Heavy ion collider facility NICA at JINR (Dubna): status and development.

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on behalf of the team

Joint Institute for Nuclear Research, Dubna

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Melbourne, ICHEP-2012

Main targets 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***

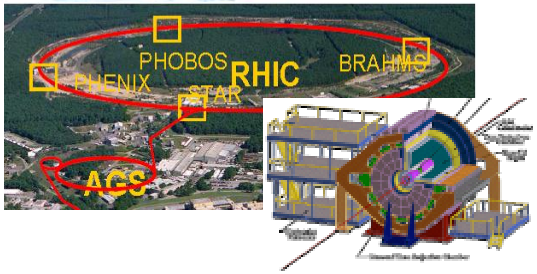
energy range $\sqrt{S_{NN}}$ *= 4..11 GeV* (Au^{79+})

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

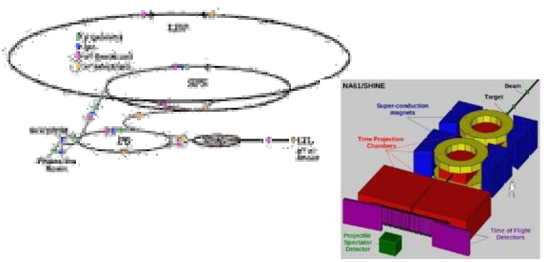
(energy range $\sqrt{S_{NN}}$ *= 4..26 GeV for p)*

Vladimir Kekelidze (JINR) Physics@NICA 06.07.12

2^{nd} generation HI experiments

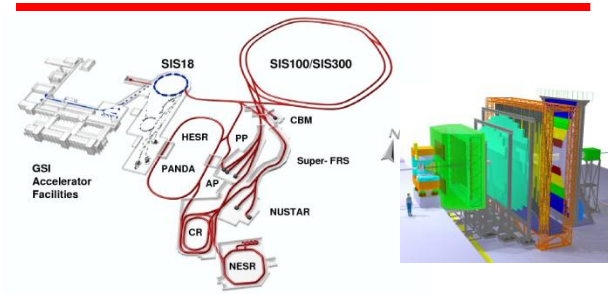


STAR/PHENIX @ BNL/RHIC. Originally designed for higher energies (s_{NN} > 20 GeV), low luminosity for LES program L<10^{26} $cm^{-2}s^{-1}$ for Au^{79+}

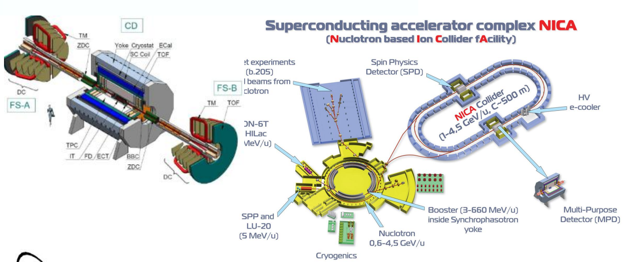


NA61 @ CERN/SPS. Fixed target, non-uniform acceptance, few energies (10,20,30,40,80,160A GeV), poor nomenclature of beam species

3^{nd} generation HI experiments

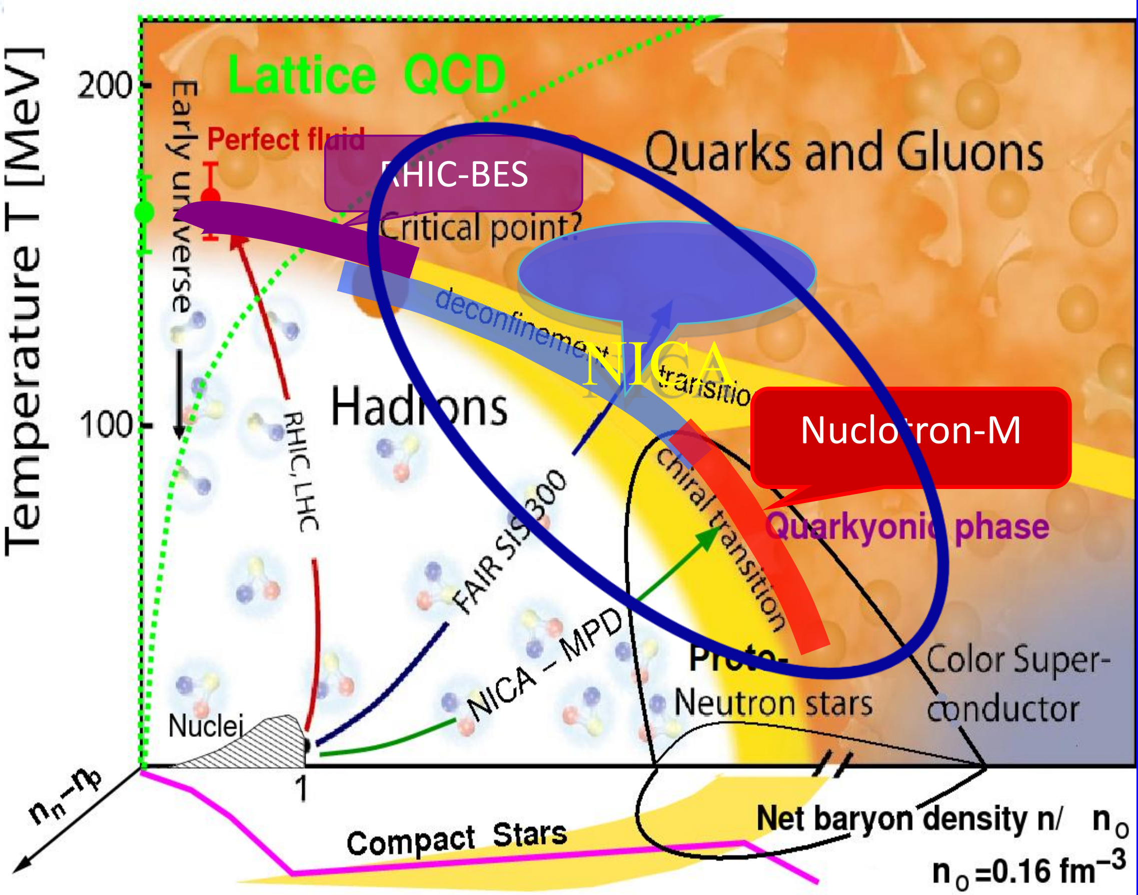


CBM @ FAIR/SIS-100/300
Fixed target, E/A=10-40 GeV, high luminosity



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



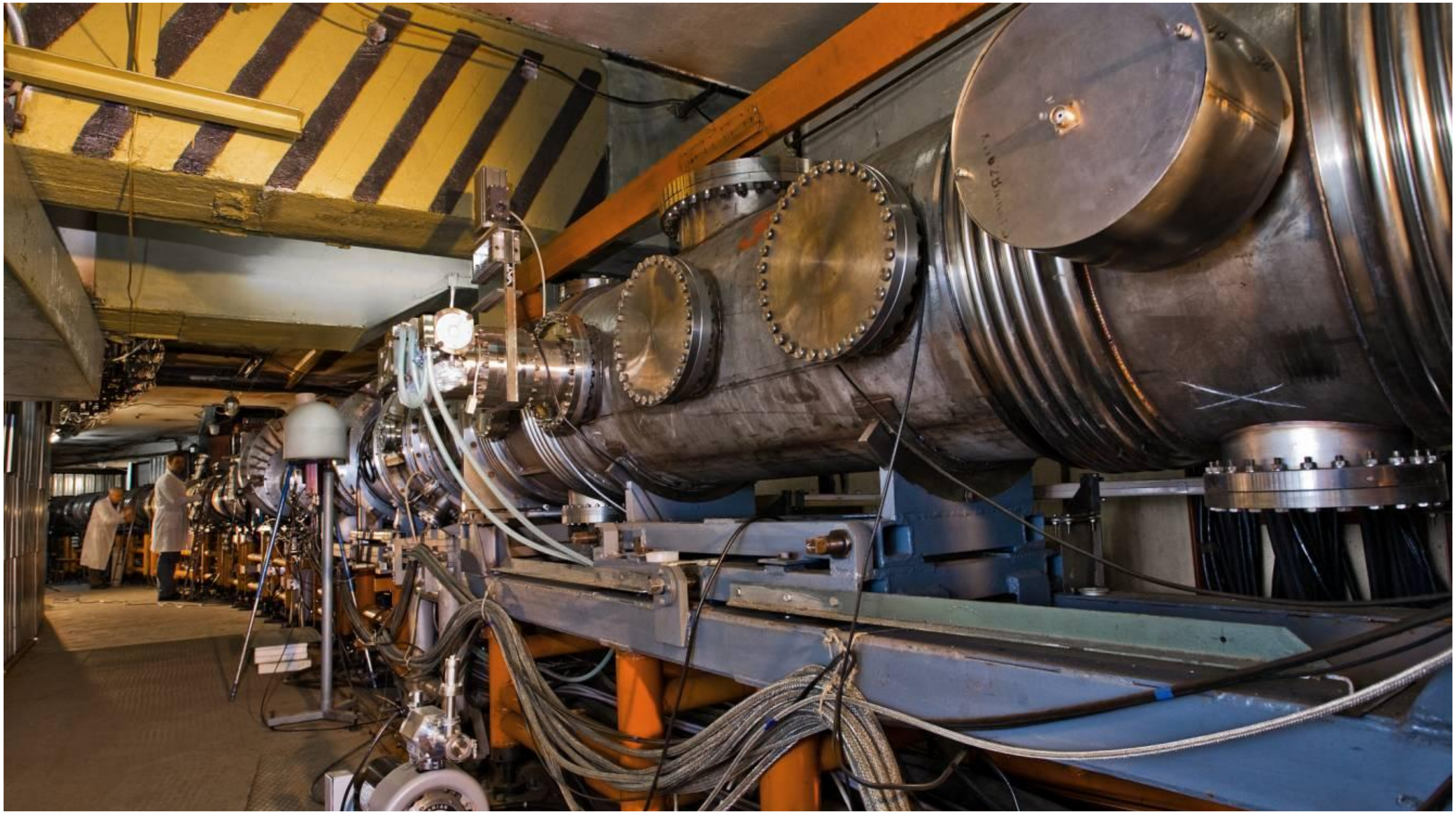
Energy Range of NICA
unexplored region of
the QCD phase diagram:

- 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)

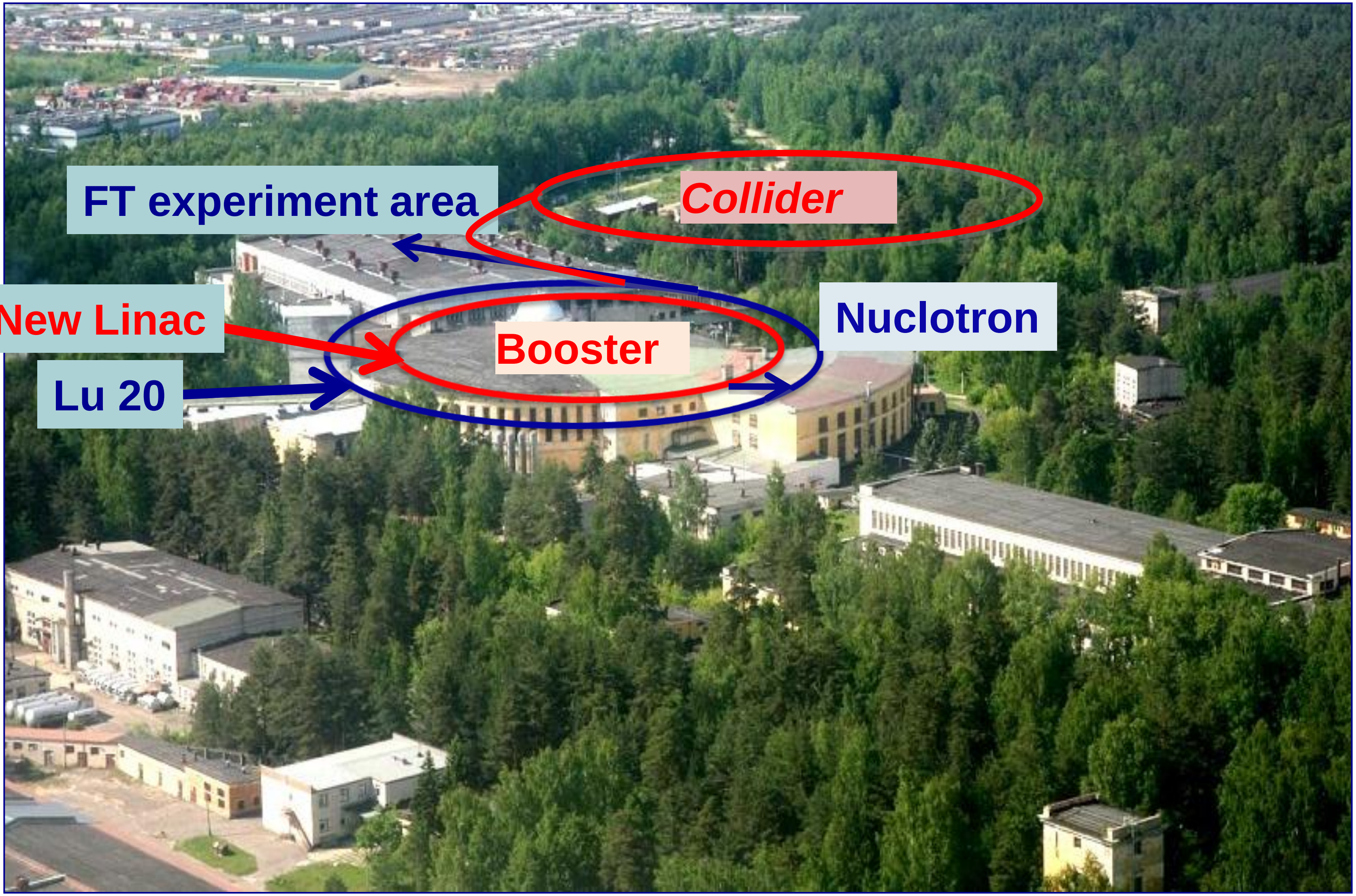
– superconducting accelerator for ions and polarized particle
– physics of ultrarelativistic heavy ions, high energy spin physics



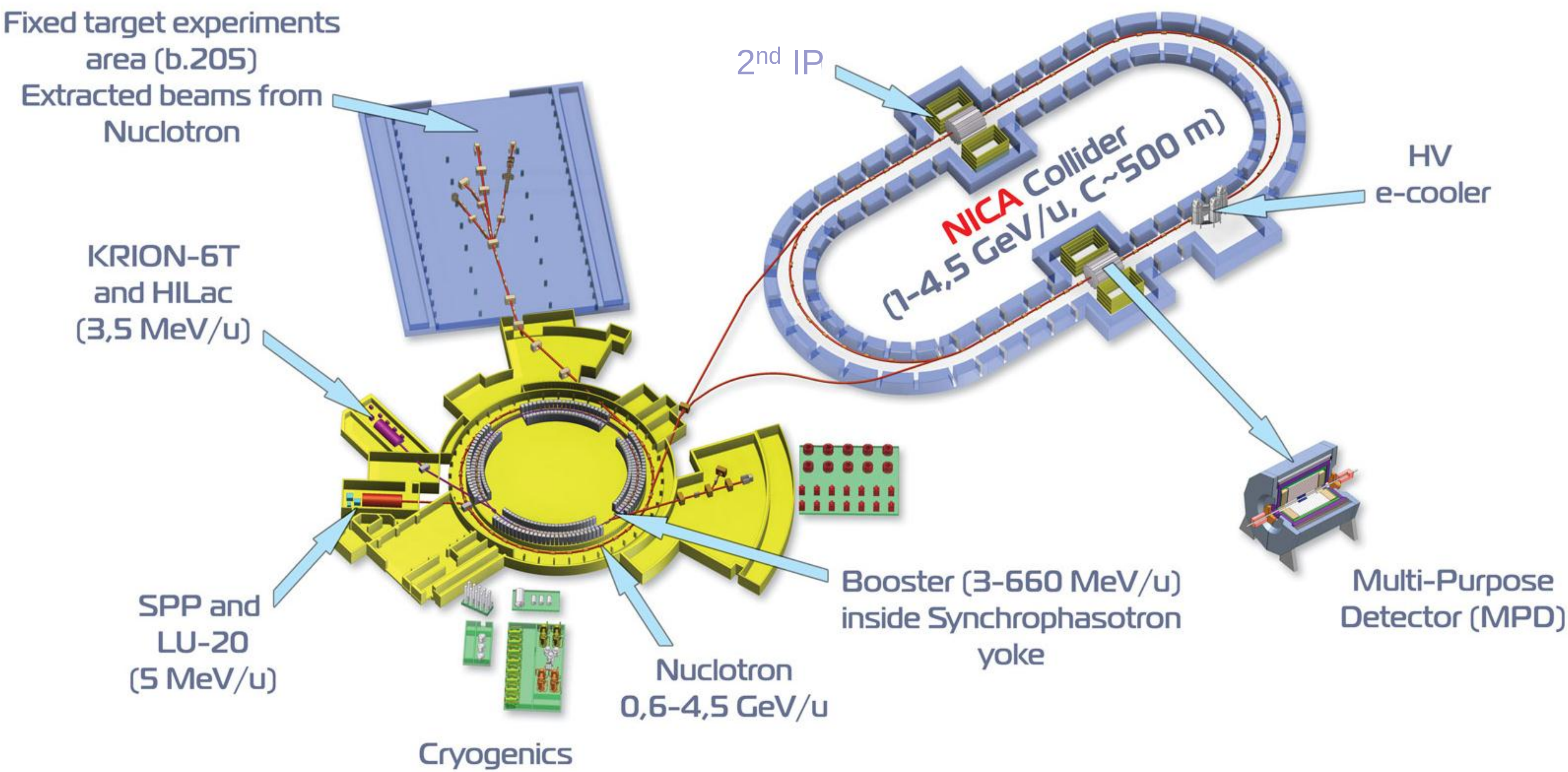
Nuclotron provides now performance of experiments on accelerated proton and ion beams (up to *Xe42+, A=124*) with energies up to 6 AGeV (Z/A = 1/2)

Beam	Nuclotron beam intensity (particle per cycle)		
	Current status	Ion source type	New ion source + booster
p	$3\cdot10^{10}$	Duoplasmotron	$5\cdot10^{12}$
d	$5\cdot10^{10}$	--- ,, ---	$5\cdot10^{12}$
^{4}He	$8\cdot10^{8}$	--- ,, ---	$1\cdot10^{12}$
d↑	$2\cdot10^{8}$	SPI	$1\cdot10^{10}$
^{7}Li	$8\cdot10^{8}$	Laser	$5\cdot10^{11}$
$^{11,10}B$	$1\cdot10^{9,8}$	--- ,, ---	
^{12}C	$5\cdot10^{9}$	--- ,, ---	$2\cdot10^{11}$
^{24}Mg	$2\cdot10^{7}$	--- ,, ---	
^{14}N	$1\cdot10^{7}$	ESIS ("Krion-6T")	$5\cdot10^{10}$
^{24}Ar	$1\cdot10^{9}$	--- ,, ---	$2\cdot10^{11}$
^{56}Fe	$2\cdot10^{6}$	--- ,, ---	$5\cdot10^{10}$
^{84}Kr	$1\cdot10^{4}$	--- ,, ---	$1\cdot10^{9}$
^{124}Xe	$1\cdot10^{4}$	--- ,, ---	$1\cdot10^{9}$
^{197}Au	-	--- ,, ---	$1\cdot10^{9}$

Complex NICA @ JINR (VBLEP)



Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



NICA goals

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

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

at $L_{average} = 1 \times 10^{27}\ cm^{-2} \cdot s^{-1}$ (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↑ $\sqrt{s_{pp}} = 12 \div 27$ GeV (5 ÷ 12.6 GeV kinetic energy)

