LABORATORY OF PARTICLE PHYSICS

The activity of LPP in 2004 was concentrated on the current particle physics experiments and preparation of the new ones, R&D of the particle detectors and different acceleration systems.

CURRENT EXPERIMENTS

The **NA48** cycle of experiments is devoted to the precision measurement of the ratio ε'/ε in $K \to 2\pi$ decays, to the study of kaon and hyperon rare decays and the CP asymmetry in charged kaon decays. The parameters under investigation have to be measured more precisely than before to explain the existence of direct CP violation predicted by the Standard Model (SM), to bring the essential contribution to study of neutral and charged kaon characteristics.

After the achievement of the main goal of the experiment the following results have been obtained within the NA48 data analysis. The $K_L \to \pi^{\pm}\pi^0 e^{\mp}\nu(\bar{\nu})$ decay was investigated [1] using a beam of long-lived neutral kaons. The branching ratio $\mathrm{Br}\,(K_L \to \pi^{\pm}\pi^0 e^{\mp}\nu(\bar{\nu})) = (5.21 \pm 0.07(\mathrm{stat.}) \pm 0.09(\mathrm{syst.})) \cdot 10^{-5}$ was measured from a sample of 5464 decay events with 62 background events. The form factors $\bar{f}_s$, $\bar{f}_p$, λ_g and $\bar{h}$ were found to be in agreement with previous measurements, but with higher accuracy. The coupling parameter of the chiral Lagrangian $L_3 = (-4.1 \pm 0.2) \cdot 10^{-3}$ was evaluated from the data. In data taken in 1999, 730 candidates of the weak radiative hyperon decay $\Xi^0 \to \Lambda\gamma$ have been found with an estimated background of 58 ± 8 events [2]. From these events the $\Xi^0 \to \Lambda\gamma$ decay asymmetry has been determined to be $\alpha(\Xi^0 \to \Lambda\gamma) = -0.78 \pm 0.18(\mathrm{stat.}) \pm 0.06(\mathrm{syst.})$, which is the first evidence of a decay asymmetry in $\Xi^0 \to \Lambda\gamma$. The branching fraction of the decay has been measured to be $\mathrm{Br}\ (\Xi^0 \to \Lambda\gamma) = (1.16 \pm 0.05(\mathrm{stat.}) \pm 0.06(\mathrm{syst.})) \cdot 10^{-3}$. The decay $K_S \to \pi^0\gamma\gamma$ has been observed for the first time [3] using the data collected in 2000: 31 decay events were selected at the background level of 13.7 ± 3.2 events, which leads to the branching ratio estimate $\mathrm{Br}\,(K_S \to \pi^0\gamma\gamma) = (4.9 \pm 1.6(\mathrm{stat.}) \pm 0.9(\mathrm{syst.})) \cdot 10^{-8}$, which is in agreement with the chiral perturbation theory.

The following results have been obtained within the framework of the physics programme of the **NA48/1** project. A new decay mode $K_S \to \pi^0\mu^+\mu^-$ (6 events over background 0.22) has been observed and its branching ratio

$$\mathrm{Br}\,(K_S \to \pi^0\mu^+\mu^-) = (2.8^{+1.5}_{-1.2}(\mathrm{stat.}) \pm \\ \pm 0.3(\mathrm{syst.}) \pm 0.8(\mathrm{theor.})) \cdot 10^{-9}$$

has been estimated (preliminarily) [4]. A branching ratio of $\Xi^0 \to \Sigma^+ e^-\nu$ decay and a value of the Cabibbo–Kobayashi–Maskawa (CKM) matrix element V_{us} have been estimated (preliminarily) [5]:

$$\mathrm{Br}\,(\Xi^0 \to \Sigma^+ e^-\nu) = (2.51 \pm 0.03(\mathrm{stat.}) \pm \\ \pm 0.11(\mathrm{syst.})) \cdot 10^{-4},$$

$$|V_{us}| = 0.214 \pm 0.006^{+0.030}_{-0.025}.$$

A clear signal (about 100 events) of $\Xi^0 \to \Sigma^+\mu^-\nu$ decay (and $\Sigma^+ \to p\pi^0$) has been observed [6].

The 60 days experimental run was prepared and carried out in the beamlines of charged kaons at CERN SPS for realization of the **NA48/2** physics programme. More than $2.15 \cdot 10^9$ events with $K^{\pm} \to \pi^{\pm}\pi^+\pi^-$ candidates and more than $1.30 \cdot 10^8$ events with $K^{\pm} \to$

$\pi^{\pm}\pi^0\pi^0$ candidates have been recorded. During two years of data taking in the NA48/2 experiment, more than 4 billion $K^{\pm} \to \pi^{\pm}\pi^+\pi^-$ and 200 million $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ events have been recorded in total. The JINR contribution to the experimental runs includes:

- maintenance and modification of the produced readout electronics for the coordinate detector of charged kaon beams — KABES, working in high-intensity charged beam;
- maintenance and operation of new readout electronics of the muon detector during the experimental run;
- maintenance of the continuous operation of the experimental control data recording system.

