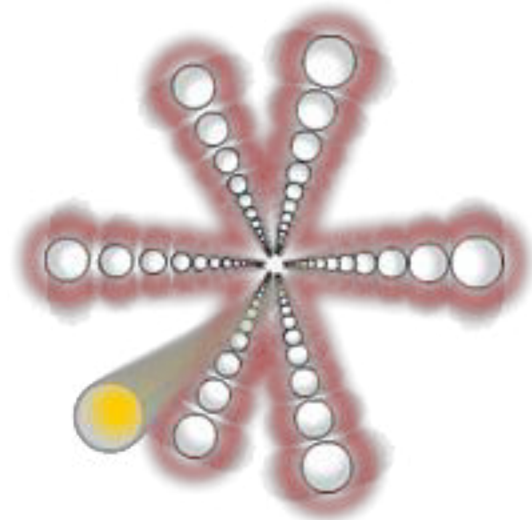

Simulations of beam channeling in spherically bent crystal

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1. Motivation

0. When the beam passages through the crystal under channeling conditions, there is the re-distribution of beam flux.

1. In recent experiments channeling in crystals is used in accelerator physics for beam shaping purposes.

2. It was shown the special preparation of crystalline target, as bending or miscut, provides new possibilities for beam management.

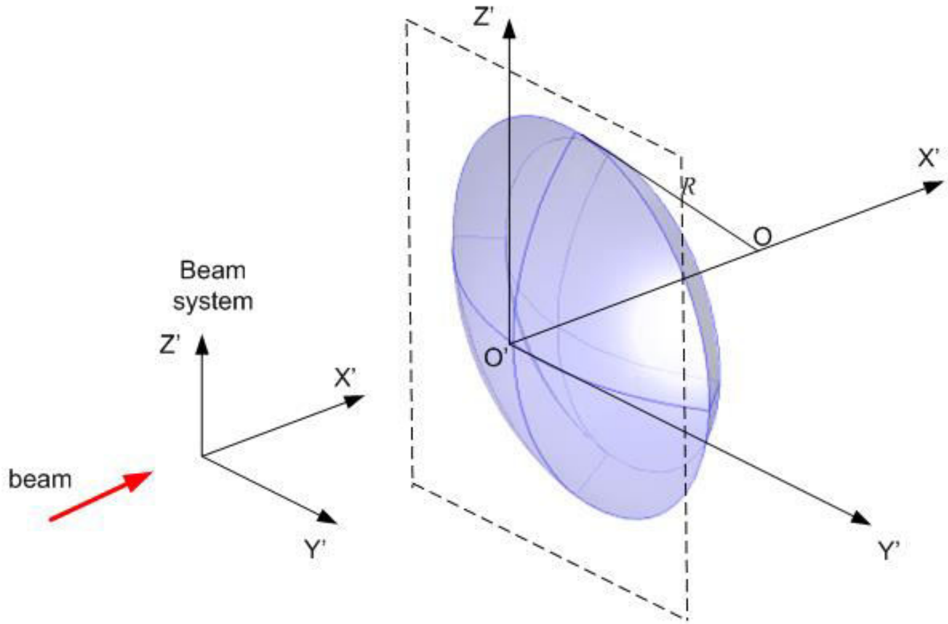
3. Many new technologies of fine work with crystals have been developed last years.

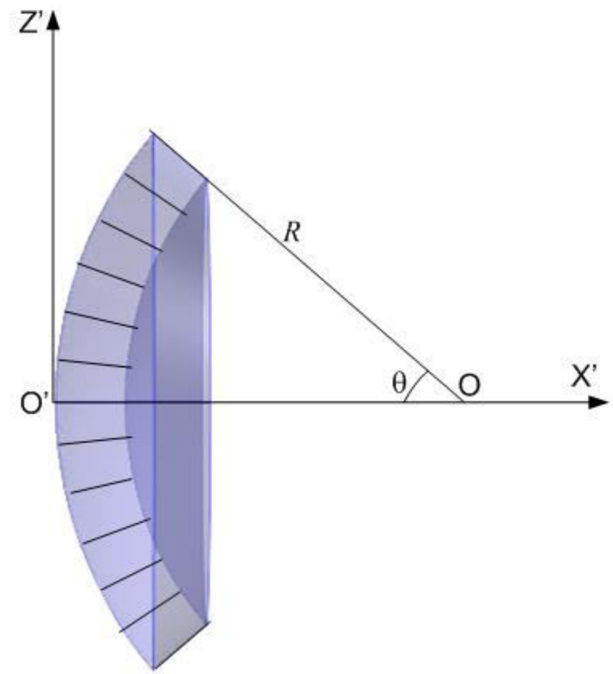
4. Various shapes of oriented crystals now could be used in channeling experiments.

