IRIS-A New Distributed Research Infrastructure on Applied Superconductivity

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(Invited Paper)

***Abstract*—In the frame of the Next Generation Europe program, the EU program to boost after-COVID recovery, the Italian Minister of University and Research has funded a project called Innovative Research Infrastructure for applied Superconductivity (IRIS). New laboratories will be built or upgraded in six poles: Milan (hub of the infrastructure), Genoa, Frascati, Naples, Salerno, and Lecce, to carry out basic research on magnetism and superconducting materials, test of wires, tapes, and large current cables, superconducting magnets construction with advanced instrumentation, power tests of magnets, and a special facility for high current-high voltage superconducting lines. The program will be executed over three years and then will operate for at least 10 years. It includes two first demonstrators: one HTS magnet to be operated at 10–20 K and a superconducting line of 1 GW (40 kA–25 kV) about 140 m long. The demonstrators anticipate the main scope of the investment in the IRIS infrastructure: to support the use of superconductivity for improving sustainability by decreasing the energy consumption without compromising performance. This article describes the global IRIS project.**

***Index Terms*—Accelerator magnets, DC power transmission lines, HTS magnets, large scale superconductivity, superconducting magnets.**

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I. Introduction

THE Italian Minister for University and Research has funded in 2022 a large program for an Innovative Research Infrastructure on applied Superconductivity (IRIS) in Italy [1], [2]. This infrastructure is a partnership among: INFN (the National Institute for Nuclear Physics), CNR-SPIN (National Council of Research) and the universities of Genoa, of Milan, of Naples, of Salento (Lecce) and of Salerno. INFN participates with 4 laboratories: LASA (attached to the INFN division of Milan), the National Laboratory of Frascati, the laboratory of INFN division of Genova, and the laboratory of Salerno (attached to the INFN division of Napoles). CNR-SPIN participates with 3 units: Genoa, Naples, and Salerno. The LASA (*Laboratorio Acceleratori e Superconduttività Applicata)* in Milan is the hub of the infrastructure and coordinates the activities. IRIS will include upgrades of existing infrastructures, with new state-of-the-art instruments, reinforcing the capability of Italy in the domain of superconductivity with focus on application to accelerators, healthcare and energy. IRIS foresees a strong coordination of the activity of the participating laboratories until 2035, at least, thus enhancing the participation of Italian laboratories to future projects requiring advanced superconducting technology, like as FCC (Future Circular Collider at CERN) and the Muon-Collider. IRIS is meant also for enhancing societal applications of technologies developed for high-energy accelerators, especially for the energy domain and the medical sector.

Beside the preparation and set up of the new infrastructure, including civil engineer work, the IRIS project contains the design and manufacture of two superconducting demonstrators: 1) a Green Superconducting Line, 130 m long and rated for 25 kV–40 kA at 20 K, that will be tested in operating conditions in one of the IRIS site; 2) a 1 m long HTS dipole magnet rated for 1–10 T operation at 20 K, with a room temperature coil bore of 50 mm × 80 mm.

This article gives a general description of the IRIS project.

II. IRIS Description

The Next Generation Europe is the program that EU has devised to emerge stronger and more resilient from the pandemic caused by the corona virus. A key ingredient is the Recovery and Resilience Facility plan that in Italy is called PNRR (*Piano Nazionale di Ripresa e Resilienza*). In this frame the Italian Minister of University and Research (MUR) has opened a call in early 2022 to fund a dozen of top class Research infrastructures. IRIS (Innovative Research Infrastructure for applied Superconductivity) has been one of the first eight projects approved in the first round (further four have been approved in a second round). The PNRR has a very strict timeline and requires that all tenders must be adjudicated by the end of 2023.

A. The Collaborating Partners

IRIS is a research infrastructure distributed over six poles across all Italy. See Fig. 1, and counts on seven Institutes:

1) INFN, *Istituto Nazionale di Fisica Nucleare*, that is the consortium leader through the laboratory LASA in Milan, the hub of the distributed infrastructure; INFN is present on the poles of Frascati (LNF, a National Laboratory near Rome), Genoa, Milan and Salerno.
2) CNR, *Consiglio Nazionale delle Ricerche*, the largest research institution in Italy,–through its SPIN Institute, devoted to superconductivity. SPIN is active in IRIS in the pole of Genova, Naples and Salerno.
3) *Università degli Studi di Genova* (Genoa)
4) *Università degli Studi di Milano* (Milan)
5) *Università degli Studi di Napoli Federico II* (Naples)
6) *Università degli Studi del Salento* (Lecce)
7) *Università degli Studi di Salerno* (Salerno)

Laboratories for superconductivity, cryogenics, or instrumentation for accelerators already exist in each of the six poles in IRIS. In IRIS, each laboratory will be upgraded and given a specific role, mutualizing competences and enhancing complementarity and collaboration.

