INTERACTION REGION DESIGN OF SUPER-CT-FACTORY IN NOVOSIBIRSK*

A.V. Bogomyagkov#, E.B. Levichev, P.A. Piminov, BINP, Novosibirsk, Russia

Abstract

Interaction region of Super-ct-factory is designed to bring stored electron-positron beams into collision with luminosity of 10^{35} $cm^{-2}sec^{-1}$. In order to achieve that CRAB waist collision scheme is implemented, which requires cross-angle collision with high Piwinski angle. The small values of the beta functions at the interaction point and distant final focus lenses are the reasons for high nonlinear chromaticity limiting energy acceptance of the whole ring. The present design allows correction of linear and nonlinear chromaticity of beta functions and of betatron tune advances, correction of second and third order geometrical aberrations from the strong sextupoles pairs, satisfies geometrical constraints, embraces realistic design of final focus quadrupoles and as close as possible positioning of CRAB sextupole to interaction point.

INTRODUCTION

Super-ct-factory is a project of an electron positron collider aimed to study physics of charmed particles and tau-lepton, with one interaction point, working in the central mass energy range from 2 GeV to 5 GeV, providing luminosity of 10^{35} $cm^{-2}sec^{-1}$ at high energies and more than 10^{34} $cm^{-2}sec^{-1}$ at low energies, with longitudinal polarization of the electrons in the whole energy range [1].

Small beta functions at IP generate high chromaticity in the final focus (FF) lenses, which at desired parameters is not linear. If it is not compensated locally, it limits energy acceptance of the collider leading to unacceptably small beam lifetime due to intra-beam scattering effect (IBS). The size of the RF basket is $\Delta E/E \approx$ [1%-1.5%], in order to have satisfactory beam life time due to IBS it is necessary to have energy acceptance of $\Delta E/E \geq 1{,}2\%$, introduction of insertions in the arcs (Siberian snakes, wigglers) decrease the energy acceptance, therefore the goal is to obtain energy acceptance about ±2%. Parameters of Super-ct-factory related to design of IR are presented in Table 1.

Table 1: Parameters of Super-ct-Factory

Energy	GeV	2
Particles per bunch/bunches		$7\cdot10^{10}/354$
Beam current, I	A	1.63
$\beta x/\beta y/\sigma s$	Mm	40/0.8/9
Emittance εx	nm rad	8
Coupling $\varepsilon y/\varepsilon x$	%	0.5
Collision angle	Mrad	60
Beam-beam tune shift ξy		0.13
Beam size at IP $\sigma x/\sigma y$	μ	17.9/0.179
Piwinsky angle	Rad	15
Luminosity geometrical/hourglass	$cm^{-2}sec^{-1}$	$1.17/1.06\cdot10^{35}$

OPTICS OF INTERACTION REGION

The basic blocks of interaction region are FF telescope (FFT), chromaticity correction section (CCS) and CRAB sextupole section (CSS). All blocks are chosen to be telescopic transformations, to simplify optical and chromatical calculations and as it was shown in [2] element T_{116}=0 could be zero in telescope system with certain symmetry properties and then the first order chromaticity of beta function vanishes. If sextupoles are tuned to provide T_{126}=0 and T_{346}=0 then linear chromaticity of betatron phase advances also vanishes in both planes respectfully.

FFT consists of two quadrupole doublets and is tuned to match optical functions with CCS, and to minimize T_{116} and T_{336}, thereby minimizing linear chromaticity of the beta functions in horizontal and vertical planes respectfully, given zero chromaticity at IP.

Detector solenoid coil envelops the FF doublet and the compensating solenoid is placed before the FF quadrupoles. Also, there is a solenoid covering both FF quadrupoles in order to screen the main detector field. The compensating solenoid and screening one provide uncoupled beam motion in the FF doublet.

The FF quadrupole possess two apertures in order for incoming and out coming beams not to experience the bending field reducing the synchrotron radiation. The crossing angle is determined by the technical requirements of the FF lens design. Figure 1 shows the placement of different elements around the IP and possible cones of detector opening.

