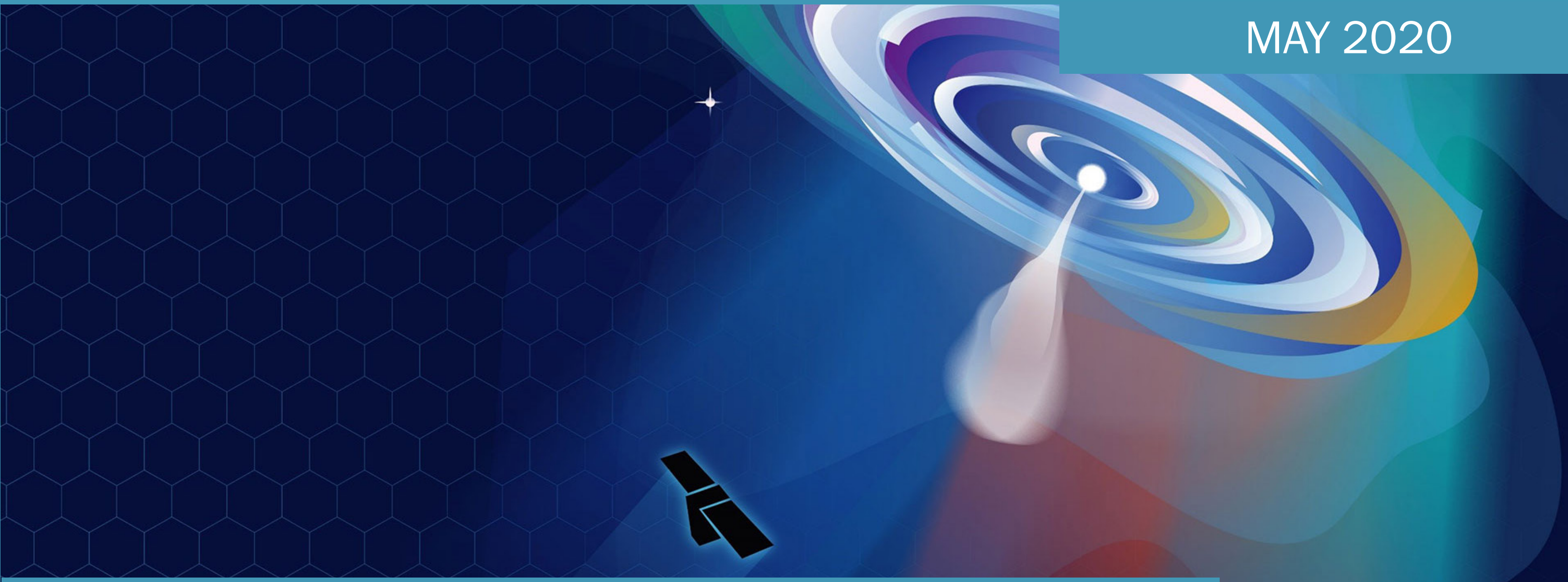

MAY 2020

NEWSLETTER 71

Istituto Nazionale di Fisica Nucleare

INTERVIEW

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MVM, FROM DARK MATTER TO LUNG VENTILATORS

Interview with Cristian Galbiati, professor at the GSSI Gran Sasso Science Institute and at Princeton University, INFN Researcher, creator of the MVM project

The rapid spread of CoViD-19 has dramatically entailed - for many of the Countries affected by the pandemic - a possible lack of ventilators as opposed to the number of patients: those who contract the virus can, in fact, develop very serious lung complications such that they require the use of a respiratory support system that pumps oxygen into the lungs and expels carbon dioxide when air is exhaled. The ventilators currently available on the market are sophisticated and expensive devices, with complex control systems and patented designs. The goal of the MVM Milan Mechanical Ventilator international collaboration was therefore to design, develop, build and certify a safe and efficient ventilator, equipped with an advanced control system that would allow to select different ventilation modes, but that at the same time would also feature a simple design, based on components easy to find on the market in order to be quickly produced in different Countries. MVM became a certified replicable prototype in just over a month: conceived as an idea on March 19, on May 1 it obtained the Emergency Use Authorization (EUA) of the Food and Drug Administration (FDA), the US certification body, and will therefore be allowed to be included as hospital equipment in Countries that acknowledge the American certification. We asked Cristian Galbiati, creator and promoter of MVM, to describe the project and recount its history.

