IR DESIGHN FOR SUPER-CT-FACTORY

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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 which limits energy acceptance of the whole ring. The present design is based on chromatic properties of telescopic transformation, on local chromaticity correction schemes and on as close as possible placement of CRAB sextupole.

INTRODUCTION

The project of Super-ct-factory is designed to provide electron positron collisions with luminosity of 10^{35} cm^{-2}sec^{-1} in the central mass energy range of 3÷4.5 GeV. Invention of the crab waist collision scheme [1, 2] allows to achieve desired luminosity without utmost parameters of the accelerator. However, there are strong constraints on the size of the ring, because of the cost of the project and available space for the tunnel. This constraints limit the size of the interaction region to be less than 200 meters.

So far there are only two designs of the interaction region with crab waist — DAFNE and SuperB factory in Italy [3, 4]. The length of the interaction region of this project is about 300 meters which is not suitable for Super-ct-factory. Therefore new design of the interaction region has been done, however interaction region of SuperB project has been studied carefully.

PARAMETERS OF THE INTERACTION REGION

Basic parameters of the interaction region presented in Table 1 allow to achieve desired luminosity with non-extreme beam current, beta function values at the interaction point and beam-beam tune shift Table 2.

The chosen coupling coefficient of 1% is providing nonextreme beam-beam tune shift thus giving freedom for possible increase of luminosity by decreasing coupling.

The interaction region (IR) must also satisfy the following constraints.

Table 1:

Energy, GeV	2
Beam current, A	1.36
Number of bunches	295
β_x, mm	20
β_y, mm	0.76
ε_x, nm rad	10
Coupling $\varepsilon_y/\varepsilon_x$, %	**1**
Beam length σ_z, cm	1
Crossing angle, mrad	34

Table 2:

Tune shift ξ_y	**0.13**
Particles per bunch	$7 \cdot 10^{10}$
Luminosity, cm^{-2}sec^{-1}	$1 \cdot 10^{35}$
Hour glass $\frac{\sigma_x}{\theta\beta_y}$	1.095
Piwinski angle $\varphi = \frac{\sigma_z\theta}{\sigma_x}$	12.021

- Due to collision with crossing angle there would be undesired synchrotron radiation background from the incoming beam in the final lens, therefore the lens is shifted to provide on axis trajectory of the incoming beam and eliminate synchrotron radiation background.
- Since accelerator is designed to operate at different energies there should be no longitudinal field integral over the final focus lenses.
- Integral of the detector longitudinal field should be compensated before each final focus lens.
- The length of the IR must be less than 200 meters.
- CRAB sextupole should be placed as close as possible to IP and at the position with low chromaticity of beta functions and phase advances to minimize its influence on dynamic aperture.

BLOCKS OF THE INTERACTION REGION

Interaction region consist of several blocks:

1. final focus telescope — provides final demagnification of the beam, consist of two symmetrical triplets;
2. vertical chromaticity correction section — one pair of sextupoles with $n\pi$ phase advance from the first final focus lens (defocusing) and separated by -I transformation;

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3. horizontal chromaticity correction section — one pair of sextupoles with $n\pi$ phase advance from the second final focus (focusing) lens and separated by -I transformation;

4. CRAB sextupole section — cancels dispersion and provides place with appropriate phase advances ($\mu_x = \pi m$ and $\mu_y = \pi(2n+1)/2$) for CRAB sextupole;

5. ending telescope section — symmetrical triplet closing IR so that there is a telescopic transformation from IP to the end of the IR;

6. matching section — matches optical functions with the arcs of the accelerator.