B. Scope and Structure of IRIS

The scope of IRIS is to have an infrastructure in Italy capable of facing the grand challenge posed by the development of superconducting magnets and related technologies for next generation colliders for particle physics [3], [4], [5].

However, the structure is thought also to enhance the societal application of superconductivity especially in the domain of the green energy [6], [7] and medical applications [8], [9]. Training of next generation scientists and engineers in superconductivity, for particle accelerators and for applications at large, is also a key goal of IRIS.

IRIS is subdivided into nine works packages, see Fig. 2:

WP1 Milan-LASA (INFN)–Project Management and Technical Coordination

Fig. 1. Six territorial poles of IRIS (blue circles). The star indicates LASA, the hub of the distributed infrastructure.

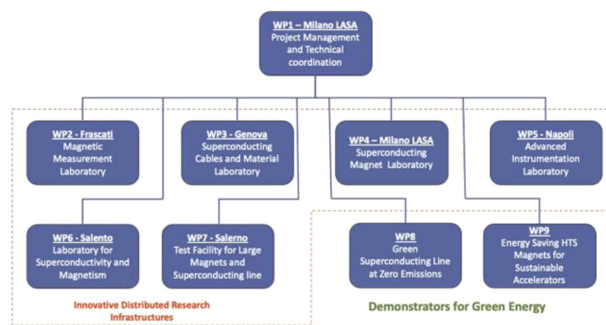

Fig. 2. WP structure of the IRIS project.

WP2 Pole of Frascati (INFN-LNF)–Magnetic Measurement Laboratory (MML);

WP3 Pole of Genoa (INFN, CNR-SPIN, and University)–Superconducting Cable and Material Laboratory (SCML)

WP4 Pole of Milan-LASA (INFN and University)–Superconducting Magnet Laboratory (SML);

WP5 Pole of Naples (University Federico II and CNR-SPIN)–Advanced Instrumentation Laboratory (AIL)

WP6 Pole of Salento (University)–Laboratory for Superconductivity and Magnetism (LSM)

WP7 Pole of Salerno (INFN, CNR-SPIN and University)–Test Facility for Large Magnets and Superconducting Lines (TFLMSL).

The construction phase include some civil works in all poles, with new large buildings in Milan and Salerno, upgrade of the existing facility (in particular of cryogenic equipment) and procurement and commissioning of new instruments.

However, in addition to the infrastructure construction activity above described, IRIS contains the design, manufacturing and first test of two important demonstrators:

WP8–Green Superconducting Line (GSL), a 130 m long electrical power transmission line, rated for 1 GW (25 kV–40 kA) and operating at 20 K.

Institution	Budget (k€)
INFN	39,572
CNR-SPIN	2,416
University of Genova	1,182
University if Milano	5,532
University of Napoli	2,044
University of Salento	3,606
University of Salerno	5,644
TOTAL	**59,996**

Fig. 3. Budget subdivision among the various IRIS partners.

WP9–Energy Saving HTS Magnet for sustainable Accelerator (ESMA), a 1 m long dipole of 10 T operating at 20 K.

Design and construction of both demonstrators are under the scope of INFN-LASA. The ESMA dipole will be eventually installed in the SCML of Genoa (WP3) to serve as background field for testing superconducting cable of large current capability. The GSL cable will be tested in Salerno (WP7).

C. Budget

The initial budget request for IRIS was 75 M€; eventually, 60 M€ have been allocated to IRIS, which has entailed a moderate descoping of the initial proposal. This budget includes general expenditures (indirect cost), fixed *a priori* in the measure of 7% of the actual expenditures (direct cost), which also include cost of temporary staff allocated to IRIS. In addition, differently to the EU directly financed programs, in the 60 M€ we must account also for taxes, which in Italy are on average 20%, which reduces the effective budget to 50 M€. Reimbursement of permanent staff, fellows an of administrative and management personnel (with the noticeable exception of the infrastructure manager) is not allowed. The subdivision of the budget by Institute is shown in Fig. 3.

