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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

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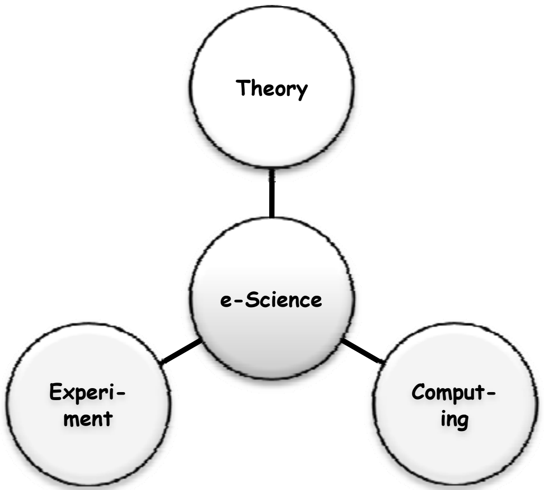
  - Junghyun Kim
  - Soo-hyeon Nam
  - Ji Hye Moon
  - Jungil Lee (Adjunct)
  - Seung Woo Ham (Adjunct)

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

Contents

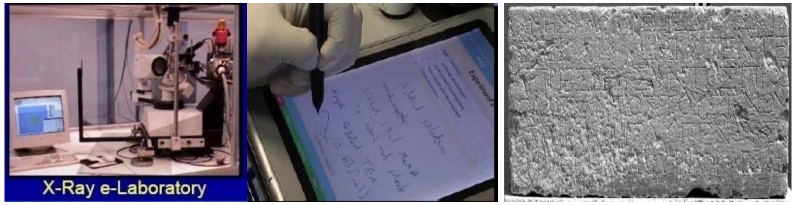
- e–Science paradigm
  - Experiment–Computing–Theory

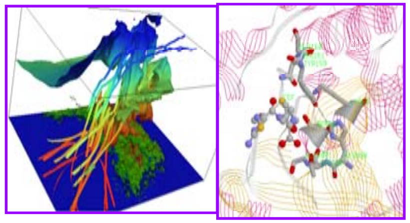


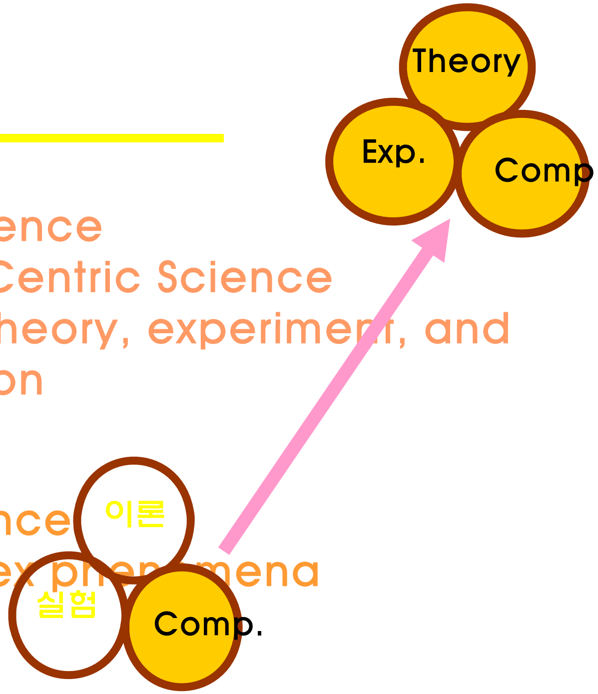
- Results
- Summary

What is e-Science Paradigm?

Hardness







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

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

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{4\pi G\rho}{3} - K\frac{c^2}{a^2}$$

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

Experimental Science

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

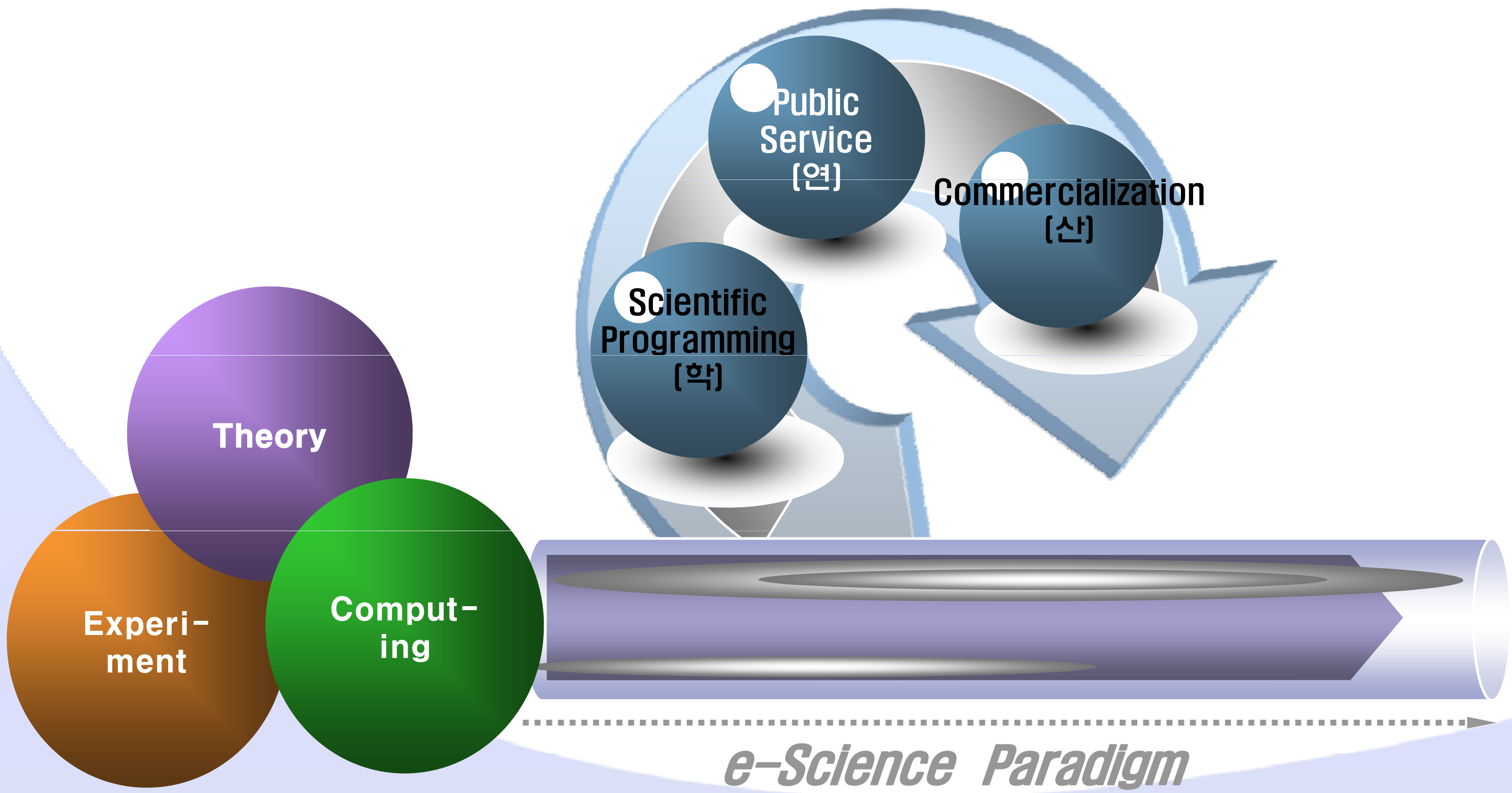
-Thousand Years ago
-Experimental Science
- description of natural phenomena

