PROPOSALS FOR B- AND PHI-MESON FACTORIES IN NOVOSIBIRSK

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I. Introduction

Currently, several electron-positron collider projects with extremely high luminosity for the 10-14, 3-5, and 1.0-1.2 GeV range of energies in the center-of-mass system are under discussion. These facilities are referred to as B-, C-, and ϕ-factories in accordance with the particle families to be studied (Refs. 1-5). The new generation of factories will offer the possibility of resolving many urgent problems in modern physics.

The possibility of creating such facilities at the INP (Novosibirsk) are being studied. These studies have resulted in a proposal to build a set of facilities capable of producing colliding electron-positron beams with high luminosity. This set includes:

- A facility with colliding electron-positron beams at an energy up to 2 x 6.55 GeV, with a luminosity of nearly 5 x 10^{33} cm^{-2} s^{-1} (B-factory);
- A facility with colliding electron-positron beams at an energy up to 2 x 0.5 GeV, with a luminosity higher than 10^{33} cm^{-2} s^{-1} (ϕ-factory);
- An injector providing intense electron and positron bunches for the above facilities.

The basic component of the injector is assumed to be a linac at an energy of 7 GeV, designed on the basis of accelerating modules being developed at the INP and intended for the VLEPP complex (Ref. 6). Several Soviet and foreign centers are expected to be involved in designing and building the detectors. The possibility of a joint effort with our colleagues abroad with respect to the acceleration aspects is also being discussed.

II. Description of the Project

The general layout of the complex is shown in Fig. 1. The complex is arranged as three functional parts: an injector and two devices with high-luminosity colliding electron-positron beams (B- and ϕ-factories).

1. Injector

To obtain high luminosities, the injector should provide at its exit electron and positron bunches with 0.5-GeV energy for a ϕ-factory and bunches with 6.5-GeV energy for a B-factory. For the two facilities, the intensity of the electrons and positrons should exceed 10^{10} particles per bunch, and the energy spread should be within $\pm$ 0.2%.

The basic unit of the B-factory injector is a linear accelerator with high accelerating gradients, using the modules designed at the INP for the VLEPP project. This accelerator is used to accelerate electron and positron bunches in turn up to 7 GeV. The accelerator is more than 100 m in length and has an initial energy of 0.5 GeV.

Intense bunches are produced and formed by two linacs (one for electrons, the other for positrons) and an accumulator (cooling) ring. It is assumed the electron and positron linacs are to be built using a traveling-wave structure; these will be powered by industrial klystrons at a wavelength λ = 10 cm. Positrons will be produced via conversion of 500-MeV electrons and acceleration in a positron linac up to 500 MeV. The electron or positron bunches will be stored and cooled and periodically extracted from the storage ring.

After extraction from the accumulator-cooler, the bunches can be injected into the magnetic system of a ϕ-factory or can be accelerated in the main linac. In view of the fact that 1-mm-long bunches are required for acceleration, a buncher is positioned between the accumulator-cooler and the main linac to shorten the bunches.

Having been accelerated in the linear accelerator, the beams are transported to B-factory rings via bending and focusing transfer lines. After a 90° turn, where the bunch lengthens due to the energy spread, there will be an accelerating section (10-cm wavelength) to monochromatize the beam energy.

In addition, the possibility of employing this injector to increase the capabilities of VEPP-4 is envisaged, in particular for the experiments with longitudinally polarized beams.

Thus, the injector is a multipurpose installation, capable of producing intense electron and positron beams for a set of colliding-beam machines of high luminosity, within the 2x0.5- to 2x6.5-GeV range of energies.

The main parameters of the injector are listed in Table 1.

2. B-Factory[3]

A B-factory will be formed by two storage rings placed at different heights in the common tunnel. In two straight sections, at the places where the detectors are positioned, the orbit will be common. The perimeter of each ring will be 650 m. One ring is intended for electrons and the other for positrons. As many as 22 bunches are assumed to circulate in each ring. They will interact with the bunches in the counter-rotating beam only in detector locations. In addition to the possibility of multibunch operation with a large number of bunches, the high luminosity of the B-factory is based on an extremely low beta-function at the interaction point, and on the arrangement of beam-beam collisions in the monochromatic regime.

Monochromatization is achieved by a large horizontal dispersion function in the interaction region. The sign of the dispersion should be different for electrons and positrons. In this case, the spread in the energy of interacting particles will be less than the energy spread excited by quantum fluctuations of synchrotron radiation. It is necessary here that the radial size of the beams at the interaction point be determined by the energy (synchrotron) motion of particles rather than by the betatron motion. Such a condition is fulfilled in this facility by using special optics in the experimental straight section. Also, obtaining the required radial size by means of the dispersion function offers the possibility of a further increase in luminosity.

