Existence of a short-lived tetraneutron predicted

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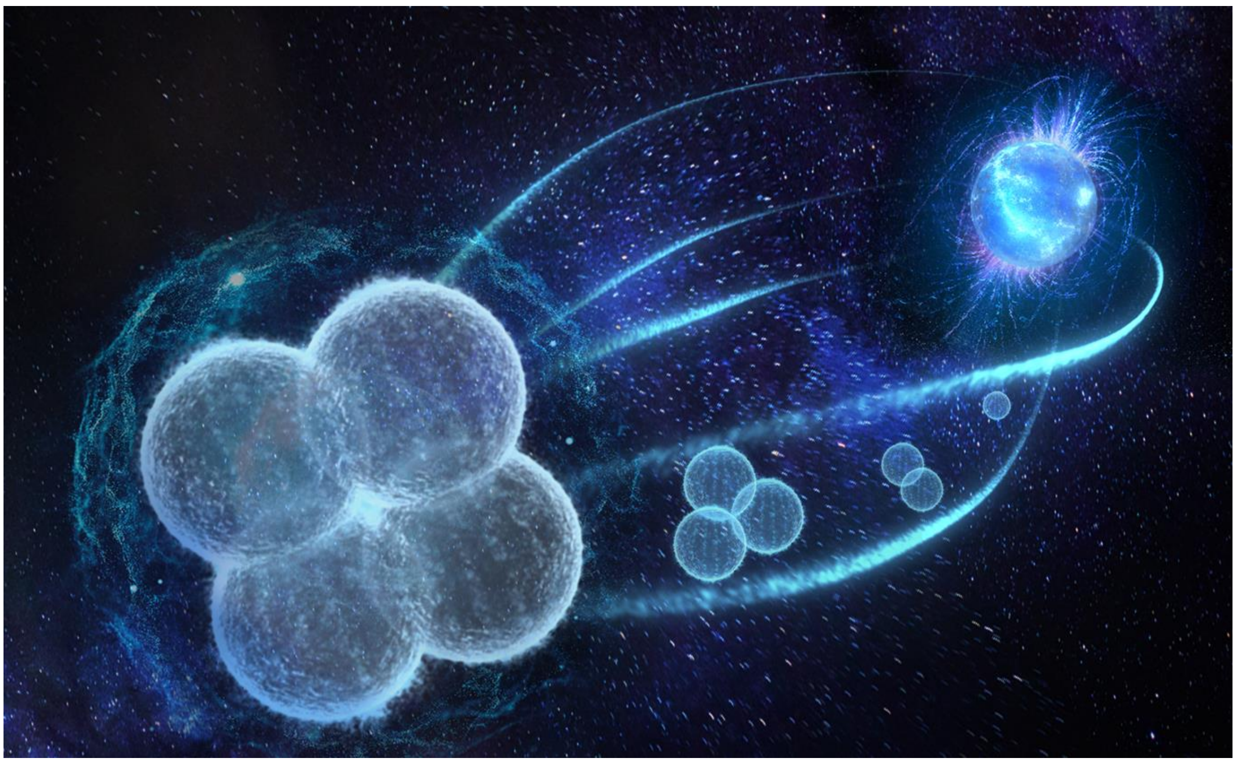


Tetraneutron. Credit: Andrey Shirokov

A research team at the Lomonosov Moscow State University, using new interaction between neutrons, has theoretically justified the low-energy tertaneutron resonance that was recently obtained experimentally. This proves the very brief existence of a particle consisting of four neutrons. According to the supercomputer simulations, the tetraneutron lifetime is

5×10^{-22} sec. The research results are published in a top-ranked journal *Physical Review Letters*.

