Correcting a Correction Weakens a Whiff of Supersymmetry

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the electrons proceeded around the storage ring, that slice became spatially separated from the rest of the bunch. The radiation from the slice could consequently be isolated, producing an x-ray pulse 300 fs long. Additionally, the extraction of the electron slice created an ultrashort hole in the radiation emitted from the remaining electrons.[3]

Planned advances in synchrotron beam lines will create shorter electron bunches and, therefore, shorter pulses of emitted radiation. The upgrades will also increase the flux and brightness. Subpicosecond x-ray pulses are part of the design specifications for x-ray free electron lasers proposed for the fourth-generation TESLA collider at the German Electron Synchrotron (DESY) and for the Linac Coherent Light Source at SLAC (see the article by William Colson, Erik Johnson, Michael Kelley, and Alan Schwettman in PHYSICS TODAY, January 2002, page 35). And energy-recovery linacs under development can also support shorter electron bunches and thus will also generate ultrashort x-ray pulses.

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Correcting a Correction Weakens a Whiff of Supersymmetry

A recent corrective paper by particle theorists Masashi Hayakawa (KEK, Tsukuba, Japan) and Toichiro Kinoshita (Cornell University) is something of a cautionary tale.[1] Since the mid-1980s, Kinoshita and various colleagues have been laboring to calculate the anomalous magnetic moment of the muon (a_μ) from the standard model of particle theory with ever greater precision. The task has taken on particular urgency in the past year, as the pioneering Brookhaven experiment led by Vernon Hughes and Lee Roberts began to improve on earlier measurements of a_μ by more than an order of magnitude.

Hughes and company attracted considerable attention last year by reporting a 2.6-standard-deviation (σ) discrepancy between their first results and the standard-model prediction.[2] (See PHYSICS TODAY, April 2001, page 18.) The discrepancy was particularly tantalizing because its magnitude and sign hinted at the much-sought-after supersymmetric extension of the standard model. (See the article by Nima Arkani-Hamed, Savas Dimopoulos, and Georgi Dvali on page 35 of this issue.) There has thus been great anticipation of the fourfold increase in the Brookhaven data, expected this spring, which might confirm the discrepancy by raising it to a convincing 5σ.

Wet blanket

The new Hayakawa–Kinoshita paper, however, has somewhat dampened all this anticipation. The standard-model prediction is a sum of Feynman-graph terms representing ever smaller higher-order corrections. Kinoshita and collaborators have, in recent years, worked particularly on the contribution of virtual π^0 mesons to the scattering of virtual photons off one another. And what they tell us in their new paper is that, ever since 1995, they and other theorists have been getting the sign of this so-called hadronic light-by-light scattering term wrong! Now we are told that it should be an additive rather than a subtractive correction to a_μ.

The term contributes less than a part per million to a_μ. But the impact of changing a sign is, of course, twice the magnitude of the problematic term. And in this case, with an extraordinarily precise experiment confronting a similarly precise theoretical calculation, flipping the sign is enough to bring the standard-model prediction up to within 1.6σ of the measurement. So now, barring statistical flukes, the anticipated fourfold increase in the Brookhaven data is not likely to yield a discrepancy much greater than 3σ. That could leave the issue of a_μ as a harbinger of "new physics" in limbo for some time to come.

The culprit appears to have been a nonstandard phase convention well hidden in the bowels of the symbolic-manipulation program FORM used by Hayakawa and Kinoshota and many other theorists. FORM, a descendant of the Schoonschip program initiated by Martinus Veltman in the 1960s (see PHYSICS TODAY, December 1999, page 17), follows the Dutch tradition of multiplying the elements of the conventional Levi-Civita tensor $\varepsilon_{\alpha\beta\gamma\delta}$ by i. Ignoring this ethnic idiosyncracy creates no problems in the purely quantum-electrodynamic calculations for which FORM has been used by Kinoshita and others with great success. But the pseudoscalar character of the π^0 that dominates the hadronic light-by-light scattering term requires contractions of Levi-Civita tensors that give the wrong sign if one doesn't take careful account of the unusual phase convention.

Hayakawa and Kinoshita discovered this calculational landmine by exhaustively scouring FORM after Marc Knecht and Andreas Nyffeler at the University of Marseille reported in November that they had gotten a plus sign for the hadronic light-by-light term with a different symbolic-manipulation program called REDUCE.[3] Furthermore, they and colleagues at Marseille have also produced a convincing qualitative argument, based on effective low-energy field theory, for why the hadronic light-by-light correction has to be positive.[4]

The sign of the hadronic light-by-light correction to a_μ has a long and bumpy history. Kinoshita originally assigned the correction a plus sign in 1985. But he changed it to a minus sign 10 years later, and most other theorists working on the problem followed this about-face, even though there were shaky plausibility arguments in favor of a plus sign. But in the end, physics once again proves itself an admirably self-correcting discipline.

The theoretical prediction having now crept closer to the measurements, it would seem harder for the experimenters to ferret out new physics beyond the standard model. But new hadron-production data from several low-energy electron–positron colliders should soon shrink the theoretical uncertainty of the lowest-order hadronic correction to a_μ, thus giving any new physics a better chance to peep through.[5]

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