Innovating Advanced Radiation Instruments

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Impact Objectives

- The Innovative Training Network STREAM trains a new generation of creative, entrepreneurial and innovative early stage researchers
- Target the development of innovative smart CMOS sensor technologies as radiation hard imaging sensors for research and industrial applications

Innovating advanced radiation instruments

***Professor Dr Norbert Wermes, Dr Ingrid Jonak-Auer, Dr Heinz Pernegger** and **Dr Luigi Mele** explain how the **STREAM** Innovative Training Network is empowering early stage researchers in the design and implementation of novel advanced radiation instruments*

Professor Dr Norbert Wermes

Dr Ingrid Jonak-Auer

Dr Heinz Pernegger

Dr Luigi Mele

Could you introduce the STREAM Innovative Training Network (ITN) and what it targets?

LM: STREAM, which stands for Smart Sensor Technologies and Training for Radiation Enhanced Applications and Measurements, is a large consortium coordinated by CERN that brings together key players in radiation-hard complementary metal-oxide-semiconductor (CMOS) technology, high-energy particle physics and electron microscopy applications. Its ultimate aim is to provide career development and training opportunities to Early Stage Researchers (ESR), empowering them to develop a new generation of radiation-hard CMOS-based detectors. This will enable future studies and discoveries in high-energy particles physics, as well as the development of innovative applications for society.

HP: For the development of novel sensors we always strive to bring academia, industry and talented young researchers together. The synergy of scientific developments at universities and industrial knowhow of our partners allows us to create novel CMOS sensor solutions for research and industry. The EU-funded Marie Skłodowska-Curie Innovative Training network STREAM provides us with an excellent framework for this collaboration and creates the ideal research and training environment for young engineers and physicists. The network will provide 17 ESRs with training. STREAM structures the research and training in four scientific work-packages which span the whole value-chain from research to application: CMOS Technologies Assessment, Smart Sensor Design and Layout, Validation and Qualification, Technology Integration, and Valorization.

How important is it to have industry representatives in STREAM? What value does this involvement bring to industry?

IJA: The value to industry is twofold. On the one hand it enables companies to do basic research with the help of ESRs to a much wider extent than is usually possible within industrial environments. On the other hand, it enables industry to train young researchers for possible later employment. Scientific and technical exchange with partner organisations is of great value as well.

You are working across multiple sites. Can you talk about some of the challenges associated with this and how you have addressed them?

LM: Coordination of activities spread over multiple locations is always challenging but also stimulating. Nowadays, this is a typical way of working in multinational organisations. It is a good learning process for the ESRs too, as they have to learn how to write clear product specifications and how to be effective via teleconference or in a one-day meeting.

What value do the ESRs gain from involvement in the Marie Sklodowska-Curie Action STREAM project?

IJA: ESRs working with STREAM industry partners gain a lot of experience in both technology and business strategies. ESRs get insight into the different approaches to technological challenges between academic institutions and companies. This experience helps them to decide on their future career.

LM: ESRs will be able to learn from institutes and industrial partners which are among the best in the world in their field in fundamental high-energy particle physics, radiation-hard CMOS detectors and electron microscopy. This is an opportunity that not all researchers have. Moreover, they will be developing new technology which has the aim to be unrivalled in the coming years: this will be a clear advantage for their professional future whether they will pursue academic or industrial career.

'STREAM'S early career researchers benefit from the international expertise, the project pressure and the collaborative atmosphere'

Training the next generation

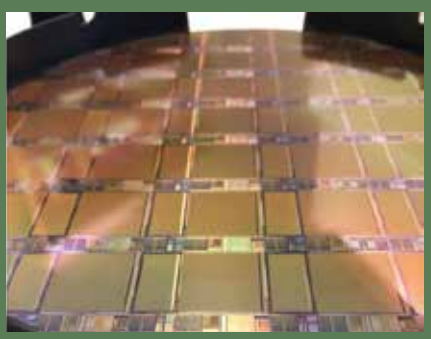
As high-end imaging applications delve deeper into the structure of particle physics, released energy and radiation increase. The ***STREAM*** *Innovative Training Network is an EU Marie Skłodowska-Curie funded project dedicated to developing the new generation of technologies and researchers that this necessitates*

