# Evidence for a narrow $|S|$ =1 baryon state at a mass of 1528 MeV in quasi-real photoproduction

After 30 years of searching several experiments have finally found evidence for particles containing five quarks. Most particles are either mesons, which contain a quark and an antiquark, or baryons, which comprise three quarks (or antiquarks). In the last 4 months physicists in Japan, Russia, the US and Europe have found evidence for the existence of a particle that contains two up quarks, two down quarks and a strange antiquark.

The first report came from Takashi Nakano and colleagues in the Laser Electron Photon experiment at SPring-8 (LEPS) collaboration who found evidence for a so-called pentaquark with a mass of about 1540 MeV. The particle was observed in an experiment in which high-energy gamma rays were scattered off neutrons in a carbon nucleus. 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.

Meanwhile the DIANA collaboration from the Institute of Theoretical and Experimental Physics (ITEP) in Moscow, Russia, was examining a 1986 data set from low-energy $K^+Xe$ collisions in a xenon bubble chamber. They also found evidence for a narrow baryon resonance at 1540 MeV. Soon thereafter the CLAS collaboration at the Thomas Jefferson National Accelerator Facility in the US reported evidence for a pentaquark with a similar mass and width. The US team scattered gamma-rays from a deuterium nucleus. A few months later the SAPHIR collaboration at the Electron Stretcher Accelerator (ELSA) also presented evidence for a narrow pentaquark state based on an experiment carried out in 1997 - 1998 using photons impinging on a hydrogen target.

The most recent experimental evidence for the pentaquark comes from the HERMES collaboration at the DESY laboratory in Hamburg. In this experiment high-energy positrons, which are accelerated and stored in the HERA electron-proton collider at DESY, were scattered of a deuterium target. The reaction products were detected and analysed in a spectrometer that surrounds the interaction point of the experiment in the forward region. By looking for combinations of a certain type of kaons (more in particular $K^0$ mesons consisting of an anti-strange quark and a down quark) and protons, a spectrum could be constructed that revealed a peak at an energy of 1528 MeV (see Fig. 1).

As compared to the other experiments, the HERMES collaboration carried out their measurements at a substantially higher incident energy thus reducing complications that may arise due to the unknown production mechanism of the pentaquark. Moreover, for the first time the measured spectrum has been compared to the results of a detailed Monte-Carlo simulation. This enabled the HERMES physicists to conclude that the peak could not originate from an unfortunate combination of kinematical requirements as they are usually applied in searches for new particles. In fact, the results of the Monte-Carlo simulation could even be verified by making artificial combinations of kaons and protons belonging to different scattering events. This sophisticated analysis also showed that -most likely- several known so-called $\Sigma^*$ resonances have also been produced in the experiment.

The statistical significance of the pentaquark signal has been estimated as well. The new HERMES results yield a significance of about 4 to 6 standard deviations, similar to what has been found by other experiments. This number is so large that the chances of the

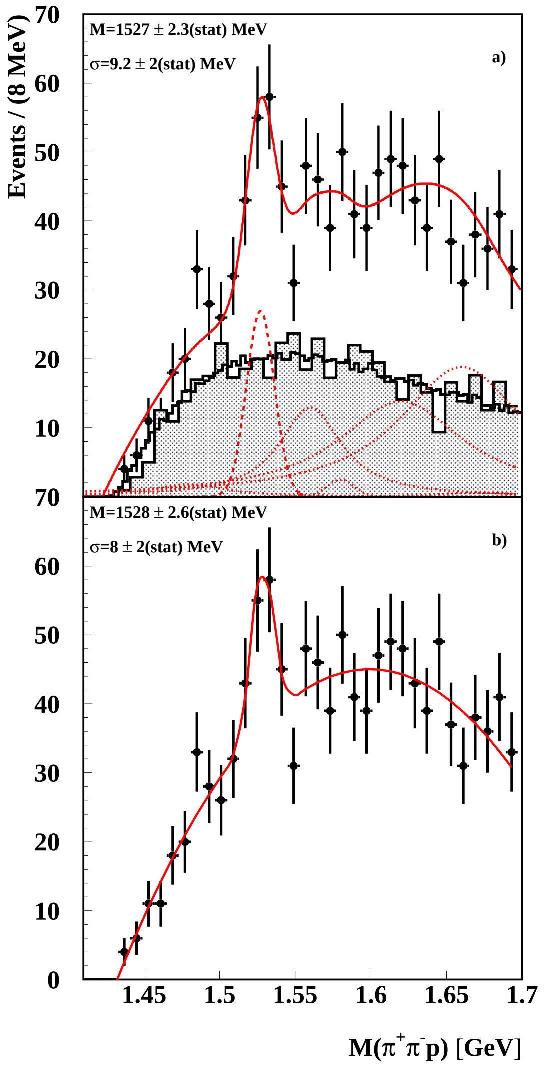


Figure 1: *Spectrum of kaon-proton combinations as found by the HERMES experiment. The top panel shows the result of a sophisticated analysis in which the background is treated on the basis of a Monte-Carlo simulation in combination with the assumed production of several $\Sigma^*$ resonances. The bottom panel represents the results of the common analysis technique also adopted by previous reports on the pentaquark.*

observation being a statistical fluke are extremely low. Moreover, a detailed comparison has been made of the mass of the pentaquark as reported by the various experiments. If the weighted average is taken the value of the pentaquark mass is found to be $1535.8 \pm 2.7$ MeV.

The HERMES experiment also searched for a similar signal in a spectrum constructed from positive kaons and protons. No signal was found, suggesting that a doubly charged pentaquark does not exist near 1535 MeV. This already rules out some of the models that have been proposed since the first report of the pentaquark particle appeared. Still it is not yet clear if the pentaquark observed in the experiments is a tightly bound five-quark state or a sort of molecule made of a kaon and a nucleon[1].

[1]The beginning of this popular summary is based on the short report on this subject that appeared in the July 2003 issue of Physics World, written by Peter Rodgers.