Jubilee International Conference
«Contribution of Andrei Budker and His Institute to World Science»

Budker Institute of Nuclear Physics in MegaProject NICA

Igor Meshkov for NICA and BINP Teams

JINR, Dubna

JOINT INSTITUTE FOR NUCLEAR RESEARCH JINR

May 4, 2018
Budker INP, Academgorodok, Novosibirsk

NICA

Outline

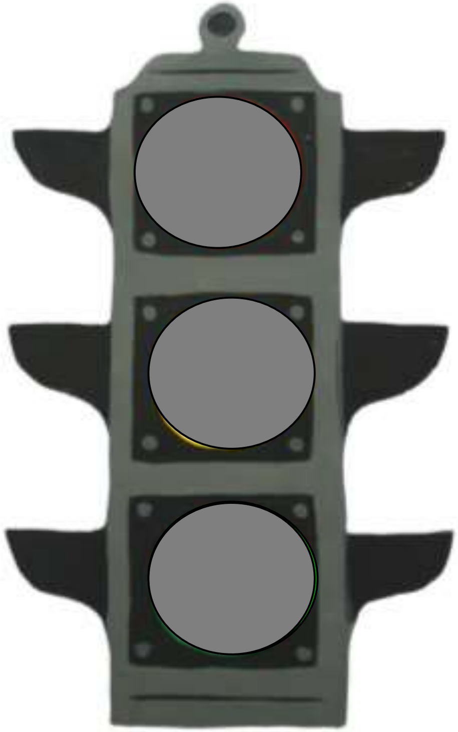
2016 г. – NICA MegaProject

Agreement between Government of Russian Federation and JINR on realization of the international mega-science project of the superconducting heavy ion collider NICA

First publications:
2006 - ICHEP'06 ("Rochester"), Moscow
2008 – EPAC08, Genoa, Italy

2013 – Technical project
Governmental expertise

The Agreement signed!
June 2nd, 2016



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 межправи... организацией Объ...

1. Two Goals and Three Stages of The NICA Project

The NICA project is planned to be commissioned in three stages:

I. Fixed target experiments at Nuclotron ion beams:

(*Baryonic Matter at Nuclotron – BM@N*)

Li ÷ Au => 1 – 4.5 GeV /u   ion kinetic energy

$\sqrt{s}$ (Au × Au) = 2.33 – 3.47 GeV/u

II. Heavy ion colliding beams up to $^{197}Au^{79+}$ x $^{197}Au^{79+}$

1 ÷ 4.5 GeV /u   ion kinetic energy

$\sqrt{s_{NN}}$ = 4 – 11 GeV , $L_{average}$= (0.05 -1)×10^{27} $cm^{-2}\cdot s^{-1}$

Light × Heavy ion colliding beams of the same $\sqrt{s_{NN}}$ and the same or higher $L_{average}$

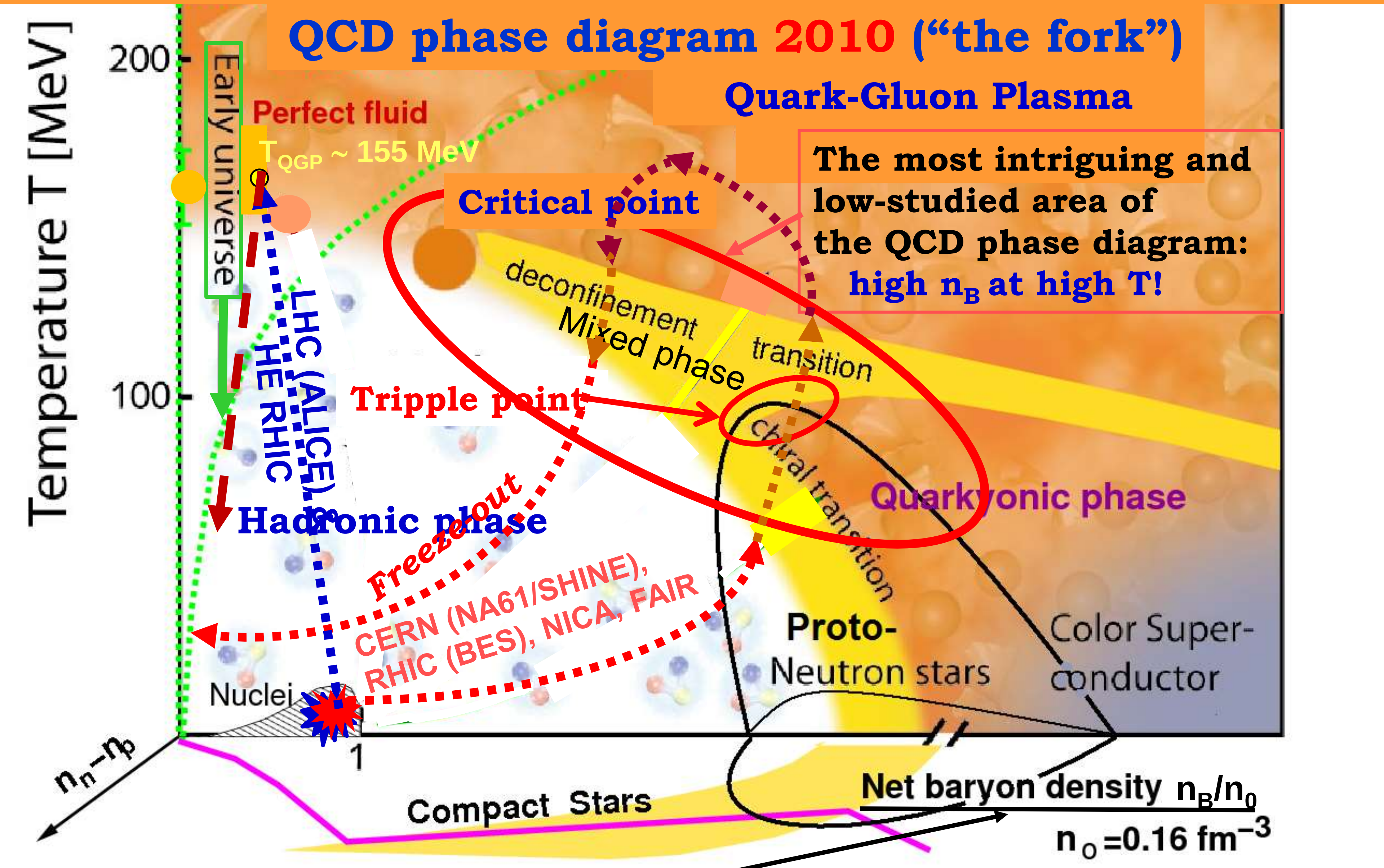
III. ***Polarized protons and deuterons***

p↑, p↑ = 5 – 12.6 GeV kinetic energy ($\sqrt{s}$ = 12 – 27 GeV)

d↑, d↑ = 2 – 5.9 GeV/u kinetic energy ($\sqrt{s}$ = 4 – 13.8GeV/u)

