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# MAIN RESULTS OF THE LABORATORY OF PARTICLE PHYSICS (LPP) IN 1997

Report to the 83rd Session of the Scientific Council of JINR
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# 1. RESEARCH ACTIVITIES AT IHEP (Serpukhov)

In the frame of the project **OSCAR** the investigations of charmed particle hadroproduction and properties are continued on the **EXCHARM** setup exposed at the U-70 accelerator in Protvino. At the end of the session more than 130 million $n$C and $n$Cu interactions were recorded. After that the first stage of data processing was accomplished using all the registered events. Total statistics is used to study hyperon and antihyperon polarization, as well as to investigate characteristics of charmed particles and models of their production to determine their cross-sections. Preliminary results have been obtained in observation of the double $\phi$-meson production [1]. Detailed measurements of the magnetic field in the spectrometer of EXCHARM set up have been performed [2]. The study of systematic errors in the given experiment is continued.

According to the experimental program on search for direct CP violation in $K \to 3\pi$ decays, the experimental run was performed at the Tagged Neutrino Facility (**TNF**). Processing of the obtained data on $K^+ \to \pi^0\pi^0\pi^+$ is in progress.

# 2. COOPERATION WITH CERN

The experiment **NA-47 (SMC)** has been completed. The events registered in the 1996 run with the polarized proton target in the kinematic range $0.0008 < x < 0.7$ and $0.2\,\mathrm{GeV}^2 < Q^2 < 100\,\mathrm{GeV}^2$ have been processed [3]. The statistical uncertainty of the measurement of the asymmetry $A_1^p(x)$ has been improved by a factor of 2 compared to the previous measurements of the SMC. The analysis of the data has been accomplished to determine the spin-dependent structure function $g_1^p$ for the data with $Q^2 > 1\,\mathrm{GeV}^2$. Using the results obtained on polarized deuterons, the momentum difference of structure functions $g_1^{p,n}$ has been determined:

$$\Gamma_1^p - \Gamma_1^n = \frac{1}{6}\left|\frac{g_A}{g_V}\right| C_1^{\mathrm{NS}} = 0.195 \pm 0.029 \quad (Q^2 = 10\ \mathrm{GeV}^2).$$

It was shown that the Bjorken sum rule is confirmed at one standard deviation level. A new analysis has been fulfilled using the data on the incident muon polarization measurements obtained by registering muon decays. It allowed to decrease systematic uncertainties in muon polarization $P_\mu$ from 5 to 2%. The QCD analysis done with all the published data along with the new SMC data on $g_1^p(x)$ measurements, made it possible to estimate the contribution of gluons $\Delta g$ to the nucleon spin-dependent structure function at $Q^2 = 1{,}0\,\mathrm{GeV}^2$:

$$\Delta g = 0.9 \pm 0.3(\mathrm{exp}) \pm 1.0(\mathrm{theory}).$$

The preparation of **NA48** setup has been completed. JINR fulfilled all its obligations on the experiment preparation. The first run was performed in 1997 to obtain experimental statistics for measurement of the ratio $\epsilon'/\epsilon$ in CP violating decays $K^0 \to 2\pi$. A fast algorithm of decoding the data from the liquid krypton cryostat (LKrC) was realized by the LPP specialists. The temperature dependence of the average pedestals and noises was investigated, and the sources of noises and errors

in photomultipliers of the charged hodoscope were studied. Precision of the LKrC calibration was checked and a possibility of the total LKrC calibration on the base of the $K_S$ anticounter coordinates measurement was estimated. Besides, the number of registered $K_L$ and $K_S$ mesons decaying into the neutral pions was estimated. Programs for the second level charged trigger and drift chambers monitoring were completed.

Within the works devoted to investigation of systematic errors in course of finding $\epsilon'/\epsilon$, some asymmetry of impact points in LKrC for $K_L$ and $K_S$ decay products was found and the programs to simulate the ratio $\epsilon'/\epsilon$ in CP violating decays were developed. All the used simulating programs were updated and the programs to select the signals in neutral and charged kaon decays have been developed. A possibility of tenzor formfactor measurement in $K_{e3}$ decays has been studied using the 1996 experimental data and the value of the vector formfactor slope $\lambda_+$ has been measured. It is in a good agreement with the standard Particle Data Group value. The analysis of $K_L \to \mu\mu\gamma$ decays has been performed.

