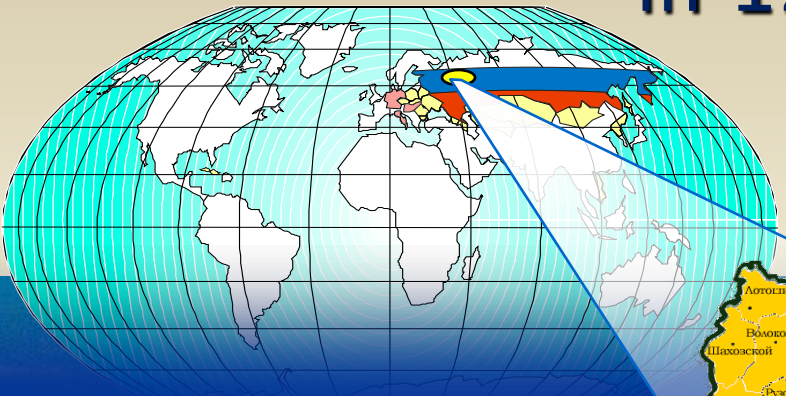

# JINR – past, present and future

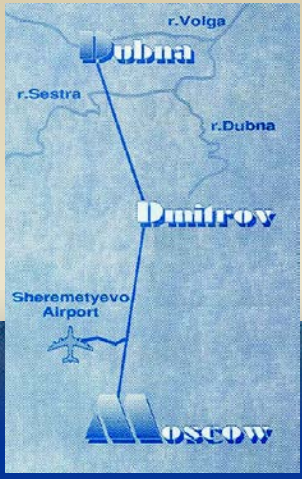
Richard Lednicky

# JINR is located in the city of Dubna in 120 km north from Moscow

Russia



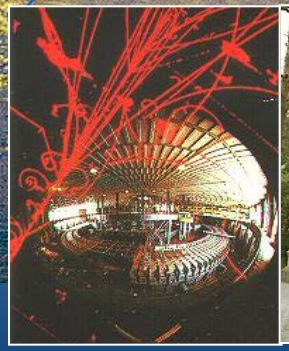
Moscow Region

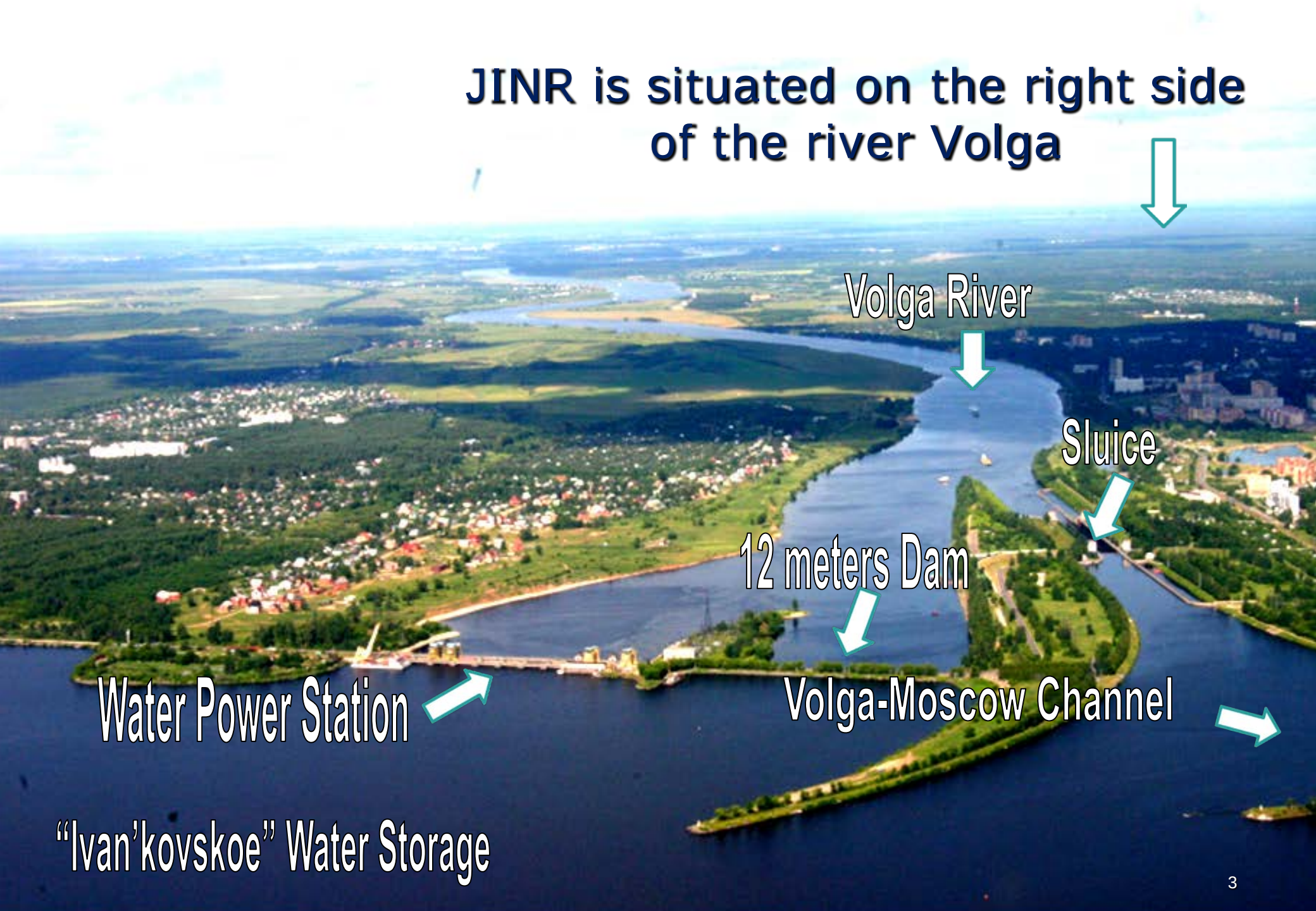


Dubna

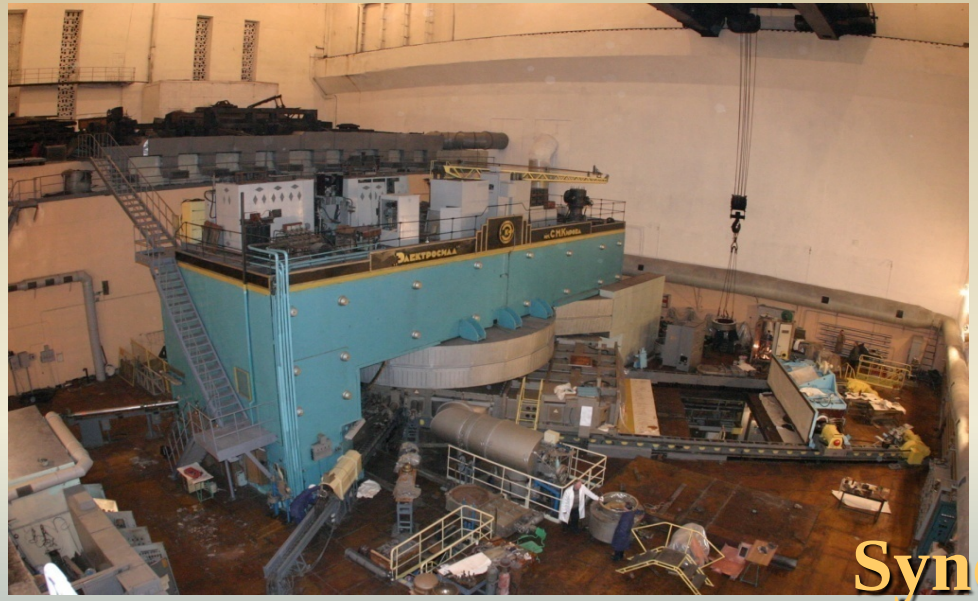
JINR

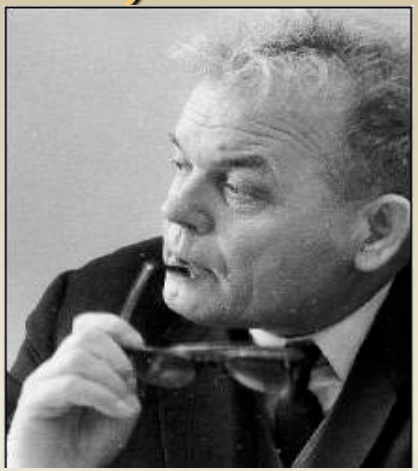


# JINR is situated on the right side of the river Volga



# Synchrocyclotron 680 MeV (1949)

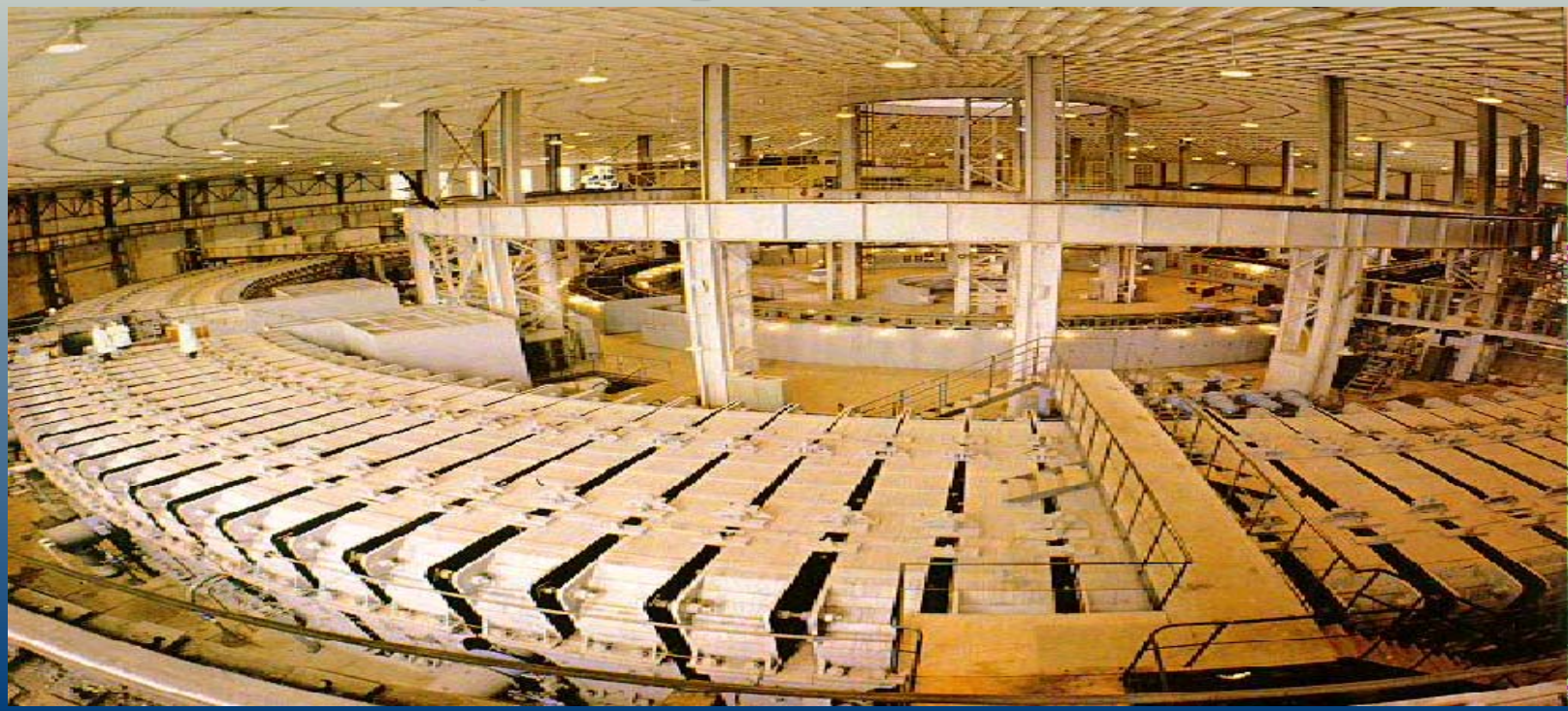




M.Meshcheryakov

# Synchrophasotron 10 GeV (1957)

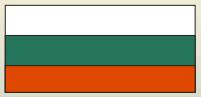
V.Veksler



# JOINT INSTITUTE for NUCLEAR RESEARCH
## International Intergovernmental Scientific Research Organization

1956


Albania


Bulgaria

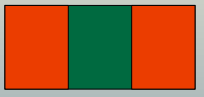

China


Czechoslovakia


GDR


Hungary


D.P.R.Korea


Mongolia


Poland


Romania


USSR


Vietnam

**The Convention on the establishment of JINR was signed on 26 March 1956 in Moscow**

*to unite scientific and material potential of its member states in order to study fundamental properties of matter*

# JINR has at present 18 Member States:


Armenia
Azerbaijan
Belarus
Bulgaria
Cuba
Czech Republic
Georgia
Kazakhstan
D. P. Republic of Korea Moldova
Mongolia
Poland
Romania
Russian Federation
Slovakia
Ukraine
Uzbekistan
Vietnam

**Participation of Egypt, Germany, Hungary, Italy, the Republic of South Africa and Serbia in JINR activities is based on bilateral agreements signed on the governmental level.**

# 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

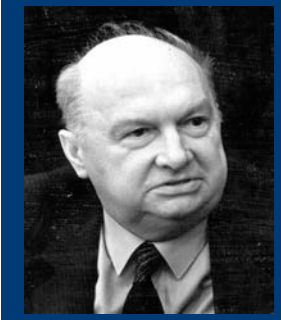
**Large and unique park of basic facilities for fundamental and applied research:**

- 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 63 countries

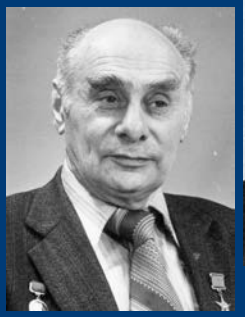
# Founders


A.Baldin

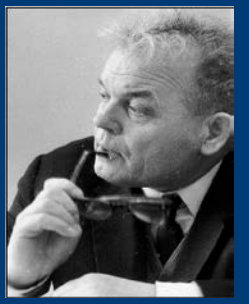

V.Dzhelepov

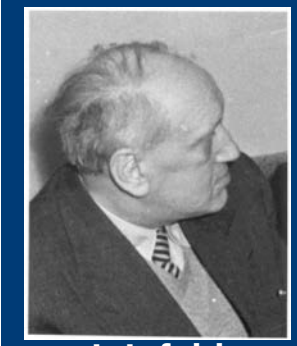

V.Veksler

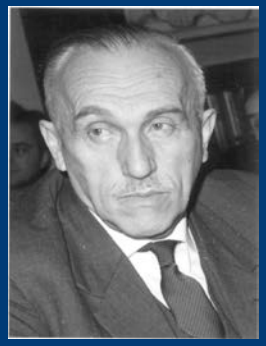

N.Bogoliubov, D.Blokhintsev

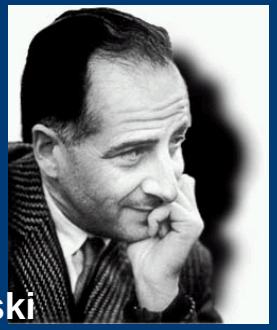

G.Flerov


I.Frank


M.Meshcheryakov

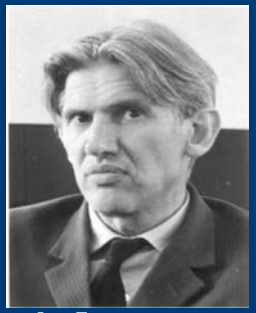

L.Infeld

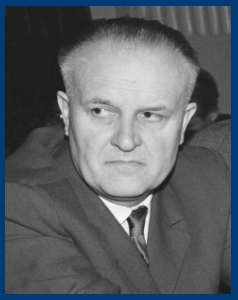

G.Nevodnichanski

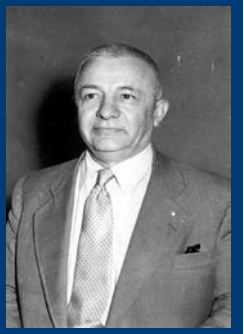

B.Pontecorvo


Wang Ganchang


H.Huluei

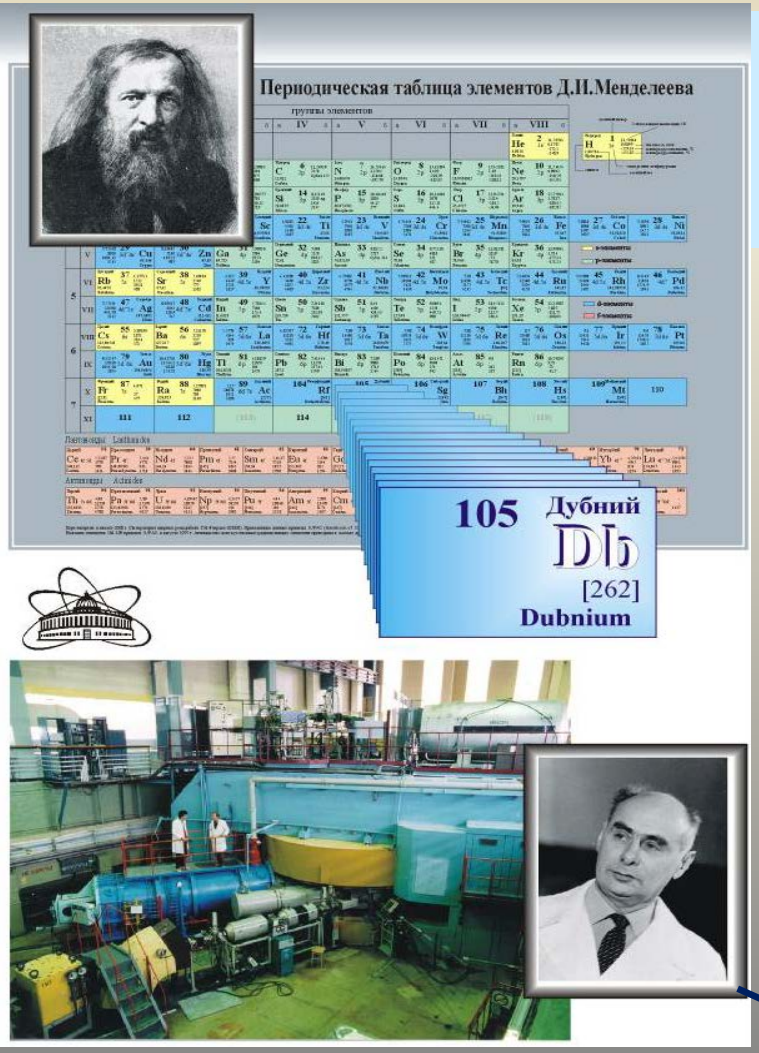

L.Janossy


V.Votruba


G.Najakov

# Discoveries

## JOINT INSTITUTE for NUCLEAR RESEARCH




- 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 105
- 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
- 1999-2010 – super-heavy elements 113-118 and their chemical identification

*Recently 114 named Florovium after ac. Flerov*

# JINR basic facilities

## *Nuclotron-M – NICA/MPD /SPD*

***Superconducting ion and polarized particle accelerator and ion collider***

***Physics of ultrarelativistic heavy ions, high energy spin physics***

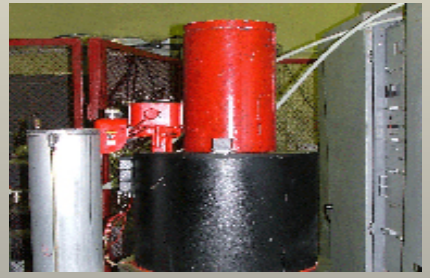
***Applied research***

## *Cyclotron complex U400, U400M*

***Acceleration of heavy ions up to 50 MeV/u***

***Synthesis of supe-heavy elements***

***Applied research***



## *Impulse reactor IBR-2M and Source of resonance neutrons IREN*

***5 Hz pulses with 1,5 GW power and $10^{16}$ neutrons/cm$^2$sec***

***Accelerator driven neutron beam of 50 GHz up to$10^{13}$ neutrons/sec***

***Nuclear physics with neutrons, Condense matter physics***

***Applied research***

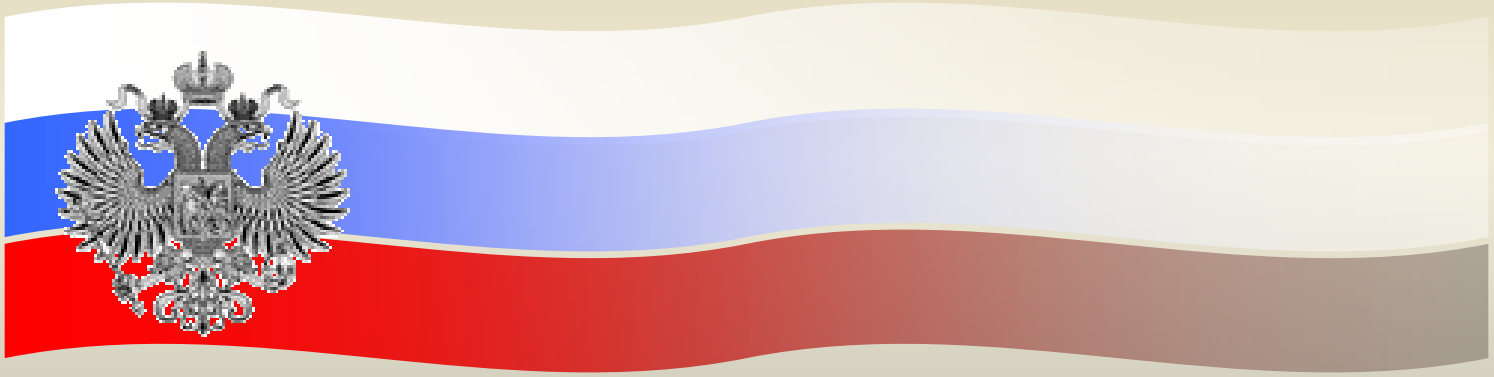
## *JINR's Phasotron*

***2 μA proton beam with the energy 660 MeV***

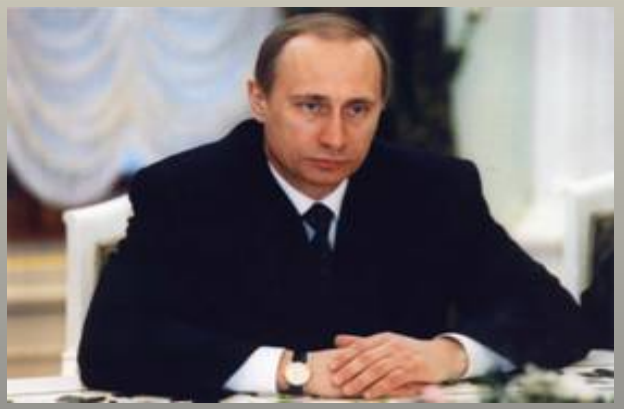
***Complex for Hadron Therapy***

***Applied research***

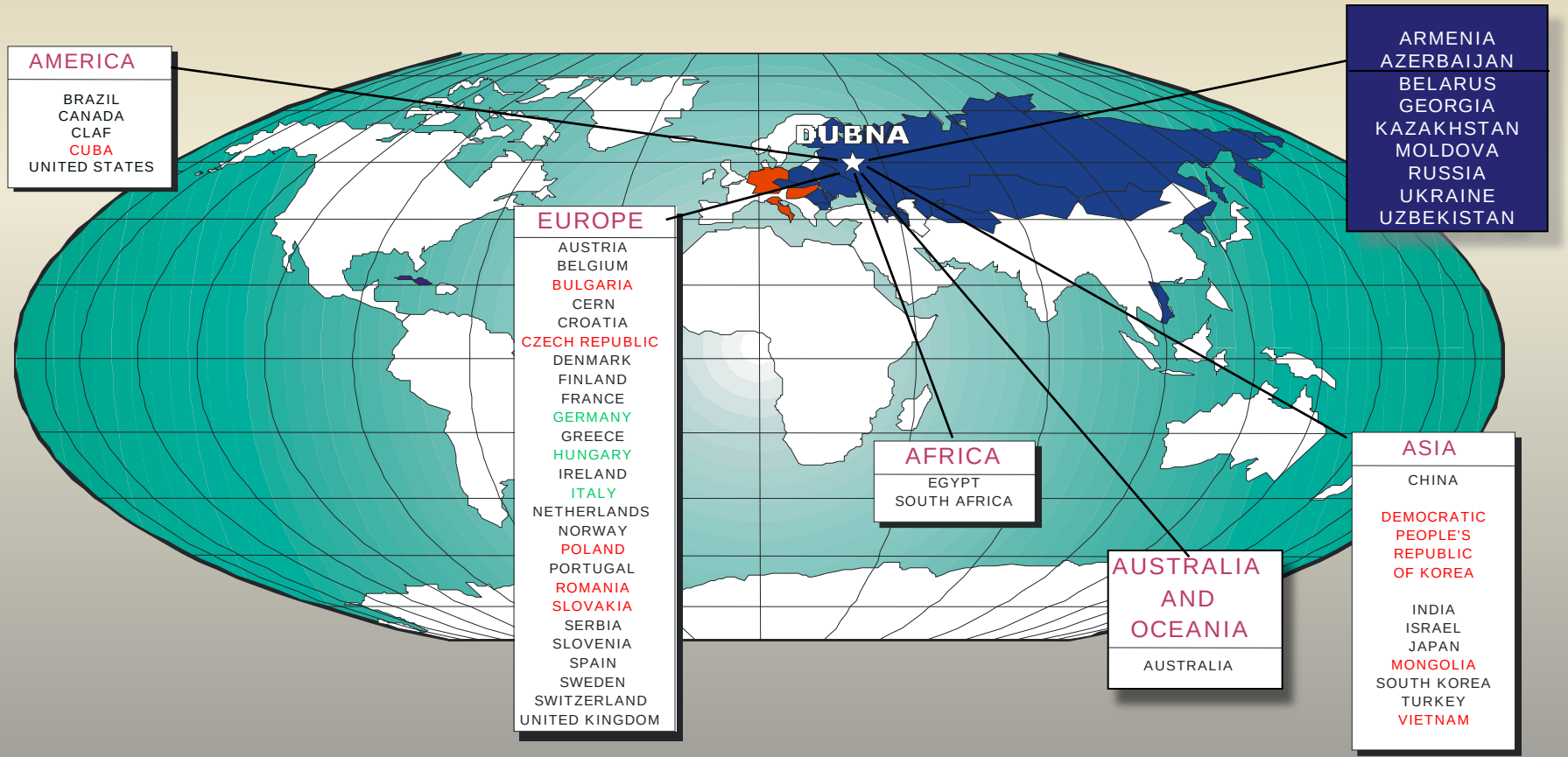
# JINR – Russia Agreement



A very important for JINR, Russian Federal law was signed by President V.Putin in 2000. This is ***"The Agreement between the Government of the Russian Federation and JINR on the Location and Terms of Activity of JINR in the Russian Federation".*** This Agreement grants privileges and immunities in accordance with established practice for international intergovernmental organizations.



