Evolving Architecture for Beyond the Standard Model

2015. 4

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(KISTI)

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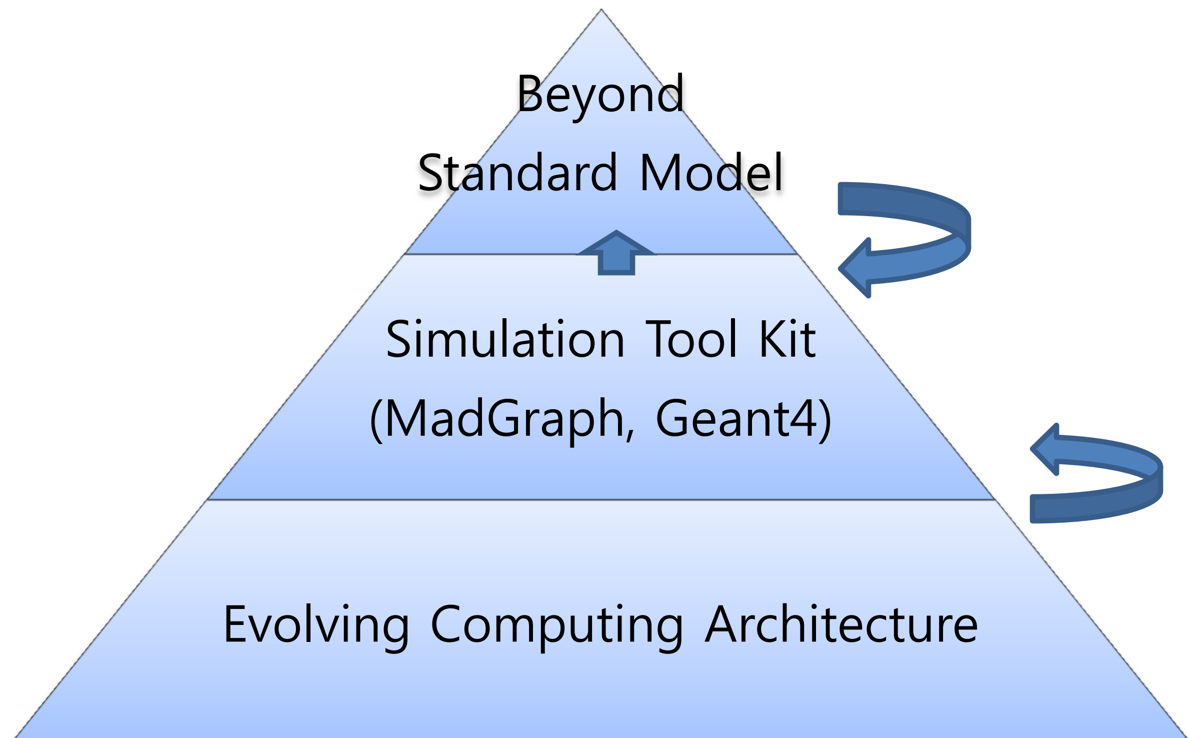
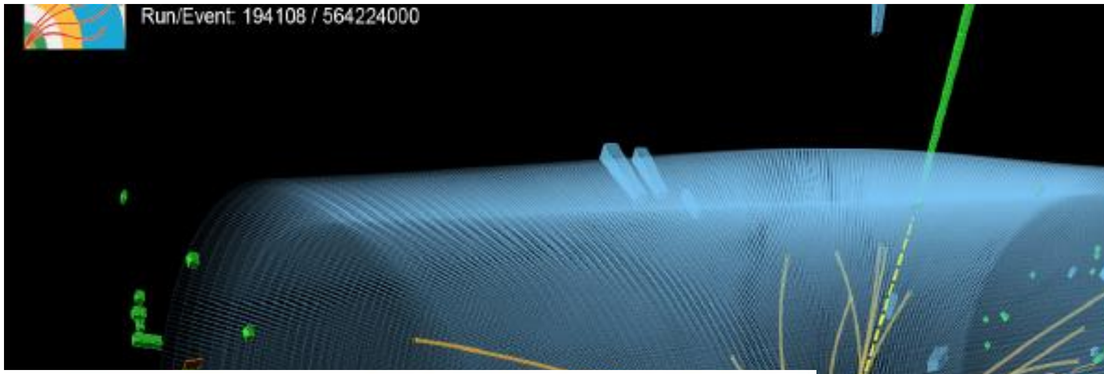
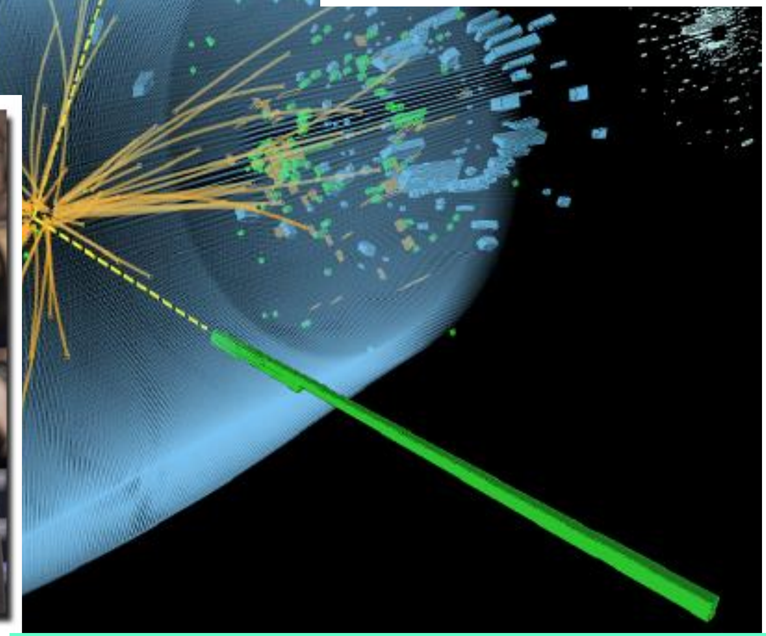
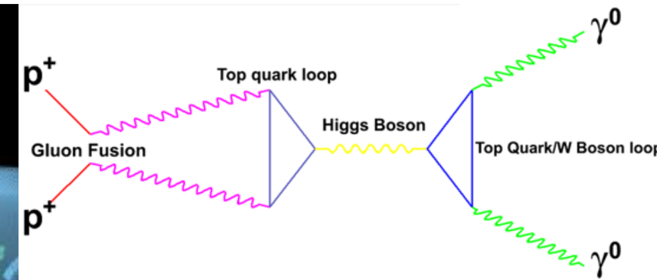
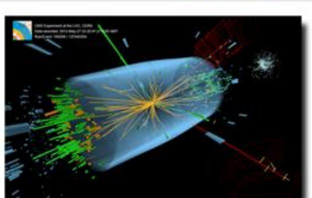


