A Study of Particle Physics based on e-Science Paradigm

Kihyeon Cho
(On behalf of High Energy Physics Team @ KISTI)
Thank HEP Team at KISTI

Members:
- Kihyeon Cho
- Junghyun Kim
- Soo-hyeon Nam
- Ji Hye Moon
- Jungil Lee (Adjunct)
- Seung Woo Ham (Adjunct)

Former members:
- Hyunwoo Kim
- Minho Jeung
- Daejung Kong
- Ilsung Cho
- Yeongseok Oh
Contents

- e-Science paradigm
  - Experiment – Computing – Theory

Results
Summary
What is e-Science Paradigm?

- **Today**
  - e-Science
  - Data Centric Science
  - unify theory, experiment, and simulation

- **Last few decades**
  - Computational Science
  - simulation of complex phenomena

- **Last few hundred years**
  - Theoretical Science
  - Newton’s Laws, Maxwell’s Equations ...

- **Thousand Years ago**
  - Experimental Science
  - description of natural phenomena

**Effects**

HPC and Information Management are Key Technologies to support e-Science Revolution

- Tony Hey (MS)
e-Science Paradigm

- Fusion research of Experiment–Computing–Theory
e-Science paradigm in HEP

Theory

Feed-back and tools

Supercomputer

e-Science

Experiment

Computing

e-HEP

⇒ To study SM and New physics
Experiment–Computing

e–HEP (High Energy Physics)
e-HEP (High Energy Physics)

To study high energy physics anytime, anywhere

2007 ~ 2008

Using e-HEP, SM, B-physics

2009

Enable Discovery

Belle-II DH leader

2010

2011

e-HEP

CDF

Belle/Belle-II

e-Science Grid

EU

USA

Asia

KISTI

FKPPL VO Farm (IN2P3, France) & LCG CAF (CDF Analysis Farm) (IN2P3, France)

North America CAF (Fermilab, USA)

Pacific CAF (AS, Taiwan), KEK Farm (KEK, Japan)

Pacific CAF, Visualization

KREONET, GLORIAD, Supercomputer & NSDC farm

Kihyeon Cho
CDF Remote Control Room @KISTI

Accumulated Hours

CDF Remote Control Room (2010.1)

Kihyeon Cho
Belle Experiment

\[ B \rightarrow \Phi \pi \]
- Pure EW penguin mode
- SM Br \( \sim O(10^{-8}) \)
- Babar with 232M BB:
  - UL(\( \Phi \pi^+ \)) < 2.4 \times 10^{-7} @90\%CL
  - UL(\( \Phi \pi^0 \)) < 2.8 \times 10^{-7} @90\%CL
- Draft is almost ready.

\[ B^+ \rightarrow \rho^0 K^{*+} \]
- Penguin dominant status
- Work on progress
Theory-Experiment
Theory—Experiment

- To develop the fusion system of phenomenology and data analysis
- Based on this system, we apply Monte Carlo system for experiments.
- To apply this system to hadron collider experiments in order to study the standard model (SM) and new physics (NP).
- To apply new tools to future experiments
  - Belle II, LHC, etc.
Higgs mass at Tevatron

- Exclusion region on SM Higgs boson mass at 95% C.L. at Tevatron
- Higgs Production of the BMSSM with spontaneous CP violation via Higgs-strahlung Process (W,Z) at Tevatron
- We can apply to the Higgs boson mass of the BMSSM by using the exclusion potential of the SM Higgs boson mass.

⇒ Under Way
Polarization of J/$\psi$ at RHIC

- PRD 81, 014020 (2010.1.22) by Jungil Lee
- PHENIX Collaboration has measured J/$\psi$ polarization.
- The paper is cited by BNL PHENIX Collaboration
Tools for future experiment

Belle II DH with AMGA ⇒ ILC etc.

Data Handling Scenario

Searching system

<table>
<thead>
<tr>
<th>Exp#</th>
<th>Run#</th>
<th>Event#</th>
<th>……</th>
<th>File Name 1</th>
<th>File Name 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>……</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Metadata 

Index Generator 

New file

MDST

Search Request 

Metadata or File Name

Command Line Tool

Internet Browser

Data Cache system

Skimming/searching 

Extract Create Analysis

Keep by user 

Result (ntuple)
Theory–Computing

- To set theoretical model
- To do parallelization and optimization for Supercomputing
- To develop PYTHIA code
CP Violation in the beyond Minimal Supersymmetric Standard Model (BMSSM)

Possibility of spontaneous CP violation in Higgs physics beyond the minimal supersymmetric model ⇒ S.W.Ham, Seung-A Shim, S.K.Oh, PRD80, 055009 (2009).
ACKNOWLEDGMENTS

S. W. Ham thanks P. Ko for the hospitality at KIAS where a part of this work has been performed. He thanks Kihyeon Cho at KISTI for the collaboration.

