Crystal optical solution for generation of high energy neutrino beams

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Abstract

The problem of creation of high energy neutrino beams on the basis of modern and future circular proton accelerators with the help of traditional technology seems to be expensive and difficult. Because of this, we propose the solution of this problem based on the usage of focusing bend single crystals. In the paper we demonstrate the possibilities of acceptance and focusing of a pion beam with the help of a crystal optical lens system. As an illustration of these features the calculated neutrino fluxes for energy of circulating proton beam equal to 6.5 TeV are presented.

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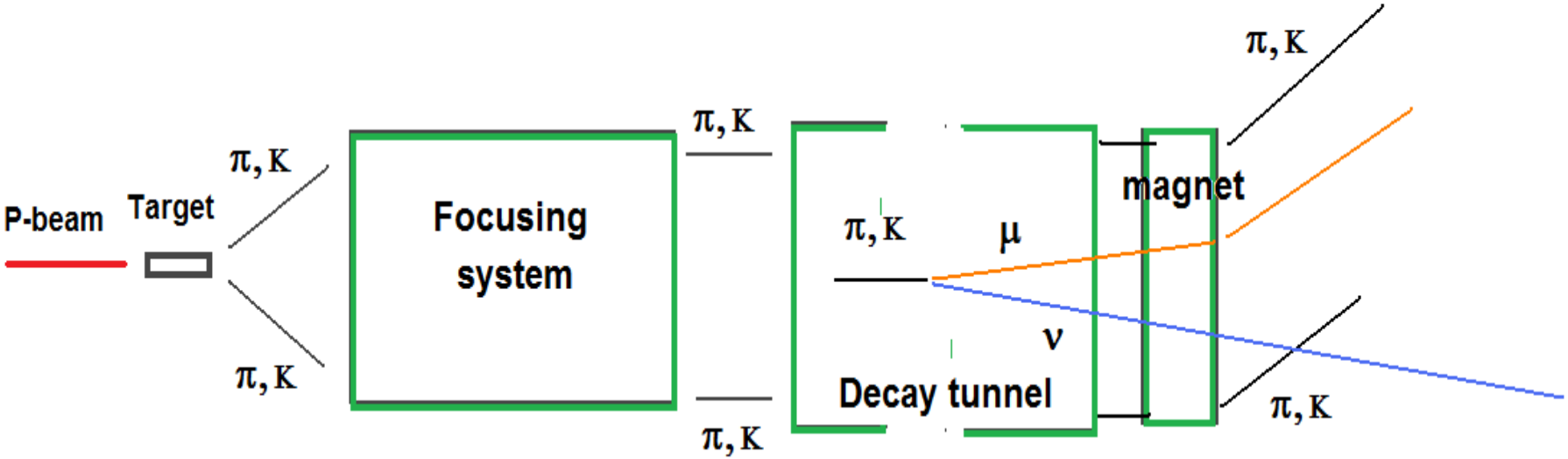
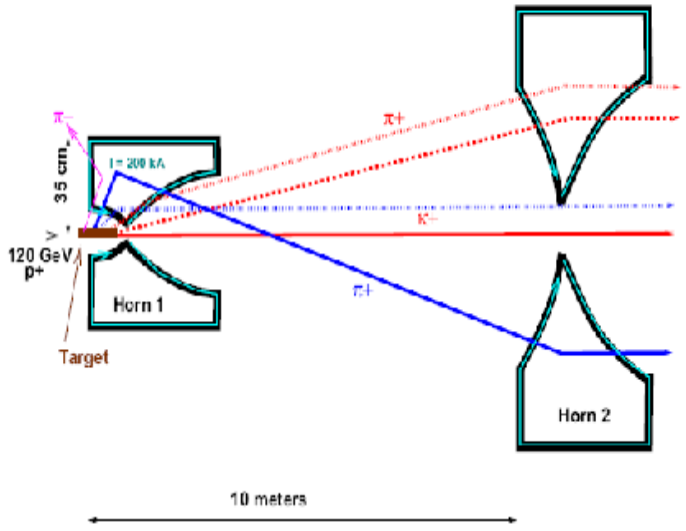
Scheme of obtaining neutrino beam





Traditional focusing system of magnetic horns.

