

*HIGH-ENERGY CHARGED PARTICLE
DEFLECTION BY A BENT CRYSTAL IN TEV
ENERGY REGION*

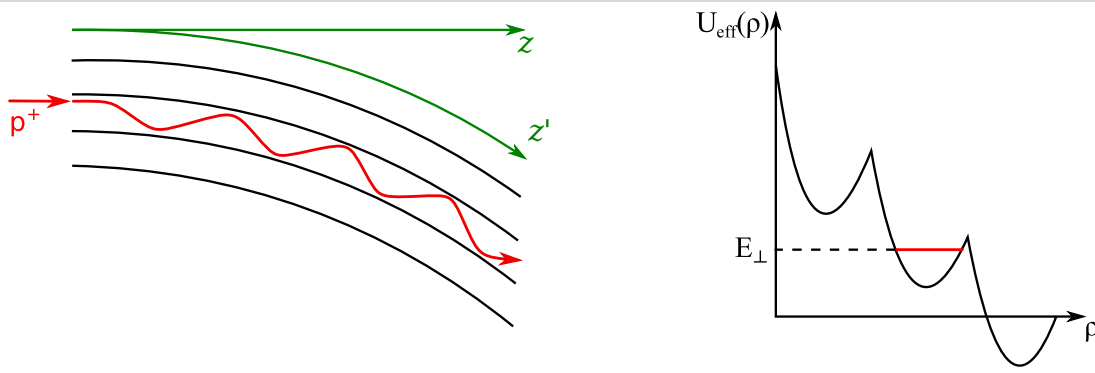
N.F. Shul'ga, I.V. Kirillin, V.I. Truten'

*Akhiezer Institute for Theoretical Physics of NSC KIPT, 61108 Kharkov,
Ukraine*

5th International Conference - Channeling 2012

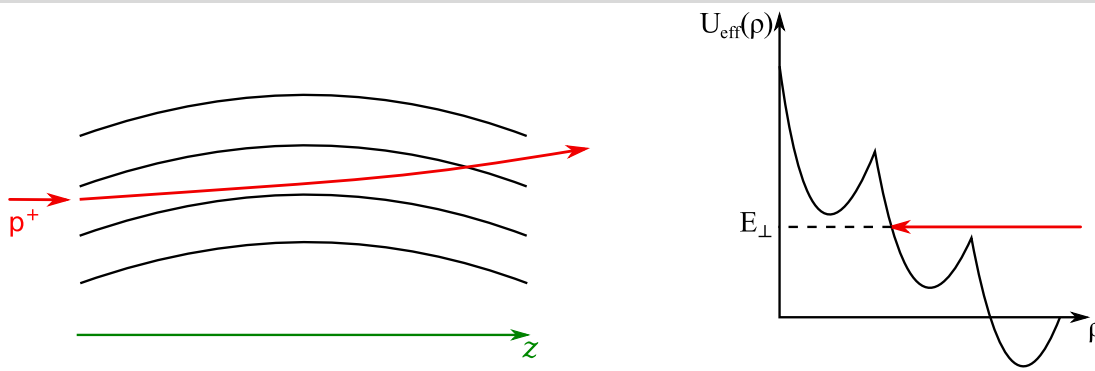
MECHANISMS OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY BENT CRYSTALS

Planar channeling in bent crystal (*E.N. Tsyganov, 1976*)



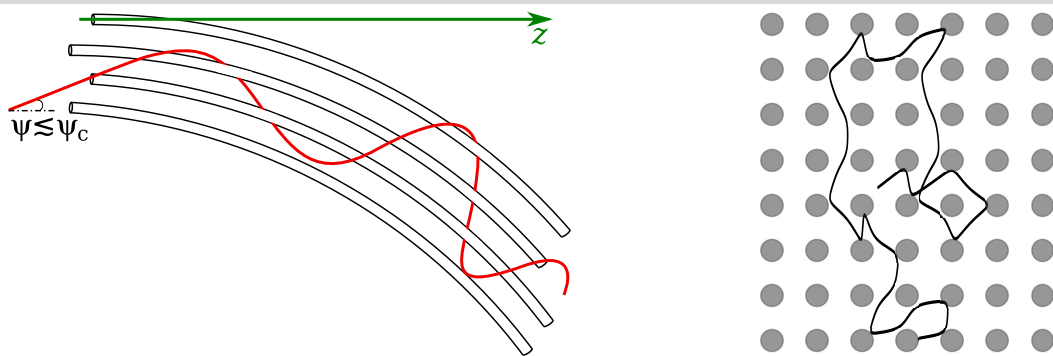
1979 — IHEP (Russia)
1980 — CERN

Volume reflection (*A.M. Taratin, S.A. Vorobiev, 1987*)



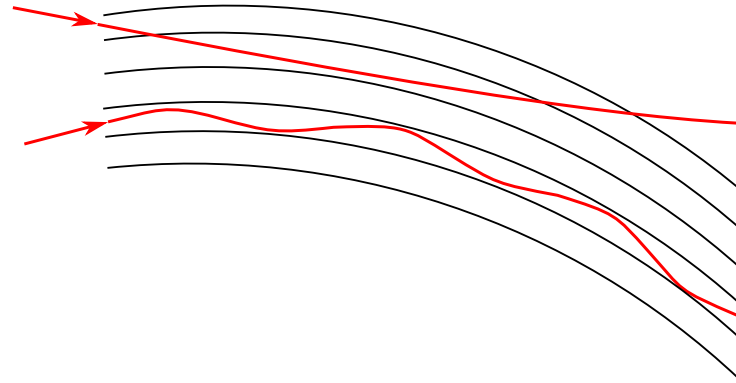
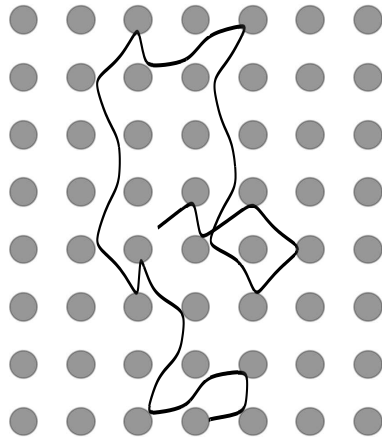
2006 — IHEP (Russia)
2006 — PNPI (Russia)
2007 — CERN

Stochastic deflection mechanism (*A.A. Greenenko, N.F. Shul'ga, 1991*)



2008 — CERN, protons
2009 — CERN, π^- -mesons

SIMULATION METHOD



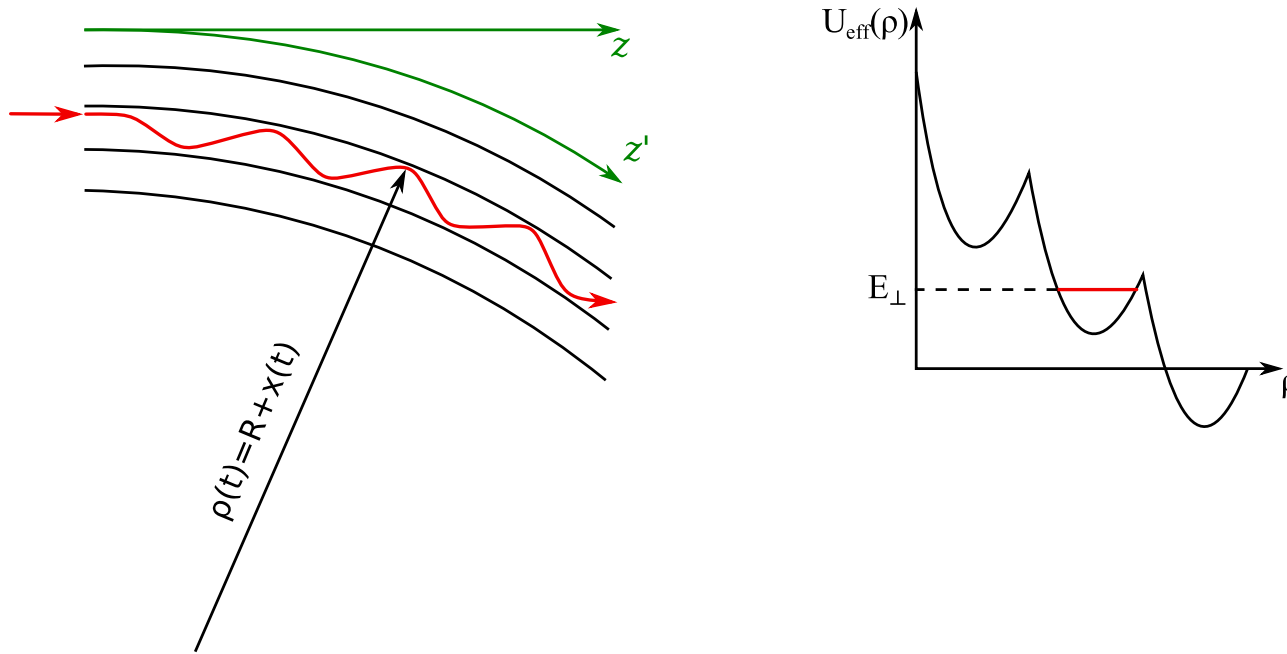
- ▶ particle motion in the field of crystal atomic strings
- ▶ incoherent scattering

