

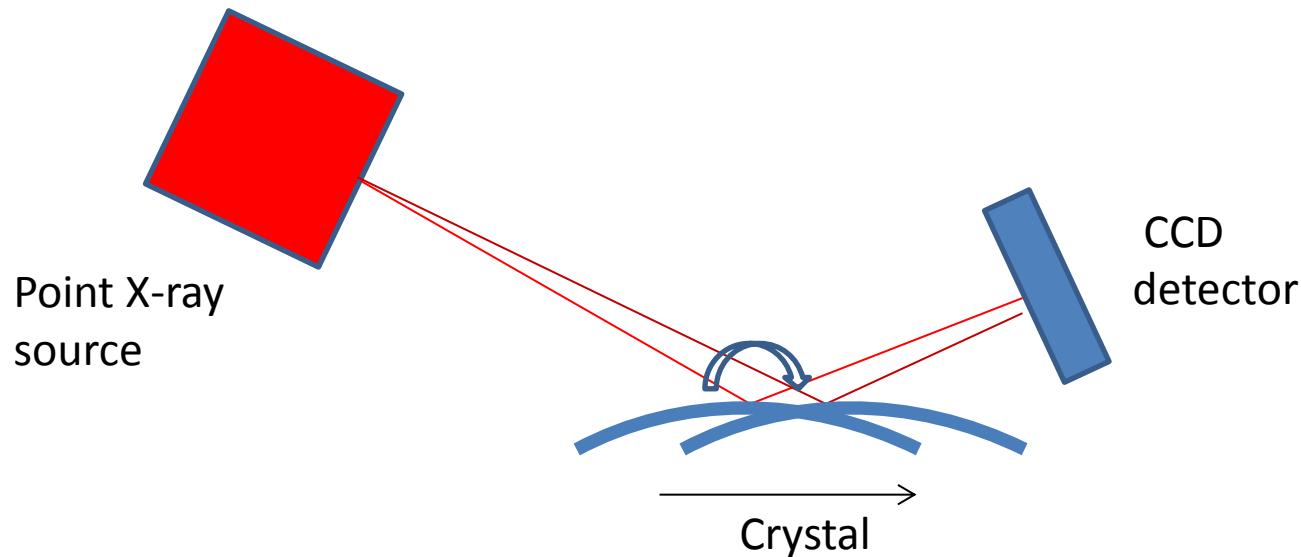
The laboratory X-ray characterization of a Bent Crystals

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Abstract

- Bent crystal real curvature was measured in laboratory by simple arrangement consisting of point X-ray source, movable tables and linear CCD as a X-ray detector. Rotational or linear movements were applied to the crystal. The Cu K moving lines were observed by CCD.
- Trajectories of the movements were calculated on the basis on geometry data. Then calculated trajectories were compared to observed data. Differences point at non perfect curvature.

