Elementary Particle Physics

Research Activities at JINR

02-7-1044-2002/2005

Priority of the project:	1
Status:	Preparation

Project NIS

Leader from JINR: A.G. Litvinenko, E.A. Strokovsky

Participating countries and international organizations: Russia, Georgia

The project, approved by the JINR PAC for Particle Physics in February 2001, was inspired by unexpected results obtained recently on the role of the strange quarks in the nucleon. Intuitively, it was expected that the $\bar{s}s$ pairs in the nucleon were not significant, being a component of the nucleon sea quarks. But the experimental results obtained in experiments at LEAR for $\bar{p}p$ annihilation at rest forced to build a model based on a nucleon wave function containing negatively polarized $\bar{s}s$ pairs. An attractive feature of this model of the nucleon polarized intrinsic strangeness is its capability to give a natural basis for explanation of the so-called "spin crisis" as well.

In particular, the model gives rather definite predictions for the ϕ meson production in nucleon-nucleon collisions. The most important of them is that the apparent violation of Okubo–Zweig–Iizuki (OZI) phenomenological rule for ϕ production in *NN* collisions must exist at energies near the threshold: the ratio $R_{pp} = \frac{\sigma(pp \to pp\phi)}{\sigma(pp \to pp\omega)}$ is to be much higher than the value predicted by the rule: $R(\phi / \omega) = 4.2 \cdot 10^{-3}$. The experimental programme of the NIS project is aimed at searching for effects of nucleon polarized strangeness in production of ϕ and ω mesons in *pp* and *np* scattering close to the thresholds. It implies:

- comparison of production cross sections of ϕ and ω mesons near their thresholds in proton-proton interactions,
- measurement of ϕ production in *np* interactions.

NIS experiment will provide data on the magnitude of the effect of the OZI violation in *pp* interactions, its energy and spin-isospin dependencies in a vicinity of the threshold (the energy excess over the threshold $\varepsilon \sim 30$–100 MeV).

The only existing data (one point) on ϕ production in *pp* -interaction near the threshold are from the DISTO experiment at SATURNE-II (France). Importance of the NIS physical case is now demonstrated by the fact that a similar experiment was proposed in October 2001 at COSY for the ANKE setup (Germany) to measure $pp \to pp\,\phi$ cross section at ε 18.5 and 34.6 MeV. It stimulated the upgrading of the COSY accelerator up to energy 2.83 GeV from 2.53 GeV.

The energy interval of NIS fills (with an overlap) the gap between the planned COSY experiment and the DISTO one (Fig.1).

As the next expected result, the ϕ production cross section in *pp* collisions will be measured with the energy step $\Delta\varepsilon$ 15 MeV at $\varepsilon \sim 18$–100 MeV. The measurements in the ε interval above 35 MeV are possible only at the JINR Nuclotron which offers rich opportunities to study the threshold and sub-threshold phenomena at $|t| > 1$ GeV^2/c^2 (Figs. 2, 3).

The experiment is being prepared by joint efforts of the LPP physicists and the VBLHE with the participation of physicists from LIT and BLTP. The main parts of the NIS magnetic spectrometer come from the completed EXCHARM experiment ($2 \cdot 1$ m^2 multiwire proportional chambers (MWPC) with all their readout electronics) and SPHERE installation (the analyzing magnet, DAQ and logical electronics, beam monitoring system). The MPWCs and their electronics have been transported from Protvino and a detailed test-bench study of the MPWCs before their mounting at the beam line is in progress, as well as the R&D of detectors for the PID system. The spectrometer can be used as itself in a number of other experiments, first of all, to investigate the lightest hypernuclei and charge exchange of lightest nuclei. Another topic where the use of the NIS setup is being considered is to investigate vector meson (ρ, ω, ϕ) production by protons and deuterons in nuclear medium.

Exploitation of relativistic medium and heavy nuclei beams of the Nuclotron may be here of vital importance. The main goal of such studies is to answer the old-standing questions concerning the possible influence of the nuclear medium on particle properties. Concerning the lowest baryon resonances, it has been established that Δ production in nuclei is strongly influenced by medium effects. But for mesons like ρ, ω, ϕ the experimental study of this problem is at the very beginning.

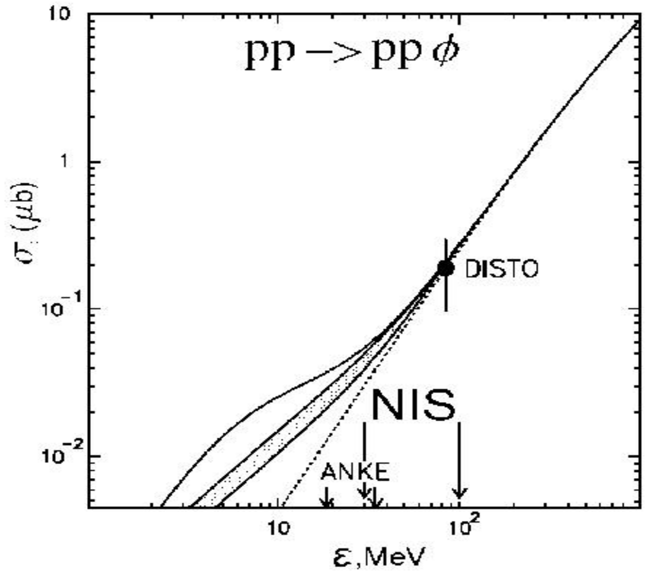


Fig.1. Present data on the ϕ meson production at the threshold. Lines: phenomenological model with final state (FSI) interaction taken into account (solid) and only phase space energy dependence without FSI (dotted). Shaded area — model uncertainties (no FSI effects). The data are from the DISTO experiment with systematic uncertainties included in the error bars. Arrows indicate the ε interval planned for measurements in the present proposal (NIS) and the ANKE proposal.

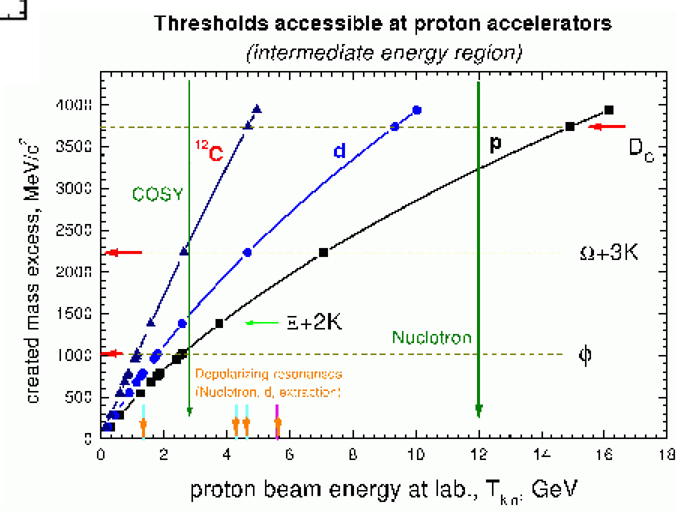


Fig.2. Access to the thresholds for particle production in *pp*, *pd*, and p^{12C} interactions. Abscise: kinetic energy of the proton beam (for the case of nuclear beam (deuterons etc.) it corresponds to kinetic energy per nucleon). Arrows at the abscise axis indicate positions of weak depolarizing resonances in the Nuclotron for a polarized deuteron beam.

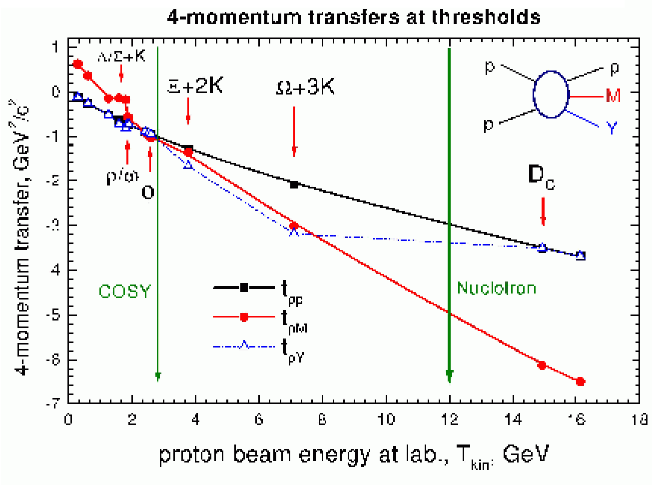


Fig.3. 4-momentum transfers squared for threshold production in *pp* interactions.

02-2-1054-2004/2006

Priority of the project:	1
Status:	New

Support of Analytic and Numeric Calculations for Experiments at Colliders (Project SANC)

Leader from JINR: D. Bardin

Participating countries and international organizations: Italy, JINR, Poland, Russia, the USA

The main idea of this project is to join the efforts of several groups of theorists:

- Dubna SANC group (sector N l, NEOVP, DLNP, JINR);
- BLTP, JINR; INR and Protvino (Russia);
- Knoxville–Krakow collaboration (USA-Poland);
- Torino University (Italy)

and of experimenters of NEOVP DLNP JINR for the realization of wide research program aimed at the theoretical support of experiments at modern and future accelerators such as TEVATRON, LHC, electron Linear Colliders (TESLA, NLC, CLIC) and muon factories. Within the first phase of this project (2001–2003), supported by NATO and INTAS grants, as well as by the grants of the JINR Directorate, we have created a four-level computer system for an automatic calculation at the one-loop precision level the realistic and pseudo-observables (event distributions and decay rates) for more and more complicated processes of elementary particle interactions.

This computer system originally got the name CalcPHEP, but later on was renamed to SANC. A demonstration version SANC v0.20 is accessible in the Internet (address: *http://brg.jinr.ru/).* By the end of first phase, we have demonstrated the work ability of the full chain of calculations "from the SM Lagrangian to event distributions" for the simplest SM processes: decays of *W, Z, H* bosons into fermion-antifermion pair.

The first level (see Fig.), written in FORMS symbolic language, realizes the chain "from the SM Lagrangian to the scalar form factors (SFF) of a process amplitude and helicity amplitudes (HA)", including amplitudes of an accompanying bremsstrahlung processes (HA-Br). A chain of programs for analytic calculations of the contributions of "soft" and "hard" photons is implemented for decays $Z(H,W)\to f\,\bar{f}$ and realized also for decay $t\to Wb$.

In the same spirit, there are realized the calculations of the one-loop scalar form factors for the decays $F\to 3f$, $H\to\gamma\gamma(Z\gamma, ZZ, WW)$ and processes $\gamma\gamma(Z\gamma, ZZ)f\bar{f}\to 0$ with off-shell vector bosons (the latter are not yet accessible for an external user).

At the second level we developed a software realizing automatic generation of FORTRAN codes for subsequent numerical computations, an s2n.f package, see recent review. At the third level one should work out an exponentiation procedure, which is still at the stage of development.

At the fourth level one has Monte Carlo event generators — the last step in the chain of calculations "from helicity amplitudes to event distributions". Monte Carlo generators are being created in a tight contacts with KK-collaboration, see joint common paper.

The present status was widely presented at large-scale International conferences, such as ACAT2002, ICHEP2002 and most comprehensively at RADCOR2002. In the second phase of the project with duration of three years (2004–2006) we plan to complete creation of a set of computer codes, accessible via an Internet-based environment and realizing the chain of calculations "from the Lagrangian to the realistic distributions" at the one-loop level of perturbation theory for a large number of processes of elementary particle interaction, for decays up to 1→4 and for processes up to 2→3 complexity level, including partonic processes, relevant for LHC physics.

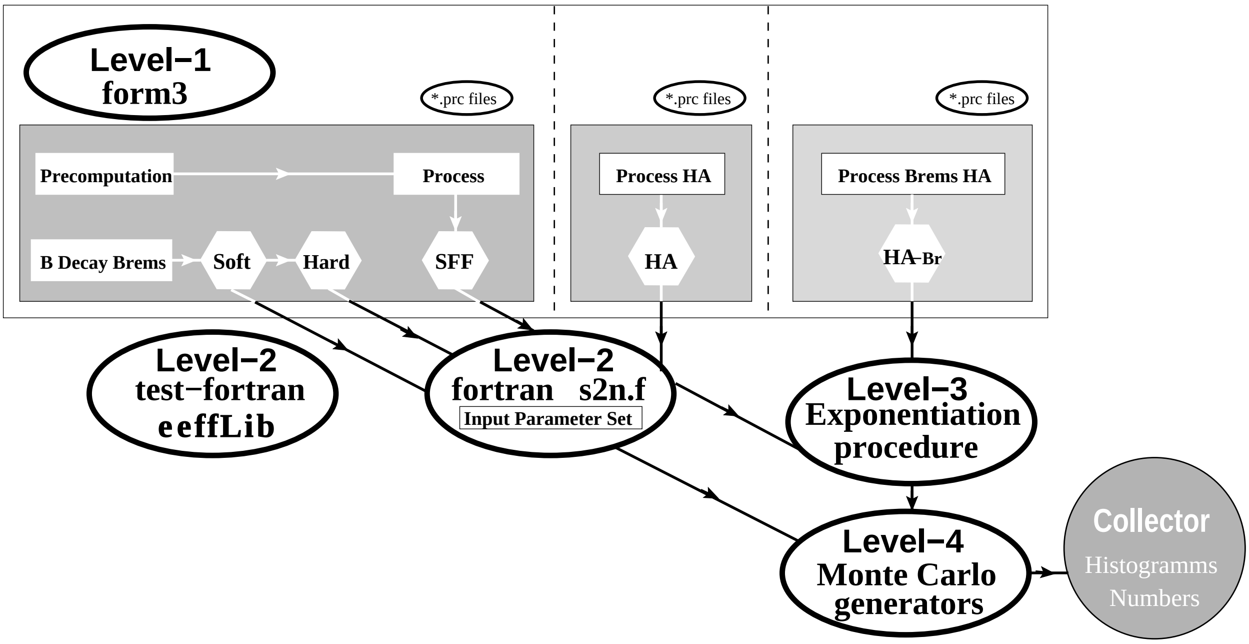

Level−1
form3
*.prc files
*.prc files
*.prc files
Precomputation
Process
Process HA
Process Brems HA
B Decay Brems
Soft
Hard
SFF
HA
HA-Br
Level−2
test−fortran
eeffLib
Level−2
fortran s2n.f
Input Parameter Set
Level−3
Exponentiation
procedure
Level−4
Monte Carlo
generators
Collector
Histogramms
Numbers

Fig.

02-2-1042-2002/2006		Priority of the project: 2
		Status: R&D

Development of the Polarized Target with 6LiD and its Use for Spin Physics Experiments (Project PoLiD)

Leader from JINR: Yu. Usov

Participating countries and international organizations: Czech Republic, France, JINR, Russia, Ukraine

The aim of the Project is the development of effective methods of production 6LiD irradiated materials for a big volume polarized deuteron target with a high polarization (> 40%). It is necessary to find the conditions of irradiation for optimum polarization build-up, maximum polarization value and relaxation time of nuclear polarization.

The result of this Project is supposed to be used on the polarized deuteron targets developed at JINR: Movable Polarized Target "MPT" — Synchrophasotron-Nuclotron accelerator complex; Protvino Target and the Target of Charles University in Prague. The polarized deuteron Targets are used for a study of elastic and inelastic reactions of nucleons and nuclei on deuterons, quasi-elastic reactions with targets nucleons weakly bound in polarized deuterons, and deep inelastic scattering. The study will be carried out using the existing polarized target of the Charles University in Prague and the Microtron of Czech Technical University for the irradiation.

02-2-1049-2003/2005

Priority of the project: 1
Status: R&D

Astrophysical Studies in TUS Experiment on Space Satellite

Leader from JINR: L. Tkatchev

Participating countries and international organizations: Czech Republic, Kazakhstan, Republic of Korea, Russia, the USA

The TUS space experiment has been proposed to address some of the most important astrophysical and particle physics problems. It is aimed to measure energy spectrum, composition and angular distribution of the Ultra High Energy Cosmic Ray (UHECR) at $E > 10^{19}$ eV to study the region of Greisen–Zatsepin–Kusmin cutoff. The existing world statistics is supposed to be increased in 2–3 times during 3 years of data taking. Existing experimental data on $2\text{-}3\cdot10^{20}$ eV particles (above the GZK cutoff) could be explained by a new type of astrophysical objects – charged particle «accelerators» situated in our Galaxy or local galactic cluster (≤ 50 Mpc distance) or by Grand Unification Theory particles with $\sim10^{24}$ eV masses created in topological defects — cosmic strings or monopoles expected in cosmological theories.

The detector allows the Extensive Air Shower events caused by UHECR neutrinos to be measured for the first time from the space orbit. The experiment is included in the Russian Program of Space Investigation and has to be designed, constructed, tested and launched to the space for data taking. The TUS space experiment TUS plan to take data in most uncertain energy region $\geq 5\cdot10^{19}$ eV during 3 years by measurements of fluorescent radiation caused by EAS, which will be initiated by different charged or neutral particles, including neutrinos. The detector TUS potentially allows us to double or even triple the world statistics in this energy region and, for the first time, to measure EAS events caused by neutrino oscillations from the space orbit.

The TUS detector on the RESURS DK1 satellite is shown in Fig.1. It consists of 2 main parts: the mirror-concentrator of area 1.5 m^2 with focal distance 1.5 m and the photodetector of 256 pixels in its focal plane. Pixels are R1894 Hamamatsu PMTs with the light guides organizing the uniform rectangular retina. Pixel size is 10 mm (respective angle is 7.5 mrad). The TUS detector has a rectangular field of view (FOV) of $0.12\cdot0.12$ rad^2 that corresponds to an area in the atmosphere $42\cdot42$ km^2 and pixel resolution of 3.5 km at the orbit perigee height (350 km) and to the area $72\cdot72$ km^2 and pixel resolution 6 km at its apogee height (600 km). Optical aberrations in this narrow FOV are small: a focal spot size is less than 0.3 of the pixel size. Signals from PMTs go to FE electronic channels which are FADC with a sampling time interval of 200 ns.

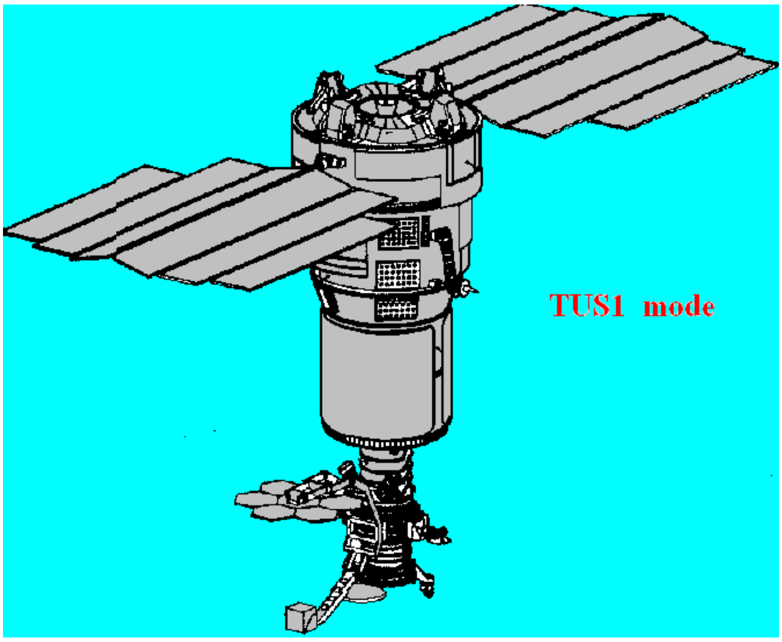


Fig.1. TUS detector location on the RESURS-DK1 satellite.

JINR participation is planned in the Fresnel mirror design, production and tests. The press-form for production of the TUS Fresnel mirror modules has already been fabricated at JINR and shown on Fig. 2. R&D of Fresnel mirror production is in progress. Moreover, the JINR contribution is to develop the complex on-line software. The software should provide data acquisition, on-line filtering and the 2-nd level trigger elaboration, data keeping and transfer to the Earth center, on-line slow control and receiving commands for the TUS management.

JINR also participates in Monte Carlo simulation and in the off-line physical analysis of the raw data including off-line software development.

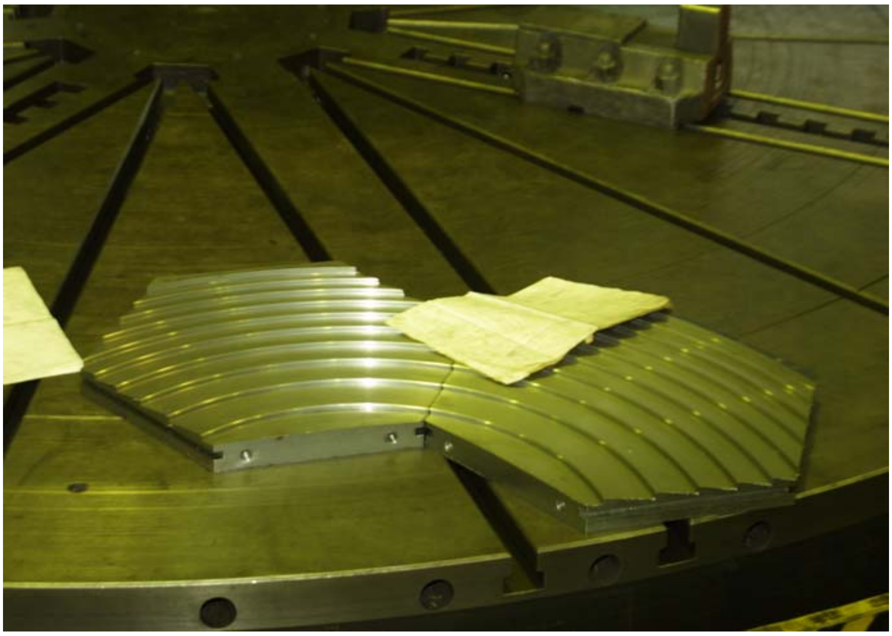


Fig.2. Press-forms fabricated at JINR (Dubna) workshop for production of Fresnel mirror modules.

