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Project of the Nuclotron-based Ion Collider fAcility (NICA) at JINR

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JINR, Dubna

Contents

Introduction: The NICA Project Goals

The goal of the project is

construction at JINR of a new accelerator facility that provides

1a) Heavy ion colliding beams $^{197}Au^{79+} \times {}^{197}Au^{79+}$ at

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

at $L_{average}$= 1E27 $cm^{-2} \cdot s^{-1}$ (at $\sqrt{s_{NN}}$ = 9 GeV)

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

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)

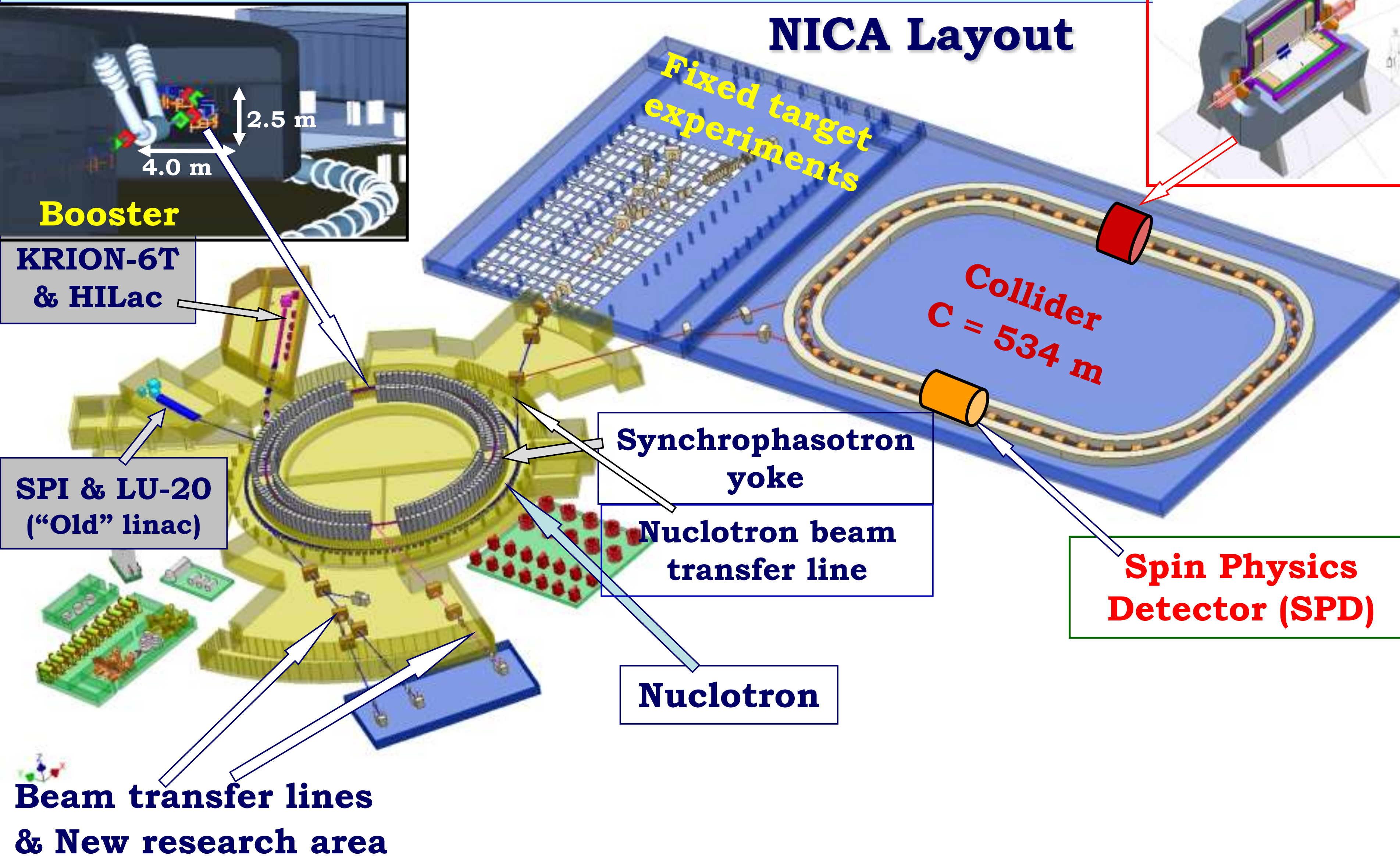
$L_{average} \geq$ 1E30 $cm^{-2} \cdot s^{-1}$ (at $\sqrt{s_{pp}}$ = 27 GeV)

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)

1. Facility Scheme and Operation Scenario



Heavy Ion Mode: Operation Regime and Parameters

Injector: 2×10^9 ions/pulse of $^{197}Au^{32+}$ at energy of 6.2 MeV/u

Collider (45 Tm)
Storage of
26 bunches by ~ $1\text{x}10^9$ ions per ring
at 1 - 4.5 GeV/u,
electron and/or stochastic cooling

Booster (25 Tm)
1(2-3) single-turn injection,
storage of 2□(4-6)$\times10^9$,
acceleration up to 100 MeV/u,
electron cooling, acceleration
up to 600 MeV/u