Outline

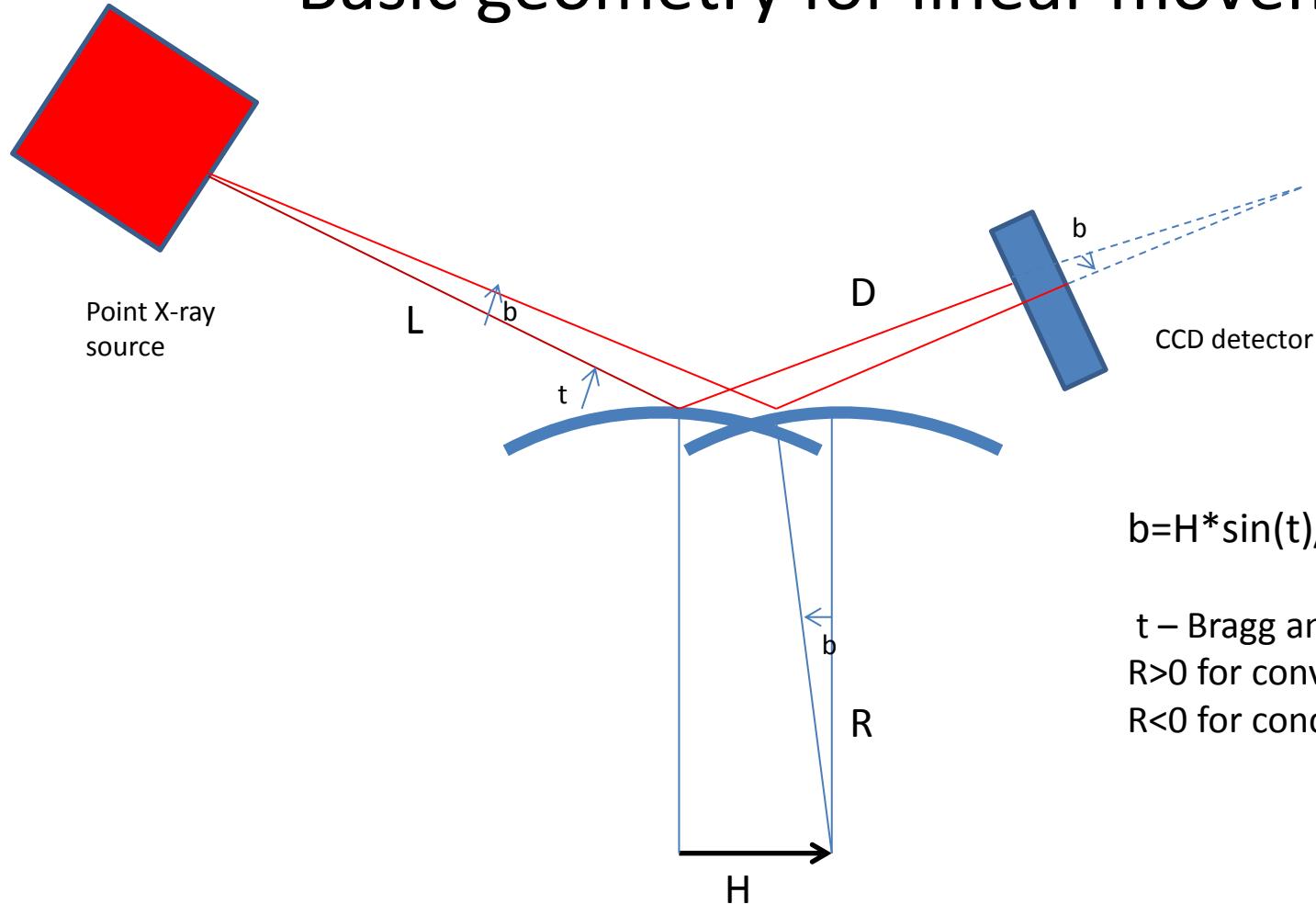


Linear or rotational movements were applied to the crystal.

The point x-ray source should produce characteristic lines appropriated for experiment: for example Cu K lines.

The movements of crystal causes changes in place where diffracted X-rays are recorded by CCD.

Basic geometry for linear movement

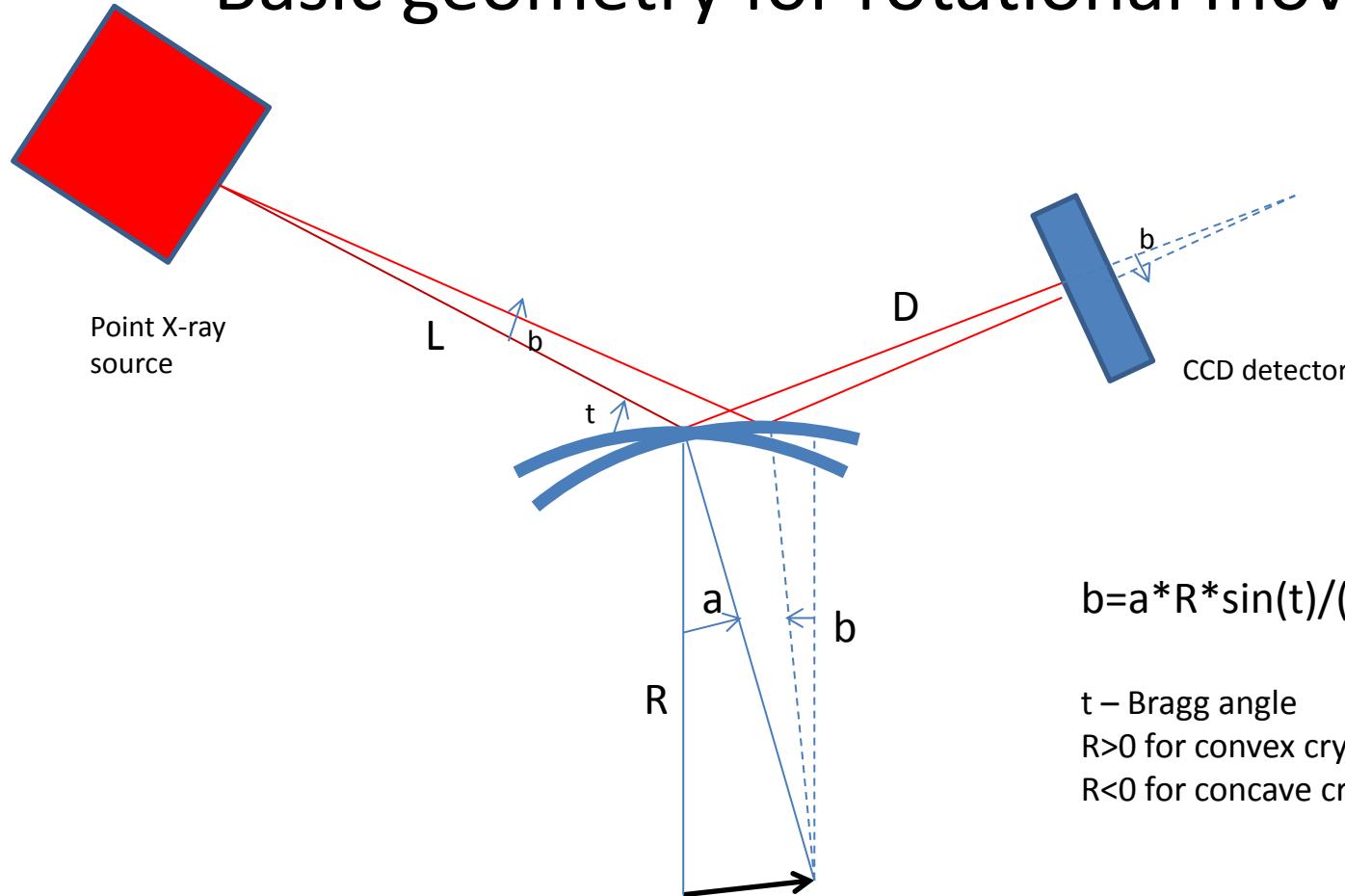


$$b = H \cdot \sin(t) / (L + R \cdot \sin(t))$$

t – Bragg angle
 $R > 0$ for convex crystals
 $R < 0$ for concave crystals

X-ray with specified wavelength is diffracted accordingly to Bragg law always at the angle „ t ”. After linear movement by distance „ H ” the diffracted ray must rotate by the angle „ b ” according to the approximated formula.

