ACCELERATOR AND INSTRUMENTATION PROSPECTS OF ELEMENTARY PARTICLE PHYSICS

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I will try consider briefly the shifts in the accelerator field and in the field of instrumentation, which were most significant in facilitating in recent years the progress of elementary particle physics and will be in the near future. The choice of questions under consideration will inevitably be quite subjective, and discussion on detector problems may be effected by my insufficient information. For these sins I ask to excuse me beforehand.

1. First of all, a few general remarks - quite obvious ones. The solution of problems of elementary particle physics, which become more and more complicated, forces to shift to larger scale for all the systems, both for accelerators and detectors. This, in its turn, becomes accessible because of a wide use of the module principle for construction of systems with maximum homogeneity of modules. This permits making systems significantly cheaper and prolonging their life time.

Of the same fundamental importance is wide and complete computerization. In the modern systems of high energy physics the computing devices became as intrinsic as magnets or counters; they are responsible for all the functions of total and continuous pick up of information on installations and processes, control of the systems and data processing.

2. The greatest event in the area under consideration is the exploration of the colliding beam method. Colliding beam experiments starting with electron-electron beams in Stanford and Novosibirsk, electron-positron in Novosibirsk, Orsay and Frascati and proton-proton at CERN became one of the main sources of fundamental information in elementary particle physics, and their significance will only increase in future. We shall have a special detailed discussion of colliding beams /1/.

3. It is well-known how important for implementation of electron-positron colliding beams was the existence of radiation cooling for light particles even at low energies. Radiation cooling enabled one to stack intense positron beams, to compress transverse dimensions of e^+e^- colliding beams down to small sizes (to a few microns even now) and to maintain the beams compressed despite strong perturbations of particle motion caused by the field of encountered beam, that, in its turn, permits

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achieving high luminosity.

Cooling will be of the same fundamental importance also for implementation of the proton-antiproton colliding beam experiments, which became accessible after development of the electron cooling in Novosibirsk and the stochastic cooling at CERN /2-4/.

These methods complement each other substantially in their possibilities. Stochastic cooling is especially effective for beams of low density with large emittance (i.e. at small 6 - dimensional phase density). Electron cooling is the most effective particularly for getting low-temperature ("narrow") beams of heavy charged particles (protons, antiprotons, ions). It is not excluded that cooling with the circulating electron beam will turn out to be useful for suppressing the diffusional beam cross-section growing with time of proton-antiproton colliding beams of high energies /3/. Let me note that at energies $\gtrsim$ 10 TeV an important and positive role will be played by radiation cooling for increasing luminosity of proton-antiproton colliding beams.

The use of ionization cooling can open up very interesting possibilities in getting intense muon beams of high energy including implementation of muon colliding beams of sufficiently high luminosity (see 10.14; 12.1).

3.1. Continuous cooling of the particle beam in a storage ring gives an important possibility for carrying out experiments with a superthin internal targets /5/ wherein diffusional growing of the beam size (because of multiple scattering on the target substance and due to fluctuations of ionization losses) is suppressed by intensive cooling. Thus, fine "spectrometric" experiments become possible with ultimate high luminosity which is only determined by the injector productivity and the cross-section for single-scattered particle loss on the target substance, that is impossible to achieve in the ordinary set-up of experiments. A very important advantage of such a set-up is that all events are continuously distributed in time. Experiments of this kind - electro-excitation of nuclei - for a few years are being performed on electron storage ring VEPP-2 /6/.

Another application of the superthin target mode of operation is generation of secondary beams with good tagging (of kind of the generated particle and its momentum) using registration of accompanying particles. Such a mode gives 100% duty cycle, the relative intensity of the secondary beam is determined by the ratio of the interaction cross-section in use and the total cross-section, beam emittance is determined by interaction properties and by the size of the primary circulating beam (cooled) at the section of interaction.

3.2. Similar set up of experiments with continuous cooling is reasonable even under conditions when the target cannot practically be made so dense that the life-time of a particle in the storage ring would be determined by the collision with target and not by residual gas in the vacuum chamber (another restriction in this case can be the difficulty of achieving of high enough stored currents). But in any case, the luminosity is much, much higher, than that in the one flight mode with the same target and accelerator, and beam qualities are the best.

Such a situation is characteristic for experiments with the polarized gas-targets which nowadays permit one to have even for hydrogen or deuterium up to 10^{12} atom/cm^2 only, which corresponds to average vacuum in a storage ring better than 10^{-9} Tor. Naturally, the most interesting work with a polarized target is in a storage ring with polarized beams.

Another interesting example of this kind is the target of free neutrons which is especially promising for detailed study of $\bar{p}n$ interaction at low and medium energies / 3 /.

4. Nowadays we are at the stage when important improvements for accelerator field are under implementation.

First of all, a wide use of superconductivity has started. The use of superconducting magnetic systems even now permits increasing the maximum guiding field from 20 kG to 45 kG (using Ni, Ti alloys) and correspondingly gaining energy for proton and antiproton beams (at a given scale of accelerator facility). There is a possibility to reach 100 kG in the near future (the use of Ni, St alloys). An important fact is the significant reduction in energy consumption which is especially high in the storage ring case.

I would like to draw attention to the fact that at small fields up to 20 kG (with ferromagnetic formation of a magnetic field in the storage ring or slow accelerator) the use of superconducting coils permits construction of extremely miniature magnet systems (design works of the High Energy Laboratory, JINR, Dubna).

However, superconducting magnet systems should still demonstrate long operation with the intense beams which are planned for most projects; that longevity requires a special care.

While the superconducting magnet systems are at the beginning of use for accelerator facilities, in the detector systems they have already permitted an important advance in producing magnetic spectrometers. It is reasonable to use superconductive systems when it is required either to attain the maximum stationary magnetic field or it is necessary to have a particularly large volume occupied by the magnetic field of the detector.

5. The use of high magnetic guide field enables one to increase the energy of heavy particle beams, but this way is closed for electrons and positrons because of excessive increase of synchrotron radiation losses. However, the use of superconductive magnetic structures turns out to be efficient for reaching higher luminosity for electron-positron colliding beams at low and average energies / 1 / and also for producing irradiating structures for various applications of synchrontron radiation.

6. The use of superconductive resonators in RF accelerating structures, which have already been used in RF separators for beams of secondary particles, will be essential for accelerator progress. Up to now it is not clear whether an increase of accelerating gradient of these systems higher than 5 or 10 MeV/m will be achieved, but, at any rate, such systems will permit increasing noticeably (by 1.5-2 times) the energy of cyclic electron-positron storage rings /7,8 /.

7. A sharp increase in acceleration rate in linear accelerating structures (up to 100 MeV/m and maybe somewhat higher) one can achieve in a pulsed mode (with normal conductivity of resonators). Such accelerators could be called superlinacs. The problem of achieving an appropriate surface strength with respect to high voltage break-down as well as the problem of developing accelerating structures for relativistic particles with minimum overvoltage, one can consider as solved in principle /9,10 /. The basis of possible progress in this field is the development of pulsed short-wave generators of a fundamentally new level of pulsed power (order of gigawatt). Two directions in the development of pumping systems seem to be most promising.

One of these directions is connected with the fast progress in the technology of high power pulsed relativistic electron beams / 9 /. Already now when solving the controlled fusion problems the pulsed power of electron beams of a few gigawatts is achieved for durations of the order of a microsecond, with transformation of a substantial part of the beam energy into the energy of the RF electromagnetic field. The present day task is to make these generators more efficient, more sensitive in control over the amplitude and phase and to develop them for the regime of comparatively high repetition rates.

