

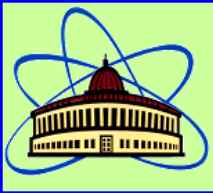
*To the 95<sup>th</sup> birthday of Alexander Mikhailovich Baldin*

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# **A.M.BALDIN and his NUCLOTRON**

*A.D.Kovalenko , LHEP Semimar , February 26, 2021*

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# 1994: THE DUBNA EFFECT



## The Dubna Effect

DUBNA—The Joint Nuclear Research (JINR) center that dominates town, 130 kilometers from Moscow, is an island in more ways than one. It is off from the surrounding three waterways—the Volga, the Tvertsa, and the Moskva—and the Moscow also an island of intention in the days when science was isolated from the rest of the world. And now it is a patchwork of firm ground, a place that pervades Russian science. Its position is pretty good: heavy-ion research is a national Laboratory, which looks for predicted stable elements in the periodic table (See p. 1225).

Although its budget is small, JINR has been seen as an international institute—mostly from its independent republics—and making the most of its long-standing contacts with the West. It seems to be working. The institute is abuzz with activity and it even boasts some new facilities. "The situation is satisfactory," says JINR director Vladimir Kadyshchuk. "It is a calm, stable center."

JINR was founded as an international center in 1956, as the Soviet bloc's reaction to the creation of the European Laboratory for Particle Physics (CERN) in Western Europe. A year later, JINR commissioned a new collider, the 10-giga-electron-volt Synchrophasotron, which is still in use today. The institute has branched out to other areas, such as nuclear structure research and heavy-ion physics, and even began forging links further afield than



High hopes. Alexander Baldin and the Nuclotron.

to maintain the link and now has a status. More importantly, the research ministry is now spending 1.2 million a year under an agreement that runs to the end of 1997, a period that many have provided an excellent "East-West" collaboration," says Kadyshchuk.

no other Western country has taken Germany's lead. But the Russian leader to Russia, Thomas von Arnim, visited the institute this year, a direct link between the Department of Energy, serious collaborations with the U.S. reflect this. JINR now has a position on its advisory science board, and the message far and wide. It is at meetings in the U.S., of course, of course.

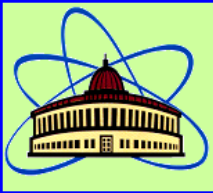
collaboration with Bulgaria and Germany, which tracks the reaction debris when ions accelerated by JINR's U-400 cyclotron hit a heavy-element target.

And a whole new accelerator has been squeezed into a circular service tunnel underneath the aging Synchrophasotron. By recycling parts of the old machine, such as the preaccelerator line and the experimental halls, the institute could afford to build a new ring with superconducting magnets. The brainchild of Alexander Baldin, chief of JINR's high-energy lab, the Nuclotron will push nuclei up to energies of 7 GeV per nucleon to study nuclear interactions at relativistic speeds. Researchers have carried out three test runs this year and will soon start experimenting. Says Kadyshchuk, "It is symbolically important to create a

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ant to build a new factory, parks and tourist facilities open a small. Using their for practice is unusual.





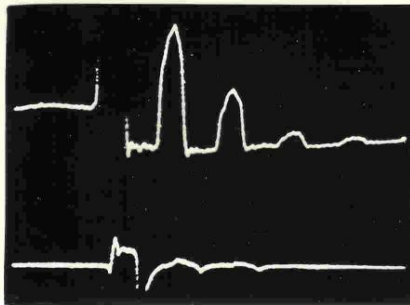
# 1993: FIRST RESULTS FROM NUCLOTRON

March 17th - 26th: THE FIRST RUN

## • THE FIRST CIRCULATING BEAM •

- DEUTERONS, 5 MeV/u;  $N_i \sim 10^{11}$  p.p.c.
- PULSE DURATION -  $\sim 5 \mu s$

