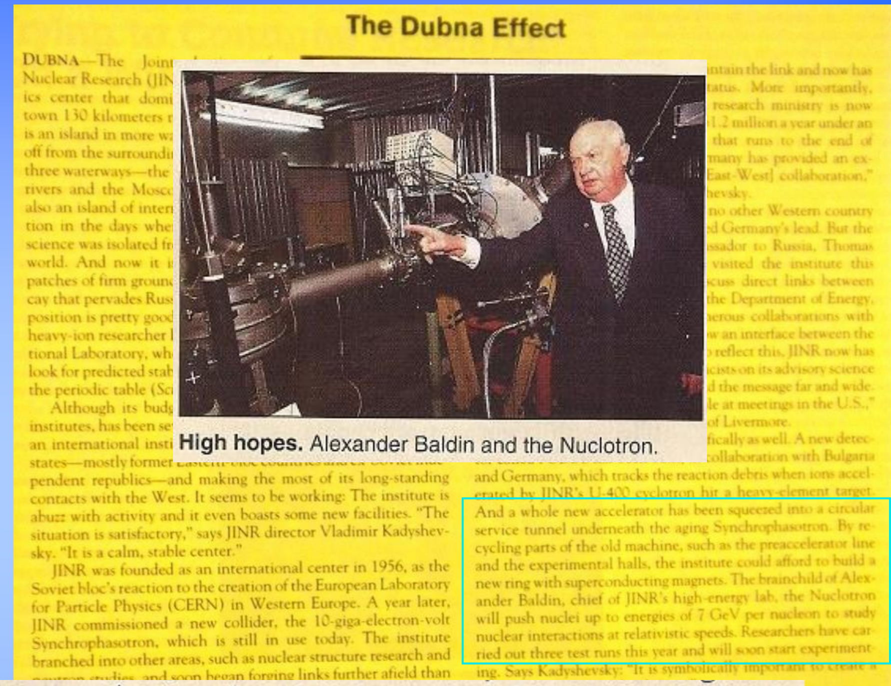
To the 95th birthday of Alexander Mikhailovich Baldin

A.M.BALDIN
and his
NUCLOTRON

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

1994: THE DUBNA EFFECT



The Dubna Effect

High hopes. Alexander Baldin and the Nuclotron.

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 experiment-

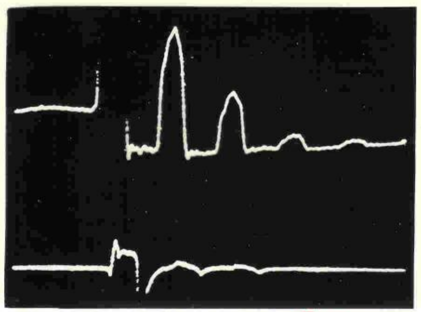
1993: FIRST RESULTS FROM NUCLOTRON

March 17th – 26th : THE FIRST RUN

• THE FIRST CIRCULATING BEAM •

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

26.03.93
4⁰⁰ – 5⁰⁰



5 μs

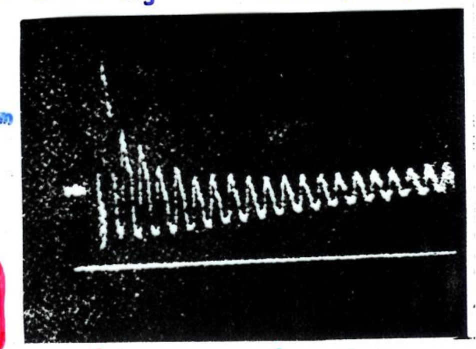
- VACUUM: $10^{-9} - 10^{-10}$ Torr (beam pipe)
- TOTAL RUNNING TIME ~ 240 hours
- RELIABILITY OF COOLING SYST. > 98%
- INJECTION, ORBIT CORRECTION, R.F., BEAM DIAGNOSTICS ETC. WERE TESTED.

