International large research infrastructure of JINR, Dubna.

M.G.Itkis

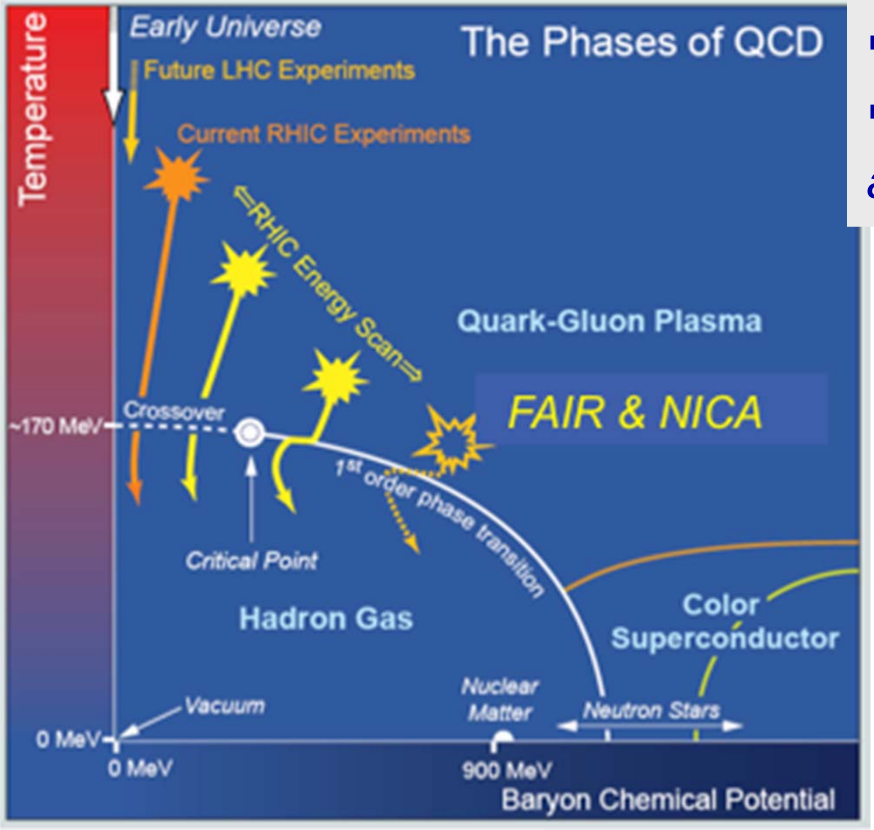
NUPECC Meeting, January 2017, Darmstadt, Germany

NICA is aimed at generation of intense heavy ion and polarized nuclear beams for searching the baryonic matter of a high density at high (comparatively) temperature and investigation of polarization phenomena.

NICA Collider parameters:

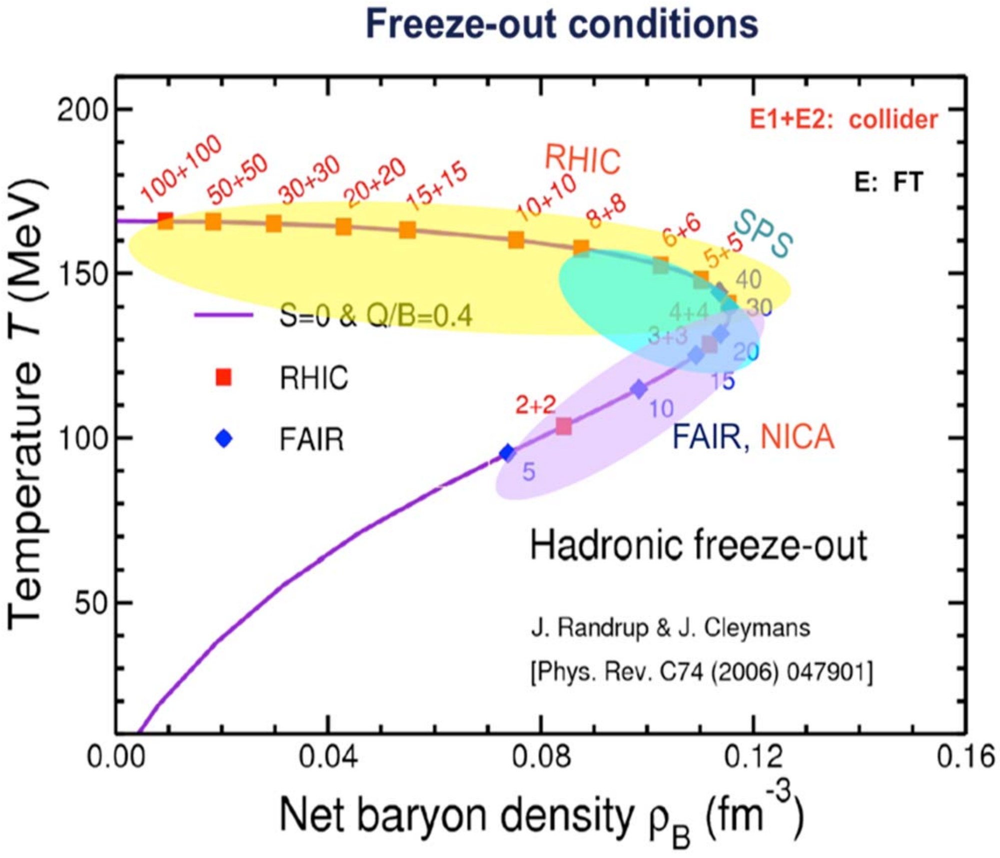
$\sqrt{s_{NN}}$ = 4-11 GeV heavy ion beams @ luminosity L~10^{27} cm^{-2} c^{-1} (Au), and polarized p↑ (d↑) of $\sqrt{s_{NN}}$ up to 26 (13) GeV at L ~ 10^{32} cm^{-2} c^{-1}

Physics

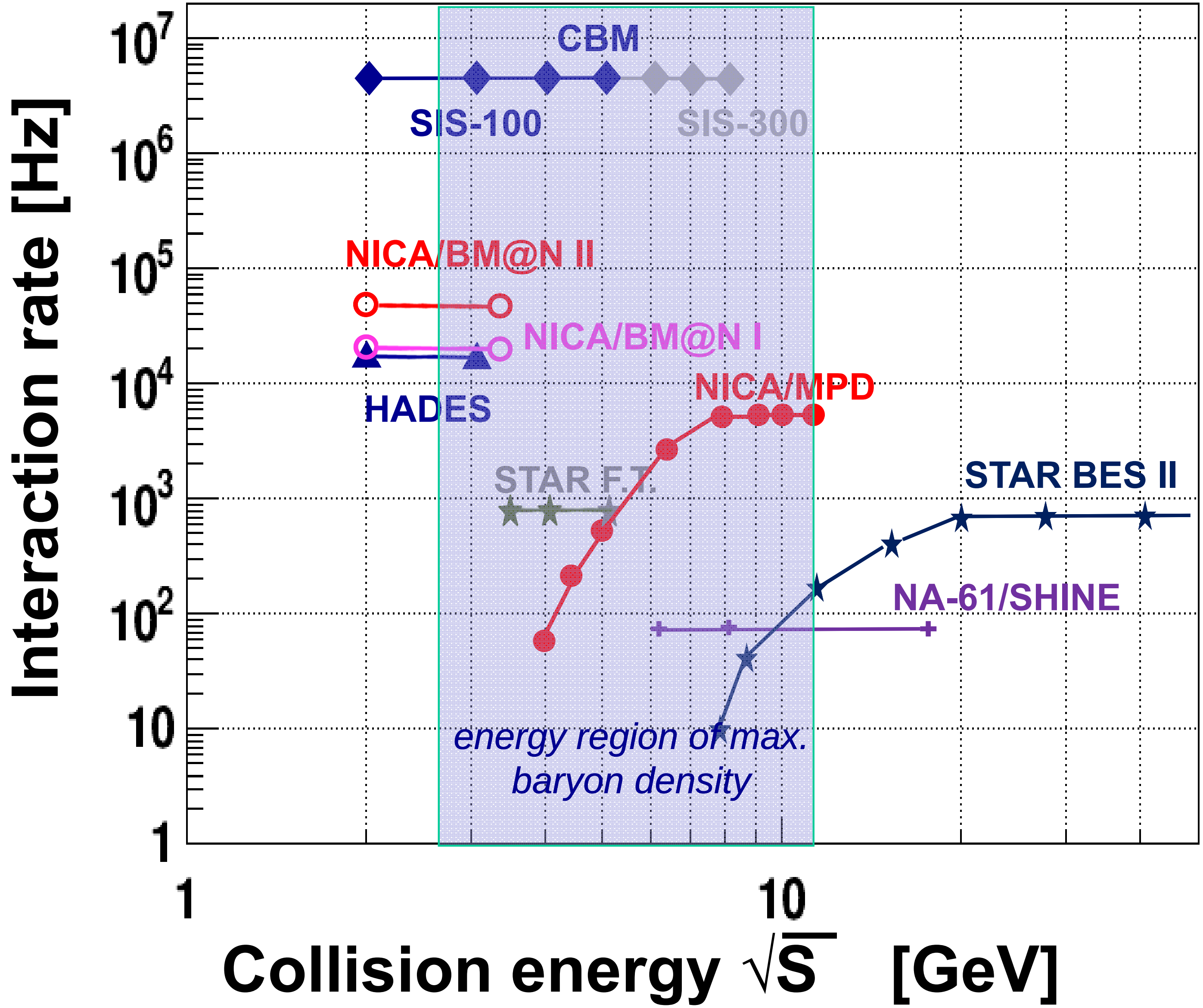


QCD matter at NICA *:*

- *Highest net baryon density*
- *Energy range covers onset of deconfinement*
- *Complementary to the RHIC LES, FAIR CBM and CERN (NA61) experimental programs*