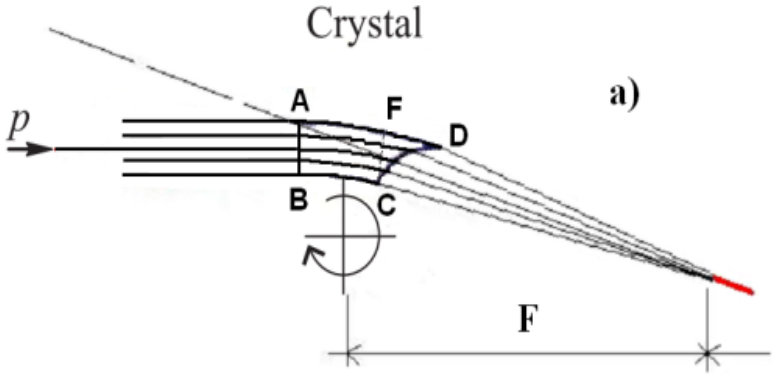
NuMI neutrino beam P Adamson et al NIMA 806, (2016) 279

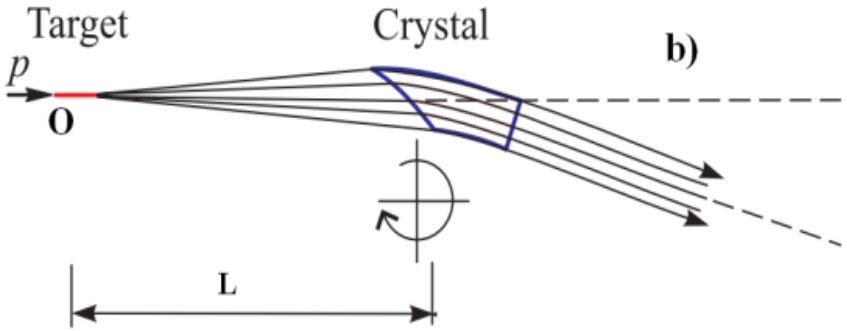
Our propsal for generation of neutrino beam is

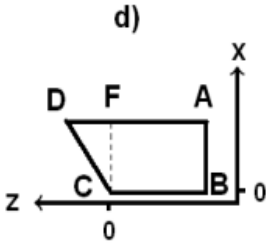
to use the system of focusing single crystals for transformation of divergent π, K beams into close to parallel

This system should be applied instead traditional system (consisting from horns)

