Status of NICA

V. Kekelidze,
A.Kovalenko, R.Lednicky, V.Matveev, I.Meshkov, G.Trubnikov, A.Sorin
Joint Institute for Nuclear Research, Dubna

6-th International Conference on New Frontiers in Physics
17-29 August 2017

NICA (Nuclotron based Ion Colider fAcility

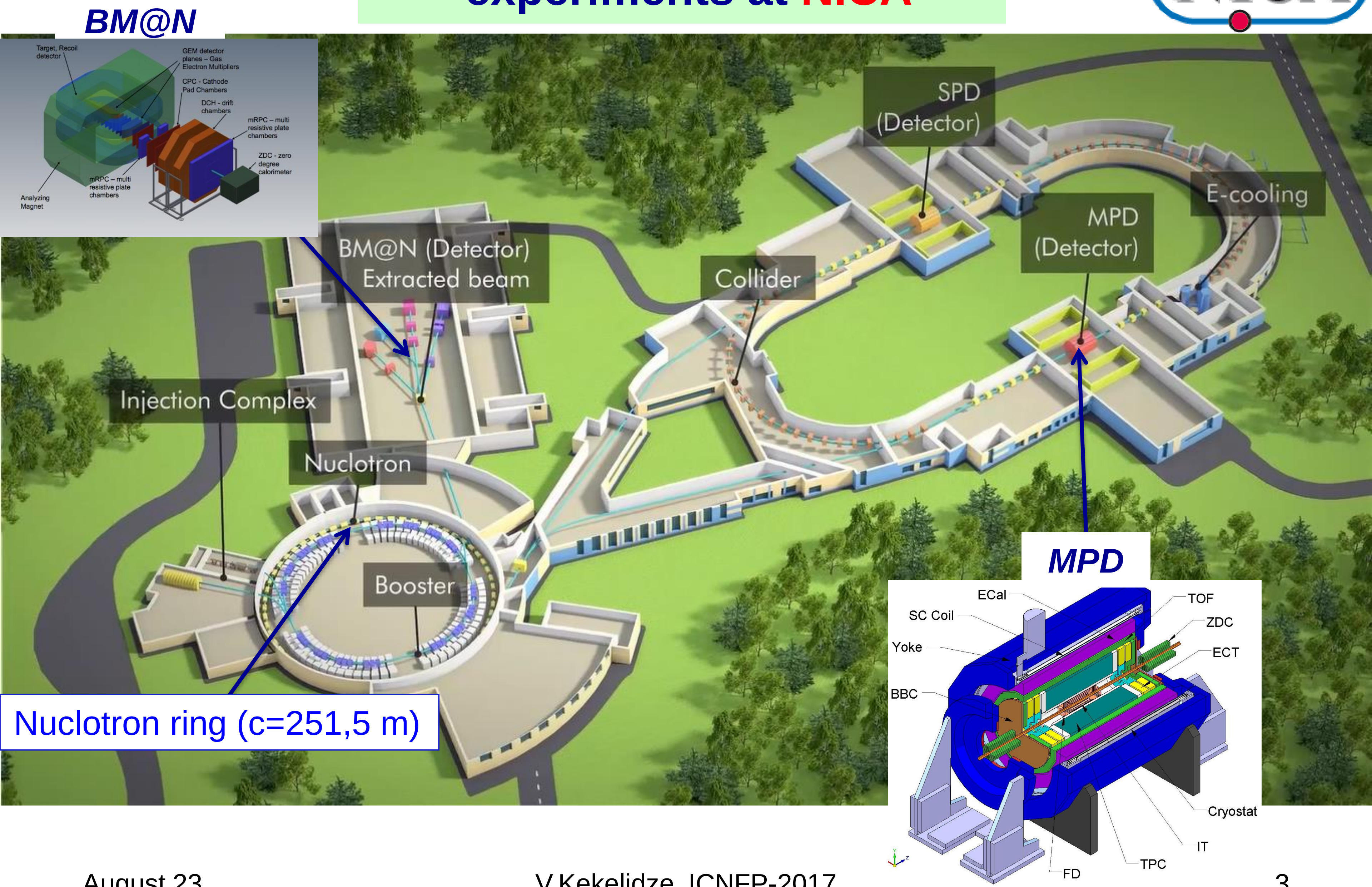
Main targets:

- *study of hot and dense baryonic matter at the energy range of max baryonic density*
- *investigation of nucleon spin structure, polarization phenomena*

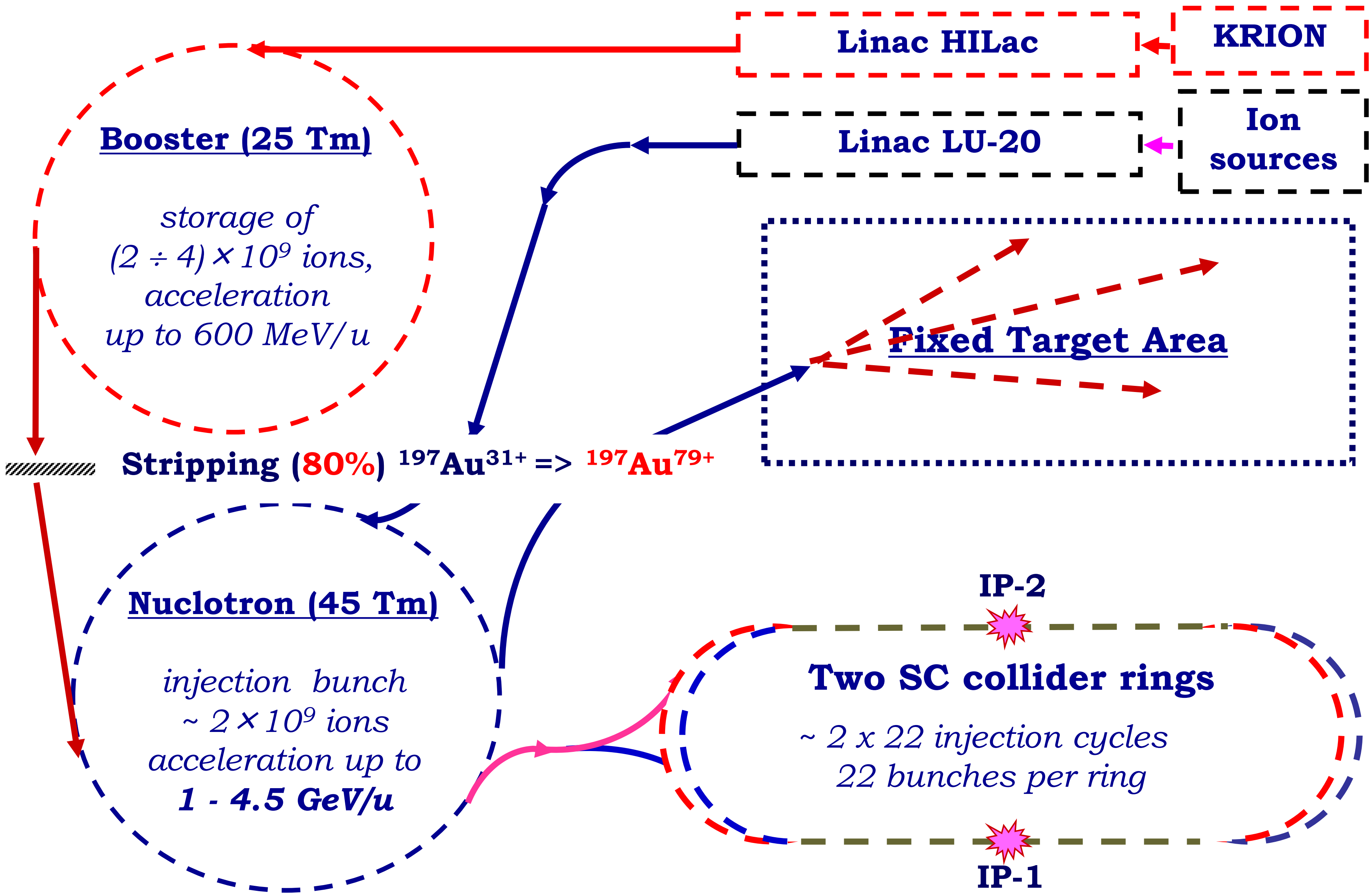
- *development of accelerator facility for HEP @ JINR*
- *construction of Collider of relativistic ions from* ***p*** *to* ***Au,*** *polarized protons and deuterons*

with max energy up to $\sqrt{S_{NN}}$ = ***11*** *GeV (Au^{79+}) and =**27** GeV (p)*

experiments at NICA



Structure and Operation Regimes

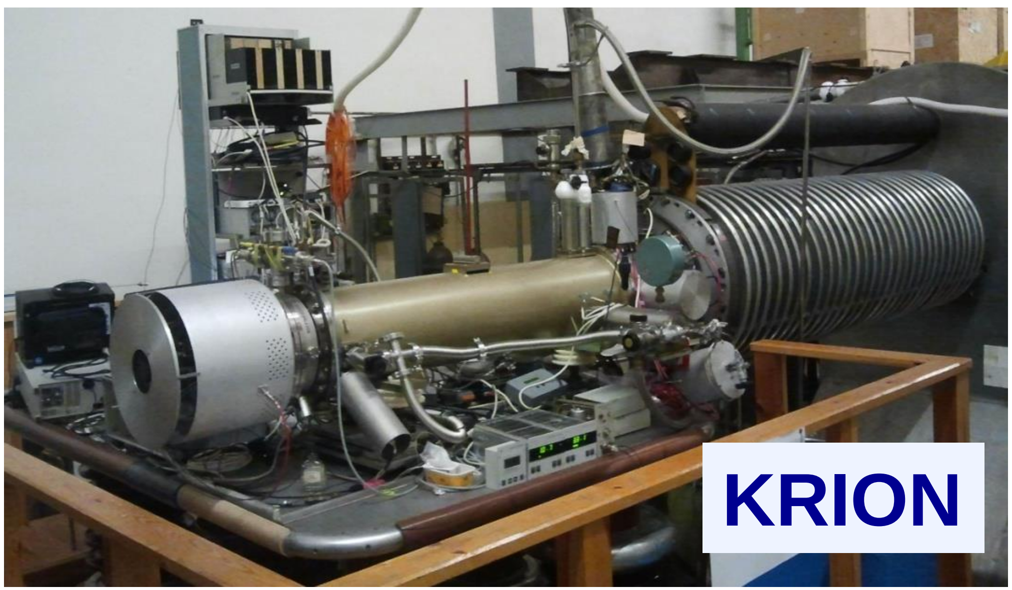


Injection complex: 4 ion sources

Source	KRION-6T	Laser	Douplasmatron	SPI new !
particles	Au^{31+}	up to Mg^{10+}	p, d, He^{2+}	$\uparrow$p, $\uparrow$d
particle/cycle	~2.5 10^{9}	~10^{11}	p, d ~5 10^{12} He^{2+} ~10^{11}	5 10^{11}
repetition, Hz	10	0,5	1	0,2

