



**CERN
AGAINST
COVID-19**

Medical Devices

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University of Liverpool



Large range of ideas

Submitted to website or by email. Including:

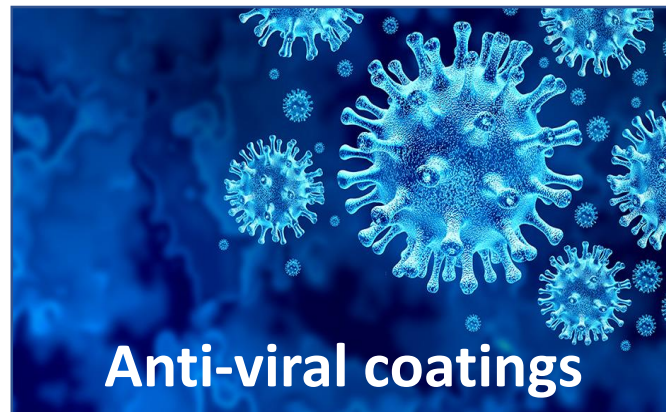
- Using magnetic fields to disrupt virus replication
- Ventilator projects (more later)
- Muon tomography of lungs
- ...

Both long term and short term projects proposed.





Today...



Ventilators



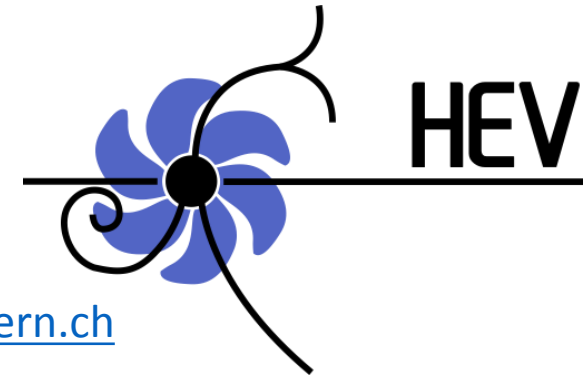


Buytaert, J., et al. "The HEV ventilator proposal." *arXiv preprint arXiv:2004.00534* (2020). <https://arxiv.org/abs/2004.00534>

20/05/2020

HEV - A versatile, low-cost high-quality ventilator

<http://hev.web.cern.ch>



- HEV is a **fully specified ventilator system suitable for hospital use**
 - COVID-19 guidelines from the MHRA, WHO and AAMI and with clinical guidance
 - both in and out of intensive care units (ICU),
 - for both intubated and mask/non-invasive cases
- patient comfort and safety first
- many pressure control modes, pressure support and CPAP provided as standard.
 - capable of supported patient controlled or machined controlled breathing
- HEV is based on inexpensive and readily available components
- **see EP Seminar- 19th May** J. Buytaert
 - <https://indico.cern.ch/event/918802/>

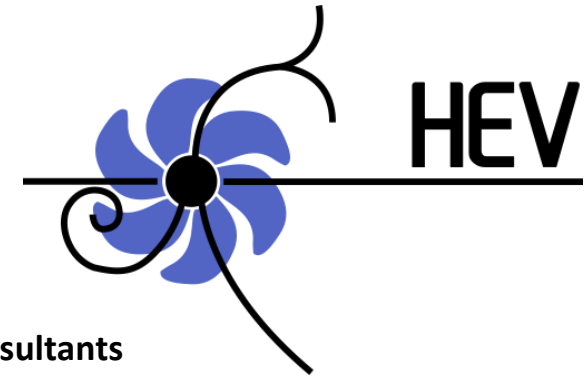




HEV collaboration

- **Core group** mainly drawn from **LHCb Members**, consisting of CERN and external institutes.
- **CERN EP-DT (Detector Technologies)** group, in particular for mechanical design, choice and control of pneumatic components
- **CERN EP-ESE (Electronics Systems)** group, in particular for electronics design and integration
- **CERN HSE (Safety at CERN)** unit
- **CERN BE-CO, BE-ICS**, webpage, open source consultation, functional safety analysis of control systems
- **CERN DG-LS, IPT-KT**, ongoing consultation on deployment, knowledge transfer and legal aspects
- University of **Liverpool**, **EPFL** (Lausanne), **UFRJ** (Rio de Janeiro), **IGFAE/USC** (Santiago de Compostela), **Nikhef** (Amsterdam), University of **Manchester**, University of **Nis**, **CUT** (Cracow), University of Applied Sciences (**Offenberg**), **Riga** Technical University

*Thanks: **HUG** have loaned equipment, via the special collaborative agreement with **CERN**, and to the Pneumology and Cardio-Respiratory services and NIC centre of **Hôpital de La Tour***



Medical experts & consultants

- Lise Piquilloud, Patrick Schoettker, **CHUV**, Lausanne
- Philipp Rostalski and Georg Mannel, **Luebeck University**
- Laurence Vignaux; **Hôpital de La Tour**, Geneve
- Josef X. Brunner: **Neosim**, and ventilator design
- Gordon Flynn and David Reiner; **Canberra Hospital**, Canberra
- Hamish Woonton: **Dandenong Hospital**, Dandenong
- Bruce Dowd, **Prince of Wales Hospital**, NSW
- Carl Roosend **University Hospital Ghent**
- M. de Carvalho, N. Dousse, M. Saucet, **HUG Geneve**

HEV support panel

- Phil Allport
- Daniela Bortoletto,
- Beate Heinemann,
- Peter Phillips,
- Jeffrey Spalding

