LABORATORY OF PARTICLE PHYSICS

The activity of LPP in 2007 was concentrated on the current particle physics experiments and preparation of the new ones, R&D of the particle detectors and the acceleration systems.

ONGOING EXPERIMENTS

In 2007, **COMPASS** has continued the data taking with muon beam using transversely and longitudinally polarized deuteron targets. During data taking, JINR group has performed the maintenance of the so-called RICH WALL, tracking detector behind RICH, and the hadron calorimeter HCAL1. The analysis of data collected in 2002–2006 has continued. The set of important results have been obtained, published and presented at various international conferences (15 talks by JINR physicists).

JINR group participates in the preparation of physics programme and R&D for new experiment (COMPASS-II). This experiment (start of data taking in 2011) will be performed to measure the Generalized Parton Distributions (GPD) [1] via studying various exclusive processes and transversity distributions via investigating the Drell–Yan processes. Status of the COMPASS analysis in 2007 is summarized in 11 internal Notes, four of which are prepared by JINR physicists. Main results of the analysis are summarized below.

The semi-inclusive (SIDIS) difference asymmetry $A^{(h^+-h^-)}$ for hadrons of opposite charge has been measured by the COMPASS for the first time [2]. The data were collected in the years 2002–2004 using a 160 GeV polarized muon beam scattered off a large polarized ^{6}LiD target and cover the kinematic range $0.006 < x < 0.7$ and $1 < Q^2 < 100$ (GeV/c)^2. In leading order QCD (LO), the deuteron asymmetry $A^{(h^+-h^-)}$, measures the valence quark polarization and provides an evaluation of the first moment of $\Delta u_v + \Delta d_v$ which is found to be equal to 0.40 ± 0.07 (stat.) ± 0.05 (syst.) over the measured range of x at $Q^2 = 10$ (GeV/c)^2 (see Fig. 1). When combined with the first moment of g_1^d previously measured on the same data, this result favours a nonsymmetric polarization of light quarks $\Delta\bar{u} = -\Delta\bar{d}$ at a confidence level of two standard deviations, in contrast to the often assumed symmetric scenario $\Delta\bar{u} = \Delta\bar{d} = \Delta s = \Delta\bar{s}$.

The longitudinal double spin asymmetry A_1^ρ for exclusive leptoproduction of ρ^0 mesons, $\mu + N \rightarrow \mu + N + \rho^0$, is studied using the COMPASS 2002 and 2003 data [3]. The measured reaction is incoherent exclusive ρ^0 production on polarized deuterons. The Q^2 and x dependence of A_1^ρ is presented in a wide kinematical range $0.003 < Q^2 < 7$ (GeV/c)^2 and $5 \cdot 10^{-5} < x < 0.05$ (see Fig. 2). The presented results are the first measurements of A_1^ρ at small Q^2 ($Q^2 < 0.1$ (GeV/c)^2) and small x ($x < 3 \cdot 10^{-3}$). The asymmetry is in general compatible with zero in the whole kinematical range.

In 2007, COMPASS has presented the first measurement of the gluon polarization in the nucleon based on the photon–gluon fusion process (PGF) tagged via charm meson production and decay [4]. The data were collected during the years 2002–2004. The result of this LO analysis is $\langle \Delta g/g \rangle_x = -0.47 \pm 0.44$ (stat.) $\pm$ 0.15 (syst.) at $\langle x \rangle \approx 0.11$ and a scale $\mu^2 \approx 13$ (GeV/c)^2, Fig. 3.

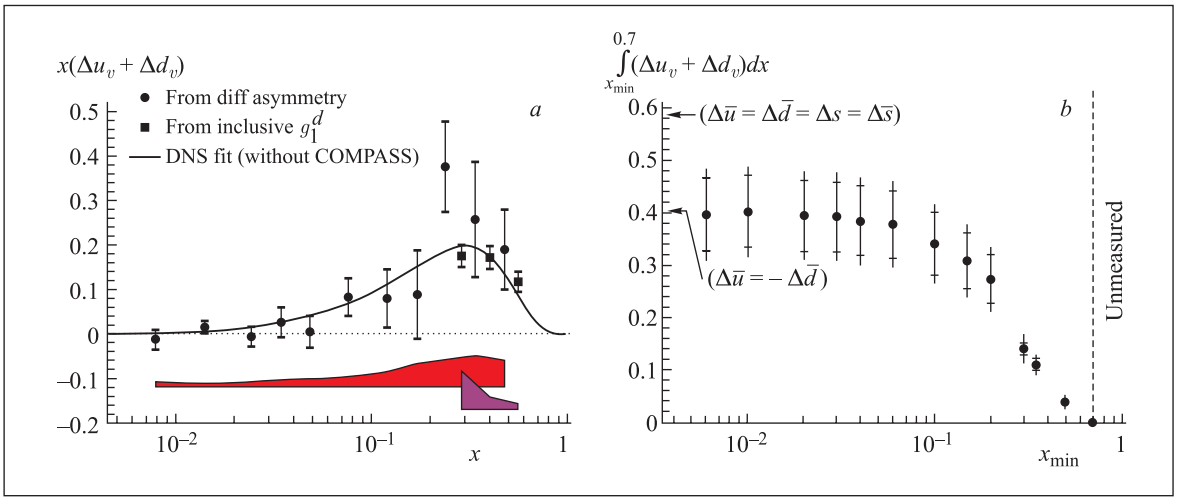

Fig. 1. *a*) Polarized valence quark distribution $x(\Delta u_v(x) + \Delta d_v(x))$ evolved to $Q^2 = 10$ (GeV/c)^2 according to the DNS fit at LO. The line shows the DNS fit which does not include the present COMPASS data. Three additional points at high x are obtained from g_1^d [2]. *b*) The integral of $\Delta u_v(x) + \Delta d_v(x)$ over the range $0.006 < x < 0.7$ as a function of the low-x limit of integration $x_{\min}$, evaluated at $Q^2 = 10$ (GeV/c)^2. SIDIS data are used in the interval $0.006 < x < 0.3$, and inclusive g_1^d data from [2] — in the interval $0.3 < x < 0.7$

