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STATUS REPORT ON JINR ACTIVITIES

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1. INTRODUCTION

The main fields of the JINR investigations are theoretical physics, elementary particle physics, relativistic nuclear physics, physics of low and intermediate energies, heavy ion physics, nuclear physics with neutrons, condensed matter physics, radiobiology and nuclear medicine, experimental instruments and methods.

After the disintegration of the USSR the membership of JINR underwent the following changes: The majority of East European countries continue to be Member States of our Institute and Germany stays as an observer. Soviet Union republics which became independent states of the CIS (Common-wealth of Independent States) entered JINR as new members.

The participation in the Institute can be realized in different forms: on the basis of membership, bilateral and multilateral agreements to perform particular scientific programmes, making JINR more and more open. New collaborating countries are welcomed to join JINR.

2. JINR SCIENTIFIC ACTIVITY AND BASIC FACILITIES

The major facilities of the Institute for experimental investigations are the nuclotron, synchrophasotron, phasotron, U-400 and U-400M cyclotrons, IBR-30 and IBR-2 neutron reactors.

2.1 *Nuclotron*

Fig. 1: The fragment of NUCLOTRON.

The new superconducting accelerator Nuclotron was put into operation three years ago [1]. It is able to perform a wide programme of research in relativistic nuclear physics both as asymptotic regime (an accelerated nuclei energy is higher of 4 GeV/u) and transition regime (less then 4 GeV/u). In the asymptotic regime the nucleons cannot be considered as quasi-particles of nuclear matter and the influence of quark-gluon degrees of freedom in interactions of hadrons and or nuclei should be observed.

The Laboratory of High Energy Physics of JINR was a pioneer in designing and constructing of the first, low cost accelerator based on low- field iron dominated superconducting magnets. The 6A GeV Nuclotron was built during five years. The main equipment of magnetic and many other systems were fabricated by JINR workshops without resource to industry.

Table 1: General parameters of the NUCLOTRON.

Parameter	Design	Achieved
Accelerated particles	1<Z<92	p, d, α, ^{12}C, ^{84}Kr
M ax Energy, *GeV/amu*	6 (A/Z =2)	3.2
Magnetic field, *T*	2.0	1.2
Injection energy, *MeV/amu*	5 (A/Z =2)	
Beam intensity: α	~$5\cdot10^{9}$	$8\cdot10^{8}$
Deutrons	~$1\cdot10^{11}$	$1,2\cdot10^{10}$
Vacuum pressure, *Torr*	$1\cdot10^{-10}$	$1\cdot10^{-10}$
Slow extraction	under manufacturing	
Flat top duration at maximum energy, *s*	10	10 (0,2*GeV/amu*) 5 (2,2 *GeV/amu*)
Repetition frequency at zero flat top, *Hz*	0,5	0,2
dB/dt, *T/s*	1,3	1,0

The Nuclotron ring of 251 m in perimeter is installed in the Synchrophasotron technological tunnel. The total «cold mass « of the magnetic system is about 80 tons (see Table 1). Cooling of the system down to 4.5 K takes about 90 hours. The cooling system was designed taking into account the fast cycling mode of the Nuclotron operation (up to 0.5-1.0 Hz), which is a specific feature of this superconducting accelerator The injection complex is being developed consisting of a buster, linac and ion sources. This complex will allow one to accelerate nuclei from hydrogen to uranium with the intensity from 10^{13} to 10^{8} particles per pulse respectively in the energy range of 6-7 *GeV* per nucleon. Polarized deutron beams are foreseen.

Research programme on NUCLOTRON is executing and one of recent new results is studying of cumulative protons production [2]. Experiment was performed on internal deuteron 2 *GeV*/nucleon beam of NUCLOTRON with the carbon target on orbit. It was found that in the cumulative proton production the transversal dimension of the interaction region for incoming deuterons is noticeably larger than for incoming protons.

2.2 Synchrophasotron

Synchrophasotron is an accelerator of 10 *GeV* protons put into operation in 1957. In the 70's the acceleration of nuclei heavier than hydrogen was accomplished in the broad energy spectrum from a few hundred *MeV* up to 4.5 *GeV* per nucleon. Average densities of beams range from 10^4 to 10^{11} ion/cm^2s depending on the atomic number of accelerated nuclei and experimental requirements. The synchrophasotron beams attracts physicists from all the world. Wide international collaboration SPHERE has recently performed the study of the nuclear matter at short distances in experiments NTS with polarized deuteron beams to separate contribution from S and D components in the deuteron wave function.