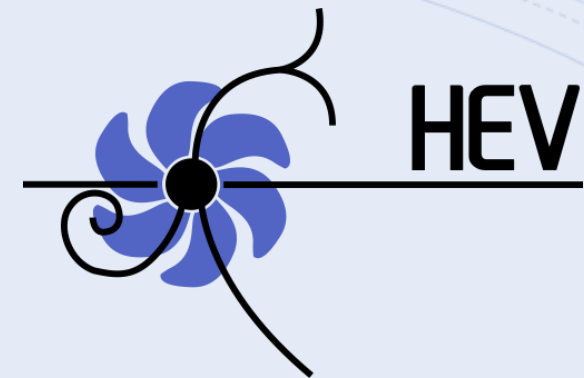




3 Prototypes built

Buffer

- **precise pressure control** more readily accessible
- natural way to **mix the gases** (no need to use separate mixer)



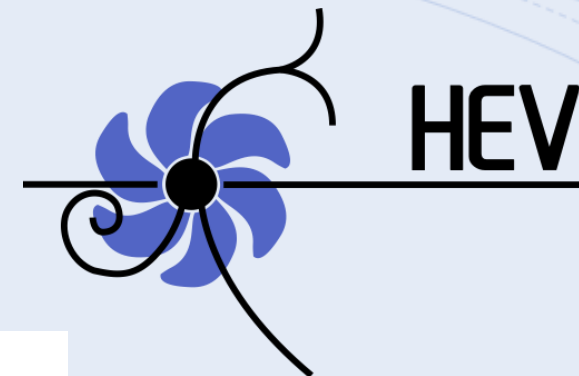
Prototypes for fast parallel development

- Pneumatics
- embedded control
- testing on a lung simulator TestChest (Neosim).

One in construction by IGFAE/USC (Santiago de Compostela)

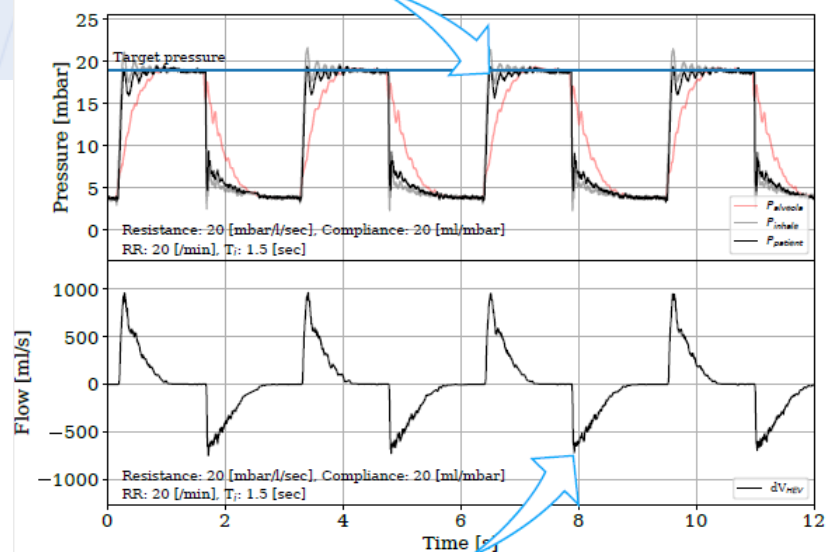


HEV Performance Plots



Adapt to patient state:

Rise time adjustable by doctor, from very fast rise time (~60ms) for patient needing lots of support, to slower for weaning patient.

