The 2019 European School of High-Energy Physics
St. Petersburg, Russia, 4-17 September 2019

JINR

CERN

"JINR Research Programme - Present Status and The Long Range Strategy of JINR development up to 2030"

Victor Matveev (JINR, Dubna)
2018 European School of HEP
Saint Petersburg, 07/09/2019

1. About JINR, shortly

2. Big questions of physics

3. Major JINR research projects

4. On JINR Long Range Strategy

5. Conclusion remarks

JINR is the International Intergovernmental Organization joining 18 Member States and 6 Associate Members, located in Dubna in 120 km to the north from Moscow

JINR today

About 780 research partners in 62 countries

18 Member States (incl. 5 from EU):

Azerbaijan
Armenia
Belarus
Bulgaria
Vietnam
Georgia
Kazakhstan
Cuba
DPRK
Moldova
Mongolia
Poland
Russia
Romania
Slovakia
Uzbekistan
Ukraine
Czech Republic

6 Associate Members (incl. 3 from EU):
Hungary, Germany, Egypt, Italy, Serbia, SAR

Nearly 5000 stuff

JINR Laboratories
and JINR University Center

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

<Nearly 5000 stuff >

JINR University Center

JINR is the Multidisciplinary Research Center
Basic science and Innovative applied research
Modern Educational programmes

Particle and High Energy Physics

Relativistic Nuclear Physics

Neutrino Physics and Astrophysics

Nuclear Physics

Super Heavy Elements and Exotic Nuclei

Condensed Matter Physics

Studies on the beams of the Pulsed Neutron Sources

Radiobiology and Astrobiology

Information technology and the High Performance Computing

Theoretical Physics and Mathematical Physics

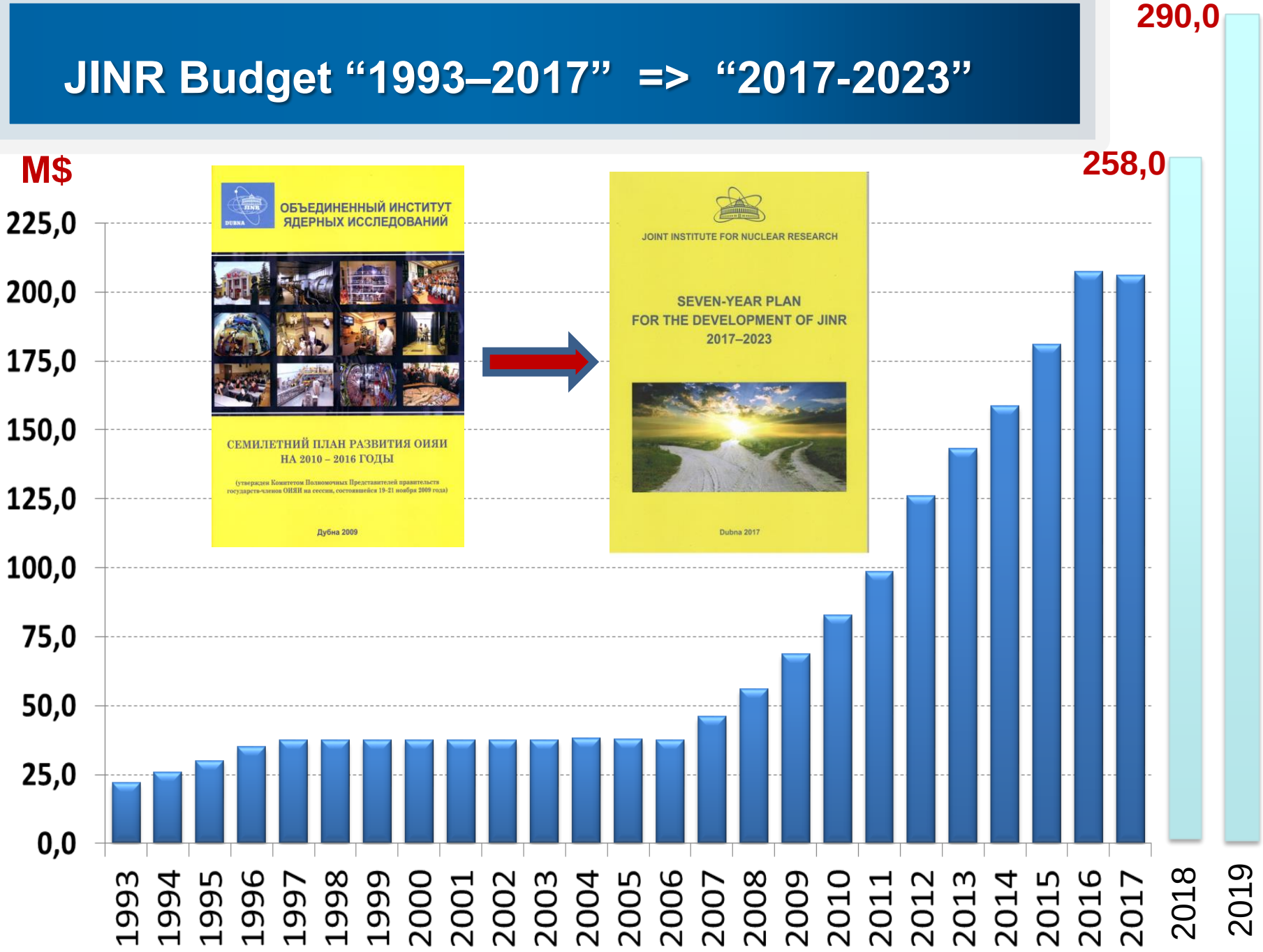
Fundamental Problems of the Life Sciences

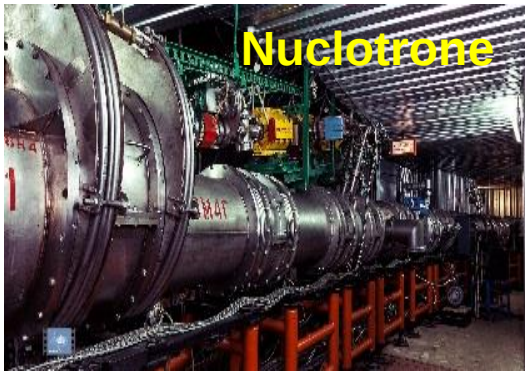
Nuclear Physics methods in Life Sciences

Cosmic Medicine and Radio Ecology

Hadron Therapy of the oncology deceases

JINR Budget “1993–2017” => “2017-2023”





JINR
priority research programmes: recent highlights

JINR Research Programme

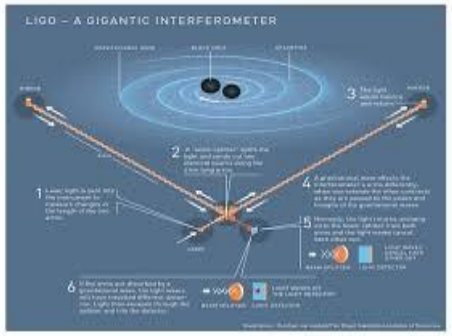
Particle and High Energy Physics
Relativistic Nuclear Physics
Hadron Matter Physics

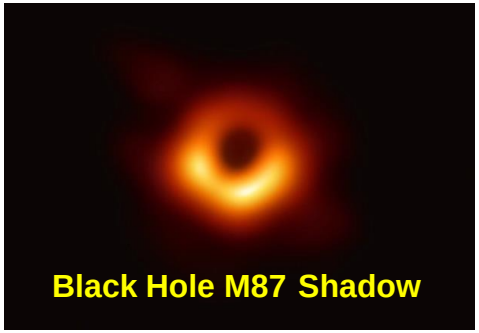
Fundamental Physics community celebrates the great success of Standard Model: Higgs, flavor physics, rare decays etc,

and seems nothing else up to the Plank scale, if not the neutrino oscillations, dark matter and energy, and what is more - getting photo of the black hole shadow and detecting the gravitation waves.

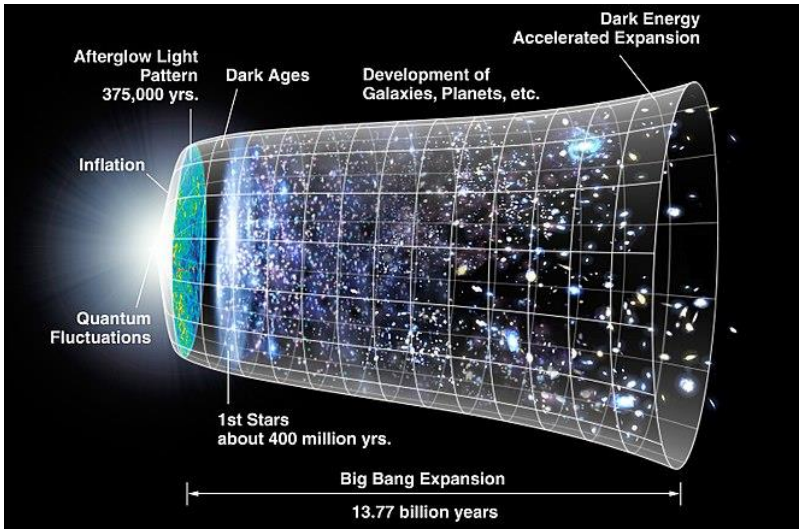
We have to look for New Physics beyond the SM !

We need New Physics paradigms after Higgs and Gravitation waves discoveries

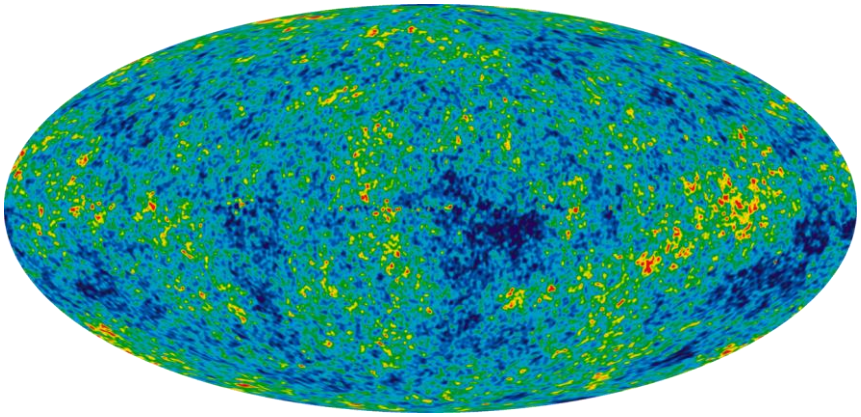




Standard Model of Particle Physics
Physical Cosmology
Theory of Big Bang and evolution of Early Universe
Physics of Dark Matter and Dark Energy



Physical Cosmology of Expanding Universe



NICA (Nuclotron based Ion Colider fAcility)

- Development of accelerator facility for HEP @ JINR,
- Construction of Collider of relativistic ions from p to Au
- and for polarized protons and deuterons

with energies up to $\sqrt{S_{NN}}$ = 11 GeV (Au^{79+}) and = 27 GeV (p, d)

«The only source of knowledge is experience»

A. Einstein

Heavy ion collisions

Particle Physics: *most of discoveries in last decades have been obtained through research guided by the Standard Model.*
But the phenomena of the quarks and gluons confinement and deconfinement still require better understanding.

Relativistic Nuclear Physics : *physics studies driven by already existing experimental data trends in high energy heavy ion collisions and by basic principles of the general physics - classic hydrodynamics and thermodynamics and others.*

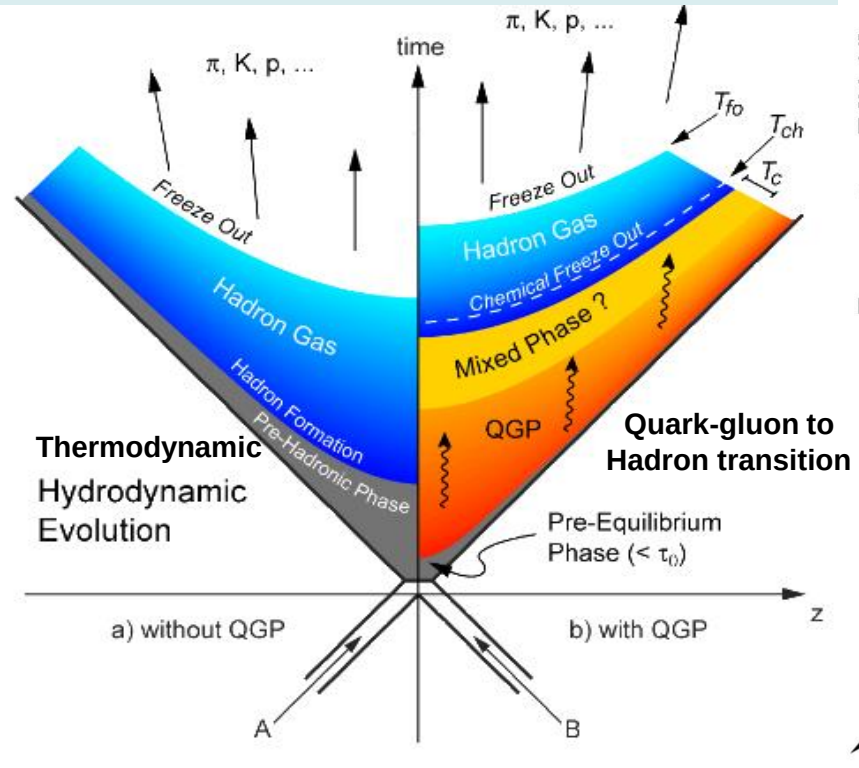
New experimental data *in the less explored region of QCD phase diagram at the maximally achievable at laboratory high baryon density of the quark-gluon media are highly needed and could lead to:*

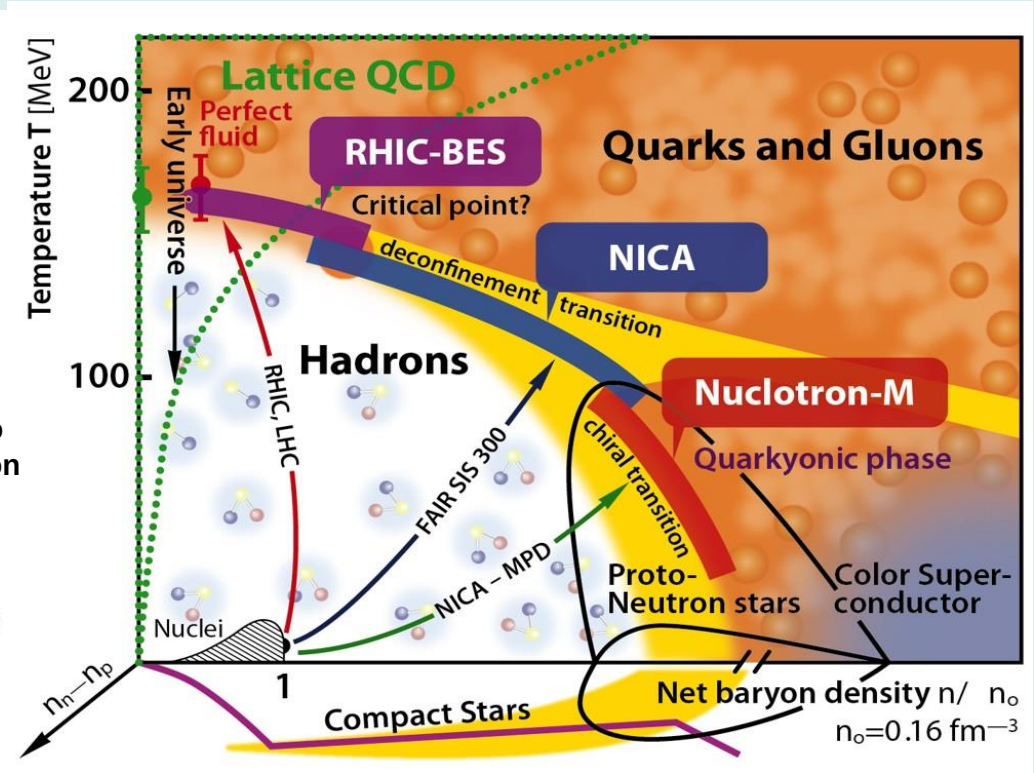
- *observation / discovery of the principally new phenomena;*
- *development of theoretical models of quark-gluon matter (deriving the EoS)*

➔ ***RHIC (BNL), LHC (CERN), FAIR (GSI), NICA (JINR)***

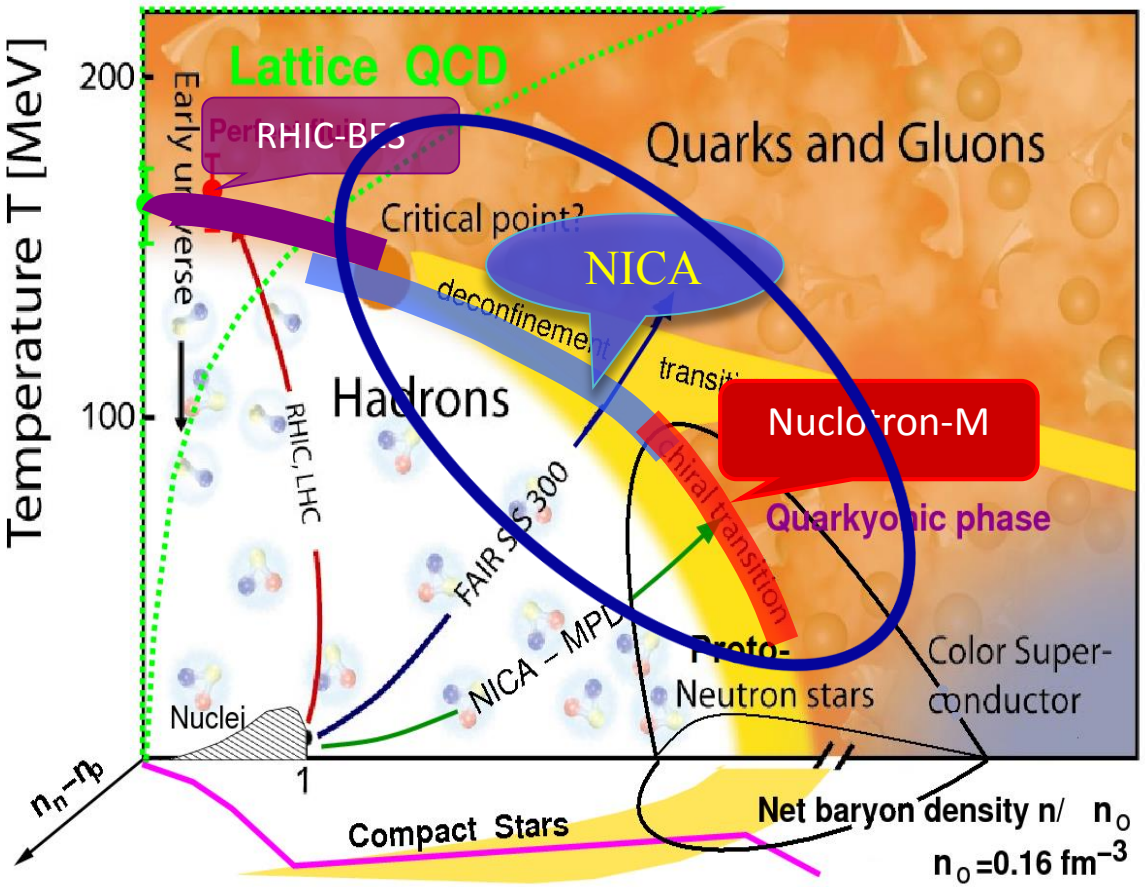
Searching for "Phase Transition" in Heavy Ion Collisions

Heavy-ion collisions can be described on the language of thermodynamics (temperature, baryon density, EoS, "chemical potential", "phase transitions", etc.)





QCD phase diagram - Prospects for NICA



NICA facilities provide unique capabilities for studying a variety of phenomena in a large region of the phase diagram

Energy Range of NICA

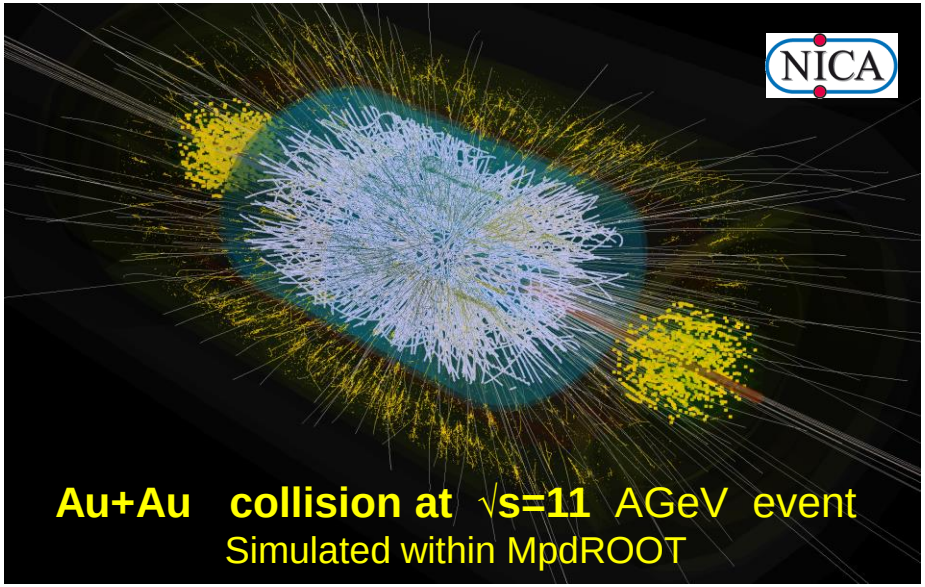
- unexplored region of the QCD phase diagram:

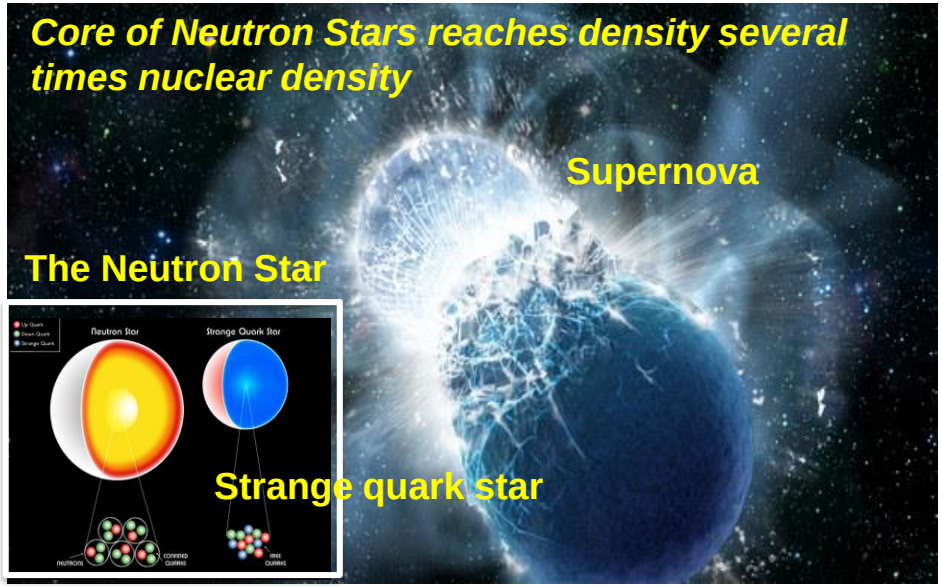
- Highest net baryon density
- Onset of deconfinement phase transition
- Strong discovery potential:
  a) Critical End Point (CEP)
  b) Chiral Symmetry Restoration
- Complementary to the RHIC, FAIR, CERN & Nuclotron/NICA experimental programs

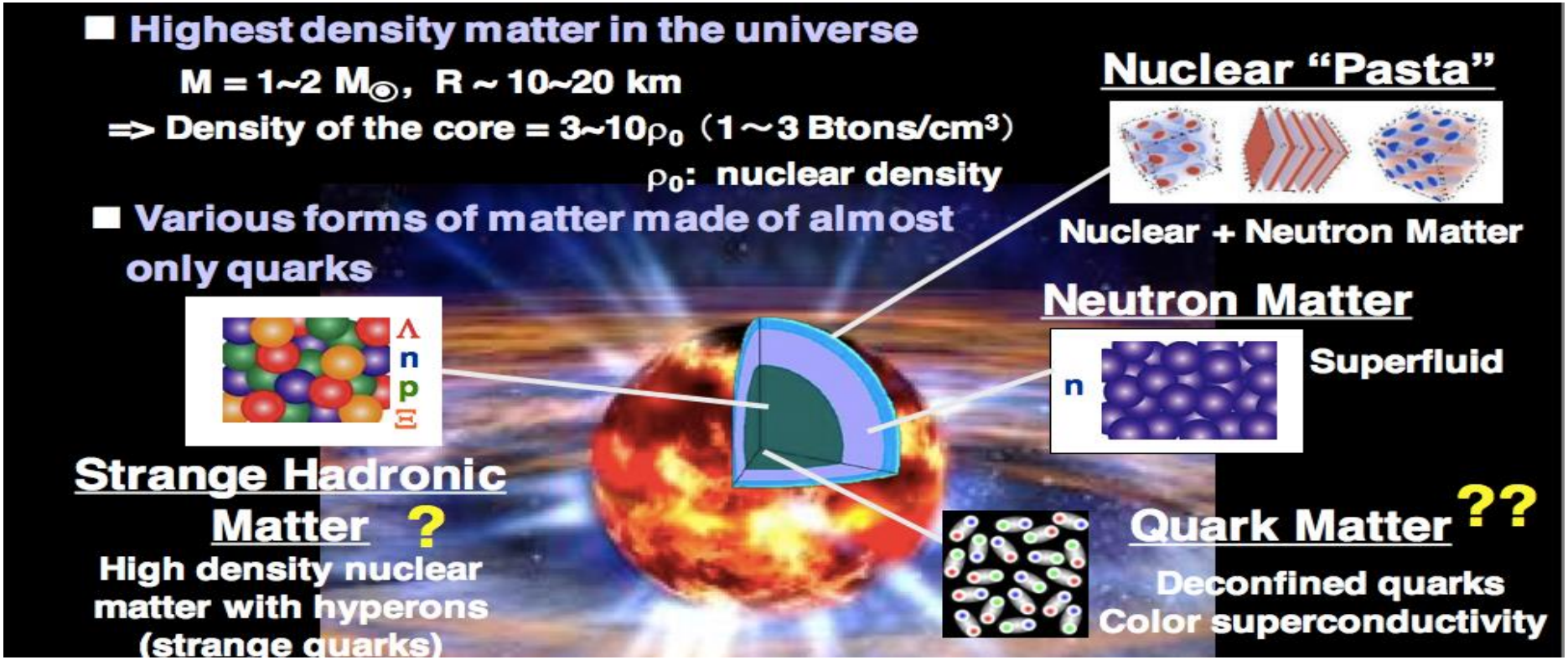
Experiments of the Heavy Ion collisions

→

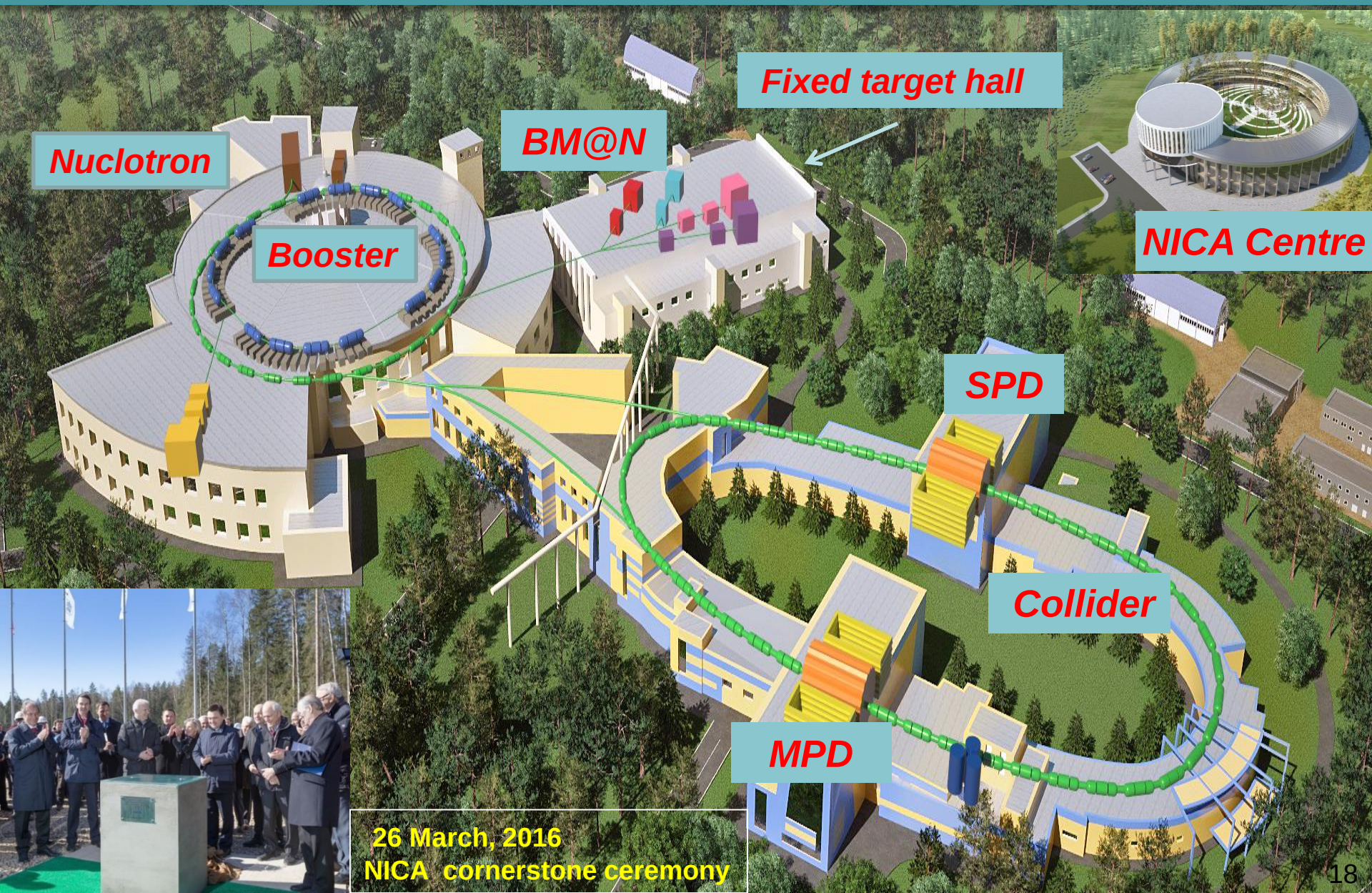
Astrophysics in laboratory and Early Universe in Laboratory


NICA
Au+Au collision at √s=11 AGeV event
Simulated within MpdROOT


Core of Neutron Stars reaches density several times nuclear density
Supernova
The Neutron Star
Neutron Star
Strange Quark Star
Strange quark star


■ Highest density matter in the universe
M = 1~2 M⊙, R ~ 10~20 km
=> Density of the core = 3~10ρ0 (1~3 Btons/cm³)
ρ0: nuclear density
■ Various forms of matter made of almost only quarks
Nuclear "Pasta"
Nuclear + Neutron Matter
Neutron Matter
n
Superfluid
Λ
n
p
Ξ
Strange Hadronic Matter ?
High density nuclear matter with hyperons (strange quarks)
Quark Matter ??
Deconfined quarks
Color superconductivity