According to the JINR obligations concerning the **ATLAS** set up, the copper absorbers have been manufactured and assembly of the fullsize module for the endcap liquid argon hadron calorimeter for ATLAS has been completed. Testing of mechanical and electrical properties under thermal conditions allows one to expect a high quality work of the manufactured device in the liquid argon cryostat in tests on the beam at CERN. Analysis of the experimental data obtained for the hadron calorimeter module prototype on the muon and electron beams has been performed at CERN. These results have shown that the developed detector fully meets the requirements to the calorimeter energy resolution defined as $50\%/\sqrt{E}+ 3\%$. In the frames of investigation on the influence of neutron radiation on the argon purity, the first part of the test – thermal tests, has been fulfilled. The pumped out container with 700 g of wolfram was exposed at the LNP to the neutron flux of IBR–2 reactor with the intensity of $1.5 \times 10^6\, n/\mathrm{cm}^2$. The residual gas was studied using mass spectrometer VS–25 (Vacuum, Prague), which enables to measure gas composition in the interval of atomic mass from 2 till 200. Measurements have shown that radiation does not cause changes of the gas production rate from the wolfram surface. The upper limit pollution of liquid argon can be estimated using these measurements at the level of $10^{-4}$. At present a specialized equipment is prepared to perform a cold test to study the pollution of liquid argon. A device has been developed, manufactured, and tested to measure temperature. It has been shown that the obtained accuracy of temperature measurements in the region of about 100°K is a part of one grade. An electronic scheme to compensate the difference in the volume of the read–out electrodes of the liquid argon hadron calorimeter, has been developed. This scheme will be one of the elements of the read–out electronics from the calorimeter.

Programmes of algorithms to search for the hadron flows and reconstruct their characteristics, have been developed and realized as well as to reconstruct the effective mass of $W$–boson from the decay into 2 flows for the hadron calorimeters of ATLAS.

A prototype of Transition Radiation and Tracking Detector for ATLAS was created and using it, thermal studies were fulfilled. An original method of integral



measurements of straw straightness was developed. The radiation of the prototype was performed on the testing beam at CERN.

In the frame of the **CMS** experiment preparation, the characteristics of separate detectors were studied and their joint operation was performed under the conditions close to a real experiment. Endcap is a substantial element of the CMS to be created as the commitment of JINR in collaboration of Russia and the JINR Member-States (RDMS). Multiware proportional chambers with cathode strip readout (CSC) were proposed as a muon detector for the CMS Endcap. A full scale prototype of CSC has been manufactured and tested with cosmic rays and prepared for tests with beams of SPS (CERN) [4]. Analysis of experimental data and modeling results made it possible to study an opportunity of using the first level information from CSC in the trigger and determine requirements to the trigger electronics. A digital algorithm to find a cluster center has been proposed and a prototype scheme has been developed to realize it.

Simulation of processes has been fulfilled where one hard photon with a big transverse momentum is produced as well as one hadron jet. The balance aspects of momentum characteristics of a jet and a photon have been studied. The contribution of the background processes has been defined and the criteria of selecting events have been formulated. The estimations have been given for the time of data taking which allows one to use these events for the hadron calorimeter calibration. For the same purpose an opportunity of using the process of the muon pair production from the $Z$–boson decay in one–jet events has been studied. The potential of the CMS setup was considered for physics research with heavy ions.

The work on technical design of the set up and preparation of a new experiment **COMPASS (NA58)** have been started. The LPP physicists take part in experimental programme devoted to study inclusive and semi-inclusive processes in deep inelastic scattering of muons on a polarized target, in particular, in the parts of the Proposal concerning the measurement of gluon contribution in the spin of nuclon, as well as detection of $\Lambda$ hyperons to test polarization of nucleon strange sea. For the experiment **COMPASS**, the hadron calorimeter (ferrum–scintillator sandwich) and the muon filter based on proportional tubes will be created at JINR. Tests of the modules of the hadron calorimeter was successfully performed at the CERN testing beams. Complete Monte Carlo simulation of the muon station was done. It allowed to optimize the construction of the muon filter.

## 3. COOPERATION WITH DESY

The Dubna group made an essential contribution to the first **HERMES** result on neutron structure function $g_1^n$ [5]. A new method to extract spin asymmetries and spin–dependent structure functions from polarized lepton–nucleon cross sections has been proposed and developed. The HERMES data obtained in 1995 with the $^3$He longitudinally polarized target from runs at HERA positron–proton storage ring, were taken for initial analysis. After applying data quality criteria and kinematic cuts ($Q^2 > 1\ (\mathrm{GeV/c})^2, W^2 > 4\ (\mathrm{GeV/c})^2$ and $y < 0.85$), about $2.7 \times 10^6$ events were available for the asymmetry analysis. The final result on value of the first moment

of structure function $g_1^n$ is found:

$$\Gamma_1^n = -0.037 \pm 0.013\,(\text{stat.}) \pm 0.005\,(\text{syst.}) \pm 0.006\,(\text{extrapol}).$$

Studies of systematical uncertainties on $A_1^n$ were performed using the new method for asymmetry extraction. It was shown that systematical effects, due to instability of the dead time of the spectrometer and reconstruction efficiency, do not exceed 1%. Special studies were done to show that systematical effects on $A_1^n$ over $Z$–coordinate of the reconstructed vertex can be also neglected.