JUNE 26th ÷ JULY 6th

THE SECOND NUCLOTRON RUN

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

stable, long term circulation



$\tau > 100$ ms

$N \simeq 0.8 N_0$

after tunning

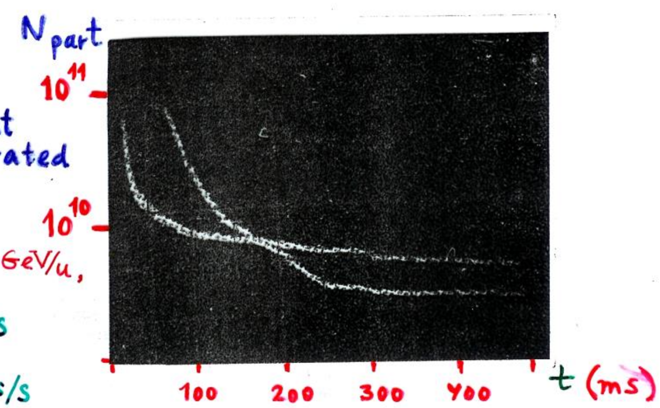
↔ ~8.3 μs (revolution time)

first accelerated beam

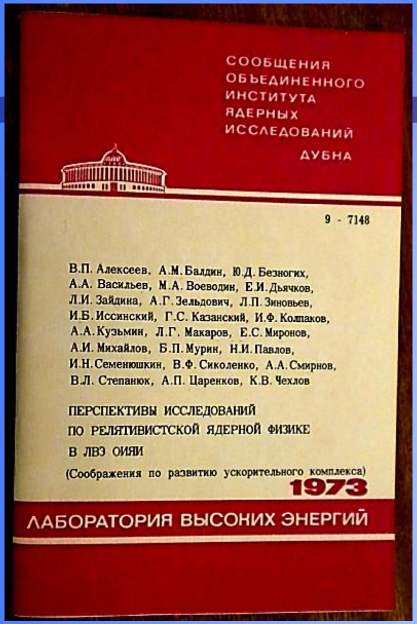
$E \simeq 0.2$ GeV/u,

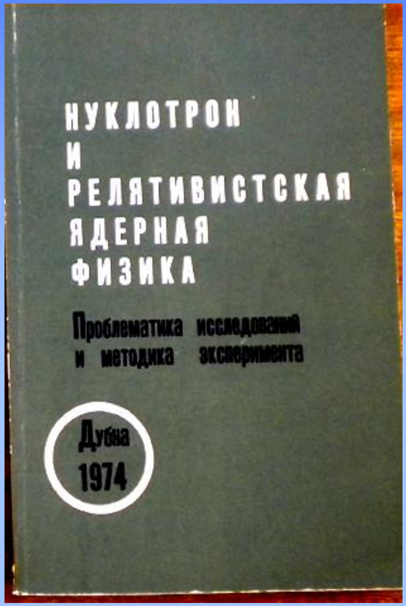
$B_m = 2$ kGs

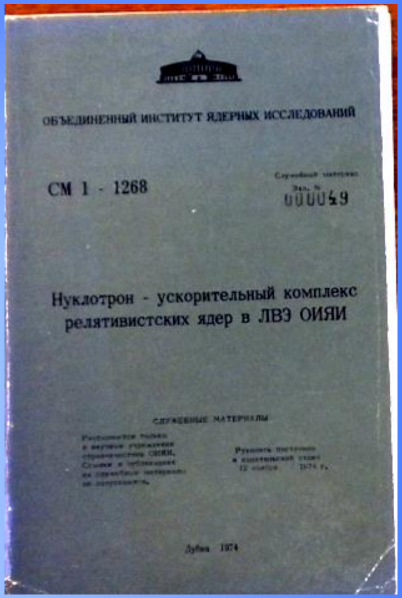
$\dot{B} = 2$ kGs/s



1973: START OF THE NUCLOTRON







MAIN ACCELERATOR – SC SYNCHROTRON BASED ON 5T COSINE (θ) 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 Falciola / Advisory Panel: J. Prentki (Chairman), J. Allaby, J. Cronin, K. Hübner, E. Lillestøl

VOLUME 23 N° 4 MAY 1983

DUBNA
Superconductivity — highway or hard way to Nuclotron?