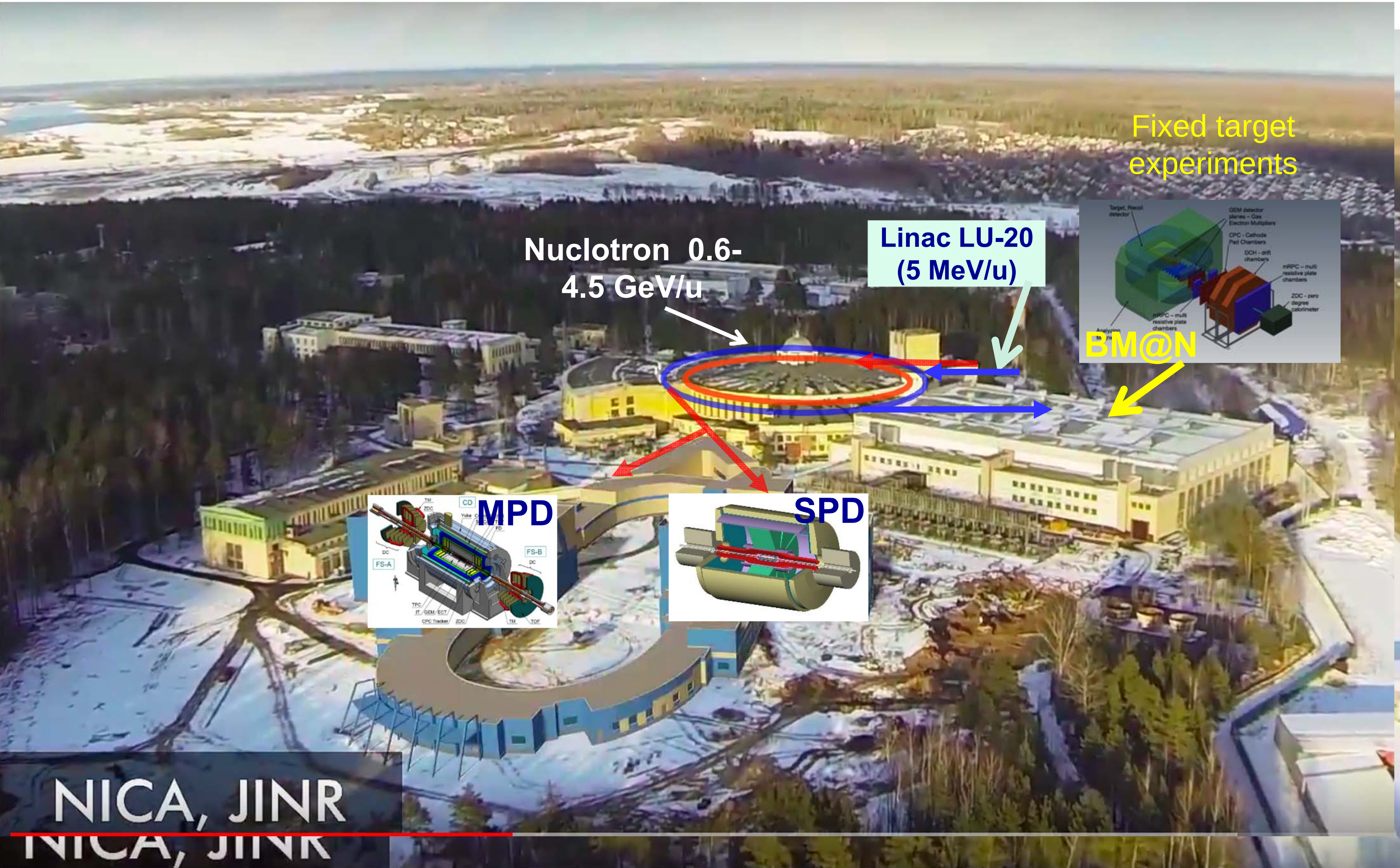


Present and future HI experiments/machines

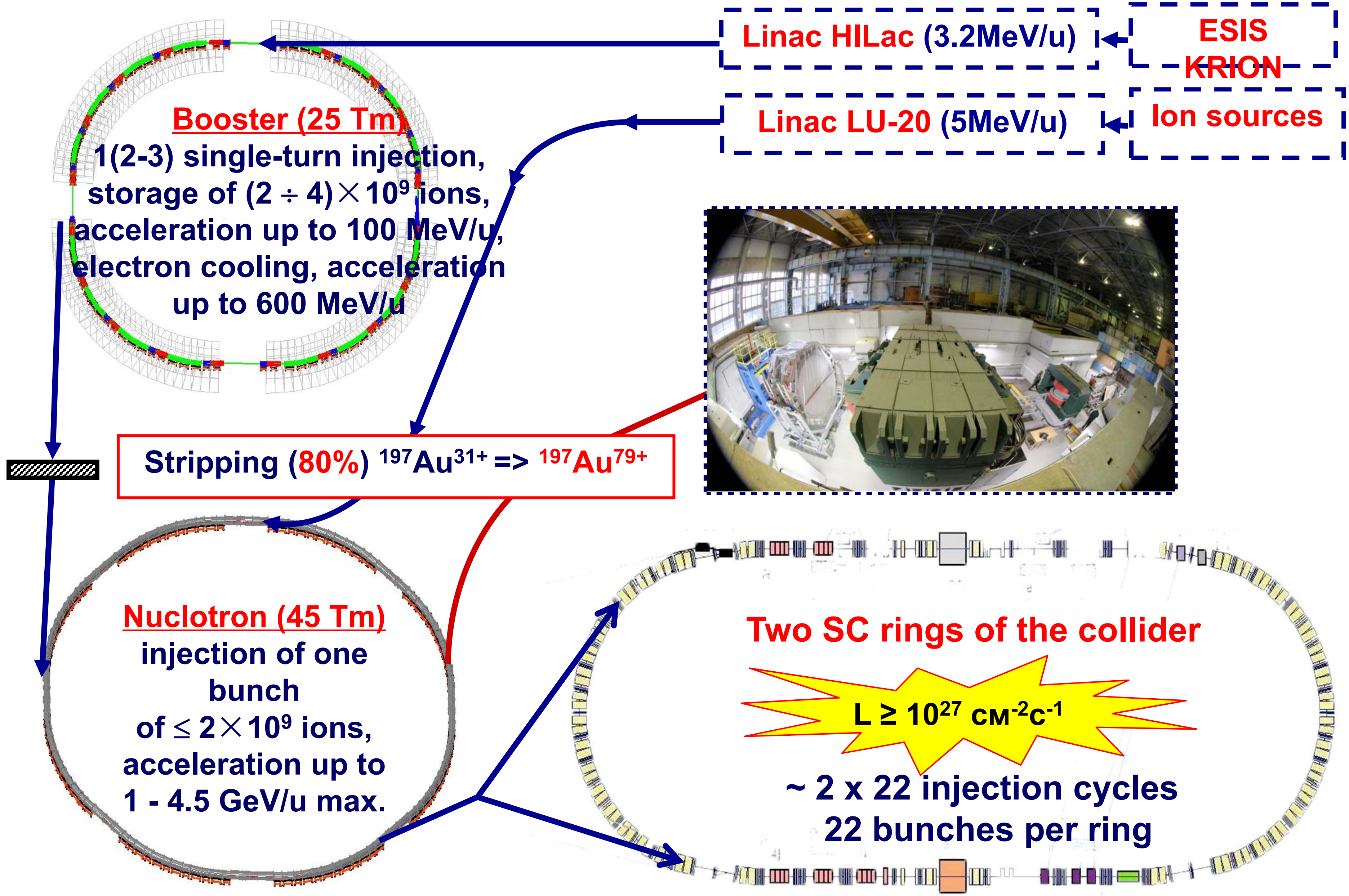


NICA facility

In operation ***Under construction***



NICA @ Heavy Ion mode



Ion sources

JINR Krion-6T (ESIS) for NICA

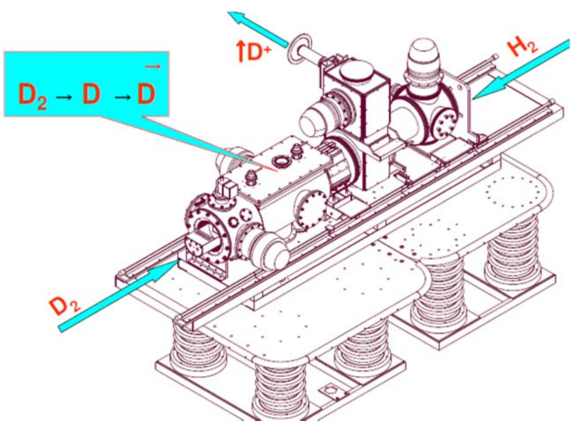
B = 6 (5.4) T
Ee = 25 (15) keV
J_el (design) = 1000 A/cm^2

