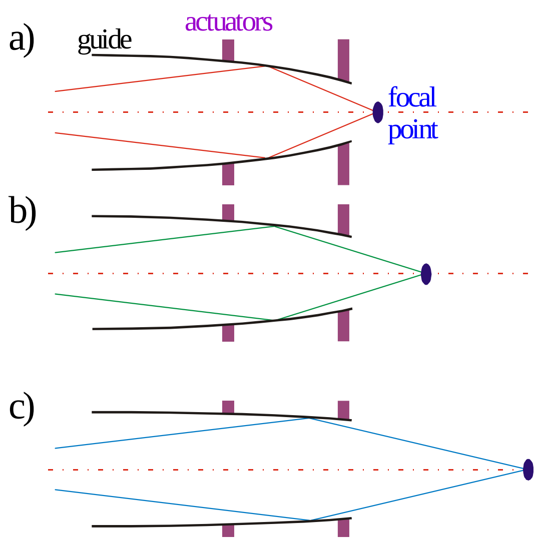


REALITY: chromatic aberration

Focus position as a function of the wavelength, fixed curvature (optimized for 4 Å)



Focus position as a function of the curvature, fixed wavelength

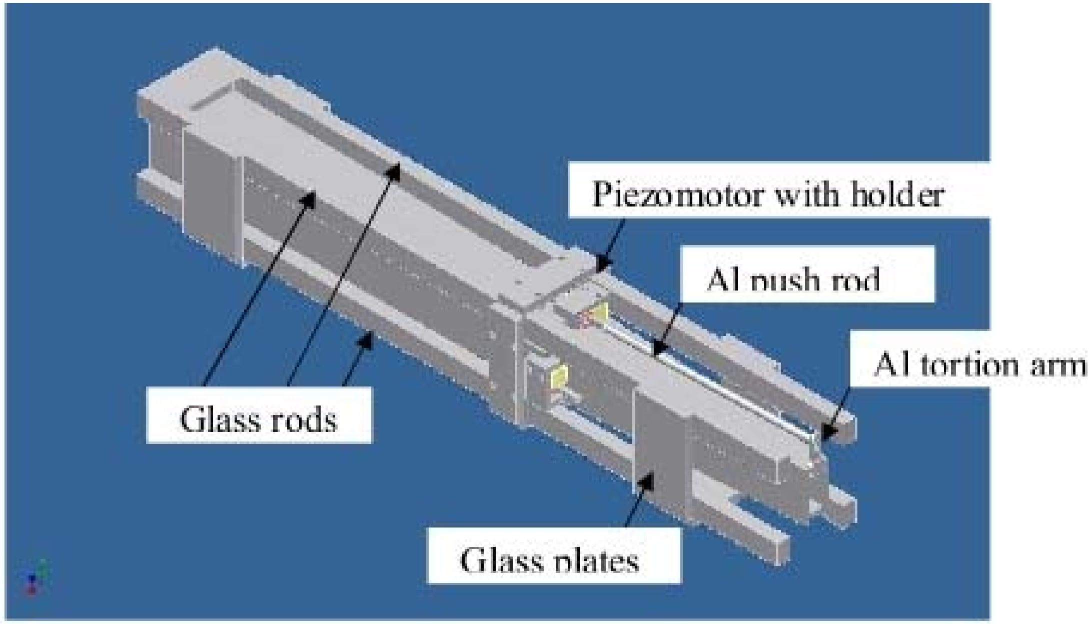


CHALLENGE:

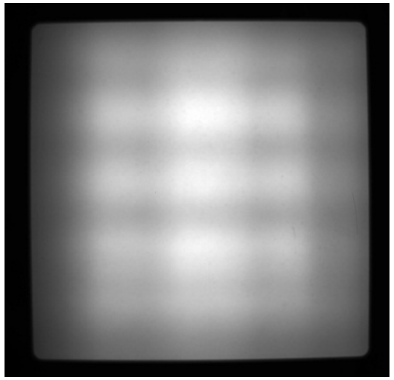
***Changing the curvature of the supermirrors as a function of the wavelength*, in order to keep the focal point at the sample position**