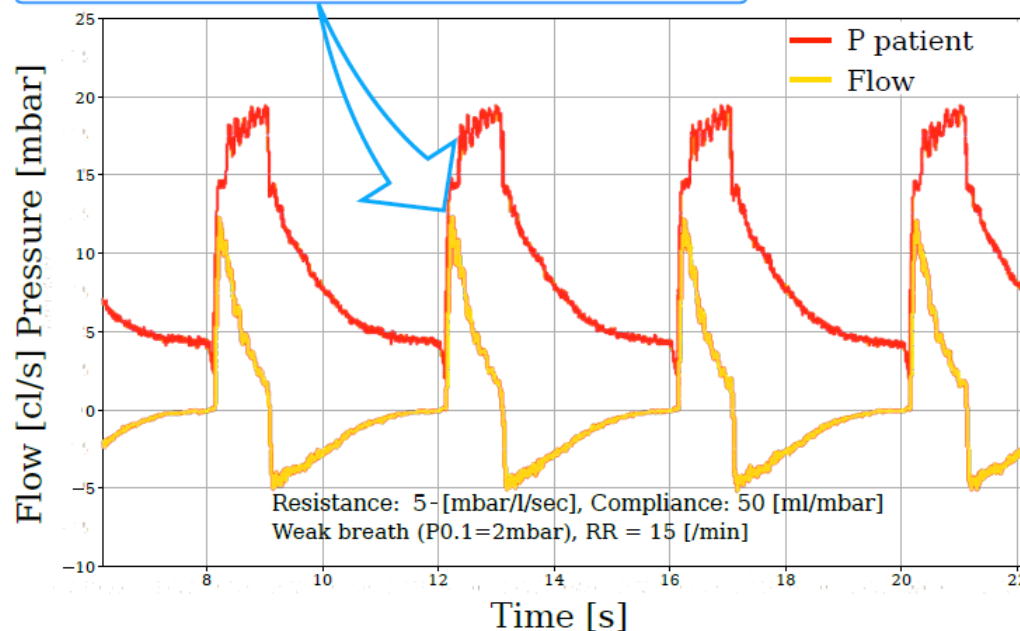


Typical pressure control mode flow

Volume control can be implemented at software level

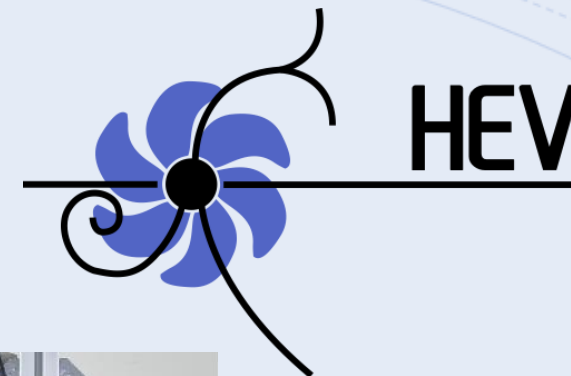
Target patient comfort:

Inhalation triggered on flow, pressurisation within 100ms and exhalation triggered by fraction of maximal flow

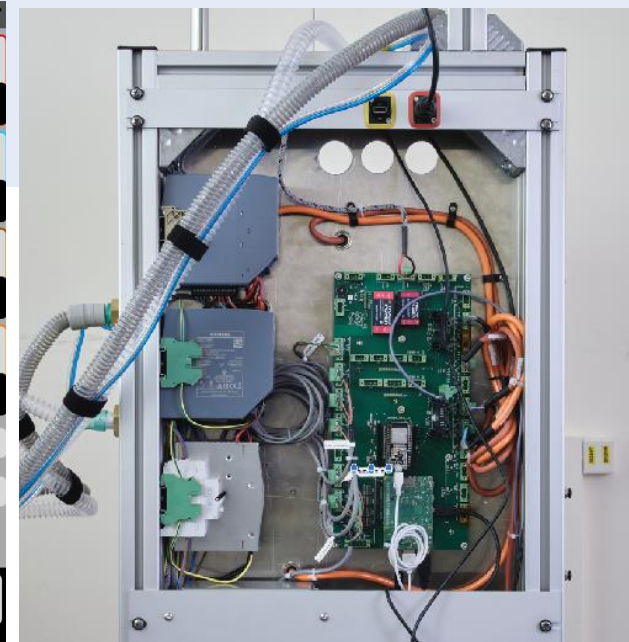




Control and User Interface



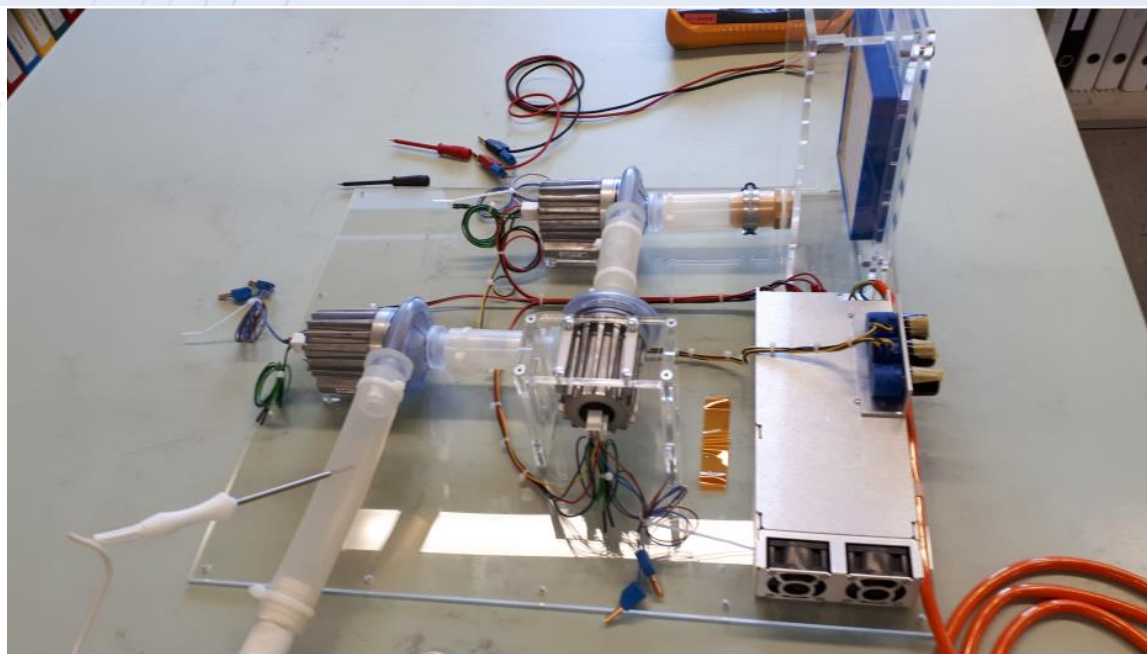
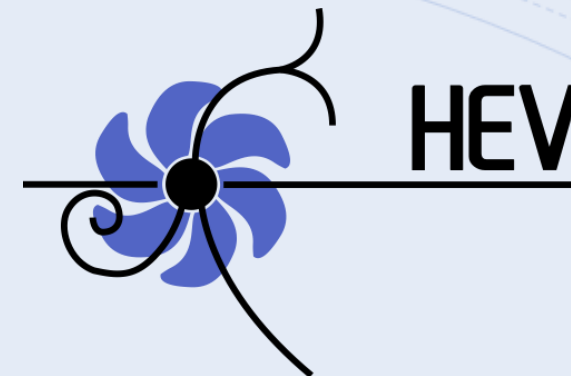
Simple to use HEV touchscreen (multilanguage)
Ergonomic design



Powered by μ computer
and μ controller



Alternative Air Supply



If hospital compressed air supply is not available, alternatives are being investigated (EPFL, Lausanne)

- dedicated turbine providing about 150 mbar pressure
- fulfils the requirement of filling the buffer in less than one second
- alternative would be the use of an oil-free commercial compressor.