Focusing crystals







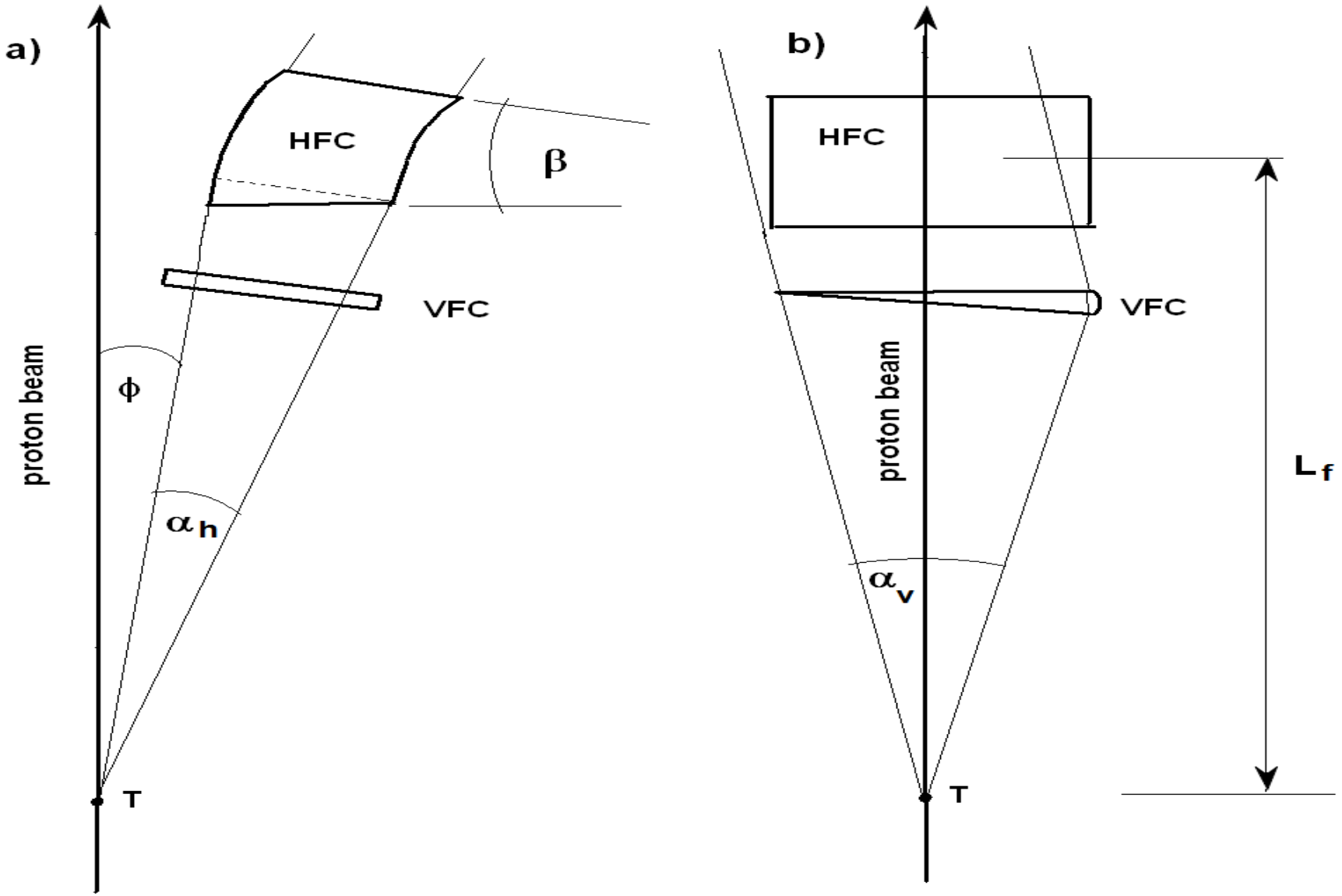
$OB = L_f$ where L_f is focal length

References about focusing single crystals

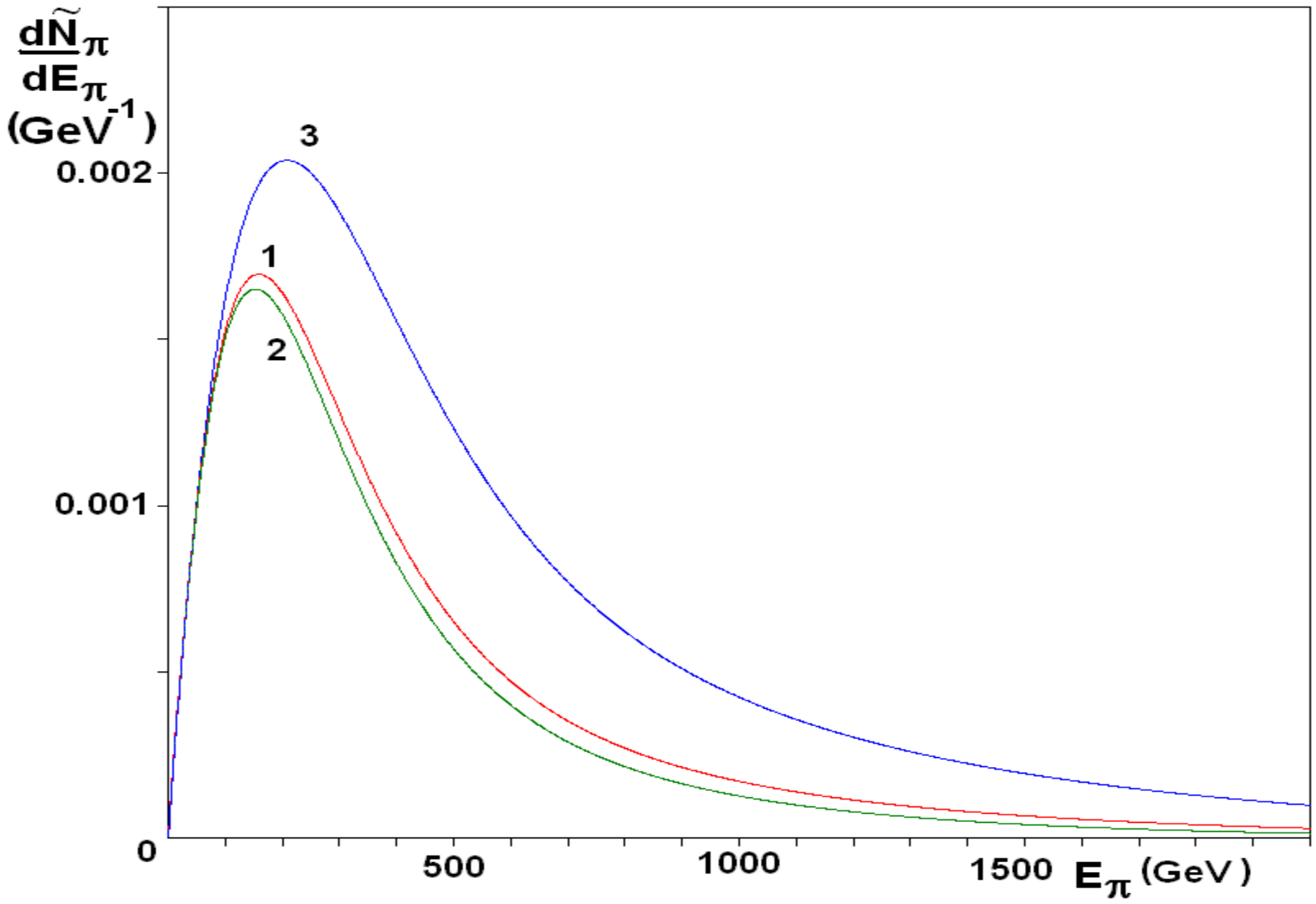
V. A. Maisheev, Y. A. Chesnokov and P. N. Chirkov, "Focusing of high energy particles with the help of bent single crystal," Nucl. Instrum. Meth. B **355**, 360 (2015). doi:10.1016/j.nimb.2015.03.002

V. A. Maisheev and Y. A. Chesnokov, New beam optics on the basis of bent single crystals, Nucl. Instrum. Methods Phys. Res., Sect. B 402, 300 (2017).

W. Scandale *et al.*, Phys. Rev. Accel. Beams **21**, no. 1, 014702 (2018). doi:10.1103/PhysRevAccelBeams.21.014702



Scheme of generation and formation of a parallel beam of pions: HFC and VFC are horizontal and vertical bent focusing single crystals, correspondingly, α_h and α_v are horizontal and vertical angles of acceptance of pions, respectively, β is the bending angle, ϕ is angle between the proton beam and the edge of the crystal, L_f is the focal length of the crystals T is the target. (a) top and (b) side view.



Calculated pion spectra at the entrance in focusing crystals. The curve 1 and 2 were calculated for $\alpha_h = \alpha_v = 2$ mrad and for $\phi = 0.1$ and 0.2 mrad, correspondingly. The curve 3 was calculated at same α_h and α_v angles but for central passage of pion beam relative to proton beam.

In the case of an approximately parallel pion beam (with the energy distribution denoted as $\frac{dN_\pi}{dE_\pi}(E_\pi)$) we can find the neutrino spectrum (at the condition that we take into account the neutrino only with angles less than some given angle θ_ν) :

$$\frac{dN_\nu}{dE_\nu}(E_\nu) = \int_\Delta \frac{dN_\pi}{dE_\pi}(E_\pi) F_1(E_\pi) F_2(E_\pi) F_3(E_\pi) dE_\pi, \tag{10}$$

where (with $\gamma_\pi = E_\pi / m_\pi$)

$$F_1(E_\pi) = 1 - \exp\left(-l/(L_0 \gamma_\pi)\right), \tag{11}$$

$$F_2(E_\pi) = 0.75^2 \exp\left(-Z_x / l_d(E_\pi)\right) \exp\left(-Z_y / l_d(E_\pi)\right), \tag{12}$$