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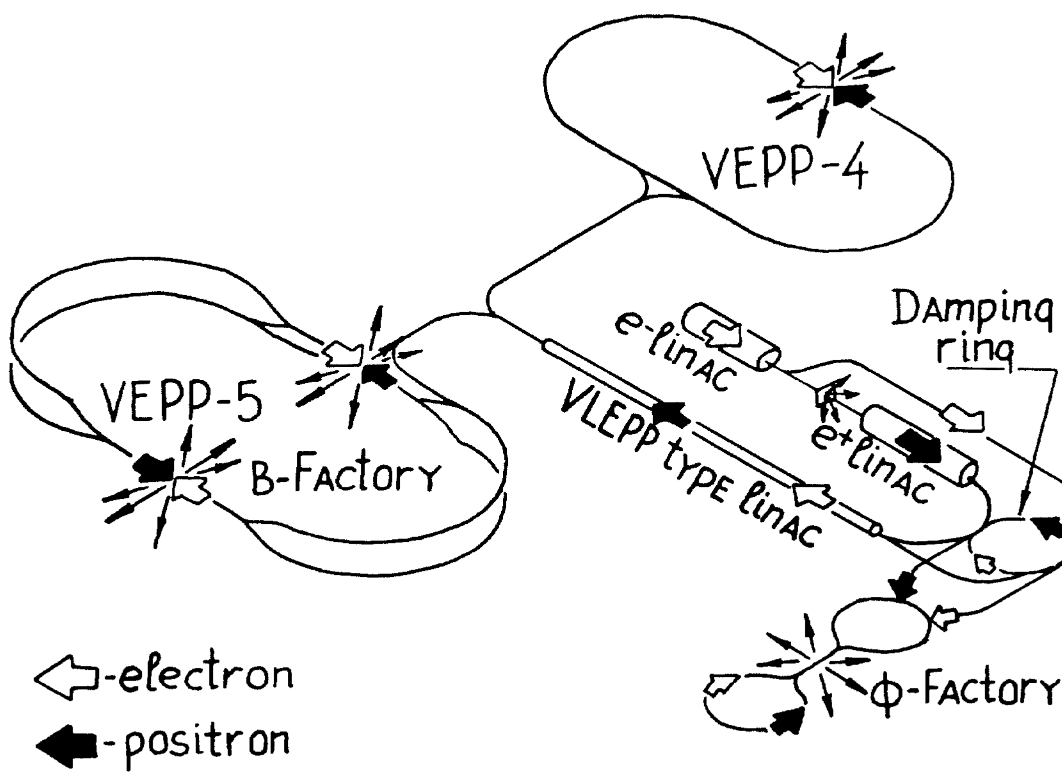

Fig. 1

Thus, both interaction energy monochromatization (increasing the event rate on narrow resonances of the upsilon type) and an increase of the integral luminosity of the facility are provided. This is the basic advantage of VEPP-5 over the BMF-PSI B-factory in Switzerland.

In this B-factory, as in the other projects, electrostatic separators will be used for orbit separation on either side of the interaction point.

The main difficulties of a B-factory are connected with the RF power necessary to compensate for the synchrotron radiation losses, as well as with obtaining short intense bunches.

As an RF power source, a generator of the new MAGNICON type developed at the INP is suggested. Its power is 2.5 MW per unit, and the required total power is 10 MW. The megawatt power klystrons under discussion are to be used in a collaborative framework.

A periodic lattice comprises lenses and uniform field magnets. Both are open on the outside for the extraction of high-power synchrotron radiation.

Long straight sections (≈ 100 m) are used to install detectors, systems for beam focusing at the interaction points, and orbit separators, as well as special optics for monochromatization etc.

The basic parameters of the B-factory facility and beams are listed in Table 2.

3. ϕ-Factory

The ϕ-factory is a new-generation facility with colliding electron-positron beams in the ϕ-meson resonance range of energies (1020 MeV).

In the single-bunch mode, the facility's luminosity reaches 10^{33} $cm^{-2}s^{-1}$, which is 300 times higher than the record luminosity set by the VEPP-2M storage ring. The possibility of increasing the number of bunches to three, thereby providing further growth in luminosity, is being considered.

In the lattice suggested for the ϕ-meson factory, two simultaneous beam-beam collisions are geometrically superimposed, thus doubling the capacity of a detector. The ϕ-factory project is based on the idea of round colliding beams. The regime of maximum

Table 1. Injector Parameters

1. Electron and Positron Linacs	
Energy (MeV)	500+500
Length (m)	25+25
Electron intensity (particles per bunch)	2.5×10^{12}
Positron intensity (particles per bunch)	4×10^{10}
Repetition rate (Hz)	50
Accelerating voltage wavelength (cm)	10
2. Accumulator (damping ring)	
Energy (MeV)	510
Circumference (m)	20
Number of particles	2×10^{10}
Injection rate (Hz)	50
Extraction rate (Hz)	1-5
Damping time (ms)	9
Bunch length (cm)	0.5
3. Main Linear Accelerator	
Maximum energy (GeV)	7
Length (m)	120
Particle intensity (per bunch)	4×10^{10}
Repetition rate (Hz)	1-5
Wavelength (cm)	2
Bunch length (cm)	0.05

Table 2. Main Parameters of the B-Factory

Maximum energy (GeV)	2x6.5
Luminosity per single interaction point at 2x5.3 GeV	$5x10^{33}$
Circumference (m)	650
Beta-function at interaction points (cm)	1
Energy spread in beam (MeV)	18
Energy spread at collision (MeV)	1.2
Losses per turn (MeV)	4.6
RF system power (MW)	10
Number of bunches	22
Number of particles in a bunch	$6x10^{11}$

luminosity is achieved at equal and extremely low beta-functions at the interaction point and, consequently, equal transverse emittances of the beams.