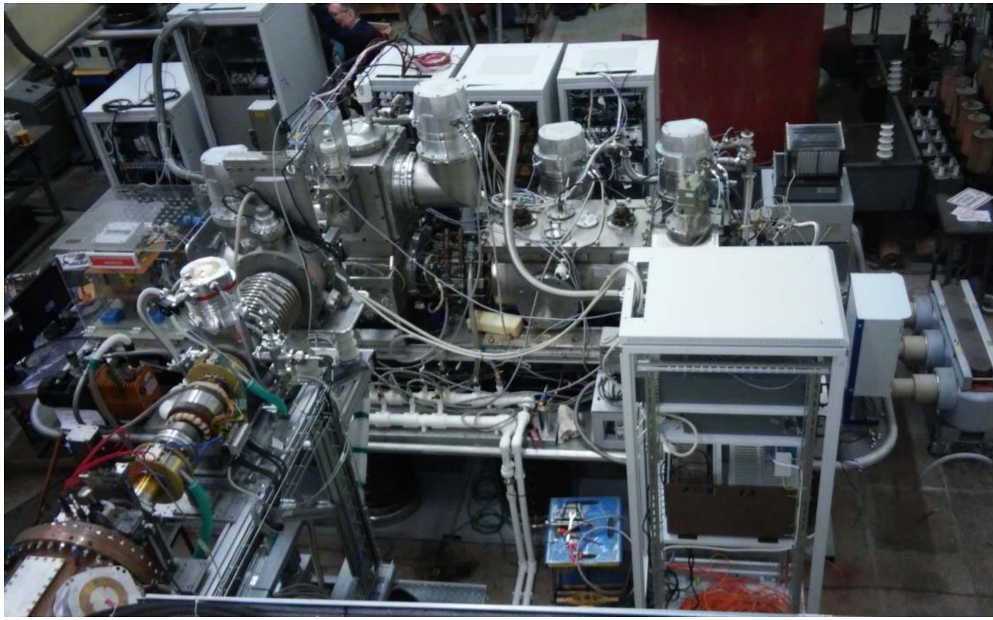
Au^{30+32+} achieved $6*10^8$ ppp, ($1*10^9$)

Peak currect = 10 mA/pulse
t_{ion} = 20 ms @ 50 (100) Hz.
Ion of $Au^{51+} \div Au^{54+}$ generated

Polarized particle (p, d, He^3) source

up to **10^{10} p/pulse, 80% polarization**





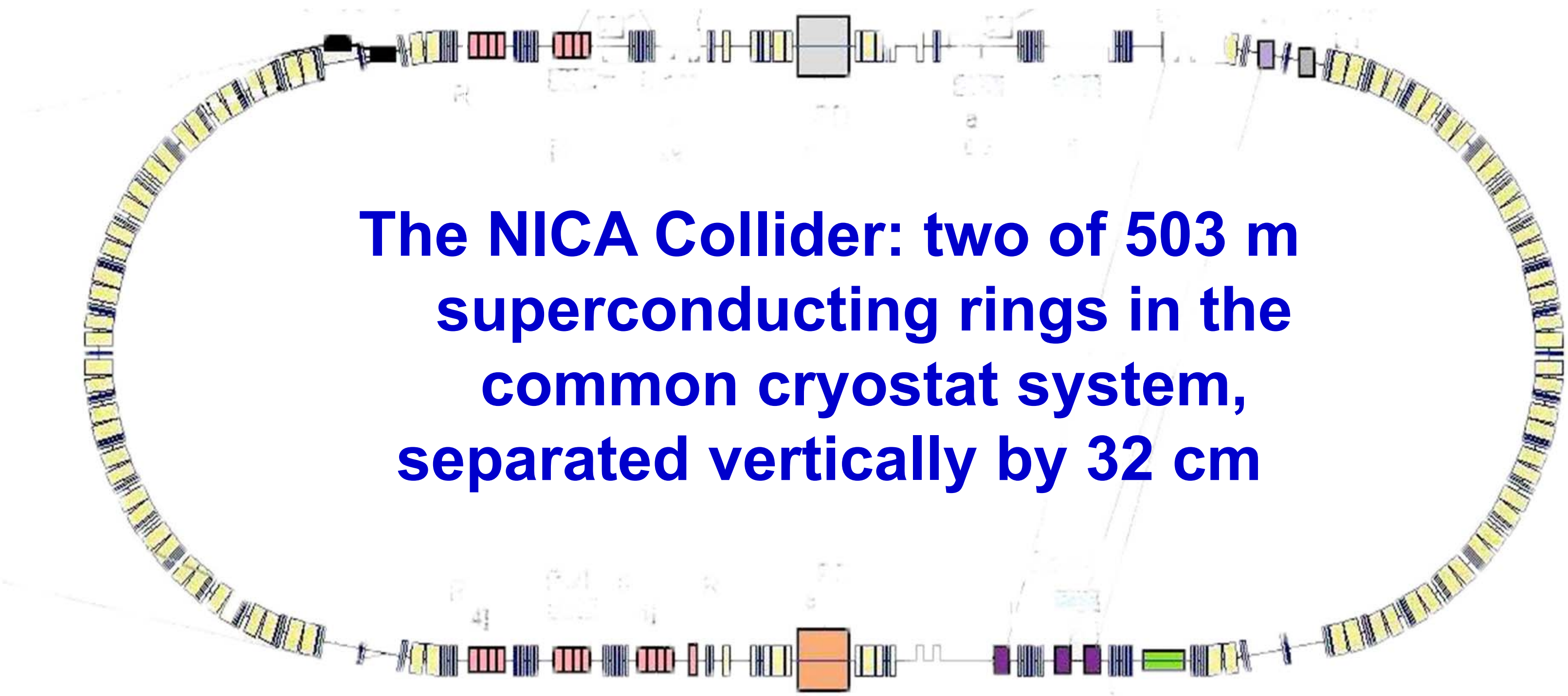
NICA collider magnets

Double-aperture SC Magnets for the NICA collider:

- 80 + 8 Dipole Magnets
- 86 + 12 Quadrupole Lenses
- 88 Corrector Magnets

Start of serial production and cryogenic tests of the magnets is scheduled for 2017.

The NICA Collider: two of 503 m superconducting rings in the common cryostat system, separated vertically by 32 cm



Collider lattice:
FODO,
12 cells x 90^0
each arc

Electron cooling & stochastic cooling

Number of bunches	22		
rms bunch length, m	0.6		
β-function in IP, m	0.35		
Kin. energy of Au^{79+}, GeV/u	1.0	3.0	4.5
Number of ions per bunch	$2.0 \cdot 10^8$	$2.4 \cdot 10^9$	$2.3 \cdot 10^9$
$\Delta p/p_{rms}$, 10^{-3}	0.55	1.15	1.5
ε_{rms}, (h/v) π mm·mrad	1.1/0.95	1.1/0.85	1.1/0.75
Luminosity, $cm^{-2}\ s^{-1}$	$0.6 \cdot 10^{25}$	$1 \cdot 10^{27}$	$1 \cdot 10^{27}$
IBS growth time, s	160	460	1800

NICA @ Start-up configuration

The beginning of the NICA accelerator complex commissioning

is scheduled for 2020

The complex will be commissioned with

- Injectors chain
- Transfer channels
- Collider in start up version, i.e:
  - with RF-1 and RF-2, but without RF-3
  - with Stoch. Coolg system - one channel per ring (long. cooling)
  - without Electron Cooler
  - without feed-back system

