Horizontal Crossing Angle Scheme for Tau-Charm Factory

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Abstract

The horizontal crossing angle scheme for the tau-charm factory (TCF) as a further development of its versatile design [1], [2], [3] is considered. With versatile design the collider gets in luminosity L$\simeq$1.0$\cdot10^{33}$cm^{-2}sec^{-1} and provides the possibility to work with the conventional flat beam scheme as well as with the monochromatization one for experiments requiring a small energy resolution. To upgrade the tau-charm facility the crossing angle scheme is incorporated into the versatile design [4], getting a luminosity L=3.5$\cdot10^{33}$cm^{-2}sec^{-1}.

1 BASIC REQUIREMENTS TO CROSSING ANGLE SCHEME

Presently the conventional scheme is considered as the basic one for the TCF [5], [6]. Following this, finite crossing angle option has been implemented into conventional design with a minimum of modifications in the storage ring. Only interaction and separation regions have been replaced, while keeping the arcs and the long straight section opposite to interaction point (I. P.) untouched. With this restriction the TCF circumference becomes slightly longer (ΔC/C=5$\cdot10^{-5}$) for crossing angle scheme compared with those for conventional one. Hence, small tuning of RF frequency becomes necessary.

2 OPTICS

Both horizontal and vertical monochromatic schemes for TCF, used crossing angles, have been discussed previously. Their comparison shows that [4]:

- the horizontal crossing angle scheme gets bigger luminosity and beam lifetime with the same current, compared with the vertical one;
- among the horizontal crossing angle solutions, the one which uses the first micro-beta insertion quadrupole Q1 (Fig. 1) common for electron and positron beams and separate other magnetic elements, gives maximum luminosity with minimum total current.

To provide the maximum independence of two rings, as well as fast beam separation, the second insertion quadrupole Q2 is separated for electron and positron beams. The magnetic element location for Dubna project is shown in Fig. 1. To help in vertical focussing and to amplify horizontal separation of beams, compact permanent quadrupole QPM is located just in front of quadrupole Q1. As well as Q1, quadrupole QPM is common for both beams. The positions and the lengths of quadrupoles QPM and Q1 are the same as in the conventional design lattice, and have been taken directly from the machine-detector interface considerations, discussed at the Marbella Workshop [7]. The long drift space after quadrupole Q1 provides horizontal beam deviation enough to have two vacuum chambers starting at the horizontally focussing quadrupole Q2 which is located in 2.3 m from I. P.

The value of crossing angle $\phi = \pm12$ mrad was chosen as a compromize between fast beam separation and reasonable orbit excursion in quadrupole Q1. After quadrupole Q1 beam deflecting angles become ±37 mrad and the horizontal distance between beam axes is of 118 mm.

According to the TCF parameters (see Table 1), the ratio of horizontal beam size to the bunch length at I. P. is 4 times bigger than the crossing angle ϕ, probably allowing to avoid synchro-betatron resonances. Nevertheless, special places with appropriate phase advances $\mu_x = \pm2\pi \times 1.75$ are foreseen for the RF crab cavity location in optical design.

The use of the same arcs in crossing angle and conventional designs puts constraints to separation region optics. The separation of beams into vertically distanced rings is performed simultaniously in horizontal and vertical planes, and the vertical bending is enclosed in the horizontal one. Hence, different horizontal and vertical phase advances are used to match horizontal and vertical dispersion. Following the principle to make minimum optics changes, arcs and straight section utilities have been taken directly from conventional 60° lattice design [2]. Lattice functions in interaction and separation regions are shown in Fig. 2, 3.

3 CHOICE OF PARAMETERS FOR TCF CROSSING ANGLE SCHEME

For the crossing angle scheme, the value of $\beta_y^* = 0.01$ m was kept the same as for the conventional one, to get high luminosity with relatively small total current. This is possible to do, because no additional problems with chromatic correction in the crossing angle scheme occur. Final focus chromaticities in this case are very close to those in the conventional one. The results of chromaticity correction for the conventional scheme show [8] that it is possible to get large energy acceptance of $\delta p = \pm1.8\%$, hence, big beam lifetime in 60° lattice. The choice of bunch spacing S_b =2.5 m was made to avoid more than two symmetrically located parasitic crossings. In this crossings the ratio of distance between beam axis to their horizontal size