to be commissioned

commissioning: June '16



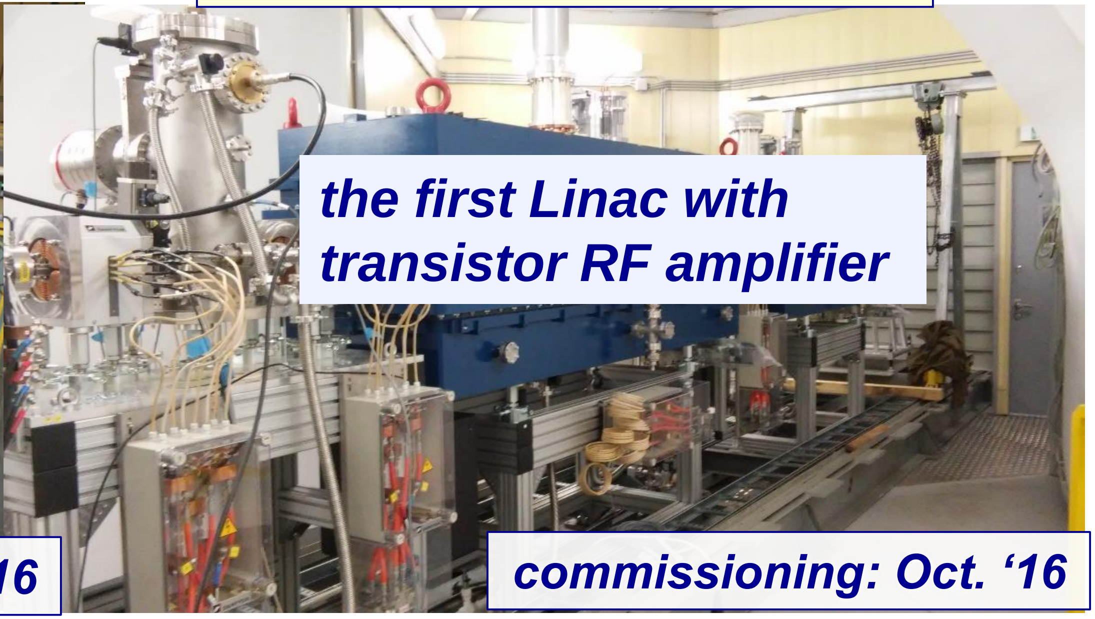
Injection complex: 2 Linacs

Linac	LU-20	HILAC **new !**
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 – new fore-injector**:*
JINR, INR, ITEP, MEPHI

commissioning: May ‘16

HILAc: “BEVATECH OHG”



the first Linac with transistor RF amplifier

commissioning: Oct. ‘16

Machines: Nuclotron *(in operation since **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

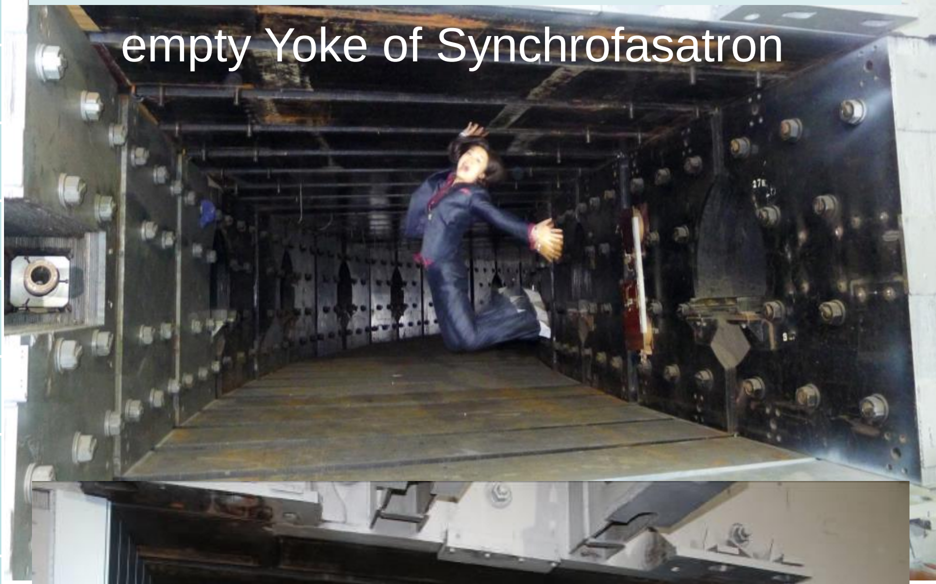
*modernized in **2010-2015***

Machine: Booster (*under construction*)

Parameter	**Booster**
type	SC synchrotron
particles	ions A/Z $\le$ 3
injection energy, MeV/u	3.2
maximum energy, GeV/u	0.6
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

Commissioning in 2019

Li So Yon (South Korean Cosmonaut)
LHEP JINR, Dubna, 7 Sep., 2011



BINP contribution to the Booster

two RF stations

- *tested at JINR - Oct. **'14***
- *commissioning - 2017*

electron cooling

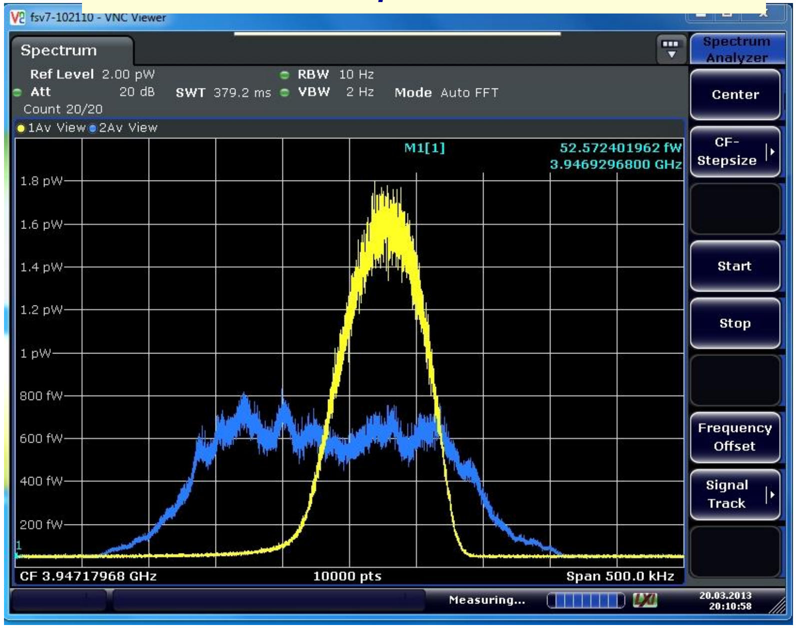
fabricated and tested at BINP in 2016
delivered to JINR in April 2017
*commissioning is planed in **2017***

Project status*:* *on schedule*

Nuclotron development

- ✧ Stable and safe operation up to maximum design energy
- ✧ Beam time for users > 70%
- ✧ Time losses < 8%
- ✧ Development of cryogenic facility
- ✧ Modern automatic control system based on TANGO
- ✧ Test of stochastic cooling
- ✧ New RFQ fore-injector for LU-20

momentum spread of d beam



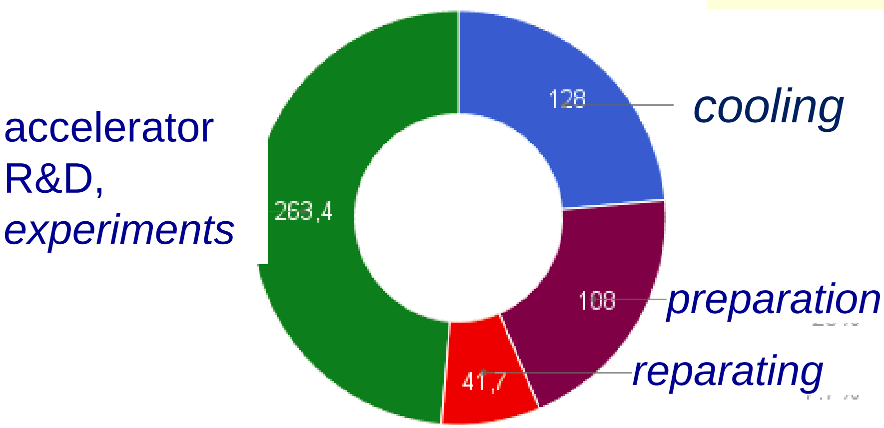
2 – 4 GHz bandwidth, the cooling of bunched and coasting deuteron and carbon beams was achieved

Nuclotron runs in 2015 -2017

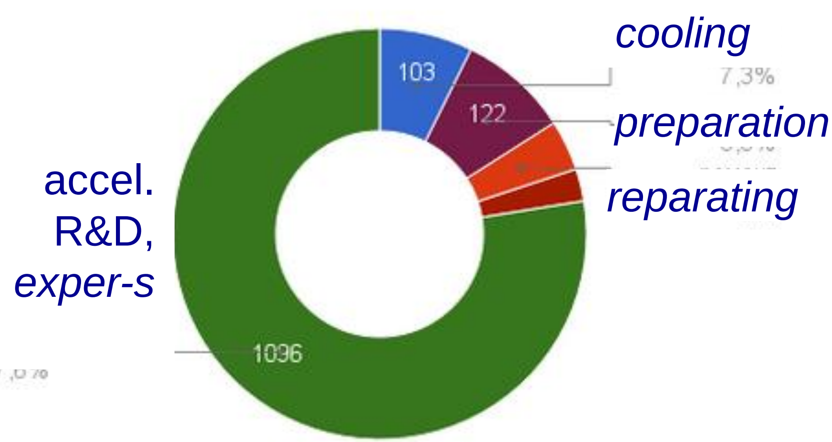
- **Run – 51 (**d, Li, C) *26 Jan. - 26 Mar., **2015***
- **Run – 52 (** d...) ***Technical*** *June 2 –July 8, **2016***
- **Run – 53 (**d↑, Li) *Oct.19 – Dec. 25 , **2016***
- **Run – 54 (**d↑,...) *Feb. 1 – Mar. 24 , **2017***
- **Run – 51 (**Kr, C) *Nov. – Dec., **2017***

