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Status of Neutron Complex of INR RAS

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Abstract

The neutron complex of INR RAS consists of two sources of neutrons, beam stop, lead slowing down spectrometer and solid state spectrometers. The description of objects and their condition, the program of planned researches, co-operation with other institutes of the Moscow Region, progress reached for last two years are introduced in the article.

1. Introduction

The Moscow Meson Factory (MMF) of the Institute for Nuclear Researches of the Russian Academy of Sciences (INR RAS) provides experimental studies in many directions of modern physics and applications.
The basic objects of the MMF are:

- Linac of protons and H^-.
- Complex for production of medical isotopes at a mark 160 MeV.
- Experimental complex of MMF, including:
  · a building and facilities,
  · a storage ring,
  · a system of distributing of a beam,
  · power sources,
  · a radioactivity protection,
  · a cooling system, water treating and special ventilations.
- Multi-purpose neutron target complexes of MMF including.
  · the trap of a beam of protons,
  · a spectrometer on time of slowing-down in lead,
  · an Intensive pulse neutron-source,
  · multi-purpose target complex in the second cell of a neutron source,
- Equipment of neutron channels and spectrometers for researches in the field of physics of a condensed state and nuclear physics:
  · a universal multifunction spectrometer of INR-Physical Institute RAS,
  · a spectrometer of RSC 'Kurchatov's Institute",
  · a spectrometer of Institute of a Crystallography of RAS,

· other spectrometers and proposals on the equipment of neutron channels,
· TOF spectrometers for researches in nuclear physics.

- Meson target and reference directions of researches.
- Spectrometer for research of exotic nuclei (experiment МАДИС).
- Complex of proton therapy.

The current situation at these objects is discussed below.

2. High current Linear accelerator of hydrogen ions of MMF.

The Injector Complex consists of two injectors of H^+ and H^- to energy 750 keV on the base of accelerator tubes and high-voltage pulse transformers. At the output of accelerator tubes the pulse current is 100-200 mA (with the project value 100 mA) and frequency of repetition 50 Hz. A system of three rotary magnets provides with coincidence of these beams at one point of the final part in the injector channel. At this part, in addition to the initial project, a booster accelerating RFQ section is deposited to accelerate the beams from 400 keV to 750 keV at frequency 198.2 MHz. The RFQ section [1] gave a possibility to increase reliability of injectors' work at energy 400 keV up to the maximum repetition frequency of injector beam pulses 190 μs avoiding saturation of iron in the high-voltage pulse transformer. At the output of the RFQ each micropulse of the beam includes about 3.6×10^4 bunches with a duration of the order of 0.8 ns. Coordination of 6D phase volume of the beam with the acceptance of the Linac is done by a system of four quadruple lenses and a storage at frequency 198.2 MHz. To increase the capture at the input of the RFQ the second storage is installed at the same frequency.

The coordinated beam is injected into the initial part of the Linac, which consists of five resonators with drift tubes operating at the frequency 198,2 MHz and accelerating hydrogen ions till energy 100.1 MeV. At this energy the beam is injected into the main part of the accelerator, which includes 27 accelerating resonators. These resonators have accelerating structure with disk and washer and operate at 991 MHz. They are gathered to three sectors of 9 resonators with energies at the output 247.32 MeV, 423.04 MeV and 602.03 MeV. The high-frequency feeding of resonators at the initial part is given by 6 triode generators, and at the main part – by 32 booster accelerating RFQ section generators with a pulse power 5 MW and 4.7 MW.

At energy 160 MeV there is an intermediate injection of a bunch in an accumbent hall with the trap on 0.1 mA of a mean current. The focusing of an accelerated beam is done by 196 quadrupole lenses in drift tubes and 120 quadrupole doublets between accelerating sections of a main body of a booster. The mean vacuum in an accelerating channel is 5×10^{-8} mm Hg. Overall length of the Linac is 450 m. The design value of a mean output current of a booster is 0.5 mA. Maximum rating of space factor of a beam is 1.9 %.

Now adjustment and exploitation of the Linac are conducted with usage of the injector of protons. The tests of the injector of ions H^- with a beam are conducted also.

During instalment adjustment the proton beam is accelerated up to energy 500 MeV. In the present moment the energy is limited by quantity of available powerful amplifying klystrons КИУ-40 and capabilities of the firm - supplier. The staff of the Linac conducted adjustment in a nominal mode of the subsequent resonators with usage of a removed klystron.

The automated system for measurement of ions losses is put into action, that has allowed to lower integral losses to a level 0.1 % and has enabled to increase a mean current of protons up to 120 μA. The maximum value of an impulse current at energy 500 MeV reaches 20 μA.

The slide control of energy of an accelerated beam is run in at a measurement accuracy of energy by a time-of-flight method ±0.2 %. The unique device [2] for measurement of longitudinal density of fragments in a bunch and absolute value of speed of a beam, being

know-how of the INR RAS, is successfully used in the Linac of MMF. Such designed by specialists of our institute devices are built for a number of foreign labs in Germany, USA, Japan and CERN.
The conditioner of short impulses of the beam with duration from 0,1 mcs up to 1,0 mcs is put into operation and used in time-of-flight experiments with neutrons on the basis of delay lines allocated in an injecting channel.
The channel for injection of a beam with energy 160 MeV to the target for isotopes production [3] is designed and constructed. With the help of two focalising doublets correcting magnets and matching resonator, which compensate power dispersion of particles, on the isotope target the beam with dimensions 20 mm in horizontal direction and 17 mm in vertical direction, keeping 98 % of a mean current 100 μA is formed.
The nuclear physics experiments are carried out in a temporary experimental zone at the end of the tunnel of the Linac at energies from 160 MeV up to 423 MeV at a mean current of the beam up to 1 μA and duty factor 1.7 %.
In 1999 and in the first half-year of 2000 the cycle of activity of the Linac consisted of 8 day-night sessions by duration from 2 up to 6 weeks each. The general burn-time with a beam in 1999 has compounded 2305 hours.

