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Report to the 91st Session
of the JINR Scientific Council
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Dubna 2001

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The activity of LPP in 2001 was concentrated on the current particle physics experiments and preparation of the new ones, R&D of the particle detectors and different acceleration systems.

1. CURRENT EXPERIMENTS

The experiment EXCHARM is devoted to the study of the charmed and strange particle production in neutron-nucleon interactions at the Serpukhov U-70 accelerator. The final results on measuring the cross-sections of the hyperon inclusive production in neutron-carbon interactions have been published [1]:

$$\begin{aligned}
\Lambda^0 &- (3330 \pm 280)\ \mu\text{b/nucleon}, \\
\Xi^- &- (95 \pm 6)\ \mu\text{b/nucleon}, \\
\Sigma(1385)^- &- (337 \pm 33)\ \mu\text{b/nucleon}, \\
\Sigma(1385)^+ &- (277 \pm 18)\ \mu\text{b/nucleon}, \\
\Xi(1530)^0 &- (17 \pm 3)\ \mu\text{b/nucleon}.
\end{aligned}$$

Preliminary results of measuring the inclusive production cross-sections of anti-hyperons were obtained as well [2]:

$$\begin{aligned}
\overline{\Lambda}^0 &- (184.3 \pm 11.2)\ \mu\text{b/nucleon}, \\
\overline{\Xi}^+ &- (6.04 \pm 0.51)\ \mu\text{b/nucleon}, \\
\overline{\Sigma}(1385)^- &- (11.9 \pm 1.3_{stat.} \pm 0,9_{syst.})\ \mu\text{b/nucleon}, \\
\overline{\Sigma}(1385)^+ &- (10.4 \pm 1.9_{stat.} \pm 0.7_{syst.})\ \mu\text{b/nucleon}.
\end{aligned}$$

An indication on the destructive correlations of the Λ^0's pairs in the region of small four momentum has been observed [3]. The fist results on the associative ϕ–Λ and ϕ–kaon production have been obtained [4].

The following studies are planned to be continued in 2002–2003:

- comparison of the inclusive production cross-sections of Ω^- and $\overline{\Omega}^+$;
- Ξ^- polarization;
- A-dependence of the inclusive production cross-sections of Λ^0 and Ξ^-;
- Bose-Einstein correlations for identical boson pairs.

The group of LPP physicists actively participates in the NA48 experiment at CERN devoted to the precision measurement of the ratio ϵ'/ϵ in CP violating decays $K_L^0 \to \pi\pi$. The value of the parameter $\mathrm{Re}(\epsilon'/\epsilon)$ has been measured [5] on the base of the data recorded in 1997–1999 runs, which is $(15.3 \pm 2.6) \times 10^{-4}$. Thus, the existence of the

direct CP-violation predicted by the Standard Model (SM) has been confirmed. The LPP group significantly contributed to this analysis.

A quadratic slope parameter in the $K_L \to 3\pi^0$ decay Dalitz plot has been measured to be equal to $(-6.1 \pm 0.9_{stat.} \pm 0.5_{syst.}) \times 10^{-3}$ [6]. This is the most precise measurement of this slope parameter. The result is based on 14.7×10^6 fully reconstructed $K_L \to 3\pi^0 \to 6\gamma$ decays.

The decay $K_S \to \pi^0 e^+ e^-$ has been searched for by using the data collected in the run with high intensity K_S beam in 1999. An upper limit for the branching ratio has been obtained as $Br(K_S \to \pi^0 e^+ e^-) < 1.4 \times 10^{-7}$ at 90% CL [7].

The experimental run has been carried out in 2001 with an active participation of the LPP group, which has a special obligation to maintain on-line monitoring of the accepted events. The test runs to investigate various triggers for charged kaon decays have been carried out in the framework of the preparation for the new experiment NA48/2. Some filtering and monitoring for these test runs have been prepared by the LPP group. The work on the restoration of the drift chambers (~100 planes) has been completed.

