Superconducting Magnetic System of the SPD set-up at NICA

A.D.Kovalenko, *JINR, Dubna,* E.E.Perepelkin *JINR Dubna/MSU Moscow* 1-LP-AM2-I03

Abstract: ***NICA*** *- Nuclotron-based Ion Collider fAcility is the new accelerator/collider Complex being under construction at the Joint Institute for Nuclear Research at Dubna. The main part of the facility is heavy ion and polarized proton, and deuteron collider of 500 m circumference based on super-ferric 1.8 T Nuclotron-type magnets, i.e. made of hollow NbTi composite cable.*

The ***SPD*** *- Spin Physics Detector should include magnetic system that is necessary for secondary particle momentum analysis over the detector inner volume of 100 m^3. It was proposed to adopt well developed at the Laboratory superconducting 10 kA cable technology for the SPD magnetic system manufacturing. The R&D program aimed at realization in coming few years technical design of the new large scale magnetic system is discussed. One of the basic research goals is minimization of the material budget in the inner volume of the detector. Optimal distribution of the magnetic field providing high accuracy momentum measurements of secondary particles is very important also.*

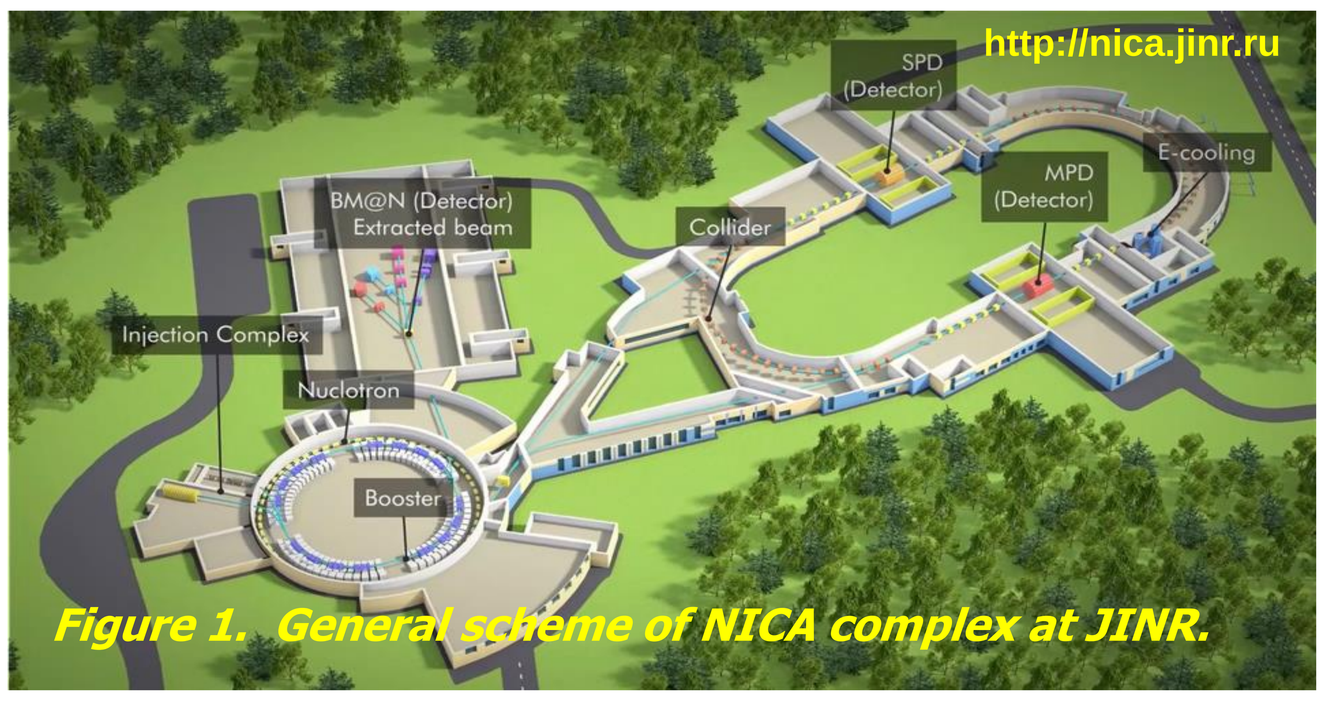


Figure 1. General scheme of NICA complex at JINR.

