DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

ELEMENTARY PARTICLE PHYSICS

The main results of the **JINR/CDF** group in 2007 are the measurement of the top-quark mass ($M_{\rm top}$) and the efficient operation of CDF II. A contribution of principal significance to precise $M_{\rm top}$ measurement $M_{\rm top} = 167.7 \pm 4.2\,({\rm stat.}) \pm 3.1\,({\rm syst.})$ GeV/c^2 in the «dilepton» mode at the integrated luminosity of 2.1 fb^{-1}, was made [1]. To increase the number of the selected dilepton decay channel events, the so-called lepton + track selection was used.

A new measurement of the top-quark mass on the basis of dilepton events was carried out using the lepton transverse momentum information [2]. The preliminary result corresponding to the integrated luminosity of 1.8 fb^{-1} is $M_{\rm top} = 156 \pm 20\,({\rm stat.}) \pm 4.6\,({\rm syst.})$ GeV/c^2.

Within the framework of the **D0** project the first direct observation of the charged beauty baryon Ξ_b, which contains quarks from all the three generations, b, s and d, occurred [3]. At the cms energy of 1.96 TeV 35 millions proton–antiproton interactions with muon pairs in the final state in the 2.5–3.6 GeV/c^2 mass region were analyzed. In these events, J/ψ particles and charged Ξ hyperons and antihyperons from the common secondary vertex were reconstructed. With additional cuts applied for suppressing the combinatorial background, 51 events with the effective mass of the $(J/\psi\Xi)$ system within the 5.2–7.0 GeV/c^2 mass region were detected. Their $(J/\psi\Xi)$ mass distribution has the peak (19 events) at 5774 MeV/c^2 of width 37 MeV/c^2. The probability for such a peak to arise from background fluctuations does not exceed $3.3 \cdot 10^{-8}$ (background level is 3.6 events). All the test samples of the events have no peculiarities within this $(J/\psi\Xi)$ mass region (Fig. 1). The peak has been interpreted as the decay $\Xi_b \to J/\psi + \Xi$. The measured mass of Ξ_b agrees with theoretical predictions.

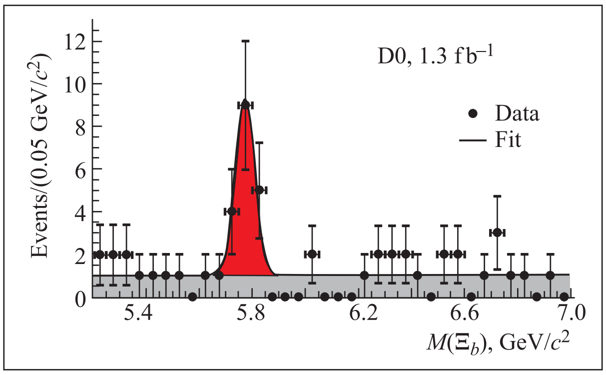

Fig. 1. The peak corresponding to the $(J/\psi\Xi)$ mass distribution

Within the framework of **ATLAS** project during 2007 all of 84 BMS/BMF muon chambers passed through pretests and now are under the cosmic muon tests. The JINR group studied the possibility of precise measurement in ATLAS the Drell–Yan processes both for measurements of the inclusive and differential cross sections and for ATLAS muon spectrometer calibration using the $Z \to \mu\mu$ decay. The event selection procedure, which is characterized by high efficiency (90%) and low background (2%), was developed. The huge statiscics (of the order of 10 million per year) would allow this channel to be used for the luminosity monitoring with the precision about 1% per 24 h.

The most efficient way to improve the knowledge of the proton structure functions is the precise measurement of the double differential cross section $pp \to Z \to \mu\mu$ (vs P_T and η). The procedure, which allows determination of this cross section with a high (2–3%) precision, has been developed by the JINR group. The accurate determination of the real efficiency of the muon spectrometer is a very important task, which is vital for various precision measurements. The JINR group has developed a method in which one of the muons from the $pp \to Z \to \mu\mu$ reaction is used as a «tag», which allows determination of the spectrometer efficiency from the probability of reconstruction of the second muon. The main difficulty of this method is a low background selection of the $Z \to \mu\mu$ events using the muon spectrometer information for only one of the two muons. The special selection procedure which provides a relatively low background level ($\sim 3.8\%$) was developed. It was demonstrated that this method allows efficiency determination with precision better than 1%.