Effects

Kihyeon Tony Hey (MS)

e-Science Paradigm

- ❑ Fusion research of Experiment-Computing-Theory



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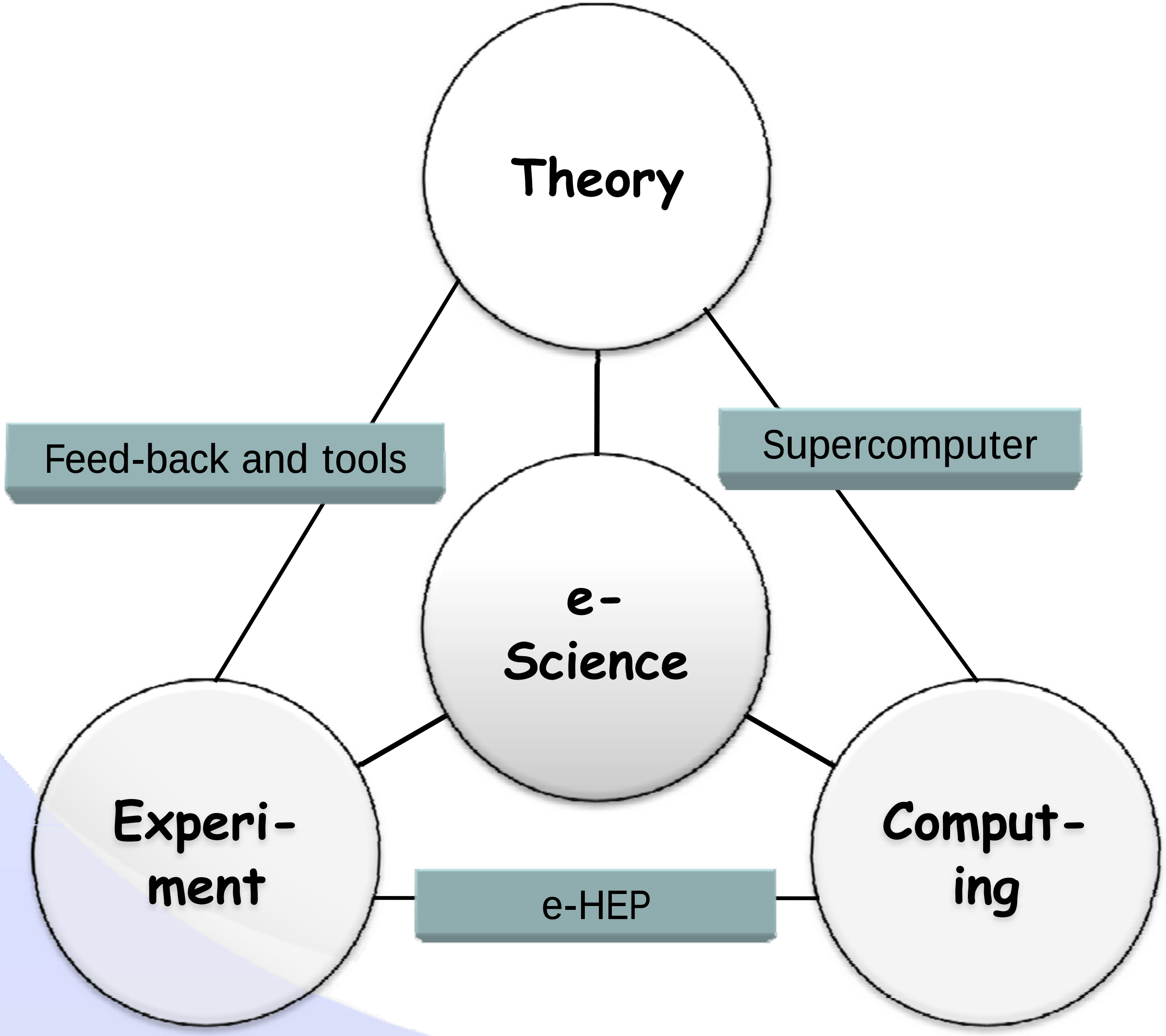
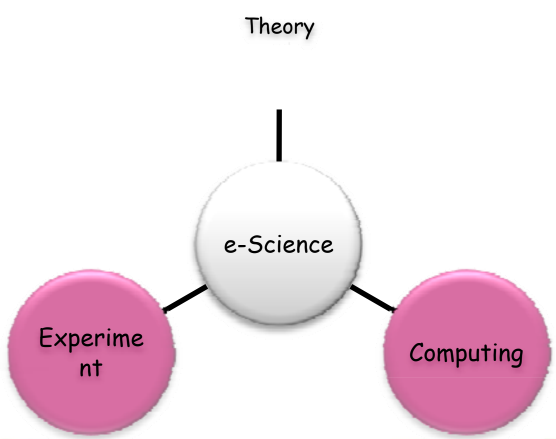
e-Science paradigm in HEP



