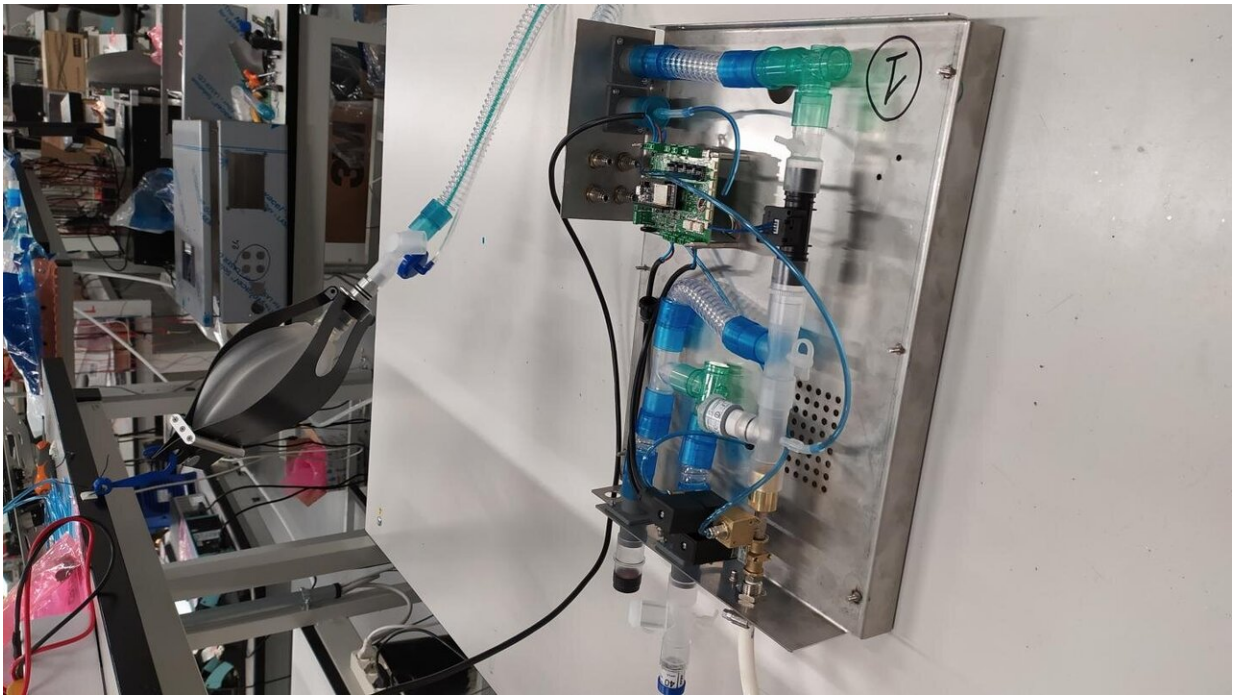
Particle physicists design simplified ventilator for COVID-19 patients

April 9 2020, by Liz Fuller-Wright



An international team of particle physicists led by Princeton's Cristian Galbiati paused their search for dark matter to focus on the growing demand for ventilators, needed for patients with serious cases of COVID-19 (coronavirus). Their Mechanical Ventilator Milano (MVM), seen here with the cover removed to reveal the simplicity of its design, can be mass produced using readily available components. Credit: Stefano Ghionna, Studio Volpi

An international team of particle physicists have paused their search for

dark matter to focus on the needs of victims of the global pandemic—in particular, their need to breathe.

In severe cases, COVID-19 can lead to pneumonia requiring mechanical ventilation, but the world's supply of ventilators has proven too small for the exponentially increasing demand.

"The public health care system in Lombardy is perhaps the strongest one in Europe, but it was near the point of buckling," said Cristian Galbiati, a professor of physics at Princeton University who has led the design of a simplified mechanical ventilator that can be mass produced using readily available components.

He and his collaborators—more than 250 physicists, engineers, physicians and others from 12 countries around the world—call their device the Mechanical Ventilator Milano (MVM). Its operation requires only electricity and a source of compressed oxygen (or a blend of oxygen and medical air), and the control and monitoring unit at its heart is being developed and programmed by "the best developers" from particle physics national laboratories in the U.S., Canada, Italy and many other nations, said Galbiati.

