THE VLEPP PROJECT STATUS REPORT

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1. The general idea of the VLEPP project[1)] consists in the use of two accelerators that "fire" at each other the bunches of electrons and positrons. In such a way the idea looks like quite trivial , but the analysis of the possibilities of modern linear accelerators shows that their parameters do not satisfy by several orders of magnitude the requirements for a sufficiently high luminosity (one has to have very intense bunches at extremely small emittance), for the power consumption, for feasible dimensions of a device.

The luminosity of such a device can be estimated as:

$$L = \frac{N^2}{4\pi\sigma_x\sigma_z} f \quad ,$$

where N is the number of particles in each of the colliding single bunches, $4\pi\sigma_x\sigma_z$ is the effective area of the beam cross-section at the collision point, f is the acceleration repetition rate.

In order to achieve the satisfactory power consumption the linear accelerator should be operated at a repetition rate of 10-100 Hz. Both by the same reasons and because of the growth of complication in the problems of a "high current" the number of accelerating particles cannot be much higher than 10^{12} particles in a bunch. Therefore, for achieving the required luminosity of the order of 10^{32} $cm^{-2}s^{-1}$ the cross-section area in the point of collision should be very small - of the order of a few square microns. Correspondingly, the beam emittance (for the case of a round cross-section) even with optimal focusing and the bunch length only 1 cm one should make an exceedingly small beam emittance of the order of

$$\Omega/\pi = \frac{s}{l_e} \simeq 10^{-8}\mathrm{cm\cdot rad} \ .$$

Both the obtaining of intense bunches of such a small emittance and its maintaining during acceleration are extremely complicated problems but we managed to show that they are solvable.

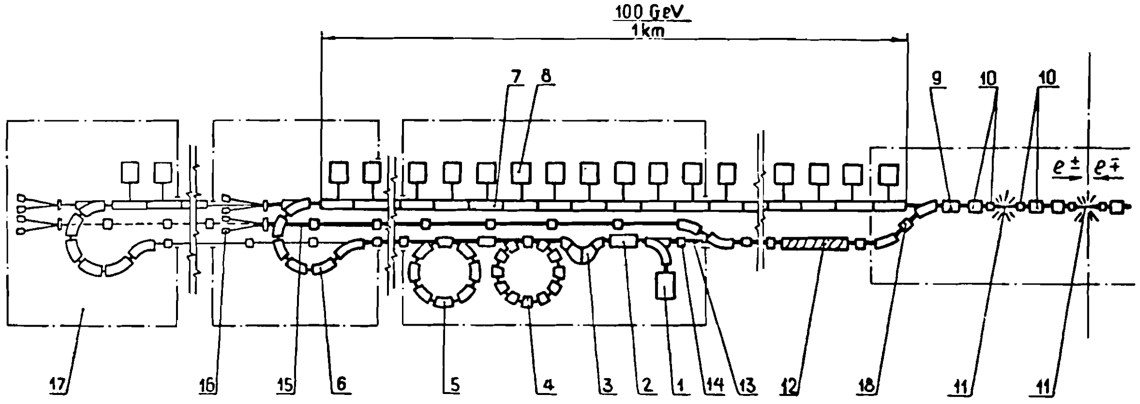
For acceleration of $2 \cdot 10^{12}$ particles up to 100 GeV one should introduce an energy of 30 kJ; the total energy stored in the accelerating structure should not be lower than 150 kJ. It should be transferred to the accelerating structure from the SHF-generators in times shorter than the damping time of electromagnetic field in accelerating structure which is $2\cdot 10^{-7}$ s at the wave length λ=5 cm. Thus, the total energy of the SHF-generators should be of 10^{12} W and, assuming that 1 generator for a 1 GeV section of accelerator is used, the power of a single generator should then be of 5 GW that is by two orders of magnitude over the record power for a commercially available generator at a wave-length of 10 cm.

Though, the progress in development of powerful electron beams gives the real basis for the solution of this problem in not too distant future.

The desire to have the shortest possible accelerator length and also the intention to simplify the solution of the problem for keeping the beam emittance small during acceleration forces us to shift to the superlinacs with an acceleration rate of 100 MeV/m. The analysis and experimental studies have shown that this problem is also solvable (5).