L_{max} ≈ 1x10^{32} $cm^{-2}\cdot s^{-1}$

Nuclei Collision and Phase Trajectories in T-n_B space

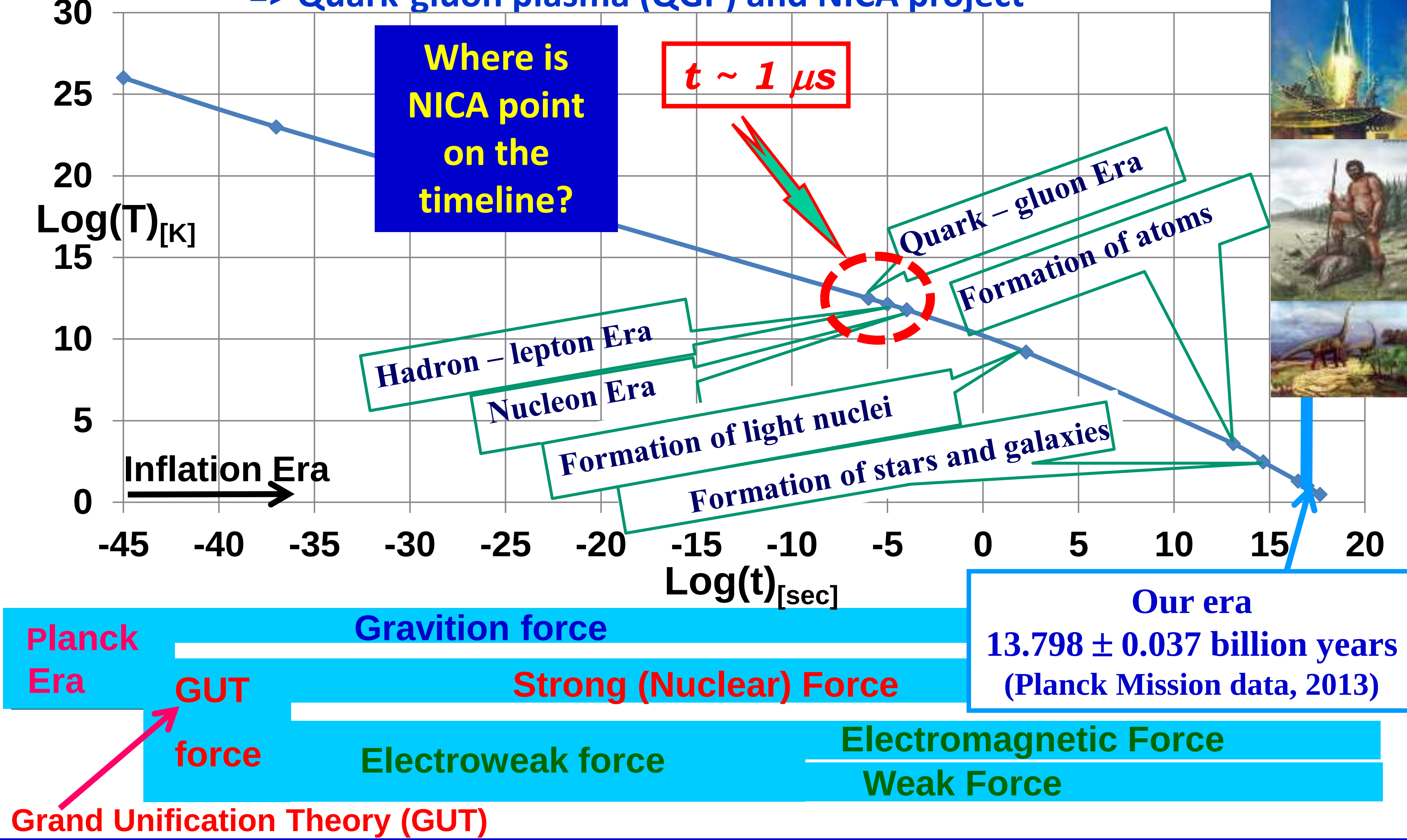


$n_B = n_{baryon} - n_{antibaryon}$

2. Physics of Dense Baryonic Matter and NICA Project

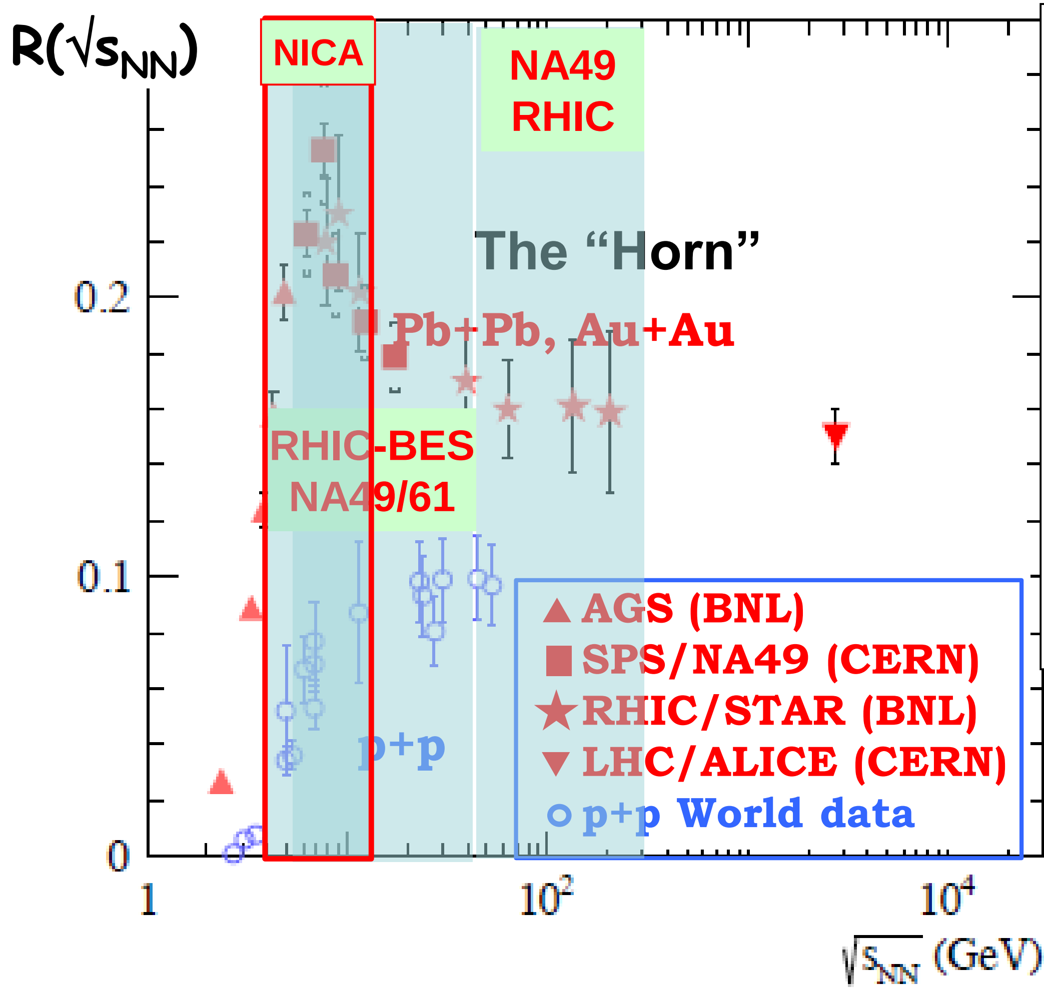
Big Bang => Hot Universe => … =>

=> Quark-gluon plasma (QGP) and NICA project



How to search for the “mixed phase”

The “Horn” – one of indicators of deconfinement beginning



One possible effect – ratio of multiplicity of kaons generation to pion one

$$R = \langle K^+\rangle/\langle \pi^+\rangle$$

measured at the registration angle $\theta \approx \pi/2$ to the beam axis as function of the energy of colliding particles. Nonmonotonic dependence $R(\sqrt{s})$ (the “Horn”) can be an indicator of **deconfinement beginning.**

This is just one example.

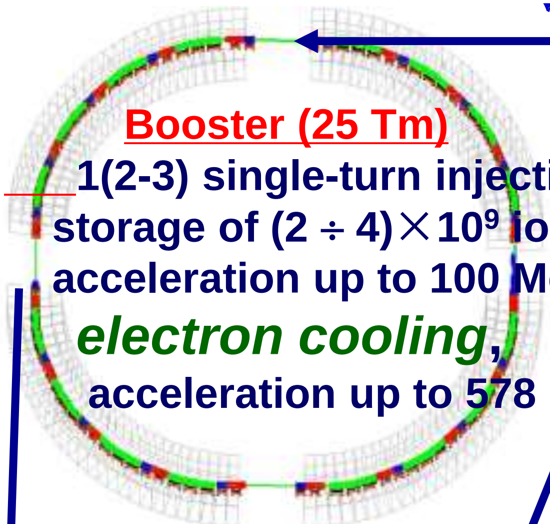
3. NICA – Stage I: Experiment "The Baryonic Matter at Nuclotron"