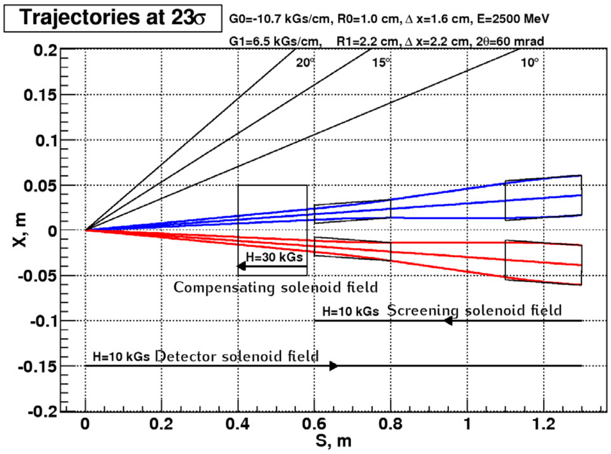

Figure 1: Arrangement of elements around IP. Shown are FF quadrupoles, compensating and screening solenoids, value of the detector field, and detector opening cones.

---

*Work supported by NN 02.740.11.(0025, 0513, 0849) FCP 2009-2013

#A.V.Bogomyagkov@inp.nsk.su

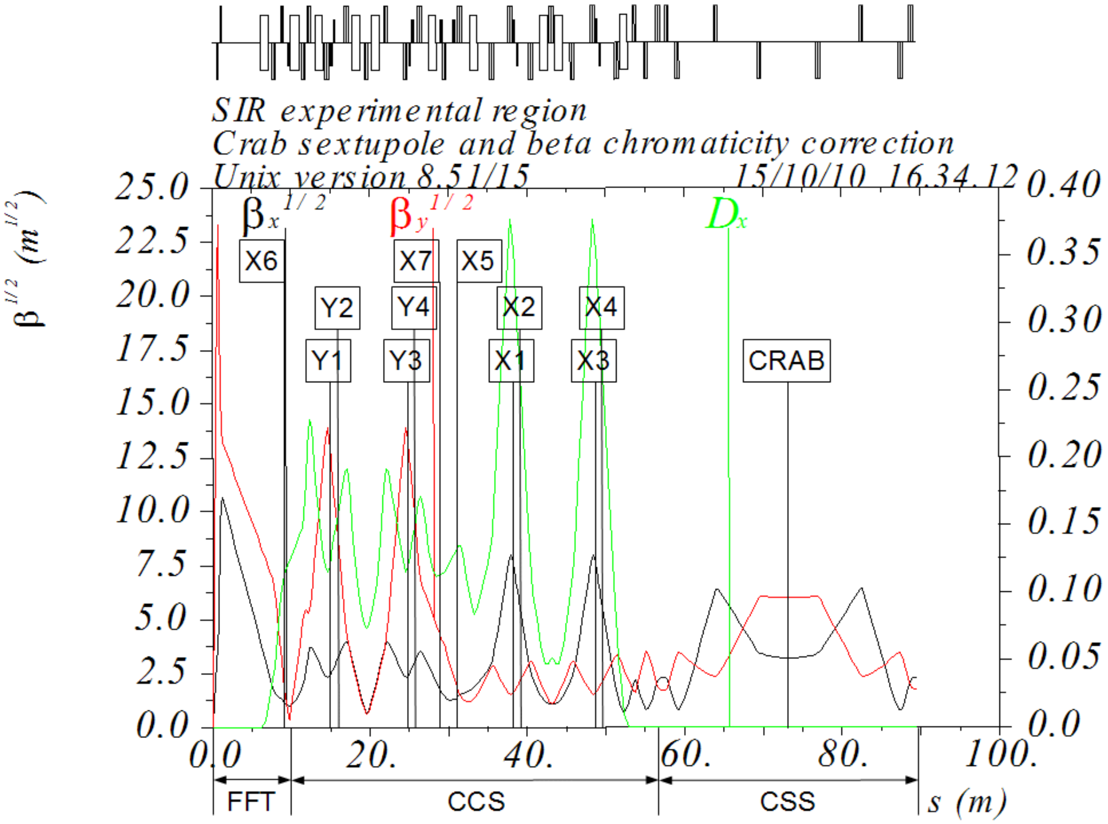

Figure 2: Optical functions and building blocks of IR. Names and positions of sextupoles are shown.