3. The Experimental Complex of the MMF

The Complex includes
- a tunnel, which is connecting Linac with a hall,
- an experimental hall with the sizes 60×130 m^2 and two cranes by bearing capacity 32 tons,
- an addition, where physics - experimenters have places with processing instrumentation, technological staff and technological systems ensuring functionability of the equipment and trial types in a hall.

The program of researches on the MMF was formulated in activity [4]. The course of its construction was repeatedly discussed on conferences and seminars.
From a beginning of construction of the Experimental Complex about 20 years had passed. For this time the program has changed also accents, which are shifted in area of fundamental and applied researches with neutrons. The channels of a proton beam and installations of a Neutron Complex are now built - on.
For beam transport to the installations the nonperishable radiation resistant equipment is built - on.
The first channel of protons on the basis of this equipment was built in 1992 in the beginning of the tunnel connecting the Linac to the hall. Its successful start has shown functionability of the made equipment. At the end of a channel the beam with a diameter 3 mm with energy up to 350 MeV was obtained. On the beam a number of physical installations was located and the physical outcomes before start of the basic beams in an experimental hall are obtained [5].
Now 253 m of a proton channel for beam transportation to the complex of a pulse neutron source are built - on and launched.
In a structure of the beam channel the automated management systems of parts of the channel, measurement of parameters of the beam and losses work. In the channel 24 beam profile recorders with thirty two channels with a step of 2 mm and 4 mm, 60 ionization chambers for measurement of beam losses at its transportation and set-up are established.
The first channel of the beam transportation was launched in 1995 on the trap of the complex of the neutron source. In the channel the place in front of the trap of the beam for realization of experiment on research of meson--x-ray - spectra in πp, πD and mild mesonic atoms on a two-crystalline diffraction spectrometer is stipulated. The geometrical parameters of the beam

in the place of targets for this installation, measured at beam transportation to the trap, confirm the requirements of experiment.

In 1997 the pulse neutron source was put into operation. The spectra of neutrons are obtained and the functionability of all system is demonstrated. On the basis of experimental transport of the beam the optimal mode of operation with a proton beam permitting without input of padding transformers to convey the beam from the Linac with energy up to 600 MeV to all installations of the experimental complex is designed.

Preparations for start of a proton channel to a 100-ton spectrometer by time of slowing down in lead [6] are now almost completed.

The equipment of the storage ring of protons is largely made [7]. The storage ring is intended for maintenance of a Neutron Complex by qualities indispensable for its successful activity in XXI century. To the present time all problems, bound with injection of the beam and fast extraction, are resolved. The electromagnetic equipment is done and ready to mounting, the vacuum chambers of magnets, kicker-magnet for a fast extraction are made. At maintenance of sufficient financing there are no insuperable problems in manufacturing of the remaining equipment.

In the storage ring the capabilities of 100 % stretching of the bunch in time and pulsation with large frequency are stipulated, which one are difficult for realizing in the nearest future [8].

The channels of beams of secondary particles, pions and muons, are designed and also indispensable equipment is made. The structure of channels should include: a channel of a beam of surfaces muons, a channel of muons with the superconducting solenoid, a short channel of mild pions. The trap of the beam is made. The power supply system, a cooling system are built – on for channels, all communications are delivered to a place of mounting of channels.

Input in operation of muonic beams will allow expanding capabilities of researches on solid-state physics, since a promising capability here will be realized to mate techniques on a neutron source and a μSR-method.

In the experimental complex the implementation of experiment on μ-e conversion [9] is stipulated.

In the nearest future a capability of a performance of experiments on research of nucleons - nuclear reactions on proton and neutron beams in the experimental hall [10] is planned to consider.

4. Neutron Complex

A complex of experimental installations for neutron researches includes pulsed neutron-source (PNS), irradiation facility for nuclear materials investigations RADEX (RADiation EXperiment) and super-sensitive neutron spectrometer on slowing-down in lead (LNS).

The basis of neutron sources of this complex is the high-current Linac of protons of the MMF and solid-state targets from heavy metals (in PNS and RADEX of a tungsten, in LNS -- lead).

The physical launch of PNS and installation RADEX was made at the end of 1998 at energy of a proton beam 209 MeV, mean current no more than 0.1 mkA, duration of a proton pulse 60 mcs and frequency 1 Hz. During launch of PNS and RADEX their infrastructure was tested, a system of transportation of the proton beam from the Linac up to targets, the measurements of background conditions in an experimental hall were conducted and the time-of-flight spectra of neutrons are gauged.

Earlier, in 1995 the small (14-ton) prototype of a large (100-ton) neutron spectrometer on slowing-down in lead was launched.

