Heavy Ion Collider Facility NICA at JINR (Dubna): Status and Development.

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for NICA team

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Main goals of the NICA accelerator facility:

- *study of hot and dense baryonic matter*

& nucleon spin structure

- *development of accelerator facility*

for HEP in JINR providing

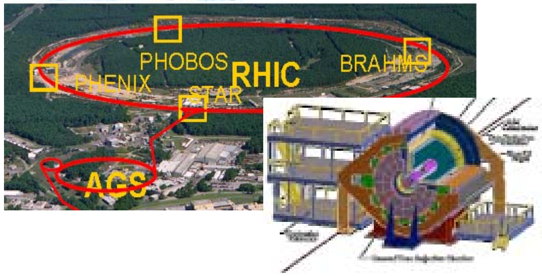
intensive beams of relativistic ions from ***p*** *to* ***Au***

energy range $\sqrt{S_{NN}}$ *= 4..11 GeV (*Au^{79+}*)*

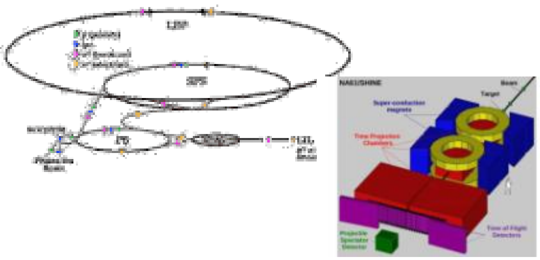
and polarized ***protons*** *and* ***deuterons***

(energy range $\sqrt{S_{NN}}$ *= 4..26 GeV for p)*

2^{nd} generation HI experiments



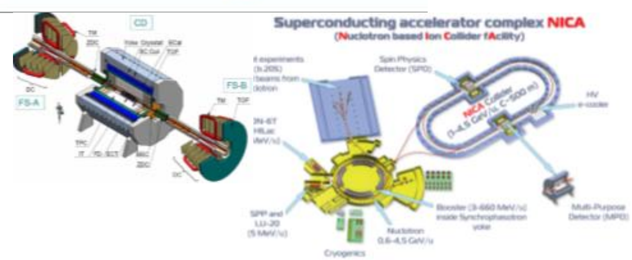
STAR/PHENIX @ BNL/RHIC. Originally designed for higher energies (s_{NN} > 20 GeV), low luminosity for LES program L<10^{26} $cm^{-2}s^{-1}$ for Au^{79+}



NA61 @ CERN/SPS. Fixed target, non-uniform acceptance, few energies (10,20,30,40,80,160A GeV), poor nomenclature of beam species

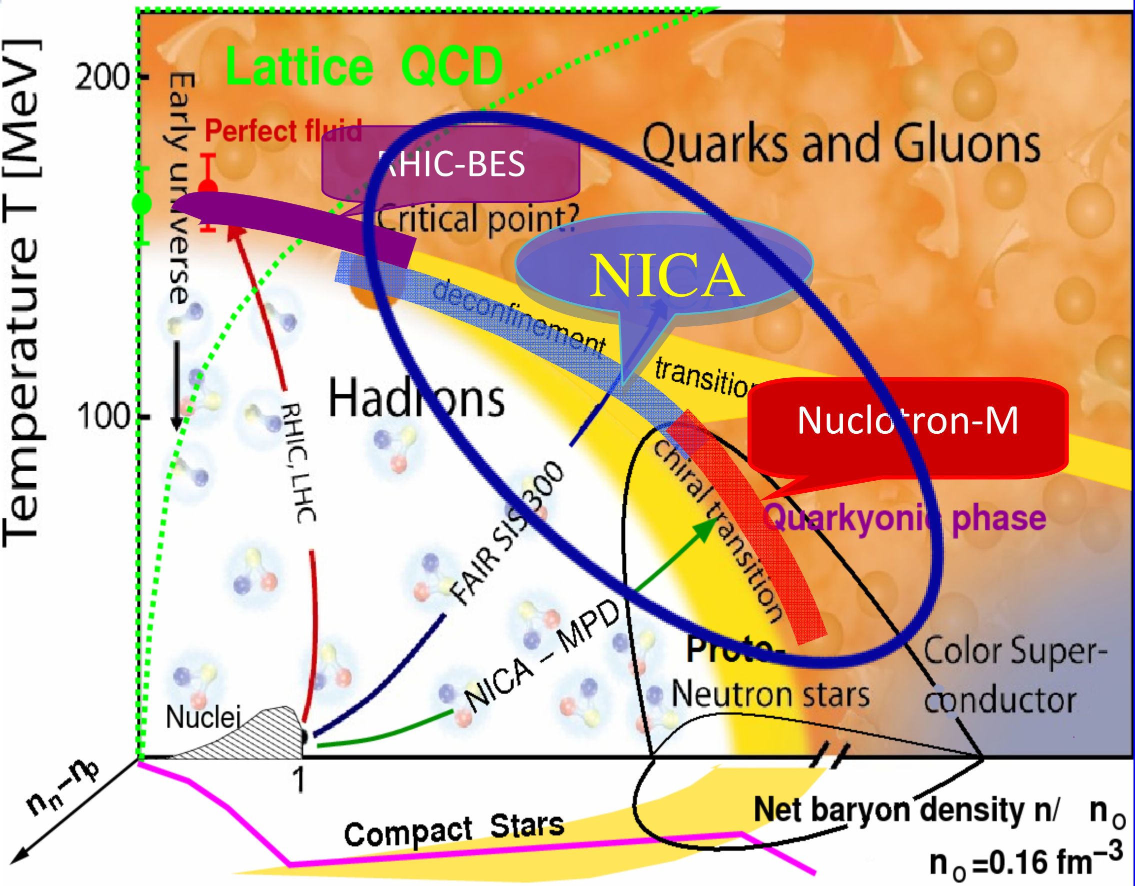
3^{nd} generation HI experiments

CBM @ FAIR/SIS-100/300
Fixed target, E/A=10-40 GeV, high luminosity



MPD & SPD @ JINR/NICA. Collider, small enough energy steps in the range s_{NN} = 4-11 GeV,
a variety of colliding systems, L~10^{27} $cm^{-2}s^{-1}$ for Au^{79+}

QCD phase diagram - Prospects for NICA



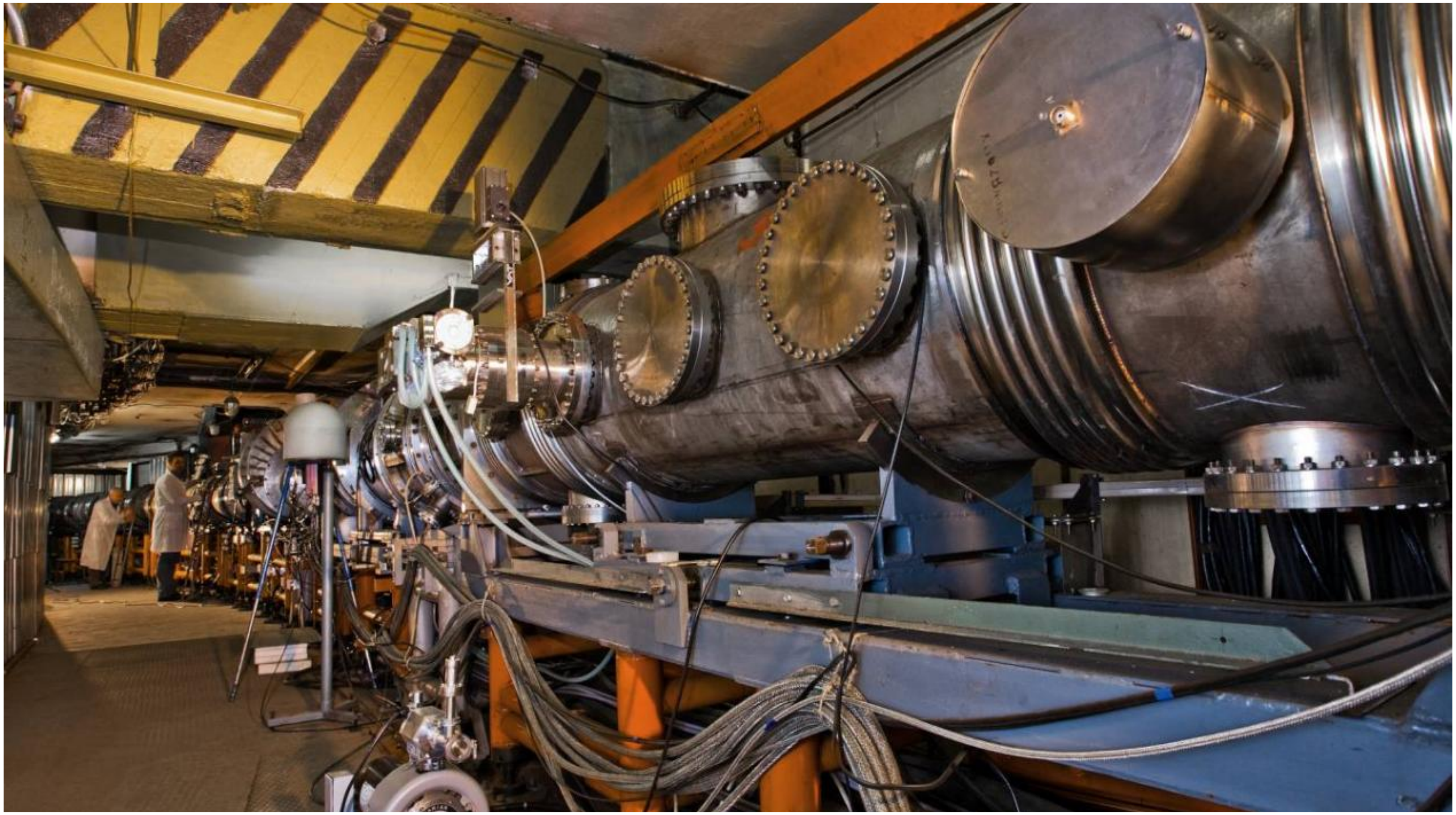
Energy Range of NICA
unexplored region of
the QCD phase diagram:

- 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/BES, FAIR, CERN & Nuclotron-M experimental programs

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

Synchrophasotron (1957-2002)→ Nuclotron (1993)

– superconducting accelerator for ions and polarized particle
– physics of ultrarelativistic heavy ions, high energy spin physics