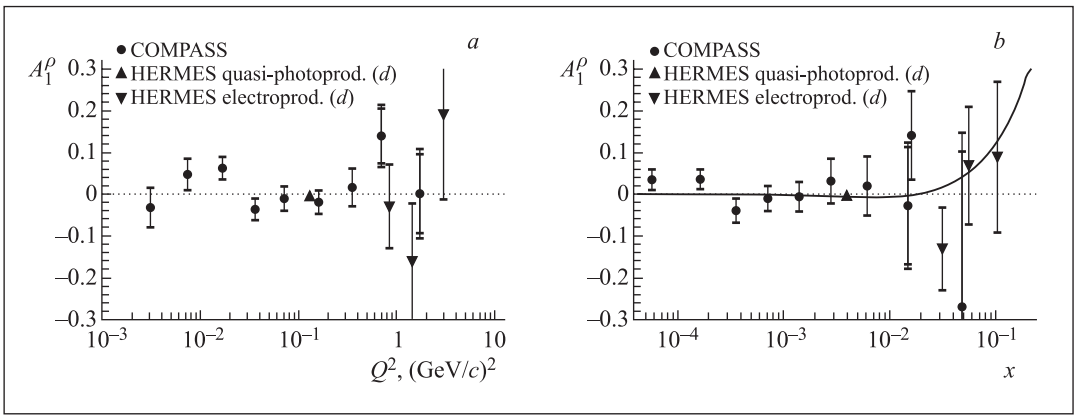

Fig. 2. A_1^p as a function of Q^2 (*a*) and x (*b*) from the present analysis (circles) compared to HERMES results on the deuteron target (triangles)

In 2007, LPP group has participated in data taking and analysis of the **HERMES** data taken in 1996–2000. At the end of June, HERMES has finished the data taking. Starting from 1997 up to the end of data taking, JINR group has performed the technical maintenance of the DVC (Drift Vertex Chambers). In August–September DVC was dismantled from HERMES experimental set-up.

The JINR LPP group efforts were focused at the analysis of the SIDIS 1996–2000 polarized data aiming to extract the polarized quark distributions and their moments in the Next-to-Leading Order of QCD (NLO). The analysis is based on a new method, which needs the data from difference and sum pion asymmetries. The main HERMES results obtained in 2007 are the following.

The exclusive electroproduction of π^+ mesons was studied by scattering 27.6 GeV positron and electron beams of an internal hydrogen gas target [5]. The virtual-photon cross sections were measured as a function of the Mandelstam variable t and the squared four momentum $-Q^2$ of the exchanged virtual photon. A model calculation based on generalized parton distributions is in fair agreement with the data at low values of $|t|$, if power corrections are included. A model calculation based on the Regge formalism gives a good description of the magnitude and the t and Q^2 dependences of the cross section.

In the HERMES experiment, the transverse polarization of Λ and anti-Λ hyperons produced in quasi-real photoproduction has been measured [6]. The transverse polarization of the Λ hyperon is found to be positive while the observed Λ polarization is compatible with zero. The values averaged over the kinematic acceptance of HERMES are 0.078 ± 0.006 (stat.) $\pm$ 0.012 (syst.) and -0.025 ± 0.015 (stat.) ± 0.018 (syst.) for Λ and anti-Λ, respectively.

Also hadron multiplicities on nucleus A relative to those on the deuteron R_A^h, are measured for various hadrons (π^+, π^-, π^0, K^+, K^-, p, and $\overline{p}$) as a function of the virtual-photon energy ν, the fraction z of this energy transferred to the hadron, the photon virtuality Q^2, and the hadron transverse momentum squared p_t^2 [7].

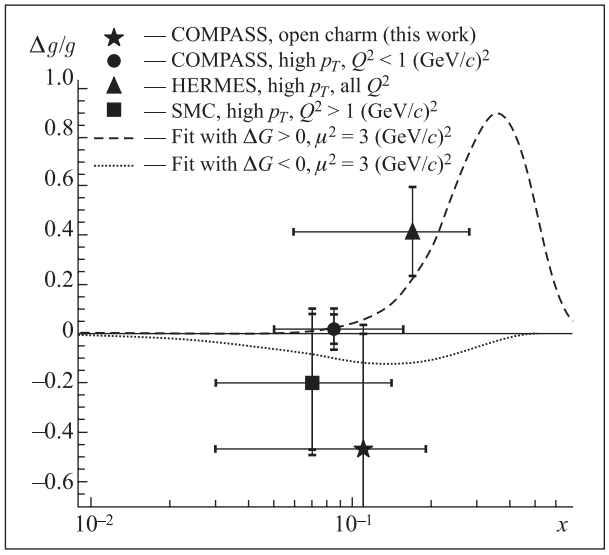

Fig. 3. Compilation of the $\langle \Delta g/g \rangle_x$ measurements from open charm and high-p_T hadron pairs production by COMPASS, SMC, and HERMES as a function of x

A measurement of the beam-spin asymmetry in the azimuthal distribution of pions produced in semi-inclusive deep-inelastic scattering of positrons off protons is performed [8]. The sinusoidal amplitude of the dependence of the asymmetry on the angle ϕ of the hadron production plane around the virtual photon direction relative to the lepton scattering plane was measured for π^+, π^- and π^0 mesons.

After the luminosity upgrade of the HERA ep collider, in the period from 2003 to 2007, the **H1** experiment accumulated luminosity of 48 pb^{-1} in collisions of 920 GeV protons to 27.6 GeV longitudinally polarized electrons (positrons). The polarization of the lepton beam allows the H1 experiment to further constrain parton distribution functions (PDF) of the proton through the measurements of the polarization asymmetries and the test of electroweak part of the Standard Model. In 2007, the H1 experiment collected data at nominal (920 GeV), low (460 GeV), and middle (575 GeV) proton energies. The goal is to measure the inclusive and diffractive longitudinal structure functions FL at low values of Bjorken x variable and photon virtuality Q^2. These runs are essential to complete the HERA ep programme, which is largely devoted to the understanding of a gluon dominated high-density system of partons.

The LPP (JINR) group, participating in the H1 experiment, has made major contribution to the following physics results:

Tests of QCD Factorization in the Diffractive Production of Dijets in Deep-Inelastic Scattering and Photoproduction at HERA [9]. Diffractive scattering is studied in positron–proton collisions in which the proton stays intact (or dissociates into a system Y of mass $M_Y < 1.6$ GeV) and loses less than 3% of its initial beam energy. Rapidity gap events are selected in which the detector is empty in a region corresponding to 3 to 4 units in pseudorapidity measured from the direction of the outgoing proton system. The events are required to contain two jets of 5 and 4 GeV minimal transverse energy. The analysis is performed in two kinematic ranges which differ in the negative photon virtuality Q^2:

1) deep-inelastic scattering (DIS, $4 < Q^2 < 80$ GeV^2): the photon behaves essentially like a point-like particle without internal structure;

2) photoproduction ($Q^2 < 0.01$ GeV^2): the photon can fluctuate into a hadronic system of which one parton with photon momentum fraction x_γ enters the hard scatter which produces the jets. An energetic photon remnant system is present in events with low x_γ.

