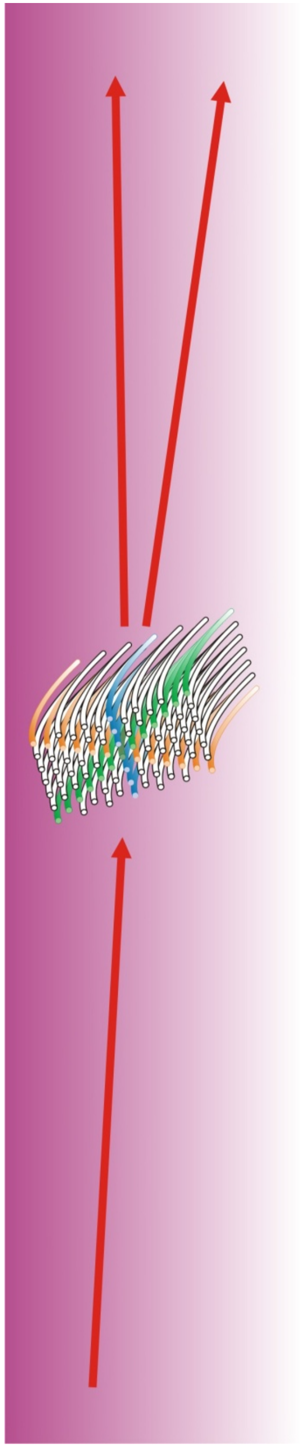
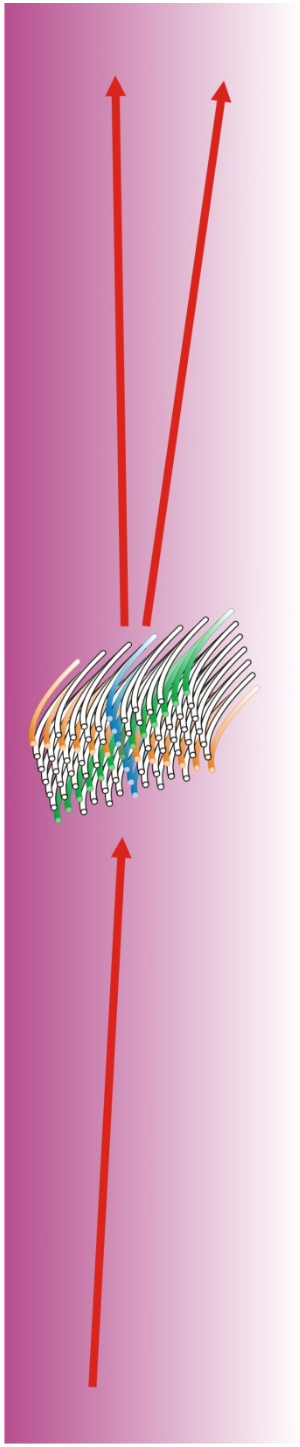


Multiple Volume Reflection as an Origin of Significant Scattering Intensity and Radiation Power Increase

Research Institute for Nuclear Problems, Minsk, Belarus
Victor Tikhomirov & Alexei Sytov

Channeling 2012 Alghero September 25



Plan

MVR idea

MVR experiments

MVR and channeling/
doughnut scattering

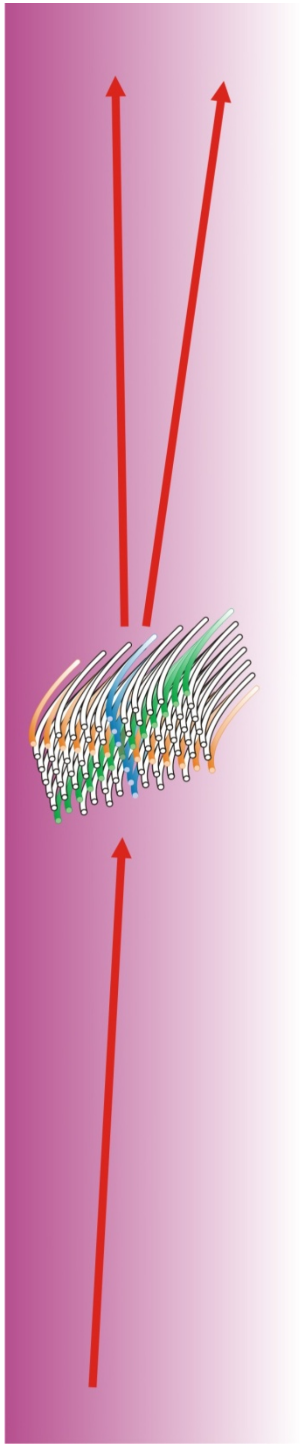
MVR and collimation

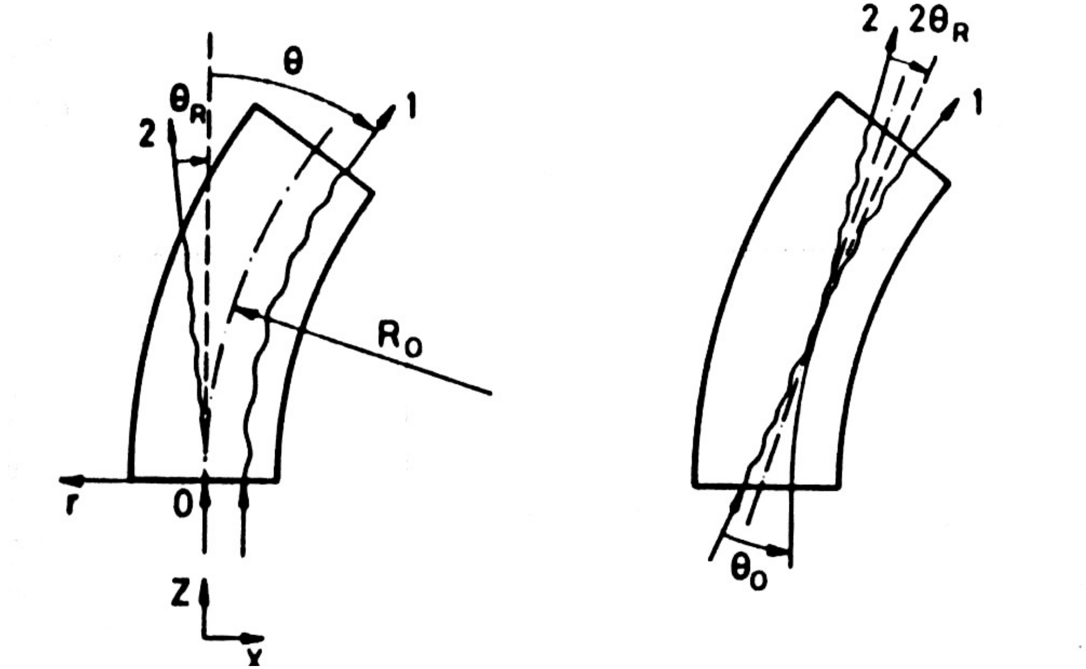
MVR and radiation

Volume Reflection prediction

A.M.Taratin and .A.Vorobiev

Phys. Lett. A119 (1987) 425, NIM B26 (1987) 512

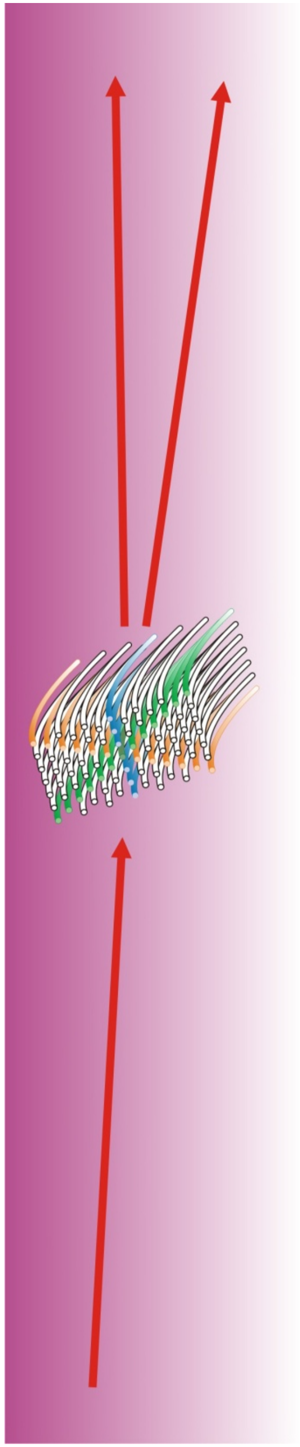




Large acceptance, however small deflection angles

CERN H8-RD22 experiment Sept 2006

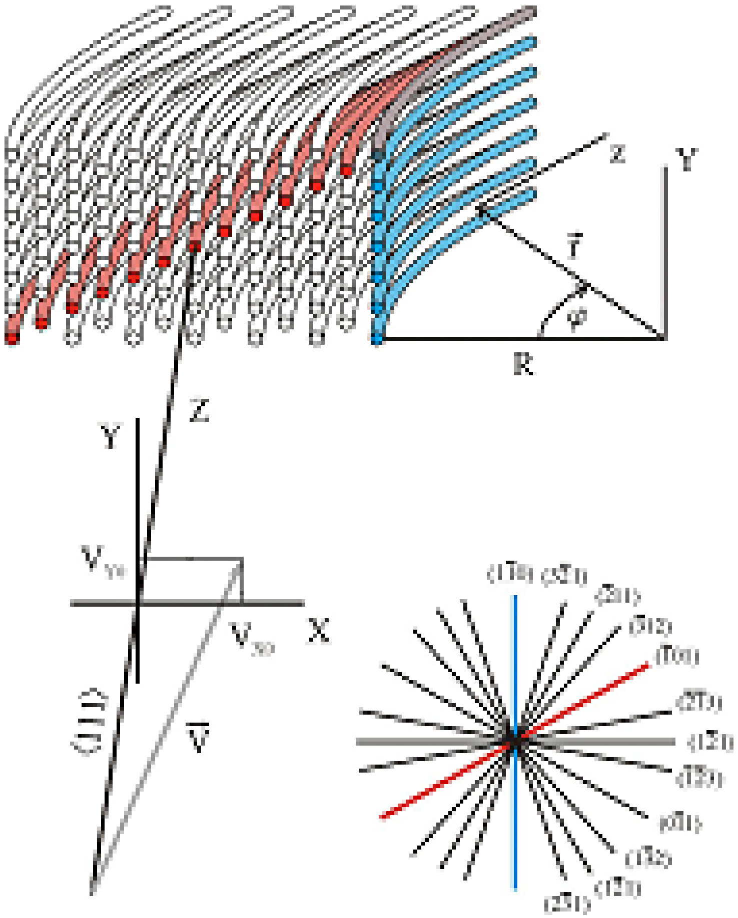
UN9 Collaboration also observed and investigated Multiple Volume Reflection in 2009-2011

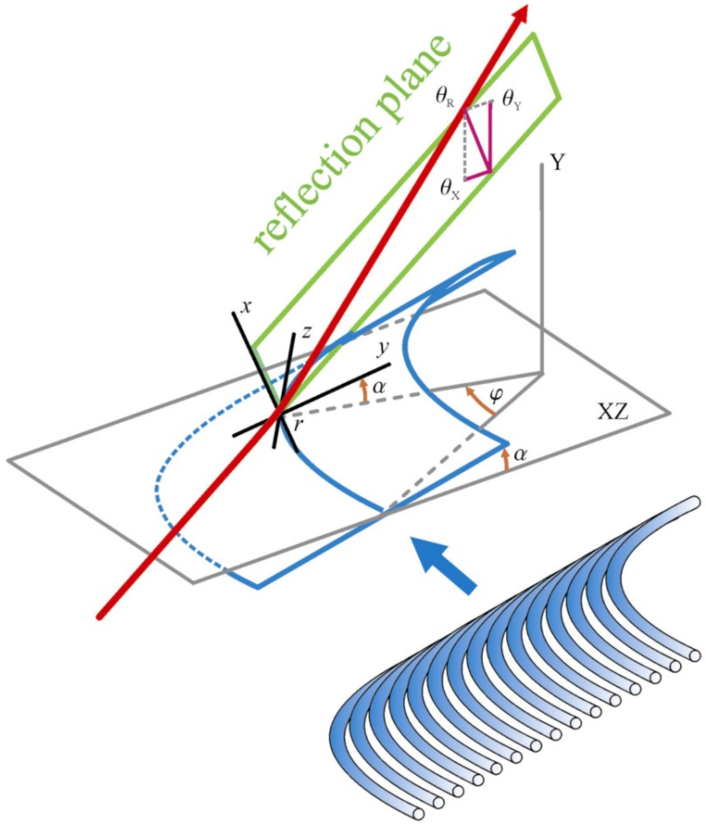


Can we **increase**
the deflection **angle**
conserving
the large acceptance?

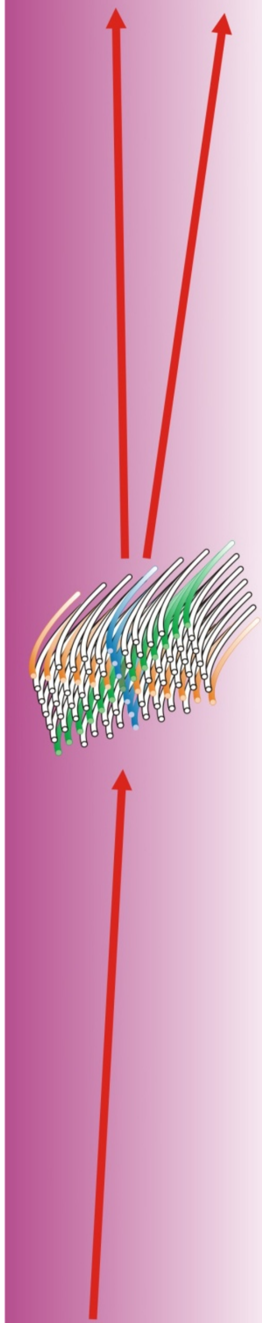
Multiple Volume Reflection in One Crystal (MVROC)

V.V. Tikhomirov, PLB 655(2007)217





Axes form ***many*** inclined reflecting planes

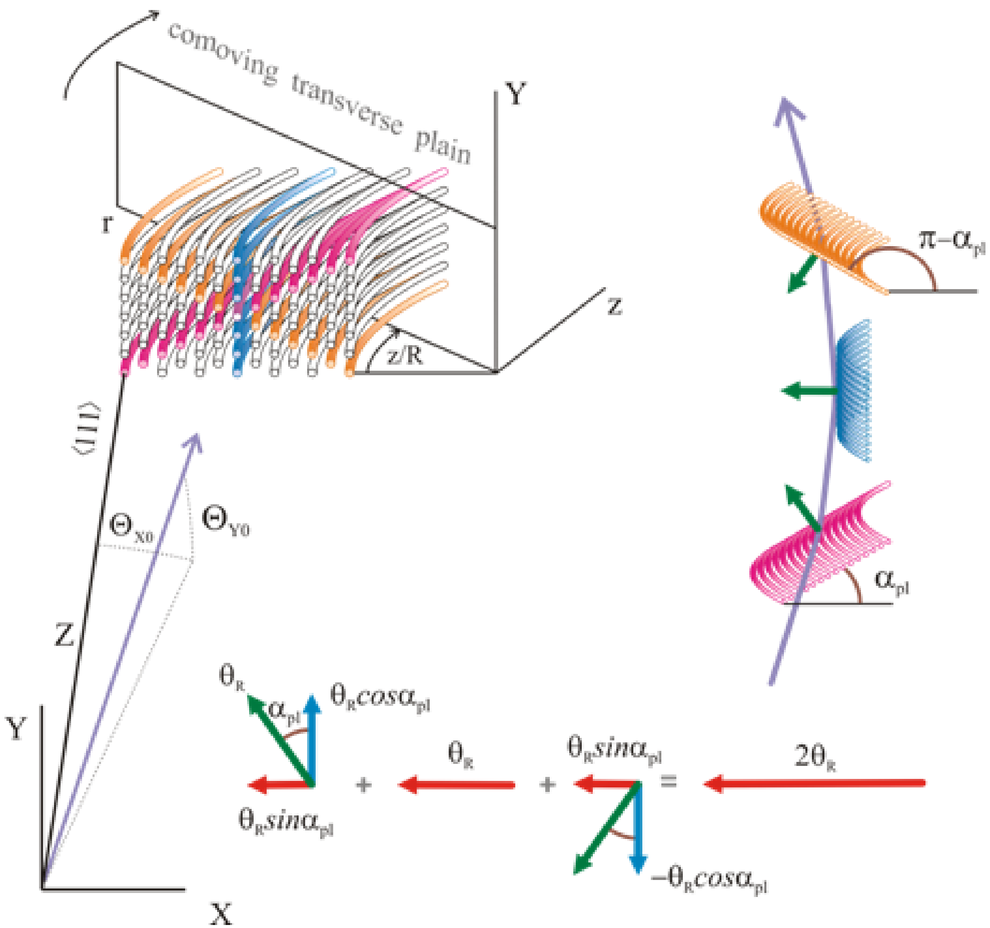


In this talk only and just for short

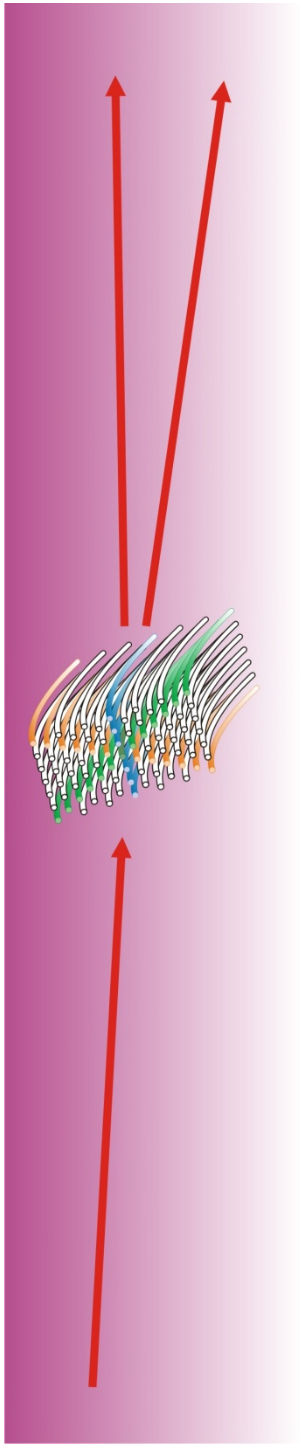
MVR = multiple volume reflection
in one crystal/”axial VR”

VR = “one plane VR”/”planar VR”

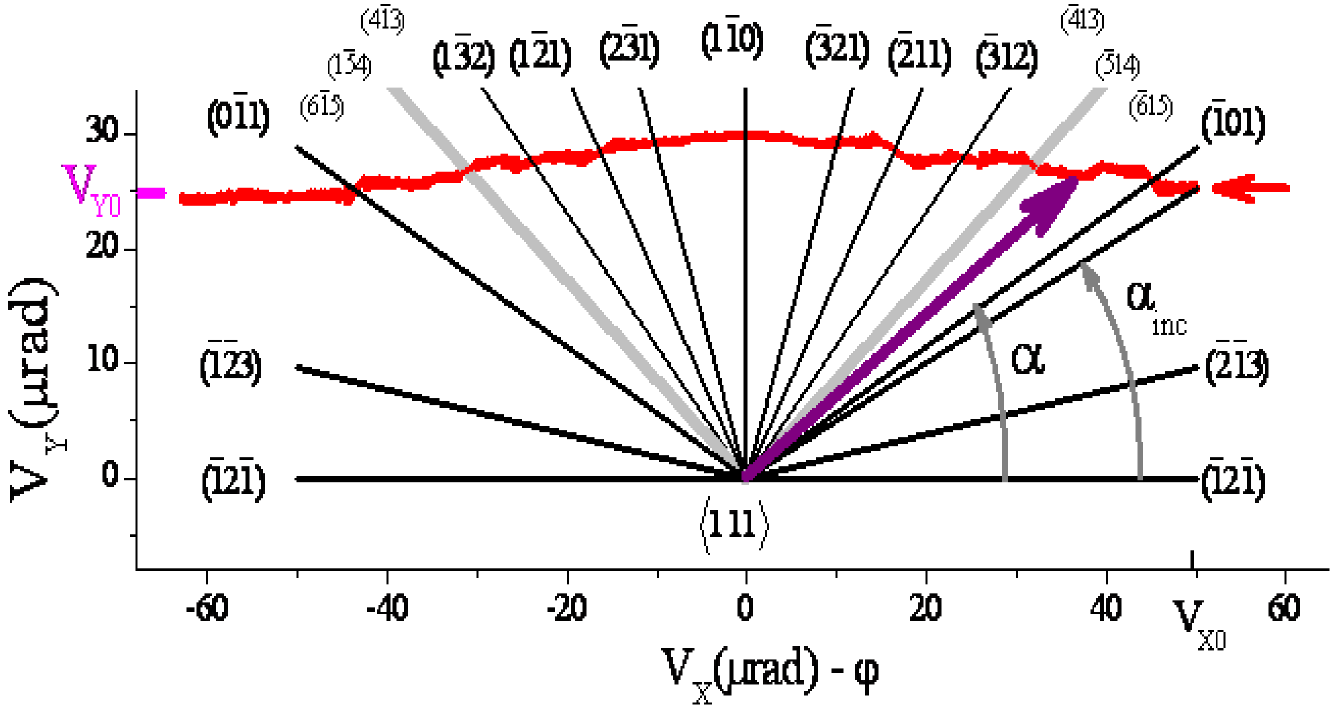
Horizon projections of the angles of reflection from different skew planes sum up giving rise to the MVROC effect while the vertical angles of reflection from symmetric skew planes, like (-101) and (0-11), mutually compensate.



Comoving reference frame *rYz* rotates with the normal bent axis direction when a particle moves through the crystal.

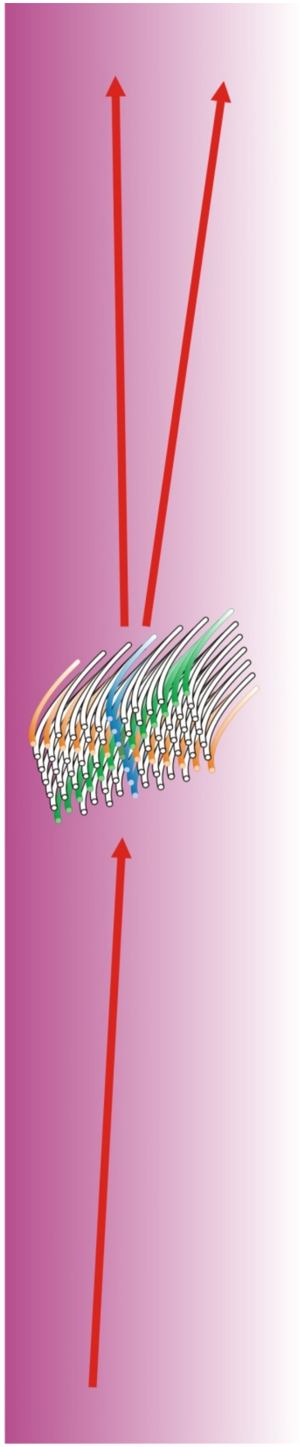


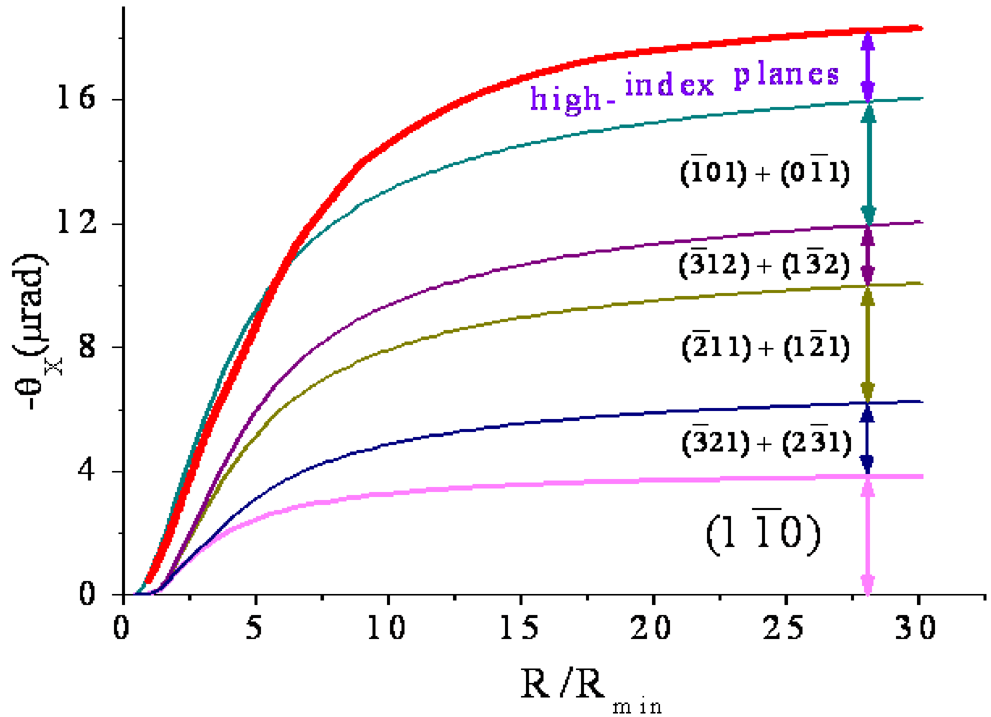
Proton motion in comoving reference plane



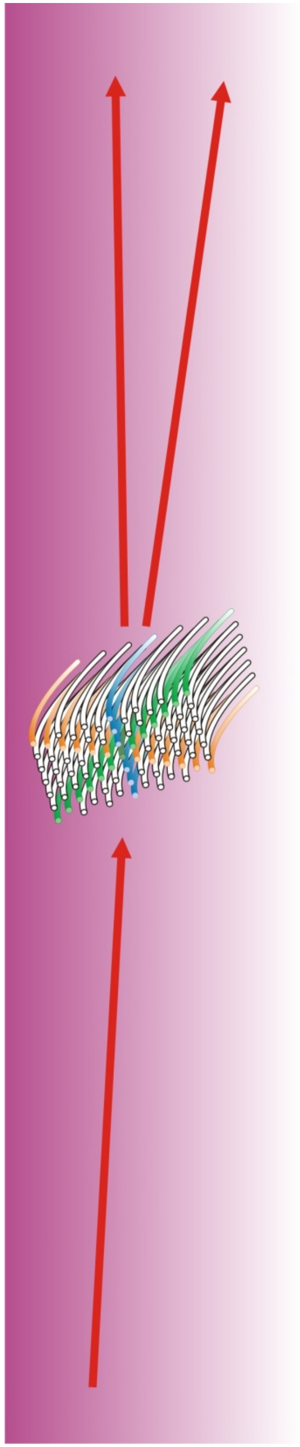
Protons are reflected from ***many*** different crystal plane sets in ***one*** crystal

Reflection angles from planes of one crystal *vs* bending radius





Reflection from different crystal planes increases VR angle about ***5 times***



Plan

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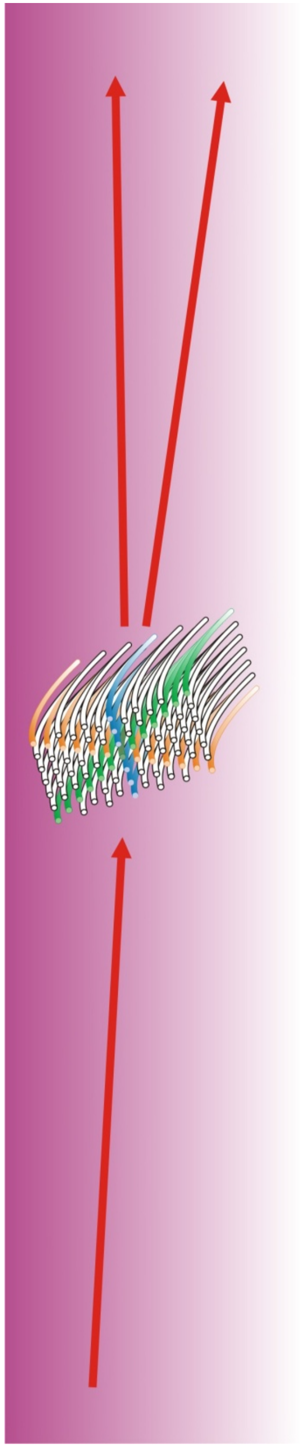
MVR and collimation

MVR and radiation



Physics Letters B 682 (2009) 274–277

Contents lists available at ScienceDirect

Physics Letters B

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First observation of multiple volume reflection by different planes in one bent silicon crystal for high-energy protons

W. Scandale[a], A. Vomiero[b], E. Bagli[c], S. Baricordi[c], P. Dalpiaz[c], M. Fiorini[c], V. Guidi[c], A. Mazzolari[c], D. Vincenzi[c], R. Milan[d], Gianantonio Della Mea[e], E. Vallazza[f], A.G. Afonin[g], Yu.A. Chesnokov[g], V.A. Maisheev[g], I.A. Yazynin[g], V.M. Golovatyuk[h], A.D. Kovalenko[h], A.M. Taratin[h,*], A.S. Denisov[i], Yu.A. Gavrikov[i], Yu.M. Ivanov[i], L.P. Lapina[i], L.G. Malyarenko[i], V.V. Skorobogatov[i], V.M. Suvorov[i], S.A. Vavilov[i], D. Bolognini[j,k], S. Hasan[j,k], A. Mattera[j,k], M. Prest[j,k], V.V. Tikhomirov[l]