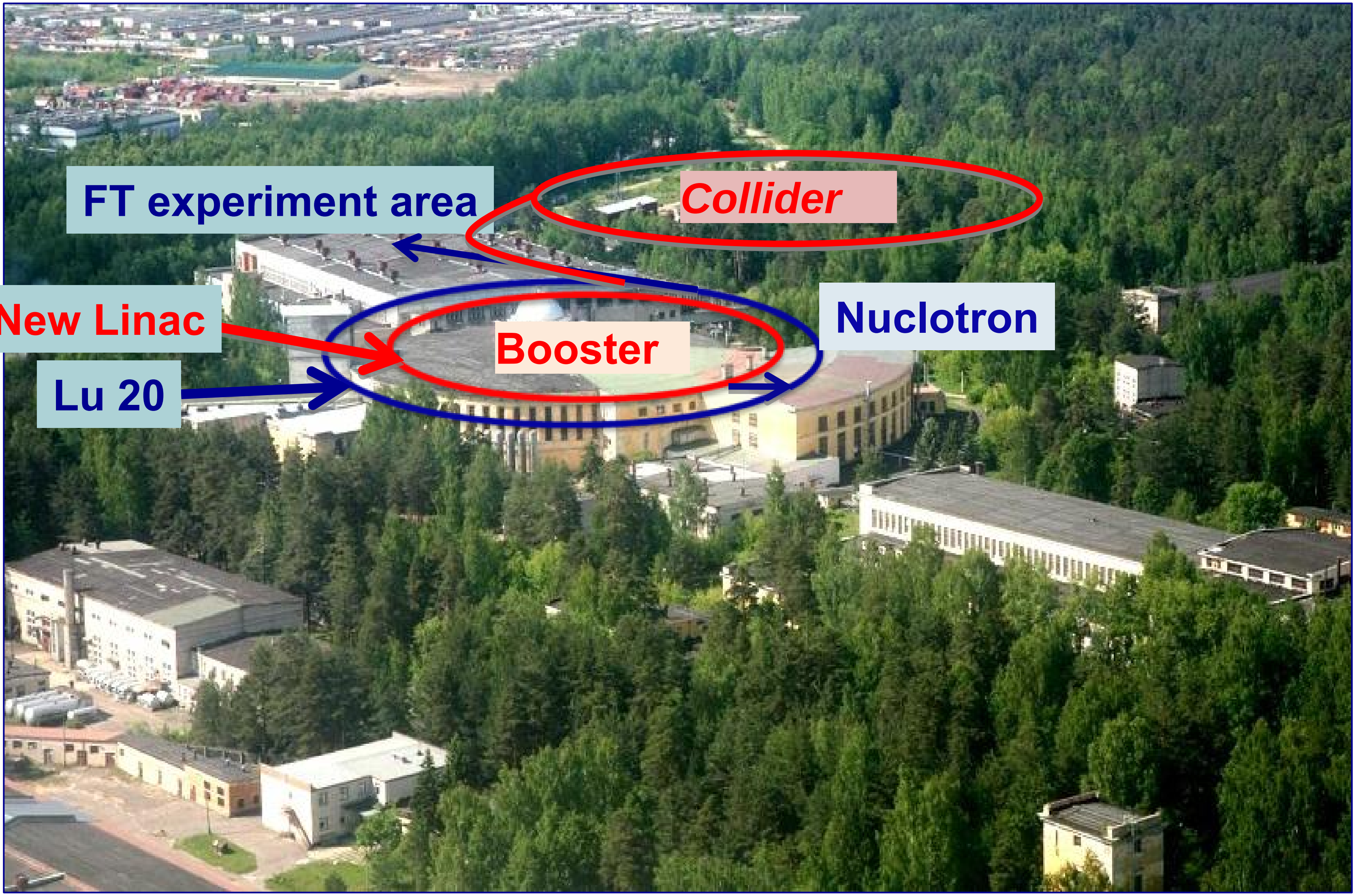


Nuclotron provides now performance of experiments with accelerated proton and ion beams (up to *Xe42+, A=124*) with energies up to 6 AGeV (Z/A = 1/2)

A.Sidorin's talk on Wednesday

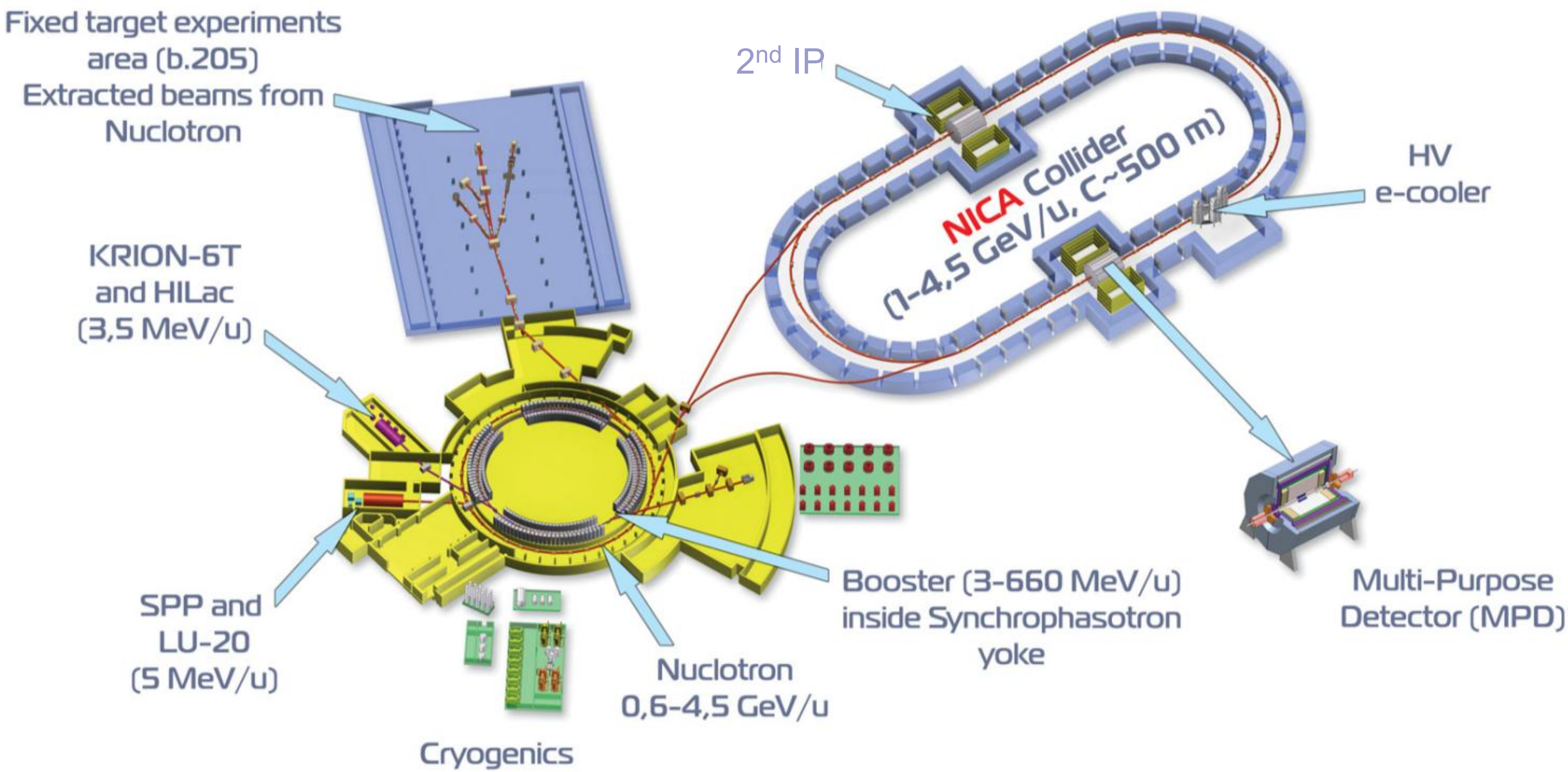
Beam	Nuclotron beam intensity (particle per cycle)		
	Current	Ion source type	New ion source + Booster
p	$3 \cdot 10^{10}$	Duoplasmotron	$5 \cdot 10^{12}$
d	$5 \cdot 10^{10}$	--- ,, ---	$5 \cdot 10^{12}$
^{4}He	$8 \cdot 10^{8}$	--- ,, ---	$1 \cdot 10^{12}$
d↑	$2 \cdot 10^{8}$	SPI	$1 \cdot 10^{10}$
^{7}Li	$8 \cdot 10^{8}$	Laser	$5 \cdot 10^{11}$
^{11,10}B	$1 \cdot 10^{9,8}$	--- ,, ---	
^{12}C	$5 \cdot 10^{9}$	--- ,, ---	$2 \cdot 10^{11}$
^{24}Mg	$2 \cdot 10^{7}$	--- ,, ---	
^{14}N	$1 \cdot 10^{7}$	ESIS ("Krion-6T")	$5 \cdot 10^{10}$
^{24}Ar	$1 \cdot 10^{9}$	--- ,, ---	$2 \cdot 10^{11}$
^{56}Fe	$2 \cdot 10^{6}$	--- ,, ---	$5 \cdot 10^{10}$
^{84}Kr	$1 \cdot 10^{4}$	--- ,, ---	$1 \cdot 10^{9}$
^{124}Xe	$1 \cdot 10^{4}$	--- ,, ---	$1 \cdot 10^{9}$
^{197}Au	-	--- ,, ---	$1 \cdot 10^{9}$

Complex NICA @ JINR (VBLHEP)



Superconducting accelerator complex NICA

(Nuclotron based Ion Collider fAcility)



NICA goals

1a) Heavy ion colliding beams 197Au79+ x 197Au79+ at

$\sqrt{s_{NN}}$ = 4 ÷ 11 GeV (1 ÷ 4.5 GeV/u ion kinetic energy)

at $L_{average}$= $1\text{x}10^{27}$ $cm^{-2}\cdot s^{-1}$ (at $\sqrt{s_{NN}}$ = 9 GeV)

1b) Light-Heavy ion colliding beams of the same energy range and L

2) Polarized beams of protons and deuterons in collider mode:

p↑p↑ $\sqrt{s_{pp}}$ = 12 ÷ 27 GeV (5 ÷ 12.6 GeV kinetic energy)

d↑d↑ $\sqrt{s_{NN}}$ = 4 ÷ 13.8 GeV (2 ÷ 5.9 GeV/u ion kinetic energy)

$L_{average} \geq 1\text{x}10^{30}$ $cm^{-2}\cdot s^{-1}$ (at $\sqrt{s_{pp}}$ = 27 GeV)

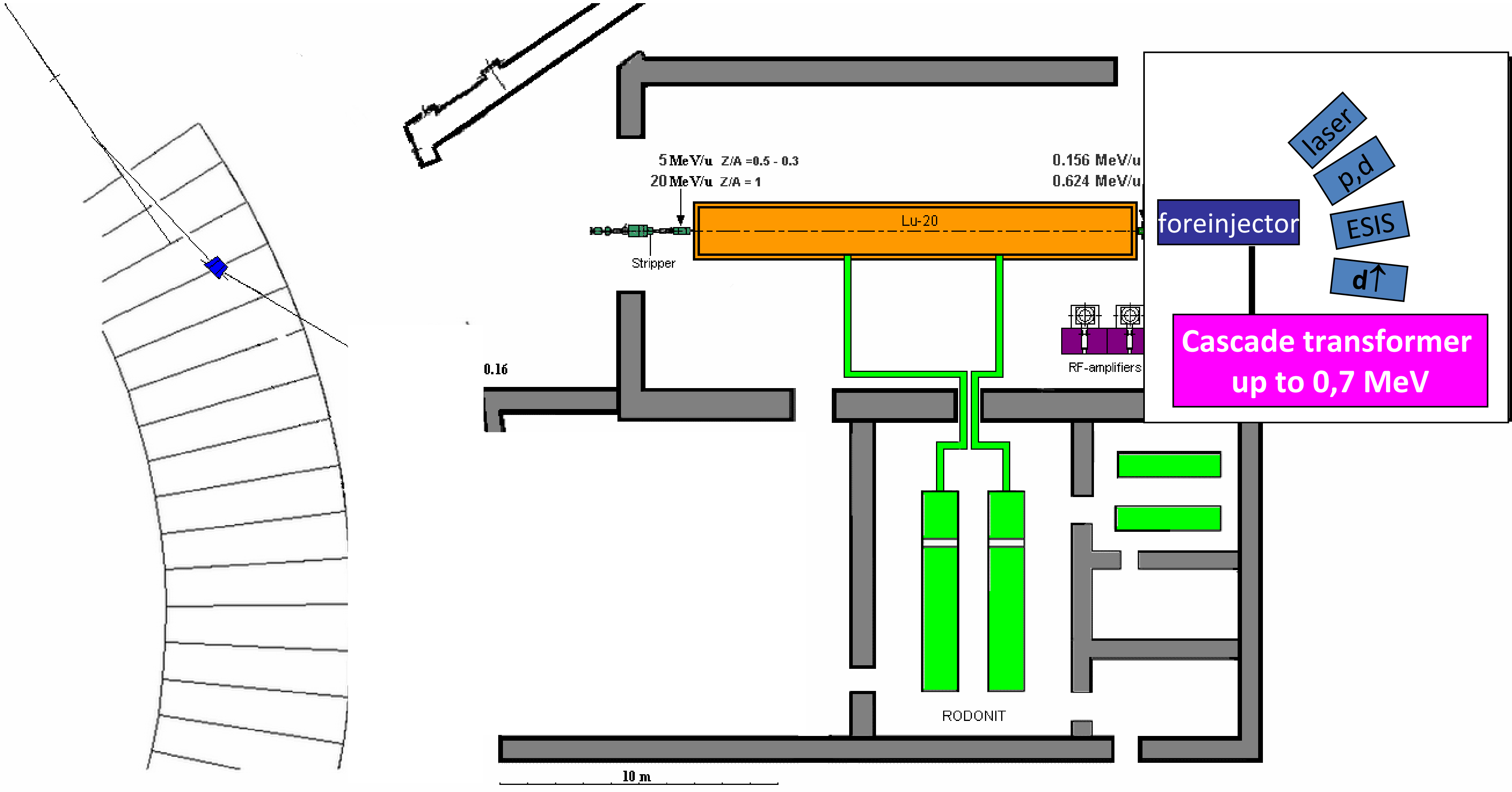
3) The beams of light ions and polarized protons and deuterons for fixed target experiments:

