RIVNO NPP UNDERGROUND LABORATORY: THE RESEARCH OF PROPERTIES AND INTERACTION OF ELECTRONIC ANTINEUTRINO WITH PROTONS AND DEUTERONS FOR FUNDAMENTAL AND PLUTONIUM MONITORING

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ABSTRACT

The purpose of this paper is to discuss an existing infrastructure for fundamental research in neutrino physics and reactor physics. Until 1991, scientists of Russia's Kurchatov Institute conducted research in the underground neutrino laboratory at the Rivno NPP, in theUkraine. The opportunity exists to continue the development of neutrino experiments at this facility, using the existing infrastructure, including large-sized scintillation multidetector systems and the capability for automation of long term experiments. This approach will promote the integration of the Ukraine into the world scientific community, will help in developing new, highly qualified scientific staff, and will encourage the development of beneficial scientific technologies. The considerable applied significance of this work lies in a proven opportunity for monitoring critical parameters within the reactor environment.

1. INTRODUCTION

Ukraine after Chernobyl became very known nuclear energy derusty, in which more than half of the electricity is produced in atomic power stations. The site management system, which was previously (in the former USSR) a part of the central nuclear power system, is not active any more in newly independent states, and a new administrative system and scientific support has not been established in this short time in Ukraine. Here we present the situation with the underground neutrino laboratory at Rivno NPP, which was designed, built and utilized by the L.A. Micaelyan group from the Kurchatov Institute, Moscow[1-3].

This laboratory for performing experiments with the reactor neutrino was designed together with the NPP. The main section of the laboratory is located under the unit N2 of the Rivno NNP on a distance 18 m from the center of the core active zone (Figure 1). It was in 1982 that the experiments begun in this laboratory.

The peculiarities of neutrino measurements require detectors of large size and weight, and minimization and identification of a physical background noise. As the investigations were conducted with the reactor neutrino, the measurements were synchronized with the reactor operating cycles. Spectra of the reactor neutrino were measured during the reactor operation (during working campaign PWR, lock N2), while the background measurements were performed during the reactor shut-down period for refueling. The results of these measurements were base for a branch of the electroweak interaction efficiency.

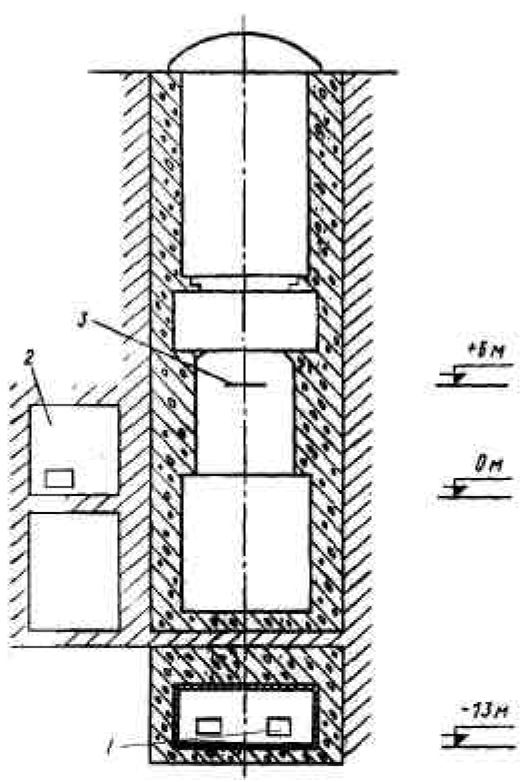

Figure 1. Scheme of the arrangement of the measuring equipment.
1 - scintillation detectors; 2 - location for ionization cameras; 3 - center of active zone

The main part of the detectors are tanks with transparent walls with volume of 1÷1.5 m^3, filled with heavy (D_2O) and light (H_2O) water. Volume of the tanks is examined by ~200 photomultipliers and their signals are processed by appropriate electronics and recorded on magnetic carriers during multiday time exposures.

2. FUNDAMENTAL INVESTIGATIONS

The fundamental goal is to perform the research of elementary particles properties (electronic antineutrino) and their interaction with protons and deuterons, structure of charged and neutral currents and fundamental constants of interaction in semi-leptonic processes. There are particularly interesting questions of neutrino physics concerning problems of neutrino mass and oscillations and its magnetic moment.

Last two problems have a chance to be solved exactly in experiments with reactor electronic antineutrino. A reactor is the most intensive source of the neutrino radiation on Earth. It is a by-product of its work. The power which neutrino carry away on a large reactor amounts to more than 120 Ì W, and flow of particles near device exceeds 10^{13} neutrino/cm^2s. This permits searching for phenomena which are outside of reference positions of standard models (anomalous magnetic moment, decay and oscillations of neutrino). For a long time, the Reines group in USA [4] was the only one involved in reactor neutrino measurements. Then there is connected by physicists of West Europe [5,6] and former USSR. At present measurements should be conducted on the international collaboration base.

Modern conditions of the research and knowledge of fundamental constants of interaction in the simple lepton systems define the real value of work under the project for Ukraine. It is connected with main result - realization of the neutrino experiments, as one of the most interesting areas of physics of elementary particles. The necessity of work realization is actually related with a huge need for determination and precise definition of constants, properties and parameters of interaction in semi-leptonic processes. There are interaction and reactions of electronic antineutrino with protons and deuterons, the knowledge of which is very necessary for development of the self-consistent theories of a matter structure.