Basic geometry for rotational movement



$$b = a * R * \sin(t) / (R * \sin(t) + L)$$

t – Bragg angle

$R > 0$ for convex crystals

$R < 0$ for concave crystals

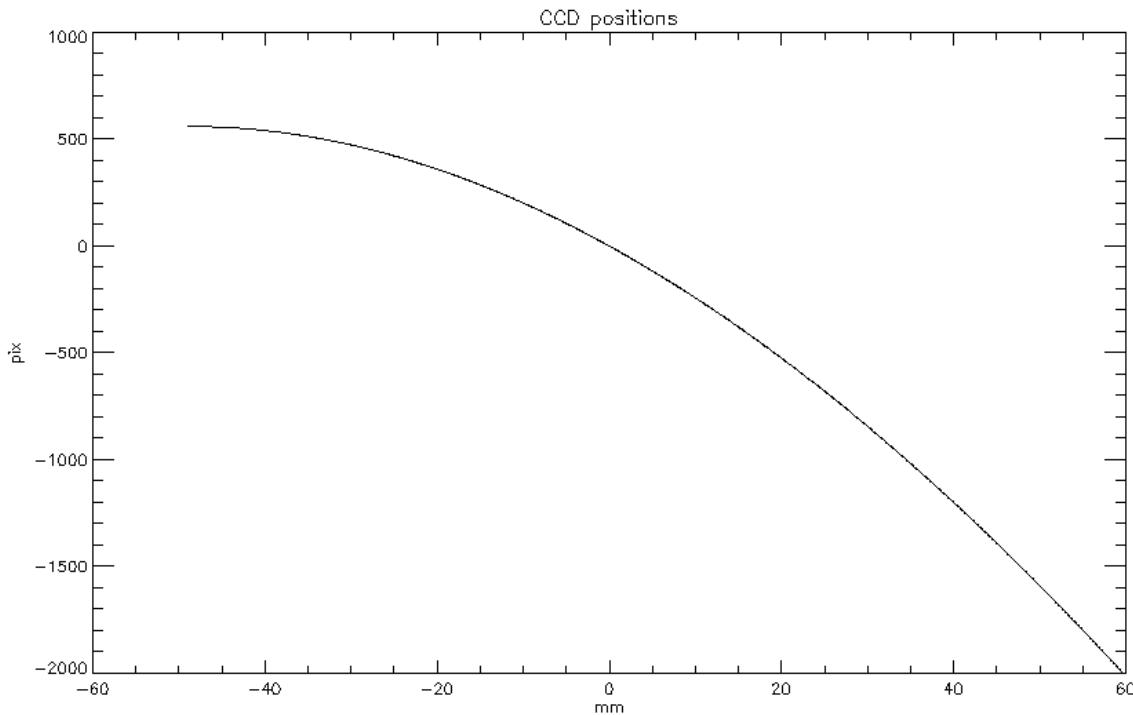
X-ray with specified wavelength is diffracted accordingly to Bragg law always at the angle „ t ”. After rotating movement by angle „ a ” the diffracted ray must rotate by angle „ b ” according to the approximated formula.

Ray tracing for linear movement

The approximated equations are useful for planning geometry of experiment.

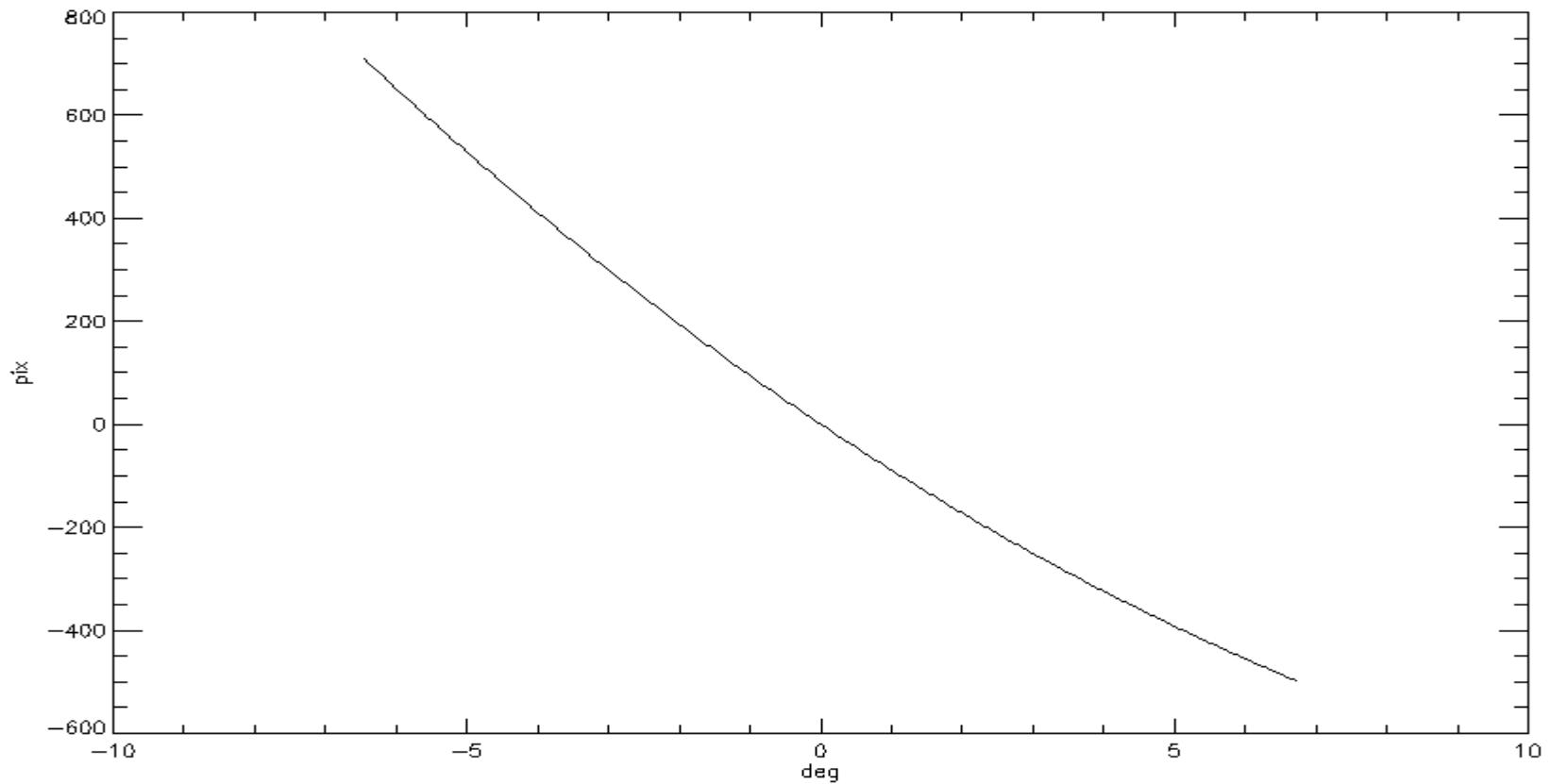
For characterization of crystal curvature the exact trajectories should be calculated and compared with recorded data.