Li ÷ Au = 1 ÷ 4.5 GeV /u ion kinetic energy
p, p↑ = 5 ÷ 12.6 GeV kinetic energy
d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

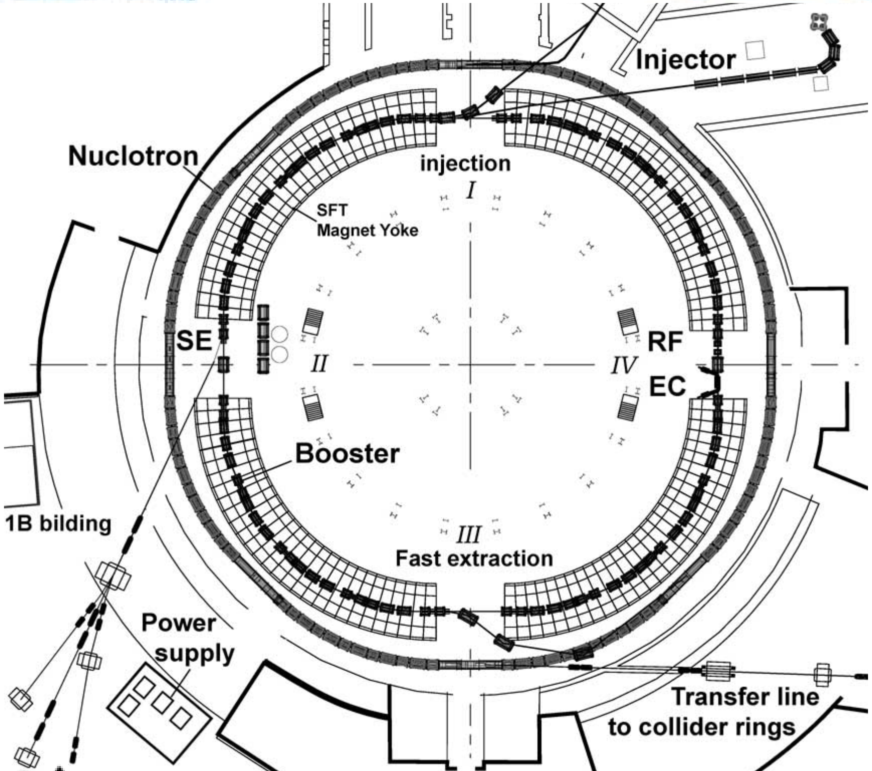
4) Applied research on ion beams at kinetic energy

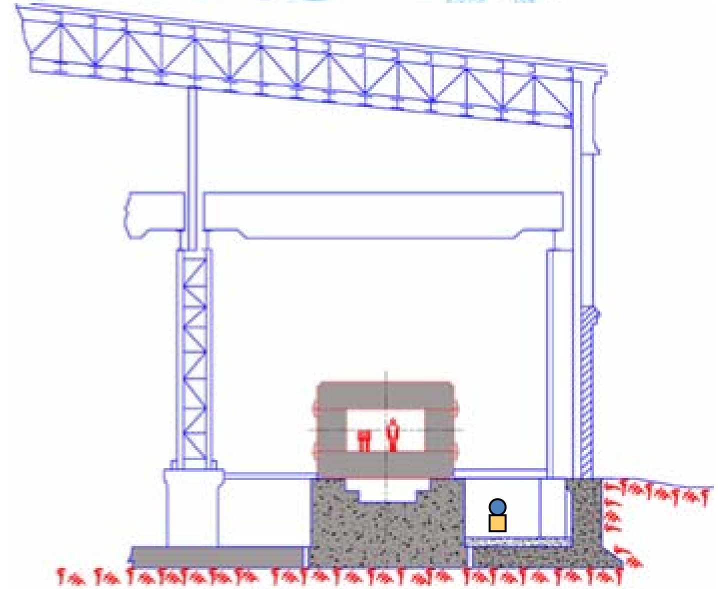
from 0.5 GeV/u up to 12.6 GeV (p) and 4.5 GeV /u (Au)