Another direction / 11 / is connected with the fact that modern big proton accelerators (not even mentioning future accelerators) have an energy stored in the beam of millions joules, good properties of high energy proton beams (small energy spread-only tens of MeV at an energy 500 GeV and a small emittance) permit rather easily (with the help of a bending modulator) deep bunching along the beam with the required wave length of the order of one centimeter. With the beam passing through the corresponding diaphragmed waveguide one can transmit an energy of a proton beam in the electromagnetic field of this linear accelerating structure with an accelerating rate up to 100 GeV/km. Let us call such a mode of operation the proton klystron mode. By injecting particles to be accelerated after the exciting proton bunch one can obtain a wide range of particles of high energies (see 10.).

So, it is possible to transfer nearly full energy E of the basic proton accelerator to accelerating particles with the beam intensities up to 10% of the initial beam intensity. By lengthening accelerating structure and exciting consecutive sections with various proton superbunches one can proportionally raise an energy of accelerating particles with corresponding loss in their intensity.

8. I am rather embarassed with the necessity to say only a few words on detectors. This area is almost limitless.

8.1 The progress in detector systems is strongly connected with permanently proceeding revolution in electronics. Namely the revolution enables one to create modern fast track devices and to handle the large flows of information.

The very rough upper estimation of information on an individual event in a big detector (10^7 resolvable elements of space x 10^2 resolvable time moments x 10^2 resolvable values of amplitudes = 10^{11} resolvable elements) shows that the number of elements is large, so that computer image of an event is quite informative - -or as it is said sometimes now - is quite pictorial. As a rule, thousands of these events should be registered in a second i.e. the full information flows are very large.

Therefore, development of faster processors is very important. Apparently the "Fast-bus system" developed at Brookhaven is the record one which provides the processing rate up to Gigabit per second / 12 /. But even this rate is insufficient for the purpose of processing the full information flow if the information is considered as totally uncorrelated and of equal value.

The wide use of parallel taking and processing of information is of great significance, as well as the use for this purpose of the more perfect programmable microprocessors, that enables to record and further to use for analysis only potentially interesting information. There could be several levels of decision on the further more detailed recording and processing the information and even several levels of triggering of the detector devices.

8.2 Detector systems using now can be huge in their size. Especially large are neutrino detectors /13/ and the multikiloton detectors for the study of proton stability /14/.*

But of extreme importance is also the line of the microdetectors development when for achieving necessary information the ultimately high spatial, time and amplitude resolutions are used (either one kind or combined). The International Symposium in Italy (September, 1980) will specially be devoted to microdetectors.

8.3 Let us consider now the progress and prospects in some certain detecting methods.

The discharge track devices are improving greatly. Revolution in electronics enables one to use the finer properties of electric discharge in various media. Already now the spatial resolution in a liquid-argon chamber is $\sigma_x = 8$ mkm /15/, in a gas chamber - 20 mkm /16/ and the time resolution achieved $\sigma_t = 20$ pikoseconds /17/.

One can confidently predict that further improvement and miniaturization of electronic components (as well as their lower cost) and, may be, the use of integrated sensitive and electronics processing components will further facilitate the progress in track detectors.

8.4 It is quite promising the direction of "active targets" with a fast (electronic) information taking which is direct outgrowth of the bubble chambers and high pressure gas chambers /18/. One of the versions of such a target is a set of fine semiconductor counters /19/ with a longitudinal resolution 10 mkm, designed, in particular, for measuring the life-time of D-mesons generated in the substance of the target itself. Possibilities of this device are expanded especially with the add of the transverse resolution for each counter (the prototype of the device is already manufactured providing transverse resolution $\sigma_x = 10$ mkm).

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* I try to cite this Conference contributed papers.

But with the use of technological means of modern microelectronics — thin silicon plates production, ion implantation, molecular epitaxy, laser and in not too distant future the X - ray lithography with the use of synchrotron radiation of electron storage rings, the use of integrated circuits in production of the whole channel with up to transport of information into processor — the prospects open up for the real revolution in the whole this field.

The latter note is valid also for the system of information read-out, optical, in particular, for the detectors of any kind.

8.5 Quite interesting possibilities appear when using the thin-wire scintillation hodoscopes / 20 /. Good results obtained for information read-out when using the avalanche photodiodes and microchannel electron multipliers. It looks realistic today to have hodoscopes with the spatial resolution up to 100 mkm, the length along filaments of 1 m and event rate up to 10^7 Hz.

8.6 Interesting prospects open up for small bubble chambers at operation with a very small bubbles / 21 / - - the resolution already achieved is of 10 mkm. Especially attractive in this case is the use of holographic information taking which enables one (maintaining the same resolution) to increase sharply the image optical depth (a 10 cm image depth is already achieved). The main efforts in this case are put on the further information processing. Note, the holographic way of taking information is apparently feasible for streamer chambers /22/. Actually, for holographical detection in the real detectors it is reasonable to tend for using the filmless way of taking information, i.e. microchannel multiplying plates, the large area semiconductor counters with the necessary spatial resolution and perhaps some other methods.

8.7 Note, the hybrid emulsion and rapid-cycle bubble chambers with the counter aiming the interesting events and adding high time resolution are still of interest, especially for operation with very high multiplicities and complex unknown events.

In particular, the hybrid bubble chambers can be adequate to the work with linear electron-positron colliding beams at super high energies / 9 / when at an average repetition rate of tens Hz the luminosity at a single interaction should be very high.

8.8 In conclusion of the detector section let me note the quite extensively developing methods of direct measurements (or at least estimates) of relativistic γ - factors of particles under study. With the energy growth this problem becomes more and more complicated and important. Among these methods I would mark the gas Čerenkov counters (especially those with measurements of the Čerenkov radiation circle /23/), detectors of transition radiation /24/, the use of relativistic dependence of ionization loss (at high energies in gases), radiation at channeling in monocrystals, which is most successfully applied for positive particles, and the synchrotron radiation. For various cases the optimal methods can be different and sometimes optimal may be their combination. Some methods, for instance, registration during channeling, is mostly applicable for tagging the secondary particles falling down the target when directions of their motion are sufficiently collinear. Total absorption calorimeters are under rapid development, too (see, in particular, /59/).

9. Let us consider now the possibilities for generation high quality beams of a possibly wide set of particles both the primarily accelerated and secondary. The progress in this direction determines to a significant extent the development of elementary particle physics. When we talk on a particle beam we have in mind in this case the situation when particles live so long, that at reasonable intensities the number of collisions between these particles and atoms (other than the nucleus which caused the generation of these particles) is sufficient for the study.

Among the characteristics of beams significant from the point of view of elementary particle physics, energy and intensity have obvious importance. An increase in the energy of projectile particles leads to an increase in reaction energy for fundamental processes under study. In ultrarelativistic case this energy increases as $\sqrt{E}$ in the experiments with stationary target and as E in colliding beams. An increase in intensity makes possible both the observation of more rare processes and higher accuracy of experimental data, which frequently supplies qualitatively new information of fundamental importance. As a bright illustration of the latter may serve the discovery in laser experiments of the parity violation in atomic transitions and, consequently, the discovery of electron-nucleon weak interaction due to neutral currents / 25 /.

In addition to energy and intensity, the following qualities of beams are of a very great importance: smallness of their emittance, monochromaticity and optimum of their time structure. The smallness of emittance permits minimizing the transversal size of interaction region between particles of a beam and the substance of the target, which improves, say, momentum analysis of reaction product. Concerning the time structure of the beams it's worth mentioning that sometimes it's beneficial to have the shortest intense bunches separated by long vacant sections for helping to avoid, for example, homogeneous cosmic background, for the use of primarily triggered detectors like bubble chambers, and for separation over the velocities; in other cases it is beneficial to have the beams, continuously distributed in time, loading optimally the detecting electronics and getting the possibility to "tag" each interesting particle by the products accompanying its production.

Note, that in the most general case the main space-time characteristics of the beam is the 6 - dimensional phase volume occupied by the beam. Its smallness permits, in principle, getting a beam structure required for given experiment by appropriate transformations.