5. Experimentalists are interested in new methods to work with “unusual” beams as muon beams, narrow beams, beams having complex phase space etc.

In this work the spherically bent crystal and its applicability for beam management is presented for the simplest case of uniform beam.

2. Spherically bent crystal





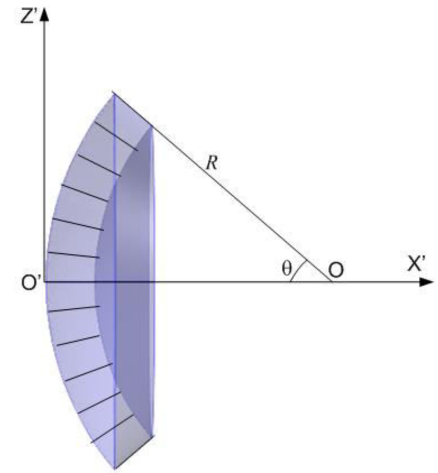
O - center of curvature; O' - the pole
Beam passage the crystal along axis X'

Crystallographic planes in X'Z' cross-section
2θ - angular dimension of the crystal
(X'Y'Z') - crystal system

The spherically bent crystal is the crystalline plate that has surfaces bent spherically, i.e surfaces represented by a fragment of sphere. Beam of charged particles enters (and then exits) the crystal through spherically bent surface. The planar channeling in the crystal was simulated for the case when planes providing the channeling are orthogonal to enter (and exit) surfaces. The re-distribution of beam flux behind the crystal was modeled.

Re-distribution of beam flux is expected in Z' direction

3. Preliminary estimations



Definitions:

α - glancing angle to crystallographic plane at the enter point

α_{lim} - crytical Lindhard angle.

Estimations:

$\alpha<\alpha_{lim}$ - planar channeling is possible

$\alpha>\alpha_{lim}$ - planar channeling is impossible

$2\theta=2\alpha_{lim}$ - maximal angular size of the crystal when flux re-distribution can be found. Wide spherically bent crystals are useless to beam focusing and flux re-distribution. (1)

$2\alpha_{lim}$ - beam divergence gained by initially non-divergent beam in thick** crystal at planar channeling.

$2\alpha_{lim}R$ - transverse size of initially point-like beam in the focal plane (at the point O). (2)

From (1) and (2):

The transverse size of the wide beam behind the crystal is comparable with the transverse size of initial beam at distamces of the order of bending radius R.

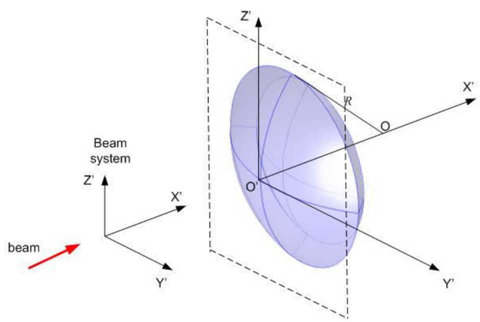
** Estimations are reasonable for thick crystals when particle makes at least several oscillations while it moves along the channel. Channeling in thin crystal may have complex features.

4. Model beam

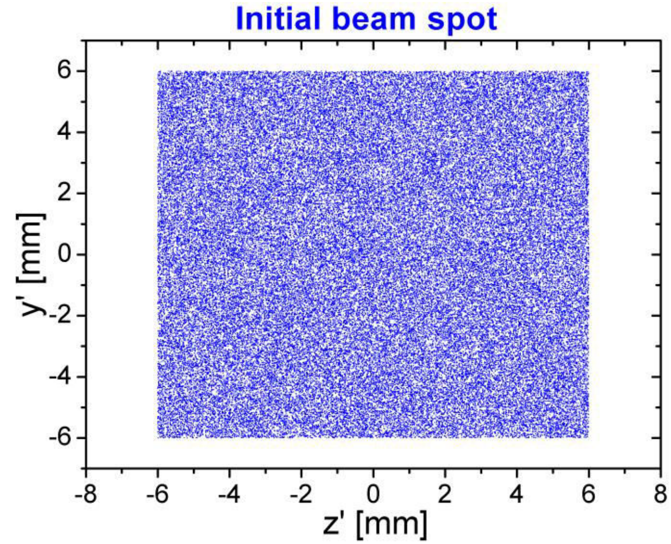
Beam:
- 35 MeV/c muons
- Beam size: 12 mm in Z' and Y'
- Non-divergent