It will allow us to provide collider operation in the energy range of

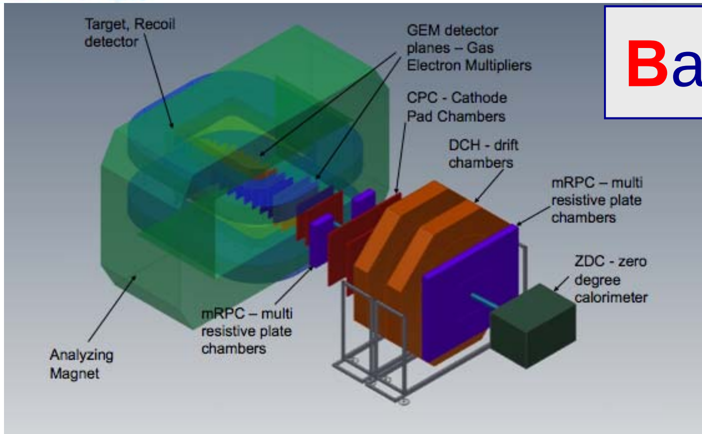
$$\sqrt{s_{NN}} \sim 5 - 9 \text{ GeV } ({}^{197}Au^{79+} \text{ ions})$$

at the luminosity of

$$L_{start} \leq 5 \times 10^{25} - 3 \times 10^{26} \, [cm^{-2} \cdot s^{-1}]$$

Advantage in luminosity when full-scale NICA configuration: a factor of 58 (@3 GeV) scaled to 13 (@4.5 GeV) times

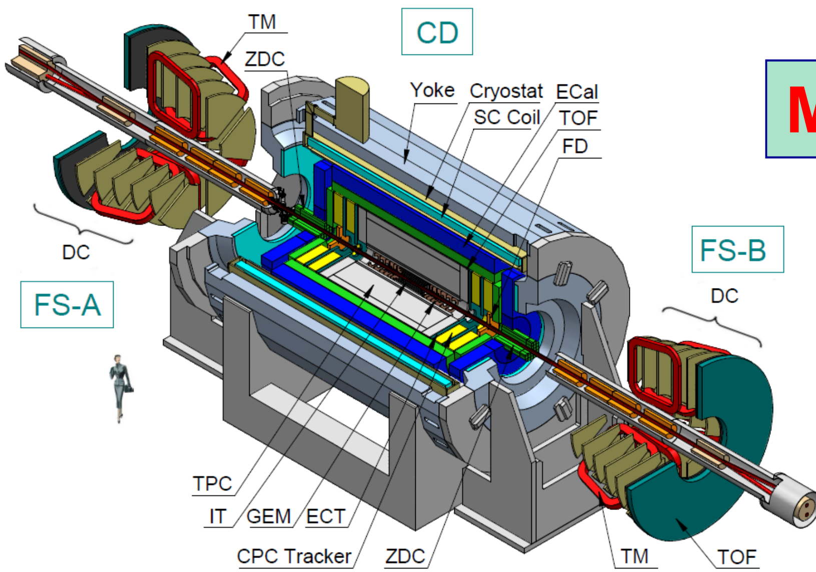
NICA: 3 detectors



Baryonic Matter at Nuclotron (BM@N)

the fixed target experiment at the Nuclotron

Stage I - 2017



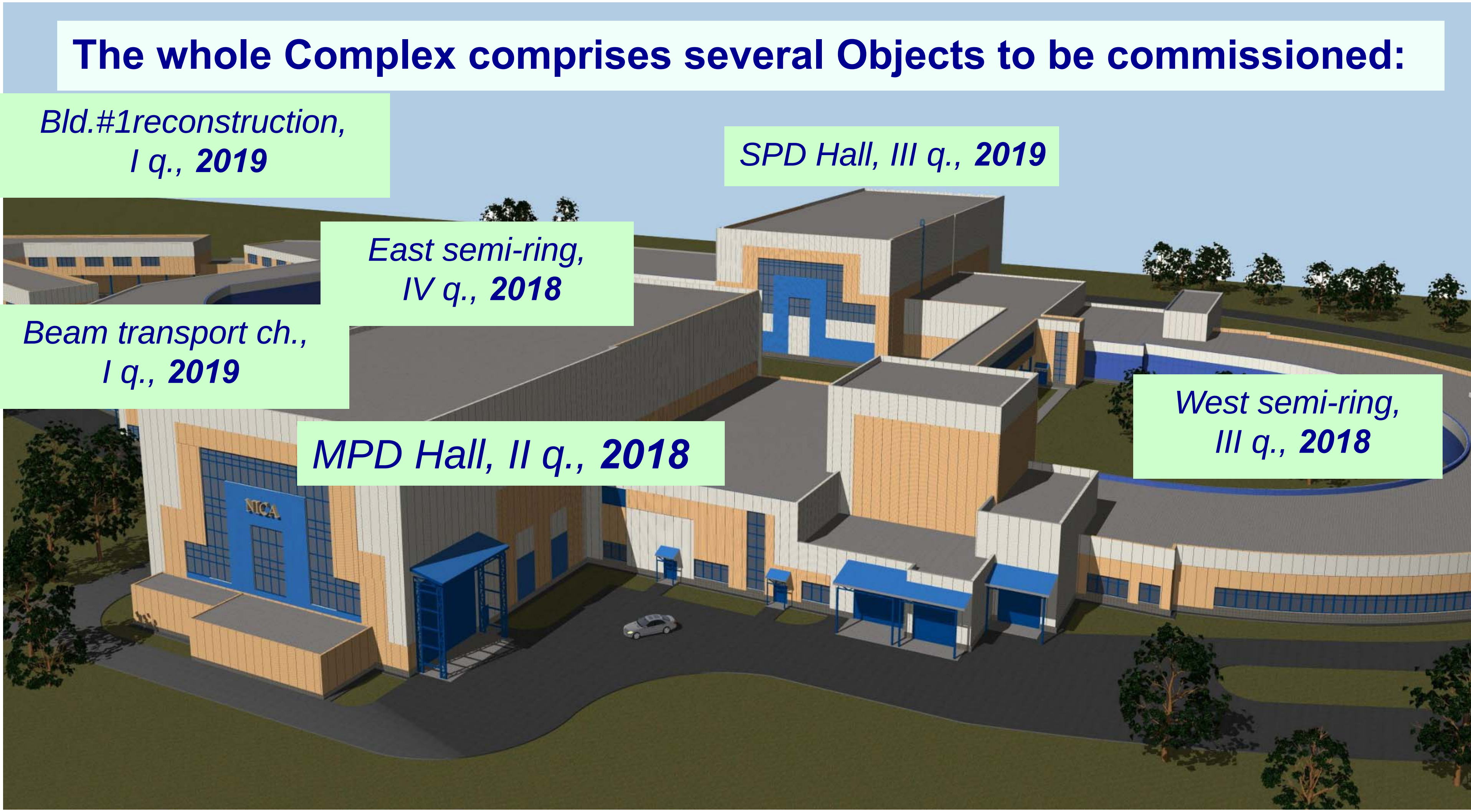
MultiPurpose Detector (MPD)

at the Collider

Stage II – 2019/2020

SPD (Spin Physics Detector) *at the Collider*

Stage III – after 2022


The whole Complex comprises several Objects to be commissioned:
Bld.#1reconstruction, I q., 2019
SPD Hall, III q., 2019
East semi-ring, IV q., 2018
Beam transport ch., I q., 2019
MPD Hall, II q., 2018
West semi-ring, III q., 2018
NICA

Support of President, Presidential Council, Ministry, NRC KI, Russian institutes, European and Asian Agencies

NICA

Status of the NICA mega-science @ JINR

ПРАВИТЕЛЬСТВО РОССИЙСКОЙ ФЕДЕРАЦИИ

РАСПОРЯЖЕНИЕ

от 27 апреля 2016 г. № 783-р

МОСКВА

О подписании Соглашения между Правительством Российской Федерации и международной межправительственной научно-исследовательской организацией Объединенным институтом ядерных исследований о создании и эксплуатации комплекса сверхпроводящих колец на встречных пучках тяжелых ионов NICA

1. В соответствии с пунктом 1 статьи 11 Федерального закона "О международных договорах Российской Федерации" одобрить представленный Минобрнауки России согласованный с МИДом России, Минфином России, Минэкономразвития России и международной межправительственной научно-исследовательской организацией Объединенным институтом ядерных исследований проект Соглашения между Правительством Российской Федерации и международной межправительственной научно-исследовательской организацией Объединенным институтом ядерных исследований о создании и эксплуатации комплекса сверхпроводящих колец на встречных пучках тяжелых ионов NICA (прилагается).

2. Поручить Минобрнауки России провести переговоры с международной межправительственной научно-исследовательской организацией Объединенным институтом ядерных исследований и по достижении договоренности подписать от имени Правительства Российской Федерации указанное в пункте 1 настоящего распоряжения Соглашение, разрешив вносить в прилагаемый проект изменения,

On 27th April 2016 the RG Prime-minister issued the Governmental Decree about establishment of the NICA mega-science on Russian territory at JINR.

Russia and JINR co-invest to the “NICA Complex.

Agreement between RF Government and JINR (signed on 2nd June 2016) in the frame of Decree formulates basic principles of the setting and development of the International collaboration “Complex NICA.