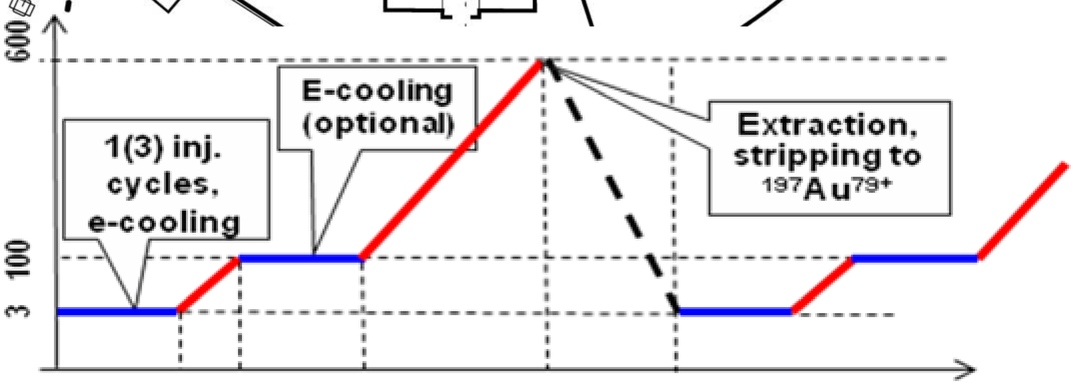
NICA injector chain

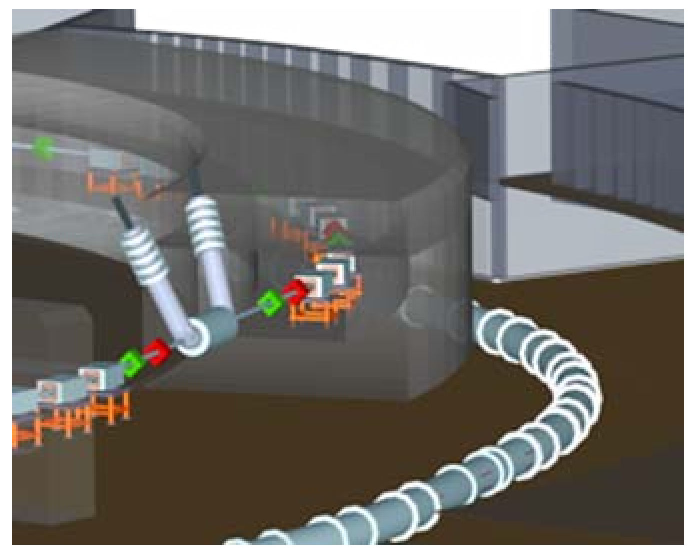


Booster Synchrotron, C = 211 m

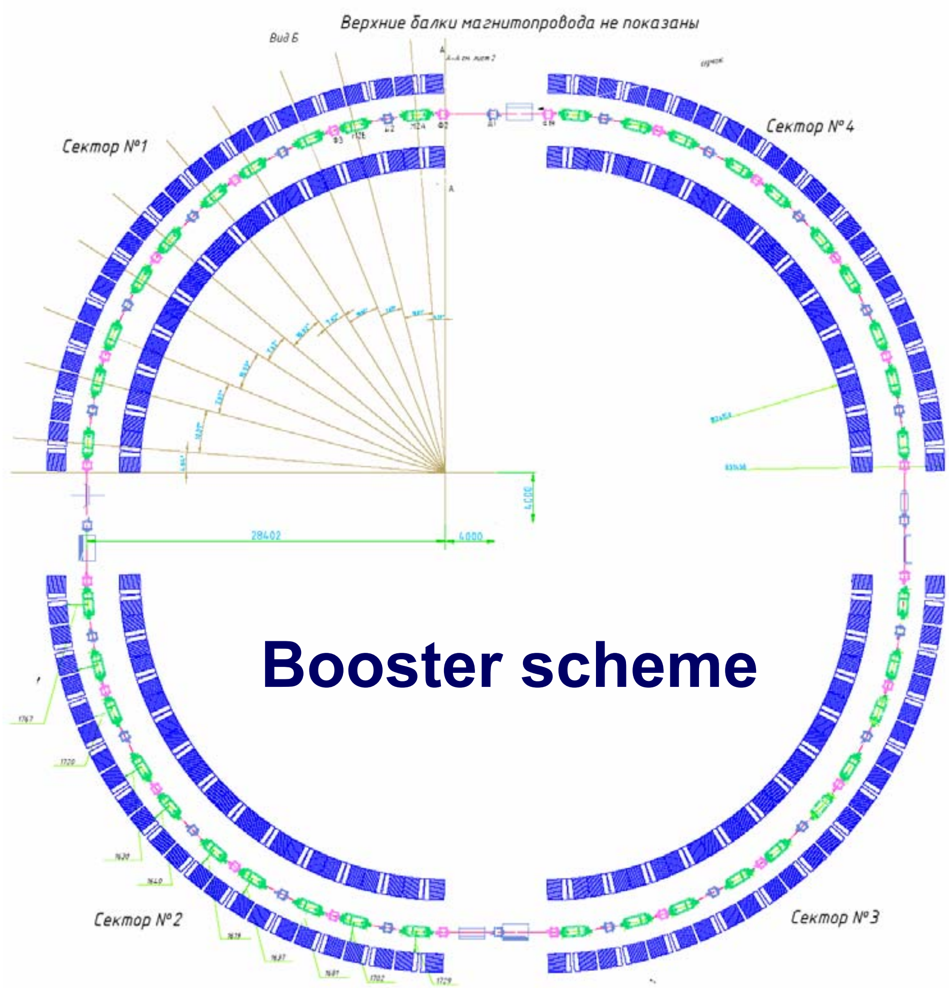








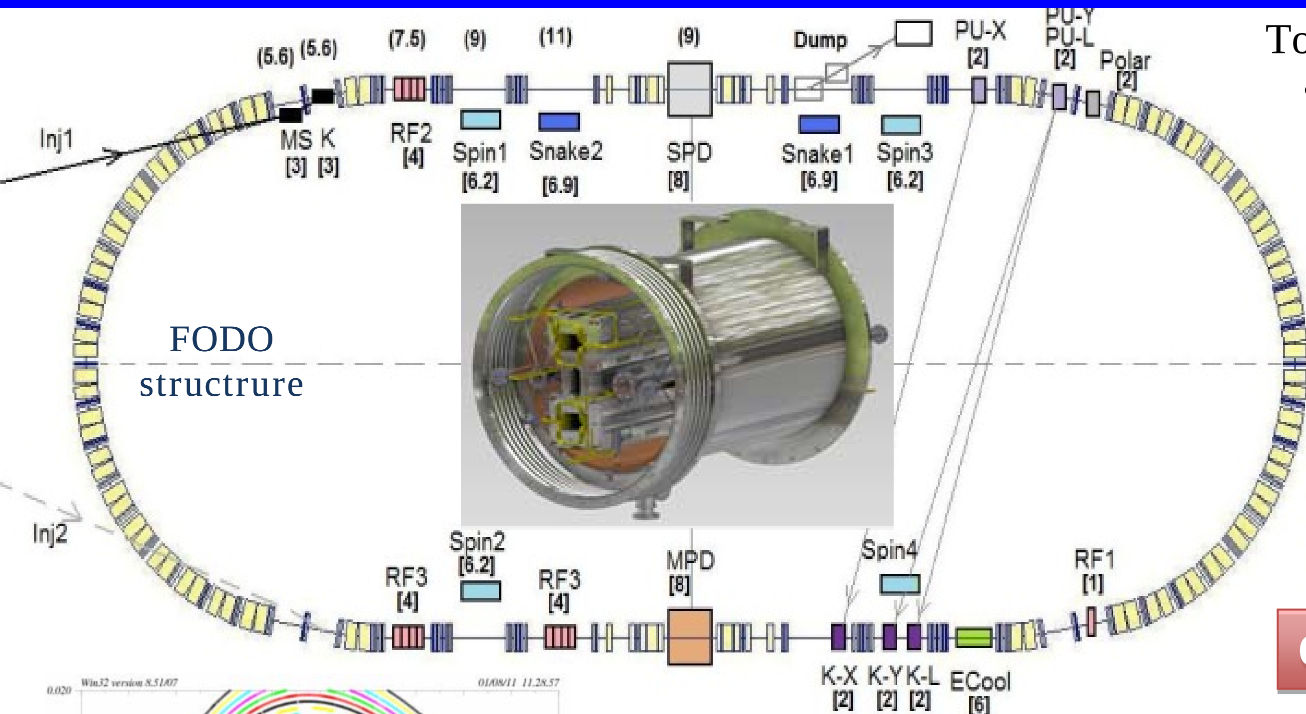
SC Booster-Synchrotron



Booster Parameters

Particles	ions A/Z≤3
Injection energy, MeV/u	3
Maximum energy, GeV/u	0.6
Magnetic rigidity, T·m	1.55 ÷ 25.0
Circumference, m	211.2
Fold symmetry	4
Quadrupole periodicity	24
Betatron tune	5.8/5.85

Unique Low Energy (1 - 4.5 GeV/u) Collider of Extremely High Luminosity L=1e27



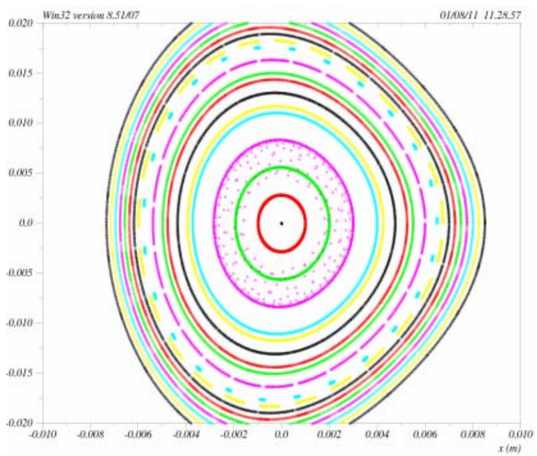
To reach maximum peak luminosity:

- minimum beta function in the IP;
- maximum bunch number;
- maximum bunch intensity;
- minimum beam emittance;
- minimum bunch length.

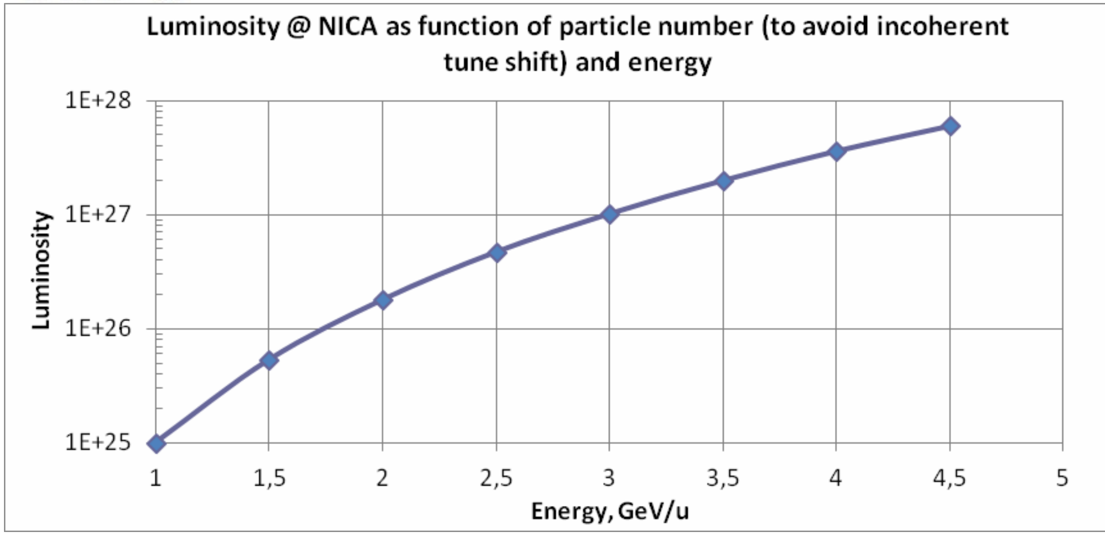
Circumference 503 m

Twin SC magnets

O.Kozlov's poster on Tuesday



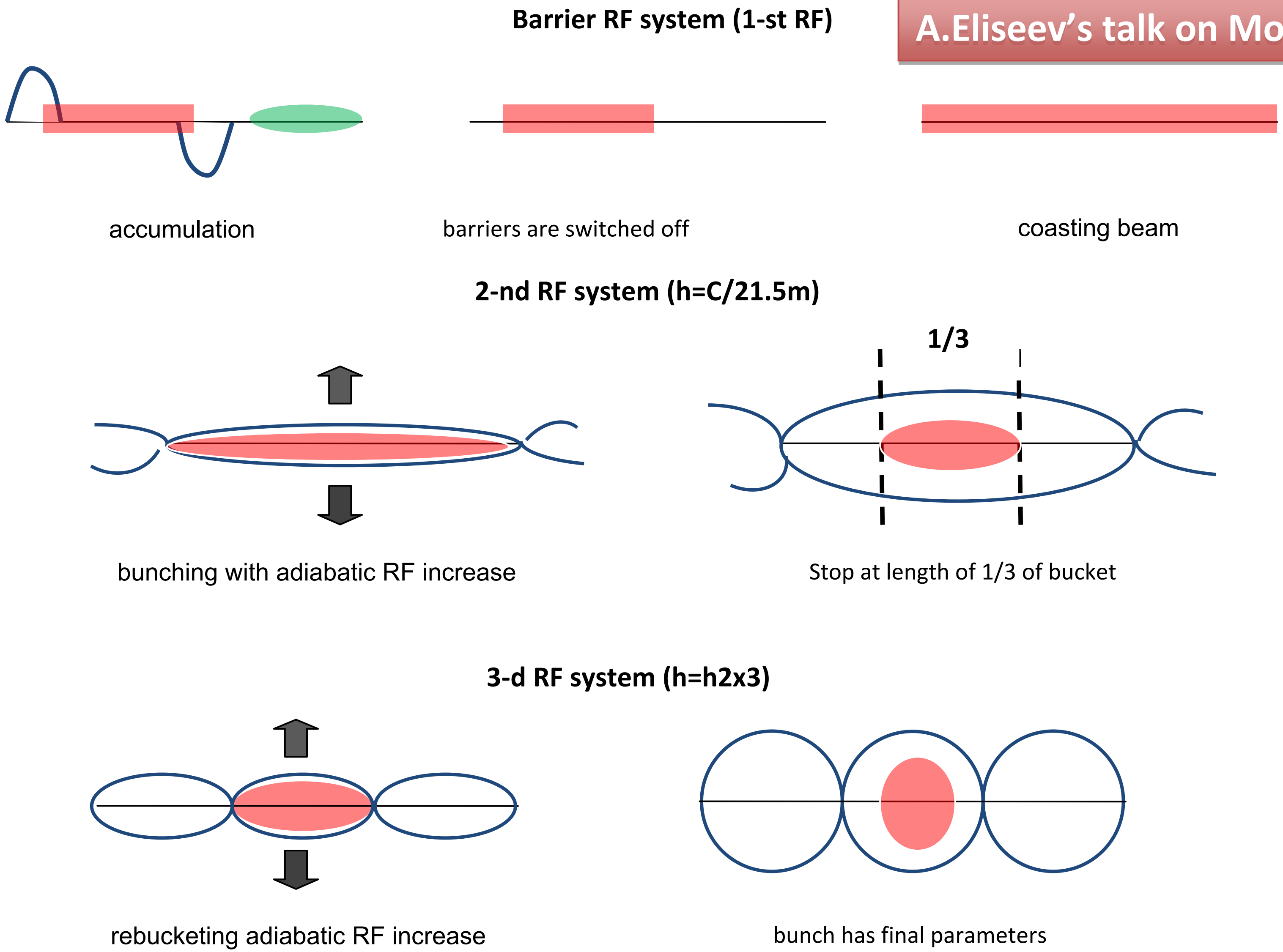
The collider dynamic aperture in the horizontal phase space.



Proposed Scheme of Ion Stacking and Bunch Formation in The Collider

A.Eliseev's talk on Monday

All stages are provided with cooling



Facility Structure and Operation Regimes

Two regimes and cooling methods

1. Ion acceleration in Linac – Booster – Nuclotron up to experiment energy $1 \le E_{ion} \le 4.5$ GeV/u, injection and storage in Collider at experiment energy;
2. Ion acceleration in Linac – Booster – Nuclotron up to "certain" energy, injection and storage in Collider, then acceleration in Collider up to the experiment energy.

Storage $\Rightarrow$ with Barrier Bucket method + Electron cooling (E_{kin}< 2.5GeV/u) or Stochastic cooling (E_{kin} > 2.5 GeV/u)

Acceleration in the collider:

if necessary – with Barrier Buckets RF system

Role of Beam Cooling
Beam Stacking with BB System and Cooling

1. Beam stacking using BB system: Injection repetition is 10s, the cooling times has to be short enough
2. Longitudinal cooling during beam bunching
3. During experiment:
- in IBS dominated mode - Suppression of IBS;
- in SC dominated mode – providing optimum phase volume

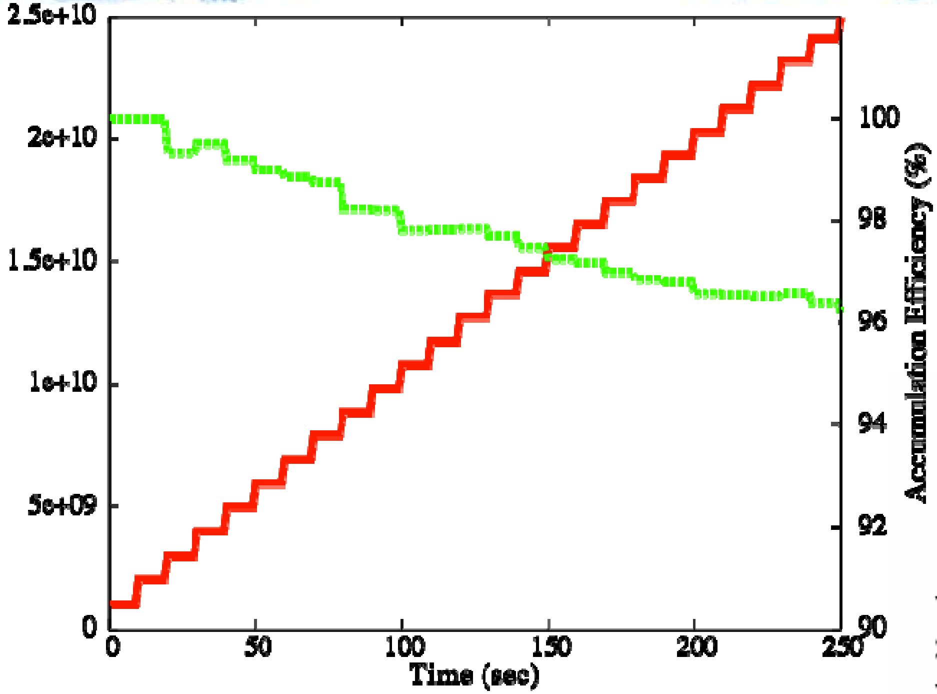
E > 2.5 GeV/u: stacking with Stochastic cooling

