

March 9~12, 2010  
ISGC 2010, Taipei, Taiwan

# **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)

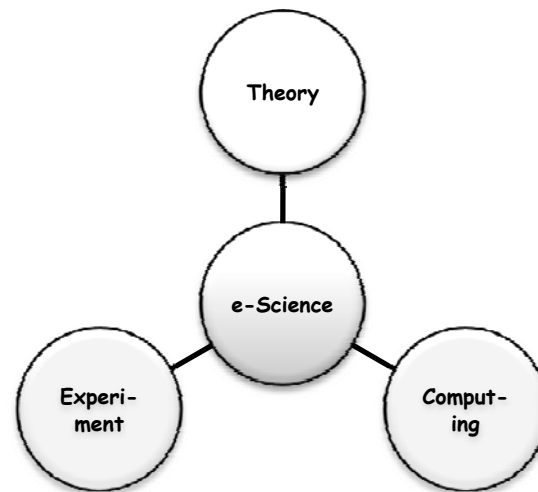
## ● Former members:

- Hyunwoo Kim
- Minho Jeung
- Daejung Kong
- Ilsung Cho
- Yeongseok Oh

# Contents



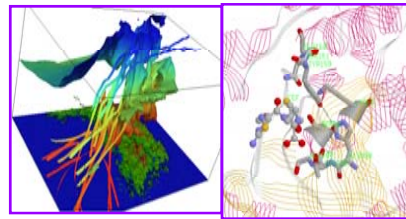
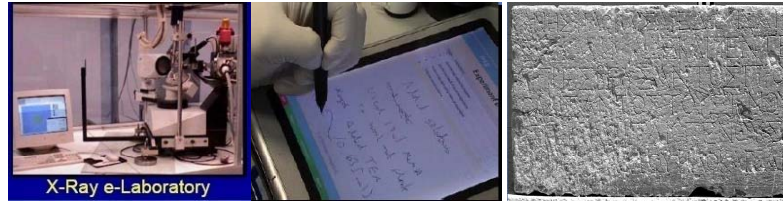
- e-Science paradigm
  - Experiment-Computing-Theory



- Results
- Summary

# What is e-Science Paradigm?

Hardness



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

Experimental Science

- Thousand Years ago
- Experimental Science



– description of natural phenomena

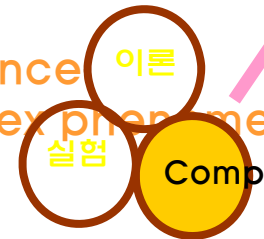
Kihyeo Tony Hey (MS)

– 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 ...

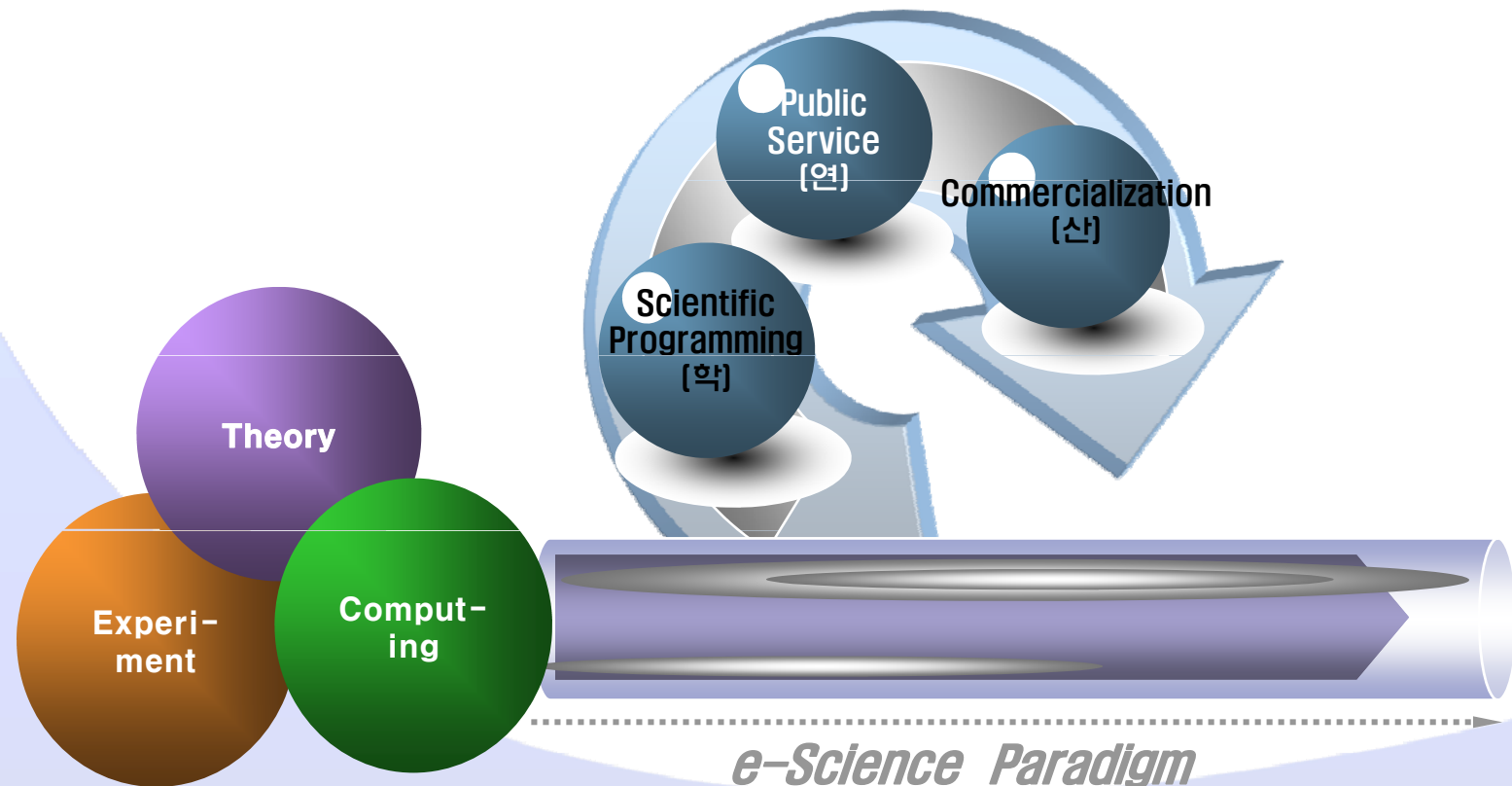
**HPC and Information Management**  
are Key Technologies to support e-Science Revolution