Introduction

NICA main targets are the following: 1) study of hot and dense baryonic matter at the energy of the maximum baryonic density; 2) investigation of nucleon spin structure and polarization phenomena [1]. Proper development of the existing facility aimed at generation high intensity heavy ion (up to gold) and polarized proton beams is in progress [2]. The maximum design collision energy of √sNN) ~11GeV (for Au79+Au79) and ~ 27 GeV (for p↑+p↑). An average luminosity of the collider is expected at the level of 10e27 cm-2·s-1 for Au(79+) and 10e32 cm-2 s-1 for polarized protons at 27 GeV. Polarized dd- and pd – collisions are possible also [3]. The collider detectors MPD and SPD are under construction and under design respectively. The setup BM@N (Baryonic Matter at Nuclotron) has been commissioned for physics data taken at the extracted ion beam from the Nuclotron in 2018 [4].

SPD General Composition

The setup contains a set of secondary particle detectors placed inside superconducting magnetic system (SMS) (vertex detector, particle tracking system), whereas electro-magnetic calorimeter (Ecal), and muon range system placed outside the coils [5,6].

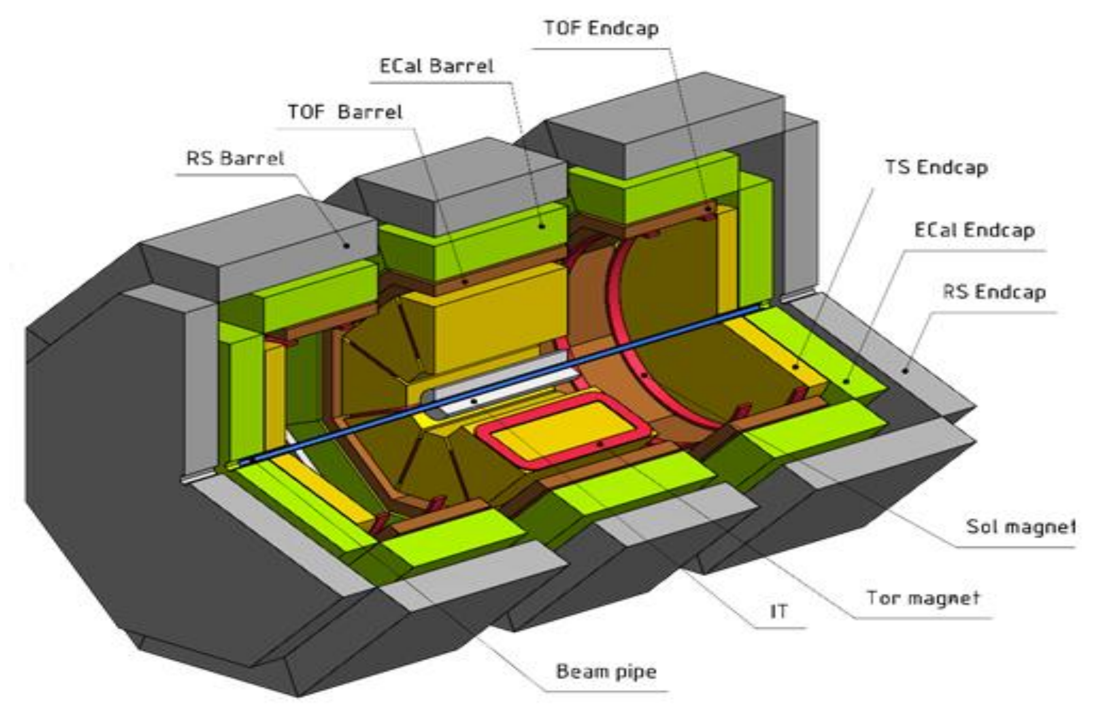


Figure 2. SPD setup option based on a combined magnetic system option: central part - toroid, forward/backward - pare of coils.

The features important for the magnetic system choice are the following:

- ***close to 4π geometrical acceptance****;*
- high-precision (~50 μm) and fast vertex detector;
- high-precision (~100 μm) and fast tracker,
- ***low material budget over the track paths,***
- ***modularity and easy access*** to the detector elements, that makes possible further reconfiguration and upgrade of the facility.

Eight different options of the SPD Magnetic System were considered and analyzed. These are: SC solenoid placed outside and inside of the Ecal; toroidal field generated by normal conducting and superconducting coils both in central and forward/backward parts; combined system consisted of central toroid and two pairs of separate coils (see Fig.2); four coils and six coils system. Variation of supplied current directions in the coils aimed at the minimizing of the magnetic field along the beam axis was tested also [7].

Magnetic Field Simulation

a. Hybrid system

Schematic view is presented in Fig.3. The total coils consists of eight coils to form toroidal field in central part and quasi-solenoidal in forward and backward parts.