III. Workpackage Description

A. WP1–Project Management and Technical Coordination

The work package, which is based in the laboratory LASA of Milano (being already a National research infrastructure, LASA is the promoter of the IRIS initiative) regroups all common activity for management, coordination and dissemination for the whole project. Beside the Scientific Coordinator and the Project Coordinator there is an Infrastructure Manager that takes care of Planning, Budget, risk monitoring and quality. Various bodies have bene formed: a Project Office (PO) and a Project Steering Committee (PSM), with all WP leaders and Institute representatives. The PSM meets at alternating week with the PO. An international Advisory Boards meets at least twice a year with the whole project, reporting to the management of INFN (as leading Institute).

The IRIS project has adopted a model of project management based on international standards and adapted to the context of fundamental research and technological non-profit development.

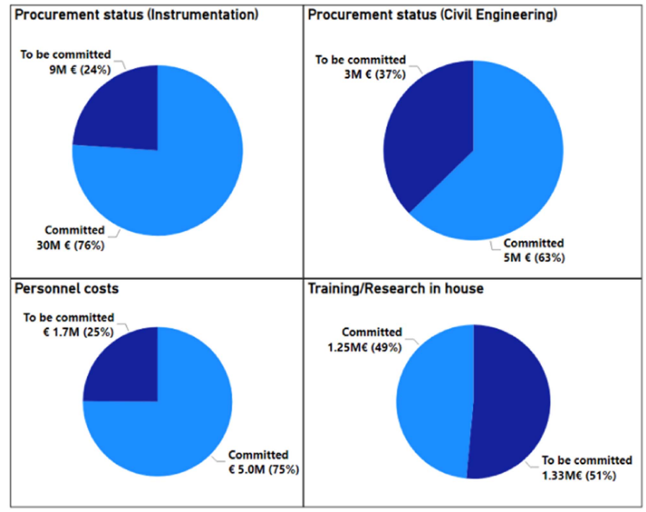

Fig. 4. Situation of the IRIS expenditures (September 2023).

The fixed schedule and budget impose constraints on the flexibility of the project, requiring a precise control of the scope and very frequent checks of the status to avoid unrecoverable issues due to delays or imprecise forecasting for the utilization of the resources. The procurement must follow a dedicated set of rigid rules and flexibility must be built during the process to face risks and use opportunities. The infrastructure to be built is distributed across Italy and the actors have a fair degree of independence, which requires frequent interactions among them and with the project management office to avoid drifts.

A dedicated set of tools, based on widely used commercial software, have been developed to better follow the project evolution and the expenditure. Quite frequent, although lightweight, reviews allow to follow the details; documents undergo approval processes developed by the project. The first year of the project is heavily focused on the procurement and hiring processes that must be completed before the end of 2023, while the following two years will be dedicated to the acquisition and installation of the various components of the infrastructure (instrumentation and new premises), while creating a network of the various actors and building a collaboration for making the realized work to continue after its end, in 2025. The situation of the budget at mid-September 2023 is reported in Fig. 4.

WP1 also includes an intensive activity of training of young scientist and engineers. In 2023 about 70 attendances to various schools or conference training courses in the domain of accelerators, applied superconductivity and magnets, will be supported by IRIS. We expect to double these figures by the end of the project.

B. WP2–Magnetic Measurement Laboratory (Frascati)

The goal of the INFN-LNF in Frascati near Rome, is to provide a magnetic measurement laboratory specifically devoted to testing superconducting coils and magnets at room temperature. These measurements are an important tool of the QC/QA plan for manufacturing of superconducting magnets, since they allow the detection of various defects or assembly errors at early stages of production, well before the expensive cryogenic tests are carried out. Their effectiveness has been shown, for example, in the LHC construction [10].

A substantial part of the required equipment is already available at the pre-existing laboratory, including a stretched wire bench, a rotating coil system, an NMR probe and several other instruments, such as gaussmeters, digital and analogic integrators, high precision electrical instruments.

The IRIS upgrade of the laboratory will include a variety of instruments: a 3D Hall probe mounted on a mole system, a pulsed wire bench, a 5-axes coordinatometer with a choice of probes holder, high-precision and high-stability power supplies of various sizes to cover a wide range of requirements, calibrated probes and calibration magnets for validating the measurements. The flexibility of the instruments will allow to cover a large range of magnetic measurements spanning from point maps to integrated values, from multipolar field analysis to fiducialization, providing support for magnets design and engineering.

C. WP3–Superconducting Cable and Material Laboratory (Genova)

The Work Package 3 (WP3) is located in the Genoa pole which is one of the most important nodes on large scale superconductivity in Italy, thanks to the presence of groups belonging to public institutions, INFN-Ge, CNR-SPIN-Ge, University of Genova (UniGe) and one of the world's leading companies for large superconducting magnets, ASG Superconductors.