The task of creating a VLEPP, thus, consists in creating linear accelerators with an acceleration rate of 100 MeV/m that is capable of accelerating the 1 cm single bunches of electrons and positrons with 10^{12} particles in a single bunch with a very small beam emittance and sufficiently monochromatic at the exit, and in creating the high-efficient and finely tunable over amplitude and phase SHF generators at a wave length of 5 cm and a pulse power of a few gigawatts with the pulse duration of 0.5 μsec and the repetition rate of tens of Hz. It is very desirable to have a possibility to work with polarized electron-positron colliding beams.

2. The general layout of the facility may be represented as follows (Fig. 1).



1. INITIAL INJECTOR
2. INTERMEDIATE ACCELERATOR
3. DEBUNCHER
4. STORAGE RING
5. COOLER -INJECTOR
6. BUNCHER
7. ACCELERATING SECTIONS
8. SHF SOURCE
9. PULSE DEFLECTOR
10. FOCUSING LENSES
11. COLLISION POINTS
12. HELICAL ONDULATOR
13. THE BEAM OF γ-QUANTA
14. CONVERSION TARGET
15. RESIDUAL ELECTRON BEAM
16. ELECTRON (POSITRON) BEAM EXPERIMENTS WITH STATIONARY TARGET
17. THE SECOND STEP
18. SPECTROMETER

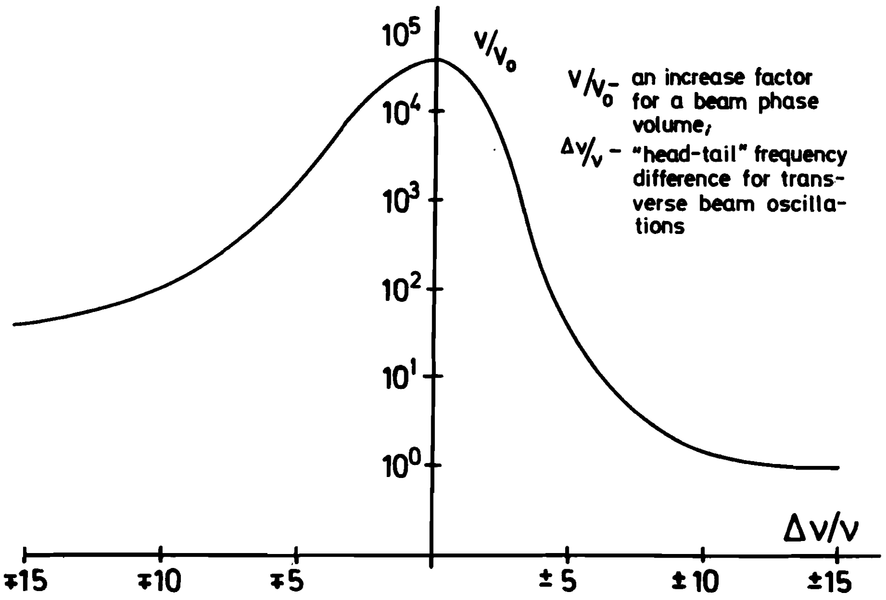
Two superlinacs at an energy, say, 100 GeV and 1 km long each, fed by high-power SHF-sources installed about 10 m apart "fire" at each other the 1 cm long (with 10^{12} particles in each) single bunches of polarized electrons and positrons with a repetition rate of the order of 10Hz. Following the collision, at the collision point the bunches are slightly deflected by a pulsed field into a small angle analyzing system enabling measurements of the energy spectrum of the colliding particles. From the analyzer the bunch enters a special conversion system - the long helical magnetic undulator. Passing through the system the particles irradiate off 1 % of their energy as circularly polarized photons with the energy of 10 MeV (6). The remained polarized beam is slightly deflected and directed, for example, into the special halls for carrying out the experiments with the stationary polarized targets and the emitted photons reach the converter. The longitudinally polarized particles with the charge sign required generated on the target, (only the upper part of the spectrum is collected) are accelerated at high acceleration rate up to an energy of 1 GeV. After the acceleration the particle polarization is transformed into the transverse (vertical) polarization, the bunch length is increased by an order of magnitude and the particles, after preliminary radiation precooling in the storage ring with a large acceptance, are transferred into a special cyclic cooler where the beam emittance goes down to the very small value required (which is not so easy to be reached for 10^{12} particles in a bunch). After full cooling the beam is transported (without aberration) to the injector end of the superlinac. Prior to injection the beam length is reduced down to 1 cm and the particle polarization is transformed into that required. Then follows the acceleration of a highest possible gradient with special care taken to prevent the beam emittance growth. After acceleration the bunches are focussed at the collision point into an elliptical area of $10(\mu m)^2$ and after that the acceleration cycle is repeated.