Stripping (80%) $^{197}Au^{32+}$ => $^{197}Au^{79+}$

Two SC collider rings

IP-1

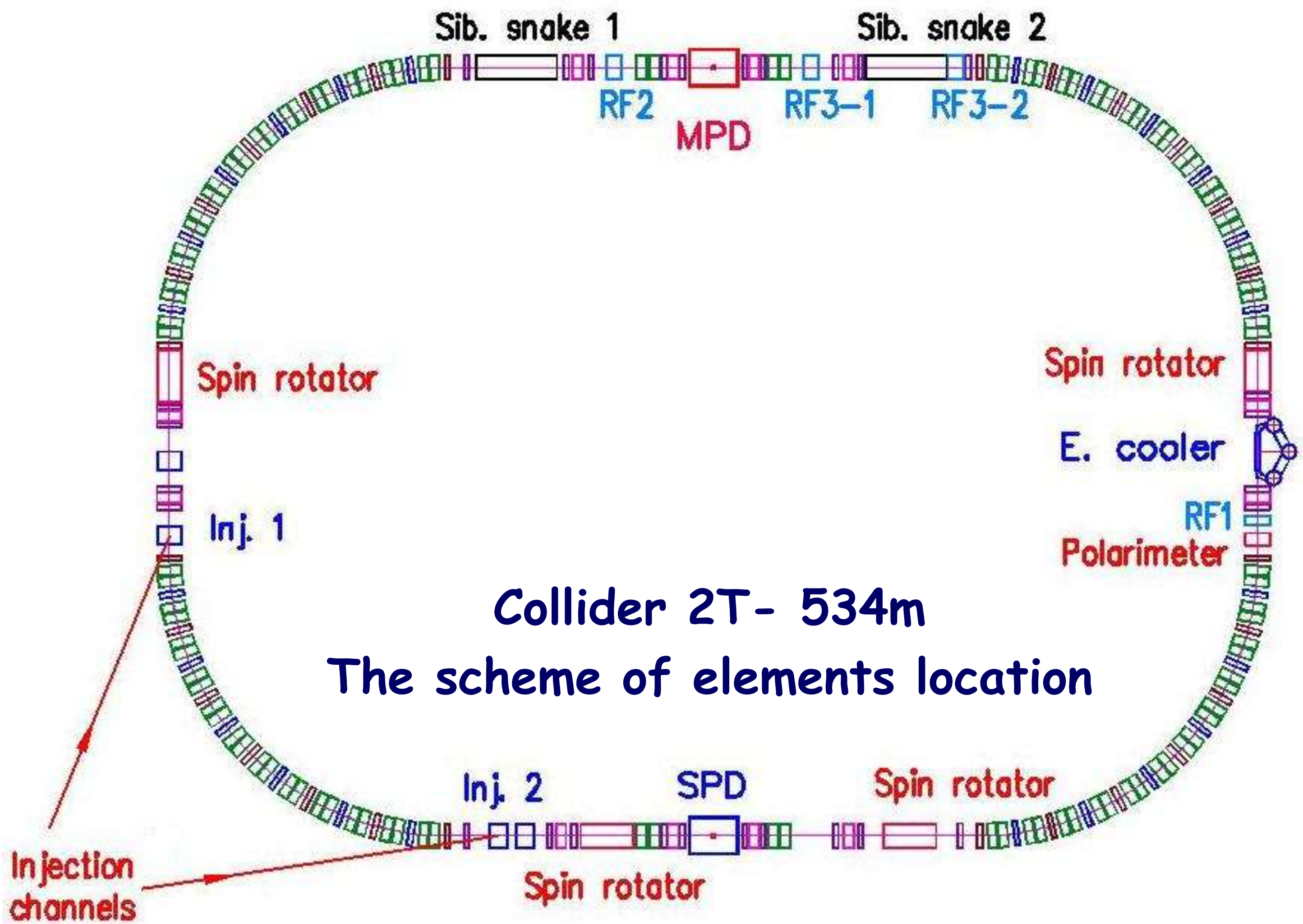
IP-2

Nuclotron (45 Tm)
injection of one bunch
of 1.1×10^9 ions,
acceleration up to
1 - 4.5 GeV/u max.

2x26 injection cycles

2. NICA Collider (Contnd)

2.1. Layout (Contnd)



Collider 2T- 534m

The scheme of elements location

2.2. Peak Luminosity

The main limitation of the collider luminosity are the beams space charge effects, which can be described by the following:

1. The Laslett tune shift:

$$\Delta Q = \frac{Z^2}{A} \cdot \frac{r_p N_i}{\beta^2 \gamma^3 4\pi\varepsilon_\sigma} \cdot k_{bunch}, \quad k_{bunch} = \frac{C_{Ring}}{\sqrt{2\pi} \cdot \sigma_s}.$$

2. The beam-beam parameter:

$$\xi = \frac{Z^2}{A} \cdot \frac{r_p N_b \left(1+\beta^2\right)}{4\pi\beta^2\gamma\varepsilon}$$

More essential is the first one. If $\Delta Q = Const$ with energy then luminosity is scaled with energy as $L \propto \beta^5\gamma^6\varepsilon_{geom} = \beta^4\gamma^5\varepsilon_{norm}$:

$$L = 8\pi^2 \beta^5 \gamma^6 \Delta Q^2 \frac{A^2}{Z^4} \cdot \frac{\varepsilon_{geom}}{r_p^2 \beta^*} \cdot \left(\frac{\sigma_s}{C_{Ring}}\right)^2 \cdot \frac{c n_{bunch}}{C_{Ring}}$$

, where σ_s is the bunch length,

f_{HG} – *"the hour-glass"* factor.