CCS is built around two pairs of sextupoles with phase advance of multiple of π in appropriate plane from one quadrupole of FF doublet and with phase advance of multiple of π in other plane from corresponding second quadrupole of FF doublet. The pairs are separated by –I transformation for cancelation of second order geometrical aberrations. Dispersion function is brought to zero at the end of the section, in order to decouple CRAB sextupole from chromatical functions.

CSS is designed to provide phase advances between IP and CRAB sextupole of $\Delta\mu x=\pi\cdot m$, $\Delta\mu y=\pi/2(2n+1)$, where m and n are integer numbers. Values of beta functions are optimized so sextupole strength K2L is reasonable.

Optical functions from IP to the end of interaction region are shown on Figure 2.

CHROMATICAL ABERRATIONS

In the structure where main sextupoles Y1 and Y3, X1 and X3 are matched to quadrupoles Q0 and Q1 respectfully beta function chromaticity is never completely compensated, due to influence of the other quadrupoles. Therefore, pairs of the main sextupoles Y1 and Y3, X1 and X3 were shifted in phase advance by $\Delta\mu_y\approx-1.65\cdot10^{-4}$ and $\Delta\mu_x\approx-4.3\cdot10^{-3}$ respectfully. Obtained dependence of phase advance and beta functions on energy deviation is shown on Figures 3, 4.

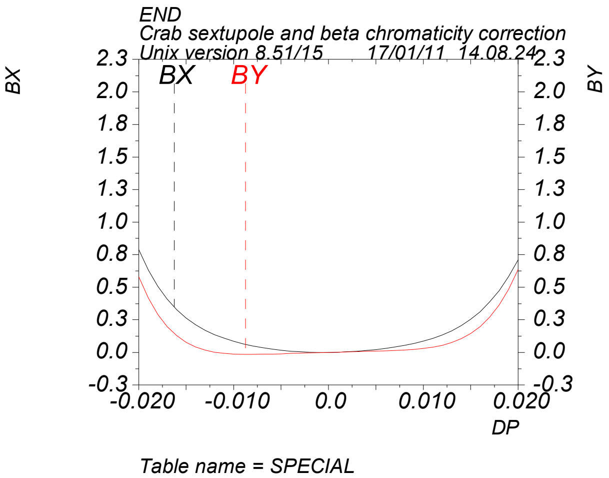

Figure 3: Beta function dependence on momentum deviation at the end of IR, sextupoles are shifted by $\Delta\mu_y\approx-1.65\cdot10^{-4}$ for Y pair, $\Delta\mu_x\approx-4.3\cdot10^{-3}$ for X pair.

As could be seen from Fig. 3 odd order chromaticity of beta functions vanished. However, Fig. 4 shows that phase advance chromaticity is mostly of 2nd and 3rd order. Usually it is proposed to correct higher order chromaticity by appropriate multipoles, in particular 2nd order chromaticity should be corrected by octupole. However, required strength of the octupole in present structure is unrealistically large. Therefore, it is more efficient to use sextupole at the place with small on

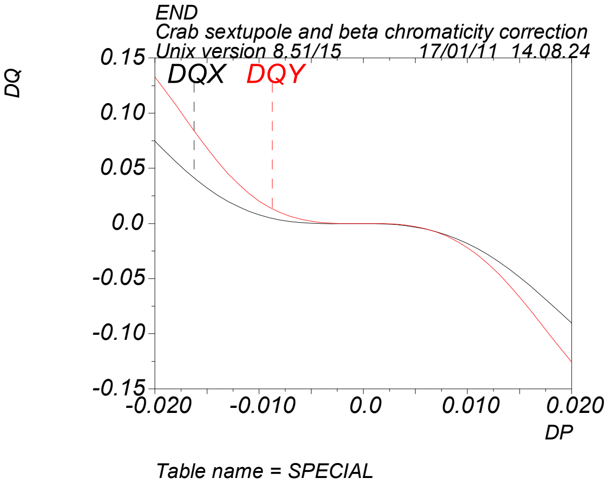

Figure 4: Phase advance dependence on momentum deviation from IP to the end of IR, sextupoles are shifted by $\Delta\mu_y \approx -1.65\cdot10^{-4}$ for Y pair, $\Delta\mu_x \approx -4.3\cdot10^{-3}$ for X pair.

