Development of high energy and cosmic ray physics in Kazakhstan

E.G. Boos, I.A. Lebedev,

A.A. Loktionov, T.KH. Sadykov

- In the Republic of Kazakhstan from the middle of last century researches are successfully developed on inelastic interactions of elementary particles and nuclei at the energies, achievable in terrestrial conditions and in cosmic rays.
- The accelerating subject develops in close cooperation with the leading world physical centers: the Joint Institute for Nuclear Researches in Dubna - JINR (Russia), Institute for High Energy Physics in Serpukhov - IHEP (Russia), the European Center of Nuclear Researches – in Geneva - CERN (Switzerland), the German scientific center in Hamburg - DESY (Germany), Institute of technology in Karlsruhe (Germany). The physics of cosmic rays gained development in the International collaboration "Pamir".
- The main directions of researches are studying are the interactions of hadrons, nuclei and leptons with nucleons and atomic nuclei of heavy and light elements, an assessment of cross-section of resonant states of hadrons in high-energy interactions, investigation of spectra of primary cosmic ray particles, development of new techniques of energy estimation for particles of a solar and galactic origin, searches of particles of a dark matter.

- Unique advantage of the Institute of Physics and Technology of Science Committee of Ministry of Education and Science of Kazakhstan Republic (IPT) is possibility to research the inelastic interactions as in the field of accelerating energies, achievable in terrestrial conditions ($E \leq 10^{15}$ eV), and in wider range of energies ($E > 10^{15}$ eV), achievable in cosmic rays.
- In IPT the Tien-Shan high-mountain station of cosmic rays at the altitude of 3340 meters above sea level and intermediate station at the altitude of 1700 meters above sea level successfully operate.
- Results of researches are published in rating magazines on high energy physics. The president of National Center of Scientific and Technical Information A. Ibrayev notes that "the importance of the received results is recognized by world scientific community, and on a quoting of publications in prestigious physical magazines the group of physicists of institute takes the leading position among other domestic scientific institutions " (A. Ibrayev. How Kazakhstan scientists are quoted by foreign colleagues – Forbes.kz, on May 22, 2015).

- Much attention is paid to training of young scientists at a modern level of science development.
- The high energy physics (physics of particles) is a relatively young component of a problem "nuclear physics". It is considered as a first line of modern science, dealing with microcosm (a matter structure, nuclear and nucleon interactions) and a macrocosm issues (an origin and age of the Universe, astrophysics, cosmic rays).
- In Kazakhstan the idea to develop high energy physics belongs to academician of Kazakhstan Academy of Scienses Zh.S. Takibayev.
- Basic researches in this field of physics were directed on studying of properties of protons and antiprotons inelastic interactions with nucleons and atom[c nuclei, using the physical data obtained at irradiation of nuclear photoemulsions and bubble chambers on accelerators of the leading world scientific centers within the international collaborations: the French hydrogen bubble chamber “Mirabelle”, the international cooperation on the basis of bubble chamber “Lyudmila” and the spark streamer chamber “RISK” in JINR, cooperation ATLAS in CERN, and cooperation with DESY on the ZEUS detector.

- It is possible to note the most essential methodical and technological developments.
- − The new method of evaluation of primary particle energy in the assumption of constancy of secondary charged particles transverse momenta is presented, the scaling-invariant model of the particles production on the basis of the minimizing wave package is created.
- − The lifting device was designed which was successfully used in ATLAS collaboration for testing of the ATLAS detector elements in CERN.
- − The measuring-computing complex was created with the systems and devices developed and made at institute. Complex was a necessary link in the cycle of operation and analysis of experimental information.
- − The software for the measuring-computing complex was created which allowed to carry out the reliable analysis of experimental data.
- Actuality of modern problems of relativistic nuclear physics is defined by exclusive importance of problems of search and analysis of phase transition of substance from a hadron state to quark-gluon plasma. Traditional - until recently - point of view in this direction of researches considered that phase transition with deconfinement of hadrons will happen in collisions of heavy nuclei at high energies, creating the best conditions of high pressures and temperatures in volume of reaction. The programs of the international researches, realized at JINR, Brookhaven national laboratory – (BNL, USA) and CERN, significantly developed and improved understanding of problems of multiple generation of particles in interactions of nuclei. The modern picture of the main stages of the excited nuclear substance (fireball) formation and disintegration includes the initial stage of interactions which is defined by a parton condition of the colliding nuclei, creation a quark-gluon plasma and the mixed phase of a hadron matter, the subsequent stages of freezing, on which experimentally observed particles are formed.

