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**INNOVATIVE TECHNOLOGIES
TO HUNT FOR DARK MATTER
AT THE GRAN SASSO LABORATORIES**

An interview with Cristian Galbiati, professor of physics at Princeton University and co-ordinator of the DarkSide experiment.

The DarkSide experiment, installed in 2011 at the Gran Sasso National Laboratories, has just presented the first results on the effectiveness of an innovative technology for the detection of dark matter, which makes use of argon extracted from underground deposits. We interviewed Cristian Galbiati, coordinator of the international collaboration.

The INFN's Gran Sasso National Laboratories, protected by 1400 metres of mountain rock that shields them from cosmic rays, are currently conducting various experiments to identify dark matter. Other projects are being conducted in various laboratories around the world. What is the difference in these experiments?

The purpose of the detectors currently used for the direct identification of dark matter is to detect the collisions of dark matter particles with the nuclei of the material used as a target mass or, in a few, limited cases, collisions with the electrons.

Of the various different technologies used, bolometric detectors using pure crystals as the target mass stand out for their low detection threshold; however, the very demanding and expensive techniques needed to build and qualify these detectors make building large detectors with this technique unattractive.

Detectors whose target mass takes the form of condensed noble gases have an intrinsically higher detection threshold but permit the recirculation and continuous cycle purification of the fiducial mass. In addition, the difficulties connected with the detector expansion programme required to continue the dark matter discovery programme are significantly smaller.

The Italian experiment DAMA (*DARK MATter experiment*) - using sodium iodide crystals for scintillation - deserves a special mention: its results have brought to light seasonal signal modulation, that could be caused by dark matter interactions or experimental backgrounds of other kinds that are currently unknown or not fully understood. We hope that in the near future the DAMA signal is independently verified by experiments using the

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same technology in order to be validated or refuted. This is the very essence of the scientific method: “Try and try again”, as Galileo used to say.

You are currently heading the international DarkSide project, a latest generation experiment studying dark matter, that started in 2011 at the Gran Sasso laboratories. What is the most innovative aspect of the detector?

The true secret weapon of the DarkSide project is the depleted argon, impoverished in the ^{39}Ar isotope, a radioactive isotope that is produced in the atmosphere by cosmic rays and that “soils” the argon extracted from the atmosphere. When we started out on this adventure almost 10 years ago, when it was initially known as the WARP experiment (*Wimp Argon Programme*), again conducted at Gran Sasso, we immediately realised that the key to this experiment’s future success lay in our ability to acquire large quantities of depleted argon. The problem facing us was that the only industrial production method, namely centrifugal isotope separation, had extremely high costs of about €50,000 per kilo and extremely long production times. We therefore launched an innovative project to extract argon from underground deposits. DarkSide argon is far purer than the atmospheric gas, in terms of radioactivity content, as it has been protected by the earth’s crust for millions of years and has not been bombarded by cosmic rays. This purity significantly reduces the background noise, considerably increasing the detector’s sensitivity and allowing the construction of far larger detectors.

The other element that makes DarkSide completely innovative compared to previous experiments using liquid gas is that ours is the only worldwide partnership that self-produces the gas used as the detector, by extracting it from the depths of the earth. Most of the processing units needed for production were designed by Italian physicists or engineers. These two factors are a matter of great pride for the whole team.

The first generation of DarkSide has been running since early April, with the first 150 kg of depleted argon extracted from an unused mine on the border between New Mexico and Colorado. The results are excellent and were presented to the Scientific Committee of the Gran Sasso National Laboratories for the first time on 28 April 2015.

Over the last few days, the researchers taking part in the AMS (*Alpha Magnetic Spectrometer*) experiment on the ISS announced the detection of a new signal that could be caused by collisions between dark matter particles. If the “dark” origin is confirmed, what implication would this have for your research?

These results are extremely interesting but cannot be interpreted immediately. We are anxiously awaiting further experimental and theoretical information from our colleagues that may contribute a fuller understanding and evaluation of the meaning of this very important data. The new phenomenon observed in cosmic rays by AMS could be due to an initial manifestation of the nature of dark matter particles, and in this case further

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and more extensive measurements performed using the same technique could provide a precise indication on the mass of dark matter particles, which would consequently encourage all the other experiments to search for dark matter within a specific mass range, including those being conducted at Gran Sasso. Alternatively, the new phenomenon could be due to new and unexplored cosmic ray generation mechanisms and in this case, new experiments attempting to confirm the results obtained by AMS and the other dedicated satellite PAMELA (*Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics*) with greater precision could make further contributions to a noble branch of particle physics that owes so much to the Italian school and to the INFN in particular.

You already have great experience in detecting weak signals such as those produced by dark matter or neutrinos. How have these experiences influenced the subsequent development of DarkSide?

I was involved for a long time in the first experiment studying dark matter with an argon target, WARP, by an international research team, devised and headed by Carlo Rubbia. DarkSide uses the same technique but with the additional use of new supporting technologies that were found to be fundamental in making the physics of argon detectors competitive.

However, the aspect that may have influenced the development of Dark Site most are my 21 years working on the Borexino experiment studying solar neutrinos. I feel truly lucky to have been at the Gran Sasso National Laboratories in 1994, during the experiment's most interesting period. Borexino gave me chance to observe first-hand the *modus operandi* of world-class physicists – among these: Gianpaolo Bellini, Frank Calaprice, Franz von Feilitzsch, Martin Deutsch, Giulio Manuzio, Raju Raghavan, and many others – true undisputed experts in whom I admired the stringent research method and the perseverance required to achieve results that once seemed outside our reach. It is no coincidence that Borexino left an indelible imprint on the development of technologies that have now been adopted successfully by many other international research projects.

Your work straddles two world-class research centres, Princeton University and the INFN. I imagine that the exchange of competence and cultural attitude between researchers in these two continents is a great stimulus to the innovation of ideas and research methods.

The experience on both sides of the ocean has been fundamental to my professional growth. My formative years in basic physics were those in Milan and Gran Sasso, in the group directed by Gianpaolo Bellini. At Princeton, in the group directed by Frank Calaprice, I acquired complimentary and crucial experience in apparatus design and engineering. The involvement in the INFN projects at the Gran Sasso Laboratories has always been the uninterrupted leitmotif of my career.

I notice that the Italian media often talk about “brain drain”; however, I believe this expression to be an unfortunate

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synecdoche. The community of particle physicists is one of the most international and young Italian physicists are true citizens of the world. They are used to dealing with difficult problems and seizing the opportunities that are most beneficial for their career and for the improvement of their culture, motivated and supported by the excellent level of preparation they receive from Italy's University Departments and their corresponding INFN sections. If you don't believe me, just take a look at the laboratories around the world. ■