26.03.93  
4<sup>00</sup>-5<sup>00</sup>



5  $\mu s$

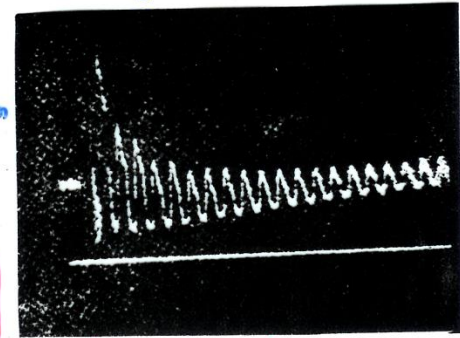
- VACUUM:  $10^{-9} - 10^{-10}$  Torr (beam pipe)
- TOTAL RUNNING TIME  $\sim 240$  hours
- RELIABILITY OF COOLING SYST.  $> 98\%$
- INJECTION, ORBIT CORRECTION, R.F., BEAM DIAGNOSTICS ETC. WERE TESTED.

JUNE 26th ÷ JULY 6th

## THE SECOND NUCLOTRON RUN

- deuterons,  $E_{inj} = 5 \text{ MeV/u}$ ,  $N_0 \sim 10^{11}$  p.p.c.

stable, long term  
circulation

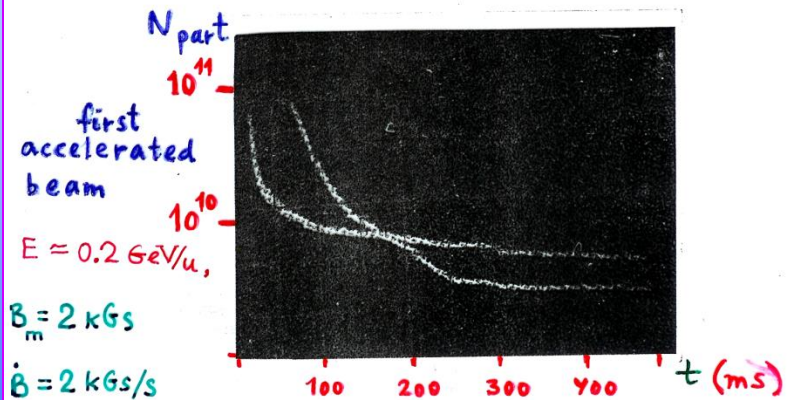


$C > 100 \text{ ms}$

$N \approx 0.8 N_0$

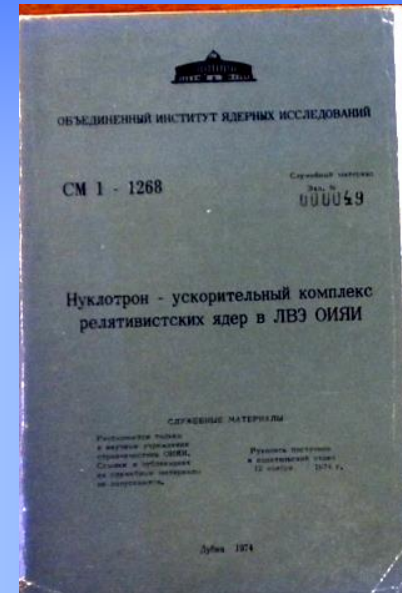
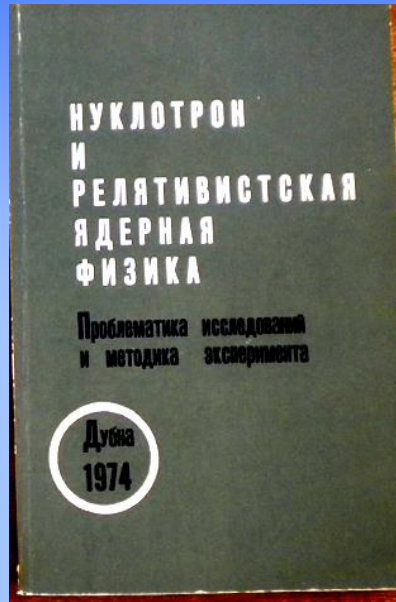
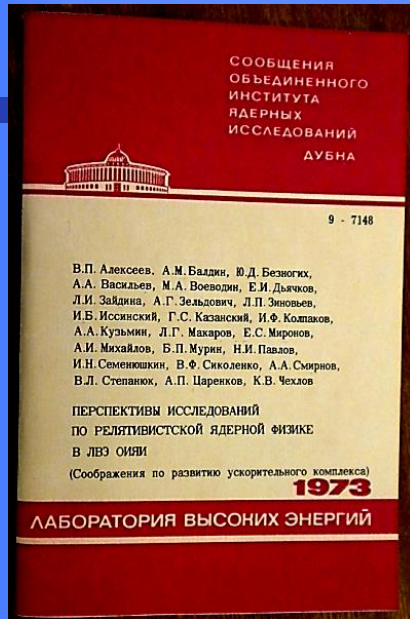
after tuning