3\. Let us consider in some details the electrodynamics of the accelerator structure and the process of acceleration. In our case the SHF-generators energize first the sectioned accelerating structure with the required shift in the excitation moments of each section with appropriate phasing in such a way to make the beam always passing in the required phase. Then the accelerating bunch which length is much shorter than the accelerator wave length is injected.

A nontrivial result of the analysis of the acceleration process lies in the fact that by selecting the bunch length with the number of particles required one can obtain a high monochromaticity after acceleration by transferring to the electrons a significant fraction of the energy stored in a structure (7). So, the ultra-relativistic bunch of 1 cm long with 10^{12} electrons passing the 5cm wave length accelerating structure at an effective acceleration gradient of 100 MeV will take 20% of the electromagnetic energy stored (20% more of the stored energy will be transformed into a parasitic energy of the higher excitation modes of the accelerating structure) with the energy spread being of 1% after acceleration. Let us note that, for operation in a stored-energy mode the π - type structure is optimal where two neighbouring resonators are excited in opposite phases. In addition, such a structure enables one to accelerate particles in both directions.

4. The problem of maintaining the small emittance of the beam in the process of acceleration has turned out to be much more complicated (7). When the bunch travelling strictly along the axis of the accelerating structure which is a periodically narrowing waveguide, the particles do not practically feel the transverse forces from the total RF field. At deflection from the axis the particle irradiates a nonsymmetric mode which field generated on the waveguide diaphragm steadily catches the bunch. In the ultrarelativistic case this field cannot catch the part of the bunch which generated the field but it makes the full transverse influence on all the succeeding parts of the bunch. The bunch portion which experienced such an effect will later be more deflected from the axis causing stronger perturbation for the following portions of the bunch. The summing effect of all diaphragms of accelerating structure (even if they are positioned with a micron accuracy) at necessary intensities leads to an inadmissible growth of the beam emittance and consequently to the catastrophic reduction of luminosity.

It turned out to be possible to overcome this problem during acceleration by introducing a high particle energy gradient along the bunch and sufficiently strong focusing with quadrupole lenses. Under these conditions the transverse oscillation frequencies for succeeding parts of the bunch will be quite different and the instability described will not develop. The results of numerical simulation of this effect confirming the feasibility in elimination of the beam emittance growth are given in Fig. 2. True, this fact imposes the requirement that the precision of adjustment for focusing lenses be on the order 1-10 μm over the length of the order of the transverse oscillations of particles.



The final adjustment of the lenses and stabilization in their position will be done directly by measuring transverse motion of the bunches.

By the end of acceleration an initial energy spread of ± 10% is reduced to the required ± 1%.

5. Let us consider now what happens during collisions of such dense bunches.

The electric and magnetic fields of the bunches of high density with a micron size reach the megagauss order of magnitude. These fields do not act on particles of "their own" bunch since the effects of the magnetic and electric fields are mutually compensated. At the same time, for the colliding particles the effects of the electric and magnetic fields are added and the maximum effective field is equal to the doubled value:

$$|H_{eff}| = |H| + |E| = \frac{4N_e}{l_e(\sigma_x+\sigma_z)} ,$$

where σ_x, σ_y are the transverse half-dimensions of a beam at the collision point, l_e is the bunch length.

Let us consider briefly three aspects of the effects of these fields.

The first: In this field the particles radiate synchrotron radiation with the length of the total energy loss being quite small under considered conditions:

$$l_{rad} = \frac{mc^2}{r_e^2 \gamma H_{eff}} .$$

The energy reaction spread will correspond to the energy spread in the bunch.

$$\frac{\Delta E}{E} = \pm \frac{2r_e^3 N^2 \gamma}{l_e(\sigma_x+\sigma_z)^2} .$$

As a result, instead of collisions of monochromatic electron-positron bunches, in case of $\sigma_x=\sigma_z$ one gets the full spectrum of e^+e^- energy reactions and additionally a number of γe and $\gamma\gamma$ collisions. Because of this fact one has to change to flat bunches with the same cross-section area for maintaining the luminosity. As we have seen before, the fields in flat beams are reduced proportionally with the growth of the bunch width.

