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# Physics beyond the Standard Model in the evolving computing architecture of the KISTI-5 supercomputer

2019. 11. 7

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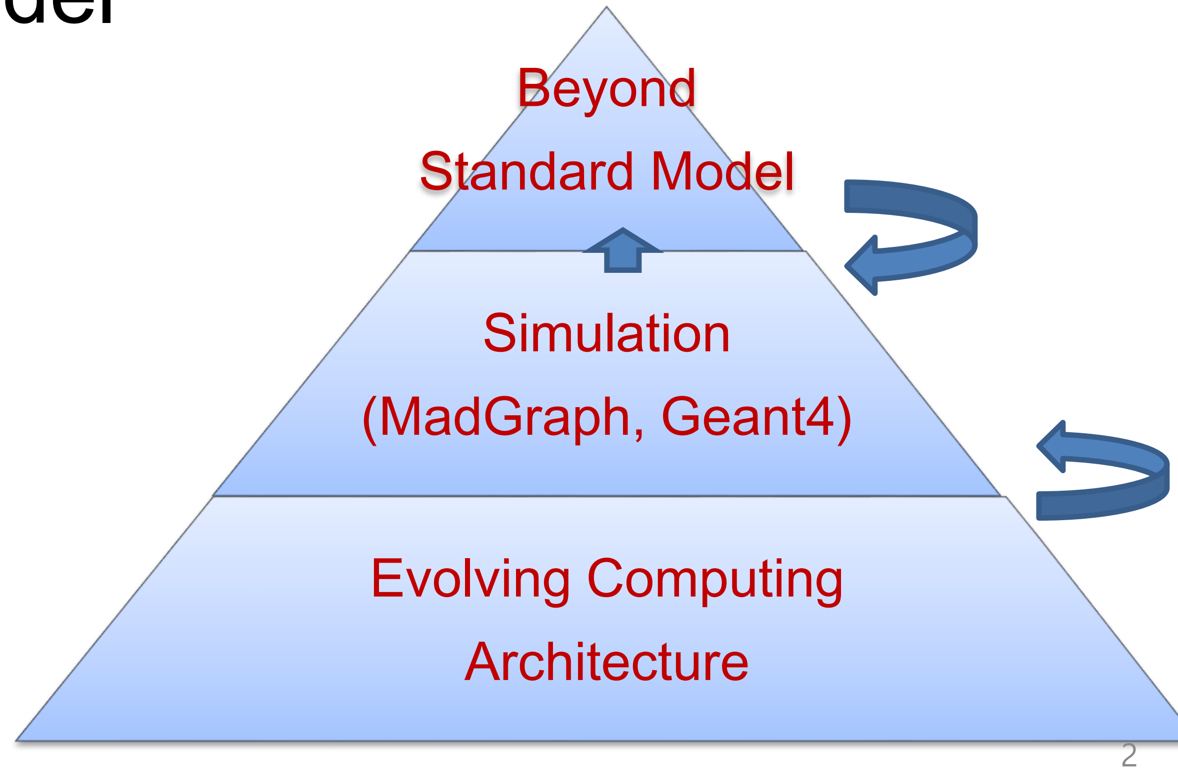
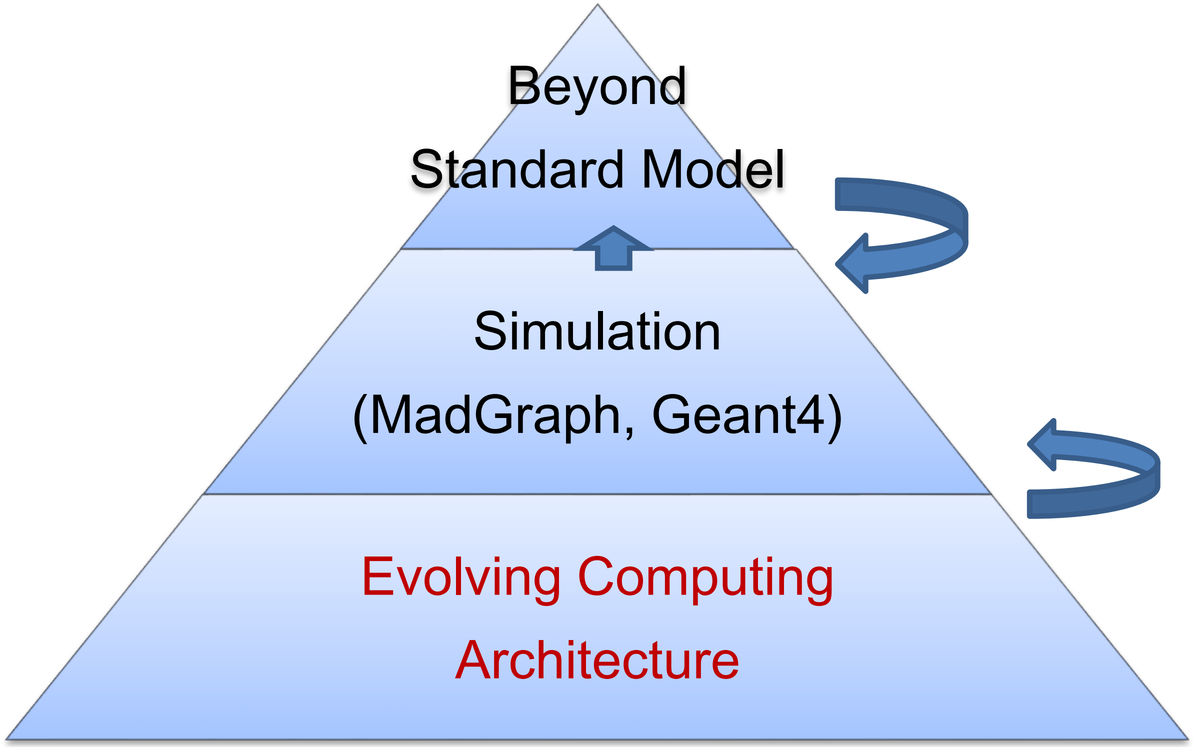


# Evolving Computing Architecture



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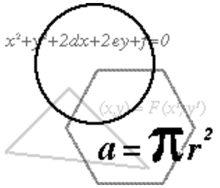
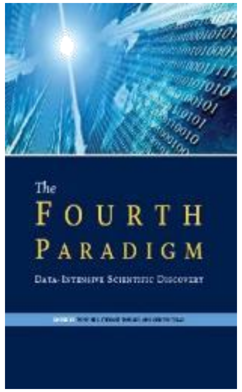
# The changing nature of scientific research

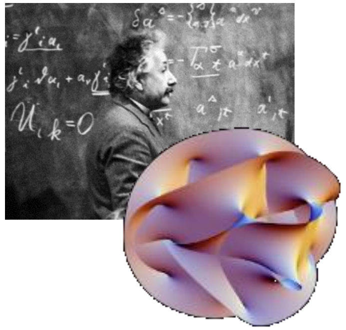


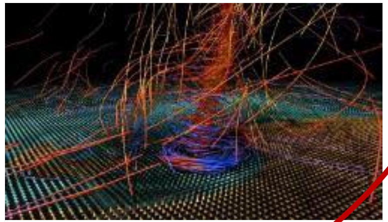

$$H(t)|\psi(t)\rangle = i\hbar\frac{\partial}{\partial t}|\psi(t)\rangle$$




Experimental → Theoretical → Computational Simulation → Big Data and Machine Learning

Large Hadron Collider





Severe Storm Model (NCSA)