$$F_3(E_\pi) = \frac{\gamma_\pi \beta_\pi}{2 p_\nu^*}. \tag{13}$$

In Eqs.(10)-(13) the function $F_1(E_\pi)$ describes losses of pions due to their decays on the length equal to l ($L_0 = 7.80$ m is the pion decay length in a rest system), the function $F_2(E_\pi)$ presents losses of pions coming in the crystal optical system (the coefficient is equal to 0.75^2) and propagating through the both crystals. Here, Z_x and Z_y are the mean longitudinal lengths of the HFC and VFC elements (see Fig. 2). l_d is the dechanneling length which is a linear function of a pion energy. Function F_3 is the energy distribution of neutrino at $\pi \to \mu + \nu$ decay [13] in a laboratory system

Parameters selected for calculations.

Silicon single crystals of (110) planar orientation.

Bending radius of crystals = 50 m

Focal length = 10 m

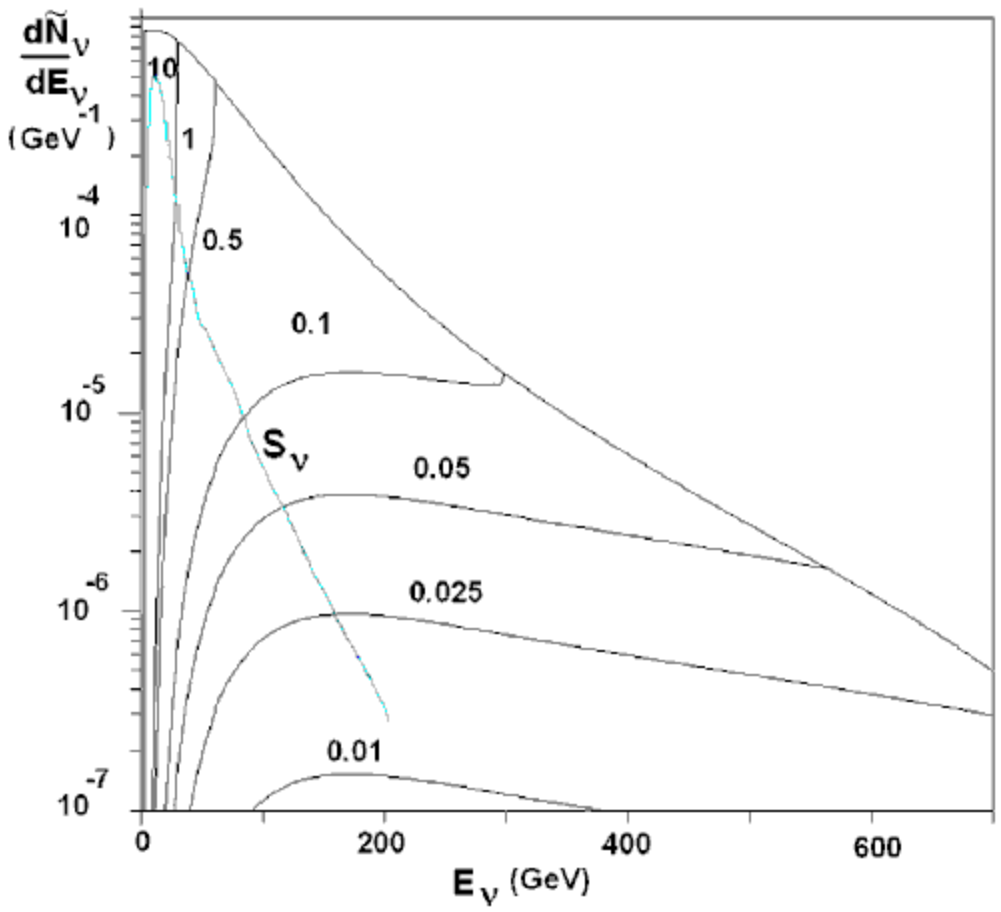
Thikness (along beam) 6 cm for 1 mrad bending
and 1 cm for small angle bending

