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Physics news on the Internet (based on electronic preprints)

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1. Pion production by neutrinos on argon

The ArgoNeuT Collaboration at the Fermi National Accelerator Laboratory (USA) has performed the first measurements of pion production cross sections upon muon neutrino and antineutrino coherent scattering by argon nuclei in processes with the assistance of charged current. The coherent scattering proceeds instantaneously from the entire nucleus and not from separate nucleons entering its composition. Studied were $\nu_\mu + \mathrm{Ar} \to \mu^- + \pi^+ + \mathrm{Ar}$ and $\bar{\nu}_\mu + \mathrm{Ar} \to \mu^+ + \pi^- + \mathrm{Ar}$ reactions with low-energy transfer to Ar nuclei where, after $\pi^\pm$ production, the states of the nuclei remained unchanged. Neutrinos from a beam passed through a reservoir filled with liquid argon, and the charged particles born in the course of interaction were accelerated by the electric field and were registered by a wire detector. Among many collision events, several of the abovementioned reactions were selected according to a number of criteria. The pion production cross section was found to be $2.6^{+1.2}_{-1.0}(\mathrm{stat.})^{+0.3}_{-0.4}(\mathrm{syst.}) \times 10^{-38}$ cm^2 for neutrinos ν_μ with an energy of 9.6 GeV, and $5.5^{+2.6}_{-2.1}(\mathrm{stat.})^{+0.6}_{-0.7}(\mathrm{syst.}) \times 10^{-39}$ cm^2 for antineutrinos $\bar{\nu}_\mu$ with 3.6 GeV. The measured cross section for $\bar{\nu}_\mu$ agrees well with the calculations performed by D Rein and L M Sehgal, whereas the result for ν_μ differs from the theoretical prediction by approximately 1.2σ.

Source: *Phys. Rev. Lett.* **113** 261801 (2014)
http://dx.doi.org/10.1103/PhysRevLett.113.261801

2. Measurement of the gravity-field curvature

G Rosi (University of Florence and the National Institute of Nuclear Physics, Bologna, Italy) and colleagues have directly measured for the first time the curvature of a gravitational field using three atomic interferometers simultaneously. The same team earlier conducted an analogous experiment with two interferometers, where the gravity's field gradient was measured. The field measurement in several places at a time makes it possible to subtract the general vibration noise and to heighten the precision of the result. The idea of such experiments was suggested by J M McGuirk and colleagues in 2001. In the new experiment, three small clouds of ultracold ^{87}Rb atoms were jolted in an evacuated vertical column to different heights. The upper part of the column was surrounded by masses of tungsten alloy with a total mass of 516 kg, inducing additional inhomogeneity of the gravitational field. Near the upper points of the trajectories, the gas clots were exposed to a series of laser pulses going up and down the column. Some of the atoms were absorbed and immediately emitted photons undergoing two-photon Raman transitions. The additional momentum received by the atoms led to a displacement of the upper point of the trajectory and, accordingly, to a phase shift relative to the atoms that did not absorb photons. The interference pattern observed using fluorescent radiation of atoms allowed measurement of the gravitational field at three heights and determination of the field curvature. The results obtained agree well with the theoretical calculations of the structure of the field generated by Earth and by the additional mass. A similar method can be employed for improving the value of the Newtonian constant of gravitation and can be applied in seeking mineral resources by variations of Earth's gravitational field above the deposits.

Source: *Phys. Rev. Lett.* **114** 013001 (2015)
http://arXiv.org/abs/1501.01500

3. Conductance quantization in a neutral matter flux

Quantized electrical conductance determining a charged particle flux has already been observed in experiments. T Esslinger (Federal Institute of Technology in Zürich (ETHZ), Switzerland) and colleagues have observed for the first time the quantization of conductance (transmission capacity) of a thin channel for a neutral atom flux. First, an elongated cloud of ultracold ($T = 42$ nK) degenerate Fermi gas consisting of $\sim 10^5$ ^{6}Li atoms was created in a magneto-optical trap. With the help of laser beams passing through a special mask and a microscope, the cloud fell into two parts joined by a channel 1.5 ± 0.3-μm wide. This width was smaller than the Fermi wavelength (2 μm); thus, the regime of single transverse conductance modes was reached and the conductance quantization could be observed. Another laser changed the channel conductance by creating an additional repulsive potential. The two parts of the cloud contained a different number of atoms, and the chemical potential difference $\delta\mu$ induced an atomic flux through the channel: $I = G\delta\mu$, where G is conductance. The electrical conductance was determined by the rate of variation of the number of atoms in the two parts of the cloud. The conductance varied in discrete steps with increasing additional potential. In the region of the first plateau, it was equal to the inverse value of the Planck constant $1/h$, as was predicted by R Landauer's theory. The graph of conductance demonstrated up to three plateaus altogether.

Source: *Nature* **517** 64 (2015).
http://dx.doi.org/10.108/nature14049

4. Iron opacity at high temperatures

The character of energy transfer in the Sun interior depends on the plasma composition and on the scattering properties of each type of ions. At the present time, a divergence exists between spectral observations of the photosphere and observations of acoustic oscillations in the Sun by the helioseismological method. A correlation of these data reveals that the solar matter opacity is approximately 15% higher than that predicted by the theory. J E Bailey (Sandia

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National Laboratories, Albuquerque, USA) and colleagues carried out the first direct measurements of iron opacity at temperatures $T_e = 1.9 - 2.3 \times 10^6$ K and electron concentrations $n_e = (0.7 - 4.0) \times 10^{22}$ cm^{-3}, i.e., in conditions close to those in the Sun interior at the boundaries between convective zones and those of a radiative transfer. Operating with Sandia's Z machine, an iron and magnesium foil was heated and evaporated by high-power X-ray pulses. In the 22 experiments carried out within three years, 450 spectra of the radiation emitted from the plasma produced were recorded. The measured iron opacity appeared to be 30–400% (depending on the radiation wavelength) higher than that predicted by the calculations. Cumulatively, this makes up about half of the increase in the general opacity necessary for consistency with the helioseismological data. To clarify the nature of the remaining part of the difference at hand, similar measurements should be taken for other chemical elements.

Source: *Nature* **517** 56 (2015)
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5. Gamma rays from the IC 310 galaxy center

Observation of the fast variability of gamma-ray emission from the center of galaxy IC 310 has shown that the size of the emitting region must make up less than 20% of the radius of the supermassive black hole horizon in the galactic center. Such small scales cannot now be investigated in direct observations, e.g., using radio telescopes. Galaxy IC 310 lies in the Perseus constellation at a distance of 260 mln light years from Earth. Its black hole mass of $3^{+4}_{-2} \times 10^8 M_\odot$ was determined from the known black hole mass correlation with the value of the central velocity dispersion. The observations were carried out using MAGIC telescopes placed on La Palma island. They detect Cherenkov radiation from cascades of charged particles produced by gamma-ray photons in the atmosphere. The characteristic time of flux doubling in the gamma-ray range amounted to 4.8 minutes. The radiation-generating processes cannot propagate faster than light, which implies the above-mentioned restriction from above on the emitting region size. Particle acceleration by the electric field in the magnetospheric gap at the base of the relativistic jet is regarded as a probable mechanism of rapidly varying gamma-ray emission. This mechanism is well known in the case of pulsars.

Source: *Science* **346** 1080 (2014)
http://arXiv.org/abs/1412.4936

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