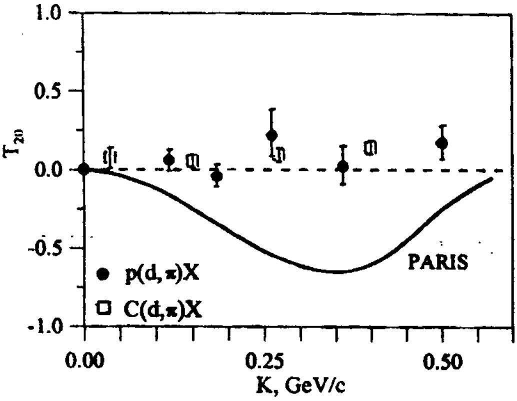


Fig. 2: The Measurement of the Tensor Analysing Power T_{20} in Inclusive Polarized Deuteron Fragmentation into Pion at Zero Angle

In order to clarify the reactions mechanism and the structure of non-nuclear degrees of freedom the new experiment with the polarized deuteron fragmentation into cumulative hadrons has been performed [3]. The observed difference of model to experiment datas is especially large for K=0.2 *GeV/c* (Fig. 2) where it would be natural to expect the manifestation of non-nucleon degrees of freedom in the deuteron wave function.

2.3. Phasotron.

Phasotron is an accelerator of 680 MeV protons. It was put into operation in 1949, reconstructed in 1984 and represent the oldest basic facility of JINR. At present the phasotron is not borne by the JINR budget. The ten beam channels are available at this machine which are used to carry out experiments with pions, muons, neutrons and protons. The five secondary beams are designed to carry out medical investigations. The intensity of the extracted proton beam is 2 mkA (see Table 2). The research programme at the phasotron includes low energy proton-nuclei interactions, mu-catalysis physics. Radiochemistry and applied physics (including cancer therapy, proton, pion, meson beam, radioisotopes etc.) are currently the noticeable part of phasotron programme.

Table 2: The parameters of the accelerated beam

Parameter	Present value	To be achieved
Energy, MeV	665	
Pulse duration, μs	20	
Repetition rate, Hz	250	
Duty factor	1/200	
Extraction efficiency	60%	90%
Average intensity (protons/sec)	2×10^{13}	3×10^{14}

On purpose to increase the intensity of the phasotron accelerated proton beam in 10-20 times, a proposal on creature of external injection of the beam into the accelerator centre was developed [4].

The very important and promising mu-catalysis investigation was performed in 1995-1998 by the Dubna-Arzamas-16 collaboration. Unique results in unexplored before area of tritium density, temperature and concentration for double D+T and triple D+H+T gas compositions were obtained. The new measurement method and appropriate electronics allowed to measure directly the primary catalysis constant – the muon-helium sticking coefficient. There are about 400 neutrons per muon.

2.4. IBR-2 Fast Reactor

The fast pulsed reactor IBR-2 is used for condensed matter research. Neutron scattering investigations in the field of condensed matter physics are conducted at IBR-2 using four main experimental techniques: diffraction, small-angle scattering, inelastic scattering, and polarized neutron optics.

IBR-2 is a pulsed reactor with average thermal power 2 MW and peak power in pulse 1500 MW. Power pulses have a frequency of 5 Hz. By 2002, the principal parts of the reactor IBR-2 will have their radiation resource exhausted and will have to be replaced. The programme for upgrading the IBR-2 reactor has been elaborated for 10 years (1996-2005) and will be executed in three directions: improvement of the reactor parameters, increase in nuclear safety and reliability of the reactor, updating of the reactor systems.

2.5 IBR-30+LUE-40.

IBR-30+LUE-40 is a pulsed neutron source consisting of old pulsed reactor IBR-30 and electron 40 *MeV* linac LUE-40. The average heat power of the reactor is 10 *kW*, the pulse power is 150 *MW*. It generates neutron pulses with frequency about or less than 100 *Hz* and duration of 4.5 *μs*. The total neutron yield is 5×10^{14} *n/s*, the flux of fast neutron at surface of

...core is about 10^{12} n/cm^2s.

It allows one to carry out a wide spectrum of investigations including study of P- and T-symmetry violation of fundamental interactions in nuclei, an electromagnetic structure of the neutron and some ... problem of fundamental nuclear physics.

The 1995 «effect» is a difference in a 0 angle scattering: of $\vec{I}_n, \vec{P}_n$ and of $\vec{S}_n, \vec{P}_n$ systems, where . $\vec{P}_n$ - neutron momentum, $\vec{S}_n$ - spin of neutron, $\vec{I}_n$ - ... of nuclei.