Effects

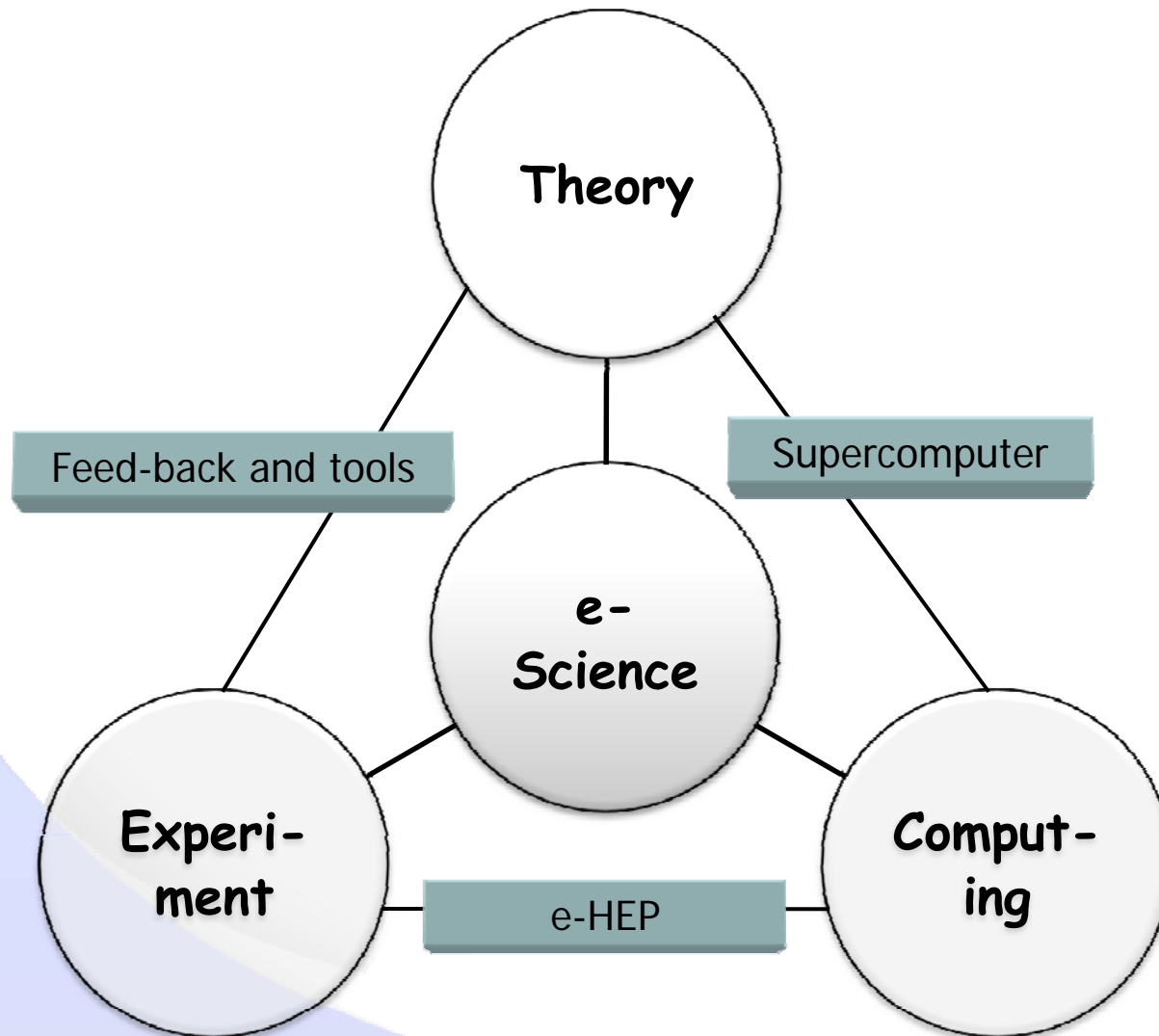
# e-Science Paradigm



## □ Fusion research of Experiment-Computing-Theory

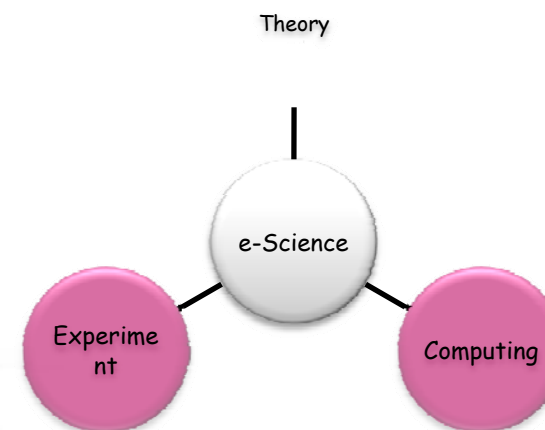


# e-Science paradigm in HEP



# Experiment-Computing

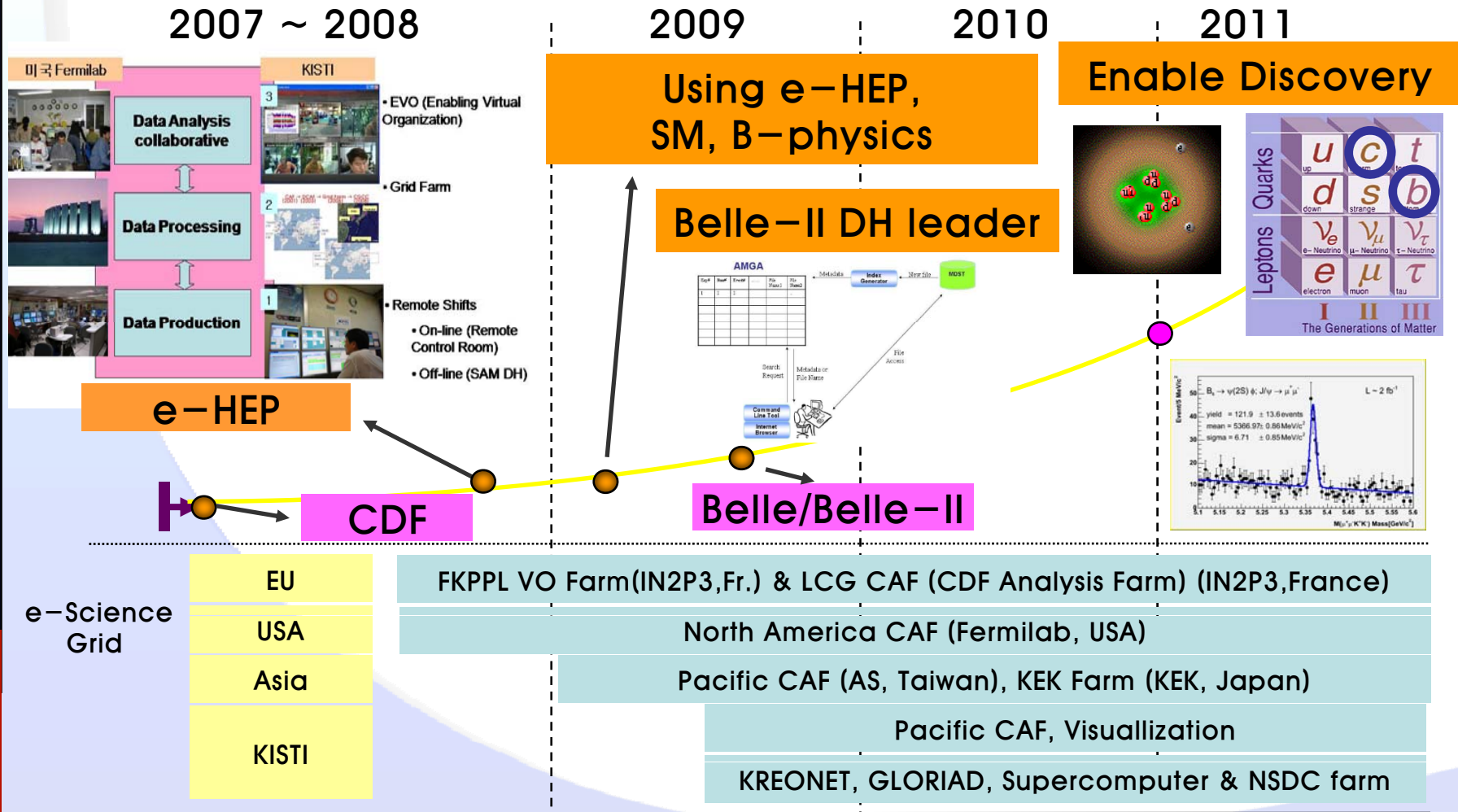
e-HEP (High Energy Physics)



# e-HEP (High Energy Physics)

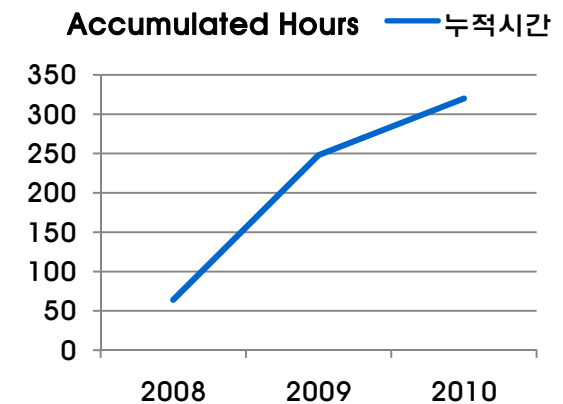
