



JINR



NUCLOTRON FACILITY



Status of the Nuclotron project **NUCLOTRON-M (1st stage of NICA/MPD project)**

Andrey Butenko for Accelerator division

- ✓ *Stages and milestones of the Nuclotron upgrade*
- ✓ *Results of the Nuclotron runs (#37, #38) and machine upgrade*
- ✓ *Works on coming Nuclotron run (#39)*
- ✓ *Conclusion*



JINR

NUCLOTRON FACILITY



The goal of Nuclotron-M 1 stage of the NICA project

Required R&D - priority task for Nuclotron runs

This stage has to be completed by **2010** providing:

- Accelerated heavy ions with $A > 100$ (for example Xe)
 - Beam intensity $\sim 10^7$ I/pulse
 - Beam energy $> 3,5$ GeV/n
 - Required infrastructure

Nuclotron provides now performance of experiments on accelerated ion beams (up to Fe^{24+} , $A=56$) with energies up to 2.5 GeV/n



JINR

NUCLOTRON FACILITY



1 stage: Nuclotron-M

*Leaders: A.D. Kovalenko, G.V. Trubnikov
Deputy leaders: V.I. Volkov, A.V. Butenko*

The Goal – to reach parameters of Nuclotron by **2010** required for realization of NICA project by:

- *Development of new injection complex*
- *Modernization of the vacuum system*
- *Modernization of RF system*
- *Upgrade of diagnostics and beam control systems*
- *Modernization of the power- and cryo- supply systems*
- *Development of the minimum required infrastructure*

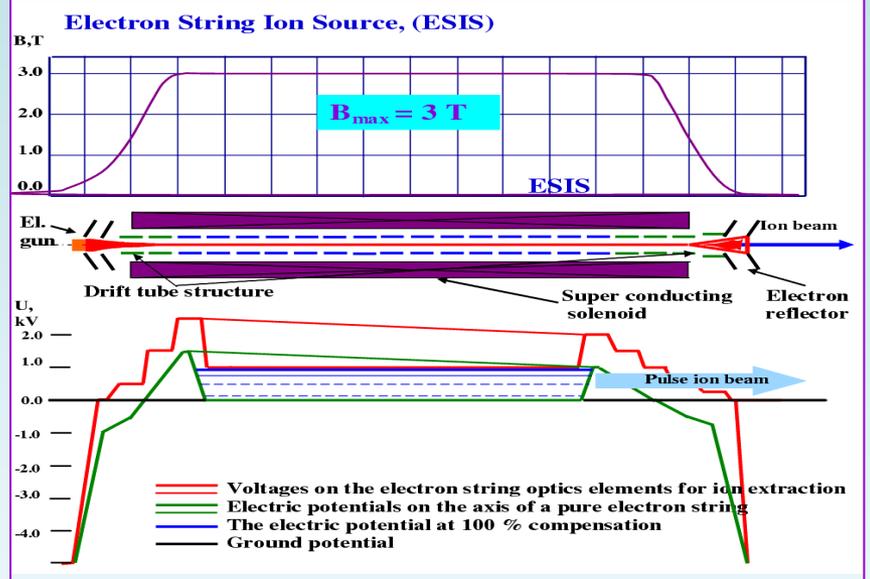


NUCLOTRON FACILITY



Development of heavy ion source KRION

(team of E.D. Donets and E.E. Donets)



Results achieved in last run at KRION 2: intensity of the Au+51 is 10^8 i/p, duration 8 μ sec

- high pulse repetition rate
- short puls duration (6-10 μ sec)
- production heavy ions at intermediate charged states

Construction and test of the new ion source with 6 T solenoid within the coming two years is the main goal of the project. **KRION 6T** (for Au65+÷Au69+ q/A~0.33)



JINR

NUCLOTRON FACILITY



Modernization at LU-20 injector complex

The following upgrade:

- the cooling system of the few “oil” vacuum pumps were upgraded for the special liquid nitrogen cooling and the cryo-pumping system was activate - this allow not to use special cooling solution (expensive) and to decrease the time for working vacuum obtaining $\sim 9 \cdot 10^{-7}$



- absolutely new system (since 1974) of timing synchronization for all 48 control channels of the LU-20 was created, tested and commissioned
- several diagnostics tools has been reassembled at injection channel



JINR

NUCLOTRON FACILITY



Upgrade of the Nuclotron vacuum system

(leader Dr. H.Khodzhibagijan)

At the present time there is no possibility to pump out gaseous He defusing into the beam pipe through non-hermetic connection near the beam extraction section inside the cryostat.