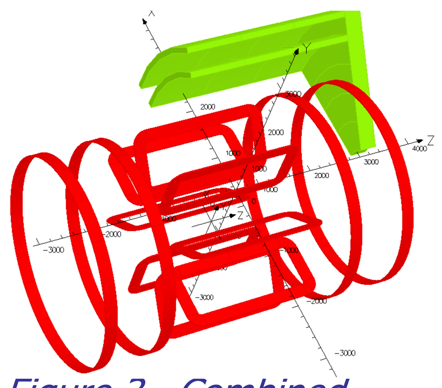


Figure 3. Combined toroid/coil configuration.

Despite of a satisfactory space distribution of the field, amount of material inserted into central SPD part is much larger, thus the background will be increased.

b. 6-Coils system

Schematic view is presented in Fig.4. The main advantage – no additional material is added to the coordinate detector space. Fig.5 illustrates the 3D-nonlinear simulation.

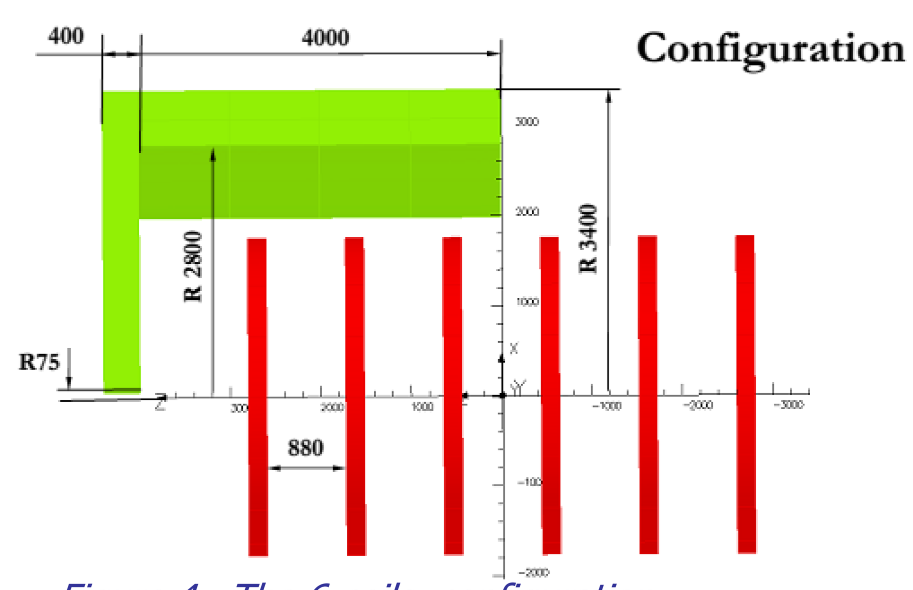
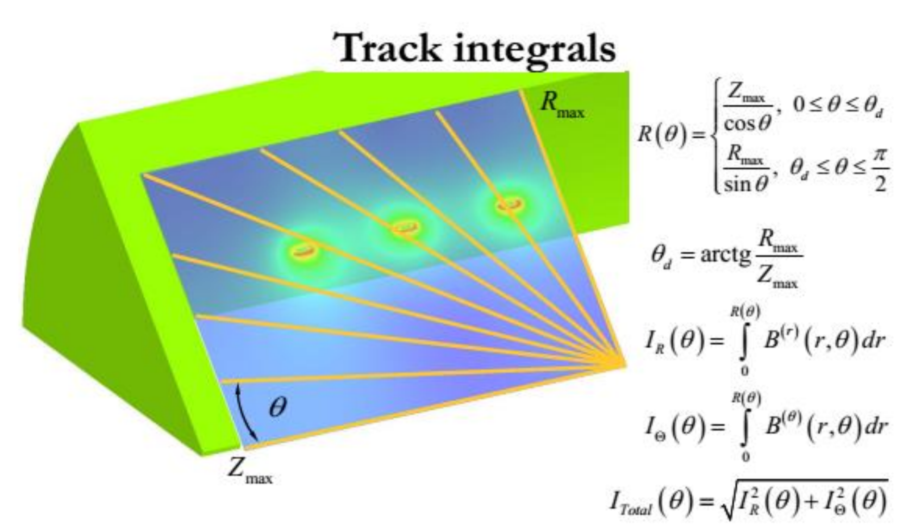


Figure 4. The 6-coils configuration.



