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NOTES TO A TUNABLE LATTICE FOR REALIZATION FLAT BEAM AND MONOCHROMATIZATION SCHEMES OF TAU-CHARM FACTORY

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Introduction

Recently a versatile magnet lattice for tau-charm factory with flat beam that includes monochromatization scheme has been proposed /1/. It has been shown that few additional quadrupoles and one or few vertical bending magnets in sloping region are necessary to introduce monochromatization in energy of colliding electron and positron beams /2-8/ in the standard flat beam scheme /9/. This new lattice allows to gain in energy resolution in $\lambda \simeq \sigma_{ys}/\sigma_{y\beta} \simeq 7.5$ times, but the total luminosity is decreased in the same factor λ and is equal to $L \simeq 0.14 \cdot 10^{33} cm^{-2} s^{-1}$. Here $\sigma_{ys} = \sigma_E \psi_y$ and $\sigma_{y\beta} = (\varepsilon_y \beta_y^*)^{1/2}$ are vertical synchrotron and betatron beam sizes, σ_E is energy spread, β_y^* and ψ_y^* are vertical beta and dispersion functions in interaction point, ε_y is vertical emittance.

To use this scheme without monochromatization as in usual flat beam case it is necessary to relocate quadrupoles in vertical slope region. The luminosity in this case is equal $L = 1 \cdot 10^{33} cm^{-2} s^{-1}$.

Few difficulties under this way were found. The first is relatively small value of total luminosity

$$L = \frac{\gamma I}{2 e r_0} \left(\frac{\xi_x}{\beta_x^*} + \frac{\xi_y}{\beta_y^*} \right) \qquad (1)$$

when monochromatization is used. Here γ is relativistic factor, I-total beam current, $r_0 = e^2/mc^2$ and beam-beam tune shifts $\xi_{x,y}$ are

$$\xi_{x,y} = \frac{N_b r_0}{2\pi\gamma} \frac{\beta_{x,y}}{(\sigma_x + \sigma_y)\sigma_{x,y}} \qquad (2)$$

with number of particles in bunch N_b and beam sizes $\sigma_x = (\varepsilon_x \beta_x^*)^{1/2}$ and $\sigma_y = (\sigma_{y\beta}^2 + \sigma_{ys}^2)^{1/2}$. In both the flat beam scheme and scheme with monochromatization in lattice /1/ the second term in brackets (1) is dominated. When monochromatization is used, ξ_y becomes in λ times smaller, and the decrease in luminosity is a consequence of the gain in energy resolution in this type of lattice.

Another difficulty concerns matching of lattice functions in vertical slope region. As a result of matching problems the vertical separation between two storage rings is equal to 5 m and seems too large.

A variant of a tunable lattice that includes flat beam and monochromatization schemes

In attempt to remove these problems, we consider another possibility to choice magnet lattice adequate both for the flat beam scheme and monochromatization one. Let search the solution in changing the polarity of the first (and others) quadrupole in micro-beta insertion when going from one scheme to another. In other words, we set $\beta^*_y=1$ cm for the flat beam case and $\beta^*_x=1$ cm for the monochromatization one. The choice $\beta^*_x=1$ cm was made in proposal[8], based on pure monochromatization. Now let us define the conditions a versatile magnet lattice of such type must satisfy to be adequate for using in both cases. When we work with monochromatization, $\sigma_x=(\varepsilon_x\beta^*_x)^{1/2}$, $\sigma_y\simeq\sigma_E\psi_y$ and from (2) we have

$$\frac{\xi_y}{\xi_x}=\frac{2\pi\gamma}{N_b r_0}\frac{\varepsilon_x\beta^*_y}{\beta^*_x}(1+\sigma_x/\sigma_y)\simeq 4.36\cdot10^7\,E(\mathrm{GeV})\frac{\varepsilon_x\beta^*_y}{\beta^*_x}\frac{\xi_x}{(N_b/10^{11})}. \qquad (3)$$