We assume that in coming years similar Agreements will be prepared, agreed and signed with other countries and International Scientific centers, expressed their interest to participate and contribute to NICA.

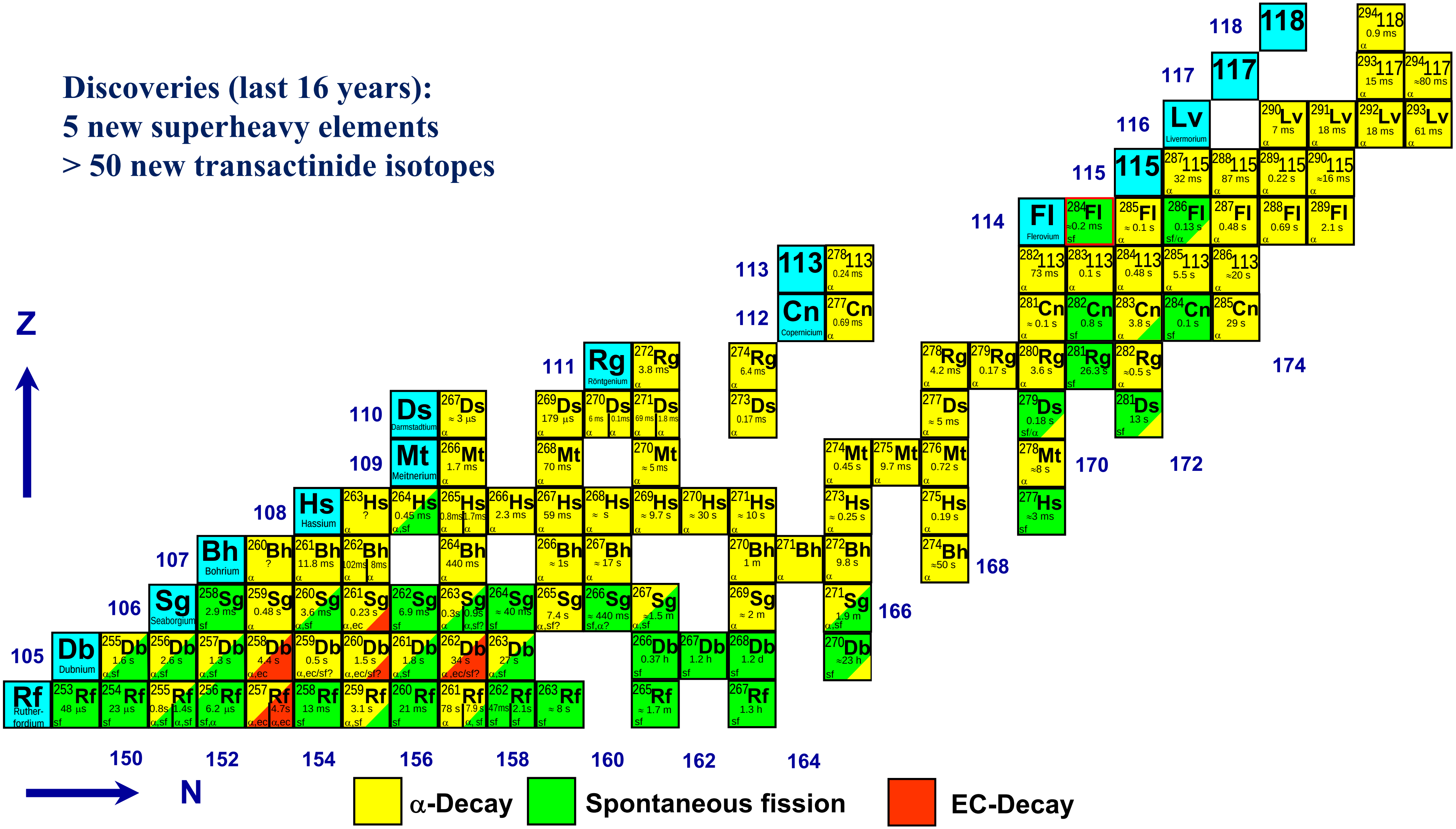
We invite new countries to join NICA (Germany, China, India, SAR, …) and leading International centers (CERN, FAIR, …), also Universities.

Support of President, Presidential Council, Ministry, NRC KI, Russian institutes, European and Asian Agencies

SUPERHEAVY ELEMENT FACTORY

Superheavy Element Research

Discoveries (last 16 years):
5 new superheavy elements
> 50 new transactinide isotopes



Периодическая таблица элементов Д.И. Менделеева

D.I. Mendeleev's Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Водород 1 H 1,00794 Hydrogen																	Гелий 2 He 4,0026 Helium
Литий 3 Li 6,941 Lithium	Бериллий 4 Be 9,01218 Beryllium											Бор 5 B 10,811 Boron	Углерод 6 C 12,011 Carbon	Азот 7 N 14,0067 Nitrogen	Кислород 8 O 15,9994 Oxygen	Фтор 9 F 18,9984 Fluorine	Неон 10 Ne 20,1797 Neon
Натрий 11 Na 22,989768 Sodium	Магний 12 Mg 24,3050 Magnesium											Алюминий 13 Al 26,981539 Aluminum	Кремний 14 Si 28,0855 Silicon	Фосфор 15 P 30,97376 Phosphorus	Сера 16 S 32,066 Sulfur	Хлор 17 Cl 35,4527 Chlorine	Аргон 18 Ar 39,948 Argon
Калий 19 K 39,0983 Potassium	Кальций 20 Ca 40,078 Calcium	Скандий 21 Sc 44,95591 Scandium	Титан 22 Ti 47,88 Titanium	Ванадий 23 V 50,9415 Vanadium	Хром 24 Cr 51,9961 Chromium	Марганец 25 Mn 54,93805 Manganese	Железо 26 Fe 55,847 Iron	Кобальт 27 Co 58,93320 Cobalt	Никель 28 Ni 58,6934 Nickel	Медь 29 Cu 63,546 Copper	Цинк 30 Zn 65,39 Zinc	Галлий 31 Ga 69,723 Gallium	Германий 32 Ge 72,61 Germanium	Мышьяк 33 As 74,92159 Arsenic	Селен 34 Se 78,96 Selenium	Бром 35 Br 79,904 Bromine	Криптон 36 Kr 83,80 Krypton
Рубидий 37 Rb 85,4678 Rubidium	Стронций 38 Sr 87,62 Strontium	Иттрий 39 Y 88,90585 Yttrium	Цирконий 40 Zr 91,224 Zirkonium	Ниобий 41 Nb 92,90638 Niobium	Молибден 42 Mo 95,94 Molybdenum	Технеций 43 Tc [98] Technetium	Рутений 44 Ru 101,07 Ruthenium	Родий 45 Rh 102,90550 Rhodium	Палладий 46 Pd 106,42 Palladium	Серебро 47 Ag 107,8682 Silver	Кадмий 48 Cd 112,411 Cadmium	Индий 49 In 114,818 Indium	Олово 50 Sn 118,710 Tin	Сурьма 51 Sb 121,757 Antimony	Теллур 52 Te 127,60 Tellurium	Иод 53 I 126,90447 Iodine	Ксенон 54 Xe 131,29 Xenon
Цезий 55 Cs 132,90543 Cesium	Барий 56 Ba 137,327 Barium	Лантан 57 La 138,9055 Lanthanum	Гафний 72 Hf 178,49 Hafnium	Тантал 73 Ta 180,9479 Tantalum	Вольфрам 74 W 183,84 Tungsten	Рений 75 Re 186,207 Rhenium	Осмий 76 Os 190,23 Osmium	Иридий 77 Ir 192,22 Iridium	Платина 78 Pt 195,08 Platinum	Золото 79 Au 196,96654 Gold	Ртуть 80 Hg 200,59 Mercury	Таллий 81 Tl 204,3833 Thallium	Свинец 82 Pb 207,2 Lead	Висмут 83 Bi 208,98037 Bismuth	Полоний 84 Po [209] Polonium	Астат 85 At [210] Astatine	Радон 86 Rn [222] Radon
Франций 87 Fr [223] Francium	Радий 88 Ra 226,025 Radium	Актиний 89 Ac [227] Actinium	Резерфордий 104 Rf [261] Rutherfordium	Дубний 105 Db [262] Dubnium	Сиборгий 106 Sg [266] Seaborgium	Борий 107 Bh [262] Bohrium	Хассий 108 Hs [269] Hassium	Мейтнерий 109 Mt [268] Meitnerium	Дармштадтий 110 Ds [269] Darmstadtium	Рентгений 111 Rg [272] Roentgenium	Коперниций 112 Cn [285] Copernicium	(Нихоний) 113 Nh (Nihonium)	Флеровий 114 Fl Flerovium	(Московий) 115 Mc (Moscovium)	Ливерморий 116 Lv Livermorium	(Теннессин) 117 Ts (Tennessine)	(Оганесон) 118 Og (Oganesson)

