Newsletter Interview

INNOVATIVE DETECTORS FOR THE ACCELERATORS OF THE FUTURE: AN ERC GRANT TO THE PROJECT COMPLEX

Interview with Valentina Sola, researcher at the University of Turin and the INFN Turin Division, winner of an ERC Consolidator Grant of €1.8 million in 2023.

The European Research Council has awarded Valentina Sola, a researcher at the University of Turin and at the INFN Turin Division, a €1.8 million Consolidator Grant for her research project called CompleX, which will study how to extend, through the development of an innovative design, the operation of silicon detectors in environments with extreme radiation levels, such as those at the next-generation particle accelerators.

ERC Consolidator Grants are European grants awarded to outstanding researchers of any nationality and age, with at least seven and up to twelve years of post-doctoral experience and a promising scientific track record, who carry out their work in a public or private research organisation based in one of the EU Member States.

CompleX has the potential to have a strong impact on the future of particle physics. We asked Valentina Sola to tell us about the goals and development expectations of the project she has conceived.

Can you tell us about the CompleX project? What are its objectives?

The CompleX project is about the development of silicon detectors for future particle accelerators, such as the eventual future accelerators at CERN in Geneva, the Future Circular Collider (FCC-hh) or the Muon collider, which are environments with extremely high radiation levels. Silicon detectors are key elements in the high-energy physics experiments and today they already have a high resistance to radiation. For example, the detectors for CERN's next accelerator, the High-Luminosity LHC, are now ready. However, accelerators such as the FCC-hh or the Muon Collider will have a much higher radiation level, so in order to enable silicon detectors to work in these environments, we need to extend their radiation resistance. However, we first need to improve our understanding of the radiation damage on silicon when it is in environments with the radiation fluxes that FCC could achieve, which are estimated to be $5x10^{17}$ particles per square centimetre. Once we have a deep understanding of what is going in the detector when it is exposed to radiation, we can use this knowledge to design new detectors. Therefore, CompleX aims to design, build these detectors and make them a state-of-the-art technology. The goal is ambitious, just think that if we installed one of High-Luminosity LHC's silicon detectors in the innermost layer of the FCC experiments, it would survive for less than 3 months.

What led you to conceive this project?

Here in Turin, I have been very lucky, and I have had the chance to work in a very stimulating and productive environment. In particular, I worked with Nicolò Cartiglia, an INFN researcher who, thanks to an ERC Advanced Grant, created the very framework where to work for the development of innovative detectors. It led to the birth not only of a thriving research group with many ideas, but also of a laboratory, established in collaboration with the Physics Department of the University of Turin, where I was trained, and I was able to learn a lot. Moreover, with the Turin group, I have always worked with the RD50 collaboration at CERN, the one that enabled the development of today's silicon detectors and devised the technology that led to the LHC High-Luminosity detectors. I therefore grew up scientifically in the research community that was working on the development of new silicon detectors, and, at some point, a question arose in this community: how do we build the new particle detectors for the accelerators of the future? I then began to try to answer this question with the first research project that I designed and coordinated: the eXFlu project, funded in 2020 as part of a Youth Grant from INFN National Scientific Commission 5, which works on technology research. At the beginning, research teams from the INFN Turin division and from the Bruno Kessler Foundation (FBK) in Trento worked on the project. They were later joined by a group of researchers from the University and INFN division of Perugia, who have a strong expertise in the simulation and study of radiation damage in silicon. The eXFlu project has thus evolved over time: today we know that the original idea of 2020 is no longer feasible, because we observed catastrophic events that caused the sensors we were developing to break. We therefore had to find another approach, which led first to the development of the eXFLu 1 project, financed within the framework of a Blue Sky Technology call for proposals by Aida Innova, and then to the drafting of the CompleX project, which was awarded this prestigious European Research Council grant.

What was the initial idea behind the eXFlu project and how did it evolve into the CompleX project?

