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Report to the 81st Session
of the Scientific Council of JINR
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High energy physics

In 1996 the **DELPHI** experiment at LEP was taking data at new energies of 161, 170, and 172 GeV, which exceed the threshold of the W-pair production. Statistics about 20 pb^{-1} as collected at high energies. For the first time the W-pair production cross section in e^+e^- collisions was measured and the results of the measurement of W-boson mass were obtained. The limits on the production of new particles were improved from the analysis of the high energy data.

Analysis of the LEPI data continued and new results of improved quality were presented by DELPHI at different sections of the recent International Conference on High Energy Physics in Warsaw. They comprise the test of the Standard Model of electroweak interactions, the new results of QCD-studies, heavy quark and two-photon physics, searches for new particles.

According to the plan, next year the energy of LEP will be increased again and the DELPHI experiment will continue data taking and physics analyses.

Data taking and data processing were continued at the **NOMAD** set-up at CERN in 1996. The main goal of the experiment is to search for $\nu_\mu \leftrightarrow \nu_\tau$ oscillations.

In participation with LNP stuff members the electron separation efficiency in transition radiation detectors made of mylar tubes filled with xenon with the methane admixture was obtained as high as 90% as π mesons were suppressed down to 10^{-3}.

The data analysis has begun to search for interactions $\nu_\tau + N \rightarrow \tau^- + X$ as a consequence of the oscillation in question with separating the electron mode of the τ lepton decay.

Using the set-up of the WA102 experiment in the CERN **OMEGA** spectrometer, the LNP scientists participate in the investigation of the $\pi^- p$ and pp interactions at high energies.

In 1996 a soft photon signal about 8 times the QCD inner bremsstrahlung was observed in pion-proton collisions at 280 GeV/c. The result confirms the observations of some previous experiments.

The $\pi^+\pi^-$ events produced in central pp interaction are studied. In was observed that the cross section for $\rho(770)$ and $f_2(1270)$ production is greater in reactions where both final state protons in lab. frame travel in opposite directions. The phenomenon appears to be due to some nontrivial meson production mechanism contributing to such kinematics.

The analysis of the data collected with the **HYPERON** spectrometer yielded values of the Dalitz-plot slope parameters for the $K^+ \to \pi^+\pi^0\pi^0$ decay. The decay parameters were measured with high precision. Because now the HYPERON spectrometer consists of two hodoscope electromagnetic calorimeters, a spectrometric magnet and proportional chambers, it was possible to perform the first electronic experiment where energies and momenta of all particles involved were measured.

The data from three independent neutrino and antineutrino exposures with the IHEP-JINR **Neutrino Detector** at energies 6-28 GeV are processed. The isoscalar structure functions xF_3 and F_2 are measured in the region of relatively small transfer momenta $0,55 < Q^2 < 4,0$ GeV^2.

An estimate of the Gross-Llewellyn Smith sum rule is obtained:

$$\int_0^1 F_3 dx = 2.13 \pm 0.38(stat.) \pm 0.26(syst.).$$

The strong interaction constant $\alpha_s(M_Z)$ and the QCD scale parameter Λ_{MS} are evaluated from the QCD analysis of the xF_3 data in the next-to-leading order approximation.

The study of spin dependence of polarized neutron-proton elastic scattering at 16 MeV/c with polarized neutron beam of

Van de Graaff accelerator of Nuclear Centre Charles University (Prague) is continued. A phase-shift analysis based on all $\Delta\sigma_{L,T}$ results obtained was performed, with a varying mixing parameter ϵ_1, which was very inaccurately defined previously.

In 1996 the JINR staff members from LNP, LPP, FLNP and LCTA who participate in the CERN **ATLAS** collaboration, carried out the following main stages of the project.

The absorber for the 0-module of the ATLAS hadron tile calorimeter was designed and built. The prototype of the liquid-argon End-Cup hadron calorimeter was constructed and tested at CERN. The design and construction of the workshop for production of muon chambers and inner tracker were carried out. The special prototype of the inner tracker of the ATLAS detector was constructed and its temperature operation condition was studied. The electronics and materials were tested for radiation hardness at the FLNP reactors. The comprehensive off-line analysis of test runs of the prototype ATLAS detector and simulation of the experiment were carried out.

The aim of the **DIRAC** project is to measure the life-time of $\pi^+\pi^-$-atoms with 10% accuracy. This will allow one to verify the chiral perturbation theory — the lower limit of QCD — in a model-independent way at an accuracy level of 5%.