Лантаноиды Lanthanides

Церий 58 Ce 140,115 Cerium	Празеодим 59 Pr 140,90765 Praseodymium	Неодим 60 Nd 144,24 Neodymium	Прометий 61 Pm [145] Promethium	Самарий 62 Sm 150,36 Samarium	Европий 63 Eu 151,965 Europium	Гадолиний 64 Gd 157,25 Gadolinium	Тербий 65 Tb 158,92534 Terbium	Диспрозий 66 Dy 162,50 Dysprosium	Гольмий 67 Ho 164,93032 Holmium	Эрбий 68 Er 167,26 Erbium	Тулий 69 Tm 168,93421 Thulium	Иттербий 70 Yb 173,04 Ytterbium	Лютеций 71 Lu 174,967 Lutetium

Актиноиды Actinides

Торий 90 Th 232,0381 Thorium	Протактиний 91 Pa 231,03588 Protactinium	Уран 92 U 238,0289 Uranium	Нептуний 93 Np [237] Neptunium	Плутоний 94 Pu [244] Plutonium	Америций 95 Am [243] Americium	Кюрий 96 Cm [247] Curium	Берклий 97 Bk [247] Berkelium	Калифорний 98 Cf [251] Californium	Эйнштейний 99 Es [252] Einsteinium	Фермий 100 Fm [257] Fermium	Менделевий 101 Md [258] Mendelevium	Нобелий 102 No [259] Nobelium	Лоуренсий 103 Lr [262] Lawrencium

Водород 1 1s¹	
H	13.59844 0,0899
1,00794 Hydrogen	-259,34 -252,87

H - символ/symbol
1,00794 - атомная масса/atomic mass
1s1 - электронная конфигурация/Electron configuration
13,59844 -1-й потенциал ионизации, эВ/1st ionization potential, eV
0,0899 - плотность, кг/м3/density, kg/m3
-259,34 - температура плавления,oC/melting temperature, oC
-252,87 - температура кипения,oC/boiling temperature, oC

S - ЭЛЕМЕНТЫ/ELEMENTS d - ЭЛЕМЕНТЫ/ELEMENTS
p - ЭЛЕМЕНТЫ/ELEMENTS f - ЭЛЕМЕНТЫ/ELEMENTS

The future of SHE research we associate

with the construction of the Superheavy Elements Factory.

Superheavy Elements (SHE) Factory – the Goals

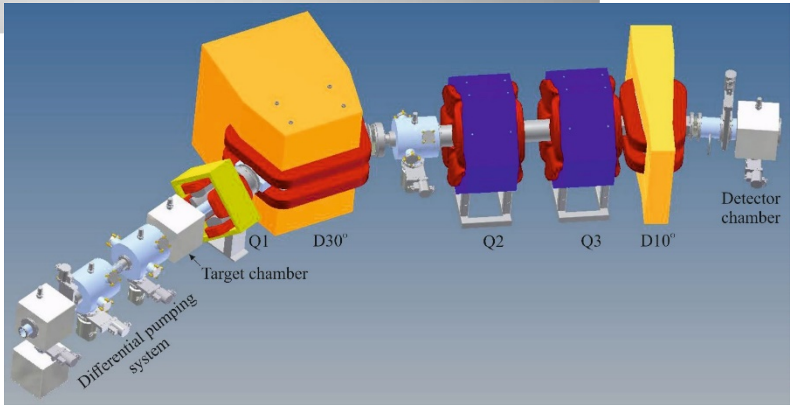
- **Experiments at the extremely low (σ<100 fb) cross sections:**
  - Synthesis of new SHE in reactions with ^{50}Ti, ^{54}Cr ...(119, 120);
  - Shaping of the region of SHE (synthesis of new isotopes of SHE);
  - Study of decay properties of SHE;
  - Study of excitation functions.

- **Experiments requiring high statistics:**
  - Nuclear spectroscopy of SHE;
  - Precise mass measurements;
  - Study of chemical properties of SHE.

SHE Factory

SHE Factory Building

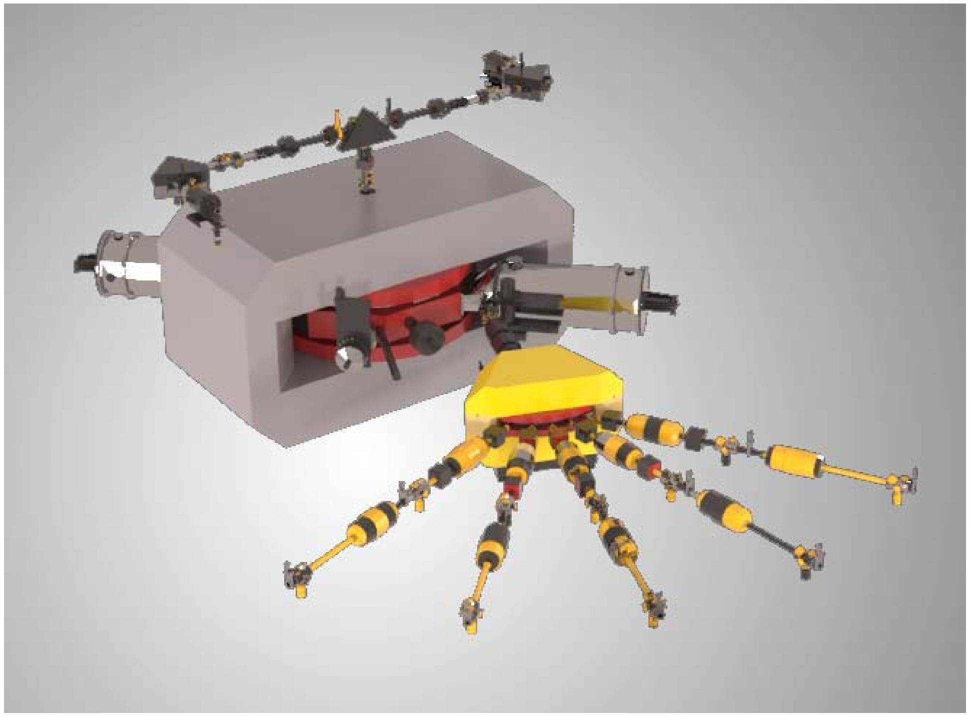
High-current cyclotron DC-280



New facilities:

- New gas-filled separator
- Pre-separator for SHE chemistry
- Separator SHELS
- Etc.

DC-280 cyclotron – stand-alone SHE factory



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

DC280 (expected) E=4÷8 MeV/A		
Ion	Ion energy [MeV/A]	Output intensity
^{7}Li	4	1×10^{14}
^{18}O	8	1×10^{14}
^{40}Ar	5	6×10^{13}
^{48}Ca	5	0,6-1,2$\times10^{14}$
^{54}Cr	5	2×10^{13}
^{58}Fe	5	1×10^{13}
^{124}Sn	5	2×10^{12}
^{136}Xe	5	1×10^{14}
^{238}U	7	5×10^{10}

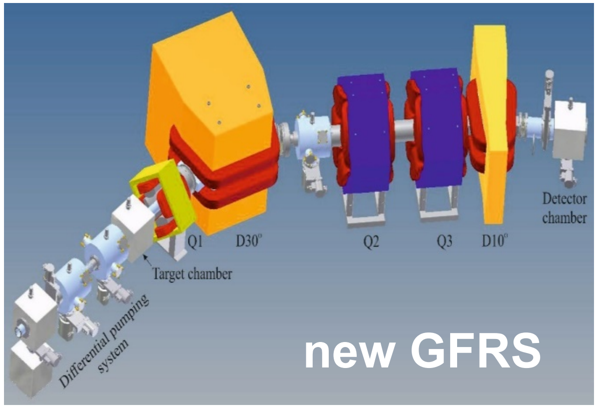
DC-280
Main Parameters

Ion source	DECRIS-4 - 14 GHz DECRIS-SC3 - 18 GHz
Injecting beam potential	Up to 100 kV
A/Z range	4÷7
Energy	4÷8 MeV/n
Magnetic field level	0.6÷1.35 T
K factor	280
Gap between plugs	400 mm
Valley/hill gap	500/208 mm/mm
Magnet weight	1000 t
Magnet power	300 kW
Dee voltage	2x130 kV
RF power consumption	2x30 kW
Flat-top dee voltage	2x14 kV

Assembling of the DC280 magnet

01.11.2016 http://lideo.ru/embed/4655

SHE Factory. Time-schedule.