High energy physics with heavy ions ...lear physics) began ...go at the Laboratory ... in Dubna. The accel... nuclei (from deute... ...nd recently polarized ...e Synchrophasotron ...ew life into the ma... ...s been in operation

1992: Russian State Prize in Physics, Mathematics & Mechanics

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^2). 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-

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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)

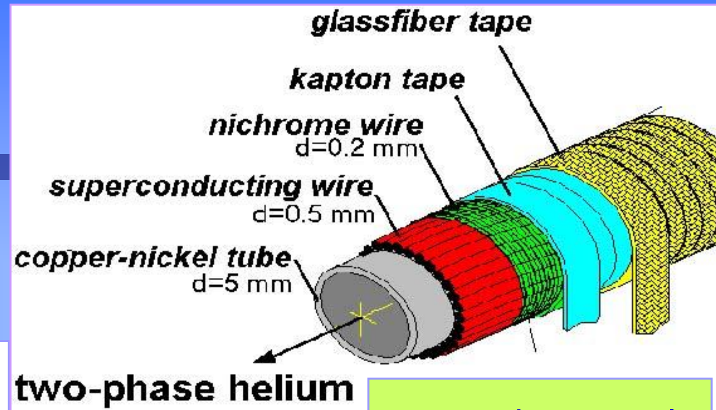
cooled by liquid helium in hollow superconducting cable. This brings the Dubna magnets still closer to conventional types. The first pulsed superconducting magnet with forced two-phase helium circulation was successfully tested in 1980 and had excellent characteristics. The predicted field value was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

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.

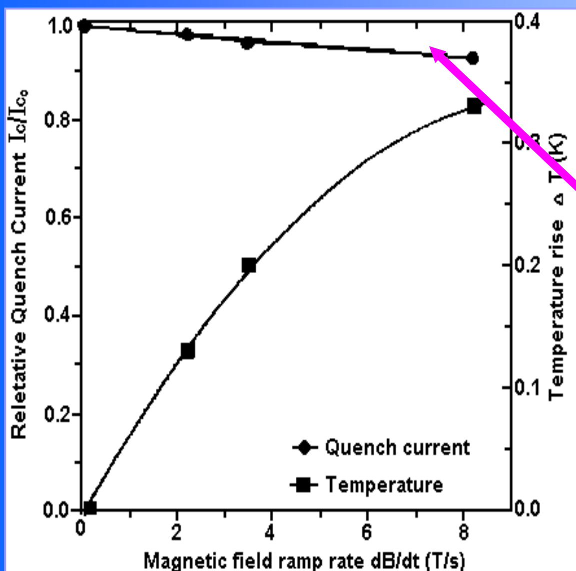
The first step was the construction of three prototype cells which have been cooled and tested. Experience with the magnet system has answered many important questions not only concerning the design of the model synchrotron, but also the eventual construction of accelerators of the Nuclotron type for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

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

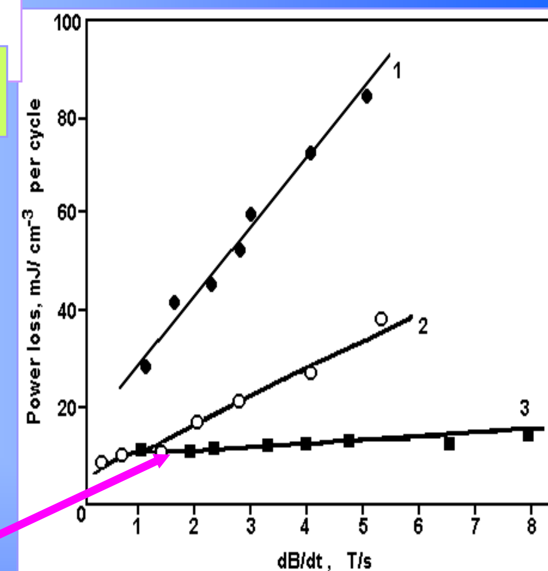
NbTi COMPOSITE HOLLOW CABLE



A.A.Smirnov et al.



