RF SYSTEMS AND BUNCH FORMATION AT NICA

Alexey V. Eliseev, Oleg I. Brovko, Igor N. Meshkov, Anatoly O. Sidorin, Grigoriy V. Trubnikov, JINR, Dubna, Moscow Region, Russia
Grigory Y. Kurkin, Victor M. Petrov, BINP SB RAS, Novosibirsk, Russia

Abstract

The NICA facility being constructed at JINR will consist of two synchrotrons (Booster and Nuclotron) and collider working at constant magnetic field. To reach required luminosity level the collider rings will be operated with short ion bunches. The bunch formation in the collider as well as longitudinal dynamics in all the rings is described. The parameters and preliminary design of RF systems are presented.

INTRODUCTION

Main goal of the NICA facility [1] in the heavy ion collision mode is to reach the luminosity level of the order of 10^{27} cm^{-2}s^{-1}. For collider of circumference of 503 m it leads to the following beam parameters: maximum number of ions in each ring is 10^{11}, number of bunches – 23, rms bunch length – 0.6 m [2].

To storage required particle number the NICA collider injection chainincludes the following elements (figure 1.):

- Ion source KRION and Heavy ion linac(HILac) producing 2×10^9 ions/pulse of $^{197}Au^{32+}$ at 6.2 MeV/u (the variant of 3 MeV/ulinac is under consideration)
- Booster (under construction) – 25 T/m
- Nuclotron – 45 T/m
- Collider rings.

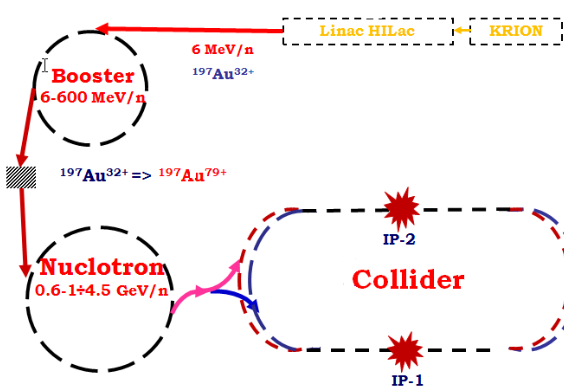

Figure 1: The layout of NICA collider facility.

Main accelerator requirements for the Booster synchrotron [3] are the following:

- accumulation of $2\div4\cdot10^9$$Au^{32+}$ ions; acceleration of the heavy ions up 600 Mev/u with two steps: up to approximately 100 Mev/u on 4th harmonics of the revolution frequency and on 1st harmonics afterwards.
- formation of the required beam emittance with electron cooling system if necessary.
- fast extraction of the accelerated beam for its injection into the Nuclotron in bucket to bucket mode.

Nuclotron as an element of the NICA collider injection chain has to accelerate single bunch of fully stripped heavy ions $Au^{79+}$from 0.6 to about 4.5 GeV/u. The required bunch intensity is about $1\div1.5\cdot10^9$ ions.

The beam accumulationin the collider is planned to be realized in longitudinal phase space with application of RF barrier bucket (BB) technique. This provides independent optimization of the bunch intensity, bunch number as well as controlling of the beam emittance and momentum spread during the bunch formation. In presence of cooling the number of the injection pulses can be large enough without decrease of the stacking efficiency. In this case the intensity of the injected portion influences on the stacking process duration only and can be arbitrary,in principle.

To achieve desirable bunch parameters for collision, three RF systems are needed in the collider: one broad-band type for ion accumulation and two narrow-band systems for the bunch formation.

After accumulation of a required ion number the barrier voltage is switched off and the beam becomes coasting. Then the second collider RF system starts operating, its voltage being increased adiabatically from “zero” level. Harmonic number of this RF is 23 - equal to the bunch number required for collision mode. In presence of cooling the emittance and bunch length continue to decrease. Then the bunch length becomes sufficiently small it is intercepted into third collider RF system working on 69th harmonics. After interception the process of adiabatic voltage increase accompanied by cooling continues this time for the third collider RF system, until bunch parameters required for collision mode are achieved.

