JINR TAU-CHARM FACTORY DESIGN CONSIDERATIONS

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Abstract: Some results of a JINR tau-charm conceptual study is given. The general considerations on the storage ring and accelerator complex in JINR, the tau-charm factory injector system and the main ring, the principles and the parameter estimations to achieve high luminosity are regarded.

1. Introduction

Presently a storage ring complex project is being studied at the JINR. This complex is expected to allow promising investigations in the traditional for the Institute fields: elementary particle physics, nuclear physics, condensed matter physics, as well as applied investigations.

The project discussed involves: heavy-ion storage rings with energy up to 1 GeV/nucleon; a tau-charm factory with colliding beam energy up to 2.5 GeV; a high resolution neutron source (HRNS); a synchrotron light source - 8-10 GeV positron (electron) storage ring (NK-10). The tau-charm factory, that must be built in the first stage is the base of the electron (positron) accelerator and storage ring complex. In the second stage it is planed to increase the injection complex energy up to 10 GeV, that is necessary for the storage ring NK-10 building. The high resolution neutron source is to be built on the base of a linac, having common elements with the tau-charm factory preinjector.

A possible layout of the electron-positron storage ring complex on the JINR territory is shown in Fig.1.We plan as far as possible to assemble the JINR buildings and its infrastructure. The tau-charm factory is expected to provide high luminosity (about 10^{33} $cm^{-2}s^{-1}$) in an energy range of the colliding beams 1.5-2.5 GeV. Following the recommendations [1,2], we plan to have a luminosity maximum at energy 2.2 GeV. The energies close to it are necessary for experiments on τ-lepton and τ-neutrino physics. The factory must also have high integral luminosity, i.e. first of all high reliability of all the facilities involved and high injector capacity. According to the overall accepted principles [2-6], the JINR factory design is based on conservative approach, i.e. the high luminosity must be obtained with systems, principles and devices tested in various scientific centers.

At present two variants of tau-charm factory are examined: one of them is similar to that, described in ref. [2-6], the other is based on the monochromatization scheme [7]. In the first variant high luminosity is obtained by using:
- multi-bunch mode of the storage ring operation with separation of the bunches after the collision;
- minimum possible value of the vertical β-function at the interaction point (about 1 cm) due to super-conducting lenses using micro-β insertions;
- high number of particles stored, owing to a thorough correction of the magnetic field and suppression of the coherent instabilities by using feed-back systems;
- magnetic lattice that provides sufficiently large beam emittance.

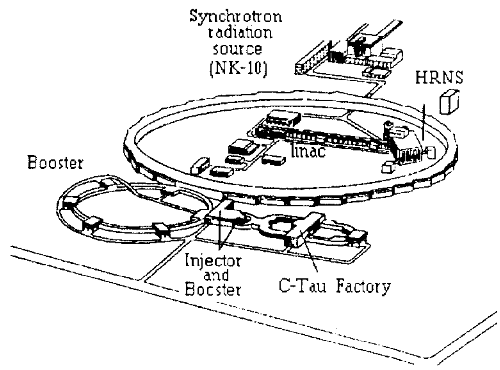

Fig.1 Layout of the JINR storage ring and accelerator complex.

The tau-charm factory structure scheme including an injection complex and main ring is shown in Fig 2. The injection complex consists of linear preinjector, damping ring and fast booster, where electrons and positrons are accelerated to the main storage ring energy. In future the preinjector is expected to be also used for initial acceleration of the particles in NK-10.

The preinjector capacity is determined by the particle losses rate and by the filling regime in the main storage ring. The particle lifetime in the ring chamber with a vacuum less than 2.10^{-9} Torr is limited by the bremsstrahlung at the interaction point and is roughly equal to 2 hours. We demand the electron number at the preinjector exit to be 5.10^{12} e^-/s and the positron number - 10^{11} e^+/s in order to obtain a mean luminosity about 90% from the maximum one.