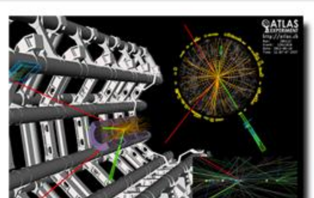
Higgs Discovery (July 4, 2012)







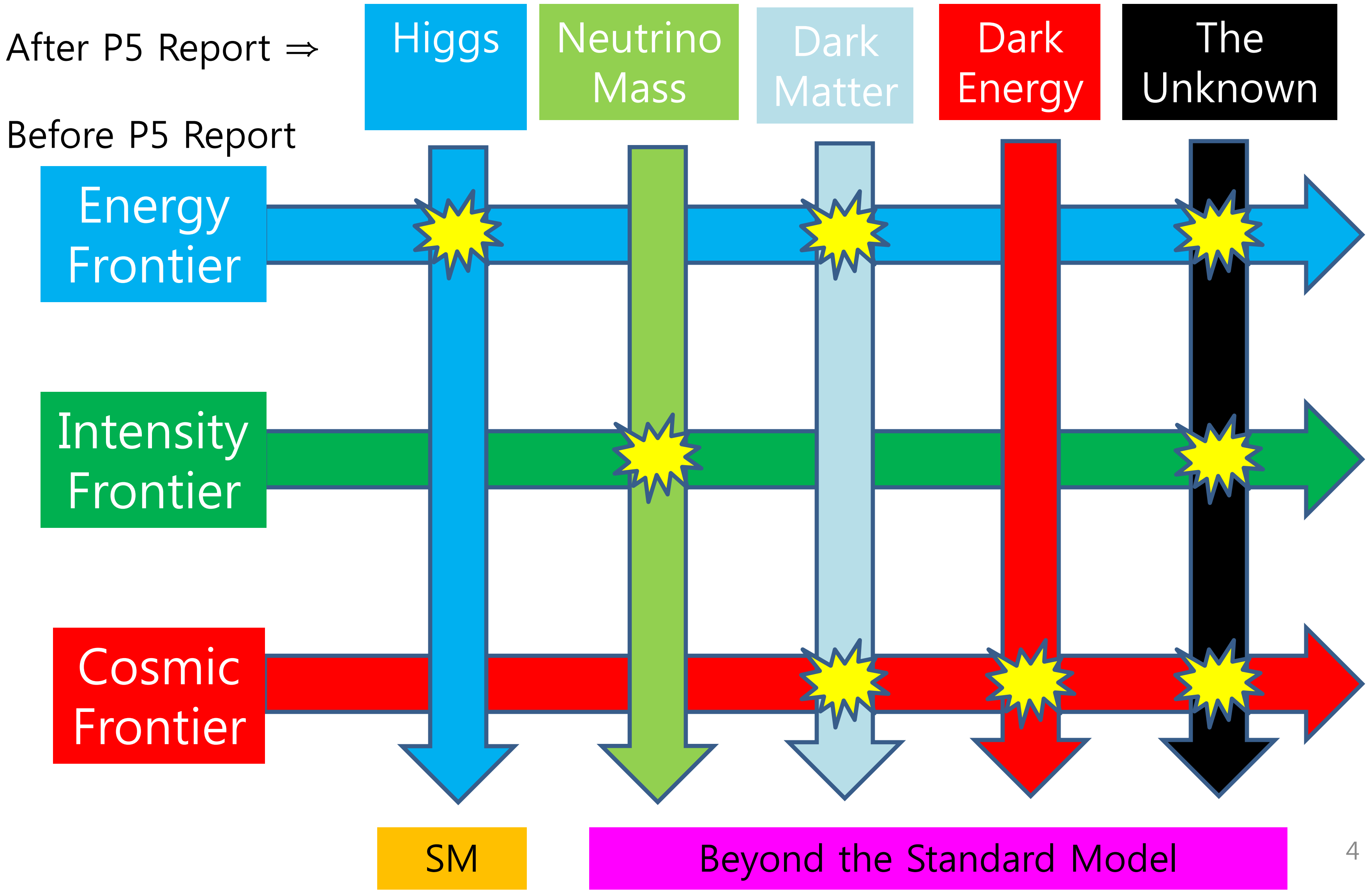




