ASPERA this month

January / February 2011

GERDA: Are neutrino and antineutrino like peas in a pod?

A new experiment to explore the elusive neutrino properties has been inaugurated last November at INFN Gran Sasso National Laboratories. GERDA (Germanium Detector Array) is searching for a very rare phenomenon which manifestation would confirm that the neutrino is a Majorana particle, meaning it is identical with its antimatter brother, the antineutrino.

Being the most widespread particles in the Universe, neutrinos recover a fundamental role in determining the evolution of our Universe. But exploring their properties is a real challenge as they are also the most elusive particles reaching the Earth from the Cosmos, interacting only rarely with matter. Facing this hard adventure is anyway a worthwhile investigation in the world of particles, as neutrinos seem to be very peculiar. In particular, some theoretical models hypothesize that the elusive uncharged neutrino could coincide with its antimatter particle, the anti-neutrino, usually referred to as a Majorana particle.

“If this unusual property were confirmed it would explain why neutrinos are so much lighter than their charge leptonic partners (electron, muon and tau particles)” said Stefan Schönert, spokesperson of GERDA. “Moreover, it would shed light on the fundamental question why today’s Universe is dominated by matter and not antimatter. The search for neutrinoless double beta decays therefore does not only probe elementary particle physics theory, but also our knowledge concerning the structure of the entire Universe”.

The questions about whether neutrinos and antineutrinos are identical particles will be studied in a new experiment which was inaugurated last November at the INFN >>

This month:

Next meetings:

> **Computing workshop**
31 March / 1 April 2011 - Barcelona / Spain

> **Theory & schools meeting**
May 2011 - Ireland

> **Undergound physics projects workshop**
30 June / 2 July 2011 - Zaragoza & Canfranc

Gran Sasso National Laboratories. GERDA (Germanium Detector Array) is searching for a very rare phenomenon concerning neutrinos, a process that could be detected by the study of the decay of the nuclei ^{76}Ge. Only if the neutrino particle coincides with the antineutrino, the double beta decay phenomenon without neutrino emission can occur. Two of the neutrons inside of the ^{76}Ge nucleus are transformed (decay) simultaneously into two protons, two electrons and two neutrinos. However, in the case of neutrinos and antineutrino they are the same particle, the neutrino is exchanged as a virtual particle amongst the two decaying neutrons and, therefore, does not emerge from the nucleus. As a result, only electrons would be released which deposit energy in one of the germanium crystals.

Weighing neutrinos

Besides the question of whether the neutrino is a Majorana particle, the observation of the double beta decay without neutrino emission would permit physicists to directly measure the effective mass of the electron neutrino, the value of which has a great impact on Universe development models.

GERDA operates bare germanium detectors enriched in the isotope ^{76}Ge submerged in about 70 m^3 liquid argon cryostat which in turn is surrounded by a water tank. The apparatus is set in the rooms of Gran Sasso National Laboratories, under a 1400-meter high mountain in the heart of Italy. The spontaneous decay of matter that GERDA is searching for is so rare that it is like perceiving a single specific note during a concert season; a room with perfect acoustics is needed to hear it.

In GERDA the detectors are used at the same time to produce and reveal the particles emitted during the decay. Each of the eight detectors – sized as a beverage can and weighing about two kilograms each - is made of high-purity germanium mono-crystals, a semiconductor material, enriched in the isotope ^{76}Ge. When a ^{76}Ge nucleus decays, the emitted electrons deposit their energy in the germanium detector. To avoid external disturbances, the crystal detectors are suspended in the cryostat, a six meter tall and four meter wide tank, filled with liquid argon (at a temperature of –186 °C). The cryostat, in turn, is placed inside a water tank with about ten-meter diameter, which serves as a further shield. The "acoustics" of the GERDA experiment are guaranteed by the liquid argon, water and rock volumes, placed in this nesting-doll structure, which protect the typical "note" of the experiment from billions of particles arriving from the Universe, but also from the Gran Sasso rocks. These disturbance "sounds" are blocked out by the rock above the laboratory, and finally by the "nesting dolls" which protect the experiment.

GERDA is an international collaboration with institutes from Belgium, Germany, Italy, Poland, Russia and Switzerland. After an initial period of commissioning the experiment with natural high-purity crystals, the enriched detectors will be deployed and the physics data taking will start in early 2011. ■

Submitted by Francesca Scianitti (INFN / Italy)
& the GERDA Collaboration

>>GERDA's website: http://www.mpi-hd.mpg.de/gerda/

>> Video: http://bit.ly/frBp2o

Studying the deep Universe at extreme energies with MAGIC

An interview with Alessandro de Angelis, physicist at University of Udine and INFN in Trieste, Italian national coordinator for the MAGIC experiment, composed of two giant telescopes in the Canary Islands.