⇒ To study SM and New physics

Experiment-Computing

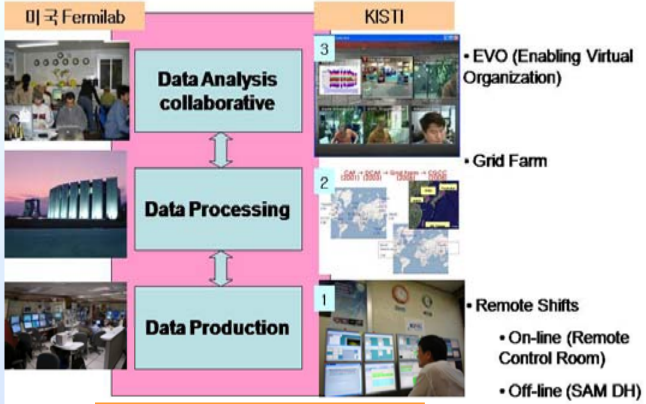
e–HEP (High Energy Physics)



e-HEP (High Energy Physics)

To study high energy physics anytime, anywhere

2007 ~ 2008	2009	2010	2011

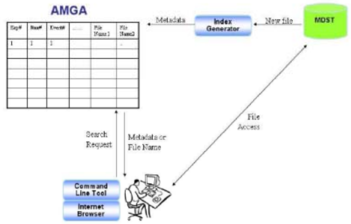


e-HEP

CDF

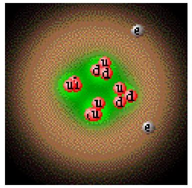
Using e-HEP, SM, B-physics

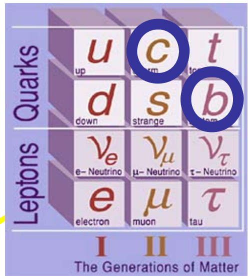
Belle-II DH leader

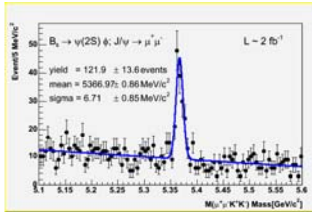


Belle/Belle-II

Enable Discovery







e-Science Grid

EU	FKPPL VO Farm(IN2P3,Fr.) & LCG CAF (CDF Analysis Farm) (IN2P3,France)
USA	North America CAF (Fermilab, USA)
Asia	Pacific CAF (AS, Taiwan), KEK Farm (KEK, Japan)
KISTI	Pacific CAF, Visuallization
	KREONET, GLORIAD, Supercomputer & NSDC farm

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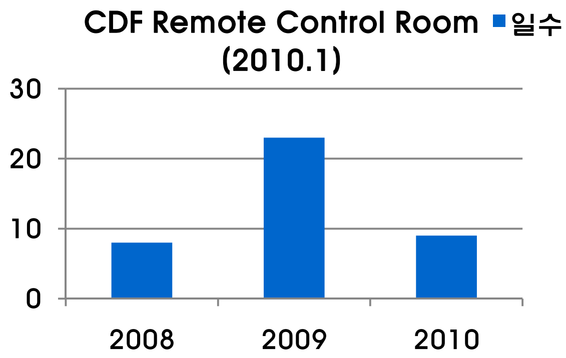
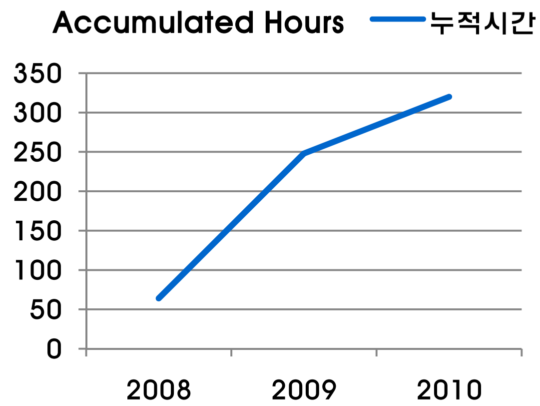
CDF Remote Control Room @KISTI





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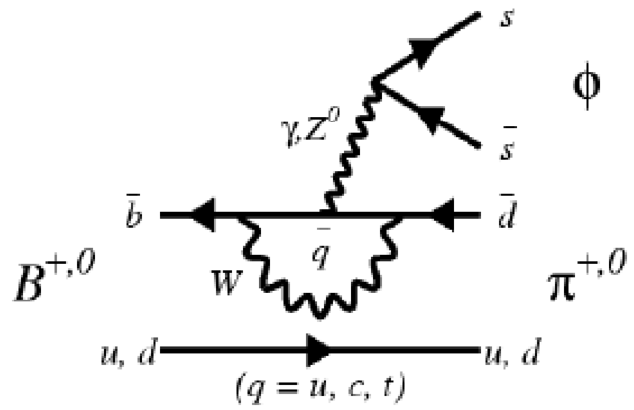
Belle Experiment