02-0-1018-96/2006

Priority of the project: 1

Status: Technical Proposal

Particle Accelerator Physics and Engineering

Leader from JINR: I. Meshkov

Participating countries and international organizations: Belarus, CERN, France, Germany, Italy, Japan, Russia, the USA

Development of electron cooling method includes theoretical and experimental studies of cooling process of heavy charged particles in storage rings (ions, antiprotons). Within the framework of the project special software libraries are developed for calculation of electron cooling process and beam dynamics of charged particles in storage rings RHIC (BNL, USA) and HESR (GSI, Germany), the development of conceptual project of electron cooling system for the Nuclotron is planned, as well as participation in the work on the development of electron cooling systems for storage rings TWN (ITEP, Russia), IR (RIKEN, Japan) and NIRS (Chiba, Japan), and testing of their elements.

The project of Low Energy Particle Toroidal Accumulator (LEPTA) is dedicated to the construction of a small positron storage ring with electron cooling of positrons circulating in the ring. Such a peculiarity of the LEPTA enables it automatically to be a generator of positronium (P_s) atoms which appear in recombination of positrons with cooling electrons inside the cooling section of the ring. The P_s atoms form an intense, up to 10^4 atoms/sec, flux which has very small angular, of order of 1 mrad, and momentum (less than 10^{-3}) spreads.

The storage ring LEPTA (Fig.1) is the cyclic system of solenoids surrounded by the common magnetic shielding. The vacuum chamber of the ring is located inside the solenoids. The positron injector has its own magnetic and vacuum system and connects with the ring at the straight section. The ring circumference is about 18 m, the magnetic field value is 400 G, intensity of circulating positron beam is 108, positron energy is 10 keV.

The focusing system with a longitudinal magnetic field and electron cooling of positrons are essential features of LEPTA. The system consists of two toroidal solenoids (positions 6) and two straight ones connected together as a racetrack. The straight solenoids, in their turn, are of two types — round cylindrical solenoids (positions 7, 8) and elliptical ones, so called septum solenoids (position 4). The electron gun, the collector and the positron source are placed inside the additional solenoids. All solenoids are surrounded by common magnetic shielding. The vacuum chamber is located inside the solenoids. The single turn injection of positrons is performed by a special kicker. The long-term stability of the positron beam is produced by an additional helical coil (position 7), which forms a quadrupole magnetic field, similar to that one of a “stellarator”. Special septum coils and centrifugal drift of the electrons are used for superposition and separation of the cooling electron beam and the circulating positrons. The positronium generation takes place inside the electron cooling section (position 8), and the orthopositronium beam leaves the magnetic system travelling through the analyzing magnets (position 9) and entering the positronium detector (position 10).

Initial stage of the LEPTA project was performed in the frame of topic 1018 during 1996–2003. In this period, the following problems were solved:

- software for particle dynamics simulation was developed, calculations of the circulating beam parameters were done, parameters of the focusing system required for technical design of the ring were evaluated;
- software for simulation of an electron cooling of positrons was developed, required parameters of the cooling system were calculated;
- technical design of the storage ring and electron cooling system was done;
- technical design of the low positron injector based on β^+ active isotope Na^{22} was performed;

- concepts of first experiments with positronium flux were elaborated;
- techology of the magnetic system construction was developed and tested;
- elements of the storage ring magnetic system were constructed and tested;
- on the basis of the existing equipment the power supply system was created, required pulse generators were manufactured and tuned;
- general elements of the positron injector were constructed;
- electron gun and solenoid of the electron cooling system were constructed and put into operation;
- test bench for tuning of the ring elements using electron beam was created;
- helical quadrupole and septum winding was tested and tuned using modelling electron beam;
- elements of the ring diagnostic system were designed and constructed;
- assembling of the storage ring was started.

Current stage of the project has the following goals:

- to complete the construction and assembly the LEPTA storage ring and to study its characteristics;
- to construct and tune positron injector based on β+ active isotope;
- to investigate the electron cooling of positrons;
- to set up first experiments with P_s in flight;
- to study a feasibility of the storage ring for antihydrogen flux generation;
- to study feasibility of particle acceleration in the machine aiming its application to electron cooling of heavy ions in GeV energy range.

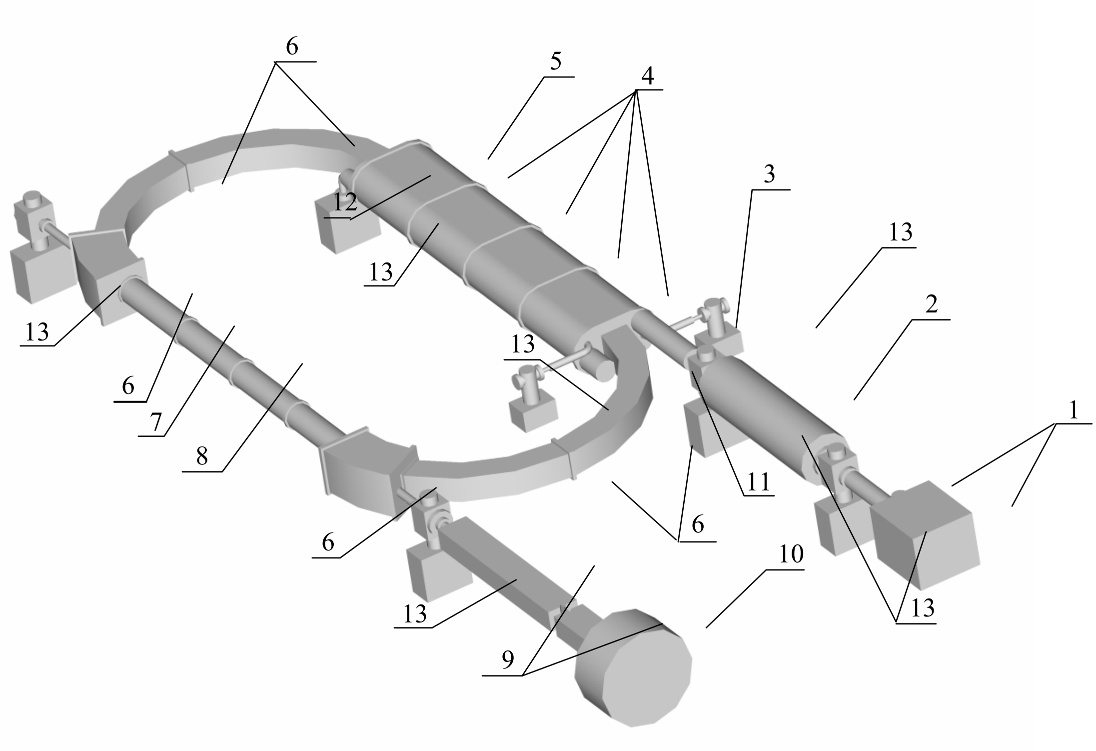


Fig.1. Design of the LEPTA. 1 — positron foreinjector; 2 — positron trap; 3 — positron transfer section; 4 — septum solenoids; 5 — kicker (inside the septum solenoid); 6 — toroidal solenoids; 7 — solenoid and quadrupole coil; 8 — electron cooling section, straight solenoid; 9 — analyzing magnets; 10 — detector; 11 — electron gun; 12 — collector of the electrons; 13 — vacuum pump.

JINR's Participation in Experiments at CERN

02-0-1007-94/2005

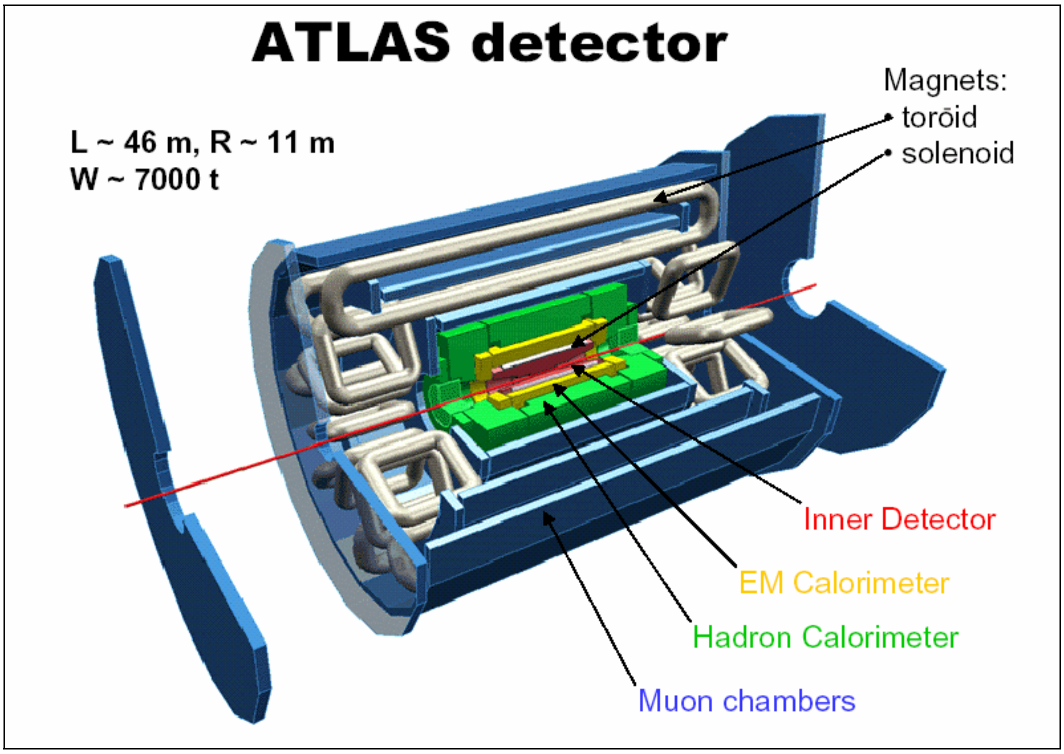
Priority of the project:	1
Status:	In-progress

ATLAS — General-Purpose pp Experiment at the Large Hadron Collider at CERN

Leader from JINR: N. Russakovich

Participating countries and international organizations: Armenia, Azerbaijan, Belarus, Canada, CERN, Czech Republic, France, Georgia, Germany, Greece, Israel, Italy, the Netherlands, Russia, Slovak Republic, Spain, Ukraine, the USA, Uzbekistan

The ATLAS detector is designed to obtain new experimental results on the most actual problems of elementary particle physics, from the precise measurement of the properties of known objects to the exploration of the high energy frontier.



The various Higgs boson searches, which resent some of the most challenging signatures, were used as benchmark processes for the setting of parameters that describe the detector performance. High-resolution measurements of electrons, photons and muons, excellent secondary vertex detection for t-leptons and *b*-quarks, high-resolution calorimetry for jets and missing transverse energy (E_T miss) are essential to explore the full range of possible Higgs boson masses.

- Searches for SUSY set the benchmarks on the impermeability and E_T miss capability of the detector, as well as on *b*-tagging at high luminosity.
- Searches for new heavy gauge bosons provided benchmark requirements for high-resolution lepton measurements and charge identification in the p_T range as large as a few TeV.
- Signatures characteristic for quark compositeness set the requirements for the measurement of very high-p_T jets.
- The precision measurements of the *W* and top-quark masses, gauge boson couplings, *CP* violation and the determination of the Cabibbo–Kobayashi–Maskawa unitarity triangle yielded benchmarks that address the need to precisely control the energy scale for jets and leptons,

determine precisely secondary vertices, reconstruct fully final states with relatively low-p_T particles and trigger on low-p_T leptons.

Muon Chambers

To use the full discovery potential of the LHC, the ATLAS detector has to have an adequate muon system which would have the momentum resolution $2 \cdot 10^{-2}$ at 100 GeV and even 10^{-1} at 1 TeV. This concern is rejected by the choice of the main components of the muon spectrometer: a system of large superconducting air-core toroid magnets, precision tracking detectors with an intrinsic resolution of 60 μm and power dedicated trigger system. The muon system contains three air-core superconducting toroids. It is designed to produce a large-volume field, covering the rapidity range $\eta < 3$, with an open structure that minimizes the multiple scattering contribution to the momentum resolution. The barrel toroid extend over a length of 25 m, with an inner bore of 9.4 m and an outer diameter of 20.1 m. Two end-cap toroids are inserted in the barrel at each end. They have a length of 5.0 m, an inner bore of 16.5 m and an outer diameter of 10.7 m. Muons with the energy from 5 to 1000 GeV will be registered by MDT chambers which are constructed from two multilayers of high-pressure drift tubes mounted on either side of the support structure. Each multilayer consists of three layers of tubes. The drift tubes are made of Al alloy. They are round tubes with the outer diameter of 30 mm. The gas mixture, gas pressure and mechanical tolerances on wire location inside the tubes allow a single-cell resolution at a level of 60 μm. The equipped and tested drift tubes will be assembled into multilayers and epoxy-bonded together to form sti. units, which are .exible enough to follow the wire sag. The tubes are closely packed and jigging is used to control the position of the tube while the epoxy is setting. For meeting all these requirements a special production area with all appropriate equipment must be designed and built.

Tile Hadronic Calorimeter

In the range $|\eta| < 1.6$ the iron-scintillating-tiles technique is used for the barrel and extended barrel Tile calorimeters. The hadronic barrel calorimeter is a cylinder with an inner radius of 2.28 m, an outer radius of 4.23 m and a total length spanning 12.66 m. The total weight of the calorimeter system is about 4000 tons. It is divided in three sections: a central barrel and two extended barrels. It is based on a sampling technique with plastic scintillator plates (tiles) embedded in an iron absorber and read out by wave length shifting .bres. The tiles are placed in plane perpendicular to the beam axis and staggered in depth, simplifying the mechanical construction and the fibre routing. It is segmented in three layers, approximately 1.4, 4.0 and 1.8 λ in thick at $\eta = 0$. Azimuthally, the barrel and extended barrels are divided into 64 modules. In the read-out cells, built by grouping fibres into a photomultiplier, are pseudo-projective to the interaction region. The resulting granularity of the Tile calorimeter are $\Delta\eta \times \Delta\varnothing = 0.1 \times 0.1$ for sampling 1, 2 and $\Delta\eta \times \Delta\varnothing = 0.2 \times 0.1$ for sampling 3. The total number of channels is of the order of 10 000. The calorimeter is placed behind the EM calorimeter (1.2 λ) and the solenoid coil. So, the total active calorimeter thickness (EM + Tile) is 9.2 λ at $\eta = 0$. The amount of material in front of the muon system, that includes the support structure of the Tile calorimeter, is 11 λ at $\eta = 0$. For the hadronic calorimeter the guidelines for the energy resolution performances are set requiring a jet energy resolution at different levels in different η regions: $\frac{\Delta E}{E} = \frac{50\%}{\sqrt{E}} \oplus 3\%$ for $|\eta| < 3$ and $\frac{\Delta E}{E} = \frac{100\%}{\sqrt{E}} \oplus 10\%$ for $3 < |\eta| < 5$. Such resolutions are adequate to the tasks of providing jet reconstruction and jet-jet mass reconstruction as well as missing p_T measurement for physical process of interest. The measured pion energy resolution obtained with the Tile calorimeter tested in stand alone mode after weighting is $\frac{\Delta E}{E} = \frac{45\%}{\sqrt{E}} \oplus 1.3\%$ and with the combined setup of the two calorimeters: electromagnetic LAr and hadronic Tile barrel calorimeters after 'H1' weigthing is $\frac{\Delta E}{E} = \left(\frac{42\%}{\sqrt{E}} + 1.6\%\right) \oplus \frac{3}{E}$.

02-7-1006-94/2005

Priority of the project:	1
Status:	In-progress

CMS — Compact Muon Solenoid

Leader from JINR: I. Golutvin

Participating countries and international organizations: Armenia, Austria, Belarus, Belgium, Bulgaria, CERN, China, Croatia, Cyprus, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, India, Iran, Italy, Pakistan, Poland, Republic of Korea, Russia, Slovak Republic, Spain, Switzerland, Turkey, Ukraine, United Kingdom, USA, Uzbekistan, Yugoslavia

The Compact Muon Solenoid, CMS, is a multipurpose Detector for the Large Hadron Collider, LHC, which is under construction at the European Laboratory for Nuclear Research, CERN (Switzerland, Geneva), to study proton interactions at the energy of 14 TeV. The experimental complex will start to operate in 2007 and will provide a unique opportunity to answer the most fundamental questions of the present-day particle physics. What is the origin of mass in nature? Is there a Supersymmetry (SUSY) leading to Grand Unification of the three forces at the energy 1016 GeV? What is the origin of the matter — antimatter asymmetry? Does the new state of matter, the quark-gluon plasma exist?

To exploit the full LHC discovery potential, the CMS design objectives are as follows: a very good and redundant muon detection system, the best possible electromagnetic calorimeter, high-quality inner tracker, good impermeability of the calorimetry. Construction of the CMS detector is a joint effort of about 2000 scientists from 32 countries forming an international CMS Collaboration. An important part of the CMS community is Russia and Dubna Member States, RDMS, CMS collaboration.

The main effort of JINR in the CMS Project is concentrated on the design and construction of the inner endcap detectors, where JINR bears full responsibility in the framework of the RDMS CMS Collaboration: Endcap Hadron Calorimeters, HE, and First Forward Muon Stations, ME1/1. Also JINR participates in Endcap Preshower, ES, and development of Physics, Reconstruction and Selection programme, PRS subsystem, Computing and Core-Software, CCS subsystem, and preparation of long-term physics programme.

JINR coordinates activity on design and construction of the HE in collaboration with NC HEPP (Minsk), IHEP (Protvino), KPTI and the Institute of Monocrystals (Kharkiv), NIKIET (Moscow), and is responsible for construction of the calorimeter absorbers. Solving the problems of both standard and new physics, depends on the energy and spatial jet resolution, and on the energy resolution of the transverse energy missed in the hadron calorimeter. It requires good impermeability, good transverse segmentation (important for separation of the two-jet events), decent energy resolution, sufficient depth of the absorber, and, lastly, minimization of the dead zones (required for the measurement of the missing energy). The calorimeter based on the light collection through a wavelength-shifting fiber imbedded into the scintillating tiles SCSN81 that are sandwiched with a brass absorber, was proposed by RDMS physicists and satisfies all the above requirements. An elegant engineering design was developed and based on a sampling structure without dead zones, and a sliding joint of the interface between the return yoke and the HE absorber to compensate considerable magnetic forces and 300 ton static load. Industry is extensively involved in the production of the endcap detectors. The brass of the absorber comes from recuperated artillery shells and is delivered by Krasny Vyborzhets plant in St.- Petersburg. Production of the absorber sectors and of the interface system, and the preliminary assembly are performed at Minsk October Revolution plant in Belarus. For the HE mechanics, the material delivery, production supervision, and the quality control at all the stages are provided by NIKIET. Scintillator tiles are produced at the

Monocrystals Institute (Kharkiv). The optical elements (megatiles) are produced and finally assembled at IHEP.

JINR and institutes from Belarus and Bulgaria are in charge for the design and construction of ME1/1. The station plays a key role in the experiment because it matches the tracks of the muon system to the tracks of the inner tracker. The required spatial resolution of 75 μm should be significantly better than the one of the endcap muon system, and timing resolution should be of a few nanoseconds for efficient identification of the bunch crossing. The station will operate in a strong axial magnetic field of about 3 T and at the maximal background rate up to 1 kHz/cm. There have been no operating detectors until now to match this challenge. The method based on the new gaseous wire chamber technology developed at JINR — Cathode Strip Chamber, CSC, with excellent timing and position resolution, high rate capability, and working in 4 Tesla magnetic field was suggested for the endcap muon chamber. JINR deliver 72 of these a chambers for two endcaps. JINR also manufacture 3300 strip electrodes for the Barrel drift tubes.

JINR and institutes from Armenia and Belarus take part in the sub-project of the ES. The preshower detector is located in front of the electromagnetic calorimeter to resolve the photon from the neutral pion, and to measure the coordinates of the photon. The detector consists of two absorbers and two layers of silicon detectors, based on the new radiation hard technology, suitable for mass-production, developed by JINR in cooperation with Belarus, Armenia, CERN and RIMST, Zelenograd. JINR has delivered 1800 Si-detectors for two endcaps.

The studies performed on numerous prototypes and final samples have confirmed that the parameters of the endcap detectors meet the CMS physics requirements.

JINR physicists participate in development of the Physics programme and software in the framework of the RDMS CMS task force on physics processes with emphasis at large η region. The new research programme of the physics beyond the Standard Model (SM) with dimuon masses in the TeV-range in the final state was proposed and developed. The programme includes the study of production of the additional gauge bosons, horizontal gauge bosons, and double charged higgs bosons, and also the signals of the heavy graviton resonance formation and other manifestation of extra dimensions. Simulation of the new gauge bosons production demonstrates a potential of the CMS detector system for Z' discovery.

Dubna physicists significantly contribute to the SM study. B-physics programme includes determination of electroweak parameters and study of CP-violation effects from the "CMS golden channel" $B_s^0 \rightarrow J/\psi\ \varphi$ and other B-decay channels. Other topics related with SM studies include QCD — cross-section of Drell–Yan muon pairs production, determination of parton structure functions using "g+jet" and "Z+jet" processes, and reconstruction of initial parton kinematics parameters at high Q^2 and small-x physics.

The principle possibility of the quark-gluon plasma formation in the light nuclei central interactions and in the non-central collisions of the heavy nuclei has been shown. The influence of the secondary interaction processes and parton shadowing effect on the A-dependence of the particle multiple production was studied. A topic of Global Characteristics of ultrarelativistic nucleus-nucleus collisions was developed.

Calibration of the detectors using the physics reaction was studied. The simulation has demonstrated that the required accuracy during the few months low-luminosity run can be expected to calibrate the CMS hadron calorimetry with processes of the direct gamma+jet and Z+jet production.

The computing group participates in the design of the concept of regional distributed centres, test and development of the CMSIM and ORCA programmes for muon tracks reconstruction in the endcap muon system.