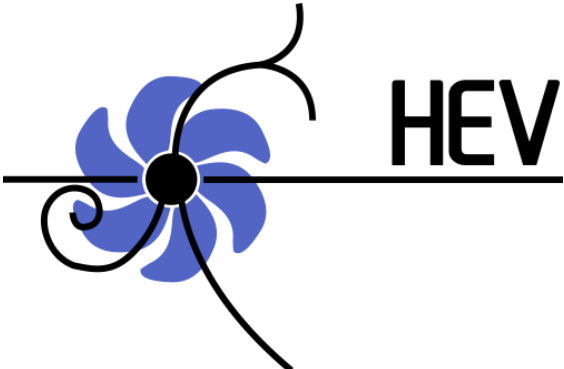
air is HEPA-13 filtered at the input





HEV Timeline


Review Panel
Phil Allport,
Giovanni Anelli,
Phillip Rostalski,
Laurence Vignaux




March 27 April 3 April 10 April 17 April 23 April 30 May 7

Project start: 12 pm Friday March 27


Pneumatic Principle Demonstrated





Demonstrator constructed



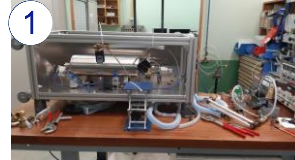
+ WHO guidelines
Demonstrator working with silicone lungs



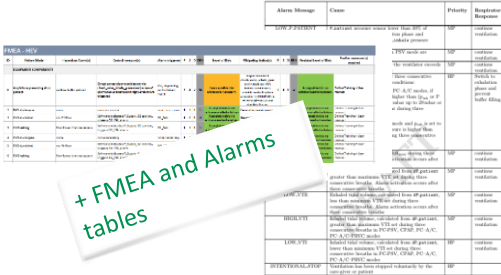
+ FDA guidelines
Prototype GUI




3 prototypes constructed; testing with lung simulator




+ FMEA and Alarms tables



UI + real data



Full functional unit with user interface



minor upgrades to finalise prototype.



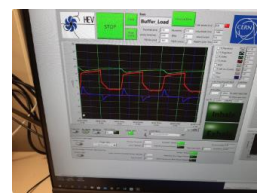
MHRA
+ Clinical advice group

Labview controls

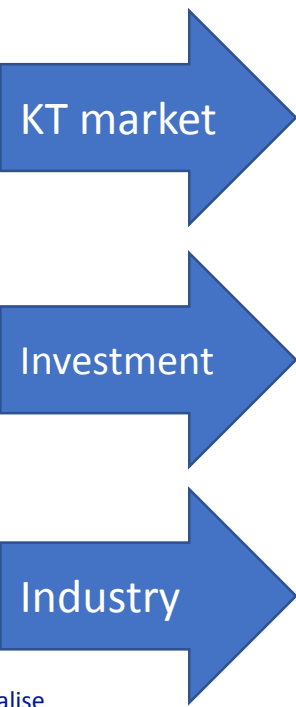
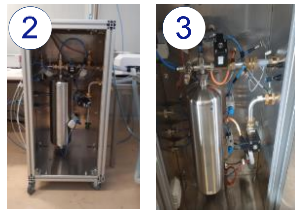


+ ISO
+ Medical + Engineering Advice Group

Full control panel

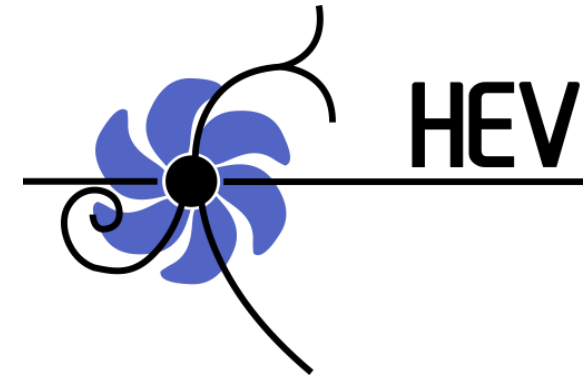


T. Bowcock





HEV next steps



- **finalize** the prototypes to full functionality within a week
- **publish** the result of the measurement campaign with the lung simulator
 - corresponding to the full set of patients specified in the regulatory guidelines
 - extra tests which were requested by the clinicians.
- **evaluation** by collaborating local hospitals and comparison with commercial ventilators
- CERN is evaluating the market needs for HEV
- CERN is contacting companies and funding bodies for potential production.
- a **regulatory prototype, built with industrial partners**, would
 - include medical grade components
 - be optimised for ergonomics
 - be submitted for **medical certification**





<https://arxiv.org/abs/2003.10405>

Mechanical Ventilator Milano

- The MVM Collaboration grew from an initiative within The Global Argon Dark Matter Collaboration (GADMC)
 - 160 collaborators (60 institutes, 9 companies)
- designed for the treatment and weaning of acute respiratory distress syndrome in COVID19 patients
- **MVM obtained Emergency Use Authorization from U.S. Food and Drug Administration on May 1, 2020**
- CE mark, FDA Permanent Use Authorization, +Health Canada authorization being sought at this time