The second: The colliding beam field of opposite sign particles makes a strong focusing influence resulting in a few oscillations of the bunch particles during collision time. At the head-on-head collisions the effective dimensions do not change for bunches with a smooth density distribution over various directions (even there is a slight compression) that has been shown with the numerical simulation for a self-consistent collision. Let us note, that the effect mentioned decreases sharply the attainable luminosity of e^-e^+ and e^+e^+ colliding beams (defocusing).

The third: An important effect of the colliding bunch's coherent fields is their influence on the spin behaviour for the polarized colliding beams. Because of the anomalous magnetic momentum at too large angles of the transverse oscillations of particles in the field of a colliding bunch the spin rotation with respect to the particle velocity leads to the full depolarization of electrons and positrons in the process of collision. The admissible angles in the beam are the following:

$$\theta_{all} \simeq \frac{1}{3}\frac{g_o}{g'\gamma} = \frac{0.15}{E(\mathrm{GeV})} .$$

To satisfy the condition it is necessary to have

$$\frac{\gamma N\sigma_z}{l_e(\sigma_x+\sigma_z)} \lesssim 0.6\cdot 10^{17}\mathrm{cm}^{-1} .$$

The shift to the flat beams solves this problem too.

A decrease in one of the bunch dimensions down to such a small value, though, requires the quadratic decrease in the beam emittance along this direction. If this requirement happens to be very hard to satisfy one can shift to a four-bunch variant of collisions of the electron and positron bunches travelling from each side. If the bunches moving from each side are superimposed before they reach the collision point, their coherent fields are mutually compensated (within the accuracy that the bunches are equal and they are superimposed exactly). Therefore, all the collisional effects are attenuated and their detrimental effect becomes insignificant. In this case, because of the single collision of the bunches the instabilities which will appear at DCI during a four-bunch mode of operation will not develop. It is logically the simplest way to obtain four bunches with four separate accelerators but it is also possible to perform the simultaneous acceleration of the electron and positron bunches in the same accelerating structure with a shift in between by a half of the wave length and subsequent delay of the first bunch after acceleration.

It is quite probable that the use of the compensating bunch mode will enable us to raise significantly the VLEPP luminosity. Let us note that for this mode of operation one half of the total luminosity will be gained from e^+e^- reactions and the second half is divided equally between e^-e^- and e^+e^+ collisions. The disadvantage of such a mode of operation is that one cannot measure the charge asymmetry of the processes under study.

6. It has been understood recently that additional extension of the reaction spectra is feasible on VLEPP (8). The laser technology is nearing the stage allowing the creation of high-efficient photon targets (of small cross-section, at any rate) which because of the Compton effect will enable one just prior to collision to transform the main part of electrons and positrons into γ-quanta with an energy close to the full energy of accelerated particles. Therefore, the possibility appears for realization of the real photon-photon colliding beams at super-high energies.

Let us consider briefly the main problems connected with the realization of these experiments drawing attention only to these aspects which are intrinsic to the VLEPP operation in this specific mode.

At an energy of primary photons of $(mc^2)^2/E$ (so much the more-higher) the photons of nearly full energy E will pass at an angle $1/\gamma$ with respect to the direction of the scattering electron. If the effective length of the primary photon pulse is smaller than the length of the electron bunch l_e and the light beam is focused down to the difraction limit with area λl_e, where λ is the primary photon wave-length and this area is still larger than the electron beam area at this place, then for achieving the conversion efficiency κ the total energy of the photon pulse is equal to:

$$E_\Sigma^{phot} \approx \frac{2\kappa mc^2 l_e}{\alpha r_e}$$

The most promising version of generation of such photon pulses is the use of the coherent radiation in appropriate undulators of the self-bunching electron beams of the VLEPP device (mirrorless electron laser) (9), since these beams will have a very high local density, very small emittance and small local energy spread, and the radiation spectrum in the appropriate undulators at an electron energy of a few GeV will be in the required range.

The parameters of the high energy electron beams are unchanged after their passage through the laser targets which should ensure regeneration of electrons for succeeding cycles.

