PARAMETRIC X-RAYS AND BACKGROUND RADIATION AT 50 GeV PROTON BEAM

ПАРАМЕТРИЧЕСКОЕ РЕНТГЕНОВСКОЕ ИЗЛУЧЕНИЕ И СПЕКТРАЛЬНЫЙ ФОН НА ПУЧКЕ ПРОТОНОВ 50 ГэВ

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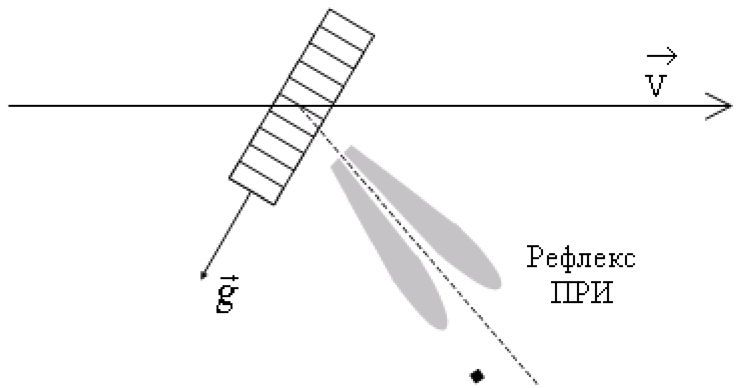
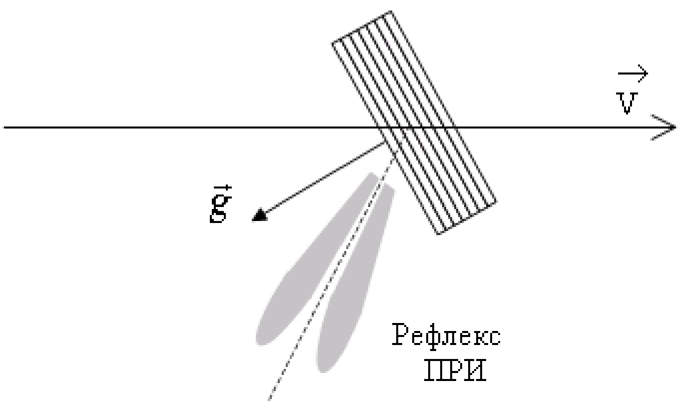
X International Symposium RREPS-13, Radiation from relativistic electrons in periodic structures, Lake Sevan, Armenia, September 23-28, 2013.