- ▶ axial channeling
- ▶ multiple scattering by atomic strings
- ▶ planar channeling
- ▶ reflection from planes
- ▶ transitions between these processes

N. Shul'ga, V. Truten' and I. Kirillin. Journ. of Phys.: Conf. Ser. 236 (2010) 012030

N. Shul'ga, I. Kirillin and V. Truten'. Phys. Lett. B 702 (2011) 100

PLANAR CHANNELING IN BENT CRYSTAL



$$\frac{d^2 x}{dt^2} = -\frac{c^2}{E} \frac{\partial}{\partial x} U_{\text{eff}}(x), \quad U_{\text{eff}}(x) = U(x) - x \frac{E}{R}$$

$$R_c = d \frac{E}{4U_{\text{max}}}$$

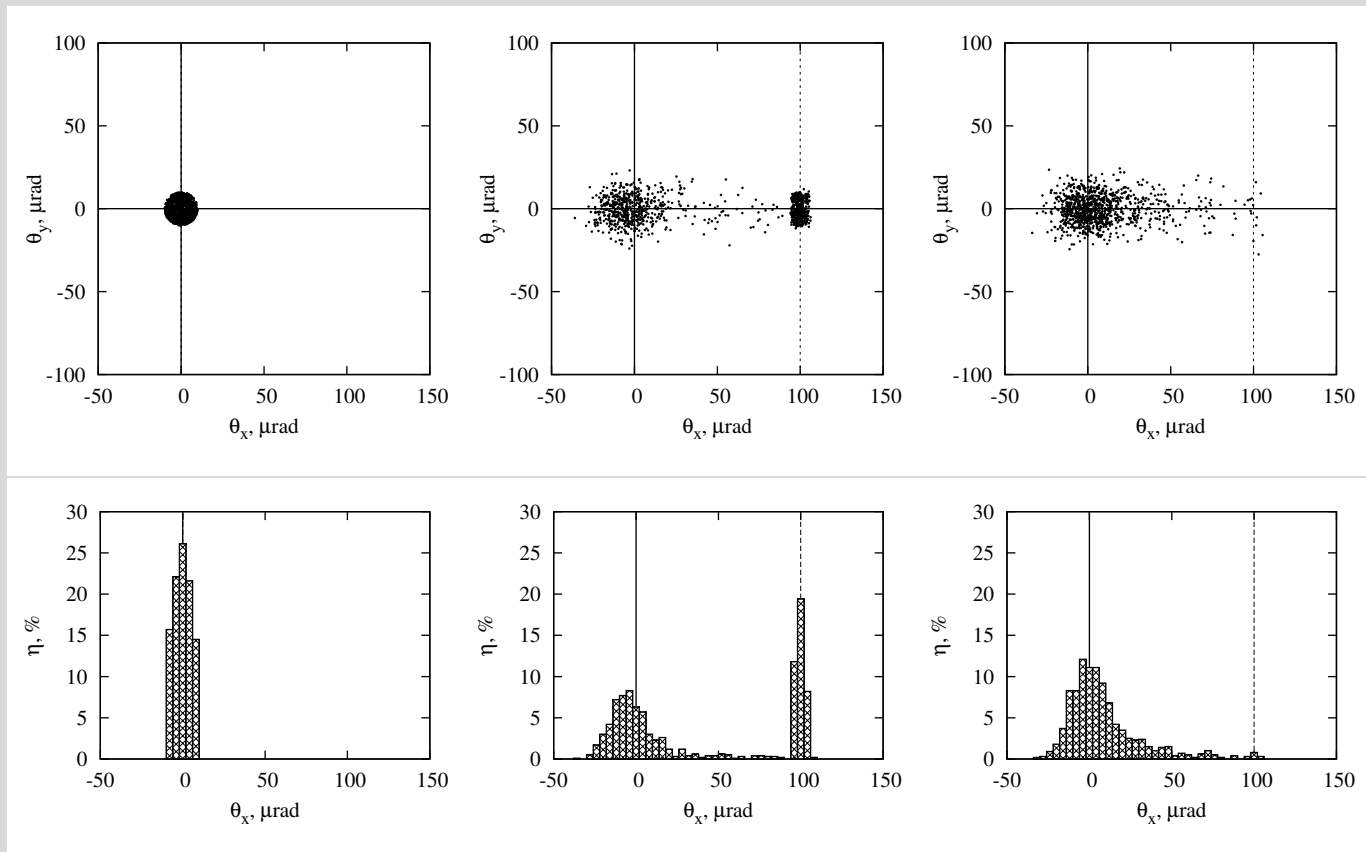
SIMULATION RESULTS

Planar channeling in bent crystal

particle beam before
entering the crystal

protons

π^- -mesons

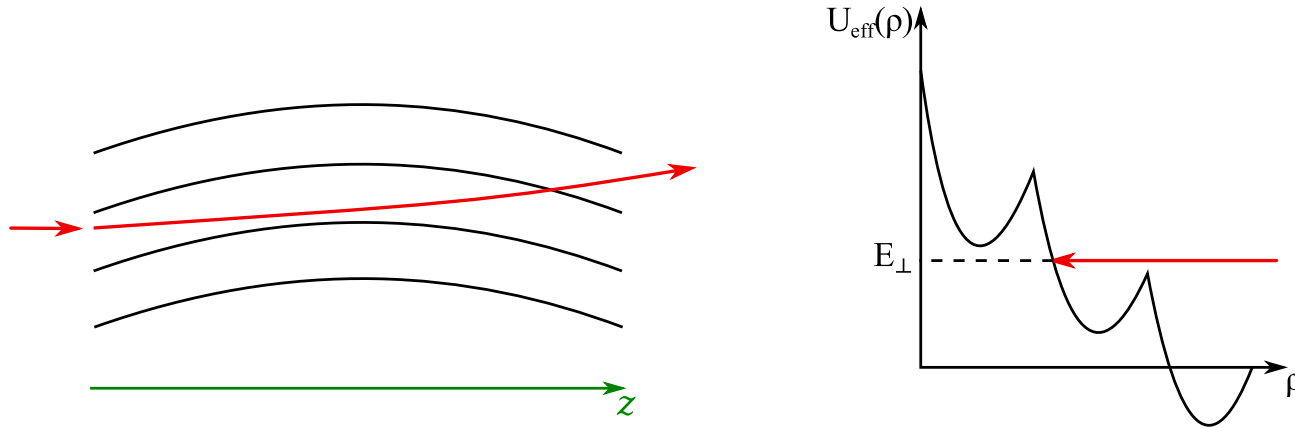


Beam center before entering the crystal had angular coordinates $(0, 500)$ μrad with
relative to the $\langle 110 \rangle$ crystal axis