1 cm for vertical bending

Width 2-4 mm

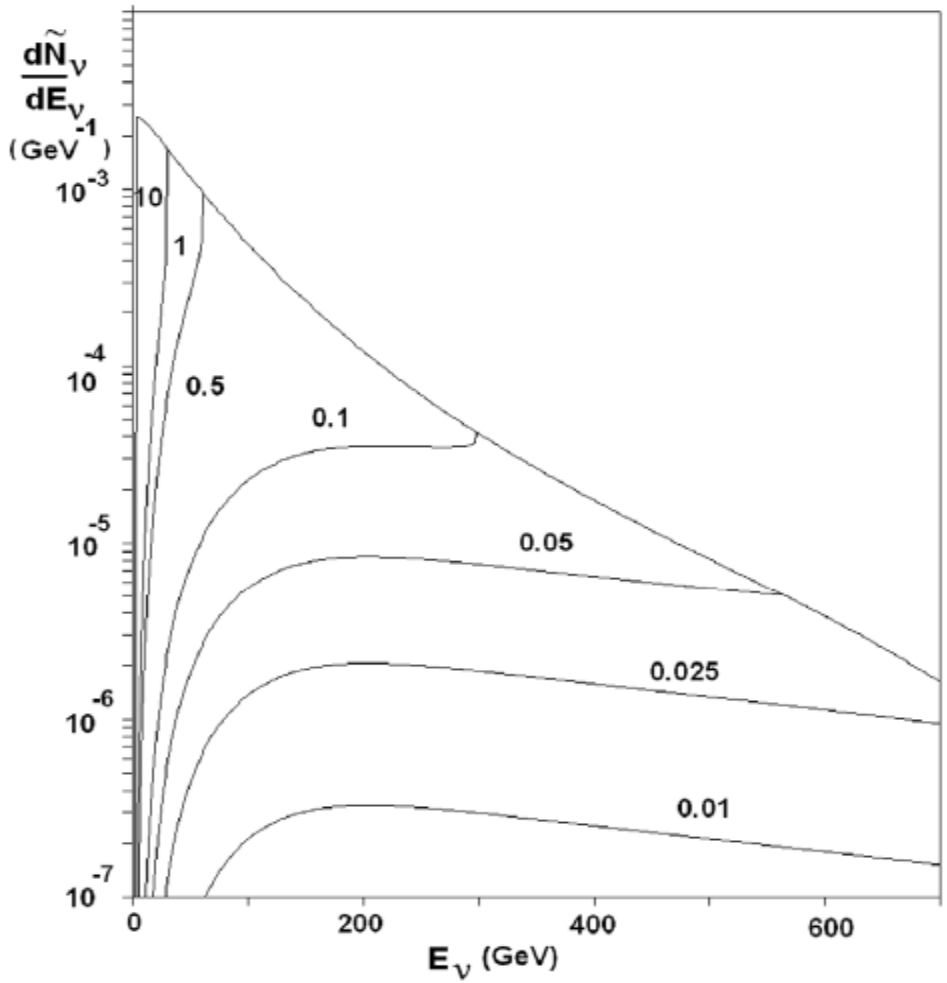
the system of 5-10 crystals covers an area of 1 cm in the transverse direction