According to the JINR commitments, LPP has started mass production of drift modules from pocalon-C for the external tracker of **HERA–B** set up aimed at studying CP–violations in $B$–meson decays on the channel $B^0 \to J/\Psi K_S^0$. A production area has been prepared consisting of 6 lines to manufacture 6 modules per week from the materials supplied from Germany. There is the equipment in this area to obtain preliminary prepared foils of semihexogonal form and their following gluing. After manufacturing all the modules are tested on the stand in cosmic rays to measure drift characteristics, efficiency as well as spatial and time resolutions. Study on chamber aging is performed for operation under a very high background. The LPP physicists also participate in the development of software for modeling and data processing in the experiments at HERA B and, first of all, to describe geometry, modeling, and digitizing of the outer tracker.

The works, devoted to upgrade the forward proton spectrometer (FPS), were made in LPP within the **H1** experiment to investigate deep inelastic scattering of electrons on protons. Position sensitive photomultipliers have been developed, produced, and tested. These photomultipliers are used as readout devices for scintillation fiber hodoscopes in two new horizontal detection stations of FPS. The installation and tests of the horizontal detection stations have been also performed. The JINR specialists participated in FPS tests, operation, and data analysis during the H1 experiment.

The works, devoted to upgrade the forward hadron plug calorimeter of H1 set up, are listed below:

– construction and tests of the plug calorimeter prototype (copper scintillator sandwich) in electron and $\pi$ meson beams at the Serpukhov accelerator.

– selection and tests of the plug calorimeter readout system in positron beam at the DESY synchrotron,

- production and tests of fine mesh photomultipliers resistive to magnetic field as readout devices for scintillator layers in the plug calorimeter.

## 4. OTHER EXPERIMENTS

A technical project of the mechanical and optical parts of the End cap Electromagnetic Calorimeter (EEMC) has been prepared for **STAR** experiments on polarised proton beams at the RHIC collider (BNL, USA). Several modifications of the attachment system of the 30-degree modules accounting for "butch plate" element were designed and proposed. The fiber routings inner and outer the 30-degree module were developed. A new more effective system of the optical readout pattern



for EEMC tiles was proposed and tested. Monte-Carlo calculations were made to investigate the parameters and response of the designed calorimeter.

For research on physics of neutrino at small energy, the detector **BOREXINO** – spectroscopical detector of high radioactive cleanliness – will be constructed at the underground laboratory in Gran Sasso, Italy. As a preparatory phase of the experiment, a 3 dimension prototype of set up (CTF) was created with a scale 1:100 for surveillance radionuclide quality of clearing materials. The registration system of cosmic muons of high energy has been installed and the veto system for the trigger has been introduced. Study of background structure and its sources was continued. To achieve high radiopurity, methods and strategy of removing radioactive impurity, dependent of the physical and chemical forms of impurities, were developed: extraction by water, vacuum distillation, application of ion-exchange processes, diffusion and microfiltration. The alpha-beta discrimination and muon identification were carried out. In the result a very high degree radionuclide cleanliness of the liquid scintillator has been achieved. The background counting rate in the region of 0.2-0.8 MeV is $10^{-3}$ event/day/kg of the liquid scintillator. Works to create DAQ system for BOREXINO have started. System of tests and calibration of large PMT on 128 photomultipliers simultaneously has been created. A calibration method of the energy scale was developed and checked on the stand at the laboratory with the accuracy of 1%.

## 5. DETECTORS R&D

Together with Zelenograd and CERN, various topology of strip silicon detectors has been designed for radiation research and choice of optimal construction of the preshower used in the CMS experiment at LHC. Full-scale silicon detectors ($60 \times 60$ mm$^2$) have been manufactured in three versions with the following features: detectors with $p^+$ strips (2 detector versions) and detector with $n^+$ strips. Radiation tests of two versions of detectors have been performed: topology with the $p^+$ strips and solid $n^+$ ohmic contact from the back side; topology with $p^+$ strips and $n^+$ ohmic contact from the back side, surrounded with the guard rings. The obtained results have shown that those detectors could work under radiation by fast neutrons with dose $\Phi = 1.4 \cdot 10^{14}$ cm$^{-2}$ that corresponds to 10 years of CMS operation.

