氏　　名	QUACH My Uyen Nhi
学位（専攻分野）	博士（理学）
学位記番号	総研大甲第 2232 号
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学位論文題目	Beam polarization effects on Higgs boson production at the International Linear Collider
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(Form 3)

Summary of Doctoral Thesis

Name in full QUACH My Uyen Nhi

Title Beam polarization effects on Higgs boson production at the International Linear Collider

ILC is the international e^+e^- linear collider with the beam energy from 250 GeV to 1 TeV. ILC starts with center of mass energy as 250 GeV as the first state to obtain the high statistics of Higgs production. This center of mass energy value is used for my calculations in this thesis.

Because of the parity violation in weak interactions, beam polarization effects are essential to resolve new phenomena of the beyond the standard model (BSM) and will play a crucial role to study it. The beam polarization and its importance to study such physics at the e^+e^- collider has been discussed in details over decades.

A precise measurement of $e^+e^- \to f\bar{f}H$ is one of the key targets of the ILC experiments to study the property of Higgs boson.

One need to know about the $O(\alpha)$ effects to those processes. Especially the analysis of the recoil mass distribution is very important, which will allow the analysis of the coupling of ZZH without any assumptions of the branching ratio of the Higgs boson decay. The $O(\alpha)$ corrections to this distribution will make a significant change through the initial radiation as so called the radiative tail.

Then this thesis will discuss the effects of the $O(\alpha)$ corrections with the Standard Model to nine processes of $e^+e^- \to f\bar{f}H$ of 3 charged leptons, electron-neutrino, μ-neutrino, up-, down- charm- and bottom-quark, except for top- and strange-quark.

For the quark cases, the QCD corrections are relevant but this correction factor is well known, so I do not discuss in detail here.

I will explain about the method of the calculation by means of the GRACE system. The GRACE is a system to calculate the tree and one-loop level cross sections automatically with beam-polarization based on the Standard Model (SM) and the Minimal Supersymmetric Standard Model (MSSM).

The first question will be that the light fermion masses can be neglected or not. I prepared programs for 9 processes of $e^+e^- \to f\bar{f}H$. From the numerical results of electron case and of μ case, and ones of up-quark case and charm-quark case, the calculations of strange-quark can be covered by ones of down-quark. Similarly, ones for τ-neutrino case are omitted because of ones for μ-neutrino case can cover it.

I made two programs based on the FULL SM model and the NOLLS SM model. The FULL SM model means all couplings of the scalar particles such as the Higgs boson or pseudo-Goldstone scalar bosons and fermions are kept; on the other hand, the NOLLS SM model means the coupling of the light mass fermions (L) and the scalar particles (S) are neglected. Here, the bottom- and top-quark are considered to be heavy fermions and other fermions are recognized to be light ones.

One should notice that in the case of the FULL SM model, the number of tree diagrams and one-loop diagrams are huge, then the integration over the phase space is not realistic. Therefore, the first check is to see the agreement between the results based on the FULL SM model and the NOLLS MS model at one phase point. The non-linear gauge parameters independence is destroyed due to the missing of LLS couplings in the NOLLS SM model. First, I confirmed 14 digits independence against changing of non-linear gauge parameters with the FULL SM model. I also confirm the 5 digits agreement between the FULL SM model and the NOLLS SM model for the μ case. Because the third-generation fermions are heavy, the b-quark case, the number of the Feynman diagrams are huge even with the NOLLS SM model is applied.

I also show the comparison with the previous works for the unpolarized cross section of $H\nu\bar{\nu}$. I confirm the consistent results for all cases with them in the integration error.

Finally, I guarantee the accuracy of my $O(\alpha)$ corrections are at the level of 0.2% for all processes, because from its soft-photon cut parameter(k_c) independence. I also calculated 9 processes $e^+e^- \to f\bar{f}H$ order $O(\alpha)$ correction with the arbitrary beam polarization for the ILC. Size of $O(\alpha)$ corrections reach around -10% without experimental cut but with polarized beams at the ILC. Originally the GRACE system can produce the codes of the polarized $O(\alpha)$ corrections, but there is no function to generate such common codes to treat the arbitrary beam polarization. Then I added it and contributed to this part. The height of the peak in the recoil mass distribution is changed by the $O(\alpha)$ effects of the radiative tail. The full electroweak one-loop corrections with the arbitrary polarization for the recoil mass technique is the first calculation in the world.

The ISR effects are the flavor blindness. When one likes to discuss around the level of 1% results for each process, one should not trust it, because ISR effects do not include the final quark mass effect. I discuss this point, too.

The process of e^+e^-H is also interesting, because of its having t-channel, then the collision of the left-handed electron and the left-handed positron, and one of the right-handed electron and the right-handed positron has sizable contributions to the cross sections. This is also the first calculation in the world by me.

Form8・Separate Sheet
（様式８・別紙１）

Results of the doctoral thesis screening

博士論文審査結果

Name in Full
氏　　名　QUACH My Uyen Nhi

Title
論文題目　Beam polarization effects on Higgs boson production at the International Linear Collider

当該博士論文は、現在計画されている国際リニアコライダー　（ILC）実験におけるヒッグス生成過程についてその実験の特徴であるビーム偏極の効果を入れた電弱理論による高次補正計算を行い、ILC 実験での精密測定への効果を議論したものである。

Quach 氏は、ILC 実験が計画している衝突の重心系エネルギー250GeV において、偏極した電子ビームと陽電子ビームでの以下の９つの素粒子反応:（１）ミューオン対とヒッグス粒子の生成過程、（２）電子・陽電子対とヒッグス粒子の生成過程、（３）タウ粒子対とヒッグス粒子の生成過程、（４）ミューオン・ニュートリノ対とヒッグス粒子の生成過程、（５）電子ニュートリノ対とヒッグス粒子の生成過程、（６）アップ・クォーク対とヒッグス粒子の生成過程、（７）ダウン・クォーク対とヒッグス粒子の生成過程、（８）チャーム・クォーク対とヒッグス粒子の生成過程、そして最後に（９）ボトム・クォーク対とヒッグス粒子の生成過程の以上の９つの素粒子反応過程に対し、質量殻繰り込み処方による１ループ補正計算と１光子放出過程を計算し、その和の一次の高次補正効果を計算、ILC 実験に及ぼす効果を考察した。

これらの計算では（１）ビーム偏極の効果が考慮されている点に加え、（２）ニュートリノを除くすべてのフェルミオンの質量効果を残しての計算であること、（３）また特にボトムクォークの湯川結合の効果が含まれている、との特徴があり、それら９つ全ての計算結果の考察は世界初である。更に Quach 氏はこれまでにも考察されてきた電子・陽電子からの多重光子放出の輻射効果（ISR）との比較も行い、Quach 氏が世界初で行った一次補正効果が実験解析で重要になることを指摘した。各過程への輻射補正効果が ILC 実験の精密解析に及ぼす効果も考察されている。また、ILC 実験は反跳不変質量の分布を用いることで理論の仮定に依存することなくヒッグス粒子と Z 粒子の結合定数を測定する解析が提案されている。Quach 氏はその解析における弱い相互作用による一次補正効果の議論も行った。これは同解析によりヒッグス粒子の直接には捉えることが難しい暗黒物質への崩壊の解析にインパクトを与え、標準理論を超える物理の探索に強力な支援を行うことを意味する。

これらの結果は学術的に十分な価値が認められるものであり、博士論文の内容として必要な水準を示していると判断でき、本論文が学位の授与に値すると判断した。