Here $E=\gamma mc^2$. Putting typical for tau-charm factory design parameters[10] E=2.2 GeV, $\beta^*_x=1$ cm, $\xi_x=0.04$, $N_b=1.5\cdot10^{11}$ and setting restriction[11] $\xi_y \ll \xi_x$, we find

$$\varepsilon_x \ll 3.91\cdot10^{-9}/\beta^*_y . \qquad (4)$$

To have luminosity $L\simeq10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ with a flat beam it is necessary for emittance to be[10,12-14] $\varepsilon_x\simeq3\div4\cdot10$ m^{-7}. So, it is necessary to make magnet lattice with the possibility to change emittance in range $1\div2\cdot10^{-8}$ - $3\div4\cdot10^{-7}$m, that is in 20÷30 times. To find this possibility we take for the flat beam magnet lattice with phase advance $\mu_1=\pi/3$ or $\pi/4$, and choice the number of regular cells to have $\varepsilon_x\simeq1\div1.5\cdot10^{-7}$m. Using dipole wigglers in dispersion suppressor, it is possible to increase emittance in 2÷3 times and achieve the necessary value, as it was supposed, for example, for initial tau-charm factory design for in Spain[15]. When beginning the work with monochromatization, we change phase advance in regular cells to $\mu_2=\pi/2$ to diminish natural emittance in $\simeq(\mu_2/\mu_1)^3=3.4\div8$ times and, if necessary, use wigglers in straight sections with zero dispersion to achieve $\varepsilon_x\simeq1\div2\cdot10^{-8}$ m. A careful design of dispersion suppressor for such type of lattice must be fulfilled, as it was done under LEP design[16]. Another important problem for this tunable lattice, which will define the choice of phase advance μ_1 in regular cells and their number, is a thorough chromatic correction to get a good dynamic aperture, especially in the presence of wigglers. For the working with monochromatization an additional exploring of problems connected with exitation of synchrobetatron resonances is necessary.

An example of main parameters of e^+e^- collider with monochromatization may be the following: energy of electron (positron) beam 2.2 GeV, horizontal emittance $\varepsilon_x=1.5\cdot10^{-8}$m, coupling $\kappa^2=\varepsilon_y/\varepsilon_x=0.05$, $\beta^*_x=1$ cm, $\beta^*_y=15$cm, $\psi^*_y=32$ cm, $\sigma_E=1\cdot10^{-3}$ (with wigglers), $N_b=1.5\cdot10^{11}$. With this values we get $\xi_x=0.04$, $\xi_y=0.023$, $\lambda=30$, and energy resolution $\sigma_W=\sqrt{2}\sigma_E E/\lambda\simeq100$ keV. The total luminosity is $L\simeq1.1\cdot10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ with the number of bunches $n_b=30$ and bunch spacing 12.6 m.

This lattice seems has few essential advantages, when compared with those proposed in[1]. It promise, at least in principle, higher total luminosity and smaller energy resolution. Another profit seems to be in matching in vertical slope region. The results of matching in pure monochromatization scheme[8] shows that a good solution is possible, when first quadrupole in micro-beta insertion is focussing in horizontal direction. It should be noted also, that one of the main difficulties in monochromatization scheme for tau-charm factory[8], a short beam lifetime caused by Touchek effect (pointed out by P.R. Zenkevich, ITEP), is not so essential here because of greater (3÷5 times) values of emittance.

Conclusions

A tunable magnet lattice for tau-charm factory was proposed to use a flat beam scheme and monochromatization one. Essential features of this lattice are the possibility to work with two values of phase advances $\pi/3$ (or $\pi/4$) and $\pi/2$ and using of wigglers to increase (in flat beam case) and to decrease (in monochromatization scheme) emittance of the beam. A thorough lattice calculations are necessary to verify this approach and find adequate solution for dispersion suppressor, chromatic correction etc. to achieve a good parameters in tau-charm collider.

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О реализации магнитной структуры c-τ-фабрики, позволяющей работать со схемами плоского пучка и монохроматизации

Предложена магнитная структура c-τ-фабрики, позволяющая реализовать как схему с плоским пучком, так и схему с монохроматизацией частиц по энергии. Переход от одной схемы к другой осуществляется путем значительного (в 20 ÷ 30 раз) изменения эмиттанса пучка и смены полярности квадруполей в микро-бета вставке. Регулировка эмиттанса в магнитной структуре достигается как за счет изменения набега фазы в элементе периодичности, так и за счет использования вигглеров.

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Notes to a Tunable Lattice for Realization Flat Beam and Monochromatization Schemes of Tau-Charm Factory

A tunable magnet lattice for realization flat beam and monochromatization schemes of tau-charm factory is proposed. The realization is achieved both by changing the emittance of colliding e^+e^- beams and by changing the polarity of quadrupoles in micro-beta insertion. Two ways of changing emittance are used. The first is a change of phase advance in regular cells. The second is using of wigglers located in dispersion suppressors in flat beam scheme to increase emittance and wigglers located in straight sections with zero dispersion to decrease emittance in monochromatization scheme.

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

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