The three institutions which operate within WP3 (INFN-Ge, CNR-SPIN-Ge, UniGe), had already founded a joint laboratory (LabCoR) with the aim to officialize and reinforce the collaboration. The laboratories are located at the Physics Department of UniGe (DIFI) equipped with cryogenic plants and dedicated instrumentation for superconducting material characterization, R&D on applied superconductivity and tests on superconducting cables and devices. Moreover, a laboratory for wire manufacturing, heat treatments, structural and morphological characterization is located in the SPIN-GE headquarter.

The target of WP3 is the creation of a new infrastructure: a Superconducting Cables and Material Laboratory (SCML) devoted to the R&D, test and characterization of superconducting cables and materials. It will be based on the renovation of the existing structures and the implementation of new instrumentation to enhance the integration in the IRIS infrastructure and to strengthen the capabilities in the domain of superconductors for high magnetic field generation (in particular High Temperature Superconductors). Moreover, the renovation of the cryogenic plant (He, liquefier, He recovery system, liquid nitrogen storage and distribution system) will ensure higher efficiency with respect to the present situation, in term of electric power, helium consumption and personnel commitment.

In particular, the following activities will be implemented:

1) INFN-Ge Activities: In the INFN-Ge, located within the Physics Department of the Genoa University, the experimental activities are carried out in a laboratory equipped with three, variable field and temperature, stations for the measurements of electrical, magnetic and thermal properties and for critical current measurements on superconducting wires and cables. One of them, the Ma.Ri.S.A. test facility [11], is a half meter bore, 6 T (up to 8 T with insert) superconducting solenoid with variable temperature sample holder used to test the large cables for accelerators and detectors up to about 100 kA. It is one of the very few test facilities in the world suitable to perform measurements at very high current on aluminum stabilized, superconducting cables.

Actions included in the IRIS project are the acquisition of new instrumentation and the revamping of the Ma.Ri.S.A. test facility that will be equipped with a Nb3Sn insert. The magnet and its insert will generate 10 T in a 300 mm bore and will be used for superconducting cable characterizations.

Another important innovation is the installation of a new measurement station based on a 10 T HTS dipole magnet that will be constructed as part of the IRIS project (WP9).

2) CNR-SPIN-Ge Activities: To enhance the capability of the CNR-SPIN lab in structural and morphological characterization of superconductors, a new field emission scanning electron microscope (FESEM) and 4-circles high resolution X-ray diffractometer (HRXRD) will be purchased and installed close to the HTS fabrication lab to increase the efficiency of the research activity. Moreover, the characterization of the structures and the interfaces of the conductors and cables is of great support in analyzing possible damages or inhomogeneity and correlating them with the transport properties. The new instrumentation will enhance the quality and potentiality of the infrastructure making it more competitive and attractive to external users such as industrial companies.

3) University of Genova Activities: The set-up of the UniGe instrumentation infrastructure will consists in a new facility to probe magnetic and thermodynamic properties of superconductors. This facility is intended to work at high field (14–18 T) in a wide temperature range (0.05–300 K), connected to the liquid He recovery-supply system (see above in i) INFN-Ge activities) This activity is coordinated with WP6 for a complete characterization of superconducting and magnetic materials.

D. WP4 Superconducting Magnet Laboratory- LASA (Milano)

At Milan-LASA pole, IRIS includes the construction of a new building to create a facility devoted to the a new Superconducting Magnet Laboratory (SML) for development of models and prototypes of the next generation superconducting magnets necessary for the realization of: a) new accelerators concepts with low energy consumption; b) new colliders, for the post High Luminosity LHC era; c) innovative, very compact and light systems for beam guidance, particularly useful for hadron therapy. For these strategic activities, high field magnet superconductivity is the key technology and the only practical solution to meet the requirements of the scientific community for the next decades. This new infrastructure for superconducting magnet construction is located at the LASA site, where a team dedicated to the design of Superconducting magnets is present and is already running a set up for the test of superconducting magnets in vertical cryostats [12].

The new SML foresees the construction of a hall (surface 600 m^2), and other technical services necessary for magnet prototyping. In the upper level a zone for light technical offices is reserved.

