Photo: Pier Oddone, Fermilab

An auspicious time for Gran Sasso

In September 2009, I began my new assignment as director of the Gran Sasso National Laboratory, the biggest underground laboratory in the world devoted to neutrino and astroparticle physics. I couldn't help thinking that 2009 was an auspicious year. It marked the thirtieth anniversary of the official birth of the project and the twentieth anniversary of the first experimental data published by Gran Sasso's MACRO experiment.

I reflected on the scientific path of these past 30 years and on the advances we have made in understanding the fundamental laws of nature and the evolution of the universe. I thought about the extraordinary growth in this type of physics, which connects elementary particle physics, astrophysics, and cosmology. The community of astroparticle physicists has increased considerably, along with the dimensions, complexity, and technology of the experiments.

The Gran Sasso National Laboratory, one of the four laboratories of Italy's Istituto Nazionale di Fisica Nucleare, or INFN, has maintained a leading role throughout these transformative years. At least two earlier Gran Sasso experiments represent major milestones in the scientific activity of the lab. GALLEX/GNO, a radiochemical experiment, measured the flux of neutrinos from the sun and made a decisive contribution to solving the famous solar-neutrino puzzle. The MACRO experiment provided the worldwide limit on the flux of magnetic monopoles and, together with the Japanese experiment Kamiokande, measured the effect of atmospheric neutrino oscillation.

Currently, our laboratory is at the height of its activity and I can say I have inherited a rich scientific legacy. Gran Sasso hosts more than a dozen experiments devoted to neutrino physics, dark matter, neutrinos from the sun and galactic collapsing stars, geoneutrinos, nuclear astrophysics, geophysics, and environmental and seismic monitoring.

Despite all the recent progress, fundamental questions remain. What is the microscopic nature of the unknown elementary particles that make up dark matter? Theoretical physicists have proposed a roster of possibilities, among them weakly interacting massive particles (WIMPS) such as neutralinos, candidates for direct detection in the laboratory. Researchers are using many different techniques based on scintillating crystals, cryogenic detectors, and noble liquids in search of a definitive dark-matter signature. Because the expected detection rate is so low—one event per day per 100 kilograms of target material—the hunt for dark matter through direct detection can succeed only in an underground laboratory using radioactively ultra-pure detector materials. The dark-matter mystery is so compelling that capturing dark-matter particles could well be the discovery of the century.

Another fundamental question may be: Why does neutrino physics matter? Neutrino oscillations may be a result of physics beyond the Standard Model of particle physics at energy scales not otherwise reachable. They could be a window on a new fundamental theory and on the evolution of the universe. The next generation of neutrino experiments could determine the absolute scale of neutrino masses, discover matter-antimatter asymmetry in neutrinos, and establish whether neutrinos are their own antiparticles. Physicists might even discover so-called sterile neutrinos, interacting with ordinary matter only through gravity. How do neutrinos relate to the matter-antimatter asymmetry of the universe? If, for example, neutrinos are their own antiparticles, it could mean they played an essential role in the survival of matter in the early universe.

Underground experiments looking for what physicists call neutrinoless double beta decay are the only ones that can determine if neutrinos are their own antiparticles. The next generation of these experiments will begin in the very near future. To complete the experimental overview, huge underground detectors will be able to dig deep into neutrino physics using neutrino beams from accelerators, as well as neutrinos raining in from the cosmos or generated below ground. At the same time, they will shed light on proton decay.

Underground physics has a glorious past at its back. Here at Gran Sasso, we see a future just as bright ahead, with the potential for unique contributions to the discovery of the laws of nature and the understanding of the evolution of the universe.

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