The structure and optical functions are shown on Fig.1

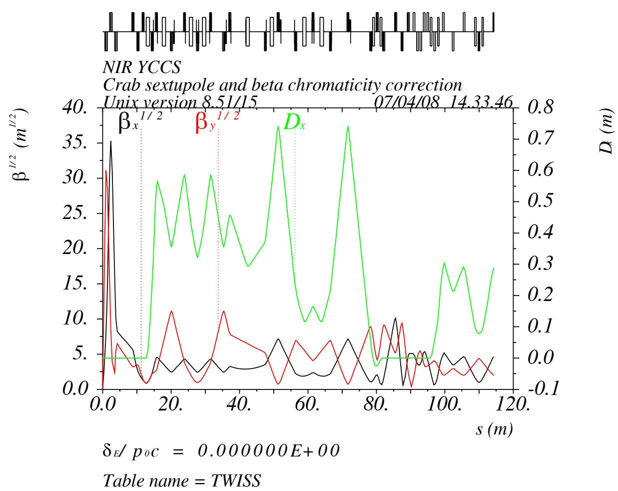

Figure 1: Optical functions of the interaction region.

The basic block of the IR is chosen to be telescopic transformation. This is done because the transfer matrix of the telescope is diagonal

$$R = \begin{pmatrix} R_{11} & 0 \\ 0 & R_{22} \end{pmatrix},$$

thus providing following relations between entering and exiting optical functions:

$$\begin{array}{ccccc} \beta & = & R_{11}^2\beta_0 & & \\ \alpha & = & \alpha_0 & = & 0 \\ \gamma & = & R_{22}^2\gamma_0 \,. & & \end{array}$$

The shown relations allow to change beta function at the IP with the help of matching section lenses without changing strengths of the IR quadrupoles. Another quality of the telescope is zero beta function chromaticity at the exit [5] with zero chromaticity at the entrance. Also symmetrical properties of the telescope provide simple relations for first and second order chromaticity of phase advance μ, beta function β and alpha function α:

$$\frac{d\mu_x}{d\delta} = \frac{T_{126}}{\beta_0 R_{11}}, \tag{1}$$

$$\frac{d^2\mu_x}{d\delta^2} = \frac{2U_{1266}}{\beta_0 R_{11}} - 2\frac{T_{126}T_{116}}{\beta_0 R_{11}^2}, \tag{2}$$

$$\begin{aligned} \beta &= R_{11}\beta_0 + \delta\Big[2R_{11}T_{116}\beta_0\Big] + \\ &+\delta^2\left[(T_{116}^2 + 2R_{11}U_{1166})\beta_0 + \frac{T_{126}^2}{\beta_0}\right], \end{aligned} \tag{3}$$

$$\begin{aligned} \alpha &= \delta\left[-R_{11}T_{216}\beta_0 - \frac{T_{126}R_{22}}{\beta_0}\right] + \\ &+\delta^2\Big[-\beta_0\Big(R_{11}U_{2166} + T_{116}T_{216}\Big) - \\ &-\gamma_0\Big(R_{12}U_{2266} + T_{126}T_{226} + U_{1266}R_{22}\Big)\Big], \end{aligned} \tag{4}$$

where T_{ijk} and U_{ijks} denote second and third order matrices as in $R_{11}(\delta) = R_{11} + T_{116}\delta + U_{1166}\delta^2$. The above relations are true and for the vertical plane with appropriate change of the indices.

TRAJECTORIES AND APERTURES OF THE FINAL FOCUS LENSES

The final focus telescope is made of two symmetrical triplets. Trajectories of the particles of incoming and outgoing beams in the first two lenses are shown on Figure 2. Analyse of the shown trajectories allows to choose apertures of the final focus lenses. Also the cone of matter free space for the detector is shown, limiting an outside dimensions of the magnets. Detailed parameters of the final focus lenses are shown in Table 3 at 2.5 GeV.

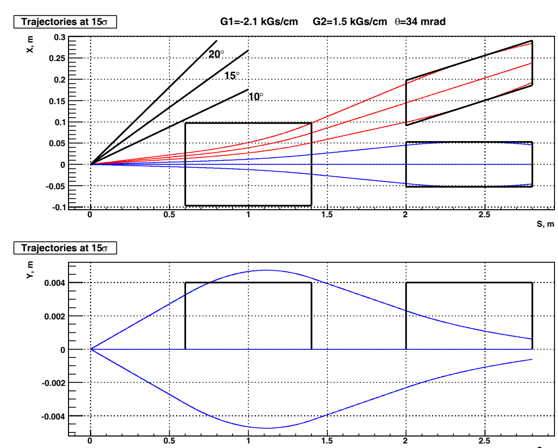

Figure 2: Horizontal and vertical trajectories of incoming and outgoing beams. Shown are central trajectories and distant at 15σ of respectful beam size. Rectangles show position of the lenses and net aperture.