<u>Pulsed Neutron-Source (PNS)</u>

Under the project PNS consists of two independent neutron-sources arranged each in the cell in general biological protection, and capable to work simultaneously. The difference is determined by pulse duration of protons dropping on the neutron target. In the first cell the tungsten target with a water moderator is placed, on which one a beam of protons with parameters controlled by the Linac moves. The foreseen possibility of using of the proton storage ring, which is ready today on 80-90 %, will allow to generate pulses of neutrons by duration up to 320 ns with mean intensity in solid angle $4\pi \sim 10^{16}$ n/s, that will essentially expand capabilities of the source for realisation of basic researches in the field of condensed matter physics, nuclear physics, biology, chemistry etc.
This neutron source by a natural mode indemnifies closing of research reactors in Moscow and is the basis for creation of new experimental base in the nearest part of Moscow Region, approximately in hour of driving distance from the majority of the interested institutes of the Russian Academy of Sciences (RAS) and the Ministry of Atomic Energy (MAE). The part of scientific community of Moscow already now is transferring here the experimental installations.
The development of the neutron source of the INR RAS with the purpose of increase of a neutron flux, in respect to one initial proton, guesses creation of the target with the beryllium reflector and propagating target with restricted multiplying ≤ 10, which one under the project is supposed to be placed in the second cell.
It is necessary to mark, that if the multiplying target is in numerical modelling - designing stage, the tungsten target with the beryllium reflector is already created for about 50 %. For its full manufacturing it is necessary about $15 thousand. The introducing in exploitation of this target will allow increasing of neutron flux twice.
The program of activities on the pulse source can be sectioned into three parts:
(i) the ascent of a pulse source to design parameters;
(ii) maintenance of PNS by the equipment, instrumental park and corresponding infrastructure, Creation of a Scientific Centre for research of condensed matter;
(iii) work out of the scientific program of researches.
For the purpose of (i) the schedule of current activities is prepared. Most labour-consuming and expensive on financing (~M$1.5) of this unit is the completion of activities and mounting of the storage ring together with Research Institute of Electro-Physical Apparatus.
In (ii) for the extraction of neutron beams from a decelerator to experimental devices the source has seven channels with diameter 204 mm. Thus four channels are directed to the experimental hall, and three – out of limits of the experimental hall. The small number of channels superimposes the specific requirements to the installations and conditions of the ascent of neutrons: multifunctionality of the installations and, whenever possible, dualization of beams of neutrons for increase of quantity of the used installations.
The maintenance of the source by the equipment and devices is parted into two stages.
The first sequential queue includes mounting in the INR RAS of the installations, designed and built early in other institutes, together with collectives of these institutes. The installation DIAS, mating a powder diffractometer, diffractometer of high-resolution of return geometry with a temporary focusing and spectrometer of inelastic scattering of return geometry, which is designed and built in RSC "Kurchatov's Institute", is one of them. This installation will allow to conduct researches both of structure and dynamics of the miscellaneous class of matters in different aggregate states and under different physical conditions.
Other installation is the powder diffractometer of the Institute for Physical Problems of RAS, on which one it is possible to conduct researches of structure both at normal conditions, and at cryogenic temperatures, strong pulse magnetic fields and at high pressures.
Specially for PNS together with Physical Institute of RAS there is a multifunction neutron spectrometer including four diffractometers, intended for research of members substructures

of a different level (with the spatial sizes from units up to thousand lobes of angstrom) and three spectrometers for definition of dynamic parameters in a broad band of transferred energies, sensitivities. For increase of range of investigated energies of neutrons and reduction of their losses in air, the mirror neutron guide is built. Now in an experimental hall the part of a multifunction neutron spectrometer, including a neutron guide, the adjusting desktop for the installation and diffractometer of high-resolution of return geometry with a temporary focusing, is installed.

Except for the listed installations, which one are already in stage of mounting, usage of such installations as DN-500 (Moscow Physical-Engineering Institute, Institute for Crystallography of RAS) and specialized diffractometer for research of structure of single crystals (Institute for Crystallography of RAS) is considered also.

For successful first-order implementation of the Scientific Centre for research of condensed matters, the special attention is required to problems of registration, collecting and analysis of the information going from the installations, creation of a computer network for communication with other Centers, data exchange. Together with Neutron Physics Laboratory of the JNR, a project is drafted on creation of xy position sensitive detectors of the large area.

The second sequential queue of PNS for research of condensed matter guesses realization together with Peterburg Institute of Nuclear Physics of activities on the equipment of channels by mirror neutron guides with their dualization for increase of quantity of the installations. This stage of activities actuates also completion of creation of a multifunction neutron spectrometer.

The design of the project, on creation of a unique spectrometer of neutrons of a direct geometry mated with a small-angle diffractometer, finishes. The capability of creation of other modern effective installations, development of methods of registration, collecting and analysis of the information is esteemed.

For effective implementation of capabilities of PNS in realization of neutron researches in concerns of different areas of science and engineering, rather urgent question is engaging organisations of the RAS, MAE and other centres to creation of the unique installations.

The scientific program of researches look as it follows.

Macroscopic properties of materials determining their operational use, such as the electrical conductivity, strength, elasticity etc., depend on atomic, supramolecular structure, and also, in a number of cases, are determined by thermal mobility of nucleus, molecules and their clusters. The major role thus is played by structural elements with the reference sizes from lobes of units up to hundreds of nanometers.

The analysis of structure and dynamic features consists in a data analysis of dissipation of radiations in matter. Capacity of neutrons to penetrate deeply into material allows studying samples under different conditions: temperatures, pressure etc.

Major property of a neutron is the availability of its magnetic moment, that affords broad capabilities in research of magnetic phenomena. Last years the neutrons are ever more applied to analysis of systems with strong magnetic correlations, namely: of low-dimension of magnetic, superconductors, heavy fermions, etc.

