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SOME NEW RESULTS OF INVESTIGATIONS IN RELATIVISTIC NUCLEAR PHYSICS AT THE LABORATORY OF HIGH ENERGIES

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Report to the 87th Session
of the JINR Scientific Council
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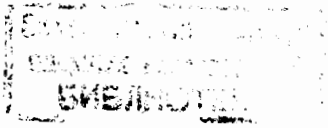


1. Introduction

The scientific program of the Laboratory of High Energies, Joint institute for Nuclear research is presently concentrated on investigations of interactions of relativistic nuclei in the energy region from a few hundred MeV to a few TeV per nucleon with the aim of searching for manifestations of quark and gluon degrees of freedom in nuclei, asymptotic laws for nuclear matter at high energy collisions as well as on the study of the spin structure of lightest nuclei. Experiments along these lines are being carried out using beams of the Synchrophasotron - Nuclotron accelerator complex as well as of other accelerators at CERN (SPS, LHC), BNL (RHIC) and at the CELSIUS storage ring in Uppsala (Sweden). LHE takes part in preparing an experiment HADES at GSI (Darmstadt).

2. Development of the Accelerator Complex

The Nuclotron accelerator complex at LHE is the basic facility of JINR for generation of proton, polarized deuteron (also neutron/proton) and multicharged ion (nuclear) beams in energy range up to 6 GeV/u. General view of the facility is shown in fig. 1.

The Nuclotron was built during 1987-92. This accelerator is based on the unique technology of superconducting magnetic system, which was proposed and investigated at the Laboratory. All design, tests and assembling works were carried out at the LHE. Mechanical production of the cryomagnetic elements was done by the JINR workshops.

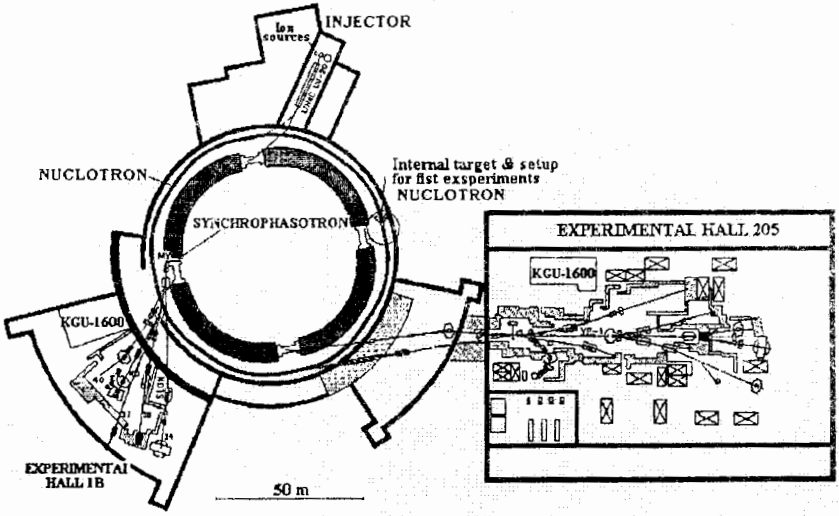


Fig. 1. The Nuclotron accelerator complex.

The 15 runs were at the Nuclotron since Match 1993. Basically all of the design parameters have been achieved. Very high reliability of the liquid helium supply and the magnet cooling system was practically demonstrated. Data taking for physics was performed at the internal target. Intensive work on the completion of the construction and tests the main elements of beam extraction system as well as reassembling of the part of the accelerator ring 12-m in length was fulfilled in 1999. The first test of the beam extraction system was performed in October of this year.

The main directions of the Nuclotron - accelerator complex development during the nearest years are the following:

- Completion of the Nuclotron beam slow extraction system and transportation of the extracted beams in the experimental hall.
- Development of the injector complex including ion sources, partial reconstruction of the linac LU-20, technical design and construction work on the Nuclotron booster.
- Upgrade of cryogenic supply, quench detection and energy dump as well as diagnostic, control and r.f. systems.

1. Commissioning of the Nuclotron ring, internal target experiments. Total running time includes: cool down ~ 1500 h, the machine development and beam investigations ~ 1330 h, internal target experiments ~ 550 h. The operational parameters have been achieved up to now are the following:

- beam kinetic energy - 4.2 · GeV/u,
- accelerated particles - p, d, α, ^{12}C, ^{84}Kr, d↑,
- beam intensity - $1.2 \cdot 10^{10}$ p.p.c for deuterons
  ~ 10^{9} p.p.c for α - particles,
- repetition rate - 0.2 Hz,
- flat top duration - 10 s.

Internal target experiments were started in March 1994. Relativistic deutron beam with momentum up to 4.2 A· GeV/c per nucleon was mainly used. Physics data taking at proton and ^{4}He beams were also provided. Normally, 3 or 4 groups of the users participated in the experiments.

2. Design and Construction of the Nuclotron beam slow extraction system. A lot of works have been done during this year. There are no unclear technical or accelerator problems. The equipment was tested at stand and installed in the accelerator ring.

The technology of beam extraction elements at the Nuclotron has no analogues. The Lambertson - type magnet based on the Nuclotron technology and high voltage electrostatic septum combined with the cryomagnetic system are unique.

