MEDIUM BETTA SUPERCONDUCTING CAVITY FOR THE NEW INJECTOR LINAC FOR NUCLOTRON-NICA*

M.A. Gusarova, K.V. Taletskiy, M.V.Lalayan, N.P. Sobenin, D.V.Surkov, National Research Nuclear University – Moscow Engineering Physics Institute, Moscow, Russia
A.V. Butenko, G.V. Trubnikov, Joint Institute for Nuclear Research, Dubna, Moscow Region, Russia
D.A. Shparla, A.I.Pokrovskiy, A.A. Bakinowskaya, V.S. Petrakovsky, Physical-Technical Institute of the National Academy of Sciences of Belarus, Minsk, Belarus

Abstract

The results of the electrodynamical and multipactor discharge simulations of the medium betta superconducting cavity for New Superconducting Injector Linac for Nuclotron-NICA are presented. Different designs of CH and Spoke cavities are compared and the optimal one is chosen.

INTRODUCTION

Development of accelerating structures for the SC Linac Nuclotron-NICA injector is underway by collaboration of Russian and Belorussian research institutions JINR, NRNU MEPhI, INP BSU, PTI NASB, BSUIR and SPMRC NASB. According to the concept of the SC Linac Nuclotron-NICA [1] second group of resonators is designed for frequency of 324 MHz, velocity of 0.21c and 7.7 MV/m accelerating gradient. Three types of cavities could fit the required parameters: HWR, CH and Spoke. The results of RF design optimization for CH and Spoke geometries for desired parameters is presented. Comparative analysis of these cavities was done. The results of this work will be used for cavity type choice for the second section of the SC Linac Nuclotron NICA.

CH-CAVITY

IAP, HIM and GSI (Germany) are the experts in development, fabrication and application of SC CH-type resonators. The 7-cell 325 MHz CH structure [2] is the closest match for our requirements and it was chosen as a prototype for the CH cavity geometry for the SC Linac Nuclotron NICA. The simulations resulting in optimized cell geometry and increased transit factor along with lower surface peak fields were carried out for infinite periodic model with periodic boundaries. Finite model was used for solving eigenmode problem in order to optimize end-cells geometry. According to the beam dynamics calculations [1], the number of cells should be less than seven. Thus, the geometry of 5-cell 324 MHz and 0.21 beta CH-cavity was developed (Fig. 1).

* This project is supportd in part by the MEPhI 5/100 Program of the Russian Academic Excellence Project

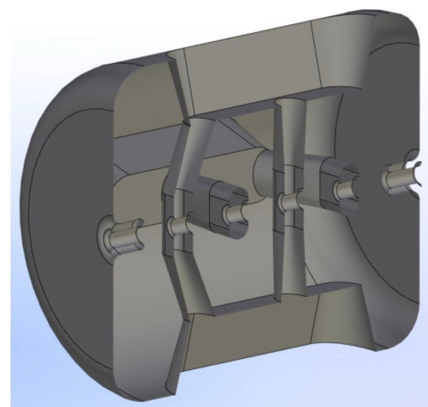

Figure 1: 324 MHz and 0.21 beta CH resonator geometry.

The initial (“reference”) cavity design [2] parameters along with ones after our modification are presented in Table 1.

Table 1: RF Parameters

Parameter	Reference	After optimization
f, MHz	325	324
β	0.16	0.21
R, mm	175	204
L, mm	505	500
Ep/Eacc	5	5.1
Bp/Eacc, [mT/(MV/m)]	13	7.5
G, [Ω]	66	84
Ra/Q	1260	615

The results show that this type of resonator could reach required accelerating gradient only in case of the maximum surface peak field exceeding 35 MV/m limit. Compared to the prototype structure, overall dimensions are increased by 14%.

For the optimized structure, a multipactor discharge simulation was done. At Fig. 2 the number of electrons growth rate dependence vs. accelerating gradient is presented. The calculation was carried out using the three-

ISBN 978-3-95450-182-3

dimensional code for multipactor discharge simulations MultP-M [3].

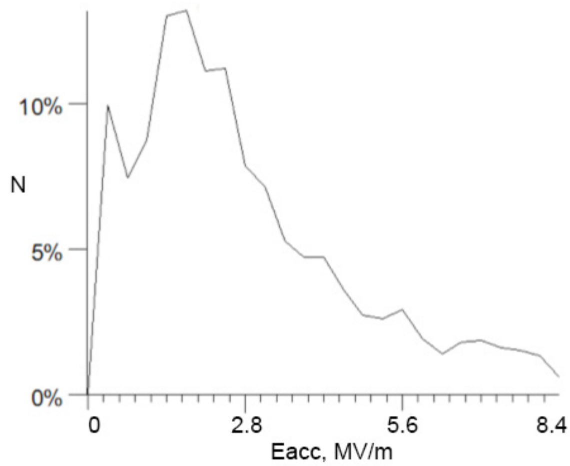

Figure 2: Number of electrons growth (N) in cavity at different accelerating gradient for CH-cavity.

At low field levels in CH-cavity multipactor electrons trajectories are mainly localized at the cavity outer surface. Single trajectories are detected at the operating field strength level of 7.7 MV / m in the area between the side wall and the pylon Fig.3.