9.1. In recent years, obtaining polarized beams has become more and more important. The opinion accepted earlier that spin effects, for strong interactions at any rate, become weaker and weaker at higher energy turned out to be absolutely incorrect. More than that, one can say that it is impossible to develop the quantitative theory of elementary particles without experimental study of the spin properties.

9.2. Of the same importance for polarization experiments, as producing polarized beams, is the progress in producing polarized targets. The best condensed targets with polarized protons and polarized or aligned deuterons, having the polarization level up to 60%, are the complex carbon-hydrogen compositions with a fraction of protons up to 10% of their weight (the recognition of a reaction with protons is carried out by kinematics) and operate at liquid helium temperatures. An important disadvantage of these targets is their insufficient irradiation damage resistance.

Gas targets with polarized protons and deuterons have effective thickness up to 10^{12} p/cm^2 only, but polarization degree is nearly 100%. These properties make them especially convenient for experiments with internal targets in storage rings. Targets with polarized electrons (ferromagnetic and gaseous) have rather limited value (e^+e^-, e^-e^- reaction energies are too small with a stationary target); so, polarized colliding beams are required (see 11.).

10. Let us consider now, very schematically, the possibilities of generation of the beams (we use the word beam in the same meaning as we used it earlier, see 9.) of all known stable enough particles. The optimal secondary

beam generation is often multi-step and complex process. And at many stages the use of cooling and super-thin target mode is effective.

10.1. Protons. The proton accelerators continue to grow in energy and intensity being the basis for the great class of experiments with beams of secondary particles, also.

Even now energies up to 500 GeV are accessible; in the not so far future the DOUBLER at I TeV will be put into operation; the UNK project at 3 TeV is under way. The subject of consideration of ICFA (International Committee on Future Accelerators) was an accelerator at energy 20 TeV. Construction of such an accelerator may become the first all over the world project and will contribute both to solution of problems of elementary particle physics and, let us hope, to solution of other problems of our unquiet world.

Modern intensity of proton beams of the highest energy is 10^{13} p/sec; further increase of their intensity is connected with a solution of a problem of further sharp improvement in the "beam hygiene", which is of particular importance for accelerators using superconductivity, that it is assumed to be used in every project for proton accelerators at super high energy. The use of superlinacs with the proton klystrons opens up interesting possibilities for getting protons of higher energies using existing facilities.

Naturally, the record intensities for medium energies belong to meson factories (up to 10^{16} p/sec). Further increase in intensity will be permitted by the growth in power of RF generators and by solution of radiation problems.

In the field of lower energies the electrostatic tandem generators ensure excellent beam properties. The biggest tandem generator, for 60 MeV protons, is nearing completion in Daresbury. However, many corresponding experiments, e.g. spectrometric appear to be feasible (and without sharp energy limit) with the help of storage rings with electron cooling in the super-thin target operation mode /3/.

Obtaining polarized proton beams is connected with the design of intense sources of polarized protons and, in the case of cyclic accelerators at high energies, with overcoming the depolarizing effects of spin resonances. The experience of Argonne laboratory has shown experimentally the possibility (and usefulness) of acceleration of polarized protons up to rather high energies.

New possibilities are already seen now for filling cyclic proton accelerators with polarized particles up to the total intensity of the given accelerator. The main way is the use of the proton polarized H^--beams, which may have the same intensity as polarized H^+-beams, and the use of charge exchange injection into the accelerator, that permits one to increase by several orders of magnitude current circulating in the accelerator compared to the current of the H^- - source /26/. Additional increase in injection multiplicity and improvement in the stored beam emittance one can achieve by introducing electron cooling during the injection process. Only for meson factories are there yet no possibilities for the intensity of polarized proton beams to approach the intensities of ordinary beams.

Acceleration up to very high energies in cyclic accelerators is accompanied by numerous spin resonances. This question was thoroughly studied theoretically and ways were found for overcoming detrimental effect of resonances, including producing magnetic structures which eliminate these resonances completely / 27 /.

The problem of obtaining polarized protons of high energies after initial stacking in a booster is especially simplified with use of superlinacs, in particular, with the use of proton klystrons.

Since presently there are no pure polarized targets of condensed substance, an especially important role could be played by the experiments in storage rings with internal gas target which enable one to operate with nearly pure initial spin states. One should pay attention that even longitudinal polarization of circulating beam near the target can be made stable / 28 / for achieving states with the given helicities.

10.2. Nuclei. "Relativistic nuclear physics" turned out to be more interesting than it was expected earlier ("porridge on porridge"). Such experiments give both ideas on supercompressed nuclear substance and supply data on fundamental interaction (study of inclusive processes). Already nowadays accelerated uranium nuclei are obtained with energy up to 10 MeV/nucleon and 10^9 U/s and nuclei to carbon with 5 GeV/nucleon energy and up to 10^7 C/s intensity. An implementation of projects is under way which sharply raise the ceiling of available energies and intensities. In some cases coherent methods of acceleration could be used, including "smoketron" devices.

This table represents the expected maximum parameters (energy and intensity) of the nuclear beams for one of the biggest projects VENUS (Berkeley):

Table 1.	1 GeV/nucleon	20 GeV/nucleon
Ne	$0.8\cdot 10^{12}$	$1.2\cdot 10^{11}$
Kr	$2\cdot 10^{11}$	$3\cdot 10^{10}$
U	$0.7\cdot 10^{11}$	$1\cdot 10^{10}$

This project also envisages an operation in colliding beam mode. Let us note that ISR is already operated in the mode colliding deuteron beams and operation is planned in the near future with colliding beams of α - - particles.

Obtaining beams of polarized deuterons of high energies is even simpler than for the case of protons (because of smallness of the anomalous magnetic moment).

10.3. Electrons. Electron accelerators and storage rings play a very essential role both in experiments on elementary particle physics and in various applications (in particular, for generation of synchrotron radiation).

The record in electron accelerators belongs to SLAC; the available energy there is in excess of 30 GeV and in the near future will attain 50 GeV at intensity up to 10^{14} e^-/s.

Both electrons and positrons of higher energies are obtained presently on proton accelerators due to the process $pZ \to \pi^0 X$; $\pi^0 \to 2\gamma$; $\gamma Z \to e^+e^- Z$. Nowadays it is possible to obtain electron beams of quite good quality with energy up to 300 GeV at intensity up to 10^8 $e^\pm$/s (separation with synchrotron radiation, for example, / 27 /).

A sharp increase in intensity (up to 10^{13} $e^\pm$/s) of electron beams with energy of hundreds GeV will feasible after design of superlinacs for linear electron-positron colliding beams (see 11.3).

Intensities of polarized electron beams have reached 10^{11} e^-/s at SLAC. Intense polarized circulating beams are obtained due to radiative polarization in storage rings. Using intense circularly-polarized radiation (e.g. laser or spiral-undulator beam) travelling against electron beam it is possible to achieve much higher polarization rate of circulating electrons (and positrons) /30,31/. A sharp extension of possibilities in obtaining beams of polarized electrons of high energies will become accessible upon development of superlinacs (see 11.3).

10.4. Positrons. In the field of electron accelerators the presently available intensity of positron beams of entirely full energy achieves 1% intensity of electron intensity at worse quality of the beam. The use of intermediate storage rings with radiation cooling can essentially improve the quality of positron beams and increase their intensity.

Obtaining beams of polarized positrons in experiment still was necessarily connected with radiative polarization in storage rings.

At energies higher than 100 GeV, as mentioned above, possibilities for positron beams, including polarized beams, are the same as those for electrons.

10.5. Photons. Intensities and energies of beams of quanta obtained as bremsstrahlung at electron accelerators and also as a result of decay of neutral pions at proton ones are quite high. However, an important problem is beam separation and energy tagging for quanta hitting the targets. The latter is especially complicated for proton accelerators, and even so complicated that first of all one has to obtain $e^{\pm}$ beams of known energy and only after that following the ordinary procedure of measuring the energy of remaining $e^{\pm}$ an energy of the bremsstrahlung quantum can be tagged. The same technique of tagging energies of photons obtained on internal (superthin) targets is also convenient for obtaining intense fluxes of gamma-quanta in electron accelerators (storage rings).