How did the MVM project start?

It started as an idea and initiative by some scientists of the GADM (Global Argon Dark Matter) international collaboration, who are engaged in research on dark matter, with experiments at the INFN Gran Sasso National Laboratories and in some Canadian laboratories. As a matter of fact, the creation of sophisticated experimental devices for research in fundamental physics has allowed the development of specific skills in the field of complex control systems and the management of gases, similar to those used in lung ventilators. Hence the idea to use these skills to create a new mechanical device for assisted ventilation.

Starting from your skills as physicists, how did you manage to achieve the industrialized prototype of a lung ventilator in just over a month?

Thanks to the ability to pool resources and work in in large collaborations and multidisciplinary contexts, combined with the great dedication of all the people who took part in it.

The first model unit of MVM was made in Lombardy, the Italian region most affected by the pandemic, and where I also live.

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We developed a first prototype at the technical support centre for respirators of the company Sapio Life in Vaprio d'Adda, near Bergamo, in direct and continuous collaboration with the Physics Department of the Università Statale of Milan. But getting the MVM ventilator all the way to patients obviously requires skills that go far beyond particle physics. So, the collaboration widened to include all the necessary sets of skills, particularly in the medical and anaesthesiologic domains. The project therefore attracted clinicians and health workers, and companies, such as Elemaster, Nuclear Instruments, AZ Pneumatica, Saturn Magnetic, Bel Power Europe and Camozzi. Elemaster, in particular, coordinated the participation of all the companies in the project, made its laboratory available for the development of the first units and manufactured the entire electronic part of the ventilator, from the printed circuit board, produced by its division, to the complete assembly, achieved thanks to the contribution of all the other companies involved. After careful testing and qualification processes of the performance of the first prototype with breathing simulators, conducted with the Department of Medicine of the Università di Milano-Bicocca at the San Gerardo Hospital in Monza, it was possible to build the first industrialised prototype in a few weeks, which demonstrated the correctness and feasibility of the design concept.

What was the INFN's contribution in particular?
INFN coordinated the development of the electronics, with the contribution of of various Divisions, of the CNAF National Computing Centre and the Gran Sasso National Laboratories. In a few days, INFN researchers designed the prototype of the board that houses the micro controller and manages the electrically driven pneumatic valves, the pressure and oxygen sensors. The computer skills available in the INFN have also made it possible to create the Graphic User Interface (GUI) that allows you to view the patient's vital parameters on an LCD display and allows medical personnel to set the operating parameters of the ventilator.

The collaboration quickly expanded throughout Italy and abroad.
Yes, the MVM project was immediately able to count on the support of many Italian institutions: in addition to the fundamental contribution of the INFN, also universities (Università di Milano-Bicocca, Milano Statale, Napoli Federico II), GSSI Gran Sasso Science Institute, STIIMA and ISTP institutes of the CNR National Research Council, and later also on the contribution of the other Lombardy universities of Bergamo, Brescia, Pavia, and Insubria, and of researchers from the Department of Chemistry and Industrial Chemistry of the Università di Pisa and of the IFC of the CNR, supported by staff of the Gabriele Monasterio Tuscany Foundation, and of the company SRA Instruments.
The first to become passionate about the project abroad and to accept the invitation to implement it was the Nobel prize for physics Arthur McDonald at Queen's University, who then involved the Canadian laboratories CNL, TRIUMF, SNOLAB, while in the United States research teams took part in it from Fermilab, the Princeton Plasma Physics Laboratory and various other Universities.
In the meantime, the collaboration base has also grown across Europe, involving researchers from French, Spanish, German

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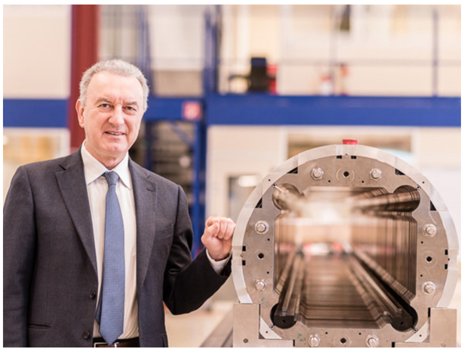
and Polish scientific institutions. We managed to create MVM in such a short time thanks to the endless commitment of all the people who, without sparing themselves, invested all their energy and resources, working tirelessly even on weekends and holidays, day and night, exploiting the different time zones.

