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HORIZONTAL CRAB-CROSSING SCHEME FOR TAU-CHARM FACTORY

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Схема $c-\tau$ фабрики со скрещенными углами в горизонтальной плоскости

Рассмотрена схема $c-\tau$ фабрики со скрещенными углами в горизонтальной плоскости. Как известно, проектная светимость в $c-\tau$ фабрике, основанной на использовании перестраиваемой магнитной структуры, может достигать 10^{33} cm^{-2}c^{-1} с возможностью работы как со стандартной схемой, так и со схемой с монохроматизацией. Предполагается, что на первом этапе работа коллайдера будет основана на использовании стандартной схемы. Для повышения светимости на втором этапе до $5 \cdot 10^{33}$ cm^{-2}c^{-1} предлагается перейти на схему со скрещенными углами в горизонтальной плоскости. В работе показано, что такой переход может быть осуществлен путем перестройки магнитной оптики на участках встречи и разведения пучков. При этом магнитная оптика остальной части кольца (полукольцо и прямолинейный участок на противоположной месту встречи стороне) может быть использована без изменений. Проведен анализ различных решений участка встречи схемы со скрещенными углами в горизонтальной плоскости, а также ее сравнение со схемой со скрещенными углами в вертикальной плоскости.

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Beloshitsky P.F., Perelstein E.A. E9-94-13
Horizontal Crab-Crossing Scheme for Tau-Charm Factory

Horizontal crab-crossing scheme is considered in this paper as further development of the versatile design of tau-charm factory. With versatile design collider gets in luminosity $L \cong 10^{33}$ cm^{-2}sec^{-1} and has a possibility to work with conventional scheme as well as with monochromatization one. To upgrade an ability of design, a change of optics in interaction region to use crab-crossing scheme is suggested. This allows to increase a luminosity up to $5 \cdot 10^{33}$ cm^{-2}sec^{-1} while keeping the other part of a ring (arcs, straight section utilities etc.) the same. The choice of micro-beta optics as a result of analysis different possible solutions is made. The comparison of horizontal crab-crossing scheme and vertical with monochromatization one is performed.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1994

1 Introduction

The horizontal crab-crossing scheme is considered in this paper as a further development of versatile design of TCF [1], [2], [3]. With this design tau-charm collider gets in luminosity $L \simeq 1.0 \cdot 10^{33} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$ and provides the possibility to work with conventional flat beam scheme as well as with monochromatization one for experiments required small energy resolution. To upgrade tau-charm facility crab-crossing scheme is considered to increase luminosity up to $4.6 \cdot 10^{33} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$. The first stage of tau-charm collider operation is planned to be conventional scheme. The next one may be monochromatic or crab-crossing optics. For crab-crossing operation it is reasonable to keep most of optical elements, which are planned to use at the first stage (arcs, straight section utilities etc.), and to modify interaction and matching regions only. So, only interaction region optics is studied. The other part of magnet lattice has been taken from conventional design [2].

2 A Choice of Optics in Horizontal Crab-Crossing Scheme

Both horizontal [5], [6] and vertical with monochromatization [7] schemes for TCF, used crab-crossing [4], have been discussed previously. The vertical crab-crossing scheme for tau-charm factory allows to get high luminosity along with small energy resolution. On the other hand, it includes composition of risky factors (both monochromatization and crab-crossing schemes never have been tested) and introduces in crab-crossing difficulties of monochromatization scheme (small beam lifetime, strong demands to broadband impedance). As a consequence, it loses in luminosity and beam lifetime compared with horizontal crab-crossing scheme under the same currents.

When starting with horizontal crab-crossing scheme, few optical solutions are possible for beam separation. A short analysis of them has been performed to make a choice of a preferable one. In the first variant the vacuum chamber is the same for electrons and positrons in the whole interaction region including crab cavity. It has been studied by Voss et al. [5] Superconducting triplet was used to get $\beta_x^* = 1.0$ m and $\beta_y^* = 0.03$ m at interaction point (I. P.). After passing the triplet electron and positron beams move parallel to horizontal axis and are distanced by 3.0 cm. The crab cavity, located after the triplet, is common for beams too. The separation of beams in two rings begins after the cavity. High luminosity $L = 4.6 \cdot 10^{33}$ $\mathrm{cm}^{-2} \mathrm{sec}^{-1}$ at energy E=2.2 GeV can be achieved in this variant. Note that very high current I=6.5 A is necessary to get it. If try to decrease the current without loss a luminosity it is necessary to diminish vertical beta function at I. P. But it is impossible because even with $\beta_y^* = 3$ cm maximum vertical beta function at micro-beta insertion is of 187 m. So, the conclusion is the optical solution with common magnetic elements for beams up to crab cavity (and zero horizontal deflection angle after insertion) allows to reach high luminosity only with very big total current.

