On Prof. Sultan Dabagov anniversary:

Review of crystal channeling studies

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1. Intro

Starting from 2007 through FAI visits and post-doc:

1. Crystal channeling tasks

2. Electromagnetic wave channeling tasks

3. And something more

More than 10 papers in English and Russian, a lot of reports at “Channeling” conferences.

Frascati station, 2007

2. Crystal channeling

Crystal channeling tasks (theory and simulations):

1. Quantum channeling theory

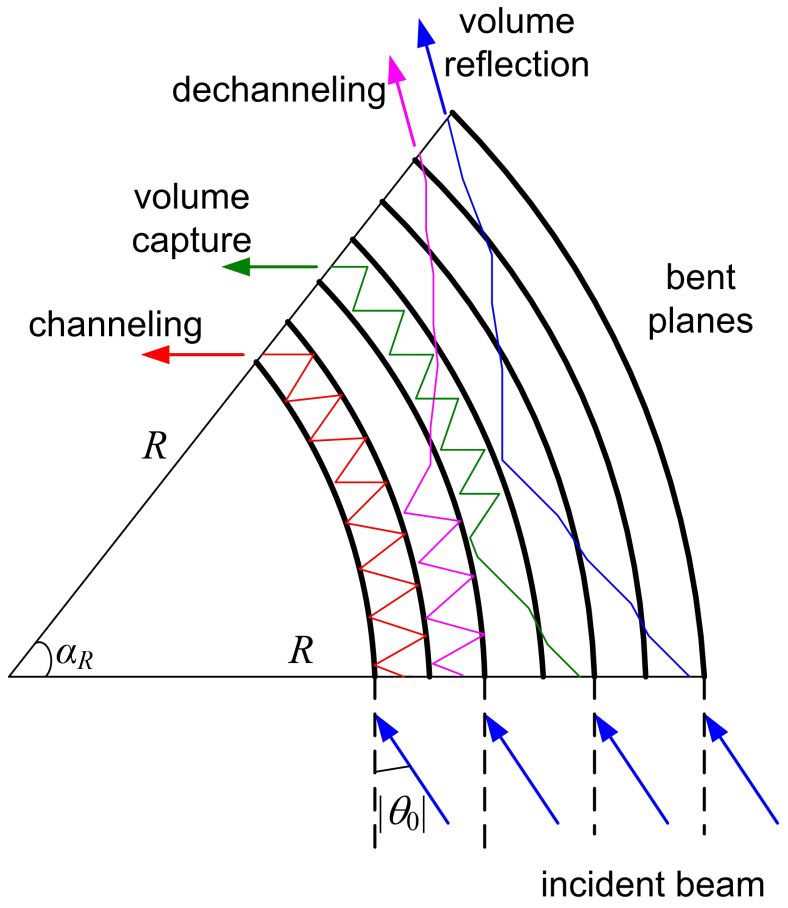
2. Planar channeling in bent crystal

3. Inelastic nuclear interactions at planar channeling

4. Beam deflection by miscut surface

5. Spherically bent crystal? (unfinished study)

Types of planar motion in bent crystal

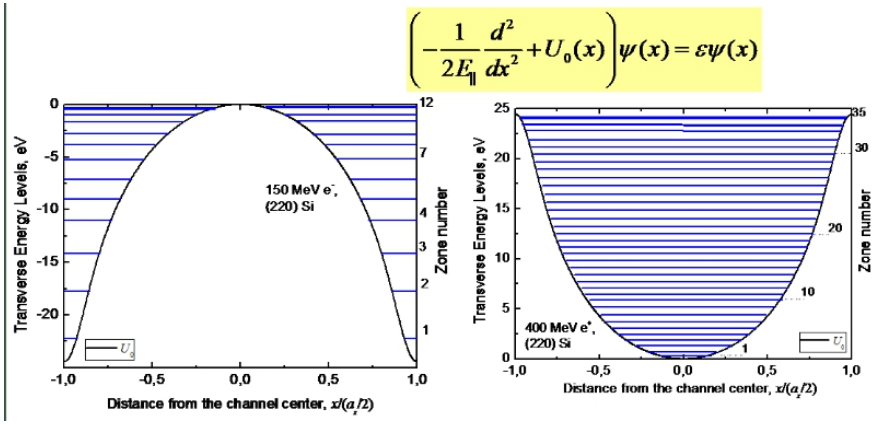


3. Quantum channeling simulations

At the general topic: “Dynamics of bound state populations for channeled electrons/positrons at BTF conditions”