Two stages of the system improvement are proposed:

Stage 1: necessary development within the “Nuclotron-M” (to achive **1·10⁻⁹ Torr**)

Stage 2: will be considered within the NICA TDR





JINR

NUCLOTRON FACILITY



Since the modernization of the vacuum system has been started we performed the following works:

- fixed and exchanged the beam pipe element with ceramic insulator which had leak ;
- fixed places of possible short circuit of the s/c cable on the chamber or shields;
- dismantled profile monitor station from the injection channel which had heightened leakage;
- dismantling of non-used ionization pumps for upgrade;
- warm section of the ring was totally reconstructed;
- mounted 2 pumping tandems and 3 TMU with fore-pumping units
- mounted new mass-spectrometer Pfifer PRISMA+for residual gas analysys and 5 vacuumeters at the ring;

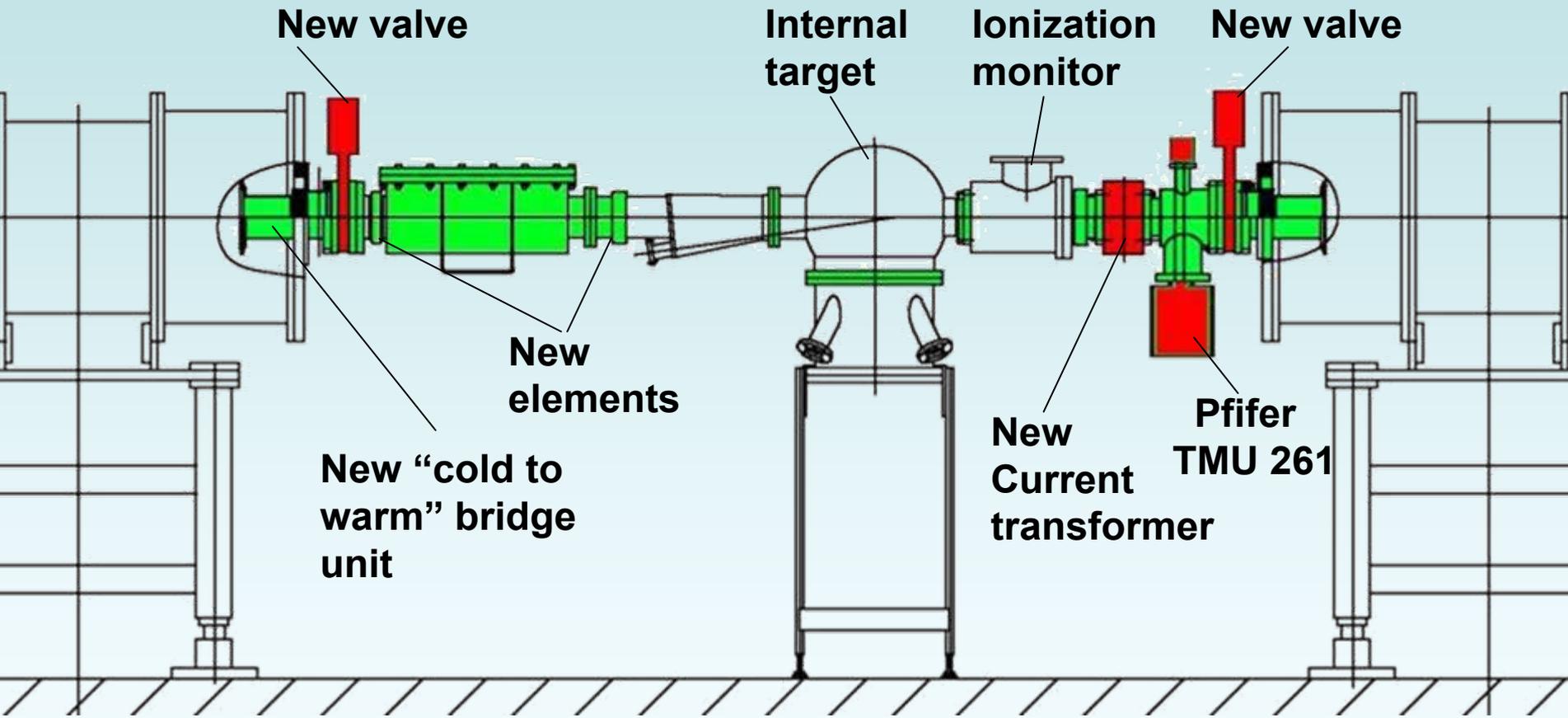


JINR

NUCLOTRON FACILITY



Totally reconstruction of the “warm” section of the ring

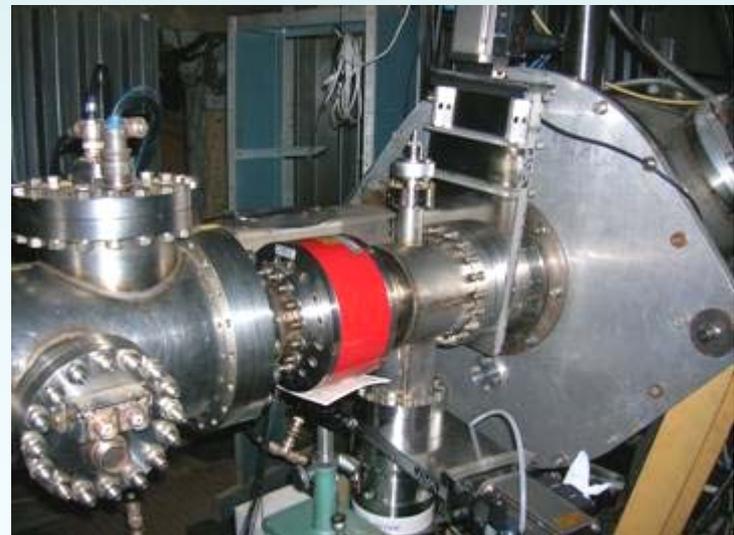
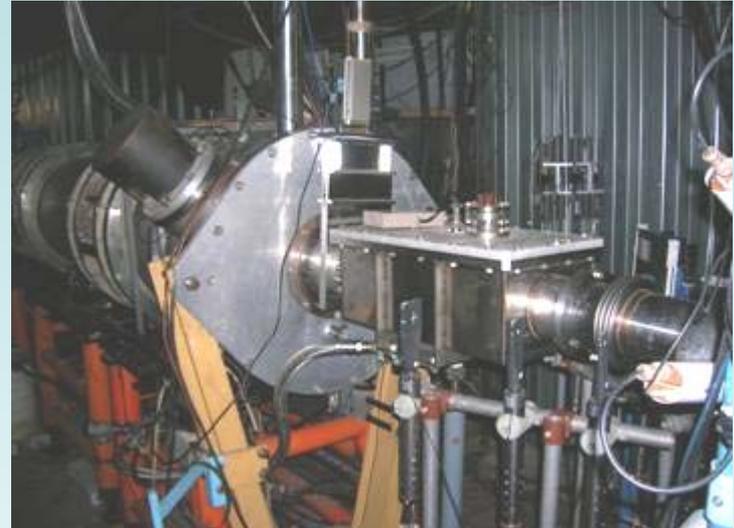


The vacuum level at this section was improved from $8 \cdot 10^{-7}$ up to $3 \cdot 10^{-8}$ Torr



