Observation of channeling and VR for negatively charged particles

Deflection due to CH and VR in bent Si crystals was observed for 150 GeV/c π^- at H4 beam line of CERN SPS

Deflection efficiency was about 30% for CH and 80% for VR

Volume reflection occurs, in spite of the attractive character of forces acting between particles and crystal planes

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Channeled particle moves along the trajectory winding on the crystal plane

Probability of close collisions with crystal atoms increases for negative particles in channeling states → these states are short-living

Deflection of negative particles in CH states by bent crystals hasn't been observed because their dechanneling length is small

Possibility of VR for negative particles

Planar potential is attractive for negative particles

Particles can't reflect from the potential well according to classical mechanics

Bend of the crystal plane near tangency point gives possibility for VR

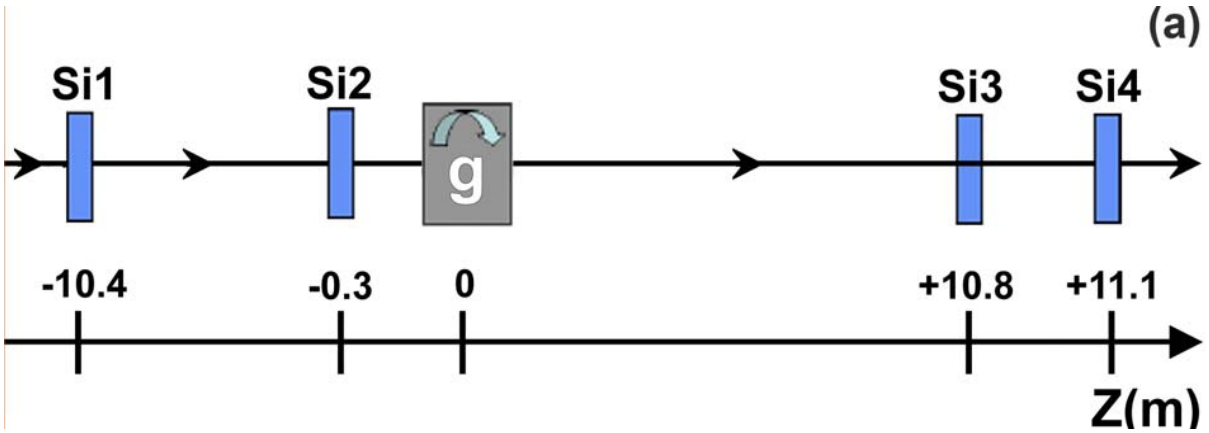
After crossing this plane during its motion at the concave side the angle of particle momentum with the plane tangent becomes smaller than the critical angle θ_c

So, particle goes back to the plane and crosses it again

Here, during the particle motion at the convex side of the plane
the angle becomes again larger θ_c

The return motion of a particle from the tangency point starts

Experimental setup



Particle angles were measured with the telescope of microstrip detectors with accuracy 3 μrad

The incident beam divergence → σ_x=(34.4±0.06) μrad and σ_y=(28.2±0.04) μrad

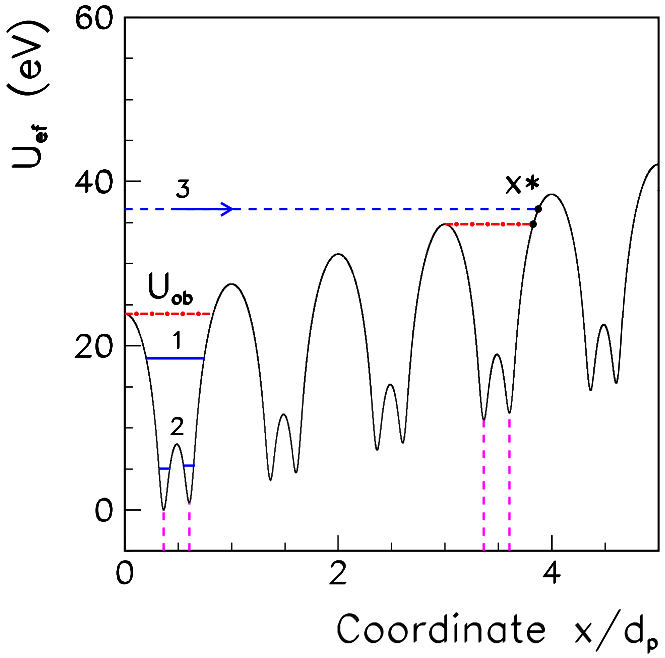
Crystal was oriented relative to the beam with a high precision goniometer with accuracy of 2 μrad

