論文内容の要旨

論文題目　Test of Bound State QED Higher Order Correction:
Precision Measurement of Orthopositronium Decay Rate

（　東縛系 QED 高次補正の検証：
オルソポジトロニウムの崩壊率の精密測定　）

氏名　片岡　洋介

Positronium (Ps) is a bound state of the electron (e^-) and the positron (e^+). Since Ps is effectively free from hadronic and weak interaction effects, Ps is considered to be the best probe to study the bound state nature of Quantum ElectroDynamics (QED). The spin triplet state of Ps, ortho-positronium (o-Ps) has the long lifetime of about 142ns and is suitable for the precision test of the bound state QED. The precision measurement of the o-Ps decay rate has reached the level of $O(\alpha^2)$ correction of about 240ppm. To test the $O(\alpha^2)$ correction term with higher accuracy, the new measurement is performed.

The features of the new measurement are as follows.

- The setup is newly constructed on the base of the fast inorganic scintillator YAP.
- The positronium formation assembly and the trigger system are totally refined.
- The Monte Carlo simulation is made on the base of the Geant4 package. The detector specific nature is also reproduced.

In the measurement, the two types of silica (SiO_2) material are used as the positron target. One is silica aerogel. The other is silica powder. The following results are obtained.

- The systematic increase near T_0 (t=0) is understood and solved.
- Other systematic errors such as the energy window dependence and the uncertainty of the detection efficiency are highly suppressed.
- The results of the two measurements (aerogel and powder) are consistent with each other, even though they have the totally different pick-off ratios (annihilation on target material / o-Ps 3γ decay).
- The combined result achieves the total error of about 150ppm. The measured decay rate is consistent with the theoretical QED prediction and the recent measurements from 1995.

The combined result: $\lambda_{o-Ps} = 7.0401 \pm 0.0006(stat.)^{+0.0007}_{-0.0009}(sys.)\mu s^{-1}$

In addition, the world average of the recent four measurements is in good agreement with the O(α^2)-corrected QED prediction and differs from the QED prediction without O(α^2) correction by 2.6σ. Then one can conclude that the measured decay rate favors the O(α^2)-corrected QED prediction rather than that of O(α) correction.