УДК 539.143/144; 539.182/184

I. M. DREMIN[1], *G. G. SAYDULLAEVA*[2]

PHYSICS AT THE LHC

Physics goals of studies at the Large Hadron Collider (LHC) are very compelling. Four major experimental installations are ready to compete in obtaining and analyzing the data from high energy hadron collisions. One hopes to get the answers to the very intricate questions ever asked. They concern the most fundamental problems of the matter, its main forces and space structure. The design of the LHC and its four detectors are briefly described. Then were view main facts revealed during previous years by experimentalists at other accelerators. The most hot topics and the stage-by-stage plans for LHC studies are discussed. Further perspectives in high energy physics are briefly mentioned.

1. Introduction. The high energy frontier ever reached in particle collisions at accelerators will be moved farther to the completely new region of energies of several tera-electron-volts (TeV) with the advent of the Large Hadron Collider (LHC) at CERN. High energies admit us to study the properties of space at smaller scales. Each step in this direction used to lead to new fundamental discoveries. That is why the data of experiments at the LHC are awaited with such an impatience.

The modern theory of forces of the nature called the Standard Model is very powerful. It is able to describe many experimental observations and has a predictive power. New ways beyond the Standard

Model [1] are also looked for, however. The experiments at the LHC may show which way has really been chosen by the nature and, moreover, find something that has not been predicted. The principles of symmetries and invariance are at the heart of all approaches. Among the most disputable problems are the origin and variety of masses, the structure of the physics vacuum, the abundance of types of matter particles in the universe, a unified description of fundamental forces including gravitation, possible existence of supersymmetric partners of all observable particles and of extra dimensions of space-time.

Here we briefly review the design of the LHC and its detectors, the major physics findings at previous accelerators, the principal goals of LHC experiments, their initial and further steps as well as the general perspectives of the high energy physics [2].

There is no reference to the existing literature because the papers are enormous and can be easily found in Internet and physics journals starting, for example, with popular articles in CERN Courier (especially, in September-November 2008 issues).

2. The LHC design. The LHC [3] is designed to collide head-on beams of protons each with energy 7 TeV or at total energy 14 TeV at the center-of-mass system (equivalent to about 10^{17} eV at the rest system of one of the protons) and ion beams at total energy 5.5 TeV per nucleon. The beams circulate in opposite directions around the 27 km circumference tunnel 50 to 175 m underground crossing Swiss and French borders near Geneva.

The 1232 superconducting dipole magnets of the length 14.3 m and the weight 3.5 T each with two apertures inside (one for each of the counterrotating beams) bend the beams. They are to produce a magnetic field up to 9 Tesla. The maximum magnetic field imposes the upper limit on the particle energy at a given geometry. The magnetic lines surround the two apertures in the shape of ∞ to guide the bunches in opposite directions. The magnetic fields are created by the electric currents up to 11.7 A in the superconducting cables of the total length 7600 km and weight 1200 T. Every cable is made of 36 strands of superconducting wire each of which contains 6300 superconducting niobium-titanium filaments. The total length of filaments is about 5 forth-and-back distances to the sun (10 AU). The magnets should be well fixed because at the full magnetic field the force loading 1 m of a dipole is about 400 T.

The magnets operate at very low temperature 1.9 K and pressure 10^{-10} Torr. The liquid helium and high vacuum are necessary to operate at designed values of temperature and pressure. Up to $1.2\cdot 10^{7}$ liters of liquid nitrogen are needed for the initial cooling of the machine and up to $7\cdot 10^{5}$ liters of liquid helium for further operation. About 40 000 leak-tight pipe junctions must be well controlled. Moreover, the machine also incorporates more than 500 superconducting quadrupole magnets and more than 4000 superconducting corrector magnets.