3. Development of the injector complex including the ion sources, upgrade of the existing linac LU-20 and booster ring design. New CO_2 - laser for the laser drived source was designed and constructed. Reflecting mode of the electron beam ionizer KRION operation was investigated. Fast extraction (T ~ 30 mks) of ions from the KRION source was tested.

The front section of the LU-20 main cavity was reconstructed to decrease the minimal charge-to-mass ratio of accelerated ions from 0.33 to 0.28. Conceptual design of the Booster ring based on the Nuclotron-type technology was made.

4. Increase of beam intensity and an extension of available nuclear beams. The following new beams were obtained during 1993-99:

- $_{32}S^{16+}$ - were accelerated at the Synchrophasotron up to E = 3.65 GeV/u and used for physics experiments;
- $_{40}Ar^{17+}$ - were accelerated at linac (E = 5 MeV/u);
- $_{84}Kr^{32+}$ - injected into the Nuclotron;
- unique beam of relativistic polarized neutrons (after stripping of polarized deuteron beam $N_n \approx 10^{-3}\ N_d$) was formed and used in experiments at polarized proton target removed from Saclay.

The peak intensity of polarized deuteron beam from POLARIS ion source was increased by factor of 3.

5. Upgrade of the Nuclotron cryogenic system. All designed parameters of the Nuclotron cryogenic system were achieved. The reliability of the system as high as 95%. The average cool down time of the Nuclotron magnetic system (cold mass ~ 80 tons) is 100 hours. About 80 tons of liquid N_2 is used during this period. After that the consumption of liquid N_2 is about (12 ÷ 15) tons/day. It can be decreased to (8-10) tons/day by means of special turbines cooled by helium flow instead of LqN_2 at the main refrigerators of liquid He. One set of such turbines was tested during the 7 Nuclotron run. The experimental results were closed to the predicted ones.

Table 1

Nuclotron development

System	Years			Cost
	1999	2000	2001	k$
Beam Extraction				**250.0**
INJECTION:				
Laser Source				**42.0**
Electron Beam Source				**30.0**
Polarized Deuterons (d⁻ - multiturn injection)				**30.0**
Linac Upgrade				**20.0**
Diagnostics, Control, RF				**210.0**
Quench Detection & Energy Dump				**55.0**
Cryogenic Supply				**125.0**
Total Cost				**762.0**

6. Development of superconducting magnets for heavy ion synchrotrons and beam transport channels. The conceptual design of the Nuclotron-type miniature low-cost superconducting magnets for a future very large hadron collider and very

rapid cycling (f ≅ 10 Hz) intermediate energy synchrotron have been made. The option of a superconducting quadrupole for beam transport lines was also considered.

The Research and Development Programme

The proposed schedule and cost of the main directions of the accelerator complex development except of the booster ring construction is shown in Table 1.

Construction of the booster will make it possible to increase significantly the intensity of accelerated beams (see Table 2). The cost of the project based on a conventional accelerator technology (published in 1991) was estimated at the level of $3M. It can be decreased to about $1.5M in the case of the Nuclotron technology application. The conceptual designs of such accelerator have been made. The period of technical design and construction is about 3 years.

Table 2

The NUCLOTRON beams

Beam	INTENSITY (Particles per cycle)		
	Nuclotron *(available)*	Nuclotron + Ion sources development	Nuclotron + Booster (have to be)
p	$2\cdot10^{10}$	$1\cdot10^{11}$	$1\cdot10^{13}$
d	$2\cdot10^{10}$	$5\cdot10^{10}$	$1\cdot10^{13}$
^{4}He	$8\cdot10^{8}$	$5\cdot10^{9}$	$2\cdot10^{12}$
^{7}Li		$2\cdot10^{10}$	$5\cdot10^{12}$
^{12}C	$1\cdot10^{8}$	$7\cdot10^{9}$	$2\cdot10^{12}$
^{20}Ne		$1\cdot10^{8}$	$5\cdot10^{9}$
^{24}Mg		$3\cdot10^{8}$	$5\cdot10^{11}$
^{40}Ar		$3\cdot10^{7}$	$2\cdot10^{9}$
^{56}Fe			$1\cdot10^{11}$
^{84}Kr	$1\cdot10^{3}$	$2\cdot10^{7}$	$5\cdot10^{8}$
^{96}Mo			$1\cdot10^{10}$
^{131}Xe		$1\cdot10^{7}$	$2\cdot10^{8}$
^{181}Ta			$1\cdot10^{8}$
^{209}Bi		$3\cdot10^{6}$	$1\cdot10^{8}$
^{238}U			$1\cdot10^{8}$
$n_{(secondary)}$	$2\cdot10^{7}$	$\sim10^{8}$	$\sim10^{9}$
$n\uparrow_{(second)}$	$3\cdot10^{5}$	$\sim10^{6}$	$5\cdot10^{7}$
$d\uparrow$	$3\cdot10^{8}$	$\sim10^{9}$	$5\cdot10^{10}$
$t_{(secondary)}$	$4\cdot10^{5}$	$\sim10^{6}$	$\sim10^{9}$