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



- $B^+ \to \rho^0 K^{*+}$
  - Penguin dominant status
  - Work on progress

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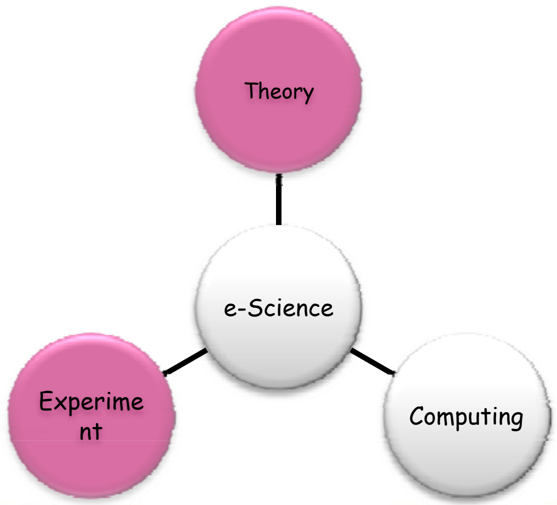
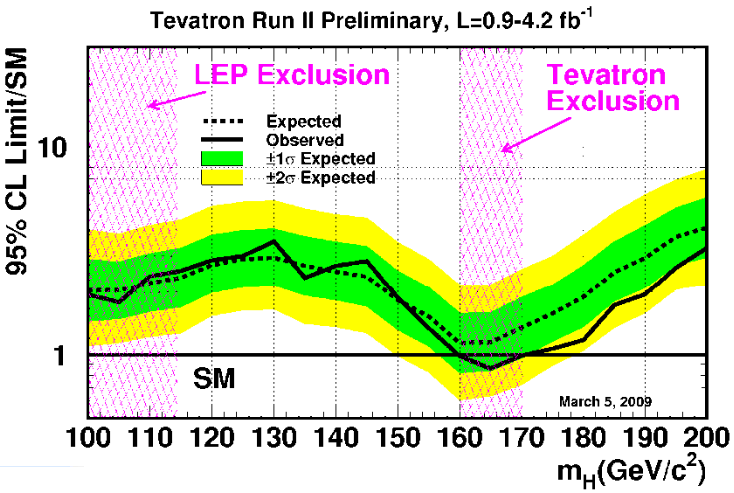
Theory-Experiment



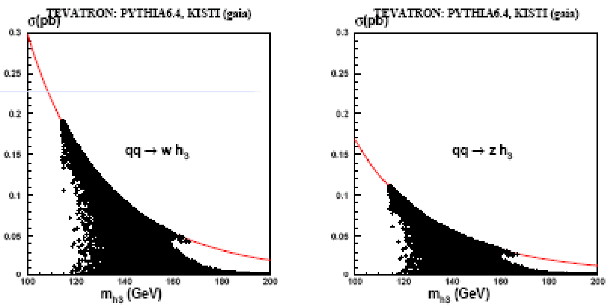
Theory–Experiment

- To develop the fusion system of pheno-menology 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



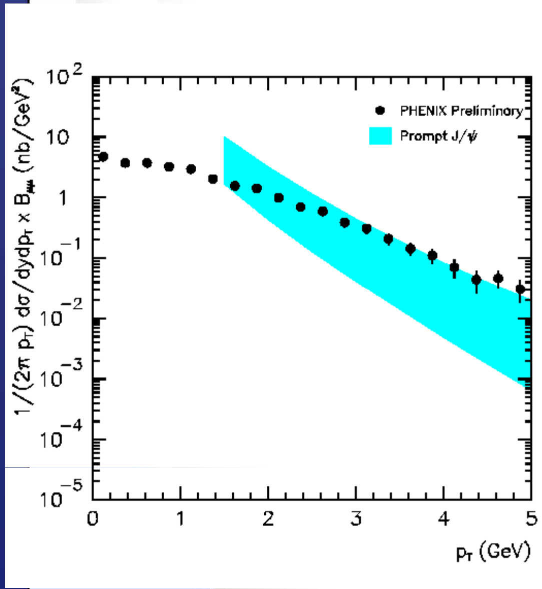
4. Higgs Production of the BMSSM with spontaneous CP violation at TEVATRON

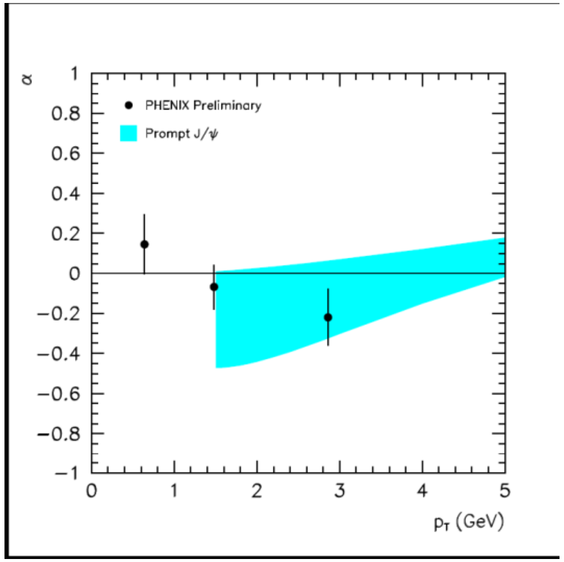


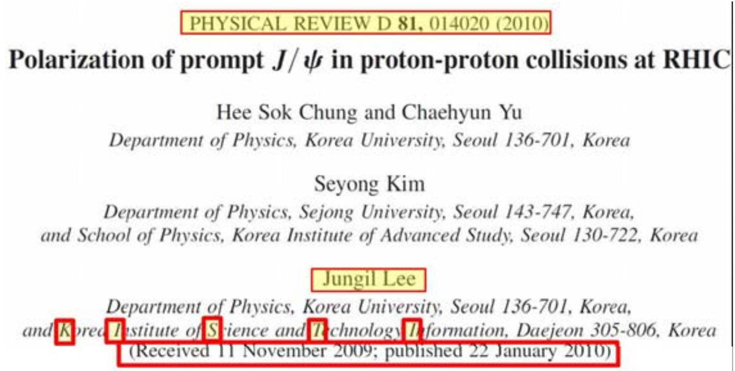
- Exclusion region on SM Higgs boson mass at 95% C.L. at Tevatron
- Higgs Production of the BMSSM with spontaneous CP violation via Higgs–strahlung Process (W,Z) at Tevatron
- We can apply to the Higgs boson mass of the BMSSM by using the exclusion potential of the SM Higgs boson mass.