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[h] Joint Institute for Nuclear Research, Joliot-Curie 6, 141980, Dubna, Moscow Region, Russia
[i] Petersburg Nuclear Physics Institute, 188300 Gatchina, Leningrad Region, Russia
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A R T I C L E   I N F O

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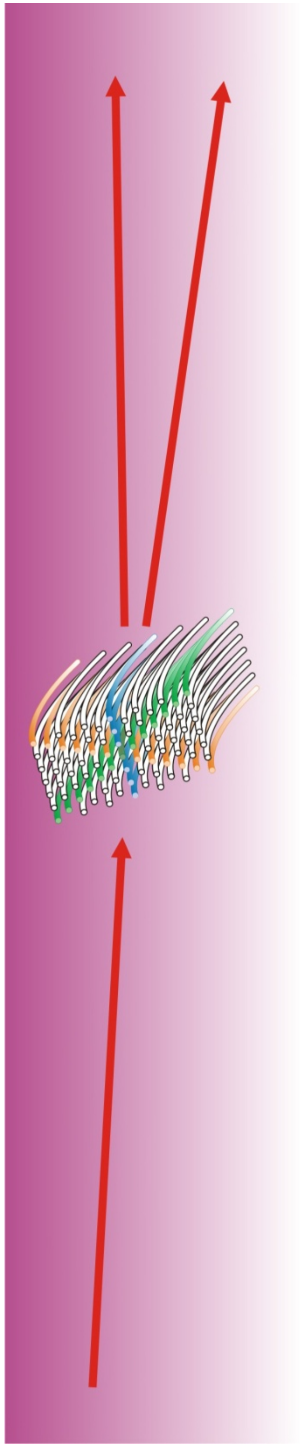
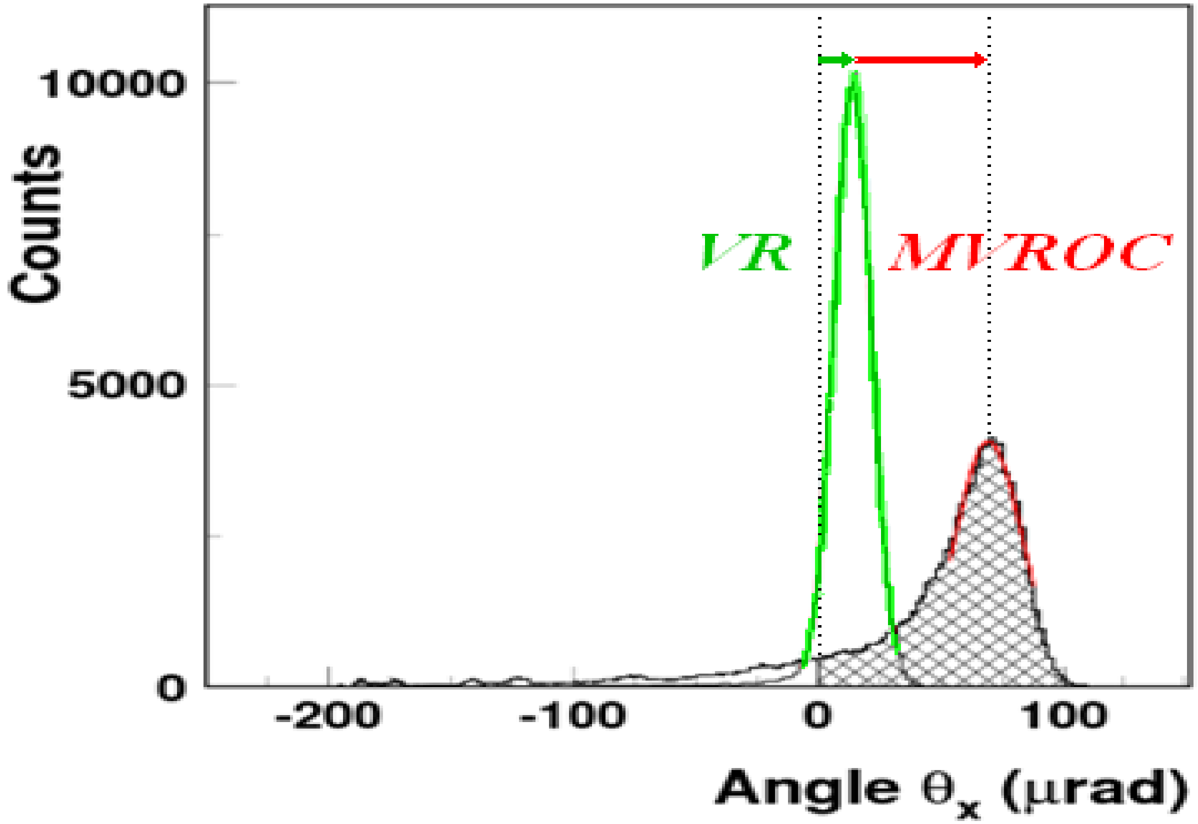
A B S T R A C T

Multiple volume reflection by different planes in a bent silicon crystal with its ⟨111⟩ axis orientation close to the beam direction was observed for the first time for 400 GeV/c protons at the CERN SPS. The proton beam was deflected to the side opposite to the crystal bend by an angle of about 67 μrad, which is five times larger than in a single volume reflection by the (110) bent planes. The registered efficiency of one side deflection was about 84%. It was shown that multiple volume reflection transforms to a single volume reflection when the orientation angle of the ⟨111⟩ axis relative to the beam direction is increased.



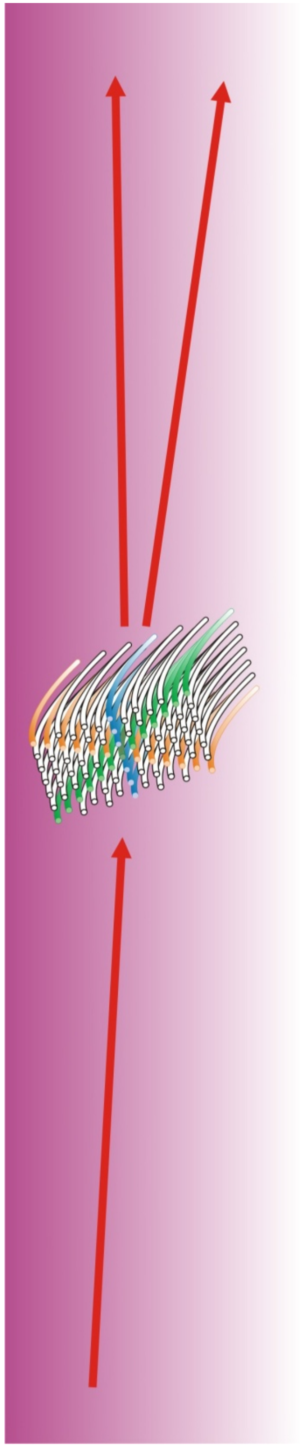
First MVROC observation

W. Scandale et al, PLB 682(2009)274



MVROC indeed increases reflection angle **5 times**

Guidi, Mazzolari, and Tikhomirov, J. Appl. Phys. **107**, 114908 (2010)



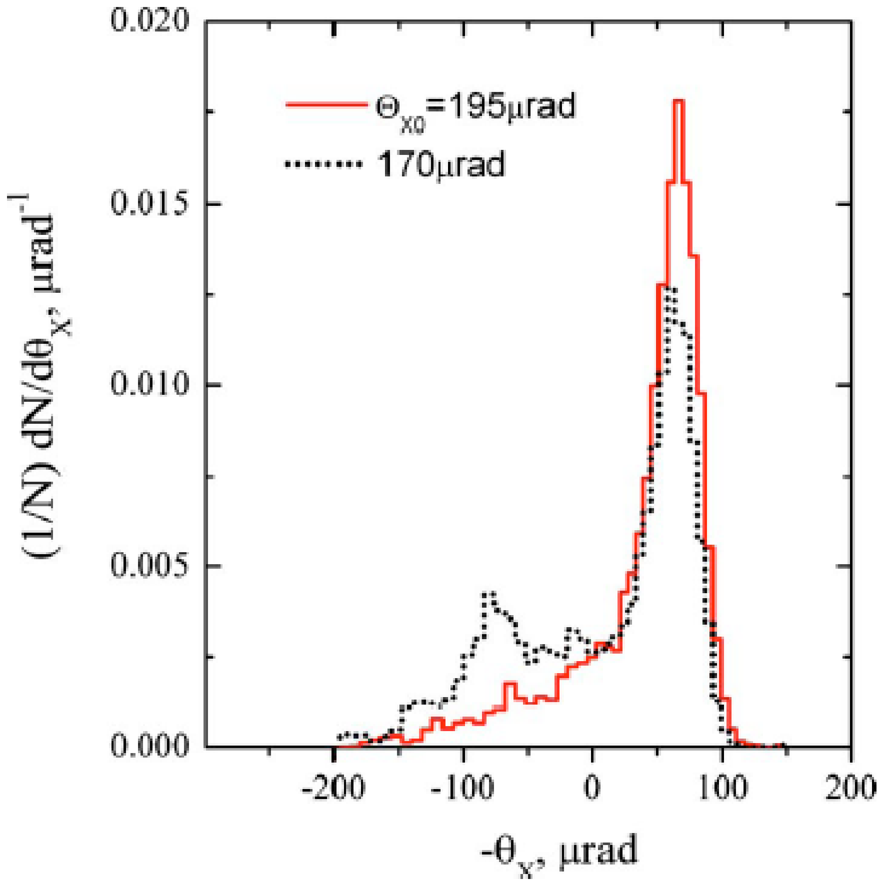
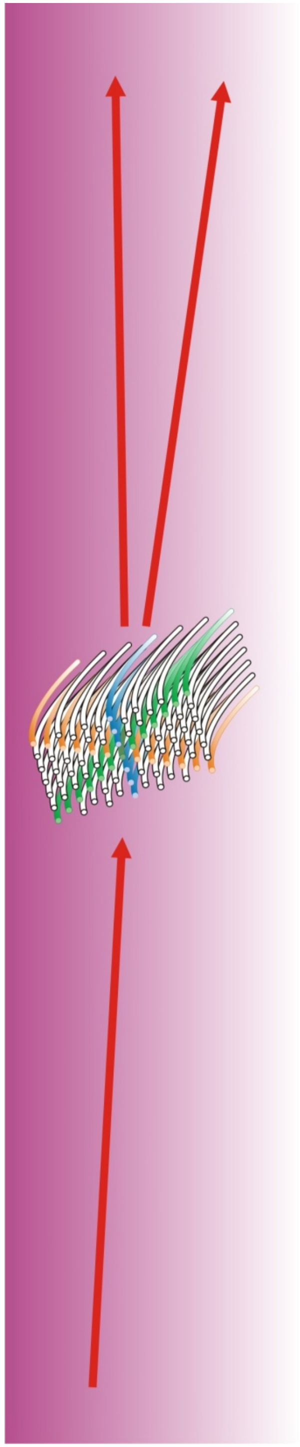


FIG. 8. (Color online) Simulated proton angular distributions in the horizontal plane under the conditions of experiment (Ref. 13) at horizontal incidence angles $\Theta_{X0}=170$ and 195 μrad. The peak in the region of $\theta_X \simeq 85$ μrad is formed by the protons captured into the channeling regime by $(\bar{1}01)$ plane at the crystal surface at $\Theta_{X0}=170$ μrad.



Письма в ЖЭТФ, том 93, вып. 4, с. 205 – 208 © 2011 г. 25 февраля

Коллимация циркулирующего пучка в синхротроне У-70 с помощью отражения частиц в кристаллах с осевой ориентацией

А. Г. Афонин, В. Т. Баранов, М. К. Булгаков, И. С. Война, В. Н. Горлов, И. В. Иванова, Д. М. Крылов, А. Н. Луньков, В. А. Маишеев, С. Ф. Решетников, Д. А. Савин, Е. А. Сыщиков, В. И. Терехов, Ю. А. Чесноков, П. Н. Чирков, И. А. Язынин

Государственный научный центр "Институт физики высоких энергий", Протвино, 142281 Московская обл., Россия

Поступила в редакцию 18 января 2011 г.

В сеансе осень-2010 на У-70 были проведены экспериментальные исследования возможностей вывода и коллимации циркулирующего пучка новым способом – за счет отражения частиц в кристаллах с осевой ориентацией. Положительные особенности таких кристаллов связаны с тем, что осевой потенциал примерно в 5 раз выше плоскостного. Показано, что эффективность коллимации за счет осевых эффектов в кристалле может достигать величины 90%. В несколько раз уменьшены потери циркулирующего пучка на коллиматоре, за счет этого подавлен мюонный факел в районе стального коллиматора циркулирующего пучка.

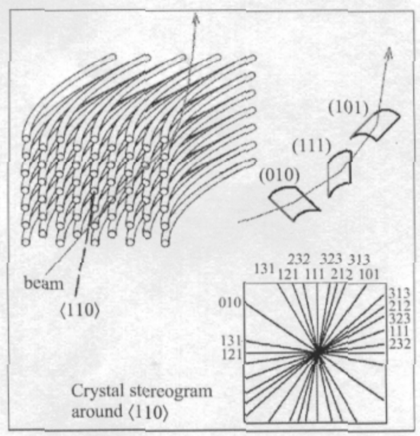


Рис.2. Схема отклонения частиц вблизи кристаллографической оси ⟨110⟩: к эффекту от основной изогнутой плоскости (111) добавляется отражение от косых плоскостей (010), (101) и других, менее сильных

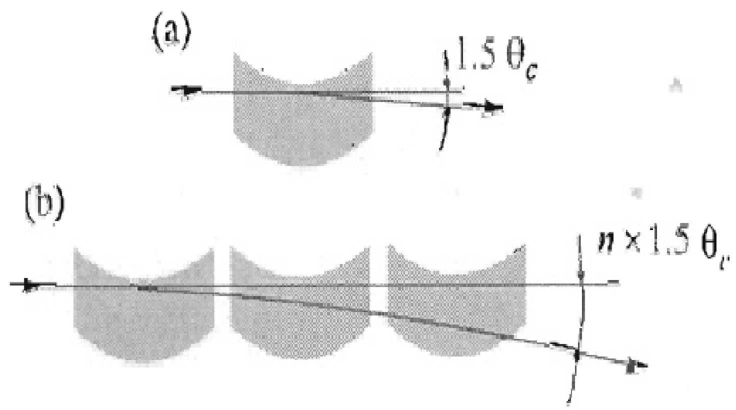
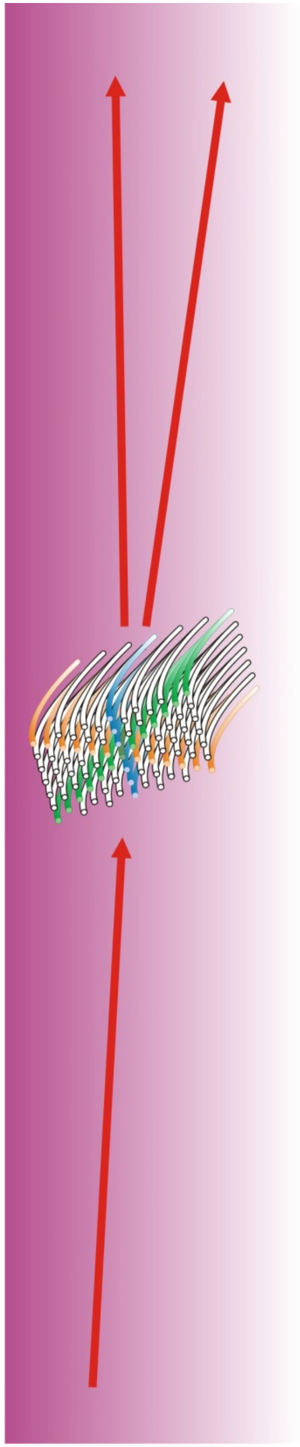


Рис.1. Усиление угла отражения на цепочке кристаллов



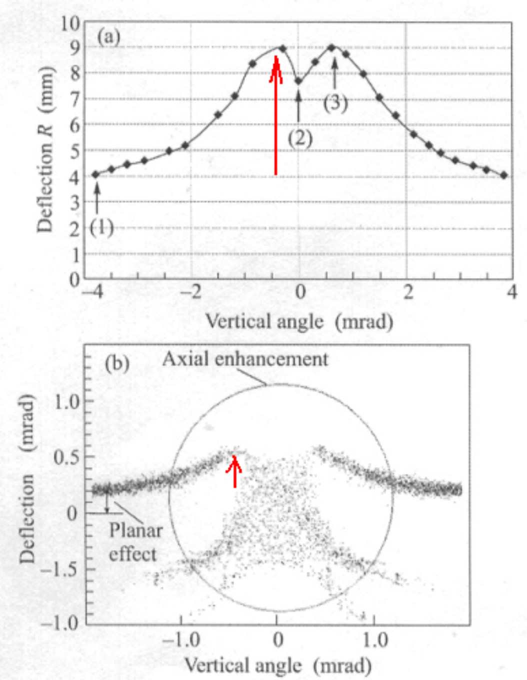


Рис.5. (a) – Глубина заброса протонов 50 ГэВ на поглотитель в зависимости от вертикального угла вращения. (b) – Расчет методом Монте-Карло увеличения угла отражения частиц в мультирефлекторе за счет осевых эффектов

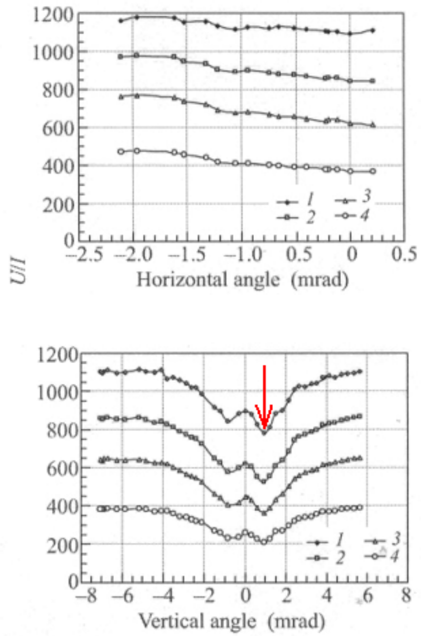


Рис.6. (a) – Уменьшение потерь при вращении горизонтального угла (плоскостное отражение). (b) – дальнейшее уменьшение потерь при настройке вертикального угла гониометра (отражение вблизи оси)

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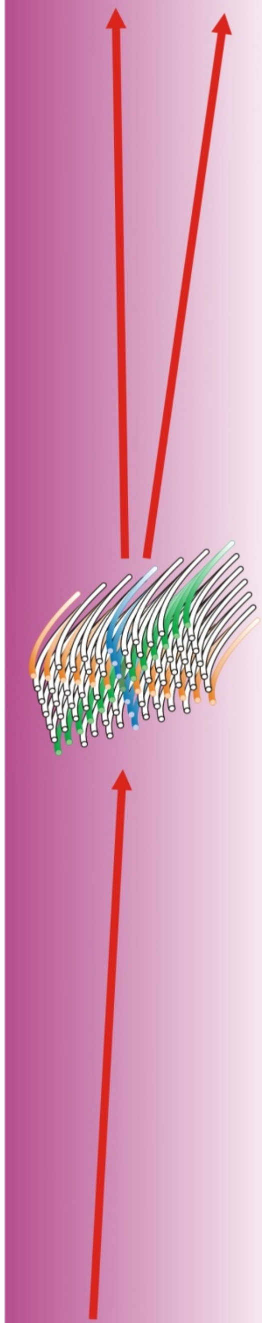

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Observation of multiple volume reflection by different planes in one bent silicon crystal for high-energy negative particles

W. Scandale[1], A. Vomiero[2], E. Bagli[3], S. Baricordi[3], P. Dalpiaz[3], M. Fiorini[3], V. Guidi[3], A. Mazzolari[3], D. Vincenzi[3], R. Milan[4], G. Della Mea[5], E. Vallazza[6], A. G. Afonin[7], Yu. A. Chesnokov[7], V. A. Maisheev[7], I. A. Yazynin[7], A. D. Kovalenko[8], A. M. Taratin[8(a)], A. S. Denisov[9], Yu. A. Gavrikov[9], Yu. M. Ivanov[9], L. P. Lapina[9], L. G. Malyarenko[9], V. V. Skorobogatov[9], V. M. Suvorov[9], S. A. Vavilov[9], D. Bolognini[10,11], S. Hasan[10,11], A. Mattera[10,11], M. Prest[10,11] and V. V. Tikhomirov[12]

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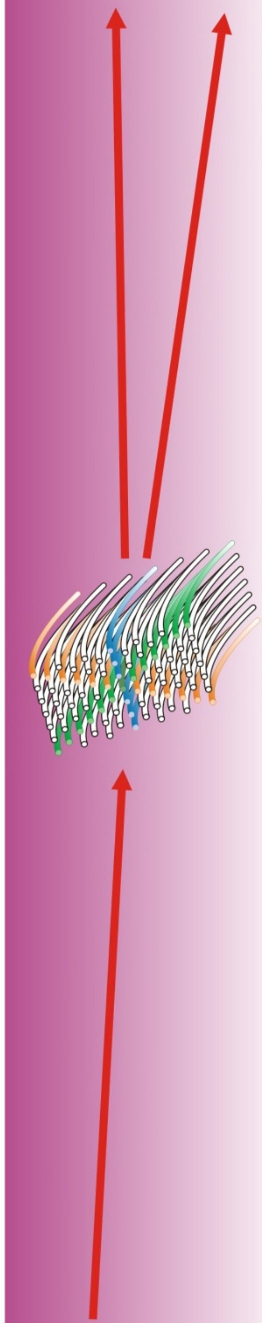
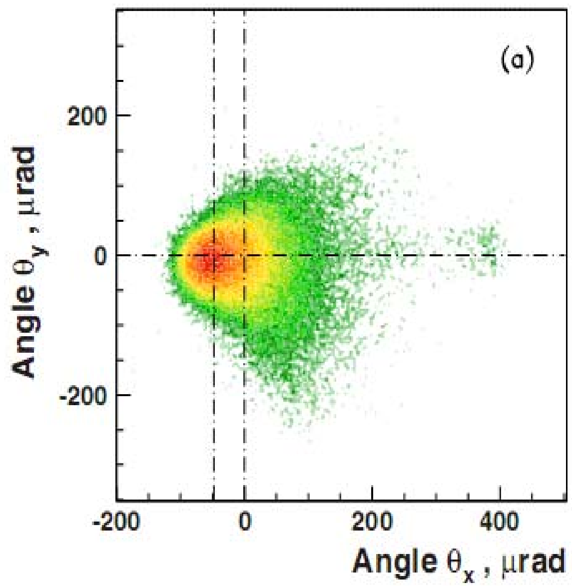
PACS 61.85.+p – Channeling phenomena (blocking, energy loss, etc.)

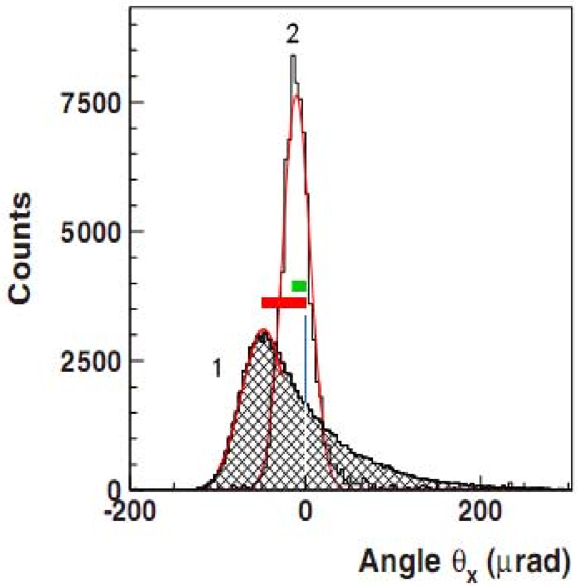
Abstract – Multiple volume reflection by different planes passing through the ⟨111⟩ axis in a bent silicon crystal was observed for the first time for 150 GeV/c negative particles, π^- mesons, at one of the secondary beams of the CERN SPS. The beam of π^- mesons was deflected opposite to the crystal bend by an angle of about 48 μrad, which is 4.6 times larger than in a single volume reflection by the (110) bent planes. The one-side deflection efficiency was about 65%. Multiple volume reflection transforms to a single volume reflection when the orientation angle of the ⟨111⟩ axis relative to the beam direction is increased.

MVR of negative pions



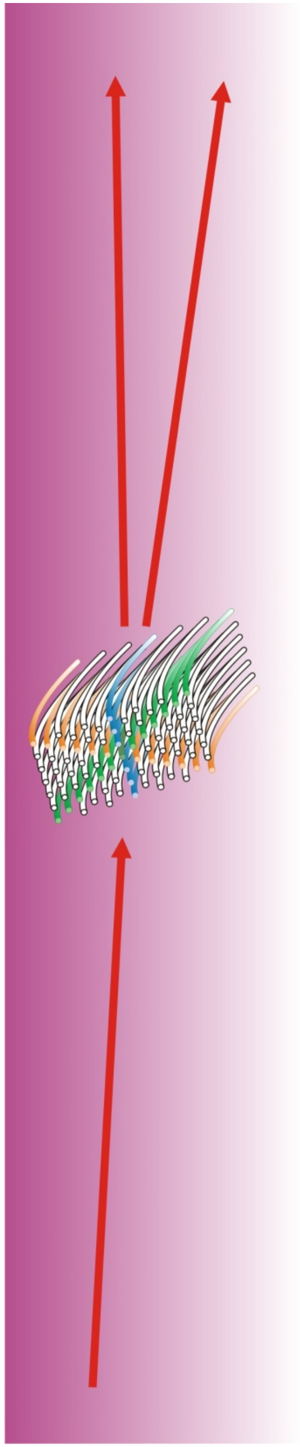


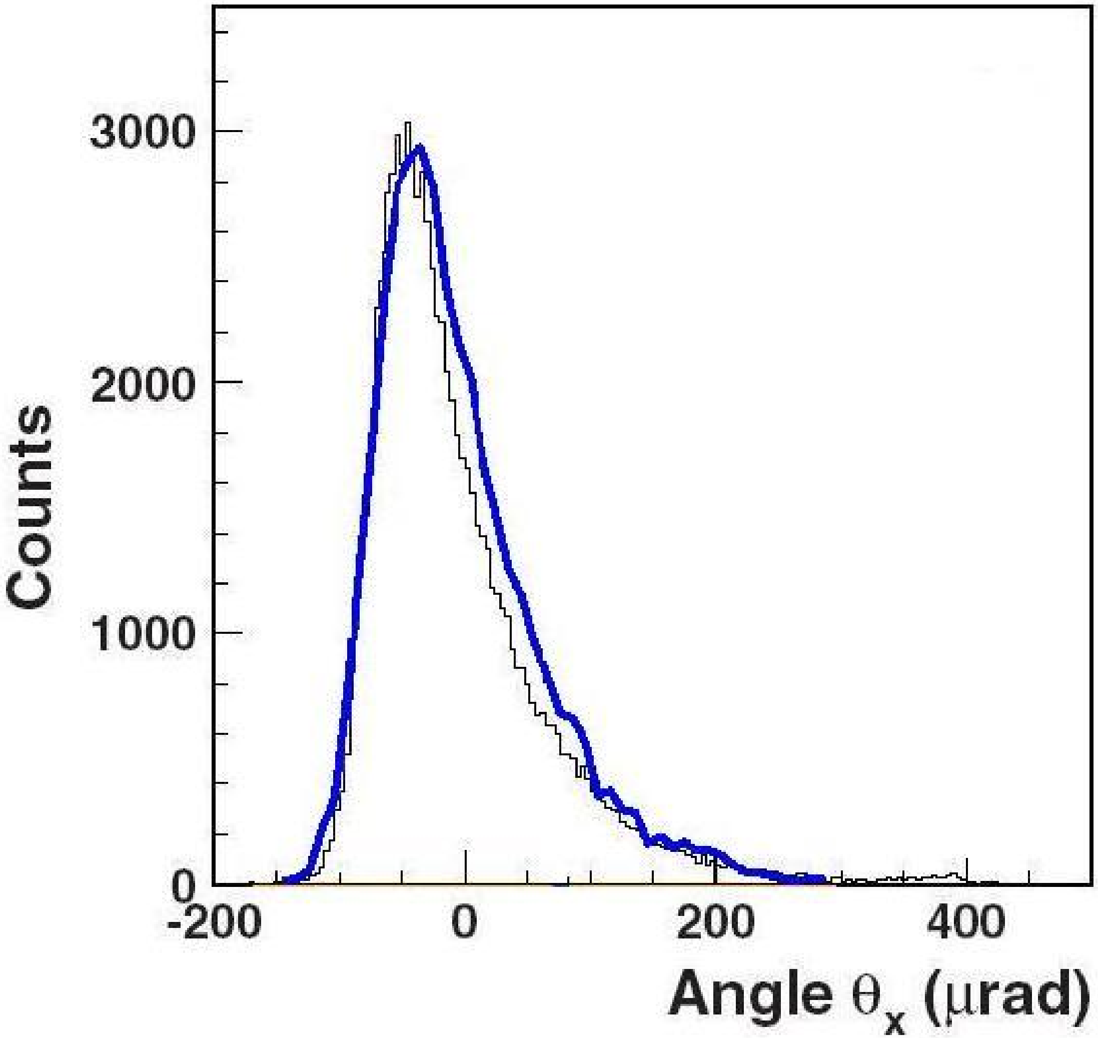
Intensity distribution of the $150\,\mathrm{GeV}/c$ π^- meson beam in the horizontal and vertical deflection angles acquired due to multiple volume reflections from different planes crossing the $\langle 111 \rangle$ axis in one bent silicon crystal.