Within the framework of the **ATLAS TileCal** electromagnetic cell level calibration constants for the TILECAL Modules at 20 and 90 deg are performed [4]. The electromagnetic calibration constants for 11% of the TILECAL Modules have been determined. The average values for these modules are 1.154 ± 0.002 pC/GeV and 1.192 ± 0.002 pC/GeV at 20 and 90 deg for the flat filter method, and 1.040 ± 0.002 pC/GeV and 1.068 ± 0.003 pC/GeV for the fit filter method. These average values for all cells of the calibrated modules agree with the weighted average calibration constants for separate modules within the errors. The global constants, which should be used for the electromagnetic calibration of the ATLAS Tile Hadronic Calorimeter data within ATHENA, are 1.15 pC/GeV in flat filter method and 1.04 pC/GeV for the fit method.

An impact of the selection criteria tested in a broad range of selection cuts has been investigated for the pseudorapidities $\eta = 0.35$ and 0.45 and incident energies in the range from 10 to 180 GeV [5]. From the investigation it follows that the experimentally used selection criteria have a noticeable but not critical impact on determination of the e/h ratio. At the same time it can be stated that the shift of the e/h ratio caused by the selection cuts has a negative sign, i.e., the events with higher π^0 energy are preferred by the criteria; the effect is more profound for higher incident energies; the average shift of the e/h for all incident energies and the experimentally used cuts is about -1.5%.

During 2007, the detailed physics program of the JINR group in the **BES-III** experiment was elaborated. A possibility to study the Lorentz structure in lepton decays of τ, including measurement of Michel parameters and a search for the anomalous tensor coupling at BES-III, was shown. The conservative estimates based on Monte-Carlo simulation suggest that the current precision of the Michel parameters can be improved by a factor of 2–4, and the limits on the anomalous coupling constant can be improved by at least a factor of 10. A detailed proposal was included in the BES-III Physics Book.

Measurement of QCD fragmentation functions can be carried out at BES-III. The excellent particle identification at BES-III makes it possible to measure separately the fragmentation functions into pions, kaons and protons, in the new region of Q^2. Preparation for the data analysis is underway. A study of the azimuthal correlation of two hadrons in the opposite hemispheres is also promising at BES-III. The acomplanarity of two hadrons may give access to the Collins fragmentation functions due to quark–antiquark transverse spin correlation in the process $ee \to q\overline{q} \to hhX$. A similar study, based on the 30 fb^{-1} data sample has been recently reported by the Belle Collaboration. A clear non-zero effect was observed.

Two-photon events with hadronic final state can act as a background for other channels studied at BES-III, and must be taken into account. However, two-photon reactions can provide interesting results as well, since the experimental knowledge of hadron production by two photons is rather poor. A detailed proposal on two-photon physics based on Monte-Carlo simulation was included into the BES-III Physics Book. Also, the JINR group takes part in the development of the physics analysis tools, where several event generators are integrated into the BES-III software.

The present status of the **SANC** project includes theoretical predictions for practically all Standard Model (SM) $1 \to 2$ and $1 \to 3$ decays and many $2 \to 2$ processes at the one-loop precision level. SANC version v1.10 is accessible from servers at CERN http://pcphsanc.cern.ch/ (137.138.180.42) and Dubna http://sanc.jinr.ru/ (159.93.75.10). Within the ATLAS project, the group continues the precision study of Drell–Yan processes [6]. The precision calculations of the semi-leptonic decay widths of the top quark were finished [7]. The recent investigations of the SANC group are devoted to the multin-cross-channel approach to the $ffbb$ processes. It allows the results to be applied both to e^+e^- and to γe modes of a linear collider, e.g., ILC. This universal approach was developed [8].

The main purpose of the **DIRAC** experiment is the lifetime measurement of $\pi^+\pi^-$ atoms to test low-energy QCD predictions. In 2007, the JINR group completed the setup tuning and the 5 month data taking run with the Pt target at the upgraded DIRAC setup for observation of π^+K^- and π^-K^+ atoms and lifetime measurement of the $\pi^+\pi^-$ atom. Data processing and analysis (processing of the data obtained in 2001–2003) yielded the value of the $\pi^+\pi^-$ atom lifetime with the systematic and theoretical errors at a level of 10%. The system of microdrift chambers was installed in the DIRAC setup. The scan over electronic thresholds and high voltage was performed at the current working loading rate to find the operating range and accuracy of the detector.

The **TUS** space experiment is aimed to measure the energy spectrum, composition and angular distribution of the Ultra High Energy Cosmic Ray (UHECR) at $E \approx 10^{19}-10^{20}$ eV. The TUS mission is now planned for operation at the Small Space Apparatus (SSA) separated from the main Foton-4 satellite, to be launched in 2010. In 2007, the technological prototypes of some TUS detector components were produced [9]. In the new design the mirror-concentrator consists of six Fresnel and one central parabolic mirror segments. The full mirror area is 2 m^2, the focal distance is 1.5 m. The new steel mold is now under production. The special software package for the analysis of the ECLIPCE raw data measurements for the mirror and mold was developed.