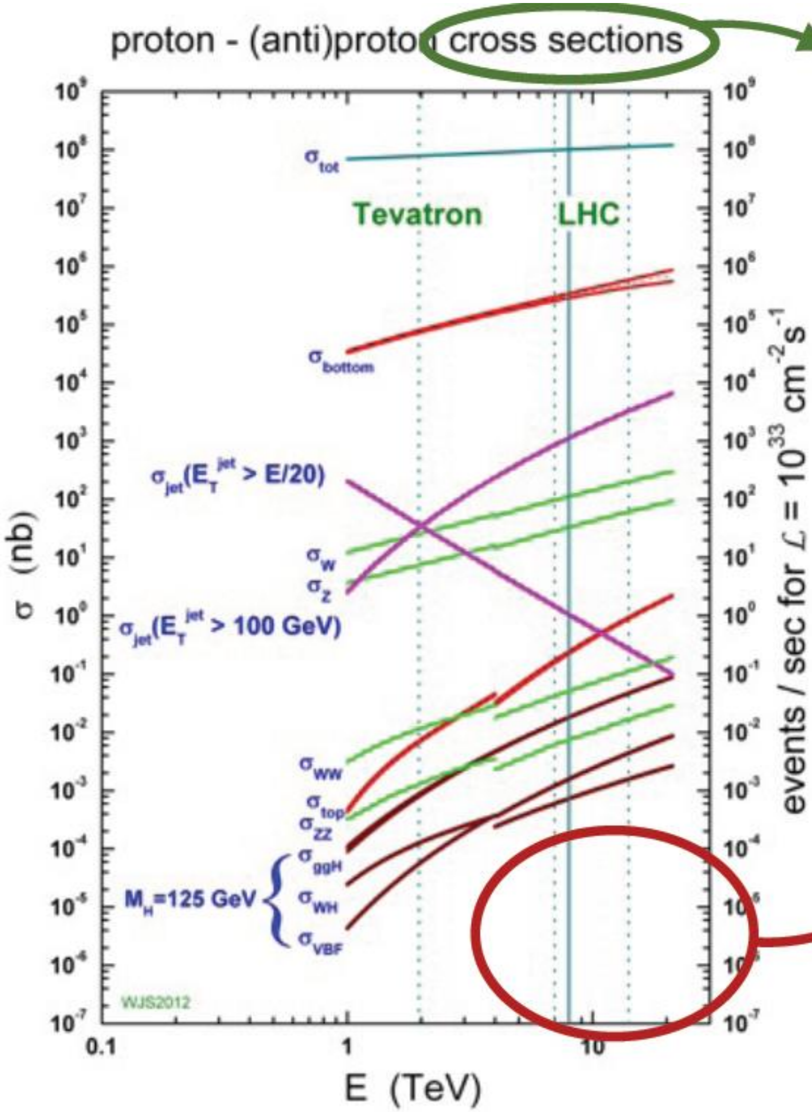
The SM is now complete?

⇒ What is next?

P5 Report (2014.5.22)