The special attention is given to research of nanocrystals. The realisation of measurements in real time is of interest that will give the information on such processes as oxidation, different relaxations, etc.

The disordered materials, including disordered crystals, glasses, liquids, often have best, as contrasted to crystalline, the mechanical and magnetic characteristics and consequently are of interest for their analysis with the help of neutrons.

One of the most developing areas of usage of neutrons is the research of high-molecular systems, the polymers, block copolymers, liquid crystals, micellar solutions, lyotropic mesomorphic phases, colloidal suspensions, paps, gels, surface-active agent. The brightest property of such systems is their broad polymorphism.

Usage of neutrons in structural chemistry will allow to create materials with given properties (ceramics, magnetic materials etc.), to investigate processes of interactions in a system metal - hydrogen. The measurements in real time will allow studying a chemical kinetics, solid-state reactions, phase transitions, relaxational processes.

A biology and biotechnology are the most perspective fields of application of neutrons. Capacity of neutrons to feel hydrogen, both in statics, and in dynamics, allows successfully to determine parts structure and operation of biological systems. However for the solution of these problems the high neutron fluxes are demanded, more long-wave portion of the spectrum of neutrons (the mirror neutron guides are necessary) and effective detectors of neutrons are indispensable for this purpose.

In separate area of researches with the help of neutrons the materials technology is excreted, which one is connected to analysis of properties of matter with the help of change of a microstructure. The point defects, dislocations, interphase borders, inner joins with microcracks, etc. concern to such microstructures. Activity on analysis of internal stresses and texture by a diffraction method of neutrons, and also related with these problems the problems of a plasticity and fatigue of materials is intensively developing last years. Thus, the neutron dissipation gives unique capabilities of analysis of an actual industrial component and elements of designs.

New area is the application of neutrons in sciences about the Earth. The experimental researches consist in analysis of texture of rocks and minerals, and also influencing of external pressure on structure is modelling. The structural researches allow receiving the information on geology of planets, prediction of earthquakes and belching of volcanoes.

Multi-purpose target complex in the second cell of a neutron source

The second cell in the given moment is free. In this cell the creation of the multi-purpose installation for implementation of following activities is supposed:

- Analysis of different aspects of transmutation, electro-nuclear way of energy production;
- Realization of experimental activities, bound with generating of tritium on the basis of a high-current proton beam;
- Manifacturing of neutron-exuberant and neutron-deficient isotopes for medicine;
- Development and maintenance of neutron therapy;
- Creation of additional experimental base on external beams for researches in the field of physics of a condensed state, nuclear physics and biology.

On the basis of the operating in INR high-current Linac of protons and built infrastructure of a neutron source, it is possible to create an adjustable bench with a mean power up to ~ 6 MW for realisation by research organisations of the MAE and RAS for a cycle of researches in the field of an electronuclear way of energy production and transmutation of radioelements. The purpose of these investigations may be a complex check of the different concepts as well as running time of technological experience. Such bench built from special plug-in modules, would have simultaneously features of a Large physical bench and reactor BR-10. The availability of such demonstration bench in frame of MAE and RAS would allow to systematise separate scientific researches in this area, to keep scientific staff and to suggest them a real activity, substantially related to practice and ensuring the fundamentals for one of probable directions of power engineering of the future. Vertical channels, intended for irradiation of samples, could be utilised for development of the new "know-how" of tritium production and manifacturing of isotopes for the medical purposes. The creation of such bench would stimulate the ascent of parameters of the Linac on design parameters. Simultaneous usage of this bench as a neutron-source with large pulse duration will allow to add at least five beams to seven neutron beams of a pulsed neutron-source arranged in the first cell. It essentially would expand capabilities of the neutron complex and ensured research institutes of the Moscow Region with additional neutron beams and experimental base for researches in the field of physics of condensed matter and nuclear physics.

2. Spectrometer on time of a neutron slowing-down in lead

Created in Troitsk the 100-ton neutron spectrometer on time of slowing down in lead (LSS) is further development of LSS the PYTHON working in the INR since 1995. These installations represent LSS of third generation, in which one the neutrons are generated at the expense of spallation processes generated by an intense proton beam. This LSS can be utilised for researches in the field of fundamental and applied physics and in radiation medicine.
Besides such leaden cube can serve as the prototype of a nuclear-power plant with a spectrum of slowing-down (one of the proposals of Rubia for realisation in CERN).
By activity on power ~ 30 kW, a usage of the liquid-metal leaden-bismuthic target is supposed. Russia possesses priority and unique experience as in creation of LSS (in the RAS), and in activities with liquid-metal targets (in organisations of the MAE). The affiliation of these two capabilities in one installation would allow deducing researches on an in essence new level.
A low gamma - background and the rather small sizes of the installation allow to organise a medical channel for neutron therapy.
The most massive LSS of the third generation is the installation TARC (300-ton LSS), launched in CERN in 1997. LSS of the third generation have the best, among neutron spectrometers, luminosity with an effective range of energies 1 eV - 30 keV. Notably losing in resolution to a method on time-of-flight, the LSS gives a scoring in intensity of neutron flux to 10^3 - 10^4 times (at the same power of a neutron source). The program of measurements on TARC, is practically directed on finding - out of capabilities of a burning out of a radioactive waste, and the luminosity of this spectrometer is rather insignificant (source of 10^{10} n/s). At the same time it is necessary to mark, that at the expense of usage of a storage ring of protons, the installation TARC provides record instantaneous densities of fast (E> 100 keV) neutrons permitting research of R-processes (double neutron capture).
The 100-ton LSS of the INR can appear outside of a competition in researches of cross-sections of rare reactions and reactions with microsamples (radioactive and rare nuclei), presenting more broad scientific interest in those experiments, where the power resolution is not determining. Thus there is a capability to have high flows of fast neutrons (at usage of a storage ring). Obtaining of neutron-deficient and neutron-exuberant isotopes and the manufacturing of radioactive targets directly in place will open unique capabilities of activity with nuclei, which have a half-life about several days.
Directions of researches on LSS of the INR
1. Measurement of cross-sections and also resonance integrals of capture, fission, treble segmentation, and also emitting of alpha-particles and protons for radioactive nuclei of interest from the point of view:
- transmutation of a radioactive waste, including far transactinides;
- design of a thorium fuel cycle;
- accumulation in structural and fission materials of gaseous helium and hydrogen (embrittlement);
- production of specific isotopes for medicine and industry;
- check of the different scripts of nucleosynthesis in the Universe, in particular, S- and R-processes in stars;
- experimental research of problems of "order" and "chaos" in neutron resonances.