In 2002, the NA48 collaboration plans to complete the current studies of neutral kaon decays and start active preparation of the experiment NA48/2 dedicated to the study of charged kaon decays:

- the ratio ϵ'/ϵ will be measured on the base of the data recorded in 2001 and some of systematical errors will be specified;
- new experimental data will be accumulated and analysed in order to study K_S and hyperons rare decays;
- the basic mass production Monte-Carlo simulation for 2001 run will be completed;
- new results on rare decays of K_S and hyperons will be obtained on the base of the data recorded in 1999–2002;
- the NA48 setup will be upgraded for the new experimental programme to study charged kaon decays;
- new programmes to monitor the data taking, simulation and data analysis will be developed by the LPP group.

The Dubna group has taken an active part in data taking, data analysis and technical maintenance of the system of mini-Drift Vertex Chambers (DVC) of HERMES Spectrometer Front Tracking at the HERA, DESY, Hamburg. During the HERA luminosity upgrade shutdown, the JINR group has started the production of the new DVC to be installed in the front part of the HERMES Spectrometer. The Dubna group has developed a new front-end card (ASD) for the DVC readout system.

They also continued the analysis of the HERMES polarized data taken in 1998-2000 to get the Q^2 dependence of the generalized Gerasimov-Drell-Hearn (GDH) integral for the deuteron and neutron [8]. The generalization of the GDH integral to non-zero photon virtuality Q^2 allows to study the transition from the polarised real photon absorption on the nucleon to the polarised inclusive lepton scattering on quarks.

One of the most interesting HERMES measurement is the doble spin asymmetry in the cross section for exclusive ρ^0 production in lepton-proton scattering [9].

Evidence for the positive longitudinal double-spin asymmety in the cross section for exclusive diffractive $\rho^0(770)$ vector meson production in polarised lepton-proton scattering was observed by the HERMES experiment. The averaged value of the double-spin asymmetry was found to be $0.24 \pm 0.11_{stat} \pm 0.02_{syst}$. The average invariant mass of the photon-proton system has a value of 4.9 GeV, while the average negative squared four-momentum of the virtual proton is 1.7 GeV^2. The ratio of the present result to the corresponding spin asymmetry in inclusive deep-inelastic scattering (DIS) is in agreement with the early theoretical prediction based on the generalized vector meson dominance model.

The hadron formation in deep inelastic scattering (DIS) of positron in the nuclear environment has been also studied in the HERMES experiment [10]. The differential multiplicity of charged hadrons and identified charged pions from nitrogen relative to that from deuterium has been measured as a function of the virtual photon energy ν and the fraction z of this energy transferred to the hadron. There are observed substantial reductions of the multiplicity ratio R_M^h at low ν and at high z, both of which are well described by a gluon-bremsstrahlung model of hadronization. A significant difference of the ν-dependence of R_M^h is found between positive and negative hadrons. This is interpreted in terms of the difference between the formation time of protons and pions, using a phenomenological model to describe the ν and z-dependence of R_M^h.

The HERMES result on multiplicity of charged and neutral pions in DIS of 27.5 GeV positrons on hydrogen has been published [11]. The average charged pion multiplicity is the same as for neutral pions, in the region of z up to 0.7. This result is consistent with the isospin invariance. The total energy fraction associated with the charged and neutral pions is $0.51 \pm 0.01_{stat.} \pm 0.08_{stat.}$ and $0.26 \pm 0.01_{stat.} \pm 0.04_{stat.}$, respectively. For fixed z, the measured multiplicities depend on both the negative squared for momentum transfer Q^2 and the Bjorken variable x. The observed dependence on Q^2 agrees qualitatively with the expected behaviour based on NLO QCD evolution, while the dependence

on x is consistent with that of the previous data after correction made for the expected Q^2 dependence.