ARRAY OF THINGS

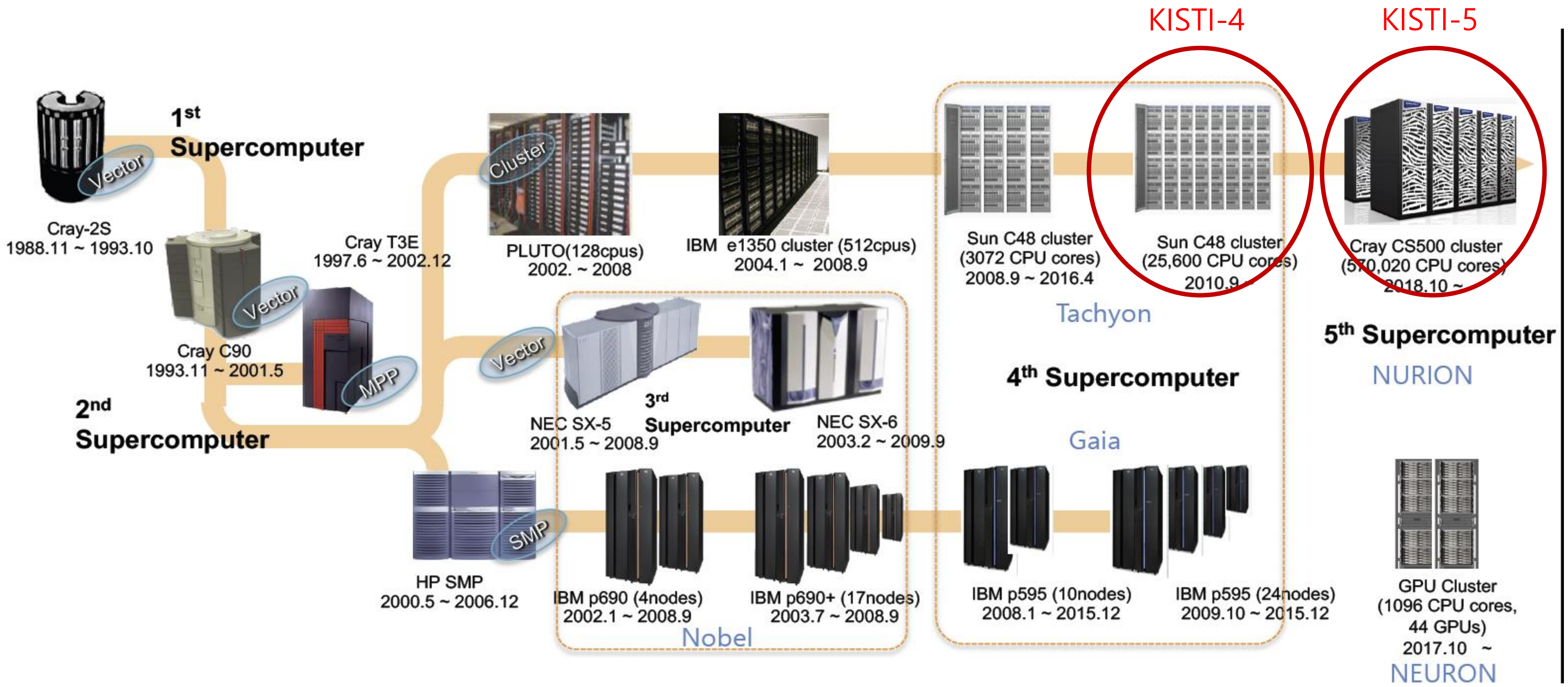
e-Science



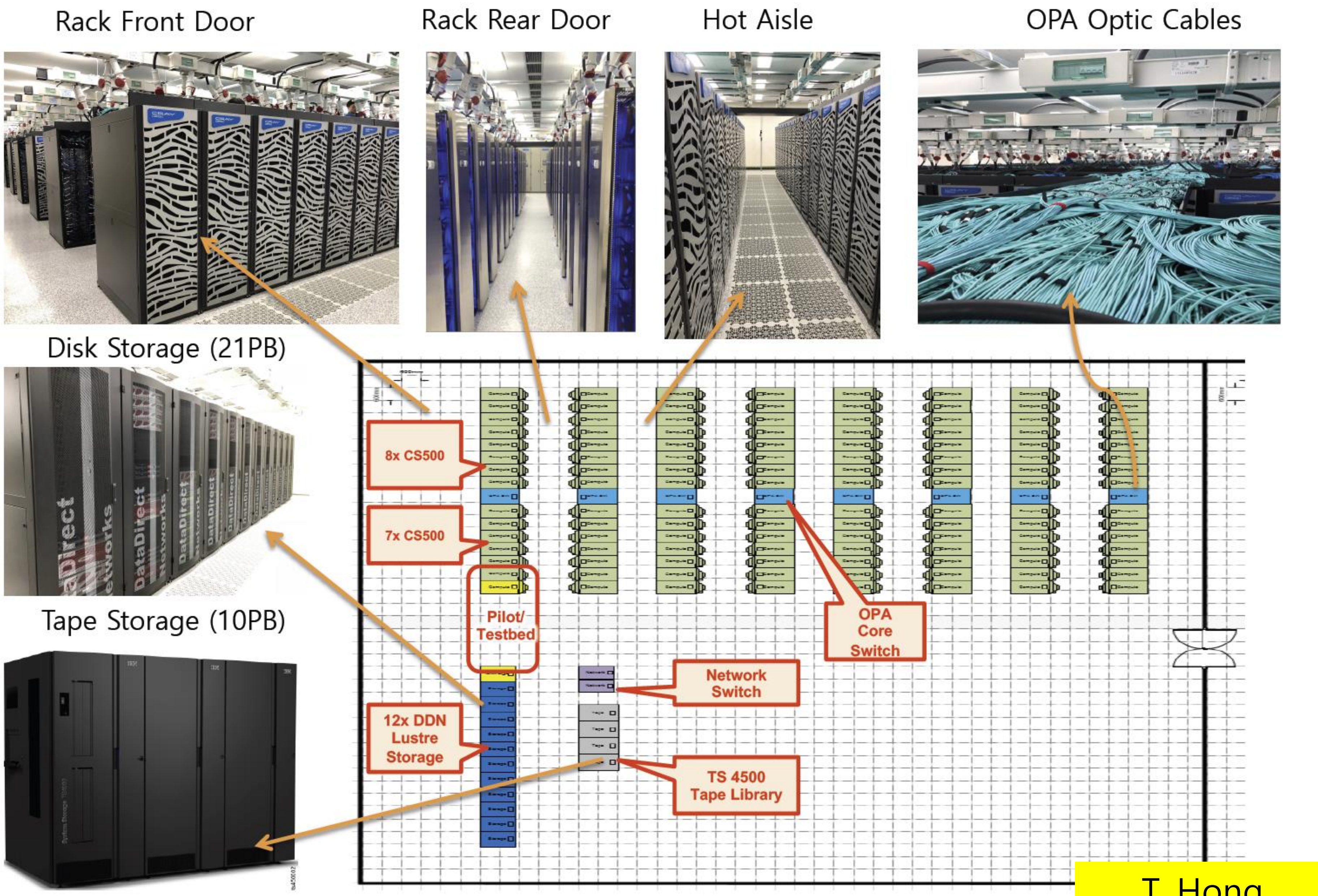
Prof. D. Reed

# Evolving Computing Architecture

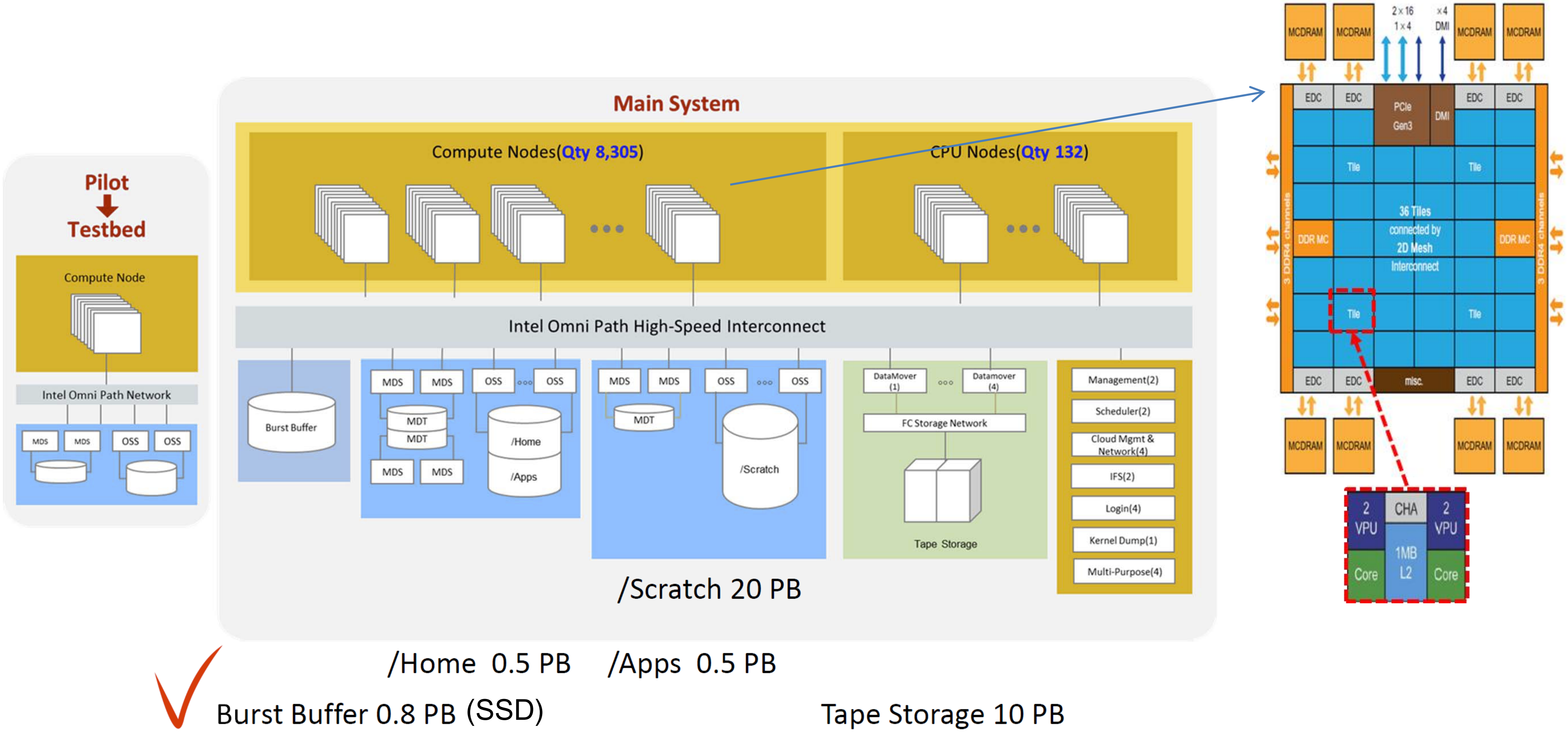
- KISTI Supercomputing Center
  - KISTI-4 ⇒ KISTI-5



# KISTI-5 supercomputer


Rack Front Door
Rack Rear Door
Hot Aisle
OPA Optic Cables
Disk Storage (21PB)
Tape Storage (10PB)
8x CS500
7x CS500
Pilot/ Testbed
OPA Core Switch
Network Switch
12x DDN Lustre Storage
TS 4500 Tape Library