In 1996 six modules of drift chambers for the experiment DIRAC were manufactured and tested with the test beams of PS CERN. A new mode of gas discharge in the chambers. It allows a high counting rate of the chambers and big pulse amplitudes. Optimization of the geometry of the set-up DIRAC is completed.

The yields of dimesoatoms in proton-nucleus interactions for the set-up DIRAC and high-energy accelerators (E_p= 30, 70, 450 and 1000 GeV) were calculated. Investigation of Coulomb correlations in the system $\pi^+\pi^-$ was completed. The calculations of form factors of hydrogen-like atoms are carried out.

Intermediate and low energies

In 1996 the data obtained during previous years at PSI in searching for **muonium to antimuonium conversion** forbidden by lepton flavour conservation law were analyzed. No decay of an antimuonium atom was found. A new upper limit is established for the muonium-antimuonium ($M\bar{M}$) conversion probability

$$P_{M\bar{M}} \leq 8 \cdot 10^{-9} \quad (90\%\ C.L.),$$

which is a factor of 80 that the previous world-known result. It corresponds to a coupling constant $G_{M\bar{M}} \leq 1.8 \cdot 10^{-2} \cdot G_F$, where G_F is the Fermi constant.

In 1996 a 4-month long data recording run was accomplished using the new set-up (about 10 times more efficient as the previous one). In the next two years these experimental data will be analyzed, which will allow additional improvement of the foregoing result by a factor of 20–50.

Manufacturing and tests of the principal parts of the **PIBETA** detector for precise measurement of the probability of the pion beta decay ($\pi^+ \to \pi^0 e^+ \nu_e$) (CsI scintillator counters for the spherical calorimeter, fast veto plastic counters, the active target, cylindrical proportional chambers to detect charged particles) were continued in 1996.

The thin-walled cylindrical proportional chambers, designed and manufactured in Dubna, have been tested at PSI. These chambers were made using a new technology developed in Dubna. The technology provides higher reliability and precision of the chambers. The chambers have better characteristics then similar foreign-made chambers. The chambers were tested with an electron beam from a ^{90}Sr source and had the efficiency close to 100% ($\geq$ 99,8%) and coordinate measurement precision (for the strips) about 100 μm.

The goal of the experiment **DISTO** is to investigate strange particle production in proton-proton interactions in a polarized proton beam at SATURNE energies. Differential cross sections and various spin variables in Λ and Σ hyperon production will be measured.

In 1996 the improvement and calibration tests of all the detectors of the installation (scintillating fibre chambers, proportional wire chambers, scintillation counter hodoscope) and of the electronics for the trigger and for data taking were performed.

One of the main detectors — a set of proportional wire chambers — was made and tested at the Laboratory of Nuclear Problems and then transported to Saclay.

The first run was carried out at the end of November at the accelerator SATURNE, and in the near future the amount of the statistics obtained will be determined.

The **OBELIX** (experiment PS201 at CERN) collaboration continues data taking and investigation of dynamics of the antiproton annihilation at rest. During 1996, 200M annihilation events were acquired. This huge amount of data is equal to the statistics obtained for all previous 8 years of the PS201 experiment data taking. Interesting results were obtained in the study of the mechanisms for production of ϕ and ω mesons in the reactions

$$\bar{p} + p \to \phi + \pi^+ + \pi^-, \qquad \bar{p} + p \to \omega + \pi^+ + \pi^-$$

of antiproton annihilation at rest in a gaseous and a liquid hydrogen target. The ratio $R = Y(\phi\pi^+\pi^-)/Y(\omega\pi^+\pi^-)$ was measured for different invariant masses of the dipion system. It was found that the value of this ratio increases with decreasing dipion mass, which demonstrates the difference between the ϕ and ω production mechanisms. For small masses of the dipion system (300 MeV/c^2 < $M_{\pi\pi}$ <500 MeV/c^2) the ratio $R(\phi/\omega)$ demonstrates a substantial deviation from the OZI rule prediction.

In 1996 stuff members of LNP participated in the search for 2β-decay of ^{82}Se and ^{96}Zr nuclei with the **NEMO-2** spectrometer installed in the Modane Underground Laboratory.

High experience in the production of thin self-supporting sample foils, purification of enriched isotopes to 10^{-10}, tracking recognition and visualization, and complete data analysis has been obtained due to exploitation of the NEMO-2. Nevertheless, in 1997 this spectrometer will be dismounted and assembling of a new big NEMO-3 spectrometer will be started.

In fact, significant part of the NEMO-3 have been already created (copper big-dimensional base of the spectrometer, 50% of plastic scintillators, tracking recognition software, etc.). Steel carpentry and iron shielding and front-end electronic cards for 2000 Geiger-cell channels are planned to be produced in JINR in 1997. Further purification of the enriched materials against radioactive impurities to 10^{-11} will be continued.

