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FURTHER STUDY OF JINR TAU-CHARM FACTORY DESIGN

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I. INTRODUCTION

At present there are several proposals of the magnet lattices suitable the standard and monochromatization regimes for tau-charm factory [?], [?],[?]. In this paper the main features of the design using versatile lattice are discussed. The beam and machine parameters and a short description of some factory systems are presented to illustrate the design feasibility.

II. MAGNET LATTICE OF TCF

Now we have changed magnet lattice of tau-charm collider. The previous one [?] was based on conventional flat beam scheme. The new lattice [?] is versatile and allows to use both standard scheme and monochromatization one. To have the possibility of a use both schemes the versatile lattice should to fulfil few conditions. Two of them are of most importance. The first is a possibility to change an emittance approximately in 20 times: from $300 \div 400$ nm for the conventional scheme up to $15 \div 20$ nm for the scheme with monochromatization. The second is a necessity of a change polarity in micro-beta quadrupoles. The last condition is a consequence of a fact one wants to gain in energy resolution without loss of a luminosity in the case the monochromatization is made in the vertical plane.

The big change of an emittance is achieved by use of different phase advances in a regular cell for conventional scheme and monochromatization scheme and by appropriate use of wigglers. In high emittance lattice (conventional scheme) 60° phase advance is used in a regular cell. Two variants of wigglers switching to increase an emittance compared with those generated in bending magnets are now under consideration. In the first variant Robinson wigglers reduce horizontal damping partition number J_x from 1 to 0.6. Robinson wiggler consists of 4 blocks each of 0.23m long. It is necessary 4 such wigglers located close to each of 4 dispersion suppressors with gradient G=4.3T/m and magnetic field B=0.35T. Four dipole wigglers each of 1.0m long with magnetic field B=1.9T, located in first half cell of suppressor, produce an additional increase of emittance. The magnetic elements location and lattice functions in this variant are shown in Fig. 1. In the second variant the dipole wigglers only are used to increase an emittance. The magnetic field in dipole wigglers is 2.6T in this case.

When comparing two variants (Table 1) one sees the first one is preferable from the point of view smaller RF voltage is needed to keep bunches short. On the other hand, in the second variant damping times are smaller that is important for the injection and beam-beam effects. The final choice can be done after comprehensive study problems mentioned above and others such as multibunch instabilities, broadband impedance restriction etc.

For monochromatization scheme, the horizontal phase advance is 90° in a regular cell. Dipole wigglers are switched off. Robinson wigglers are switched on in a way to reduce an emittance by increasing horizontal damping partition number J_x from 1 to 2. The value of gradient in wiggler is G=7.3T/m and magnetic field B=1.9T. The dispersion suppressor is made flexible enough to cancel dispersion in both 60° lattice and 90° one.

To make a small beta's at interaction point (I.P.) $\beta_x^* =$ 0.30m and $\beta_y^* = 0.01$m two quadrupoles are used instead of triplet [?]. When changing polarities in quads for monochromator optics (Fig. 2), the values of beta's become $\beta_x^* = 0.01$m, $\beta_y^* = 0.15$m and vertical dispersion $D_y^* = 0.36$m. The preliminary vertical separation is made by vertical separator. The vertical distance between beam axis in parasitic I.P. is $24\sigma_y$ for conventional scheme and $11\sigma_y$ for monochromatization scheme.

The chromaticity correction is made now for high emittance lattice. With 60° phase advance per regular cell 6 sextupole families have been used to correct chromatic properties. The solution have been found provides ±1.8% of energy acceptance. The beam lifetime for conventional scheme is defined by beam-beam breamstrahlung predominantly and, to some extent, by neutral gas scattering. With longitudinal acceptance 1.8% and average pressure in vacuum chamber of $2 \cdot 10^{-7}$ Pa it is of 5 hours. The beam lifetime for monochromatization scheme is defined by Touschek effect and depends strongly on dynamic aperture. Its estimate gives $1 \div 3$ hours [?], [?]. The main parameters of tau-charm collider are presented in Table 1.