JINR

NUCLOTRON FACILITY



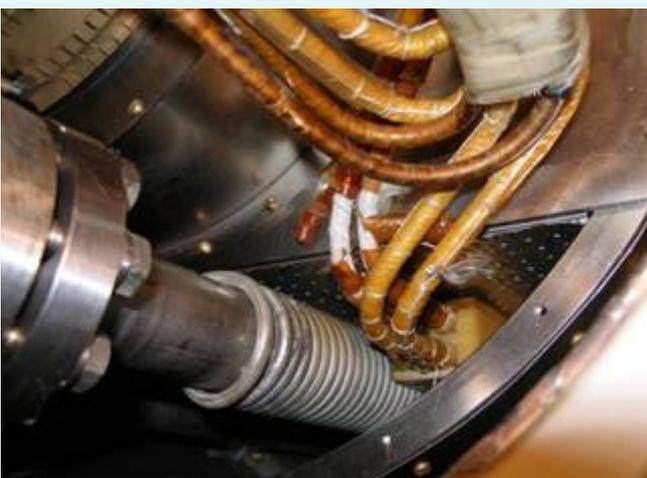
JINR

RuPAC 2008, Nuclotron-M project status. A. Butenko



JINR

NUCLOTRON FACILITY



JINR

RuPAC 2008, Nuclotron-M project status. A. Butenko



JINR

NUCLOTRON FACILITY



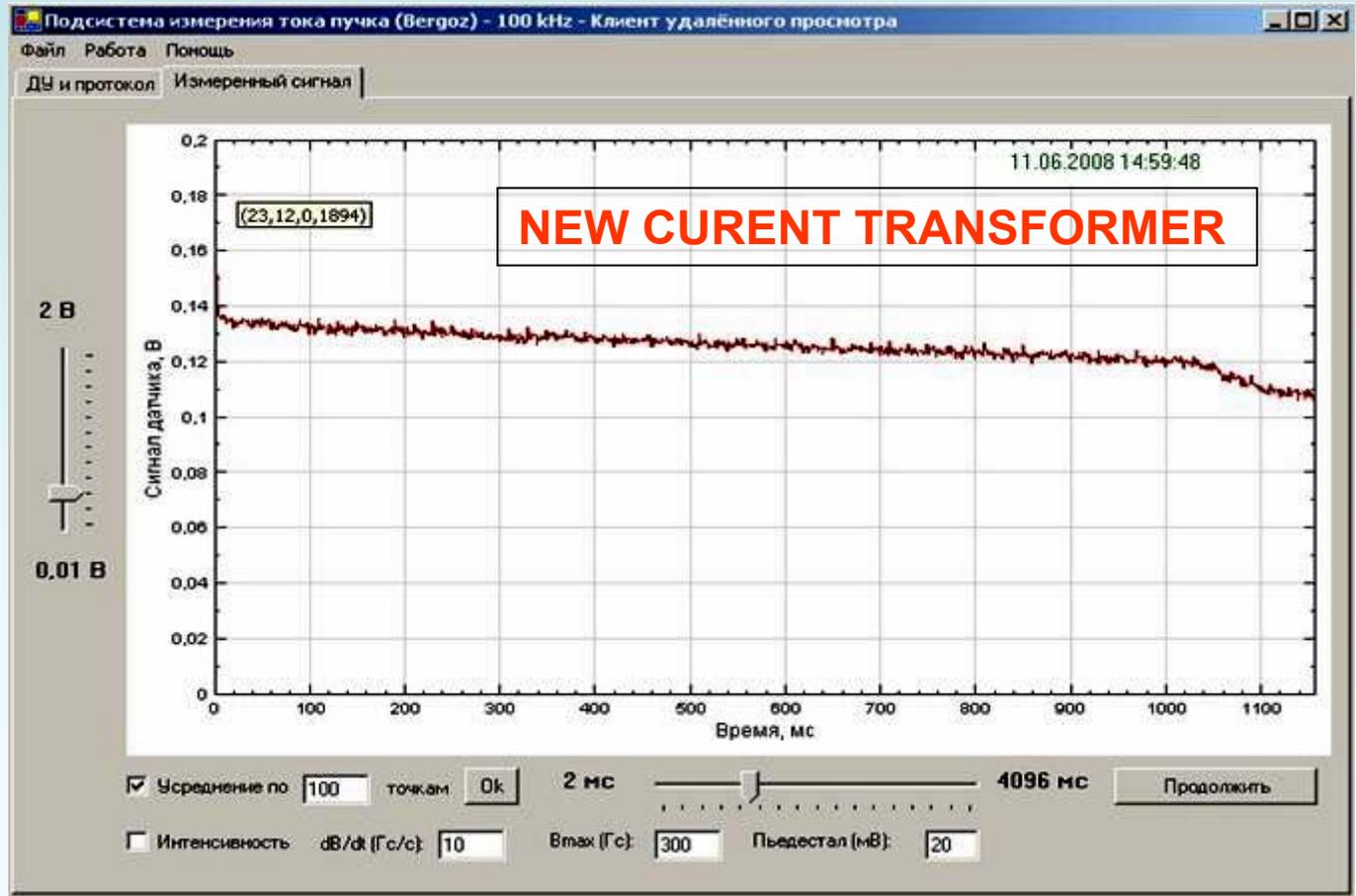
At 2007 the averaged pressure in the Nuclotron beam pipe was $\sim 5 \cdot 10^{-7}$ (nitrogen equivalent at 300K).

In run 37 residual gass pressure was estimated about $\sim 2-3 \cdot 10^{-8}$ Torr.

In run 38 measured average value of pressure is about $\sim 2-3 \cdot 10^{-9}$ Torr.