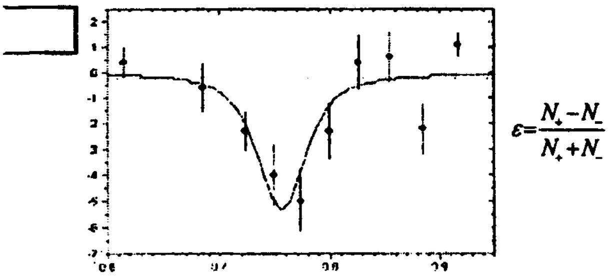


Fig 3. ^{139}La Transmission effect (0 angle scattering).: Results of $(\vec{I}_n \vec{P}_n)$ measurement at IBR-30

At IBR - 30 the first measurement of the P-odd effects with polarized nuclei was performed. The main results are illustrated at the Fig 3. Joint analysis of $(\vec{S}_n \vec{P}_n)$ and $(\vec{I}_n \vec{P}_n)$ data permits to determine *for the first* time the matrix element of weak N-N interaction for ^{139}La.

2.6 *IREN.*

IREN (Intense Resonance Neutron Source) is a project aimed at constructing a high-flux pulsed neutron source to carry out investigations with resonance neutrons.

The facility will comprise a modern 200 *MeV* electron linac [5] and subcritical plutonium booster having neutron multiplication coefficient 30. The pulse rate is 150 *Hz*, duration 0.4 μs, total neutron yield ~10^{15} ... The research programme for the IREN includes investigation of P- and CP-violations in slow neutron interaction with nuclei and other fundamental nuclear physics topics.

2.7 *U- 400 and U- 400M*

At present the complex of two heavy ion cyclotrons is an experimental base of the Flerov Laboratory of Nuclear Reactions. It is well-known the ... element which was discovered at this laboratory ... named Dubnium in honour of Dubna.

U-400 is a heavy ion isochronous cyclotron ... The range of accelerated nuclei is ... energy is 650 $Z^2/AMeV$, beam intensity ...—10^{14} *ion/s*.

U-400M is an isochronous cyclotron put into operation in 1991-92 to accelerate heavy ions. It produces ion beams of atomic masses from 4 to 100 and maximum energy up to 25 *MeV/nucleon* and beam intensity from 10^{12} up to 10^{14} *ion/s*. It is designed to operate in the cyclotron U-400+U-400M complex and allows to accelerate ions from hydrogen up to uranium in the range of energy 120—20 *MeV* per nucleon respectively with the average beam intensity of 4×10^{13}—10^{11} *ion/s*.

The main areas of research include synthesis of new elements, investigation in the chemistry of new transferium elements, and studies of the radioactive decay of heavy nuclei far from beta-stability.

On the U-400M accelerator there was recently obtained quite a new result. In the study of the reaction of 2 neutrons transfer from ^{6}He to ^{4}He the di-neutron bounded state in the nuclei field have been detected for the first time [6].. Secondary ^{6}He was registered in CMS angular interval of 10—160^0. The observed effect is the increase of ^{6}He yield at the angles $\Theta > 100^0$.

The experiment is expected to be continued with another configuration which provide a detection of low-energy ^{6}He in angular range more than 160 degrees.

Another very interesting achievement is that during 1998 experiment there was synthesized the most heavy of known nuclei $^{283}Z_{112}$ [7] in the reaction chain

$U + ^{48}Ca \rightarrow (compound) \rightarrow 3n + ^{283}Z_{112}$.

3. ACCELERATOR INTERNATIONAL COLLABORATION

A fruitful scientific co-operation is being held with CERN, especially in the last years, as well as with many physics laboratories in USA, France, Germany, Italy, and other countries. Co-operation with Nuclear Scientific Centre of Peking University (China) is being developed, a Protocol on collaboration has been signed between JINR and the Institute of Modern Physics of Academia Sinica.

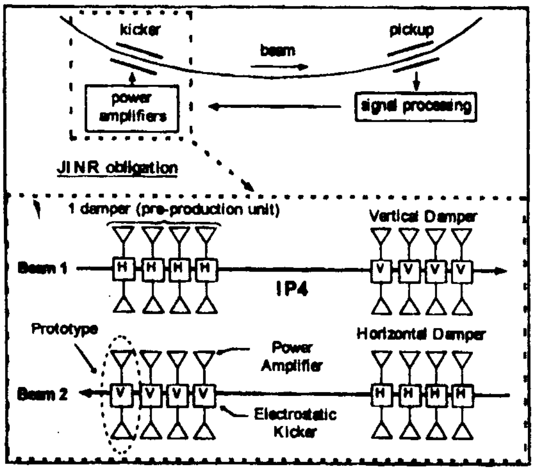
The JINR Directorate is ready to maintain constant and long-term contacts with laboratories of other countries as well.

3.1. JINR- CERN collaboration- LHC damper[8]

The main goal of the participation of JINR in LHC Project to manufacture a Powerful amplifier and a kicker of the Transverse Feed-back System for LHC. The JINR obligation is indicated at the transparent by dote lines.

At JINR a special power device was proposed to design for regimes of amplification. This allows to investigate and use different types of damping (including non-linear "bang-bang" and "logical" ones). Joint experiments CERN-JINR on SPS (SL RF) have shown high effectiveness of this solution. emittance growth.