Time distribution

Run – 52



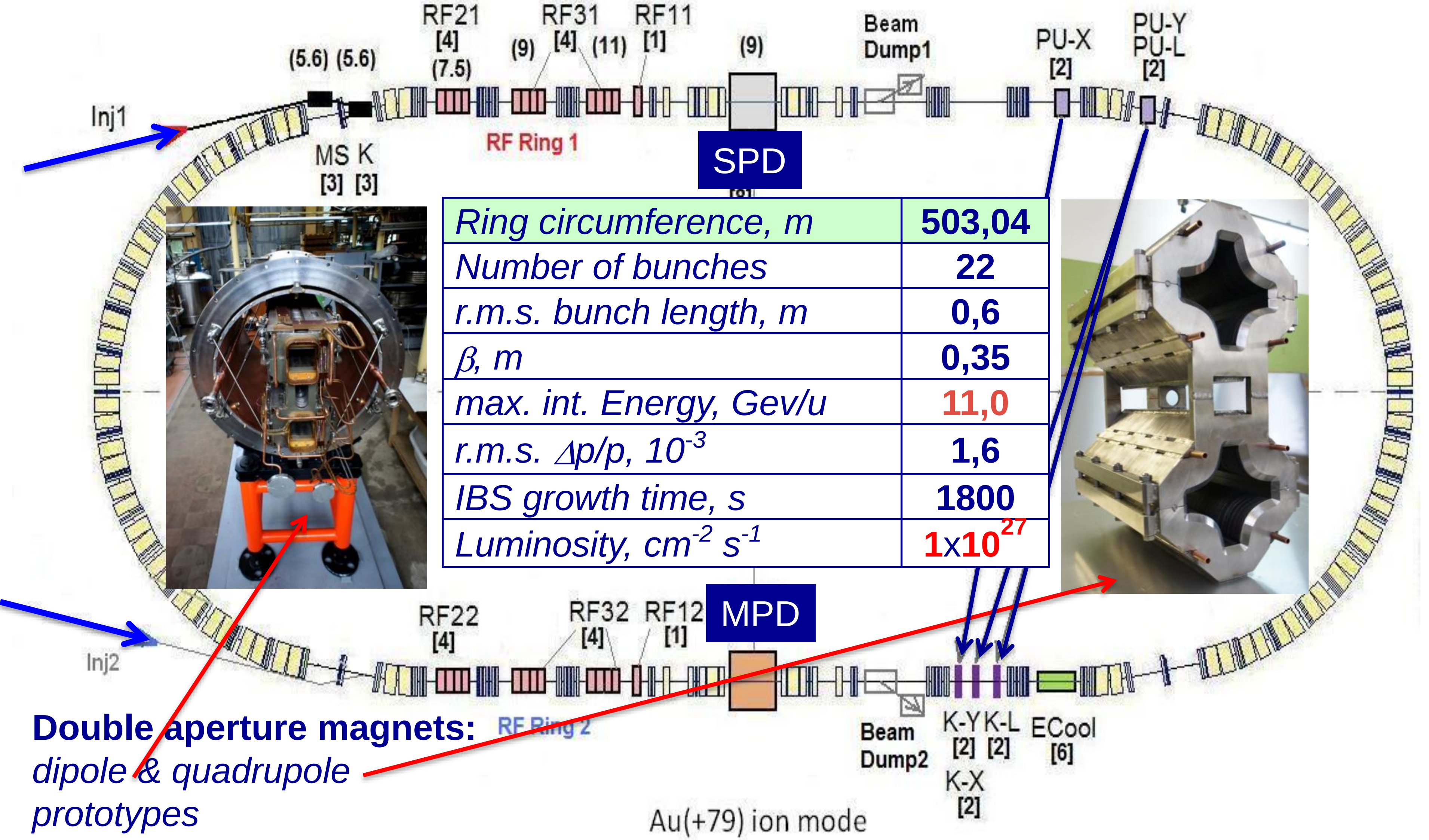
Run – 53



The 5th Workshop of Nuclotron users will take place on 5–6 October, 2017

The Collider

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

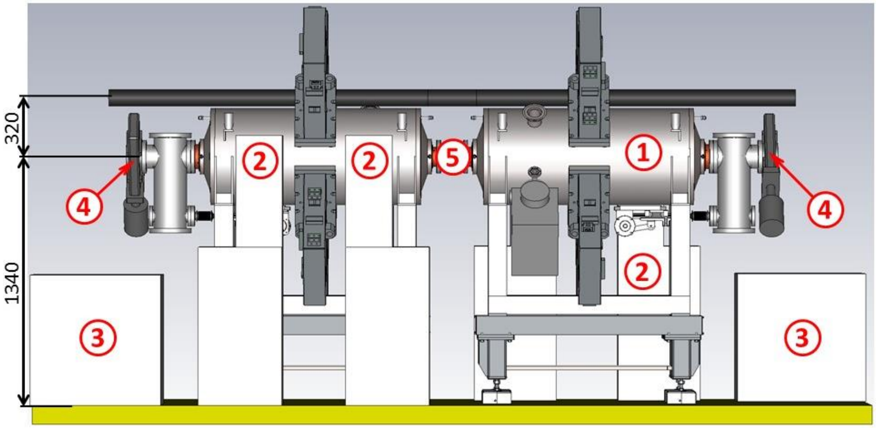


Ring circumference, m	**503,04**
Number of bunches	**22**
r.m.s. bunch length, m	**0,6**
β, m	**0,35**
max. int. Energy, Gev/u	**11,0**
r.m.s. $\Delta p/p$, 10^{-3}	**1,6**
IBS growth time, s	**1800**
Luminosity, cm^{-2} s^{-1}	**$1x10^{27}$**

Double aperture magnets:
dipole & quadrupole prototypes

BINP contribution to the Collider

RF: *Leader A.Tribendis*
(stage of working design)



Electron Cooler
Leader ac. V. Parkhomchuk
(stage of working design)

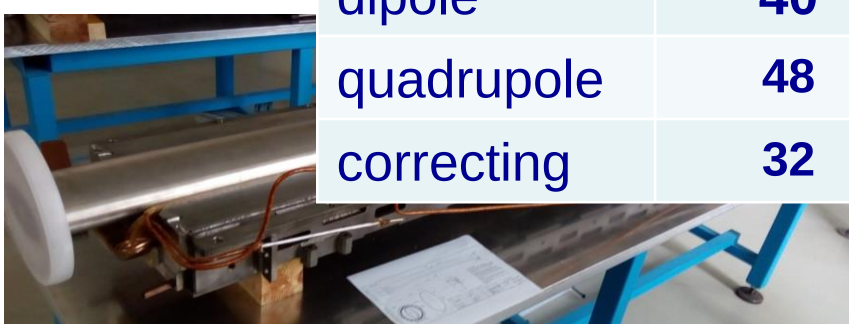
Electron energy, max., MeV	*2.5*
Electron beam current, A	*0.1 – 1.0*

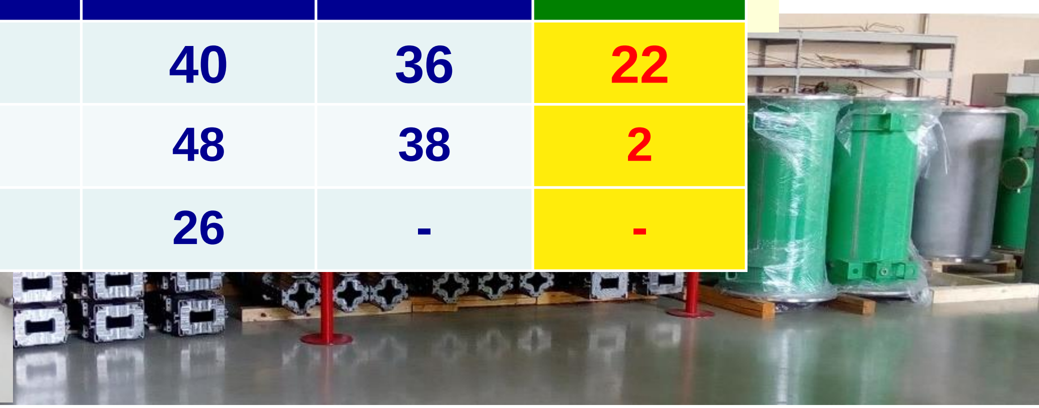
SC Magnets for Booster, Collider & SIS-100/FAIR workshop at VBLHEP JINR *(bld. 217)*