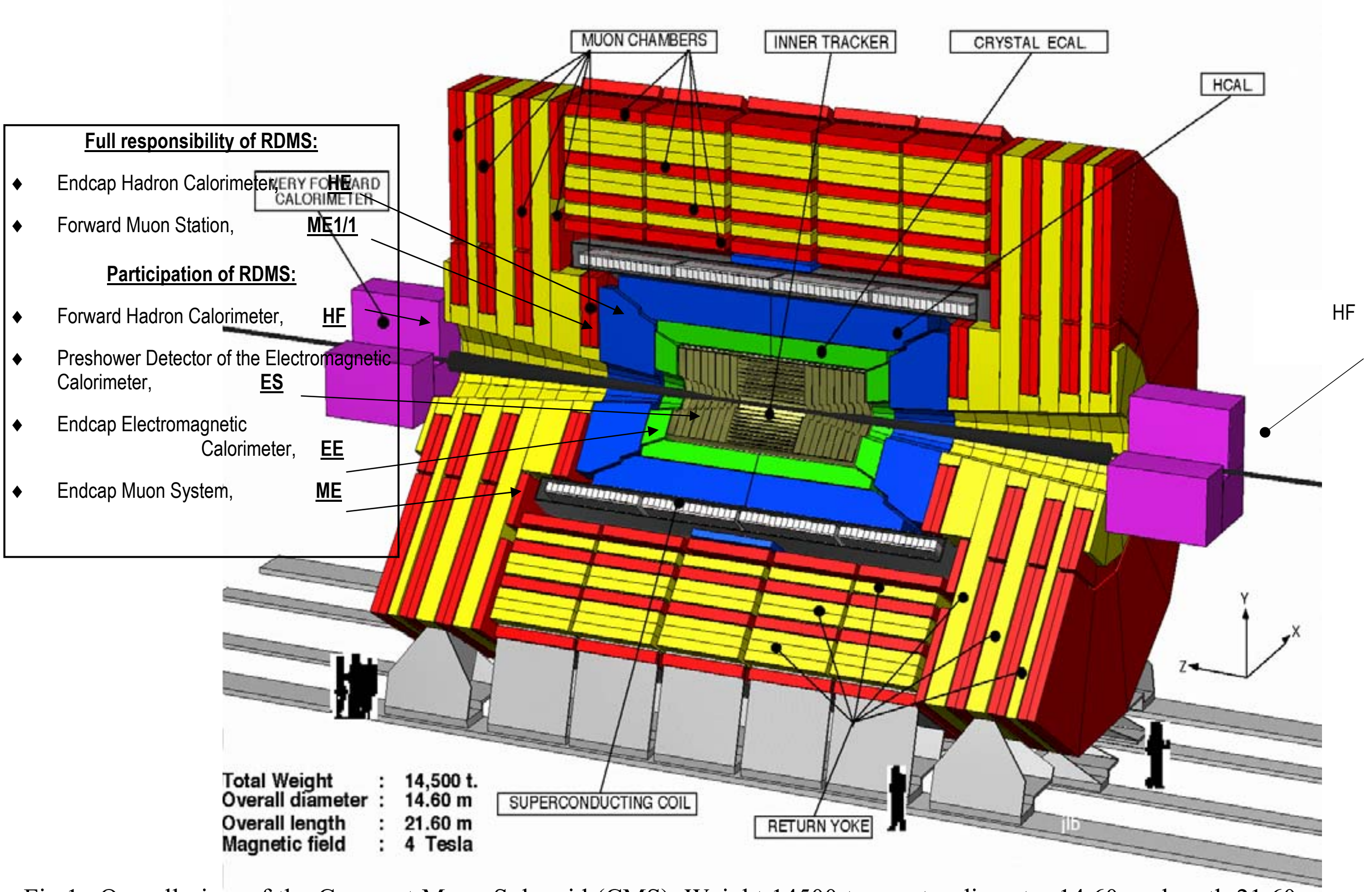


Fig.1. Overall view of the Compact Muon Solenoid (CMS). Weight 14500 ton, outer diameter 14.60 m, length 21.60 m, solenoid magnetic field 4 T. The insertion shows the systems whose construction Russia and Dubna member states (RDMS) CMS collaboration is responsible for. JINR bears full responsibility for Endcap Hadron calorimeters, HE, and Forward Muon Stations, ME1/1, and participates in Preshower, ES.

Fig.2. The first CMS inner endcap detector with the absorber of HE-1 hadron calorimeter and the HE/YE interface serve to suspend the endcap detectors SE, EE, HE, and ME1/1 whose total weight is 300 ton on the iron disk of the return yoke installed at the CMS ground SX5 assembly hall at CERN.

On photo: Directors of the Russian firm ENTEK and Belarus Company MZOR that received CMS Gold Awards on 7 March 2003 at the CMS assembly site, where they stand in front of the hadron calorimeter together with visiting dignitaries from their countries and CMS collaboration leaders.

MZOR and ENTEK designed, produced and assembled the mechanical parts for the CMS endcap hadron calorimeters. The MZOR machine-tools company fabricated the absorber plates and interfaces, and also produced special assembly tooling. In addition, ENTEK manufactured components for the calorimeter and took responsibility for its final assembly at CERN.

02-7-0003-2003/2007		Priority of the project: 1
		Status: New

Transverse Damping System at LHC (JINR's participation in the "LHC Damper" Project)

Leader from JINR: V. Zhabitsky

Participating countries and international organizations: CERN, Belarus, Bulgaria, Russia

The Transverse Damping System at LHC is developed and constructed at the Laboratory of Particle Physics (JINR) in collaboration with AB/RF (CERN).

There are three principle tasks for the Transverse Damping System:

- correction of injection errors,
- damping of transverse coupled bunch instabilities (dipole modes),
- excitation of transverse oscillations for beam measurements.

Transverse Damping System must quickly reduce injection errors to minimize beam losses to remove the risk of quench, and preserve emittance for high luminosity. It should work in a wide frequency range of 20 MHz to fight transverse coupled bunch instabilities.

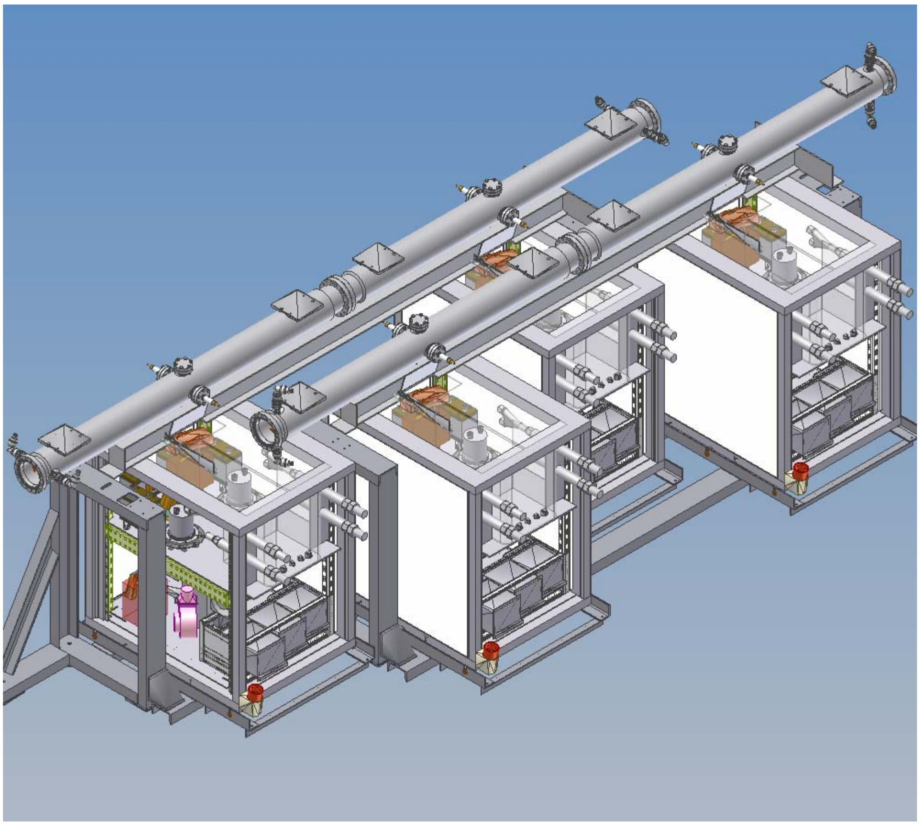
JINR's obligations are to manufacture 20 damping units (20 kickers and 40 power amplifiers). A low frequency electrostatic kicker with tetrode amplifiers has been chosen and designed by using Inventor ™. The kicker design took into account the heating caused by the electron cloud effect and the high order modes' energy evacuation.

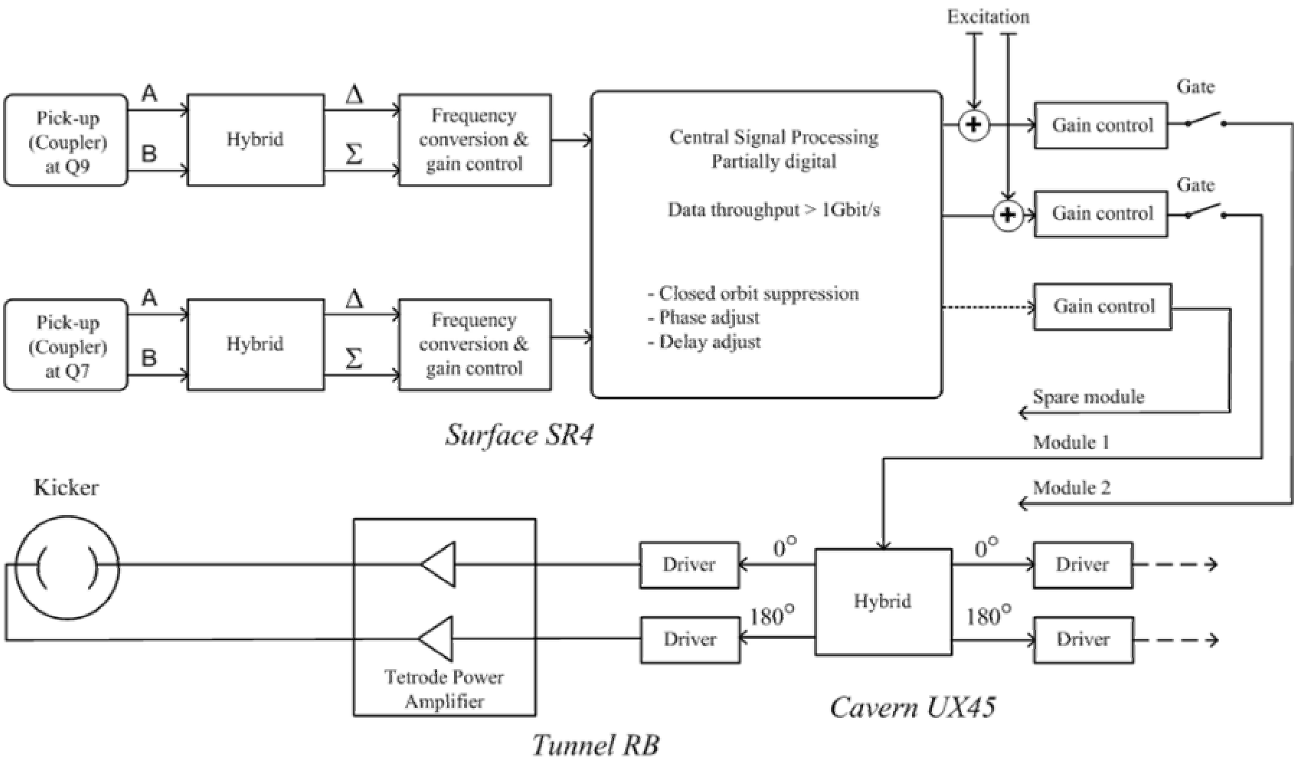
The damper power amplifier includes two vacuum tetrodes Siemens RS-2048 (CJ) work in the push-pull mode. The electrical circuit was modeled by using Microsim PSpice ™ which allows full simulation of the non-linear modes including DC, AC (frequency domain) and transient (time domain) analyses. A model of the tetrode has been developed which takes into account the dependence of the anode and screen grid currents on the anode, screen grid, and control grid voltages.

The design of the damping units is executed in view of the requirements on installation alignment and survey in the LHC tunnel.

Transverse beam dynamics in colliders is studied to optimize damping modes. A nonlinear scenario (including "bang-bang") of the damping is studied for achieving higher efficiency. A cascode circuit is also developed as a perspective way of the power amplifier.

Results of the R&D studies of the Transverse Damping System are used for different applications of the modern powerful and wideband electronics for accelerators. They can be applied for ion beam scanning, ecology electron accelerators and modern high technologies.





Excitation
Pick-up
(Coupler)
at Q9
A
B
Hybrid
Δ
Σ
Frequency
conversion &
gain control
Central Signal Processing
Partially digital
Data throughput > 1Gbit/s
- Closed orbit suppression
- Phase adjust
- Delay adjust
Gate
Gain control
Gate
Gain control
Gain control
Pick-up
(Coupler)
at Q7
A
B
Hybrid
Δ
Σ
Frequency
conversion &
gain control
Spare module
Surface SR4
Module 1
Kicker
Module 2
Driver
0°
0°
Driver
Hybrid
180°
180°
Driver
Driver
Tetrode Power
Amplifier
Cavern UX45
Tunnel RB

02-7-1016-96/2006		Priority of the project: 1

Status: Data taking

Project NA48

Leader from JINR: V. Kekelidze

Participating countries and international organizations: Austria, CERN, France, Germany, Great Britain, Italy, JINR, Poland, Russia, USA

The main goal of the NA48 experiment was the precision measurement of the direct CP violation parameter ε' in the neutral kaon system. It has been successfully achieved in 2002. The overall value Re(ε'/ε)=(14.7 ± 2.2) has been obtained from the statistics, collected in 1997–1999 and 2001. The importance of the measurement is defined by the presence of the direct *CP* violation in the very basis of the contemporary particle physics, as well as in modern cosmology.

The JINR group has contributed significantly into this success from the very beginning of the project. The Dubna group has fulfilled one of the independent final analyses of NA48 data. It has produced the Overlaid Monte Carlo data necessary to calculate the effects induced by accidental activity in the detector. JINR participants were responsible for the on-line Compact Monitoring, which is a separate software package developed for the strong check of the collected physical data quality during data taking runs. The technical personnel from Dubna carried out the main part of the Drift Chambers remount (the total reconstruction of the wires) after the chambers, damaged in 1999.

Many other physical results have been obtained by NA48 collaboration with the considerable JINR contribution in addition to the main goal. They are: measurement of the quadratic slope parameter of the Dalitz plot in the $K_L \to 3\pi^0$ decay, precision measurements of K_S lifetime and masses of η and K_L, measurements of the decay rates of $K_S \to \gamma\gamma$, $K_L \to \gamma\gamma$, $K_L \to \pi^0\gamma\gamma$, $\Xi^0 \to \Sigma^0\gamma$, new upper limits for some rare kaon and hyperon decays — all these additional results clarify new details in the particle physics and are very useful for the future experiment analyses as well as for theoretical calculations.

The JINR group is working on the analysis of NA48/1 data, obtained in the high intensity K_S beam. The physical interest of these data is defined by the possibility to measure with the highest precision some rare K_S and hyperon decays, which are important for the particle physics theory. One more aim of this programme is the attempt to measure the parameter of indirect CP violation η_{000}.

The new charged kaon programme — experiment NA48/2, is aimed at precision measuring the direct CP violation via the asymmetry of the $K^\pm$ decays. More than $4 \cdot 10^9$ $K^\pm \to \pi^\pm\pi^\pm\pi^+$ and $3 \cdot 10^8$ $K^\pm \to \pi^0\pi^0\pi^\pm$ fully reconstructed decays are expected to be recorded. The estimated error for the charge asymmetry of the linear Dalitz plot parameters is of the order of 10^{-4} for both decays. The additional goals of NA48/2 programme are the measurement of K_{e4} decays in order to check the hypothesis of Chiral symmetry breaking and formation of QCD vacuum condensate, and measurements of a number of rare decay branching ratios that have a significant interest for the theory development.

The JINR group participates in preparation of the NA48/2 experiment, carries out physical analysis of the accumulated data; the group is responsible for important parts of hardware (read-out electronics for novel beam spectrometer KABES, muon veto detector) and software (compact monitoring, overlaid Monte-Carlo package, development of the third level trigger filters). The role of JINR in the NA48 Collaboration is stressed by the fact that the spokesman of the NA48/2 experiment at present is Prof. Vladimir Kekelidze, the representative of JINR.

The common view of the NA48 set-up and the scheme of simultaneous beams for NA48/2 experiment are shown in the following pictures:

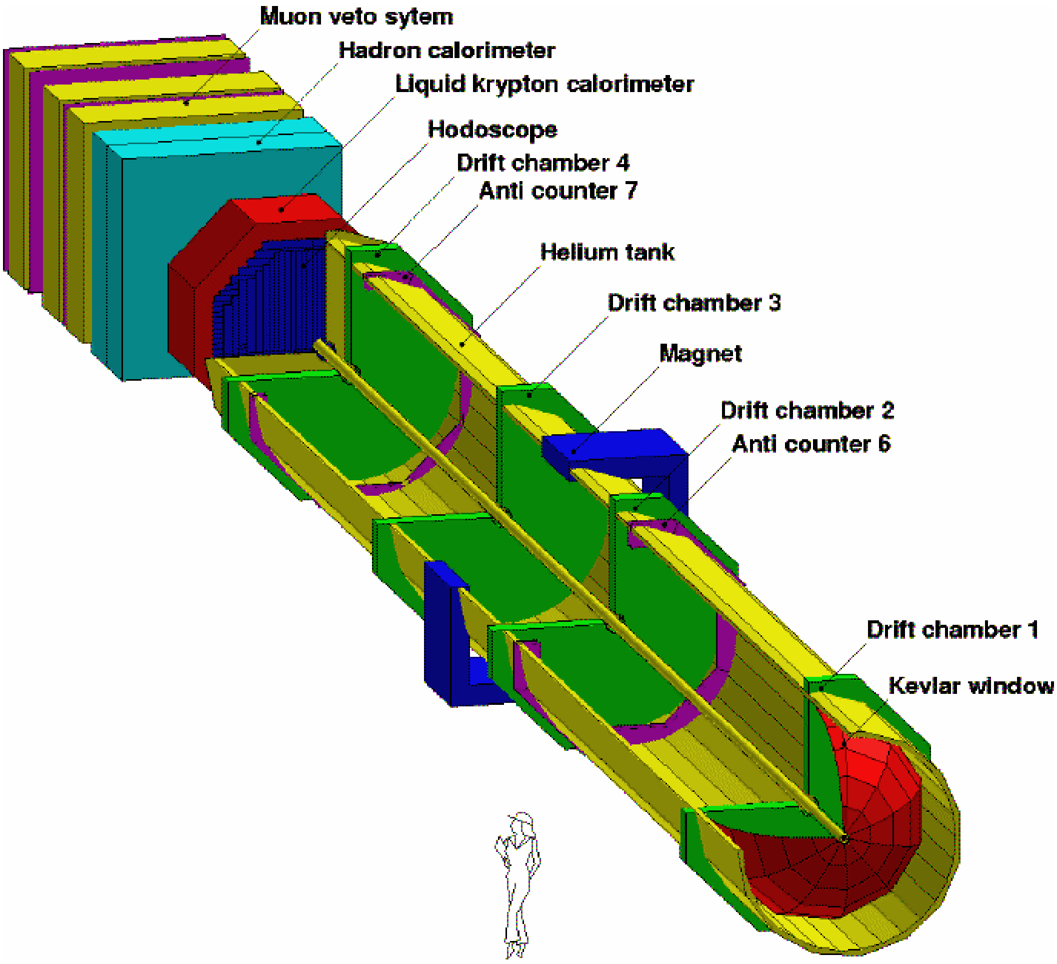
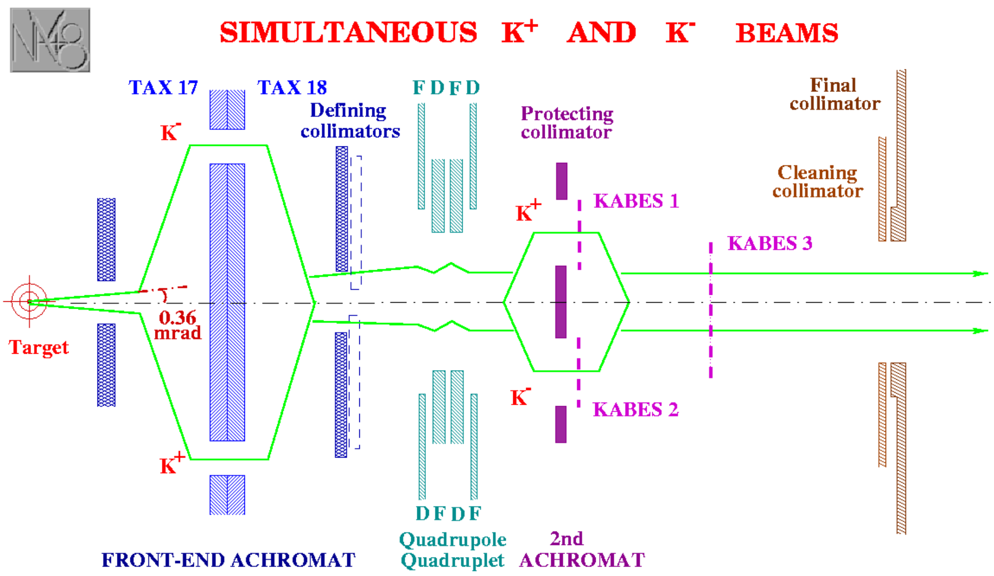


Fig. General view of the NA48 set-up



02-0-1025-98/2005

Priority of the project:	1
Status:	Data taking

Studies of the Hadron Structure Using the COMPASS Spectrometer (COMPASS, NA58)

Leader from JINR: I. Savin

Participating countries and international organizations: CERN, Czech Republic, Finland, France, Germany, India, Israel, Italy, Japan, JINR, Poland, Portugal, Russia

The experiment NA58 (COMPASS) at the CERN SPS has been approved to run in 2000–2006 with possible extension up to 2010 and beyond.