Building the LHC is a very challenging technological project that has no counterparts up to now. It is also at the frontier of characteristics important for experimentation. Besides the highest energies, the LHC project is aimed at very high luminosity of 10^{34} cm^{-2}s^{-1} (with the initial operation at the luminosity about 5 times lower). To appreciate importance of high luminosity, let us consider a simple example. A collider operates usually about 10^{7} s during a year so that the integrated luminosity per year is estimated as 10^{41}cm^{-2} or 100 fb^{-1}. The total cross section of interaction of colliding protons is estimated about 80 mb = $8\cdot 10^{-26}$ cm^{2} (and about 60 mb for inelastic collisions). Thus, in principle, there could be $8\cdot 10^{15}$ events per year. There will be thousands of particles created in most of them. It is clear that no electronic and computer systems will be able to read all the data and store them. However, the high luminosity is crucial for studies of rare events with very small cross sections. Namely such events will become most important for new physics searches. With good triggers (i.e. selection of events according to the prescribed features) one can get about 100 events with very low cross section 1 fb during a year. Therefore the detector systems should contain very good triggers which reduce the original crossing bunch rates to the rate of much less abundant interesting events and reject all others. Thus the large LHC luminosity is required for studying the processes with low cross sections. For processes with larger cross sections the lower luminosity is sufficient. It can be achieved by different methods (e.g., by defocusing the beams at the collision points as is done at LHCb).

3. Detectors and collaborations. The four major detectors named ATLAS [4], CMS, ALICE [5] and LHCb will register the products of beam collisions created at the interaction points. Correspondingly, there are four main international collaborations of physicists dealing with them. The number of participants in the biggest ATLAS collaboration exceeds 2000. These detectors and collaborations are both competitors and allies in searches for new physics. Time will compare di?erent choices.

The largest detectors ATLAS and CMS have been designed to record both pp and AA collisions. ALICE is more specialized on AA interactions even though some work on pp will be also done there. LHCb detector has a special design aimed at registration of events with b-quarks involved. Beside four major detectors there are smaller subdetectors called LHCf, TOTEM, ZDC, FMS, roman pots, CASTOR and FP420 (the last one still waits for the approval). They will work in combination with some of the main detectors and are aimed at recording the particles produced at small angles. Therefore they are placed at large distances up to several hundred meters from the collision points of the main detectors along the beam direction.

The sizes of main detectors are really impressive. The height of ATLAS is 25 m (about the height of 8-store building), its length is 46 m and it weighs 7000 T. It is necessary to host all the trackers and calorimeters and cover as large region of angles as possible to record the produced particles. With uniform azimuthal coverage, it is attempted to detect the particles produced at polar angles и as small as a fraction of the degree with respect to the incoming beams. In terms of the pseudorapidity $\eta = -\log[\tan\theta/2]$ it means that the region up to $\eta = 5$ will be available. However, the different detector elements can cover different regions in pseudorapidity, and particular physics measurements can be done with different accuracy depending on physics selection. The forward subdetectors extend the available range of the angles up to pseudorapidities as large as 9, i.e. to angles of the order of 10^{-2} degrees. It is important to detect these particles not allowing them to be captured inside the accelerator tube with the main stream of protons. This asks for special technical solutions of the problem.

The detectors are shaped like cylinders ("barrels") to surround the interaction regions by the uniform magnetic fields. Their segmentation should be fine to avoid overlapping signals. No charged particle should escape unseen. Many paticles move almost along the beam direction. "End-caps" of the major detectors and "forward" subdetectors provide the coverage of this region. There are several trigger levels.

There is some specifics in the beam structure. The beams are not the homogeneous streams of protons inside a pipe but are composed of bunches following each other at the time intervals of 25 ns or at the distance about 7.5 m which is much shorter than the detectors lengths. Therefore the bunch crossing rate is 40 MHz that effectively will be reduced to about 30 MHz. Most protons in a bunch do not interact at a crossing point and continue their motion along the accelerator pipe. Even then each bunch crossing gives rise to about 20-40 proton-proton interactions within a very short distance along the beam trajectory inside a detector. The trigger systems should distinguish separate scatterings and, moreover, choose those which are of physics interest. Due to the limits imposed by electronic and computer systems, there should be left 100-200 events per second to record and store them. Thus the triggers must be very fast, specialized, suitable for detector purposes, reprogrammable in case of changing physics requirements and radiation resistant because of huge flux of charged particles.

