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Istituto Nazionale di Fisica Nucleare

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RESOURCES, TECHNOLOGIES AND NEW PROJECTS FROM INFN IN RESPONSE TO THE COVID-19 CRISIS

Interview with Diego Bettoni, researcher and member of INFN's Executive Board.

On 11 March 2020, the World Health Organisation raised the alarm level linked to the spread of the new coronavirus SARS-CoV 2, bringing it to the pandemic level. An event, that of the worldwide spread of the virus, which immediately placed the responsibility for rapid responses in the hands of science. And while the scientific community, due to its make-up, is able to coordinate itself very quickly to achieve a shared objective, on this occasion it also showed a versatility that was far from given, establishing cooperation and procedural paradigms that will change the way it moves forward in the short and long term future. When faced with the emergency, even scientific sectors for which life sciences are not their primary mission, have been able to focus their resources. They have made their skills and technologies available to society and established themselves as promoters of research and development initiatives to support the fight against the pandemic and to limit its impact on the health system.

Like many other research bodies, as well as coordinating the internal emergency, through a special crisis committee, INFN has also developed several public utility initiatives to support medical research and the implementation of medical devices for treating the disease and limiting its spread. The INFN initiatives in this field range from the offer for huge computing resources to drug research, to the analysis of air-borne virus and bacteria, the design of medical devices for assisted breathing and the sterilisation, the analysis of materials for anti-infection masks, or the monitoring of the data on the virus spread.

We asked Diego Bettoni, a member of INFN's Executive Committee, to outline the path that, in a very short time, led to the creation of INFN projects to support the battle against the pandemic.

INFN works mainly on particle, nuclear, theoretical, and astroparticle physics, and on the applications of innovations developed in these sectors to public utility. How does the battle against the pandemic that is underway fit into this context?

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Fundamental research requires the construction of complex experimental apparatuses consisting of sophisticated detectors with very high performance both in terms of sensitivity and precision. It is therefore essential, for the realization of our experiments, to develop innovative technologies, which then find their natural application also to other disciplines, including biomedical research. Furthermore, INFN has various technical and technological infrastructures for the development and construction of experimental equipment, large computing centers for the storage and analysis of experimental data, as well as national centers and laboratories. All these ingredients (innovation capabilities, technical and scientific infrastructures, competence and expertise in data analysis) make it possible for INFN to give qualified contributions to the study and contrast of the covid-19 pandemic.

Some of the new projects born in support of the pandemic contrast are due to cutting edge computing infrastructures inside INFN.

Yes, several projects exploit the great computing capabilities of INFN, the competence and expertise in Monte Carlo simulations and data analysis acquired in experimental particle and nuclear physics. Some of them employ the large computing infrastructures built by INFN for the analysis of the data from the LHC experiments. **Sibylla Biotech**, an INFN spinoff, makes simulations in the field of protein folding with the aim of identifying molecules able to interfere with the replication process of the SARS-COV2 virus, in order to slow down its spread while we wait for a vaccine. The project focuses in particular on the ACE2 protein, the cellular receptor located mainly in human cells in tissues in the lungs, heart and intestines, to which the Spike viral protein present on the virus surface binds. INFN makes a significant fraction of its computing resources available (approximately 30000 computing units working in parallel in 8 data centers) available for the simulations of Sibylla Biotech. The results are open access and available to the scientific communities. The project **EXSCALATE4CoV (Horizon 2020)** deals with the simulation and in-silico drug design for the identification of covid-19 inhibitors among the already tested pharmaceuticals and molecules. Also, in this case INFN contributes with its computing resources. **COVIDSTAT INFN** is a website realized by INFN to make available to the INFN covid-19 crisis unit a statistical analysis of the data, provided daily by the Civil Protection Department, on the spread of the pandemic in Italy. The site shows a strictly statistical analysis of the data and provides an up-to-date status report featuring synoptic tables and interactive maps. Other INFN researchers also perform **data analysis** on the covid-19 diffusion in Italy and in other countries, using statistical and epidemiological models in order to study and predict the trend of the pandemic. Among the computing infrastructures which INFN makes available for covid-19 studies

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there is also the **INFN CLOUD** open platform. Finally, other projects pursue the development of models for diagnosis, prognosis and therapy.