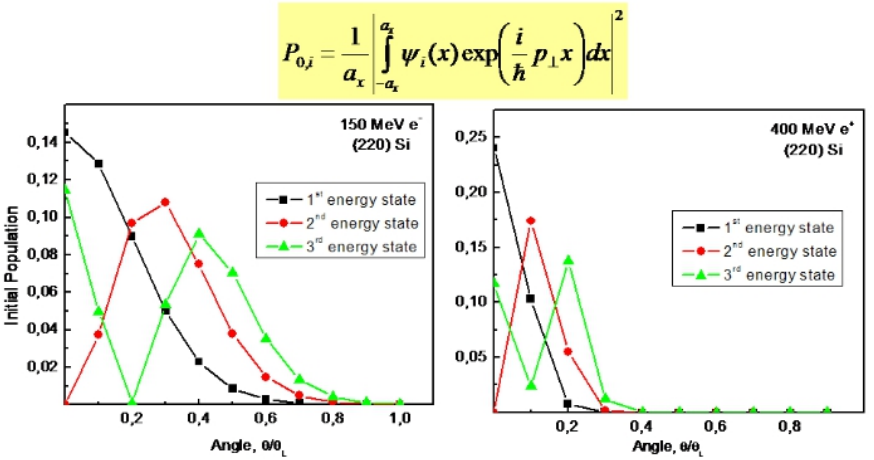
Results:

1. Spectrum of bound states at planar channeling.



2. Populations of bound states at different incident angles.

3. Dynamics of populations while the beam propagates along the crystal.



4. Planar channeling in bent crystal

Classical channeling theory: trajectory modeling. Results summary in:

Springer Link

Regular Article | Published: 04 June 2012

Simulations of planar channeling of relativistic nuclei in a bent crystal

A. Babaev & S. B. Dabagov

The European Physical Journal Plus **127**, Article number: 62 (2012) | Cite this article

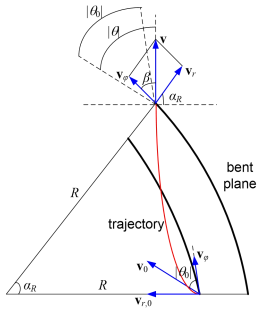
124 Accesses | **21** Citations | Metrics

Abstract

The motion of relativistic nuclei through an oriented bent crystal was considered on the basis of a developed computer code. To get the angular distributions of projectiles behind the crystals and to estimate the influence of multiple scattering on beam deflection, a detailed study of the beam dynamics due to the processes of channeling, dechanneling and quasichanneling of the particles is presented. The analysis of the beam redistribution in a crystal was performed simulating the main features of the scattering of relativistic Pb ions and protons in the field of bent crystal planes. The comparison of simulated data with experimental ones has been also carried out.

- It looks, this is one of most comprehensive paper on the simulations of channeling in bent crystal.

- Our work includes trajectories determination, dechanneling and volume reflection, divergent beams etc.



5. Beam tracking: NSBC code

The code "Nuclei scattering in bent crystal":

1. Tracking of beams with arbitrary initial phase space distribution through the bent crystal.

2. Determination of angular distribution of scattered protons/nuclei.

3. Phase space modeling.

4. Multi-pass and collimation studies.

5. Multi-crystal systems.

Experiment:

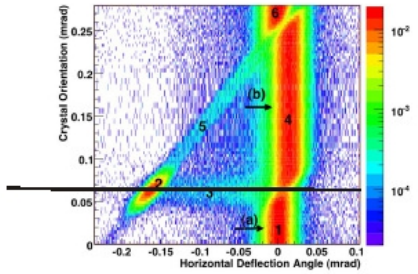
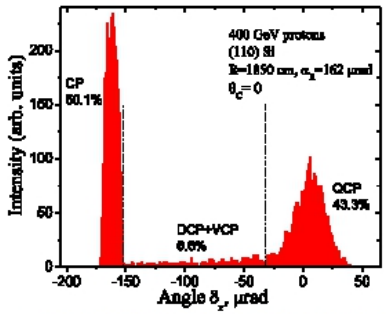


FIG. 3 (color online). Beam intensity recorded by the silicon microstrip detectors as a function of the horizontal deflection angle (x axis) and the crystal orientation (y axis). Six regions can be distinguished: (1) and (6) nonchanneling mode; (2) channeling; (3) dechanneling; (4) volume reflection; (5) volume capture. The wider angular acceptance of volume reflection compared to channeling is clearly visible in the figure.

