# A Versatile Lattice for a Tau-Charm Factory that includes a Monochromatization Scheme (Low-Emittance) and a Standard Scheme (High-Emittance)

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*Abstract*

A versatile lattice for a tau-charm factory working at 4 GeV center of mass energy with $10^{33}$ cm$^{-2}$ s$^{-1}$ luminosity is considered in this paper. The main goal of this study due to absence of experience in this kind of features, is the possibility to use easily the same lattice for either monochromatization (low-emittance) scheme or standard (high-emittance) scheme. This monochromatization scheme permits to reduce the spread of collision energies at the interaction point to the level of 0.1 MeV. In this paper we consider a low-emittance arc ($10^{-8}$ m rad) typical from synchrotron radiation lattices and the passage from low-emittance to high-emittance ($10^{-7}$ m rad) is obtained by detuning of the low-emittance arc.

## I MONOCHROMATIZATION AND EMITTANCE

From [1] and [2] we can deduce that a non-optimized monochromatizion scheme gives a factor gain $\lambda$ in energy resolution, $\Sigma_w$, but a loss by the same factor in luminosity.

Assuming that $D^*_{y-}$=-$D^*_{y+}$=$D^*_y$ and $D^*_{x-}$=-$D^*_{x+}$=0 we obtain:

$$L = \frac{L_0}{\lambda} \;;\Sigma_w = \frac{\sqrt{2}E_0\sigma_\epsilon}{\lambda} \tag{1}$$

with

$$\lambda \simeq \frac{\sigma_\epsilon D^*_y}{\sigma^*_{\beta y}} \;;L_0 = \frac{k_b f_r N_+ N-}{4\pi\sigma^*_{\beta y}\sigma^*_{\beta x}} \tag{2}$$

where $\lambda$ is the gain factor, $L_0$ the total luminosity with zero dispersion at the interaction point, $\sigma_\epsilon$ denotes the relative energy deviation of each beam , $E_0$ the nominal energy per beam, $k_b$ the number of bunches per beam, $f_r$ the revolution frequency, $N_{+-}$ the number of particles in each bunch and $\sigma^*_{\beta xy}$ the betatron size at the interaction point (IP).

To achieve a factor $\lambda$ in energy resolution, without loss in total luminosity, it is necessary to optimize the beam parameters as described in the following.

The total luminosity can be defined as a function of beam-beam parameters, $\xi_{xy}$:

$$L = \frac{\gamma I}{2er_e}\,(\frac{\xi_x}{\beta^*_x} + \frac{\xi_y}{\beta^*_y}) \tag{3}$$

where I is the total beam current, $r_e$ the classical electron radius, $\gamma$=$E_0$/mc$^2$ and $\beta^*_{xy}$ the values of beta functions at IP.

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The beam-beam effect for the case of a large dispersion at the IP was analysed in [5] and the following recommendations were pointed out.

- Beams in collision must be flat.
- Dispersion must be in a plane where beams are wide (easier matching).
- The beam-beam parameters for a plane with dispersion must be less than 0.04 and for a plane without dispersion approximately 0.04.

With these requirements if we have $D^*_y \neq 0$ and $D^*_x$=0 then $\sigma^*_x \ll \sigma^*_y$ and $\xi_y \ll \xi_x$. From the first look to equation 3 it seems that decreasing $\xi_y$ should result in a fall of the luminosity but if one takes $\beta^*_x \ll \beta^*_y$ the total luminosity is given essentially by:

$$L \simeq \frac{\gamma I}{2er_e}\,(\frac{\xi_x}{\beta^*_x}) \tag{4}$$

To preserve $\xi_x$ with enlarged $\sigma^*_y$ one should increase N (but the possibility to increase N is limited by the coherent stability requirements) or reduce $\sigma^*_x$ but the latter requires a low-emittance lattice. These requirements for the typical parameters of the Tau-Charm factory ($E_0$=2.0 GeV, $\beta^*_x$=0.01 m, $\xi_x$=0.04, N=1.2 $10^{11}$) set a limit on the maximum value of the horizontal emittance at the level of $\epsilon_x \simeq$1-2 $10^{-8}$ m rad. This emittance is the typical emittance of synchrotron radation machines of the third generation.