The cooling time is proportional to the bunching factor for "almost" coasting beam in BB the cooling times ~ 10 sec

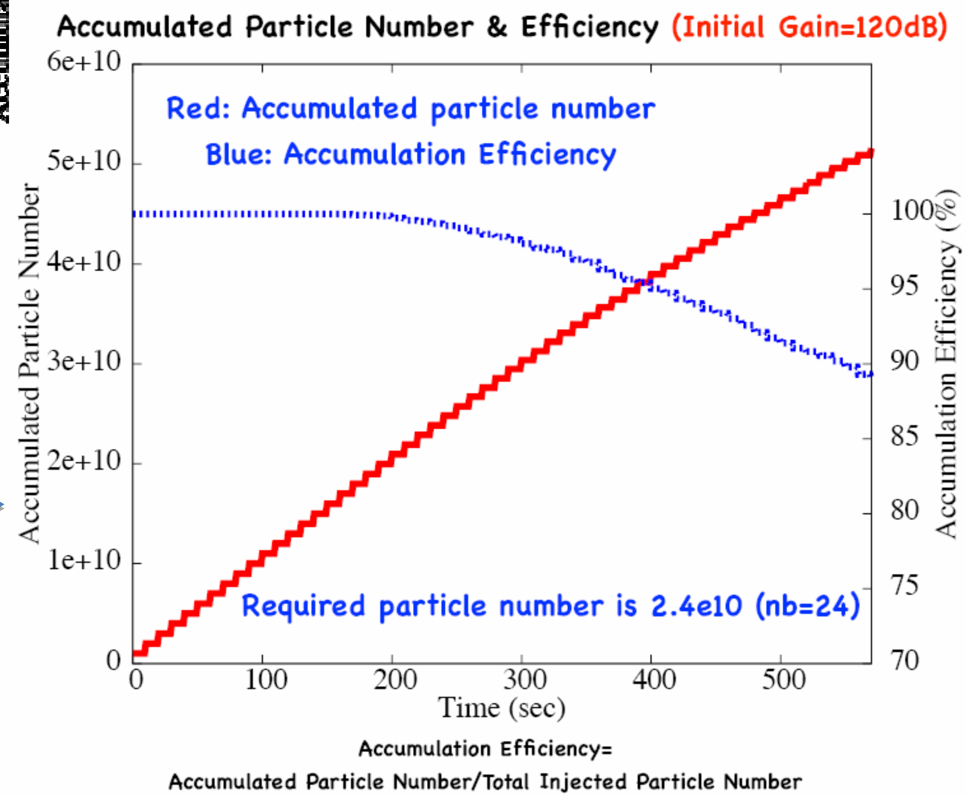
E < 2.5 GeV/u: Stacking with Electron cooling

Problem – cooling time strongly depends on energy and does not depend on bunching factor. The cooling power sufficient for experiment can be insufficient for effective stacking

Simulations by T.Katayama (GSI), Talk on Tuesday



Beam stacking with electron cooling @1.5 GeV/u



Beam stacking with stochastic cooling @3.5 GeV/u

Beam Cooling at Experiment

Two modes of the collider operation

IBS dominated mode	Space charge dominated mode
Cooling time is comparable with IBS times	Cooling time is sufficiently shorter IBS times
Emittance and momentum spread are related to each other in accordance with "equi-partitioning": $\tau_{IBS,long} = \tau_{IBS,h} = \tau_{IBS,v}$ In opposite case – fast bunch relaxation	Emittance and momentum spread are optimized independently, The bunch relaxation is suppressed by cooling
At the large energy, where required luminosity can be obtained at small tune shift	At small energy, where luminosity is limited by space charge effects

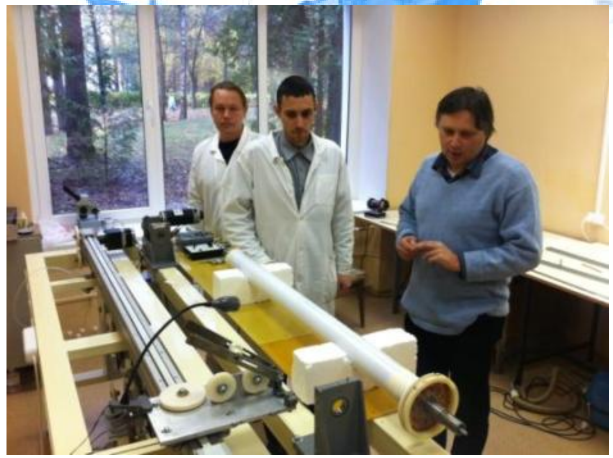
Ring circumference, m	503,04		
Number of bunches	24		
Rms bunch length, m	0.6		
Beta-function in the IP, m	0.35		
Ring acceptance (FF lenses)	40 π·mm·mrad		
Long. acceptance, $\Delta p/p$	±0.010		
Gamma-transition, γ_{tr}	7.091		
Ion energy, GeV/u	1.0	3.0	4.5
Ion number per bunch	$2.75 \cdot 10^8$	$2.4 \cdot 10^9$	$2.2 \cdot 10^9$
Rms momentum spread, 10^{-3}	0.62	1.25	1.65
Rms beam emittance, h/v, (unnormalized), π·mm·mrad	1.1/ 1.01	1.1/ 0.89	1.1/ 0.76
Luminosity, $cm^{-2}s^{-1}$	1.1e25	1e27	1e27

SC dominated

IBS dominated

($\Delta Q < 0.05$)

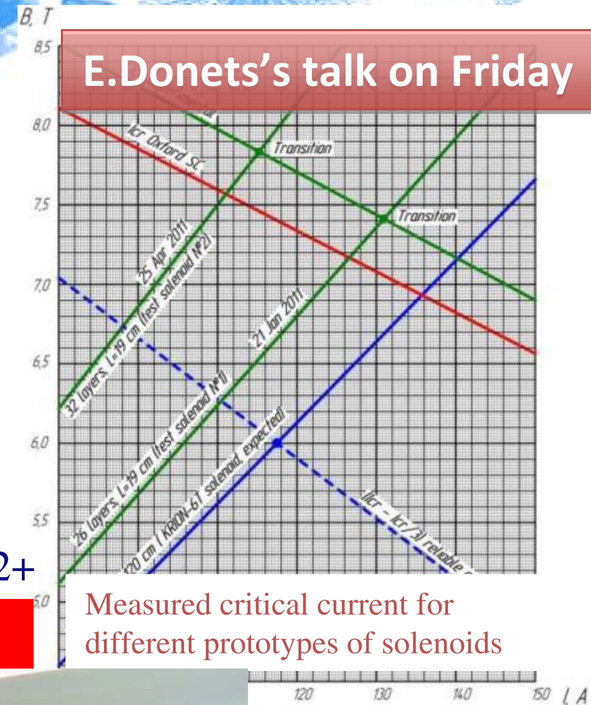
Unique SC Heavy Ion Source KRION with 3T and 6T SC solenoid



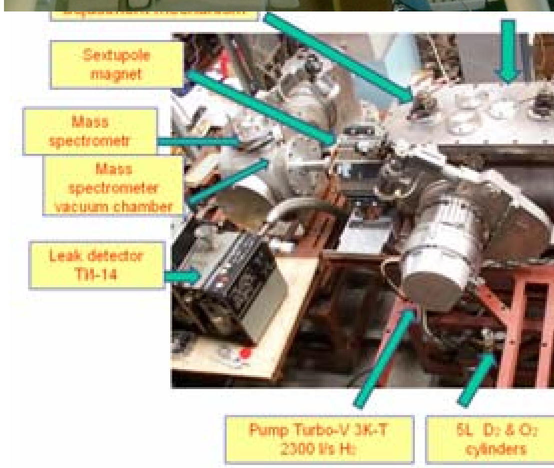
Highly charge ion state for heavy ions
th high intensity, f.e.: Kr 28+, Xe 44+, Au 52+

echnologies + unique accelerator physics

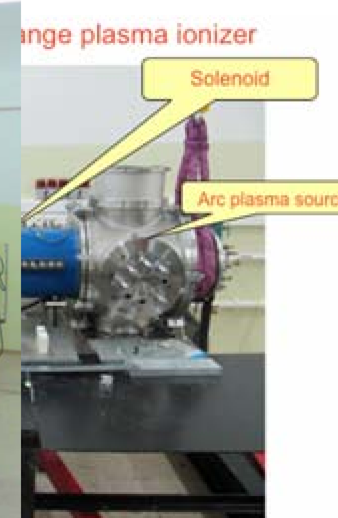
E.Donets’s talk on Friday



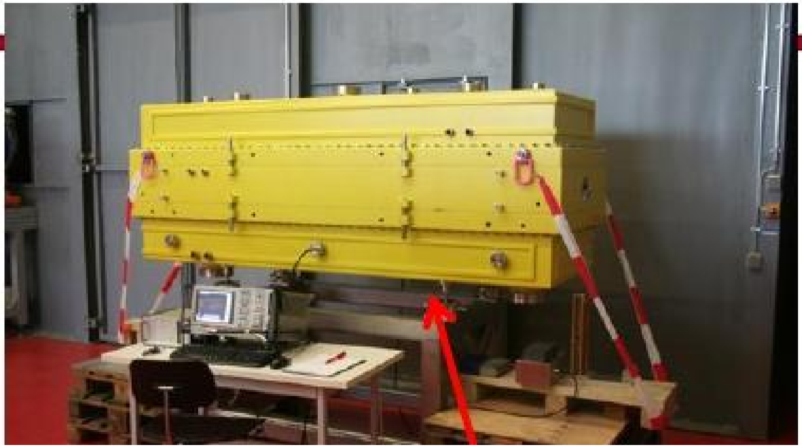
Measured critical current for different prototypes of solenoids



Atomic Beam Source setup gen



ELECTRON BEAM ION SOURCE



Heavy Ion Linac (HILac) 3MeV/u

Design and fabrication under contract with “BEVATECH OHG”

Germany, Offenbach/Main

(IAP, Frankfurt University)

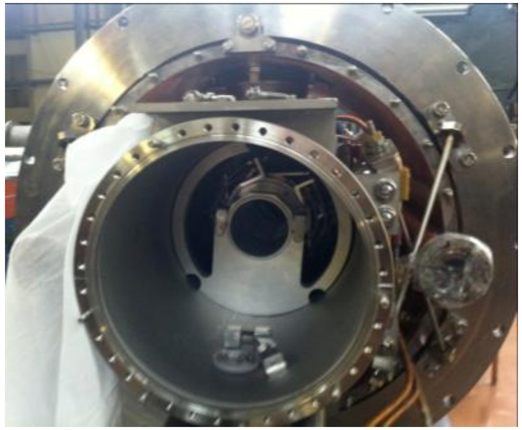
to be delivered at JINR September 2013.