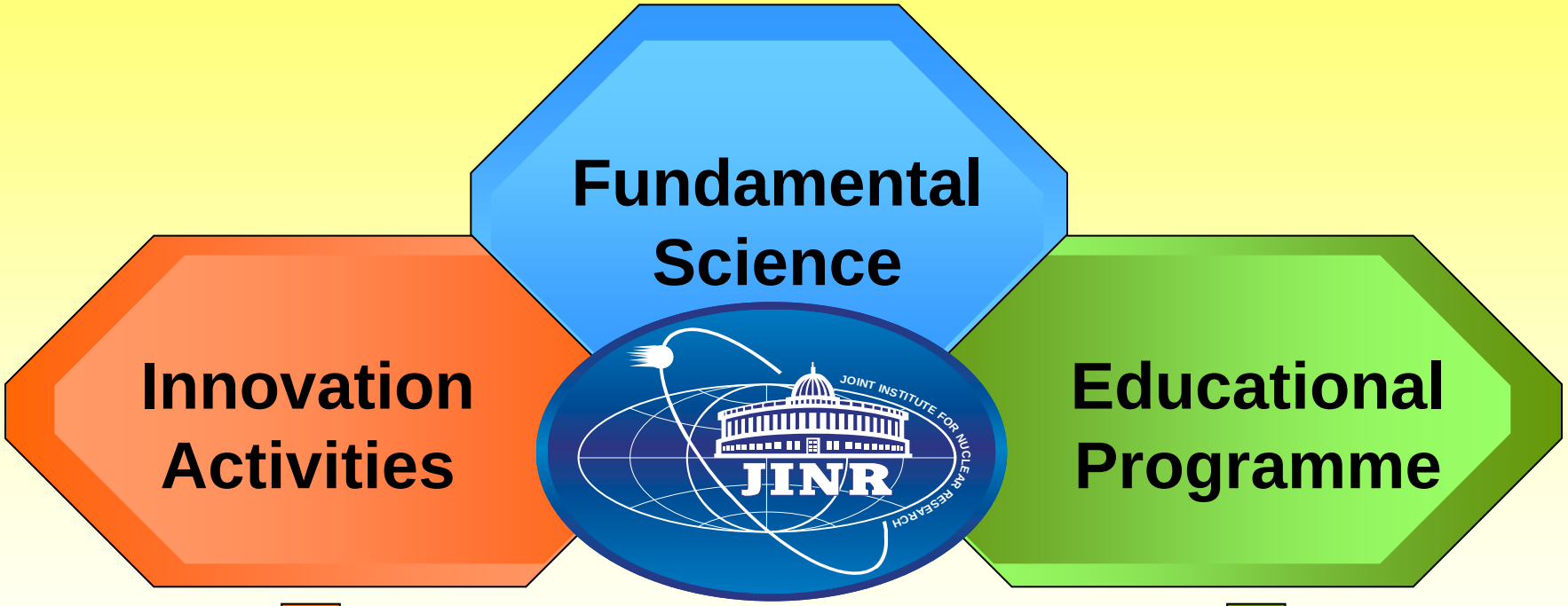
# Science Bringing Nations Together




**JINR's partners are about 700 institutions located in 63 countries, including about 300 institutions and universities from the JINR Member States**

# JINR's Science Policy

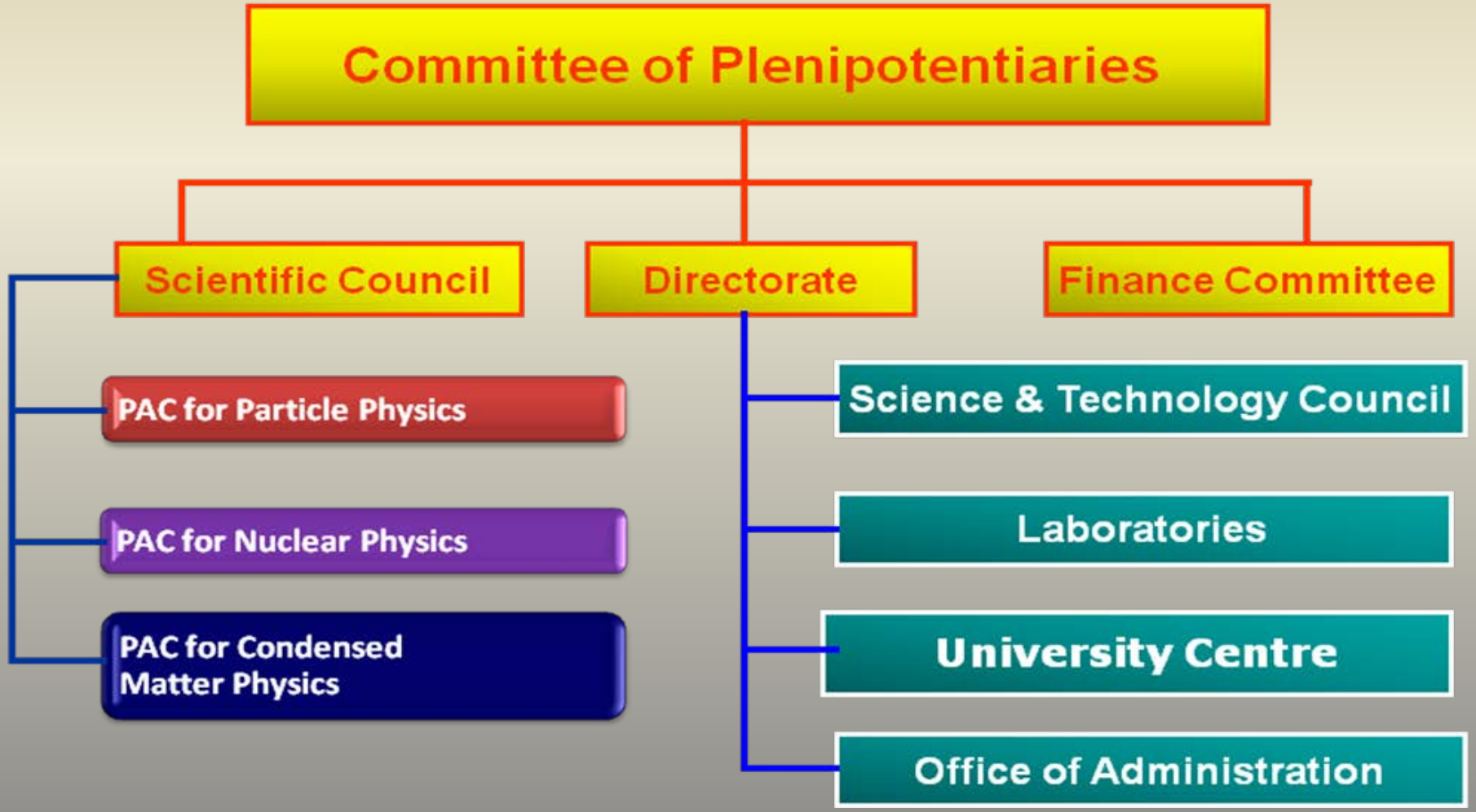
## 7-Year Programme (2003-2009); (2010-2016)
## Road Map (2006-2017)




Special Economic Zone
Technopark "Dubna"
Public-Private-Partnership

UC, DIAS-TH
International Univ. "Dubna"

# Governing Bodies & Structure



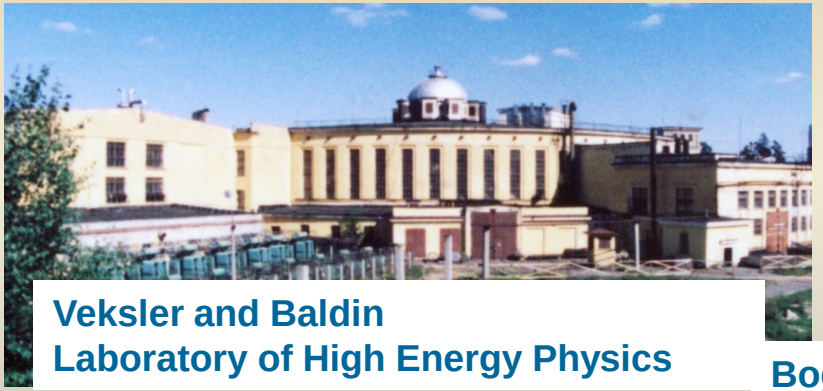
# The Supreme governing body of JINR is the Committee of Plenipotentiaries of the governments of JINR Member States

The research policy of JINR is determined by the Scientific Council, which consists of eminent scientists from the Member States, as well as famous researchers from China, France, Germany, Greece, Hungary, India, Italy, and CERN

**At the session of the Scientific Council**

# JINR comprises 7 Laboratories, each being comparable with a large institute in the scale and scope of investigations performed

**Dzhelepov**
**Laboratory of Nuclear Problems**



**Veksler and Baldin**
**Laboratory of High Energy Physics**

**Bogoliubov**
**Laboratory of Theoretical Physics**

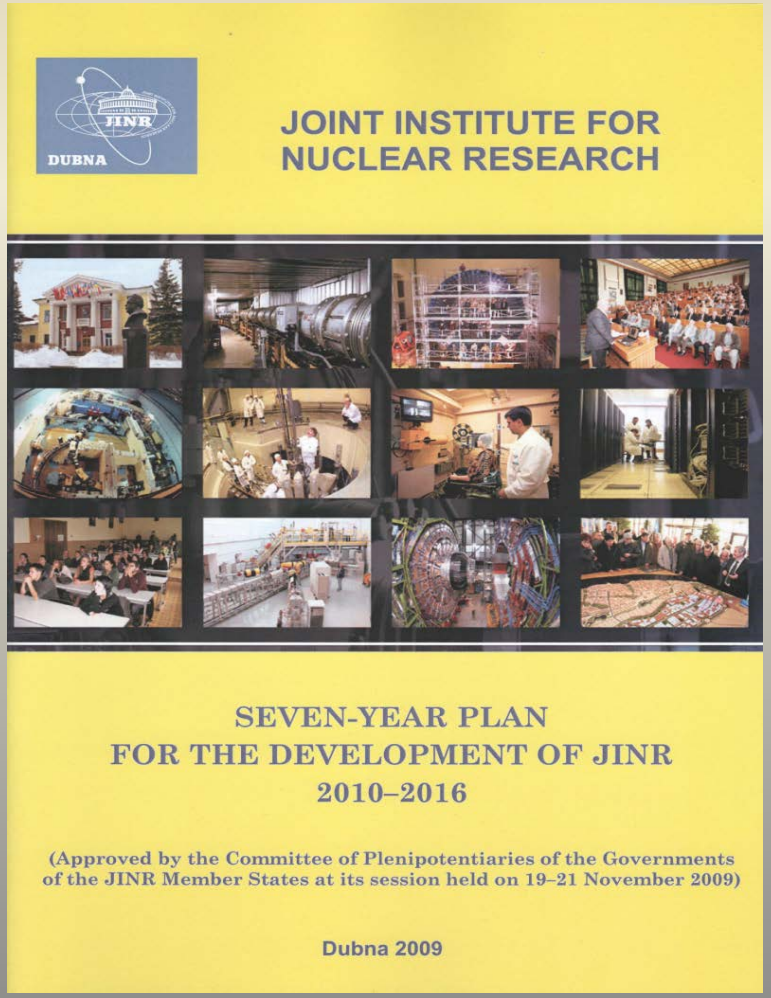
**Flerov**
**Laboratory of Nuclear Reactions**

**Frank Laboratory of Neutron Physics**

**Laboratory of**
**Information Technologies**

**Laboratory of Radiation Biology**

# 7-Year Plan (2010 – 2016)




***The concept of the Seven-Year Plan is based on the concentration of resources to update the accelerator and reactor base of the Institute.***
***The key elements of the qualitative improvement of the research infrastructure are the following basic facilities:***

– the ion collider NICA (Nuclotron-based Ion Collider fAcility) for research in the field of high-energy heavy-ion physics ;

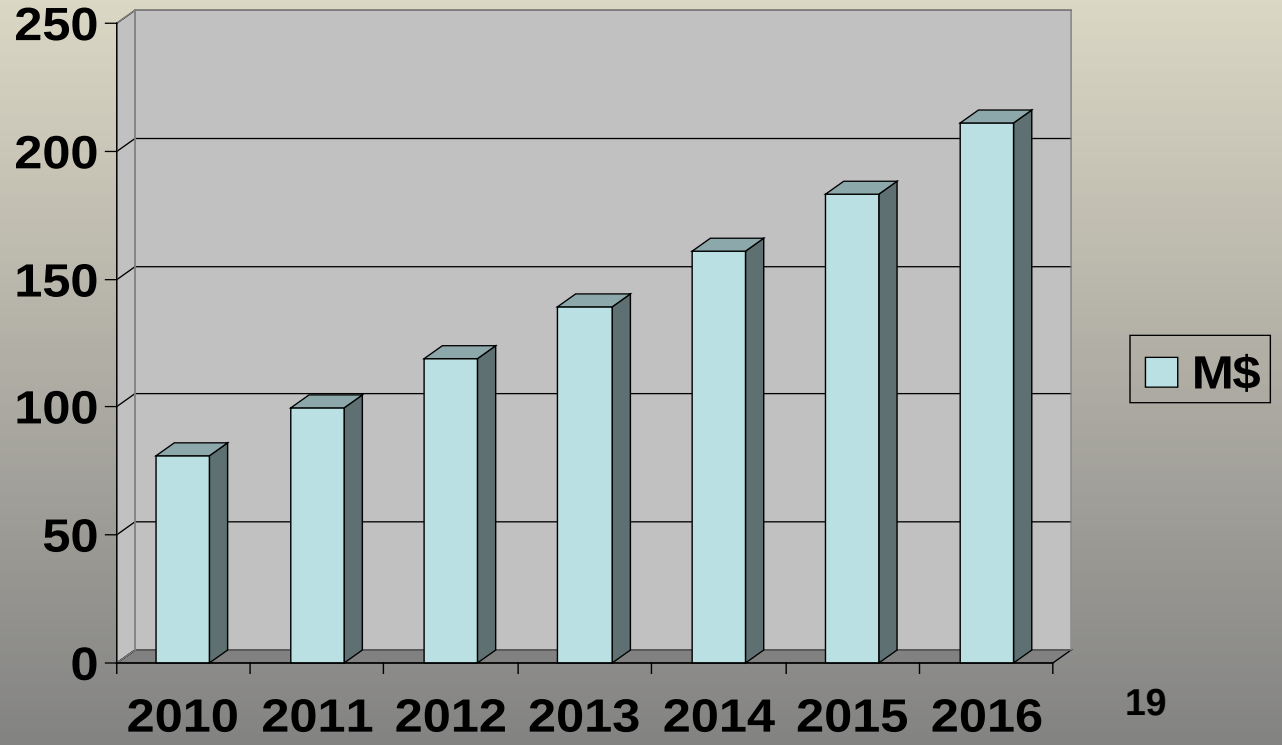
– the cyclotron complex DRIBs-III (Dubna Radioactive Ion Beams) for the search for new superheavy elements of Mendeleev's Periodic Table and for studies of the properties of radioactive and exotic neutron-rich nuclei;

– the modernized reactor IBR-2M for research in condensed matter physics and particularly in the fields of nanoscience and nanotechnology.

# JINR in some figures

- **JINR's staff members ~ 4500**
- **researchers ~ 1200**
  **including from the Member States (but Russia) ~ 400**
- **Doctors and PhD ~ 1000**

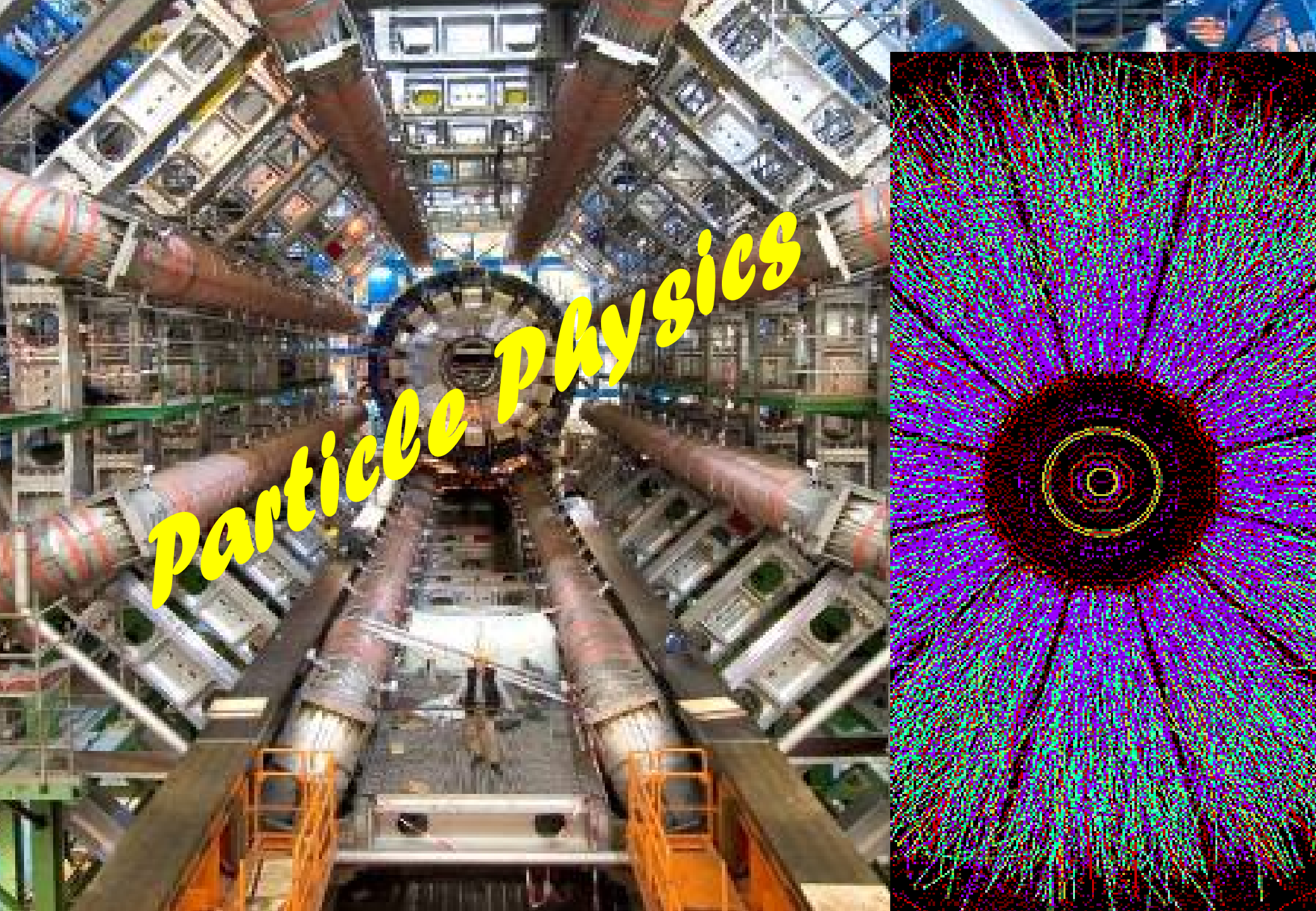
**JINR Budget (actual and foreseen in the 7-year Plan)**



# Basic Scientific Directions

- **High Energy Physics**
- **Nuclear Physics**
- **Condensed Matter Physics (including Radiobiology)**

- ***Main Supporting Activities***
  - **Theory of PP, NP, CMP**
  - **Networking and computing**
  - **Physics instruments and methods**
  - **Training of young staff**