		Monochrom. scheme	Standard Var.1	scheme Var.2
Energy, GeV	E	2.0	2.0	2.0
Luminosity, $cm^{-2}sec^{-1}$	L	$8.0 \cdot 10^{32}$	$9.2 \cdot 10^{32}$	$9.4 \cdot 10^{32}$
C.M. energy resolution, MeV	σ_w	0.14	1.8	2.4
Circumference, m	C	378	378	378
Natural emittance, nm	ϵ_0	15.1	388	393
Bending radius in arc, m	ρ	11.5	11.5	11.5
Damping times, msec	$\tau_x/\tau_y/\tau_s$	19/39/39	43/25/11	19/19/9.7
Momentum compaction	α	$7.85 \cdot 10^{-3}$	$1.63 \cdot 10^{-2}$	$1.63 \cdot 10^{-2}$
Energy spread	σ_E	$7.18 \cdot 10^{-4}$	$6.23 \cdot 10^{-4}$	$8.50 \cdot 10^{-4}$
Total current, mA	I	441	516	536
Number of bunches	k_b	30	30	30
RF voltage, MV	V	5	10	16
RF frequency, MHz	f_{RF}	476	476	476
Harmonic number	q	600	600	600
Energy losses per turn, kV	U_0	131	200	262
Bunch length, mm	σ_s	7.83	6.93	7.47
Longitudinal impedance, Ohm	$\lvert Z_n/n \rvert$	0.18	0.21	0.42
Beta functions at I.P., m	β_x^*/β_y^*	0.01/0.15	0.30/0.01	0.30/0.01
Vertical dispersion at I.P., m	0.36	0.	0.	
Beam-beam parameters	ξ_x/ξ_y	0.040/0.029	0.04/0.04	0.04/0.04

Table 1: List of parameters of tau-charm collider

	N	AC A	DC A	R mΩ	L mH	Power kW
Dipoles	48	585	865	11	6.0	1700
Quads I	36	565	865	10	1.8	1200
Quads II	36	565	865	3	0.23	300
Sext. I	30	86	140	8.4	1.6	30
Sext. II	30	115	185	8.4	1.6	40

Table 2: Booster Power Supply Dates

III. MAGNET SYSTEM

According to the factory cyclogram [?] the booster repetition rate is 25 Hz. The ceramic booster vacuum chamber is designed here and the white-circuit type of the resonant scheme of booster power supply is adopted. The compensation of the pulse loss is realized by the isolation reactors from the special pulse power supplies. The design dates of the booster power supply are presented in Table 2.

There are a three subsystems for the system of the power supply of the tau-charm factory storage ring. They feed: 1) superconducting quadrupoles and dypole wigglers; 2) septum magnets; 3) dipoles, quadrupoles, sextupoles, Robinson wigglers. The third group has a big energy capacitance and is quit expensive. It consists of 160 dipole magnets, 8 vertical bend magnets, 16 wigglers, 234 quads and 112 arc sextupoles. There are a 48 group for the power supply to this system. Each chain has got a separate power source. The prototype of the power source is DC Sources that have been designed at Institute of Electrophysical Apparatus (St.Petersburg) and "Electrotechnic" firm (Tallin, Estonia). The parameters of this power sources allow to get the driving range (0.6-1.0)$\cdot P_{nom}$ with stability coefficient $\pm 10^{-5}$.

The cores of the storage ring magnet is made from the laminated electrical steel (type 2212) with thickness of 1.5 mm. The main ring dipoles have C-shape with the dimensions 440×580 mm with the gap of 60 mm. and will be made from laminated electrical steel (type 2411) with thickness of 0.5 mm.

IV. VACUUM SYSTEM

The beam particle breamstrahlung in the residual gas atmosphere contributes to the beam lifetime. For the typical residual gas composition (70% H_2, 20% CO,10% CO_2) and the pressure $2 \cdot 10^{-7}$ Pa vacuum lifetime is about 30h. The gas loading is defined mainly by synchrotron radiation (SR) desorbtion. The photodesorbtion coefficient is adopted to be equal to $\eta = 10^{-6}$[mol/phot], that corresponds to the dose of 50 A·h [?]. Providing the chemical cleaning and heating of the vacuum chamber the outgassing rate of aluminum doesn't exceed $g = 10^{-9}$[m·Pa/sec], that much less then stimulated desorbtion.