Serial tests of Booster magnets have started

*status of **booster** magnet fabrication 16.08.2017*

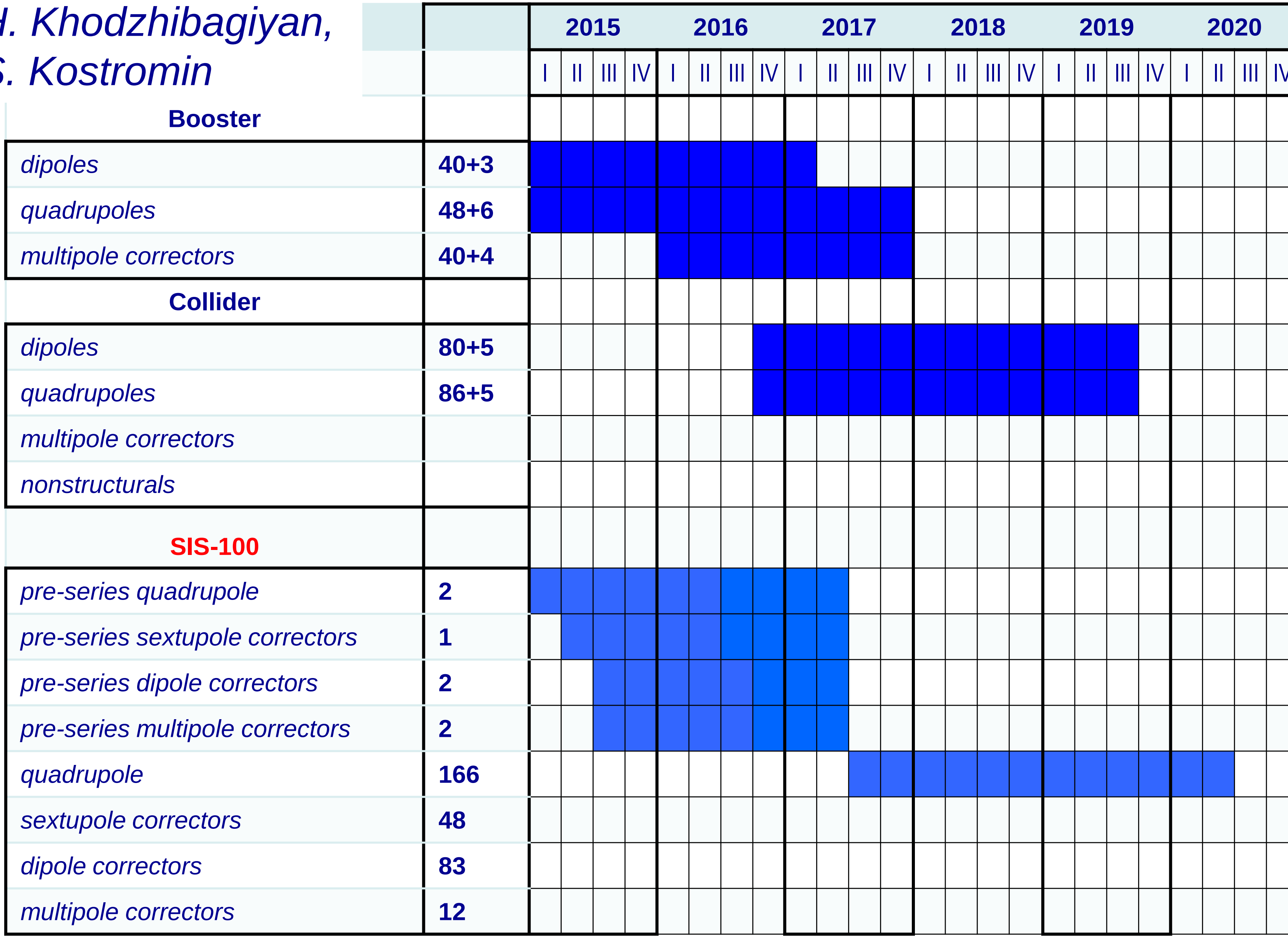
magnet type	required	produced		tested
		yokes	*coils*	
dipole	**40**	**40**	**36**	**22**
quadrupole	**48**	**48**	**38**	**2**
correcting	**32**	**26**	**-**	**-**





Magnet production plan

H. Khodzhibagiyan,
S. Kostromin



He liquefier has been put in operation, 1000 l/h

Largest in Russia

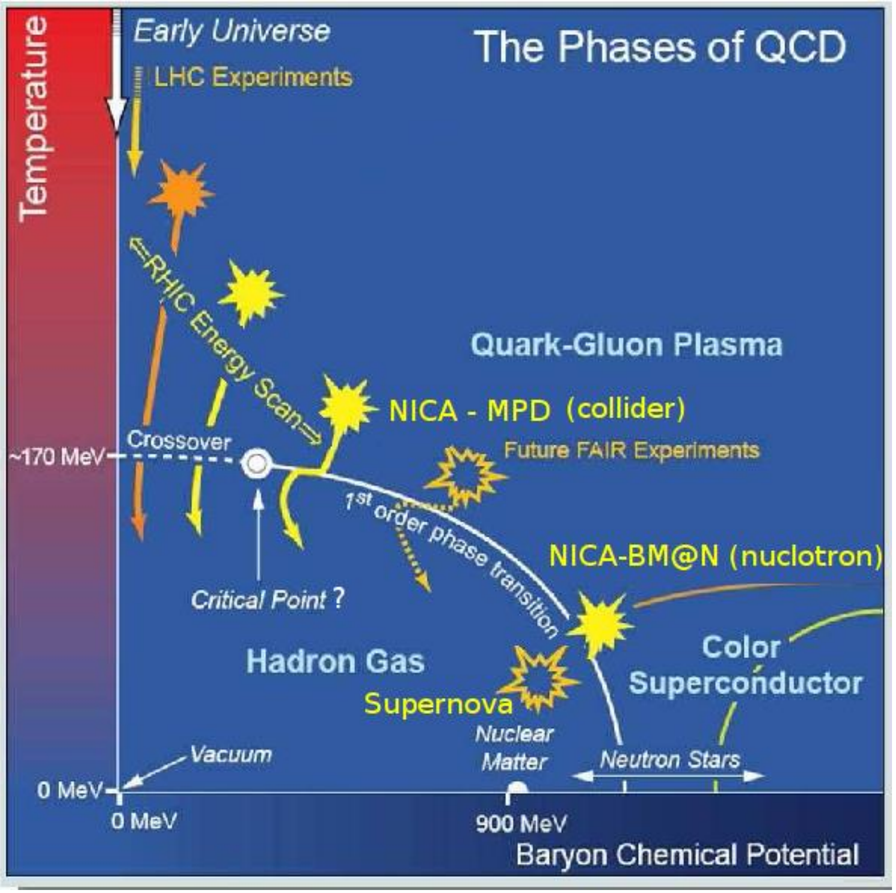
Finally the cooling power should be doubled from 4 kW to 8 kW @ 4.5K

21.08.2017

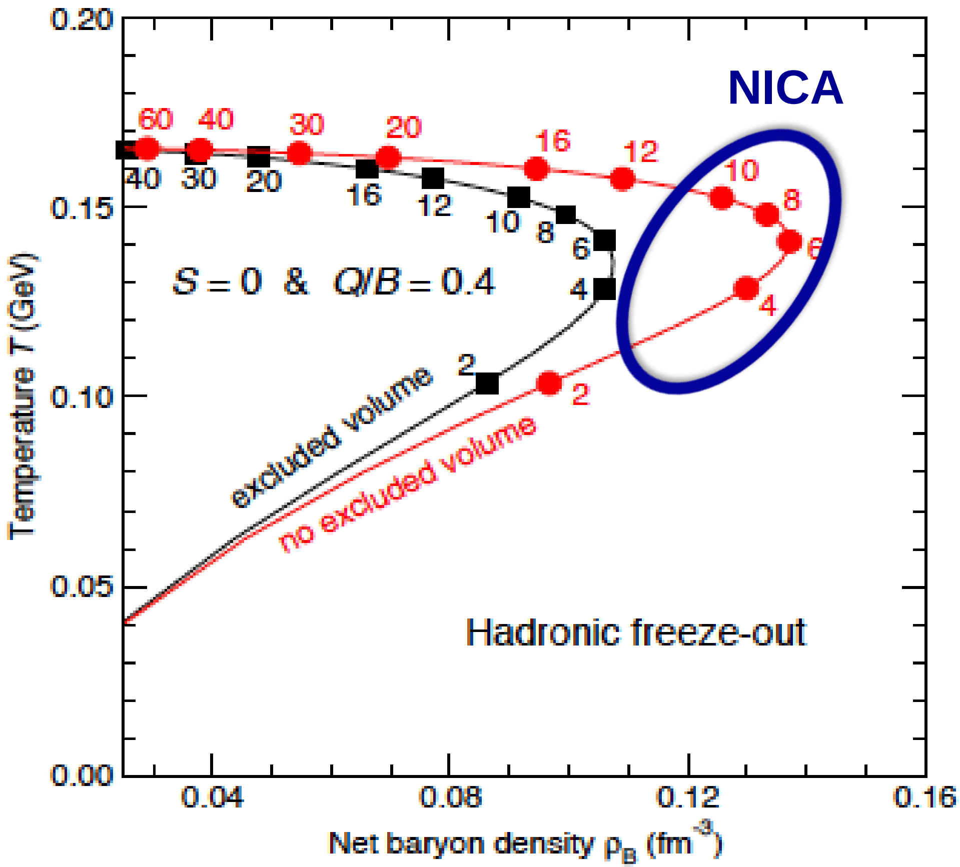
Physics program at NICA

Exploration of the QCD PD - Density Frontier

Exploring high-density baryonic matter: maximum freeze-out density



J. Randrup, J. Cleymans; White Paper



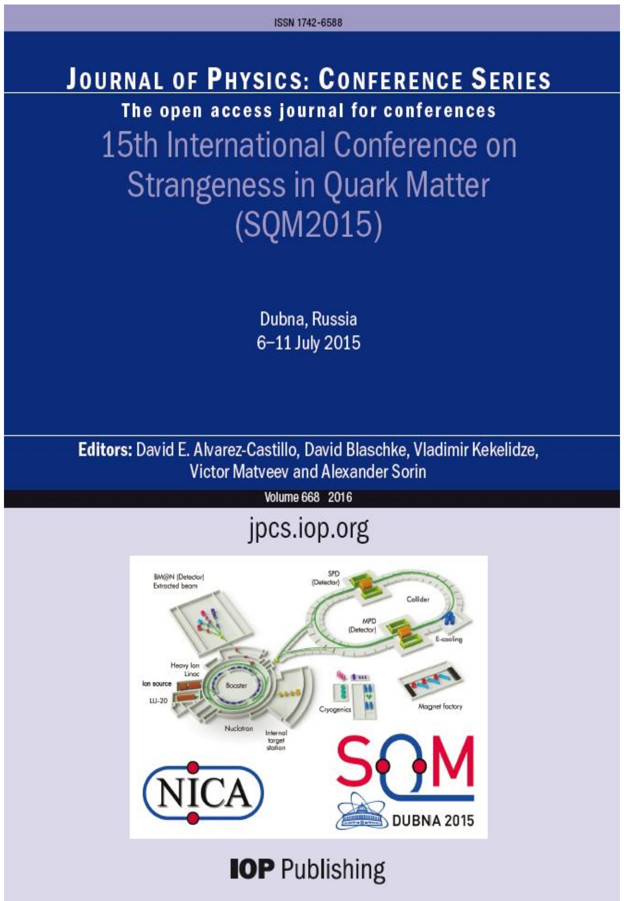
NICA is well suited for exploring the transition between the hadronic and q-g phases at the highest baryon density. This is the top priority of the NICA program.