The single-spin azimuthal asymmetry in electroproduction of neutral pions in semi-inclusive DIS has been studied [12]. This asymmetry in azimuthal distribution of neutral pions relative to the lepton scattering plane has been measured for the first time in DIS of positrons of longitudinally polarised protons. The analysing power in the $\sin\phi$ moment of the cross section is $0.019 \pm 0.007_{stat.} \pm 0.003_{syst.}$. This result is compared to single-spin asymmetries for charged π^+ asymmetry and shows a similar dependence on the relevant kinematic variables. The asymmetry is described by a phenomenological calculation based on a fragmentation function that represents sensitivity to the transverse polarization of the struck quark. The beam-spin azimuthal asymmetry associated with Deeply Virtual Compton Scattering (DVCS) has been studied in [13]. The beam-spin analyzing power in the $\sin\phi$ moment was measured to be $-0.23 \pm 0.04_{stat.} \pm 0.03_{syst.}$ in the missing-mass range below 1.7 GeV. The observed asymmetry is attributed to the interference of the Bethe-Heitler and DVCS processes.

For 2002, the Dubna group proposed to upgrade the Forward Tracking System by additional DVCs to improve the redundancy and resolution of the HERMES spectrometer. It is important to provide

- the study of the transverse effects in semi-inclusive and exclusive DIS processes;
- the study of the gluon contribution to the nucleon spin and contribution to the nucleon spin from orbital momenta of gluons and quarks.

After upgrading the HERA the luminosity can be increased by a factor of 4.7 as compared to the original HERA design. The electron machine of HERA operates routinely with polarized beam, typically 50–60%, which is used by the internal fixed target experiment HERMES. It is planned to achive comparable polarization levels as in the present machine. In 2002 the JINR LPP group in cooperation with other groups intends to participate in the following topics of the analysis of future HERMES experimental data:

- spin dependent structure function $g_2(x, Q^2)$;
- role of g_2 in the Generalized Gerasimov-Drell-Hearn Integral;
- pion transition form factor;
- structure function b_1;
- single spin asymmetry in DVCS;
- nuclear effect in DIS.

The LPP participates in the H1 detector upgrade to investigate DIS processes at the ep collider HERA, DESY, specifically, in the software/hardware support of the Forward Proton Spectrometer (FPS) operation and in the upgrading of the hadron Plug calorimeter and Backward Proportional Chambers (BPC). During the HERA shutdown, a new Plug detector has been assembled, tested and installed into the H1 set-up to close the gap of the H1 acceptance in the forward direction arround the beam pipe and get the time-of-light trigger signal to suppress the beam-gas background. A new BPS has been assembled, tested and installed into the H1 set-up to measure polar and azimuthal angles of the scattered electron in DIS processes and reject the photo-production background.

The LPP group made a major contribution to the analysis of data on the processes with a leading proton detected in the H1 FPS: photo-production, semi-inclusive diffractive DIS, and the elastic ρ meson photo-production.

The total cross section for the photo-production process with a leading proton in the final state has been measured at γp centre-of-mass energies W of 91, 181 and 231 GeV [14]. The measured cross sections apply to the kinematic range with the transverse momentum of the scattered proton restricted by $p_T < 0.2$ GeV and $0.68 < z < 0.88$, where $z = E'_p/E_p$ is the scattered proton energy normalized to the beam energy. The cross section $d\sigma_{\gamma p \to Xp'}(W,z)/dz$ is observed to be independent of W and z within the measurement errors and amounts to $8.05 \pm 0.06_{stat.} \pm 0.89_{syst.}$ μb on the average. The data are well described by the Triple Regge model in which the process is mediated by a mixture of exchanges with an effective Regge trajectory of intercept $\alpha_i(0) = 0.33 \pm 0.04_{stat.} \pm 0.04_{syst.}$. The total cross section for the interaction of the photon with this mixture ($\gamma\alpha_i \to X$) can be described by an effective trajectory of intercept $\alpha_k(0) = 0.99 \pm 0.01_{stat.} \pm 0.05_{syst.}$. The measured cross sections are compared with DIS leading proton data in the same region of z and p_T for photon virtuality $Q^2 > 2.5$ GeV^2. The ratio of the cross section for the leading proton production to the total cross section is found to rise with Q^2.

