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MAIN RESULTS OF THE LABORATORY OF PARTICLE PHYSICS (LPP) IN 1996

Report to the 81st Session
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1. EXPERIMENTS

1.1 RESEARCH ACTIVITIES AT IHEP

EXCHARM: Two runs on the EXCHARM set-up in the experimental area of U-70 accelerator (channel 5N) have been carried out in 1996. To decrease the systematical errors, thorough measurements of the magnetic field of the spectrometer magnet were made before the first run (March-April 1996), additional components have been included into the read-out system of the set-up to record information from all trigger elements. Additional 65 mln. raw neutron-carbon events were recorded in the first run. During the second run (November-December, 1996) the parameters of the beam monitoring system and beam structure (presence of long-life kaons admixture in neutron beam), were studied.

130 mln. events have been analysed and the obtained results are as follows:

1. A search for charmed baryon Σ_c^0 has been carried out via decays into $\Lambda_c^+\pi^-$ with following decays of Λ_c^+ into $\Lambda_c^+ \rightarrow \Lambda^0\pi^+\pi^+\pi^-$ and $\Lambda_c^+ \rightarrow \bar{K}^0 p\pi^+\pi^-$ [1]. About 100 decays of Σ_c^0 were registered and the mass difference between Σ_c^0 and Λ_c^+ was measured: $M(\Sigma_c^0) - M(\Lambda_c^+) = (167.8 \pm 0.6 \pm 0.2)$ MeV/c^2. The partial width ratio of Λ_c^+ decays was estimated as $\Gamma(\Lambda_c^+ \rightarrow \bar{K}^0 p\pi^+\pi^-)/\Gamma(\Lambda_c^+ \rightarrow \Lambda^0\pi^+\pi^+\pi^-) = 2.6 \pm 1.2$.

2. The investigation of ϕ meson inclusive production characteristics in nC-interactions has been carried out [2]. The values of ϕ mass and width were determined: $M = (1019.5 \pm 0.2)$ MeV/c^2, $\Gamma = (4.5 \pm 0.1)$ MeV/c^2. The cross-section of ϕ meson inclusive production was obtained in the region of $X_f > 0.1$: $(92 \pm 20 \pm 3)$ μb/nucleon. Its model dependent extrapolation into full kinematical region leads to the value $(276 \pm 60 \pm 9)$ μb/nucleon.

Studies of hyperon production in nC-interactions, investigations on double ϕ production and a search for exotic multiquark states were continued [3]. The models describing particle hadroproduction have been developed and included into the simulation programs of the experiment [4]. New computational methods have been developed to increase the rate of event processing using the parametrization of the magnetic field of spectrometer magnet [5].

TNF: Processing of ~ 8 mln triggers of $K^+ \to \pi^0\pi^0\pi^+$ has been completed and 182200 candidates were selected for the physical analysis satisfying the kinematic fit used to define the energy of the charged pion and Dalitz-plot variables. Value $g = 0.705 \pm 0.018 \pm 0.020$ [6] has been obtained for the linear slope parameter. This result is in a good agreement with the recent result of HYPERON experiment and about 3σ bigger as compared with the value measured in Protvino at ISTRA experiment.

SVD: Investigations of the open charm production in *pp*-interactions have been completed at the hybrid spectrometer SVD. About 75000 of the candidates have been found originating in the fiducial volume of the bubble chamber. The data processing was done using the programme of geometrical reconstruction of events [7]. The upper limit of the charm production in *pp*-interactions has been determined to be equal 4 μb at 70 GeV/c. The experiment has been completed this year.

NEPTUN: R&D work is continued to create an ultracold target where the principle of storage and thermolization of hydrogen atoms in the magnetic trap is used at the temperature of 0.3 K and the magnetic field of 7 T. The storage of the atomic hydrogen in the magnetic trap has been obtained. The walls of the trap are covered with superfluid helium-4 to reduce the recombination of atoms into molecules. A new method has been developed and realized to extract the cold atomic beam from the trap using the fringe gradient magnetic field.

R&D on two types of Semiconductor Detectors (SD) have been completed to increase substantially the spectrometer angle resolution. The first type is a planar surface-barrier detector of size 8×30 mm^2 and the thickness of the sensitive layer from 15 to 1000 μm. The second type is a strip SD of size 60×60 mm^2, thickness 300 μm with number of stripes – 30 and the pitch of 2 mm. The fabrication of big scintillation counters and proportional chambers is in progress.