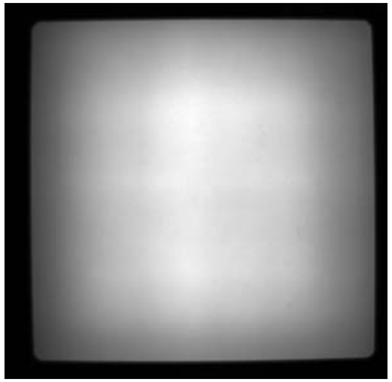
THE PROTOTYPE:
general layout

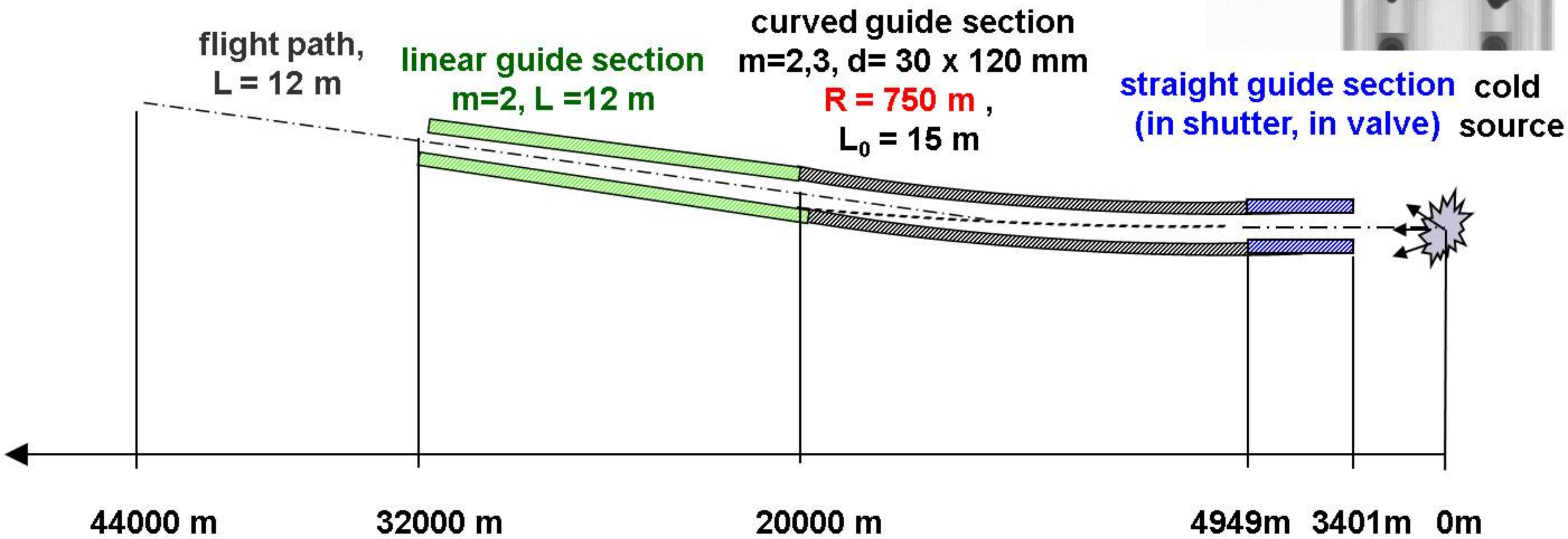
Total length = 495 mm
Entrance cross section = 23x52.18mm^2
Exit cross section = 12.4 x28.13 mm^2
coating m-factor= 3.5
4 piezomotors with holders



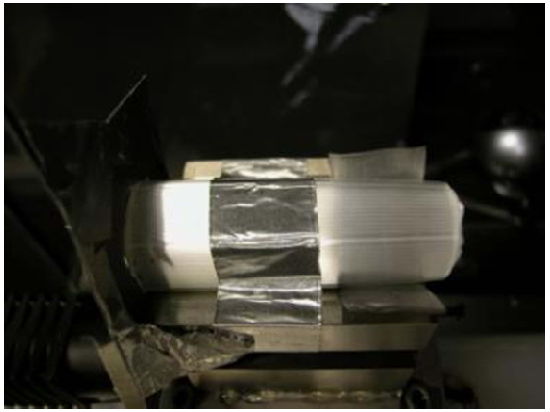
High resolution imaging using reflective optics (HZB, N. Kardjilov, T. Krist)

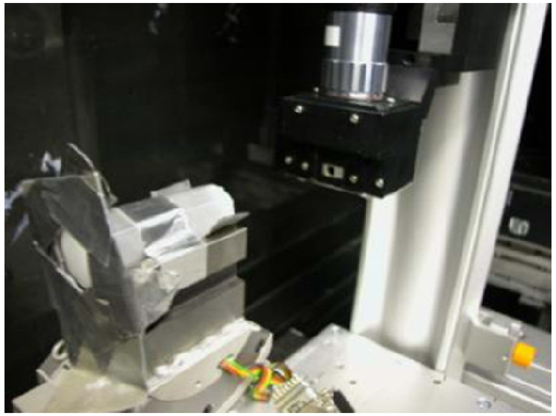


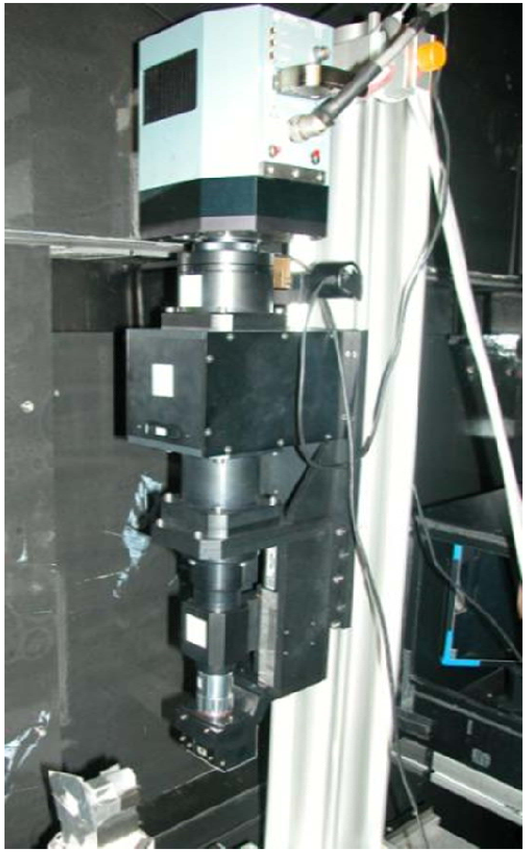




High resolution imaging using focussing optics (HZB, N. Kardjilov, T. Krist)