The differential cross section $d\sigma/dt$ and the structure function $F_2^{D(3)}(x_{I\!P}, x, Q^2)$ have been measured in diffractive DIS processes with the leading proton in the final state [15]. A fit of the differential cross section $d\sigma/dt \propto \exp(Bt)$ yields a slope parameter $B = 5.0 \pm 0.3_{stat.} \pm 0.8_{syst.}$ GeV^{-2} in the range of 2 GeV^2 $< Q^2 <$ 50 GeV^2, $x_{I\!P} = 1 - z < 0.1$, where $x_{I\!P}$ is the fractional momentum of the beam proton carried by Pomeron. No dependence of t-slope on $x_{I\!P}$ is observed within the measurement errors. Comparison of the $F_2^{D(3)}$ data with the previous result obtained by H1 FPS in the non-diffractive high $x_{I\!P}$ range shows the

behaviour to be consistent with the transition from Pomeron exchange at $x_{IP} < 0.05$ to the dominance of Reggeon and π exchange at $x_{IP} > 0.05$. Comparison of the leading proton data with $F_2^{D(3)}$ [16] obtained from the presence of a large rapidity gap in the central detector has shown a good agreement between two methods and proved a small contribution of the proton dissociation in the large rapidity gap data. The saturation model based on the colour dipole approach is able to give a good description of the new $F_2^{D(3)}$ data with the leading proton.

The elastic photo-production of ρ mesons has been also studied by measuring the final state leading proton [17]. The measurement extends the centre-of-mass energy range to 25 GeV $< W <$ 70 GeV, thereby further reducing the kinematic separation between the HERA and fixed target measurements. The results are in agreement with assumptions of the Vector Meson Dominance model and Regge theory. The measured slope of the Pomeron trajectory is compatible with a value of $\alpha'_{IP} = 0.25$ GeV^2 extracted from the hadron-hadron elastic scattering cross sections. The t-slope of the $d\sigma/dt \propto \exp(Bt)$ cross section $B = 10.3 \pm 0.8_{stat.} \pm 0.5_{syst.}$ GeV^{-2} is in good agreement with earlier photo-production results from H1 and ZEUS experiments. The decay angular distribution analysis shows a compatibility with the assumption that s-channel helicity is conserved in this process.

In 2002, the LPP group plans to measure diffractive structure function F_2^D and photo-production cross section in semi-inclusive processes with a leading proton detected in the FPS and compare the results with predictions of QCD and Regge model.

2. PREPARATION OF NEW EXPERIMENTS

The Common Muon and Proton Apparatus for Structure and Spectroscopy, COMPASS (NA58), has been proposed to perform a series of experiments with the high energy muon and hadron beams at CERN. According to the commitments defined in the Memorandum of Understanding, 480 modules of the hadron calorimeter HCAL1 have been completely mounted, tuned by means of sources and on the beam and given to the COMPASS collaboration for temporal exploitation. The muon wall MW1 of the COMPASS spectrometer first stage has been completely mounted on the beam and equipped with the analog part of the electronics. All the chambers of the multiwire proportional chambers of the COMPASS tracking have undergone the purification and prophylaxy procedures to establish the non-sensitive zones, and have been installed and tuned on the beam. The "straw" chambers of the COMPASS tracking have been manufactured at LPP JINR in the framework of the contract with Munich. Four double planes, with sizes

of 3.5×2.5 m^2, have been transported to CERN according to the agreed manufacturing schedule. Now on the request of the Collaboration to speed up the production of the chambers, the second production line has been constructed at LPP. Manufacturing of all 15 planes will be completed by using the two production lines in July 2002. The JINR specialists have participated in mounting and start up of the detectors as well as in the COMPASS runs during July-October 2001.

The plans of the Dubna group in 2002 include:

- participation in the upgrade of the COMPASS initial setup;
- QCD analysis of the spin dependent structure functions $g_{1,2}$ to be measured with a high precision at the highest accessible Q^2;
- study of Λ polarization produced in DIS.