NICA Complex: mega-science project at JINR

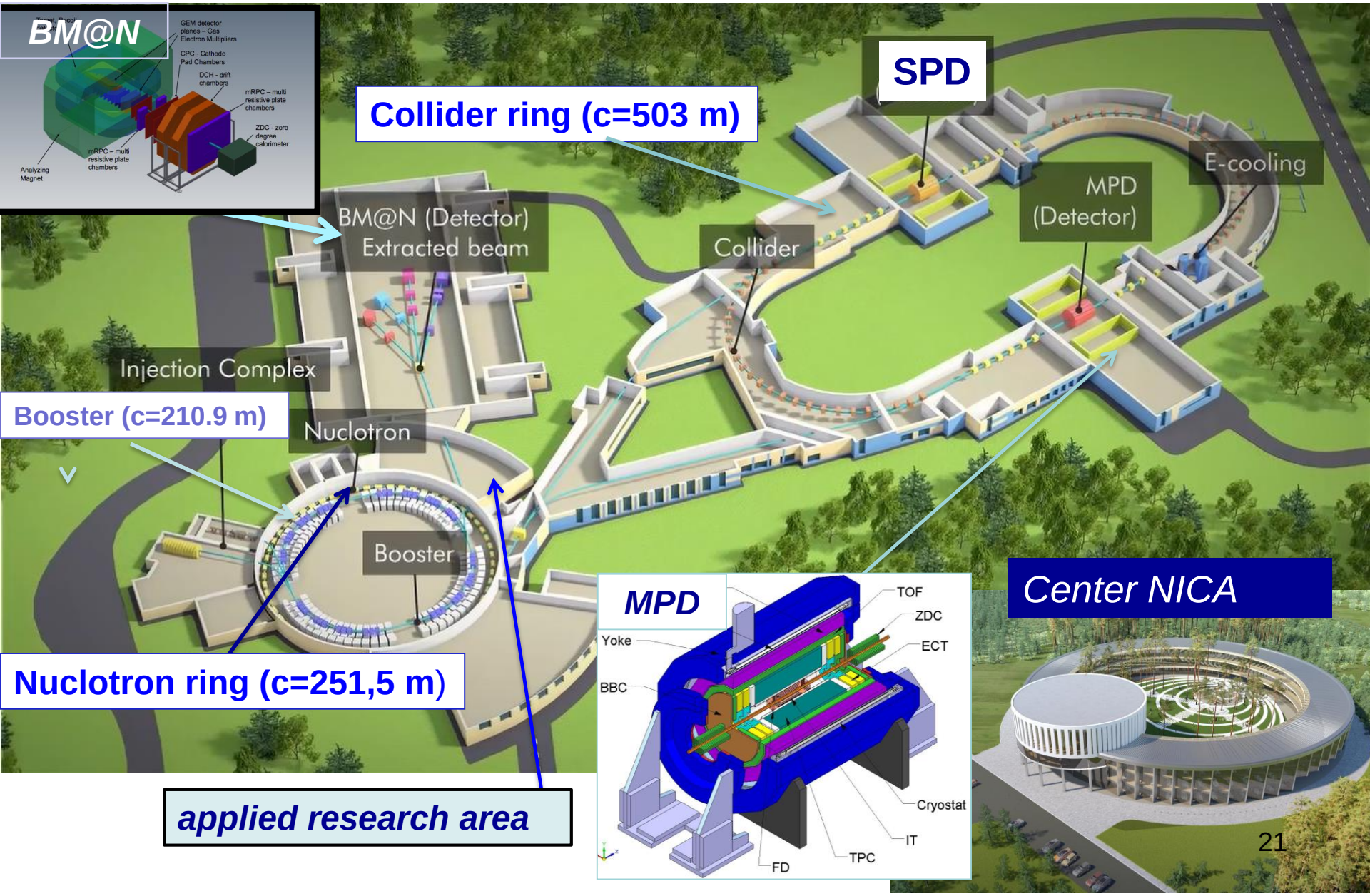


Construction of NICA Collider Building

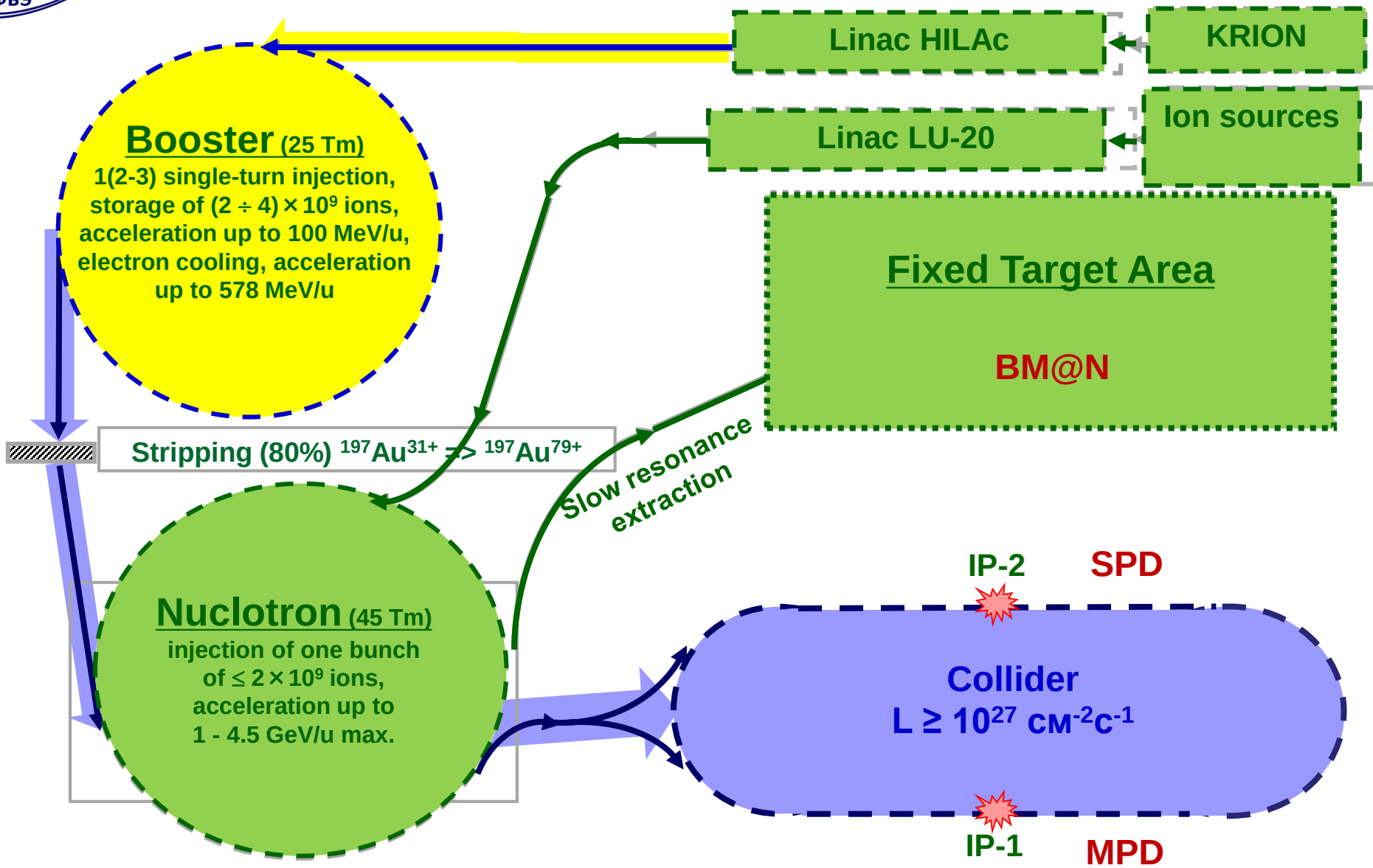
Construction of NICA Collaider Building

http://nucloweb.jinr.ru/nucloserv/205corp.htm

Structure of the NICA / Nuclotrone Complex



NICA facility elements – present status (2019)



work in progress	assembly	commissioned / existing

Nuclotron:

Superconducting synchrotron, put in operation in 1993 and

modernized in 2010-2015

Parameters	**Nuclotron**
type	SC synchrotron
particles	**p**, ↑**d**, ↑**nuclei**
injection energy, MeV/u	5 (**p**, ↑**d**)↑ 570-685 (**Au**)
max. kin. energy, GeV/u	**12.07** (**p**);↑ **5.62** (**d**)↑ **4.38** (**Au**)
magnetic rigidity, T m	25 – 43.25
circumference, m	251.52
cycle for collider mode, s	1.5-4.2 (active); 5.0 (total)
vacuum, Torr	10^{-9}
*intensity, **Au** ions/pulse*	1 10^{9}
transition energy, GeV/u	7.0
RF range, MHz	0.6 -6.9 (p,↑d)↑ 0.947 – 1.147 (nuclei)
spill of slow extraction, s	up to 10

The first experiment at BM@N :
"Probing the Short-Range Correlations"

BM@N collaboration +

***Israel**: Tel Aviv University*

***Germany**: TUD and GSI*

***USA**: FIU, MIT, ODU, PSU*

***France**: CEA*

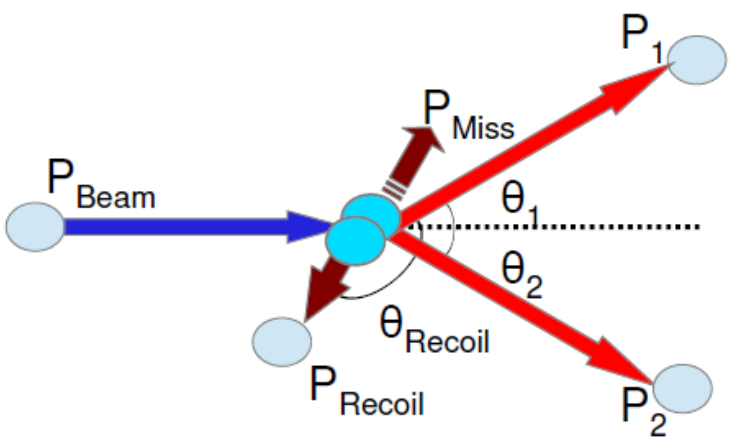
The first run with ^{12}C beam from Nuclotrone has started on March 3-17, 2019:

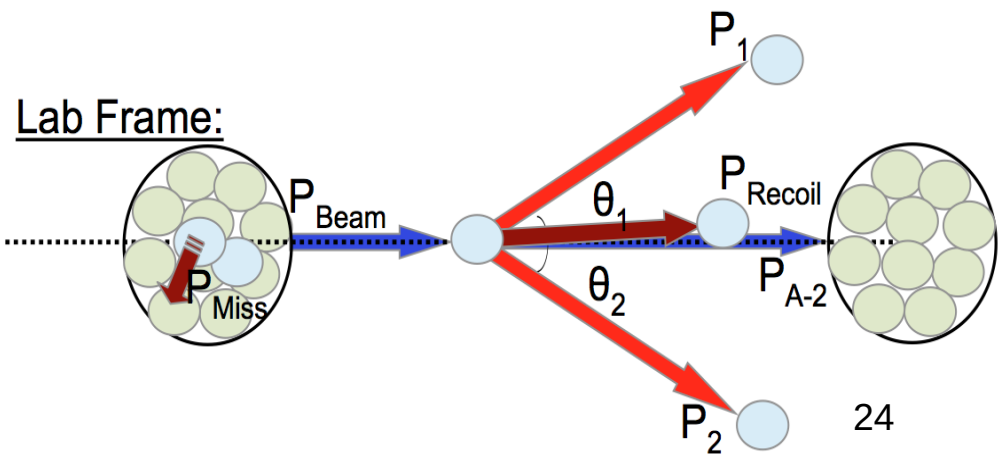
- ***^{12}C beam 4 GeV/u;***
- ***Hydrogen target;***
- ***time 324 hours;***
- ***20M events recorded (19Tb).***

$$^{12}C + p \rightarrow 2p + {}^{11}_{5}B \qquad \text{QE}$$

$$^{12}C + p \rightarrow 2p + {}^{10}_{5}B + n \qquad \text{np SRC}$$

$$^{12}C + p \rightarrow 2p + {}^{10}_{4}Be + p \qquad \text{pp SRC}$$



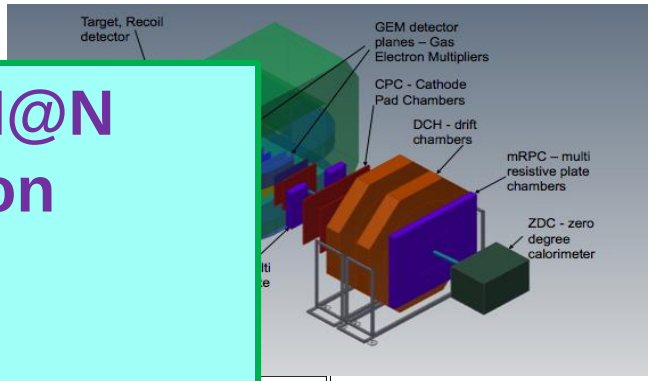


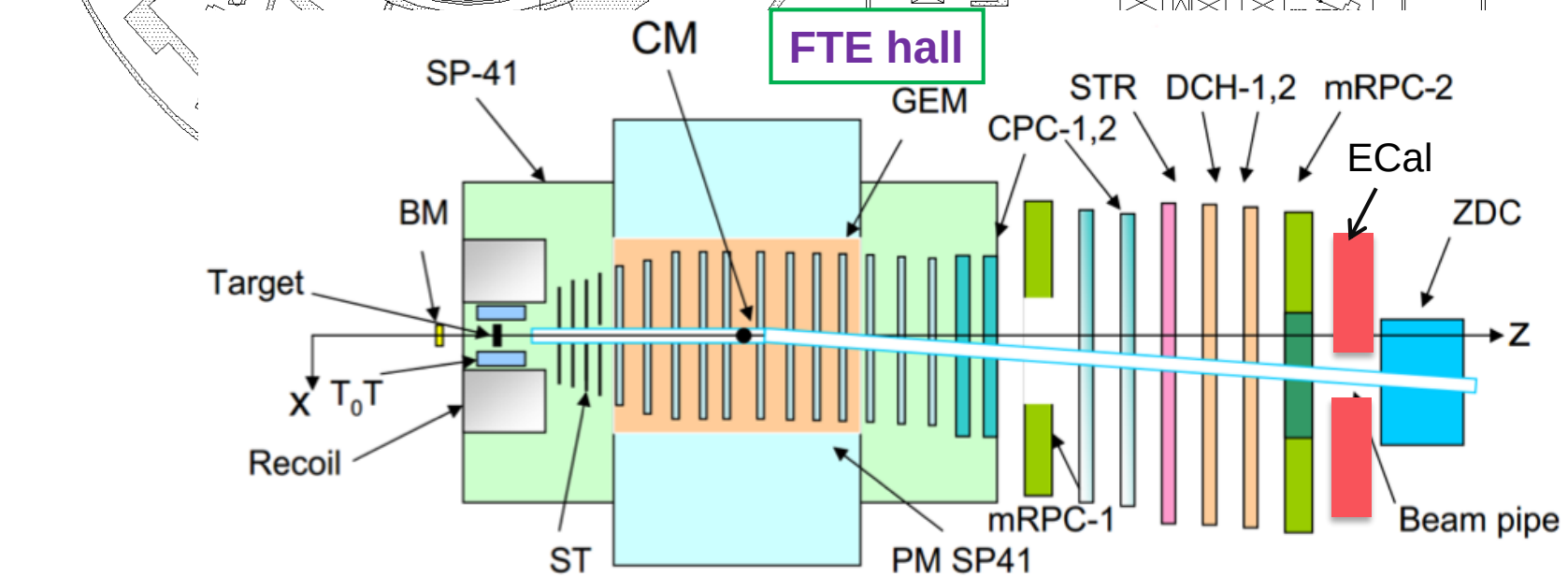
Baryonic Matter at Nuclotron (BM@N)

BM@N coop
Russia: *INR*
Bulgaria: *P*
China: *Tsing*
Poland: *Wa*
Israel: *Tel A*
Germany: *F*
USA: *MIT, FI*
France: *CEA*

The first heavy ion run at BM@N in the FTE hall has started on March 22, 2018:

- ***^{40}Ar beam 3,2 GeV/u;***
- ***targets: C - Pb***
- ***20M events already recorded.***





BM@N *schematic view*

Booster

Start of commissioning at the end of 2019

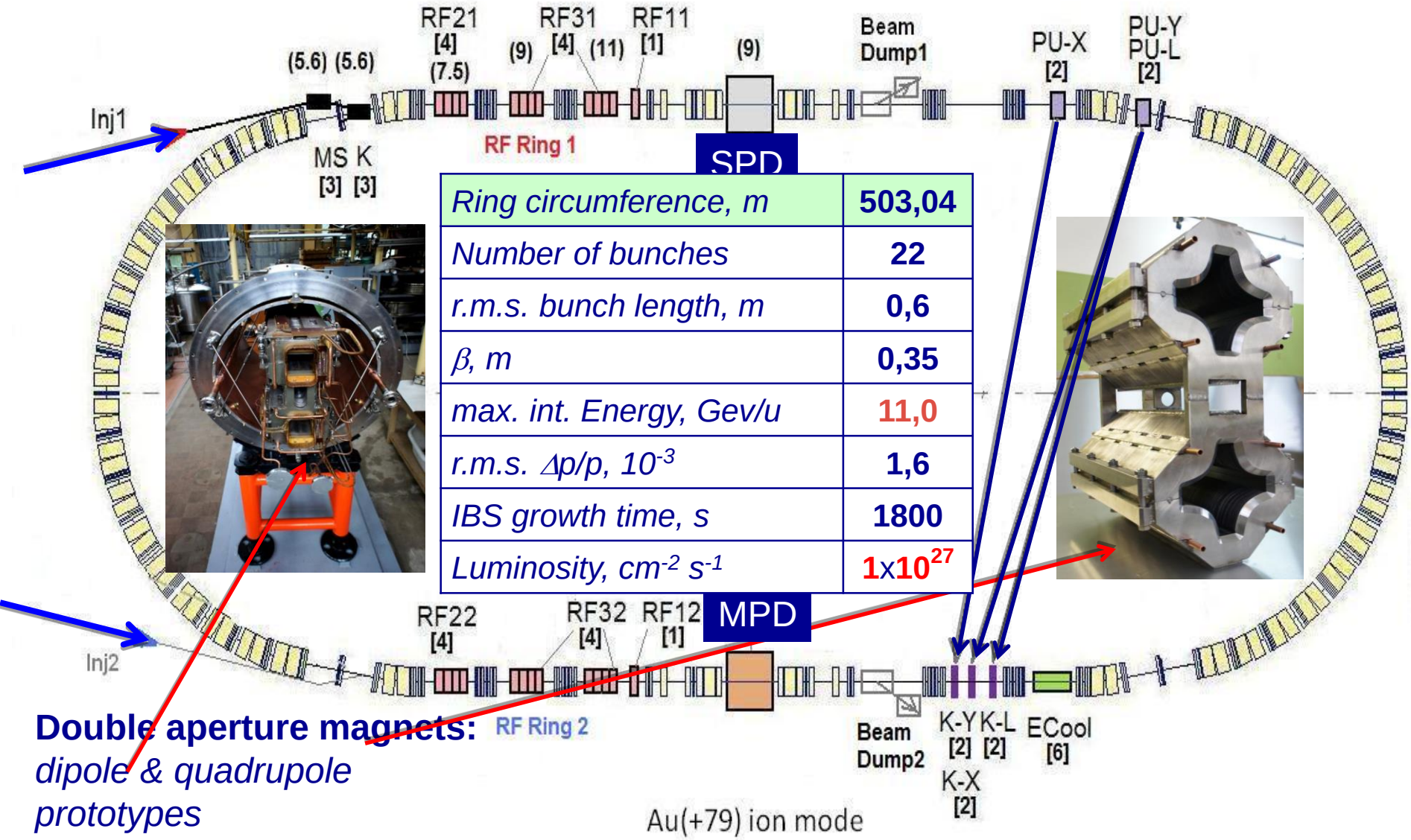
Parameter	**Booster**
type	SC synchrotron
particles	ions A/Z < 3
injection energy, MeV/u	3.2
maximum energy, MeV/u	**600**
magnetic rigidity, T m	1.6 – 25.0
circumference, m	210.96
cycle for collider mode, s	4.02 (active); 5.0 (total)
vacuum, Torr	10^{-11}
*intensity, **Au** ions/pulse*	$1.5\ 10^{9}$
transition energy, GeV/u	3.25
RF range, MHz	0.5 -2.53
spill of slow extraction, s	up to 10

Electron Cooling System --
2 RF stations (Budker INP) - installed

tunnel is ready

The Collider

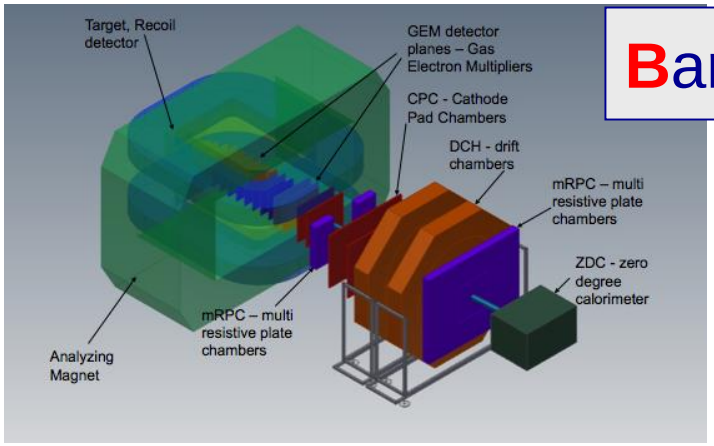
45 T*m, *4.5 GeV/u for* ***Au^{79+}***



Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
max. int. Energy, Gev/u	**11,0**
r.m.s. $\Delta p/p$, 10^{-3}	**1,6**
IBS growth time, s	**1800**
Luminosity, cm^{-2} s^{-1}	**1×10^{27}**

Double aperture magnets: *dipole & quadrupole prototypes*

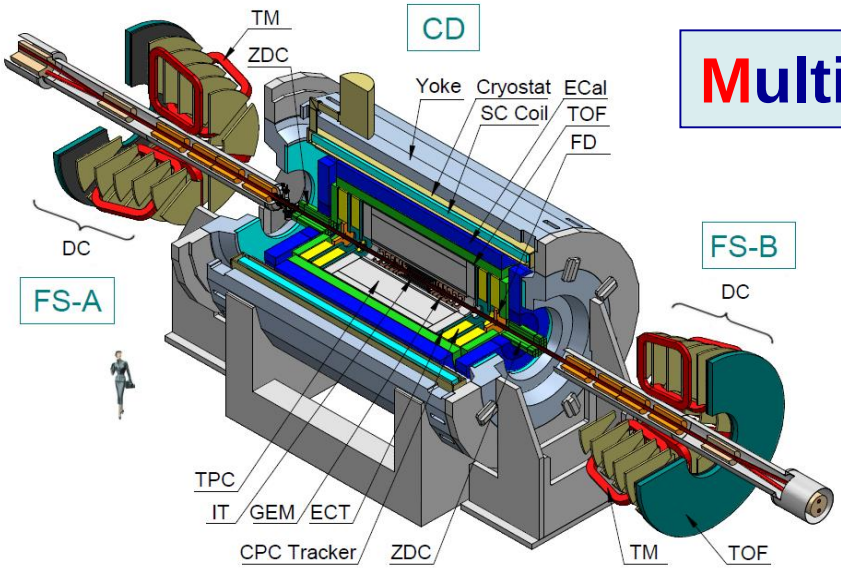
NICA Physics: three detectors at IP-1,2 and FTE hall



Baryonic **M**atter at **N**uclotron (**BM@N**)

the fixed target experiment at the NICA FTE hall

Stage I 2017



MultiPurpose Detector (MPD)

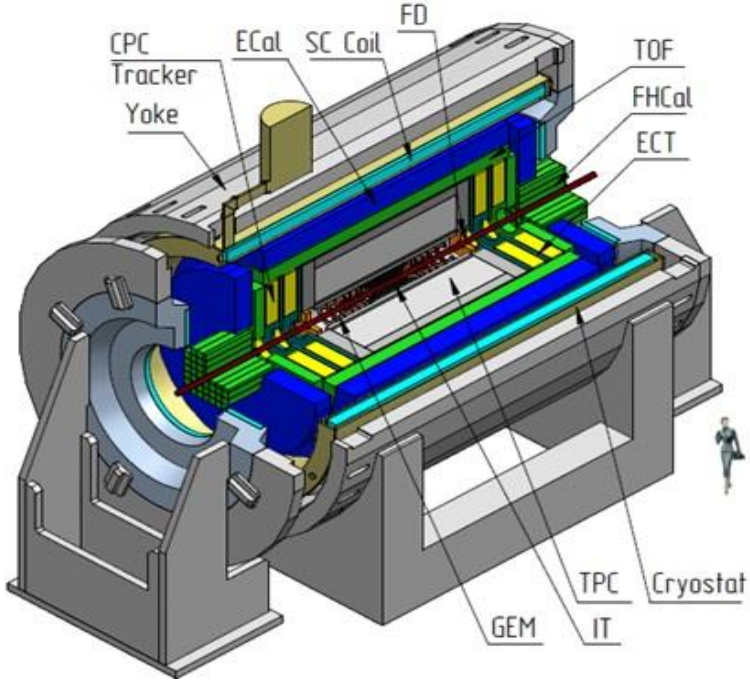
at the NICA Collider, IP-1

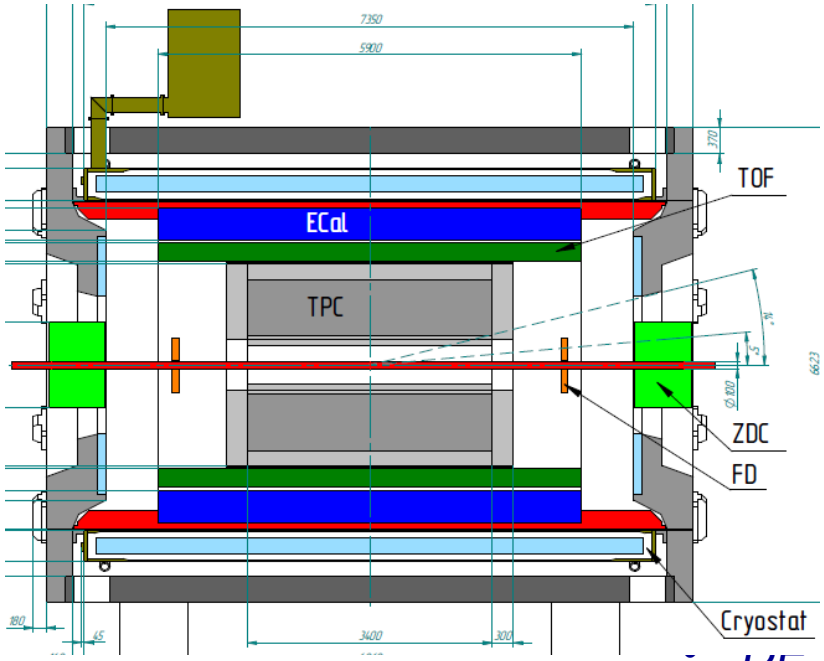
Stage I 2019

Stage II 2022

Project of the SPD (Spin Physics Detector) ***at the NICA Collider, IP-2, CDR is under preparation***

Multi Purpose Detector @ NICA





MPD Collaboration:

- *JINR, Dubna;*
- *Tsinghua University, Beijing, China;*
- *GSI, Germany*
- *MEPhI, Moscow, Russia.*
- *INR, RAS, Russia;*
- *PPC BSU, Minsk, Belarus;*
- *WUT, Warsaw, Poland;*

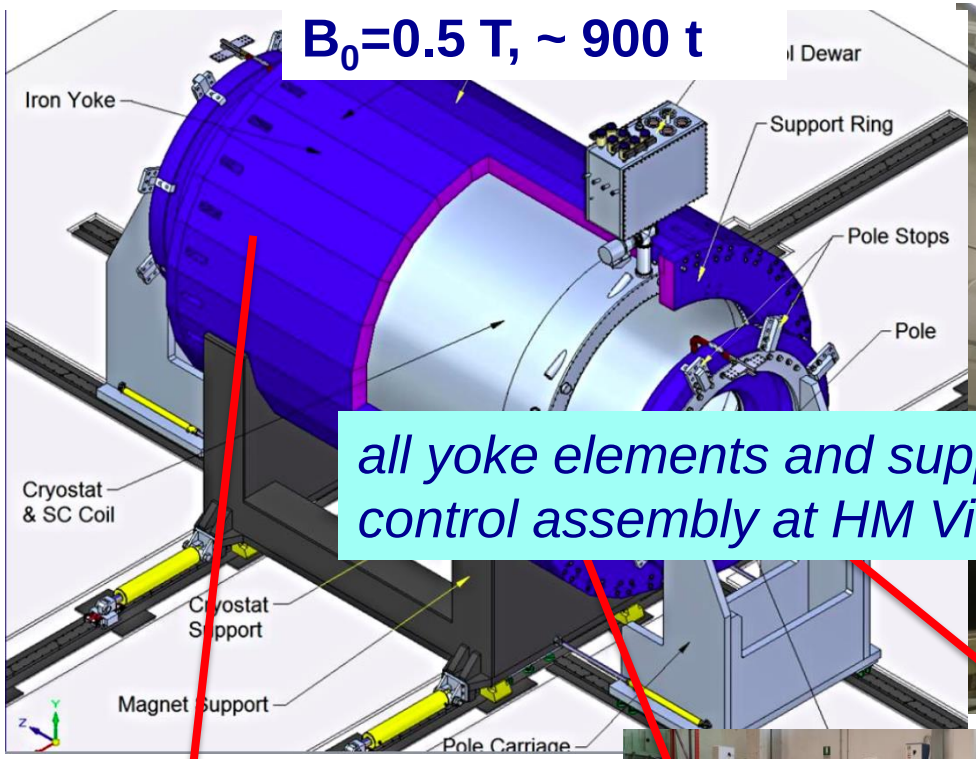
Foundation of collaboration
April, 2018

expression of interest:

- *CERN;*
- *DF, US, Mexico;*
- *ICN UNA; Mexico;*
- *DF, CIEA del I.P.N, Mexico;*
- *FCF-M UAS, Sinaloa, Mexico;*
- *FCF-MB UAP, Puebla, Mexico;*
- *PI Az.AS, Baku, Azerbaijan;*
- *ITEP, NC KI, Moscow, Russia;*
- *PNPI NC KI, Saint Petersburg, Russia;*
- *CPPT USTC, Hefei, China;*
- *SS, HU, Huzhou, Republic of South Africa.*

Magnet production: *at ASG (Genova) & Vitkovice HM*

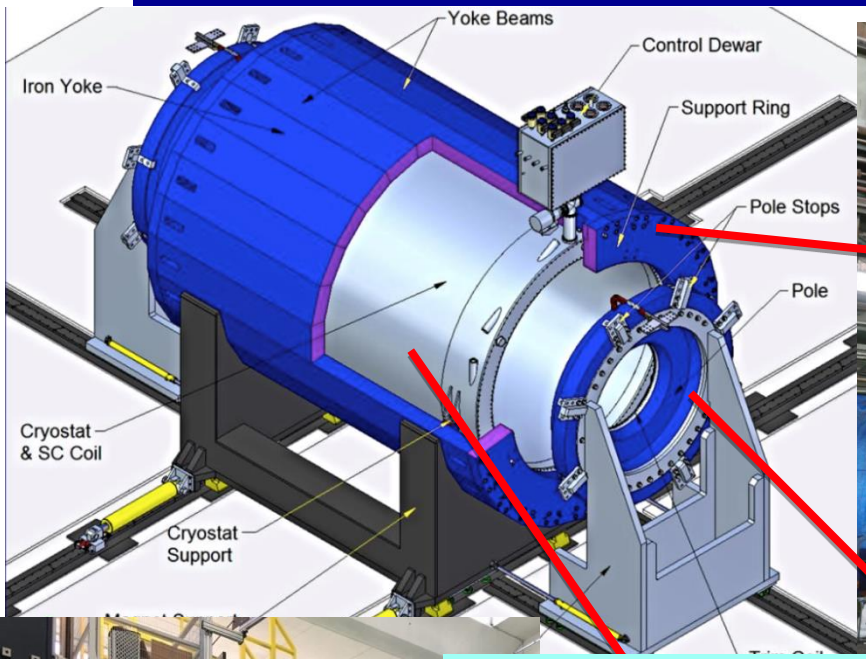
B_0=0.5 T, ~ 900 t



the first SC coil winding has started

all yoke elements and support structure are produced; control assembly at HM Vitkovice will start soon