Scientific facilities such as those at CERN, the European particle physics laboratory, thrive on the use of complementary metal-oxide-semiconductor (CMOS) sensors to carry out specialised and highly accurate imaging work. Because the demands of the research continually call for ever more advanced equipment, CMOS sensors are constantly under development, to cope with the increasing radiation environments of the experiments at the Large Hadron Collider (LHC).

Training in the development of the next generation of sensors from the ground up is hugely important in the fast-moving field of imaging technology. This is where STREAM ITN steps in. STREAM has been designed as a career development pathway for early stage researchers (ESRs), with the goal of producing a new generation of subject matter experts in this complex field. According to one of its project leaders, Professor Dr Norbert Wermes of the University of Bonn: 'Our ESRs benefit from the international expertise, the project pressure and the collaborative atmosphere'.

PAN-EUROPEAN INVOLVEMENT

The project management team behind STREAM recognise the need to develop the right skills for future sensor developers. Dr Mar Capeans, STREAM Work Package Leader for Training, notes 'we understood the importance of developing the right skills for future sensor developers, the requirements of the science community, and we are driving the ESRs through a range of academic and non-academic placements to ensure that they get the most rounded experience. STREAM ITN training also covers topics such as innovation management and technology transfer. This means the ESRs are involved in pure research studies as well as in product development and technology transfer projects.



STREAM CMOS wafer produced in a 0.18 um CMOS imaging process (MALTA and MONOPIX)

The Marie Skłodowska Curie ITN brings together participating partners from a total of 16 European educational and scientific organisations spanning Austria, France, Germany, Switzerland, Italy, Norway, the Netherlands and the UK. Its members comprise eight universities, three research centres and five industrial partners. 'The involvement of industry in STREAM is very crucial,' Dr Luigi Mele, a senior scientist at FEI, explains. 'It enables the technology developed for fundamental research to find a commercial application thus reaching a broader community which can benefit from the advances in radiation-hard CMOS technology.' 'Actually, this is the most productive network that I have ever been involved with. The ESRs are almost always above average, and the network provides the intellectual competence in electronics engineering that often is not easily obtainable in physical sciences,' says Wermes.

SETTING THE BAR HIGH

The STREAM ITN is not only aiming to produce the next generation of advanced radiation instrument experts. Another important goal is to contribute to the formulation of novel sensor technologies. This is being achieved by employing a holistic approach that focuses on all aspects of product development, including their design, production and application. Moreover, by using the LHC the STREAM ESRs are kicking off the four-year project at a high level of sophistication. It is therefore hoped that the programme will produce a huge leap forward in detector technology.

Due to the very nature of CERN's research, the sensors used have to be able to withstand significant radiation and this is recognised as a shortcoming. The ability of the LHC to observe sub-atomic interactions is highly dependent upon the detector systems used, so they have to be hardened against the background radiation of the system. As the LHC delves further into the building blocks of the universe, the radiation will intensify, requiring ever-more advanced levels of detectors to cope with it.

CERN AND BEYOND

The ITN has already produced some promising results. For example, according to Dr Ingrid Jonak-Auer, Manager of Photonic Devices at ams AG: 'Concerning the development of radiation hard X-ray sensors for medical applications, we were able to set up a technology computer-aided design (TCAD) simulation environment that allows accurate prediction of optical and electrical parameters of the sensor.'

In the process, the ESRs will also develop an in-depth understanding of all aspects of the development and commercialisation process. This will produce ESRs that are just as comfortable engaging with industry as with academia. The focus of STREAM is on entrepreneurial and innovative skills as much as pure research and technology developments, and by engaging with some of Europe's premiere imaging companies as well as research institutes, the ESRs will be in a perfect position to accomplish that.

