Critical Point and Onset of Deconfinement (CPOD)

23 - 29 August 2010 at Joint Institute for Nuclear Research

Status of NICA Project

I.Meshkov for NICA Project Group

JINR, Dubna

Nuclotron-based Ion Collider fAcility (NICA)

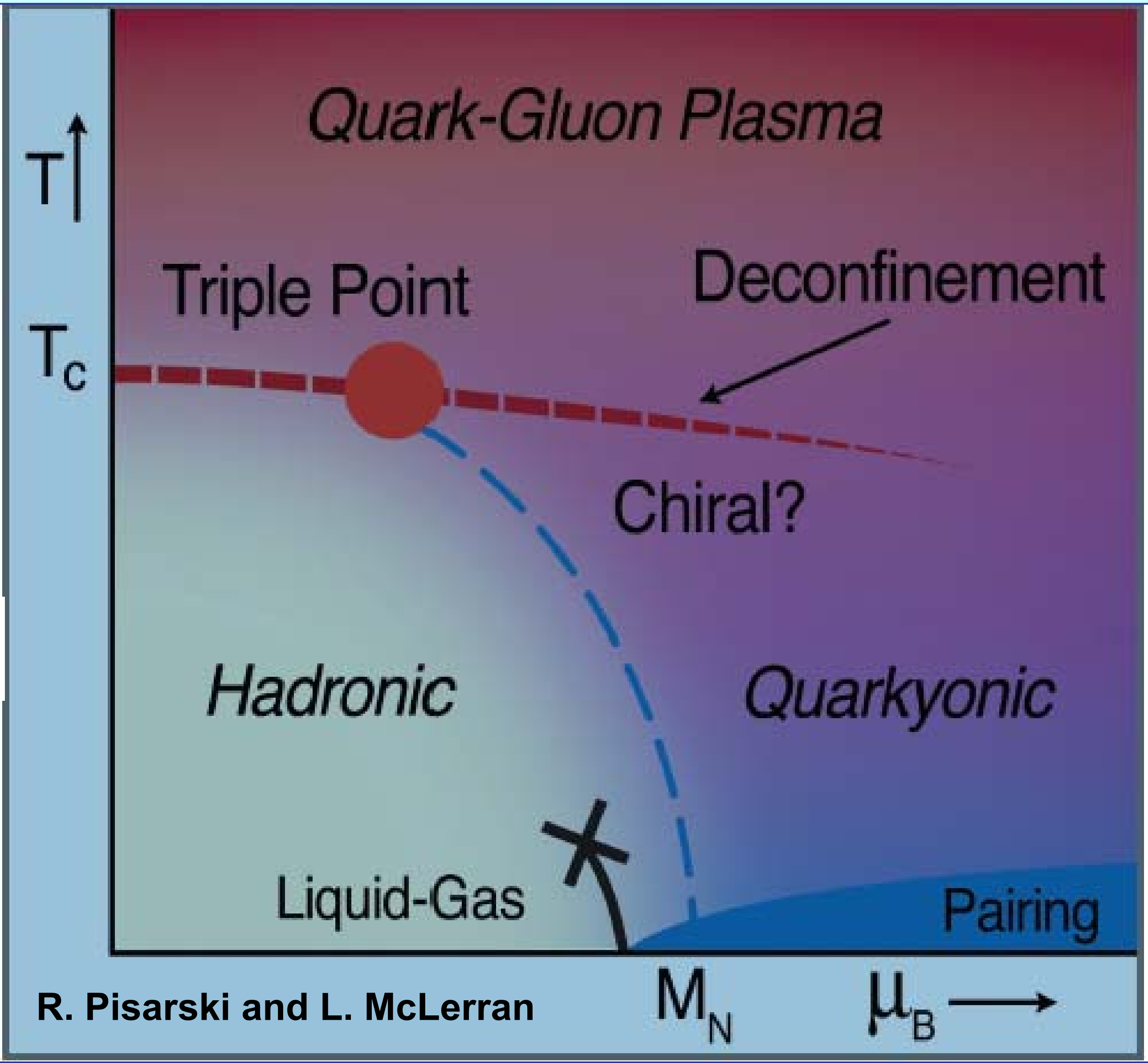
Contents

Introduction: The NICA Project Goals

J.Clemans,
19 Feb. 2010,
Sci. Council of JINR

L.McLerran,
15 July 2010,
JINR Seminar

CPOD'2010,
August 2010



Introduction: The NICA Project Goals

The goal of the project is

<u>construction at JINR of a new accelerator facility</u>

that provides

1a) Heavy ion colliding beams $^{197}Au^{79+}$ x $^{197}Au^{79+}$ 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:

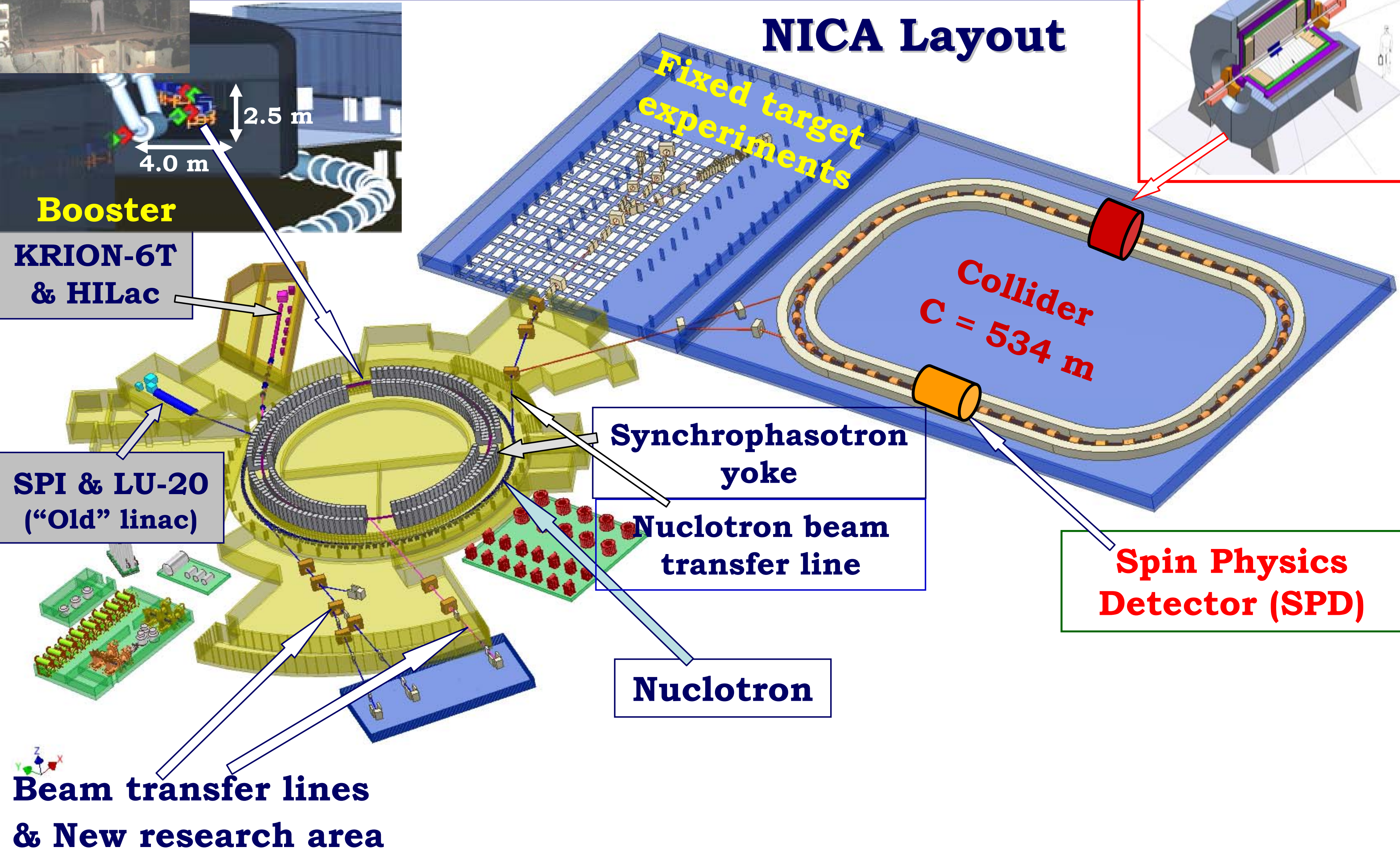
Li ÷ Au = 1 ÷ 4.5 GeV /u ion kinetic energy

