Hi James and Tania,

We had a little problem assembling the video and we couldn't merge the answers, which we report here.

All the best,
Moreno & Celas

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"***Alba*** asks about the nature of oscillations and "how neutrinos affect the universe"

This is a broad question but the starting point is that neutrinos have two representations, mass states and flavor states. Neutrinos exist as a superposition of these states but when they interact they do so in a flavor state, either as an electron neutrino, muon neutrino, or tau neutrino. There is a theory that allows us to calculate the probability of each of those outcomes if the initial state, location (hence distance they have traveled to reach the detector) and energy of the neutrino is known. We can learn about the properties of the neutrinos by measuring these probabilities.

This is usually done by looking from neutrinos created in nuclear reactors, by creating a beam of neutrinos by directing a beam of high energy protons at an accelerator lab into a target. In those cases, the type of neutrinos that are created and their energy, and location are well known. We can also look for neutrinos from the sun. All these produces neutrinos at an energy lower than IceCube can measure.

IceCube studies oscillations by looking for neutrinos created when cosmic rays (primarily protons) hit the Earth's atmosphere. We know the distribution of energy and flavor of neutrinos that are produced in those interactions. We then measure the neutrinos at the South Pole with IceCube, determining their energy, direction, and likely flavor. We see deficits at some energies and directions for some types of neutrinos, and excesses for others. This variations allow us to determine the properties of the neutrinos.

Neutrinos are important whenever particles change identities. This happens during fission, fusion, radioactive decay, and when high energy particles collide with other matter or even light like the microwave background radiation. These processes would conserve energy or momentum without the neutrino.

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"***Vera*** asks about the practical application of neutrino physics and IceCube"

IceCube is doing fundamental science so our main goal is to better understand the universe. However, we have to develop many new technologies and ways of analyzing data to make that possible. A few quick examples of IceCube innovations is developing GPU computer clusters to greatly increase the ability to simulate our data at a significantly lower cost. For some types of simulations, the improvement is almost a factor of 100.

IceCube is also one of the early adopters of machine learning to analyze data.

IceCube has developed techniques to handle large data sets, looking for both rare events that happen once in a billion times or less and also utilizing larger data sets to extract general properties that cannot be determined an an event by event basis.

All these techniques can be applied more generally to other large data sets. The skills that are developed are readily utilized in a wide range of applications.

A more immediate example is that IceCube has very extensive measurements of the optical properties of the ice at the South Pole. These properties depend on depth, direction, and even vary across the width of the in-ice array. What we learn about the ice is useful for other fields including glaciology and climate research.

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“***Mathilde*** asks about conducting research in such challenging surroundings"

Antarctica is the coldest, driest, highest, and windiest continent on Earth. Such an extreme environment poses many challenges to both exploration and research. Transporting personnel, materials, and everything needed to build a station and then maintain such infrastructure, providing a living environment for the research personnel all year around, is just part of these challenges. Building infrastructures in a way that can keep them operating during the antarctic winter, for years, and through constant snow accumulation isn't trivial at all.

There are two main seasons in Antarctica, summer and winter, and they differ significantly. Most activities are conducted during the summer, when the temperature reaches -20C/-30C. During this season there are no particular limitations for outdoor activities, and most maintenance and upgrades to both infrastructures and research projects are conducted in these 3 months when the sun is shining 24/7. Also, supplies of fuel and food for the winter are transported and stored in this relatively short period.

In contrast, the winter is affected by temperatures that can reach -80C with no sun for more than 5 months. During this season, personnel not only face extreme weather, but also other stress factors like confinement and the isolation that lasts for 9 months. While it's possible to conduct activites outside, the range is quite limited by the fact that no vehicles can be used during the winter due to the cold temperatures. Also, the time spent outdoor in these temperatures is limited to few hours, and frostbite is a constant risk while working outside, as exposed skin can freeze in minutes to seconds.

During the 9 months of isolation, the antarctic stations on the plateau cannot be reached by any means, medical evacuations are extremely rare. Due to the low temperatures, most airplanes cannot operate in these areas. There have only been 2 medical evacuations in 59 years, both of which at the South Pole where the temperature is occasionally high enough during the winter. Some research stations on the coast can be reached for most of the year.

Despite all this, the continent offers many opportunities for scientific research, and working here is a privilege and an unique experience, with memories that lasts a lifetime. The night sky is indescribable, and even the amazing photos can't make justice to the unforgettable view. Most of the personnel that operate in Antarctica are composed of people that have already spent many winters and countless summer seasons on the continent, and keep returning.

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