# Architecture of KISTI-5 supercomputer




@ Available KNL CORE Time = Available SRU Time x 4,352

@ Available SKL CORE Time = Available SRU Time x 1,280

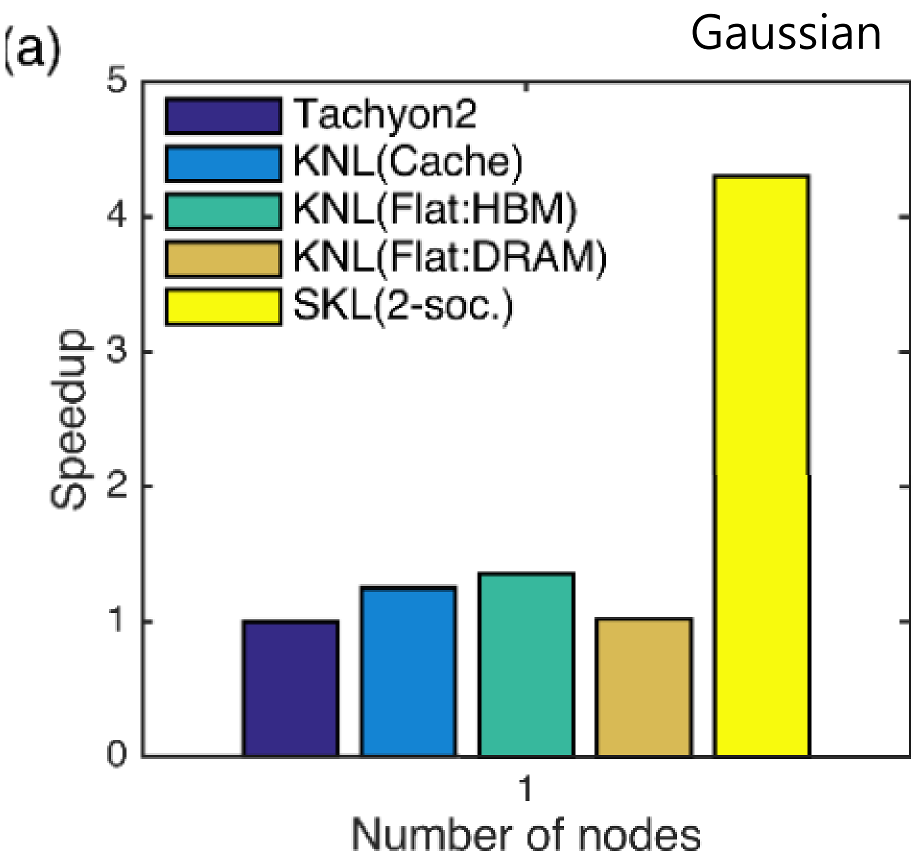
1 account: 20,000 CPU*hour

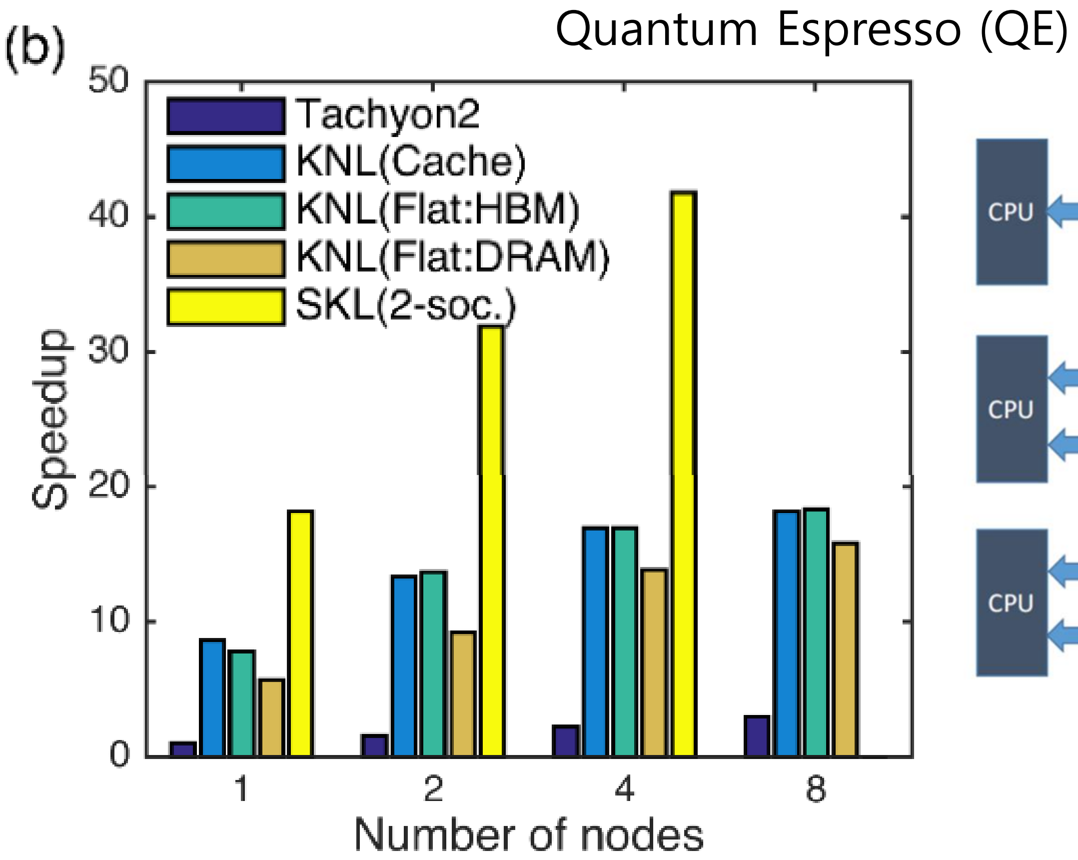
M.S. Joh

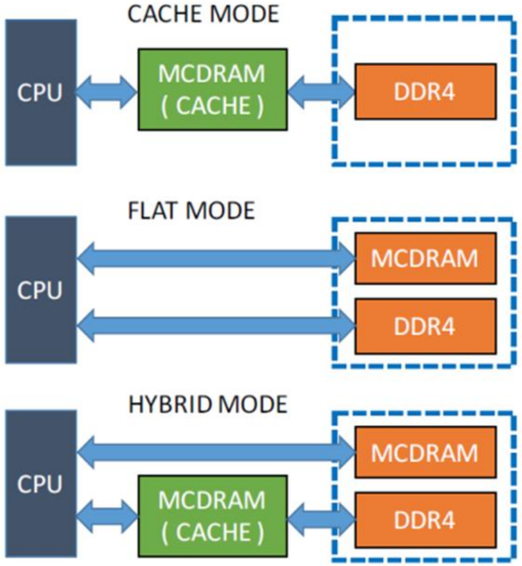
# KISTI-4 vs. KISTI-5

| Specification | KISTI-4 | KISTI-5 | |
|---|---|---|---|
| Name | Tachyon2 | Nurion KNL | Nurion Skylake |
| Model | SUN Blade 6275 | Cray C5500 | |
| Process | Intel Xeon X5570<br>(Nehalem)<br>2.93GHz | Intel Xeon Phi 7250<br>(KNL)<br>3.0464 TFlops/CPU | Intel Xeon 6148<br>(Skylake)<br>1.536 TFLops/CPU |
| Node | 8core/node<br><br>3,200 node | 68core/CPU<br>1CPU/node<br>8,305 node | 20core/CPU<br>2CPU/node<br>132 node |
| Core | 25,408 | 564,740 | 5,280 |
| Rpeak | 0.3 Pflops | 25.3 Pflops | 0.4 Pflops |
| Memory | DDR3/1333MHz<br><br>76.8TB | 16GBx6, 6Ch/CPU<br>96GB/node<br>778.6 TB | 16GBx12, 6Ch/CPU<br>192GB/node<br>24.8 TB |
| Storage | 234 TB disk<br>2.3 PB disk<br><br>2.1 PB Tape | 21 PB disk<br>0.8 PB SSD<br><br>10 PB Tape | |
| Interconnect | Infiniband 40G 4XQDR | OPA@12.3GB/s Fat-Tree, 50% Blocking | |
| Service date | 2010.8~2018.11 | 2018.10~ | |

# KISTI-4 vs. KISTI-5



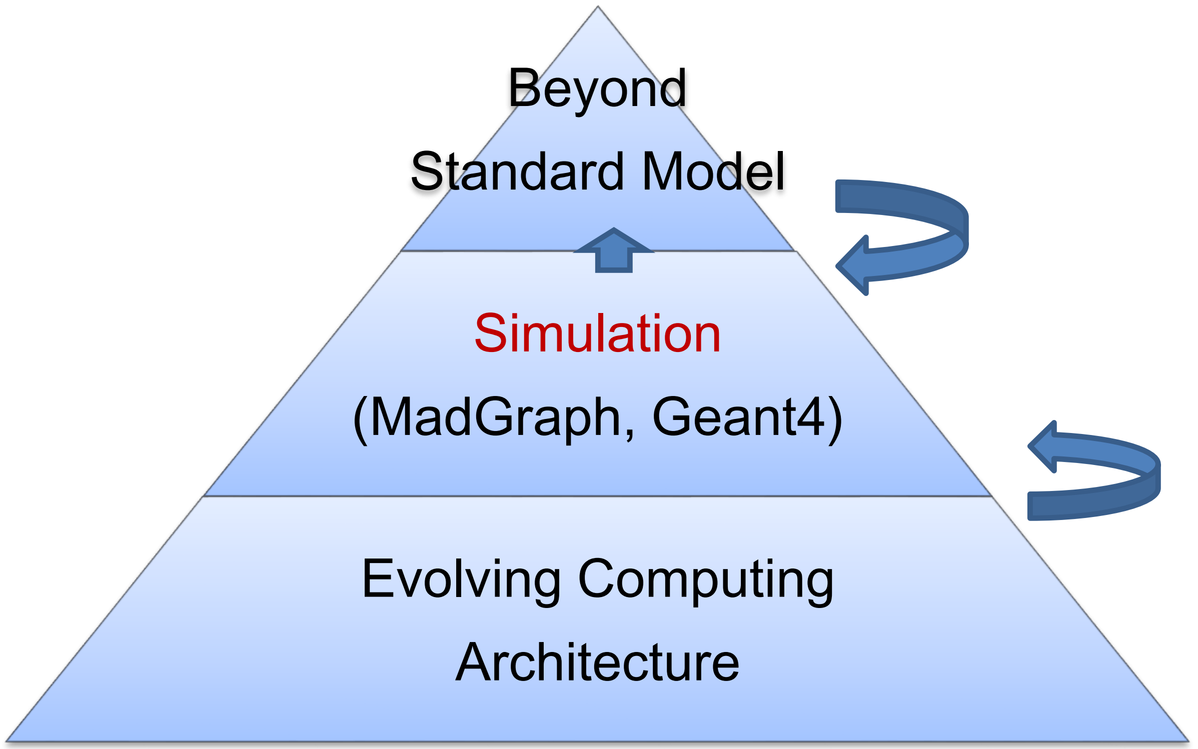




- No significant performance improvement for Gaussian
- ~8x performance improvement for QE on single node.

⇒ How about HEP simulation?