What is the project's strength and the advantage it offers compared to standard ventilators?
Its strength is represented by the simplicity of its mechanical design. MVM draws inspiration from the ventilator developed by Roger Manley in 1961, based on the principle of "the possibility of using the pressure of the gases emitted by the anaesthesia device as a driving force for a simple device for lung ventilation in patients in the operating room". Designed to be as simple as possible, The MVM features electrically driven pneumatic valves rather than mechanical switches, thus integrating the advanced features proposed by the anaesthesiologists taking part in the project and who are active in Lombardy's hospital wards.
Its main advantage lies in its modular design, that makes it possible to exchange components based on availability in different parts of the world, so that it can be produced on a large scale and at low costs in different Countries.
Just to facilitate its easy, fast and wide reproduction, the MVM design is open access, i.e. it is not patented: each step of the project has been published on arXiv.org, where the scientific article of the final project is also available.

What does this experience teach us?
That basic research is an extraordinary driver for growth and innovation. The MVM case history is an example of some of the typical elements that make basic research, particularly in fundamental physics, a knowledge and progress resource not only in its specific area of action but also in more distant domains, with cascading technological effects and applications for the public. This is made possible by the fact that these researches develop the ability to react quickly, to take on new challenges by going beyond current limits, to face problems with vision, to create and work in international and multidisciplinary collaborations. Scientific research represents our key resource to face the great challenges of our times, we must always be aware of it and invest in it with vision and persistence, if we want to be able and prepared to better manage future challenges. ■

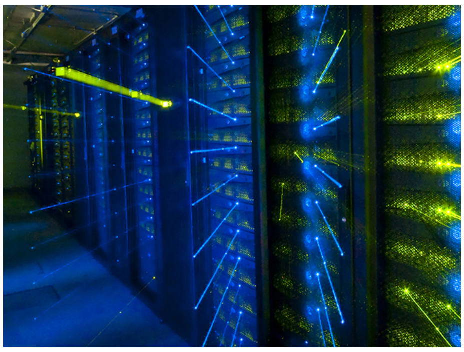


AWARDS

LUCIO ROSSI WINS THE ROLF WIDERÖE 2020 AWARD

The EPS European Physical Society has awarded Lucio Rossi, physicist of CERN and INFN, the Rolf Wideröe 2020 prize. The prize was officially awarded on Thursday 14th May during the IPAC International Particle Accelerator Conference, which this year was held in video conference mode because of the Covid-19 emergency. Rossi was awarded the prestigious recognition "for his pioneering role in the development of superconducting magnet technology for accelerators and experiments, its application to complex projects in High Energy Physics including strongly driving industrial capability, and for his tireless effort in promoting the field of accelerator science and technology."

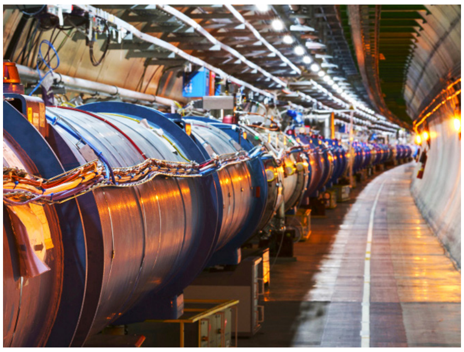
The Rolf Wideröe award represents the recognition of the scientific community of particle physics to Lucio Rossi's decisive contribution, both from a scientific and managerial point of view, in the design and development of CERN's LHC dipole magnets. Lucio Rossi has been professor of Physics at Università di Milano Statale since 1992. His work is in the field of large superconductivity applications for accelerators and particle detectors. He was in charge of the first LHC dipole magnets for the INFN, and then of the first ATLAS toroidal coils. Since May 2001, Rossi has been at CERN, where he has been in charge of Magnet&Superconductor project for LHC, and is currently in charge of the High-Luminosity LHC, the accelerator enhancement project that will start after 2025. ■