LPP's group carries full responsibility for software development for detector simulation, reconstruction of data obtained by the new readout electronics of the muon detector, data filtering and monitoring of physical characteristics. On the basis of 2003 data the errors of the asymmetry in $K^{\pm} \to \pi^{\pm}\pi^+\pi^-$ and $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ decays have been estimated [6] which are one order of magnitude less than in other experiments. The branching ratio of $K^{\pm} \to \pi^0 e^{\pm}\nu$ decays has also been measured with preliminary results [4]:

$$\mathrm{Br}\,(K^+ \to \pi^0 e^+ \nu) = (5.163 \pm 0.021(\mathrm{stat.}) \pm \pm 0.056(\mathrm{syst.})) \cdot 10^{-2},$$

$$\mathrm{Br}\,(K^- \to \pi^0 e^- \nu) = (5.093 \pm 0.028(\mathrm{stat.}) \pm \pm 0.056(\mathrm{syst.})) \cdot 10^{-2},$$

$$\mathrm{Br}\,(K^{\pm} \to \pi^0 e^{\pm} \nu) = (5.14 \pm 0.02(\mathrm{stat.}) \pm \pm 0.06(\mathrm{syst.})) \cdot 10^{-2},$$

which allowed one to define the value of CKM matrix element

$$|V_{us}| = 0.2241 \pm 0.0013(\mathrm{exp.}) \pm 0.0023(\mathrm{theor.}).$$

This value is in good agreement with the result of the E865 experiment at BNL and predictions of the SM, which confirms the unitarity of the CKM matrix.

An LPP group took part in analysis of the **HERMES** data collected in 2002–2003 and performed the technical maintenance of the minidrift vertex chambers.

The evidence for a narrow baryon state was found in quasi-real photoproduction on a deuterium target through the decay channel $pK_S \to p\pi^+\pi^-$. A peak is observed in the pK_S invariant mass spectrum at $(1528 \pm 2.6(\mathrm{stat.}) \pm 2.1(\mathrm{syst.}))$ MeV/c^2 [7]. Depending on the background model, the naive statistical significance of the peak is 4–6 standard deviations and its width may be somewhat larger than the experimental resolution of $\sigma = 4.3$–6.2 MeV. This state may be interpreted as the predicted $S = +1$ exotic $\Theta^+(1540)$ pentaquark baryon. No signal for a hypothetical Θ^{++} baryon was observed in the pK^+ invariant mass distribution. The absence of such a signal indicates that isotensor Θ is excluded and isovector Θ is unlikely. The invariant mass spectra are shown in Fig. 1.

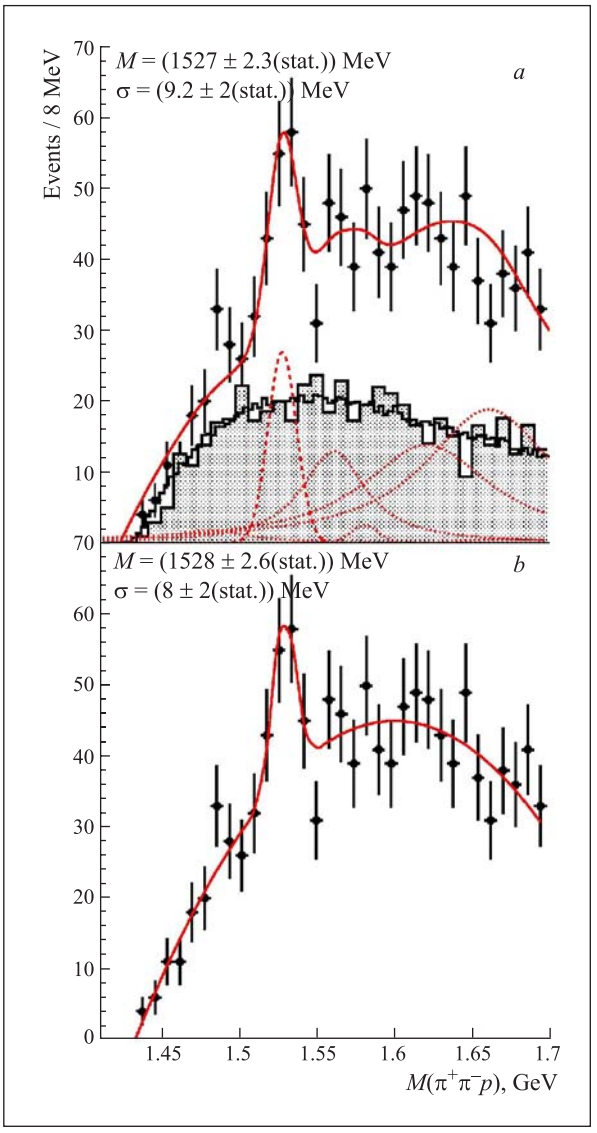

Fig. 1. Distribution in invariant mass of the $p\pi^+\pi^-$ system subject to various constraints described in the text. The experimental data are represented by the solid circles with statistical error bars, while the fitted smooth curves result in the indicated position and width of the peak of interest. *a*) The Pythia6 Monte Carlo simulation is represented by the gray shaded histogram, the mixed-event model normalized to the Pythia6 simulation is represented by the fine-binned histogram, and the fitted curve is described in the text. *b*) A fit to the data of a Gaussian plus a third-order polynomial is shown

One of the most interesting new HERMES studies is measuring the transversity distributions in the nucleon. Single-spin asymmetries for semi-inclusive electroproduction of charged pions in deep-inelastic scattering (DIS) of positrons are measured for the first time

with transverse target polarization [8]. The asymmetry depends on the azimuthal angles of both the pion (ϕ) and the target spin axis (ϕ_S) about the virtual photon direction and relative to the lepton scattering plane. The extracted Fourier component $\langle \sin(\phi+\phi_S)\rangle^{\pi}_{UT}$ is a signal of the previously unmeasured quark transversity distribution, in conjunction with the so-called Collins fragmentation function, also unknown. The Fourier component $\langle \sin(\phi-\phi_S)\rangle^{\pi}_{UT}$ of the asymmetry arises from a correlation between the transverse polarization of the target nucleon and the intrinsic transverse momentum of quarks, as represented by the previously unmeasured Sivers distribution function. Evidence for the both signals is observed, but the Sivers asymmetry may be affected by the exclusive vector meson production. This result is presented in Fig. 2.