⇒ Under Way

Polarization of J/ψ at RHIC






PHYSICAL REVIEW D **81**, 014020 (2010)

Polarization of prompt J/ψ in proton-proton collisions at RHIC

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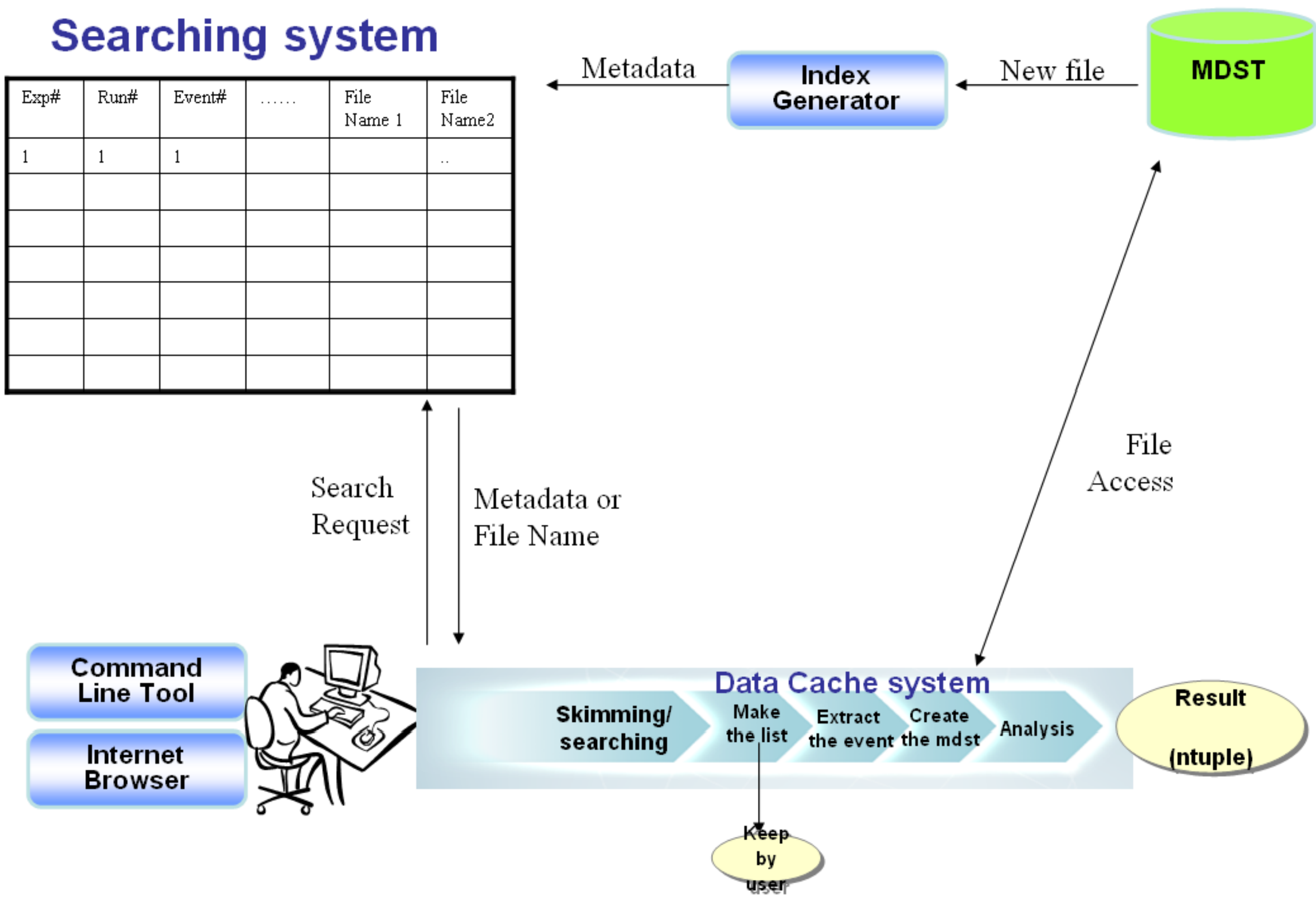
- PRD 81, 014020 (2010.1.22) by Jungil Lee
- PHENIX Collaboration has measured J/ψ polarization.
- The paper is cited by BNL PHENIX Collaboration

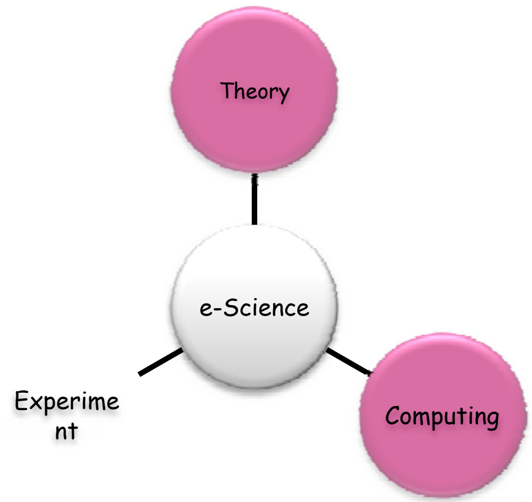
Tools for future experiment

- Belle II DH with AMGA ⇒ ILC etc.

Data Handling Scenario



Theory-Computing



Theory–Computing

- To set theoretical model
- To do parallelization and optimization for Supercomputing
- To develop PYTHIA code

BMSSM

- CP Violation in the beyond Minimal Supersymmetric Standard Model (BMSSM)
- Possibility of spontaneous CP violation in Higgs physics beyond the minimal supersymetric model ⇒ S.W.Ham, Seung-A Shim, S.K.Oh, PRD80, 055009 (2009).

