JINR today and tomorrow

Nikolai Russakovich, JINR

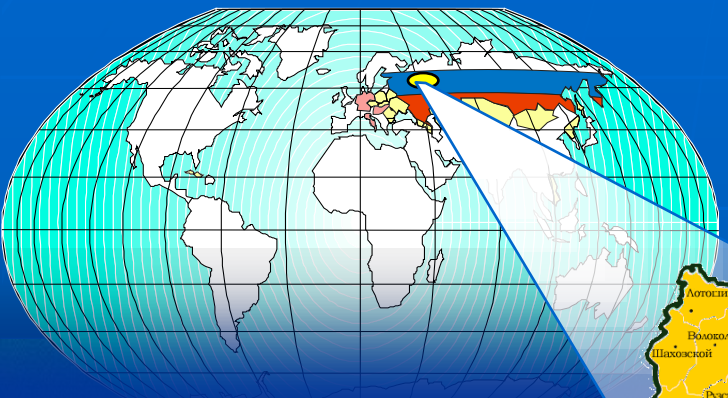
2010 European School of High-Energy Physics

Raseborg, Finland

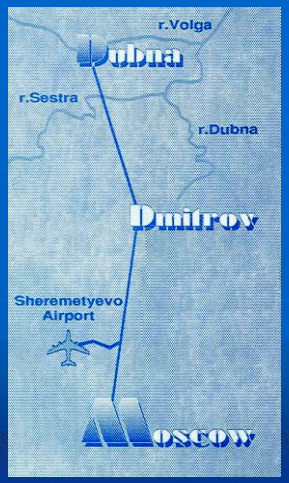
20 June - 3 July, 2010

Academician Alexey Sissakian
14.10.1944 – 01.05.2010

Russia

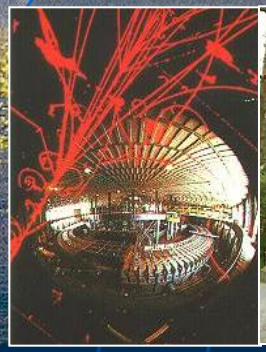


Moscow Region



Dubna

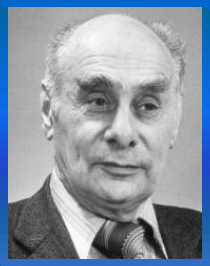
JINR



Established in March 1956

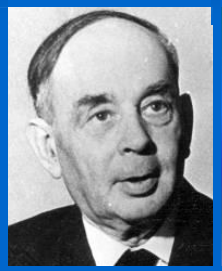
Mission: Promoting international cooperation in Fundamental Science for non-commercial & non-military use

Founders

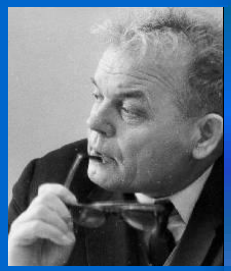


G.Flerov

V.Veksler



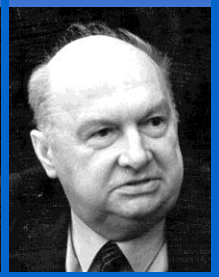
I.Frank



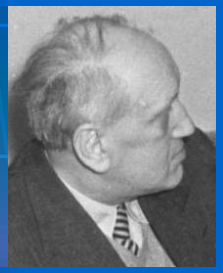
M.Meshcheryakov

V.Dzhelepov

N.Bogoliubov,
D.Blokhintsev



A.Baldin



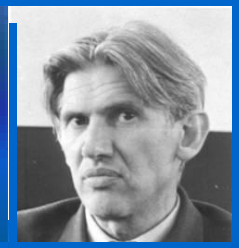
L.Infeld

B.Pontecorvo

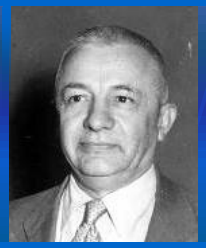
H.Hulubei

Wang Ganchang

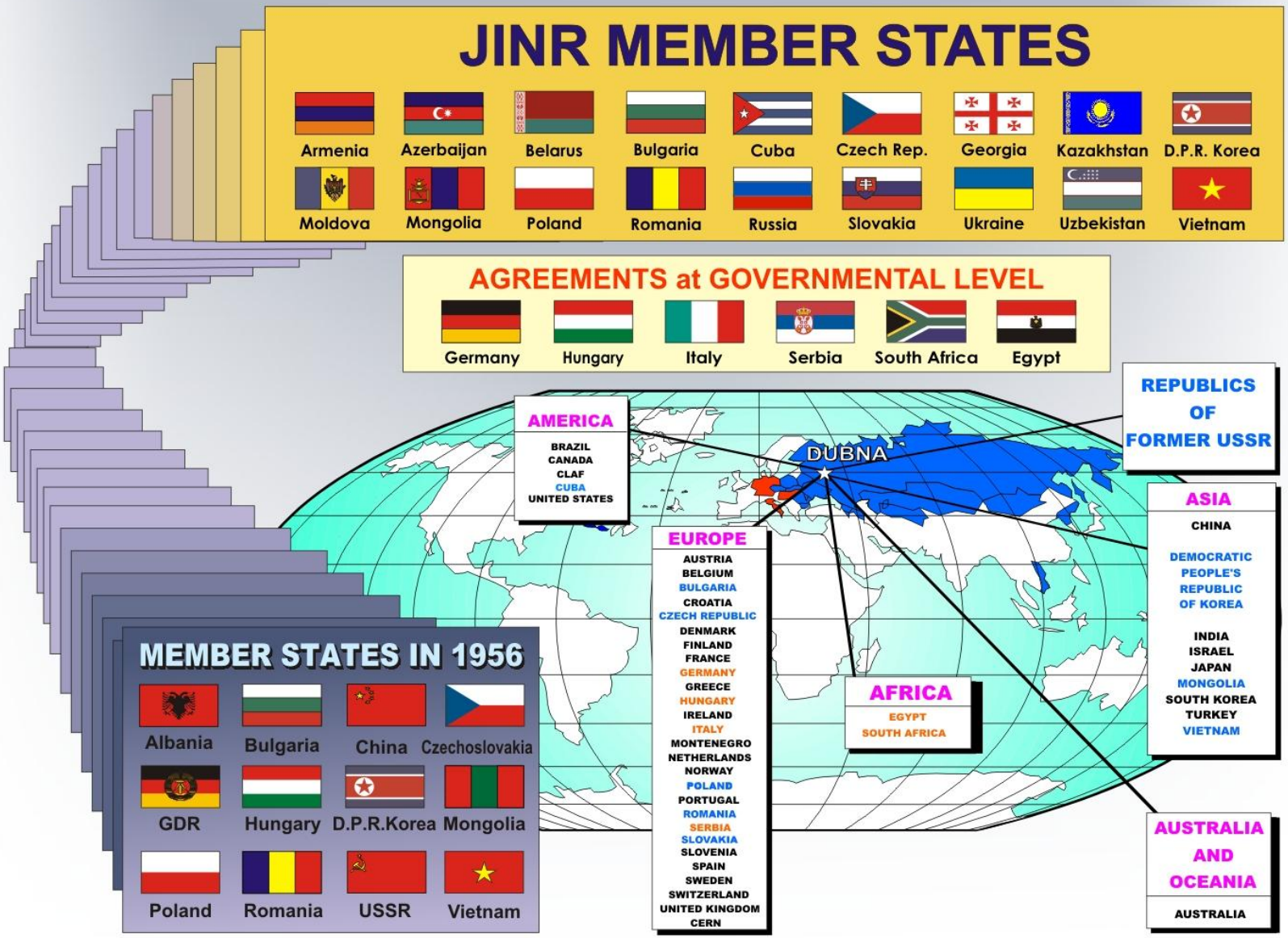
H.Niewodniczanski



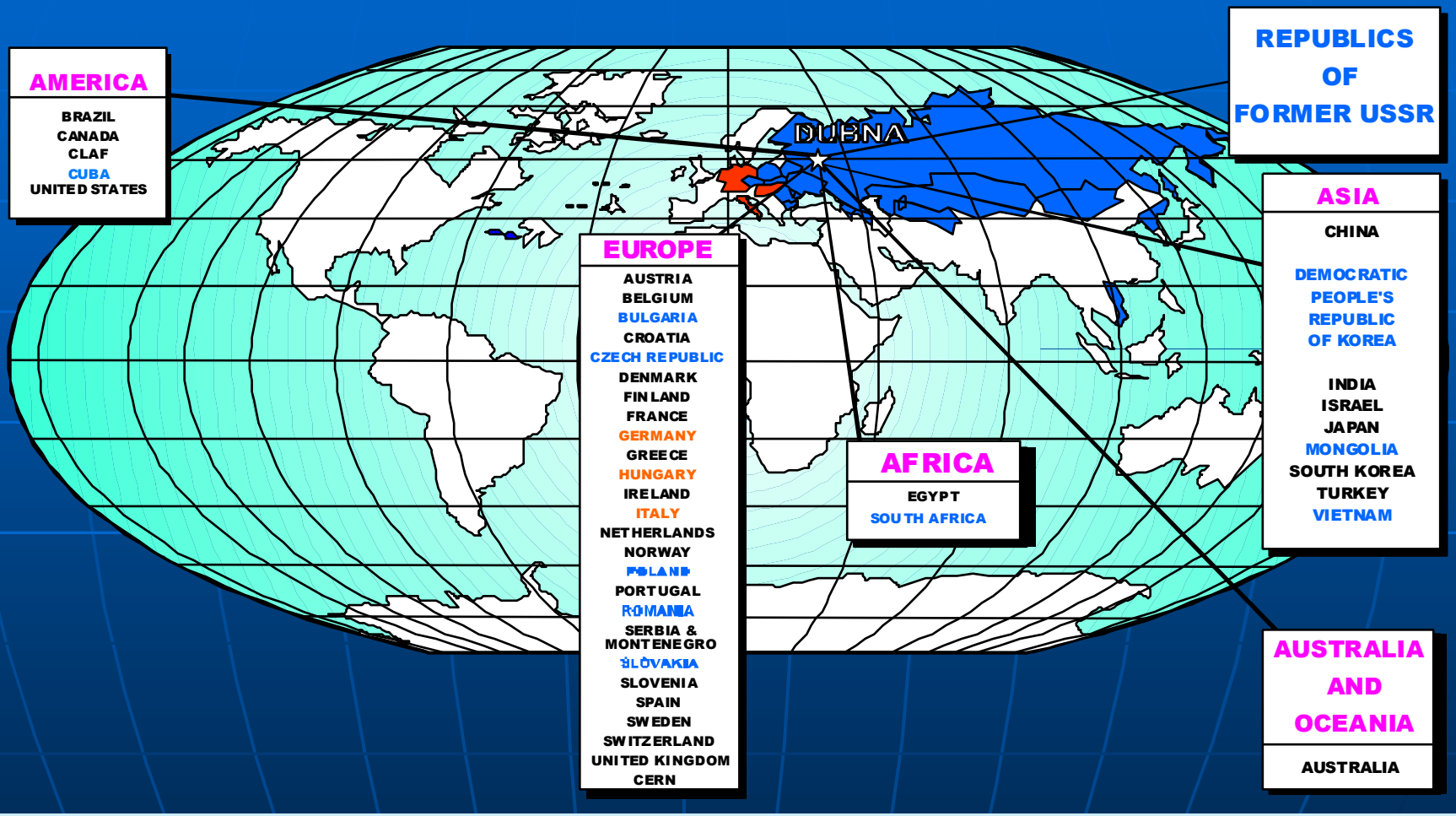
L.Janossy



G.Najakov


JINR MEMBER STATES
Armenia
Azerbaijan
Belarus
Bulgaria
Cuba
Czech Rep.
Georgia
Kazakhstan
D.P.R. Korea
Moldova
Mongolia
Poland
Romania
Russia
Slovakia
Ukraine
Uzbekistan
Vietnam
AGREEMENTS at GOVERNMENTAL LEVEL
Germany
Hungary
Italy
Serbia
South Africa
Egypt
MEMBER STATES IN 1956
Albania
Bulgaria
China
Czechoslovakia
GDR
Hungary
D.P.R.Korea
Mongolia
Poland
Romania
USSR
Vietnam
AMERICA
BRAZIL
CANADA
CLAF
CUBA
UNITED STATES
DUBNA
EUROPE
AUSTRIA
BELGIUM
BULGARIA
CROATIA
CZECH REPUBLIC
DENMARK
FINLAND
FRANCE
GERMANY
GREECE
HUNGARY
IRELAND
ITALY
MONTENEGRO
NETHERLANDS
NORWAY
POLAND
PORTUGAL
ROMANIA
SERBIA
SLOVAKIA
SLOVENIA
SPAIN
SWEDEN
SWITZERLAND
UNITED KINGDOM
CERN
AFRICA
EGYPT
SOUTH AFRICA
REPUBLICS OF FORMER USSR
ASIA
CHINA
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA
INDIA
ISRAEL
JAPAN
MONGOLIA
SOUTH KOREA
TURKEY
VIETNAM
AUSTRALIA AND OCEANIA
AUSTRALIA

International Cooperation



JINR's partners are about 700 institutions located in 60 countries

Collaboration with CERN

The history of cooperation between CERN and JINR spans over about 50 years.

CERN is JINR's main partner in Particle Physics.

Dubna physicists are widely involved in more than 20 CERN projects, including 3 LHC experiments

1963, JINR, Dubna
CERN Director-General
Prof. V.Weisskopf,
Prof. V.Dzhelepov and
Prof. B.Pontecorvo

2004, CERN Director-General
Dr R.Aymar in Dubna

1971, Dubna
CERN Director-General
Prof. W.Jentschke
and JINR Director
Prof. N.Bogoliubov

CERN-JINR Partnership in Particle Physics

ICA-RU-0111

CO-OPERATION AGREEMENT

between

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

and

THE JOINT INSTITUTE FOR NUCLEAR RESEARCH (JINR)

concerning

Scientific and Technical Co-operation in High-Energy Physics

2010

Done at Geneva on 28 January 2010, in two copies in the English language.