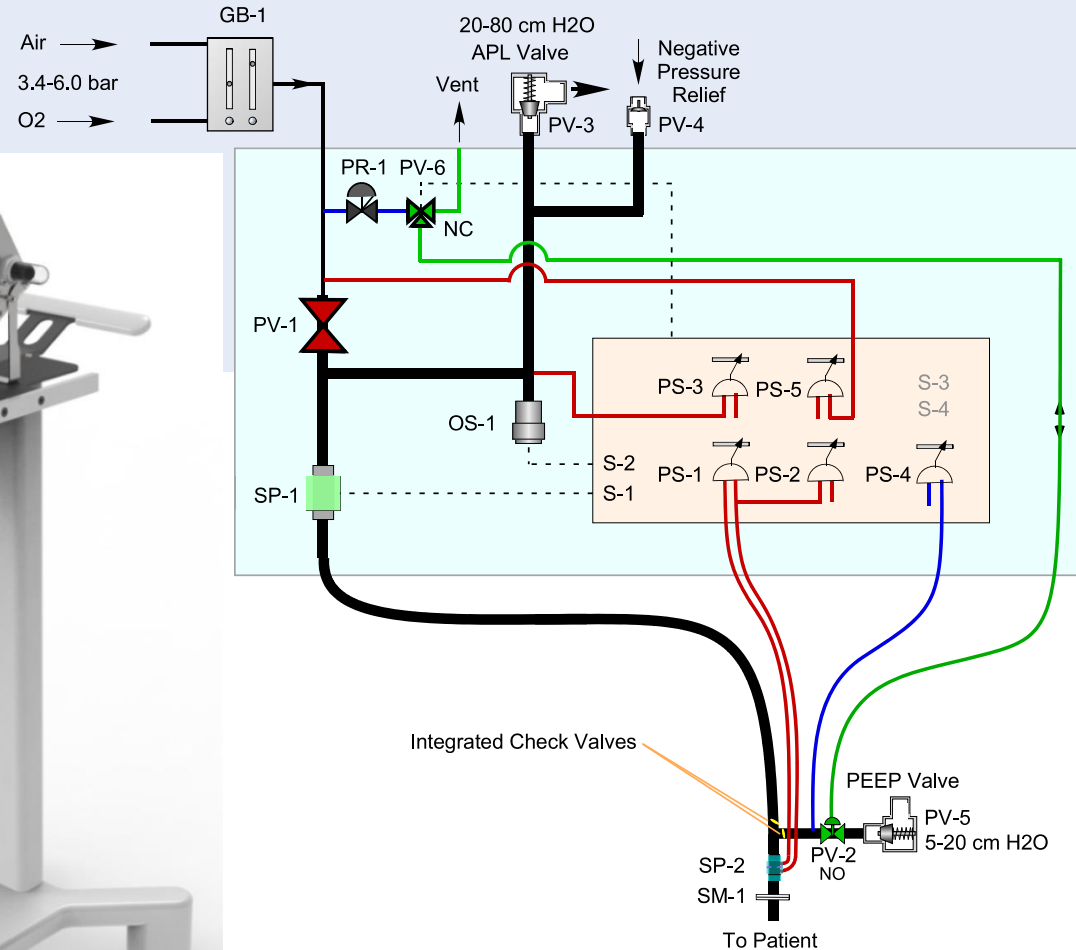


<https://mvm.care/>





Designed under direct guidance of anaesthesiologists caring for COVID-19 patients, with most direct influence from doctors in Lombardy



- Two main modes
- mandated ventilation (**PCV**) for sedated patients
 - Patient-assisted control modes (**PSV**) for their weaning





MVM Timeline



- **March 19: project conception**
- March 20: first experiments at SAPIO Life in Vaprio d'Adda (BG)
- March 21: engagement of GADMC collaborators, drafting of first paper
- March 22: engagement of EMD builder Elemaster in Lomagna (LC)
- **March 23: first submission of arxiv paper**
- **March 29: first test at San Gerardo hospital in Monza**
- March 31: second revised submission of arxiv paper
- April 10: third revised submission of arxiv paper
- April 23: submission to FDA of ISO 80601-2-80 report
- **May 1: FDA EUA authorization granted**