EMITTANCE

The IR possesses strong bending magnets in order to couple sextupoles with chromatic functions. In order to minimize emittance growth in the IR all bending magnets are placed at the positions with minimum dispersion. However, the first final focus lens for outgoing beam (off axis)

Table 3: Parameters of the final focus symmetrical triplet at 2.5 GeV

Name	Q0	Q1	Q2
Position	0.6 m	2 m	3.4 m
Length	0.8 m	0.8 m	0.8 m
Gradient	-2.1 kGs/cm	1.5 kGs/cm	-2.1 kGs/cm
Bend	0.083 rad		
Net aperture	10 cm	5 cm	
β_x/β_y	66 / 970 m	1241 / 67 m	110 / 32 m

provides strong deflection of its trajectory. Combining with high values of beta functions and excited dispersion it gives rise to high value of H interval (Figure 3). Designed emittance of Super-ct-factory is $\varepsilon = 10$ nm and about 40% of it comes from IR bending magnets.

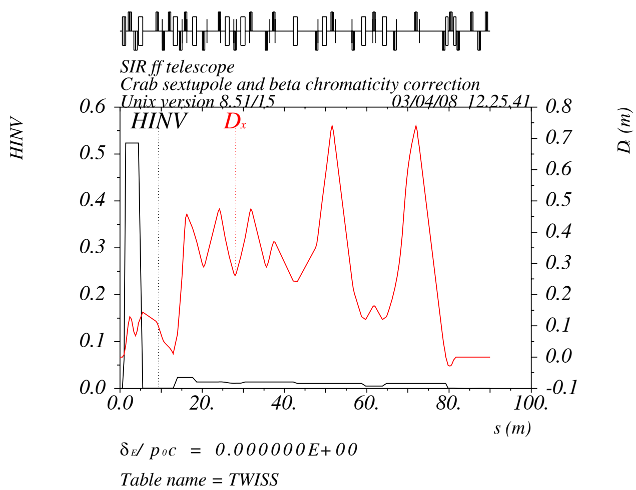

Figure 3: H invariant and dispersion the IR.

ENERGY ACCEPTANCE

High beta functions and strong quadrupoles of final focus telescope give rise to nonlinear chromatic terms in phase advance and optical functions. To cancel chromaticity of the final focus lenses two pairs of sextupoles are placed at $n\pi$ phase advance from each lens respectfully. However, as it is shown on figures (4, 5, 6) they are not suffiecent to compensate high order phase advance chromaticity. Therefore additional sextupoles and octupoles have been inserted in the structure with following principles:

- additional sextupoles — low beta functions but high beta chromaticity, high second order dispersion, weaker than main sextupoles;
- octupoles — high beta and dispersion.

The energy acceptance of $[-0.35, +0.55]\%$ was obtained (Figure 7) with the presented IR and its chromaticty tuning.

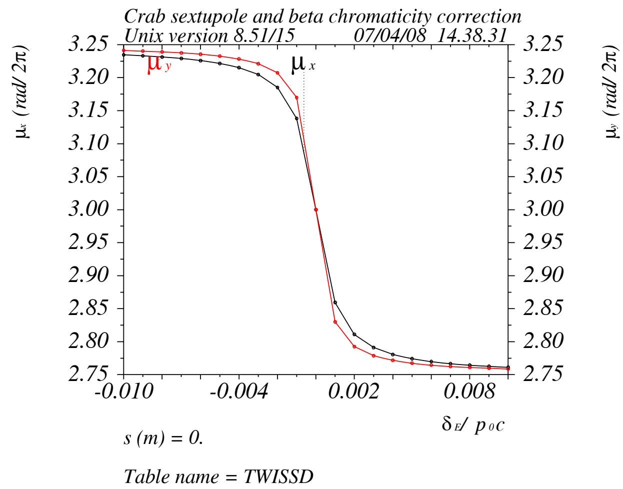

Figure 4: Phase advance at the exit of ending telescope. All sextupoles are off.