COMPASS is a new fixed target experiment to study the hadron structure with polarized muon beams of 100–200 GeV and hadron spectroscopy with hadron beams up to 300 GeV.

The main physics objectives of the muon programme are the measurement of ΔG, the gluon polarization in a longitudinally polarized nucleon. More generally, it is planned to measure the flavor separated spin structure functions of the nucleons in polarized muon — polarized nucleon deep inelastic scattering, both with longitudinal and transverse target polarization modes. For these measurements a new 1.3 m long polarized target will be used.

The hadronic program comprises a search for glueballs in the high mass region (above 2 GeV/c^2) in exclusive diffractive pp scattering, a study of leptonic and semileptonic decays of charmed hadrons with high statistics and precision, and Primakoff scattering with various probes. A detailed investigation of charmed baryons will be performed in the second stage of the experiment. For these measurements a highly segmented silicon target detector and high resolution electromagnetic calorimeters will be used.

The most challenging requirement of these physics programs are large integrated luminosities, powerful tracking and hadron identification systems. To achieve these, a new state-of-the-art spectrometer complex is proposed with excellent particle identification and calorimetry, capable of standing beam intensities up to $2\cdot10^8$ particles/spill. The set up consists of two independent spectrometers, one for small angles and one for large angles, providing thus a large angle acceptance for all particles. Each spectrometer comprises full particle identification using Ring Imaging Cherenkov Counters — RICH, electromagnetic and hadronic calorimetry and muon detection. Owing to precision tracking with silicon detectors, gaseous strip detectors and drift tubes, high momentum resolution is obtained. Dedicated triggers and a fast pipelined readout capable to cope with trigger rates of about 100 kHz without noticeable deadtime complement outstanding performance of the spectrometer.

The beam for setting up the first stage of the spectrometer complex was foreseen for the year 2000 and the physics measurement — for the year 2001.

The presently funded COMPASS set up is shown in Fig.1. It includes:

- the polarized target PT,
- two magnets SM1 and SM2,
- two RICH counters RICH1 and RICH2,
- two electromagnetic calorimeters ECAL1 and ECAL2,
- two hadron calorimeters HCAL1 and HCAL2,
- two muon detectors (filters) μWALL1 (or MW1) and μWALL2 (or MW2),
- μ-Stations to identify muons in the region close to the beam,

various tracking detectors shown by vertical lines to trace the particles along the set up.

According to MoU the obligations of JINR concern the HCAL1, MW1, Large Area Straw Chambers behind the SM1 and MultiWire Proportional Chambers (MWPC) distributed along the set up. These obligations are (quoted from MoU):

- construction of the Hadron Calorimeter 1 (HCAL1) consisting of 500 modules 15x15 cm^2 in cross section, calibration system, HV and LV computer-controlled systems (home made), related read-out (COMPASS standard), and mechanics,
- design and construction of 2 stations of proportional tubes (1200 tubes, 9600 channels, including related electronics (amplifiers, discriminators and TDC), HV and LV computer-controlled system (home made) and mechanical support,
- design, construction and tests of prototype straw tube tracker. Production of straw tubes and construction of tracker planes including HV and gas distribution system under general responsibility of LMU, Munich with participation of Dubna (no capital investment),
- check and refurbishing of existing MWPCs for a total of 18000 channels (no capital investment).

According to MoU JINR is expected also to:

- provide enough technical and scientific manpower for construction, installation and operation of its equipment until the end of the experiment,
- participate in the COMPASS Computing Farm,
- fund the running cost, the load of which for JINR is fixed to 3% of the total annual running costs.

Participating in the experiment NA58 within the common JINR team, the JINR member states contribute to the construction of the COMPASS. Particularly:

- Armenia contributed to manufacturing of the plastic materials (spacers, end- plugs etc.) for MW1
- Belarus participated in the design and fabrication of electronics for MW1
- Czech Republic performs a study of the polarized target material ^{6}LiD (within the separately approved project) and participates in design and construction of the RICH mirrors
- Romania under contract with JINR designed and constructed the movable platforme for HCAL1.

The complete set of the COMPASS physics motivations is presented in the Proposal. Here we will comment only a part of these motivations in which the Dubna groups traditionally have special interests, namely measurements of the gluon polarization in the longitudinally polarized nucleons, studies of the proton spin structure by precision measurements of the spin dependent structure functions, studies of the proton intrinsic strangeness via measurement of Λ and $\overline{\Lambda}$ polarization produced in DIS, studies of proton transversity distributions via measurement of spin azimuthal asymmetries in longitudinally and transversally polarized nucleon, Primakoff reactions and some others. COMPASS started to run in 2001 (technical run) and has taken data since 2002.

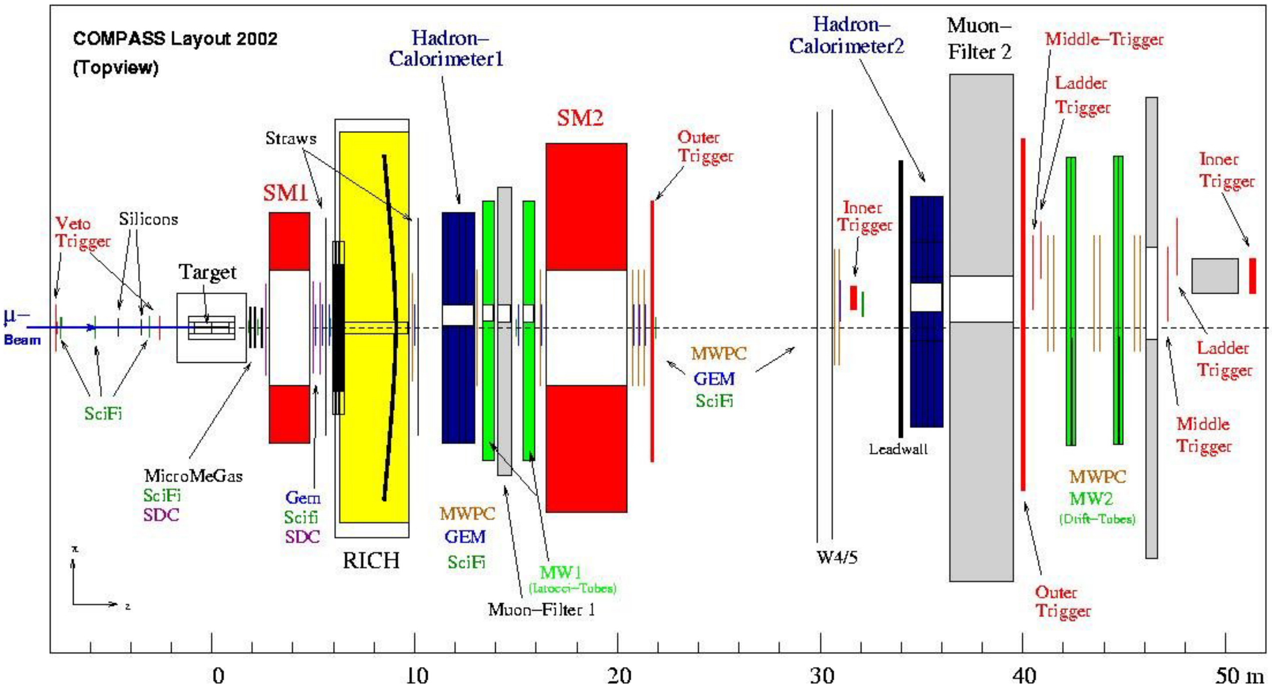


Fig.1.

02-2-1034-2000/2004

Priority of the project: 1

Status: Completed

The NOMAD (Neutrino Oscillation Magnetic Detector, WA96) Experiment at CERN SPS

Leader from JINR: S. Bunyatov

Participating countries and international organizations: CERN, France, Italy, Russia, Switzerland

Scientific Programme

The primary goal of the NOMAD experiment is the search for neutrino oscillations in a wide-band neutrino beam from CERN SPS.

Search for $\nu_\mu \rightarrow \nu_\tau$, $\nu_e \rightarrow \nu_\tau$ and $\nu_\mu \rightarrow \nu_e$ oscillations.

Main NOMAD results are based on a sample of 1.3 million ν_μ CC interactions collected during 1995–1998. The analysis of the full data sample yields no evidence for the oscillation signal in the Δm^2 range of $1 < \Delta m^2 < 1000$ (eV^2). The final limits for the $\nu_\mu \rightarrow \nu_\tau$ oscillation probability ($P_{\nu\mu\nu\tau}$) and for the oscillation amplitude ($\sin^2 2\theta_{\nu_\mu \nu_\tau}$ at 90% C.L. for large Δm^2 (> 50 eV^2) are:

$P_{\nu_\mu \nu_\tau} < 1.63 \times 10^{-4}$, $\sin^2 2\theta_{\nu_\mu \nu_\tau} < 3.3 \times 10^{-4}$

(see Fig.1, left). The NOMAD limit is an order of magnitude better (lower) than the previous best result (FNAL CCFR-1995). The upper limit on the probability of the $\nu_e \rightarrow \nu_\tau$ oscillation is set to $P_{\nu_e \nu_\tau} < 0.74 \times 10^{-2}$ which corresponds to $\sin^2 2\theta_{\nu_e \nu_\tau} < 1.5 \times 10^{-2}$ at large Δm^2 (see Fig.1, right).

The final results on a search for $\nu_\mu \rightarrow \nu_e$ oscillation in the NOMAD experiments have been obtained. The 90% C.L. limits are $\Delta m^2 < 0.4$ eV^2 for maximal mixing and $\sin^2 2\theta_{\nu_\mu \nu_e} < 1.4 \times 10^{-3}$ for large Δm^2.

This limit (see Fig.2) was published in 2003 and presented at international conferences. This result rules out the interpretation of the LSND measurements in terms of $\nu_\mu \rightarrow \nu_e$ oscillations with $\Delta m^2 > 10$ eV^2.

Non-Oscillation Physics

A dedicated study of the Λ^0 and $\overline{\Lambda}^0$ polarization and strange particle production in neutrino interactions has been performed by the JINR group. A sample of neutral strange particles has been selected in ν_μ CC interactions: 15075 K^0_s, 8087Λ^0 and 649$\overline{\Lambda}^0$. The statistics of this event sample is about an order of magnitude larger than that of previous bubble chamber experiments, while the quality of event reconstruction is comparable. The A° polarization in ν_μ CC interactions has been measured. We observed negative polarization along the W-boson direction which is enhanced in the target fragmentation region: $P_x(x_F < 0) = -0.21 \pm 0.04$(stat) $\pm$ 0.02(syst). In the current fragmentation region we found $P_X(X_F > 0) = -0.09 \pm 0.06$(stat) $\pm$ 0.03(syst). These results provide a test of different models describing the nucleon spin composition and the spin transfer mechanisms. A significant transverse polarization (in the direction orthogonal to the Δ^0 production plane) has been observed for the first time in a neutrino experiment: $P_y = - 0.22 \pm 0.03$(stat) $\pm$ 0.0l(syst).

The first measurement of the $\overline{\Lambda}^0$ polarization in neutrino interactions has been reported. The polarization vector is found to be compatible with zero. The results on the Δ° and $\overline{\Lambda}^0$ polarization measurements have been presented by the members of the JINR group at 7 international conferences during last three years.

Yields of neutral strange particles (K^0_s, Λ^0, $\overline{\Lambda}^0$) in ν_μ CC interactions have been measured with the precision several times better than previous results: $\tau_{K^o_s}$ = (6.76±0.06)%, τ_Λ = (5.04±0.06)%, $\tau_{\overline{\Lambda}}$ = (0.37±0.02)%.

Decays of resonances and heavy hyperons with identified K^0_s and Λ^0 in the final state have been analyzed. Clear signals corresponding to $K^{*\pm}$, $\Sigma^{*\pm}$, Ξ^- and Σ^0 have been observed. These results are compared to the predictions of the LUND model. A striking difference has been observed between the NOMAD data and the LUND model predictions for relative yields of resonances and heavy hyperons (a factor of 2 or 3 times less in the data than in Monte-Carlo).

The results of this analysis combined with our previous measurements of the Λ^0 and $\overline{\Lambda}^0$ polarization in ν_μ CC interactions have been used for theoretical attempts to improve the model of polarized strangeness in the nucleon. It has been shown that the struck-quark and target fragmentation regions overlap significantly in experiments in the energy range currently available. Predictions have been made for the A polarization in the on-going and future experiments, including charged-lepton DIS from the COMPASS experiment.

In 2003 we obtained first results on the measurements of the Λ^0 and $\overline{\Lambda}^0$ polarization in ν_μ neutral current (NC) interactions. We also measured for the first time the production rates of neutral strange particle and the yields of heavy strange hyperons and resonances in ν_μ NC interactions.

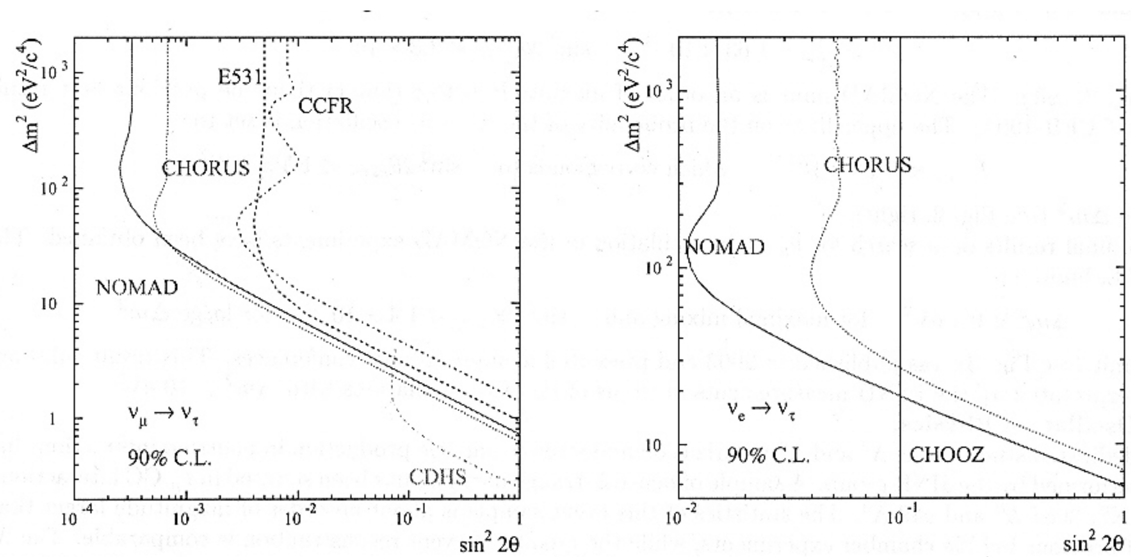


Fig.1. The Δm^2 — $\sin^2 2\theta$ plane for $\nu_\mu \to \nu_\tau$ (left) and $\nu_e \to \nu_\tau$ (right) oscillations. The regions excluded by NOMAD at 90% C.L. are shown together with limits published by other experiments.

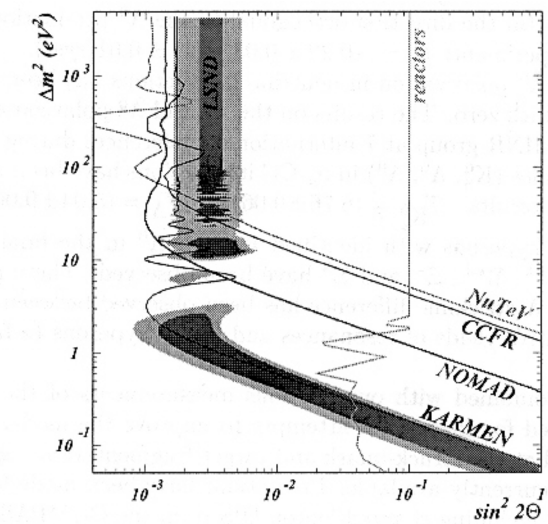


Fig.2. The final NOMAD 90% C.L. exclusion region in the Δm^2 — $\sin^2 2\theta$ plane for $\nu_\mu \to \nu_e$ oscillations superimposed on the results of other experiments.

02-0-0907-91/2005

Priority of the project:	1
Status:	Data analysis

DELPHI
JINR's participation in the DELPHI experiment

Leader from JINR: A. Olchevski

Participating countries and international organizations: Belarus, Belgium, Bulgaria, CERN, Czech Republic, Finland, France, Georgia, Hungary, Norway, Russia, Sweden, the UK, Ukraine, Uzbekistan

DELPHI was a general purpose detector with a fine granularity and almost 4π geometry which provided measurements of track 3-momenta and particle energy deposition as well as identification of leptons and hadrons. Together with other LEP experiments (ALEPH, L3 and OPAL) DELPHI has produced an enormous amount of physics results. Among them are the precise determination of electroweak parameters during the energy scan of Z-resonance region (88–94 GeV), precision W-boson physics, QCD studies, setting upper limits on masses of Higgs-boson and other new particles and many other results.

Although the LEP collider was stopped at the end of 2000, the analysis of the DELPHI experiment data is still in progress. It will require several more years to complete. From the very beginning of DELPHI the JINR group was and is playing an important role in the experiment, both in hardware construction and support and in data analysis. Here we give a brief review of ongoing studies in which members of the JINR group are involved.

Electroweak physics

The precision electroweak studies at the Z-resonance have been .finished and now the analysis of the LEP-2 data is under way. Although the precision is lower (~1%), the record-high collision energy (up to 209 GeV) provides an increased sensitivity to a new physics at extremely large energy scales (up to several TeV, or sometimes even tens of TeV). The JINR group is involved in the following studies:

- Fermion pair production (cross-sections and asymmetries)
- Measurement of tau-lepton polarization at LEP2
- Interpretations and global fits
- Using the electroweak measurement to probe a new physics
- Precision theoretical calculations.

W physics

At present the accuracy of W mass measurement is limited by two major systematic uncertainties. One of them is the uncertainty of LEP energy determination, another is introduced by limited knowledge on .final state interactions (FIS) between particles from W decays. JINR group is participating in studies aimed to reduce both these systematic uncertainties. Two FIS models are being studied: Bose-Einstein correlations and color reconnection model. The LEP energy measurement is improved using the kinematics of "Z-return" fermion pair production events in which annihilation takes place at Z-resonance energies.

γγ physics

The experimental studies at LEP mainly concentrate on the processes which take place in e^+e^- annihilations. A remarkable exception is the reaction of virtual photons collisions $\gamma\gamma \to f\bar{f}$, where *f* is a charged lepton or a quark. A wide variety of physics results can be obtained from studies of this process. The JINR group is playing a leading role in the following DELPHI studies of γγ physics:

- Study of photon structure function
- Tau pair production in γγ collisions

- Proton pair production in γγ collisions
- Light resonance production in γγ collisions
- Open charm production in γγ collisions
- Exclusive processes at very high Q^2
- Two-photon physics at very low Q^2.

LEP1 physics

The LEP-1 data taking was finished eight years ago, however some analyzes are still in progress. The studies with active JINR group participation are:

- Study of quark polarization
- Other QCD studies
- Charged kaon production in tau decays
- Measurement of the tau neutrino mass.

02-2-1043-2002/2004		Priority of the project: 1
		Status: Data analysis

Lifetime Measurement of $\pi^+\pi^-$ Atoms to Test Low Energy QCD Predictions (Experiment DIRAC)

Leader from JINR: L. Nemenov

Participating countries and international organizations: CERN, Czech Republic, France, Greece, Italy, Japan, Romania, Russia, Spain, Switzerland

Scientific Program

The DIRAC experiment aims to measure the lifetime of $\pi^+\pi^-$ atoms in the ground state with 10% precision, using the 24 GeV/c proton beam of the CERN Proton Synchrotron. As the value of the above lifetime of order 10^{-15}s is dictated by a strong interaction at low energy, the precise measurement of this quantity enables to determine by the model-independent way a combination of S-wave pion scattering lengths ($|a_0 - a_2|$) to 5%. The $\pi\pi$ scattering lengths a_0, a_2 have been calculated in the framework of Chiral Perturbation Theory by means of an effective Lagrangian with a precision of better than 2.5%. Hence, the lifetime of $A_{2\pi}$ in the ground state is predicted to be $\tau = (2.9 \pm 0.1)\cdot 10^{-15}$s. These results are based on the assumption that the spontaneous chiral symmetry breaking is due to a strong quark condensate. An alternative scenario with an arbitrary value of the quark condensate admits larger a_0, a_2 compared with those of the standard scheme. This is the reason why measurement of scattering lengths provides an opportunity to verify the current understanding of chiral symmetry breaking in QCD and to check the magnitude of the quark condensate.

Actuality of the problem

Pion scattering is one of the rare examples in the strong interactions where the theoretical predictions are more accurate than the available experimental results.

The most recent result of the experiment E865 from the K_{e4} decay has the statistical accuracy of 10%. After invoke of an additional input from the chiral perturbation theory and model-dependent experimental values this accuracy goes down to 6%. Other planned experiments on the K_{e4} decay suffer from the same weakness and their expected accuracy will be on the same level.

The DIRAC experiment has already observed around 15000 $\pi^+\pi^-$ atoms that will allow one to measure the lifetime with the statistical accuracy of 10–14% and hence, to obtain the pion scattering lengths within 5–7%. Continuation of the experiment at PS CERN and/or J-PARC (see below) will allow us to reduce the error in the lifetime to the level of 5–6% and thus to get the pion scattering lengths with the accuracy comparable with those of the theoretical prediction.

Method of observation

The Coulomb bound state of $\pi^+\pi^-$ mesons ($\pi^+\pi^-$ atoms) are produced in hadron-nuclear interactions as well as free pion pairs These pionium atoms may either annihilate into two π^0 due to the strong interaction of pions or break up into $\pi^+\pi^-$ pairs ("atomic" pairs) after interaction with target atoms. For thin targets ($10^{-3}X_0$) the "atomic" pairs relative momentum Q, in the pair system, is $\leq$ 3MeV/c and their number is 10÷20% of the free pair number at the same Q. Therefore, the number of "atomic" pairs can be found by subtracting from the $\pi^+\pi^-$ data sample the intrinsic background consisting of free pairs. As the break-up is one of two competitive processes, measurement of its rate allows one to obtain the rate the another process, annihilation, and thus to measure the pionium lifetime.

