The 21 Century COE Project

Exploring New Science by Bridging Particle-Matter Hierarchy

Short-term Foreign Researchers

Research Report

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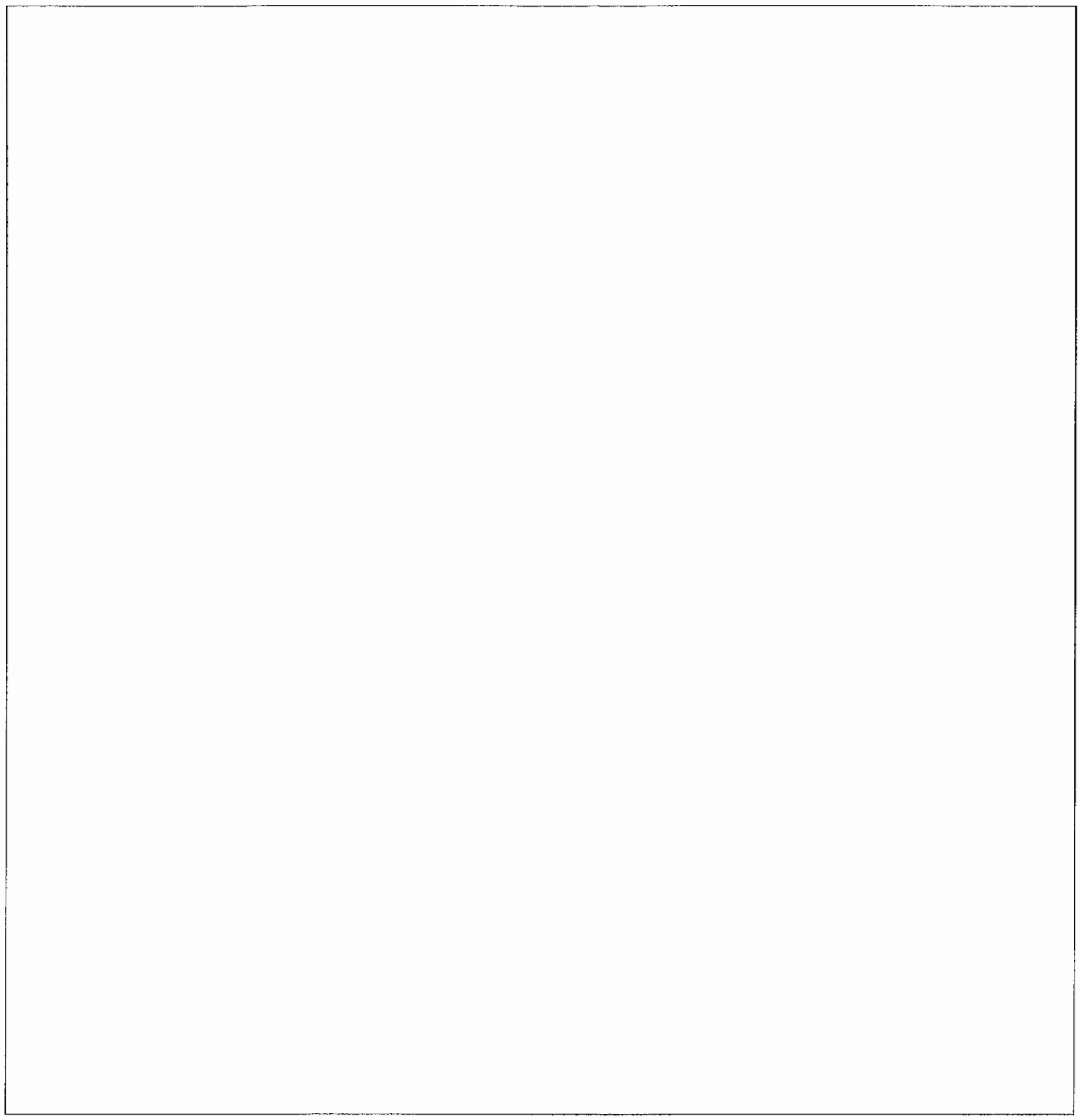
Host Researcher in Tohoku University: Dr. Yukinari Sumino

Your Stay Period in Japan: From Feb. 1 to Feb. 14

Title of Research in Japan:

Computations of higher-order corrections to observables of heavy quarkonium states



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Please write a research report of one or more pages and submit it with this cover to your host researcher till the end of this March.

Research Report

In the first half of my stay at Tohoku University, elementary particle theory group, I gave a lecture course on "vNRQCD". "vNRQCD" is an effective field theory which describes the heavy quarkonium system; it is used for contemporary perturbative computations of physical observables of heavy quarkonium systems, when the binding energy of the system is much larger than the hadron scale of order $\Lambda_{\rm QCD}$. In the lecture course, I covered 3 topics: (1) The construction of this effective field theory, main idea and Lagrangian, (2) Scaling of fields and power counting in dimensional regularization, and (3) Computation of the anomalous dimension of the $\gamma \to t\bar{t}$ external current in vNRQCD (threshold region).

I also gave a seminar, focusing on the recent results obtained on the next-to-next-to-leading logarithmic corrections to the $e^+e^- \to t\bar{t}$ cross section in the threshold region. The three-loop non-mixing contributions to the anomalous dimension of the leading order quark pair production current in non-relativistic QCD are computed. At this level the renormalizability of the effective theory is tested for the first time at a non-trivial subleading level. It is demonstrated that the renormalization procedure can be carried out consistently if the dynamics of both soft and the ultrasoft degrees of freedom is present for all scales below the heavy quark mass, and if the soft and ultrasoft renormalization scales are always correlated. I also discussed its phenomenological impact.

In the latter half of my stay, I had discussions with the members of the institute, mainly with Dr. Y. Sumino, on the recent progress of heavy quarkonium physics and related subjects. In particular, we discussed the problems of renormalons caused by the ultrasoft degrees of freedom. Since the $e^+e^- \to t\bar{t}$ cross section in the threshold region received a large correction even at the next-to-next-to-leading logarithmic order from the ultrasoft region, Dr. Sumino suggested that it may be related to the uncancelled renormalon at u=3/2 in heavy quarkonium spectrum. These renormalons might eventually be eliminated by a certain reorganization of perturbative expansion . We briefly studied this possibility, but a concrete answer was not found yet, since certain conceptual aspects with respect to the power-counting need to be clarified.

I also had discussions with Dr. Sumino and Dr. Taekoon Lee on renormalons in the heavy quarkonium spectrum. We discussed advantage and disadvantage of a renormalon-subtracted pole quark mass advocated by Dr. Lee. Furthermore, I had discussions on recent progress in the minimal-supersymmetric-standard-model Higgs mass spectrum with other members of the institute.

In summary, my visit to Tohoku University was very fruitful for myself and, I believe,

also for its high energy group. I could exchange information on the recent progress of the physics in heavy quarkonium states/non-relativistic systems, and new insights into possible directions of the future research were gained.

Finally, I would like to thank for the warm hospitality at the Tohoku University and, in particular, Dr. Sumino who made my stay a very pleasant one.