The magnetic fields in detectors are necessary to bend the charged particles produced. They areupto2 Tesla inATLAS andupto4 Tesla inCMS. The curvatures of particle trajectories tell us about their momentum and their nature (masses). This is the main information one gets about a particular process. The detection technique is based on properties of interactions of charged particles with matter inside the detector. The overall design of ATLAS, CMS and ALICE detectors is somewhat similar while LHCb is more forward-oriented to pay special attention to the forward-moving b-quarks. The central region closest to the beam interaction point is filled by tracking systems to determine the particle trajectory and measure their momenta. Then follows the electromagnetic calorimeter which absorbs electrons and photons and measures their total energy. Since hadrons are absorbed at larger lengths, the hadronic calorimeter is placed at ever larger distance from the interaction point. Muons are even more penetrating particles. Therefore, the layers of muon detectors are positioned at the outskirts of the whole system.

The inner detector systems are based on silicon pixel detectors covering about 2 m^2 at the radii as small as 4.5 cm and silicon micro-strip detectors at larger ones (20-55 cm). They are well segmented to follow accurately the particle motion and provide enough precision in detecting the track position. ATLAS has in addition the transition radiation tracker (TRT) which uses the effect of transition radiation of charged particles (at radii from 56 cm up to 1 m). It is effective in separation of electrons from hadrons and provides a large number of tracking points (about 30 -40 per a track). This system allows continuous track following, identification of the nature of produced particles and measurement of their momenta as well as the reconstruction of primary and secondary vertices of decays and interactions. Special attention has been paid for materials used in this system to be radiative resistant in view of huge fluxes of charged particles especially dense at small radii. It is also crucial for the electronic system which gets all the information from the detector system and transfers it to computers.

Then follow the calorimeters that absorb and measure the energies of electrons, photons and hadrons. They contribute their part to triggering signatures of events suspected, in particular, for new physics signals. The ATLAS electromagnetic calorimeter consists of layers of lead and liquid argon while in CMS the high-density crystals are used. The energy of electromagnetic showers developing in the high-density matter is measured. The hadron calorimeters surround the electromagnetic calorimeters and measure the energy and directions of hadronic showers (especially, jets) as well as the missing energy which can be related, e.g., to neutrinos, undetected neutral particles etc. The last outposts of the detectors are the large-area gas-based detectors used in muon systems at the periphery to identify muons and measure their momenta. Their work is synchronized with the whole trigger system. Moreover, some systems provide independent momentum measurements and admit cross-checking.

Dealing with such elaborated systems asks for high qualification of physicists who must understand and calibrate the various parts of the detectors. Surely, there are some special problems in each of them. For example, the high priority in LHCb is given to very precise determination of the decay vertices that defines the accuracy of the data about B-mesons. Similar problems exist in each detector. What is in common, their tests with cosmic ray showers must be performed for their calibration to get the initial startup.

A vast amount of the computer power is needed to select, store, distribute and analyze the information which will come from the LHC (tens of petabytes per year). Therefore, the special project (GRID) including sites all over the world is developing. It relies on many "Tiers"-levels (0, 1, 2) which compile the raw data, process and reconstruct it (0), share it with the experiments physics analysis groups (1) with de?nite trigger paths and use it for comparison with Monte Carlo simulations and further analysis (2).

All this shows how complicated are the problems confronting engineers and physicists even before the experimentation starts. It became especially clear in September 2008. The very first attempt to operate the LHC was on 10.09.2008. It appeared to be extremely successful. The ?rst interactions in the detectors were recorded. Even some preliminary data on distributions at lower energies were compiled. More impressive for specialists was the demonstration of the well controlled shape of the beam bunches. The ability to operate the LHC at somewhat lower energies and intensities has been demonstrated. However, the further attempt to reach higher energies and luminosities on 19.09.2008 failed. An incident occured because of a large helium leak in the LHC tunnel. According to the CERN Courier "preliminary investigations indicate that the most likely cause of the problem was a faulty connection between two magnets, which probably melted at high current, leading to a rupture of the helium vessel and the release of high-pressure gas into the cryostat. The gas then discharged into the tunnel through the pressure-relief valves designed for this purpose". It would be very unlikely if no problems appeared at all because "the LHC ... has been built at the cutting edge of technology ... with unprecedented complexity". The LHC restart is planned in the second half of 2009 after the tunnel is warmed up and everything repaired. Surely, initial values of energy and luminosity will be lower than prescribed ones. Pragmatic physicists are not very disappointed, however. According to the spokesman of ATLAS P. Jenni "this will already give us a lot of data to calibrate, as well as understand all the subdetectors and the chain of data preparation and analysis. Before any discovery can be claimed we ?rst have to show that the known physics is reproduced and that the detector performs well". The LHC inauguration was held at CERN on 21.10.2008. In December 2009 the world record for energies at accelerators 2.36 TeV was achieved.