The analysis of the situation showed that it is reasonable to have the tau-charm factory preinjector similar to that of the VEPP-5 complex preinjector with close required parameters [8].

2. The preinjector

The preinjector comprises two resonant travelling-wave linacs similar to Ref.[8] with a frequency close to 3000 MHz. One accelerator with energy 240 MeV is to produce positrons in the conversion target of tungsten and the another is to accelerate the elec-

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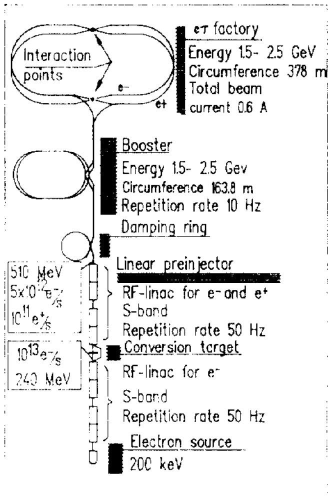

Fig.2 Structure scheme of the tau-charm factory.

trons and the positrons to the final energy. The total length of the preinjector is about 40 m. The accelerator operates in a pulsed mode with a repetition rate 50 Hz. The microwave power is supplied to the accelerating wave guides by klystron amplifiers which ensure an accelerating gradient up to 25 MeV/m. The electron flow on the conversion target must be equal to 10^{13} e^-/s.

According to one of the options under consideration, the beam is produced in a single bunch acceleration regime by a grid-controlled gun, that together with the subharmonic and working-frequency bunching systems provides the obtaining of short intense bunches. The beam pulse duration of the gun is 3 ns with a current 10 A . In the another option a multibunch acceleration regime is realized in a linac before the conversion target with a current 0.5 A and a macropulse duration 50 ns. The preinjector produces 5 10^{11} e/s for filling the main storage ring.

The accelerated positron and electron bunches are transported over channels to the damping ring and then to the booster. Five preinjector macropulses are stored in the damping ring. The damping ring perimeter is equal approximately to 30 m, the damping time 10 ms corresponds to magnetic field induction in the bending magnets 3 T.

3. The booster

The booster is designing for acceleration of the electrons that are injected from the damping ring with energy 510 MeV up to the full energy. With a repetition rate 10 Hz the booster allows 0.6 A positron current to be stored in the tau-charm factory within about 10 minutes.

The magnet lattice of the booster consist of six superperiods, each containing four FODO cell. 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 are assigned for injection devices, three others - for extraction devices to the tau-charm factory injection channels and for the NK-10 booster. The sixth section houses an RF station.

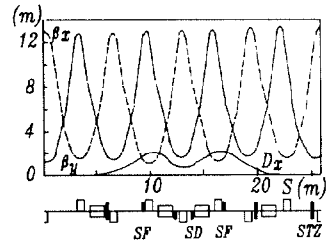

Fig.3 Lattice functions in the booster superperiod.

Every superperiod (Fig.3) consist of one standard cell, two cells each containing one bending magnet - dispersion suppressors and one straight section. The sextupoles SD and SF and the location of the vertical orbit correctors STZ are also shown in Fig.3. It is assumed to use additional coils in the dipoles for horizontal orbit correction.

The lattice functions for one superperiod are shown in Fig. 3. In the straight sections the dispersion function (D_x) does not exceed 1 mm. Under the chosen length of the cell and tunes Q_x=7.35 and Q_y=7.42 the natural emittance is ε_x=4 10^{-7}m.

The chromaticity ξ_x=-11.0 and ξ_y=-10.6 is corrected by two sextupole families located near the focusing and defocusing quadrupoles.

The main booster parameters are given in Table 1.