The aim of the **NUCLEON** project is direct CR measurements in the energy range $10^{11}-10^{15}$ eV and charge range up to $Z \approx 40$ in the near-Earth space to resolve mainly the «knee problem»: a change in the slope and composition of the CR spectrum from $E^{-2.7}$ to $E^{-3.0}$ at $\sim 10^{15}$ eV. Of special interest to JINR is the search for a signal of a heavy particle with mass 0.5 TeV as expected for the lightest and stable SUSY or WIMP particle that is needed for the dark matter understanding. The NUCLEON mission is planned for operation at the COSMOS type satellite to be launched in 2009. Technological NUCLEON trigger modules were designed and produced. The technological trigger modules were successfully tested in the 300 GeV CERN SPS accelerator pion beam [10].

LOW- AND INTERMEDIATE-ENERGY PHYSICS

The **GEMMA** spectrometer consists of a 1.5 kg HPGe detector surrounded with a combined active + passive shielding and placed under a 3 GW reactor 2 of the Kalininskaya Nuclear Power Plant 13.9 m away from the core center. The antineutrino flux of $2.73 \cdot 10^{13}$ ν/cm^2/s scatters weakly on the electrons of the Ge crystal, and the energy spectrum of the recoil electrons is registered. Comparing the low-energy part of the spectra measured with the reactor ON and OFF, one can extract the electromagnetic contribution and thus to estimate the neutrino magnetic moment value. Different techniques are used to suppress the background (physical and instrumental); as a result, one succeeded in reducing the threshold to as low as 3 keV (Fig. 2). Analysis of the 2005/2006 data taken for 6200 (reactor ON) and 2064 (OFF) h allowed [11] the world's best upper limit for the NMM: $\mu_\nu \leqslant 5.8 \cdot 10^{-11}$ in units of Bohr magneton (90% CL). At present, further data taking is in progress.

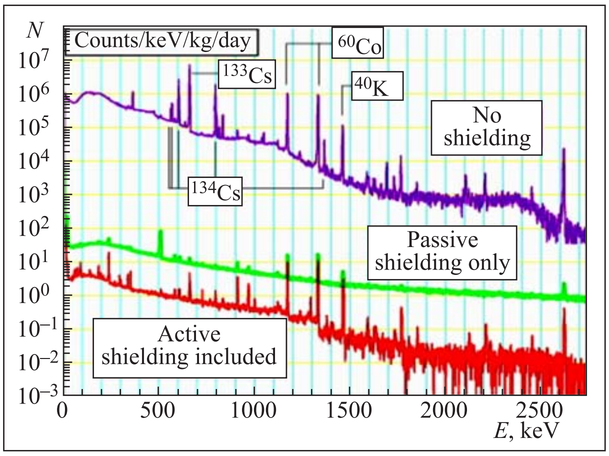

Fig. 2. Background suppression with shielding

The **NEMO-3** detector located in the Modane Underground Laboratory (LSM, France) is searching for the neutrinoless double-beta decay ($0\nu\beta\beta$). The goals of the NEMO/SuperNEMO projects are to reach sensitivities 0.2–1.0/0.04–0.1 eV for the effective Majorana neutrino mass $\langle m_\nu \rangle$ ($T_{1/2}^{0\nu\beta\beta}\,(^{100}\mathrm{Mo}) \sim 4 \cdot 10^{24}/T_{1/2}^{0\nu\beta\beta}\,(^{82}\mathrm{Se}) \sim 2 \cdot 10^{26}$ y) respectively. In 2007, the NEMO-3 detector was taking data under conditions kept stable since February 2003. The current NEMO-3 exposure is ~ 1178 d. The detailed analysis of background components was carried out during 2007. The preliminary results were obtained for $2\nu\beta\beta$-decay of ^{130}Te (Fig. 3): $T_{1/2}^{2\nu\beta\beta}\,(^{130}\mathrm{Te}) = 7.6 \pm 1.5(\mathrm{stat.}) \pm 0.8(\mathrm{syst.}) \cdot 10^{20}$ y, and for the $2\nu\beta\beta$-decay of ^{130}Mo to the excited state [12]: $T_{1/2}^{2\nu\beta\beta}\,(^{130}\mathrm{Mo}\,(0^+,\ 1130\ \mathrm{keV})) = 5.7^{+1.3}_{-0.9}\,(\mathrm{stat.}) \pm 0.8\,(\mathrm{syst.}) \cdot 10^{20}$ y.