From [6] we can deduce that a luminosity at the level of L$\simeq 10^{33}$ cm$^{-2}$ s$^{-1}$ for a standard scheme with a flat beam, requires the horizontal emittance at 2.0 GeV to be of the order of $\epsilon_x \simeq$3-4 $10^{-7}$ m rad.

As analysed previously a total luminosity at the level of L$\simeq 10^{33}$ cm$^{-2}$ s$^{-1}$ for both standard and monochromatization schemes requires to vary the emittance over a wide range from $\epsilon_x \simeq$1-2 $10^{-8}$ m rad up to $\epsilon_x \simeq$3-4 $10^{-7}$ m rad, ie. a versatile lattice.

With this philosophy and with FODO cells in the arc two studies [3] and [4] have been proposed. In our case the idea is to use DBA or TBA cells in the arc optimized for low-emittance and the high emittance is achieved by detuning this low-emittance lattice.

## II VERSATILE LATTICE

To describe the lattice one can divide it in three sections: interaction region, arc (DBA or TBA) and utility insertion. The versatile lattice has been designed in such a way that with some additional quadrupoles in the interaction region and changing the strength of the quadrupoles it is possible to pass from monochromatization optics to standard optics. This is precisely the main goal of this study, ie. the possibility to use easily the same lattice for either monochromatization and standard scheme.

Two differents arcs DBA and TBA have been studied with the same interaction region. The description of the interaction region, the differents arcs and the utility section is accomplish in the following sections.

### A Interaction region

Standard choice of optics in the micro-beta insertion for a Tau-Charm factory design is used in both schemes (monochromatization and standard) [3] and [4]. The distance between the first superconducting quadrupole and the IP is kept at 0.8 m to locate the detector, but the distance between the first and the second quadrupole has been reduced to avoid the growth of the high beta function in this region, which is responsible for the high vertical chromaticity in this kind of lattices.

The parameters of the micro-beta insertion and the lattices functions in this region for the two schemes are shown in table 1 and on figures 1-4.

### B Arc: DBA

In this first study we have taken a DBA cell in the arc with a doublet in the dispersive section and a triplet in the non-dispersive section to have more flexibility in matching of the optics, since the same lattice is used for both low and high emittance arcs.

For the monochromatization scheme the arc has been optimized to obtain $\epsilon_x$=2 $10^{-8}$ m rad (10 periods) at $E_0$=2.0 GeV with $J_x$=1.0. The change from low-emittance ($\epsilon_x$=2 $10^{-8}$ m rad) to high-emittance ($\epsilon_x$=3 $10^{-7}$ m rad) is achieved by decreasing the strength of the quadrupoles in the dispersive doublet and a mismatch of the dispersion in the achromat. This mismatch implies that $D_x \neq 0$ and $D'_x$=0 between cells hence it is necessary to rematch the dispersion at the entrance and exit of the arc; this is done by independent quadrupoles.

The performances and the lattice functions of half a ring for both shemes are shown in table 1 and on figures 1 and 2.

### C Arc: TBA

For the second study we have used a TBA cell in the arc with six quadrupoles by half cell, three in the dispersive section and three in the non-dispersive section. This high number of quadrupoles permits to have more flexibility in matching the optics.

As in the previous case the arc has been optimized to have $\epsilon_x$=2 $10^{-8}$ m rad (12 periods) at $E_0$=2.0 GeV with $J_x$=1.0, the change from low-emittance to high-emittance being achieved in the same way as in the previous case.

The performances and the lattice functions of half a ring for both shemes are shown in table 1 and on figures 3 and 4.