$\star \star \sim 8.3 \mu s$  (revolution time)



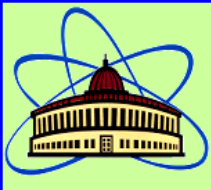


# 1973: START OF THE NUCLOTRON



**MAIN ACCELERATOR – SC SYNCHROTRON BASED ON 5T COSINE ( $\theta$ ) MAGNETS. (First sample was tested at LHE)**

**NEVERTHELESS: NO ACCEPTED TECHNOLOGY, NO MONEY.**



# HIGHWAY or HARDWAY to NUCLOTRON?

## CERN COURIER

International Journal of the High Energy Physics Community

Editors: Brian Southworth, Gordon Fraser, Henri-Luc Felder (French edition) /  
Advertisements: Micheline Falcicola / Advisory Panel: J. Prentki (Chairman),  
J. Allaby, J. Cronin, K. Hübner, E. Lillstøl

VOLUME 23 N° 4

MAY 1983



**DUBNA**  
Superconductivity —  
highway or hard way  
to Nuclotron?

High energy physics with heavy ions (heavy ion physics) began at the Laboratory of High Energies in Dubna. The accelerator for heavy nuclei (from deuterium to uranium) recently polarized the Synchrophasotron and has been in operation

Following this work a superconducting synchrotron of energy 15–25 GeV, called the Nuclotron, is considered of great interest for the further development of relativistic nuclear physics. To this end, the Laboratory of High Energies has been working on the technology of 2 to 2.5 T superconducting iron yoke magnets. Such magnets have some advantages over both conventional magnets and 5 T superconducting magnets.

The weight of the superconducting magnet can be up to twenty times smaller than a 'warm' magnet of the same aperture due to the high current density in the superconducting coil (up to 500 A per mm<sup>2</sup>). Moreover, because of the smaller energy consumption the operation cost is much lower even taking into account costs for the helium cryostat and refrigerator.

Comparing the Dubna magnets with 5 T superconducting magnets, the quantity of superconductor per magnet unit length is smaller by a factor of ten. This decreases energy losses under pulsed operation and field shape distortions, inherent in superconducting coils due to 'frozen' currents and so on. A closely wrapped iron yoke lowers the number of required ampere turns of the coil by a factor of two, shapes the field and shields external fields. It also acts as a restraining band to fix the coil geometry. The absence of a non-magnetic band makes the structure simpler and less expensive, as well as decreasing the stored energy. Lower stored energy affects both the necessary power supply for the accelerator magnets and their reliability, allowing easier evacuation of the energy in any accidental transition to normal state.

A further lowering of the cost is possible by eliminating the helium cryostat. The magnet is then force-

Three prototype cells for a model 1.5 GeV superconducting synchrotron being assembled at Dubna prior to successful tests. The 2.5 T magnets have been specially designed with a view to eventually building a synchrotron, called the Nuclotron.

(Photo Dubna)



Besides the magnet design, the application of superconductivity in an accelerator leads to some problems of integration of the magnets with the r.f., vacuum, injection and extraction systems, etc. A model 1.5 GeV superconducting synchrotron is being designed at the Laboratory of High Energies to solve these problems and gain experience. The accelerator will contain more than 100 superconducting dipole and quadrupole magnets, in 24 regular FODO cells each 1.5 m long, and two matched 9 m straight sections.