- Low degradation of the cable critical current at fast ramping operation (4.8 %. @ dB/dt= 4 T/s)
- Weak dependence of the eddy current loss on the magnetic field ramp



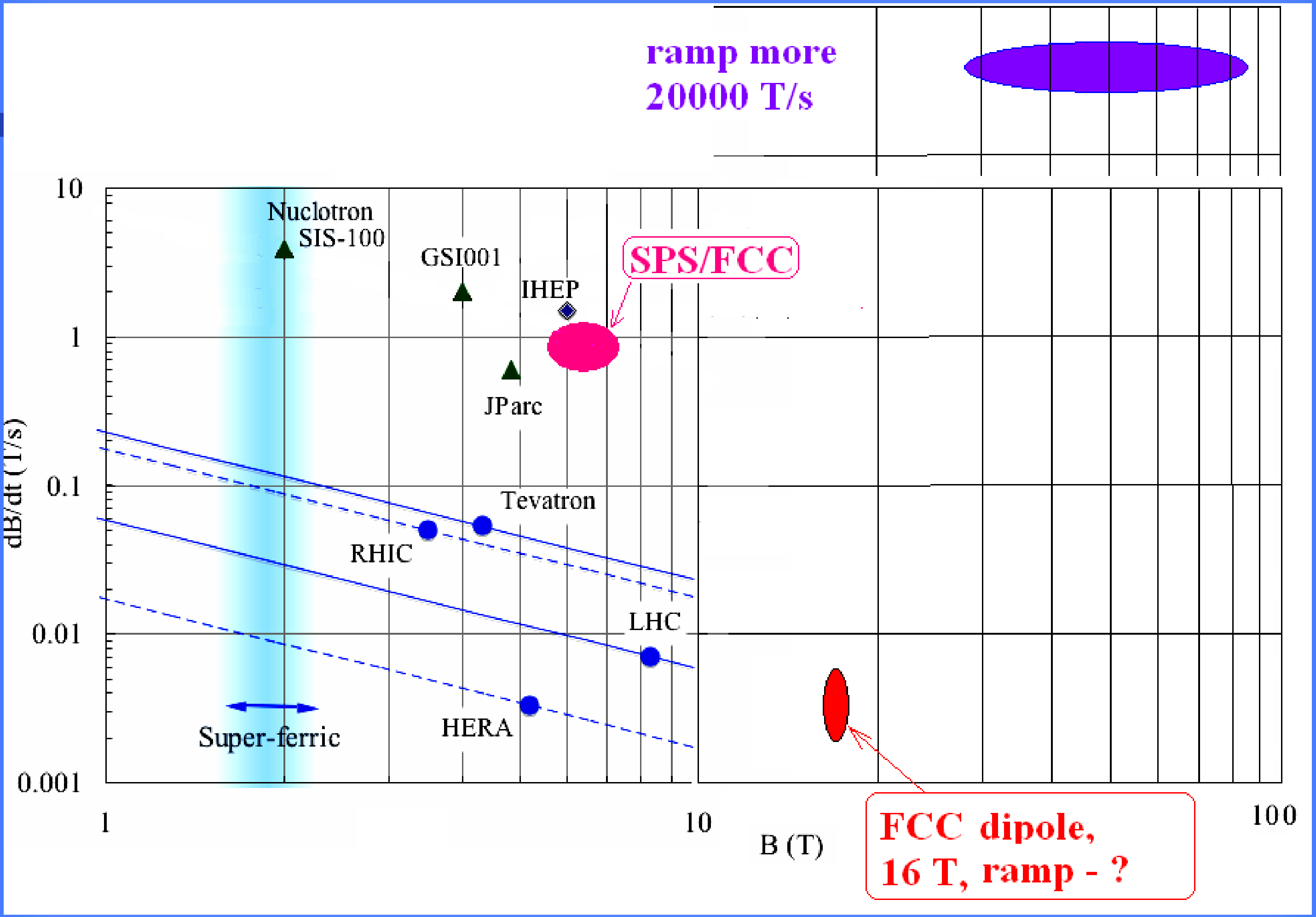
UNIQUE CHARACTERISTICS – FAST CYCLING OPERATION