Common schemes for generation of PXR

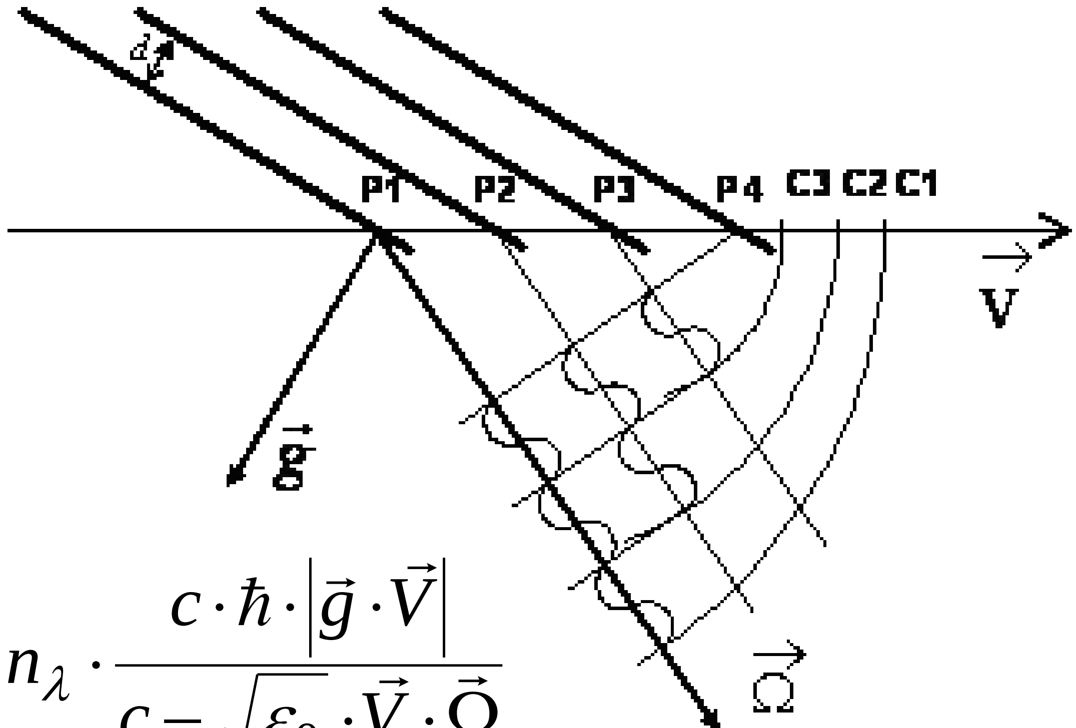




Laue geometry **Bragg geometry**

The Huygens construction for generation of parametric X-ray radiation (PXR)

Shchagin A.V., Maruyama X.K. “Accelerator-Based Atomic Physics Techniques and Applications”, eds. S.M. Shafrothб J.C. Austin, AIP Press, New York, 279-307 (1997).



$$E_{CR} = \hbar \cdot \omega_{CR} = n_{\lambda} \cdot \frac{c \cdot \hbar \cdot \left|\vec{g} \cdot \vec{V}\right|}{c - \sqrt{\varepsilon_0} \cdot \vec{V} \cdot \vec{\Omega}}$$

Схема Гюйгенса-Френеля формирования параметрического черенковского (рентгеновского) излучения (**ПРИ**). Заряженная частица движется в периодической среде со скоростью V, не превышающей фазовую скорость волн в среде. Сферические волны излучения, возбуждаемого частицей в среде, распространяются из точек P1-P4, периодически расположенных вдоль траектории частицы. ПРИ распространяется вдоль вектора Omega

Focusing of PXR

A.V. Shchagin JETP Letters 80 (2004)469-473.

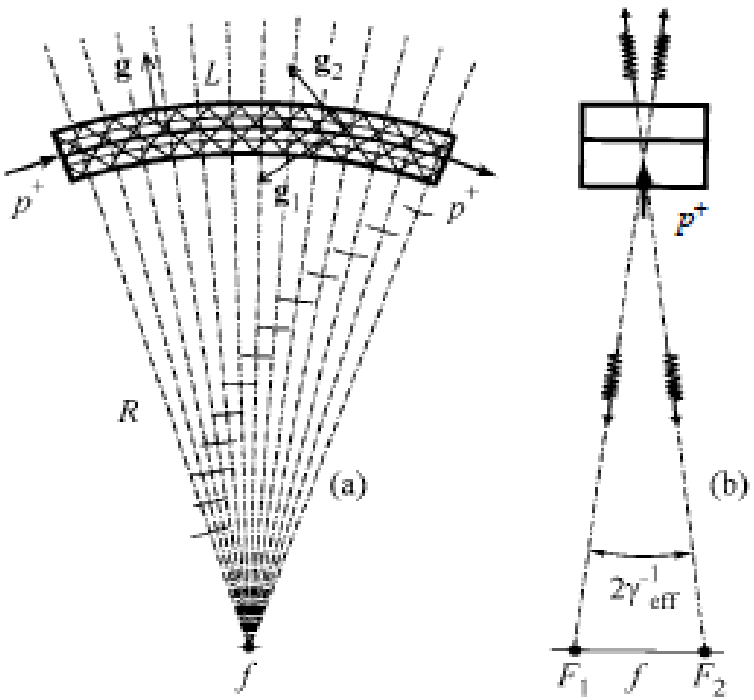


Fig. 1. Huygens picture and focusing PXRs emitted by channeled particles moving along a thin bent single-crystal plate: (a) side and (b) front views. The trajectory of a parti-

Experiment in CERN

Phys. Lett. B 701(2011)180

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Observation of parametric X-rays produced by 400 GeV/c protons in bent crystals