To overcome this difficulty one can to refuse the condition of zero deflection angle and to redefine gradients in micro-beta quadrupoles to decrease vertical beta functions. Calculations show that it is possible to find the solution with $\beta_y^* = 1$ cm and $\beta_y^{max} = 90$ m in this case. But the beam convergence to horizontal axis after insertion appears in this case and it is of 2.5 mrad. To remove it electrostatic separator is necessary in this variant. But a use of separator introduces into a scheme additional difficulties such as breakdowns under synchrotron radiation and HOM losses. Along with these problems a big number of parasitic I. P. in this variant occurs.

The second variant is based on a use of independent magnetic elements for electron and positron beams [6]. This option has two attractive features, namely the absence of parasitic interaction points and optical independence of lattices. Unfortunately, to locate separately quadrupoles Q1, vertically focussing and nearest to I. P., a big distance from it is necessary, along with large crossing angle. As a consequence, vertical beta function in Q1 is very large, $\beta_y \geq 400$ m with $\beta_y^* = 0.01$ m. Then, to keep vacuum chamber aperture reasonable, it is necessary for emittance to be $\epsilon_x \leq 100$ nm, hence we are limited in luminosity $L \leq 1.5 \cdot 10^{33} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$ at energy E= 2.0 GeV.

Third variant with quadrupole Q1 common for electron and positron beams and their separation in the second horizontally focussing quadrupole Q2 has been chosen for detailed studies of optics. It is close to those considered in Cornell B-Factory proposal [8]. The magnetic elements and crab cavity location are shown in Fig. 1. Calculations show that it is possible (and good) to use compact permanent magnet QPM located before quadrupole Q1 to help in vertical focussing and to amplify horizontal separation of beams, as it is made in conventional scheme [9]. Its parameters (see Table 1) are taken directly from [9], as well as distance from QPM to Q1 and length of both superconducting quadrupoles. As well as quadrupole Q1, permanent magnet is common for electron and positron beams.

The value of crossing angle $\phi = \pm 12$ mrad has been chosen to make separation of vacuum chambers enough in quadrupole Q2. After passing quadrupole Q1 beams deflecting angles become to be of ±37 mrad. The horizontal distance between beam orbit and axis of quadrupole is of 22 mm at the exit of it. There is long drift space after quadrupole Q1 to get horizontal deviation of beams enough to separate them in two vacuum chambers starting at horizontally focussing quadrupole Q2. The horizontal distance between beam axes at the entrance of Q2 is of 118 mm, and $2 \cdot 10 \sigma_x = 94$ mm for beam envelopes and 2×5 mm for closed orbit exursions are necessary. Fringing field effects in quadrupoles QPM and Q1 contributes to tune shifts because of closed orbit errors [10], but they are small, $\Delta Q_{x,y} \leq 0.001$. Parameters of micro-beta quadrupoles are given in Table 1.

To use parameters of crab cavity in crossing angle design, RF crab cavity similar to those described in Cornell B-Factory proposal [8] has been considered. It can produce up to 2 MV of transverse kick and is of 1.1 m in transverse size with cryostat. The crab cavities should be located at positions with horizontal phase advances $\mu_x = 2\pi \cdot (n \pm 1/2)$, n-integer, if starting with I. P., and zero dispersion. For these reasons they are placed after separation region before the arcs. The value of horizontal beta function at crab cavity is of 12 m, hence moderate voltage in crab cavity is needed to rotate the bunches, $V_c = 1.0$ MV.

Standard procedure of matching of vertical and horizontal dispersion by appropriate choice of horizontal and vertical phase advances and positions of horizontal BH1 and vertical BV1 bending magnets has been used. The transverse distance between electron and positron orbits at the separation region has its minimum value of 2×19.4 cm at the entrance of BV1, it is of 2×24.5 cm at the entrance of BH1 and is greater than 26 cm at

positions of matching quadrupoles. Lattice functions in interaction region and separation region are shown in Fig. 2.

	Distance from I. P. m	Length m	Gradient T/m
QPM	0.40	0.25	-20.0
Q1	1.0	0.30	-27.6
Q2	2.3	0.30	16.7

Table 1: Parameters of micro-beta quadrupoles

Following the principle to make minimum of changes in optics, arcs and straight section utilities has been taken directly from conventional 60° lattice design [2], [11]. The natural emittance is of 388 nm in this lattice, and it is reached with dipole and Robinson wigglers. If wigglers are switched off, it is of 95 nm, so one has a big flexibility in lattice that is convinient for scheme with crossing angles. The list of parameters of tau-charm collider is given in Table 2.

