Project: Implementation status and prospects for applied research

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Joint Institute for Nuclear Research, Dubna

International Round Table on Applied Research & Innovations @ NICA
15-16 September, Dubna,

Main goals:

- *study of hot and dense baryonic matter*
  at the energy range of max baryonic density;
- *investigation of nucleon spin structure, polarization phenomena;*
- *provide infrastructure for applied research.*

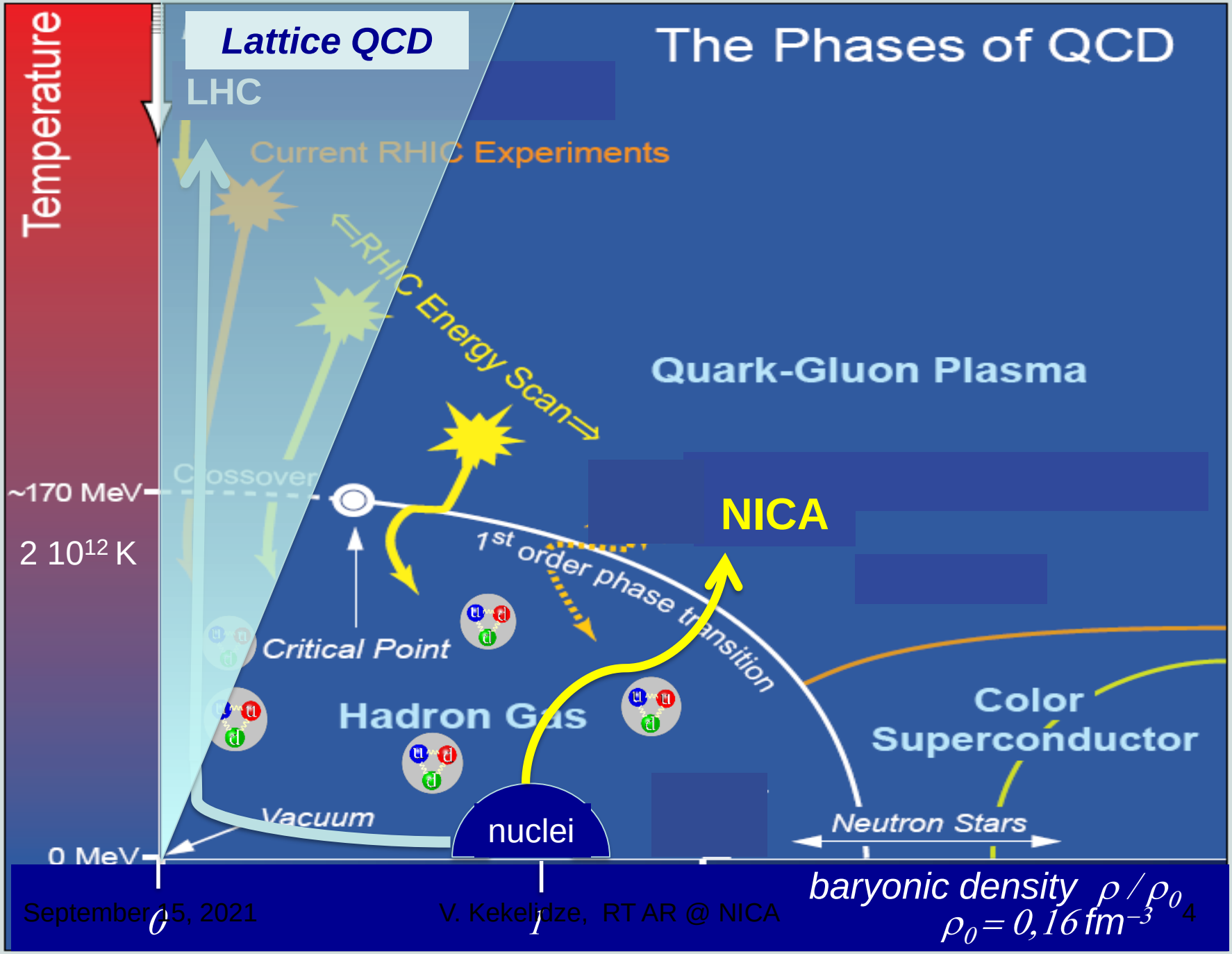
- *modernization of existing accelerator facility*
- *construction of **Collider** to collide*
  - *relativistic ions from **p** to **Au** at energy range $\sqrt{S_{NN}}$= **4** - **11** GeV*
  - *polarized **p** and **d** at energy up to $\sqrt{S}$ =**27** GeV (p)*

Strong interactions play a central role in particle physics and are well described by QCD, but questions remain :

- *long-distance phenomena, for example, confinement;*
- *collective behaviour in extreme conditions,*
  at high temperature, or high density;
- *reliable predictions in nonperturbative mode.*

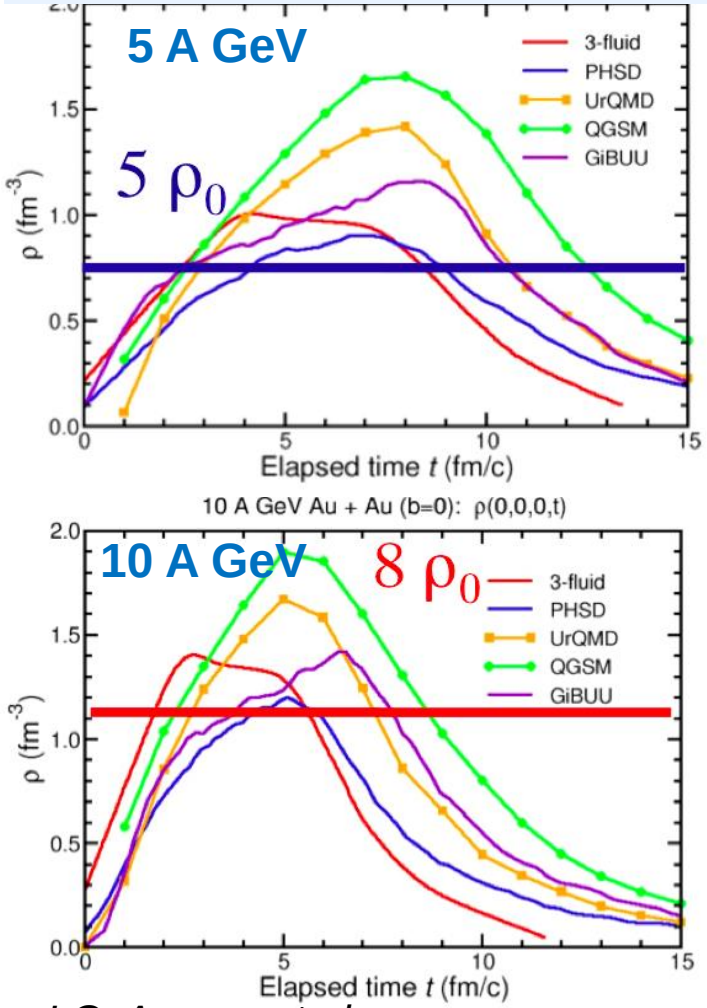
- *is it possible to describe phenomena on the border of low and high energies from the first principles of QCD?*
- *how fast moving quarks and gluons are grouped in colour-singlet hadrons?*

QCD lattice *calculations predict the transition of matter in quark-gluon plasma (QGP), in which partons are not confinement and chiral symmetry is restored.*