Table 1: Performances for both schemes and both arcs

| | | Monochr. Low-Emit | Standard High-Emit | |
|---|---|---|---|---|
| | $E_0$ | 2.0 | 2.0 | GeV |
| | $\beta_x^*$ | 0.01 | 0.3 | m |
| | $\beta_y^*$ | 0.15 | 0.01 | m |
| | $D_y^*$ | 0.32 | 0.0 | m |
| | $\kappa$ | 0.067 | 0.033 | |
| | $\xi_x$ | 0.04 | 0.04 | |
| | $\xi_y$ | 0.035 | 0.04 | |
| DBA | $\sigma_\epsilon$ | 5.42 $10^{-4}$ | 5.42 $10^{-4}$ | |
| | $\epsilon_x$ | 1.93 $10^{-8}$ | 2.97 $10^{-7}$ | m rad |
| | $\epsilon_y$ | 1.28 $10^{-9}$ | 9.91 $10^{-9}$ | m rad |
| | C | 321.687 | 321.687 | m |
| | $k_b f_r$ | 27.957 | 27.957 | MHz |
| | $N_b$ | 1.31 $10^{11}$ | 1.1 $10^{11}$ | |
| | $I_b$ | 0.585 | 0.49 | A |
| | L | 1.09 $10^{33}$ | 8.97 $10^{32}$ | $cm^{-2}s^{-1}$ |
| | $\lambda$ | 12.545 | 1.0 | |
| | $\Sigma_w$ | 0.122 | 1.533 | MeV |
| TBA | $\sigma_\epsilon$ | 6.81 $10^{-4}$ | 6.81 $10^{-4}$ | |
| | $\epsilon_x$ | 1.9 $10^{-8}$ | 2.86 $10^{-7}$ | m rad |
| | $\epsilon_y$ | 1.27 $10^{-9}$ | 9.52 $10^{-9}$ | m rad |
| | C | 387.008 | 387.008 | m |
| | $k_b f_r$ | 27.886 | 27.886 | MHz |
| | $N_b$ | 1.23 $10^{11}$ | 1.05 $10^{11}$ | |
| | $I_b$ | 0.551 | 0.470 | A |
| | L | 1.01 $10^{33}$ | 8.43 $10^{32}$ | $cm^{-2}s^{-1}$ |
| | $\lambda$ | 15.834 | 1.0 | |
| | $\Sigma_w$ | 0.122 | 1.926 | MeV |

### D Utility section

This section has almost the same length as the insertion region. It is made of regular FODO cells and it is designed to house the RF cavities, the beam instrumentation devices and to locate additional sextupoles to help the correction of chromaticity should it be necessary.

The lattice functions in this region for both shemes and both cases are shown on figures 1-4.

## III REFERENCES


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tion point" (Nuclear Instruments and Methods in Physics Research A305(1991) 25-29)

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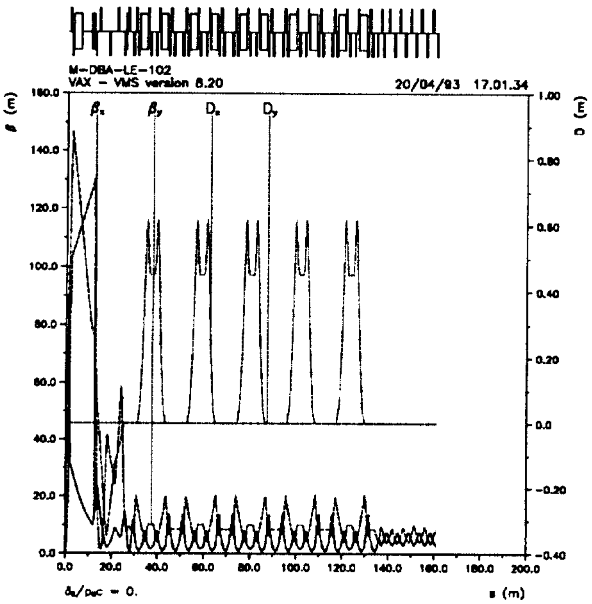