The trajectory was calculated by ray tracing: the angles „b” were established by solving numerically exact equations, and then the location of points was calculated where the diffracted x-rays crossed the CCD detector. The calculations were stopped if the edge of the crystal was achieved.



Linear movement
Data for start: $L=245$ mm,
 $D=120$ mm
 $R=250$ mm, $t=32.75$ deg
 $\text{pix}=8$ μm
Length of the crystal : 36.2 mm

Ray tracing for rotational movement



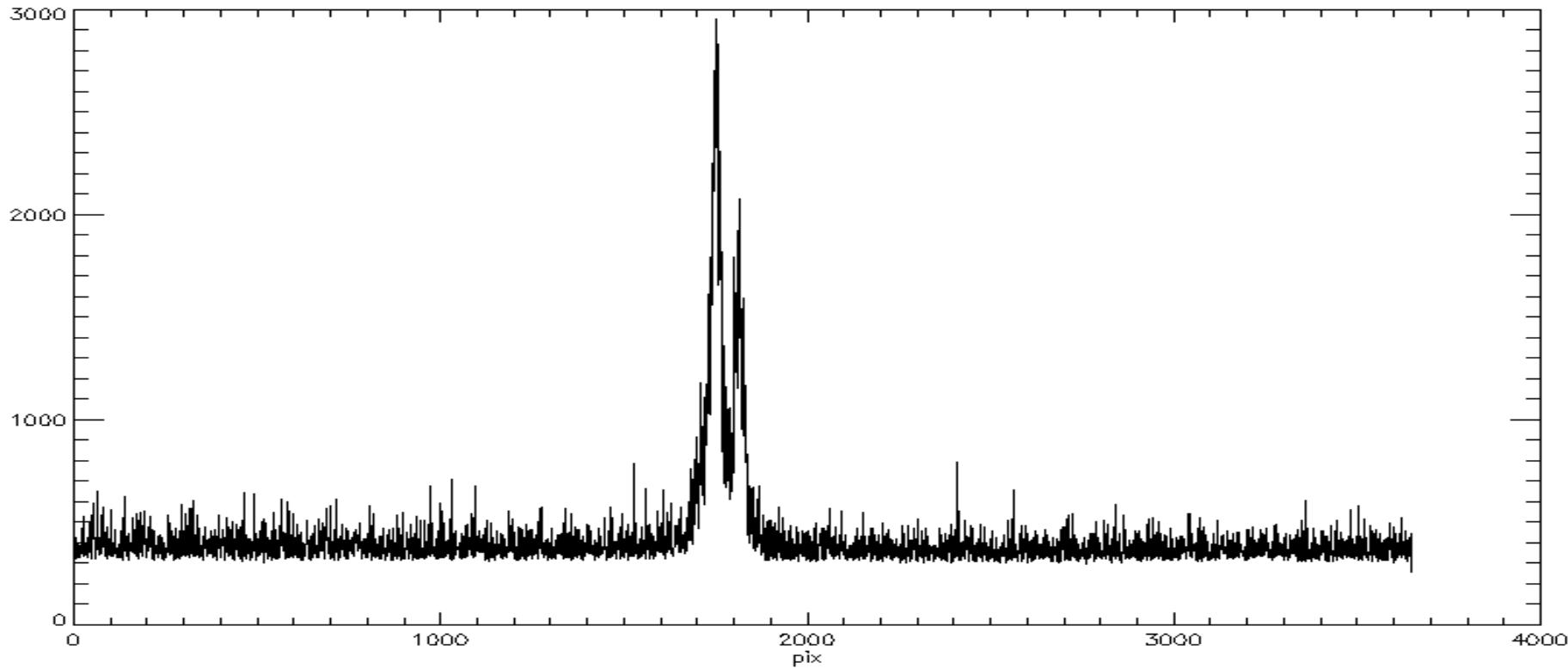
Rotational movement

Start data: $mxh=+/-18.1$ mm , $L=245$ mm, $D=120$ mm.