The mechanics of the **preshower detector** prototype has been manufactured. The developed technology of the micromodule assembling includes: positioning of the detector at the ceramic support and detector gluing to the ceramics using the conductive silver glue; ultrasonic bonding of the detector to ceramics with the 27 mm diameter Al wire; precise ( 50 $\mu$m) positioning of the ceramic support with a detector on the Al holder; monitoring of static parameters of detectors while micromodule assembling. At the technological laboratory of LPP the test structures from high-resistivity $n$-type silicon have been manufactured using the planar technology. The technological cycle includes thermal growth of $SiO_2$ film, photolithography, $B^+$ and $P^+$ ion implantation and Al vacuum evaporation. The energetic resolution of the detectors measured with the radioactive source $^{241}$Am (5.485 MeV) is about 30 keV.

A full-scale 6 layer prototype of **cathode readout chambers** of the muon station ME1/1 for experiment CMS has been developed and manufactured. In comparison

with the previous ones, this prototype has a less number of strips in the layer (64 instead of 80), and the strips are solid, without deletion for reading out and balancing. A prototype is of a trapezie form with a length of the larger side ~800 mm, a smaller one of ~390 mm and the height of ~1600 mm. A particular property of the prototype is added by the precision cathode strips manufactured using a diamond disk in the device developed at LPP. The prototype is equipped with readout electronics on the schemes of large integration supplied by Research Center of PPHE (Minsk, Belarus). The prototype tests were performed at CERN in the magnetic field on the high intensity beam up to 50 kHz/strip and at GIF (Gamma Irradiation Facility) at the background loading up to $2 \cdot 10^6 \gamma/cm^2$. The tests have shown high efficiency of the pion track registration. Under the background conditions with respect to LHC, insignificant reduction of the spatial and time resolutions of the prototype equipment with new electronics is observed.

The main works to create the **track radiation detector** (TRT) for the ATLAS setup have been completed at the LPP [6]. A full scale prototype of the detector module has been developed and manufactured. Thermometrical measurements and studies have been performed on the test beam at CERN. The principle of gas cooling of the TRT module has been tested. The results of measuring have shown a necessity of compulsory cooling of the detector to reduce the radiation heating. The range of the temperature distribution in the prototype is about 15°C for the $N_2$ flow with the velocity of 90 l/min at the temperature of the cooling nitrogen equal to 19°C. Substitution of $N_2$ for $CO_2$ provides reducing the gas flow velocity by 19%.

Spatial characteristics of the **straw detector with cathode readout** have been studied [7]. The spatial resolution was shown in the range from $70 \div 90\,\mu m$. Fast current preamplifiers were used in the work. $\gamma$-quants from source Fe–55 were registered. The detector has a good spatial linearity and uniformity. These detectors can be applied as precision coordinate detectors in experiments on accelerators and in image detectors, as well as in other experiments using nuclear physics methods. The R&D of long straws have shown that 3.5 m straws up to 10mm in diameter can be used for a tracking detector, for example, in COMPASS.

## 6. ACCELERATION TECHNIQUES

In the frame of DESY-JINR collaboration on the **TESLA** project, the LPP specialists take an active part in research on the linear collider and free electron laser (FEL) physics, development of accelerator components, electronics, and instrumentation [8]. Conceptual designs for an X-ray FEL and second interaction region for $\gamma\gamma$- and $\gamma e$ collisions at a Linear Collider have been elaborated. The FEL parameters were studied for TESLA Test Facility and calculations and design of bunch compressor have been performed. The dynamic aperture at HERA-e storage ring has been studied.

Works on FEL multimeter range [9] for linear colliders are conducted in two directions:

– development of RF sources for high gradient accelerating structures of electron–position colliders;



– development of the grouper of the collider driving beam and diagnostic system for the grouped beam.

Together with IPP, RAN (Nizhny Novgorod) the LPP continued research on FEL generator with Bragg–resonator. In the experiments on the base of linear induction accelerator LIU–3000 (0.8 MeV, 200 a, 200 nc) at frequency of 31 GHz, a high production coefficient of 26% was obtained, a record one for FEL generators. A possibility was shown to realize one mode or multimode generation regimes in dependence on the resonator quality. The irradiation spectrum width of this generator in one mode regime enables it to use to us for feeding the high gradient accelerating structures of colliders. Upgrading of modulators for the first section of linear induction accelerator LUEK–2 (3 MeV, 700 A, 7 ns) has been done and, is the result, the energy spread out in the beam has been reduced significantly. Together with IPP, RAN, a principally new knot has been developed and manufactured to introduce the RF power for FEL amplifier based on the beam osculation multiplicity. Measurements have proved a high efficiency power introduction (up to 85 %) into the channel. A knot of the optical diagnostics of the grouped electron beam FEL has been developed and manufactured.