Decay length = 5 km

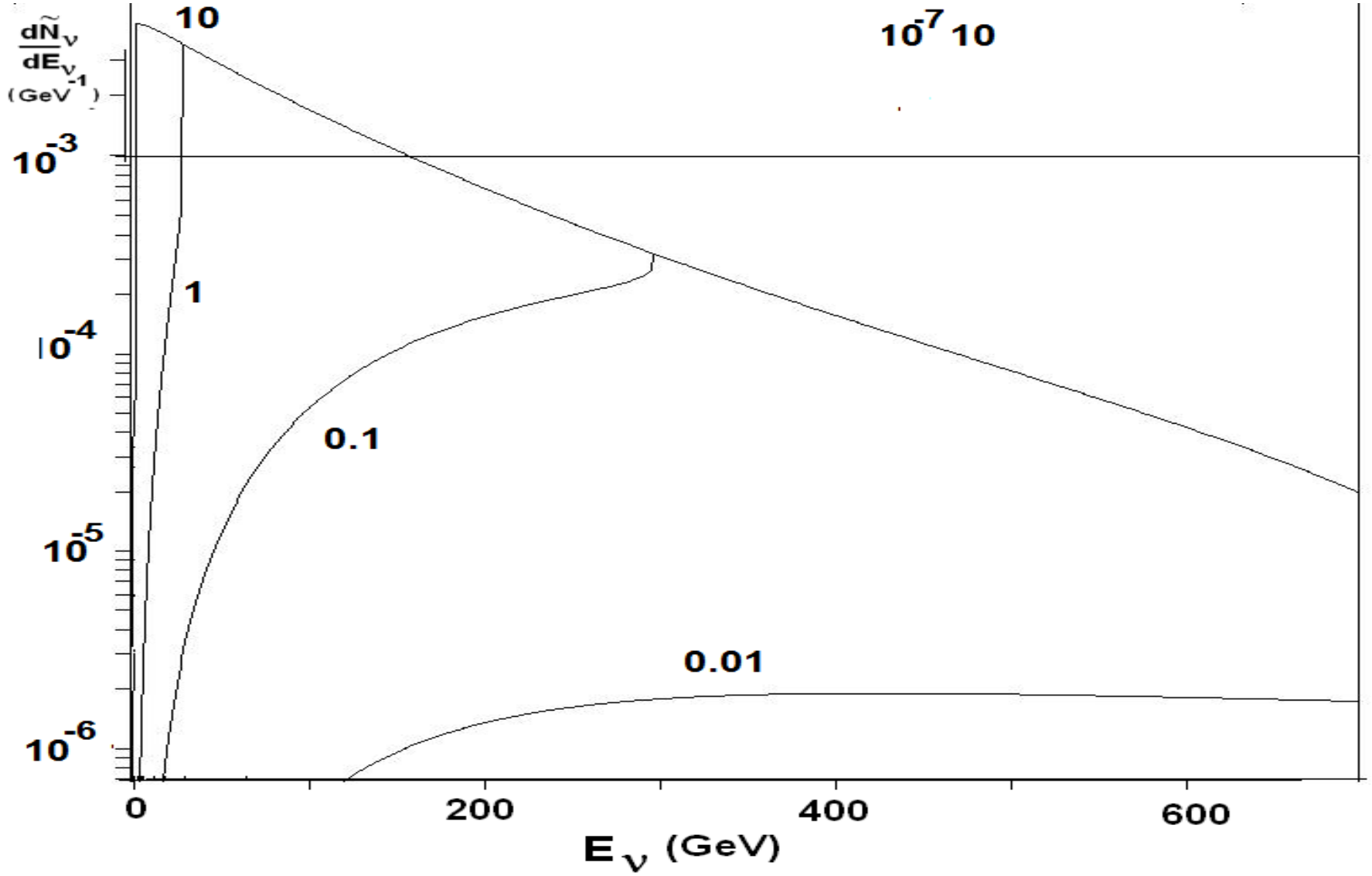


The calculated energy distributions of neutrino beams. They are calculated for neutrino from zero neutrino emission angle θ_ν up to some its value in mrad (the numbers near curves). The proton energy 6.5 TeV. It is assumed that target is placed in vacuum chamber. The blue curve S_ν is the calculations [10]. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

[10] M. Bonesini et.al. Eur. Phys. J. C20 (2001) 13.



The calculated energy distributions of neutrino beams. They are calculated f neutrino from zero neutrino emission angle θ_ν up to some its value in mrad (the numbe near curves). The proton energy 6.5 TeV. It is assumed that target is placed outside vacuu chamber.



The calculated energy distributions of neutrino beams. They are calculated f
neutrino from zero neutrino emission angle θ_ν up to some its value in mrad (the numbe
near curves). The proton energy **100 TeV** It is assumed that target is placed outside vacuu
chamber. **(preliminary)**

Conclusions

1)The new scheme of generation neutrino beams on high energy colliders are proposed, The scheme based on focusing bent single crystals.

2) The spectra neutrino were calculated for 6,5 and 100 GeV circulating protons.

3) In general this recearch points on prospects of application of lens system from single crystals to generate high energy neutrino beams.

Thank you!!!