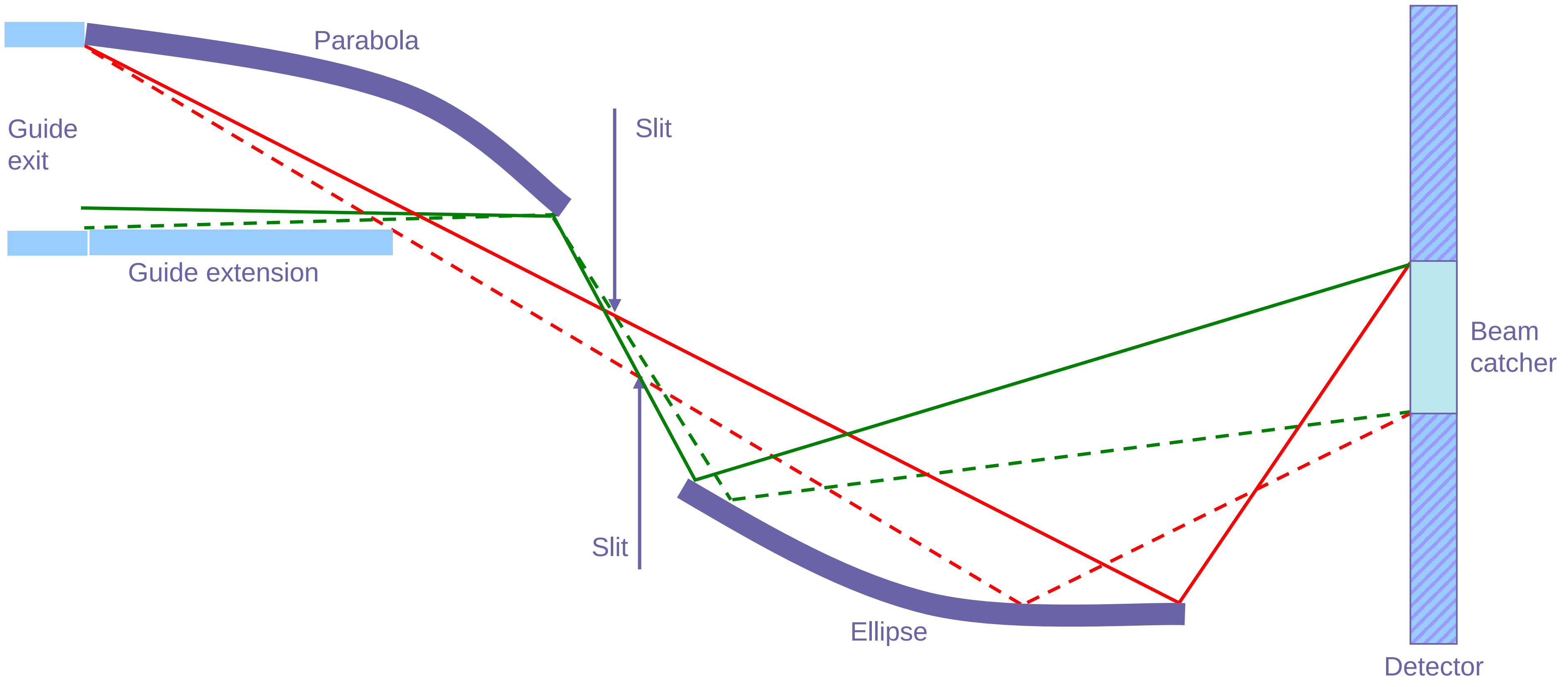




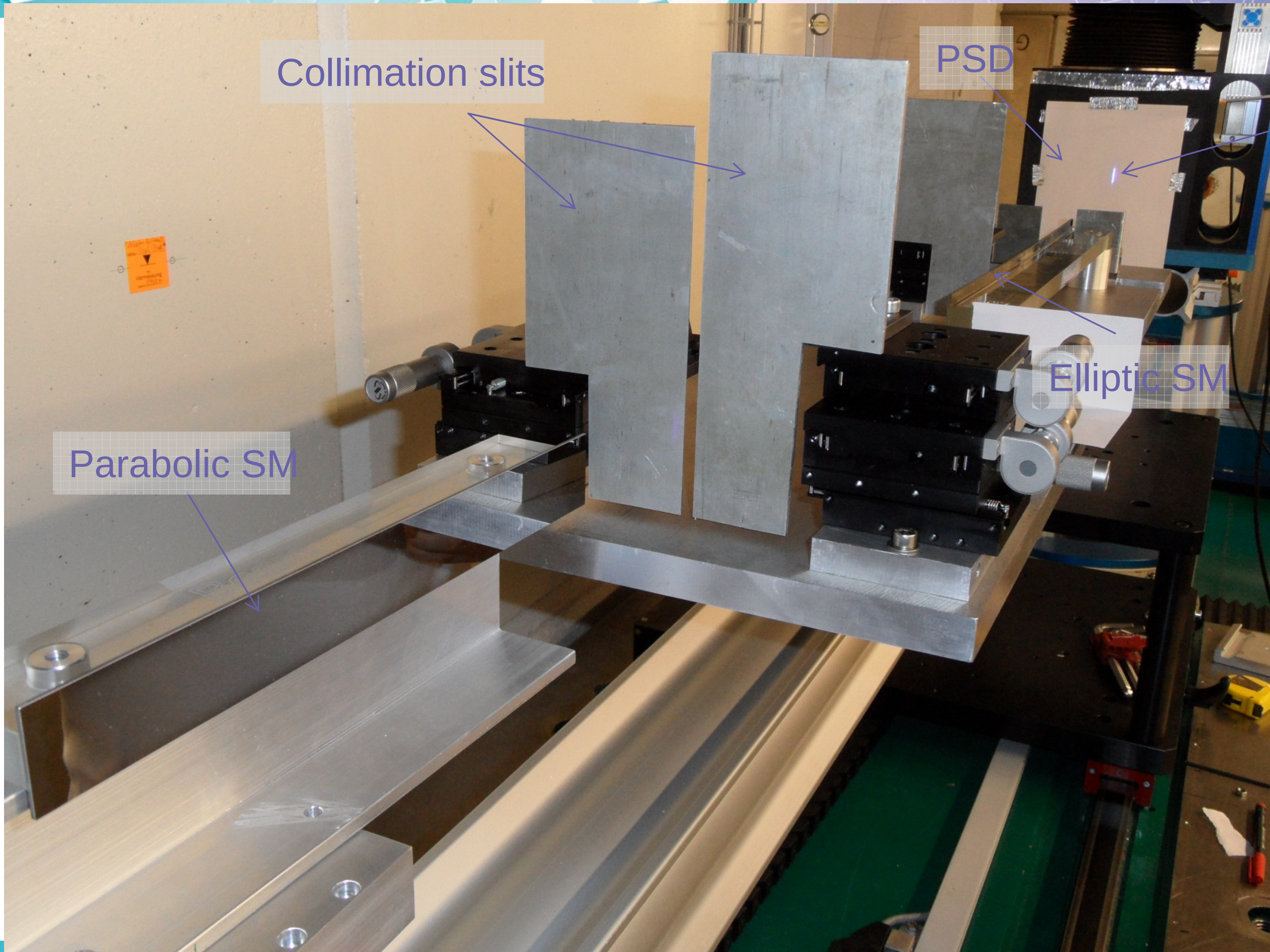


- *Focussing over an area of 2x2mm² using a Kumakhov lens*