d^+ beam circulation at the injection energy 5 MeV/amu (static main magnetic field).

$\tau \geq 9$ sec



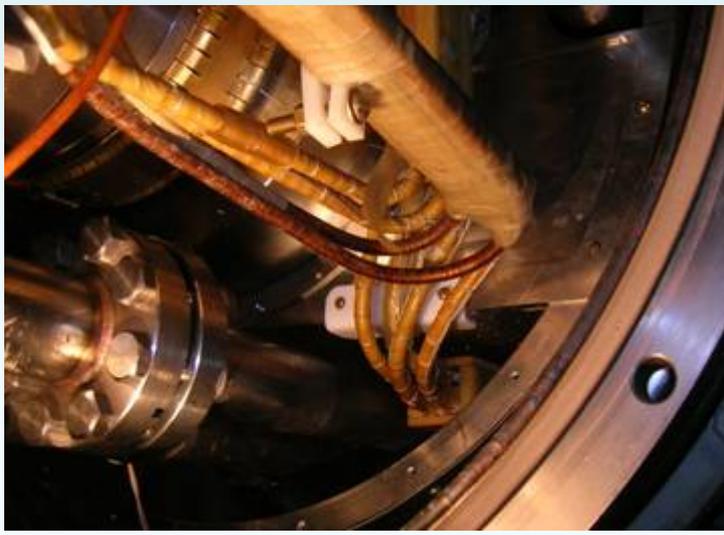
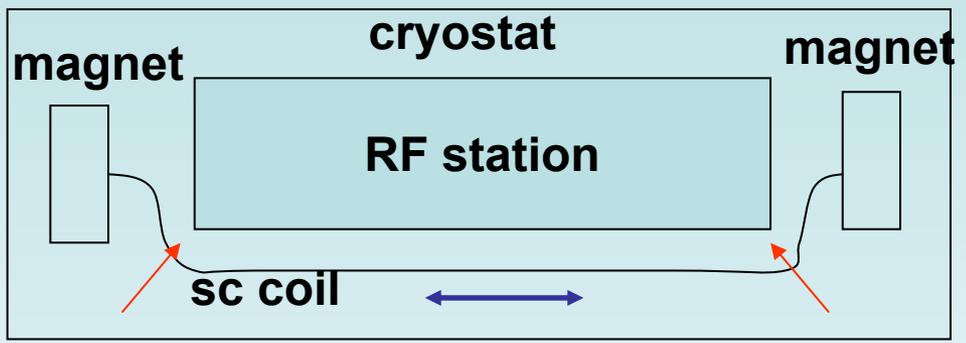


JINR

NUCLOTRON FACILITY



Fixed places of possible short circuit of the s/c cable on the chamber or shields





JINR

NUCLOTRON FACILITY



Development of the accelerator RF system, upgrade of the electronics and the particle capture scheme

(leaders O.Brovko, A.Eliseev, V.Slepnev)

Construction and put into operation the third RF station that will allow to provide acceleration of the particles at the magnetic field ramp up to 2 T/s.