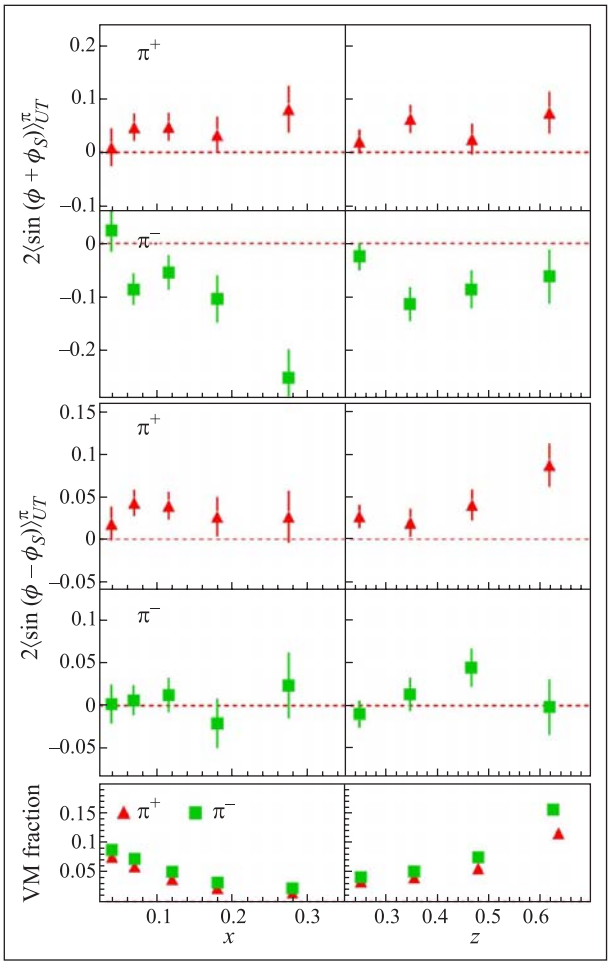

Fig. 2. Virtual photon Collins (Sivers) moments for charged pions as labelled in the upper (middle) panel, as a function of x and z, multiplied by two to have a possible range ± 1. The error bars represent the statistical uncertainties. In addition, there is a common 8% scale uncertainty in the moments. The lower panel shows the relative contributions to the data from the simulated exclusive vector meson production

The extraction of the polarized SIDIS asymmetries and quark polarized distributions is one of the main goals of the HERMES. Polarized DIS data on the longitudinally polarized hydrogen and deuterium targets have been used to determine double spin asymmetries of cross sections [9, 10]. Inclusive and semi-inclusive asymmetries for the production of positive and negative pions from hydrogen were obtained in a re-analysis of the data published previously. Inclusive and semi-inclusive asymmetries for the production of negative and positive pions and kaons were measured on the polarized deuterium target. Separate helicity densities for the up and down and the anti-up, anti-down, and strange sea quarks were computed from these asymmetries in a «leading-order» QCD analysis. The polarization of the up-quark is positive and that of the down-quark is negative. All the extracted sea quark polarizations are consistent with zero, and the light quark sea helicity densities are flavour symmetric within the experimental uncertainties. First and second moments of the extracted quark helicity densities in the measured range are consistent with fits of the inclusive data. The obtained data are shown in Fig. 3.

LPP participates in the upgrade of **H1** detector to investigate DIS processes at the ep collider HERA, DESY, specifically in the upgrade, installation, operation, and software support of three important detectors: Forward Proton Spectrometer (FPS), Backward Proportional Chambers (BPC), and Plug Detector. In 2004 the HERA collider continued operation after the luminosity upgrade and delivered 80 pb^{-1} luminosity. The ep collision data have been taken with longitudinally polarized positrons for the first time. The polarization of the lepton beam allows the HERA experiments to futher constrain the parton densities of the proton through measurements of the polarization asymmetries and test Electroweak part of the SM.

New data taken with the H1 detector, for longitudinally polarized positrons in the left- and right-handed states in collision with unpolarized protons at HERA, are used to measure the total charged current (CC) cross section for $Q^2 > 400$ GeV^2 [11]. The polarization dependence of the total CC cross section is compared with the SM expectations in Fig. 4. The SM predicts that the CC cross section should have a linear dependence on polarization, and, futhermore, the cross section for fully left-handed positrons should be zero (similarly for fully right-handed electrons). This follows from nonexistence of right-handed currents within the framework of the SM. The data of the H1 and ZEUS experiments are used to obtain the extrapolated total charged current cross section for a fully left-handed positron beam: $\sigma = (0.2 \pm 1.8(\text{stat.}) \pm 1.6(\text{syst.}))$ pb. This extrapolation is found to be consistent with the expectations of the SM shown in Fig. 1.