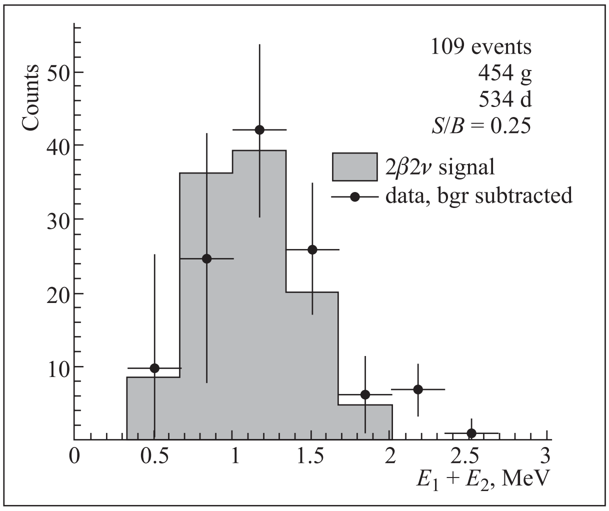

Fig. 3. Signal of the $2\nu\beta\beta$-decay of ^{130}Te from the NEMO-3 data

Considerable progress in development of the new international **GERDA** (GERmanium Detector Array) experiment was made in 2007. The main purpose of the experiment is to search for neutrinoless double-beta decays ($0\nu\beta\beta$) of ^{76}Ge. GERDA will operate with bare germanium detectors (enriched in ^{76}Ge) immersed in liquid argon (LAr). The experimental setup is under construction in the underground laboratory of LNGS (Italy). In Phase I the existing enriched detectors from the previous Heidelberg–Moscow (HdM) and IGEX experiments are employed, in Phase II the new segmented detectors made from recently produced enriched material will be added.

Construction of the main experimental infrastructure started with ordering water tank and the cryogenic vessel. The bottom part of the water tank has been installed in Hall A of LNGS. The final construction of the water tank will be resumed when the cryostat is erected. Welding of the vessel heads and cylindrical parts of the cryostat is underway. The existing eight enriched germanium detectors of HdM and IGEX are handled, characterized and tested, the same energy resolutions as previously are obtained. They are being refurbished for mounting in the cryo liquid. 35 kg of new enriched Ge was procured from Russia for Phase II detectors. Non-enriched and 18-fold segmented detectors were successfully tested for resolution and pulse shape analysis. New background suppression methods such as detector segmentation and anticoincidence with LAr scintillation are developed. The performance of the water Cherenkov veto was studied and the main photodetector was developed. The sensitive radon detector was developed and tested in the underground laboratory. The LArGe test facility with 1 t of liquid argon was designed. All elements of LArGe are produced and prepared for building up [13].

The **EDELWEISS** experiment is aimed at the searching for non-baryonic cold dark matter in the form of WIMPs in Laboratoire Souterrain de Modane (LSM). The direct detection principle consists in the measurement of the energy released by nuclear recoils produced in an ordinary matter target by elastic collisions of WIMPs from the galactic halo. The EDELWEISS detectors are cryogenic Ge bolometers with simultaneous measurement of phonon and ionization signals. A comparison of the two signals provides a highly efficient event-by-event discrimination between nuclear recoils (induced by WIMP and also by neutron scattering) and electronic recoils (induced by β or γ radioactivity). EDELWEISS-II uses three different types of detectors: 320 g Ge/NTD, 400 g Ge/NbSi with two NbSi Anderson insulator thermometric layers for active surface event rejection that were developed within the EDELWEISS collaboration, and a new type of detectors, the 400 g Ge/NTD/INTERDIGIT recently developed for the same purpose of active surface event rejection due to a special interdigitized electrodes scheme. EDELWEISS-II was initially funded for a 28 detector stage (21 Ge/NTD and 7 Ge/NbSi detectors). Data acquisition with this setup started in the summer 2007. The EDELWEISS-II experiment installation was completed at the end of 2005.

To study low background at EDELWEISS-II, Dubna group builds and runs high sensitive neutron and radon detectors at underground laboratory. The results of measurements at LSM demonstrated that the average detected rate corresponding to the «neutron» peak at the ^{3}He counters underground was ~ 150 counts/d. The internal background rate of the detector is estimated to be below 3 counts/d from measurements performed underground with the detector placed inside the additional 30 cm shielding. As follows from the preliminary results of MC estimation of the detector efficiency, the detector has sensitivity to the neutron flux at a level of $\sim 10^{-8}$ neutrons per cm^2 per second. The Dubna group plans to build one more neutron detector with bare ^{3}He counters for direct monitoring of the flux of thermalized neutrons.