S. W. Ham, S. K. Oh, PRD80, 055009 (2009).
Explicit CP violation in the Dine–Seiberg–Thomas model

S.W. Ham\textsuperscript{1,2,a}, Seong-A Shim\textsuperscript{3}, S.K. Oh\textsuperscript{4}

\textsuperscript{1}Department of Physics, Korea University, Seoul 136-701, Korea  
\textsuperscript{2}School of Physics, KIAS, Seoul 130-722, Korea  
\textsuperscript{3}Department of Mathematics, Sungshin Women’s University, Seoul 136-742, Korea  
\textsuperscript{4}Department of Physics, Konkuk University, Seoul 143-701, Korea

Received: 28 September 2009  
© Springer-Verlag / Società Italiana di Fisica 2009

Abstract The possibility of explicit CP violation is studied in a supersymmetric model proposed by Dine, Seiberg, and Thomas, with two effective dimension-five operators. The explicit CP violation may be triggered by complex phases in the coefficients for the dimension-five operators in the Higgs potential, and by a complex phase in the scalar top quark masses. Although the scenario of explicit CP violation is found to be inconsistent with the experimental data at LEP2 at tree level, it may be possible at the one-loop level. For a reasonable parameter space, the masses of the neutral Higgs bosons and their couplings to a pair of Z bosons are consistent with the LEP2 data, at the one-loop level.

Acknowledgements We thank Kihyeon Cho at KISTI for the collaboration. This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2009-0086961, 2009-0070667).

The requirement that we have at least two Higgs doublets in order to generate the masses for up-like quarks and down-like quarks independently [6–9].

Thus, a large number of articles have been devoted to investigate the possibility of CP violation in supersymmetric standard models. The minimal supersymmetric standard model (MSSM), the simplest version of supersymmetric standard models, has just two Higgs doublets. Therefore, in principle, the MSSM may accommodate CP violation by means of complex phases in its neutral Higgs sector. In practice, it has been found that CP violation is impossible to occur either explicitly or spontaneously in the Higgs sector.
Fig. 1 The distribution of 50,000 points of $(\tan \beta, m_{h_1})$, at the one-loop level. The allowed ranges of the parameter values are $|\epsilon_1| < 0.025$, $|\epsilon_2| < 0.025$, $|\varphi_2| < \pi/2$, $|\varphi| < \pi/2$, $0 < m_{\lambda^0} < 1,000$ GeV, $100 < |\mu| < 500$ GeV, $|A_t| < 1,000$ GeV, and $50 < m_Q - m_T < 500$ GeV. Note that the points are evenly distributed with respect to $\tan \beta$, showing no dependence of $m_{h_1}$ on $\tan \beta$. This feature of the DSTM is different from the CP-conserving MSSM, where the maximum of $m_{h_1}$ occurs for large $\tan \beta$.

Fig. 2 The distribution of 50,000 points of $(m_{h_1}, G_{ZZh_1}^2)$, the square of normalized coupling strength of the lightest Higgs boson of the DSTM versus its mass, at the one-loop level. The allowed ranges of the parameter values are the same as in Fig. 1.
Study of Higgs self couplings of a supersymmetric $E_6$ model at the International Linear Collider

S. W. Ham$^{(1,2)}$, Kideok Han$^{(1)}$, Jungil Lee$^{(1,3)}$, and S. K. Oh$^{(4)}$

(1) Department of Physics, Korea University, Seoul 136-701, Korea
(2) School of Physics, KIAS, Seoul 130-722, Korea
(3) Korea Institute of Science and Technology Information
Daejeon, 305-806, Korea
(4) Department of Physics, Konkuk University, Seoul 143-701, Korea

VI. Acknowledgments

S. W. Ham thanks P. Ko for the hospitality at KIAS where a part of this work has been performed. He thanks Kihyeok Cho at High Energy Physics Team, KISTI for the collaboration. This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2009-0086961, 2009-0070667).

20\%, we expect that at least 5 events of the lightest scalar Higgs boson may be produced at the ILC via double Higgs-strahlung process.
H – A mixing in PYTHIA

Higgs-strahlung process at the ILC

H Decay : ff, WW, ZZ, gg, ...

A Decay : ff, WW, ZZ, gg, ...