- *CCD associated with scintillator with a 1µm² effective resolution*

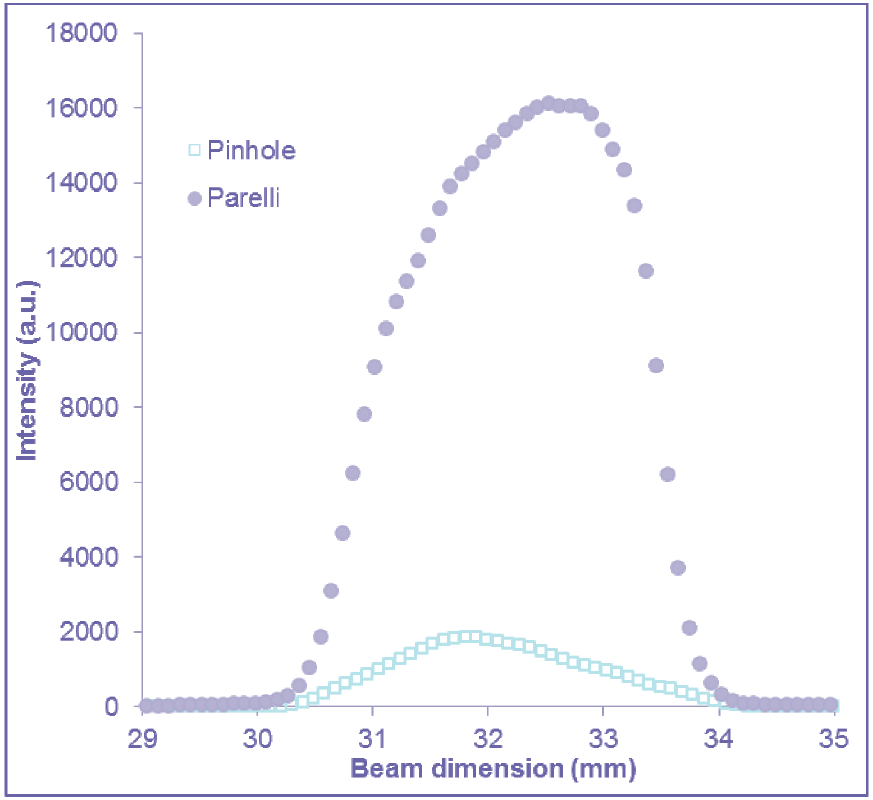
Focussing SANS using reflective optics (LLB, S. Désert et al)