Both kind of crystals – quasimosaic (111) Si and striplike (110) Si were used

Effective potential and its parameters for negative particles

(111) Si crystal, quasimosaic QM2, L=0.84 mm

(111) Si, 150 GeV/c π^-,R=12.92 m



For the pair of planes

Potential well depth U_{ob}=23.88 eV

Critical angle θ_{cb}=17.84 μrad

For every plane of the pair

U_{1b}=8.01 eV and U_{2b}=7.14 eV

For $E_{xo}<U_{ob}$ – channeling states

(1) – molecular type, (2) – atomic type

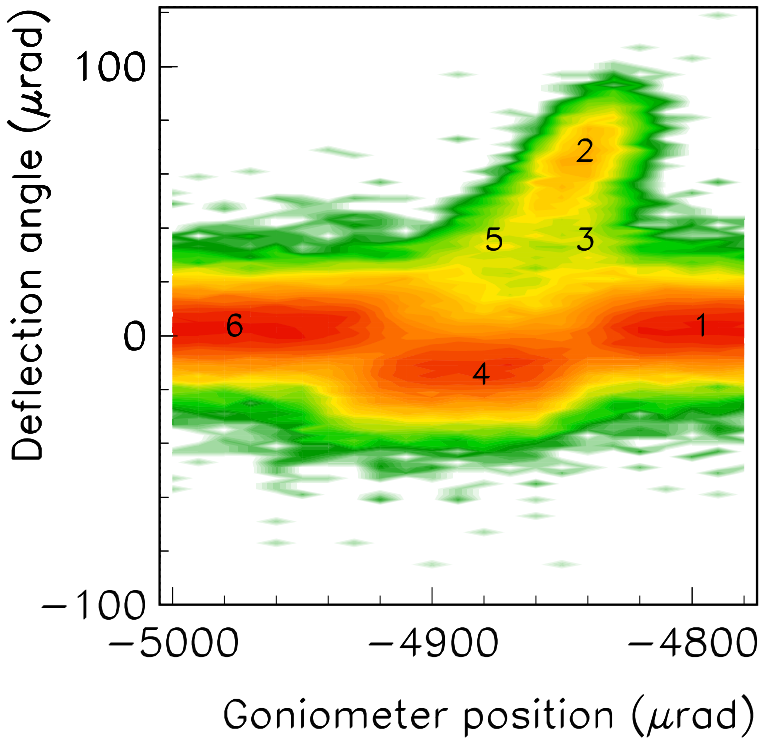
For $E_{xo}>U_{ob}$ – quasi-channeling states (3), x* – turn point in the potential