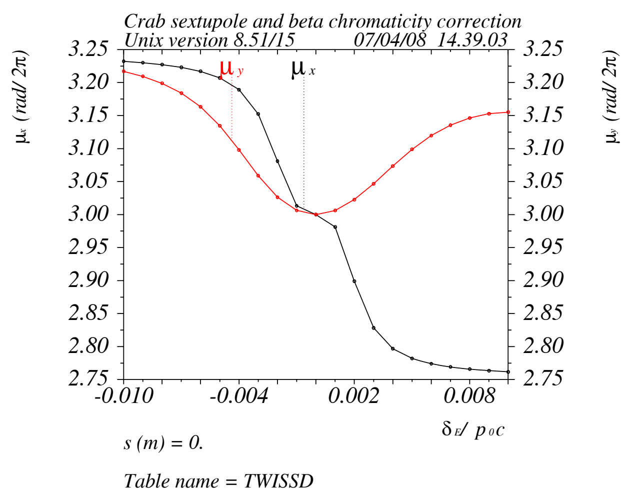

Figure 5: Phase advance at the exit of ending telescope. Only main sextupoles are on.

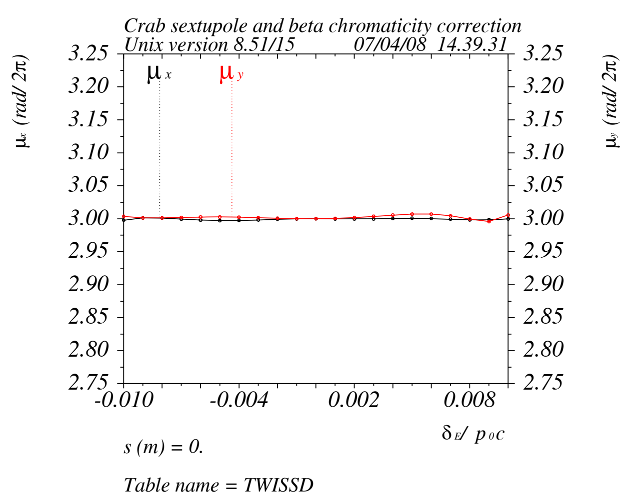

Figure 6: Phase advance at the exit of ending telescope. All sextupoles and octupoles are on.

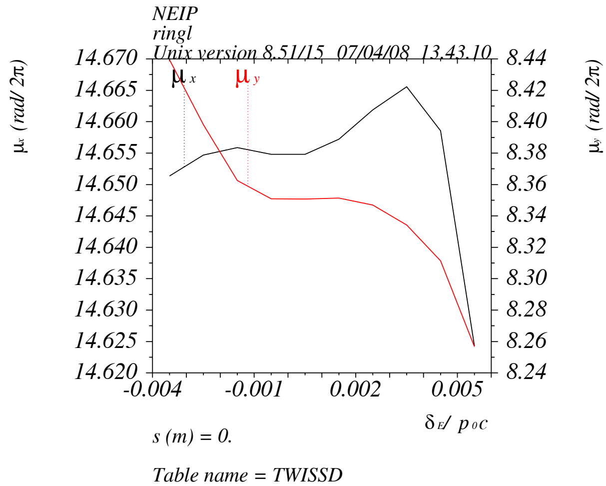

Figure 7: Phase advance of the whole ring versus energy deviation.

CONCLUSION

Designed interaction region provides luminosity of 10^{35} cm^{-2}sec^{-1} with not utmost parameters. There is freedom in beam-beam tune shift, which allows to reduce the coupling coefficient and increase the luminosity. The presented interaction region satisfies all geometrical constraints. Obtained energy acceptance of the Super-ct-factory is small and requires further optimization of the nonlinear chromaticity correction schemes in the interaction region and in the arcs.

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[5] Karl L. Brown, SLAC-PUB-3381, ”First and Second Order Charged Particle Optics”.