For the European Organization for Nuclear Research (CERN)	For the Joint Institute for Nuclear Research (JINR)
Prof. Rolf-Dieter Heuer	Prof. Alexei N. Sissakian

28 January 2010, CERN Signing of the Agreement between CERN and JINR

3.2 Possible projects at the date of this Agreement include:

- the commissioning and operation of the Large Hadron Collider ("LHC") at CERN, including the ALICE, ATLAS and CMS experiments using the LHC;
- upgrades of the Nuclotron and the construction, commissioning and operation of the NICA collider project at JINR, including the MPD and SPD experiments using NICA;
- upgrades of the LHC injector chain, including the Linac4, SPL and PS2 projects;

Three Pillars of JINR

Great experience and world-wide recognized traditions of scientific schools:

- more than 40 discoveries
- 46 prestigious academic and state awards of Member States and other countries

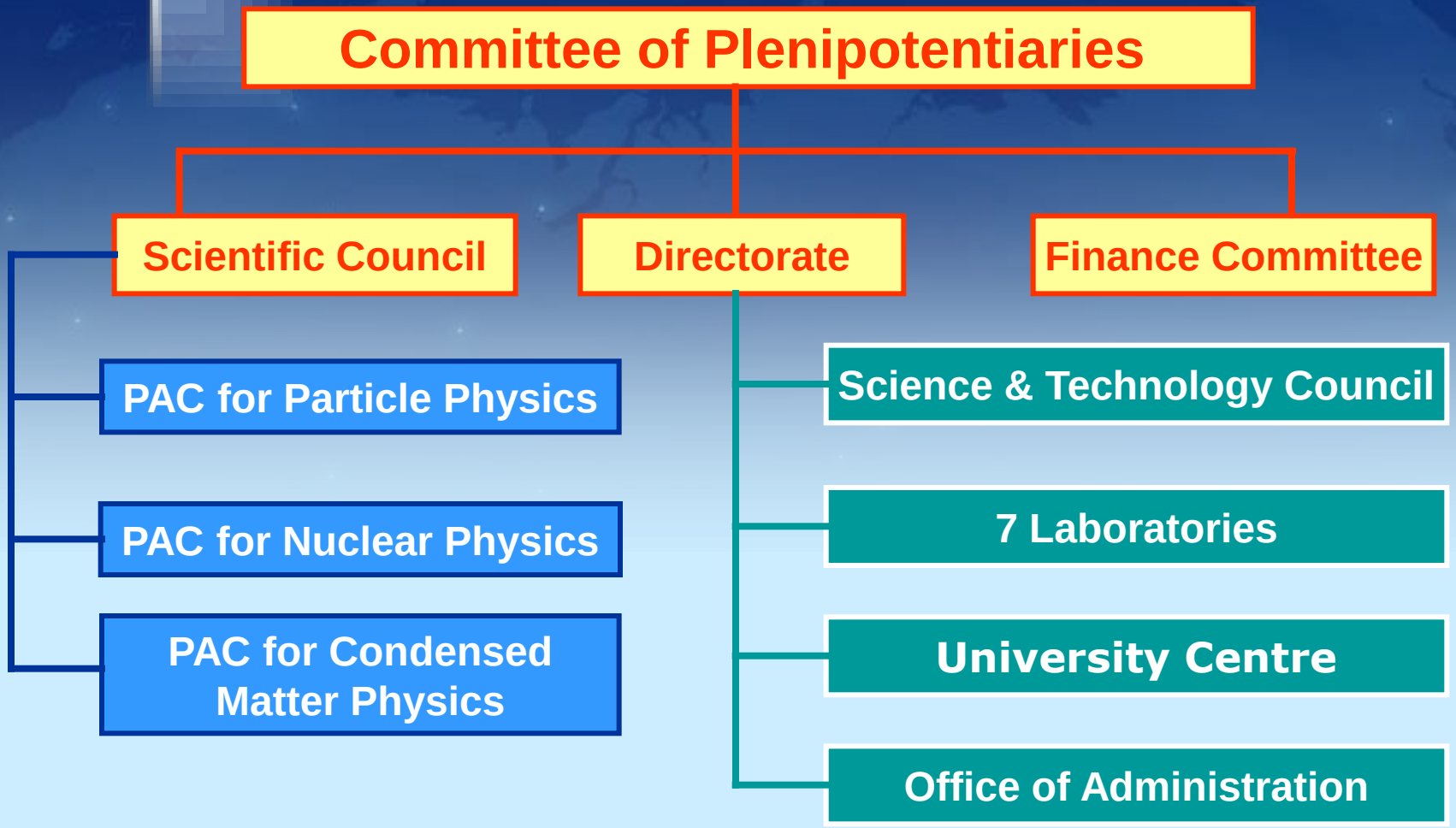
Large and unique park of basic facilities for fundamental and applied research:

- various types of particle accelerators
- high flux pulsed reactor

Status of an international intergovernmental organization:

- JINR was established through the Convention signed on 26 March 1956 by eleven founding States and registered with the United Nations on 1 Feb. 1957
- Russian Federal Law on Ratification of “The Agreement between the Government of the RF and JINR on the Location and Terms of Activity of JINR in the Russian Federation” (January 2000)
- broad international cooperation – more than 700 institutions located in 60 countries

JINR Governing Bodies & Structure



Some figures

JINR's staff members ~ 4500

Researchers ~ 1200

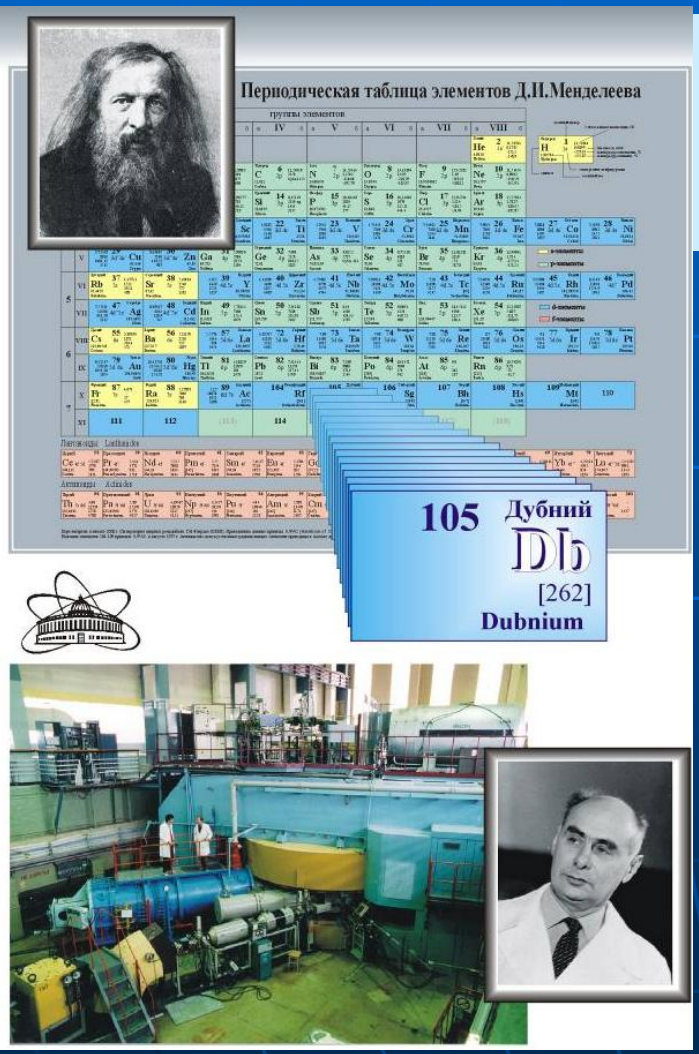
including from the Member States (but Russia) ~ 500

Doctors and PhD ~ 1000

More than 50 Conferences/Workshops yearly

Budget forecast

Discoveries

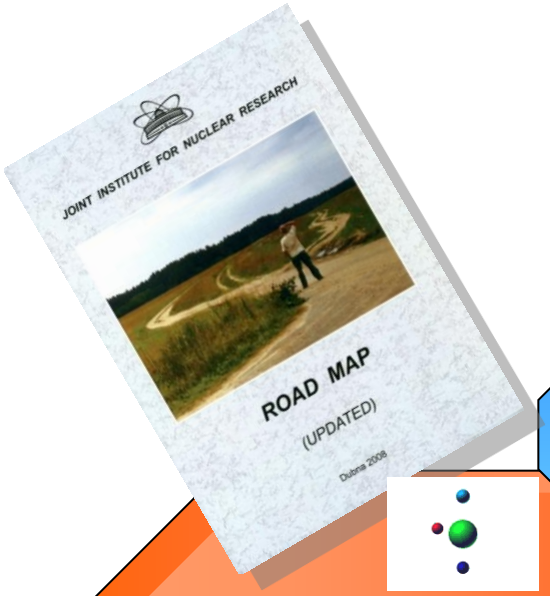


- **46 prestigious academic and state awards, and prizes of Russia, Bulgaria, Georgia, Romania, Czech Republic, Uzbekistan and other countries.**

More than 40 discoveries, including:

- **1959 – nonradiative transitions in mesoatoms**
- **1960 – antisigma-minus hyperon**
- **1963 – element 102**
- **1972 – postradiative regeneration of cells**
- **1973 – quark counting rule**
- **1975 – phenomenon of slow neutron confinement**
- **1988 – regularity of resonant formation of muonic molecules in deuterium**
- **1999-2005 – elements 114, 116, 118, 115 and 113**
- **2006-2009 – chemical identification of superheavy elements**

JINR's Science Policy



Fundamental Science

Innovative activities

Education programme

JOINT INSTITUTE FOR NUCLEAR RESEARCH
JINR

Special Economic Zone
Public-Private-Partnership

UC, DIAS-TH
International Univ. "Dubna"

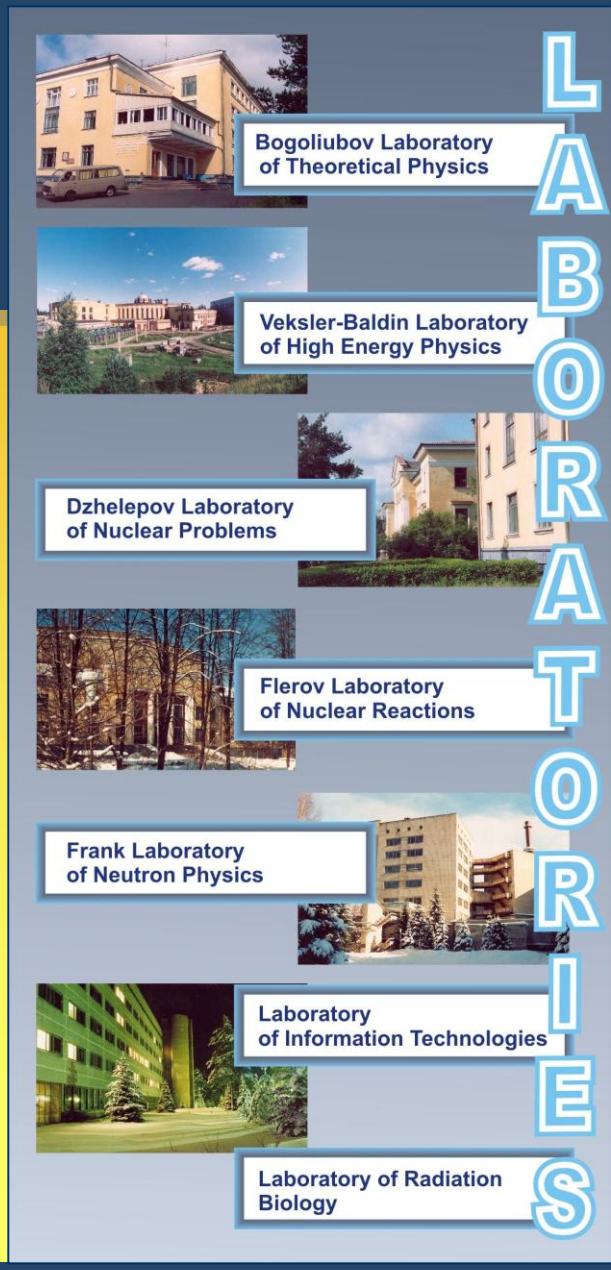
JINR's ROAD MAP

Basic Scientific Directions

- **High Energy Physics**
- **Nuclear Physics**
- **Condensed Matter Physics**

Main Supporting Activities:

- Theory of PP, NP, CMP
- Networking and computing
- Physics instruments and methods
- Education



The concept of the Road Map

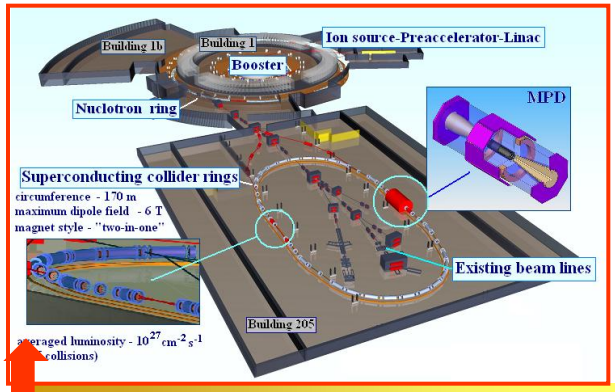
JINR should develop its role as a world leader in certain research domains!

The home experimental base, its upgrade programme should become a priority task for the Institute's further development.

Special attention should be given to the interests of the JINR Member States in developing the Road Map

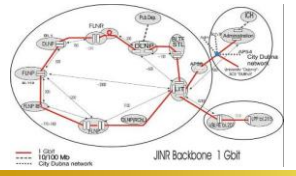
Available at http://www.jinr.ru/

Upgrade of JINR Basic Facilities

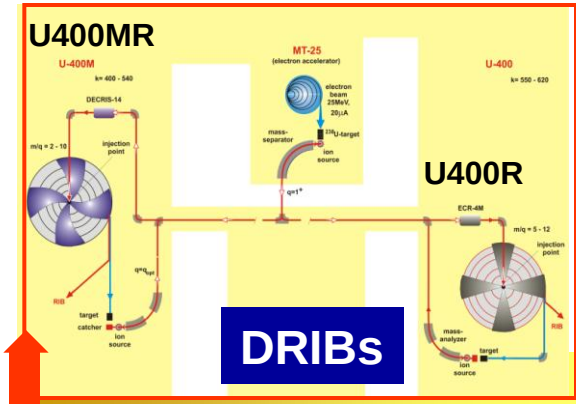


Upgraded Nuclotron-M (2009 – 2010) + NICA (2013-2014)

Telecommunication channels:
20 Gbps – 2009
800 Gbps – 2016



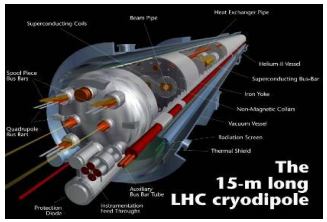
JINR networks:
- **GRID technology**
- **improvement of computer links with Member States (2010-2016)**

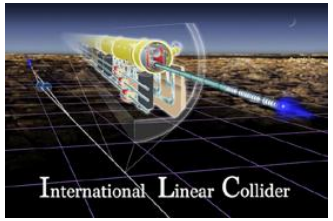


DRIBs II – (2009-2010)
DRIBs III – (2011-2015)

New reactor IBR-2M – 2010
Complex of modern neutron spectrometers (2011-2016)

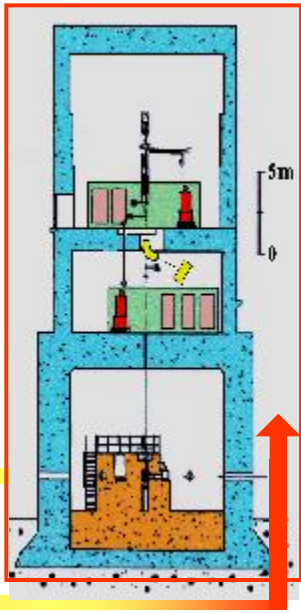
Participating in LHC, RHIC, TEVATRON…
In future: FAIR, ILC …





LHC-2008 **FAIR-2015** **ILC – after 2020 (?)**

IREN-I 2008



JINR's ROAD MAP

JINR's research niche offered by home facilities

- **Heavy-Ion Physics at "high" energies: Nuclotron-M (up to 4.5 GeV/n), NICA/MPD facility: $\sqrt{s_{NN}}$ = (4 – 11) GeV corresponding to $E_{lab.}$ ~ (8 – 60) GeV/n**

- **Nuclear Physics (Heavy-Ion Physics at low and Intermediate energies (5 – 100 MeV/n), U400MR, U400R, DRIBs**

- Condensed Matter Physics **using nuclear physics methods, (neutron sources: IBR-2M, IREN-I)**

High Energy Ion Physics

Nuclotron is a superconducting synchrotron for heavy ions

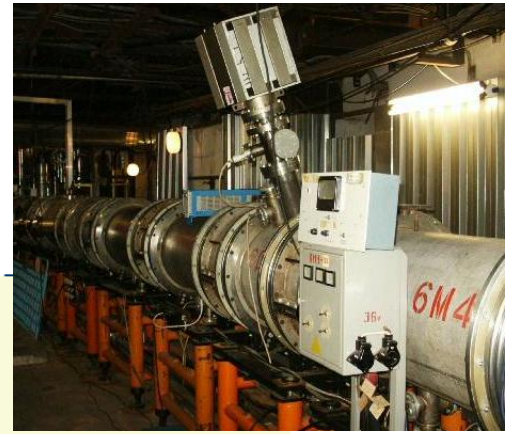
(has been operating since 1993).