Energy, GeV	E	2.0
Luminosity, $cm^{-2}sec^{-1}$	L	$3.5 \cdot 10^{33}$
Beam lifetime, hours	τ	5
Energy resolution, MeV	σ_w	1.7
Circumference, m	C	377.8
Natural emittance, nm	ε_0	299
Damping part. numbers	$J_x/J_y/J_\varepsilon$	0.6/1/2.4
Bending radius in arc, m	ρ	10.5
Damping times, msec	$\tau_x/\tau_y/\tau_s$	41/25/11
Momentum compaction	α	$1.59 \cdot 10^{-2}$
Energy spread	σ_E	$5.89 \cdot 10^{-4}$
Total current, A	I	2.0
Particles in a bunch	N_b	$1.05 \cdot 10^{11}$
Number of bunches	k_b	150
Energy loss per turn, kV	U_0	199
RF voltage, MV	V	7
Crab cavity voltage, MV	V_c	0.96
Crab angle, mrad	ϕ_c	12
RF frequency, MHz	f_{RF}	476
Harmonic number	q	600
Bunch length, mm	σ_s	7.72
Bunch spacing, m	S_b	2.52
Long. impedance, Ohm	$\lvert Z_n/n \rvert$	0.27
Beta functions at I.P., m	β_x^*/β_y^*	0.50/0.01
Beam-beam parameter	ξ_y	0.04

Table 1: List of parameters of tau-charm collider

$2\delta_x/\sigma_x$ =28 for ϵ_x =299 nm, that is close to the same ratio in the conventional scheme design. With this bunch spacing 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, and to a total beam current of 2.6 A. Howerever, the safer value of 2.0 A was adopted as the design parameter. For a beam-beam parameter equal to 0.04, an emittance of $3 \cdot 10^{-7}$ m is required, which is easy to get with 60° lattice by properly adjusted wigglers. As a result, a luminosity of $3.6 \cdot 10^{33}$ cm^{-2} s^{-1} is achieved. The list of TCF parameters is given in Table 1.

4 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 kept too. A big flexibility of conventional design based on use of wigglers is good for crossing angles scheme.

5 REFERENCES

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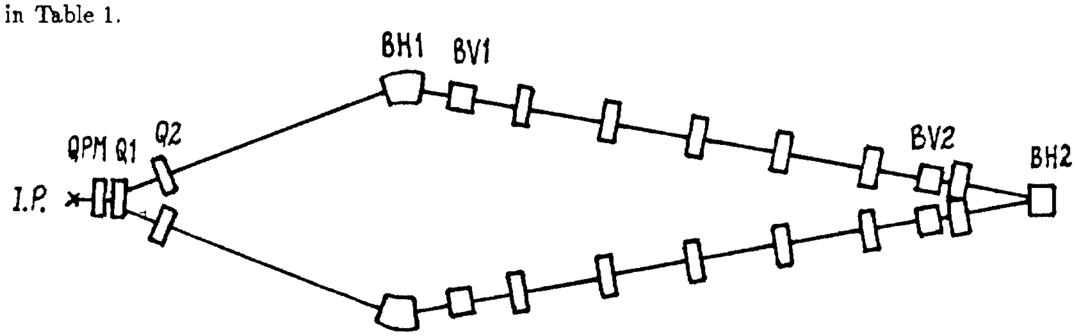

Fig. 1a. Schematic view of element location in horizontal plane.

