Breit correction to the parity nonconserving amplitude in cesium

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The most accurate low-energy test of the Standard model was done in the precision measurement of the parity nonconserving (PNC) $6s \longrightarrow 7s$ amplitude in ^{133}Cs [1]. In 1999, Bennet and Wieman [2] have accurately measured transition polarizability $\vec{\beta}$ for $6s \longrightarrow 7s$ transition. Combining the most precise calculations of the PNC amplitude [3, 4] with the measurement of the PNC amplitude [1] and their measurement of $\vec{\beta}$, they have found the following value of the weak nuclear charge of ^{133}Cs: $Q_W = -72.06(28)(34)$. The first error is the actual experimental error, while the second error corresponds to the theoretical uncertainty in extracting the weak charge from the measured transition amplitude. This value differs from the prediction of the Standard model $Q_W = -73.20(13)$ [5] by 2.5 standard deviations. Here we want to discuss one of the possible sources of the theoretical uncertainty, namely the correction due to the Breit interaction.

There were two most accurate calculations of the PNC amplitude in Cs [3, 4]. In the first one the Breit interaction was neglected completely. In the second calculation it was partly included and corresponding correction to the PNC amplitude was found to be 0.2%. We have calculated the PNC amplitude once again in attempt to determine Breit correction in a more consistent manner. We found out that it was not sufficient to include Breit interaction on the stage of the solution of the Dirac-Fock equations for atomic orbitals. It was equally important to calculate Breit corrections to the random phase approximation (RPA) equations and to the self-energy of the valence electron. All three corrections to the PNC amplitude had the same sign and were of comparable size.

Numerically the Breit correction to the PNC amplitude in Cs appeared to be 0.4%. The two times smaller result of [4] did not account for the Breit corrections to RPA and to self-energy. On the other hand, we want to point out that it is essential to treat Breit interaction self-consistently, i.e to include it into the Dirac-Fock equations rather than calculate corresponding corrections in the frozen core approximation. The relaxation of the core effectively screens the Breit interaction between the valence electrons and the innermost core electrons. Thus, the resultant corrections appears to be much smaller than in the frozen core approximation. This screening was not included in the recent calculation by Derevianko [6], and therefore his result probably overestimated Breit correction.

We also calculated Breit corrections to the hyperfine constants and E1 transition amplitudes and found that they were generally smaller than Breit correction to the PNC amplitude. This result is in agreement with calculations [4, 6]. Thus, we can conclude that the analysis of the theoretical uncertainty by Bennet and Wieman [2], which was based on the comparison of the calculations [3, 4] with the experiment for the hyperfine constants, E1 amplitudes, and transition polarizabilities was insensitive to the Breit correction. Note, that other corrections to the PNC amplitude are well correlated with those for hyperfine structure constants and/or for E1 amplitudes. Therefore, we assume that with Breit correction added to the results of calculations [3, 4] the other corrections can be estimated as in [2]. Then, we get the following final result for the weak charge

$$Q_W = -72.35(28)(34).$$

We conclude that the Breit correction to the PNC amplitude is too small to explain the 2.5σ deviation of the Standard model prediction from the cesium experiment.

[1] C. S. Wood et al, *Science* **275** 1759 (1997).

[2] S. C. Bennet and C. E. Wieman, *Phys.Rev.Lett.* **82** 2484 (1999);
Erratum: *Phys.Rev.Lett.* **83** 889 (1999).

[3] V. A. Dzuba, V. V. Flambaum, and O. P. Sushkov, *Phys.Lett.A* **141** 147 (1989).

[4] S. A. Blundell, J. Sapirstein, and W. R. Johnson, *Phys.Rev.D* **45** 1602 (1992).

[5] W. J. Marciano and J. L. Rosner, *Phys.Rev.Lett.* **65** 2963 (1990);
Phys.Rev.Lett. **68** 898 (1992).

[6] A. Derevianko. *E-print:* physics/0001046.