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

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

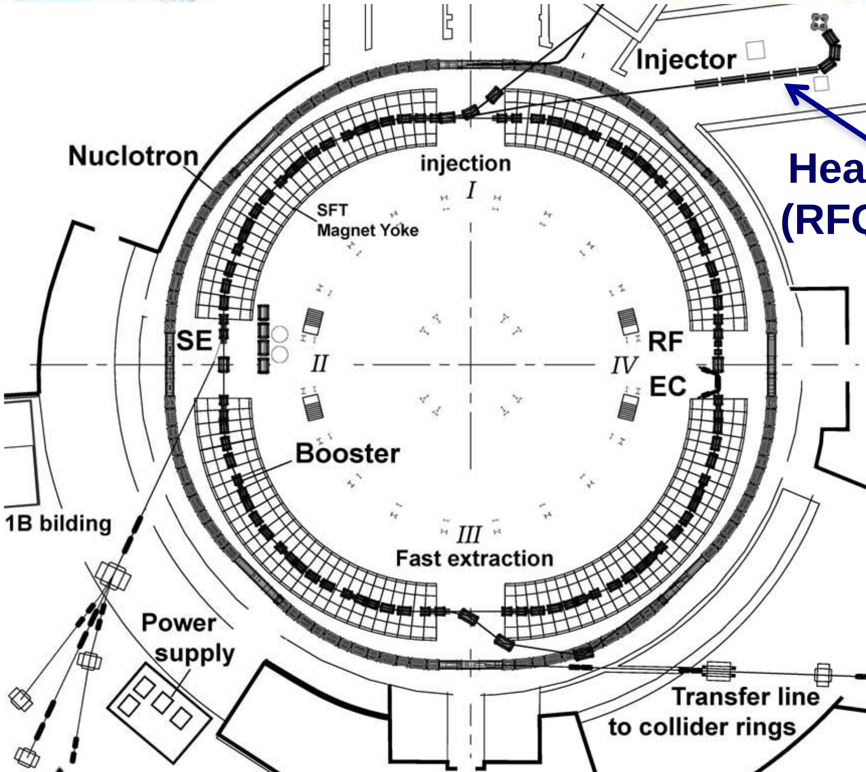
3) The beams of light ions and polarized protons and deuterons for fixed target experiments:

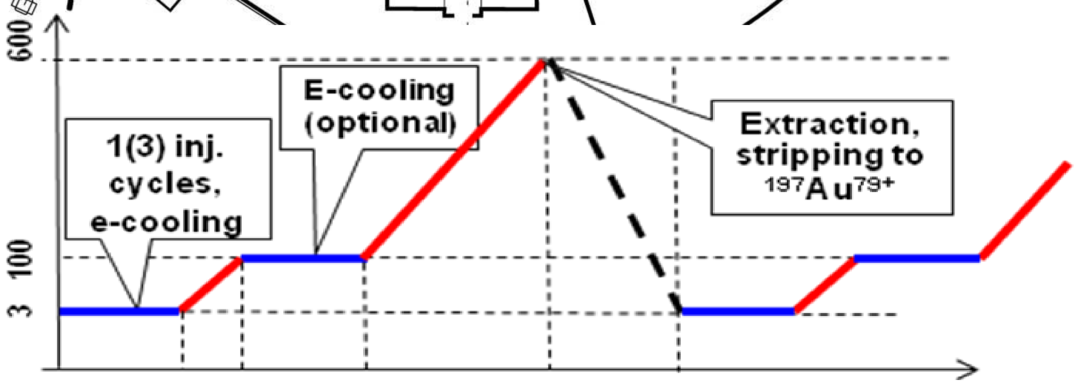
Li ÷ Au = 1 ÷ 4.5 GeV /u ion kinetic energy
p, p↑ = 5 ÷ 12.6 GeV kinetic energy
d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

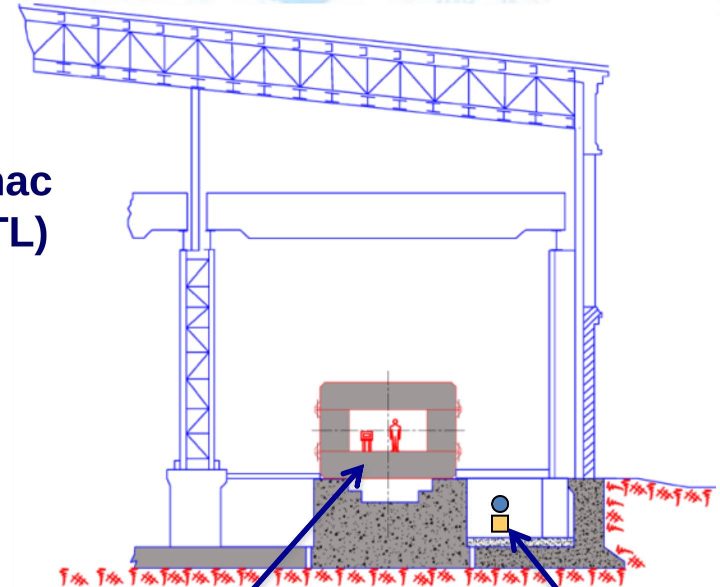
4) Applied research on ion beams at kinetic energy

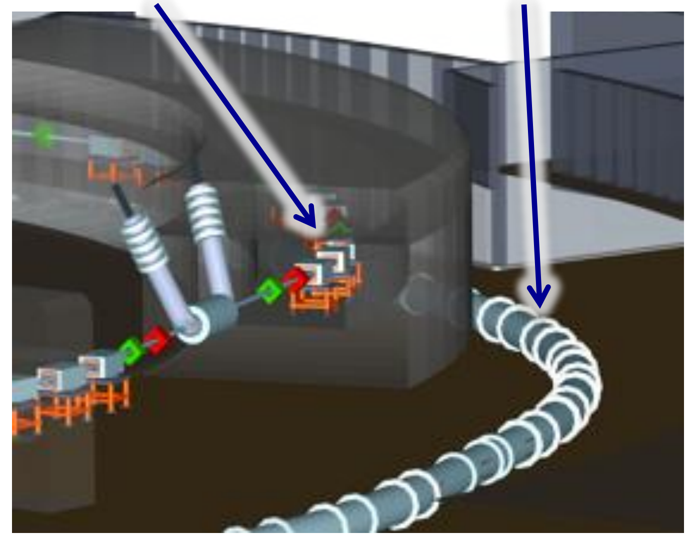
from 0.5 GeV/u up to 12.6 GeV (p) and 4.5 GeV /u (Au)

Superconducting Booster synchrotron, E = 3..600 MeV/u, C=211 m

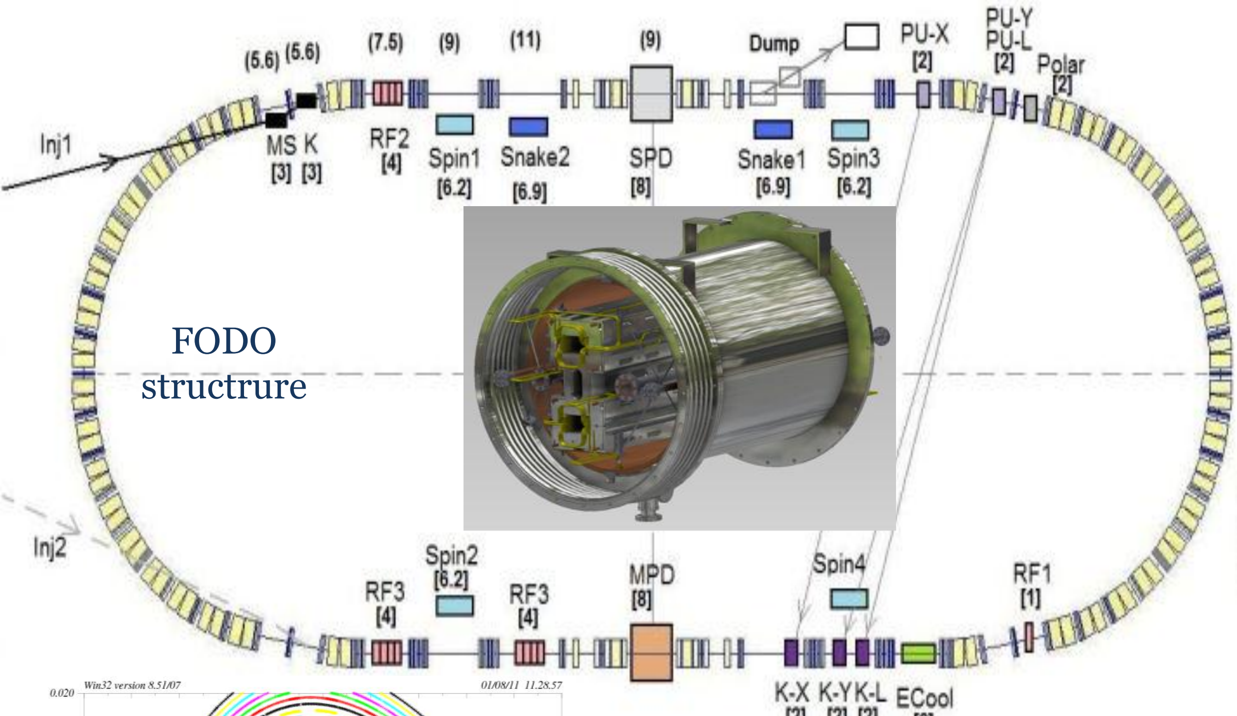








Unique low energy (1 - 4.5 GeV/u) collider with extremely high luminosity L=1e27

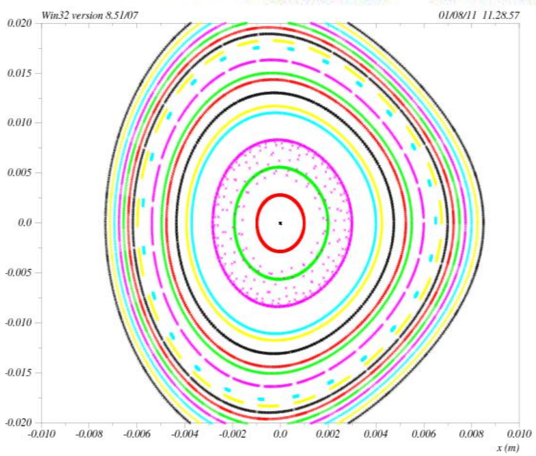


To reach maximum peak luminosity:

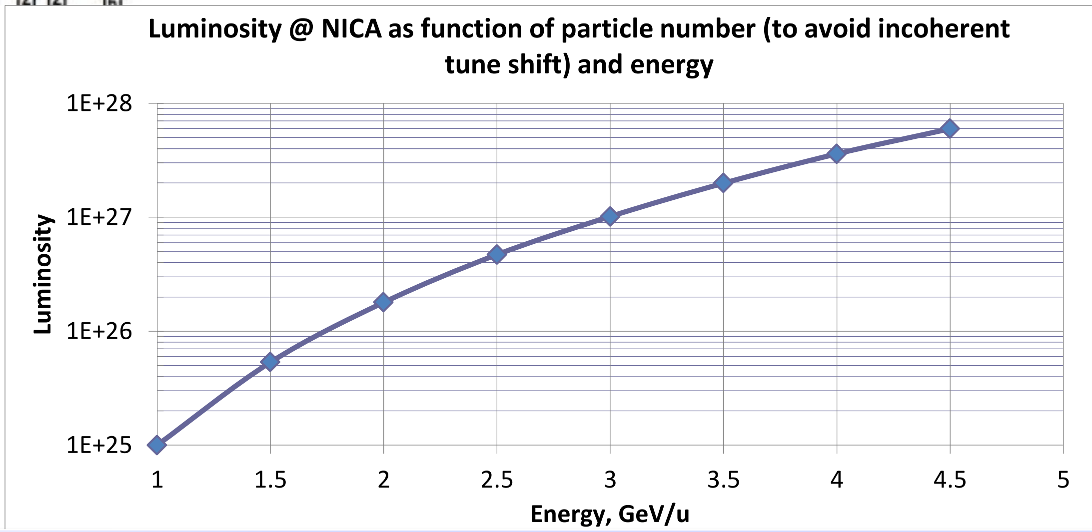
- minimum beta function in the IP;
- maximum bunch number;
- maximum bunch intensity;
- minimum beam emittance;
- minimum bunch length.

Circumference 503 m

Twin SC magnets



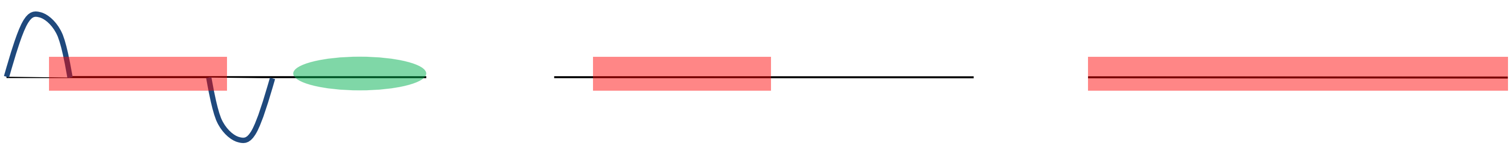
The collider dynamic aperture in the horizontal phase space.



Proposed scheme of RF cycle in collider

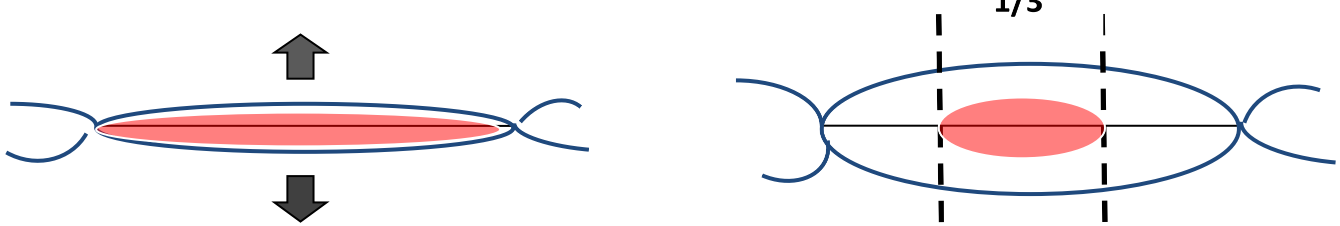
All stages are provided with cooling

Barrier RF system (1-st RF)



accumulation | barriers are switched off | coasting beam

2-nd RF system (h=C/21.5m)



bunching with adiabatic RF increase | Stop at length of 1/3 of bucket

3-d RF system (h=h2x3)

rebucketing adiabatic RF increase | bunch has final parameters

Facility structure and operation regimes

The problems and the solutions

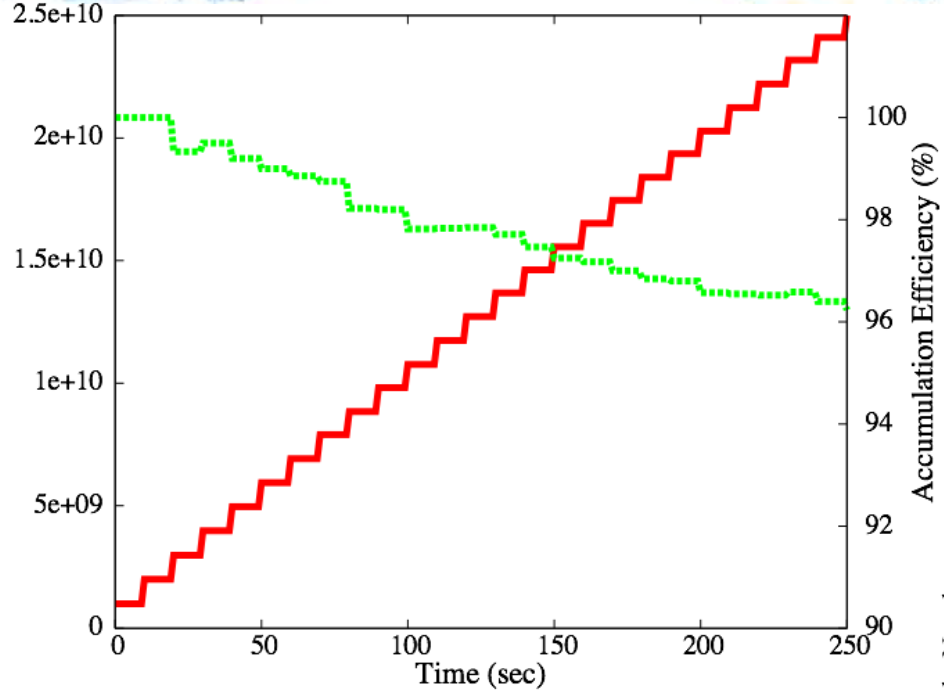
The problems:

- ✓ Beam space charge effects
- ✓ Beam-beam effects
- ✓ IntraBeam scattering (IBS) ⇒
  ⇒ luminosity degradation
- ✓ Recombination in e-cooler
- ✓ Bunch halo formation ⇒
  ⇒ parasitic collisions,
  background growth

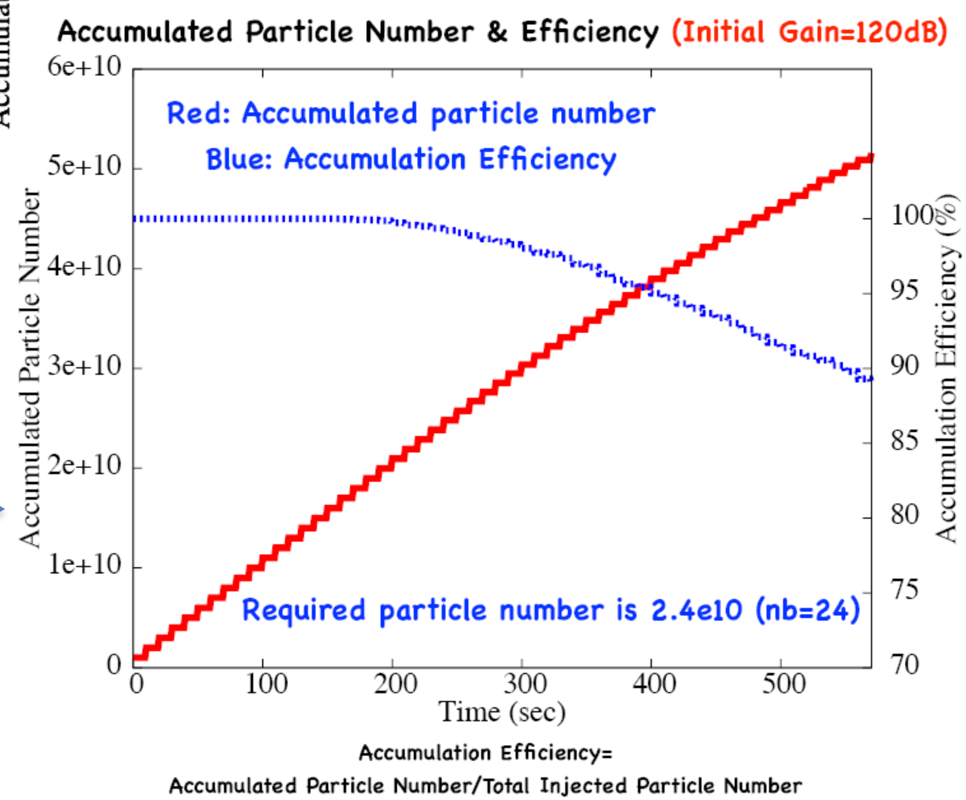
The solutions:

- ➢ Electron cooling application
- ➢ Stochastic cooling application
- ➢ Beam parameters choice
- ➢ Operation scenario optimisation
- ➢ Scrappers and collimators

Simulations by T.Katayama (GSI)