The ratio $C_{Ring}/n_{bunch} = l_{interbunch} = Const$ because it is limited by design of the collider lattice (a necessity to avoid "parasitic" bunch-bunch collisions in straight section). Thus

$$L(E) \propto (\sigma_s / C_{Ring})^2 / \beta^*$$

2.3. Luminosity preservation

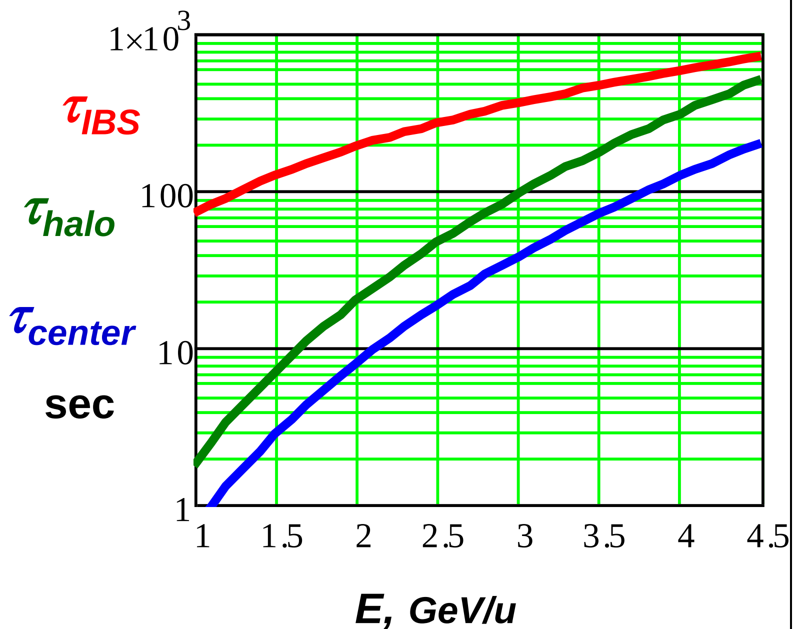
Beam life time defined by IBS

If ΔQ is fixed as before then beam life time by IBS is proportional to

$$\tau_{IBS} \propto \frac{A}{Z^2} \cdot \frac{\beta^2 \gamma^2 \varepsilon_{geom} \cdot (\Delta p / p) \cdot \sigma_s}{\Delta Q} \cdot f(\sigma_x, \sigma_y, \sigma_s, lattice\ functions)$$

Collider 2T - 534

τ_{IBS} and τ_{cool} (I_e = 1 A) vs ion energy



How to resolve the problem?

⇒ Smooth lattice functions to increase τ_{IBS}

(S.Kostromin, JINR & V.Lebedev, FNAL)

⇒ Stochastic cooling at

2.5 GeV/u < E < 4.5 GeV/u

(T.Katayama, G.Trubnikov, N.Shurkhno);

⇒ Electron cooling at

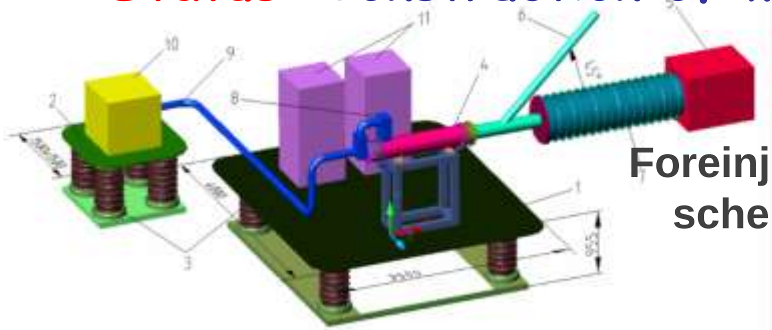
1.0 GeV/u < E < 2.5 GeV/u .

3. Status and plan of NICA elements development

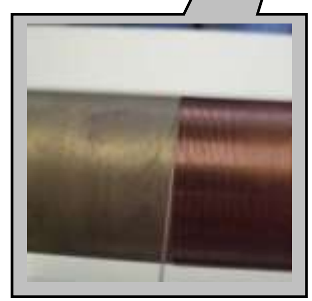
3.1. Heavy Ion Source KRION-6T

(E.D.Donets, E.E.Donets)

Status: Construction of working prototype



Foreinjector scheme

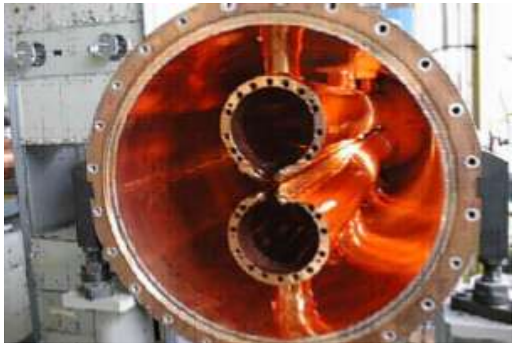


Automa[illegible] tool for solenoid spooling

Assembled vacuum and cryogenic vessels of the KRION-6T

3.2. Heavy Ion Linac (HILAc)

HILAC – 1 section of RFQ + 4 sections of Drift Tube Linac (DTL),



2H cavities of "Ural" RFQ (prototype)

Sector H-cavity of "Ural" RFQ DTL (prototype)

Status: Design at IHEP (Protvino) and JINR,

Construction at VNIIEF (Sarov) – recent agreement.