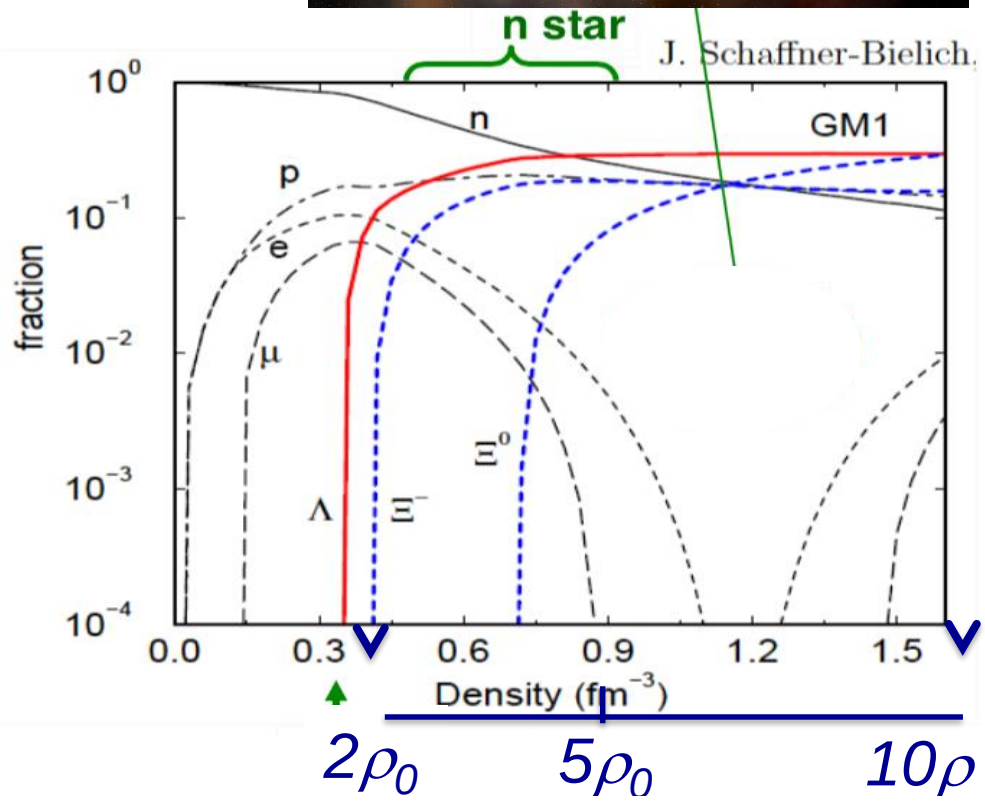

The Phases of QCD
Lattice QCD
LHC
Current RHIC Experiments
⇐RHIC Energy Scan⇒
Quark-Gluon Plasma
Temperature
~170 MeV
2 10^12 K
Crossover
NICA
1st order phase transition
Critical Point
Hadron Gas
Color Superconductor
Vacuum
nuclei
Neutron Stars
0 MeV
0
1
baryonic density ρ / ρ_0
$\rho_0 = 0,16\ fm^{-3}$

Similarity of Stellar Objects & Heavy Ion Collisions

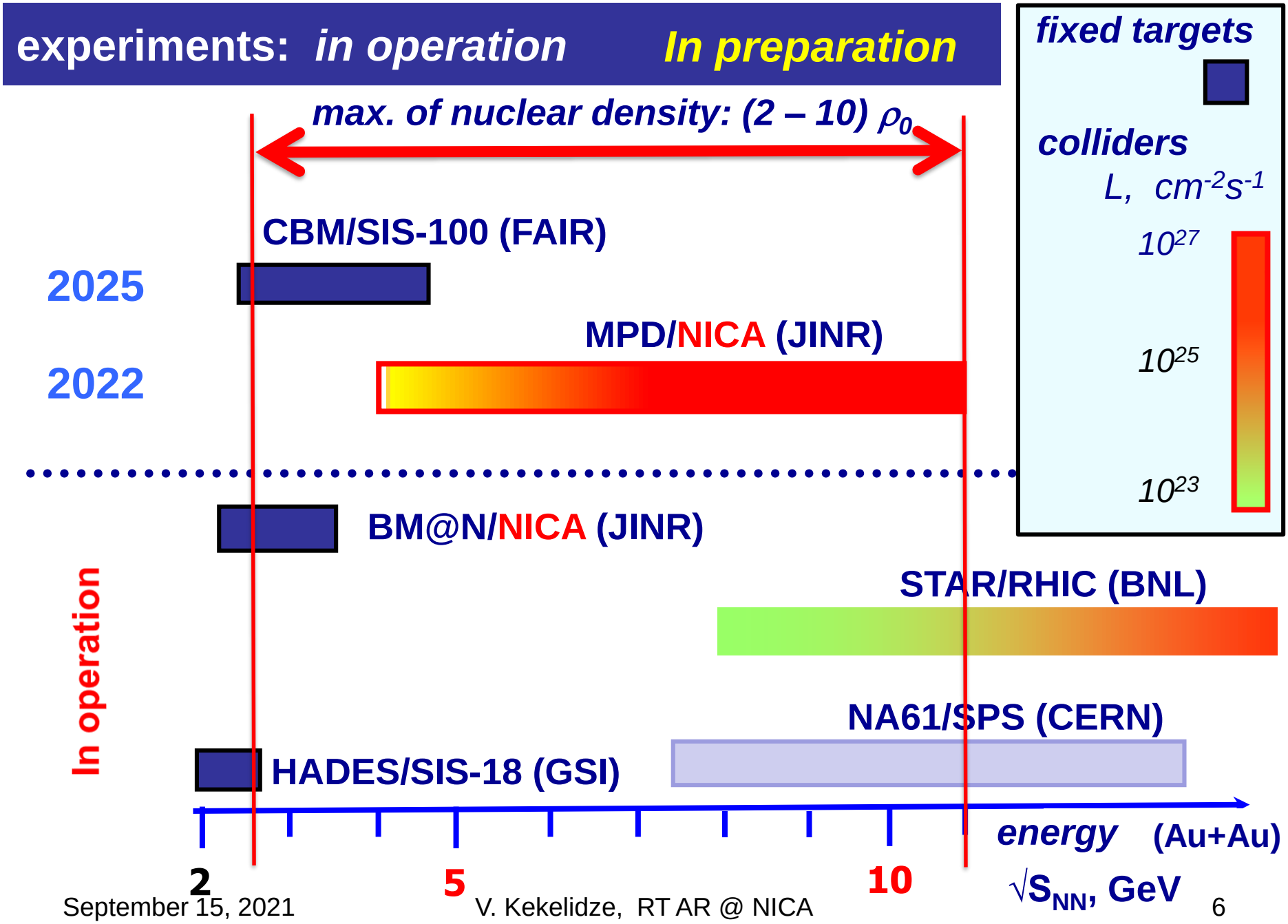
Net Baryonic density in Au + Au collisions

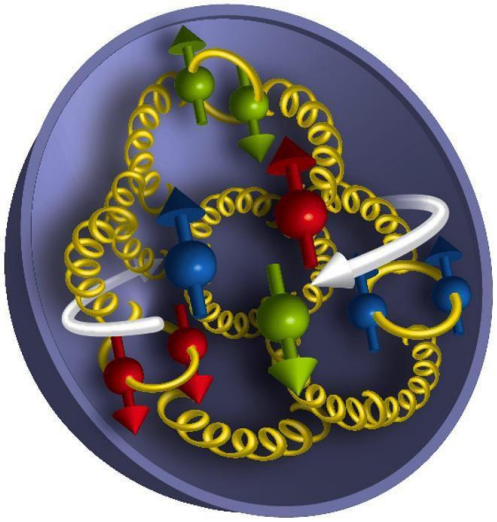


I.C. Arsene at al., Phys. Rev. C75 (2007) 24902.