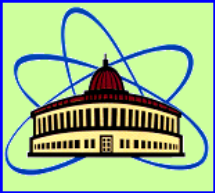
The first step was the construction of three prototype cells which have been cooled and tested. Experience with the magnet system has answered many important questions not only concerning the design of the model synchrotron, but also the eventual construction of accelerators of the Nuclotron type for the acceleration of heavy ions.

**1992: Russian State Prize in  
Physics, Mathematics  
& Mechanics**

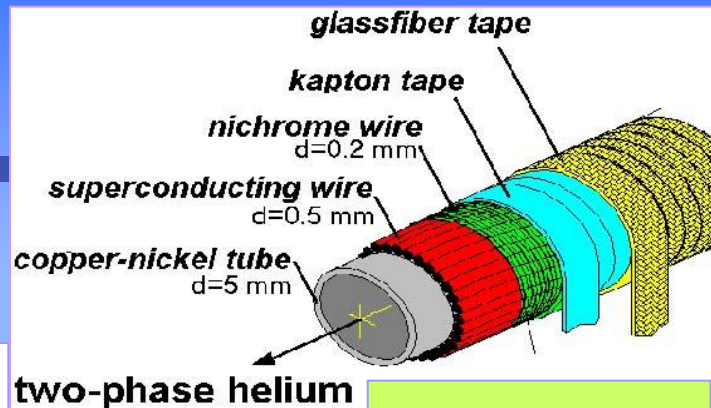
- Superferric 2.5T magnets,
- Setup "SPIN",
- SC technology,
- Low cost,

cooled by liquid helium in hollow superconducting cable. This brings the Dubna magnets still closer to conventional types. The first pulsed superconducting magnet with forced two-phase helium circulation was successfully tested in 1980 and had excellent characteristics. The predicted field value was achieved without training and the same field was reached when the frequency of triangular cycles was as high as 1 Hz.

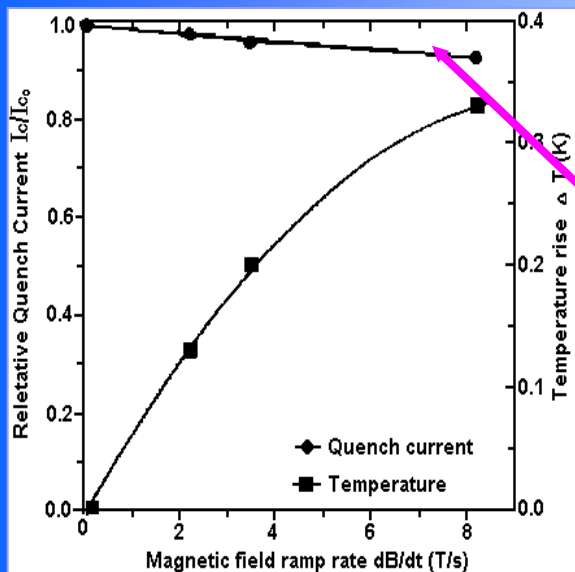




# NbTi COMPOSITE HOLLOW CABLE

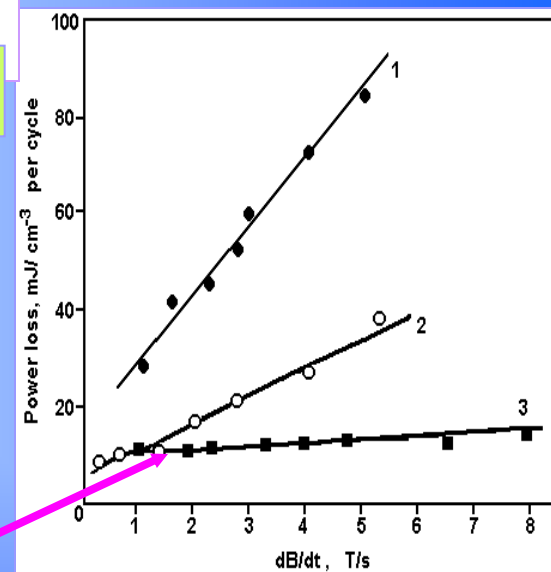


A.A.Smirnov et al.