Interesting prospects in obtaining intense, monochromatic and, at the same time, appropriately polarized beams of gamma-quanta of high energies is a backward Compton-effect on electrons travelling in cyclic storage rings at high energies.

For obtaining such quanta with energy E one should have electrons with energy E and polarized photons with energy higher than $(m_e c^2)^2/E$. Under these conditions, zero-angle scattered photons will have full energy E (almost independently on the initial photon energy). At the scattering angle $m_e c^2/E$ the photon energy will be much less. So, for effective monochromatization one needs to measure scattering angle (e.g. the position of photon event on a long-distant located target), and electron beam should have as small angular spread as possible. It is useful, additionaly, to measure an energy of the simultaneously scattered electron. At energies up to 50 GeV it is reasonable to employ synchrotron radiation in spiral undulators. In this case, it is necessary to ensure the electron interaction exclusively with photons, emitted inside the angle $m_e c^2/E_{rad}$. Irradiating particles can travel either in the same storage ring (e^+e^- colliding beams) or in a special storage ring at a substantially lower energy. Some interesting possibilities can arise if the photon beams of short-wave intense electron beam lasers (without mirrors) could be used / 32 /. At energies higher than 50 GeV one can use photons of short-wave lasers of usual type.

Intensity of such beams of gamma-quanta corresponds to transfer of all stored electrons to these quanta with the life-time due to this process of thousands seconds (up to 10^8 γ /s).

10.6. Neutrons. Neutron fluxes with an energy up to tens of MeV are obtained mainly with nuclear reactors (including pulsed reactors) and at deuteron and proton accelerators. For monochromatization of reaction energy the fast separators and the time-of-flight methods of detection are used. I cannot help but drawing attention to the fact that it is a very attractive possibility for the energy range from tens eV to hundreds keV to use very powerful and highly collimated synchrotron radiation (with the quantum energy higher than 1.6 MeV) from electron storage rings at an energy $\gtrsim$ 10 GeV irradiating a berrilium target. Small transverse dimensions of the effective neutron source (achievable dimensions are down to 10 mkmx1 mm), short pulse (fractions of nanosecond) and a very low duty factor ($\lesssim 10^{-5}$) at high average intensity (up to 10^{14} n/s) ensure by many orders of magnitude better conditions for the study of neutron reactions using the time-of-flight method. In the lower part of the mentioned energy range the small transverse dimensions of the source make very effective the use of Bragg's monochromatization with the use of bent crystals, and also make effective obtaining polarized neutrons with the help of magnetic mirrors.

At higher energies an interesting pulsed source of neutrons can be obtained at meson factories with the use of charge-exchange ($H^- \to H^+$, $D^- \to D^+$) stacking of accelerated protons or deuterons in a cyclic storage ring, and using fast extraction onto the target.

At energies > 100 MeV an optimum method for obtaining quite monochromatic and well directed neutrons is the use of the decay reaction for accelerated deuterons with required energy per nucleon. In the superthin target mode an intensity for well collimated and quite monochromatic neutron flux can be achieved close to that for the deuterons and also good tagging with the remaining proton of the same energy. The use of polarized deuterons enables one to have neutrons with a good degree of polarization.

The use of charge-exchange reaction $pZ \to n(Z+1)$ permits doubling energy for neutrons obtained at a given cyclic accelerator but the beam quality in this case is worse. The cross-section of elastic charge-exchange falls down rapidly with proton energy growth ($\sigma_{ex} \approx 2/E^2_{GeV}$ mb) and at energies higher than tens of GeV one has to use the reaction pp $\rightarrow n\pi^+p$ with the useful cross-section of 0.2 mb having with proton accelerators up to 0.5% efficiency of transforming of protons to neutrons.

10.7 Antiprotons. Development of electron and stochastic cooling gives the possibility of obtaining the high intensity, absolutely pure, monochromatic and small-emittance antiproton beams. The first projects of antiproton storage rings under implementation and under preparation /33-36/ will give $(1\div5)\cdot10^7$ $\bar{p}$/s but the ways are visible for increase by two orders of magnitude in production efficiency /3/.

The stacking will be performed at an energy $0.5\div5$ GeV. The antiprotons can be decelerated to very low energies   or be accelerated up to energies available for proton accelerators (or even higher when using proton klystrons). Of special interest are the studies with antiprotons at low energies with continuous electron cooling in obtaining intense and long-life protonium fluxes -$p\bar{p}$-electromagnetically-bound states /3,58/.

When using continuously cooled with electrons antiproton beams, which interact with a longitudinally polarized gas target at the storage ring section with stable longitudinal polarization of the circulating beam, one can achieve polarized antiproton beams with intensity up to 10% of the intensity of the initial antiprotons / 3 / with their subsequent acceleration (or deceleration) up (or down) to the energy required.

10.8. Antideuterons. With the same storage rings being designed for obtaining antiprotons one can get absolitely pure beams of antideuterons with intensity only by 3-4 orders of magnitude lower than that for antiprotons / 3 /. Such beams can turn out to be interesting for the study of nuclear states consisting of nucleons and two antinucleons.

10.9. Antineutrons. At energies up to tens of GeV the most profitable is to obtain antineutrons due to elastic charge-exchange reaction $\bar{p}p \rightarrow \bar{n}n$ (the cross-section at high energies is about $\sigma_{ex} = 15/E^2(\text{GeV})$ mb) with tagging, if possible, by the remaining neutron of low energy. The intensity of antineutrons will be up to σ_{ex}/σ_{tot} of the system efficiency for antiprotons. The use of polarized antiprotons will enable obtaining the beams of polarized antineutrons with an intensity one more order of magnitude lower additionally (because of losses during antiproton polarization).

At still higher energies one has to get antineutrons in the reaction $\bar{p}p \rightarrow \bar{n}\pi^- p$ with cross-section of fractions of mb having worsened quality of the resulting beam (even with tagging). The antineutron intensity can reach a fraction of a percent of the antiproton intensity.

The antineutron beam with excellent quality, intensity up to 10^{-4} that of the antiprotons and with ideal tagging by the remaining $\bar{p}$ can be obtained by stored and accelerated antideuterons: $\bar{d}p \rightarrow \bar{n}\bar{p}p$.

10.10 Pions. Obtaining beams of charged pions is the most explored way among the secondary particle beams production at high energies. Here, I would like to draw attention only to the tempting prospects for obtaining pure, rather monochromatic and well-collimated pion beams by their acceleration in superlinacs with acceleration rate higher than $2m_\pi c/\tau_\pi = 0.4$ MeV/cm; in this case, the most natural is the use of a proton klystron / 11 /. When using optimal conversion systems, for each ten protons with energy $\gtrsim$ 100 GeV one can have one either positive or (and) negative pion with energy of a few GeV which is fit for further acceleration. In order to decrease the number of muons accompanying the beam of accelerated pions one should tend maximum acceleration rate.

Let me note here that at energies higher than hundreds GeV the number of events with full cross-section induced by neutral pions in a condensed target becomes substantial. So, at initial proton energy of 1 TeV with intensity 10^{13} p/s more than 10^5 events will be caused by neutral pions having average flight length of 20 mkm. But, of course, the problem of identification of these events is extremely difficult.