Dijet production cross sections are measured and compared to the next-to-leading order perturbative QCD calculations which are based on the diffractive proton structure (quark and gluon momentum densities) extracted in inclusive diffractive DIS [10].

The calculations describe diffractive dijet production in DIS well within experimental and theoretical uncertainties. In diffractive DIS, dijet production and inclusive scattering are described using the same proton structure (QCD collinear factorization). QCD factorization breaks down in photoproduction where the prediction has to be suppressed by a factor of approximately 0.5 to describe the measurement. The ratio of dijet measurement to NLO prediction in photoproduction is a factor of 0.5 ± 0.1 smaller than the same ratio in DIS. No dependence of the suppression on x_γ was found, so the photon remnant does not seem to be the reason for the suppression.

Dijet Cross Sections and Parton Densities in Diffractive DIS at HERA [11]. Differential dijet cross sections in diffractive deep-inelastic scattering are measured with the H1 detector at HERA using an integrated luminosity of 51.5 pb^{-1}. The selected events are of the $ep \to eXY$ type, where the system X contains at least two jets and is well separated in rapidity from the low mass proton dissociation system Y. The dijet data are compared with QCD predictions at the next-to-leading order based on diffractive parton distribution functions previously extracted from measurements of inclusive diffractive deep-inelastic scattering [10]. The prediction describes the dijet data well at low and intermediate $z_{\rm IP}$ (the fraction of the momentum of the diffractive exchange carried by the parton entering the hard interaction) where the gluon density is well determined from the inclusive diffractive data, supporting QCD collinear factorization. A new set of diffractive

parton distribution functions is obtained through a simultaneous fit to the diffractive inclusive and dijet cross sections. This allows for a precise determination of both the diffractive quark and gluon distributions in the range $0.05 < z_{\rm IP} < 0.9$. In particular, the precision on the gluon density at high momentum fractions is improved compared to previous extractions. The recent physics results have been presented by the LPP (JINR) group on behalf of the H1 Collaboration at the international conference «Hadron Structure 2007» [12] and the international workshop «HERA and the LHC» [13]. Members of the LPP group are co-authors of 9 articles published on behalf of the H1 Collaboration in physics journals in 2007.

The **NA48** Collaboration has fulfilled the sequence of experiments NA48 [14], NA48/1, and NA48/2 and started the preparation of a new one with a K^+ beam — NA48/3 or NA62 (proposal P326). All these experiments are devoted to the search for or precise measurement of direct CP-violation parameters in kaon decays and study of kaon and hyperon rare decays. The NA48, NA48/1, and NA48/2 experiments have completed their data taking and have achieved the main goals. Data analysis is continued to search for and to study the rare (up to 10^{-9} of branching ratio) kaon decays. The responsibility of JINR in the framework of these experiments is a study of three pions, πee and $\pi^0\pi e\nu$ charged kaon decays. The Collaboration has started a new programme preparation — NA48/3 or NA62 (P326) at CERN SPS, which is devoted to study a very rare decay of charged kaon into pion and two neutrinos. The responsibility of JINR in the framework of this programme is R&D of straw detector working in vacuum, development of the simulation and reconstruction software for straw detector.

The following results have been obtained using the data accumulated in 2003–2004 in the NA48/2 experiment.

• The final results on the measurement of the direct CP-violating charge asymmetries of the Dalitz plot linear slopes $A_g = (g^+ - g^-)/(g^+ + g^-)$ in $K^\pm \to \pi^+\pi^-\pi^\pm$ and $K^\pm \to \pi^0\pi^0\pi^\pm$ decays have been obtained by the NA48/2 experiment [15]. A new technique of asymmetry measurement involving simultaneous K^+ and K^- beams and a large data sample collected allowed obtaining of a result of an unprecedented precision. The charge asymmetries were measured to be $A_g^c = (-1.5 \pm 2.2) \cdot 10^{-4}$ with $3.11 \cdot 10^9$ $K^\pm \to \pi^+\pi^-\pi^\pm$ decays, and $A_g^n = (1.8 \pm 1.8) \cdot 10^{-4}$ with $9.13 \cdot 10^7$ $K^\pm \to \pi^0\pi^0\pi^\pm$ decays. The precision of the results is limited mainly by the size of the data sample.

• The distribution of the $K^\pm \to \pi^+\pi^-\pi^\pm$ decays on the Dalitz plot has been measured in the NA48/2 experiment with a sample of $4.71 \cdot 10^8$ fully reconstructed events [16]. With the standard Particle Data Group (PDG) parameterization the following values of the slope parameters were obtained: $g = (-21.134 \pm 0.017)\%$, $h = (1.848 \pm 0.040)\%$, $k = (-0.463 \pm 0.014)\%$. The quality and statistical accuracy of the data have allowed an improvement in precision by more than an order of magnitude and are such as to warrant a more elaborate theoretical treatment, including pion–pion rescattering, which is in preparation.

• Ratios of decay rates for $K_{e3}/K_{2\pi}$, $K_{\mu 3}/K_{2\pi}$ and $K_{\mu 3}/K_{e3}$ have been measured [17]. These measurements are based on $K^\pm$ decays collected in a dedicated run in 2003 by the NA48/2 experiment. The results obtained are $K_{e3}/K_{2\pi} = 0.2470 \pm 0.0009$ (stat.)$\pm$ ± 0.0004 (syst.) and $K_{\mu 3}/K_{2\pi} = 0.1637 \pm 0.0006$ (stat.) $\pm$ 0.0003 (syst). Using the PDG average for the $K^\pm \to \pi^\pm\pi^0$ normalization mode, both values are found to be larger than the current values given by the Particle Data Book and lead to a larger magnitude of the $|V_{us}|$ CKM element than previously accepted. When combined with the latest Particle Data Book value of $|V_{ud}|$, the result is in agreement with unitarity of the CKM matrix. In addition, a new measured value of $K_{\mu 3}/K_{e3} = 0.663 \pm 0.003$ (stat.) $\pm$ 0.001 (syst.) is found to be consistent with the semi-empirical predictions based on the latest form-factor measurements.