DUBNA TECHNOLOGY OF SC MAGNETS

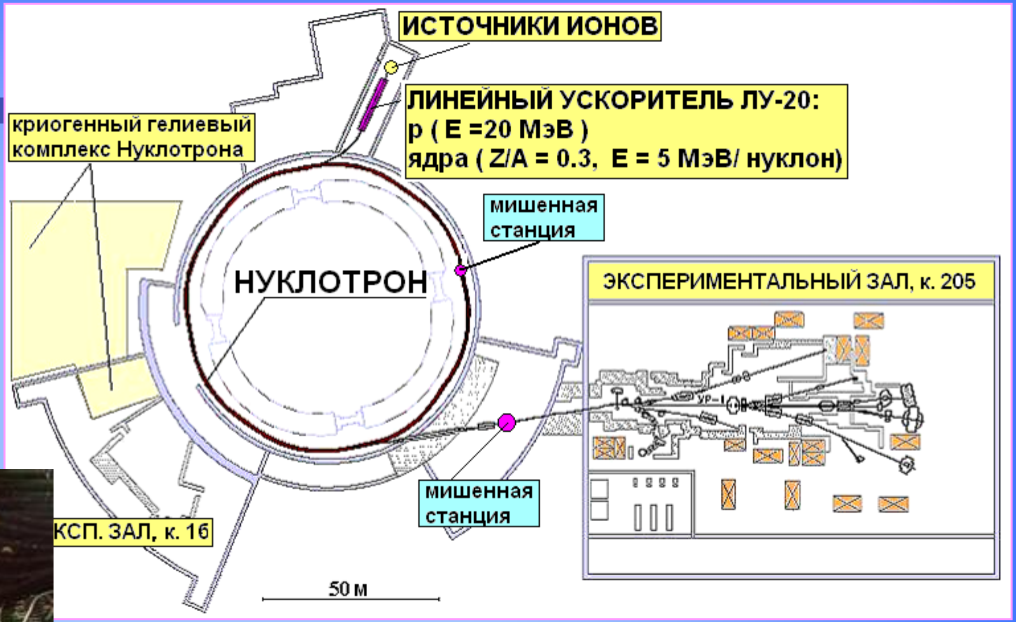
- *IRON DOMINATED*
- *HOLLOW TUBE SC CABLE*
- *TWO PHASE HELIUM, T = 4.5 K*

UNIVERSALITY: FAST CYCLED AND QUASI – CONTINUES 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 fullfiled by Heliummash Company.