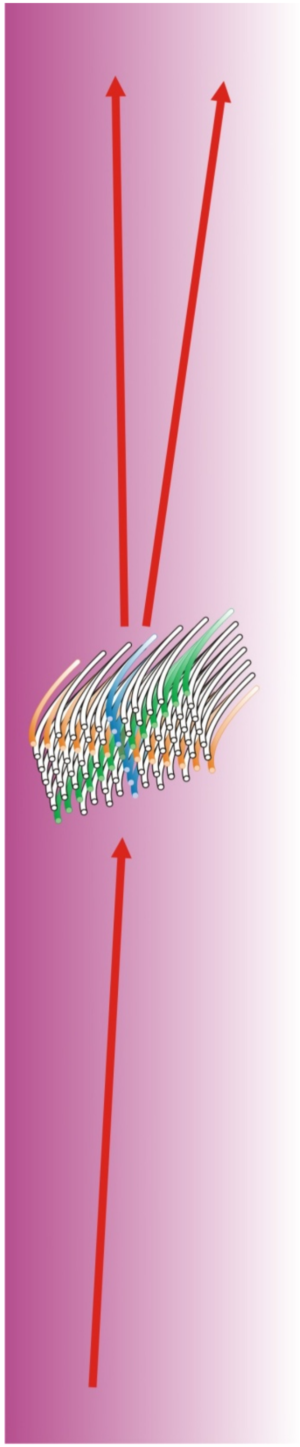


Deflection angle distributions of $150\,\mathrm{GeV}/c$ π^- mesons by a bent silicon crystal observed in the case of MVR near the $\langle 111 \rangle$ axis (1) and in the case of a single volume reflection by the (110) vertical planes (2).

MVR angular distribution







Plan

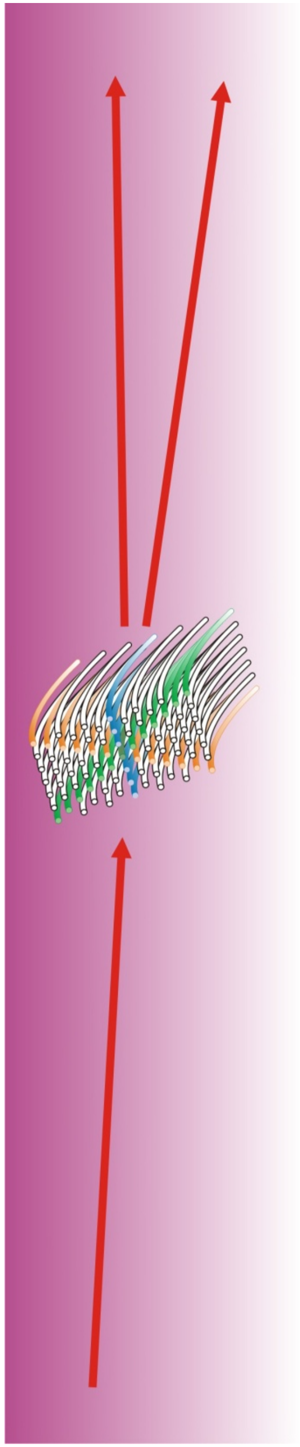
MVR idea

MVR experiments

MVR and channeling/ doughnut scattering

MVR and collimation

MVR and radiation



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Physics Letters B

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Deflection of high-energy negative particles in a bent crystal through axial channeling and multiple volume reflection stimulated by doughnut scattering

W. Scandale [a], A. Vomiero [b], E. Bagli [c], S. Baricordi [c], P. Dalpiaz [c], M. Fiorini [c], V. Guidi [c], A. Mazzolari [c], D. Vincenzi [c], R. Milan [d], Gianantonio Della Mea [e], E. Vallazza [f], A.G. Afonin [g], Yu.A. Chesnokov [g], V.A. Maisheev [g], I.A. Yazynin [g], V.M. Golovatyuk [h], A.D. Kovalenko [h], A.M. Taratin [h,*], A.S. Denisov [i], Yu.A. Gavrikov [i], Yu.M. Ivanov [i], L.P. Lapina [i], L.G. Malyarenko [i], V.V. Skorobogatov [i], V.M. Suvorov [i], S.A. Vavilov [i], D. Bolognini [j,k], S. Hasan [j,k], M. Prest [j,k]

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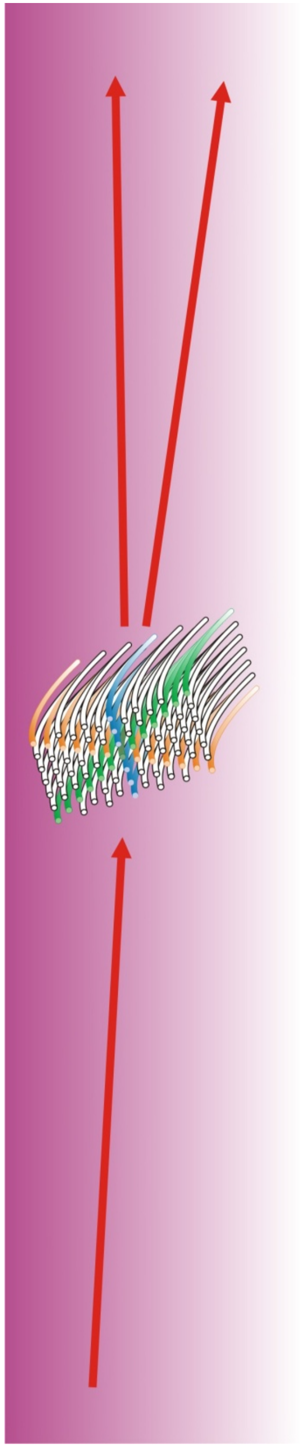
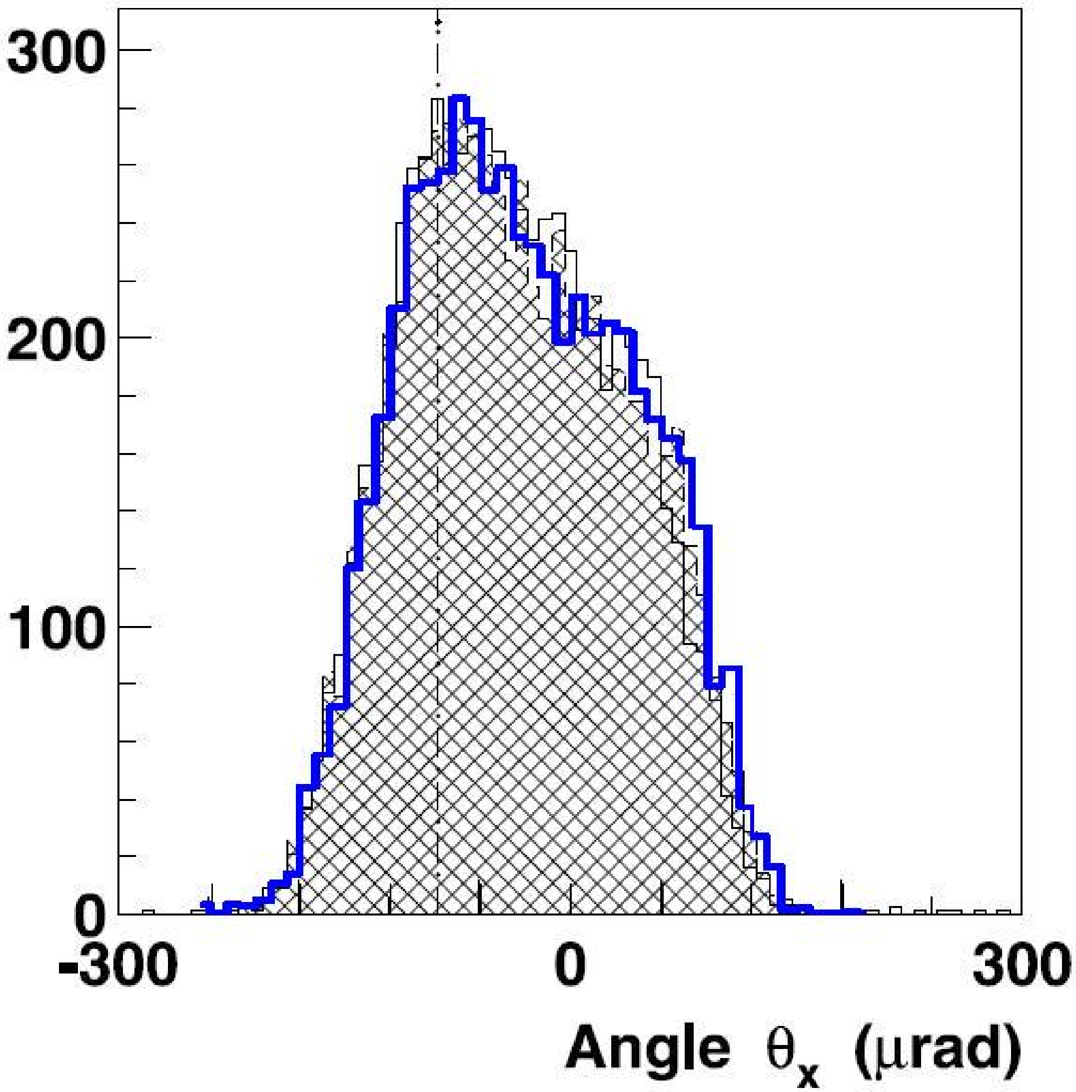
ABSTRACT

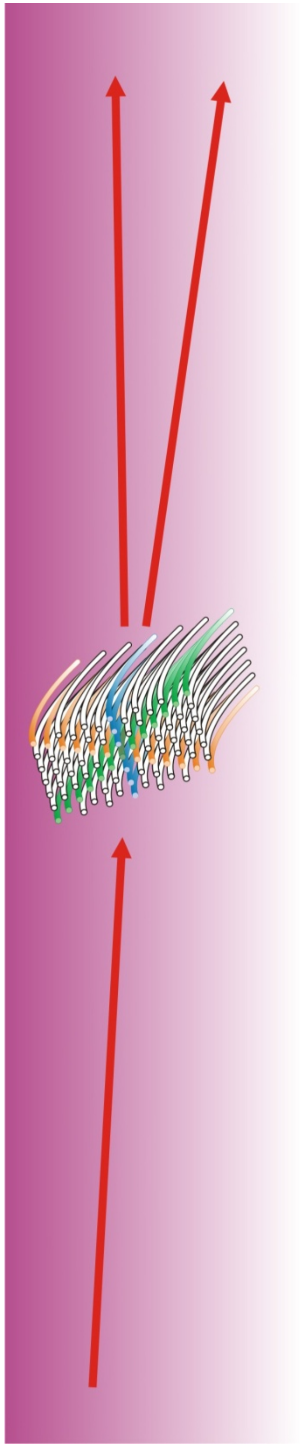
Different kinds of deflection in a silicon crystal bent along the ⟨111⟩ axis was observed for 150 GeV/c negative particles, mainly π^- mesons, at one of the secondary beams of the CERN SPS. The whole beam was deflected to one side in quasi-bound states of doughnut scattering (DSB) by atomic strings with the efficiency $(95.4 \pm 0.2)\%$ and with the peak position close to the bend crystal angle, $\alpha = 185$ μrad. It was observed volume capture of π^- mesons into the DSB states with a probability higher than 7%. A beam deflection opposite to the crystal bend was observed for some orientations of the crystal axis due to doughnut scattering and subsequent multiple volume reflections of π^- mesons by different bent planes crossing the axis.

Doughnut + MVR angular distribution

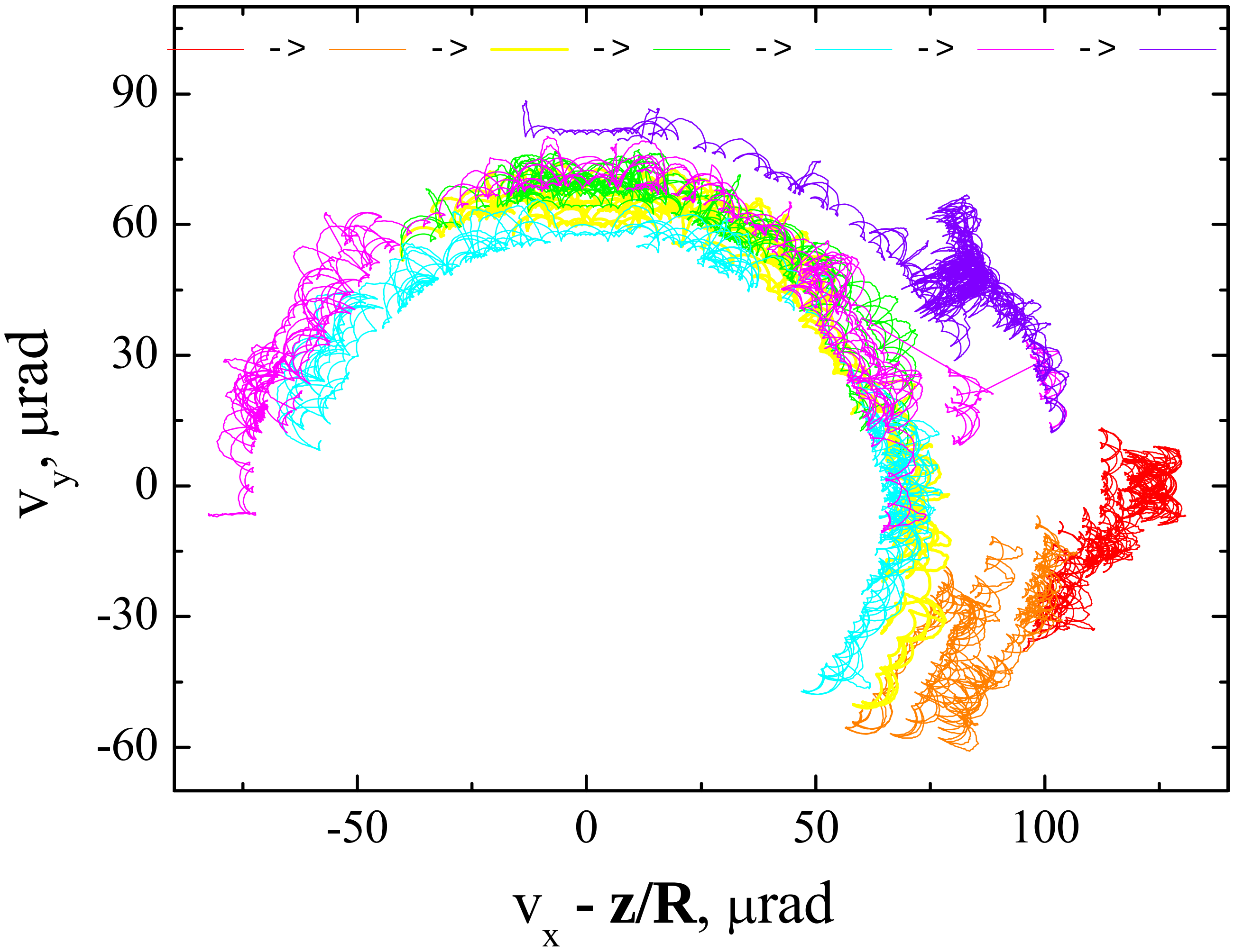


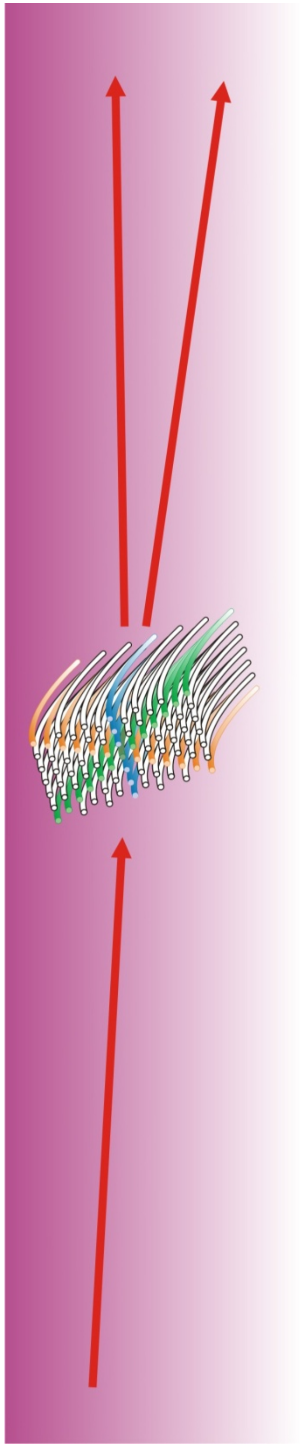


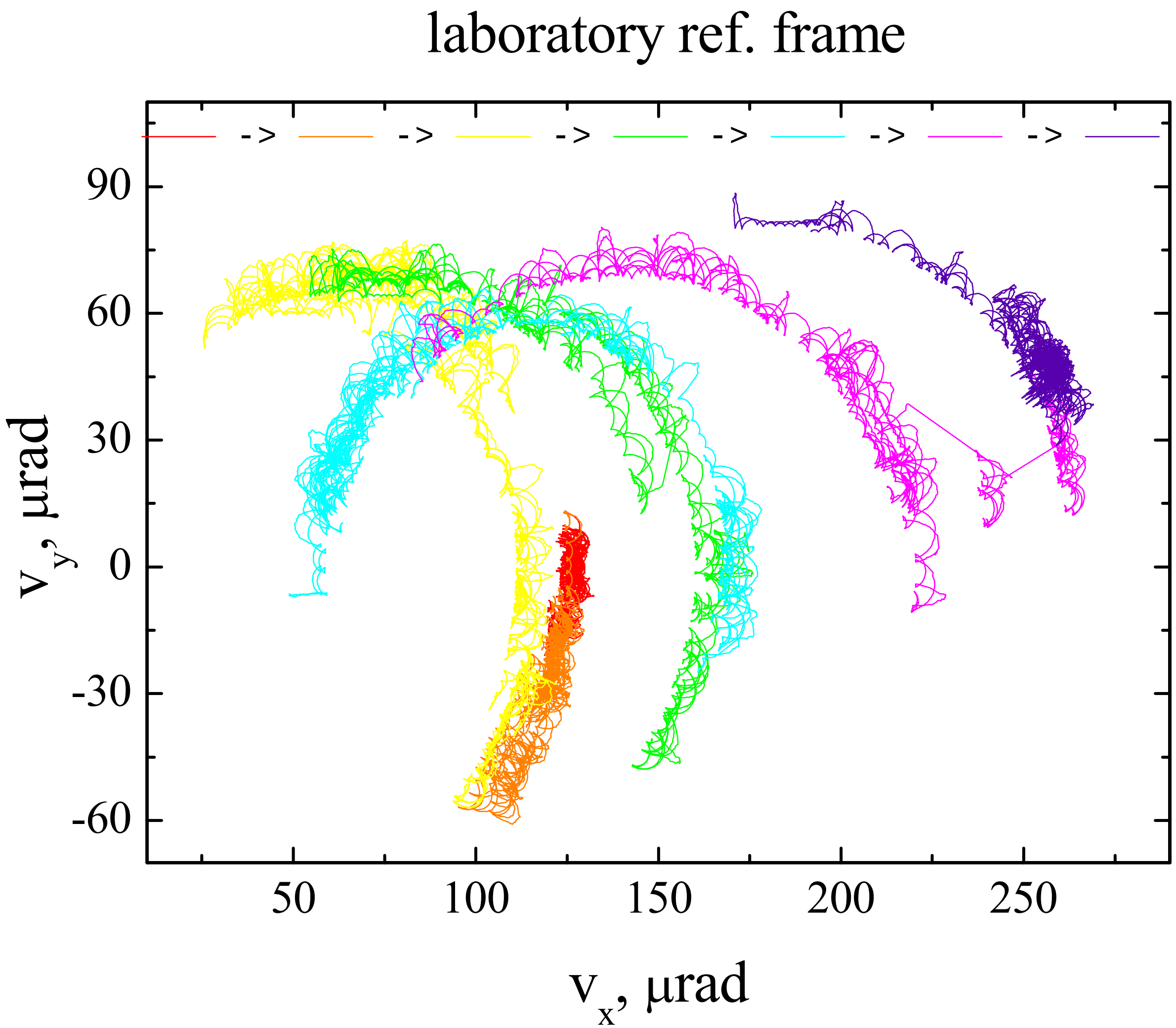
Simultaneous doughnut scattering and MVR



comoving ref. frame



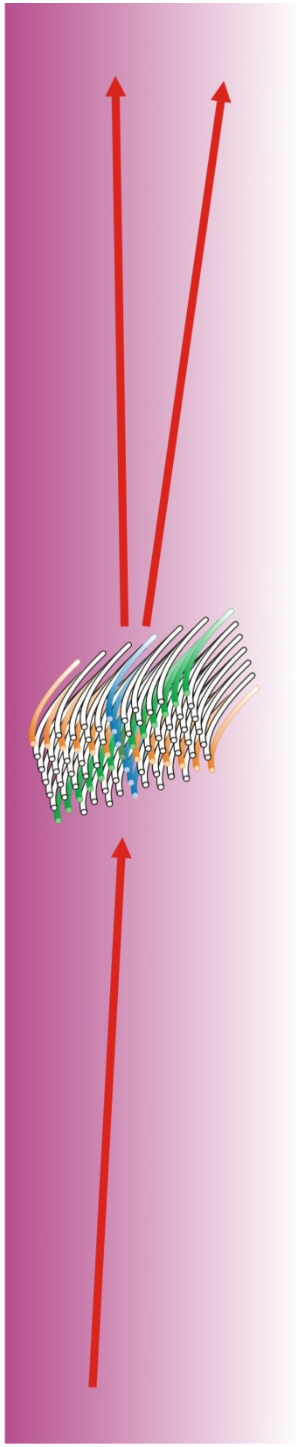




MVR manifests itself

at smallest incidence angles!

Large MVR angular acceptance



Guidi, Mazzolari, and Tikhomirov J. Appl. Phys. **107**, 114908 (2010)

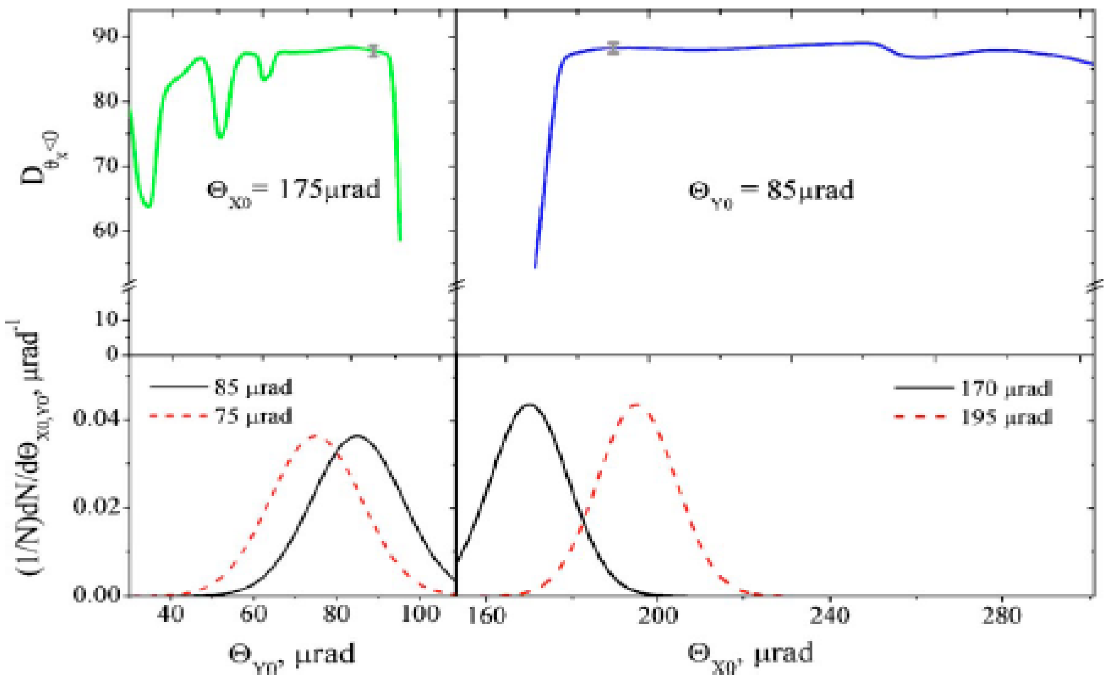
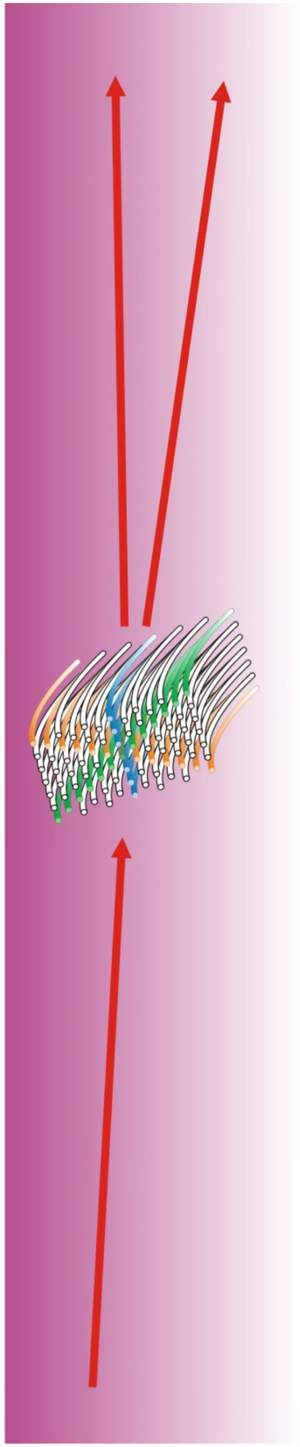


FIG. 6. (Color online) Top: probability of 400 GeV proton deflection in 4 mm Si crystal bent with $R=11.43$ m vs vertical incidence angle with the horizontal one fixed at 175 μrad (left) and vs the horizontal incidence angle with the vertical one fixed at 85 μrad (right). Bottom: proton angular distributions in vertical (left) and horizontal (right) planes under the conditions of experiment (Ref. 13).