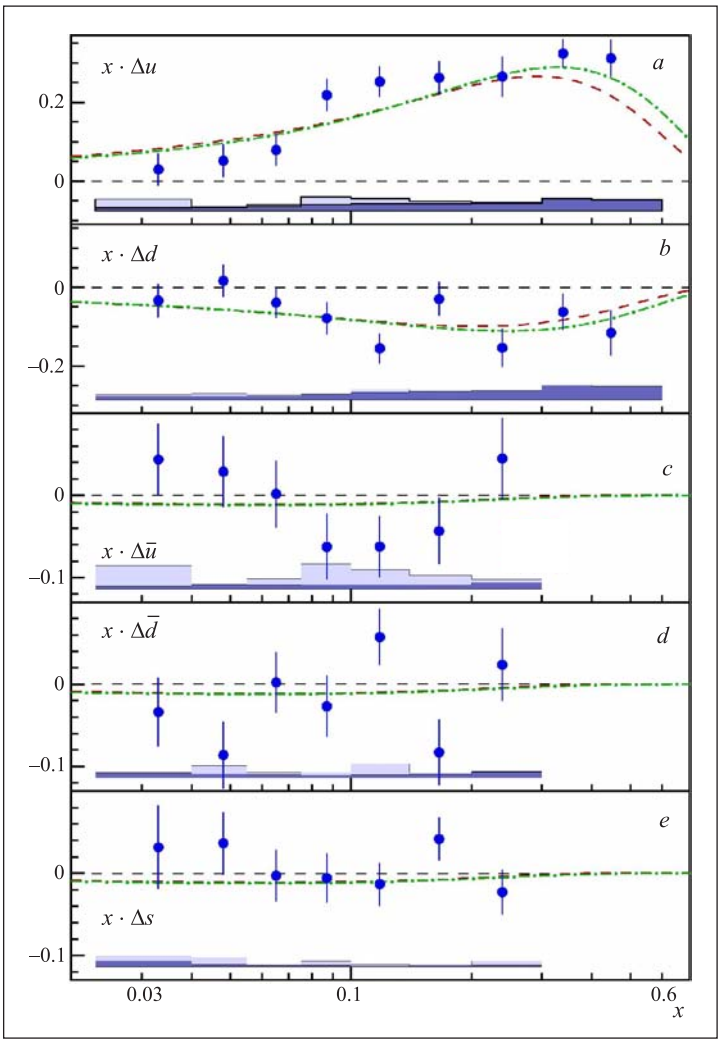

Fig. 3. The quark helicity distributions $x\Delta q(x, Q_0^2)$ evaluated at a common value of $Q_0^2 = 2.5$ GeV^2 as a function of x. The dashed line is the GRSV2000 parameterization (LO, valence scenario) scaled with $1/(1 + R)$ and the dot-and-dash line is the Blumlein–Bottcher (BB) parameterization (LO, scenario 1)

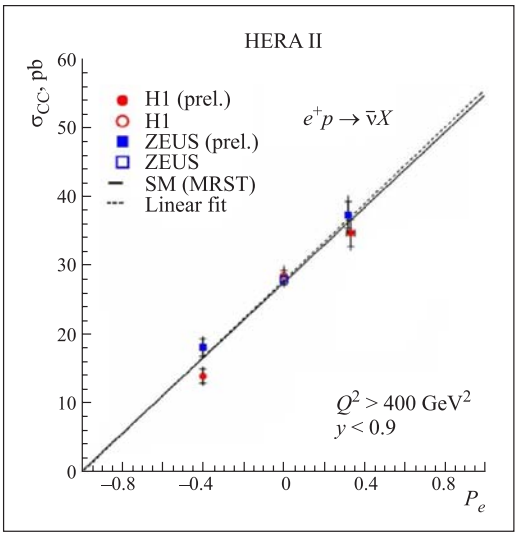

Fig. 4. The dependence of the e^+p CC cross section with the lepton beam polarization P_e measured by the H1 and ZEUS experiments. The data are compared with the prediction of the SM. The dashed line is the result of a linear fit to the data

The LPP group participating in the H1 experiment has made a major contribution to the measurement of diffractive structure function F_2^D in DIS processes with a leading proton detected in the H1 FPS [12, 13]. Comparison of the H1 FPS leading-proton structure function with the result of the analogous measurement by the ZEUS experiment and F_2^D obtained by H1 from the data with a large rapidity gap in the central detector has shown good agreement between two experiments and two methods (see Fig. 5). The result proves a small contribution of the proton dissociation in the large rapidity gap data. Diffractive parton density functions (PDFs) are extracted from NLO DGLAP QCD fit to the large rapidity data. The QCD predictions based on the diffractive PDFs describe the new H1 diffractive neutral current and charge current measurements at high Q^2 [14, 15].

According to the JINR commitments, LPP participated in the commissioning of the Outer Tracker (OTR) of the **HERA-B** detector, which is a large-aperture spec-