$$(500 \mu\text{rad} \approx 50 \theta_c)$$

$$E=1 \text{ TeV}, L=2 \text{ cm}, R=200 \text{ m}$$

CHARGED PARTICLE REFLECTION FROM BENT CRYSTAL ATOMIC PLANES

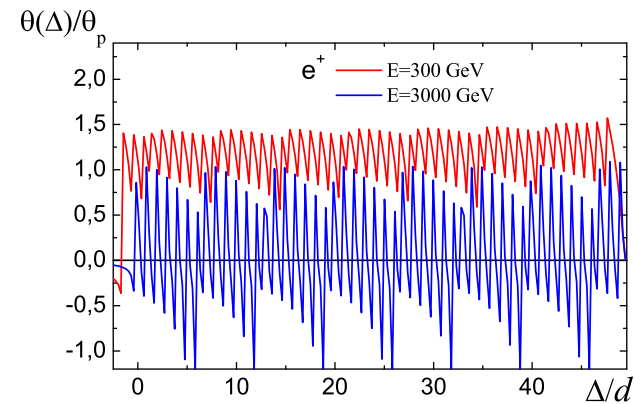
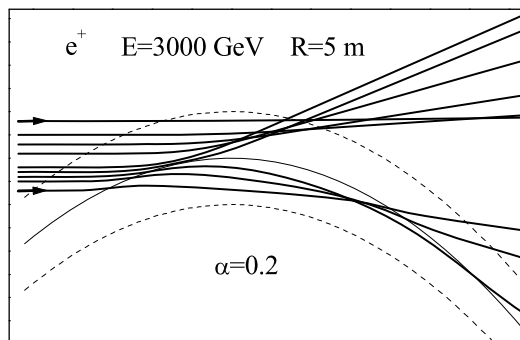
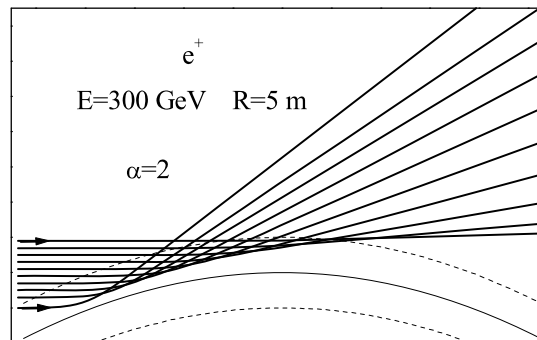
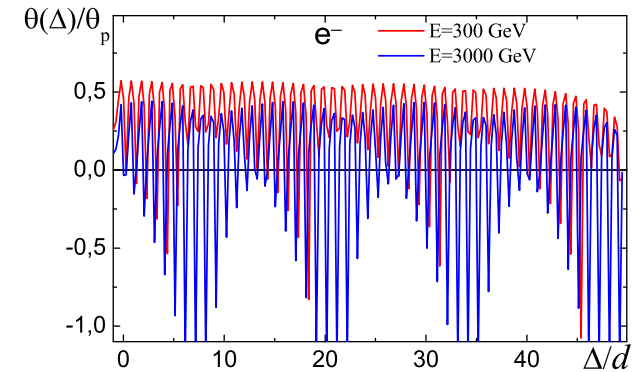
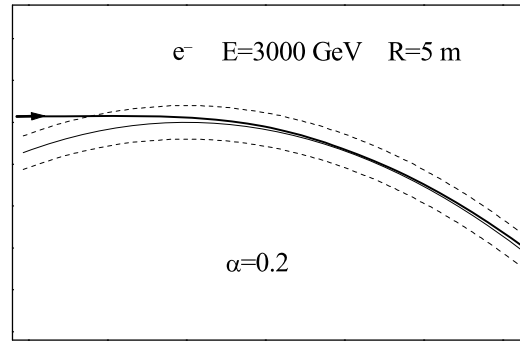
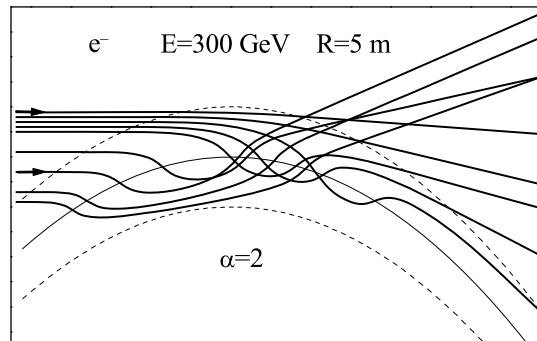


Particle reflection in the field of bent atomic planes can be considered as particle scattering in a cylindrically symmetric field.

$$\theta(b) = \pi - 2Mc \int_{\rho_0}^{\infty} \frac{d\rho}{\rho^2 \sqrt{(E - U(\rho))^2 - M^2 c^2 / \rho^2 - m^2 c^4}},$$

N.F. Shul'ga, V.I. Truten' et al. Phys. Lett. A 376 (2012) 2617

CHARGED PARTICLE REFLECTION FROM BENT CRYSTAL ATOMIC PLANES



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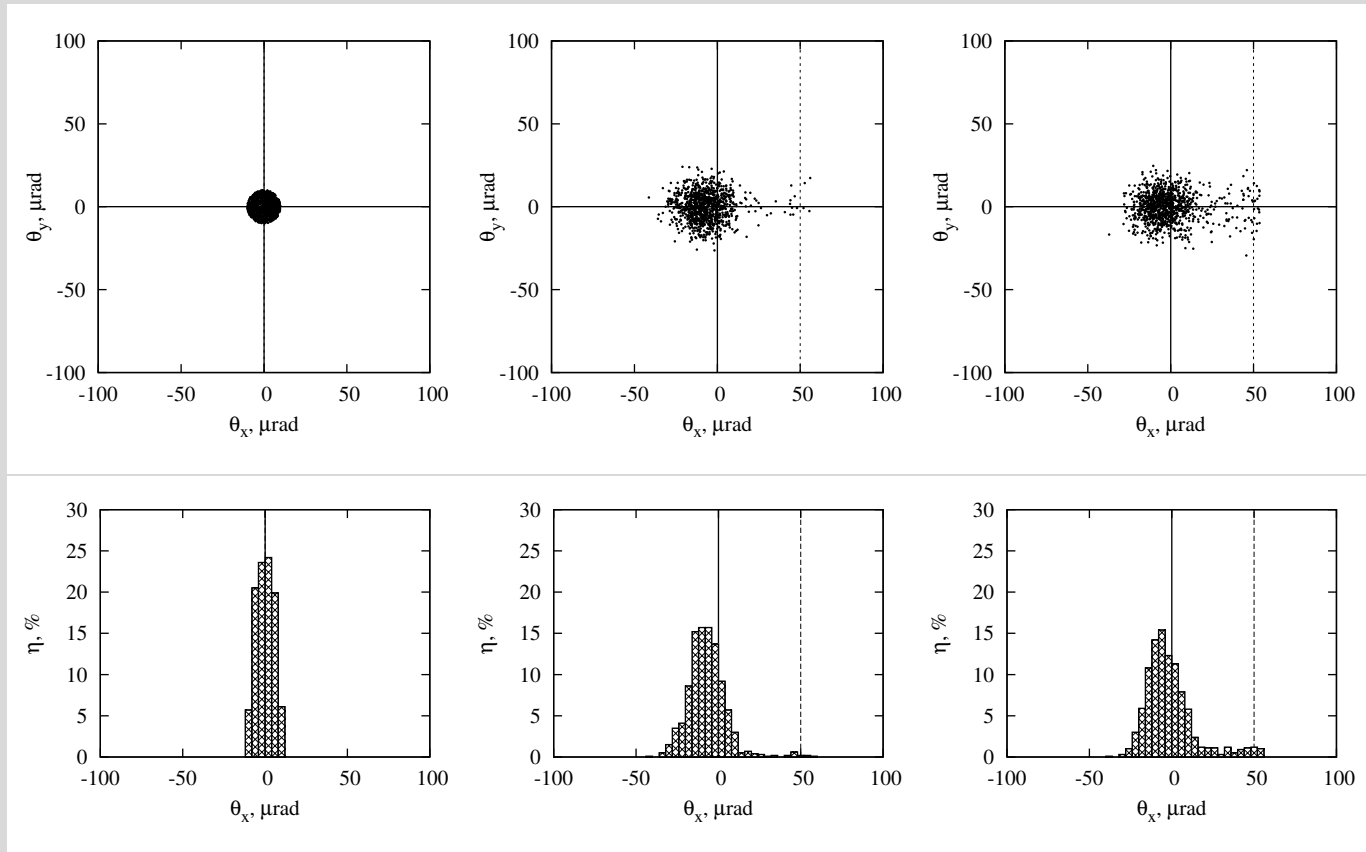
SIMULATION RESULTS