p, p↑ = 5 ÷ 12.6 GeV kinetic energy

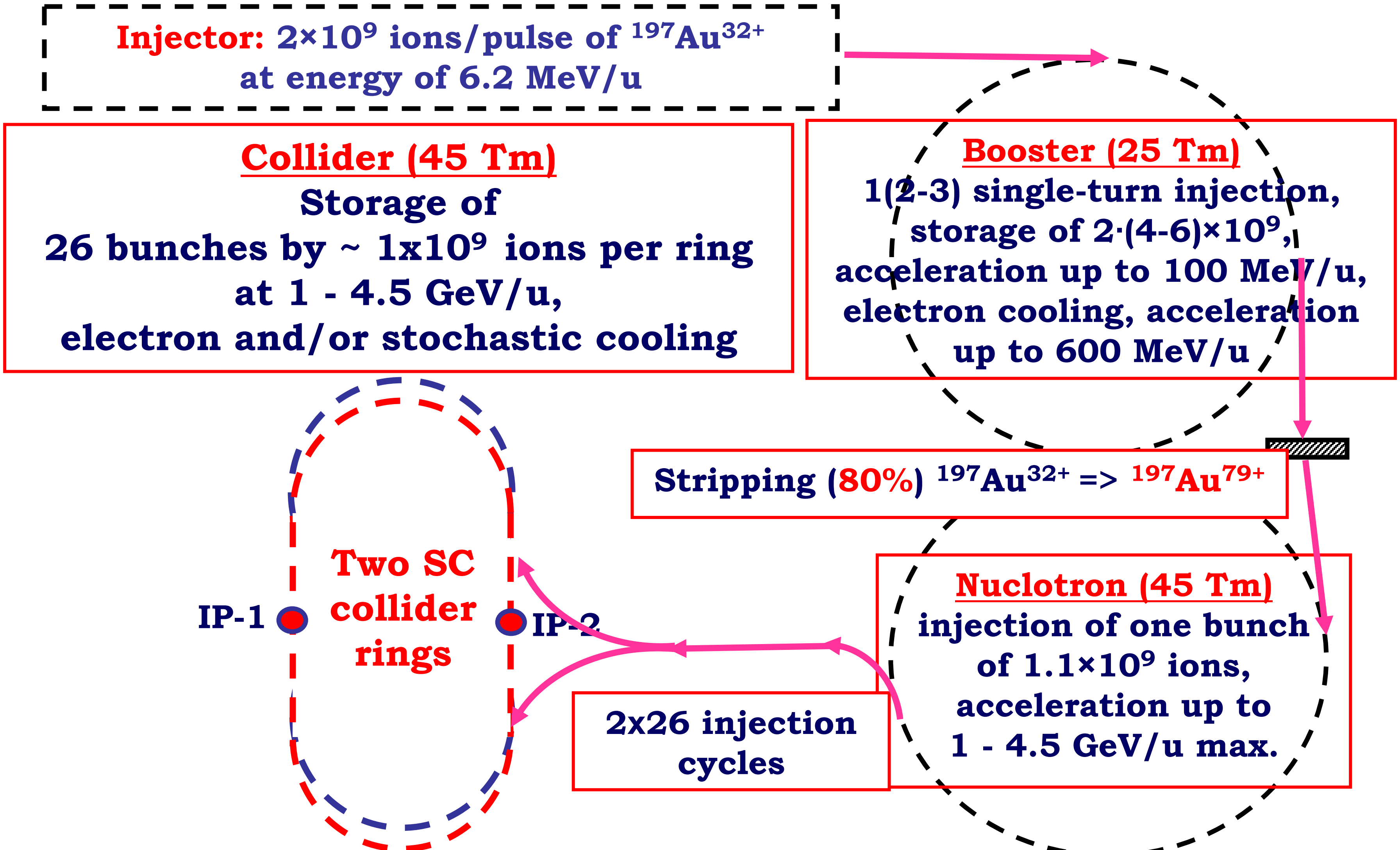
d, d↑ = 2 ÷ 5.9 GeV/u ion kinetic energy