Table 1. BOOSTER PARAMETERS

Beam energy	2.5 GeV
Natural emittance	4 10^{-7}m.rad
Total current	4 mA
Energy spread	8 10^{-4}
Circumference	163.8 m
Repetition rate	10 Hz
Harmonic number	260
Energy loss per turn	0.46 MeV
RF voltage	2.95 MV
Horizontal/Vertical betatron tune	7.35/7.416
Momentum compaction	0.027
Bending radius	7.45 m
Horiz./Vert./Long. damping time	6.5/5.9/2.8 ms

4. The tau-charm factory

The tau-charm factory has two storage rings (see Fig.4), each with a circumference of 378 m. They are assembled at different levels in the same tunnel with 1.3 m distance between the orbits. In the middle of two 102.9 m straight sections there are places for two universal detectors, one of them being designed at JINR now. The micro-β insertions (two triplets of superconducting quadrupoles) installed symmetrically about the interaction point are constructive combined with the detector. The value of the vertical β-function must be about 1 cm at the interaction point. The gradients of about 30 T/m are created by the superconducting quadrupoles Q1- Q3 (Fig.5). The two quadrupoles Q1 are located at a distance ±0.8 m from the interaction point and diminish the solid angle of the detector registration approximately by 4%. The straight sections also house electrostatic separators, defocusing quadrupoles, vertical bends BV1 and BV2, injection devices, RF cavities to compensate synchrotron radiation losses and to maintain the longitudinal bunch dimension less than 1 cm, and also dipole vigglers for obtaining the necessary energy spread at energies below 2.2 GeV. The preliminary separation of the beams with a view to avoid the parasitic interaction between electrons and positrons is made by vertical electrostatic separator. Under the restriction of the electric field E=2.5 MV/m and separator length 3.4 m, the deflection angle is 3.4 mrad and the bunch vertical separation is $27\sigma_y$ (the betatron coupling is k^2=0.05). The bunch spacing is 12.6 m. The vertically defocusing quadrupole Q4 adds 5.3 mrad to the deflection angle. The main vertical bending is finally done by use of the magnets BV1 and BV2.

Six equally spaced quadrupoles between the magnets BV1 and BV2 are used to match the β-functions and the vertical dispersion. Moderate quadrupole strength (up to 10 T/m) and bore diameter are required in this variant of matching, but a special construction of the nearest to BV1 lense is necessary.

The positron (electron) beam is injected into the tau-charm factory in the horizontal plane. The septum magnet is located before the last focusing quadrupole in the long straight section. The kicker , that removes the angle $\theta_2 \cong 3.4$ mrad of the beam is located

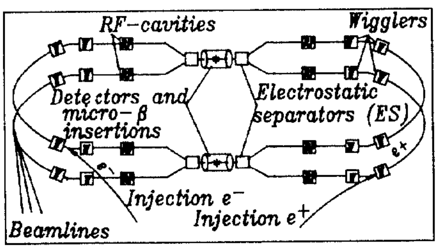

Fig.4. The tau-charm factory storage rings.

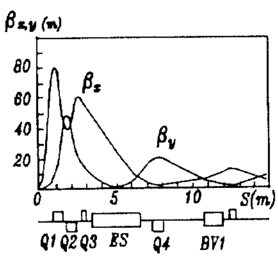

Fig.5. Lattice functions in the interaction region.

in the dispersion suppressor. The strength of another kicker θ_2=3 mrad is enough to move the orbit of the stored beam about 25 mm. The pulse rise and back front in the kickers then must be less than 42 ns.

The choice of the RF cavities is defined by strict requirements for single- and multi-bunch stability. Superconducting RF cavities with frequency $\approx$ 500 MHz and special cell shape as well as additional measures for high order modes suppression are planed for using in the tau-charm factory. The careful design of the cavity, as well as vacuum chamber and elements of diagnostics, control, injection etc., must provide small radiation losses of the bunched beam. The excitation of parasitic fields in the superconducting cavities by the bunches requires to solve the difficult power extraction problem. Along with the careful design of the RF system and the vacuum chamber a power feedback system for control of the beam stability must be applied.