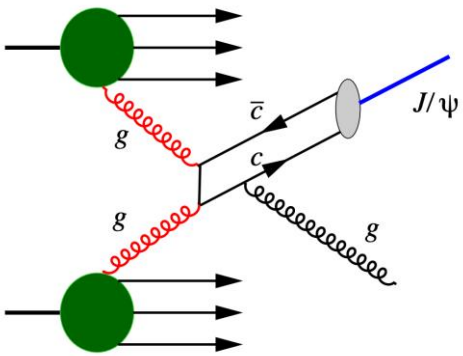
Bauswein et. al., arXiv:1809.01116


experiments: in operation
In preparation
fixed targets
colliders
L, cm-2s-1
10^27
10^25
10^23
max. of nuclear density: (2 – 10) ρ0
CBM/SIS-100 (FAIR)
2025
MPD/NICA (JINR)
2022
BM@N/NICA (JINR)
In operation
STAR/RHIC (BNL)
NA61/SPS (CERN)
HADES/SIS-18 (GSI)
energy (Au+Au)
√SNN, GeV
2
5
10

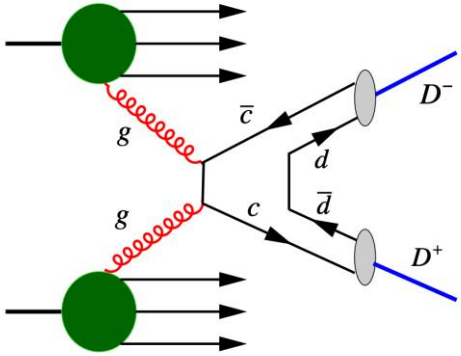


Physic @ SPD

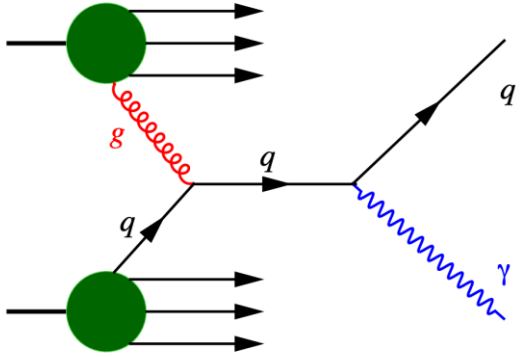
SPD - a universal facility for comprehensive study of polarized gluon content (TMD PDFs) in proton and deuteron at large x in proton and deuteron with complementary probes:



Charmonia



Open charm

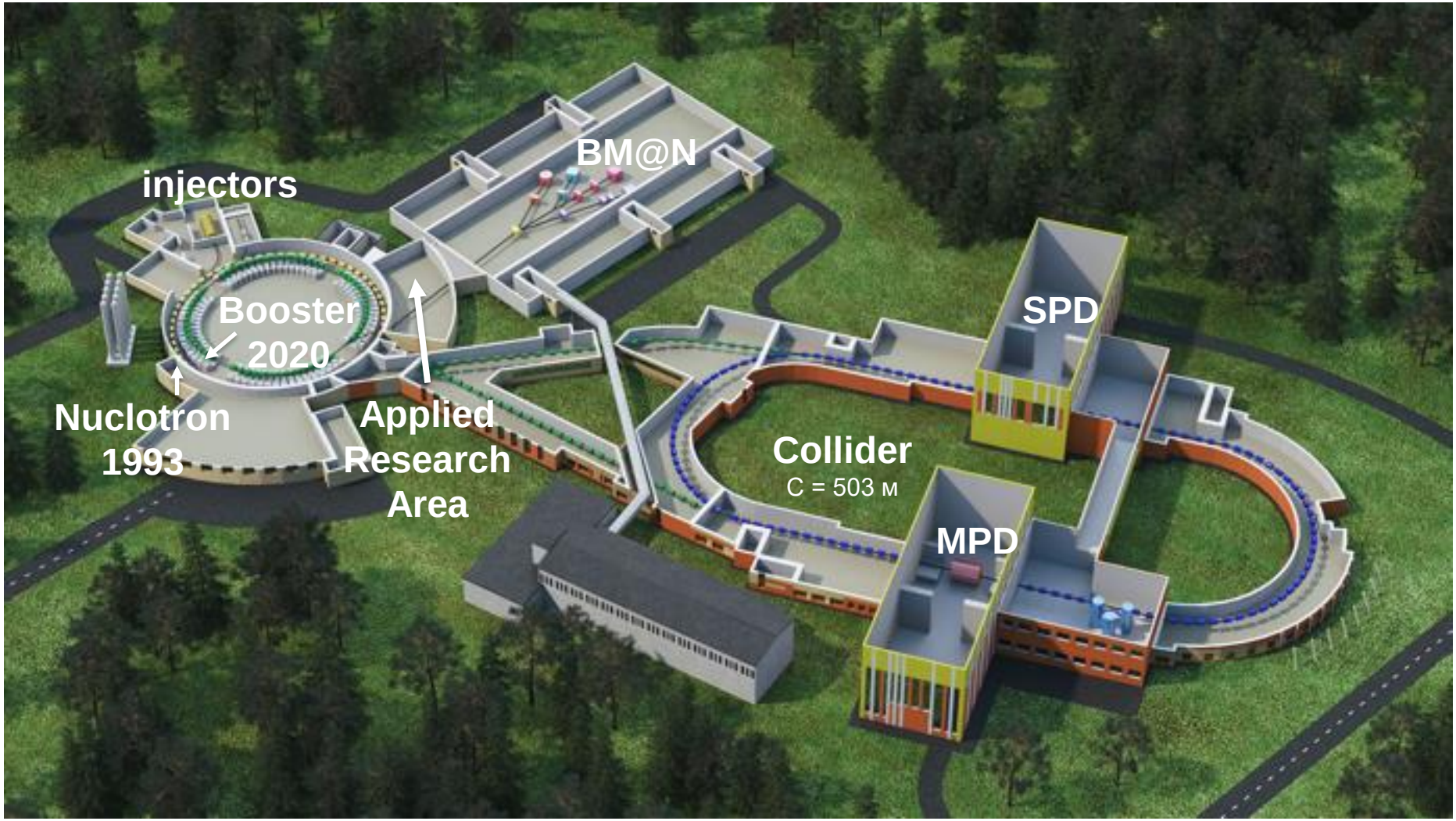


Prompt photons

Main objects of the NICA Complex

Accelerators: 2 injectors, Booster, Nuclotron, Collider

3 experiments: BM@N, MPD, SPD; Applied Research Area



Nuclotron: *superconducting synchrotron, put in operation in 1993*

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

*modernized in **2010-2015***

Linacs

Linac	LU-20	HILAC
structure (section number)	RFQ + Alvarez type	RFQ + IH DTL(2)
mass to charge ratio A/Z	1-3	1-6
injection energy, keV/amu	150 for A/Z 1-3	17
extraction energy, MeV/amu	**5** (A/Z 1-3)	**3.24** (A/Z=6)
input current, mA	up to 20	up to 10

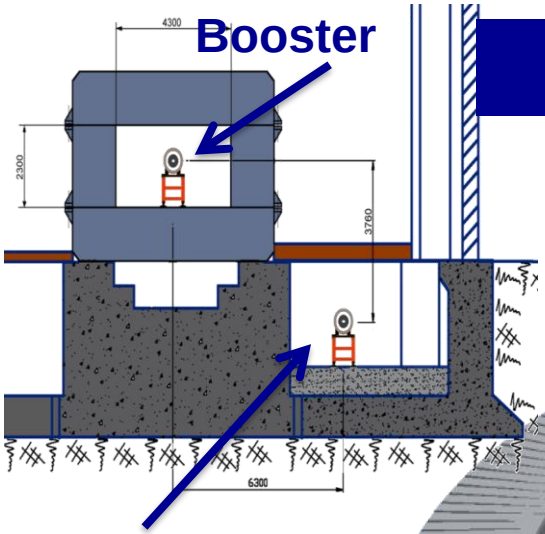
LU-20 – *JINR**, INR, ITEP, MEPI***

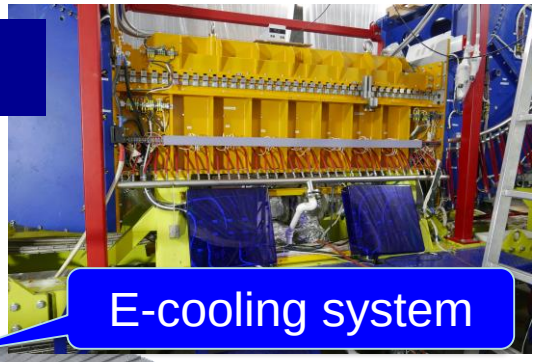
put in operation: May '16

HILAC: "BEVATECH OHG"