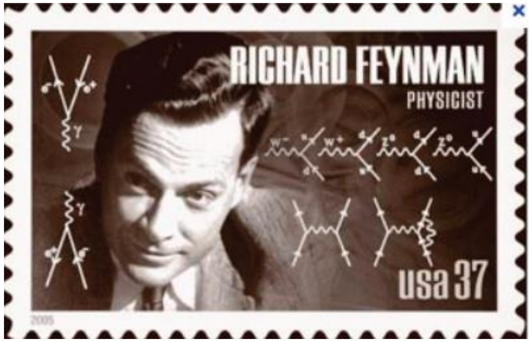
Beyond the Standard Model

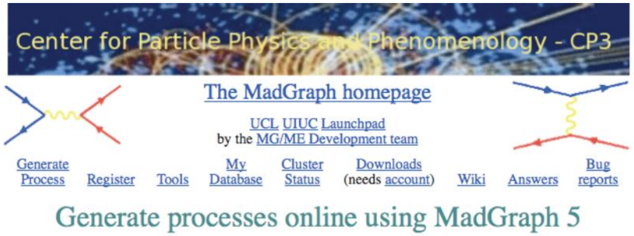


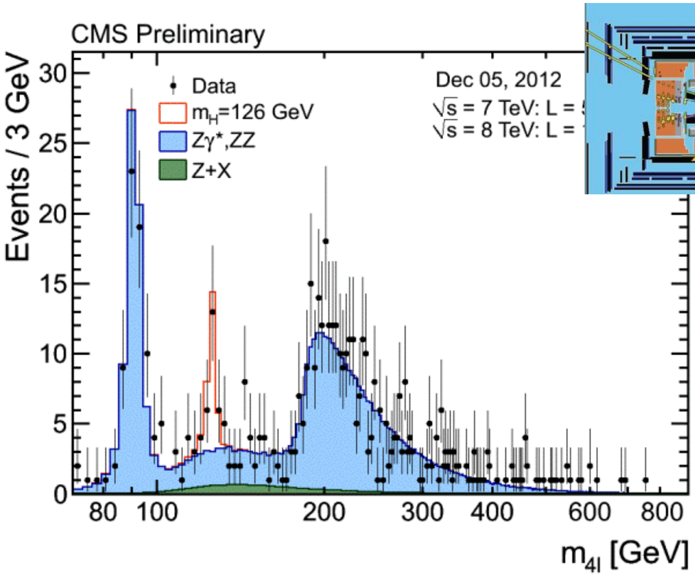
= production rate: to be calculated

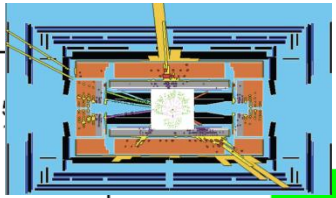
- This is where any new phenomenon would hide
  - Supersymmetry
  - Extra-dimensions
  - Grand-Unified Theories
  - *etc.*
- Cross sections = production rate
  - 1 possible new physics event (if any)
  - 1.000 Higgs events
  - 1.000.000.000.000 Standard Model events

HEP Simulation









New Physics Model

⇓ ⇒ Feynman rules calculation

FeynRules

⇓ ⇒ Model implementation

MadGraph/CalcHEP

⇓ ⇒ Process creation

PYTHIA

⇓ ⇒ Event generation (physics)

PGS/Delphes/Geant4

⇓ ⇒ Detector simulation

MadAnalysis/ROOT/Mathematica

We focus on MadGraph & Geant4.

- Geant4 is the most successful model in HEP.
- HEP user community – BaBar(2001), LHC(2003), Belle II
- Other community: Medical, Space, DNA physics, Solid

Vision for HEP Simulation

- To have a massively parallelized particle transportation engine
- To comply with different architecture (GPU, MIC and etc.)
- To draw community interests for collateral effort

P5 report Enabling R&D (Computing)

- The recent *Report from the Topical Panel Meeting on Computing and Simulations in High Energy Physics* articulated the challenges involved in meeting the increasing computational needs of the field and suggested steps to take full advantage of cost-effective computing solutions. The present practice is to handle much of the computing within individual projects. Rapidly evolving computer architectures and increasing data volumes require effective crosscutting solutions that are being developed in other science disciplines and in industry. Mechanisms are needed for the continued maintenance and development of major software frameworks and tools for particle physics and long-term data and software preservation, as well as investments to exploit next-generation hardware and computing models. Close collaboration of national laboratories and universities across the research areas will be needed to take advantage of industrial developments and to avoid duplication.

- **Recommendation 29: Strengthen the global cooperation among laboratories and universities to address computing and scientific software needs, and provide efficient training in next-generation hardware and data-science software relevant to particle physics. Investigate models for the development and maintenance of major software within and across research areas, including long-term data and software preservation.**

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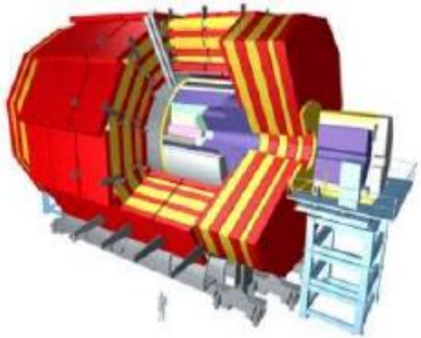
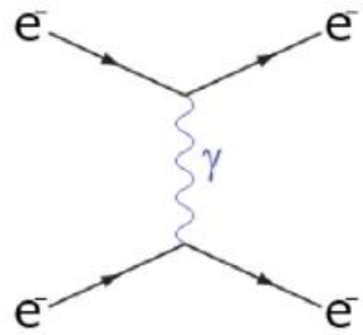
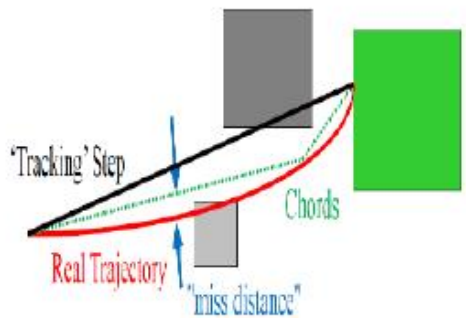
⇒ Evolving Computing Architecture