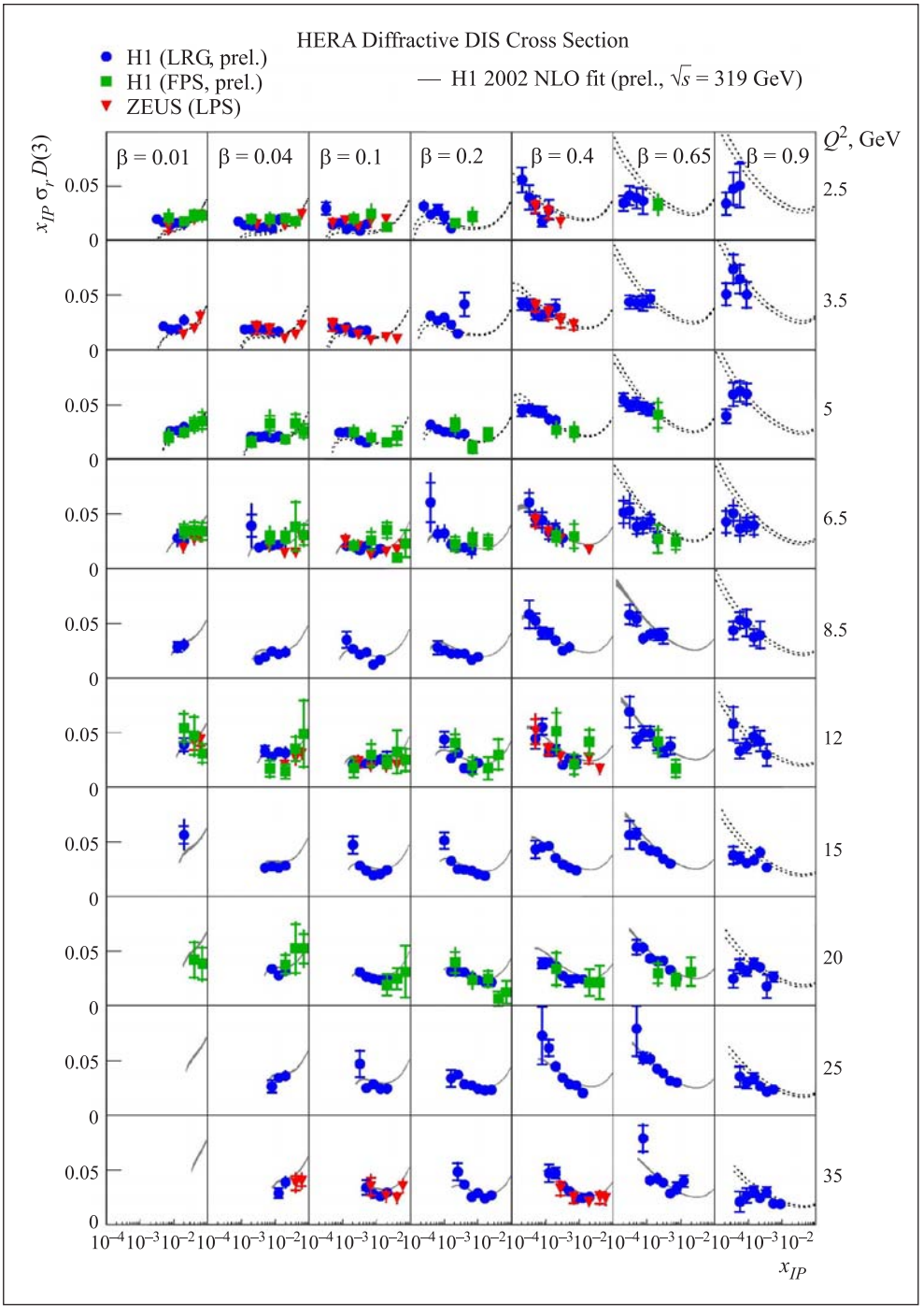

Fig. 5. Diffractive structure function $x_{IP}F_2^{D(3)}$ measured in DIS processes with a leading proton in the final state (H1 and ZEUS) and in Large Rapidity Gap processes (H1). The result of the NLO DGLAP QCD fit to the H1 LRG data is also presented

trometer built to study collisions of 920-GeV protons with the nuclei of target wires positioned in the halo of the HERA proton beam. Data taking at the HERA-B detector was finished in 2003, and Dubna physicists concentrated completely on the physics analysis.

The Dubna group participates in the study of A-dependence of J/ψ production via the decay mode $J/\psi \to e^+e^-$, which is a first-priority task in the HERA-B data analysis programme. Various algorithms for building e^+e^- invariant mass spectra, as well as fitting of J/ψ signal and its behaviour for different runs and targets (carbon or tungsten), have been studied in various intervals of the Feynman variable x_F. The Dubna group contributed considerably to the testing of the MC trigger simulation procedure. Special investigations were made to select the $\chi_c \to J/\psi\,\gamma$ signal from the background [16].

By using $5 \cdot 10^7$ events recorded with a dimuon trigger, the dimuon mass spectrum in a search for the flavour-changing neutral current decay $D^0 \to \mu^+\mu^-$

has been investigated [17]. No evidence for such decays has been found. By using the values of D^0 and J/ψ production cross sections published in the literature, the upper limit on the branching fraction Br $(D^0 \to \mu^+\mu^-) < 2.0 \cdot 10^{-6}$ was set on the 90% confidence level (CL).

The search for $\Theta^+(1540)$ and $\Xi^{--}(1540)$ pentaquark candidates was carried out in proton-induced reactions on carbon, titanium and tungsten targets at mid-rapidity ($y_{\rm cm} \approx 0$) and $\sqrt{s} = 41.6$ GeV [18]. In $2 \cdot 10^8$ inelastic events, no evidence for narrow ($\sigma \approx 5$ MeV/c^2) signals in the $\Theta^+ \to pK_S \to p\pi^+\pi^-$ and $\Xi^{--} \to \Xi^{--}\pi^- \to \Lambda\pi^+\pi^-$ channels was found. The 95% CL upper limits for the inclusive production cross section multipled by branching fraction Br $d\sigma/dy|_{y\approx 0}$ are 3.7 and 2.5 μb/N. The upper limit of the yield ratio of $\Theta^+/\Lambda(1520) < 2.7\%$ is significantly lower than model predictions. The upper limit of Br $\Xi^{--}/\Xi(1530)^0 < 4\%$ is at variance with the results that have provided first evidence for the Ξ^{--} signal.

The **EXCHARM** experiment is aimed at studying the charmed and strange particle production characteristics and at searching for narrow baryonia in neutron–nuclon interactions at the Serpukhov accelerator.