Simulations:



The effect which brings the main contribution to the angular distribution: CP — channeling; QCP — quasichanneling; DCP — dechanneling; VRP — volume reflection; VCP — volume capture.

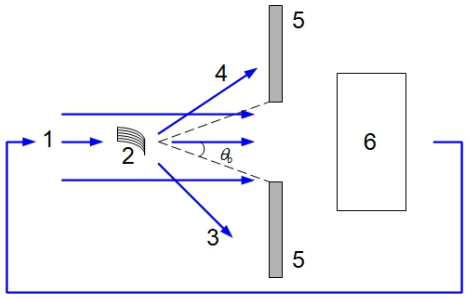
δ_x — is the angle between beam direction and projectile X-velocity at crystal exit;
θ_C — is the crystal orientation angle.
Simulated distribution is cross-section of experimental angular scan;
The approximate position of simulated distribution is pointed out by solid line;
The dot line designates the approximate position of θ_C=0.

6. Inelastic nuclear interactions (INI)

Multi-turn model for beam passage approriate for beam collimation studies.

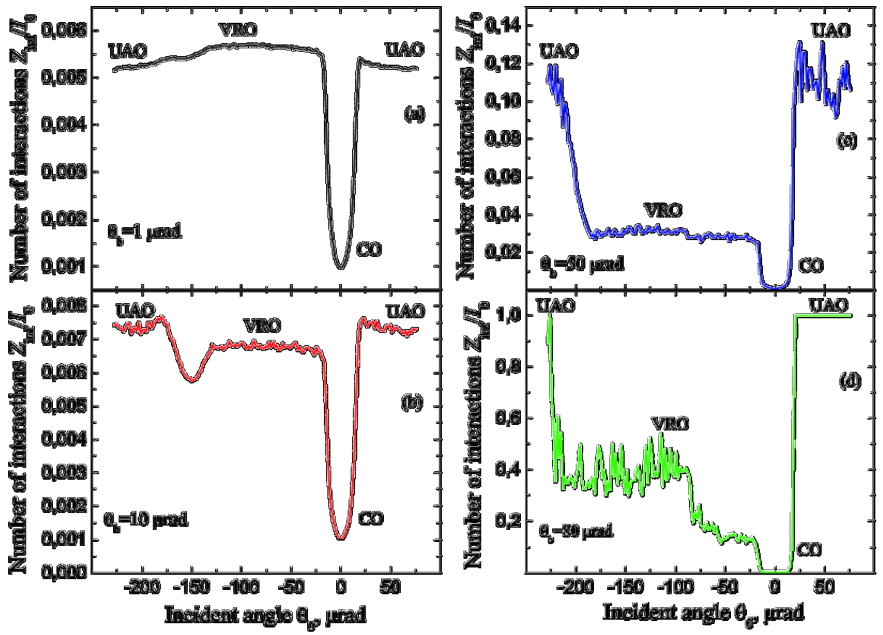
- INI simulations at beam passage in the bent crystal (between beam protons/nuclei and crystal nuclei).
- Beam particles “feel” different crystal nuclei density in average depending on their motion mode (channeling, quasichanneling, volume reflection) => INI probability depends on crystal orientation (CO, UAO, VRO).