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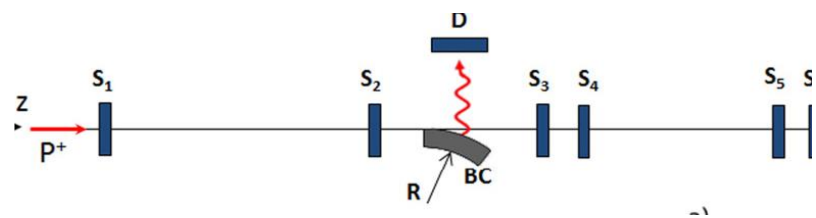

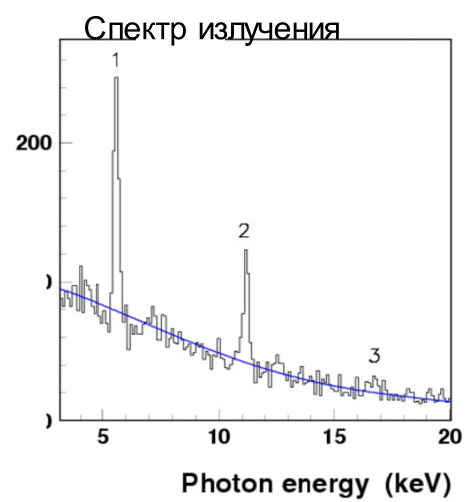

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Experiment in Protvino at 50 GeV proton beam (March 2013)
Typical proton beam current was about 5-8 ·10 6 protons/extraction. X-ray detector Amptek of thickness 500 mkm/

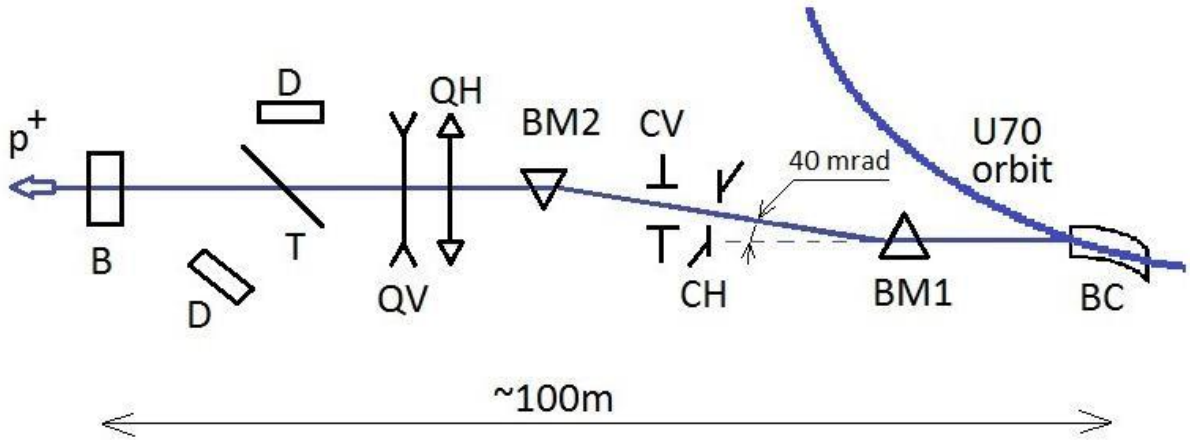


Fig. 1. The experimental layout. The proton beam of energy 50GeV is extracted from the circle by a bent crystal BC. Then, the beam passes two bending magnets BM2, BM1, collimator C, target T. The number of protons in the beam is calculated by a scintillated counter B. The X-ray radiation and the background radiation is measured by the detector D that is shown in two positions.

