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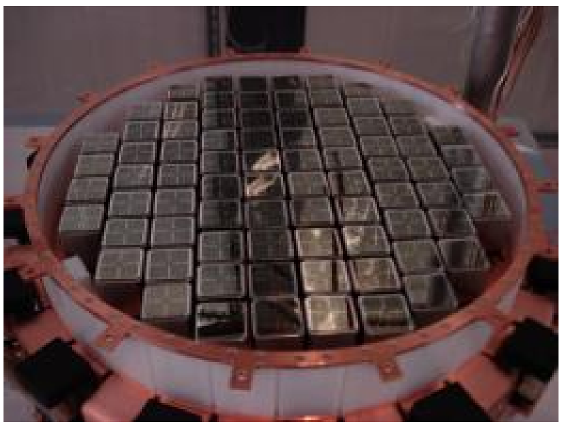
Xenon100: 'We hope to detect the largest proportion of the matter in space'

April 28 2011



Trap for dark matter: The Xenon100 experiment is located beneath 1400 metres of rock in the Gran Sasso underground laboratory in Italy to protect it from cosmic radiation. WIMPs can penetrate the earth and reach the detector, which is shielded against radioactivity from the rock with several layers of water, lead, plastic and copper. When a WIMP reacts in the liquid xenon, flashes of light are generated which are registered by photomultipliers (illustration). Credit: Rice University

The underground laboratory at Gran Sasso in Italy is the home of the Xenon100 experiment, which is being conducted as an international collaboration that includes the Heidelberg-based Max Planck Institute for Nuclear Physics to detect the mysterious particles directly. The researchers recently published the evaluations of one hundred days of measurement time. The result: although there is no significant signal for dark matter as yet, the world's best limits for the masses and interaction strengths of the WIMPs have been obtained, and already noticeably reach into the predicted range.

For many decades there have been mounting indications that the stuff of which all stars, planets and even we humans are composed accounts for just under five percent of the total matter existing in the universe. Dark matter contributes 23 percent, the lion's share of 72 percent being provided by dark energy. Theoretical and experimental indications point towards it consisting of yet unknown elementary particles which are present everywhere in the universe. Physicists call them WIMPs (Weakly Interacting Massive Particles), because they have as good as no interaction with normal matter. This is why the particles have so far evaded any direct detection and only make themselves felt in astronomical observations by their gravitational force.

The latest results of the Xenon100 detector have implications for the theory of particle physics and the experiments at the LHC accelerator at CERN in Geneva. Which conclusions can be drawn? We spoke with Manfred Lindner, Head of Xenon100 at the Max Planck Institute for Nuclear Physics.

Can you describe how Xenon100 works in a few words?

The detector consists of a tank which is filled with 162 kilograms of extremely pure liquid xenon. If a WIMP collides with an atom here, a flash of light is triggered and electric charges are generated at the same time. If such a double event is registered, it is an indication for the existence of a dark matter particle whose mass could also be determined. An enormous technical challenge is to protect the detector from interfering radiation – caused mainly by natural radioactivity. To this end, the xenon was purified to a very high degree and the detector shielded from external influences with several layers of different materials.

You registered three events in your measurement data from the first half of last year. Could these be WIMPs?

The three events agree with our prediction of the interfering events to be expected statistically in a hundred days. We therefore say that the result provides only limits for WIMPs. At the moment, the detector is operating with much higher purity so we can't wait to see what the analysis of these data will provide later in the year.

What can one conclude from this null effect?

We have greatly narrowed down the range in which WIMPs can exist. Theoretical predictions set a most probable mass range for these particles which is in the order of 100 gigaelectronvolts, roughly corresponding to the mass of a xenon nucleus. With Xenon100 we ventured precisely into this mass range and narrowed it down enormously. The permissible range for the WIMPs is thus becoming smaller and smaller.

Could the LHC already be able to detect the theoretically predicted WIMPs?

This should be possible with the upcoming data if the WIMPs are present in the mass range predicted.

Couldn't the WIMPs also be much lighter? In the

range below ten gigaelectronvolts, which corresponds to the mass of a carbon atom, Xenon100 is no longer sensitive.

In principle, this cannot be excluded, but the so-called WIMP miracle is then lost. This denotes the fact that new particles, which become necessary because of the shortcomings of the standard model of particle physics, automatically provide the correct quantity of dark matter from the Big Bang. It is easy to see that we are in a way putting together a multi-part puzzle, and it is remarkable how many indications from very different fields fit together consistently. Light or very light WIMPs do not fit into the overall picture nearly as well here. But they cannot be excluded.

What's the next step?

First of all, we will continue measuring with Xenon100. We have already been able to reduce the interfering krypton background to almost one tenth so that the next series of measurements, which we want to evaluate by the autumn, will already provide even more accurate results. At the same time we are already planning an enlarged version of Xenon100 for the next few years - Xenon1T with 2.5 tonnes of xenon.

When is Xenon1T expected to be completed?

The construction should be completed by the end of 2014, and in 2015 we want to begin with the measurements. A very ambitious schedule, but quite realistic for experiments of this size.

And what happens if you cannot find WIMPs with this either?

Because of the WIMP miracle we hope to of course have a very good chance of seeing a signal and thus directly detect the largest proportion of the matter in the universe.

But even if we don't see anything, this would be extremely interesting because it would make the question as to what dark matter really is even more mysterious.

More information: XENON100 Collaboration, Dark Matter Results from 100 Live Days of XENON100 Data, *Physical Review Letters* / arXiv.org / astro-ph

Provided by Max-Planck-Gesellschaft

Citation: Xenon100: 'We hope to detect the largest proportion of the matter in space' (2011, April 28) retrieved 30 June 2024 from https://phys.org/news/2011-04-xenon100-largest-proportion-space.html