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

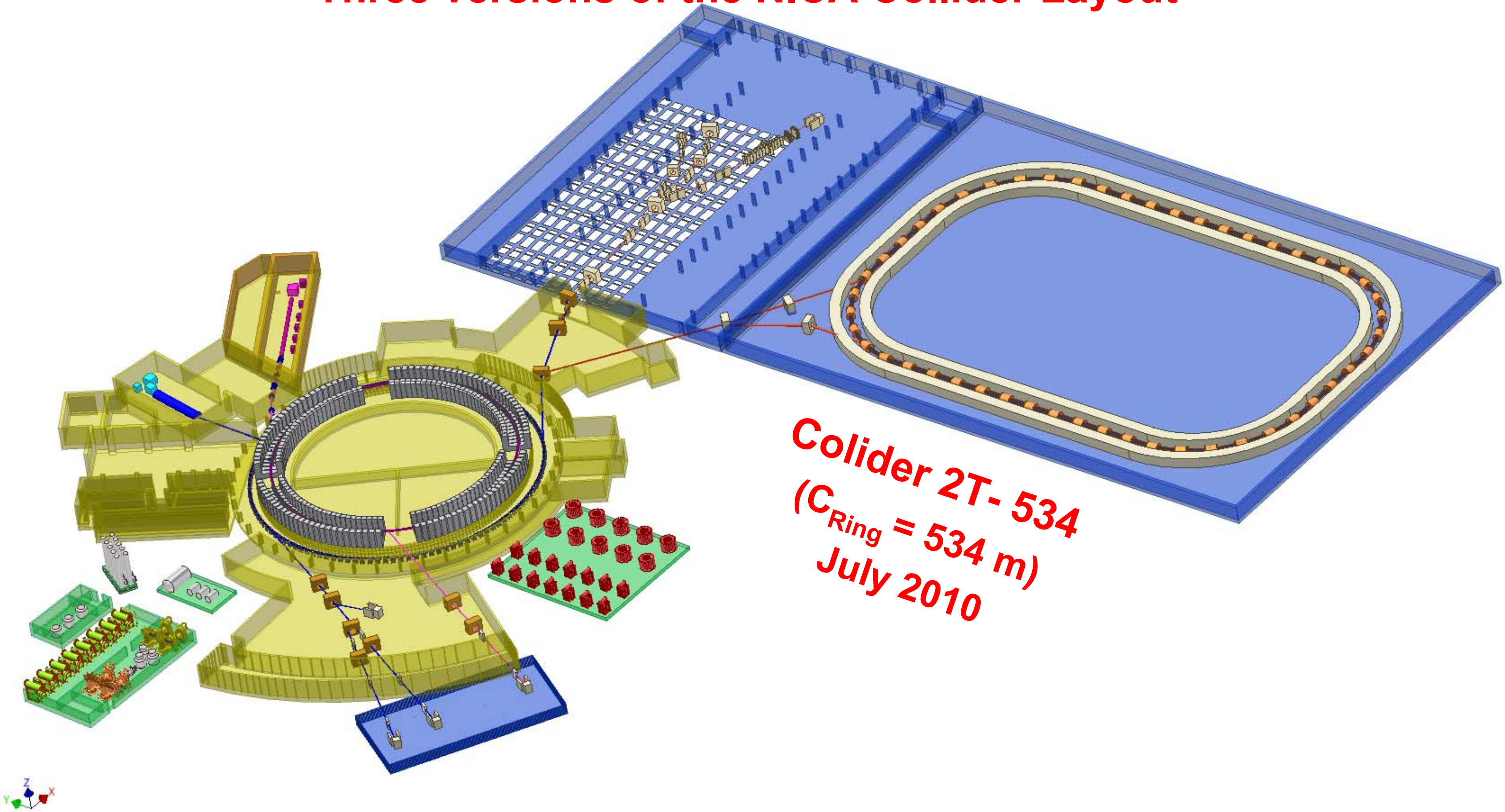


Heavy Ion Mode: Operation Regime and Parameters



2. NICA Collider
2.1. Layout

Three versions of the NICA Collider Layout

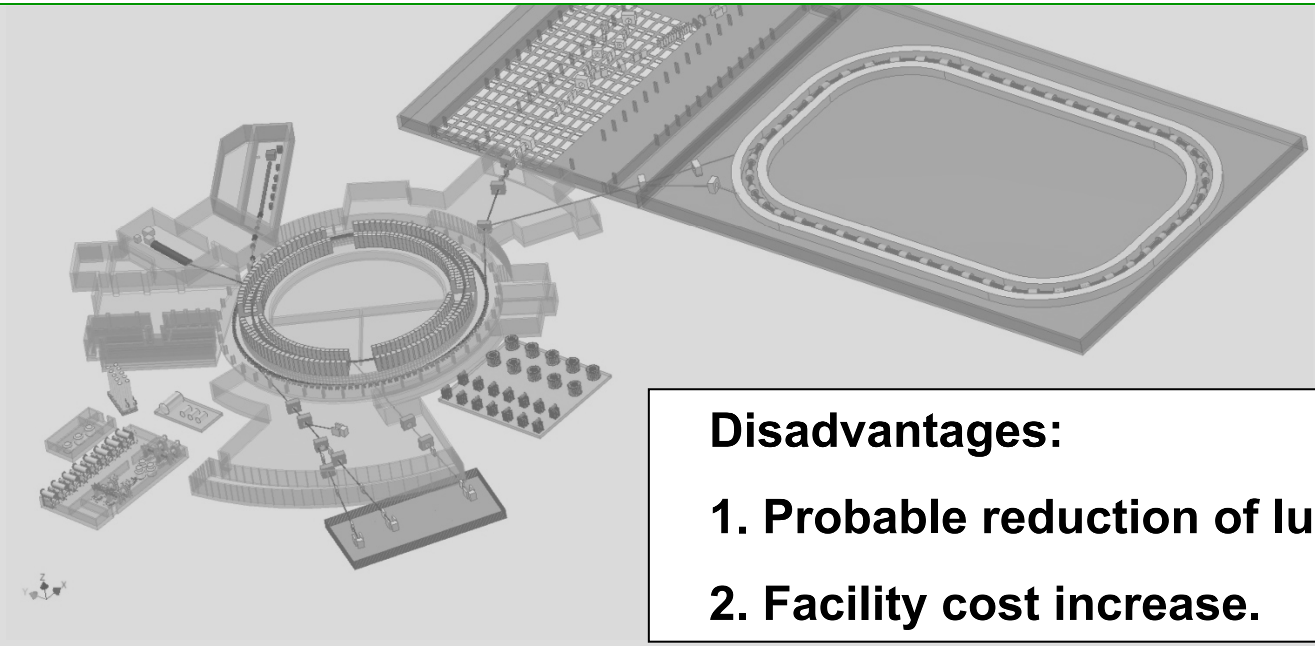


2.1. Layout (Contnd)

Collider 2T- 534

Advantages of such a large circumference:

1. Sufficient space for lattice elements and "insertion devices" (RF cavities, inflectors, electron and stochastic coolers, spin rotators, etc.) that makes possible to construct such a multifunctional collider;
2. Continuation of existing fixed target experiments and independent construction of new ones (including test lines for MPD and SPD elements).

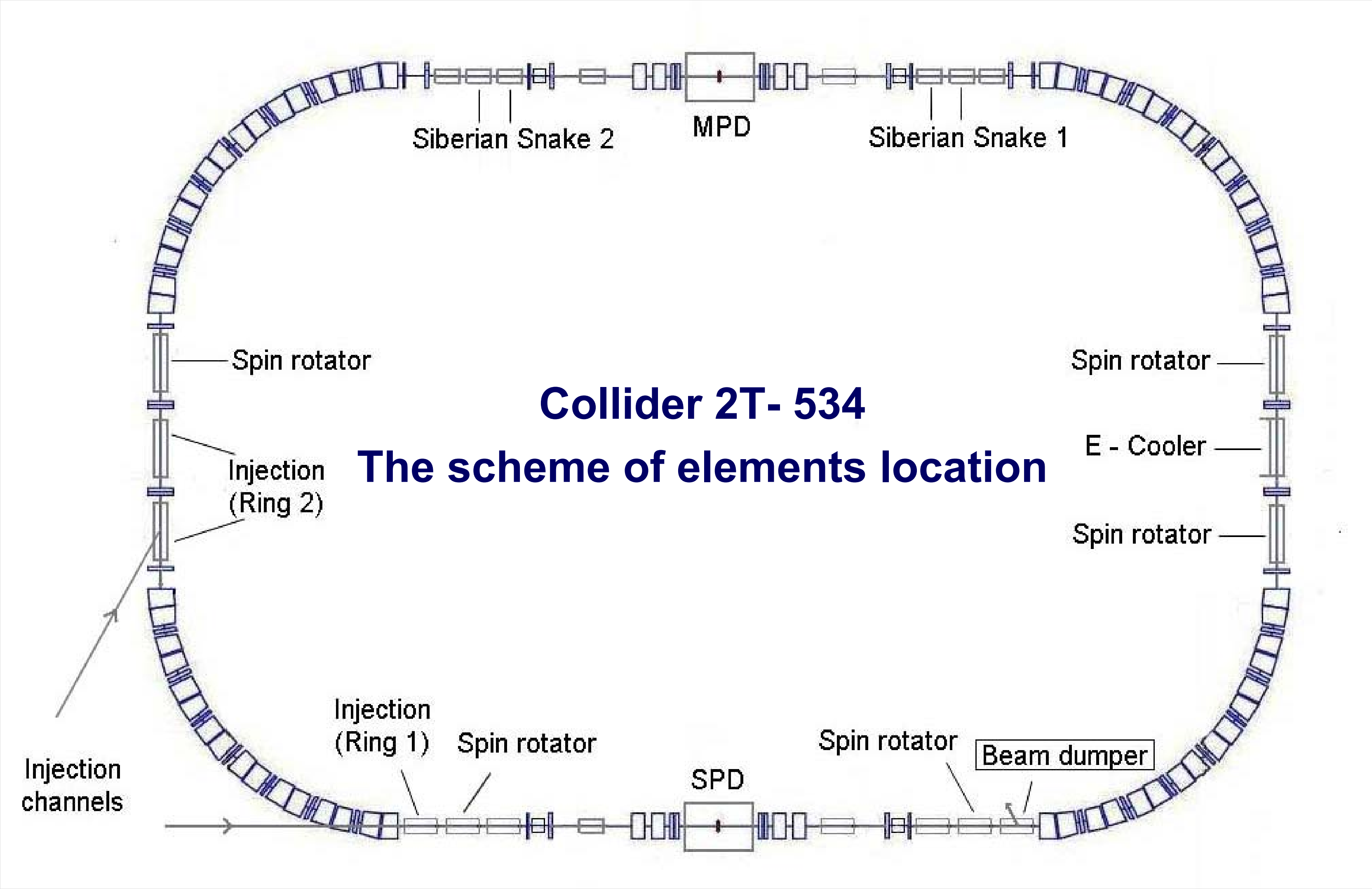


Disadvantages:

1. Probable reduction of luminosity (?);
2. Facility cost increase.

2. NICA Collider (Contnd)

2.1. Layout (Contnd)



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:

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

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

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

, 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

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

2.2. Peak Luminosity (Contnd)

The reduction of peak luminosity with collider circumference enlargement can be compensated by a proper choice of the beam and lattice parameters:

C_{Ring}, m	251	534
σ_s, m	0.3	0.6
β^*, m	0.5	0.35
L_{534} / L_{251}	0.86	

$$L(E) \propto (\sigma_s / CRing)^2 / \beta^*$$

2.2. Peak Luminosity (Contnd)

Luminosity scaling with energy

When ΔQ is fixed the peak luminosity is scaled with energy as the following (two outmost cases):

1. $L_1(E) = Const \cdot \beta^5 \cdot \gamma^6$ if unnormalized ("geometrical") emittance is constant;

2. $L_2(E) = Const \cdot \beta^4 \cdot \gamma^5$ if normalized emittance is constant.

Here $\beta(E)$ and $\gamma(E)$ are Lorenz factors.

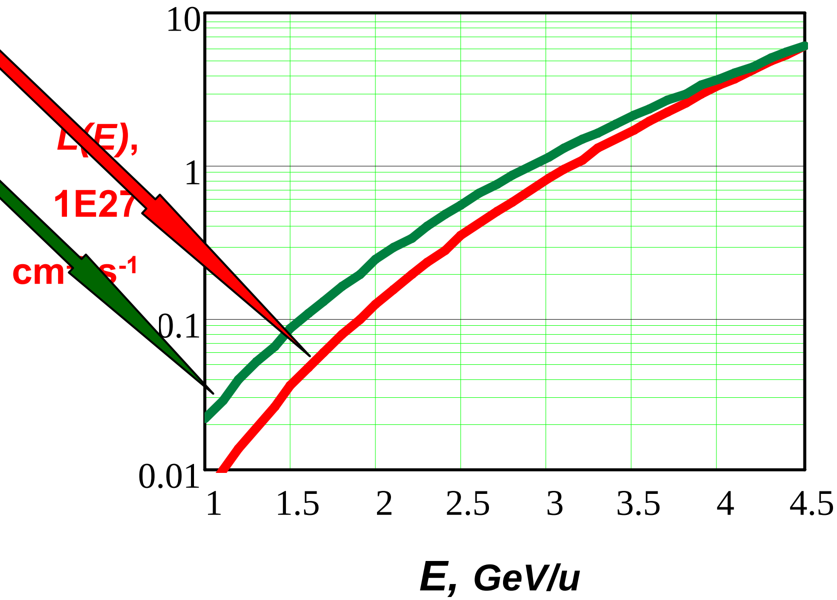
Luminosity scaling

for collider 2T- 534

L(4.5 GeV/u) = 6E27 $cm^{-2} \cdot s^{-1}$

L (3.5 GeV/u) = (1.7÷2.1)E27

L(1 GeV/u) = (0.7÷2.1)E25



2.3. Luminosity preservation

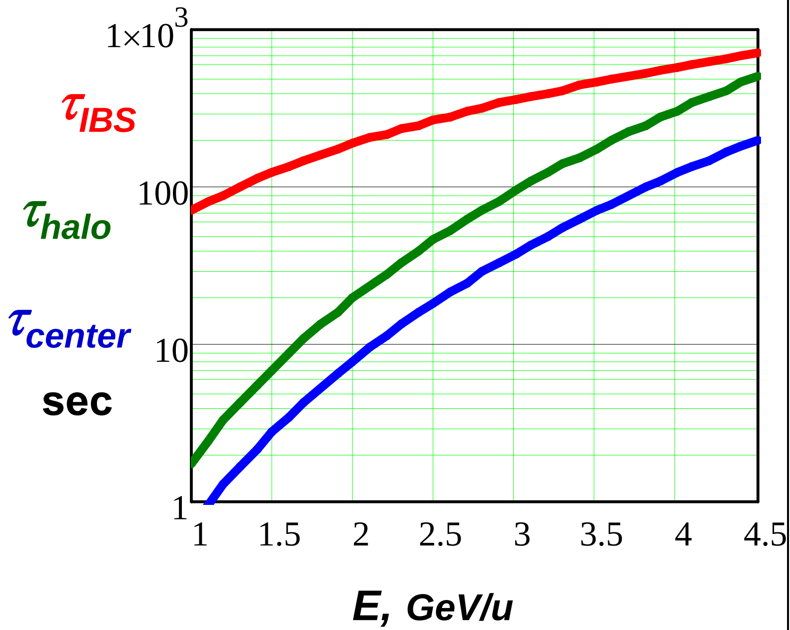
Beam life time defined by IBS

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);

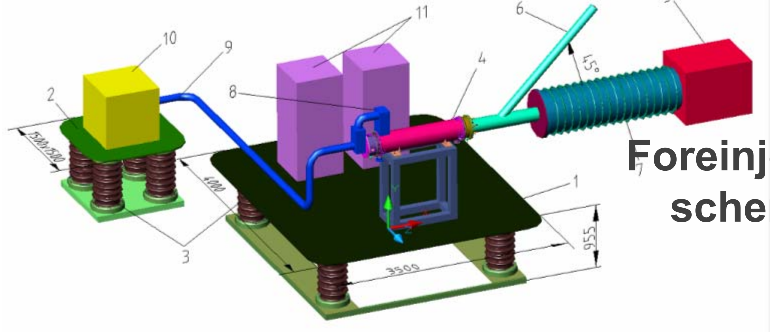
⇒ Electron cooling at 1.0 GeV/u < E < 2.5 GeV/u .