20 member states of CERN and 5 non-member states (including Russia) with observer status

contribute to the LHC project. Russian institutes participate at each stage of this work. This includes the design and construction of the accelerator and detectors, transfer line from the SPS to the LHC, equipment and materials supply, radiation studies, programs of detector calibration, development of programs of physics researches, online and off-line processing of forthcoming data, participation in all LHC experimental collaborations and theorists contacts.

4. What has been learnt from previous studies. Before discussing the scientific program of the LHC let us briefly discuss what has been done at major particles accelerators built earlier.

The SPS accelerator in CERN serves now mostly as the injector of beams with energy up to 450 GeV to the LHC. Among its major observations are precise measurements of general characteristics of hadron interactions at energies up to 540 GeV (total cross sections, real parts of the forward scattering amplitudes, diffraction processes, inclusive distributions, correlations etc) as well as the first indication on collective effects in ion-ion collisions which lead to the notion of the Quark-Gluon Plasma (QGP). Nowadays, it is also the source of the neutrino beam sent to Gran Sasso laboratory in Italy and some experiments on fixed targets are still going on in CERN (e.g., measurements of dilepton spectra etc).

Let us mention that the LHC uses the tunnel first built for the Large Electron Positron (LEP) accelerator to get colliding electron-positron beams with energy up to 200 GeV. The LEP accelerator was extremely successful. The quark and gluon jets were first observed and studied in detail there, the QCD coupling constant б*S*and its scale dependence were precisely measured (at present accuracy *бS*(*MZ*)= 0.1176 ± 0.002), the carriers of weak forces W and Z-bosons were discovered and studied, the lower limit on the mass of the Higgs boson (114 GeV) was imposed, not to say about many other achievements. It is closed now and its place is used by the LHC.

Another recently closed accelerator HERA in Hamburg used the electron-proton colliding beams with 27.5 GeV energy of electrons and 920 GeV energy of protons. This enabled physicists to study the so called structure functions of protons, i.e. to dissolve the quark-gluon content of high energy protons. Most important findings concern the increase of the number of soft gluons contained in the proton cloud and its energy dependence (the scaling and its violation).

Most close to the LHC in energy and the nature of colliding partners is the TEVATRON at Fermilab near Chicago. The proton and antiproton beams collide there with the center-of-mass energy up to about 2 TeV. Each of them by itself can be considered as the bunch of quarks, antiquarks and gluons distributed according to the structure functions. Thus it is the source of *q*.

q, gg, гг and *г*-Pomeron processes. The studies of masses and widths of W, Z-bosons and the top-quark were especially intensive and fruitful (the approximate values of their masses are correspondingly 80.4; 91.2; 172 GeV). The limits on the mass of the Higgs boson were imposed. QCD jets and large p*T*processes were studied in detail. Some surprises come from there even now (recently recorded multi-muon events?). All these processes will be studied at the LHC with better precision. The statistics of similar events (e.g., jets with the same energy) will be about 10^3 times larger at the LHC than at TEVATRON during the same sampling time.

5. Main goals of the LHC experimentation. As always, the major task of the LHC experimentalists will be to find something yet undiscovered. The theory provides some hints to it.

The primary attention is paid nowadays to searches for the so called Higgs boson. It lies at the basis of the ideas about the origin and variety of masses. In theory, the origin of mass is ascribed to the exchange by the Higgs boson. We do not yet understand why the masses of the most ”elementary” constituents of the matter differ so strongly. The mass of the top-quark is 10^{14}times larger than the neutrino masses (!), not to say about the zero mass of the photon.