Beam stacking with electron cooling @1.5 GeV/u



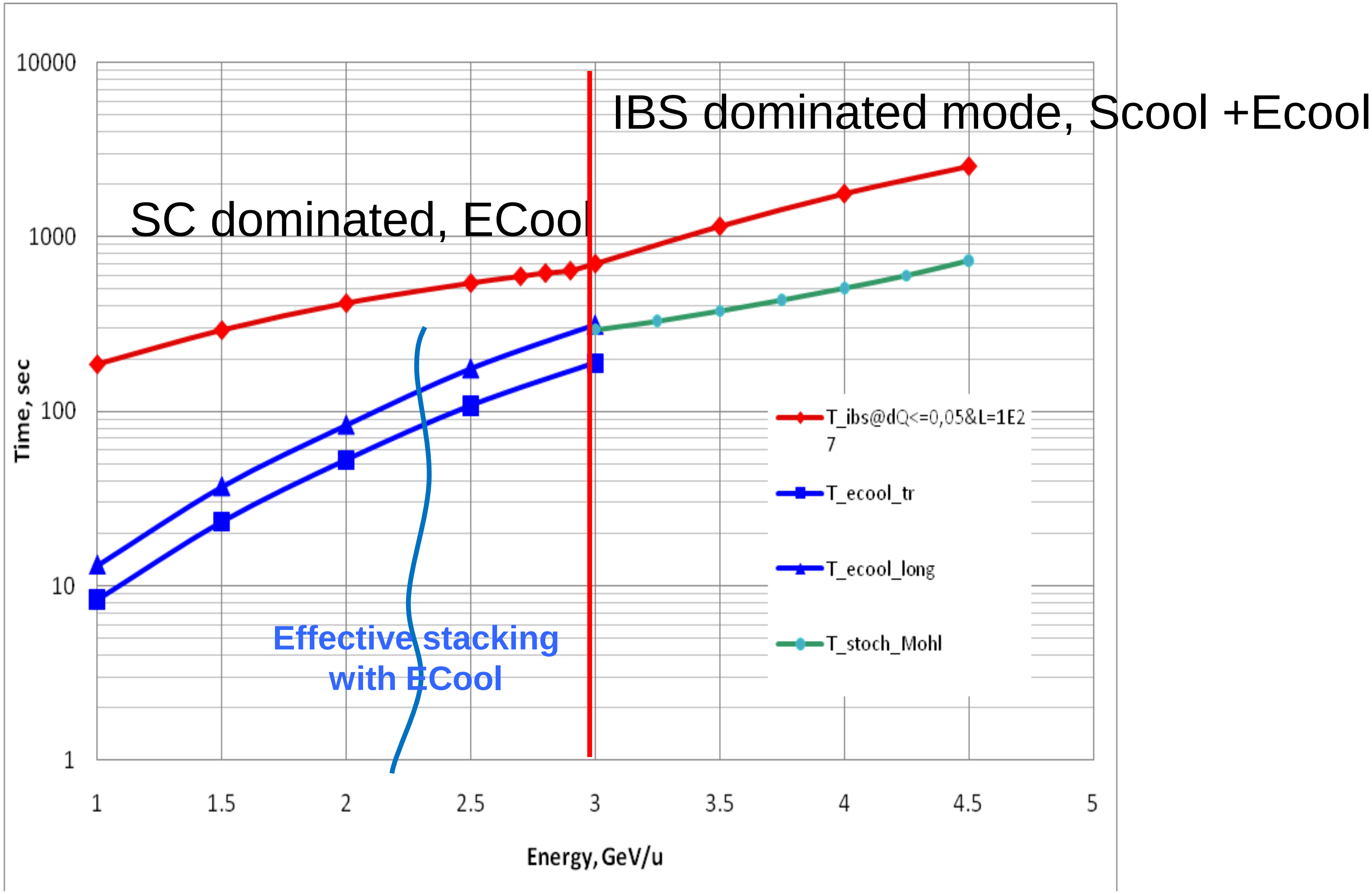
Beam stacking with stochastic cooling @3.5 GeV/u

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	$2.75\cdot10^8$	$2.4\cdot10^9$	$2.5\cdot10^9$
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	5e27

SC dominated

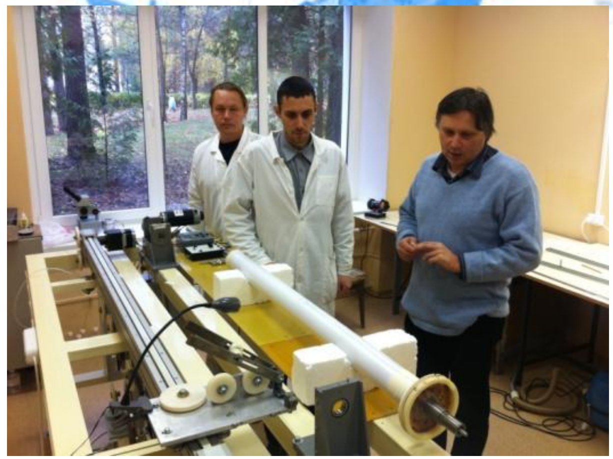
IBS dominated ($\Delta Q < 0.05$)

Strategy of the cooling at experiment

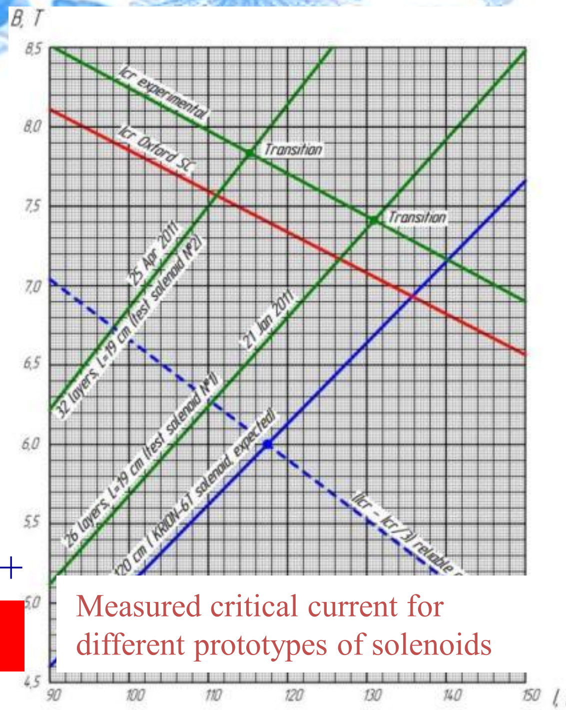


IBS is calculated for equal rates in 3 degrees of freedom, **I_e = 0.5 A**

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

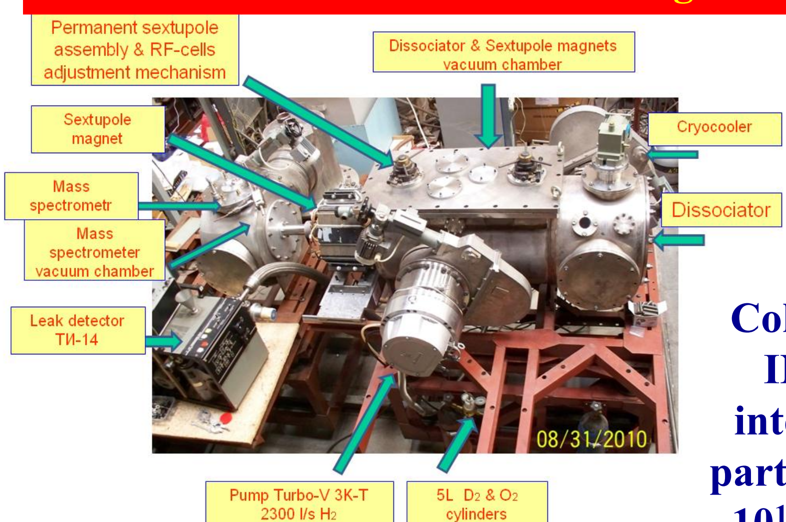


Highly charge ion state for heavy ions
with high intensity, f.e.: Kr 28+, Xe 44+, Au 52+



Measured critical current for different prototypes of solenoids

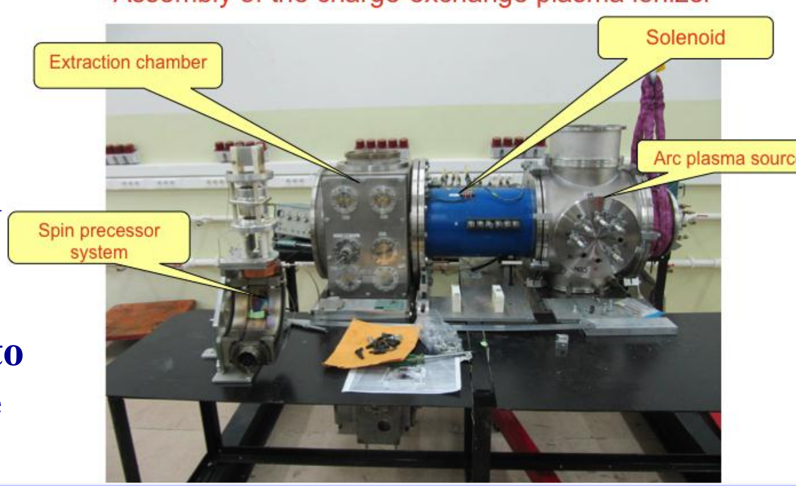
Excellent and modern SC technologies + unique accelerator physics



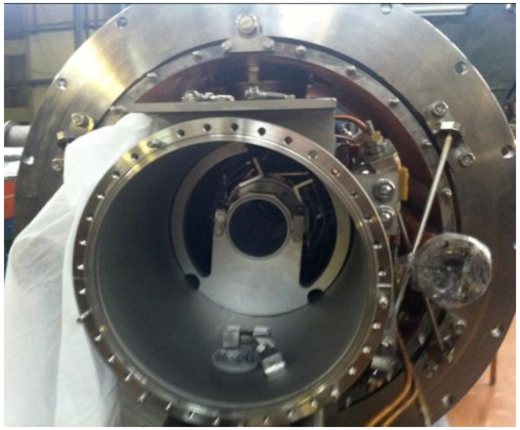
Atomic Beam Source setup general view

Collaboration with INR RAS: high intensity polarized particle source: up to 10^{11} particles/pulse

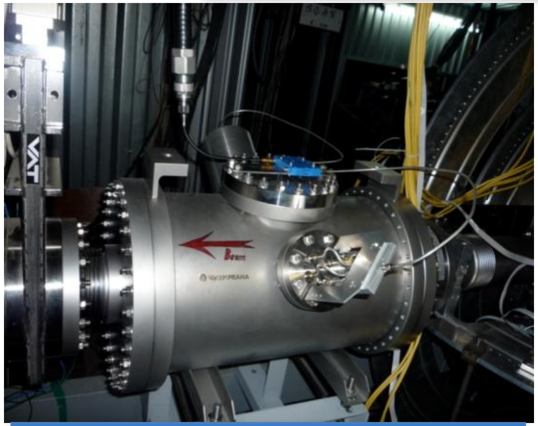
Assembly of the charge-exchange plasma ionizer