The angular spread (at a given point) of electrons in VLEPP out of the collision point is much smaller than $1/\gamma$, therefore, if the photon target is placed in the converging flux not far from the collision at a distance L_o the useful photons with an energy E will form a spot with an area $\pi(L_o/\gamma)^2$. Between the photon targets and the collision point one should introduce a moderate magnetic field in order to shift apart the electron beams at the collision point by the value larger than the electron spot size (from this view point it is convenient to operate just in the electron-electron mode). For this purpose, in particular, L_o should be sufficiently large. In this case, the only γ - quanta of full energy will effectively be met with an ultimate luminosity of the order:

$$L_\Sigma^{\gamma\gamma} = \frac{N_\gamma^2}{S_{eff}^{\gamma\gamma}} f = \frac{\kappa^2 N_e^2 \gamma^2 f}{2\pi L_o^2} .$$

The energy spread for $\gamma\gamma$ reactions will be of 10% in this conditions. If necessary, the reaction monochromaticity can be improved by the use of the shorter wave lasers (with the proportional increase of the laser pulse energy).

If only one electron beam is converted into photons, one can obtain $e\gamma$ colliding beams of nearly full energy with an even smaller energy spread and the luminosity

$$L_{e\gamma} = \frac{N_e N_\gamma}{S^\gamma_{eff}} f = \frac{\kappa N_e^2 \gamma^2}{\pi L_o^2} f .$$

Note, that if the conditions for e^+e^- collisions in the operation mode without compensation are chosen in such a way to have not too high fields in the bunches, in the case of $\gamma\gamma$ and $e\gamma$ collisions there is no such a limit and the luminosity, in principle, could be even higher.

For an energy of 1o J in the laser momentum one can hope for (already at 2 x 100 GeV) achieving on VLEPP rather monochromatic colliding beams of $\gamma\gamma$ and $e\gamma$ with the respective luminosities:

$$L_{\gamma\gamma} \gtrsim 3\cdot 10^{30}\text{cm}^{-2}\,\text{s}^{-1} ;$$
$$L_{e\gamma} \gtrsim 1\cdot 10^{31}\text{cm}^{-2}\,\text{s}^{-1} .$$

Let us note that obtaining luminosity for the photon-photon collisions of the same order of magnitude as for electron-positron (or electron) colliding beams is accessible only on installations with single collisions of bunches of charged particles. The storage rings have no such possibilities.

The study of $\gamma\gamma$ and $e\gamma$ collisions with helicities of colliding particles being arbitrarily chosen (due to the appropriate selection of the laser beam polarization) may become an important field of application of VLEPP.

With respect to the main body of events with generation of hadrons, $\gamma\gamma$ collisions are similar to the hadron-hadron collisions of the same energy and $e\gamma$ reactions will contribute information similar to that supplied by the deep-inelastic ep reactions.

In this case, the total cross-section of hadron generation in $\gamma\gamma$ collisions will apparently be very large - of the order of 0.3 μb. The main body of these events will yield hadrons flying at small angles with respect to the photon direction and, therefore, will hardly be accessible for studying, though, in principle, with the help of magnetic field one can separate the initial γ-beams and the charged hadrons generated.

More promising seems to be the study of electromagnetic generation of the quark (and antiquark) jets. For all kinds of quarks with masses much lower than the photon energy the cross-sections for the jet generation are the same (within the accuracy of their squared charges ratio). This is the radical advantage of the photon-photon collisions compared to pp and $p\bar{p}$ colliding beams in which the quark content results in the generation of jets with the d, ∂, u, $\bar{u}$ - quarks. In addition, $\gamma\gamma$ collisions give effectively the gluon jets also. The partial cross-section of these processes at energies of hundreds of GeV is of order 10^{-35}cm² and therefore is in principle accessible for studying on VLEPP.

In the region of electro-weak interaction the most interesting is the study of reactions:

$$\gamma\gamma \rightarrow W^+W^- .$$

The cross-section of this process is of the order 10^{-32}cm^2 and in the first approximation does not fall down with enery growth (differing, for example, from $e^+e^- \rightarrow W^+W^-$). The study of this process supplies information of the by now unknown γW^+W^--interaction (anomalous magnetic moment of W, formfactor of W etc.).

