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JINR TAU-CHARM FACTORY DESIGN STUDY

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Abstract

The review on the JINR Tau-Charm Factory (TCF) is presented. The magnet lattice of the tau-charm collider gives a possibility to realize the conventional flat beam scheme, monochromatic one and the crossing angle scheme to get a luminosity up to $3.5 \cdot 10^{33} \mathrm{cm}^{-2} \mathrm{sec}^{-1}$. The list of parameters of tau-charm collider is given. The technical proposal of booster and collider magnet elements and their power supplies is made, as well as the RF power supply of the collider and the vacuum system in its periodic cell.

Energy, GeV	E	2.5
Circumference, m	C	189
Emittance, m	ϵ_0	$1.2 \cdot 10^{-7}$
Tunes	Q_x/Q_z	8.55 / 8.62
Bending radius, m	ρ	9.93
Damping times, msec	$\tau_x/\tau_y/\tau_s$	9/9/4.5
Momentum compaction	α	0.0193
Energy spread	σ_E/E	$7 \cdot 10^{-4}$
Nominal current, mA	I_{e^-}/I_{e^+}	6/0.6
RF voltage, MV	V	2.5
RF frequency, MHz	f_{RF}	476
Harmonic number	q	300
Energy losses per turn, MeV	U_0	0.35
Bunch length, mm	σ_s	13.1
Repetition rate, Hz		25

Table 1: List of booster parameters

1 INTRODUCTION

Presently two TCF projects with a center-of-mass energy range 3-5.7 GeV are being studied. The first one aims at CERN-ISR site, so taking advantage of the existing powerful injector, and the second one is directed towards construction at Dubna. These projects have many common features, apart from the site, because of well identified constraints and a strong collaboration between designers.

The requirements for TCF physics, machine and detector have been discussed at many workshops [1],[2], [3],[4],[5]. We have three possible phases for the TCF project [6].

The first phase of JINR TCF operation is planned to be conventional scheme. The next one may be monochromatization [7] or crossing angle scheme [8],which provides a luminosity of $3 \div 5 \cdot 10^{33}$ cm^{-2} s^{-1}.

The main features of the design prepared by JINR (Dubna), SRIEA (St. Petersburg), RIPR (St. Petersburg) on the base of the versatile lattice were discussed in [7].

2 STRUCTURE SCHEME AND BEAM INTENSITY OF TCF

The layout and structure scheme of the TCF with an injection complex and the main ring are shown in Fig. 1 [9]. The injection complex consists of a preinjector and a fast booster synchrotron, where electrons and positrons are finally accelerated up to the main ring energy. The preinjector energy 500 MeV will be also suitable for initial acceleration of particles for the Synchrotron Radiation (SR)-source NK-10 in future. The average luminosity is ensured at the level of 80 % of peak one. The positron number in the TCF must be $4.8 \cdot 10^{12}$ to get necessary luminosity value in the conventional scheme variant. Then taking in account that the transfer efficiency from the injection complex through the booster into the TCF is supposed to be 10%, and the filling time is chosen equal to 15 min we obtain that the productivity of the injection complex ought to be $5.4 \cdot 10^{10} e^+/s$. The positron production resolved efficiency is limited by the reasonable positron energy spread and emittance acceptable by the booster and is estimated as 0.3 %. Therefore the electron flux impinging the conversion target must be about $2 \cdot 10^{13} e^-/s$. The bunching efficiency will be of the order of 50% and the whole electron flux from the gun must be of $3.7 \cdot 10^{13} e^-/s$.

3 BOOSTER

The booster synchrotron will be used for acceleration of 500 MeV electrons and positrons injected from the preinjector up to the full energy of the TCF. Its circumference is of 189 m and allows to inject 15 bunches per a single turn into the main ring. With the repetition rate of 25 Hz and 2 turn injection the booster provides 0.6 A positron current to be stored in the tau-charm factory and the 10^{33} cm^{-2}s^{-1} peak luminosity to be effectively maintained. The magnetic structure of the booster consists of 6 superperiods, each containing 6 FODO-type cells. The hexagonal shape of the booster is determined by the disposition of the injection channels in the configuration chosen for the complex. Two long straight sections house injection devices, three others are used for extraction into the injection channels of the TCF and the NK-10 booster. The sixth section houses an RF station.

Each superperiod consists of 2 standard FODO cells and 4 cells with the dispersion suppressed. To avoid a time varying sextupole component, created due to the rising magnetic field, we suppose to use ceramic vacuum chambers in the dipole magnets [10]. The main booster parameters are given in Table 1.

4 MAGNET LATTICE OF TCF

The conventional scheme is considered as the basic one for the JINR TCF. The versatile design of the collider provides the possibility to work with the monochromatization for the experiments requiring a small energy resolution [7]. The horizontal crossing angle option with minimum modifications in the storage ring is discussed in [8]. Only interaction and separation regions have been replaced, while keeping the arcs and the long straight section opposite to interaction point untouched. The interaction region layout in crossing angle scheme is shown in Fig.2. The list of TCF parameters for three options is given in Table 2.