1986-1991 NUCLOTRON-SUPERNUCLOTRON

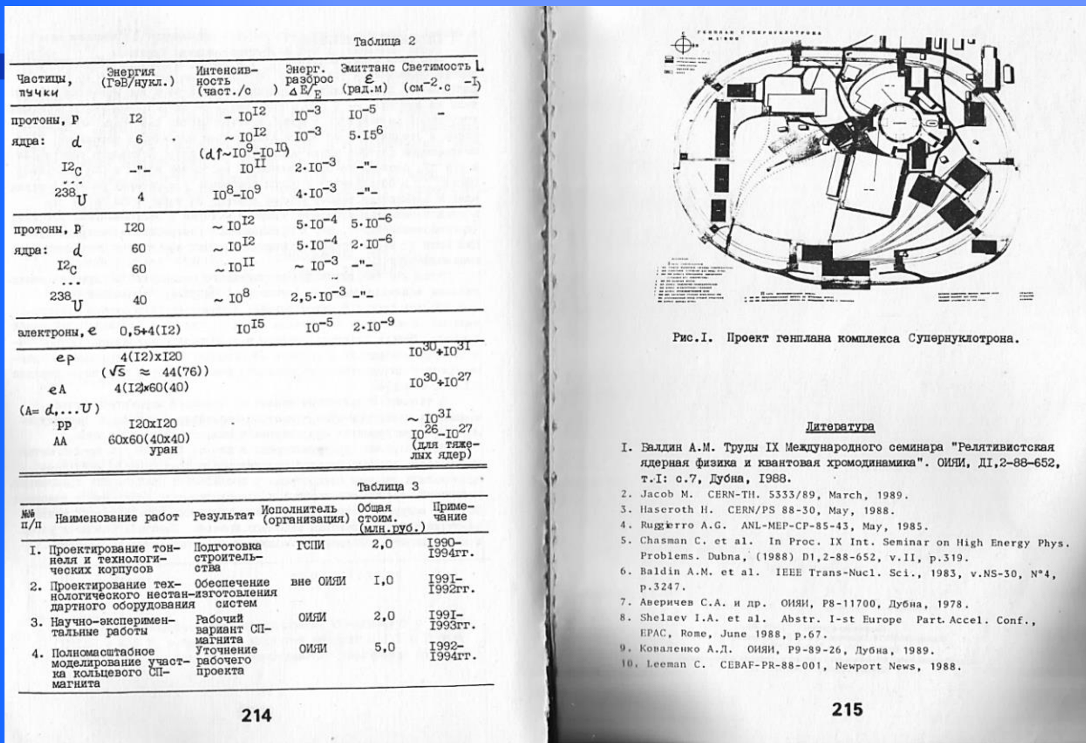


Таблица 2

Частицы, пучки	Энергия (ГэВ/нукл.)	Интенсивность (част./с)	Энерг. разброс $\Delta E/E$	Эмиттанс ε (рад.м)	Светимость L ($см^{-2}\cdot с^{-1}$)
протоны, p	I2	-10^{12}	10^{-3}	10^{-5}	–
ядра: d	6	$\sim 10^{12}$ ($d\uparrow \sim 10^{9}-10^{10}$)	10^{-3}	$5\cdot 15^{6}$	
^{12}C	-"-	10^{11}	$2\cdot 10^{-3}$	-"-	
...					
^{238}U	4	$10^{8}-10^{9}$	$4\cdot 10^{-3}$	-"-	
протоны, p	I20	$\sim 10^{12}$	$5\cdot 10^{-4}$	$5\cdot 10^{-6}$	
ядра: d	60	$\sim 10^{12}$	$5\cdot 10^{-4}$	$2\cdot 10^{-6}$	
^{12}C	60	$\sim 10^{11}$	$\sim 10^{-3}$	-"-	
...					
^{238}U	40	$\sim 10^{8}$	$2,5\cdot 10^{-3}$	-"-	
электроны, e	0,5+4(I2)	10^{15}	10^{-5}	$2\cdot 10^{-9}$	
ep	4(I2)xI20 ($\sqrt{s} \approx 44(76)$)				$10^{30}+10^{31}$
eA (A= d,...U)	4(I2)x60(40)				$10^{30}+10^{27}$
pp	I20xI20				$\sim 10^{31}$
AA	60x60(40x40) уран				$10^{26}-10^{27}$ (для тяжелых ядер)

Таблица 3

№№ п/п	Наименование работ	Результат	Исполнитель (организация)	Общая стоим. (млн.руб.)	Примечание
I.	Проектирование тоннеля и технологических корпусов	Подготовка строительства	ГСПИ	2,0	I990-I994гг.
2.	Проектирование технологического нестандартного оборудования	Обеспечение изготовления систем	вне ОИЯИ	I,0	I99I-I992гг.
3.	Научно-экспериментальные работы	Рабочий вариант СП-магнита	ОИЯИ	2,0	I99I-I993гг.
4.	Полномасштабное моделирование участка кольцевого СП-магнита	Уточнение рабочего проекта	ОИЯИ	5,0	I992-I994гг.

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Рис.I. Проект генплана комплекса Супернуклотрона.