3. Measurements with relativistic nuclei

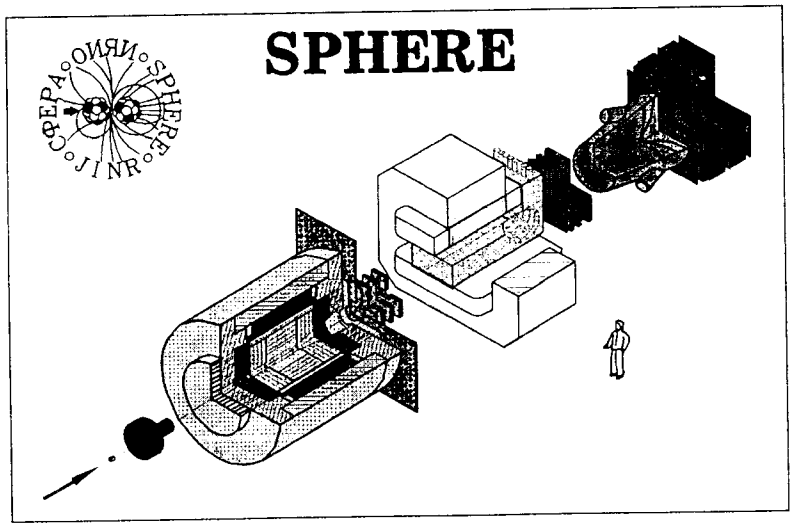


Fig.2. Shematic view of the SPHERE setup.

The inclusive spectra were measured for deuteron fragmentation into cumulative π^- mesons on a nuclear target, and the relevant cross section was investigated as function of the atomic number A of a target nucleus at SPHERE setup with Synchrophasotron beams (Fig.2). The deuteron beam momentum was varied between 7.3 and 8.9 *GeV/c*, and data were collected for the π^- meson momenta of $p_\pi =$ 3.0 and 4.9 *GeV/c*. The shapes of the pion spectra are found to be similar for all investigated targets (*H*, *C*, *Cu*, and *Pb*). The cross section shows a characteristic peripheral dependence on the target atomic number A *for* $A \geq 12$ ($d\sigma_\pi \sim A^{0.4}$) and a steeper decrease toward a hydrogen target (Fig.3). The proposed theoretical interpretation of the observed A dependence takes into account the interactions of the deuteron and of the emitted pion with target nucleons. The best description of the data is obtained under the assumption that the pion-formation length is $l_\pi = 3 \pm 1$ *fm*.

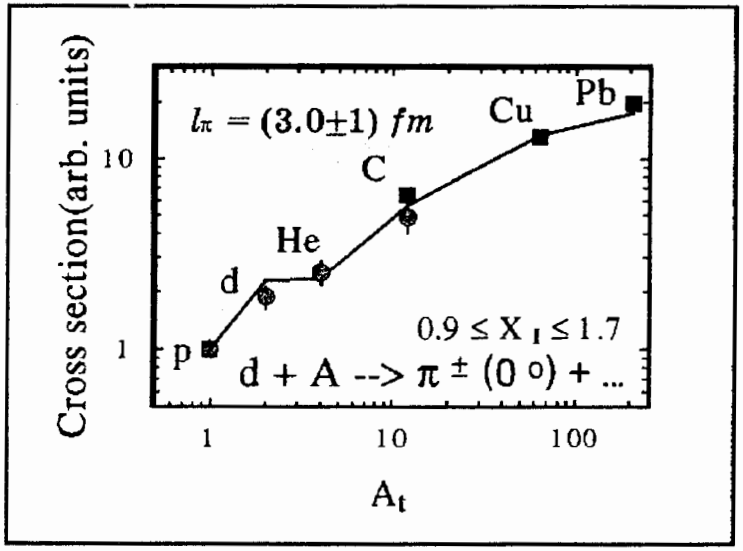


Fig.3. Cross section for production of cumulative pions as function of atomic number A of the nucleus.

M.I. Podgoretsky suggested a method to measure the velocity (and size) of the source by the interference method. This method allows one to get direct experimental evidence for the nonstationary state of the pion generation volume. This evidence was first obtained with the setup GIBS at JINR's LHE for central Mg-*Mg* interactions at **4.4** *GeV/c*. The pictures were taken in a streamer chamber with a magnesium target inside, exposed to the extracted magnesium beam from the Dubna Synchrophasotron.

The fig. 4 displays rapidities ($y=0.5ln[(1+\beta)/(1-\beta)]$) of sources Y_{source} obtained by fitting the correlation function for subsets of pions from different region of the kinematic spectrum. Average rapidities of these subsets y_{subset} are plotted on the horizontal axis. The data are given for subsets moving both along the reaction axis and across it (horizontally in the *Mg-Mg* c.m.s.). It is seen that pions from different regions of the kinematic spectrum are emitted by different "elements" of the source, moving with respect to one another with almost highest possible velocities. For a stationary source, all points must be on the horizontal axis.