TOMORROW

Linac HILAc (3.2MeV/u) ← ESIS KRION

TODAY

Linac LU-20 (5MeV/u) ← Ion sources

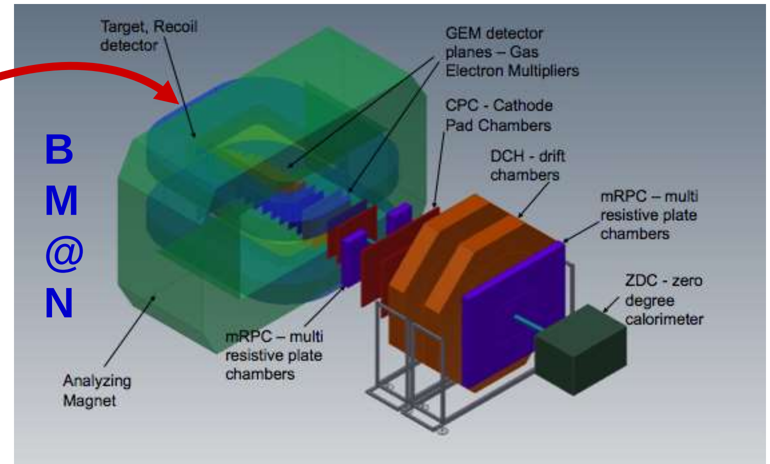


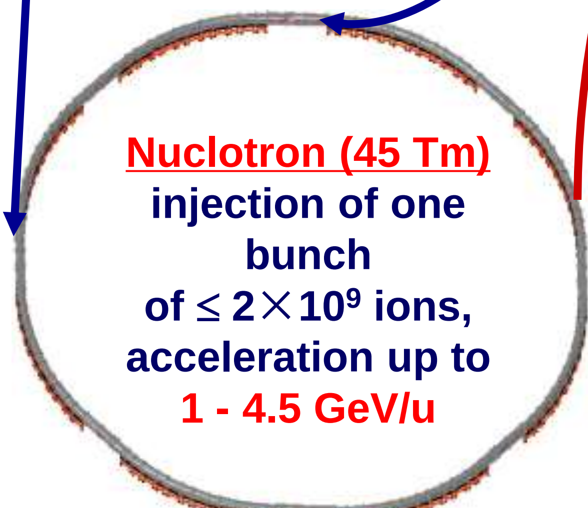
Booster (25 Tm)

1(2-3) single-turn injection,
storage of (2 ÷ 4)$\times$10^{9} ions,
acceleration up to 100 MeV/u,
electron cooling,
acceleration up to 578 MeV/u

Stripping (80%)
$^{197}Au^{31+}$ => $^{197}Au^{79+}$

Slow resonance extraction





Nuclotron (45 Tm)
injection of one bunch
of ≤ 2$\times$10^{9} ions,
acceleration up to
1 - 4.5 GeV/u

Why d…
1) To pro…
from H…
2) To avoi…
3) The ma…
accelerati…
kinetic en…

Baryonic Matter at Nuclotron (BM@N):
a fixed target experiment dedicated to search for formation of the mixed phase of baryonic matter in nucleon-nucleon collisions in energy range of

$\sqrt{s_{NN}}$ = 2.3 – 3.4 GeV

3. NICA – Stage I: Experiment “The Baryonic Matter at Nuclotron”

Beginning of Booster mounting
August 2018

3. NICA – Stage I: Experiment "The Baryonic Matter at Nuclotron"

The Booster

Parameter	Value
Ions	p => $^{197}Au^{31+}$
Circumference, m	211
Max. magnetic rigidity, *T·m*	25
Injection energy, *MeV/u*	3.2
Extraction energy, *MeV/u*	578 ($^{197}Au^{31+}$)
Max. magnetic field, *T*	1.8
Vacuum pressure, *pTor*	10.0

"Первые ласточки" (2014)

First Signs: RF system for the Booster (2014)

Testing at BINP
E.A.Rotov, O.I.Brovko (JINR), I.K.Sedliarov, A.M.Pilan

Testing at JINR
A.M.Pilan, A.M.Batrakov, G.A.Fat'kin, O.I.Brovko, A.Eliseev (both JINR) G.Ya.Kurkin

3. NICA – Stage I: Experiment “The Baryonic Matter at Nuclotron”

Electron Cooler for the Booster

Designed, fabricated and presently under commissioning by BINP Team

Parameter	Value
Ions to be cooled	p => $^{197}Au^{31+}$
Electron energy, *keV*	1.5 – 50
Beam current, *Amp*	0.2 – 1.0
Cooling section length, *m*	1.9
Electron energy variation, $\Delta E/E$	$\leq 1\cdot10^{-5}$
Solenoid magnetic field, *T*	0.1 – 0.2
Field ripples, $\Delta B/B$ on 15 cm	$\leq 3\cdot10^{-5}$

Why do we need an electron cooler for the Booster:

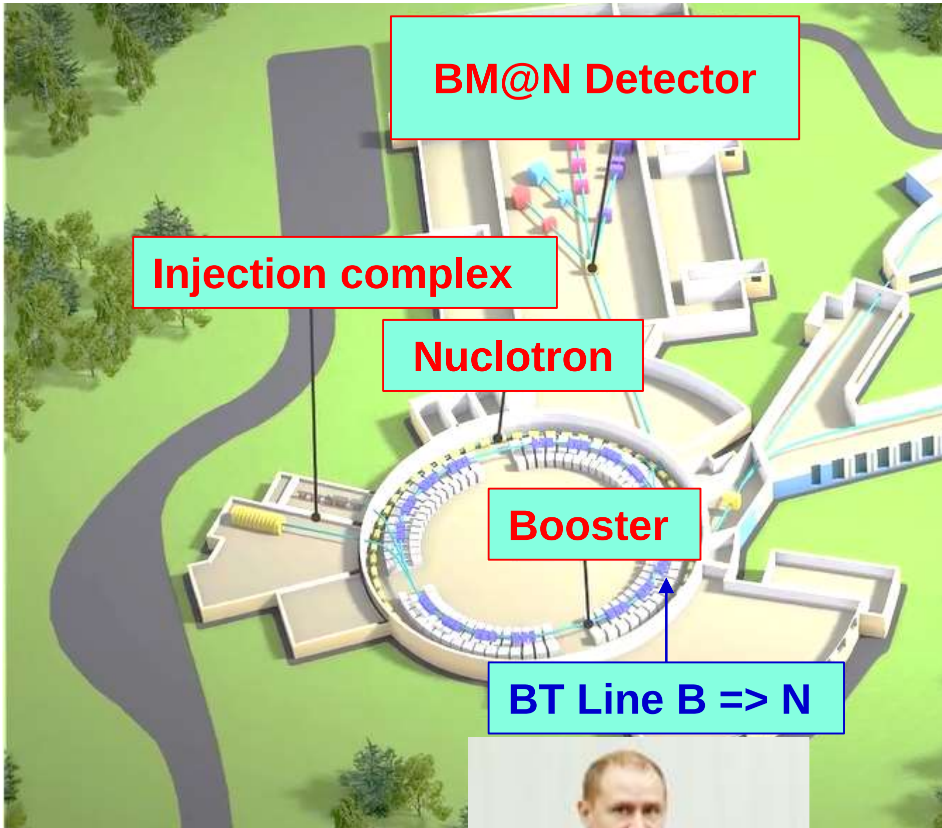
1) To provide a multiturn or multicycle (*3 pulses at 10 Hz repetition*) injection;

2) To form ion bunches of a small 6D emittance for injection into Nuclotron and, after acceleration, slow extraction to BM@N and single turn extraction for injection into Collider

3. NICA – Stage I: Experiment “The Baryonic Matter at Nuclotron”

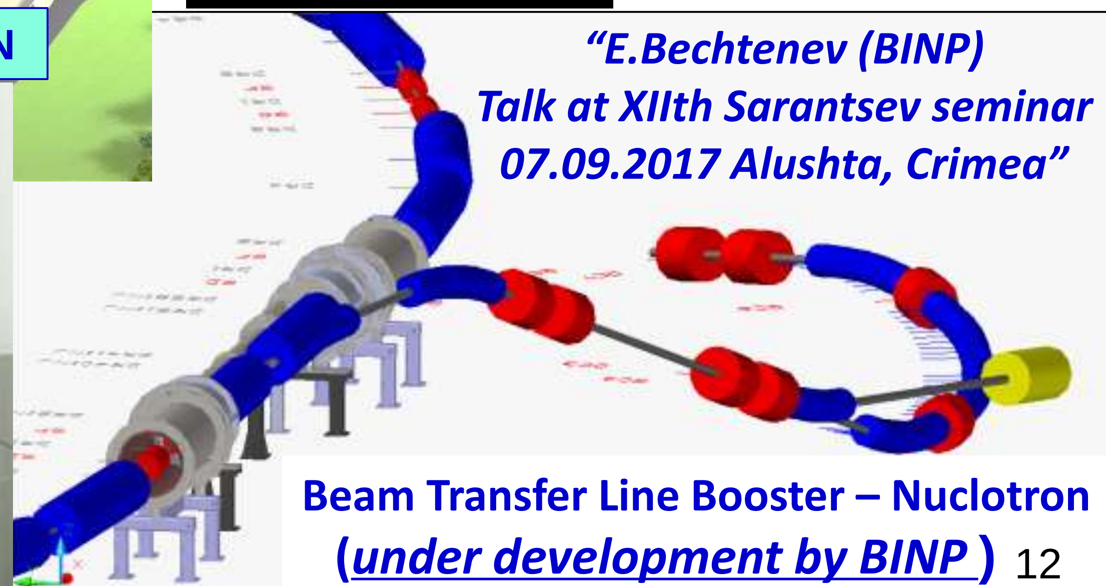
We need for **full scale BM@N commissioning** in 2019 :

- ❑ Injection complex: KRION, HILAc, LU20
- ❑ Booster
- ❑ Nuclotron upgraded
- ❑ BM@N Detector



V.A.Kiselev – designer of BTL B=N

A.N.Zhuravlev – leader of BTL B => N development.