Particle Physics

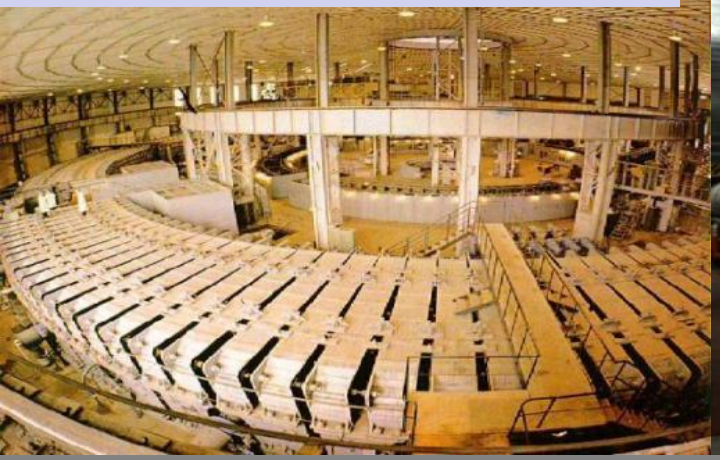
# Synchrophasotron – Nuclotron – NICA

## 1957 – 2002 Synchrophasotron

***10 GeV proton accelerator – world leader in energy.***

***Beginning of era of high-energy physics***

**V.Veksler – phase stability principle discovery**



## 1993 – Nuclotron

***First in the world Superconducting Synchrotron of heavy ions***

**A.Baldin –start of relativistic nuclear physics era**

## 2019 – NICA

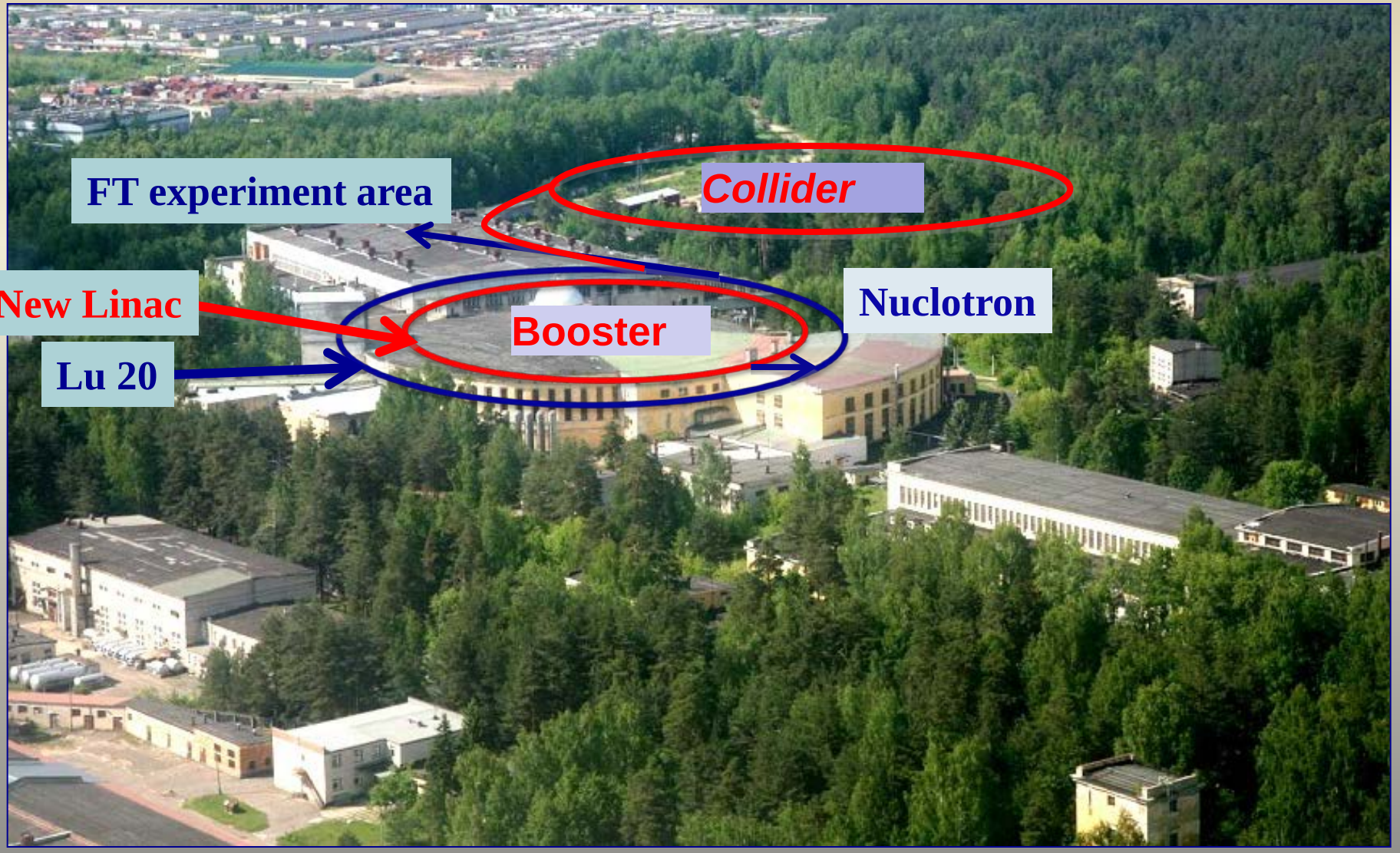
***Superconducting collider of heavy ions***

***Study of baryonic matter at extreme conditions (max net baryon density)***

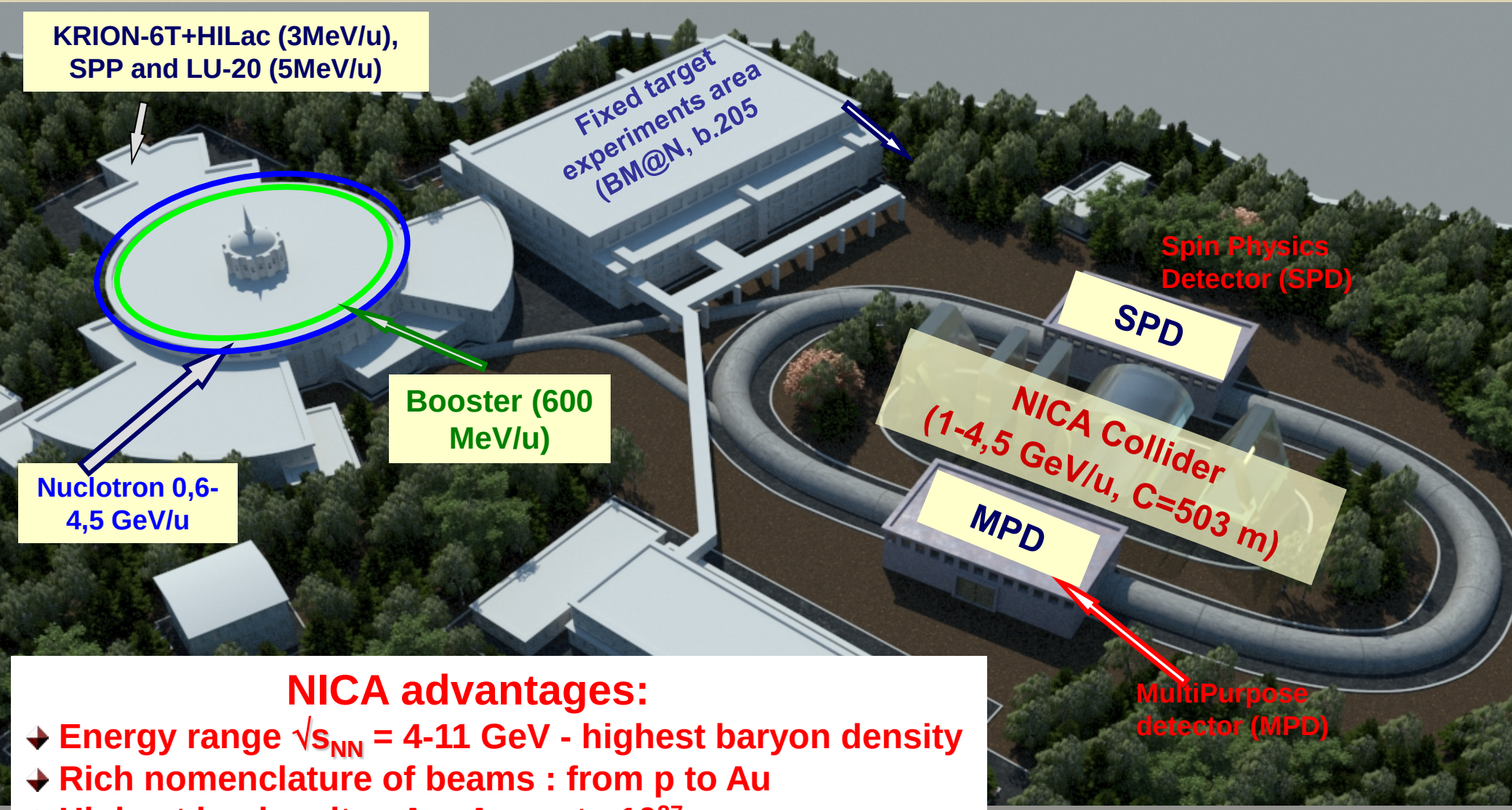
**The JINR 7-year plan for 2010-2016 approved by CPP in 2009:**

***NICA – the JINR flagship project in HEP***

# Area of Nuclotron-NICA Facility



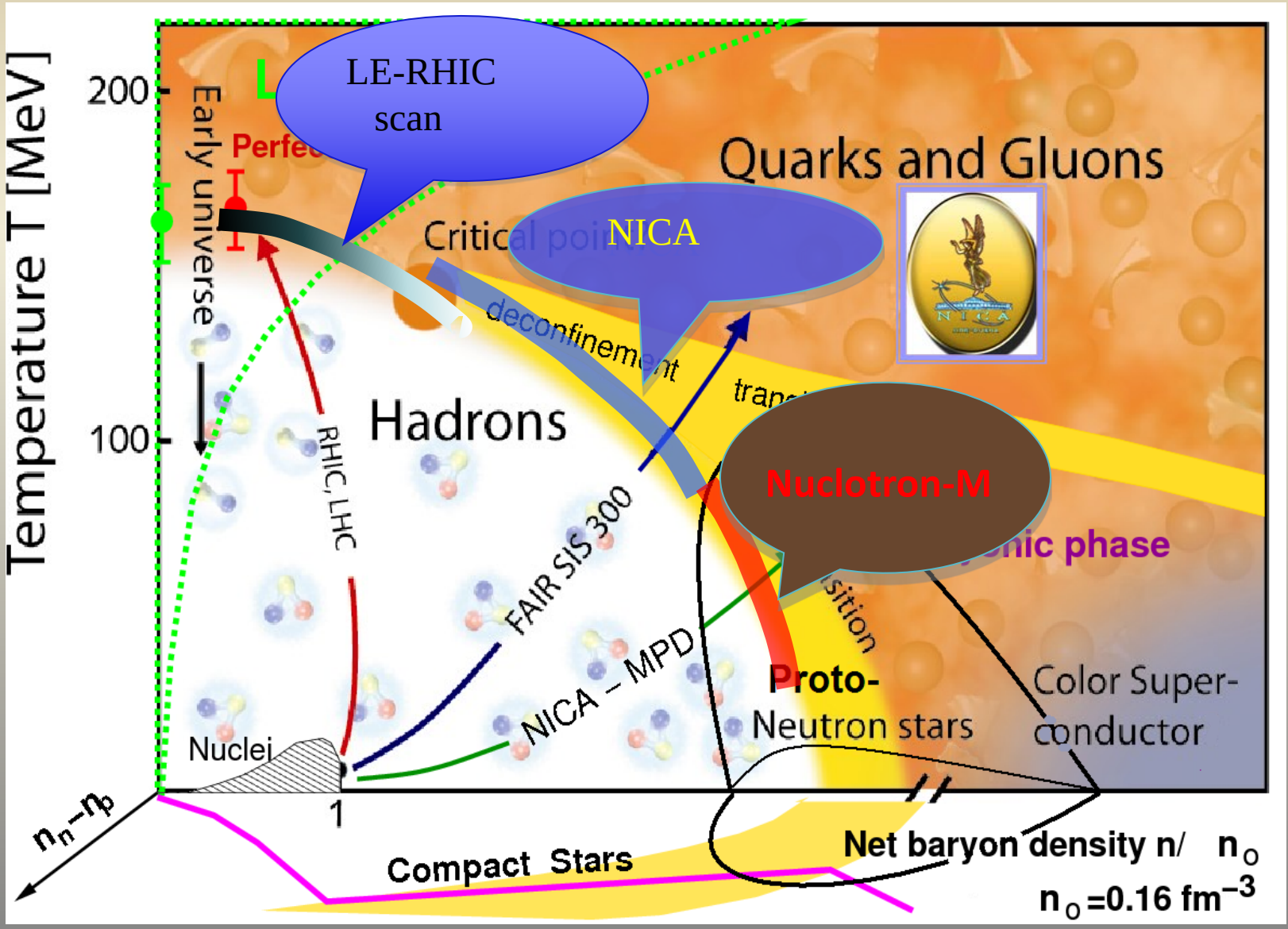
# Superconducting accelerator complex NICA (Nuclotron based Ion Collider fAcility)




## NICA advantages:

- Energy range $\sqrt{s_{NN}}$ = 4-11 GeV - highest baryon density
- Rich nomenclature of beams : from p to Au
- Highest luminosity : Au+Au up to $10^{27}$
- Polarized proton and deuteron beams

# QCD Phase Diagram



April, **1822**

# Critical opalescence

THE ANNALS OF PHILOSOPHY.

NEW SERIES.

JANUARY TO JUNE, 1823.



ARTICLE IX.

## *An Account of some Results obtained by the combined Action of Heat and Compression upon certain Fluids, such as Water, Alcohol, Sulphuric Ether, and the rectified Oil of Petroleum.*

By M. le Baron Cagniard de la Tour.*

**Water liquid-gas CEP**: 374 °C and 218 atm

The last experiment was made with a glass tube about one-third full of water; this tube lost its transparency, and broke a few seconds afterwards. It appears that at a high temperature water is capable of decomposing glass by combining with its alkali; this suggests the idea that some other result interesting to chemistry may, perhaps, be obtained by increasing the applications of this process of decomposition.

It took a century to explain the phenomenon of critical opalescence – divergent $\xi$ of density fluctuations (Smoluchowski, Einstein). And another 1/2 century to describe critical phenomena quantitatively – scaling, universality, RG (Landau, Kadanoff, Wilson).


On-line web-camera
http://nucloweb.jinr.ru/

STRABAG PSJ budostal 3sa

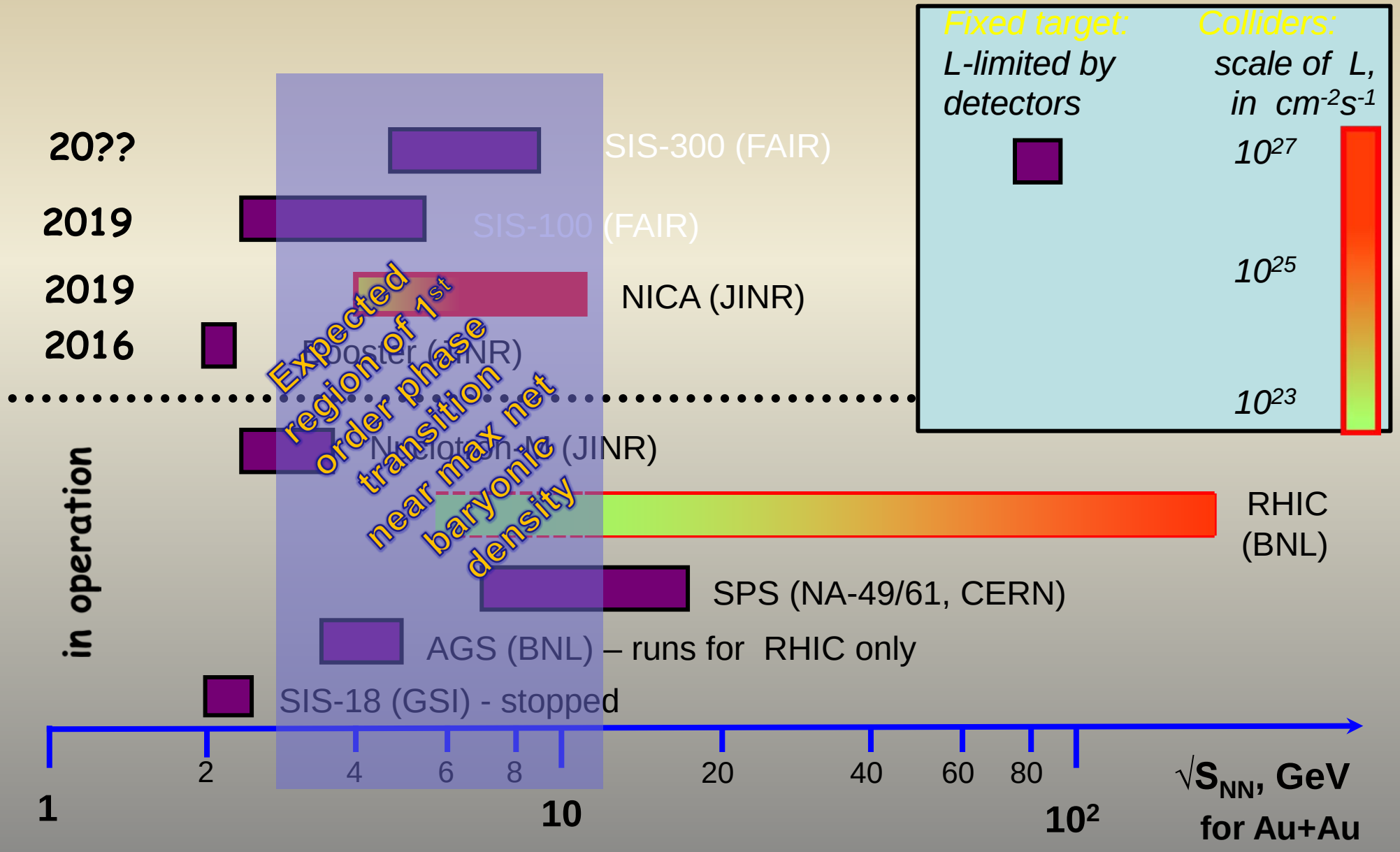
**Consortium of 3 large European companies (chosen out of 15 companies in an international tender) to build the collider tunnel and detector experimental halls.**

JINR and Strabag representatives on the future construction area

Contract for Construction area mobilization (construction site, temporary building new pass-gate, 250 test piles) – final discussion. Start – October 2014, ~ 3 months.

Contract for Civil Construction (**~70M$**)
– goal to sign in Jan 2015.
– basic ground works in spring 2015.

# NICA among existed & future HI accelerators

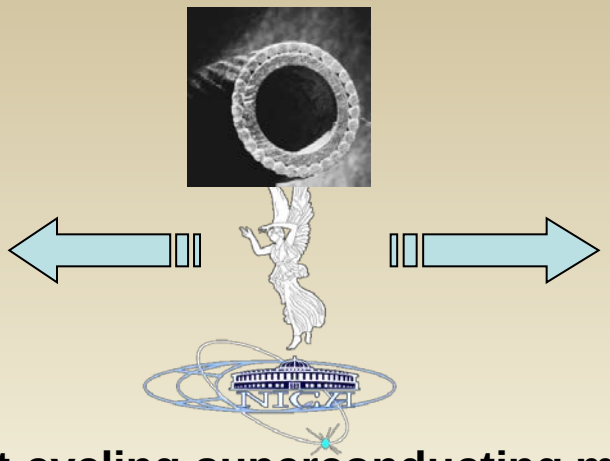


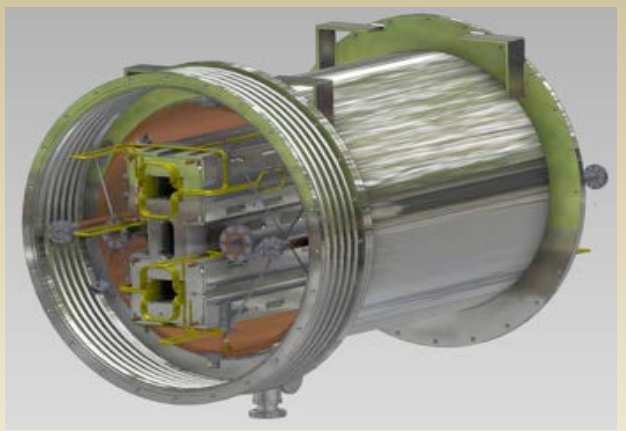
# NICA as one of the 6 mega-science projects in RF

08 Aug'13: Representatives of 13 countries, 6 signed to join the mega-science project NICA

08 Aug'13: Representatives of 13 countries, 6 signed: **Belarus, Bulgaria, Germany, Kazakhstan, RF, Ukraine**.
Ready to join: **China and South Africa .**
The Parties have agreed to inform their Governments about the Meeting on Prospects for Collaboration in the Mega-Science Project "NICA Complex" and to express their interest in preparing corresponding multilateral Agreement and in taking steps for approval by their countries

Germany (BMBF, GSI) – to the Test Facility for SC magnets and Si tracker Lab; **MoU**
China (ASIPP) – to the HTSC current leads, SC magnets, vacuum systems; **MoU**
USA (FNAL) – to the NICA collider stochastic and electron cooling systems; **MoU**
CERN – to the BM@N and MPD elements (drift chambers, MM systems…); **MoU**
Rep. of South Africa – cryostats, diagnostics for SC ion source, cryogenics. **MoU**

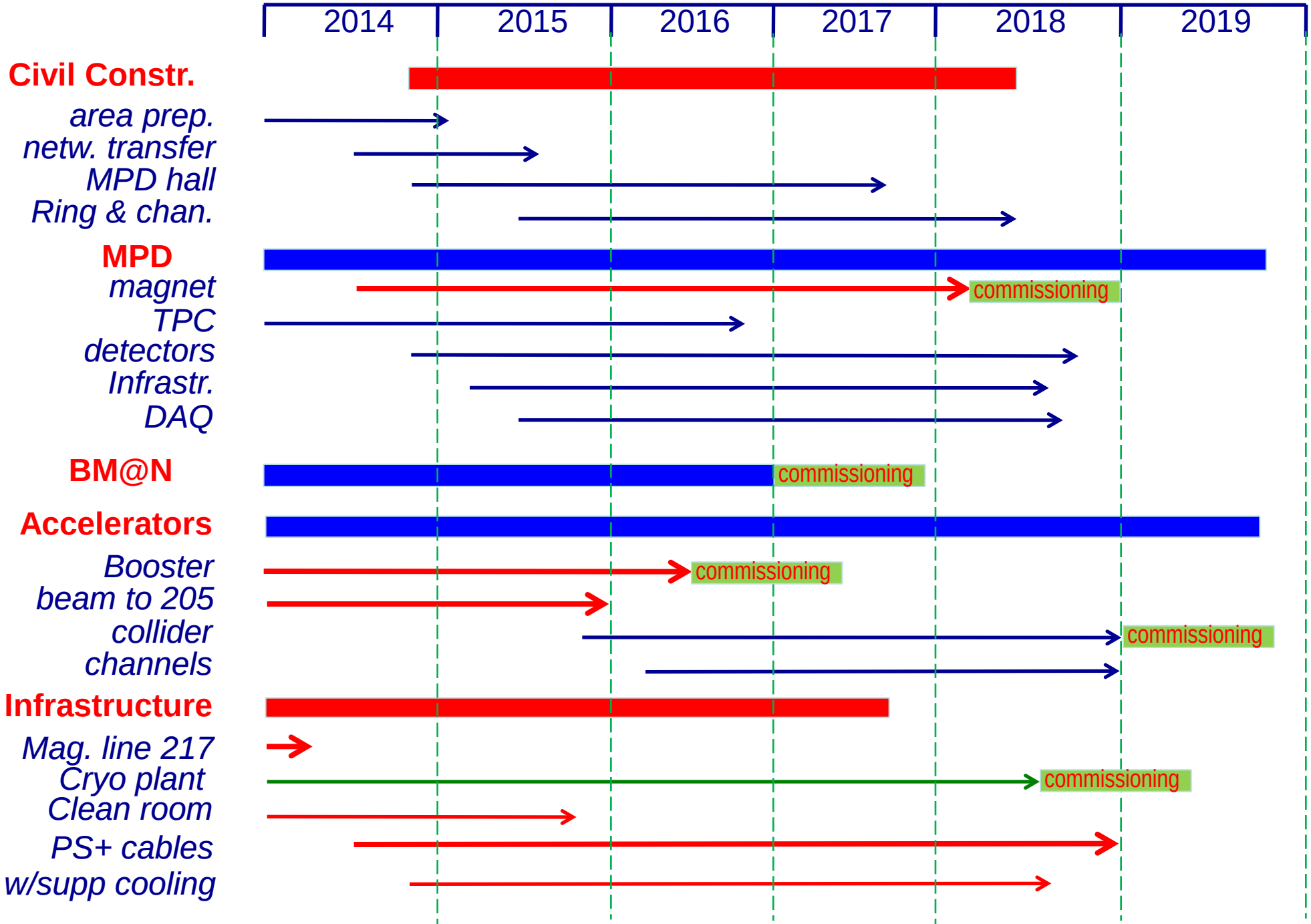


**Unique Dubna technologies of fast-cycling superconducting magnets tested during several tens of Nuclotron runs and chosen as basic for accelerator complexes NICA and FAIR.**

**Germany already invested ~17 MEuro in the JINR test facility for SC magnets.**

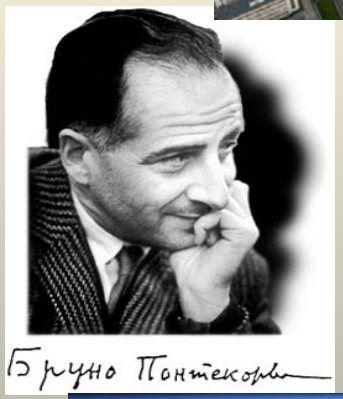
## Common European Research infrastructure for Heavy Ion High Energy Physics: NICA + FAIR


2014
2015
2016
2017
2018
2019
Civil Constr.
area prep.
netw. transfer
MPD hall
Ring & chan.
MPD
magnet
commissioning
TPC
detectors
Infrastr.
DAQ
BM@N
commissioning
Accelerators
Booster
commissioning
beam to 205
collider
commissioning
channels
Infrastructure
Mag. line 217
Cryo plant
commissioning
Clean room
PS+ cables
w/supp cooling