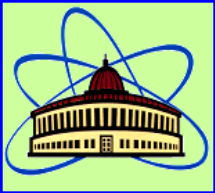


Low degradation of the cable critical current at fast ramping operation (4.8 % @  $dB/dt = 4\text{ T/s}$ )

Weak dependence of the eddy current loss on the magnetic field ramp



## UNIQUE CHARACTERISTICS – FAST CYCLING OPERATION



# DUBNA TECHNOLOGY OF SC MAGNETS



685 MM

ДИПОЛЬНЫЙ  
МАГНИТ:  
 $B = 2 \text{ Тл}$ ,  $\dot{B} = 4 \text{ Т/с}$



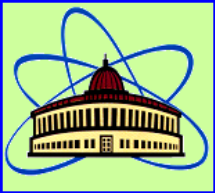
КВАДРУПОЛЬНАЯ  
ЛИНЗА:  $G = 34 \text{ Т/м}$ ,  
 $\dot{G} = 68 \text{ Т/м} \cdot \text{с}$

- *IRON DOMINATED*

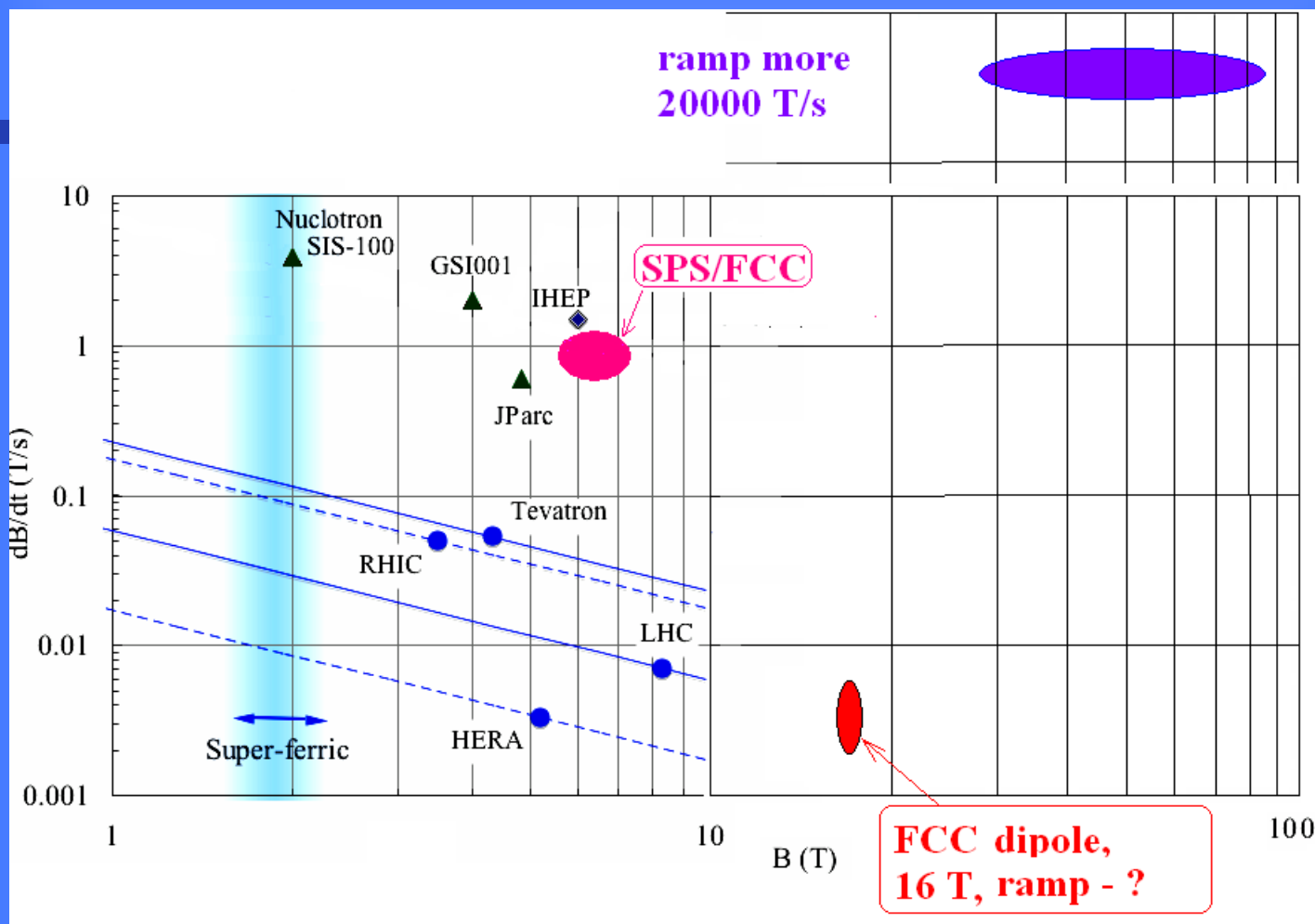
- *HOLLOW TUBE SC CABLE*

- *TWO PHASE HELIUM,  $T = 4.5 \text{ K}$*

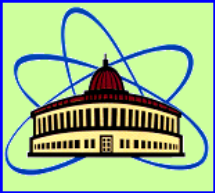
**UNIVERSALITY: FAST CYCLED AND QUASI – CONTINUOUS MODES**



# WORLD LANDSCAPE OF SC MAGNETS



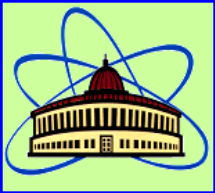




# LHE ACCELERATOR FACILITY



- **ПРОЕКТ УТВЕРЖДЕН В ДЕКАБРЕ 1986 года**
- **ИЗГОТОВЛЕНИЕ И МОНТАЖ ЗАВЕРШЕНЫ в ДЕК. 1992г.**
- **ПЕРВЫЙ СЕАНС РАБОТЫ - март 1993 года**



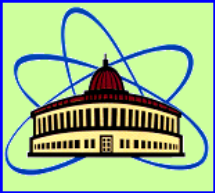
# NUCLOTRON vs SYNCHROPHASOTRON

- **ВЕС МАГНИТА  
СИНХРОФАЗОТРОНА**  
- 170 т/м



- **ВЕС МАГНИТА  
НУКЛОТРОНА** - 0.3 т/м





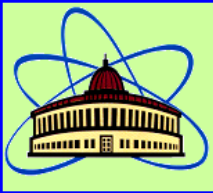