Magnet fabrication: *ASG (Genova) & Vitkovice HM*



yoke control assembly at HM Vitkovice

*final assembly in the MPD hall - Autumn **2019***

winding machine

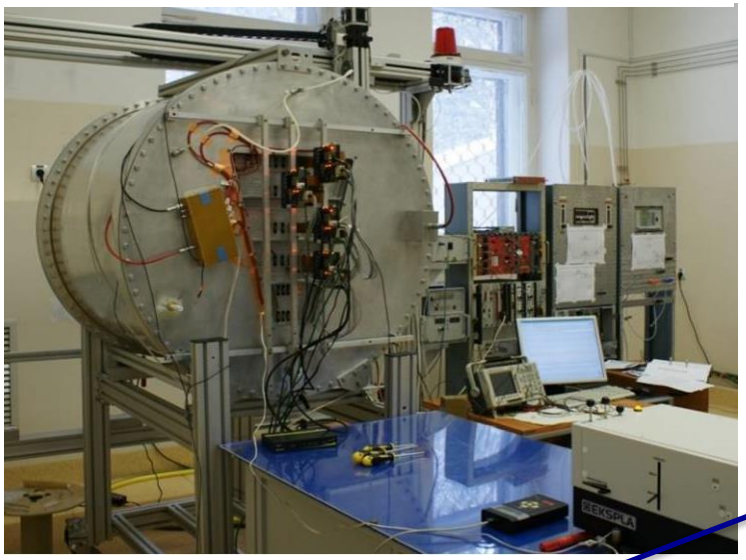
cryostat

trim coil

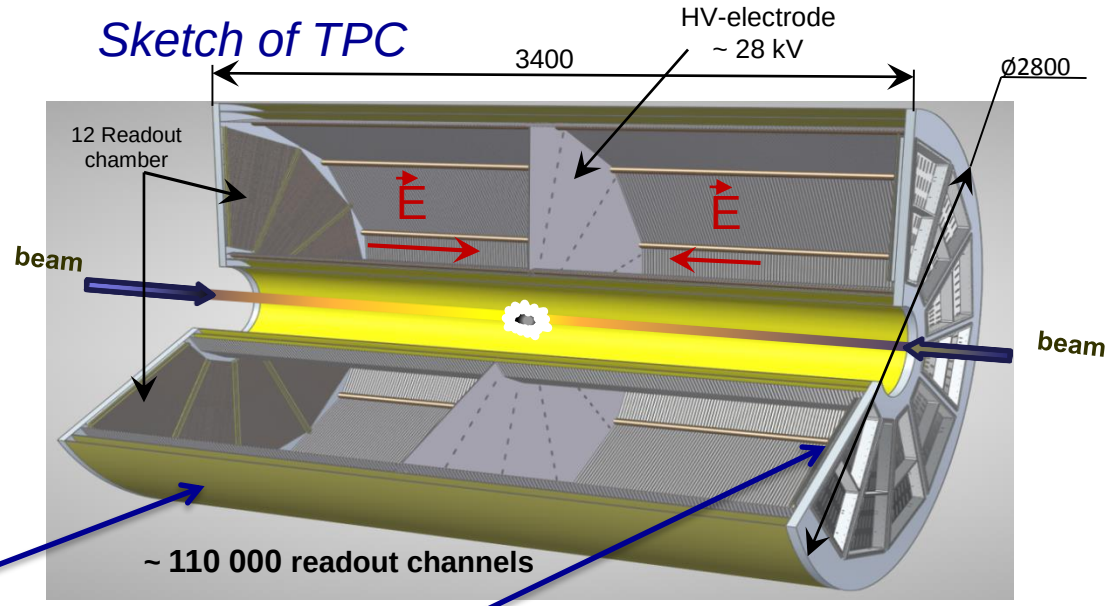
Time Projection Chamber

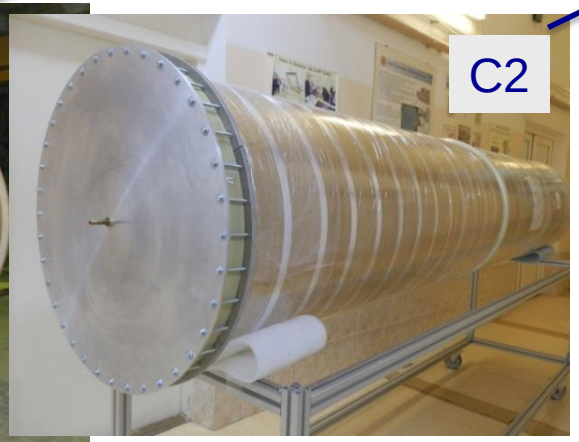
Leaders: *S. Movchan, Yu. Zanevsky*

TPC Prototype



Sketch of TPC





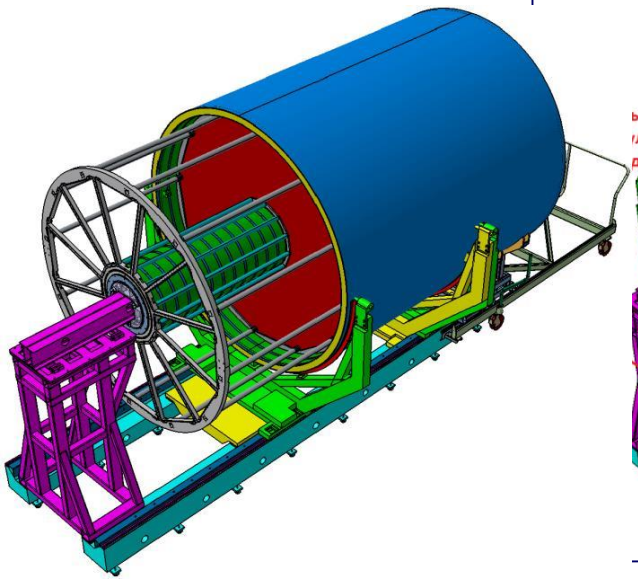
Project status:

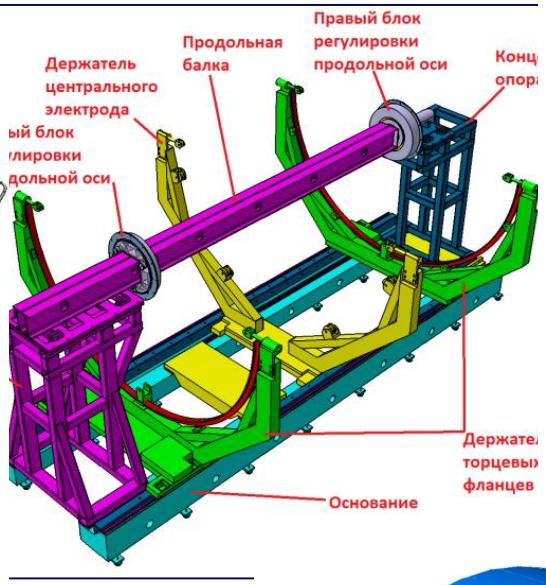
-basic R&D finished,
(cont. alternative RO Ch.);

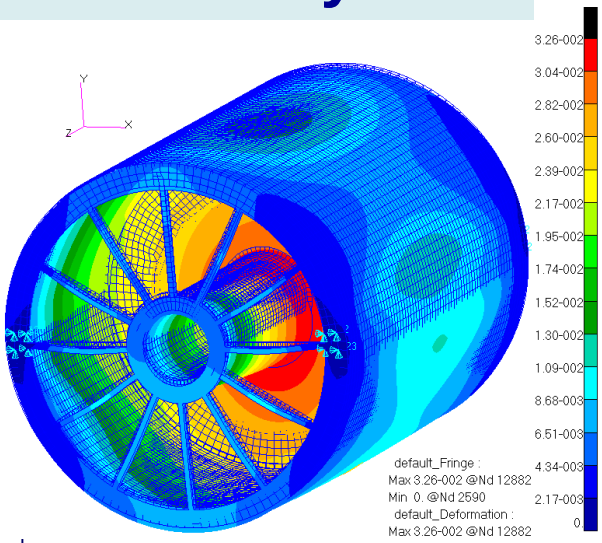
-assembly workshop
in preparation
*(readiness – **2019**)*

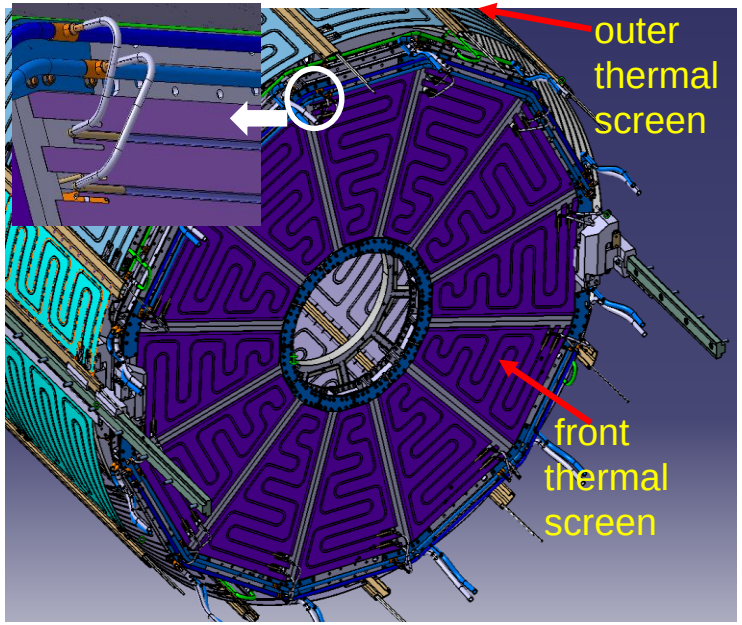
Works are going in accordance with the schedule

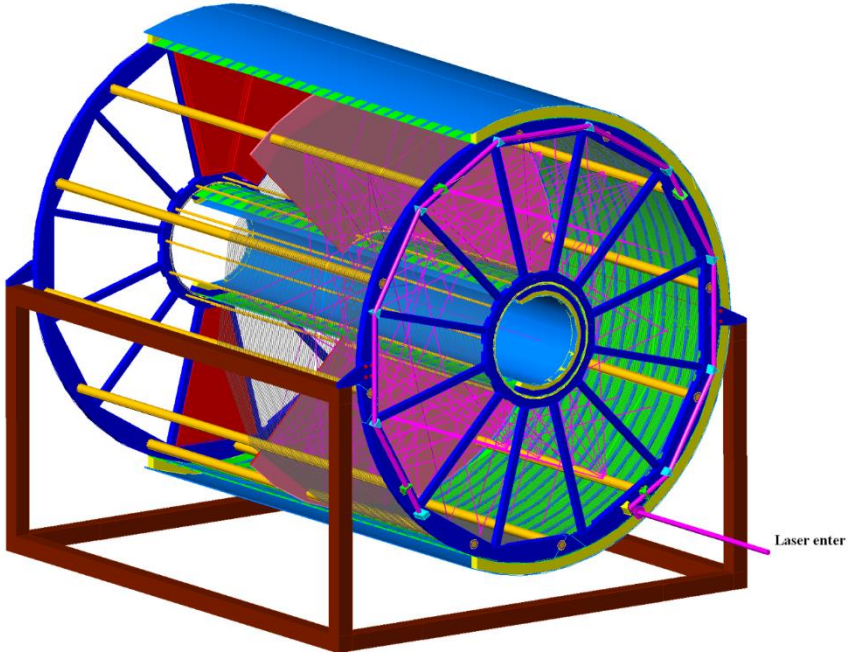
TPC assembly tools, cooling & laser calibration system





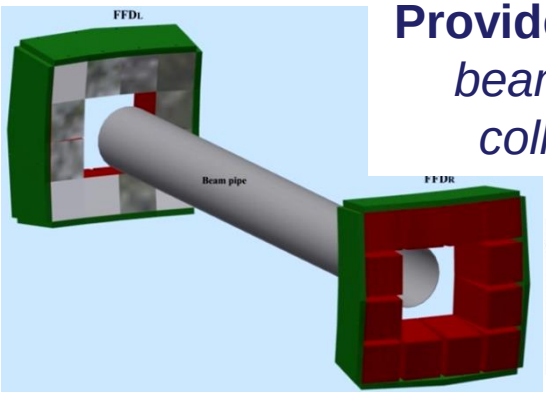




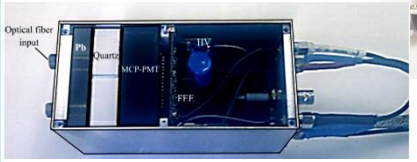


Time of Flight system (TOF)

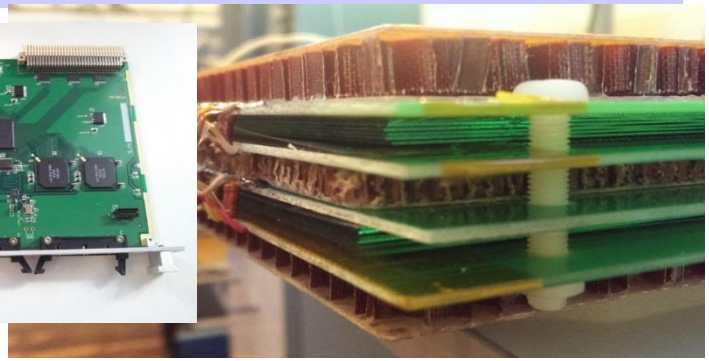
Fast Forward Detector (FFD):
production stage



Provides: *T0 for TOF, beam adjustment & collision L0-trigger*

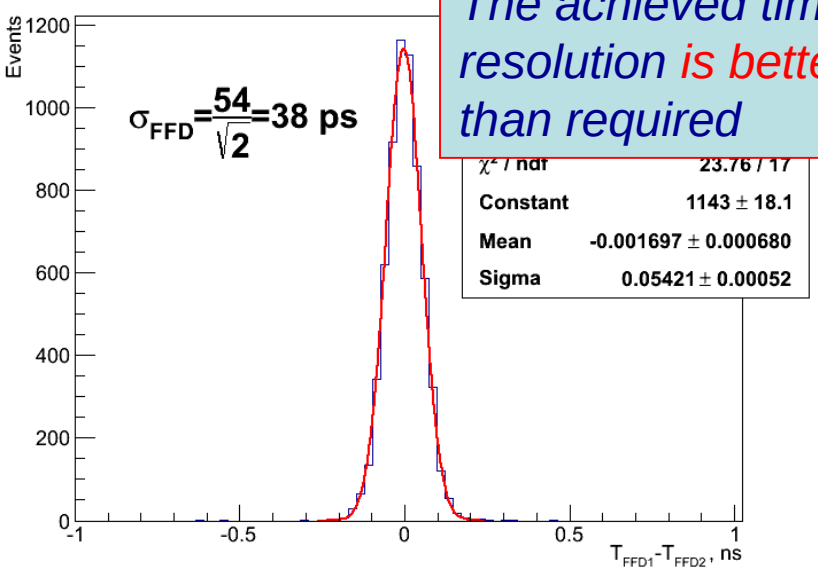


mRPC – TDR has been prepared,
ready for mass production

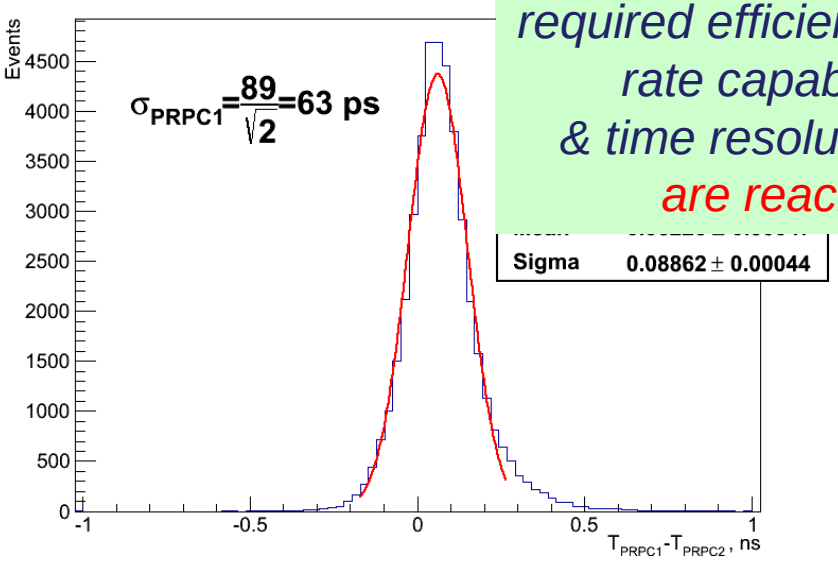


Zhu Weipinga, Wang Yi, Feng Shengqin, Wang Jingbo, Huang Xinjie, Shi Li, V. Babkin, V. Golovatyuk, M. Rumiantcev, G. Eppley, T. Nussbaum, ***NIM A 735, 277–282, 2014***

The achieved time resolution is better than required



required efficiency, rate capability & time resolution are reached

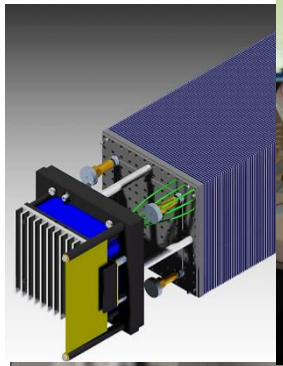


Calorimetry

ECAL – *TDR - in preparation*

L ~35 cm (~ 14 X_0), Pb+Scint. (4x4 cm^2)
read-out: WLS fibers + MAPD

Energy resolution **2.5% / √E**

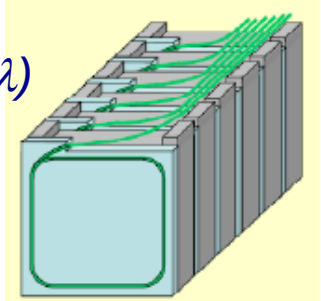


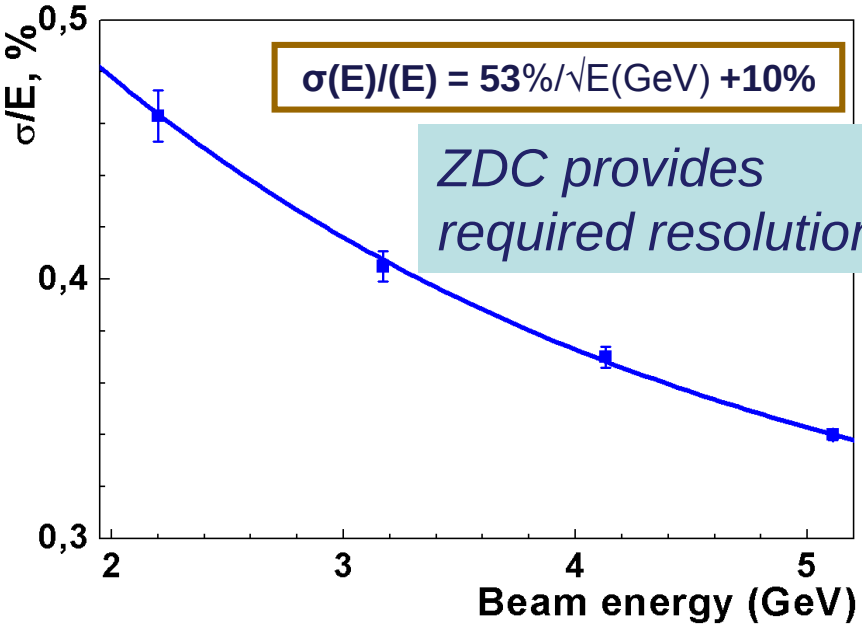
Preparation for tests with electron beams at DESY (December'13)

Zero Degree Calorimeter (ZDC): TDR stage

ZDC coverage: 3.2<|η|< 4.8

Pb-scintillator sampling (5λ)
Read-out: fibers + AvalanchePD



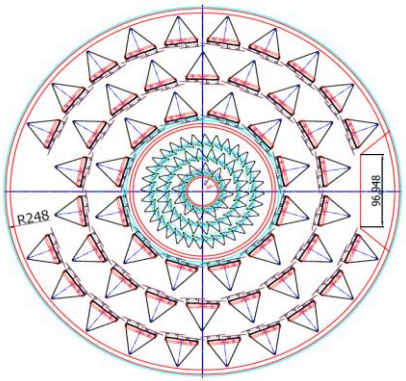


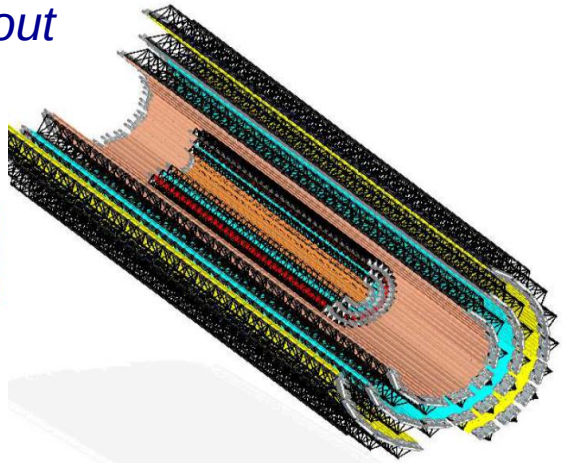
ZDC provides required resolution

Inner Tracking System

*cooperation with **CBM/FAIR**, **ALICE/CERN**:*
- *manufacturing the **ITS** carbon fiber space frames for **NICA** (BM@N & MPD)& **FAIR;***
- *construction of **ALICE type** (MAPS) **ITS***

***ITS MPD** layout*

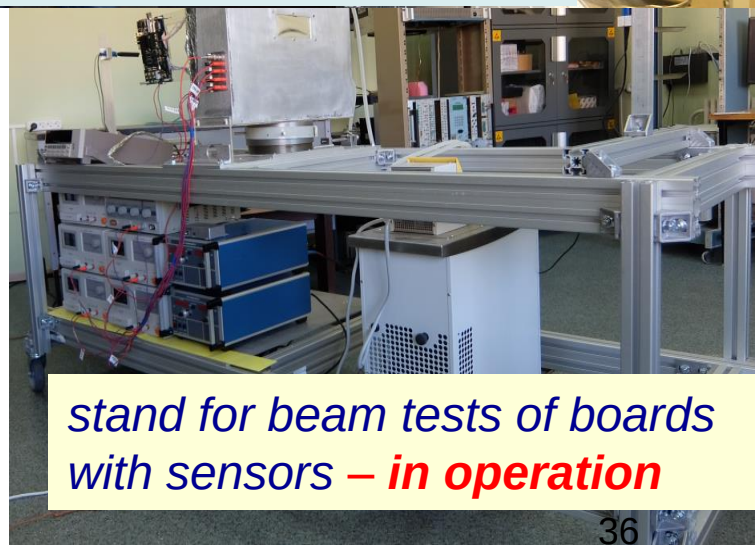




*workshop for detector assembly & test was put in operation in **2015***

D. Gross in the workshop

# layer	R0 mm	Active l, mm	N of staves	N of chips / layer	active area, cm2	number of pixel cells,
1	24,4	542,4	12	216	889,9	113 246 208
2	42,0	542,4	22	396	1 087,7	207 618 048
3	60,0	542,4	32	576	1 582,1	301 989 888
4	107,	1477,5	12	2 352	4 845,1	1 233 125 376
5	156,5	1477,5	18	3 528	7 267,7	1 849 688 064
6	206,5	1477,5	24	3 920	9 690,2	2 055 209 960
Total:				10 988	25 362,7	5 760 877 544



*stand for beam tests of boards with sensors – **in operation***

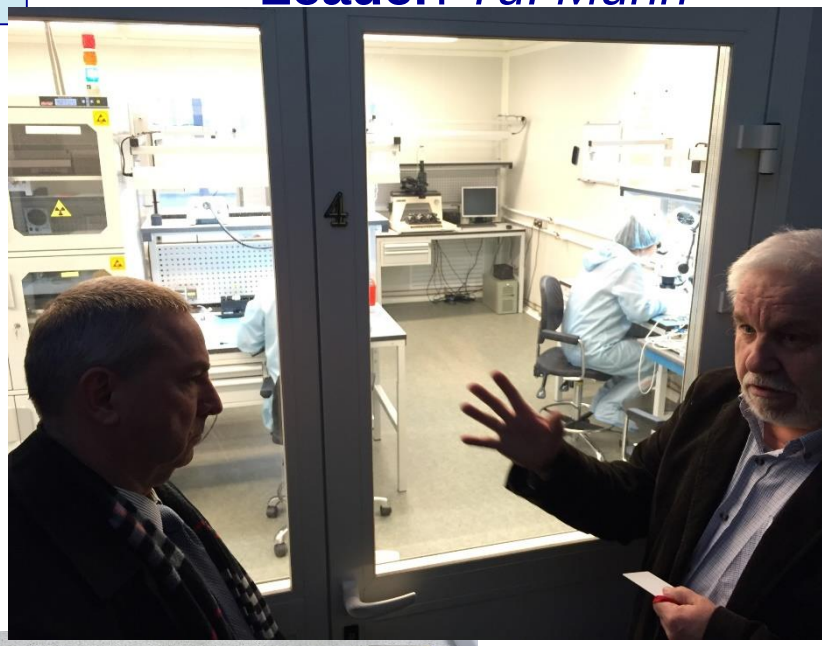
Workshop for microstrip detector assembly & test

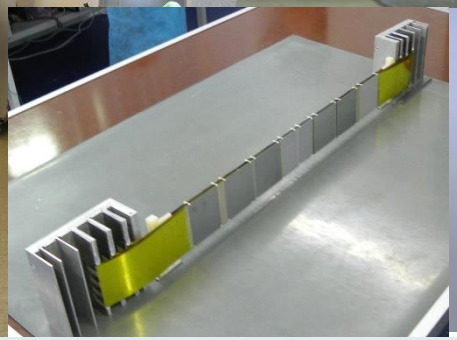
CBM-MPD Consortium

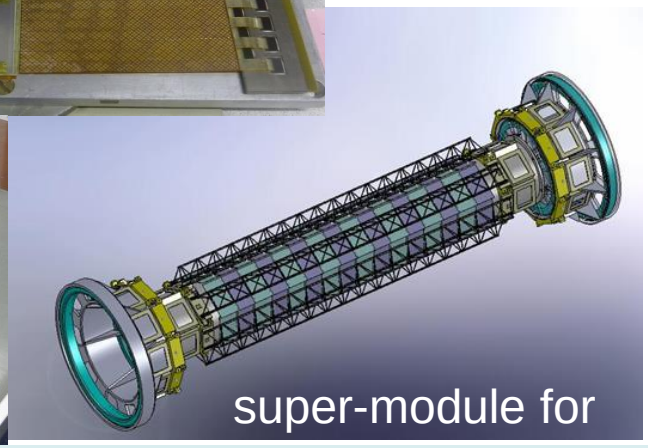
Leader: *Yu. Murin*

the clean workshop
has started operation in 2015.

CERN *&* ***JINR*** *have signed* ***MoU*** *for manufacturing the STS carbon fiber frames for* ***NICA*** *(BM@N & MPD)*
and ***FAIR*** *(CBM)*

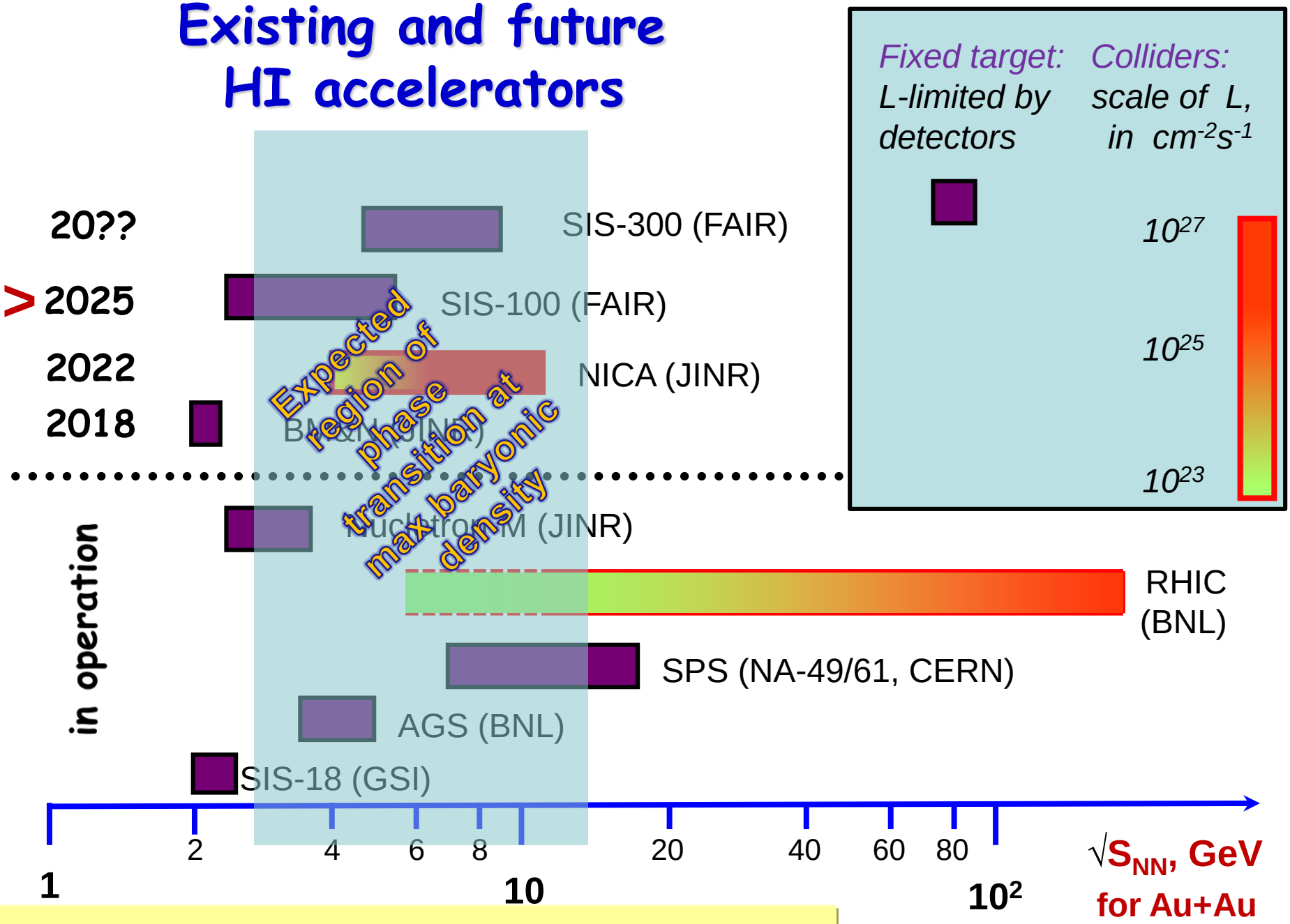






project is supported by the **CREMLIN** grant *(framework of HORIZON-2020)*

Existing and future HI accelerators

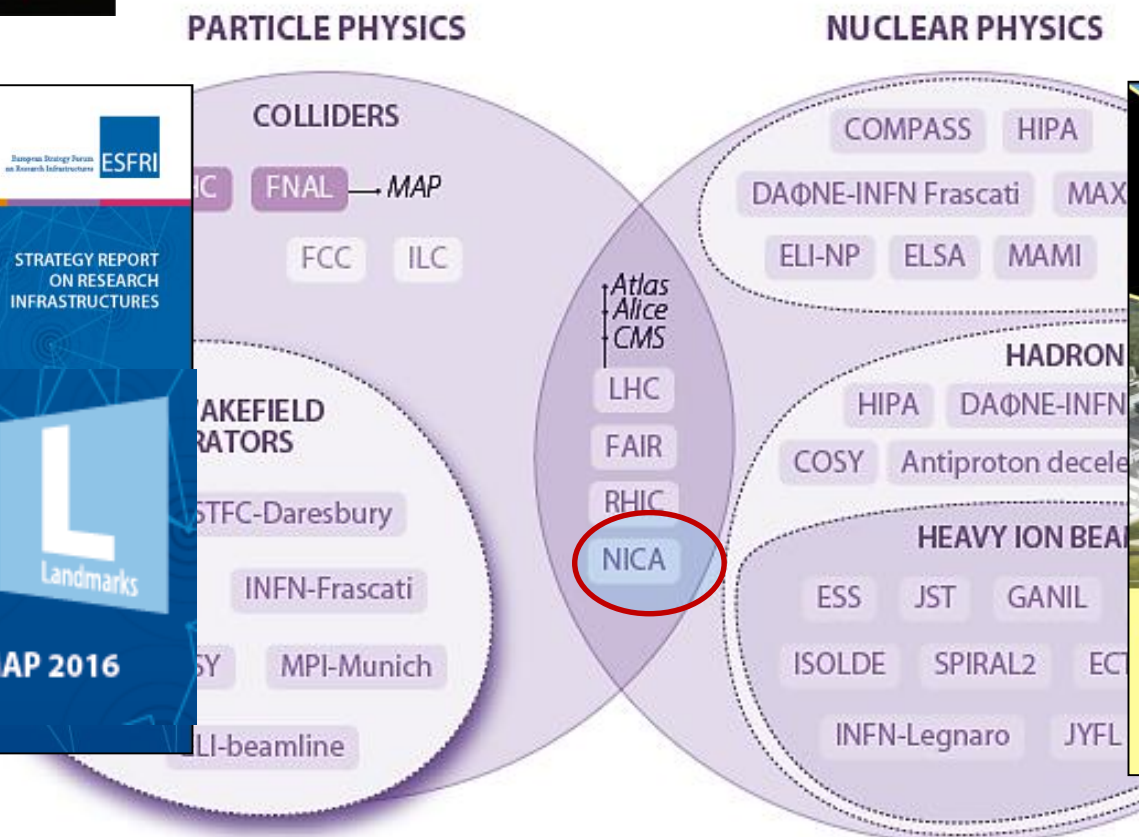


FAIR – NICA co-operation agreement

BARYONIC MATTER DENSITY FRONTIER

NICA is included in the ESFRI ROADMAP-2016 and in the NuPECC Long Range Plan 2017 - Perspectives in Nuclear Physics

Main Research Infrastructures in Particle and Nuclear Physics



NICA - FAIR – Complementary Projects

The kick-off meeting on formation of the MPD and BM@N Collaborations

took place in Dubna on 11-13 April, 2018.

detailed information about the meeting can be found at:
https://indico.jinr.ru/conferenceDisplay.py?confId=385

“Team for the future of NICA”

Attracting students and young staff from the member states to work for NICA

Grant support for initiative teams of physicists from Russian Institutes, Universities and scientific organizations

Russian Foundation for Basic Research

An open competition:
Fundamental properties of the baryon and quark-gluon matter phase transition – mega-science project "Complex NICA"

Period of the grant:	***3 years***
Maximal grant size:	***6 M roubles/year***
Minimal grant size:	***3 M roubles/year***

97 proposals were submitted.