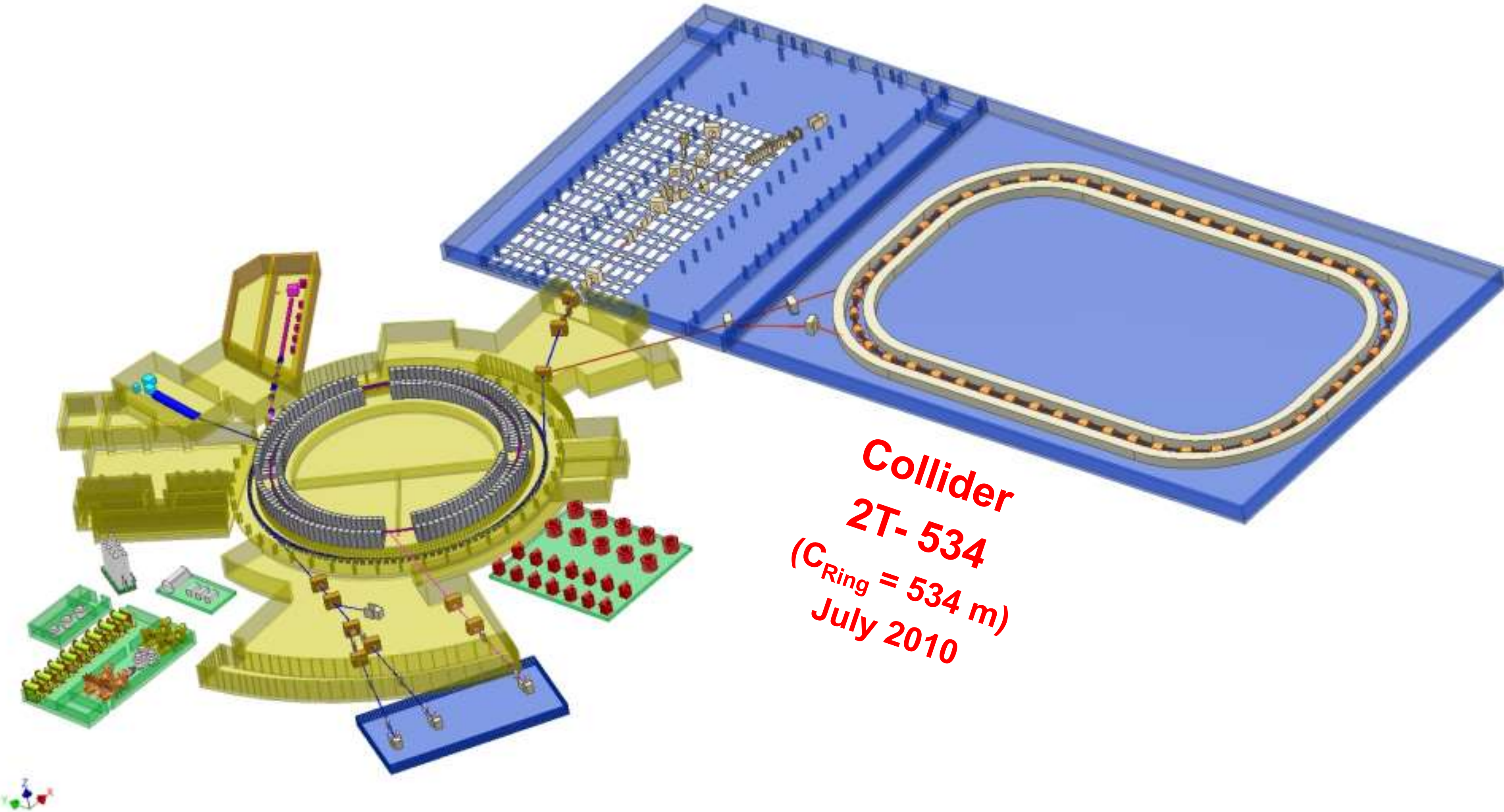
“E.Bechtenev (BINP) Talk at XIIth Sarantsev seminar 07.09.2017 Alushta, Crimea”

Beam Transfer Line Booster – Nuclotron (*under development by BINP*)