BROOKHAVEN NATIONAL LABORATORY

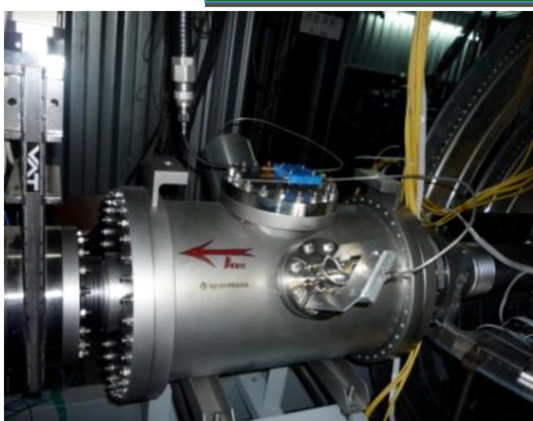
NICA

Stochastic cooling system installed at Nuclotron – prototype for Collider: W = 2-4 GHz, P = 60 W. (collaboration JINR - IKP FZJ - CERN)

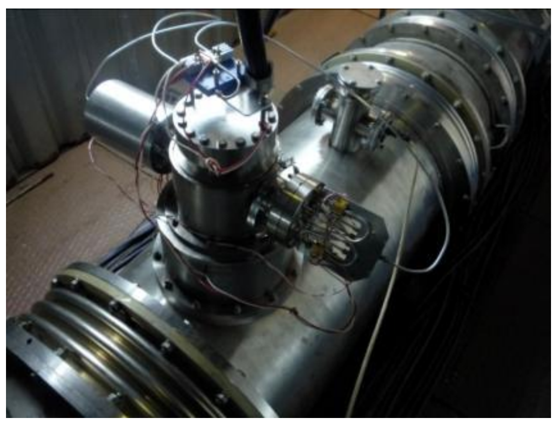
Poster N.Shurkhno, Tuesday



Slot-coupler RF structure (by IKP FZJ)

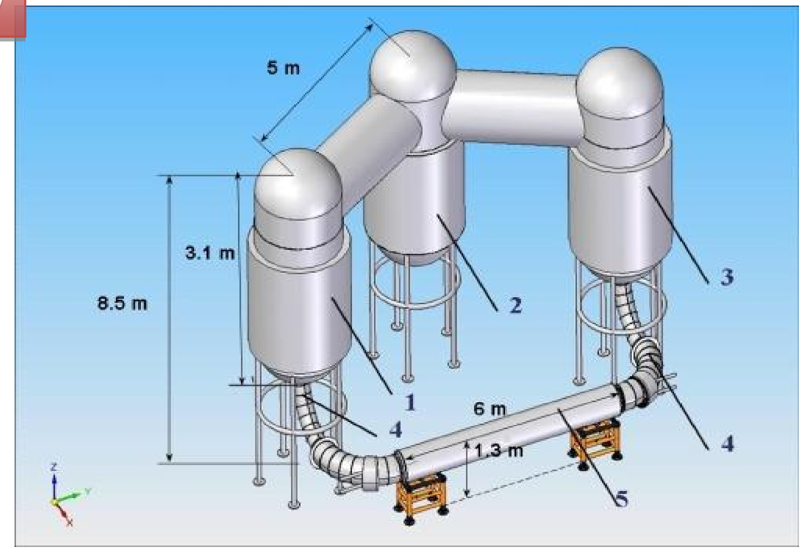


Kicker station



Pick-Up station

HV Electron cooling system design and prototyping: Collaboration JINR – AREI - BINP

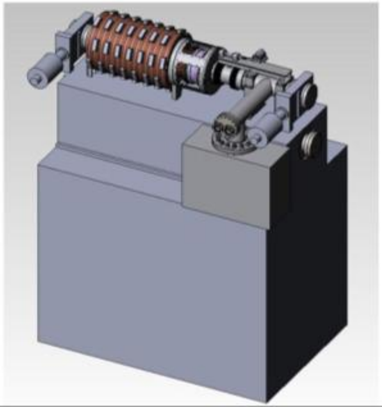


HV Generator prototype U=250 kV, I=1mA

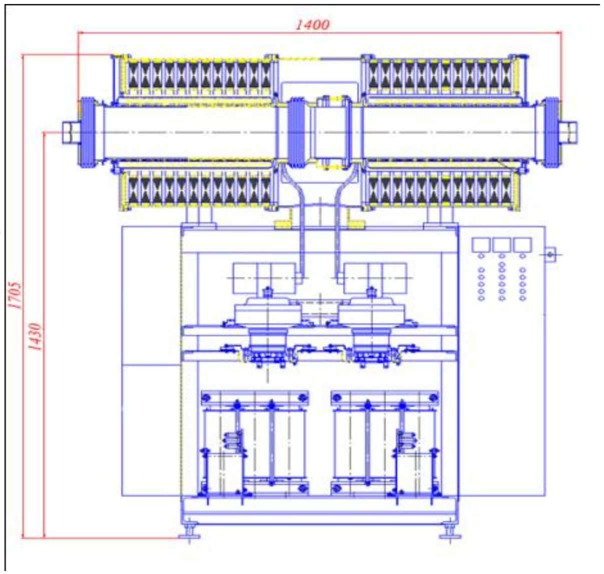
S.Yakovenko's talk on Tuesday

RF stations for booster – manufacturing is under completion (BINP)

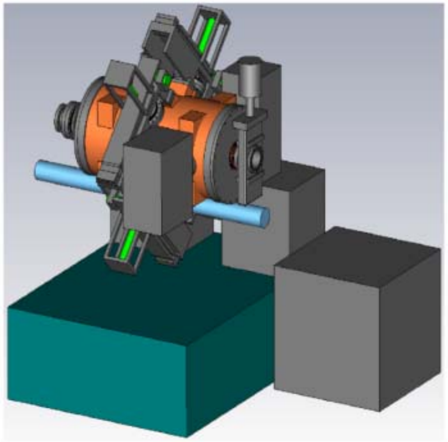
RF stations for collider – under conceptual design (BINP)



Barrier Bucket cavity (preliminary design, BINP)



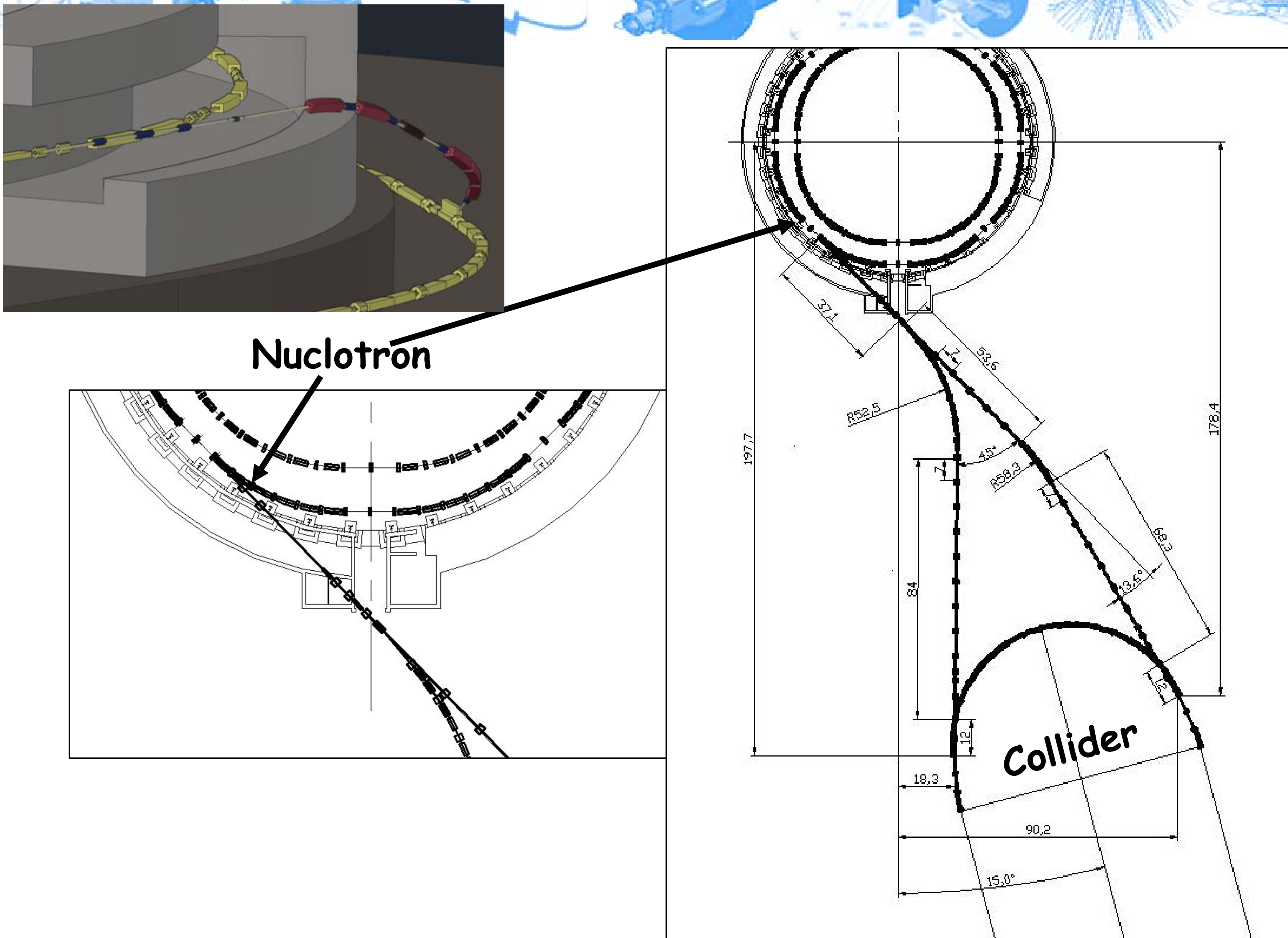
RF-2 and RF-3 resonators preliminary design (BINP)



