Double success for neutrino lab

The Gran Sasso National Laboratory in Italy is celebrating two key developments in the field of neutrino physics. Number one is the first ever detection, by the OPERA experiment, of a possible tau neutrino that has switched its identity from a muon neutrino as it travelled from its origins at CERN in Switzerland to the Italian lab. Number two is the successful start-up of the ICARUS detector, which, like OPERA, is designed to study neutrinos that “oscillate” between types.

The idea that neutrinos can oscillate from one flavour to another was first predicted in the 1970s by the Italian physicist Bruno Pontecorvo. At the time, neutrino oscillation was controversial, because it implies that neutrinos have mass, a feature that contradicts the Standard Model of particle physics. However, this idea was subsequently supported by experiments revealing that the Sun produces fewer electron neutrinos than had been expected, and by experiments in the 1990s that detected a shortfall in muon neutrinos produced by cosmic rays interacting in the Earth’s atmosphere.

OPERA—located some 1400 m under the Gran Sasso mountain in central Italy—takes a different approach by looking for a direct detection of a neutrino that has oscillated. It is designed to detect a beam of muon neutrinos fired from CERN that travels 730 km through the Earth to Gran Sasso. If the detector can spot a tau neutrino directly, it would rule out the slim possibility that any muon neutrinos have instead decayed or disappeared into higher dimensions.

Weighing 1250 tonnes, the OPERA instrument consists of 150,000 “bricks” made from 36 layers of lead. Any tau neutrinos interacting with the lead nuclei would produce a tau lepton, which then decays into a muon, hadron or electron, thereby generating a very short track with a distinctive kink. Since it started up in 2006, the experiment has detected a few thousand muon neutrinos, but it was not until last year that it detected its first tau-neutrino event, with a confidence of 98% (arXiv:1006.1623).

The ICARUS detector, which recorded its first events on 27 May, uses a different detection technique. It consists of a tank filled with 600 tonnes of liquid argon, with a large potential difference established across the container. If any neutrinos, again produced at CERN, pass through the liquid argon, they should trigger a reaction that results in the generation of new charged particles. As with OPERA, the tracks of the charged particles can identify the type of neutrino.

‘Nuclear clock’ unveiled

Physicists in the US have published plans to build the first “nuclear clock”, which could provide better accuracy than the current leaders in timekeeping. The researchers want to take advantage of a very narrow nuclear transition in thorium-229 that occurs at about 7.6 eV. They suggest that, by bombarding thorium with vacuum-ultraviolet radiation, they can create a consistent feedback loop between the frequency of radiation and the rate of the transition. This is the same basic principle that underpins atomic and optical clocks, but these rely on wider electronic transitions corresponding to lower frequencies. The leading optical clocks can keep time to an accuracy of one part in 10^13, but the thorium mechanism could improve on this by up to three orders of magnitude, claim the THOR collaboration.

The nuclear clock also differs from existing atomic and optical timekeepers—which use dilute gases—because the thorium nuclei will be embedded within a solid material, thus making it more convenient to manufacture. "Because nuclear transitions are so insensitive to their environment, we believe that we can build a nuclear-transition-based frequency reference by simply doping thorium into high-quality crystals," says Eric Hudson, a THOR member based at the University of California, Los Angeles. Hudson and his team have already carried out experiments to determine the best host crystal for the thorium, with CaF_2 and LiCsAlF_6, showing the most promise (Phys. Rev. Lett. 104 200802). One challenge will be to secure a supply of thorium-229, which currently costs a staggering $500 per gram. "We are working with the Los Alamos National Laboratory to open a new supply line through extraction from old uranium samples," says Hudson.