On the base of the NA48 and NA48/1 experimental data the following results have been published:

• The weak radiative decay $\Xi^0 \to \Lambda^0 e^+ e^-$ has been detected for the first time [18]. 412 candidates in the signal region have been found, with an estimated background of 15 ± 5 events. The branching fraction $\Xi^0 \to \Lambda^0 e^+ e^-) = [7.6 \pm 0.4$ (stat.) $\pm$ 0.4 (syst.) $\pm$ 0.2 (norm.)$] \cdot 10^{-6}$ is consistent with an internal bremsstrahlung process, and the decay asymmetry parameter $\alpha_{\Xi\Lambda ee} = -0.8 \pm 0.2$ is consistent with that of $\Xi^0 \to \Lambda^0\gamma$. The charge conjugate reaction $\Xi^0 \to \Lambda^0 e^+ e^-$ has also been observed.

• A new high-precision measurement of the form factors of the $K_L \to \pi^\pm\mu^\mp\nu_\mu$ decay has been made [19] on the base of the data sample of about $2.3{\cdot}10^6$ events recorded in 1999 by the NA48 experiment.

• The ratio of the decay rates $\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_L \to \pi e\nu)$, denoted as $\Gamma(K2\pi)/\Gamma(Ke3)$, has been measured [20]. The analysis is based on the data taken during a dedicated run in 1999 by the NA48 experiment. Using a sample of 47000 $K2\pi$ and five million $Ke3$ decays $\Gamma(K2\pi)/\Gamma(Ke3) = (4.835 \pm 0.022$ (stat.) $\pm$ 0.016 (syst.)$) \cdot 10^{-3}$ has been obtained. The branching ratio of the CP-violating decay $K_L \to \pi^+\pi^-$ and the CP-violation parameter $|\eta_\pm|$ have been derived. Excluding the CP-conserving direct photon emission component $K_L \to \pi^+\pi^-\gamma$, the following results were observed: Br$(K_L \to \pi^+\pi^-) = (1.941 \pm 0.019) \cdot 10^{-3}$ and $|\eta_\pm| = (2.223 \pm 0.012) \cdot 10^{-3}$. The JINR group contribution to the analyses and the new experiment preparation includes:

• The leading role in the $K^\pm \to 3\pi^\pm$ and $K^\pm \to \pi^0\pi^0\pi^\pm$ asymmetry analysis.

• Theoretical explanation of the electromagnetic effects in cusp effect [21].

• Essential contribution to the study of semileptonic decays.

• R&D of the straw-detector prototype working in vacuum: design and construction of the straw prototype with 48 straws.

• Preparation and carrying out of the straw-detector prototype tests in cosmic rays and at CERN SPS.

• Participation in the R&D of full-scale high-resolution straw detector working in vacuum.

• Development of the simulation and reconstruction programmes for straw detector in the new experiment NA62.

The LPP group participates in the experiments on the detector **STAR** at Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL). During 2007, the STAR Collaboration published 9 papers on nuclear and spin effects in $p+p$, $d+$Au and Au + Au collisions at RHIC; two LPP physicists are among principle authors of the paper on nonphotonic electron suppression in Au+Au collisions [22] — the deduced unexpectedly large suppression of the open charm and beauty hadrons lead to the improvement of existing and development of new theoretical models, showing the necessity of the formation of hot and dense QCD matter (see Fig. 4).

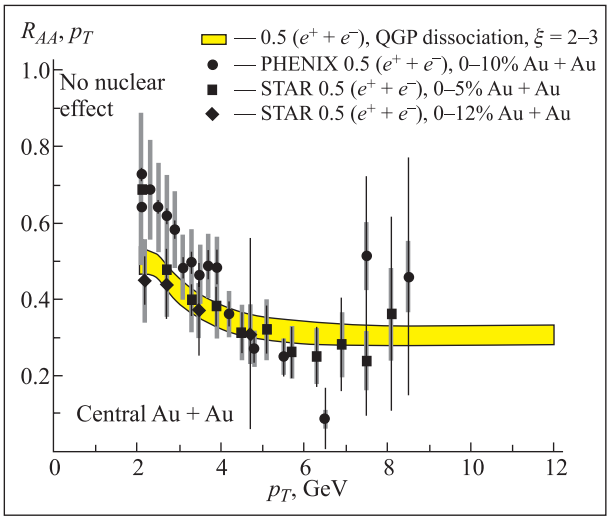

Fig. 4. The dissociation of open charm and beauty hadrons in hot and dense QCD matter created in central Au + Au collision at RHIC may explain the observed heavy flavor suppression (see A. Adil, I. Vitev, Phys. Lett. B. 2007. V. 649. P. 139)

This observation has been discussed in a number of recent international conferences and is already one of the most cited STAR results. Besides the participation in 48 shifts during the data taking, the LPP physicists carried out the following tasks:

1. Study of the possibility of separation of charm and bottom quarks input to electron spectra. Such a separation allows one to severely constrain theoretical models of energy loss in hot and dense matter formed in central heavy-ion collisions. This study also serves as a basis for upcoming Y suppression studies.

2. Study of soft photon spectra in $p+p$, $d+$Au, Au + Au collisions at RHIC. The method of ultra low-p_T photon reconstruction using conversion pairs registered in Time Projection Chamber (TPC) has been developed. This method is complementary to that based on the dedicated calorimeter — Crystal Detector (CrD).

3. Continuation of the work on the CrD proposal for soft photon measurement at STAR — joint effort of the LPP, UCLA, and Lanzhou. Detailed detector geometry has been finalized and first steps towards prototype construction have been made, including initial design of front-end electronics and data acquisition system. First tests of CsI(Tl) crystals from Kharkov and Lanzhou have been performed.

4. Critical comparison of the properties of the quark–gluon and electromagnetic plasmas and suggestion of possible experimental tests [23].

5. The creation of the specialized system for SSH key management required for a successful and safe performance of the protected STAR servers [24].

6. Study of systematical effects in correlator calculations, originating from multiplicity dependence of observable mean [25]. Evaluation of correlators in $d+$Au collisions recorded by STAR detector has been started.

7. Study of fluctuations of elliptic-flow strength in central Au + Au collisions with the emphasis on a possible ground-state gold nucleus deformation [26].

8. Study of femtoscopic correlations and their consequences for particle-production dynamics [27–30].

9. Work on models of particle-production dynamics and computer generators. Comparison of the model calculations with the RHIC data on particle spectra, elliptic flow, femtoscopic correlations and predictions for future data from Large Hadron Collider.