The LPP participates in the construction of the Liquid Argon Hadronic End-cap Calorimeter (LArHEC) and Transition Radiation Tracker (TRT), according to the JINR obligations in the ATLAS experiment which is under preparation at CERN. The copper absorber production for LArHEC is going at the JINR and MZOR – the plant in Minsk, Belarus. The assembly of the modules is going at JINR. In 2001, 6 sets of the absorbers for the 6 calorimeter modules were produced. The 3 sets were sent out to the Max Plank Institute (Munich, Germany) according to the Agreement. At JINR, the 3 modules were assembled. They succesfully passed through the tests at Dubna and CERN.

By means of the apparatus, developed at the beam channel N3 of IBR2 reactor, an investigation of the properties of materials, used for the serial modules production, were done. Electrodes of the calorimeter were placed in the cryostat, filled with liquid argon, and irradiated by fast neutrons. The total fluence was equal to 10^{16} n/cm^2. The measurements of the liquid argon purity, done by the ionization chamber before and after irradiation, have shown that irradiation does not cause outgasing from the material surfaces to liquid argon of electronegative components, which decrease the charge collected in liquid argon.

The studies of electrical and functional characteristics of the 64 preshapers at the full scale chain of readout electronics for the LArHEC have been performed. The precise calibration of the temperature sensors, to be used for measuring the liquid argon temperature in the ATLAS detector cryostats, was completed. 700 PT-100 sensors were calibrated at JINR and sent to the ATLAS collaboration.

The analysis of the new experimental data, accumulated at the SPS accelerator during the modules tests, is continued. Spin effects in the processes of the single and pair production of t-quarks in pp-collisions at LHC are studied.

The assembling of the ATLAS TRT has been started.
The plans for 2002 are:

- LArHEC group:
  - finishing of the absorber production and modules of the HEC;
  - assembly of the front wheel of HEC for the cryostat "C";
  - preparation and installation of the temperature measurement system for the HEC "C" modules;
  - production of the preshaper system for the readout electronics of HEC;
  - study of the material and electronics properties under intensive neutron and gamma irradiation.

- TRT group:
  - completing of the straws reinforcing;
  - continuation of the straw preparation;
  - assembly of the "B" type wheels of the TRT;
  - start of the "B" type wheels testing with the Fe-55 source and in the test beam at CERN.

The main activity of LPP within the Compact Muon Solenoid Project, CMS, was concentrated on the study, design, integration, and production of the CMS Endcap detectors, where JINR takes a full responsibility in the frame of the Russia and Dubna Member States (RDMS) of the CMS Collaboration. The JINR group participates in the following projects:

- Endcap Hadron Calorimetry, HE – full RDMS responsibility;
- First Forward muon Station, ME1/1 – full responsibility;
- Endcap Preshower, SE – participation;
- Physics Task Force – participation.

The JINR group leader, Prof. I.A.Golutvin, co-ordinates the RDMS CMS Collaboration activity on the design and construction of the HE. JINR is responsible for the HE absorber. The full chain of mechanics and optics mass-production is well going on. The first HE-1 absorber has been manufactured at MZOR plant in Minsk and delivered to CERN. Scintillator sheets for both calorimeters were delivered to Kharkov via Dubna. All tiles for HE-1 were manufactured and delivered. Calculations of radiation field taking into account realistic coverage of the electromagnetic calorimeter were performed and demonstrated a high radiation dose for HE at the pseudo-rapidity value of about 3. The first set of 38 mass-produced megatiles was tested and calibrated by pions and muons with PPP3 prototype at CERN.

ME1/1 CSC chamber production in Dubna is going on [19]. About 90% of CSC panels have been manufactured with a production rate of 50 panels per month and within EDR requirements on strip tolerance and panel flatness. Production of CSC parts is in progress. The chamber assembly has been started according to CMS Milestone. ME1/1 anode electronics is on the production stage. First 18 AFEB boards have been assembled. The first set of the electronics cooling system has been produced. The test of the cooling system has started. Prototyping of the low voltage system and mass production of the high voltage system is going on in Bulgaria. Work on integration of the ME1/1 zone is continued with a full-scale mock-up.

The preshower project is well in progress. Mechanical EDR has been successfully passed. Mass-production of silicon detectors in cooperation with RIMST, Zelenograd is going on. In 2001, 215 radiation hard detectors have been produced, and 2% of these detectors were irradiated by fast neutrons. The radiation study of the Si-strip detectors is continued.

