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***PERSONALIA***

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# In memory of Aleksandr Evgen'evich Chudakov

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Aleksandr Evgen'evich Chudakov, full member of the Academy of Sciences, an expert in cosmic ray physics and elementary particle physics, died on January 25, 2001. Aleksandr Chudakov was born on June 16, 1921 in Moscow in the family of the academician E A Chudakov, a famous engineer and scientist, the founder of the car industry in the USSR. Having graduated from school in 1939, Aleksandr Evgen'evich enrolled in the Physics Department of Moscow State University (MGU), which he graduated *cum laude* in 1948 (his student years were interrupted by the Second World War).

A E Chudakov began to work at the Physics Institute of the Academy of Sciences (FIAN) in 1946 while still a student of MGU, in a group which was created to study cosmic rays using rocket launches. This work succeeded in measuring the intensity of cosmic rays outside the atmosphere and revealed the first bounds on the flux of gamma quanta with energies from 1 to 100 MeV. Using the technique of the so-called transition effect in thin lead layers, the group discovered that the primary particles (protons) generate the electron-photon component in dense matter. As a result, two years before the $\pi$-meson was discovered in accelerator experiments, the group concluded that the meson responsible for the generation of photons and electrons had a lifetime less than $10^{-9}$ s.

In 1949 Aleksandr Evgen'evich realized that the mutual screening of the electron and positron fields must reduce ionization at high energies for narrow electron – positron pairs. This phenomenon became known later as the Chudakov effect and in its time was used to measure the energy of electron – positron pairs when nuclear interactions were studied by photoemulsion techniques. It was understood much later that the effect was essentially universal and that it manifests itself in quantum chromodynamics as the screening of color charges of two quarks or gluons passing near each other. Incidentally, Aleksandr Evgen'evich published the paper describing this effect only in 1955.

In 1953 A E Chudakov started a study of the Vavilov – Cherenkov radiation of extensive air showers (EAS).

As a side research while preparing this experiment, Chudakov studied the 'ionization glow' — the luminescence of air due to an ionizing radiation. This effect was studied at various pressures and it was discovered that a low-intensity glow was observed after the air was completely pumped out of the vessel. Studying the nature of this glow, A E Chudakov introduced additional metal foils into the electron beam and concluded that the phenomenon that he discovered was the transition radiation which was produced when electric charges crossed the interface between two media. This was the first experimental confirmation of the transition radiation effect predicted in 1945 by V L Ginzburg and I M Frank. The 'ionization glow' in the air proved to be sufficiently weak, and usually it does not hinder the Cherenkov experiments;

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nevertheless, its isotropy allows, at least in principle, to record giant EAS at very large distances (of the order of several tens of kilometers). A E Chudakov was the first to formulate this suggestion, which was later implemented in the Fly's Eye detector in the USA and after that in several more systems.

The Cherenkov theme continued in the work of A E Chudakov with the creation in 1957 – 1960 of the first Cherenkov water calorimeter. It contained 100 tonnes of water and in its time was also the largest such detector. As almost always, Aleksandr Evgen'evich generated ideas and methods that were destined to have a long life and fruitful evolution. Gigantic modern underground Cherenkov water detectors like the Super-Kamiokande in Japan should be traced back to his detector.

In 1960 Aleksandr Evgen'evich together with G T Zatsepin suggested using the Cherenkov radiation of atmospheric showers to search for local sources of high-energy gamma rays of cosmic origin (with energies of the order of $10^{12}$ eV). Almost immediately, Aleksandr Evgen'evich pioneered an experiment in gamma ray astronomy and created the first

Cherenkov gamma ray telescope in Crimea, which operated in 1960 – 1963. This experiment was far ahead of its time. The design and construction of telescopes of comparable parameters began in the West more than a decade later. Chudakov's experiment was run at a time when objects emitting gamma radiation in this range of energies (pulsars and blazars) had not jet been discovered. Typically, radio galaxies were observed and no gamma ray sources were revealed. Nevertheless, this negative result proved quite important for the Crab Nebula since the upper limit yielded by the experiment was a proof of direct acceleration of electrons in this object.