A unique training opportunity

Barbara Mehner and Ettore Zaffaroni, two Early Stage Researchers within STREAM, outline how their research and employment prospects are benefiting from their involvement in the Innovative Training Network

Barbara Mehner

Ettore Zaffaroni

Why is a career development network on scientific design, construction and manufacturing of advanced radiation instrumentation needed?

BM: Especially in an area concerning such highly complex problems as the development of radiation-hard, smart CMOS sensor technologies, an interdisciplinary approach with experts from many different fields and backgrounds is essential. Only in a highly diverse network and with additional support through extensive training (such as to enable an optimal collaboration across disciplines, overcoming cultural and mind-set barriers and facilitating common understanding) can the required level of quality and innovativeness of solutions be accomplished.

What value do the ESRs gain from involvement in the Marie Sklodowska-Curie Action STREAM ITN?

EZ: Being involved in the STREAM project allows us ESRs to get more skills than a normal PhD, since we have the possibility to be trained on both scientific and 'non-scientific' topics, like business, innovation, presentation and communication techniques, etc. Furthermore, it easily allows us to get in contact with people from different institutes around the world and to work with them, so we can see how different groups work and learn from them. For example, I just had a two-week secondment in Liverpool, UK, and in the future will have another secondment in Milan, Italy. Moreover, I have had the possibility to present my work on different occasions: with a poster at a STREAM winter school and at the Swiss Physics Society annual meeting, in a seminar to master students at the University of Milan, and at the STREAM annual meeting in Bonn. I will also give a talk about it at the next ITk week at CERN, where the upgrade of the ATLAS inner tracker is discussed by all the community at large.

BM: The fellowship offers ESRs vast training opportunities that otherwise would not have been possible. The provided resources facilitate the dissemination of our scientific results to other researchers at conferences and workshops and to continuously improve our work through extensive feedback from experts with diverse backgrounds at these events. Also, the interdisciplinary and intercultural exchange with fellow ESRs and other researchers in the programme helps me to expand my horizon and showed me different application fields. Having a background in economics and psychology, I highly appreciate the opportunity to engage in scientific exchange with physicists and engineers and my research benefits tremendously from including these new perspectives.

In what ways do you think researchers can better engage with the public to demonstrate the impact of their work?

EZ: I think it can be a good idea to involve industry partners in outreach events like the Researcher's Night and to explain how scientific research has a true impact on the everyday life and on the progress in completely different fields (such as a development in silicon detectors can improve imaging techniques in biology and medicine, leading to new and more accurate diagnosis methods and treatments). I think that we should show that scientific research aims to a progress that benefits everyone, not just itself.

Project Insights

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PARTNERS
The STREAM consortium is composed of 11 research organisations and 5 industrial partners. STREAM is coordinated by CERN. CERN (Switzerland) • WU Wien (Austria) ThermoFisher Scientific (Netherlands) • Fraunhofer IZM (Germany) • Centre de Physique des Particules de Marseille (France) • Universität Bonn (Germany) • Karlsruher Institut für Technologie (Germany) • University of Glasgow (UK) • Université de Genève (Switzerland) • ams AG (Austria) • CiS Forschungs- Institute für Mikrosensorik GmbH (Germany) • CIVIDEC Instrumentation GmbH (Austria) • INFN Milano (Italy) • University of Oslo (Norway) • University of Liverpool (UK) • Technical University Berlin (Germany)

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Dr Heinz Pernegger is a CERN Senior Physicist and co-leads the development of novel CMOS sensors as tracking detectors for the ATLAS experiment at CERN's Large Hardon Collider. He received his PhD from the Technical University Vienna in 1996 and spent years of post-doctoral studies at Bookhaven National Laboratory and Massachusetts Institute of Technology. Since 2000 his research focuses at the development and construction of novel silicon detector systems for experiments at CERN.

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