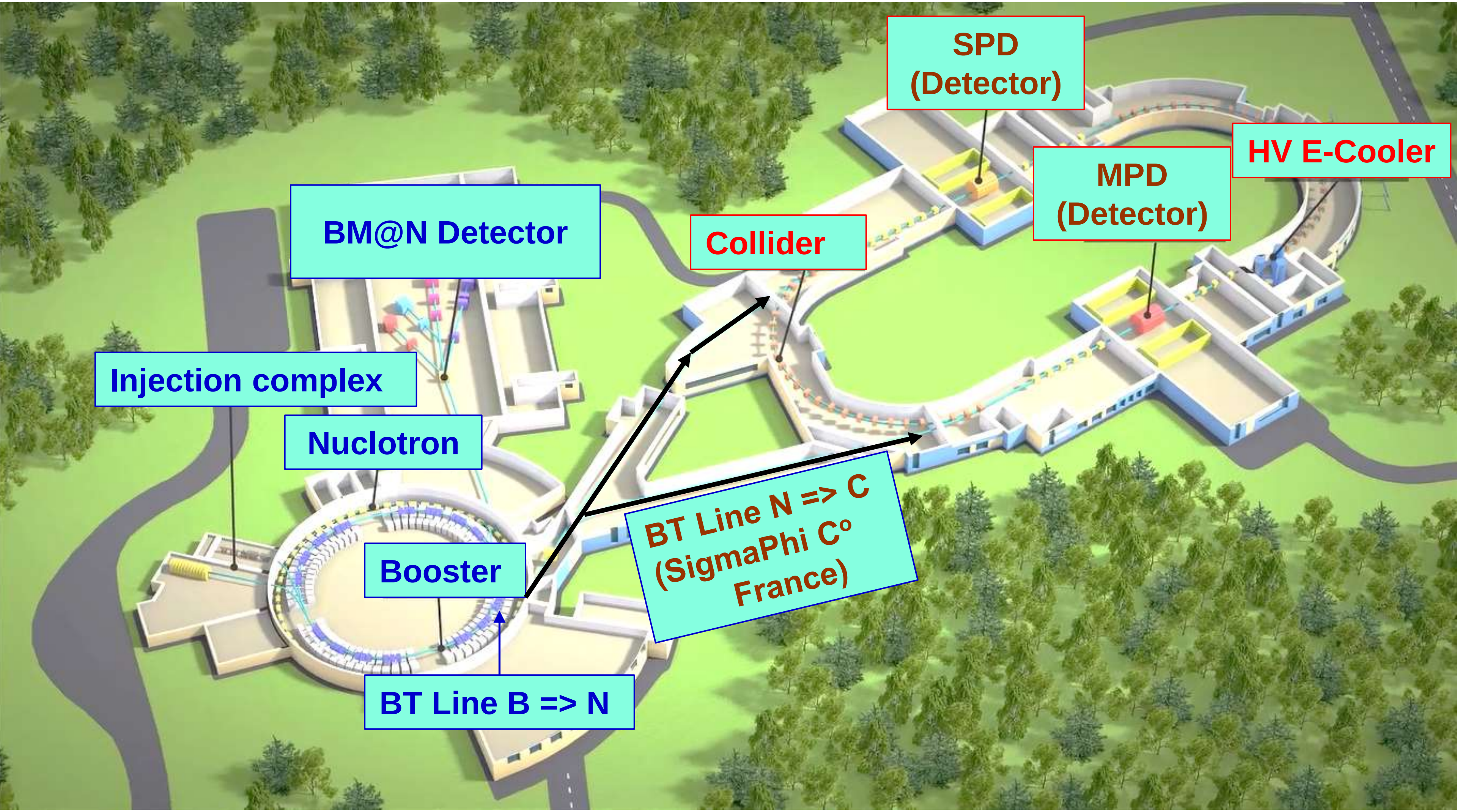

NICA
NUCLOTRON BASED ION COLLIDER FACILITY

3. NICA – Stage II

Three first versions of NICA Collider



4. NICA – Stage II



In red => designed and constructed with contributions of BINP

4. NICA – Stage II

4.1. The NICA Collider

Circumference, m	503.04		
Number of bunches	22		
rms bunch length, m	0.6		
β-function in IP, m	0.35		
Betatron tunes, Q_x/Q_y	9.44 / 9.44 // 9.10/9.10		
Chromaticities, Q'_x/Q'_y	-33 / -28		
Ring Acceptance, π mm·mrad	40		
Momentum acceptance, $\Delta p/p$	±0.010		
γ_{tr}	7.088		
Kinetic energy of Au^{79+}, GeV/u	1.0	3.0	4.5
Number of ions per bunch	$2.0\cdot10^8$	$2.4\cdot10^9$	$2.3\cdot10^9$
$\Delta p/p_{rms}$, 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}	$0.6\cdot10^{25}$	$1\cdot10^{27}$	$1\cdot10^{27}$
IBS growth time, s	160	460	1800
Tune shift, $\Delta Q_{total} = \Delta Q_{SC} + 2\xi$	-0.050	-0.037	-0.011

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

4. NICA – Stage II

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

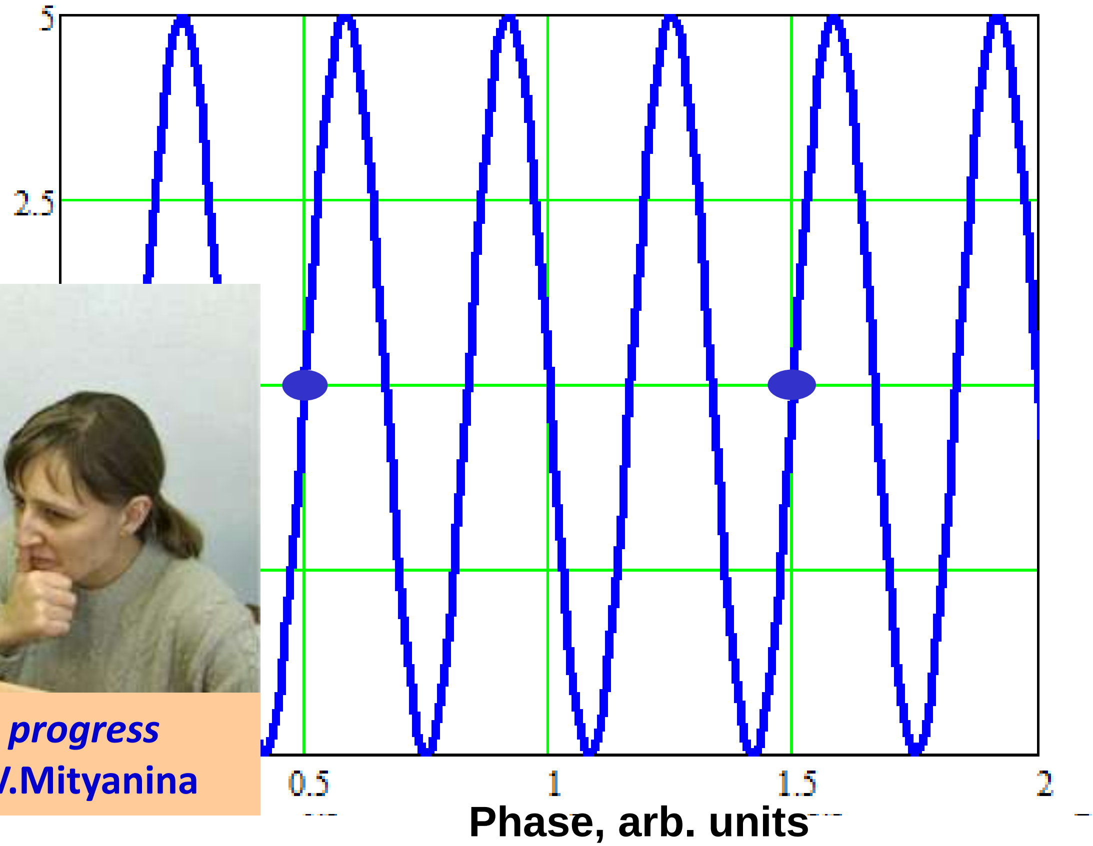
Step 1: **Cooling and stacking with RF1 barrier voltage (< 5 kV). Accumulation efficiency ~ 95%, about 44 - 100 injection pulses (22-50 to each ring) every 5 sec. Total accumulation time ≤ 10 min.**

Ion momentum spread is limited by microwave instability.

Steps 2-3. Formation of the short ion bunches at presence of cooling:

RF-2 (100 kV, 4 resonators) => RF-3 (1MV, 8 resonators).

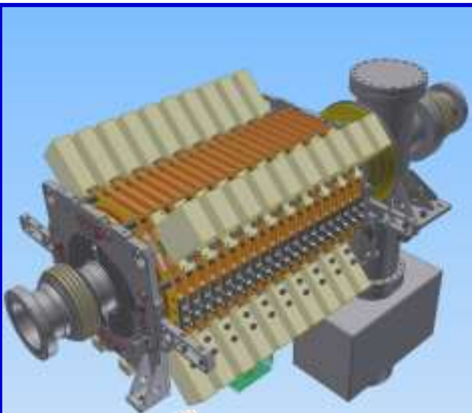
From coasting beam to => 22nd harmonics => 66th harmonics



RF gymnastics in progress
V.M.Petrov and N.V.Mityanina

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

Three Steps and Three RF Systems



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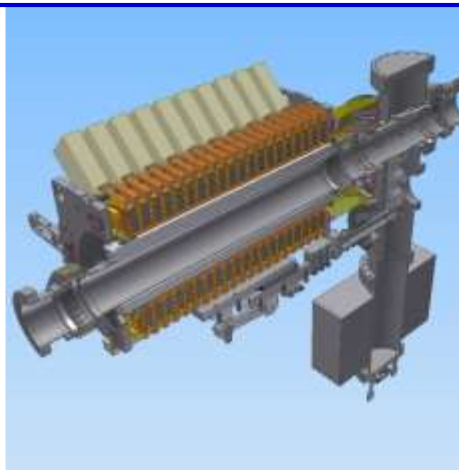
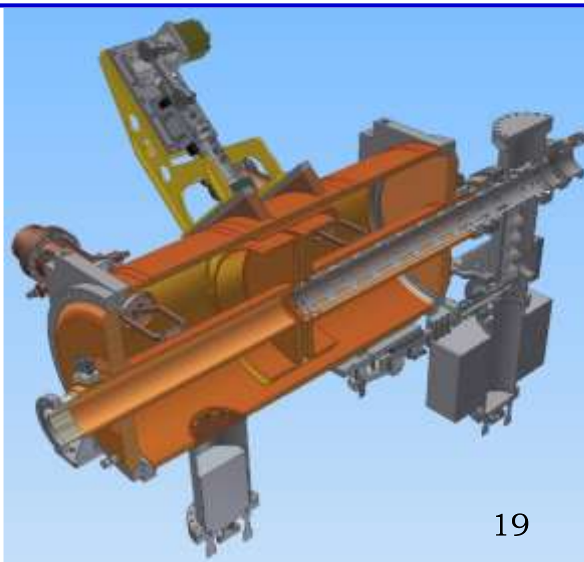


Step 2: **Formation of the short ion bunches at presence of cooling:**
RF-2 (100 kV, 4 cavities) ***from coasting beam to => 22nd harmonics***

Step 3: **Interception of the short ion bunches into separatrix of** ***66th harmonics*** **RF-3 (1MV, 8 cavities).**