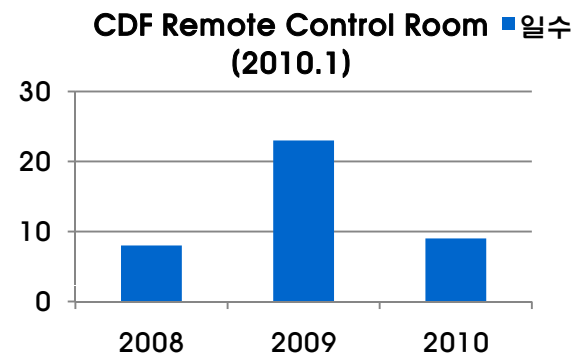
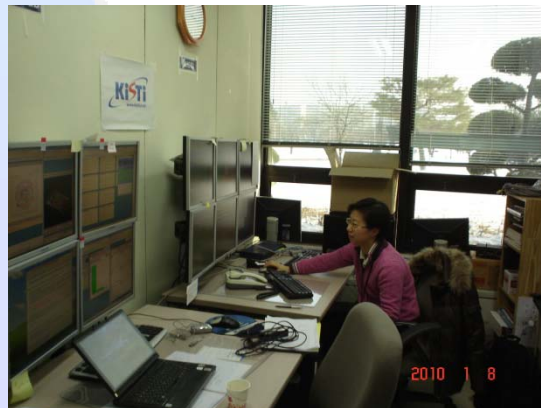


To study high energy physics anytime, anywhere





# CDF Remote Control Room @KISTI



# 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 \cdot 10^{-7}\$  @90%CL](#)

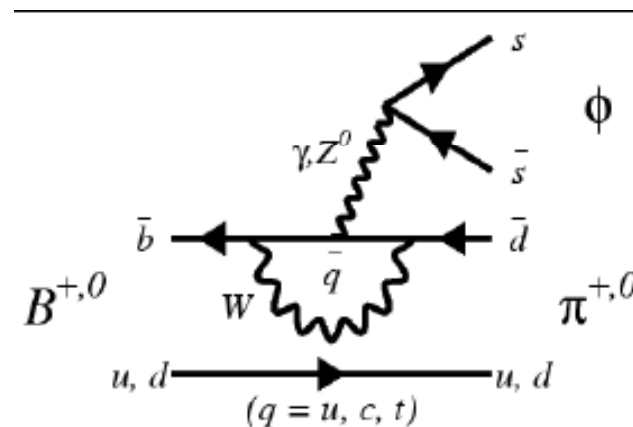
  - UL( $\phi \pi^0$ ) <  [\$2.8 \cdot 10^{-7}\$  @90%CL](#)

- Draft is almost ready.