10.11. Kaons. Unfortunately, for acceleration of charged kaons the accelerating gradients higher than 3 MeV/cm are required; that is still out of reality. There is some hope to achieve such gradients using special modification of proton klystron: all the protons, occupying the whole circumference of a big proton accelerator should be compressed into one (or several, with long distances in-between) bunch about 1 cm long and injected into a special linear wave-guide structure /37 /. In this case, inside the bunch a very strong longitudinal electric field shall appear, breaking (decelerating) the protons of the bunch. Consequently, negative particles travelling with protons together inside the bunch shall be accelerated. So, the scheme gives possibility, in very principle, to accelerate K^-. Neutral kaons could be produced using charge exchange or charge loss reaction of accelerated K^- with a target. The development and design of enough damage-resistant systems of such kind is, of course, a task for the future. But up-to-now at high energies an optimum method for setting up kaon-beams production may turn out to be the use of the thin target mode (and at energies and intensities enabling effective cooling - the superthin target mode) at proton storage ring with the best available tagging (correspondingly with very complicated trigger). Since the total cross-section for generation of every kind of kaons in p-p reactions is large (fractions of mb), there are many kaons generated on this target. Naturally, for making more pure experiment one will have to use the whole set of the charge, momentum, velocity and gamma factor selection techniques, and, while recording products of KN reaction, one should most carefully take into account the quantum numbers of particles produced.

10.12. Hyperons. A new circumstance at superhigh energies is the long life-time for hyperons. Even at 100 GeV the long-lived hyperons live for tens of meters distances. Nevertheless, for separation of initial beam from the beam of produced negative and neutral hyperons (or positive of significantly deviated momentum) one should use strong magnetic fields, but this problem becomes easier linearly with energy growth. All the rest said on carrying out experiments with kaons remains valid even in this case (inclusive cross-sections, in particular, are of the same order).

10.13. Antihyperons. At not very high energies (rather to hundreds of GeV) the use of elastic charge-exchange reactions $\bar{p}p \to \tilde{Y}Y$ ($\sigma_{ex}/\sigma_{tot} \approx 10^{-2}/E^2_{GeV}$) with tagging using by-product hyperons (being nearly at rest) in the (super) thin target mode in antiproton storage ring seems to be the optimum for obtaining antihyperon beams. Apparently, antihyperons produced in such a process by polarized antiprotons will preserve a noticeable polarization level.

At higher energies one will have to proceed in the same way as in the case of hyperons; the inclusive cross-section for antihyperon production in pp collisions is by only one order of magnitude lower than that for hyperons.

10.14. Muons. In order to have very pure, high energy and most intense muon beams with a very small emittance and good monochromaticity it is reasonable to proceed as follows /11/:

a) to obtain as many as possible pions with energy of 1 GeV on the target, with strong focusing, in nuclear cascade using the proton beams of energy $\gtrsim$ 100 GeV;

to let pions decay in the possibly stronger focusing channel;

c) to cool muons (with ionization cooling) in a special ring with targets placed at the sections with a very strong focusing;

d) to accelerate muons up to required energy in the short-pulse cyclic accelerator or (better) in a superlinac. The intensity of the muon beam can reach up to 10% of the intensity of the basic proton synchrotron (with use of the proton klystron mode).

In order to get polarized muon beams of high energy it seems to be most profitable to use monochromatic pion beams accelerated in a superlinac by injecting them into a special ring with strong magnetic field pulsed or superconducting). The structure of the ring should be designed in the way to have dynamically stable longitudinal polarization / 28 / of circulating muons (at injection energy, at any rate) equal in both long straight sections, which occupy, say, 3/4 of the circumference of the ring. The muons produced in the forward hemisphere will have momentum quite close to the pion momentum; muons of inverse helicity (moving backward in rest frame of the pions) deviate strongly over the momentum and can easily be removed from the ring. Polarization of the produced muon beams can be quite high (approaching the ratio of straight sections length to the circumference).

10.15. Neutrinos. The beams of muon neutrinos of high energies, well-directed and of useful intensity of a few percent of the intensity of the basic proton synchrotron, can be obtained with beams of accelerated pions. In order to decrease the neutrino beam diameter near the detecting facilities, which are located behind shielding of required thickness, it is profitable to perform the pion decay in a special storage ring with relatively long straight sections /11/.

Both muon and electron neutrinos of the same intensity can be obtained in the track of this kind by injecting into the track the accelerated cooled muons /11/.

Thus, a combination: "superlinac - special race--track" can be a multipurpose installation.

As to the beams of τ - neutrinos connected with a heavy lepton, it might turn out that their main source will be decay of τ - leptons of $\tau^{\pm}$- pairs produced by γ - quanta on the target nuclei / 37 /. At high enough energies nuclear form-factor does not decrease the τ - pair production. γ - quanta can be obtained both with the help of proton and electron beams of high energy. More specifically one can evaluate the flux of τ - neutrinos with electrons. In a thick target the number of produced $\tau^\pm$ pairs will be of about $(m_e/m_\tau)^2 = 10^{-7}$ with respect to the number of incident electrons. So, the neutrino flux from a superlinac can be of the order of 10^6 ν_τ/sec inside the angle $m_\tau c^2/E_e$ with average energy about $E_e/4$. It is hard to expect that in the case of protons the neutrino beam quality will be higher.

It is not excluded, that in a 100% duty cycle mode it would be possible to design the trigger system on τ - lepton and similar events production, for facilitating selection of ν_τ events in neutrino target.

11. Colliding beam experiments became the main supplier of fundamental data in physics of elementary particles. Many electron-positron storage rings are in operation now (see Table 2 and Figure 1). Certainly, the colliding beam experiments are essentially needed at the highest energies.

11.1 However, the e^+e^- colliding beams shall necessarily be developed and advanced not only at the highest energies. In particular, this necessity is connected with the fact that detailed study of quark-gluon systems in the field of low and average energies is of primary importance at present since it permits quantitative study of quantum chromodynamic effects, in particular, connected with the asymptotic freedom to confinement transition. Such experiments are especially suitable for electron-positron colliding beams, but to this end a sharp increase in luminosity of installations is required. The possibility and usefulness of this were proved by experience of VEPP-2M designed specificaly for increased luminosity and, correspondingly, yielding increased accuracy of experimental data in the energy range up to $\sqrt{s}$ = 1.5 GeV. Even now the possibilities are seen for making installations with luminosity up to 10^{33} cm^{-2}s^{-1} at full energy of 4-5 GeV.

Other directions in improvement of electron-positron installations also promise to give important result. The possibility to work with polarized beams is very useful. In addition to sharp increase in absolute accuracy of measurements of produced particle masses /38,39/ (see Table 3), even the work with transversely polarized colliding beams helps in understanding the spins of produced final and intermediate formations. Implementation of experiments with longitudinally polarized beams permits obtaining qualitatively new information on the spin dependent strong interactions, and to study weak interactions, for instance, of b-quarks in the region of Υ -mesons.

Table 2.

Storage ring laboratory	Particles	$\sqrt{S}$ (GeV)	Lmax($cm^{-2}sec^{-1}$)	Start
VEP-1 (Novosibirsk)	$e^- e^-$	0,32	$5 \cdot 10^{27}$	1965 Stop
Stanford storage rings	$e^- e^-$	1	$2 \cdot 10^{28}$	1965 Stop
VEPP-2 (Novosibirsk)	$e^+ e^-$	1,4	$3 \cdot 10^{28}$	1966 Stop
ACO (ORSAY)	$e^+ e^-$	1,1	$1 \cdot 10^{29}$	1967
ADONE (Frascati)	$e^+ e^-$	3	$6 \cdot 10^{29}$	1970
CEA (Cambridge)	$e^+ e^-$	4	$3 \cdot 10^{28}$	1971 Stop
SPEAR (Stanford)	$e^+ e^-$	8,2	$2 \cdot 10^{31}$	1972
VEPP-2M (Novosibirsk)	$e^+ e^-$	1,4	$3 \cdot 10^{30}$	1974
DORIS (Hamburg)	$e^+ e^-$	11	10^{30}	1974
DCI (ORSAY)	$e^+ e^-$	4	10^{30}	1976
VEPP-4 (Novosibirsk)	$e^+ e^-$	4(11)	$3 \cdot 10^{28}(10^{31})$	1979 (1981)
PETRA (Hamburg)	$e^+ e^-$	38	$5 \cdot 10^{30}(10^{32})$	1979 (1980)
CESR (Cornell)	$e^+ e^-$	11(16)	$2 \cdot 10^{30}(10^{32})$	1979 (1980)
PEP (Stanford)	$e^+ e^-$	28(36)	$2 \cdot 10^{30}(10^{32})$	1980 (1981)