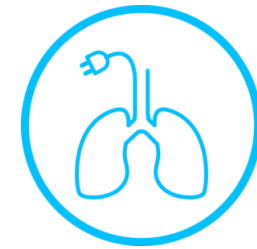


<https://www.ohwr.org/openbreath/lungventilator/wikis/home>

20/05/2020

Openbreath

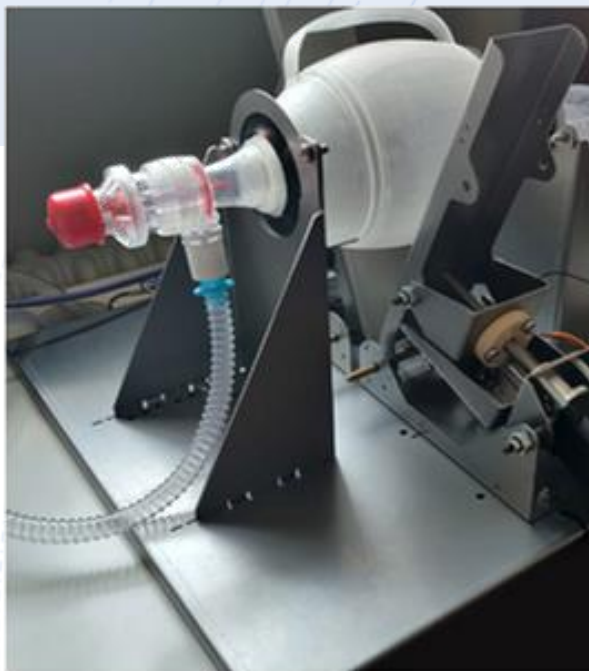
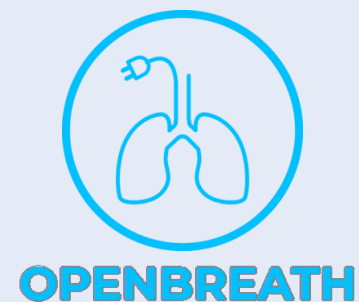
- construction simplicity and speed of realization using bag valve mask
- Extremely low cost
- PEEP, SIMV, CPAP modes
- 20 scientists/engineers
 - International support



OPENBREATH

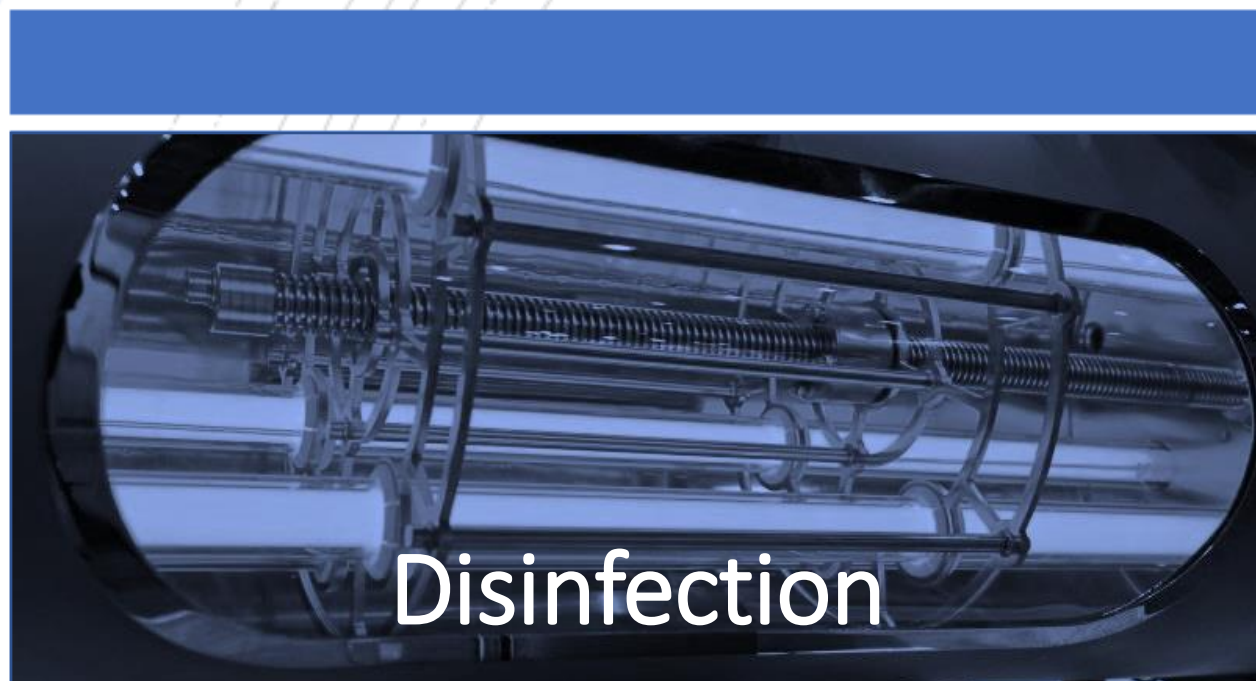
<https://www.openbreath.it/en/>





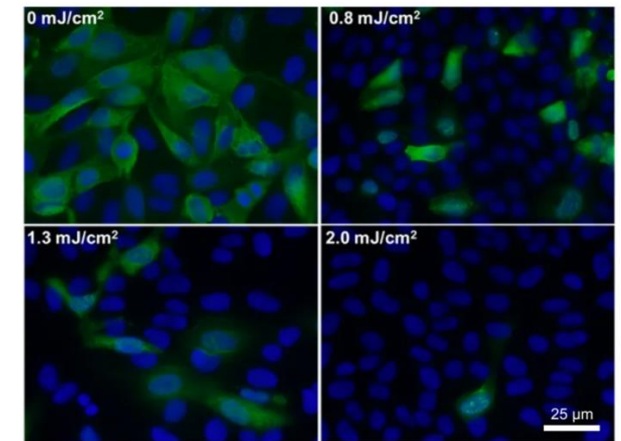
EN/MME designed the main mechanical support for the OpenBreath ventilator





UV disinfection

- “UVC light has been used extensively for more than 40 years in disinfecting drinking water, waste water, air, pharmaceutical products, and surfaces against a whole suite of human pathogens”
- Germicidal range 200-280nm (4 to 12 eV)
- <https://www.nist.gov/news-events/events/2020/01/workshop-ultraviolet-disinfection-technologies-healthcare-associated>
- No natural UVC radiation reaches the surface of the earth.
- UVC can damage eyes and cause burns
- UVC photons create defects including [pyrimidine dimers](#).
 - These dimers can prevent replication/prevent the expression of necessary proteins
 - 2 to 8 mW s/cm² kills 90% virus ~ 10²⁰ photons /m²
 - Cross-section of virus O(10⁻¹⁴m²)