The results have been presented by LPP physicists in 7 talks at LPP seminars, international workshops and conferences.

LPP actively participates in **Thermalization** experiment, U-70 IHEP, Protvino. In 2007 the following tasks were performed [31–39]:

• The work had been underway on the preparation of the vertex-detector electronics. Software development and debugging is in progress. The aim of the software is on-line control of strip-detectors performance and further information analysis.

• During the current period the works were realized to hold drift tracker in working state. The coordinate resolution and the registration efficiency of tubes had been determined using data taken in 2006 run.

• The mail functioning of the magnetic spectrometer has been eliminated.

• The automation control of the liquid helium consumption and temperature regime has been established.

• The gamma-detector has been renewed and included in data acquisition system.

• At the expense of project theme and grants (RFBR and JINR), the renovation of the hardware was carried out that makes up the base of computer complex of 2007 run.

• The packages of alignment programs permit one to realize the positioning of vertex-detector planes. Data processing of 2006 are carried out. About 2 million events are analyzed, few thousands of events were selected by means of the first level trigger with more than 10 charged particles. The multiplicity distribution in pp interactions at beam energy of 50 GeV were obtained with vertex detector data up to 22 charged particles.

• The Monte-Carlo simulation of vertex detector performance made it possible to determine the efficiency of algorithms of track reconstruction. One of them is based on Kalman filter. The similar simulation work is carried out for track reconstruction in drifts tracker and magnetic spectrometer.

• The electromagnetic calorimeter calibration is fulfilled and data processing procedure is debugged. The observation of pick from $\pi^0 \to \gamma\gamma$ decay and the determination of its mass — 0.1349 ± 0.009 (GeV) is the confirmation of the correct determination of the calibration coefficients. Using small portion of the high multiplicity events statistics (< 100) it is shown that the mean multiplicity of neutral mesons is increasing as charged ones.

The development of the theoretical approach to high multiplicity event description was performed:

• The development of the Gluon Dominant Model is in line with modern conceptions on the phase transitions of hadrons to quark–gluon matter and inversely (hadronization).

• The possibility of Bose–Einstein condensate detection (BEC) in pp collisions with high multiplicity (higher than mean value) at beam energy 50–70 GeV is studied in collaborations with BITP, Kiev. It had been shown by theory that the experimental manifestation of BEC is the sharp increase of neutral and charged meson multiplicity fluctuations (scaled variance, ω) at fixed total multiplicity.

The ring event search is continued in pp and pA interactions with high multiplicities. In pA interactions the indication of the ring structure is found for charged multiplicity more than 18.

PREPARATION OF NEW EXPERIMENTS

JINR participates in the **CMS** Project in the framework of the Russia and Dubna Member States Collaboration (RDMS). The main effort of JINR in the CMS Project is concentrated on the construction of the CMS inner endcap detectors, where RDMS bears a full responsibility on Endcap Hadron calorimeters (HE) and first forward muon stations (ME1/1). Also JINR participates in Endcap Preshower (ES). In line with commissioning of the detectors, JINR actively participates in the development of start-up and long-term physics research programme with CMS.

In 2007, the first inner endcap YE + 1 was lowered into an underground experimental hall, assembled, precommissioned and prepared for operation in the global run. The second — YE − 1 — is commissioned in a surface hall and ready for lowering. Analysis of experimental data of the first magnet test in the surface hall (MTCC-2006) of the CMS detector 60-degree sector is completed.

The main JINR obligation on construction of endcap hadron calorimeters is fulfilled. In co-operation with IHEP (Protvino), NC PHEP (Minsk), HTTC NIKIET (Moscow), MZOR plant (Minsk), ISC and NSC KIPT (Kharkov) both HE endcaps were delivered, assembled, dressed with front-end electronics and tested at CERN. Industry of Russia and JINR Member–States, such as «Krasny Vyborjets» and «Izhorskie Zavody» in St. Petersburg, October Revolution Plant in Minsk, Single Crystal Institute in Kharkov, and others were deeply involved in the construction of endcap hadron calorimeters. In particular, a technology of brass production out of artillery case cartridges for calorimeter absorbers was developed by NIKIET (Moscow) in cooperation with St. Petersburg plants.

In 2007, after lowering, HE + 1 was assembled in the underground experimental hall and precommissioned. Preparation of service systems in this hall is in progress. HE − 1 is commissioned in the surface hall and ready for lowering. Analysis of experimental data of 2006 magnet test with cosmic muons in the surface hall confirms predicted performance in magnetic field.

JINR obligation on proportional cathode-strip chamber construction for ME1/1 muon stations is also fulfilled. All ME1/1 cathode strip chambers are delivered (including spares), installed and tested repeatedly at CERN.

In 2007, after lowering, ME + 1/1 station is assembled in the underground experimental hall and precommissioned. Analysis of experimental data of 2006

magnet test with cosmic muons in the surface hall shows predicted ME1/1 CSC spatial resolution.

Mass-production of silicon radiation hard detectors 63×63 mm^2 (paid by Russia) in co-operation with RIMST (Zelenograd) is completed. Part of the produced detectors was tested for radiation hardness at IBR-2. Detector database was developed at JINR and installed at CERN to manage with the data of the detector measurements.

In 2007, the combined beam test of endcap calorimetry, initiated and coordinated by JINR, successfully completed a long term of about 2 month data taking run at H2 beam line at SPS. This test continued the RDMS tradition of combined test of the CMS endcap detector prototypes since 1995. In respect to the very first 1995 combined test, which was very important for optimization and integration of each detector and full inner endcap system, the main goal of 2007 beam test was the calibration of the endcap calorimetry in configuration similar to the real CMS experiment.

Each of HE, EE, and ES endcap detectors were calibrated standalone and, for the first time, tested in the combined configuration very close to the real CMS installation with various very low energy and high energy beams from 2 up to 300 GeV, with a good identification of muons, electrons, pions, kaons, and protons. Three independent HCAL, ECAL and preshower x-DAQs, combined CMS DAQ with CMS run control, as well as 3 subdetectors data quality monitoring, and combined express analysis, were used for tests. In line with participation of many hardware and software experts, combined test also attracted many young physicists and students due to a good training for future operation with the CMS detector.