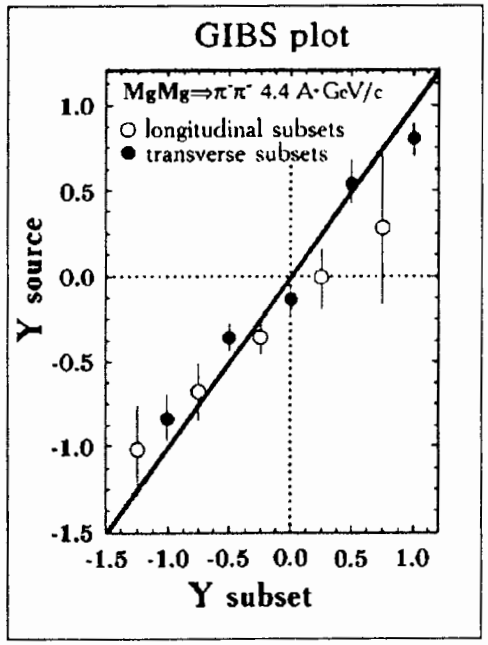


Fig.4. Rapidities Y_{source} of the pion production volume elements corresponding to different pion subset moving with different rapidities y_{subset} along (full circles) and across (open circles) the reaction axis in the Mg-Mg rest frame.

A number of experiments have been conducted with the proton and alpha beams of Synchrophasotron on 4π-device FAZA. The following main result is obtained: the hot target spectator expands before the fragment emission. The break-up density is found to be ~ 1/3 of normal one (Fig. 5).

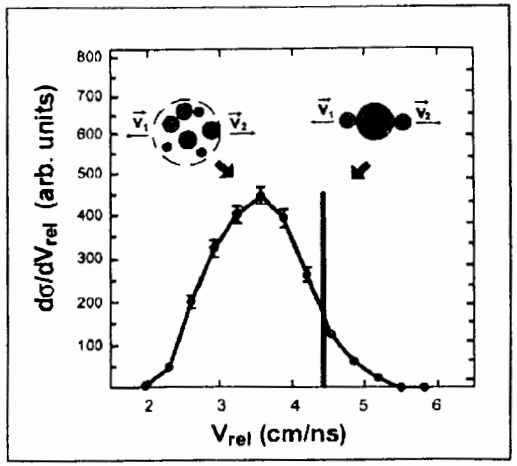


Fig.5. Distribution of relative velocities for the coincident fragments from α + Au collisions measured at correlation angles 150°-180°. The vertical line shows the expected maximum position for fragments evaporation from the nucleus surface. The experimental distribution is shifted to lower velocities, corresponding to the volume distribution of the expanded system.

4. *Investigations with polarized beams*

Detail data were obtained at the Synchrophasotron on the tensor analyzing power T_{20} of inelastic scattering and elastic backward (in the center of mass) deuteron-proton scattering. Inclusive deuteron breakup, *p(d,p)X*, with the emission of the protons at 0^0, is one of the relevant processes to study the high-momentum tail of the deuteron wave function; the backward elastic scattering, *p(d,p)d*, has long been thought to lead to the short distance information as well. Now this quantity is measured for both reactions up to the momenta of nucleons in the deuteron k close to 1 *GeV/c* what corresponds to distances of 0.2 – 0.3 *fm*.

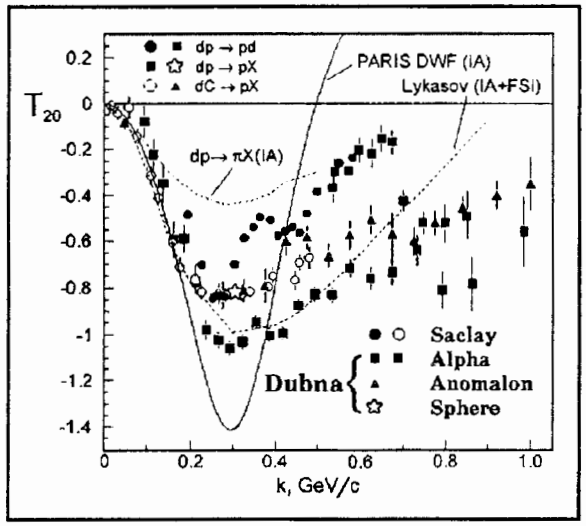


Fig.6. T_{20} data.

This became possible due to the unique beam of polarized deuterons of the highest energy, available today in the world, accelerated at the Synchrophasotron. The data are shown in fig.6. These data demonstrate an unexpected behaviour and need to be interpreted.

The tensor analyzing power T_{20} for the cumulative pion production $d\uparrow + {}^{12}C \rightarrow \pi^{+} (0^0) + \ldots$ has been measured changing deuteron momenta from 6.2 to 9.0 *GeV/c* at a fixed pion momentum of 3.0 *GeV/c* at the SPHERE setup. This experiment is focused on "cumulatively produced pions", which are produced beyond the kinematically nucleon-nucleon collisions (Fig.7). The measured values of T_{20} are in disagreement with the result of our impulse approximation calculation that is based on a single NN → *πNN* interaction and takes into account the internal motion of nucleons in the deuteron.