- Completion of the **SHE Factory building** and its **engineering systems** (*2016 – June 2017*)
- Assembling the **DC-280** cyclotron. Installation of new **G**as-**F**illed **R**ecoil **S**eparator. (*September 2016 – December 2017*)
- **First experiments** (*2018*)

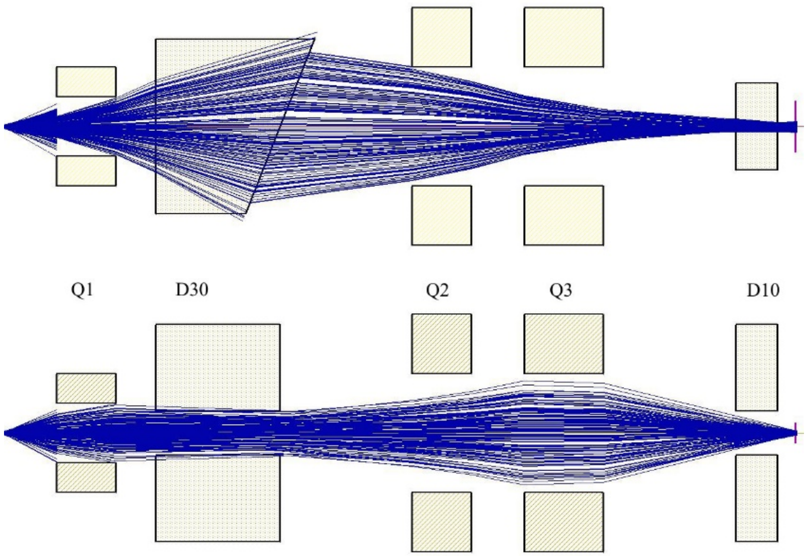
New experimental setup - velocity filter SHELS (Separator for Heavy ELement Spectroscopy)

This year 1st prize of JINR in the field of instruments and methods

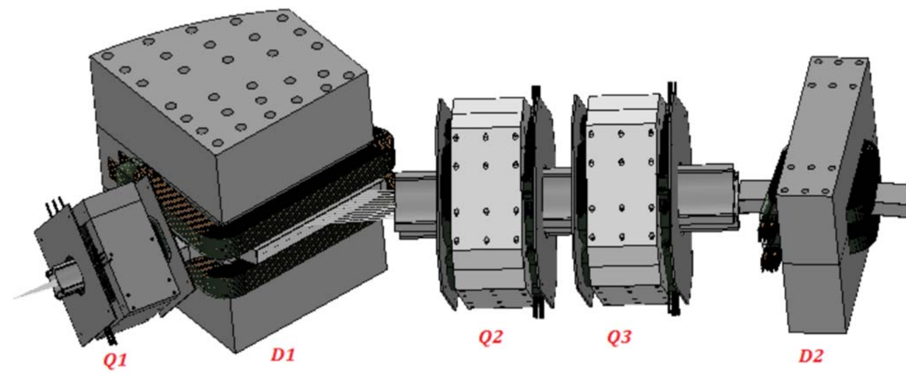
New focal plane detector GABRIELA

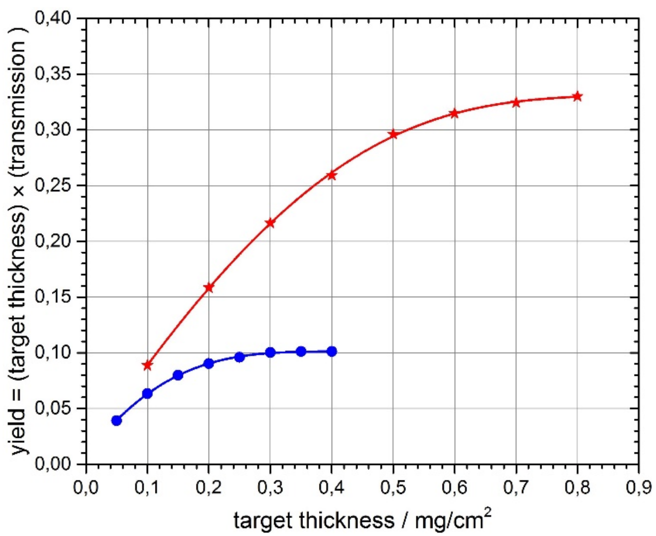
GABRIELA - Gamma Alpha Beta Recoil Investigation with the Electromagnetic Analyser

New FLNR gas-filled separator (contracted)



Technical Design
Report No 412923





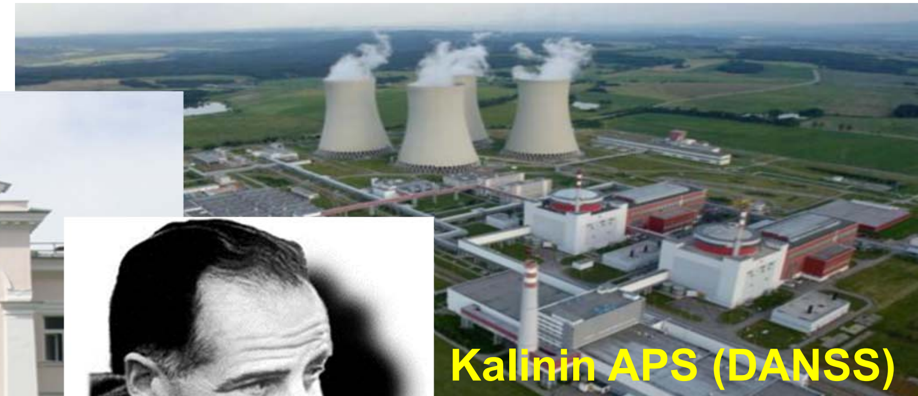
Reaction	Transmission
$^{244}Pu(^{48}Ca,3n)^{289}114$	60 %
$^{244}Pu(^{58}Fe,4n)^{298}120$	75 %

2016÷2024 years FLNR accelerators running, construction and modernization schedule (2016)

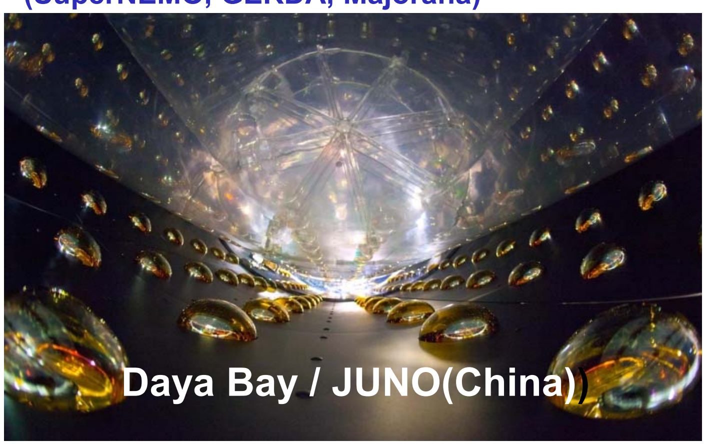
Accelerator \ Year	2016	2017	2018	2019	2020	2021	2022	2023	2024
DC280	Assembling	Assembling; Beam tuning	5000	5000	5000	5000	5000	5000	5000
U400M-U400MR	5000	5000	5000	Reconstruction	5000	5000	5000	5000	5000
U400-U400R	5000	5000	5000	5000	2000; Reassembling	Building	Assembling	2000; Beam tuning	5000
Beam time on the targets	10 000	10 000	15 000	10 000	12 000	10 000	10 000	12 000	15 000

Hour - annual beam time on the targets.

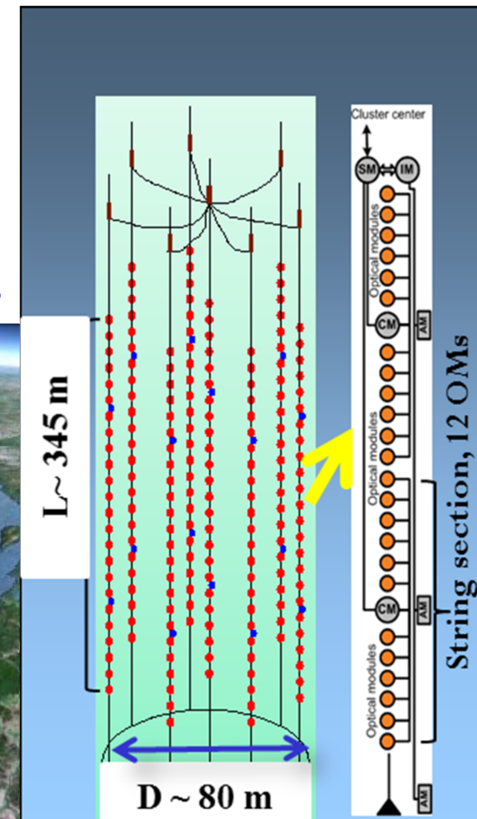
Neutrino program



Coherent neutrino-nucleus scattering (νGEN)
Precise measurements of neutrino oscillations (Daya Bay, BOREXINO)
Neutrino mass hierarchy (JUNO, NOvA)
Neutrinoless 2β –Decay search: (SuperNEMO, GERDA, Majorana)



Astrophysical neutrino sources



"White Book" documents the JINR neutrino program

Every experiment — participant of the neutrino program — is described in a uniform format in the Book (about 300 pages):

THE WHITE BOOK
JINR NEUTRINO PROGRAM

Editors: Vadim A.Bednyakov, Dmitry V.Naumov.
Dubna/JINR. May 13, 2014

Contents

Chapter 3

BAIKAL Experiment

Editors: I.A.Belolaptikov, V.B.Brudanin

3.1 Front Matter

Project Title

BAIKAL Experiment. Deep underwater muon and neutrino detector in the Baikal Lake.