Expected results

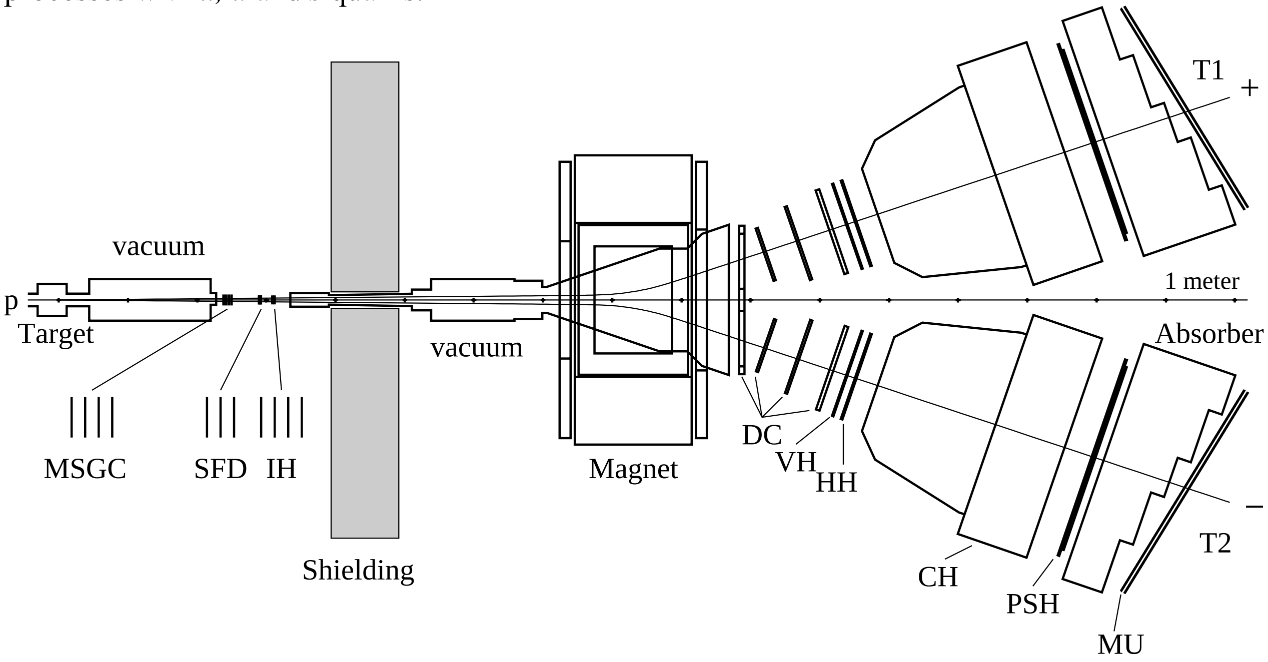
1. Experimental runs in 1999–2003 at PS CERN on data taking for the $\pi^+\pi^-$ atom lifetime measurements with 10–14% precision.

2. As a result of an experimental data analysis, obtaining of the $\pi^+\pi^-$-scattering lengths within 5% to check the precise prediction of QCD for processes with u and d quarks.

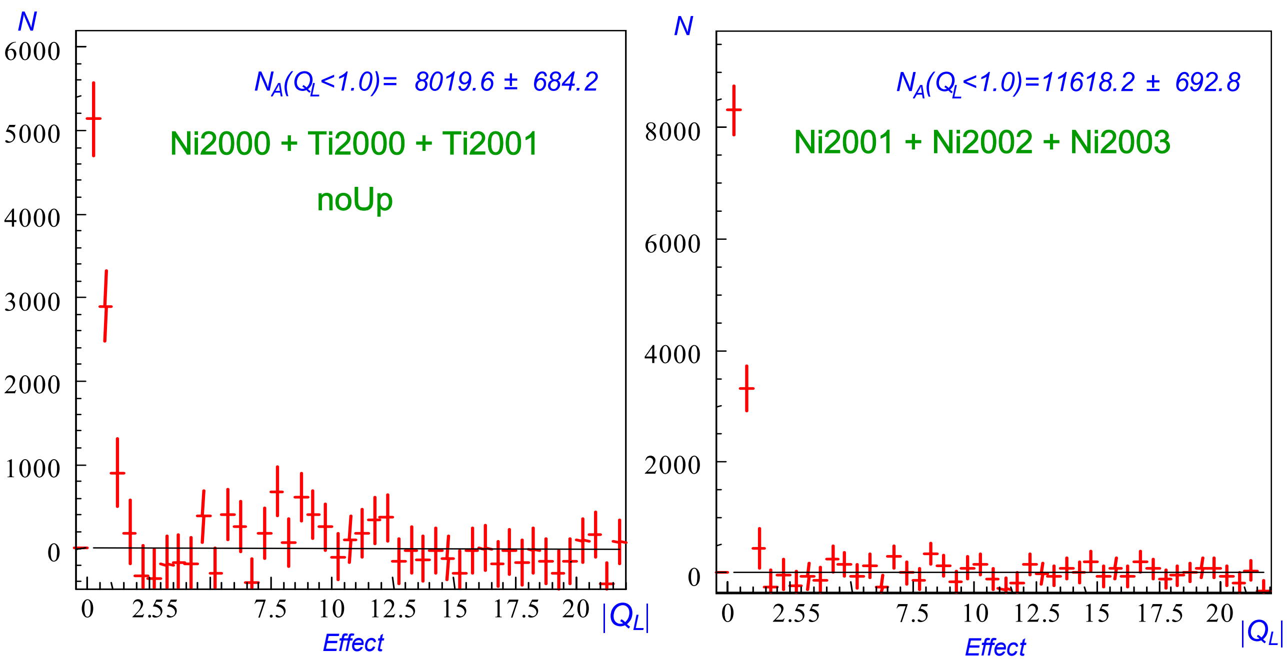
3. Preparation of the experiment extension at PS CERN to measure the $\pi^+\pi^-$ atom lifetime with accuracy about 6%, observation of atoms consisting from π and K mesons and their lifetime measurement, and observation the long-lived states of $\pi^+\pi^-$ atom. 2004–2005.

4. Preparation of a proposal for continuation of the experiment for the accelerator J-PARC in Japan following the recommendation of J-PARC directorate after approval of the Letter of Intent. 2004.

5. In the case of approval of the experiment on the πK atom observation, measurement of πK-scattering length and refining of $\pi\pi$-scattering lengths to check the precise prediction of QCD for processes with *u, d* and *s* quarks.



Schematic top view of the DIRAC spectrometer. Upstream of the magnet: microstrip gas chambers (MSGC), scintillating fiber detectors (SFD), ionization hodoscopes (IH) and Shielding of iron. Downstream of the magnet, in each arm of the spectrometer: drift chambers (DC), vertical and horizontal scintillation hodoscopes (VH, HH), gas Cherenkov counter (CH), preshower detector (PSH) and, behind the iron absorber, muon detector (MU).



$\pi^+\pi^-$ pairs for the pionium break-up are observed in the distribution over the longitudinal projection of the relative momentum $|Q_L|$ as the narrow peak at very small values. Data obtained with Nickel and Titanium targets during runs in 2000-2003 are shown on two pictures.

02-0-1034-2000/2004

Priority of the project:	1
Status:	Data analysis

Hadron Production Studies for the Neutrino Factory and for the Atmospheric Neutrino Flux (HARP, PS 214)

Leader from JINR: G. Chelkov

Participating countries and international organizations: Belgium, Bulgaria, CERN, France, Germany, Italy, Russia, Spain, Switzerland, the UK

The HARP experiment was designed to perform a systematic and precise study of hadron production for beam momenta between 2 and 15 GeV/c, for target nuclei ranging from hydrogen to lead. A scheme of the apparatus is shown in Fig.1. It is a large acceptance spectrometer, with two distinct regions: a forward region (up to polar angles of about 350 mrads) where the main tracking device is a set of drift chambers recuperated from the NOMAD experiment (NDC) and a large angle region, where the main tracking device and the particle-id detector as a TPC, complemented by a set of RPC detectors. HARP physics goals are the measurements of pion yields to enable a quantitative design of the proton driver of neutrino factories and to make more precise calculations of the atmospheric neutrino flux possible.

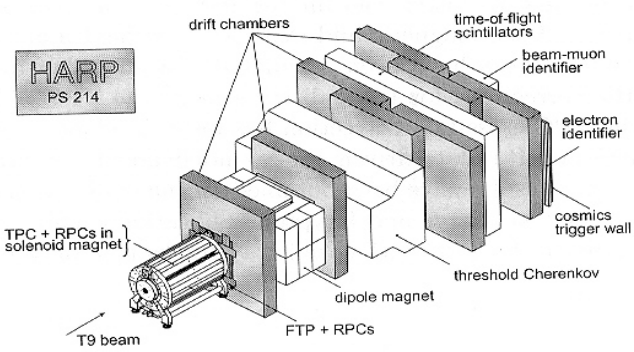


Fig.1. Layout of the HARP spectrometer.

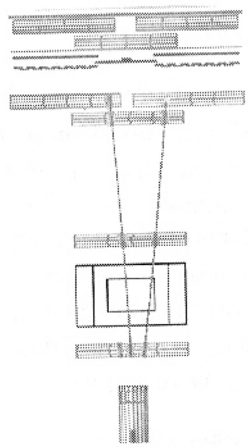


Fig.2. An event from real data (K2K replica target) with tracks reconstructed from the hits in the drift chambers.

In addition, the energy-range is sutable to measure particle yields for the prediction of neutrino fluxes for the MiniBooNe and K2K experiments. In 2003, major progress in the detector calibration and event reconstruction in the HARP spectrometer have been achieved.

Forward spectrometer with NDCs. The responsibility of the JINR group in the HARP experiment is refurbishing, installation, commissioning and operation of the NOMAD drift chambers in the HARP experiment, including work on the DAQ and software. The physicists from JINR are now involved in the detector calibration, development of the simulation and reconstruction software and the data analysis. The first set of calibration and alignment of NDCs has been performed. The spatial resolution of the NDCs about 350 microns has been achieved after a careful alignment procedure. A technical paper with a description of the NDC performance in the HARP experiment is being prepared. The algorithms for the NDC reconstruction have been developed. Reconstruction of tracks and momentum measurement in the NDC's is not an easy task given a relatively small amount of NDC measurement planes and a rather low efficiency of the chambers (~ 80%) related to the usage of non-flammable gas. The segment reconstruction algorithm in NDC's proposed by the JINR group has now been chosen as the default reconstruction algorithm by the collaboration due to its high efficiency and purity. The Kalman filter technique is used afterwards for matching track segments and hit collection, taking into account multiple scattering and exact field map of the spectrometer magnet (see Fig.2). This approach allows for an easy matching with other HARP subdetectors to provide particle identification. An advanced version of the HARP event display developed by the JINR group plays a crucial role in the efficient development of the reconstruction algorithms. The performance of the algorithms is always cross-checked with both the data and the MC simulation.

Large angle spectrometer with the Time Projection Chamber (TPC). A systematic hardware measurement and data analysis to understand various distortions affecting TPC have been performed. Inhomogeneities of the magnetic and electric fields in the active TPC volume lead to displacements of cluster coordinates and therefore to track distortions. Based on a detailed modeling of the magnetic and static electric field, irihomo-geneities precise correction maps for both effects have been calculated. Results shown in Fig.3 demonstrate the necessity of the corrections for track distortions in TPC. The CERN–Dubna–Milano algorithm for TPC cross-talk correction has been developed with an active participation of the JINR physicists. It is data-driven, model-independent approach to the problem of the cross-talk correction. Results have been obtained on the application of the CERN–Dubna–Milano algorithm to the test-charge and Krypton calibration events (see Fig.4). At present a programme to calibrate the TPC with cosmic ray tracks is underway.

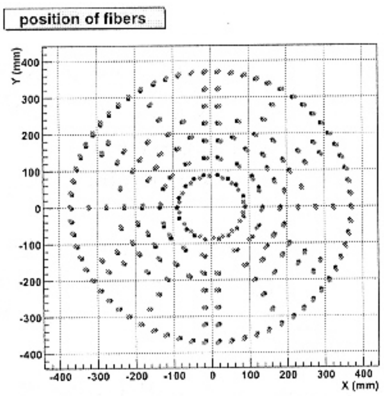


Fig.3 Position of the optical fibers (black) and the predicted displacements of clusters (grey) from magnetic and electric fields in the active TPC volume.

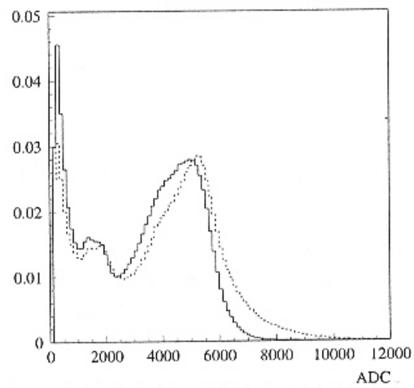


Fig.4 Krypton energy spectrum used for TPC calibration before (dashed) and after (full) the cross-talk correction.

02-2-1055-2004/2006

Priority of the project: 1
Status: New

OPERA — an Appearance Experiment on $\nu_\mu \leftrightarrow \nu_\tau$ Oscillation Search in CNGS Beam (JINR participation)

Leader from JINR: Yu. Gornushkin

Participating countries and international organizations: CERN, JINR

The possibility of a non-vanishing mass for the neutrino is one of the most intriguing questions of the particle physics. The search for the process which can only occur if the neutrino has non-vanishing mass is crucial to asses this issue. Neutrino oscillations are such a process originally postulated by B.M. Pontecorvo when he was working at JINR.

In terms of the oscillation search one can consider two types of experiments — disappearance experiments, where you look for a reduced flux of the original flavour as a function of distance, and energy and appearance experiments, where you look for the of neutrinos of the wrong flavour in the beam. One of the strongest evidences of neutrino oscillations comes from the experimental results on the atmospheric neutrino anomaly**.** The Super-Kamiokande (S-K) experiment (and previously the Kamiokande collaboration) provided strong evidences of the anomalous ratio of atmospheric muon neutrinos to electron neutrinos and their zenith angle dependence. The most likely explanation of the atmospheric neutrino anomaly from the modern point of view is $\nu_\mu \leftrightarrow \nu_\tau$ oscillations. The most crucial confirmation of this solution is expected to come from the appearance experiment OPERA, where the $\nu_\mu \rightarrow \nu_\tau$ hypothesis will be unambiguously tested via the direct observation of ν_μ appearance in an initially pure ν_μ beam. The experiment will be located in the underground Gran Sasso Laboratory and will use CNGS neutrino beam with average energy of 17 GeV from CERN.

The experiment is based on the idea of so-called Emulsion Cloud Chamber (ECC) detector, a modular structure made of a sandwich of passive material plates interspaced with emulsion layers (bricks). Nuclear emulsions are a very high resolution tracking device which allows the direct detection of τ-particles produced in the charge current (CC) interactions of the ν_τ with the target.

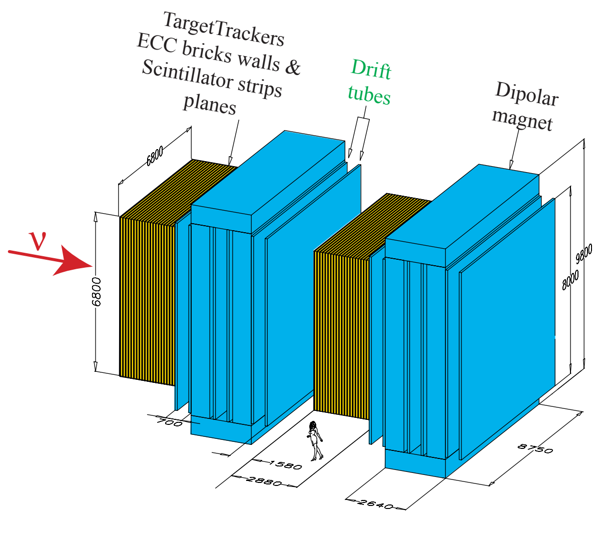


Fig.1. General structure of OPERA detector.

By piling-up the bricks, we obtain more massive planar structures (walls). A wall made of 3264 bricks accompanied by two planes of the electronic Target Tracker (for the real time determination of the event position) comprises a module. A supermodule is made of a target section which is a sequence of 24 modules, and of the downstream muon spectrometer for muons identification and for the reconstruction of their charge and momentum. The detector consists of 2 supemodules. Finally, we get a ~1800 t fine-grained vertex detector optimized for the study of ν_τ appearance. The schematic view of the OPERA detector is shown in Fig.1. The detector is located 1400 m underground in Hall C of the Gran Sasso Laboratory (Italy) at the distance of 732 km from CERN.

The present interest to emulsion technique is linked to the production of emulsion films on an industrial scale and to the impressive progress in the field of computer controlled microscopes read out by CCD cameras, with automatic pattern recognition and track reconstruction. The Target Tracker (TT), made of extruded plastic scintillator strips and read out by wave length shifting (WLS) fibers, serves as an electronic detector which allows one to determine an emulsion brick where the neutrino interaction took place and which is to be processed for deeper analysis.

The JINR group will participate in the stintillator strip production where it has a responsibility for the full control of the plastic scintillator strips quality**.** A semiautomatic production line in Kharkov will be equipped with the electronic control devices provided by JINR, since a large amount of the plastic extrusion as well as tough quality specifications, require automatic control systems integration. JINR specialists will also take part in the further assembly of the TT planes and their calibration.

When neutrino interaction takes place in the detector, the brick is identified by TT and removed. It's dismounted and emulsion sheets have to be scanned then by automatic scanning stations. The different stations for ECC brick analysis will be spread out over the world. This is similar to the large and completely electronic experiments, with the difference that the emulsion films, instead of DSTs, play the role of data storage. JINR plans to create a scanning station and participate in the emulsion processing as well.

Finally, under the assumption of 5 years of running in the CNGS beam, operated in shared mode and with nominal beam intensity, OPERA will collect the number of signal and background events listed in Table 1 for different Δm^2 values and maximal mixing. The signal to background ratio ranges from 7 to 80.

τ decay mode	**Signal ($1.5\text{x}10^{-3}$ eV^2)**	**Signal ($3.2 \text{ x } 10^{-3}$ eV^2)**	**Signal ($5.0 \text{ x } 10^{-3}$ eV^2)**	**Background**
e^- long	1.3	5.9	14.2	0.16
μ^- long	1.3	5.7	13.8	0.13
h^- long	1.1	4.9	11.8	0.25
e^- short	0.4	1.8	4.3	0.03
Total	**4.1**	**18.3**	**44.1**	**0.57**

The participation of JINR in OPERA — an appearance experiment for neutrino oscillation search is proposed. The interest to these studies is motivated by a very exciting physics, scientific traditions of the Institute and by the experience in the detection technique of the team making the proposal. The scientific goals and responsibilities of the JINR group are well defined and the contribution of the Institute is going to be appreciated by the Collaboration. The required resources look to be reasonably estimated. JINR group is planning to participate in all the stage of the experiment from detector construction to the emulsion scanning and final physics analysis. This makes the proposed experiment to be an interesting direction of the JINR's high-energy programme for the next few years.

02-7-1056-2004/2006

Priority of the project: 2

Status: New

Project CLIC

Leader from JINR: A. Kaminsky

Participating countries and international organizations: Armenia, Belarus, Russia, CERN, United Kingdom

The major aim of the Project is to create at JINR, using the LPP accelerator base, a high-efficiency, narrow-band, frequency tunable free electron laser (FEL) in a millimeter range — FEM. A source of millimeter-range RF power has been created at LPP by the 2001 group jointly with colleagues from RAS Institute of Applied Physics. The facility is based on the LIU-3000 linac (0.8 MeV, 200 A, 250 ns) commissioned at the Department of New Accelerating Methods of JINR in the late 1960s. The created RF source possesses a row of parameters being the record ones for millimeter-wave generators: a possibility of precise frequency tuning (with precision of ~0.1%), possibility of fixing the operating frequency (with precision of ~0.1%), a large interval of frequency tuning (about 5%), narrow spectrum width (about 0.1%), large duration of the generated pulse (not less than 140 ns). The set of such characteristics has been obtained mainly due to two factors:
1) a successfully chosen FEM scheme proposed by the FEL group participants later named as FEL with reversed guide field; 2) use of Bragg resonators for providing the feedback in FEM oscillator.

The creation of FEM with such characteristics was considered as a necessary condition for obtaining the physical/technical results valuable for the modern accelerating (collider) research area. The operating frequency of accelerating structures of CLIC collider has been chosen as a frequency reference of RF source. Distinctive features of the CLIC project compared to other colliders are: the largest electron and positron energy — 3 TeV, the highest accelerating gradient — 150 MV/m, the highest operating frequency — 30 GHz.

The majority of the obtained characteristics of the constructed FEM oscillator meet the requirements for the RF power source needed for test experiments to investigate lifetime of collider accelerating structures (AS) with respect to pulsed repetitive RF heating. The Agreement K723/PS has been concluded on the suggestion of CLIC group (CERN). Accordingly to it, a test facility to investigate the collider AS lifetime is created at LPP JINR.

In the project of a new research topic “R&D of facilities in millimeter and submillimeter wavelength region for investigation in collider technology and condensed matter physics” for 2004–2007 three basic directions are stated: 1) considerable enhancement of FEM output power with compression output RF pulse. In this case the group can obtain FEM parameters providing the investigation of AS lifetime with respect to the electric breakdown; 2) creation of a powerful submillimeter-range pulsed source on the base of existing FEM oscillator scheme. This work is supported by the Grant of Plenipotentiary of the Belarus Republic at JINR; 3) sufficient extension of application area of powerful pulsed sources of coherent radiation and electron beam. The programme of their application for objectives in condensed matter physics has been developed, the problems of biophysical applications are under discussion, meaning collaboration with the Laboratory of Neutron Physics and Division of Radiation and Radiobiological Research at JINR.