MSUB(171)=1 : H Production
MSUB(172)=1 : A Production
PARU(181)=1 : A Decay into Down-Type Quark
PARU(182)= 1 : A Decay into Up-Type Quark
1=PARU(183)=PARU(184)=PARU(185) ...
: A Decay into Lepton, Gauge Bosons, ...
## Event listing (summary): Under Way

### A0 → b bbar decay for MA=100 GeV

<table>
<thead>
<tr>
<th>Particle/jet</th>
<th>KS</th>
<th>KF</th>
<th>orig</th>
<th>p_x</th>
<th>p_y</th>
<th>p_z</th>
<th>E</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 e+!</td>
<td>21</td>
<td>-11</td>
<td>0</td>
<td>0.000</td>
<td>0.000</td>
<td>250.000</td>
<td>250.000</td>
<td>0.001</td>
</tr>
<tr>
<td>2 e−!</td>
<td>21</td>
<td>11</td>
<td>0</td>
<td>0.000</td>
<td>0.000</td>
<td>-250.000</td>
<td>250.000</td>
<td>0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Particle/jet</th>
<th>KS</th>
<th>KF</th>
<th>orig</th>
<th>p_x</th>
<th>p_y</th>
<th>p_z</th>
<th>E</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 e+!</td>
<td>21</td>
<td>-11</td>
<td>1</td>
<td>0.000</td>
<td>0.000</td>
<td>250.000</td>
<td>250.000</td>
<td>0.000</td>
</tr>
<tr>
<td>4 e−!</td>
<td>21</td>
<td>11</td>
<td>2</td>
<td>0.000</td>
<td>0.000</td>
<td>-249.975</td>
<td>249.975</td>
<td>0.000</td>
</tr>
<tr>
<td>5 e+!</td>
<td>21</td>
<td>-11</td>
<td>3</td>
<td>0.000</td>
<td>0.000</td>
<td>250.000</td>
<td>250.000</td>
<td>0.000</td>
</tr>
<tr>
<td>6 e−!</td>
<td>21</td>
<td>11</td>
<td>4</td>
<td>0.000</td>
<td>0.000</td>
<td>-249.975</td>
<td>249.975</td>
<td>0.000</td>
</tr>
<tr>
<td>7 Z0!</td>
<td>21</td>
<td>23</td>
<td>0</td>
<td>-16.048</td>
<td>56.237</td>
<td>223.638</td>
<td>248.136</td>
<td>90.209</td>
</tr>
<tr>
<td>8 A0!</td>
<td>21</td>
<td>36</td>
<td>0</td>
<td>16.048</td>
<td>-56.237</td>
<td>-223.613</td>
<td>251.839</td>
<td>100.000</td>
</tr>
<tr>
<td>9 u!</td>
<td>21</td>
<td>2</td>
<td>7</td>
<td>-2.172</td>
<td>-19.845</td>
<td>102.428</td>
<td>104.356</td>
<td>0.330</td>
</tr>
<tr>
<td>10 ubar!</td>
<td>21</td>
<td>-2</td>
<td>7</td>
<td>-13.876</td>
<td>76.082</td>
<td>121.209</td>
<td>143.780</td>
<td>0.330</td>
</tr>
<tr>
<td>11 b!</td>
<td>21</td>
<td>5</td>
<td>8</td>
<td>-20.904</td>
<td>-30.147</td>
<td>-17.796</td>
<td>41.055</td>
<td>4.800</td>
</tr>
<tr>
<td>12 bbar!</td>
<td>21</td>
<td>-5</td>
<td>8</td>
<td>36.951</td>
<td>-26.090</td>
<td>-205.817</td>
<td>210.784</td>
<td>4.800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Particle/jet</th>
<th>KS</th>
<th>KF</th>
<th>orig</th>
<th>p_x</th>
<th>p_y</th>
<th>p_z</th>
<th>E</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 (Z0)</td>
<td>11</td>
<td>23</td>
<td>7</td>
<td>-16.048</td>
<td>56.237</td>
<td>223.638</td>
<td>248.136</td>
<td>90.209</td>
</tr>
<tr>
<td>14 (A0)</td>
<td>11</td>
<td>36</td>
<td>8</td>
<td>16.048</td>
<td>-56.237</td>
<td>-223.613</td>
<td>251.839</td>
<td>100.000</td>
</tr>
<tr>
<td>15 gamma</td>
<td>1</td>
<td>22</td>
<td>1</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>16 gamma</td>
<td>1</td>
<td>22</td>
<td>2</td>
<td>0.000</td>
<td>0.000</td>
<td>-0.025</td>
<td>0.025</td>
<td>0.000</td>
</tr>
<tr>
<td>17 u</td>
<td>A</td>
<td>2</td>
<td>9</td>
<td>-2.172</td>
<td>-19.845</td>
<td>102.428</td>
<td>104.356</td>
<td>0.330</td>
</tr>
<tr>
<td>18 ubar</td>
<td>V</td>
<td>1</td>
<td>-2</td>
<td>-13.876</td>
<td>76.082</td>
<td>121.209</td>
<td>143.780</td>
<td>0.330</td>
</tr>
<tr>
<td>19 b</td>
<td>A</td>
<td>2</td>
<td>5</td>
<td>-20.904</td>
<td>-30.147</td>
<td>-17.796</td>
<td>41.055</td>
<td>4.800</td>
</tr>
<tr>
<td>20 bbar</td>
<td>V</td>
<td>1</td>
<td>-5</td>
<td>36.951</td>
<td>-26.090</td>
<td>-205.817</td>
<td>210.784</td>
<td>4.800</td>
</tr>
</tbody>
</table>