- The new view on a problem was reached in theoretical researches (JINR) of the last five years, in which it was shown that the "mixed phase of the excited hadron matter", including both free quarks and gluons, and protons with neutrons is realized with the greatest probability at rather low energies, in the range from 4 to 9 GeV per nucleon in the center of masses system. Respectively experiments on Brookhaven's Relativistic Heavy Ion Collider (RHIC) were reoriented in the RHICII project on an interval of smaller energies around the first tens of GeV.
- In work on research of energy dependence of evolution of the excited fireball the comparative analysis of gold Au and lead Pb nuclei interactions with emulsion heavy nuclei Ag or Br at energies 10.7 A GeV and 158 A GeV was carried out on the basis of the analysis of experiments AGS and SPS. The method of nuclear emulsions allowed to estimate with high precision the key experimentally observed parameters of interactions: multiplicity ¨C number of produced relativistic particles in each event (mainly, pions) and pseudo-rapidity $\eta = - \ln tg\theta /2$, where θ - a solid emission angle of the corresponding track. The comparison of results on allocation of the central interactions of nuclei with nuclei of Ag or Br and the new results on the "forward-backward " multiplicity fluctuations in c.m.s. and on strong dynamical fluctuations allowed to gain physically more clear idea on processes of multiple generation of particles at these energies.

- The analysis of interactions of lead nuclei with primary energy 158 A GeV was carried out in the same way, as well as for collisions of gold nuclei at energy 10.7 A GeV.
- Results of the comparative analysis of the central and peripheral interactions of heavy nuclei Au and Pb with emulsion heavy nuclei Ag, Br at essential - fifteenfold - change of energy of primary nuclei from 10.7 to 158 A GeV allow to draw the following conclusions:
- In both experiments the central interactions are characterized by high multiplicity of events and high density of energy, which is proportional to $dN/\Delta \mid \eta = 0$.
- Both experiments are characterized by strong fluctuations of asymmetry and an excess of the psedorapidity distributions in separate events, with an essential deviation from a gaussian. Fluctuations are significantly higher for the central interactions of Au nuclei in AGS experiment in comparison with interactions of Pb nuclei in SPS experiment: fluctuations of asymmetry values are twice more, and fluctuations of an excess values ¨C three times.
- It is necessary to emphasize that increase of the "forward-backward " multiplicity fluctuations in c.m.s. is expected near the region of phase transition of substance from a hadron state to a quark-gluon plasma. It just the energy region of " Dubna glade", to which experiment AGS gets. On the contrary, experiment SPS goes far beyond this energy interval.

- Both experiments are characterized by collective type of a fireball disintegration into observed particles, at which the factorial momenta
- $< Fq (\delta) >$ don't depend on size of δ bin on sequence of being decreasing elements of phase space. Only for peripheral interactions of Au nuclei with significantly smaller energy density the weak component of cascade process of disintegration is observed.
- The tempting prospect of detection of the mixed phase of a nuclear matter caused not only a new view on a research problem of "the excited hadron matter", but also resulted now in new purposeful concentration of both theoretical, and experimental studies in this area.
- Available at our disposal data on interactions of nuclei with emulsion nuclei in a wide range of masses and energies allow to carry out actual researches of parameters of nuclei - nuclei interactions in a wide interval of change of entry conditions.
- Results of research of various characteristics of hadron-nuclei and nuclei-nuclei interactions at high energies in a wide interval of initial parameters are very important for search and the analysis of conditions, at which the emergence of quark-gluon plasma and mixed phase of nuclear matter is the most probable.