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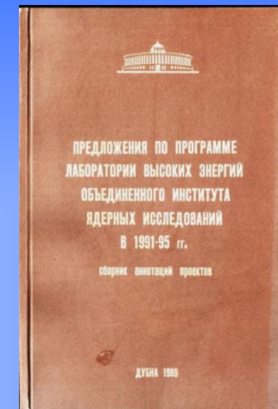
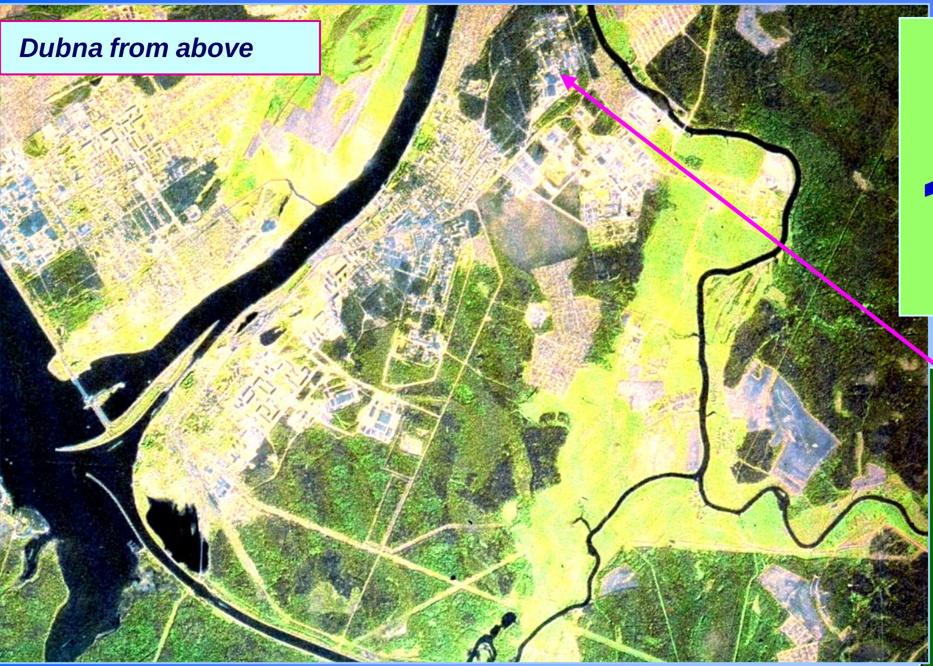


SUPERNUCLOTRON ***was not supported at that time, nevertheless later proposed (2002) 2x6 AGeV ion collider NICA are constructing now.***