During the year 2007, the main efforts of JINR physicists in CMS were focused on preparation for the first data taking and continuation of development of CMS physics programme. They made a major contribution to calibration of the endcap hadron calorimeters, development of core and reconstruction software for muon and jet, beam test data analysis, development of data processing and analysis scenarios. The field of a special interest of JINR group is the programme for studies of processes with heavy dimuons which is an integral part of the CMS physics programme.

The main results based on a full simulation and reconstruction analyses and with taking into account possible systematic effects performed by JINR group are as follows:

1. The new version of the CMS programme package (CMSSW) for event reconstruction and data analysis was tested and validated to study physics with muons and jets.

2. The update results on CMS performances for triggering and off-line reconstruction of dimuon pairs have been obtained. The total efficiency of triggering including reconstruction and trigger selection efficiency is 95%. The off-line reconstruction efficiency for samples with SM Drell–Yan events is about 98–94% for masses 0.2–5 TeV/c^2. The overall efficiency of the full reconstruction procedure taking into account trigger and off-line reconstruction inefficiency is about 90% for a wide mass range.

3. The realistic misalignment scenario based on 10 pb^{-1}data has been tested. Misalignment scenarios utilize the mounting precisions of various parts of the CMS as well as the estimated accuracies after the use of optical alignment systems and track based alignment. These numbers are more or less rough estimates and will be updated once better estimates become available from alignment studies during data taking.

4. The potential of the CMS experiment to measure the forward–backward asymmetry for dimuon pairs up to the highest masses that will be accessible at the LHC has been explored in detail. This asymmetry can be used to test the Standard Model up to very high momentum transfers in a new and unexplored energy range. Various methods to determine the forward–backward asymmetry in the dimuon channel in CMS are considered. The effects of mistag probabilities due to the quark direction known only on the statistical basis have been taken into account, as well as the detector acceptance and trigger and reconstruction efficiencies. The largest systematic uncertainty comes from the PDF uncertainties. The statistical errors dominate for the invariant mass larger than 1 TeV/c^2 even for 100 fb^{-1}. For high invariant mass regions the uncertainty of the forward–backward asymmetry is limited by the number of events (e.g., 0.04 for masses above 1 TeV/c^2 and 100 fb^{-1}) and systematic effects (below 0.05 for the cut on the dimuon invariant mass of 2 TeV/c^2).

5. A procedure is improved for evaluating the jet energy scale from direct photons in $\gamma+$ jet events. The systematic shifts obtained on the jet energy scale with this technique are estimated with CMSSW. It is shown that the process $\gamma+$ jet can provide sufficient statistics for the calibration of jets up to an $E_T^{\rm jet} \approx 1000$ GeV.

6. The analysis of the experimental data of the combined ES–EE–HE beam test has started. New calibration method based on pion and electron showers with different energies was proposed, developed and tested with experimental data. For HE, the standalone preliminary result with this method shows that stochastic term for energy resolution is around 114% and constant term is 2.7%.

These results were published in the 11 CMS Notes and external journals. Also the results were presented and discussed at CMS Collaboration meetings and international conferences.

The development of the RDMS LCG regional center was continued. The new CMS software framework was installed in the LIT (JINR). The CMS data model, data services, system of job submission were tested. The important works aimed on development of CERN–JINR data management system were completed during

CSA07. Validation of data transformation chains, Tier-0 → Tier-1 → Tier-2 has been performed. The publications on CMS activity are given in [40–55].

During the year 2007, the efforts in the framework of **ATLAS LAr** project were focused on the following tasks [56–57]:

1. The analysis of the data to test HEC readout electronics of the ATLAS detector.

2. The analysis of the data taken for cosmic muons was also performed.

3. The work for calorimeter calibration is still continuing. The bulk of more than 100 Gbyte of Monte-Carlo information characterizing the passage of charged pions in the ATLAS detector was transferred from CERN PC farm to the LPP PC farm.

4. The work for further understanding and implementation of the basic ATLAS software products for simulation of different physical processes in the real experimental conditions (PHYTHIA, ATHENA, etc.) was continuing. On this base, the work to investigate associative production of top-quark pair and Higgs boson has been started. This process essentially increases an experimental possibility to find the Higgs boson.

5. In the frame of the INTAS project, the work on preparation of experiment to study performance of hadronic calorimeter for the sLHC is carried out. It will be conducted on the 60 GeV extracted proton beam of U-70 IHEP proton accelerator in Protvino. The JINR obligations are to construct two the so-called minimodules of hadronic liquid argon calorimeter, to provide properly calibrated 20 temperature probes to monitor liquid argon temperature, and to construct liquid nitrogen cryogenic system, which allows one to condensate argon in all 3 cryostats with minimodules inside. All equipment produced at JINR was transported to Protvino and installed in the beam area. The first run with the 60 GeV proton beam was performed from 9 till 17 of November.

Within an accounting year with participation of the LPP specialists all amount integration works and preparation for the start of the internal detector of **ATLAS TRT** have been finished [58–60]. They are: installation in the cavern of the silicon and straw detectors, cable harnesses, LV/HV systems, lines of gas maintenance, systems of cooling, etc. High-voltage supply systems of the detectors and all service systems are tested. Start TRT is carried out. With participation of the LPP staffs, works on the TRT monitoring, simulation of some physical processes and the session with space beams were spent. The unique ATLAS opportunities are illustrated on an example of simulation of the process known as Hawking radiation (see Fig. 5).

The prototypes of the segment straw detector and the straw detector with high differential pressure of their gas filling (up to 4 Bar) are developed and investigated. The bench researches of the segment straw detector have shown opportunity of its high granularity (up to 2 sm^2). Simulation of the information reading processes is also made and requirements to lines of reading are generated. The high pressure straw researches, made at the stand and on the Nuclotron bunch, have shown an opportunity of creation on their basis of the MIR detectors and the photons with the energy of quanta up to ~ 15 keV.

In 2007, the work on **NIS** project was carried out in two main directions [61–63]:

— development of software tools (on-line and off-line);

— hardware development (including production of electronics).

1. Software development (results of 2007).

The following work was done:

• New event reconstruction tools were modernized.

• Monte-Carlo estimations of the set-up characteristics were revised using new reconstruction tools.

• Software for TOF data analysis was created and developed. Software procedure for alignment of trackers was developed and used in the analysis of the data taken in the commissioning run (March 2007).

New on-line software tools were developed and used in the commissioning run in March 2007.