Charged particle reflection from bent crystal atomic planes

particle beam before
entering the crystal

protons

π^- -mesons



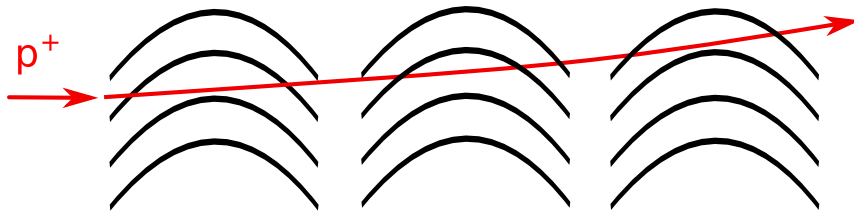
Beam center before entering the crystal had angular coordinates $(50,500)$ μrad with
relative to the $\langle 110 \rangle$ crystal axis

$$(500 \mu\text{rad} \approx 50 \theta_c)$$

$$E=1 \text{ TeV}, L=2 \text{ cm}, R=200 \text{ m}$$

THE WAYS TO ENHANCE CHARGED PARTICLE REFLECTION ANGLE

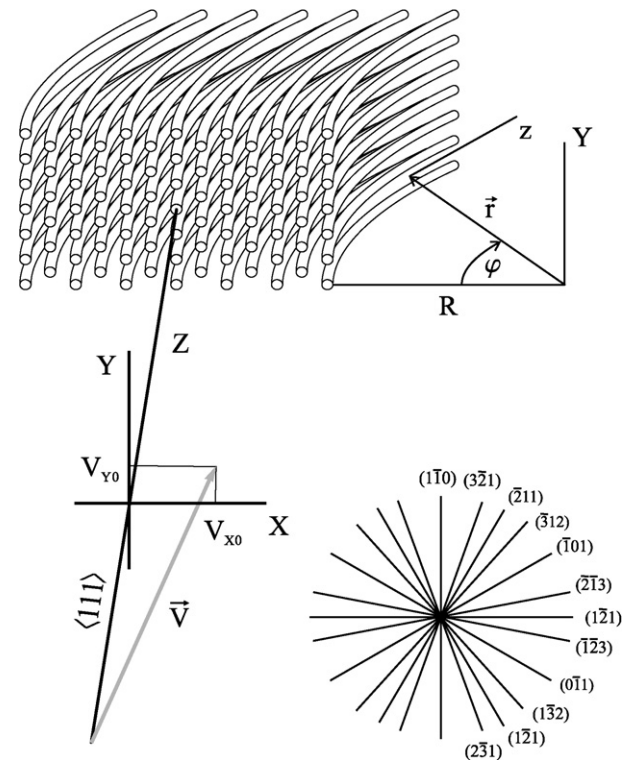
Volume reflection on several bent crystals



*W. Scandale et al. Phys. Rev. Lett. 102
(2009) 084801*

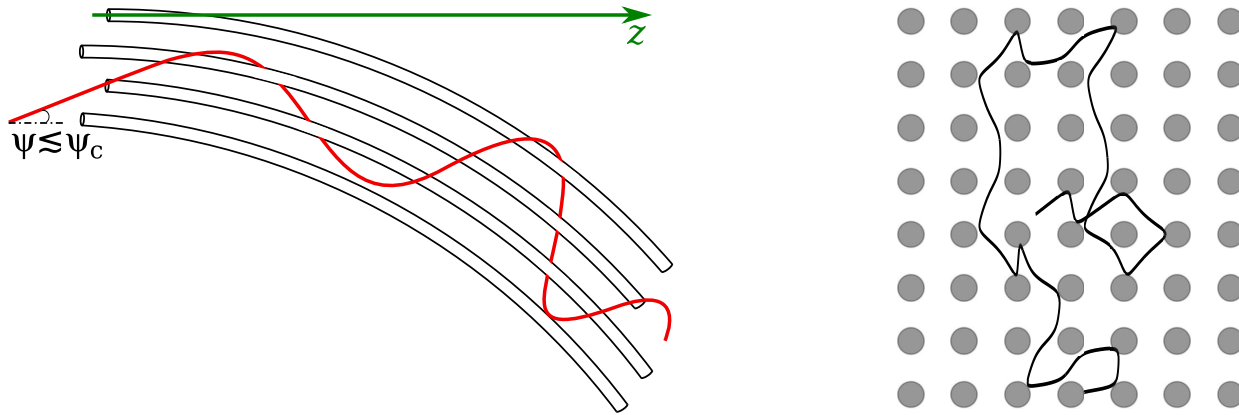
*A.G. Afonin et al. JETP Lett. 92 №4
(2010) 206*

Multiple volume reflection from different planes inside one bent crystal



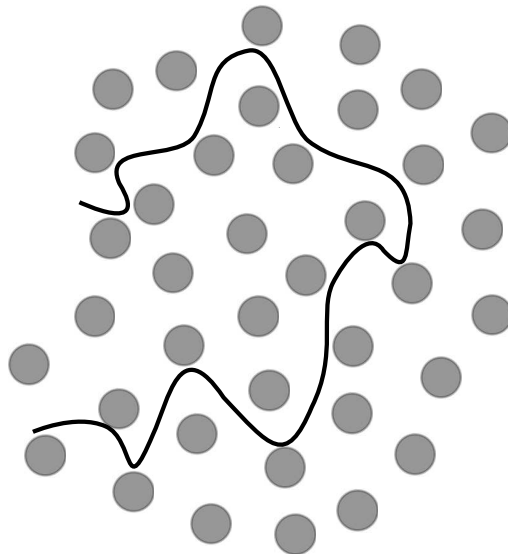
*V. Tikhomirov. Physics Letters B
655 (2007) 217*

STOCHASTIC DEFLECTION MECHANISM (DYNAMICAL CHAOS)



Greenenko-Shul'ga criterion: $\frac{l_{\perp}}{R\psi_c} \frac{L}{R\psi_c} < 1$

Analogy with particle scattering in random string approximation:



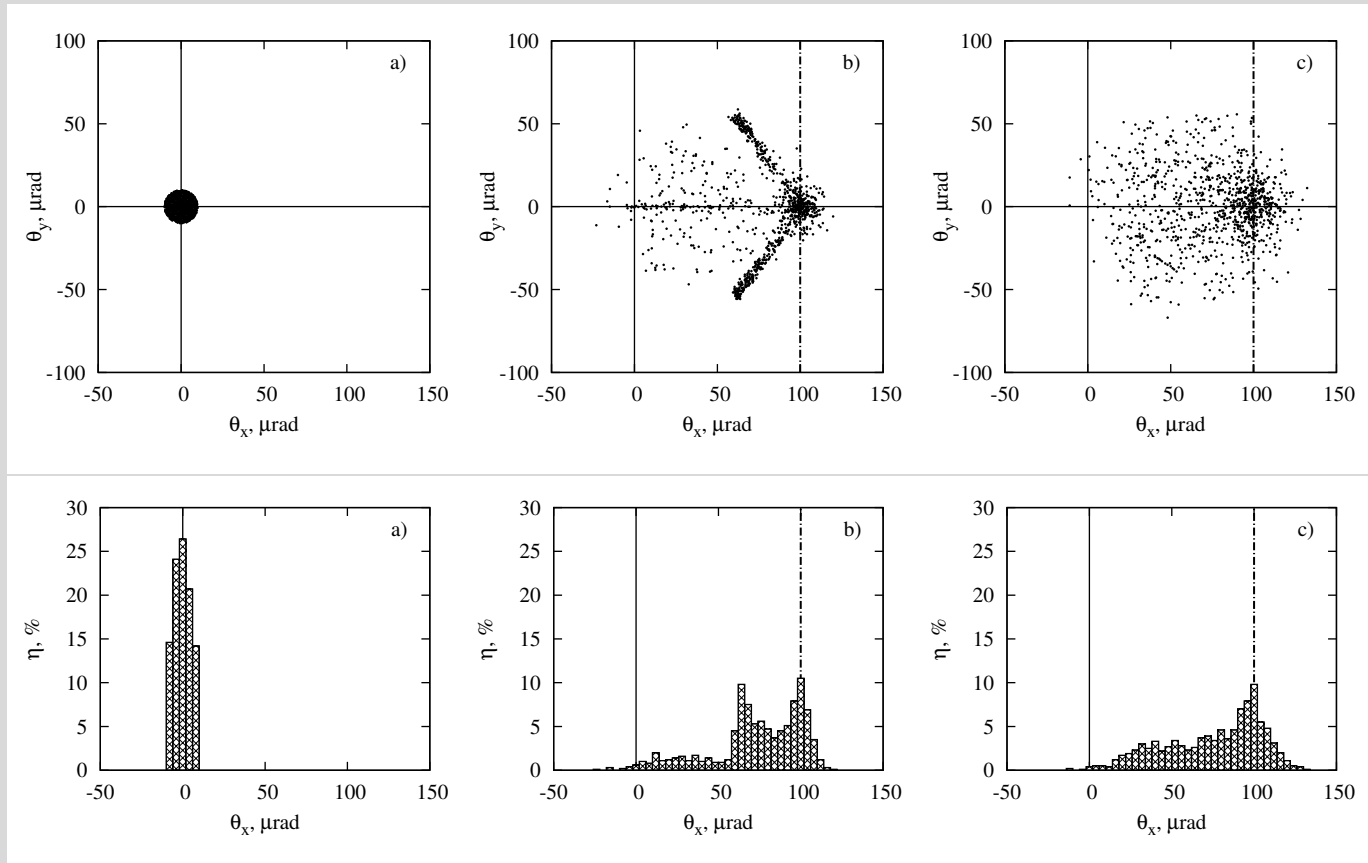
SIMULATION RESULTS

Stochastic deflection mechanism

particle beam before
entering the crystal

protons

π^- -mesons



Beam center before entering the crystal had the same angular coordinates as the $\langle 110 \rangle$ crystal axis

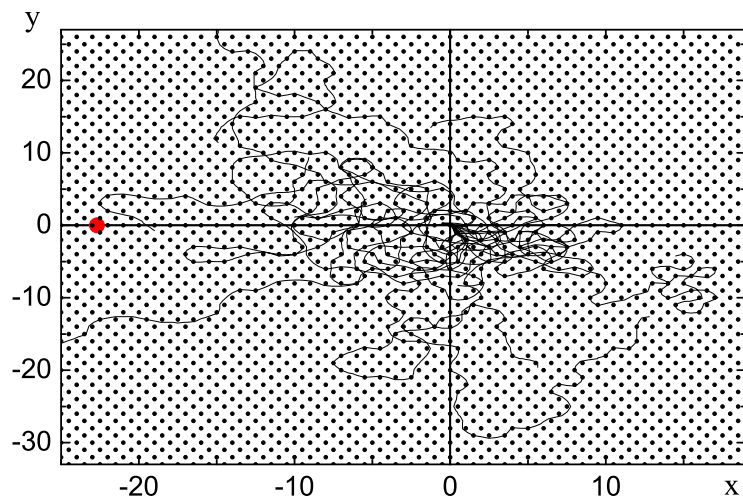
$$E=1 \text{ TeV}, L=2 \text{ cm}, R=200 \text{ m}$$

STOCHASTIC MECHANISM OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY A BENT CRYSTAL

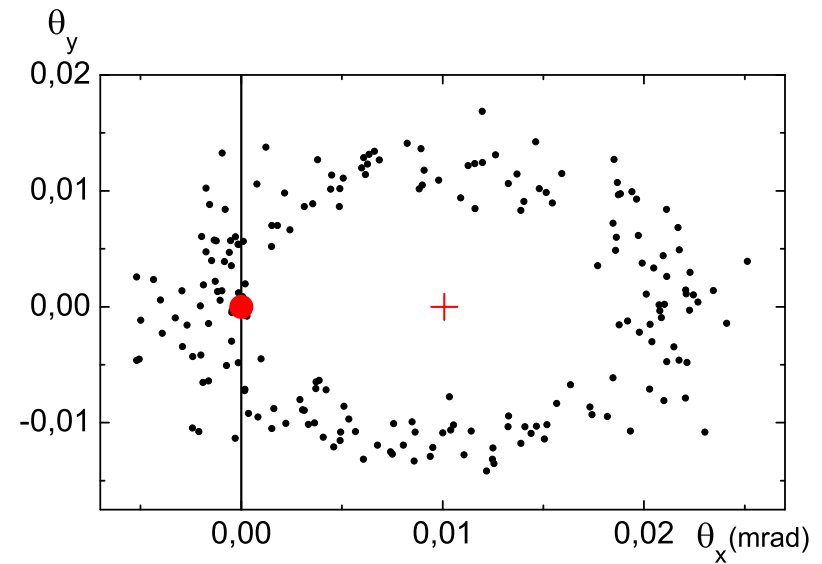
e^-

$L=0.1$ cm

trajectories



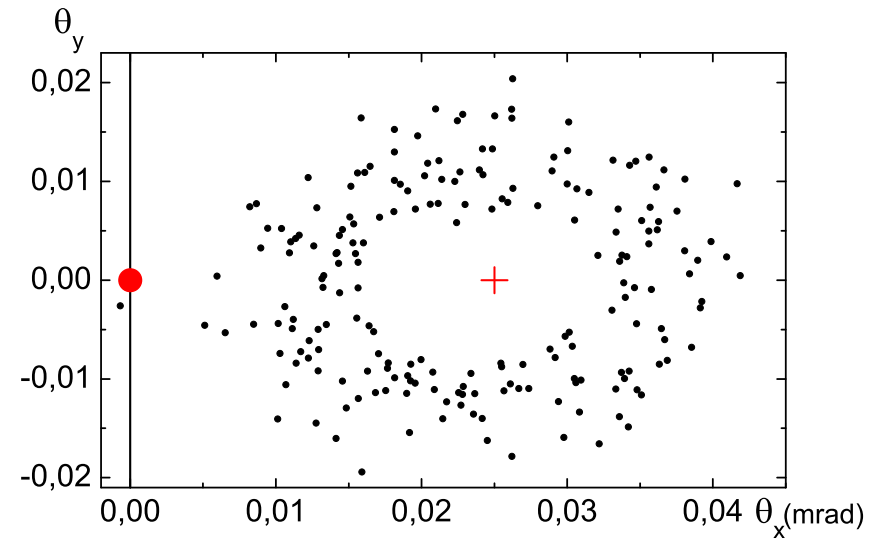
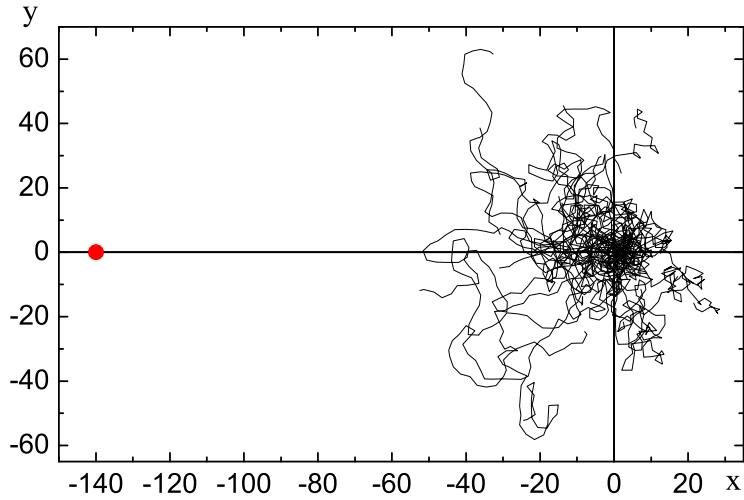
angular distributions