APPLICATIONS - COVID-19

ITALIAN PUBLIC SUPER-COMPUTING SUPPORTING THE FIGHT AGAINST THE PANDEMIC

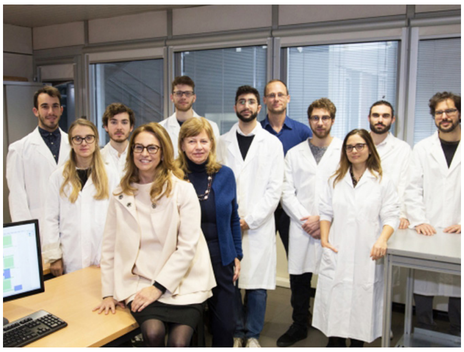
Over 8 million hours of computing available to researchers for projects aimed at fighting the CoViD-19 epidemic. This is the commitment of the INFN CNAF National Data and Computing Centre together with CINECA, CMCC and ENEA, which represent the main public supercomputing entities in Italy, in an initiative promoted by the Big Data Association, in close cooperation with the international foundation Big Data and Artificial Intelligence for Human Development. The goal is to support public and private research groups for a wide range of projects, without disciplinary limits: from biomolecular, biochemical and bioinformatics research to bio-simulations, from epidemiological analyses to mitigation of the pandemic's impact. The initiative responds to the growing demand for computing resources and is aimed at supporting research projects in which the use of supercomputers is necessary for simulations and the management of large amounts of data, as in the case with the identification of therapies, the study of viral antibodies, the knowledge of the molecular structure of the virus and its mutations, the preparation of vaccines, as well as the development of models of diffusion and containment of CoViD-19. The announcement takes into consideration the working groups' need to be able to get on with research quickly: the initiative hence provides for the possibility of presenting projects on an ongoing basis. Furthermore, proposals will be evaluated upon submission, in a couple of days, by a technical-scientific commission, and they will be able to start immediately. Researchers of all nationalities, as long as they are affiliated with public or private Italian institutions, can present their research projects. ■



APPLICATIONS - COVID-19

A SUPPORT WEB SITE FOR ITALIAN BIG SCIENCE COMPANIES

A new tool to support SMEs and Big Science industries, in this phase of business recovery following the crisis caused by the Covid-19 pandemic. This is the objective of the new site created by INI-ILO (Ilo Network Italia), the network of ILOs (Industrial Liaison Officers), made up of expert representatives of the major Italian research bodies - in addition to INFN, also CNR, ENEA and INAF -, which play a connection role between national companies, considered worldwide an excellence in the sector, and large research infrastructures, such as CERN, ESO, ESRF, ESS, F4E / ITER. The big European laboratories are sharing their plans for the gradual reopening and now important challenges await the Italian companies that operate in these centres with their own staff. In fact, companies will face difficulties of various kinds, such as extra costs, restrictions on travel to and from Italy, stringent safety rules. With the cooperation of the laboratories, ILOs are committed to finding the best way to manage these new hurdles. Thanks to this new tool, the first in the sector in Europe, companies will be able to report directly to INI and to their related ILOs any problems encountered in their activities, but they will also be able to access updates on any measures regarding the Covid-19 emergency and information on the reopening of the laboratories of the major international research infrastructures. ■



APPLICATIONS
X-RAY DETECTION AND ORGANIC SEMICONDUCTORS

A thin film of organic material can turn into a powerful X-ray detector. A research team coordinated by researchers from the University of Bologna and the INFN Bologna Division has identified several characteristics thanks to which it is possible to maximise this technology's capabilities. The study, published in Nature Communications, shows how it is possible to improve both the detection limitation and the sensitivity of this innovative technology, which has potential applications in different fields, from medical diagnostics to public safety, from space applications to the preservation of cultural heritage and environmental monitoring. The results are a crucial step in understanding the parameters and physical processes that control the detection of X-rays by organic thin film semiconductors (a few hundred nanometres): a fundamental knowledge for the effective implementation of ionizing radiation detectors based on such materials in real life applications.
Since they are able to alter the structure of molecules and atoms, X-rays can prove to be harmful to health and to the functioning of electronic instruments and devices. This is why it is very important to monitor and control this type of radiation, especially in environments such as radiation therapy medical facilities, space missions, nuclear waste management, high energy physics experiments. ■