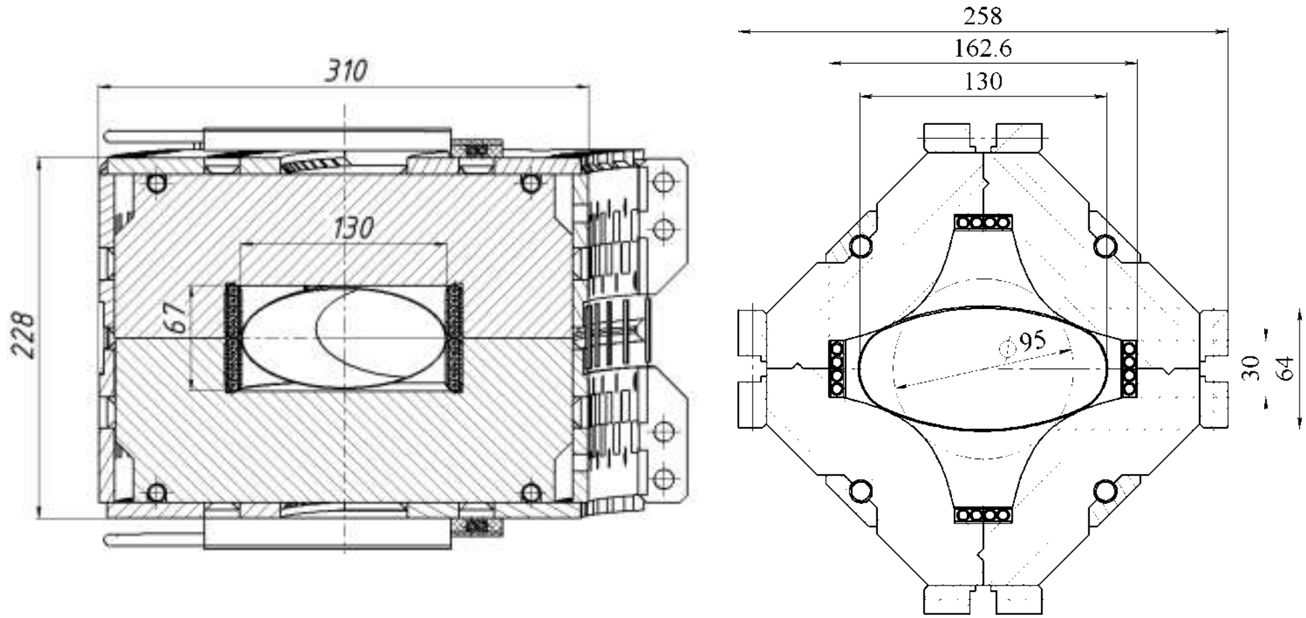
3.3. Booster

RF system: working design and manufacturing

(G.Kurkin and team, Budker INP, by contract)

3.3. Booster

SC magnetic system: manufacturing of magnet prototypes (H.Khodzhibagiyan and team)



Cross section of the Booster dipole and quadrupole lens

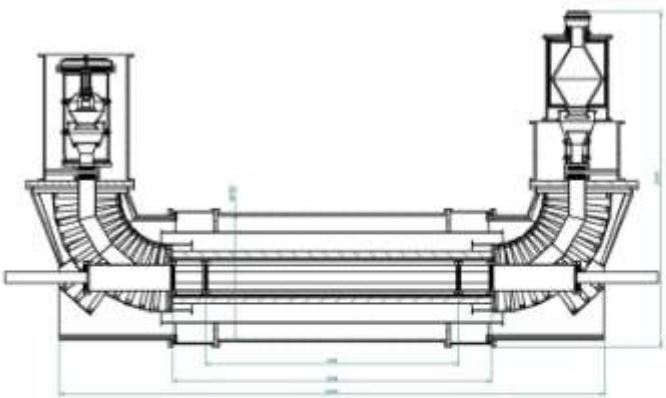
The tool for assembling a curved yoke for the Booster dipoles

Booster dipole yoke at assembling

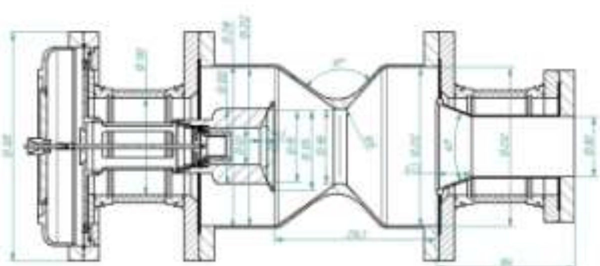
3.3. Booster

Electron cooler: working design

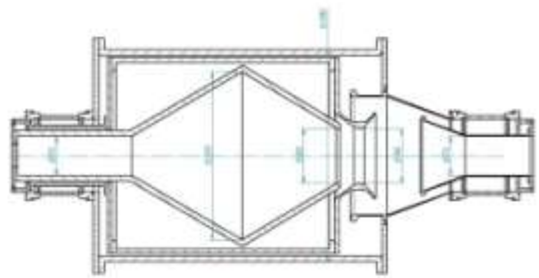
(A.Shabunov, A.Smirnov, N.Topilin, Yu.Tumanova, S.Yakovenko)