Booster RF stations (2 p.) under manufacturing at BINP

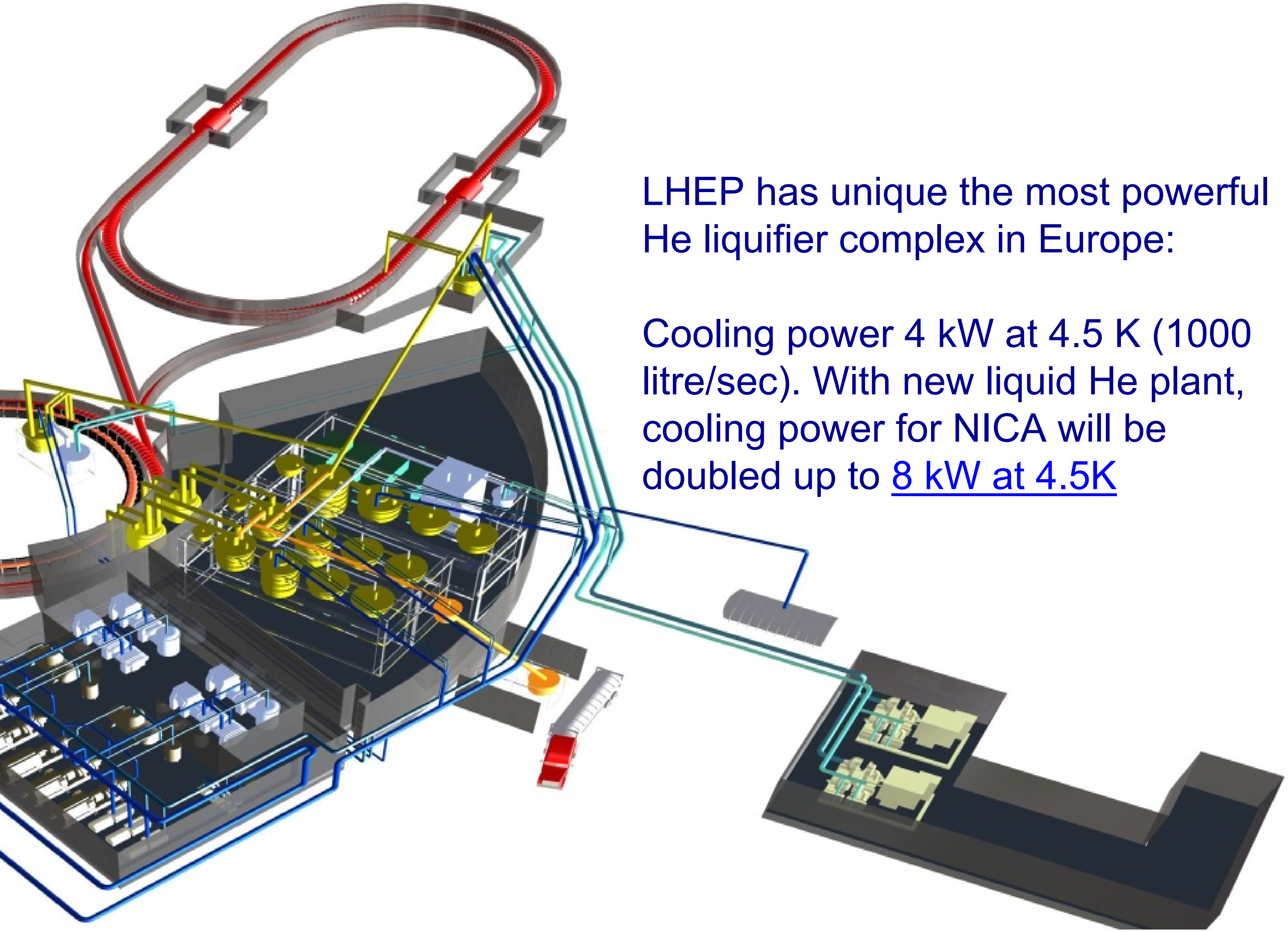
A.Eliseev's talk on Monday

Transfer channels



NICA Cryogenics

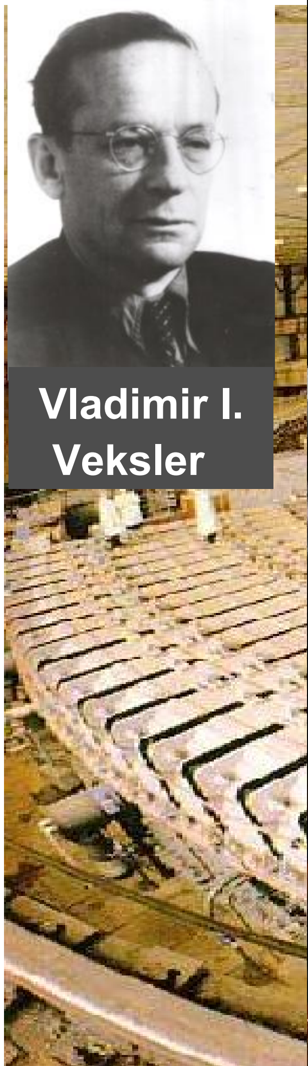
wet turboexpander
(300 000 terns/min)



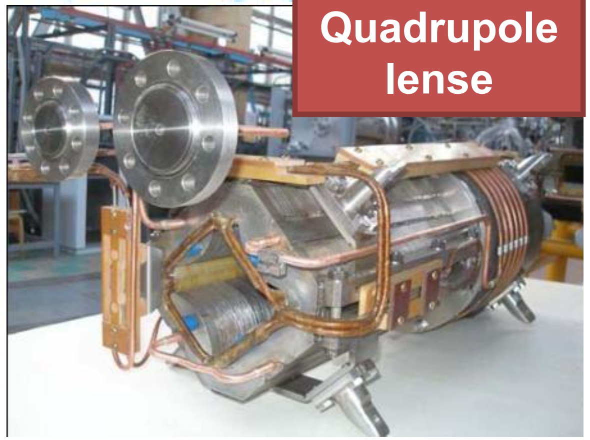
LHEP has unique the most powerful He liquifier complex in Europe:

Cooling power 4 kW at 4.5 K (1000 litre/sec). With new liquid He plant, cooling power for NICA will be doubled up to 8 kW at 4.5K

Booster Synchrotron for NICA

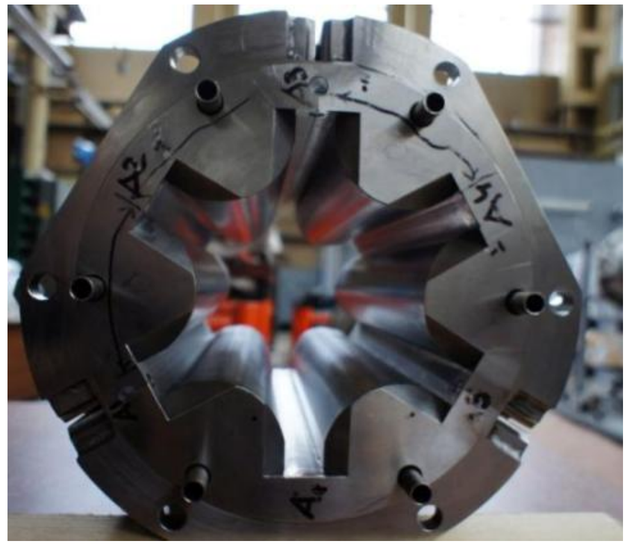


Magnets for the Booster



Quadrupole lense

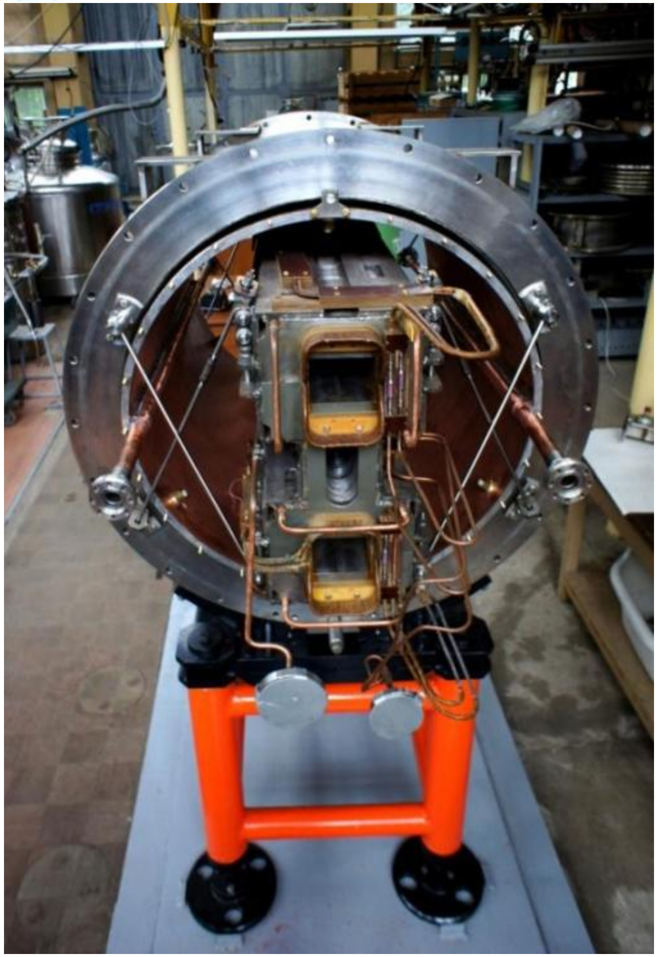
Booster dipole at cryo-test (9690A) and magnetic measurements

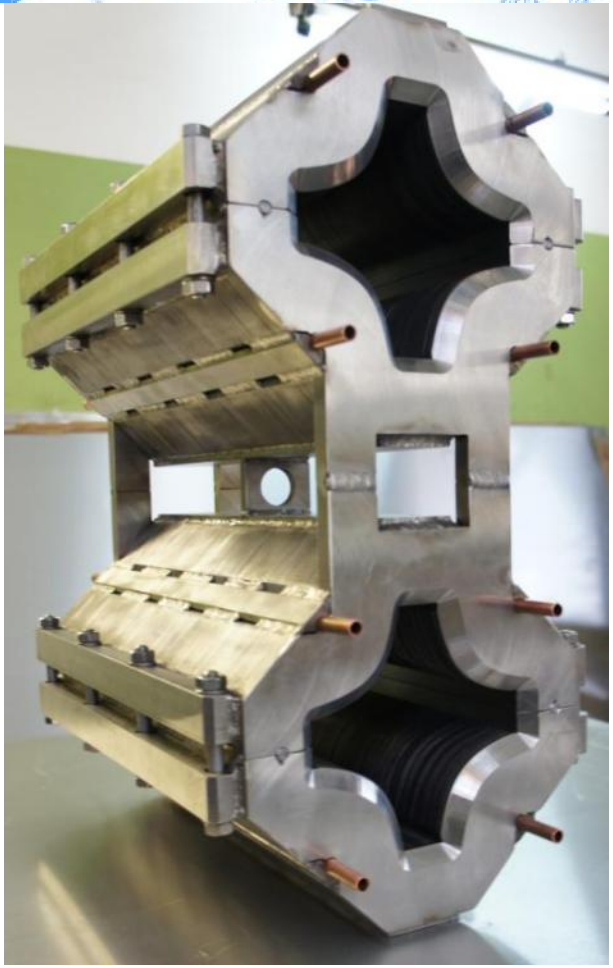


Beampipe for booster magnet

Sextupole corrector prototype for SIS100 at assembly

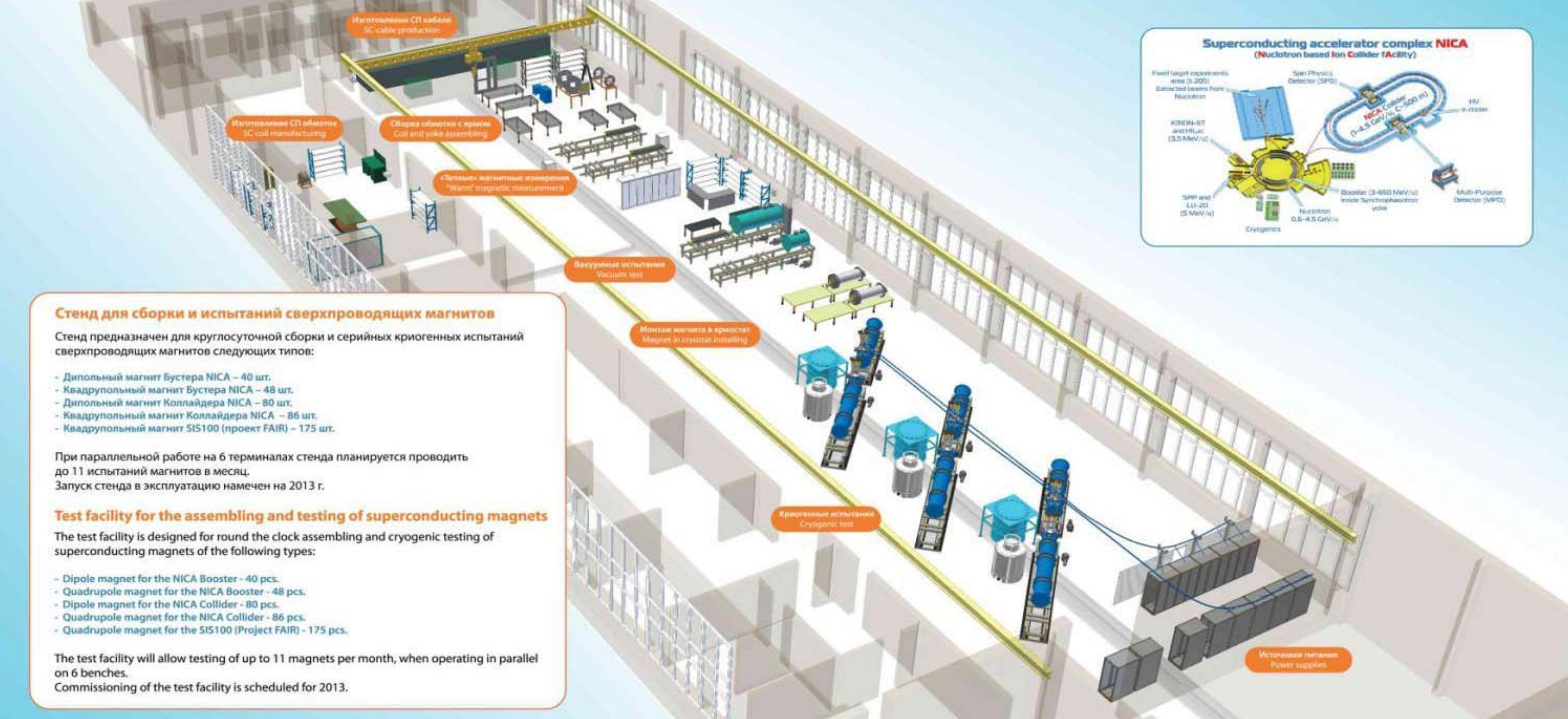
Magnets for the Collider





Cryo-tests (autumn 2012), magnetic measurements, new cryo-plant at b.217 (power convertors, cryogenics, etc.)serial production…