MAGIC was inaugurated in 2003. Now it became MAGIC-II with a second telescope. What is the current status of the project?

We finished the commissioning of the second telescope in May 2010. We are running now stably with a stereo configuration and we discovered already some six new extragalactic objects and a couple of new galactic objects. It works very well, slightly better than the design performance.

Why did you build a second MAGIC telescope?

We needed the stereo configuration for two reasons. First, to increase our sensitivity which is now more or less doubled. We can see more sources now, and we need a smaller observation time to detect variability. Second, to improve our angular resolution in a sense that we can now image many galactic sources. With just one telescope our spatial resolution was not good enough to really see the details of many galactic emitters. Making an image from which you can infer the morphology of the source is important. Now, MAGIC can spot the points from which the high energy cosmic rays are produced in the source. And we got some bonuses as well: with two telescopes the signal is much cleaner especially at low energies. Life is much easier for the analysis.

What was your personal science driver for MAGIC-II?

I like fundamental physics very much, in particular the questions that are difficult to address with accelerators. One of these is the test of fundamental symmetry that you can do by studying photons propagating through cosmological distances. There is the possibility to detect violations of the Lorentz invariance, by comparing the arrival times of photons of different energies produced in transients: if the speed of light turns out not to be constant, but dependent on energy, we are on top of a new physics – and MAGIC is the most sensitive instrument for this kind of study. The possibility to detect new particles in the vacuum, belonging to the family of the so-called axions, is another line of research that I am following. Those particles could mix to photons (i.e., photons transform into axion-like-particles and vice versa), and detecting this phenomenon would be a breakthrough in our understanding of the vacuum and of the energy of the Universe. All this requires the study of the deep Universe at extremely high energies. That's very exciting!

How do you select your targets for MAGIC?

We go through a democratic procedure. There is a time allocation committee which evaluates the proposals. The good thing is that many of the proposals are signed by young people who have a strong motivation for selecting a target. Then there is a committee made by seniors evaluating which ideas are more worth to be pushed. On top of this there are the targets of opportunity given by detectors like the Fermi satellite. Because we are able to turn MAGIC within 20 seconds towards whatever source on the sky, we are very keen to react to targets of opportunities related to fast transients in the Universe, in particular gamma ray bursts.

Did you catch a burst during the explosion?

Not yet, unfortunately. A couple of times, we were really unlucky. Sometimes the gamma ray burst came in a bit of a wrong position, sometimes it came late in the day and so on. But we are in the limit of sensitivity and always hoping for the right burst.

Two magic telescopes

MAGIC is a system of two telescopes located at the Roque de los Muchachos Observatory on La Palma, one of the Canary Islands. MAGIC detects particle showers released by gamma rays, using Cherenkov radiation. With a diameter of 17 meters for the reflecting surface, these telescopes are the largest in the world of their kind. The first telescope started in 2004. A second telescope was added and started taking data in July 2009.

MAGIC Collaboration

Does very-high-energy gamma astrophysics belong to physics or to astronomy?

The history is full of cases in which the interplay between the two sciences has been the key for the advancement of science, I am thinking to the Greek philosophers, of Galilei and Newton, and Einstein. I believe this can be such a case. Modern gamma-ray astrophysics is such a frontier science that it cannot be properly classified into physics or astronomy: it is at the edge of both.

Will the Cherenkov Telescope Array (CTA) made by many telescopes be the natural next step?

I think CTA is important and it will be done. I still think that we have to take the maximum profit of what we have and move on to CTA through a prototyping phase, which increases step by step the power of the existing detectors.

What's the role of international collaboration for a project like this?

Before doing this job I was at CERN for six years in a very international environment. I believe that worldwide collaboration in the 21st century is the only way to go. The size of the projects are so enormous that it needs a worldwide collaboration. In a sense, CTA is becoming the world project for very high energy cosmic ray physics.

What's your advice to any student considering a career in physics?