PHYSICAL REVIEW D **80**, 055009 (2009)

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

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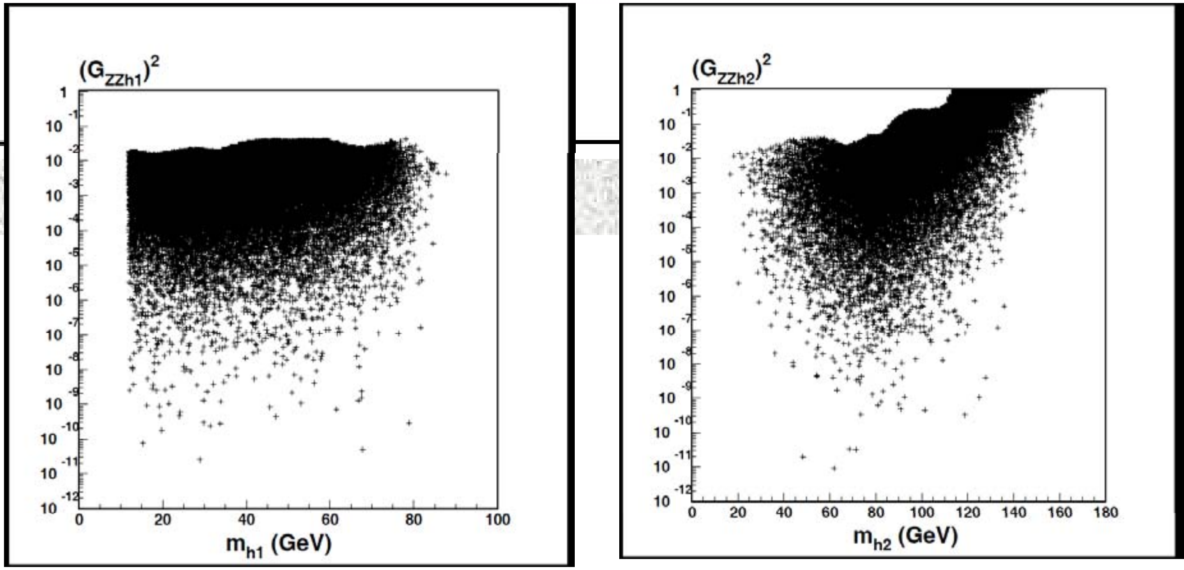
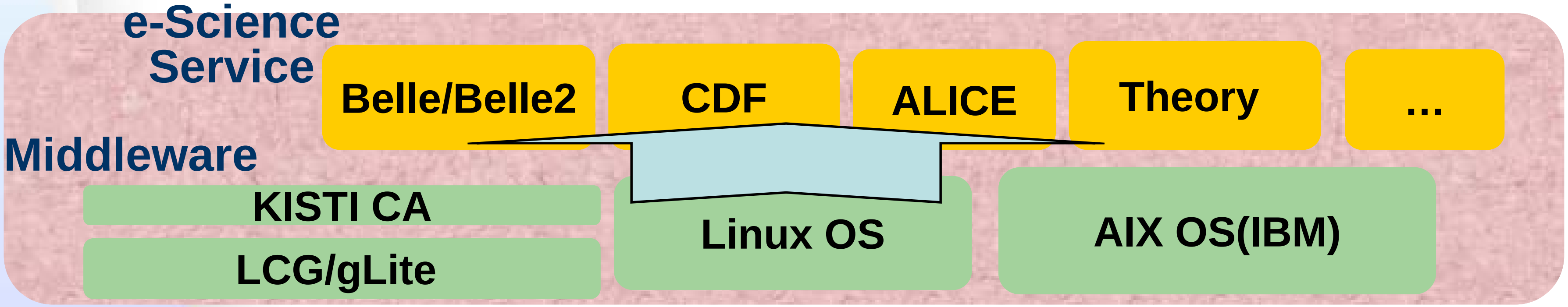
The Dine-Seiberg-Thomas model (DSTM) is the simplest version of the new physics beyond the minimal supersymmetric standard model (MSSM), in the sense that its Higgs sector has just two dimension-five operators, which are obtained from the power series of the energy scale for the new physics in the effective 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 spontaneously by a complex phase, obtained as the relative phase between the vacuum expectation values of the two Higgs doublets. At the tree level, for a reasonably established parameter region, the masses of the three neutral Higgs bosons and their corresponding coupling coefficients to a pair of *Z* bosons in the DSTM are calculated such that the results are inconsistent with the experimental constraint by the LEP data. Thus, the LEP2 data exclude the possibility of spontaneous *CP* violation in the DSTM at the tree 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. The upper bound on the radiatively corrected mass of the lightest neutral Higgs boson of the DSTM is about 87 GeV, in the spontaneous *CP* violation scenario. We confirm that the LEP data does not exclude this numerical result.

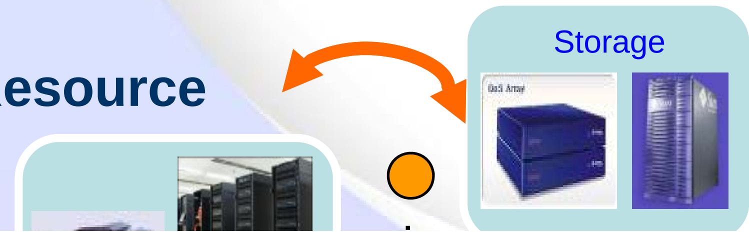
DOI: 10.1103/PhysRevD.80.055009 PACS numbers: 12.60.Jv, 11.30.Er, 14.80.Cp

KISTI





Resource



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A Shim, S.K.Oh, PRD80, 055009 (2009).