The same interaction can be studied in the reaction

$$\gamma e^\pm \rightarrow W^\pm \nu ,$$

which cross-section is of the same level but the threshold is lower. The feature of this reaction is that the generated W is single that enables one to study clearly the decay properties of these bosons. In addition, the dependence of the $e\nu W$ interaction on the electron helicity is very clear.

7. Let us consider some features of the experimentation on the VLEPP facility. The VLEPP machine differs from the conventional colliding beam systems by that the bunch interactions in VLEPP are very rare - of ten times per second - at a high total luminosity at one collision. This circumstance makes difficult the separation of events as well as elimination of the background reactions.

The most principal limitation of the useful luminosity per one collision of the bunches is that the total cross-section of electrodynamic processes of the kind

$$e^+e^- \rightarrow e^+e^- + X$$

is very large; though it decreases rapidly with transverse momentum even for one of final $e^\pm$. Consequently, every collision of bunches and every interesting event is accompanied by a large number of charged particles and photons with energies much lower than the total energy of initial particles. Therefore, special measures should be taken including, for example, installing the absorbing material in front of the detector, introducing the longitudinal magnetic field, avoiding the registration of the small angle particles, developing the special versions of a trigger etc., for ensuring the detection, separation and analysis of the events of interest. Naturally, one can make the probability of superposition for two interesting events negligibly small by the appropriate decrease in luminosity maintaining the high rate of statistics gathering for these events.

Another source of the background are the photons of synchrotron radiation accompanying a collision, which are generated in the coherent field of the colliding bunch. These fields as mentioned above are to be made sufficiently small in order to achieve the average synchrotron radiation energy loss not higher than, say, 1%. In this case, each electron and positron radiates a few photons which can interact with the counter-flying photons and electrons. The main back-ground processes of this origin are the generation of electron and muon pairs. The background can be suppressed with the means mentioned above.

With the use of a four-beam mode of operation with compensation for coherent fields this source of the background can be practically eliminated.

Some other kinds of background of "technical" origin can occur. So, together with the bunch of electrons which has in the device under consideration exceedingly small mean-square dimensions, some strongly deflected particles can appear, for example, because of a single scattering on the nuclei of residual gas in the cooler ring (the beam "hallo"). The interaction of such particles with material in the detector region results in producing the total energy showers. Therefore, a very high level of the "beam hygiene" is needed by including high vacuum both in the storage ring and linac and also by installing the special diaphragms far from the collision point.

Another source of the technical background can be originated in the detector region by the products of interaction between the beam-beam synchrotron radiation quanta with material of the vacuum chamber, lenses etc. It forces to take care for that. The place where the material is struck by photons should be far enough from the collision point. In this case, the moment for the background particles entering the detector will be much delayed with respect to the particles under study. In addition, the solid angle and consequently the total number of secondary particles that reach the detector can be sharply decreased with help of collimation. The background of this origin vanishes naturally in a four-beam mode of operation.

Thus, we have seen that the study (an inclusive, at any rate) of events producing electrons, muons and photons with an energy which is a substantial fraction of the initial particle energy will not cause much difficulties. This type of processes includes electrodynamical, weak and mixed two-particle reactions and generation of intermediate bosons. It will also not be of principal difficulty to study reactions producing hadron jets which carry a considerable fraction of the initial particle energy. At the same time, the study of all interesting processes will require the solution of the very complicated background problems.

Let us note that the physical background during studying $\gamma\gamma$ and $e\gamma$ reactions on VLEPP will be substantially lower.

The pulsed character of the VLEPP luminosity, the high resulting multiplicity of the majority of the most interesting processes as well as a number of quite low-energy background particles force the development of quite special detecting systems especially in their internal, "geometric", track part. It is not excluded that one of the possible solutions can be the use of the hybrid rapid cycling bubble chambers with electronic indication.

Let us emphasize that the VLEPP average luminosity can be distributed between several separate experiments. In this case, in any certain cycle only one collision point is switched on; the succession of switching can be arbitrarily given.

8. Let us remind that VLEPP can be used parallel to the colliding

beam regime as an accelerator supplying 10^{13} as appropriately polarized electrons and positrons per second with full energy E, as well (supplying the used $e^{\pm}$ when using the laser conversion) as a source of polarized γ-quanta of nearly full energy with moderate monochromaticity and intensity of order $10^{12}s^{-1}$ for experiments with the stationary targets.