The peculiarities of the Collider- complicated beam structure, permissible emittance grows after injection less than 2.5%, etc. – require high power and large bandwidth of supply amplifiers, as one can see at the table 3.



.Fig 4 Transverse feed-back system of LHC.

Table 3: Requirements on the power amplifier.

Amplitude of the signal on the kicker	±7.5 kV
Average power per tube	16 kW
Bandwidth	10^{-3}÷3 MHz (3÷20 MHz - dB/octave)

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3.2. Tesla

Regarding the TESLA project the JINR activity in 1996--1998 consists of: elaboration of conceptual design for an X-ray free electron laser at a Linear Collider; elaboration of conceptual design for a second interaction region for γ-γ and γ-e collisions at a Linear Collider (the upper figure at the transparent)[9]; Parameter study of the Vacuum UltraViolet free electron laser at the TESLA Test Facility; development of a two-stage FEL scheme for the 6 nm option of Self Amplified Spontaneous Emission (SASE) FEL at the TESLA Test Facility [10]; conceptual design of the Regenerative FEL Amplifier at Phase I of the TTF FEL project [11].

3.3. Fermilab.

An application of traditional scheme of electron cooler to cooling of heavy particles of a few GeV energy meets obvious problems of generation of high intense electron beams at energy of several MeV. One can avoid these problems using an electron beam circulating in a storage ring [12].

So called "modified betatron" is one of possible schemes of the storage ring with cooling electron beam. Its application to the electron cooling is under investigation in JINR in collaboration with Fermilab having the concrete goal to construct the cooling system for Fermilab Recycler. The prototype of the system is being manufactured in JINR.

3.4. Two Beam Accelerator.

Two possible applications of millimeter-wave free-electron masers (FEM) for Two-Beam Accelerators have been studied at JINR: as a source of RF-power for high-gradient accelerating structures; as a drive-beam buncher (according to JINR- USA co-operation on investigations of fundamental properties of the matter).
A FEM-oscillator was developed with a high efficiency and very narrow radiation spectrum width in single-mode regime [13]. It allows using the FEM-oscillator as a RF source for high-gradient accelerating structures of electron-positron colliders. Preliminary experiments on beam bunch observation inside the FEM-oscillator were fulfilled recently. At the transparent you can see a scheme of the experimental set-up and a streak-camera image of bunched electron beam.

4. DESIGNING

4.1. Tau Charm Factory.

The project for an electron - positron storage complex is currently studied at JINR [14]. It will provide significant contribution to the Institute's traditional research activities: elementary particle physics, nuclear physics, condensed matter physics, and applied investigations. The project involves: a high resolution neutron source (IREN), a Tau Charm Factory (TCF), and in a far future an 8-10 GeV positron (electron) storage ring (NK-10).

The Tau Charm-Factory is a project of a new accelerator complex to comprise an electron-positron collider with an energy of 1.7—3 *GeV* in each beam and an injection system. The main parameters of the Tau Charm Factory are depicted in the table 4 .

The research programme will include the study of Tau-lepton and τ-neutrino physics, τ-charmonium spectroscopy, CP violation, charmed baryon physics and meson spectroscopy.

4.2. Synchrotron Light Source.

The design of specialized synchrotron radiation source (8—10 *GeV*, NK-10) is under consideration. Presently a source of synchrotron radiation for the energy of 1.2 GeV as a more modest part of designed JINR storage ring complex is being studied [15]. The source has to ensure conditions for carrying out experiments on the condensed matter physics with use of hard X-ray, vacuum ultraviolet radiation and coherent

Table 4: List of Main Parameters of Tau-Charm Factory

		Standard scheme	Monochr. scheme	Cross.angle scheme
Beam energy, GeV	E	2.0	2.0	2.0
Luminosity, $cm^{-2}sec^{-1}$	L	10^{33}	$0.9 \cdot 10^{33}$	$3.5 \cdot 10^{33}$
C.M. energy resolution, MeV	S_W	1.9	0.14	1.7
Circumference, m	C	377.8	377.8	377.8

...ed radiation with the re-tuning frequency. ...imum photon fluxes are of $1.4 \cdot 10^{13}$ (bend) and 4

5. CONCLUSIONS

This short review presents only some general ...ation about the JINR accelerator research ...ity. It should be noted that the scientific and ...ological potential in this area of research is ...ined not only by a wide variety of academic, ...rsity and civil atomic energy science but also ...ful industry of the participating countries and a ...et of FSU military defence nuclear Institutions, ...ly involved nowadays in conversion programmes. ... potential is rather high. It allows one to state that ... scientists may and will be active participants of ...'s various largest projects. The industry of the ...-countries may be involved in implementation of ...ific orders.

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