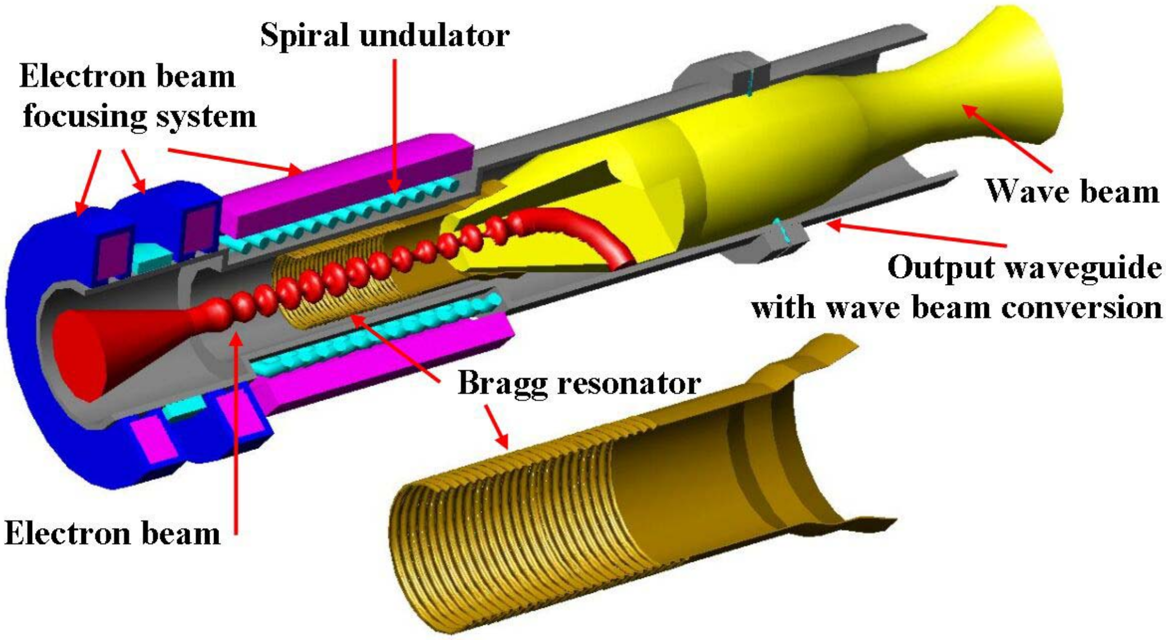


Fig.1. Layout of the Free-electron Maser oscillator with Bragg resonator.

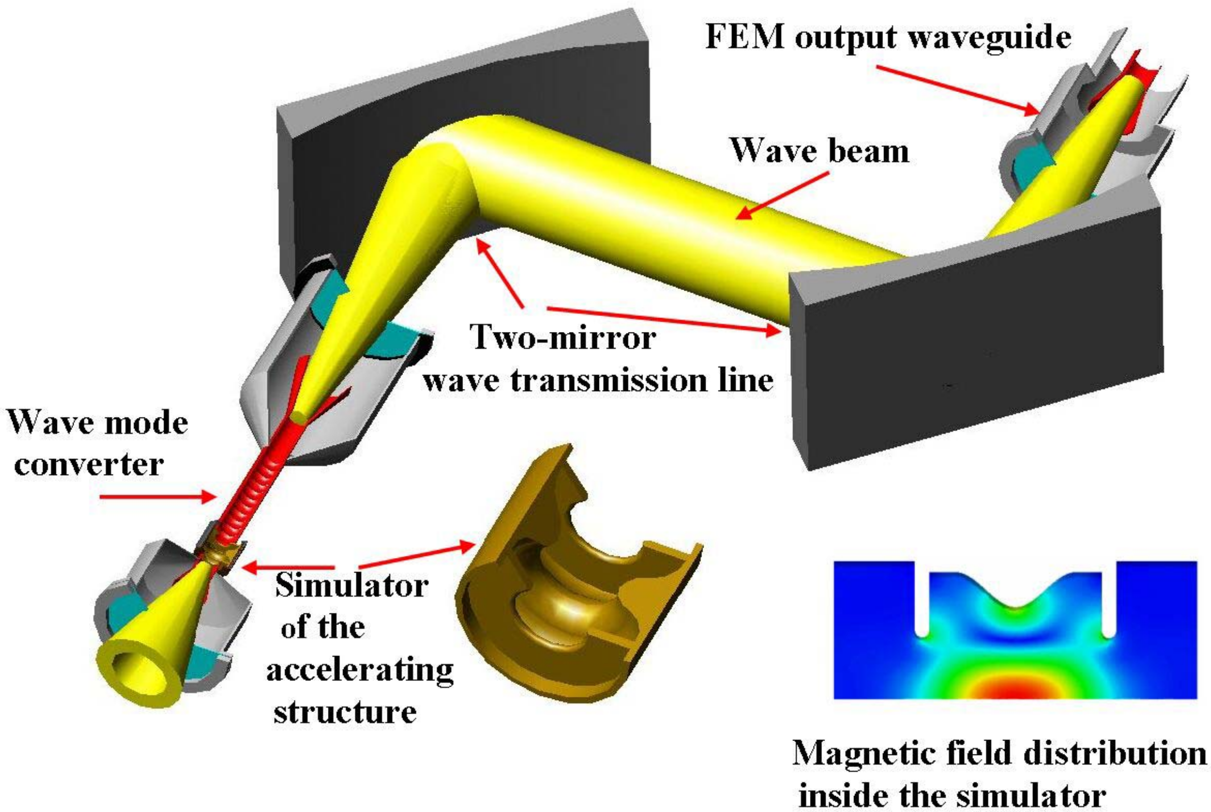


Fig.2. Layout of the facility for high-power testing the simulator of the accelerating structure of the electron-positron collider CLIC.

JINR's Participation in Experiments at U70 (Protvino)

02-7-1016-96/2006

Priority of the project:	2
Status:	Data analysis

Project EXCHARM

Leader from JINR: V. Kekelidze, Yu.K.Potrebenikov

Participating countries and international organizations: Belarus, Bulgaria, Georgia, JINR, Kazakhstan, Romania, Russia

The EXCHARM experiment is dedicated to the study of charmed and strange particle production characteristics and to search for narrow baryonia in neutron-nucleon interactions at the Serpukhov accelerator. With this purpose a special experimental zone including the channel of neutrons 5N, experimental set-up and building 450 with the corresponding infrastructure is created. Work to carry out the experiment was started in 1990. The first experimental data, used for the physical analysis, were recorded in 1992. During the exposition of the experimental set-up till 1998 (including the methodological ones) there were 15 experimental runs. About $6{\cdot}10^8$ events were recorded.

The most important results of the experiment were related to the research of the charmed baryon Σ_c^0 inclusive production. The measured Σ_c^0 mass was included into the table of particle properties and is used to define the average value of this value. The estimation of the ratio of branching ratios of Λ_c^+ decays to $K^0p\pi^+\pi^-$ *and* $\Lambda^0\pi^+\pi^+\pi^-$ is given and is included into the table of particle properties as well.

Inclusive production characteristics of strange vector meson K (892), φ-mesons, φ-meson pair, hyperons and anti-hyperons were investigated. The new data have been received on interference correlations in a Λ^0 hyperon pairs, pairs of identical pions and kaons inclusive production. Preliminary data have been obtained on measurements of parameter α in expression for dependence of inclusive cross-sections from nuclear mass of a target nucleus ($\sigma = \sigma_0 \cdot A^{\alpha}$).

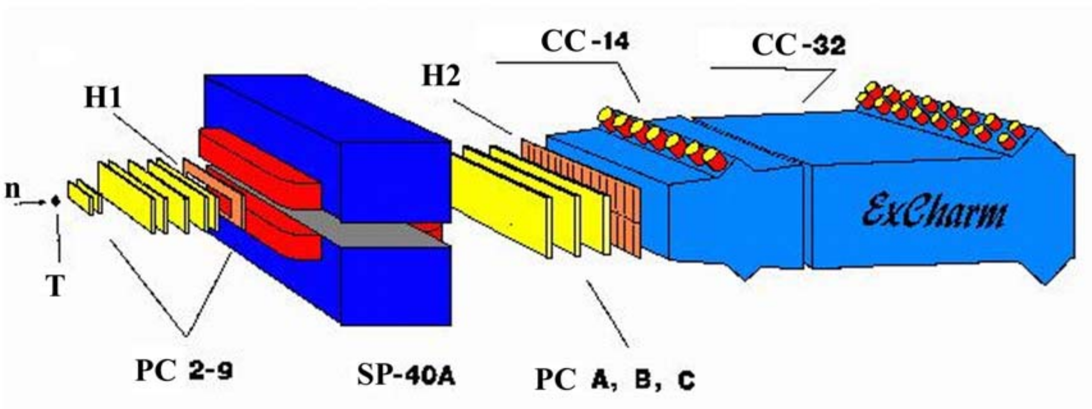


Fig. Schematic view of the EXCHARM setup. T — target; PC — proportional chambers; CC — Cherenkov counters; H1, H2 — hodoscopes of scintillator counters; SP-40A — spectrometric magnet.

02-2-1050-2003/2004

Priority of the project:	2
Status:	R&D

Experimental Study of the Meson-Nuclear Interactions at the “Hyperon-M” setup (Project Hyperon-M)

Leader from JINR: N. Russakovich

Participating countries and international organizations: Russia

High statistical experiments on charge exchange meson nuclear reactions are of great importance in view of studying of processes which occur while mesons pass through the nuclear matter. In the QCD framework these phenomena are described in terms of color screening, color transparency and hadron formation length (see: B.Z. Kopeliovich et al. hep-ph/0107227; P. Jain et al. Phys. Rep. 271 (1996) 67). All these quantities can be studied in the proposed experiment.

Measurements of the cross-sections of the π-p charge exchange reactions on different nuclei were performed at IHEP at 70-th: (see: V.N. Bolotov et al. Yad. Phys. rus. 20, 249 (1974)).
Statistics of these first measurements was rather limited, and theoretical interpretation of the results was at initial stage. Similar experiments were carried out at JINR up to 1993, and, in particular, the color-screening effect in this experiment was discovered (G.S. Bitsadze et al. Nucl. Phys. B279 (1987) 770; B.S. Kopeliovich, N.A. Russakovich, Preprint JINR, E2-86-298, 1986). The results have caused large interest and the first JINR prizes were given to the authors in 1987 and 1991.

Increasing of the statistics by 2–3 orders of magnitude, considered in this project is quite real with modern experimental technique. It opens prospects for detailed study of the effects predicted by the modern theory for meson-nuclear interactions.

It is proposed that the results of these investigations will be published in 2004–2005. Investigations require about 4 months of the IHEP accelerator work.

The next step (2005–2009) is the high statistic study of rare decays of neutral mesons: $\eta\to 3\gamma$ (c-forbidden), $\eta\to\pi^0\gamma\gamma$; $w\to\pi^0\gamma\gamma$ (c-forbidden), $w\to\pi^0\pi^0\gamma$, … , $\eta'\to$neutrals … . the list of participants of this program:

02-7-1051-2003/2005

Priority of the project: 1

Status: Preparation

Project TERMALIZATION

Leader from JINR: V. Nikitin

Participating countries and international organizations: Belarus, Italy, Russia

The goal of the proposed experiment is the investigation of collective behavior of particles in the process of multiple hadron production in pp interaction $pp \rightarrow n_\pi \pi + 2N$ at the beam energy E_{lab}=70 GeV. The domain of high multiplicity n_π=20–35, will be studied. Near the threshold of reaction $n_\pi \rightarrow 69$, all particles get small relative momentum $\Delta q<1/R$, where R is the dimension of the particles production region. As a consequence of multiboson interference, a number of collective effects may show up.

- Drastic increase of partial cross section $\sigma(n)$ of n identical particles production is expected, comparing with commonly accepted extrapolation.
- The jets formation consisting of identical particles may occur.
- Large fluctuation of charged $n(\pi^+, \pi^-)$ and neutral $n(\pi^0)$ components, onset of centauros or chiral condensate effects is anticipated.
- Increase of the rate of the direct photons as the result of the bremsstrahlung in partonic cascade and annihilation $\pi^+ + \pi^- \rightarrow n\gamma$ in dense and cold pionic gas or condensate is expected.
- In the domain of high multiplicity, the major part of the center of mass energy $E_{c.m.s.}$=11.6 GeV is materialized leading to high density of hadronic system. At this condition a phase transition to cold QGP may occur.

The search for QGP signatures like large intermittency in the phase space particle distribution, enhanced rate of direct photons will be performed.

Experiment is carried out on modernized installation SVD - the Spectrometer with the Vertex Detector which is supplied with the trigger system for registration of rare events with high multiplicity. It includes the following basic elements: the vertex detector on the basis of strip silicon sensors, a liquid hydrogen target, a magnetic spectrometer, a threshold Cherenkov detector, an electromagnetic calorimeter. The experiment is carried out on the extracted proton beam of IHEP (Protvino) 70 GeV accelerator. Required beam intensity is $\sim 10^7$ /s. Assuming partial cross section $\sigma(n_\pi=30)$=0.2 mcb, we expect counting rate 10^2 events per hour. The multiboson interference enhancement may drastically increase the counting rate.

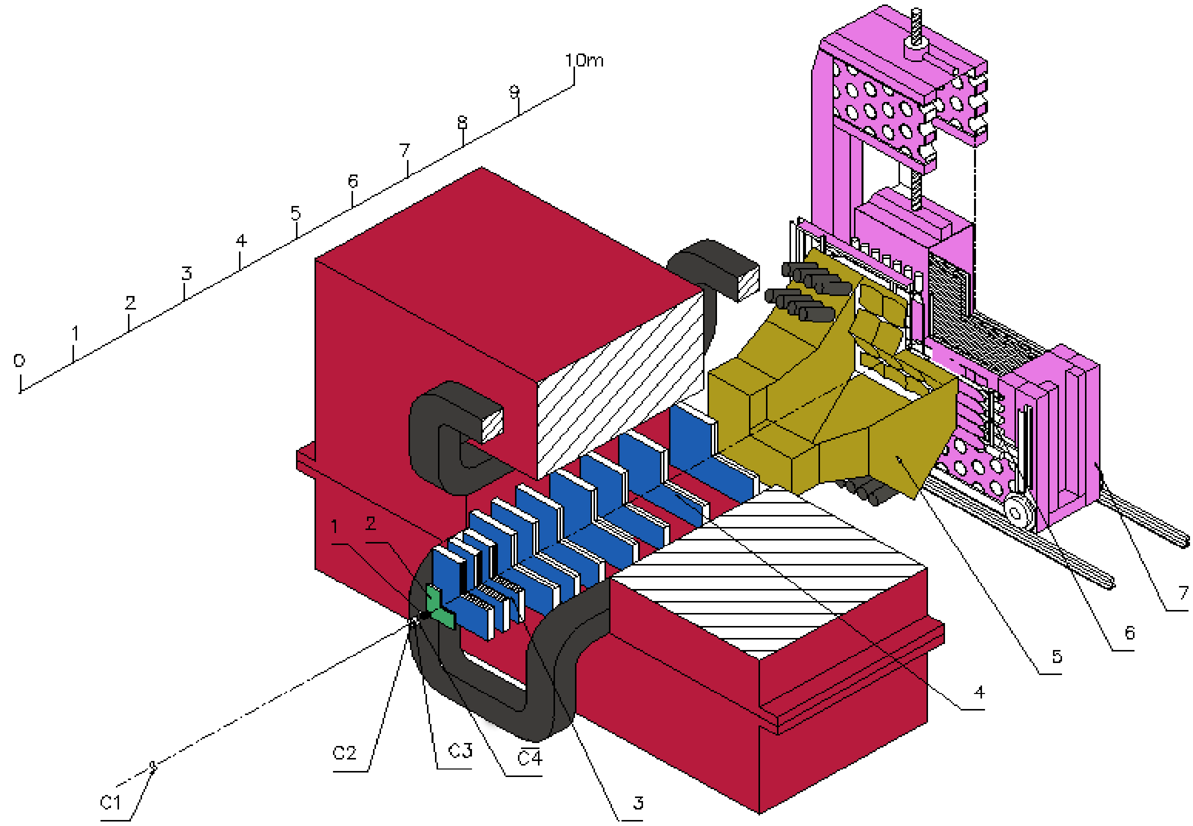


Fig. Schematic view of the SVD installation at U-70. C1, C2 — beam scintillation and Si-hodoscope; C3, C4 — target station and vertex Si-detector; 1, 2, 3 — the drift tubes track system; 4 — magnetic spectrometer proportional chambers; 5 — threshold Cherenkov counter; 6 — scintillation hodoscope; 7 — electromagnetic calorimeter.

JINR's Participation in Experiments in Prague

02-2-1042-2002/2006

Priority of the project: 1

Status: R&D

Experimental Search of the NN Scattering with Polarized Particles at the VdG Accelerator of the Charles University (Project NN–Interactions)

Leader from JINR: Yu. Usov

Participating countries and international organizations: Czech Republic, France, Russia, Ukraine

The purpose of the project is to study three-nucleon interactions using the 14–16 MeV polarized neutron beam in conjunction with a polarized deuteron target. Spin-dependent total cross-section differences ΔσL and Δσ T will be measured in the energy range, where there are no experimental data, with sufficient accuracy to check the contribution of the three-nucleon forces. A long-standing problem in nuclear physics has been a theoretical prediction of the triton binding energy. All realistic and local nucleon-nucleon potentials underbind it by about 500–800 keV, and three-nucleon forces (3NF) are natural candidates to fill the gap. The most promising approach has been presented by Bochum-Krakow group. It has become possible to perform exact numerical calculations of the Faddeev type calculation for neutron-deuteron scattering using modern NN forces. The authors of the Project propose to use for the polarization measurements the existing solid state Frozen Target at the Charles University.

In the test run, the obtained deuteron vector polarizations were P_= (-39.5±2)% and P + = (32.9 ±2)%. The proposed experiment is the continuation of the preceding measurement of the same quantities in the “np” scattering at the Van de Graaff of the Charles University. It is planned to reduce the relative errors of the existing expe-rimental set-up from 12% to 5%, which permit to observe reliably the 3NF. The proposed experiment is the only example at the Institute of carrying out the experiment on the accelerator of the country-participant of JNR.

JINR's Participation in Experiments at FNAL

02-0-1022-97/2005

Priority of the project:	1
Status:	Data taking

Participation of JINR in Upgraded Tevatron Physical Program (Project D0)

Leader from JINR: G. Alexeev

Participating countries and international organizations: Belarus, the USA

The JINR group is actively involved in conducting the D0 experiment at Tevatron (Fermilab) having the highest for the moment proton-antiproton c.m.s. collision energy of 2 TeV. The group has made a valuable contribution to upgrading of the D0 detector for Run II, capable of running at highest possible luminosity around 10^{32} l/(cm^2)s. It comprises about 6300 drift wire chambers (Mini-Drift Tubes having 8 wire cells each) and 50000 front-end electronics channels which form the basis for forward-backward D0 muon tracking system. The corresponding software to run the system and analyze its performance was also developed. Important consequence of this project is the creation of the full cycle for mass scale detectors and electronics production in JINR Member States like Armenia, Belarus and Russia.

The main goals of D0 collaboration include: search for Higgs boson and effects of SUSY, copious production of top quarks and W bosons, QCD studies and *b*-physics, search for unexpected phenomena which may happen at this highest energy, etc. Two areas of the JINR`s group interest are QCD studies and *b*-baryon physics.

The study of the hadronic decay channels of those particles that are characterized by two and more hadron jets production in the final state is very perspective. Thus, the task of the most precise hadron jet energy calibration (also called as the task of “the absolute jet energy scale determination”) becomes extremely important for the Collaboration. It is worth emphasizing that at the present time the main contribution to the top quark mass error comes from an existing uncertainty in the jet energy scale.

The JINR group at D0 has developed the new selection criteria for events with an associated production of hadronic jets and the direct photons allowing one to improve essentially the precision of setting of absolute jet energy scale for the conditions of D0 experiment. It is shown that the main source of the photon (or Z^0) and jet transverse momenta imbalance is the radiation in the initial (ISR) and final states (FSR). Another new requirement of jet isolation, introduced for the first time, allows one to select topologically clean “photon/Z^0+jet” events which would provide almost 1% accuracy of the absolute jet energy scale determination.

In parallel to the solution of the jet energy calibration task, a possibility to carry out experimental research of a proton structure, namely, gluon distribution function, is proved. It was shown that the samples of the “γ+jet” events selected for the jet energy calibration can be used for this aim. The proposal to study at D0 the gluon distribution in earlier unexplored kinematical region (by HERA, DESY) was accepted by the D0 collaboration and it is meant to be a good development of the traditional investigations of nucleon structure functions started earlier by JINR in the framework of BCDMS collaboration (NA4 experiment, CERN).

Our interest will be also focused on the b-baryon physics, namely b-baryon spectroscopy. Until now, this area was explored rather weakly. We are trying to investigate non-leptonic decays of b-baryons to fully reconstructable final states: $\Lambda_b \rightarrow J/\Psi + \Lambda$ and $\Xi_b \rightarrow J/\Psi + \Xi$ with further leptonic decay of J/Ψ ($\mu^+\mu^-$ or e^+e^-). It is possible with these decays to determine unambiguously the mass and lifetime of those b-baryons (the same is valid also for antibaryons). Expected mass resolution of Ξ_b in D0 detector was estimated with Monte-Carlo simulation and equals 0.14 GeV/c^2 FWHM at the mass peak of 5.84 GeV/c^2.