**sum:** 0.00 0.000 0.000 0.000 500.000 500.000

Kihyeon Cho
Results of e-Science paradigm

PHYSICAL REVIEW D 81, 014020 (2010)

Polarization of prompt $J/\psi$ in proton-proton collisions at RHIC

Hee Sok Chung and Chaehyun Yu
Department of Physics, Korea University, Seoul 136-701, Korea

Seyong Kim
Department of Physics, Sejong University, Seoul 143-747, Korea, and School of Physics, Korea Institute of Advanced Study, Seoul 130-722, Korea

Jungil Lee
Department of Physics, Korea University, Seoul 136-701, Korea, and Korea Institute of Science and Technology Information, Daejeon 305-806, Korea

(Received 11 November 2009; published 22 January 2010)

PHYSICAL REVIEW D 80, 055009 (2009)

Possibility of spontaneous CP violation in Higgs physics beyond the minimal supersymmetric standard model

S. W. Ham, Seong-A Shim, and S. K. Oh
1Department of Physics, Korea University, Seoul 136-701, Korea
2Department of Mathematics, Sungshin Women's University, Seoul 136-742, Korea
(Received 19 July 2009; revised manuscript received 17 August 2009; published 8 September 2009)

The Dine-Seiberg-Thomas model (DSTM) is the simplest version of the new physics beyond the minimal supersymmetric standard model (MSSM), in the sense that its Higgs sector has just two dimension-five operators, which are obtained from the power series of the energy scale for the new physics in the effective action analysis. We study the possibility of spontaneous CP violation in the Higgs sector of the DSTM, which consists of two Higgs doublets. We find that the CP violation may be triggered by vacuum expectation values of Z bosons in the region, the masses of $\mu$ and a part of Z bosons in the total constraint by the LEP data. Thus, the LEP2 data exclude the possibility of spontaneous CP violation in the DSTM at the three level. On the other hand, we find that, for a wide area in the parameter region, the CP symmetry may be broken spontaneously in the Higgs sector of the DSTM at the one-loop level, where top quark and scalar top quark loops are taken into account.

Acknowledgements

We thank Kihyeon Cho at KISTI for the collaboration. This research was supported by Basic Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2009-006861, 2009-007667).

VI. Acknowledgments

S. W. Ham thanks P. Ko for the hospitality at KIAS where a part of this work has been performed. He thanks Kihyeon Cho at High Energy Physics Theory, KISTI for the collaboration. This research was supported by Basic Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2009-006861, 2009-007667).

Study of Higgs self couplings of a supersymmetric $E_6$ model at the International Linear Collider

S. W. Ham(1,2); Kidook Han(1,3); Jungil Lee(3,4) and S. K. Oh(3,4)

(1) Department of Physics, Korea University, Seoul 136-701, Korea
(2) School of Physics, KIAS, Seoul 139-701, Korea
(3) Korea Institute of Science and Technology Information, Daejeon 305-806, Korea
(4) Department of Physics, Konkuk University, Seoul 143-701, Korea

The European Physical Journal C

Regular Article - Theoretical Physics

Explicit CP violation in the Dine–Seiberg–Thomas model

S. W. Ham(1,2), Seong-A Shim(1), S. K. Oh(2)

1Department of Physics, Korea University, Seoul 136-701, Korea
2Department of Mathematics, Sungshin Women’s University, Seoul 136-742, Korea

Acknowledgments

S. W. Ham thanks P. Ko for the hospitality at KIAS where a part of this work has been performed. He thanks Kihyeon Cho at KISTI for the collaboration.

Abstract

The possibility of explicit CP violation in a supersymmetric model with a two effective dim. Thomas, with two effective dim. explicit CP violation may be triggered by complex phases in the coefficients for the dimension-five operators in the Higgs potential, and by a complex phase in the scalar top quark masses. Although the scenario of explicit CP violation is found to be inconsistent with the experimental data at LEP level, it may be possible at the one-loop level. For a reasonable parameter space, the masses of the neutral Higgs bosons and their couplings to a pair of Z bosons are consistent with the LEP data at the one-loop level.

PACS: 12.60.Jv; 11.30.Er; 14.80.Cp

1 Introduction

It is reasonable to assume that any phenomenological model should accommodate the violation of the CP symmetry as one of its features, since the CP violation has been observed in nature.
Great success of Experiment-Computing-Theory
Summary

- The paradigm of e-Science
  - Experiment–Computing–Theory

- Have applied the paradigm to HEP
  ⇒ Great success.

- Hope to extend this concept to other areas of physics
Thank you.