

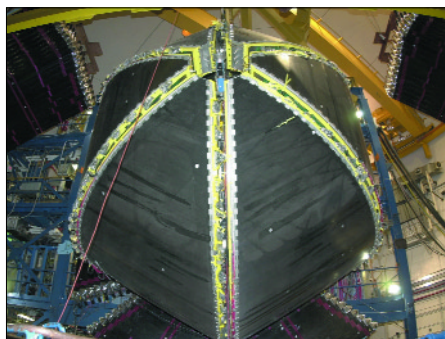
Pentaquarks arrive en masse

After 30 years of searching, physicists have finally found evidence for pentaquarks – particles that contain five quarks. Most particles are either mesons, which contain a quark and an antiquark, or baryons, which comprise three quarks or three antiquarks. Now nuclear physicists in Japan, Russia, the US and Germany have discovered a particle that contains two up quarks, two down quarks and a strange antiquark. The official name of the new particle, which has the same charge as the proton, is theta-plus (Θ^+).

The pentaquark made its first appearance last October when Takashi Nakano of Osaka University and colleagues in the LEPS collaboration reported evidence for a particle with a mass of 1.54 GeV at a conference in Japan. Both the mass of the particle and the width of the particle peak – less than 25 MeV – were in agreement with theoretical predictions made by Dmitri Diakonov, Victor Petrov and Maxim Polyakov of the Petersburg Nuclear Physics Institute in 1997 (*Z. Phys. A* **359** 305).

Diakonov had met Nakano at a conference in Adelaide in Australia in 2000 and encouraged him to search for pentaquarks with the LEPS experiment, which is based at the SPring-8 synchrotron-radiation facility in Japan. Many physicists questioned whether the LEPS team had really detected pentaquarks, but these doubts disappeared when four other experiments – one each in the US and Russia, and two in Germany – reported similar results in quick succession.

The particle peaks observed in the three experiments that have published papers so far – LEPS, the CLAS experiment at the Jefferson Laboratory in Virginia, and the DIANA collaboration at the ITEP laboratory in Moscow – are significant to 4.6, 5.3



Five star – the CLAS experiment in the US is one of five experiments to have detected pentaquarks.

and 4.4 standard deviations, respectively, which means that there is only a very small chance that any of them is due to a statistical fluke. The HERMES experiment at the DESY laboratory in Germany and another group at the ELSA accelerator in Bonn have also seen evidence for pentaquarks.

So what does the new discovery mean for quantum chromodynamics (QCD), the theory that describes the strong force in the Standard Model of particle physics? QCD is a notoriously difficult theory, and exact calculations are not currently possible at the low energies relevant to pentaquarks and less exotic baryons such as protons and neutrons. “99% of the mass of the visible matter around us is made of nucleons – protons and neutrons – but we still do not fully understand them,” says Diakonov, who is now based at NORDITA in Copenhagen. “For me, Θ^+ is first and foremost important because it sheds new light on old nucleons.”

Diakonov and his colleagues actually predicted 10 new particles – an antidecuplet – in their 1997 paper. He believes that another two of these have already been de-

tected, only to be confused with resonances of another particle. The next experimental step, he says, will be to measure the quantum numbers of the Θ^+ such as its spin, isospin and parity. It will also be important, he adds, to measure the size of the new particle to learn if it is a five-quark bound state or a “molecule” made up of two-quark state bound to a three-quark state.

In the Japanese experiment, low-energy photons from a laser were scattered from electrons in the SPring-8 storage ring to produce high-energy gamma rays, which were then directed at a plastic target. The LEPS team searched for evidence of collisions in which a gamma-ray photon interacted with a neutron in the target to produce a negative kaon (a meson that contains a strange quark) and a pentaquark, which subsequently decayed into a positive kaon and a neutron.

“The next stage is to obtain more data,” says Ken Hicks of Ohio University in the US, and a member of both the LEPS and CLAS teams. A modified version of the CLAS experiment designed to specifically study pentaquarks has just been approved at the Jefferson lab.

This experiment will produce 20 times as many pentaquarks as the first experiment and will allow Hicks and co-workers to measure its lifetime and quantum numbers, as well as looking for related particles such as a “partner” with no charge. “There are theoretical predictions for other, higher mass, pentaquarks, and even septaquark particles,” he adds, “but we will not know if they exist unless we look for them experimentally.”

Peter Rodgers

- LEPS: arXiv.org/abs/hep-ex/0301020
- DIANA: arXiv.org/abs/hep-ex/0304040
- CLAS: arXiv.org/abs/hep-ex/0307018

Superheavy elements: nuclear physicists confirm discovery of element 110

The production of an element that has already been seen in three different laboratories would not normally be newsworthy. However, confirmation that element 110 can be made in collisions between nickel and lead nuclei is noteworthy given the recent scandal over element 118 at the Lawrence Berkeley National Laboratory.

Last year the US laboratory sacked physicist Victor Ninov after an internal review committee found that he had fabricated data purporting to show the existence of a new superheavy element containing 118 protons (see *Physics World* November 2002 p7). Now an international team of nuclear physicists led by Ken Gregorich from Berkeley – and containing many of Ninov’s former co-workers – has provided the first

confirmation of the discovery of an isotope of element 110 made at another laboratory (T Ginter *et al.* 2003 *Phys. Rev. C* **67** 064609).

Element 110 was first discovered at GSI heavy-ion research centre in Darmstadt, Germany, in 1994 and was quickly seen in other experiments at Berkeley and the JINR laboratory in Dubna, Russia. However, none of the observations confirmed the others because they all produced different isotopes of the new element; a total of seven isotopes have now been created.

In 1998 the GSI team produced an isotope containing 161 neutrons, $^{271}110$, by colliding lead-208 and nickel-64 nuclei. Now, Gregorich and colleagues have repeated this reaction at Berkeley. They observed two chains of events that signalled the

production and decay of element 110, and said they were in “striking agreement” with those reported by the GSI team.

The Berkeley committee that investigated the element-118 affair was critical of the fact that no one in the experiment, apart from Ninov, had traced the three events purporting to show the production of element 118 all the way back to the raw-data tapes (see *Physics World* June 2003 p16). The latest element-110 paper points out that “the raw data containing each of the two decay chains have been subjected to close scrutiny to ensure that these events are not the result of the same process leading to the incorrect report of element 118”. Although Ninov is not one of the co-authors, he is acknowledged for his participation in the work.