As a result, NEMO collaboration will have for investigation the following *pure enriched samples*: 9 kg of ^{100}Mo, 0.8 kg of ^{116}Cd, 1 kg of ^{82}Se, 2 kg of ^{76}Ge, 1 kg of ^{130}Te, 30 g of ^{96}Zr.

The prototype **TGV** spectrometer consisting of 16 HPGe planar detectors has been created and mounted in the LSM (Modane, France). It was tested in *on-ground* and *under-ground* conditions.

The background measurements were carried out with and without natural samples. After two-year tests, the experiment on the search for the 2β-decay in enriched ^{48}Ca sample (3 g) has been started.

The aim of the **AnCor** experiments is to search for an admixture of Scalar Interaction by measuring the correlation coefficient in the super-allowed β-decay. The direction of neutrino flight is defined by the accurate measurement of the Doppler γ-ray shift caused by the nuclear recoil after β-decay.

In 1995 the ^{16}O(^{3}He,n)^{18}Ne reaction in a solid B_2O_3 target was investigated in the main on-line experiment using a multidetector set-up (14 Si(Li) positron detectors and 2 HPGe γ-detectors). The preliminary result $\alpha = 1.06 \pm 0.19$ leads to the upper limit for the scalar coupling constant $C_s/C_v \leq 0.26$. at 95% C.L. In order to improve the existing upper limit by a factor of 2, a gas target system has been developed and tested. In 1996 it was used in the experiments with ^{14}O.

The aim of the **ANKE COSY** project is participation in building of the wide purpose magnetic spectrometer ANKE at the internal cooled beam of the proton storage ring COSY and study of the cooperative proton-nucleus interaction using the spectrometer. Two reactions are chosen for the study — the deuteron break-up in cumulative kinematics and the subthreshold kaon production.

The responsibility of the JINR group includes development and construction of two detector systems from the four of systems approved for ANKE. The scintillation counter hodoscope and the drift chambers for the Backward Detector system are designed and manufactured. The hodoscope is delivered to Juilich.

Dubna group participates in development and manufacturing of the Side Detector MWPC and the fast trigger electronics. New modification of the threshold Cherenkov counters is proposed and tested.

The **μ-catalysis** in a mixture of hydrogen isotopes is under experimental and theoretical study at the LNP.

In 1996 the spin and temperature dependence of the $dd\mu$ mesomolecule formation rate was measured. The measurement with a high pressure target in the 20–200 K range resulted in clear evidence for the density effect. The liquid tritium target is assembled and tested in the muon beam of the JINR Phasotron. The measurements will started in the beginning of 1997.

The study of hard two-photon production process in proton-proton interaction have began at the Phasotron. The main goal of the experimental investigations is the search for narrow **dibaryon** six-quark states with masses $M_B \leq 2m_p + m_\pi$. The searching method is based on the measurement of the γ-ray energy spectrum for the $pp \rightarrow pp\gamma\gamma$ reaction with detection of both photons in coincidence.

In 1996 the major effort was directed towards development of the γ-ray spectrometer of the experimental set-up. The goal was to raise the efficiency of the set-up and to improve its energy and time resolutions.

Under the programme for investigation of the muon properties and the muon interactions with matter (**MUON**) the following results were obtained. The first experimental study of the negative muon capture in xenon with natural isotopic proportions was performed. For this purpose a new cryostat for cryoliquids was designed and constructed. The measured negative muon lifetime (104 ± 3ns) gives the nuclear capture rate $\Lambda_c(Xe) = 9.2 \pm 0.3 \times 10^6$ s^{-1}. This result is in good agreement with the theoretical calculations.

The study of condensed matter by the μSR-technique was continued. The investigations of the microscopic phase separation (PS) in high T_c superconductor La_2CuO_{4+y} by the muon spectroscopy technique were performed. The data obtained allow the conclusion that at y about 0.03 the crystal consists of microscopic (100 Å) regions possessing different hole concentration connected with electronic phase separation. The crystals do not reveal any macroscopic structural PS. The PS problem is very important for many fields of condensed matter physics. The μSR study of the phase separation phenomena was performed for the first time.

A project for precise measurements of the μ and π life-times using track information about pions and positrons is prepared.

At the experimental complex **YASNAPP-2**, new data on the structure of excited states in ^{213}Bi and ^{213}Po have been obtained in investigation of the decay of the short-lived nuclides ^{217}At (32ms) and ^{213}Bi (46min) in the ^{225}Ac decay chain.

