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ARIA, FROM THE SEARCH FOR DARK MATTER AT THE GRAN SASSO LABORATORIES TO AN INNOVATIVE HIGH TECHNOLOGY INFRASTRUCTURE IN SARDINIA

It stems from basic research, in particular from fundamental physics, to respond to an experimental need: having large amounts of argon available, currently obtained only from gas wells in Colorado, United States, for the search for dark matter. But in the future it could also be used for the distillation of other isotopes increasingly used in medicine, both in advanced diagnostics and in cancer therapy, and also in environmental and agricultural sciences. The ARIA project was inaugurated today, 21 September, in Sardinia, in the Monte Sinni mine, in Sulcis-Iglesiente, by INFN, the scientific sponsor of the project together with Princeton University, the Autonomous Region of Sardinia and Carbosulcis, an investee company of the Sardinia Region that manages the mining plant. The project consists in the construction of a cryogenic distillation tower for the production of very high purity stable isotopes. The plant will be the first of its kind in Europe, and the first in the world implemented with innovative technology that should allow the achievement of hitherto unprecedented performance. In this phase of the project, INFN has already invested 6 million euros, the Sardinia Region 2.7 million euros and Carbosulcis already contributed for the upgrade of the mining infrastructure with a cost of over 1.5 million euros and has an investment of over 2 million euros in progress for installation of the plant in the Seruci well 1.

The objective of the project is to separate air into its fundamental components, elements which are useful in various areas of research and application. In particular, one of these components, argon-40 (^{40}Ar), will allow the development of an innovative technique for the search for dark matter at the INFN Gran Sasso National Laboratories (LNGS), designed and implemented by the scientific collaboration of the DarkSide experiment. The infrastructure for the production of the argon and other elements will consist of a 350-metre cryogenic distillation tower, which will be installed in well 1 of the Seruci area. The tower will consist of 28 modules tested at CERN, and then transported to the Nuraxi Figus shipyards. Here, the modules will be partially assembled on the surface for the first preparatory tests

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for the installation of the entire column inside Well 1, where the upgrading activities have already been taking place since last year. The height and diameter of the wells, their configuration, with multiple accesses and integrated security systems and, above all, the availability of a truck road from the surface to a depth of 500 metres, are ideal conditions for safe installation of a plant that will have dimensions unequalled anywhere else in the world. Thanks to its advanced infrastructure, built almost entirely inside an existing mining well, ARIA will be able to significantly lower production energy costs, making the precious elements obtained from the distillation of air more accessible and usable.

Cryogenic distillation is the most effective method for producing stable isotopes. The distillation tower, in addition to producing the stable isotope ^{40}Ar of interest for dark matter research programmes, will also serve to carry out pilot studies for the production of isotopes ^{76}Ge, ^{82}Se, and ^{136}Xe, considered of interest for neutrino research programmes, again carried out at the INFN Gran Sasso Laboratories. In addition, ARIA will allow the experimentation and development of the new technology for the subsequent large-scale production of stable isotopes of commercial interest, such as ^{13}C, ^{15}N, and ^{18}O, which are used, for example, in medicine and have a major international market.

The Gran Sasso Laboratories are world leaders in the direct search for dark matter: in fact, various experiments are carried out, based on different technologies, all of which have the objective of detecting the interaction of dark matter particles with the nuclei of the detector's target material. In particular, the DarkSide detector is based on the use of argon as a means of interaction: it consists of a biphasic, liquid and gaseous argon Time Projection Chamber (TPC). The results of a prototype detector in operation at the Laboratories since 2013 have already reached the best sensitivity in the world for the search for low mass dark matter particles. The next detector, DarkSide-20k, has been designed to implement the most ambitious dark matter search and discovery program. It will enter operation in 2022, and will require the use of 50 tons of argon processed by the ARIA plant. Therefore, the ARIA project plays a fundamental role in the strategy of the possible discovery of dark matter through argon detectors. The uniqueness and perspectives of the project have brought together scientists from the four corners of the globe to form a single international collaboration of all the researchers who have so far developed argon detectors for dark matter: we are talking about the Global Argon Dark Matter Collaboration, whose first step is the DarkSide programme at LNGS. DarkSide-20k is an experiment approved and funded by INFN and by the US National Science Foundation. Further important contributions will be provided by ten other countries: Brazil, Canada, China, France, Germany, Great Britain, Mexico, Poland, Spain, Switzerland and Russia. ■