Serpukhov Scientific Experimental Division (SSED) has fully provided 2 runs on data taking at set-ups EXCHARM, SVD, HYPERON as well as methodical runs at TNF and SVD. The division has completed the works connected with the commisioning the second muon station of TNF. A test run has been performed. The computer

net of SSED has been developed and created at IHEP to provide registration of experimental data. Dismounting of the head part of set-up POSITRONY and ECM-1040, has been done.

1.2. COOPERATION WITH CERN

NA-47 (SMC): New measurements of asymmetries have been fulfilled in scattering of longitudinal polarized muons on polarized protons. 76 mln events have been registered, i.e. about 3 times bigger than in 1993. Frozen ammonia has been used as substance of the polarized target for the first time in this experiment. Precision measurements of the background asymmetry caused by polarized nitrogen neuclei have been fulfilled.

The analysis of the data obtained in 1993 on the polarized protons, has been completed. Additional analysis has been done on measurements of incident muons polarization that provided to decrease systematic errors. Processing and analysis of the data obtained in 1995 on polarized deuterons have been completed [8]. Spin-dependent structure function of deuteron $g_1^d(x)$ has been measured in the interval $0.003 < x < 0.7$ at the mean 4–momentum transfer $Q^2 = 10$ GeV^2. The value of the first momentum of structure function $g_1^d(x)$ is $\Gamma_1^d = 0.0409 \pm 0.0059 \pm 0.0037$. It means that the predicted value $\Gamma_1^d = 0.071 \pm 0.003$ from the Ellis-Jaffe sum rule is by 3.7 standard deviations higher than the measured value.

NA48: The helium window, tooling to mount/dismount vacuum and He windows, storage frames for the windows and other constructions for the liquid krypton cryostat (LKrC) have been manufactured and tested in Russia and delivered to CERN. The cryostat was transported to CERN in 1995 for this experiment. Software was developed for simulations related to operation of the LKrC, which was tested in the electron and kaon beams of SPS CERN. Four electronics modules have been developed and manufactured at the JINR to check the operation of the read-out electronics of LKrC. Results of methodical studies were published in [9].

WA–98: The 500 elements of the scintillating hodoscope have been constructed at the JINR to measure the particle time of flight. Two test runs were performed in the lead beam with the energy of 160 GeV at CERN SPS. A preliminary analysis has shown that with the time of flight system one can identify π, K, $\bar{p}$ up to momentum 3 GeV/c. To measure a "forward" energy, a fully compensated Zero Degree Calorimeter (ZDC), has been designed, manufactured and tested at CERN by LPP and LHE. The ZDC has a modular structure with a cell of 150×150 mm^2 and with the light collection system using WLS.

ATLAS: The groups participated in preparation of the "Technical Design Report" - a document with a description of the technical, financial and management tasks.

The prototype of the hadron calorimeter manufactured at JINR, has been tested in the CERN beam together with the other analogous 3 modules representing the 1/16 part of the full scale prototype of the liquid-argon hadron calorimeter. The study of uniformity, energy and spatial resolution has been performed in the energy range from 20 till 200 GeV using beams of π–mesons, electrons, and muons. Study on radiation resistivity of electronics and materials [10] has shown that the expected sum of fluxes of neutrons and gamma-quanta will not cause any substantial (> 20%) changes in characteristics of electronics and mechanics of the calorimeter during 10 years of operation.

A very important result has been obtained using the mass spectrometry. The contamination of the pumped volume with different fractions released under the influence of the neutron irradiation from the surface of materials, has been determined. The first samples of the amplifiers–shapers for the hadron calorimeter, have been designed, manufactured and tested. A device has been proposed and tested to measure the liquid argon temperature from 32 sensors.

CMS: An important element of detector CMS is an end cap, whose construction is the responsibility of JINR. The study of the properties of separate parts of CMS end cap has been performed as well as of the characteristics of their joint work under the conditions close to the real experiment [11].

The full scale prototype of the chamber with the cathode readout (CSC) as an element of the end cap muon detection system has been manufactured and tested [12]. The results have shown that in the energy range of 100-300 GeV, the muons having passed the spectrometer in 20% – 30% are accompanied by electromagnetic

background (correlated background). A new algorithm to calculate coordinates of the particle trajectories has been developed to provide the track reconstruction with the accuracy better than 100 μm and efficiency of 92% at the muon energy of 300 GeV. Influence of the non-correlated background on the muon registration efficiency has been studied. The estimations of the track reconstruction efficiency in the conditions of the combined correlated and non-correlated backgrounds, have been obtained. Besides, the effect of strong ionizing radiation on the CSC capabilities has been studied and the corresponding improvements of the electronics have been proposed. The 96 channel cart to register the information from the cathode strips has been developed as well as the 24 channel cart to register the information from the anode wires of the full scale CSC prototype.