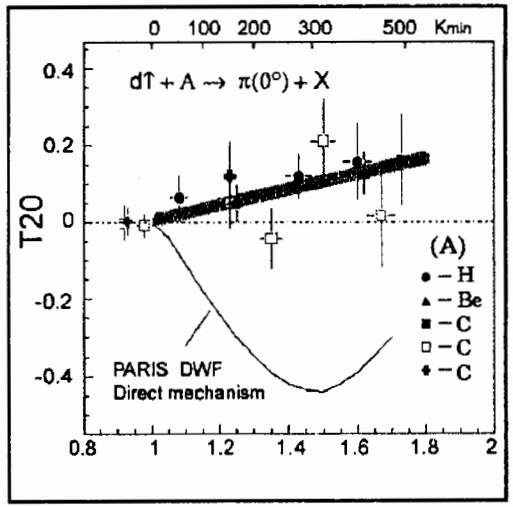


Fig.7. Tensor analyzing power allowed limit for free T_{20} against cumulative number *X*.

Delta-Sigma setup. New results for the *np* spin-dependent total cross section difference $\Delta\sigma_L$(np) at neutron beam kinetic energies of 1.59, 1.79, and 2.20 GeV are presented (Fig.8). Measurements of the $\Delta\sigma_L$(np) energy dependence were carried out at the Synchrophasotron of the Laboratory of High Energies of the Joint Institute for Nuclear Research in Dubna. A quasi-monochromatic neutron beam was produced by break-up of accelerated and extracted polarized deuterons. The neutrons were transmitted through a large proton polarized target.

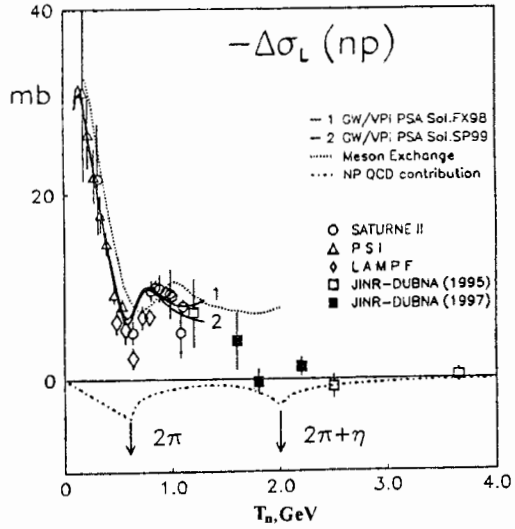


Fig.8. Energy dependence of the -$\Delta\sigma_L$(np) observables obtained with free neutron polarized beams.

The values of $\Delta\sigma_L$ were measured as a difference between the *np* total cross sections for parallel and antiparallel beam and target polarizations, both oriented along the beam momentum. The results at the two higher energies were obtained using four combinations of two opposite polarization directions for both the beam and the target. Only one target polarization direction was available at 1.59 GeV. A fast decrease of $\Delta\sigma_L$(np) with increasing energy above 1.1 GeV, as it was first seen from our previous data, was confirmed. The new results are also compared with model predictions and with the phase shift analysis fits. The $\Delta\sigma_L$ quantities for isosinglet state I=0, deduced from the measured values of $\Delta\sigma_L$(np) and known $\Delta\sigma_L$(pp) data, are given.

5. *Investigations at the Nuclotron internal beam*

In the processes of investigation is a target fragmentation into two cumulative protons with help of the SKAN setup at the internal beam of the Nuclotron (Fig.9). The goal of experiment is measuring of transfer dimension of nucleus-nucleus interaction region. Method is the measurement correlation of cumulative protons, emitted at small relative momentum. Experimental data are obtained for reactions:

p + C → p + p + ...,

d + C → p + p ... at momentum 5.5 GeV/c and

d + C, Al, Cu → p + p ... at momentum 7.6 GeV/c.

The transfer sizes of the proton emission region are obtained for pC and dC reactions (Fig.10).

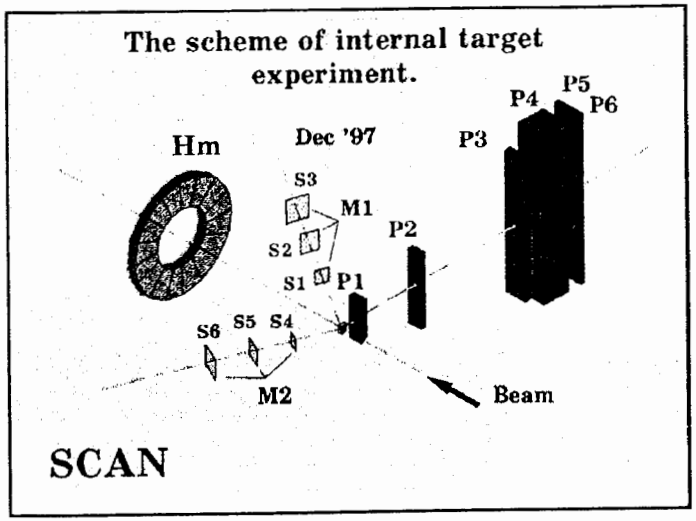
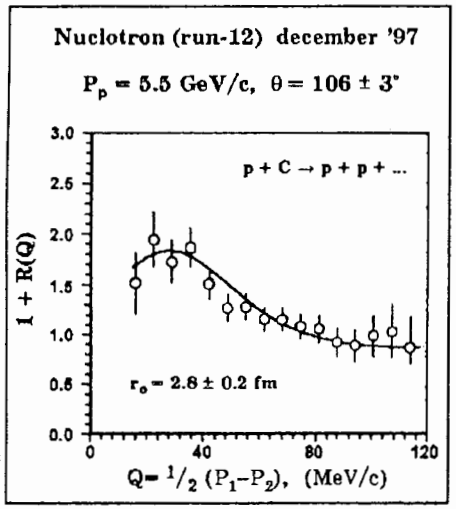


Fig.9. Design of the scintillation spectrometer SCAN for study of transfer dimension of nucleus-nucleus interaction region.