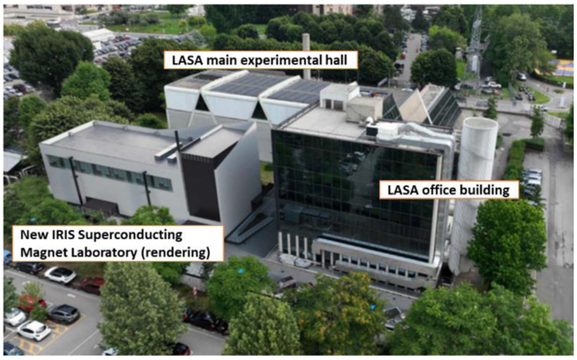

Fig. 5. New Superconducting Magnet Laboratory integrated in the present LASA facilities and offices.

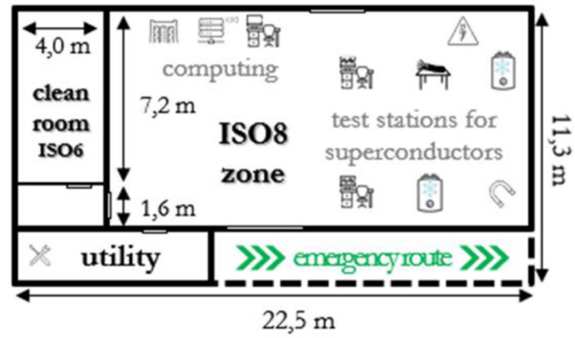

Fig. 6. Plan of the new IRIS laboratory in Naples.

The ground level of the building will host the tooling necessary for magnet constructions, with procurement is also part of the scope of WP4, which include winding machine with vertical axis and double movement (covering all coil topology, single cable and multiple tapes), press system for high pressure polymerization, special ovens for vacuum impregnation and for Nb_3Sn coils heat treatment, precision device, 1–10 μm, for coil measurement under 3000 ton/m, welding robot for precision assembly of cold mass (20 μm) and welding under prestress, yoke lamination assembly, etc.. The magnet laboratory activity will be supported by a rapid prototyping 3D additive manufacturing system for metals and plastics. In Fig. 4 a drawing of the new building is shown near the existing LASA facilities.

The main experimental hall, see Fig. 5, which host the facilities for the cryogenic test of the magnets will be upgraded, too, with a new i.e., large Variable Temperature Insert (VTI) to test coils inside a 8 T superconducting solenoid SOLEMI [13] also above liquid helium, a new cryogenic distribution remotely controlled and a new power converter for superconducting magnet capable of 10 kA at $\pm$40V (or 30 kA at $\pm$20 V). Quick test in vertical cryostat at operational conditions of models and prototype magnets is a critical tool for fast feedback on design and manufacturing technologies, while rapid prototyping of components to shorten the fabrication time, are keys for a successful research and development of innovative magnets. The new infrastructure will be open to other laboratories, projects and Industries.

E. WP5 Advanced Instrumentation Laboratory (Napoli)

The Neapolitan pole of the IRIS project, which includes both the University CIRMIS center and the Physics department as well as the CNR-SPIN of Naples, is establishing an advanced instrumentation laboratory aiming at characterizing superconducting devices, as well as developing and validating innovative diagnostics systems. Such instruments will be used for characterizing HTS-based cables and magnets.

Civil engineering renovation works in an existing area are ongoing to create a new test site of about 200 m^2, with a new cryogenic plant with storage tanks, new cryostats, a cryogenic probe station, and an ultra-high vacuum systems. This new infrastructure extends the existing "cryolab" facility [14], which already involves liquid nitrogen (77 K), liquid argon (86 K) and a clean room with temperature and humidity control. A similar ISO 6 clean room (about 30 m^2) is foreseen for the new test site too. The other zones instead comply with the ISO 8 class and involve (i) a test station for superconducting cables, (ii) a test station for superconducting magnets, and (iii) an area for advanced computing. A sketch of the described laboratory is shown in Fig. 6.

The two test stations are for electrical characterization of the superconducting devices with 30 kW (1 kA at few tens of volts). Thus, the Neapolitan test site will offer a service for assessing the functionality and performance of superconducting devices and components, which will be latterly mounted into the green superconducting lines and the accelerator magnets of the IRIS project.

Research and development will be also carried on developing novel measurement methods. For instance, the aim will be to detect online resistance variations at $\mu\Omega$ level. Furthermore, machine learning techniques will be applied to data, e.g., for detecting anomalies offline or to proactively predict faulty conditions. The analysis will be performed at a multiscale level, starting from small portions of tape, whose magneto-transport and magneto-optical properties will be analyzed in cryostat equipped with a 12 T field, to analyze the effects of magnetic field penetration. Overall, the accuracy of the measurement will be guaranteed by the possibility to generate stable currents and magnetic fields, to control ambient factor like temperature and humidity, and to rigorously calibrate the data acquisition instruments.