put in operation: Oct. .'16

Booster- *assembled in 2020*



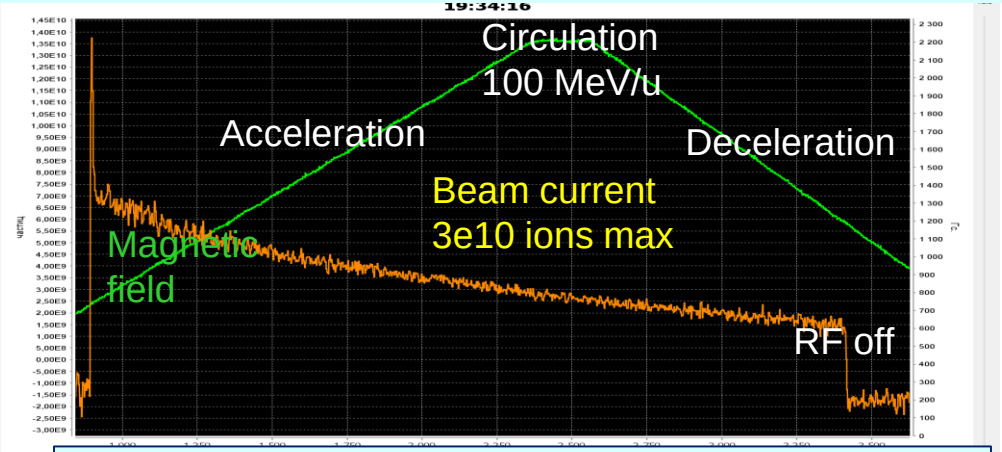


	value
ion species	A/Z ≤ 3
max. energy, MeV/u	**600**
injection energy, MeV/u	3.2
magnetic rigidity, T m	1.6 – 25.0
circumference, m	210.96
vacuum, Tor	10^{-11}
*intensity, **Au** /p*	$1.5\ 10^{9}$
RF region,MHz	0.5 -2.53

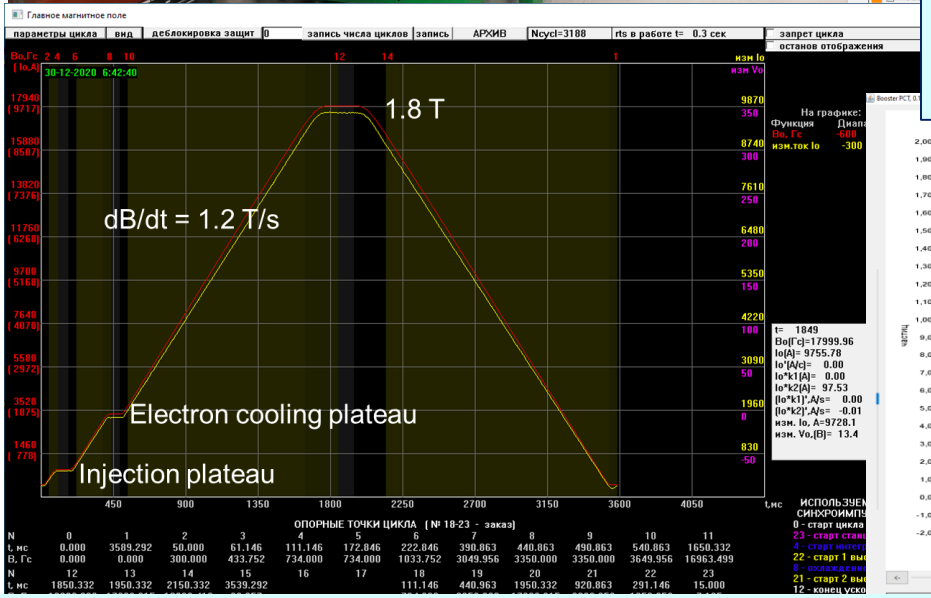
An important milestone has been reached

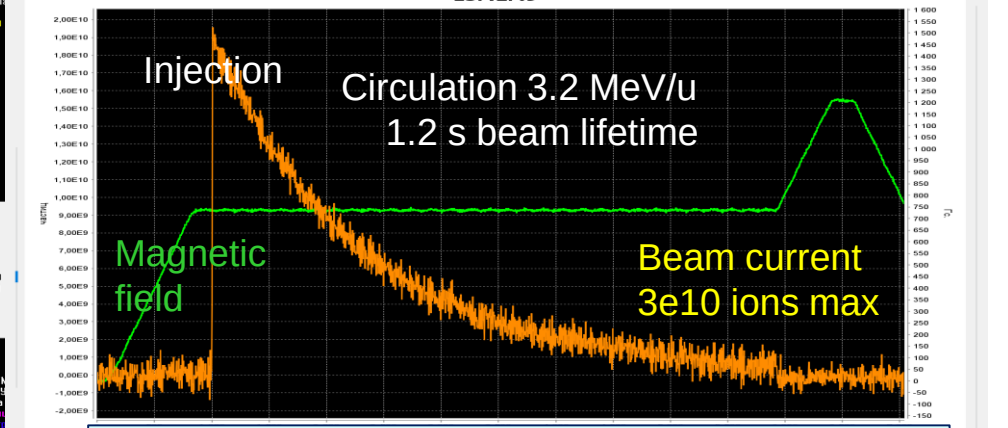
*– the first Booster technical run (completed on **30/12/20**)*

injected He^{1+}, 3,2MeV/u, $6,5*10^{10}$ ppp



FCT signal when injecting into rising field, capturing (~60%), accelerating & decelerating: no transient losses on the MF table & after.





operation at design magnetic field & ramp rate

*Beam loss indicated the integral pressure in the beam pipe ~ 2-3 * 10^{-10} Torr*

Collider magnets assembly and testing

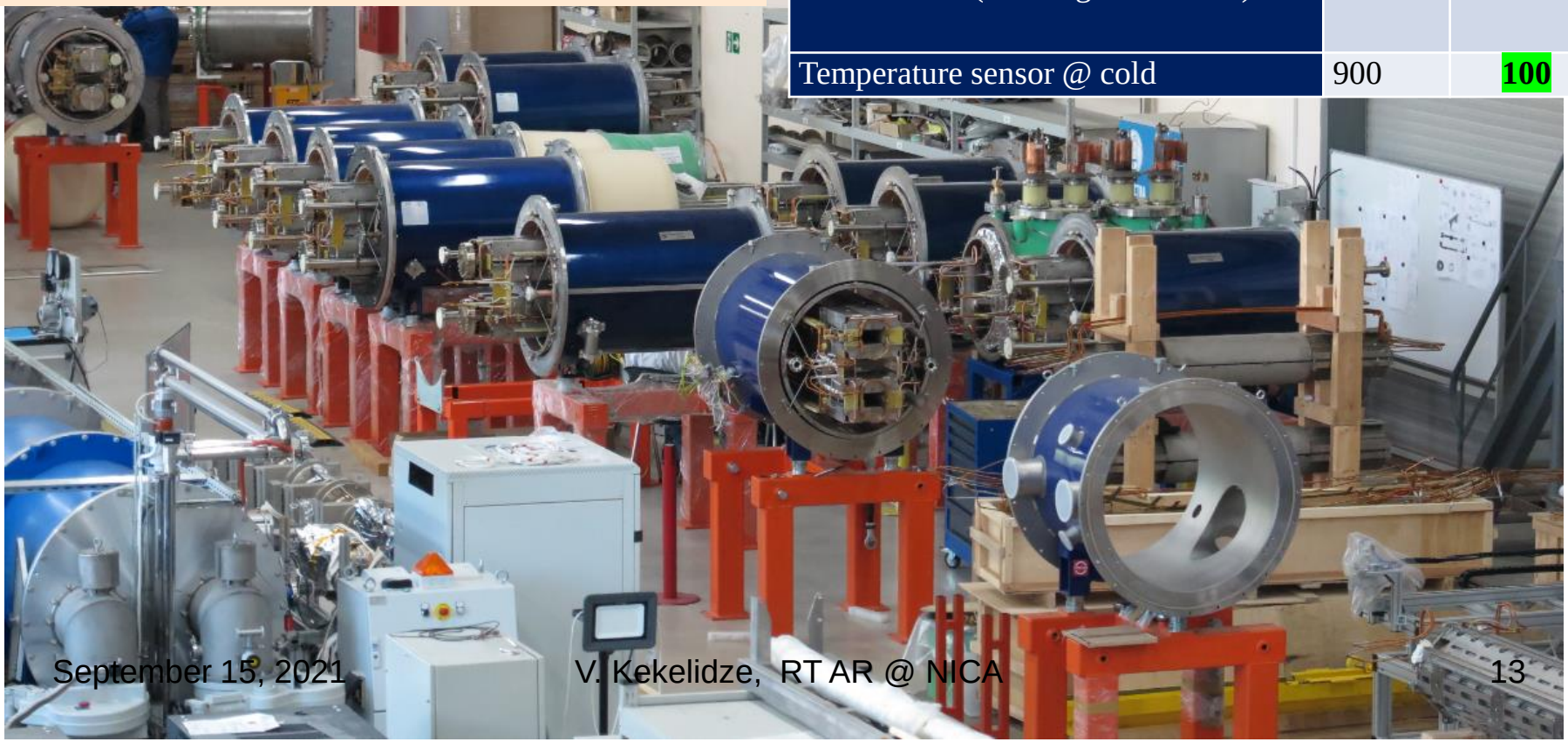
Cryogenic-tests per year:

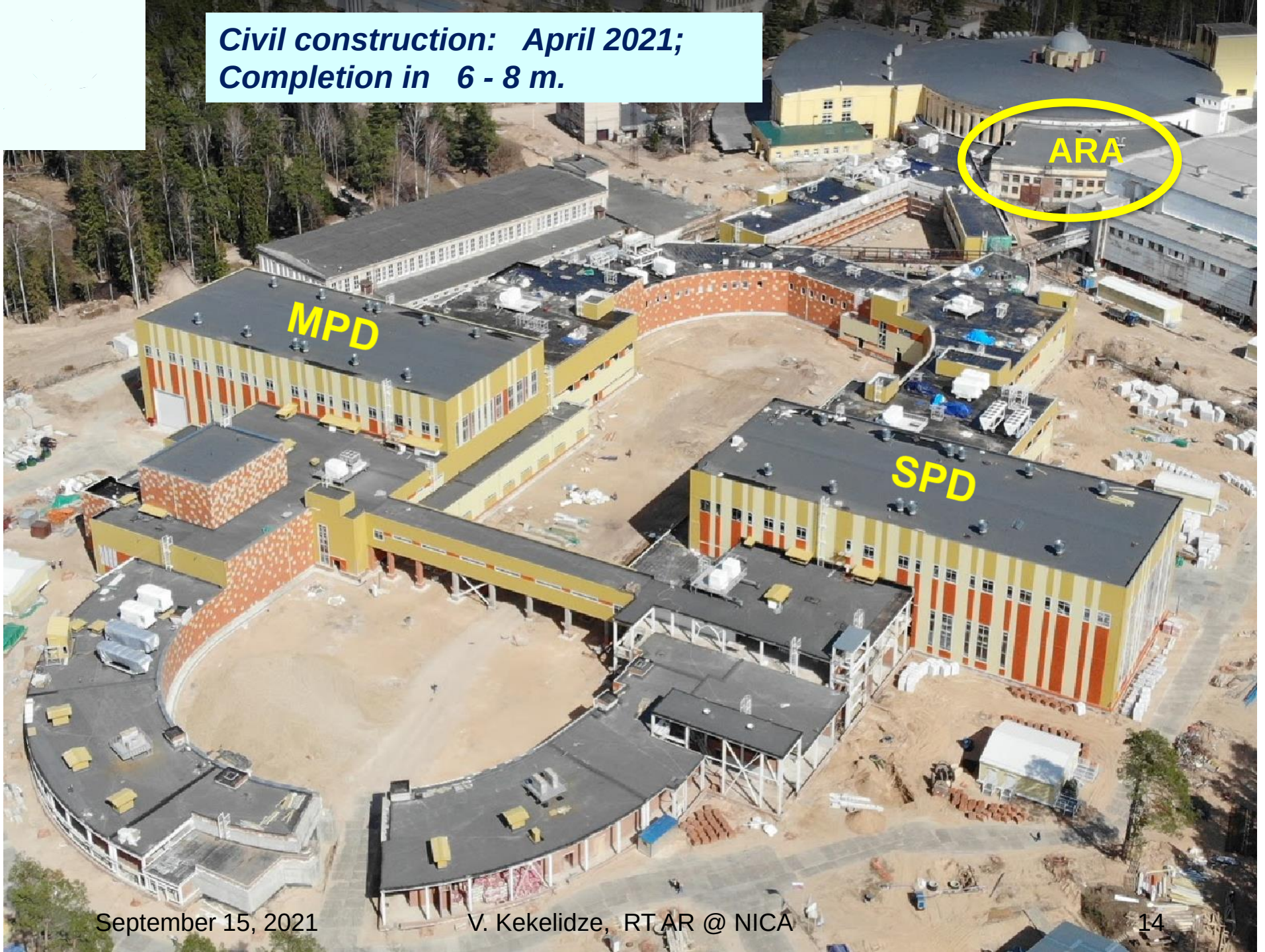
2016	2017	2018	2019	2020		2021
20	60	58	76	72	➡	**120**