3. Status and plan of NICA elements development

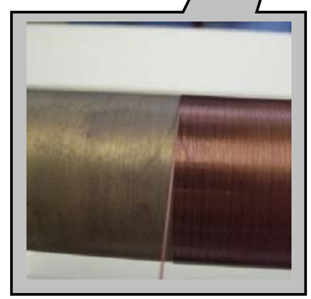
3.1. Heavy Ion Source KRION-6T

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

Status: Construction of working prototype



Foreinjector scheme



Automa tool for solenoid spooling

Assembled vacuum and cryogenic vessels of the KRION-6T

3.1. Heavy Ion Source KRION-6T (Contnd)

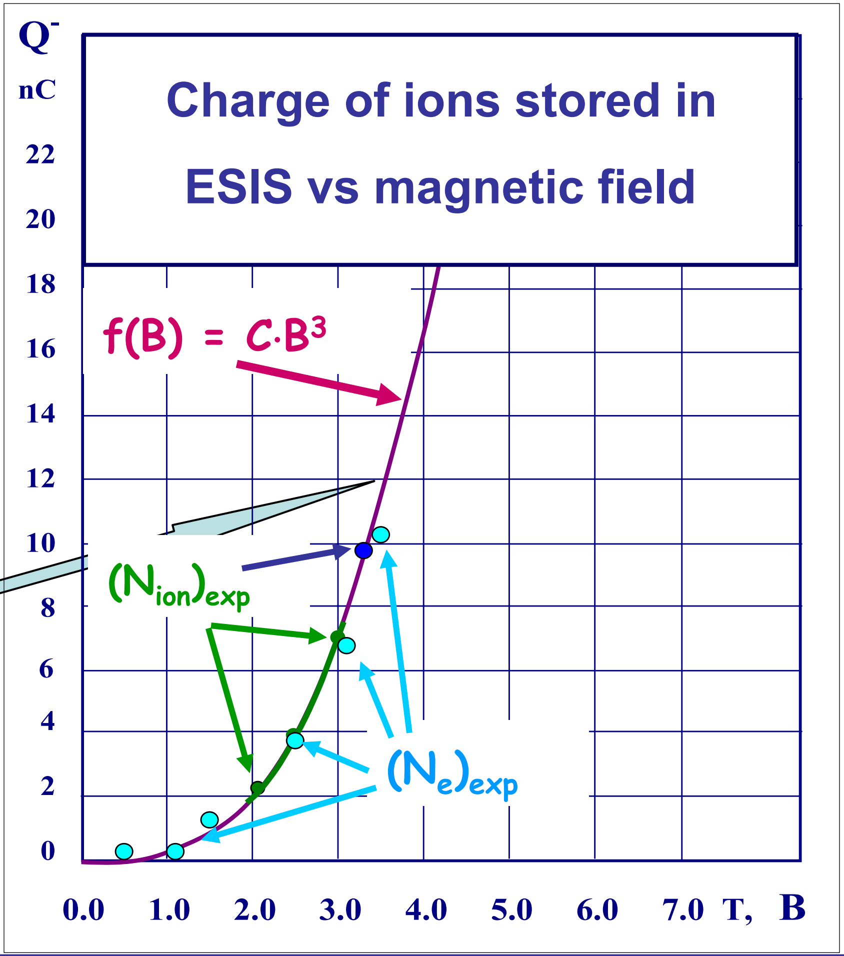
(E.D.Donets, E.E.Donets)

What is KRION?

Electron Beam Ion Source (EBIS) and its modification Electron String Ion Source (ESIS) ⇒ KRION source (Cryogenic Ion Source)

Why 6 T ?

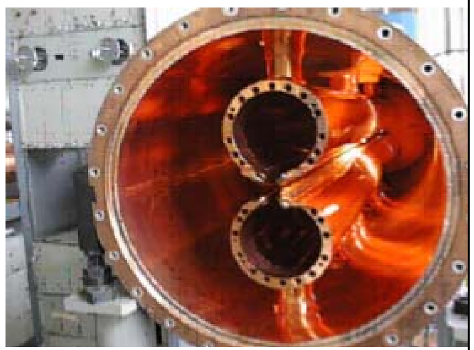
$Q(B) = C \cdot B^3$



3. Status and plan of NICA elements de

3.2. Heavy Ion

HILAC – 1 section of RFQ + 4 sect



2H cavities of "Ural
RFQ (prototype)

Status: Design at IHEP (Prot

Construction at VNIIE

JT:ИЯРФ НОМЕР ТЕЛЕФОНА:8313045569 25 АВГ. 2010 10:39 СТР1

РФЯЦ ВНИИЭФ

Государственная корпорация по атомной энергии "Росатом"
Федеральное государственное унитарное предприятие
РОССИЙСКИЙ ФЕДЕРАЛЬНЫЙ ЯДЕРНЫЙ ЦЕНТР
Всероссийский научно-исследовательский институт экспериментальной физики
ФГУП "РФЯЦ – ВНИИЭФ"

607188, Нижегородская обл. г.Саров, пр. Мира, д.37
Телетайп 151535 "Мимоза" Факс 83130 29494
E-mail staff@vniief.ru

25.08.10 № 594дп
на № 010-36/1063 от 02.08.2010

Главному инженеру ОИЯИ, г.Дубна
Г.Д. Ширкову
Руководителю проекта NICA
И.Н. Мешкову

О возможности изготовления линейного ускорителя

Прошу вас для оценки возможности изготовления в РФЯЦ-ВНИИЭФ линейного ускорителя (линака) тяжелых ионов типа RFQ выслать в наш адрес по электронной почте (zavyalov@expd.vniief.ru) комплект рабочей конструкторской документации в формате *.cdw (CAD-пакет «Компас») или *.pdf (редактор Adobe Acrobat).

С уважением,

Директор ИЯРФ Н.В. Завьялов

Будников Дмитрий
Владимирович 29000
БД 1 24.08.2010

…институт …ных исследований
…ходящий 557
25 08 2010
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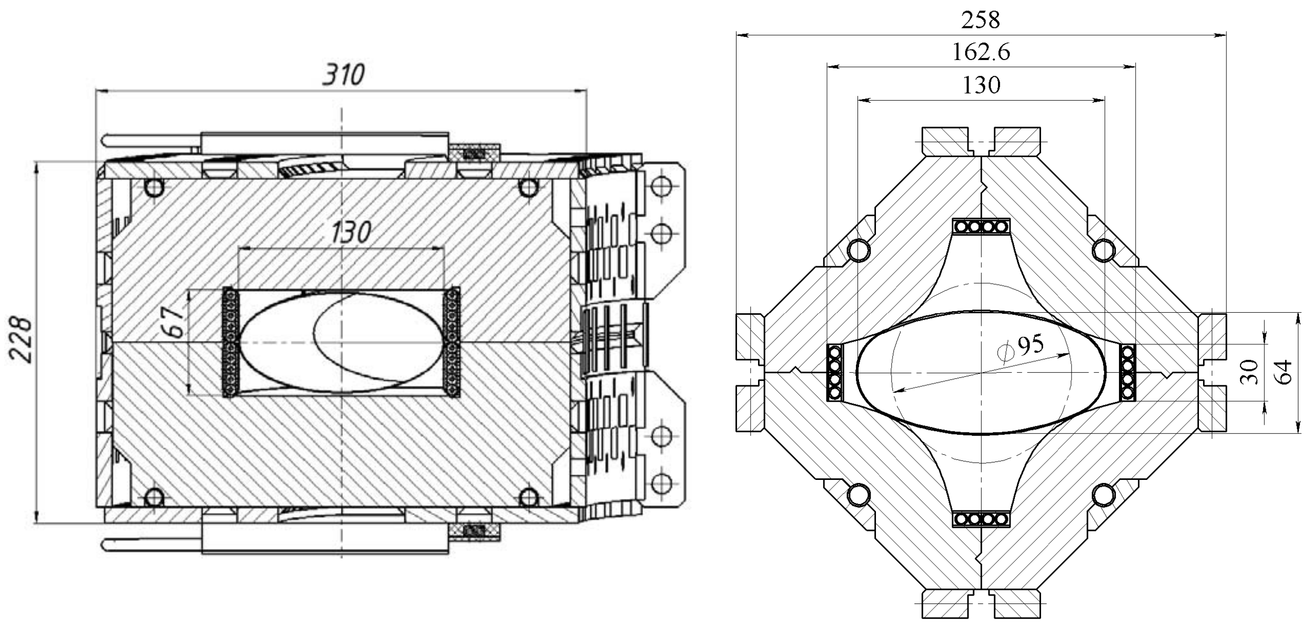
3.3. Booster