# Simulation





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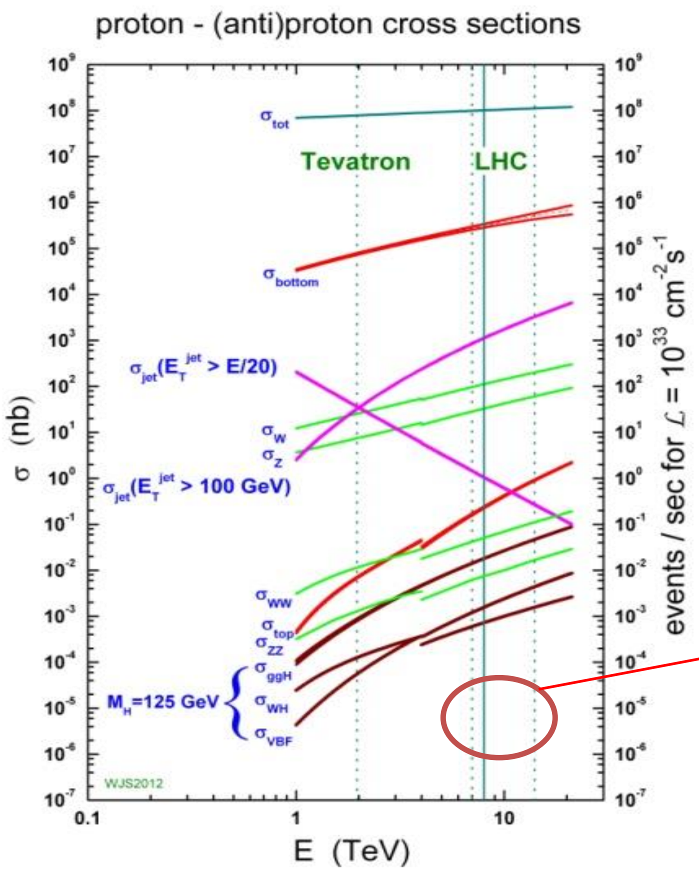
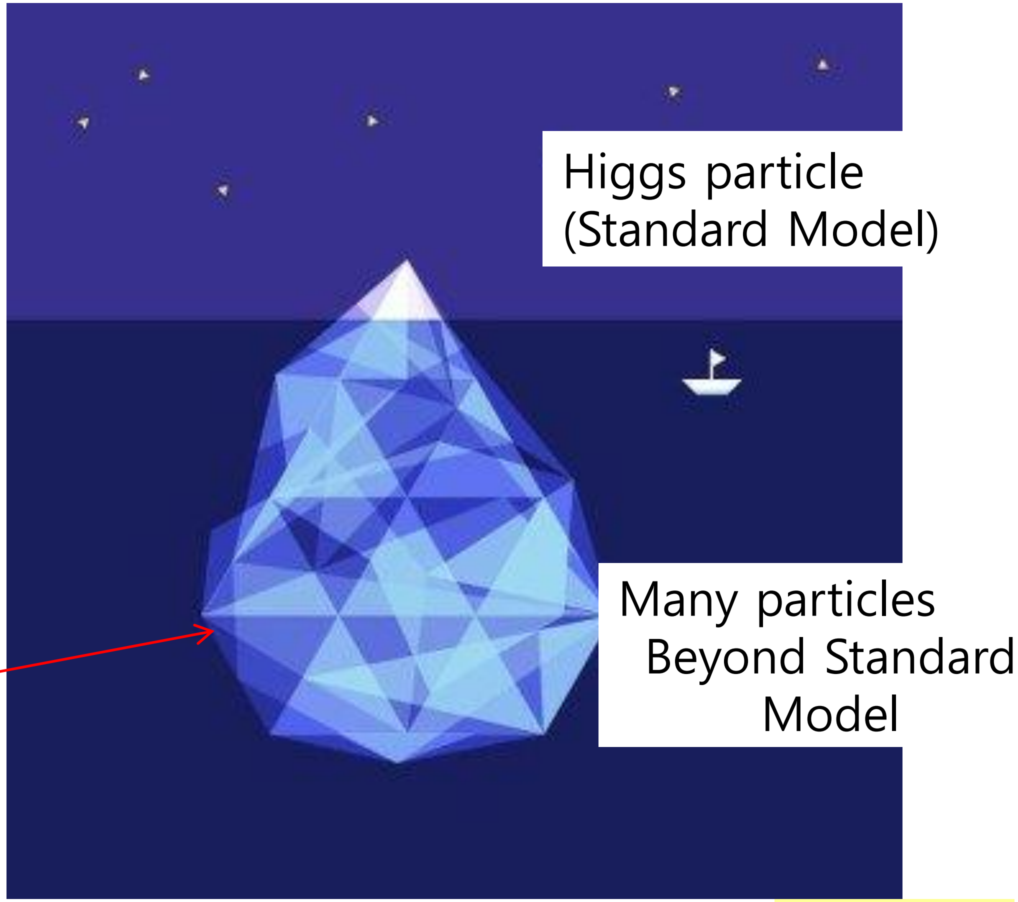
# Beyond the Standard Model



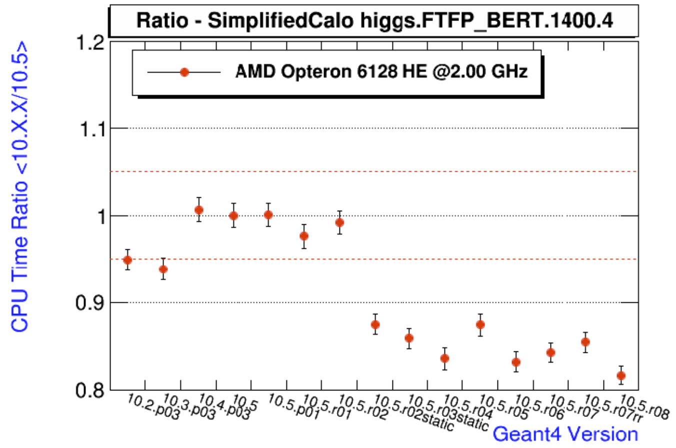

Adam Martin

⇒ BSM needs at least 1000 more Higgs events

⇒ Simulation S/W upgrade needed

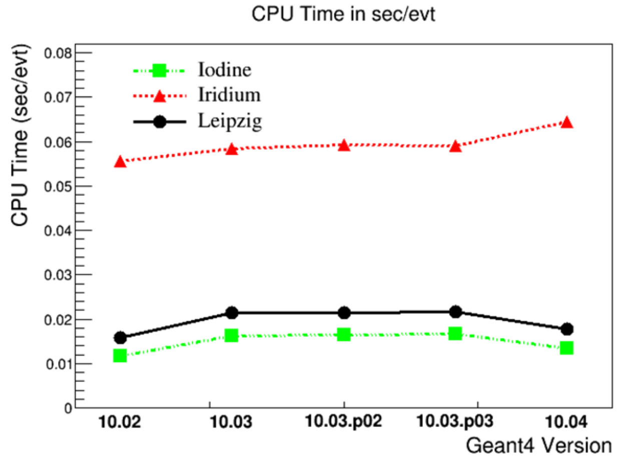
# Geant4 Profiling system

- Current status
  - High energy physics profiling (Fermilab)
    - SimpliCarlo (Sequential)
    - CMSExp (Multi-Thread)
  - Low energy physics profiling (KISTI)
    - Using Brachytherapy code
    - Sequential
    - KISTI-4 vs. KISTI-5 (KNL and SKL)
    - CPU time and Memory