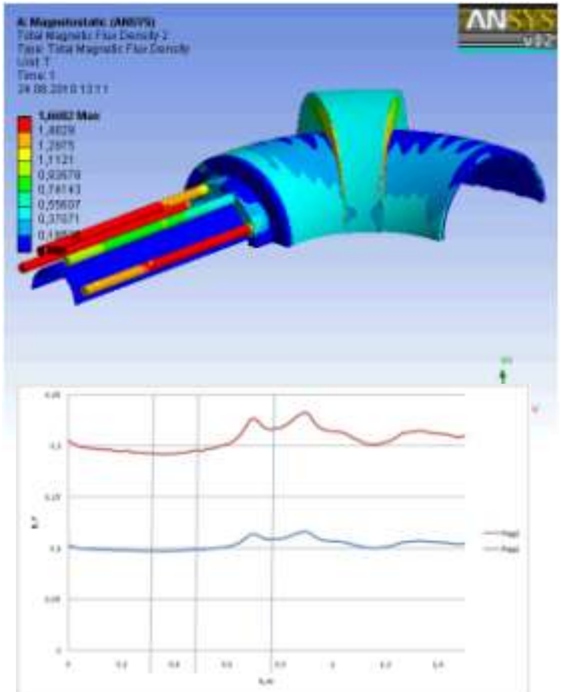
General view of the electron cooler



Electron gun



Electron collector



SC Solenoid field simulation (R.Pivin)

3.4. Nuclotron

Thorough upgrade since 2007 - after 14 years running

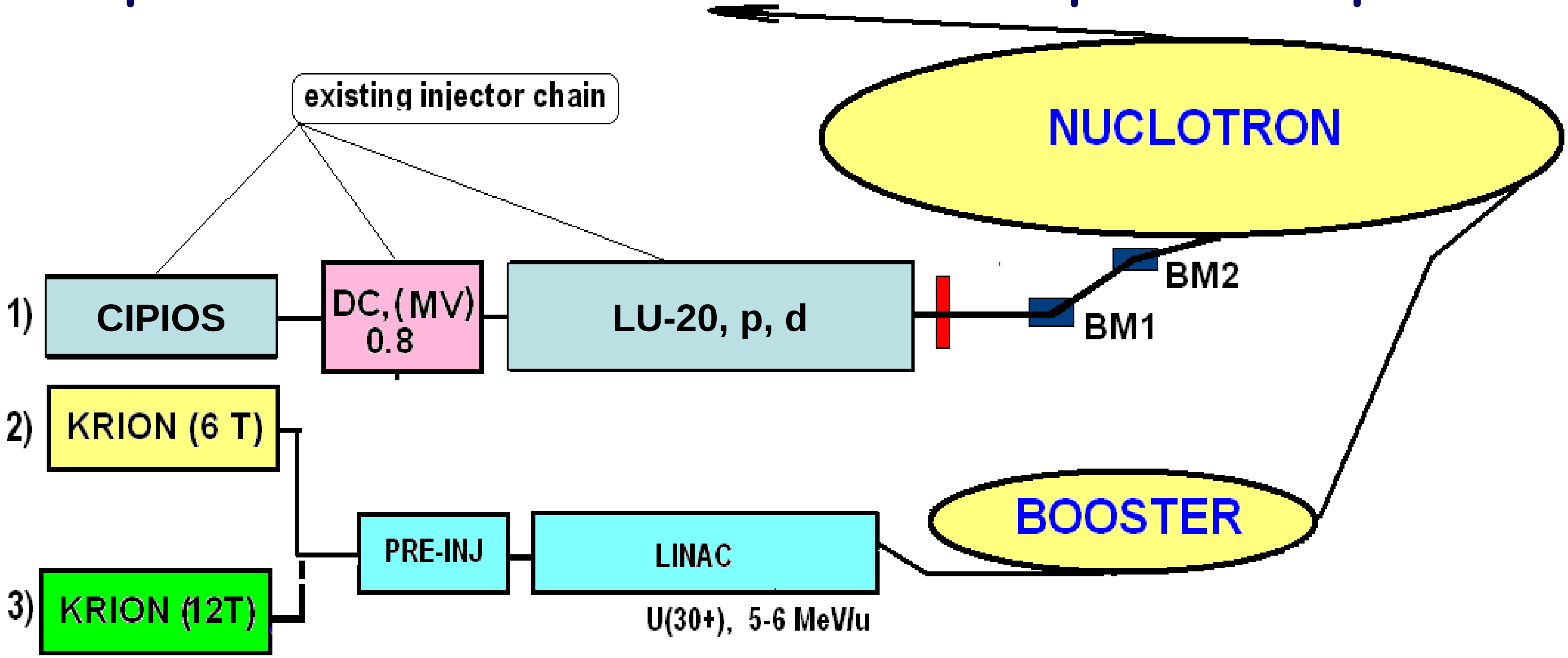
G.Trubnikov, N.Agapov, A.Bazanov, O.Brovko, A.Butenko, A.Govorov, E.Ivanov, V.Karpinsky H.Khodzhibagiyan, V.Mikhailov, V.Monchinsky, A,Sidorin, V.Slepnev, A.Smirnov, V.Volkov

3.4. Nuclotron (Contnd)

Parameter	Project	Status (March 2010)
Max. magn. field, T	2.05	1.8
Magn. rigidity, T·m	45	39.5
Cycle duration, s	2.0	5.0
B-field ramp, T/s	2.0	1.0
Accelerated particles	p–U, p↑, d↑	p-Xe, d↑
Max. energy, GeV/u	12.6(p), 5.87(d) 4.5($^{197}Au^{79+}$)	5.1(d), 1.0($^{124}Xe^{42+}$)
Intensity, ions/cycle	1E11(p,d), 1E9 (A > 100)	3E10 (p,d), 1E10 (d↑) 1E6 (Xe^{24+})