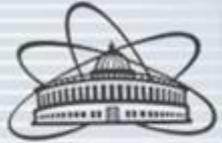
Increase of the Nuclotron longitudinal acceptance by means of design and put into operation adiabatic scheme of the particle trapping and adequate increase of the particle trapping efficiency (by a factor of two).

Modernization of the system of the frequency/ field control electronics.

The following systems and equipment was installed:

- full-scale diagnostics of the acceleration voltage,
- experimental equipment for realization the adiabatic trapping,
- step-by-step modernization of the drive circuit electronics.
- It was manufactured and installed in a tunnel a special shielding for RF stations. This allowed to decrease noise by factor of 10-15.





JINR

NUCLOTRON FACILITY

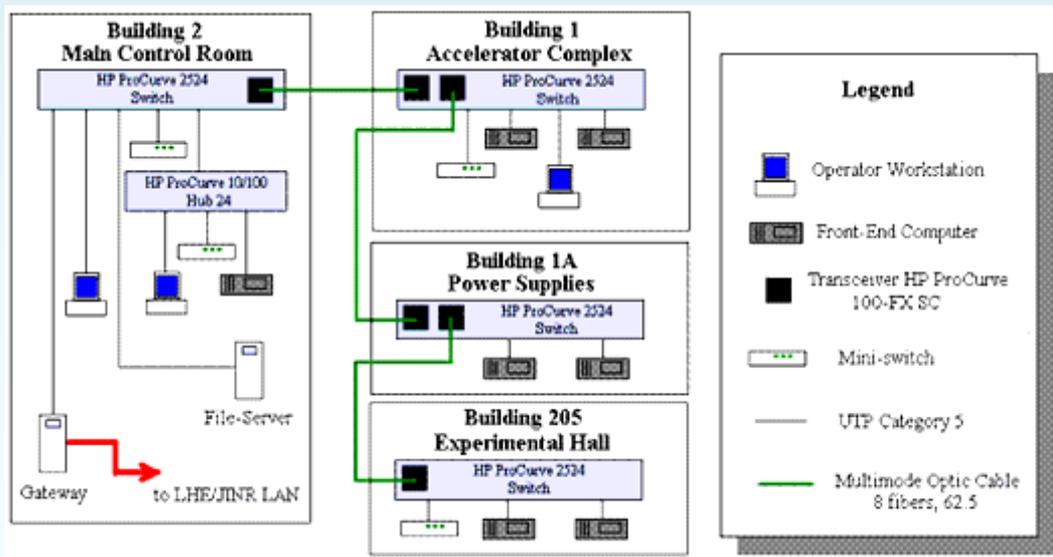
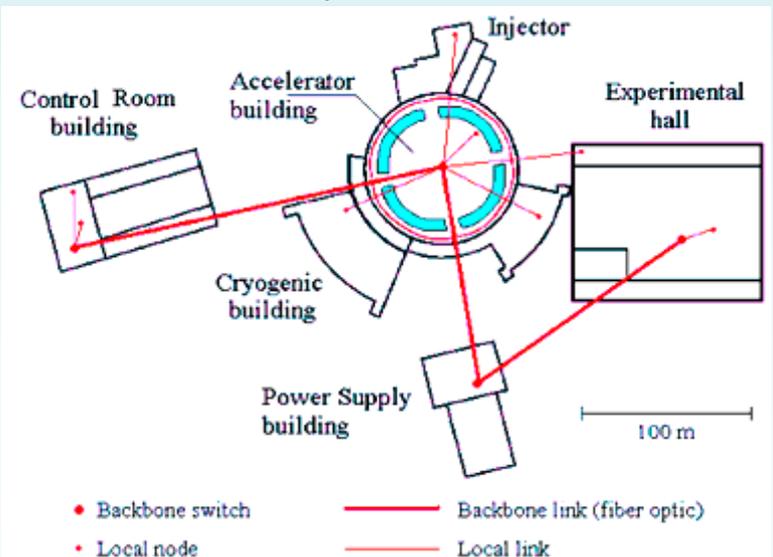


Modernization of the control system and beam diagnostics.

(V.Volkov, B.Vasilishin, V.Andreev)

Basic goals:

- Development of the Nuclotron control and local network systems for higher reliability, extended possibilities of the existing system, put into operation the advanced industrial PC farm;
- Upgrade of the sub-system for the accelerator magnetic field control;
- Modernization of the sub-system for beam extraction control;
- New sub-system of beam closed orbit measurements.