There is a new trend of researches - neutron spectroscopy of nuclei removed from a band of beta - stability. This will be promoted also by a capability of secure arrangement, during measurement, of radioactive samples inside the eaden decelerator - protection.

The power range of LSS successfully overlaps the main power range of Maxwell's spectra in stars. The data on speeds of capture of neutrons at temperatures kT = 10-12 keV are now especially relevant for selection of the script of nucleosynthesis in stars (check of a role of reacting ^{13}C (α, n) during generating neutrons in stars). Research of rare processes with resonant neutrons.

For the first stage of creation of LSS in INR the following steps are offered.

Simultaneously to construction of LSS on a beam of protons and analysis of its characteristics, to create detectors of neutrons, of segmentation and radiative capture of neutrons (not sensitive to the shape of a gamma-spectrum of decay), and also detectors of alpha-particles and protons. To find out a capability of creation of spectrometers for alpha-particles and protons working in intensive fields of a gamma-radiation (gamma rays from capture of neutrons in lead and impurities) and at pulse overloads at the moment of a proton pulse.

Designing of a fast (not overstrained) electronics for the collecting and analysis of experimental data (including multidimensional spectra) should be done. It becomes specially actual, because already in experiments, which one were conducted on LSS the PYTHON, it was remarked, that the miscalculations in analogue and digital channels of registration of events result in unpredictable systematic unremovable distortings of spectra of reactings, that is a common problem of usage of superintensive neutron spectrometers.

System development of computer programs for corrective action on distorting of a neutron field by a sample, on a resonant self-shielding and neutron capture after resonant dissipation in samples is necessary. Besides the programs of precise calculation of spacing of a neutron density in miscellaneous points of LSS in time dependence are indispensable. As against power area with $E < 10$ keV, in the field of 10-50 keV speed of neutron moderation and their spacing in LSS have a composite time and spatial dependence. The availability of such programs will allow essentially increasing a measurement accuracy of neutron resonances and measurements of integral cross-sections in the field of stellar temperatures.

Obtaining of ultra-pure samples of fissionable nuclei and of samples for research of neutron capture would be done. LSS of a third generation can work with samples of weight 1-10 μg. It is specially important at researches of such processes, as under-barrier fission, where even the small impurity of an extraneous isotope essentially distorts outcomes of experiment.

Some of techniques for researches in these directions are designed together with LNP of JINR and with IPPE.

It is necessary to mark, that the first experiments on LSS TARC (leaden cube on a beam of protons at 2,5 GeV), have shown capabilities of a burning out with usage of a method ARC (ARC-Adiabatic Resonance Crossing Method in a nomenclature of CERN) plenties of such segmentations as ^{99}Tc and ^{129}I with speeds superior rates of their generation.

3. Installation for irradiation of structural materials

The installation for irradiation of structural materials RADEX consists mainly of tungsten water-cooled layers. It has a vertical channel for irradiation of objects with diameter ~ 50 mm and altitude of 100-150 mm. RADEX is intended for irradiation of samples of structural materials in mixed proton and neutron fields with their subsequent delivery in hot labs of IPPE (Obninsk) for post-irradiation researches.

In the modified installation with a special insert usage of liquid-metal cooling (Pb-Bi, Na or Hg) of standard tubular samples of structural materials is possible. In this case samples will be simultaneously in constant mechanical stress in medium of metal and in radiation fields. Thus density of heat release in samples of stainless steels from a narrow beam of protons (~ 1 cm in diameter) can reach ~ 1-1,5 kW / cm^3, that practically is impossible to achieve with the help of nuclear reactors.

High damaging capacity of protons and high local density of heat release open a capability of reduction of terms of irradiation of materials up to a given level of displacement per atom and to elaborate methods of proximate analysis of structural materials in concerns of development of nuclear power engineering and recent trends in the field of accelerator-controlled systems and thermonuclear power engineering. Besides on the installation RADEX the operating time of neutron-deficient isotopes for the medical purposes is probable.