JINR physicists participate in the RDMS CMS task force on development of software and simulation of physics processes with emphasis to the endcap and forward region. The study of direct gamma production is continued. The CMS hadron calorimeter response of the combined HE/HF system was simulated to investigate the "gamma+jet" calibration of the hadron calorimeter. The CMSIM and ORCA programmes were tested and modified for muon track reconstruction in the endcap muon system. Computing group participates in the design of the concept of regional distributed centres. Development of the CMS Heavy Ion Physics Programme on a topic of Global Characteristics of ultrarelativistic nucleus-nucleus collisions is in progress [19]. The package SIMUB for simulation of the B-meson production and decays is developed at Dubna for B-physics studies at CMS. The mass production of the "golden mode" $B_s^0 \to J/\psi\phi$ is in progress for the exclusive B-trigger.

According to the JINR commitments, LPP participates in the commissioning of the Outer Tracker (OTR) of the HERA-B detector which is a large-aperture spectrometer built for studies of collisions of 920 GeV protons with the nuclei of target wires positioned in the halo of the HERA proton beam. JINR physicists participate in software development, HERA-B running and data analysis. In 2001, the Dubna group played a major role in upgrading of the OTR during the HERA luminosity shutdown. The further development of the OTR software as well as the study of the OTR performance have been continued with the experimental data collected during the run 2000 [20].

In 2002, the Dubna group activity is planned to be concentrated on the following tasks:

- participation in the OTR commissioning, detector running and data taking;
- OTR performance study after the detector upgrade, using new experimental data;
- further development of the data-quality and track reconstruction software;
- participation in J/ψ analysis and muon misidentification studies;
- participation in further development of the topics for HERA-B physics programme after 2002.

The physics programme of HERA-B beyond 2002 depends on the level of sensitivity acheived in the upcoming run. Possible topics include further measurements of heavy flavor production in the nuclear matter, studies of B-hadrons (B-baryons searching, B_S mixing, rare decays), charmonium spectroscopy and studies of charmed mesons.

The LPP takes part in the design and construction of both Barrel (BEMC) and End-cap (EEMC) Electro-Magnetic Calorimeter systems for the 4π-detector STAR for the collider RHIC at the Brookhaven National Laboratory (BNL). This activity, carried out in collaboration with WSU (Detroit, USA), includes:

- construction and assembling of the BEMC modules at the WSU as well as their installation and test at STAR magnet detector in BNL;
- design, production and prototyping the PMT box pilot pattern as well as their serial manufacturing at the JINR Workshop and assembling at the STAR magnet in BNL;
- developement of a computer programme package for recognition of electron (positron) tracks under a high level of the hadronic background at STAR;
- development of physics programme for further investigation at RHIC as well as related processes simulation (Handedness measurement possibilities, new experimental approach to the search for quark-gluon plasma, very high multiplicity production events etc.).

In 2001 the LPP group participated in the first measurement of inclusive antiproton production at mid–rapidity in Au–Au collisions at 130 GeV by the STAR experiment at RHIC [21]. The antiproton transverse mass distributions in the measured transverse momentum

range of 0.25 GeV/c < p_T <0.95 GeV/c have been found to fall less steeply for more central collisions. The extrapolated antiproton rapidity density has been found to scale approximately with the negative hadron multiplicity density. These data indicate the large difference of parton progation inside nuclear matter in heavy ion collisions as compared with the elementary proton/anti-proton case. The ratio of the mid-rapidity anti-proton to proton yields in Au-Au collisions per nucleon pair has been measured. Within the rapidity and transverse momentum range of $|y| < 0.5$ and 0.4 GeV/c < p_T <1.0 GeV/c, the ratio is essentially independent of either transverse momentum or rapidity, with an average of $0.65 \pm 0.01_{stat.} \pm 0.07_{syst.}$ for minimum bias collisions. Within the errors, no strong centrality dependence has been observed. The results indicate that at this RHIC energy, although the $p\bar{p}$ pair production becomes important at mid-rapidity, a significant excess of baryons over anti-barions is still present.