New data on negative kaons interference correlations have been obtained [19]. The production area size R for identical kaon pairs was estimated in the framework of Goldhaber parameterization. The behaviour of R indicates the reduction of the particle generation area size with increasing of produced particle masses. The coherent parameter λ was measured as $\lambda = 1.70 \pm 0.01$. Preliminary data were obtained on the measurement of α parameter indicating a power dependence of $\bar{\Lambda}^0$-hyperon inclusive production cross section σ on target nuclear masses ($\sigma = \sigma^0 \cdot A^\alpha$) [20]. The result obtained with C and Cu targets, $\alpha = 0.72 \pm 0.07$, is in good agreement with the theoretical predictions $\alpha = 2/3$.

The results of the investigation of ϕ-meson and Λ^0-hyperon associative production have been published in [21]. The study of the characteristics of charmed baryon Λ_c^+ by their decays to neutral kaon K^0 and proton p is in progress. There was obtained an indication of a signal in the region of the PDG mass of Λ_c^+ in the spectra of the K^0p effective mass.

The effective mass spectrum of K^0p was investigated in the region of 1540–1550 MeV/c^2. At the K^0p effective mass equal to 1548 MeV/c^2 there is an indication of a signal (at the level of a triple standard deviation) that could be interpreted as a pentaquark state Θ^+ decay.

LPP specialists participate in the international project for the precise and direct determination of the flux of the solar neutrinos produced in the ^{7}Be electron capture process in the Sun and study of the phenomenon of neutrino oscillations for the low-energy solar neutrino spectrum using a calorimetric liquid scintillator and a low-background detector **BOREXINO** placed at the Gran Sasso underground laboratory, Italy. The prototype of the BOREXINO detector, the Counting Test Facility (CTF), has provided the convincing evidence that the technological challenge of the experiment, the achievement of unprecedented radiopurity levels in the scintillator were accomplished successfully, thus opening the way to realize the milestone of the experiment. The Dubna group has performed mounting and cleaning of PMTs, testing of VME electronics, and production of the analog electronic modules for the experiment. The proposal to upgrade the CTF was developed to be able to study solar pp neutrino. The CTF data analysis has given new physical results on the limit of the flux of antineutrino from the Sun in the region of small energy by using the process of the inverse beta decay of proton, as well as a new limit on the violation of the Pauli exclusion principle in nuclear processes and search for weak-interacting pseudoscalar particles emitted in M1 transition of the excited nuclei ^{7}Li.

The COmmon Muon and Proton Apparatus for Structure and Spectroscopy, **COMPASS (NA58)**, has been proposed to perform a series of experiments at CERN SPS, including studies of the nucleon spin structure by using the longitudinally polarized muon beam and polarized targets, as well as study of nucleon spectroscopy by using high-energy hadron beams and various targets. The COMPASS spectrometer, including detectors under JINR responsibilities, operates very reliaby from the start of the run in May 2004. JINR participants have taken an active part in preparations of the hadron run. The COMPASS collaboration continues the analysis of data accumulated with the muon beam in 2002 and 2003 [22].

The preliminary data on the asymmetry $A_1^d(x)$ in scattering of virtual photons on longitudinally polarized deuterons as a function of the Bjorken variable x have been obtained from the 2002 data. This asymmetry is related to the polarized structure function $g_1^d(x)$. Full statistics of 2002–2004 is expected to be four times larger. It is required for the QCD analysis of g_1 and determination of the parton distributions, particularly ΔG. The reconstruction of D^{*+} and D^0 mesons produced in DIS of muons on the longitudinally polarized deuterons has been performed to determine the gluon contribution to the spin of nucleon. The expected 2002–2004 statistics will allow one to determine $\Delta G/G$ from all the D-meson decays with an accuracy of about $\sigma(\Delta G/G) \sim 0.25$. For the first time, the so-called Collins azimuthal asymmetries of hadron produced in DIS of muons on the transversely polarized deuterons have been extracted as a function of x and partial energy of hadrons. Also the spin transfer from the longitudinally polarized muons to Λ and $\bar{\Lambda}$, produced in DIS of muons on deuterons, has been obtained.

LPP takes part in the experiments on the 4π-detector **STAR** at the RHIC collider at the Brookhaven National Laboratory (BNL). Scientific activity of the LPP group is based on the JINR contributions to the construction

of the first half of the STAR Barrel Electro-Magnetic Calorimeter (BEMC) and the development of related subsystems and software. The LPP STAR group has completed manufacturing at the WSU (Detroit) of all 120 modules of the BEMC and the installation of the modules on the STAR magnet. The performance of BEMC Shower-Mass Detectors (SMD) has been studied. The integration of the device into the STAR data-taking system was done.

The Dubna group participates in estimation of the inclusive output of the direct photons, as well as electron and positron spectra in Au–Au collisions at 200 GeV. The inclusive spectra of electrons produced in dAu collisions at 200 GeV have been measured. The hadronization geometry and charge-dependent number of autocorrelations on axial momentum space [23], as well as transverse momentum correlations and minijet dissipation [24], have been studied in Au–Au collisions at $\sqrt{s_{NN}} = 130$ GeV. The azimuthal anisotropy and correlations at large transverse momenta [25], as well as φ-meson production, have also been studied in pp and Au–Au collisions at $\sqrt{s_{NN}} = 200$ GeV [26].

The total production cross sections of $c\bar{c}$ and $b\bar{b}$ states have been estimated by using these data. A study of the proton (antiproton)–lambda (antilambda) correlations in Au–Au collisions at 200 GeV has been done in a collaboration between Dubna and Nantes. Based on the known proton–lambda scattering lengths, the average size of the proton and lambda sources was found to be about 3 fm, close to the size of the proton source determined from the proton–proton correlation function. For the proton–antilambda and antiproton–lambda systems, the correlation functions have been measured for the first time and the corresponding spin averaged scattering length was estimated, showing a positive imaginary part (a significant contribution of the annihilation channels) and/or a negative real part. This result opens a door in a new field — the correlation study of particle scattering in the systems that can hardly be accessible by other means.