3.4. Nuclotron (Contnd)

Conceptual scheme of the accelerator complex development

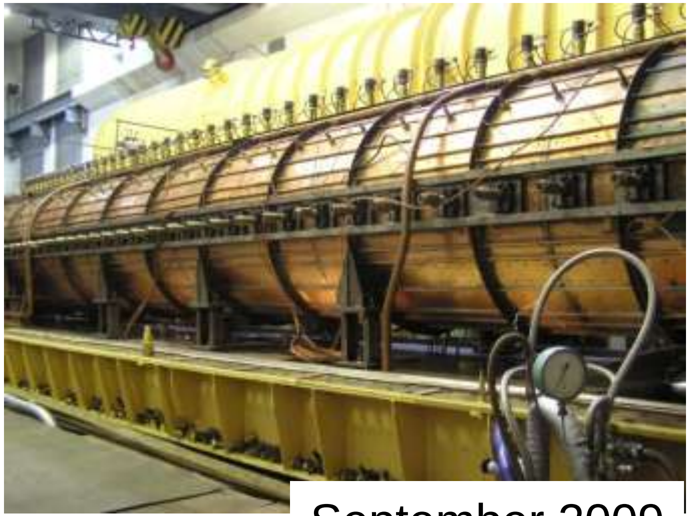


Polarized p↑ and d↑ beams and protons for p x Au collisions are planned to be accelerated with existing Linac LU-20.

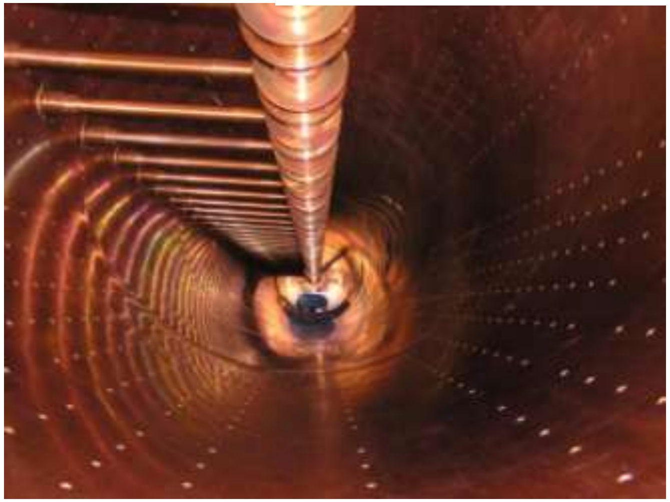
3.4. Nuclotron (Contnd)

Injector (LU-20) modernization

- Upgrade of the power supply system for injection channel;
- Upgrade of vacuum system for fore-injector.

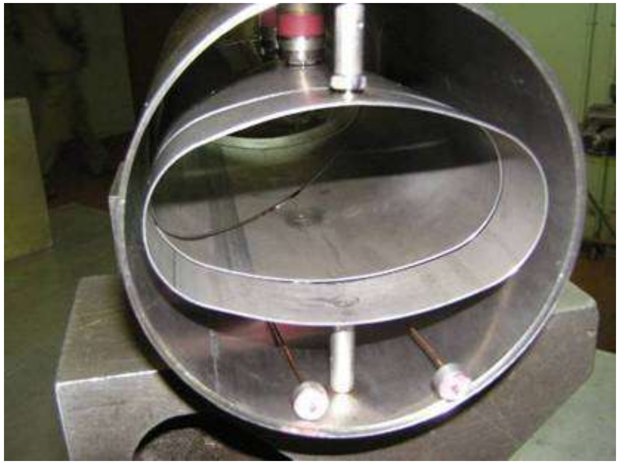


September 2009



3.4. Nuclotron (Contnd)

- Upgrade of Nuclotron vacuum system
- Upgrade of Nuclotron beam diagnostics system



Elliptical pick-up station

Assembled pick-up station

- Beam slow extraction system at maximum energy
- Upgrade of the power supplies and energy evacuation system of the SC magnets
- Upgrade of Nuclotron RF (acceleration) system
- Upgrade of the cryogenic supply system (towards NICA)

3.4. Nuclotron (Contnd)

Nuclotron-NICA

To be designed, constructed and commissioned:

1. Injection system (to accept Booster beam)
2. RF system – new version with bunch compression
3. Dedicated diagnostics
4. Single turn extraction with fine synchronization
5. Polarized protons acceleration in Nuclotron*)

*) Can be postponed

To be commissioned in 2014

3.4. Nuclotron (Contnd)

Test experiment on stochastic cooling at Nuclotron

Collaboration JINR / FZ Jülich

Slot-coupler structure

Stochastic cooling system prototype at Nuclotron for HESR/NICA

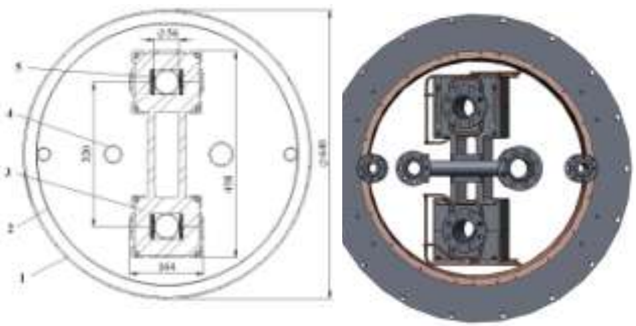
$2 \div 4$ GHz (~10 sec)