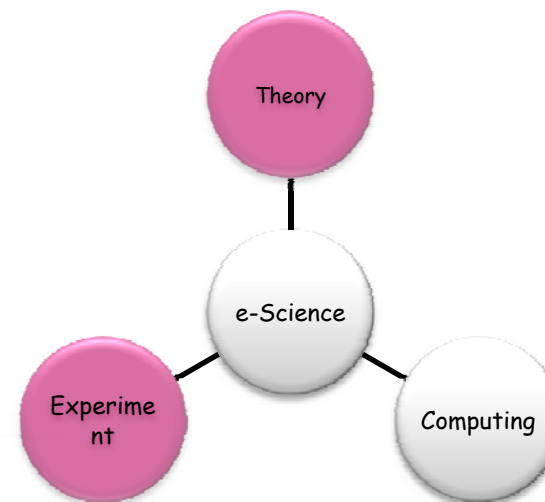
## ● $B^+ \rightarrow \rho^0 K^{*+}$

- Penguin dominant status

- Work on progress

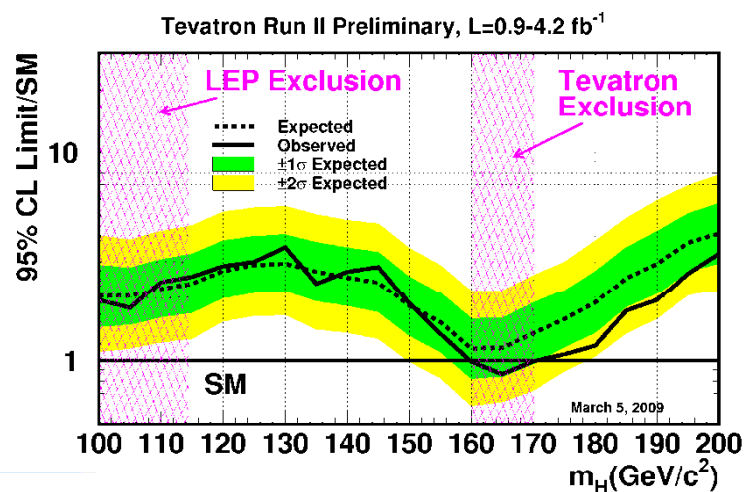


# Theory-Experiment



- 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.

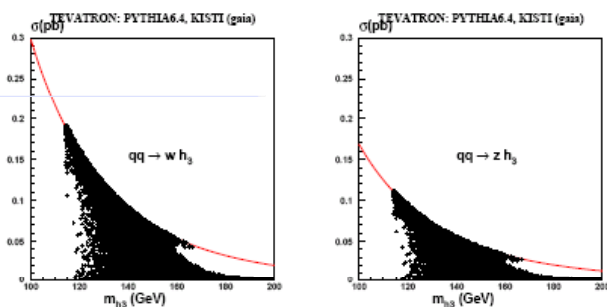
# Higgs mass at Tevatron



■ 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

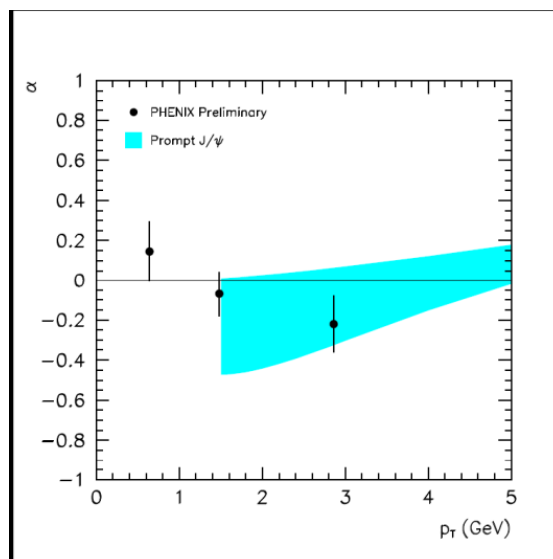
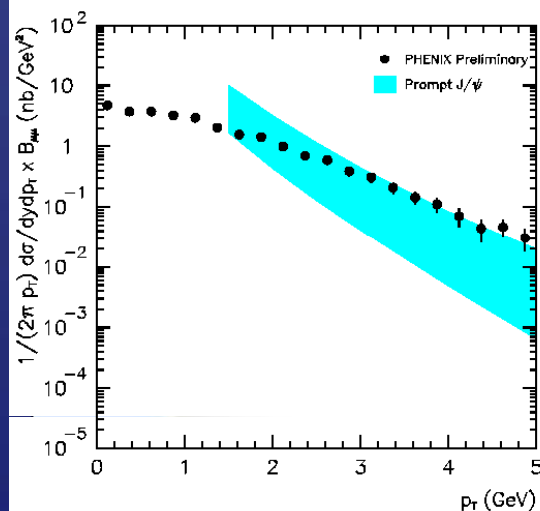
## 4. Higgs Production of the BMSSM with spontaneous CP violation at TEVATRON



■ 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



PHYSICAL REVIEW D 81, 014020 (2010)

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

Hee Sok Chung and Chaehyun Yu

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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

