Status report for the CERN-KEK Committee 2008

Hiroshi Yokoya (Physics Department, Theory Group)

Overview

As a first year of the CERN-JAPAN Fellowship, I have worked on the phenomenological studies on collider physics for the CERN LHC. In the CERN, I am belonging to the Theory Group in Physics Department. As a custom of the group, particular supervisor is not addressed to myself.

In this year, the main subject of my work is on the top-quark pair-production at hadron colliders. I published one paper on the "Binding effects to the top-quark production at hadron colliders" in collaboration with K. Hagiwawa (KEK) and Y. Sumino (Tohoku U.) [1], and present one talk at the CERN Theory Group seminar [2]. Moreover, following studies have been performed and are ongoing;

- Binding effects to the $t\bar{t}h$ production at the LHC, in collaboration with K. Hagiwara and Y. Sumino. However, we found that the effect cannot be significant in the total cross-section at the LHC, for any mass of the Higgs-boson (unpublished).
- Exclusive distributions in the top-quark pair-production event including binding effects. This work is ongoing in collaboration with K. Hagiwara, J. Kanzaki (KEK) and Y. Sumino.
- Threshold resummation to the invariant-mass distribution in top-pair productions at hadron colliders. This work is ongoing in collaboration with M. Mangano (CERN).
- As an application to the new physics search, binding corrections to the gluino pair-production cross-section. This work is ongoing in collaboration with K. Hagiwara and Y. Sumino.

Binding effects to the top-quark productions at hadron colliders

In the LHC, top-quarks will be produced copiously, and a huge number of pair-production event is considered as a good template for performing various physics studies as well as detector calibrations. For this purpose, it is important that we understand physics of the top-quark production and decay accurately.

At the LHC, top-quarks are produced dominantly via gluon-gluon fusion process, in contrast to the Tevatron where top-quarks are produced dominantly via quark-anti-quark annihilation process. Due to the rapidly decreasing function of the gluon momentum distribution in the proton, substantial amount of top-quarks are expected to be produced near its threshold. Near the threshold, two important origins of large QCD correction are known, the soft-gluon emission and the Coulomb interaction. Before our study, beyond

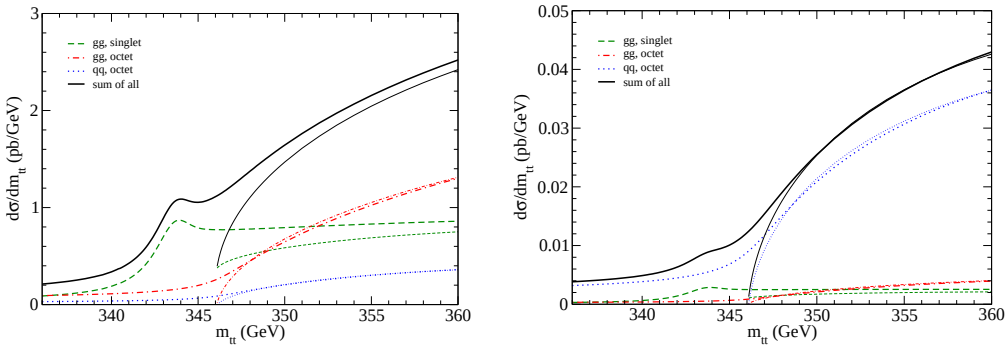

Figure 1: $t\bar{t}$ invariant-mass distributions for the top-quark production in the threshold region at LHC (left) and Tevatron (right). The color–singlet (green dashed) and octet (red dot-dashed) in gg channel, color–octet in $q\bar{q}$ channel (blue dotted), and the sum of them (black solid) are plotted. Thick lines include both bound-state and ISR effects, while thin lines represent the cross sections with only $\mathcal{O}(\alpha_s)$ effects.

the known fixed-order corrections in QCD (NLO), only the summation of soft-gluon corrections are investigated for the hadron colliders. On the other hand, the Coulomb corrections are well-investigated only in the e^+e^- colliders. We focus on the impact of the Coulomb corrections at hadron colliders, and calculate the invariant-mass distributions of top-pair at the LHC and the Tevatron. Our prediction utilizes the Green's function formalism which sums Coulomb singularity terms up to all-order of perturbative series and also which takes into account the finite top-width, combining the initial-state radiation of soft-gluons up to NLO. We showed that Coulomb correction is sizable at the threshold region, and the resonance peak of the $t\bar{t}$ pair may be seen at the LHC (see Fig. 1). It is interesting that color–singlet top-pair can be substantial at the LHC because the gluon-gluon fusion process dominates, while most of the $t\bar{t}$ pairs form color–octet at the Tevatron.

Further studies including the $bWbW$ exclusive distributions are ongoing. It is known that the binding effects affect the energy distributions and the angular correlations of the decaying particles from the top-quarks. However, in the existing event generators, these effects are not included at all or in a proper way. The aim of our studies is to generate the events of top-pair productions and these decays properly including the binding effects near the threshold. Then, realistic studies of the reconstruction of the top-pair event near the threshold shall be possible. We plan to study them including the jet-finding algorithm and detector performance, in collaboration with J. Kanzaki.

Threshold resummation to the $t\bar{t}$ invariant-mass distribution

So far, I have been considered the top-quark production in the threshold regions. On the other hands, recently, top-pairs with very high invariant-mass

have been considered as signals of production of new heavier particles at the LHC, in several models beyond the standard model, such like KK gluons in extra-dimension models or top-partner in little-Higgs models. Therefore, it is important to make the QCD prediction under control accurately. Due to the presence of the threshold logs $\{\ln(1-z)/(1-z)\}_+$, the QCD corrections increase with the $t\bar{t}$ invariant-mass. These logs are taken into account to all-order in perturbative series of QCD, using the technique called "threshold resummation". I am working on this topic, in collaboration with M. Mangano.

gluino-pair productions in the threshold region

At the LHC, as a signal of new physics at TeV scale, a discovery of new heavy particles is anticipated. It must be natural to expect that colored-particles play an important role at hadron colliders, due to the large cross-sections. One of the well-motivated ones is gluino and squarks in supersymmetric extensions of the standard model. Production cross-sections of these particles are predicted including QCD NLO correction, as well as soft-gluon resummations. However, as has been true for the $t\bar{t}$ production case, the Coulomb corrections can be large, but not enough investigated in my sense.

I found that due to the heavy mass and the large color-charge of gluino, Coulomb corrections are significant and these enhance the cross-section largely in lower invariant-mass regions of gluino-pair. I plan to proceed this work to include the squark productions and initial-state radiations.

References

[1] K. Hagiwara, Y. Sumino and H. Yokoya, Phys. Lett. B **666** (2008) 71.

[2] H. Yokoya, "Bound-state Effects on Top Quark Production at Hadron Colliders", Seminar at the CERN TH Group, 27th, March, 2008.