$R=250$ mm, $t=32.75$ deg, $\text{pix}=8\mu\text{m}$,

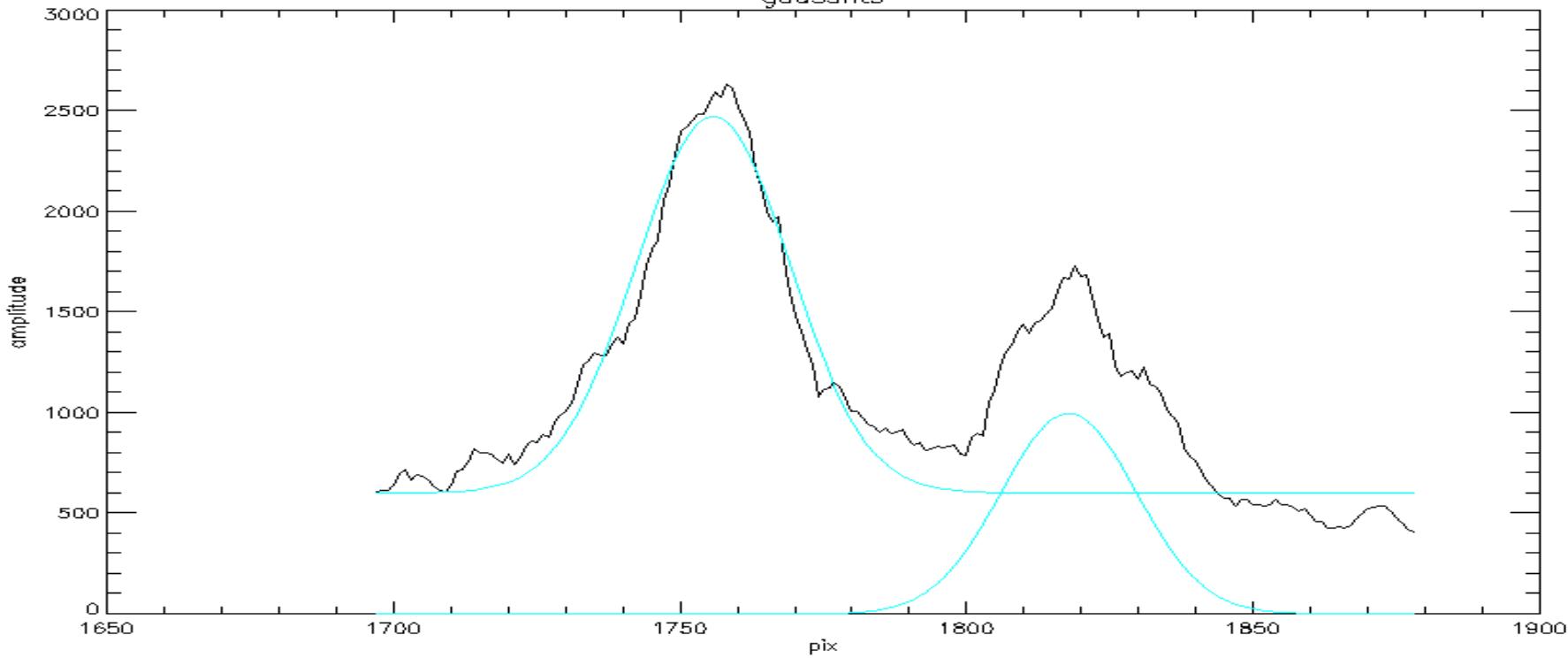
Length of the crystal : 36.2 mm

Example of measurements with convex (R=250 mm) crystal LiF(220)



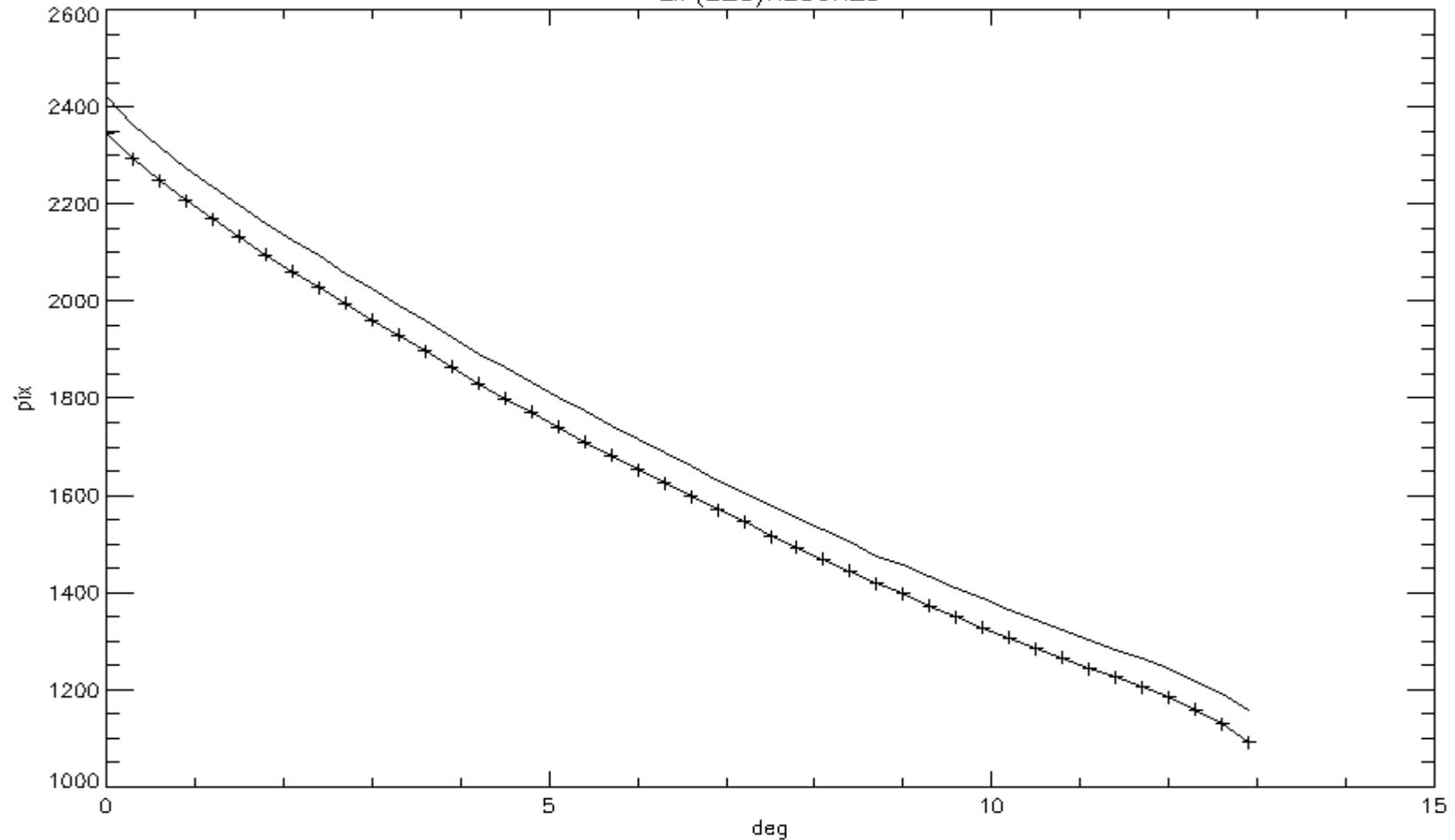
As a X ray detector was used linear CCD with 3650 pixels (each 8x200 μm size).
At the record it is seen two Cu spectral lines Ka1 ($\lambda=154.06$ pm) and Ka2 ($\lambda=154.40$ pm).
For these lines, Bragg angles are $t_1=32.748$ deg and $t_2=32.839$ deg.