Let us also remind that by striking the target with the electron and especially with the photon beams of VLEPP one can obtain quite intense and well collimated fluxes of any kind of high energy neutrinos. It is of special interest that these fluxes have a lot of τ - leptons (and, if they exist, the neutrinos from heavier leptons). In this case, the flux can reach 10^6 ν_τ/s in the angle $M_\tau c^2/E$ with the energy of the order 1/4E.

In the special experimental mode one can obtain the polarized electrons, positrons and photons of doubled energy by making e± pass succeedingly both linacs (in this case the sections of the second linac should be energized with a time shift opposite to the normal shift in time).

If the VLEPP machine is added with the intense sources of charged pions and cooled muons, it can be also used for their acceleration.

9. Finally, let us give the list of the main parameters of the VLEPP project.

	I stage		Full project
Energy	2×150 GeV		2×500 GeV
Length	2×1.5 km		2×5 km
Total luminosity		$10^{32}cm^{-1}s^{-1}$	
Collision points		5	
Repetition frequency		10 Hz	
Number of particles in a bunch		10^{12}	
Average beam power	2×250 kw		2×900 kw
Pulse power of SHF sources	1000 GW		4000 GW
Total consumption power from the mains	15 MW		40 MW

References

(1) Skrinsky A.N.: "Intersecting Storage Rings at Novosibirsk", Morges Seminar, Switzerland, (1971).

(2) Balakin V.E., Budker G.I., Skrinsky A.N.: "Feasibility of creating a superhigh energy colliding electron-positron beam facility , The Budker's Memorial Seminar", Novosibirsk, (1978).

(3) Balakin V.E. et al., Proc. of the 6th All-Union conf. on Charged Particle Accelerators. Dubna, (1978), p. 140; ICFA-I, Switzerland, (1978).
Balakin V.E., Budker G.I., Skrinsky A.N., "Feasibility of creating a superhigh energy colliding electron-positron beam facility", preprint INP 78-101, Novosibirsk, (1978).

(4) Balakin V.E., Skrinsky A.N. "A superhigh energy colliding electron-positron beam facility (VLEPP); Proceedings of ICFA-2, Switzerland, (1979).

(5) Balakin V.E., Brezhnev O.N., Novokhatsky A.V., and Semenov Yu.I.: "The Accelerating Structure of the Colliding Linear Electron-Positron Beam", A Study of the Maximum Attainable Acceleration Rate. A paper presented at the 6th All-Union Conference on Charged Particle Accelerators. Dubna, (1978).

(6) Balakin V.E., Mikhailichenko A.A.: "The conversion system for obtaining high polarized electrons and positrons", preprint INP 79-85, Novosibirsk, (1979).

(7) Balakin V.E., Koop I.A., Novokhatsky A.V., Skrinsky A.N., and Smirnov V.P.: "Beam Dynamics of a Colliding Linear Electron-Positron Beam." A paper presented at the 6th All-Union Conference on Charged Particle Accelerators. Dubna, (1978).

(8) Ginzburg I.F., Kotkin G.L., Serbo V.G., Telnov V.I.: "On possibility to obtain colliding $\gamma\gamma$-and γe-beams with high energy and luminosity using accelerators of VLEPP type", preprint INP 81-50, Novosibirsk, (1981).

(9) Kondratenko A.M., Pakhtusova E.V., Saldin E.L.: "The use of free electron laser for generation of high energy photon colliding beams", preprint INP 81-85, Novosibirsk, (1981).

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[1] Footnote: The prospects of the super-high energy linear colliders were first discussed in the Novosibirsk report presented at the International Seminar on the Prospects for High Energy Physics in Morges (Switzerland, 1971). The VLEPP project was first reported at the International Seminar on the Problems of High Energy Physics and Thermonuclear Research devoted to the 60th birthday of academician G.I. Budker in April, 1978. Further progress and some certain aspects of the project were given in References (3-8).

Discussion

J. Kirby, Stanford: A few years ago several of us were fortunate enough to visit Novosibirsk, where we saw VEP IV under construction. In addition there were designs for some ambitious detectors, which included one with a large transverse field. I would like to hear what is the status of the VEP IV experimental program.

Note added by the editor : No answer, since none of the Novosibirsk colleagues could attend the conference.