Vacuum tank with slot-coupler (FZJ)

3.5. Collider

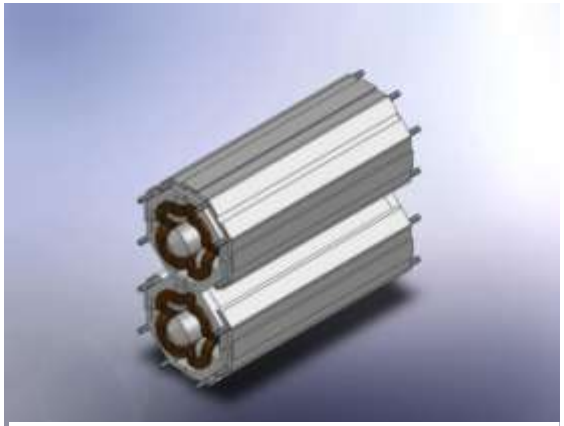
SC magnetic system: manufacturing of magnet prototypes

(H.Khodzhibagiyan and team)



a) Dipole cross-section

b) Dipole 3D view



c) Quadrupole

"Twin" magnets of NICA collider:

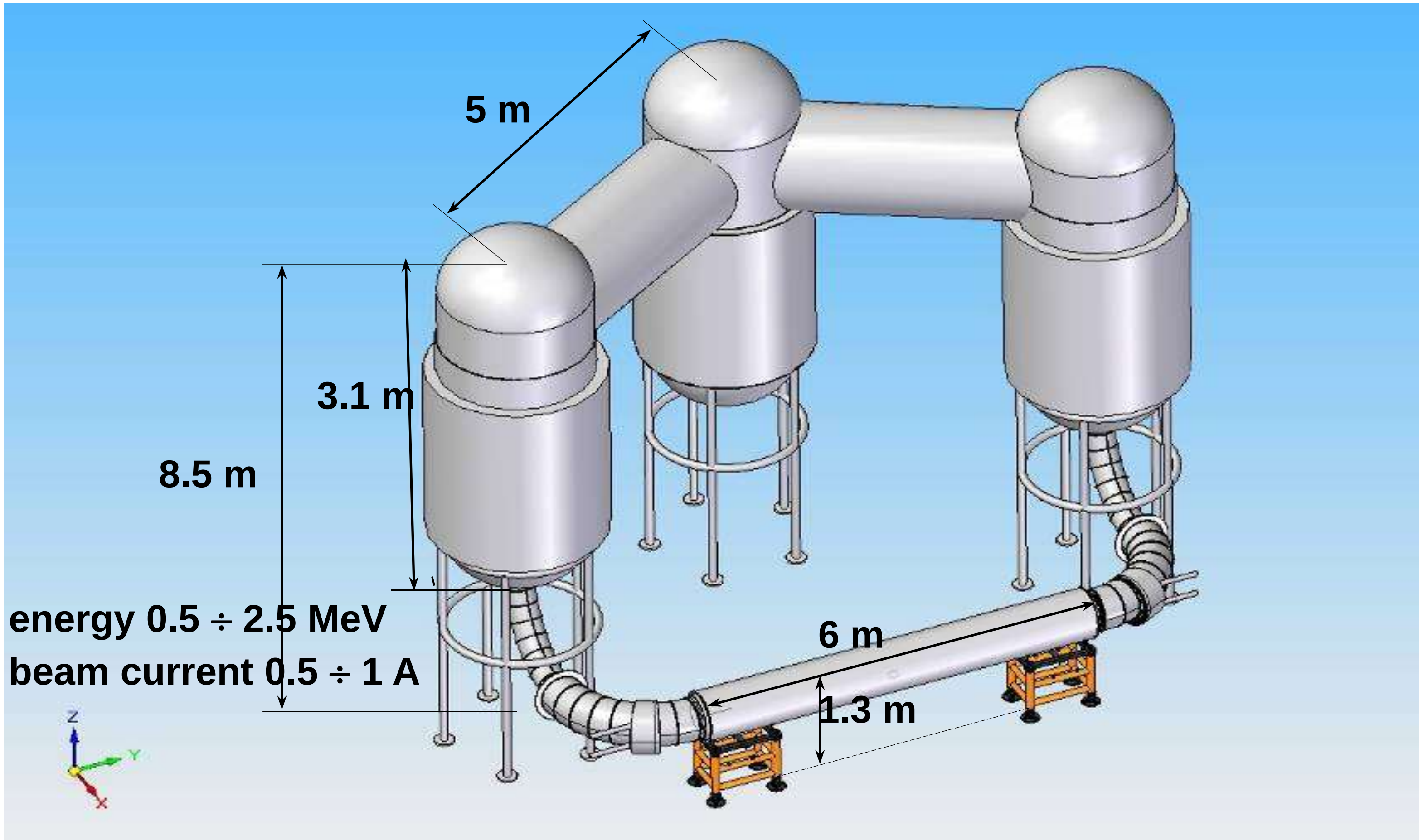
Max. field - 2T, super-ferric (Nuclotron-like), double aperture

3. Status and plan of NICA elements development (Contnd)

3.5. Collider (Contnd)

HV Electron cooler: working design

A.Shabunov, A.Smirnov, N.Topilin, Yu.Tumanova, S.Yakovenko – JINR
A.Filippov, M.Pashin, L.Fisher – All-Russian Institute for Electrotechnique