RF SYSTEMS OF BOOSTER AND NUCLOTRON

Booster

The duration of Booster’s acceleration cycle with plateau for harmonic number change was chosen to be equal to that of Nuclotron ~2 s. Voltage of 10 kV amplitude allows doing that with synchronous phase of 30°. To decrease required RF power, this value will be obtained using two identical stations. Main RF parameters are represented in Table 1.

Table 1: Parameters of Booster RF system

Frequency range, MHz (NICA)	0.5-2.5
Frequency range, MHz (autonomic mode)	0.5-5.5
Harmonics (NICA)	4/1
Number of cavities	2
Cavity length	1.4
Min/max amplitudes, kV	0.1/10
Max ramp, T/s	1.2

The Booster acceleration system is being designed and constructed in Budker Institute for Nuclear Physics (BINP, Novosibirsk). It is based on amorphous iron loaded cavity for the acceleration. The cavity consists of two coaxial quarter-wave resonators, working in push-pull mode onto a common accelerating gap (figure 2).

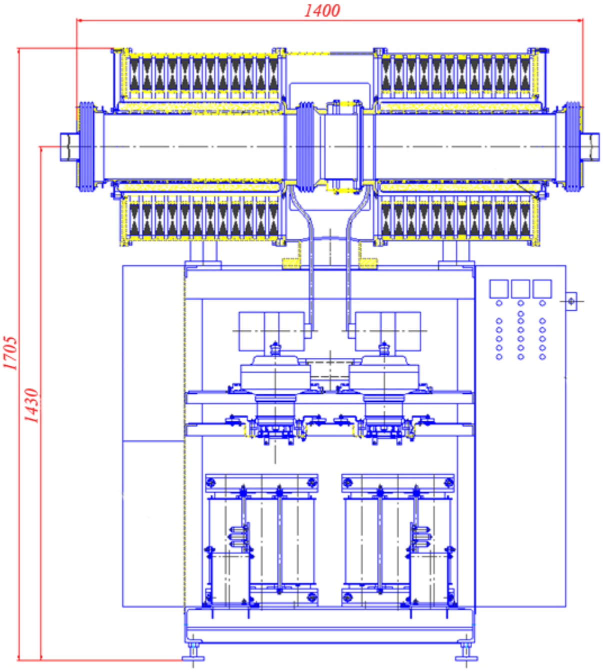

Figure 2: View of the Booster RF station.

Nuclotron

Two existing RF stations with total voltage of 10 kV allows to accelerate $^{197}Au^{79+}$ ions with ramp of 1 T/c and after modernization will be able to work in NICA injection chain.

Nuclotron's RF stations base on λ/4 ferrite loaded cavities. The resonant frequency is changed by bias current supply. Isolated part of beam pipeline serves as a load. Required modernization of the Nuclotron RF system is in progress [4].

RF SYSTEMS OF COLLIDER

Collider RF1

First collider RF system of BB type serves for ion accumulation. Rectangular pulses at 5 kV of amplitude and phase duration $\pi/6$ are able to accept particles with relative momentum deviation of $\pm 10^{-2}$. Phase distance between the pulses is equal to π. In this case the accumulation zone is half of the collider's perimeter and equal to that of Nuclotron.

The BB RF system as well as other Collider RF will be designed and produced by BINP. The cavity is supposed to be similar to the Booster one.

Collider RF2

RF2 serves for obtaining of desired number of bunches – 23. It will be switch ON until the length of the bunch shrinks enough to get into RF3 acceptance. The voltage of 100 kV amplitudewas chosen with a reserve. After further considerations this voltage can be reduced.

Collider RF3

RF3 is the principal station of the collider. It provides collision regime. The bunch momentum spread is the result of equilibrium of two processes – intrabeam scattering and cooling either electron or stochastic and varies with energy as shown on figure 3.

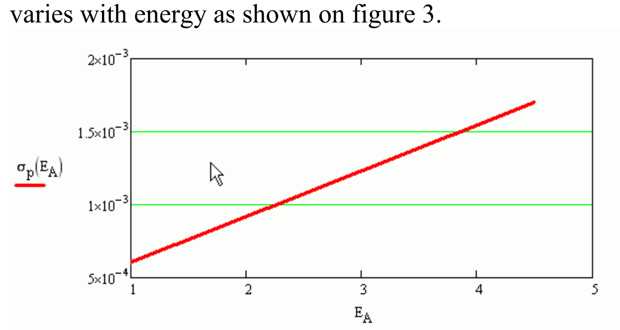

Figure 3: Momentum spread vs. ion energy in collision mode.

