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Physics news on the Internet (based on electronic preprints)

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1. Weak charge of the proton

The Q_{weak} Collaboration of the DOE's Jefferson Laboratory (Newport News, USA) has determined for the first time the weak charge (i.e., the charge of the weak interaction) of the proton by measuring the parity-violating asymmetry in elastic $e^- - p$ scattering for the small momentum transferred. Spin-polarized e^- beams were sent on a liquid hydrogen target and the characteristics of beam scattering (depending on the weak charge) were compared for the e^- spins directed along the e^- velocity vector and its opposite counterpart. The obtained asymmetry parameter was $A_{\text{ep}} = (-279 \pm 35(\text{stat}) \pm 31(\text{syst})) \times 10^{-9}$, thus providing the smallest and most precise asymmetry ever measured in polarized $e^- - p$ scattering. Using the proton form factors taken from the results of other experiments, the weak charge of the proton $Q_{\text{W}}^{\text{p}} = 0.064 \pm 0.012$ was calculated. This magnitude is found to be in good agreement with the Standard Model prediction of $Q_{\text{W}}^{\text{p}}(\text{SM}) = 0.0710 \pm 0.0007$. The weak charge was successfully determined by using only 4% of the data collected in the Q_{weak} experiment, and this error is expected to reduce by a factor of about 5 in the course of subsequent analysis. Measuring the weak charge is a promising direction in searching for new effects beyond the confines of the Standard Model of elementary particles.

Source: *Phys. Rev. Lett.* **111** 141803 (2013)
http://arXiv.org/abs/1307.5275

2. Quantum metamaterial

P Macha (ARC Centre of Excellence for Engineered Quantum Systems, the University of Queensland, Australia and the Karlsruhe Institute of Technology in Germany) and his colleagues from Germany and Russia have created and tested the first metamaterial which is an array of 20 qubits (quantum two-level systems) based on superconducting Josephson junctions. In the past, metamaterials were designed only of classical (nonquantum) elements. A qubit array was embedded in a microwave resonator. Owing to the inductive coupling between qubits and the resonator, the problem of dephasing of qubits due to their unavoidable spread in parameters was solved. As a result, the qubit array was able to have unified resonance frequencies: the eigenfrequency of the resonator and its harmonics. It was shown in the experiment that the metamaterial changes the frequency and the phase of the signals transmitted through it. Note that the signal produced a collective resonant effect simultaneously on up to eight qubits. The use of superconducting elements with low losses in this artificial metamaterial imparts unique properties to it, and promises practical implementation, for instance, in microwave single-photon detectors.

Source: http://arXiv.org/abs/1309.5268

3. Photon 'molecule'

A group of researchers headed by M Lukin (Harvard University) and V Vuletić (Massachusetts Institute of Technology) has observed the formation of bound pairs of photons in an ultracold gas of rubidium atoms. A laser pulse excited a collective Rydberg state in the gas. This state emerges when the electron is distributed between highly excited levels of several neighboring atoms simultaneously. The propagation of a given electromagnetic excitation can be interpreted as motion of a photon possessing some efficient mass through a quantum nonlinear medium. Owing to the effect of Rydberg blockade, a second such excitation could not be generated in the immediate vicinity of the first. However, the second photon could follow the first one if they formed a bound state resembling a photon 'molecule'. The photons in such pairs did not interact with each other directly but via a nonlinear medium. Measurements revealed that photons escaped from the atomic trap simultaneously, i.e., the photons moved through the medium as a bound entity. The bound states of photons could be implemented in all-optical switching, as well as find applications both in quantum logical devices and optical elements of classical (not quantum) computers.

Source: *Nature* **502** 71 (2013)
http://dx.doi.org/10.1038/nature12512

4. Bound states of magnons

T Fukuhara (Max Planck Institute for Quantum Optics, Garching, Germany) and his colleagues have observed in experiment the effect (predicted by Hans Bethe in 1931) of binding free magnons into their pairs (a magnon is a quasiparticle constituting excitation in a system of interacting spins). Pairs of magnons were earlier revealed only indirectly in the spectra of solids. In the new experiments, the atoms of an ultracold gaseous rubidium-87 were trapped into an optical lattice making up a periodic potential barrier created by laser beams. Ultracold bosonic atoms were aligned in one-dimensional Heisenberg spin chains in whose central segments magnons were excited. Two directions of spin corresponded to two sublevels of hyperfine splitting. As the potential barrier started to be lowered, magnons would start moving along the chains, and sometime later the experimentalists again raised the barrier, fixing the magnons in their new positions. Magnons were detected by observing the fluorescent emission from atoms excited by the laser light in the field of a microscope. This emission depended on atomic spin state. Such technique allowed the experimentalists to observe the position of individual magnons to an accuracy of one cell of the lattice. By calculating the spatial correlation functions, it was shown that two-magnon moving pairs were detected

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along with individual magnons. Also, the mean time of decay for bound pairs of magnons — about 210 ms — was measured. This time is probably limited by scattering of bound magnons on inhomogeneities created by thermal fluctuations in the system.

Source: *Nature* **502** 76 (2013)

http://dx.doi.org/10.1038/nature12541

5. Search for gamma-ray lines in the data of Fermi-LAT

In addition to experiments on the direct detection of particles of dark matter, whose results have so far yielded no unequivocal interpretation, attempts have been made to indirectly detect dark matter particles by searching for a signal generated when these particles annihilate. An interesting line of inquiry is the search for monochromatic spectral lines corresponding to the channel of annihilation to two photons. The recording of such lines would provide decisive arguments in favor of the presence of an annihilation signal produced by dark matter. Certain indications of a line at an energy of 133 GeV have been obtained in gamma-ray observations using the orbital Fermi Large Area Telescope (LAT). The Fermi-LAT Collaboration has performed a new processing of the data collected over 4.4 years of observations carried out with a view to test the presence of such lines. The lines were sought in the energy range from 5 to 300 GeV in 5 sky regions around the Galactic center. If a small excess of gamma radiation near an energy of 133 GeV is indeed observed locally in one of the regions at a confidence level of 2.9σ, then the CL over the entire set of data from all sky regions drops to 1σ. In view of such a low global significance, the presence of a gamma line at an energy of 133 GeV from the region of the Galactic center has not been confirmed yet, and the suspected peculiarities in the gamma-ray spectrum may prove to be mere statistical fluctuations.

Source: http://arXiv.org/abs/1310.2953

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