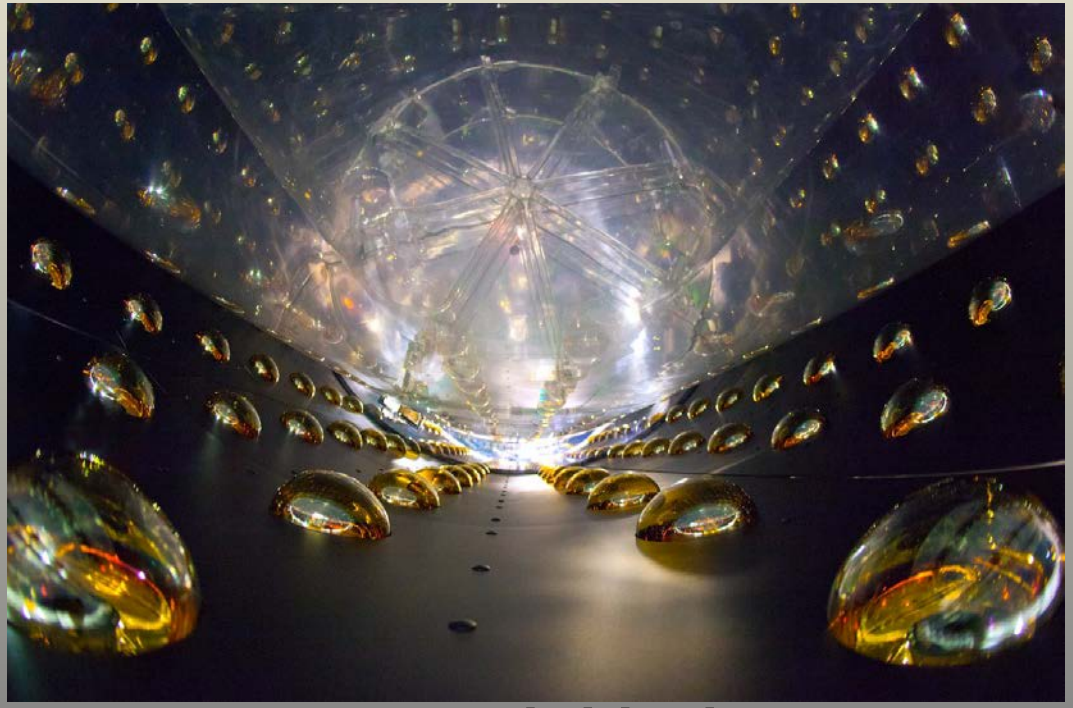
# DLNP. JINR Neutrino Program

Astrophysical neutrino sources (**BAIKAL GVD**)
Sterile neutrino searches (**DANSS/KNPP**)
Coherent neutrino-nucleus scattering (**vGEN**)
Precise measurements of neutrino oscillations (**Daya Bay, BOREXINO, OPERA**)
Neutrino mass hierarchy (**JUNO, NOVA**)
Dirac or Majorana? (**SuperNEMO, GERDA, Majorana**)

Kalinin NPP




**Solar**
**Reactor**
**Accelerator**
**Astrophysical**
**Atmospheric**

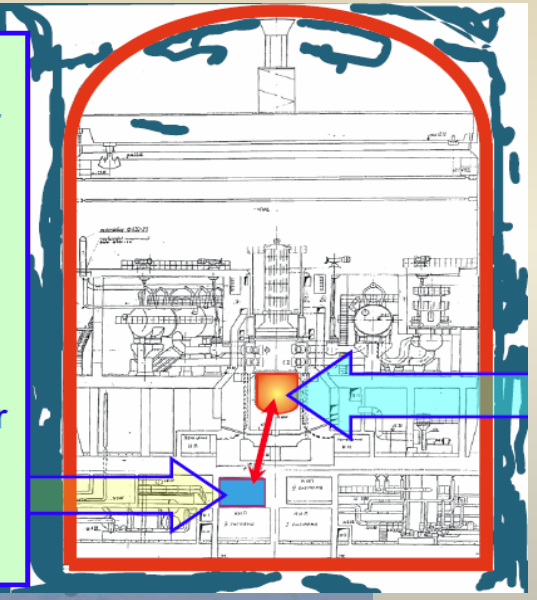


**Daya Bay (China)**

# Experiments at Kalinin NPP

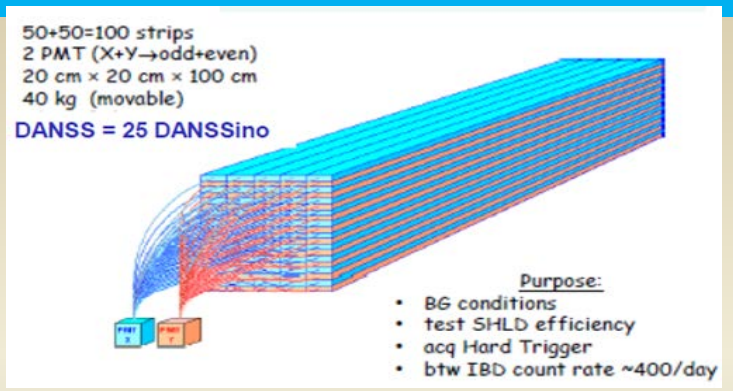
**Overburden**
*(reactor, equipment, etc.):*
**~70 m of W.E.**

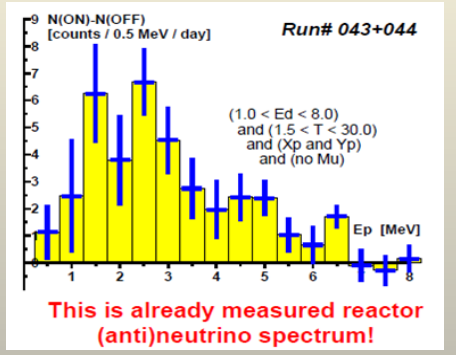
**Technological room just under reactor**
**13.9 m only!**
$2.7\times10^{13}$ ν/cm²/s

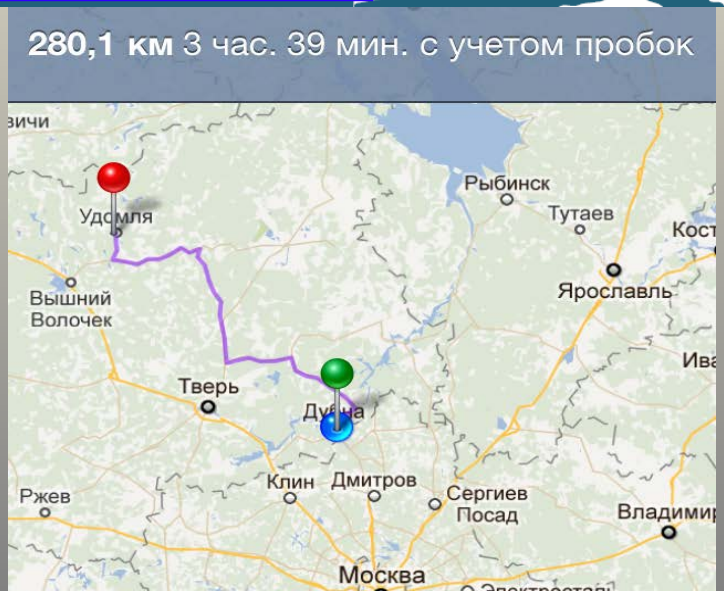


Power: 3 $GW_{th}$
ON: 315 days/yr
OFF: 50 days/yr

$2.7\times10^{13}$ ν/cm²/s



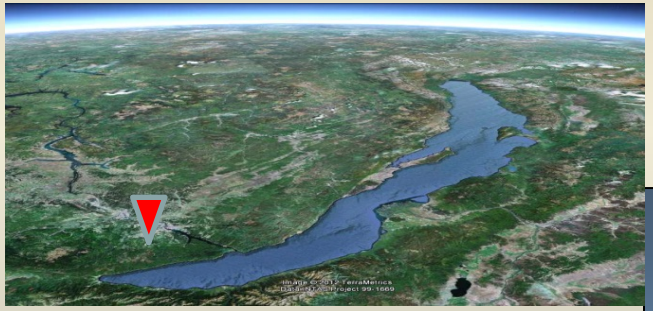



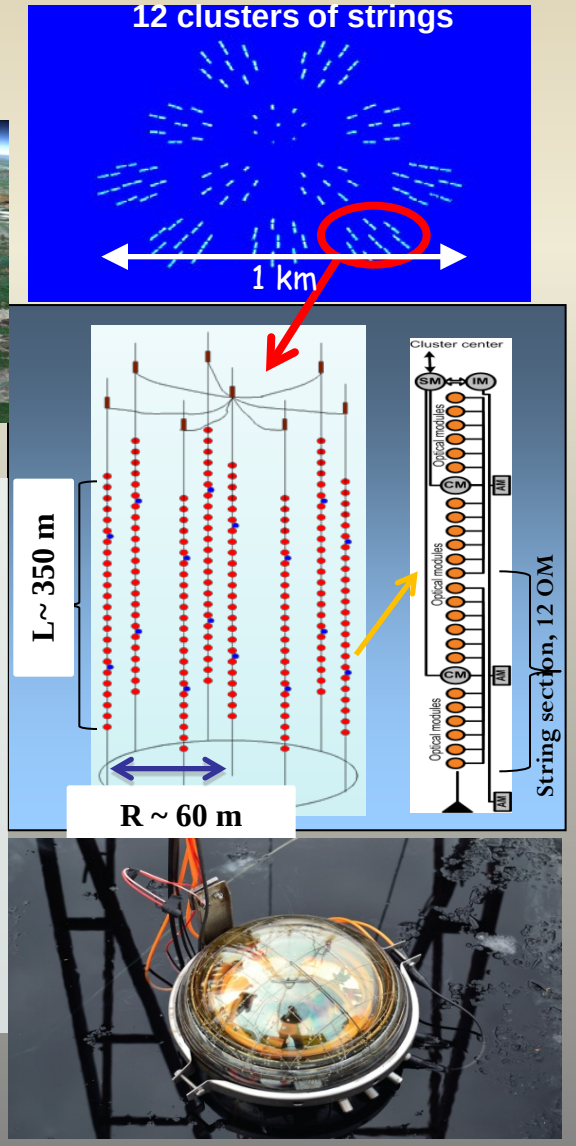




## Fundamental and Applied Research:

- ✓ Search for Neutrino Magnetic Moment
- ✓ Measurement of Neutrino Fluxes and Spectra
- ✓ Search for Sterile Neutrino States

# Baikal project: Gigaton Volume Detector (GVD)






**Configuration:** 96 Strings × 24 OM
Instr. Volume 0.3 km$^3$

**Expected parameters:**

Effective cascade volume

Cascade energy >100TeV
$V_{eff}$ = 0.1– 0.7km$^3$,
$\delta(lgE) \sim 0.1$, $\Delta\theta_{med} \sim 5^o$-$7^o$

Effective muon area

Muon energy >*3 TeV*
$S_{eff}$ ~ 0.1– 0.8 km$^2$,
$\delta(lgE) \sim 0.4$, $\Delta\theta_{med} \sim 0.5^o$

## Central Physics Goals:

- Investigate Galactic and extragalactic neutrino "point sources" in energy range > 3 TeV
- Diffuse neutrino flux – energy spectrum, local and global anisotropy, flavor content
- Transient sources (GRB, …)
- Dark matter – indirect search
- Exotic particles – monopoles, Q-balls, nuclearites, …

## Conclusions:

- During 2006-2010 the key elements and systems of the GVD have been developed, produced and tested in Lake Baikal. Scientific-Technical Report (STR) has been prepared
- Prototyping & Construction Phase of Project is started in 2011 with deployment of the 3-string engineering array – prototype of the GVD Cluster in Lake Baikal
- Prototyping Phase of project will conclude in 2015 with deployment in Lake Baikal of the ANTARES-scale array , the first Cluster "DUBNA" of BAIKAL-GVD.

# External Activities in Particle Physics

**CERN, FNAL, BNL, DESY, GSI, IN2P3, INFN, RIKEN…**

**In collaboration with ~100 institutions from Member States**

**I. CERN (LHC):** LHC development – consolidation of SC magnets;
CMS, ALICE and ATLAS – data taking & analysis & ***upgrade***;

**II. CERN (SPS):**
COMPASS – finished 1st phase. Detector modification to measure GPD (DVCS) and polarized/unpolarized D-Y;
NA61 – neutrino and heavy-ion programs;
NA62 – measurement of extremely rare decays **($K^+ \to \pi^+ \nu\nu$)** ;
DIRAC – lifetime measurement of $\pi\pi$ and $\pi K$ atoms completed at PS; collaboration formed to continue at SPS (20-40 gain in stat.)

**III. BNL (RHIC):**
STAR - energy scan HI program and physics with polarized beams (important experience for future research at NICA)

**IV. Fermilab:**
CDF, D0 – data analysis: the most precise masses of W and t-quark
Mu2e **($\mu \to e$),** ORKA **($K^+ \to \pi^+ \nu\nu$)** – in discussion

**V. GSI, FAIR (SIS-18/100/300):**
HADES – data analysis, CBM, PANDA – in preparation

**VI. J-PARC & KEK:** COMET ($\mu \to e$) – in discussion

**VII. BEPCII:** BESIII – new narrow mesons around 4 GeV with hidden charm

**VIII. $\nu$-oscillations:** OPERA (direct $\nu_\mu \to \nu_\tau$) - data analysis
BOREXINO (Solar $\nu$) – confirmed MSW theory of oscill. in matter
Daya Bay (Reactor $\nu$) – measured nonzero $\theta_{13} \Rightarrow$ open a way to solve $\nu$ mass hierarchy in long base projects Daya Bay II (JUNO), NOVA …

# Cooperation with CERN

**The history of cooperation between CERN and JINR spans over 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 & LHC itself**

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;

# CP Session (March 2014)

## DECISIONS

The CP has supported the initiative of the SC to approach the CERN Council with a suggestion for a reciprocal arrangement to establish observership of JINR at CERN and of CERN at JINR.

CERN Council (Sept. 2014):

approved the observership of JINR at CERN and of CERN at JINR.

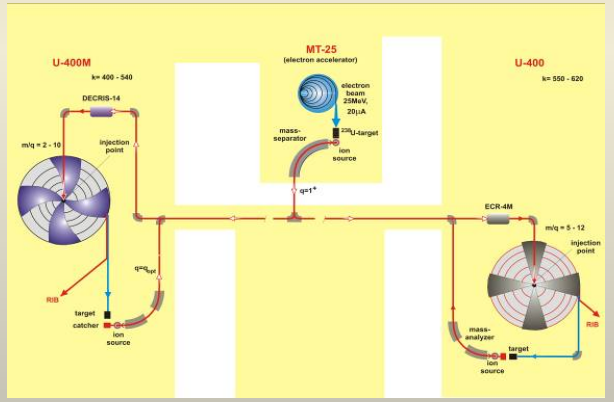
This will further promote and intensify the cooperation between CERN & JINR.

# Nuclear Physics and Low Energy Heavy Ion Physics

# JINR isochronous cyclotrons

**For the last decade JINR has become one of the world's leading scientific centres in low-energy heavy-ion physics.**

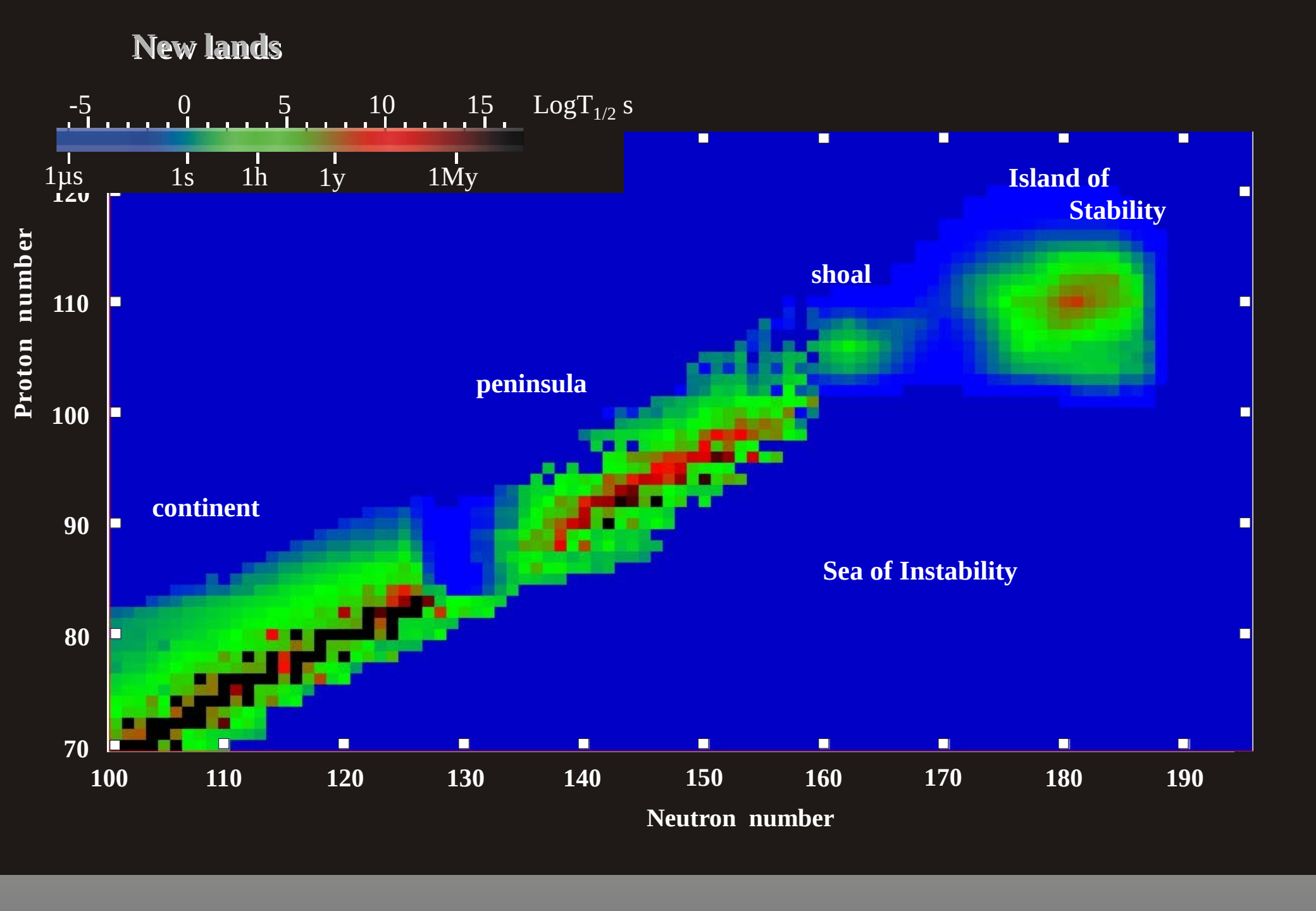
**U-400: energy factor K 305÷650**
**mass-to-charge ratio range 5÷12**



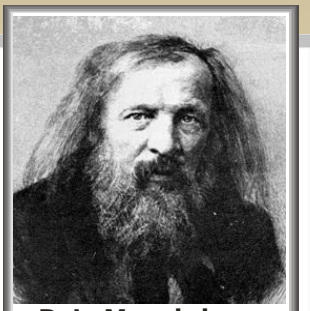

**DRIBs (I,II,III) –**
**Dubna Radioactive Ion Beams**

**U-400M: accelerated ion mass 4÷238**
**energy 20÷120 MeV/n; mass-to-charge ratio 2÷5**

**U400 and U400M isochronous cyclotrons are combined into accelerator complex – the project DRIBs – which deals with production of beams of exotic light neutron-deficient and neutron-rich nuclei in reactions with light ions.**


New lands
-5
0
5
10
15
LogT1/2 s
1μs
1s
1h
1y
1My
Island of
Stability
shoal
peninsula
continent
Sea of Instability
Proton number
Neutron number
70
80
90
100
110
120
100
110
120
130
140
150
160
170
180
190

# Achievements in the last decade:
# 6 new elements, 49 new isotopes



D.I. Mendeleev
1834 - 1907

s-элементы
p-элементы
d-элементы
f-элементы

| 113 | 114 | 115 | 116 | 117 | 118 |
|---|---|---|---|---|---|
| Discovered at JINR in 2003 | Discovered at JINR in 1999 | Discovered at JINR in 2003 | Discovered at JINR in 2000 | Discovered at JINR in 2009 | Discovered at JINR in 2001 |

# Dubnium and Flerovium

As recognition of the outstanding contribution of JINR scientists to the research in the modern physics and chemistry, the International Union of Pure and Applied Chemistry named element 105 of the D.Mendeleev Periodic system of chemical elements "***Dubnium***".

Recently IUPAC has officially approved the name ***Flerovium***, with symbol Fl, for the element of atomic number 114 and the name ***Livermorium***, with symbol Lv, for the element of atomic number 116. Priority for the discovery of these elements was assigned to the collaboration between the JINR (Dubna, Russia) and the Lawrence Livermore National Laboratory (Livermore, California, USA).

| | | |
|---|---|---|
| 104 Резерфордий<br>**Rf**<br>[261]<br>Rutherfordium | 105 Дубний<br>**Db**<br>[262]<br>Dubnium | 106 Сиборгий<br>**Sg**<br>[266]<br>Seaborgium |
| 114 Флеровий<br>**Fl**<br>[287]<br>Flerovium | 115 | 116 Ливерморий<br>**Lv**<br>[291]<br>Livermorium |

# PROSPECTS

## Road map

## Superheavy elements (SHE)

- Nuclear structure and properties of SHE
- Chemical properties of SHE
- Electron structure of SH atoms
- Search for new nuclear shells
- Search for SHE in nature.

## Project «DRIBs-III»

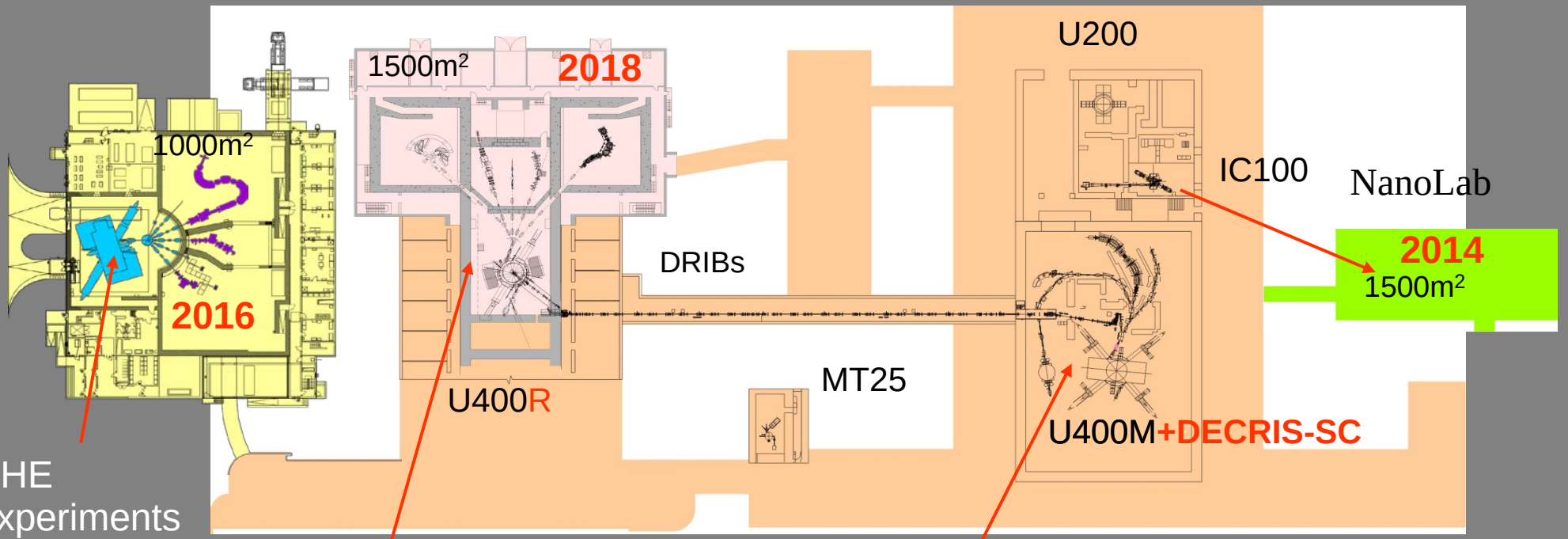
## experimental base

- Upgrade of the running accelerators U400 and U400M
- Construction of the new experimental hall (≈ 2600 м$^2$)
- Development and construction of the next-generation set-ups
- Development of high current heavy ion accelerator.