- The High-mountain Scientific Station of Cosmic Rays (HMSSCR) is located on the pass Dzhusaly-Kezen, at the altitude of 3340 meters above sea level in Tien - Shan Mountains and is intended for research of interactions of particles of cosmic radiation with ultrahigh energies, and also a number of applied tasks. The main task of scientific works is carrying out basic researches in the following areas:
- - astrophysics of ultrahigh energies;
- - cosmic rays;
- - monitoring of cosmic rays for the purpose of control and the prediction of space weather, studying of its influence on geo-and biosphere;
- - research of the storm phenomena;
- - prediction of earthquakes.
- The main experimental base of the Center is the multi-purpose “ATHLET” (Almaty Three Level Experiment Technique) complex, which consists of three distributed on heights of observation installations of the external air showers, located at different altitudes above sea level (3340 m - on HMSSCR, 1700 m - at the IPT Intermediate station and 850 m - in Almaty).


Тянь-Шаньская
высокогорная станция
(3340 м н.у.м.)
Промежуточная
станция
(1700 м н.у.м.)
КазГУ
(850 м н.у.м.)
КазНПУ
им.Абая

- Need of carrying out mountain researches of space radiation is dictated by the following circumstances:
- 1. At hign levels of cosmic rays registration especially exact information can be received about primary act of nuclear interaction as repeated interactions of particles of cosmic radiation in the thickness of the Earth atmosphere distort a true picture of the elementary act.
- 2. Enormous range of energies of cosmic rays allows to study nuclear interactions of extremely high energies, unapproachable on modern accelerators. The natural source of particles of such energies gives us such opportunity.
- 3. For increasing the number of superenergetic events it is supposed to the research complex, located on highlands, connect a net of the autonomous detecting points at some schools, colleges and universities of the Almaty city , and further of all RK, united in a uniform network on the basis of Internet. Implementation of this program will lead to the solution at once of two important problems.
- 4. It is important to research the opportunities of short-term forecasting of earthquakes on the basis of studying of connection of tectonic motions with solar activity and the whole set of variations of the cosmic rays caused by local change of Earth magnetic field in this region.
- 5. Space stations with their personnel and the equipment constantly are under the influence of many factors : electromagnetic radiation and influence of plasma of a wind from the Sun, cosmic rays and particles of radiation belts of Earth, etc. Often observed changes of intensity of these factors, especially during powerful flashes on the Sun, very significantly influence a condition of the equipment and the cosmonauts who are in an orbit. In this situation development of exact methods is necessary to predict and control of a condition of space weather, allowing to take a number of the preventive measures, reducing degree of the risk, caused by the changing situation in a space.

- 6. Very important question is research of the storm phenomena. HMSSCR is situated just at height of passing of clouds. With the advent of new technologies and communication systems new aspects of influence of lightnings on practical activities of the person are found. It is so far established that initiation of charge-lightnings is caused by space radiation. Researches at mountain stations of this terrible phenomenon will allow to choose methods of protection.
- Thus, continuation of research works at Tien-Shan alpine station and their development together with scientists of other countries will promote the statement of the Republic of Kazakhstan in the status of one of the leading countries of the world in research of cosmic rays physics.

- In Kazakhstan researches on high energy and cosmic ray physics are realized on the basis of the international cooperation with JINR, P.N. Lebedev Physical Institute of the Russian Academy of Sciences FIAN (Moscow), IHEP, DESY, Institute of technology in Karlsruhe (Germany). Involvement of the international organizations promotes to raise of the general level of researches, to use of new methodical development, leads to enrichment of domestic science. Implementation of development of cooperation assumes expansion of a bilateral exchange of experts, creation of base for training of young scientists and students for development of the best scientific practices.

Thank you for your attention!!!