The ways to search for the Higgs boson are determined by various production channels and decay modes of this particle. The most probable interval of masses of the Higgs boson is 120±6 GeV as given by the modern theory. The forward subdetectors would allow to study the central exclusive processes of Higgs production (in this range of its masses) by separating events with large pseudorapidity gaps between the two final protons. The ”golden” decay mode of Higgs to two Z bosons each of which decays to two muons is preferred at masses above 200 GeV. Namely search for this mode determined in early days the design of ATLAS and CMS detectors and their proportions. ATLAS is longer than CMS but with much lower magnetic field. This is determined by the requirement to measure the muon momenta with at least 10 percent accuracy. The relative error in measuring the momenta is inverse proportional to the magnetic field and to the square of the track length inside the detector. One has also to record photons, bottom quarks, tau leptons to get the convincing signal. If it happens that the Higgs mass is of the order of 1 TeV, then one should consider the decay modes with production of W, Z and jets in various combinations. The increase of the number of the available channels leads to the noticeable increase of the Higgs width. We do not know yet whether there exist one or several Higgs bosons, have they any internal structure and do they overlap in masses with the general increase of the widths that might lead to problems in distinguishing them from the background.

Another important line of searches are supersymmetric partners (sparticles) of the already observed particles. They are predicted theoretically as the corollary of the statement about possible supersymmetry of the world. These particles must be very heavy due to some violation of the supersymmetry and have not been yet recorded. Their experimental signatures are defined by their heavyness. The cross sections for beyond the Standard Model processes are estimated to be in the range of femtobarns to picobarns.

In general, new very heavy resonances must be looked for.

The experimental program of the LHC includes also the "old" QCD-processes such as inclusive processes, jets, top-quarks, B-mesons or mesons containing both bottom and strange quarks, dilepton spectra, collective effects in ion-ion collisions etc. The LHC can be called a "heavy-quark" factory because the cross sections for bb pair production is of the order of 1 μb and for top-quark production of the order of 1 nb. The forward detectors can help clear up the cosmic ray problems, e.g., by calibrating the hadron interaction models used for description of extremely high energy cosmic rays.

Surely, one waits especially for ?nding something completely new and unexpected as it often happened previously when new energy region became available.

From the theoretical side, the most intriguing problem is the structure of the physics vacuum. It is believed that the broken symmetries play a crucial role in our world. The ideas widely used in superconductivity (recall the Ginzburg-Landau potential!), ferromagnetism and many other problems of condensed matter are, actually, at the origin of Higgs, supersymmetry, CP-violation etc in particle physics. The complicated structure of the physics vacuum with many minima (like an oldfashioned washing board!) and special asymmetries is blamed for numerous effects. It is not well understood up to now. It is believed that the physics vacuum is not empty but filled in by the scalar Higgs fields.

There are many unexplained facts in the framework of the Standard Model. In particular, we do not have answers to such questions as why there are exactly three generations of quark-lepton families, what lies at the origin of their masses and where major forces converge.

The registration of decays of the Higgs boson at the LHC would imply that we are on the correct way in revealing the mass puzzle. At the same time it will open many new questions of whether it is single (nowadays, this possibility is considered as rather unrealistic and disappointing) or there are other Higgs bosons, or there are composite Higgs fields. The proportionality of Higgs coupling to masses should be carefully looked for by searching for different decay modes. Higgs fields are related to such astrophysical observations as dark energy (or to the cosmological constant of the gravitation theory, in the theorists terms).

The fundamental supersymmetry can show up at the LHC by recording the lightest sparticles, e.g., such as neutralino or gravitino. Supersymmetry pairs fermions with sbosons and bosons with sfermions. The radiative corrections due to pairs of virtual fermions and bosons cancel in supersymmetric theories. There is no such pairing in the Standard Model. This is the way out of it. It asks for sparticles to exist. This is a completely new world. If found, it will provide a natural candidate for explaining the dark matter and facilitate the unification of the fundamental forces of the nature.

Another way beyond the Standard Model is opened by the idea about extra dimensions of space. These additional dimensions can be curled up so that they were unobservable up to now but, may be, will become noticable at energies exceeding 1 TeV. This happens in some variants of the string theory. In particular, the gravity might become strong and microscopic black holes might be created in collisions at LHC energies. The new world of Kaluza-Klein particles[2]might appear.

What concerns CP violation, we are sure that our description in terms of the 3x3 CKM-matrix is main-ly correct. However, we should understand deeper why namely 3 generations of quarks and leptons are chosen by nature. More precise measurements of the angles of the unitarity triangle are needed. There should exist additional sources of CP violation to explain the cosmological matter-antimatter asym-metry. These might be the yet undiscovered heavy particles. The data from ATLAS, CMS, LHCb can contribute to the solution of this problem by measu-ring the rare B-meson decays. For ATLAS and CMS this is one of the experiments where high luminosity of the LHC is crucial. At the LHCb colliding point the bunches are even somewhat defocused, on the contrary. If the new particles are very heavy, it might happen that they are not directly seen at ATLAS and CMS but their virtual effects are discovered by LHCb.