4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

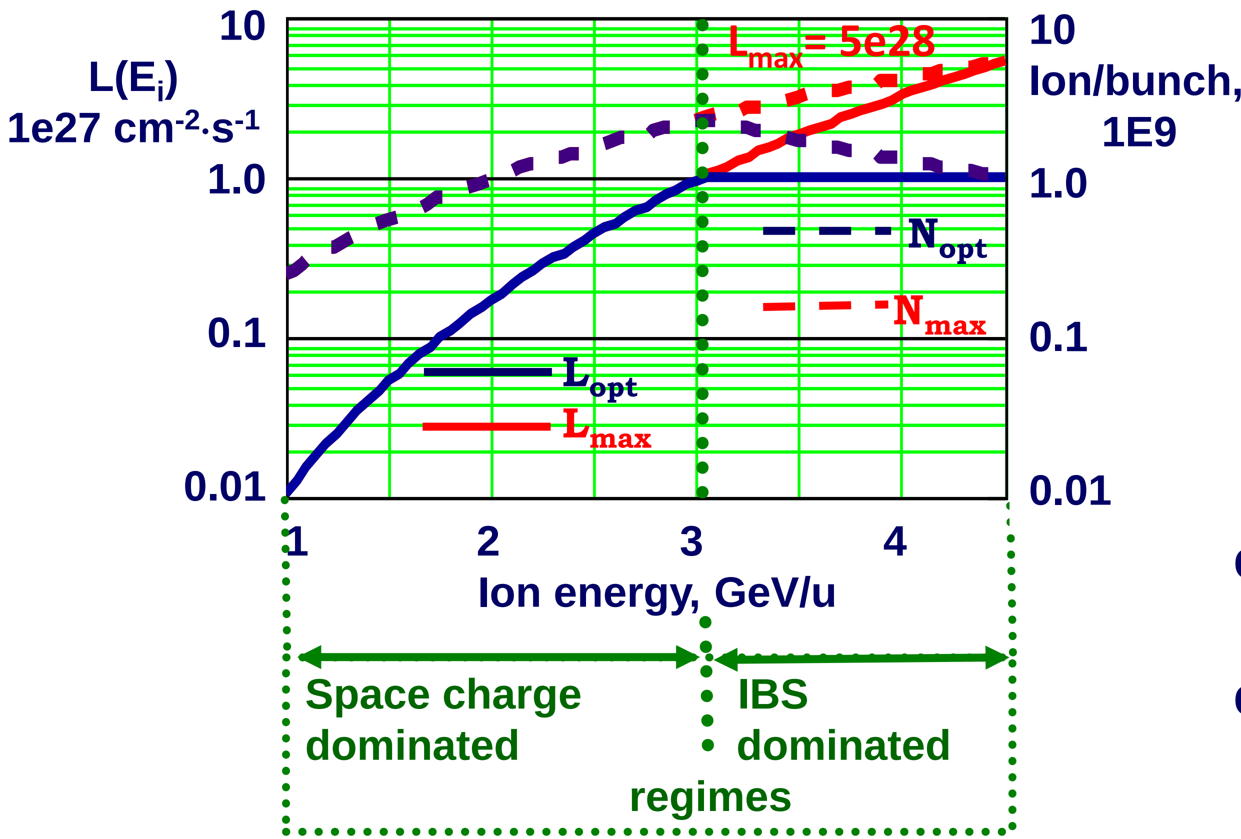
Three Steps and Three RF Systems

Working Meetings and Hot Discussions

4. NICA – Stage II

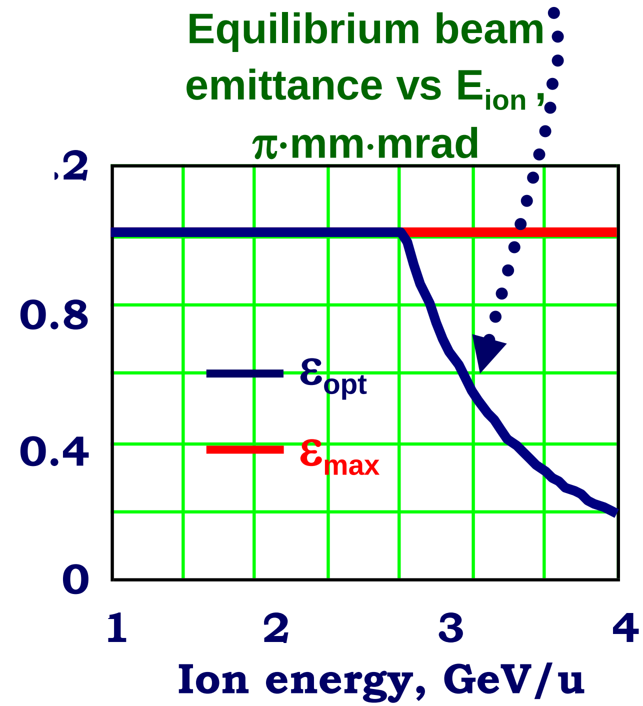
4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

Two operation regimes



Electron and stochastic cooling application!

Emittance reduction with energy:

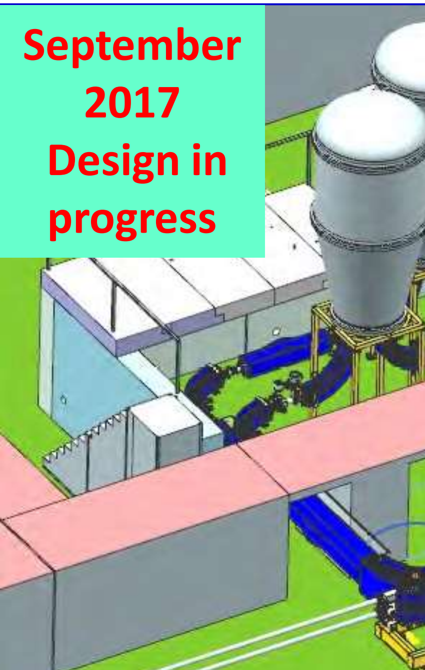


4. NICA – Stage II

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

High Energy Electron Cooler

September 2017 Design in progress



Nov. 2013 COSY E-Cooler commissioning
V.V.Parkhomchuk, V.B.Reva, and M.I.Bryzgunov

02.02.2018 1st solenoid section

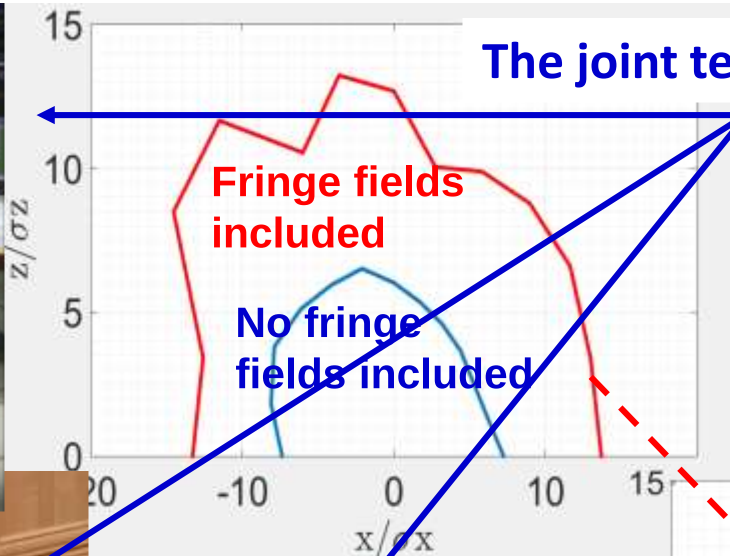
…f HV generator	
	Value
	0.2÷2.5
	≤1e-4
	0.1÷1
…m	5÷20
Length of cooling section, m	6
Magnetic field in the cooling section, kG	0.5÷2
Vacuum pressure in the cooling section, pTor	10
Total power consumption, kW	500-700