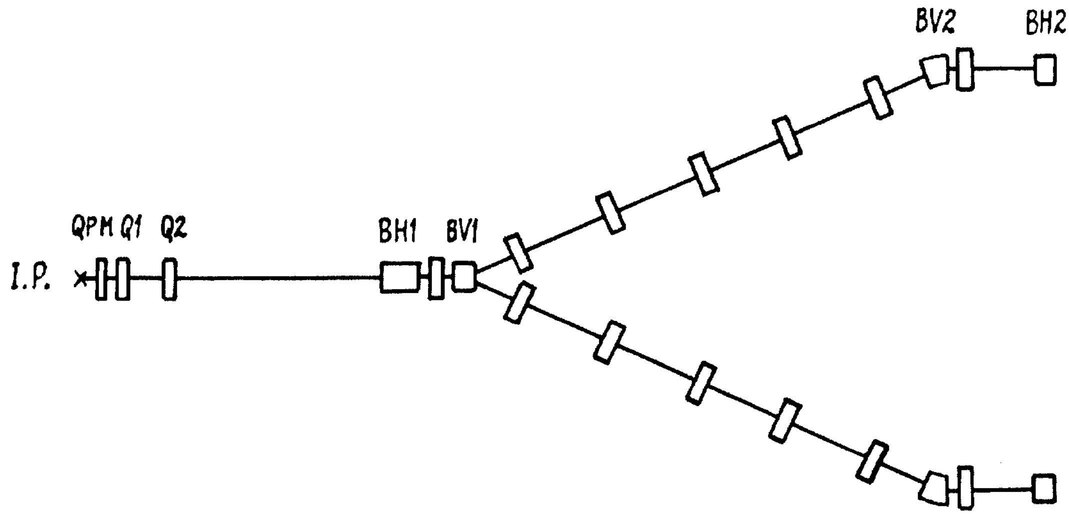

Fig. 1b. Schematic view of element location in vertical plane.

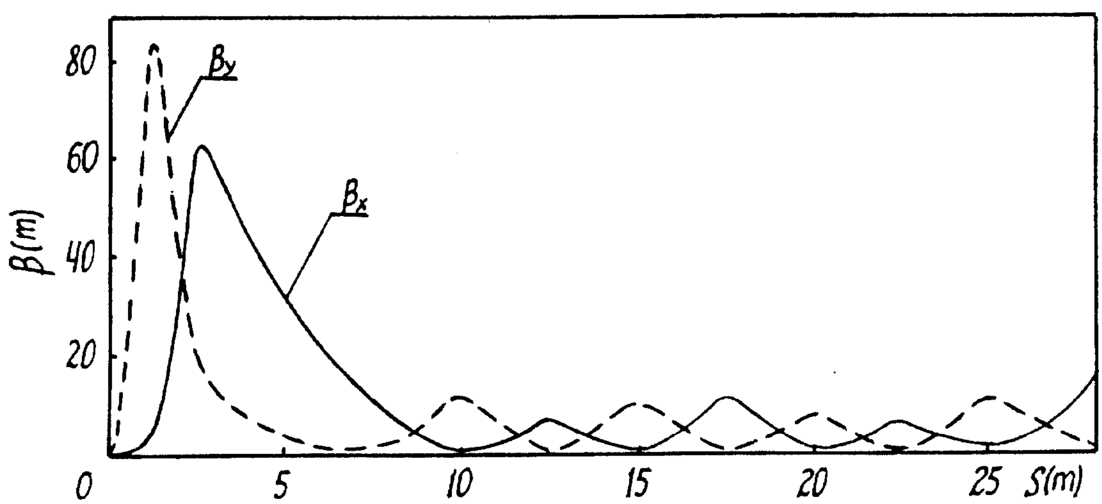

Fig. 2. Beta functions in interaction and separation regions.

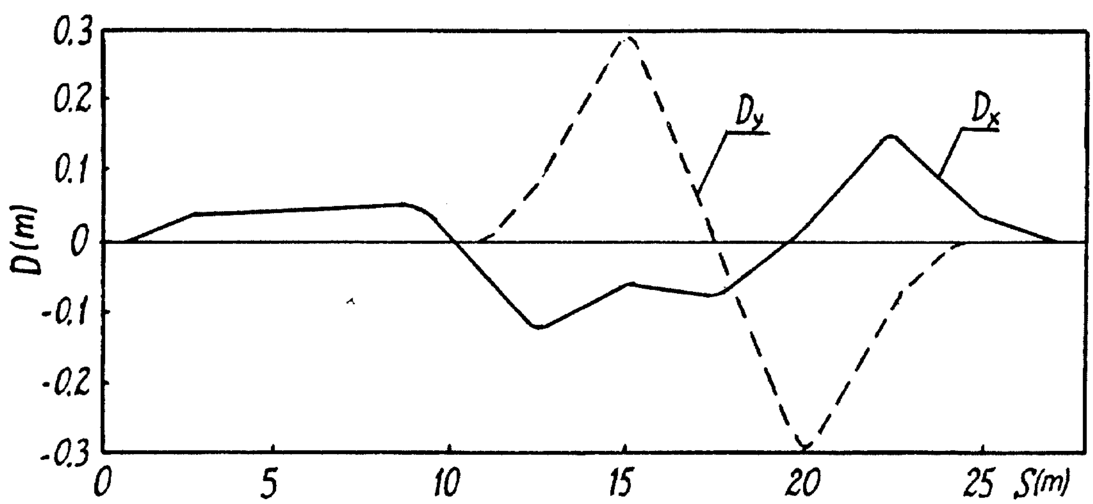

Fig. 3. Horizontal and vertical dispersion in interaction and separation regions.