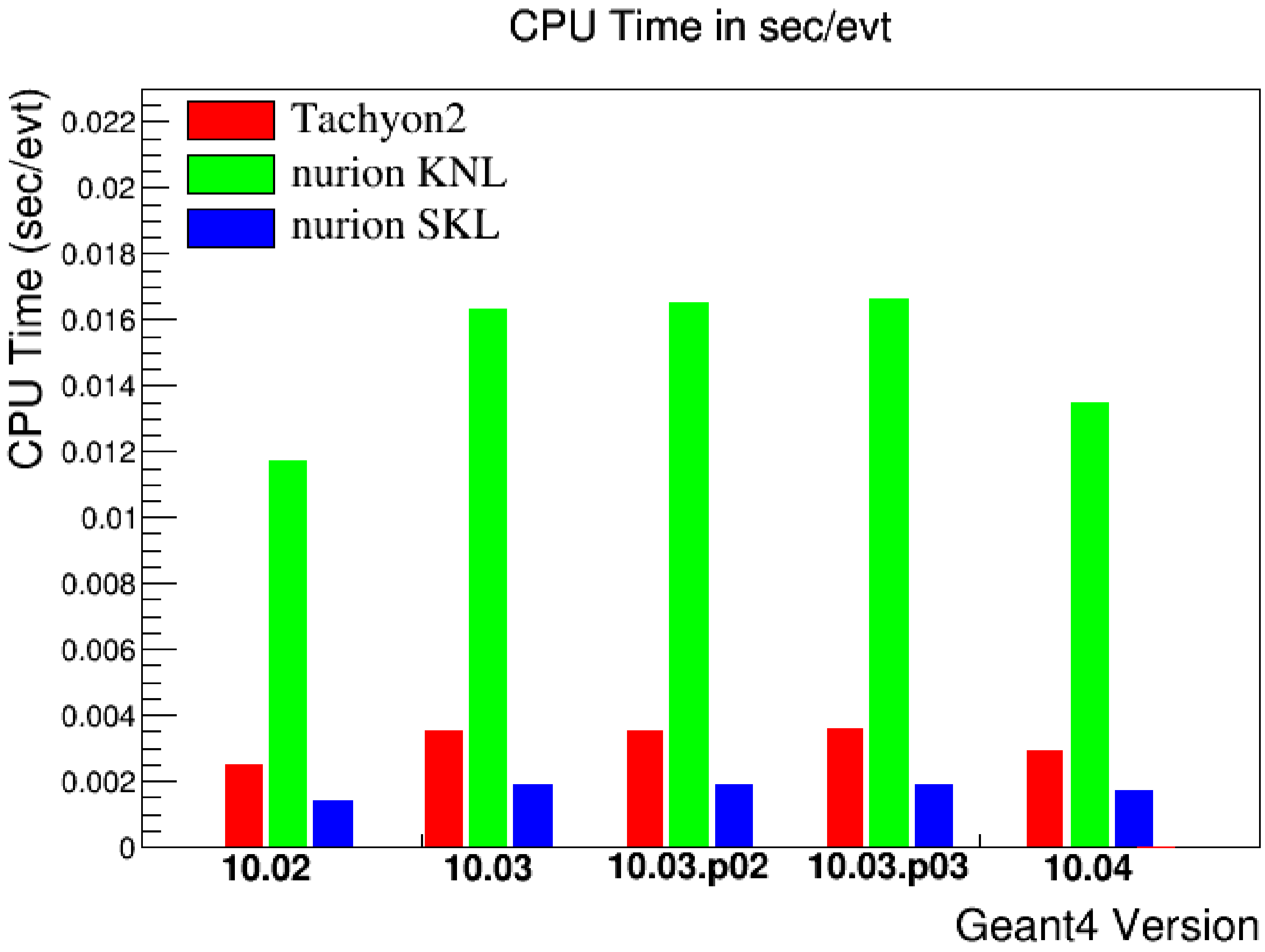

Julia Yabara

KISTI-5 KNL



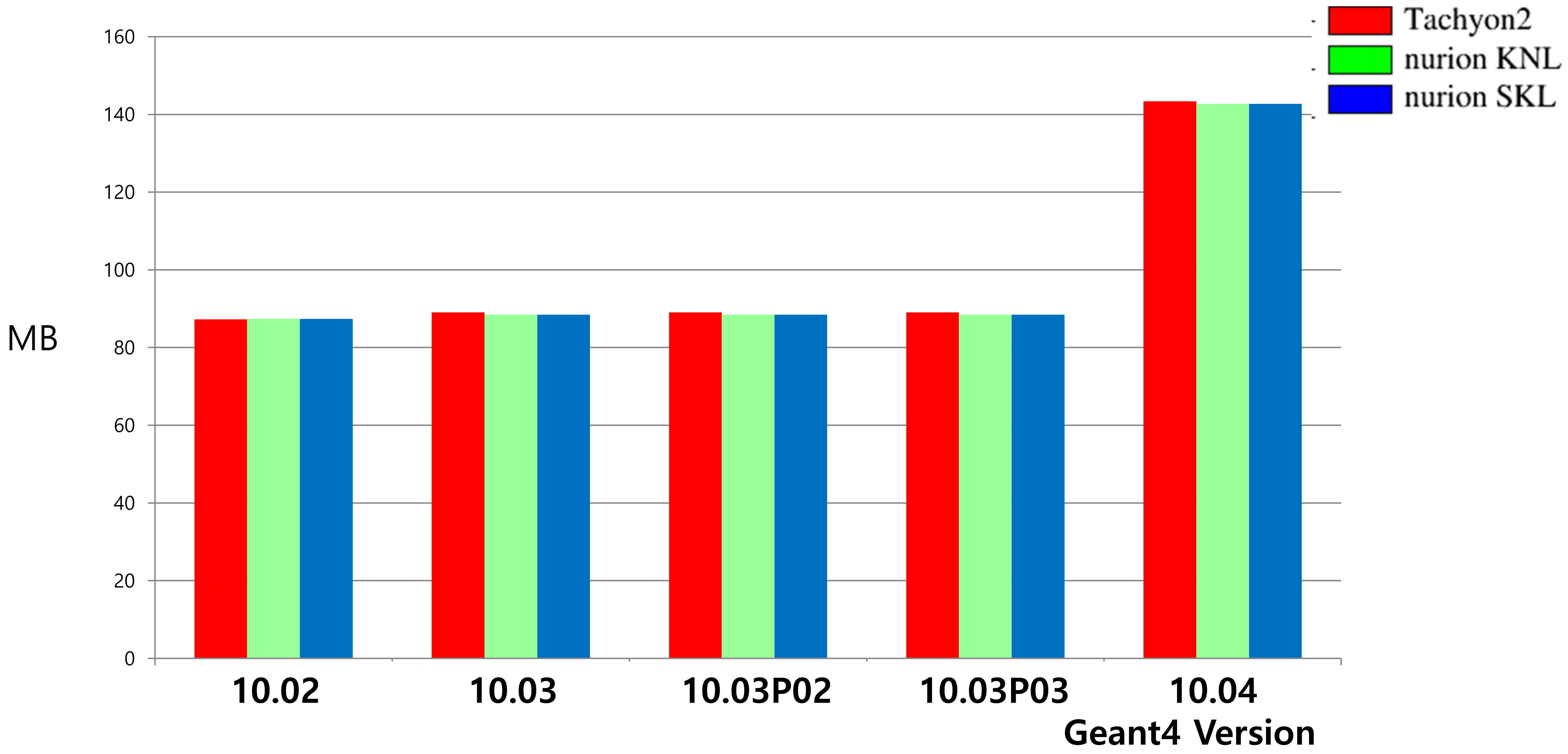
QGSP_BIC_EMZ (Iodine)

# CPU Time



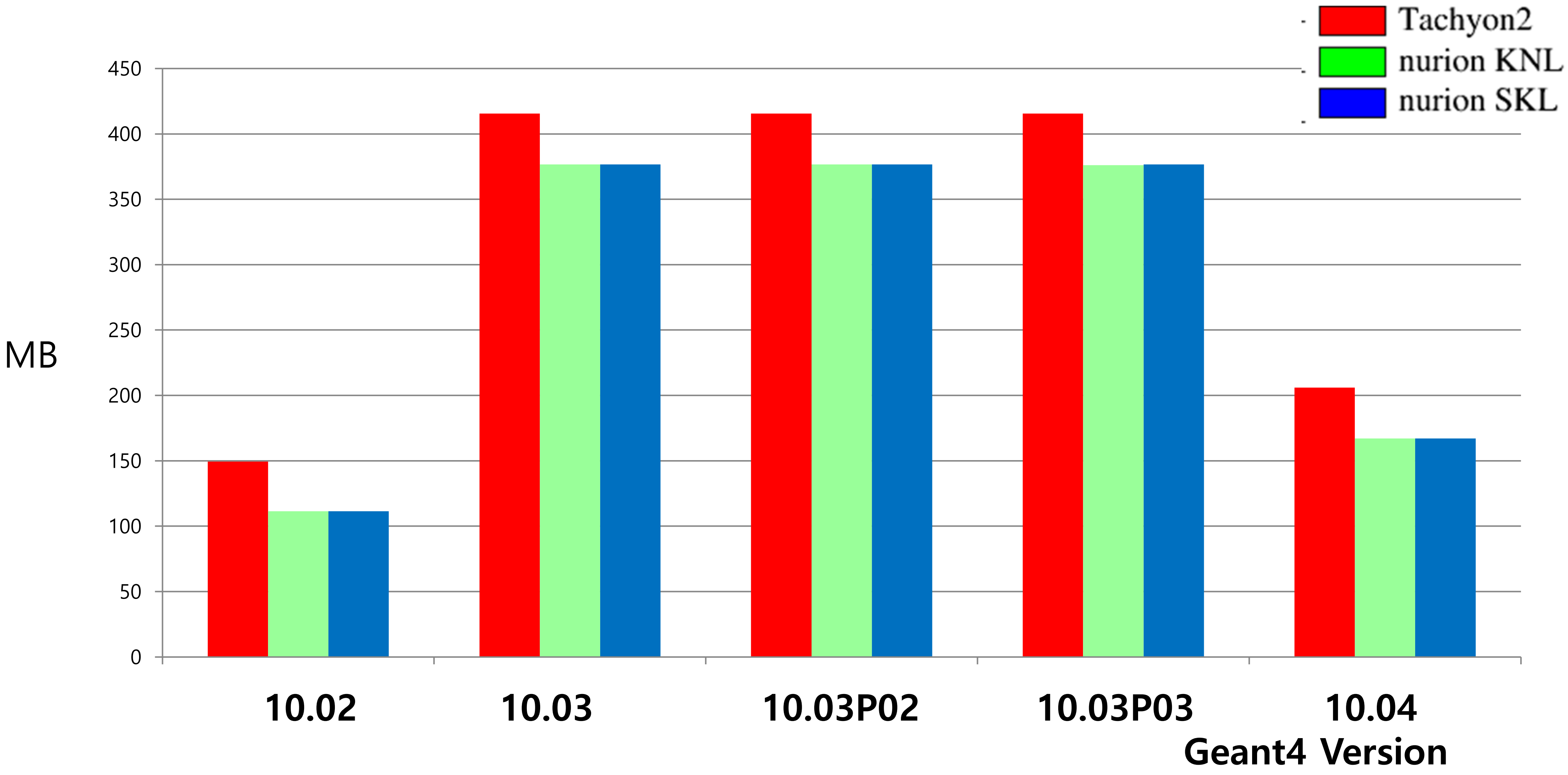
QGSP_BIC_EMZ (Iodine)

# Total memory in count (First event)



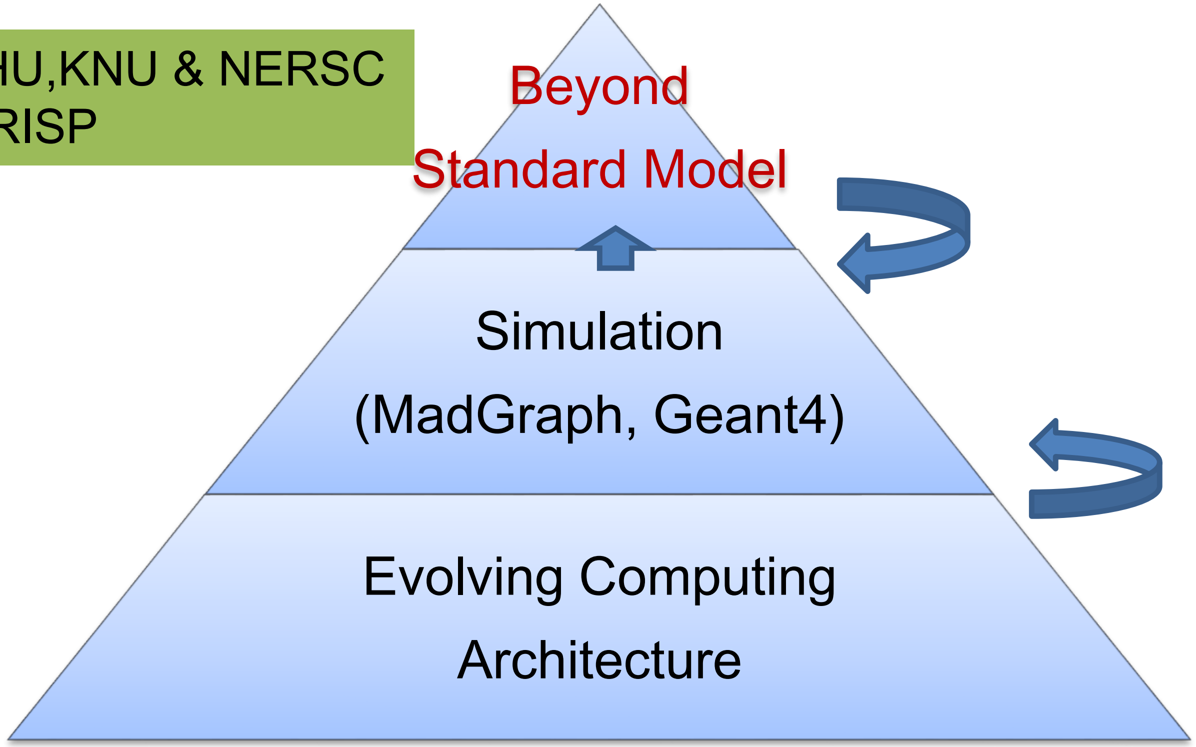
QGSP_BIC_EMZ (Iodine)