Electron energy 0.5 ÷ 2.5 MeV
Electron beam current 0.5 ÷ 1 A

3. Status and plan of NICA elements development (Contnd)

3.5. Collider (Contnd)

- **Stochastic cooling system: conceptual design, test experiment**

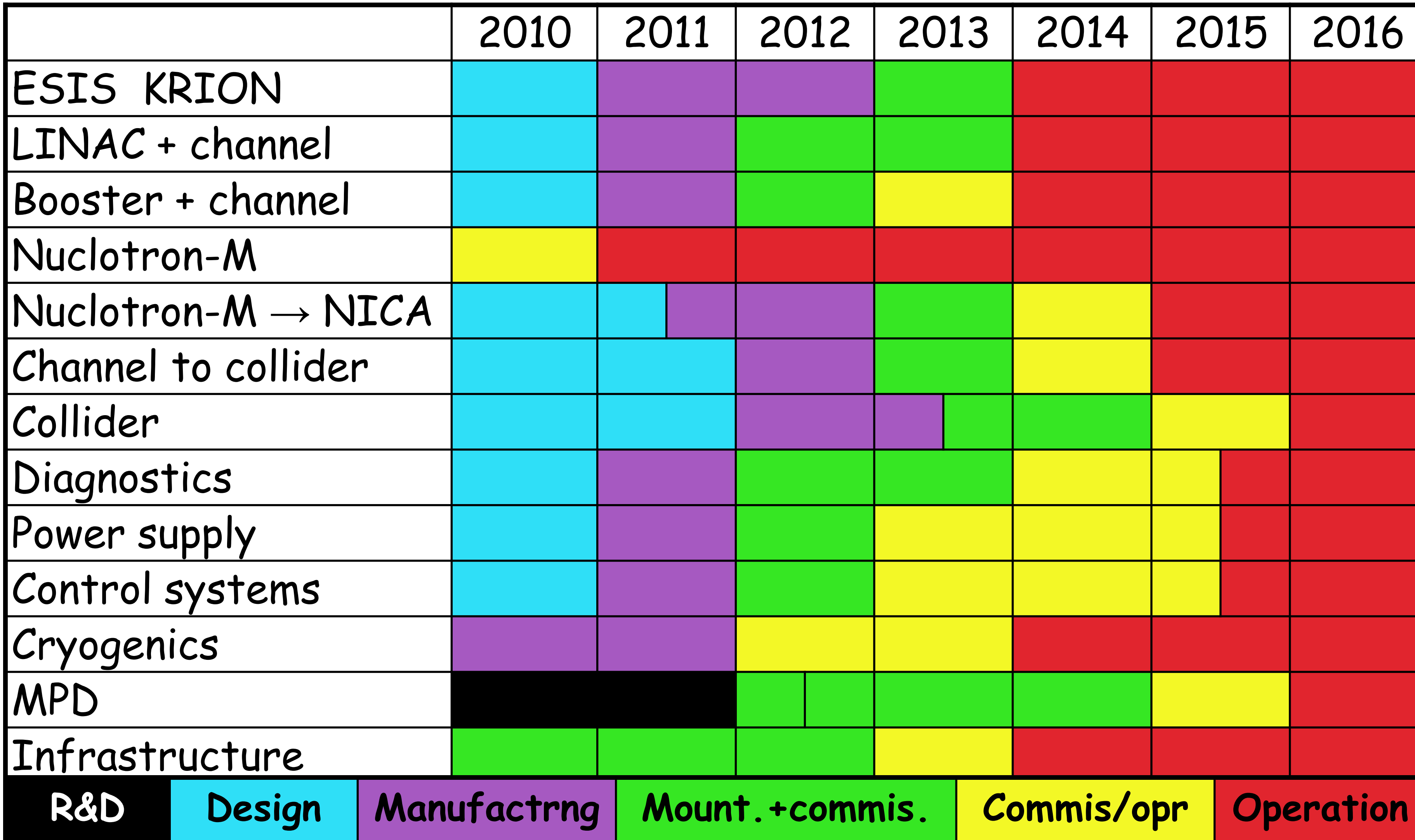
G.Trubnikov, N.Shurkhno, V.Seleznev– JINR, T.Katayama – Tokyo univ., R.Stassen – FZJ, L.Thorndahl - CERN

- **RF systems (Barrier Bucket system, bunching and maintaining RF systems): working design and manufacturing**

A.Eliseev, JINR

G.Kurkin and team, Budker INP, by contract

3.7. NICA construction schedule



3.7. NICA construction schedule (Contnd)

The main tasks for the NICA project

In 2010:

- Conceptual / working design of the collider,
- Preparation of the project for the state expertise in accordance with regulations of Russian Federation (under preparation in *The State Specialized Project Institute*, Moscow),
- Construction of SC magnets prototypes.

In 2011:

- Passing through the state expertise,
- Beginning of construction of the HILAC, KRION (working version),

  Booster, the Collider elements,
- Stochastic cooling experiment at Nuclotron.

Conclusion

The NICA design passed the phase of concept formulation and is presently under

- ✓ detailed simulation of accelerator elements parameters,
- ✓ development of working project,
- ✓ manufacturing and construction of prototypes,
- ✓ preparation of the project for state expertise in accordance with regulations of Russian Federation.

The project realization plan foresees a staged construction and commissioning of accelerators forming the facility. The main goal is the facility commissioning in 2015.

NICA

Thank you for your attention!