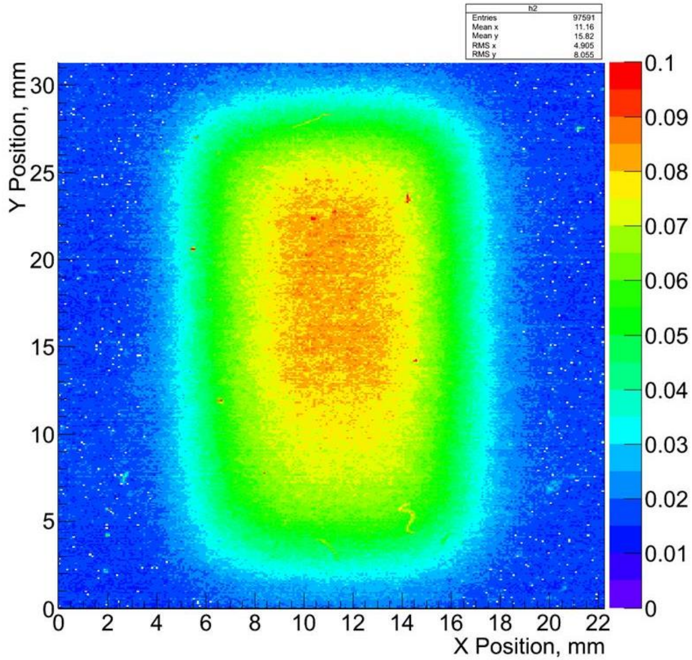


Fig. 2. The proton beam profile in the vicinity of the target.

The transverse proton beam dimensions on the target were about 25 mm in vertical direction and 10 mm in horizontal direction.

Observation of characteristic X-ray radiation (медь)

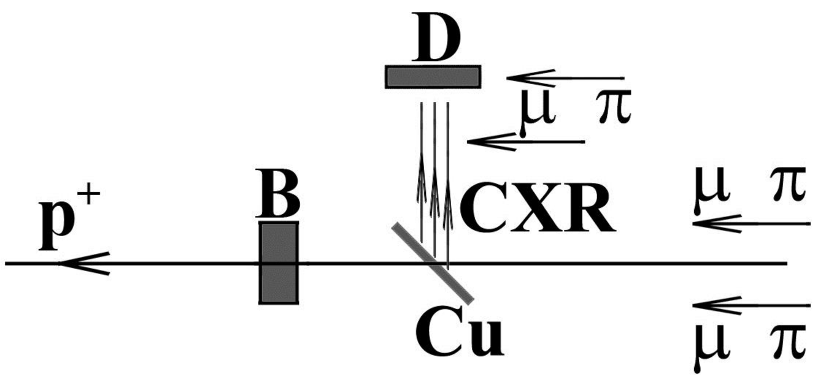


Fig. 3. The experimental setup for observation of characteristic X-ray radiation. Beam protons excite characteristic X-ray radiation in a copper foil. The spectrum of x-rays is measured by the detector D. The secondary relativistic particles like muons and pions accompanying the proton beam also cross the detector along its surface