F. WP6 Laboratory for Superconductivity and Magnetism (Salento)

The IRIS research infrastructure pole in Lecce is established at University of Salento which is already the central node of an Italian network of research laboratories active on magnetism and basic superconductivity, using high magnetic field to study, modify and control states of matter in extreme conditions. This is extremely relevant to support basic research and technological innovation through the development of advanced materials and new key enabling technologies, for electronics and spintronics, data storage, quantum computing, sensors, energy and biomedical applications. This node operates in synergy with the *AIMagn* (*Associazione Italiana di Magnetismo*).

The IRIS project improves Lecce infrastructure and equipment. In particular, the laboratory is already equipped with (1) an Oxford Triton dilution refrigerator (10 mK base temperature, 6T/1T/1T vector magnet) for quantum computation applications, (2) a Cryogenics superconducting magnet (10.5 T, 0.3–300 K) for magneto-transport and magnetometry, (3) a Lakeshore Cryogenic RF probe station (8 K, 0.5 T and 70 GHz) for spintronics and magnonics.

IRIS contributes to add to the facility: (4) a Cryogenic split pair cryogen-free magnet system for combined magneto-optical and FMR measurements, (5) an attoDRY2200 AFM/MFM/PFM system with base temperature < 2 K and 9 T vector magnet, (6) a 3rd Generation MPMS SQUID Magnetometer with Evercool close-cycle system (2–400 K, 7T) and (7) a PPMS DynaCool 9 tesla Cryogen-free System for physical properties measurements (2–400 K, 9T), see Fig. 7. As a result, Lecce pole will become a reference facility at international level for research on applied superconductivity and magnetism with a very relevant set of state-of-the-art equipment and will provide open and transnational access within the successful dual access procedure scheme already established within the EMFL-Isabel European Research Infrastructure [15]. Furthermore, IRIS project allows the University of Salento to upgrade the Italian participation to the ESFRI EMFL from regional node to the status of ordinary member of EMFL, supporting Italian user access to foster physics studies on magnetism and superconductivity.

Fig. 7. Main instruments of the WP6 pole of University of Salento. From (d) to (g) are the IRIS procured instruments.

G. WP7 Test Facility for Large Magnets and Superconducting Lines (Salerno)

One of the largest installations in the IRIS project is the Test Facility for Large Magnets and Superconducting Lines in Salerno.

The new test laboratory will be located at the University of Salerno, Fisciano Campus, with the participation of the INFN (group of Salerno), of the University of and CNR-SPIN sited in Salerno. The Physics department of the University has a long-standing tradition in superconductivity, with research on Josephson effects that started 50 years ago, which has recently expanded to include topics related to materials science. The research activities include the fabrication of superconducting thin films and multilayers, the investigation of their structural and transport properties, and exploration in both large-scale applications and superconducting devices (including superconducting single-photon detectors). The laboratories of the department are well-equipped with cryostats for low-temperature and high-magnetic-field measurements, deposition systems, and a lithographic facility for creating micrometer-scale structures.

The physics department, together with INFN and CNR-SPIN will set up testing equipment for large-scale superconducting devices. These devices will be examined for their properties under high magnetic fields and various temperatures.

Moreover, the department will oversee all the civil engineering activities related to WP7, especially the main building for superconducting cable power test, assuring also a seamless integration of all technological services to enable the infrastructure's activities to be as integrated as possible. The design, project planning, construction, and building activities will all fall under this responsibility.

A new IRIS building and related services (including a 75 m long dugout) will be placed nearby the existing THOR facility [16], a laboratory operated by INFN where large superconducting magnets completed in their cryostat can be tested, thus realizing a unique large reference pole in southern Italy. For this reasons additional laboratories will also be created within the same IRIS building, to strengthen the capacity of investigation on new superconducting devices and materials for applications.

The new infrastructure mainly aims at testing superconducting power transmission line and will be commissioned with the test of the IRIS Green Superconducting Line of 1 GW (see WP8 description in the following). The Test laboratory, operated by INFN, has very challenging figures: in this test area currents as large as 40 kA will be available, and voltages level up to 25 kV are foreseen.