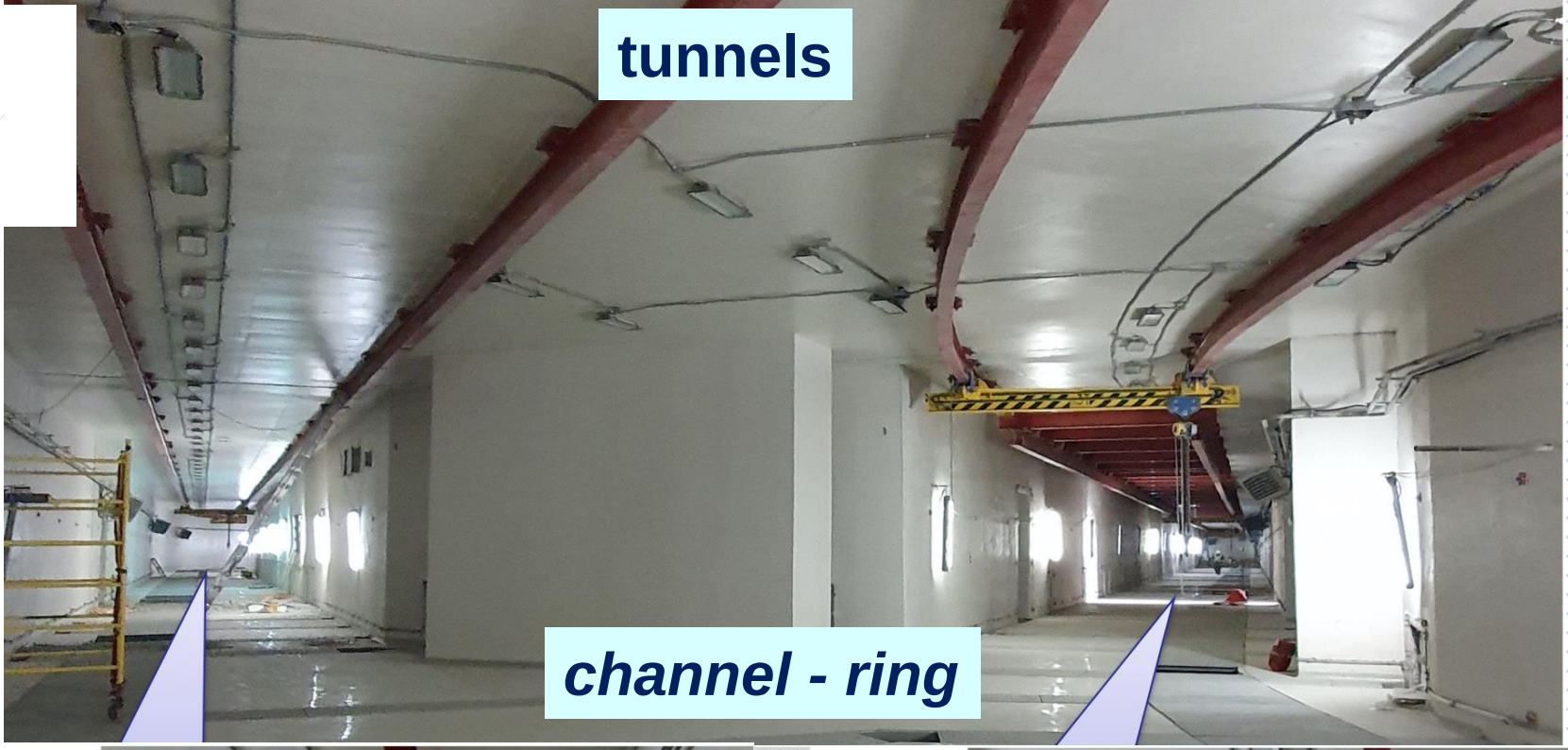
Collider dipoles: ***100 % tested***

Collider quadrupoles: ***35 % tested***

	total	prod. %
Dipole magnet coil	80+1	100
Quadrupole magnet coil	46+24	100
Corrector magnet coil	124+4	75
Final focus quadrupole coil	12	20
Vertical bending magnet coil	8	20
Dipole magnet heat screen	80+1	100
Quadrupole magnet heat screen	46+12	100
interconnections' heat screen	181	50
Cryogenic by-pass heat screens	2	20
Heat screens (ref. mag.& feed b-x)	2	80
Temperature sensor @ cold	900	100




Civil construction: April 2021;
Completion in 6 - 8 m.
ARA
MPD
SPD


tunnels
channel - ring


04.21
1 – тоннель
W semiring

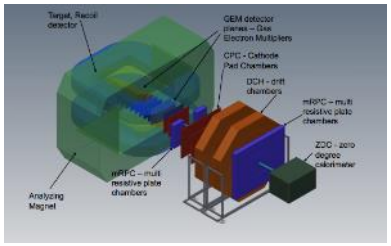

.04.21
1 - тоннель
E semiring

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

took place in Dubna on 11-13 April, 2018

https://indico.jinr.ru/conferenceDisplay.py?ovw=True&confId=385

***Two** Institutional **B**oards **(IB)** were formed for both collaborations:*
***18** members for **BM@N**, and **27** members for **MPD**.*
*The **bylaws** have been **adopted** and signed by the **IB's.***



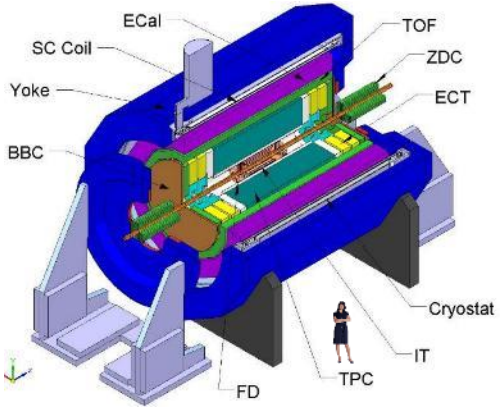
Baryonic Matter at Nuclotron (BM@N) Collaboration:

*19 Institutions from **10** Countries, **234** participants*

*spokesperson – **M. Kapishin***

*in the first run (**2018**) **> 200 M** events accumulated*

*targets: **C, Al, Cu, Sn, Pb;** beams: $^{12}C^{6}$, $^{40}Ar^{16+}$,$^{84}Kr^{26}$*

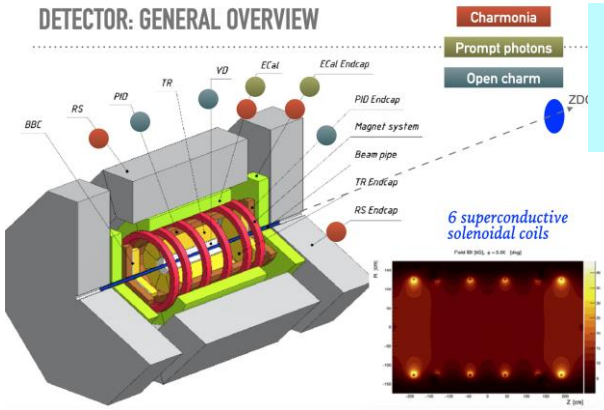


MultiPurpose Detector (MPD) Collaboration:

*42 Institutes from **12** Countries, > **500** participants*

*spokesperson – **A. Kisiel***

MPD** systems**: SC Magnet, TPC, TOR, ECal, FHCal, FFD** etc.- are in production for the first run in **2022



Spin Physics Detector (SPD) Collaboration:

*32 Institutes from **14** Countries,, ~ **300** participants*

*spokesperson – **A. Guskov***

***CDR** presented at **PAC PP**;*

***TDR** – under preparation.*

Beam parameters and setup at different stages of the BM@N experiment

Year	2018 spring	2022 spring	2023	After 2023
Beam	Ar,Kr, C(SRC)	Xe (Kr)	Au (Bi)	Au (Bi)
Max. Intensity, Hz	0.5M	0.5M	0.5M	2M
Trigger rate, Hz	10k	10k	10k	up to 50k
general tracker Status	6 GEM half planes + 3 forward Si planes	7 GEM full planes + 3 forward Si planes	7 GEM full planes + 4 forward Si + 2 large STS planes	7 GEM full planes + 4 large STS planes
Experiment status	technical run+physics	stage 1 physics	stage1 physics	High rate stage 2 physics

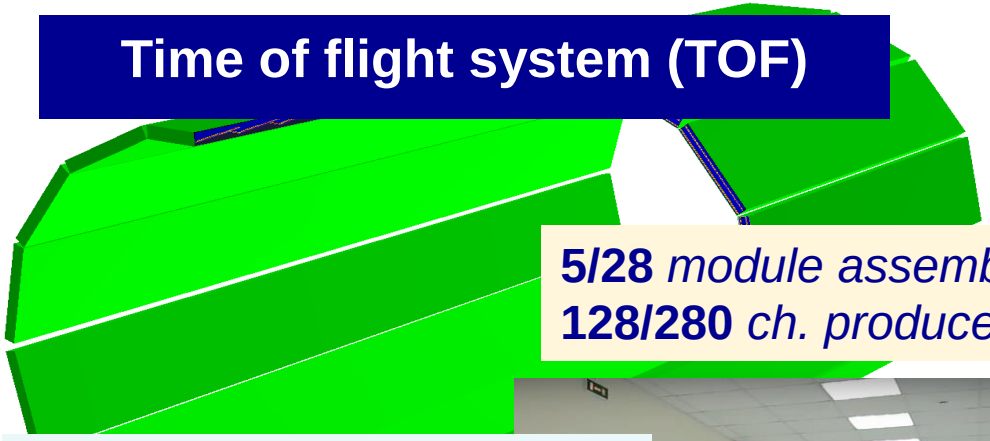
MPD Hall – magnet assembly

- *installation of Solenoid into Magnet Yoke, position measurement ,adjustments;*
- *assembling the Magnet Yoke;*
- *installation the Top platform;*
- *cryogenic tests;*
- *field measurement.*