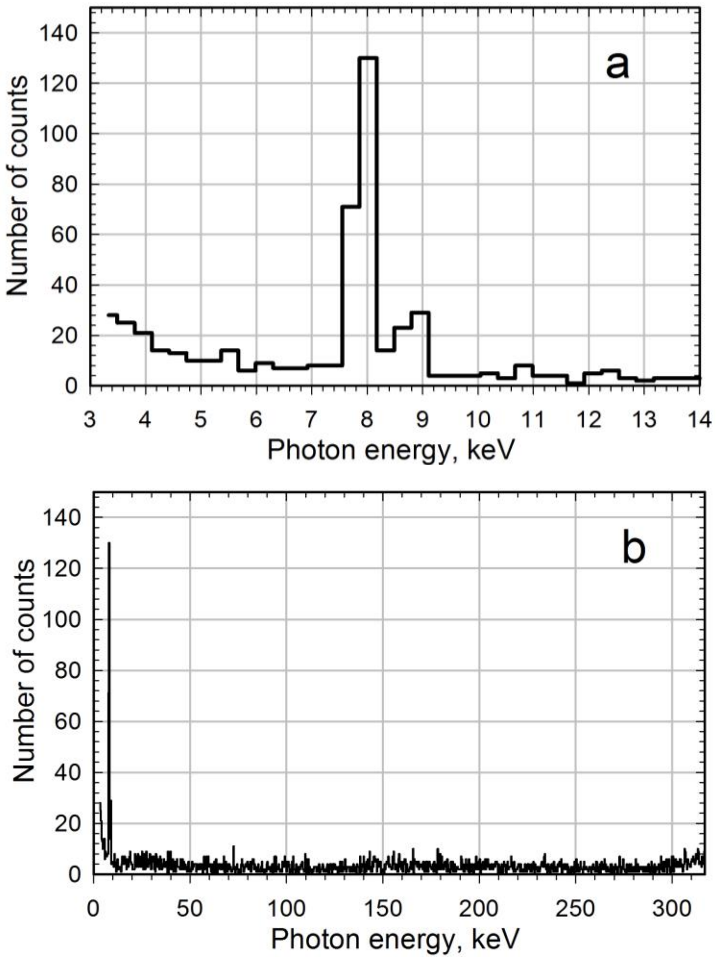


Fig. 4. The measured spectrum of characteristic X-ray radiation is shown without background subtraction in the range of 3…13 keV in Fig. a and in the range of 3…317 keV in Fig. b. Peaks with energies of 8.0 keV and 8.9 keV are due to Kα and Kβ characteristic X-ray radiation from the Cu target

Observation of parametric X-ray radiation

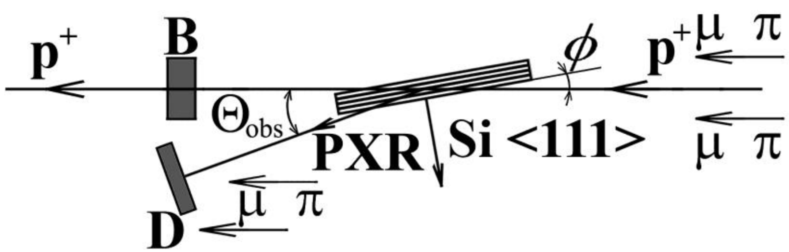
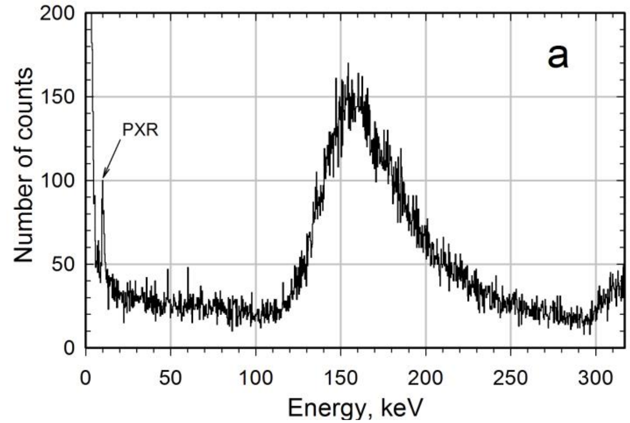


Fig. 5. The experimental setup for the PXR measurements



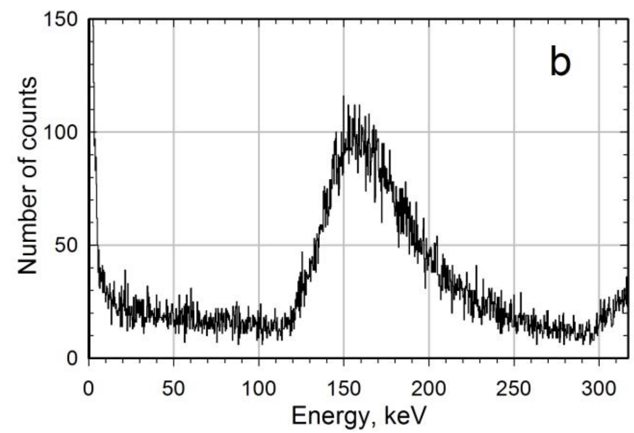
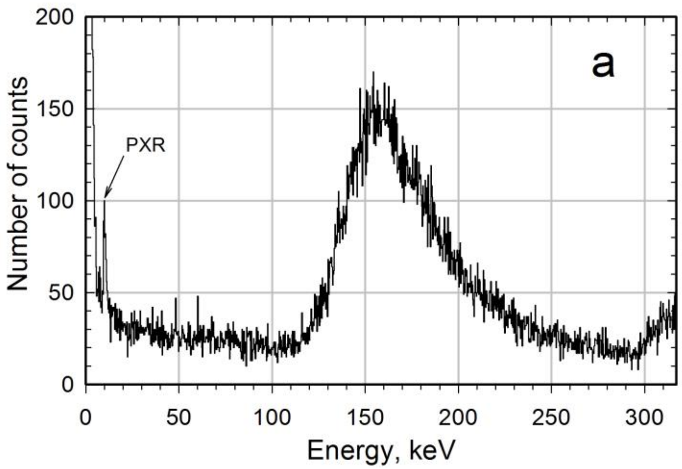