These figures mean a nominal power transmission for the superconducting line up to 1 GW. The test itself will be carried

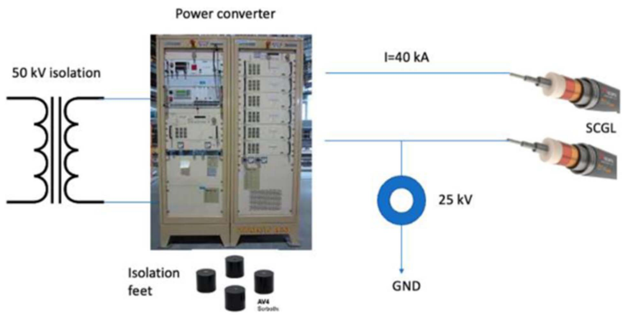

Fig. 8. Electrical scheme of the test set up for the testing 40 kA and 25 kV in operative conditions.

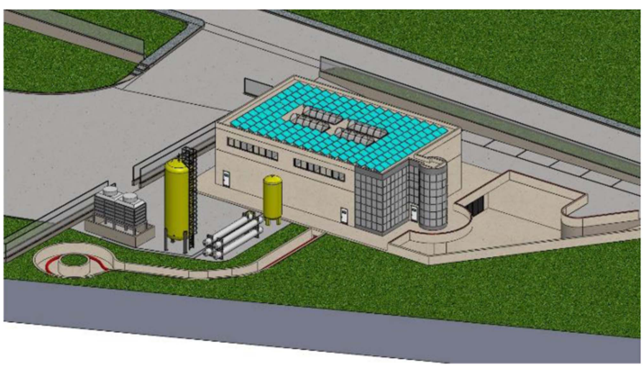

Fig. 9. Sketch of the new laboratory for the cable test and other cryogenic laboratories in Salerno. The dugout for hosting the 130 m long cable is in the forefront.

by placing the current source of 40 kA at ±20 V on an insulated platform kept at medium voltage (MV), up to 50 kV, with respect to ground, as shown in Fig. 8, to test the insulation level with high current flowing though the superconducting line.

The test of the superconducting line requires an average temperature of 20 K of the cooling He gas, with a cryogenic power of 500 W. The 40 kA current leads will be provided by the manufacturer of the line, and they are based on HTS current lead cooled at 77 K by LN2. The laboratory design is made according to those base parameters and, like all IRIS infrastructure will be accessible by third parties according to open, transnational access. Fig. 9 shows a rendering of the basic layout of the new IRIS laboratory, provided with power converter, cryogenic refrigeration system and ancillary equipment. The 75 m long dugout for the cable test with a return roundabout of about 10 m diameter is also shown.

The CNR-SPIN Institute, which has well-recognized expertise in the electrical characterization of superconducting materials both for applications and basic research., will take care of electrical properties and superconducting materials subject to different types of deformations (stress/strain), both due to e.m. stresses and to cryogenic cooling. Especially the critical current density of the cables is extremely sensitive to mechanical stresses and deformations. For these purposes, the CNR-SPIN Unit will procure a cryomagnetic system which will operate down to 2 K and in presence of magnetic fields up to 9 T, equipped with strain gauges that using piezoelectric systems, allow to control deformations and directions. The refrigeration of the system will be based on liquid helium made available by the recovery/liquefaction line set up by INFN within IRIS.

IV. The IRIS Demonstrators

A. WP 8 Green Superconducting Line

The Green superconducting Line (GSL) is a 130 m long cable intended to demonstrate electrical power transmission by use of MgB_2 superconducting cable, cooled by 20 K He gas. The design is based on an cable capable to carry 40 kA at an operating voltage of 25 kV in a flexible cryostat. The design heavily depends on the work done by CERN for the work package 6A of the High Luminosity LHC Project [17], [18]. The cryostat will host twice the conductor as needed, i.e., four cables instead of two cables, each rated for 40 kA. This will provide a full redundancy in case of conductor damages, without need to dismantling the line itself. A study to make the GSL compatible with cooling by liquid hydrogen, rather than He gas, will be carried out. However, its implementation is beyond the IRIS construction timeline. The engineering design and the construction of the whole cable system, with its feeders and all necessary cryogenic box for the interface, as well as the protection system, has been entrusted by INFN-Milano to ASG Superconductors (Genoa), that is also the principal industrial manufacturers of MgB_2 wires.

The GSL demonstrator will be then installed by the supplier in the Salerno Test Facility (see previous section) to "debug" the facility itself and to test the line in conditions as near as possible to the operative ones, i.e., with conductor kept at of "high" voltage (25 kV) to ground and between them, while the full current of 40 kA is flowing. The cables have joints at one termination while are connected to the feeder at the other extremity. This is not strictly necessary, since is possible to make a single conductor of 260 m, however is deemed a key feature to test joint technology on the final system. A sketch of the GSL is shown in Fig. 10.