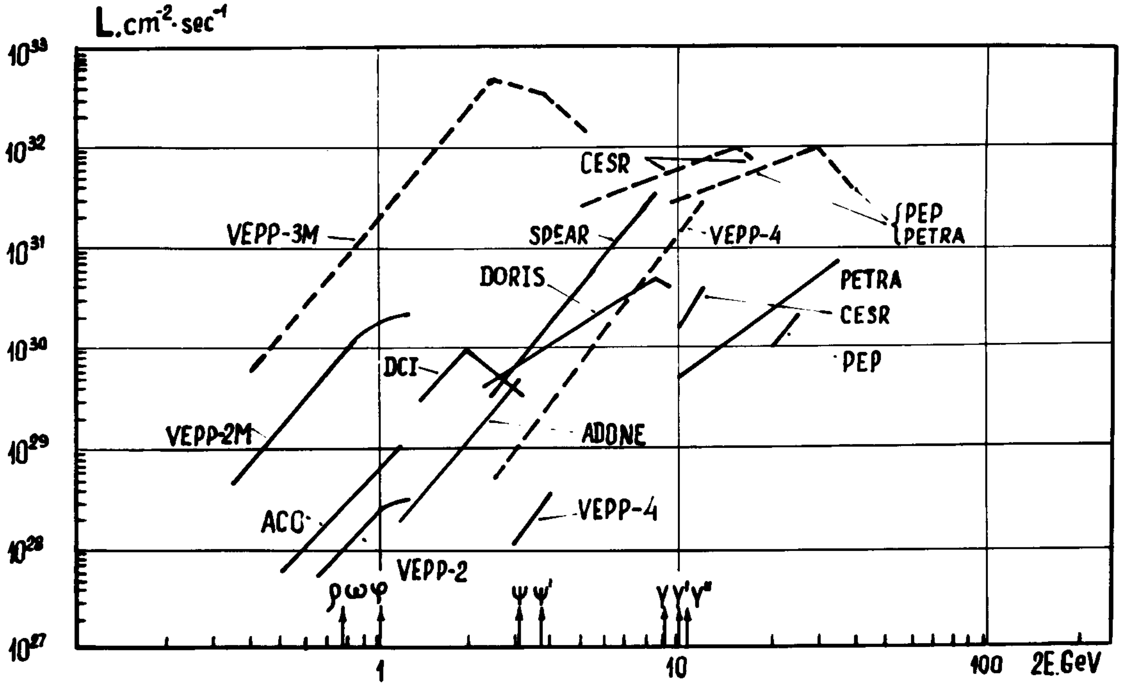


Fig. 1. Achieved (solid line) and design (dashed line) luminosity for e$^+$ e$^-$ storage rings.

Table 3

Particle	Mass, MeV	
	High Precision Measurement*	Old World Average
$K^\pm$	493.670±0.029	493.668±0.018
ϕ	1019.54±0.12 1019.52±0.13	1019.62±0.24
ψ	3096.93±0.09	3097.1±0.9
ψ'	3686.00±0.10	3685.3±1.2

* High precision measurements have been performed at VEPP-2M and VEPP-4 using the resonance depolarization method of the absolute energy calibration.

The possible sharp increase (higher than one order of magnitude) in monochromaticity of electron-positron reactions opens up interesting possibilities /40 /. So, one can proportionally raise the fraction of resonance reactions, that is of special importance for Υ - mesons, and study the inner structure of Ψ - mesons (even for the purpose of proving that it does not exist). Note, that even higher monochromaticity can be achieved with $p\bar{p}$ - colliding beams under continuous electron cooling / 3 /.

11.2. But the main trend in the field of electron-positron colliding beams remains the tendency to higher energies.

Already now the total energies up to $\sqrt{S}$ = 40 GeV become accessible (PETRA, PEP). An intensive development of the LEP project is under way (first stage-up to $\sqrt{S}$ = 100 GeV, second - up to 250 GeV), the project of the new storage ring at Cornell and also the HERA project enables, in principle, obtaining e^+e^- energies up to 100 GeV (see Table 4). Note, that at these high energies in cyclic storage rings (despite the overlapping of spin resonances) implementation of e^+e^- polarized colliding beams is feasible / 41 /. The new and interesting is the project of quasilinear single-pass e^+e^- colliding beams at SLAC / 42 / (Fig. 2) at an energy up to $\sqrt{S}$ = = 100 - 140 GeV.

Further increase in energy of electron-positron colliding beams in cyclic storage rings (now conventional) is almost unrealistic because of the catastrophic rise in loss by synchrotron radiation that forces to enlarge the installation both in dimensions and power consumptions as the square of energy. Therefore, the main direction in development becomes linear colliding beams / 9 /.

In the plans for linear colliders at super high energies even from the initial stage the possibilities are considered of using long superconducting structures with recuperation of accelerated particle energy and of using pulsed superlinacs / 43 /. Several projects of linear e^+e^- superconducting colliders are being developed now - Cornell, CERN, Hamburg /44-46/. The collider project VLEPP based on superlinacs is being developed in Novosibirsk and adjustment of its most important components is being performed /9,10,47,48/. Let me outline briefly the schematic of the Novosibirsk project and its possibilities.

11.3. The general layout of the facility may be represented as follows (Fig. 3). Two superlinacs at an energy 100 GeV and 1 km long each, fed by high power SHF sources installed about 10 m apart, "fire" at each other

Table 4

Project/ Laboratory	Particles	$\sqrt{S}$ (GeV)	L($cm^{-2}s^{-1}$)	Start
LEP (CERN)	e^+e^-	Ist 100	10^{32}	1986 (?)
		IIst 250		
New Cornell Ring	e^+e^-	100	$3\cdot10^{31}$	1986 (?)
Stanford Single-pass Collider	e^+e^-	100	$1\cdot10^{30}$	1985 (?)
VLEPP (Novosibirsk)	e^+e^-	Ist 200	$1\cdot10^{32}$	1989 (?)
		IIst 600	$1\cdot10^{32}$	

