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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. ■