# FLNR – 2016(18)

SHE factory

U400R Accelerator Complex




SHE experiments

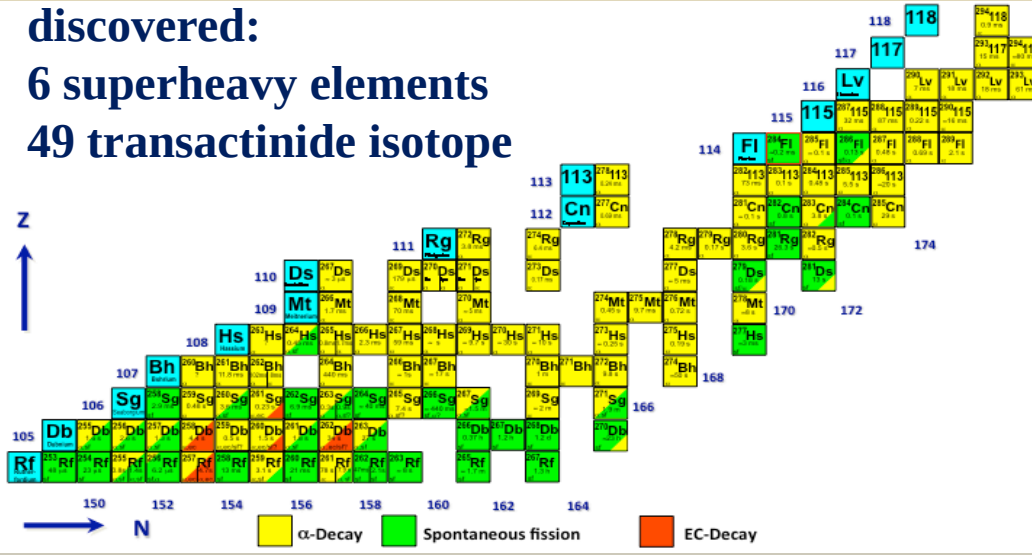
Nuclear Physics

Exotic Nuclei
E = 30 ÷ 60 MeV/n
A < 60

# Superheavy Element Research

## DC280-cyclotron – SHE-factory

**discovered:**
**6 superheavy elements**
**49 transactinide isotope**

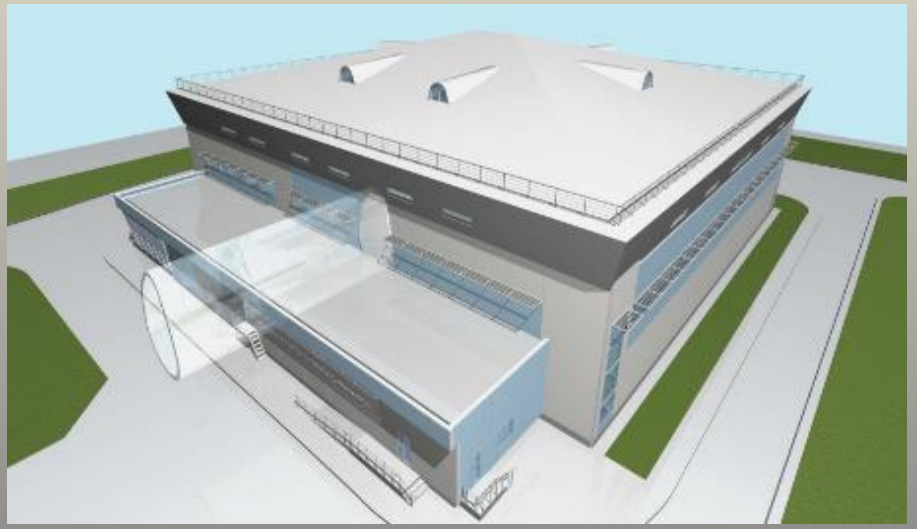



- **- Synthesis and study of properties of superheavy elements.**
- **- Search for new reactions for SHE-synthesis.**
- **- Chemistry of new elements.**

# Schedule of the SHE factory creation

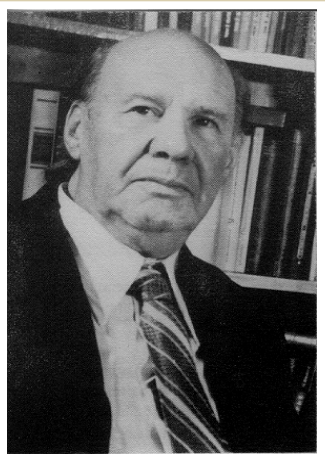
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Experimental Building | | | | | | |
| Cyclotron DC 280 | | | | | | |
| Main magnet yoke creation | | | | | | |
| Equipment creation, completion. | | | | | | |
| Assembling, testing | | | | | | |
| First experiment | | | | | | |

**on-line: http://inflnr.jinr.ru/dc280.html**



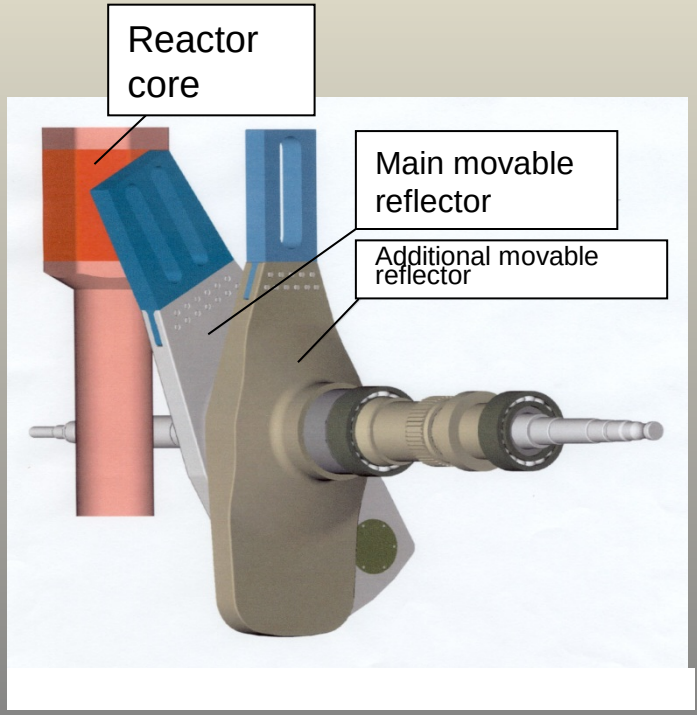
# Condensed Matter Physics

# The IBR reactor idea: D. Blokhintsev (1955).



D. Blokhintsev

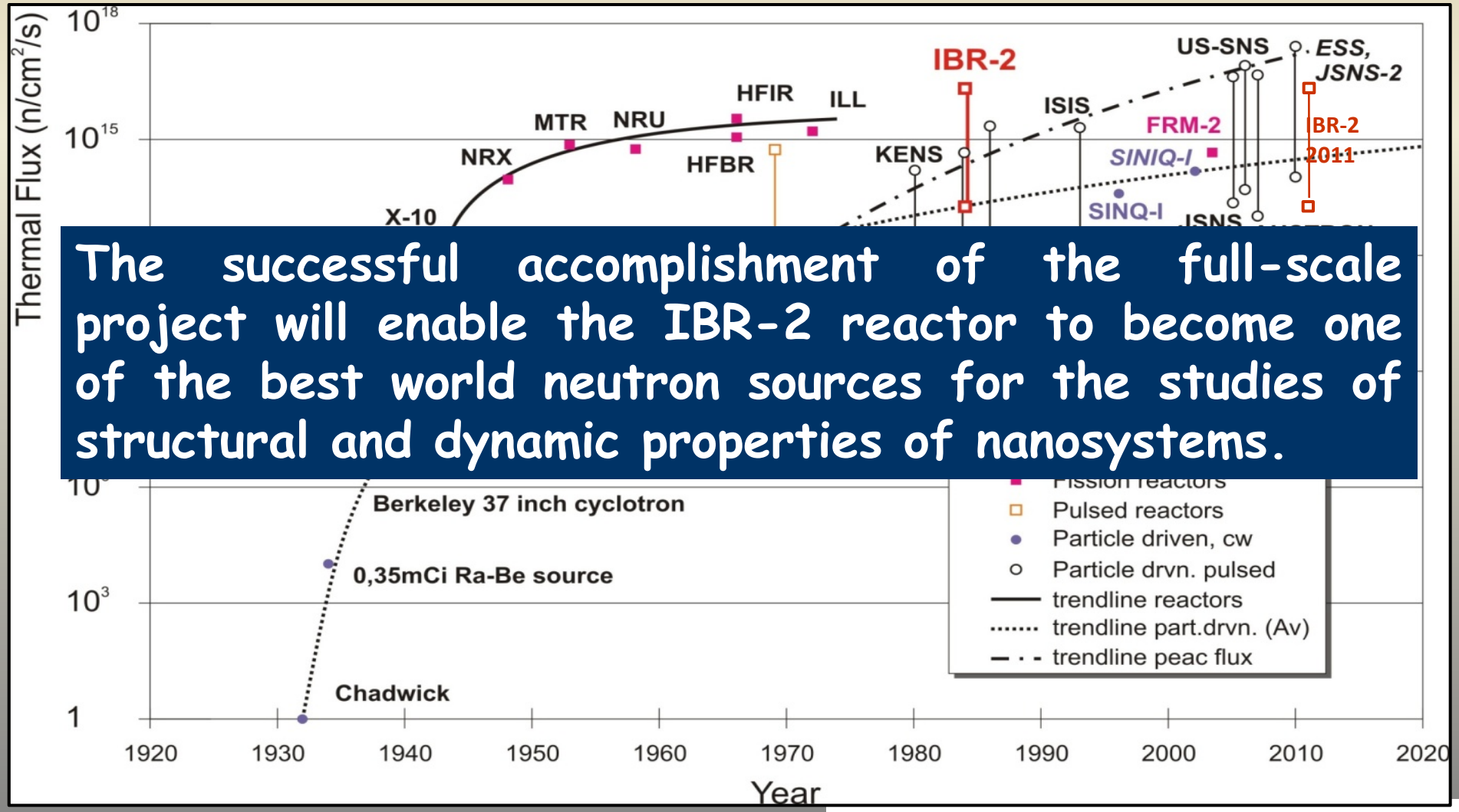
| | |
|---|---|
| Fuel | $PuO_2$ |
| Active core volume | 22 $dm^3$ |
| Cooling | liquid Na |
| Average power | 2 MW |
| Pulsed power | 1500 MW |
| Repetition rate | 5 $s^{-1}$ |
| Average flux | $8 \cdot 10^{12}$ $n/cm^2/s$ |
| Pulsed flux | $5 \cdot 10^{15}$ $n/cm^2/s$ |
| Pulse width | |
| (fast /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




**Fundamental and applied research in condensed matter physics and related fields –– biology, medicine, material sciences, geophysics, engineer diagnostics — aimed at probing the structure and properties of nanosystems, new materials, and biological objects, and at developing new electronic, bio- and information nanotechnologies.**

# The physical start-up of the modernized IBR-2 reactor began on 17 December 2010 in accordance with schedule

## Competitiveness

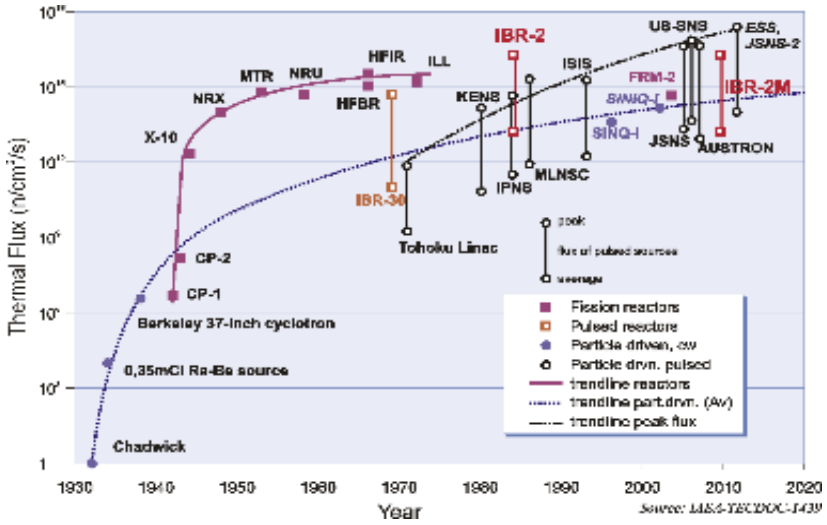



The successful accomplishment of the full-scale project will enable the IBR-2 reactor to become one of the best world neutron sources for the studies of structural and dynamic properties of nanosystems.

Source: IAEA-TECDOC-1439, February 2005

# Neutrons: indispensable tool in investigation of condensed matter!

## We have one of the best source in the world for thermal neutrons !




# Frank LNP

Creation and testing of the stand for the 2nd cold moderator

2010

2011

2012

2013

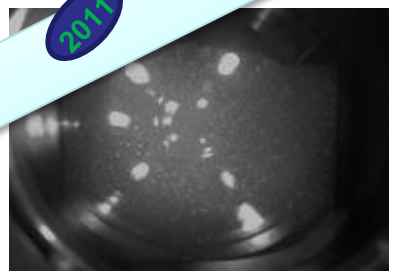
2014

2015

2016

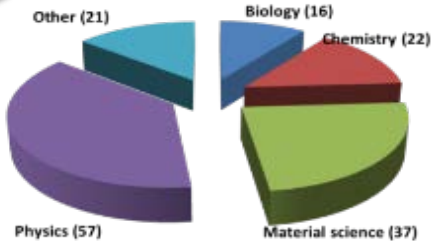
The modernized IBR-2 reactor physical start up was commenced according to the plan

- The user program restarts
- Physical start up of the 1st cold moderator: **first cold neutrons** for users!



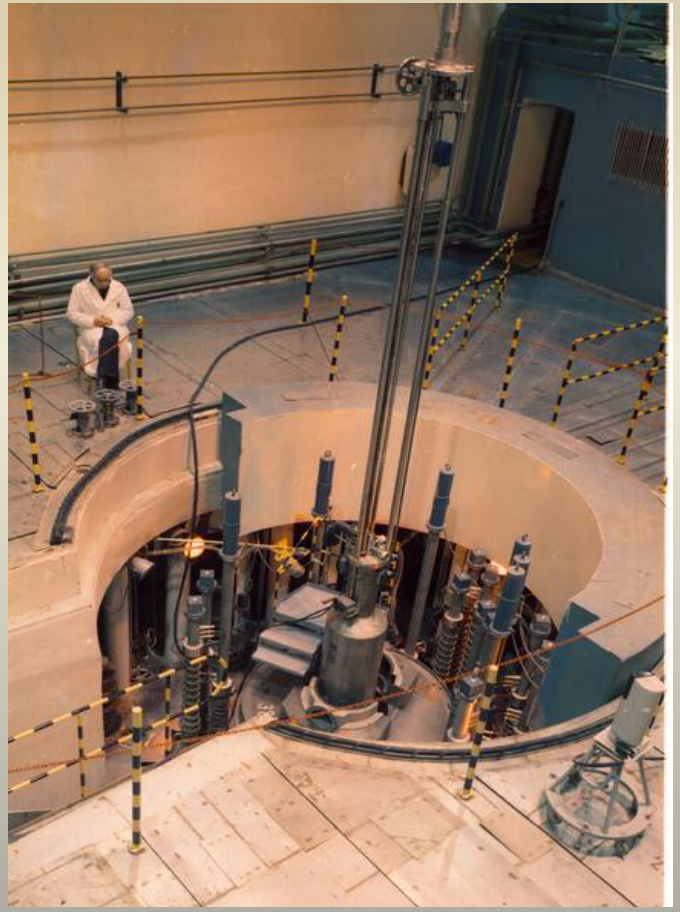
- Starting of the work for physical experiments
- Testing of the stand for the 1st cold moderator

Commissioning of **two new** spectrometers: DN-6 and GRAINS



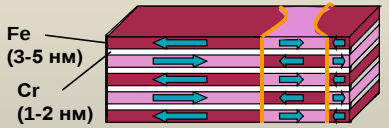

Development of three new spectrometers NRT, FSS and RTD

Technical design and manufacturing of the 2nd cold moderator

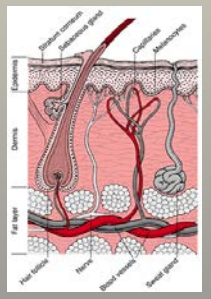


**IBR-2 is included in the 20-year European strategic research program in the field of neutron scattering**

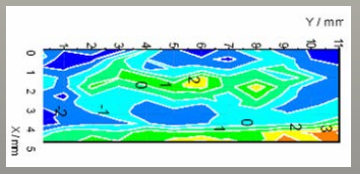
## Nanosystems and Nanotechnology




## Biomedical research



## New materials



## Diagnostics. Earth science.

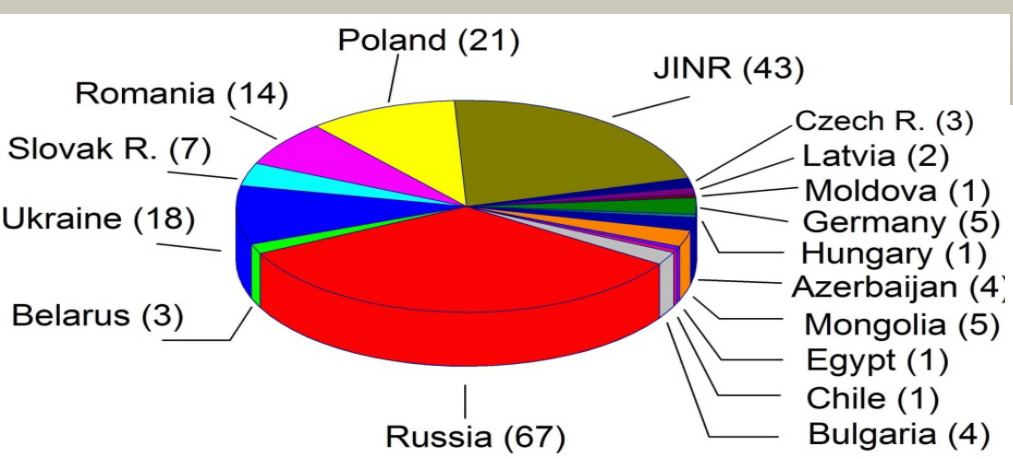
**IBR-2M**

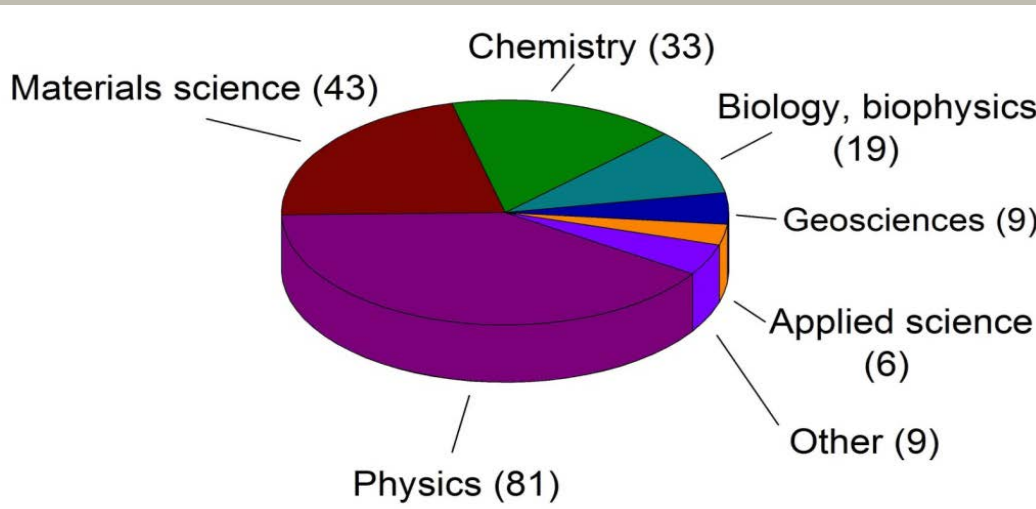
- Physics of high-temperature superconductivity
- Geological texture research
- Nanotechnology

# IBR-2 in 2013

**2578 hours for physical experiments, 12 cycles:**
**7 – water moderator, 5 – cryogenic moderator**

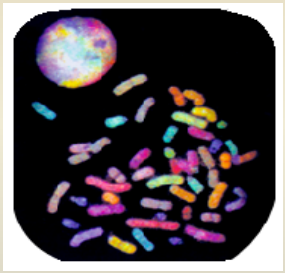
- **195 proposals received for realization in 2013 during two calls (20% increase compared to 2012)**
- **70% accepted for realization according to recommendations of Expert Committees**
- **118 visits in the FLNP**



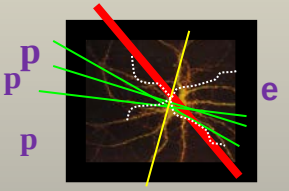



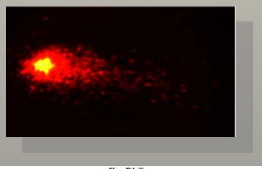
# Radiation Biology at JINR

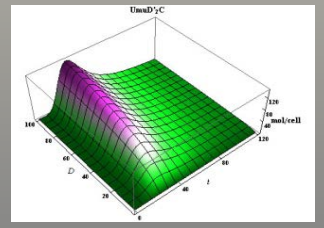
Based on experiments at JINR's accelerators, the LRB resolved one of the central issues of radiobiology: the problem of the **genetic effectiveness of ionizing radiations**.



## Outlook for research





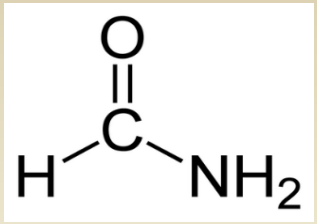
- study of the regularities and mechanisms of the effect of heavy charged particles on ***eye structures:*** the lens and retina;

- evaluation of the risk of the damaging effect of ionizing radiations with different physical characteristics on ***the nervous system and higher nervous activity*** (regularities of nervous cell death; impairments of the intercellular signal transmission; and disorders in mental functions: learning, memory, behavior, and consciousness);

- research on the mechanisms of the ***genetic effect*** of radiations with different physical characteristics (formation and repair of different DNA lesions; programmed cell death mechanisms; and genetic instability);

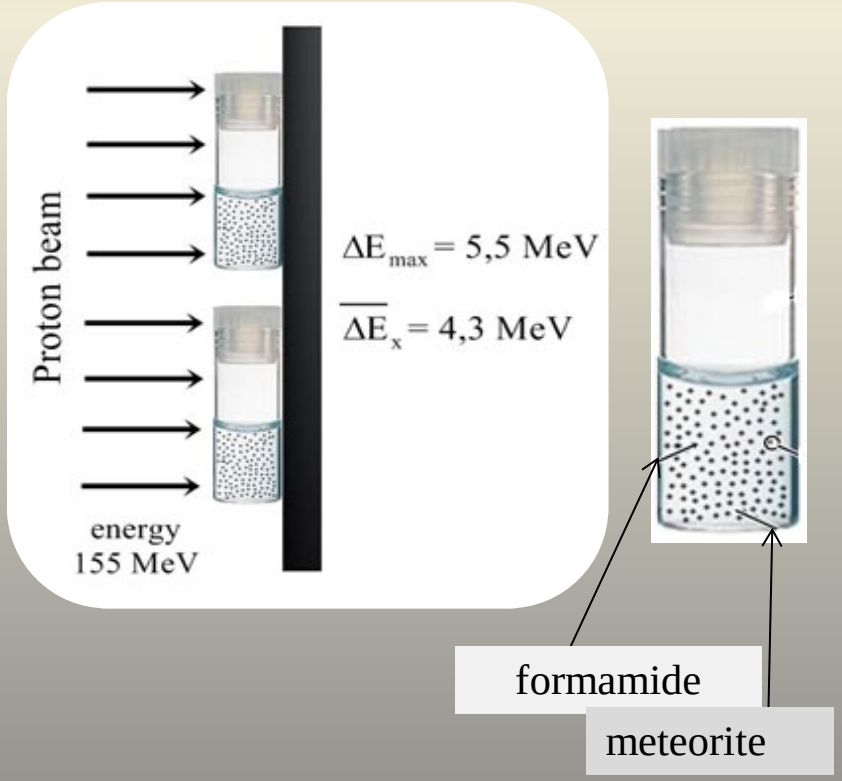
- ***mathematical modeling*** of biophysical systems.