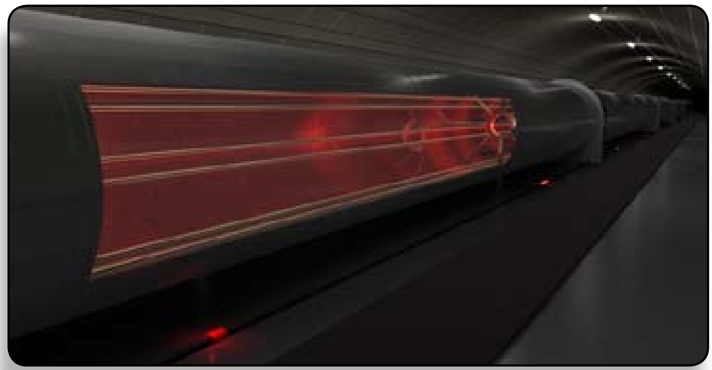
I would recommend to be very careful to pursue a career in physics in an interdisciplinary culture, and with care to a strong mathematical basis. I mean in such a way that one can react fast to changes. I can not tell what will be the main drivers of physics in 20 or 30 years from now. But I am sure that physics will be always among the great actors of science. ■

Submitted by Dirk Lorenzen (Germany)

MAGIC's website: http://wwwmagic.mppmu.mpg.de/

Home stretch for the Design Study of the Einstein Telescope

While current gravitational detectors are moving to their advanced version for reaching a higher sensitivity, the community is designing the Einstein Telescope, the detector of the future that will open the window to precision gravitational wave astronomy.



Artistic view of the Einstein Telescope (Credit: ASPERA).

Interferometric gravitational wave (GW) detectors have demonstrated the validity of their working principle by coming close to, or even exceeding, the design sensitivity of the initial instruments: Virgo and GEO600 in Europe, LIGO in the USA and TAMA in Japan. In the same infrastructures, currently hosting the initial GW detectors a second generation of interferometers (so-called "advanced detectors": "Advanced LIGO, "Advanced Virgo" and GEO-HF) will be implemented over the next few years. These advanced detectors, based on technologies currently available, and partly already tested in reduced scale prototypes, but still to be implemented in full scale, will show a sensitivity improved roughly by a factor of ten with respect to the initial interferometers.

But apart from extremely rare events, the signal-to-noise ratio (SNR) of detections in the "advanced" detectors will be still too low for precise astronomical studies of the GW sources and for complementing optical and X-ray observations in the study of fundamental systems and processes in the Universe. These considerations led the GW community to investigate the possibility of building a third generation of detectors, permitting both to observe, with excellent SNR, GW sources at distances similar to those detectable in the advanced detectors and to reveal GW signals at distances comparable with the sight distance of the electromagnetic telescopes. A detector with these capabilities has been included in the ASPERA "roadmap" as one of the "Magnificent Seven" projects to be achieved in the next future.

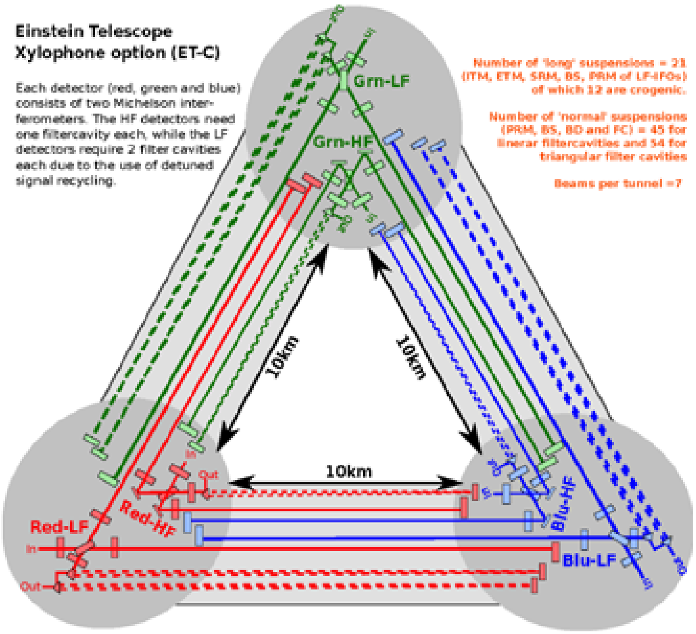
The Einstein gravitational wave Telescope will be a third generation gravitational wave observatory that will put Europe at the forefront of the gravitational wave astronomy; ET, thanks to its capability to inspect the GW signal in great detail, will herald a new era of routine GW astronomy.

The ET project is currently in its third and last year of the conceptual design phase, supported by the European Commission in FP7-Capacities-Design Studies. The ET design study is an initiative of eight institutes, leading the GW search in Europe, that aggregates a community (the ET science team) of more than 220 (European, American and Japanese) scientists interested in the ET project.