When started with the choice of collider parameters, the value of $\beta_y^* = 0.01$ m was kept the same as in conventional scheme, to get high luminosity with relatively small total current. It is possible to do this, because no additional problems with chromatic correction in crab-crossing scheme occur. Final focus chromaticities in this case are very close to those in conventional one. The results of chromaticity correction in conventional scheme show [12] that it is possible to get large longitudinal acceptance of $\delta p = \pm 1.8\%$ and, hence, big beam lifetime in 60° lattice. The number of particles in a bunch corresponds to conventional design too, because nothing is changed in arcs and the broadband impedance restriction is the same.

The choice of bunch spacing $S_b = 2.5$ m has been taken to avoid more than one parasitic I. P. Under this choice the number of bunches in a ring becomes to be $n_b = 150$, i. e. 5 times higher compared with conventional design [2]. This leads directly to 5 times higher luminosity $4.6 \cdot 10^{33} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$, and 5 times higher RF power is required. The feedback systems to suppress multi-bunch instabilities in the case of so small bunch spacing is now under design at CESR and LHC. The ratio of distance between beam axis to their horizontal size at parasitic I. P. $\delta_x / \sigma_x = 24$ for $\epsilon_x = 388$ nm, that is close to the same ratio in conventional design.

3 Conclusions

It has been shown the possibility to develope conventional scheme into the scheme with horizontal crossing angles. Only interaction region and separation region should be modified, and the same arcs and straight section utilities can be used. The possibility to work with monochromatization of beams is preserved too. A big flexibility of conventional design based on use of wigglers is good for crossing angles scheme. The choice of micro-beta optics has been made as a result of analysis of different possible solutions.

Energy, GeV	E	2.0
Luminosity, $cm^{-2}sec^{-1}$	L	$4.6 \cdot 10^{33}$
Beam lifetime, hours	τ	5
C.M. energy resolution, MeV	σ_w	1.8
Circumference, m	C	378
Natural emittance, nm	ε_0	388
Damping partition numbers	$J_x/J_y/J_\varepsilon$	0.59/1/2.41
Bending radius in arc, m	ρ	11.5
Damping times, msec	$\tau_x/\tau_y/\tau_s$	43/25/11
Momentum compaction	α	$1.63 \cdot 10^{-2}$
Energy spread	σ_E	$6.23 \cdot 10^{-4}$
Total current, A	I	2.6
Number of particles in a bunch	N_b	$1.35 \cdot 10^{11}$
Number of bunches	k_b	150
RF voltage, MV	V	10
Crab cavity voltage, MV	V_c	0.98
Crab angle, mrad	ϕ_c	12
RF frequency, MHz	f_{RF}	476
Harmonic number	q	600
Bunch length, mm	σ_s	6.93
Bunch spacing, m	S_b	2.5
Longitudinal impedance, Ohm	$\|Z_n/n\|$	0.21
Beta functions at I.P., m	β_x^*/β_y^*	0.50/0.01
Beam-beam parameters	ξ_x/ξ_y	0.04/0.04

Table 2: List of parameters of tau-charm collider

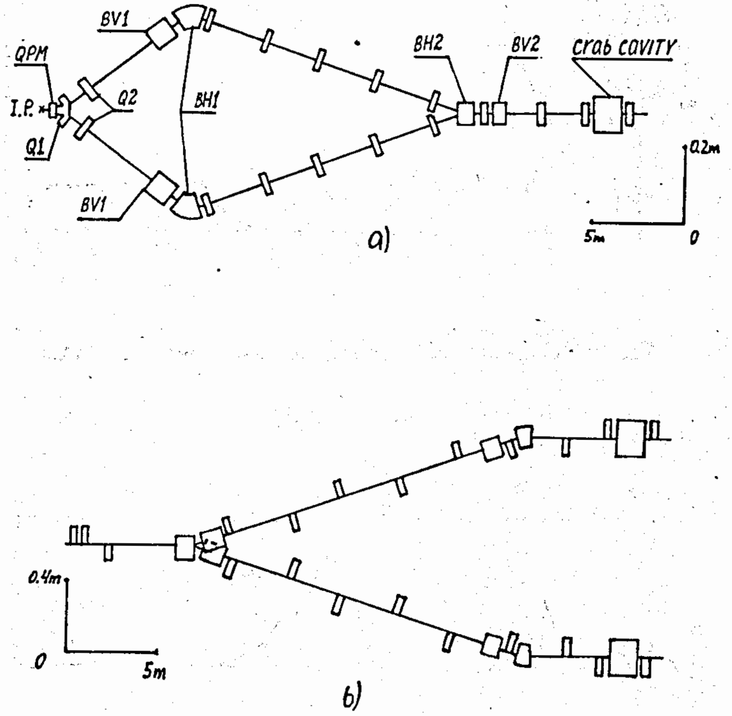

Fig. 1. Schematic view of element location in horizontal (a) and vertical (b) planes.