RF system: working design and manufacturing

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

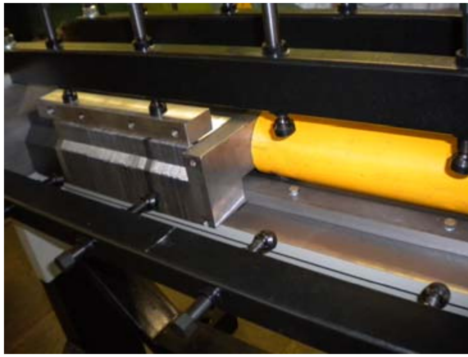
3.3. Booster

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

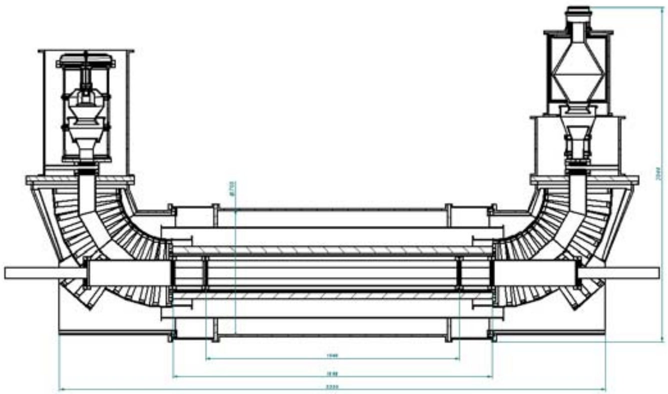


Booster dipole yoke at assembling

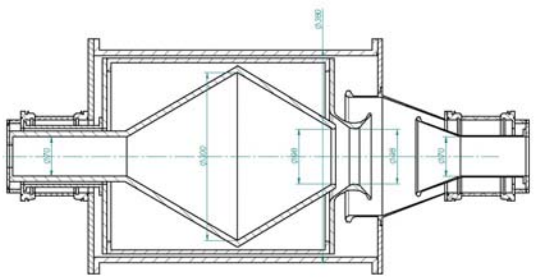
3.3. Booster

Electron cooler: working design

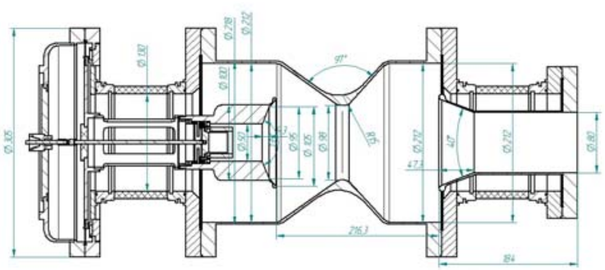
(A.Shabunov, A.Smirnov, N.Topilin, Yu.Tumanova, S.Yakovenko)



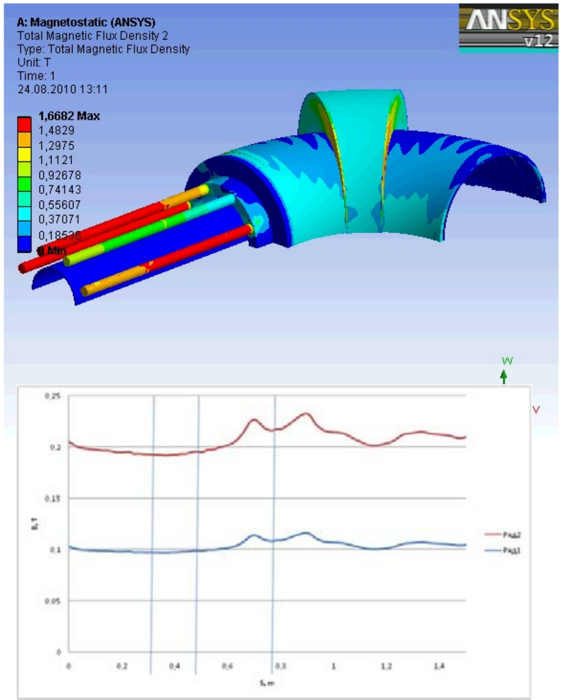
General view of the electron cooler



Electron collector



Electron gun

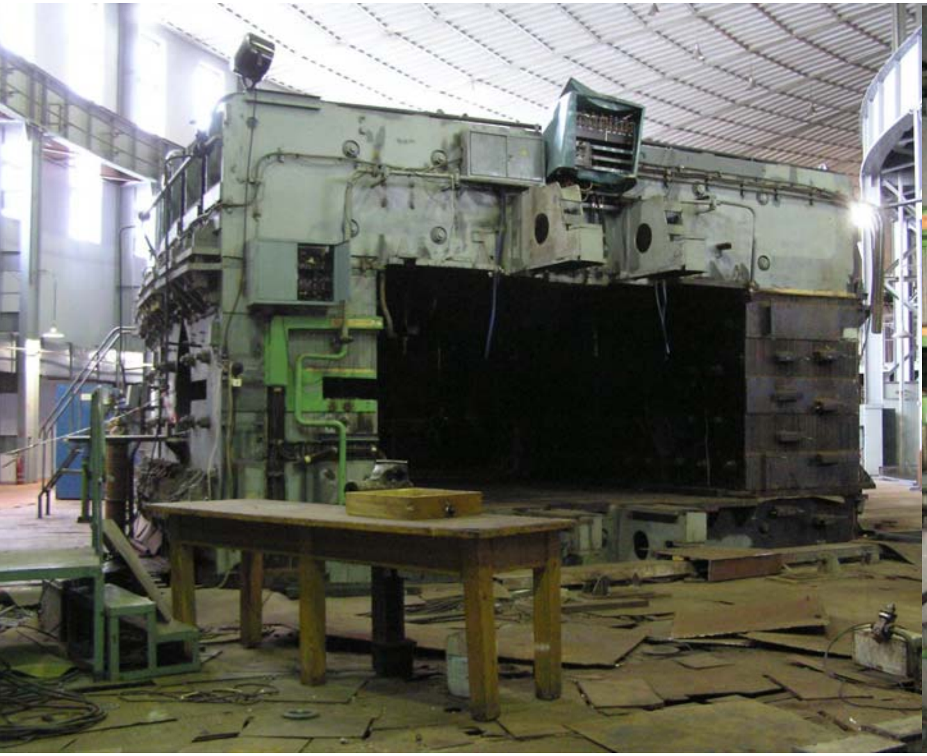


SC Solenoid field simulation (R.Pivin)