The plans for 2002 include participation of the LPP group in the STAR detector upgrade, software development for the STAR BEMC as well as in data taking and analysis.

The LPP specialists participate in the construction of the low-noise neutrino detector BOREXINO located at the underground laboratory in Gran Sasso (Italy). The responsibilities shared by the JINR group are mainly related to the DAQ system, detector calibration, testing, cleaning and mounting of PMT. The prototype of the BOREXINO detector, CTF2, has been installed, it is aimed at studying a new type of the liquid scintillator, the efficiency of radiopurification as well as the methods of low radioactivity control. The main part of the stainless steel sphere of 12 m in diameter has been completed. The water purification system is ready and has been tested. Specialists from Dubna and Gatchina elaborated the method of decreasing the threshold of the detector and modified the prototype CTF2 to be able to registe the solar pp-neutrino with a low energy threshold. The space resolution of CTF2 has been improved by a factor 1.5 by applying a new method of event reconstruction developed by Dubna physicists.

The prototype CTF2 has been used for studies of the stability of electron. The new lower limit of the mean life time definded by the data is $\tau(e \to \gamma\nu) > 4.6 \times 10^{26}$ years at 90% CL [22].

In 2001, the BOREXINO experiment has been officially included in the Joint Protocol between Italy and the Russian Federation as the high priority experiment. In 2002, the running of the BOREXINO detector in a full scale is foreseen first to be filled with water then gradually it would be replaced by scintillating liquid of 300 tons.

3. ACCELERATION TECHNIQUES

In accordance with the schedule of operations for the project LHC Damper the 2001 activities were focused on the design and manufacturing of the electrostatic kickers and power amplifiers of the Transverse Oscillation Damping System (TODS) for LHC as well as on the investigations of the power amplifier circuit and damping regimes for future upgrade of TODS. The mechanical documentation of the electrostatic kicker has been prepared and transferred to CERN CDD Archive. Test of the power amplifier (classical variant) at CERN has shown the full conformity of its parameters to the Project requirements. The methodics of the vacuum tubes simulation has been gradually improved. The cascode amplifier of the power up to 16 kW has been built and tested at JINR. The measured characteristics correspond to the results of the simulation with an accuracy of 3-5%. The development of the resistive coating of the ceramic insulators is in progress.

The plans for 2002 include manufacturing of the 20 kickers and 20 amplifiers.

During 2001 the (FEL) group continued the experimental and theoretical investigations of the millimeter-wave Free Electron Maser (FEM) oscillators as possible microwave power sources for the linear collider the next of the generation CLIC at CERN. Two new techniques for frequency measurements have been put into operation: precise mechanical wavemeter and the heterodyne spectrum meter. A new technology of Bragg resonators manufacturing – by pressing out from a stainless steel tube – has been introduced. The stability of the FEM operation has been investigated experimentally. The processes of oscillation building-up in the FEM with various Bragg resonators were simulated numerically. A possibility of considerable enhancement of the oscillator efficiency due to the novel excitation mechanism ("starting mode" regime) has been shown.

Plans of FEL group for 2002:

- improvement of the operation characteristics of the FEM oscillator;
- creating of the facility based upon the FEM oscillator test the narrow-band resonator systems including accelerating structures of linear colliders;
- test of the narrow-band resonator systems.

Year 2001 saw the completion of the TESLA Technical Design Report which provides the technical basis for a future collider. Main fields

of contributions from JINR are X-ray Free Electron Lasers (FEL) and gamma-gamma collider option.

Since first lasing of the VUV SASE FEL at DESY (February 2000) its operation has been gradually improved. The radiation wavelength is continuously tunable in a wide range from 80 to 180 nm. At present the SASE FEL gain is tuned to the value of about 10^6, the energy in the radiation pulse is about 10-20 μJ, pulse duration is 0.5-1 ps, peak and the average radiation power are about 20 MW and 0.2-0.3 mW, respectively [23]. Peak brilliance is about 10^{27} phot./sec/mrad^2/mm^2/(0.1% BW.) which exceeds the corresponding value for modern SR sources by six orders of the magnitude.