The main goal of the **NN** project is to measure spin-dependent total cross-section differences $\Delta\sigma_L$ and $\Delta\sigma_T$ for the neutron energy 16.2 MeV. During 2007, the experimental study of the nd-scattering with polarized particles was continued at the VdG accelerator of the Charles University. The total cross-section difference was measured using the classical transmission method. Two thin scintillation detectors monitored the polarized neutron beam incident on the polarized target. Behind the target two scintillation detectors were placed to detect transmitted neutrons. All detectors are located along the beam axis. The main responsibility of the JINR LNP group was modification of the polarized target and operation of the target system during experimental runs. In October 2007, $\Delta\sigma_L$ measurements were carried out. The measurement consisted of several 24-h runs for each deuteron spin orientation. After each run the spin of the target was reversed. During the run over 20 000 000 raw events were collected with 5 pairs (positive and negative) of deuteron spin polarization, the average negative polarization being about 34% and the average positive polarization — about 28%. The expected statistical error of the $\Delta\sigma_L$ is about 60 mb.

The **GDH** project [14] covers an important spin physics problem — experimental verification of the Gerasimov–Drell–Hearn (GDH) sum rule with the new «MAMI C» accelerator stage. Measurement using the combination of the new Mainz–Dubna frozen spin target, the linearly and circularly polarized photon beam and the Crystal Ball detector will allow the determination of polarization observables with high quality. The JINR part of the collaboration is the design and construction of the ^{3}He/^{4}He dilution cryostat for New Frozen-Spin Polarized Proton-Deuterium Target. This Cryostat was tested at JINR in January–April 2007 and after that was transferred to Mainz. At present this Cryostat is installed as a part of the New Polarized Target and its main parameters are under tuning now.

Within the framework of the **PIBETA** project the final results of the analysis of the experimental data on radiative pion decay were obtained. The decay $\pi^+ \to e^+\nu\gamma$ was studied in three broad kinematic regions using the PIBETA detector and a stopped pion beam. The $\pi^+ \to e^+\nu\gamma$ data set was used to extract the weak axial F_A and vector F_V pion form factors. As a result, the amount of data acquired during the PIBETA experiment is an order of magnitude greater than that obtained in previous studies. Radiative pion events were recorded in three overlapping phase space regions (with opening angle $\theta_{e^+\gamma} > 40.0\,^\circ$). The results of SM minimizations $F_V = 0.0259$ are fixed. A hypothetical tensor term to the decay rate amplitude resulted in the upper limit $|F_T(0)| \leqslant 5.1 \cdot 10^{-4}$ at the 90% confidence limit. This limit is more than an order of magnitude, smaller than the ISTRA collaboration re-analysis result.

Within the framework of the **SPRING** project single-pion production was studied with the ANKE setup at COSY, Jülich. The differential cross section of the reaction $pp \to pp\pi^0$ was measured in the beam energy range T_p between 0.5 and 2.0 GeV at forward angles of the proton pair production $\theta_{pp}^{cm} = 0{-}18\,^\circ$. When the excitation energy of proton pairs $E_{pp} < 3$ MeV, such diprotons $\{pp\}_s$ are in the $^1S_0$ state. Therefore, the reaction $pp \to \{pp\}_s\pi^0$ is the isospin–spin partner of the kinematically analogous process $pp \to d\pi^+$, which was the subject of extensive experimental study for many years. On the contrary, for the $pp \to \{pp\}_s\pi^0$ reaction the only data away from the threshold energy region were limited to $T_p < 0.425$ GeV. Combined study of both reactions at ANKE aims to get a better insight into the reaction dynamics. In the measured angular dependences of the cross section at the zero diproton angle a minimum is observed for $T_p \leqslant 1.4$ GeV, whereas at 2.0 GeV a forward peaking is seen (Fig. 4). An increase in the cross section at 2.0 GeV together with a drastic change of the angular distribution form indicate transition to another reaction mechanism at energies where isobar states higher than $\Delta(1232)$ are excited. Some of the observed features are similar to those of $pp \to d\pi^+$. However, the ratio of the forward differential cross sections of the two reactions, corrected for different FSI in the relevant nucleon pairs, is very low and hence demonstrates significant suppression of the single-pion production associated with a spin-singlet final nucleon pair (Fig. 5). While such a suppression is known and understandable in the near-threshold and the $\Delta(1232)$ regions, its explanation at higher energies requires new theoretical investigations.