Test of prototype on BOA (T. Panzner) @ PSI, 03-06 Oct. 2011



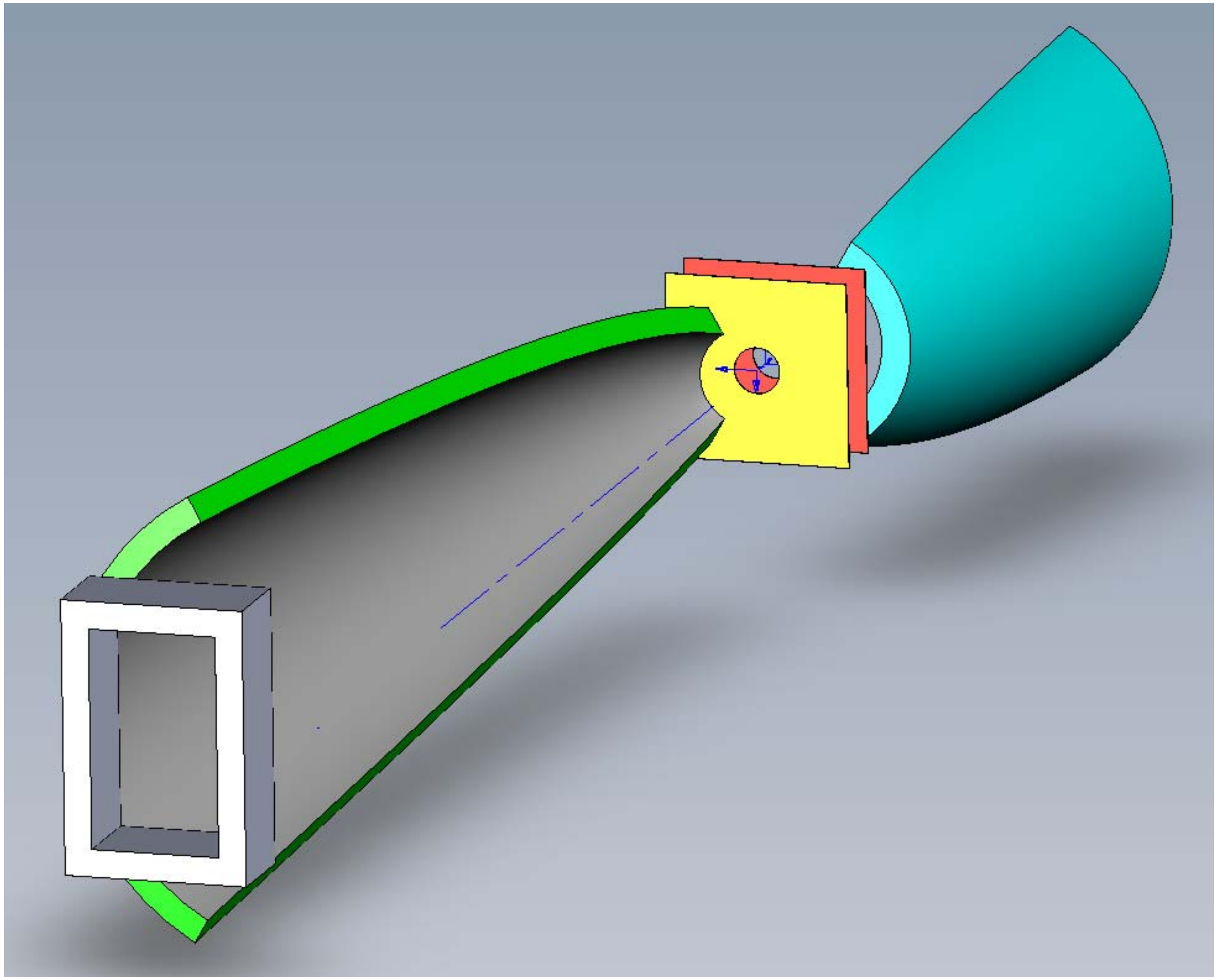
Laser spot after reflexion on both SM (for alignment purpose)



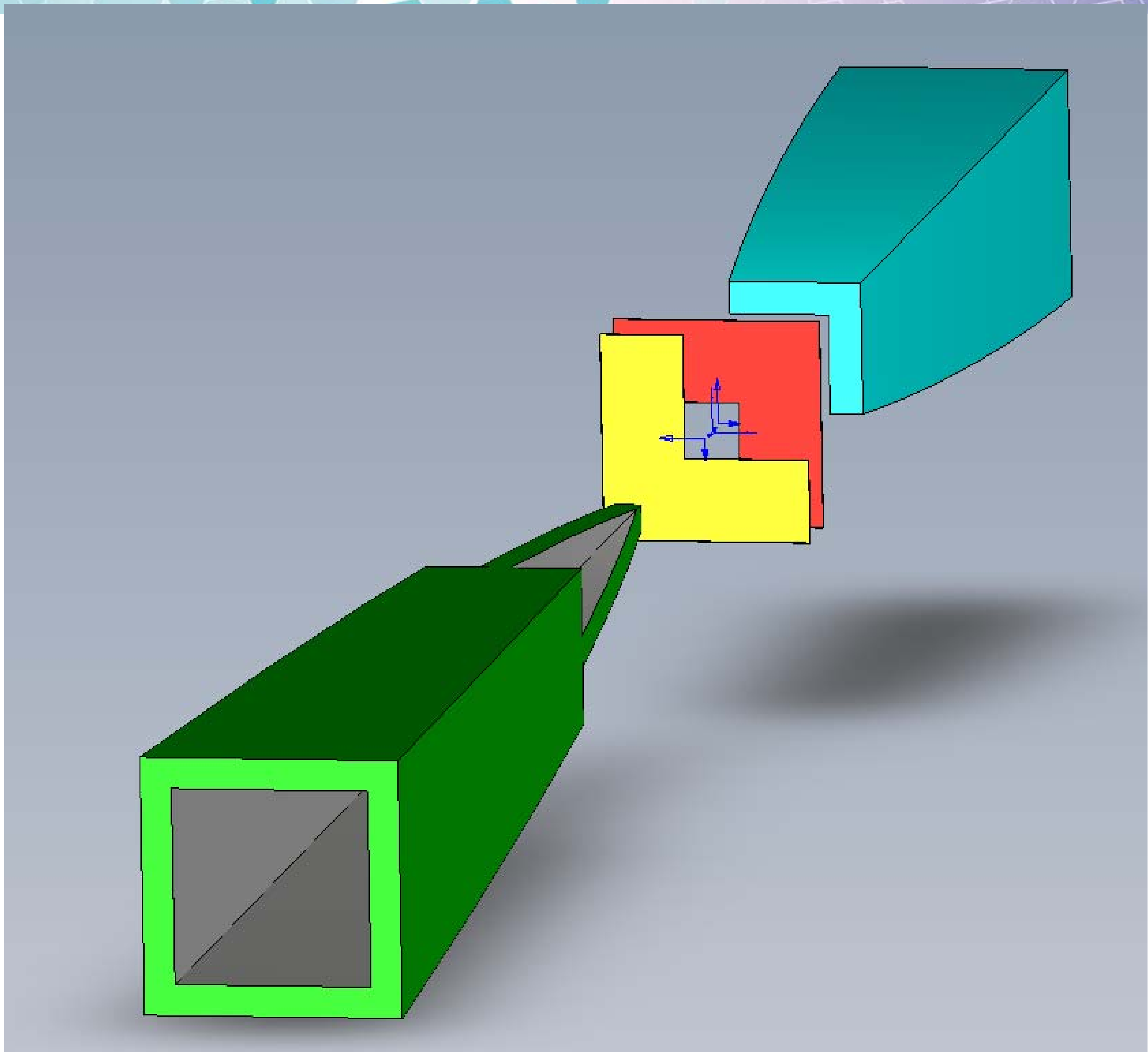
Gain 10 along one axis
➔ 100 with a 3D setup.