Guidi, Mazzolari, and Tikhomirov J. Appl. Phys. **107**, 114908 (2010)

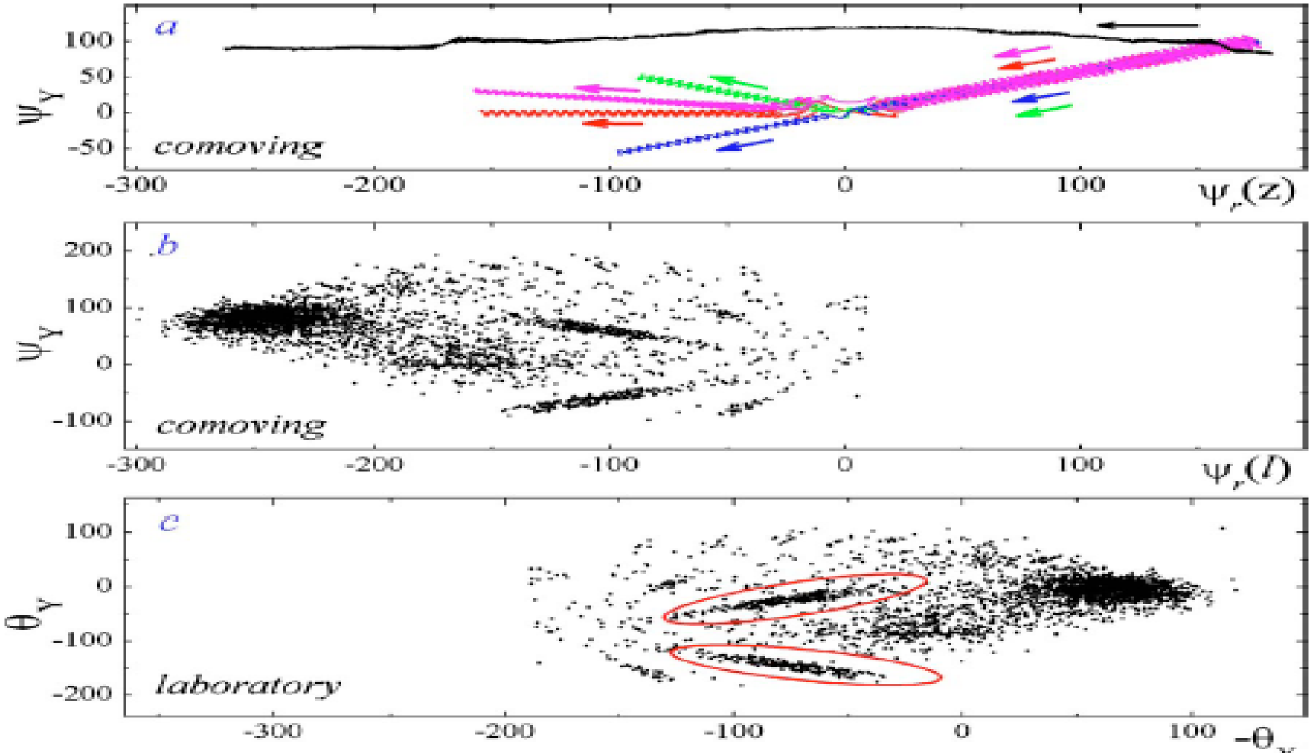
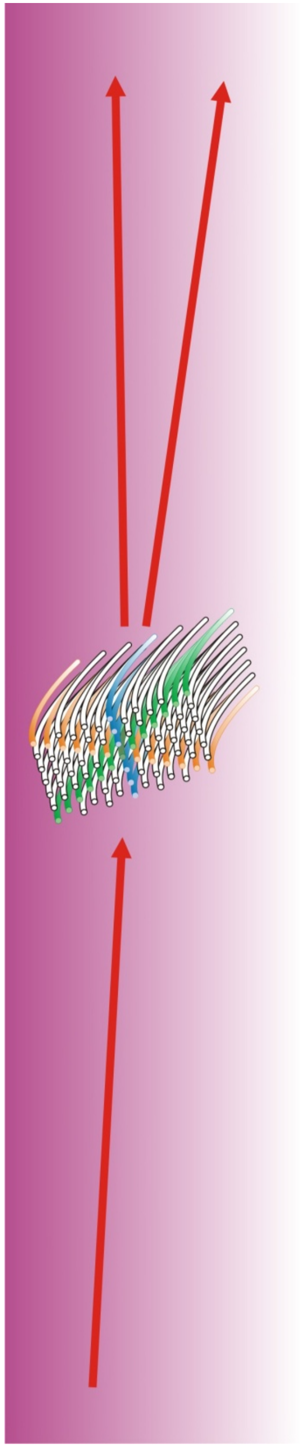


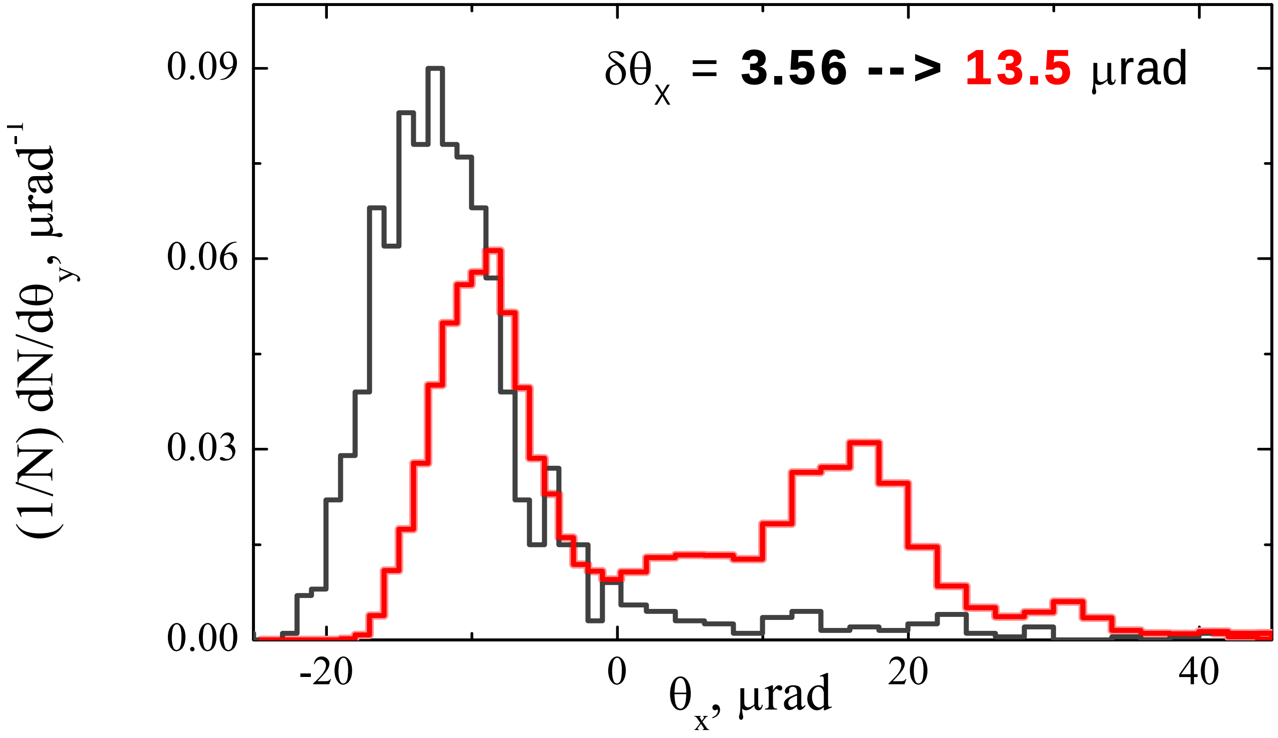
FIG. 7. (Color online) Evolution of the proton deflection angles with crystal depth in the comoving reference frame: one proton experiences MVROC (top) while the other four are first captured by $(\bar{1}01)$ planes, then scattered by $\langle 111 \rangle$ axes and finally recaptured by various crystal planes (a). Proton angular distribution behind the crystal in comoving (b) and laboratory (c) reference frames. All the angles are measured in microradiants. Both crystal and beam parameters correspond to the conditions of the experiment (Ref. 13).

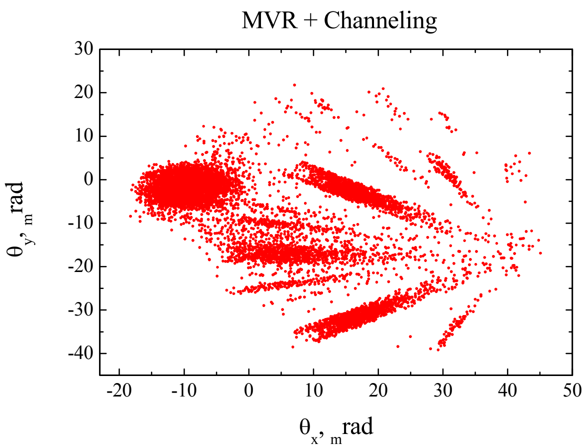
Channeling manifests itself specifically under the MVR conditions

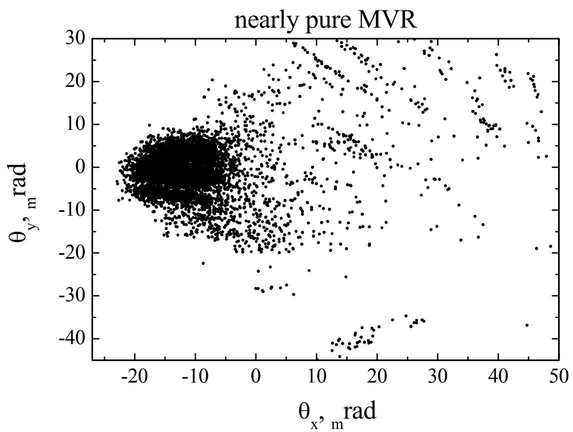
7 TeV *p* MVR and Planar Channeling in SI

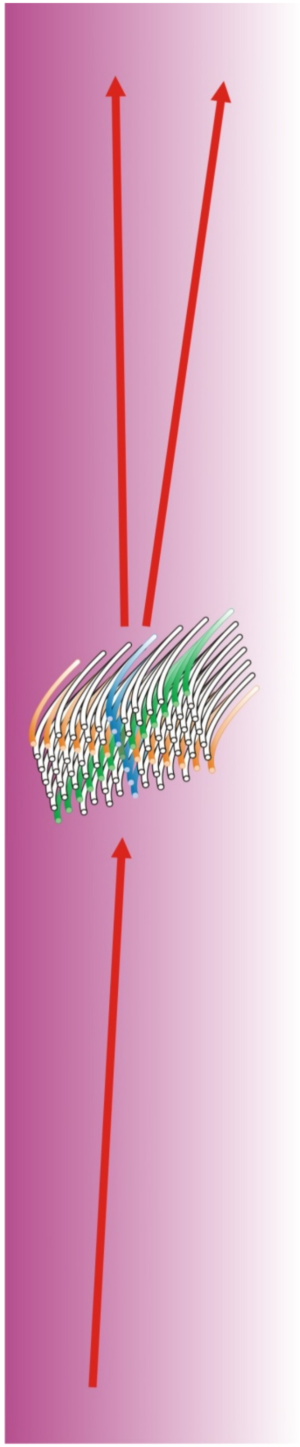
drastic MVR angular divergion increase by channeling





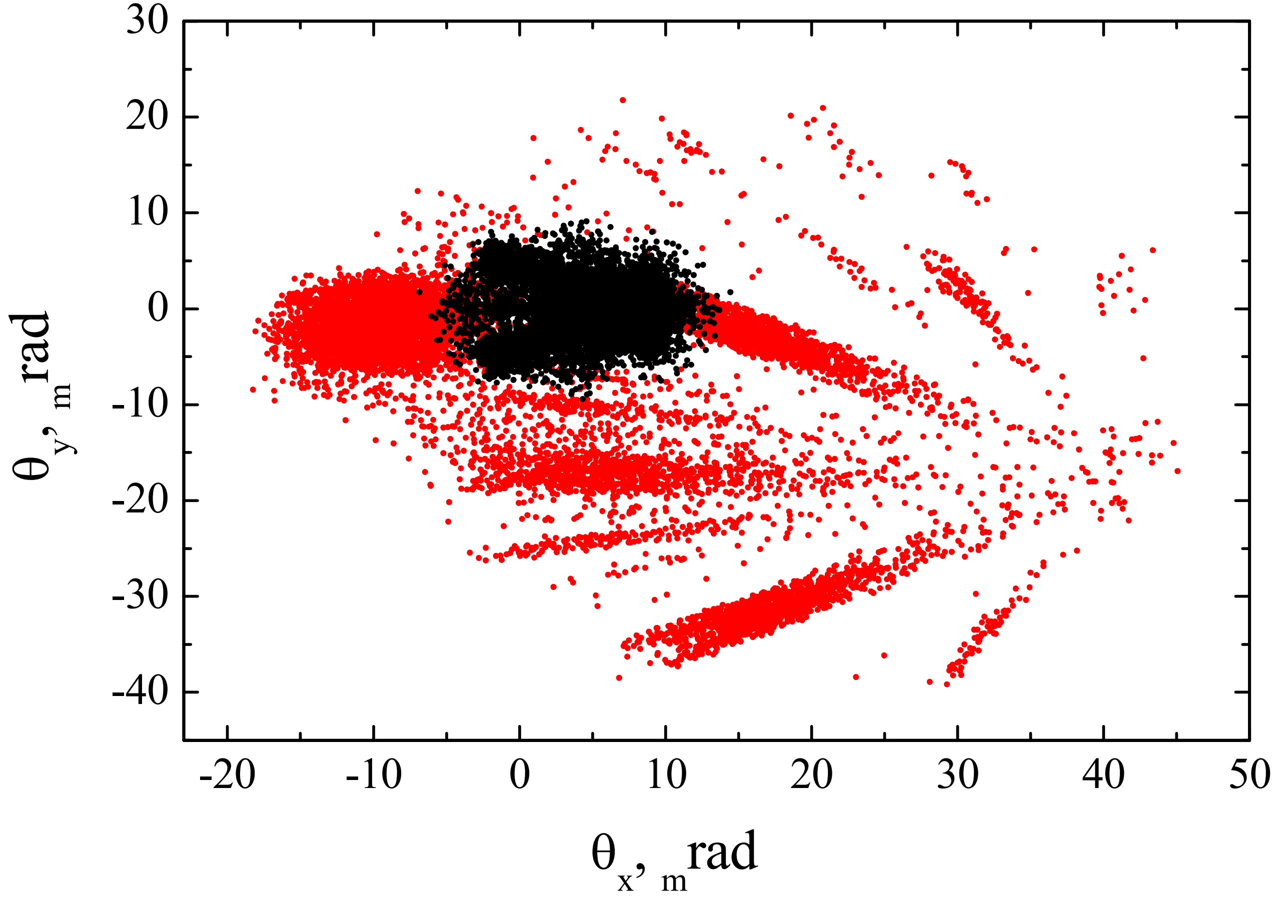


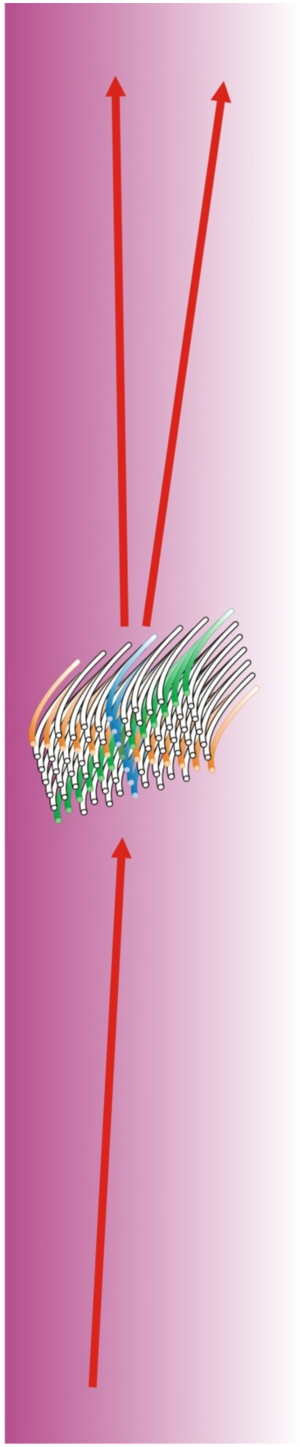




Comparison Axial Channeling

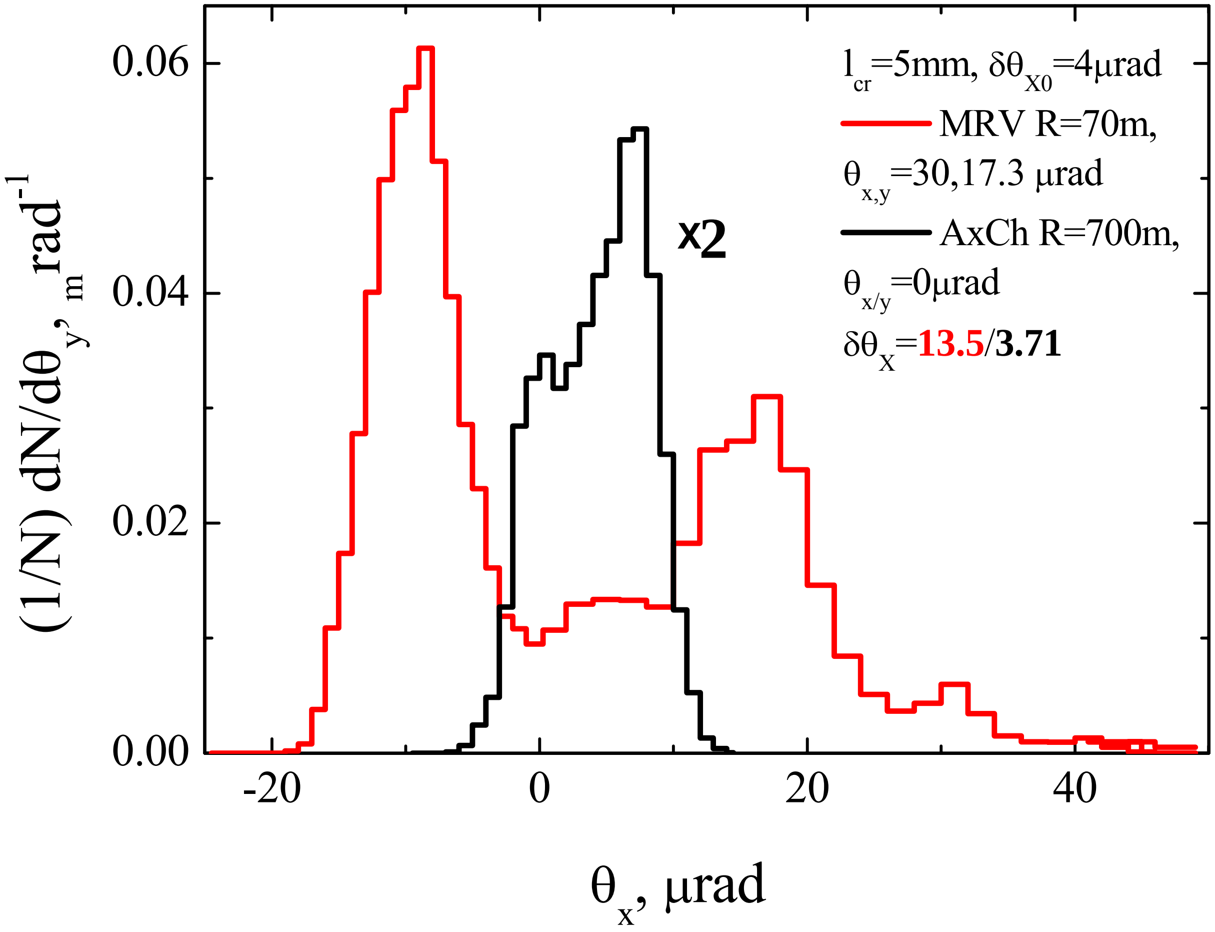
MVR + Planar Channeling vs Axial Channeling

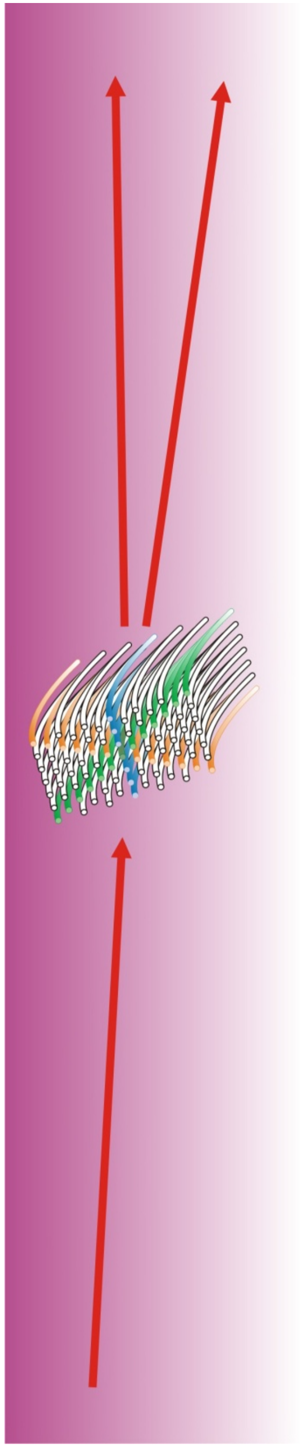




Comparison with Axial Channeling

7 TeV ***p*** MVR and Axial Channeling in SI





Plan

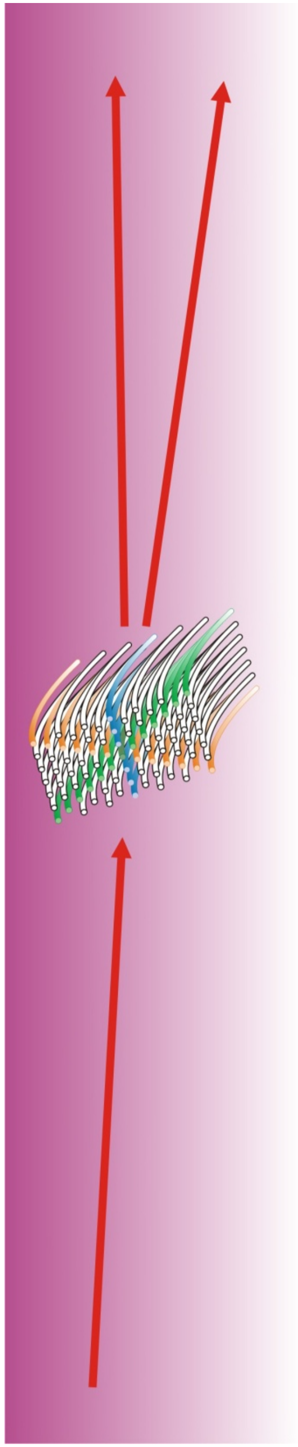
MVR idea

MVR experiments

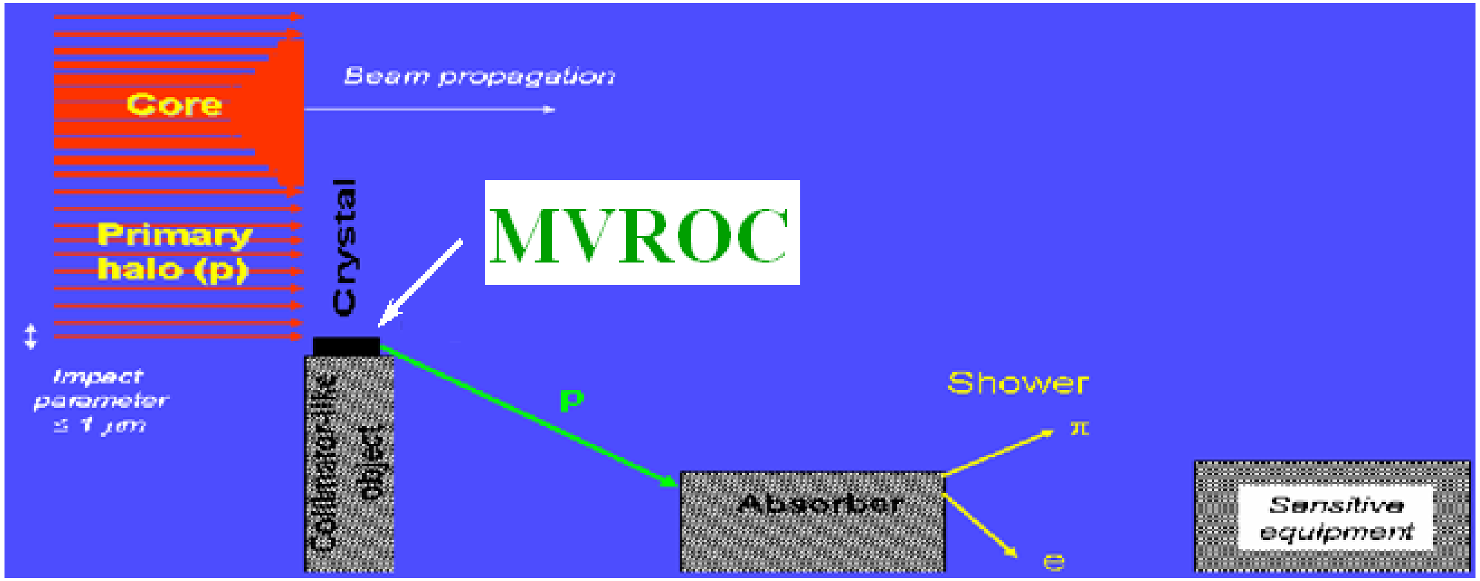
MVR and channeling/ doughnut scattering

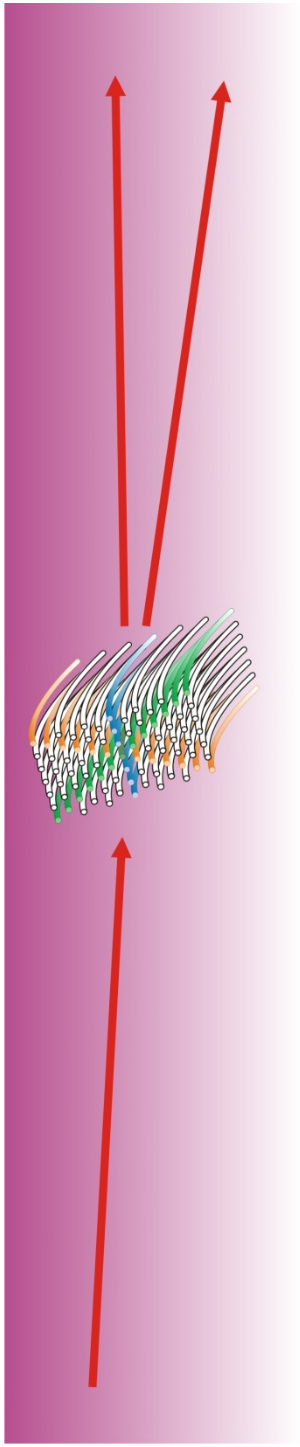
MVR and collimation

MVR and radiation



MVROC application to crystal collimation

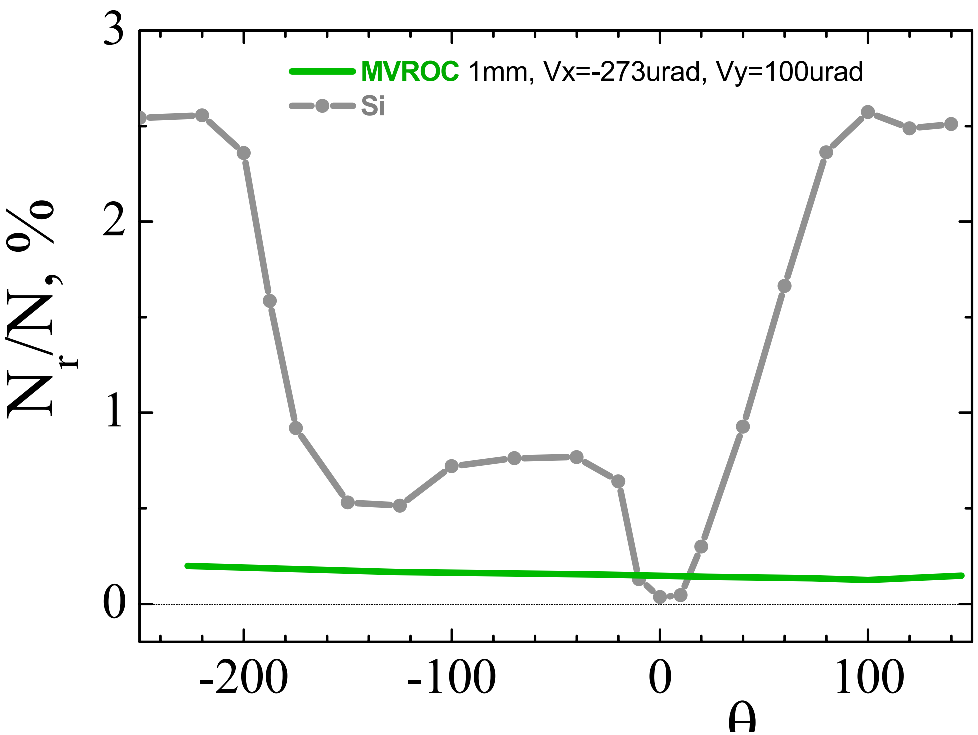




Inelastic loss fraction

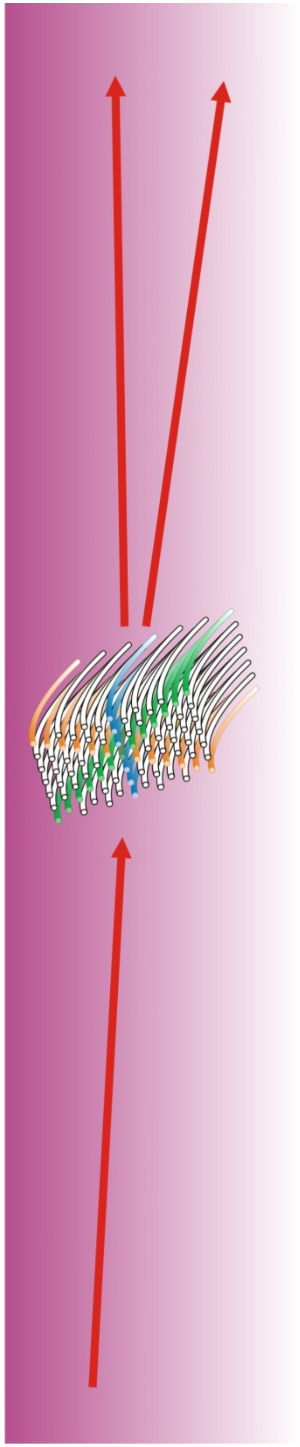
as a function of the crystal orientation

in the usual crystal, **crystal with cut** and a **crystal in MVROC orientation** *)