According to independent evaluation,

36 projects were supported.

РОССИЙСКИЙ ФОНД ФУНДАМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ
РФФИ

Results at: http://www.rfbr.ru/rffi/ru/rffi_contest_results/o_2083349

"NAUKA" NATIONAL PROJECT

Decree of the President of RF № 204 on 7 May, 2018

TIMELINE: 01.10.2018 – 31.12.2024

GOALS AND TARGETS:

1. Ensuring the presence of the Russia among the 5 leading countries engaged in R&D in priority areas of science and technology development.
2. Ensuring the attractiveness of employment in Russia for Russian and foreign leading scientists and distinguished young researchers.
3. Advanced increase of internal R&D expenditures using all possible sources in comparison with the growth of the gross domestic product of the country.

Budget of the "NAUKA" National Project

Development of the scientific and industri cooperation. — 215,0

Development of the advanced infrastructu for R&D in Russia. — 350,0

Development of the human resources for R&D. — 70,9

2020	Establishing 4 world-class international mathematical centers. Establishing 3 world-class genomic research centers. Beginning of international research at the megascience facility of the International Center for Neutron Research (based on the PIK high-flux reactor).
2021	Establishing 3 world-class research centers for R&D in priority fields of scientific and technological development.
2022	Holding of 29th World Mathematical Congress (St. Petersburg) **Beginning of international research at the megascience facility "The complex of superconducting rings on colliding heavy ion beams – NICA".**
2024	**The operation of 3 national bioresource network centers.** **International research at megascience facilities "The 4th generation synchrotron radiation source (ISSI-4) and the Siberian Ring Photon Source (SKIF) (first stage)".** Translation support tools will be formed and the systems of technology transfer as well as research protection, research management and intellectual property issues will be organized that ensures a rapid transition of scientific results to the practical application stage. The developed technologies will be implemented into organizations operating in the real sector of the economy. A set of measures will be formed on orientating government customers to purchasing the high-tech and innovative products developed on the basis of Russian technologies.

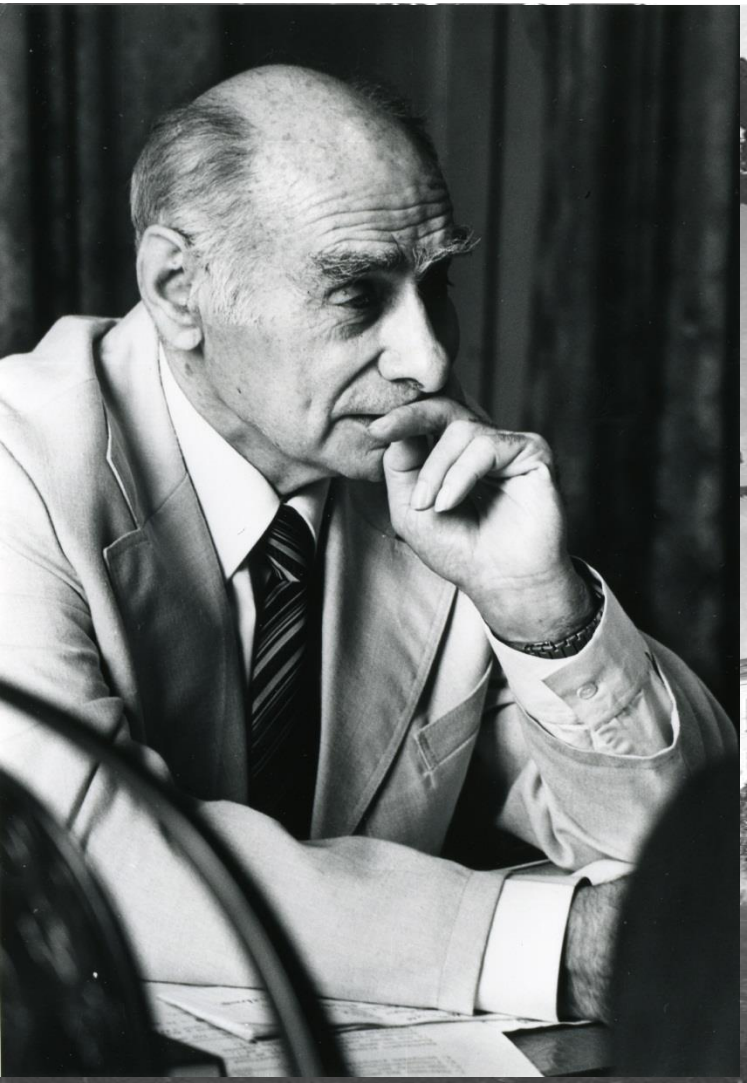
SUPERVISOR
T. GOLIKOVA
Deputy Prime Minister of Russia

HEAD
M. KOTYUKOV
Minister of Science & Higher Education, Plenipotentiary of Russia at JINR

ADMINISTRATOR
A. MEDVEDEV
Deputy Minister of Science & Higher Education

Nuclear Physics at Low energies
Physics of Supper Heavy Elements
Neutron reach or Exotic nuclei
Physics of extreme strong Coulomb fields

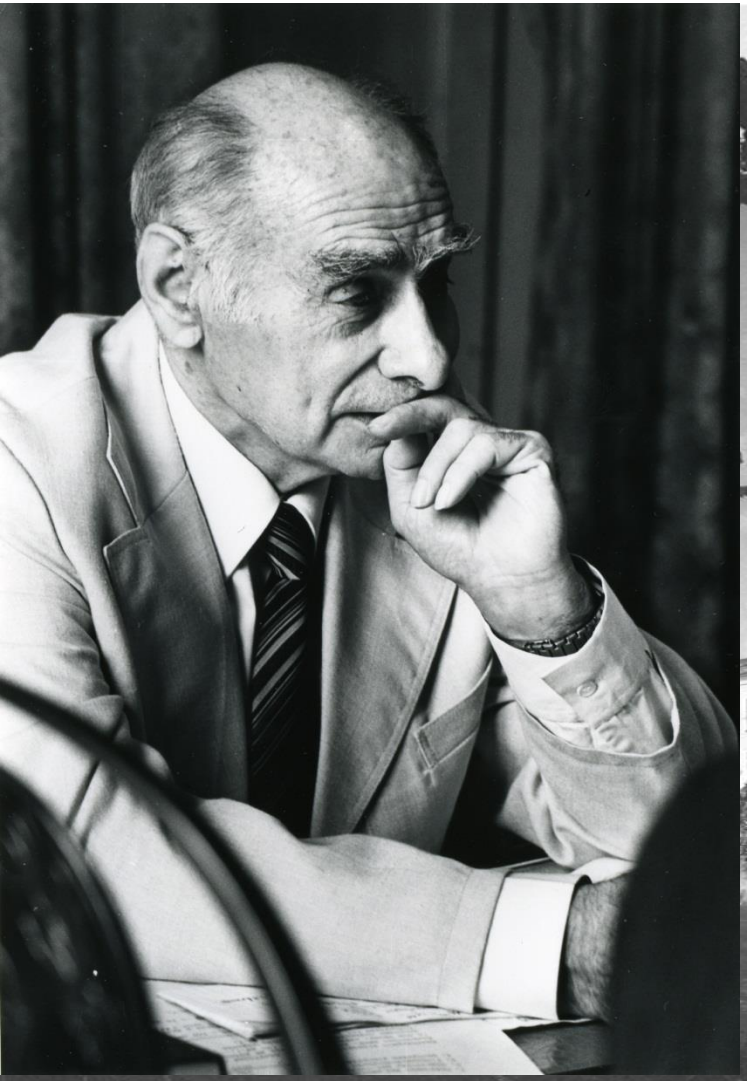
Ac. G.N. Flerov, JINR Lab. of Nuclear Reactions under his name



Lab. founded in 1957

FLEROV LABORATORY of NUCLEAR REACTIONS

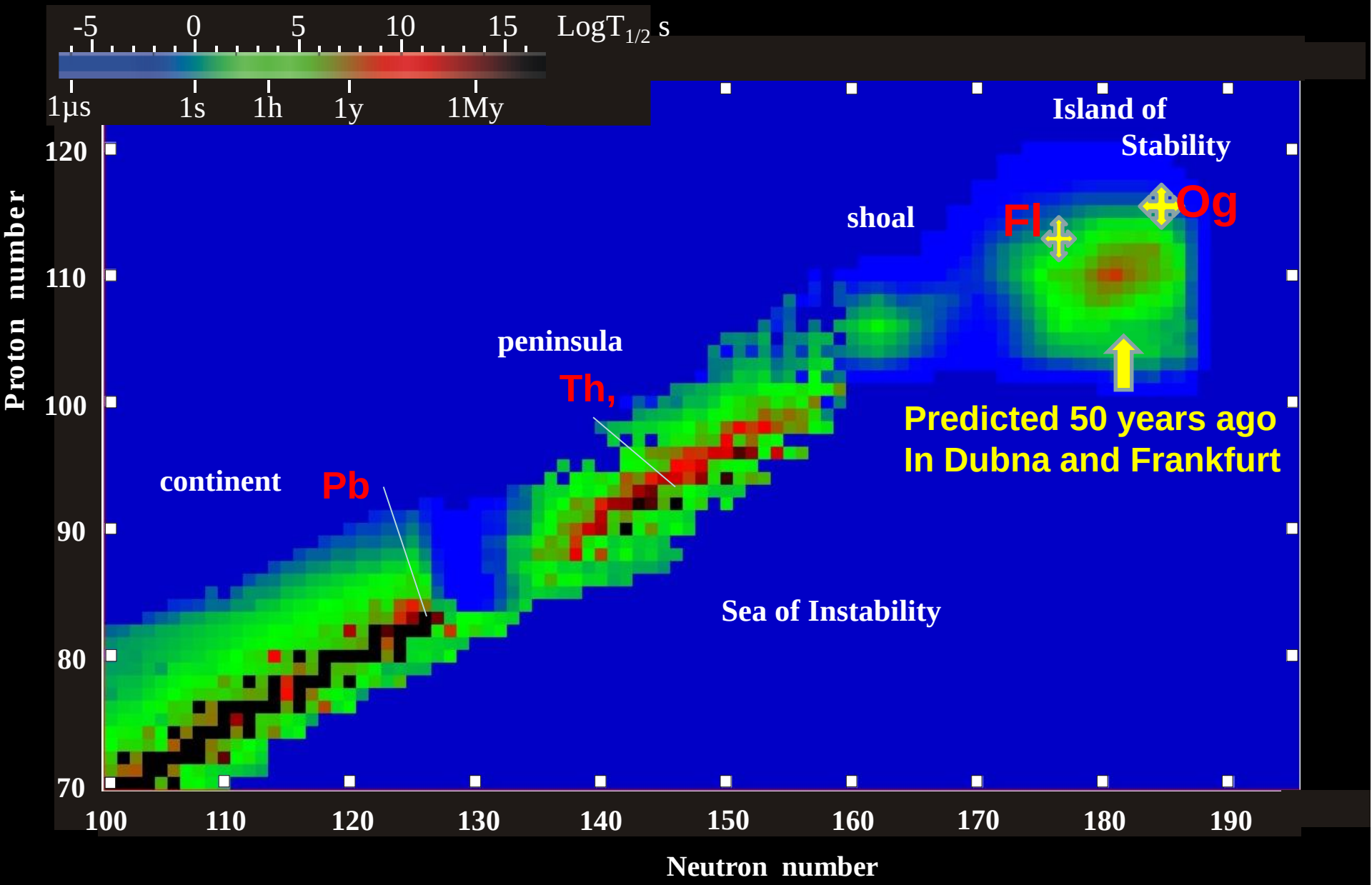
Ac. G.N. Flerov, JINR Lab. of Nuclear Reactions under his name



Lab. founded in 1957

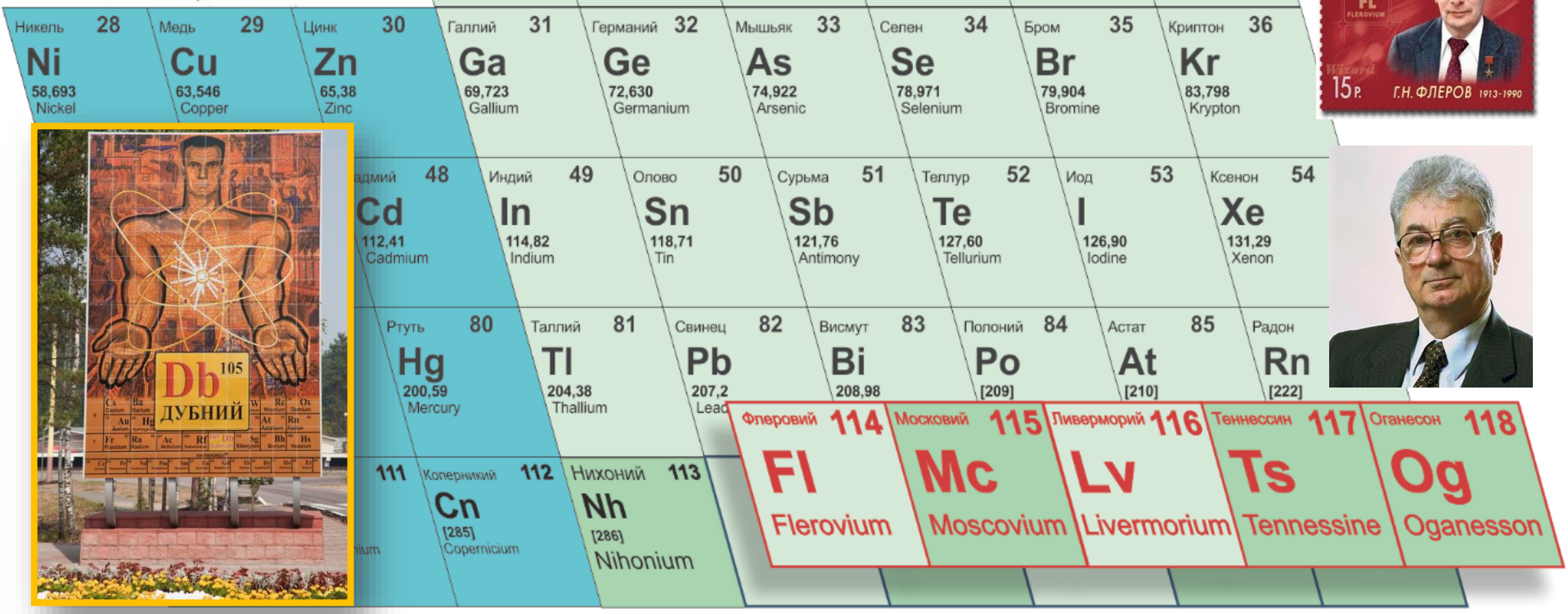
FLEROV LABORATORY of NUCLEAR REACTIONS

New lands Search for new Island of Stability

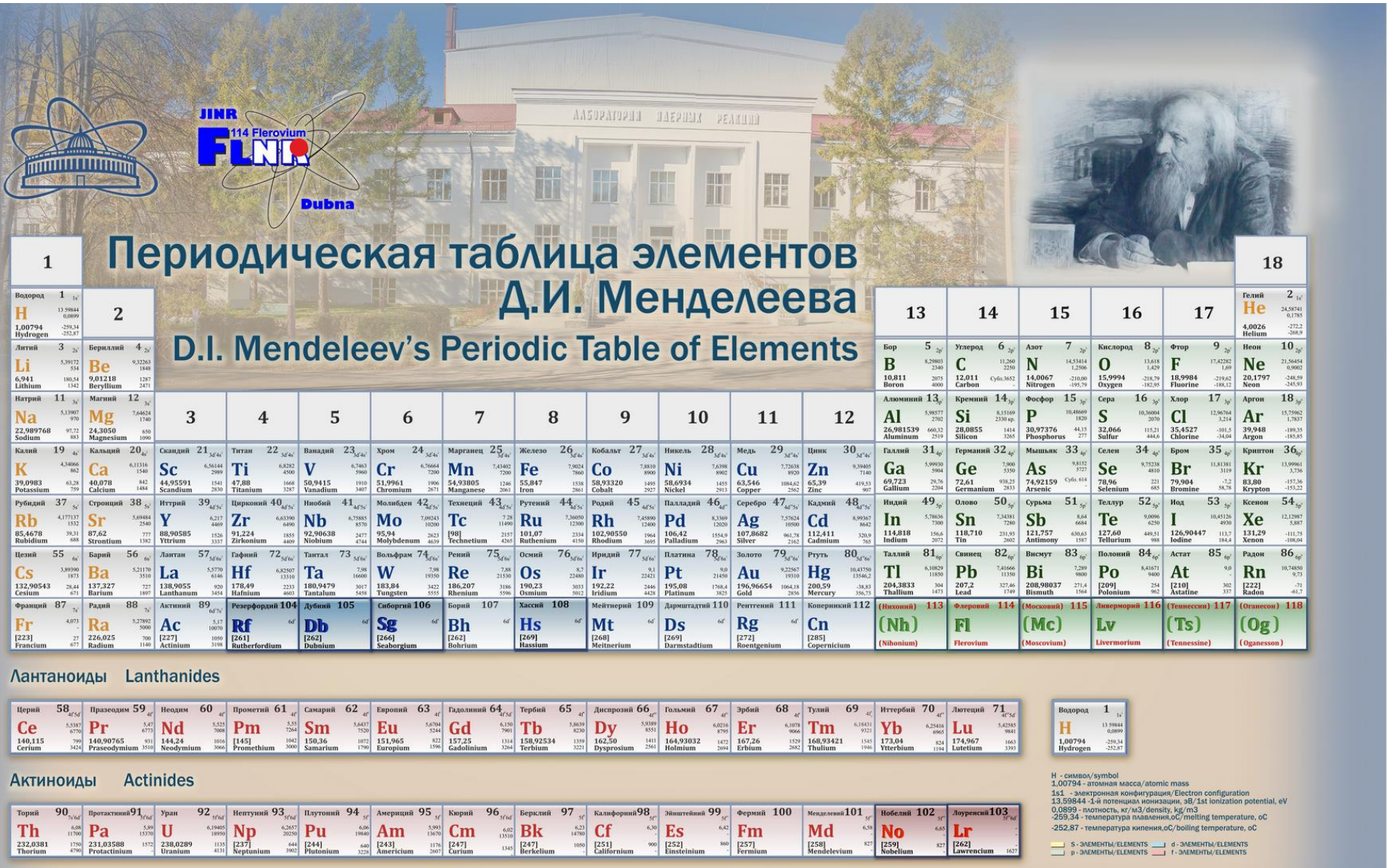


D.I. Mendeleev's Periodic table of elements

105
Db
Dubnium



Mendeleev’s Table Today



11 of 18 elements discovered during last 60 years

were first synthesized in Dubna

2019: International Year of the Periodic Table of Chemical Elements (IYPT)

United Nations
Educational, Scientific and
Cultural Organization

In support of

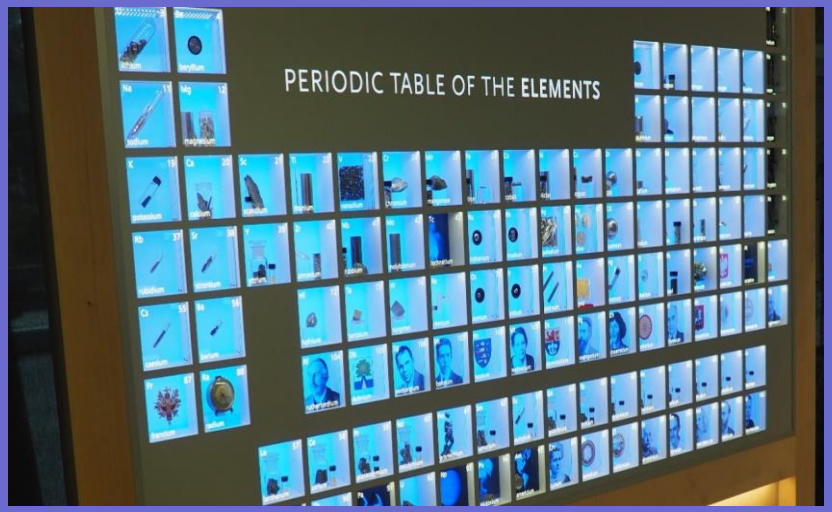
2019
IYPT

International Year
of the Periodic Table
of Chemical Elements

Inauguration of the International Year of the Periodic Table of Chemical Elements

DG of UNESCO Ms. Audrey Azoulay

Nobel Prize Laureate
Ben Feringa



Yu.Ts. Oganessian

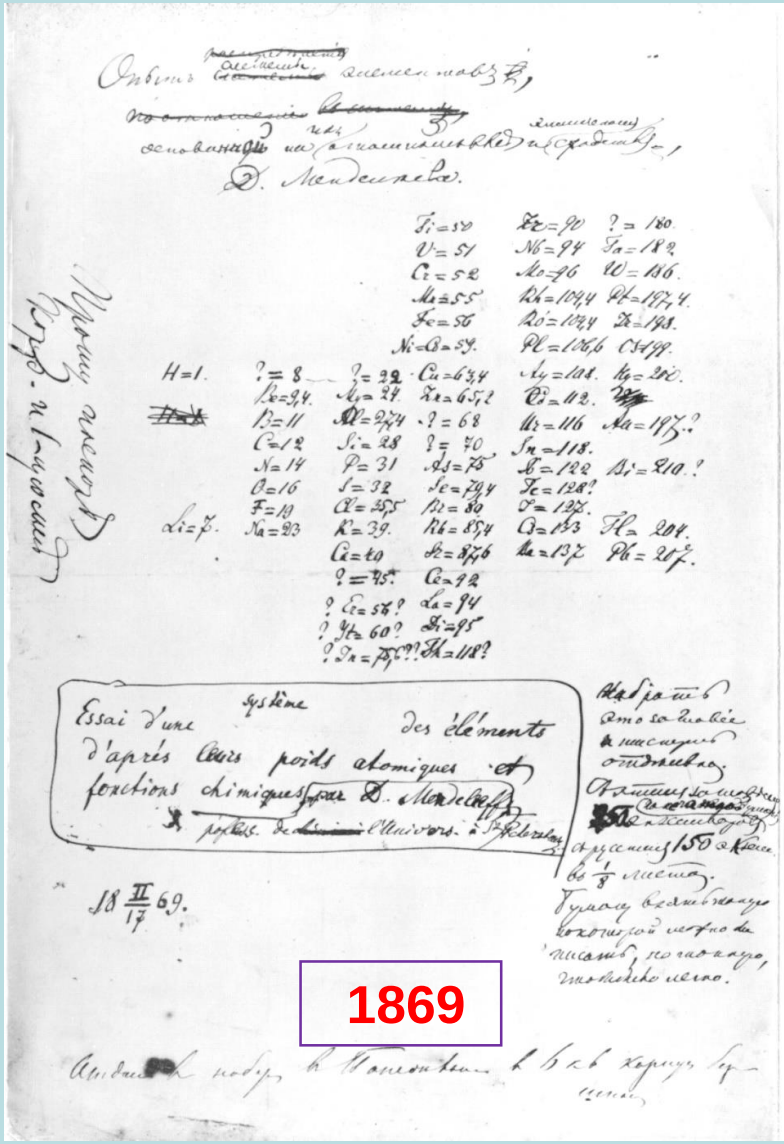
United Nations Educational, Scientific and Cultural Organization

2019 IYPT

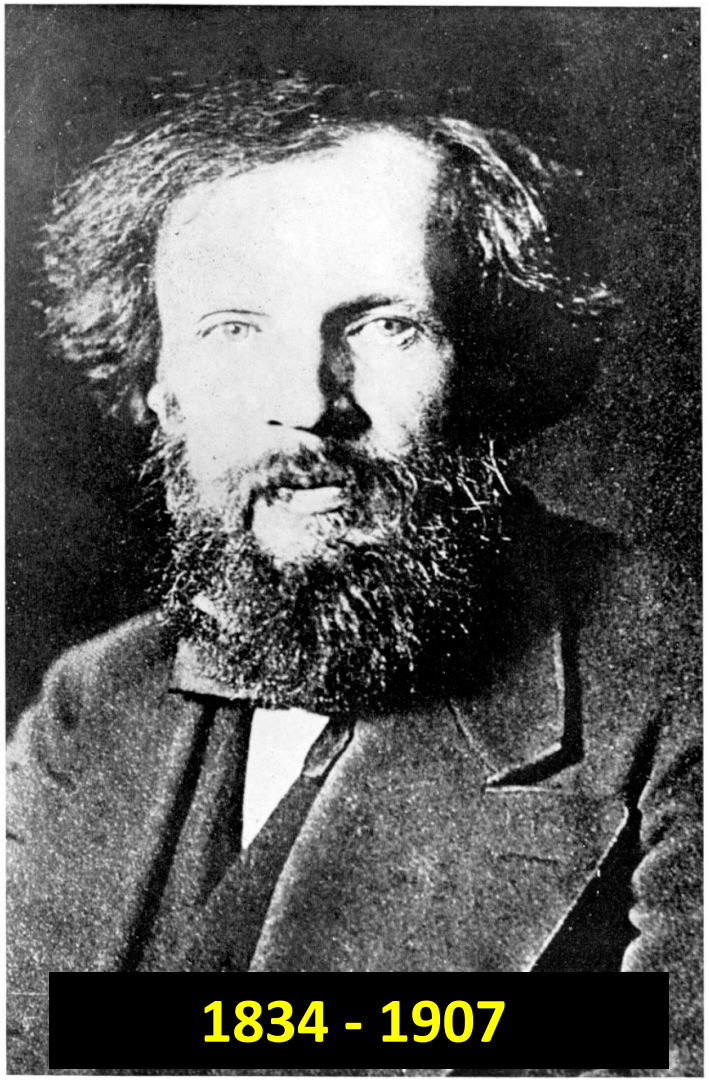
International Year of the Periodic Table of Chemical Elements

IYPT Opening ceremony at UNESCO,
29 January 2019, Paris

Physics of SHE – testing the triumph of the Mendeleev Periodic Law connecting the chemical properties of elements with their atomic numbers



1869



1834 - 1907

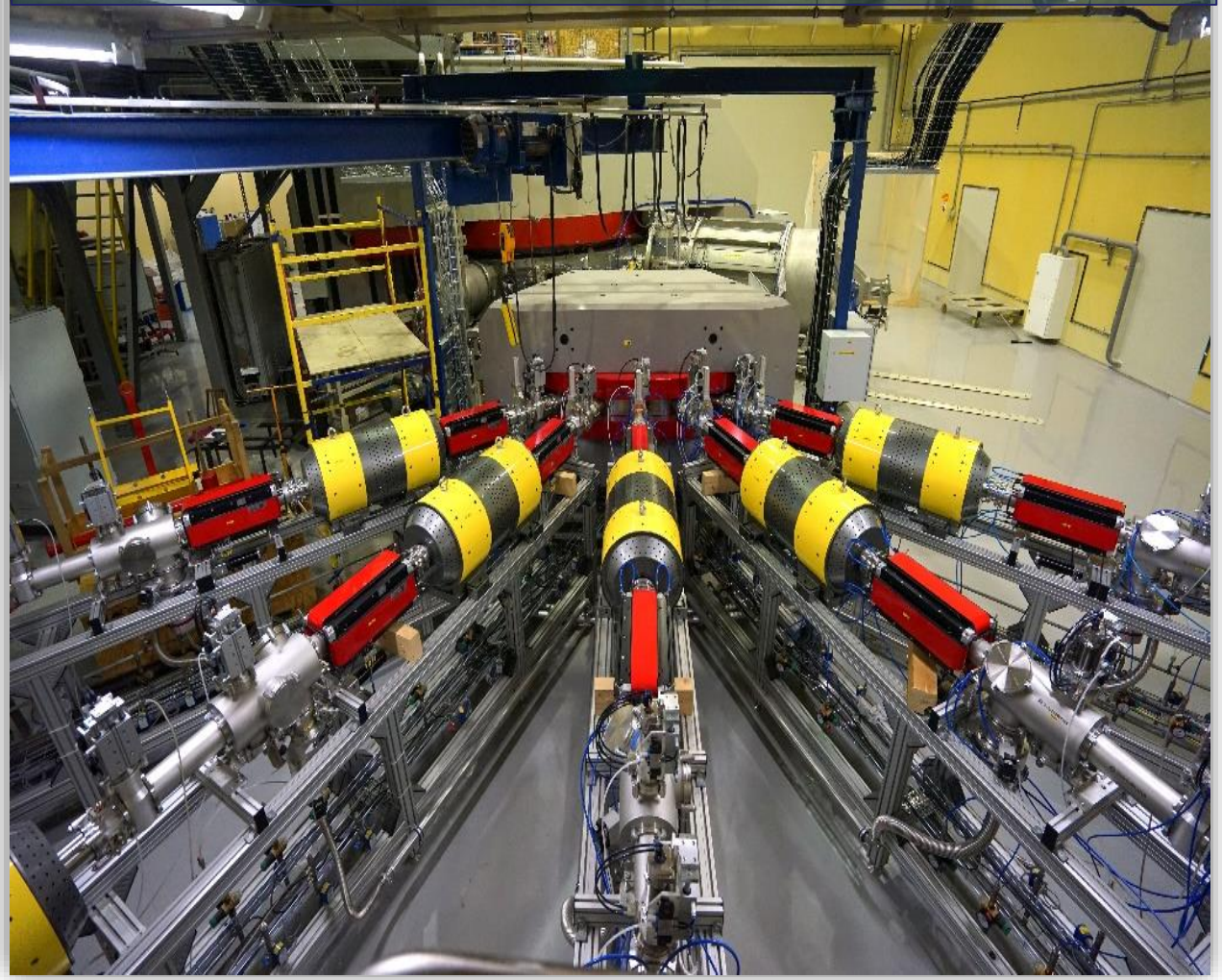
Commissioning of the Super Heavy Elements Factory

SHE Factory building

Gas-Filled Recoil Separator

DC-280 cyclotron:

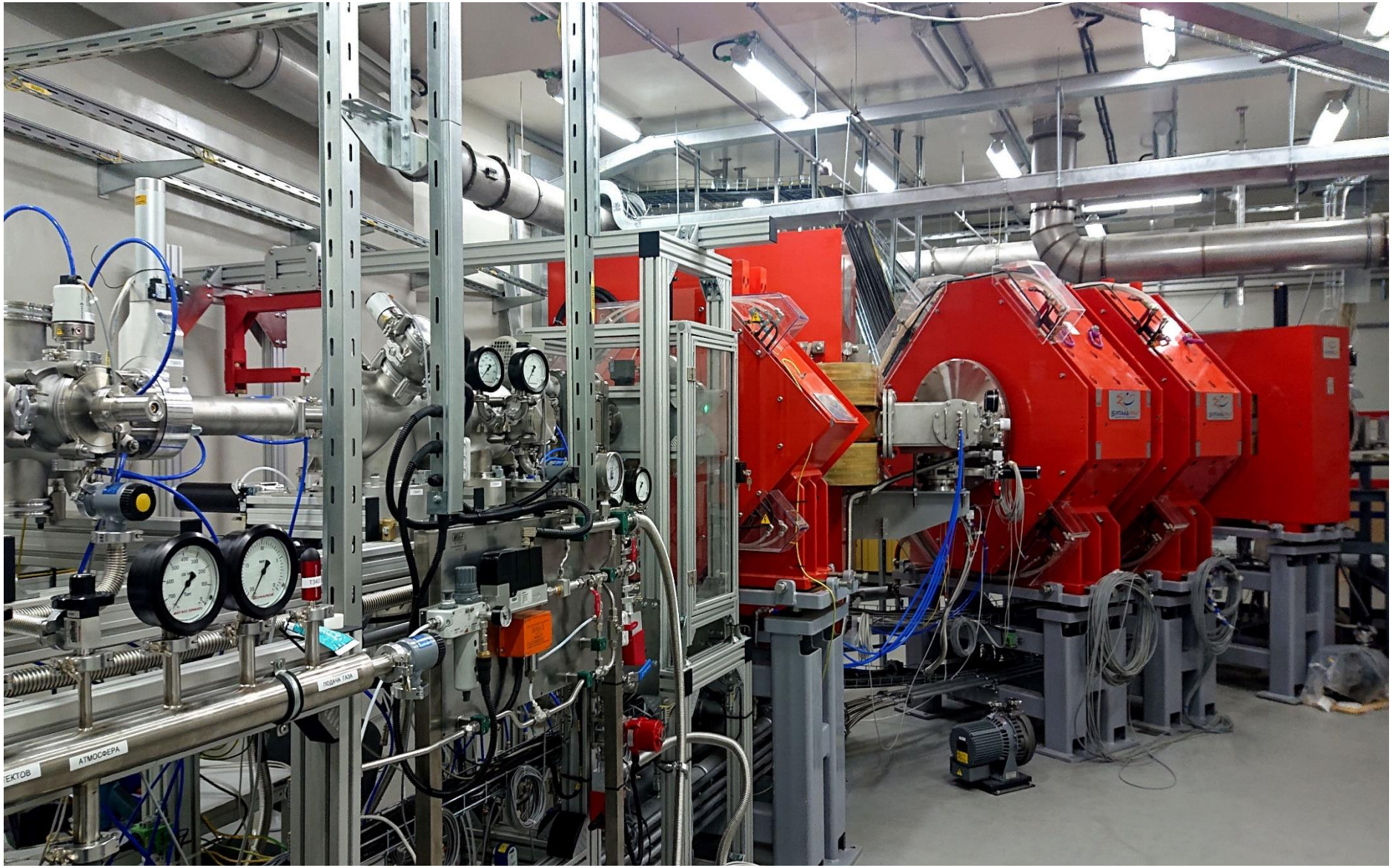
(26 December 2018-first test beam)



Ions	Intensity of ion beams
^{20}Ne	$1 \cdot 10^{14}$
^{48}Ca	$6 \cdot 10^{13}$
^{50}Ti	$3 \cdot 10^{13}$
^{70}Zn	$2 \cdot 10^{13}$
^{86}Kr	$3 \cdot 10^{13}$
^{100}Mo	$2 \cdot 10^{12}$
^{124}Sn	$2 \cdot 10^{12}$
^{136}Xe	$2 \cdot 10^{13}$
^{208}Pb	$1 \cdot 10^{12}$
^{238}U	$1 \cdot 10^{11}$

The new cyclotron of heavy ions DC-280

Gas-Filled Recoil Separator GFS-II



Gas-Filled Recoil Separator GFS-II

Opening of the SHE Factory building and DC-280

March 25, 2019

Status of the Factory of Superheavy Elements: Programme of Day-1 experiments at the SHE Factory

Synthesis of new element 120

Synthesis of new element 119

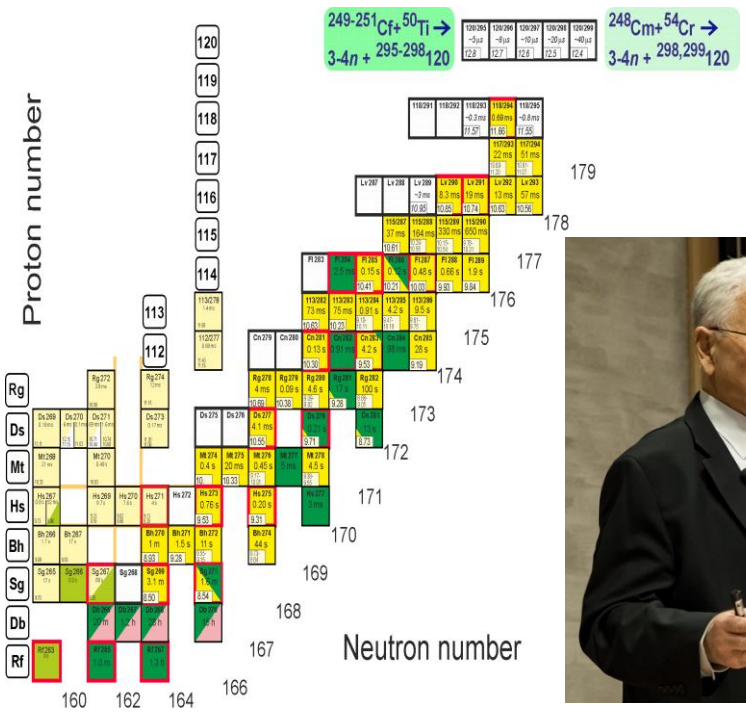
σ=50 fb, h_t=0.3 mg/cm^2, ε_{coll}=0.6, I_{beam}=3 pμA $\rightarrow \approx$1 event per month

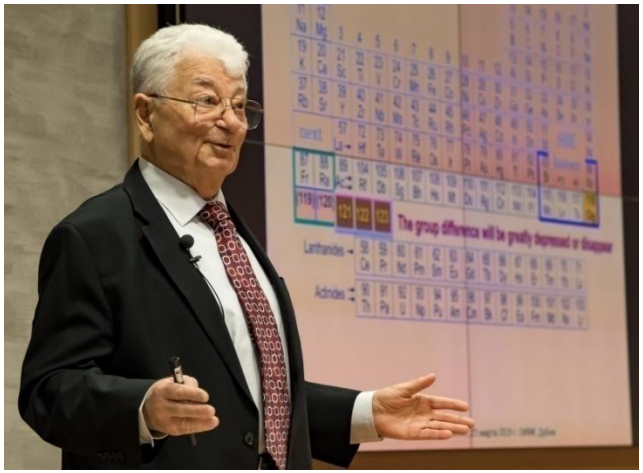
^{249}Cf(^{50}Ti,3-4*n*)^{295,296}120

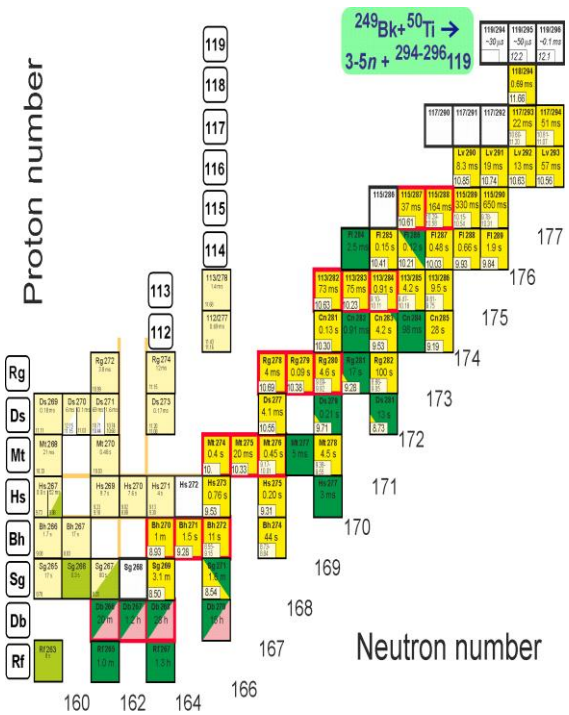
^{251}Cf(^{50}Ti,3-4*n*)^{297,298}120

^{248}Cm(^{54}Cr,3-4*n*)^{298,299}120

^{249}Bk(^{50}Ti,3-4*n*)^{295,296}119

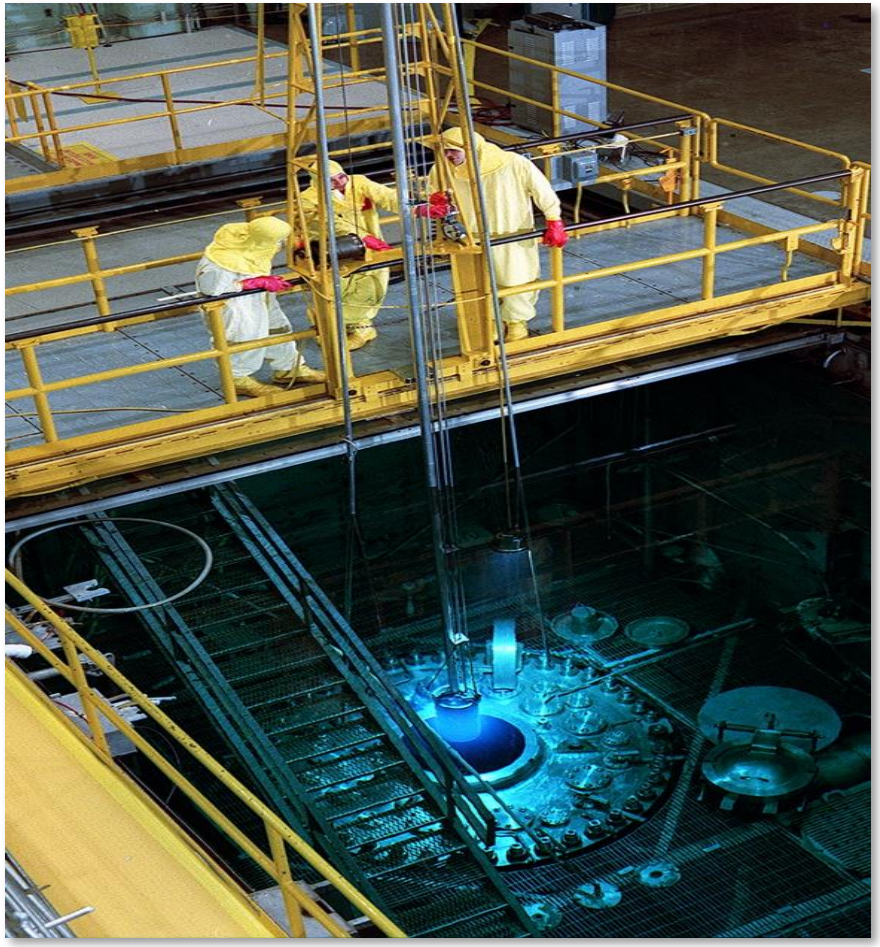




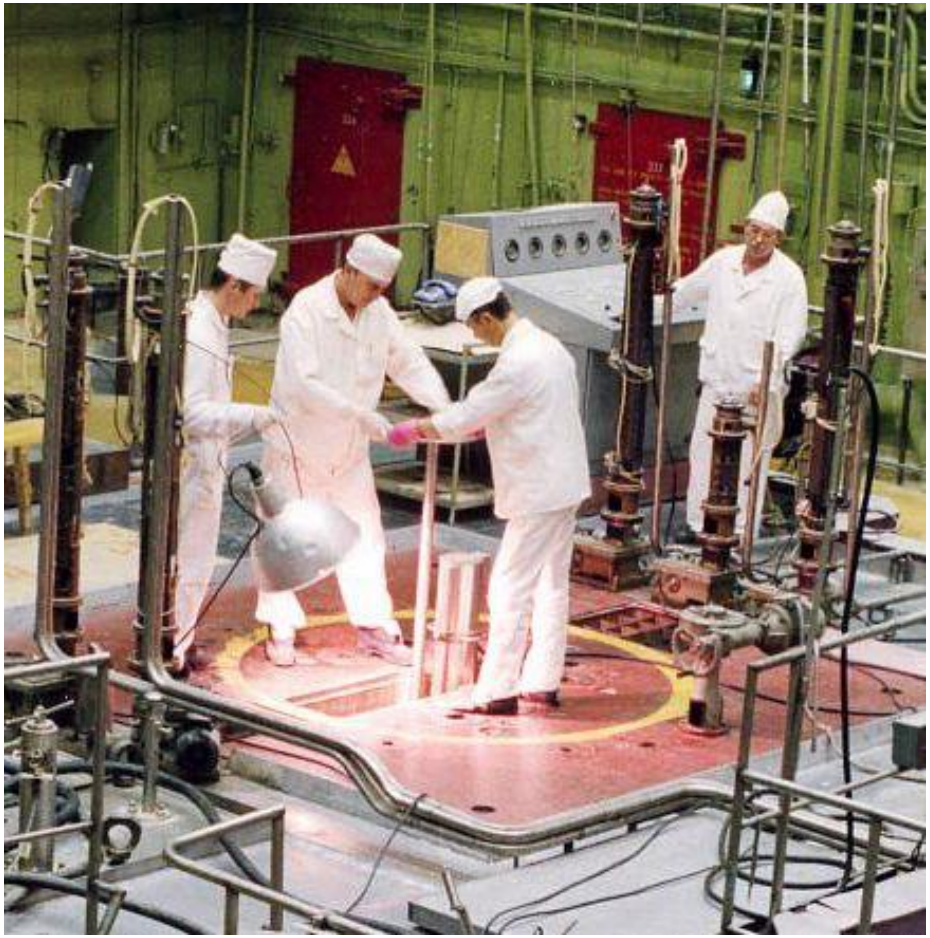


Isotope production in the reactors for the targets

HFIR, ORNL, Oak Ridge, USA, 85 MW

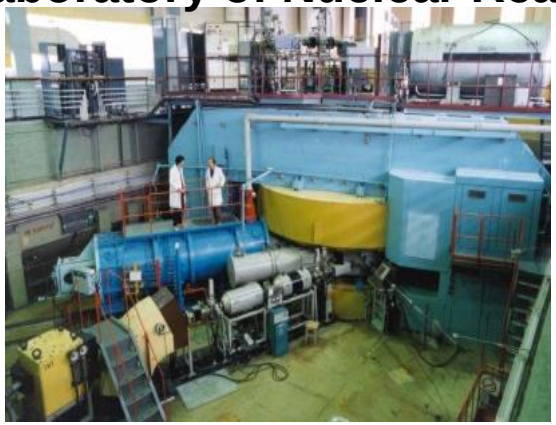


CM-3, IAR, Dimitrovgrad, RF, 100 MW



DRIBs – Dubna Radioactive Ion Beams complex

Flerov Laboratory of Nuclear Reactions



Empty "thematic niche" in the RIB research infrastructure

Storage ring physics with RIBs

Studies of RIBs in electron-RIB collider

RIB storage ring

Isochronous mass spectrometry

Precision reaction studies on internal gas jet target

Atomic physics studies with striped ions

Radioactivity studies with striped ions

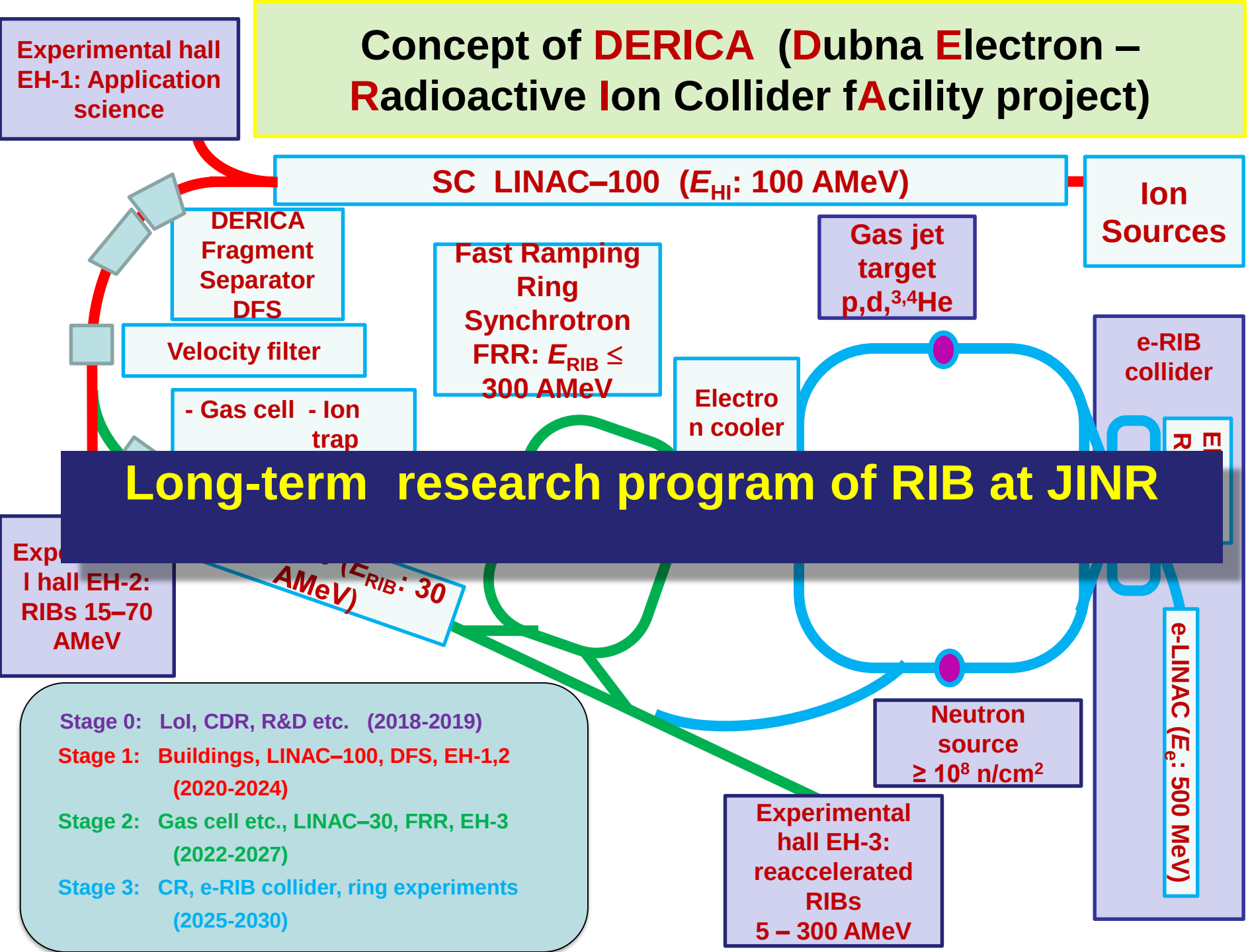
?

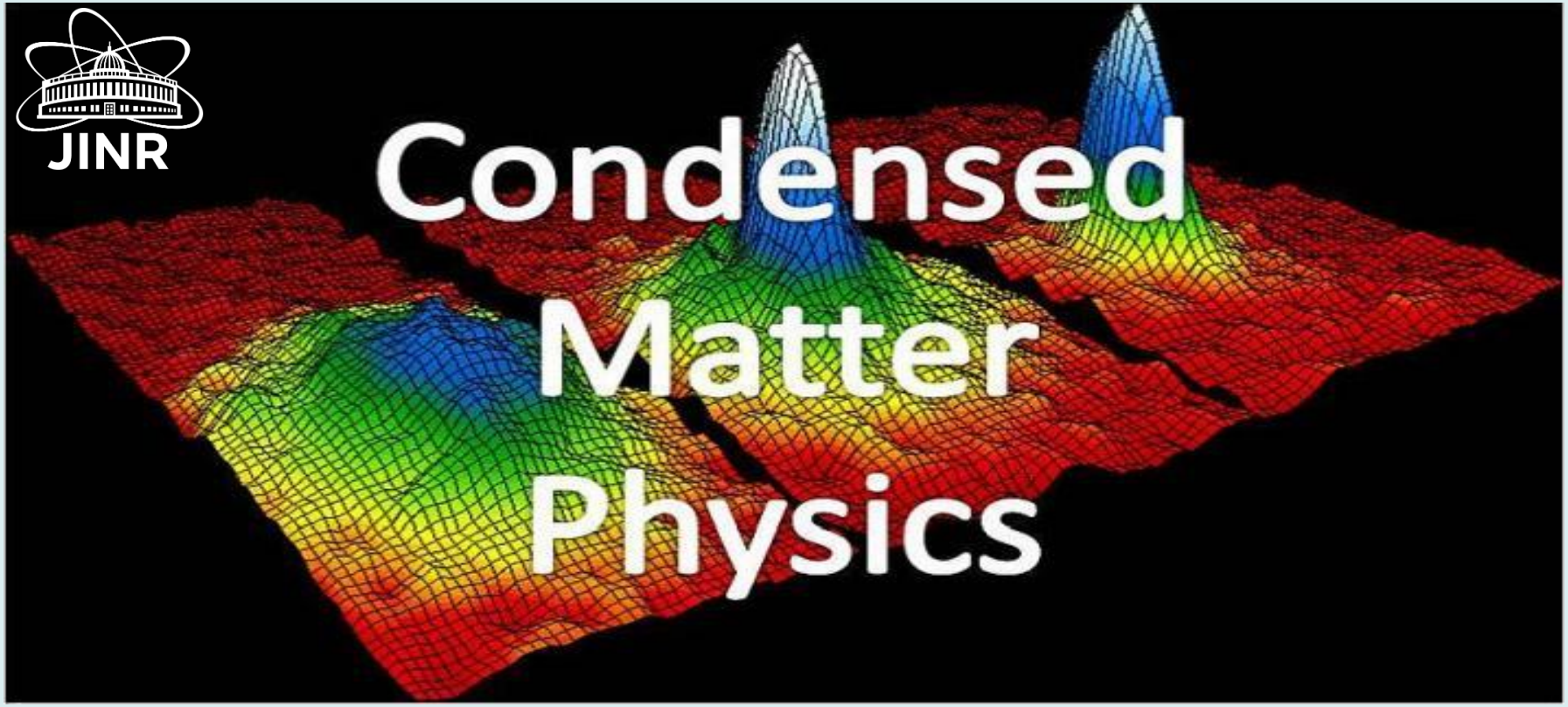
electron storage ring

Studies of electromagnetic form factors of exotic nuclei in e-RIB collider

New applications

Concept of DERICA (Dubna Electron – Radioactive Ion Collider fAcility project)

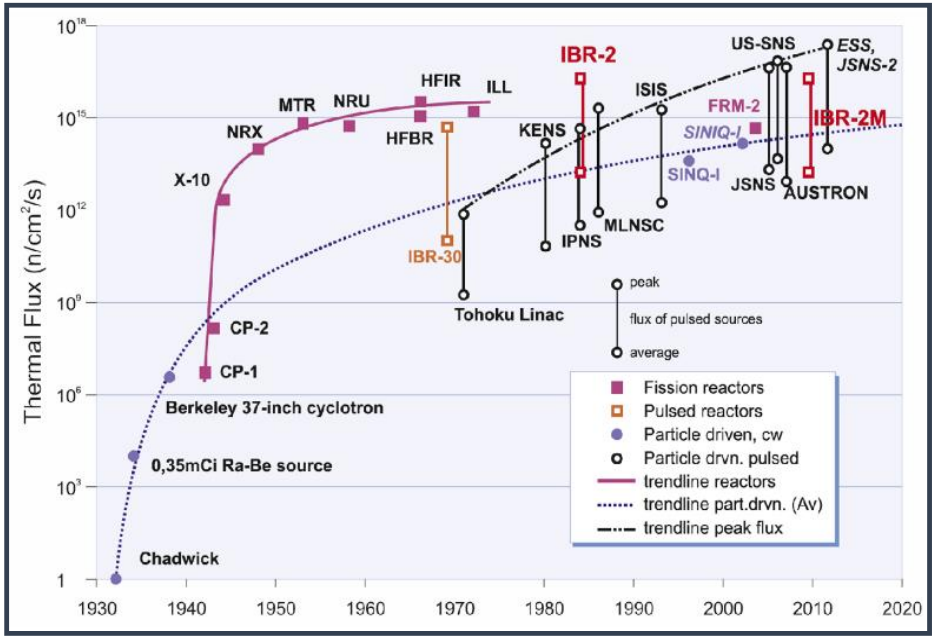




Neutron scattering & Nuclear Structure
Life Science Problems
Radiobiology & Astrobiology
Nuclear Ecology & Cosmic Medicine

IBR-2M pulsed research reactor

mean power: ***2 MW***
pulse frequency: ***5 Hz***
pulse width for fast neutrons: ***200 μs***
thermal neutrons flux density on the moderator surface: ***10^{13} n/cm^2 /s***
maximum in pulse: ***10^{16} n/cm^2 /s***

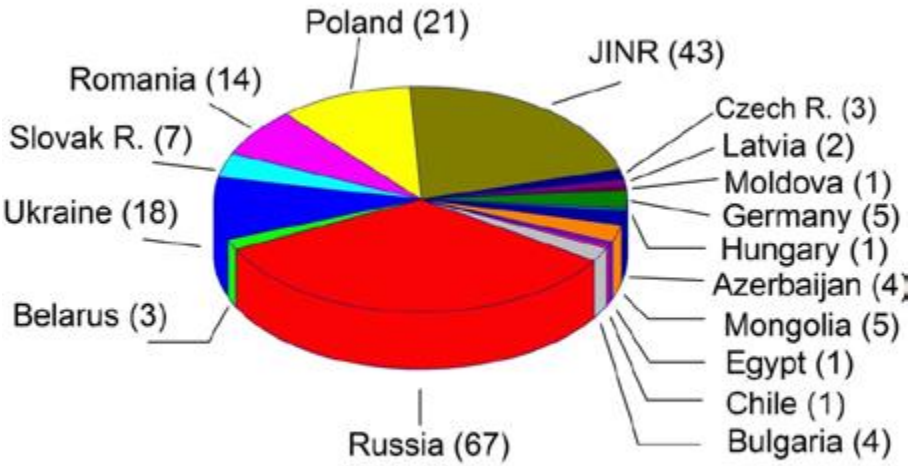


IBR-2M is one of the best sources of the thermal neutrons and its program is a part of the European strategic research program in the field of neutron scattering.

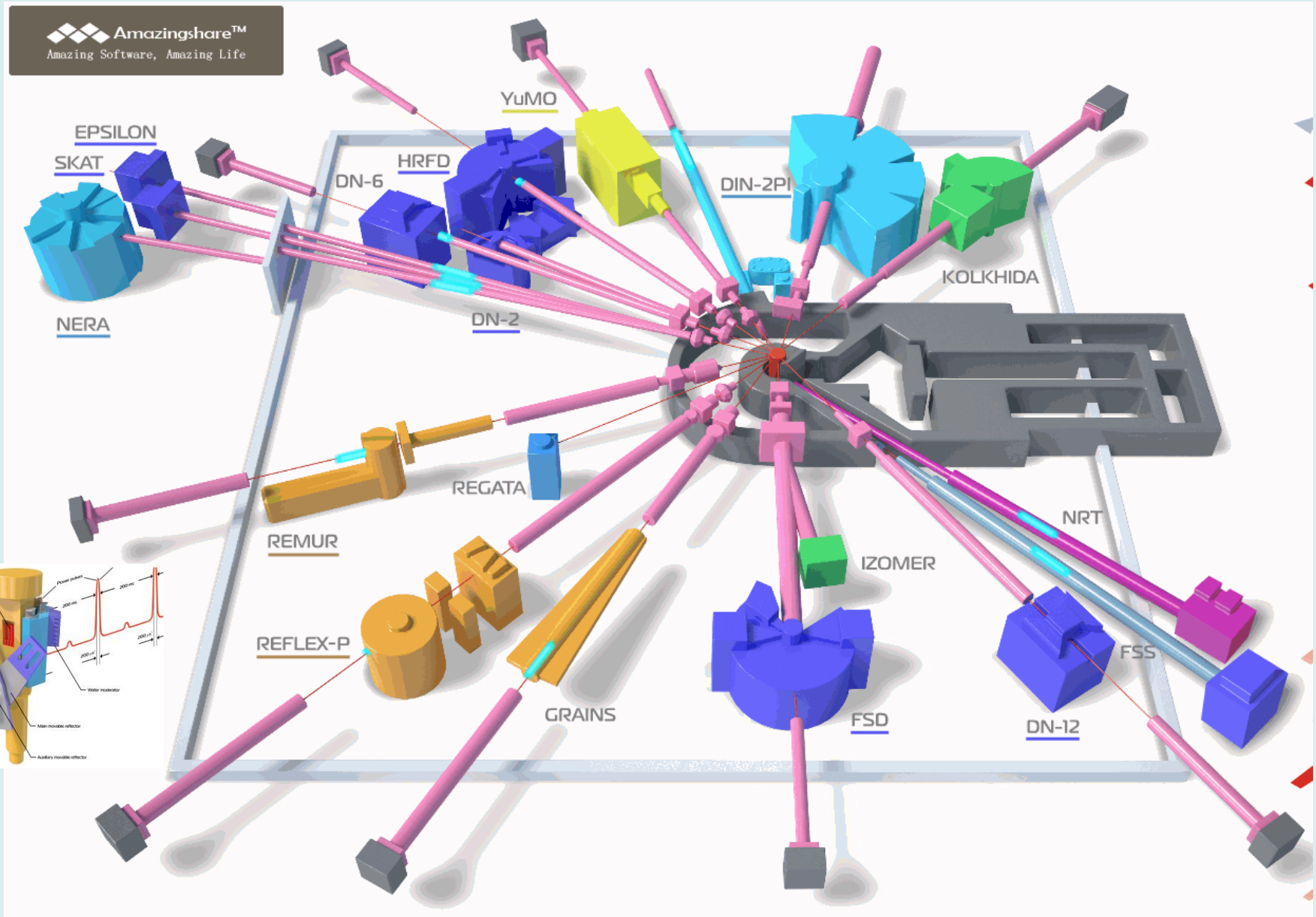
FLNP User Programme

The User Programme at the spectrometer complex of the upgraded IBR-2 reactor is implemented successfully. At the reactor, specialists from many countries conduct experiments in physics, material science, biology, geology, etc.