- Interests of the setup:
  - Beam focusing without abberation
  - Gain approx. 3 compared to pinhole with same sample size
- The beam size on the detector is independant of the sample size
- Large samples can be used for large intensity gains

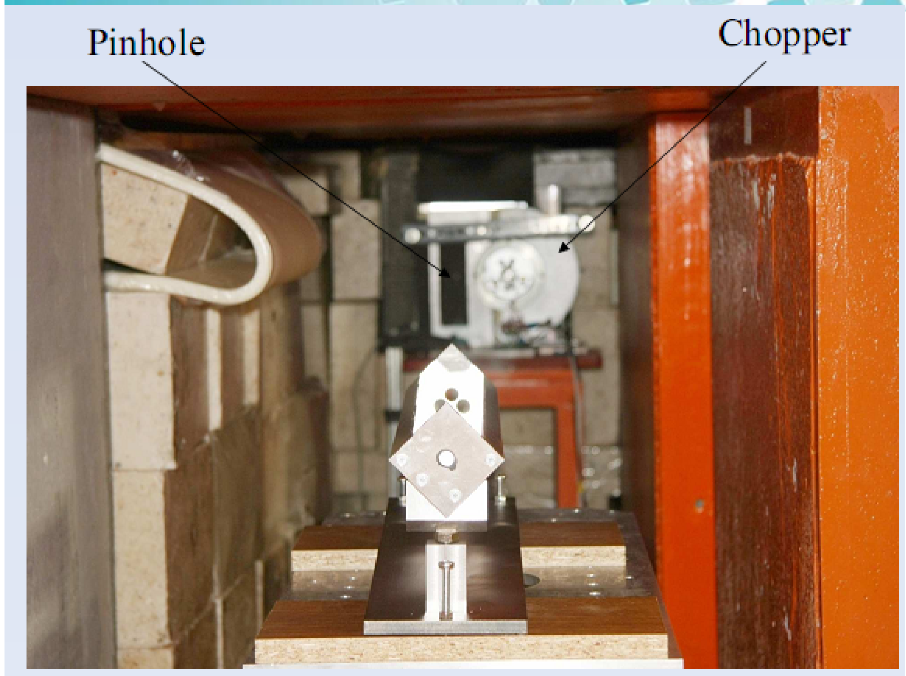
3D View (2 reflections)



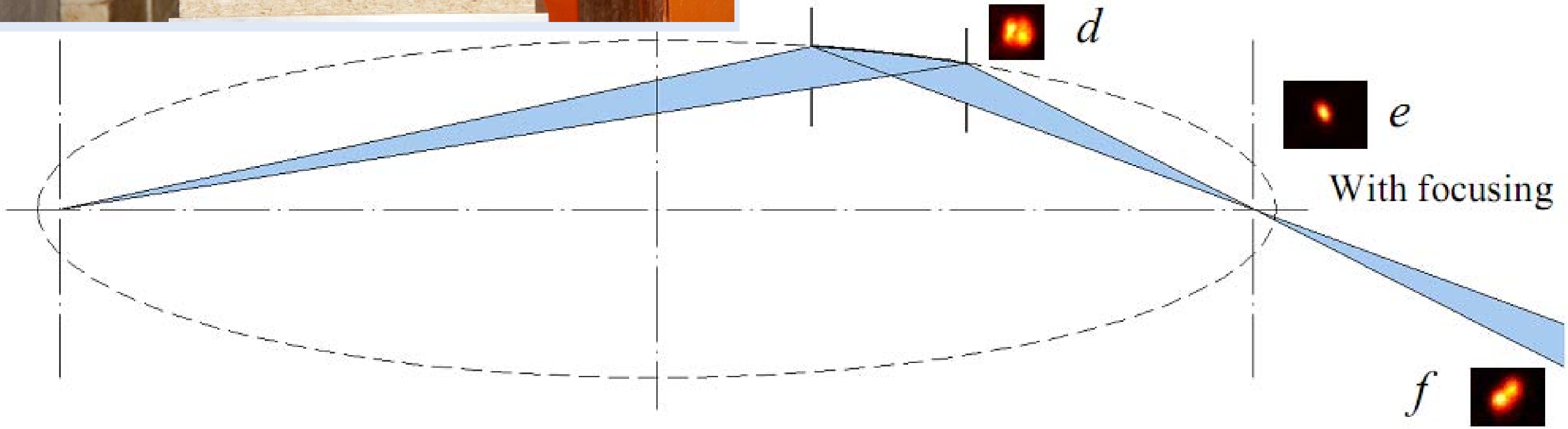
3D View (4 reflections)