The upgrade of the automation and diagnostic systems is in very active phase. We purchased and installed on the ring and already use new beam current transformer which is very effective tool for diagnostics of the beam intensity.

- Pick-up station at the warm part of the ring is totally reassembled and new software was created.
- Upgrade of beam closed orbit correction system was started.
- Prototype of the new beam orbit measurement system has been created. Commissioning of full-scale system (28 stations) is planned in the 39th run.



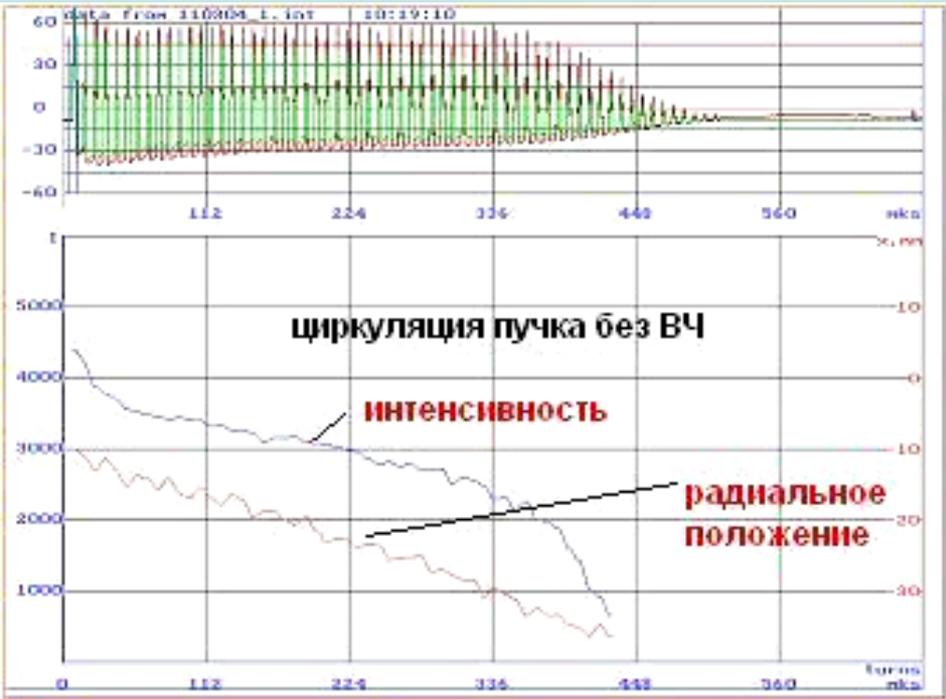


JINR

NUCLOTRON FACILITY



Beam dynamics study and minimization of the particle losses at all the stages of accelerator cycle



The losses can be reduced by factor 5-6 due to improvement of RF trapping scheme and precise beam dynamics study during first 100-200 μ s after injection



JINR

NUCLOTRON FACILITY

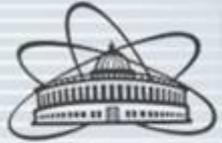


Heavy ion beam extraction at maximum beam energy

(leaders *V.Volkov, P.Rukoyatkin*)

- Modernization of electrostatic septum (ESS) aimed at increase of operation voltage up to 200 kV to provide necessary deflection of the extracting particles up to the magnetic rigidity of the Nuclotron correspond to the NICA specification ($B > 1.8 \text{ T}$)
- Put into operation additional correcting power supply for the Lambertson magnet of the beam extraction system
- Design and realization of heavy ion extraction scheme with the use of a crystal septum (for slow/fast extraction system).
- Design of a scheme for fast extraction of compressed heavy ion bunch.