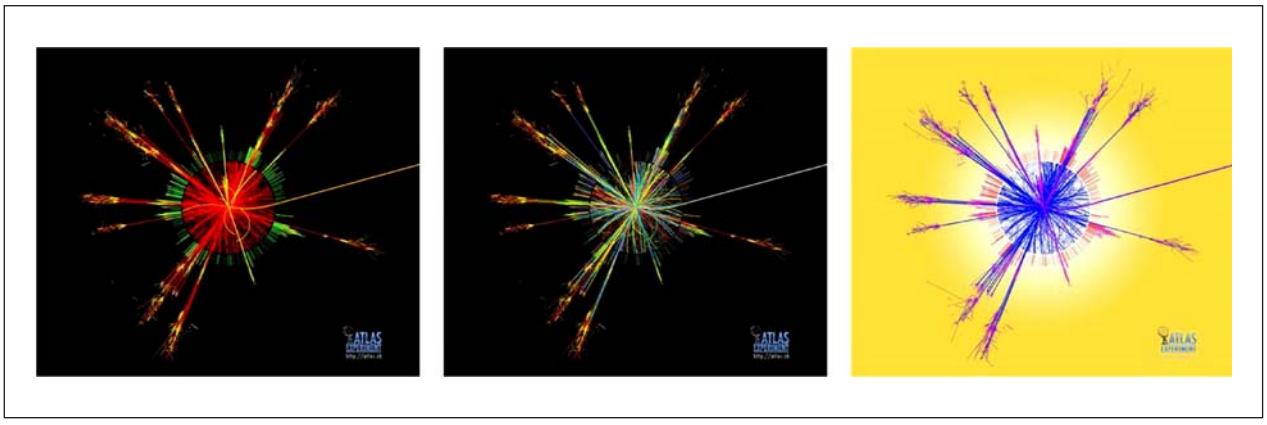

Fig. 5. An example of the Hawking radiation process simulation

2. Hardware development (results of 2007).

The following works were fulfilled in this direction:

• Production of the liquid hydrogen target (10 cm in length, 3 cm in diameter) has been finished. The target was installed in the set-up in January 2007 and commissioned in November 2007. The profile of empty target was measured during the run in March 2007.

• TOF detectors (RPC) were tested and studied at the test-bench with cosmic rays and during the March 2007 run; the optimal working regime was defined. Two TOF walls from the RPC are mounted at the planned place. A part of the electronics (TQDC modules) was produced. A part of the high voltage connectors are purchased as well as a part of the HV supply system was produced. But this work is not completed.

• Proportional chambers with their electronics were prepared and used in the March run. New modules of electronics were produced for PC and the whole system was ready for the November run.

• Minidtrift chamber (MDC) production (gas container) has been finished in the JINR Workshop. It is expected that the chamber will be ready in the 1st half of 2008.

• R&D of start-TOF detector was done; tests of this detector were done in the March run at the Nuclotron and on the test-bench in October 2007.

• Data acquisition system was prepared; trigger module was produced. The system was tested during preparation for the beam runs and the beam time. All the DAQ electronics as well as the electronics for RPC and MDC was developed and produced by LHE team. The corresponding software was prepared.

ACCELERATION TECHNIQUES

Construction of the **LHC** transverse damping system was continued in 2007 by specialists of the Laboratory of Particle Physics (JINR) in collaboration with Radio Frequency Group of Accelerators and Beams Department (ABRF) at CERN. The LHC damper will be used for preventing transverse coupled bunch instabilities, for damping the transverse injection errors and for excitation of transverse oscillations for beam measurements. The design and series production of 20 deflectors and 20 push-pull wideband power amplifiers for the LHC damper in the framework of the CERN–Russia–JINR agreements were completed by LPP in 2006. All deflectors and amplifiers were accepted by CERN and correspond globally to the LHC specifications. The LHC damper is in the list of the systems that must operate already for the first beam injection into the LHC, and final assembly works, tests, and tuning of all systems of the LHC damper were started in 2007. Sixteen deflectors with supports were installed in the LHC tunnel, and then adjusted and preliminary tested. All the high-voltage feeders (strip connectors to the kickers) were mounted to their supports in the LHC tunnel, too. Sixteen push-pull wideband power amplifiers were tested at the CERN test stand at full DC anode voltage of 12 kV, 7 A of DC current per amplifier and with 0 dB · m signal source. Tests showed similarity of the characteristics of amplifiers with tetrodes of the same type. The difference in gain between amplifiers with RS2048-CJC and RS2048-CJ tetrodes was about 2 dB due to difference of tubes transconductance. Sockets heating tests with the working cooling system of the amplifier were made, too. The temperature of the tetrode socket was up to 90 centigrade degree that is allowable. Results of preliminary measurements of gain and phase characteristics of power amplifier loaded by the kicker were used in the low level processing card implementation. Eight push-pull wideband power amplifiers were installed into the LHC tunnel and were successfully tested at low power (12 kV/2 A, with –10 dB · m signal source to the drivers). Full-scale tests of the push-pull wideband power amplifier have shown that the experimental results correspond to the design specifications. Theoretical studies of the transverse feedback systems for modern synchrotrons are being continued. The problem of transverse emittance blow-up from beam injection errors in synchrotrons with nonlinear feedback systems was considered [64]. The relative emittance growth was calculated for linear and nonlinear feedback transfer functions. An increase of the damping decrement of the beam coherent oscillations and a decrease of the coherent transverse amplitude spread of different bunches in case of the damper with a positive cubic term in the feedback transfer function are predicted. The stability of a beam in synchrotrons with digital filters in the feedback loop of a transverse damper was treated with the use of the characteristic equation which allows one to calculate the achievable damping rates as a function of instability growth rate, feedback gain, and other parameters of the signal processing. It was obtained that the phase shift introduced by the notch filter in the feedback loop can be compensated by the all-pass filter with constant frequency-response magnitude, but variable, adjustable, phase advance. The implemented analysis of the feedback system with notch filter and

first order all-pass filter shows that in the low gain regime the characteristics coincide with an ideal feedback system.

Future plans of the LPP team are determined by participation in the commissioning of the LHC damper as well as in the investigations of transverse beam dynamics with the aim of obtaining the ultimate beam parameters at the LHC. The nearest plans in 2008 concern the hardware commissioning of 16 push-pull wideband power amplifiers and 16 deflectors installed in the LHC tunnel in junction with the preamplifiers and the high-voltage power converters located in the LHC POINT 4 ground hall. Beam commissioning of the LHC damper is planned in 2008, too. At the same time, the first measurements with the beam to optimize LHC damper performance will be started.