When studying the single particle resonances in storage rings with low emittance optics (**LEP2, HERA-e**), a theoretical explanation was given to the effect of spontaneous onsets of particle losses and increase in vertical beam emittance, observed at LEP. Methods to eliminate the losses and reduce the vertical emittance in LEP with 108/90 optics have been proposed [10]. A possibility of radiation antidamping of the longitudinal oscillations of particles trapped in a betatron resonance island (Radiative Beta-Synchrotron Instability) has been theoretically discovered [11]. Analysis has shown that this instability does not occur in LEP, but it can be dangerous in electron storage rings with a lower energy, such as Tau-Charm Factory. Single particle stability in the upgraded HERA-e lattice has been studied [12]. The dynamic aperture at the working point chosen for the moment of the study was shown to be limited by synchro-betatron resonances and recommendations were given to choose another working point.

A mathematically rigorous theory of **coherent synchro-betatron oscillations** in colliding beams has been developed which, in particular, allows one to study the beam-beam influence on stability of coupled "head-tail" oscillations. This problem is important for both $e^+e^-$-factories and large hadron colliders. It is shown that the beam-beam interaction in a Tau-Charm Factory with monochromatization in collision energy can lead to the Transverse Mode Coupling Instability in the case of a large beam-beam offset at the interaction point.

According to the LPP plans, the works are going on to research and optimize electrophysical parameters of a working layer of NbCu superconducting cavities (SCC) [13]. A magnetron of a planar type was developed and assembled on the vacuum chamber with a niobium target of the 95 mm diameter to produce superconducting NbN films by a method of sputtering. A theoretical analysis of the amplitude dependence of the surface resistance of niobium coated copper cavities has been performed. The explanation of non quadratic losses in NbCu cavity was proposed. It is on the penetration of vortices into the working layer when the magnetic RF amplitude is

larger than the first critical field. The vortices penetration time calculated by the known experimental results has turned out to be much less than the RF field period. To reduce nonquadratic losses is possible if to shield HNF against magnetic fields. To reduce the tempo of these losses is possible by shielding SCC against external magnetic field. In this plan the most effective decision is preparing SC shielding layer directly on the cavity with the subsequent of a working layer in-situ, i.e., in one operation cycle.

According to the CERN-JINR Addendum of 1997, the contribution of JINR is defined to supply electrostatic kickers and their powerful wideband amplifiers for the **LHC** transverse oscillation damping systems [14]. The proposed mechanical construction of the electrostatic kicker allows one to obtain automatically the alignment and centering of the deflecting plates with respect to the chamber axis. The vacuum, impedance, and other specific aspects of this device require a detailed investigation, modeling, and technological research. Two variants of a wideband amplifier circuit were proposed. The first one is a conventional class AB amplifier (basic variant), the second is the cascode circuit with parallel control (alternative variant). The both amplifiers were simulated with PSpice (using the real vacuum tube model) and tested at a special bench with a power up to 2 kW. The advantages of the cascode amplifier have been shown as well as a principal possibility of a perspective upgrading device on its base. Works to create a special full-power bench for this device have already started.

A lot of work has been done on **multicharged ion sources** for hadron accelerators of JINR and CERN [15]. The vacuum chamber has been constructed to study the intense fluxes of particles produced with the solid target illuminated by a laser beam. The PC-based data acquisition and control systems were developed. They studied the charged and neutral fluxes of laser ablation plasma. A new method to measure the neutral particles density was developed using the corpuscular probing of particles by the ion beam. The experiments are performed to determine the influence of the external injection on the parameters of plasma obtained at the electrical discharge in magnetic bottle field. The geometry of the external injection into the ECR ion sources was chosen.

The code libraries based on the momentum method of distribution function and the finite-size particle method were developed to calculate and optimize the beam transport channels of highly charged ions. The numerical simulation of experimental results of the Ta ion beam transport was continued to optimize the "warm" LEBT at CERN. Analysis of experimental results of the ECR ion source at RIKEN, Japan, was carried out and allowed to estimate the parameters of the electron component of the ECR plasma and the required RF input power.



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