These projects are based on the LGAD Technology. LGAD, Low Gain Avalanche Diods, are innovative detectors developed between 2014 and 2015, who have a moderate gain, meaning that they are based on a mechanism that allows to amplify the signal internally. The signal coming out of the LGAD detectors can be five, ten, twenty times larger than the incoming signal, and it can easily be controlled from the outside by acting on a parameter called 'bias voltage' that is supplied to the sensors. Unfortunately, this gain decreases with irradiation, but we have noticed that by turning up the 'bias voltage' knob when irradiation occurs, we recover the gain. The initial idea of the eXFLu project was to use thin sensors that are less affected by radiation and need a lower 'bias voltage' to achieve good working conditions. Unfortunately, we observed that these sensors when irradiated by particle beams systematically break when a certain very high 'bias voltage' is reached. We thus took another route and at the heart of the CompleX project is an innovative design for the LGAD detectors, based on a phenomenon called "compensation". To extend the internal gain of the LGAD detectors, up to extreme fluences, two types of atoms called 'dopants' are added to the detectors, creating zones of positive and negative charge. Before the design of the CompleX project, we needed an intermediate step: thanks to the eXFlu and eXFlu-innova projects, it was possible to build the eXFLu1 sensor batch at FBK, which represents the proof-of-concept of the compensated LGAD technology, the core of the development proposed in the CompleX project.

What will the applications of CompleX be?

The ultimate goal is definitely to employ the sensors we will develop in the vertex detectors of the FCC-hh or the Muon-collider, for the area of the detectors closest to the collision point. Therefore, what we would like to do is to have four-dimensional detectors that measure very well the position and passage-time of the particles in these experiments. These detectors could then be employed in all those environments where the particle radiation is very high, and it is necessary to use a detector to understand what is happening and to photograph the particles. For example, they could be applied in the future nuclear fusion reactors, now under development.

How is it possible to be awarded such a prestigious grant? What was, in your opinion, the key to your success?

The key for me was perseverance. I submitted the project three times before being able to receive the grant. The first time in 2020 as a starting grant, then in 2021 as a consolidator, and lastly this year, finally succeeding. Moreover, the writing stage required a lot of study and commitment. Unfortunately, I had to take time away from holidays and therefore from the family. I wrote a large part of the project during the past Christmas holidays and for this I must make a special mention to my daughter who had admirable patience to see her mum spending the holidays writing. It was also interesting to prepare the interview, here, I would like to thank my colleagues for all the help and support they gave me. We did a lot of rehearsals together and everyone's point of view was crucial for the final success.

How will you spend the grant?

The management of the project's funding is not easy, not only because it is an ambitious project but also because there are three beneficiary organisations: the University of Turin, which is the host institution, the Bruno Kessler Foundation and INFN with its Perugia and Turin divisions. Of course, part of the budget will be used for personnel, something I consider very important, because it is not just a vision for the present, but a vision for the future. We will have the opportunity to hire new people, new young researchers and teach them the art of developing particle detectors. Moreover, of course, there are costs associated with the production of the sensors and the equipment to be bought. Fortunately, we started from a solid base, we have well-functioning laboratories, and this has enabled us to achieve this result, but we want to improve them further by upgrading the infrastructure we have. Not forgetting the expenses related to trips and to the dissemination of our results to the scientific community.

What challenges do you expect to face during the five years of the project?

The main difficulties I expect are related to science. For example, during the project, it could emerge a phenomenon that shows that we cannot go in the expected direction, and we have to change strategy, as occurred during the eXFlu project. This would be the most difficult challenge, but I believe that with a good team, with good discussion and work within the group, we could open up other possibilities that we had not yet thought of.

From a personal point of view, what does it mean for you to have been awarded this grant?

It is certainly a great joy and a great pride, but I have the feeling that I still have to discover the scale of this achievement day by day. I am very grateful to those who helped me to achieve it. The team I work in has been an important part of my success and the people I am most grateful to are the people I work with, who have trained me and who allow me to do my research daily. Now, I really want to start this project because I think it will be a wonderful adventure.