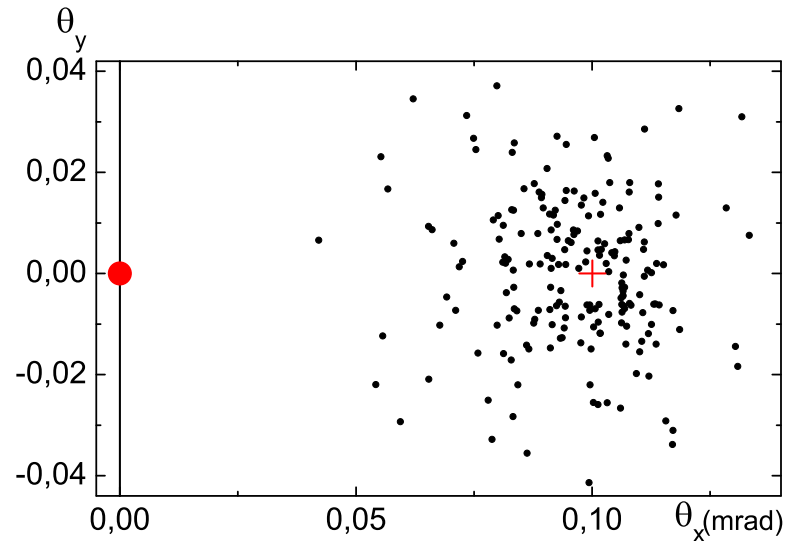
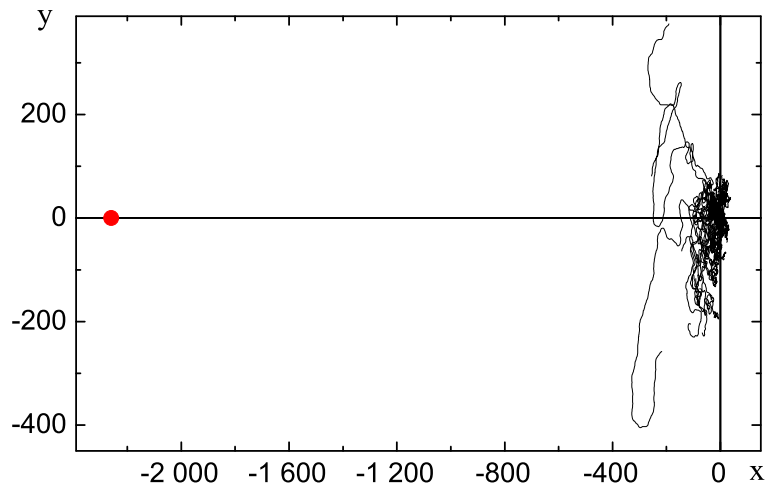
STOCHASTIC MECHANISM OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY A BENT CRYSTAL

e^-

$L=0.25$ cm



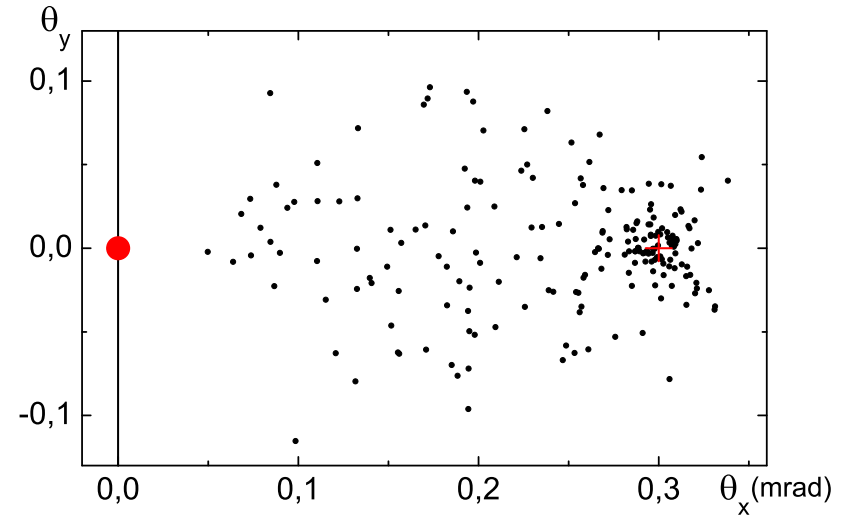
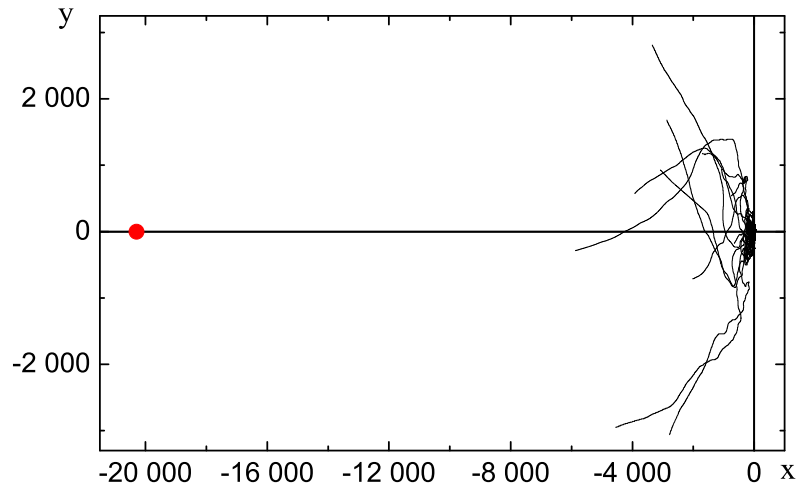
$L=1$ cm



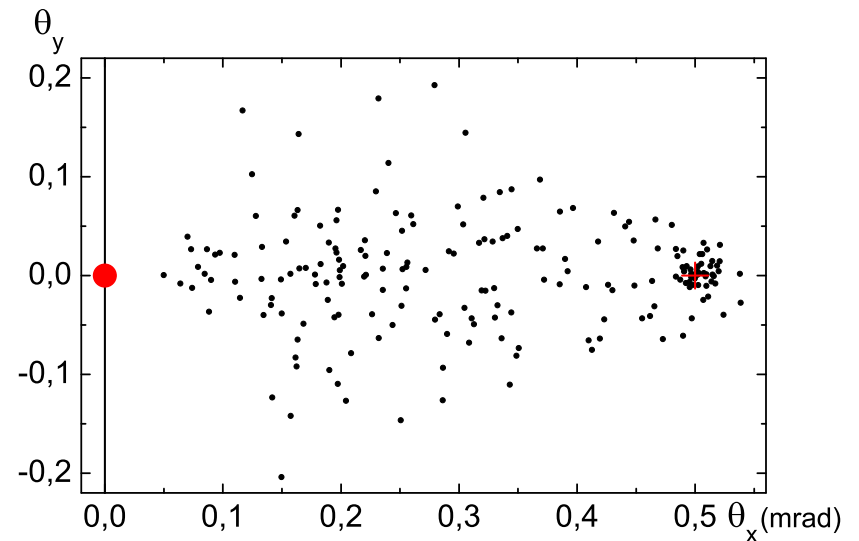
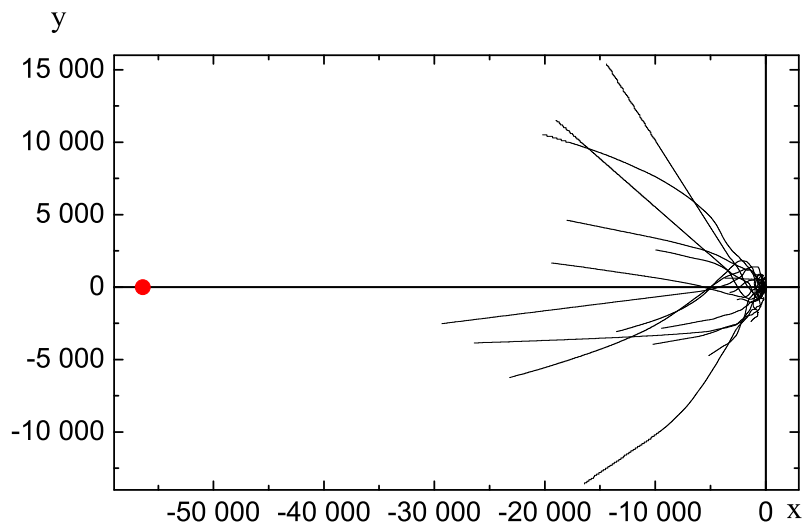
STOCHASTIC MECHANISM OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY A BENT CRYSTAL