JINR

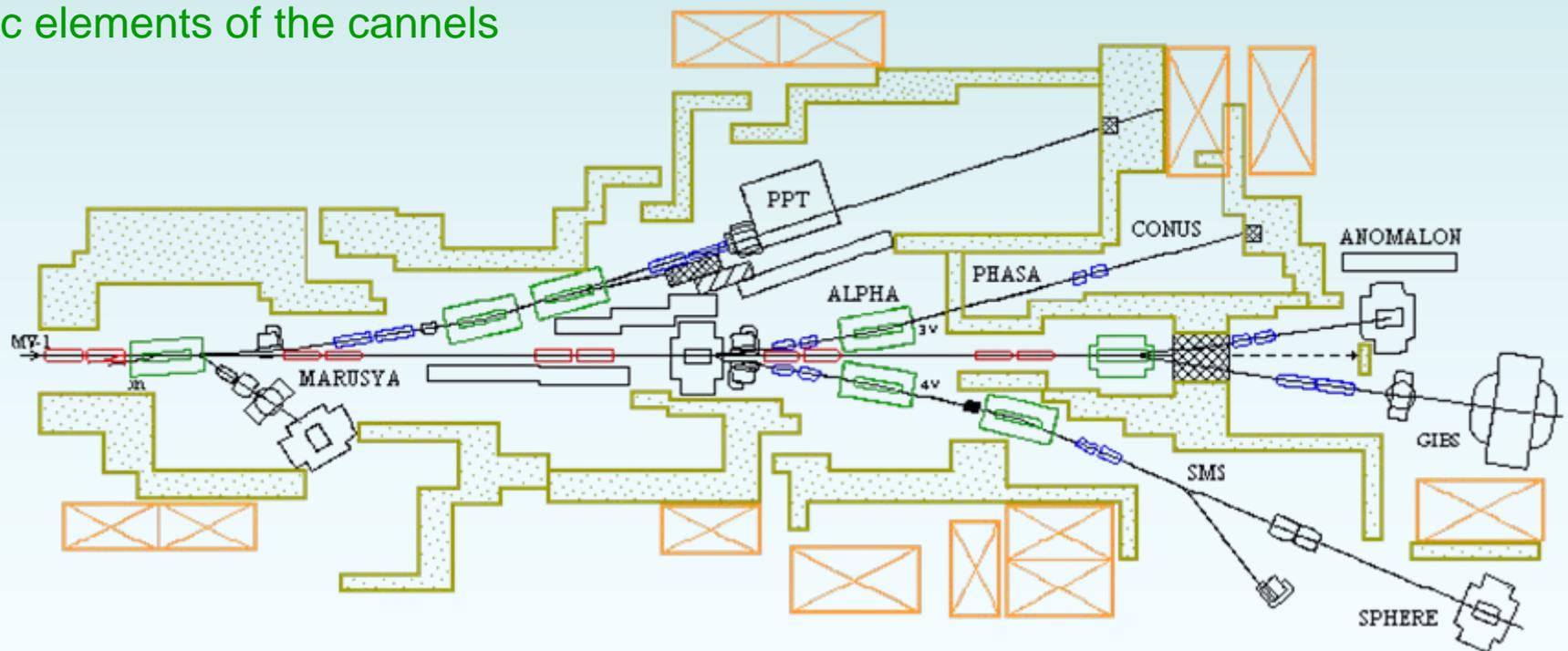
NUCLOTRON FACILITY



Beam transfer lines and radiation shield

(leader *P.Rukojatkin*)

- Modernization of the main beam extraction and transport line from the Nuclotron beam output window to the building 205;
- **Minimization of the material along the beam path;**
- Design and mounting of automatic system of the power supply control for optic elements of the cannels





JINR

NUCLOTRON FACILITY



Modernization of the power supply system , quench detection and energy evacuation system

(team of V.Karpinsky, E.Ivanov)

New power evacuation systems, modernization of power supply for magnets, lenses, correctors, new quench detectors –

Most expensive works:

~3000-4000 man/day

(several km's of 6 kA cables in the tunnels and channels, copper buses, ...)



Transformer point (b. 1B)



Systems of energy evacuation



JINR

NUCLOTRON FACILITY



Improvement of the cryogenic supply system *(team of N.Agapov)*

- Modernization of the control system for cryogenic complex was started. Here we signed two agreements – with Bulgarian institutes and with KRIOGENMASH for development, construction and installing at Nuclotron complex. Prototype of such system is already created and tested.

- The system intended to economize the liquid nitrogen is under design and we expect to realize it by 2009.

- One of the helium compressors was totally reconstructed and reassembled.

- A negotiation with KRIOGENMASH about leasing in the nearest time of special auto-tank for liquid helium is agreed.

- The filterin system of cryogenic complex is under totally reconstruction now.





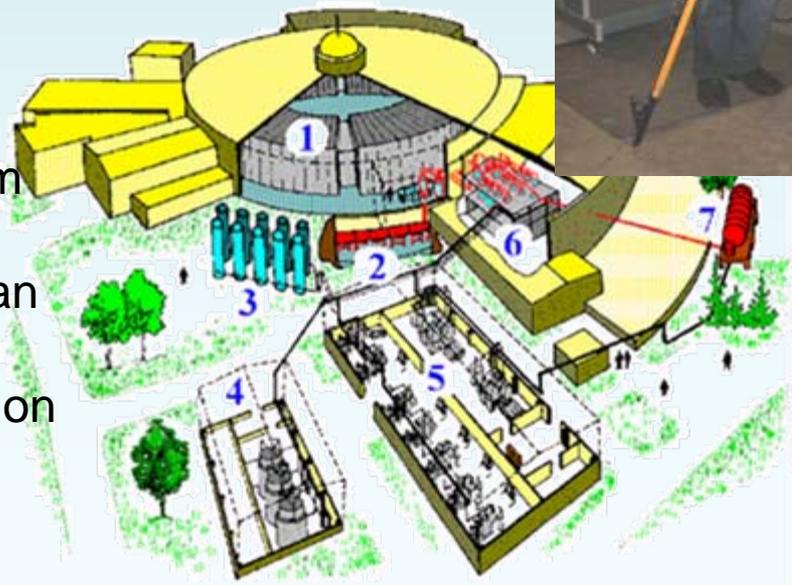
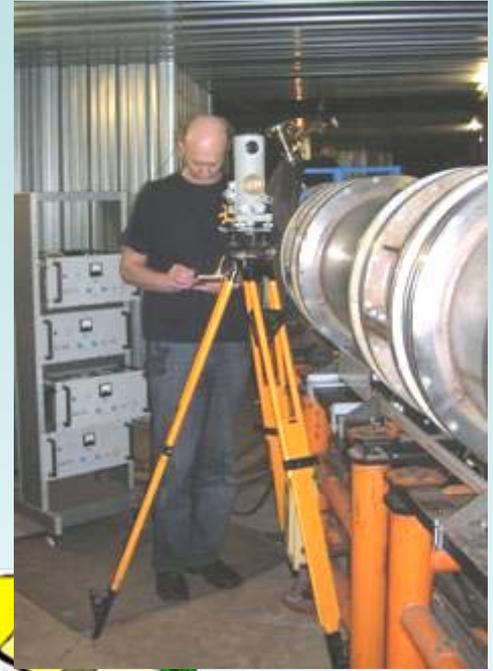
JINR