# Total Memory in count (Last event)



# Beyond Standard Model

- Deep Learning for BSM with KHU,KNU & NERSC
- Evolution of Universe with IBS/RISP





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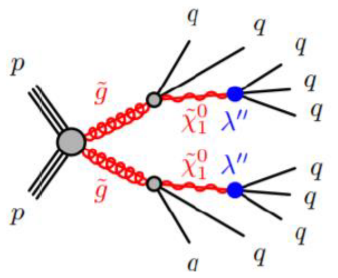
# Deep Learning for BSM

LHC experiment with KNL System ⇒ Deep Learning for SUSY search at CMS

Basic Research → Model → Large Scale → Results

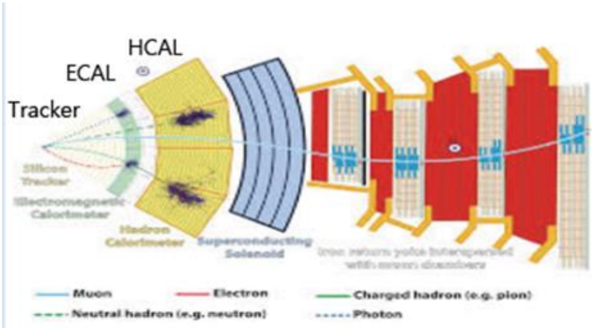
- Signal process: gluino cascade decay




$\tilde{g}$: gluino
$\tilde{X}_1^0$: Neutralino
$\lambda''$: RPV coupling

Mass(Gluino): 1400 GeV
Mass(Neutralino): 850 GeV

- Background process: QCD multi-jet process



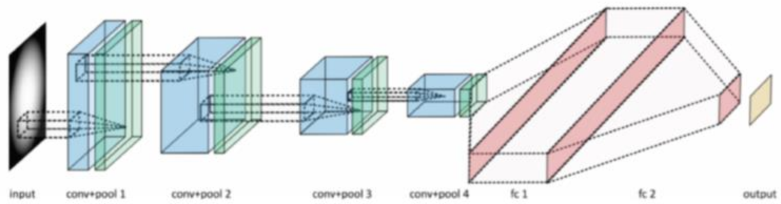

- NERSC case
  - ➢ R-parity violating SUSY with ATLAS detector fast simulation with CNN
- We explore CMS detector with similar DNN architecture, RPV SUSY & fully hadronic top quarks
- Base: Different detector, computing environment, new SW
- Improvement: realistic scenario, processes in SM

J. Goh

# Why HEP-CNN?

## Convolution Neural Network (CNN) modeling

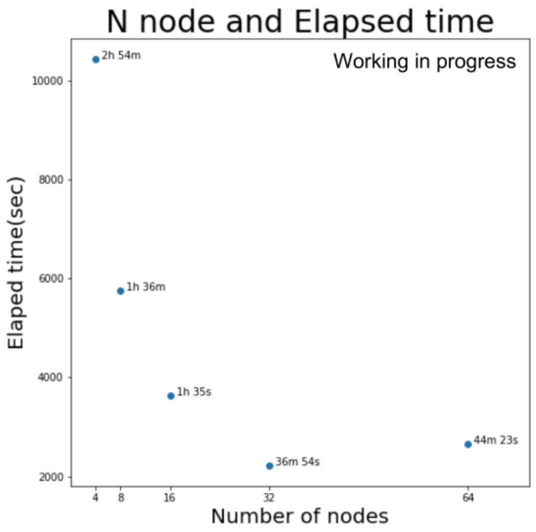
- Input: (64x64x1) image -> 3 channel merging (64x64x3) image
- 4 convolutional layers + 2 Fully connected layers



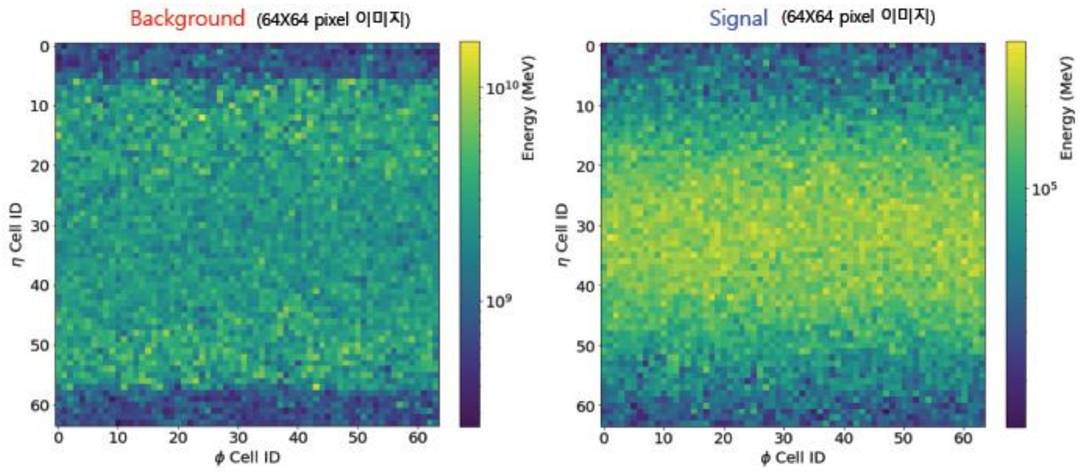

Conv+pool1: Conv:3x3 kernel 64개 1 stride 0 padding 2x2 Kernel max pooling, ReLu, Batch normalization, 0.5 dropout
Conv+pool2: Conv:3x3 kernel 128개 2 stride 0 padding 2x2 Kernel max pooling, ReLu, Batch normalization, 0.5 dropout
Conv+pool3: Conv:3x3 kernel 256개 2 stride 1 padding 2x2 Kernel max pooling, ReLu, Batch normalization, 0.5 dropout
Conv+pool4: Conv:3x3 kernel 256개 ,Batch Normalization
FC1: 512 neurons, ReLu
FC2: Sigmoid output