Idealized scheme of bent crystal collimator:

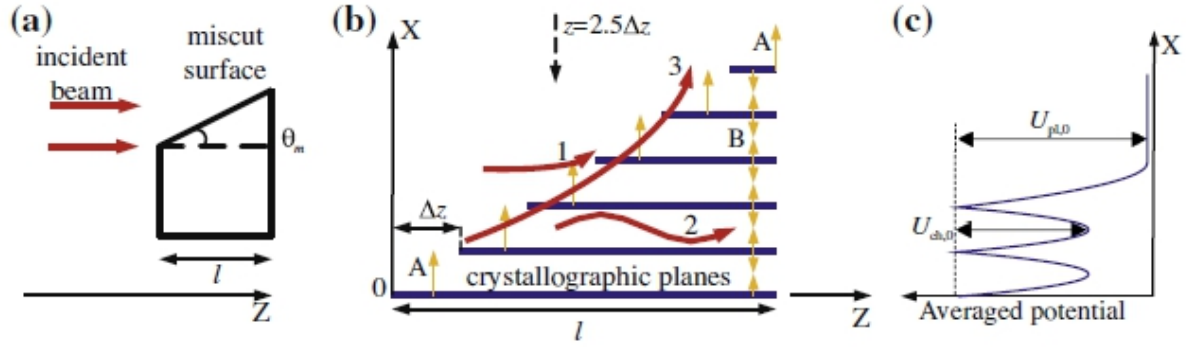


1 – the initial parallel proton beam, 2 – the bent crystal, 3 – the channeled protons, 4 – the reflected protons, 5 – the absorber, 6 – the focusing system making the beam parallel, restoring initial beam profile; θ_b – cutting angle; the particles deflected at angles $|\theta|>\theta_b$ hit the absorber and leave the beam.

Beam fraction (top estimation) can be lost due to INI at different cut-off angles θ_b as the function of crystal orientation angle



7. Beam deflection by miscat surface



- The idea: Particles (3) moving along miscut surface are deflected outward the surface due to successive kicks provided by single-plane fields (A) forming the staircase structure.

The question: How effective this kind of deflection could be?

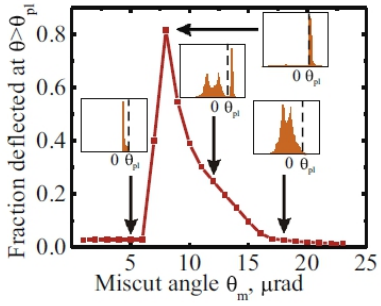


Fig. 3. Beam fraction deflected at $\theta > \theta_{pl}$ as a function of miscut angle θ_m. Insets: angular distributions corresponding to miscut angles shown by arrows. The distributions are shown in Fig. 2 and one corresponds to the curve maximum. The non-divergent 270 GeV per unit charge beam of Pb nuclei hits the ideal miscut surface of Si crystal along (1 1 0) planes, $\theta_{pl} \approx 15$ μrad.

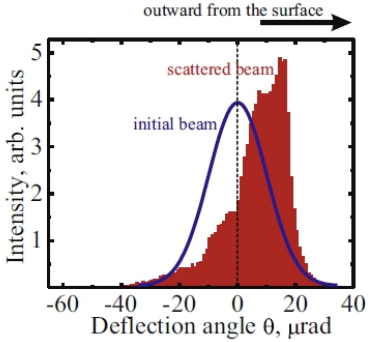


Fig. 5. Angular distribution of 270 GeV per unit charge Pb nuclei beam scattered by the ideal (1 1 0) Si miscut surface (θ_m = 8 μrad). The initial beam is Gauss-divergent with σ = 10 μrad.

8. Many thanks and Congratulations

[1] A A Babaev, S B Dabagov, Simulations of Electron and Positron Planar Channeling for BTF and SPARC Beams. *J. Phys.: Conf. Ser.* **236** (2010) 012028.

[2] Babaev A. A. , Dabagov S. B., Inelastic nuclear interactions at protons multiple passage in bent crystals. *Journal of Physics: Conference Series* **357** (2012) 012032.

[3] A A Babaev, S B Dabagov, Simulations of planar channeling of relativistic nuclei in a bent crystal, *European Physical Journal Plus* **127** (2012) 62.

[4] A Babaev, G Cavoto, S. B. Dabagov, The loss of ions at beam multiple passage through a bent crystal, *Nucl. Instr. and Meth. in Phys. Res. B* **309** (2013) 120.

[5] A Babaev, G Cavoto, S B Dabagov. On the deflection of a positron beam by the miscut surface of an oriented crystal. *JETP Letters* **100(9)** (2014) 550.