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THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

Explicit CP violation in the Dine–Seiberg–Thomas model

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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).

Abstract The possibility of explicit CP violation is stu 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.

PACS 12.60.Jv · 11.30.Er · 14.80.Cp

the requirement that Weinberg has demanded, because they 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 sec-

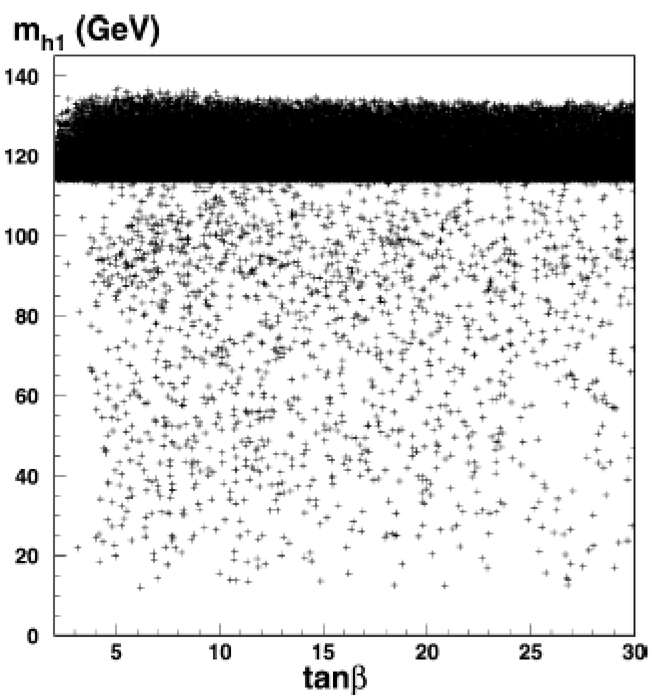

Fig. 1 The distribution of 50,000 points of ($\tan\beta$, m_{h_1}), at the one-loop level. The allowed ranges of the parameter values are $|\epsilon_1| < 0.025$, $|\epsilon_2| < 0.025$, $|\varphi_2| < \pi/2$, $|\varphi| < \pi/2$, $0 < m_{A^0} < 1{,}000$ GeV, $100 < |\mu| < 500$ GeV, $|A_t| < 1{,}000$ 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 $\tan\beta$

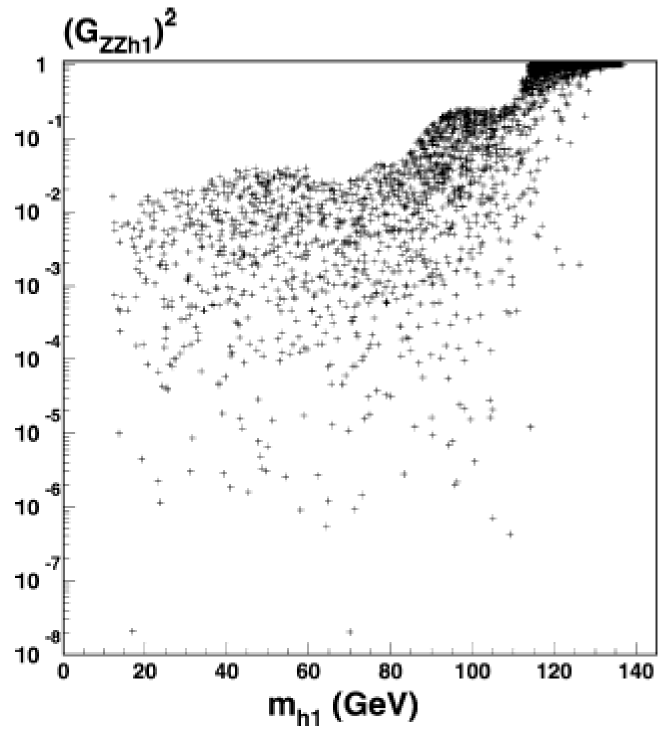

Fig. 2 The distribution of 50,000 points of (m_{h_1}, $G^2_{ZZh_1}$), the square of normalized coupling strength of the lightest Higgs boson of the DSTM versus its mass, at the one-loop level. The allowed ranges of the parameter values are the same as in Fig. 1

Kihyeon Cho

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

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(2) School of Physics, KIAS, Seoul 130-722, Korea
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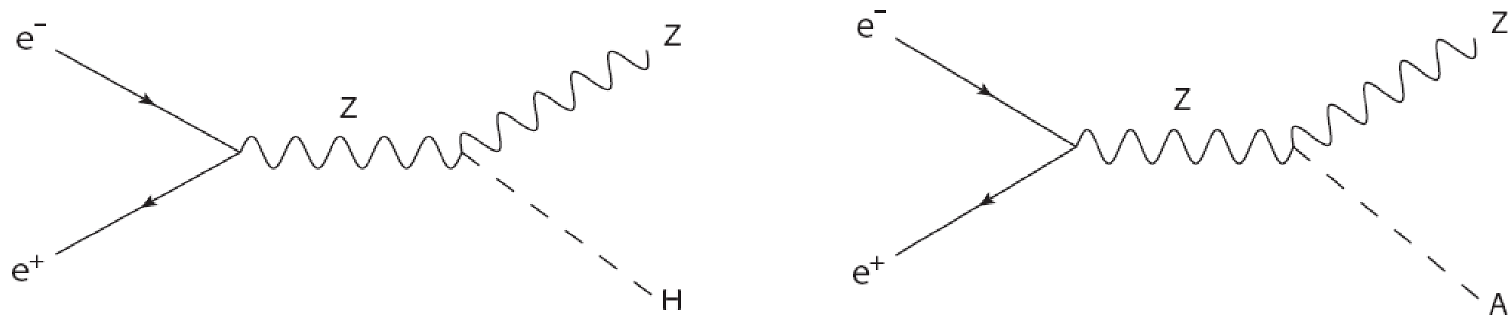
20 %, we expect that at least 5 events of the lightest scalar Higgs boson may be produced at the ILC via double Higgs-strahlung process.