Which other capabilities and technologies, besides the computing ones, have demonstrated do to be useful in this context?
Several projects arise from the technological competences acquired in the development and construction of experimental equipment and exploit the technical infrastructures of our institute. **ANTI_COVID_LAB** is a laboratory in Catania for the test of the functional features of fabrics to be employed in the realization of masks and other kinds of PPE (Personal Protection Equipment). The laboratory, to which the Istituto Superiore di Sanità (ISS) has given the green light for the evaluation tests of the Filtering Bacterium Effect (BFE), in accordance with the UNI14683 standard, provides companies with the technical and scientific assistance required to test PPE fabrics according to the standards foreseen by current regulations. The **MVM project (Milano Mechanical Ventilator)** is aimed at the design, development, construction and certification of a safe and effective mechanical ventilator complete with an advanced control system allowing the various ventilation modes. The aim is for the ventilator to be based on a simple design and easily available components allowing its quick production in various countries. MVM is an open access project that has already led to the creation of the first prototypes. It has submitted an application and is now awaiting the certification. Another project is aimed at the realization of an instrument based on a **radiogenic source**, to be used for the sterilization of surfaces.
I will finally mention two projects of environmental context: one studies the **characterization of bacteria and viruses** in the atmosphere and the possible relations between concentration of atmospheric pollutants, metereological parameters and the biological component of the atmospheric aerosol; the other project studies the possible relations between **the atmospheric concentration of some pollutants (in particular aerosols)** and the diffusion of bacterial and viral strains.

Research and development projects like these, launched to respond to the historical moment of crisis, respond to the body's overall strategy or are they instead the result of autonomous initiatives of research groups already engaged, in other ways, in biomedical applications?
Applied and interdisciplinary research has always been an integral part of INFN activity. The relevance of this research is however the result of a precise strategy of the management of INFN, a strategy which has led to the establishment of various applied research programs in fields such as the biomedical, environmental, cultural heritage, to name but a few. In line with the tradition of our

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institute these programs are born both on the initiative of individual researchers or research groups and as response to precise strategic lines coming from the management. In the specific case of Covid19 it has been a deliberate choice of INFN to stimulate the development of projects in this field with the establishment of a coordination at the national level of the individual proposals.

How has it been possible to create a varied set of projects in sectors that aren't priorities for INFN's research activities, and within such time constraints?
We did not start from scratch. As I was saying, interdisciplinary and societal applications have always been part of the DNA of INFN and, in this context, biomedical research has always played a particularly significant role. Let me mention activities such as the development of technology and instrumentation for PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computerized Tomography); studies in dosimetry and radiobiology; the protontherapy programs in Catania and Trento; the construction and utilization of particle accelerators for biomedical applications at the CNAO (National Center of Oncological Hadrontherapy), at the INFN Legnaro and Southern National Laboratories (LNL and LNS). All these activities have contributed not only to strengthen our technological expertise, but they have also allowed us to establish collaborations and synergies with the biomedical and pharmaceutical communities thanks to which we develop truly interdisciplinary research programs.

Which of the skills belonging to your scientific community have proved winners in this context?
Research activities in physics require great flexibility, an open mind and the ability to deal with and find solutions to problems of all kinds. These features are an integral part of our culture and allow us to interact effectively with other communities. As I was saying before, the construction of nuclear and particle physics experiments requires the ability to develop advanced innovative technologies ranging from mechanics to electronics and computing. Of fundamental importance are our competences in computer science, statistics, simulation techniques, data analysis. These competences have allowed us to play a crucial role in the groundbreaking discoveries in basic science, from the Higgs Boson to gravitational waves, and they enable us today to give a qualified contribution to the covid-19 research.

Do you think that this effort by INFN could have an impact on its future strategies? Has the paradigm for conducting research in this scientific community changed in any way?
I am convinced that the events of this period will contribute to consolidate the dedication of our

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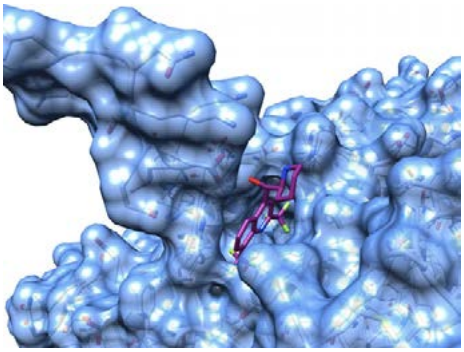
institute to applied and interdisciplinary research and that they will further strengthen the synergy between basic and applied science. I believe that this will make our community even more conscious of the societal impact of our research. The exploit of these applications and the transfer of our knowledge and technology to society is the natural fallback of our research. Our community is characterized by a strong sense of belonging of all its components which, at the end of this period, will be enriched by the pride in having given our contribution in this dramatic period in the history of our country. ■