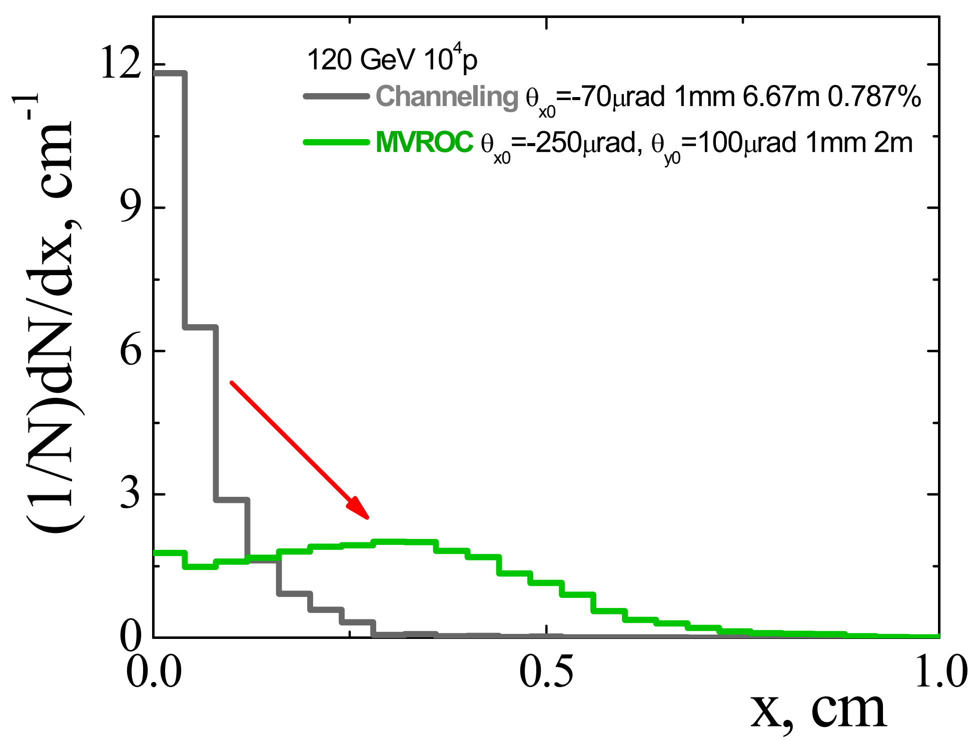
MVROC increases angular acceptance

*) MVROC orientation with Θ_{X0} = -273urad, Θ_{Y0} = 100urad and R=2m



Distributions of the impact parameter

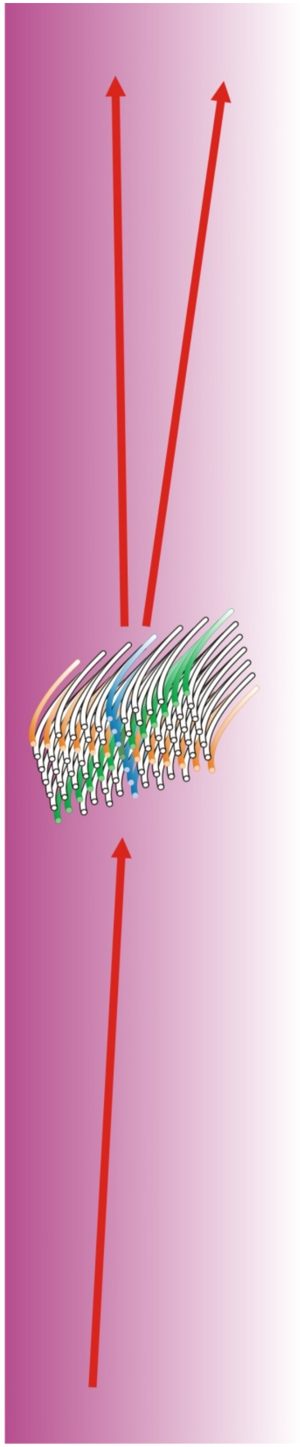
in usual Si crystal *) and **crystal in MVROC orientation** +)

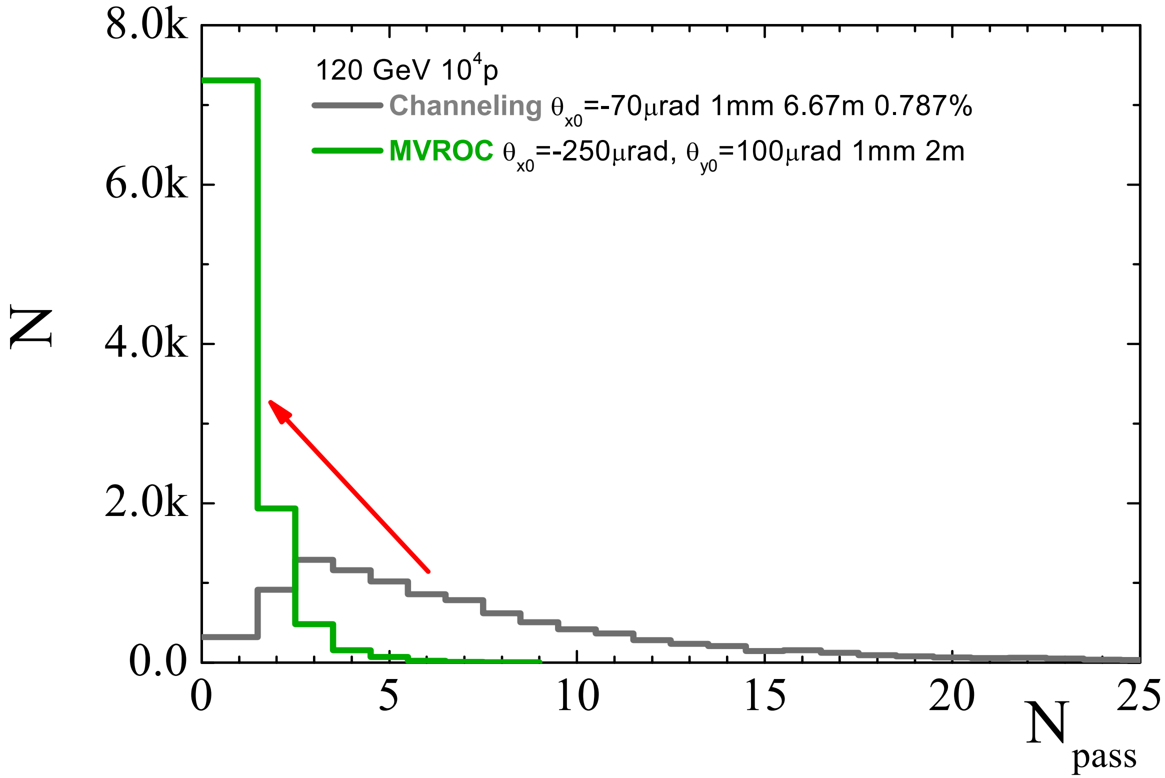


MVROC both increases the impact parameter and decreases the crystal transversals number *at rough alignment*

) Θ_{X0} = -70urad!*　　　+) Θ_{X0} = -250urad, Θ_{Y0} = 100urad and R=2m

Distributions of the number of the crystal transversals in usual Si crystal *) and crystal in MVROC orientation+)





MVROC decreases the crystal transversals number

at rough alignment

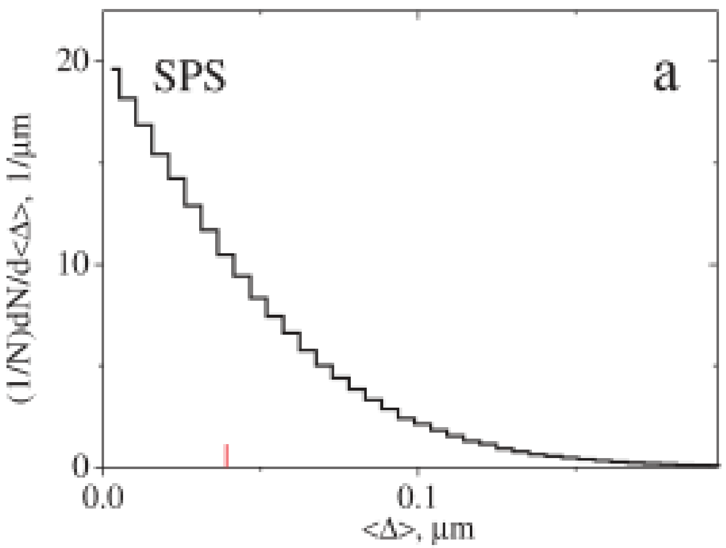
) Θ_{X0} = -70urad!*

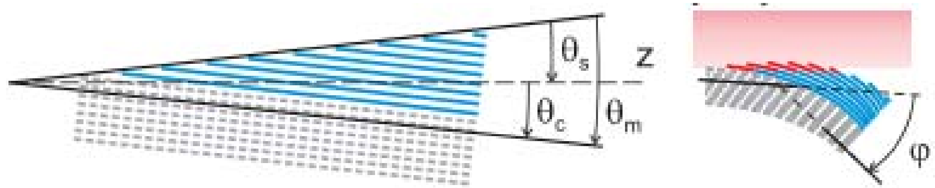
+) Θ_{X0} = -250urad, Θ_{Y0} = 100urad and R=2m

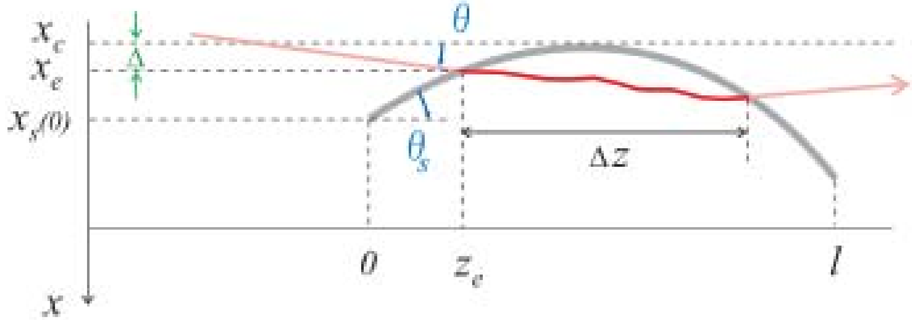
The talk coauthor **Alexei Sytov**

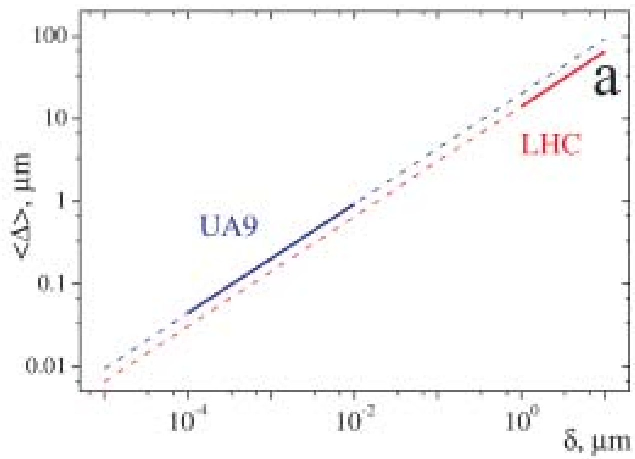
Institute for Nuclear Problems, Belarusian State University

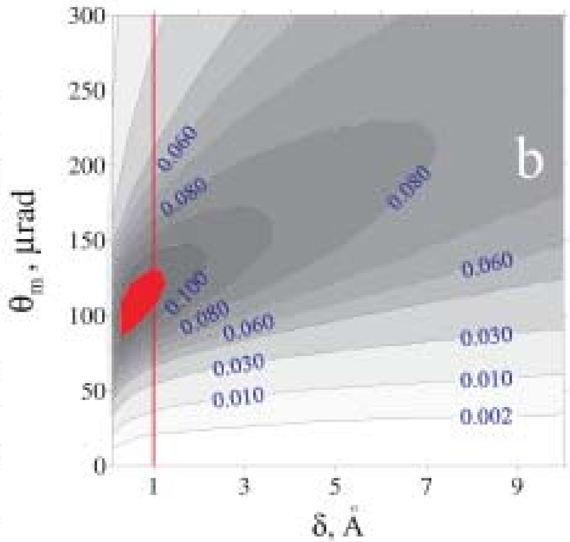
The role of *positive* miscut

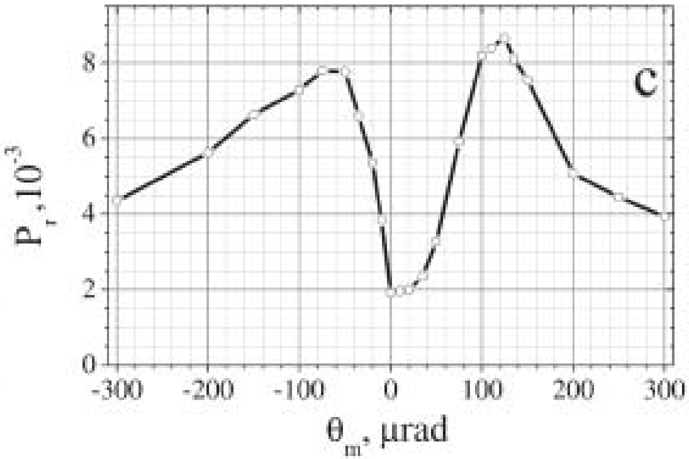












Fermilab, Accelerator Physics Center (APC)

Vladimir Shiltsev
Director of Accelerator Physics Center at Fermi National Accelerator Lab

Nikolai Mokhov
Head of the Energy Deposition Department in the Accelerator Physics Center

Tevatron beam halo collimation system: design, operational experience and new methods[1]

N. Mokhov,[2] J. Annala, R. Carrigan, M. Church, A. Drozhdin, T. Johnson, R. Reilly, V. Shiltsev, G. Stancari,[3] D. Still, A. Valishev, X.-L. Zhang and V. Zvoda

Fermi National Accelerator Laboratory,
P.O. Box 500, Batavia, IL, 60510, U.S.A.

E-mail: mokhov@fnal.gov

2011 JINST

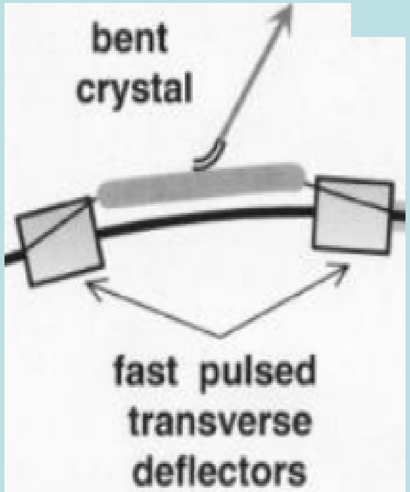
Beam extraction from the Recycler Ring*

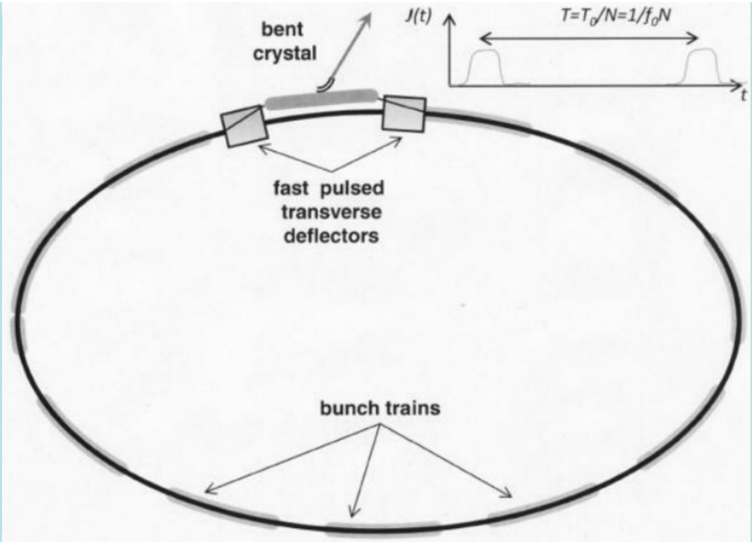
NOVEL SLOW EXTRACTION SCHEME FOR PROTON ACCELERATORS USING PULSED DIPOLE CORRECTORS AND CRYSTALS*

V. Shiltsev[#], FNAL, Batavia, IL 60510, USA

Crystal and beam parameters**:

- E = 8 GeV
- Crystal length = 1mm
- Crystal thickness = 1mm
- Bending angle = 0.5mrad

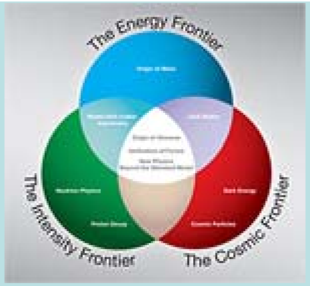




Intensity Frontier

Possible application:

Extraction of *very intensive beam* for:



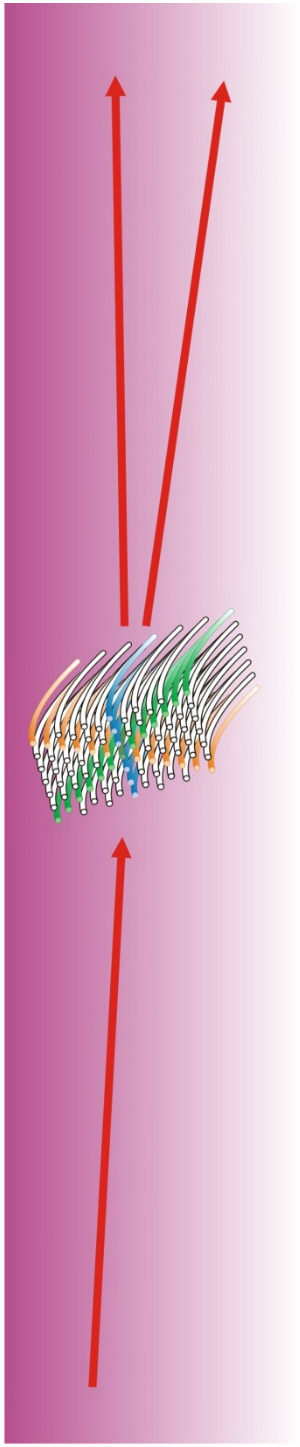
- **Neutrino experiments** (ArgoNeuT, MINERvA, MiniBooNE, MINOS, NOvA, LBNE)
- **Experiments with muons** (Mu2e, MICE)

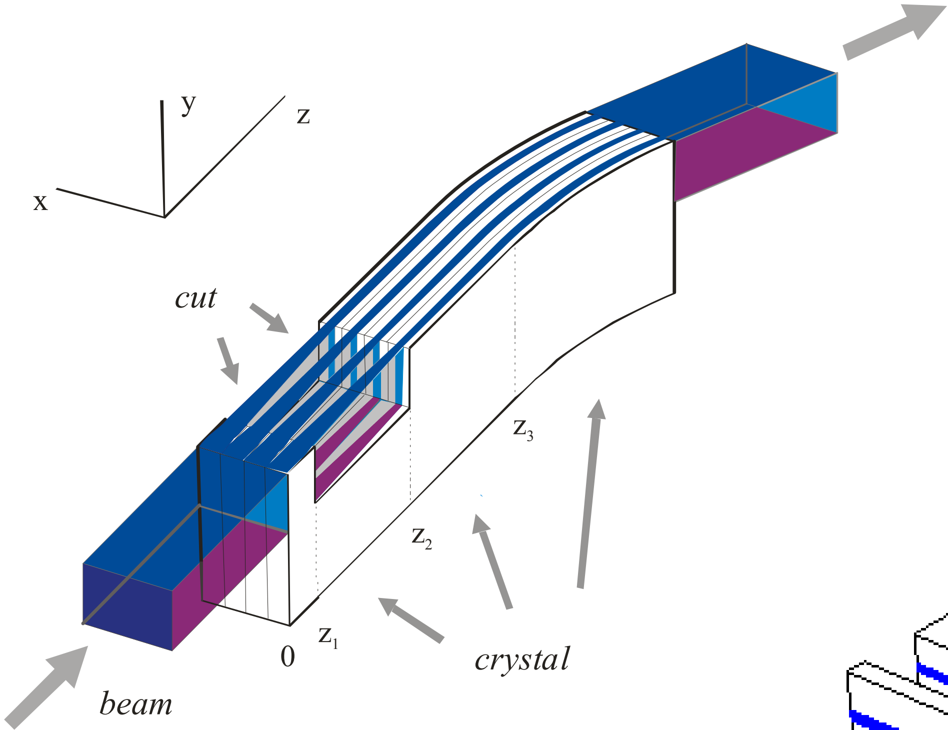
*__V. Shiltsev__, FNAL, No. DE-AC02-07CH11359;

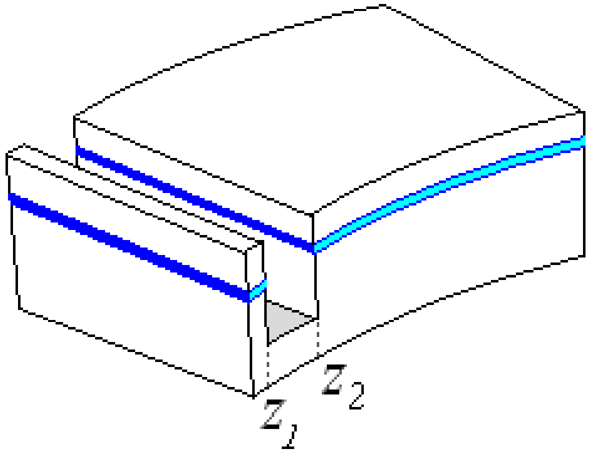
**__A.I. Drozhdin__, FNAL,

The capture probability increase by **crystal cut**

V.V.*Tikhomirov, JINST, 2(2007)P08006*

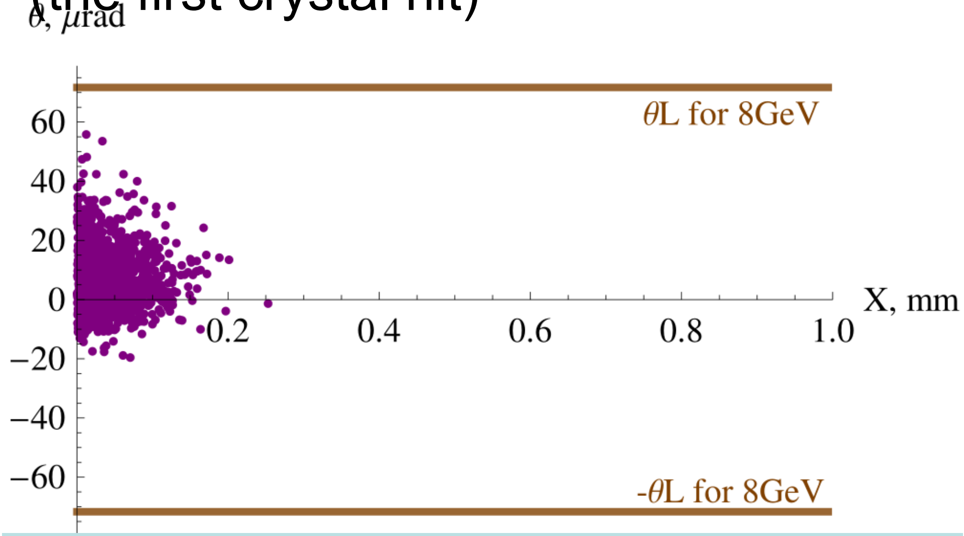




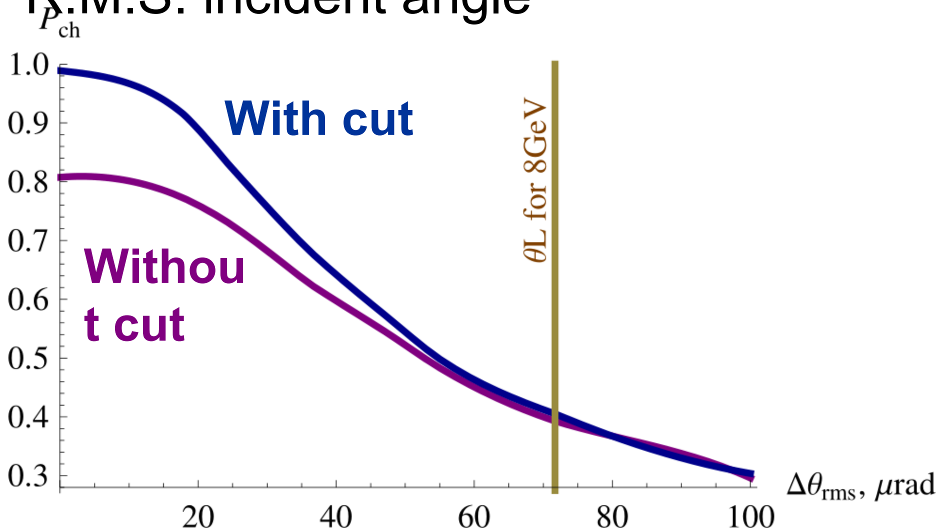


Cut modification for Recycler Ring

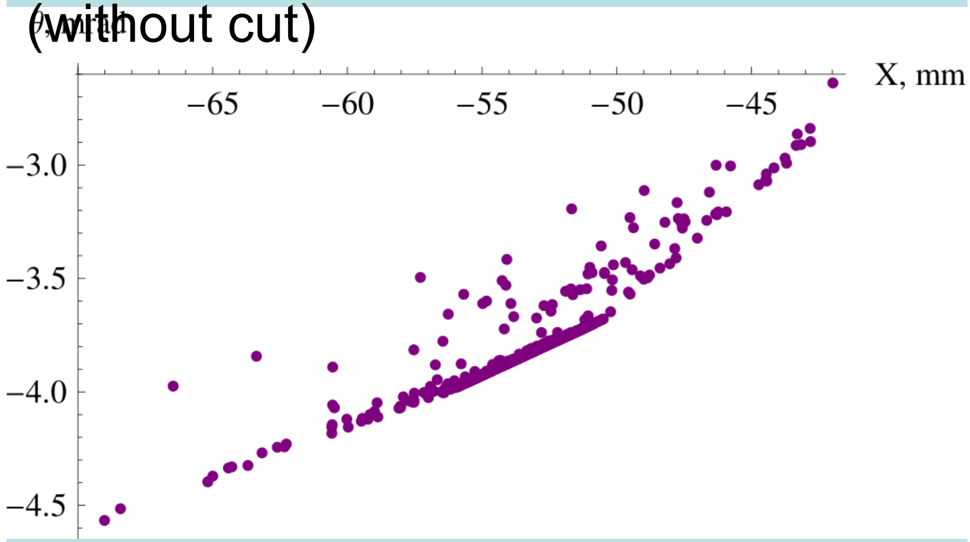
Phase space at the crystal entrance (the first crystal hit)



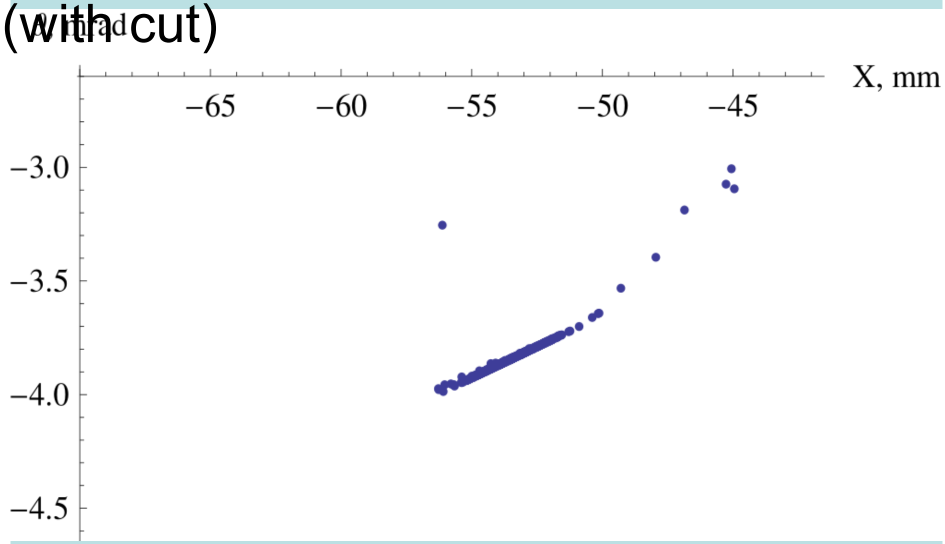
Channeling efficiency *vs* R.M.S. incident angle



Phase space at the beam Dump (without cut)



Phase space at the beam Dump (with cut)



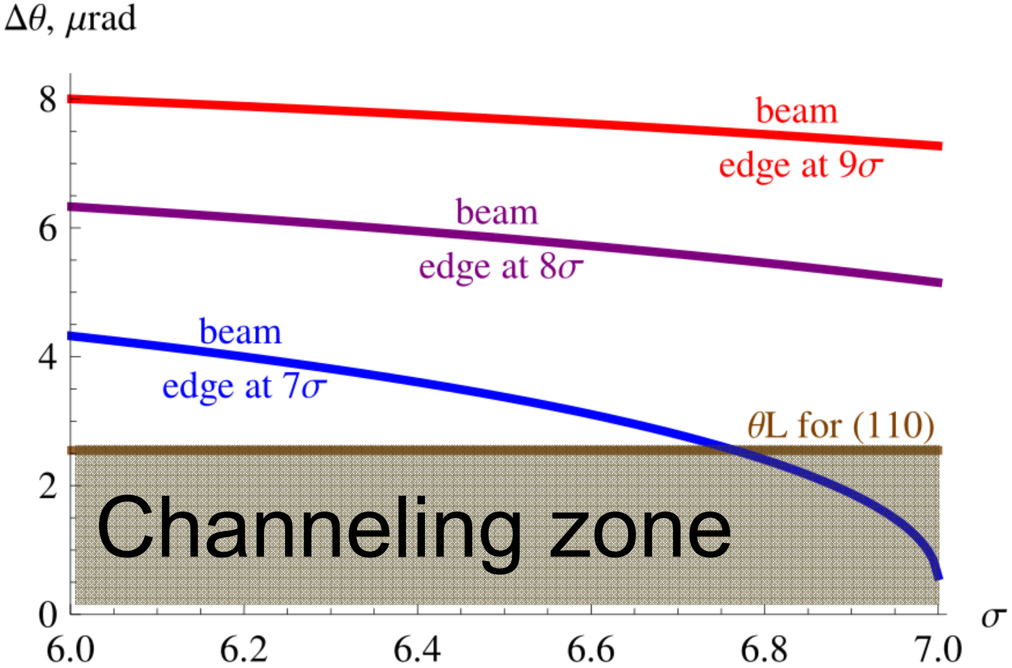
Main effects of beam losses at the LHC*

<table>
<tr><th>Effect</th><th colspan="4">Beam life time, h</th></tr>
<tr><td>Inelastic scattering in IP</td><td>108</td><td>108</td><td rowspan="3">70</td><td rowspan="5">41</td></tr>
<tr><td>Elastic scattering in IP</td><td>310</td><td rowspan="2">197</td></tr>
<tr><td>Diffractive scattering in IP</td><td>539</td></tr>
<tr><td>Inelastic scattering on residual gas</td><td>129</td><td colspan="2" rowspan="2">101</td></tr>
<tr><td>Elastic scattering on residual gas</td><td>459</td></tr>
</table>