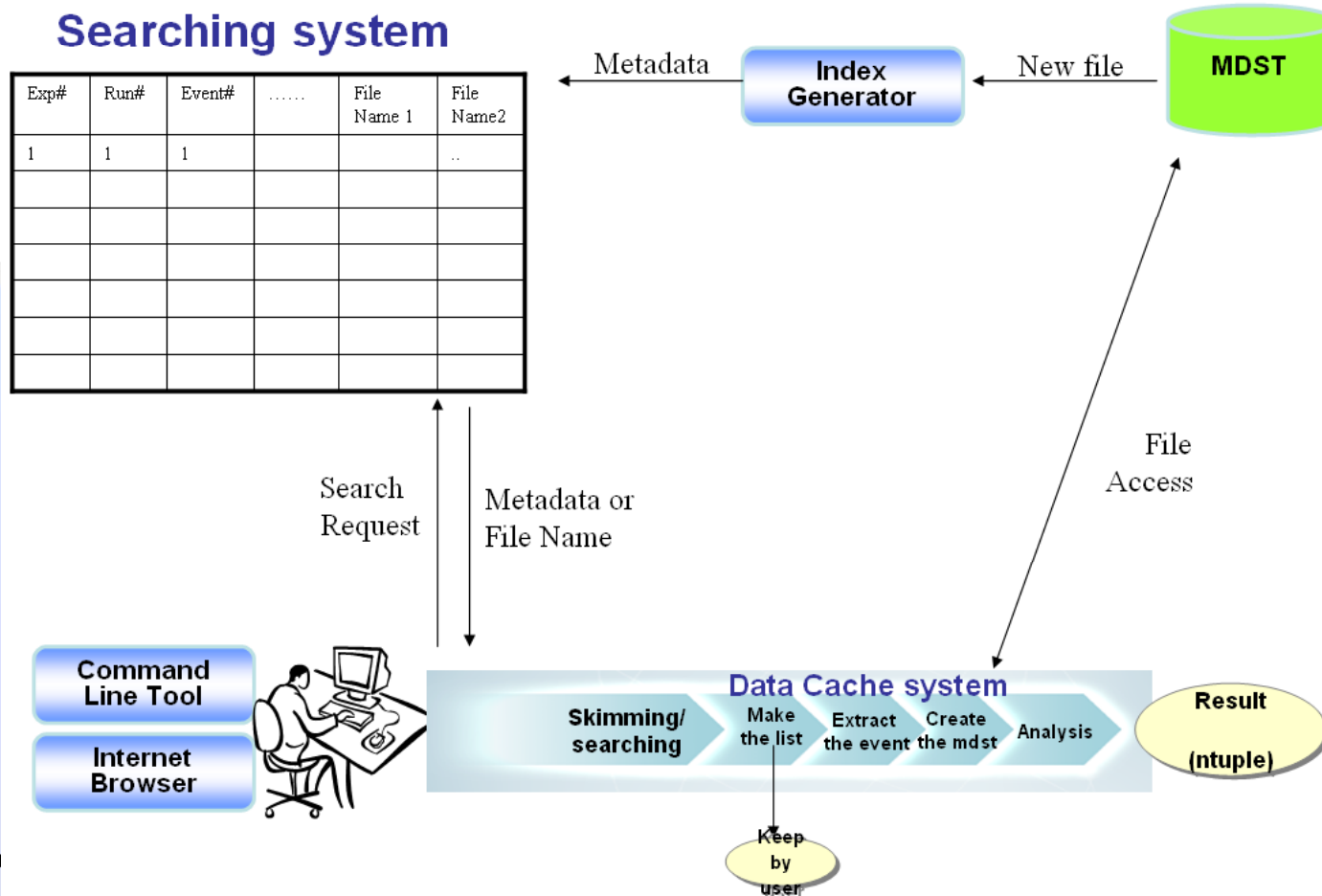
*Department of Physics, Korea University, Seoul 136-701, Korea,  
and Korea Institute of Science and Technology Information, Daejeon 305-806, Korea*  
(Received 11 November 2009; published 22 January 2010)

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

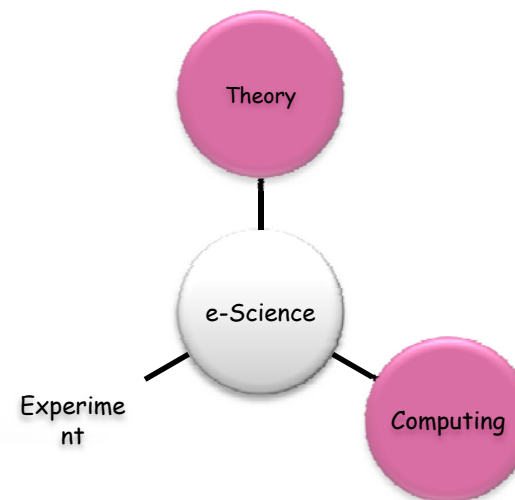
# Tools for future experiment

- Belle II DH with AMGA  $\Rightarrow$  ILC etc.

## Data Handling Scenario



# Theory-Computing





# 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  $\Rightarrow$  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**

S. W. Ham,<sup>1</sup> Seong-A Shim,<sup>2</sup> and S. K. Oh<sup>3</sup>

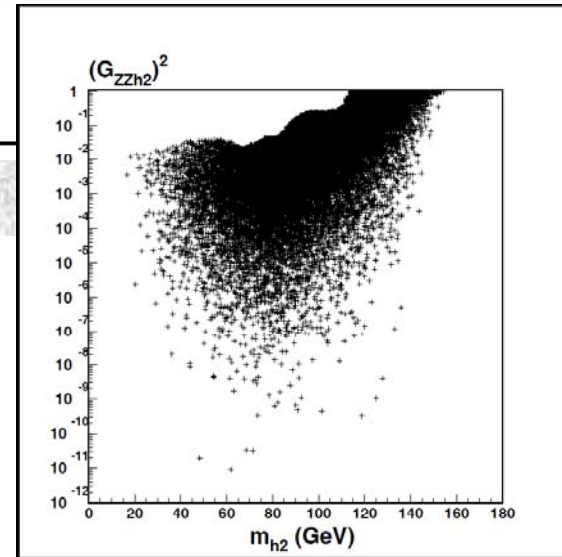
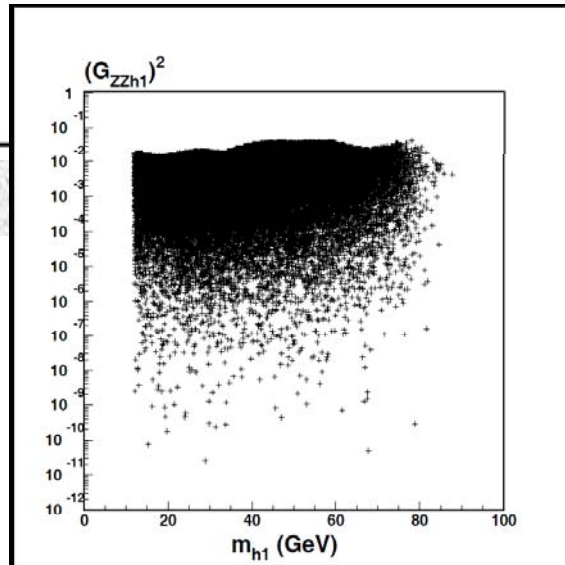
<sup>1</sup>Department of Physics, Korea University, Seoul 136-701

<sup>2</sup>Department of Mathematics, Sungshin Women's University, Seoul 136-742

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(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 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.