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

```
 I particle/jet  KS     KF  orig    p_x      p_y      p_z       E        m

   1 !e+!        21    -11    0    0.000    0.000  250.000  250.000    0.001
   2 !e-!        21     11    0    0.000    0.000 -250.000  250.000    0.001
 ==============================================================================
   3 !e+!        21    -11    1    0.000    0.000  250.000  250.000    0.000
   4 !e-!        21     11    2    0.000    0.000 -249.975  249.975    0.000
   5 !e+!        21    -11    3    0.000    0.000  250.000  250.000    0.000
   6 !e-!        21     11    4    0.000    0.000 -249.975  249.975    0.000
   7 !Z0!        21     23    0  -16.048   56.237  223.638  248.136   90.209
   8 !A0!        21     36    0   16.048  -56.237 -223.613  251.839  100.000
   9 !u!         21      2    7   -2.172  -19.845  102.428  104.356    0.330
  10 !ubar!      21     -2    7  -13.876   76.082  121.209  143.780    0.330
  11 !b!         21      5    8  -20.904  -30.147  -17.796   41.055    4.800
  12 !bbar!      21     -5    8   36.951  -26.090 -205.817  210.784    4.800
 ==============================================================================
  13 (Z0)        11     23    7  -16.048   56.237  223.638  248.136   90.209
  14 (A0)        11     36    8   16.048  -56.237 -223.613  251.839  100.000
  15 gamma        1     22    1    0.000    0.000    0.000    0.000    0.000
  16 gamma        1     22    2    0.000    0.000   -0.025    0.025    0.000
  17 u         A  2      2    9   -2.172  -19.845  102.428  104.356    0.330
  18 ubar      V  1     -2   10  -13.876   76.082  121.209  143.780    0.330
  19 b         A  2      5   11  -20.904  -30.147  -17.796   41.055    4.800
  20 bbar      V  1     -5   12   36.951  -26.090 -205.817  210.784    4.800
 ==============================================================================
                  sum:  0.00         0.000    0.000    0.000  500.000  500.000
```

Results of e-Science paradigm

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Polarization of prompt J/ψ in proton-proton collisions at RHIC

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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)§

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ep-ph] 30 Nov 2009

PHYSICAL REVIEW D **80**, 055009 (2009)

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

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Abstract The possibility of expli... in a supersymmetric model propo... 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 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.

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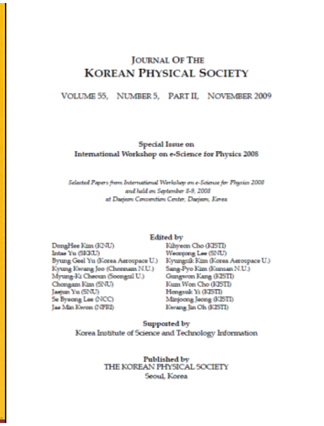
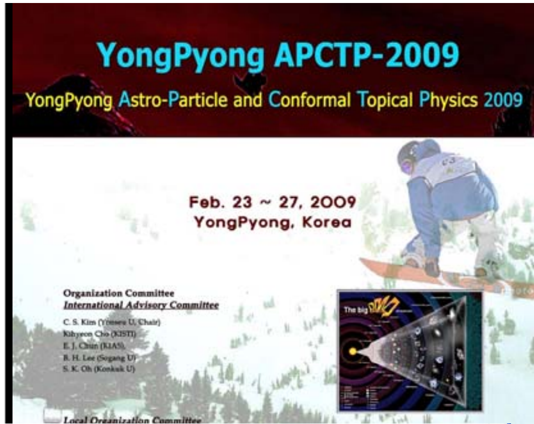
1 Introduction

It is reasonable to assume that any phenomenological model should accommodate the violation of the CP symmetry as one of key features, since the CP violation has been observed

... models satisfy ... l, because they ... o 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 of the MSSM at tree level. If the μ parameter and the soft supersymmetry breaking parameters may possess complex phases, the redefinition of Higgs fields can always eliminate them. A global phase rotation can further eliminate any complex phases in the vacuum expectation values of two Higgs doublets. At the one-loop level, it has been studied that explicit CP violation is possible in the MSSM, but a





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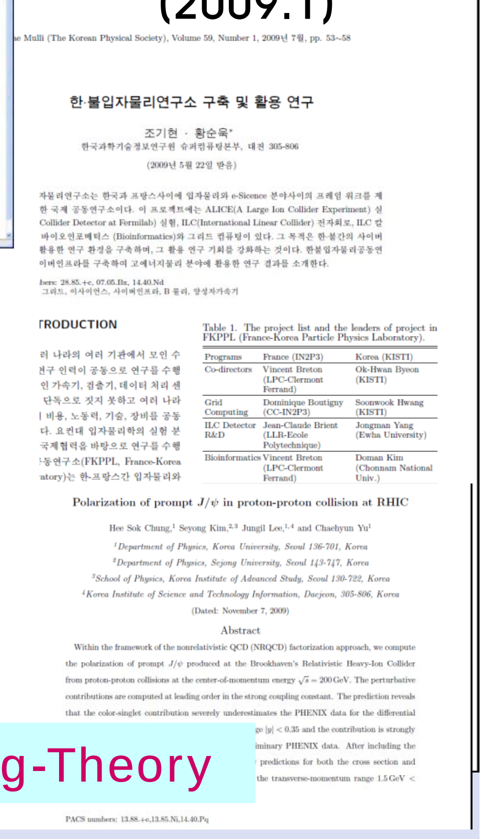

⇒ Great success of Experiment-Computing-Theory

Summary

- The paradigm of e-Science
  - Experiment–Computing–Theory
- Have applied the paradigm to HEP
  $\Rightarrow$ Great success.
- Hope to extend this concept to other areas of physics

Thank you.