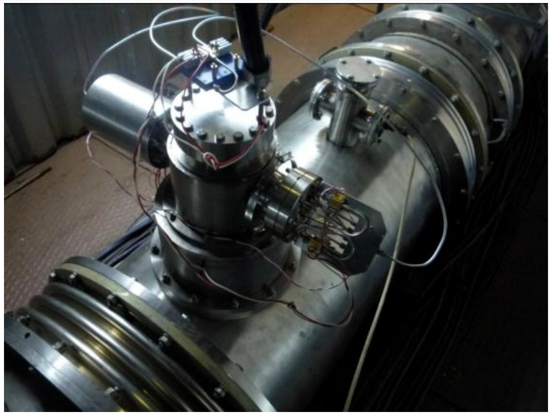
Stochastic cooling system installed at Nuclotron – prototype for Collider: W = 2-4 GHz, P = 60 W. (collaboration JINR - IKP FZJ - CERN)



Slot-coupler RF structure (by IKP FZJ)

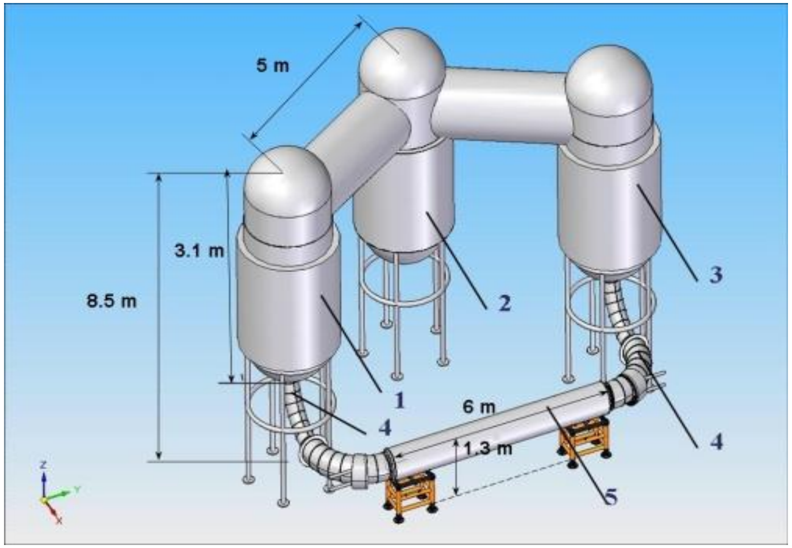


Kicker station

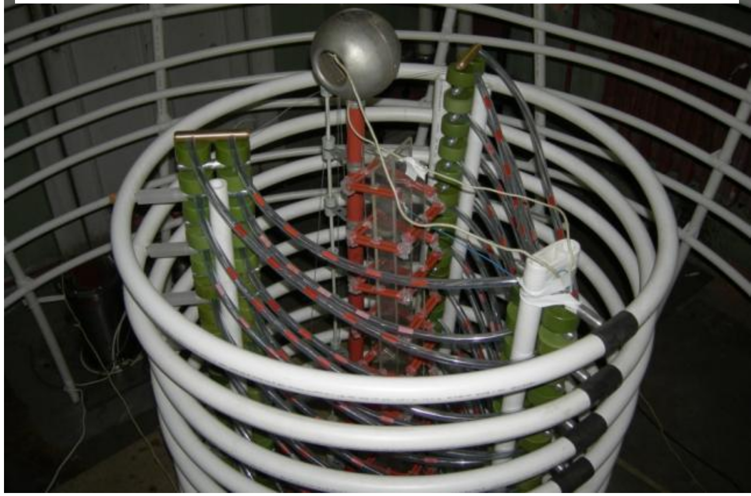


Pick-Up station

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



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

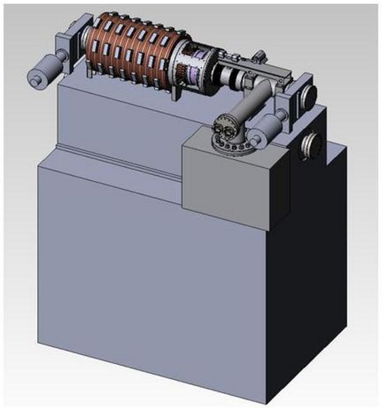


RF stations for booster – manufacturing is under completion (BINP)

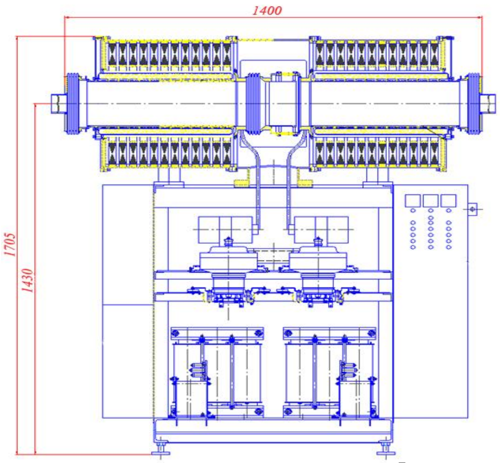
RF stations for collider – under design (BINP)

HV generator for collider HV e-cooler – tested up to 250 kV

Cryostats – first prototypes are tested at JINR

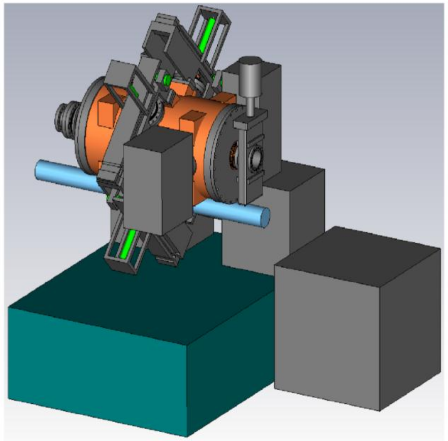


Barrier Bucket cavity (preliminary design, BINP)



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

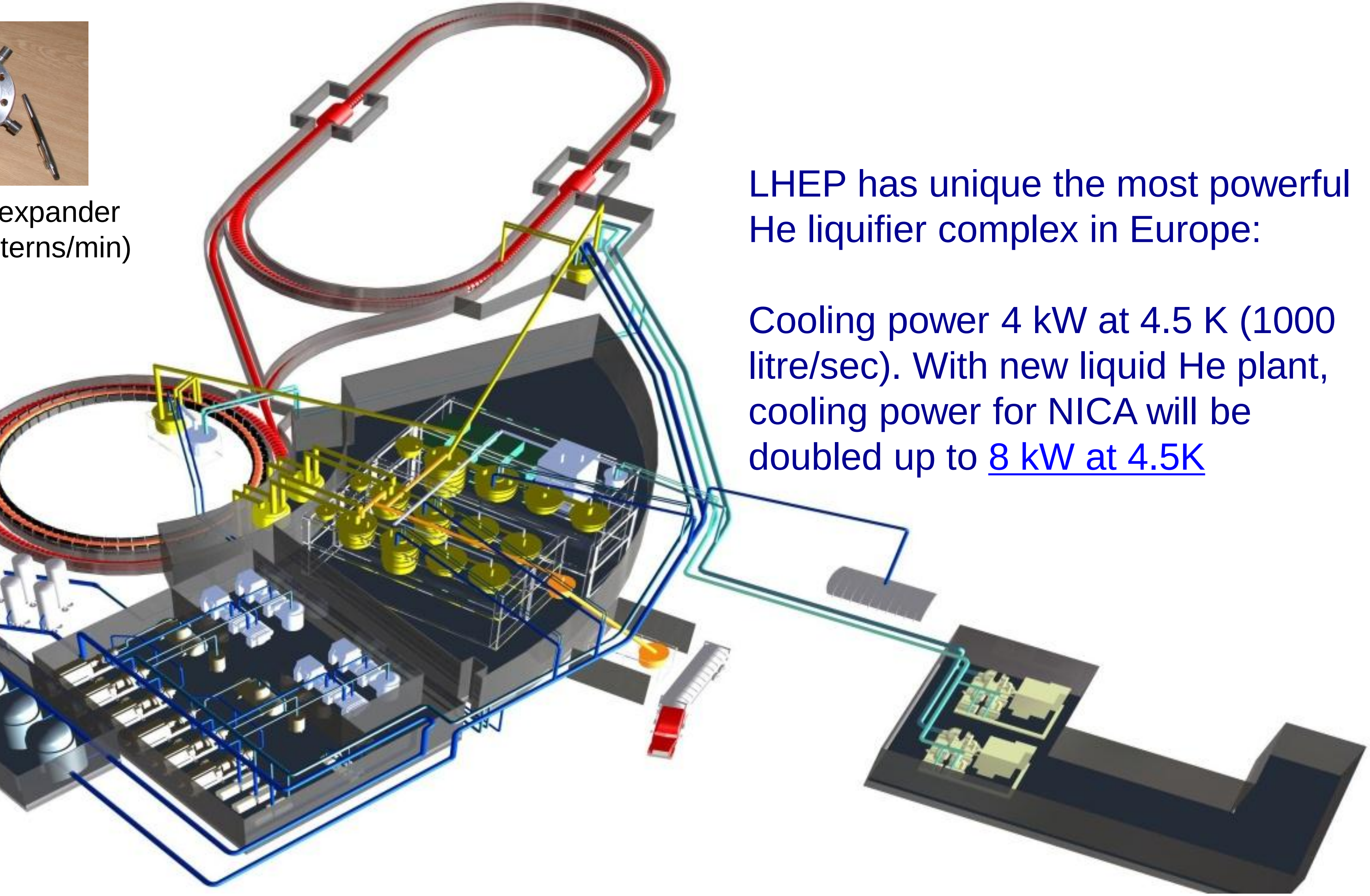
Booster RF stations manufactured at BINP



Curved vacuum chambers for booster

NICA cryogenics

wet turboexpander
(300 000 terns/min)