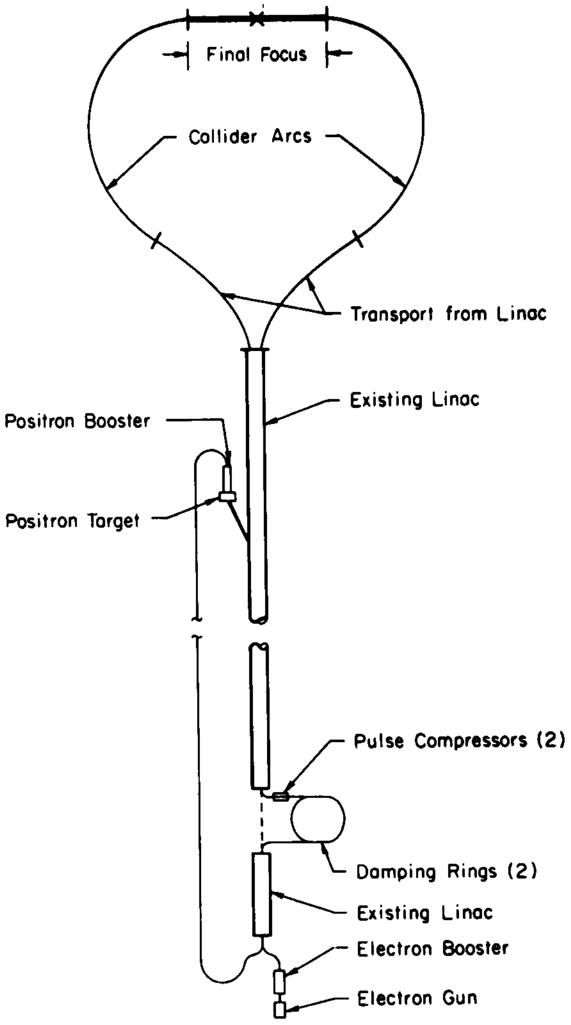
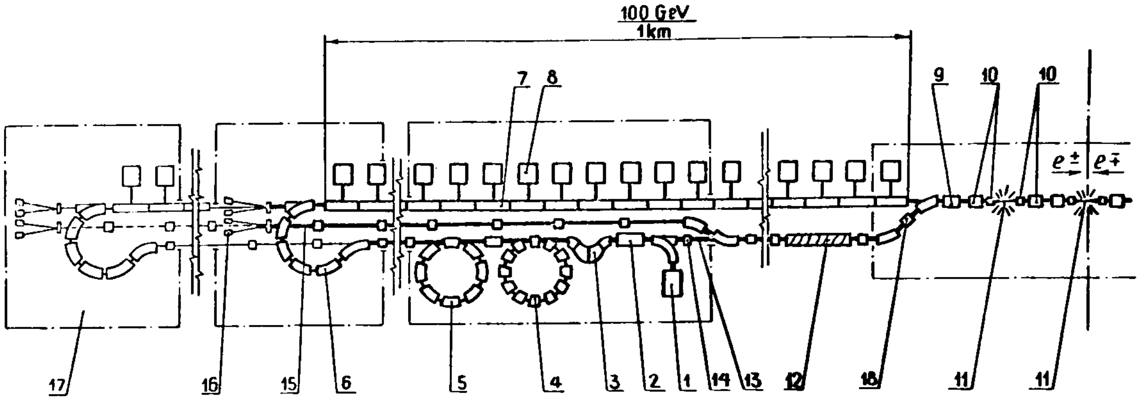


Fig. 2. General layout of the SLAC Linear Collider.



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

Fig. 3. The Novosibirsk Linear e^+e^- Collider (VLEPP).

with single bunches 1 cm long with 10^{12} particles in each bunch of polarized electrons and positrons at a repetition rate of order 10 Hz. After collision the bunches are slightly deflected by a pulsed field into a small-angle analyzing system that makes it possible to measure the energy spectrum of the colliding particles. Then the bunch enters the conversion system - a long spiral magnetic undulator - where particles irradiate of 1% of their energy as circularly polarized photons with energy about 10 MeV (the photons emitted inside the angle $1/\gamma$ should be used only). Then remained polarized beam is slightly deflected and directed into special halls designed for performing experiments with stationary polarized targets. The~10 MeV longitudinally polarized photons reach the converter. The longitudinally polarized particles of required sign produced in pairs on the target (only the upper part of spectrum should be taken) are collected and accelerated with high acceleration rate up to 1 GeV. Then, polarization of particles is transformed into transverse polarization and bunch length is increased by one order of magnitude. After radiation cooling in the storage ring with large acceptance the particles are transfered into a special storage ring-cooler, where the beam emittance is damped down to a very small value (the problem to reach a very small emittance is far from simple for 10^{12} particles in the beam). Upon total cooling the beam is transported to the injector end of a superlinac. Prior to injection the beam is shortened down to 1 cm long and the beam polarization is transformed in the way desired.

After that, acceleration follows with the highest acceleration rate and special care undertaken to avoid an increase in emittance. After acceleration the bunches are focussed (at the collision point) into ellipses with effective area of the order of 1 mkm^2, and the cycle is repeated. With further increase in collider energy, in order to avoid an excessive rise in synchrotron radiation loss in the field of the interacting bunch and especially to overcome the depolarizing effect, one apparently has to proceed to a four-bunch scheme with mutual compensation for coherent fields at the collision point / 9 /.

A colliding beam facility based on the scheme described has the pleasant feature that it is possible to increase the length and consequently the energy of the accelerator step by step. For example, initially an accelerator with a maximum energy of 2 x 100 GeV may be put into operation. While experiments are being conducted in this energy range, accelerator sections that raise the energy to 2 x 200 GeV are built, and so forth.

Finally, let us recall that VLEPP can be used as a conventional double-energy accelerator with rather high average current of polarized e^+e^-. This is itself quite interesting.

A rough table of the parameters of an accelerator at energies of 2 x 100 and 2 x 300 GeV can be presented as follows:

Table 5

Energy	2 x 100 GeV	2 x 300 GeV
Length	2 x 1 km	2 x 3 km
Luminosity	$10^{32}cm^{-1}s^{-1}$	$10^{32}cm^{-2}s^{-1}$
Average beam power	2 x 160 kW	2 x 480 kW
Number of particles in a beam	10^{12}	10^{12}
Average mains power	7 - 10 MW	20 - 30 MW
Repetition frequency	10 Hz	10 Hz

11.4. The first proton colliding beam facility (ISR) has been operating at CERN since 1971. Its maximum energy is 2 x 33 GeV, the maximum number of stored particles is up to 10^{14} in each beam, ultimate luminosity is $0.7 \cdot 10^{32}cm^{-2}s^{-1}$. During this period a number of important experiments have been conducted which provided valuable information.

Construction of the big superconducting storage rings is being carried out at Brookhaven proton-proton colliding beams at energy $\sqrt{S} = 800$ GeV - ISABELLE - with very high design luminosity ($10^{33}cm^{-2}s^{-1}$). Implementation of proton-proton experiments on the Main Ring-Doubler facility is under consideration at Fermilab at an energy $\sqrt{S} = 1100$ GeV (300 GeV on 1000 GeV). Proton-proton colliding beams are envisaged in the accelerating facility at Serpukhov (UNK) at an energy up to 2 x 3 TeV. So, we see, colliding beam energies will increase rather rapidly. But experimental feasibility of reactions, now of intense interest, with energy 0,1 megajoul in elementary interaction (beloved 10^{15} GeV in rest frame!)- is the question for not so near future (see Table 6).

11.5 The closest new installation with hadron colliding beams will be proton synchrotron SPS already in operation at CERN. This installation is being modified now for the mode of proton-antiproton colliding beams with energy up to $\sqrt{S} = 600$ GeV /33 /. Next will be commissioning of the proton-antiproton installatior at an energy up to $\sqrt{S} = 2000$ GeV based on the superconducting proton

Table 6

Project/ Laboratory	Particles	$\sqrt{S}$ (GeV)	L($cm^{-2}s^{-1}$)	Start
ISR (CERN)	pp	62	$0.7\cdot10^{32}$	1971
ISABELLA (Brookhaven)	pp	800	$2\cdot10^{32}(1\cdot10^{33})$	1986
Main Ring/Doubler (Fermilab)	pp	1,100		
UNK (Serpukhov)	pp	6,000		
ISR (CERN)	$p\bar{p}$	62		1981
SPS (CERN)	$p\bar{p}$	600	$\geqslant1\cdot10^{30}$	1981
Tevatron, Phase I (Fermilab)	$p\bar{p}$	2,000	$\geqslant1\cdot10^{30}$	1984
UNK (Serpukhov-Novosibirsk)	$p\bar{p}$	6,000	$3\cdot10^{30}$	1990
Pentavac (Fermilab)	$p\bar{p}$	10,000		
HERA (Hamburg)	$e^{\pm}p$	300 (30e ↔ 800p)	$4\cdot10^{31}$	1988
CHEER (Fermilab)	$e^{-}p$	200 (10e ↔ 1,000p)	$5\cdot10^{31}$	1985 (?)
TRISTAN (KEK)	$e^{-}p$	170 (25e ↔ 300p)	$1\cdot10^{31}$	1988

synchrotron Doubler (Tevatron, Phase I) being built at Fermilab /34/. The $p\bar{p}$ project is designed for UNK (Novosibirsk-Serpukhov collaboration) at the energy up to $\sqrt{s} = 6$ TeV /35,36/.