A review and consequences of the correlation femtoscopy results from STAR and other experiments have been published [27]. It appears that with increasing energy of heavy-ion collisions from AGS and SPS up to the highest energies at RHIC, the data on like pion correlations show a rather weak energy dependence and point to the kinetic freeze-out temperature somewhat below the pion mass, a strong transverse flow (with the mean transverse flow velocity at RHIC exceeding half the velocity of light), a short evolution time of 8–10 fm/c and a very short emission duration of about 2 fm/c. The short evolution and emission duration at RHIC are also supported by the correlation analysis with respect to the reaction plane. The small time scales at RHIC were not expected in the transport and hydrodynamic models and may indicate an explosive character of particle production. A rather direct evidence for a strong transverse flow in heavy-ion collisions at RHIC is coming also from pion–kaon correlation asymmetries. The technique of unlike particle correlation asymmetries has been developed in a collaboration between Dubna and Nantes [28]. Being sensitive to relative time delays and collective flows, it can be especially useful to study the effects of the quark–gluon plasma phase transition.

PREPARATION OF NEW EXPERIMENTS

According to the JINR obligations in the **ATLAS** experiment, which is under preparation at CERN, physicists of LPP participate in the construction of the Liquid Argon Hadronic Endcap Calorimeter (LArHEC) and Transition Radiation Tracker (TRT).

In 2004 the fulfilment of JINR MoU obligations for the ATLAS detector construction in the field of liquid argon calorimetry was completed. About 2000 channels of preshaper circuits have been produced and mounted on the front-end boards of the LArHEC. Assembly of 50 temperature probes on the rear face of the HEC2A wheel has been done. The liquid argon endcap calorimeters have been inserted into cryostats, and cold tests of the full systems (cryostat and calorimeters) were completed by the end of the year. The combined test of endcap calorimeters has been performed at the SPS test beam. Study of different physics issues for the LHC collider (in particular, top-quark physics) and analysis of 2002 and 2004 test beam data have been carried out.

The fulfilment of JINR obligations on the ATLAS TRT detectors assembly is going on well. In 2004, 8 four-layer wheels were completely assembled and tested at JINR, and 3 eight-layer wheels were assembled, too — two of them were delivered to CERN. The automatic system for the quality control of straws installed in the ATLAS TRT detector is developed [29]. The equipment for cables manufacturing for the barrel and inner detector is adjusted and checked up. The trial sample of a cable was made and delivered to CERN.

The main effort of JINR in the **CMS** project is concentrated on the design and construction of the endcap detectors, where JINR bears full responsibility within the framework of the RDMS CMS collaboration: Endcap Hadron Calorimetry (HE) and First Forward Muon

Station (ME1/1). JINR also participates in the Endcap Preshower (ES), development of physics programme, and computing and core-software.

The **NIS** experiment at the JINR Nuclotron is aimed at searching for effects of the hidden polarized strangeness of nucleons, namely the search for OZI-rule violation in reaction of ϕ and ω production close to the corresponding thresholds in pp and np interactions at the energy excesses above the thresholds from 30 to 100 MeV. In 2004, the addendum to the NIS project for Θ^+ pentaquark search in pp interactions near the threshold was prepared and approved with the first priority. Physicists from LPP, VBLHE, DLNP, BLTP and LIT are participating in the project.

In 2004, tests of the EXCHARM 2×1 m chambers and the data readout electronics with a β source at the test-bench were continued**.** The work on design and production of the chamber supports was completed. To test the RPC counters and their front-end electronics delivered from CERN, the test-bench is arranged, and a simplified gas supply system is prepared. Several counters were tested using a prototype of the registering electronics. The design of the Forward MDC (Mini-Drift Chambers) is practically finished. The advanced version of the Monte-Carlo simulation software for the NIS experiment is developed. The field map measurement has been performed. The data are in agreement with the theoretically calculated field map. The prototypes of the main modules for the TOF measurements in the RPC walls, as well as the drift-time measurements in MDC, are developed and produced. The R&D of the module for amplitude measurements is in progress, and preparatory work to develop and produce the trigger logics module prototype was fulfilled. Production of the elements of the liquid hydrogen target was started. The pilot calculations of the beam transport line from the focus F5 up to the NIS target have been carried out.

Within the **THERMALIZATION** project started in 2003 at the Serpukhov accelerator and aimed at studying multiparticle production in pp interactions with high multiplicity at 70 GeV, work is being continued on the renewal of the electronics and the vertex detector, the design and the production of the drift tube tracker for the magnetic spectrometer upgrade, the creation of the hydrogen target and the trigger system for the registration of the high-multiplicity events based on the silicon strip detectors and scintillation counters. The SVD-2 experimental data obtained in proton–nucleus collisions at 70 GeV/c at the IHEP accelerator have been analyzed to search for an exotic pentaquark ($uudd\bar{s}$) Θ^+ baryon in a pK^0_S decay mode. The pK^0_S invariant mass spectrum shows a resonance structure at a mass of 1526 MeV/c^2 with the statistical significance of 5.6 standard deviations. The values of the mass and width of this exotic baryon state are compatible with those predicted and recently reported in a number of experiments. The gluon dominance model was developed for the description of multiplicity distributions in pp interactions. In the region from 70 to 800 GeV/c the model shows that protons remain leading particles, and the process of multiparticle production is realized by so-called active gluons characterized by the same hadronization parameters as in the e^+e^- annihilation. To estimate the size of the hadronization region, a method has been suggested based on the soft photon data. The results are presented in [30–32].