# LIQUID HELIUM FACILITY



**V.S.CHERNOMYRDIN'S VISIT TO JINR:**  
He had a look at our exposition on helium facility where Orenburg gaseous plant was mentioned. Later A.M. signed letter to him with our requests. Everything was fulfilled by Heliummash Company.







# 1986-1991 NUCLOTRON-SUPERNUCLOTRON

Частицы, ячки	Энергия (ГэВ/нукл.)	Интенсивность (част./с)	Энерг. Резерв (д.ж.г)	Эмиттанс (рад.м)	Светимость L (см <sup>-2</sup> .с <sup>-1</sup> )
протоны, p	12	~ 10 <sup>12</sup>	10 <sup>-3</sup>	10 <sup>-5</sup>	-
ядра: d	6	~ 10 <sup>12</sup>	10 <sup>-3</sup>	5·10 <sup>6</sup>	-
I <sup>2</sup> C	—	(d.f.~10 <sup>9</sup> -10 <sup>10</sup> )	2·10 <sup>-3</sup>	—	—
238U	4	10 <sup>8</sup> -10 <sup>9</sup>	4·10 <sup>-3</sup>	—	—
протоны, p	120	~ 10 <sup>12</sup>	5·10 <sup>-4</sup>	5·10 <sup>-6</sup>	-
ядра: d	60	~ 10 <sup>12</sup>	5·10 <sup>-4</sup>	2·10 <sup>-6</sup>	-
I <sup>2</sup> C	60	~ 10 <sup>12</sup>	~ 10 <sup>-3</sup>	—	—
238U	40	~ 10 <sup>8</sup>	2,5·10 <sup>-3</sup>	—	—
электроны, e	0,5-4 (12)	10 <sup>15</sup>	10 <sup>-5</sup>	2·10 <sup>-9</sup>	-
e.p	4(12)х120				10 <sup>30</sup> ·10 <sup>31</sup>
eA	(√S ≈ 44(76))				10 <sup>30</sup> ·10 <sup>27</sup>
(A= d,...U)	4(12)х60(40)				
PP	120х120				~ 10 <sup>31</sup>
AA	60х60(40х40) уран				10 <sup>26</sup> -10 <sup>27</sup> (для тяжелых ядер)