TPC – basic tracker

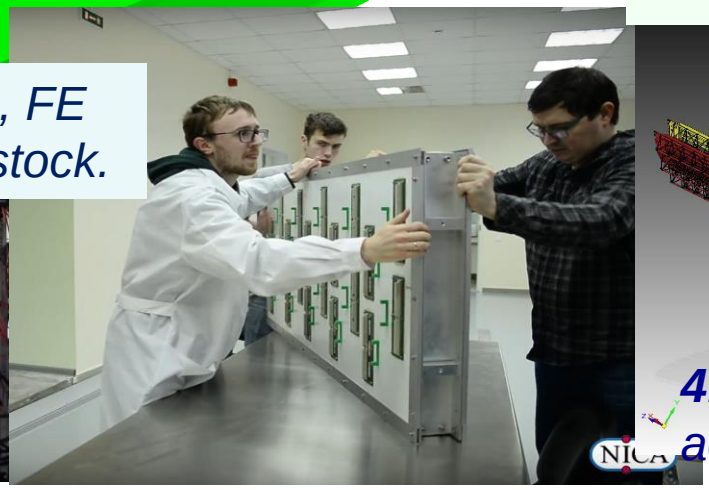
frame: C3-C4 *assembled*
C1-C2 *assembled*
ROC: ***24 / 26*** *produced*

Time of flight system (TOF)



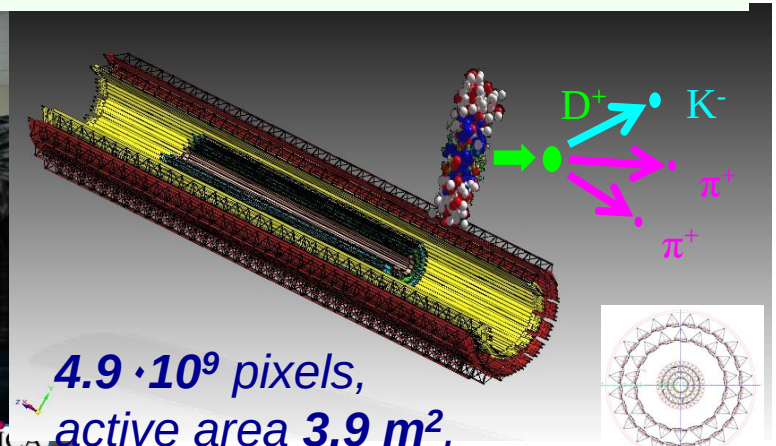
5/28 *module assembled*
128/280 *ch. produced*

All crates, HV & LV PS, FE & R-O electronics - in stock.



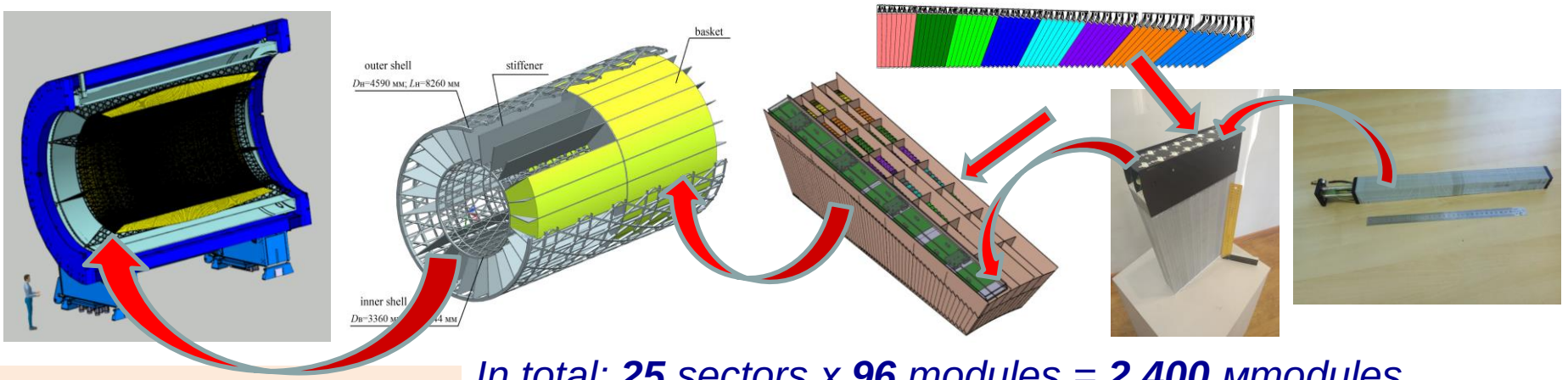
Inner Tracker

ALPIDE MAPS: *in* ***5*** *cylinders of* ***2*** *barrels*



4.9 ·10⁹ *pixels, active area* ***3.9 m²****.*

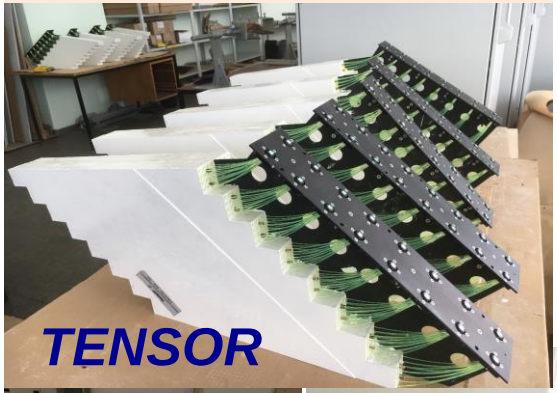
Electromagnetic calorimeter (ECal) system

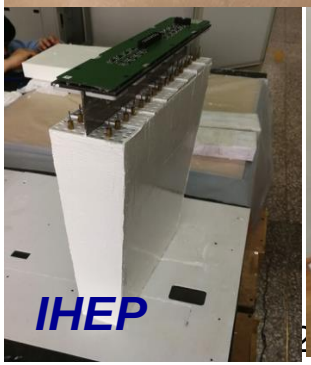


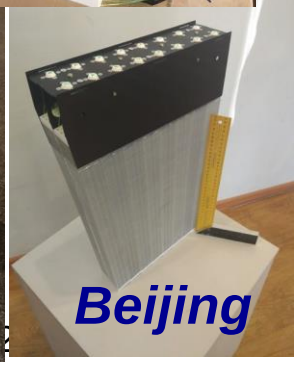
In total: ***25*** *sectors x* ***96*** *modules =* ***2 400*** *modules*
*(**16** channels each)*

- ***JINR, IHEP, TENSOR*** *-* ***25%*** *- December* ***2021***
- ***China*** *-* ***25%***

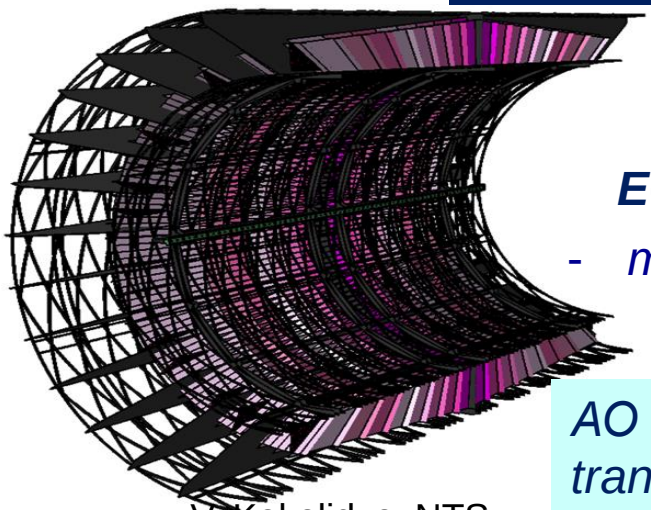
blocks of modules:







Support structure



carbon fiber

ECal ~ 100 t

- *material budget (R)* ***0,13X$_0$***
- *sagita ~* ***5 mm***

АО «ЦНИИСМ»
transport to Dubna: ***Dec. 2021***

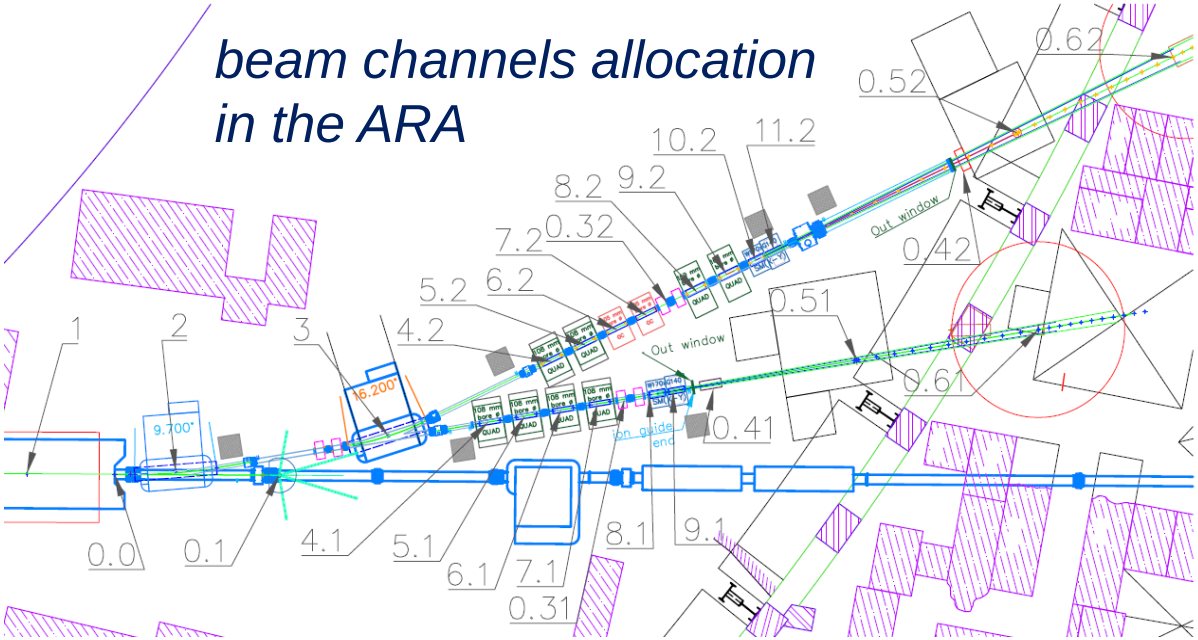
CONCEPTUAL DESIGN REPORT OF THE SPIN PHYSICS DETECTOR

A. Guskov on behalf of the SPD proto-collaboration

~300 authors from 23 institutes from 10 countries
+ individual contributors

Applied Research Area

- ***S**tation **O**f **C**hip **I**rradiation*
- ***S**etup for **I**nvestigation of **M**edical **B**iological **O**bjects*



Station for Chip Irradiation

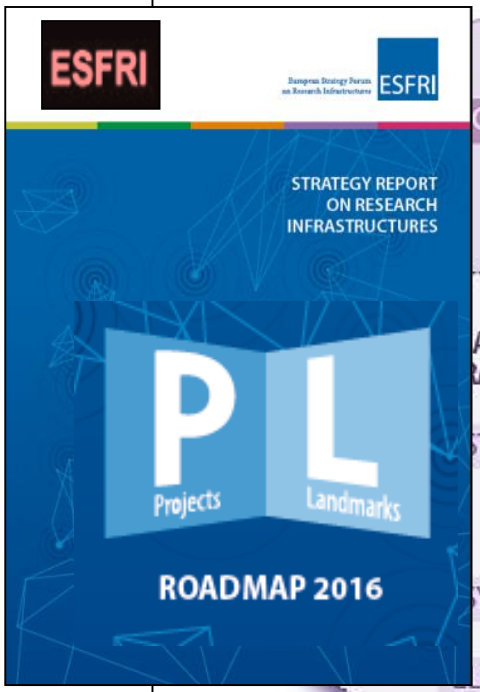
The applied research area development is in progress:

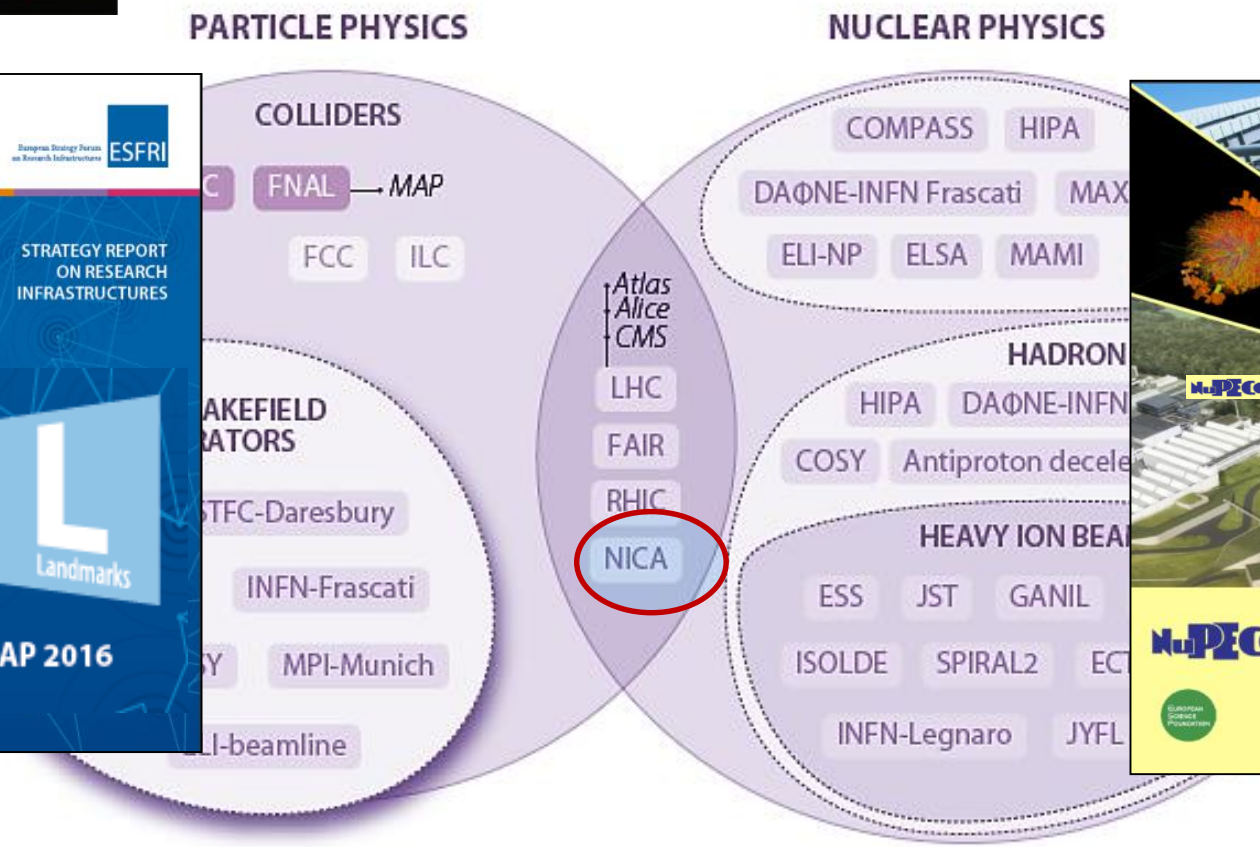
- *design and construction of beam channels;*
- *vacuum systems and technologies upgrade;*
- *design and manufacture of chip irradiation station;*
- *design and construction of setups for biological research.*

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





Concluding remarks:

- The NICA Complex being implemented at JINR is dedicated to the study of baryon-rich matter and spin physics, as well as *providing infrastructure for applied research and innovations*.

- The construction of the accelerator complex and BM@N, MPD and SPD detectors is progressing well; *corresponding Collaborations are constantly expanding.*

- *Cooperation in applied research and innovations is currently underway, and we are looking forward to establishing dedicated Collaborations.*

Thank you !