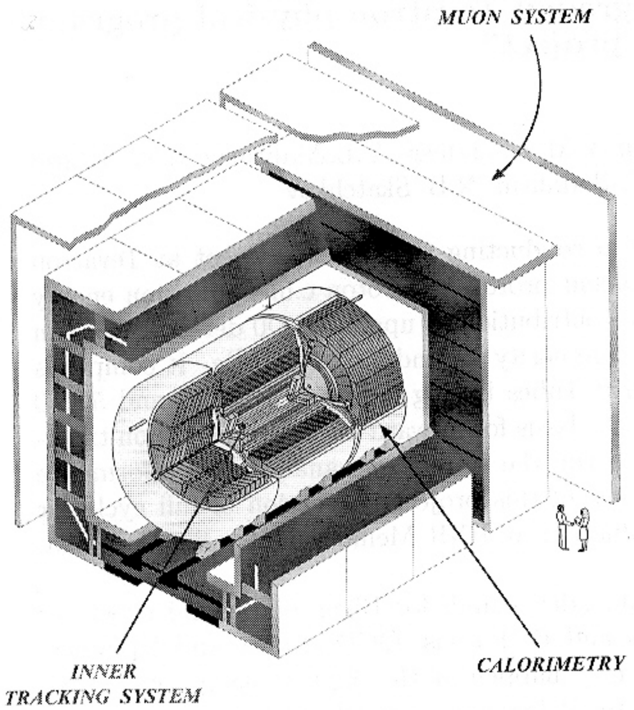


Fig.1. The D0-detector 3d-view.

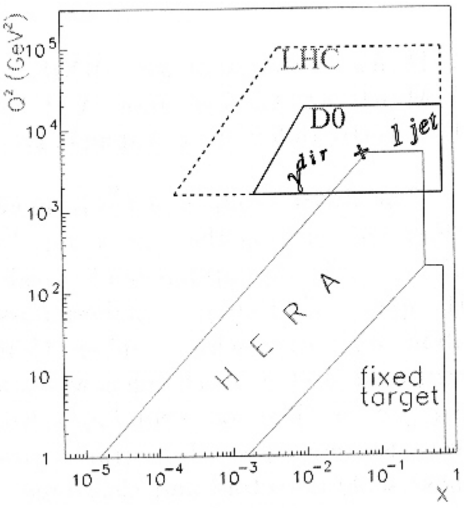


Fig.2. The kinematical region of the pp → γ+jet at Tevatron and LHC. Fixed traget experiments and HERA regions are also given.

02-0-1022-97/2005

Priority of the project:	1
Status:	Data taking

JINR's Participation in the Physics Research Programme at the Upgraded Fermilab Tevatron (Project CDF)

Leader from JINR: J. Budagov

Participating countries and international organizations: Georgia, Greece, Italy, Romania, Slovak Republic, Ukraine, the USA, Uzbekistan

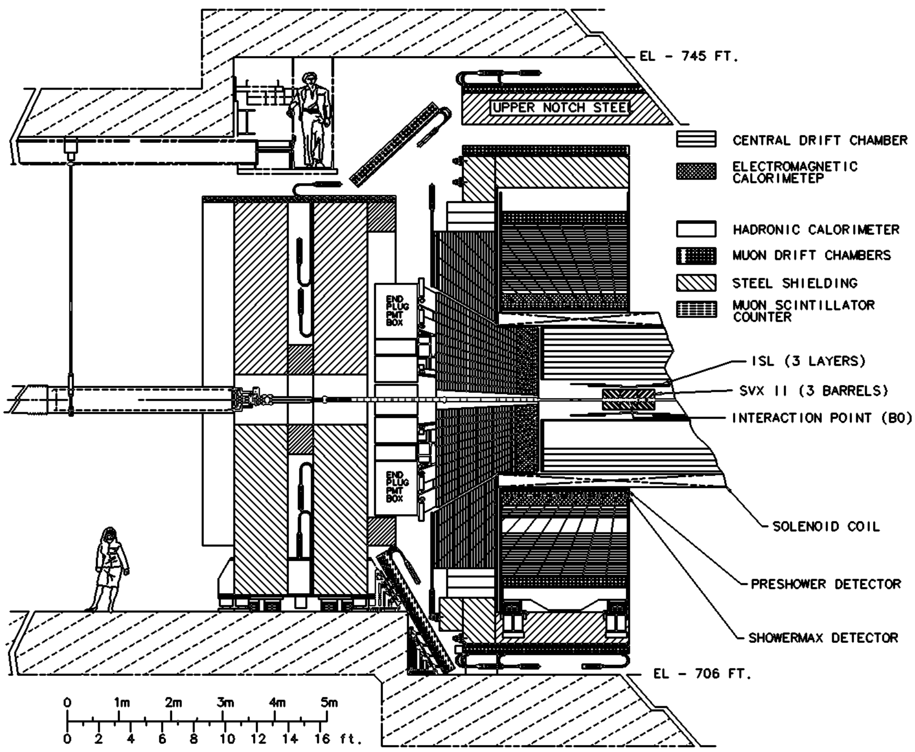


Fig.1. The CDF detector.

After extensive upgrades in the past few years the Collider Detector at Fermilab (CDF-2) began to collect data at the beginning of March 2001. The JINR–CDF group has contributed significantly to the improvement and later on to the commissioning of the detector. Since February 2002, the CDF detector has been in stable operation mode and JINR CDF group has participates in data collection and physics analysis.

The experiments at the Upgraded Fermilab Tevatron Collider are in the unique position to study heavy quarks: charm, bottom and top. The instantaneous luminosity of $(5–8)\cdot 10^{31}$ см$^{-2}$с$^{-1}$ with a center of mass energy of 1.96 TeV is expected at Tevatron during the first phase of Run2 (Run2 A). The planned integrated luminosity expected by the end of Run2 A is fixed to 2 fb^{-1}. High statistics for the events with c, b and t quarks in Run2 will provide new level of precision in measurements of top mass, as well as of cross section of the single and pair top-production. It also makes possible a critical checking of the Standard Model predictions concerning the CKM matrix elements, CP-violation and B-mixing. Tevatron could serve also as an extraordinary laboratory to search for Higgs and SUSY particles.

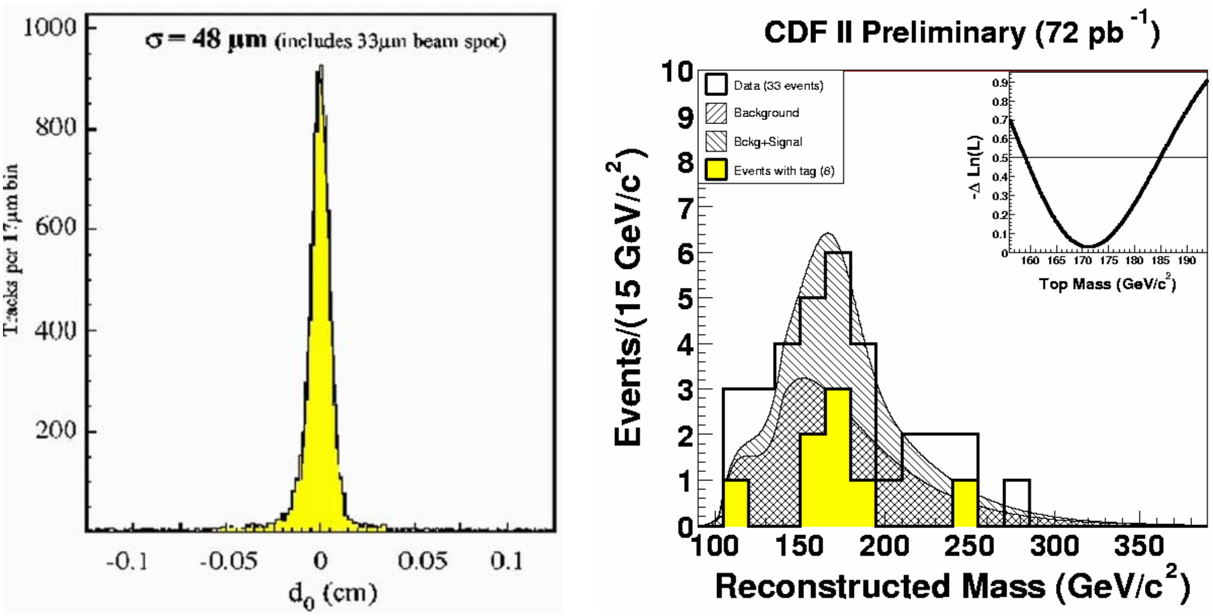


Fig.2. Left: Distribution of tracks impact parameter (d_0), obtained by Level-2 trigger using the Silicon Vertex Tracker (SVT).
Right: Fitted top mass distribution. Mt = 171.2 +/-14.4(stat) +/–9.9(syst) GeV/c^2; number of signal events 14.1 +/– 6.7, number of background events 20.1 +/–7.8

A new research direction at CDF was proposed by JINR — the investigations of the Very High Multiplicity processes. Correlations in hadron yields will be measured and information on the "thermalisation" in the process of a final (observable) state will be obtained.

Main JINR contributions to the CDF-2 program are:

Development of the new powerful trigger (SVT) for large impact parameter tracks selection based on the silicon vertex detector. For the first time, at a hadron collider a unique Level-2 trigger based on the measurement of the track impact parameter is realized.

Development and installation of an automated slow control complex for the CDF muon system.

Physics analysis of the data obtained from CDF-2 detector, and detector simulation using CdfSim package or specially developed software.

Development, creation and commissioning of the new detectors to be used at CDF in Run2 B (second phase of Run2): scintillator based "preshower" detector and time-of-flight system.

JINR's Participation in Experiments at BNL

02-7-1009-95/2005		Priority of the project: 1
		Status: Data taking

Project STAR

Leader from JINR: R. Zulkarneev

Participating countries and international organizations: Brazil, France, Czech Republic, Germany, Poland, Russia, the USA

STAR is one of the largest detectors at RHIC, which is intended to investigate properties of nuclear matter being compressed and extremely heated and look for the QGP signals. Another purpose of the device is to realize an extensive experimental programme with colliding polarized proton-proton beams in order to solve the "Spin crisis" problem, as well as search for possible effects beyond the Standard Model scope.

The extremely important component of the STAR detector is the Barrel Electromagnetic Calorimeter (BEMC), which provides broad capabilities necessary to observe quark–gluon plasma (QGP) and will play a crucial part when the polarized programme of the STAR experiments is implemented.

Since 1999, the LPP STAR group has participated in the construction of the BEMC within the collaboration with the US University groups of WSU (Detroit), UCLA (Los Angeles) and MSU (Michigan).

Bilateral BNL–JINR and WSU–LPP Agreements regulate the LPP STAR contributions into the STAR detector.

BEMC is a design of cylindrical geometry covering a space within the azimuth $0<\phi<2\pi$ and pseudorapidity $-1<\eta<1$. That one is filled up with 120 BEMC modules, each one consist with of 40 separate detectors (towers). Each tower is supplied with SMD — a gas-detector fixing the position and shape of shower maxima — and with PSD. The latter registers the initial stage of showers. The total weight of that design is above 300 t; whole sizes are 0.5m · 0.5m · 3.0m; the total number of spectrometric channels is 9600, and of the coordinate one — 67200. The calorimeter measures energies of electron-photon showers in the interval from 0.3 GeV up to ~100 GeV with high precision and allows one to make observations of rare processes of neutral particle production (ϕ, J/ψ, W- and Z-bosons).

According to the official documents, the LPP STAR group contribution to the BEMC constructions is identified as follows:

- assembling of 120 BEMC modules and their mounting on the STAR magnet (together with the BNL group);
- participation (jointly with MSU and WSU) in development and fabrication of the BEMC optical readout and control system (above 250000 channels);
- manufacture of the Bulkheads for BEMC modules (240 pcs) and magnetic shields (5100 pcs) for the PMT boxes;
- design and construction of the PMT boxes (60 pcs) — some optic and electrical interfaces for transmitting the calorimeter light signals into the STAR DAQ system;
- participation in fabrication of the EMC mega-tiles.

According to the STAR collaboration schedule, during 2003 a half of the STAR BEMC (60 fully equipped modules) was assembled, installed on the STAR magnet in BNL and operated in both $\sqrt{s}$=200 GeV d+Au- and pp-runs at RHIC. Completing the BEMC construction is scheduled for November 2004 before the next STAR run begins.

In addition, the LPP group makes contribution to software development and MC calculations related with BEMC and its substructures SMD and PSD. In particular, the group dominates in the development of the electron/hadron identification technique, as well as in the study of BEMC SMD performance and its calibration.

In Spin Physics the LPP group efforts will be focused on measuring the spin distributions valence/sea quarks of proton, as well as on studying the flavor dependence of proton constituent polarization. These investigations are assumed to be realized in a new generation of polarized experiments: $p^{\rightarrow}p \rightarrow W^{\pm} + X$, $p^{\uparrow}p^{\uparrow} \rightarrow Z^{\circ} + X$, $p^{\rightarrow}p^{\rightarrow} \rightarrow e^{+}e^{-} + X$. Such information is coupled with the "Spin crisis" problem and can resolve some disputed points.

In nuclei-nuclei collisions the observation of single electrons/positrons and dilepton pairs is of the LPP group interest. It is expected that the class of experiments being made in a wide effective mass of the system will cast light on the nuclei fireball properties in the earliest stage of its development. Another topic is the space-time correlations between particles produced in nuclear collisions.

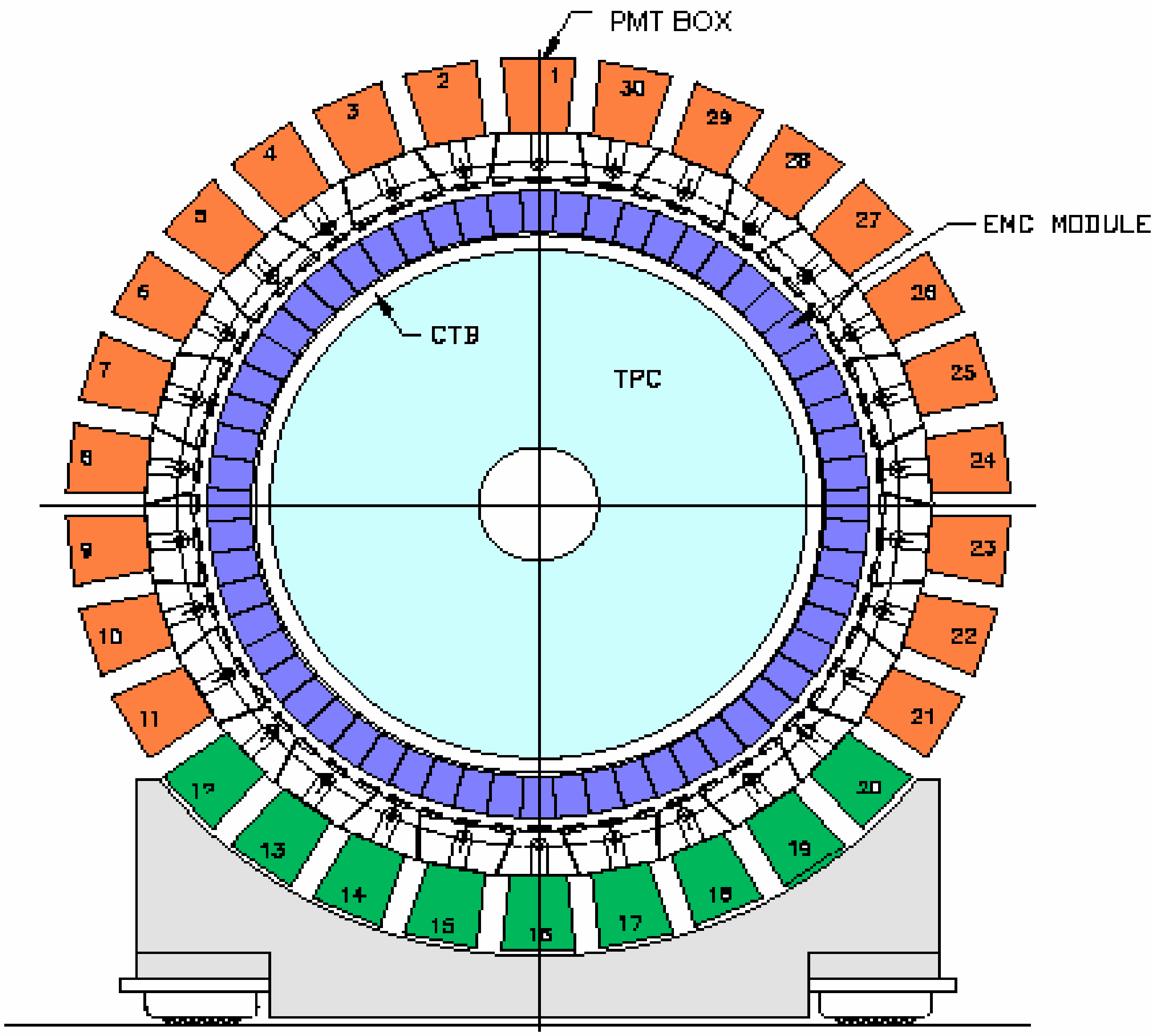


Fig. General view of the STAR detector

JINR's Participation in Experiments at DESY

02-7-0984-92/2005

Priority of the project:	1
Status:	Data analysis

HERA-B Experiment

Leader from JINR: I. Golutvin

Participating countries and international organizations: Belarus, Bulgaria, Germany, Russia, Slovenia, Ukraine, USA

The HERA-B detector 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 proton beam of the HERA *ep* collider. The HERA-B detector provides magnetic spectrometry and the identification of charged particles $e^{\pm}$, $\mu^{\pm}$ and $K^{\pm}$, the reconstruction of primary and secondary vertices, as well as the identification of events using trigger for tracks with a large transverse momentum and an invariant mass of two oppositely charged leptons in the region of the J/ψ resonance.

According to the JINR commitments, LPP participated in the construction and commissioning of the Outer Tracker (OTR) of the HERA-B detector; development and debugging of software for off-line reconstruction, calibration, and on-line monitoring of the OTR operation during data-taking runs. The LPP specialists contributed considerably to the mass production of the OTR modules. In total, about 300 modules of the honeycomb drift chambers for the OTR were produced and sent from Dubna to DESY; this corresponds to almost 40000 detection channels covering 30% of the total number of the OTR channels. The Dubna group has made a fundamental contribution to the preparation and installation of the OTR, as well as testing and adjustment of its superlayers at DESY. When the assembly of the OTR superlayers was completed at the end of 1999, physicists from Dubna focused on the data analysis.

The HERA-B physics programme for the 2002–2004 data-taking and period was concentrated on the measurements of the $b\bar{b}$ cross section in 920 GeV p-nucleon collisions and charmonium suppression in proton-nucleus interactions, including studies of J/ψ, ψ' and χ_c states. Other topics are as follows: A-dependence of open charm production, B_s mixing, Drell–Yan production, hard-photon production, charmonium spectroscopy, and asymmetries in beauty, charm and strange production.

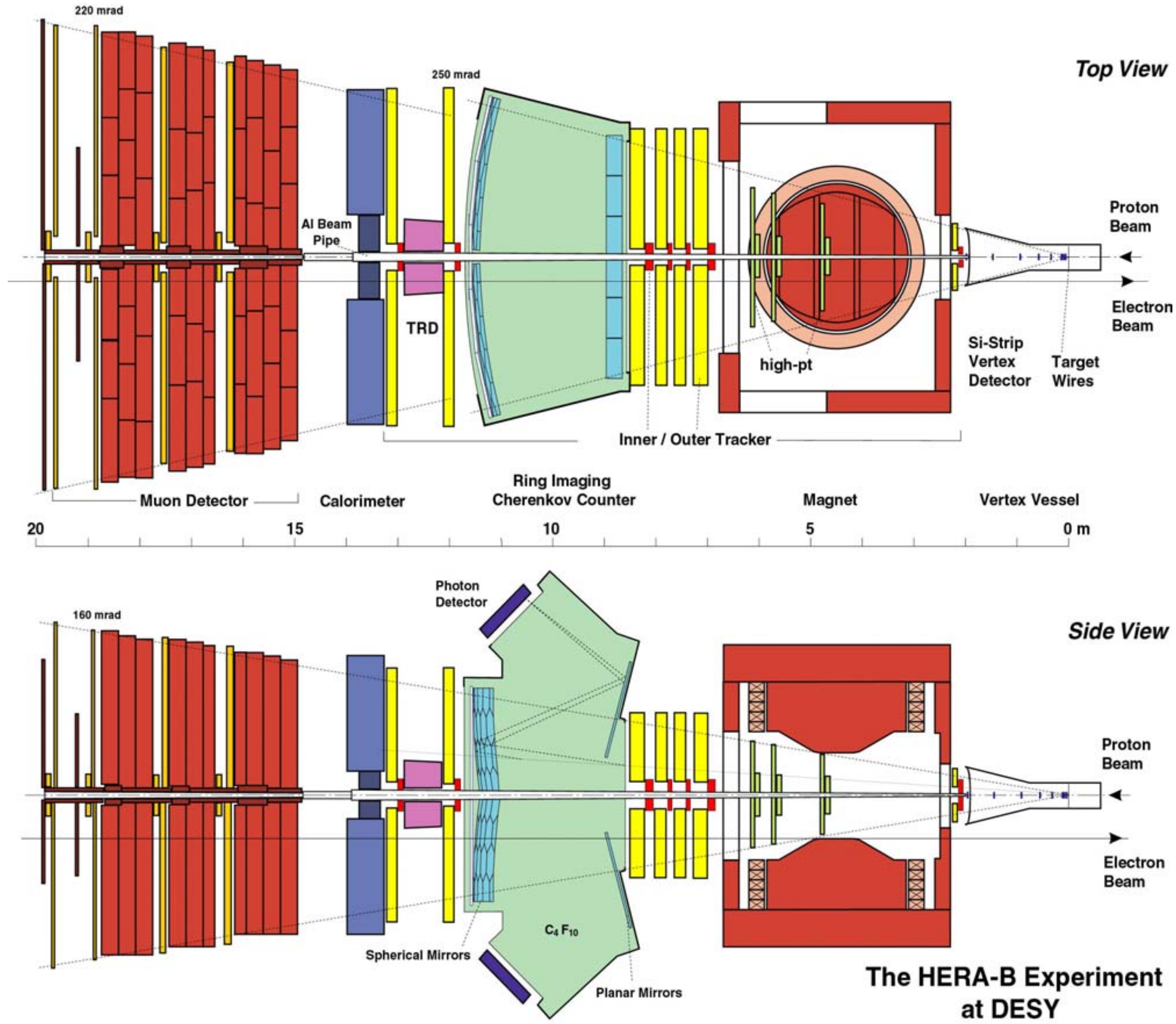


Fig. The general block diagram of the HERA-B experimental setup: vertex detector (VDS), superlayers (MC, PC, and TC) of the outer detector, the detector of Cherenkov rings (RICH), transition-radiation detector (TRD), and electromagnetic calorimeter (ECAL).