Overview of key components





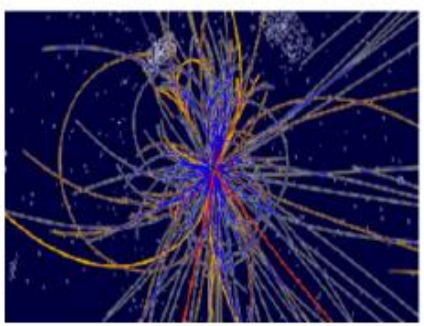


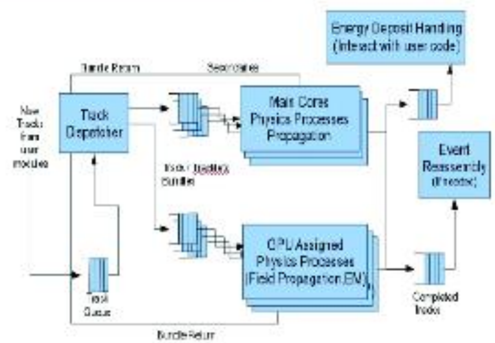
Detector and Magnetic Field

EM Physics and pRNG

Navigation and Transportation

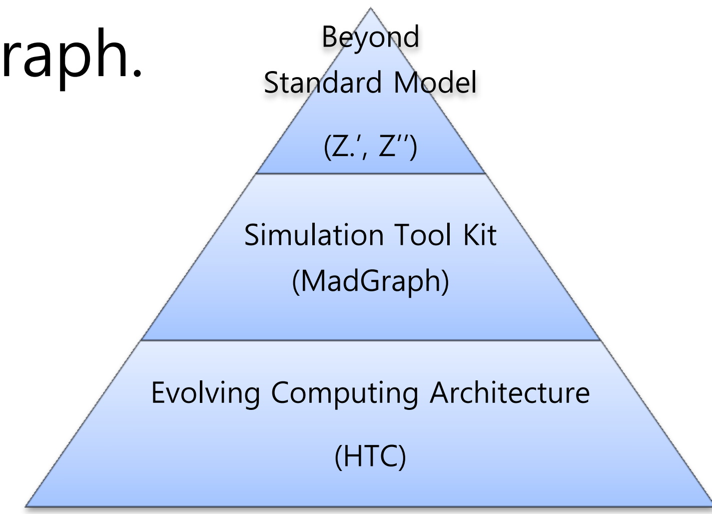
Primary/Secondary Particles → GPU Engine (CUDA C/C++) → Track Dispatcher





1. HTC module into MadGraph

- We embed HTC module into MadGraph.
  - ⇒ Korean Economic News (2014.10.31)
- Then, using it we study BSM.
  - ⇒ arXiv: 1412.1541 [hep-ph]



11/6/2014 KISTI, 대규모 계산처리 시스템 '에이치티시아스'...세계적으로 사용된다

한국경제

기사프린트 창닫기

입력: 2014-10-31 15:58:43 / 수정: 2014-11-04 09:09:30

KISTI, 대규모 계산처리 시스템 '에이치티시아스'…세계적으로 사용된다

한국과학기술정보연구원(KISTI)이 개발한 '다중 응용 및 사용자 지원 대규모 계산 작업 처리 시스템(에이치티시아스·HTCaaS)'이 세계적으로 인정받고 있다.

31일 KISTI에 따르면 에이치티시아스(HTCaaS)는 분산된 컴퓨팅 자원을 하나의 통합된 형태로 연동하는 시스템이다. 대규모 계산 시 소요되는 시간을 대폭 단축할 수 있다.

최근 국제적인 고에너지 입자물리 시뮬레이션 소프트웨어 패키지인 매드그래프 5(MadGraph5)에 에이치티시아스 연동 모듈이 탑재됐다. 매드그래프5는 고에너지 입자 물리 분야 시뮬레이션에서 가장 많이 활용되고 있는 소프트웨어 패키지다. 힉스 입자 발견 실험에 사용된 것으로 유명하다.