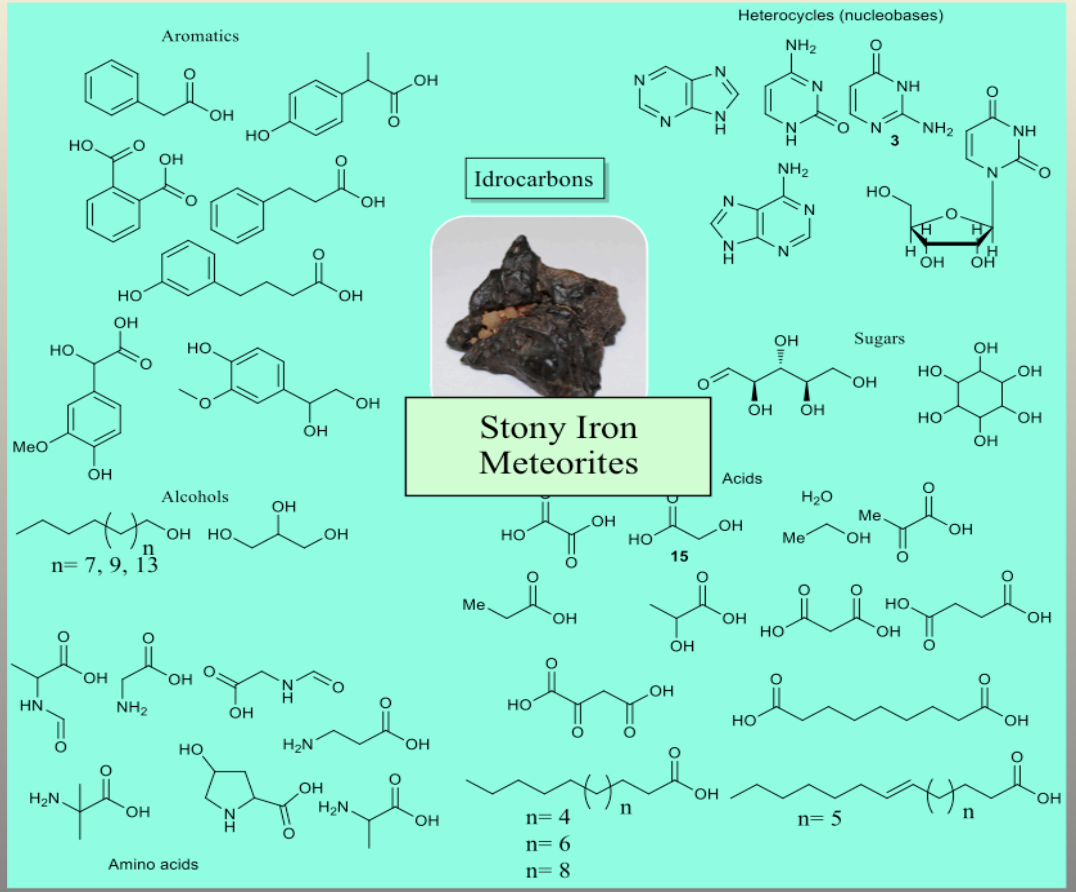
# Astrobiology – origin of life ?




formamide

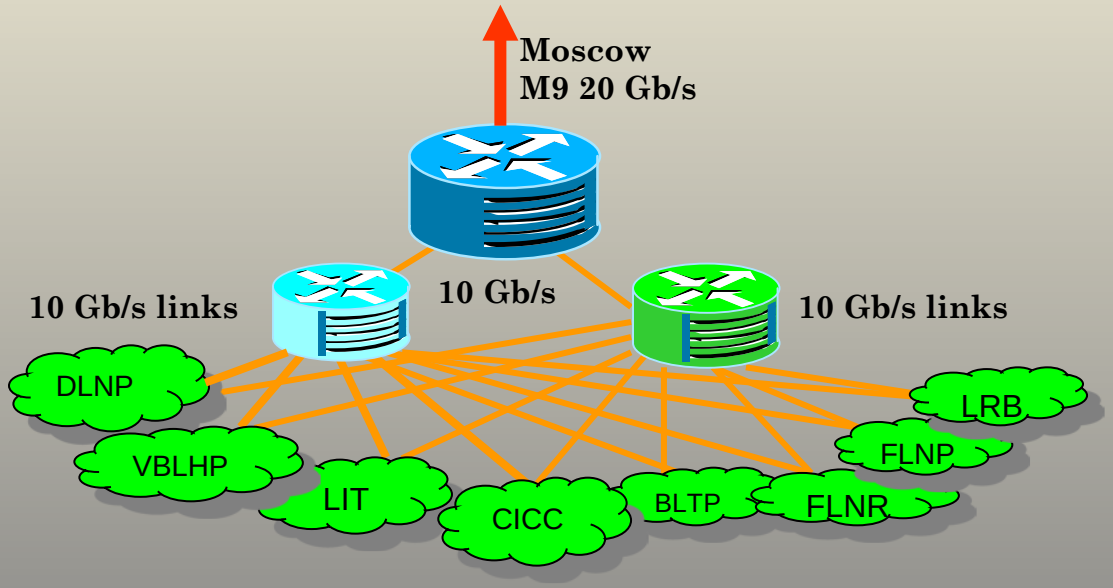
Prebiotic macromolecules up to nucleosides –
main fragments of information macromolecules –
are formed in the meteorites exposed to radiation

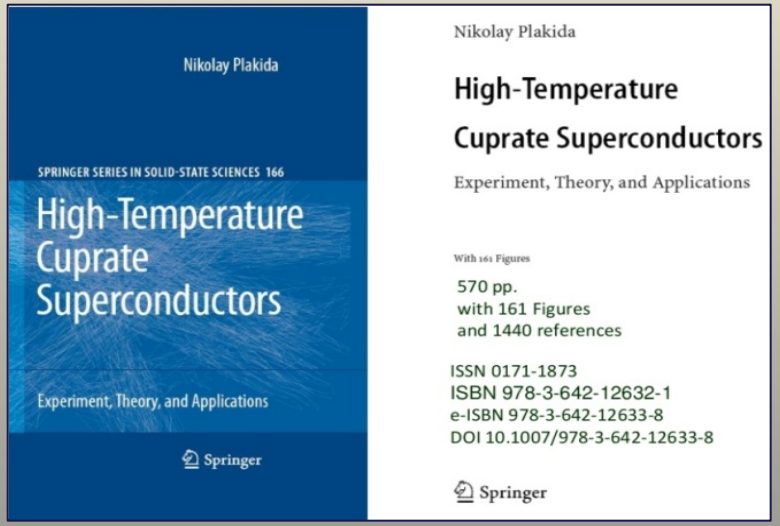


# THEORETICAL STUDIES
# and
# INFORMATION TECHNOLOGIES (including GRID)

**are of utmost importance for the successful activities of the Joint Institute and research centres of the Member States**



# JINR Central Information and Computing Complex

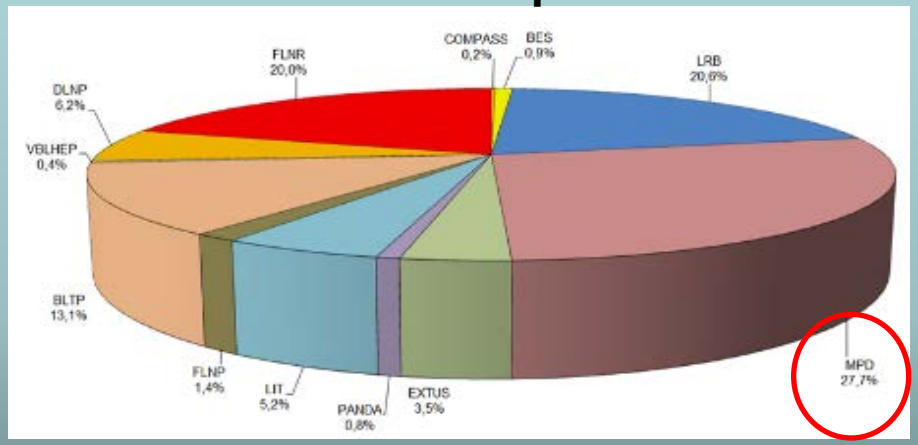
# JINR-LCG2 Tier2 Site

# JINR-CMS Tier1 Site

**~ 4 million Jobs (using ~166 million normalized CPU time) were executed during the first eight months of 2014**

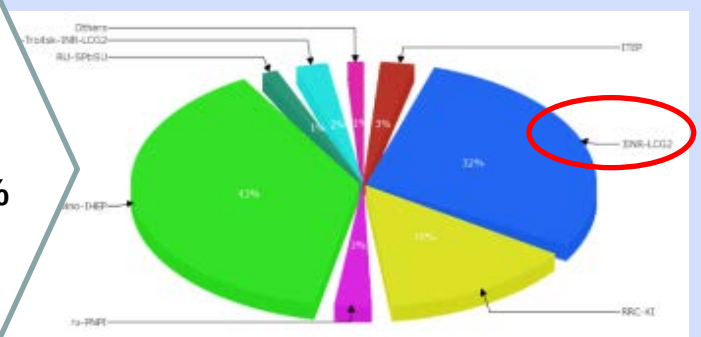
## Local users (no grid)

**Normalized CPU time share: JINR Laboratories and experiments in 2014.**

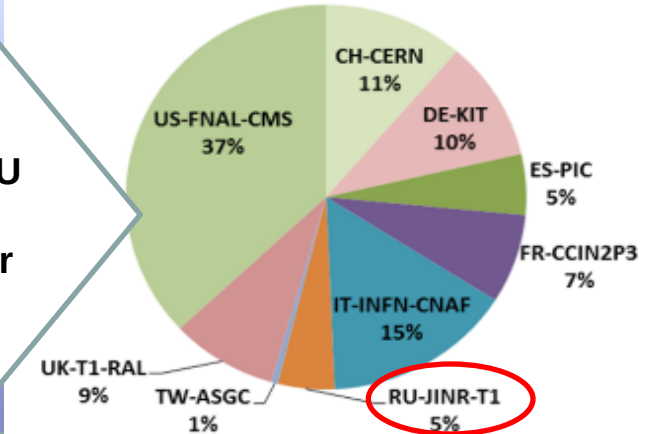



## Grid users

**JINR-Tier2 Normalized CPU time share was 32% of RDIG in 2014**




**JINR-Tier1 Normalized CPU time share was 5% in WLCG for CMS in 2014**

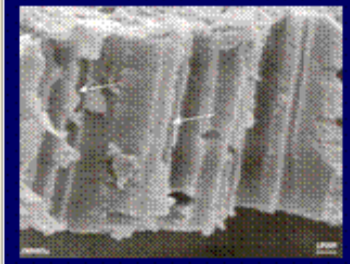


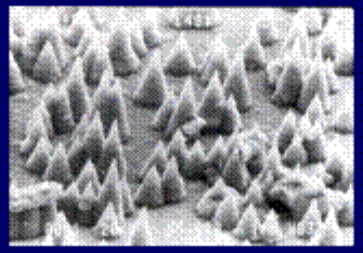

micro
Track
Applied Research
membranes
nano
20 nm
IC-100

# The Special Economic Zone in Dubna, Moscow region

# SEZ main specialization

## Nanotechnologies

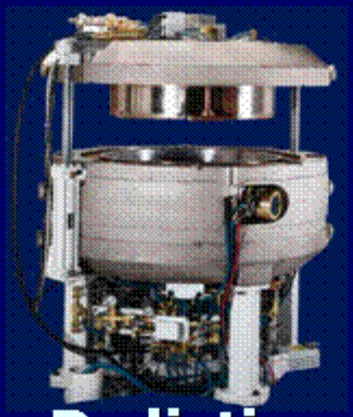


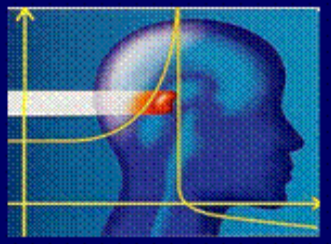


COPPER MICROTUBES

METALLIC NEEDLES

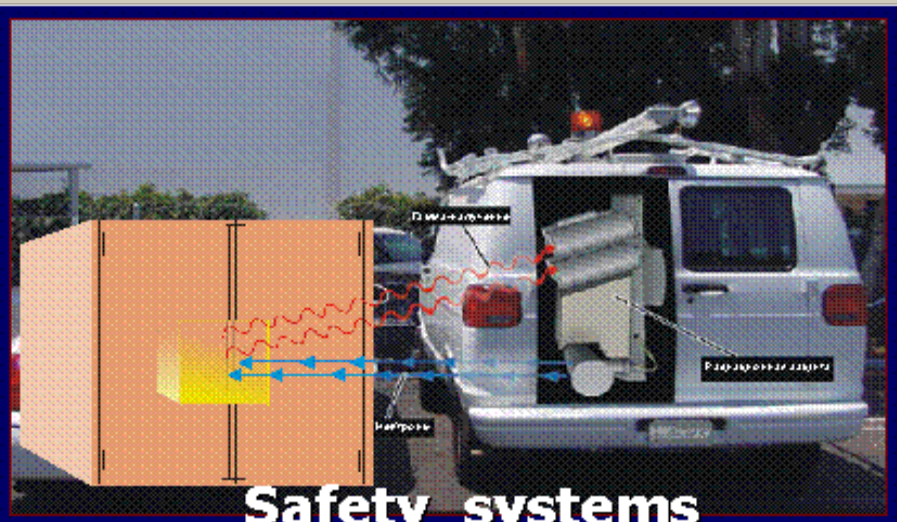
## Radiation medicine



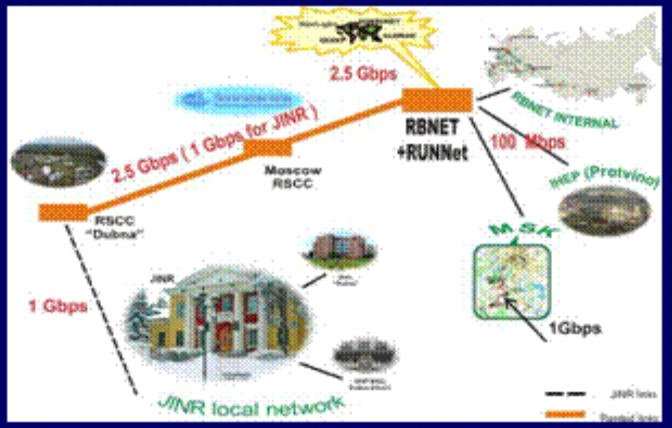


Hadron therapy

## Safety systems



## IT and Telecommunication



# Spin-off: Cyclotron DC-110 constructed in FLNR for the Scientific industrial complex “BETA” in the Special economic zone was commissioned

**Mass-production of track membranes for medical purposes (≤ 30 мкм)**

**Ion spices: Ar, Kr, Xe**

**Beam energy 2.5 MeV/u**

**Beam current 1 pμA ($6x10^{12}$ $s^{-1}$)**

**2 channels for irradiation are available**

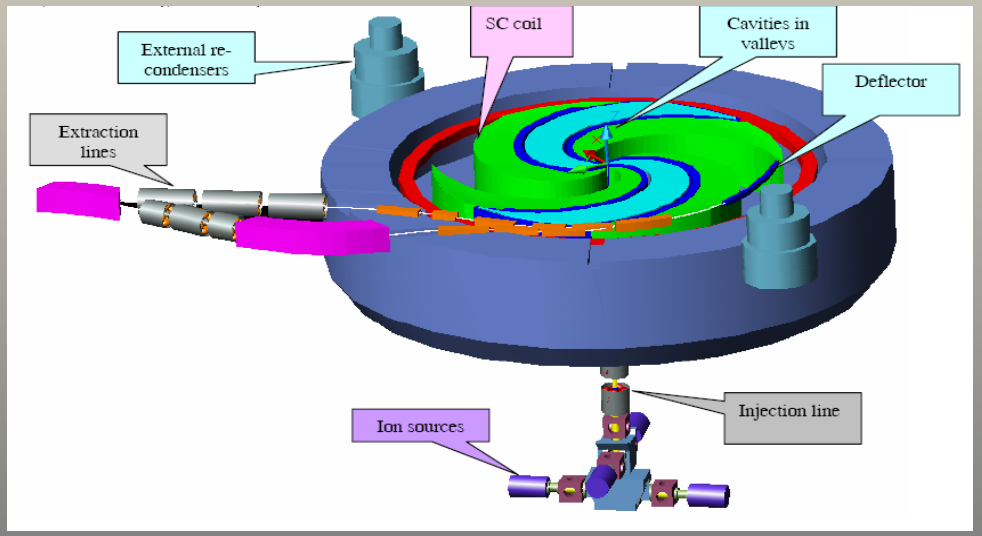
**Operation hours: 7000 h/year**


# Applied Research: proton therapy and medical accelerators development

## Proton Therapy at DLNP Phasotron

- Unique in Russia experience of application of conformal 3D therapy method
- About 100 patients per year since 2000
- Development of the project of PT Center

## C400 SC Cyclotron Project for p & C Therapy (together with IBA, AFK “Sistema”, …)




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

## *EDUCATIONAL PROGRAMME*

## JINR UNIVERSITY CENTRE

More than 300 students and post-graduates 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

BLTP

**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

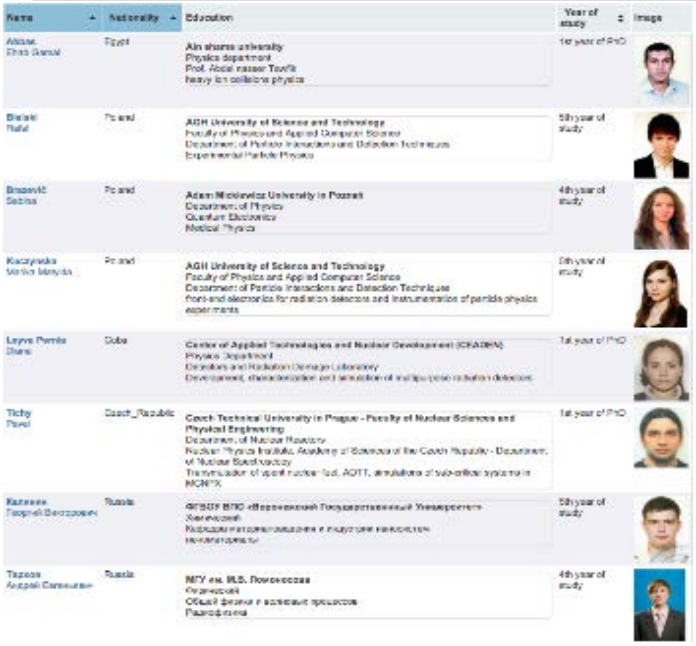
education

# JINR UC Educational Program in 2014

By the beginning of 2014/2015 academic year 226 graduate students have taken part in various JINR educational programs. The JINR PhD program is currently being updated according to a new "Law on Education in RF" and according to the goals of the JINR seven-year plan.

## International Student Practice (ISP)

In total 139 students from 9 JINR Member States have participated in three stages of ISP-2014 (129 last year): ARE-24, Belarus-8, Bulgaria-2, Czech Republic-23, Poland-22, Romania-13, Slovakia-9, South Africa-32, Serbia-5



| Name | Nationality | Education | Year of study | Image |
|---|---|---|---|---|
| Abdel... | Egypt | Ain shams university<br>Physics department<br>Prof. Abdel nasser Tawfik<br>heavy ion collisions physics | 1st year of PhD | |
| Bielski | Poland | AGH University of Science and Technology<br>Faculty of Physics and Applied Computer Science<br>Department of Particle Interactions and Detection Technique<br>Experimental Particle Physics | 5th year of study | |
| Brasović | Poland | Adam Mickiewicz University in Poznań<br>Department of Physics<br>Quantum Electronics<br>Medical Physics | 4th year of study | |
| Kaczyńska | Poland | AGH University of Science and Technology<br>Faculty of Physics and Applied Computer Science<br>Department of Particle Interactions and Detection Technique<br>Front-end electronics for radiation detectors and instrumentation of particle physics experiments | 5th year of study | |
| Leyva Pernia | Cuba | Center of Applied Technologies and Nuclear Development (CEADEN)<br>Physics Department<br>Detectors and Radiation Damage Laboratory<br>Development, characterization and simulation of multipurpose radiation detectors | 1st year of PhD | |
| Tichy | Czech_Republic | Czech Technical University in Prague - Faculty of Nuclear Sciences and Physical Engineering<br>Department of Nuclear Reactors<br>Nuclear Physics Institute, Academy of Sciences of the Czech Republic - Department of Nuclear Spectroscopy<br>Transmutation of spent nuclear fuel, ADTT, simulations of sub-critical systems in MCNPX | 1st year of PhD | |
| Kazarov | Russia | ФГБОУ ВПО «Воронежский Государственный Университет»<br>Химический<br>Кафедра математического анализа и дифференциальных уравнений | 5th year of study | |
| Tazaxa | Russia | МГУ им. М.В. Ломоносова<br>Физический<br>Общей физики и волновых процессов<br>Радиофизика | 4th year of study | |

## JINR Summer Student Program (SSP)

**http://students.jinr.ru**

In 2014 JINR UC has launched the Summer Student Program. The main distinction of SSP from ISP is a selection of participants on a competitive basis. In 2014 the SSP was organized in the field of accelerator physics and information technologies. 30 applications were received and 8 participants in SSP from ARE, Poland, Czech Republic and Russia were selected by VBLHEP and LIT. In 2015 SSP the scientific fields will be extended to include all JINR research areas.

# Scientific-engineering group at UC

The scientific-engineering group at the University Center was created to implement training programs for engineering physicists.

## JINR Outreach Activity in 2014


The programs for the teachers from JINR Member States at CERN and JINR started in November 2009. Up to now 5 programs at CERN (193 participants) and 5 programs at JINR (212 participants) have been held.

New department "Development of the modern education programmes" was created at JINR University Center. One of the goals is a creation of the educational programs to include current scientific data into the educational process, conduct virtual and online laboratory research based on information and communication technologies

# JINR cooperation with CR

**The Joint Institute for Nuclear Research maintains fruitful and mutually beneficial relations with many Czech scientific centres and universities.**

16 Czech Czech scientific institutions cooperate within
35 scientific themes covering all the scientific JINR activities:

5 themes in Theoretical Physics
16 themes in Elementary Particle and Relativistic Nuclear Physics
5 themes in Nuclear Physics
6 themes in Condensed matter Physics and Radiobiology
2 themes in Network, Computing and Computation Physics
1 theme in Educational Programme

# The most active Czech partners

- INP ASCR, Rez
- Charles University, Prague
- CTU, Prague
- INR, Rez
- IP ASCR, Prague
- Vacuum-Praha
- Institute of Biophysics ASCR, Brno
- TU, Brno
- LTU, Liberec
- Institute of Geology ASCR, Prague
- ….