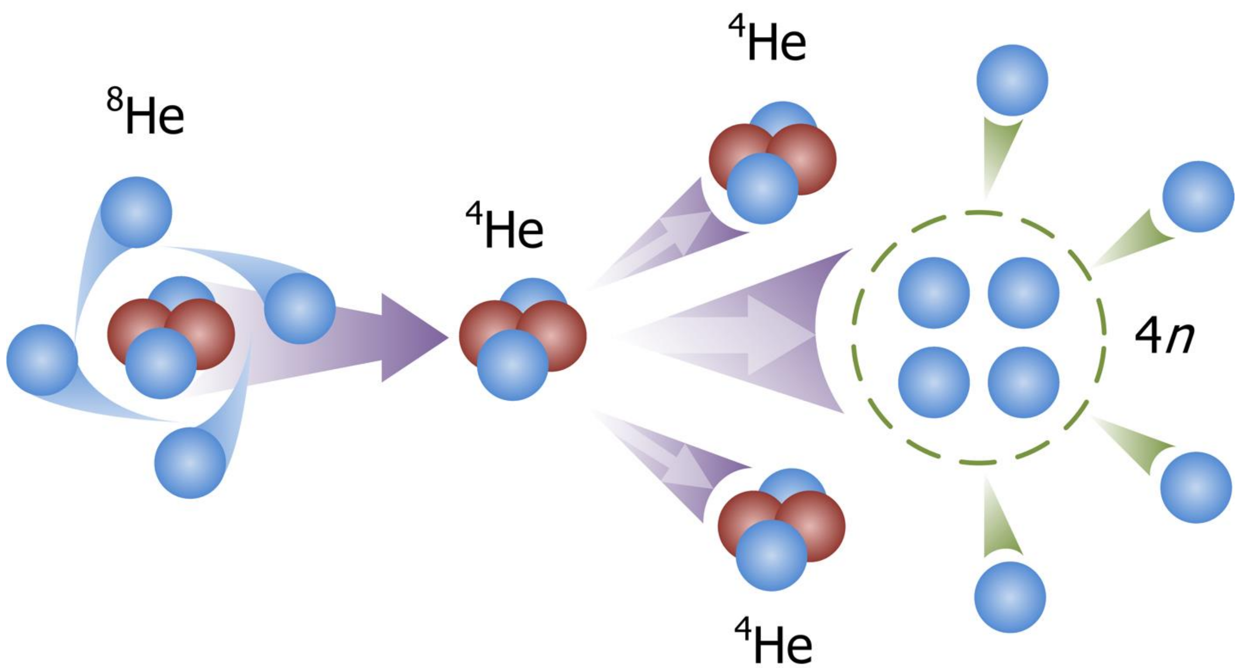
A team consisting of Russian, German and American scientists, including Andrey Shirokov, senior researcher at the Skobeltsyn Institute of Nuclear Physics, has calculated the energy of the resonant tetraneutron state. Their theoretical computations, based on a new approach and new interaction between neutrons, correlate with the results of an experiment in which a tetraneutron was produced.

Searching for neutron stability

A neutron lives about 15 minutes before it decays, producing a proton, electron and an antineutrino. There is also another known stable system consisting of a huge number of neutrons—neutron stars. Scientists have aimed to find out whether there are other systems, even short-lived, composed purely of neutrons.

A system made up of two neutrons doesn't form even a short-lived state. After multi-year experimental and fundamental studies, scientists concluded that there are no such states in a system made up of three neutrons. Searches for a tetraneutron, a cluster of four neutrons, has proceeded for more than 50 years. These searches were fruitless until 2002, when a group of French researchers in an experiment at the Large Heavy Ion National Accelerator in Caen found six events that could be interpreted as tetraneutron production. However, the reproduction of this experiment failed, and some scientists believe that at least a part of the original data analysis was incorrect.

A new phase of the tetraneutron searches took place at the Radioactive Ion Beam Factoryin the RIKEN Institute, Japan, which operates a high-quality beam of ^{8}He nuclei. The ^{8}He nucleus consists of an α-particle (the ^{4}He nuclei) and four neutrons. A few research teams had proposed the tetraneutron searches in RIKEN. In the first of these experiments, the ^{8}He nuclei bombarded the ^{4}He target. As a result of the collision, the α-particle was knocked from the ^{8}He, leaving behind the system of four neutrons. Four events interpreted as the short-lived tetraneutron resonant state have been detected. This experiment was reported at the beginning of 2016, and continues.



As a result of a collision in the experiment α-particle was beaten out of ^{8}He nuclei, leaving a system of 4 neutron (tetraneutron). Credit: Andrey Shirokov

How long could a tetraneutron exist?

The researchers from Lomonosov Moscow State University published in their article on theoretical evaluations of the tetraneutron resonant state energy and its lifetime. They contributed to the preparation of one of the proposed experimental searches for the tetraneutron when a group of experimentalists from Germany asked for the assistance.

Andrey Shirokov, the first author of the article, says: "We made such evaluations in different models, and the obtained results were used to support the experiment. Afterwards, we thoroughly elaborated the theoretical approach and performed numerous simulations on supercomputers. The results have been published in our paper in *Physical Review Letters*."

The theoretical results for the energy of tetraneutron resonance of 0.84 MeV correlate well with the Japanese experimental finding of 0.83 MeV, which is, however, characterized by a large uncertainty (about ±2 MeV). The calculated width of the resonant tetraneutron state is 1.4 MeV, which corresponds to the lifetime of about 5×10^{-22} sec.

Shirokov says, "It's worth noting that none of the previous theoretical papers has predicted the existence of the resonant tetraneutron state at such low energies of about 1 MeV."

The new result probably stems from a new theoretical approach to the studies of resonant states in nuclear systems developed by the scientists. This approach has been carefully tested on model problems and in less complicated systems, and only afterwards applied to the tetraneutron studies accounting for the specifics of the four-particle decay of this system.

Shirokov, however, indicates an alternative possibility: "Another possible reason is the fact that we've used a new interaction between neutrons elaborated by our team. Our tetraneutron studies will continue, we'll perform simulations with other more traditional interactions. At the same time, our French colleagues are going to study the tetraneutron with our interaction within their approach. Of course, all of us are looking forward to the results of new experimental tetraneutron searches."

More information: A. M. Shirokov et al, Prediction for a Four-Neutron Resonance, *Physical Review Letters* (2016). DOI: 10.1103/PhysRevLett.117.182502

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