The main home facility today:
Nuclotron complex of VBLHEP (under upgrade till the end 2010)
Future plan: NICA/MPD –
Nuclotron-Based Ion Collider Facility and Multipurpose Detector (2014)

Nuclotron-M: 1st stage of the NICA

The main goal: **development of the existing accelerator facility (Nuclotron-M project) as a basis to generate intense beams over atomic mass range from protons to gold and light polarized ions:**

- **accelerated heavy ions A~200**
- **beam intensity ~ 10^9 A/cycle (0.2-0.4 Hz) at kinetic energy ~ (1,0-4,5) GeV/u for Au^{79+}**



BASIC ACTIVITIES in 2008-2010:

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

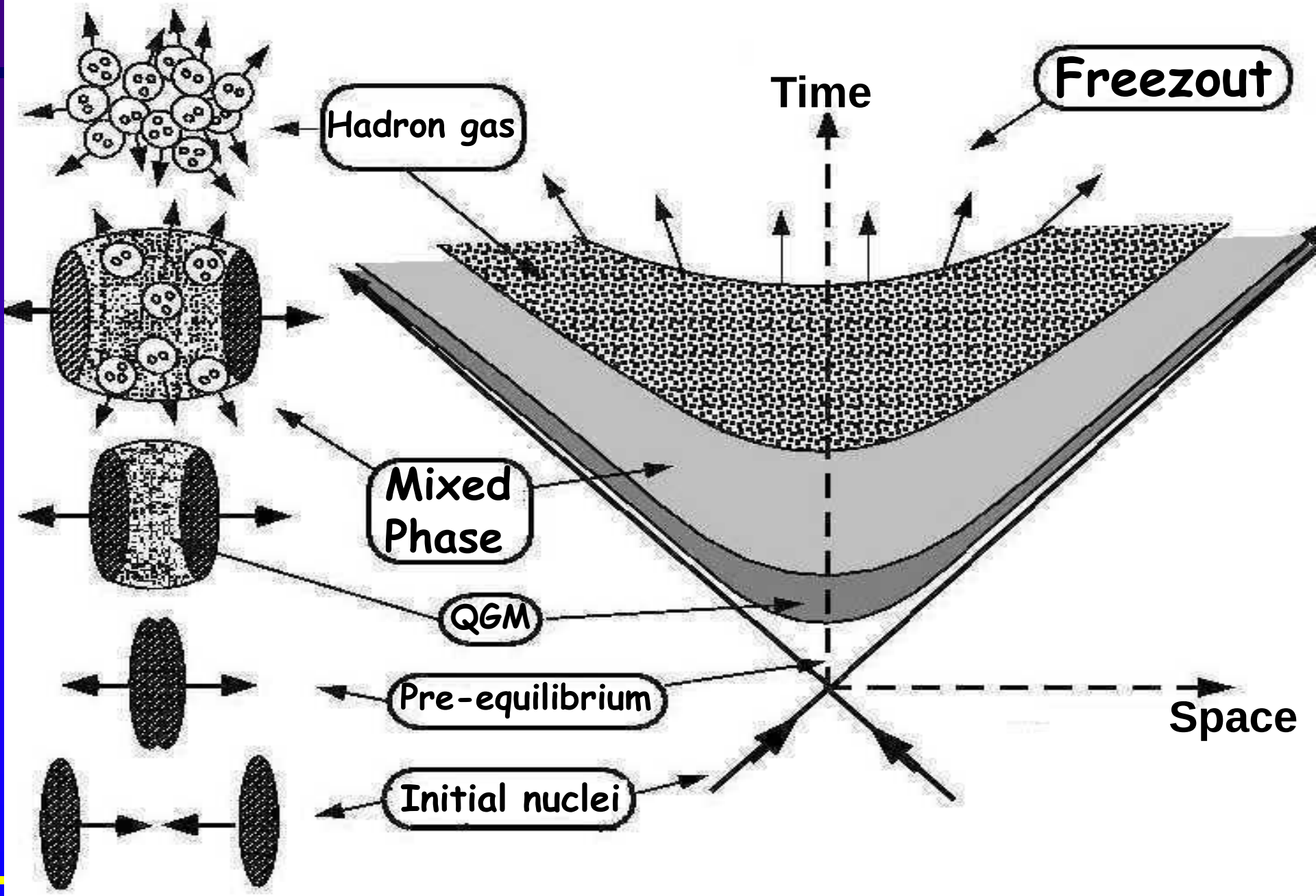
Nuclotron-based Ion Collider fAcility (NICA) at JINR: New Prospect for Heavy Ion Collisions and Spin Physics

NICA / MPD – JINR's highest priority project for 2010 - 2016

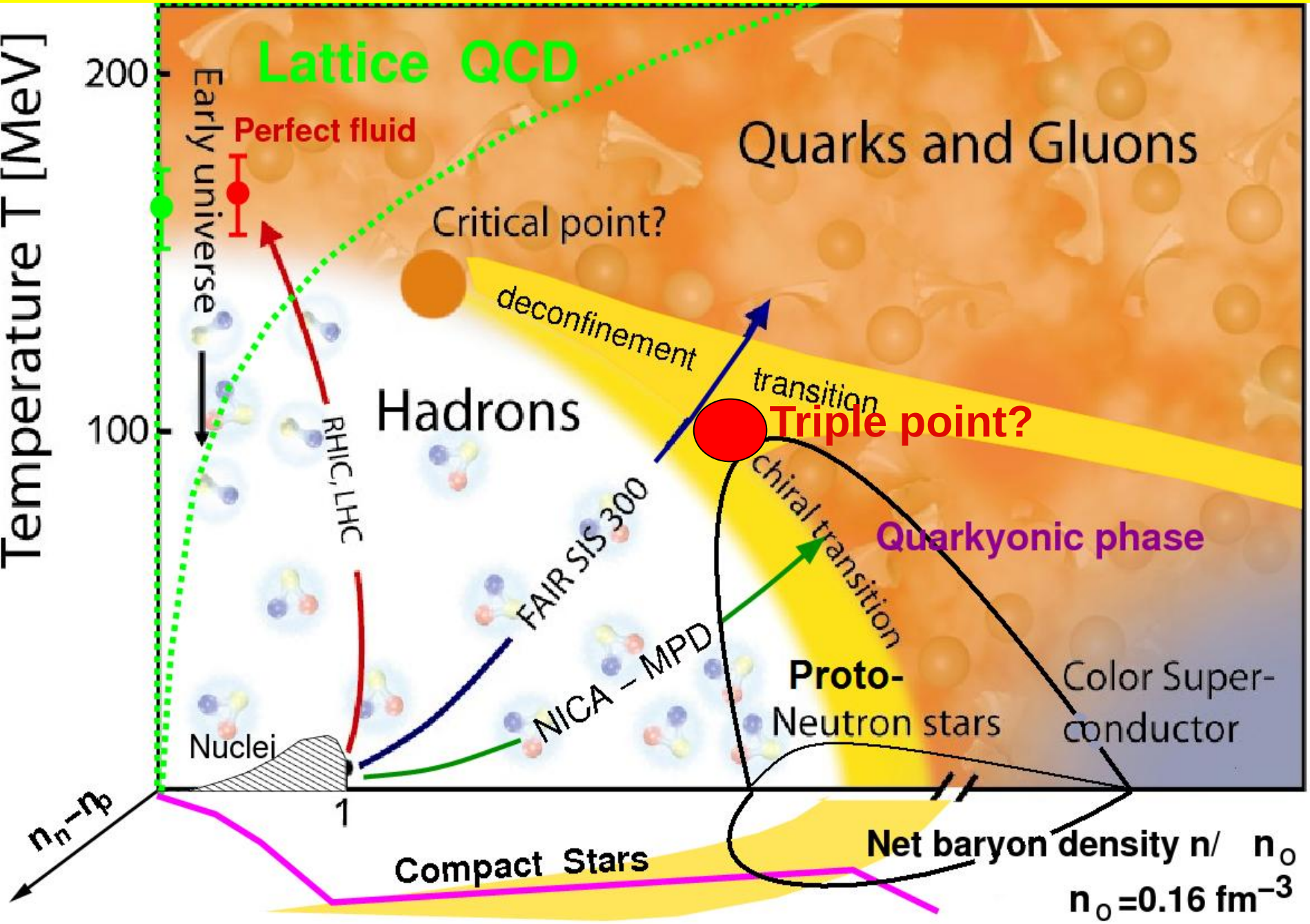
The main goal of the NICA project is an experimental study of hot and dense strongly interacting QCD matter and spin physics at the new JINR facility

Fields of research:

- High Energy Relativistic Ion Physics
- Spin Physics
- SM checks & search for new physics at LHC
- Flavour physics (new physics)
- Neutrino physics and rare phenomena
- International Partnership programs on unique accelerator facilities
- Applied research (medicine, nanotechnology,…)


Time
Freezout
Hadron gas
Mixed Phase
QGM
Pre-equilibrium
Space
Initial nuclei

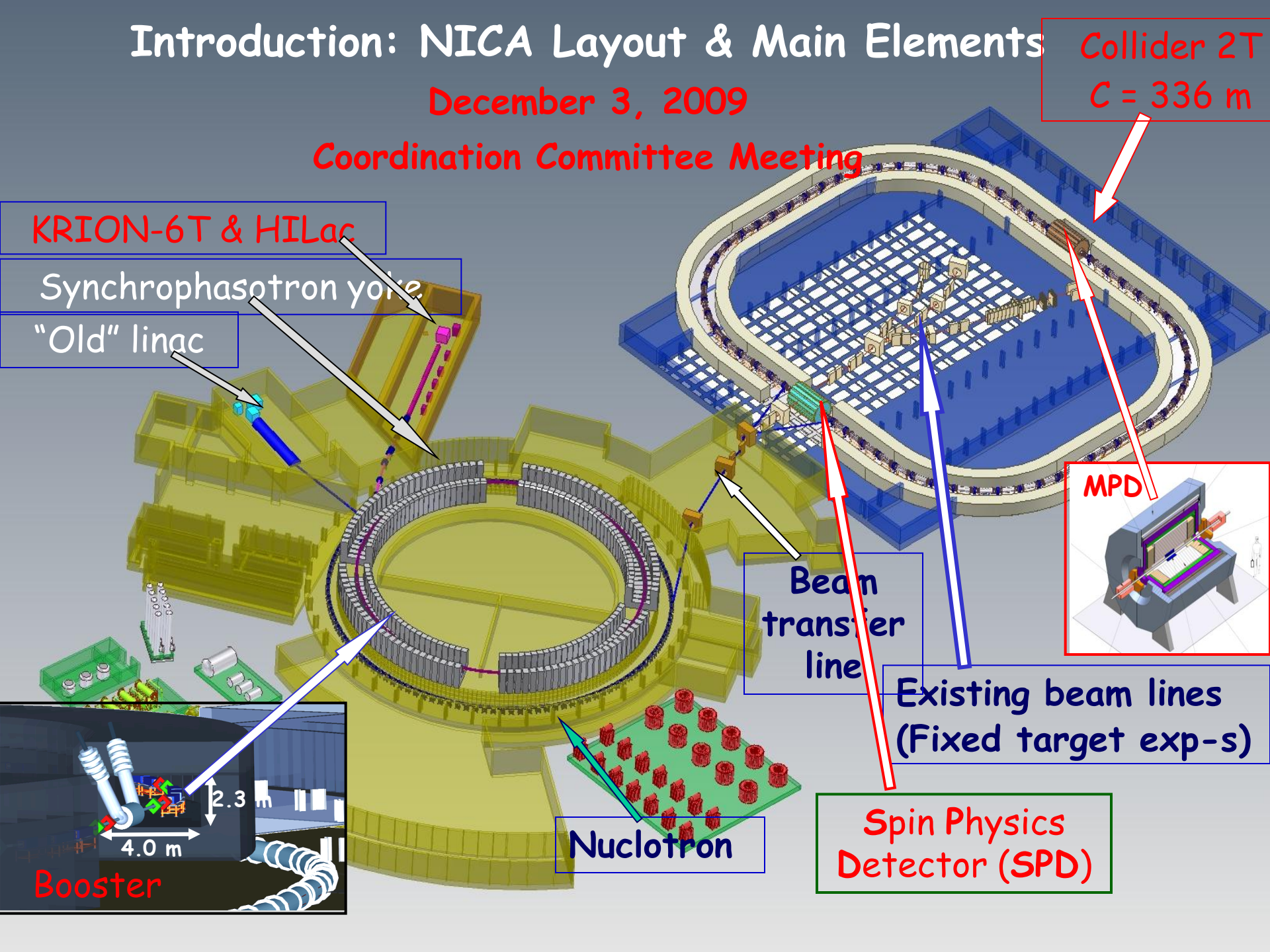
http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome



Introduction: NICA Layout & Main Elements

December 3, 2009

Coordination Committee Meeting



NICA parameters

Circumference	m	336
Number of collision points		2
Beta function in the collision point	m	0.5
Rms momentum spread		0.001
Rms bunch length	m	0.3
Number of ions in the bunch		10^9
Number of bunches		15
Incoherent tune shift		0.05
Rms beam emittance at 1 GeV/u / at 3.5 GeV/u	π mm mrad	3.8 / 0.26
Luminosity per one interaction point at 1 GeV/u at 3.5 GeV/u	$cm^{-2}s^{-1}$	$6.6 \cdot 10^{25}$ $1.1 \cdot 10^{27}$

The NICA Project Milestones

- **Stage 1: years 2007 – 2009**

- Upgrate and Development of the Nuclotron facility

– Preparation of Technical Design Report of the NICA and MPD

– Start prototyping of the MPD and NICA elements

- **Stage 2: years 2008 – 2012**

– Design and Construction of NICA and MPD

- **Stage 3: years 2010 – 2013**

– Assembling

- **Stage 4: year 2013 - 2014**

– Commissioning

NICA/MPD TENTATIVE LIST OF OBSERVABLES

- Anti-proton to proton ratio
- Baryon to meson ratios
- Charged particle directed flow
- Charged particle elliptic flow
- DCC searches
- Elliptic flow for identified charged hadrons & photons
- Femtoscopy of identical particles
- Femtoscopy of Kπ, Ξπ, Ωπ , etc
- Fluctuations of particle ratios, esp. K/π, p/π
- Fluctuations of $<p_T>$, $<v_2>$, photon multiplicity, etc
- Hyperons and light hypernuclei
- Invariant mass and p_T distributions of leptons
- Longe-range forward-backward correlations
- Net-proton and net charge kurtosis
- Nuclear modification factor
- Production of light nuclei and antinuclei
- Standard femtoscopy source parametrs
- Strong parity violation
- Triggered azimuthal correlations
- Untriggered pair correlation in Δφ and Δη
- Yields of strange particles

…

Progress towards a White Paper on the NICA/MPD


Draft v 1.01
June 04, 2009

SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY (NICA White Paper)

Editorial board:
D. Blaschke
D. Kharzeev
A. Sissakian
A. Sorin
O. Teryaev
V. Toneev
I. Tserruya

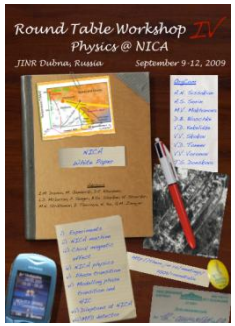
31 research centres in 15 countries (including 8 JINR Member States).

Welcome to the collaboration!

