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1. Search for supersymmetry at the Large Hadron Collider

The supersymmetry theory, which unites the fermion and boson fields, is regarded as a possible generalization of the Standard Model of elementary particles. A search was conducted with the ATLAS detector of the Large Hadron Collider (LHC) at CERN for the effects predicted by models of supersymmetry for pp collisions with a center-of-mass energy amounting to 7 TeV. The transformation processes of the particles have been studied in which the final state may include one isolated electron or muon, hadron jets, or 'missing transverse momentum', i.e., momentum carried away by supersymmetric particles (sparticles) with a very small interaction cross section. Specifically, dark matter particles in the Universe, which so far remain undetectable, may constitute such particles. The ATLAS experiment failed to detect deviations from the predictions of the Standard Model; this imposes new constraints on the parameters of supersymmetric models. For instance, one of the versions of supersymmetry — the minimal supergravity (mSUGRA) having squarks and gluinos of equal mass — excludes a squark mass below 700 GeV at the confidence level of 95%. A similar constraint, but without specifying the supersymmetry model, was obtained at the LHC in the CMS experiment. The CMS results point to a squark mass of greater than 400 GeV. It is expected that this mass is less than a few TeV, since supersymmetry then gives an elegant solution to the problem of radiative corrections to the mass of the Higgs boson. In this case, the probability of detecting the effects of supersymmetry at the LHC is fairly high.

Sources: *Phys. Rev. Lett.* **106** 131802 (2011)
http://dx.doi.org/10.1103/PhysRevLett.106.131802

2. Nuclei of antihelium-4 have been created

The STAR Collaboration has reported the first ever observation of antihelium-4 ($^4\overline{\mathrm{He}}$) nuclei at the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory in the US; the nuclei consist of two antiprotons and two antineutrons. Previously, the most massive antinuclei observed had been $^3\overline{\mathrm{He}}$ nuclei produced by Yu D Prokoshkin and his colleagues at the IHEP acceleration facility (town of Protvino) in 1970. Collisions of ions in RHIC create the conditions similar to those of the Universe microseconds after the Big Bang; in particular, there are indications that the quark–gluon plasma was formed. An important feature of the accelerator experiment is the very rapid cooling of the collision products, so that an appreciable fraction of antiparticles has no time to annihilate, and fairly heavy antinuclei are synthesized out of many of them. The STAR experiment recorded 10^9 binary (Au + Au) collisions of gold ions at center-of-mass energies of 200 GeV. A drift multiwire chamber (Time Projection Chamber) was employed as the main detector to measure both the bending of the particle trajectories in a magnetic field and energy loss by particles in collisions with gas molecules. Over the time of the experiment, this selection made it possible to identify 18 events of $^4\overline{\mathrm{He}}$ creation. The number of $^4\overline{\mathrm{He}}$ antinuclei obtained in the experiment is consistent with expectations from the simple thermodynamic model which predicts an equilibrium concentration; this result is confirmed by more accurate models. This experiment is also important from the point of view of the search for $^4\overline{\mathrm{He}}$ in cosmic rays, planned for the near future. A positive result in the search would point to unconventional mechanisms for creating antinuclei.

Sources: http://arXiv.org/abs/1103.3312v2
http://www.bnl.gov/rhic/news2/news.asp?a = 1259&t = pr

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Translated by V I Kisin

3. Repulsion of clouds of a degenerate gas

M W Zwierlein (Massachusetts Institute of Technology, or MIT) and his colleagues observed in their experiment conducted at the MIT–Harvard Center for Ultracold Atoms a repulsion of two clouds of degenerate gas of ^{6}Li atoms in a magnetic field. First, a magnetic field gradient was used to split the ultracold gas into two clouds of atoms with oppositely directed spins; this created a strong repulsive potential which prevented interpenetration of the gas clouds. Feshbach resonance conditions were reached at a certain magnitude of the magnetic field, so that the strength of the interaction between atoms became the maximum possible. The clouds were observed using the absorption and phase-contrast techniques. The atomic clouds executed several oscillations in the harmonic potential along the axis of the cylindrical trap, and then, being spatially separated, they started slowly approaching each other through diffusion. Over a time on the order of one second, during which the clouds were separated, the mean free path of atoms did not exceed the cloud diameter, i.e., the interaction occurred in the hydrodynamic regime. In this process, the diffusion coefficient of the clouds into each other reached the minimum value of $6.3\hbar/m$ predicted by quantum mechanics. The experiment also established that at sufficiently low temperatures the spin drag coefficient between gas clouds decreases with decreasing temperature. This suggests that Pauli-blocking dominates in this case over the contribution from collective excitations, which cause the drag coefficient to increase.

Sources: *Nature* **472** 201 (2011)
http://dx.doi.org/10.1038/nature09989

4. Powerful sonoluminescence

A team of researchers led by S Putterman (University of California, USA) conducted an experiment in which they observed record-strong sonoluminescence — that is, the emission of light from gas bubbles collapsing in a liquid when exposed to sound waves. The achieved peak power of emitted broadband light exceeded 100 W, which is two orders of magnitude greater than the previous maximum power recorded by A Walton and his colleagues at the University of Cambridge in 2004. Xenon bubbles in phosphoric acid filling a vertically suspended steel cylinder collapsed when the cylinder sharply impacted a solid steel base, which caused an intense acoustic wave. This generated a light pulse 150 ns long; its spectral temperature reached 10,200 K. One possible mechanism of sonoluminescence is radiation emission from the hot plasma produced in the collapsing gas bubbles.

Sources: *Physical Review E* (accepted), http://pre.aps.org
http://physicsworld.com/cws/article/news/45708

5. The equation of state of the dark energy

Project SNLS3, in which observers recorded 472 class-Ia supernovas in three years, provided data for an improved equation of state of cosmological dark energy with an accuracy of 6.5%. Class-Ia supernovae are remarkable in that they can serve as 'standard candles' in cosmological observations. In 1998, the observations of supernovae made it possible to establish that the Universe expands with acceleration. In the framework of general relativity, this corresponds to the presence of a substance with negative pressure — known as dark energy. The results of SNLS3, combined with the observational data obtained by the WMAP satellite and with those of the SDSS and SHOES projects, yield the value of $w = p/\rho = -1.061^{+0.069}_{-0.068}$ for the dark energy equation-of-state parameter w in the flat universe model. If the flatness assumption is relaxed, w changes to $w = -1.069^{+0.091}_{-0.092}$, and the constraint on the curvature parameter takes the form $\Omega_k = -0.002 \pm 0.006$. The value of $w_0 = -0.905 \pm 0.196$ is obtained by assuming linear evolution $w = w_0 + w_a(1 - a)$, where a is the scale factor in the Universe. The systematic error is dominated mostly by the uncertainty of photometric calibration, not by astrophysical uncertainties associated with the models of supernovas themselves. In the future, eliminating this source of error can improve the accuracy to $\sim 2\%$. So far, the data obtained are in good agreement with the simplest case of the cosmological constant: $p = -\rho$.

Source: http://arXiv.org/abs/1104.1444

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