***M. Lamont, LHC Project Note 375**

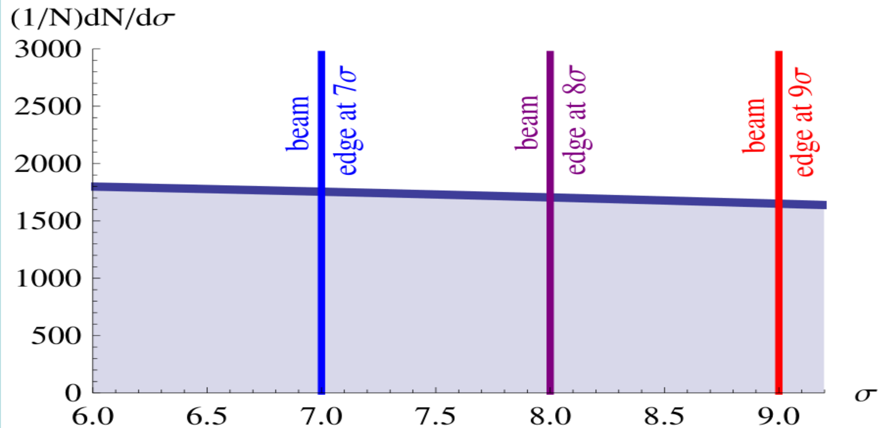
Beam profile and angular divergence for channeling

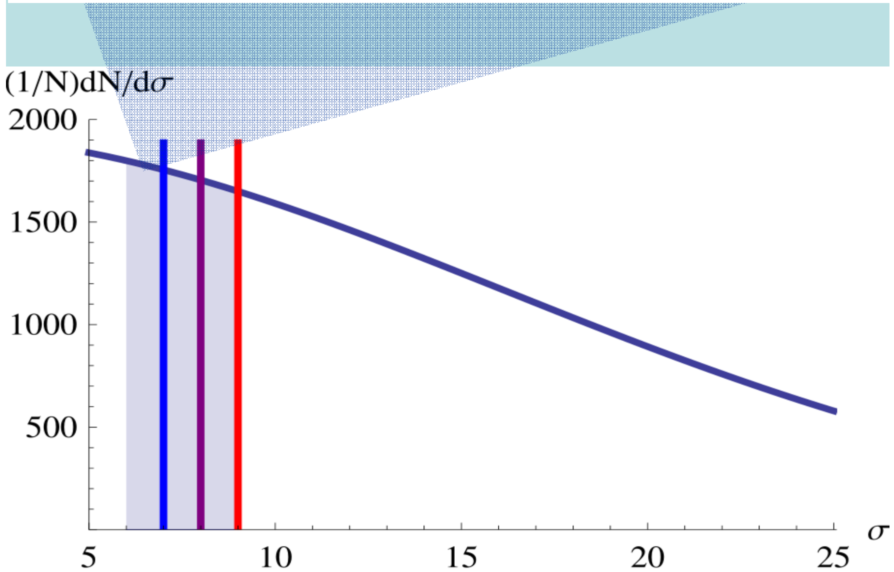
Average angular divergence vs impact parameter for different beam edges



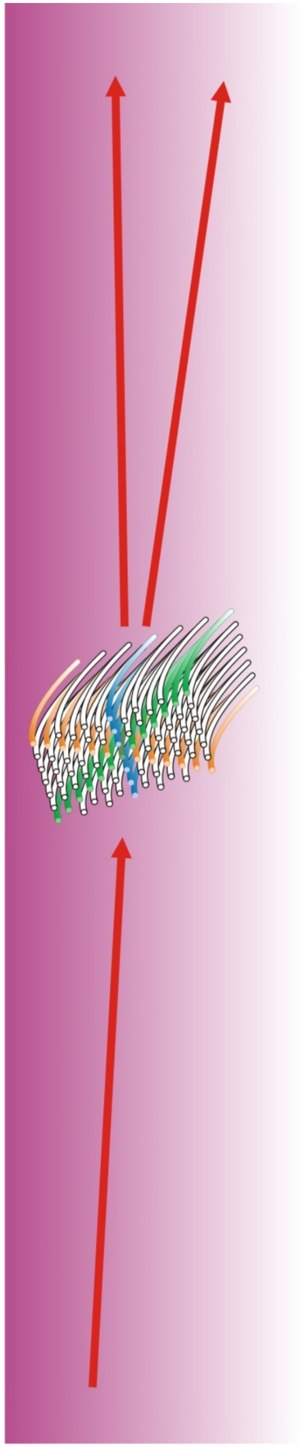
Conclusion:
The angular divergence is much larger than the critical angle of capture in the channeling regime. So, the channeling effect is not applicable for the LHC case.

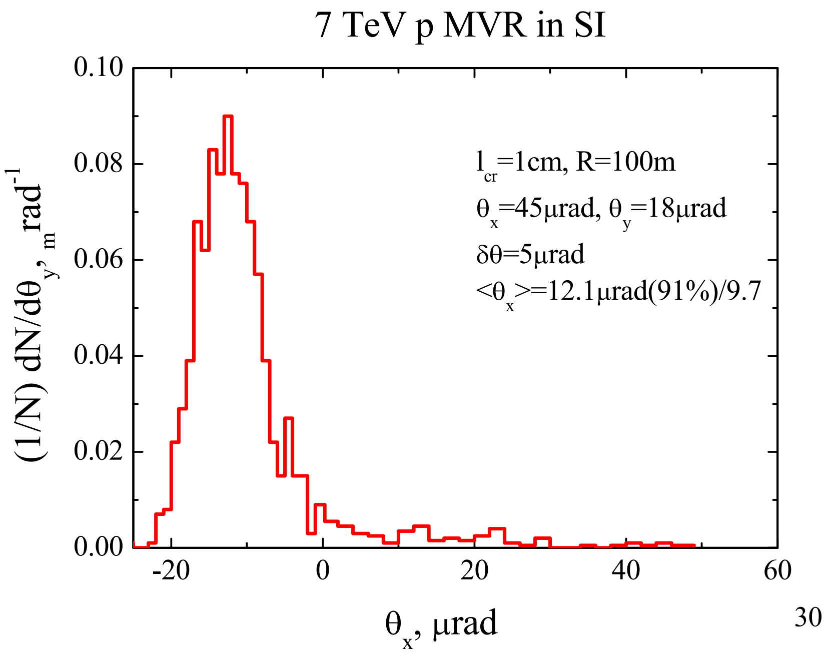
Beam profile at large σ due to elastic nuclear scattering on the residual gas

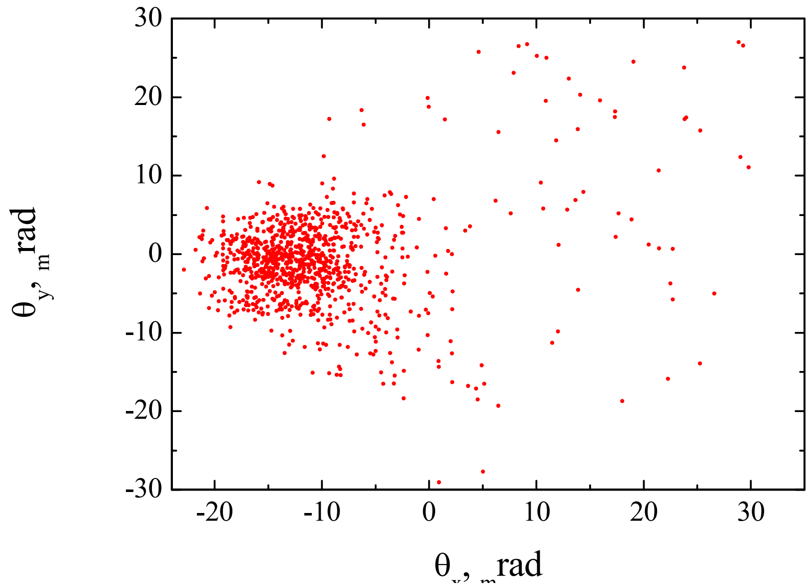




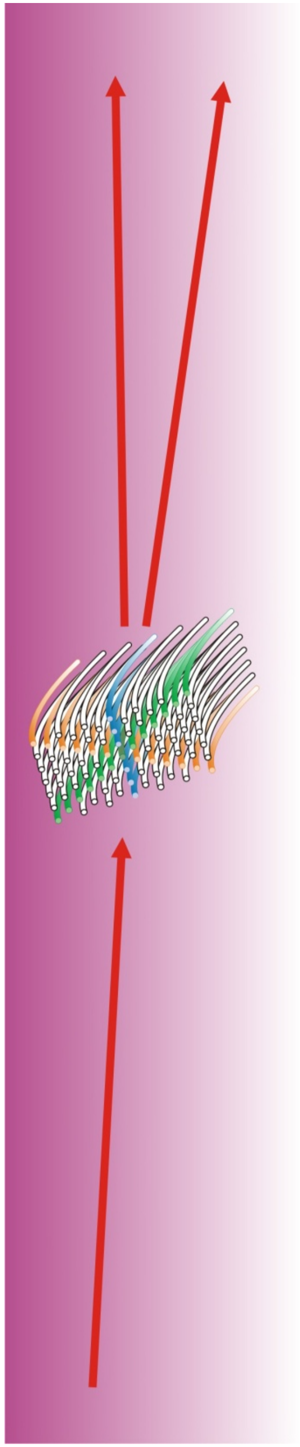
LHC collimation (7 GeV p) by Si

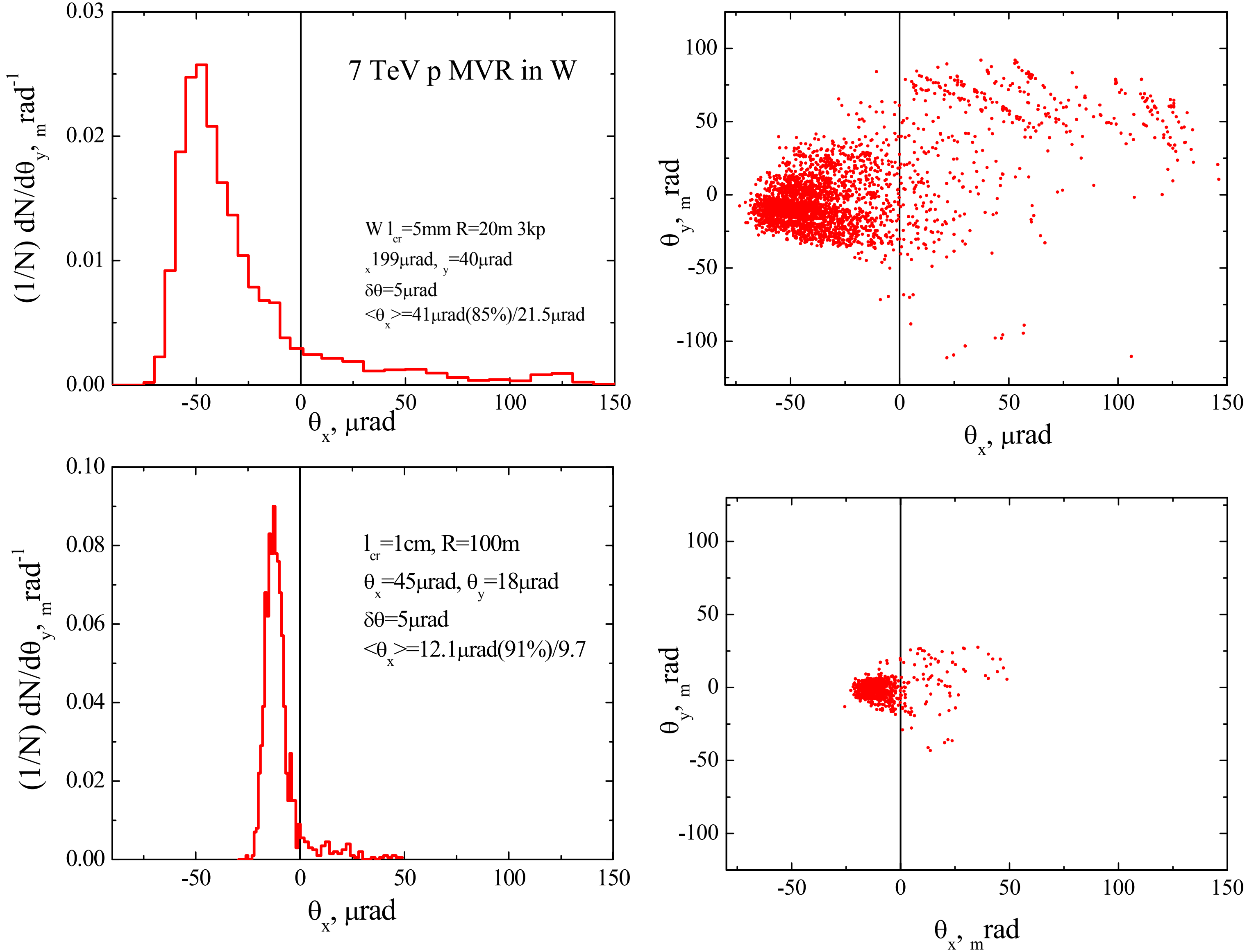




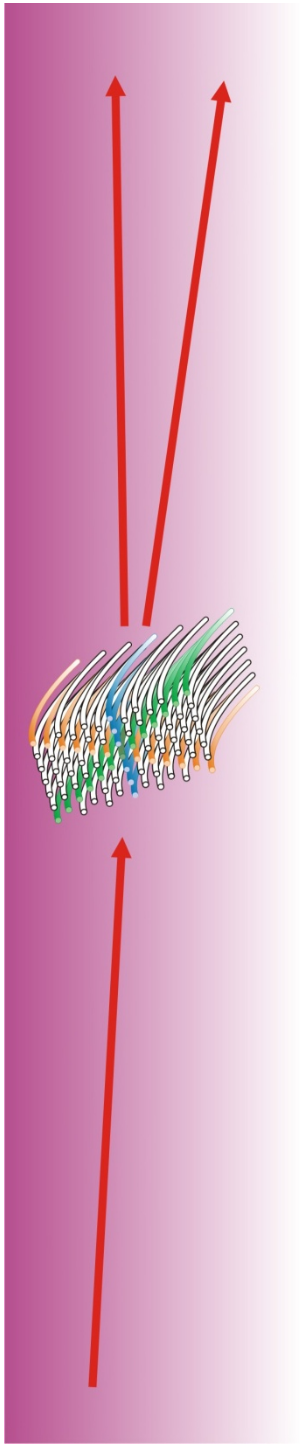


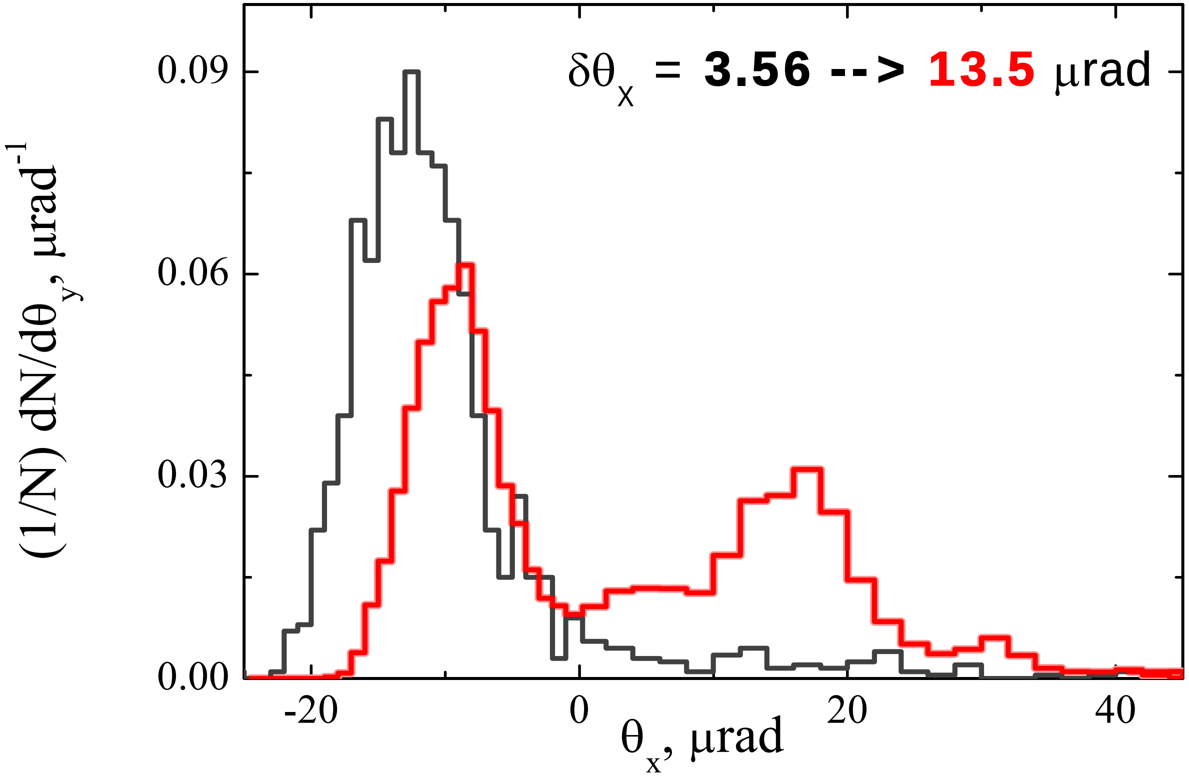
LHC collimation (7 GeV p) by *W*

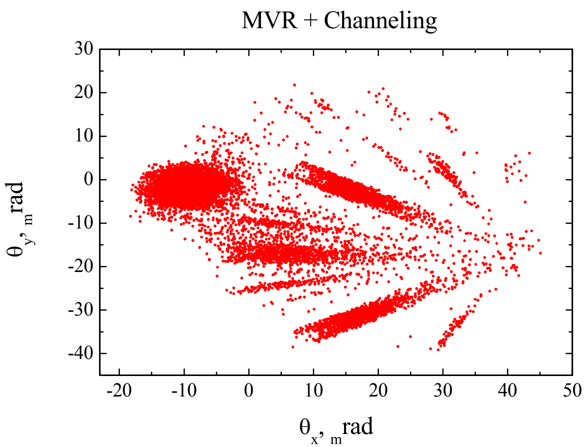


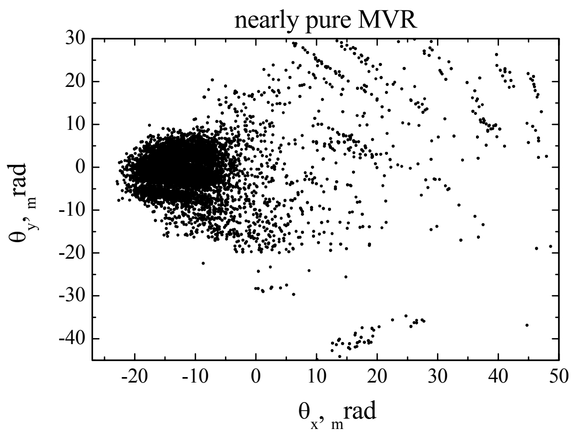


drastic MVR angular divergion increase by channeling

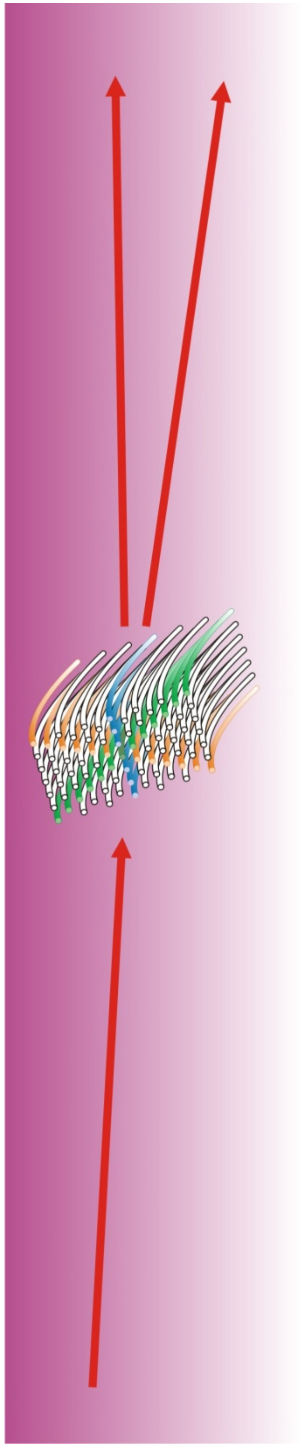




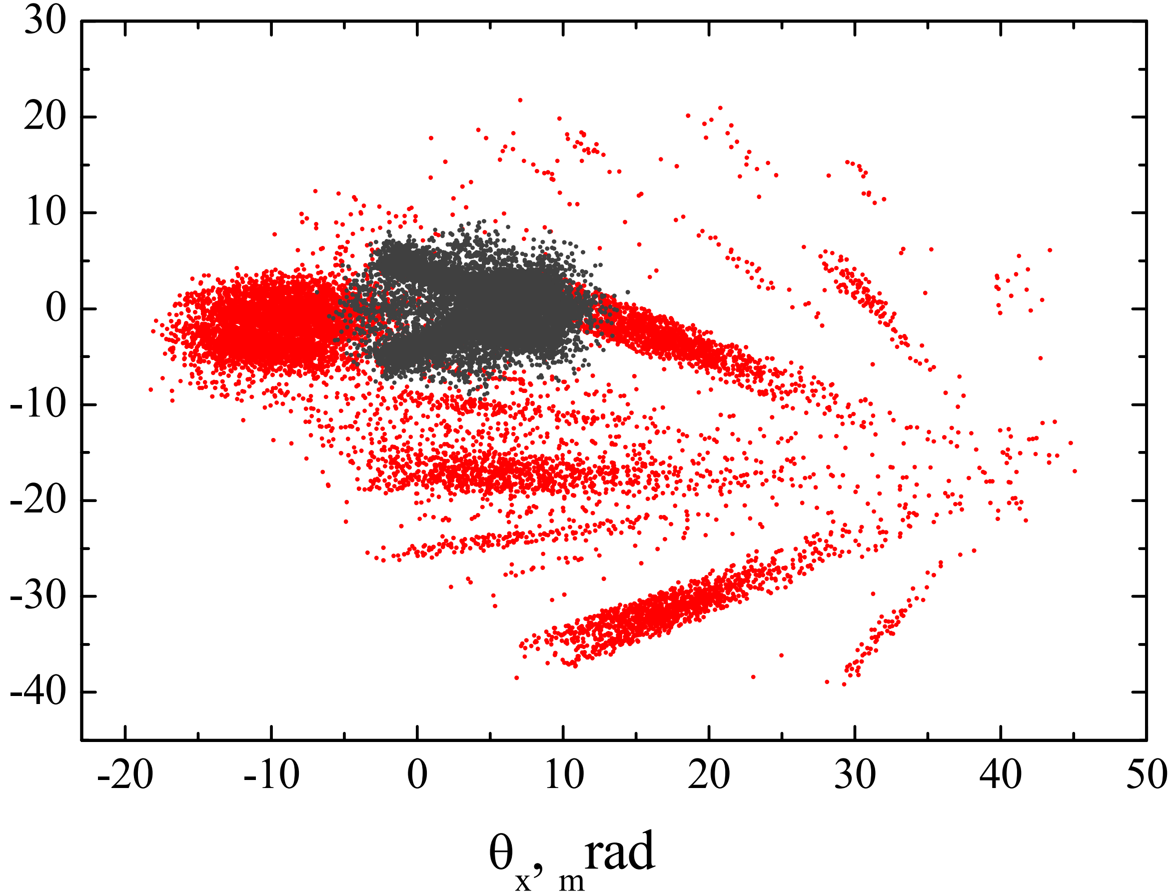




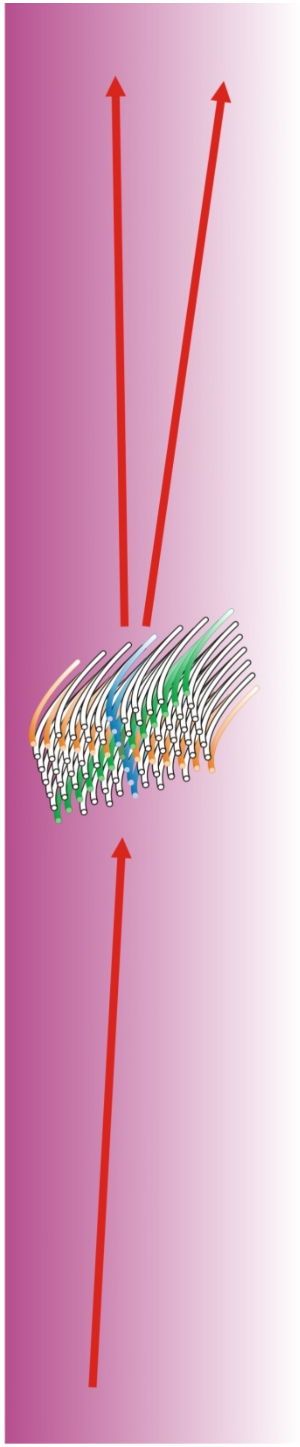
Comparison with Axial Channeling

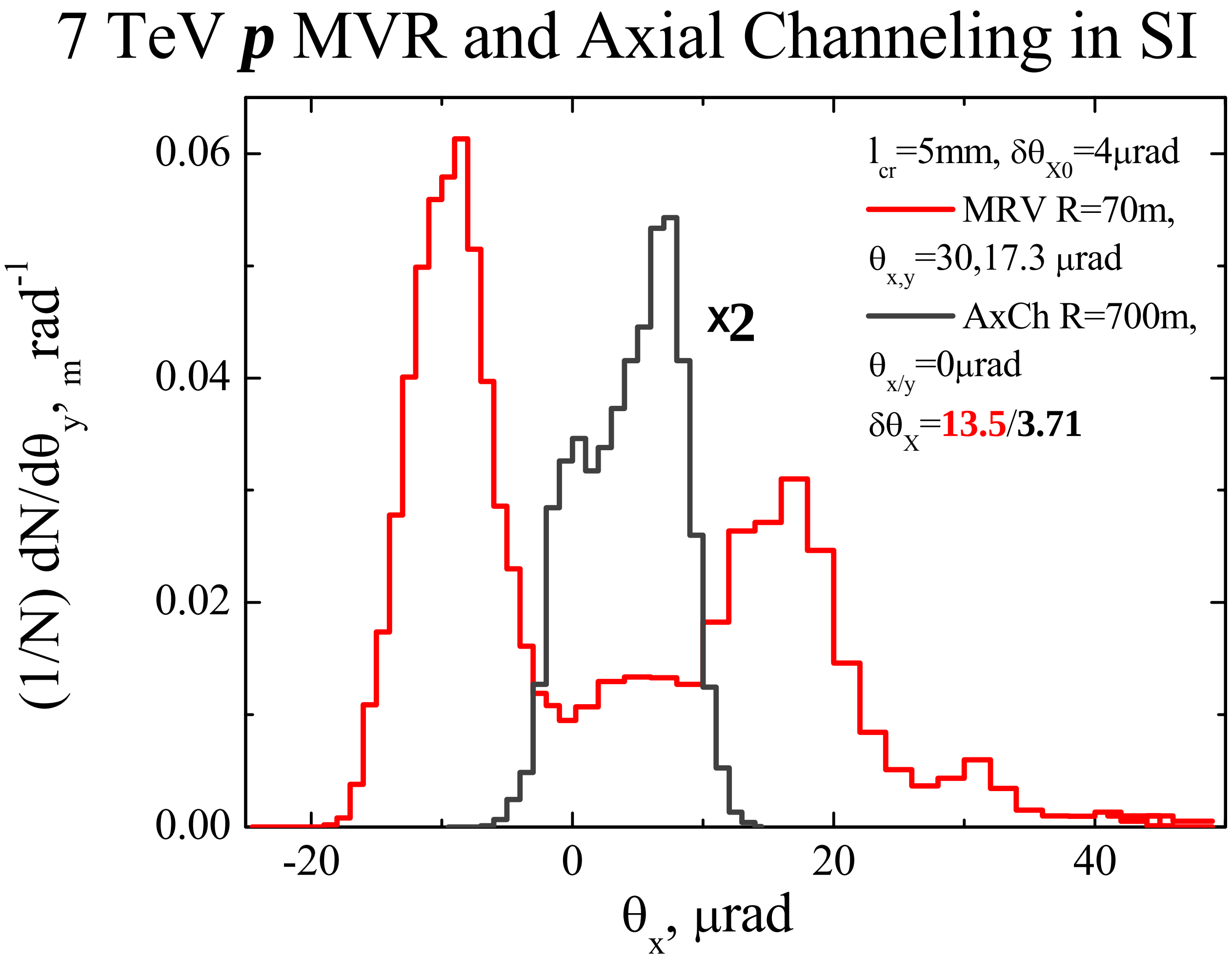


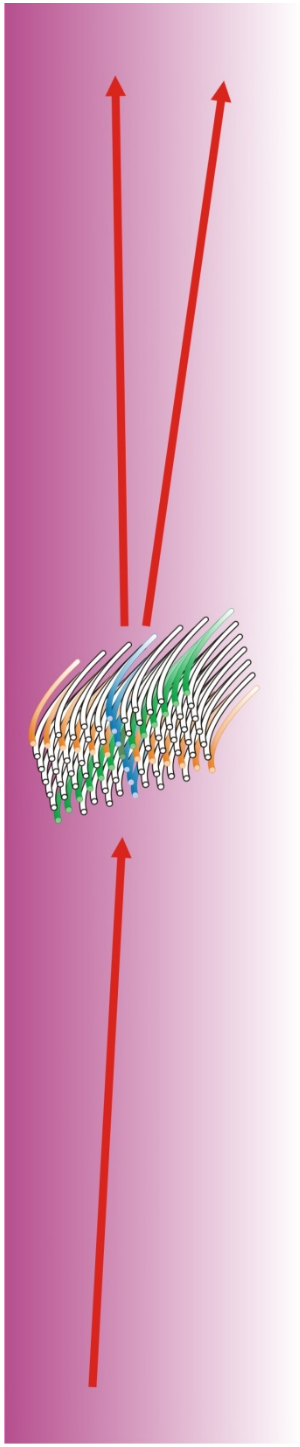
MVR + Planar Channeling vs Axial Channeling