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

Progress towards NICA/MPD : International Expertise and the White Paper

Round Table Discussion IV
Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA (White Paper)
JINR (Dubna), 9-12 September 2009
http://theor.jinr.ru/meetings/2009/roundtable/



First R–ECFA meeting in Russia

8 – 10 October 2009

Moscow, Dubna

"Concerning the NICA project, its already existing infrastructure and modern standards that are higher than in the present accelerators should be definitely considered as its advantages. The collider's physics programme is very interesting".

ECFA Chairman Prof. Tatsuya Nakada

Round Table Italy-Russia in Dubna

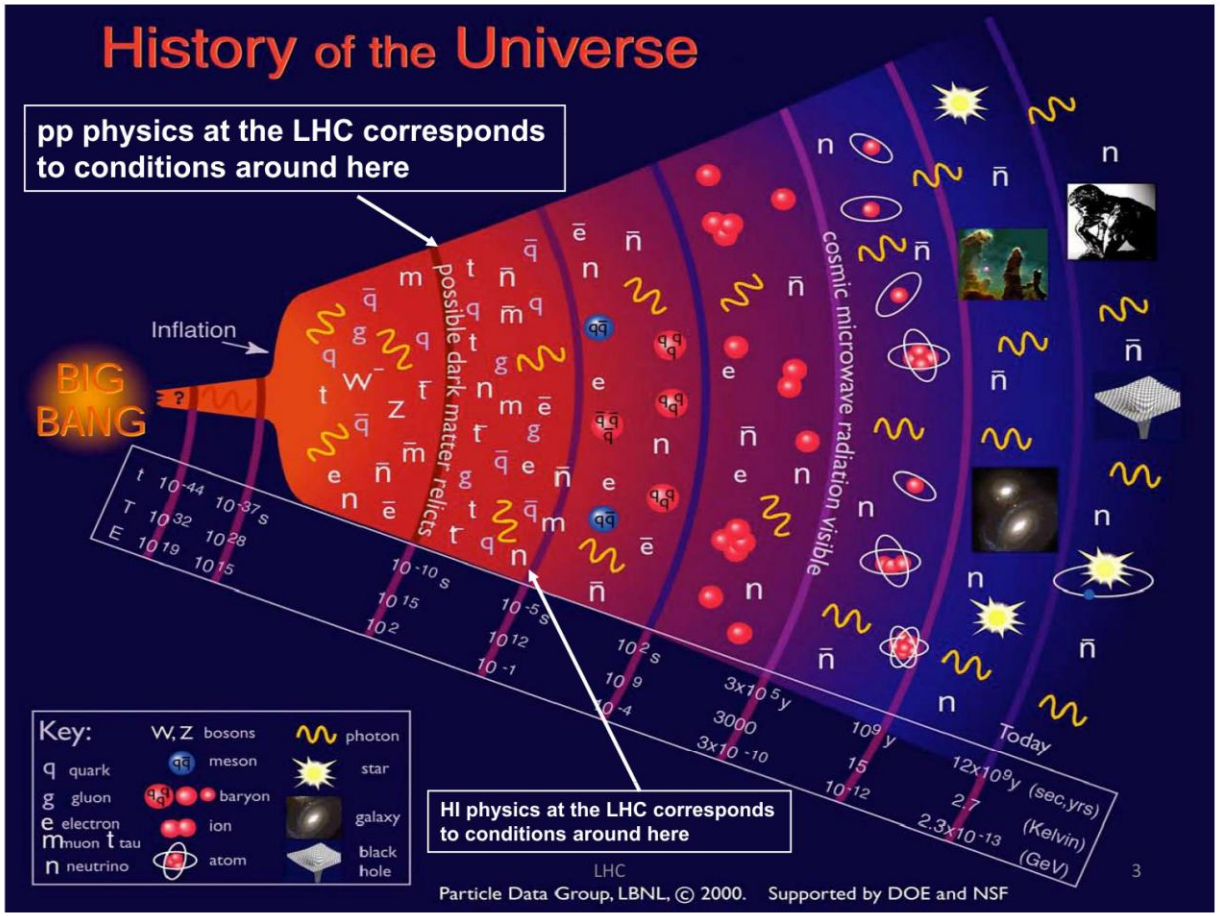
JINR, 18-19 December 2009

Nuclotron-M/NICA Machine Advisory Committee (MAC)

JINR, 14-15 January 2010

Programme Advisory Committee for PP

Particle Physics on external facilities - examples



Participation in the LHC projects

ATLAS

- ✓Tile & Liq. Ar Calorimeters
- ✓Monitored Drift Tubes (Muon system)
- ✓TRT (34 straw wheels 3072 ch.each)

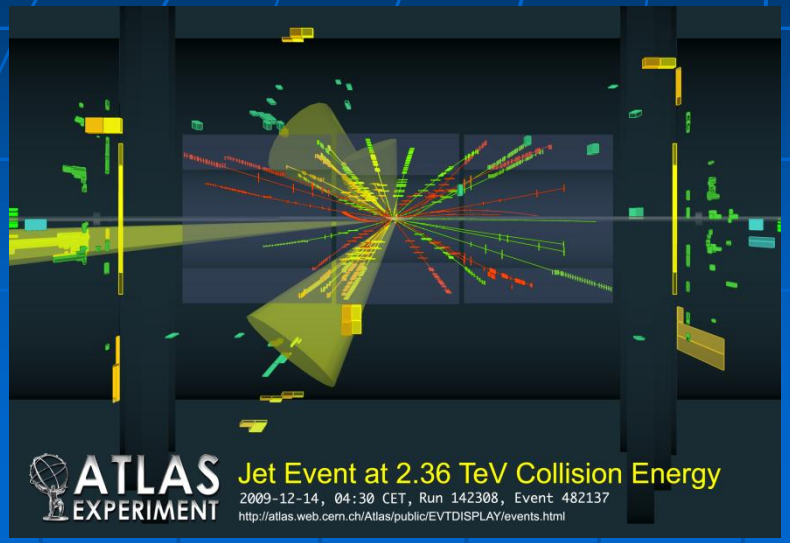
CMS

- ✓End-cap Hadron Calorimeter
- ✓Part of muon system (ME1)
- ✓Preshower (participation)

ALICE

- ✓TRD (125 modules)
- ✓Dipole magnet (forward μ spectrometer)
- ✓800 PWO crystals for PHOS

ATLAS



JINR has started ATLAS data taking and data analysis

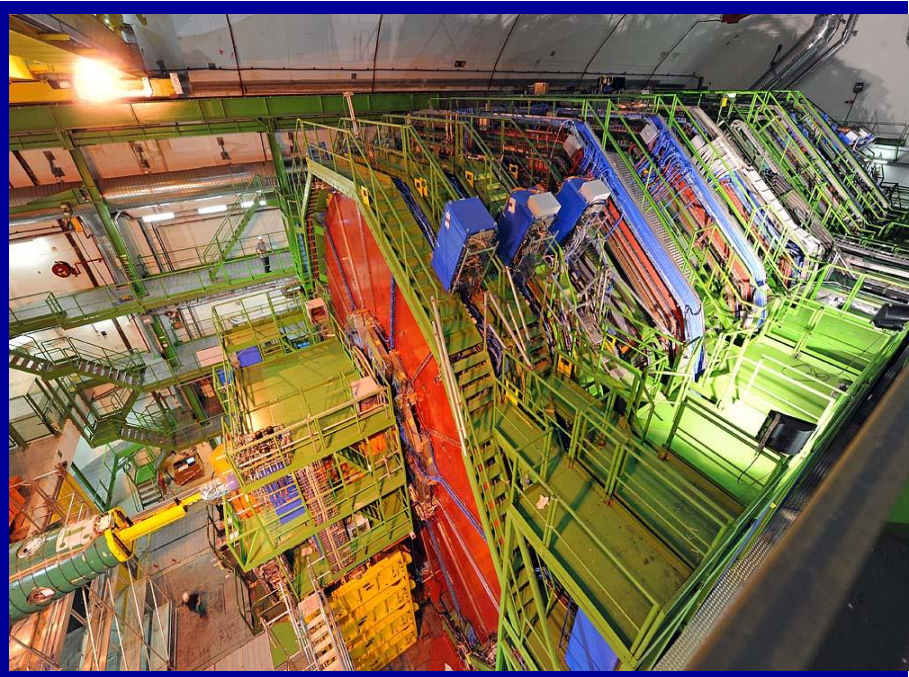
- Top-quark
- QCD @ Standard Model Physics
- Higgs Physics
- SUSY Physics
- Exotics Physics
- b-quarks
- Heavy Ions Physics

The real time ATLAS remote monitoring system is operational at JINR

MOTIVATION

- Monitoring of the detector and data flows at any time
- Participation of the subsystem experts from Dubna in the shifts and data quality checks remotely
- Training the shifters before they come to CERN

CMS



Study phenomena in the frame of the Standard Model and beyond.

The JINR group has the following plans for 2010-2016:

data taking, monitoring of the detection systems, maintenance of operation, data processing

Participation in the physics investigations where JINR physicists reached the advantages at the preparation stage of the CMS Physics Program :

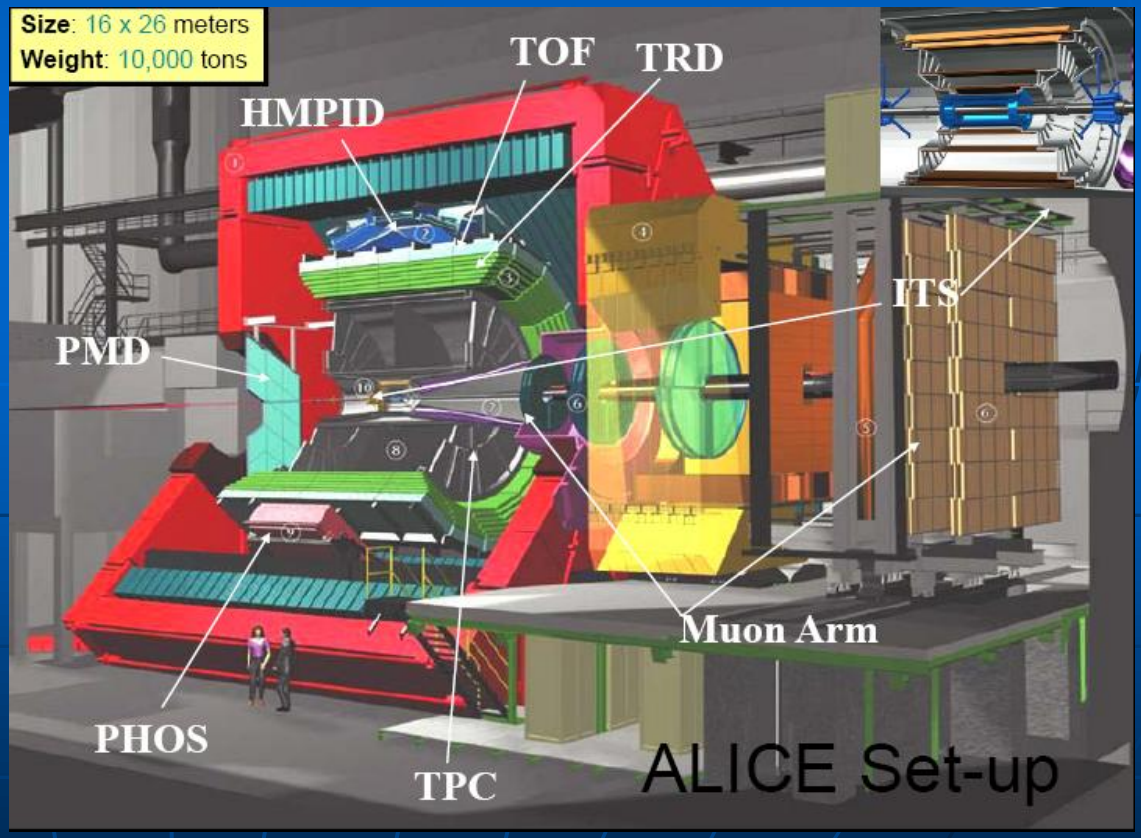
- Study of Higgs bosons
- Testing of the SM in the MMT-DY processes
- Study of inclusive jet production and gamma+jet
- etc.

ALICE

The goal is to study strongly interacting matter at extremely high energy densities, a new form of matter – quark-gluon plasma.

The JINR team is planning to participate in:

- the studies of light vector meson production;
- the investigation of heavy quarkonium production;
- the study femtoscopic correlations;
- the measurements of direct photon and dilepton yields;



NA48/2

Two major parameters - *a0* and *a2* of pi-pi scattering lengths have been extracted with an unprecedented experimental precision of few percents.

This result is highlighted at CERN as experimental achievement in 2008

Measurement of pi-pi sc. length in two processes

- ***Cusp :*** $a_0 = 0.224 \pm 0.004 \pm 0.011_{theor.}$
- ***Ke4 (FF phases):*** $a_0 = 0.220 \pm 0.008$

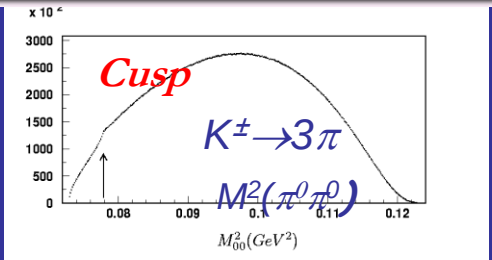
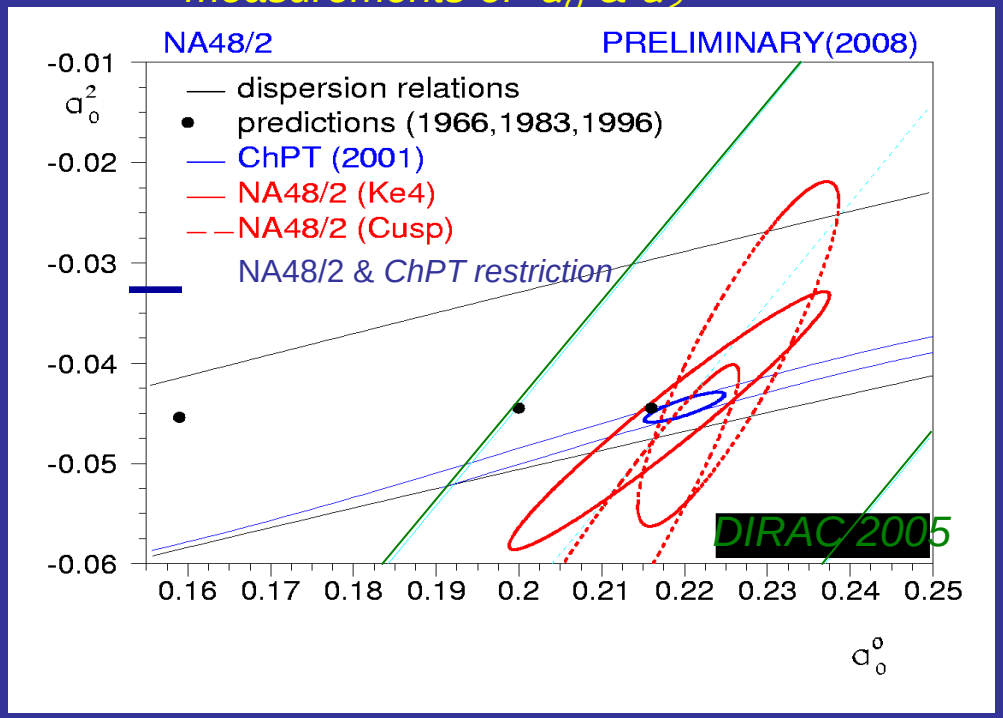
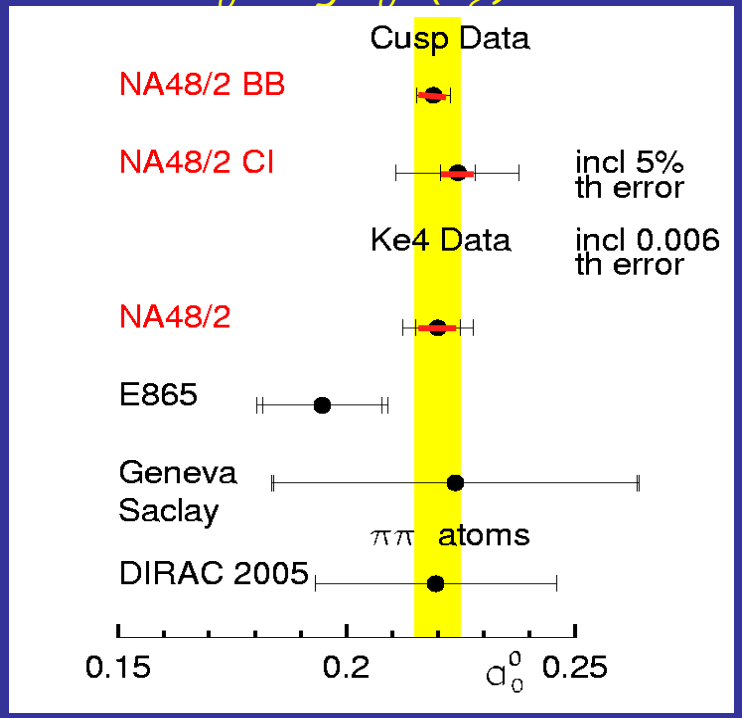