ACCELERATION TECHNIQUES

LPP specialists participate in construction of the Transverse Damping System at **LHC**. The creation of deflectors and powerful broadband amplifiers for the transverse feedback system (TFBS) for LHC beam was a main direction of activity in 2004. A successful vacuum test of samples of vacuum chambers produced in cooperation with Elektrokhimpribor Integrated Plant (Lesnoi) and at the Urals State Technical University (Yekaterinburg) was carried out at CERN. Audit of the equipment of the high-voltage bench and its partial modernization is carried out at LPP. Two amplifiers have been istalled and tested. The equipment of the electronic accelerator for Chinese People's Republic is handed over in operation. Tests of scanning system for the ion beam of the cyclotron IC100 at LNR are carried out; work on the scanner for DC72 and DC60 has been started. Manufacturing systems of stabilization for LIA3000 (LPP JINR) is in progress.

The cathode module of LIA3000 linac has been modernized. As a result, the magnitudes of the electron current at the linac output and at the FEM oscillator output have been increased by 25–30%. This work is an essential step to enhance the RF power level and attain high recurrence of the linac operating regimes. Besides, in order to reach the required beam stability, the axial centering of the beam should be improved several times. Beam position nondestructive monitors have been developed for this purpose. The microwave test facility being developed and continued at LPP is designed for experimental definition of lifetime of the accelerating structure for an electron–positron collider with respect to pulsed cyclic heating at a frequency of 30 GHz, the operating frequency of the **CLIC** collider.

A novel system of laser alignment of the RF transmission line has been introduced in cold measurements jointly with IAP RAS (Nizhni Novgorod) collaborators.

It allowed one to reduce the radiation loss within the line significantly and obtain the cold-measurement parameters close to the designed ones. A modernization of the RF line has been proposed and performed to increase considerably the value of the RF power amplitude W multipled by RF pulse duration τ limiting in terms of the electric breakdown. Due to this modernization it became possible to approach the designed values of the power and RF pulse duration in beam-loaded experiments.

Two current sources for powerful focusing magnetic lenses have been manufactured and adjusted. The power supplies of the pre-injector and modulators are under adjustment process. The stabilization of the power-supply systems is of special importance to provide high recurrence of the amplitude and duration of the beam-current and RF pulses. It should save the operation time at the stage of the facility adjustment and is very important for the statistics acquiring.

The system of on-line control of the linac and FEM output parameters has been developed and built. It will provide control and measurement of beam-current pulses and RF signals in every operation cycle. The alignment of the system has been started.

The wiggler water-cooling system has been developed and manufactured (instead of the air-cooling system operated by tradition). The water cooling of the wiggler is needed to provide the operation with a repetition rate of more than 0.5 Hz. The new system is under testing.

The main fields of the LPP contributions to the **TESLA** project are X-ray FEL, $\gamma\gamma$-collider option, and participation in the accelerator and FEL experiments on the TESLA Test Facility (TTF) at DESY. In 2004, the photon diagnostic unit, equipment for photon beamline, and mirror chamber for pump-probe experiments at the TTF FEL, Phase II, were manufactured at JINR and delivered to DESY. The design of the wiggler for PETRA storage ring was completed. Analysis of the beam and FEL physics for Phase I of the TTF FEL project was finished successfully. It confirmed that TTF FEL was driven by the electron bunch having 3 kA peak current. Formation of the driving beam was strongly influenced by space charge effects. JINR experts took part in the theoretical and design work on diagnostic tool based on the FIR (Far Intra Red) coherent undulator. Perspective potential extensions of TTF FEL were studied in detail: the two-colour FEL amplifier and the efficient frequency doubler.

Within the **IREN** activity, the installation project for modulator MK1 of the first accelerating section of LAE200 was prepared in 2004. The settlement-theoretical work to optimize operating modes of the accelerating and focusing systems of the linac are carried out. About 70% of coils of the focusing solenoid of the first accelerating section have been produced. The installation of the basic carrying constructions of the linac is completed. In cooperation with FLNP, the installation of the equipment of modulator MK1 has been started. The control assembly of the electron source — an electron gun with a pulse feed of 200 kV — is carried out. The source is under bench testing. The test of the accelerating sections and units of the RF feeder has been performed at the full-scale RF stand.

DEVELOPMENT OF A COMPUTER INFRACTRUCTURE

The goal of the project is to manufacture the computer cluster with parameters 5 times superior to existing, integrated into a distributed computer infrastructure of JINR. This cluster is considered to be a basis for support of investigations into particle and nuclear physics at LPP. The effective features for a fast access to the computer resources from the problem-oriented supported working places will be provided.

As a result of the development of LPP–VBLHE PC-farm for non-budget resources, the number of used PCs has been increased from 20 to 29, a full power of their processors has been increased more than three times — up to 28.5K SI95, including from 0.7 up to 2.4K SI95 for batch computer; a disk space for users has been more than doubled, up to 6.5 TByte. The released low-power computers (with a frequency of CPU 400 MHz) are given to the Laboratory to be used as workstations. An upgrade of the local computer network of the Laboratory up to Gigabit Ethernet equipment has been carried out. Four local subnets of the Laboratory have been organized. The total number of the network users through the local subnets has been increased.

Equipment for wireless access of part of users to the local JINR network has been installed and tested. The conference hall and hall for videoconferences have been equipped with video projectors. Special CASTOR program system has been installed on PC-farm computers to work with large data volumes. A method of integration of different PC-farm computer resources has been proposed and tested on the basis of this system.

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