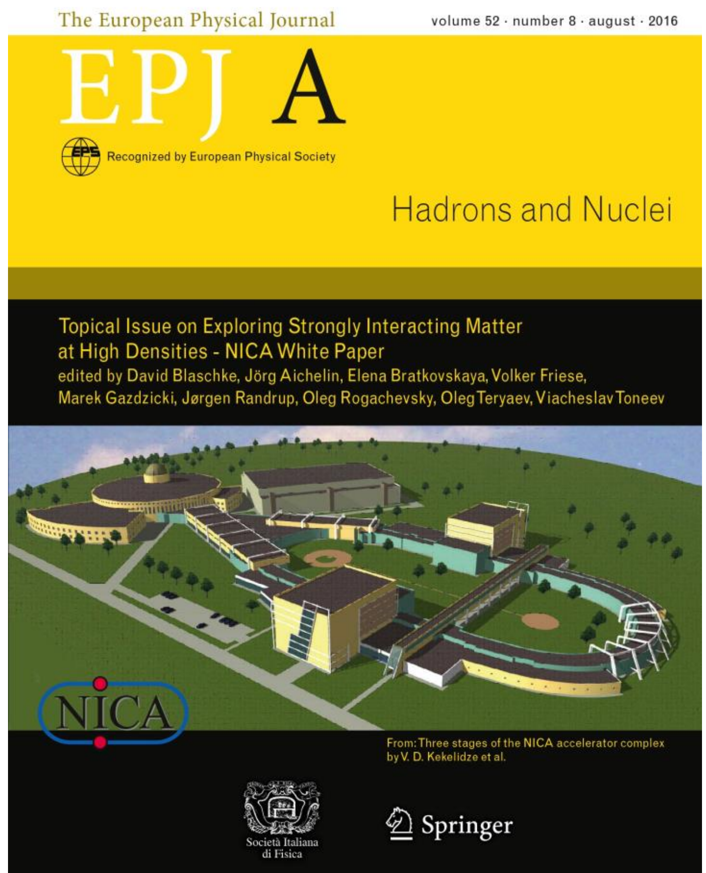
Physics objectives

- *Bulk properties, EOS*
  - particle yields & spectra, ratios, femtoscopy, flow
- *In-Medium modification of hadron properties*
  - onset of low-mass dilepton enhancement
- *Deconfinement (chiral) phase transition at high ρ_B*
  - enhanced strangeness production
- *QCD Critical Point*
  - event-by-event fluctuations & correlations
- *Chiral Magnetic (Vortical) effect, Λ polarization*
- *Y-N interactions in dense nuclear matter*
  - hypernuclei

New issues: NICA White Paper, SQM proceedings

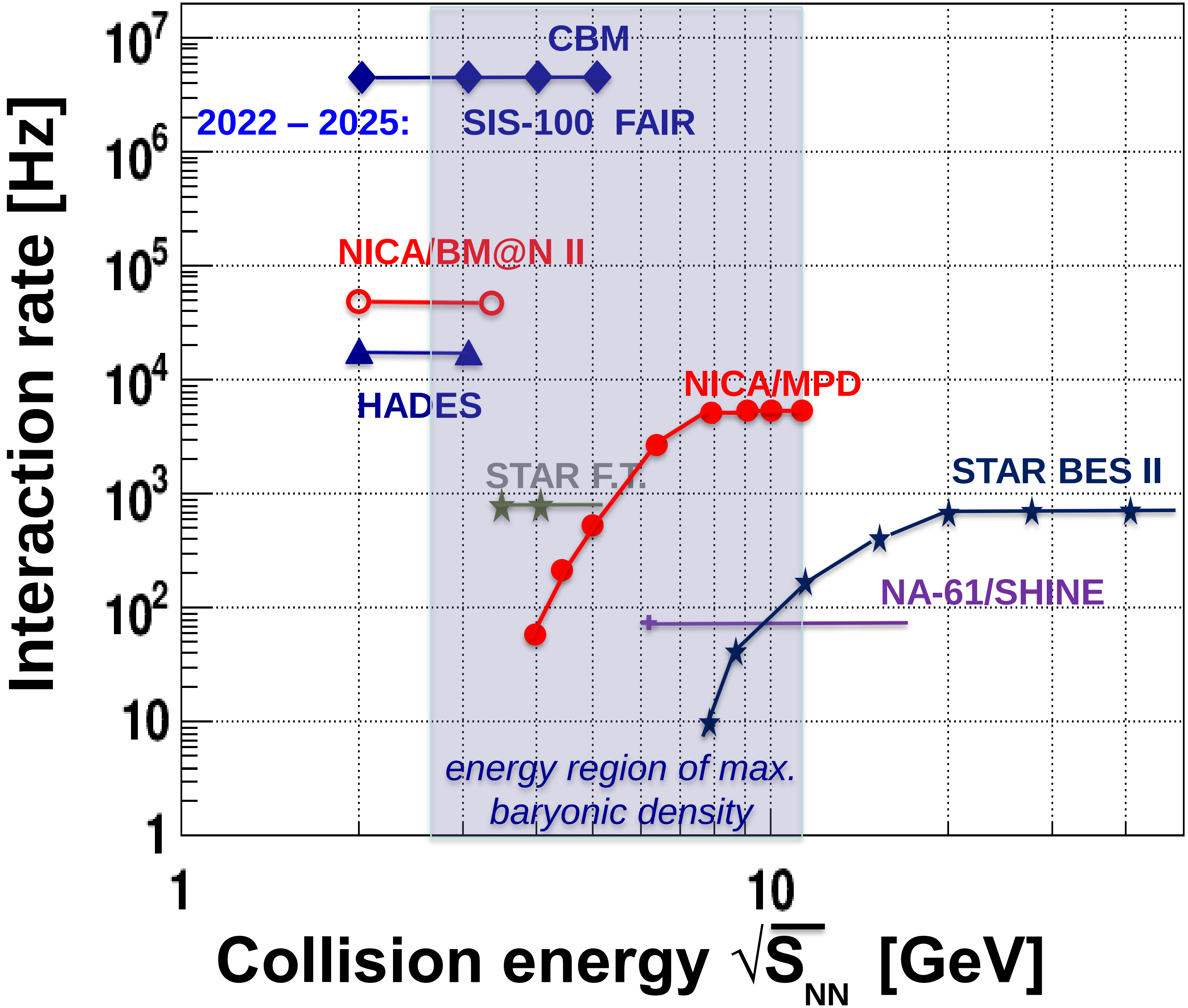
*Physics targets for the exploration of first order phase transitions in the region of the QCD phase diagram accessible to NICA & CBM and possible observable effects of a "mixed phase culminates this year in the release of the "NICA White Paper" as a Topical Issue of the **EPJ A** (July 2016).*