| Training | Validation |
|---|---|
| 400,000 | 130,000 |

256 batch size

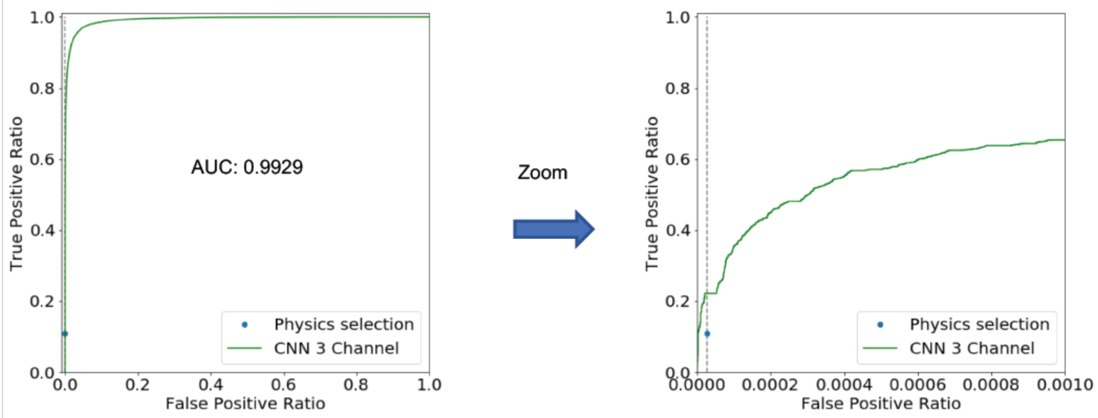



## Data visualization: ECAL




## Nurion test using 2018 dataset

| Training | Validation |
|---|---|
| 425,653 | 141,883 |

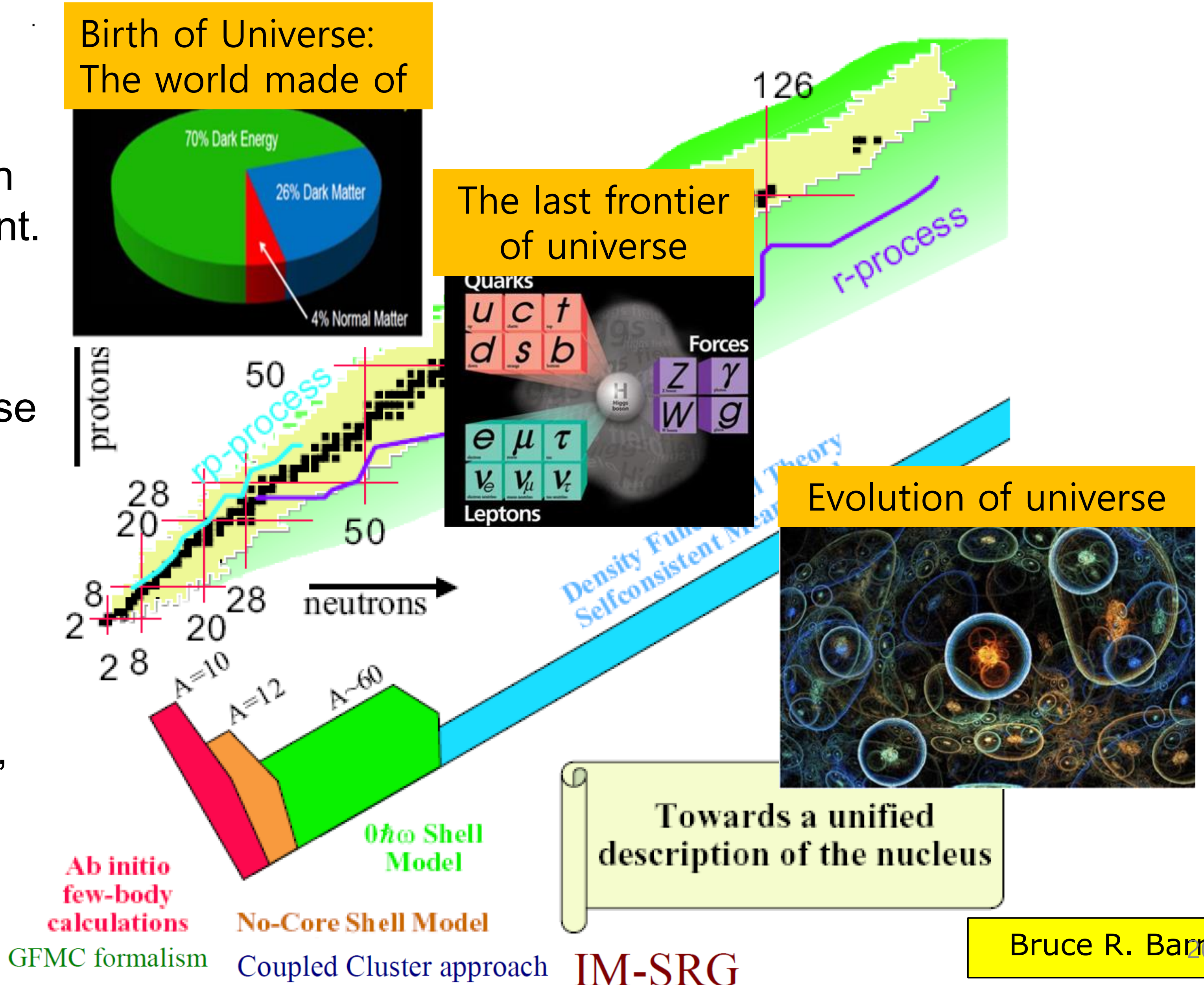



4 node, 68 cpu, 1 mpiprocs, 64 omthread, 20 Epoch, 256 batch size

C.S. Moon

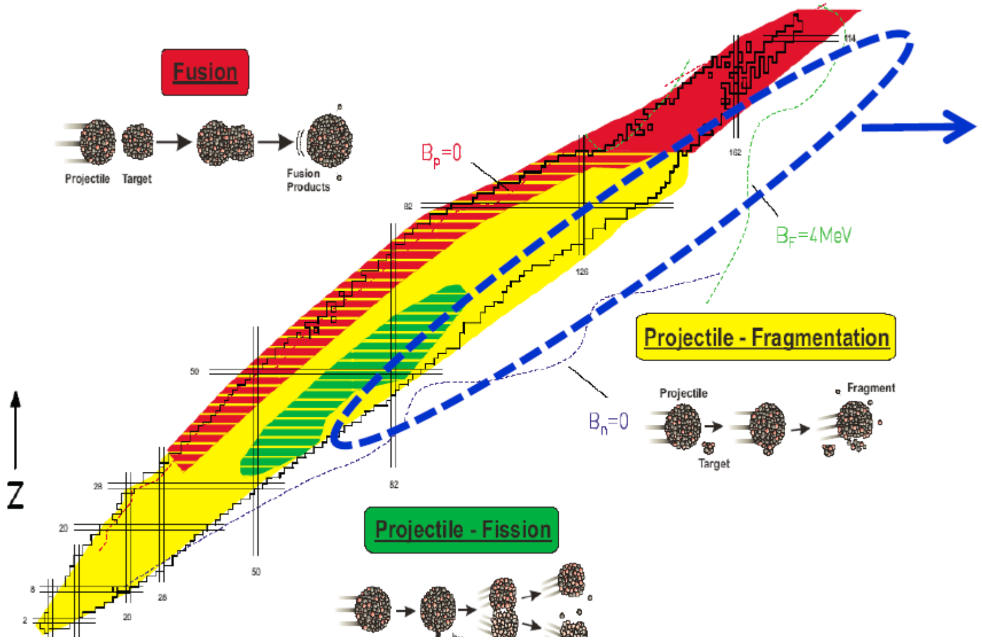
# Evolution of Universe with KISTI-5

- Dark Matter Experiment
  - The characteristic & reaction of rare isotopes are important.
- Nuclear Chart
  - The secret of birth of universe ⇒ dark matter
  - The origin of element of universe
  - The evolution of star
- Using 235 accounts of KISTI-5,




Bruce R. Barrett

# 1. Production of exotic nuclei and heavy elements




How to create nuclides with neutron numbers larger than in projectile or target?

**Multi-nucleon Transfer reactions**

PHYSICAL REVIEW C **99**, 054627 (2019)

**Possible production of neutron-rich Md isotopes in multinucleon transfer reactions with Cf and Es targets**

Myeong-Hwan Mun,[1,2] Kyujin Kwak,[2,*] G. G. Adamian,[3] and N. V. Antonenko[3,4]
[1]*Korea Institute of Science and Technology Information, Daejeon, 34141, Korea*
[2]*Ulsan National Institute of Science and Technology, Ulsan, 44919, Korea*
[3]*Joint Institute for Nuclear Research, 141980 Dubna, Russia*
[4]*Mathematical Physics Department, Tomsk Polytechnic University, 634050 Tomsk, Russia*

(Received 13 January 2019; revised manuscript received 23 April 2019; published 30 May 2019)

Possible production of neutron-rich No isotopes

Myeong-Hwan Mun
*Korea Institute of Science and Technology Information, Daejeon, 34141, Korea*

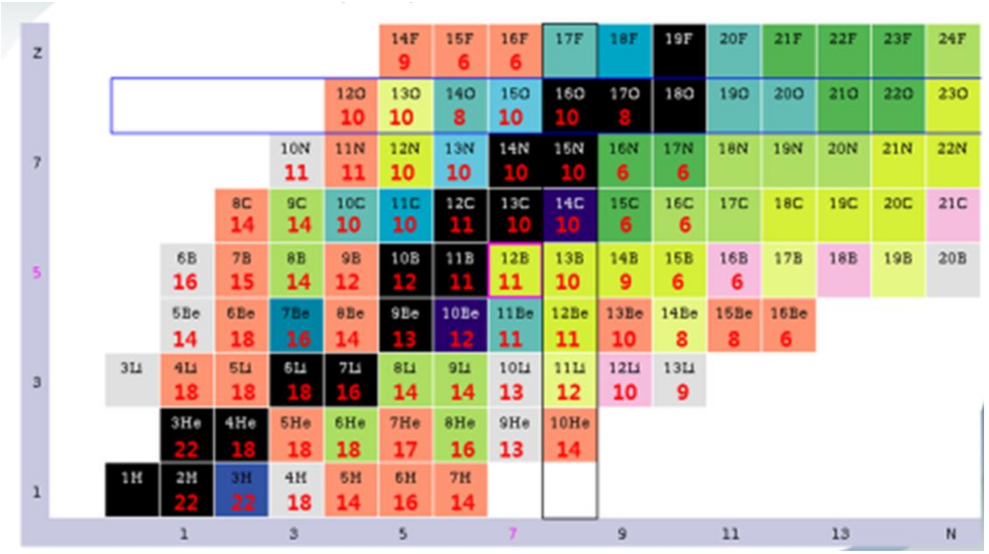
Kyujin Kwak*
*Ulsan National Institute of Science and Technology, Ulsan, 44919, Korea*

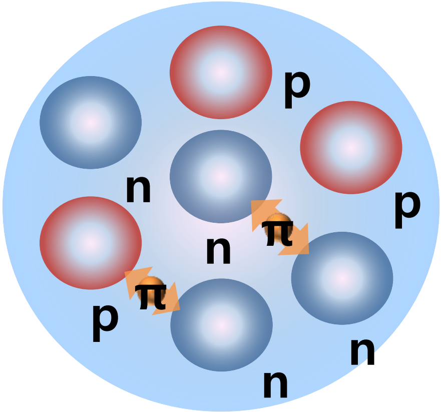
G.G. Adamian a
*Joint Institute for Nuclear R*

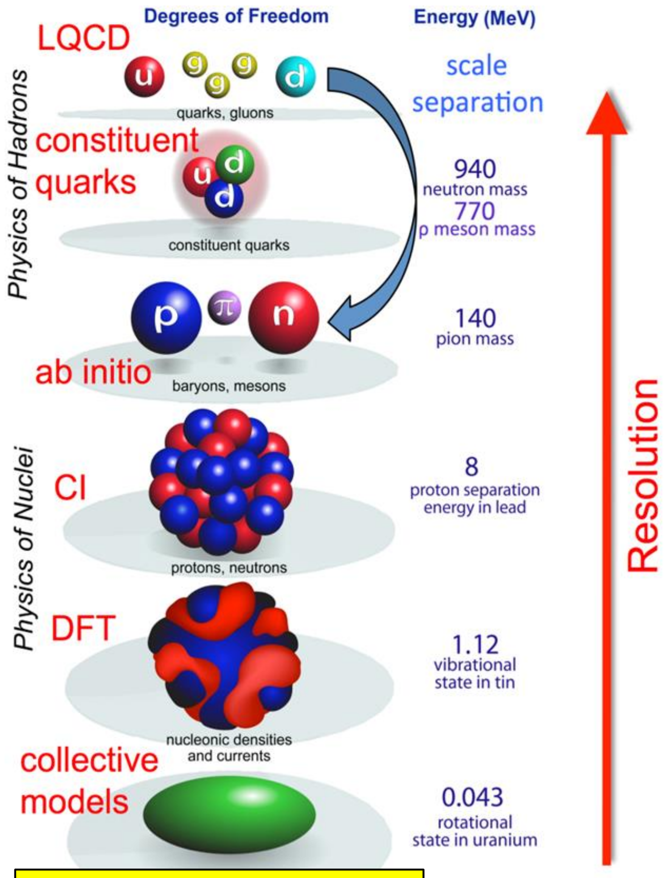
M.H. Mun

# 2. Nuclear Structure and reactions from first principles

- Ab initio: nuclei from **first principles** using fundamental interactions without uncontrolled approximations.
- No core: all nucleons are active, no inert core
  - Ideally infinite basis, but in practice truncated basis ($\sim N_{max}$)
- Shell model: harmonic oscillator basis
- What has done ($N_{max}$)



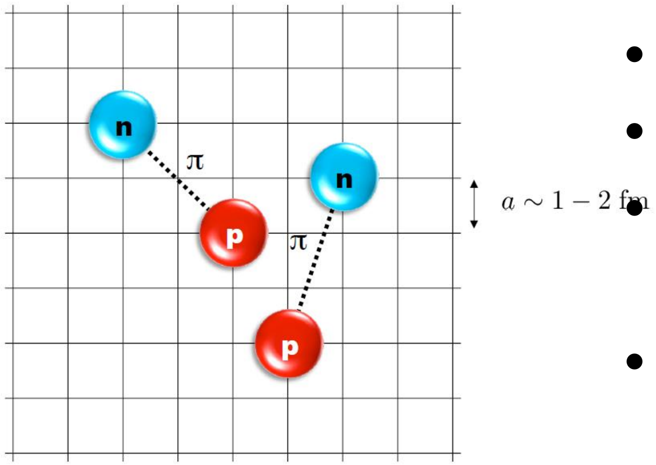



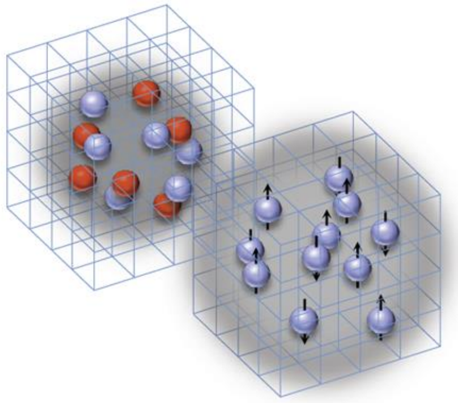




Y. Song

# 3. Nuclear Lattice EFT (NLEFT)

Nucleons as point particle on the lattice



- NLEFT can be an ideal tool for Nuclear Physics
- Alpha clustering emerges naturally
- For a starter, work on Unitary Fermion Gas in BCC lattice is under progress.
- Towards:
  - Neutron-rich halo nuclei
  - Asymmetric nuclear matter
  - Limits of nuclear stability
  - Unification of structure and reaction: Triple alpha reactions.