In 2018:
203 proposals for experiments came from 17 countries

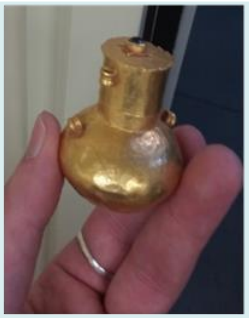


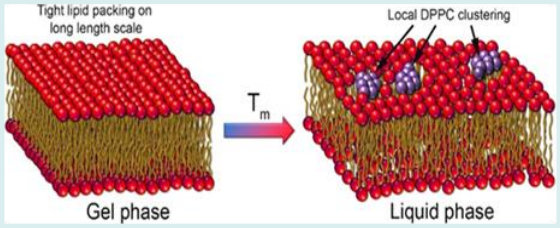
Neutron source channels at IBR-2M

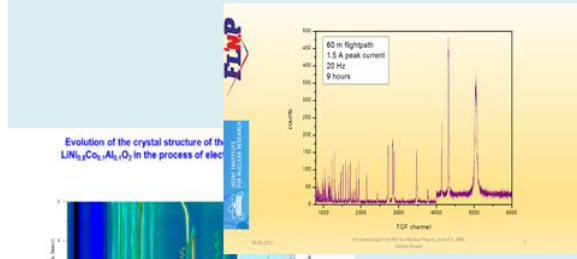


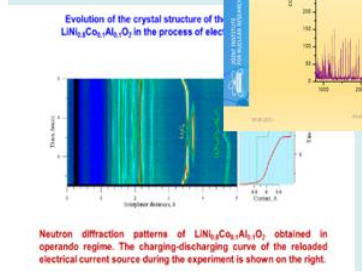
Condensed matter physics at JINR

- Physics and Chemistry of Novel Functional Materials;
- Physics of Nanosystems and Nanoscale Phenomena;
- Physics and Chemistry of Complex Liquids and Polymers;
- Molecular Biology and Pharmacology;
- Materials and Engineering Sciences;
- Neutron Radiography and Tomography
- Neutron Ecological studies
- Neutron beams as the method for solving problems of Life Science



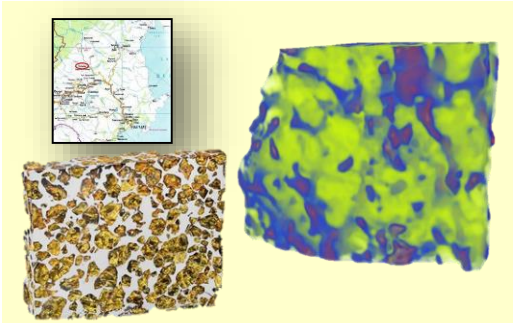




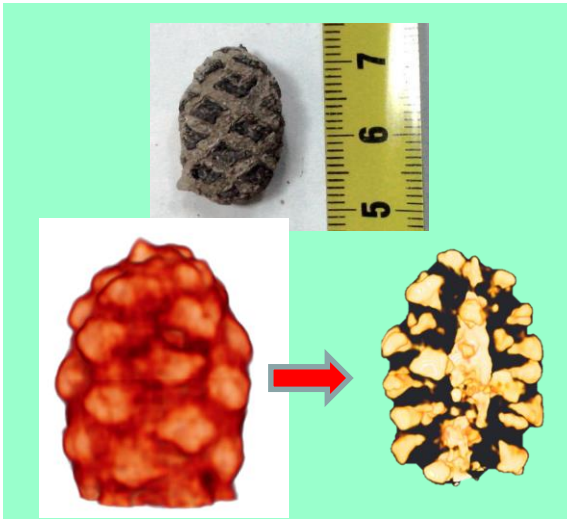


Development of neutron imaging techniques at IBR-2 and applications to natural heritage objects

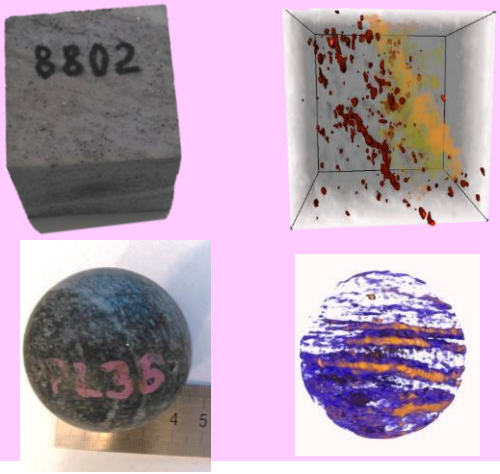
Neutron imaging instrument: Sample and detector position



3D reconstruction of Fe-Ni alloy distribution in Seimchan meteorite from neutron tomography data

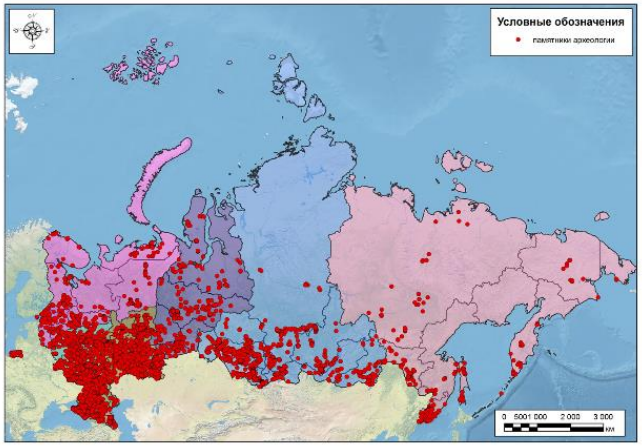


3D reconstruction of internal structure of Protosequoia cone (cretaceous period) from Paleontological Institute RAS using neutron tomography data

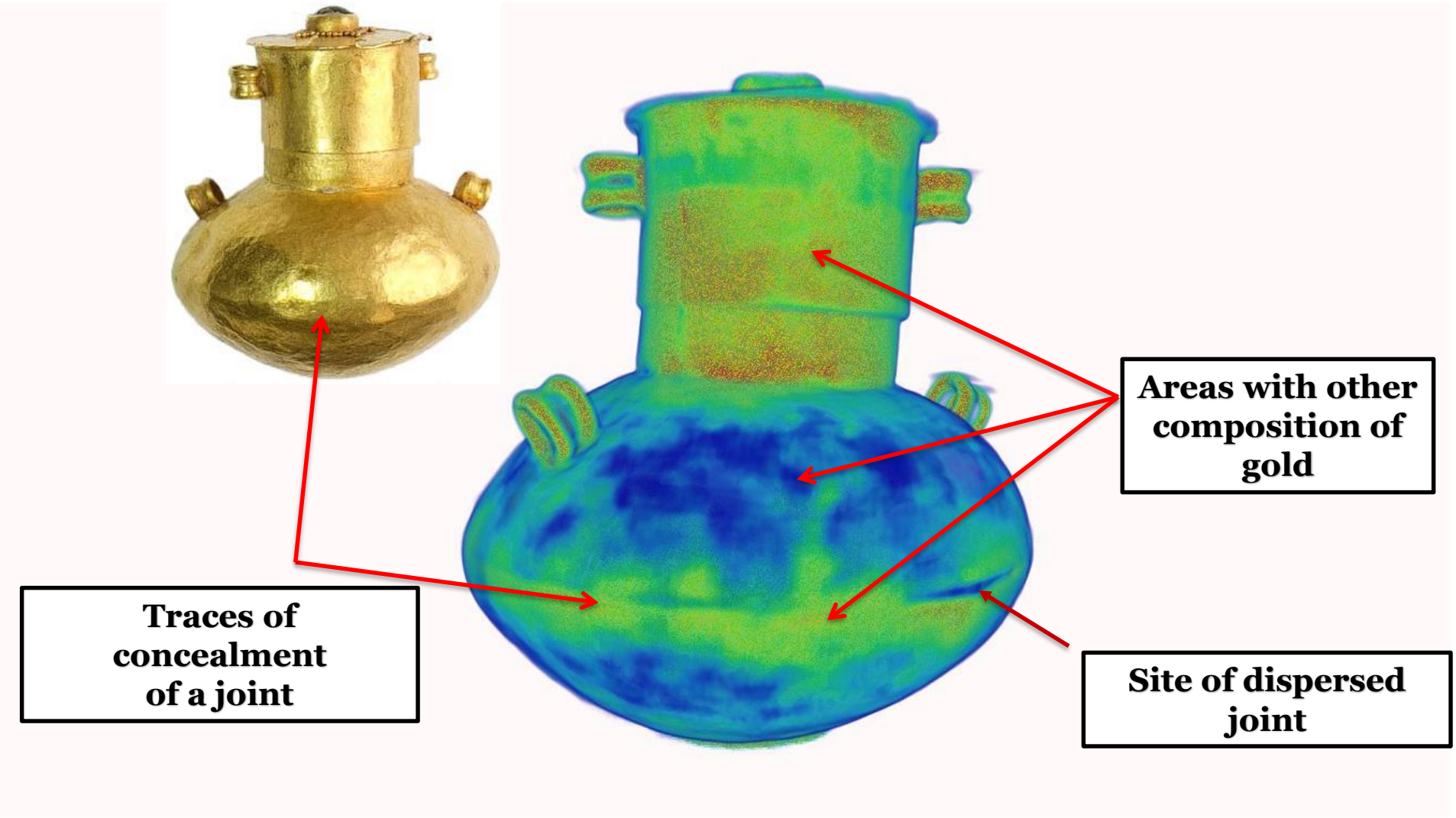


3D reconstruction of internal structure of the biotite gneiss sample from Kola Superdeep Borehole, depth 8802 m and its surface analogue using neutron tomography data

Neutron radiography and tomography at the Beam #14 are used to study archeological objects, especially metallic artifacts



Neutron radiography and tomography used to study archeological objects, especially metallic artifacts

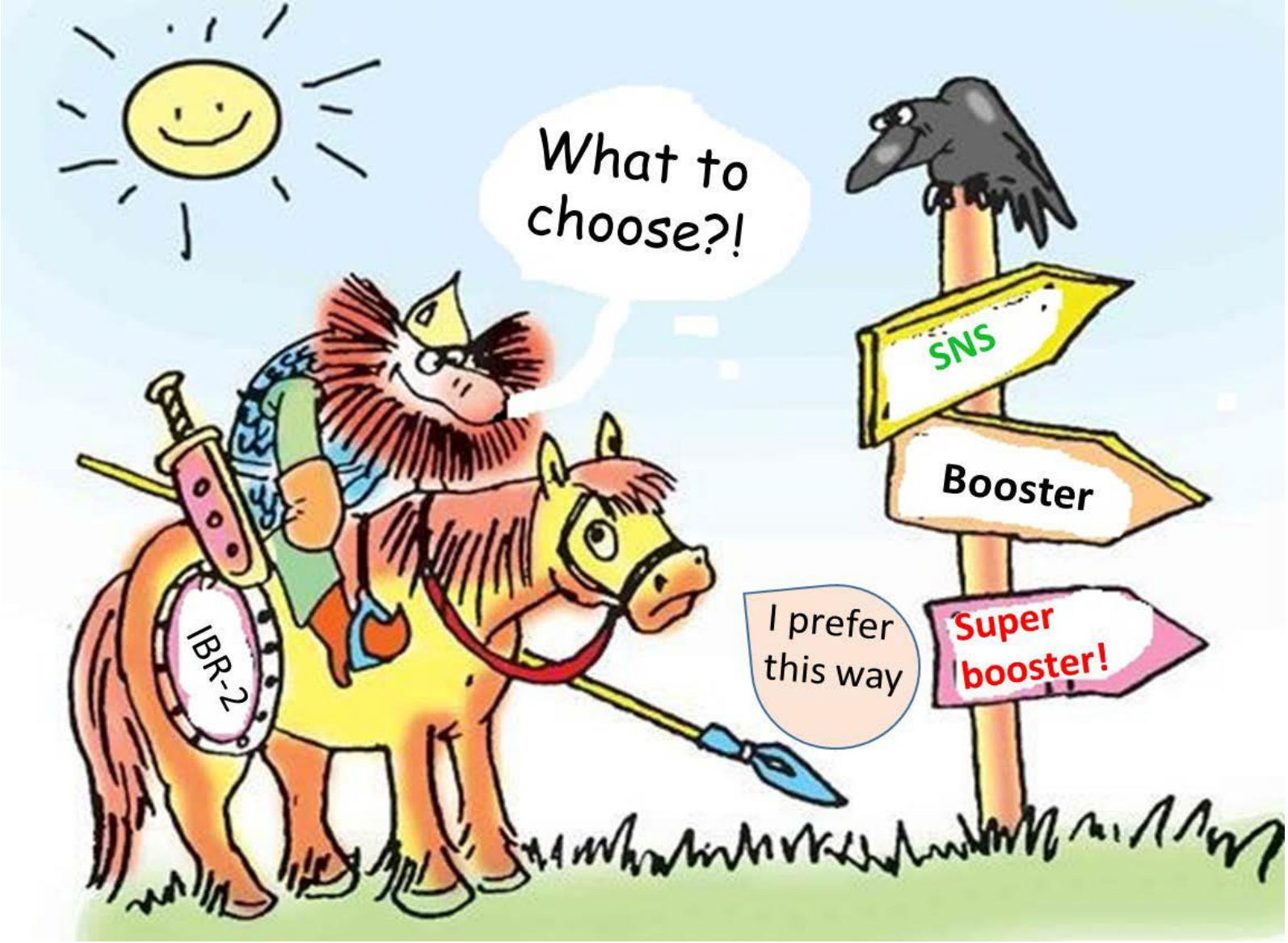


IBR-2 Future

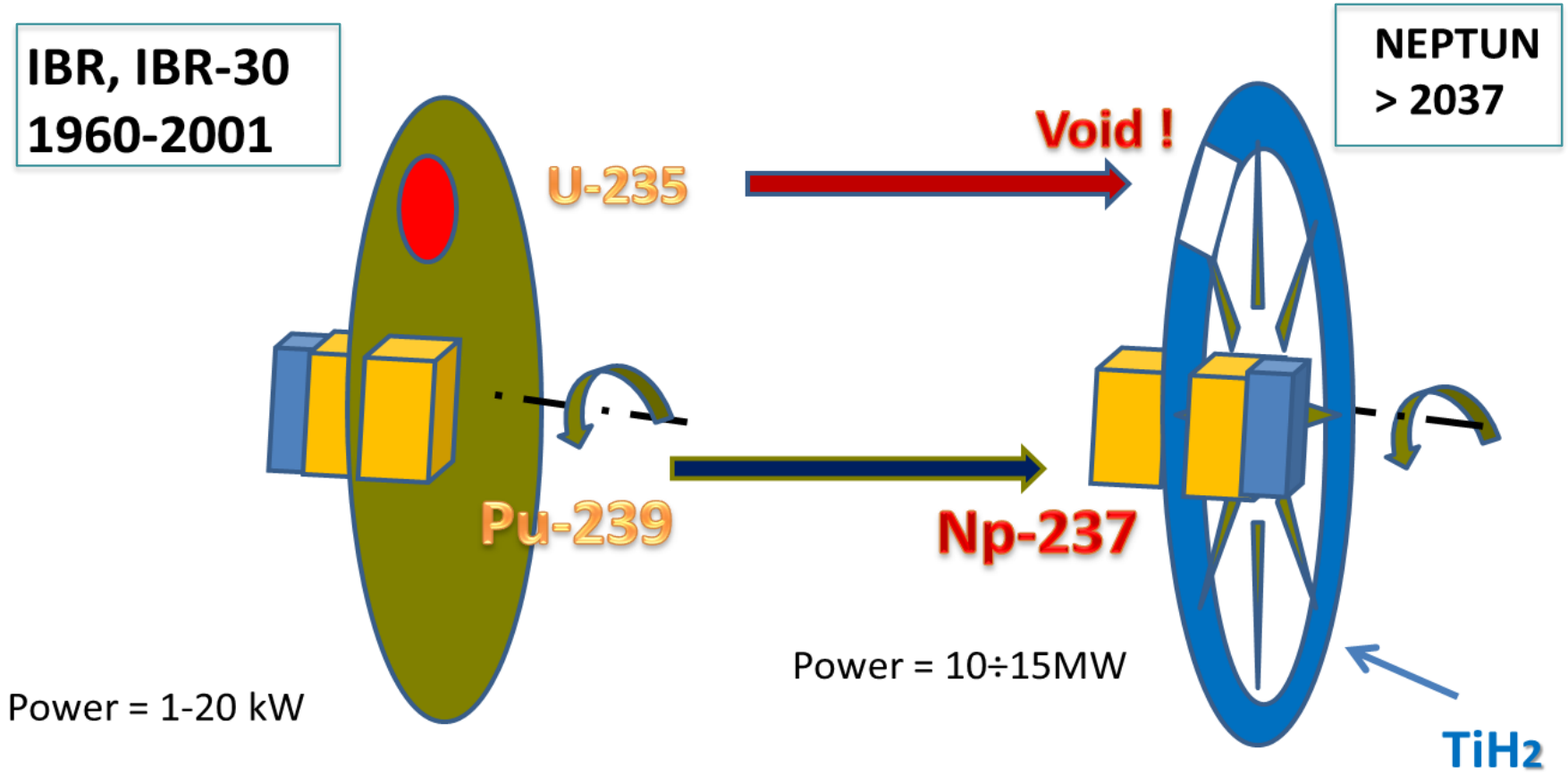
- **Short term perspectives:**
  - **Development and upgrade of the IBR-2 instruments. Already now there are examples at JINR of more than 10-fold increase in efficiency**
  - **Startup of the IREN source at designed parameters;**
- **Long term perspectives – new accelerator based neutron source in order to replace IBR-2 after the end of its lifetime > Superbooster NEPTUN**

The Long Range Strategy for JINR up to 2030

Why a superbooster



Fourth generation Dubna Pulsed Neutron Source

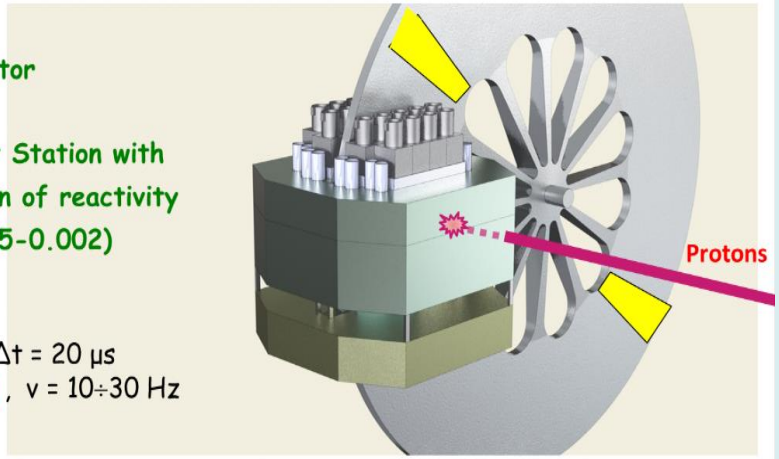


Evolution & Continuity

Dubna Neutron Source of the Fourth Generation two options

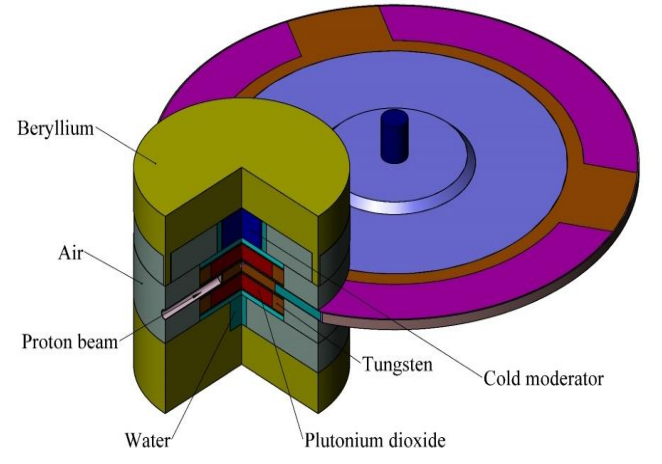
Superbooster NEPTUN

Linear p-Accelerator
+
Multiplying Target Station with
periodic modulation of reactivity
(subcriticality 0.05-0.002)



Ep =1.2 GeV, Δt = 20 μs
I max = 50 mA , ν = 10÷30 Hz
W ≤ 100 kW

PuO_2 based superbooster

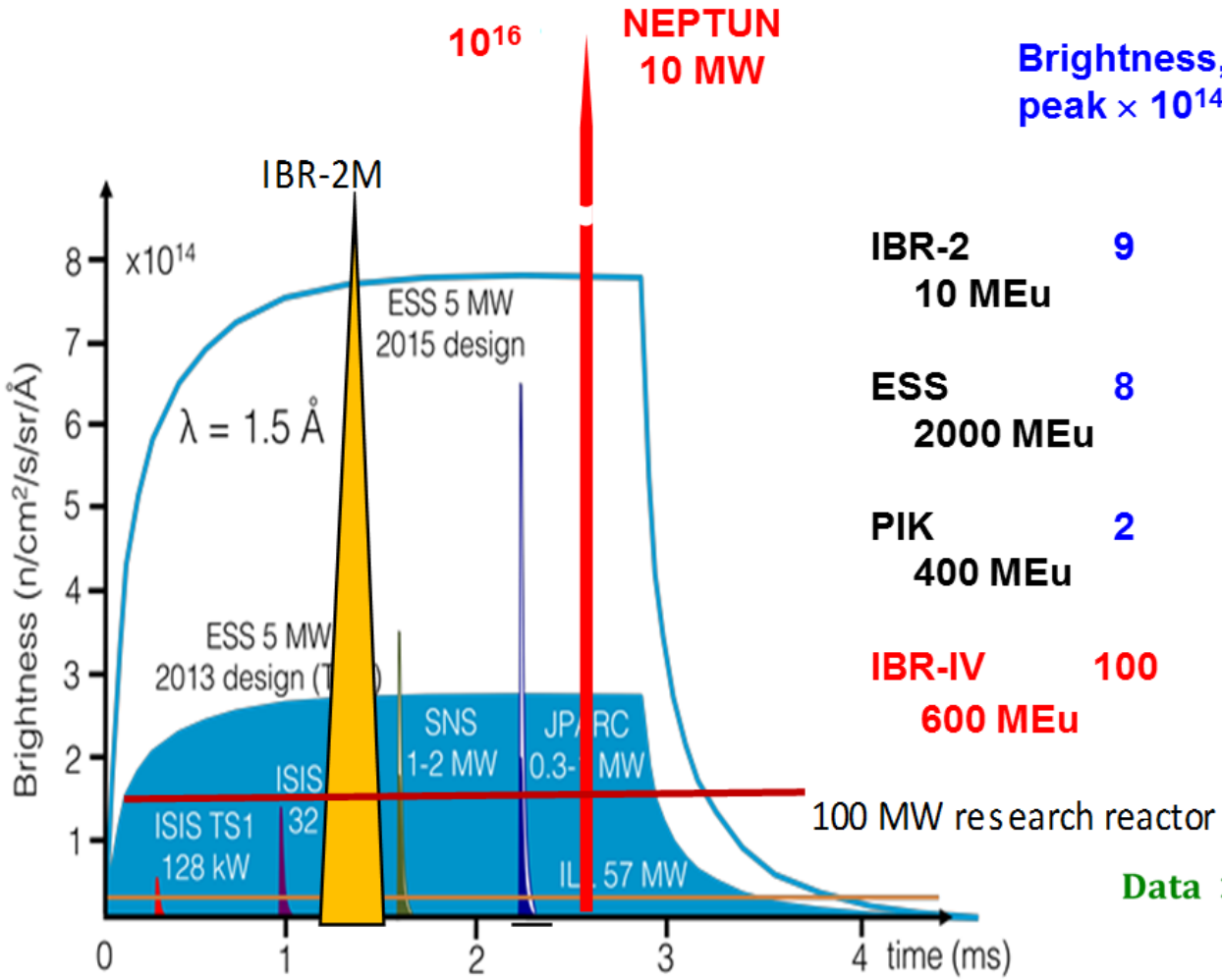


Progress outline:

1. **A superbooster (multiplying target of proton linear accelerator with periodic reactivity modulation) is being considered for the new neutron source**
2. **Feasibility study of 2 concepts (neptunium and plutonium based) has been started**
3. **Time schedule road map has been developed that establishes 6 major stages and proposes the finalization in 2035 – replacing the present source IBR-2M smoothly**

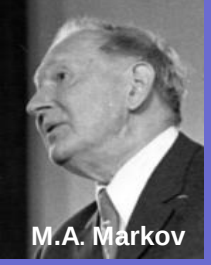
N. Kučerka & E.V. Lychagin: **Development of the scientific case for a new source of neutrons at JINR**
E. Shabalin & Yu.N. Pepelyshev: **Concepts of JINR's high-flux pulsed neutron source**
V.N. Shvetsov & V.L. Aksenov: **Milestones and time schedule proposal to the strategy plan of JINR**

Comparison of NEPTUN with other sources (basic data from the ESS report).

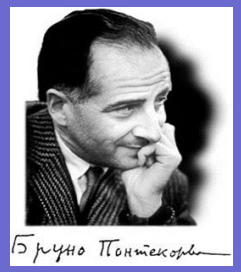


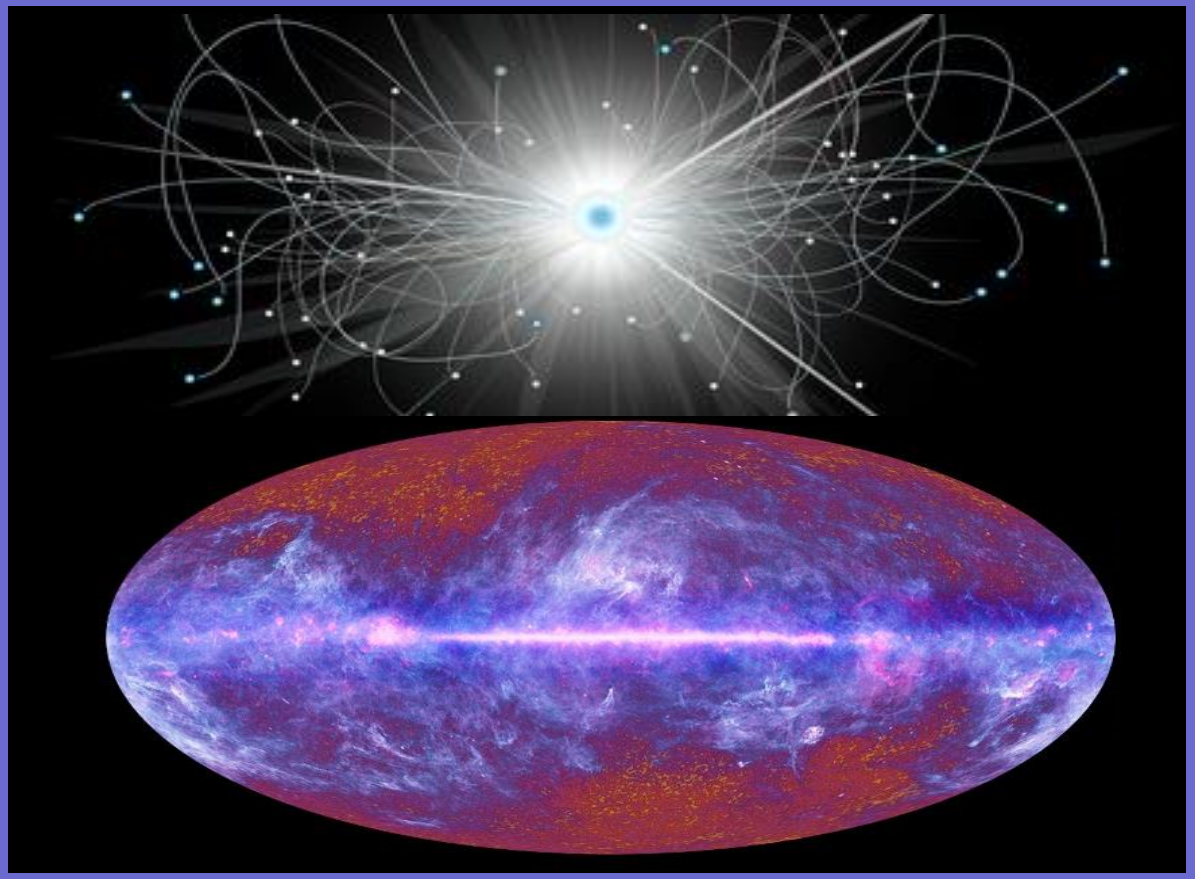
	Brightness, peak × 10^{14}	Flux density, time aver.
IBR-2 10 MEu	9	0.1
ESS 2000 MEu	8	2
PIK 400 MEu	2	14
IBR-IV 600 MEu	100	3

Data $\times 10^{14}\,[n \cdot cm^{-2} \cdot s^{-1}]$

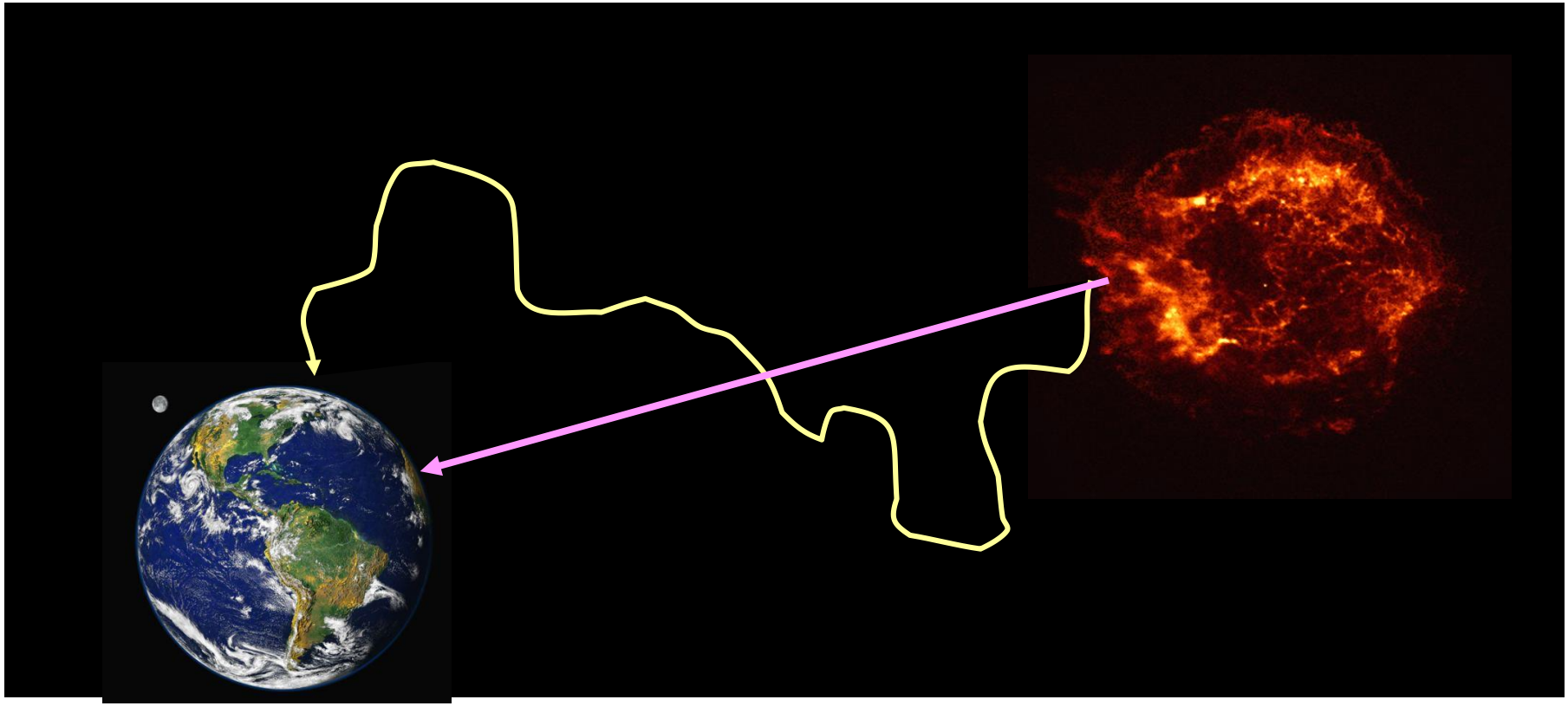


Fundamental problems of Particle and Nuclear Physics
Neutrino Physics and Astrophysics
Neutrino Astronomy





Neutrino Astronomy



- Charged particles propagating in cosmic space lose their initial direction and energy. Photons are getting absorbed.

Neutrino astronomy is possible because of weak interaction neutrino with cosmic matter and magnetic fields in space.

Idea of the Neutrino Telescopes

Program DUMAND –

Installation of the Deep Underwater Muon and of Neutrino Detectors

M.A. Markov:

«We propose to install detectors deep in a lake or in the sea and determine the direction of charged particles with the help of Cherenkov radiation».

Dubna, 1960

The pace of development of the DUMAND Program

1960 - M.Markov - main idea.

1976 - Discussions of DUMAND project

1980 - Start of works on construction BAIKAL Detector lead by G. Domogatsky (INR of RAS)

1993 - NT-36 (36 OM) @BAIKAL

1996 - NT-96 (96 OM)

1997 - AMANDA B10 (302 OM) @ South Pole

1998 - NT-200 (192 OM)

2000 - AMANDA II (677 OM)

2005 - NT-200+ (228 OM)

2005 – Ice Cube (first string)

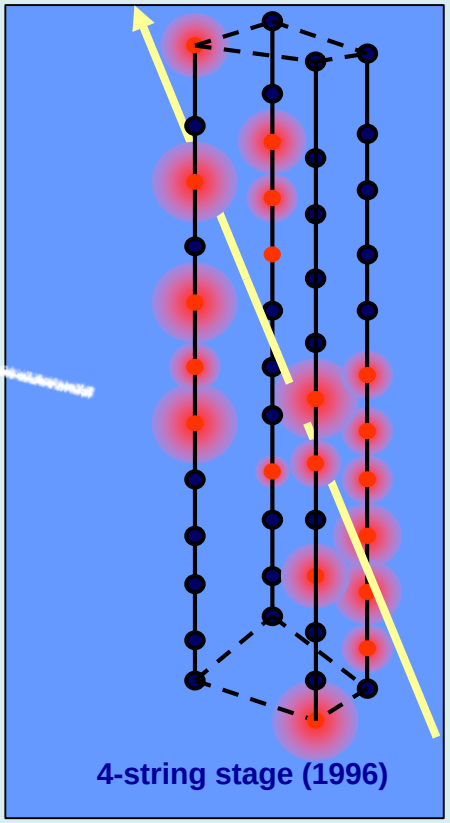
2010 – Ice Cube (last string)

2016 - BAIKAL GVD («Dubna» cluster)

2017 and 2018 – BAIKAL GVD (two more clusters)

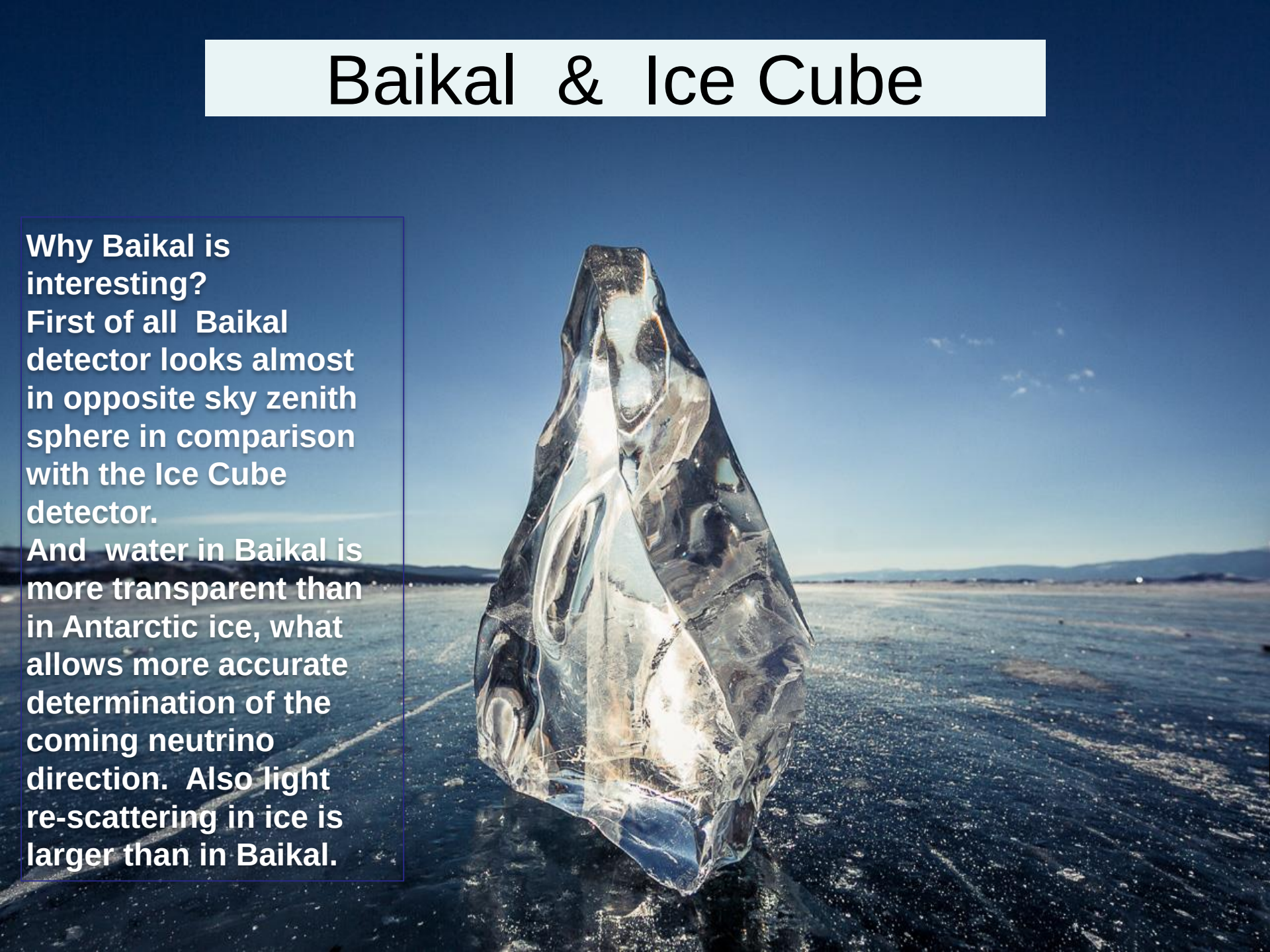
2019 –BAIKAL GVD (added two more new clusters)

Now Baikal GVD have in total 5 clusters of 0,25 km`3 !)