To create low beta-functions in two planes simultaneously, solenoidal magnetic focusing has been chosen. The optical scheme consists of two pairs of superconducting solenoids with 11.0-T fields, which are placed symmetrically around the interaction point. The solenoids are incorporated in the detector cryostat and housing design.

The solenoidal optics are variable. Each pair of solenoids is powered to generate opposite fields. With the lattice parameters fixed, this allows the 90° rotation of betatron oscillation planes in each beam passage between the semi-rings. In this case, the horizontal emittance is excited in one of the semi-rings by quantum fluctuations of synchrotron radiation. A distinctive feature of the suggested type of solenoidal-focusing lattice is the absence of coupling of the transverse modes of betatron oscillations. Consequently, no splitting of the frequencies of normal modes occurs when the operating point is placed on the main coupling resonance, $\nu_x = \nu_z$.

In the general case, the maximum luminosity is limited by the effects of electromagnetic interaction of colliding beams. The interaction intensity is characterized by the linear tune shift parameters ξ_x and ξ_z. The value usually attainable on existing facilities with colliding beams is below 0.03-0.05 (Ref 7). Choosing the operating point with equal frequencies of normal modes of betatron oscillations, in close vicinity to the integer resonance, the properties of the ϕ-factory lattice favor the higher thresholds of the coherent instability of colliding bunches.

To increase the thresholds of different kinds of instabilities, it is useful to have sufficiently large radiation damping decrements. For this purpose, superconducting bending magnets with a field of 6.0 T are to be used. Due to this, the radiation damping decrements will be increased by nearly a factor of ten as compared with the VEPP-2M storage ring.

All these factors will enable a higher value of ξ to be obtained. In our project, a value of $\xi = 0.07$ is expected, though we hope to achieve higher values.

Table 3. Main Parameters of the ϕ-Factory

Maximum energy (MeV)	2x520
Circumference (m)	26.4
Momentum compaction factor	0.003
Emittance (cm rad)	$2.8x10^{-5}$
Radiation loss per turn (keV)	40
R.M.S. longitudinal size (cm)	0.4
Beta-function at the interaction point (cm)	0.5
Betatron tune	6.08
Number of particles per bunch	$9x10^{10}$
Linear tune shift parameters	0.07
Luminosity in single-bunch regime ($cm^{-2}s^{-1}$)	10^{33}

The basic parameters of the facility and beams are listed in Table 3.

III. Conclusion

At present the conceptual design of the project is being developed, and the technical design of the serial elements has been started.

The complex running-in is planned in two stages. First, the low-energy part of the injector (500 MeV) and ϕ-factory are constructed. This part of the project involves less expense and can be constructed in a shorter time. Next, the 6.5-GeV linac and B-factory are run-in.

In the early stages of operation, the detectors currently used (or planned) for VEPP-2M and VEPP-4 will be adequate. Construction of advanced detectors for the ϕ- and B-factories is conceivable only in collaboration with other Soviet or foreign laboratories. Collaborations in the accelerator part of the project are also expedient.

References

1. A.E. Blinov, A.G. Chiligarov, S.I. Eidelman, "Physical Experiments on the B-Factories," INP Preprint 88-123, Novosibirsk, 1988.
2. K. Wille, "B-Factories," Proc. First EPAC Conf., Rome, 1988.
3. A.N. Dubrovin et al., "Conceptual Design of a Ring Beauty Factory," Proc. First EPAC Conf., Rome, 1988.
4. G.M. Tumaikin, "B-Meson Factories," Proc. Eleventh USSR Conf. on Accelerators, Dubna, 1988.
5. R.A. Eichler, "The HIPHI-Machine, a e^+e^- Storage Ring with Luminosity," ETHZ-IMP-P 85/4, Zurich, 1986.
6. V.E. Balakin, A.N. Skrinsky, "VLEPP -- Status Report," Proc. Thirteenth Int. Conf. on High Energy Accelerators, I:101-108, Novosibirsk, 1986.
7. G.M. Tumaikin, A.B. Temnykh, "Beam-Beam Interaction and Luminosity Limit in Storage Rings," Proc. Thirteenth Int. Conf. on High Energy Accelerators, II:88-96, Novosibirsk, 1986.
8. A.N. Belov et al., "Magnicon -- A New Microwave Generator for Accelerators," Proc. Thirteenth Int. Conf. on High Energy Accelerators, II:300-302, Novosibirsk, 1986.