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

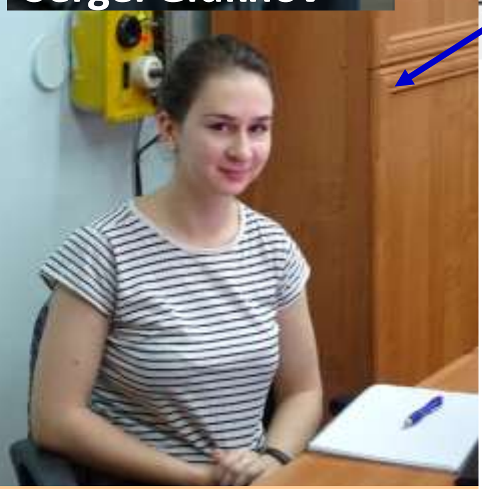
The struggle for dynamic aperture

The joint team members

Sergei Glukhov



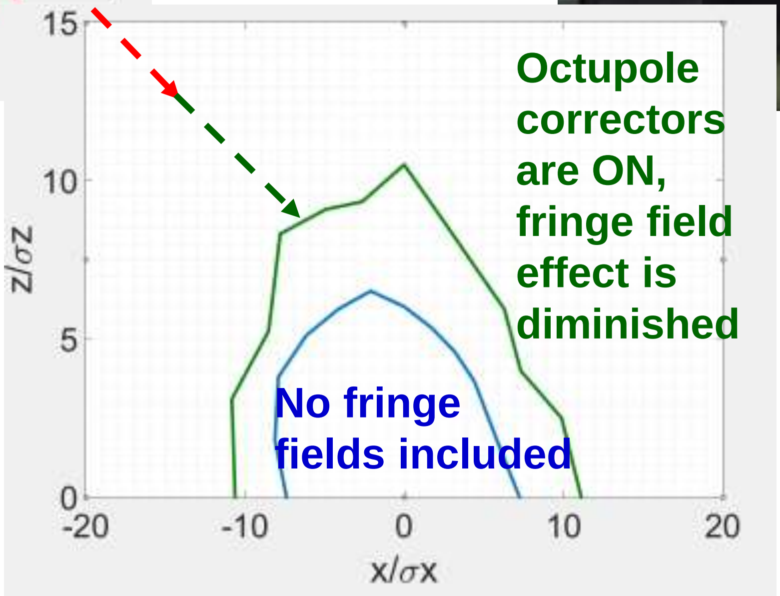
E.B.Levichev



Kseniya Karyukina

S.Kostromin
O.Kozlov
(JINR)

V.Lebedev
(Fermilab)



4. NICA – Stage II

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

Superhigh Vacuum and Electron Clouds

A.A.Krasnov and colleagues

Fruitful cooperation in high vacuum technology and physics of electron clouds

4. NICA – Stage II

4.2. Collider Luminosity and The Strategy of Its Achievement and Maintenance

Trilateral Collaboration for Particle Dynamics Studies in Collider

04.04.2018 One of regular working meetings of the groups of Budker INP – Alikhanov ITEP and NICA JINR

Visiting NICA site…
Behind – the building for HE Electron Cooler

Now – with construction engineers (in helmets) from Strabag C°

5. NICA – Stage III: Collider of Polarized Beams

Spin physics studies are presently being performed at

1) NA58 experiment, or COMPASS (*Common Muon and Proton Apparatus for Structure and Spectroscopy*), CERN with JINR participation

2) CEBAF (JLab,USA) 3) RHIC (BNL, USA),

3) COSY (FZJ, BDR) 5) Nuclotron (JINR),

Basic parameters of the NICA Collider in the polarized particles' mode (2030?): $\sqrt{s_{NN}}$ = **14 - 27 GeV polarized p↑ (d↑)**

at L ≤ 10^{32} $cm^{-2}\cdot c^{-1}$

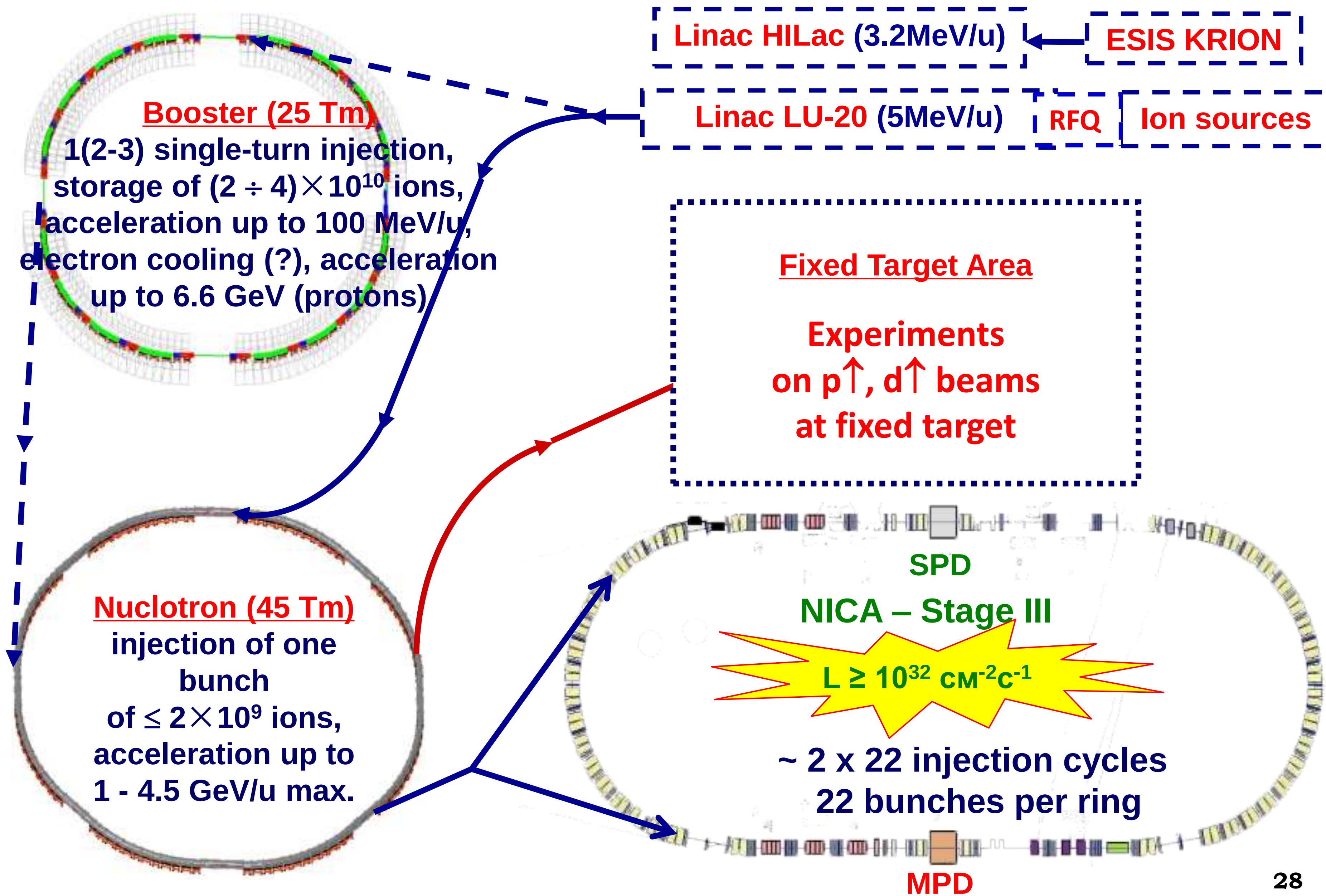
Today - fixed target experiments with polarized deuteron beam from Nuclotron:

- deuterons from the source (INR RAS + JINR)
- acceleration in linac LU-20
- injection into Nuclotron and acceleration
- slow extraction at magnetic field plateau ($\Delta t_{plateau}$ = 1 – 3 s)