After the first sputnik was launched in 1957, rockets offered new possibilities for studying cosmic rays, and Aleksandr Evgen'evich eagerly returned to this work. For a series of papers in this field A E Chudakov together with S N Vernov received the Lenin Prize for "The discovery and investigation of the outer radiation belt of the Earth" (1960).

In 1963 in connection with the decision to create the neutrino observatory of the Lebedev Institute of Physics in the Northern Caucasus (now the Baksan Neutrino Observatory of the Institute for Nuclear Research of the Russian Academy of Sciences) A E Chudakov began to work on an underground scintillation telescope project for studying the muons and neutrinos components of cosmic rays. The scintillation telescope was launched in 1978. By our current standards, the 15 years separating the draft plans from the launch date is a very considerable period, especially for experimental nuclear physics. Consequently we can only be amazed by the degree of flexibility and perfection of the initial design developed by A E Chudakov for this detector since, after the launch, it was not only able to deal with problems contemporary to the launch year but was found to be the best suited in the world for tackling problems that were not even contemplated by nuclear physicists at the beginning of the 1960s when the design of the scintillation telescope was started. The end of the 1960s revived interest in B M Pontecorvo's hypothesis on the existence of oscillations of various species of neutrinos. The intensity of the muon-neutrino flux generated when primary cosmic rays interact with the atmosphere of the Earth and passing through the entire thickness of the globe was measured by the scintillation telescope (it was the first ever measurement of the vertical neutrino flux) and made it possible to conclude that the intensity of the flux of these neutrinos does not vary significantly over a length of 10,000 kilometers; it was then possible to calculate the upper bounds on the oscillation parameters which for a long time were the best in the world.

The problem at the center of attention of elementary particle physicists in the mid-1970s was that of proton stability. Proton decay violating the baryon number conservation was the only prediction of the models that unified the weak, the electromagnetic and the strong interactions and could be experimentally verified. Such an experiment was run on the Baksan telescope after slight modifications in its design. The lifetime limit for nucleons with respect to neutrinoless decay channels was found to be above $10^{30}$ years (also the best estimate in the world at the time albeit not for long) which, together with subsequent experimental results, made it possible to reject the so-called minimal standard unification model which before that seemed to be a favorite.

At the beginning of the 1980s, several theoretical papers discussed a superheavy magnetic monopole so a search for this particle was launched. The Baksan telescope again proved to be the most suitable instrument in the world for this search. The upper limit obtained on the flux of the monopoles was the strongest for many years and remains such at this moment (the Italian – American experiment MACRO, which was designed specially for this problem, was only able to reach the level of the Baksan telescope but failed to improve it). In addition, Aleksandr Evgen'evich was the first to obtain the upper limit on the monopole flux, estimated on the basis of astrophysical arguments, so that the Parker limit mentioned in the literature should in all fairness be referred to as the Chudakov – Parker limit.

Later in the 1990s, when the huge interest in the dark matter problem stimulated a search for various particles suggested by theoreticians as candidates for this role, it was again found that the parameters of the Baksan telescope were among the best. By processing the Baksan data it proved possible to deduce the strongest bounds on the neutrino flux generated by neutralino annihilations (neutralinos: hypothetical particles of cold dark matter).

Chudakov's work was widely recognized. He was elected a full member and also a member of the Presidium of the Academy of Sciences of the USSR (now the Russian Academy of Sciences), received the Lenin and State Prizes. At various times he was a member, a secretary and the chairman of the Commission on Cosmic Rays of the International Union of Pure and Applied Physics. For 20 years he headed the Scientific Council on Cosmic Rays of the Russian Academy of Sciences. As a professor of Moscow University, he devoted many years to training experts in experimental nuclear physics. However, the role of A E Chudakov in the capacity of scientist stemmed not only from this. By his enormous range of activities he was hugely influential for many generations of physicists in the field of cosmic rays, for the formation of their approach to physics, their ideology of science and their research style. It should be emphasized that at the present moment, which is not the best one for science in this country, the time when staying abreast of the international trends and achievements is glorified as the greatest courage (but which in reality means stagnation at the rear of the leading group), it is especially instructive to look at an example of a scientist who was a pioneer in all his undertakings and as a rule stayed ahead of the world level by many years.

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