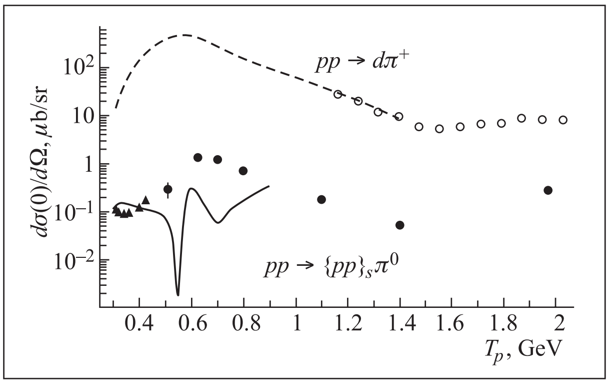

Fig. 4. Differential cross section for the $pp \to \{pp\}_s\pi^0$ reaction with $E_{\{pp\}} < 3$ MeV. Closed circles are the ANKE result, the triangles are the CELSIUS data. The solid curve corresponds to the prediction of the J. Niskanen model. For comparison, the cross section for the $pp \to d\pi^+$ reaction is shown: the dashed curve is the SAID parametrization, open circles are the KEK results

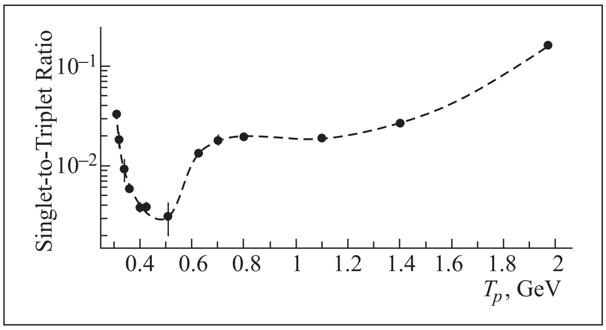

Fig. 5. Energy dependence of the singlet-to-triplet ratio $|A_s|^2/|A_t|^2$ obtained from comparison of cross sections of the $pp \to \{pp\}_s\pi^0$ and $pp \to d\pi^+$ reactions

A joint JINR–INFN (Italy) **DUBTO** experiment is dedicated to studies of pion–nuclear interactions at energies below the Δ-resonance making use of visualization techniques such as the self-shunted streamer chamber technique, developed at JINR, and nuclear photoemulsion. The main results of the experiment include: increased statistics for determination of the branching ratios of the following two-prong $\pi^-{}^4$He reaction channels with application of the ANN technique ($\pi^- + {}^4\mathrm{He} \to \pi^- + {}^4\mathrm{He}$, $\pi^- + {}^4\mathrm{He} \to \pi^- + {}^4\mathrm{He} + \gamma$, $\pi^- + {}^4\mathrm{He} \to \pi^- + {}^4\mathrm{He} + n$); the first observation of the reaction channel $\pi^- + {}^4\mathrm{He} \to \pi^- + {}^4\mathrm{He} + \gamma$; the first experimental evidence for excitation of the negative Δ-resonance in the knockout of a neutron bound in the ^{4}He nucleus: $M_\Delta^- = 1160$ MeV, $\Gamma/2 = 20$ MeV; further study of resonance behaviour of the invariant masses M_{π^+nn} and M_{π^-pp} measured in breakup reactions $\pi^{\pm 4}\mathrm{He} \to \pi^{\pm 4}ppnn$ in helium and in nuclear photoemulsion; first direct estimation of the muon neutrino mass from a $\pi^+ \to \mu^+\nu$ decay event ($m_\nu < 2.2$ MeV).

Within the framework of the **CATALYSIS** project the gamma detection system with cosmic background rejection was developed [15]. The main part of the detection system (Fig. 1) consists of two large γ detectors covering the solid angle $\approx 25\%$. They are of sandwich-type (BGO + plastic) viewed by the same PMs. The BGO crystal is aimed to detect 23.8 MeV $\gamma - s$ from the reaction $d(d,\,{}^4\mathrm{He})\gamma$. Plastic scintillator casing surrounding BGO crystal serves as an active shield for the accidental radiation (mainly cosmic rays).

