# PROJECT OF A NEW ELECTRON-POSITRON COLLIDER VEPP-2000

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*Abstract*

The status of VEPP-2M collider is presented. Implementation of Round Colliding Beams (RCB) concept in the new collider VEPP-2000 is outlined, potential advantages of RCB over the flat colliding beams are discussed. The main design parameters and features of this VEPP-2000 collider are reported.

## 1 STATUS OF VEPP-2M AND MOTIVATION FOR THE CONSTRUCTION OF A NEW COLLIDER

Since the end of 1992 the $e^+e^-$ collider VEPP-2M in Novosibirsk has been successfully running in the c.m. energy range from threshold of hadron production up to 1.4 GeV. Since 1984 VEPP-2M is operating with the five poles superconducting wiggler with the maximum field $B = 8$ T, which increases the beam emittance by a factor of $\simeq 3$. The integrated luminosity of about 50 pb$^{-1}$ was collected with two modern detectors SND[1] and CMD-2[2] allowing precise measurements of most of the hadronic channels of $e^+e^-$ annihilation. Together with 24 pb$^{-1}$ collected at VEPP-2M in the previous generation of experiments in 1974-1987, this integrated luminosity is more than one order of magnitude higher than about 6 pb$^{-1}$ accumulated by various experimental groups in Frascati and Orsay in the c.m. energy range from 1.4 to 2 GeV. Thus, there is a serious energy gap between the maximum energy attainable at VEPP-2M and 2 GeV in which existing data on $e^+e^-$ annihilation into hadrons are rather imprecise. Accurate measurements of hadronic cross sections in this energy range are crucial for better understanding of many phenomena in high energy physics.

A recent decision to upgrade the VEPP-2M complex by replacing the existing collider with a new one, in order to improve the luminosity and at the same time increase the maximum attainable energy up to 2 GeV, will significantly broaden the potential of experiments performed at the collider. Following modern trends, the new project was named VEPP-2000.

## 2 ROUND COLLIDING BEAMS

During the last decade at BINP the concept of Round Colliding Beams (RCB)[3] was proposed.

The evident advantage of round colliding beams is that with the fixed particle density, the tune shift from the opposite bunch becomes twice as small as the tune shift in the case of flat colliding beams. Besides, the linear beam-beam tuneshift in the round beams becomes independent of the longitudinal position in the bunch, thereby weakening the action of synchro-betatron resonances.

The main feature of the RCB is rotational symmetry of the kick from the round opposite beam; complemented with the $X-Z$ symmetry of the betatron transfer matrix between the collisions, it results in conservation of particle's angular momentum. Thus, the transverse motion becomes equivalent to a one-dimensional (1D) motion. Resulting elimination of all betatron coupling resonances is of crucial importance, since they are believed to cause the beam lifetime degradation and blow-up.

The above arguments in favour of RCB have been checked out by the computer simulations of the beam-beam effects in RCB option[4]. The simulations have also demonstrated stability of RCB against the "flip-flop" effect, similarly to conclusions from simple flip-flop models[5].

## 3 VEPP-2000 PROJECT

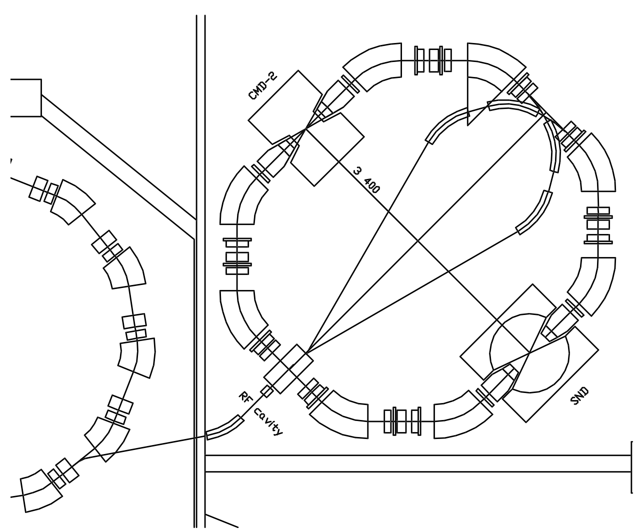


Figure 1: The VEPP-2000 collider layout

### 3.1 Collider Optics

Our approach to the new collider optics is based on the idea of round colliding beams [3]. The main principles of round beam mode will be satisfied by placing SC solenoids in the two Interaction Regions equipped with existing particle detectors (Fig. 1).

The superconducting solenoids will provide equal $\beta^*$-functions and rotate by $\pi/2$ the planes of betatron oscillations. This will result in alternation of vertical and horizontal orientations of the planar betatron eigen-modes over each half-turn, which in turn will lead to their equal tunes and emittances. The optical functions of the round beam lattice are presented in Fig. 2.