**There are ~150 visits/year of JINR scientists to CR and about the same number of visits of Czech specialists to JINR.**

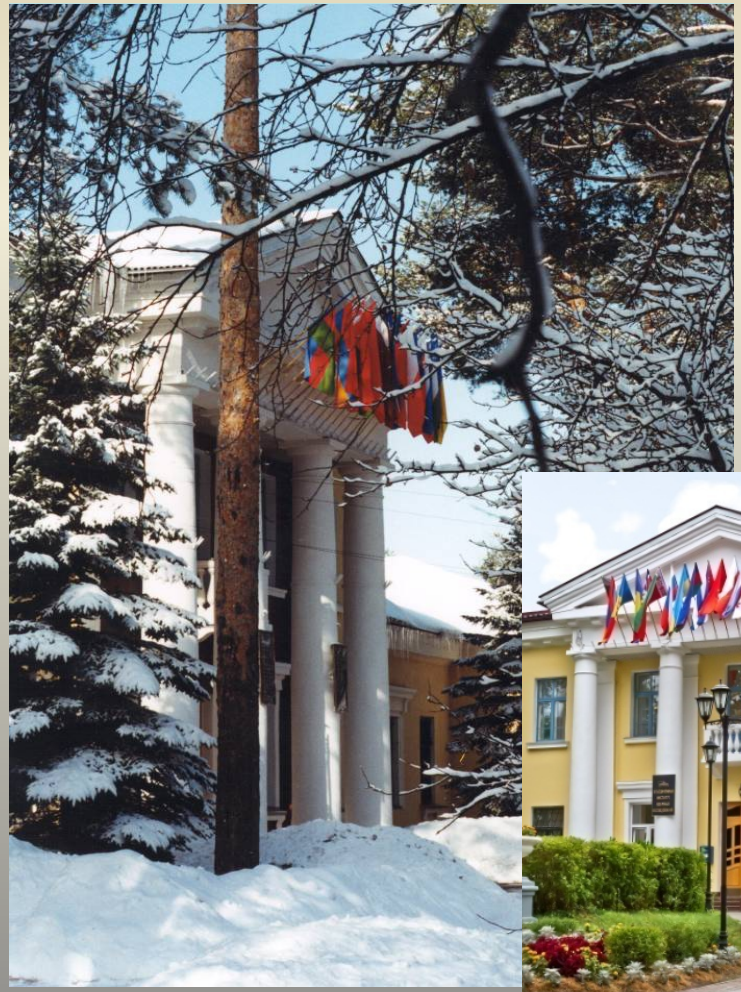
# Czech specialists at JINR
(presently 29 at long visits)

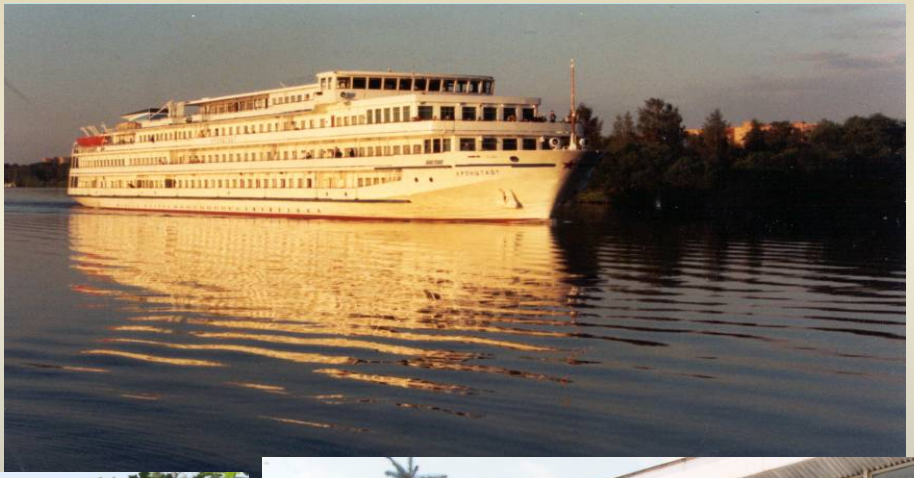
- can not only be involved in World Leading Projects
- but also can get high level Training and Education at

  - JINR UNIVERSITY CENTRE,
  - ”Dubna” International University,
  - Dubna International Advanced School on Theoretical Physics

# Welcome to JINR (Dubna)

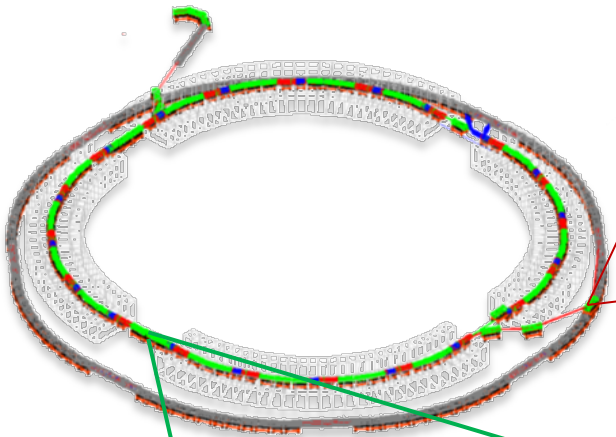
www.jinr.ru

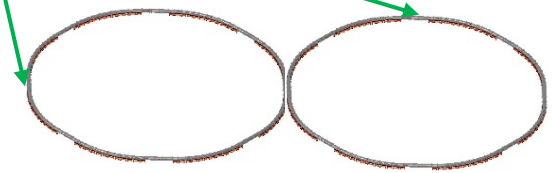


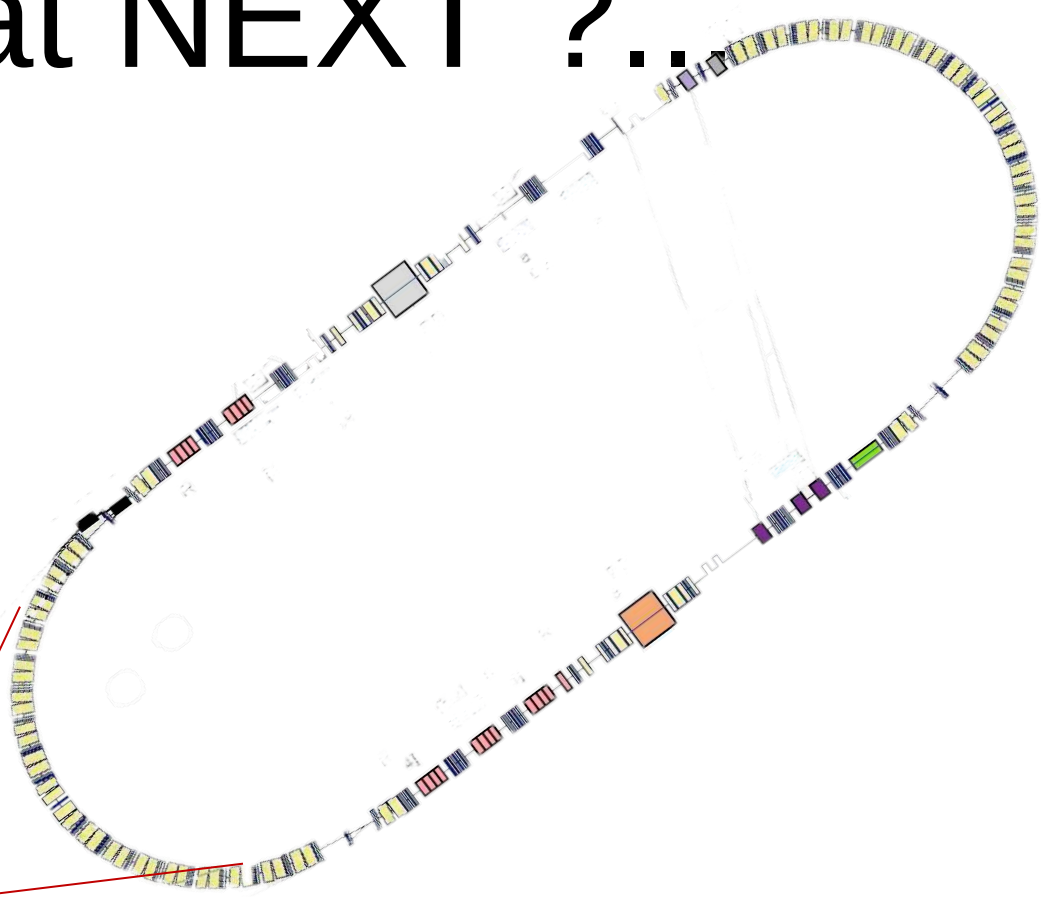


# …What NEXT ?...

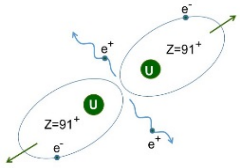
SIMULATION OF
THE SUPERHEAVY ATOM



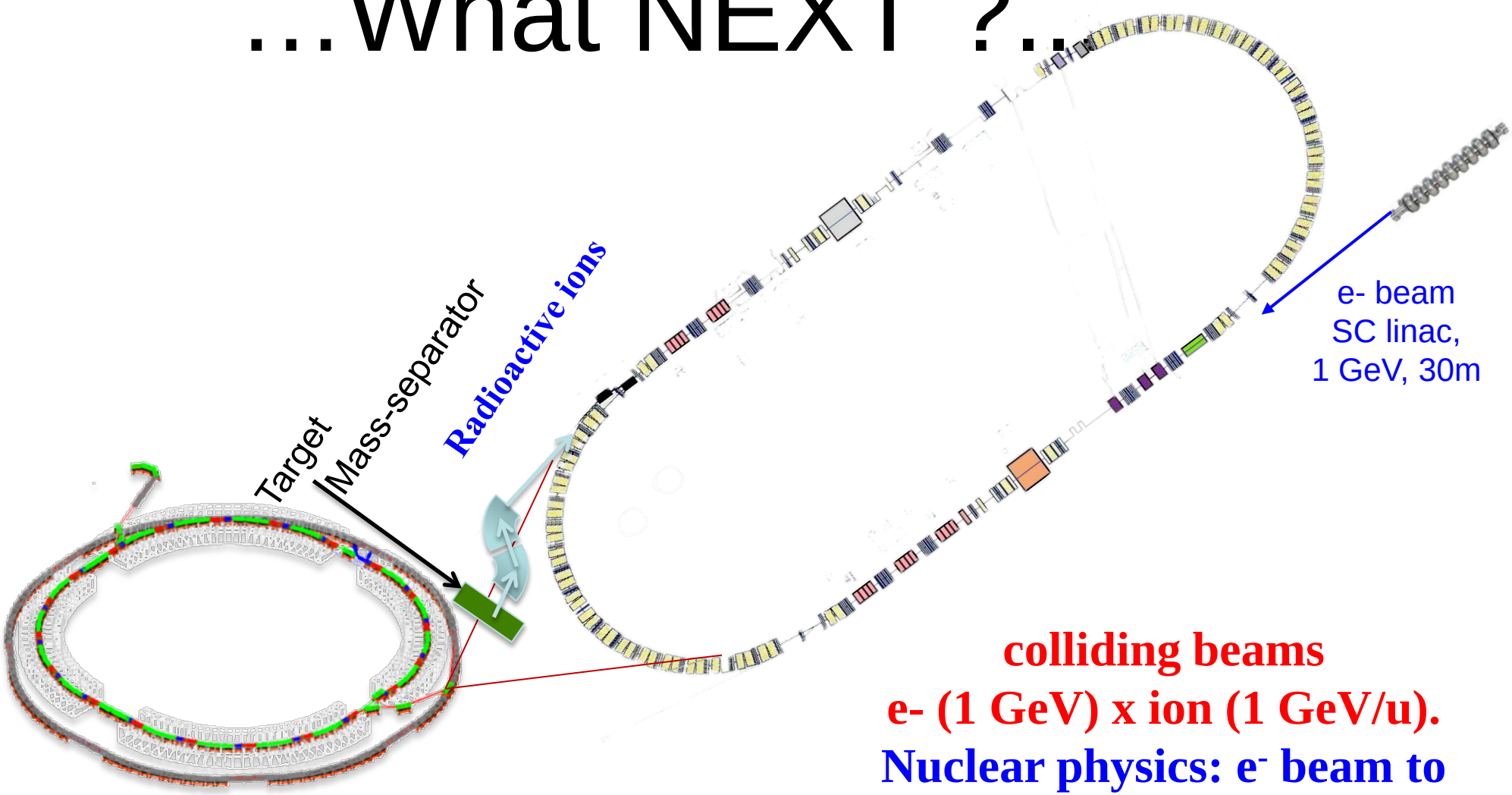




Merging $^{92+}U^{235}$ beams
E~ 0,6 GeV/u
~ 11 Tm ring



# …What NEXT ?...




**colliding beams**
**e- (1 GeV) x ion (1 GeV/u).**
**Nuclear physics: $e^-$ beam to scan for heavy nuclei PDF**

# …What NEXT ?...



**Goal: MW proton beam to the target**

| JINR (Web of Science) | CERN (Web of Science) |
|---|---|
| **2011-2013** | |
| Total number of publications: **2618**<br>Total number of citations: **20370**<br>h-index: **47**<br>budget (2012): **126** million USD | Total number of publications: **3127**<br>Total number of citations: **27093**<br>h-index: **55**<br>budget (2012): ≈ **1 206** million USD |
| **2013** | |
| Total number of publications: **852**<br>Total number of citations: **1291**<br>h-index: **13**<br>budget (2013): **143.2** million USD | Total number of publications: **1116**<br>Total number of citations: **2264**<br>h-index: **16**<br>budget (2013): ≈ **1 264** million USD |

# Session of the Government Commission on High Technology and Innovation in Dubna

*chaired by V. Putin on June 5, 2011*

Prior to the session, the Ministry of Education and Science of the Russian Federation, jointly with the interagency working group, selected 6 out of 28 submitted applications which meet the highest requirements imposed to specify the class of "mega-science" facilities.

***NICA is among the 6 selected mega-science international projects***

- Tokamak IGNITOR
- High-flux research reactor, PIK
- Synchrotron radiation source of IV generation, ISSI-4
- Complex of superconducting rings with colliding beams of heavy ions, NICA
- International research centre for extreme light fields based on sub-exawatt power laser complex
- Accelerator complex with electron-positron colliding beams

# NICA fixed target mode
# @ Nuclotron beams

| Beam | Intensities, particles per cycle | | | | |
|---|---|---|---|---|---|
| | *Energy* | *GSI (SIS18)* | *Nuclotron-M (2011)* | *Planned with Nuclotron-N (2015)* | *Planned with new ion source and booster (2016)* |
| p | 4,5 GeV | $2 \cdot 10^{10}$ | - | $5 \cdot 10^{11}$ | $5 \cdot 10^{12}$ |
| d | 2,2 GeV | $5 \cdot 10^{11}$ | $6 \cdot 10^{10}$ | $5 \cdot 10^{11}$ | $5 \cdot 10^{12}$ |
| $^{4}He$ | | | $2 \cdot 10^{9}$ | $3 \cdot 10^{10}$ | $1 \cdot 10^{12}$ |
| d↑ | | | $2 \cdot 10^{8}$ | $7 \cdot 10^{10}$ *(SPI)* | $7 \cdot 10^{10}$ *(SPI)* |
| $^{7}Li^{6+}$ | | | $7 \cdot 10^{9}$ | $3 \cdot 10^{10}$ | $5 \cdot 10^{11}$ |
| $^{12}C^{6+}$ | 300 MeV | $7 \cdot 10^{10}$ | $6 \cdot 10^{9}$ | $3 \cdot 10^{10}$ | $3 \cdot 10^{11}$ |
| $^{24}Mg^{12+}$ | 300 MeV | $5 \cdot 10^{10}$ | $7 \cdot 10^{8}$ | $4 \cdot 10^{9}$ | $5 \cdot 10^{10}$ |
| $^{40}Ar^{18+}$ | 300 MeV | $6 \cdot 10^{10}$ | $8 \cdot 10^{6}$ | $2 \cdot 10^{9}$ | $2 \cdot 10^{10}$ |
| $^{56}Fe^{28+}$ | | | $4 \cdot 10^{6}$ | $2 \cdot 10^{9}$ | $5 \cdot 10^{10}$ |
| $^{58}Ni^{26+}$ | 300 MeV | $8 \cdot 10^{9}$ | | | |
| $^{84}Kr^{34+}$ | 0,3 -1 GeV | $2 \cdot 10^{10}$ | $2 \cdot 10^{5}$ | $1 \cdot 10^{8}$ | $1 \cdot 10^{9}$ |
| $^{124}Xe^{48/42+}$ | 0,3 -1 GeV | $1 \cdot 10^{10}$ | $1 \cdot 10^{5}$ | $7 \cdot 10^{7}$ | $1 \cdot 10^{9}$ |
| $^{181}Ta^{61+}$ | 1 GeV | $2 \cdot 10^{9}$ | | | |
| $^{197}Au^{65/79+}$ | | $3 \cdot 10^{9}$ | | $1 \cdot 10^{8}$ | $1 \cdot 10^{9}$ |
| $^{238}U^{28+/73+}$ | 0,05-1 GeV | $6 \cdot 10^{9}/2 \cdot 10^{10}$ | | | |

# Experiments & activities at Nuclotron

- ALPOM-2
- DSS

- ✓ Cross-section measurements in elastic & inelastic scatterings of polarized & unpolarized beams on polarized & unpolarized targets, measurements of polarization analyzing power
- ✓ Study of 3-nucleon forces

- HyperNIS

- ✓ Study of properties of lightest hypernuclei and search for the effects of hidden strangeness

- PHASA-3

- ✓ Study of phase transitions in nuclear matter

- BM@N

- ✓ Study of baryonic matter with strangeness

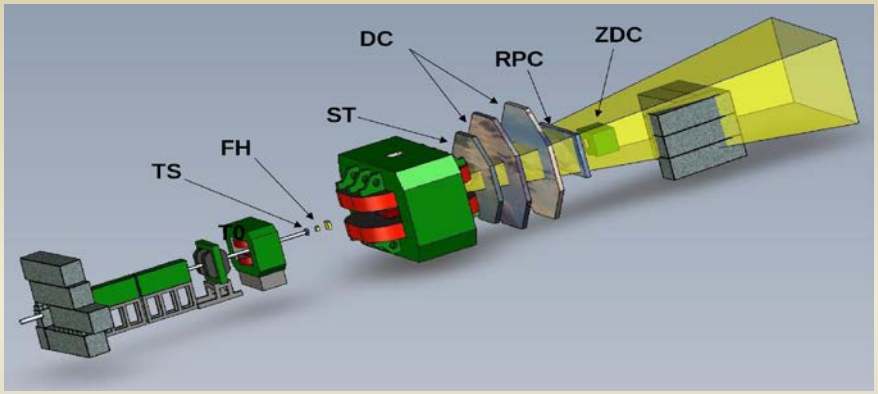
- Energy & transmutation
- Compact electron & ion accelerators
- ….

***BM@N (2016) :  Study of dense baryonic matter at < 6 GeV/n***

***Physics is complementary to the MPD (2019) program & will be up-to-date even after MPD start-up***

# BM@N project – 1st (fixed target) stage of the NICA

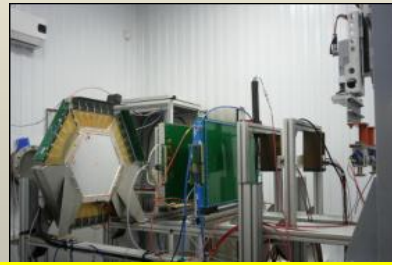
*(approved in 2012 JINR SC)*



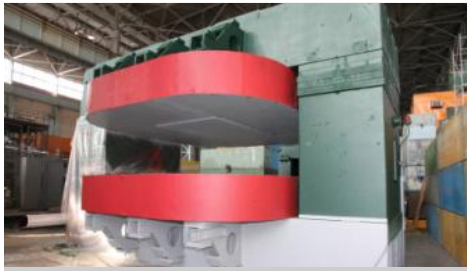

**19 scientific centers:** INR, SINP MSU, IHEP + 2 Universities (Russia); GSI, Frankfurt U., Gissen U. (Germany): CBM (FAIR) **+ …**

**Physics :**

- *in-medium effects for strangeness and vector mesons decaying in hadron modes*
- *hyperon production (BM EoS)*
- *hadron femtoscopy*
- ***pp** and **pA** reactions as Ref. for **AA** interactions*
- *electromagnetic probes (optional)*



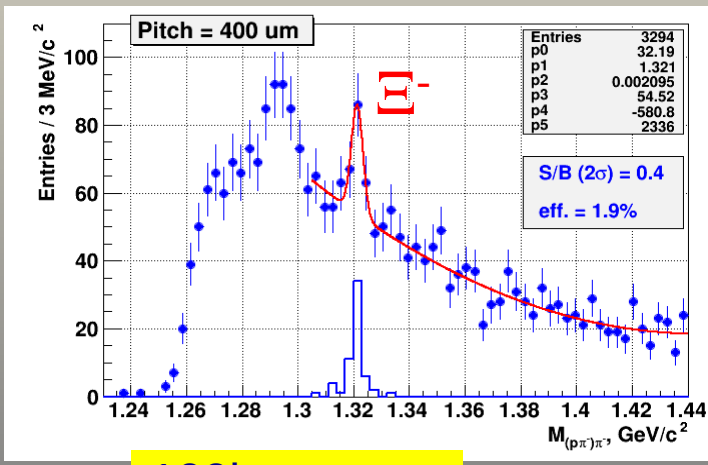
The GEM detector in the test beam at Nuclotron



modernized magnet SP-41

## Required setup:

- *central tracker to reconstruct AA interactions*
- *outer tracker to link central tracks to the ToF detector*
- *ToF system and T0 detectors (40 ps resolution achieved) to identify hadrons and light nucleus*
- *ZDC to measure collision centrality and to trigger*
- *ECAL to identify γ,e*




100k events

# NICA collider mode

*MPD (2019) & SPD (>2019)*

# The MultiPurpose Detector (MPD) project

*- approved in 2010*

**The goal:**

***Search for the mixed phase and phase transition of strongly interacting matter in processes:***

*AA, pA and pp interactions*

*using variety of nuclei A (from p to Au)*

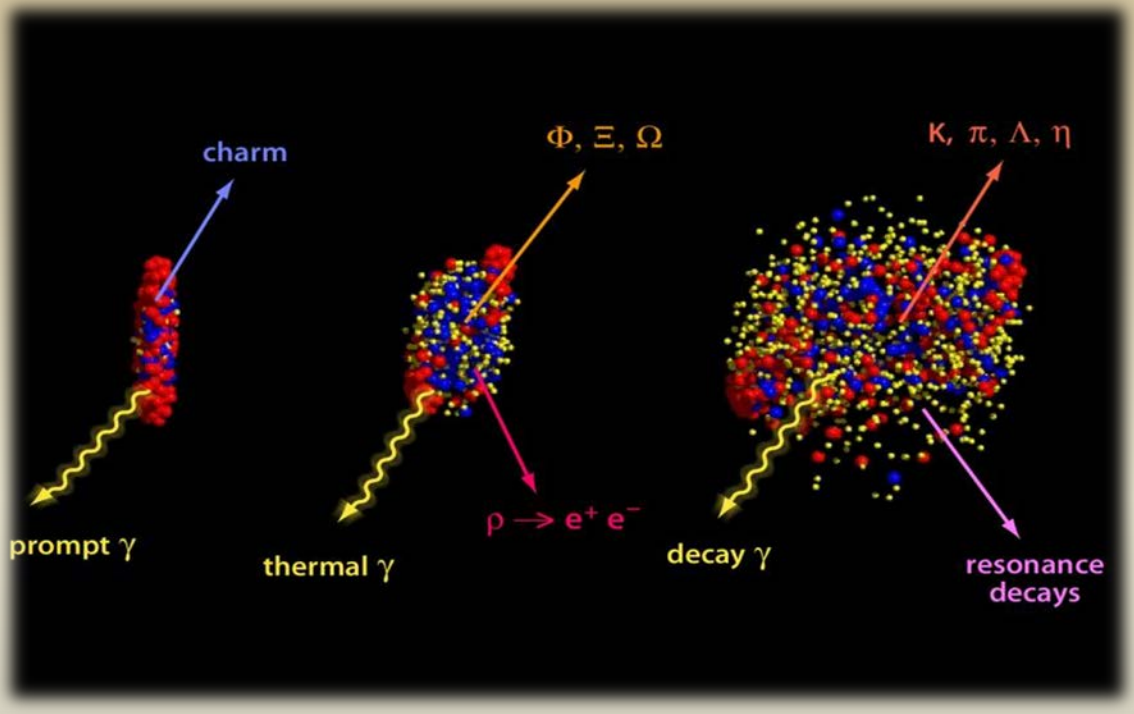
*scanning over energy range:* $\sqrt{s_{NN}}$ = *4 – 11 GeV*

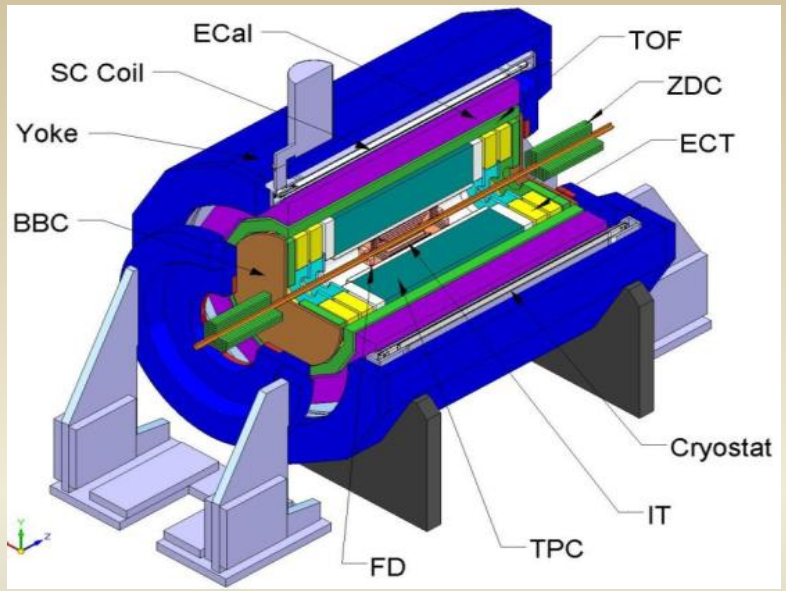
*with a fine steps*

**Strategy:** detailed energy & system size scan

*with a step ~ 10 MeV/u in selected regions*

at high **L** allowing the high statistic (*precision*) studies




**Magnet:** ***0.66T SC solenoid***
**Tracking:** ***TPC, IT, ECT***
**ParticleID:** ***TOF, ECAL, TPC***
**T0, Triggering:** ***FFD***
**Centrality, Event plane: ZDC**