5. Conclusion

The presented above information about the current situation at the Neutron Complex of the INR RAS clearly demonstrates that there is an obvious progress in developing of the neutron targets and preparations for researches at secondary beams of spallation neutrons. The Neutron Complex of the INR RAS is considered as a perspective center for joint activity of a number of centers of the Academy and the Ministry of Atomic Energy in the Moscow Region. The progress is ensured by the stable operation of the Linac. The project parameters may be definitely reached if reasonable financial support would be available. The Complex may provide possibilities for perspective studies of fundamental and applied problems.

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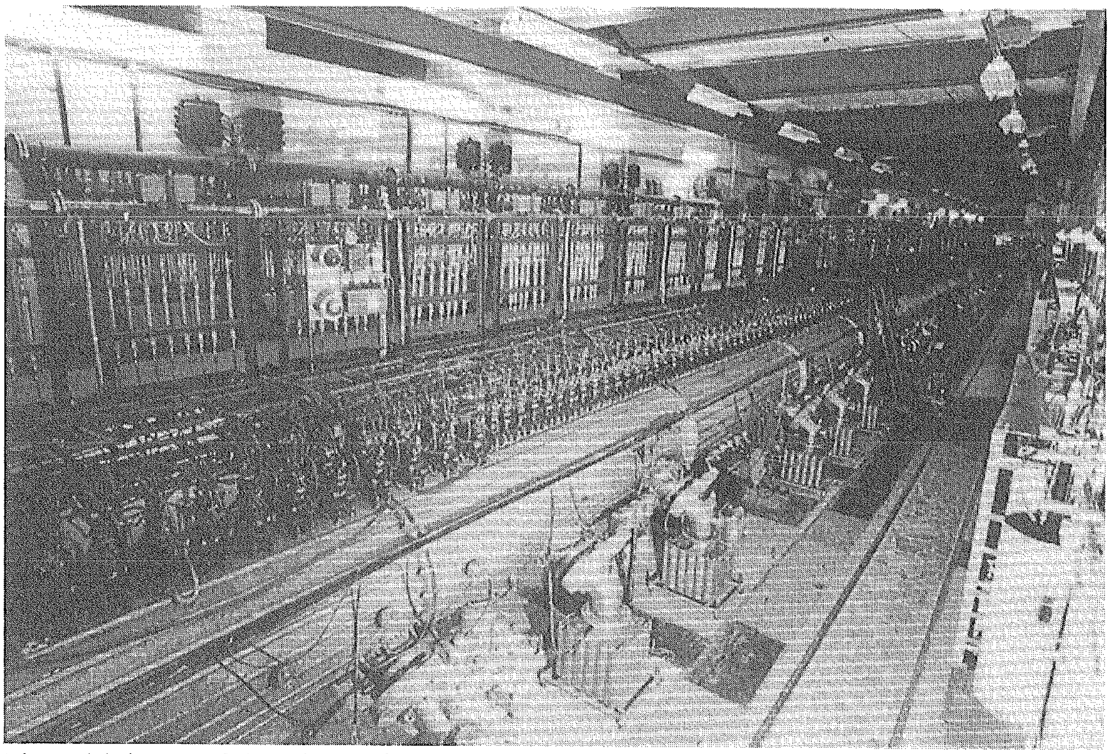
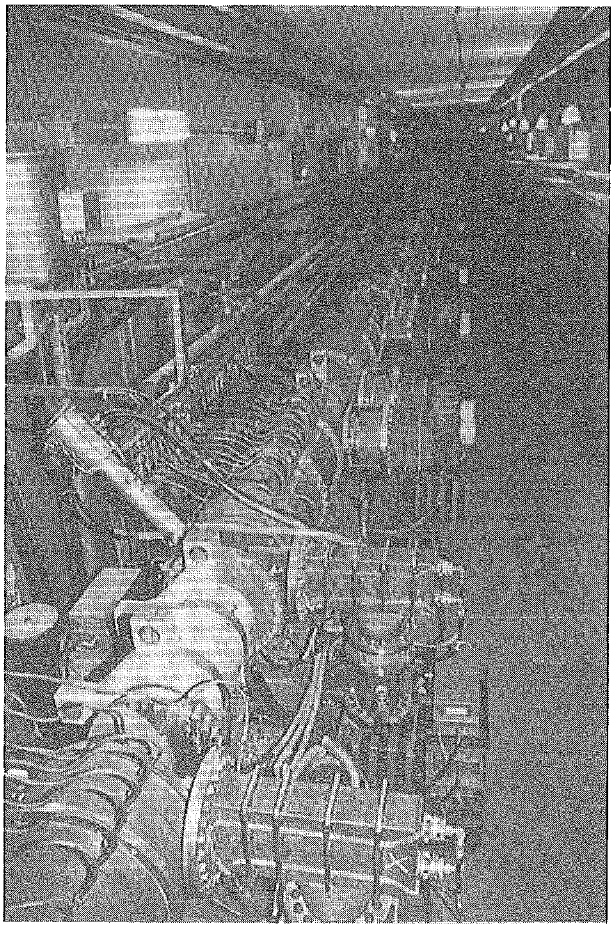
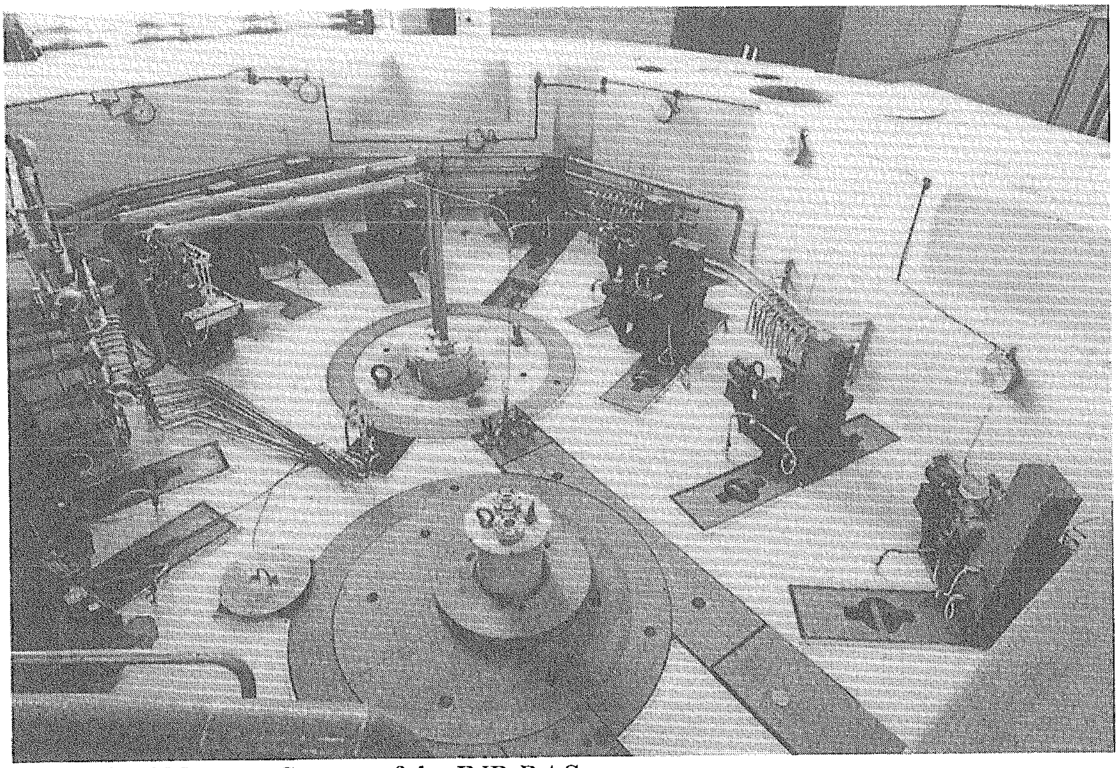