gaussfits

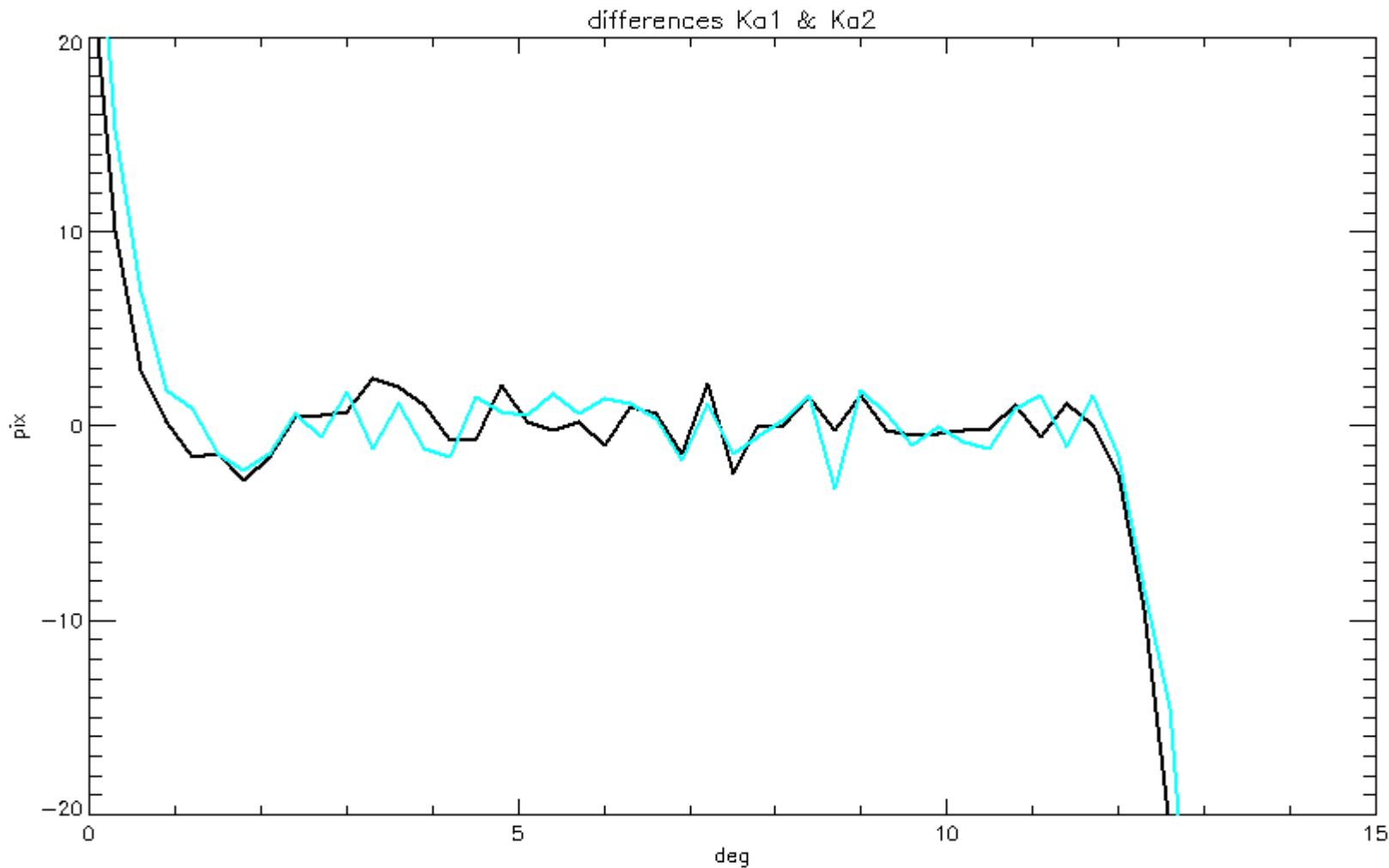


The two spectral lines were fitted by two Gauss curves and then the exact position of the recorded lines were established.