기존 매드그래프5는 다양한 클러스터(여러 대의 컴퓨터들을 연결해 하나의 시스템처럼 동작하는 컴퓨터들의 집합)를 연동하기 어려운 단점이 있었다. 그러나 에이치티시아스 연동 모듈을 탑재함으로써 동시에 다양한 자원들을 효율적으로 통합해 사용할 수 있게 됐다.

ec 2014

LHC Phenomenology of Z' and Z'' bosons in the $SU(4)_L \times U(1)_X$ little Higgs model

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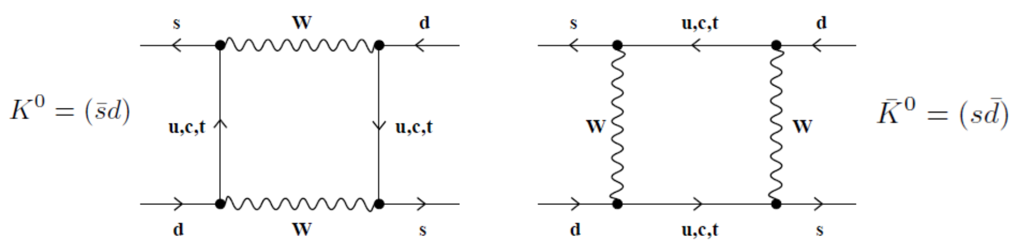
National Institute of Supercomputing and Networking, KISTI, Daejeon 305-806, Korea
(Dated: December 5, 2014)

We examine direct limits on masses of the extra neutral gauge bosons in the $SU(4)_L \times U(1)_X$ model with a little Higgs mechanism confronted with the LHC data. There exist two extra neutral gauge bosons, calling Z' and Z'', in this model. The lower exclusion limit of the mass of the lighter extra neutral gauge boson is about 3 TeV while that of the heavier one 5 TeV. For comparison, we examine the mass limit of Z'_3 boson in the $SU(3)_L \times U(1)_X$ model as well, and discuss the implication of our result in the $SU(4)_L \times U(1)_X$ model with a standard Higgs mechanism. We also discuss the discovery potential of Z' and Z'' at the future LHC with the center-of-momentum energy of 14 TeV.

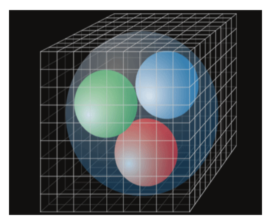
2. Finite Volume Effects on B_K

CP violation in Kaon System



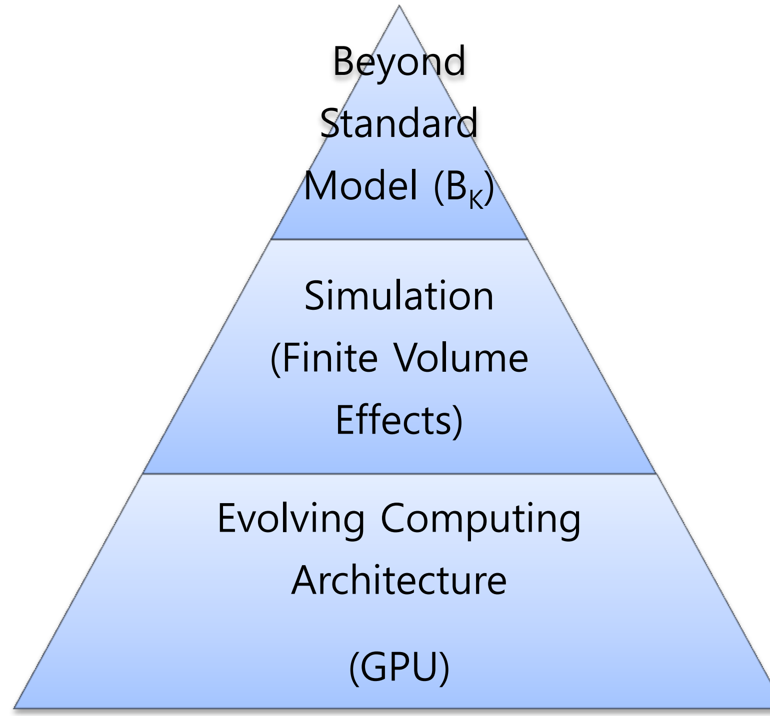
$$B_K = \frac{\langle \bar{K}_0 | [\bar{s}\gamma_\mu(1-\gamma_5)d][\bar{s}\gamma_\mu(1-\gamma_5)d] | K_0 \rangle}{\frac{8}{3}\langle \bar{K}_0 | \bar{s}\gamma_\mu\gamma_5 d | 0 \rangle \langle 0 | \bar{s}\gamma_\mu\gamma_5 d | K_0 \rangle}$$