Project Leaders

- I.A.Belolaptikov

Abstract

The BAIKAL-GVD Project in the Lake Baikal [1] is an extension of the research and development work performed over the past several years by the BAIKAL Collaboration on the first phase. The optical properties of the deep water lake have been established, and the detection of high-energy neutrinos has been demonstrated with the existing detector NT200/NT200+. This achievement represents a proof of concept for commissioning a new instrument, the Gigaton Volume Detector (BAIKAL-GVD), with superior detector performance and an effective telescope size at or above the kilometer-scale.

The second-stage neutrino telescope BAIKAL-GVD will be a new research infrastructure aimed primarily at studying astrophysical neutrino fluxes. The detector will utilize Lake Baikal water instrumented at depth with optical sensors that detect the Cherenkov radiation from secondary particles produced in interactions of high-energy neutrinos inside or near the instrumented volume. The concept of BAIKAL-GVD is based on a number of evident requirements to the design and architecture of the recording system of the new array: the utmost use of the advantages of array deployment from the ice cover of Lake Baikal, the extendability of the facility and provision of its effective operation even in the first stage of deployment, and the possibility of implementing different versions of arrangement and spatial distribution of light sensors within the same measuring system.

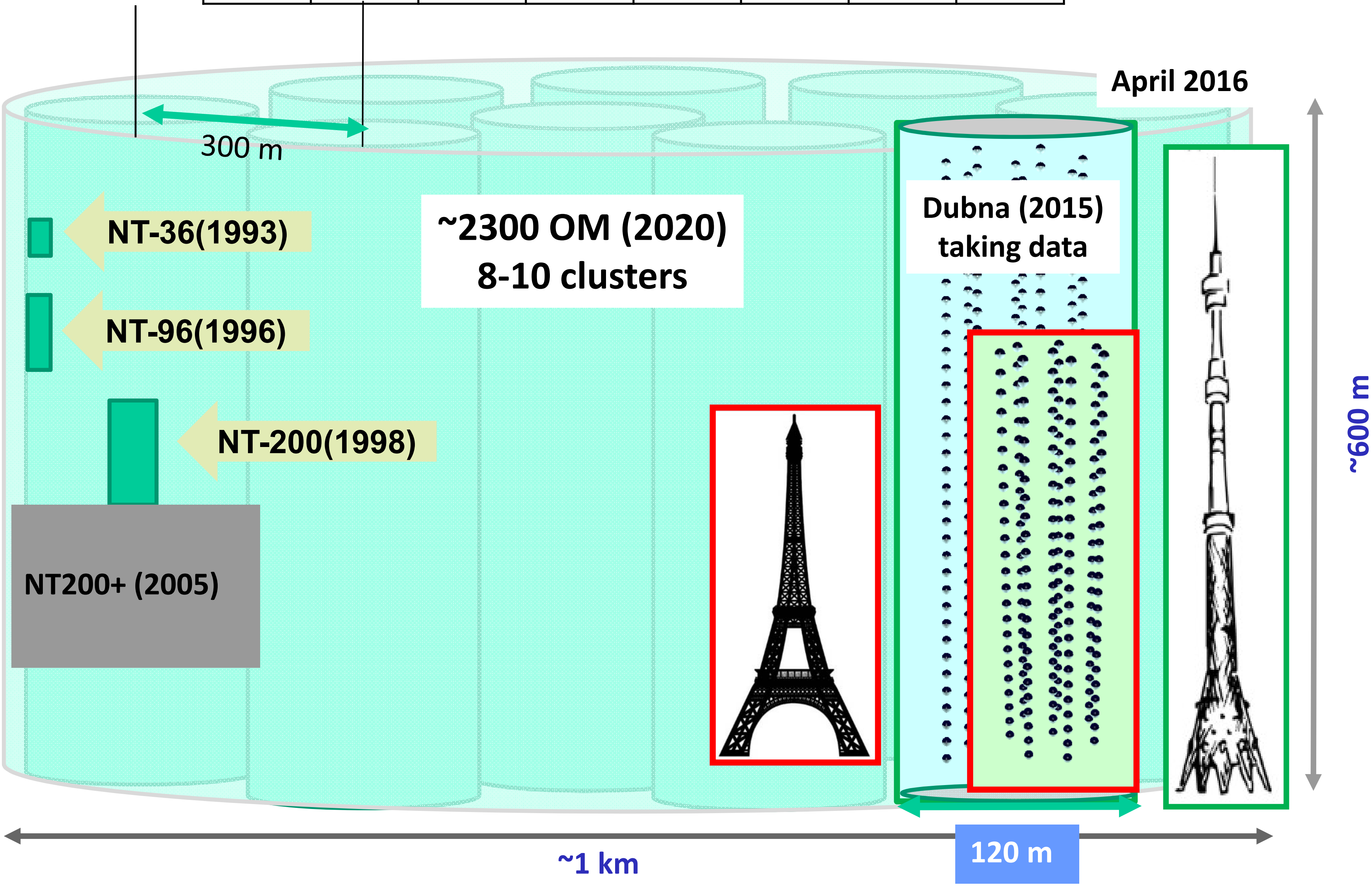
keywords: neutrino oscillations, neutrino mass hierarchy, astrophysical neutrinos

45

About 200 (100) participants (scientists) take part in the JINR neutrino program, 60 of them are younger 35 years old. JINR member-states are strongly involved. Internationality — NOvA, JUNO, EDELWEISS, SuperNEMO, ... → http://dlnp.jinr.ru/en/neutrino-research

BAIKAL-GVD Project Financing Schedule for 2017–2023 (M$):

2017	2018	2019	2020	2021	2022	2023	Sum
5.50	5.75	6.00	6.00	6.00	6.00	6.00	41.25



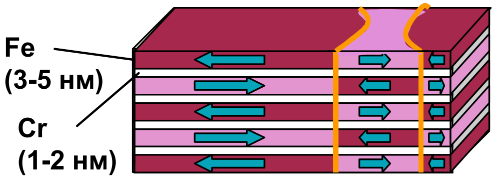
JINR's Large-Scale Basic Facilities

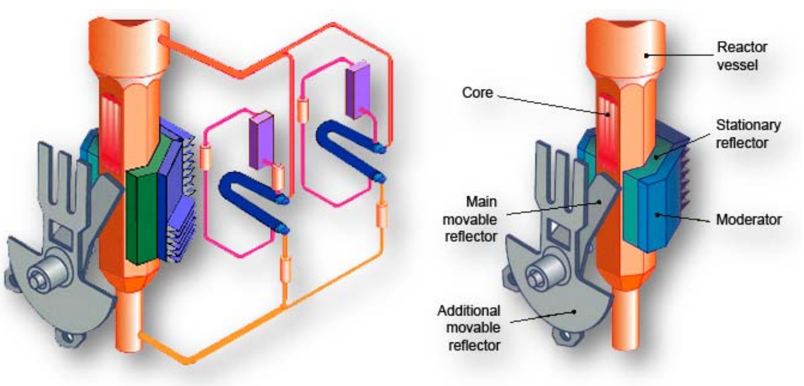
The IBR-2M pulsed reactor of periodic action is included in the 20-year European strategic programme of neutron scattering research.

Fuel: PuO_2, Average power: 2 MW ($8 \cdot 10^{12}$ n/cm²/s), 5Hz, Pulsed power:1500 MW ($5 \cdot 10^{15}$ n/cm²/s), width: 215/320 μs, 14 neutron channels.

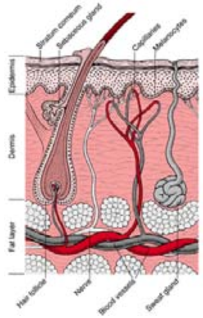
Nanosystems and Nanotechnologies

Novel Materials

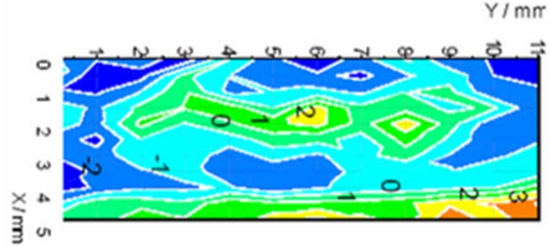




Biomedical Research



Engineering diagnostics. Earth Sciences



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.

Thank You!