Рис. 1: Distribution of the $\pi^0\pi^0$ invariant mass squared in $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ decays for NA48/2 experimental data

measurements of a_0 & a_2



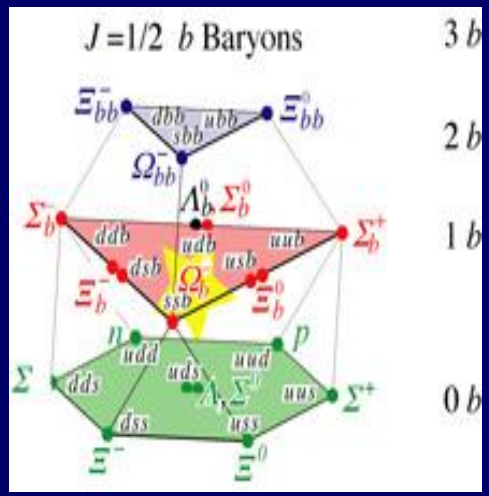
measurement of a_0 using a_0=f(a_2) from ChPT

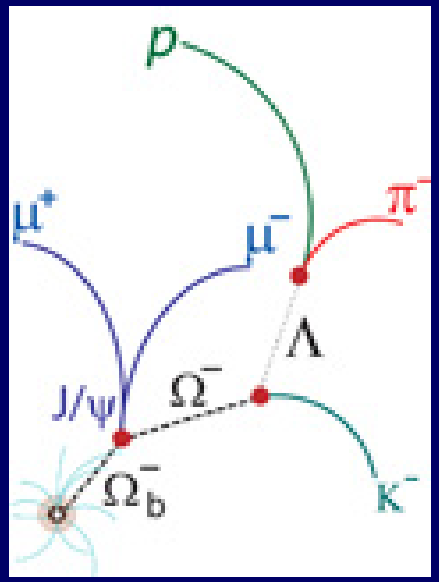


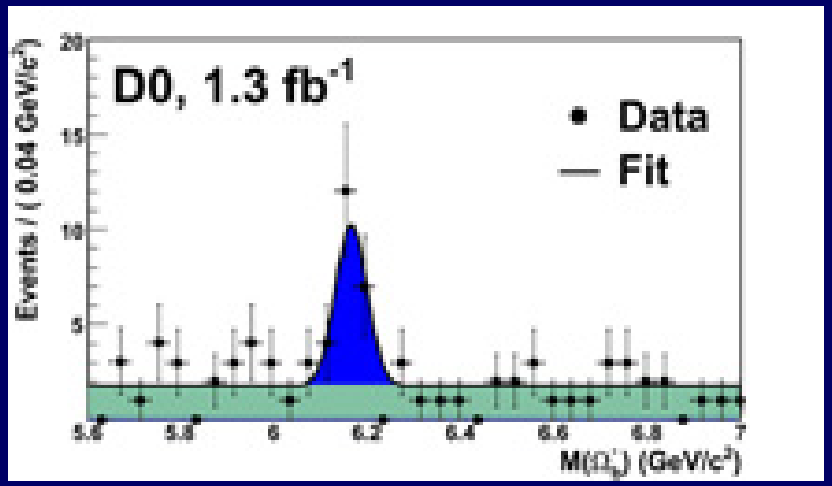
Fermilab, DO experiment:

JINR physicists significantly contributed to the physics analysis of the DO data which resulted in the first observation of new "doubly strange" particle Ω_b.

Discovery of the OMEGA_b baryon was ranked among the ten most significant achievements in physics in 2008 by the American Physics Society



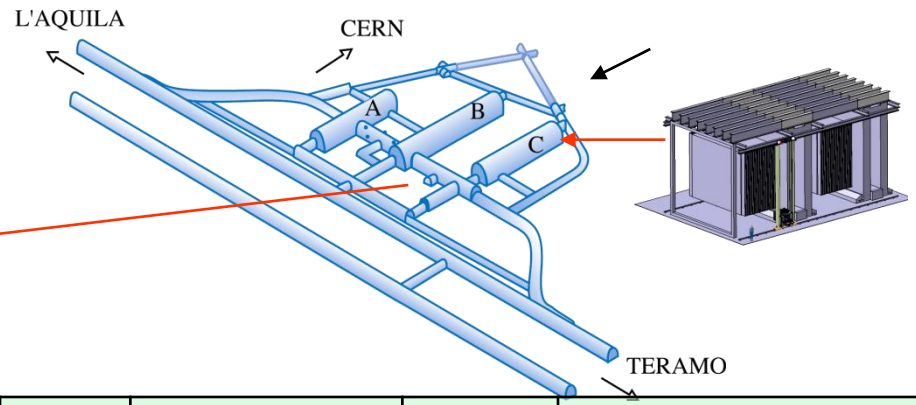




The D0 collaboration identified 18 events that have the distinctive signature of the expected decay products of the Omega-sub-b. The mass of the particle is 6.165 ± 0.016 GeV/c2

OPERA

Direct search for ν oscillations by looking at the appearance of ν_τ in a pure ν_μ beam to explain atmospheric neutrinos anomaly and results of K2K and MINOS



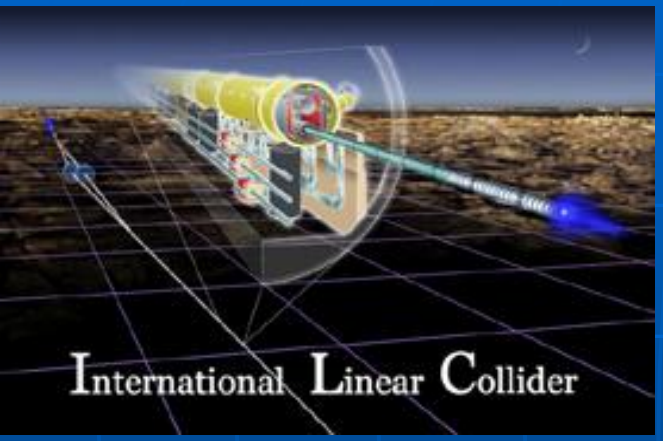
2006	**0.076x10^{19} pot**	**0 int.**	**Commissioning**
2007	**0.082x10^{19} pot**	**38 int.**	**Commissioning**
2008	**1.78x10^{19}** pot	**1663 int.**	**First physics run**
2009	**1.93x10^{19} pot up to now (Sep 6th)**	**2036 int.**	Extrapolation is **3.5x10^{19}** pot at end of the run. ~**2 tau expected** in total
Nominal	**4.5 x 10^{19} pot x 5 year. total 22.5 x 10^{19} pot**		

Experiment is taking data now

Expected produced interactions (22.5x10^{19}):
~25400 ν_μ CC + NC
~170 $\nu_e + \nu_{\bar{e}}$ CC
~125 ν_τ CC ($\Delta m^2 = 2.5 \times 10^{-3}$ eV^2)

~10 tau decays are expected to be observed
Less than 1 background after 5 years running

Look onto far Future (International Linear Collider)

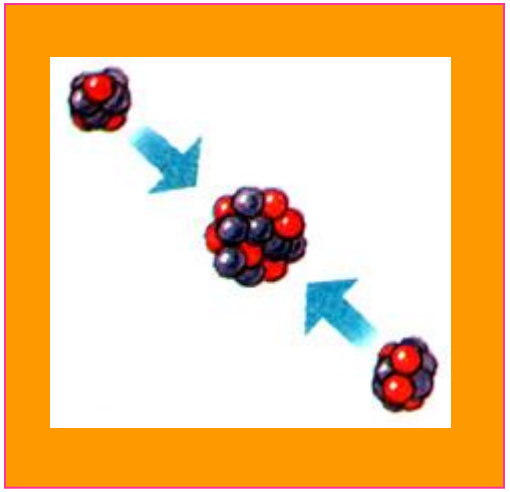


The activities at JINR on Physics and Detector for ILC are underway and will be continued in order to provide JINR's visible participation in this ambitious project.

Challenging tasks

- Factory of the Higgs boson
- Supersymmetry
- Dark matter, dark energy
- …

NUCLEAR PHYSICS



Home Research programme in Nuclear Physics:

- Heavy ion physics at low energies
- Nuclear physics with neutrons
- Low and intermediate energy nuclear physics

The main home facilities (today):
Cyclotrons U400MR and U400,
accelerator complex DRIBs-I, IREN-I, Phasotron.

Future plans:

- U400R, accelerator complex DRIBs-II (2009), DRIBs-III (2015)

Low Energy Heavy Ion Physics

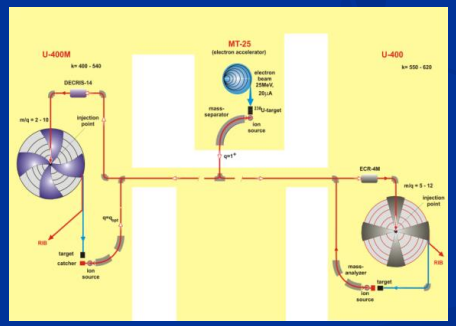
The main home facilities (today):
Cyclotrons U400 and U400MR,
accelerator complex DRIBs-I

Future plans:
U400R, accelerator complex DRIBs-II

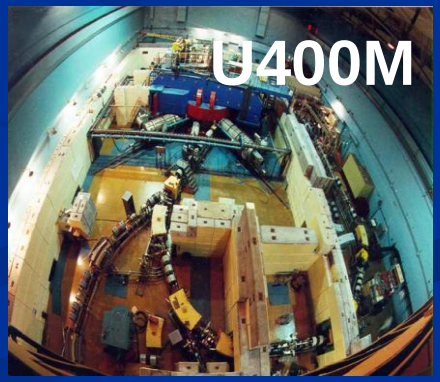
PRIORITIES:

- **Physics and chemistry investigations of the superheavy nuclei with Z ≥ 112; structure and properties of the neutron-rich light exotic nuclei**
- **Heavy ion interaction with matter; accelerator technology, applied research.**

(in operation since 1979)

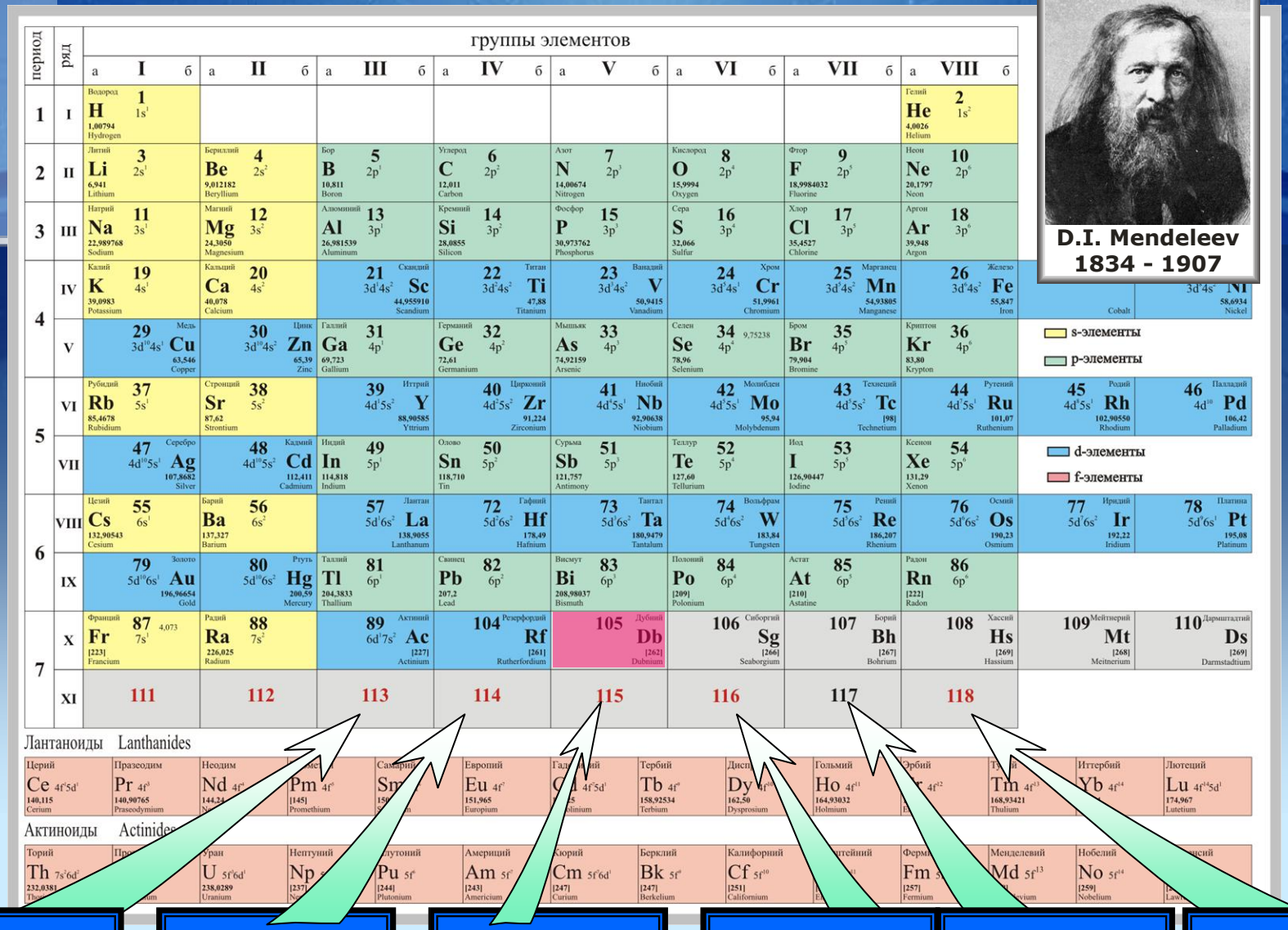


DRIBs –
Dubna Radioactive Ion Beams



(in operation since 1993)