The new experimental data allowed a shell-model reliable interpretation of the level structure.

It was known, that α-decay of ^{217}At proceeds mostly (99.9%) to the ground state of ^{213}Bi. The study of $\alpha - \alpha$-coincidence spectra allows one to obtain the most precise data on the energy and intensity of the α and γ transitions in the ^{217}At decay. A new $\alpha-\alpha$-decay branch Ea=6322 keV with intensity $I_\alpha = 0.005\%$ per decay and a new ^{213}Bi 759 keV level are found. Delayed $(\beta-\gamma)$, $(\gamma-\gamma)$ and $(\beta-\alpha)$ coincidences were used to determine the half-lives of the 440.5 keV ($T_{1/2}$=93(8) ps), 292.8 keV (78(14) ps) and ground (3.75(4) ms) states in ^{213}Po nucleus, populated by the β-decay of ^{213}Bi. The reduced are deduced probabilities for the 440.5 (M1), 147.6 (M1,E2) and 292.8 keV (M1)g-transitions.

The final analysis of the experimental data on ^{147g}Tb obtained in preceding years was finished in 1996. The study of γ-ray, internal conversion electron and $\gamma\gamma$ coincidence spectra at the β-decay of the ^{147}Tb $\pi 3s_{1/2}$ ground state allows extensive new data on properties of low spin states of ^{147}Gd. The intensities of all γ-rays with $I_\gamma > 0.06\%$ ^{147g}Tb are measured. The multipolarities of a number of γ-transitions with energies up to 2 MeV are established. A new ^{147g}Tb decay scheme including 44 excited states of ^{147}Gd is proposed. The probabilities of β-transitions (ln ft) to the ^{147}Gd levels are determined. Conclusions on the spin and parity of the level are drawn.

A direct experimental estimate of the upper limit for the $dd \rightarrow {}^3\mathrm{He} + n$ cross section at deuteron energy below the keV region is obtained for the first time. The experiment was performed at the Pulsed Ion Beam Accelerator of the High Current Electronic Insti-

tute in Tomsk, using high-intensity radially converging deuteron beams, generated during implosion of the plasma. The upper limit obtained for the $d+d \to {}^3\mathrm{He}+n$ cross section for deuteron energy of 400 eV at 90% C.L. is

$$\sigma(dd) \leq 2 \times 10^{-34}\mathrm{cm}^2.$$

The objective of the project **FASA**, which is under way at JINR Synhrophasotron is to clarify the mechanism for multiple emission of intermediate-mass fragments by very hot nuclei, which is related to the liquid-gas phase transition in nuclear matter.

The FASA collaboration has already obtained the following results. The fragment spectra are found to change with increasing multiplicity, which results in a decrease in the average energy with increasing multiplicity. This is explained by transition from surface emission of fragments to volume emission as the multiplicity increases. Hence the conclusion can be drawn that multiple emission of fragments is a volume process.

Multiple emission of fragments is shown to occur after considerable expansion of the system due to thermal pressure. The time scale of the process is found: the average emission time does not exceed 2×10^{-22} s. This result completely rules out the trivial mechanism of successive independent evaporation of fragments. Thus, added to the three known types (radiative decay, evaporation of particles, and fission) a fourth one is discovered — thermal multifragmentation.

Research and Design

Development of the Si-based cryogenic bolometer is started. The cryogenic part of the device (a ${}^3\mathrm{He}/{}^4\mathrm{He}$ dilution refrigerator which is able to cool a sample down to 10–15 mK) is created. Test investigations with the InSb:Mn-based semiconductor thermometer are undertaken.

Technology for production of polystyrene-based plastic scintillators with POPOP (0.05%) and p-therephenyl (2%) admixtures is developed. Investigation of the main properties (energy and time resolution) of the scintillator detectors were carried out. Good characteristics ($\mathrm{FWHM}_E/\mathrm{E}(975\ \mathrm{keV}) \leq 12\%$, $\mathrm{FWHM}_T(511\ \mathrm{keV}) \leq 1\mathrm{ns}$) made it possible to use these scintillators in the calorimetric part of the NEMO-2 and NEMO-3 double beta-spectrometers. In 1995–1996 about 50% of the scintillators for the NEMO-3 project (~3 t) were produced.

Important R&D have been carried out at the ISOL-facility YASNAPP-2. The electronic optical parameters of the mass-separator were improved ($\Delta M/M = 1800$). Operation of the surface-ionization ion source was optimized. A prototype plasma ion source was designed and tested.

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