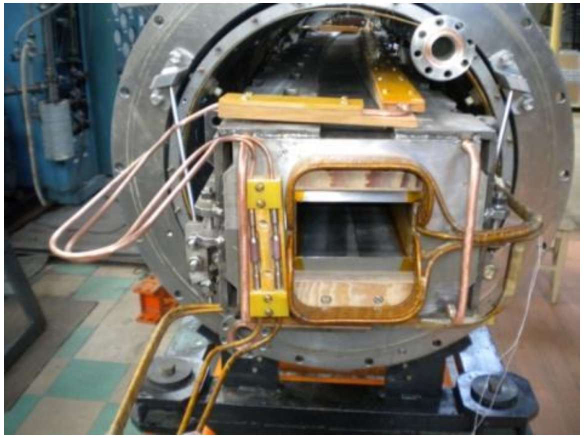


LHEP has unique the most powerful He liquifier complex in Europe:

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

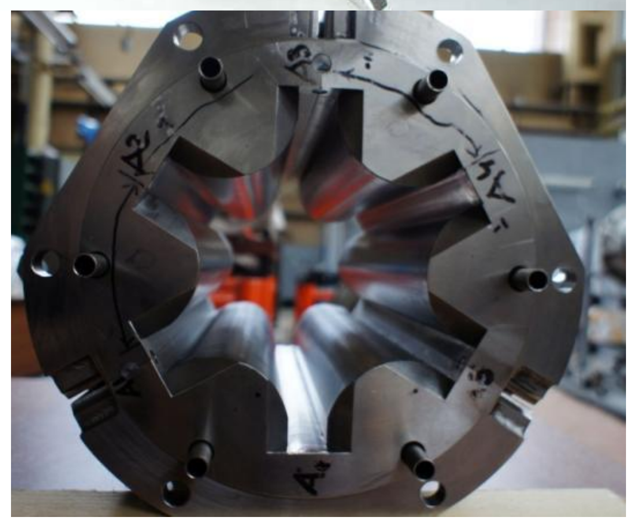
Booster synchrotron for NICA

Magnets for the Booster



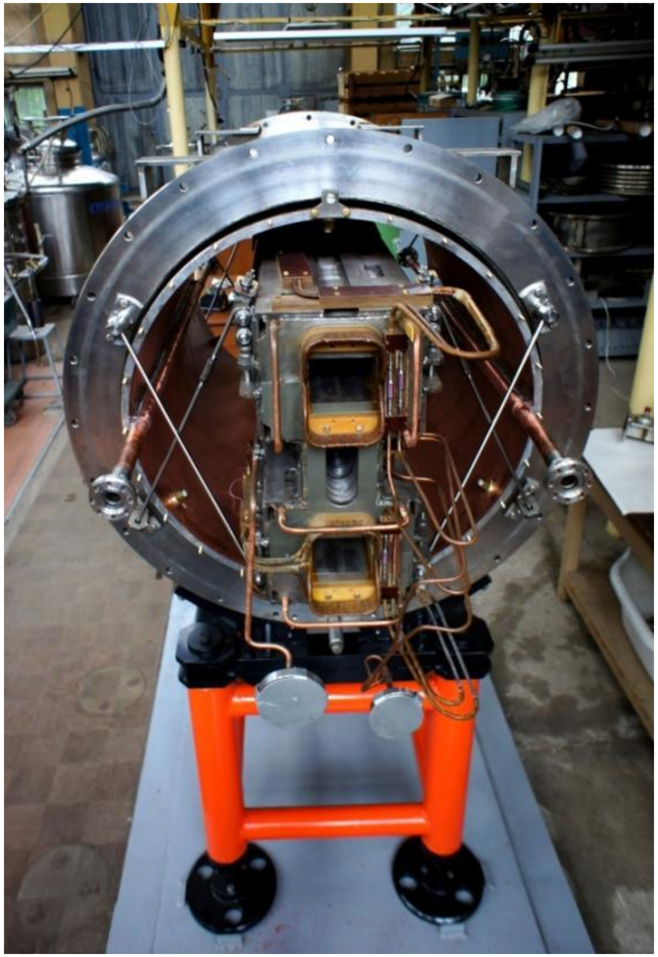
Booster dipole at cryo-test (9690A) and magnetic measurements