LiF(220)R250R2b



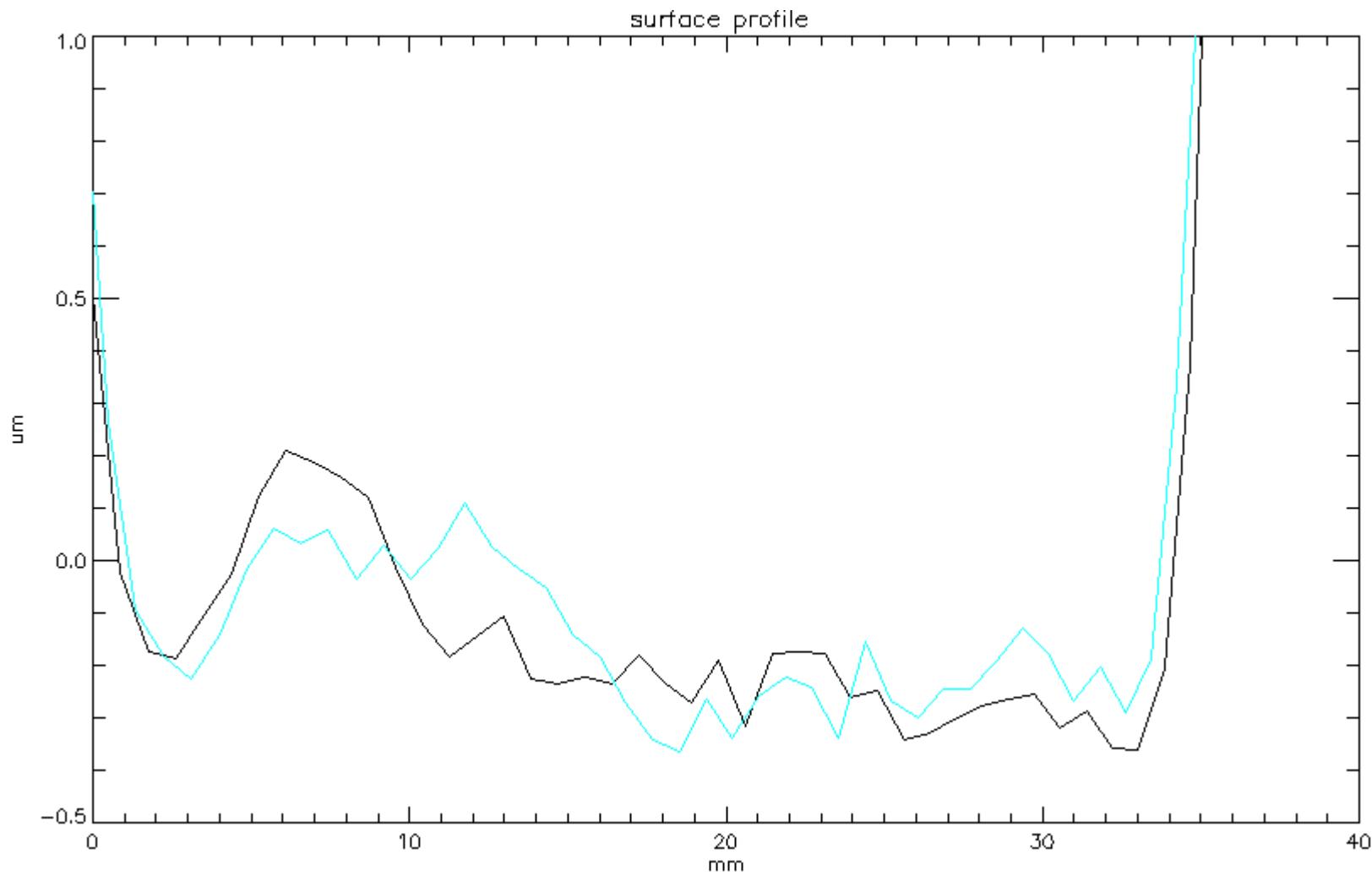
When the rotational movement of the LiF crystal rotational was applied the change in positions of the recorded lines gives the trajectories for Ka1 and Ka2 lines. The movements were stopped if edge of crystal was achieved.



Observed trajectory was compared to calculated trajectory with geometry data:
 $mxh=+/-18.1$ mm, $L=245$ mm, $D=120$ mm.