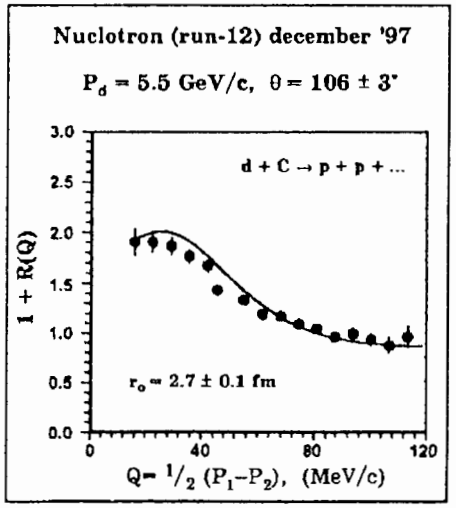


Fig.10. The correlation functions of cumulative protons emitted at small relative momentum Q for pC and dC reactions.

6. *Asymptotics in Relativistic Nuclear Physics*

The principles of symmetry and self-similarity have been used to obtain an explicit analytical expression for inclusive cross sections of production of particles, nuclear fragments and antinuclei in relativistic nuclear collisions in the central rapidity region (y=0). The result is in agreement with available experimental data. It is shown that the effective number of nucleons participating in nuclear collision decreases with increasing energy and the cross section tends to a constant value equal both for particles and antiparticles. The analysis of the obtained results makes it possible to predict asymptotic behaviour of production cross section of particles, nuclear fragments and antinuclei. One example of such prediction is presented in fig.11 from Dubna up to LHC energies.

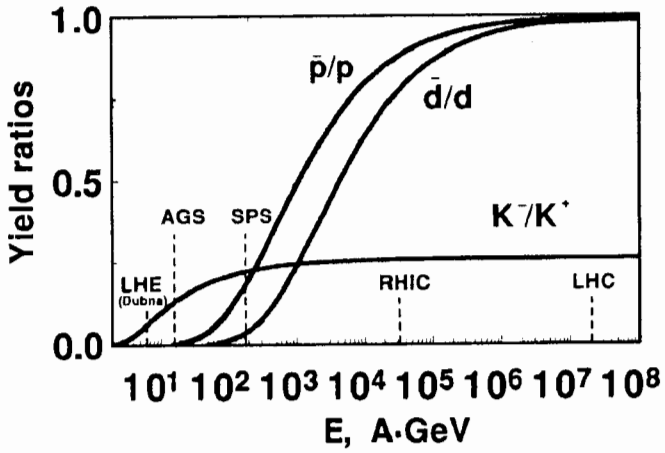


Fig.11. Predictions of the production cross-section ratios for antiparticles to particles versus laboratory collision energy.

7. *Cooperation with Scientific Centres of Russia*

DELTA Project (INR RAS - JINR). /P.N. Lebedev Physical Institute RAS, Institute for Nuclear Research RAS et al./ The physics goal of measurements in 1999 – 2001 is to search for polarization phenomena of π^0 and η- meson production in **NN** collisions with a polarized beam and a target (probably, deuteron production in the final state) at energies of 1-2.5 GeV.

Recent advances in accelerator and beam-target technology at JINR have opened up new possibilities in nuclear physics. Using slowly extracted polarized deuterons, available at the Synchrophasotron-Nuclotron accelerator complex of LHE, JINR polarized quasi-monochromatic neutrons and protons of momenta from 1.1 to 4.5 GeV/c were generated. The mean value for neutron beam polarization $|P_B(n)|$ = 0.535±0.009. In addition, for the JINR physics program, the Argonne-Saclay frozen spin proton polarized target was updated and installed on the LHE polarized neutron beam line.

The experimental setup ensures a high-resolution and high-aperture detection of neutral π^0 and η- mesons with an energy of 100 MeV and more, and charged particles **(π^+,p,d)** within 40-300 MeV. These are the following main units: a 300 channel Cherenkov spectrometer consisting of two blocks (**CH1** and **CH2**) each based on 150

lead-glass prisms and a telescope of detectors (**ΔE-E** arm) based on plastic scintillators and used to identify charged particles and to measure their energy by the method of repeated ionization loss measurements (Fig.12).