INFN Projects - CoViD-19



RESEARCH COVID-19

FIRST RESULTS OF BIOMOLECULAR SIMULATIONS OF SIBYLLA BIOTECH

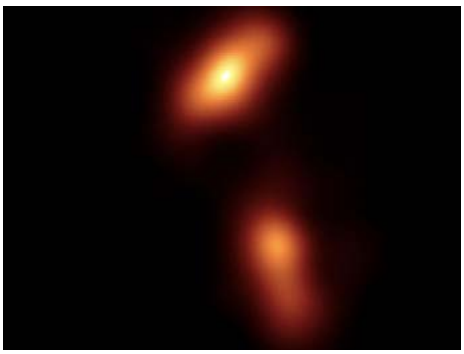
Sibylla Biotech, spin-off of INFN and of the Universities of Trento and Perugia, published on ArXiv the first results of the biomolecular simulations launched in March thanks to the 30,000 computing units made available by INFN. The study, carried out in collaboration with INFN, reports the identification of two targets, hitherto unknown, for the design of drugs: two binding pockets in the intermediate folding structures of ACE2, a protein normally found on the surface of lung cells (and of other organs such as heart and gut), exploited by the SARS-CoV-2 virus as its entry gate to the cell.

Thanks to the INFN computing resources, these two intermediate states of the protein were analysed very quickly to verify their ability to bind with the approximately 9000 drugs already commercially available or in the clinical trial phase. In this preliminary phase, that will necessarily be followed by laboratory tests in order to give definitive answers, Sibylla Biotech has already identified 35 promising molecules. Among these, one belongs to the chemical family of hydroxychloroquine, a readily available drug used to prevent and treat malaria. This promising molecule appears to bind the intermediate of ACE2 and it is going to be tested in the laboratory together with 6 other similar molecules of the same family and the 35 selected on the computer. ■

RESEARCH

NEUTRINOS: NEW RESULTS FROM THE T2K EXPERIMENT ON NATURE COVER STORY

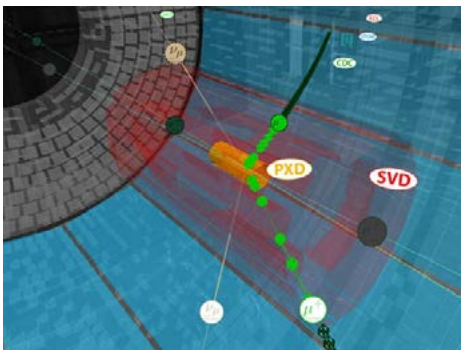
The T2K (*Tokai to Kamioka*) scientific collaboration, which has been studying phenomena connected to neutrino oscillations for more than ten years, has published a study on Nature. This research provides increasingly convincing indications of the existence of a difference in the behaviour of neutrinos and their antiparticles (the antineutrinos). The new results show that the oscillation phenomenon, with which neutrinos “transform” into neutrinos of another kind, takes place with different probabilities for neutrinos in comparison to antineutrinos (CP violation). The research provides a glimpse into understanding one of the great mysteries concerning our universe: the clear prevalence of matter over antimatter. T2K is an international collaboration in which the Italian Institute for Nuclear Physics (INFN) has participated from the first planning stages, occupying roles with great responsibility. The collaboration receives contributions from INFN Divisions and the University of Naples Federico II, the University of Padua, Sapienza University of Rome, the Polytechnic University of Bari, and the INFN Legnaro National Laboratories. ■



RESEARCH

AT THE HEART OF THE QUASAR 3C 279: FIRST IMAGE OF THE RELATIVISTIC JET OF A BLACK HOLE

The Event Horizon Telescope (EHT) collaboration, which made the famous first image of a black hole, has gone to the heart of the quasar 3C 279, capturing a relativistic jet for the first time. The jet probably originated from nearby a supermassive black hole. The results have been published on the 7 April issue of Astronomy and Astrophysics. The technique that the EHT used, called very-long-baseline interferometry (VLBI), has facilitated the study of the jet's morphology close to its base, where it is thought that a highly variable gamma-ray emission originates from. 3C 279 is a galaxy classified as quasar because, at its centre, an extremely luminous and variable point shines. The black hole at its centre, which has a mass around one billion times that of the Sun, "swallows" the stars and gas that approach it, then it expels a part of them, almost at the speed of light, in two plasma jets. EHT has collected the details of this process with a resolution much higher than one light year, showing the jet and the accretion disc while they are at work. The jet has an unexpectedly contorted shape at its base and perpendicular structures are observed at the jet, which could be the accretion disc from the poles of which the jets are expelled. Comparing images over successive days, these structures change. Perhaps, then, what is observed is the rotation of the disc and of the matter falling into it: another process that had never before been observed, except in numerical simulations. The EHT collaboration continues, thus, to extract fundamental information from the exceptional data collection of the global observation campaign conducted in April 2017. ■