Figure 1: Lattice functions of half a ring for monochromatization scheme, arc DBA

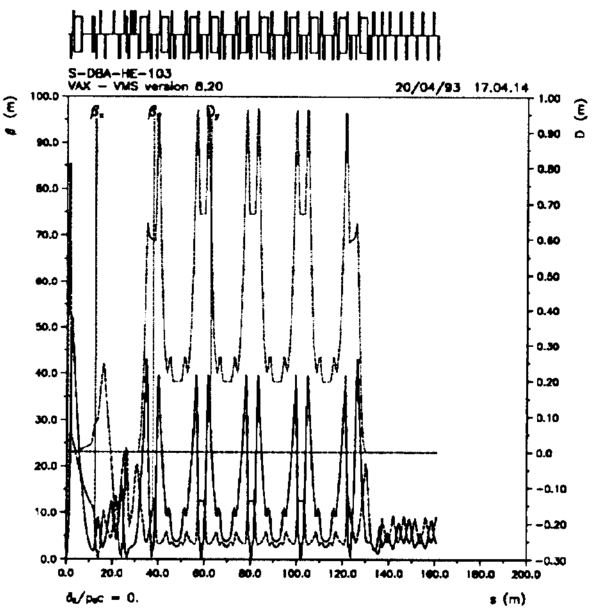


Figure 2: Lattice functions of half a ring for standard scheme, arc DBA

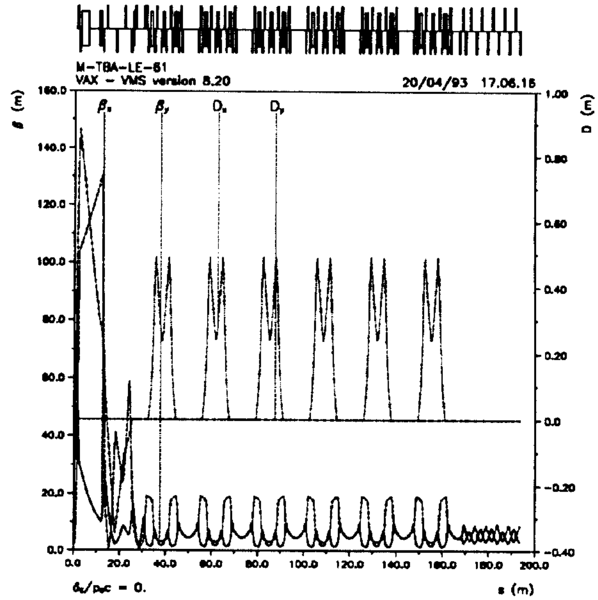


Figure 3: Lattice functions of half a ring for monochromatization scheme, arc TBA

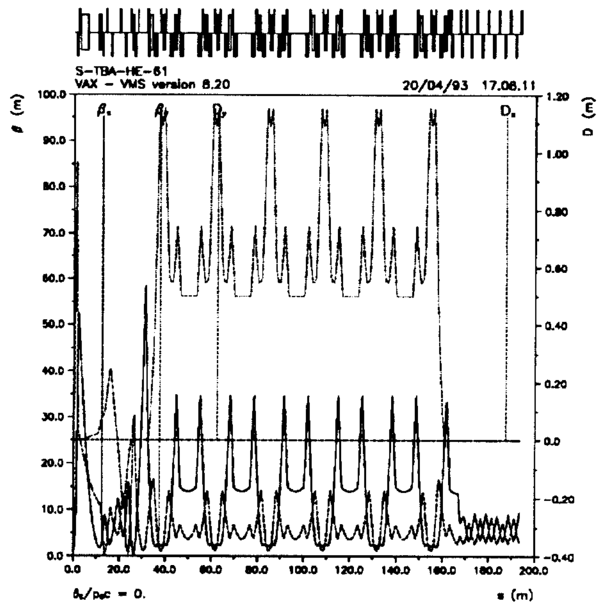


Figure 4: Lattice functions of half a ring for standard scheme, arc TBA