Physicists Use Underground Lab to Detect Rare Particles, Peek into Earth's Center

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(PhysOrg.com) -- Using a delicate instrument located under a mountain in central Italy, two University of Massachusetts Amherst physicists are measuring some of the faintest and rarest particles ever detected, geo-neutrinos, with the greatest precision yet achieved. The data reveal, for the first time, a well defined signal, above background noise, of the extremely rare geo-neutrino particle from deep within Earth.

Funded by the National Science Foundation, UMass Amherst researchers Laura Cadonati and Andrea Pocar are part of the Borexino international team whose results are available in the current online edition of the journal *Physics Letters B*.

Geo-neutrinos are anti-neutrinos produced in the radioactive decays of uranium, thorium, potassium and rubidium found in ancient rocks deep within our planet. These decays are believed to contribute a significant but unknown fraction of the heat generated inside Earth, where this heat influences volcanic activity and tectonic plate movements, for example. Borexino, the large neutrino detector, serves as a window to look deep into the Earth's core and report on the planet's structure.

Borexino is located at the Laboratorio Nazionale del Gran Sasso underground physics laboratory in a 10 km-long tunnel about 5,000 feet (1.5 km) under Gran Sasso, or Great Rock Mountain, in the Appenines and operated by Italy's Institute of Nuclear Physics. The instrument detects anti-neutrinos and other subatomic particles that interact in its special liquid center, a 300-ton sphere of scintillator fluid surrounded by a thin, 27.8-foot (8.5-meter) diameter transparent nylon balloon. This all "floats" inside another 700 tons of buffer fluid in a 45-foot (13.7-meter) diameter stainless steel tank immersed in ultra-purified water. The buffering fluid shields the scintillator from radiation from the outer layers of the detector and its surroundings.

The scintillator fluid is so named because when neutrinos pass through it, they release their energy as small flashes of light. Neutrinos and their antiparticles, called anti-neutrinos, have no electric charge and a minuscule mass. Except for gravity, they only interact with matter via the weak nuclear force, which makes them extremely rare and hard to detect, as neutrinos do not "feel" the other two known forces of nature, the electromagnetic and the strong nuclear force.

Borexino is one of only a handful of such underground detectors in the world and is supported by institutions from Italy, the United States, Germany, Russia, Poland and France. Designed to observe and study neutrinos produced inside the Sun, it has turned out to be one of the most effective observatories of its kind in the world, with 100 times lower background noise, in part due to extremely effective scintillator purification and use of radiation-free construction materials.

Borexino is not the first instrument to look for geo-neutrinos. In 2005, a Japanese-United States collaboration operating a similar detector in Japan was able to identify some of these rare particles. But those measurements were affected by radioactive background noise, anti-neutrinos emitted from several nuclear reactors operating in Japan.

By contrast, the new Borexino data have stronger significance because of their purity and the absence of nuclear reactors. As Pocar explains, "the Borexino detector is very clean and has lower levels of radioactive impurities than ever achieved in experiments of this kind. It is indeed a very 'quiet' apparatus for the observation of low energy neutrinos, and exceptionally precise for distinguishing these particles by origin, either solar, geo or human-made." Italy has no nuclear power plants, he adds.

The small number of anti-neutrinos detected at

Borexino, only a couple each month, helps to settle a long-standing question among geophysicists and geologists about whether our planet harbors a huge, natural nuclear reactor at its core. Based on the unprecedently clear geo anti-neutrino data, the answer is no, say the UMass Amherst physicists. "This is all new information we are receiving from inside the Earth from the geo-neutrino probe," Cadonati explains. "Our data are exciting because they open a new frontier. This is the beginning. More work is needed for a detailed understanding of Earth's interior and the source of its heat, with new geo-neutrino detectors above continental and oceanic crust."

In the future the international researchers hope that observations from similar detectors in Canada, Japan and Borexino in Italy can be coordinated to improve geo-neutrino detection and analysis even further.

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Provided by University of Massachusetts Amherst