Fig. 6. Spectra without background subtraction measured when the PXR reflection is directed towards the detector (a) and when the PXR reflection is aligned aside from the detector (b). The arrow shows the PXR spectral peak

The origin of the spectral background

Distribution of ionization loss by muons and distribution Landau. The most probable ionization loss: experimental 155.1 keV, calculated 154.7 keV . Relation of the number of the PXR quanta to the number of particle is 1·10-2

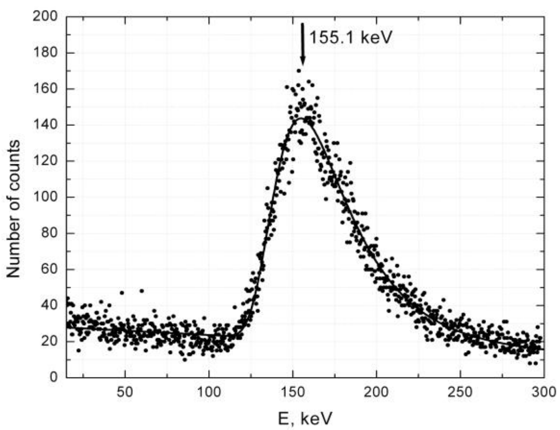
The detector works simultaneously as an X-ray detector and as a detector of charged particles.



$$\Delta_p \underset{\beta\gamma \gtrsim 100}{\longrightarrow} \xi \left[\ln \frac{2mc^2\xi}{(\hbar\omega_p)^2} + j \right] . \qquad (27.11)$$

Thus the Landau-Vavilov most probable energy loss, like the restricted energy loss, reaches a Fermi plateau. The Bethe

K. Nakamura *et al.* (Particle Data Group), J. Phys. G **37 (2010) 075021**



D.A. Sanzharevsky:

Fitting of experimental data by the method of least squares by the Landau function from:

K.K. Andersen et al, Restricted energy loss of ultrarelativistic particles in thin targets – a search for deviations from constancy // Nuclear Instruments and Methods in Physics Research B 268 (2010) 1412-1415**.**

Distribution of secondary particles (muons) around of the proton beam

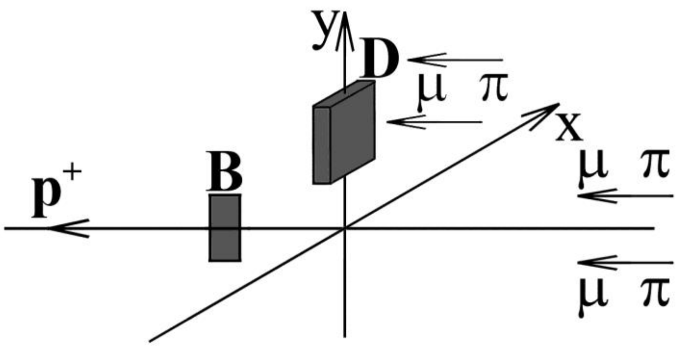


Fig. 7. The experimental setup for measurements of the spatial distribution of the secondary ultra-relativistic particles in horizontal and vertical directions