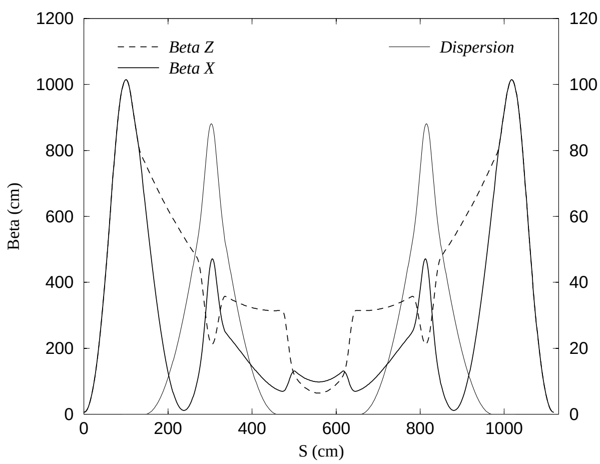


Figure 2: Half period lattice functions. $S = 0$ corresponds to IP

An essential advantage of the found optics is zero dispersion in the IRs, RF cavity, and injection straight sections.

The chosen optics has another very useful feature. Variation of the focusing strength of the solenoids changes $\beta^*$ and the beam emittance in inverse proportion, at fixed energy. Changing energy, we can squeeze $\beta^*$, conserving the maximum beam size at the solenoids, thus giving a possibility to tune optics for better perfomance. Apparently, this feature provides the luminosity scaling at lower energies approximately as $\gamma^2$ (instead of $\gamma^4$ for the option with fixed $\beta^*$).

The main parameters of the new collider are given in Table 1.

### 3.2 Injection

The injection of beams into the storage ring is planned to be done in the horizontal plane into the long drift opposite to the RF cavity. The inflector plates will be placed on the inner side of the vacuum chamber in the bending magnets at the ends of the drift. The advantage of such a scheme is independence of the injected beam trajectory on the solenoids field. This gives us an opportunity to test different options of optics: usual round beams, “Möbius”, and flat beams with zero rotation of the betatron oscillation plane.

The BEP booster is capable of production beams with the energy of up to 900 MeV. Thus, operation at lower energies will be continuous, with injection of the beam at the experiment energy. In region from 900 MeV to 1 GeV the energy ramping from 900 MeV to the experiment energy is required.

Table 1: Main parameters of the collider at E=900 MeV

| | | |
|---|---|---|
| Circumference, m | C | 24.388 |
| RF frequency, MHz | $f_0$ | 172. |
| RF voltage, kV | V | 100 |
| RF harmonic number | q | 14 |
| Momentum compaction | $\alpha$ | 0.036 |
| Synchrotron tune | $\nu_s$ | .003 ($\alpha = 0.04$) |
| Emmitances, cm·rad | $\varepsilon_x$ | $2.2 \cdot 10^{-5}$ |
| | $\varepsilon_z$ | $2.2 \cdot 10^{-5}$ |
| Energy loss/turn, keV | $\Delta E_0$ | 41.5 |
| Dimensionless | $\delta_z$ | $2.3 \cdot 10^{-5}$ |
| damping | $\delta_x$ | $2.3 \cdot 10^{-5}$ |
| decrements | $\delta_s$ | $4.6 \cdot 10^{-5}$ |
| Energy spread | $\sigma_\varepsilon$ | $6.4 \cdot 10^{-4}$ |
| $\beta_x$ at IP, cm | $\beta_x$ | 6.3 |
| $\beta_z$ at IP, cm | $\beta_z$ | 6.3 |
| Betatron tunes | $\nu_x, \nu_z$ | 4.1, 2.1 |
| Particles/bunch | $e^-$, $e^+$ | $1.0 \cdot 10^{11}$ |
| Bunches/beam | | 1 |
| Tune shifts | $\xi_x, \xi_z$ | 0.075, 0.075 |
| Luminosity/IP, cm$^{-2}$·s$^{-1}$ | $L_{\max}$ | $1.0 \cdot 10^{32}$ |

### 3.3 Chromaticity correction

The chromaticity correction is performed by the sextupole families $S_x$ and $S_z$, placed near the quadrupoles of triplets, where the dispersion function is non-zero. Another variant discussed implies a special correction of pole profiles of the horizontally focusing quadrupoles in the triplets. The scheme with only two sextupole families leaves the problem of dynamical aperture unresolved, this forces us to use an additional sextupole correction family to control the sextupole perturbation harmonics. These sextupoles are placed in dispersion-free regions: in the injection and RF cavity drifts, between the bending magnets and quadrupoles. Application of these correctors yields dynamical aperture of about $14\sigma$ ($\simeq$ 17 mm inside the solenoid) which is still less than mechanical aperture. So, search for a better solution is in progress.