Calculated using Lattice QCD



Error Budget of B_K

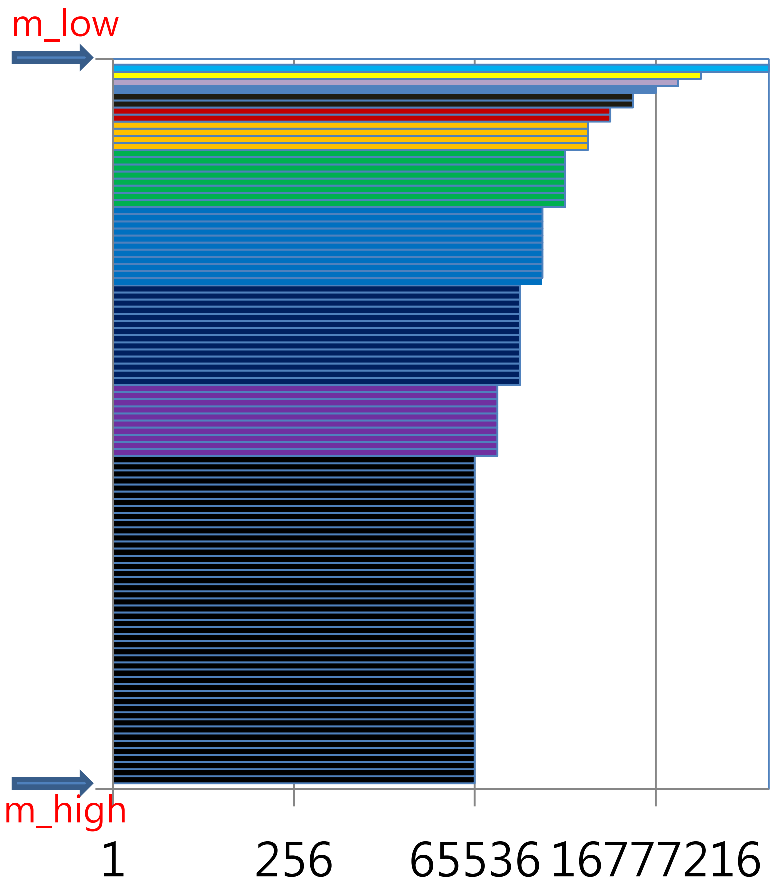
cause	error (%)	memo
statistics	0.64	
matching factor	4.4	one-loop matching
{ discretization, am_ℓ extrap, am_s extrap }	0.9	diff. of B1 and B4 fits
X-fits	0.1	varying Bayesian priors
Y-fits	2.0	diff. of linear and quad
finite volume	0.4	diff. of $V = \infty$ and FV fit
r_1	0.3	r_1 error propagation (F1)
f_π	0.1	132 MeV vs. 124.2 MeV



⇒ To reduce the error of B_K, we have to calculate the finite volume effect on the lattice.

Reference: Kim, Jangho *et al.* Phys.Rev. D83 (2011) 117501 arXiv:1101.2685 [hep-lat]

GPU programming using CUDA

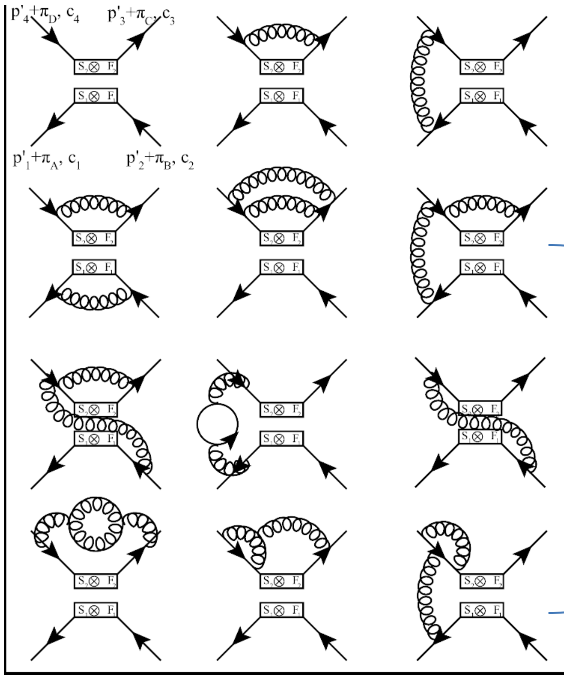


Parallel processing in GPU

Amount of calculation for FV

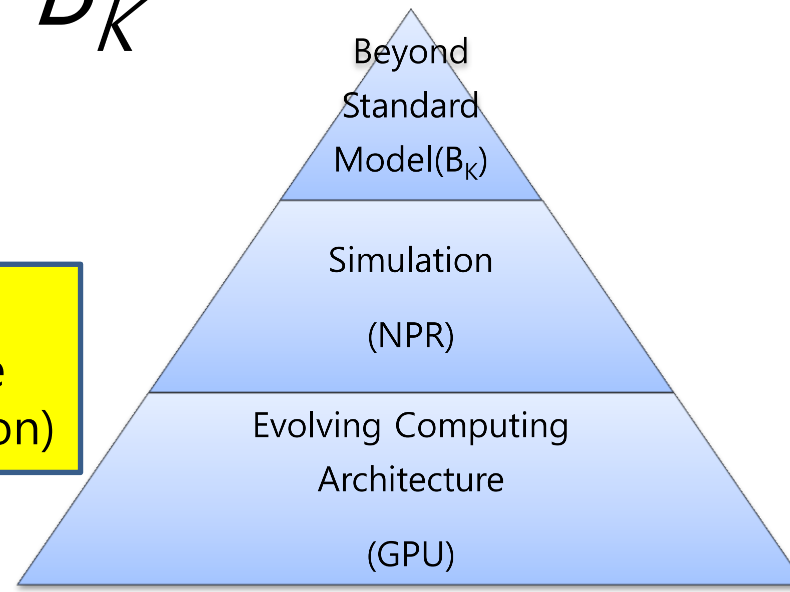
- X-axis : the number of norms.
- Y-axis : various quark masses.
- $K_{1,0}(|n|ML)$, when the pion mass is small, the number of norms becomes large.
- Calculate Bessel function for every point in this plot and sum over them for same mass.
- CPU(single core) calculates point by point in serial order.
- It takes about **two months** to calculate FV correction in double precision for all the lattice samples we have.
- If we use GPU, it takes **1 day** to calculate same thing.