### e-Science Service

Belle/Belle2

CDF

ALICE

Theory

...

### Middleware

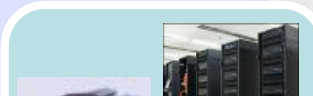
KISTI CA

LCG/gLite

Linux OS

AIX OS(IBM)

### Resource



Storage



KREONET



GLORIAD

### ACKNOWLEDGMENTS

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

# Explicit CP violation in the Dine–Seiberg–Thomas model

S.W. Ham<sup>1,2,a</sup>, Seong-A Shim<sup>3</sup>, S.K. Oh<sup>4</sup>

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**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 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-

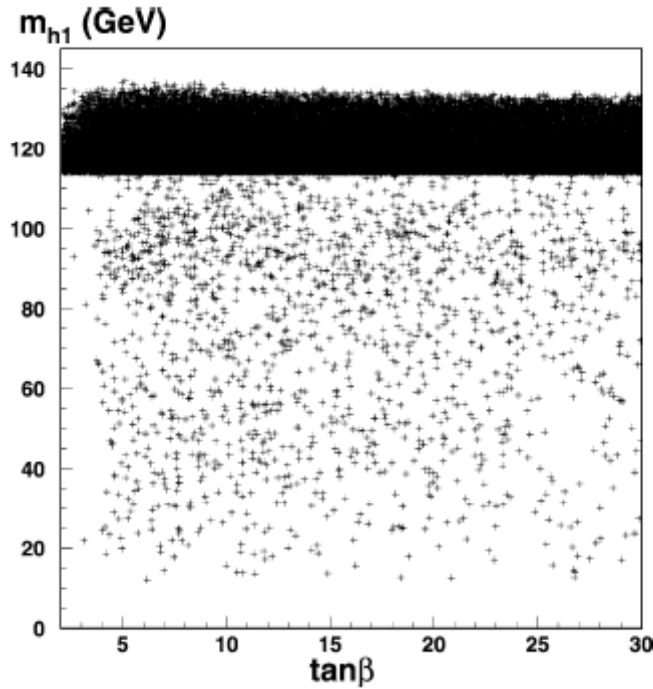


Fig. 1 The distribution of 50,000 points of  $(\tan\beta, m_{h_1})$ , at the one-loop level. The allowed ranges of the parameter values are  $|\epsilon_1| < 0.025$ ,  $|\epsilon_2| < 0.025$ ,  $|\varphi_2| < \pi/2$ ,  $|\varphi| < \pi/2$ ,  $0 < m_{A^0} < 1,000$  GeV,  $100 < |\mu| < 500$  GeV,  $|A_t|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

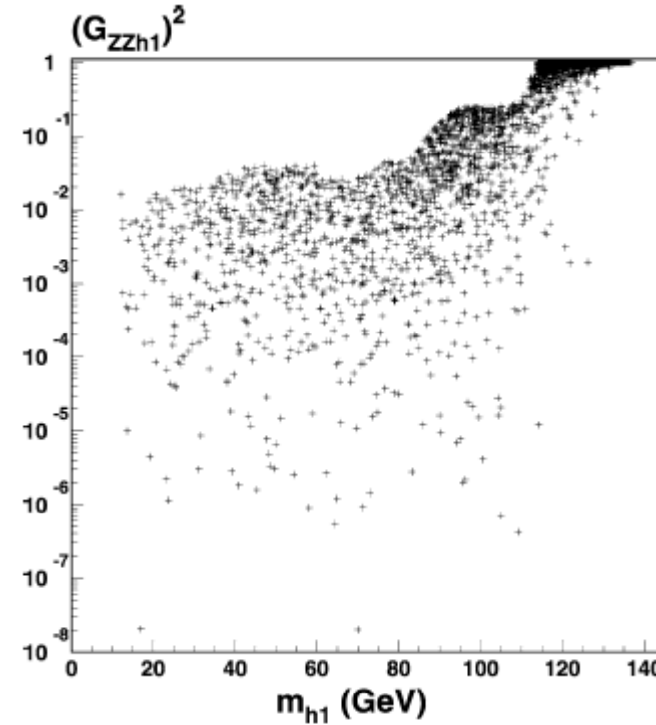


Fig. 2 The distribution of 50,000 points of  $(m_{h_1}, G_{ZZh_1}^2)$ , the square of normalized coupling strength of the lightest Higgs boson of the DSTM versus its mass, at the one-loop level. The allowed ranges of the parameter values are the same as in Fig. 1



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

S. W. Ham<sup>(1,2)\*</sup>, Kideok Han<sup>(1)†</sup>, Jungil Lee<sup>(1,3)‡</sup>, and S. K. Oh<sup>(4)§</sup>

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## VI. Acknowledgments

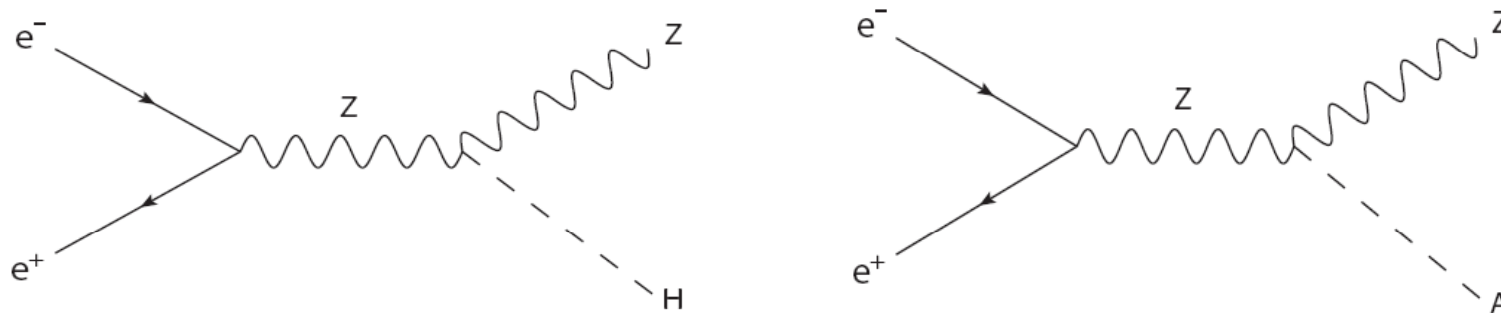
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20 %, we expect that at least 5 events of the lightest scalar Higgs boson may be produced at the ILC via double Higgs-strahlung process.