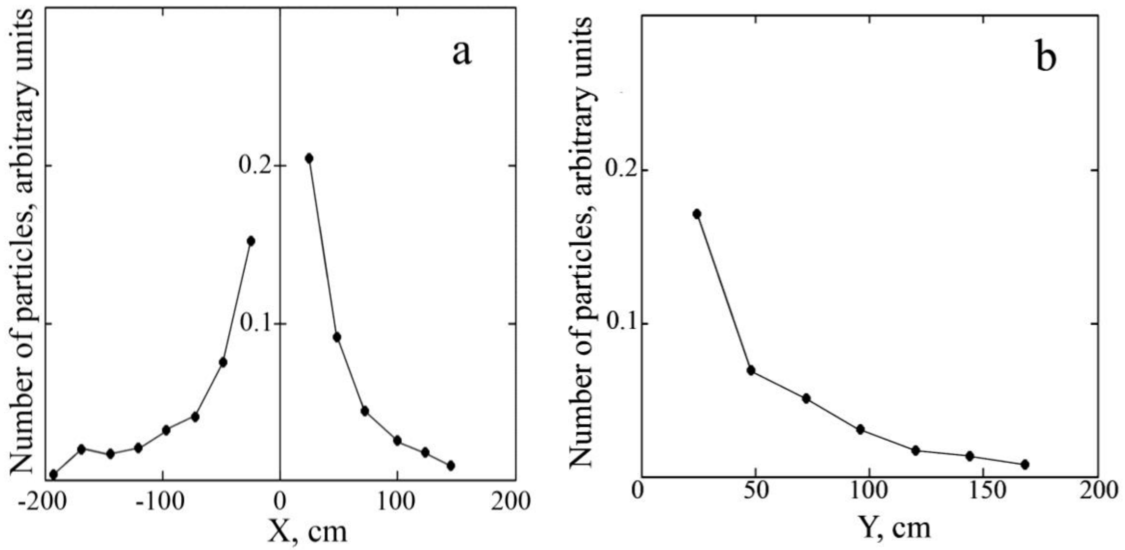


Fig. 8. The number of ultra-relativistic charged particles crossed the detector as a function of the distance from the proton beam to the detector in horizontal (a) and vertical (b) planes

RESULTS AND DISCUSSION

We succeeded in observation of X-ray radiation excited by 50 GeV proton beam despite of a strong radiation background. In particular, the clear spectral peaks of characteristic X-ray radiation from a copper target and the spectral peak of parametric X-ray radiation emitted from (111) crystallographic plane of a flat Si crystal in forward hemisphere in Bragg geometry were observed. In both cases the spectral peaks were observed on a significant spectral background.

We found that the main source of spectral background is due to the secondary relativistic particles like muons that crosses the detector and create ionization losses in the X-ray detector. We measured the spectrum of ionization losses and found that it is well described by the Landau function. Besides, we measured spatial distribution of the secondary particles around of the proton beam.

This experiment is a basis for forthcoming studies of properties of the focused PXR emitted by protons in a bent crystal as well as properties of the PXR emitted by heavy ions and other kinds of particles like positrons in crystals.

Publications

1. A.G. Afonin, G.I. Britvich, Yu.A. Chesnokov, P.N. Chirkov, A.A. Durum, M.Yu. Kostin, A.V. Lutchev, V.A. Maisheev, A.A. Yanovich, A.V. Shchagin, V.I. Truten', V.B. Ganenko, I.V. Kirillin, N.F. Shul'ga, A.S. Kubankin, N.N. Nasonov, A.P. Potylitsyn, A.S. Gogolev, S.R. Uglov, Yu.M. Cherepennikov, P. Karataev. Observation of parametric x-ray radiation excited by 50 GeV protons and identification of background radiation origin // Problems of Atomic Science and Technology, accepted for publication, 2013.
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Thank you for yours attention

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FRESNEL COEFFICIENTS FOR PARAMETRIC X-RAY RADIATION

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Abstract

Formulae for amplitude Fresnel coefficients of parametric X-ray radiation (PXR) are found in kinematic approach.

The expressions for PXR **frequency**, and **spectral peak width**, and **yield**, and **linear polarization** direction are obtained in approximation of small angles.