5. NICA – Stage III: Collider of Polarized Beams

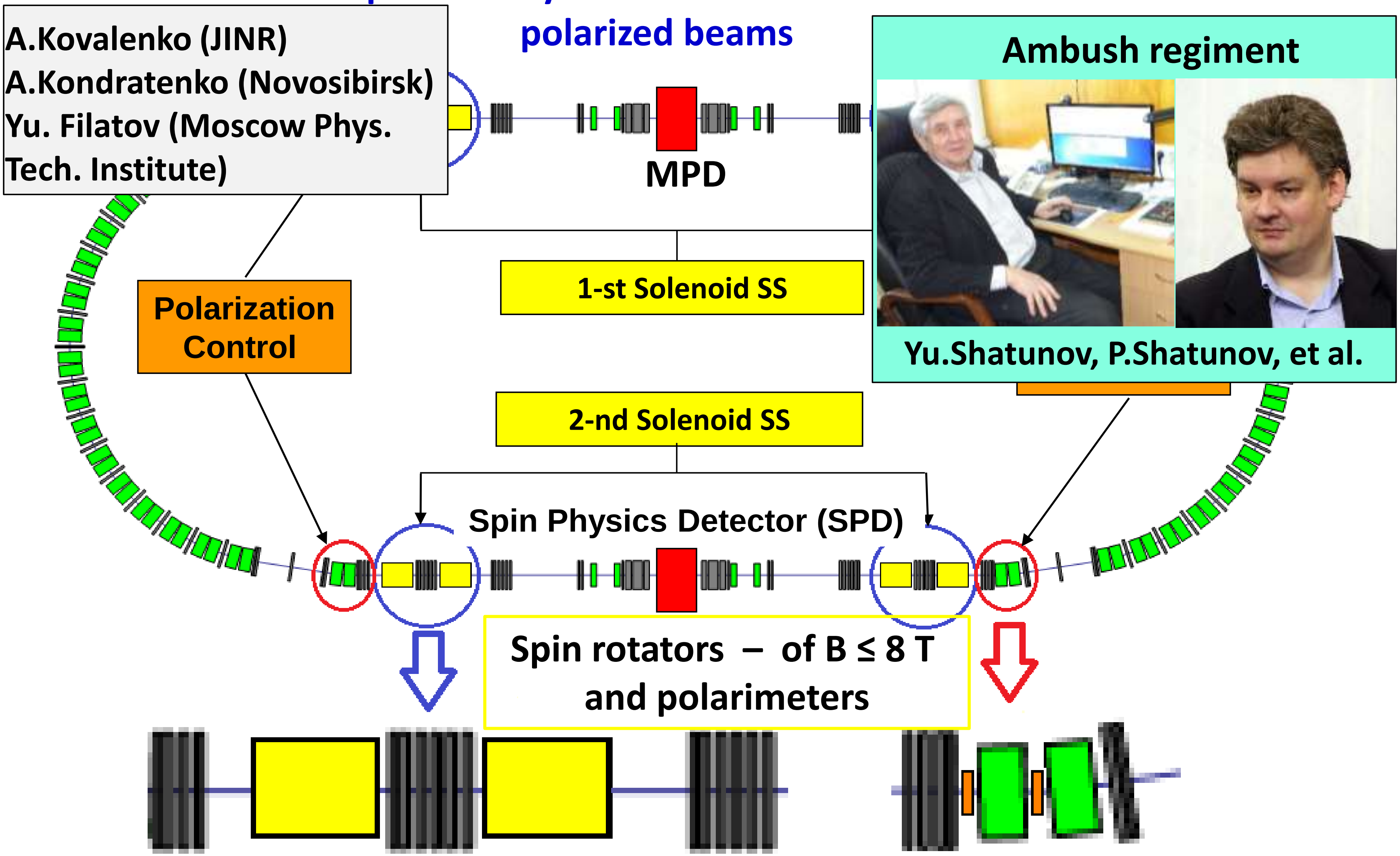
Fixed target experiments with polarized deuterons at Nuclotron have been resumed with new polarized ion source since 2016

5. NICA – Stage III: Collider of Polarized Beams



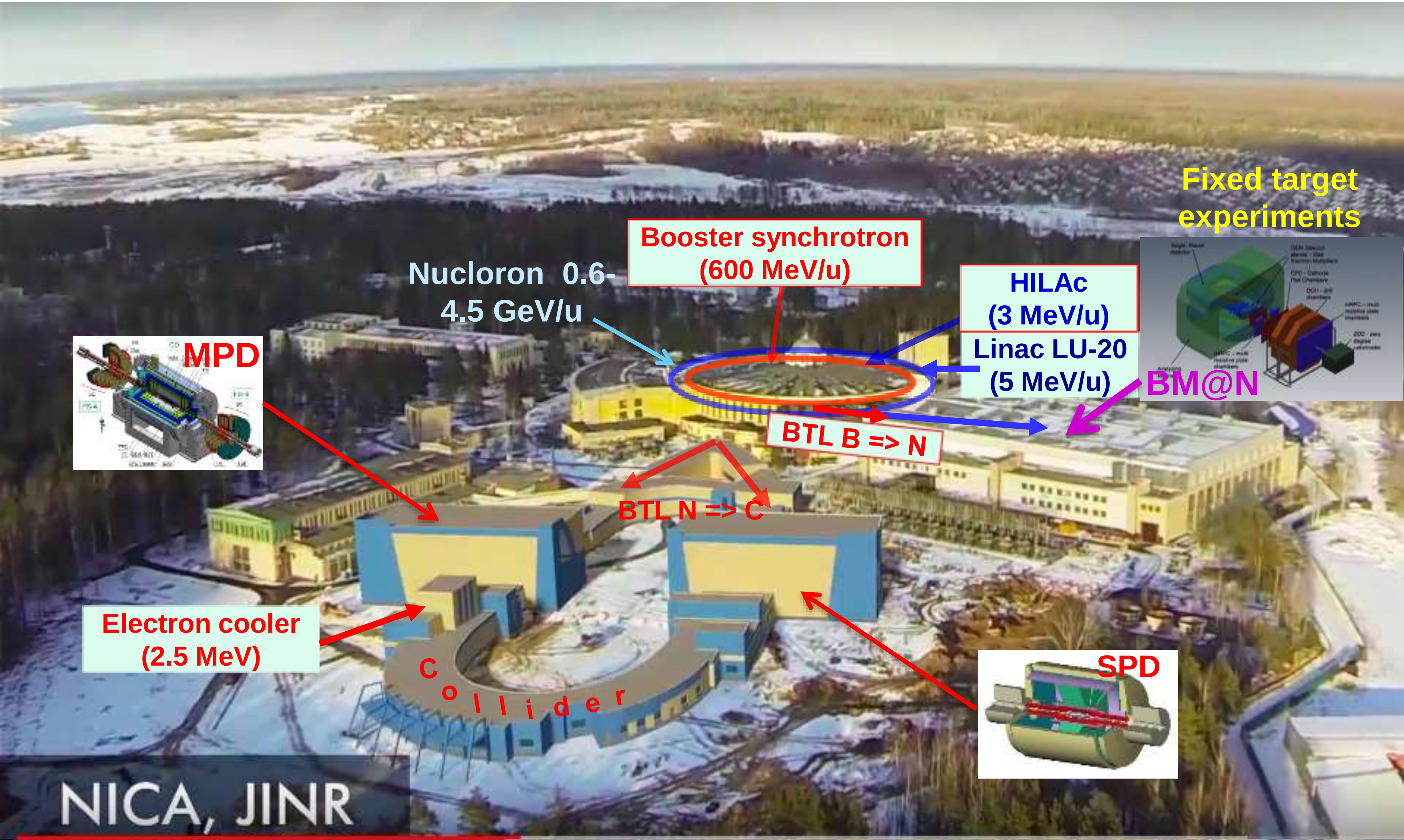
5. NICA – Stage III: Collider of Polarized Beams

One of the preliminary schemes of the NICA Collider with polarized beams



6. NICA Construction

In operation ***Under construction***

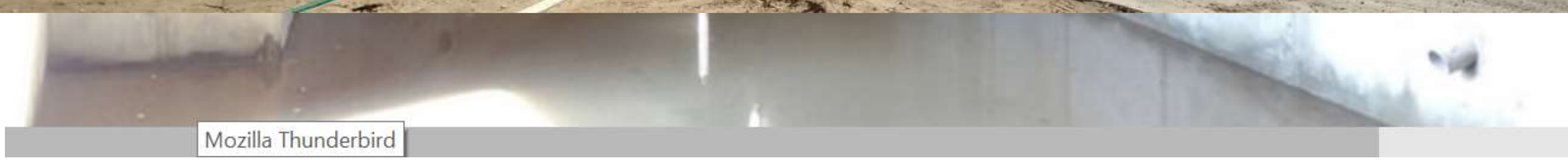


6. NICA Construction

Time to start mounting comes!

26-27.04.2018. 1st meeting dedicated to plans of mounting of BTL B => N, RF stations of the Collider and HE E-Cooler

Construction of The Collider Building



Outlook

Photo:
Valery Petrov (BINP)   Nikolai Topilin (JINR)
Igor Meshkov (JINR)   Roman Pivin & webcamera NICA (JINR)