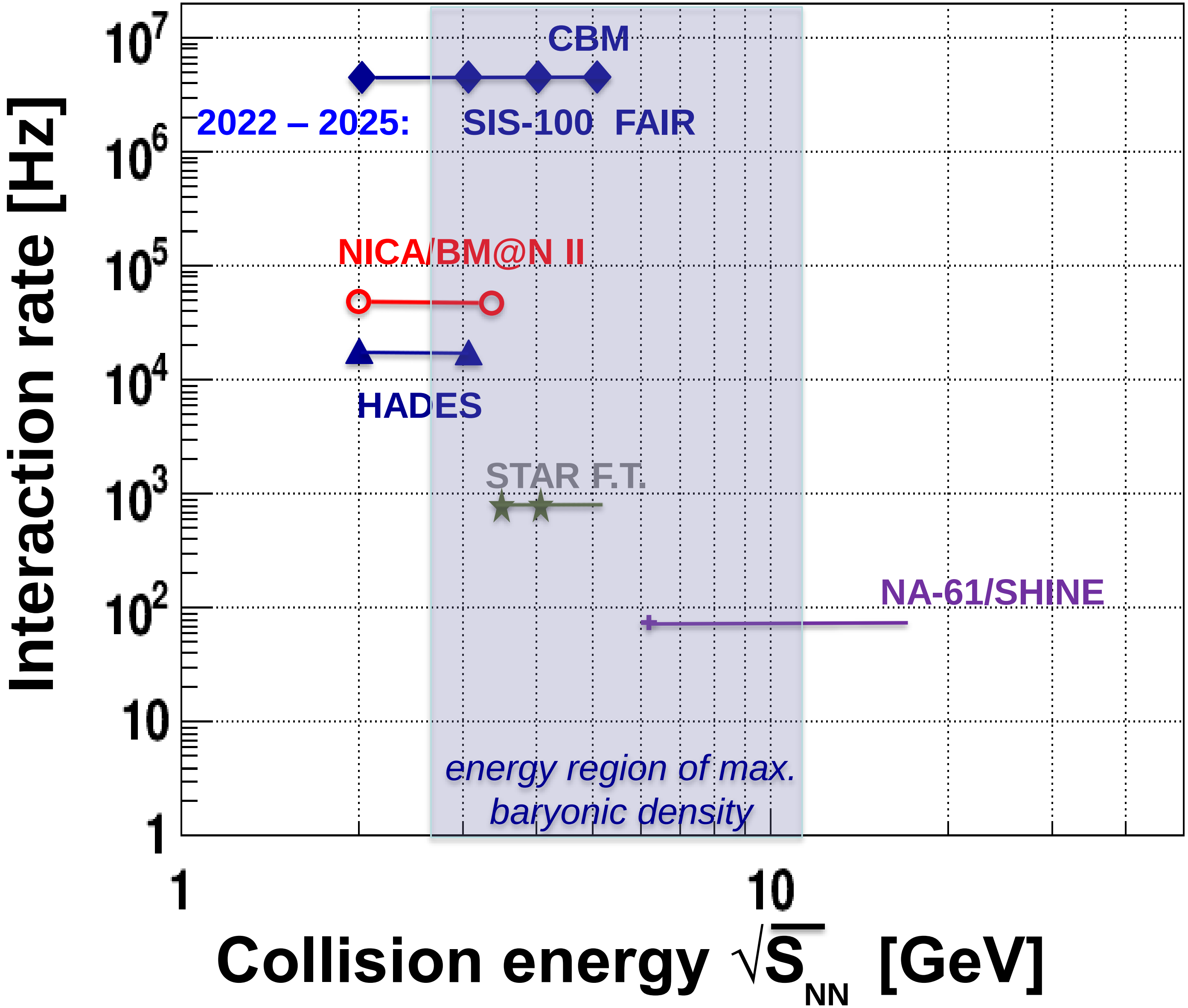


111 contributions,
188 authors
from **24** countries

Present and future HI experiments



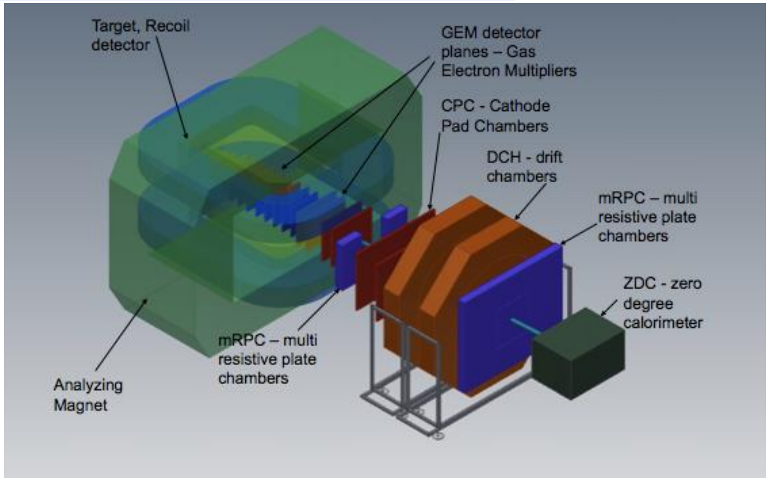
Present and future HI F.T. experiments

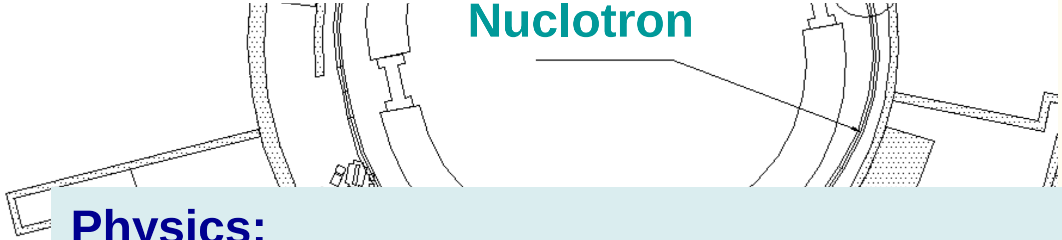


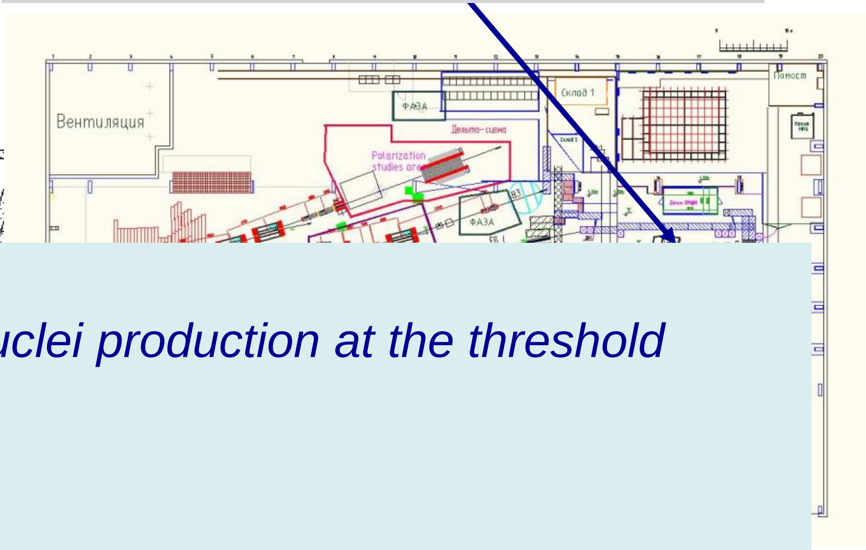
Baryonic Matter at Nuclotron (BM@N)

experiment at Nuclotron extracted beams

BM@N Collaboration:
Russia: *INR, MEPhi, SINP, MSU,*
IHEP, S-Ptr Radium Inst.
Bulgaria: *Plovdiv University;*
China: *Tsinghua University, Beijin;*
Poland: *Warsaw Tech.Uni.*
Israel: *Tel Aviv Uni., Weitzman Inst.*
Germany: *Frankfurt Uni.; eoi GSI*
USA: *MIT*







Physics:

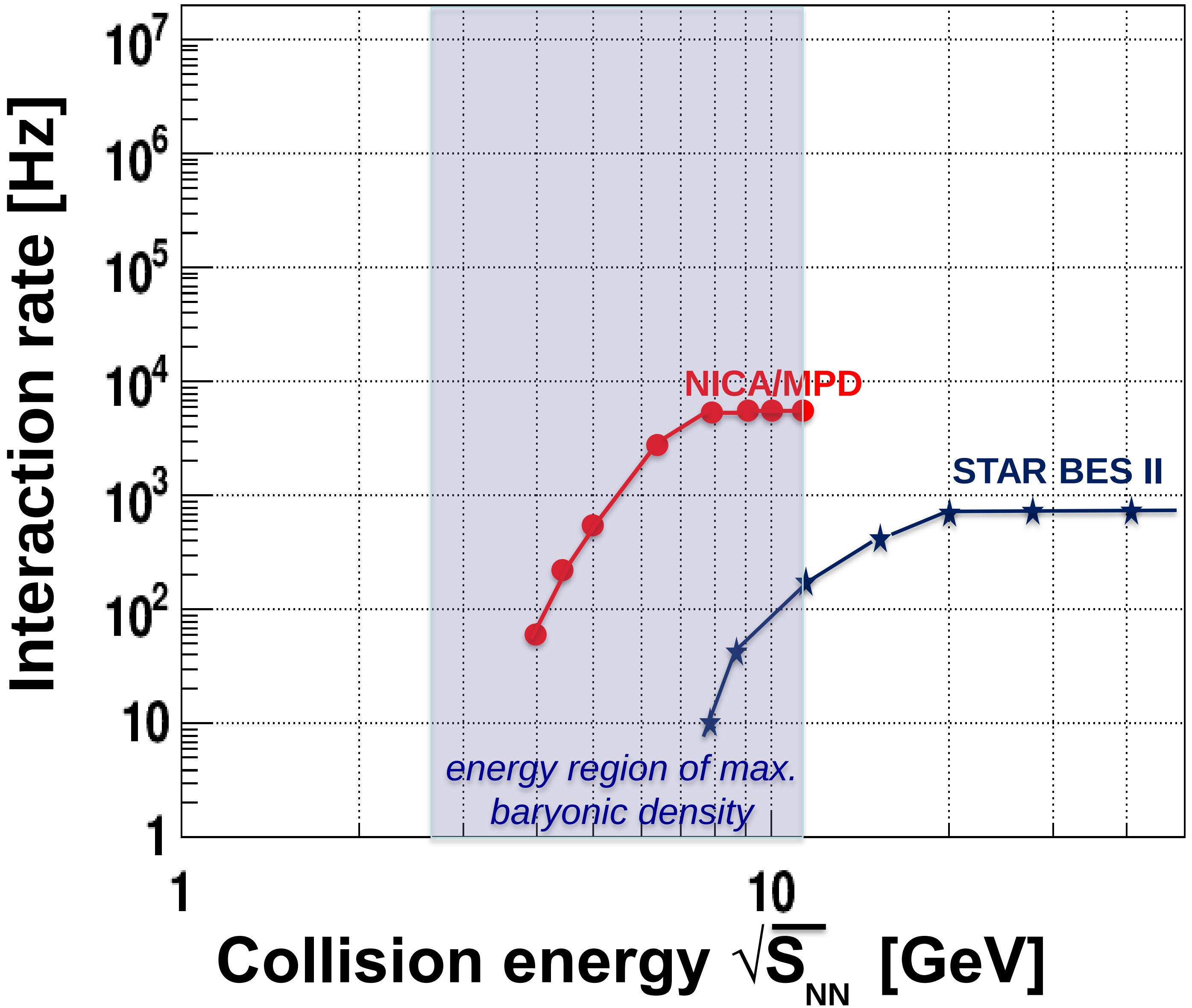
- *strange / multi-strange hyperon and hypernuclei production at the threshold*
- *hadron femtoscopy*
- *short range correlations*
- *event-by event fluctuations*
- *in-medium modifications of strange & vector mesons in dense nuclear matter*
- *electromagnetic probes, states decaying into γ, e (with ECAL)*