While it may sound odd for a dark matter researcher to have taken up medical manufacturing, it makes more sense when put another way: an expert in constructing sensitive instruments for compressed argon decided to experiment with compressed oxygen and nitrogen.

Galbiati and his colleagues in the DarkSide-20k project have spent 15 years designing and refining equipment that uses a highly pressurized liquid form of the noble gas to detect a dark matter particle. They pivoted from astrophysics to medicine just in the past few weeks.

After research travel to Italy got Galbiati stuck in the country, he texted

a friend whose family owns a major gas distribution company to congratulate the family on their donation for a rapidly constructed ward for COVID-19 patients in Milan. He was shocked to learn that the family's order for ventilators in support of the ward was canceled. Galbiati then spoke with his brother Filippo, an emergency room doctor at the Niguarda Hospital in Milan, whose practice had by then constricted to only COVID-19 patients. The other Dr. Galbiati explained to the physics professor the increasingly difficult situation facing Italian physicians who needed to treat oxygen-starved patients with limited ventilators at the peak of the local epidemic.

"We are doing so many complex projects with technical gases," said Professor Galbiati. He wanted to use his expertise "to find the best way—a way that is more scalable—to put oxygen into people's lungs when they need it."

Galbiati reached out to the same friend, whose company also commercializes and repairs ventilators, and obtained permission from the Italian government to carry out tests at his friend's facility. Once they had a design, he secured government permission to build and test a prototype. Then he reached out to the DarkSide-20k team.

"Particle physicists are a strange bunch of people," said Fernando Ferroni, president of the Italian National Institute for Nuclear Physics and a leading collaborator on the MVM, as well as the director of communication for the project. "We have a particular affinity for intellectual problems. We have a problem? We have to solve it." In addition, he added, one advantage to a global collaboration is that someone is always awake, to keep the project moving forward 24 hours a day.

The team sought input from Italian anesthesiologists. "They spent the last four weeks on the front lines, caring for patients, just being

devastated by this," Galbiati said. "They bring incredible experience. They know exactly what needs to be done to save the patients—and to help them recover."

One feature that the doctors suggested is single-button access to procedures for measuring parameters that have proven crucial for setting the best recovery path for COVID-19 patients. "In most traditional machines, designed for a more general use, these procedures require pressing five or six or seven buttons, or switching between different operating modes," said Galbiati.

"As recommended by Dr. [Giuseppe] Foti and Dr. [Giacomo] Bellani of San Gerardo Hospital in Monza, we are working to implement advanced features such as single-button measurement of the plateau pressure, the pressure reached inside the alveoli at the end of the inspiratory cycle, and of the 'AutoPEEP,' normally referred to as the air-trapping in the exhalation phase, which may be zero for most healthy patients or significantly different from zero for patients that have obstructions in the exhalation channel, as possibly generated by secretions," he said.

The MVM team have shared their design via the open-source science repositories arXiv (pronounced "archive") and medRχiv ("med archive"), both to disseminate the conceptual design broadly and to speed feedback from the scientific and medical community. At this point, they have advanced from the design phase, through the prototype phase, and into preparations for mass manufacturing. Materials for the first 1,000 MVMs should arrive in a week. They are working closely with the United States Air Force, the US Food and Drug Administration, Health Canada, and Italian regulatory agencies to secure approvals.

"Creating something that is constructed from readily available parts, that is simple but capable of doing everything that is needed in the way of a ventilator—that was Cristian's original vision, and I think it's panning out

very well," said Arthur McDonald, a key member of the MVM team and a recipient of the 2015 Nobel Prize in Physics. He is an emeritus physics professor at Queen's University in Canada who was on the Princeton faculty from 1982 to 1989.

The first ventilators will go directly to Italian hospitals, followed shortly by those in the U.S. and Canada, said McDonald, but the team also hopes to secure funding to build and distribute MVMs in countries that cannot afford to build their own, said McDonald. "We're all very conscious of the fact that in the longer term, the less developed parts of the world are going to be hit hard by this epidemic, and there's going to be great need around the world."

Provided by Princeton University