The additional test run was performed in the H4 beam of SPS. CERN to define the energy and spatial resolutions of the hadron calorimeter using the prototype with the absorber plate thickness 8 cm chosen according to the results of the previous tests. The preshower detector module is being manufactured with the sizes of 24×24 cm^2. Together with other collaborators a new technology of the strip detectors has been developed to provide their long lasting operation under the strong radiation.

Theoretical works have been done to study direct photon production in proton collisions at the energy of 14 TeV to check QCD and measure the gluon distributions in proton in the region of small x. To optimize the CMS detector parameters, the jet production cross sections have been estimated.

1.3. COOPERATION WITH DESY

HERMES: Experimental data have been taken using a polarized positron beam with the energy of 27.5 GeV and the polarized gaseous proton target. The first data on the structure function $g_1^n(x)$ have been obtained using the data collected in 1995 with the polarized nuclei of He-3. The JINR group has developed a new method of extraction of structure functions [13]. New data on structure function $F_2(x, Q^2)$ have been obtained using the statistics of about 120 thous. events. The JINR group has proposed a new method to extract the asymmetry and spin dependent structure function g_1, based on the definition of the spin dependent and spin independent parts of the cross section using the method of maximal likelihood taking into account the statistical errors of the beam and target polarization [14]. This approach is helpful to minimize systematic errors caused by the time dependence of the measurements. The JINR group has developed additional drift vertex chambers, whose usage in front of the spectrometrical magnet will improve the angle and momentum resolutions as well as the track efficiency of the set-up.

HERA-B: The main goal of the experiment is to study CP-violation in decays $B \rightarrow J/\Psi K_S^0$ using the internal target of the HERA proton ring. LPP participates in R&D of the Outer Tracking Detector as well as in physics simulations of the set-up and software development to calibrate the detector and reconstruct the events [15].

H1: In the framework of Project OSCAR the JINR participation is foreseen in upgrading of H1 detector, namely in development of Forward Proton Spectrometer (FPS) and construction of PLUG-calorimeter located in the hole of return yoke of H1 magnet around the beam pipe of the accelerator. In 1996 the works have been completed in research and development of the signal readout system from track detectors of FPS. These track detectors are hodoscopes of scintillation fibers with position sensitive photomultipliers (PSPMP) as light signal receivers. The PSPMPs are based on microchannel plates, 124 channel each, which were developed in co-operation with Scientific Research Institute for Electronic Devices (SRIE, Moscow). Eight PSPMPs necessary to equip two stations of FPS, have been produced. New readout electronics has been developed in collaboration with DESY and Hamburg University. Tests of the track system have been completed at JINR and DESY. The basic parameters have been measured and they meet the requirements. The design of PLUG-calorimeter construction has been prepared, research and development of its basic elements have started. In 1996 JINR has become a full member of the H1 Collaboration.

1.4. OTHER EXPERIMENTS

BOREXINO: Detector BOREXINO is a low background spectrometrical neutrino detector. It will be located in the underground

Laboratory at Grand Sasso (Italy) and aimed to study the solar neutrino fluxes [16]. The calorimetrical measurements performed at the prototype of Borexino, so called Counting Test Facilities (CTF), have confirmed feasibility of this type of the detector. All the detector materials are specially cleaned against natural radioactive impurities. The products of the natural Uranium-Thorium row accumulated in water shielding, are removed permanently using a specially developed system. The measured content of impurities has been found within the limits required in the experiment.

STAR: In 1996 a technical project of the mechanical part of the End cap Electromagnetic Calorimeter (EEMC) has been completed for the experiments with the STAR detector in the polarized proton beams of RHIC collider (USA) [17]. A small prototype of the EEMC has been constructed and tested in the U-70 electron beam at Protvino. The main components of this device - WLS fibers and scintillator tiles fabricated using the molding under pressure, have been tested in this prototype. The energy resolution obtained in this research turned out to correspond to the project value of $17\%/\sqrt{E}$ [18]. A thermoplastautomat to produce scintillator tiles has been purchased and installed in the LPP. An optical control system has been designed for EEMC. A stand has been constructed to test this system and the first tests of this system have been successfully performed. A stand to control the geometrical characteristics of the scintillator tiles has been designed and manufactured. A large volume of works has been done on simulations of the EEMC response to the gamma-quanta pass through it [19].