H.Khodzhibagiyan's talk on Thursday



Стенд для сборки и испытаний сверхпроводящих магнитов

Стенд предназначен для круглосуточной сборки и серийных криогенных испытаний сверхпроводящих магнитов следующих типов:

- Дипольный магнит Бустера NICA – 40 шт.
- Квадрупольный магнит Бустера NICA – 48 шт.
- Дипольный магнит Коллайдера NICA – 80 шт.
- Квадрупольный магнит Коллайдера NICA – 86 шт.
- Квадрупольный магнит SIS100 (проект FAIR) – 175 шт.

При параллельной работе на 6 терминалах стенда планируется проводить до 11 испытаний магнитов в месяц.
Запуск стенда в эксплуатацию намечен на 2013 г.

Test facility for the assembling and testing of superconducting magnets

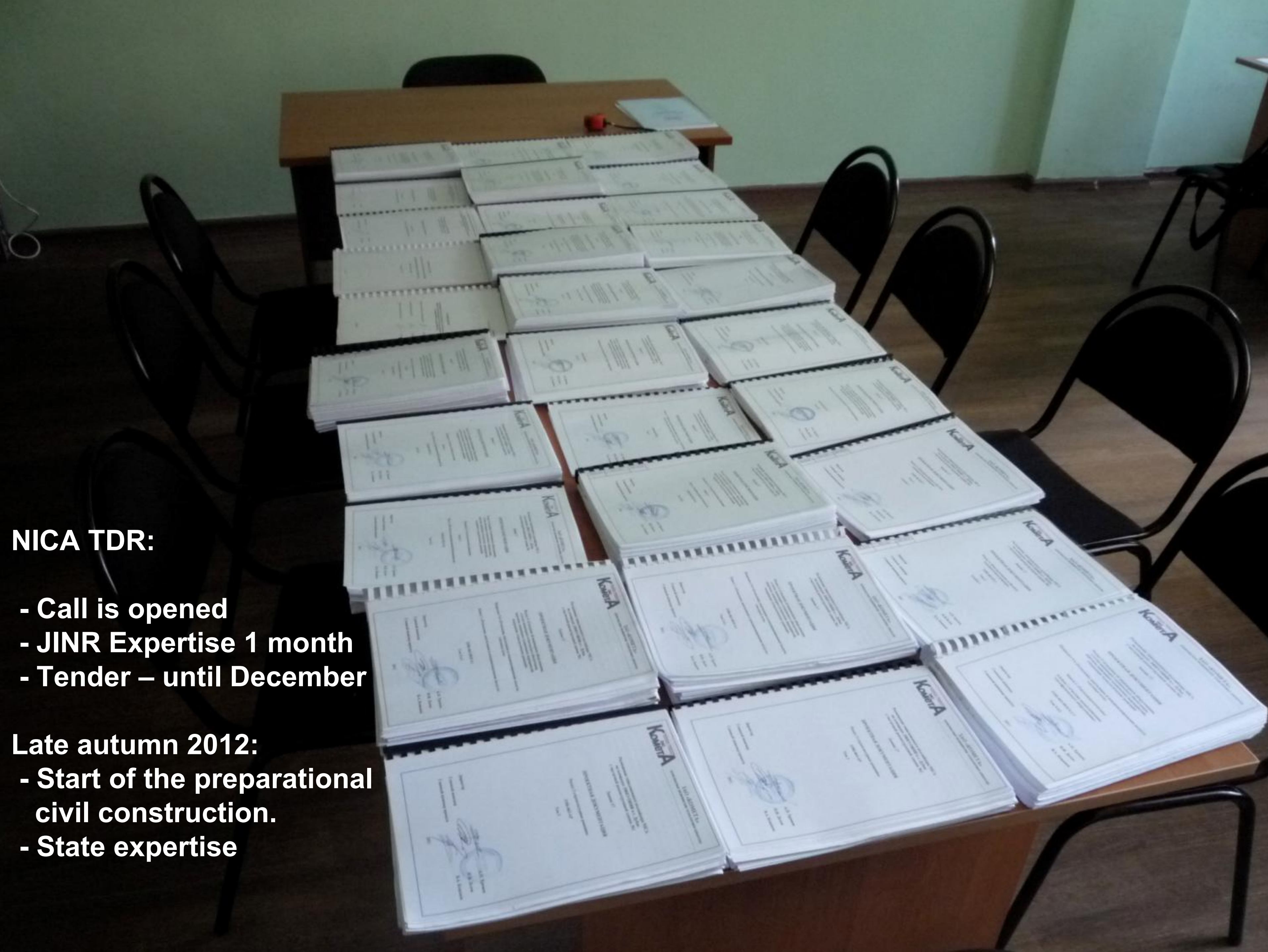
The test facility is designed for round the clock assembling and cryogenic testing of superconducting magnets of the following types:

- Dipole magnet for the NICA Booster - 40 pcs.
- Quadrupole magnet for the NICA Booster - 48 pcs.
- Dipole magnet for the NICA Collider - 80 pcs.
- Quadrupole magnet for the NICA Collider - 86 pcs.
- Quadrupole magnet for the SIS100 (Project FAIR) - 175 pcs.

The test facility will allow testing of up to 11 magnets per month, when operating in parallel on 6 benches.
Commissioning of the test facility is scheduled for 2013.

NICA CF&S

Technological part of the TDR (main equipment, engineering systems, etc), radiation and environmental safety, architecture had been fulfilled. Now – the final stage: capital spending sights. Plan – to submit all documents to the State Expertise – end of 2012.



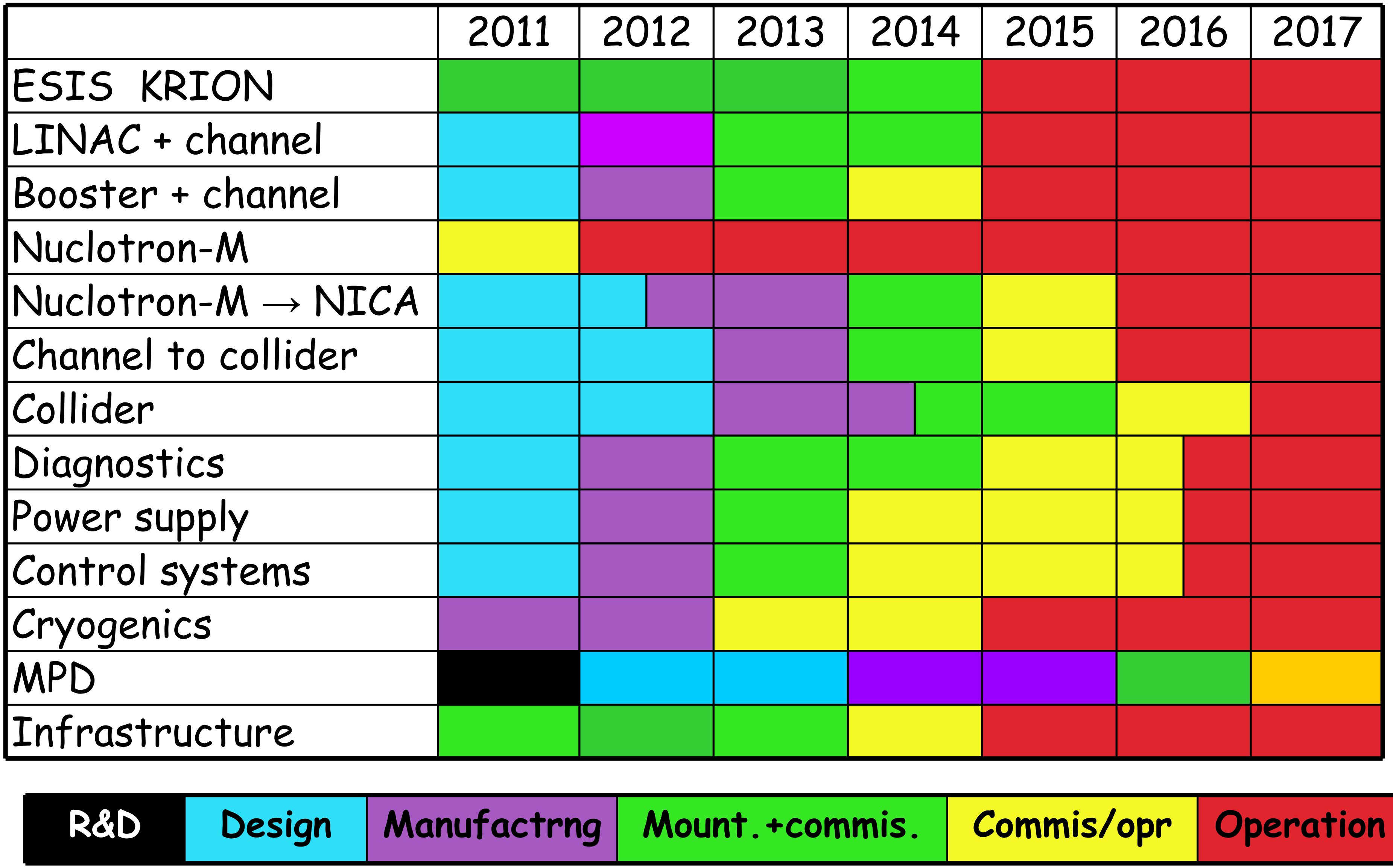
NICA TDR:

- Call is opened
- JINR Expertise 1 month
- Tender – until December

Late autumn 2012:

- Start of the preparational civil construction.
- State expertise

NICA schedule



NICA Collaboration

МИФИ, МЭИ, МФТИ, КГТУ, СПбГУ,...

Budker INP
Booster RF system, e-cooler
Collider RF system
✓ HV e-cooler for collider
✓ Electronics

НПО ГЕЛИЙМАШ

КРИОГЕНМАШ

INR RAS, Troitsk polarised source, Linacs, beam diagnostics

All-Russian Inst. for Electrotechnique
HV Electron cooler

ВЭИ

GSI/FAIR
SC dipoles for Booster/SIS-100
beam cooling, diagnostics

Corporation "Powder Metallurgy" (Minsk, Belorussia): Technology of TiN coating of vacuum chamber walls for reduction of secondary emission

IHEP (Protvino)
RFQ,beam dynamics, RF,
Feed-back systems

FZ Juelich (IKP)
HV Electron cooler
Stoch. cooling

CERN
SC technologies, Rad.safety, energetics, beam cooling and dynamics

FNAL
HV Electron cooler
Beam dynamics,Stoch.cooling

BNL (RHIC)
Beam dynamics,
Stoch. Cooling

ITEP
Beam dynamics in the collider,RFQ linac

Thank you for your attention !

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