Minutes of the meeting of the Committee for comparative examination of two SPD magnet projects

The meeting took place by Zoom on December 6, 2022.

Members of the Committee:

- Anosov V. (LHEP JINR)
- Alexeev G. (LNP JINR)
- Guskov A. (LNP JINR)
- Korzenev A. (LHEP JINR)
- Ladygin V. (LHEP JINR)

Subject of the meeting: Consideration of two projects of the SPD magnet based on TDR, reviewer's report and authors' responses. Formulation of recommendations. The final choice of one of the two projects will be made by the SPD Technical board.

Documents that were reviewed by the Committee (all written in Russian):

- Reviewer's report: "Comparative analysis of two projects of superconducting magnets of the SPD NICA experiment" prepared by E.Koshurnikov (founder of the company "Neva-Magnet", St. Petersburg).
- Responses to the Reviewer's comments on the review by the leader of the BINP project E.Pyata.
- Responses to the Reviewer's comments on the review by the leader of the LHEP JINR project H.Khojibagiyan.

Brief description of two projects:

Both projects present the concept of a superconducting magnet proposed for the SPD detector. The following dimensional parameters of the magnet were used as the initial data for the conceptual project. The magnet cryostat should have a cylindrical shape with a length of 4 m, an inner shell diameter of 3.3 m and a thickness of 25 cm. It will be fixed inside a steel yoke, which in the case of SPD also acts as a muon detector. The inner shell of the magnet should have a rail structure in the middle plane for hanging the internal detectors.

Essentially, the difference between the two projects is related to the cable type technologies are being considered for the magnet and the associated cooling methods.

- **BINP project:** The use of a Rutherford-type cable made of NbTi/Cu superconductor. The cable will be encased in an aluminum stabiliser using a co-extrusion process that provides a good bond between aluminum and superconductor in order to ensure quench protection during operation. Indirect cooling of the superconductor will be provided by two-phase helium, which will circulate in pipes welded to the outside of the coil former.
- **LHEP JINR project:** The technology of superconducting coils manufacturing is based on a hollow high-current cable similar to the one used for the Nuclotron magnets or the one used in the ITER systems. The manufacturing technology of the hollow cable made of NbTi/Cu composite wires is well developed at LHEP JINR. The cooling system is supposed to use a single-phase cooling scheme with supercritical helium.

A cryostat made of stainless steel, which will have to withstand the ambient air pressure, bear the weight of the cold mass and provide the thermal shield, was presented only by the BINP group. The project of the JINR group is limited to the description of superconducting coils.

Evaluation of the reliability of the magnetic system:

Technical solutions presented in the BINP project for the design of the cryostat and superconducting winding correspond to modern trends in the design of superconducting magnets. The reliability of these solutions is confirmed by the successful operation of previously created magnetic systems, such as magnets of ATLAS, CMS, Zeus, BaBar, KEDR (BINP) and other experiments.

According to the Reviewer's report, the advantage of the JINR coil technology over that proposed by the BINP group is not obvious (at least not presented in the TDR text). The following disadvantages were pointed out:

- The cooling scheme proposed by the JINR group assumes continuous operation of the compressor, which pushes the flow of liquid helium through the cable. An emergency power outage will stop helium circulation and will require 15 MJ of energy to be withdrawn from the coils. A re-cooling procedure will lead to a significant pause in detector data-taking. The BINP cooling scheme is free from this problem, since cooling proceeds due to natural convection of two-phase helium (thermosiphon effect). The system can operate for many hours after the power interruption.

  According to H.Khojibagiyan, this issue of the JINR scheme can be solved by adding a backup power supply for the compressor.

- The JINR scheme with direct cable cooling is generally less reliable due to the presence of a large number of cooling tube connections and electrical interconnections in the winding. The more connections, the less reliability. Such connections are the weak point of all types of magnets. If a leak is detected in the cooling tubes located in the superconducting winding, the entire coil section will have to be discarded. There is no such problem in the scheme of indirect cooling of BINP.

  Response by H.Khojibagiyan: The Nuclotron has several thousand helium solderings and more than 800 high-current electrical connections. Over the 30 years of his work, sometimes leaks were opened and successfully eliminated.

- The BINP scheme of cooling with two-phase (boiling helium) has many advantages in comparison with JINR cooling with single-phase (liquid) helium. For example, this is exactly why the Nuclotron in JINR is cooled by a two-phase helium flow. Unfortunately, two-phase helium can not be used for a Nuclotron-type cable in the SPD case, since liquid and vapor separation will occur in the areas of vertical rise and fall of the flow, which in turn will lead to the breakdown of superconductivity. Furthermore, designing a new single-phase helium circuit in JINR can require significant development time.

  H.Khojibagiyan has agreed with this statement.

Possibility of implementing the proposed projects in the current conditions:

It was discussed with both groups and they confirmed that the production of all magnet parts will be carried out by local Russian manufacturers. While the overall fabrication of the magnet elements is not in doubt, the presence of ultra-pure materials such as copper and aluminum is a concern. In past years, they were ordered from abroad.

- The recently developed and already partially manufactured magnet of the PANDA experiment confirms the ability of the BINP team to cope with the production requirements of the SPD magnet. BINP has more than 40 years experience in the manufacture of coils, including superconducting coils, has personnel and equipment that allow the production of coils with a diameter of up to 7 meters.

- For the case of the JINR variant of the magnet, it must be taken into account that the JINR group will have to develop the design of the cryostat and the superconducting winding without the possibility of relying on the experience of previously manufactured magnets. The possibility of manufacturing the superconductor cable at JINR is beyond doubt.

Human resources and group experience:

In view of the fact that the beginning of the first stage of data-taking is scheduled for 2028, it is important to make sure that the proposed projects can be realized within next 5-6 yeahs. In this regard, having a strong experienced team is crucial.

- The BINP group has experience in the manufacture and operation of large-aperture superconducting magnets. For example, they designed, assembled and successfully operate the superconducting solenoid of the KEDR experiment at BINP. Furthermore, the BINP group spent about four years designing and doing R&D for the PANDA magnet (FAIR, GSI). The BINP project contains quite some borrowings from the PANDA Magnet Technical Project, which allows us to expect that the magnet will be made in line with modern solutions.

- The JINR project is based, first of all, on the well-developed technology of manufacturing cables for Nuclotron magnets at JINR. Those magnets, however, are very different in design from the large-aperture magnet of SPD. The working group is still to be formed and extensive research and development will be required.

Recommendation of the Committee:

In conclusion, the Committee appreciates the work done by the JINR and BINP groups on the preparation of the conceptual design of the SPD magnet. Based on the criteria for the reliability of the operation of the magnetic system, the possibility of implementing the proposed projects in the current conditions, as well as availability of human resources and their experience gained in the implementation of similar projects, the Committee makes the following recommendation. The BINP project is considered to be more realistic in terms of the SPD time schedule, manufacturing and commissioning, as well as guarantees of reliability in operation. The Committee recommends the SPD Technical Board to support this project for further development. The Committee would also like to point out that since the magnet will eventually operate in JINR, close cooperation between the two groups that submitted the projects is important to achieve the final result.