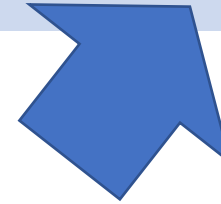
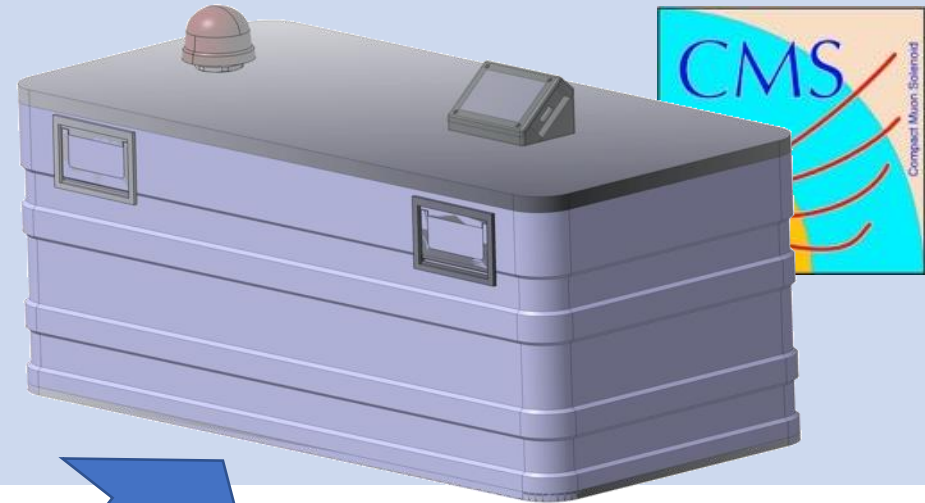


N1H1 virus Blue fluorescence: number of sterilized *Sci Rep* **8**, 2752 (2018).





A bus is disinfected using UVC in Shanghai, China (Credit: Getty Images)



- UVC source: 8 x Mercury vapour based CFL
- Mirrored Inner Surface / Uniform Illumination
- Time based dose regulation
- Dose, temperature and humidity monitoring
- Console for local or remote (wifi) control
- Interlock system for radiation and high voltage safety
- Masks and tools

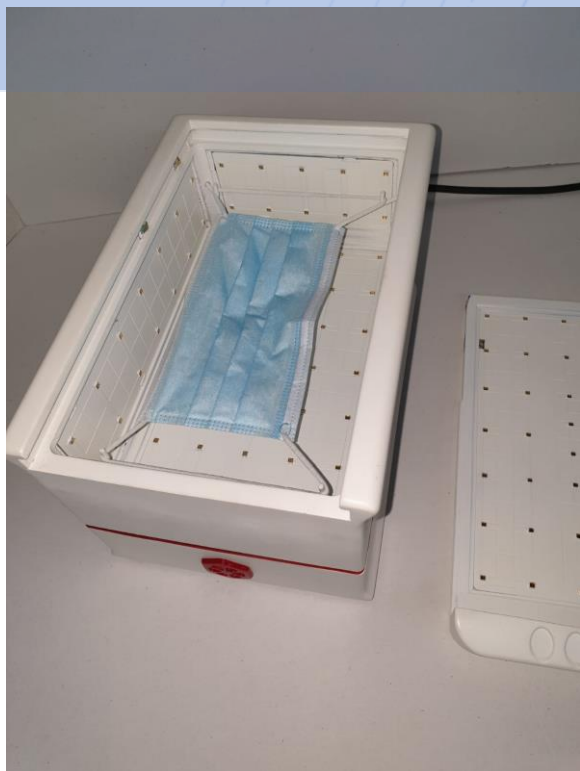


- Produce several V1 disinfection boxes at 904 in the CMS laboratory
- Evaluate electrical and radiation safety
- Biological test - SARS-CoV-2 virus
- Mask Filtering tests after UVC disinfection treatment





UVC LED Disinfection Box



- First working prototype designed and manufactured by I.M.E. firm in Italy
- Being delivered next WEEK
 - Box includes 120 x 0.5 W UV-C LED
 - **Biological tests planned**
- UCSB is working on the development of UV-LED to sanitise surfaces, and possibly, air and water

https://www.novuslight.com/developing-uv-leds-to-decontaminate-surfaces-of-covid-19_N10313.html





Ionizing radiation sterilization

STAR DOME

(STerilizzAzione e Riutilizzo di DispOsitivi e Mascherine Ecosostenibili per Covid-19)

STAR DOME. A proposal to Lombardy region

- NUCLEAR DETECTION INNOVATION s.r.l. (Capofila), GAMMATOM s.r.l. (a company near Como performing industrial irradiation of medical equipment, food, etc),
- M3R s.r.l. (a spin-off company of University Milano Bicocca having access to the microbiology laboratory of the Polytechnic of Milan,
- CERN HSE-RP. CLEAR
- University of Brescia

Solving the following problem

- Billions of facial masks needed per month worldwide
- Up to 24 PPE/day/patient needed in hospitals (source ECDC)
- production & distribution issues
- Most PPE are single use, made with of non-recyclable material and after use potentially contaminated with bacterial and viral pathogens
- Logistics and environmental problem