Comparison with Axial Channeling







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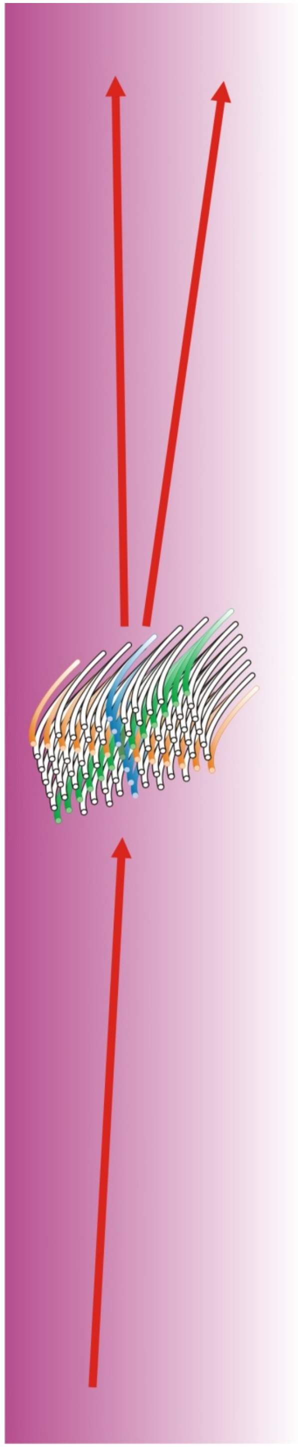
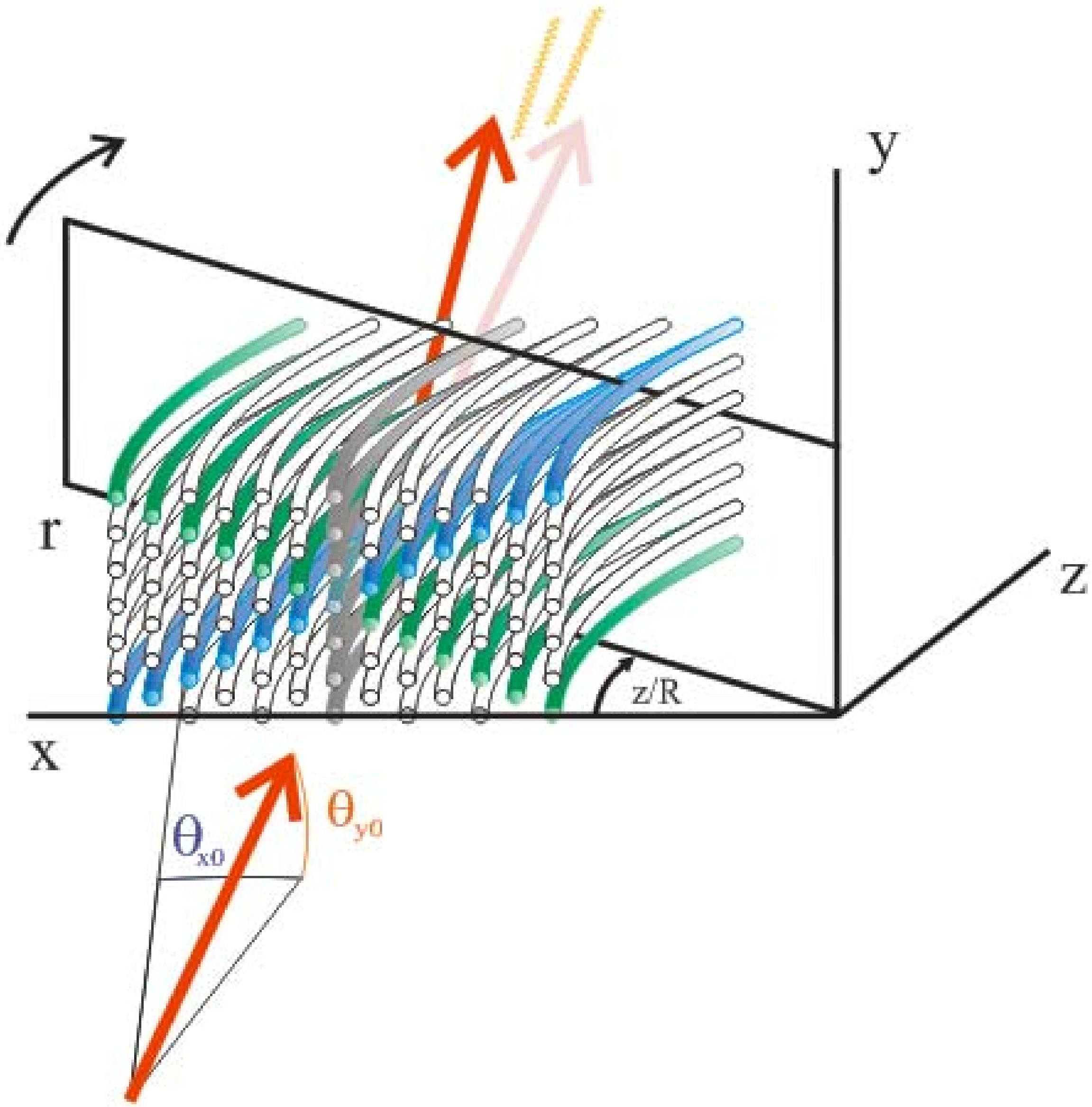
doughnut scattering

MVR and collimation

MVR and radiation




y
r
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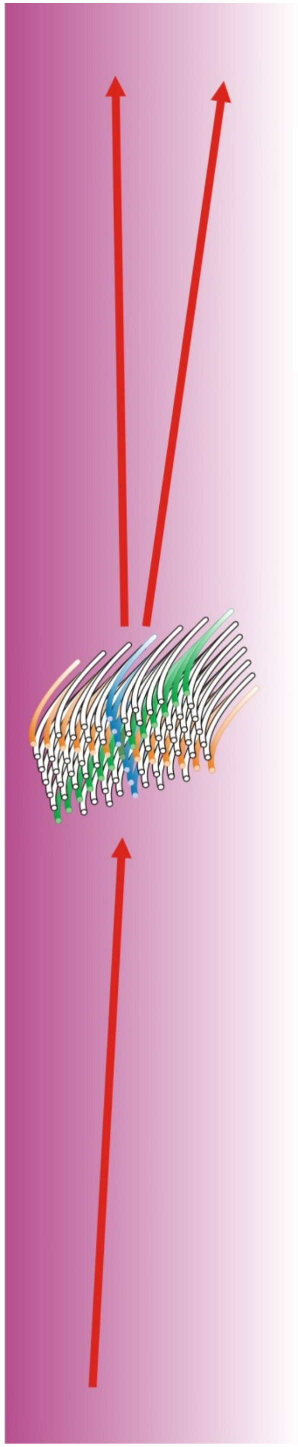


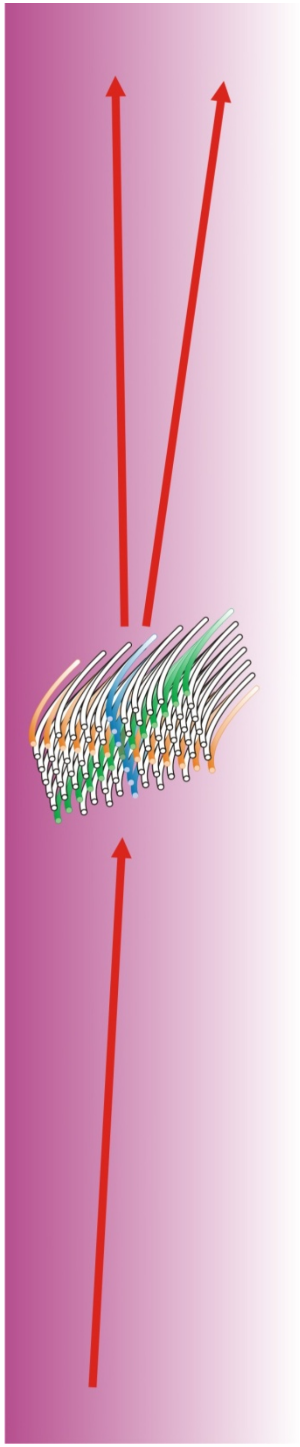
The radiation accompanyimg MVR is the most general and complex case ***ever***

Dipole, synchrotron-like and *intermediate* **radiation** cases

Interference of planar and axial radiation

Strong **scattering** by both planes and axes

Channeling by both planes and axes



Radiation process simulations from the *“First Principles”*

The general expression for radiation intensity

$$\frac{d^2 I}{d\omega d^2\theta} = \frac{\alpha\omega^2 d\omega}{8\pi^2\varepsilon'^2} \times \int\int dt_1 dt_2 \left[(\varepsilon^2+\varepsilon'^2)(\mathbf{v}_\perp(t_1)-\boldsymbol{\theta})(\mathbf{v}_\perp(t_2)-\boldsymbol{\theta}) + \omega^2/\gamma^2\right]$$

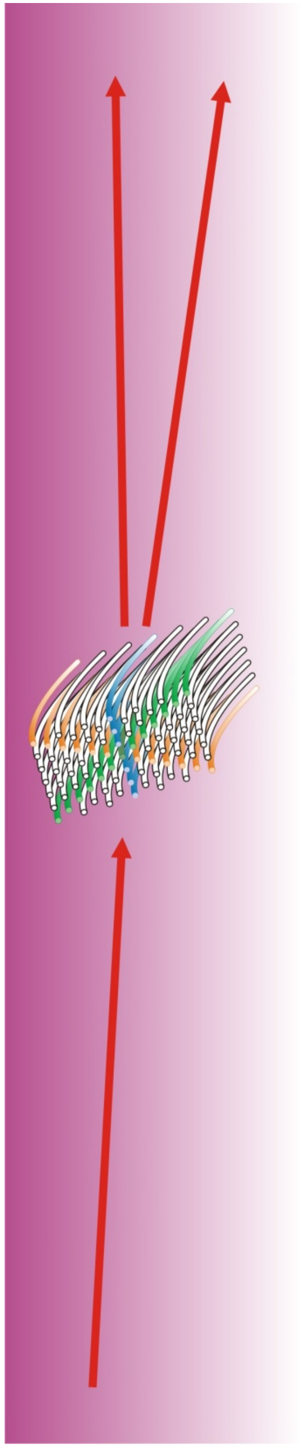
$$\exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'}\left[\int_{-\infty}^{t_1}\left(\gamma^{-2}+(\mathbf{v}_\perp(t')-\boldsymbol{\theta})^2\right)dt' + \int_{-\infty}^{t_2}\left(\gamma^{-2}+(\mathbf{v}_\perp(t'')-\boldsymbol{\theta})^2\right)dt''\right]\right\}$$

contains two integrals

$$A = \int \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'}\int_{-\infty}^{t}\left[\gamma^{-2}+(\mathbf{v}_\perp(t')-\boldsymbol{\theta})^2\right]dt'\right\} dt,$$

$$\mathbf{B} = \int (\mathbf{v}_\perp(t)-\boldsymbol{\theta}) \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'}\int_{-\infty}^{t}\left[\gamma^{-2}+(\mathbf{v}_\perp(t')-\boldsymbol{\theta})^2\right]dt'\right\} dt$$

and slowly decreases with radiation angle $\boldsymbol{\theta}$, complicating its numerical integration.



Partial integration in integrals I and $\mathbf{J}$ is suggested to be undertaken to improve to improve the situation:

$$A = \int \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'} \int_{-\infty}^{t} \left[\gamma^{-2} + (\mathbf{v}_\perp(t') - \boldsymbol{\theta})^2\right] dt' \right\} dt$$

$$= \int \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'} \int_{-\infty}^{t} \left[\gamma^{-2} + (\mathbf{v}_\perp(t') - \boldsymbol{\theta})^2\right] dt' \right\} \frac{d\left\{\int_{-\infty}^{t} [\gamma^{-2} + (\mathbf{v}_\perp(t) - \boldsymbol{\theta})^2]\, dt\right\}}{\gamma^{-2} + (\mathbf{v}_\perp(t) - \boldsymbol{\theta})^2}$$

$$= \underline{\frac{2\varepsilon'}{i\omega\varepsilon} \frac{\exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'} \int_{-\infty}^{t} \left[\gamma^{-2} + (\mathbf{v}_\perp(t') - \boldsymbol{\theta})^2\right] dt' \right\}}{\gamma^{-2} + (\mathbf{v}_\perp(t) - \boldsymbol{\theta})^2} \Bigg|_{-\infty}^{\infty}}$$

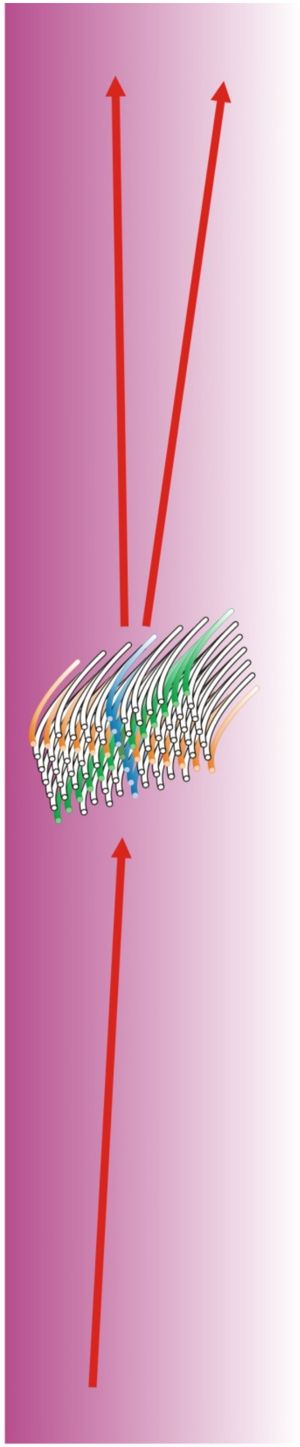
$$+ \int_{-\infty}^{\infty} \frac{2\varepsilon'}{i\omega\varepsilon} \frac{d\mathbf{v}_\perp(t)}{dt} \frac{2(\mathbf{v}_\perp(t') - \boldsymbol{\theta})}{[\gamma^{-2} + (\mathbf{v}_\perp(t) - \boldsymbol{\theta})^2]^2} \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'} \int_{-\infty}^{t} \left[\gamma^{-2} + (\mathbf{v}_\perp(t') - \boldsymbol{\theta})^2\right] dt' \right\} dt$$

$$\mathbf{B} = \int (\mathbf{v}_\perp(t) - \boldsymbol{\theta}) \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'} \int_{-\infty}^{t} \left[\gamma^{-2} + (\mathbf{v}_\perp(t') - \boldsymbol{\theta})^2\right] dt' \right\} dt$$

$$= -\frac{2\varepsilon'}{i\omega\varepsilon} \int_{-\infty}^{\infty} \left\{ \frac{\dot{\mathbf{v}}_\perp(t)}{\gamma^{-2} + (\mathbf{v}_\perp(t) - \boldsymbol{\theta})^2} - (\mathbf{v}_\perp(t') - \boldsymbol{\theta}) \frac{2\dot{\mathbf{v}}_\perp(t) \cdot (\mathbf{v}_\perp(t') - \boldsymbol{\theta})}{[\gamma^{-2} + (\mathbf{v}_\perp(t) - \boldsymbol{\theta})^2]^2} \right\}$$

$$\times \exp\left\{ i\frac{\omega\varepsilon}{2\varepsilon'} \int_{-\infty}^{t} \left[\gamma^{-2} + (\mathbf{v}_\perp(t') - \boldsymbol{\theta})^2\right] dt' \right\} dt$$

allows to neglect the contribution of trajectory ends, improving the angular integral convergence.



Key simulation points:

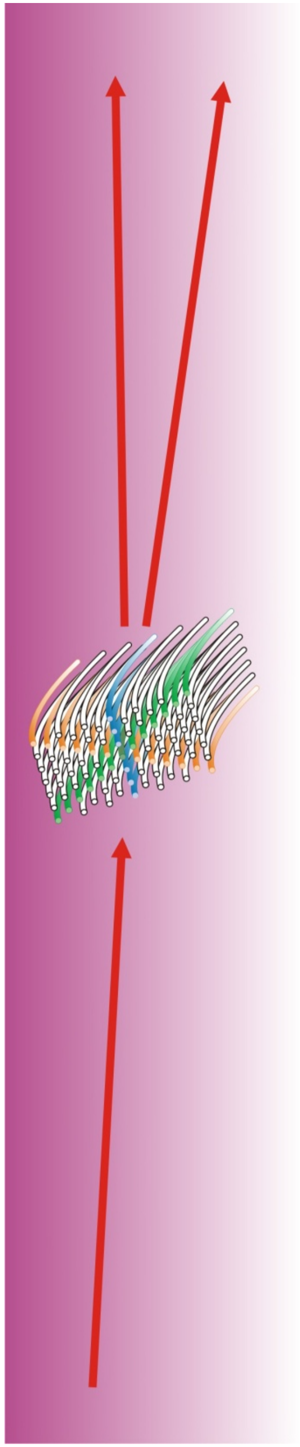
Trajectory simulations in most **realistic potentials**

Incoherent scattering simulations on both nuclei and electrons

Separate simulation of **single** and **multiple** scattering

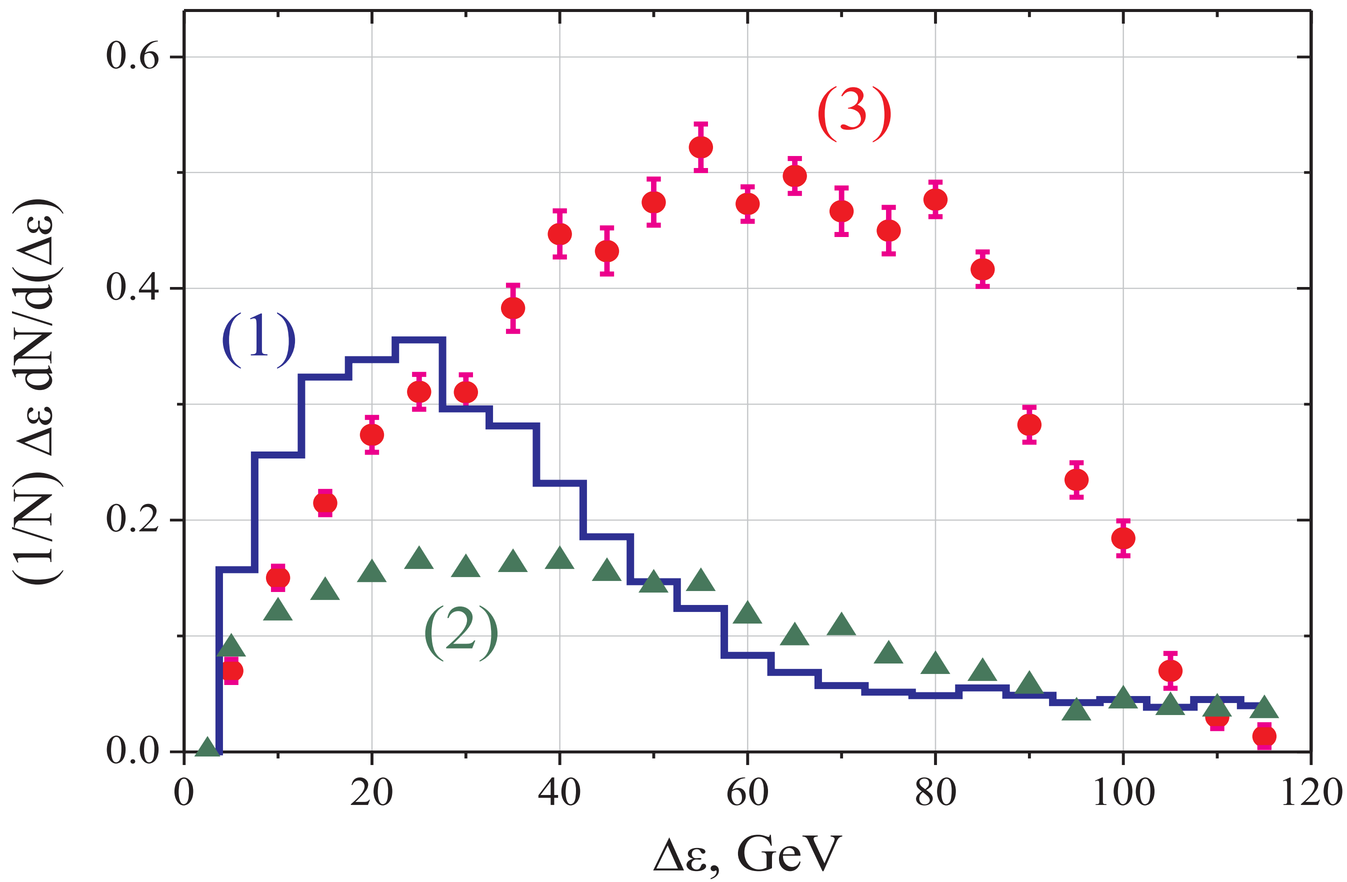
Direct integration of **Baier-Katkov formula**

Infinite trajectories, **density** effect…

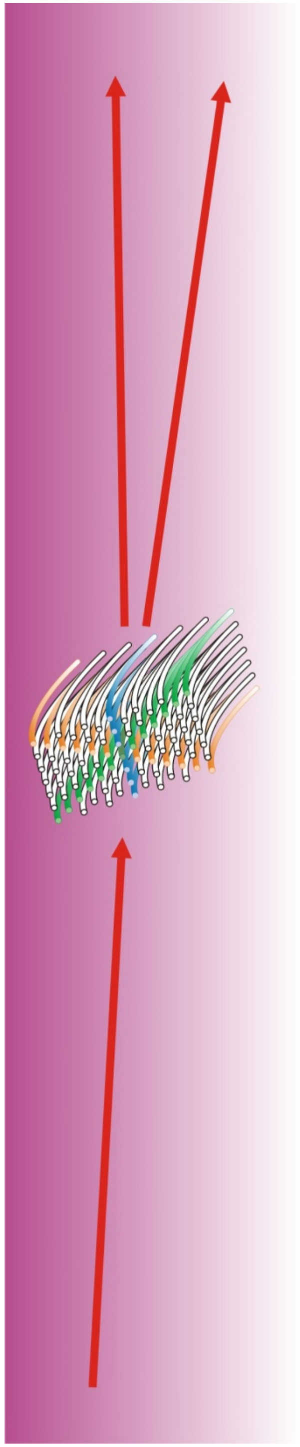


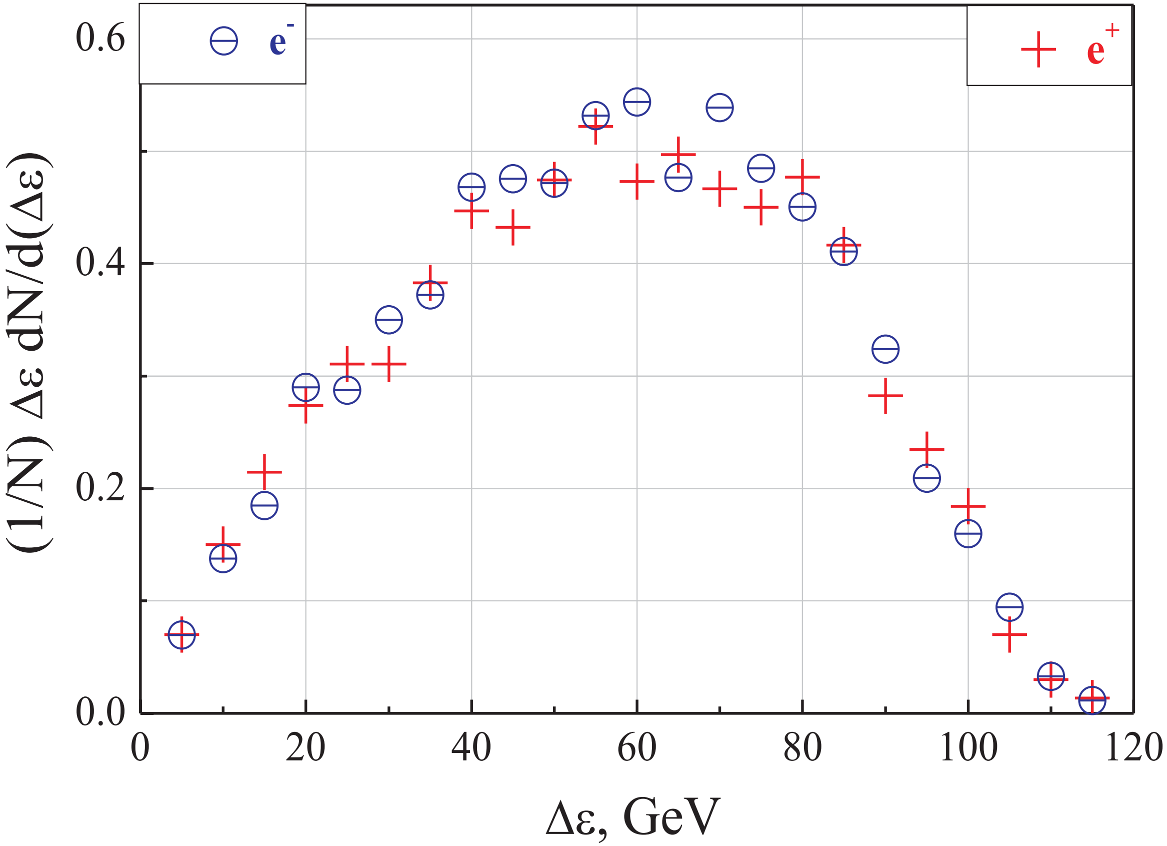
Energy loss spectrum of 120 GeV positrons in 2 mm Si (110) crystal, bent by 700 μrad.

(1) — is for planar MVR, (2) — VR by only $(110)_V$ plane and (3)) — <111> axes. Positrons initially move with 50 μ rad divergence and average incidence angles of 350 and 150 μ rad with respect to the axis in horizontal and vertical planes.



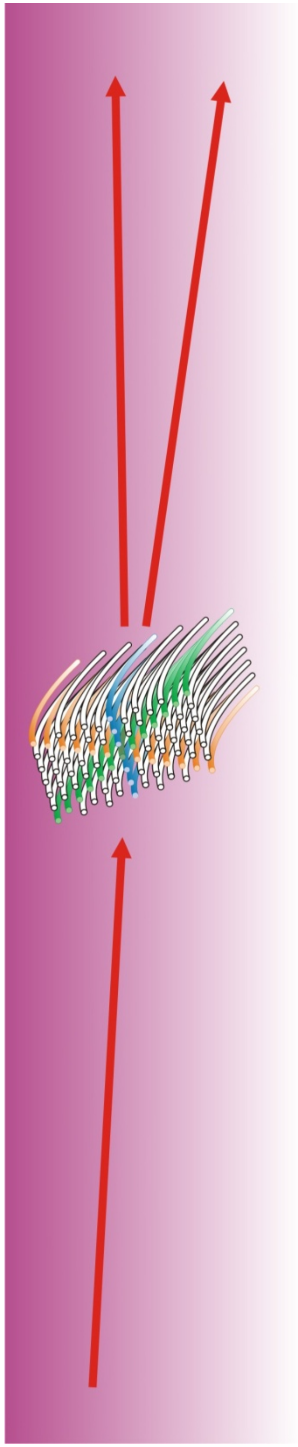
Same distributions for both 120 GeV positron (crosses) and electron (circles) radiation in the field of <111> axes.