Once the test in Salerno will be completed, well after the IRIS construction phase, the GSL might be installed in some place of the Italian electric network, for example as HVDC back-to-back system.

B. WP9 Energy Saving HTS Magnet for Sustainable Accelerator

This demonstrator, called ESMA, aims at generating a transverse field of 10 T in a 1 m length, with a room temperature bore of H80 mm × V50 mm [19]. The coils are made by 2 × 4 pancakes in shape of flat racetrack. The conductor is composed by a double face-to-face 12 mm wide coated conductor tape, with a highly resistive metal tape on the outside to improve mechanical strength and especially to provide sufficient turn-to-turn electrical resistance, according to the concept of metal as insulation [2]. This allows a charging time of 1 T/h, approximately, while providing the necessary current sharing among conductor turns to protect the magnet. The ramp rate cannot be slower since the magnet will be used in the pole of Genova as background field for cable test. Therefore, a time of 1

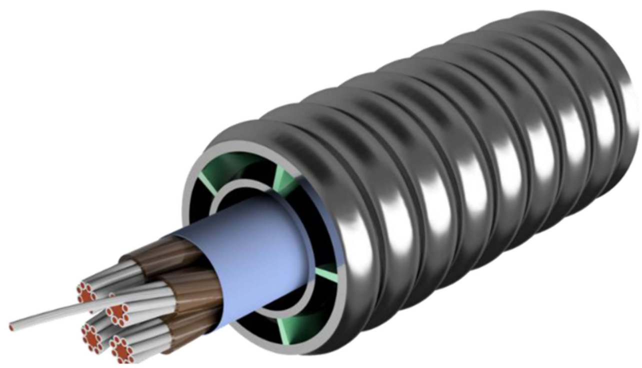

Fig. 10. Artistic view of the superconducting line demonstrator.

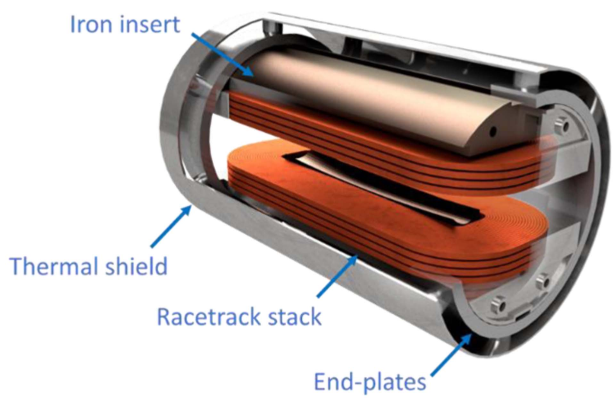

Fig. 11. 10 T dipole HTS IRIS demonstrator.

hours to change a field of 1 T has been set as target. To minimize the amount of expensive REBCO tape, the coil current density is indeed $J_{\mathrm{overall}} \cong 500$ A/mm^2, considerably high at 14 T peak field and 20 K. The little amount of copper would imply, for a fully quenched conductor, a peak copper current density of $J_{\mathrm{Cu}} \cong 2000$ A/mm^2, a value considered unsafe for a coil featuring about 3 MJ of stored energy. This consideration is the main driver to select for baseline the non-insulated conductor technology, with a suitable inter-turn resistance given by the metal tape. Fig. 11 shows a sketch of the present ESMA dipole design.

The design is currently under refinement with the company awarded of the contract for the manufacturing of the complete cryo-magnet system, ASG Superconductors, Genoa, Italy. The REBCO tape, about 15 km in length of 12 mm width, will be supplied by the Faraday Factory Japan LLC.

V. Conclusion

The IRIS project is the largest Italian project dedicated to the development of applied superconductivity since at least 30 years, with the scope to support long term development of new accelerators and societal application of superconductivity, namely for green energy and the medical sector. Initiated on November 1, 2022, the project has still 2 years to reach the objectives of upgrading the six-territorial pole, coordinating the various activities, and to manufacture and test the two large superconducting demonstrators. The project is well on route, and approximately 70% of the budget has been committed. However, a few criticalities on tendering and late hiring of personnel have generated some delays that need to be recovered with a vigorous action since all budget must be committed, except 10% for remaining general cost and training, by end of 2023.

The IRIS infrastructure will continue to operate under a consortium agreement among partners, providing open and transnational access, until 2035, at least. Actions to secure funds and activity for the ten years to come are already under way, both through National and International collaborations.

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