№ п/п	Наименование работ	Результат	Исполнитель (организация)	Объем стоим. (млн.руб.)	Примечание
1.	Проектирование тоннеля и технологических корпусов	Подготовка строительных	ИСИИ	2,0	1990-1994гг.
2.	Проектирование технологического нестационарного оборудования	Обеспечение изготовления систем	ИИИ	1,0	1991-1992гг.
3.	Научно-экспериментальные работы	Рабочий вариант магнита	ОИИИ	2,0	1991-1993гг.
4.	Полномасштабное моделирование участка кольцевого магнита	Уточнение рабочего проекта	ОИИИ	5,0	1992-1994гг.

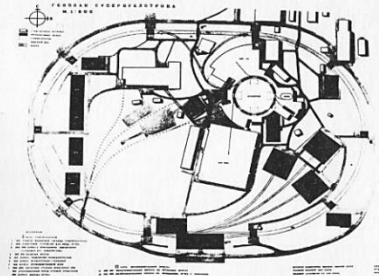
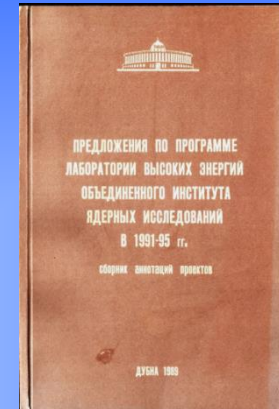


Рис.1. Проект генплана комплекса Суперпротона.

## Литература

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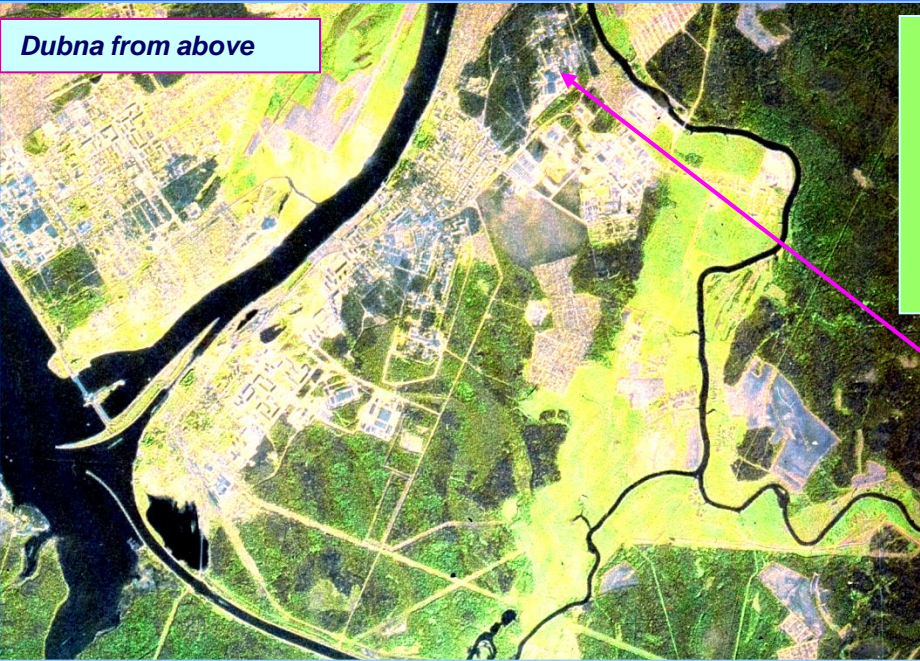
**SUPERNUCLOTRON**  
*was not supported at that time, nevertheless later proposed (2002) 2x6 AGeV ion collider NICA are constructing now.*