energy beta function and large first order chromaticity of beta function and dispersion to correct second order phase advance chromaticity. Similar speculations give a solution for 3rd order compensation by sextupole with large second order beta function chromaticity. In the places with given conditions sextupoles X5, X6 and X7 (see Fig. 2) have been introduced. Adjustment of additional sextupoles allows significant compensation of nonlinear chromaticity (Figures 5, 6).

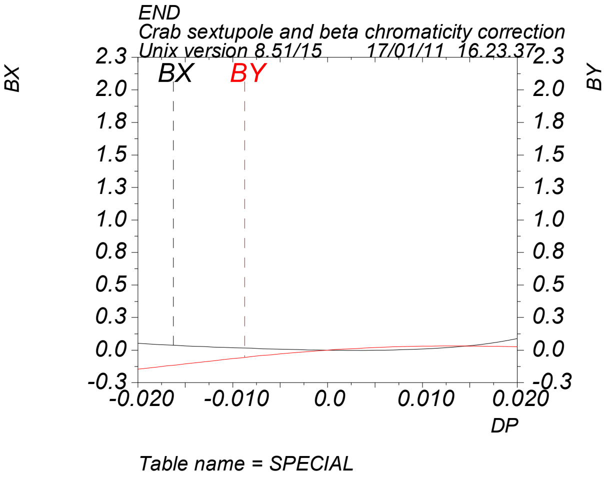

Figure 5: Beta function dependence on momentum deviation at the end of IR, main and additional sextupoles are on.

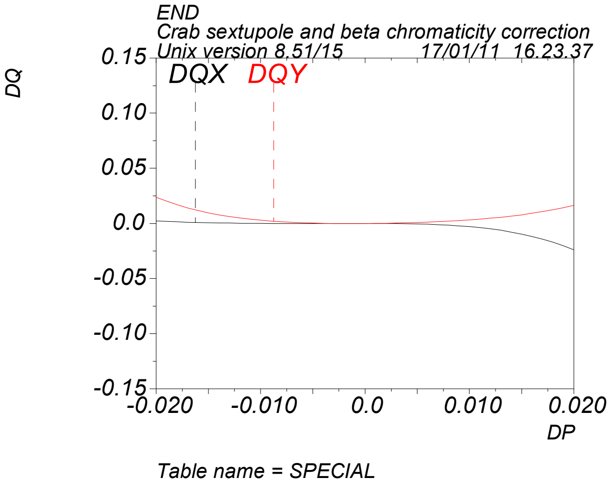

Figure 6: Phase advance dependence on momentum deviation from IP to the end of IR, main and additional sextupoles are on.

GEOMETRICAL ABERRATIONS

It has been shown that all high order geometrical aberrations from sextupole can be cancelled exactly by another sextupole with the same strength placed at –I map [3]. But it is correct only for thin sextupoles, in case of finite length magnets only second order vanishes, while the third order becomes large and limits dynamic aperture of present IR design. However, it was observed in [4] that placing additional weak sextupoles at the same distance from the main ones allows partial compensation of the third order geometrical aberrations, these are Y2 and Y4, X2 and X4 sextupoles (Figure 2).

CONCLUSION

Designed interaction region for Super-ct-factory in Novosibirsk provides luminosity of 10^{35} $cm^{-2}sec^{-1}$, possesses correct geometry, small geometrical and chromatical aberrations, knobs to control higher order chromaticity, realistic parameters of final focus doublet, enough room for solenoids and quadrupoles, band width is of ±2%.

ACKNOWLEDGEMENT

I wish to thank Pantaleo Raimondi for discussions about IR designs of SuperB and Super-ct factories.

REFERENCES

[1] Conceptual Design Report, BINP, Novosibirsk, 2011.
[2] Karl L. Brown, SLAC-PUB-4159.
[3] Karl L. Brown, SLAC-PUB-3381.
[4] http://arxiv.org/abs/0909.4872