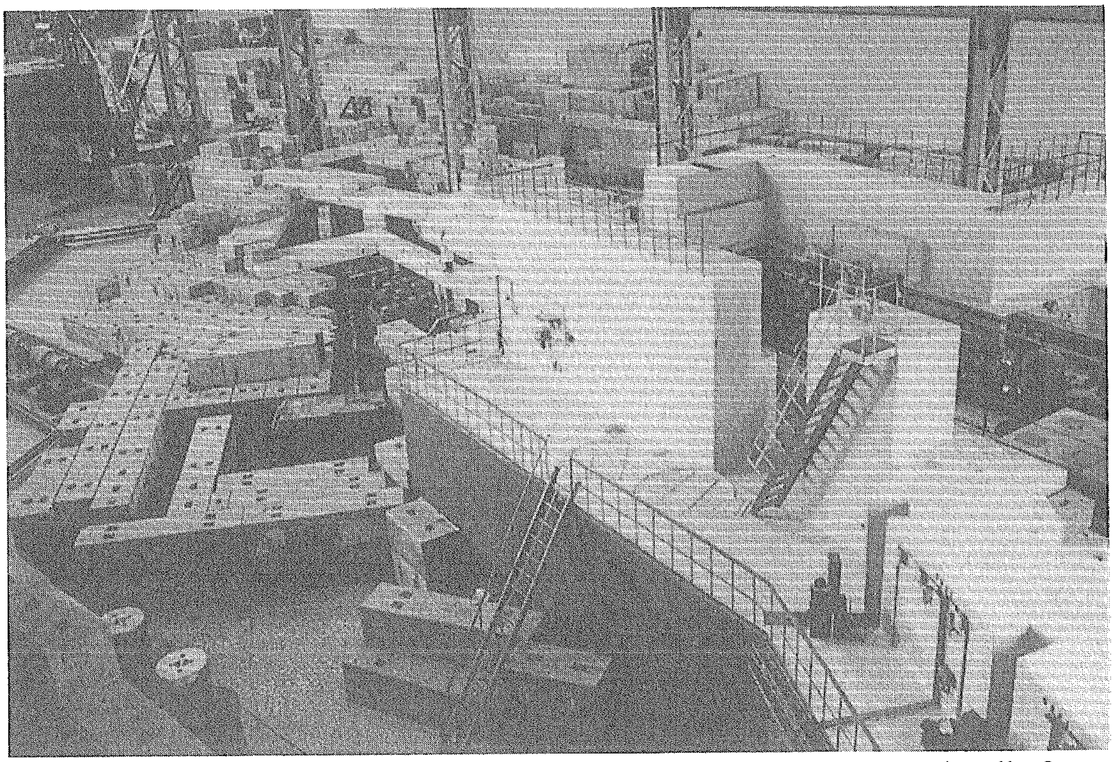
The Initial part of the Linac of MMF



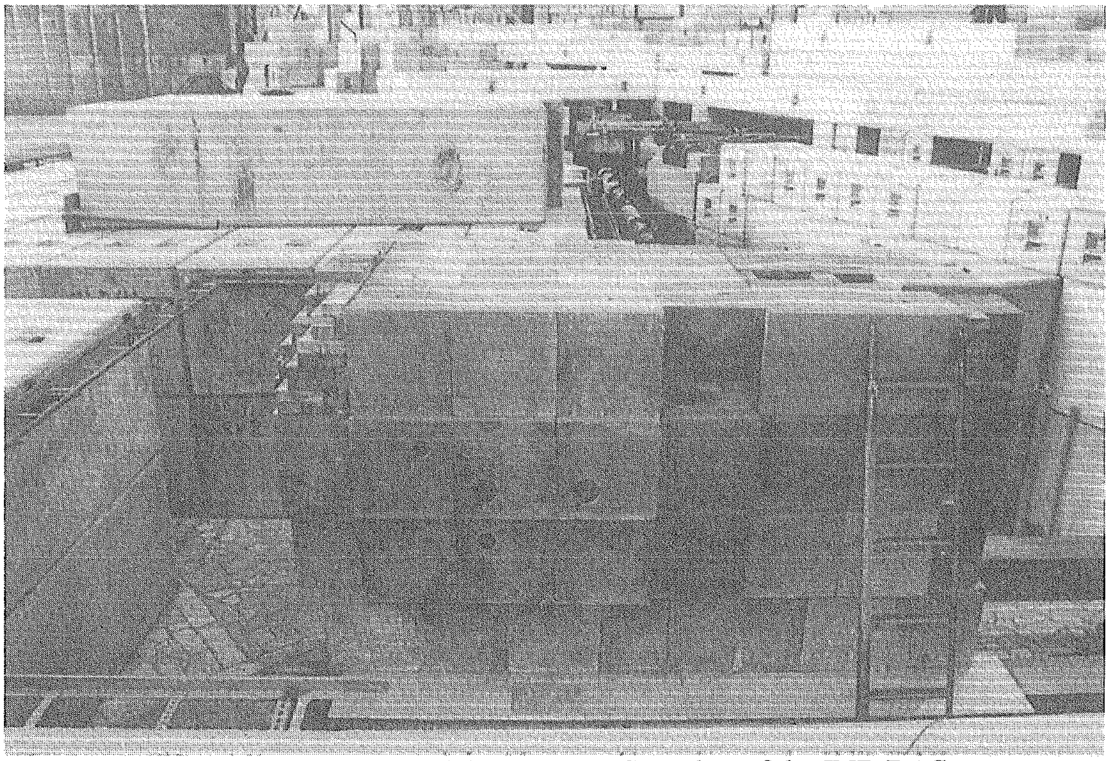
The Main part of the Linac of MMF



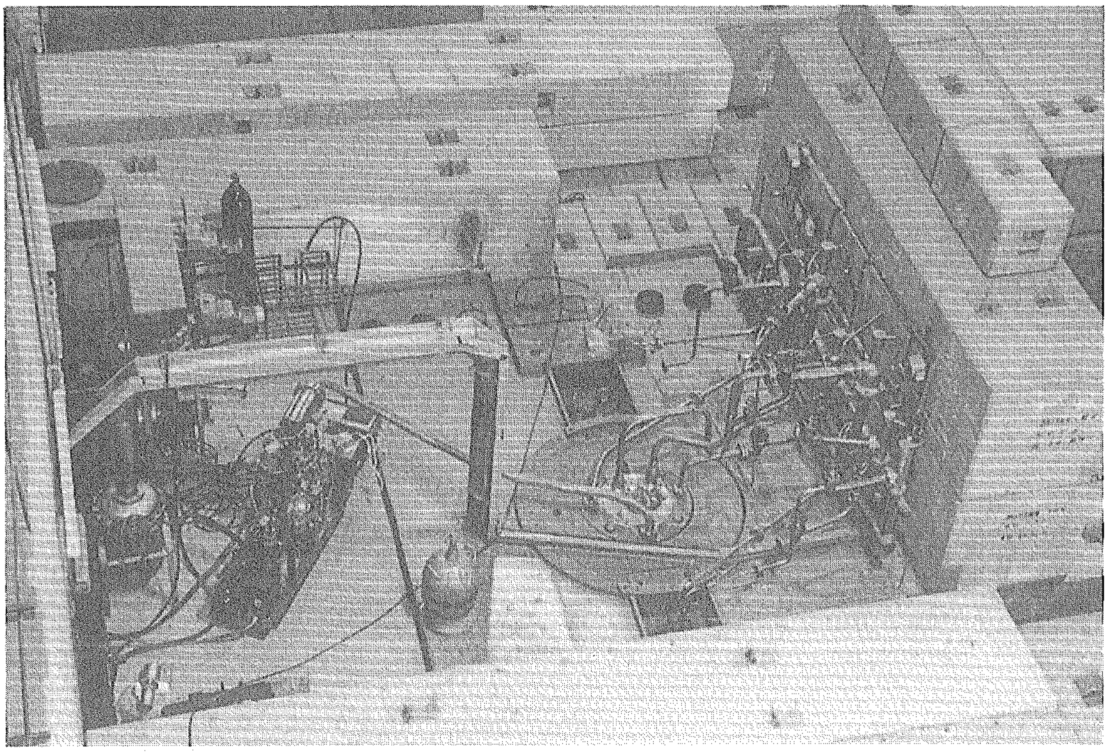
The Pulsed Neutron Source of the INR RAS



General view to installations of the Neutron Complex in the Experimental Hall of MMF



The 100-ton Lead Spectrometer of the Neutron Complex of the INR RAS



The RADEX facility of the Neutron Complex of the INR RAS