**Electron-ion option is included in the future JINR prospect**



# VEKSLER-BALDIN LABORATORY IN DUBNA

Dubna from above



**1944:** phase stability principle;  
**1956:** new methods of acceleration



В.И.Векслер

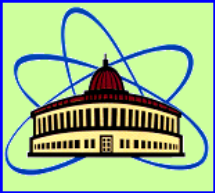
**1970:** relativistic nuclear physics;  
**1973-1993:** Nuclotron proposal design&construction,



А.М.Валдин





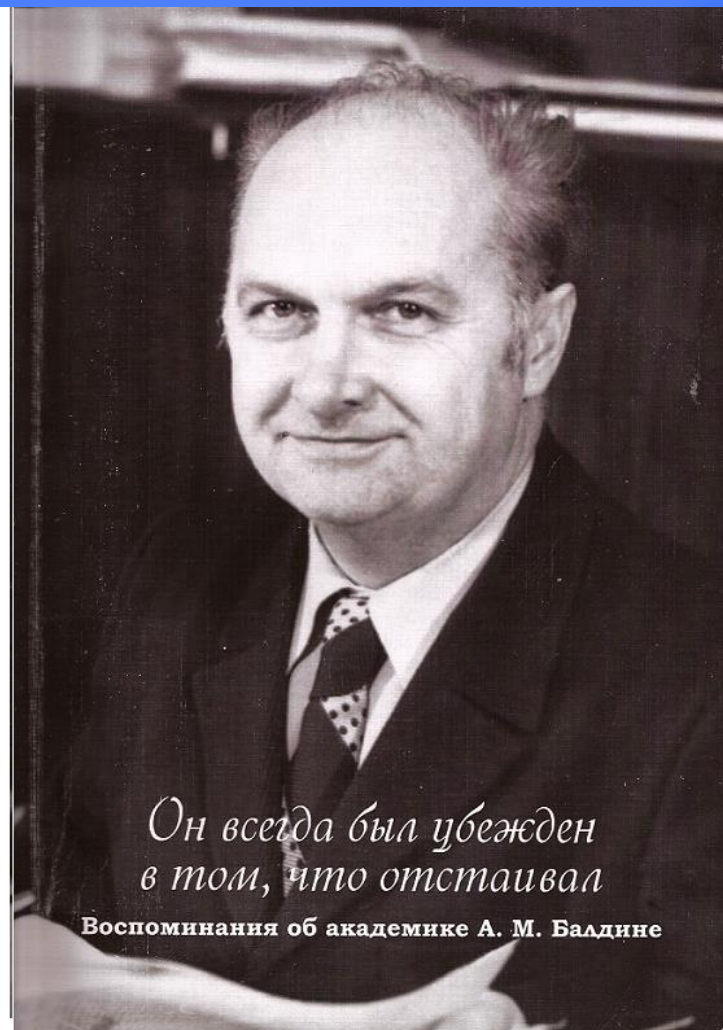


ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

## ОН ВСЕГДА БЫЛ УБЕЖДЕН В ТОМ, ЧТО ОТСТАИВАЛ

*Воспоминания об академике  
Александре Михайловиче Балдине*

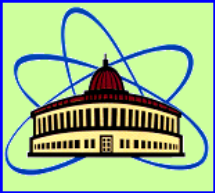
Составители: А. И. Малахов, Б. М. Старченко



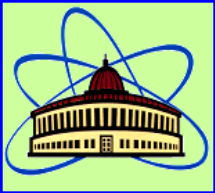
*Он всегда был убежден  
в том, что отстаивал*

Воспоминания об академике А. М. Балдине





• this is oak tree planted by AM



---

**MANY THANKS FOR YOUR  
ATTENTION**