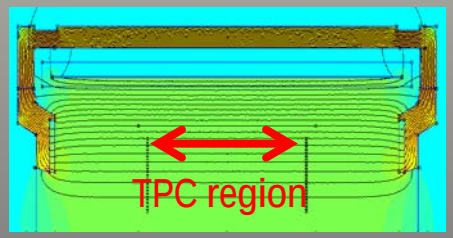
**MPD observables:**

- ✓ *Event-by-event fluctuations*
- ✓ *Femtoscopy involving π, K, p, Λ*
- ✓ *Hadron multiplicities (4-π yields : π, K, p, Λ, Ξ, Ω)*
- ✓ *Collective flow for identified hadrons and resonances*
- ✓ *Electromagnetic probes: e-, γ, vector meson decays*
- ✓ *Hyper Nuclei & other exotic*

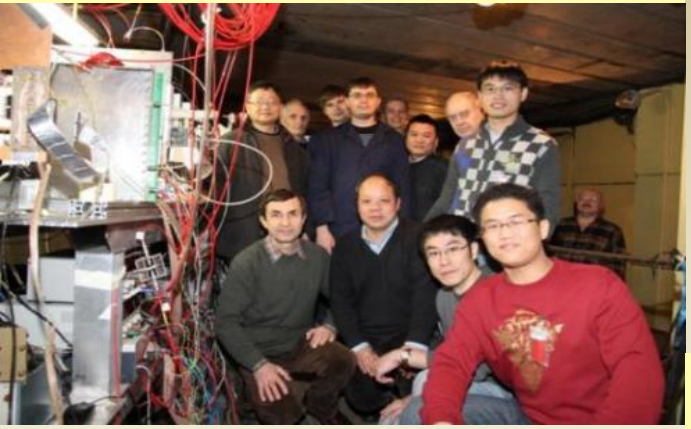
**MPD advantages:**

- ❑ *Hermetic & homogenous acceptance (2π in azimuth), low material budget*
- ❑ *Good tracking performance and powerful PID (nuclei, hadrons, e, γ)*
- ❑ *High event rate capability and reliable event separation*

**MPD Superconducting solenoid**
$B_0$=0.66 T: **challenging project**
*to reach high level (~ $10^{-4}$)*
*of magnetic field homogeneity.*

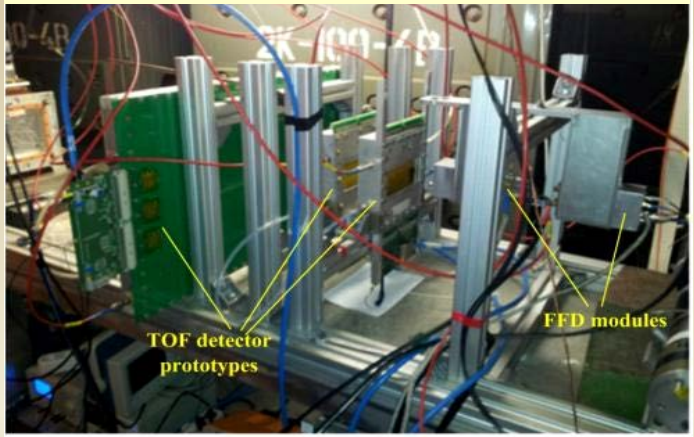


**RPC deam test at NUCLOTRON: cooperation with SPb, China**



**Preproduction ECAL prototypes: co-operation with ISM *(Kharkiv, Ukraine)***

FFD tested with beam: achieved time resolution (38 ps) is better than required

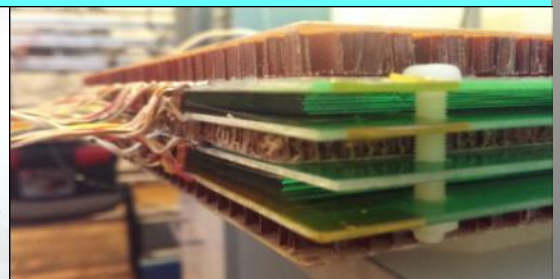



**TPC: Cylinder C3 manufactured in Dec'13**

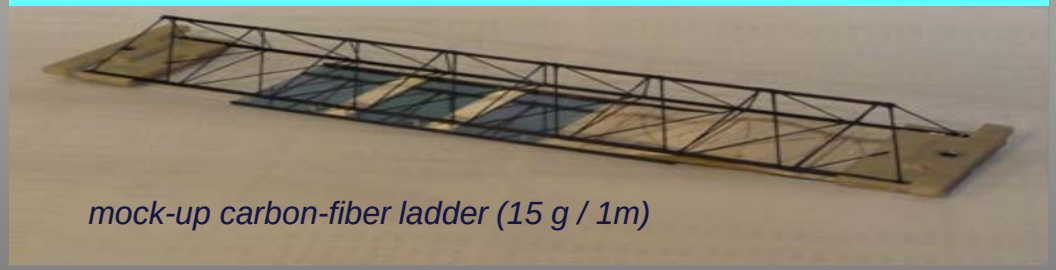
**ZDC coverage confirmed: 2.2<|η|< 4.8**


**Readout Electronics developed for *TPC, TOF, and ECAL (*64 ch,13-bit,65 MSPS*)***

**RPC performance : *required efficiency, rate capability & time resolution (63 ps) are reached***



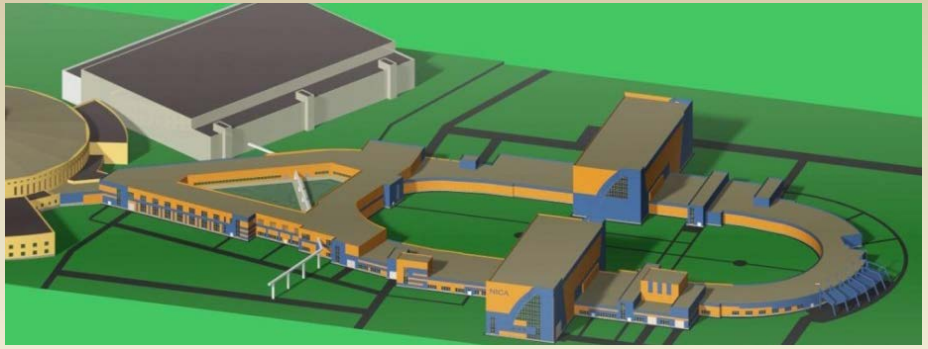
**The CBM - MPD consortium:** *development & production of STS for* ***CBM*** *(FAIR),* ***MPD*** *&* ***BM@N***



*mock-up carbon-fiber ladder (15 g / 1m)*

# SPIN PHYSICS EXPERIMENTS AT NICA-SPD WITH POLARIZED PROTON AND DEUTERON BEAMS

**(LoI is under preparation)**

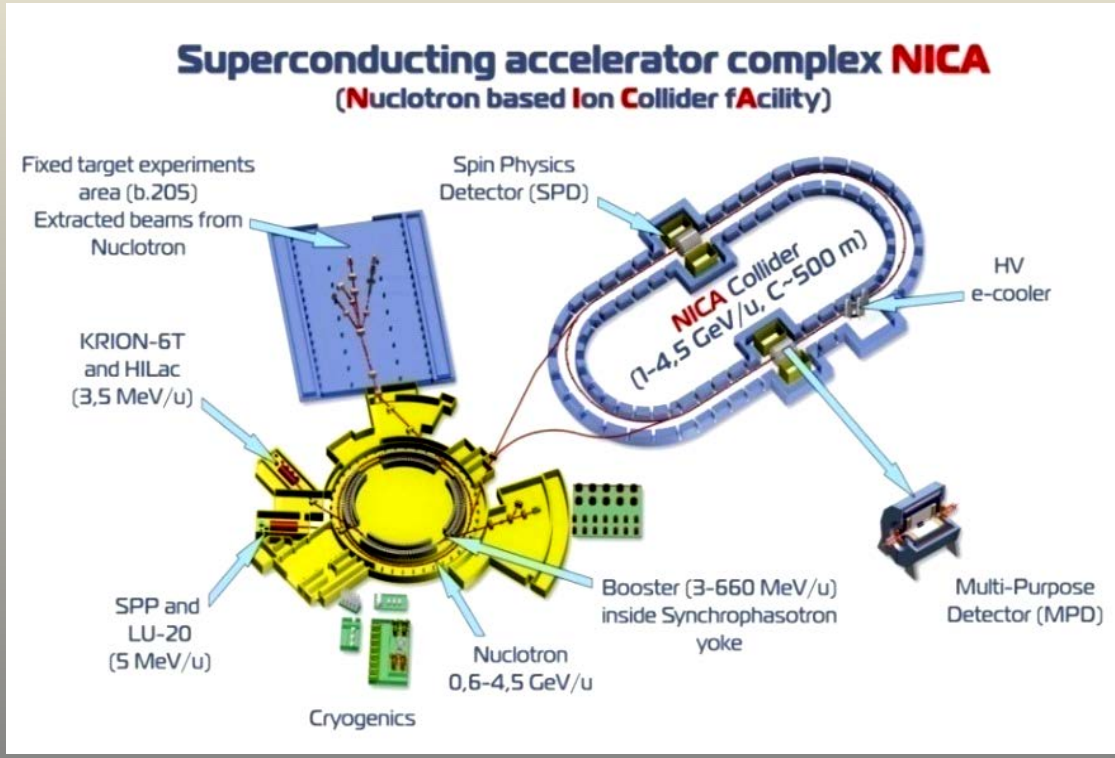


**The proposed measurements:**

- ► DY & J/ψ production processes
- ► Direct (prompt) photons
  much less background than at higher energies

*solving spin crisis*

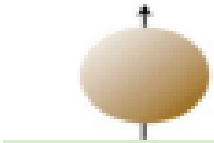
- ► Spin effects in inclusive high-$p_T$ reactions.
- ► Polarization effects in heavy ion collisions.
- ► Spin-dependent effects in elastic pp, dp, dd scattering



# The Present: Proton Spin

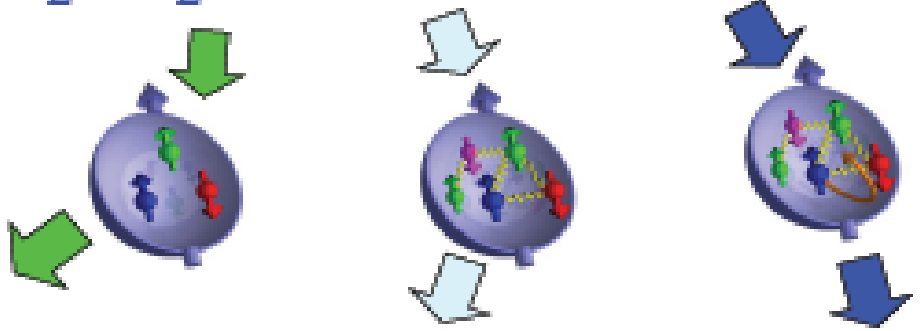
- The sum rule: $S(\mu) = \sum_f \langle P,S|\hat{J}^z_f(\mu)|P,S\rangle = \frac{1}{2} \equiv J_q(\mu) + J_g(\mu)$
  - Infinite possibilities of decompositions – connection to observables?
  - Intrinsic properties + dynamical motion and interactions
- An incomplete story:

Jaffe-Manohar, 90
Ji, 96, …



Proton Spin

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + (L_q + L_g)$$



**Quark helicity**
**Best known**

$$\frac{1}{2}\int dx\left(\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s}\right)$$
$$\sim 30\%$$

**Gluon helicity**
**Start to know**

$$\Delta G = \int dx \Delta g(x)$$
$$\sim 20\%(\text{STAR Data})$$

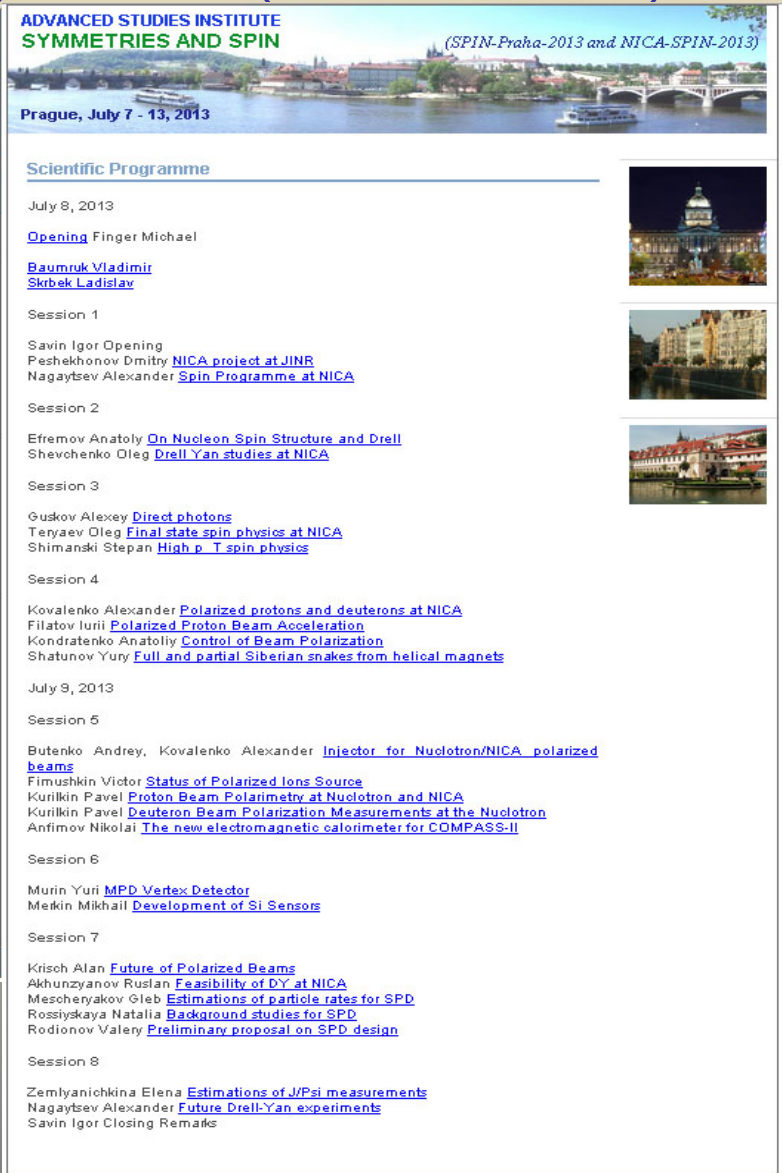
**Orbital Angular Momentum of quarks and gluons**
**Little known**

Net effect of partons' transverse motion?

# SPD Collaboration is formed

## Series of dedicated workshops started in 2013 :

## Dubna (March 17-19), Prague (July 7-13), Dubna (October 8-12)


**LoI is under preparation**

# NICA White Paper – International Effort

NICA

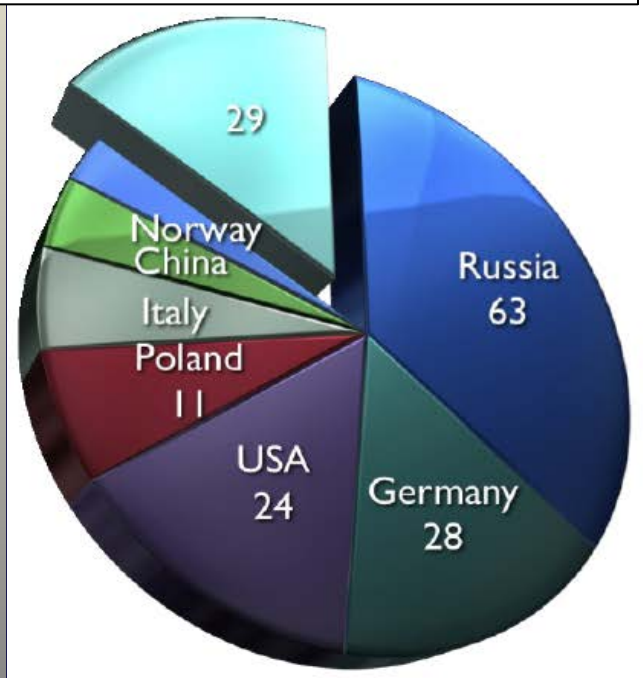
Draft v 8.03
January 24, 2013

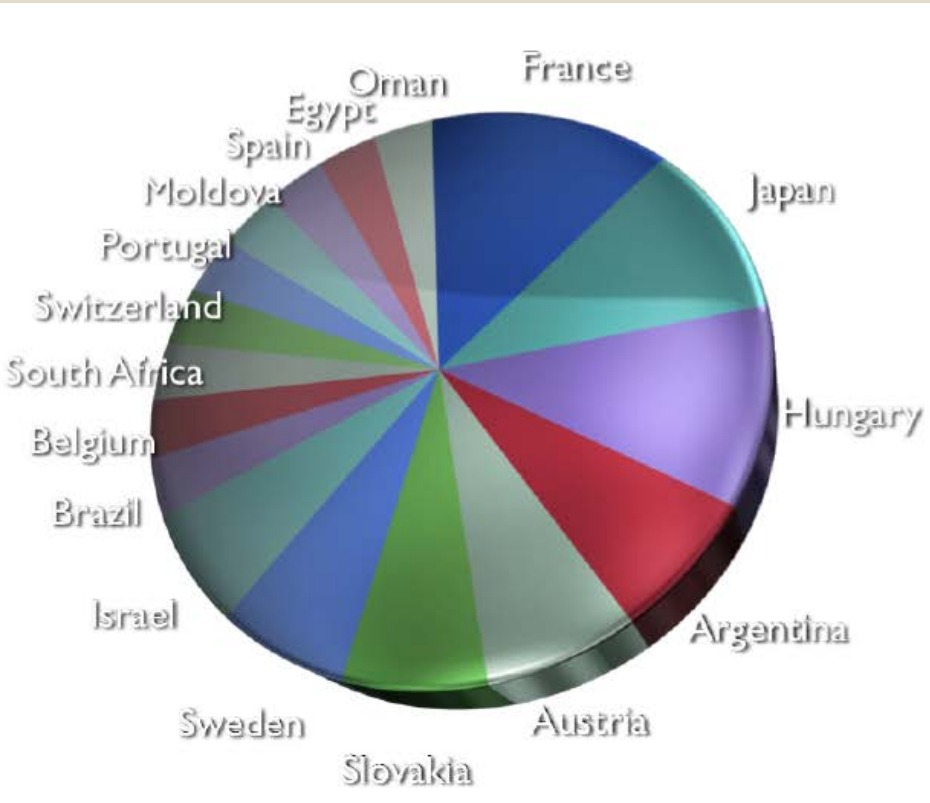
SEARCHING for a QCD MIXED PHASE at the
NUCLOTRON-BASED ION COLLIDER FACILITY
(NICA White Paper)

*Statistics of White Paper Contributions*

**104** *contributions:*
**188** *authors from* **70** *centers in* **24** *countries*

***A wide international interest to the physics at BM@N & MPD & SPD***



Town Meeting at CERN, 2012: *"The NICA project offers important complementarities to the beam energy scan program at RHIC & the programs at FAIR"*

**The EU experts met in** *Ministry of Education and Science (Moscow 16 May, 2013) & JINR (Dubna, 17 May, 2013) to discuss* ***mega-science projects in RF*** *(NICA is one of 6)*

**HORIZON – 2020** ⇒ **NICA offers the European scientific community new opportunities for widening the cooperation**

*EU experts at JINR*

# The meeting with EU experts in Brussels on 19-th June 2013

*"The fact that **NICA/JINR** is a part of the European research infrastructure landscape has already been recognized by **ESFRI**.*

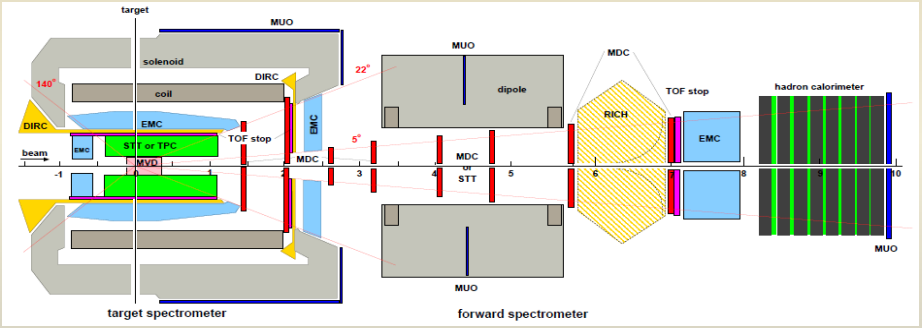
***The Expert Group** recommends that the **NICA project** be fully taken into account in the forthcoming discussions on the next update of the **ESFRI** Roadmap"*

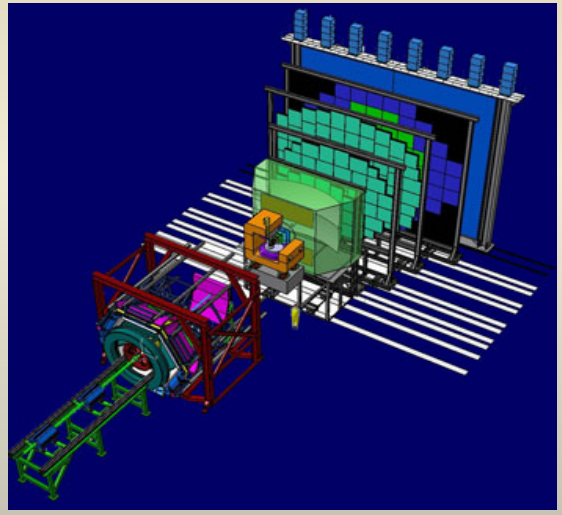
# Future Experiments:FAIR

**GSI – project FAIR (Facility for Antiproton and Ion Research)**

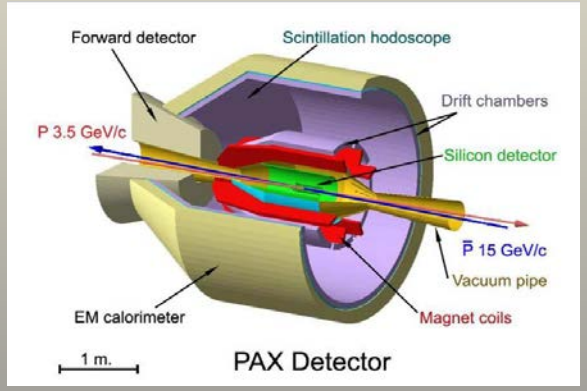
**at Darmstadt is an international accelerator facility of the next generation.**

**PANDA**

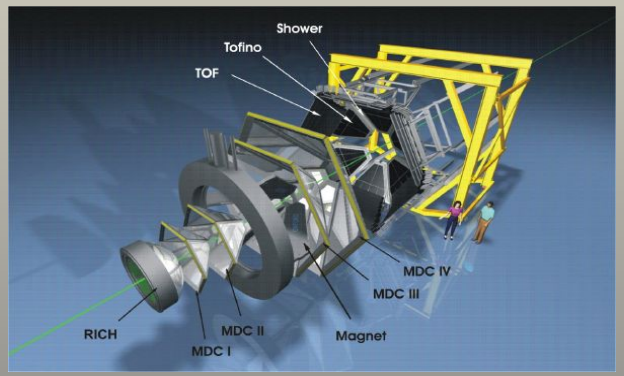


**CBM**




**PAX**

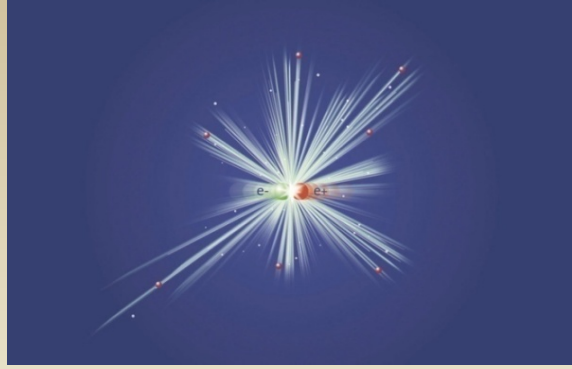



**HADES**

**It is expected that the main contribution of JINR to FAIR will be financed in the framework of Russia-FAIR agreement.**

# Very Future Experiments: ILC

## International Linear Collider



- A new electron-positron collider is to complement the LHC program and to extend very significantly the window of opportunity for high precision measurements and additional new discoveries.

- JINR participates in both accelerator and detector activities within the ILC project.

- Dubna is one of the five official places considered for ILC (the detailed geological studies have been done in the direction to Taldom)