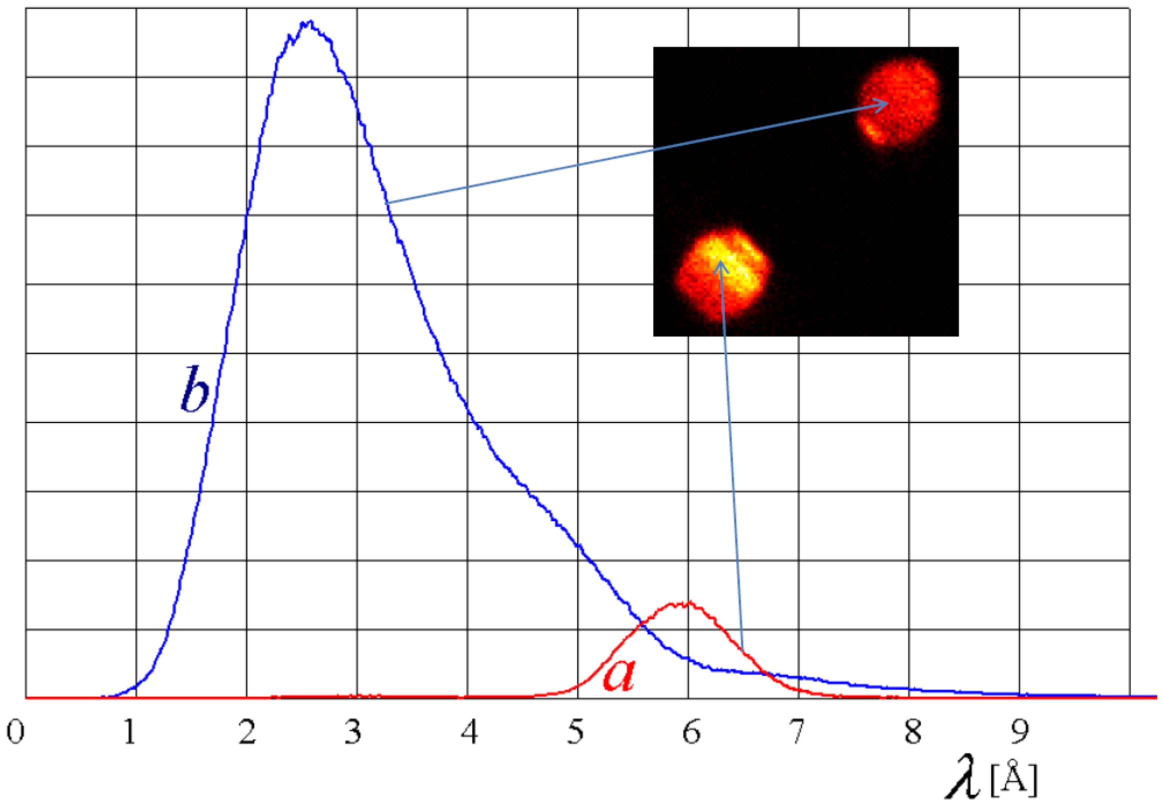
Focusing SANS with Nested Elliptical Mirrors (J. Fuzi et al, BNC) KB set-up



Proceedings of ECNS Prague



- Energy selective focusing by bandpass coating on elliptic surfaces

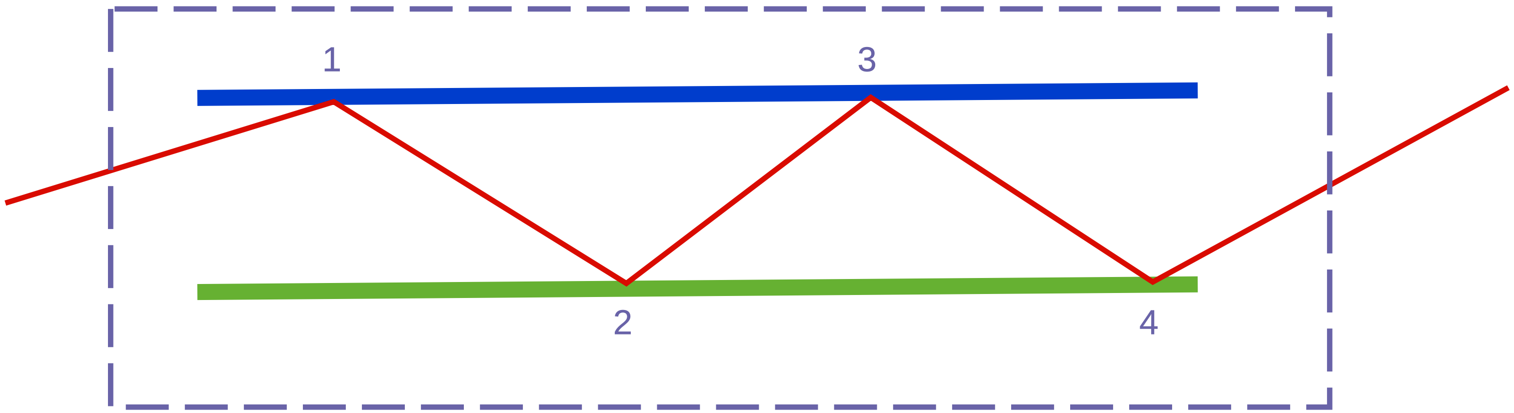


Task 3:

Monte-Carlo simulations of complex optics

McStas, component assemblies

- Wish among users to avoid writing new components to describe new geometries / devices
- Many existing, useful components to build from
- Obstacle: Intrinsic linear flow in McStas
  - Basic idea: Combine existing components, e.g. Mirror.comp, to create new functionality



Solution: In code

```
COMPONENT Origin = Progress_bar()
  AT (0,0,0) ABSOLUTE
EXTEND %{
        Scatt = 0; EverScatt = 0;
%}
 .
 .
 .

COMPONENT ArmMid = Arm()
  AT (0,0,ML/2.0) RELATIVE ArmEntry
EXTEND %{
        Scatt = 0; SCATTER;
%}
```

```
COMPONENT Mirror1 = Mirror(
    xwidth = 0.1, yheight = ML, center=1)
  WHEN (Guide==0)  AT (0, 0.05, 0) RELATIVE ArmMid
ROTATED (-90, 0, 0) RELATIVE ArmMid
EXTEND %{
  if (SCATTERED) {
        Scatt = 1; PROP_DT(1e-9); SCATTER;
  }
%}

 .
 .
 .

COMPONENT ArmMid3 = Arm ()
  AT (0,0,0) RELATIVE ArmMid JUMP ArmMid WHEN (Scatt > 0)
```