3. REACTOR CHARACTERISTICS MONITORING

In an extremity of the 70-th years the difference of a spectrum an antineutrino for ^{235}U and ^{239}Pu especially in rigid range was shown in model calculations. It was followed by a long phase of searching of adequate models by comparisons them with outcomes of measurements. Burning out ^{235}U and accumulation ^{239}Pu determine changes of a spectrum an antineutrino for reactor campaign. The calculations have shown that the spectrum deformation makes from a few up to 10 %, therefore exact data on distinction of spectra an antineutrino and β-partiñle for ^{235}U and ^{239}Pu isotopes are necessary for a reliable prediction of the deformation.

The direct method of the definition of an antineutrino spectrum from nuclear reactor is based on a measurement of a spectrum of positrons and restoring on it of a spectrum an antineutrino. The measurements of a spectrum with a high exactitude become possible to the beginning of the 80-th years after development of a new generation of neutrino detectors and creation of the specialize neutrino laboratories.

The arrangement of the neutrino detector in one of Rivno NPP locations (*2* on figure 1) is shown on figure 2. The possibility of a measurement of burning out of nuclear fuel in reactor was proved in measurements of neutrino radiation [7].

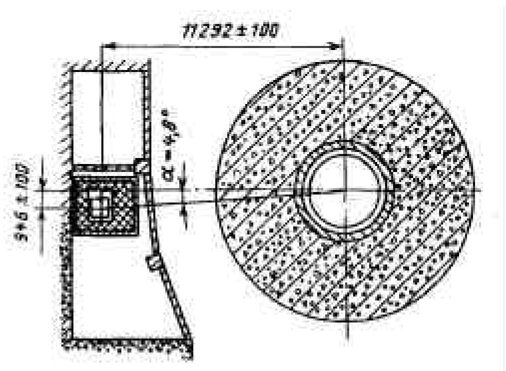

Figure 2. The arrangement of the neutrino detector for reactor monitoring.

Registration of the reactor neutrino gives performance to number of the nuclei that have tested fission and for producing of energy. From data of figure 3 it is visible, that the neutrino detector data follow a modification of a reactor power [8].

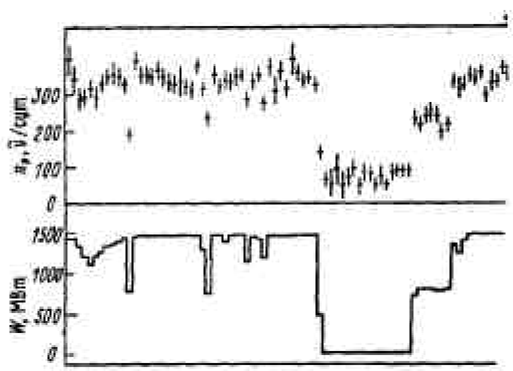

Figure 3. Neutrino detector data (above) and modification of a reactor power (below).

The flowing data of neutrino detector are reduced on figure 3(upper). There have included counts per day for 8 months phases of reactor work at various levels of a power and including phase of a reactor overload stopping. The daily average power has obtained from thermal measurements and is reduced on figure 3(lower).

Thus the neutrino radiation is directly connected to basic magnitudes which describe work of reactor. There are full number of fission acts in active zone and mass of the burnt fuel and full energy that had made. In this sense the neutrino method has advantages of a principal character. The neutrino method is distant on the nature. Its application does not require contact to active zone, tank or outlines of reactor. In this sense this application is safe, that can be especially essential, for example, in case of high-temperature installations.

4. COMPUTATIONAL GUIDANCE

Using equipment and systems, based on software, on nuclear power plants noticeably has been growing at last years, as a result of need to replace obsolete analogue equipment, so and as perfecting facility and ensure of satisfactory fitness level and safety. Software possible presently to find in applications in accordance with safety (for instance, protection systems), exhibits, refers to safety (control systems), as well as in exhibits not important for safety (for instance, data logging). The use of computers in nuclear power plants is not new. Computerized data collection systems and display systems given are used already for many years, and computers, most often as programmed logical controllers, are broadly used in exhibits for checking.

Computer based systems of starting the checking systems and safe working a reactor not so widespread, however are already carry in the formation in many countries. Exactly such computerized protection systems and their value for safety have caused an interest and have to dependencies of software and fairness of its integrity.

We consider important to present information about connecting to the computer accompanying of nuclear power installation. Very important is that this work is coordinated within the framework of international projects. The collaboration is in particular realized in the project on thermal and hydraulic calculations for nuclear blocks of Rivno NPP with 440 MW and 1000 MW power by means of RELAP5 Code [9]. This program already is long ago use in the world for the forecasting of operating lines of safe working a nucleus reactor. Qualifications for using this program is very important and certainly a necessity for the Ukraine’s nuclear energy industry.

CONCLUSIONS

This paper proposes a project of high scientific priority for the Ukraine. First of all, it promotes a greater role for the Ukraine in the world scientific community, along with the development of intensive bilateral exchanges, contacts, joint work and projects. Second, such work promotes and stimulates the professional growth of Ukrainian scientists. Third, a complete research capability will be created in new fields of fundamental science within the Ukraine, as well as new approaches toward applied technology research. Finally, this development will provide advanced monitoring technologies to support diagnostics and control of the operating parameters of nuclear power reactors.

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