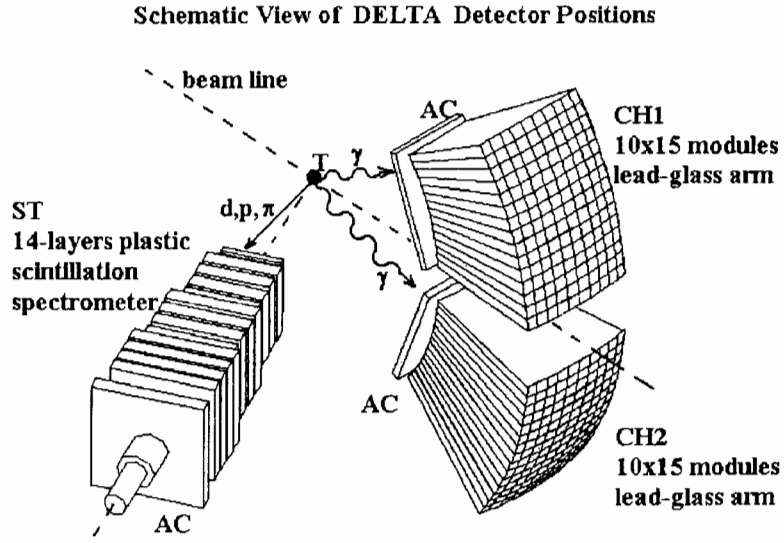


Fig.12. A schematic view of the DELTA detector positions. T- polarized proton target PPT; CH1,CH2 - two arms of the Cherenkov lead glass spectrometer for two gammas after neutral meson decay measurements, ST - 14-layer fiber-optics scintillation telescope for multi-ΔE measurements of charged particles; AC - anticoincidence detectors.

THE RESEARCH PROGRAM of the experiment is the following:

Interest in the π^0 production follows from the fact that $NN \to NN\pi$ is the dominant inelastic process in NN interactions, and a relatively large momentum transfer (~360 MeV/c at threshold) to the nucleon allows one to probe a short-range part of the NN interaction. Since the pion can rescatter on the nucleon before its emission, it is also possible to study the off-shell properties of the πN interaction. Furthermore, the reaction $NN \to NN\pi$ can serve as a testing ground for theoretical models of meson production which can be applicable to the production of such heavier mesons as σ and ω. The role of different pion production mechanisms can be investigated in the reactions with a polarized nucleon (in addition with $NN \to \pi^0 d$).

A possible existence of hidden strangeness in the nucleon has recently become one of the most controversial problems in nuclear and hadron physics. Some analyses of the pion-nucleon sigma term and polarized deep-inelastic lepton-proton scattering indicate a significant role of strange see quarks in the nucleon structure. Therefore it

would be interesting to study the process of η-meson production in *pp* and *np* collisions with polarized nucleons. In this model, some double polarization observables are very sensitive to the hidden strangeness content of the proton. The value of η-production cross section is due to the transfer of a ss component from the nucleon to the final η. For a model-independent theoretical analysis of this problem, it is necessary to measure a relative role of singlet and triplet contributions to this reaction in polarized nucleon collisions.

MARUSYA Project. /B.P. Konstantinov St. Peterburg Nuclear Physics Institute RAS, Russian Research Centre "Kurchatov Institute" et al./ The experimental setup consists of magnetic channel, system of beam diagnostics and monitoring, beam counters, spectrometric detectors, multiwire proportional chambers, threshold Cherenkov counter, multiplicity detector, zero degree hadronic calorimeter, electronics and data acquisition system, graphic representation and data analysis apparatus and target device. The main parameters of the spectrometer are: acceptance 50 - 80 mstr.; momentum resolution $\Delta P/P \sim 0.5\%$.

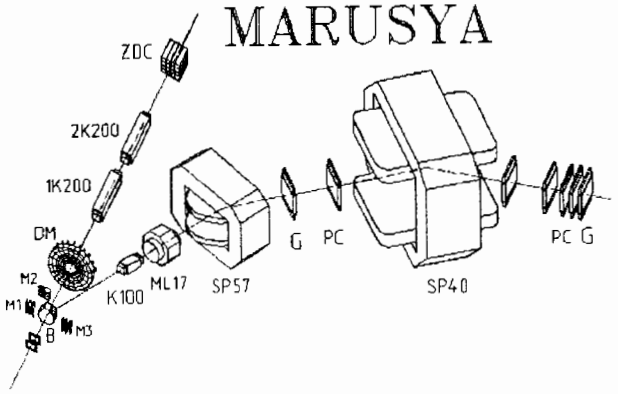


Fig.13. Schematic view of the MARUSYA setup.

THE PHYSICS PROGRAM proposed for the investigated range of the energy of nuclear collisions (2-6 GeV/nucleon) also implies the study of the nuclear matter phenomena at a high baryon density and relatively low temperature. These phenomena are planned to study via "side-splash" and "squeeze-out" effects, i.e. effects depending on the mass of an emitted fragment. These experiments were performed at energies of about 1GeV/nucleon and their interpretation in the framework of thermodynamical approach allowed to determine the ratio of the energy of "the squeezing" to the "thermal" energy.