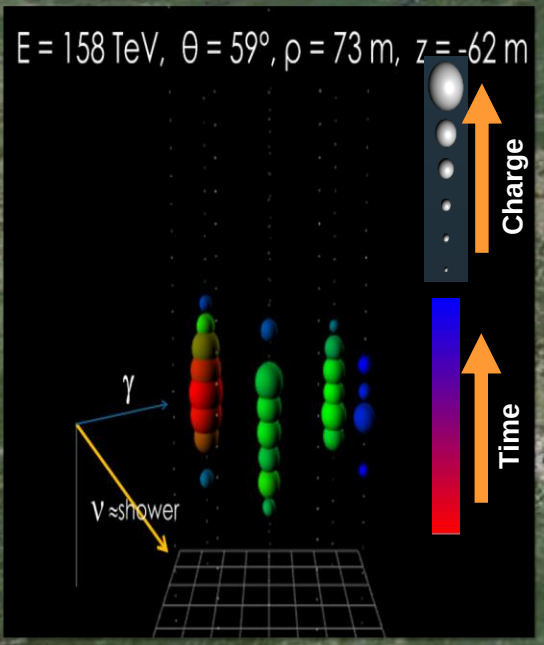


Baikal & Ice Cube

Why Baikal is interesting?
First of all Baikal detector looks almost in opposite sky zenith sphere in comparison with the Ice Cube detector.
And water in Baikal is more transparent than in Antarctic ice, what allows more accurate determination of the coming neutrino direction. Also light re-scattering in ice is larger than in Baikal.

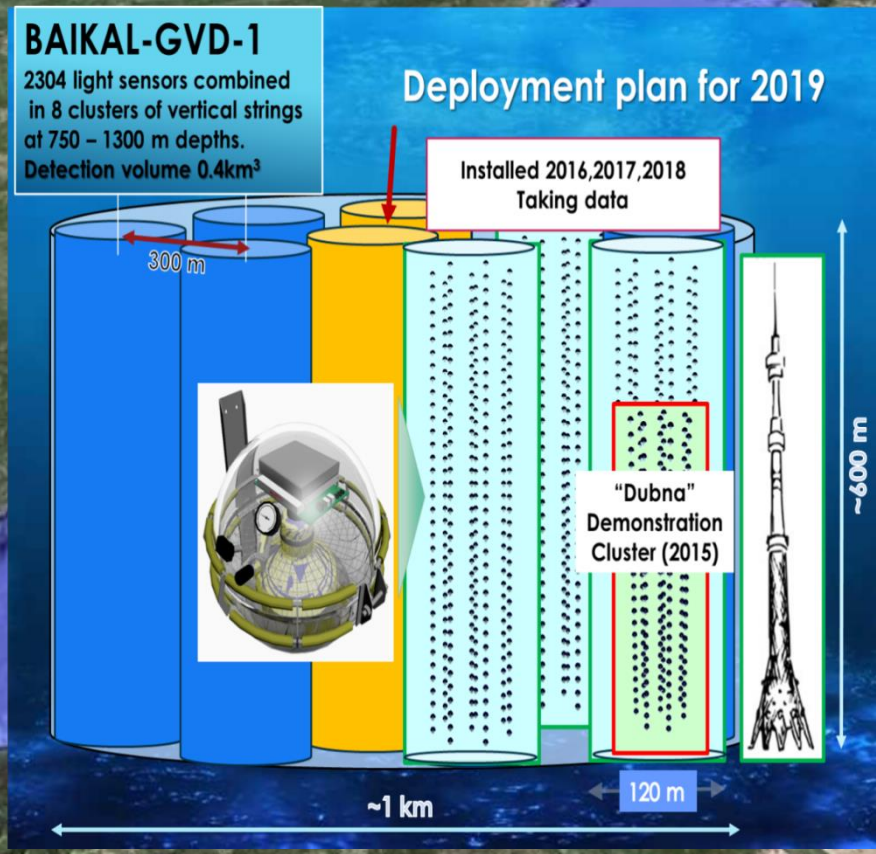


Neutrino programme: Baikal-GVD



Project NT-1000 International Collaboration BAIKAL GVD

- Search for the extragalactic neutrino "point sources" in energy range > 3 TeV
- Study local diffuse neutrino flux – energy spectrum



Shore station

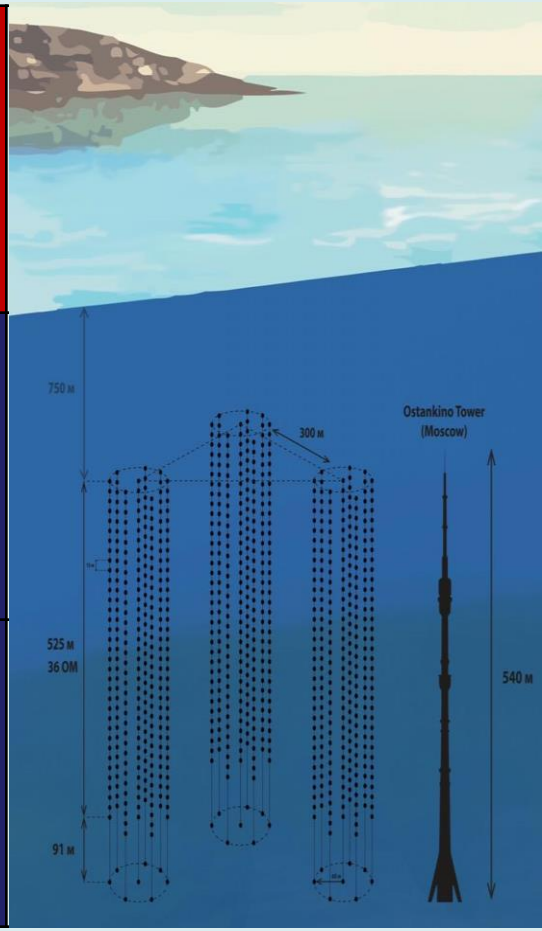
	GVD-1
OMs	2304
Clusters (8 Strings)	8
Depths, m	750 – 1275
Eff. Volume (E_{SH} > 100 TeV)	0.4 km^3

Directional resolution
Cascades: ~3°
Muons: 0.25° - 0.5°

Expedition 2019 has achieved its goal: two more clusters were installed

Baikal GVD deployment status

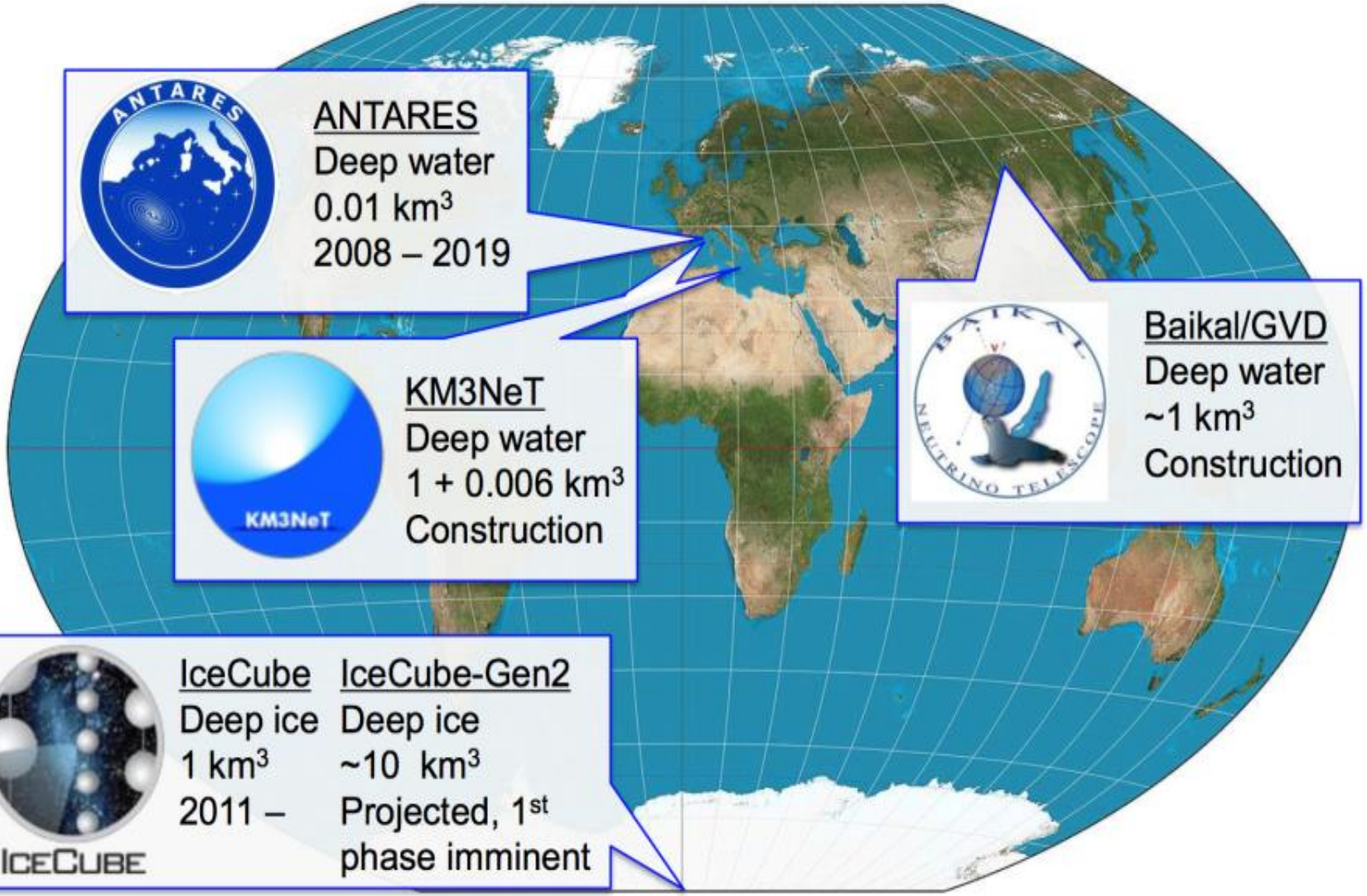
	2015	2016	2017	2018	**2019**
Number of clusters	≤1	1	2	3	5
Number of OM	192	288	576	864	**1440**



March 2019: Baikal GVD - the largest Neutrino Telescope in Northern hemisphere

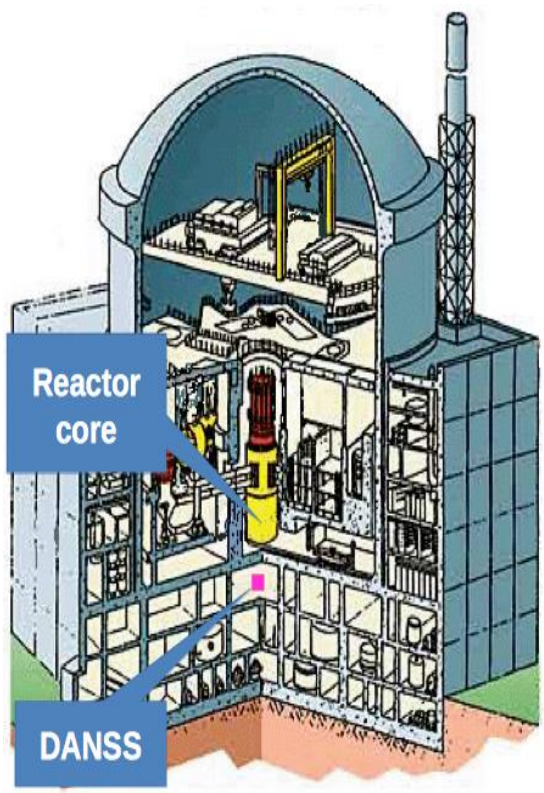
The neutrino telescope world map 2018

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS



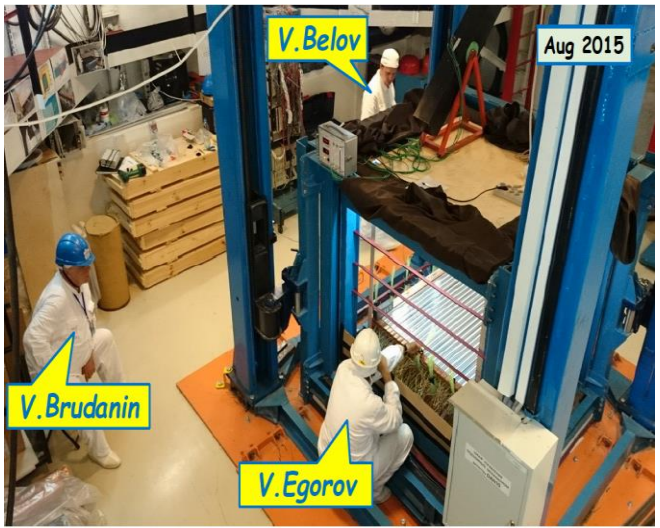
Neutrino programme: DANSS

Detector of AntiNeutrino based on Solid state Scintillator:
Reactor monitoring and search for short-range neutrino oscillations — JINST 11 (2016) no.11, P11011; arXiv:1606.02896



Kalinin Nuclear Rower Station
Reactor # 4

– Segmented XY plastic scintillator (1.1 t) close to the core of the KNPP reactor 4
– Overburden 50 m w.e. (reactor cauldron, cooling pond, concrete)
– 3D-information about each event
– Lifting platform, distance is varied on-line (from 10.7 to 12.7 m) within 5 min each 2-3 days
– Evolution of the flux and spectrum with distance, model-independent analysis



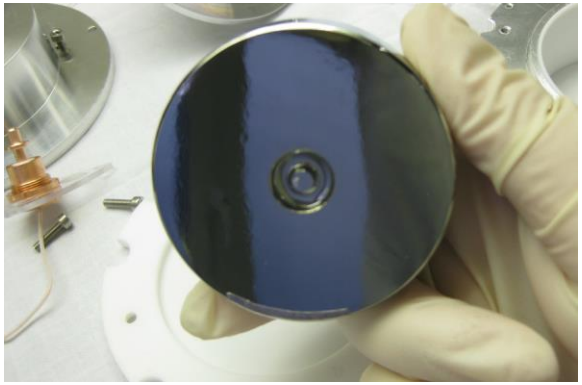
The νGeN Experiment at the Kalinin Nuclear Power Plant

Experiment for Detection Coherent ν – Ge Nucleus Elastic Scattering

Detectors with low energy threshold

Point contact HPGe detectors produced by Dubna in cooperation with BSI (Riga) (4x400 g).

The energy thresholds from 300-350 eV



Low background cryostat (material selection: Dubna, production: BSI), and low noise electronics

For correct interpretation of results many methodical studies (energy calibration for E~1 keV, fiducial volume, own background).
We use one of the best low background infrastructure available – EDELWEISS-I shield in the LSM underground laboratory.

Measurements with highest available neutrino flux

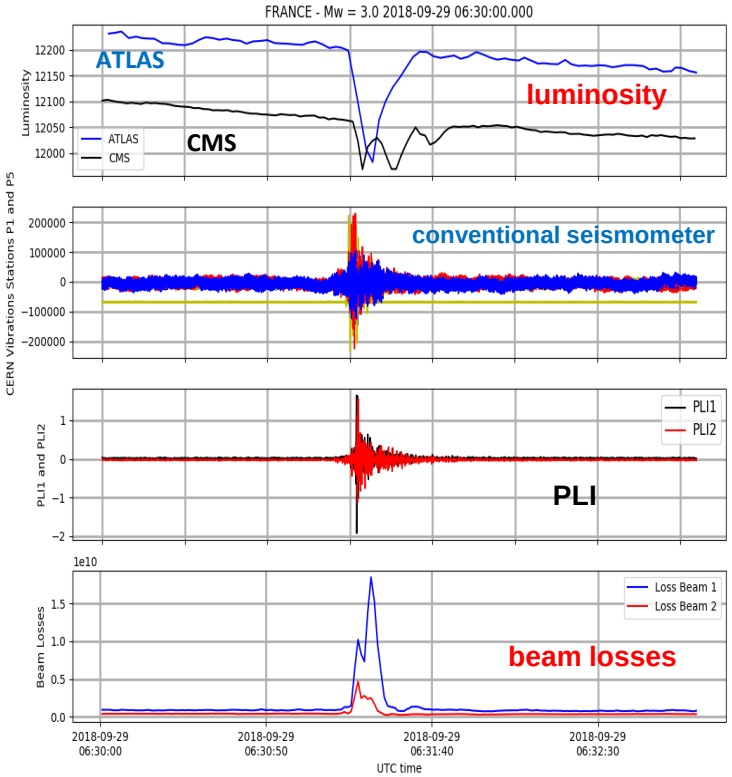
Kalinin Nuclear Power Plant at 10 m from the reactor core the flux is 5.4 x 10^{13} cm^2 per sec.

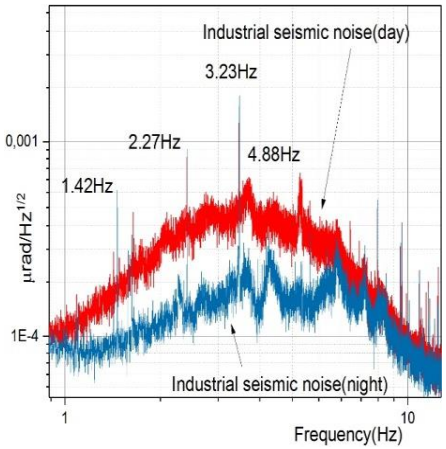
Improved low background shield of GEMMA experiment (world leader of neutrino magnetic moment measururements) .
The available place for measurements is just under the reactor, which provides about 70 m.w.e. shielding from cosmic rays.

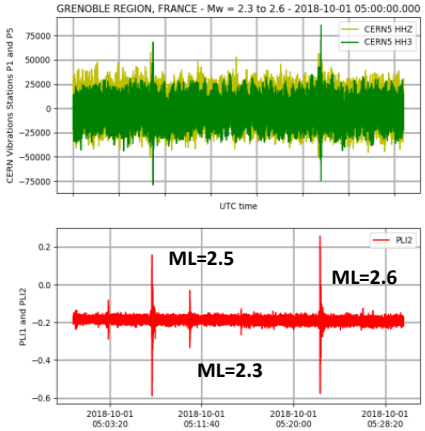
Applied Research: Precision Laser Inclinometer (PLI)

Achieved a precision of $2.4 \cdot 10^{-11}$ rad/Hz$^{1/2}$ in the frequency range $[10^{-3}, 12.4]$ Hz

High precision monitoring of even tiny Earthquake effects on LHC collisions (Magnitude 3 in the picture)







The PLI is more sensitive than classic seismometers – Magnitude 2.3 to 2.6 Earthquakes in France in October 2018

Professional PLI is commissioned at CERN in TT1 tunnel since Sept. 2017.

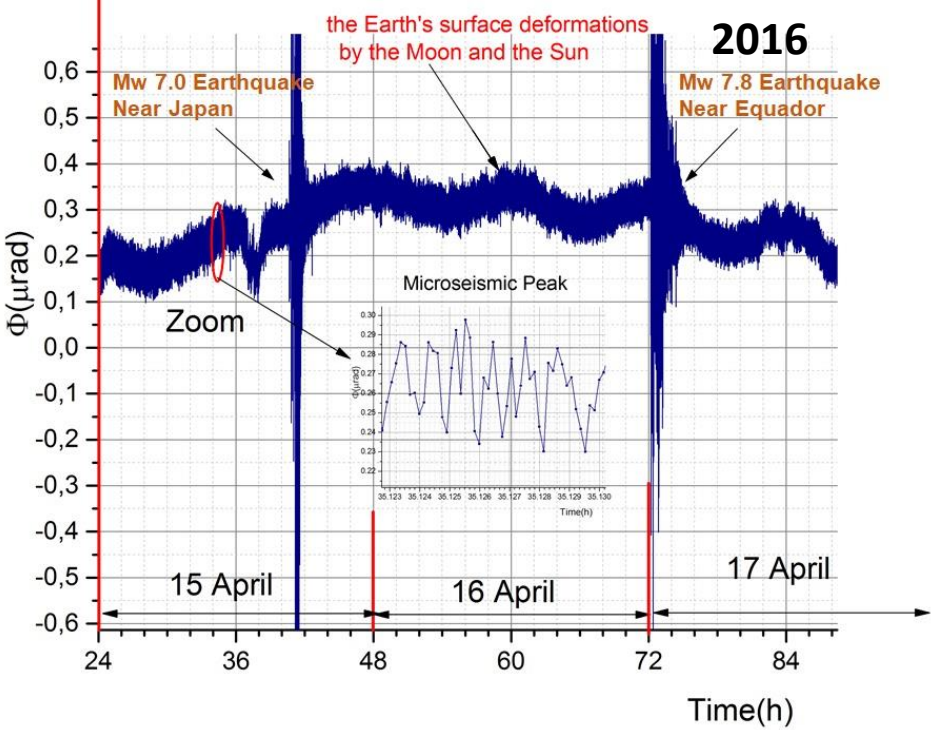
It detects any type of Earth movement due to seismic events and cultural noise in a wide frequency range. Wide applications and expressed interest: from multi-TeV colliders (HL-LHC, FCC, CLIC, ILC) to dark matter search and gravitational wave experiments, to societal applications for Earthquakes warning.

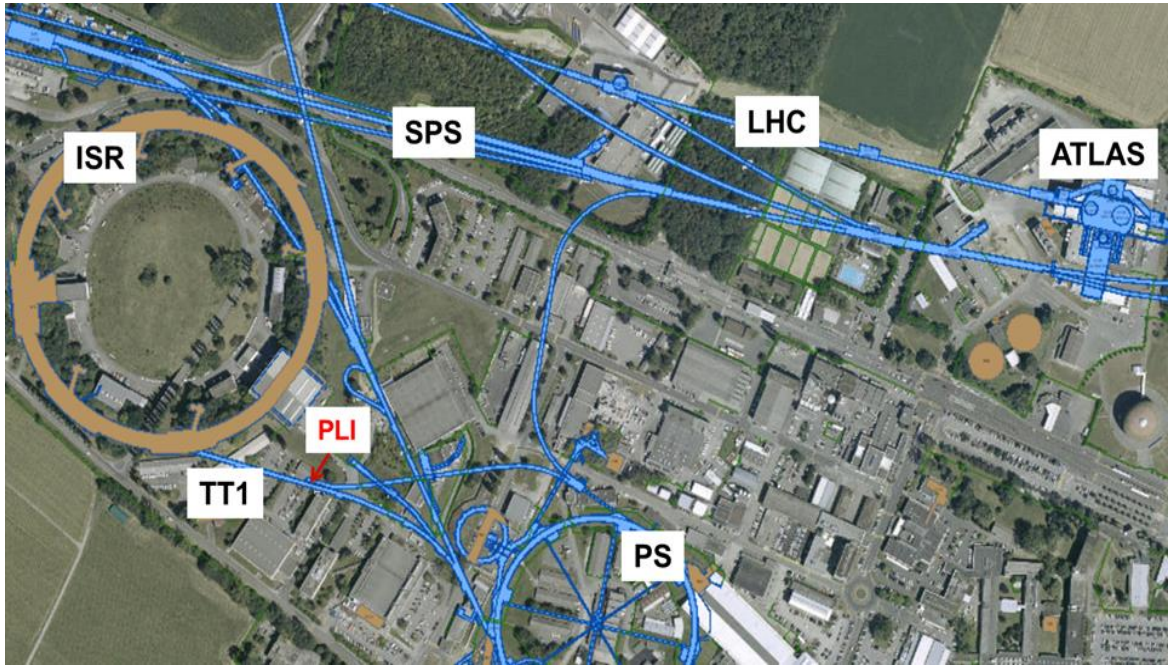
Precision Laser Inclinometer (PLI)

The device confidently registers the angular slopes of the Earth's surface caused by the Moon, the Sun, remote (more than 10^4 km) earthquakes, micro seismic peaks and sources of industrial origin, the Unique detector of angular oscillations the earth's surface in two orthogonal directions:

-frequency range 10^{-6} – 4 Hz

-sensitivity $2.4 \cdot 10^{-11}$ rad/Hz$^{1/2}$



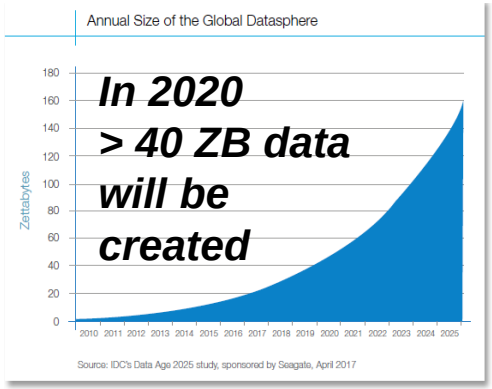


CERN and JINR discuss the use of PLI to stabilize the spatial position of beams in the priority CERN program for increasing the luminosity of the Large Hadron Collider.

2019: JINR/CERN/ INFN has agreed to use PLI in LIGO/Virgo experiment for detecting GW .

Strategy of Information Technologies and Scientific Computing in JINR

BIG DATA or HPDA - High Performance Data Analysis

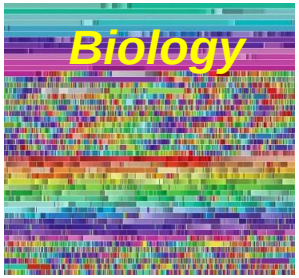


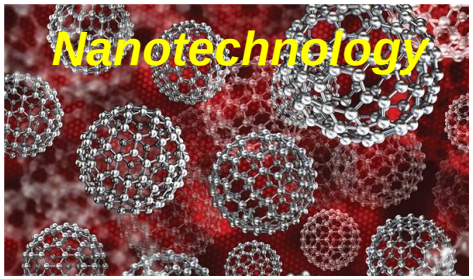
Annual data production follows to exponential the law.

Baisic Science

High Energy Physics

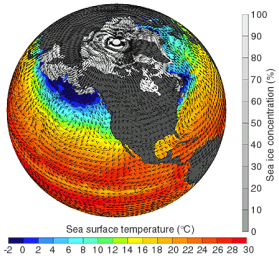
CERN Large Hadron Collider > 20 Pb/Year, > 200 Pb stored





Life sciences and innovations

Climate



...et cetera

Astrophysics

Square Kilometre Array radio telescope (SKA) > 20 Pb/Day (estimation)

An International radiotelescope for the 21st century

Large Synoptic Survey Telescope (LSST) > 10 Pb/Year (estimation)

Supercomputer at JINR

The aims:

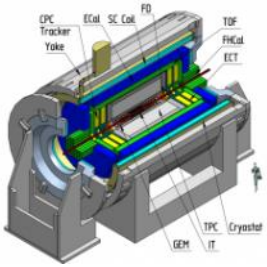
- Increase of computational power for massive parallel computations required for acceleration of the complex theoretical investigations held at LTP in collaboration with BLTP and VB LPHE in frames of **"Hadronic matter under extreme conditions"**, theme 01-3-1113, "Theory of fundamental interactions"

- Development of a test bed for study a feasibility of use of the newest computation platforms for computing on **NICA** project

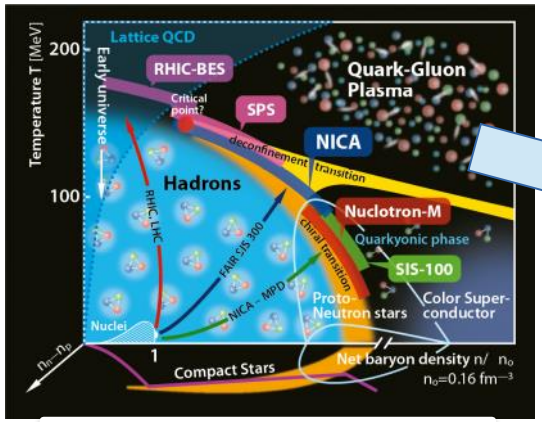
Total performance: 5 Pflops (x10)

Putting into operation: March 27, 2018

NICA computing challenge

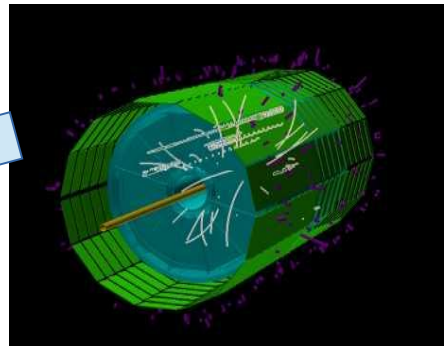


MPD experiment

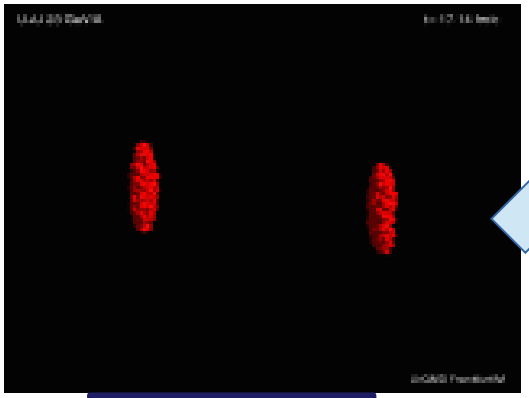


QCD phase diagram

Super-Computer
" GOVORUN "

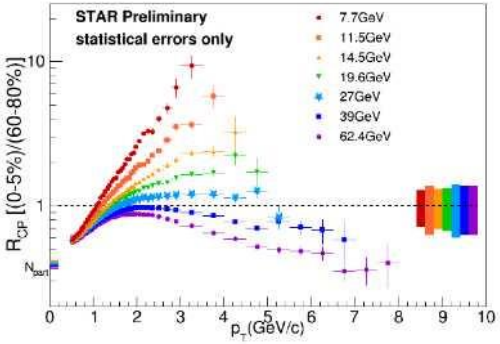


Events reconstruction



Simulations

Big Data + HPC

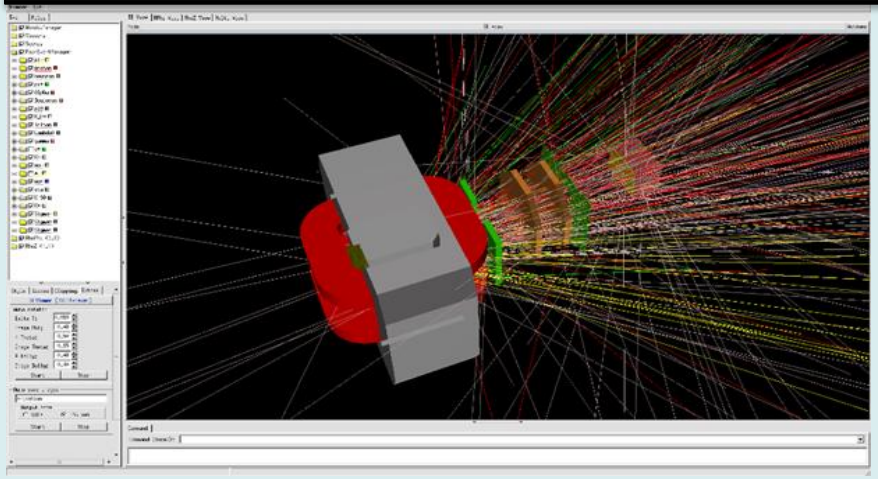


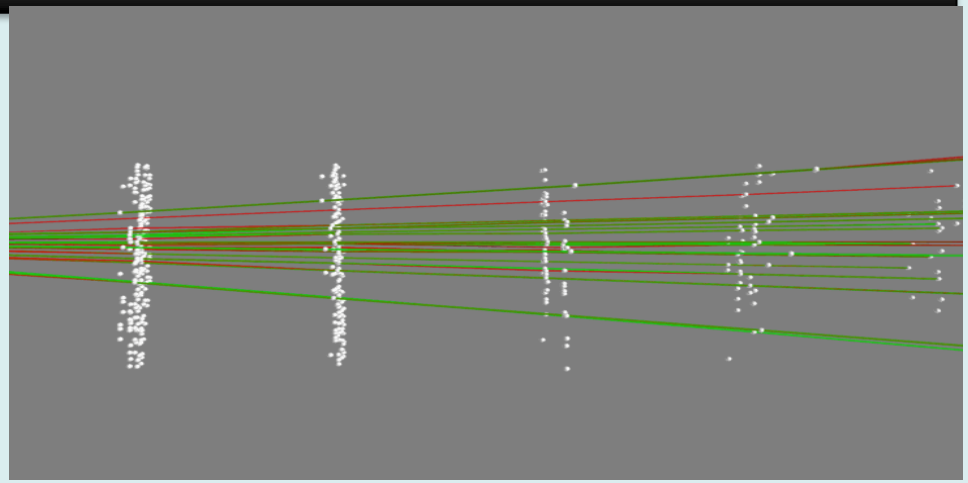
Physics analysis

ML Tracks Reconstruction BM@N

Machine learning algorithms bring a lot of potential to the tracks reconstruction problem due to their capability to learn effective representations of high-dimensional data through training, and to parallelize on HPC architectures.