Does it work? - Comparison with std. Guide

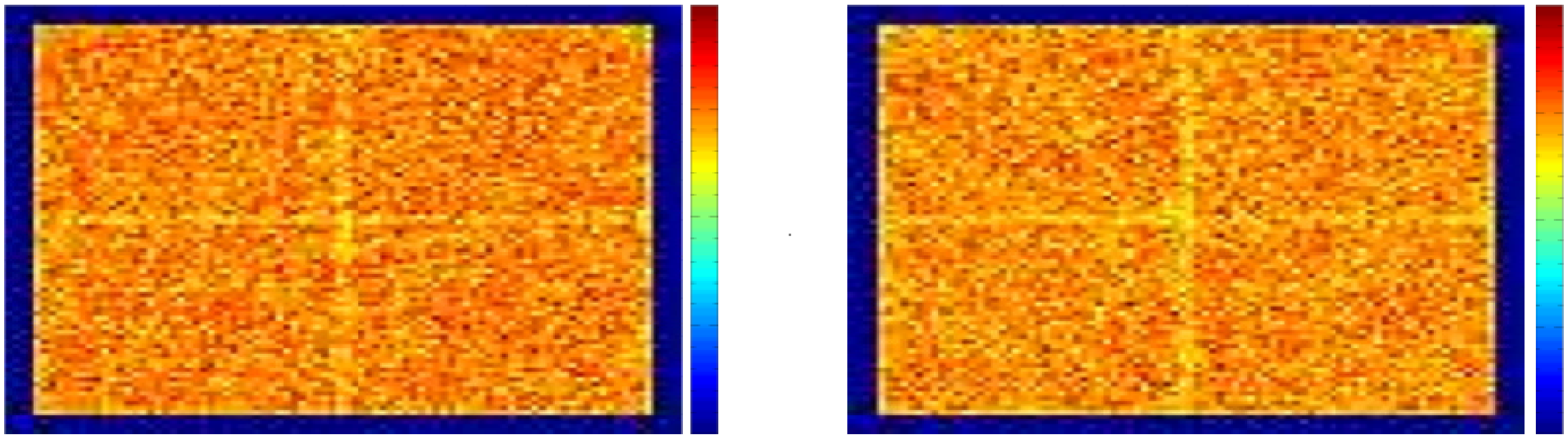


Figure 1: *Left: Intensity transported by standard McStas guide component. Right: Intensity transported by single-mirror type guide. In complete agreement*

Also the energy dependence is in complete agreement

Findings

- It is feasible to combine e.g. McStas mirror components into more complex assemblies
- Advantage: avoids writing a new component from scratch, but can rely on existing components.
- Problem: The neutron state at component exit is not handled in exactly the same way across components.
- Some components could require more extensive logic, e.g. parallel comps.
- McStas team will further explore possibilities and boundary conditions
- Metalanguage - e.g. ASSEMBLY / existing GROUP

Miscellaneous

Collaborations - Common experiments

- LLB (S. Desert et al) performed experiments at PSI on BOA
  with T. Panzner
  on Focussing SANS with reflective optics

- ILL (R. Cubitt) performed experiments at PSI on AMOR
  with J. Stahn
  on Energy Encoding using prisms

- HZB (J. Schultz et al) performed experiments on EROS at LLB
  with F. Ott
  on Energy Encoding and focussing using prisms

- INFM (F. Sacchetti et al) performed experiments at PSI on lenses

Publications

- Stahn, J.; Filges, U.; Panzner, T., EUROPEAN PHYSICAL JOURNAL-APPLIED PHYSICS 58 , 11001 (2012)
  Focusing specular neutron reflectometry for small samples
- P.K. Willendrup, L. Udby, E. Knudsen, E. Farhi, and K. Lefmann,, Nucl. Instr. Meth. A **634**, S150-S155 (2011)
  Using McStas for modeling complex optics, using simple buildings brick
- Stahn, J.; Panzner, T.; Filges, U.; et al. Conference: International Workshop on Neutron Optics Location: Grenoble, FRANCE Date: MAR 17-19, 2010 NIM A 634 Supplement: 1 Pages: S12-S16 (2011)
  Study on a focusing, low-background neutron delivery system
- Kardjilov, N.; Hilger, A.; Dawson, M.; et al. J. Appl. Phys. 108, 034905 (2010)
  Neutron tomography using an elliptic focusing guide
- R. Cubitt & J. Stahn, Eur. Phys. J. Plus **126**, 111 (2011).
  Neutron reflectometry by refractive encoding.
- P. Mikula, M. Vrána, J. Šaroun, V. Em, B.S. Seong, W. Woo,, In Proc. of the ECNS 2011 conf. 18-23, July, Journal of Physics: Conference Series **340** (2012)
  Double bent crystal dispersive arrangement for high resolution diffractometry
- P. Mikula, M. Vrána, J. Šaroun, B.S. Seong, W. Woo,, In Proceedings of EPDIC 13 held in Grenoble October 28-31, 2012, submitted to Powder Diffraction.
  Double Bent Crystal Monochromator for High Resolution Neutron Powder Diffraction
- S. Desert et al, to appear in J. Appl. Cryst.
  SANS using parabolic-elliptic fosussing optics.

CONCLUSION

- Several proofs of concept have been demonstrated and look viable
  - SELENE
  - Prism energy analysis for reflectivity
  - Adaptive optics for sub-mm samples
  - Focussing SANS
  - Reflective optics for imaging

- Gains in flux in the range 5-50

- Need to be used/evaluated in « real life » on everyday experiments