The harmonic number 69 was chosen as optimal, because in that case the bucket is still large enough (±6 sigma in length and ±4 sigmain height) and maximum voltage is still at reasonable value (figure 4).

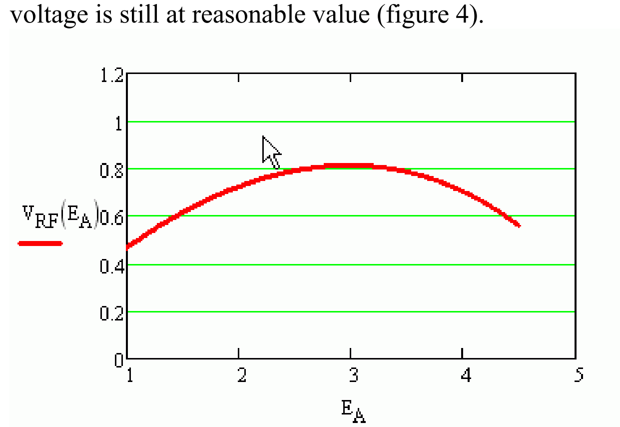

Figure 4: RF3 amplitude (MV) vs. ion energy (GeV).

Main parameters of Collider RF systems are presented in the table 2.

Table 2: Parameters of Collider RF systems

	RF2	RF3
Frequency, MHz	11.4÷12.8	34.2÷38.4
Total voltage amplitude, kV	100	1000
Voltage per cavity, kV	25	125
Power consumption per cavity	25	50
Number of cavities	4	8
Total power, kW	100	400
Cavity length, m	1.1	1.1
Total length, m	4.4	8.8

The preliminary design of the stations for RF2 and RF3 has been done by BINP. The stations are supposed to be based on the shortened λ/4 cavities. The resonant frequency can be varied within 13%. The geometry dimensions of the proposed RF stations are practically equalfor both systems – RF2 and RF3.

In the figure 5 the schematics of RF station for lower ring is presented with the following positions:

1- maximum dimension of electric drives of capacitors for the frequency change.
2- vacuum chamber of the upper ring.
3. Resonator's frame.
4. Final amplifier of RF oscillator.
5. Vacuum pump.
6. Trunk for final amplifier elements.
7. Cooling pipes (distilled voter).
8. Cable trays.

For the upper ring the RF resonator is rotated by 180° and displaced vertically by the distance between vacuum chambers of the lower and upper rings.

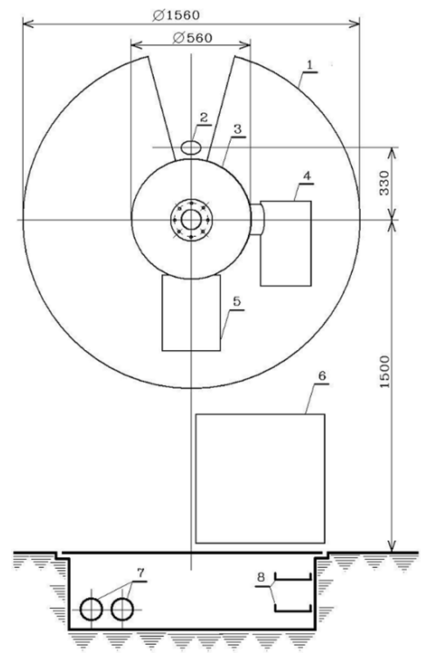

Figure 5: Preliminary design of RF station for 2nd and 3rd RF systems.

CONCLUSIONS

Chosen structure and paramerters of the NICA RF systems satisfy to the requirements of bunch formation in the collider rings.

Booster RF stations are designed in BINP. Construction will be completed in the middle of the next year. Nuclotron RF are under modernization. RF stations for collider will be designed and constructed in BINP

REFERENCES

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[4] N. Agapov, V. Alexandrov, O. Brovko, et. al., Status of the Nuclotron.Nuclotron-M project, ibid.