Electron-ion option is includied in the future JINR prospect

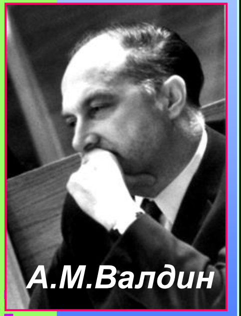
VEKSLER-BALDIN LABORATORY IN DUBNA

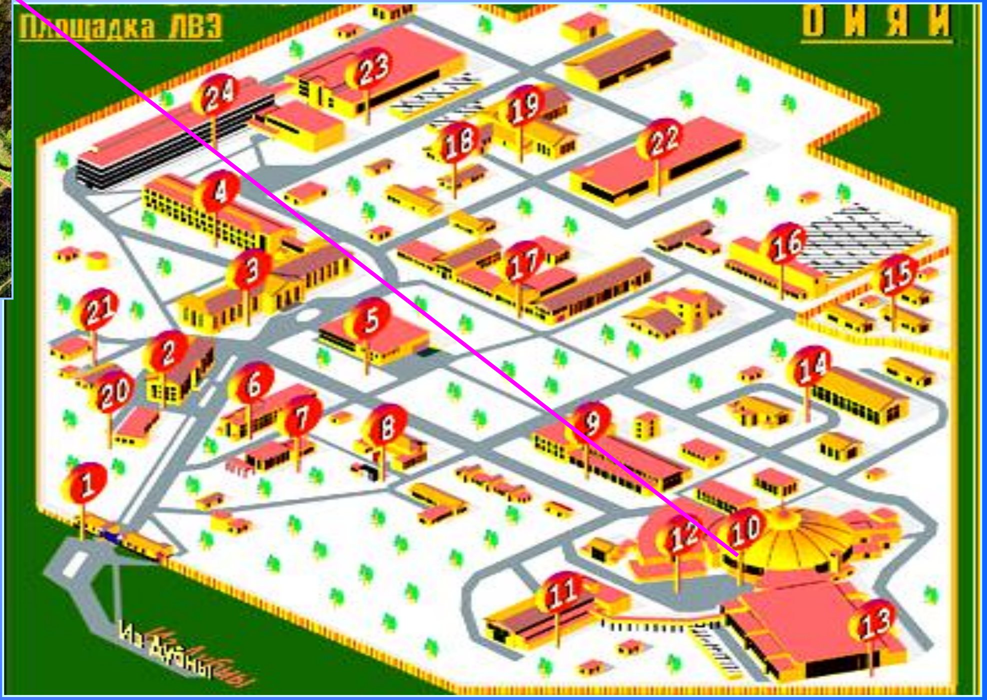


Dubna from above

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

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



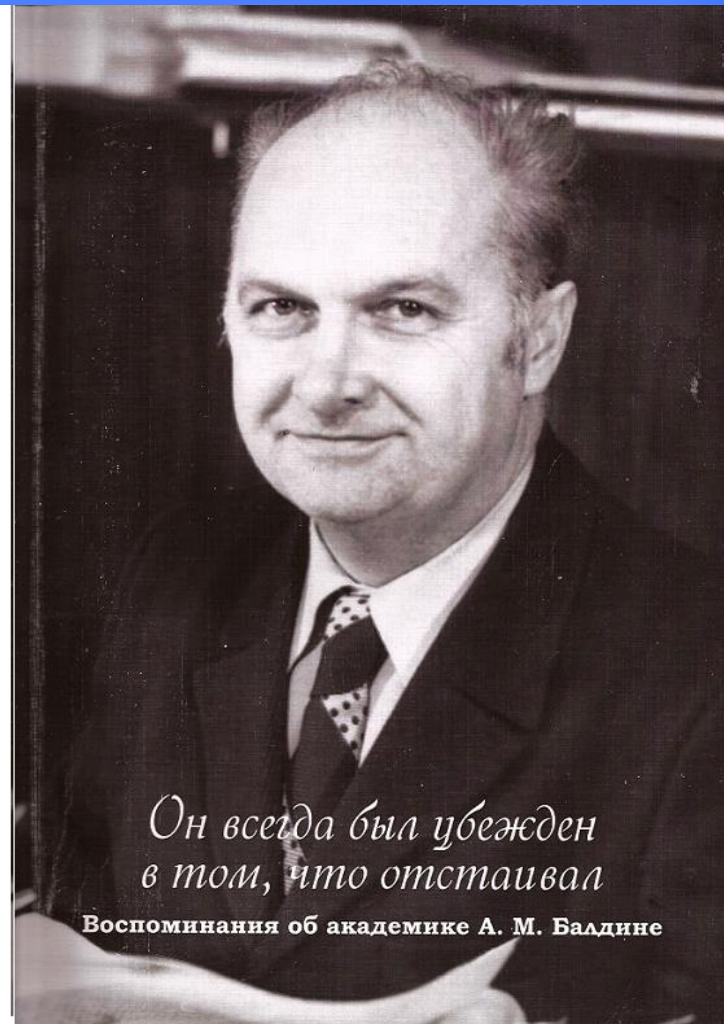


ОБЪЕДИНЕННЫЙ ИНСТИТУТ ЯДЕРНЫХ ИССЛЕДОВАНИЙ

ОН ВСЕГДА БЫЛ УБЕЖДЕН В ТОМ, ЧТО ОТСТАИВАЛ

Воспоминания об академике Александре Михайловиче Балдине

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



• ***this is oak tree planted by AM***

MANY THANKS FOR YOUR ATTENTION