3.3. Booster

Synchrophasotron dismantling ⇒ in progress

July 2010



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

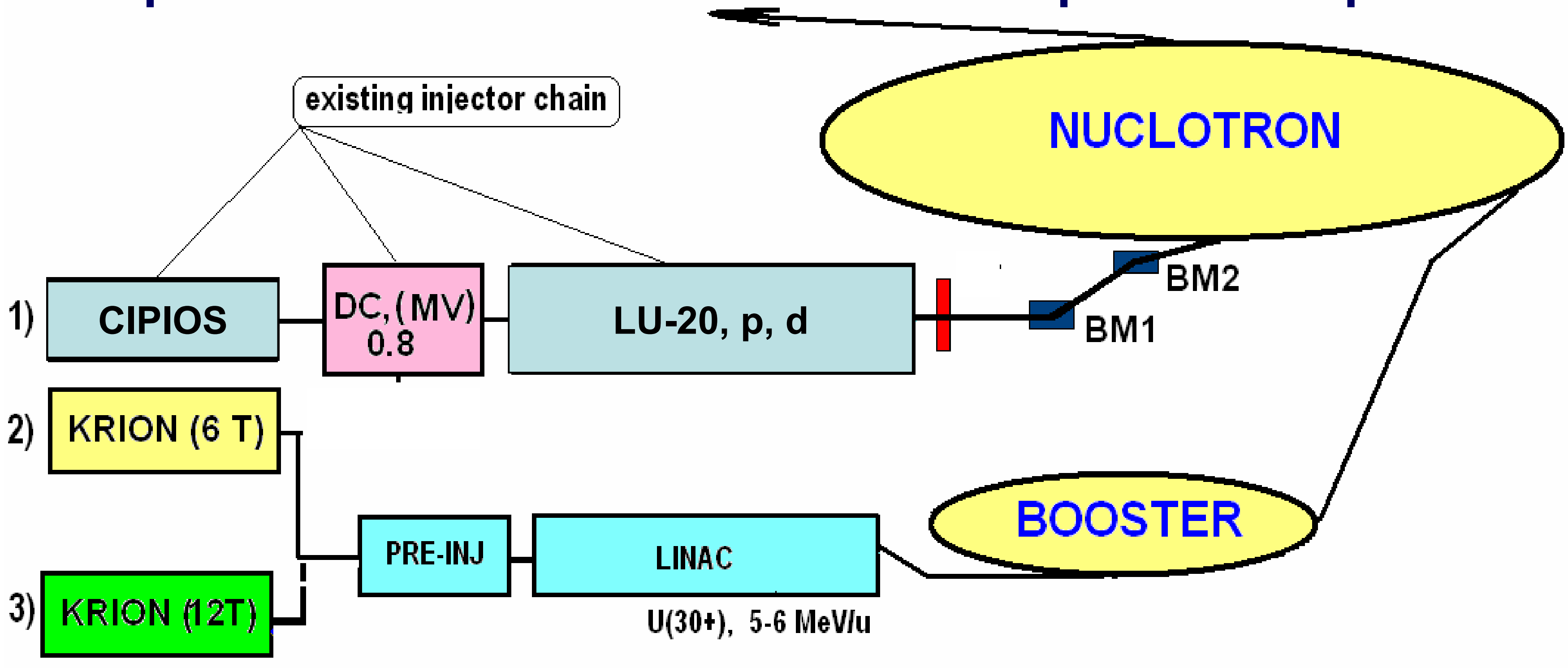
3.4. Nuclotron

(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



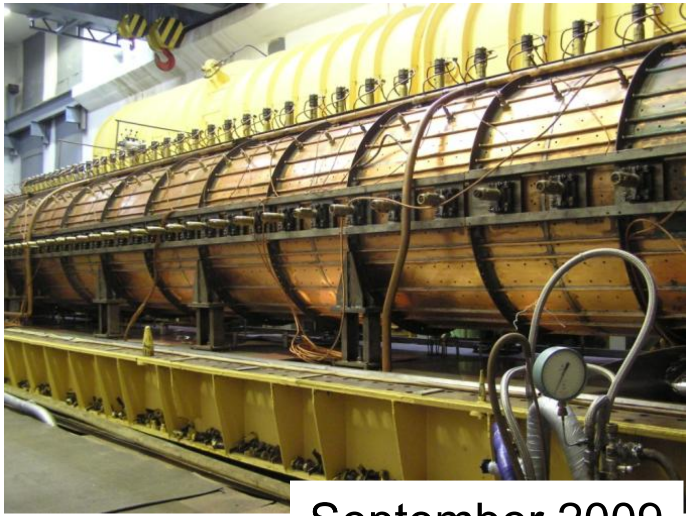
Polarized p↑ and d↑ beams and protons for p x Au collisions are planned to be accelerated with existing Linac LU-20.

3.4. Nuclotron (Contnd)

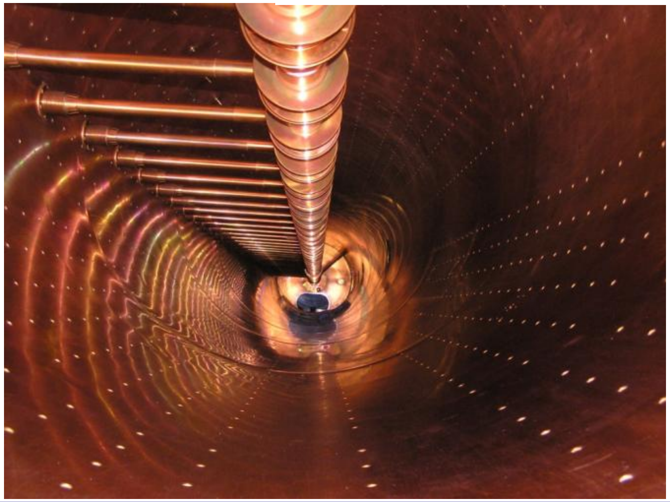
Injector (LU-20) modernization

- Upgrade of the power supply system for injection channel;

- Upgrade of vacuum system for fore-injector.

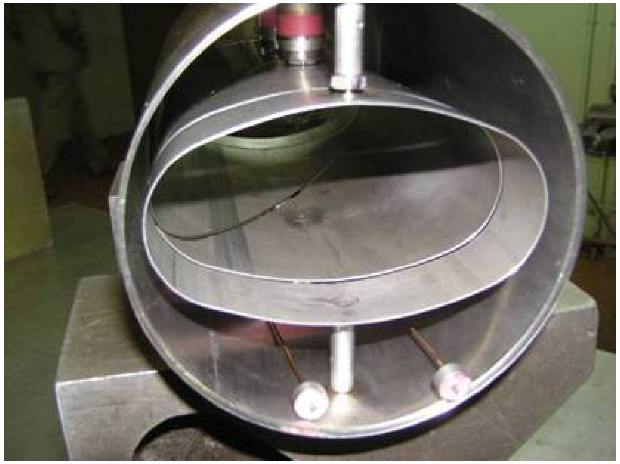


September 2009

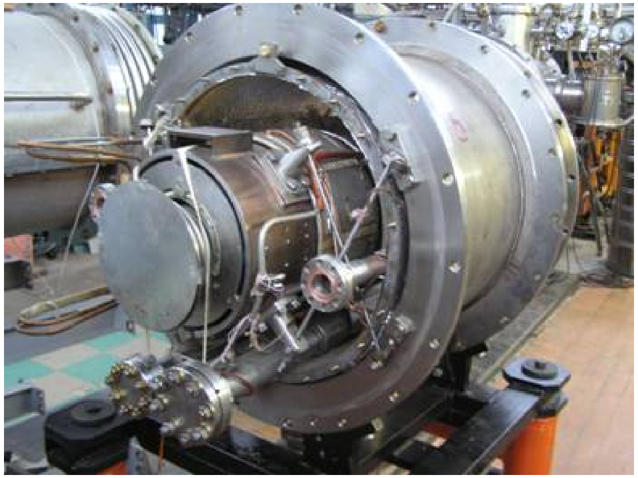


3.4. Nuclotron (Contnd)

- ❑ 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

Nuclotron - NICA

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

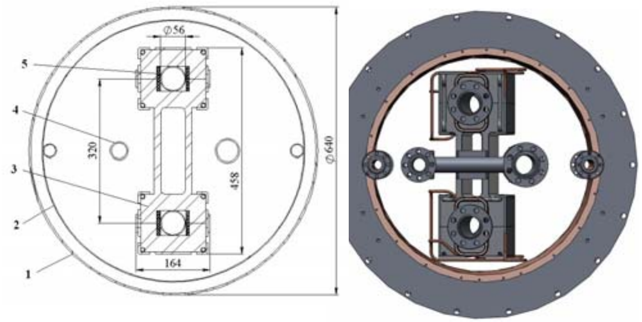
2 ÷ 4 GHz (~10 sec)

Vacuum tank
with slot-coupler (FZJ)

3.5. Collider

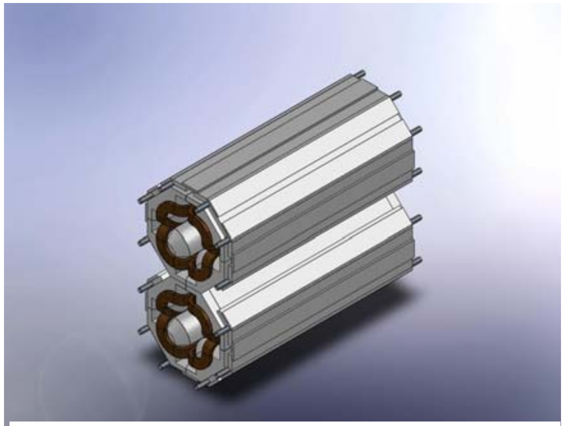
SC magnetic system: manufacturing of magnet prototypes