D.I. Mendeleev
1834 - 1907



113

Discovered at JINR in 2003

114

Discovered at JINR in 1999

115

Discovered at JINR in 2003

116

Discovered at JINR in 2000

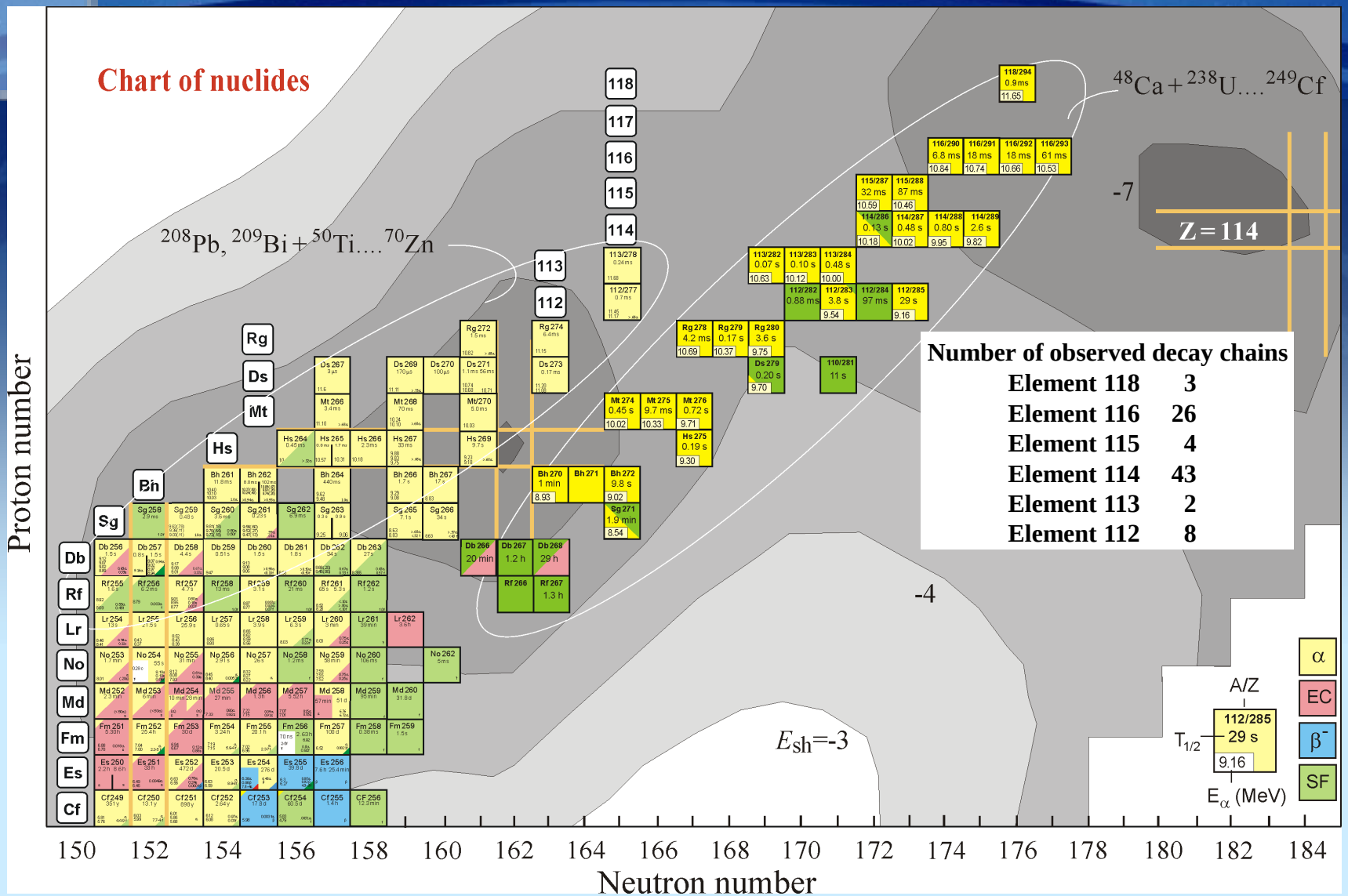
117

Discovered at JINR in 2009

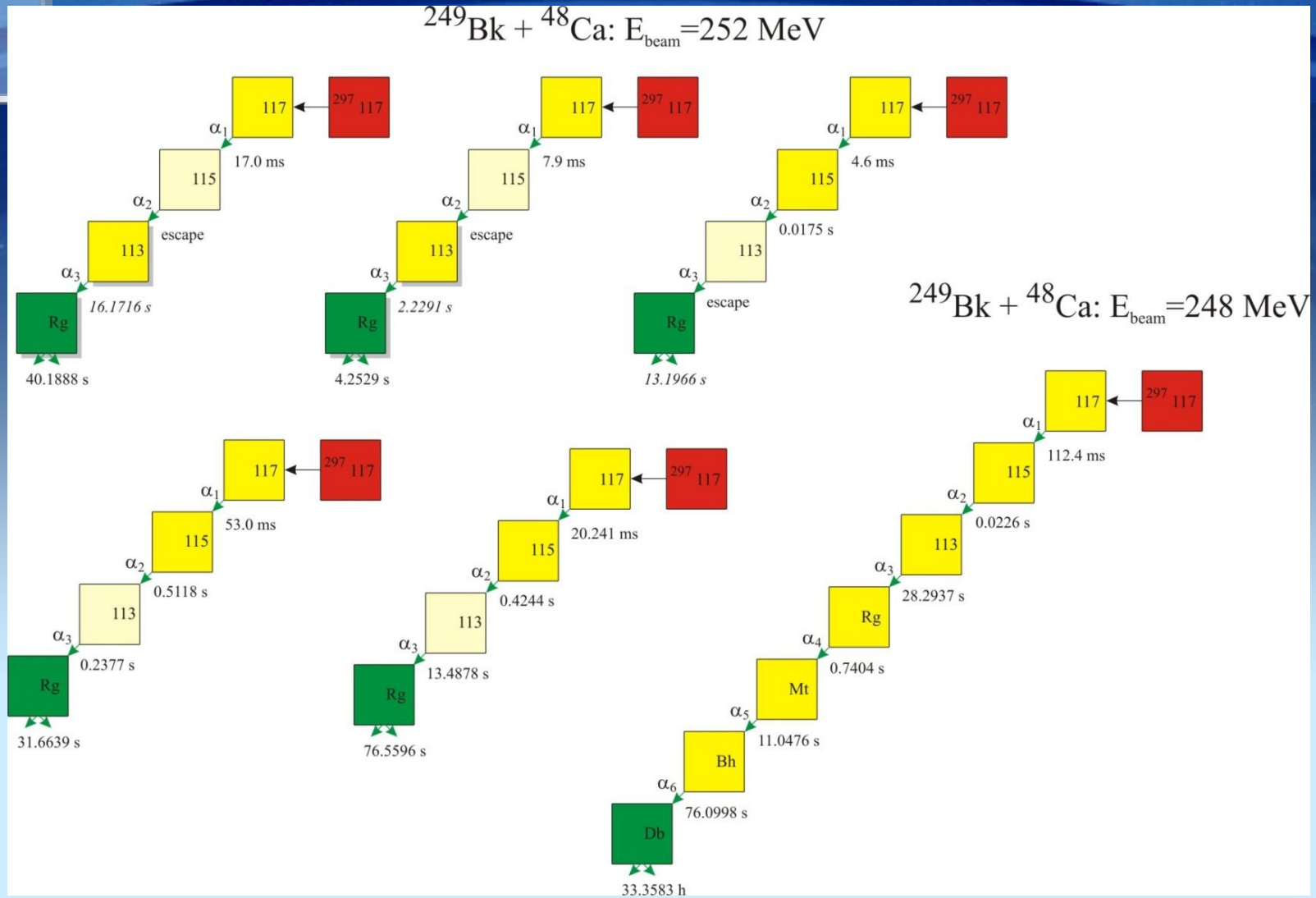
118

Discovered at JINR in 2001

New elements in the reactions Ac + ^{48}Ca



Synthesis of element 117



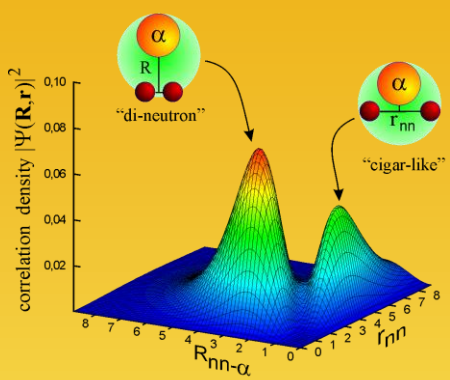
JINR's LIGHT EXOTIC NUCLEI PROGRAMME

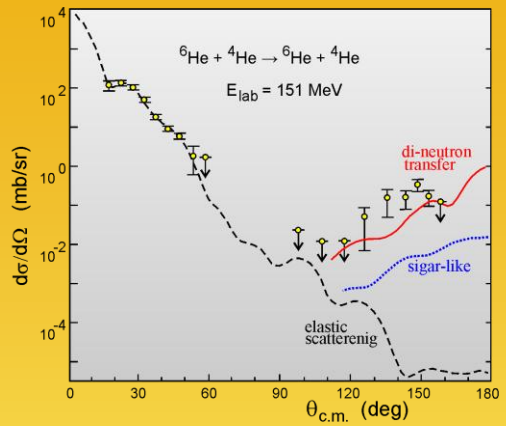
"MULTI" multi-detector setup was designed to study properties of light nuclei, such as ^{6}He, ^{6}Li and exotic-nuclei reaction mechanism.

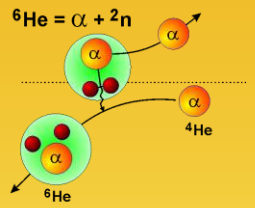
U400 and the transport line with U400MR

Some results in study of light exotic nuclei

Discovery of di-neutron inside ^{6}He

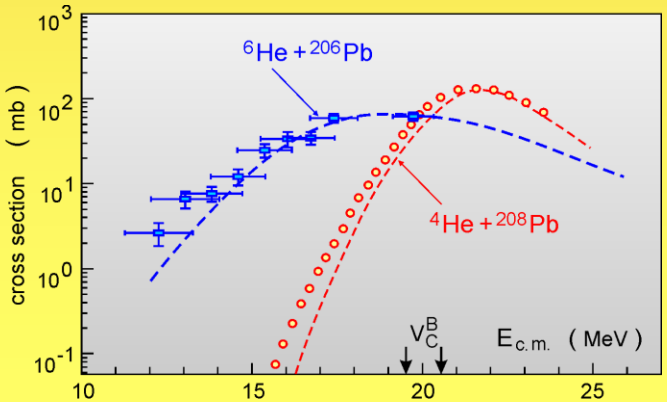






Observation of sub-barrier fusion enhancement of ^{6}He

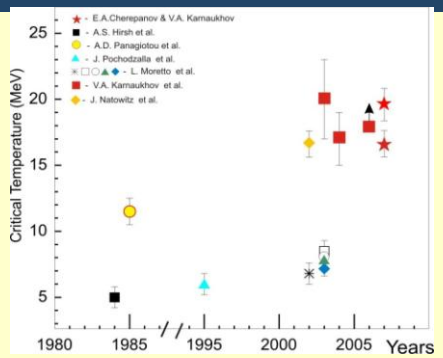
$$\left.\frac{\sigma(^6\mathrm{He} + {}^{206}\mathrm{Pb} \rightarrow {}^{212}\mathrm{Po})}{\sigma(^4\mathrm{He} + {}^{208}\mathrm{Pb} \rightarrow {}^{212}\mathrm{Po})}\right|_{E_{c.m.}=15\ \mathrm{MeV}} = 1000\ !$$



Nuclear Physics - more examples

FASA:

Reliable measurement of Critical Temperature parameter for liquid-gas phase transition of nuclear matter solved the long standing contradiction that existed previously



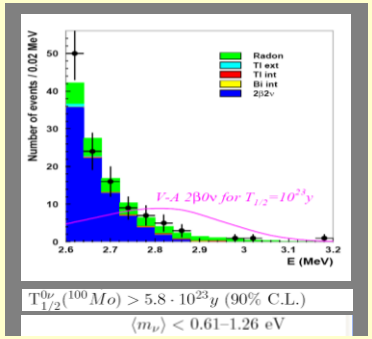
GEMMA:

Best limit on neutrino magnetic moment was obtained in GEMMA experiment at Kalinin Power Plant

MUNU (Bugey, 2003)	$\mu\nu < 0.9 \times 10^{-10}\ \mu B$
TEXONO (Taiwan, 2003):	$\mu\nu < 7.4 \times 10^{-11}\ \mu B$
GEMMA-1 (2006):	$\mu\nu < 5.8 \times 10^{-11}\ \mu B$
BOREXINO (2008)	$\mu\nu < 5.4 \times 10^{-11}\ \mu B$
GEMMA-1 (2008):	$\mu\nu < 5.2 \times 10^{-11}\ \mu B$

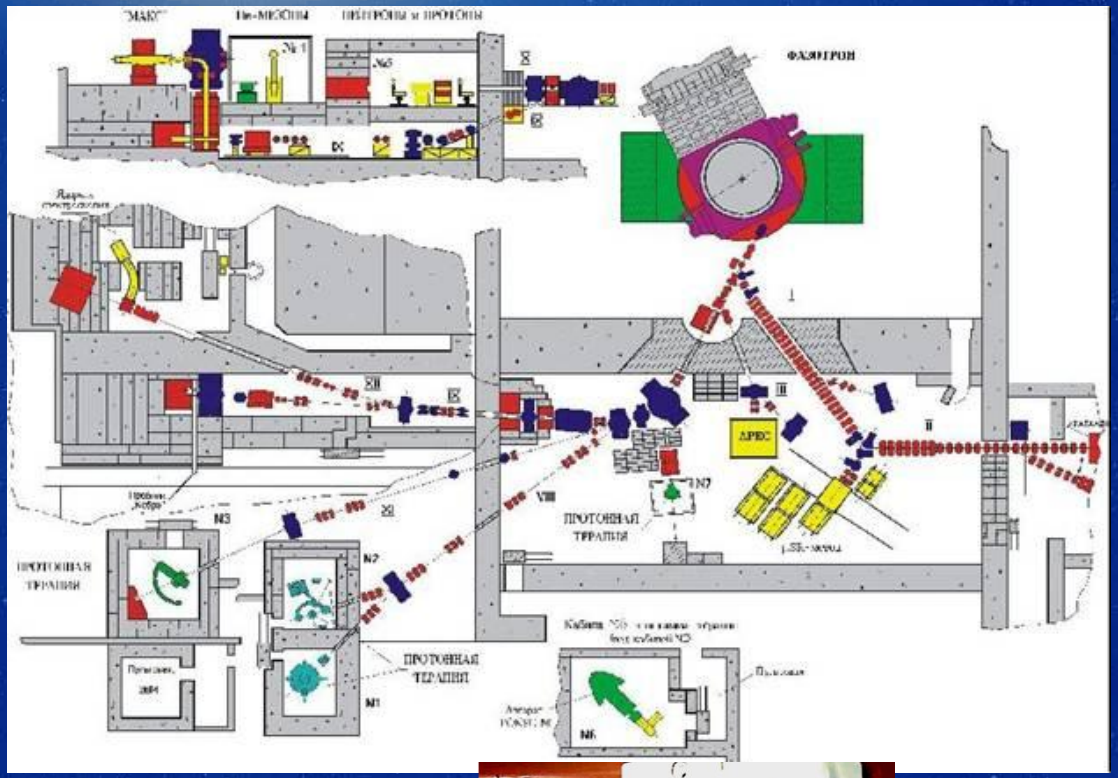
NEMO:

World class results were obtained on double beta decay from NEMO experiment



Nuclear Physics spin-off:

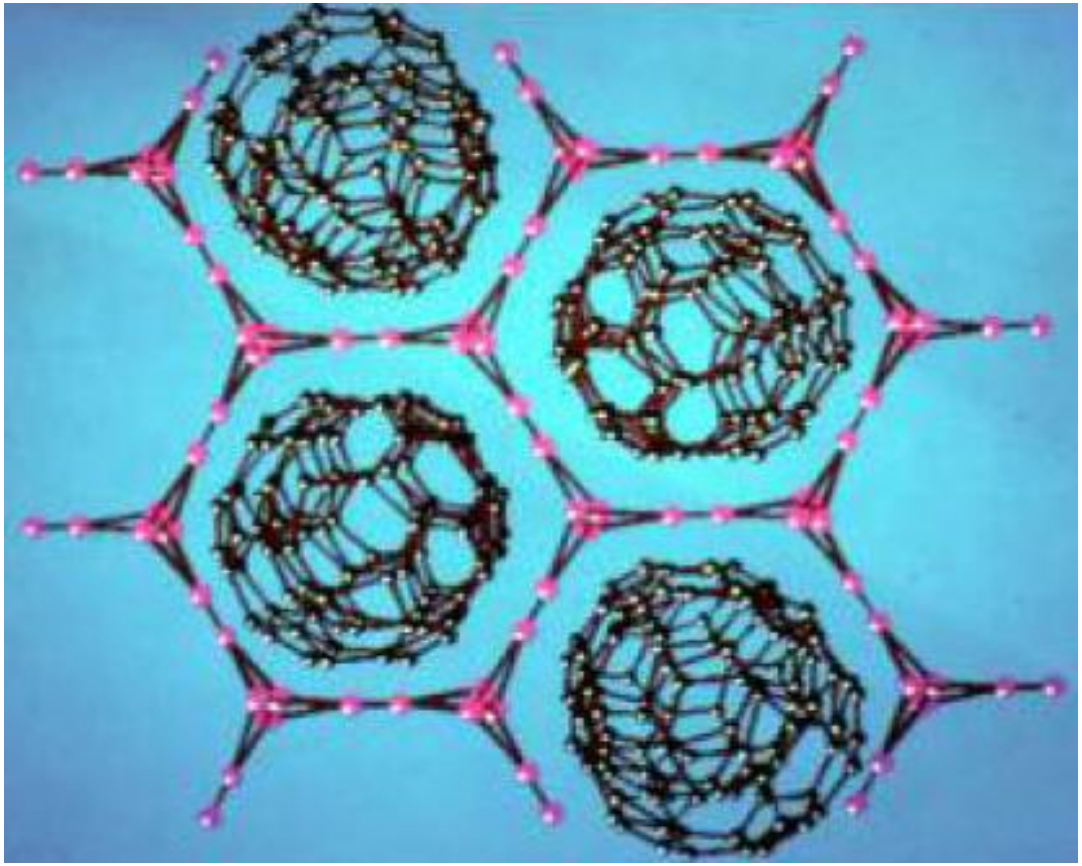
Medico-technical complex for hadron (proton) therapy



Proton therapy

γ-therapy

CONDENSED MATTER PHYSICS



IBR idea

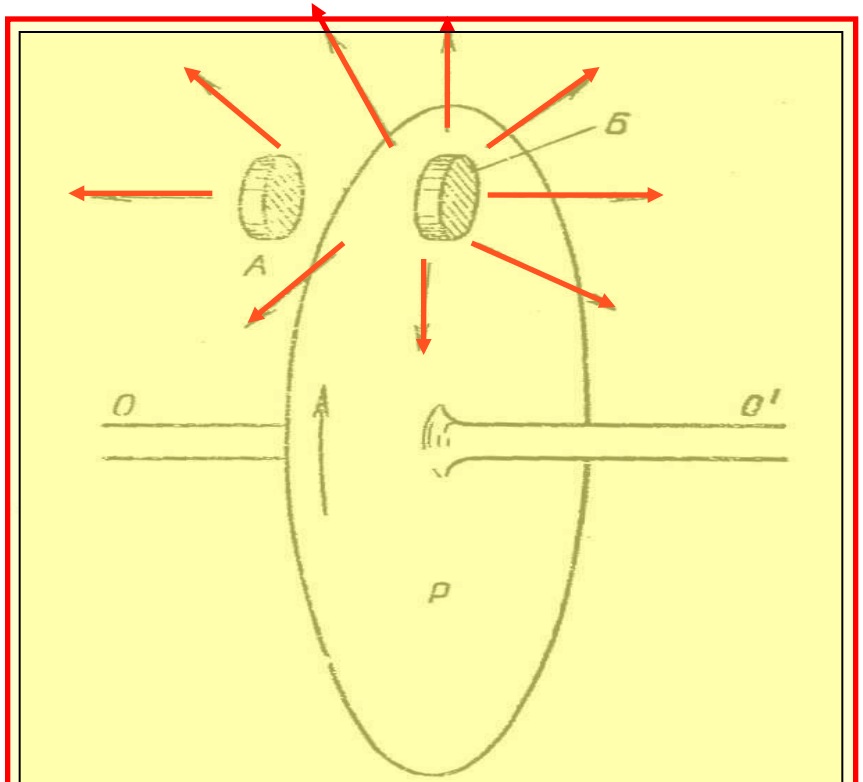


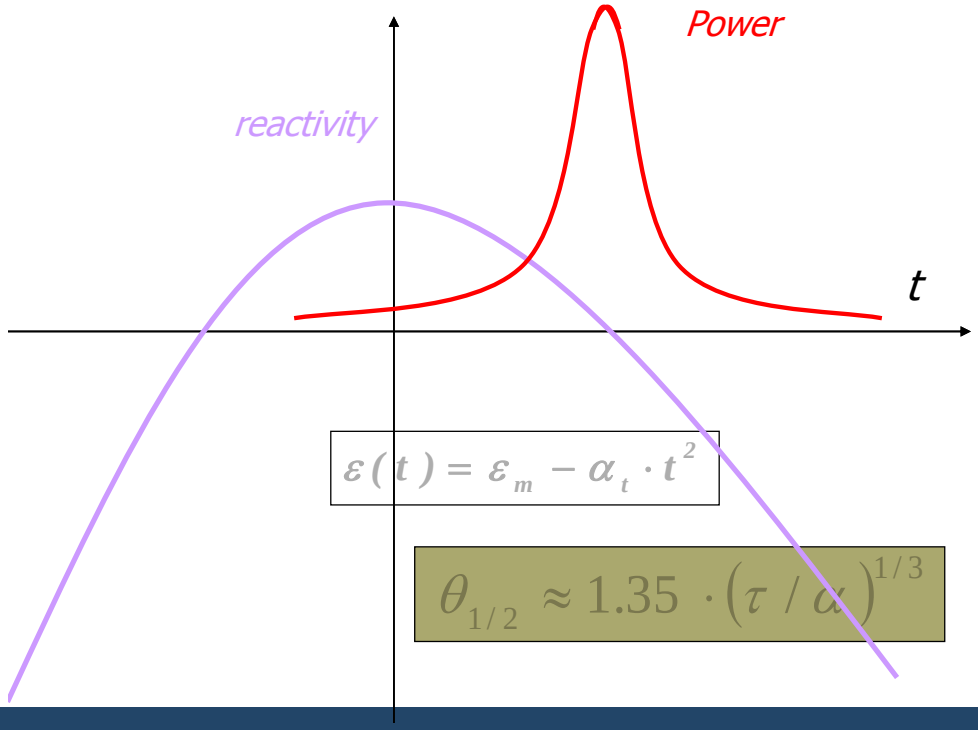
Рис. 7. Принцип действия периодического импульсного реактора ИБР:

Р — быстро вращающийся диск — ротор; *Б* — кусок урана, вмонтированный в диск; *А* — статор — неподвижный кусок урана; стрелки показывают поток нейтронов в момент прохождения *Б* около *А*

Idea (1955) – D.I.Blokhintsev

Theory (1956) – I.I.Bondarenko, Yu.Ya.Stavisski

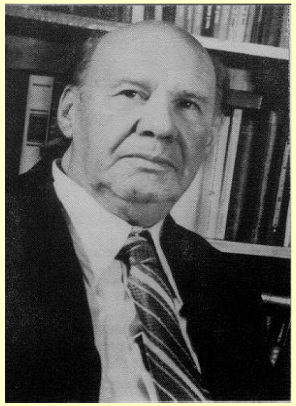
IBR theory was further developed by Shabalin, Govorkov, Asaoka, Larrimore, Blaeser, Schwalm, Kozik.



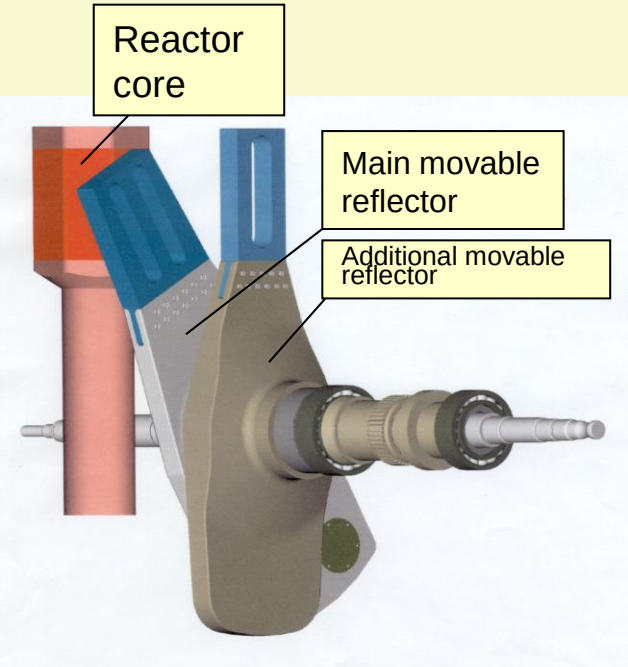
$$\varepsilon(t) = \varepsilon_m - \alpha_t \cdot t^2$$

$$\theta_{1/2} \approx 1.35 \cdot (\tau / \alpha)^{1/3}$$

The IBR-2 reactor is included in the 20-year European strategic programme of neutron scattering research.



D. Blokhintsev



Parameters

Fuel	PuO_2
Active core volume	22 dm^3
Cooling	liquid Na
Average power	2 MW
Pulsed power	1500 MW
Repetition rate	5 s^{-1}
Average flux	$8 \cdot 10^{12}$ $n/cm^2/s$
Pulsed flux	$5 \cdot 10^{15}$ $n/cm^2/s$
Pulse width	
(fast / therm.)	215 / 320 μs
Number of channels	14

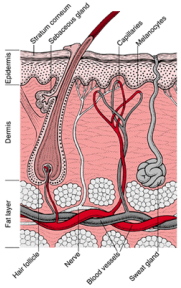
Milestones in Condensed Matter Physics

- IBR-2M: operation at design parameters of the reactor
- Realization of the full-scale cryogenic complex
- Complex of modern neutron spectrometers
- Wide international user policy

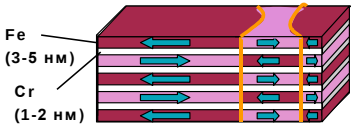
Condensed Matter Physics at IBR-2M
(priority directions)

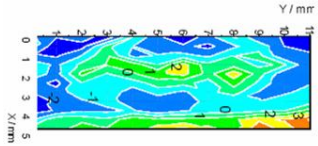
Nanosystems and Nanotechnologies

Biomedical Research



Novel Materials

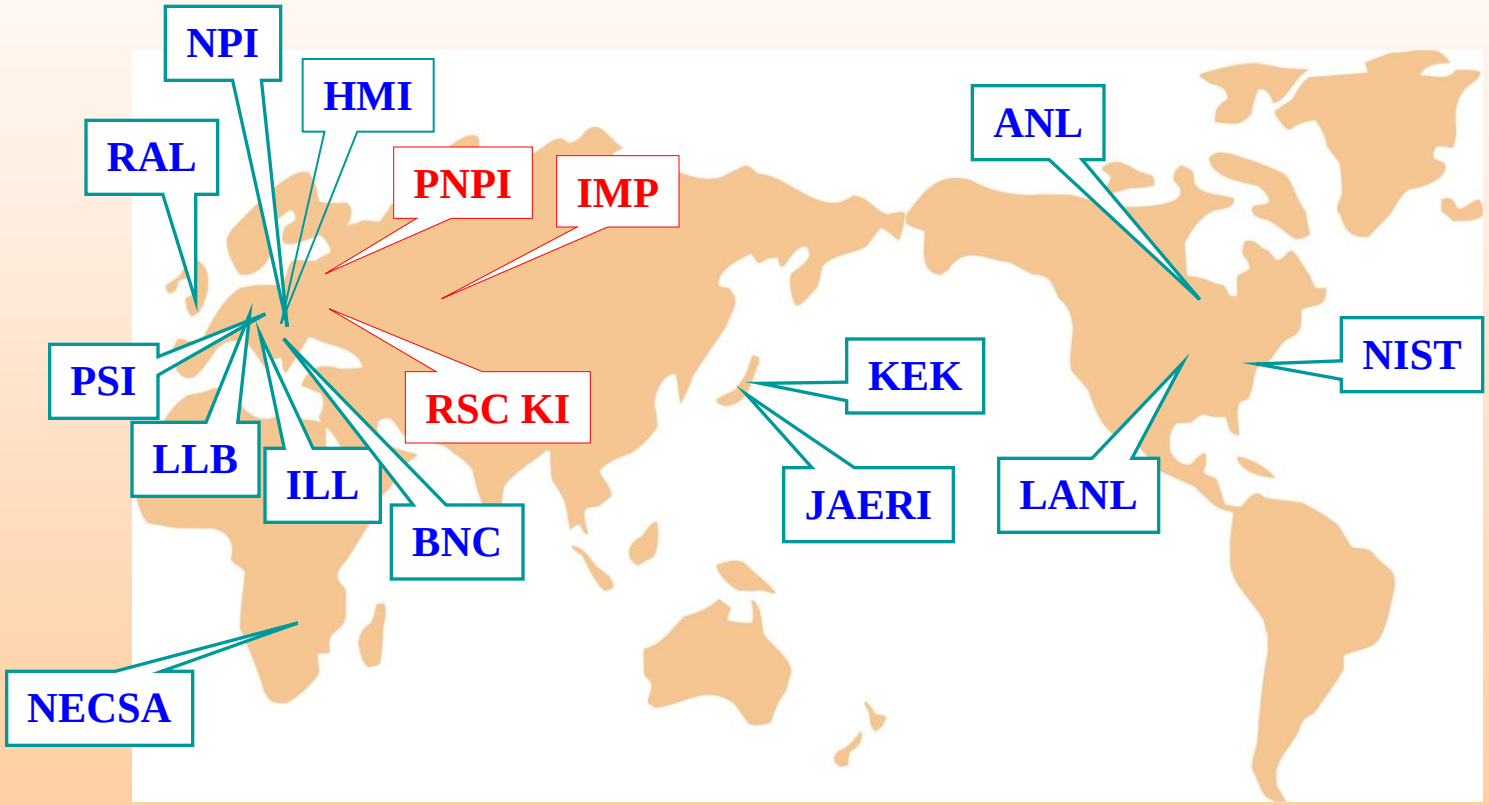




Engineering Diagnostics. Earth Sciences

Neutron scattering investigations of condensed matter in 2007 - 2010

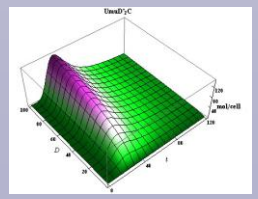
Collaboration with other neutron centers in Russia, Europe, USA, Japan, and South Africa

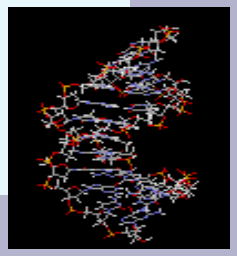


Main fields of research for 2010-2016:

- Research into the mechanisms of the ***genetic action*** of accelerated heavy ions and neutrons with different energies.
- Study of the action of heavy particles and neutrons on the ***eye's lens and retina.***

- Research into the regularities of the biological action of accelerated heavy ions on the ***central nervous system***.
- ***Mathematical modelling*** of biophysical systems.
- ***Radiation protection***.