Here volume reflection occurs

Angular scan for (111) Si crystal

Intensity as function of deflection angle for different goniometer positions

Picture is similar to the one obtained for 400 GeV/c protons



(1),(6) – amorphous scattering

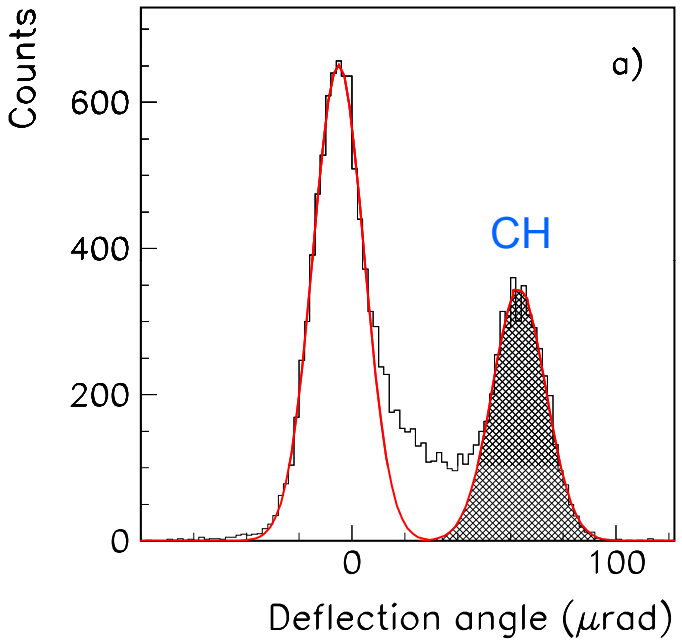
(2) – deflection due to channeling

(3) – dechanneling

(4) – volume reflection

(5) – deflection of volume captured particles

Distribution of deflection angles for orientation optimal for channeling



Gaussian fit parameters for CH peak

θ_d= (63.24 ± 0.24) μrad

σ_d=(10.16±0.19) μrad

$\theta_d \rightarrow$ bend radius R=12.92 m

Particles non-captured in CH states were reflected in opposite side

Outside Gaussian fits – dechanneled fraction (about 14%)

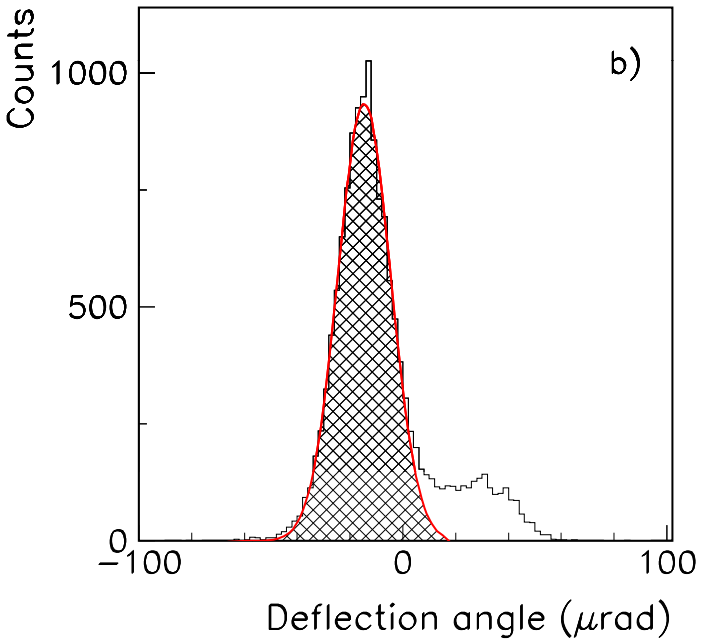
Deflection efficiency P_d=(30.24±0.38)% – fraction of the fit with $\theta > \theta_d - 3\sigma_d$

Distribution of deflection angles for orientation in center of VR area

Gaussian fit parameters for VR peak → θ_{vr}=(-14.64±0.12) μrad

σ_{vr}=(10.06±0.11) μrad

VR efficiency P_{vr}=(82.74±0.28)% – fraction of the fit with $\theta<\theta_{vr}-3\sigma_{vr}$