(H.Khodzhibagiyan and team)



a) Dipole cross-section

b) Dipole 3D view



c) Quadrupole

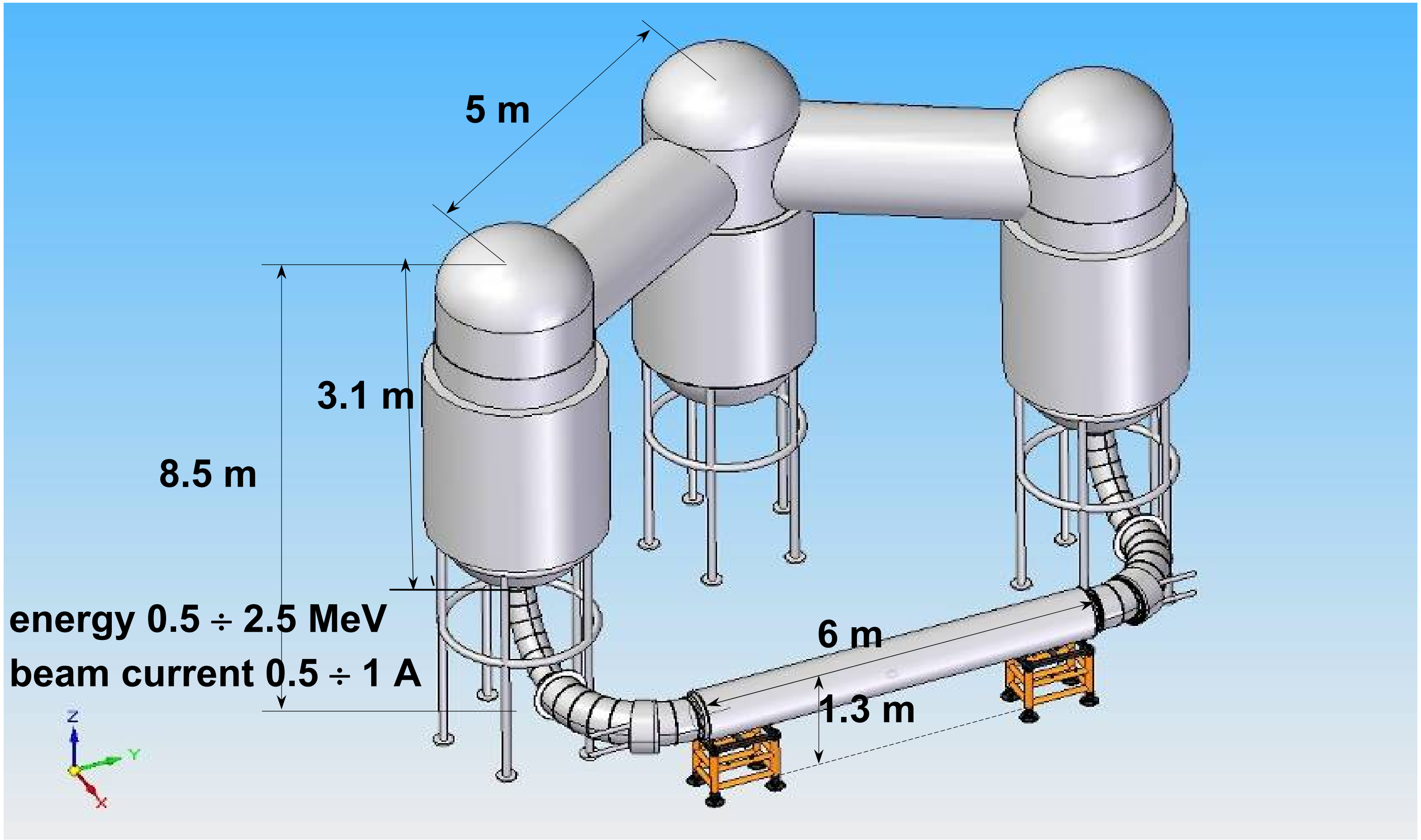
"Twin" magnets of NICA collider:
Max. field - 2T, super-ferric (Nuclotron-like), double aperture

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

3.5. Collider (Contnd)

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

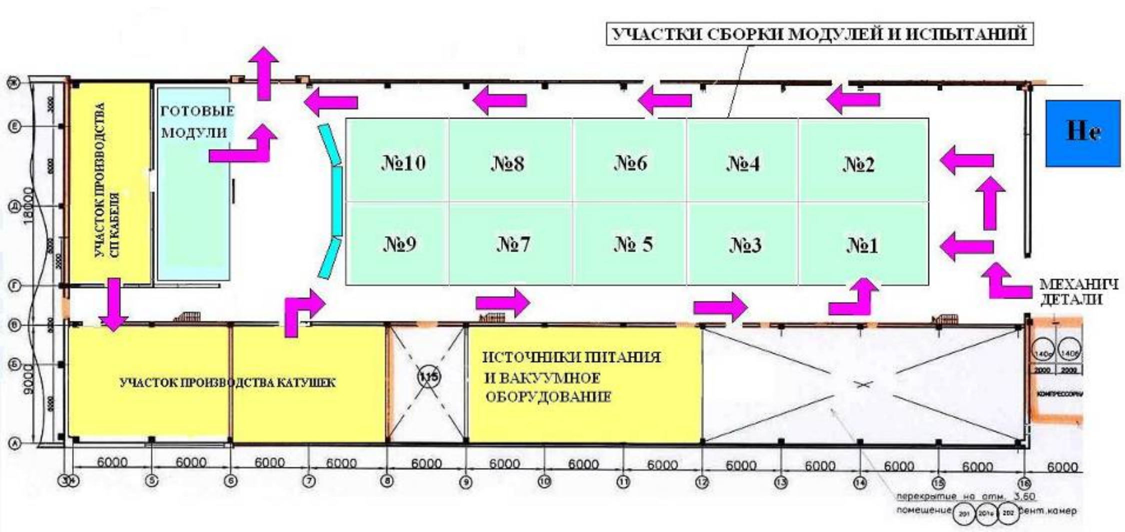
  G.Trubnikov, N.Shurkhno, V.Seleznev– JINR, T.Katayama – Tokyo univ., R.Stassen – FZJ, L.Thorndahl - CERN

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

  A.Eliseev, JINR

  G.Kurkin and team, Budker INP, by contract

3.6. Infrastructure Development



Building 217 (former LPP workshop)

New cryo-magnetic factory

Production, assembly, cryo- and vacuum tests for superconducting magnets serial production for NICA and FAIR (SIS-100)

30 x 75 m^2

3.7. NICA construction schedule

	2010	2011	2012	2013	2014	2015	2016
ESIS KRION	Design	Manufactrng	Manufactrng	Mount.+commis.	Operation	Operation	Operation
LINAC + channel	Design	Manufactrng	Mount.+commis.	Mount.+commis.	Operation	Operation	Operation
Booster + channel	Design	Manufactrng	Mount.+commis.	Commis/opr	Operation	Operation	Operation
Nuclotron-M	Commis/opr	Operation	Operation	Operation	Operation	Operation	Operation
Nuclotron-M → NICA	Design	Design / Manufactrng	Manufactrng	Mount.+commis.	Commis/opr	Operation	Operation
Channel to collider	Design	Design	Manufactrng	Mount.+commis.	Commis/opr	Operation	Operation
Collider	Design	Design	Manufactrng	Manufactrng / Mount.+commis.	Mount.+commis.	Commis/opr	Operation
Diagnostics	Design	Manufactrng	Mount.+commis.	Mount.+commis.	Commis/opr	Commis/opr / Operation	Operation
Power supply	Design	Manufactrng	Mount.+commis.	Commis/opr	Commis/opr	Commis/opr / Operation	Operation
Control systems	Design	Manufactrng	Mount.+commis.	Commis/opr	Commis/opr	Commis/opr / Operation	Operation
Cryogenics	Manufactrng	Manufactrng	Commis/opr	Commis/opr	Operation	Operation	Operation
MPD	R&D	R&D	Mount.+commis. / Mount.+commis.	Mount.+commis.	Mount.+commis.	Commis/opr	Operation
Infrastructure	Mount.+commis.	Mount.+commis.	Mount.+commis.	Commis/opr	Operation	Operation	Operation

R&D	Design	Manufactrng	Mount.+commis.	Commis/opr	Operation

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.**

Thank you for your attention!