New properties of the hadronic matter might show up in the new region of densities and temperatures provided by high energy of colliding nuclei at the LHC. The jump in energy density at the LHC is really huge (it is 28 times higher than at the RHIC and 300 times higher than at the SPS). This is important for understanding the behavior of the matter at these conditions and, therefrom, of the processes in the early universe when quarks and gluons were "free" and were not yet confined inside hadrons. The evolution of the collective effects with energy (when compared with RHIC data) might indicate the nature of transition from hadrons inside the nuclei to the quark-gluon matter during the short time of overlap of colliding nuclei before the final hadronization starts. Beside the hot and dense quark-gluon plasma, the search for the cold and dense color glass condensate (CGC) is very promising to discover new aspects of the fields described by QCD.

The problems of very small and very large distances intermingle in the LHC studies. Our understanding of fundamental forces and their unification at very high energies and very small scales is crucial for theories of universe both at the initial stage and at present. Such topics as the dark matter, dark energy, black holes are widely discussed in connection with LHC experiments.

6. Initial period of LHC experiments. After the incident with helium leakage, the LHC schedule was changed. New attempts to get the beams of protons at designed energy and somewhat lower luminosity will start in the middle of 2009. If they turn successful, the experimentation will start soon afterwards. Some time will be needed to check all the systems of the detectors, to understand and calibrate them. Their response at low intensities is checked with cosmic rays already since 2006. The response to physics signals at high luminosity will be first tried with effects well known from minimum-bias events with relatively low momentum particles in the final state and jet events where a single high-momentum jet is produced with other remnants of a proton forming the underlying event. The inclusive characteristics will be measured. Then other Standard Model processes like W, Z and top-quark production will be studied. More accurate values of masses of W, Z and t obtained by ATLAS and CMS might enable to estimate the Higgs mass with high precision within the Standard Model. It will be confronted with results on radiative corrections supplied by LHCb. All this is also needed to establish the correspondence to results obtained at lower energies.

Only then the searches for Higgs boson must begin. They will require very careful separation of special signals (like two-photon modes of its decay) from many different signatures coming from other sources. Various channels of its production have also been considered. The estimates show that for smallest masses the integrated luminosity about $5fb^{-1}$ is sufficient so that such Higgs can be detected soon but analysis will take more time.

The situation with sparticles depends very much on the values of their masses. For example, if the mass of the gluino is less than 1.2 TeV, then even 0.1 fb^{-1} of integrated luminosity will be sufficient for discovery claims after the careful analysis. Clear indications might be obtained by LHCb where measurements of processes strongly influenced by virtual radiative corrections due to supersymmetric particles might go ahead of their direct detection. Optimists say that we can wait for important news coming after several months of stable running of the LHC if we are lucky with mass values being low enough.

We hope that b-quarks studied at a greater detail at the LHC will tell us about intricate features of CP violation. This might solve the puzzle of the baryonic asymmetry of the universe.

Since a proton can be considered as a wide-energy-band source of partons various exclusive processes can be studied. For example, one can separate quark-quark, gluon-gluon and quark-gluon scatterings. The mutual interaction of Pomerons and their interactions with these fields are especially interesting. Strong electromagnetic ?elds of ions can lead to special effects like unexpected asymmetries in $\varepsilon - \varepsilon$ processes.

Above all, there are expectations for new unpredicted effects.

7. Next steps. Further direction of investigations at the LHC depends very much on discoveries of the initial stage. If found, Higgs will become the major attractor. Its characteristics like the mass, spin, flavor, coupling strength and its dependence on masses, CP-properties etc will be intensively studied with enlarged statistics.

The same will happen if, say, the gluino or gravitino will be discovered. The LHC luminosity admits studies of sparticles as heavy as 3 TeV according to some estimates. The cascade decays of such heavy sparticles can lead to the lighter ones (among them stau might be especially interesting). The different spins of the cascade partners can lead to special correlations and help in distinguishing between various possible theories (supersymmetry or extra dimensions) by observation of correlations of final particles. However, these are tiny effects and they will put a hard task for Monte Carlo models.