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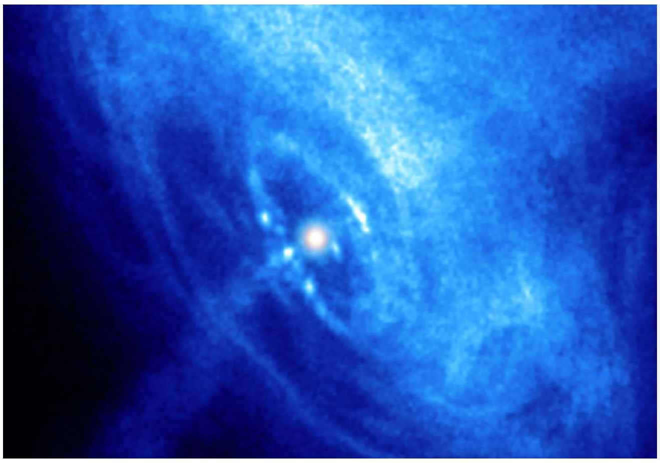

THE CRAB PULSAR X-RAY: POLARLIGHT CONFIRMS THE SUCCESS OF THE ALL-ITALIAN TECHNOLOGY

Super efficient X-ray detectors deriving from Italian technology are studying the Crab Pulsar from a nano satellite in Earth orbit: it is the Chinese space mission PolarLight, which published its first results on May 12 on Nature Astronomy. The PolarLight collaboration, which also involves researchers from the INFN and the National Institute for Astrophysics INAF, appears to have recorded a decrease in the degree of polarization in the radiation emitted by the Crab Pulsar during a glitch, a rapid acceleration of the neutron star's rotation, due to a sudden rearrangement of its nucleus. This variation could be linked to a readjustment of the pulsar's magnetosphere and the consequent variation over time of the polarization angle of the high energy radiation emitted.

However, in addition to the scientific result, PolarLight confirms the success of the technology used, and this is crucial in view of the future IXPE mission. The PolarLight mission, which is the result of a collaboration between Italy and China, was born, in fact, as a technological demonstrator, i.e. with the aim of testing the new observation technique, developed in 20 years by the INFN Pisa Division and INAF-IAPS of Rome, and based on the Gas Pixel Detectors (GPD). This is the same technology as the detectors on IXPE (Imaging X-ray Polarimetry Explore), the NASA satellite that will be launched in 2021, in collaboration with the Italian Space Agency ASI, in which INFN and INAF take part.

PolarLight is a payload the size of a 10 cm cube, installed in a Cubesat consisting of 6 units and launched in a low heliosynchronous orbit on October 28, 2018. In addition to the detector, this cube houses the reading electronics, developed by INFN, which manage both the detector, by acquiring its data and transferring it to memory, and the high voltage lines.

More specifically, PolarLight flies with an electronic reading chip that is the technological heart of the detector, developed entirely in INFN laboratories, which functions as a sort of "camera" for traces of low-

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energy electrons. The main challenge in its realisation consisted in being able to achieve the granularity necessary to reconstruct the morphology of these microscopic traces and track their direction, which is the direct link with the polarization of the incident radiation that needs to be measured. The difficulty lays in putting together a series of conflicting and difficult to reconcile requirements: a very finely segmented pixel device (a 50 micron step), but at the same time a large area to work on the focus of an X-ray optic, that could be read quickly, equipped with very low noise electronics, and low consumption in order to operate in space. It also required reading electronics that would be able to guide and extract the signal for a subsequent analysis, which from a technical point of view is far from being a negligible task. One of the peculiar characteristics of the chip is the ability to automatically select the region inside which an electron has left its mark: returning to the parallel with the photographic camera, it would be like having an intelligent CCD (Charged Coupled Device) that selects the object you are interested in a photo by itself. This allows to significantly reduce the reading time. This chip is the result of a process that lasted for years which, through the design and construction of three generations of chips (gradually larger and more performing), led to the current version, which has flown on PolarLight and which allowed us to plan the future IXPE polarimetry mission.

The technological success of the PolarLight mission, therefore, marks the culmination of a long R&D program, brought forward thanks to the fundamental contribution of Rolando Bellazzini, who allowed to bring a new all-Italian technology into space for the first time, and provides confirmation of the potential of the future IXPE mission, which will use the exact same chip. ■

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Istituto Nazionale di Fisica Nucleare
MAY 2020

Italian National Institute for Nuclear Physics

CONTACTS
Communications Office
comunicazione@presid.infn.it
+ 39 06 6868162