BM@N plans

year	2016	2017 Feb.-Mar.	2017 Nov.-Dec.	2019	2020 + ..
beam	**d (↑)**	**C, Ar**	**Kr**	**Au**	**Au, p**
maximum intensity, Hz	**1M**	**1M**	**1M**	**1M**	**10M**
trig. rate, Hz	**10k**	**10k**	**20k**	**20k**	**50k**
central tracker	**6 GEM half pl.**	**8 GEM half pl.**	**10 GEM half pl.**	**8 GEM full pl.**	**12 GEM or 8+2Si**
expiment status	**techn. run**	**techn. run**	**physics run**	**physics stage 1**	**physics stage 2**

beam: E_{kin} = 3.5, 4.0, 4.5 AGeV

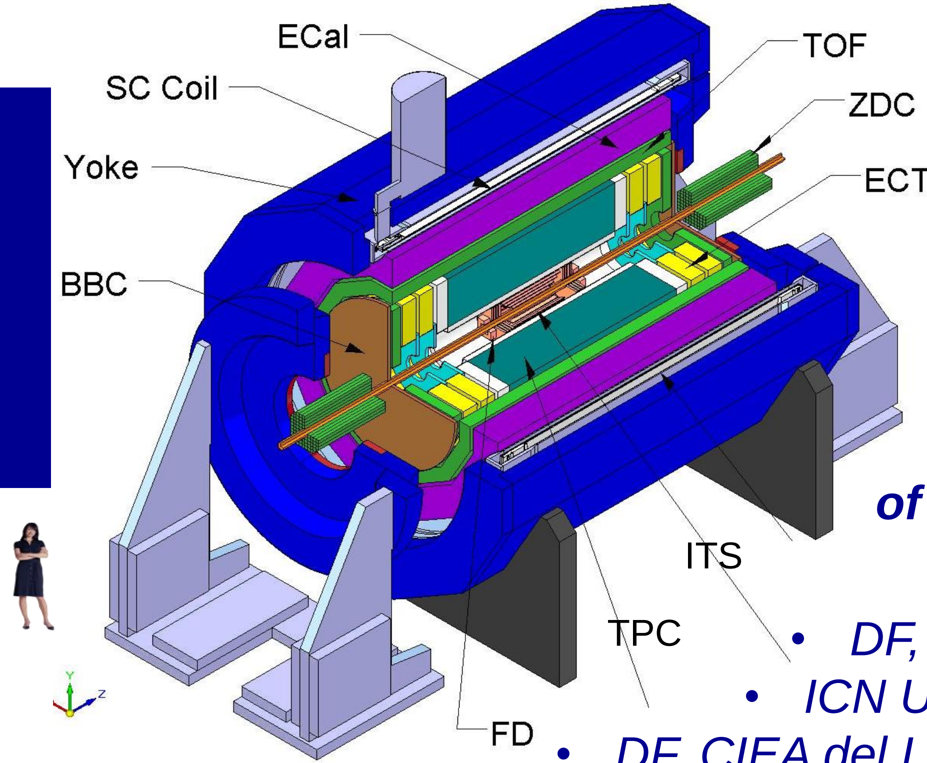
Present and future HI collider experiments



MultiPurpose Detector (MPD)

Main target:

- *study of hot and dense baryonic matter at the energy range of max net baryonic density*



expression of interest by:

- *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.*

MPD Collaboration:

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

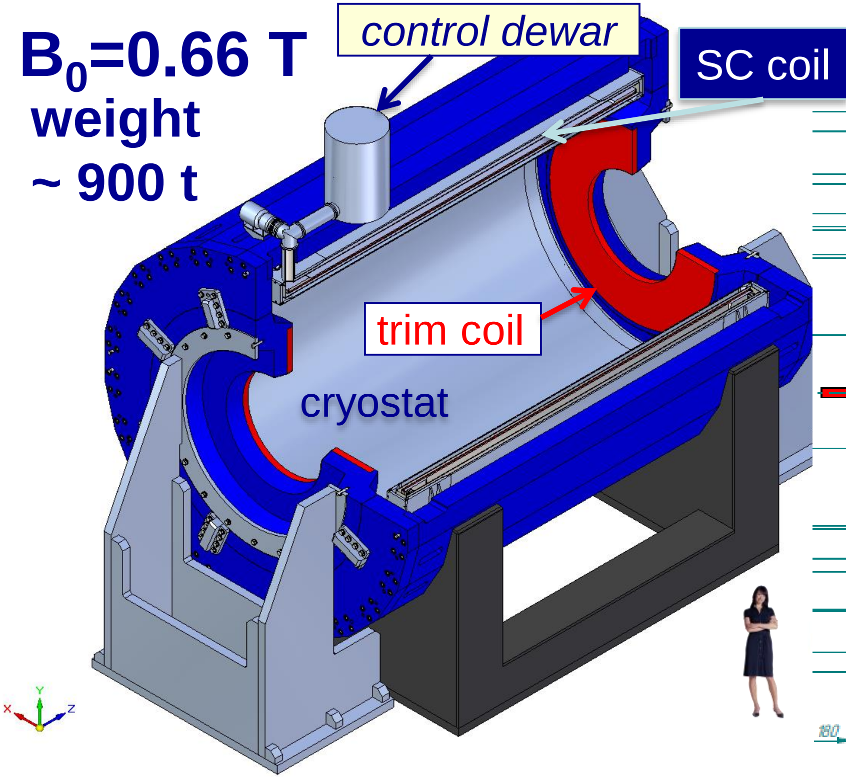
MPD detector for Heavy-Ion Collisions @ NICA

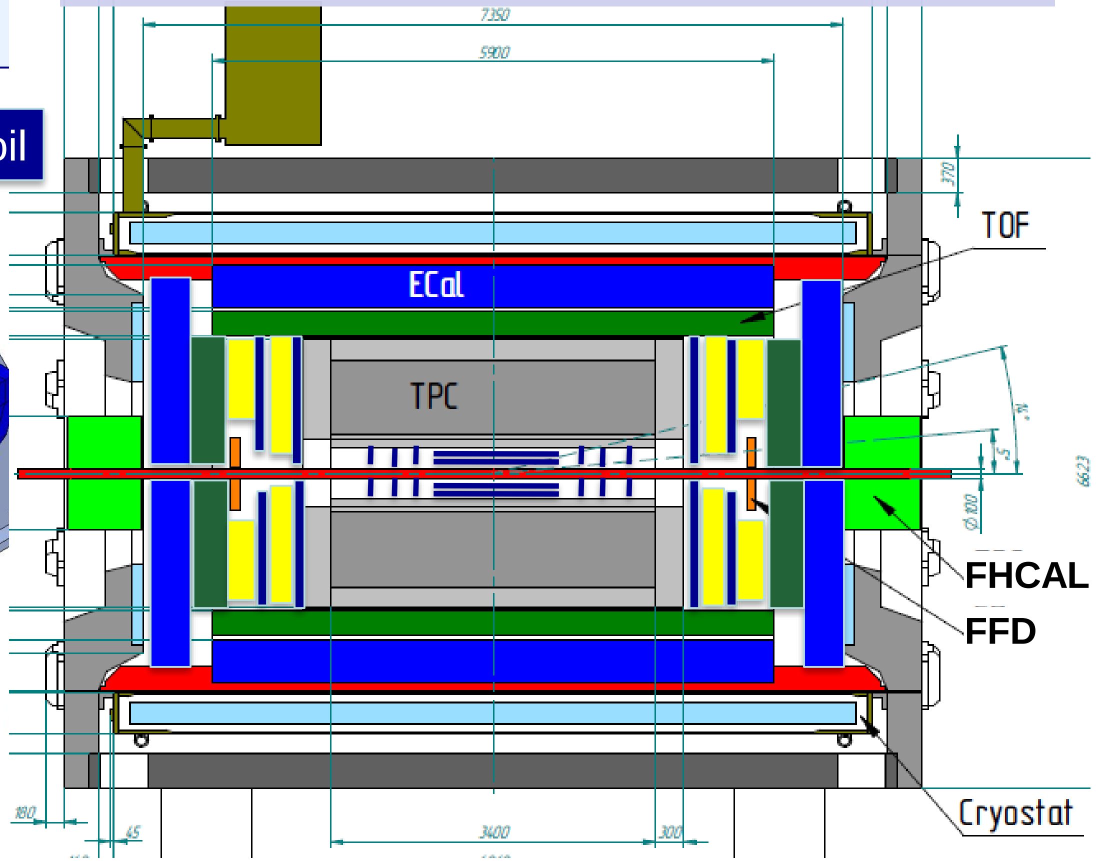
Tracking: up to |η|<1.8 (TPC)
PID: hadrons, e, γ (TOF, TPC, ECAL)
Event characterization:
centrality & event plane (FHCAL)

Stage 1: **TPC, TOF, ECAL, FHCAL, FFD**

Stage 2: **ITs + Endcaps (tracker, TOF, ECAL)**

B_0=0.66 T
weight
~ 900 t

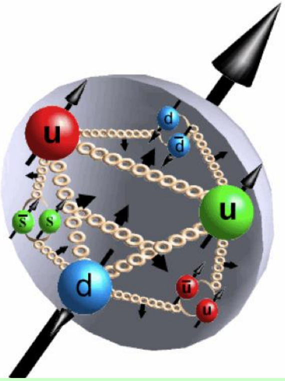




General contractor:
ASG Superconductors,
Genova, Italy

Status: *technical design – completed / close to completion;*
preparation for the mass production

Study of nucleon spin structure



must confirm

the sum rule:

$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g .$$

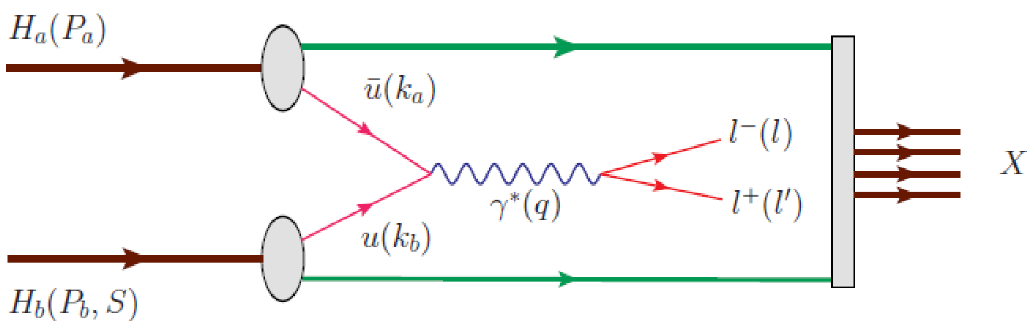
NICA collider will provide collisions of protons and deuterons with all combinations of polarization – *transversal and longitudinal*

*It will allow to measure all **8** intrinsic-transverse-momentum dependent **PDF**s (at leading twist)* ***in one experiment***