I. Shin

# Summary

- New physics beyond Standard Model needs evolving computing architecture.
- KISTI launched evolving computing architecture - KISTI-5 supercomputer.

⇒ KISTI-5 will play an important role to study new physics beyond standard model.

# Acknowledgement

- Fermilab, NERSC
- KHU, KNU and IBS/RISP

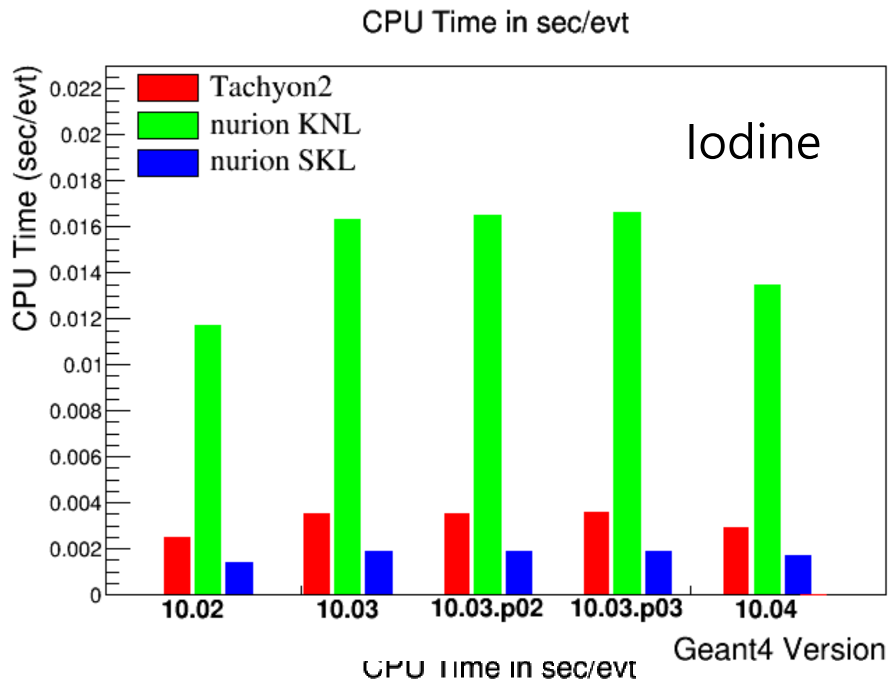
Thank you for your attentions.

(cho@kisti.re.kr)

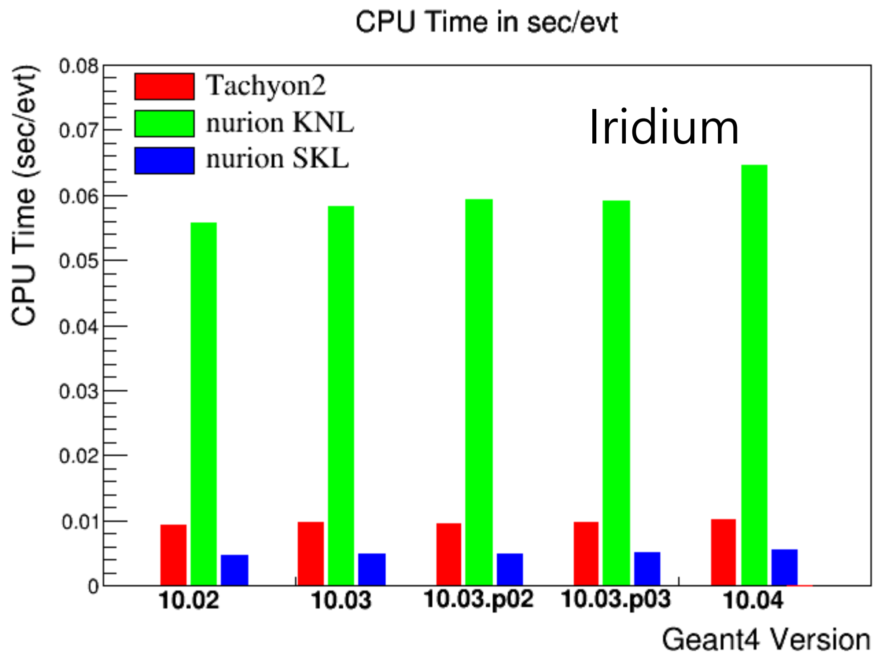
# Backup

# KISTI-5 supercomputer building

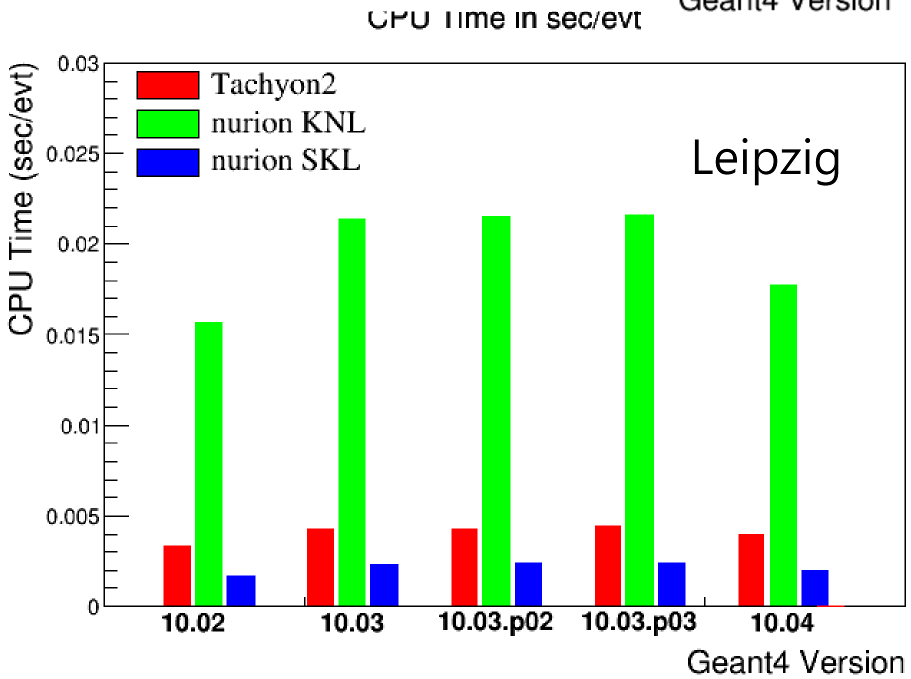
# QGSP BIC EMZ



CPU Time in sec/evt
CPU Time (sec/evt)
Tachyon2
nurion KNL
nurion SKL
Iodine
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
10.02
10.03
10.03.p02
10.03.p03
10.04
Geant4 Version

CPU Time in sec/evt
CPU Time (sec/evt)
Tachyon2
nurion KNL
nurion SKL
Iridium
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
10.02
10.03
10.03.p02
10.03.p03
10.04
Geant4 Version

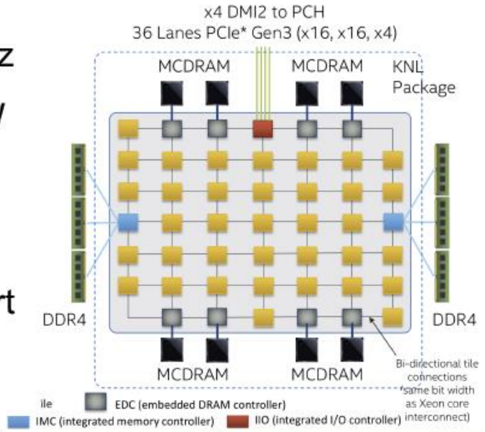
CPU Time in sec/evt
CPU Time (sec/evt)
Tachyon2
nurion KNL
nurion SKL
Leipzig
0.03
0.025
0.02
0.015
0.01
0.005
0
10.02
10.03
10.03.p02
10.03.p03
10.04
Geant4 Version

# KISTI-5 Supercomputer Specification

The Largest KNL/OPA based Cluster System
Rpeak 25.7PFlops, Rmax 13.9PFlops

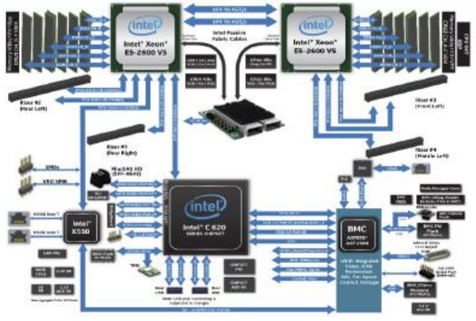
**Compute nodes** 8,305 KNL Computing modules, 119 Racks, 25.3PF

- 1x Intel Xeon Phi KNL 7250, 68Cores,1.4GHz
- 3TFlops Peak, ~0.2 Bytes/Flops Memory BW
- 96GB (6x16GB) DDR4-2400 6channel RAM,
- 16GB HBM (460GB/s)
- 1x 100Gbps OPA HFI, 1x On-board GigE Port




**CPU-only nodes** 132 Skylake Computing modules, 4 Racks, 0.4PF

- 2x Intel Xeon SKX 6148, 20Cores, 2.4GHz
- 192GB (12x 16GB) DDR4-2666 RAM
- 1x Single-port 100Gbps OPA HFI card
- 1x On-board GigE (RJ45) port



T. Hong

# Thank you for your attentions.

(cho@kisti.re.kr)