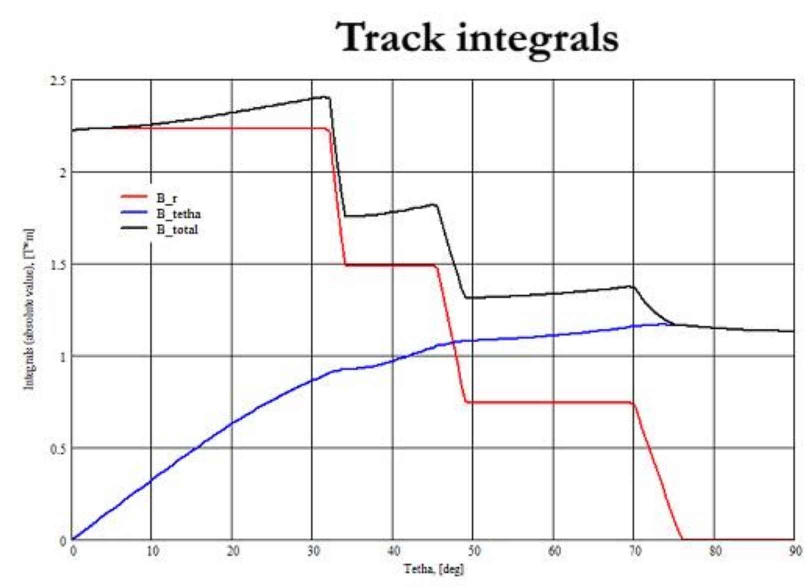


Figure 5. The magnetic field integral for different particle trajectories in 6-coils MS.

The 6-coil MS provides necessary integral of the field (1.2 T· m) at 2 T at the coil surface is provided specified accuracy of the particle momentum measurements.

SPD MS Technology

The unique design approach and technological base of 2T level superferric magnets manufacturing were developed at the Laboratory of High Energies of JINR for the Nuclotron [8,9]. The new SC magnet manufacturing and test facility was put into operation few years ago. It's used now for NICA booster and collider magnets manufacturing [10].

- *Coil of the booster magnet (photo from the left) is made of hollow NbTi composite cable, operating current 10 kA (critical current 17 kA), cooled at 4.5 K. The cable length of 60 m.*
- *Coil length of the first full size SIS100 dipole prototype manufactured at the Laboratory [11] according the same technology is about 90 m.*

It was proposed [12] to use the technology of a hollow SC Nuclotron-type cable or CICC approach for the SPD magnet coils manufacturing. This is well developed and tested design that can provide minimization of the material in the detector space, good mechanical rigidity of the construction and reliable operation. CICC technology is used usually for tokamaks, nevertheless application to the accelerator magnet was tested also [13]. Some of the SPD MS parameters in comparison with the CMS is presented in Table 1.

Table 1

Parameter	Unit	SPD/NICA	CMS/LHC
Volume: dia./length	m/m	3.6/6.0	6.5/12.7
Magnetic system		6 coils	solenoid
Peak magnetic field	T	2.0	4.5
Coil average diam.	m	~ 3.6	~ 6.5
Field volume	m³	~ 65	~ 414
Stored energy	MJ	~ 100	~2800
Coil turns		6x40	2112
Operating current	kA	10	20
Total inductance	H	~ 2	12,6

As it follow from the Table 1, the SPD MS design parameters are modest, nevertheless stored energy is large enough thus careful consideration of all safety and control systems is necessary.

References

[1] V.D.Kekelidze et al. ICHEP, Melbourne, 2012, PoS, 411 (2013).
[2] E.Syresin et al. IPAC 2019, Melbourne, 2019, paper MOPMP014.
[3] A.D. Kovalenko et al. SPIN 2016, Urbana, USA, 25-30 Sept. 2016.
[4] M.Kapishin et al. Nucl.Phys. A982 (2019) 967-970, (2019-02).
[5] I.A.Savin et al. arXiv: 1408.3959[hep-ex], August 2014.
[6] R.Tsenov. SPIN 2018, Ferrara, Italy, 10-14 Sept. 2018,
[7] E.E.Perepelkin et al. Physics of Particles and Nuclei, 2019, Vol. 50, No. 3, pp. 341–394, DOI: 10.1134/S1063779619030043.
[8] A.M.Baldin et al. IEEE Trans. Appl. Supercond., V. 5 , Iss: 2 , 1995.
[9] A.M. Baldin et al. IEEE Trans. Nucl., Vol. NS-30, No.4, Aug. 1983.
[10] V.D.Kekelidze et al. Nucl.Phys. A904-905 (2013) 945c-948c.
[11] E.Fisher, H. Khodzhibagiyan, A.Kovalenko . IEEE Trans. on Appl. Superconductivity, Vol: 18 , Issue: 2 , June 2008.
[12] A.D.Kovalenko. Int. Workshop on Spin Physics at NICA, July 08-14, Prague, Czech Republic.
[13] P.McIntyer et al. IPAC2019, Melbourne, 2019, paper MOPMP049.

Joint Institute for Nuclear Research.
141980, Dubna, Russia

kovalen@dubna.ru

www.eucas2019.org
EUCAS 2019
GLASGOW
1 – 5 SEPTEMBER 2019