02-7-1016-96/2006		Priority of the project: 1

Status: Data taking

The H1 Experiment at the HERA Collider (DESY)

Leader from JINR: M. Kapishin

Participating countries and international organizations: Armenia, Belgium, Czech Republic, France, Germany, Great Britain, Italy, Mexico, Poland, Russia, Slovak Republic, Sweden, Switzerland

The H1 experiment devoted to the study of deep-inelastic *ep* scattering processes has operated successfully at the HERA collider since 1992. As the integrated luminosity has accumulated, a rich programme of physics has been developed to carry out precision measurements of low *x* proton structure, photon structure, QCD dynamics and the first observation of high Q^2 interactions. It is also important to appreciate that the design of the H1 detector was originally motivated by and optimized for physics at high Q^2, where event signatures are distinct and therefore easy to identify, and where backgrounds are very small. An increase in integrated luminosity of the HERA collider will extend the physics programme on the validity of the Standard Model. The longitudinal polarization of $e^{\pm}$ beam is also an important factor to achieve maximal sensitivity of the measurements. An increase of HERA delivered luminosity to ~ 150 pb^{-1} y^{-1} (about 1 fb^{-1} in the period 2001 to 2006) will make possible new and very important measurements in the "hard scale" (Q^2 or $p^2{}_T$) range beyond 2000 GeV^2. This will have a major impact on Standard Model physics in both electroweak and QCD sectors, and will provide new sensitivity to physics at HERA beyond the Standard Model. Below are outlined possible results in physics after the HERA luminosity upgrade. However, in the light of recent experience at the highest Q^2, the unexpected, and therefore the unpredicted, remains the prime motivation for high luminosity *ep* running. Upgrade of the H1 detector has been carried out to meet the precision and scope of future measurements.

The LPP JINR group participating in the H1 experiment is in charge of three important detectors: Forward Proton Spectrometer (FPS), Backward Proportional Chamber (BPC) and Plug Detector. The purpose of the FPS spectrometer is to measure leading protons in the final state, BPC chamber — to measure the angle of the scattered electron in deep-inelastic *ep* interactions, Plug detector — to close a gap in the H1 acceptance in the forward direction around the beam pipe. Within the HERA upgrade programme, the new BPC chamber and Plug detector have been constructed and installed into the H1 setup. The FPS spectrometer was modified to increase the detection efficiency and life time.

The LPP JINR group found its own way within the physics analysis programme of the H1 experiment. Their efforts are concentrated on the analysis of DIS ($Q^2 > 0$) and photo-production processes ($Q^2 \sim 0$) with the leading proton detected in the FPS spectrometer. The diffractive structure function $F_2{}^D$, inclusive photo-production and elastic ρ-meson photo-production cross section were measured and confronted with the Saturation model based on the colour dipole approach and the Regge model of high energy hadron scattering.

New high statistics data collected after the HERA luminosity upgrade will allow to study diffractive processes in which the hard scale is defined by high p_T jet or high Q^2 virtual photon and perturbative QCD is applicable.

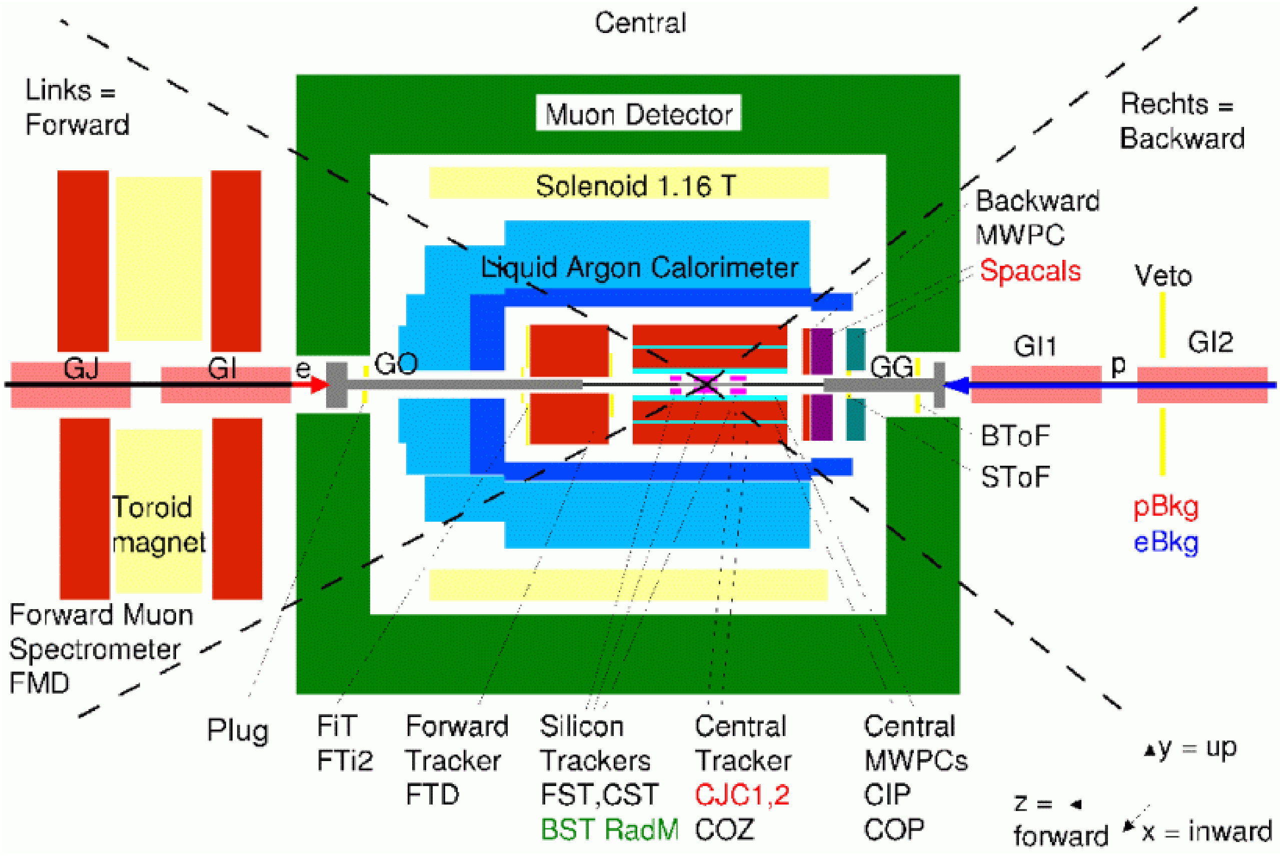


Fig. Schematic view of the upgraded H1 detector.

02-7-1025-98/2005

Priority of the project: 1

Status: Data taking

HERMES Experiment

Leader from JINR: V. Krivokhizhin

Participating countries and international organizations: Armenia, Belgium, Canada, China, Germany, Holland, Italia, Japan, Poland, Russia, Scotland, United Kingdom, USA

The HERMES experiment (HERA Measurement of Spin) is a second generation polarized deep inelastic scattering (DIS) experiment to study the spin structure of the nucleon. It is being run at the HERA storage ring at DESY. The physics program for HERMES is very broad. The experiment contributes inclusive data with qualitatively different systematic uncertainties to improve the world data set for the x-dependence and the integral of the spin structure function $g_1(x)$ for both the proton and the neutron. Most importantly, HERMES is providing new precise data on inclusive, semi-inclusive and exclusive processes by virtue of the good acceptance of the spectrometer combined with hadron identification and purity of the targets.

LPP group has taken active part in the analysis of the HERMES experimental data and development of the software procedures. With participation of the LPP physicists the following set of the HERMES results was obtained and published: measurements of the neutron and proton spin structure function g_1; the Q^2-dependence of the generalized Gerasimov–Drell–Hearn integrals for proton, deuteron and neutron; the first results on beam single spin asymmetry in Deeply Virtual Compton Scattering (DVCS). Also, in cooperation with colleagues from Armenia and Belarus the new method of structure function extraction from polarized data on lepton-nucleon deep inelastic scattering was developed.

The essential contribution was done in upgrading the HERMES spectrometer. The set of min-drift chambers (DVC) for the front part of the spectrometer was designed and produced in JINR. It has led to the essential improvement of the spectrometer resolution and tracking efficiency. In 2000–2002 the new set of DVC's with front-end electronic cards was produced in JINR. Note that electronic cards were developed, designed and prepared for data taking.

In 2003–2006 HERMES is planning to perform the number of measurements:

- the transversity nucleon spin structure functions h_1 and g_2;
- the longitudinal polarization of strange quarks $\Delta S(x)$;
- the single-spin asymmetries in Deeply Virtual Compton Scattering (DVCS) and study of exclusive processes with vector and scalar mesons production.

The main interests of JINR LPP group are as follows:

- transversity quark distributions,
- the spin dependent structure function $g_2(x,Q^2)$,
- single spin asymmetry in Deeply Virtual Compton Scattering (DVCS);
- the role of g_2 in the generalized Gerasimov–Drell–Hearn integrals.

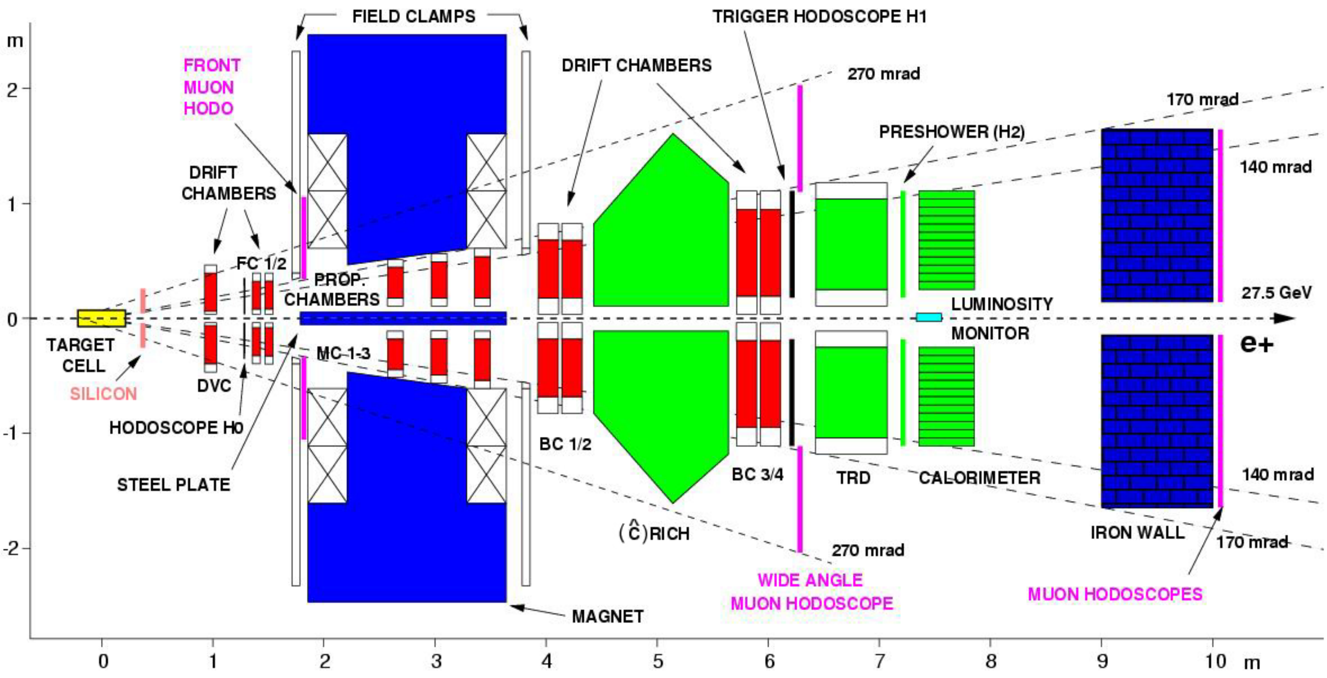


Fig. The view of the HERMES Spectrometer.

02-7-1057-2004/2006

Priority of the project:	1
Status:	New

Project TESLA

Leader from JINR: M. Yurkov

Participating countries and international organizations:

JINR participates in the collaboration TESLA on the construction of linear lepton collider with the energy in the centre of mass system of the order of 1 TeV. The experience of construction of the Regenerative Amplifier Free Electron Lasers (RAFEL will be applied at TTF-II and later on at the collider TESLA, where the activities on spontaneous radiation will be continued. This mode was successfully realized on TTF-I in 2000 with active and decisive participation of the LPP people. The development of FEL, feed back system devices to obtain powerful mono wave irradiation for the direct usage and for the gamma-gamma mode of the collider, as well as in the x-ray and infra red parts of the spectrum, can become the basis for the JINR contribution to this programme, since our specialists have rich experience and a long history of co-operation with DESY.

JINR's Participation in Experiments at RIKEN

02-2-1042-2002/2006

Priority of the project:	1
Status:	R&D

Measurement of the CP Violating decay $K_L^0 \to \pi^0 \nu \bar{\nu}$ (Project E391a)

Leader from JINR: A. Kurilin

Participating countries and international organizations: Belarus, Czech Republic, France, Georgia, Japan, Russia, USA

The $K_L^0 \to \pi^0 \nu\bar{\nu}$ decay is unique in the meaning of a small theoretical ambiguity, and precise measurement of the branching ratio will provide a clean determination of some parameters of the modern particle physics. It will also play an important role in a new physics search and understanding of the CP-violation.

The standard model of particle physics (SM) predicts the $K_L^0 \to \pi^0 \nu\bar{\nu}$ branching ratio to be around $3 \cdot 10^{-11}$. Since the present experimental upper-limit is equal to $5.9 \cdot 10^{-7}$, it is quite challenging to start a high sensitivity experiment which aims for a branching-ratio measurement at a level of few per cents by an observation of hundreds of SM events.

In order to reach the final goal, we plan a series of experiments: the first one (E391a) is an experiment at the present KEK 12-GeV proton synchrotron (PS) and the second one is planned to be at the U70 (IHEP, Protvino) or any other high intensity accelerator.

The experiment E391a is at a stage of detector production and assembling at KEK 12-GeV PS. E391a started in 2002 with engineering run with the aim of starting data-taking in 2004.

JINR’s Participation in Experiments at Gran Sasso

02-7-1017-96/2006

Priority of the project:	1
Status:	Preparation

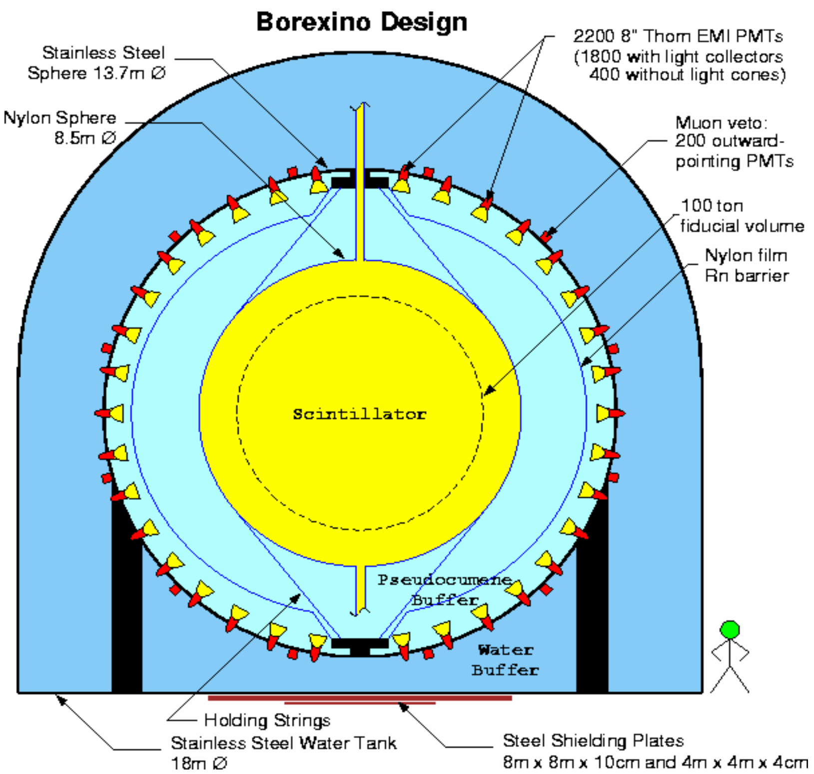
Project BOREXINO

Leader from JINR: O. Zaymidoroga

Participating countries and international organizations: Belgium, Czech Republic, France, Germany, Hungary, Italy, Russia, USA

The international project BOREXINO is devoted to the precise and direct determination of the flux of the solar neutrinos produced in the Be-7 electron capture process in the Sun and study the phenomenon of neutrino oscillations for the low energy solar neutrino spectrum by using a calorimetric, liquid scintillator and a low background detector. A pilot programme for the full-size detector, the Counting Test Facility (CTF) provided the convincing evidence that the technological challenge of the experiment, the achievement in the scintillator of unprecedented radiopurity levels were accomplished successfully, thus opening the way to the realization of the milestone of the experiment. The following physics results have been obtained by using CTF:

1. The magnetic moment of pp- and ^{7}Be-neutrinos:	$\mu_H \leq$ Â $5.5\mathrm{x}10^{-10}\ \mu_B$
2. Neutrino radiative decay $\nu_H \rightarrow \nu_L + \gamma$:	$\tau/m_H \geq 4.2 \times 10^{3}$ s·eV^{-1}
3. Electron decay mode $e \rightarrow \gamma + \nu$:	$\tau \geq 4.6 \times 10^{26}$ years
4. Nucleon decays ($N \rightarrow 3\nu$, $NN \rightarrow 2\nu$):	$\tau \geq (10^{25} - 10^{26})$ years



Applied Research

02-7-1045-2002/2004

Priority of the project:	2
Status:	Data taking

Application of Nuclear Physics Methods for Identification of Complex Chemical Substances Project DVIN

Leader from JINR: V. Bystritsky, M. Sapozhnikov

Participating countries and international organizations: Italy, Russia, the USA

The main aim of the project is to develop methods for identification of complex chemical substances by registration of the γ spectra induced by fast neutrons. The neutrons are formed in the reaction $d+t \rightarrow \alpha+n$. The gamma quanta are registered in coincidence with the α- particles. For each event the coordinates and the arrival time of α-particles in the alpha-detector are measured as well as amplitudes and arrival time of γ in the gamma-detectors. This information allows one to find 3D position of an object inside the interrogated volume.

Investigation of different detectors for α and γ registration will be performed. The data acquisition and data analysis systems will be developed.

Simulation of the neutrons and gamma-quanta interactions in the interrogated volume will be done to optimize the detector. A prototype of the detector for identification of hidden substances will be created.

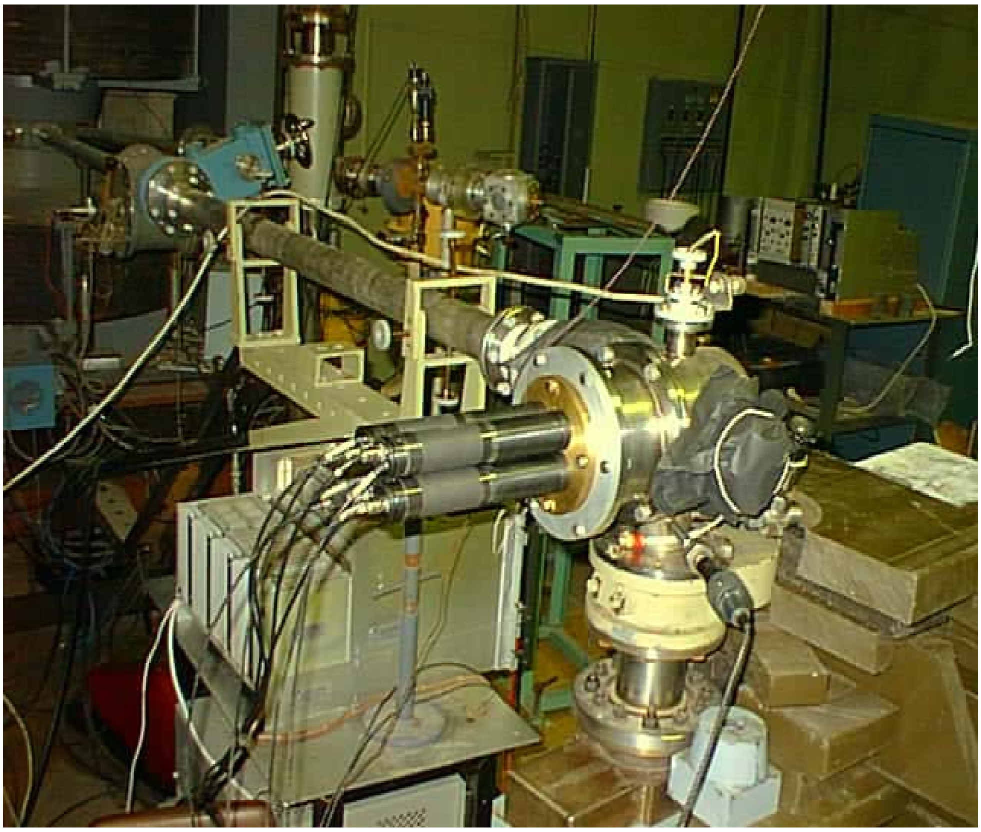


Fig. Experimental apparatus of the DVIN project at the Van de Graaf accelerator of JINR LNF.

02-7-1032-99/2005	Priority of the project: 2
	Status: R&D

Development of Accelerators for Radiation Technologies

Leader from JINR: G. Dolbilov

Participating countries and international organizations: Belarus, Bulgaria, China, Japan, Russia

A new, non-traditional direction in technique of electron accelerators for radiation technologies is performed at LPP. The multi-beam high repetition rate accelerators, developed at LPP, provide the possibility to apply a very cheap direct current electric field to accelerate the secondary electrons. Original design and low cost of the accelerator attract the attention of experts of 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 till 2005.