Experiment at TRIUMF Cyclotron: A set-up including 80 scintillation counters and 6 planes of proportional chambers, was created at the polarized beam of cyclotron TRIUMF. In two runs $3 \cdot 10^6$ events of the type $pA \rightarrow 2pX$ and $pA \rightarrow 2dX$ have been registered to measure the spectra of the effective masses of the proton pairs and search for diproton resonances. The CH_2, Al, Cu, Pb films were used as targets. The peculiarity of this project lies in the measurement of the analyzing power of reactions $A(p,2p)$ and $A(p,pd)$. These data are important to obtain an additional independent criterion to search for resonances, to clarify the mechanism of emission of fast protons and deuterons from nuclei and determine the cluster structure of the nucleons [20].

2. DETECTORS R&D

Drift Tubes (DT) of the round cross section have been suggested for particle experiments as precision track devices. Thin walled (~250 μm) stainless steel tubes, each with 50 μm concentrically wire, form the basic element of the technology. With a suitable choice of gas mixture and high voltage, the DT can be operated in either proportional mode or the limited streamer mode. Very rigid and light-weight modules 4×1 m^2 are fabricated by stacking and gluing tubes together forming honeycomb structures. The mechanical design allows the tubes to be pressurized without distorting the precision of mechanical alignment of the system. This was shown to improve the spatial resolution by $1/\sqrt{P}$, where P is the gas pressure. Spatial resolution of two full-scale prototypes was 100 μm at one atmosphere and 50 μm at a pressure of 4.8 atmosphere. Taking into account that the DT wall thickness can be 0.3mm Al, it is possible to manufacture a 4-layer module and achieve 0.026X_o per module.

The **Cathode Strip Chambers (CSC)** technology is the best candidate for the muon system because such chambers are able to operate in a high magnetic field and intensive charged particle beams. Many measurements have been performed at Dubna and CERN using the CSC prototypes. Effects which degrade the resolution of CSC chambers are diffusion of drifting electrons, inclined tracks, absorption of δ-electrons and a Lorentz force along the anode wires in the presence of a magnetic field which is not collinear with the electric field of the chamber. The same gas mixture was used in all the measurements: 30%Ar+50%CO_2+20%CF_4. The measured spatial resolution was better than 50 μm independent of the magnetic field. Other tests have managed to achieve a simultaneous operation of the anode and cathode electronics and work in nonuniform magnetic field. The chamber efficiency across all the sensitive area has been studied and measured as well as time resolution of the CSC chamber and other parameters.

A new technology of **straw tubes** fabrication has been developed. The ultrasonic welding is used to fix the band edges. This technology

will allow to produce straw tubes without limitation in length at the speed of order of 1 m/min and minimal diameter of about 5 mm.

The production line to fabricate the prototypes of **silicon detectors** has been completed. A few prototypes of silicon strip detectors with dimensions 6×6 cm^2 have been fabricated in cooperation with ELMA (Zelenograd), to use in the preshower of EM calorimeter for the CMS experiment. Performance measurements of silicon detectors and the preshower have been done at CERN. It was found that the spatial resolution of the preshower depends on the electron beam energy E as $2.1\sqrt{E}\oplus0.4$. The radiation hardness testing of strip silicon detectors at the neutron facility of FLNP has shown that strip silicon detectors are feasible at very high radiation fluxes.

A possibility was studied to create a telescope for the **slow particle detector** of $dE-E$ type, where dE element is a silicon detector and E element is a scintillator with a photodiode. The telescope was designed and tested at the storage ring Celsius (Sweden). The obtained noise level of dE-detector is 17 keV, and of photodiode – 14 keV. The energy resolution of this technique for light nuclides is 5%. This technique has been used at Celsius accelerator to investigate interaction of ^{14}N nuclei at the energy of 144 and 324 MeV with ^{112}Sn and ^{124}Sn and study the properties of the nuclear thermometer [21]. The temperature of the excited nuclei has been measured using a relative rate of fragments.

OTHER DETECTORS: Together with IHEP, CERN and INFN R&D works were performed on track detectors with liquid scintillator capillaries. A special trigger system has been developed and installed at the set-up HORUS. Track capillary detectors are included into project LHCB.