The vacuum chamber of tau-charm factory is manufactured from aluminum and designed in such a manner that SR goes through next straight section and is absorbed at the bending magnet end (Fig. 2). The vacuum volume at the bending magnet region is divided on two parts: the beam chamber and the antechamber. The chamber aperture is 49×64mm and it isn't varied along the whole chamber length. The gap between the beam chamber and antechamber has been chosen to fulfil the condition of 95% SR passing through. The SR absorber is made as water-cooling couplers tube with extended surface. The absorbers have the outlet SR extracting windows for the user purposes.

The stimulated outgassing per a bending magnet is equal to $8{\cdot}10^{-6}$ [$m^3{\cdot}Pa/sec$]. Using the combined pumps with the pumping speed $0.4m^3/sec$, one gets the pressure about $2{\cdot}10^{-7}$Pa at the absorber location. The additional pump is used for the pumping of the remaining part of vacuum volume and provides the pressure at the level $2{\cdot}10^{-8}$Pa.

V. RF SYSTEM

To compensate energy beam losses and to keep bunches short 500 MHz superconducting RF cavities is planned to use. The total value of SR and HOM losses at energy $E = 2.0$ GeV is of order 300 kW and the maximum RF voltage is of 16 MV for one ring. The voltage amplitude and phase tolerances are defined by beam quality demands. The fluctuations in voltage amplitude enhance beam spread. Putting the tolerable increase of beam spread 5% one gets limitation for RF voltage fluctuations $\Delta V/V \leq 5 \cdot 10^{-3}$. The phase shift between RF modules excites the synchrotron oscillations. Putting restriction for their amplitude to be ≤1 mm, one gets $|\delta\phi_s| \leq 1°$.

The RF power supply scheme for tau-charm factory is grounded on the principle of separate supply of each cavity like [7]. The main questions are the choice of an adequate final stage amplifier and the feeder line design. Klystrons developed at "SVETLANA" (St.Petersburg) satisfied tau-charm factory requirements and have the following parameters: output power - 80 kW, frequency - 500 MHz, efficiency - 0.58, amplification - 45 dB, collector voltage - 16 kV, collector current - 8.6 A.

Each feeder line includes a ferrite circulator with a ballast load, that allows to refuse from phase shifter using. The effective automatic phase control is provided by the electronic phase shifter in a preliminary stage of a RF amplifier. The main coaxial feeder connecting a circulator output and a cavity input has the cross section dimensions 160 x 70 mm and the wave impedance 50 Ohm. Thus the RF power supplier consists of 4 independent FR lines with the total output power 320 kW.

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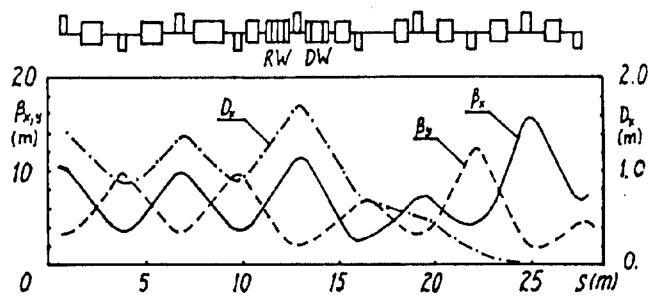

Fig. 1. Lattice functions in regular cell and dispersion suppressor.

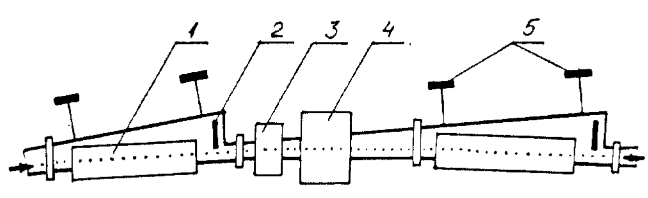

Fig. 2. Periodic cell scheme (1-dipole, 2-SR absorber, 3-sextupole, 4-quadrupole, 5-pumps).