Simulation data





Input data for the first step algorithm were simulated by GEANT in MPDRoot framework for the real detector BM@N configuration.

Real track

True found track

Ghost track

White dots are both hits and fakes

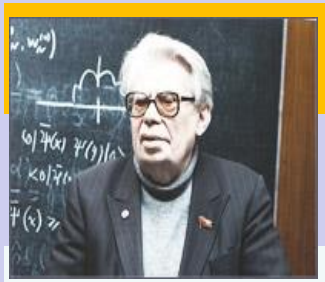
Efficiency 97,5%

Hot theoretical physics topics for HPC

THEORY OF HADRONIC MATTER UNDER EXTREME CONDITIONS

Wide international cooperation in parallel and single-core computing at LIT for HMEC-TH

IMP CAS (Lanzhou, China),
Helsinki Univ. (Helsinki, Finland),
ITP Uni. Graz (Graz, Austria),
ITP Heidelberg Uni. (Germany), Jena Uni. (Jena, Germany),
ITP Giessen Uni. (Giessen, Germany), Technische Uni. Dresden (Dresden, Germany),
ITP Goethe-Uni. (Frankfurt, Germany), GSI (Darmstadt, Germany),
ITP Leipzig Uni. (Leipzig, Germany), ZOQ Hamburg Uni. (Hamburg, Germany),
Tokyo Institute of Technology (Tokyo, Japan), RCNP Osaka Uni. (Osaka, Japan),
RIKEN (Wako, Japan),
IOP Bhubaneswar (Bhubaneswar, India),
INFN Frascati (Rome, Italy), INFN (Pisa, Italy),
Uni. of Wroclaw (Wroclaw, Poland),
FEFU (Vladivostok, Russia),
NRC Kurchatov Institute (Moscow, Russia), ITEP NRC KI (Moscow, Russia),
IHEP NRC KI (Protvino, Russia), MEPhI (Moscow, Russia),
IDSTU SB RAS (Irkutsk, Russia), Saratov Uni. (Saratov, Russia),
SINP MSU (Moscow, Russia), St. Petersburg Uni. (St. Petersburg, Russia),
P.J. Safarik University (Kosice, Slovakia), Matej Bel Uni. (Banska Bystrica, Slovakia),
Valencia Uni. IFIC (Valencia, Spain),
BITP (Kiev, Ukraine)

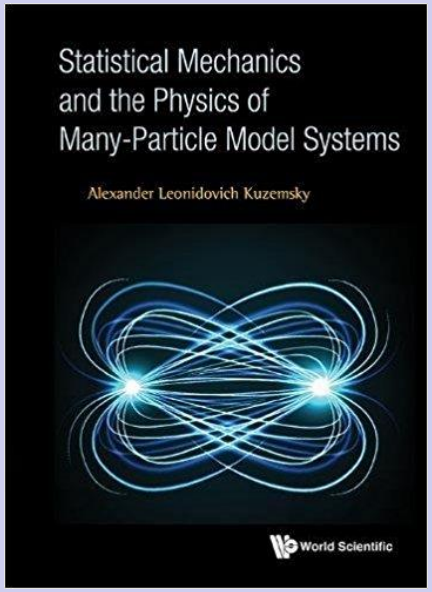


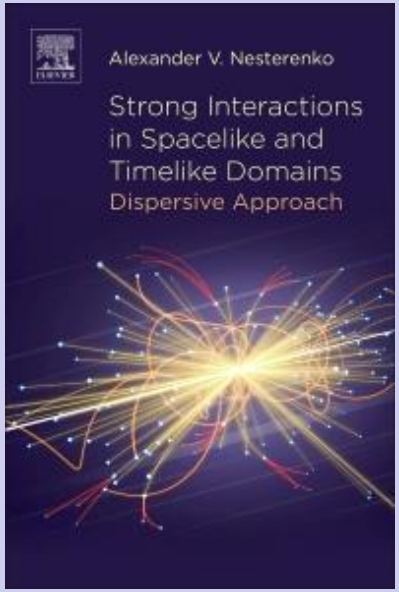
Theoretical Physics at JINR

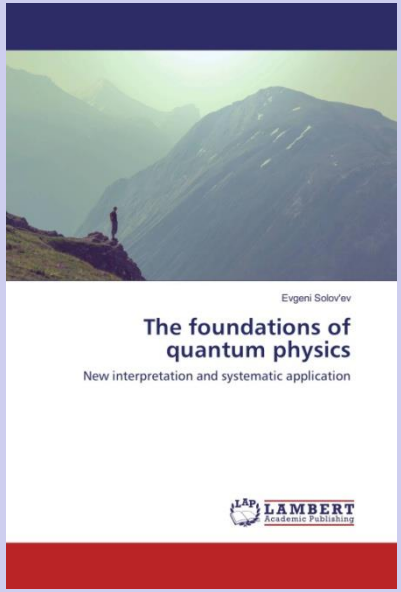
BLTP

Multidisciplinary research:

- Theory of Fundamental Interactions
- Particle Physics and Cosmology
- Theory of Nuclear Structure and Nuclear Reactions
- Theory of Condensed Matter
- Mathematical Physics: Strings and Gravity, Supersymmetry, Integrability
- Quantum Statistics
- Research and Educational Project “Dubna International Advanced School of Theoretical Physics (DIAS-TH)







INTERNATIONAL BOGOLYUBOV CONFERENCE
PROBLEMS OF THEORETICAL AND MATHEMATICAL PHYSICS
dedicated to the 110th anniversary of N.N. Bogolyubov's birth
September 9-13, 2019
Moscow-Dubna, Russia

Russian Academy of Sciences
Steklov Mathematical Institute RAS, Moscow
Joint Institute for Nuclear Research, Dubna

Modern trends in radiobiology

Fundamental radiobiological research: *studying mechanisms of radiation action at the molecular, cellular, tissue, and organismal levels of biological organization*

Radiation and nuclear medicine: *refinement of tumor radiation therapy techniques (proton and carbon therapy); designing new radio sensitizers and radio protectors; extension of the list of the radionuclide pharmaceuticals for diagnostics and treatment*

Radiation safety of deep space flights: *refinement of the approaches to human protection from heavy charged particles*

JINR's Laboratory of Radiation Biology

Origin of Life on the Earth, Astrobiology

Fundamental aspects of radioecology: *research at thelevel of ecosystems and populations, participation in EU programs*

Applied radiation technologies: *development of methods of raising crop capacity and improvement of agricultural product quality; elimination of pathogenic micro- and macroflora; disinfection of agricultural waste, etc.*

LRB *New method of enhancing the biological effectiveness of ionizing radiation*

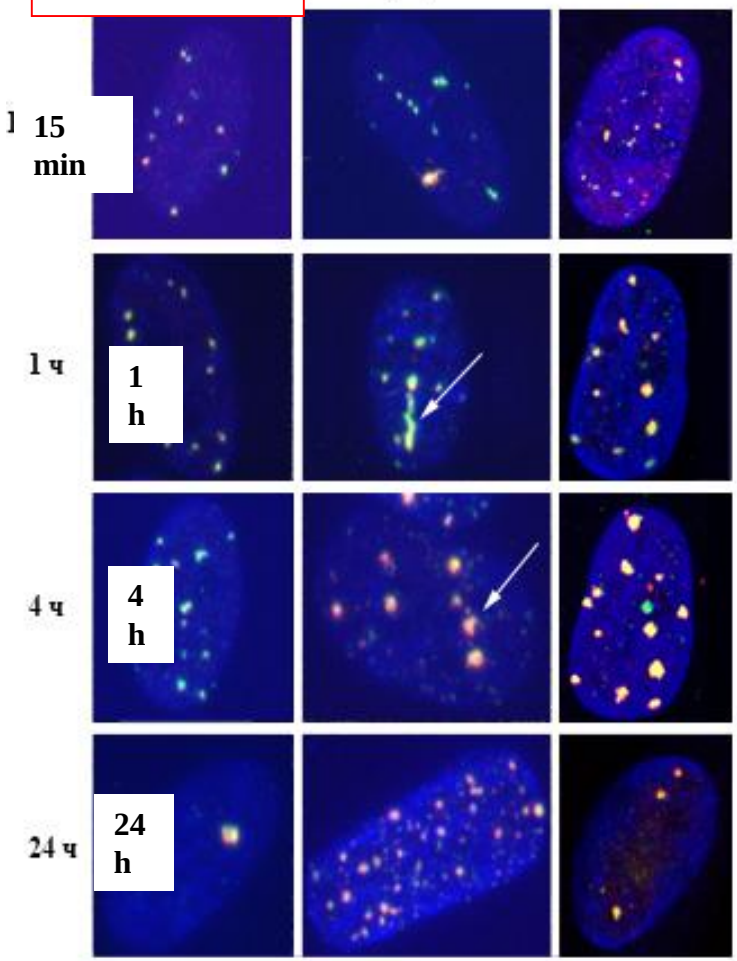
New Results!

Protons 0.6 Gy
Bragg peak

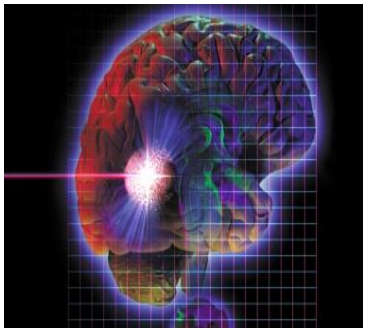
Without Ara C

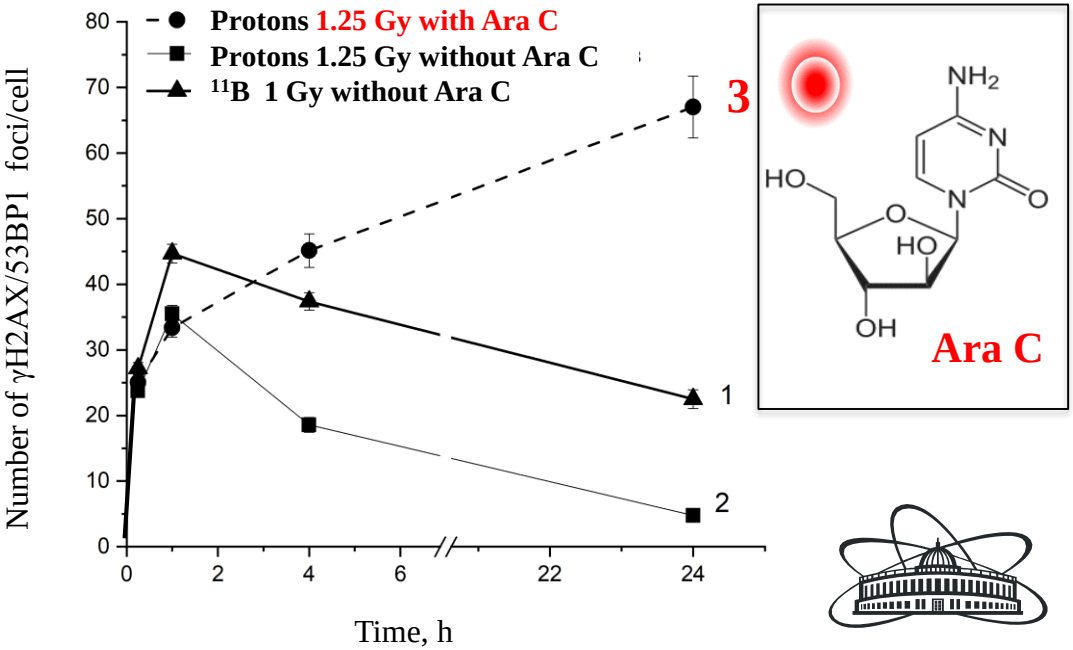
With Ara C

^{11}B ions 1Gy
8 MeV/u



Human cells

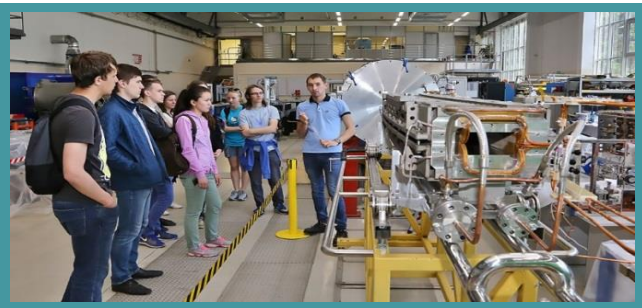




JINR UC Educational Programmes

and 7-year Plan for the Development of JINR

Implementing the goal "Attracting Youth to Science"



Major JINR UC educational activities:

- **Outreach programmes for school students and teachers;**
- **Preparation of qualification works at Bachelor, Master, or PhD level;**
- **International Student Practices at JINR;**
- **Summer Student Programme;**
- **Training programmes for engineers, etc.**

- **In 2019 JINR has received from Russian Government the right to have the JINR own system of defending theses at JINR and assigning the JINR PhD degree.**
- **JINR has established a special fund to support JINR postdoc positions.**

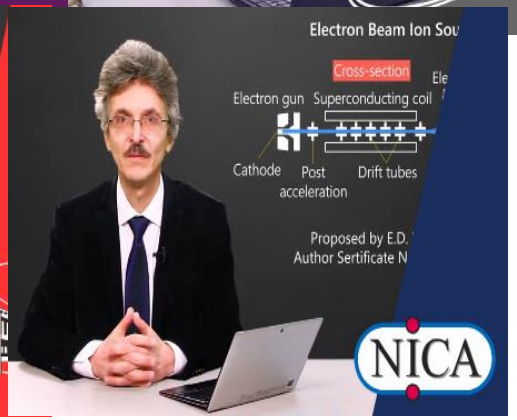
JINR UC outreach activity

- Scientific Schools for physics teachers at CERN and JINR (started in 2009) http://teachers.jinr.ru/
- Visits to the JINR laboratories for school and university students;
- Festivals of sciences, etc.

Outreach (popularisation of science achievements)

Open education at JINR edu.jinr.ru

Video lectures



We started to do video lectures with our colleagues:

- **Experimental high energy physics**
- **Detectors in the nuclear and high energy physics**
- **Heavy ions and the synthesis of heavy elements**
- **Mega-science project NICA**
- **Quantum Computation and Quantum Information**

JINR, Bldg. #113, Studio 510

http://edu.jinr.ru/courses

JINR Distinguished Postdoctoral Research Fellowship Programme

The programme for the selection of young researchers within a specialized international competition for nominal positions, bearing the names of distinguished JINR scientists (Distinguished Postdoctoral Research Fellowship), is aimed at staffing of main research directions and flagship projects of JINR.

The programme provides young talented scientists an opportunity to actively participate in JINR's scientific research being conducted at the world-level.

The JINR Director Order has been signed which established the Special International Coordination Committee with the task to workout together with the laboratories the list of the topics and scientific themes and announce a call for the candidates using a number of scientific magazines, the internet sites and mass media.

2030

The Long Range Strategy for JINR development

From the Seven Year Plan for JINR development for the period 2017 – 2023

JINR's Long Range Strategy plan for up to 2030

- **NICA – II (SpinPD, MPD-Upgr., NICA-HL, Innov.Centre)**
- **DRIBS-III (Dubna Radioactive Beam Complex for Super-Heavy Elements and Exotic Nuclei studies)**
- **SC HI LINAC-100 and DERICA Project (Dubna Electron Radioactive Ion Collider fAcility)**
- **Physics with the ultra cold neutrons at IBR-2M**
- **Dubna PNS-IV: Super booster "NEPTUN" (Proton beam initiated Pulsed Np-237 Neutron Reactor)**
- **Baikal–GVD Neutrino Telescope Upgrade above 1 km^3**
- **BIG DATA and DATA LAKES IT Technologies Center, Supercomputer "Govorun" Upgrade**
- **Hadron Therapy research complex, Radiobiology Center**
- **Participation in the World Global Projects (ILC, Fcc, etc)**

Concluding Remarks

2017-2023

2023-2030

- Realization of all the priority projects of the JINR 7-year program is going successfully according the plans.
- Construction of NICA complex is going close to the schedule with a small delay.
- Construction of the SHE complex is finished and the First Day program of experiments on synthesis of the new 119 and 120 elements will start this year.
- Both projects got recognition as part of European research infrastructure and both are open for new participants and users.
- Deep underwater neutrino telescope Baikal GVD achieved ¼ of km3 volume.
- Other major IR projects – Pulsed neutron reactor IBR-2, Multifunctional Computer Center with Supercomputer “Govorun” are successfully developing.

- Long Range Strategy of JINR development up to 2030 under consideration which requires development of new accelerator technologies (SC HI cavities, RIB physics with storage rings, e-RIB collider rings or the DERICA - ISOL technology, crystalline beams in CR, etc.) and of the new Pulsed Neutron Rector projects like super booster “NEPTUNE” or the Hadron Therapy research complex.
- Cooperation with world physics research and accelerator community is very much appreciated as well as expanding the scientific ties with countries not presently having the full or associated membership in JINR.

JINR – CERN strategic partnerships

- JINR actively participates in the LHC programmes including the ATLAS, CMS , ALICE and the Collider itself and planning to contribute to the LHC detectors upgrade.
- Besides, JINR participate in the four SPS projects:
- Compass-II (NA58) – nucleon spin structure, hadron spectroscopy (with interests to future SPD at NICA);
- NA61 – (intersects with BM@Nuclotrone and MPD);
- NA62 – CP-violation and rare decays;
- NA64 – search for the dark sector;
- Accelerator development: **HL-LHC CLIC**,**ILC LHeC**, **FCC**, Precise laser metrology (super sensitive inclinometr) ,
- Computing and Information Technologies, **WLCG, Tier-1,2**
- Neutrino platform, DUNE; other - nTOF, DIRAC,
- Education and Teachers programs etc.

2014: CERN – JINR reciprocal Observer status

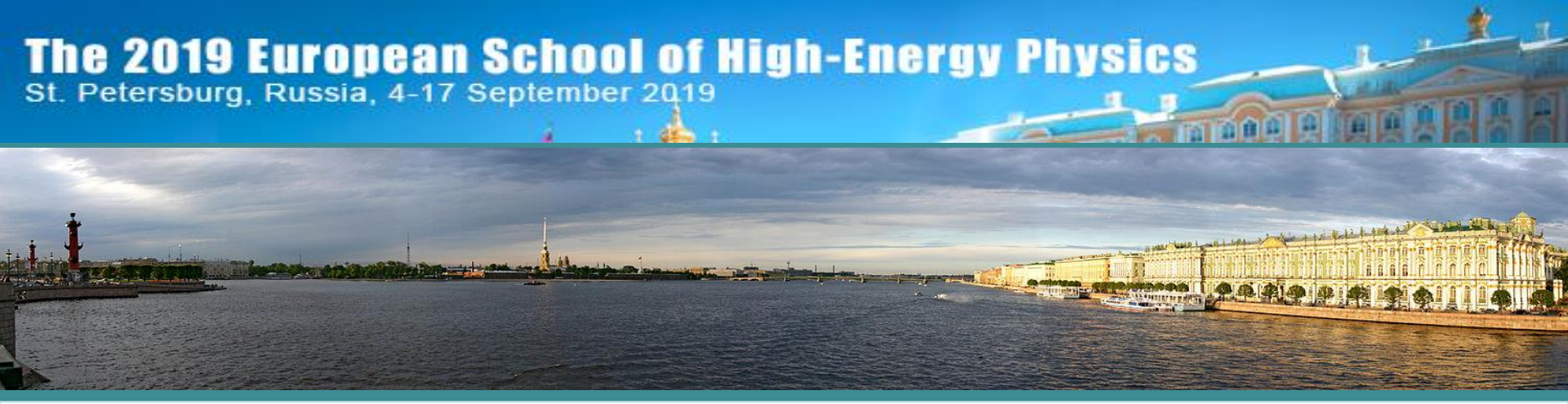
Observer Status allows non-member states to attend Council meetings and to receive Council documents without taking part in the decision-maki procedures of the organization.
For today, Observer states and organizations at CERN are:
the European Commission, India, Japan, Russian Federation, Turkey, UNESCO and the USA. And now the new one – the JINR.

Strategic step towards intensifying the mutually beneficial partnership between two international organizations which have a long story of cooperation

Approval of mutual observerships of JINR at CERN and of CERN at JINR

Session of the Committee of Plenipotentiaries of the Governments of the Member States of JINR, November 2014.


CERN
CERN



Acknowledgements
to organizers of the EU-HEP (CERN-JINR) School
in Saint-Petersburg, March, 2019

Thank you!

Science Bringing Nations Together

(1860 – 1904)

"Science cannot be national, in the same way that a multiplication table cannot be national.
If a science becomes national it ceases to be a science".

Anton Chekhov

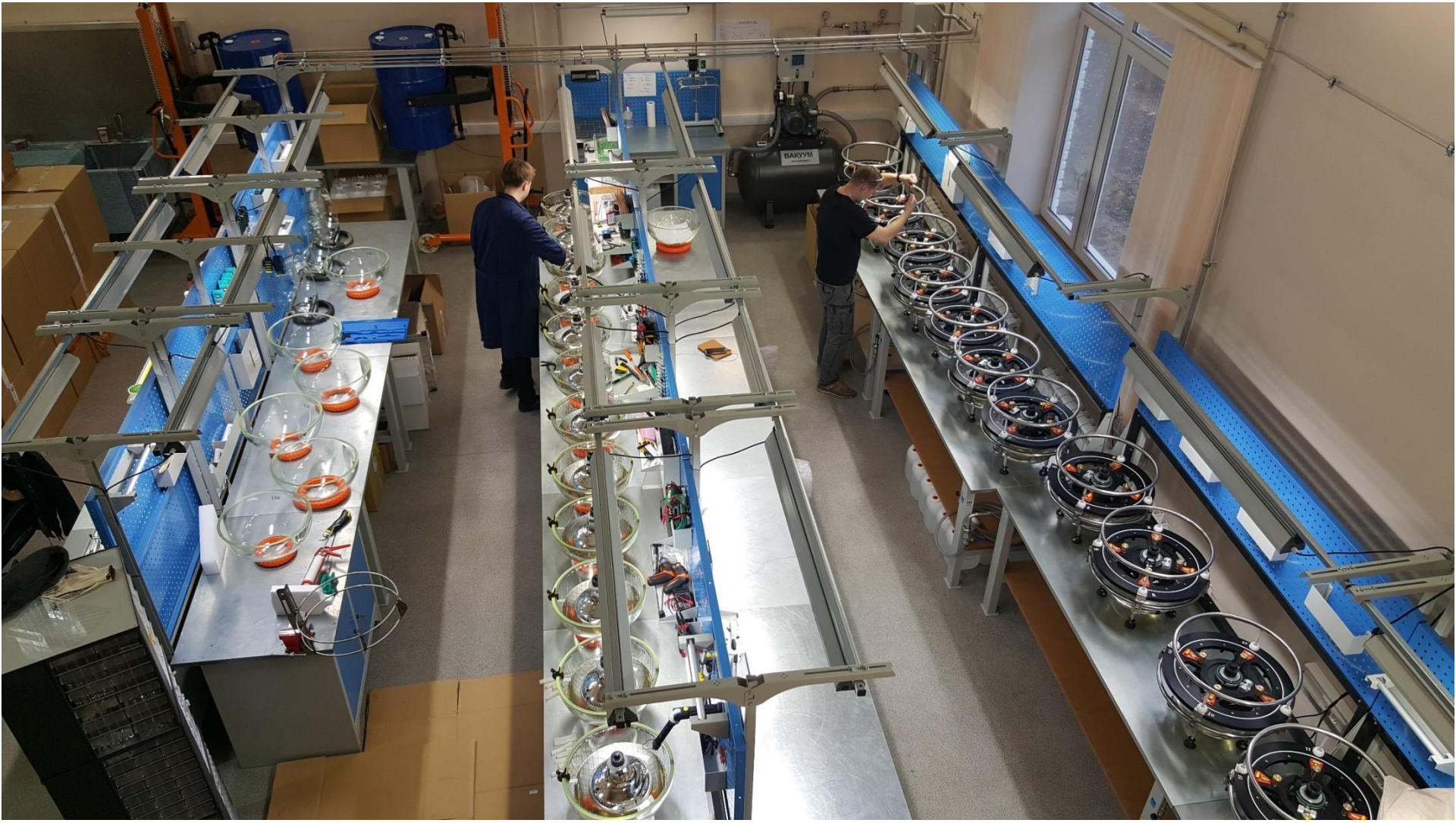

MASTER
11-12-17

News from our colleagues from China

Prof. Gao Jie:

“I have attended the CPCC Conference which is like SENATE meeting in your country. I have made proposal to President Xi in a face to face meeting on suggestions including China should apply to Dubna associate membership. My written proposal has been deposited to MOST. We think it is good for China and Dubna”.

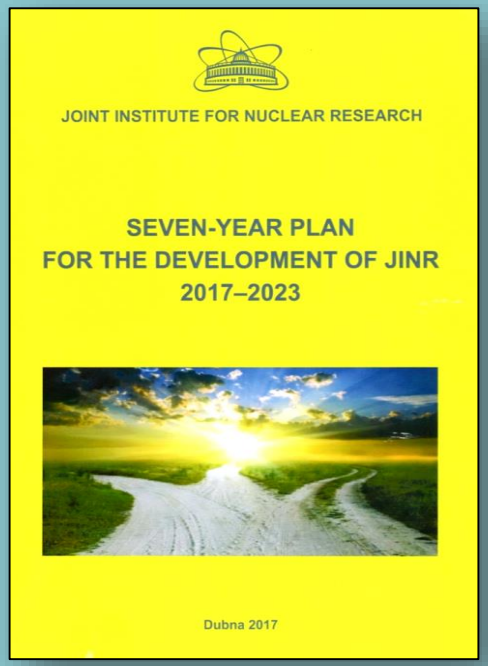
OM assembling hall @DLNP JINR

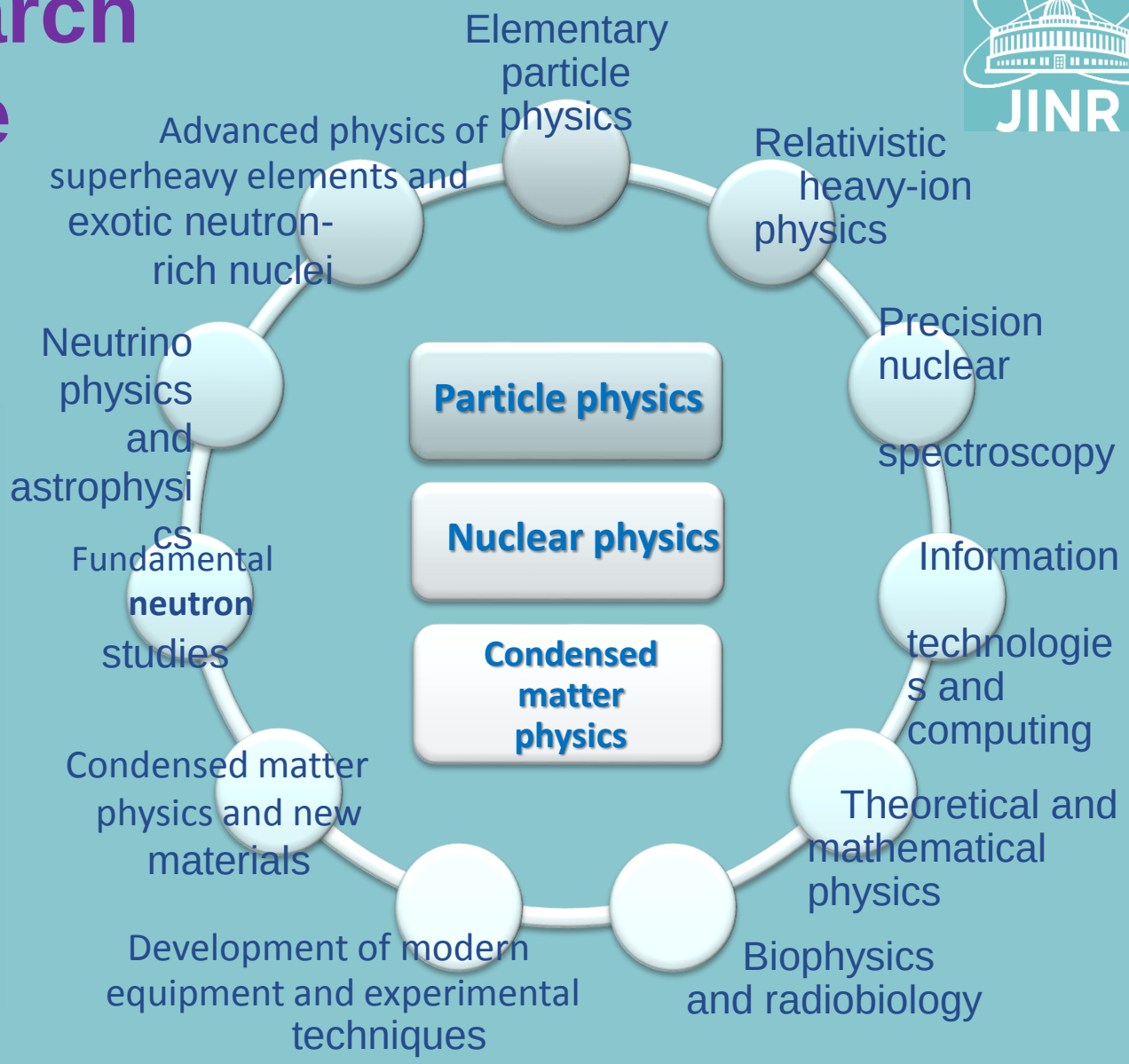


12 OM/day

JINR Research Programme

The Seven Year Plan for 2017-2023





The Long Range Strategy of JINR development up to 2030