5 MAGNET SYSTEM

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. There are a three subsystems for the system of the power supply of the TCF 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. In the conventional scheme variant 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 (Tallinn, Estonia). The parameters of this power sources allow to get the driving range $(0.6\text{-}1.0)\cdot P_{nom}$ with stability coefficient $\pm 10^{-5}$.

6 VACUUM SYSTEM

The gas loading is defined mainly by SR desorbtion. Providing the chemical cleaning and heating of the vacuum chamber the outgassing rate of aluminum much less then stimulated desorbtion. The vacuum chamber of TCF is designed in such a manner that SR goes through next straight section and is absorbed at the bending magnet end. The chamber aperture is 49×64mm and it isn't varied along the whole chamber length. The stimulated outgassing per a bending magnet is equal to $8\cdot 10^{-8}$ 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, which corresponds to the beam lifetime of 30 h. 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.

The vacuum chamber resistive part of the broad-band longitudinal impedance contributes 70 mOm. The contribution from the interaction region, slots, absorbers and RF-cavities are about 25 mOm.

7 RF SYSTEM

The 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 RF power supply scheme for TCF is grounded on the principle of separate supply of each cavity. The main questions are the choice of an adequate final stage amplifier and the feeder line design. Klystrons developed at "SVETLANA" (St.Petersburg) satisfy TCF 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. The RF power supplier consists of 4 independent FR lines with the total output power 320 kW.

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		Standard scheme	Monochrom. scheme	Cros. angle scheme
Beam energy, GeV	E	2.0	2.0	2.0
Luminosity, $cm^{-2}s^{-1}$	L	$1.0 \cdot 10^{33}$	$0.9 \cdot 10^{33}$	$3.5 \cdot 10^{33}$
C.M. energy resolution, MeV	σ_w	1.9	0.14	1.7
Circumference, m	C	377.8	377.8	377.8
Natural emittance, nm	ε_0	426	17.0	299
Bending radius in arc, m	ρ	10.5	10.5	10.5
Damping times, msec	$\tau_x/\tau_y/\tau_s$	37/22/9	18/35/34	41/25/11
Momentum compaction	α	$1.58 \cdot 10^{-2}$	$8.02 \cdot 10^{-3}$	$1.59 \cdot 10^{-2}$
Energy spread	σ_E	$6.66 \cdot 10^{-4}$	$7.32 \cdot 10^{-4}$	$5.89 \cdot 10^{-4}$
Total current, A	I	0.566	0.479	2.0
Number of particles per bunch	N_b	$1.49 \cdot 10^{11}$	$1.26 \cdot 10^{11}$	$1.05 \cdot 10^{11}$
Number of bunches	k_b	30	30	150
RF voltage, MV	V	8	5	7
RF frequency, MHz	f_{RF}	476	476	476
Harmonic number	q	600	600	600
Energy loss per turn, kV	U_0	226	143	199
Bunch length, mm	σ_s	8.15	8.06	7.72
Required long. impedance, Ohm	$\|Z_n/n\|$	0.25	0.18	0.27
Beta functions at I.P., m	β_x^*/β_y^*	0.20/0.01	0.01/0.15	0.50/0.01
Vertical dispersion at I.P., m	D_y^*	0.	0.36	0.
Beam-beam parameters	ξ_x/ξ_y	0.04/0.04	0.04/0.03	0.04/0.04

Table 1: List of parameters of tau-charm collider

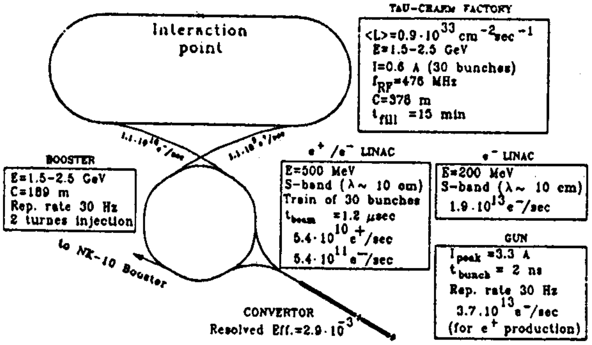

Fig.1. Layout and structure scheme of tau-charm factory.

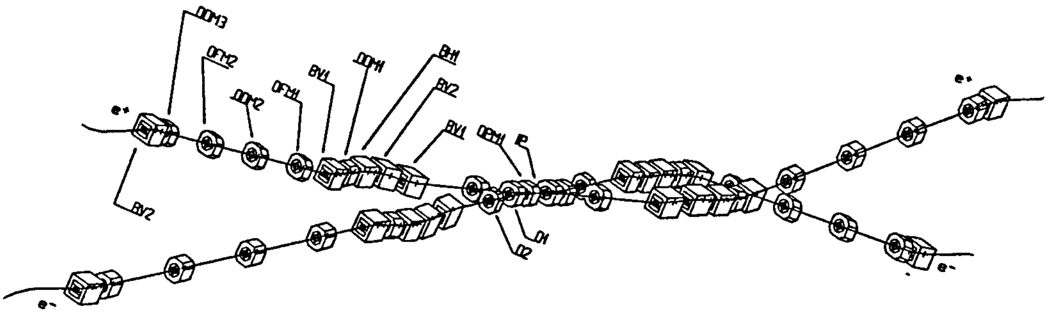

Fig.2. Interaction region layout in crossing angle scheme.