Equipment for Regenerative FEL Amplifier (RAFEL) has been installed and tested with the electron beam and radiation in the TESLA Test Facility (TTF) tunnel. The experiment is in progress [24]. Success of the RAFEL experiment would allow to reach extra high peak brilliance of about 10^{30} phot./sec/mrad^2/mm^2/(0.1% BW).

Theoretical and design studies in FEL physics and applications involve the following topics: FEL physics, optimization of the user facility at TTF FEL, FEL schemes providing femtosecond-scale pulse duration [25], analysis of perspective industrial applications [26].

The conceptual study of Far Infrared Radiator at the TTF is in progress. Realization of this device would allow to run powerful source (up to 100 MW peak power) in the THz frequency band. Application of Thomson backscattering would allow to run the intensive, polarized, monochromatic X-ray source with femtosecond-scale pulse duration.

Plans for 2002:

- participation in the development of the TESLA project and X-ray Laboratory at the TESLA Linear Collider;
- development of the Far Infrared Radiator at the TESLA Test Facility;
- FEL-related experiments at the TESLA Test Facility, including experimental study of Regenerative FEL amplifier (RAFEL) option;
- development of photon diagnostics for SASE FELs;
- theoretical and design studies in FEL physics and applications covering the following topics: FEL physics, optimization of the user facility at the TTF FEL and X-ray FEL, FEL schemes providing femtosecond-scale pulse duration, and analysis of perspective industrial applications.

The experimental and theoretical investigations on the multi-charged ion sources have been continued in 2001 [27]. The biased-disk effect in

the Electron Cyclotron Resonance Ion Sources (ECRIS) has been studied by using special double-electrode structure. The relative contributions of the secondary electron emission from the electrode and of the reflection of lost electrons back to ECR plasma have been determined. It has been found that the electron reflection is more important. The measurements of plasma potential by using the Langmuir probe have been performed.

The scheme of laser ablation plasma injection into ECRIS has been tested at Frankfurt University. The LPP group also participates in the laser ablation experiments at INFN LNS, Catania, Italy. The analysis of experimental measurements of ECR plasma parameters made in FLNR, RIKEN and Frankfurt has been performed.

A new version of computer codes based on balance equations for all ionic charge states and on the theory of the electron and ion confinement in the open magnetic trap of ECR ion source has been used for the numerical simulation of the ion or neutral injection into the ECR plasma. A modified programme library based on the macro particle method was applied optimize the ion beam line from the 18 GHz ECR Ion Source to the linear RFQ accelerator of the RIKEN Beam Factory. The physical motivation and mathematical methods for simulation of ECR plasma with the particle-in-cell model have been developed.

A new, non-traditional direction in technique of the electron accelerators for radiation technologies is performed at LPP. In the developed multi-beam high repetition rate accelerators, the average ratio of the repetition period to the pulse duration is equal to 10, so the possibility to apply a very cheap direct current (DC) electric field has appeared to accelerate the secondary electrons.

In 2001 the adaptation of 200 keV accelerator was curried out to perform the experiments with electron multi-beam injected into DC field of the irradiation vessel. The design and construction of the experimental irradiation vessel with DC electric field as well as the development and construction of units of the 500-700 keV, 30 kW accelerator for electron beam processing have been performed. Original design and low cost of the accelerator attract the attention of the experts from many countries and involve new participants in the international collaboration with JINR. Now there are new agreements for co-operation in the field of accelerators for radiation technologies between JINR and USTC (Hefei, China) and firm MUS (Tokyo, Japan). These agreements foresee financing of this activity during next few years.

Plans for 2002 iclude:

- R&D multi-beam pulsed accelerator with extracted into atmo-

sphere electrons: E=300 keV, P=10 kW, f=100 kHz;

- manufacture and tentative maintenance of the 300 keV accelerator;
- manufacture of the 700 keV, 10 kW, 100 kHz accelerator for radiation technologies.

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