In the first years after announcing the first proton-antiproton colliding beam project (1966 VAPP-NAP, Novosibirsk /49,50/) the proton-antiproton experiments at maximum accessible energy were considered by many physicists as an exceedingly complicated addition to proton-proton experiments at the same energies. Even then, of course, it was evident that this addition is rather important. So, two classes of experiments are specific to proton-antiproton colliding beams: first, the study of hadron annihilation, second, the study of two-particle charge-exchange reactions, i.e., reactions with conservation of baryon charge of each colliding particle. The annihilation cross-section apparently decreases only inversely as the energy of the colliding beams and even at an energy 2 x 1000 GeV the cross-section will be of the order 10^{-30} cm^2. So, main problem will be the separation of annihilation processes from the vast majority of "the events of the total cross-section". At the same time, the cross-section of the process like

$$p\bar{p} \rightarrow \Lambda\bar{\Lambda}$$

decreases (in the energy region presently known) as E^{-4} and only with a luminosity of the order $10^{32} cm^{-2} s^{-1}$ one can manage to get some data about these processes at energies above 100 GeV.

In recent years the attitude toward proton-antiproton colliding beams has changed greatly. The quark model is acquiring more and more dynamical content and more and more "public opinion" is inclined to consider hadrons as consisting of quarks interacting as point-like particles. Accordingly, processes with very large momentum transfer will occur through the interaction of quarks, the components of the colliding hadrons (Drell-Yan processes). Here protonproton collisions give quark-quark reactions, while proton-antiproton collisions give quark-antiquark reactions. In this sense one can say that in experiments in colliding proton-antiproton beams it is possible to obtain the same fundamental information as in colliding electron-positron beams of the same luminosity and with an energy of the order of one-sixth of the energy of the baryons. Similarly, proton-proton colliding beams are equivalent to electron-electron collisions. Of course, for strongly interacting particles such as protons and antiprotons we cannot say that they consist only of quarks of one "polarity". However, according to contemporary neutrino data the content of antiquarks in a proton is about 5% (this is also the estimate of the content of quarks in the antiproton). Therefore quark-antiquark interactions are dominant in proton-antiproton collisions, and quark-quark interactions provide only a small admixture. For proton-proton collisions the ratio will be the reverse. In addition, the average energy of quark-antiquark reactions in proton-proton collisions will be substantially lower than in proton-antiproton collisions.

Note, (see 10.) that it is feasible to obtain proton-proton polarized beams with full luminosity and also the proton-antiproton beam with luminosity one order of magnitude lower than that for unpolarized, including experiments with given helicities of initial particles.

Some interesting possibilities will open up when the cooling of high energy colliding $p\bar{p}$ beams using circulating electron beam /51-53/ will be developed. For high luminosity colliding beams the effective cooling achievement requires a solution of the very complicated technical problems and it is not so easy to predict correctly the prospects of this method.

But for luminosity about 10^{28} $cm^{-2}s^{-1}$ the circulating beam electron cooling looks like a not an extremely difficult problem. Using this cooling technique at energy more than 100 GeV one shall have very small equilibrium sizes of colliding beam. So, one shall have the possibility to measure precisely differential cross-section of $p\bar{p}$ elastic scattering at the angles of effective interference of strong and Coulomb interactions. Such measurement will give the information about behaviour of total cross-section at energies by the order of magnitude higher than the energy of $p\bar{p}$ collisions.

12. A few words about the "strategy" of advancing to the ultra-high energies. One can distinguish (quite schematically) four stages of exploring new regions at energies of hundreds GeV and higher /1/.

In the first stage only interactions of any point-like objects (nowadays - leptons, quarks) should be accessible which enable one to produce as large as possible momentum transfer both in scattering and in production of massive objects (space- and time-like momentum transfers). In the first stage it is not too important for which pairs it will be done. The question of primary importance is the question of having beams available for the first stage experiments. Colliding beams of particles and antiparticles seem to give more experimental information as the systems have less quantum numbers prohibitions for generation of new objects. From this point of view, the most advantageous variant for the experiments will be proton-antiproton colliding beams which will enable studying the fundamental quark-antiquark interactions at an energy of one-sixth of the energy of the proton-antiproton colliding pair.

Of course, when we are talking now about the study of fundamental interactions of different objects, it is just a way to classify the experiments over the initial states. Each certain class of experiments will also provide vast additional information.

At the second stage one can consider the experiments which cover the interactions of all fundamental particles i.e. the study of lepton-lepton, lepton-antilepton, quark-lepton, quark-antilepton, quark-quark and quark-antiquark interactions. In this case, the choice of concrete particles is still determined by which is most realistic to realize.

These problems will be solved soon, most probable, in the following colliding beam experiments:

a) lepton-lepton and lepton-antilepton - $e^- + e^-$ and $e^- + e^+$;

b) lepton-quark and antilepton-quark - $e^- + p$ and $e^+ + p$;

(the experiments of this kind are already planned at installations at superhigh energies which are being built and designed /54-57/;

c) quark- and antiquark interactions will primarily studied in pp and $p\bar{p}$ experiments. The feasibility of these experiments, the difficulties that will arise and the now visible ways to overcome them are sufficiently clear from the above discussions.

In the next stage it will apparently be important to obtain as complete as possible set pairs of fundamental particles in the initial state. And finally, for advance in understanding of fundamental interactions at ultimate high energies it will become necessary to study the collisions of all elementary particles and even nuclei.

12.1. In this connection, it is worth paying attention that many of those experiments which now seem exotic and unreal will become available in the not distant future.

So, quite soon after exploring proton-antiproton colliding beams deuteron-antideuteron experiments will become accessible (for the study of neutron-antineutron interactions): for the effectivness of stacking antideuterons is only four orders of magnitude lower than that for antiprotons, the luminosity of the order 10^{27} $cm^{-2}s^{-1}$

will be achieved immediately and one should not wait too long for progress in this field /3/.

With time, colliding beam experiments with unstable particles will become accessible. Good prospects for muons and pions acceleration are opened up with the use of intense beams of modern and future proton accelerators in proton klystron mode for superlinacs excitation (see s. 7) / 11 /.

Using the pions accelerated in this way with already up-to-date accelerators SPS and Main Ring it is possible to obtain pion-proton and pion-pion colliding beam luminosity of the order 10^{27} cm^{-2}s^{-1} (with the use of a 100 KG pion magnetic track and the proton storage ring)/11/.

The muon colliding beam experiments will also be accessible /58,11/. For this purpose it is required to accelerate the cooled muon beams in the linear accelerator up to the required energy and make them collide in the sections with very strong focusing in a special ring with magnetic field as high as possible in order to increase the number of collisions during the life-time of the muons. Evaluations have shown that this way would enable one to achieve the satisfactory luminosity of the order 10^{31} cm^{-2}s^{-1} at energies of hundreds GeV.

13. In conclusion, a rather trivial truth could be expressed: high energy physics nowadays not only advances rapidly but it is at the stage when qualitatively new accelerator and instrumentation possibilities are about to appear and their use will have crucial influence on elementary particle physics progress. The progress toward this goal is undoubtedly the main result of the efforts of our high energy physics community. But the use of current achievements becomes also more and more important for solution of applied problems put at present in front of us all.

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DISCUSSION

Q1: Wallraff, RWTH Aachen: Would you please show again the numbers on the mass of the Ψ and Ψ' measured at Novosibirsk?

Q2: Schuler, Yale: Do you know of anyone who has tried the "Siberian Snake" experimentally?

A2: (no response found)