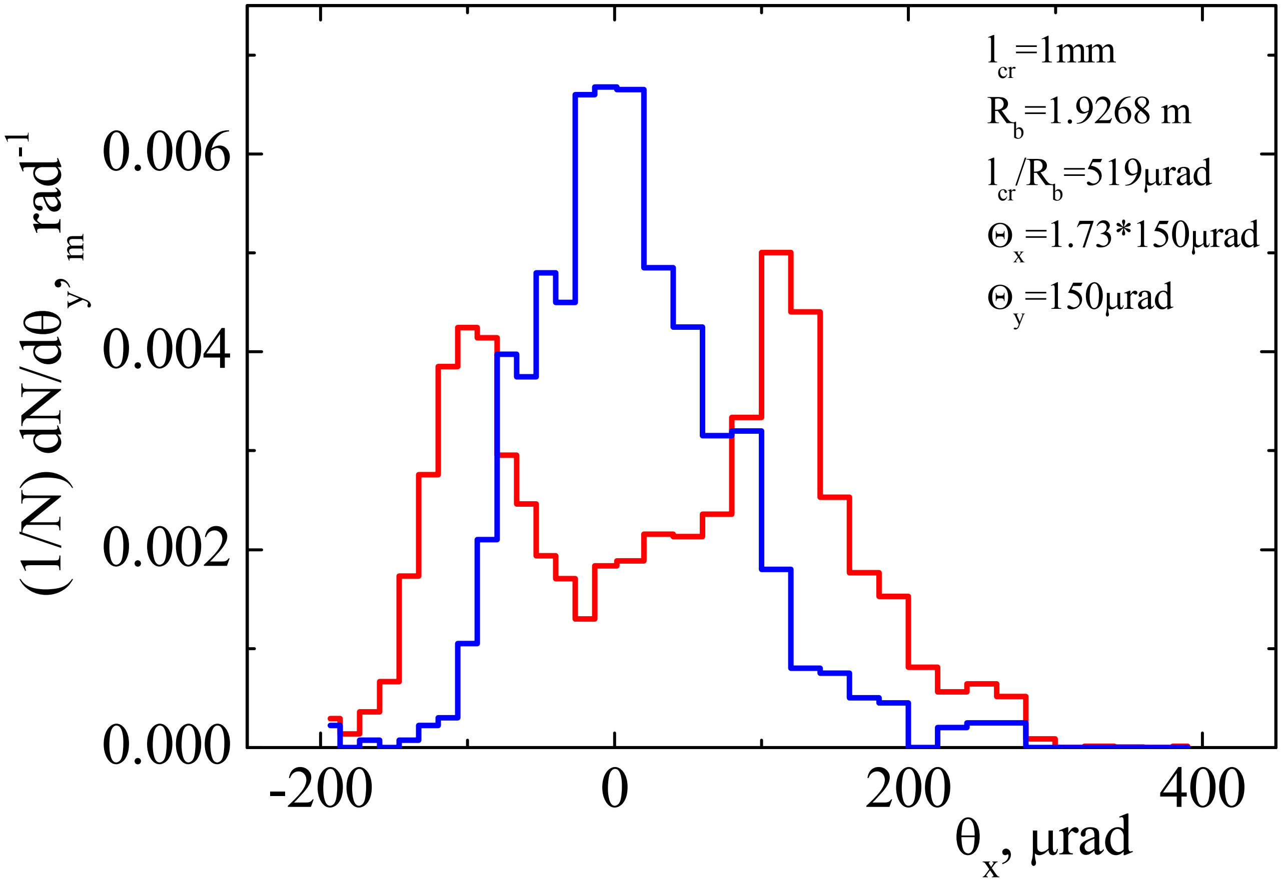


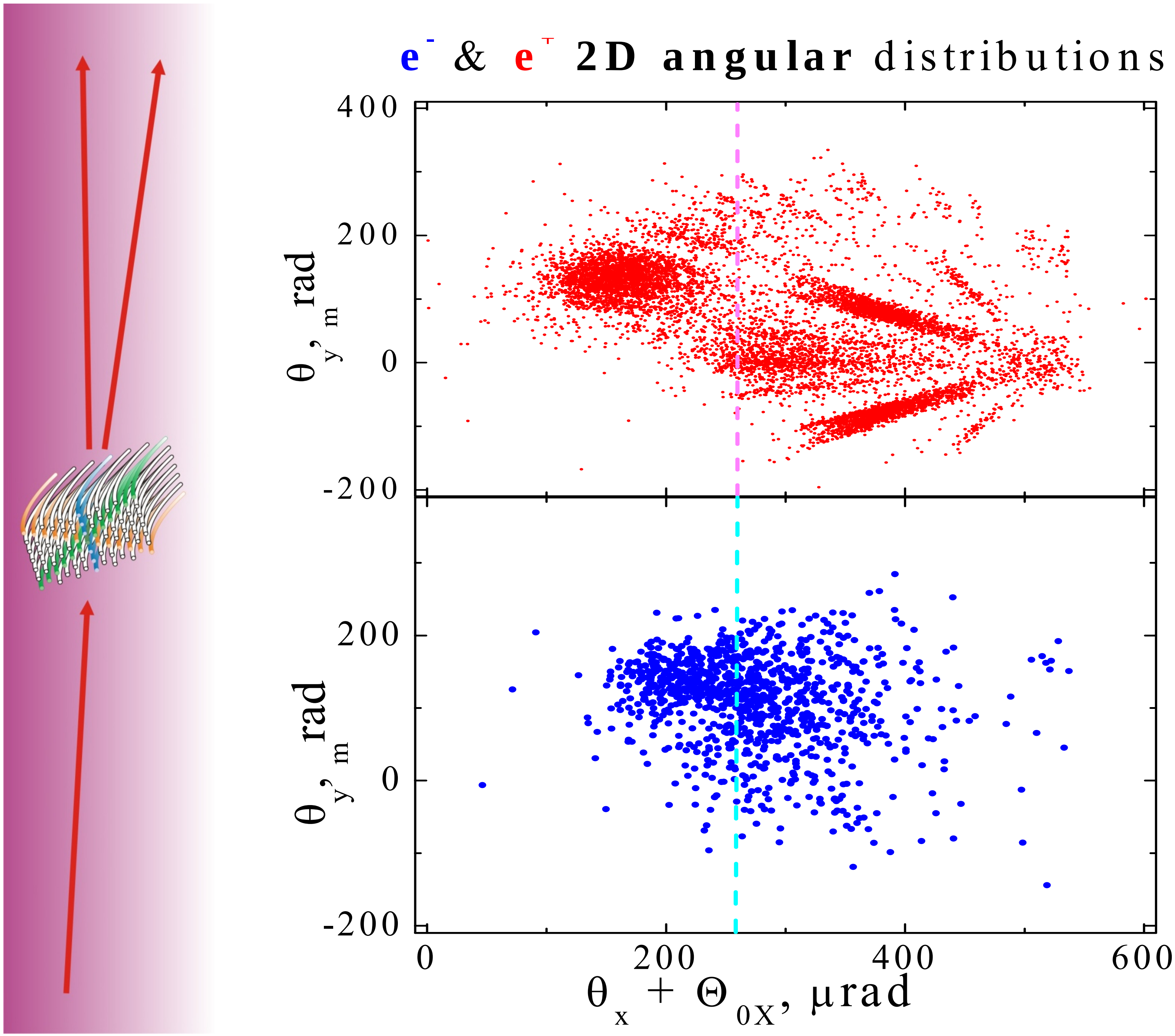
Radiation intensity independence is observed.

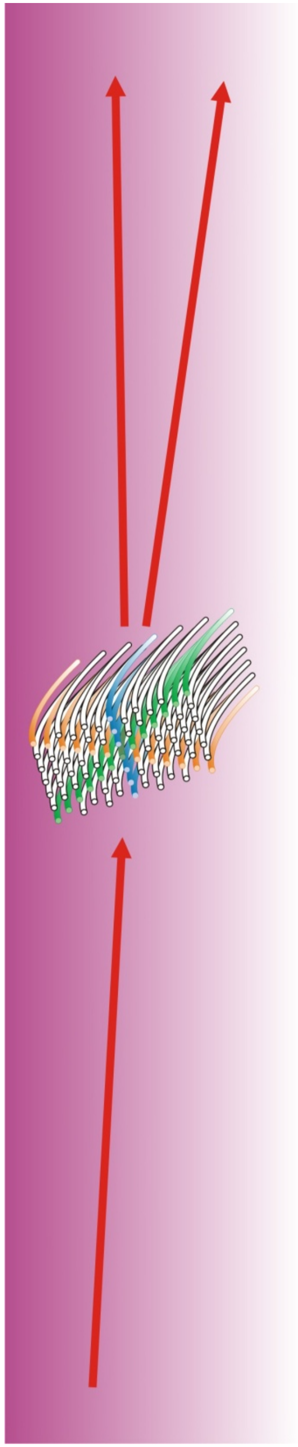
New suggestion: radiation accompanying MVR & Channeling



e⁻ & e⁺ angular distributions

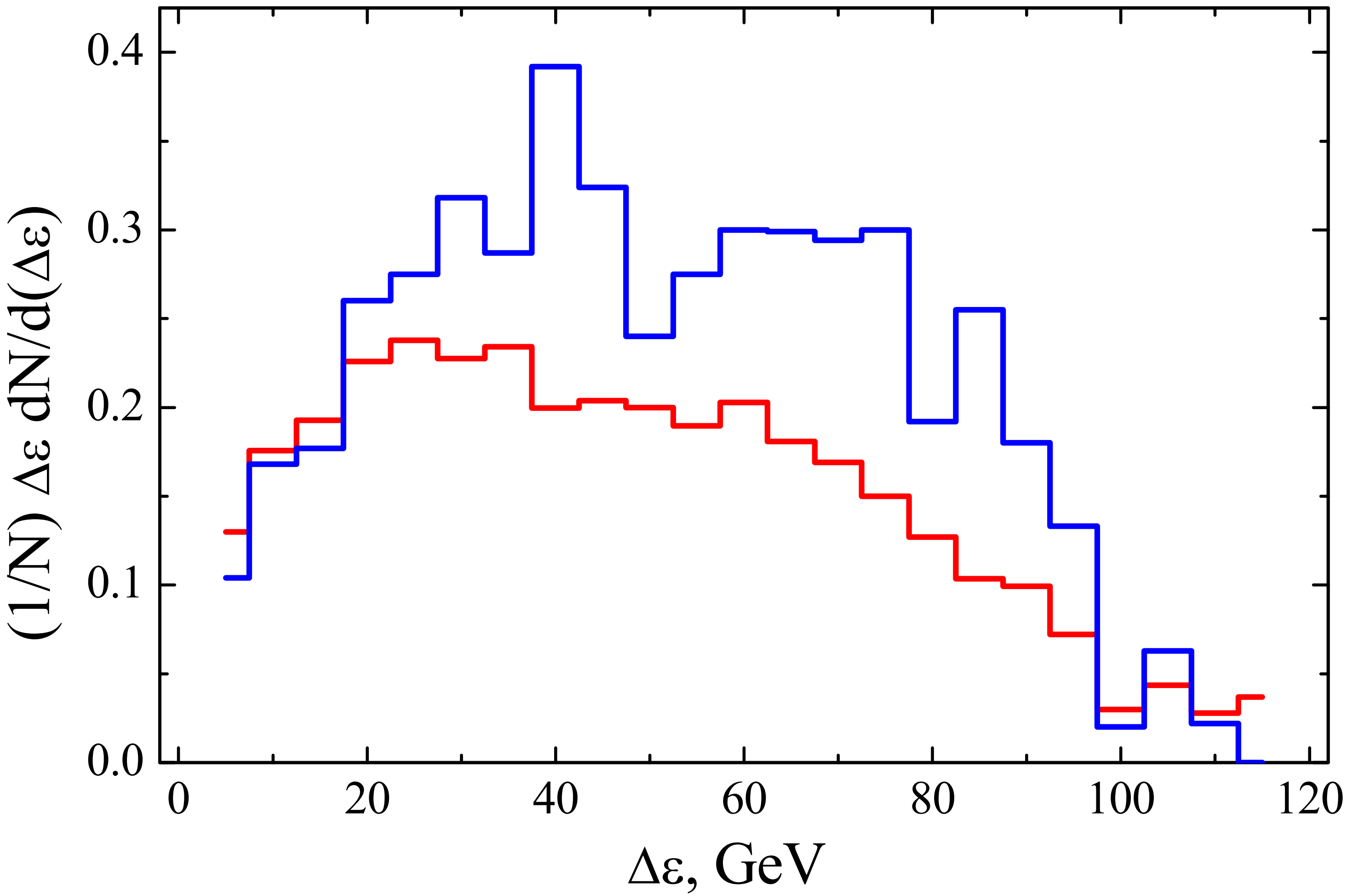


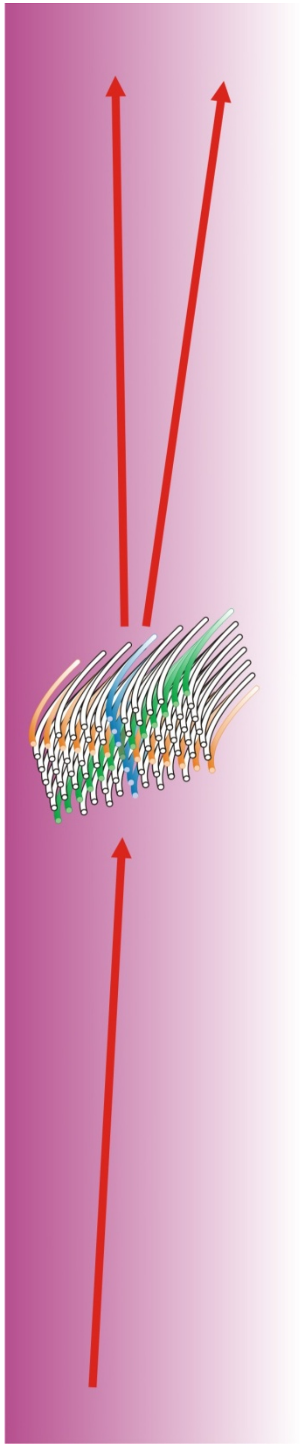

e⁻ & e⁺ 2D angular distributions
400
200
0
-200
200
0
-200
θy, μrad
θy, μrad
0
200
400
600
θx + Θ0X, μrad



Radiation accompanying MVR & Channeling

e^- & e^+ energy distributions

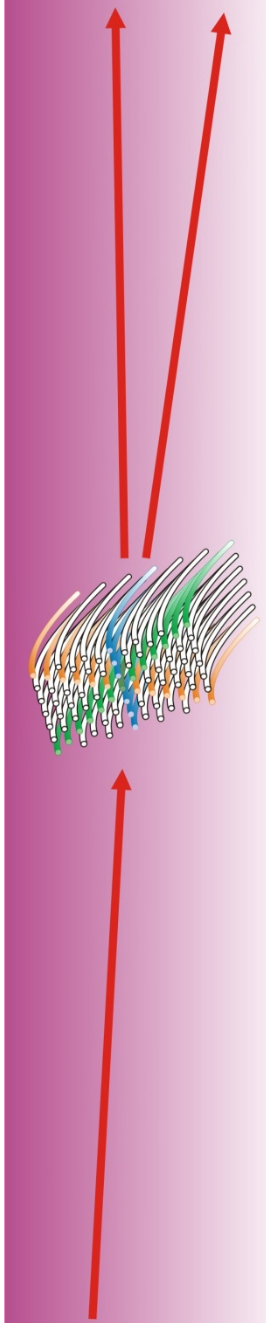




The general
method of radiation process
simulation from the
“*First Principles*”
is under final testing

Tests and suggestions

are timely and welcome!



About *radiation* in more detail

Sunday, 23 September — Teatro Civico di Alghero

"CHANNELING PRIMER"

13:00-14:00 *Registration*

14:00 S.B. Dabagov *Opening*

14:15 S. Lubrano *Greetings from Comune di Alghero*

14:45 U. Dosselli *LNF: new trends of Frascati*

15:15 E. Tsyganov, R. Carrigan *High Energy Channeling History*

15:45 S. Bertolucci *LHC: Status & Future*

16:15 S. Guiducci *SuperB: a new Frascati collider facility*

16:45 V. Malka *Electron & X ray beam with Laser-Plasma accelerators*

17:15 M.L. Carvalho *Focusing systems for X-ray micro beam: an overview*

17:45 R. Bonifacio *Quantum FEL*

19:00-20:00 Welcome Party

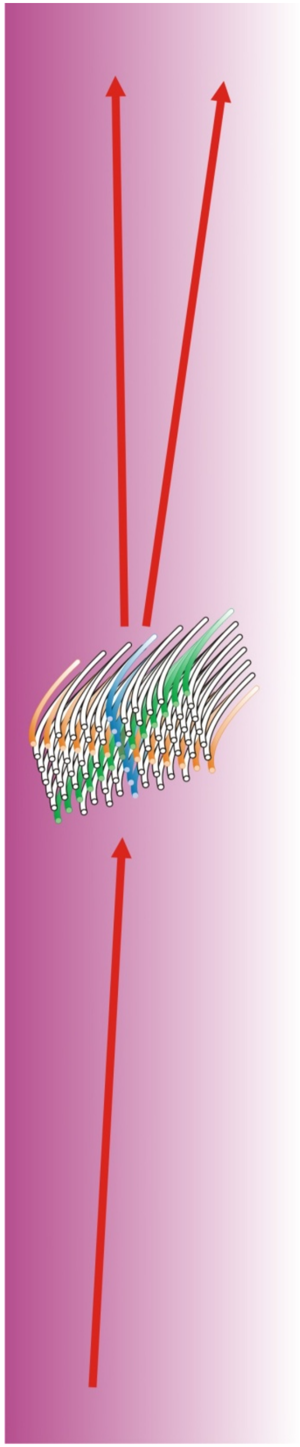
Time	*Monday* **24 September** *Hotel Calabona*	*Tuesday* **25 September** *Hotel Calabona*	*Wednesday* **26 September** *Hotel Calabona*	*Thursday* **27 September** *Hotel Calabona*	*Friday* **28 September** *Hotel Calabona*	Time
	S1.1 Chair: R.Avakian	***S3.1 Chair: W.Scandale***	***S4.3 Chair: A.Potylitsyn***	***S2.3 Chair: X.Artru***	***S5.3 Chair: M.Ferrario***	
9:00-9:25	N. Shul'ga	V. Tikhomirov	W. Gabella	H. Backe	L. Rinolfi	9:00-9:25
9:30-9:45	M. Bondarenco	A. Kovalenko	A. Lobko	V. Tikhomirov	R. Chehab	9:30-9:45
9:50-10:05	S. Trofymenko	I. Kyryllin	M. Mazuritsky	A. Kostyuk	A. Tishchenko	9:50-10:05
10:10-10:25	D. Karlovets	G. Kovalev	Art. Mkrtchyan	B. Azadegan	G. Naumenko	10:10-10:25
10:30-10:45	Yu. Pivovarov	L. Bandiera	V. Kocharyan	O. Bogdanov	E. Fiks	10:30-10:45
	Coffee break (20 min)			*Coffee break (20 min)*		
	S1.2 Chair: R.Chehab	***S3.2 Chair: F.Murtas***	***S4-S5 Chair: A[illegible]athak***	***S3.3 Chair: V.Guidi***	***S5.4 Chair: D.Giulietti***	
11:10-11:35	K. Ispiryan	M. Motapothula	X. Artru	Yu. Chesnokov	L. Gizzi	11:10-11:35
11:40-11:55	S. Fomin	A. Mazzolari	S. Blazhev[illegible]n	W. Scandale	M. Ferrario	11:40-11:55
12:00-12:15	Yu. Kunashenko	M. Bondarenco	A. Movsis[illegible]n	A. Taratin	P. Valente	12:00-12:15
12:20-12:35	V. Ganenko	E. Bagli	D. Karlov[illegible]s	G. Smirnov	G. Gatti	12:20-12:35
12:40-12:55	E. Tsyganov	E. Mazur	V. Gui[illegible]	E. Babakhanyan	E. Frolov	12:40-12:55
	Lunch break (3 h)		*Excur[illegible]on /Grotte di [illegible]ettuno/*	*Lunch break (3 h)*	**Closing**	
	S2.1 Chair: H.Backe	***S4.1 Chair: T.Childs***		***S5.1Chair: N.Shul'ga***		
16:00-16:25	V. Baryshevsky	P. von Ballmoos		A. Potylitsyn		16:00-16:25
16:30-16:45	R. Avakian	Y. Hayakawa		A. Jochmann		16:30-16:45
16:50-17:05	N. Kalashnikov	A. Shchagin		L. Grigoryan		16:50-17:05
17:10-17:25	K. Korotchenko	A. Mkrtchyan		M. Shevelev		17:10-17:25
	Coffee break (20 min)			*Coffee break (20 min)*		
	S2.2 Chair: D.Dauvergne	***S4.2 Chair: A.Esposito***		***S5.2 Chair:A.Mkrtchyan***		
17:50-18:15	A. Pathak	K. Tsuji		M. Borghesi		17:50-18:15
18:20-18:35	V. Fedorov	D. Hampai		D. Giiulietti		18:20-18:35
18:40-18:55	A. Ananyeva	L. Allocca		A. Schiavi		18:40-18:55
19:00-19:15	Yu. Adischev	A. Gorghinian		V. Zvorykin		19:00-19:15
19:20-20:20	***PS1 Chair: D. Hampai***			***PS2 Chair: O.Bogdanov***		19:20-20:20
		21:00-22:00 Round Table 1 E. Tsyganov	21:00-22:00 [illegible]und Table 2 E. Be[illegible]sonov	*21:00 Social Dinner*		

S1: Coherent Bremsstrahlung	S2: Channeling Radiation & Related Phenomena	S3: [illegible]hanneling & Crystal Collimation	S4: X-ray Channeling & X-ray Optics
S5: Novel sources: PXR&TR&FEL&Plasma	PS: Poster session	Lunch/Coffee/Social event	INVITED SPEAKERS

Tuesday **25 September** *Hotel Calabona*	*Wednesday* **26 September** *Hotel Calabona*	*Thursday* **27 September** *Hotel Calabona*
S3.1 Chair: W.Scandale	***S4.3 Chair: A.Potylitsyn***	***S2.3 Chair: X.Artru***
V. Tikhomirov	W. Gabella	H. Backe
A. Kovalenko	A. Lobko	V. Tikhomirov
I. Kyryllin	M. Mazuritsky	A. Kostyuk
G. Kovalev	Art. Mkrtchyan	B. Azadegan
L. Bandiera	V. Kocharyan	O. Bogdanov

CU radiation and γ-laser

VR and MVR radiation



Conclusions

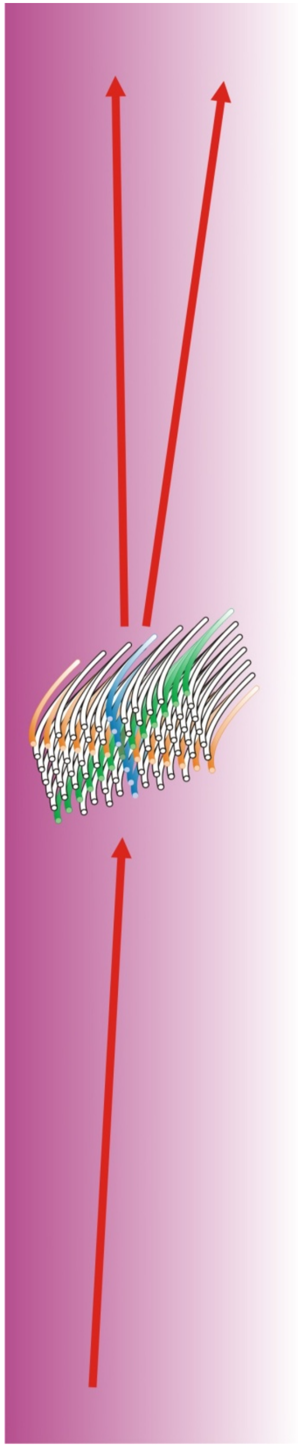
MVR is characterized by both **large** angular **acceptance** and scattering **angles**

MVR experiment results are readily **reproduced** by “first principle” **simulationsis**

MVR provides the best testbed for development of **radiation** simulations

MVR is very effective for **collimation**

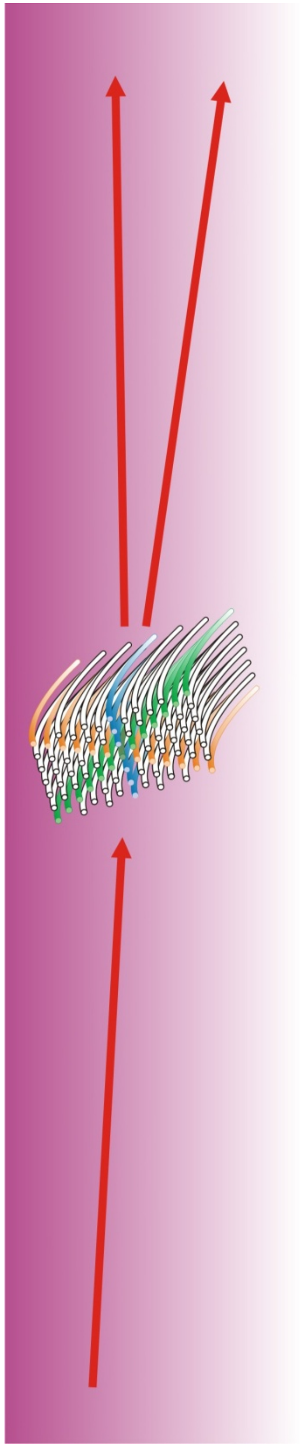
MVR **combinations** with either **channeling** or **doughnut scattering** are interesting for both radiation and collimation and are waiting for experimental study



Under essential **support** of

Prof. V.G. Baryshevsky, Director of the Institute for Nuclear Problems, Minsk

Prof. V. Guidi, Head of the Laboratory of Censors and Semiconductors, Ferrara University



Under 30-year **influence** of

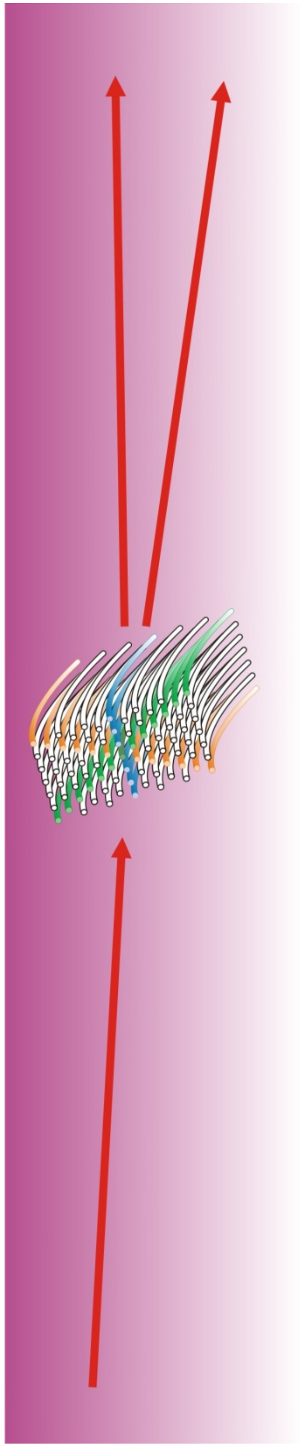
Prof. V. G. Baryshevski

Prof. V. N. Baier

Prof. N. F. Shul´ga

Prof. X. Artru

Dr. V. N. Maisheev



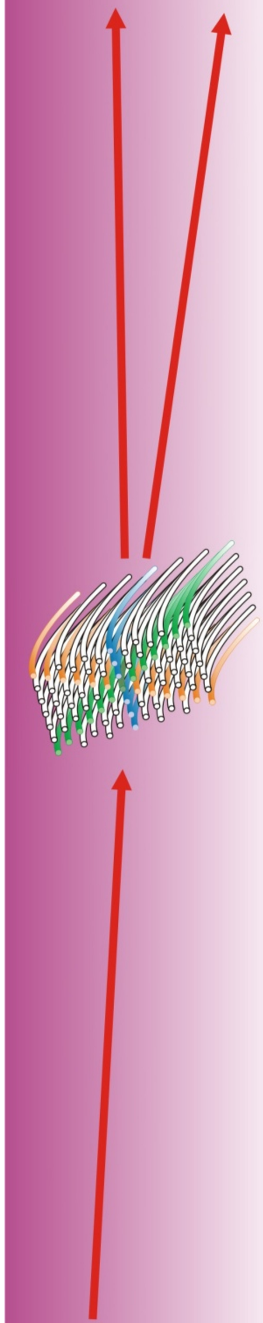
Under the **assistance** of

Laura Bandiera, *Ferrara University*

Andrea Mazzolari, *Ferrara University*

Enrico Bagli, *Ferrara University*

Ivan Novikov, *Belarus State University*



Thank you for attention!