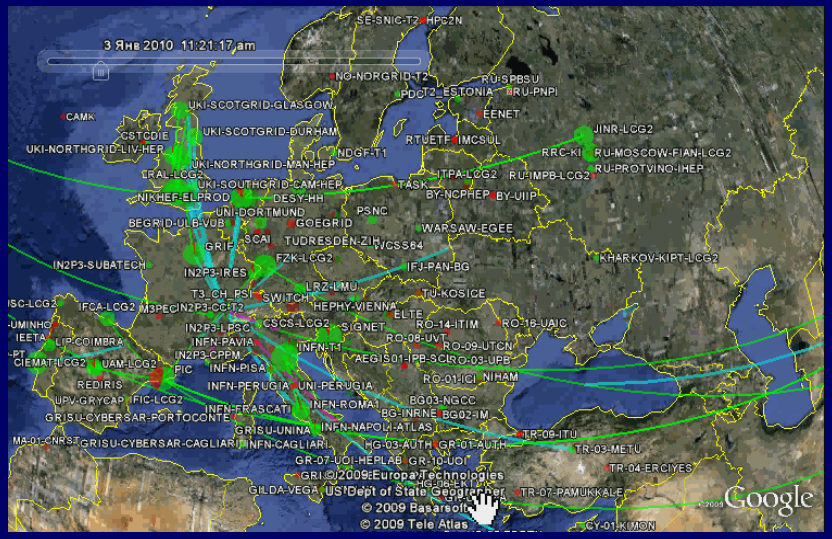


IT & TELECOMMUNICATIONS

2009 - two important projects completed

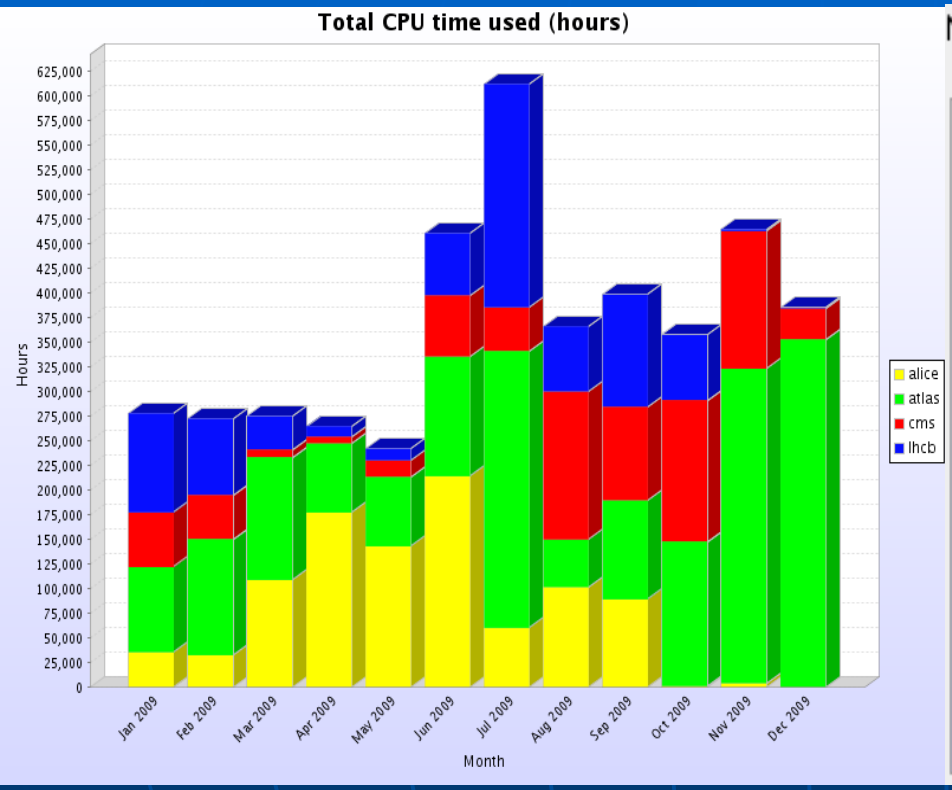
1. JINR - Moscow 20Gbps telecommunication channel was put into operation.
2. Increase of the JINR Central Information and Computing Complex performance up to 2400 kSI2K and the disk storage capacity up to 500 TB.

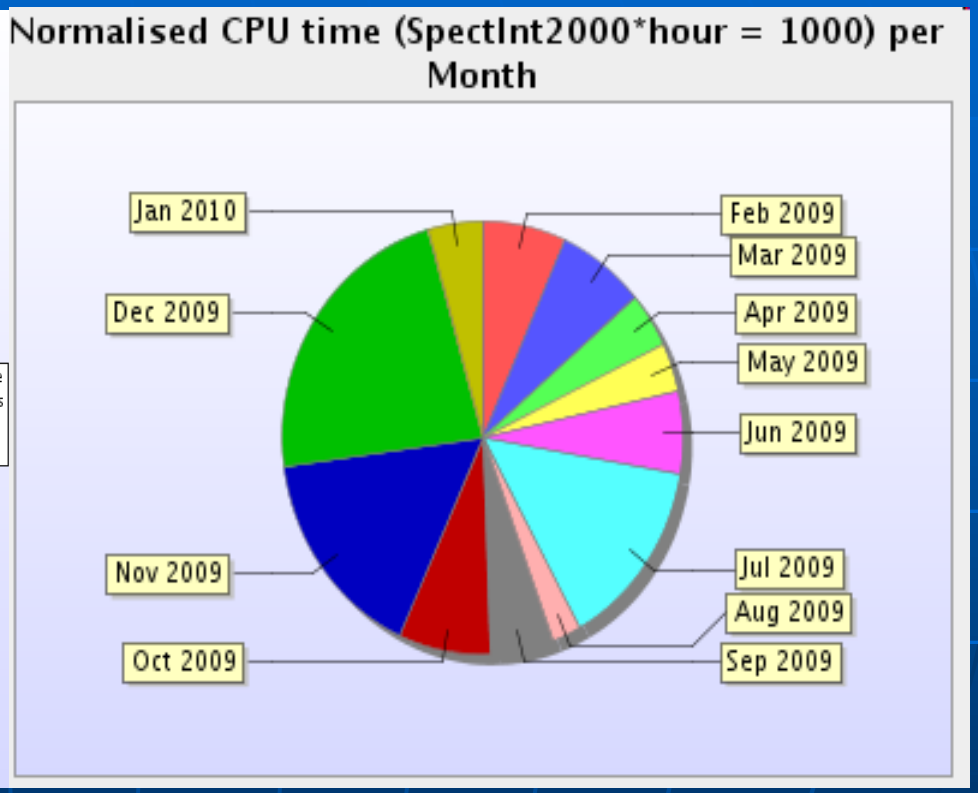
At present, JINR segment is one of the 10 best segments of the worldwide Grid infrastructure (WLCG).



JINR in LHC Computing and Grid

ATLAS, CMS and ALICE at JINR Grid Tier-2 from Feb 2009 to Jan 2010





GRID computing works very well at JINR

First LHC data were transferred and stored in Dubna. *Plots* show: JINR LHS teams uses these data and works at Dubna (via GRID)

A vitally important task is attracting young people from all the Member States to science

EDUCATIONAL PROGRAMME

JINR UNIVERSITY CENTRE

More than 300 students and postgraduates from Member States are trained at the UC

Chairs: MSU | MIPT | MEPI | MIREA | others

JINR is a school of excellence for the Member States!

"Dubna" International University

DIAS - TH

Dubna International Advanced School on Theoretical Physics

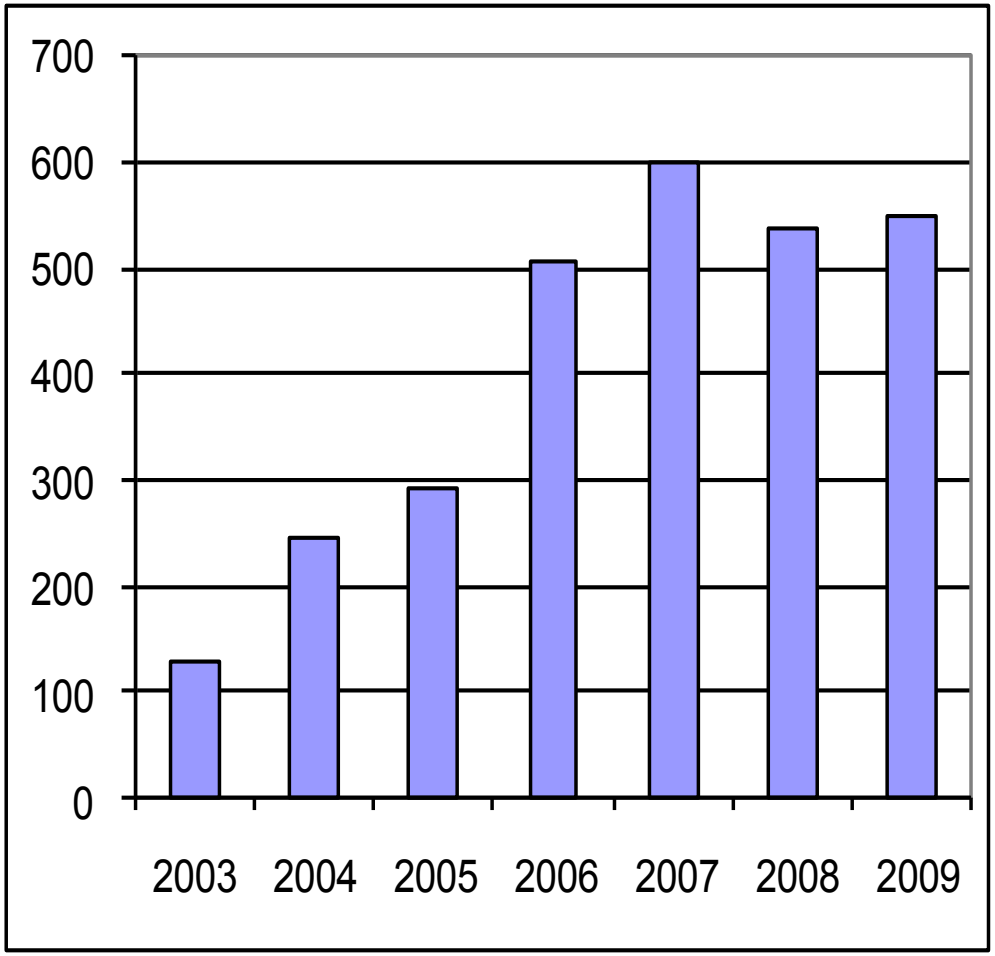
The UC offers graduate programmes in the fields of:

- Elementary Particle Physics
- Nuclear Physics
- Theoretical Physics
- Condensed Matter Physics
- Technical Physics
- Radiobiology

Main directions of University Centre activity

- Students, JINR-based departments
- JINR postgraduate programmes
- International education actions
- Student laboratory infrastructure
- Secondary-school oriented activity
- Technical staff retraining

Students at UC in 2003-2009



424 students from the JINR-based departments of MPhTI, MSU, MIREA, Dubna International University (DIU) studied in 2009/2010 at the University Center.

There were also 146 students from the different universities of JINR member-states.

International Student Practice in 2010

May 17 – June 6:

Students from Arab Republic of Egypt
(15 participants)

July 6 - July 25:

Czech Republic, Poland, Bulgaria Slovak Republic, Romania, Belorussia
(expecting 70 participants)

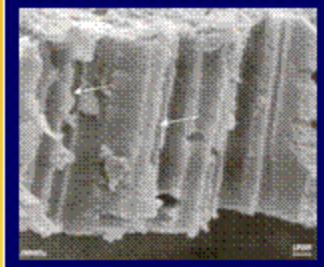
September 6 - 25:

South African students
(expecting 20 part.)

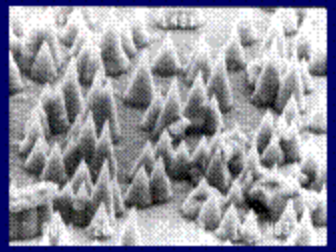
Innovations and the Special Economic Zone in Dubna

JINR contrubution to SEZ activities - examples

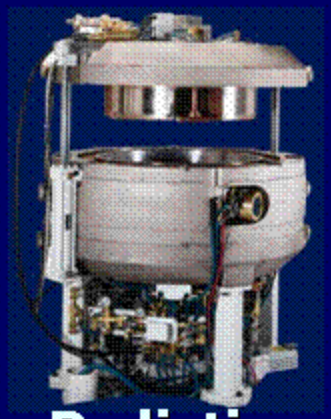
Nanotechnologies

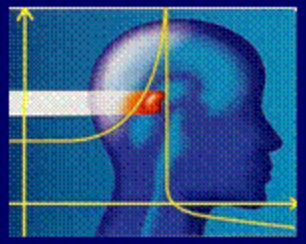


COPPER MICROTUBES



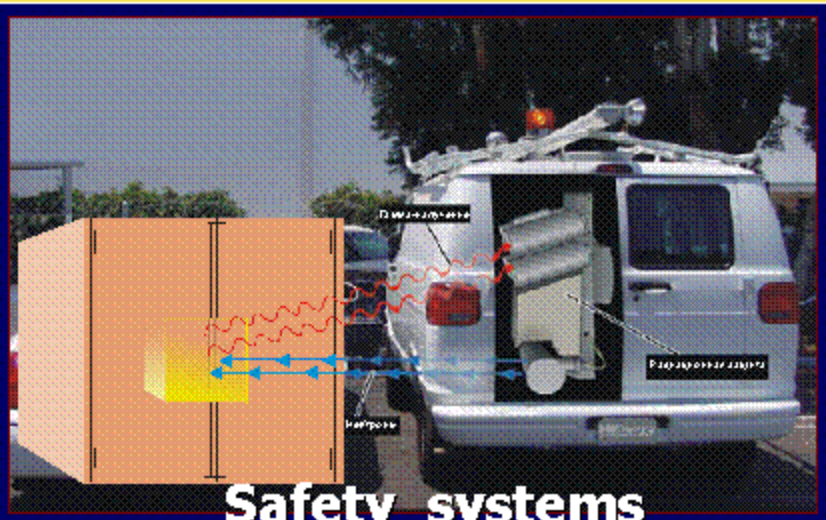
METALLIC NEEDLES





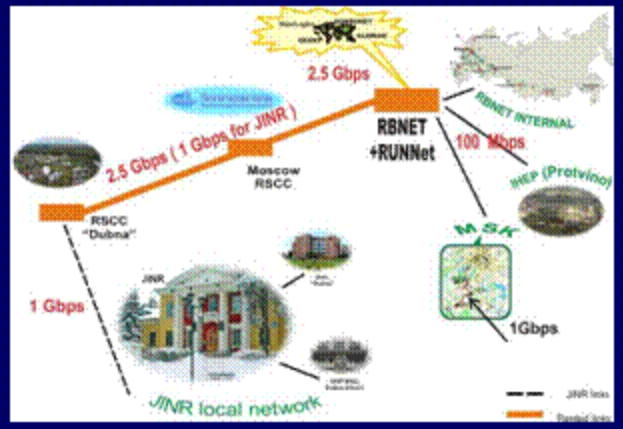
Hadron therapy

Radiation medicine



Safety systems

IT and Telecommunication



CONCLUSION

"Science will overcome everything, and the financial crisis as well".

Academician B.E. Paton

December 8, 2008, Moscow

"At such a difficult moment, there are those who say we cannot afford to invest in science, that support for research is somehow a luxury at moments defined by necessities. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before".

Barack Obama
President of the USA
April 27, 2009

Welcome to JINR (Dubna)