During 2007, the following works were performed in the framework of **CLIC** project:

1. Data of preliminary experiments on test cavity heating were analyzed and compared with the results of numerical simulation. Two possible ways of increasing the temperature rise have been suggested: 1) to slightly decrease the heated area by changing the shape of central ring of the test cavity and 2) to increase the field amplitude by increasing the quality factor of the test cavity.

2. New central ring and two variants of diaphragms which allow increasing the quality factor of the test cavity have been designed and manufactured using high-precision diamond tools. Electrodynamic measurements showed that new variants of the test cavity are ready for high-power experiments.

3. Series of high-power experiments have been fulfilled using different variants of test cavity for several Bragg resonators of the FEM oscillator. Maximal temperature rise in the experiments of (150–190) °C has been registered for test cavity with new central ring and quality factor 1500. This temperature is high enough for final stage of the experiments.

4. These results have been reported at the Workshop «CLIC 2007» in October and discussed with the leaders of CLIC project. It was stated that the second stage of the Contract No. K723/PS is completed.

5. The detailed programme of further experiments in the frames of the third stage of the Contract has been discussed and approved during CLIC–JINR–IAP RAS meeting at CERN.

6. New workplace for 3D electrodynamic simulation was put into operation using 4-core processor and 8 Gbytes of operating memory. It is used for optimization of Bragg resonators, test cavity, and elements of RF transmission line.

7. Step-by-step upgrade of power supplies for focusing magnetic system has been continued.

8. Preliminary experiments on biological objects irradiation by high power 30 GHz wave have been fulfilled. The goal of this activity is a possible medical application.

In the framework of the theme **Development of Accelerators for Radiation Technologies** the following tasks were performed.

1. The basic units of new accelerator R–300/10 with parameters: energy $E = 300$ keV, average current $I = 5 \div 10$ mA, the size multibeam cathode $\varnothing 200$ mm have been made and adjusted.

2. Efforts under the decision of the basic experimental problem have been concentrated on development and adjustment of the stabilization system. It is planned to receive by the end of 2008 design values of voltage $E = 300$ keV, a current $I = 10$ mA with stability $\pm 5\%$.

3. The new system of the raising transformer which has allowed one to increase efficiency of the accelerator from 70 up to 95% is developed and made.

4. Creation of the system of stabilization of an accelerating voltage and current of electron beam has been completed. Works on training multibeam cathodes of the accelerator and adjustment of the stabilization system above beam are started.

5. Peculiarity of formation of a working surface of cold cathodes from fibrous pyrolitic carbon will be the impossiblity to create required amount of a working surface by machining cathodes. Therefore for reception of design parameters of the voltamper characteristics of cathodes, their training is required during which an electropolishing of a surface takes plase.

6. Training is conducted in a boundary mode of transition of field issue of cathodes microinhomogeneities into explosive issue. Polishing is carried out by evaporation of microinhomogeneities.

7. The narrow range of a training mode imposes specific requirements on operation of the system of stabilization of an accelerating voltage and a current of a beam electrons. It is necessary to react quickly to transition in prebreakdown state and to protect cathodes from electric discharge.

8. Training of cathodes is conducted up to the voltage exceeding the maximal working voltage by 10%. After the end of training, work is conducted in a stable mode of field issue of all cathodes of multibeam accelerators.

COMPUTING

The goal of the **F-Cluster** project is a construction at JINR of modern computing infrastructure for ongoing experiment on particle and nuclear physics. Main results obtained in 2007:

- A power of the LPP–LHE PC-farm has been increased by more than 1.2 times in comparison with

2006 up to 70K SI2K due to including into its structure of a new computer cluster oriented for the NICA/MPD project.

• A disc space for users has been increased by 1.3 times in comparison with 2006 and is 20 Tbytes at the moment.

• The MPD experiment which is now under preparation has started to actively use LPP–LHE PC-farm.

• A special NICA/MPD server equipped with modern software is organized (thanks to JINR Director's Grant).

• Special works are carried out to connect, by Gigabit optical channel, building No. 2 with a central LHE networking node (thanks to JINR Director's Grant).

• A number of working places connected in different ways to the local subnets of the Laboratory has increased.

• Stable work of the IP-telephones has been achieved.

• Works on stabilization of power and condition of LPP–LHE PC-farm have been carried out.

INNOVATION ACTIVITY

In the framework of **DVIN** project during 2007 we have continuing construction of the systems for remote nondestructive identification of illicit substances, based on the method of tagged neutrons (MTN). The MTN uses fast monochromatic neutrons with the energy of 14.1 MeV produced in binary reaction $d + t \rightarrow {}^4\mathrm{He} + n$. In this reaction the α particle with the energy of 3.5 MeV flights back-to-back with the neutron (in c.m. system). By measuring the α-particle trajectory the direction of the corresponding neutron is determined. These «tagged» neutrons interact with the interrogated object and can produce γ quanta in $A(n,\gamma)A'$ reactions with energy spectra which are unique for each chemical element in the object. The characteristic γ spectra could serve as «fingerprints» to identify the hidden substance. The main advantage of the MTN is the sensitivity to the elemental content of the hidden substances rather than to its density contrast as many X- and γ-rays introscopes can define. Tagging of the neutrons provides the time information, which could be used to select the events from a particular time interval, which results in the drastic decrease of the background. It is shown that the use of $(\alpha - \gamma)$ coincidences reduces the background-to-signal ratio by a factor of more than 200, that allows one to identify small quantities of explosives. The fast 14 MeV neutrons are suitable for interrogation of the hidden objects because of their high penetration into the bulk material. They are specially convenient to inspect the medium (luggage) and large (cargo containers) scale objects. The development of the system is being successfully performed in a collaborative project between the Joint Institute for Nuclear Research (Dubna) and Federal Security Service (FSS) of the Russian Federation.

In 2007, we have tested the stationary system at the FSS laboratory. The system has demonstrated high efficiency of identification of explosives hidden in a suitcase with a low probability of false alarms [65]. At present the system is under experimental exploitation at the FSS laboratory. During 2007, we have also performed the following:

• Mobile system based on MTN for identification of explosives has been constructed.

• New alpha detector on 64 channels has been constructed and tested.

• Data acquisition electronics and decision making software was prepared and tested for the prototype of the system for the airport security. The work has been performed on the contract with «Kyungwon Entreprise» Co. Ltd., Seoul, Korea.

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