LEADING PARTICLES Project. (SMS MSU). /Lomonosov Moscow State University D.V. Skobeltsyn Institute of Nuclear Physics et al./ In the framework of the programme of the investigation of interaction of polarized protons with nuclei (begun in 1992-1998) we propose the experimental investigation of single-spin asymmetries of polarized proton scattering on intranuclear nucleons to be compared with the analogous characteristics for the scattering on free nucleons in the region of energies 1-4 GeV. The main subject of measurements is vector analyzing power (a.p.) $A(\theta)$, determined as normalized on $P^{\rightarrow}$ left-right asymmetry. The reaction of the polarized proton scattering on carbon target is considered. Existing experimental data (including preliminary ones, obtained at SMS MSU experimental installation) permit to assume an indication to significantly different reduction of a.p. for the scattering on intranuclear nucleons in comparison with the one on free nucleons, and strong dependence of this effect on energy. Proposed experiment has to confirm or to reject supposed phenomenon and to answer the question about its physical nature. As hypotheses of reduction mechanism the next ones are considered: • relativistic effects for bounded state of target nucleon; • nucleon clusterisation in nuclei; • excitation of non-nucleon degrees of freedom.

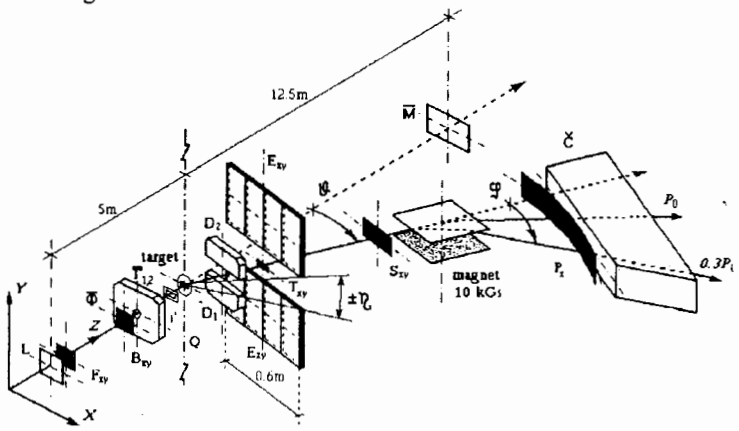


Fig.14. Schematic view of the Scintillation Magnetic Spectrometer MSU setup.

In the November 1999, at Synchrophasotron according to demand of the groups «FIAN» at first was conducted **the experiment for photoemulsion** nuclear irradiation by the beam of the nuclei ^3H and ^6He. The accelerator run in the regime nuclei acceleration ^6Li, forming via laser ion source in ration Z/A = ½. The ion intensity ^6Li at the Synchrophasotron ring was to 10^8 ions at acceleration cycle at value pc/z = 5,34 GeV. The second-order ion beam ^3H and ^6He was formatted on the magnetic channel.

During the total work time (16 hours) was formed the beam of the second-nuclei and determined its parameters, and also conducted the irradiation of three cassettes with nuclear photoemulsion for next viewing and determination of physics parameters in

nuclei interaction ^{6}He with photoemulsion nuclei with impulse 8 GeV/c. Expecting statistics for nuclei interaction helium-6 is over 100 events in emulsion material. This experiment is the first stage in research of interaction the light relativistic nuclei, possessed exotic structure, with emulsion nuclei. These works were initiated and supported by large collective from Russia and also by the scientists from the other countries (Egypt, China, Slovakia, etc.).

8. Applied research

Using the Synchrophasotron - Nuclotron accelerator complex beams there were following applied research:

- radiobiology and space medicine
- influence of nuclear beams on microelectronic components
- transmutation of radioactive waste products
- aspects of the electronuclear method of energy generation and so on.

The GAMMA2 setup was used in the run performed on proton beams of the LHE synchrophasotron at the beginning of November. The laboratories of JINR (LHE, LNP, LCTA, DRRR, LNR), Germany, France, Greece, China, Australia and the USA are taking part in experiments on the GAMMA2 setup. Works on GAMMA2 are aimed at studying neutron yields and measuring the transmutation cross-sections of radioactive isotopes on heavy targets irradiated with relativistic nuclei.

Basic tasks of the run are the following:

- expansion of a set of targets irradiated with relativistic ions;
- expansion of a number of radioactive isotopes obtained as wastes from nuclear stations to measure transmutation cross-sections ;
- measurement of neutron yields for low energy primary beams (rather important for designing electronuclear setups), where a serious discrepancy of the results obtained by different experimental groups (C. Rubbia, M. Zucker) is observed.

The measurements in the run were carried out using proton beams of 0.5 and 1.0GeV kinetic energies on lead, mercury and uranium targets. The transmutation cross-sections of Am, Pu, Np and I radioactive isotopes were measured during the run.

Except for an incomplete set of statistics for a 0.5 GeV energy, the suggested program of the run was implemented. This is explained by the characteristics of the synchrophasotron for low energies and a limited time of the run. An increase in statistics at 0.5 GeV can be easily reached in a run on the nuclotron in 2000.

Now we prepare new project ENERGIYA-TRANSMIUTATSIYA for continuation of these investigations at the Nuclotron. In realization of this project will participate physicists from many JINR Member States.

A new user of the LHE beams is the ENERGIA-YADRO enterprise working in the framework of the S.P. KOROLEV ENERGIA Space-missile Corporation. The enterprise carries out experiments on the exploration of the cosmic ray influence on microelectronic components. The ever-growing role of microelectronics in control the MIR space station of gives a special topicality to the program. The application of the Nuclotron energy beam makes it possible to improve reliability of space research equipment.

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