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INNOVATIVE TECHNOLOGY IN SEARCH OF DARK MATTER

Interview with Elisabetta Baracchini, assistant professor at the GSSI Gran Sasso Science Institute and INFN researcher, winner of an ERC Consolidator Grant

The ERC Consolidator Grant is addressed to excellent researchers of any nationality and age, with at least seven and up to twelve years of post-PhD experience, and a promising scientific curriculum. The 2018 award was won by Elisabetta Baracchini, assistant professor at the GSSI Gran Sasso Science Institute and INFN researcher; a grant of 1,995,719 euros. Candidates must do their work in a public or private research organisation based in one of the EU Member States or associated countries. The grant (on average of 2 million euros per grant) is for a maximum of five years and mainly covers the employment of researchers and other personnel to consolidate the work team of the beneficiaries.
The project proposed by Elisabetta Baracchini, INITIUM (an Innovative Negative Ion TIme projection chamber for Underground dark Matter searches), aims to implement an innovative detector for the direct search for dark matter, currently one of the leading sectors of investigation of fundamental physics. INITIUM envisages the development and implementation of a 1 m^3 gas Time Projection Chamber (TPC), able to reconstruct the traces of detected events in high precision 3D, thanks to a sophisticated signal-reading technology. The 5-year project envisages the installation of INITIUM at the INFN Gran Sasso National Laboratories.
We asked Elisabetta Baracchini to explain to us the investment strategy of the grant that was awarded to her, as well as the aims and development prospects of the project.

First of all, how did you come to work on a sector of fundamental research characterised by so few certainties and many unknowns: the search for dark matter?
I am motivated by the fact that we cannot explain the behaviour of most of the mass of our universe. And although there is incontrovertible proof of the existence of dark matter – that is the name we use for this unknown mass – on the true nature of this large part of the cosmos we have only hypotheses, because all the existing proof is indirect. Directly observing dark matter in our detectors would give

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us the opportunity to open a completely new window on our understanding of the cosmos and the fundamental interactions that govern it.
This is a purely experimental challenge, since direct observation of dark matter is based on the ability to detect very small amounts of energy released by an atom struck by dark matter in our detector, and on the possibility of distinguishing these events from interactions caused by common particles, which are hundreds or thousands of billions of times more frequent. This research therefore represents one of the forefronts in the development of new technologies and, in general, of new approaches to particle detection: a characteristic that makes this sector a work environment rich in stimuli and new possibilities.

Can you explain your project and its premises? In your opinion, why was it considered promising by the ERC?
My project is based on the idea of measuring and identifying the direction of arrival of the particles detected, in order to distinguish the events caused by dark matter from those due to the interactions of ordinary matter: this could be the key to the positive and unambiguous identification of a dark matter signal. This approach represents a total innovation with respect to the experiments that are currently operational and which can only detect the energy deposited.
The technique is based on a reasonable expectation. Due to the movement of the Earth with respect to the centre of our galaxy, in fact, dark matter is expected to have a preferential direction in space, unlike anything that can mimic its interaction. To do this, our project involves the use of a gas, as a detection material, and of CMOS cameras (Complementary Metal Oxyde Semiconductor, the same sensors that we have in mobile phones) capable of "photographing" the trace released by the passage of the particles in the gas, after an appropriate signal amplification.
I believe that the ERC was awarded to me because the technique we proposed is innovative for the type of research to which it applies; moreover, in the context of the development of the sector of directional search for dark matter, this innovative approach comes at the right time, since only in recent years it has reached an adequate maturity to compete with the other techniques in use.

How are you investing the grant? Has it allowed you to strengthen your team?
Approximately half of the grant will be dedicated to personnel and the expansion of the research team. In particular, the grant has already allowed me to open two 4-year positions for the next PhD cycle at the Gran Sasso Science Institute (GSSI), whose announcement was recently published. We are also counting on hiring two more post-PhD researchers in our team.

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I am particularly pleased to be able to open these positions, because they will allow me to create a young and motivated team and start developing with them this and other lines of research at the GSSI. Part of the grant, amounting to approximately 600 thousand euros, will be used to purchase new components and build the detector itself, implement its services and, finally, install it in one of the tunnels of the INFN Gran Sasso National Laboratories.

What are the main difficulties you think you will have to face, in terms of technological limitations but also obstacles in the research as well as personal and team motivation process?

From a practical point of view, obviously my main concern is not being able to build a detector with competitive performance and, consequently, not being able to demonstrate the validity of our approach. In fact, the first 18 months of the project still include a phase of development of our technique, in terms of optimisation of the gas mixture, amplification type and camera sensor.

From a personal point of view, the possibility of pursuing this project is certainly a qualitative leap in my career, but also in the extent of my responsibilities and of what, in general, I will have to manage from now on. All this represents a challenge for me and a great possibility of personal and professional growth, but at the same time it sometimes scares me a little. Fortunately, our work team consists of close-knit and motivated colleagues, whose help is extremely valuable for managing and achieving the success of the project. This is why I have great confidence in the future.

What results do you expect in the short and long term?

First of all, this ERC Grant will give us the possibility to significantly accelerate the development of our research, both from the point of view of financial availability for procurement as well as manpower. And, above all, in less than 4 years, it will allow us to complete and install at the Gran Sasso National Laboratories the first directional dark matter detector (for WIMP masses below 10 GeV/c), with performance that we hope will be competitive with the other approaches. In general, this will produce an advancement in the development of high-precision gaseous Time Projection Chambers for different applications; if it were to demonstrate the expected performance, it could actually open the way to the implementation of a dark matter directional detector on the scale of the tonne, projecting the search for dark matter into a new era. From a personal point of view, I hope that the new young research group that will be created around this experiment will become the basis for the application of our approach in other fields and for the development of other projects. ■