RESEARCH

BELLE II NARROWS THE Z' PARTICLE RESEARCH FIELD

A portal, a transition point between ordinary matter and dark matter: this could be what Z', a hypothetical boson-type particle, represents. The Belle II international collaboration, in which INFN also participates, is looking for the Z' particle in collisions between electrons and positrons in the SuperKEKB accelerator, in the KEK laboratory, in Tsukuba, Japan. The scientists of Belle II have finished analysing the data collected in the 2018 collisions, and on 6 April published their research in Physical Review Letters (PRL), which the magazine selected as an Editor's Suggestion. The results place new limits on the existence of Z', narrowing the field in which this particle could be observed. The Z' boson is one of the most promising candidates for connecting dark matter to the Standard Model, and could be produced in collisions between electrons and positrons, before decaying into invisible constituents of dark matter. Theoretic models and detailed simulations predict that the Belle II experiment would be capable of detecting a clear Z' production signal, by searching for an excess of events in which two muons of opposite charge are produced. The data available up until today, and presented in the article published in PRL, does not, thus, show evidence of this signal. The final research, which will be conducted by the Belle II collaboration over the next years on vast samples of data, will, therefore, be determining in either confirming the existence of a Z' boson that interacts weakly with ordinary matter particles, or excluding it. ■

APPOINTMENTS

GIOVANNI LOSURDO ELECTED SPOKESPERSON OF THE VIRGO COLLABORATION

From 1 May, the physicist Giovanni Losurdo will lead the international scientific collaboration of the Virgo experiment, the gravitational wave detector installed at EGO, the European Gravitational Observatory in Cascina, near Pisa. Losurdo, INFN's research director with the Pisa Division, has been working on the Virgo experiment since the 1990s. Between 2009 and 2017, he was the Project Leader of Advanced Virgo, the Virgo detector enhancement programme that, in August 2017, made it possible to observe gravitational waves. The scientist has won the Galileo Galilei Medal and the Luigi Tartufari Prize for Physics and Chemistry of the Accademia dei Lincei. In addition, President Mattarella has invested him with the honour of Commander of the Order of Merit of the Italian Republic, and, since 2019, he has been a Corresponding Member of the Accademia Nazionale dei Lincei. Losurdo succeeds Jo Van den Brand, a Dutch physicist from the Nikhef Institute (Amsterdam) and professor at the University of Maastricht, in the role of spokesperson. Van den Brand held this role from May 2017 to April 2020. ■

APPOINTMENTS

MARIAFELICIA DE LAURENTIS ELECTED TO THE EHT SCIENCE COUNCIL

Mariafelicia De Laurentis, Professor of Astronomy and Astrophysics at the University of Naples Federico II and researcher with INFN, has been nominated to the Science Council of the Event Horizon Telescope (EHT). The EHT Science Council, which is composed of 14 international experts, is the “core” of the collaboration: it outlines the research strategies, decides on future observations and the development of various scientific activities. Within this body, De Laurentis will have the task of coordinating the experiment’s theoretical research activities. Mariafelicia De Laurentis is the local head for the TEONGRAV (Theory of Gravitational Waves) initiative. She has been professor of theoretical physics at the Tomsk State Pedagogical University (Russia) and visiting professor at the Institute for Theoretical Physics at Goethe University in Frankfurt (Germany), where she began to take part in the Black Hole Cam (BHCam) and Event Horizon Telescope (EHT) projects in 2015. Her scientific research is focused on theories of gravitation in their theoretical and phenomenological aspects. She has received several awards and recognitions, including the Breakthrough Prize in Fundamental Physics, the SIGRAV (Italian Society on General Relativity and Gravitation) award, the Einstein medal, the Turin Polytechnic Quality Award, and the research award at the University of Tomsk. ■