STAR DOME

IRRADIATION WITH Co-60

STERILIZATION WITH ELECTRON BEAMS

Microbiological analysis of PPE pre-irradiation

- Irradiation at different doses
- Microbiological analysis post-irradiation
- Verification of mechanical and filtration integrity of PPE



CERN Linear Electron Accelerator for Research

With STAR DOME we already have the embryo of a larger consortium in which CERN can be full partner





Anti-Viral Coatings



Used by ICARUS: Liquid Glass Nanopool GmbH <http://nanopool.eu>

- A very thin coating of glass applied via aerosol/spray/dip to almost any surface
- Renders it hydrophobic and easier to clean
 - Fabrics(masks, gowns, surface)
- Possible addition of antiviral agents in matrix
- CERN's role to make connections for testing on COVID-19.
- Other functionally similar activities brought to our attention include
 - <https://heiq.com/technologies/heiq-viroblock/>
 - These will also be investigated

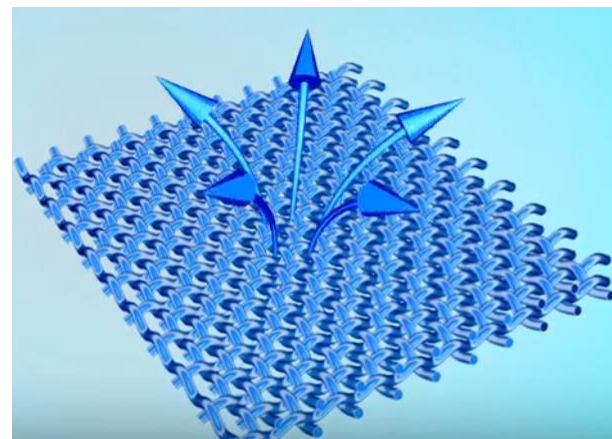
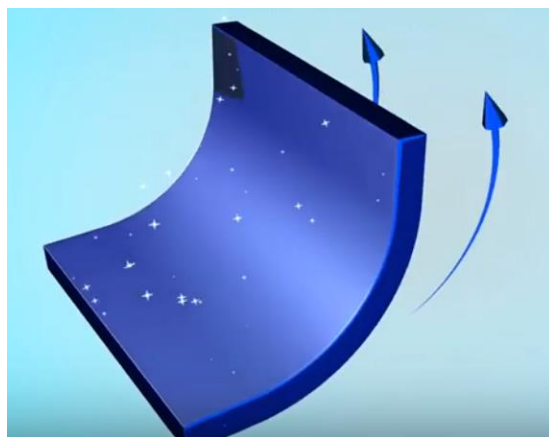




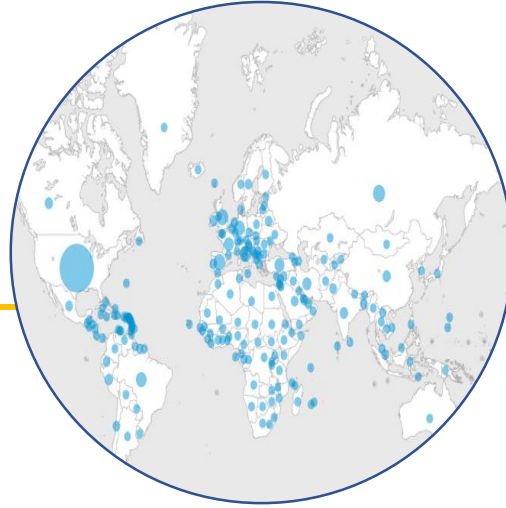
<https://www.youtube.com/watch?v=eARwlCYAwd0&feature=youtu.be>



Glass layer $O(500)\text{nm}$



Summary

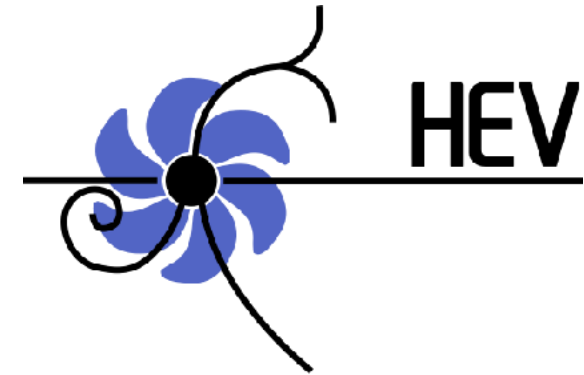


- Thank you to all that contributed
- Many exciting ideas and useful contributions
 - How do we go from ideas to making a difference?
- Technology transfer
 - KT and legal services are vital





HEV Supported Ventilation Modes



	Inhalation Start	Exhalation Start	Breath Frequency	Comment
Pressure Control Modes				
PC-A/C	Machine / Patient triggered	Machine cycled	Minimum programmed. Patient effort can increase rate	Constant Pressure
PC-A/C-PRVC	Machine / Patient triggered	Machine cycled	Minimum Programmed. Patient effort can increase rate	Volume guarantee via Pressure variation
Pressure Support Modes				
PC-PSV	Patient triggered	Patient cycled	Spontaneous. Failsafe possible to PC-A/C	Constant Pressure
CPAP	Constant Postive Airway Pressure. Spontaneous Breaths. Failsafe in case of apnea.			

- Limited to the essential modes recommended by clinicians.
- The system is flexible and could provide volume control modes via firmware update only