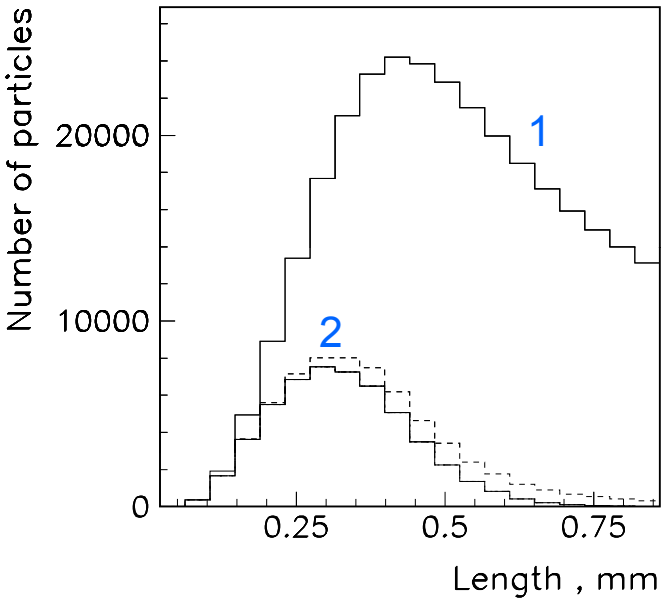


Large tail → high probability of volume capture

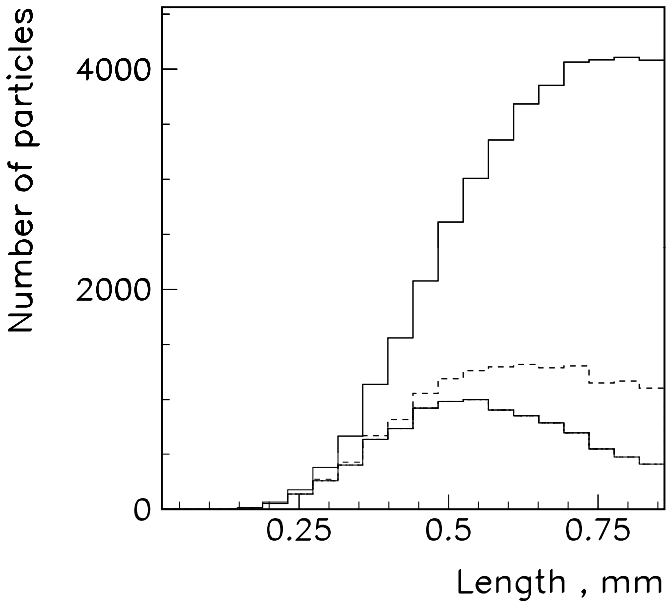
Because MS occurs in the middle area of the potential well

Volume captured fraction as function of crystal depth – simulation

All states – $E_x < U_{ob}$



Atomic type – $E_x<U_{b1},U_{b2}$



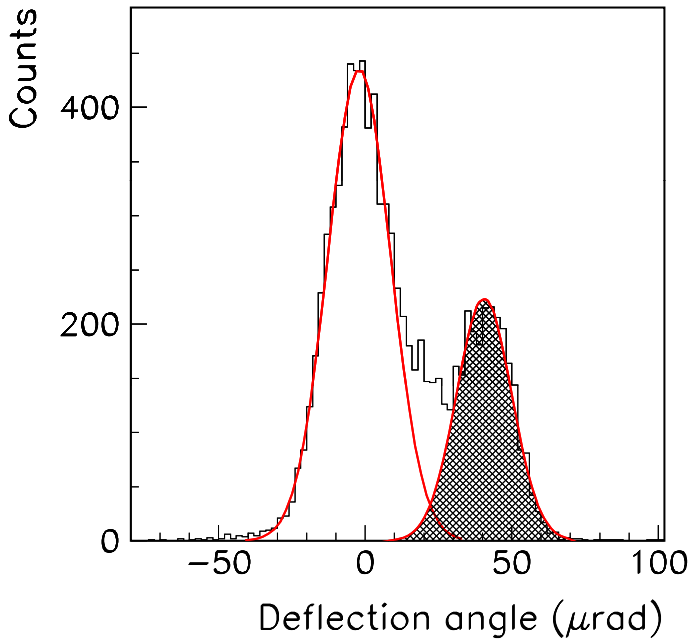
(1) – all CH particles, (2) – captured in this layer

The whole fraction of VC particles – sum of (2) – about 50%

Observation of π^- channeling in (110) Si strip crystal

Crystal was fabricated with large R, L=0.98 mm

Bend angle is small and two fits are partly overlapped



Gaussian fit parameters for CH peak

θ_d= (40.54 ± 0.36) μrad

σ_d=(9.41±0.29) μrad

Deflection efficiency

P_d=(28.81±0.47)%

VR deflection angle for this crystal → θ_{vr}=(11.53±0.23) μrad

Comparison of experimental results with simulation

Crystal	θ_{vr} (μrad)	P_{vr} (%)	P_d (%)
QM2 Experiment	14.64±0.12	82.74±0.28	30.24±0.38
Qm2 Simulation	16.6±0.07	78±0.13	30.11±0.15
ST10 Experiment	11.53±0.23	76.75±0.32	28.81±0.47
ST10 Simulation	12.84±0.11	74.77±0.14	28.67±0.14