e^-

L=3 cm



L=5 cm

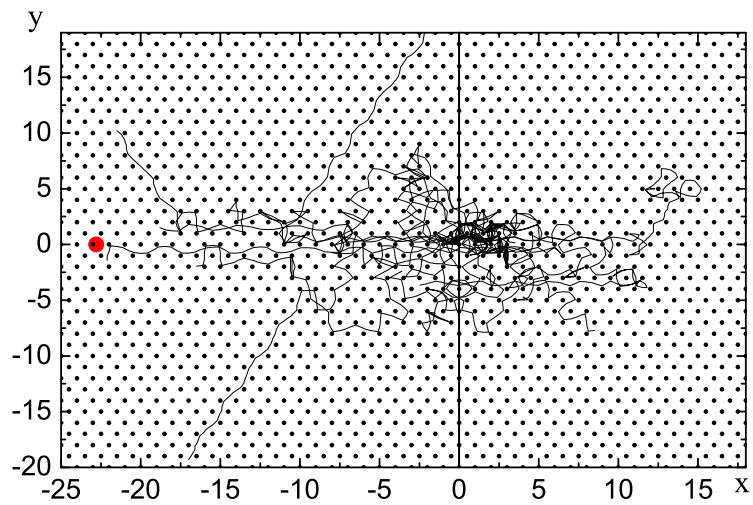


STOCHASTIC MECHANISM OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY A BENT CRYSTAL

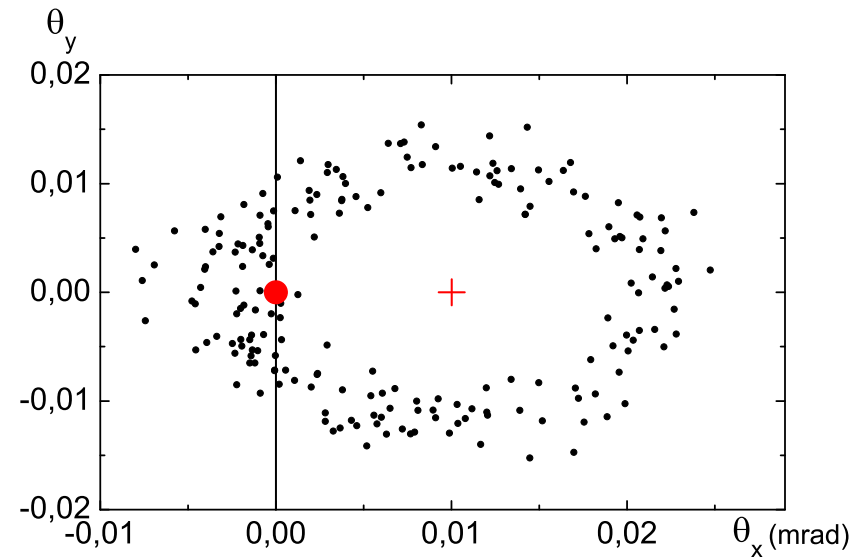
e^+

$L=0.1$ cm

trajectories



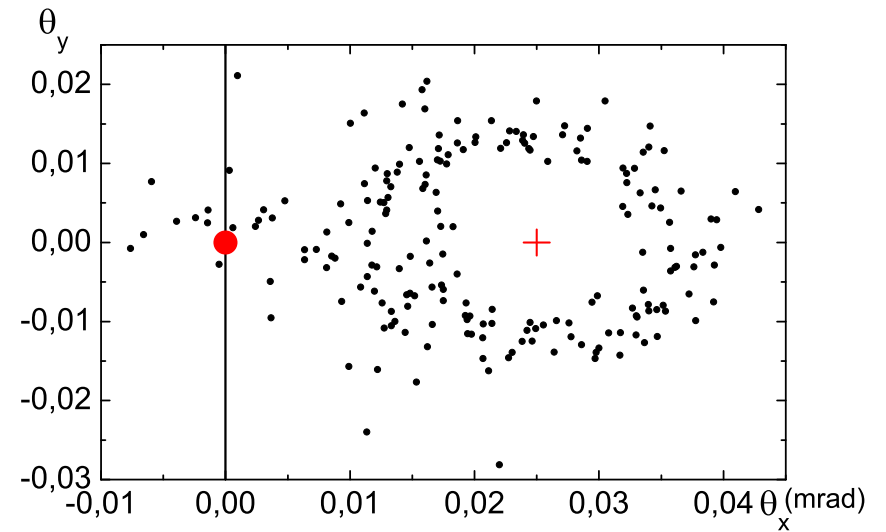
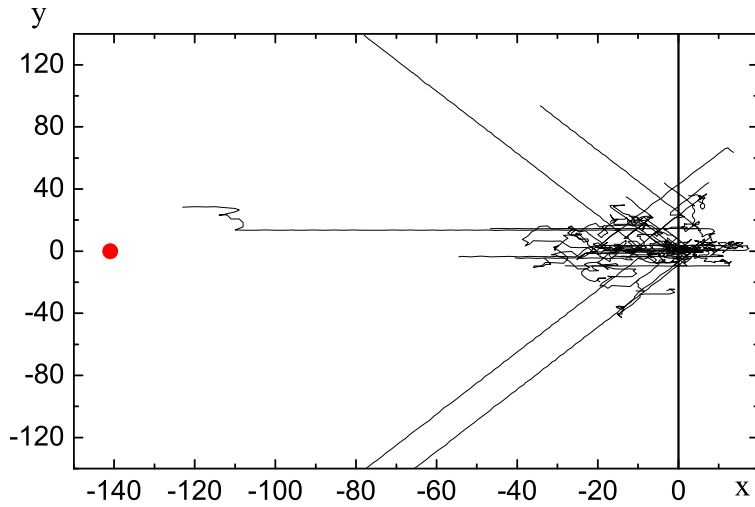
angular distributions