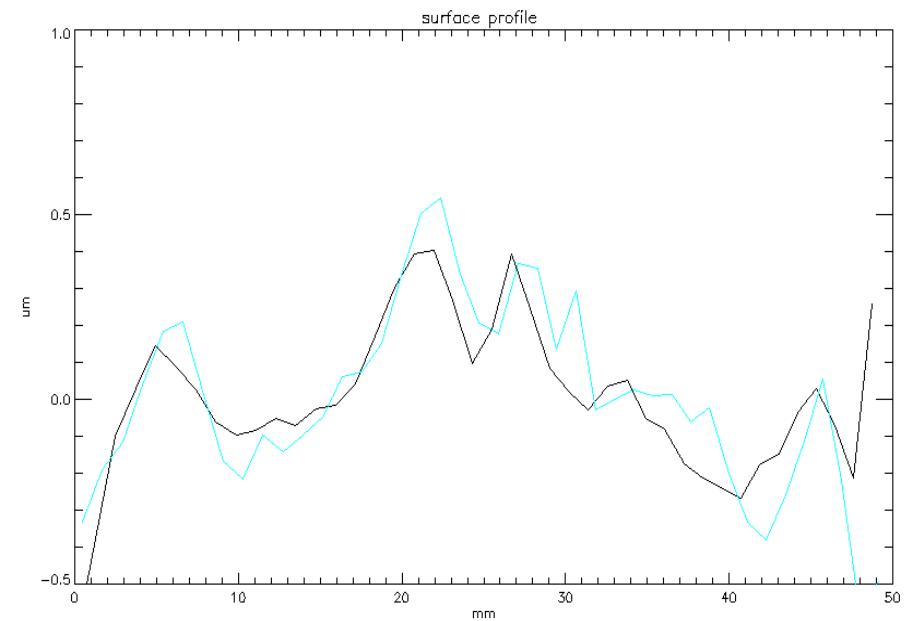
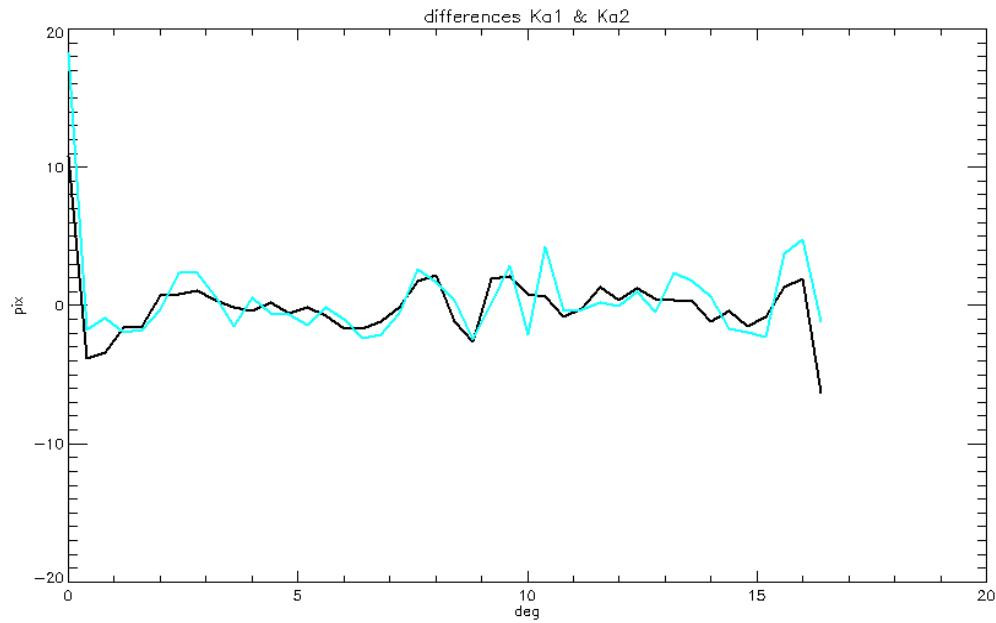
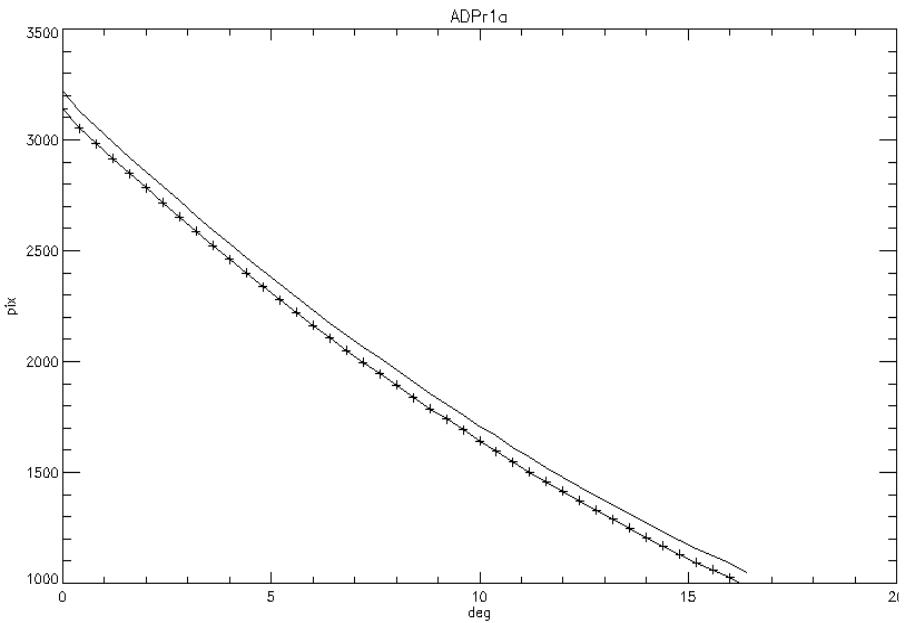
The calculated trajectory was subtracted from observed trajectory.

Discrepances point at the crystal surface tilt did not match with perfect curvature.
(1 pix discrepancy is equivalent 0.068 mrad=14" tilt)



The discrepancies were converted to surface tilt and then integrated over scanning steps . As a result of the integration we get the surface profile.
The presented profile show differences between real profile and perfect concave cylinder.

Result of measurements for convex ADP(404) crystal.



1. Trajectories for Cu Ka1 and Ka2 lines.
2. Differences between observed and calculated trajectories.
3. Surface profile.

Summary and discussion

The presented procedure enable to make precisely x-ray measurements of bent or flat crystal profile.

For future experiments CCD area detector may be used instead of linear CCD detector. It makes possible to measure crystal profiles at multi lines at the same time.