Each arc of the tau-charm factory contains 12 cells with phase advance $\pi/3$ divided between six 20° cells and six 10° cells. The 10° bend cell is different only in that it contains two 5° magnets instead of one 10° magnet. Three such cells in both sides of the arc are used to suppress the horizontal dispersion. In the suppressors we can locate wigglers for emittance control. Two families of sextupoles are used to correct the chromaticity. As usually for a standard FODO channel they are located close to the arc quadrupoles.

Table 2.

TAU-CHARM FACTORY PARAMETERS

Energy at maximum luminosity	2.2 GeV
Luminosity	$1.2 \cdot 10^{33} cm^{-2} s^{-1}$
Beam lifetime	2 hours
Number of collision points	2
Circumference	378 m
Bending radius	11.92 m
Momentum compaction	$3.43\ 10^{-2}$
Horizontal emittance	$4.1\ 10^{-7}$ m.rad
Vertical emittance	$2\ 10^{-8}$ m.rad
Energy spread	$5\ 10^{-4}$
Dumping time of	
longit. oscillations	16.0 ms
transv. oscillations	32.0 ms
RF frequency	476 MHz
RF voltage	16 MV
Number of RF-cavities	2 x 4
Harmonic number	600
Number of bunches	30
Total current	600 mA
Particles per bunch	$1.6\ 10^{11}$
Energy loss per turn	0.174 MeV
SR power per unit length	1.4 kW/m
Max. tolerable wide band impedance	0.34 Ohm
Horiz./Vert. β-function at the interaction point	0.20/0.01 m
R.m.s. length of bunch	7.3 mm
Beam-beam parameter	0.04

The vacuum chamber dimensions have been determined from requirements of a long beam lifetime and efficient injection. We plan a 120 mm diameter circular vacuum chamber in the interaction region and up to the first vertical magnet BV1 and an elliptical vacuum chamber with halve axes 45 mm and 25 mm in the matching region (from BV1 to BV2), long straight sections and arcs.

List of the main parameters of the tau-charm factory is given in Table 2.

The approximate cost of the tau-charm factory in JINR with using the institute's infrastructure is 130 millions roubles, 20.5 millions of them being spent for civil engineering and installation works.

REFERENCES:

1. M.B.Voloshin, M.V.Danilov, Yu.M.Zaitsev. Physics on the Tau-Charm Factory. Preprint ITEP, 89-56, 1989.
2. Proceedings of the Tau-Charm Factory Workshop, Editor L. Beers, SLAC-REPORT-343, 1989.
3. J.M.Jowett, Initial Design of a τ-charm Factory at CERN, Preprint CERN LEP-TH/87-56, CERN, 1987.
4. J.Gonichon, J.Le Duff, B.Mouton, C.Travier, Preliminary study of a high luminosity e^+e^- storage ring at a c.m. energy of 5 GeV, Preprint LAL/RT 90-02, Orsay, 1990.
5. B.Barish, R.Stroynowski, A.Weinstein et.al., Tau-charm Factory Design, Preprint SLAC-PUB-5180, Stanford, 1990.
6. Y. Baconnier, J.-L.Baldy, J.-P.Delahaye et. al., Tau-Charm Factory Laboratory in Spain combined with a Synchrotron Light Source. (A conceptual study), Preprint CERN/AC/90-07, CERN, 1990.
7. Yu.I.Aleksahin, M.B.Voloshin, I.A.Golutvin et. al.,The storage-ring complex of electrons and positrons for charm particle and tau-lepton study (tau-charm factory), Preprint ITEP,67-90, Moscow, 1990.
8. M.S.Avilov, S.B.Vasserman, N.S.Dykanski et.al., Project of the complex VEPP-5 preinjector, In: 12 Vsesoyuzn. Conf. on the particle accelerat. theses, ITEP, Moscow, 1990, p.227.