Physicists will be disappointed if no principally new effects found. Nevertheless, there are many interesting problems to be solved. They appear even now, e.g., from TEVATRON experiments with detection of unexpected and yet unexplained muon bunches far from the collision axis. The traditional QCD physics must become more accurate with higher order corrections understood and compared at higher energies. More precise determination of CKM matrix elements might reveal some new puzzles. The behavior of the hadronic matter in ion collisions at the LHC energies can be very far from simple extrapolations. In general, it is hard to predict which way from proposed by us is chosen by the nature or it will be absolutely new in this new energy region. We have to wait for experimental data coming from the LHC to get the answer.

8. Perspectives of high energy physics. Will the run to ever higher energies stop after the LHC? Surely, not, even though each new stage becomes more and more expensive and asks for principal technological and engineering improvements. It can be done only within large international collaborations.

The most foreseen possibility is to increase the LHC luminosity by an order of magnitude. This proposal is known as the SLHC. This will become especially appealing if some signatures of heavy Higgs are found during the nominal LHC running and it would be necessary to enlarge the statistics to get more definite conclusions. In general, it would extend the region of masses where one searches for Higgses, supersymmetry and extra dimensions. The electroweak effects and CP violation could be studied with greater precision as well.

Another ambitious project is the International Linear Collider (ILC). The electrons and positrons, moving along the straight trajectories, will collide head-on with the total energy 1 TeV. These collisions are simpler for theoretical treatment because electrons and positrons do not have such complicated internal structure as protons. The supersymmetric world can be studied with good accuracy and at larger masses. May be, the quest for energies of several TeV (the CLIC project) will come if sparticles with the ever higher masses must be studied.

These projects will compete with existing proposals of doubling the LHC energy (DLHC) or even enlarging it by a factor of three (TLHC).

The discussion and comparison of these possibilities is going on already now. The real conclusions can be finalized only after the LHC will provide experimental information about all the key questions raised above. The future of high energy physics strongly depends on the LHC results. Sooner or later, these possibilities will become a reality (may be, in a somewhat different form) because it is in the nature of human beings to try to learn as much as possible about the structure of the surrounding world and its major forces.

REFERENCES

1. *Dremin I.M., Kaidalov A.B.* // UPhN. V. 176. P. 275 (2006).

2. *Dremin I.M.* UPhN. V. 179. P. 571 (2009).

3. *Petrov V.A., Ryutin R.A.* // European Phys. Jour. C. V. 65. N 3-4 (2010).

4. *Batuson V., Budagov Yu.* and et. al. // Phys. Particl and Nucl. Letter. V. 6, N 4 (2009).

5. *Wang F., Wang W., Xu F.* // European Physics Jour C. V. 51, N 3 (2007).

Резюме

Үлкен адрондық коллайдердің физикада зерттеу мақсаты түсініктірек. Жоғарғы энергиялы адрондардың бір-бірімен соқтығысудағы мәліметтерді негізгі үлкен төрт эксперименталды құралдар арқылы алады, олар бір-бірімен жарысуда. Ең күрделі сұрақтарға жауап аламыз деп үмітенеміз. Үлкен адрондық коллайдердің және оның төрт детекторының конструкциясы қысқа жазылған. Ең қызықты тақырыптар және Үлкен адрондық коллайдерді зерттеу кезеңді жоспары талқыланған. Жоғарғы энергиялы физиканың болашағы қысқаша еске алынған.

Резюме

Цель исследования в физике на Большом адронном коллайдере очень убедительны. Четыре основных экспериментальных установок готовы конкурировать в получении и в анализе данных столкновений адронов с высокими энергиями. Остается надеяться, что удастся получить ответы на самые сложные вопросы. Они касаются самых фундаментальных проблем материи, основные силы и структуры пространство. Конструкция БАК и его четыре детектора кратко описаны. Затем были замечены основные факты, выявленные в ходе предыдущих лет экспериментаторов на других ускорителях. Обсуждаются самые горячие темы и поэтапный план исследования БАК. Дальнейшие перспективы в физике высоких энергий, кратко упоминается.

[1]Lebedev Physical Institute, Moscow
119991, Russia;
[2]Al-Farabi Kazakh National University,
Almaty, Kazakhstan

Поступила 20.01.10г.