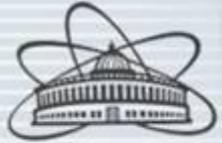
NUCLOTRON FACILITY



We restarted regular geodetical measurements in the tunnel (during different seasons) – a special *LEICA* digital level was purchased and is actively used now.

- - A large volume of works was performed and in progress on the modernization of the infrastructure: repairing and fixing works in the experimental areas (the budget of works is more about 200 k\$)
- – fixing of roofs over LU-20 complex, exchange of several tens meters of the water cooling and water supply system.
- - New filter for the water supply system was purchased
- - We have an agreement with Bulgarian Institute of Nuclear Research on the development of the control automatization system of the water cooling and water supply of the accelerator complex.





JINR

NUCLOTRON FACILITY



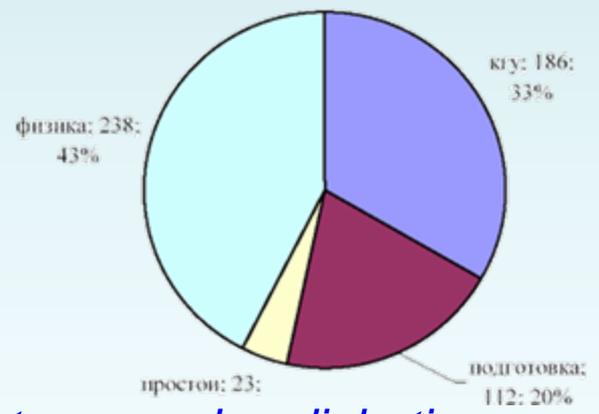
Run # 37 29.10.07 – 16.11.07 (450 hours)

- Ions of ${}^6\text{Li}$ had been accelerated;
- Measured average value of pressure $\sim 2 \cdot 10^{-8}$ Torr (for N_2 equivalent)
- First experiments were successfully started with pseudoadiabatic trapping at magnetic field plateau.
- Experiments on series connection of magnets and lenses – allowed to decrease amplitude of magnetic field ripple up to 15 times;

Run № 38 26.05.08 – 18.06.08 (560 hours)

- Realized program:
 - Preparation & tuning ~ 200 hours
 - Physical shifts ~ 260 hours
 - Methodical shifts ~ 110 hours:

vacuum improvement, measurements and spectrometry, pseudo-adiabatic trapping, new current transformer, RF system upgrade and diagnostics, injection matching, LU20 modernization,...





JINR

NUCLOTRON FACILITY



Run № 39

- 15 Nov. – 20 Dec. 2008 (~ 600 hours) or
01 Feb. – 20 Mar. 2009 (~1000 h)
- Strategy: prolongation of runs, step-by-step commissioning of upgrade systems
- Program:
 - Preparation, tuning ~ 200 hours;
 - Physical shifts ~ 260 hours :
NIS-GIBS (~80), SCAN (~60), Marusya (~60), TPD (~40), FAZA (~30)
 - Methodical shifts ~ 150 hours:
New diagnostic, main field control system, closed orbit measurements and correction, vacuum measurements, RF system tuning, main power supply system tuning...



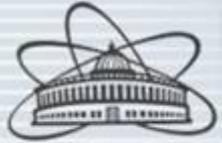
JINR

NUCLOTRON FACILITY



Conclusion

- *Strategic plan of the JINR accelerator complex is development in the High Energy physics + adequate scientific program. Priority task - project **NICA/MPD***
- *Realization of the 1st stage in 2008-2010 has principal importance for **critical decision** on the proposed strategy of JINR accelerator complex development*
- *Program of physics research at Nuclotron is directly coordinated to strategy development of accelerator complex at the 1st stage (**Nuclotron-M**)*



JINR



NUCLOTRON FACILITY



Thank you for your attention !