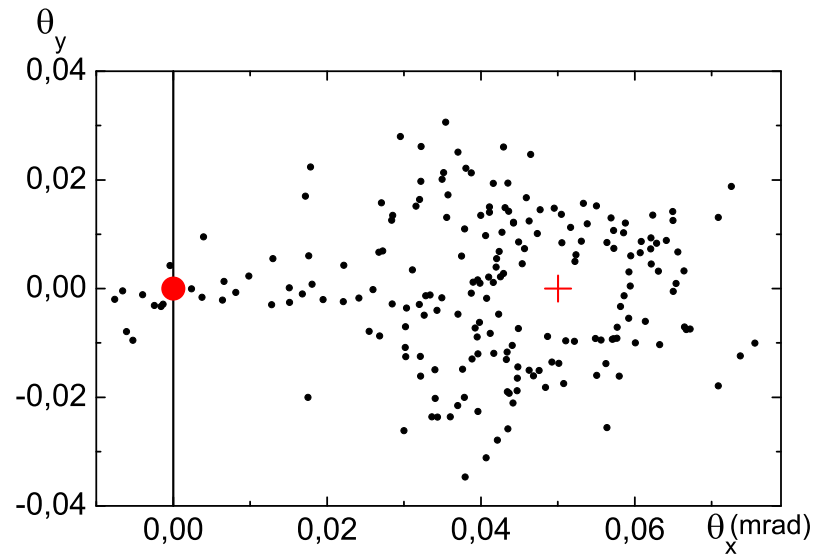
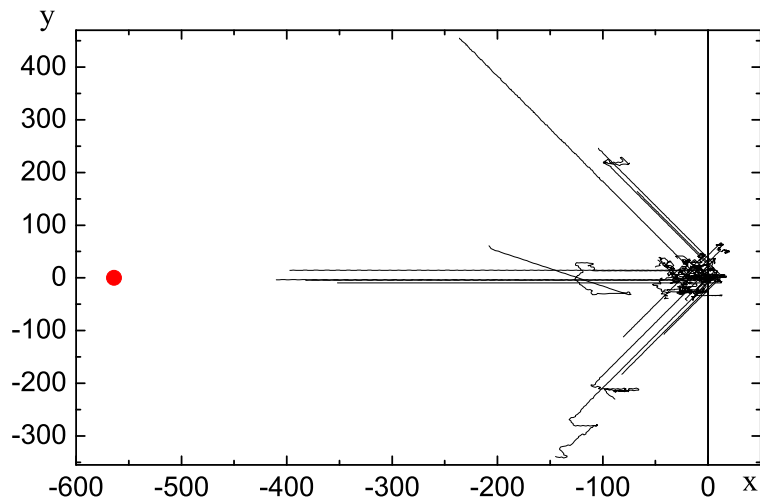
STOCHASTIC MECHANISM OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY A BENT CRYSTAL

e^+

$L=0.25$ cm



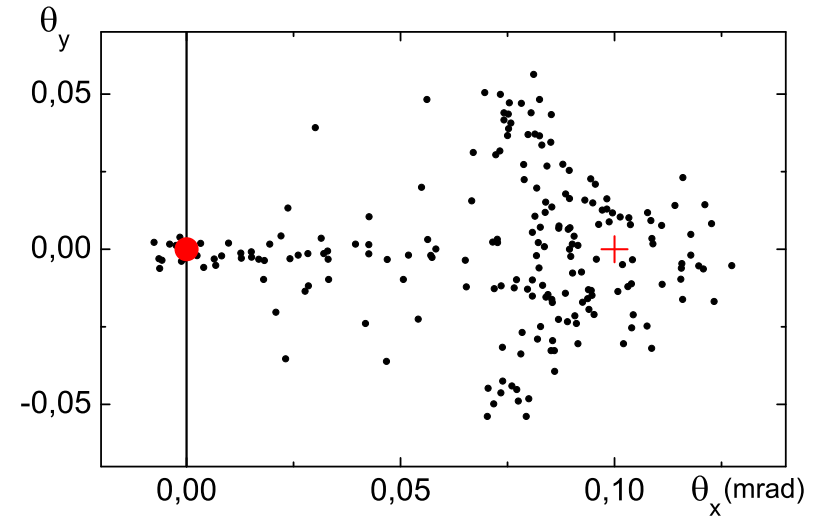
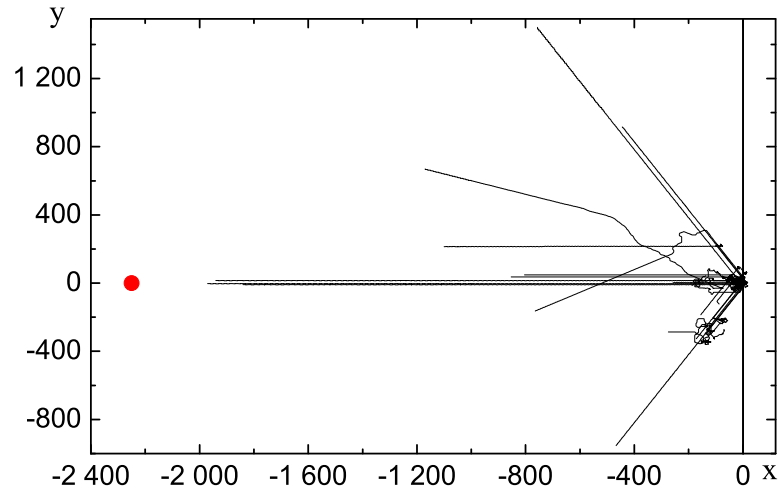
$L=1$ cm



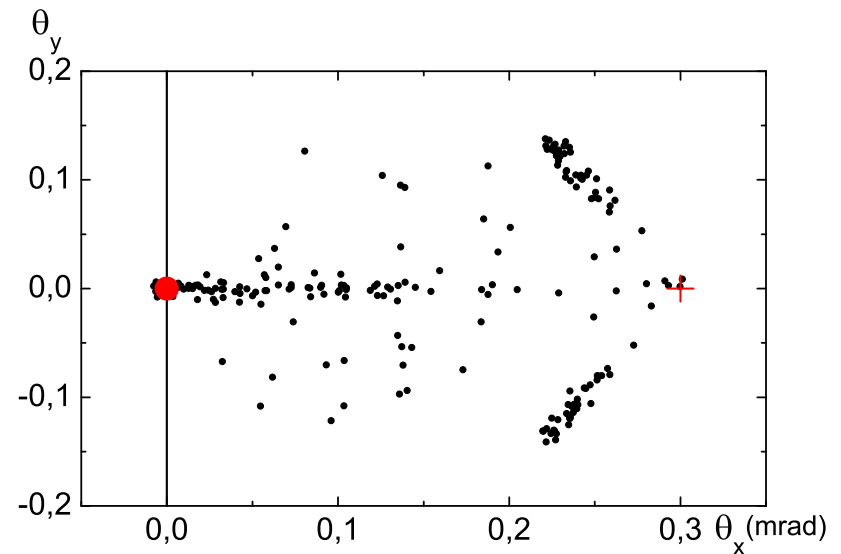
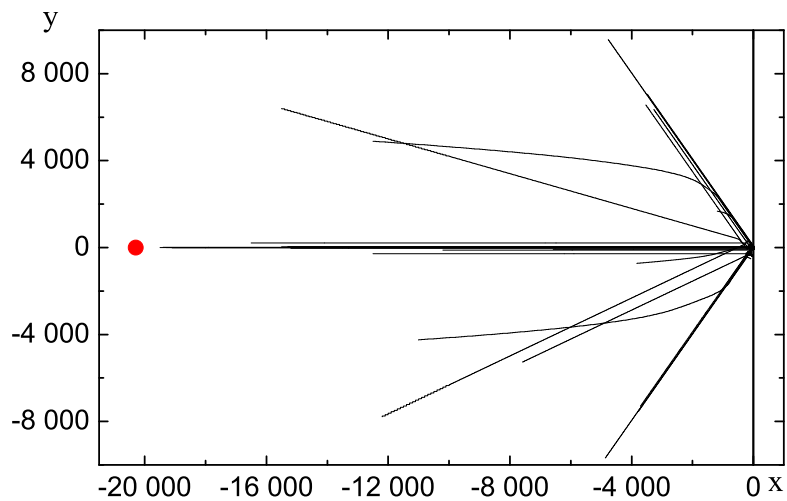
STOCHASTIC MECHANISM OF HIGH-ENERGY CHARGED PARTICLE DEFLECTION BY A BENT CRYSTAL

e^+

L=3 cm



L=5 cm



CONCLUSIONS FOR $E \sim 1$ TEV

- ▶ planar channeling is good for q^+
 - ▶ $\theta \gg \theta_c$
 - ▶ $\Delta\theta \lesssim \theta_c$
- ▶ volume reflection from bent crystal planes is good for q^+
 - ▶ $\theta \lesssim 2\theta_c$
 - ▶ deflection decreases with $E \rightarrow \infty$
- ▶ stochastic mechanism of deflection by bent atomic strings is good for q^+ and q^-
 - ▶ $\theta \gtrsim 3\psi_c$
 - ▶ beam splitting for q^+

Thank you for your attention!