3. NPR to calculate the matching factor of B_K



One-Loop

NPR (Non-perturbative Renormalization)



Error Budget of B_K

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r_1	0.3	r_1 error propagation (F1)
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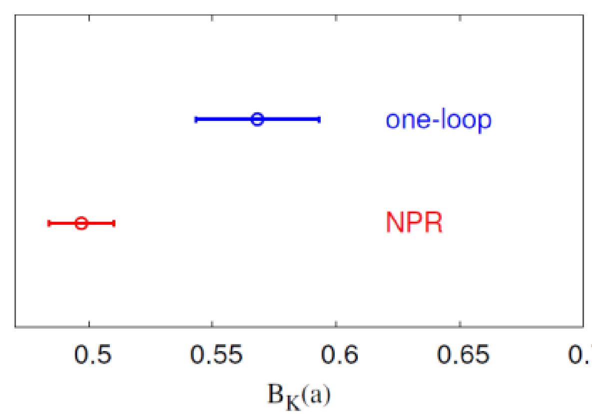
B_K in $\overline{MS}$ scheme on coarse lattice $(20^3 \times 64)$



NPR to calculate the matching factor of B_K (cont'd)

- The calculation of the Green's function for the one-color four-fermion takes 97% of total calculation time.

$$\mathrm{H}^{\alpha}_{\mathrm{i;ABCD;c_1c_2c_3c_4}}\left(\tilde{p}_1+\pi_A,\tilde{p}_2+\pi_B,\tilde{p}_3+\pi_C,\tilde{p}_4+\pi_D,\tilde{k}\right)=$$
$$\frac{1}{\mathrm{N_{conf}}}\sum_i^{N_{conf}}(2a)^4\sum_y e^{-i\tilde{k}y}\sum_{EFGH}$$
$$\psi_{\mathrm{i;AE;c_1c_1'}}(\tilde{p}_1,y)\overline{\left(\gamma_{S_1}\otimes\xi_{F_1}\right)}_{\mathrm{EF}}\phi_{\mathrm{i;FB;c_2'c_2}}(\mathrm{y},\tilde{\mathrm{p}}_2)\mathrm{U}_{\mathrm{i;EH;c'_1c'_4}}(\mathrm{y})$$
$$\psi_{\mathrm{i;CG;c_3c_3'}}(\tilde{p}_3,y)\overline{\left(\gamma_{S_2}\otimes\xi_{F_2}\right)}_{\mathrm{GH}}\phi_{\mathrm{i;HD;c_4'c_4}}(\mathrm{y},\tilde{\mathrm{p}}_4)\mathrm{U}_{\mathrm{i;FG;c'_2c'_3}}(\mathrm{y})$$

  - ψ,ϕ: quark propagator.
  - U : gauge link.
  - α : indicates operator in the Green's function ($[S_1\otimes F_1][S_2\otimes F_2]$).
  - i : gauge configuration index.
  - N_{conf}: the number of gauge configurations.
  - a : lattice spacing.
  - $\mathrm{A,B,C,D,E,F,G,H}$: hypercubic vectors:
    - for example, $\mathrm{A}=(1,1,0,0)$. 16 cases are possible.
  - $\mathrm{c_1,c_2,c_3,c_4}$: color index (0 ~ 2).
  - z : lattice site whose spacing is $2a$.
  - $\mathrm{z_A}=2\mathrm{z}+\mathrm{A}$.

Reference: Hwancheol Jeong, Jangho Kim *et al.* PoS(LATTICE2014)286 (2014) arXiv:1410.6607[hep-lat]

GPU Performance

Program	CPU		GPU			GPU vs. CPU
	CPU Spec.	GFLOPS	VGA (Peak Performance in double precision)	GFLOPS	Optimi-zation	
Finite Volume Effect of B_K	Xeon E5-2620	0.5	GTX 480 (168 GFLOPS)	64.3	38%	128.6
Non-perturbative Renormalization(NPR) measurement	Core i7-4820K	1.13	GTX 480 (168 GFLOPS)	66.6	40%	58.9
			GTX 580 (198 GFLOPS)	76.19		67.2
			GTX Titan Black (1707 GFLOPS)	113.36		100.3

- NPR measurement code is optimized for GTX 480.

Summary

- Physics goes beyond discovery.
- Computing needs solutions for the evolving architecture.

⇒ To fulfill the gap between physics and computing, we need to focus on simulation R&D.

Acknowledgement

- Dr. Soo-hyeon Nam
- Dr. Soon Yung Jun
- Prof. Weonjong Lee