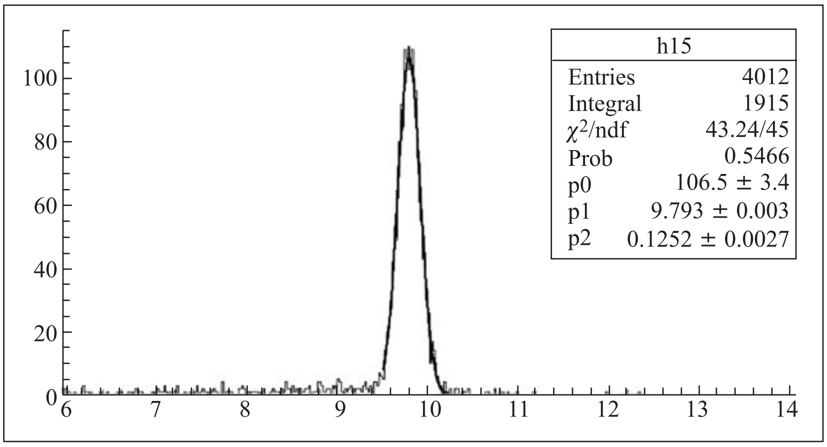

Fig. 6. The result of simulation for 23.8 MeV gamma-line including selection criteria

The pulse-shape analysis was applied to select «useful» and background events in Monte-Carlo simulation using the difference in scintillation time (300 ns for BGO and 10 ns for plastic). The calculations and modeling of the main physical processes in the detectors and the target were performed (Fig. 6) in order to optimize the overall geometry and to develop the design of the overall apparatus [16].

RELATIVISTIC NUCLEAR PHYSICS

In 2007, the **FASA** collaboration had a data taking on the Nuclotron to study dynamics of thermal multifragmentation in collisions of relativistic deuterons (2.5 GeV per nucleon) with a gold target.

For this experiment a new counter array was added to the FASA setup [17]. It consists of 25 telescope-spectrometers, which make it possibile to measure the correlations of intermediate mass fragments (IMF). The total number of fragmentation events detected during this experiment is 10^8. The IMF–IMF correlation data are under analysis now, it is very time consuming. The value of the critical temperature for the nuclear liquid-gas phase transition is a crucial parameter of the nuclear equation of state. It is found to be $T_c = (19.5 \pm 1.2)$ MeV by analysis of the fissility of hot nuclei. This result is in accordance with the value obtained by the FASA collaboration from the multifragmentation data [18].

Thus, the contradictory situation in this field is resolved (Fig. 7).

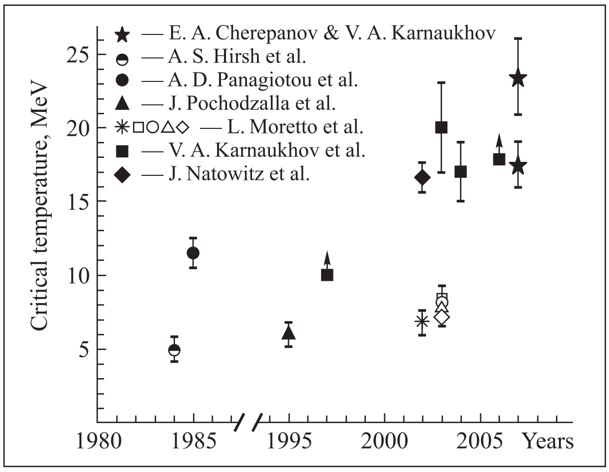

Fig. 7. Experimental estimations of critical temperature for the nuclear liquid-gas phase transition. The values by the FASA collaboration are located in the upper-right corner. The values from the fragmentation study (black squares) are significantly larger than those obtained by Moretto et al. in Berkeley. This contradictory situation is resolved in favor of the Dubna results by our analysis of the fission data (stars)

APPLIED SCIENTIFIC RESEARCH

The main goal of the topic «Further Development of Methods and Instrumentation for Radiotherapy and Associated Diagnostics with the JINR Hadron Beams» is to carry out medico-biological and clinical investigations on cancer treatment, to upgrade equipment and instrumentation, and to develop new techniques for treatment of malignant tumours and for associated diagnostics with medical hadron beams of the JINR Phasotron in the Medico-Technical Complex (MTC) of DLNP [19].

In January 2007, the transportation channel of the therapeutic proton beam to treatment room № 1 which had been damaged by the fire of 2005 was completely repaired. Since January till November 2007 six treatment sessions, total duration of 25 weeks, were carried out and an extra session is supposed to be in December. 80 new patients were fractionally treated with the medical proton beam. The total number of the single-proton irradiations (fields) has exceeded 3700. Other 42 patients were irradiated with the Co-60 gamma-unit «Rokus-M» (more than 1000 fields).