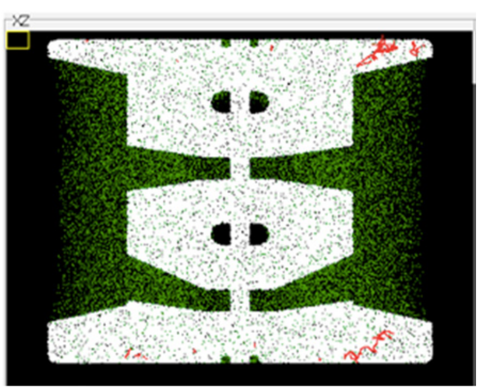

Figure 3: Areas multipactor trajectories localization at the operating field strength.

Detailed study of multipactor shows that the trajectories could be maintained only for about 30 RF periods, after that all trajectories are damped. Nevertheless the optimization of the specified area is required.

SPOKE-CAVITY

The most closely matching geometry of the Spoke type is SSR1 cavity developed, which is fabricated and tested at Fermilab [4 - 6]. It was taken as a prototype for the 324 MHz 0.21 beta Spoke cavity design proposed. The cavity geometry which satisfies our requirements is presented on Fig. 4.

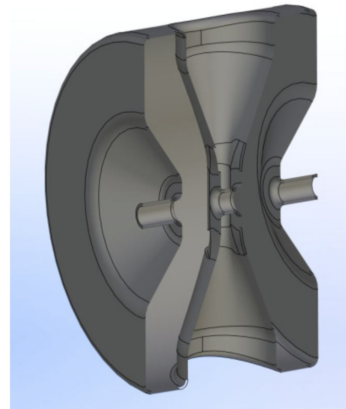

Figure 4: 324 MHz 0.21 beta Single Spoke Resonator geometry.

Numerical simulations for this geometry were performed in order to diminish peak surface electric and magnetic fields and increase shunt impedance of the structure. Simulations results are shown in Table 2.

Table 2: RF Parameters

Parameter	Reference	After optimization
f, MHz	325	324
β	0.22	0.21
R, mm	205	215
L, mm	251	250
Ep/Eacc	7.84	4.0
Bp/Eacc, [mT/(MV/m)]	9.81	6.3
G, [Ω]	84	79
R_a/Q	242	253

For the optimized structure multipactor discharge simulation was performed. In Fig. 5, electrons population growth for the different accelerating gradient is presented.

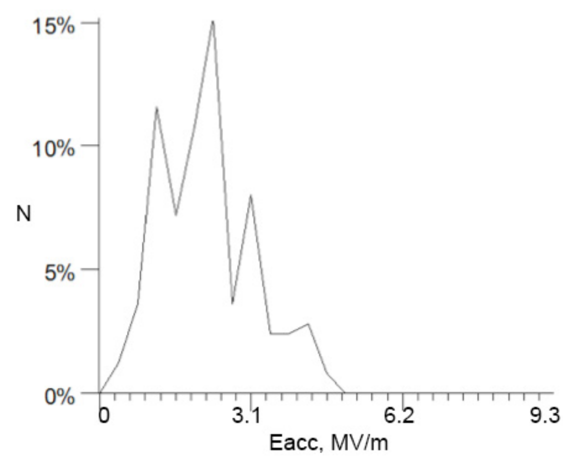

Figure 5: Number of electrons growth (N) in cavity for the different accelerating gradient.

It can be seen that in the Spoke structure multipactor trajectories at the operating field level are not detected. A

40 RF periods long simulation showed at low field levels the trajectories decay.

GEOMETRIES COMPARISON

The optimization results f 324 MHz 0.21 beta CH and Spoke cavities are summarized in Table 3. The maximum accelerating field strength values are given with respect to the limitation of the peak electric field at the surface of 35 MV/m and the magnetic field of 75 mT.

Table 3: RF Parameters

Parameter	CH	Spoke
f, MHz	324	324
β	0.21	0.21
R, mm	204	215
L, mm	500	250
Ep/Eacc	5.1	4.0
Bp/Eacc, [mT/(MV/m)]	7.5	6.3
G, [Ω]	84	79
R_a/Q	615	253

The multicell CH cavity is preferable from the point of overall dimensions and necessary auxiliary equipment: cryostats, tuners, power couplers. The Spoke geometry benefits higher accelerating gradient and Q-factor values.

CONCLUSION

Comparative analysis of CH and Spoke type cavities for the second group of resonators for SC Linac Nuclotron NICA injector was performed in cooperation with JINR and SPMRC NASB.

Obtained results show that multicell CH structure is more convenient, but Spoke type cavity better satisfies desired parameters, so this geometry is the most preferable. Thorough multipator and mechanical simulation and analysis are planned.

REFERENCES

[1] M.A. Batouritski, A.V. Butenko, M.A. Gusarova et al., The Perspective of JINR LU-20 Replacement by a Superconducting Linac. Proceedings of RuPAC’16.

[2] M. Busch, M. Basten, F. Dziuba et al., Recent measurements on the SC 325 MHz CH-Cavity. Proceedings of SRF2015, Whistler, BC, Canada.

[3] Gusarova M.A., Petrushina I.I., Khudyakov S.A. et al., New possibilities of MultP-M code. Proceedings of IPAC 2016, pp. 433-435.

[4] G.Lanfranco, G. Apollinari, I. Gonin et. al., Design of 325MHz Single and Triple Spoke Resonators at FNAL. FERMILAB-CONF-06-307-TD.

[5] G. Lanfranco , G. Apollinari, I.V. Gonin, et. al., Production of 325 MHz single spoke resonators at FNAL. FERMILAB-CONF-07-241-TD.

[6] R. Madrak , J. Branlard, B. Chase, et. al., First high power pulsed tests of a dressed 325 MHz superconducting single spoke resonator at Fermilab. FERMILAB-CONF-11-063-APC.

ISBN 978-3-95450-182-3