# 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



$A0 \rightarrow b \bar{b}$  decay for  $M_A=100$  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



PHYSICAL REVIEW D 81, 014020 (2010)

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

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(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

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vacuum expectation values in the parameter region, the masses of a pair of  $Z$  bosons in the neutral 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

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

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Regular Article - Theoretical Physics

THE EUROPEAN  
PHYSICAL JOURNAL C

## Explicit $CP$ violation in the Dine-Seiberg-Thomas model

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## ACKNOWLEDGMENTS

**Abstract** The possibility of explicit  $CP$  violation in a supersymmetric model proposed by Dine, Seiberg, and Thomas, with two effective dimension-five operators, is studied. 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

## 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

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. models satisfy the  $CP$  symmetry, because they do not 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  $\mu$  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

ep-ph] 30 Nov 2009



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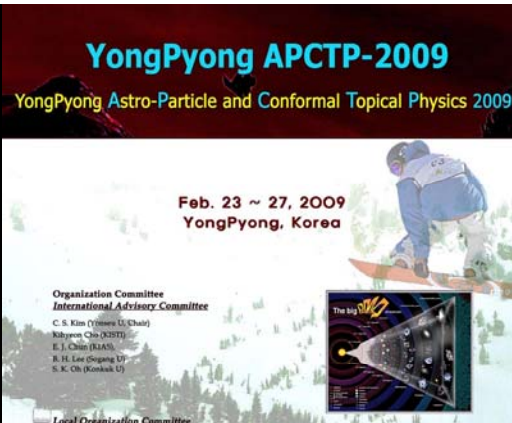
Special Issue on  
International Workshop on e-Science for Physics 2008

Edited Papers from International Workshop on e-Science for Physics 2008  
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from 16:00 to 17:00  
Asia/Tokyo  
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## Data Handling Working Group Meeting

Description: Belle II Data Handling Working Group Meeting

Wednesday 27 May 2009

16:00 Introduction (10) Slides (10) document (10)

16:10 Meta data (10) Slides (10) document (10)

16:20 Interaction between AMGA and Tom's activities (10) Architecture: Link to MDST Data Search, Link to RunInfo Command, Schema (20)

Thomas Kuhr

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Tom Fiffeld

## Deuteron production and elliptic flow in relativistic heavy ion collisions

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(Date: October 1, 2009)

The hadronic transport model ART is extended to include the production and annihilation of deuterons via the reaction  $BB \rightarrow dM$ , where  $B$  and  $M$  stand for baryons and mesons, respectively, as well as their elastic scattering with mesons and baryons in the hadronic matter. The new hadronic transport model is then used to study the transverse momentum spectrum and elliptic flow of deuterons in relativistic heavy ion collisions, with the initial hadron distributions after hadronization of produced quark-gluon plasma taken from a blast wave model. The results are compared with those measured by the PHENIX and STAR Collaborations for Au-Au collisions at  $\sqrt{s_{NN}} = 200$  GeV, and also with those obtained from the coalescence model based on free-nucleon deuterons in the transport model.

PACS numbers: 25.75.-d, 25.75.Ld, 25.75.Nr

## I. INTRODUCTION

An important observable in heavy ion collisions at the Relativistic Heavy Ion Collider (RHIC) is the azimuthal anisotropy of the momentum distributions of produced particles in the plane perpendicular to the beam direction, particularly the so-called elliptic flow ( $v_2$ ), that corresponds to the second Fourier coefficient in their azimuthal angle distribution [1, 2]. The measured elliptic flow is not only large but also shows a constituent quark number scaling, especially at intermediate transverse momenta, i.e., the dependence of the elliptic flows of identified hadrons on their transverse momenta becomes similar if both are divided by the number of constituent quarks in a hadron. This scaling behavior of hadron elliptic flows is well described by the quark coalescence model for hadron production from the quark-gluon plasma (QGP) formed in relativistic heavy-ion collisions [3, 4, 5, 6, 7, 8]. Also, the measured elliptic flows of identified hadrons follow a mass ordering at low transverse momenta, namely, the strength of the elliptic flow becomes smaller as the hadron mass increases. This has also been well described by the transport model [9] as well as by the ideal hydrodynamics [10, 11].

Recently, the elliptic flow of deuterons has been measured in Au-Au collisions at energy  $\sqrt{s_{NN}} = 200$  GeV [12, 13]. The data from the PHENIX Collaboration covers the intermediate transverse momentum ( $p_T$ ) region [12], while the STAR Collaboration has made measurements in a wider range of  $p_T$  including the low  $p_T$  region [13]. The two measurements agree well at intermediate  $p_T$  region ( $p_T > 1.5$  GeV/c) except that the STAR data show a negative elliptic flow at low  $p_T$ .

to overcome the shortcomings of

we use in the present work a blast wave

Deuteron production and elliptic flow

collisions. We assume that th

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## The Data Processing of e-Science for High-energy Physics

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(Received 18 August 2008)

The goal of high-energy physics is to understand the basic properties of elementary particles and their interactions. High-energy physics is usually conducted at major accelerator sites, in which detector design, construction, signal processing, data acquisition, and data analysis are performed on a large scale. However, in order to study high-energy physics anytime and anywhere even if we are not on-site at accelerator laboratories, we have created a new research paradigm, e-Science. The e-Science for high-energy physics has four components: data production, data processing, and data analysis. In this paper, we focus on the data processing of e-Science for high-energy physics. We show current implementations and experiments of data processing for the ALICE (A Large Ion Collider Experiment) The 2 center and for CDF (Collider Detector at Fermilab) at Large Hadron Collider.