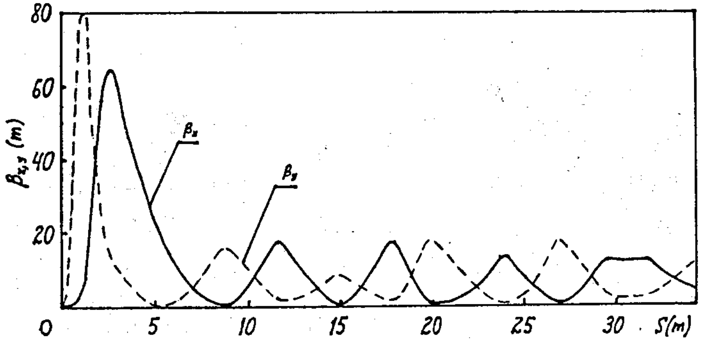

Fig. 2. Beta functions in interaction and separation regions.

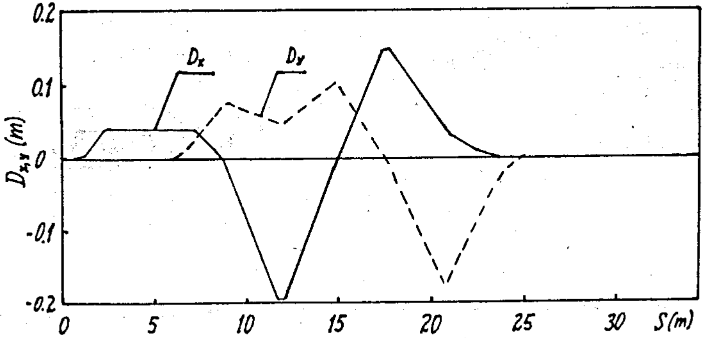

Fig. 3. Horizontal and vertical dispersion in interaction and separation regions.

References

[1] Alexander Zholents "Polirized J/ψ Mesons at a Tau-Charm Factory with a Monochromatization Scheme", CERN SL/92-27(AP), 1992.

[2] Paul Beloshitsky "A Magnet Lattice for a Tau-Charm Factory Suitable for Both Standard Scheme and Monochromatization Scheme", LAL/RT 92-09, 1992.

[3] A. Faus-Golfe and J. Le Duff "A Versatile Lattice for a Tau-Charm Factory that includes a Monochromatization Scheme (Low-Emittance) and a Standard Scheme (High-Emittance)", Proceedings of IEEE Particle Accelerator Conference, Washington, 1993 (to be published).

[4] R. Palmer, "Energy Scaling, Crab-Crossing and the Pair problem", SLAC-PUB-4707, 1988.

[5] G.-A. Voss, J. M. Paterson, and S. A. Kheitfets, "Crab-Crossing in a Tau-Charm Facility", SLAC-PUB-5011, 1989.

[6] Katsunobu Oide, "Design of a High Luminosity Collider for the Tau-Charm Factory", SLAC-Report-343, 1989, p.31.

[7] Yu. I. Alexahin, "A Scheme of Monochromatic Tau-Charm Factory with Finite Crossing Angle", Proceedings of the II Workshop on JINR c-tau Factory, 27-29 April 1993, JINR, Dubna, D1, 9, 13-93-459, 1993.

[8] K. Berkelman et al. CESR-B (Conceptual Design for a B Factory Based on CESR), CLNS 91-1050.

[9] T. Taylor, "Machine-Detector Interface", Proceedings on Third Workshop on the Tau-Charm Factory, Marbella, Spain, 1993 (to be published).

[10] J. Le Duff, "Fringing Field Effect of the Insertion Quadrupoles in DORIS", DESY H-74/1, 1974.

[11] P. F. Beloshitsky, "A Versatile Magnet Lattice for Tau-Carm Factory", Proceedings of the II Workshop on JINR c-tau Factory, 27-29 April 1993, JINR, Dubna, D1, 9, 13-93-459, 1993.

[12] P.F. Beloshitsky, "Chromaticity Correction in JINR Tau-Charm Factory High Emittance Lattice", Proceedings of the II Workshop on JINR c-tau Factory, 27-29 April 1993, JINR, Dubna, D1, 9, 13-93-459, 1993.

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