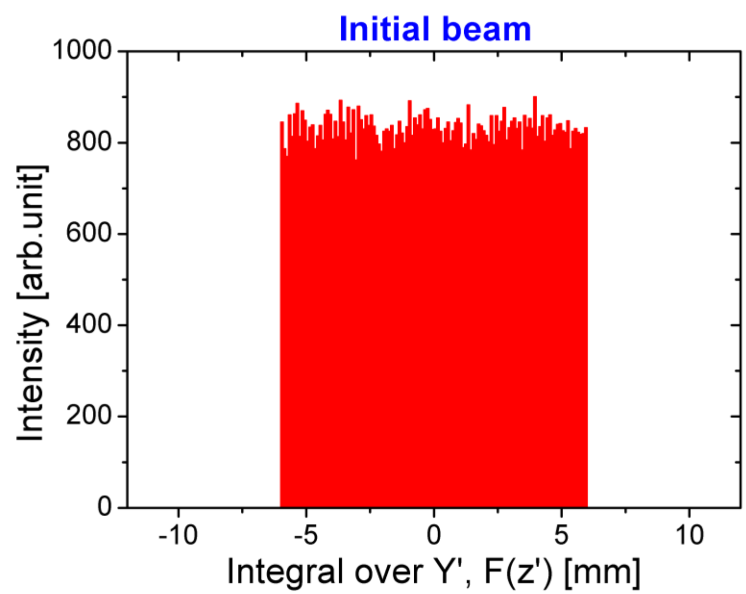
Crystal:
- (100)Si; R=4 m
- Crystal size: $\theta=\alpha_{lim}$=1.5 mrad (maximal effective size for that beam)
- thin crystal: 0.16 μm, 0.24 μm
- thick crystal: 3.2 μm

Simulations:
- Classical channeling model;
- Trajectories are tracked through a crystal;
- Deflection angle and particle's position are defined



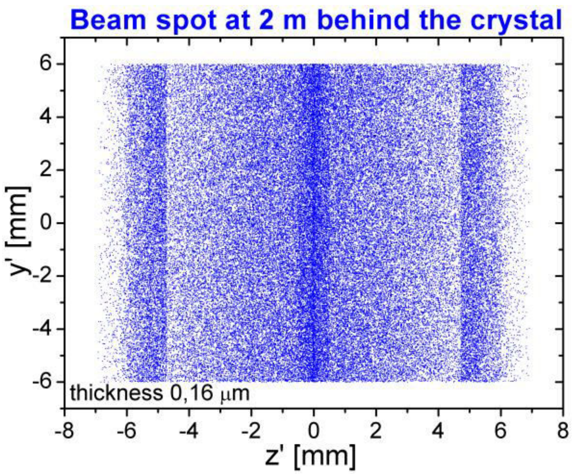
Initial beam: uniform, non-divergent:

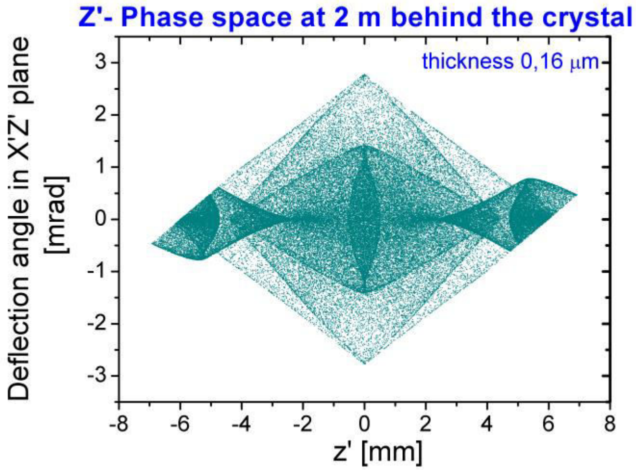




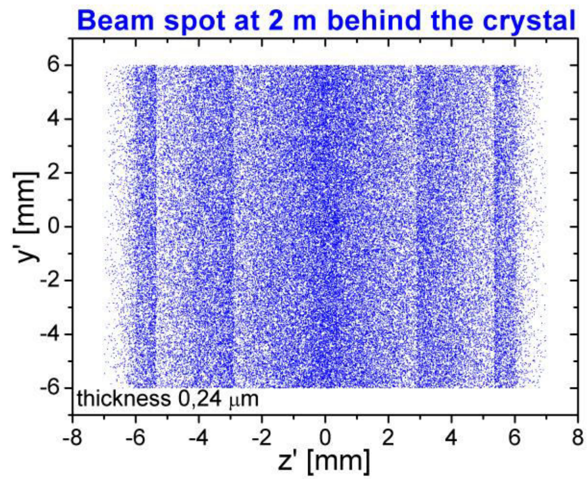
5. Beam at the distance 2m (R/2) behind the crystal

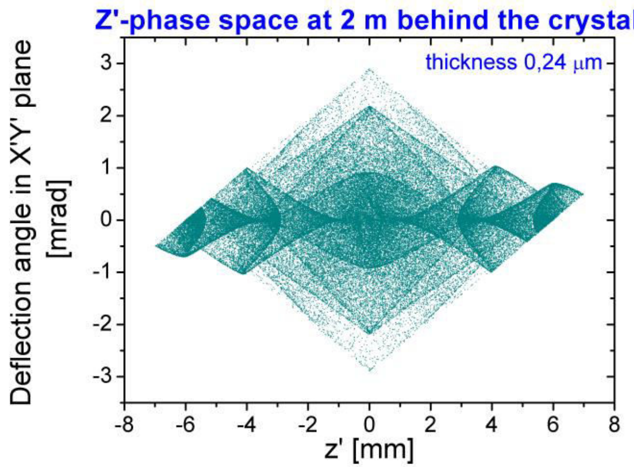
Thickness 0.16 μm:



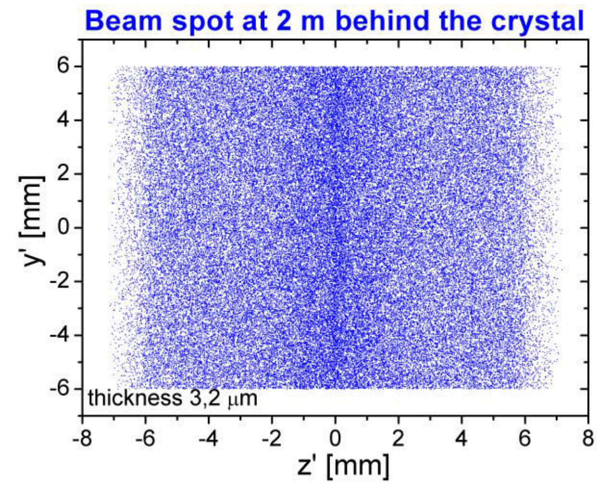


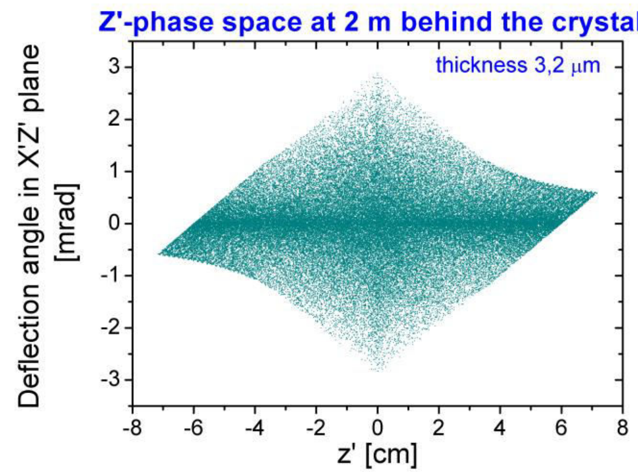
Thickness 0.24 μm:





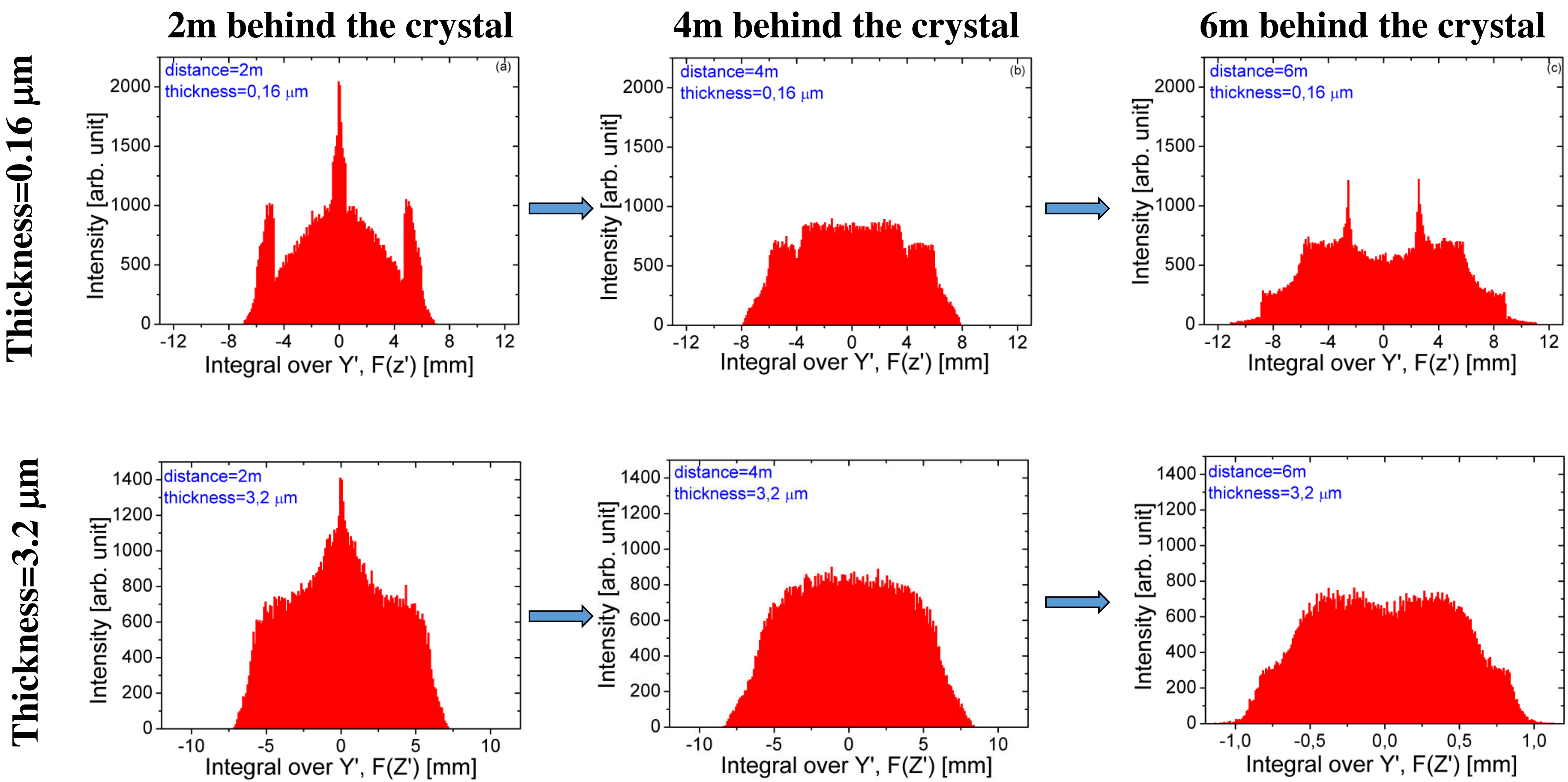
Thickness 3.2 μm:





- for thin crystals there are features arising due to particles have not time to complete one oscillation.
- for thick crystals that features are smashed and picture looks like something regular

6. Flux evolution behind the crystal



Integral of beam spot over Y' characterizes heterogeneity arising in the beam flux due to planar channeling in the crystal. This is the function of z'.

- both for thin and thick crystals the beam re-distribution is found as thin peaks of intensity.

7. Conclusion

- General picture of beam re-distribution is explained by the fact there is the variety of initial conditions (initial glancing angles) of channeling that provides variety of deflection angles behind the crystal.

- The narrow local maximuma of the flux are possible where intensity is higher than intensity of initial beam. That could be useful for beam shaping purposes.

- The beam distribution behind bent crystal can provide a partial focusing for optimized crystal thickness that is defined by the particles scattering due to interactions in averaged channeling potential.