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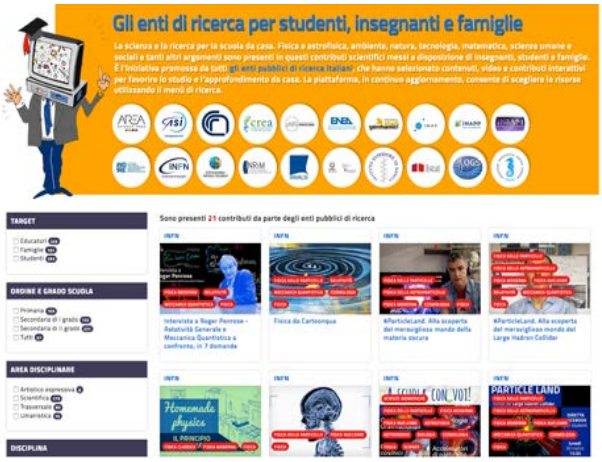

RESEARCH ORGANISATIONS FOR SCHOOL

Contributing to distance teaching with high-level, in-depth content produced by Italian research communities: this is one of the objectives of the Council of Presidents of Public Research Bodies (ConPER). The Council has hence decided to offer schools - today reorganised via distance teaching due to the COVID-19 crisis - the vast library of video materials, documentaries, video-lessons, virtual visits, interactive materials, and social initiatives produced by the Research Bodies to inform students, teachers and families about research subjects and methods in Italy. The meeting place is the platform "*Research bodies for students, teachers and families*", which was specially set-up by the National Institute for Documentation, Innovation and Educational Research (INDIRE). Here, all the material was gathered and indexed in a very short time, being organised by themes, tags, and participating institutes. Continuously updated, the catalogue is not just a teaching and learning tool, but also a spur to become familiarised with less well-known research fields.

INFN has responded to the initiative by making available not only the documentaries and archive recordings made at numerous Public Engagement initiatives produced over the years, such as public exhibitions and events, but also by presenting the new material has been developed precisely to support the distance teaching the state of emergency has enforced. Gravitational waves, antimatter, dark matter, and Higgs boson are some of the characters of the content offered by INFN; there are also cartoons and educational shows for children. To respond to schools' need for content and activities, INFN has also kicked off, especially via social media, numerous initiatives for dialogue between students and the scientific community. From the first day of school closure, the INFN community opened up to students with the social media initiative "Particle Land": a weekly Facebook Live event during which researchers describe their research activity and the physics behind them and respond

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to questions from the online audience. The initiative met with immediate success among students, and not just students, consistently attracting an audience of some hundreds of spectators.
“At school with you” is the in-depth teaching path on modern physics that was launched through INFN’s communication portal ScienzaPerTutti [Science for Everyone]: the path involves a series of hypertextual knots that re-traverse the great themes of contemporary physics. INFN’s national projects for disseminating scientific culture have also refurbished their offerings according to the needs of this chance historical moment. For example, Art&Science Across Italy has launched the Art&Science KIDS initiative, an artistic contest for primary and middle schools, broadcast via a series of YouTube Live streams during which the conversation with children revolves around the history of the evolution of the universe. The “Aggiornamenti” project, addressed to teachers at middle school, has offered students, as well as their teachers, simple experiments from classical physics that can be replicated at home, on the Facebook and YouTube platforms. Together with seminars and lessons periodically proposed by the INFN Divisions and laboratories on their Facebook and YouTube channels, all the materials produced merge, in turn, on the Research Bodies’ platform, thus adding to the Bodies’ overall offering.
Overall, “Research bodies for students, teachers and families” hosts themes that range from physics, astrophysics, space, the environment, nature, technology, and mathematics to human and social sciences, innovation, energy saving, and research in a broader sense. ■

*All the Public Research Bodies contribute an extraordinary wealth of material:; besides INFN: Area Science Park, Italian Space Agency, National Research Council, Council for Agricultural Research and Economics, Fermi Centre, ENEA, National Institute of Astrophysics, National Institute of Higher Mathematics, National Institute for Documentation, Innovation and Educational Research, National Institute of Geophysics and Volcanology, National Institute of Metrology Research, National Institute for the Assessment of the Education and Training System, Italian Institute for Germanic Studies, Italian Institute for Environmental Protection and Research, Italian Institute of Health, Italian National Institute of Statistics, National System for Environmental Protection, Stazione Zoologica Anton Dohrn research institute.

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COVER
The T2K (Tokai to Kamioka) experiment's detector Super-Kamiokande

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