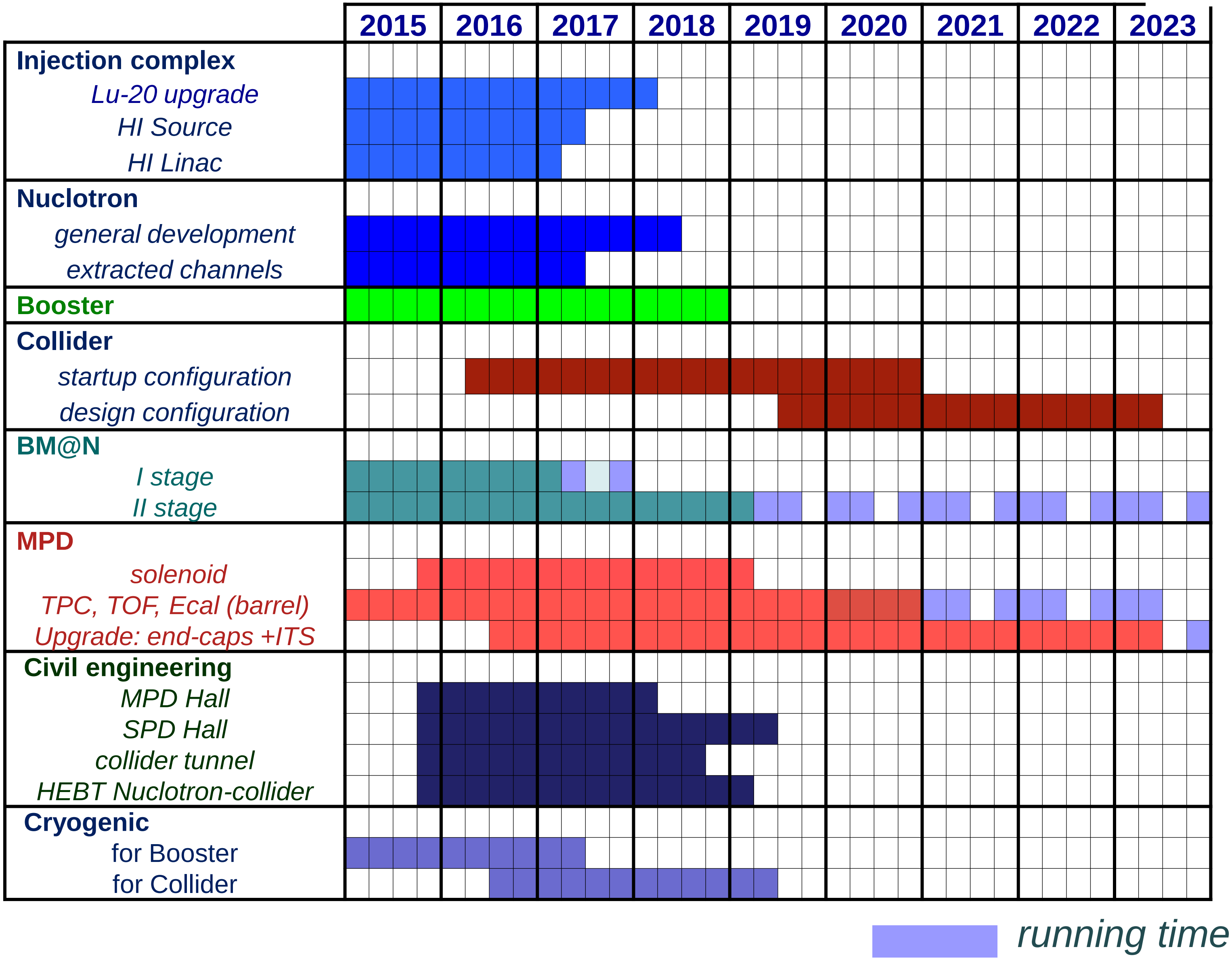
Matveev-Muradyan-Tavkhelidze-Drell-Yan mechanism and **SIDIS** processes **–** *are good tools for these measurements*

Direct photons production

(*gluon polarization***)**



NICA schedule



XXIII International Seminar

Relativistic Nuclear Physics & Quantum Chromodynamics

Dubna, 19 – 24 September, 2016

In the medium-term prospect the NICA complex will be the only facility in Europe providing unique high intensity ion beams (from ***p*** *to* ***Au***, ***p***$\uparrow$ *and* ***d***$\uparrow$*)* ***in the energy range*** *from* ***2 – 27 GeV*** *(c.m.s.), which could be used for both fundamental and applied researches.*

Researches at the NICA complex will contribute to

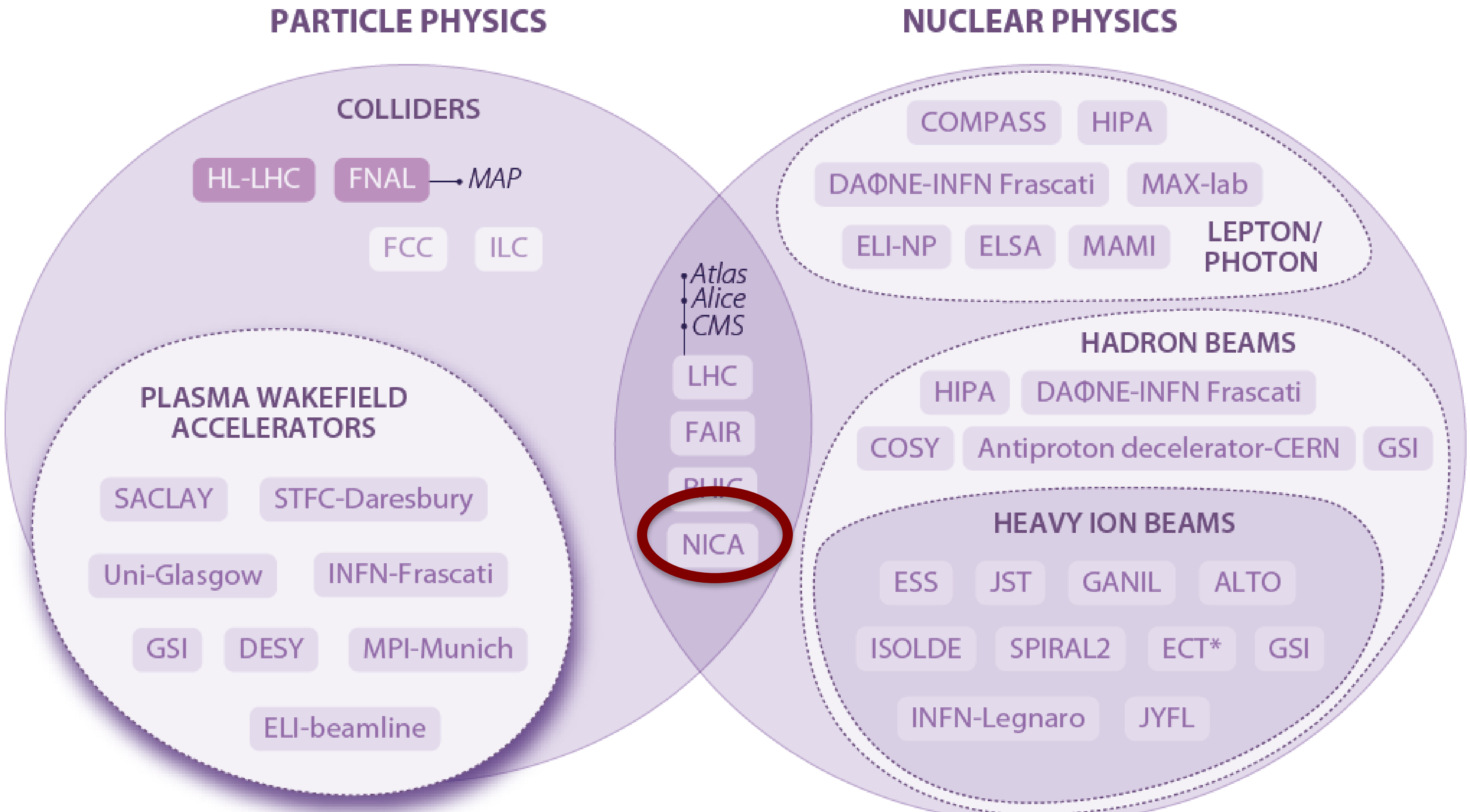
- *discovery and study of new forms of nuclear matter;*
- *comprehensive study of nucleon spin structure;*
- *applied researches, like irradiation of biological objects by heavy ion beams (space mission program) etc.*

ESFRI initiated a hearing of the **NICA** project in **Brussels** on September 7, 2015, in order to consider its inclusion to the **ESFRI Roadmap**

"It is clear that both ***FAIR*** *and* ***NICA*** *could have an advantage in developing and extending explicitely their collaboration…."*

New issue of the ESFRI Roadmap

Main Research Infrastructure in Particle and Nuclear Physics



NICA – Complementary Project

RF Government disposal

Agreement between
the RF Government
and
the Joint Institute for
Nuclear Research

has been signed on June 3-d

ПРАВИТЕЛЬСТВО РОССИЙСКОЙ ФЕДЕРАЦИИ

РАСПОРЯЖЕНИЕ

от 27 апреля 2016 г. № 783-р

МОСКВА

О подписании Соглашения между
Российской Федерации и международной
научно-исследовательской организацией О
ядерных исследований о создании и экс
сверхпроводящих колец на встречных пуч

1. В соответствии с пунктом 1 стать
"О международных договорах Российско
представленный Минобрнауки России соглас
Минфином России, Минэкономразвития
межправительственной научно-исследова
Объединенным институтом ядерных исследо
между Правительством Российской Феде
межправительственной научно-исследова
Объединенным институтом ядерных ис
и эксплуатации комплекса сверхпроводящих
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, не имеющие принципиального характера.

2947103

3. Определить вклад Российской Федерации в создание базовой конфигурации комплекса сверхпроводящих колец на встречных пучках тяжелых ионов NICA до 2020 года в размере 8800 млн. рублей (в ценах 2013 года) за счет средств федерального бюджета.

4. Минобрнауки России выделить в 2016 году 4837,9 млн. рублей
в международную
скую организацию
в целях финансового
х колец на встречных
жетных ассигнований,
едеральным законом
м числе за 2016 год
еме 2340 млн. рублей,

ачиная с формирования
последующие периоды
джетные ассигнования
ов финансирования
ции "Развитие науки и
ния вклада Российской
лекса сверхпроводящих
колец на встречных пучках тяжелых ионов NICA до размера, указанного в пункте 3 настоящего распоряжения.

Председатель Правительства
Российской Федерации Д.Медведев

№1

Concluding remarks

- **NICA complex has a potential for competitive research *in dense baryonic matter and spin physics***
- **The construction of accelerator complex is going well *in close cooperation with BINP***
- **The construction of both detectors BM@N & MPD *is going close to the schedule***
- **Project NICA got a recognition as a part of European research infrastructure**
- **NICA got a status of *mega-project developed at RF***
- **NICA is open for new participants**


Thank you!
© west-crete.com