Hunting for "extreme objects" in the Universe

The first target of the ET team has been to further elaborate the ET scientific targets; ET will have a sensitivity a factor 10 better than an advanced detector, with particular focus to the low (3-10Hz) frequency range; this will open a new avenue for understanding the physical phenomena of "extreme objects" in the Universe.

The design study team has detailed the scientific scope of ET in a vision document. For instance, ET will help to observe compact binary coalescences, allowing for an accurate measurement of the masses of neutron stars and black holes; it will then be possible to infer the maximum



Possible simplified scheme of the ET lay-out. The observatory will be able to host up to three detectors, each composed by one or two interferometers (courtesy S.Hild).

mass of a neutron star, a long-standing open problem in theoretical physics. By observing binary neutron stars in coincidence with short hard gamma ray bursts, ET will also help in measuring cosmological parameters as such cosmic bodies are ideal standard candles. In addition, ET should allow for testing general relativity and constrain alternative theories of gravity.

To achieve the sensitivity required by these science targets, the ET observatory must implement new technologies and new solutions in many fields: optics and opto-electronics (new high power laser, crystalline material optics, low dissipation coatings or coating-less optics), cryogenics (low vibration cryocoolers, cryogenic test masses), mechanics (seismic filters), gravity gradient noise subtraction through seismic sensor network. An intense and coordinated R&D programme will be necessary in the next years to master all the technologies required by ET.

But the main characteristic of the ET project is to consider it as a long-lasting European Research infrastructure, capable to host a family of evolving GW detectors. For this reason the design study focused on the site and infrastructure requirements of the ET observatory. ET will be a large underground installation located at least 100 metres below ground and having a triangular shape, each arm being about 10 km long.

The ET infrastructure will allow to implement up to three different detectors, each of them realized by one or two interferometers, tuned at different frequency ranges, in a so-called "xylophone" configuration.

The draft version of the ET conceptual design study document has been released by the ET collaboration in October 2010 at the third annual meeting in Budapest. The final version including the ET cost evaluation will be completed by July 2011. The conceptual design study marks a key milestone towards the realization of a new gravitational wave observatory in Europe. ■

Submitted by Michele Punturo, ET scientific coordinator

Einstein Telescope's website: http://www.et-gw.eu/

Budapest meeting: http://www.et-gw.eu/3rd-annualworkshop

ASPERA in Hungary

Hungary is one of the latest countries to join ASPERA. Last october, a visit to Budapest was organized, providing an overview of astroparticle physics activities and of the research funding system of Hungary.

The 16th ASPERA National Day was organized by the National Office for Research and Technology (NKTH) on 15 October 2010. Invited by NKTH, representatives of the ASPERA network, the Hungarian science funding system and astropraticle physics research have conferred in Budapest, Hungary. The main purpose of the ASPERA Hungarian National Day was to present the astroparticle physics activities and the science funding system in Hungary to the other ASPERA partners.

There were approximately 50 participants in the National Day who received a full review of institute structure of the Hungarian R&D; they were informed about the R&D funding opportunities and the main trends and achievements of Hungarian astroparticle physics researches. In Hungary three organisations, the Hungarian Scientific

From left to right: Zsolt Frei of Institute of Physics at Eötvös University, Vilmos Németh from the National Office for Research and Technology (NKTH) and Thomas Berghöfer, ASPERA coordinator.

Istockphoto

Research Fund (OTKA), the National Office for Research and Technology (NKTH) and the Hungarian Academy of Sciences (MTA) provide the largest contribution to astroparticle physics research. Representatives of these organisations gave presentations about their funding opportunities and future plans.

Hungarian researchers have a strong involvement in gravitational wave research and are also active in several other fields of astroparticle physics such as neutrino physics (KATRIN, Borexino) and cosmic rays. They are looking forward to playing a more significant role in the European research area. Astroparticle physics activities in Hungary include research carried out at three major universities (at Eötvös Loránd University in Budapest, at the University of Szeged and at the University of Debrecen), and research activities at two major research institutes run by the Hungarian Academy of Sciences (at the Research Institute for Particle and Nuclear Physics in Budapest and at the Institute of Nuclear Research in Debrecen). There were eight presentations by researchers from all these places on the National Day. The focus was on activities at CERN (which Hungary joined more than a decade ago) and participation at both the LIGO and VIRGO gravitational wave observatories, a recent addition to activities in Hungary. During the discussions on the ASPERA Hungarian National Day it was mentioned that Hungary could be a suitable building site for one of the proposed magnificent seven research infrastructures. ■

Presentations of the meeting are available at: http://bit.ly/hpwtGY