Precision measurements of the positronium decay rate and Energy level

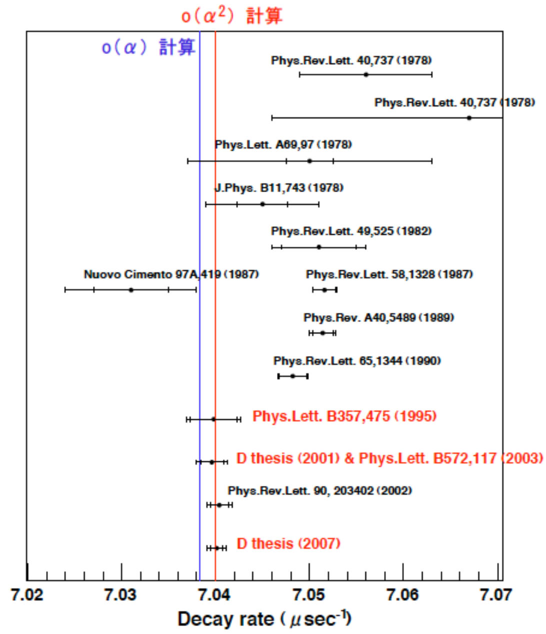
Shoji Asai[1], Toshio Namba[1], Tomio Kobayashi[1] and Haruo Saito[2]

[1] *ICEPP, University of Tokyo, Hongo, Bunkyou-ku, Tokyo, 113-0033, Japan*

[2] *Institute of Physics, University of Tokyo, Komaba, Meguro-ku, Tokyo, 153-8902, Japan*

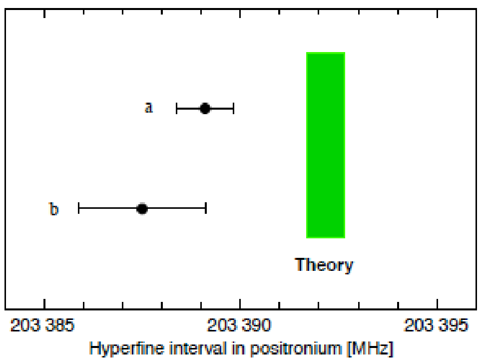
Positronium, the bound state of an electron and positron, is a pure quantum electro-dynamical (QED) system providing a highly sensitive field for study of the bound state QED. The higher order calculations of 2nd and 4th order have been performed recently on the orthopositronium(o-Ps Triples State 1^3S_1) decay rate and the energy splitting between o-Ps and parapositroniumu(p-Ps: singlet State 1^1S_0), respectively. The spin-spin interaction and an annihilation diagram (o-Ps -> gamma* -> o-Ps) contribute the energy splitting (HFS: Hyperfine Splitting), which is very sensitive a new physics beyond the Standard Model because of the quantum effects of the new physics to the annihilation diagram. The precision measurements of the decay rate and HFS give a good test of the bound state calculations and probe the new Physics.

Large discrepancy (>1000ppm), called as "o-Ps lifetime puzzle", has been reported in the 1980s and 90s. We found that a thermalisation process of o-Ps is slower than our expectation and the unthermalized o-Ps makes large bias on the measurement of the o-Ps decay rate. We proposed the new method to determine the thermalization process and the effect of the collision between the o-Ps and the materials directly. We performed precision measurements with this method and obtained the consistent with the QED predictions as shown in the right figure.



New measurement with the fast scintillator, YAP, has been performed in 2007, and obtain the most precise result with an accuracy of 130 ppm. The world average of the resent four measurements is 7.0401 +- 0.0007 μ s-^{1} (error 100ppm) , which is consistent with the 2nd order correction and differ by 2.6 σ from the 1st order prediction. This is the first result on the 2nd order prediction. The summary of the latest experiment will be given in the first half of my talk, especially focusing on the method to control the unthermalized o-Ps.

The measurements of the HFS have been performed in 1970s and 80s with the an accuracy of 3.5 ppm, and these results were consistent with each other and with the 2nd order calculations. Recently the 3rd and 4th order calculations can be performed with the new method (Non-Relativistic approximation), it turns out that there is discrepancy (3.5 σ) between the QED prediction(green band) and the previous measurements (arrows) as shown in the right figure. There are two possible systematic uncertainties in the previous all experiments:



(1) the unthermalized o-Ps contributes to underestimation of the material effect as already shown in the decay rate measurements.

(2) The uncertainties of the magnetic field which was the most significant error in the previous experiments. HFS was not directly measured in the previous experiments. The energy shift due to the Zeeman effect was measured and converted into HFS. Accuracy and homogeneous of the magnetic field was essential in the previous experiments.

We propose new methods to measure the HFS directly without these systematic uncertainties, and this is the second half of my talk.