3. ACCELERATION TECHNIQUES

In 1996 all the JINR obligations for IHEP Protvino have been completed concerning the development of the **UNK-I** system. A generator for beam oscillation damping caused by the injection errors has been constructed and tested. An experiment has been performed where the beam deviations were imitated by the accidental signal at the control system input. The results have shown a full correspondence to the given technical requirements. The adjustment works on the modulator for the beam bunching station of U-70 were fulfilled. All the equipment is ready to be transferred to the IHEP.

A new design of high current **klystron** with the distributed suppression of the parasitic modes of self-excitation has been developed [22]. The increments of all the parasitic modes are less than their reducing in the klystron. The construction of this klystron required to develop the technology of production of special RF absorbing materials. After modernization of the 14 GHz klystron, all the parasitic modes of self-excitation were suppressed with the RF absorbing drift tubes and about 75 MW of the output power was obtained at the pulse duration of 250 ns and about 100 MW – at a short 50 ns output pulse.

Works to create a technical and research basis, to develop technology of **superconducting cavities** and optimize their electrophysical parameters, are continued. The model of the magnetron of the axial (cylindrical) type has been designed, fabricated and tested on the basis of the permanent magnet with a frame made of copper. The magnetron operation is stable at the pressure of the working gas Argon in the range from 10^{-3} to 10^{-2} mm and at the voltage of the supply source from 7000 V to 3000 V. The mean velocity of the copper fall was 30 nm $\cdot$ $\sec^{-1}$, source at the power of 4 kW and location of the substance at a distance of 60 mm from the target. The dimensions of the magnetron allow one to operate with the cavities at the frequency of 3 GHz.

A **horizontal cryostat** has been developed, constructed and successfully tested for the 1.3 GHz superconducting cavity [23]. The heat flow into the volume with the liquid helium from the environment was about 3.5 W, the obtained minimal temperature was 1.43 K. An original cryocommutator has been developed and constructed to work with the resistance thermometers in the temperature range of 1–323 K. The commutator provides to reduce significantly the number of the wires going to the thermometers in the cold volume. Preliminary radiative tests of the commutator were done and they have proved that the commutator is feasible at the temperature of 77 K and neutron flux till $3 \cdot 10^{13}$ n/cm^2 at the gamma radiation doze till 10000 Gr. In the frames of the research program on superfluid turbulence and nonlinear acoustics of H-II, the numerical simulation and experiments have shown, in particular, that the superfluid turbulence generation is

more probable in the second–sound wave media but not on its front.

Theoretical works on the analysis of the non–linear system influence on the beam dynamics at different operation stages of the collider **LHC** [24] are in progress. A mathematically strict theory on transverse oscillations in colliding beams has been developed to study the energy exchange processes between coherent and non–coherent oscillations. The developed theory has been used for the analysis of coherent stability and emmitance growth of the colliding beams in LHC.

Multicharged ion sources [25] are developed for hadron accelerators of JINR and CERN. A magnetic system for such sources using permanent magnets with a magnetic field on the axis till 0.5 T and plug ratio 1.5 to 2.0, has been developed and constructed. A system to obtain the flows of ions and neutrals using 2 solid state lasers, has been developed. A "warm" low energy beam transport line (LEBT) has been optimized. The regimes have been found to increase its efficiency by 2–3 times. A new variant of LEBT with superconducting solenoids has been proposed to increase the transported ion current up to 100 mA and higher.

A new interpretation of the experimental results obtained at CERN on "neon cooling" has been offered and proposals on new approach to the experiment have been prepared [26]. Together with KVI (Groningen) numerical simulation and interpretation of the experimental results of the ECR ion source in Grenoble, have been done, in particular, the first estimations of the parameters of the ECR plasma electron component have been obtained [27]. A theoretical analysis of the ion accumulation and space charge neutralization processes in the electron beams for the electron cooling systems and electron beam sources, has been carried out [28]. Creation of the computer data base of ionization potentials of atoms and ions of all the elements in the periodic system, is in progress [29].

A theoretical analysis of the particle stability in **LEP** at high energies (> 85 GeV/beam) [30] has been done and on the basis of this analysis a new variant has been proposed to tune the accelerator magnetic structure. The results of the theoretical analysis have been confirmed at LEP and since November 1996, after the necessary reconnection of the sextapoles, it has operated with this optics.

For the conceptial project **TESLA–500** [31], the data for RF radiation sources in the x–ray and ultraviolet regions, as well as a scheme of gamma–gamma collider, have been prepared.

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