PACS numbers: 20.45.+v, 07.05.+k, 07.05.Bc

Keywords: e-Science, High-energy physics data grid, Grid computing, Data processing

DOI: 10.3938/jkps.59.0-0

## I. INTRODUCTION

The goal of HEP (high-energy physics) is to understand the basic properties of elementary particles and their interactions. Since the invention of the cyclotron by Ernest Orlando Lawrence at the University of California [1], HEP has usually been investigated at major accelerator sites, in which detector design, construction, signal processing, data acquisition, and data analysis are performed on a large scale. In order to cope with more data and more collaboration, we have created the concept of e-Science. The goal of e-Science for high-energy physics is to study high-energy physics anytime and anywhere even if we are not on-site at an accelerator laboratory. If computing processing is to be performed on the required HEP scale, data grid technology is a strong requirement [2]. The amazing advance in IT (information technology), such as Moore's law, and the wide spread use of IT help computing processing [3].

The objective of a HEP data grid is to construct a system to manage and process HEP data and to support a high-energy physics community. In this paper, we introduce data processing as a component of e-Science for ALICE (A Large Ion Collider Experiment) and CDF (Collider Detector at Fermilab) at Large Hadron Collider.

2. Data Processing as a Component of e-Science

## $SU(4)_L \times U(1)_X$ models with little Higgs

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(Date: September 21, 2009)

We discuss the aspects of the fermions and gauge bosons in  $SU(4)_L \times U(1)_X$  models with little Higgs. We introduce a set of fermions which ensures the cancellation of gauge anomaly, and explicitly show the cancellation of one-loop quadratic divergence to the Higgs mass from all fermion multiplets and all gauge bosons. We present the interactions of the standard model fermions with the physical gauge bosons. We also discuss some phenomenological implications of the model based on recent experimental results.

## I. INTRODUCTION

An extension of the standard model (SM) gauge group  $SU(2)_L \times U(1)_Y$  to  $SU(4)_L \times U(1)_X$  has been proposed by various authors due to its several distinctive features. For instance, electroweak unification could be obtained in an  $SU(4)_L$  model with its subgroup  $SU(2)_L \times SU(2)_R \times U(1)$  and  $\sin^2 \theta_W = 1/4$  in the left-right symmetry limit [1]. Also, one can construct a  $SU(4)_L$  model in the lepton sector in which the hypothetical large neutrino magnetic moment around  $10^{-11}$  of the Bohr magneton is naturally compatible with acceptably small neutrino mass of a few eV [2]. Most interestingly, the gauged  $SU(4)_L \times U(1)_X$  gauge group including both quarks and leptons can provide an answer to the question why we only observe three families of fermions in nature, in a sense that anomaly cancellation is achieved when  $N_f = N_c = 3$  where  $N_f(N_c)$  is the number of families (colors) [3]. A systematic way of constructing anomaly-free fermion spectra with  $SU(4)_L \times U(1)_X$  gauge group has been discussed in Ref. [4].

Instead of the usual Higgs mechanism, recently, the little Higgs mechanism has been implemented in  $SU(4)_L \times U(1)_X$  gauge group by Kaplan and Schmaltz (KS) as an alternative solution to the hierarchy and fine-tuning issues [5]. Little Higgs models (LHM) adopt the early idea that Higgs can be considered as a Nambu-Goldstone boson from global symmetry breaking at some higher scale  $\Lambda \sim 4\pi f$  [6] and acquires a mass radiatively through symmetry breaking at the electroweak scale by collective breaking [7]. The LHM

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## 한·불입자물리연구소 구축 및 활용 연구

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한국과학기술정보연구원 승리관정보분부, 대전 305-806

(2009년 5월 22일 받음)

자물리연구소는 한국과 프랑스 사이에 입자물리와 e-Science 분야의 프론티어 워크를 제 한·국제 공동연구소이다. 이 프로젝트에는 ALICE(A Large Ion Collider Experiment) 및 Collider Detector at Fermilab) 실험, ILIC(International Linear Collider) 전자-양자, ILC 및 페이온-양자(Photon)의 고에너지 입자물리 실험이 있다. 그 목적은 한·불간의 과학적 활용 연구 활동을 촉진하여, 그 활용 연구 기회를 강화하는 것이다. 한·불입자물리공동연구는 입자물리 연구를 촉진하여 고에너지물리 분야의 활용 연구 결과를 소개한다.

Keywords: 입자물리, 입자물리, 입자물리, 입자물리, 입자물리

## REFERENCES

리 나리의 여러 기관에서 모인 수

연구 인력이 공동으로 연구를 수행

한·국제 공동연구소이다. 이 프로젝트에는

실험, ILIC(International Linear Collider) 전자-양자,

ILC 및 페이온-양자(Photon)의 고에너지 입자물리 실험이 있다.

그 목적은 한·불간의 과학적 활용 연구 활동을 촉진하여,

그 활용 연구 기회를 강화하는 것이다. 한·불입자물리공동연구는

입자물리 연구를 촉진하여 고에너지물리 분야의 활용 연구 결과를 소개한다.

Keywords: 입자물리, 입자물리, 입자물리, 입자물리, 입자물리

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

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(Date: November 7, 2009)

## Abstract

Within the framework of the nonrelativistic QCD (NRQCD) factorization approach, we compute the polarization of prompt  $J/\psi$  produced at the Brookhaven's Relativistic Heavy-Ion Collider from proton-proton collisions at the center-of-momentum energy  $\sqrt{s} = 200$  GeV. The perturbative contribution is computed at leading order in the strong coupling constant. The prediction reveals that the color-singlet production severely underestimates the PHENIX data for the differential

production cross section  $d\sigma/dp_T$  and the contribution is strongly

improved by including the color-octet production. After including the

production for both the cross section and the

transverse-momentum range  $1.5 < p_T <$

⇒ Great success of Experiment-Computing-Theory

PACS numbers: 13.88.+e, 13.85.Ni, 14.40.Pg

# 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.**