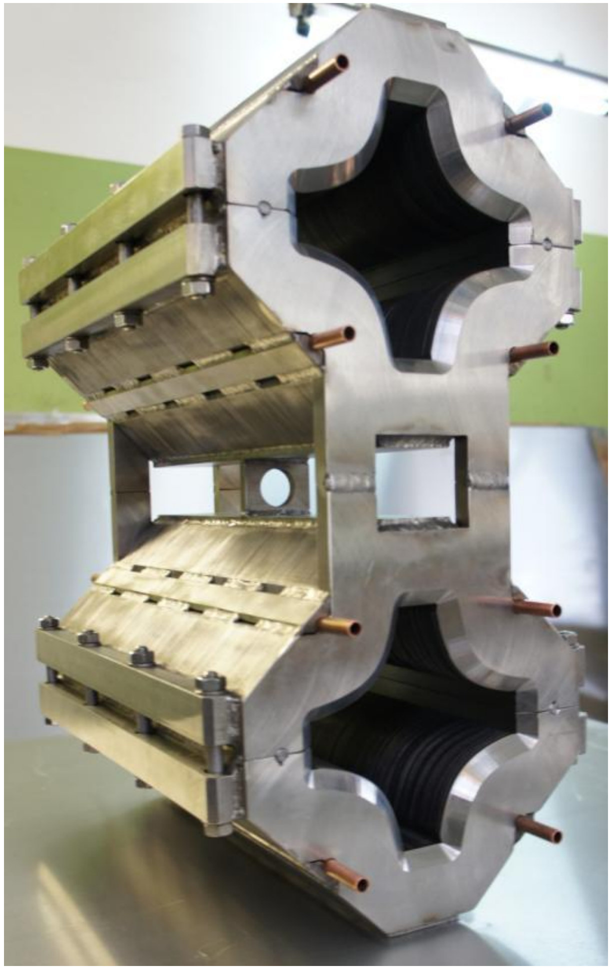
Quadrupole lense



Sextupole corrector prototype (for SIS100 and NICA booster) at assembly

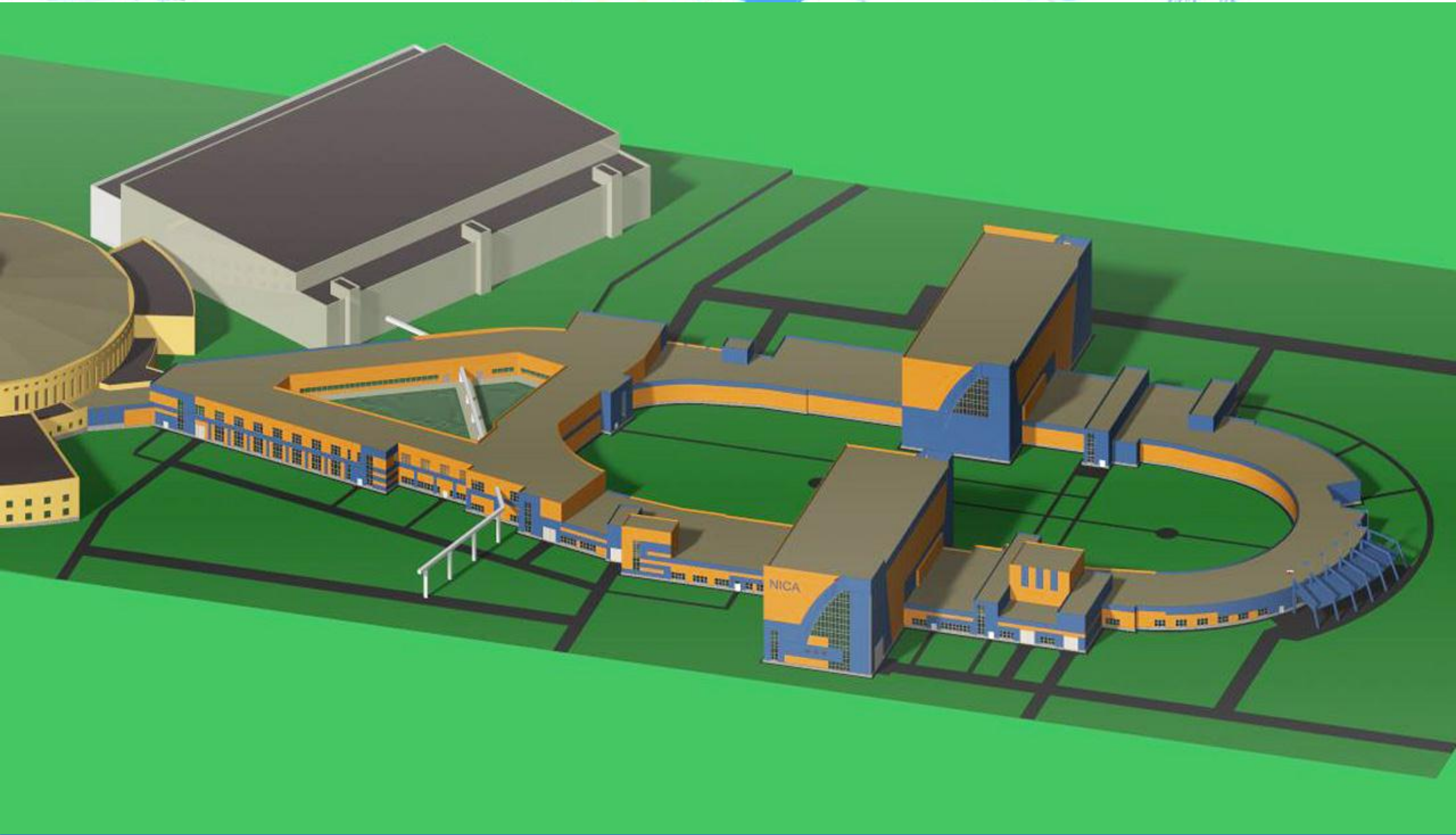
Magnets for the Collider





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

NICA CF&S

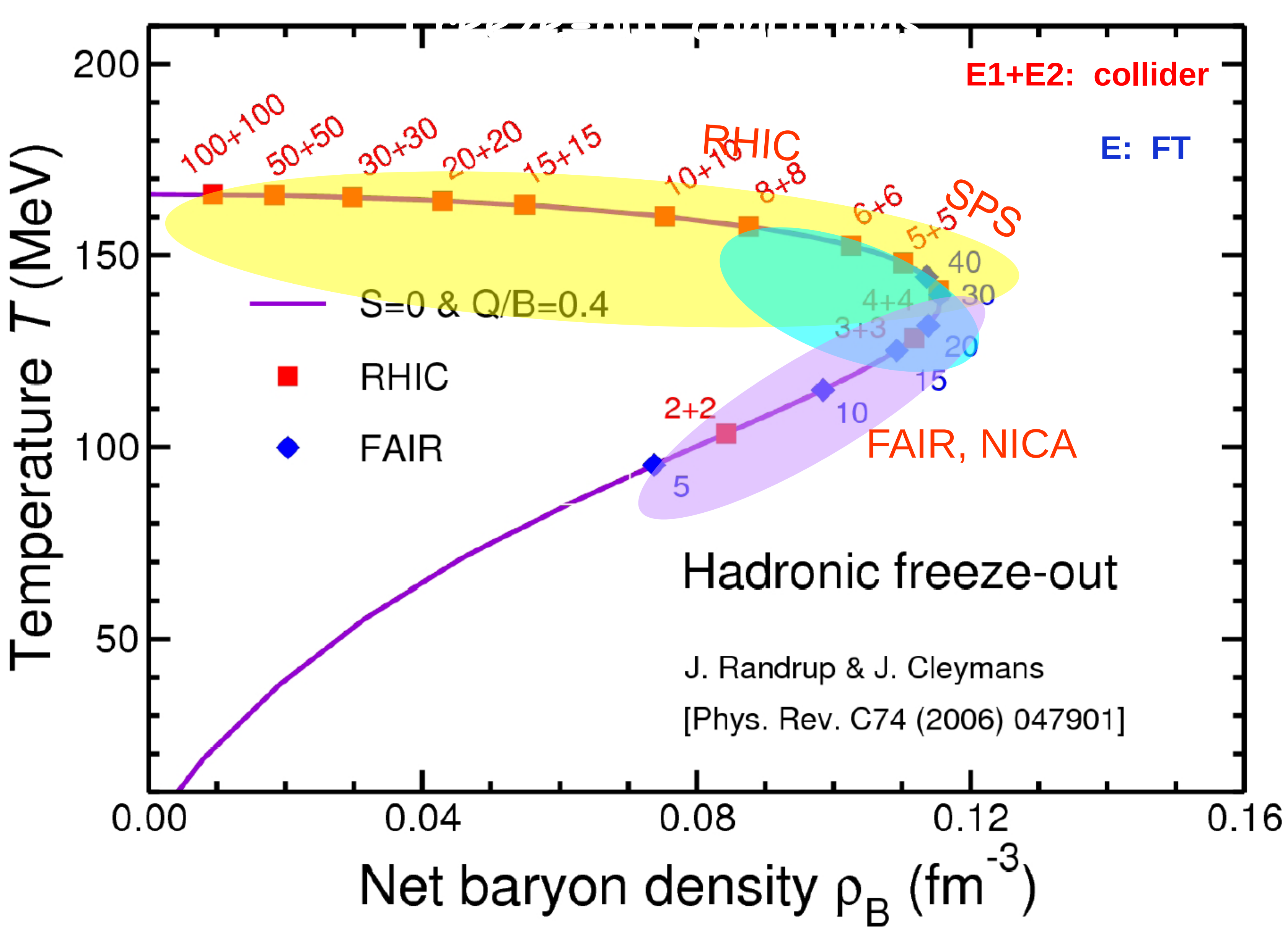


Technological part of the TDR (main equipment, engineering systems, etc), radiation and environmental safety, architecture had been fulfilled. Now – the final stage: capital spending sights. Plan – to submit all documents to the State Expertise – end of 2012.

Thank you for your attention !

NICA

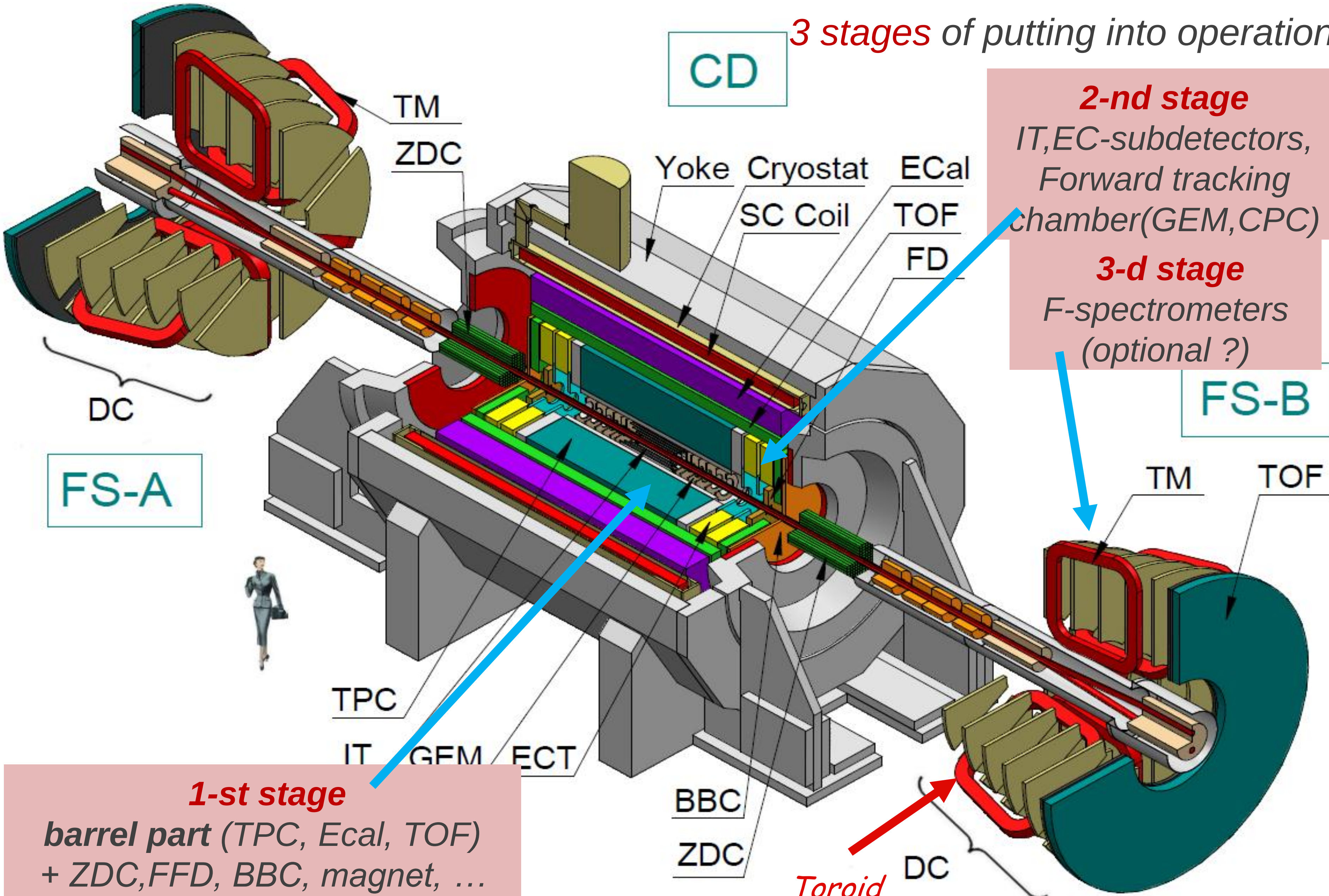
http://nica.jinr.ru



E1+E2: collider
E: FT
RHIC
SPS
FAIR, NICA
100+100
50+50
30+30
20+20
15+15
10+10
8+8
6+6
5+5
4+4
3+3
2+2
40
30
20
15
10
5
S=0 & Q/B=0.4
RHIC
FAIR
Hadronic freeze-out
J. Randrup & J. Cleymans
[Phys. Rev. C74 (2006) 047901]
Temperature T (MeV)
Net baryon density ρB (fm-3)
200
150
100
50
0.00
0.04
0.08
0.12
0.16

MultiPurpose Detector (MPD)

3 stages of putting into operation



2-nd stage
IT,EC-subdetectors,
Forward tracking
chamber(GEM,CPC)

3-d stage
F-spectrometers
(optional ?)

1-st stage
barrel part *(TPC, Ecal, TOF)*
+ ZDC,FFD, BBC, magnet, …

Particle yields, Au+Au @ $\sqrt{s_{NN}}$ = 8 GeV *(central collisions)*

Expectations for 10 weeks of running at L = $10^{27}cm^{-2}s^{-1}$ *(duty factor = 0.5)*

Particle	Yields		Decay mode	BR	*Effic. %	Yield/10 w
	4π	y=0				
π^+	293	97	----	---	61	$2.6 \cdot 10^{11}$
K^+	59	20	---	----	50	$4.3 \cdot 10^{10}$
p	140	41	---	----	60	$1.2 \cdot 10^{11}$
ρ	31	17	e+e-	$4.7 \cdot 10^{-5}$	35	$7.3 \cdot 10^{5}$
ω	20	11	e+e-	$7.1 \cdot 10^{-5}$	35	$7.2 \cdot 10^{5}$
φ	2.6	1.2	e+e-	$3 \cdot 10^{-4}$	35	$1.7 \cdot 10^{5}$
Ω	0.14	0.1	ΛK	0.68	2	$2.7 \cdot 10^{6}$
D^0	$2 \cdot 10^{-3}$	$1.6 \cdot 10^{-3}$	$K^+\pi^-$	0.038	20	$2.2 \cdot 10^{4}$
J/ψ	$8 \cdot 10^{-5}$	$6 \cdot 10^{-5}$	e+e-	0.06	15	10^{3}

***Efficiency includes the MPD acceptance, realistic tracking and particle ID.**
Particle Yields from experimental data (NA49), statistical and HSD models.
Efficiency from MPD simulations. **Typical efficiency from published data (STAR)**