Radiobiological research was also continued [20]. Earlier it was already shown that both preliminary and subsequent laser irradiation of fibroblasts led to an increase in the survival of cells damaged by ionizing radiation. Further investigation of the mechanism of radioprotective effect of 633 nm optical radiation on fibroblast cells shows that the radioprotective action of the laser radiation is transferred to the fibroblast cells according to the mechanism of the «bystander» effect via direct intercellular communication through gap junctions, as well as via medium transfer from the laser-irradiated ones to non-irradiated cell population.

The study of the combined action of gamma radiation and protons on mouse cells for the determination of the optimum combined irradiation regimen in radiotherapy shows that the result of combined irradiation depends on the sequence of radiation, each irradiation dose, and also on the time interval between two types of irradiation. In collaboration with the Laboratory of Radiation Biology the research on chromosomal damages in cells was continued using the model of human blood lymphocytes at different stages of the cell cycle after the proton beam irradiation.

A set of experiments on verification of the treatment planning software algorithms of the dose field calculation using radiochromic films and anthropomorphous Alderson phantom was continued. Influence of the collimator material and aperture on the shape of the clinical proton beam depth-dose distributions was studied. For small collimator apertures the shape of the depth-dose distribution is distorted especially in the collimators made of materials with large atomic number.

REFERENCES

1. *Bellettini G. et al.* Top Quark Mass Measurement in the 2 fb^{-1} Tight Lepton and Isolated Track Sample Using Neutrino Phi Weighting Method. CDF/PHYS/TOP/GROUP/9048. 2007.
2. *Giakoumopoulou V. et al.* Measurement of the Top Quark Mass from the Lepton Pt in the Dilepton Channel, at 1.8 fb^{-1}. CDF/PHYS/TOP/PUBLIC/8959. 2007.
3. *Abazov V. M. et al.* // Phys. Rev. Lett. 2007. V. 99. P. 052001.
4. *Kulchitsky Y. et al.* Electromagnetic Cell Level Calibration for ATLAS Tile Calorimeter Modules. ATL-TILECAL-PUB-2007-001; CERN-ATL-TILECAL-PUB-2007-001. CERN, Geneva, 2007. 82 p.
5. *Budagov J. et al.* Study of the Selection Criteria Impact on the e/h Ratio Measurement in Tile Calorimeter. ATL-COM-TILECAL-2007-004. CERN, Geneva, 2007. 14 p.
6. *Andonov A. et al.* // Part. Nucl., Lett. 2007. V. 4, No. 6(142). P. 757–771.
7. *Arbuzov A. et al.* // Eur. Phys. J. C. 2007. V. 51. P. 585–591.
8. *Bardin D. et al.* // Ibid. V. 52. P. 83–92.
9. *Tkachev L. et al.* Status of the TUS Space Detector Preparation for UHECR Study // Proc. of the 30th ICRC, Merida, Yucatan, Mexico, 3–11 July, 2007.
10. *Voronin A. G. et al.* // Instr. Exp. Techn. 2007. V. 50, No. 2. P. 39–49 (in Russian).
11. *Beda A. et al.* // Yad. Fiz. 2007. V. 70. P. 1; hep-ex/0705.4576.
12. *Arnold R. (NEMO Collab.)* // Nucl. Phys. A. 2007. V. 781. P. 209.
13. *Pandola L. et al.* Monte-Carlo Evaluation of the Muon-Induced Background in the GERDA Double Beta Decay Experiment // Nucl. Instr. Meth. A. 2007. V. 570. P. 149–158.
14. *Usov Yu.* The Cryostat for Mainz University // JINR News. 2007. No. 3.
15. *Demin D. L. et al.* Status of the dd-Gamma Experiment // Proc. of MCF-07, Dubna, June 18–21, 2007.
16. *Volnykh V. P.* Application of GEANT4 Toolkit in dd-Gamma Experiment in Dubna // Ibid.
17. *Kirakosyan V. V. et al.* // Instr. Exp. Techn. 2008. No. 1. P. 1 (in Russian).
18. *Karnaukhov V. A. et al.* Critical Temperature for the Nuclear Liquid–Gas Phase Transition (from Multifragmentation and Fission) // Phys. Rev. C (submitted); nucl-th/070310v1. 2007.
19. *Molokanov A. G.* Forming of the Depth-Dose Distribution of the Radiotherapy Proton Beam of the JINR Phasotron. JINR Commun. P18-2007-90. Dubna, 2007 (in Russian).
20. *Voskanyan K. Sh., Mitsyn G. V., Gaevsky V. N.* // Aviakosmicheskaya i ekologicheskaya meditsina. 2007. No. 3. P. 32–35.