## 4 TECHNICAL FEATURES

### 4.1 Superconducting Solenoids

Focusing in the two interaction regions is performed by SC solenoids, installed symmetrically with respect to the IPs. Each solenoidal block consists of a main solenoid which is longitudinally divided into two parts, and a compensating solenoid with reverse field to adjust longitudinal field integral and focussing. Such a scheme gives an additional possibility to control the $\beta^*$ value by feeding only one half of the main solenoid at lower energies.

The solenoid coil is divided into three sections: inner section has thickness 30 mm and is made of $Nb_3Sn$ wire 1.23 mm in diameter (50% Cu + 50% $Nb_3Sn$); middle section has thickness 20 mm and is wound with a NbTi wire 1.2 mm in diameter (48% Cu + 52% NbTi) and outer layer has thickness of 10 mm, made of NbTi wire 0.85 mm in diameter (48% Cu + 52% NbTi). To feed this three-section coil we plan to use two power supply units. Connection scheme implies that the current in the outer section is the sum of currents in the inner ones. The distribution of currents in the sections is: inner section - 145 A, intermediate section - 167 A, outer section - 312 A. The peak magnetic field is 12.1 T.

Magnetic flux is closed by the iron return yoke located together with all the coils in a common LHe cryostat. Aperture of the coil is 50.0 mm. The inner tube of the helium vessel is a part of the collider vacuum chamber. A nitrogen vapour cooled liner is envisaged to protect the surface of the helium cryostat from heating by synchrotron radiation.

### 4.2 Dipole Magnets, Quadrupoles and Sextupoles

Constrained VEPP-2M complex area restricts the machine dimensions leading to necessity of using strong dipole magnets. To achieve the beam energy of 1 GeV guiding field of 2.4 T is required. The design of the BEP booster ring magnet[6] which works at this field level is intended to be used. Magnet bending radius is 1400 mm, the gap is 40 mm. Number of coil turns is 10. At maximum current 9.5 kA the power consumption is 100 kW/magnet.

New lattice will include 5 families of quadrupoles with maximum gradient of 50 T/m and 3 families of sextupoles. Inscribed circle diameter of quadrupoles and sextupoles is 40 mm. Chromaticity correction sextupoles (two families) are located between quadrupoles of the triplets. Similar 5 kW power supply units will be used to feed the coils in the quadrupole magnets and in the sextupoles. All other low-current coils of the closed orbit steering and gradient correction coils in the quadrupole magnets will be powered using existing power supplies.

### 4.3 RF System

Beam revolution frequency is 12.292 MHz. The accelerating RF frequency was chosen at 14-th revolution frequency harmonic i.e. 172 MHz. With accelerating voltage of 100 kV the bunch length is about $\sigma = 3$ cm at the energy of 1 GeV. Energy loss per turn is 64 keV, and with colliding beam currents of $2 \times 0.1$ A the power delivered to the beams is 12.8 kW. The so-called single-mode cavity is proposed to be used to ease suppression of coherent instabilities, see Fig. 3. Two coaxial damping loads are foreseen to absorb the energy from high-order modes excitation. The fundamental mode is isolated from the upper load by the tunable choke.

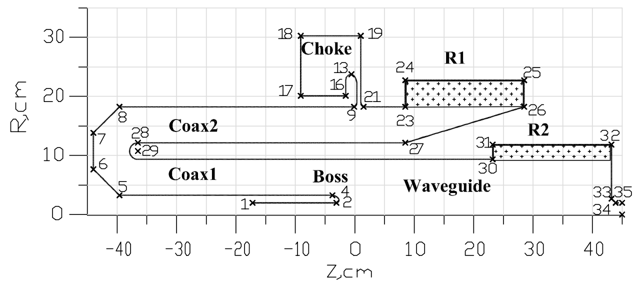


Figure 3: Cross-section of the cavity. The locations of HOM damping loads are shown cross-hatched.

### 4.4 Vacuum System

High vacuum pumping of the experimantal straight sections will be performed by the internal tube of the LHe vessel. For this purpose it is planned to make slits in the nitrogen cooled liner which protects the LHe surface from heating by the synchrotron radiation. In the rest regions combined ion-pumping and getter pumping are intended to be used. Average vacuum in the ring at the working currents should be higher than $10^{-8}$ torr.

## 5 CONCLUSIONS

- Experimental testing of RCB at VEPP-2000 should verify predictions on extremely high attainable space charge parameters for the round beams.
- The machine tune-up procedures will be worked out for implementation of such a non-conventional optics.
- The efforts and expenses needed to build VEPP-2000 are moderate and so this work can be carried out within the next year.

## 6 REFERENCES


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